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Laboratori Nazionali di Frascati

Book of abstracts

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A magnetic spectrometer for laser plasma acceleration experiments

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The design, construction and commissioning of the magnetic spectrometer for the self-injection experiments with the Flame laser at LNF has demostrated extremely challenging: the characteristics of the detector are highly non conventional for laser-plasma physicists (high energy electrons), accelerator physicists (large angular divergence, energy spread) and particle phycisists (huge number of electrons to measure and very large electronic noise).

This talk presents the design considerations and the difficulties encountered in building such a detector, together with the adopted solutions and the results of the laser-plasma interaction shots.

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From NIF to Dark Matter: Extreme Measurements

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One of the major advantages of working at a National Laboratory is the opportunity to contribute to a diverse collection of physics experiments and the unique diagnostic technologies to make the measurements. It seems that the most interesting physics and thus the measurements are in extreme physical environments such as high-energy and flux laser, x-ray, neutron, gamma ray and EMP. In other experiments the challenge is the location of the detector itself. Such is the case with the noble liquid based dark matter detector MiniCLEAN we are constructing that will be located 6800' underground in the active nickel mine at the SNOLab laboratory in Sudbury, Canada. In this talk we will present details on the Gated X-ray Detector (GXD)1 , the Neutron Imaging System (NIS)2 presently in place at the National Ignition Facility (NIF) and also the current challenges of fielding a Dark Matter detector underground.3 Finally, we will give a view of the future MARIE facility to be built at LANL and the opportunities for new unique measurements in extreme environments.
1 J. A. Oertel, Rev. Sci. Instrum. 77, 10E308 (2006).
2 M.D Wilke, Rev. Sci. Instrum. 79, 10E529 (2008)
3 K. Rielage, http:// meetings.aps.org/link/BAPS.2010.DNP.FE.1
4 http://marie.lanl.gov/.

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From Shannon Communication Theory to Semantic Coding: Towards Mining Zettabytes of Satellite Images

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Abstract During the past years, our capability to store, organize, and access large volumes of data has greatly exceeded our capability to extract information from the data. This has led to an enormous problem in accessing the data content, to extract the meaningful and useful information and knowledge. Thus, there have been developed new concepts and methods to deal with large data sets as: query by image content, data mining, and knowledge discovery. A broad range of techniques has been developed to deal with particular data types, such as natural language text, sound, and numerical records, and with heterogeneous data types, e.g. combining video and sound. Particularly, image information mining systems require both database, visual and linguistic capabilities, but there is an important bottleneck between these information concepts: the semantic gap. In his seminal paper "A mathematical theory of communication", Shannon identified and recognized from the very beginning the semantic role of messages. However, at that moment he discarded its discussion, only considering as relevant the fact that communication system shall work independently of the message nature. From the Communication Theory perspective, a main challenge in extracting the image content is the fundamental difference between a traditional database record and images as signs. Faced with the image content extraction and communication to people, it is assured that the distinction between the perceptions of information as signals-signs-symbols is generally not dependent on the form in which the information is presented but rather on the content in which it is perceived, i.e. upon the intentions and expectations of the perceiver. The relation between the image as a sign and its information content expressed at semantic level is generally given by a similarity function. However, the relation of similarity is too generic to represent signification. Therefore, the image database requires specific interaction with the users, in form of a dialogue that enables the definition of an image semantics adapted to the user conjecture. The proposed solution is the assimilation in the Coding Theory of the Principle of Semantic Compositionality: the meaning of a whole is a function only of the meanings of its parts together with the manner in which these parts were combined. In this frame, there will be presented the basic evolution steps from Shannon communication channel to a semantic communication system, in which the image content is coded as a meaningful message: semantic coding. The semantic communication channel is modeled hierarchically from the signal level to the abstract semantic representation of the user. Generative models are used for conceptual representations, and latency is analyzed to extract the meaningful content. The presentation will continue with recent results in the algorithmic theory of complexity and their computational approximations. Finally, examples of applications dealing with parameter free data and image mining will be shown. The new concepts are exemplified with a variety of methods and systems for Image Information Mining, and Image Semantic Coding.

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The key role of radar images in the understanding of earthquakes

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The investigation and the understanding of the reasons underlying an earthquake have been greatly improved thanks to the exploitation of radar images acquired from satellite. Following the pioneer applications in the eighties, Interferometry from Synthetic Aperture Radar (InSAR) gained a prominent role as source of geodetic data; the capability of measuring small deformations of few millimeters for wide areas and the large data availability, from the early nineties, lead InSAR technique to be accepted as standard tool in the tectonic studies. Though several factors can worsen the quality of the results, InSAR, often with GPS measurements, is commonly used to infer the seismic source of an earthquake by means of inversion techniques applied to analytical and/or numerical models. Newly developed algorithms, known as InSAR time-series, allowed to further improve the data accuracy and completeness, strengthening the InSAR contribution even in the study of the inter- and post-seismic phase. Today, almost all the inshore earthquakes and the most active tectonic regions are investigated with the support of InSAR data.

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Imaging Radars: system architectures and technologies

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The potentiality of multichannel SAR, to provide wideswath and high resolution at the same time, has been described in many papers in the last past years. The scope of this paper is to address some of the architectural and technological aspects related to the implementation of a multichannel receiver for a multibeam SAR, with the objective to provide some solutions for different configurations with increased complexity. A further point is the exploitation of the multichannel configuration for the implementation of very high resolution modes.

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Dark matter search in Space

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Cosmological observations are giving us a coherent picture of the Universe dominated by dark matter and dark energy. There are increasingly convincing evidences that non-baryonic dark matter is the building block of all structures in the Universe. The favorite candidates for the non-baryonic component are neutral weakly interacting massive particles (WIMP's) with a mass in the range between 10's GeV to TeV. The each other annihilation of these particles results in the symmetric production of particles and antiparticles, as protons and antiprotons, electrons and positrons, neutrinos and antineutrinos as well as gammas. An extensive search of these signals of dark matter, started many years ago by experiments on board stratospheric balloons, is now conducted in space by the magnetic spectrometers PAMELA and AMS-02 and the gamma telescope Fermi. The main space techniques in particle detection and the most relevant results will be presented.

Energy Spectrum of Particles / 13

Measurements of Fast particles in magnetic fusion devices

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In magnetically confined plasmas suprathermal ions can drive instability associated to the shear Alfvén wave. These instabilities have been observed in several machines worldwide and are the subject of dedicated theoretical and experimental investigations because of the threat they constitute for the confinement of α particles in a burning deuterium-tritium plasma. Alfvén waves have a peculiar dispersion relation. Due to toroidal simmetry, the refraction index is periodic and the continuum wave spectrum has gaps where the radial group velocity of the wave vanishes. Here reside discrete and weakly damped Alfvén eigenmodes of various origins, which can be excited by ions with orbital frequencies matching that of the wave. Once a mode is driven unstable, its evolution is intrinsically non linear and depends on the fast ion energy distribution, that is in turn affected by the eigenmode itself. In addition to these instabilities, if the energetic ion pressure is sufficiently large, additional modes not pertaining to the background plasma, called energetic particle modes, are manifested.

From the experimental point of view dedicated diagnostics have been developed on present day machines to measure the energy distribution of suprathermal ions in the hundreds keV range, to identify unstable modes and to study their interaction with the energetic ion population. Neutral particle analyzers are commonly adopted to determine the distribution function of fast ions. Mirnov coils displaced along the toroidal and poloidal direction allow to measure the mode frequencies and to identify the associated toroidal and poloidal mode numbers. Time traces from neutron counters are used to monitor drops in the neutron emission produced by energetic ion redistribution or losses. More recently, an application of charge exchange recombination spectroscopy based of the Balmer Dα emission, named FIDA, has allowed precise measurements of fast ion redistribution and comparison with simulations. Fast ion loss detectors with unprecedented time resolution have been used to characterize losses due to energetic ion driven instabilities. For the first time, the spatial structure of the eigenmodes has been measured through an imaging technique based on electron cyclotron emission and provided good agreement with the simulations.

As the energy of the fast ions is increased towards the MeV range, such as that expected in next step fusion devices, many of the mentioned techniques present limitations and nuclear physics based diagnostics must be employed. Interesting candidates are represented by neutron and gamma ray emission spectroscopy, as demonstrated in recent experiments at the Joint European Torus.

In this work the various techniques used to diagnose fast ions in today's magnetic fusion devices will be reviewed, with emphasis on the detection principles and on the plasma parameters which can be measured. The talk will also outline the challenges that must be faced to perform fast ion measurements on future burning plasma experiments such as ITER. Of special interest is the diagnose of the fusion alpha particle population of a DT fusion plasma (D +T -> n +α). The 3.5 MeV α particle population, by depositing its energy via slowing down in the bulk plasma, is the key actor to reach the goal of a self sustaining thermonuclear plasma. The techniques proposed for diagnosing the α particle population will be reviewed with the experimental results achieved.

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Analysis of massive datasets: the next ten years

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ROOT a database and analysis tool

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The ROOT system has become the de facto standard in High Energy and Nuclear Physics for the experiment independent software. ROOT provides a powerful object data store that supports vertical data storage for highly efficient data access during data mining. In addition the system comes with a rich set of mathematical and statistical tools and a full set of 2D and 3D graphical data presentation classes. The system is written in C++ and includes also a C++ interpreter allowing for fast prototyping. In this presentation I'll give an overview of the system, how it is used in HEP and the exciting new features we're working on.

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Large Datasets and High Energy Physics

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High Energy Physics (HEP) has a long tradition of pushing scientific computing to its limits. In particular the use of very large datasets has always been required in order to search for the rare phenomonen of interest in the field. This presentation will describe the manner in which large datesets are acquired, processed, managed and analyzed in HEP, using the Large Hadron Collider (LHC) at CERN as a concrete example.

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Overview of conformal predictors applications in experimental nuclear fusion environments

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Conformal predictors (CP) are a particular case of machine learning methods. Two important characteristics of conformal predictors should be mentioned. On the one hand, a unique hypothesis about the samples is needed: all samples are considered to be independent from each other and identically distributed from the same (but unknown) distribution. No other prior information is required. On the other hand, CP provide estimations of the accuracy and reliability of their predictions not only in classification tasks but also in regression problems. Several applications of CP have shown the potential of the conformal predictors in nuclear fusion:
- Management of high dimensionality problems (102-105 dimensions).
- Real-time predictions.
- Estimation of uncertainty intervals in the determination of transition times in phase transitions.
- Assessment of error bars in non-parametric regression models.
- Determination of outliers in regression problems.
- Automatic increase of the training dataset of classifiers as new predictions are carried out (depending on the accuracy and reliability of the classification).

Applications covering all the above aspects have been developed in the experimental environments of the TJ-II stellarator and the JET tokamak. Results will be presented about (a) the Thomson Scattering diagnostic of the TJ-II fusion device (both real-time and off-line image recognition for automatic data processing), (b) the estimation of uncertainty intervals in the automatic determination of time instants in JET L/H transitions and (c) non-parametric regression models for JET L/H transitions.

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Advanced acceleration techniques

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Particle acceleration around shocks

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We review the basic features of particle acceleration theory around collisionless shocks in astrophisical environments.
Special attention will be devoted to observational and theoretical facts about acceleration of Galactic cosmic rays in supernova remnants, discussing the arguments in favor and against a connection between cosmic rays and supernova remnants, the so-called supernova remnant paradigm for the origin of Galactic cosmic rays. Recent developments in the modeling of the mechanism of diffusive shock acceleration are discussed, with emphasis on the role of 1) magnetic field amplification, 2) acceleration of nuclei heavier than hydrogen, 3) presence of neutrals in the circumstellar environment. The status of the supernova-cosmic ray connection in the time of Fermi-LAT and Cherenkov telescopes is also discussed.

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Dark Matter search in space

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Cosmological observations are giving us a coherent picture of the Universe dominated by dark matter and dark energy. There are increasingly convincing evidences that non-baryonic dark matter is the building block of all structures in the Universe. The favorite candidates for the non-baryonic component are neutral weakly interacting massive particles (WIMP's) with a mass in the range between 10's GeV to TeV. The each other annihilation of these particles results in the symmetric production of particles and antiparticles, as protons and antiprotons, electrons and positrons, neutrinos and antineutrinos as well as gammas. An extensive search of these signals of dark matter, started many years ago by experiments on board stratospheric balloons, is now conducted in space by the magnetic spectrometers PAMELA and AMS-02 and the gamma telescope Fermi. The main space techniques in particle detection and the most relevant results will be presented.

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Laser-driven ion acceleration

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Ion acceleration from solid targets irradiated by high-intensity pulses is a burgeoning area of research, attracting a phenomenal amount of experimental and theoretical attention worldwide. Key to this interest are the ultra-compact spatial scale of the accelerator and the properties of the laser-driven ion beams, under several aspects markedly different from those of "conventional" accelerator beams. In view of such properties they have the potential to be employed, in the future, in many innovative applications in scientific, technological and medical areas. From the point of view of fundamental physics, the underlying dynamics of laser-plasma interaction at ultrahigh field intensities, dominated by a surprisingly vast amount of new challenging phenomena, and the acceleration of macroscopic quantities of matter towards GeV/nucleon energies represent unique examples of relativistic many-body systems which can be studied in a small laboratory scale. The research conducted so far naturally leads to a number of crucial, fundamental questions which the community needs to face to obtain ground-breaking advances in this field.

In this presentation, the subject of laser-driven ion acceleration will be reviewed, with special focus on the description of the ion acceleration mechanisms, a discussion of the role played by the solid target in this physical system and a brief survey of foreseen applications of these ion beams. Also, some novel ideas to optimize the maximum ion energy through an active control of target properties will be presented, with particular reference to experimental and theoretical studies dealing with the fabrication of nano-engineered multilayered targets composed by a main solid foil with an ultralow-density layer on the illuminated side.

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Introduction to Spectroscopy

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Spectroscopy and the quest for eso planets

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Planck: microwave glasses to study the universe history

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Measurements of Temperature and Density / 25

A novel single-shot, spectrally resolved X-ray imaging technique of ICF relevant plasmas

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A new diagnostic tool has recently been developed, which allows to get 2D X-ray images of ICF relevant plasmas with simultaneous energy encoded information. This is achieved by using a pinhole camera scheme in which a CCD camera, forced to operate in the single-photon regime, is used as a detector. The use of this method, initially limited to a single-pin-hole, multi-shot basis, has recently been extended to single-shot experiments typical of large scale laser installations using custom pin-hole arrays of sub-10 micron diameter. Preliminary tests have been carried out at the PALS facility and the diagnostics has been successfully employed in a PW environment in a recent experiment at RAL. The details of the method as well as some results from such recent experiments will be given.

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Temperature and density measurements in laser-produced plasmas

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Several diagnostics based on electromagnetic radiation are used to measure temperature and density in laser-produced plasmas. They can essentially grouped in two categories. A first involves the analysis of the emission spectrum from the plasma. The typical temperature of a laser-produced plasmas being in 10-10^3 eV range, most of the emission lies in the ultra-violet to the soft X-ray region, at energies several order of magnitude greater than the plasma characteristic frequencies. So the detection of such radiation is not complicated by refraction or other collective effects . A second categories involves the use of photon beam probe which propagates through the plasma. In this case the information about plasma parameters are held in the scattered radiation properties. The refraction affecting the probe beam is commonly used in interferometric techniques to retrieve the spatial density distribution of the plasma. Depending on the pulse duration of the laser producing plasma, such techniques can be operated in time resolved mode.

