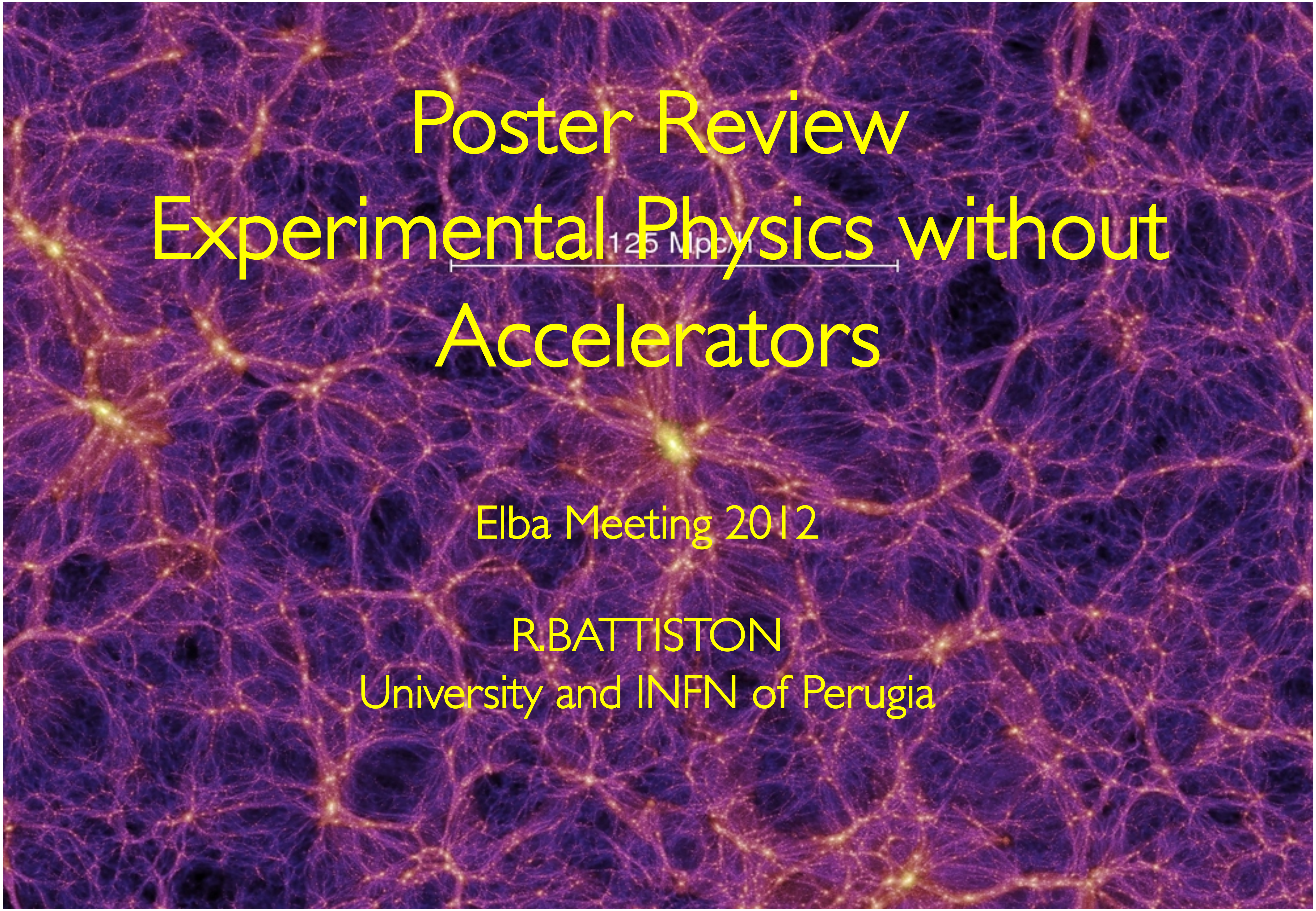
Poster Review
Experimental Physics without Accelerators



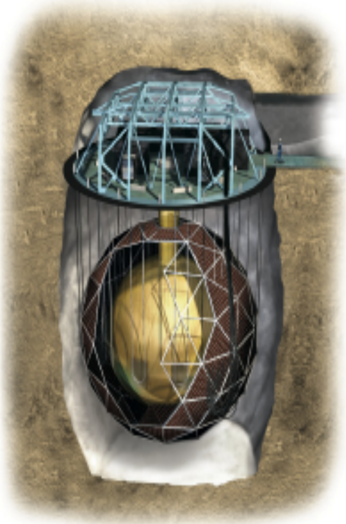
Elba Meeting 2012

R.BATTISTON
University and INFN of Perugia

From SNO to SNO+
Upgrading a Neutrino Experiment

Gwenaëlle LEFEUVRE, for the SNO+ Collaboration

The SNO+ experiment is the follow up of SNO, completed in 2006. The detector is being upgraded to replace the SNO heavy water target by liquid scintillator (LS). The lower energy threshold will turn SNO+ into a new experiment with a new set of technical challenges.

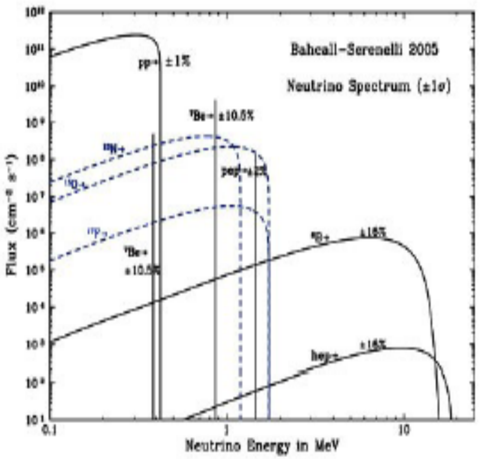


Calibration

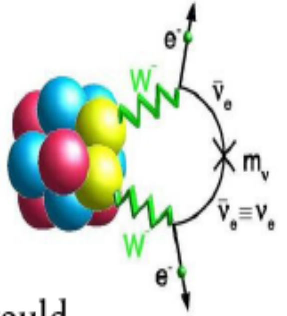
The calibration and monitoring programme is a very delicate task: it must provide a comprehensive understanding of the entire detector over a wide energy range (0.1 to 10 MeV). Among the most important parameters, it must establish:

Physics Goals

SNO+ is a **multi-purpose neutrino detector** composed of a 12m diameter acrylic vessel filled with liquid scintillator and surveyed by ~9.500 photomultiplier tubes. It will address several aspects of neutrino physics, linking to particle physics, astrophysics and cosmology:



Low Energy Solar Neutrinos: SNO+ will detect the pep and CNO solar neutrinos, helping to understand better the mechanisms at work within the Sun.



Neutrinoless Double Beta Decay: the detection of this decay would prove that neutrinos are their own antiparticles, and would help determining the absolute mass scale of the neutrino. For this, Neodymium will be added in the liquid scintillator.

But also – SNO+ will study the heat generation within the

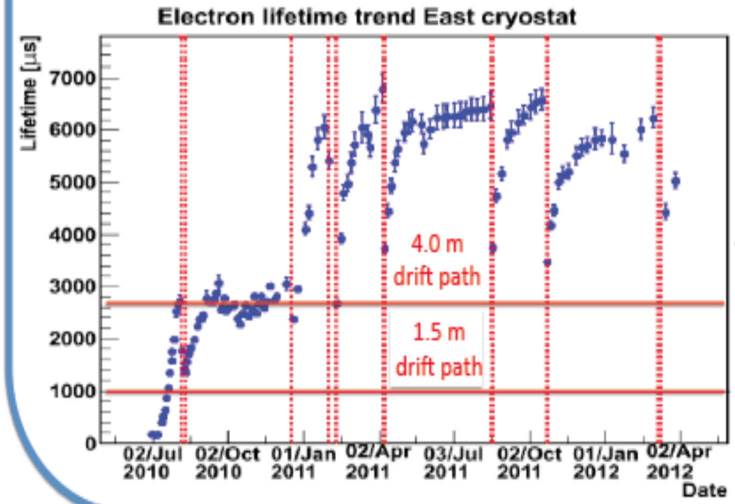
ICARUS T-600 and the status of LAr TPC

D. Dequal for the ICARUS Collaboration
Università degli Studi di Padova, INFN Padova

The ICARUS-T600 detector at LNGS is the largest Liquid Argon TPC (LAr-TPC) operating in an underground laboratory. Its calorimetric resolution and topology reconstruction capabilities permit a wide physics program, which goes from the study of neutrino oscillation on CNGS neutrino beam to nucleon decay searches. Atmospheric as well as solar neutrinos are also a case of study.

LAr Purity

Key feature for ICARUS, and for any larger LAr TPC, is the Ar purity: electronegative molecules (O_2, H_2O, CO_2) trap the electrons, thus reducing the collected signal. The level of purity reached is well above the limit required for a 1,5 m of drift (ICARUS) and could be suited for longer drift path (e.g. Modular arXiv:0704.1422).

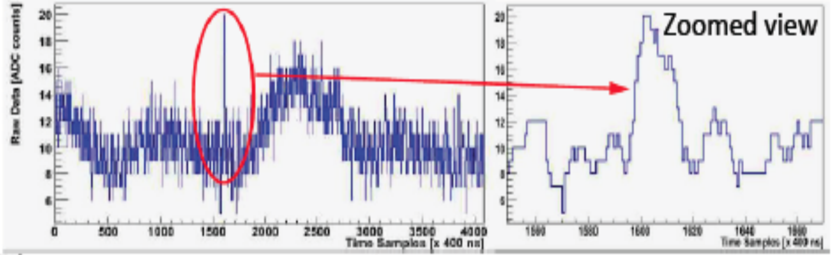


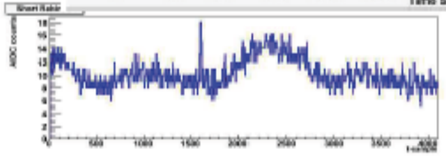
$\tau_{ele} > 5$ ms
~60 ppt $[O_2]_{eq}$

$\tau_e \sim 0{,}3$ ms/ppb $[O_2]_{eq}$

"DR-slw" filtering algorithm

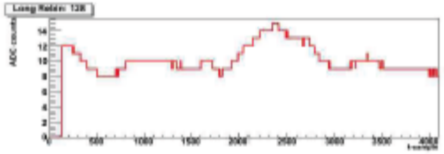
To extract a trigger from the charge signal a new algorithm has been developed and tested; the double average filters out low and high frequency noise components.





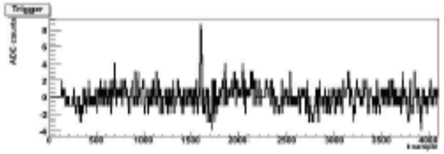
$$Q_8(t)=\frac{1}{8}\sum_{i=0}^{8}Q(t-i)$$

8-samples average filters out high freq. noise component



$$Q_{128}(t)=\frac{1}{128}\sum_{i=0}^{128}Q(t-i)$$

128-samples average follows baseline modulation

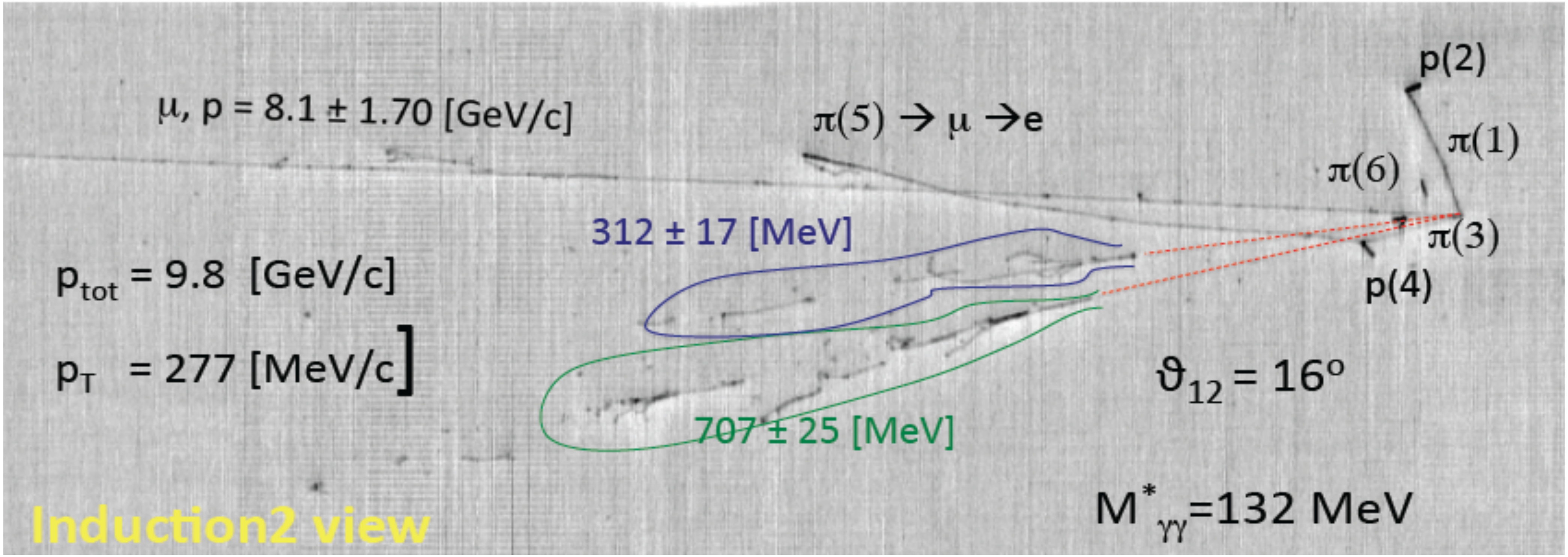


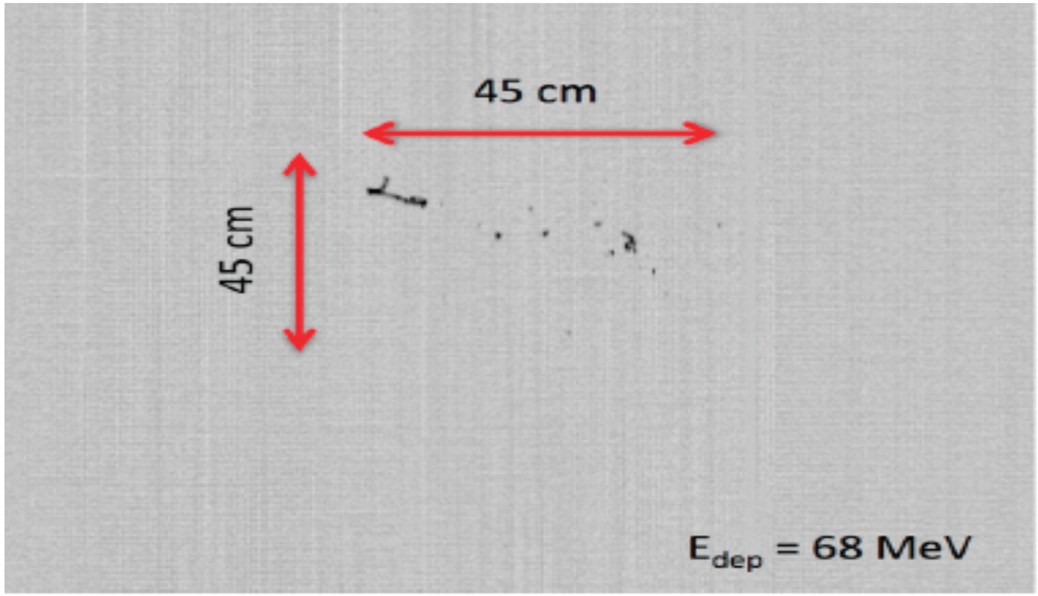
$$S(t)=Q_8(t)-Q_{128}(t)$$

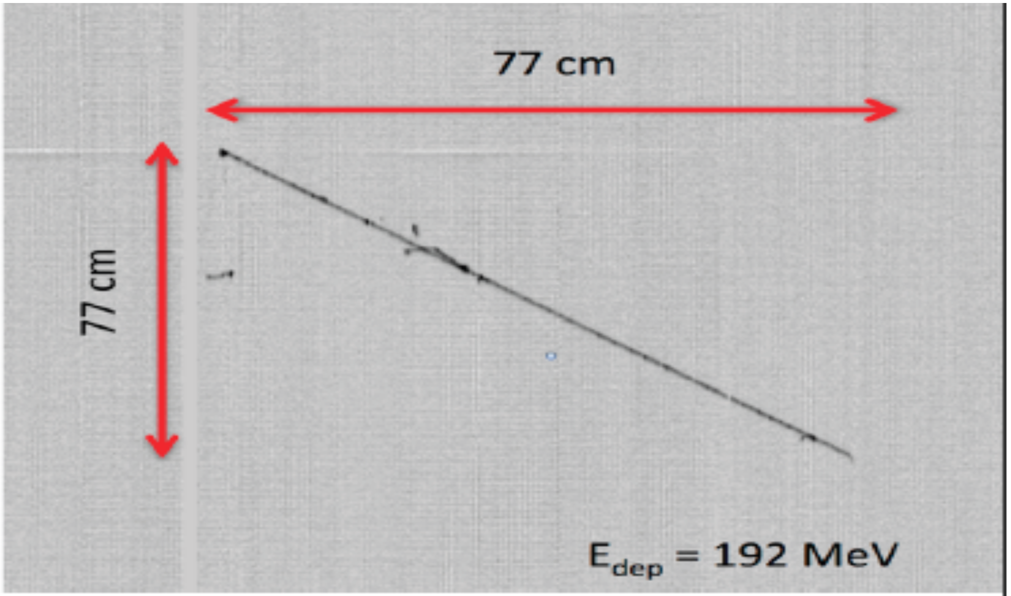
S(t) is discriminated to generate a "peak"

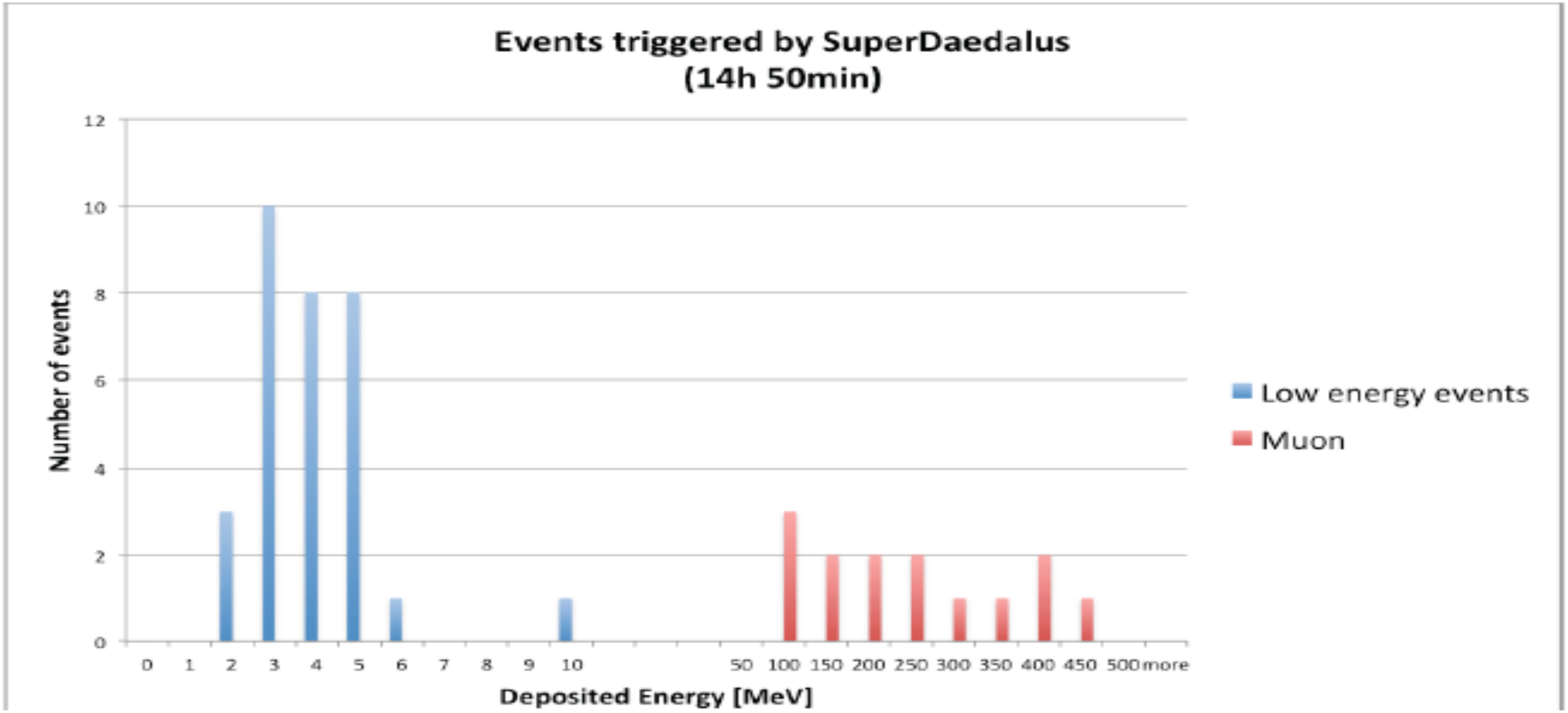
Data taking

	PID	E_{dep} [MeV]	Range [cm]	Momentum [MeV/c]
1	π	113 ± 10	39.3	304 ± 18
2	p	81 ± 7	4.1	399 ± 18
3	(π)	22 ± 2	15.0	599 ± 41
4	p	61 ± 5	3.5	343 ± 15
5	π	358 ± 30	112.8	477 ± 32
6	(π)	-	8.6	180 ± 9




45 cm
45 cm
E_{dep} = 68 MeV


77 cm
77 cm
E_{dep} = 192 MeV


Events triggered by SuperDaedalus
(14h 50min)
Number of events
0
2
4
6
8
10
12
0
1
2
3
4
5
6
7
8
9
10
50
100
150
200
250
300
350
400
450
500
more
Deposited Energy [MeV]
Low energy events
Muon

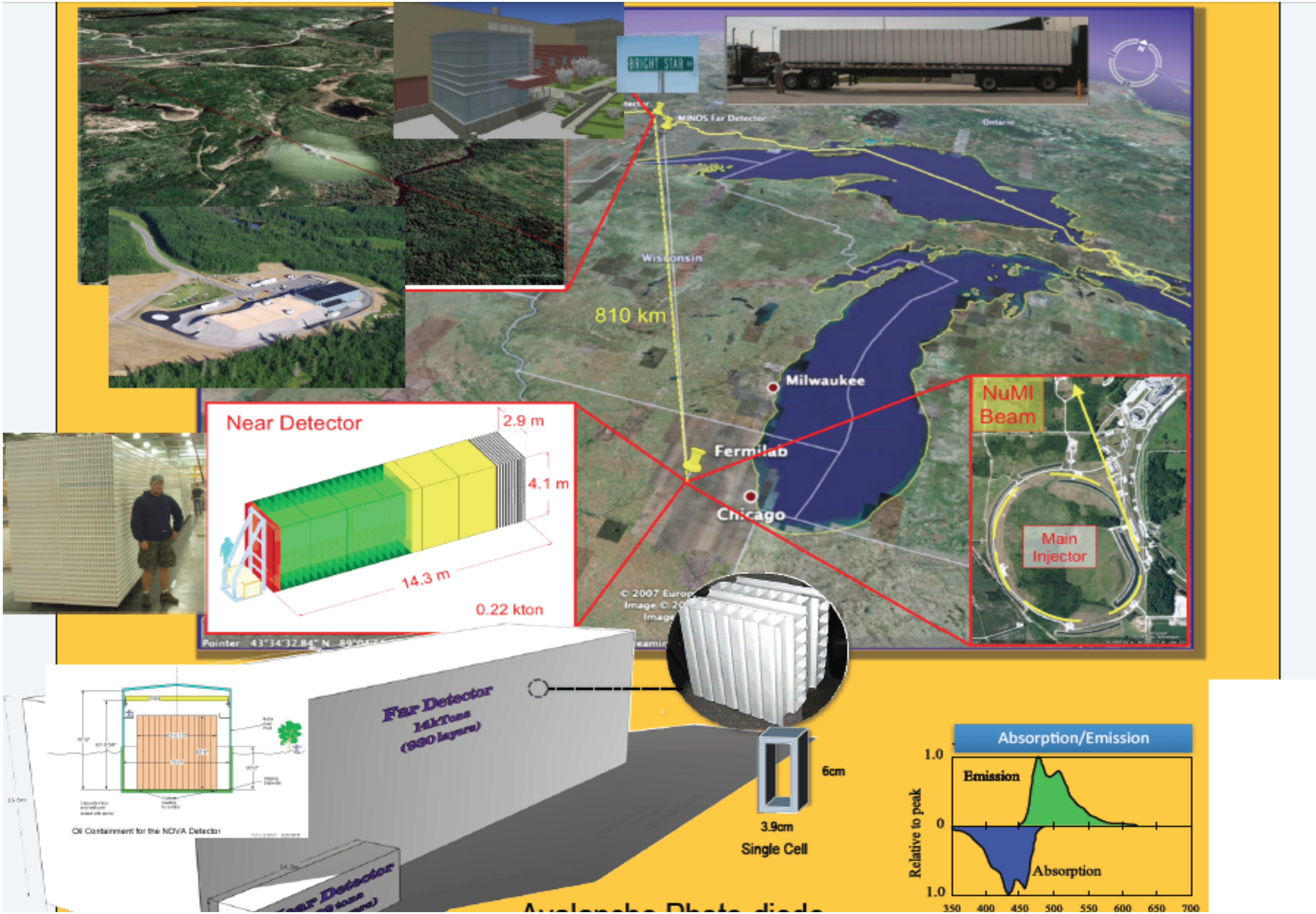
Detecting Long Baseline Neutrinos in the NOvA Experiment

