Dalla Fisica delle Alte Energie alle Applicazioni: alcuni esempi

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« La Sapienza »

Istituto di Fisica

Schema della lezione

17 Marzo

- TT un processo di trasferimento della conoscenza
- Terapia adronica
- PET
- Elaborazione di immagini
- Elettronica e rivelatori
- GRID Applicazioni mediche ed ambientali

Ringraziamenti

Beatrice Bressan	Knowledge Transfer
Ugo Amaldi	Hadrontherapy
Raymond Miralbell	Radiotherapy and Proton therapy
Mauro Belli	Hadrontherapy
Giacomo Cuttone	CATANA
Manjit Dosanjh	ENLIGHT
David W. Townsend	PET
Piergiorgio Cerello	Elaboration of Images
Fabio Sauli	GEM Detectors
Michael Campbell	Medipix
	Health-e-Child
Maria Grazia Pia	Geant4

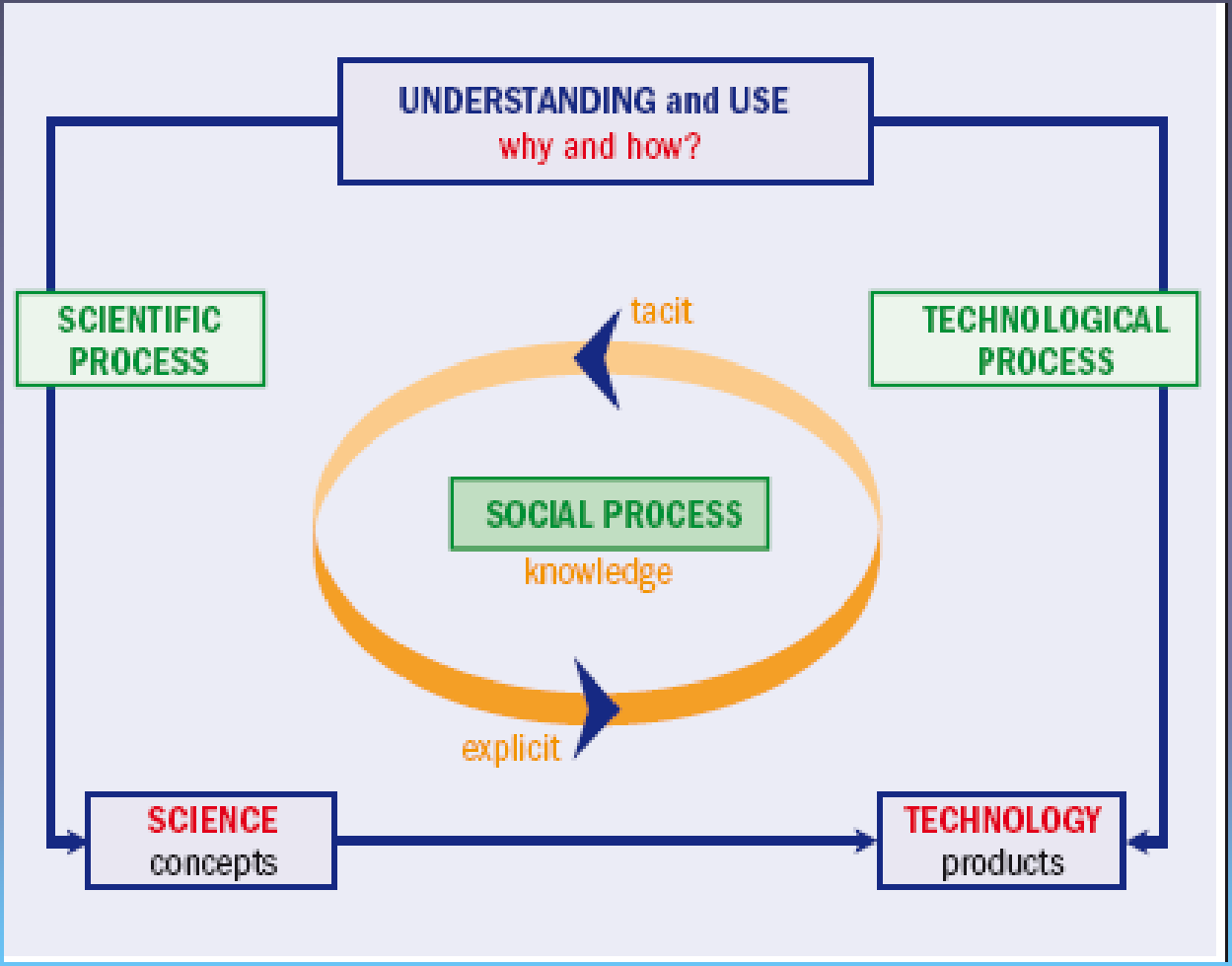
Fisica delle Alte energie

- Multidisciplinarità
- Fertilizzazione grazie ai nuovi network
- Sviluppa nuovi linguaggi e tipi di interazione