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Photoelectric X-Ray Polarimetry with Gas Pixel Detectors

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The Gas Pixel Detector, recently developed and continuously improved by Pisa INFN in collaboration with IASF-Roma of INAF, can visualize the tracks produced within a low Z gas by photoelectrons of few keV. By reconstructing the impact point and the original direction of the photoelectrons, the GPD can measure the linear polarization of X-rays, while preserving the information on the absorption point, the energy and the time of arrival of individual photons. Applied to X-ray Astrophysics, in the focus of grazing incidence telescopes, it can perform angular resolved polarimetry with a huge improvement of sensitivity, when compared with the conventional techniques of Bragg diffraction at 45 degrees and Compton scattering around 90 degrees. This configuration has been the basis of POLARIX and HXMT, two pathfinder missions, and was included in the baseline design of IXO, the very large X-ray telescope under study by NASA, ESA and JAXA.

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DIAGNOSTICS FOR FUSION REACTORS

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In the future generation of fusion reactors, the power generated by the fusion reactions substantially exceeds the external input power (Pfusion/Pin ≥ 50). Twenty percent of the generated fusion power is carried by the charged alpha particles that carry a large fraction of the plasma kinetic energy and can collectively drive certain types of magneto-hydrodynamic (MHD) modes, while they can suppress other MHD modes. The scientific challenge in the field of burn control is to find the proper balance between desired and detrimental effects of the various MHD modes and to develop methods and tools for active feedback control of such modes. An important complication arises from the fact that the external heating power is small compared to the heating power of the alpha particles. To be able to develop control strategies, it is necessary to understand the dynamics of the system, in this case the mutual interactions between the fast alpha particles and the MHD instabilities.

As a demonstration fusion power plant, DEMO will have to demonstrate reliability and steady-state operation, which calls for unprecedented robustness and reliability of all diagnostics (also requiring adequate redundancy). But DEMO will have higher levels of neutron flux, fluence, nuclear heating, gamma irradiation and plasma irradiation than ITER. In particular the neutron fluence will be ~50 times higher than in ITER. This implies that diagnostics that marginally work in ITER are likely to be inappropriate in DEMO. This holds especially to many in-vessel diagnostics, for which there seems little prospect for improvements that would make it possible to use them in DEMO in a similar way as in ITER.

The development and demonstration of new DEMO-proof diagnostic techniques is a time-consuming process that should be started now. This specifically holds for the irradiation testing because of the high fluence levels in DEMO: Although future experience with diagnostics in ITER and irradiation testing in IFMIF will give important input for the DEMO diagnostics, many of the results will come too late, since at the end of the DEMO Conceptual Design Activity one has to have a good idea of which diagnostics will work and how they can be integrated into DEMO. It is likely that some DEMO-relevant diagnostics will not provide measurements of certain parameters with the same quality as non-DEMO-relevant diagnostics on present devices, and therefore will not be of benefit as a diagnostic to those devices. Nevertheless, such new diagnostic techniques must be developed and this needs to become an accepted part of the fusion programme.

It is important to develop a new way of thinking with respect to the present one in which diagnostics are often afterthoughts: if certain diagnostics are essential for the control of DEMO and the future fusion reactors, they have to be taken seriously during the entire design phase, as for example their replaceability or the required screening against radiation may have a large impact on the design of the reactor. One should realize that the lack of suitable diagnostic techniques may affect the options for controlling the reactor plasma, in particular the ability to run "advanced" scenarios. This lack of diagnostics, and thus the reduced set of plasma parameters that can be measured, will make modelling more important in fusion reactors to derive the other parameters. Advanced predictive/analysis codes need to be developed to combine data from various diagnostics in an intelligent way in order to reduce the number of required diagnostics. Benchmarking of this should be done on ITER.

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Laser Opto-Acoustic Imaging Coregistered with Ultrasound: Towards New Technology for Biomedical Diagnostics

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In 1880 Alexander Bell heard "a pure musical tone" in a closed gas volume that had absorbed a modulated sunlight beam. Later discoveries revealed that detection of ultrasound resulting from the optical absorption of modulated laser energy represents a very sensitive means for detection of various molecules in gases and liquids. Biomedical applications of laser optoacoustics exploded after our discovery of the physical principles governing acquisition of spatially resolved images in the depth of live tissues.

This lecture will discuss the state of the art and prospectives of the optoacoustic imaging starting with its physical principles, systems and finally biomedical applications. Ideas that made this rapidly developing technology possible were that (1) laser pulses may be effectively used to produce acoustic pressure in biological tissues, (2) the resulting acoustic (ultrasonic) waves can propagate in tissues with minimal distortion, (3) 2D and 3D maps (images) of the absorbed optical energy can be reconstructed with high resolution under the illumination condition of pressure confinement in the course of the optical energy deposition into a voxel to be resolved.

An optoacoustic system provides optical contrast in tissue while mapping tissue structures with ultrasonic resolution. The main advantages of the optical contrast is the applicability of spectroscopic optoacoustic imaging to (1) map distributions of blood concentration and its oxygen saturation (functional imaging) in the given tissue, and (2) map distribution of molecules of interest, such as cancer receptors or other biomarkers (molecular imaging) using nanoparticles as contrast agents. For example, high optical contrast of blood (specifically hypoxic blood) makes visualization of the tumor angiogenesis possible, thereby providing functional information for differentiation of malignant and benign tumors. On the other hand, ultrasonic imaging based on reflection of ultrasound beams from the boundaries of acoustic impedance can produce high resolution maps of anatomical tissue structures. The idea that drives present developments in the field of optoacoustic imaging is that coregistration of optoacoustic and ultrasonic images would be a useful enhancement of almost every application of medical ultrasound, yielding accurate biomedical diagnostics based on comprehensive information that may be obtained from functional maps of tissues correlated with anatomical maps. New laser technologies, such as monoblock diode pumped solid state systems, bring the opportunity to produce compact, robust and cost-effective systems for the laser optoacoustic imaging.

Evening Session / 31

Dai buchi neri alla Terra: Risultati e sorprese del satellite Italiano AGILE

Marco Tavani
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AGILE, lanciato il 23 aprile 2007, è una missione spaziale dell'Agenzia Spaziale Italiana dedicata allo studio dell'Universo alle più alte energie rivelabili da satellite. La configurazione compatta e tecnologicamente avanzata dello strumento permette di rivelare con grande efficienza sorgenti cosmiche nella banda di energia dei raggi gamma (30 MeV-50 GeV) e raggi X (18-60 keV). Nei suoi primi quattro anni di operazioni AGILE ha fornito una grande quantità di dati sulle sorgenti cosmiche più energetiche con molte sorprese. La missione ha rivelato emissione gamma dalla nostra Galassia e da sorgenti stellari vicine, come anche da sorgenti molto remote associate a galassie lontane. I raggi gamma sono prodotti dall'accelerazione di particelle in stelle di neutroni, buchi neri e resti di esplosioni stellari. AGILE sta contribuendo in modo unico alla comprensione di questi processi di accelerazione. In particolare, ha ottenuto elementi essenziali per la comprensione del problema dell'origine dei raggi cosmici e ha sorprendentemente scoperto emissione gamma transiente dalla Nebulosa del Granchio, fino ad ora considerata la sorgente stabile per eccellenza in astrofisica delle alte energie. Comprendere i processi di accelerazione associati a questi fenomeni è importante per la loro possibile applicazione ai laboratori terrestri di produzione di energia da plasmi. Oltre che al cosmo lontano, la strumentazione di AGILE è rivolta anche al pianeta Terra. In particolare, AGILE ha scoperto di recente l'esistenza di emissione molto energetica da parte di una classe particolare di lampi denominati Lampi Gamma Terrestri. La scoperta di AGILE porta a rivedere sostanzialmente i modelli di produzione e di accelerazione di particelle in fenomeni atmosferici. Dal cosmo remoto alla Terra, i contributi del satellite AGILE sono importanti per la comunità scientifica internazionale e per i giovani ricercatori che partecipano al progetto scientifico e alle sue applicazioni

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From NIF to Dark Matter: Extreme Measurements

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From NIF to Dark Matter: Extreme Measurements

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One of the major advantages of working at a National Laboratory is the opportunity to contribute to a diverse collection of physics experiments and the unique diagnostic technologies to make the measurements. It seems that the most interesting physics and thus the measurements are in extreme physical environments such as high-energy and flux laser, x-ray, neutron, gamma ray and EMP. In other experiments the challenge is the location of the detector itself. Such is the case with the noble liquid based dark matter detector MiniCLEAN we are constructing that will be located 6800' underground in the active nickel mine at the SNOLab laboratory in Sudbury, Canada. In this talk we will present details on the Gated X-ray Detector (GXD)1 , the Neutron Imaging System (NIS)2 presently in place at the National Ignition Facility (NIF) and also the current challenges of fielding a Dark Matter detector underground.3 Finally, we will give a view of the future MARIE facility to be built at LANL and the opportunities for new unique measurements in extreme environments.

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3 K. Rielage, http:// meetings.aps.org/link/BAPS.2010.DNP.FE.1
4 http://marie.lanl.gov/.

Measurements of Temperature and Density / 33

Temperature and density measurements in laser-produced plasmas.

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Several diagnostics based on electromagnetic radiation are used to measure temperature and density in laser-produced plasmas. They can essentially grouped in two categories. A first involves the analysis of the emission spectrum from the plasma. The typical temperature of a laser-produced plasmas being in 10-10^3 eV range, most of the emission lies in the ultra-violet to the soft X-ray region, at energies several order of magnitude greater than the plasma characteristic frequencies. So the detection of such radiation is not complicated by refraction or other collective effects . A second categories involves the use of photon beam probe which propagates through the plasma. In this case the information about plasma parameters are held in the scattered radiation properties. The refraction affecting the probe beam is commonly used in interferometric techniques to retrieve the spatial density distribution of the plasma. Depending on the pulse duration of the laser producing plasma, such techniques can be operated in time resolved mode.

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Frequency Combs for High Precision Spectroscopy in Astronomy

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The past years have seen the birth of precision spectroscopy in astrophysics. Outstanding scientific questions can be tackled with this technique. Possible slow variations of fundamental constants, such as the fine structure constant or the electron-proton mass ratio, may be detected or limited in magnitude by observing fine structure multiplets in gas clouds and comparison with current laboratory values. Small periodic Doppler shift modulations of stellar spectra caused by their recoiling quiver motion can reveal the existence of extra solar planets that cannot be resolved by optical means. Ultimately, the direct observation of the acceleration of the cosmic expansion is envisioned to be detectable with next-generation, extremely large telescopes.
Doppler shifts of about 1 cm/s, corresponding to ~20 kHz at 500 nm would need to be resolvable to realize these observations. Traditional calibration sources like spectral lamps or absorption cells, however, are limited in their repeatability at the 10-100 cm/s level. Frequency combs have therefore been proposed to serve as calibrators for astronomical spectrographs. They can outperform the traditional sources in all important characteristics such as line density, line intensity distribution and line tunability. But most important, their repeatability is fundamentally limited only by the atomic clock to which it is referenced.
We have set up a frequency comb capable of calibrating an astronomical spectrograph and tested it at the HARPS instrument at La Silla observatory in Chile. The major challenge is to match the comb's parameters to the spectrograph's resolution and spectral bandwidth. In my talk I will present the comb system we have developed and some of the results we could obtain in our calibration campaigns at the telescope.

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Innovative multilayer coatings and their use in spectroscopic applications

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Multilayer coatings are key elements in the extreme ultraviolet spectral range due to the fact that they provide significant reflectance in normal incidence optical configurations. Since their working principle is based on an interferential effect, they perform only in a limited spectral range, therefore having also filtering properties. For this reason they are largely used in imaging spectroscopy, for example to observe plasma emissions in satellite instrumentation, and in laboratory applications, for example to manipulate the High Order Harmonics spectrum generated in the laser-matter interaction. Very recently they have been proposed also to manipulate the free electron lasers pulse, in the beam transport systems as well as in the experimental chambers. Innovative structures for EUV plasma observations and FEL beam manipulation have been developed. Their characteristics in term of reflectance, filtering properties, stability over time and under specific environmental agents exposition have been experimentally tested.

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Innovative multilayer coatings and their use in spectroscopic applications

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Soft X-ray imaging techniques in tokamak plasmas: present status and possible future developments

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This paper is focused on the X-ray tomography system set-up at Tore Supra and the recent developments made to get precise information about plasma features from the raw or inverted data.
The Soft X-ray diagnostic which is implemented on Tore Supra has been recently totally refurbished in order to improve the quality of the measurement and associated treatments. Particular efforts have been made for designing the electronics part where the simultaneous requirements of low noise, high gain and high time resolution placed strong demands on the new system design. It uses 45 viewing lines in a horizontally oriented fan and 37 in a vertical fan providing a poloidal and toroidal resolution of about 3 cm and 10 cm respectively. It records the integrated Soft X-ray emission between 3 to 25 keV using Silicon diodes polarized with a tension of 55V. Acquisition, in VME technology for Real-Time (RT), is split in two: slow (0.125 -1 kHz) and fast (1-250 kHz) signals are simultaneously acquired.
A very accurate calibration of the SXR poloidal tomography cameras at Tore Supra was previously performed, where all the 82 SXR diodes were absolutely calibrated in their X-ray domain, including electronics and geometrical corrections. This is absolutely crucial for real time, because the data cannot be manually validated and the algorithms used for reconstruction and parameter evaluation must rely on good data, otherwise artifacts can affect the results.

The ultimate aim is to use this information in real time for visualisation but also potential feedback, with a particular emphasis on the optimization of the reconstruction techniques and on simple analysis tools developed for an automatic treatment of these inverted data. The issue is to adapt the inversion techniques in order to minimize the required computational time due to the real time constraint, commensurate with the accuracy of tomography cameras and automatic analysis tools. It will be shown that 2-D reconstructions with an arbitrary higher spatial resolution produce no additional information and slow down uselessly the computational time.
Particular emphasis of the recent progress made on the optimisation of the free parameters used for the tomographic inversion will be presented. An interesting and very useful application to the reconstruction of the magnetic axis will be then detailed, including a relevant comparison with some results produced by magnetic equilibrium solvers.
Finally, future techniques using advanced imaging detector will be presented. In particular preliminary investigation on Tore Supra about the use of Gas Electron Multiplier (GEM) detector for imaging purposes will be described including also some first observations in situ.