David DeMuth, Jr.
University of Minnesota, Crookston

QA/QC During the Construction of a Modular Neutrino Detector, NOvA

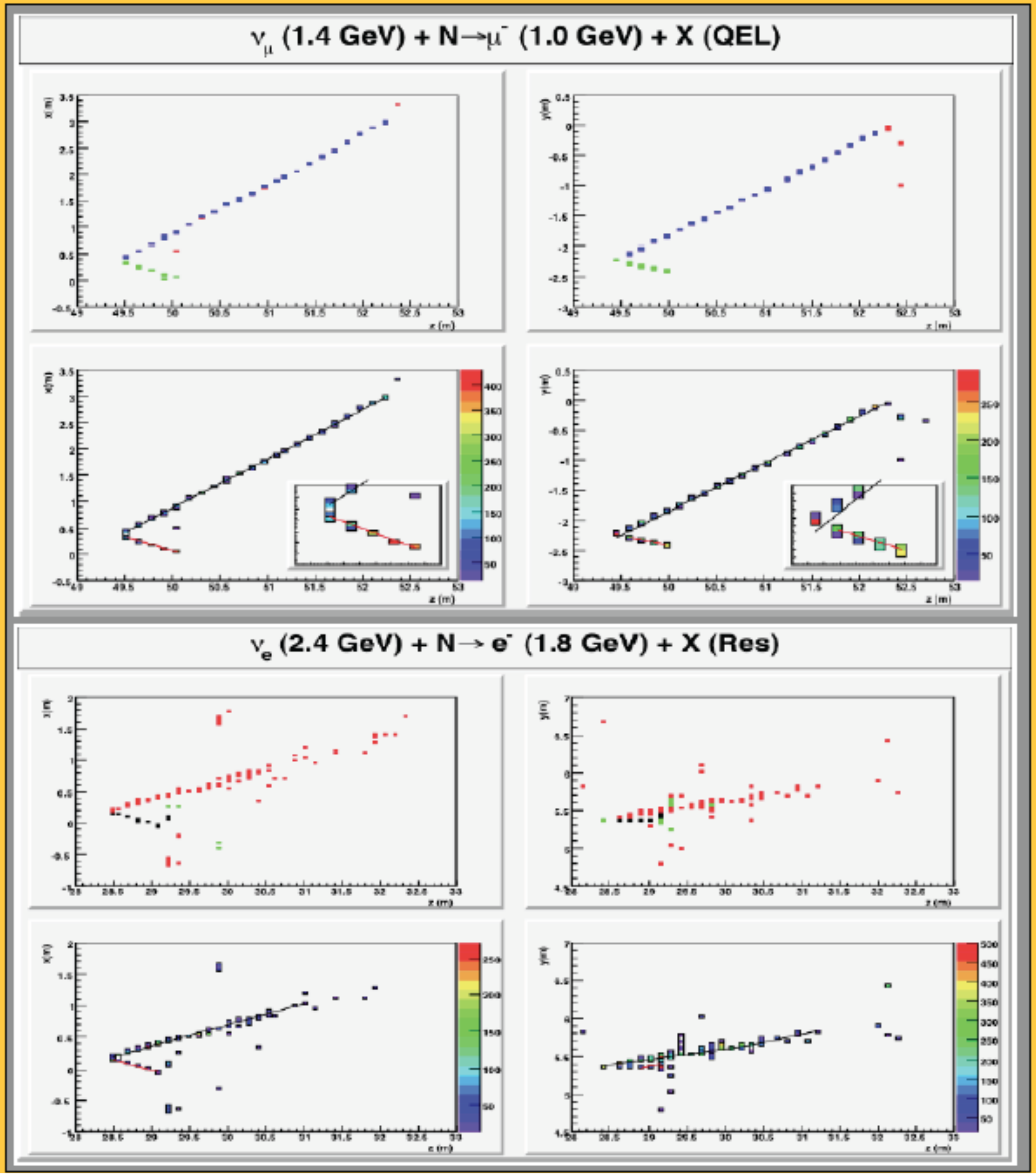
Andrey Anfilofieff, Tyler Brazier, Kurt Prudhomme, Michael Schliep, Dr. David DeMuth, Jr.
University of Minnesota, Crookston

ABSTRACT: The NOvA Collaboration is building a massive tracking liquid-scintillator calorimeter at a location in Northeastern Minnesota, which is 14 mrad off-axis of a high power muon neutrino beam (NuMI) originating 810 km away at the Fermi National Accelerator Laboratory (near Chicago), for the purpose of recording the appearance of electron neutrino events. The principle goals are in comparing neutrino events in a near and far detectors to establish electron neutrino appearance and a non-zero neutrino mixing angle theta_13, thus observing CP violation in neutrinos and resolving the neutrino mass hierarchy. Other important oscillation parameters will be recorded to improve knowledge of this phenomena. This calorimeter will be sensitive to supernova neutrinos. Building such a detector is not without challenges. In this talk we discuss the physics goals, describe the detecting components, and provide a status report on its installation and operation.


BRIGHT STAR
MINOS Far Detector
Ontario
Wisconsin
810 km
Milwaukee
Fermilab
Chicago
NuMI Beam
Main Injector
Near Detector
2.9 m
4.1 m
14.3 m
0.22 kton
© 2007 Europ
Image © 20
Image
Pointer 43°34'32.84" N 89°04'
Far Detector
14kTons
(930 layers)
Near Detector
Oil Containment for the NOVA Detector
6cm
3.9cm
Single Cell
Absorption/Emission
Emission
Absorption
Relative to peak
1.0
0
1.0
350
400
450
500
550
600
650
700
Avalanche Photo-diode

Neutrino Interacting Inside the NOvA Detector

Neutrino events as simulated by Monte-Carlo in the NOvA Detector where in both cases, the short track of the recoil proton is observed, as is the long track of the lepton. An electron shower is distinguished as a fragmented profile.



The installation of the NOvA detector is now underway with the placement of the first 384 module block scheduled for August 2012, with a second block following in September, forming di-block 1, when scintillator filling and electronics outfitting following. Installation will continue as the upgraded Fermilab beam is powered on, with a 30-block detector being completed in the Fall of 2014.

THE ANTARES DETECTOR

Creusot Alexandre[1], for the Antares Collaboration[2]
[1]`Laboratoire APC - Paris, creusot@in2p3.fr`
[2]`http://antares.in2p3.fr/`

INTRODUCTION

The Antares telescope [1] is a large area water Cherenkov detector meant to perform neutrino Astronomy in the deep Mediterranean sea. Among many other considerations, the detector has been designed to be efficient to the detection of neutrinos emitted by high energy sources such as active galactic nuclei, gamma ray bursts, micro-quasars or super- nova remnants. In order to maximize the sensitivity in this point source search, the estimation of the arrival direction of the neutrino has to be as accurate as possible. The second crucial point for the neutrino astronomy is the energy estimation. In order to discriminate between the point source signal and the background due to cosmic ray interaction with the atmosphere, the energy has also to be estimated accurately. This poster presents the performances of the Antares detector with respect to the scientific objectives mentioned.

PRINCIPLE OF DETECTION

Detect the Cherenkov light emitted by the leptons issued from the interaction between up-going neutrinos and the matter surrounding the detector. Arrival direction and energy of the neutrino are extracted from the time and charge of the signal of each hit *OM*.

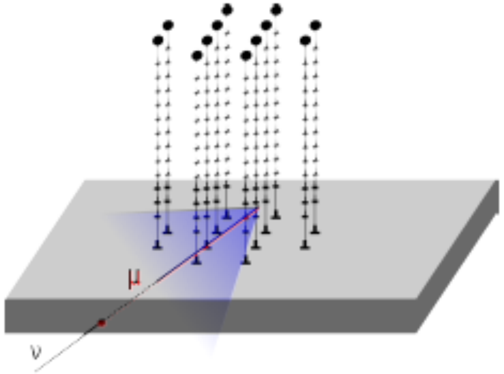


Figure 1: An up-going neutrino interacts in the earth, the secondary lepton emits cherenkov light.

DETECTOR

Configuration

The Antares telescope is a tri-dimensional array of light detectors. 12 vertical lines are anchored on the ground. Each line is composed of 25 storeys, each storey consisting in 3 optical modules [2] (*OM*: photomultiplier tube glued in a glass sphere). The 3 *OMs* are looking down at 45 ° to the up-going cherenkov light.

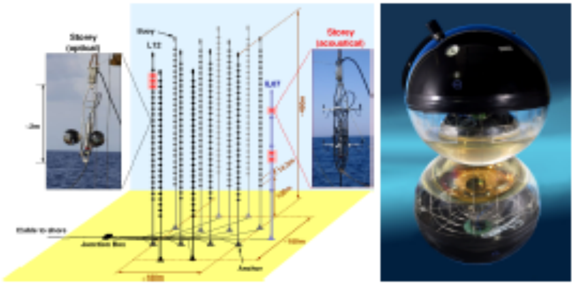


Figure 2: The tri-dimensional array of light detectors can be seen on the left. An optical module on the right.

Acquisition

OM signals are sent to the Local Control Module where their time and charge are digitized provided their amplitude exceeds a L0 threshold set at 0.3 pe [3]. All data are sent to shore for triggering and registration.

Triggers

- L1: local coincidence or charge above a high threshold (3 pe)
- physics trigger based on combination of L1s

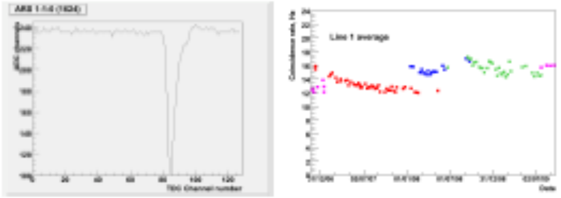
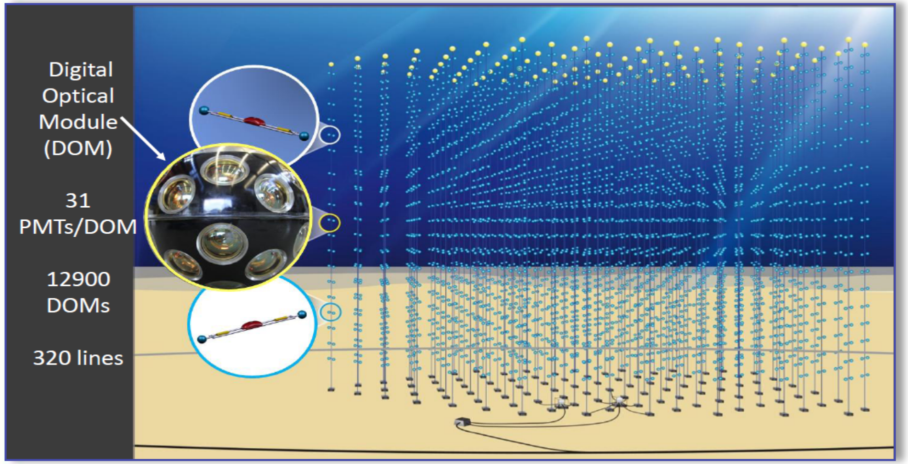
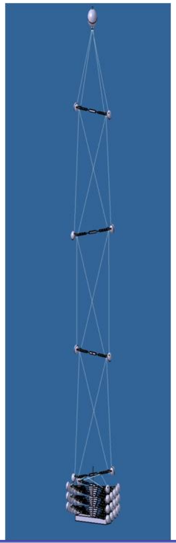


Figure 3: On the left, *OM* signal digitized in oscilloscope mode (640 MHz sampling). On the right, event rate for L1 trigger, color code corresponds to readjustment of the *PMT* gain.

KM3NeT - a future underwater neutrino telescope

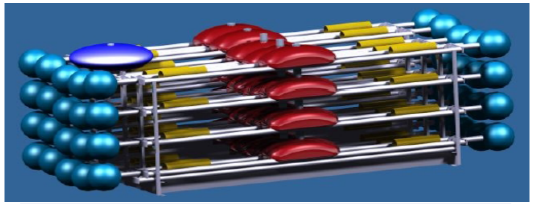


- **KM3NeT** is an European Consortium with the goal to build and operate a multi-cubic km detector in the Mediterranean Sea.
- The detector will be composed of at least 300 vertical semi rigid structures of several hundred metres length, named detection units (DUs), anchored on the seabed and kept vertical with a buoy.
- The DU will host optical sensors able to detect the faint Cherenkov light emitted in the deep sea by the muon generated after a neutrino interaction.
- A precise knowledge of the optical sensor relative positions of not worse than 20 cm is needed for an accurate reconstruction of the charged particle tracks.
- The buoys (and sensors) of the DUs are moved due to marine currents and can have displacements of up to several tens of meters from their nominal positions.
- An **Acoustic Positioning System** (**APS**) is necessary to monitor the positions of sensors in deep sea continuosly.



Flexible tower

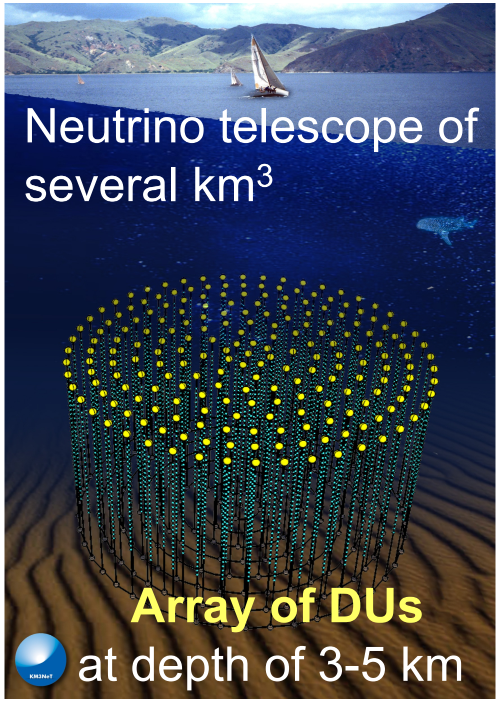
The compact package of the DU allows a fast and efficient way for deploying the detector. The DU unfurls once it is placed on the seafloor.



Compact package of the DU

The multi-PMT Optical Module for KM3NeT

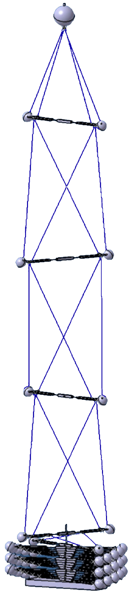
Q. Dorosti-Hasankiadeh, O. Kavatsyuk, H. Löhner ; KVI, University of Groningen;
D. Gajanana, E. Heine, P. Kooijman, C. Kopper, H. Peek, J. Steijger, P. Timmer,
E. de Wolf; Nikhef, Amsterdam, The Netherlands
on behalf of the KM3NeT Consortium



Neutrino telescope of several km^3

Array of DUs at depth of 3-5 km

Detection Unit (DU) of 20 storeys



Storey with 6m long bars and **2 multi-PMT Optical Modules (OM)**

multi-PMT OM

31 3-inch PMTs, foam supported in glass pressure sphere.

Adjustable HV supply for each PMT.

Power consumption: 7 W / OM

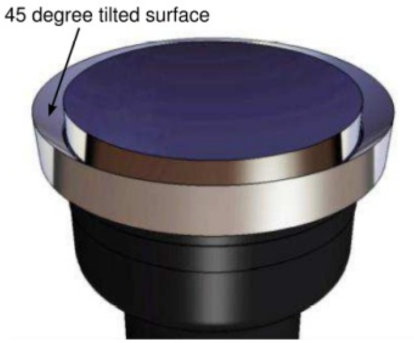
➔ **Digital OM (DOM):**

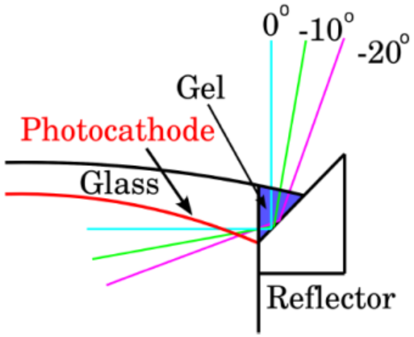
Optical point-to-point connection of each of ≈13k DOMs to shore

Advantages of multi-PMT DOM

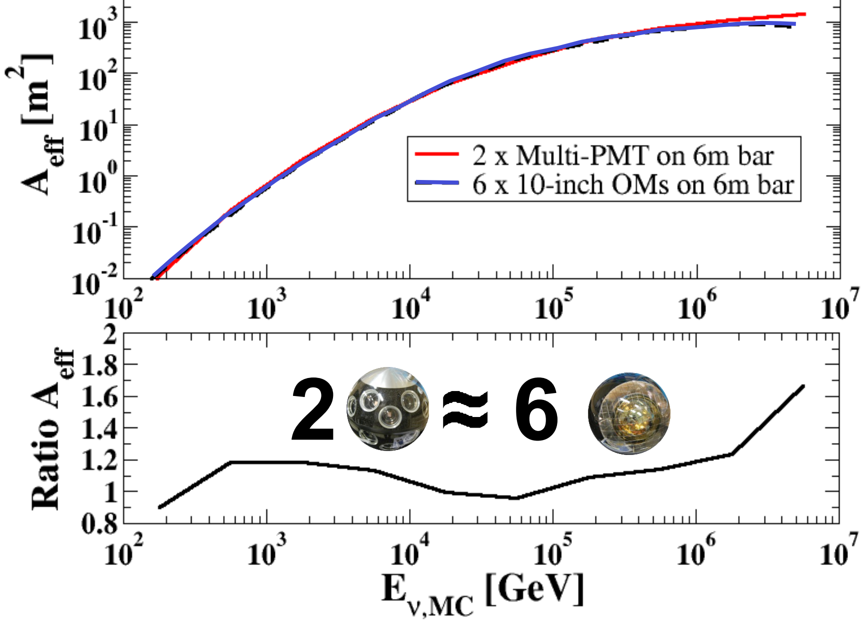
developed, tested, prototyped

**Directional sensitivity,
Background suppression by coincidences,
Extended light collection by
expansion cone: ca. 30% light gain**





More effective area for less OMs

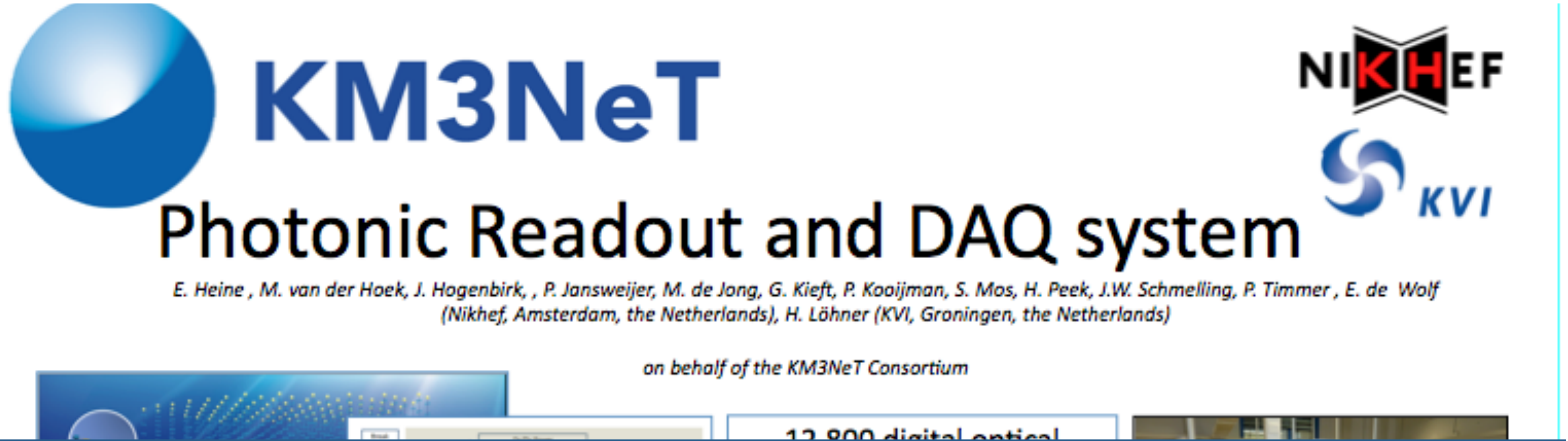


**new 3-inch PMTs with
low dark rate,
small Transit Time Spread,
homogeneous and high
quantum efficiency.**

Monte Carlo simulations: energy dependence of neutrino effective area for 2 design options: with **conventional OMs (10-inch PMT)** or with **multi-PMT OMs.**

x9 better signal-to-background.

ongoing: prototyping for deployment



KM3NeT

Photonic Readout and DAQ system

E. Heine , M. van der Hoek, J. Hogenbirk, , P. Jansweijer, M. de Jong, G. Kieft, P. Kooijman, S. Mos, H. Peek, J.W. Schmelling, P. Timmer , E. de Wolf
(Nikhef, Amsterdam, the Netherlands), H. Löhner (KVI, Groningen, the Netherlands)

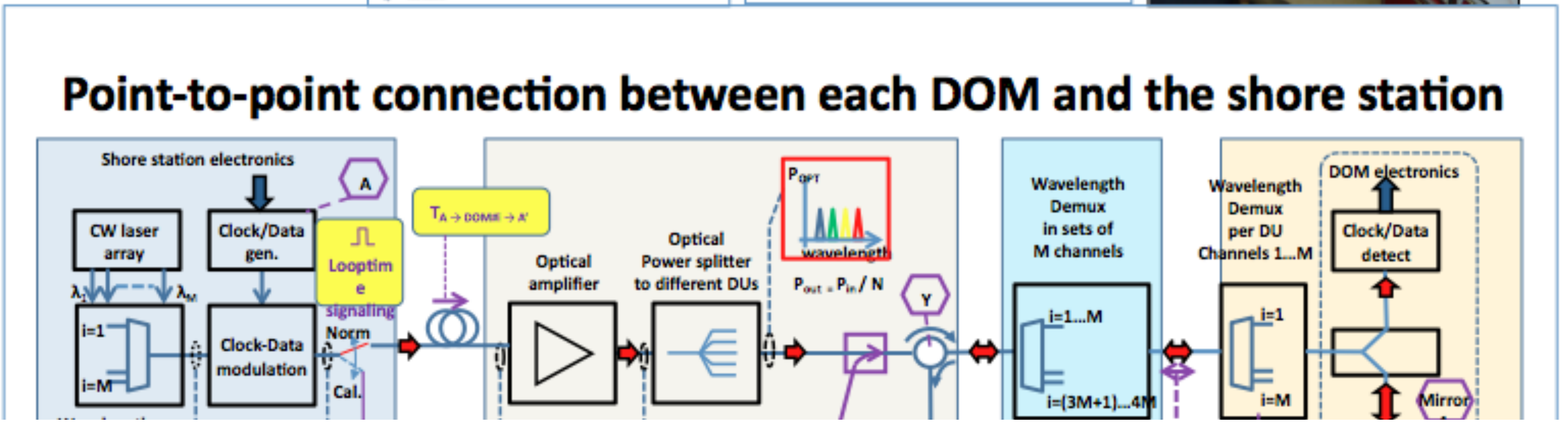
on behalf of the KM3NeT Consortium

Conclusions

Signal amplification adapted to transmission over 100 km cable to shore.

Reflected R-EAM modulated signal of -10 dBm
with an extinction ratio of $\varepsilon_r = 7$ fits in the return path of the network.