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LIBS for Tritium Cartography on Tokamak Plasma Facing Components

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Tritium retention on plasma facing components (PFCs) of tokamak vacuum chamber is seen as a serious problem for a secure operation of modern nuclear fusion installations. Tritium surface cartography with tritium overall content determination is required for consecutive detritiation of PFCs. To achieve this goal, one may apply the spectroscopic analysis of the plasma produced by laser ablation of the PFCs (laser-induced breakdown spectroscopy, known as LIBS), which is seen as a promising technique.
The feasibility of in-situ LIBS remote measurements (5-10 meters from target) under a reduced pressure with the graphite PFCs from the European tokamaks (TORE SUPRA, CEA Cadarache, France and TEXTOR, Julich, Germany) has been extensively studied in laboratory using Q-switched nanosecond Nd-YAG lasers within the frames of the ITER project and EFDA programs[1-3]. The in-depth spectral line emission profiles of hydrogen, carbon, and some trace elements (B, Ca, Cr, Fe, K, Li, Na, Ni, Si) were obtained.
LIBS method was in-situ tested on the Joint European Torus (JET) in the UK with the EDGE LIDAR Laser System (Ruby laser, 3 Joules, 690 nm wavelength, 300 ps pulse duration, intensity up to 70 GW/cm2). These LIBS tests were undertaken in order to analyse a JET tile where eroded PFCs material was deposited on top of a tungsten stripe. Several analytical spectral lines of the plasma were observed in 400-600 nm spectral range with the optimised LIBS and detection system (improved optical collection system, adapted spectrometer, ICCD-detector). During the first laser pulses, the spectral lines of H, CII, CrI, and BeII are identified. Then, with the increase of the number of laser shots applied on the same divertor surface, the spectral line intensity of hydrogen decreased with the appearance of tungsten (WI) spectral lines, while those of the impurities (Cr, Be) were decreasing somewhat slower. The LIBS in-depth cartography was in agreement with the surface properties of the analysed tile. Thus, the LIBS in-situ proof of principle has been achieved[4].
In this presentation, after recalling some nanosecond LIBS results and pointing some limitations of this method, we will present several major improvements of the technique needed to measure accurately in-depth in-situ tritium concentration. Especially, LIBS measurements with femtosecond double pulses [5] in the tokamak environment with hydrogen isotopes resolution will be described and discussed.

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Satellite Meeting / 41

Particle acceleration around shocks

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We review the basic features of particle acceleration theory around collisionless shocks in astrophisical environments.
Special attention will be devoted to observational and theoretical facts about acceleration of Galactic cosmic rays in supernova remnants, discussing the arguments in favor and against a connection between cosmic rays and supernova remnants, the so-called supernova remnant paradigm for the origin of Galactic cosmic rays. Recent developments in the modeling of the mechanism of diffusive shock acceleration are discussed, with emphasis on the role of 1) magnetic field amplification, 2) acceleration of nuclei heavier than hydrogen, 3) presence of neutrals in the circumstellar environment. The status of the supernova-cosmic ray connection in the time of Fermi-LAT and Cherenkov telescopes is also discussed.

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Neutron detector development at the ILL. Prospects for 3He alternatives

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3He is often used as the neutron convertor for detectors in neutron scattering science, but this gas has become rare and very expensive since 2008. The growing lack of Large Area Neutron Detectors becoming a major concern in most of the research neutron institutes, the development of techniques based on alternative convertors is of the highest priority. 10B is another popular neutron convertor which can be used either in solid scintillators, or in proportional counters as thin films (10B or 10B4C) or gas compound (10BF3). In the so-called Multi-Grid detector, the volume of the detector is filled with grids, electrically insulated and stacked together to form square tubes. Each tube has a wire at its centre for charge collection and gas amplification. The mechanics of this design allows building large area vacuum compatible detectors with no dead space. In a 10B Multi-Grid detector, one grid consists of blades coated with thin Boron films on both sides mounted on a frame, whereas in a 10BF3 Multi-Grid detector, one grid is made of a single block of Aluminium, machined to create the holes. A 10B Multi-Grid prototype with 30 layers of B4C has been tested on a monochromatic neutron beam line. The absorption profile through the detection planes has been measured for films containing natB and 10B. Preliminary results agree with the simulated performance, and show that this technique allows to reach a detection efficiency > 50% for thermal neutrons.

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GEM gas detectors for Soft X-ray imaging in Fusion devices with neutron-gamma background and polycapillary lenses

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A triple Gas Electron Multiplier (GEM) detector has been built and characterized, in a collaboration between ENEA, INFN and CEA to develop a soft X ray imaging diagnostic for magnetic fusion plasmas. It has an active area of 10x10 cm2, 128 pixels and electronics in counting mode. Since burning plasma experiments will have a very large background of radiation, this prototype has been tested with contemporary X, neutron and gamma irradiation, to study the detection efficiencies, and the discrimination capabilities. The detector has been preliminary characterized under D-D neutron irradiation (2.45MeV) up to 2.2 106 n/s on the detector active area, showing a detection efficiency of about 10-4, while the detection efficiency of X-rays is more than three orders of magnitude higher. The detector has been also tested then under D-T neutron flux (14MeV) up to 2.8 108 n/s on the whole detector, with a detection efficiency of about 10-5. Thanks to the adjustable gain of the detector and the discrimination threshold of the electronics, it is possible to minimize the sensitivity to neutrons and gamma, and discriminate the X-ray signals even with very high radiative background. We investigated also the possibility of transporting the SXR radiation far from the machine, by means of polycapillary lenses. They appear promising for these purposes and suitable for Magnetic Fusion Plasma (MFP) X-Ray both imaging and tomography. The tests have been performed in laboratory for characterizing the polycapillary lenses for distances much larger than the optical focal length (15 times) and assessing their optical and imaging properties, in the SXR range 5-25 keV.

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Diagnostics for fusion reactors

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In the future generation of fusion reactors, the power generated by the fusion reactions substantially exceeds the external input power (Pfusion/Pin ≥ 50). Twenty percent of the generated fusion power is carried by the charged alpha particles that carry a large fraction of the plasma kinetic energy and can collectively drive certain types of magneto-hydrodynamic (MHD) modes, while they can suppress other MHD modes. The scientific challenge in the field of burn control is to find the proper balance between desired and detrimental effects of the various MHD modes and to develop methods and tools for active feedback control of such modes. An important complication arises from the fact that the external heating power is small compared to the heating power of the alpha particles. To be able to develop control strategies, it is necessary to understand the dynamics of the system, in this case the mutual interactions between the fast alpha particles and the MHD instabilities.

As a demonstration fusion power plant, DEMO will have to demonstrate reliability and steady-state operation, which calls for unprecedented robustness and reliability of all diagnostics (also requiring adequate redundancy). But DEMO will have higher levels of neutron flux, fluence, nuclear heating, gamma irradiation and plasma irradiation than ITER. In particular the neutron fluence will be ~50 times higher than in ITER. This implies that diagnostics that marginally work in ITER are likely to be inappropriate in DEMO. This holds especially to many in-vessel diagnostics, for which there seems little prospect for improvements that would make it possible to use them in DEMO in a similar way as in ITER.

The development and demonstration of new DEMO-proof diagnostic techniques is a time-consuming process that should be started now. This specifically holds for the irradiation testing because of the high fluence levels in DEMO: Although future experience with diagnostics in ITER and irradiation testing in IFMIF will give important input for the DEMO diagnostics, many of the results will come too late, since at the end of the DEMO Conceptual Design Activity one has to have a good idea of which diagnostics will work and how they can be integrated into DEMO. It is likely that some DEMO-relevant diagnostics will not provide measurements of certain parameters with the same quality as non-DEMO-relevant diagnostics on present devices, and therefore will not be of benefit as a diagnostic to those devices. Nevertheless, such new diagnostic techniques must be developed and this needs to become an accepted part of the fusion programme.

It is important to develop a new way of thinking with respect to the present one in which diagnostics are often afterthoughts: if certain diagnostics are essential for the control of DEMO and the future fusion reactors, they have to be taken seriously during the entire design phase, as for example their replaceability or the required screening against radiation may have a large impact on the design of the reactor. One should realize that the lack of suitable diagnostic techniques may affect the options for controlling the reactor plasma, in particular the ability to run "advanced" scenarios. This lack of diagnostics, and thus the reduced set of plasma parameters that can be measured, will make modelling more important in fusion reactors to derive the other parameters. Advanced predictive/analysis codes need to be developed to combine data from various diagnostics in an intelligent way in order to reduce the number of required diagnostics. Benchmarking of this should be done on ITER.

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Understanding solar wind acceleration: Solar Probe Plus.

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The magnetic field is fundamental to solar activity and shapes the interplanetary environment, as clearly shown by the full three dimensional monitoring of the heliosphere provided by the measurements of the Helios, Ulysses, SOHO, ACE, Wind, STEREO and Voyager spacecraft. Magnetic fields are also the source for coronal heating and the very existence of the solar wind; produced by the sun's dynamo and emerging into the corona magnetic fields become a conduit for waves, act to store energy, and then propel plasma into the heliosphere in the form of Coronal Mass Ejections (CMEs). Transformation of magnetic energy is also the source solar energetic particle events.
The way in which solar convective energy couples to magnetic fields to produce the multifaceted heliosphere is at the heart of Solar Probe Plus (SPP) exploration. This contribution highlights the exciting perspectives for discovery provided by the first direct exploration of the solar corona. Tests of current theoretical models of coronal heating and wind acceleration will be described and focus areas for further numerical and theoretical efforts illustrated in the light of the SPP observations.

Spectroscopy / 46

X-Ray Spectroscopy for Diagnosis and Analysis

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X-ray spectroscopy is a powerful tool for diagnosing the emission characteristics of x-ray sources. It may also be used in characterizing the elemental and chemical states present in compound materials, including the spatial distribution of these states. This presentation will describe the appropriate spectroscopic techniques along with examples of their use. The possibility of using laboratory-scale sources, as opposed to synchrotrons, will be discussed, taking into account the signal to noise ratios that are required to provide the necessary precision.

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Beam spectroscopy and monitoring at particle accelerators

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Beam monitoring is vital for current particle accelerators. High currents and/or energy of the beams transported means that they have a high potential for damage from several mechanisms: radiation dose, single event upsets, electronic or even physical damage. Examples of the various aspects that this might take on are the subject of this contribution. Throughout this presentation, a few of these aspects are demonstrated by detailed examples of the equipment and techniques that are presently used, with a bias towards the Large Hadron Collider for examples.

Interlocks based upon beam monitoring play an important role in limiting the possibility of serious damage to equipment. The role of particle type and spectra are important factors in determining safety levels when monitoring measurements are typically of particle flux or rate of energy deposited.

Beam monitoring also has a role in both determining that the beam is transported correctly and cleanly and in feedback so that corrections can be made to optimize beam transport. Monitoring here takes several forms; measuring beam position/timing, flux of losses, as well as more advanced techniques aimed at determining the energies and particle types of losses. Maximising the "luminosity", the "deliverable" of the accelerator, is another important function that monitoring plays.

Another essential aspect in understanding this complex environment at modern accelerators is detailed and well-qualified simulations. The simulation is essential for both the design of the accelerators as well as for understanding the bigger picture given the necessarily incomplete measurements from diagnostic measurements. An outline of how state of the art codes can be used is given, along with an example of how the simulation is qualified and subsequently leads to understanding the underlying mechanism for losses. In particular, it is often the simulation that gives true clarity as to the energy and particle spectra.

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Environmental Quality Control in space systems: the experience of the International Space Station

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Human spaceflight is a challenging endeavor, requiring a high degree of environmental control and life support for astronauts comfort and safety. The control of environmental conditions in a broad sense is of paramount importance, involving the monitoring of both natural and artificial environmental parameters. The International Space Station (ISS) is the main current human space infrastructure, in Low Earth Orbit, displaying an array of monitoring and control features for the control of its confined environment.

Ionizing radiation from Solar and Galactic sources is a major threat in space, monitored via a set of particle detectors and dosimeters.
The control of the confined atmospheric environment includes monitoring of e.g.:
• Total pressure
• Major constituents (N_2, O_2, CO_2, …)
• Trace gas contaminants
• Cabin air temperature

Smoke detectors ensure early warning for potential fires on board.
Measurements are fed into control logics locally, within a pressurized module, or centrally, in the core station. They can assist Fault Detection, Isolation and Recovery (FDIR), and be transmitted to ground via telemetry. This paper describes in particular the Columbus approach, which is under direct European control.

The ISS environment monitoring experience is of special interest when looking at future long duration exploration missions. In fact, for such missions there will be challenging and possibly conflicting requirements of increased control and crew versus ground autonomy.

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2D motional Stark effect imaging on the KSTAR tokamak

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Motional Stark effect polarimetry of D-alpha emission from heating neutral beams is a standard diagnostic for inferring the internal magnetic field pitch angle in toroidal confinement devices. Due to technical limitations, the measurement is restricted to a modest number of independent measurement channels viewing across the machine mid-plane.

We have developed a simple and compact spatial heterodyne polarization interferometer for fully 2D imaging of the polarization properties of the Doppler shifted D-alpha multiplet. First results obtained on the KSTAR tokamak show excellent agreement with forward models of the expected Doppler phase shift and polarization orientation. We will discuss the instrument operating principles, calibration and performance and will consider new areas of investigation that are opened up by the imaging capability.

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Planck: microwave glasses to study the universe history

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The ESA Planck satellite, launched on May 14th, 2009, is the third generation space mission dedicated to the measurement of the Cosmic Microwave Background (CMB), the first light in the Universe. Planck observes the full sky in nine frequency bands from 30 to 857 GHz and is designed to measure the CMB anisotropies with an unprecedented combination of sensitivity, angular resolution and control of systematic effects. In this presentation we summarise the Planck instruments performance and discuss the main scientific results obtained after one year of operations in the fields of galactic and extragalactic astrophysics.

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Data Preservation and Long Term Accessibility in High Energy Physics

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Recently there have been significant developments in high energy physics (HEP) data preservation projects while other large data volume experiments are now also facing for the first time insuring the long term accessibility of their data. In this presentation, the status of advanced HEP data preservation projects as well as the challenges and plans for projects newly facing this task will be presented. The continuing efforts to develop guidelines and tools, the justifications for these efforts and the state of discussions of more open accessibility of the data and how this is foreseen to be managed are included.

Poster Session: presentation of posters / 53

Lessons from the Comprehensive First Mirrors Test for ITER in JET with Carbon Walls

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Metallic mirrors will be essential components of all optical systems for plasma diagnosis in a reactor-class device. First Mirror Test (FMT) has been carried out at JET on the request of the ITER Design Team. Up to date two exposures have been performed in JET with carbon walls: 35 h of plasma operation (Step 1 in 2005-2007) and recently accomplished Step 2 (2008-2009): 45 h exposure with 32.7 h of X-point operation. The entire test (i.e. two steps) was performed with over 60 mirrors made of stainless steel (16 samples only in Step 1) polycrystalline molybdenum (Mo-poly) including 4 specimens coated with a 1 µm thick layer of rhodium (Rh). Mirrors were installed in carriers (cassettes with channels) placed on the outer wall and in the divertor: inner leg, outer leg and base plate under the load bearing tile. Before and after exposure mirrors underwent detailed surface analysis with optical methods and ion and electron spectroscopy.

The aims of this work are: (a) to provide an overview of results based on the outcome of the two campaigns; (b) to discuss the performance of Rh-coated mirrors; (c) to consider options for mirror maintenance and cleaning in a steady-state reactor. Essential results are summarized by several points.

Divertor: Reflectivity of all mirrors in the divertor region has been degraded by 80-90 %. It is caused by deposition of thick (> 35 µm), flaking-off coatings on surfaces. The growth of a new layer is observed in places where such thick deposit peeled-off. This leads to dust formation and large local differences in surface roughness and composition.

Outer Wall (midplane): The most important result is that only small reflectivity losses (5-10 %) occur on Mo-poly mirrors at the channel mouth. This is due to the in-situ removal of deposited species by charge exchange (CX) neutrals.

Composition: Deuterium and 12C are the main species detected on surfaces, but other isotopes (9Be and 13C) are also found in some locations thus indicating differences in the material migration.

Rh-coatings have 30% better initial reflectivity than Mo-poly. The coatings survived the test without detachment from the Mo substrate, but co-implantation of D and impurity atoms in mirrors on the outer wall caused material mixing: resultant reflectivity of pure Mo and Rh-coated mirrors was the same. It may indicate a limited use of coated mirrors.

Deposition in channels in the divertor cassettes is pronounced at the very entrance; the deposition sharply decreases with depth in the channel, decay length ~ 5-7 mm.

Implications of these results for first mirrors and their maintenance in a reactor-class device with carbon components will be discussed. The preparation for the next step of FMT in JET with the ITER-Like Wall will also be presented.

Poster Session: presentation of posters / 54

Monte Carlo simulation of the pulse height spectra produced in diamond detectors by quasi-monoenergetic neutrons. Comparison with experimental data

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The accurate simulation of fusion neutronics experiments is required for the development of the techniques aiming at monitoring the neutron flux and performing spectral analyses in the forthcoming ITER reactor. The interplay between experimental activity and simulation is the mean for proving and generalising the assumptions on ITER neutronics until it will be built. The work is carried out in view of the possible use of diamond detectors as high resolution neutron spectrometer for ITER project. The characteristics of such diamond based neutron spectrometers, like the carbon nuclear data, the electronics and the response pulse height spectra, need to be precisely assessed.
In the summer 2011 a team from the Frascati Neutron Generator (FNG-ENEA Fusione, Rome, Italy) performed a set of measurements with several diamond detectors at the Van der Graaff laboratory at the Institute for Reference Material and Measurements (IRMM, Geel, Belgium) in collaboration with the VdG team in order to determine the response functions of diamond detector to quasi monoenergetic neutrons in the energy range 8-20 MeV. Source neutrons were produced by accelerating deuterons onto solid targets containing deuterium or tritium.
The energy spectrum of the source neutrons (indeed, they are never monoenergetic because of target effects) are simulated with an ad-hoc source routine, which is to compile within the MCNPX or MCNP5 distribution. It is possible to develop computational models that reasonably include any contribution to an experimental neutron source from deuteron-deuteron or deuteron-triton reactions.
The front end of the simulation involves a detector routine (TALLYX, also to compile within an MCNP source distribution) that reproduces the measured pulse height spectrum. It is triggered upon interaction of a neutron (generated and transported inside MCNP) with carbon. The C-12 nuclear data are those from ENDF/B-VII.0, TENDL-2009, ENSDF and spare literature to include: elastic, inelastic, (n,a), (n,p) (n,d) reaction channels. The high resolution of the diamond detectors underpins the validation of the evaluated cross sections above 10 MeV and consequently some sets of measurements have been performed with this purpose.
The high quality of the available measurements allowed the definitive validation of the computational tools, especially the detector routine, which might be adopted for the perspective activities related with the ITER project.

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Challenges in plasma and laser wakefield accelerated beams diagnostic

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The new frontier in the particle beam accelerator is the so called plasma acceleration. Using the strong electric field inside a plasma is possible to achieve accelerating gradients order of magnitude larger in respect to the actual technologies. Different schemes have been proposed and several already tested, producing beams of energy of several GeV. Mainly two approaches are followed: the beam is directly produced by the interaction of a TW/PW class laser with a gas jet, or a preexisting particle beam is accelerated in a plasma channel. In both cases a precise determination of the emerging beam parameter is mandatory for the fine tuning of the devices. The measurement of these parameters, in particular the emittance, is not trivial, mainly due to the large energy spread and tight focusing of these beams or to the background noise produced in the plasma channel. We show the problems related to the diagnostic of this kind of beams and the proposed or already realized solutions.

Poster Session: presentation of posters / 56

Initial operation of the tangential x-ray pinhole camera diagnostic system for KSTAR plasma

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A fast, two-dimensional (2-D) tangential soft x-ray pinhole camera (TXPC), which is a soft x-ray imaging diagnostic system with a wide angle toroidal view, has been developed for KSTAR plasmas. It consists of 50x50 channel multi-wire proportional counter (MWPC) filled with a gas mixture of 78% Kr, 20% C2H6, and 2% CF4 at atmospheric pressure and a selection of beryllium filters for discriminating low-energy photons. It can measure 2-D x-ray emissivity with a high and controllable intrinsic gain (> 10^4), high spatial (< 2 cm) and high temporal (> 10 kHz) resolution with a 100 MHz DAQ system. They can assist analysis of plasma profile, MHD modes, effects of auxiliary heating and transport phenomena from core to edge. Also, the TXPC employs a duplex multi-wire proportional x-ray (DMPX) detector that combines two MWPCs in series. It will provide simultaneous measurements of plasma x-ray emission in two spectral ranges using the first MWPC as an absorber filter for the second one. The signals of the first and the second MWPC allow providing the fast 2-D measurement of electron temperature by the two-absorber method. The TXPC system has been installed on KSTAR in 2011, and the initial plasma data and an assessment of the system performance are presented.

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Computational science and new perspectives for the analysis of massive data sets

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The last decade has witnessed an exponential growth in both size and quality of scientific data sets. The exploitation of the useful information in these Massive Data Sets (MDS) has triggered the birth of new disciplines, the so called X-informatics, which are at the crossroads of domain expertise, computer science, mathematics and statistics. X-informatics is being recognized as the "fourth leg" (after experiment, theory and simulation) of the scientific methodology. The various X-informatics (where the X stays for bio, astro, geo, chem, etc) share a common background of problems and methods which, in the near future, will necessarily become a crucial part of the cultural background of any scientist. The talk will present a short summary of these problems and methods and will focus on the specific problems (interoperability, scalability, data access, visualization, etc.) posed by the use of innovative data mining methodologies

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Laser frequency combs for optical diagnostic and spectroscopy

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Introduced in the late 1990s, laser frequency combs have revolutionized precise measurements of frequency and time. The regular pulse train of a mode-locked femtosecond laser can give rise to a regular comb spectrum of millions of laser modes with a spacing precisely equal to the pulse repetition frequency. Optical frequency combs have enabled the development of new ultra-precise optical atomic clocks and commercially available combs have quickly matured to routine instruments for precise optical spectroscopy. Emerging novel techniques for frequency comb generation include four-wave mixing of whispering gallery modes in microscopic toroidal optical resonators and hold much promise for on-chip miniaturized comb generators. Frequency combs are now becoming enabling tools for an increasing number of applications, from attosecond science to chemical sensing.

In this lecture, the principles of operation and advances in the technology of optical combs will be introduced. Recent promising applications of laser frequency combs to optical diagnostic will be reviewed. They include molecular spectroscopy, trace gas detection, interferometric distance measurements, optical coherence tomography and calibration of astronomical spectrographs.

Poster Session: presentation of posters / 59

Spectroscopic investigations of plasma in the range of very high frequencies

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Employing frequencies high than 13.56 MHz in capacitively coupled plasma reactors may result in a greatly improved performance in industrial plasma applications. For plasma diagnostic at such frequencies the method of emission spectroscopy is mostly preferable, since it is insensitive to discharge frequency (in contrast to Langmuir probe measurements). In this work we perform spectroscopic measurements of plasma emission at the discharge frequency which is varied between 13.56 and 260 MHz. The experimental chamber consists of two parallel plate electrodes of 3.8 cm diameter with the distance between the electrodes of 3 cm. The walls and the lower electrode of the chamber are grounded and the upper electrode is radio-frequency driven. The frequency is specified by the function generator, whose signal is amplified and applied to the plasma chamber. Using the power meter it is possible to measure forward and backward power and keep it fixed for the whole frequency range by matching the system with the phase shifter. The experiments are performed in argon gas at pressures of 20, 50 and 80 Pa. The light from the chamber is collected by small lens and guided to a spectrometer by an optic fiber cable. The results are analyzed using the collisional-radiative model.

Measurements of Temperature and Density / 60

Measurements of density fluctuations in magnetic confined plasmas

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Magnetic confinement fusion, which is one of two major branches of fusion energy research, has experienced major progress during the last decades. However, performances of actual magnetic confinement machines, such as tokamaks, are limited by the development of micro-turbulence that generates most of the radial transport of heat and particles. The prediction and the control of energy confinement, and therefore of performance of such machines are then important issues. A key element in the effort for understanding of turbulent transport is the confrontation between precise measurements and theoretical predictions.

Different types of diagnostic systems are generally used in order to measure and characterize various fluctuations in the core of hot magnetized plasmas, where probes and cameras are not usable. Among those are two major diagnostic families which rely on scattering of electromagnetic waves on plasma fluctuations. On one hand, there is reflectometry that uses microwave frequency range to obtain a cut-off layer inside the plasma. On the other hand, there are wave-scattering systems based on the detection of probing waves scattered by the fluctuations of the plasma.

The Doppler backscattering technique combines advantages of both reflectometry and scattering techniques. It is based on the detection of the field backscattered on density fluctuations in the vicinity of the cut-off layer. This technique gives access to both spatial scales and dynamic of density fluctuations and with a good spatial localization due to the presence of a cut-off layer. Doppler backscattering systems installed on the French tokamak Tore Supra, provides the repartition of energy fluctuation over the different spatial scales, which corresponds to the wavenumber spectrum, and radial profiles of density fluctuation velocity.

Description of these techniques and their applications on fusion plasmas micro-turbulence studies will be presented.

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Introduction of a single-shot electron bunch charge monitor with organic EO Pockels crystals

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We developed a three-dimentional electron bunch charge distribution (3D-BCD) monitor with single-shot detection. The monitor adopts a spectral decoding based Electro-Optic (EO) sampling technique that is non-invasive and enables real-time reconstruction of the 3D-BCD with 30- to 40-fs (FWHM) of noble temporal resolution. These goals are realized by simultaneously probing a number of Pockels EO crystals that surround the electron beam axis with hollow and radial polarized laser pulse. So far, such EO sampling based BCD monitors have been developed by utilizing inorganic EO Pockels crystals such as ZnTe and GaP and their temporal resolutions are limited to ~130 fs (FWHM). In the conference, these above backgrounds are briefly described and we will dedicate to focus on the introduction of organic Pockels EO crystals to the 3D-BCD monitor with some experimental results of feasibility tests and numerical calculations.

Poster Session: presentation of posters / 63

Tungsten spectroscopy for fusion diagnostics using the Shanghai permament magnet electron beam ion trap

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Using the Shanghai permanent magnet electron beam ion trap, Shanghai-PermEBIT, we have established a program on the spectroscopy of low to medium charge states of Tungsten. The motivation of this program is to provide spectroscopic data for Tungsten of interest to Tokamak fusion plasma diagnostics. Due to thermal and mechanical properties, Tungsten has been chosen as one of the materials which will face to the plasma in the ITER Tokamamk. Unfortunately, for diagnostic purposes, there is very little spectroscopic data for Tungsten in the charge states between W6+ and W28+. The atomic structure for many of the ions in this region is very complicated, and in some cases it is not even possible to easily establish the electronic ground configuration due to a conflict between 4f and 5p orbitals. For both W7+ and W27+ there is some evidence that the ground state is quite simple and, if the predictions are correct, a limited number of forbidden transitions should be observable in the visible spectral region. Accurate measurements of the wavelengths of these lines would give precise values for the ground state fine structures in these ions. These fine structures would in turn be useful for establishing more reliable theoretical models for these complex ions. There are also some previously observed lines from W13+ in the soft X-ray region. These observations indicate there should be a number of lines from close by charge states in the same wavelength region. Similar to the above, accurate wavelength measurements can help to establish good theoretical models for tungsten ions with charge states around 13+. This paper will describe some of our spectroscopic measurements to tackle the above mentioned problems.

Poster Session: presentation of posters / 64

ACTIVE PIXEL SENSOR AS DOSIMETRIC DEVICE FOR INTERVENTIONAL RADIOLOGY

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Interventional Radiology (IR) is a subspecialty of radiology comprehensive of all minimally invasive diagnostic and therapeutic procedures performed using radiological devices to obtain image guidance. The interventional procedures are potentially harmful for interventional radiologists and medical staff due to the X-ray diffusion by the patient's body. The characteristic energy range of the diffused photons spans few tens of keV. Individual operators safety is very important and is performed via effective dose (whole body) and equivalent dose (hands, arms, legs, lens and thyroid) monitoring.
In this work we will present a study of CMOS Active Pixel Sensors as sensor elements for an X-ray dosimeter prototype, capable of real-time measurements, packaged in a small form-factor, with wireless communication and no external power supply to be used for individual operators dosimetry for IR procedures.

The performance of several sensors, both research prototypes and standard CMOS imagers have been studied in realistic Interventional Radiology conditions.
Two dosimetric quantities have been studied, the number of detected photons and the measured energy deposition. Both show a linear dependence with the dose measured by commercial dosimeters. The uncertainties in the measurement are dominated by statistic effects and can be pushed below 5%.

The acquisition frequency can be kept at 1 Hz thus allowing a fast enough dose rate measurement. The high sensor segmentation permits to measure high photon fluxes (tens of thousands of photons in each frame) without signal saturation.

Another desirable characteristic of Active Pixel Sensors is the sensitivity to low energy photons (down to few keV) considerably lower than the commercially available dosimeters, allowing to measure this radiation component, important for the evaluation of epidermis damages.

We conclude that CMOS Active Pixel Sensors could be used as sensitive element for X-ray dosimeter in the energy range characteristic of IR procedures.

Poster Session: presentation of posters / 65

Neutral Particle Analyzer for Studies of Fast Ion Population in Plasma

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Analysis of the energy distribution of charge-exchange neutrals is an informative diagnostic for fusion plasmas. Both passive and active (beam-assisted) diagnostics of charge-exchange particles are widely used and different types of neutral particle analyzers based on electric or magnetic field for particle separation have been designed. With the recent achievements in electronics and particle detection technique, a new advanced neutral particle analyzer (ANPA) has been developed in the Budker Institute of Nuclear Physics for better performance and additional plasma diagnostic possibilities. In the analyzer, charge-exchange neutrals are stripped on a thin (10 nm) solid carbon film, accelerated and focused by an electric field, split in energies by a permanent magnet-separator, and separated vertically based on their masses by a transverse electric field. As a result, the energy distributions of both hydrogen and deuterium ions can be measured simultaneously. This feature makes it possible to perform a new class of experiments to distinguish between different sources of ions, such as originated by preliminary plasma, gas puffing, heating and diagnostic injection. The examples of such experiments may be measurements of mass dependence of lifetime, mean energy, spatial distribution of fast ions, or efficiency of gas puffing. Twenty channels of registration (ten for each mass) are used for detection of charge exchange particles. The channels cover energy range 0 – 40 keV with energy resolution of 2-3 keV. Calculations of registration efficiency show that analyzer can simultaneously measure ion temperature of bulk plasma from 500 eV and the energy distribution of fast ions in the range of 3-40 keV.
The analyzer was used in two plasma facilities with injection of fast neutrals – on the MST reversed field pinch (University of Wisconsin) and the field reversed configuration C-2 (Tri Alpha Energy). In this paper, the design of the analyzer, calculation of efficiency of registration, results of analyzer calibration and experimental results from MST and C-2 experiments are presented.

This work was partially supported by Russian Ministry of Education, Russian Academy of Science, Project N 30.