Point-to-point connection between each DOM and the shore station



Frontier Detectors for Frontier Physics
12th Pisa meeting on advanced detectors

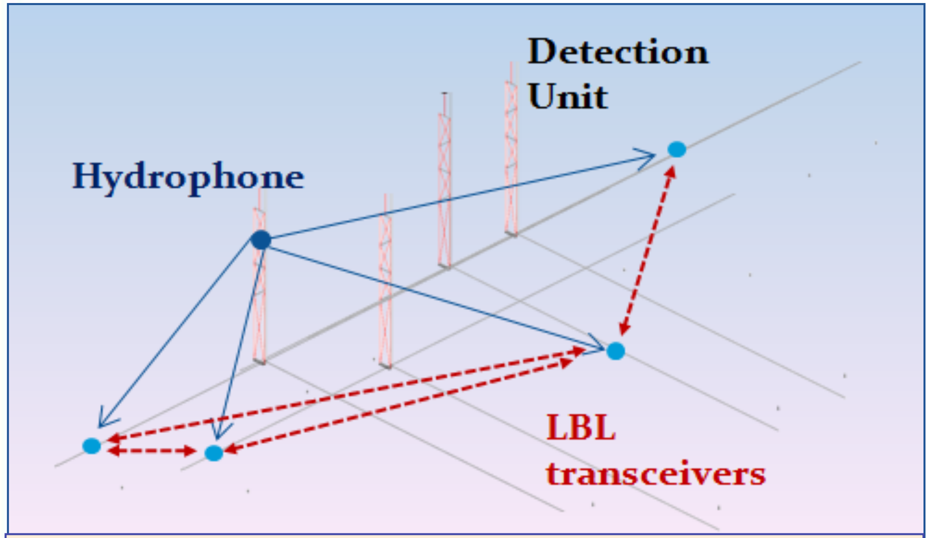
La Biodola, Isola d'Elba (Italy)
May 20 – 26, 2012

Acoustic Position Calibration of the KM3NeT Neutrino Telescope

G. Larosa, M. Ardid (for the KM3NeT Consortium)

Institut d'Investigació per a la Gestió Integrada de les Zones Costaneres - Universitat Politècnica de València

Acoustic Positioning System (APS)



Scheme of the Acoustic Positioning System

Key elements for the Acoustic Positioning System:

- Auto-calibrating Long Baseline of acoustic transceivers anchored in known and fixed positions. They define the reference frame.
- Array of acoustic sensors (hydrophones) in the Detection Unit mechanical structure.
- Auxiliary devices: tiltmeters and compasses, CTDs, sound celerimeters, sea current metres (ADCPs).
- Data acquisition and transmission system.
- Data analysis system on-shore.

Measurement and Analysis Technique:

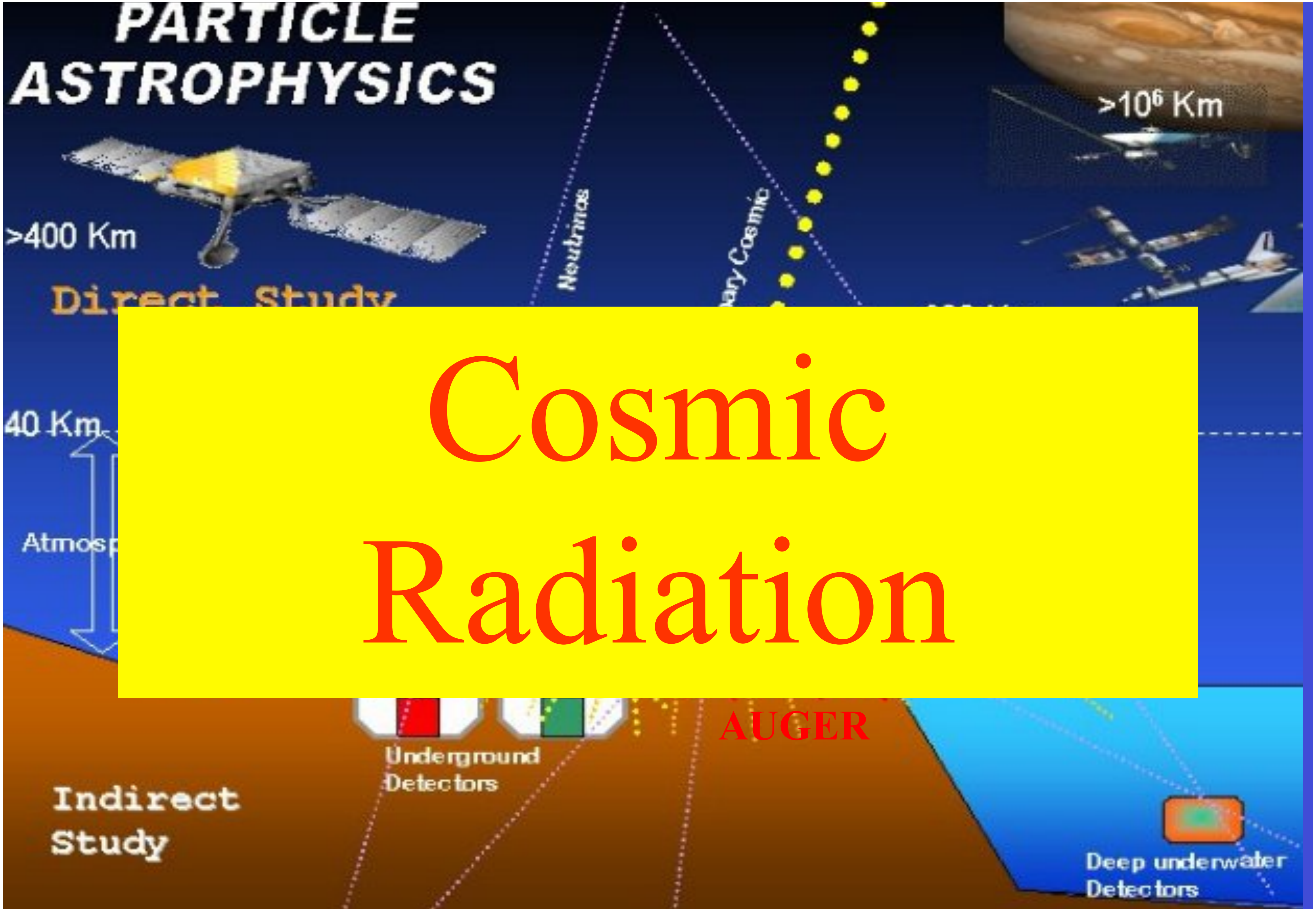
1.T_{Rec}(Hydro) – T_{Em}(Beacon) → Distance

2. Geometrical Triangulation → Position

Hydrophones will be sampled continuously at a rate of about 200 kHz and a continuous stream of data will be sent to shore for positioning and acoustic monitoring studies.

All elements have been tested in lab, and will be tested in situ In NEMO-Phase II (2012) and in the KM3NeT Pre-Production Model.

Cosmic Radiation

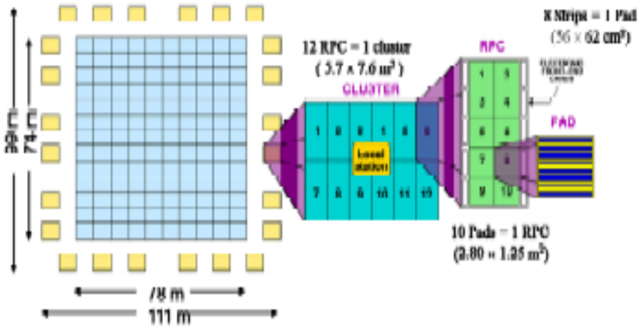


ARGO-YBJ: physics results and detector stabilization

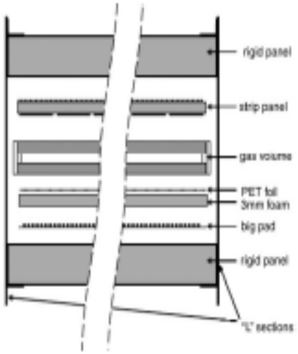
12th Pisa Meeting on Advanced Detectors
La Biodola, Isola d'Elba (Italy) May 20 - 26, 2012

P. Camarri [1,2], on behalf of the ARGO-YBJ collaboration
1 Università degli Studi di Roma “Tor Vergata”,
2 INFN Sezione di Roma Tor Vergata

The ARGO-YBJ experiment



Layout of the ARGO-YBJ detector



Expanded cross section of an ARGO-YBJ Resistive Plate Chamber

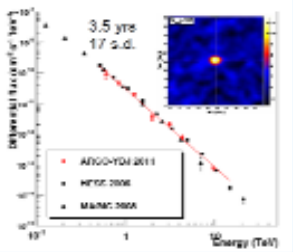
ARGO-YBJ is a collaboration between the INFN (Italy) and the IHEP/CAS (China).
ARGO-YBJ is a ground-based detector of air-shower particles.
It is a wide field-of-view γ-ray and cosmic-ray telescope, optimized to detect air showers induced by primaries with energy greater that a few hundred GeV.
This low-energy threshold is achieved by operating at very high altitude and by using a “full-coverage” detection surface of Resistive Plate Chambers (RPCs).

ARGO-YBJ is located at YangBaJing (Tibet, China), 90 km North of Lhasa, at an altitude of 4300 m a.s.l.
Longitude 90° 31′ 50″ East
Latitude 30° 06′ 38″ North
ARGO-YBJ has a full-coverage detection area (5600 m^2) surrounded by a guard ring, covering a total area of 10^4 m^2. The detection unit is a “pad”, namely the logical OR of 8 adjacent read-out strips. Each ARGO-YBJ RPC contains 10 pads.
The whole detector was built with 1836 RPCs (18360 pads and 146880 read-out strips overall).
ARGO-YBJ started taking data in July 2006 for the commissioning phase, and in November 2007 with the completed layout. Since then the experiment has been running smoothly and uninterruptedly.

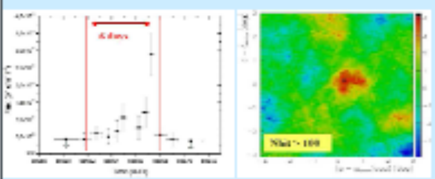
The ARGO-YBJ RPCs are operated in streamer mode at 7200 V with a gas mixture Ar/iC$_4$H$_{10}$/C$_2$H$_2$F$_4$ = 15/10/75.
The gap width is 2 mm.
The single-hit time resolution is about 1.5 ns.
Average duty cycle: 85%
Average trigger rate: 3.4 kHz at a 20-pad lower threshold on the central carpet within a 400 ns time window.
Over 4x10^{11} events have been recorded so far.
220 GBytes/day are transferred to the data centers of IHEP (Beijing) and CNAF (Bologna).

Physics results

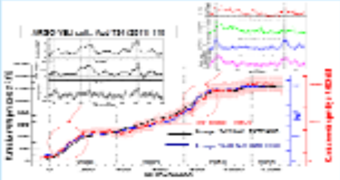
The main goals of ARGO-YBJ are γ-ray astronomy at energy greater than a few hundred GeV and cosmic-ray physics at energy greater than 1 TeV.
A conical fit of the shower fronts allows the reconstruction of the arrival direction of the primaries.
No γ-hadron discrimination has been applied so far. Background estimation is made by using the "time-swapping" and the "equi-zenith" methods.
ARGO-YBJ performed an all-sky survey in the declination range from –10° to 70°. In 3.5 years, five sources with significance greater than 5 standard deviations have been detected: Crab (17 s.d.), MRK 421 (12 s.d.), MGRO J1908+06 (6 s.d.), MGRO J2031+41 (6.3 s.d.). Interesting results were obtained on long-term variability, correlation between TeV and X-ray emission, and spectra [1, 2, 3].



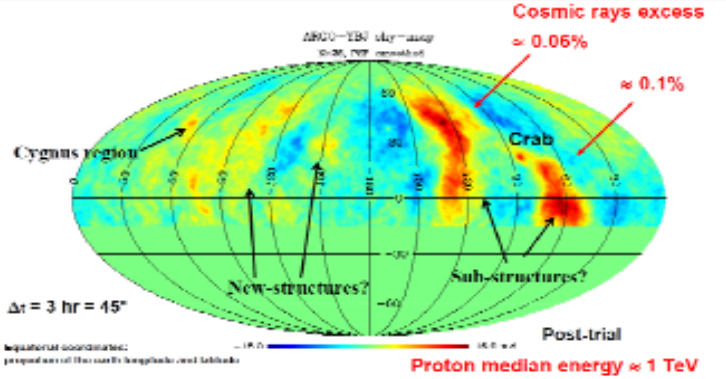
Comparison of the differential flux of TeV γ-rays from the Crab measured by ARGO-YBJ (red circles), HESS (black squares) and MAGIC (black triangles). The ARGO-YBJ significance map of the Crab sky region is also shown (top right).



LEFT: light curve measured by AGILE in the time interval April 14th-20th, 2011 (6 days).
RIGHT: ARGO-YBJ significance map of the Crab sky region in the same time period. The maximum measured significance was 3.5 s.d. To be compared with the expected value of about 0.5 s.d.
This sky map was obtained by selecting events with a median energy of about 3 TeV.



Cumulative light curves for the AGN MRK 421 measured by ARGO-YBJ in the TeV range (red), RXTE/ASM in the 2-12 keV range (black) and SWIFT/BAT in the 15-50 keV range (blue). The curves are shown on the same plot after being rescaled suitably. Good correlation between X-ray and γ-ray emission was found. ARGO-YBJ was the first experiment (and the only one so far) to carry on a long-term monitoring of an extragalactic source in the TeV energy range.



The study of the arrival directions of cosmic rays at energy greater than 1 TeV shows significant evidence for a puzzling anisotropy, as Milagro and Tibet AS-γ had noticed. Currently no explanation for this effect has been given yet. ARGO-YBJ is studying this effect in great detail by selecting events with median energy of about 1 TeV. Two extended excess regions in the sky map are evident, with maximum significance of about 15 s.d. so far. The possibility that these excesses may be due to peculiar fluxes of photons or electrons had been ruled out already. Neutron fluxes from nearby stars can be excluded as well. So this is peculiar of the hadron arrival directions in the heliosphere in the TeV energy range. The rightmost excess region is aligned with the direction of the heliotail, and the direction of both regions is nearly perpendicular to the expected direction of the interstellar magnetic field. Several authors proposed a possible connection between this anisotropy and a nearby supernova [4].

Detector stabilization

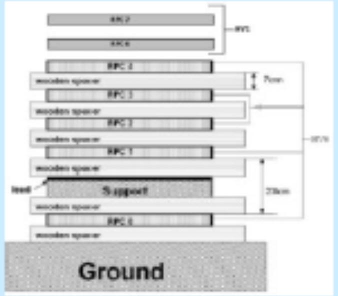
The gas gain in RPCs depends on the environmental conditions, namely on the local temperature and barometric pressure [4]. If V_{app} is the fixed applied voltage when the measured absolute temperature is T and the measured barometric pressure is p, then the effective voltage, if the reference absolute temperature and barometric pressure are chosen to be T_0 and p_0 respectively, is

$$V_{eff} = V_{app}\frac{T}{T_0}\frac{p_0}{p} \qquad (1)$$

Standard operating conditions for the ARGO-YBJ RPCs correspond to applied voltage V_0 at absolute temperature T_0 and barometric pressure p_0. Accounting for the fact that the effect of temperature changes affects the ARGO-YBJ RPCs with a delay of about one hour [5], the "operating-point" follow-up can be obtained according to the following rule:

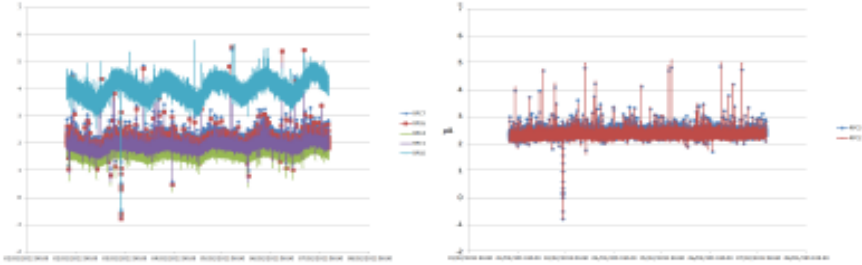
$$V_{app}(t) = V_0\frac{T_0}{p_0}\frac{p(t)}{T(t-1\,hour)} \qquad (2)$$

This algorithm is meant to stabilize the gas gain inside the RPCs, so that the detector can always work at constant operating conditions. However, it must always be kept in mind that this procedure only concerns the gas gain in the RPCs, and does not account for possible further effects connected to temperature changes in the whole acquisition chain.

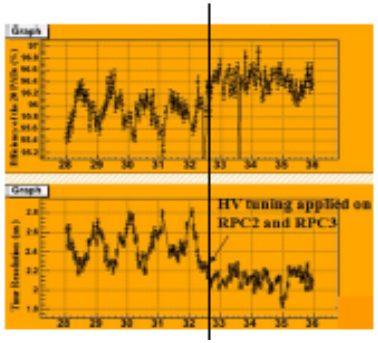


A small-size cosmic-ray telescope was installed close to the South side of the ARGO-YBJ carpet as a monitoring and testing facility for the RPCs. This telescope is connected to the general ARGO-YBJ acquisition system, so its data are recorded according to the standard trigger condition on the ARGO-YBJ carpet. Therefore, the analysis on the telescope must be performed with an off-line procedure. Cosmic-ray tracks are tagged by a coincidence of chambers 0, 1 and 4. These three chambers, together with chambers 2 and 3, are powered at 7200 V which is the standard voltage applied to the RPCs in the ARGO-YBJ carpet. The telescope has been running since 2009, using chambers 2 and 3 as the test chambers. The effect of the varying environmental conditions could be studied in detail.

The chambers 2 and 3 were powered according to the algorithm described previously in Eq. (2). This way, a continuous comparison could be made between a "standard" behaviour of the other chambers in which the applied voltage is left unchanged and a "corrected" behaviour in which the applied voltage is suitably regulated to compensate the gas-gain changes. The reference values for the absolute temperature and the barometric pressure are chosen to be close to the yearly average values provided by the monitoring system (DCS), namely T_0 = 288.65 K and p_0 = 600 mbar. The DCS, which includes all the monitoring and control procedures of the ARGO-YBJ experiment, must act on RPCs 2 and 3 at regular time intervals so that the voltage change to be applied each time is not greater than a few Volts. In this test the time interval was chosen to be 15 minutes. The complete high-voltage control algorithm also includes safety checks: for instance, the "new" voltage to be applied is used only if it is close enough to the previous applied voltage, to avoid critical mistakes induced by possible failures in the read-out of the environmental sensors. In addition, limits on the current absorbed by the power supply are set, so that the detectors are protected against any possible dangerous increase of current.



The voltage-control procedure was applied on the chambers 2, 3 in the cosmic-ray telescope from February 1st till February 8th, 2012. The current absorbed by all the chambers in the telescope was monitored, and the results are shown above for the chambers kept at fixed voltage (LEFT) and for the chambers 2, 3 (RIGHT). The effectiveness of the regulation algorithm is definitely apparent from the extreme stability of the current absorbed by the chambers 2 and 3 throughout the test, compared to the daily trend shown by the other chambers.



The detection efficiency and the time resolution of the chambers 2, 3 were monitored as well, and their behaviours before and after the start of the voltage-regulation test were compared. The result is shown in the charts to the left. The vertical line marks the time when the test was started. Before that time the voltage applied to the RPCs 2 and 3 was constant (7.2 kV). These plots show unambiguously that both the efficiency and the time resolution became more stable after applying the voltage-regulation procedure.

The devised feedback on the RPC applied voltage turned out to be reliable and stable. It is ready to be applied to the ARGO-YBJ full detector, and to any other detector with a response depending on the environmental parameters.

Measurement of cosmic ray air showers using radio-detection techniques at the Pierre Auger Observatory

M. Kleifges[1] for the Pierre Auger Collaboration[2]

[1]Karlsruhe Institute of Technology - Campus North - Institut für Prozessdatenverarbeitung und Elektronik, Karlsruhe, Germany
[2]Observatorio Pierre Auger, Av. San Martin Norte 304, 5613 Malargüe, Argentina, http://www.auger.org/archive/authors_2012_04.html

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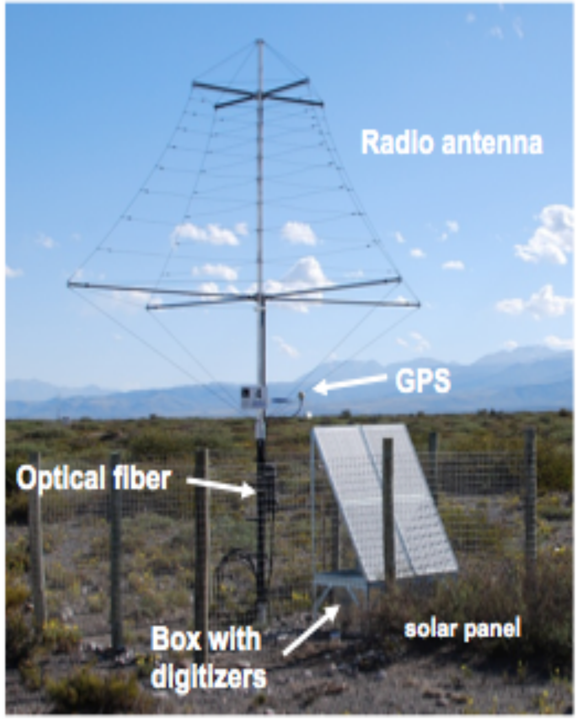
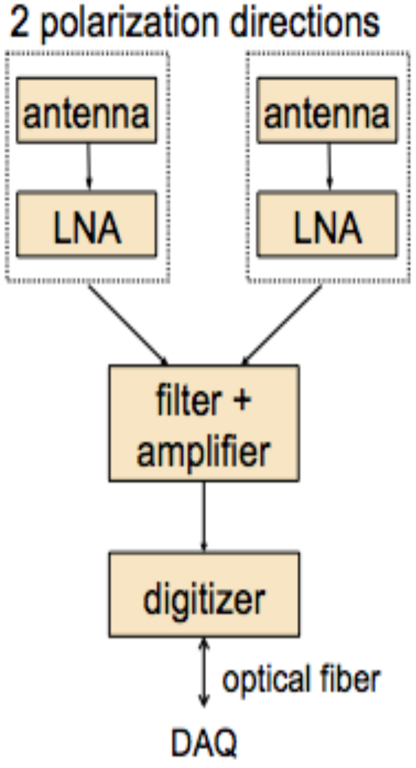
Auger Engineering Radio Array (AERA)



Radio detector station at the AERA site

Stage 1:

- 24 radio station with 150 m spacing deployed at the Pierre Auger Observatory site in Malargüe, Argentina
- wideband logarithmic-periodic dipole antenna with east–west and north--south polarization
- low noise amplifier (LNA) integrated at antenna
- analog filter and amplifier for the 30…80 MHz band
- engineering array to test different design options
- digitization with 12-bit at 180 / 200 MHz sampling rate
- RFI and transients rejection in time or frequency domain
- GPS system is used for time synchronization
- data readout via optical fibers from central station (CRS)
- sophisticated local trigger (T2) and coincidences between neighbor stations (T3)
- power (<20 W) provided photovoltaic system



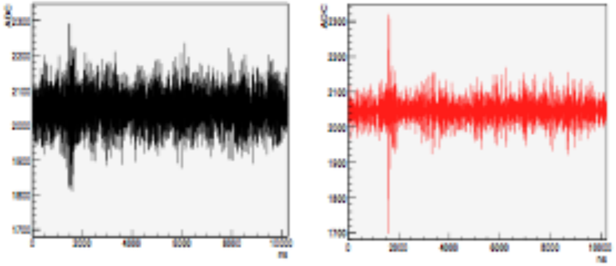
AERA signal chain

Digitizer and Trigger Concepts for AERA stage 1:

Nikhef design:

- 12-bit ADCs 200 MSPS
- Altera Cyclone 3 FPGA for control and trigger
- Voipac PXA 270M module with ARM CPU and Linux
- Trimble resolution-T GPS receiver
- Ethernet interface
- robust IP-67 housing

Trigger algorithm in time domain

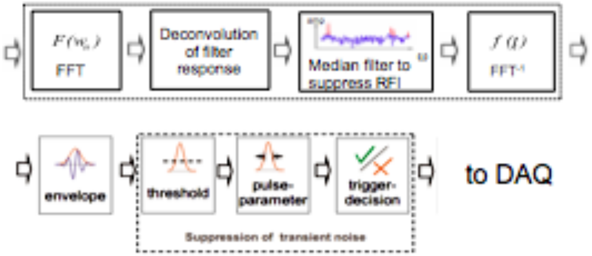


- 4 IIR filters implemented to reduce RFI- noise
- several threshold trigger to filter afterpulses
- Filtered and unfiltered data are recorded.