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A PASSIVE CHARGE EXCHANGE DIAGNOSTICS AT ADITYA TOKAMAK FOR ION TEMPERATURE ESTIMATION USING ELECTROSTATIC PARALLEL PLATE ANALYZER [EPPA]

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Passive CX-NPA has been designed and developed for the Aditya tokamak ion temperature measurement. Ion temperature measurements have been carried out by the energy analysis of passive Charge Exchange (CX) neutrals escaping out of the ADITYA-tokamak (Minor radius a = 25 cm, major radius R = 75 cm) plasma using a 45-degree Electrostatic Parallel Plate Analyzer [EPPA]. The upgraded the EPPA with its tested UV-rejection capabilities was found to perform during the APPS Plasma discharges with a fairly good signal to noise ratio of ~ 50.

Temporal evaluation of Ion temperature has been presented during the flat top of the plasma current and ion temperature for some recent APPS discharges were found to be typically 200 ± 30 eV (~ 40% to 45% of the central electron temperature). The results for the ICRH heating along with ohmically heated plasma discharges have also been discussed.

Key words: Tokamak, Ion temperature, Electrostatic Parallel Plate Analyzer [EPPA].

Poster Session: presentation of posters / 67

Statistical analysis of Plasma Shape Influence on the Power Threshold to access the H-mode

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Various empirical models are available to determine the power threshold between the L and H mode of confinement. They are typically the results of regression analysis of the data collected in different machines and they are presented in terms of equations in power law monomial form. Even if the positive effects of the plasma shape on the confinement time have been clearly documented, the dependence of the L-H power threshold on elongation and triangularity is still an aspect no completely clarified. In this paper, linear and nonlinear regression are applied to the ITPA database to determine the empirical scaling laws to access the H mode. The dependence on elongation and triangularity is first formulated as a hypothesis testing problem for each individual device. Once determined on which machines there is evidence for this dependence to be statistically significant, various model selection techniques have been applied, to determine the most likely values of the exponents for elongation and triangularity. The main results of this analysis is that the dependence on elongation and triangularity is different for individual machines, which questions the statistical relevance of building multi-machine databases to extract a general scaling laws for these two variables.

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Two-pulse Thomson Scattering System for Measurements of Fast Fluctuation of Electron Density Profile in Multi-Mirror trap GOL-3

Dr. POPOV, Sergei [1]; Prof. BURDAKOV, Alexander [1]; IVANTSIVSKIY, M.V. [1]; KASATOV, A.A. [2]; Dr. POLOSATKIN, Sergey [3]; POSTUPAEV, V.V. [1]; VYACHESLAVOV, L.N. [1]

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At the GOL-3 set up in BINP experiments on studying the relaxation mechanism of a powerful relativistic electron beam, and plasma confinement in multimirror magnetic field are carried out. At present, the mechanisms of generation of microwave radiation in plasma with Langmuir turbulence are investigated. An important place in these studies is the observation of the dynamics of plasma density in the spatial and temporal scales typical for turbulent processes. These include the modulation instability and Langmuir collapse observed in beam-plasma experiments [1]. Characteristic time scale in similar plasma [1] can be reach order of 10 ns, the spatial - the order of 1 mm. Measuring the density dynamics of high-temperature plasma with a similar time resolution represents a significant challenge. Traditional approach (repletion-rate, burst-mode) [2] is not applicable under the experimental conditions on the GOL-3. Therefore double-pulse Thomson scattering system has been developed [3].
This paper presents the modification of Thomson scattering system for studying the density profile dynamics, which allows measurements at 8 points along plasma radius at two points in time. Two pulses from a neodymium laser λ = 1054 nm, with a time interval between t = 60-150 ns, the energy E = 10-20 J and a duration of τ = 20-40 ns, have been used for scattering in the plasma.
In result from the experiments the data on a fast local dynamics of the plasma density in the various operation regimes have been obtained. The dynamics of the plasma density in some registration channels has reached 30% in during 100 ns.
This work was supported by the Ministry of Education and Science, grant № 11.G34.31.0033 from Russian government for scientific research under the direction of leading scientists at Russian institutions of higher education on November 24, 2010.
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Development of a hardened imaging system for the Laser MegaJoule

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The Laser MegaJoule (LMJ) facility will host inertial confinement fusion experiments in order to achieve ignition by imploding a Deuterium-Tritium target. In order to understand reasons for failures, a X-ray imager is necessary to diagnose the core size and the shape of the DT-microballoon in the 10-100 keV band in complement of neutron imaging system. Such a diagnostic will be composed of two parts: an X-ray imaging system and a detection assembly. Each element might be affected by the harsh environment created by fusion reactions.

The design of this diagnostic will take into account optics and detectors vulnerability up to a maximum neutron yield of 1016 in 4π sr.

One way to protect the diagnostic from particles generated during the implosion consists in recording image in a shielded box. The X-ray image of the core will be formed on a scintillator through the X-ray optical system. Then the image is converted into visible light by the scintillator. It is easily transferred through an optical relay to shielded box and finally focused on a detector.

A work of optimization, including Monte-Carlo simulation and experimental studies, is led to maximize the X-ray core emission sensibility and minimize neutron and gamma ray response. Two optical relay systems have been exposed to harsh environment and have been compared in terms of robustness.

First experimental results tend to promote one solution but a compromise between optical performance and robustness might still be found.

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Compact Spectrometer for On-Line Photon Diagnostics at FLASH

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We present the design and characterization of a compact and portable spectrometer especially realized to analyse in real time the high-order harmonic contents of the FEL beam at FLASH.
The instrument can be installed behind a generic experiment, at the end of a FEL beam line. It can monitor both the fluctuations of the fundamental FEL emission and its high-order harmonic content. The design is based on the use of two flat-field grazing-incidence gratings and a EUV-enhanced CCD detector to cover the spectral range 2–40 nm. The absolute response of the instrument has been calibrated in the whole spectral region of operation to make calibrated measurements.
We present here the design of the instrument, the calibration procedure and some experimental data taken at FLASH in the beamline BL1. High-order harmonic emission up to the V harmonic has been measured.

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Evaluation of energy distribution of quasi-monochromatic x-ray beams for sources with extremely high instantaneous flux using k-edge subtraction technique

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The characterization of novel x-ray sources includes the measurement of the photon flux and the energy distribution of the beam produced.
The aim of BEATS2 experiment at INFN-LNF is the study of medical applications of an x-ray source based on Thomson relativistic backscattering. This source is expected to produce pulsed quasi-monochromatic x-ray beam with an instantaneous flux of 10^20 ph/s in pulses 10 ps long and with an average energy of 20 keV.
A direct measurement of energy distribution of this beam with traditional detectors, such as HPGe, CZT or CdTe, is very difficult because of the extremely high photon flux. For this reason we have planned to use a technique based on beam filtration using k-edge absorbing foils in the energy range of interest (16-22 keV).
The measurement system is made of a free-air ionization chamber, a filter-wheel and a silicon PIN photodiode. The ionization chamber is used as beam monitor, in order to check the shot-to-shot repeatability. The filter-wheel is equipped with foils of Al, Mo, Nb and Zr. The thickness of each filter is chosen in such a way that the attenuation of photon with energy lower than the k-edge is the same for all materials. Thus the difference of the signals induced in the silicon photodiode by the beam attenuated with two different filters is related to the number of photons in the energy band ranging between the k-edges. By knowing the response function of photodiode is possible to reconstruct the energy distribution of the unfiltered beam from the subtraction of photocurrents induced by filtered beam.
The technique was tested using an x-ray tube with a tungsten anode at 22 kVp, filtered with 3.1 mm of Al providing an x-ray spectrum with an energy distribution similar to that expected from Thomson source.
In order to verify the proper selection of the filters thicknesses, the spectra transmitted by foils of Al (1.30mm), Mo (98 microns), Nb (125 microns) and Zr (175 microns), having k-edge energies at 20 keV, 19 keV and 18 keV respectively, were acquired with an HPGe detector.
Then the method has been tested by measuring the photocurrent induced in the PIN diode by the beam transmitted by the filters. The comparison between the results obtained analyzing the full measured spectra and those of the k-edge subtraction technique showed good agreement, confirming the goodness of the method.

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Characterization of laser plasma coupling in the Shock-Ignition Regime

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In 2007 Betti et al. [1] proposed a novel approach to ICF. It consists of igniting the target by a very strong converging shock (P≈ several hundreds of Mbar), produced by intense laser spikes (1e16W/cm2). The shock must hit the target at the end of the compression phase and before the stagnation of the target center. The scheme represents a very attractive solution for HiPER high repetition rate regime. Within this framework, we performed an experiment at the Prague Asterix Laser Laboratory, using two beams of the PALS source, with time duration of 300ps. The first beam, at intensity I=1.2 e13W/cme2, was used to create almost 1 mm preformed plasma, and the second, at I=10e16W/cme2, to create the shock for compressing the central part of the pre-compressed fuel and reaching ignition conditions.
Several diagnostics were employed to characterize either the preformed plasma (Phase 1) or the shock formation and laser plasma interaction Phase 2). They include: Phase 1 – X-ray deflectometry for the plasma density profile; X-ray spectroscopy and x-ray pin-hole cameras to get plasma temperature but also to give evidence of the presence of hot electrons.
Phase 2 – Energy Encoded pin-hole camera to measure plasma extension and characterize its emission; shock cronometry to measure the ability to produce a strong shock and the effect of the extended plasma corona on the laser-shock coupling; optical imaging, spectroscopy, and calorimetry to get the amount of backreflected light from parametric instabilities (SRS, SBS, TDP).

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Multi-Purpose Fast Neutron Spectrum Analyzer with Real-Time Signal Processing

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Neutron counting is one of most important diagnostic tool of high-temperature plasma experiment. Informativeness and relevance of this diagnostic can be increased with analysis of shapes and amplitude distribution of count pulses, which allows to separate gamma-quanta background and pulse overlapping, or to find timing of the counts in relation to some events in plasma. At the same time modern fusion plasma facilities with quasi-continuous regime of operation issue the challenge for such analysis because of the huge amount of memory needed to store the primary data from detector. A solution is to combine DAQ electronics with real-time signal processing that should implement algorithms of pulse shape analysis. This approach can significantly reduce the flow of data and possibly even include this diagnostic to a facility feedback system.

In the Budker Institute of Nuclear Physics (Novosibirsk, Russia) multi-purpose neutron spectrum analyzer with real-time signal processing has developed. Detector part of the analyzer consisting on stilbene crystal and spectrometric PMT responds to incoming particle by 20-ns-wide pulse with a tail sensitive to a sort of the particle (neutron or gamma). DAQ electronics includes 12-bit 500 MHz ADC and the FPGA-based unit of stream data processing. Processing algorithms in controller firmware can be modified according to the required task, that allows to use analyzer in the wide range of different applications. The analyzer was tested and calibrated with 252Cf source, and then have been used in fusion experiments on GDT facility as well in development of pulsed neutron generators for industrial applications.

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Analysis of JET Polarimeter Lateral Chords with a dedicated Propagation Code

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Internal magnetic measurements are essential to obtain reliable and accurate magnetic reconstructions in the interior of the plasma column in Tokamaks. In the last years, polarimetry has been increasingly used to provide global constraints to equilibrium codes. JET polarimeter1 has four vertical and four lateral chords, whose arrangement is similar to the topology of the diagnostic foreseen in ITER. Analysis of JET polarimetry measurements were carried out for vertical chords using a polarimetry propagation code based on Stokes vector formalism2. A new propagation code has been developed therefore for lateral chords to simulate and interpret the measurements of the Faraday rotation and Cotton-mouton phase shift in JET. After proper benchmarking with experimental measurements, the code has been used to study the effect of the input polarisation on the quality of the measurements. The results allow to choose the best polarisation to optimise the polarimetric measurements for the various experiments. Polarimetry can also be used to complement the density measurements of interferometry (and of the other diagnostics providing the electron density). Therefore an analysis of the various approximations to obtain the line integrated density from the Faraday angle/Cotton Mouton Phase shift have also been performed.

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Development of a 1D Triple GEM X-ray detector for a high-resolution x-ray diagnostics at JET

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ITER-oriented JET research program imposes new requirements on the high-resolution X-ray diagnostics instrumentation (KX1) for the impurity monitoring. Therefore, in addition to the upgrade of the Ni monitoring diagnostics system, one has to design and construct a new diagnostic instrument implemented in the same KX1 spectrometer for W impurity monitoring. Both, Ni and W characteristic X-ray lines at 7.8 and 2.4 keV, respectively, will be measured by new generation energy-resolved micropattern gas detectors with 1-D position reconstruction capability. The detection structure is based on triple GEM (T-GEM) amplification structure followed by the strip readout electrode. Each detector will consist of the strip readout plane with 0.8 mm pitch (256 strips in each detector). The analog signal processing electronics should allow on-line energy measurement and position reconstruction with the precision better than the strip pitch. The monitoring system should allow the measurements of the plasma evolution in time-slices corresponding to 20 ms exposures. Two such processing units dedicated to the 'low-energy' (2.4 keV) and 'high-energy' (7.8 keV) X-ray emission will be installed at KX1 at the end of 2011. The main objectives and characteristics of the new detectors for the KX1 diagnostics are described. The first laboratory tests of the prototype T-GEM detector are also presented.

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Preliminary investigations of Equilibrium Reconstruction Quality during ELMy and ELM-free phases on JET

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On JET the magnetic topology is normally derived from the code EFIT, which solves the Grad-Shafranov equation with constraints imposed by the available measurements, typically the pick-up coils. Both the code and the measurements are expected to perform worse during ELMs. To assess this hypothesis, various statistical indicators, based on the values of the residuals and their probability distribution, have been calculated. They all show that the quality of EFIT reconstructions is clearly better in absence of ELMs. The use of internal magnetic measurements, in particular the Faraday rotation measured by polarimetry, does not change significantly the results of the analysis. How the responsibility, for the lower quality of the reconstructions, is shared between the measurements and EFIT is a subject under investigation.

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Optical characterization of lithium fluoride detectors for broadband X-ray imaging

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Novel X-ray imaging detectors based on photoluminescence of color centers in lithium fluoride have been proposed and tested for extreme ultraviolet, soft and hard X-rays up to 10 keV. For the first time we present the optical characterization of LiF crystals and thin films irradiated at the TOPO-TOMO beamline of synchroton light source Anka (Karlsruhe, Germany) in the energy range (2-40 keV) for several exposure times. Absorption and photoluminescence spectra were analysed to obtain the optical response of the LiF-based detectors, which are characterized by a linear behaviour over two decades in the investigated radiation dose interval. High resolved X-ray imaging of commercial test patterns has been obtained on LiF crystals and films by optical readout with a confocal laser fluorescence microscope.