KIT/BUW design:

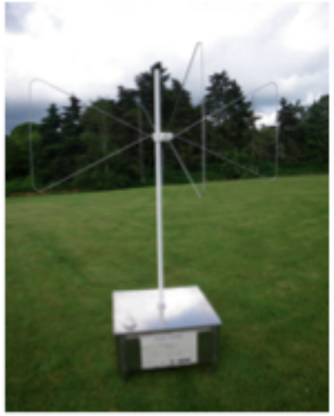
- 12-bit ADCs 180 MSPS
- Altera Cyclone 3 FPGA for control and trigger
- NIOS-II core in FPGA with uC-Linux
- 4GB SODIMM as ring buffer memory
- ſ-Lotus M12M GPS receiver
- Ethernet & CAN interface

Trigger algorithm in frequency domain



- correct filter response & remove RFI carriers
- threshold and parameter cut in time domain
- external trigger from SD with latency < 7 sec

Outlook: AERA stage 2:



Butterfly antenna for stage 2

- Deployment of 100 additional stations scheduled until end 2012
- stations will be equipped with Butterfly antennas
- more robust mechanics
- lower power consumption of digital electronics
- integration of analog filters
- transition from optical fiber network to wireless communications
- improved trigger algorithms

Conclusion:

- AERA proved radio detection technique on a larger scale
- within 1 year about 130 cosmic showers are recorded as super-hybrid in coincidence with the Pierre Auger Observatory
- alternative options for the digitial electronics and triger under test
- AERA stage 2 will soon extend the array size to about 16 km²

References:

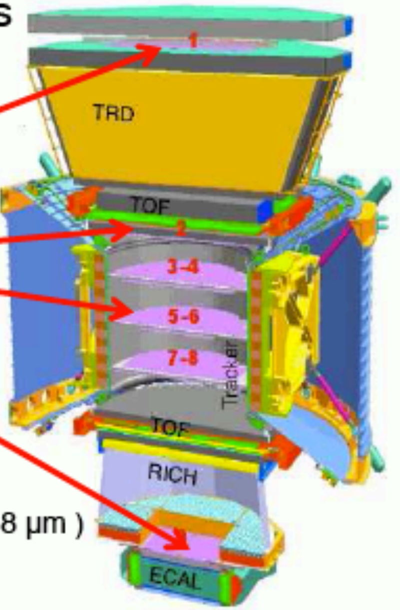
- ➢ The Pierre Auger Collaboration, NIM A 620 (2010), 227251
- ➢ H. Falcke, et al., Nature 435 (2005), 313-316
- ➢ J. Kelly (Pierre Auger Collaboration), arXiv:1205.2104v1 [astro-ph.IM]
- ➢ C. Ruehle, (Pierre Auger Collaboration), NIM A 662 (2012), 146-149
- ➢ The Pierre Auger Collaboration, NIM A 635 (2011), 92102

The AMS-02 Silicon Tracker : *First Year on ISS in Space*

Divic Rapin, DPNC, Université de Genève, *on behalf of the AMS-Tracker Collaboration*

7 m² of *double sided* microstrip detectors arranged in 9 layers

196’608 channels



Upper tracker
(1 layer)

Inner tracker
(7 layers)

Lower tracker
(1 layer)

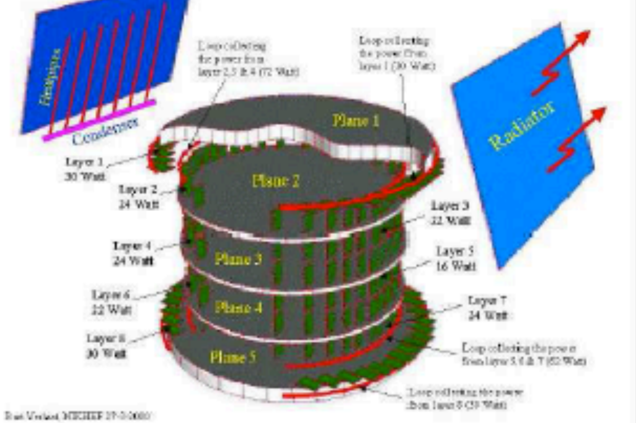
Pitch p-side:**Y** (bend)

- 27.5 µm (110 read-out σ_{th}: 8 µm)

Pitch n-side:**X** (non-bend)

- 104 µm (208 read-out)

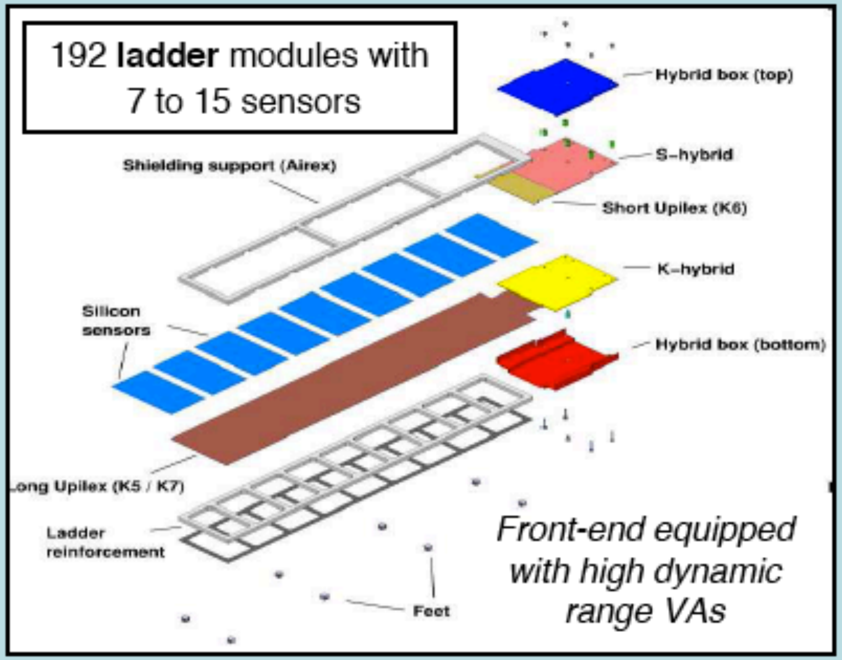
TTCS: Mechanically pumped 2-phases cooling system.



B.Verlaat 2000.

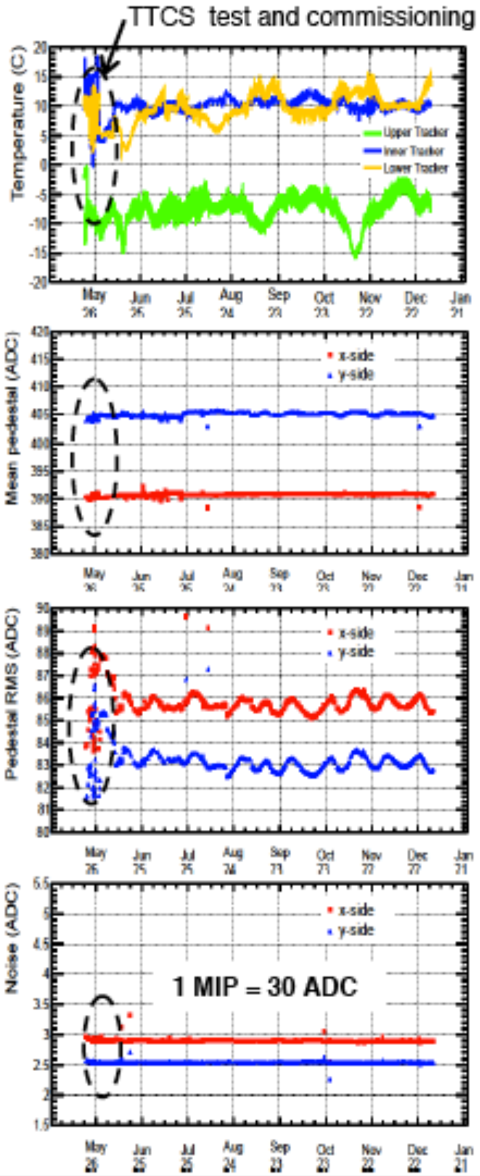
J. van Es

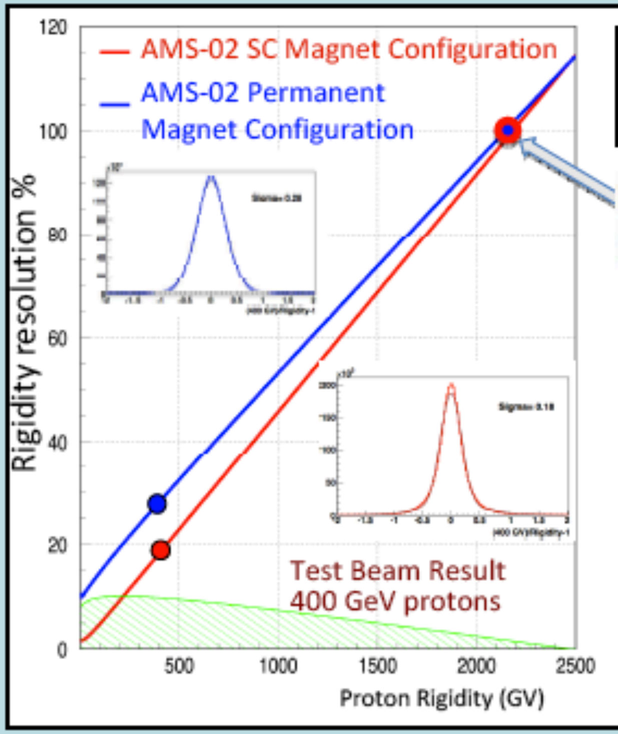
192 **ladder** modules with
7 to 15 sensors



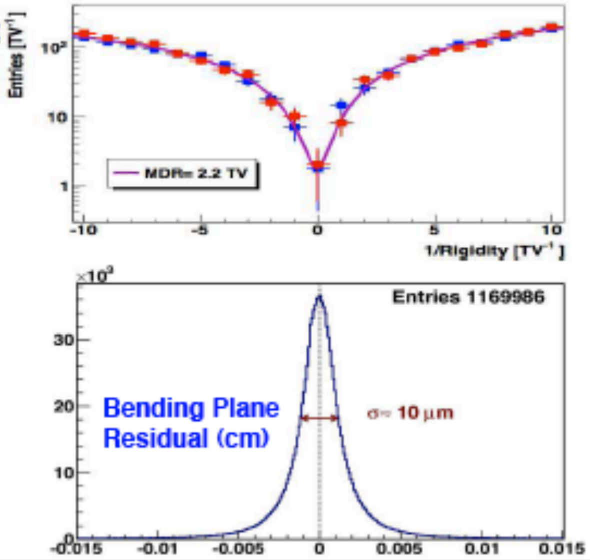
Front-end equipped with high dynamic range VAs

Tracker Environmental Conditions and Stability

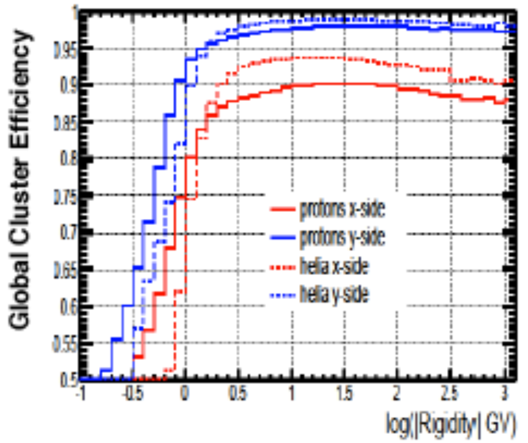




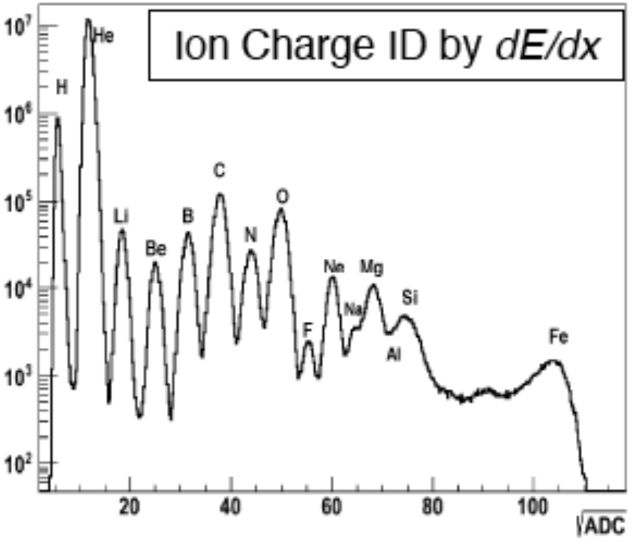
Performances with Test Beam and Atmospheric Muons



In Flight Performances



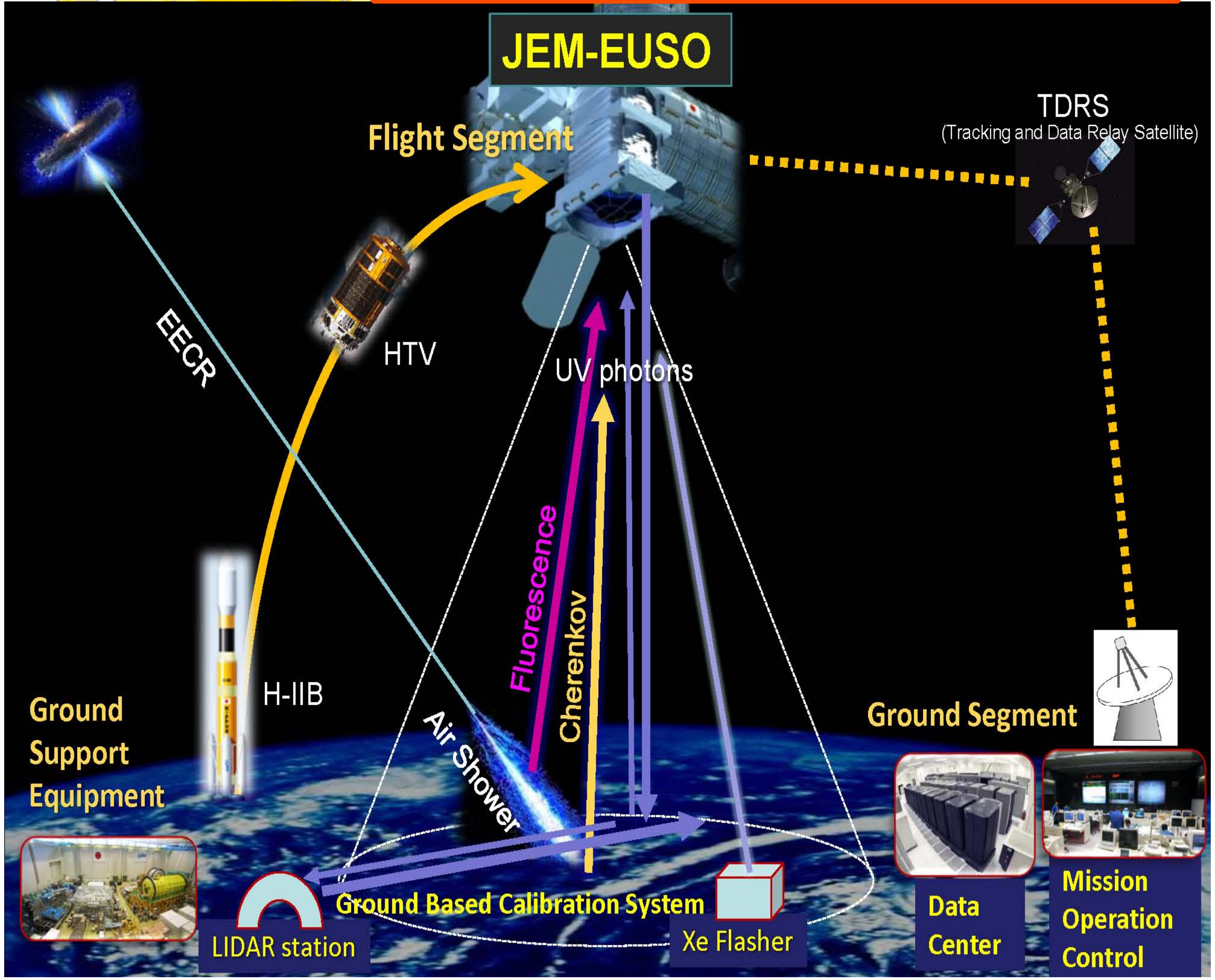
Ion Charge ID by *dE/dx*



Conceptual view of JEM-EUSO

- JEM-EUSO apparatus has been designed to detect the UV photons (330-400nm) emitted in the shower produced by the Extreme Energy Comic Ray (EECR) interactions with the atmosphere.
- This will be possible thanks to a super-wide-field of view (60°) telescope of about 2.5m looking downward from the ISS to the night sky.
- JEM-EUSO is designed to detect, in 5 years, more than 1000 events E<7×10^{19} eV.

Doing astronomy by looking downward

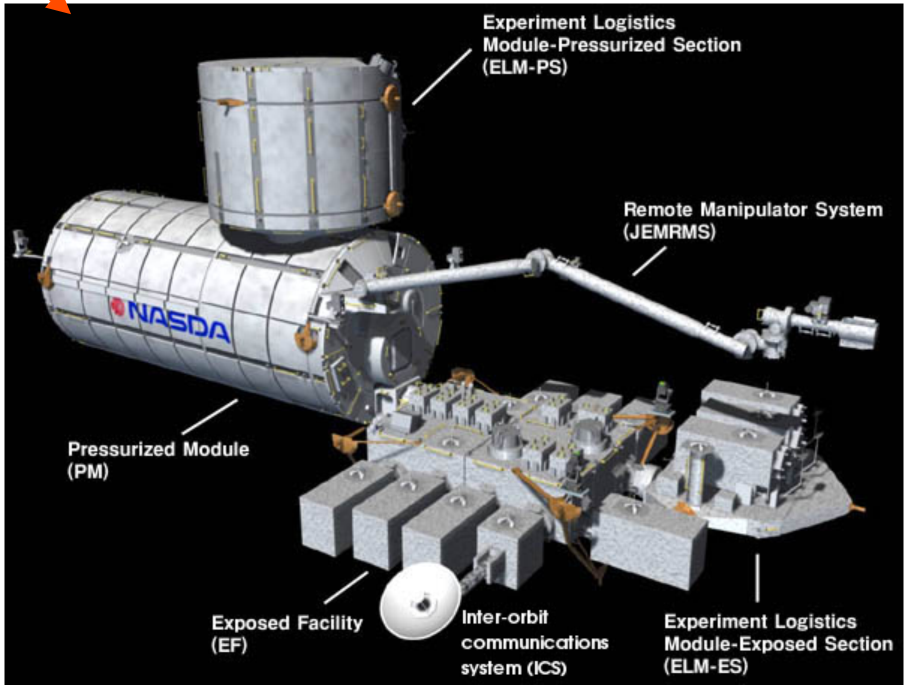


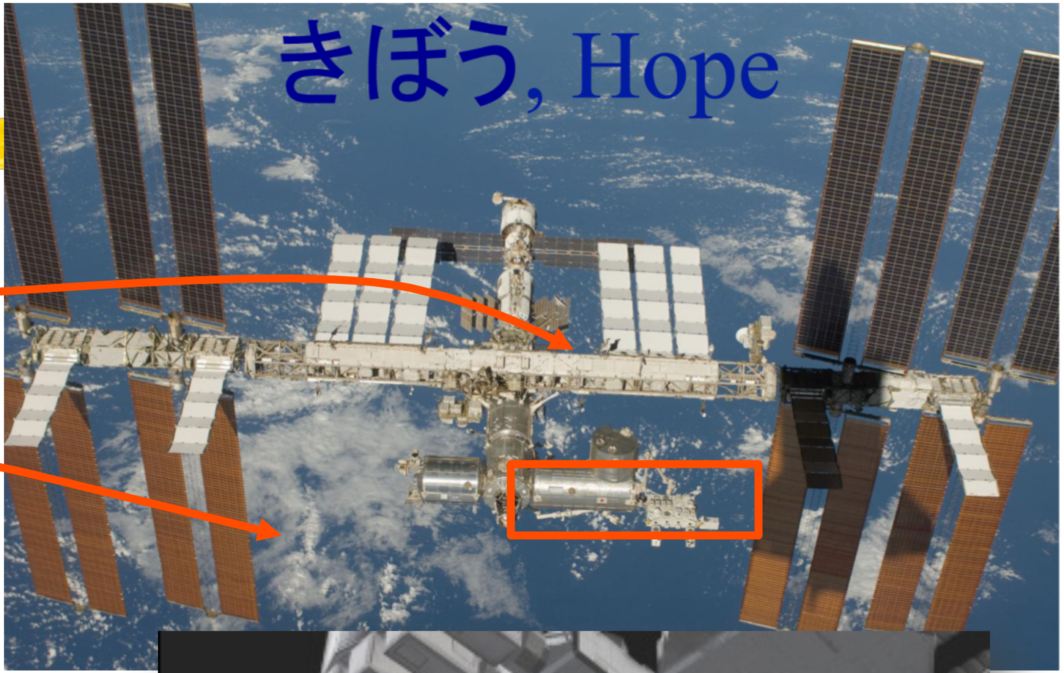
Scientific objectives

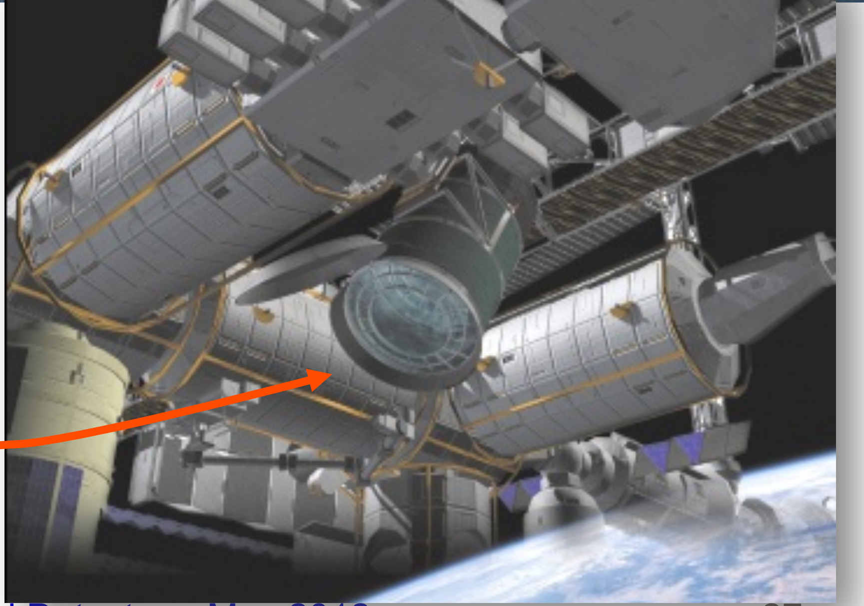
- **Astronomy and Astrophysics through the particle channel**:
  - Identification of sources and study of the acceleration or emission mechanisms by high-statistics arrival direction analysis;
  - Measurement of the energy spectra of individual sources (spectral shape, flux, power);
  - High Statistics measurement of the trans-GZK (Greisen-Zatsepin-Kuzmin) limit spectrum.
- **Physics and Astrophysics at $E>5.\times10^{19}$eV**
- Exploratory and Secondary Objectives:
  - New messengers:
  - Discovery of UHE neutrinos by neutrino discrimination and identification via X_0 and X_{max};
  - Discovery of UHE Gammas by discrimination of X_{max} due to geomagnetic and LPM (Landau–Pomeranchuk–Migdal) effect.
  - Magnetic field studies:
  - Constrains on the galactic and local extragalactic fields.
  - Atmospheric science.

The JEM module

The Japanese Experiment Module (JEM), Kibo, on the ISS







The JEM-EUSO detector on the JEM exposed facility

Neutrinoless Double Beta
&
Dark Matter

Status Report of the GERDA Experiment Phase I

S. Riboldi on behalf of the **GERDA Collaboration**

(95 Physicists and 17 Institutions from Germany, Italy, Russia, Poland, Belgium, Switzerland, China)

Frontier Detectors for Frontier Physics

12th Pisa meeting on advanced detectors

La Biodola • Isola d'Elba • Italy

May 20 - 26, 2012

GERDA Experiment - Phase I - is active at INFN LNGS since November 2011,

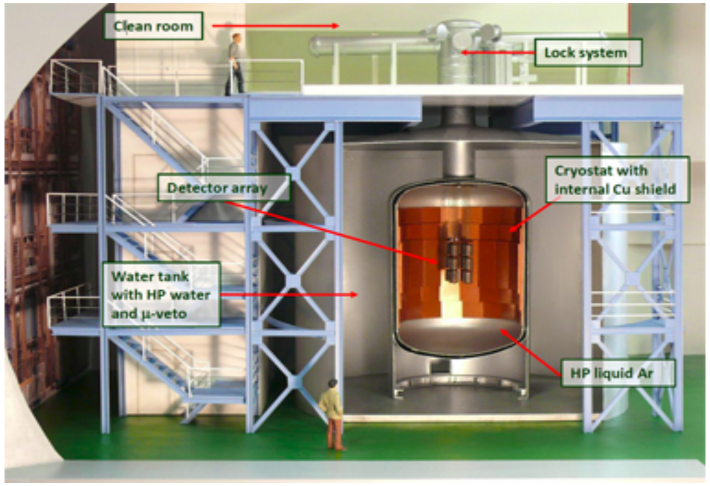
investigating neutrino-less double beta decay of ^{76}Ge, with 4 goals:

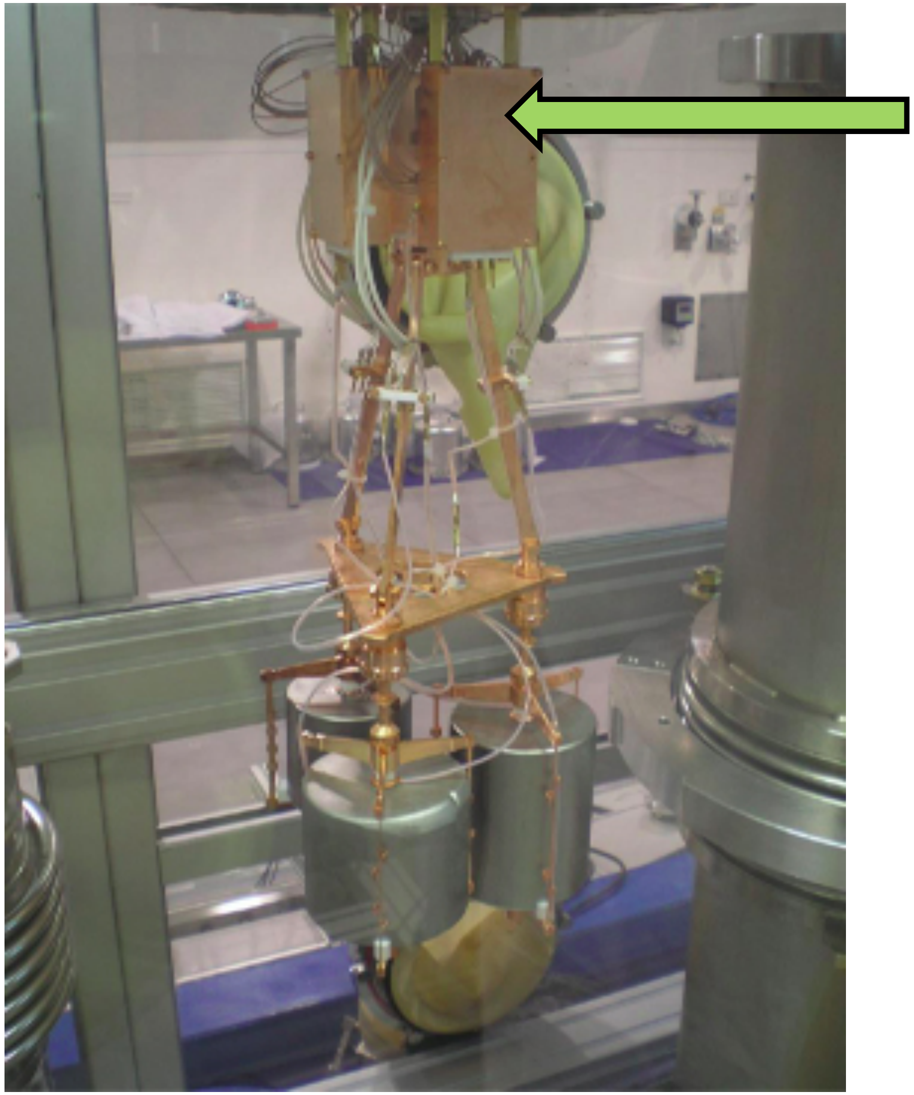
i)prove the Majorana nature by searching for the $0\nu\beta\beta$ of ^{76}Ge with a sensitivity of $T_{1/2} > 10^{25}$ y

ii)probe the neutrino mass at the level of 300 meV in a couple of years of data taking

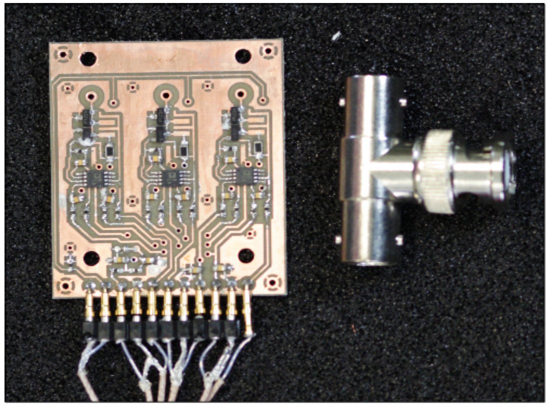
iii)demonstrate a low radiation level facility with background reduction by 2 orders of magnitude

iv)definitely validate the operation of non-encapsulated Germanium detectors in liquid Argon

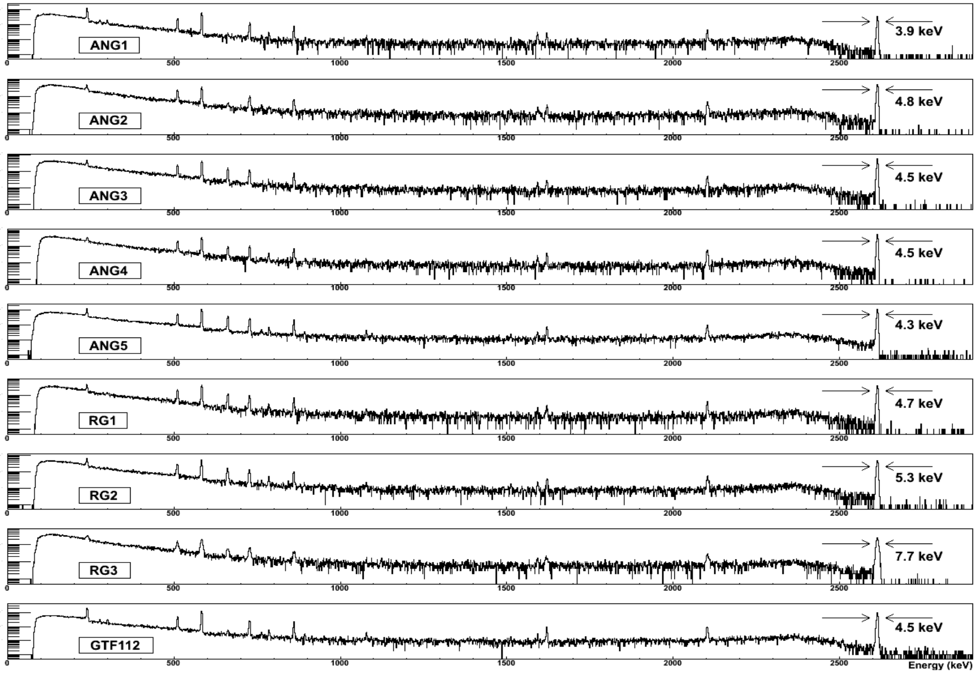




The 3-string arm inside the GERDA glove box, holding 3 naked Germanium detectors (at the end of the set-up phase there will be 9 in total), to be subsequently lowered in the liquid Argon cryostat.



The front-end readout electronics, based on the CC2, a 3-channel, cryogenic charge sensitive preamplifier designed and manufactured to cope with the requirements of the GERDA experiment, including radio-purity.



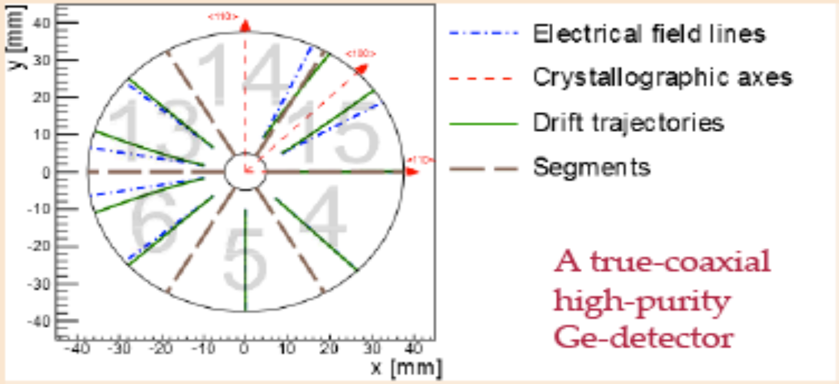
The naked, enriched Ge detectors operate satisfactory in liquid Argon since months, almost of them providing the expected energy resolution and stability of leakage current. Calibration spectra are shown.

Data taking is in progress…

Bulk and Surface Effects in Segmented High-Purity Germanium Detectors

I. Abt, A. Caldwell, B. Dönmez, S. Irlbeck, B. Majorovits, O. Volynets*

Anisotropy



A true-coaxial high-purity Ge-detector

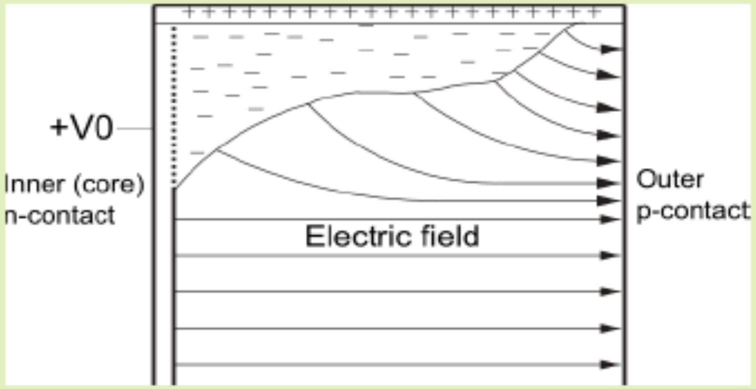
Mobility, μ, relates velocity of charge carriers, $\boldsymbol{v}(r)$, and electric field, $\boldsymbol{E}(r)$:

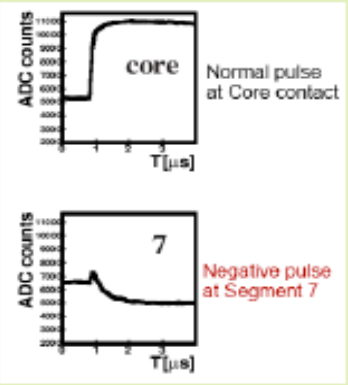
$$\boldsymbol{v}(r) = \mu \cdot \boldsymbol{E}(r).$$

Mobility is a ***tensor*** ⇒ charges do not drift ***radially*** ⇒ non-flat occupancy patterns seen in segments.

Application: fast determination of crystallographic axes using simulated occupancy patterns and comparison to the measured patterns.

Surface effects





Drifting charges may be trapped close to the surface (inactive layers) ⇒ *strange pulses* seen on detector electrodes.

A new test stand, ***GALATEA***, was designed and commissioned to study such effects.

Key feature: direct proximity of a radioactive source to the detector

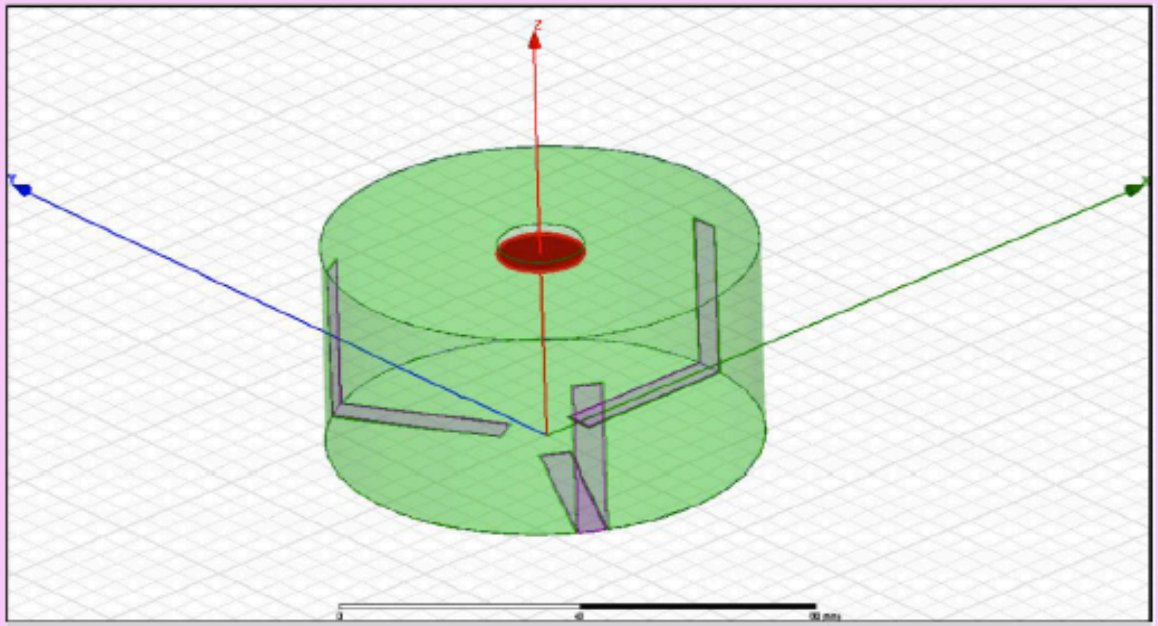
Milestones:

- Cooling system
- Vacuum conditions
- Movable source
- Readout electronics

Bulk and Surface Effects in Segmented High-Purity Germanium Detectors

I. Abt, A. Caldwell, B. Dönmez, S. Irlbeck, B. Majorovits, O. Volynets*

Novel design of Segmented BEGe detectors



- Low capacitance:
  - low energy threshold
  - better energy resolution
- Use of segmentation for event topology reconstruction:
  - ***Core*** point-like ***contact***: energy and timing information
  - ***Segments***: position reconstruction using the so-called *mirror pulses*
- Possibility to distinguish between single- and multi-site events known for BEGes

Milestones in progress:

- Electric field calculation for various geometries using ANSYS Maxwell
- Pulse shape simulation
- Position reconstruction algorithms

Characterization of BEGe detectors in the HADES underground laboratory

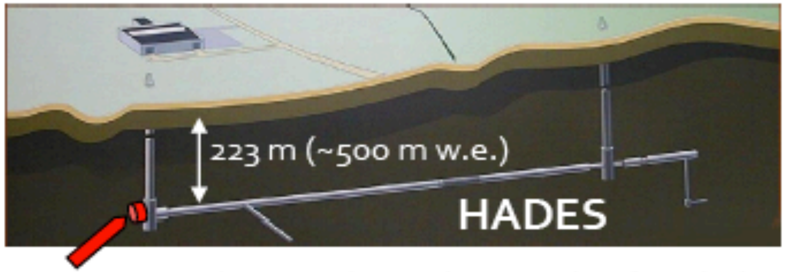
Erica Andreotti

Joint Research Centre - Institute for Reference Materials and Measurements

Newly produced **Broad Energy Germanium detectors (BEGe),** enriched in the isotope ^{76}**Ge**, are being characterized in the frame of the **GERDA** experiment.

AIM: determination of all the important operational parameters.

- Energy resolution at operational high voltage;
- High voltage scan up to the operational value;
- Detector stability in time;
- Dead layer thickness and uniformity;
- Active volume;
- Quality of pulse shape discrimination.



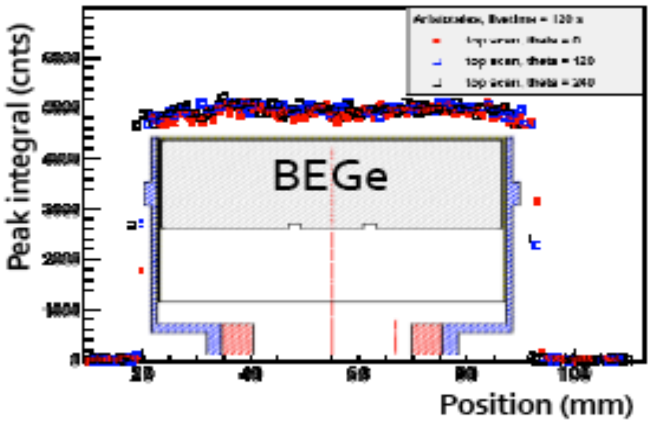
HEROICA: Hades Experimental Research Of Intrinsic Crystal Appliances

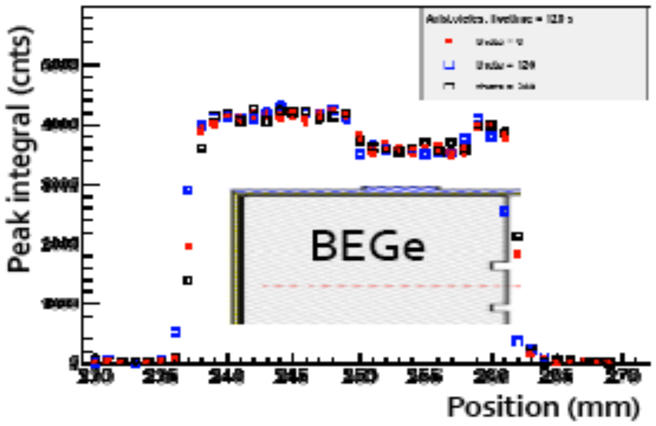
The characterization is being carried out at the **HADES** underground laboratory, in Mol (Belgium) in order to **minimize diodes exposure to cosmic radiation**. The **~500 m w.e.** overburden guarantees a muon flux reduction of order 10^4 with respect to the ground level.

A test facility for the fast screening of the BEGe detectors has been developed in the course of the first half of 2012.

Two different types of mechanical set-ups have been developed:

1. Two **simple measurement stands**, provided with a lead and copper shielding, allowing the positioning of a radioactive source at the chosen fixed position; this is used for all those **measurements which do not require collimated sources**.
2. Three copies of an **automated scanning set-up** provided with a movable, motor controlled arm, for the **automated full area scan of the diode using a ^{241}Am collimated source**; this is used to study the **uniformity of the dead layer** along the whole detector surface and the variation of the **pulse form in different active regions**.

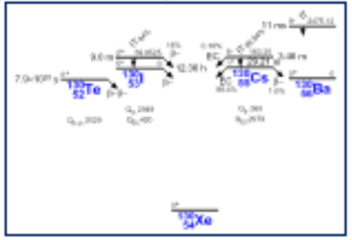


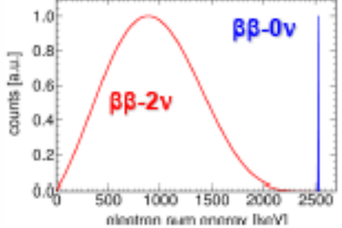


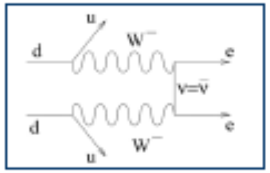
CUORE: a Neutrinoless Double Beta Decay experiment

Ezio Previtali on behalf of the CUORE Collaboration

Search for neutrinoless double beta decay





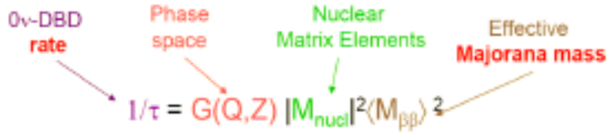


$(A,Z) \rightarrow (A,Z+2) + 2\,e^-$

Forbidden by standard model ($\Delta L=2$)

ββ0ν ⇔

- $m_\nu \neq 0$
- Majorana nature $(\nu = \bar{\nu})$



0ν-DBD **rate**

Phase space

Nuclear Matrix Elements

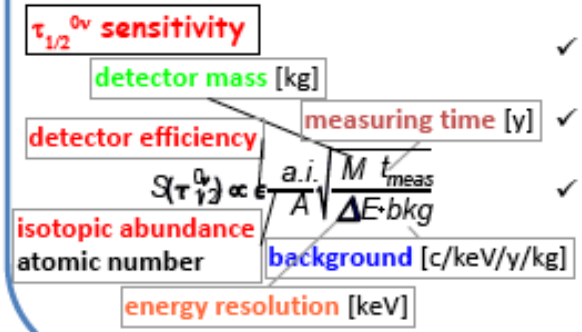
Effective **Majorana mass**

$$1/\tau = G(Q,Z)\,|M_{nucl}|^2 \langle M_{\beta\beta}\rangle^2$$

Experimental Sensitivity

Experimental sensitivity to $\tau^{1/2}_{0\nu}$ with no ββ-0ν decay observed

$N_{\beta\beta} \leq (bkg \cdot \Delta E \cdot M \cdot t_{meas})^{1/2}$ at 1σ



$\tau_{1/2}^{0\nu}$ sensitivity

detector mass [kg]

measuring time [y]

detector efficiency

$$S(\tau^{0\nu}_{1/2}) \propto \varepsilon \frac{a.i.}{A} \sqrt{\frac{M\, t_{meas}}{\Delta E \cdot bkg}}$$

isotopic abundance

atomic number

background [c/keV/y/kg]

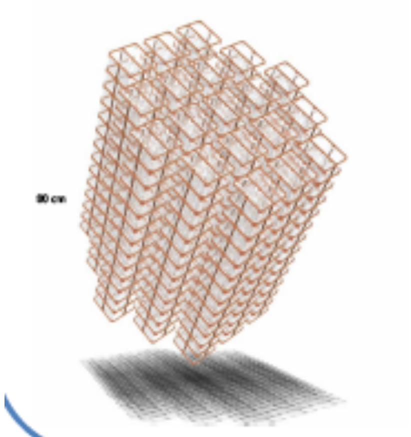
energy resolution [keV]

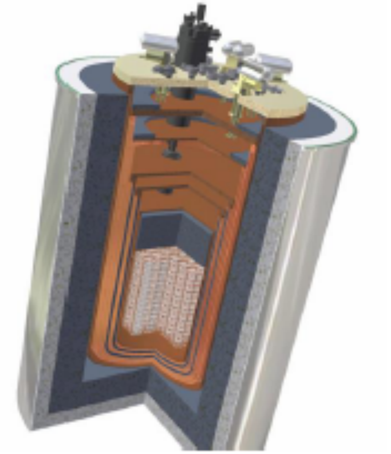
To improve sensitivity we need:

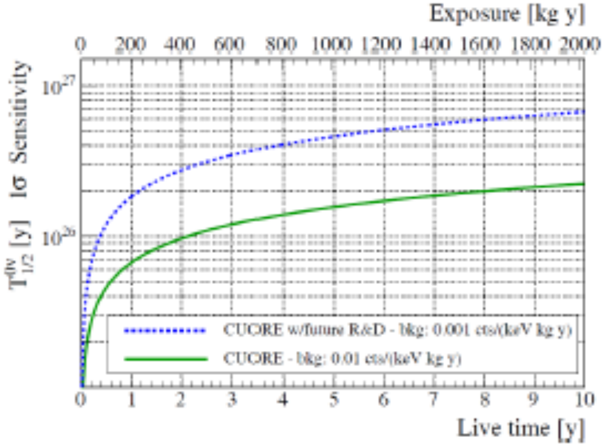
- ✓ M very large - 1 ton scale experiment
- ✓ a.i. high - isotopically enriched materials
  - ^{130}Te a.i. is 34.167% in natural Te
- ✓ ε high - high volume detectors
  - single module is 750 g TeO_2 crystal
- ✓ ΔE very good - good energy resolution detectors
  - TeO_2 bolometric detectors
- ✓ bkg very low - low radioactivity measurements
  - experiment installed in Hall A of LNGS
  - low radioactivity material selected
  - heavy lead shield for environmental bkg

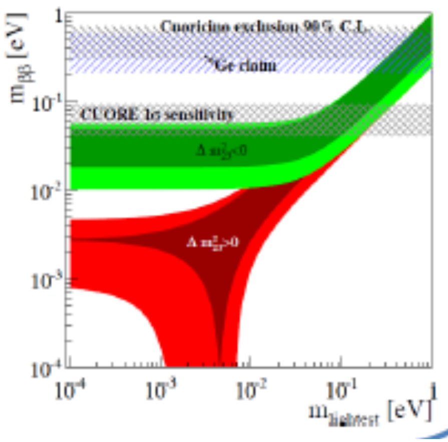
CUORE - Cryogenic Underground Observatory for Rare Events

Array of 988 TeO_2 bolometers, 5x5x5 cm³ each, total detector mass 741 kg, 130Te mass 206 kg, 128Te mass 189
CUORE detector will be operated at 8-10 mK in specifically designed cryostat

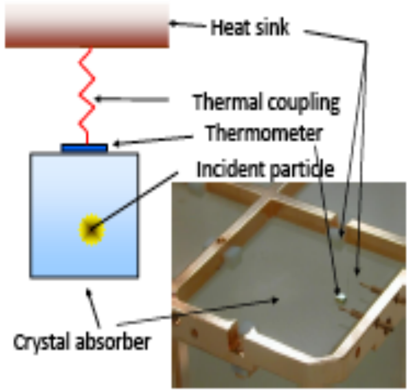








Thermal Detector Technique



Detection Principle

DT = E/C

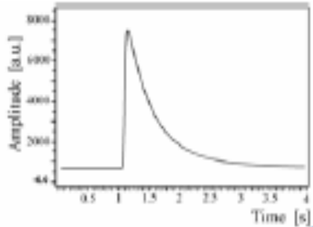
C: thermal capacity

low C ⇒ low T (i.e. T ≈ 10 mK)

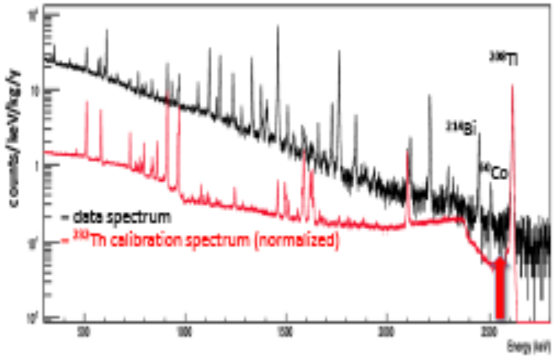
$C \approx 2$ nJ/K @10mK => 1 MeV => 100 mK
e.g. TeO_2
$I \approx 0.1$ nA
$dR/dT \approx 0.1$ MΩ/mK
$dV \approx 1$ mV
ΔE (FWHM) ≈ 1 keV

Thermal Detectors Properties

- ▲ good energy resolution
- ▲ wide choice of absorber materials
- ▲ true calorimeters
- ▼ slow $t = C/G \sim 1 \div 10^3$ ms



Radioactive Background Evaluation



Backgrounds in region of interest (2430-2630 keV):

- (~40%) Compton events from 2615 keV peak of ^{208}Tl
- (~50%) Degraded alphas from copper surfaces
- (~10%) Degraded alphas from crystal surfaces

Three Tower Test (TTT) run

Measurement in Hall A cryostat: same as Cuoricino
Crystals from Cuoricino and repolished on surfaces
Three different copper cleaning were tested

Total statistics, no anticoincidence cut

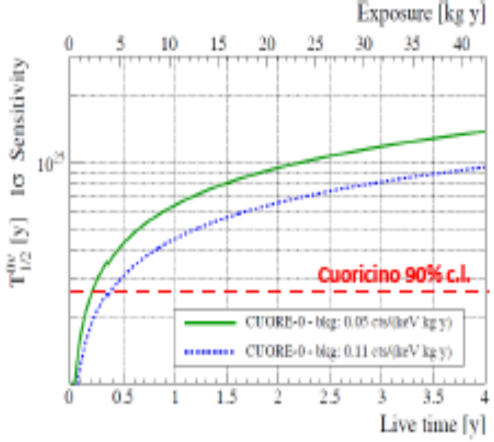
Tower c/keV/kg/y	2.7-3.9 MeV (excluded Pt peak)	Error (1σ)
T1	0.068	0.006
T2	0.120	0.012
T3	0.072	0.008

T1 and T3 are compatible and show lower background then Cuoricino

CUORE-0 the first complete tower of CUORE

CUORE-0 is realized:
- with the same procedure of CUORE
- crystals from the same production line
- same copper and PTFE spacers
- CUORE-like copper surface cleaning
- same assembly line
- installed in HallA cryostat (as Cuoricino)

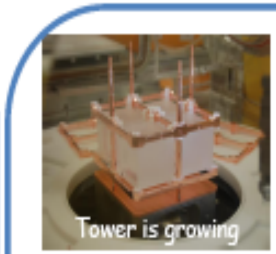
Many aspects will be analyzed with CUORE-0:
- detector performances
- radioactive background
- electronics and data acquisition
- data analysis



But also new very senitive measurements on ββ-0ν decay of ^{130}Te can be done

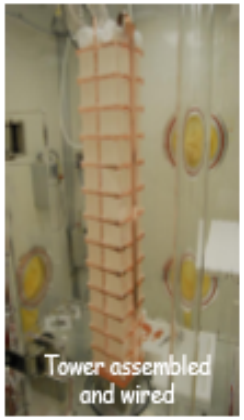
In one year of live running time we double the Curicino limit

CUORE-0 Assembly Phases


Tower is growing

Assembly of CUORE-0 was done with the tools that will be used in CUORE
- Specific glow boxes were installed in the CUORE Clean Room
- Continuous flux of nitrogen was maintained to prevent Rn exposure
- NTDs and heaters were bonded in place directly on the tower
- A nitrogen fluxed "garage" store CUORE-0 before the installation


Bonding NTD and heaters


Tower assembled and wired


Installation of copper shield

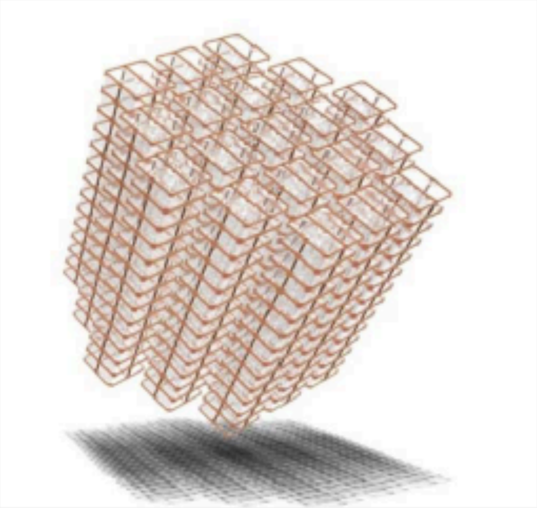

CUORE-0 ready to start

Surface induced background in CUORE

Cryogenic Underground Observatory for Rare Events

The CUORE experiment aims to search for neutrinoless Double Beta Decay (0νDBD) of ^{130}Te with an array of 988 TeO_2 bolometers.