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A new GEM based neutron diagnostic concept for high power deuterium beams

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The ITER neutral beam test facility under construction in Padova will host two experimental devices: SPIDER, a 100 kV negative hydrogen/deuterium RF source, and MITICA, a full scale, 1 MeV deuterium beam injector. A number of diagnostics will be deployed in the two facilities to qualify the beams [1]. This paper reports the design of a neutron diagnostic for SPIDER, as a first step towards the application of this diagnostic technique to MITICA, where it would be particularly useful to resolve the horizontal beam intensity profile.
The proposed detection system is called CNESM which stands for Close-contact Neutron Emission Surface Mapping. The CNESM diagnostic is placed right behind the SPIDER beam dump, as close to the neutron emitting surface as possible and aims at providing the map of the neutron emission on the beam dump surface.
The CNESM uses nGEM as neutron detectors [2]. These are Gas Electron Multiplier equipped with a cathode that also serves as neutron-proton converter foil. The cathode is at about 30 mm from the beam dump front surface. It is designed to ensure that most of the detected neutrons at a point of the nGEM surface are emitted from the corresponding 40x22 mm2 beamlet footprint on the dump front surface. The nGEM readout pads (area 20x22 mm2) will record a useful count rate of ≈5 kHz providing a time resolution of better than 1 s. Each nGEM detector maps the neutron emission from a group of 5x16 beamlets: 16 nGEM would be needed to cover the entire beam dump.
The diagnostic was designed on the basis of simulations of the different steps from the deuteron beam interaction with the beam dump to the neutron detection in the nGEM. The deuteron deposition inside the dump was simulated with the TRIM code providing the deposition profiles. Neutron scattering was simulated with the MCNPX code. The scattering contribution is estimated at ≈10% of the neutrons recorded by the nGEM when only neutrons with energy > 2 MeV are detected. The directional response of the nGEM to neutrons reduces the scattering contribution to a much lower level.
The CNESM can be complemented by a number of Fission Diamond Detectors (FDD) [3]. FDDs combine the neutron response of a uranium foil with the radiation hardness of a diamond detector. FDDs can be mounted directly on the beam dump and can operate in vacuum as well as at room pressure.
The main difference between SPIDER and MITICA is the x100 larger neutron fluxes expected. This requires a reassessment including further tests of the radiation hardness of the signal readout electronics. The beam dump geometry with alternating 20 mm diameter swirl tubes means that the detectors can be placed at a distance ≈40 mm from the neutron source compared to ≈30 mm on SPIDER. The effective spatial resolution of the measurement will scale with the achieved source-detector distance.

This work was set up in collaboration and financial support of F4E.

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Poster Session: presentation of posters / 80

LiF detectors-Polycapillary Systems as a New Approach for Advanced X-Ray Imaging

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One branch of X-ray imaging studies at X Lab Frascati has been dedicated to the design of novel optics-detector solutions aiming in creating a compact laboratory X-ray microscopy apparatus. Based on our experience in the use of both capillary/polycapillary optical systems and LiF imaging detectors we have recently tested a new combination of these techniques. The potential of the optics both to concentrate and to shape X-ray radiation enforced by the high performances in terms of spatial resolution/dynamic range of LiF imaging detectors allow us to use very simple imaging techniques, like the contact one, particularly suitable for compact imaging systems. In this report we are going to present our first results on submicron X-ray imaging of solid thick samples, as well as possible future development of the proposed schemes in the fields of biomedical imaging, characterization of X-ray sources, material science, photonics, etc.

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First preliminary results from the new sub-PetaWatt FLAME facility.

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A new era of laser based plasma accelerators is emerging following the commissioning of many high power laser facilities around the world. Extremely short laser pulses with energy of few or multi-joule level are available with these newly built facilities.

Preliminary results obtained last year at LNF with the sub-PetaWatt FLAME facility during the first phase of the self-injection test experiment (SITE) up to Joule level will be discussed with an overview on laser beam quality and effects on accelerated electrons beam. Different regimes will be shown to be indicated for various applications from high-energy physic to radio-biological and medical applications.

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New diagnostics for density measurement on Frascati Tokamak Upgrade.

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The plasma density in tokamaks, as in many laboratory plasmas, is measured using plasma optical properties at appropriate wavelength. The mostly applied technique is the interferometry but also other techniques as the reflectometry, polarimetry and time-of-flight radar are employed. Recently in FTU, a CO/CO2 scanning interferometer and a time-of-flight radar (denominated refractometry) has been installed. The first, using two scanning beams, can provide a plasma density profile every 62.5 μs (8 kHz scanning frequency). Two lasers are employed a 10 W CO2 (λ=10.6 μm) as main wavelegth and a 1W CO (λ = 5.4 μm) for compensation of mechanical vibration of optical components. The scanning component is a small mirror (∅=5 mm) resonantly tilting at 8 kHz. The oscillation is compensated by a double pass into this mirror. The time-of- flight refractometer is a two frequencies radar (50.5 and 60.5 GHz) which measures the plasma refractive index from the delay time of an RF pulse that goes through the plasma and is reflected back by the metallic vacuum vessel.

A brief description of various techniques for the density measurements in tokamaks will be presented analyzing in details the two diagnostics recently installed in FTU.

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Diagnosing transient fusion plasmas with neutrons – recent progress in time-of-flight and thin-foil proton recoil techniques

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Neutron spectroscopy has proven to be a versatile method for probing the state of plasmas (fuel) used in fusion energy research. Therefore, it is likely that the next generation fusion experimental reactors, like ITER, will be equipped with a suit of neutron spectrometers. Parameters like fuel ion temperature, fuel ion non-thermal energy distribution, fuel ion density, fusion power, etc. can be extracted from data provided by such instruments. However, the application of neutron spectroscopy to fusion plasmas put special demands on the instruments. Since fusion plasma conditions can vary rapidly, one of the most important requirements is high count rate capability to provide data of high statistical significance over short time periods and thereby good time resolution in the extracted plasma parameters. This requirement can be met in different ways depending on plasma conditions and the diagnostic technique employed. In addition, the harsh radiation and demanding interfacing conditions on ITER can restrict the application of certain techniques. In this contribution we review recent progress in two of the most promising neutron spectroscopy techniques suitable for ITER, namely, the time-of-flight (ToF) and the thin-foil proton recoil (TPR) techniques.

In fusion time-of-flight neutron spectroscopy the highest signal rates to date have been achieved with the TOFOR spectrometer at JET. Signal rates of about 50 kHz over several seconds were achieved in high performance plasma operations in 2009, with a maximum signal rate capacity estimated to 500 kHz in 2.45 MeV neutron measurements. At such rates it has until recently been possible to record only the most crucial event information, i.e., the precise time of each eligible event; additional event information (e.g. pulse heights) has been sacrificed for the sake of acquisition speed. Developments in digital data acquisition technology has now made it possible to record correlated time and pulse shapes (energy) at rates approaching those required for use in high-rate ToF applications. We present results from tests on a set of data acquisition boards provided and customized by Signal Processing Devices. The boards digitize the detector pulses at rates up to 2 Giga-Samples per Second with 12 bit ADC resolution, as well as offering flexible triggering and time synchronization options – we show that such cards indeed are suitable for the intended ToF application.

As shown by the present MPR installation on JET, the thin-foil proton recoil technique can provide results of high quality in the most demanding fusion experimental conditions (high power DT plasma discharges). The non-magnetic TPR technique is an interesting option for a 14-MeV neutron spectrometer on ITER as it combines many of the positive traits of the MPR with a simplified interfacing, due to the absence of a magnetic spectrometer. We show results from simulations of TPR performance in terms of signal to background, and indicate a conceptual design of a TPR instrument for ITER.

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Classification and dimensionality reduction of international tokamak confinement data on a probabilistic manifold

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Any measurement process involves the sampling from a latent probability distribution. This distribution contains all information about the quantity of interest and learning algorithms can benefit considerably from the inclusion of probabilistic information. The field of information geometry, which is well-established from the theoretical point of view, describes probability distribution families using the framework of differential geometry. The Fisher information serves as a metric tensor and allows the calculation of geodesic distances (GDs) between distributions. Equipped with a genuine distance measure, machine learning techniques can be adapted to operate on probabilistic manifolds, enabling regression, classification and dimensionality reduction. In this work we concentrate on classification and dimensionality reduction, with an application to the public international database (PID) of tokamak confinement data. We model each physical variable with a Gaussian distribution and, with the aid of the GD, we show that this leads to an improved performance of classification according to the confinement mode, compared to the classification of only the measured values in a Euclidean space. We furthermore compare a k-nearest-neighbor classifier with a support vector machine algorithm using a geodesic kernel. We also consider projection of the data on a tangent plane at the geodesic centroid of the data cloud, followed by classification in this hyperplane. We next show the advantage of dimensionality reduction of the confinement data on a Gaussian probabilistic manifold, respecting the inherent probabilistic nature of both the original and the reduced space for dimensionality estimation.

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Effects of the finite beam size of the ECE diagnostic in Tore Supra tokamak

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Tore Supra is a French tokamak with a circular cross section of 2.4m of major radius and 0.7m of minor radius. The ECE diagnostic of Tore Supra [J.-L.Ségui, Rev. Sci. Instrum. 76 (2005) 123501] has 32 channels which signals can be recorded in two acquisition rates: the slow mode, at 1kHz, which register the ECE measurements during the whole discharge and the fast acquisition mode, recently upgraded to 1MHz, which can recover up to 7s of measurements in selected time intervals (the duration of a plasma discharge in Tore Supra ranges from tens of seconds up to few minutes). The ECE antenna is placed on the external equatorial plane of the vacuum vessel and in the most usual plasma conditions (it is, central magnetic field of 3.8T and plasma current of 1MA) the ECE is able to cover a radial interval that corresponds to more than half of the plasma column.
This work reports a study of the ECE measurements of core MHD modes. It is observed that the measured signal of modes with poloidal mode numbers equal or bigger than 2 are strongly affected by the finite size of the ECE beam. Indeed, the profiles of the ECE oscillations have radial structures that are much more complex than the real electronic temperature oscillations. It will be presented a simple model of the ECE measurements that can reproduce the observed complex radial structures. Moreover, it will be shown how the poloidal mode numbers can be determined from the ECE measurements thanks to these effects. On the other hand, due to this effect the phase shift between ECE measurements in two radial positions are not exactly equal to the phase of the electronic temperature at those positions. It will be shown than this difference implies in several restrictions for advanced uses of the ECE measurements, for example, when using ECE to perform tomographic reconstructions or to evaluate MHD displacements or when computing the phase shifts with measurements from other diagnostics.

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Measuring density in the ITER fusion plasma

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The operation of ITER requires high-quality estimates of the plasma density over multiple regions in the plasma for plasma evaluation, plasma control and machine protection purposes. Although the density regimes of ITER are not very different from those of existing tokamaks (10^18 – 10^21 m^-3), the severe conditions of the fusion plasma environment present particular challenges to implementing these density diagnostics. An overview will be presented of the array of ITER density diagnostics designed to measure over the entire ITER regime: plasma core, pedestal, edge, scrape-off layer and divertor. It will focus on the challenges faced in making these measurements, and the technical solutions of the current designs.

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The calibration features of Thomson scattering diagnostics for ITER divertor

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The Thomson scattering (TS) diagnostics for ITER divertor will operate using a number of optical elements placed inside the vacuum chamber. The survival of front-end optical components has been discussed since the ITER project started. Nevertheless, no solution guaranteeing operational stability of all in-vessel optical components in ITER has been found up to now.
Because of possible degradation of in-vessel optic spectral transmission resulting in the TS spectra distortion and following inaccuracy in ne and Te measurements, the repeated recalibrations are required during operational lifetime. Relative calibration of spectral channels sensitivity is usually performed with a blackbody radiation source illuminating all or more frequently only part of the collection optics. Two calibration methods are being proposed for the ITER divertor TS system: a) a diffuser or retroreflector array with internal light source or back illumination scheme [1] and b) the Raman scattering on the gas target. The latter is discussed in this report.
Raman scattering on different gases is a technique routinely used for calibration in a number TS system in the world [2-5]. This technique gives possibility to measure collection optics transmittance for all working spectral range. The main problem for implementation this technique in ITER is that the application of usually used nitrogen will be probably restricted since any off-nominal gases in ITER may be taboo. The comparable assessment of the calibration technique for the use of nitrogen, hydrogen and deuterium is fulfilled with a view of implementation for divertor TS calibration.

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Poster Session: presentation of posters / 88

Spectral and intensity diagnostics of the SPARC free-electron-laser

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We present the instrument that is used for the spectral and intensity diagnostics of the SPARC FEL test facility. The SPARC FEL is composed by a high brightness accelerator providing a high quality beam at energies between 110 and 180 MeV and an undulator beam line composed by six, variable gap, modules. The flexibility offered by the variable gap configuration of the SPARC undulator and the natural synchronization of the electron beam with the laser driving the photo-injector, makes the SPARC layout particularly suited for a number of experiments, where the FEL amplifier is seeded by an external laser source. Both chirped pulse operation in the SASE mode and seeded emissions have been demonstrated.
The spectral and intensity diagnostics at SPARC are performed through a normal-incidence grating spectrometer designed and realized by CNR-IFN. The instrument hosts three interchangeable gratings covering the 40-600 nm spectral region and an EUV-enhanced CCD detector. The spectral resolution in the single pixel is in the range lambda/(Delta lambda) = 5000-10000, giving the FEL spectrum in the single-shot operation with high resolution.
Furthermore, all the optical elements after the exit from the last undulator module, i.e. the mirror to deviate the light toward the spectrometer, the gratings and the CCD detector, have been calibrated, to obtain finally the total absolute response of the instrument in the whole spectral range of operation. This allow to measure also the absolute intensity of the FEL emission.
The design, characterization and calibration of the instrument will be presented. Some results obtained at SPARC will be discussed.

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NUMERICAL METHOD TO STUDY AN SPR SENSOR

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The applied studies based on the resonance of the surface Plasmon's are particularly interesting for different stains; notably the utilization as sensors. Indeed, several studies carried, with the aide of the numeric simulations, on the optimization of the performances of the static and dynamic sensors thus that on some bio-sensors.
Some works on the process of realization of the midget sensors to optic fiber are in progress [1]. The elaboration and the characterization one SPR sensor is therefore the objective of our work, this type of sensor having a good sensitivity and a good precision necessitates some conditions of preparation, on the excitation system, in this paper we present some profiles permitting the exploitation of the technique like bio-sensor.
Others works on SPR sensors has to use optic fibers using the optic configuration of Kretschmann allowed to reach some substantial results notably in the domain of the cosmetics or alimentary. The results are obtained has it helps some analytic patterns in order to describe the SPR resonance in an optic fiber, in taking into account at the same time of the variations of angles and some variations of lengths of wave[3,4]

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Electron Cyclotron Emission Imaging of Magnetic Fusion Plasmas

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2D Electron Cyclotron Emission Imaging (ECEI) is a unique radiometric technique for real time imaging of the high temperature structures and fluctuations in toroidal fusion devices with high spatial and temporal resolution. Since the initial prototype system installed on the TEXTOR tokamak, it has matured into a powerful diagnostic tool for plasma visualization with systems installed on major fusion devices around the world including AUG, DIII-D, EAST, HL-2A and KSTAR. ECEI systems have contributed greatly to the understanding of core MHD physics such as Alfvén eigenmodes, sawteeth, Neoclassical Tearing Modes, and Edge Localized Modes. Details regarding the ECEI technique, as well as new advances in ECEI hardware and analysis techniques which continue to expand the scope and flexibility of the diagnostic, will be presented.