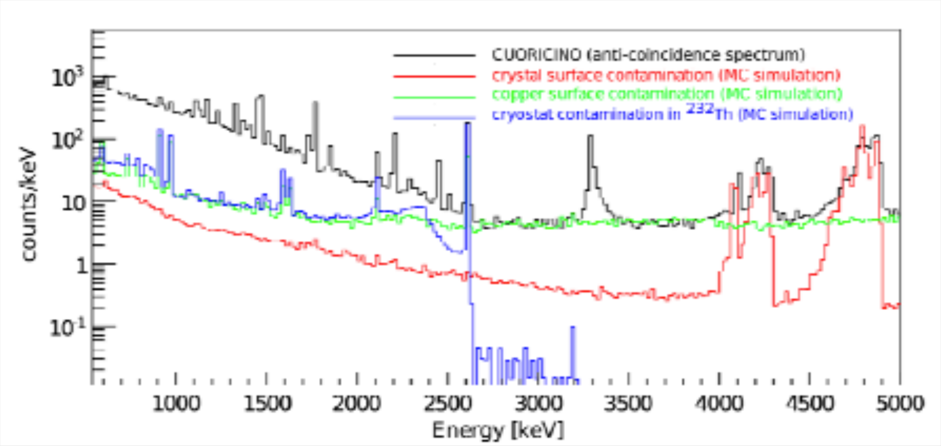
Discovery of 0νDBD will provide outstanding insight into neutrino mass and nature (Dirac or Majorana).



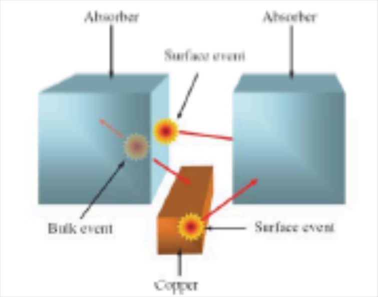
The CUORE background model is based mainly on the knowledge acquired on the bolometric technique thanks to Cuoricino.

Cuoricino background

The Cuoricino detector was built as a prototype for the CUORE experiment. Cuoricino counting rate in the region of interest:



Alpha surface contaminations



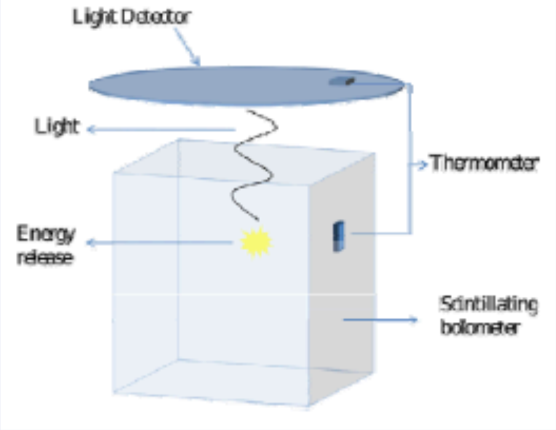
α particles give contributions the region of interest only if they loose a limited fraction of their energy in the bolometer. This condition happens whenever the contamination is localized on the surface of the crystal or of the material facing the detector.

Surface induced background in CUORE

Surface contaminations studies with scintillating bolometer

Working principle of scintillating bolometers

Scintillating bolometer: a bolometer coupled to a light detector.

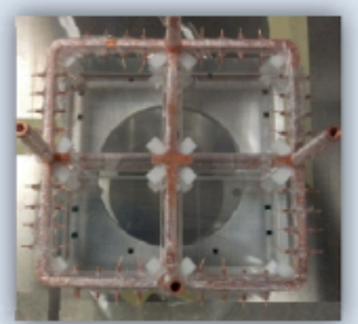


The leading idea: to combine the two available information (heat and scintillation light) to distinguish the nature of the interacting particles, exploiting the different scintillation yield of β/γ, α and neutrons.

Thanks to the capability to recognize the nature of the interacting particles, scintillating crystals can be used to study surface contaminations of materials faced to the detector with a much higher sensitivity than conventional techniques

Array of 4 BGO crystals (5x5x5 cm^3) + Light detector (Ge, Ø=6.6 cm)

BGO crystals ($Bi_4Ge_3O_{12}$) are particularly suitable because of their very high light yield and commercial availability.



Surface inert material ≈ 450 cm^2

Live time = 1364 h

α background (3-8 MeV)

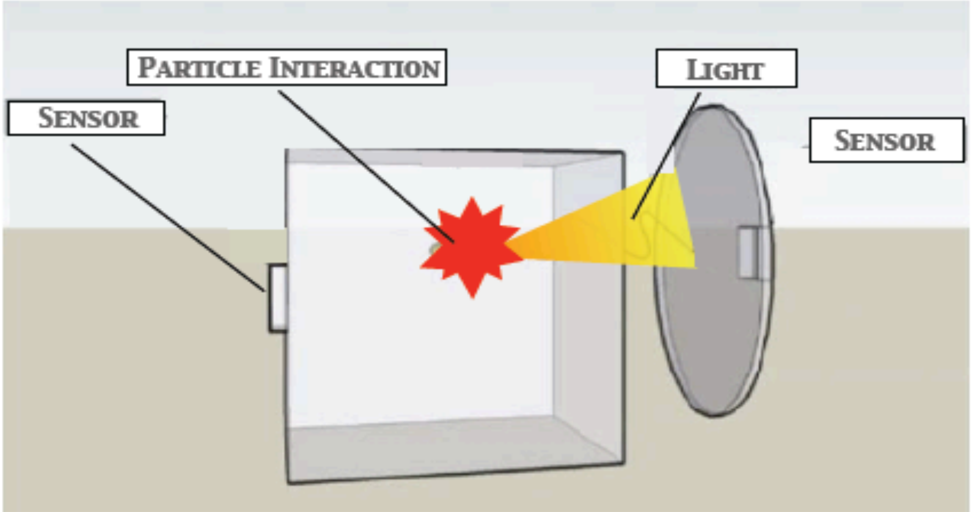
≈ 0.0001 count/h/cm^2

The assembly is the same (except for the light detector) of the one used for studies of surface contaminations done with TeO_2 crystals.

Study of Rare Alpha Decays with Scintillating Bolometers

Laura Cardani
Sapienza, University of Roma and INFN Roma

Standard detectors (gas counters, semiconductors..) do not achieve the necessary sensitivity to study rare α decays
New detection technique: scintillating bolometers



Double read-out

Heat released by an interaction

- Excellent energy resolution
- Very high efficiency

Scintillation light emitted by the same interaction

Recognition of the nature of the interaction (α, electrons) through the scintillation yield

Rejection of the background due to electrons, muons, γ's..

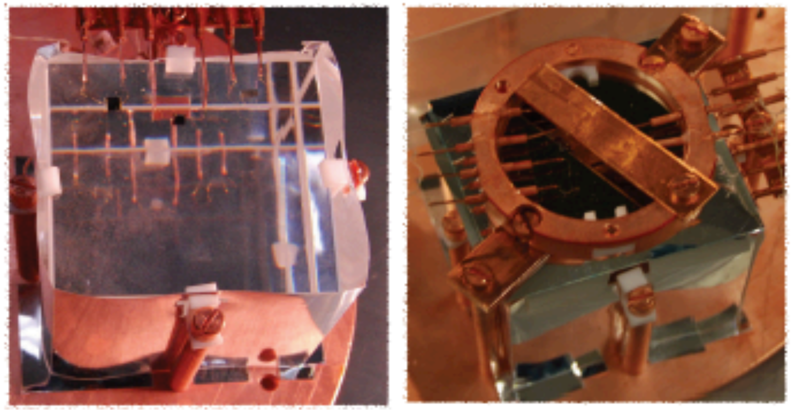
Thanks to this technique we could study the rare α decays of several isotopes
We operated a $PbWO_4$ bolometer in order to study the lead isotopes, achieving an unprecedented sensitivity on their decays.

Isotope	Energy of emitted α	Sensitivity on α decay
^{204}Pb	1971.8 keV	$\sim 10^{20}$ years
^{206}Pb	1136.6 keV	$\sim 10^{21}$ years
^{208}Pb	391.5 keV	$\sim 10^{20}$ years
^{207}Pb	518.8 keV	$\sim 10^{19}$ years

Study of Rare Alpha Decays with Scintillating Bolometers

Laura Cardani
Sapienza, University of Roma and INFN Roma

We used the same technological approach to study the rare decay of ^{209}Bi



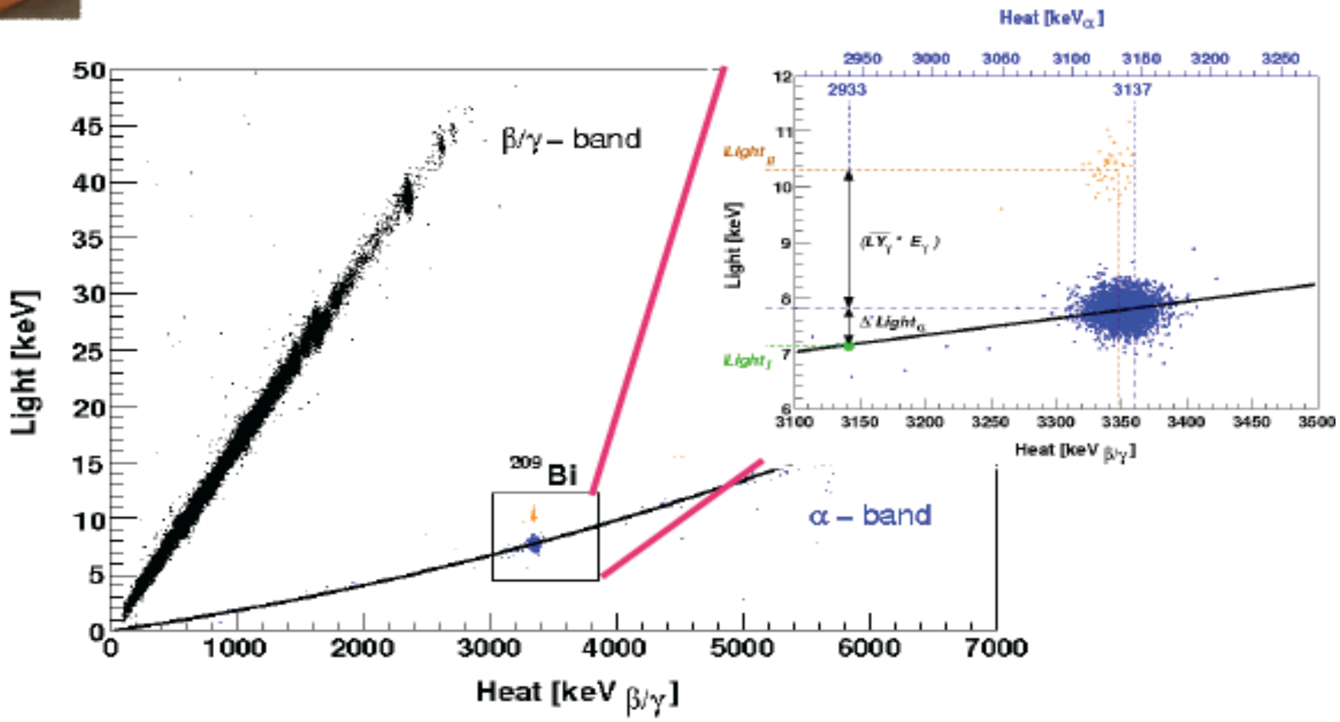
^{209}Bi was considered as the heaviest stable isotope, until its α decay on the ground state of ^{205}Tl was observed.

We operated a 889 g BGO scintillating crystal in a cryostat in the Laboratori Nazionali del Gran Sasso (L'Aquila, Italy) in order to detect the decay on the first excited state.

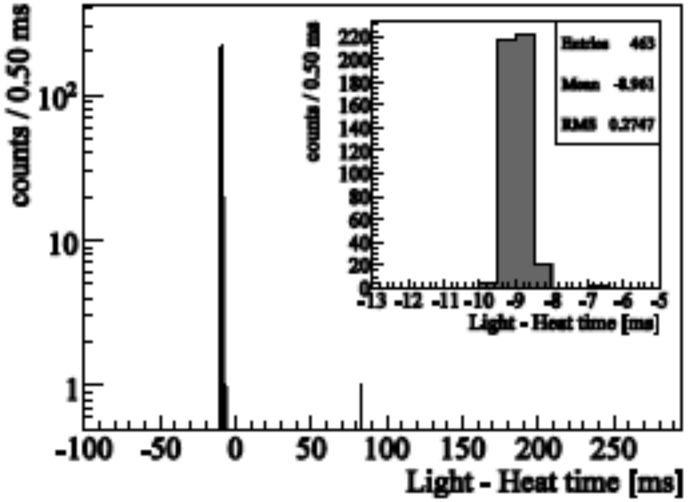
First evidence of the excited state decay of ^{209}Bi:

- the background due to electrons (β/γ band) is fully disentangled thanks to the read-out of the light
- $T_{1/2}(^{209}\text{Bi}) = (2.01 \pm 0.08) \times 10^{19}$ years
- Branching ground/excited level transitions = (98.8 ± 0.3) %

Phys. Rev. Lett. 108 (2012) 062501



New algorithm



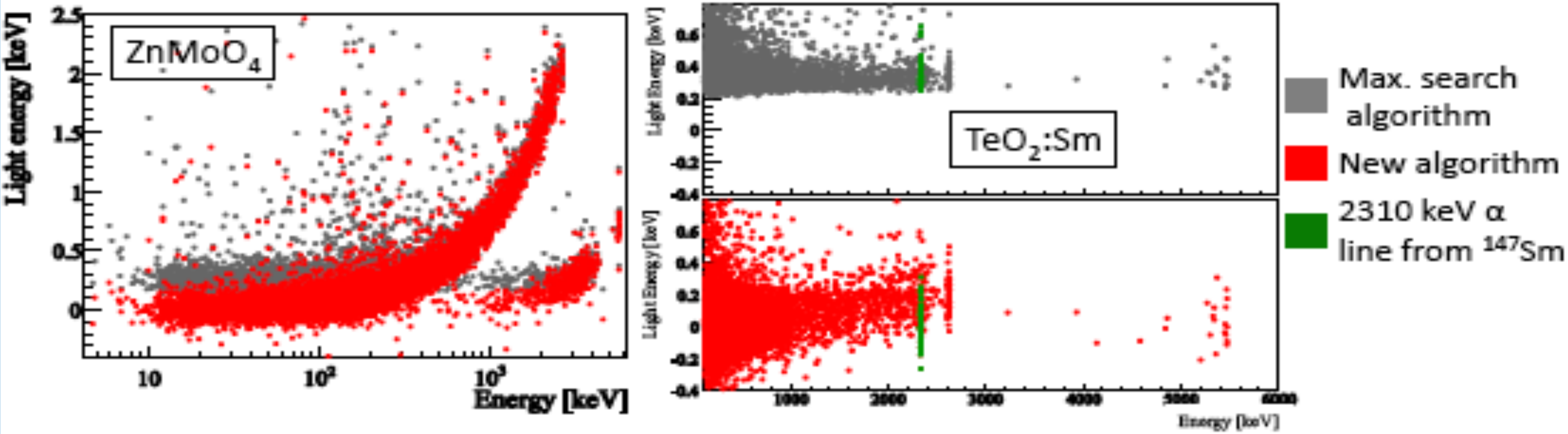
To eliminate the pedestal it is possible to use a new algorithm:

1) select events with much energy released in both heat and light channels (pulses are well defined)
2) apply maximum search algorithm
3) event by event evaluate the time delay between the two channels and make the distribution
4) select the mode of the distribution as the time delay of the two channels (*jitter*)

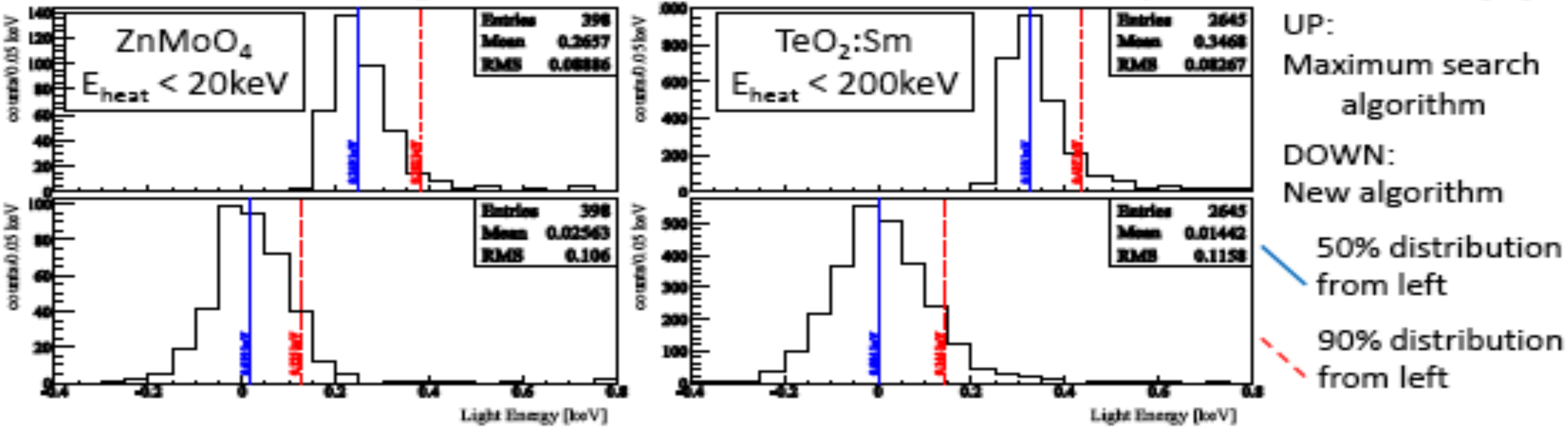
Now light pulse height is evaluated as the amplitude in the acquired window at the time:

$$\boxed{t_{light} = t_{heat\ max} + jitter}$$

Pedestal disappear and for TeO_2:Sm crystal seen (first time at criogenic temperature) the Čerenkov light [1].



Distributions for light detectors: tresholds lowered by a factor of ≈ 3 [1].



[1] Piperno, Pirro, Vignati, *JINST* 6, P10005 (2011)

MKIDs: Microwave Kinetic Inductance Detectors

Ionizing particle E > 2Δ (gap parameter, ~meV)

↓

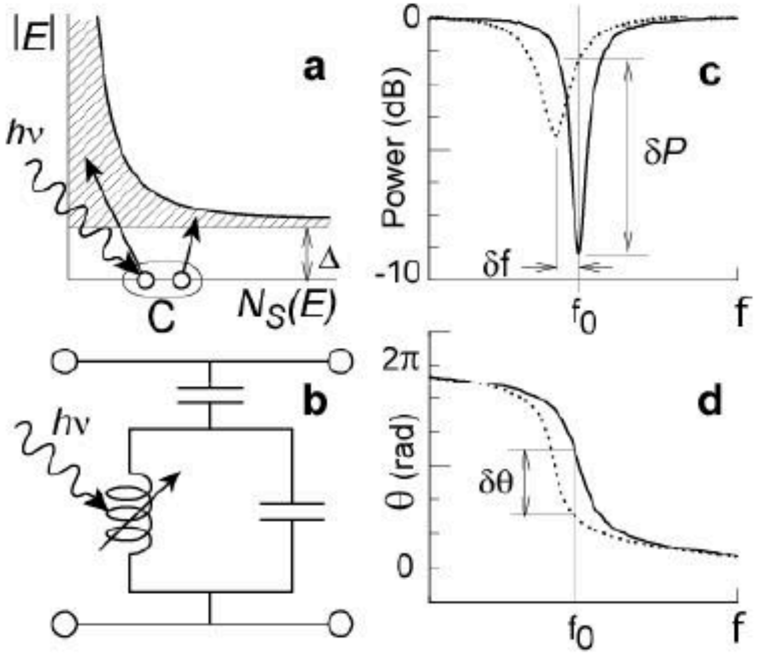
Cooper Pairs break, quasiparticles produced

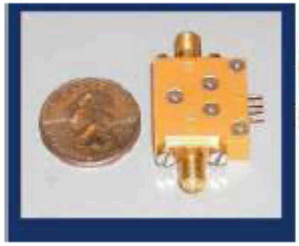
↓

Complex conductance changes

↓

$$\frac{\delta f_r}{f_r} = -\frac{\alpha}{2}\frac{\delta L_s}{L_s} \qquad \delta Q^{-1} = \alpha \frac{\delta R_s}{\omega L_s}$$

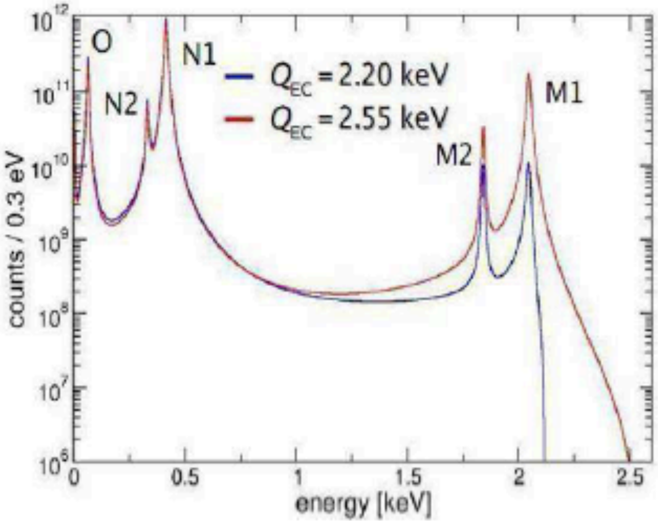


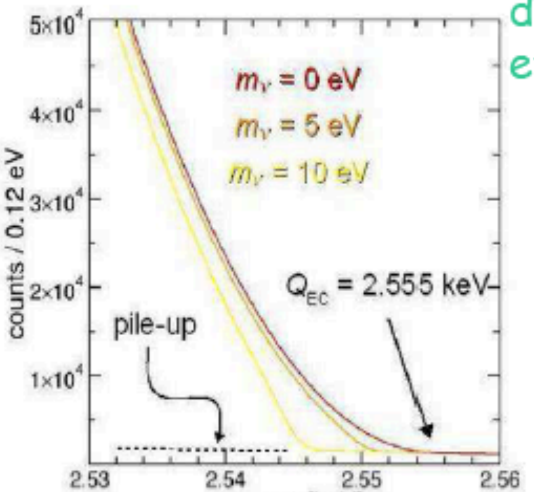


4-12 GHz cryo amp

Microresonators work in frequency domain: with a single feedline coupled to a microwave amplifier thousands channels multiplex is possible

Microresonators for ν mass measurement



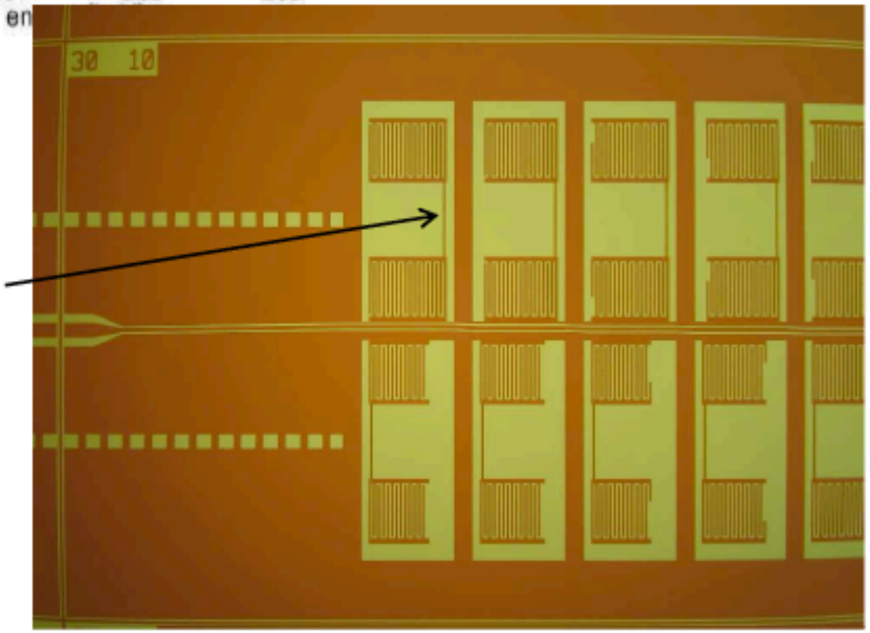


Measurement of Dy atomic de-exitation (mostly auger e-), Q ~ 2-3 keV

^{163}Ho + e$^-$ → ^{163}Dy* + ν_e

A. De Rujula and M. Lusignoli, Phys. Lett. B 118 (1982) 429

The ^{163}Ho will be embedded in the inductive part of the resonator



XENON1T WATER CHERENKOV MUON VETO

- XENON is a dark matter direct detection experiment, consisting of a time-projection chamber (TPC) using xenon in double phase as sensitive detector medium.