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Calibration of Image Plate response to energetic Carbon ions

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A wide range of detectors has been developed to reveal the different existing types of radiation. Among those detectors, scintillators are a broadly used option. The Image Plate (IP) is a type of scintillator and is made of phosphors with phosphorescent properties which can release the store energy in a long-lasting de-excitation (typically few hours). The energy stored in the IP can be retrieved by stimulating the excited metastable state. The stimulation can be done by photons, and then the energy is released as light and called photo-stimulated luminescence (PSL). The PSL signal emitted during the reading of the IP is proportional to the energy stored in the IP active medium. The IP has a high sensitivity to the stimulating radiation and the response to the signal is very well linear in all the dynamic range that is about five orders of magnitude.
The response of the IP detector type BAS-TR to protons has been reported in earlier works[1,2]. We present here results providing the calibration of the IP response to high energy Carbon ions. The experiment was performed at the Rutherford Appleton Laboratory (RAL), using the Vulcan laser that operates in the infrared range and can deliver onto the target an intensity of the order of 10^20 W/cm2. Such an intense laser pulse can generate, by the well-known TNSA mechanism[3], protons and ion beams from hydrocarbons and water vapour impurities usually present on the target surface. In particular, we were able to generate carbon ions in a broad energy range useful for calibration purposes (i.e. up to 40 MeV Carbon ion). In order to obtain the calibration of the IP for Carbon ions of different energies, a Thomson Parabola is used to disperse the ion beam onto the CR39 and IP. A system make of a slotted CR39 placed on the IP was used as detector so that carbon ions having reasonably close energies can be recorded at the same time around the edges of the slots, both on the CR39 and IP. The PSL signal from the IP and the pits number on the CR39 were compared at a given ion energy, giving a calibration curve as the ratio of those two values, PSL/Carbon. The IP showed the ability to detect even a single carbon ion in the range investigated, ranging from 0.5 to about 3.3 MeV/nucleon.

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Energy Spectrum of Particles / 93

Fast Proton Diagnostic in Inerzial Fusion experiments

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A new era of plasma science started with the first experiments on the National Ignition Facility (NIF) in the US and will be soon followed by the Laser Mégajoule (LMJ) in France.
Such facilities, whose one of the objectives is to reach the ignition by imploding deuterium-tritium targets using high-energy laser beams, will provide a unique tool not only for ICF physics but also for basic science fields such as astrophysics, planetary & stellar science, nuclear & physics.
A petawatt short pulse laser will be added to the ns pulse beams of the LMJ. This is the PETAL system (PETawatt Aquitaine Laser), under construction on the LMJ site near Bordeaux (France), with the ultimate goal of reaching 7 PW (3.5 kJ with 0.5 ps pulses). In a first phase (beginning in 2015) PETAL will provide 1 kJ in 1 ps and will be coupled to the first four LMJ Quads. Once in operation, LMJ & PETAL will form a unique facility in Europe for High Energy Density Physics (HEDP).
PETAL is aiming at providing secondary sources of particles and radiation to diagnose high energy density plasmas generated by the LMJ beams..
The Petal+ project is a dedicated one to design and to provide diagnostics dedicated to experiments with PETAL laser beam.
Within this project, three types of diagnostics are planned: a proton spectrometer, an electron spectrometer & a large-range X-ray spectrometer. Because of the particular characteristics of the PETAL beam, large dynamical ranges have to be covered by these diagnostics. The goal of these diagnostics will be to assess the characteristics of the secondary sources produced with PETAL, as well as the performance of PETAL itself. Further diagnostics will be installed in the future on the LMJ/PETAL facility to allow HEDP experiments.
During the presentation to the conference, the PETAL & Petal+ projects will be presented in detail, in particular the first three diagnostics planned for 2015.

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Satellite Meeting / 94

Terrestrial Gamma-ray Flashes

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Lightning and thunderstorm systems in general have been recently recognized as powerful particle accelerators, capable of producing electrons, positrons, gamma-rays and neutrons with energies as high as several tens of MeV. In fact, these natural systems turn out to be the highest energy and most efficient natural particle accelerators on Earth. Terrestrial Gamma-ray Flashes (TGFs) are few milliseconds long, very intense bursts of gamma-rays and are one of the most intriguing manifestation of these natural accelerators. Only three currently operative missions are capable of detecting TGFs from space: the RHESSI, Fermi and AGILE satellites. The basic physical mechanism responsible for TGF production is commonly believed to be the so called Relativistic Runaway Electron Avalanche (RREA) process, which allows a seed electron of sufficiently high energy in a thundercloud electric field to overcome the friction force and increase its energy up to relativistic values, and possibly produce secondary electrons that can drive an avalanche multiplication. Subsequent collision of relativistic electrons with air molecules lead to gamma-ray production by Bremsstrahlung, while further interaction of gamma-rays with matter can produce electron-positron pairs and neutrons. Although this model is widely accepted, there are several points still obscure, namely: the highest achievable energies, which translates into the maximum voltage drop that can be established within thunderclouds, the connection with lightning and cloud microphysics and the overall occurrence rate of TGFs. In this presentation I will review the characteristics of TGFs and the basic principles of the associated production models. Then I will focus on the recent AGILE discoveries concerning the high energy extension of the TGF spectrum, which is difficult to reconcile with current theoretical models.

Techniques of Analysis of Massive Database / 95

Valid Predictions for Diagnostic Purposes

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The application of traditional machine-learning algorithms to modern high-throughput and high-dimensional (with many thousands of features) data sets often leads to serious computational di culties. Several new algorithms, foremost support vector machines (SVM) and other kernel methods, have been developed recently with the goal of tackling highdimensional problems. However, a typical drawback of the new algorithms is that they usually do not provide any useful measures of con dence in their predictions for new unclassi ed examples.

This talk will describe a novel technique for \hedging" predictions produced by the new and traditional machine-learning algorithms, including, for example, SVM, (kernel) ridge regression, (kernel) nearest neighbors, (kernel) logistic regression, decision trees, boosting, and neural networks. We call our algorithms for producing hedged predictions conformal predictors [1, 2].

The basic ideas of this approach are closely connected to the problem of de ning random sequences, and the ideal conformal predictor can be constructed using the universal notion of algorithmic randomness. This notion was de ned by A. Kolmogorov, P. Martin-L of, and L. Levin based on the existence of universal Turing machines. Because of its universality, algorithmic randomness is not computable, and conformal predictors are based on computable approximations to it. It has been shown that such approximations can be developed using typical machine-learning algorithms; for example, for SVM the Lagrange multipliers of the support vectors can be used to approximate the randomness level of the data set.

The talk will introduce this method, paying particular attention to the following advantages of the hedging technique:

- it gives provably valid measures of con dence, in the sense that they never overrate the accuracy and reliability of the predictions;
- it does not make any additional assumptions about the data beyond the IID assumption (the examples are independent and identically distributed);
- it allows to estimate the con dence in the prediction of individual examples;

1

- conformal predictors can be used as region predictors, allowed to output a range of labels as their prediction, so that one can control the number of erroneous predictions by selecting a suitable con dence level;
- the well-calibrated prediction regions produced by conformal predictors can be used in both on-line and o -line modes of learning, as well as in several intermediate modes, allowing, for example, \slow" and \lazy" teachers.

Applications of conformal predictors to a number of real-world problems, including medical diagnosis, homeland security, automated target recognition have already been successful. The results of these applications will be presented and discussed.

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Measurements of Temperature and Density / 96

"The challenge of producing narrow bandwidth high brightness gamma ray beams"

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Nuclear Photonics is an emerging field of physics research, promising new advancements both in fundamental knowledge of nuclear physics, and in envisioning new technologies for nuclear engineering, mainly in the fields of national security and radioactive waste treatment, and, eventually, astrophysics related studies. The advent of this new reasearch field is made possible by the onset of new kind of gamma ray sources, based on Compton back-scattering of high brightness electron beams by high intensity lasers. These sources aim at producing spectral densities up to 4 orders of magnitude higher than present bremstrahlung conventional sources, with very narrow bandwidth beams of gamma photons, down to 0.1%. We will discuss the rationale of these new tecnhology, and a practical example of a project presently under design in the context of the european ELI-NP initiative.

Poster Session: presentation of posters / 98

New technique for aberration diagnostics and alignment of an extreme ultraviolet Schwarzschild objective

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Schwarzschild objectives are widely used in the extreme ultraviolet (EUV)/soft X-ray spectral region both as reduction and magnification optics, e.g. for small-field projection lithography and microscopy, respectively.
When using a Schwarzschild objective as a micro-exposure tool (MET) at high spatial resolution (half-pitch ≤ 0.1 μm), in addition to the tight requirements on the design and surface figure for the single optics, also an accurate alignment between the two mirrors is needed to reach the planned spatial imaging detail.
Ideally, at-wavelength alignment should be done in order to overcome limitations due to diffractive effects. While this can be easily performed on synchrotron beam lines, it could become time expensive (and components consuming) on low-power laboratory plasma sources.
In this work a new technique has been applied to align a EUV Schwarzschild objective with magnification M=1/10 and numerical aperture NA=0.23 by means of ultraviolet light. Quantifiable aberration amounts have been repeatedly induced by controlled misalignments (with 3 degrees of freedom), whose effects have been revealed by the Foucault technique and analysed with the help of numerical modelling, finally allowing the determination of the best alignment values by interpolation, going beyond the limits imposed by diffraction.
The aligned objective allowed the attainment of lithographic patterning with edge response of 90 nm, as part of the laboratory-scale MET for EUV projection lithography realized at the ENEA Frascati Research Centre in the frame of a National Project [1].

Poster Session: presentation of posters / 99

Laser-driven proton imaging for High-density plasmas

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Generation of high intensity and well collimated multi energetic proton beams from laser-matter interaction extend the possibility to use protons as a diagnostic to image imploding target in Inertial Confinement Fusion experiments in the framework of experimental road map of Hiper project (the European High Power laser Energy Research facility Project). Point projection proton backlighting was recently used to image a cylindrical imploding target at Vulcan laser system at Rutherford Appleton laboratory (UK). Due to the relatively low energy (Ep from 1 to 10 MeV) and to the very large mass densities reached during implosion processes (Areal density ~ from 0.005 to 0.1 g/cm2) , protons traveling through the target undergo a very large number of collisions which deviate protons from their original trajectory reducing Proton Radiography resolution.
Here we present a simple analytical model to study the Proton Radiography performance as a function of the main experimental parameters such as proton beam energy and target areal density. This approach leads to define two different criteria for PR resolution ("strong" and "weak" condition) describing different experimental conditions. Finally numerical simulations using both Hydrodynamic and Monte Carlo codes are presented to validate analytical predictions for the energy and density values available at the moment (Ep < 50 MeV and Areal density~0.2 g/cm2).

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Poster Session: presentation of posters / 100

Imaging diagnostics of soft X-ray emission from KSTAR plasmas with multi-channel photodiode array detector

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The soft X-ray tomography is one of powerful tokamak diagnostics to investigate plasma shape or physical activities in the core region. It is possible to detect the core plasma behavior transparently, since the optical thickness of soft X-ray is thin. Therefore, the magnetohydrodynamic(MHD) instability and transport phenomena in the core plasma can be observed clearly. According to the bremsstrahlung radiation of the soft X-ray, the soft X-ray emission power is strongly correlated with the magnetic flux surface, therefore, the time evolution of the shape of plasmas can be visualized as well. The photodiode array detector is useful due to the cost-effective feature with high time resolution of ~ 0.5 us. It is enough to inquiry the Alfven eigen mode, which has the time scale of 5 us in KSTAR. In this research, the beryllium filter with thickness of 50 um was applied to the detector equipment, and the tomography reconstruction was performed with Cormack method and Phillips-Tikhonov method. The 2-D reconstruction results visualized the time evolution of the sawtooth oscillations, which has the period of 33 ms and collapse time of 3 ms.

Poster Session: presentation of posters / 101

Charge Exchange Recombination Spectroscopy (CXRS) diagnostic system design for the ion temperature profile measurements at ITER.

Charge Exchange Recombination Spectroscopy (CXRS) diagnostic with use of diagnostic or heating beams of atoms is widely used practically in all modern tokamaks. This technique is utilized for a wide variety of measurements in the plasma edge and core, including ion temperature (via Doppler broadening of intrinsic impurity lines, which are efficiently populated by charge exchange from beam atoms), plasma rotation (via Doppler shift of the same impu¬rity lines), and impurity density profile information (via quantitative spectroscopy of the impurity line intensities). One of the major advantages of CXRS diagnostic is the ability to carry out local measurements of the plasma parameters. It is happened due to the fact that the detected active signal is coming from the intersection area of viewchord and injected atomic beam. Therefore, CXRS diagnostic allow to measured ion temperature profile with the very good spatial resolution.
The general conception and detail description of active CXRS diagnostic system for ITER are stated in the current report. Measurement requirements and technical descriptions of the spectroscopic equipment prototypes for ITER are stated in the current report.

Poster Session: presentation of posters / 102

A real-time data acquisition and elaboration system for instabilities control in the FTU tokamak.

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Tokamak plasmas are prone to various kind of magnetohydrodynamic instabilities which may affect the energy and particle confinement time or lead in some cases to disruptive plasma termination. Such instabilities take the form of magnetic islands driven by the reduction of bootstrap current where the pressure profile is flattened (Neoclassical Tearing Modes) or by the radial gradient of the toroidal current (Tearing Modes) often in association with the so called sawteeth instability. Injection of powerful Electron Cyclotron waves into the magnetic islands has been proven highly effective in suppressing or at least controlling the size of tearing instabilities.
The detection of the islands and prompt reaction with accurate aiming of the EC power are crucial for the effectiveness of the control. For such reason a great effort is being addressed in many fusion laboratories to the development of complex equipments with real-time capabilities.
The system under development for FTU (major radius R=0.935m, minor radius r=0.31m, max toroidal field 8T, max plasma current 1.6MA, max flat top pulse duration 1.5s) encompasses existing diagnostics whose data are acquired with two different sampling rates. A first set of (fast) signals (20 kHz sampling rate, collected with 1x16 channels ADC board, 12 bit) is based on the 12 high pass filtered channels of the Electron Cyclotron Emission polycromator, on 28 signals of pickup coils and two gyrotron (ECH) driving signals. The slow signals set (2 kHz sampling rate, collected with 3x16 channels ADC boards, 12 bit) includes calibrated electron radiative temperature, calibrated density data, magnetic signals for the reconstruction of the position of the last closed magnetic surface of the plasma, toroidal magnetic field and plasma current. This last group of data is used for real-time computation of the magnetic equilibrium and of the ray trajectories of the EC waves beams in plasma.
Data acquisition and processing is performed using two VME based system. Each industrial PC runs Linux RTAI operating system and uses the MARTe framework to implement the control/processing cycle. One VME is devoted to fast signals preprocessing and runs a real-time thread at 20kHz feeding preprocessed data to the other VME on a RTNet Ethernet link. The other VME runs a real-time thread at 2kHz which handles the main part of the control algorithms generating controlling signals for actuators.
At present only a subset of ten fast signals (including two ECHs) can be actually acquired in the same plasma pulse. Processing of these signals is aimed to evaluate the cross-correlations of temperature and/or magnetic fluctuations in order to detect the existence and the radial position of the magnetic island (rmhd, being r the minor radius of the plasma). The cross correlation of ECE and ECH allows the detection of the injected power deposition layer (rdep). The real-time data acquisition and processing system constitutes a real-time rdep and rmhd diagnostics, so far validated by off-line analysis of dedicated plasma shots. The controller driving the ECH steering parameters and power switching-on can be based on the diagnostic data elaborated in this way, possibly integrated (or substituted) by the a-priori estimate of rdep and rmhd using the real-time equilibrium and ray tracing. Preliminary estimates how that islands producing temperature fluctuations of about 20 eV between contiguous ECE channels (Dr»3cm average separation) can be detected and trigger the actuator in less than 30ms. First system tests about island detection and actuator's control by using these methods are discussed in this paper.

Poster Session: presentation of posters / 103

Statistical analysis of temporal and spatial evolution of in-vessel dust particles in fusion devices by using CCD images

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Study of dust particles in tokamaks will be an important issue for future large tokamaks like International Thermonuclear Experimental Reactor (ITER) because of their physical and chemical behaviors in vacuum vessel: 1) damage to first wall & diagnostics due to high velocity impact, 2) flaking of radioactive tritiated co-deposits of nano- to micrometer size, 3) a strong chemical reactivity with air (hot dusts, ITER accidental scenario). In order to control the amount of dusts inside the vacuum vessel, it is important to monitor the dust creation events and the spatial location of the origins of dust creation.
Images of wide-angle visible standard CCD cameras contain information on Dust Creation Events (DCEs) that occur during plasma operations. Analyzing the straight line-like dust traces in shallow cylindrical shell-structured scrape-off layer along the vacuum vessel, caused by plasma-dust interaction, database on the DCEs are built. The database provides short/long term temporal evolution and spatial distribution of origins of DCEs in fusion devices. We have studied DCEs of CIMES (2006) and DITS (2007) Tore Supra (TS) campaigns, 2007 ASDEX Upgrade (AUG) campaign, 2010 and 2011 KSTAR campaign. The results from the TS CIMES campaign show different patterns of DCEs meaning different plasma-wall interaction depending on power coupling. TS DITS campaign indicates that dusts may be an operational limit if a fixed plasma operation scenario is used repeatedly. Different behaviours of DCEs between carbon limiter machine and full tungsten divertor machine are found. Huge amount of dust creation events were observed in KSTAR due to severe damage of PFCs. An analysis software, with which the location of dust trajectories in 3D position in the KSTAR vacuum vessel is identified, is developed and the dust velocity distributions in 2010, 1011 campaigns are measured.

Poster Session: presentation of posters / 104

A new position sensitive anode for plasmas diagnostic

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The studies of plasma generated by laser - matter interaction requires detectors able to perform the time resolved imaging of photons and charged particles. Such information are necessary in order to characterize the time evolution of fundamental parameters (like temperature, density, etc.) of plasma. One of the key elements of such diagnostics is the position sensitive anode.
In this contribution we present the study of a new type of position-sensitive anode which will be realized by using silicon planar technology. Starting from the original idea of Vernier [1-6] we performed a several simulations and test in order to design a new structure: a trapezes and stripes resistive anode (TSRA). The new TSRA is a two-dimensional system which can be coupled with one o two stage multichannel plate (MCP) for the particles detection or for photons.

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Poster Session: presentation of posters / 105

Diagnostics improvement in the ABC facility and preliminary tests on a laser-cluster experiment

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The research on Inertial Confinement Fusion (ICF) is mainly developed using high power laser facilities. In this context the diagnostics of particle flows is a delicate issue, due to the fast timescales and to the strong electromagnetic and radiative contributions. The discrimination of the different particles emitted by the plasma is therefore not trivial, and it requires the use of several diagnostic techniques. The ABC facility employs a two beams 100J/4ns Nd phosphate glass laser which can be focused up to about 1015 W/cm2 on targets, from opposite sides, for investigation of high density plasmas. The experimental chamber is equipped with diagnostics for the measurement of the main plasma characteristics and for the evaluation of the target accelleration stability. In this contribution we describe the diagnostics improvement, which will provide a more detailed analysis of the particles and of the eletromagnetic fields originating from the interaction of the laser with targets foreseen for future experiments. We also discuss the use of metal strips and diamond detectors to achieve a time resolved diagnostics of the particle flows.

Poster Session: presentation of posters / 106

Metal strips and diamond detectors for diagnostics in ultra-intense laser facilities for nuclear fusion applications

The research on Inertial Confinement Fusion (ICF) is mainly developed using high power laser facilities. In this context the diagnostics of particle flows is a delicate issue, due to the fast timescales and to the strong electromagnetic and radiative contributions. The discrimination of the different particles emitted by the plasma is therefore not trivial, and it requires the use of several diagnostic techniques. In this work we discuss the use of metal strips and diamond detectors to achieve a time resolved diagnostics in this type of experiments.

Spectroscopy / 107

Scanning hyperspectral lidar fluorosensor for remote diagnostic of surfaces

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The application of laser-based techniques as analytical tools in materials science is widespread and very promising by now, also due to the continuous development of the laser technology.
In particular, the Laser Induced Fluorescence (LIF) technique is a molecular spectroscopy based on the interaction of the ultraviolet radiation emitted by a laser with the matter. This technique, for a surface analysis, is fast, remote, non invasive and specific.
Scanning hyperspectral systems based on LIF have been developed and realized in the Diagnostic and Metrology laboratory of ENEA Frascati allowing to obtain information of analytical and qualitative interest on different materials by the study of the laser induced fluorescence.
A new compact set up will be presented. It has been recently built with the aim to increase the performances in terms of space resolution, time resolved capabilities and data acquisition speed. Major achievements have been reached by a critical review of the optical design. With these upgrades, an image of 1.5×5 m2 is now scanned in less than 2 minutes.
The results recently obtained during laboratory and in-situ measurements of interest for applications in the field of Cultural heritage will be shown.

Measurements of Temperature and Density / 108

SUMMARY of FDT2

Satellite Meeting / 109

Beam-driven, Plasma-based Particle Acceleration

Particle accelerators at the energy frontier are getting ever larger. Plasma-based particle accelerators operate at gradients in the 1-100GeV/m and could become a new, more compact and therefore cheaper accelerator technology. In the plasma wakefield accelerator (PWFA) the accelerating gradient is driven by a short particle bunch. PWFA experiments have already demonstrated energy gain by trailing electrons of 42GeV in only 85cm of plasma. Future experiments are geared toward multi-GeV acceleration of a high quality witness bunch (SLA_FACET), the extraction of large amounts of energy from a proton drive bunch (MPP-CERN), and large relative energy gain and basic PWFA physics with MeV bunches (BNL-ATF). An introduction to the PWFA, a summary of experimental results, as well as an outlook to future experiments will be given.

Satellite Meeting / 110

Extreme Field Science

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The development of Extreme Field Science will make it possible to explore novel phenomena, to study processes of basic importance for physics, and to model in the laboratory processes of key importance for relativistic astrophysics. Experiments in this field will allow allow us to model in a terrestrial laboratory the state of matter that is thought to occur in cosmic Gamma Ray Bursts and in the Leptonic Era of the Universe.
In addition it will open a new way for developing hard EM radiation sources: multi-MeV, several fs, gamma-ray bursts.

Poster Session: presentation of posters / 111

POLARIZATION PROPERTIES OF METAL CUBE-CORNER RETROREFLECTOR

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The polarization state of the infrared beam reflected from a metallic cube-corner retroreflector (CCR) is analyzed using the Mueller matrix formalism, as it was suggested by Segre and Zanza [1]. In a given paper polarization changes of an electromagnetic beam reflected from CCR are studied in a rather wide range of parameters: complex reflection coefficients of metalic surfaces, beam wavelength, initial polarization state and incidence angle. It is shown that for definite parameters combination polarization changes could be minimized, what is very important for plasma polarimetry on thermonuclear devices.
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Poster Session: presentation of posters / 112

TWO APPROACHES TO PLASMA POLARIMETRY: ANGULAR VARIABLES TECHNIQUE (AVT) AND STOKES VECTOR FORMALISM (SVF)

The modern plasma polarimetry is based on Stokes vector formalism (SVF) suggested and developed in depth by Segre (see [1] and cited there references). Segre's equations describe evolution of the Stokes vector along the ray in the weakly inhomogeneous and weakly anisotropic plasma. Alternative approach – Angular Variables technique (AVT) suggested by Czyż, Bieg, Kravtsov [2] in distinction to SVF, deals with angular parameters of the polarization ellipse. Equations for angular parameters drastically differ from the SVF equations, however, AVT and SVF equations happen to be equivalent to each other.
This paper proves equivalence of the SVF and AVT and in the sometime reveals some practical distinctions between two approaches. Though all the results of SVF can be obtained in frame of the AVT and vice versa, in specific problems one of the methods can be more convenient. Generally, AVT may serve as a valuable compliment to traditional SVF, providing sometimes more simple an less laborious solution of polarimetric problems.

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Satellite Meeting / 113

Neutrino velocity measurements

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The OPERA neutrino experiment in the underground Gran Sasso Laboratory
has measured the velocity of neutrinos from the CERN CNGS beam over a baseline of 730 km with unprecedented accuracy. The measurement is based on the high-statistics data taken by OPERA in the years 2009, 2010 and 2011.
Dedicated upgrades of the CNGS timing system and of the OPERA detector, as well as a high-precision geodesy campaign for the measurement of the neutrino baseline allowed reaching comparable systematic and statistical accuracies. A neutrino time of flight corresponding to a velocity higher than the speed of
light was observed.

Imaging / 114

Diagnostic Technologies in modern radiotherapy

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Over the past years radiotherapy has undergone a substantial development that has led to improved outcome (both in terms of survival and toxicity) and widening of indications. This is mainly due to more advanced dose delivery techniques that allow performing curative treatments without exceeding normal tissues tolerance limits. These new developments cannot be fully exploited without an adequate imaging. The role of imaging is fundamental in several steps of modern high precision radiotherapy. Different imaging technologies are employed: to define volumes to be irradiated, to check patient positioning and to evaluate response to treatment. Volumes to be irradiated are defined according to ICRU reports. Traditionally morphologically pathological areas are considered. According to body site multiple imaging modalities can be used (e.g. CT and MR) and fused to better evaluate gross tumor volume (GTV). A potential improvement from the simple morphological approach can be achieved adding functional imaging (PET, perfusion/diffusion MR, spectroscopy) for GTV contouring. The concept of GTV can be extended to consider different sub-volumes that may have more aggressive behavior (Biological target volume or BTV). So far hypoxia has been the more extensively investigated parameter to define BTV. Hypoxia imaging is performed with PET employing dedicated radiotracers like 18F-MISO, 18F-FAZA or Cu-ATSM (several isotopes of copper can be employed with 60-Cu being the most common one). Hypoxia imaging has been shown to correlate with survival in head and neck and in gynecological cancers. Response to radiotherapy rarely result in a total disappearance of the neoplastic mass. Persistence of a fibrotic nodule is compatible with a positive result. Criteria usually employed to evaluate tumor response (RECIST criteria) were developed mainly in the setting of surgical and pharmacological treatments and consider all residual nodule as active disease. In clinical practice only long term stability of residual nodules can be considered a sure sign of their non active nature. Functional imaging can be used to anticipate this information investigating: changes in blood flow (perfusion MR and or CT) changes in cellularity and related water diffusivity (diffusion weighted MR), changes in predominant molecular content (MR spectroscopy) and changes in metabolism (PET with glucidic, aminoacidic, or nucleic acid tracers). Anticipation of response can be used in follow up but more interestingly can also be used during delivery of radiotherapy to fine tune the treatment with an adaptive approach. PET and spectroscopy have a spatial resolution limit that should be carefully considered if they are to be used in the setting of target volume definition. Moreover dedicated imaging devices (X-Ray, KV and MV cone beam CT, ultrasound) are more and more often used to check patient positioning in the framework of the so called image guided radiotherapy (IGRT).

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High rate diamond detectors for fast neutron beams

Abstract. Fast neutron monitors are being developed for accelerator applications such as the study of neutron-induced single event effects (SEE) in microelectronics components, which are been recognized as a key threat to the reliability of advanced electronic systems. A new beam line (CHIPIR) dedicated to neutron SEE testing is being built at the ISIS spallation source (UK) to provide fluxes of 105-107 neutrons s-1 cm-2 in the 1-800 MeV energy range. Commercial high purity single crystal diamonds (SDD) with contacts made in aluminium or gold and coupled to a fast digital data acquisition system have been tested at the ROTAX and VESUVIO beam lines. They feature a pulsed neutron beam generated by proton induced spallation on a tungsten target at 50 Hz repetition rate. The SDD event signal is digitalized at 1 Gsample to reconstruct its deposited energy (pulse-height) and arrival time; the event time of flight (tToF) is obtained from the recorded proton beam signal t0. The SDD stability during the measurements has been investigated since the polarization of the diamond induced by the radiation field can degrade its resolution. The analysis has been carried out in terms of count rate and of its effects on pulse-height and tToF spectra. Results from the first measurements at ROTAX indicate that the SDD performance became stable after few hours of irradiation. The SDD's used at VESUVIO instead proved stable for all the experimental campaign.
Keywords: Fast diamond neutron detector, digitized pulse-height and ToF measurements, high-energy neutron beam monitor, neutron-gamma energy discrimination.
PACS: 28.50.Dr; 29.27.Fh; 29.30.Hs; 29.40.Wk; 81.05.ug.

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Signal shape of a PET detector based on LSO:Ce,Ca crystals and SiPM

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Time Of Flight PET is a promising technique that can improve the image quality of a PET scanner. A TOF PET detector must be designed by optimizing its energy and time resolution. Several researches are being performed
to improve the time performances of the PET detectors. Recent studies demonstrate that LSO:Ce codoped with Ca (LSO:Ce,Ca) shows an higher light output, a reduced decay times and better energy resolution compared to the standard LSO:Ce. For what concerns the photodetectors, a valid alternative to photomultiplier tubes (PMT) is represented by the Silicon PhotoMultipliers (SiPM). They show high gain at rather low operating bias, they are
inherently fast (the single photon timing resolution is of 60 ps) and insensitive to magnetic elds, making them attractive for new development of PET like TOF-PET and hybrid PET-MRI imaging. For these reasons, a detector
based on SiPM coupled to an LSO:Ce,Ca could introduce several improvements with respect to the currently used
PET modules.
The de nition of the most performing detector con guration requires a study of the shape of the current pulse produced in response to an incident photon. The study aims to assess the overall performance of a PET detector
composed by a SiPM coupled to LSO:Ce,Ca and connected to a fast transimpedance ampli er. A suitable electrical
model for the SiPM and the scintillator has been considered to estimate the best timing resolution achievable by
the detector. The model is useful to predict system characteristics like the time jitter of the signals evaluated at di erent thresholds. Measurements have been performed to validate the model and to characterize the system in
terms of energy resolution, decay time of the crystal and timing performances.
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Characterization of an imaging system demonstrator for PET applications

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Silicon Photomultipliers (SiPM) represent an effective alternative to photomultiplier tubes used in actual Positron Emission Tomography (PET) scanners. Exploiting the design solutions offered by the Silicon technology it is now possible to build small devices and to pack them in monolithic arrays at millimetric pitch. This feature allows overcoming the limit in spatial resolution imposed by the current devices.
A demonstrator of PET imaging system based on LYSO crystal arrays coupled to SiPM matrices is under construction at the University and INFN of Pisa. Two SiPM matrices, composed by 8 x 8 SiPM pixels, 1.5 mm pitch, have been coupled one to one to a LYSO crystals array and read-out by a custom electronics system.
Front-End ASICs were used to read 64 channels of each matrix. Data from each Front-End were multiplexed and sent to a DAQ board for the digital conversion; a motherboard collects the data and communicates with a host computer through a USB port for the storage and off-line data processing.
In this paper we describe the methods adopted for testing the imaging system and the results obtained in terms of the parameters that qualify the performance of the system for PET application.

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welcome

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Concert “Duo Violin & Piano” by Barbara Cattabiani and Giovanni Pandolfo

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Light buffet