- The XENON project is currently taking dark matter data at the Gran Sasso Underground Laboratory (Italy) with the XENON100 experiment (100 kg scale mass of target volume) devoted to explore the spin-indipendent elastic WIMP-nucleon scattering cross section at the sensitivity in the order of ~10^{-45} cm^2.

- The next generation experiment **XENON1T**, with construction at LNGS starting this fall, aims at a further sensitivity improvement by two orders of magnitude to about **$2 \cdot 10^{-47}$ cm^2**. This requires a similar reduction in background and a fiducial mass of about 1 ton liquid xenon.

Serena Fattori - Mainz University

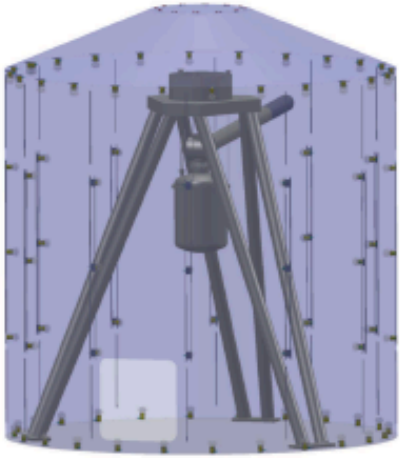
12th Pisa Meeting on Advanced Detectors - May 20-26, 2012

XENON1T WATER CHERENKOV MUON VETO

- Backgrounds result from natural radioactivity in the detector materials and surroundings as well as from high-energy neutrons from cosmic ray muons penetrating the rock.

- Looking inside out, backgrounds are reduced by the self-shielding properties of high Z and high density liquid xenon, enabled by the 3D position reconstruction ability of the TPC, and by discrimination of electronic and nuclear recoils. Materials are screened and selected for radiopurity.

- Here we present the <u>water Cherenkov muon veto system</u>, which will attenuate all backgrounds from environmental natural radioactivity and tag energetic neutrons from muon interactions.



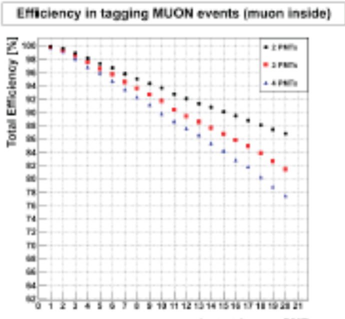
Serena Fattori - Mainz University
12th Pisa Meeting on Advanced Detectors - May 20-26, 2012

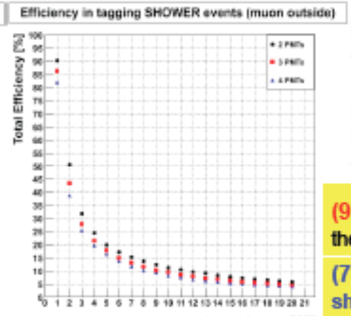
GEANT4 MC Simulations

Muon Veto "ingredients":

- water tank (WT) 9.6m diameter
  10.5m high
- 84 Hamamatsu R5912assy PMTs
- VM2000 reflective foil

A detailed MC study has been performed with GEANT4 simulations in order to optimized the choice of the reflective foil, the shape of the water tank and the PMTs type, number and positioning.



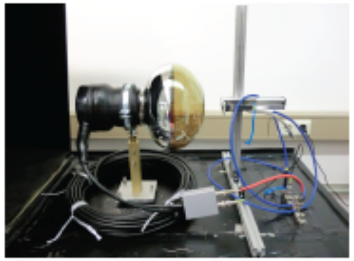


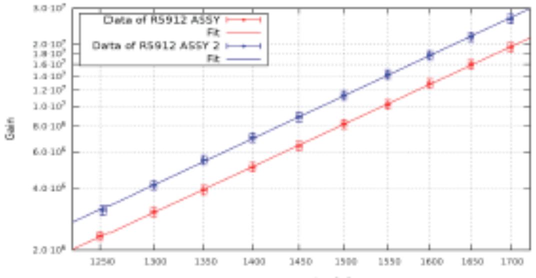
Triggering at 1 photoelectron/PMT, 4-fold coincidence in 300 ns (verified with measurements), we have the efficiency values of:

(99.73 ± 0.05)% μ-event
the muon hits the WT

(78.3 ± 0.4)% shower-event
only the μ secondaries hit the WT

HAMAMATSU PMTs Tests





Tests done to the PMTs in different institutions:

- Bologna,
- Mainz,
- Torino

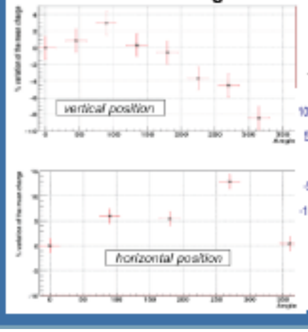
We had measurements of:

- dark rate vs. threshold;
- gain vs. high voltage;
- gain vs. magnetic field;
- gain stability vs. time;
- response vs light position

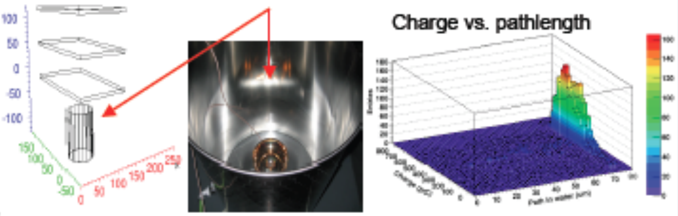
PMTs were tested:

- in air;
- in water;
- above ground
- underground

Gain variation with magnetic field



Test of PMT inside small water tank with cosmic muons (SQE PMT)



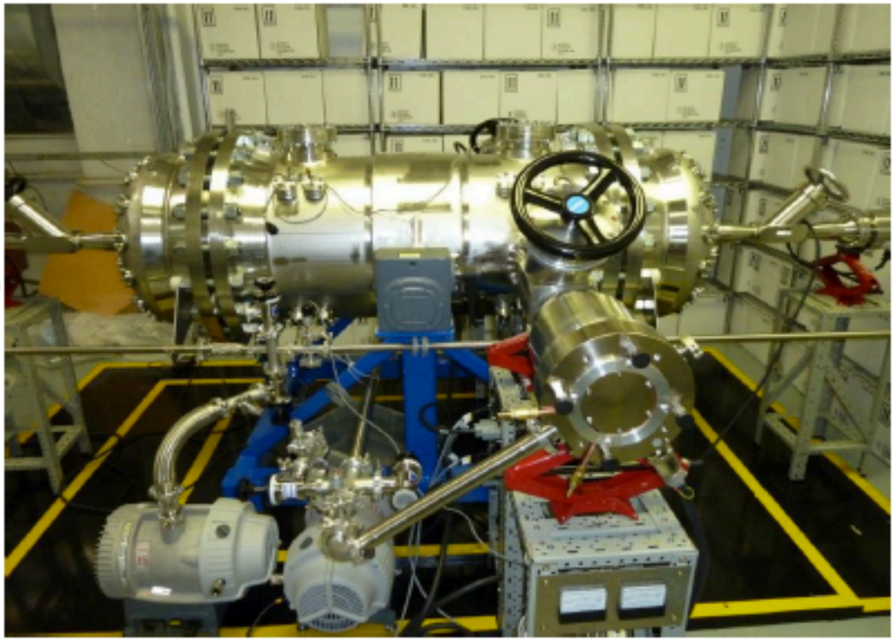
12th Pisa Meeting on Advanced Detectors
May 20-26, 2012

R&D for the EXO-GAS experiment to search for neutrinoless double beta decay

Kirill Pushkin
On behalf of the EXO collaboration

Goals of R&D

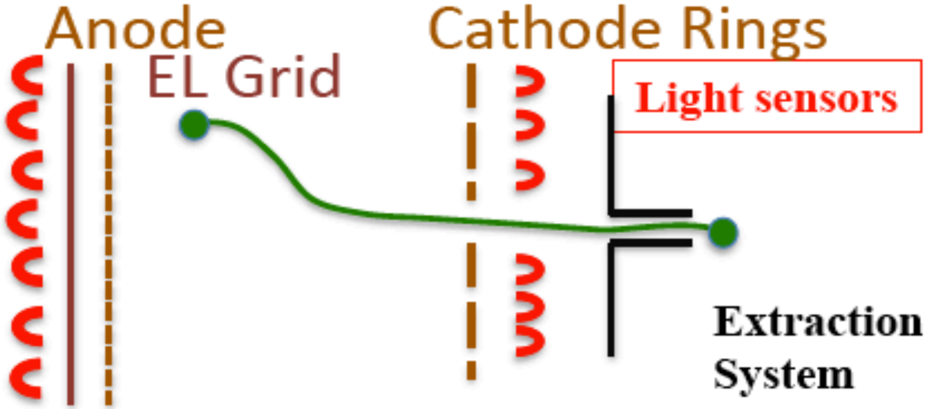
- Obtain energy resolution in xenon gas, in the range of pressures of 1-10 Atm, less than σ=1% using proportional scintillation light (use CsI photo detectors
- Reconstruct electron tracks
- Purify xenon gas using reliable purification techniques and certify impurities using gas purity analysis system (crucial for extraction of electrons and Ba ions)



A High Pressure Xenon gas detector for EXO-GAS

Ba tagging in Xenon gas

- Need to investigate basic properties of Ba^{++} ions in high pressure xenon gas (mobility, diffusion, identification, possibility of attachments to other impurities)
- Do Ba^{++} ions stay Ba^{++} in xenon gas? Seem to be normal in Ar gas.
- Dealing with possible Ba^{++} or Ba^{+} extracting issues (calculations show it is efficient if mass of ion=mass of gas-carrier)
- In the future, it is planned to construct and test the full extraction and counting system (construction of a new quadrupole system is on the way)



Anode

EL Grid

Cathode Rings

Light sensors

Extraction System

A new quadrupole system for EXO-GAS

Fine Grained Nuclear Emulsion as High Resolution Tracking Detector

Tatsuhiro Naka

Institute for Advanced Research, Nagoya University

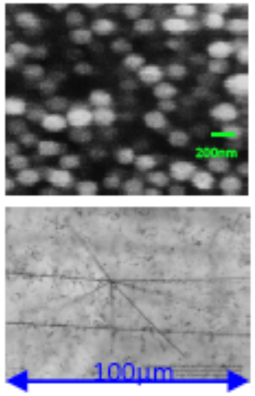
T. Asada, T. Katsuragawa, K. Hakamata, M. Yoshimoto, M. Nakamura, O. Sato, T. Nakano, Y. Tawara, K. Kuwabara G. D. Lellis, C. Sirignano and others.

1. Introduction

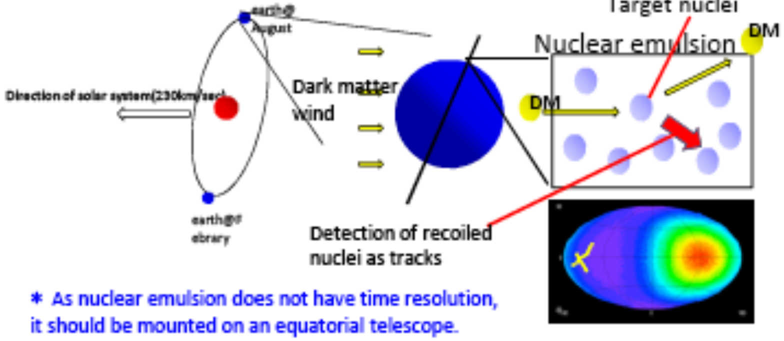
1.1 Nuclear emulsion

Nuclear emulsion is a type of photographic film, and 3D tracking detector for charged particles. Nuclear emulsion has extreme high spatial resolution. In recent experiments, very large nuclear emulsion detector was used because automatic high speed readout with optical microscope became possible.

Recently, we developed the fine grained nuclear emulsion, it can achieved higher spatial resolution. This make possible to search a physics of new energy region. Here, we propose a directional dark matter search with nuclear emulsion.



1.2 Directional dark matter search with nuclear emulsion

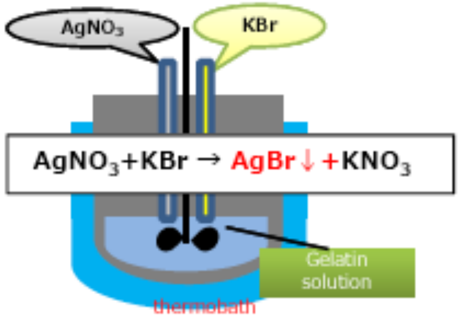


＊ As nuclear emulsion does not have time resolution, it should be mounted on an equatorial telescope.

2. Production facility of fine grained nuclear Emulsion

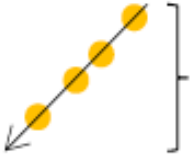
2.1 Nuclear emulsion production by ourselves

Now, we can produce the nuclear emulsion by ourselves in Nagoya university , Japan. By this technology, various type of emulsion can be produced.



$AgNO_3 + KBr \rightarrow AgBr\downarrow + KNO_3$

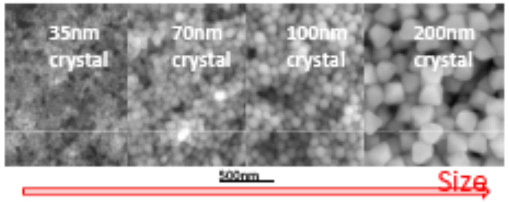
Silver halide crystals are generated via reaction between $AgNO_3$ and KBr. Here, temperature, rotation speed and addition speed is essential factor to define the crystal size.



Spatial resolution depends on crystal size and density

↓

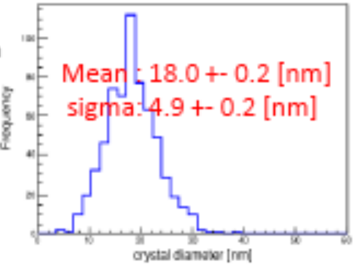
Fine grain is essential for higher spatial resolution.



2.2 Status silver halide crystal size

Small crystal size is very important because it can lower detectable range threshold (i.e., energy threshold) . However, to produce stable fine grained nuclear emulsion is very difficult because condensation of crystals is easy to occur.

We resolved this problem by using Polyvinyl Alchol (PVA). By combining PVA with gelatin, condensation and crystal growth are supressed, stable fine grain can be generated.



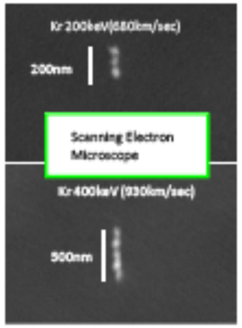
Usual binder	→	New binder
Gelatin		Gelatin (85 %) + PVA (15 %)

Very important for suppression of crystal condensation

2.3 Low-velocity ion tracking

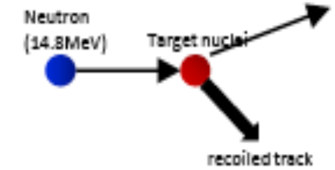
Low velocity ion is good demonstration for submicron tracking test and directional dark matter detection.

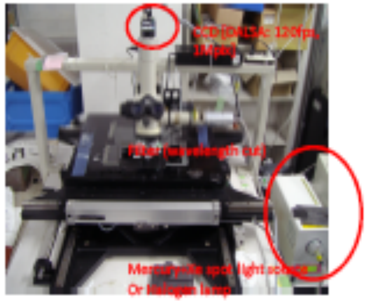
It can be dosed by ion implant system. By using this, we confirmed our fine grained nuclear emulsion can detect the signal as track of more than 100 nm.



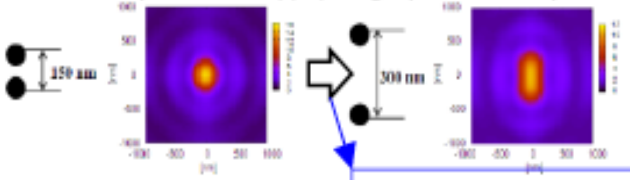
3. Readout technique of submicron tracks

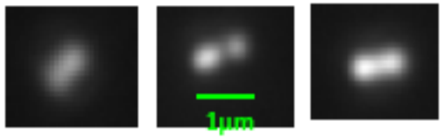
3.1 Readout of submicron tracks induced by neutron with optical microscopy



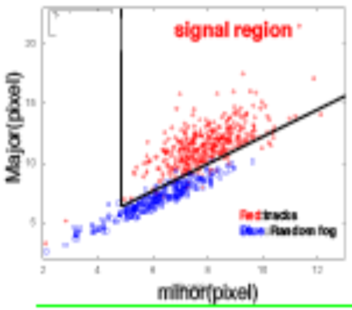


Neutron is good simulation of dark matter detection. Here, to produce the submicron tracks of heavy target nuclei (e.g., Ag or Br), 14.8 MeV neutrons due to D-T reaction were exposed to emulsion film. And, we detected the submicron tracks with optical microscopy by using expansion technique.



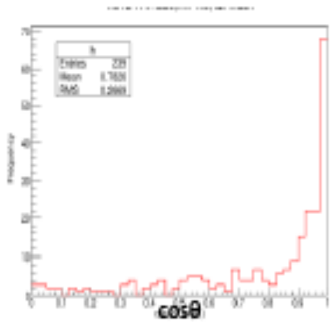


By treatment of mechanical expansion of emulsion film, tracks are elongated, and they are distinguished by optical resolution. Here, expansion factor is 2 times.



Elongated signals can be read out by optical microscopy using image processing. Here, by applying the elliptical fitting, signal region can be defined in high ellipticity.

By this system, we could observe the angular distribution of recoil tracks induced by neutron. This result is consistent with simulation.

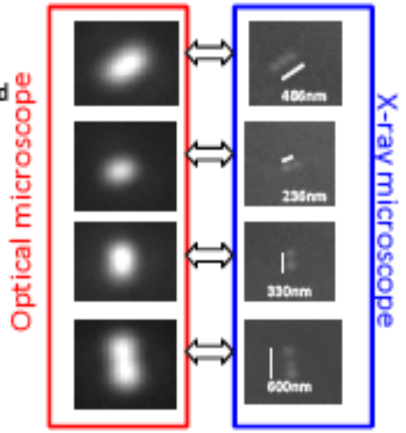


3.2 Detailed confirmation with pin-point by X-ray microscopy.

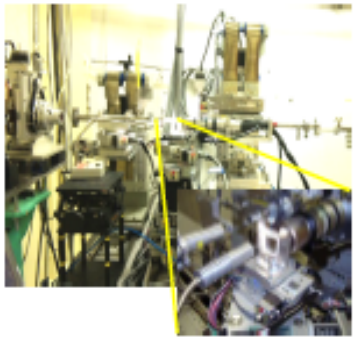
X-ray microscope is available for final check to confirm the selected candidated tracks by optical readout because it has higher spatial resolution and non-distractive observation is possible.

Here, we developed the X-ray microscope system collaborated with Spring-8.

We achieved the pinpoint checking of candidate tracks selected by optical microscope with more than 99 % efficiency.



Matching efficiency > 99%



Readout efficiency

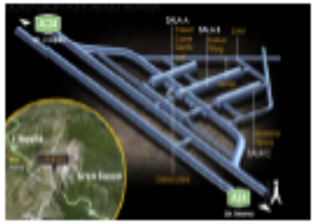
90-100nm : 60 %
100- 110 nm : 80 %
110- 120 nm : 90 %
>120nm : > 95%

	angular resolution [degree]
optical microscope	31.4 +- 4.7 degree @original range: 150-250nm
X-ray microscope	16.8+-2.9 degree @original range: 150-250nm

4. Future planning of underground facility in Gran Sasso

4.1 Construction of underground facility for R&D in Gran Sasso

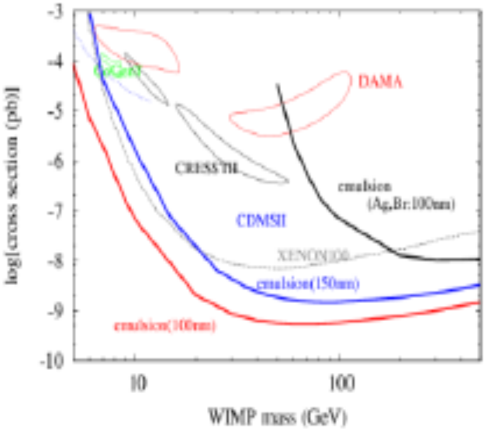
We started to construct an underground facility in Gran Sasso laboratory (LNGS). As this facility had been using in OPERA experiment which big experiment using nuclear emulsion, we can start the test production and R&D study quickly. First, we will start neutron flux measurement with nuclear emulsion. After that, we will start background run with fine grained nuclear emulsion for directional dark matter search.



4.2 Sensitivity for dark matter search

Our first aim is to search the region of DAMA or other experiments which have positive results. Right figure shows the ideal sensitivity of nuclear emulsion for dark matter search for dark matter mass vs. dark matter-ncleon cross section with 1000 kg・year exposure and 90 %CL.

Target nuclei for nuclear emulsion are divided on light target (C,N,O) and heavy targets(Ag, Br). By optimization of sensitivity which can detect recoiled light target nuclei induced by dark matter, we will be able to search in wide dark matter mass region with high sensitivity. For search of heavy dark matter, only Ag and Br targets are available. In this situation, background rejection is easier because recoiled nuclei of heavy targets have large dE/dx, we can use lower sensitivity detector.



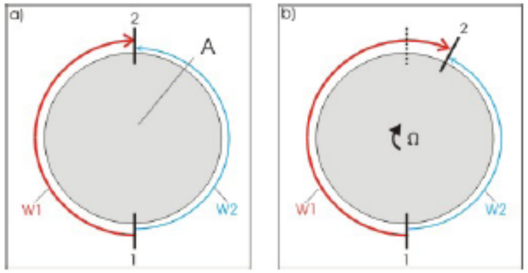
Other experiments on fundamental physics

RingLaser as Gyroscope

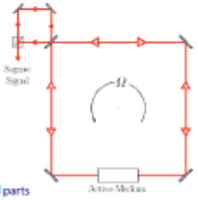
Angela D. Di Virgilio, Maria Allegrini, Jacopo Belfi, Nicoló Beverini, Filippo Bosi, Bachir Bouhadef, Giorgio Carelli, Giancarlo Cella, Enrico Maccioni, Fabio Stefani, and Giuseppe Terreni

Pisa INFN Section, Pisa, Italy and Physics Departement, University of Pisa, Pisa, Italy

THE SAGNAC EFFECT IS BASED ON A SIMPLE OBSERVATION: TWO BEAMS COUNTER-PROPAGATING INSIDE A RING OF RADIUS R COMPLETE THE PATH AT DIFFERENT TIME IF THE RING IS ROTATING WITH ANGULAR VELOCITY Ω: $\Delta t = \frac{4\pi R^2 \Omega}{c^2}$



Ring laser gyroscopes



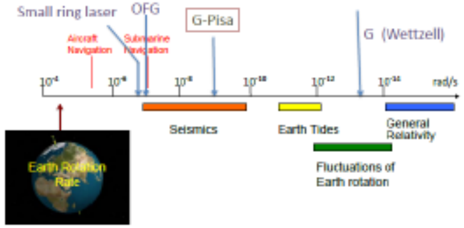
In a ring laser rotating with respect to an inertial frame, the cavity optical lengths for the two counter-propagating laser beams becomes different.

Sagnac interferometric signal:

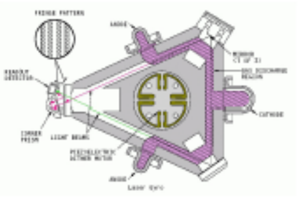
$$\boxed{\Delta f = \frac{4A}{\lambda p}\vec{n}\cdot\vec{\Omega}}$$

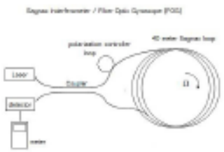
- Entirely insensitive to translations
- Generated from light - no mechanical parts
- Extremely high linearity
- Very large dynamical range

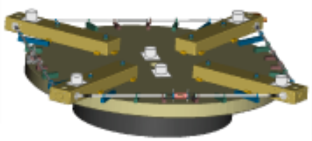
Measuring rotations

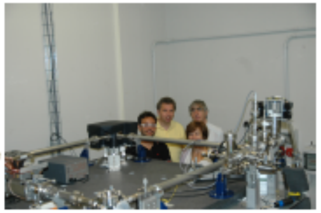


Several Devices have been developed based on: fiber optics (FOG),passive resonant cavity, and active cavity (ring-laser, gyro-laser). Not only light, but atom interferometry is used as well. They are very special gyroscopes, since they measure absolute (inertial) angular velocity. Several instruments have been developed for different purpose, in general inertial navigation (air-plane, submarine...) and more recently for geophysics study. The main advantage of this kind of devices is that there are not moving parts, and the response of the apparatus is a pure rotation. It must be taken into account that the linear motions of the Earth crust is much higher than the rotations and tilts in general, so why is very difficult to provide good rotational motion measurements if the device has a coupling with the other degrees of freedom.





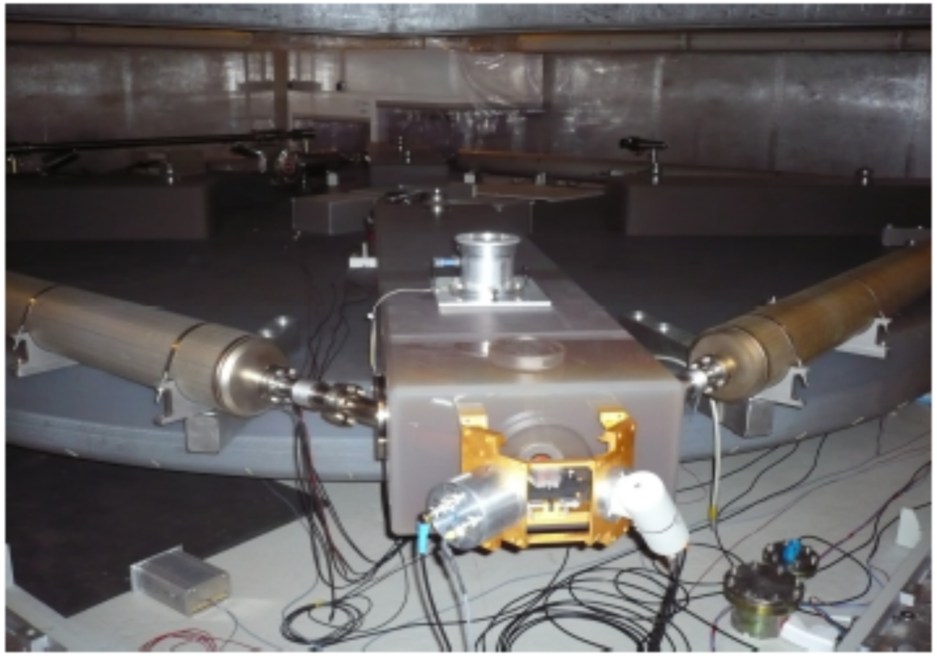


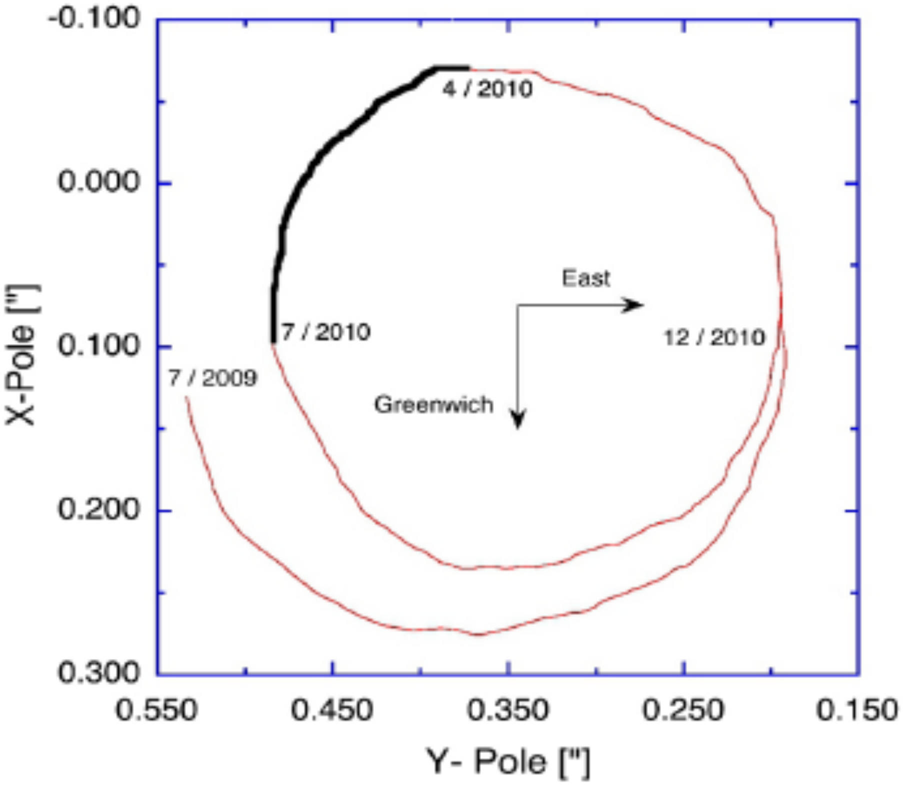


In general FOGs have applications when $10^{-4} rad/s$ is required, ringlasers can have higher sensitivity and accuracy; pushing to the shot noise limit the performance of ringlasers it is possible to make not only important measurements on Geodesy, but as well General Relativity tests

G IN WETTZELL, THE MOST ACCURATE RINGLASER IN THE WORLD AND THE CHANDLER WOBBLER MEASUREMENT

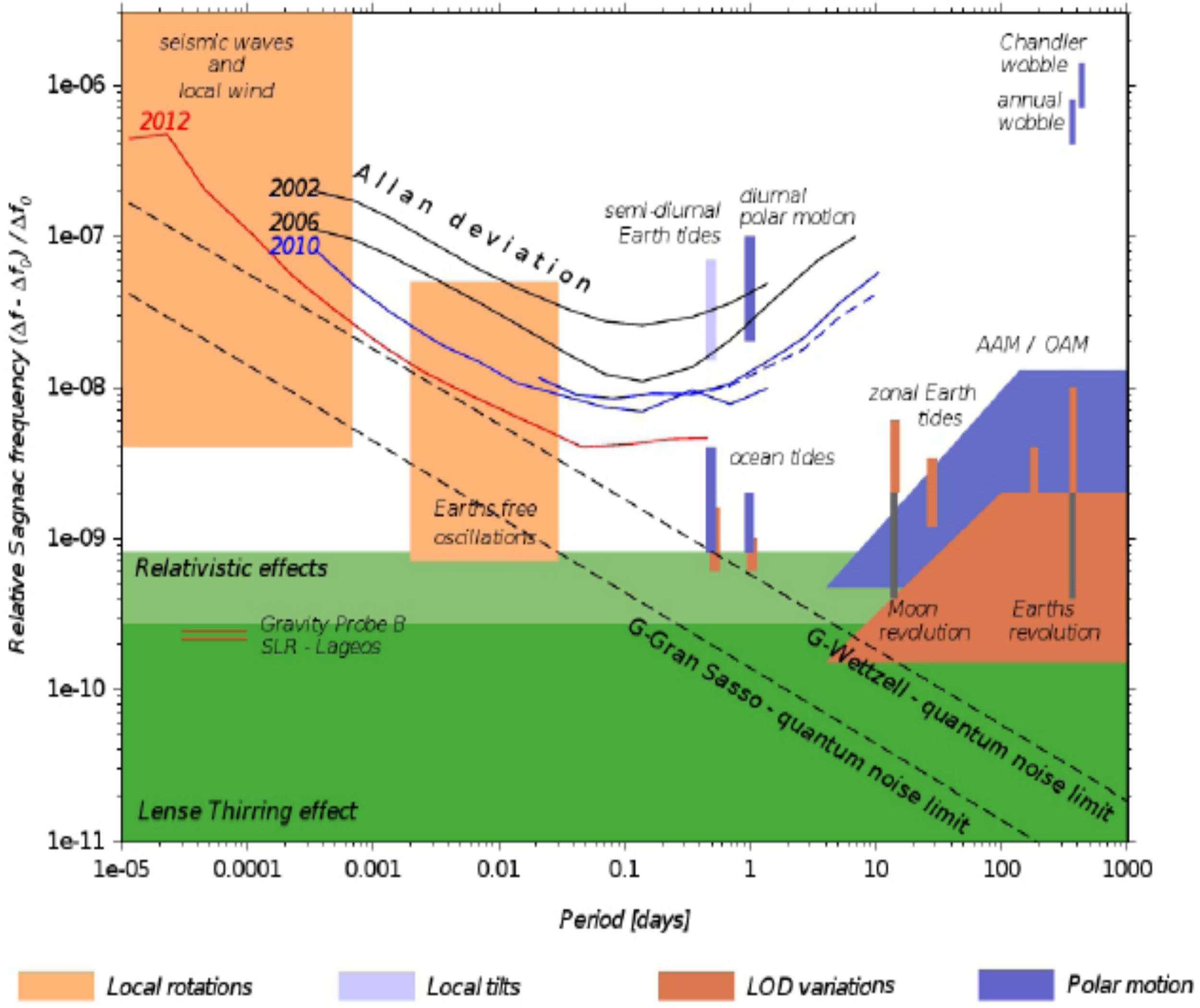
G is a square ring with 4 m side, which operates inside the Wettzell laser ranging station. It is based on a monolithic design, which uses a single block of Zerodur, a very low thermal expansion glass. It has been constructed for Geodesy.





U. Schreiber et al., PRL 107, 173904 (2011), highlighted and reported from Science, Nature Photonics News and Views, local newspapers in Germany and Italy as well

SIGNALS AND ACCURACY (ALLAN DEVIATION OF G IN WETTZELL)



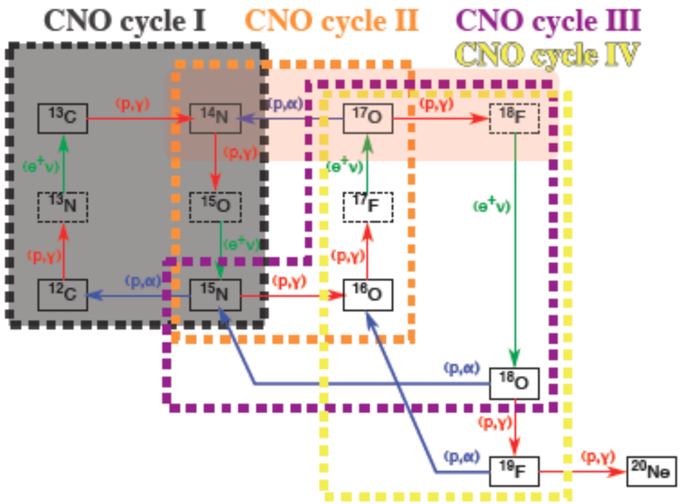
^{17}O(P, α)^{14}N STUDY AT THE LUNA ACCELERATOR

D. A. Scott, C. Bruno and A. Caciolli for the LUNA Collaboration

The Physical Case

Classical novae represent a frequent phenomenon in our Galaxy and have been proposed as the most significant source of ^{13}C, ^{15}N and ^{17}O isotopes in the Universe. They can also produce the short-lived radioisotope ^{18}F. The observation of these γ rays is one of the goals of satellite missions such as INTEGRAL [1] and their detection would help put constraints on current nova models [2].

In particular, hydrogen burning of ^{17}O is believed to play a key role on the destruction of ^{17}O and on the formation of 18 F, mainly through the competing reaction ^{17}O(p,γ)^{18}F (Q = 5606.5 ± 0.5 keV) and ^{17}O(p,α)^{14}N (Q = 1191.8±0.1 keV). Thus, the thermonuclear rates of both reactions should be determined with a high degree of accuracy in the temperature range T = 0.03 – 0.4 GK relevant for AGB and RBG stars and classical novae.



The LUNA collaboration has already studied deeply the ^{17}O(p,γ)^{18}F reaction in the framework of classical novae [3]. Its cross section has been determined in a range from 180 keV up to 400 keV in the laboratory system and also the ωγ of the resonance at 194 keV was determined with small uncertainty (2% statistics and less than 10% systematics). In 2012 it has been planned to investigate the cross section of the ^{17}O(p,α)^{14}N by using the LUNAII accelerator and Ta_2O_5 (enriched in ^{17}O at a level of 90%) targets [4] produced at the Laboratori Nazionali del Gran Sasso.

LUNA aims to perform the challenging measurement of the 70 keV resonance for the ^{17}O(p,α)^{14}N reaction, for which the expected reaction rate is of the order of a few reaction per hour.

The new PVLAS apparatus for detection of magnetic birefringence of vacuum

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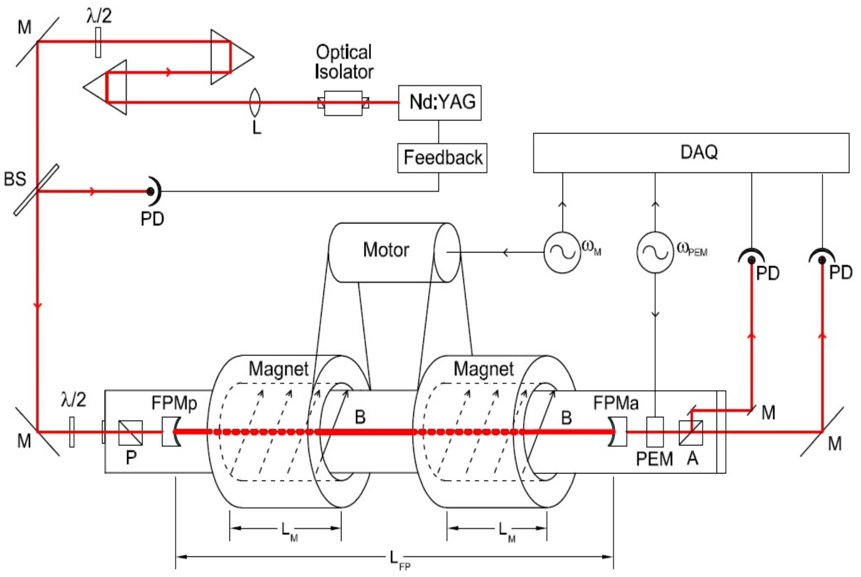
Magnetic Birefringence of Vacuum (MBV) has been predicted since long, but never observed so far, and is the consequence of non linear terms present in the QED Lagrangian. These terms result from vacuum fluctuations due to creation and annihilation of pairs of virtual charged particles and antiparticles. Light in vacuum with a B field moves slower and linear polarized light acquires an induced ellipticity. The new PVLAS apparatus aims at observing a vacuum induced ellipticity of 4 10^{-11}.

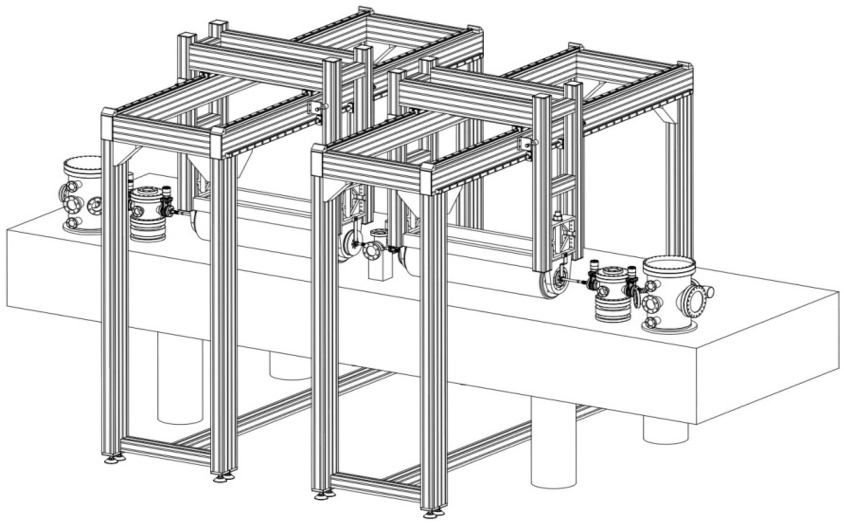
Scheme of the experiment



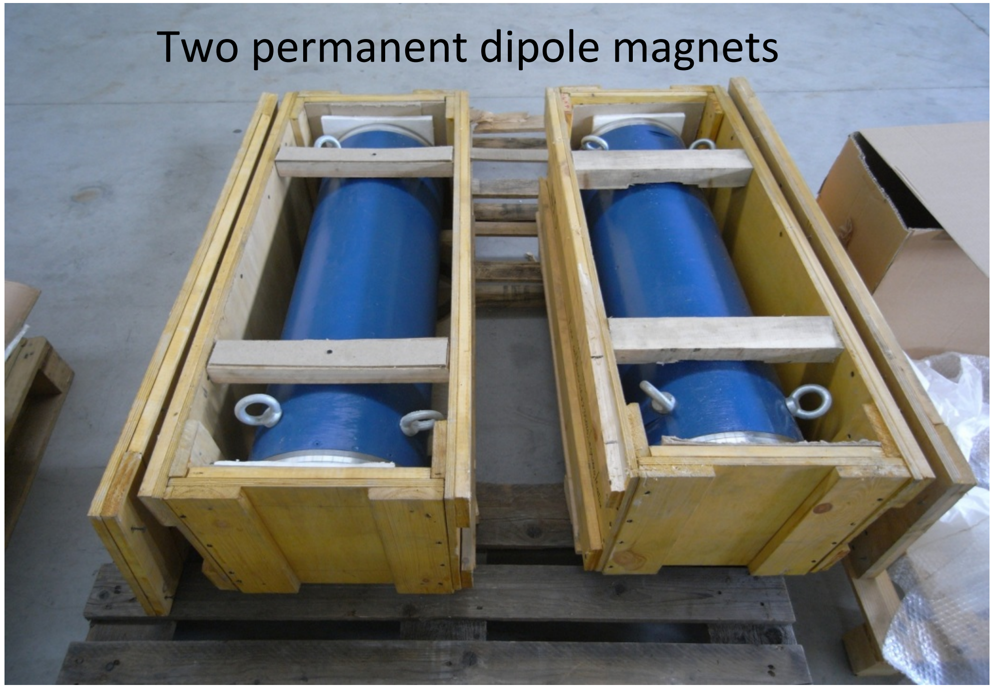
P polarizer, FPM Fabry-Perot mirror, B magnetic field in bore of rotating permanent dipole magnet, PEM Photo-Elastic-Modulator, A analyzer, PD photodiode.

Light in vacuum

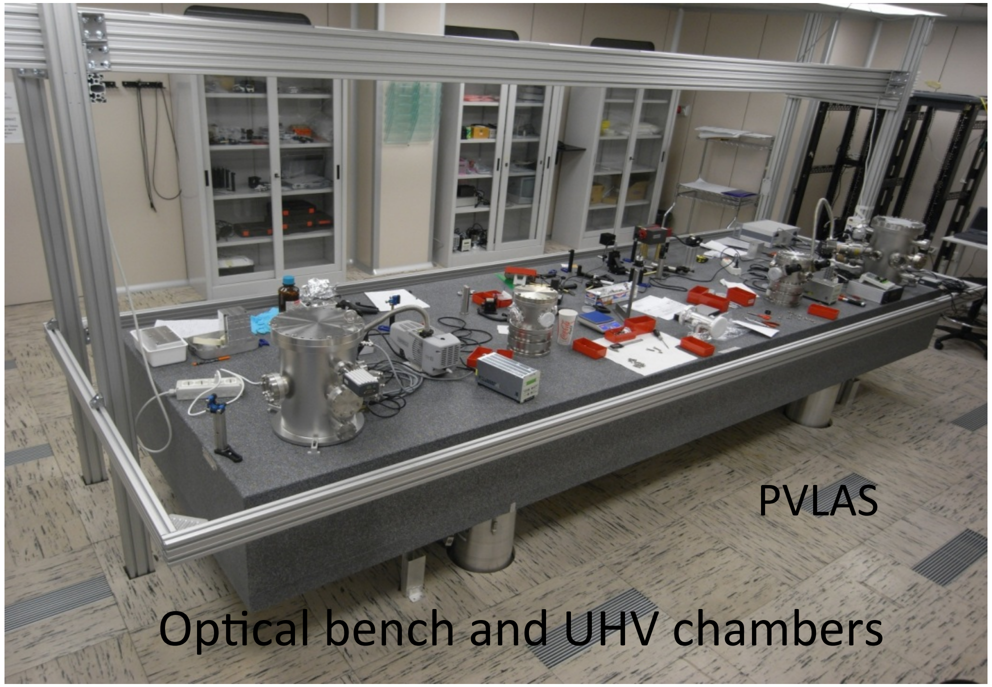
Light in vacuum with B field



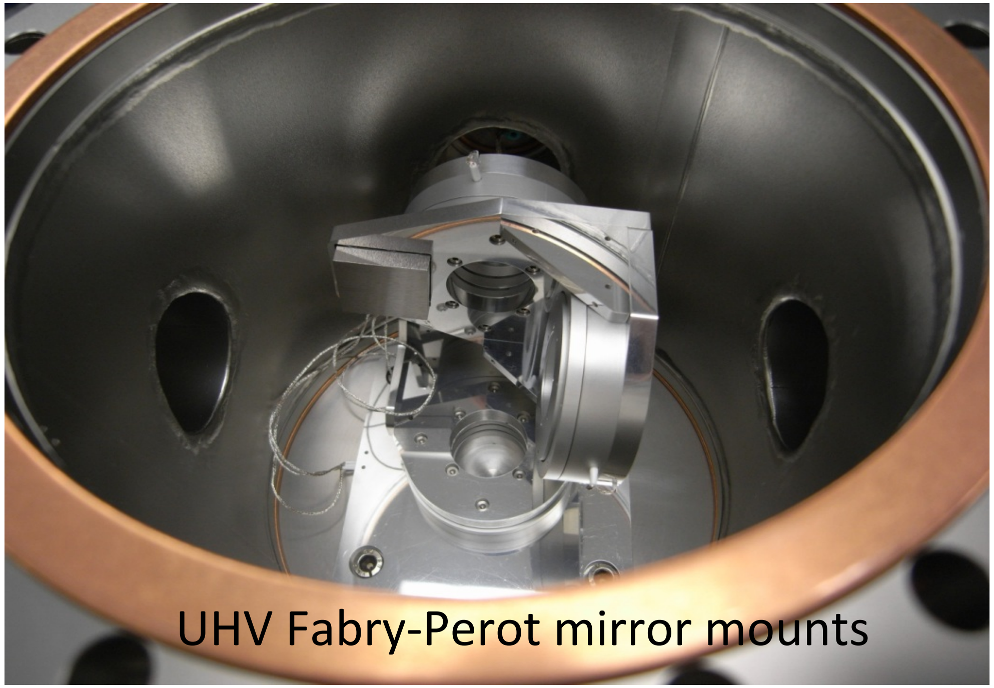
Experimental set-up


Two permanent dipole magnets


Magnet supports



Optical bench and UHV chambers


UHV Fabry-Perot mirror mounts

Thank you !