IMPLICA

- Cambiamenti al livello dell'educazione superiore scolastica e universitaria con maggiore accento sul lavoro di gruppo, gestione di progetti e multidisciplinarità

Il processo scientifico e tecnologico sorgenti di conoscenza



Ref. Bressan B. et al. 2008

Tipi di «capitale sociale» nell'acquisizione della conoscenza

- *Strutturale* – come gli individui sono capaci di utilizzare le risorse del network dell'organizzazione di cui fanno parte –strutture, procedure, etc.
- *Relazionale* – capacità di interagire con gli altri per acquisire, sviluppare e trasmettere la conoscenza
- *Cognitivo* – quantità di conoscenza che si costruisce lavorando in un progetto.

Nahapiet e Goshal 1998, Boisot e Bressan in publicazione

La conoscenza è spesso condivisa tramite interazioni sociali tra individui.

Le organizzazioni giocano un ruolo importante come facilitatori o inibitori dei processi di acquisizione e trasferimento della conoscenza

Come si genera il TT?

Attraverso il trasferimento delle conoscenze conseguente una richiesta interna (a) o esterna (b).

- a) Ricercatore cosciente di possibili applicazioni industriali in campi diversi dalla fisica delle alte energie si rivolge agli enti preposti al TT per la promozione della tecnologia.

- b) industria interessata dall'utilizzazione delle tecnologie sviluppate per la fisica per lo sviluppo, in collaborazione o no con i ricercatori, di un prodotto in un settore specifico.

Present Status of Radiotherapy

- After surgery, radiotherapy (RT) is the most effective cancer treatment.
- Around 40% of the population will develop cancer and 60% will require RT.
- Of patients having RT, 60-70% are treated with curative intent.

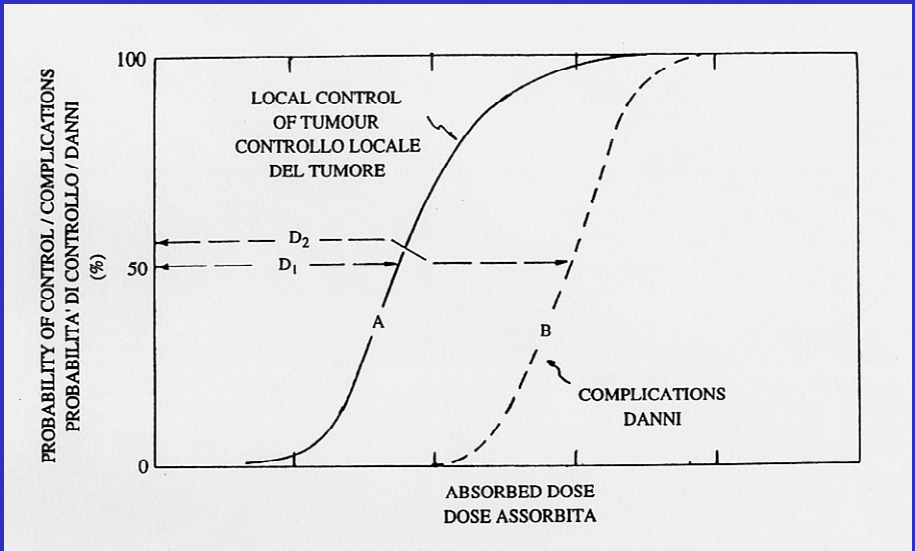
Present Limitation of RT

30% of patients still fail locally after curative intent RT

Ref. R. Miralbell 2007

Obiettivi della radioterapia

Fornire al "bersaglio" una dose tanto alta da distruggerlo mantenendo al tempo stesso la dose ai tessuti circostanti, inevitabilmente irradiati, entro limiti tali da non comportare complicazioni e danni gravi o irreversibili.



Rapporto Terapeutico: rapporto tra la dose D_2 corrispondente al 50% di probabilità di fare danni e la dose D_1 corrispondente al 50% di probabilità di ottenere il controllo locale del tumore.

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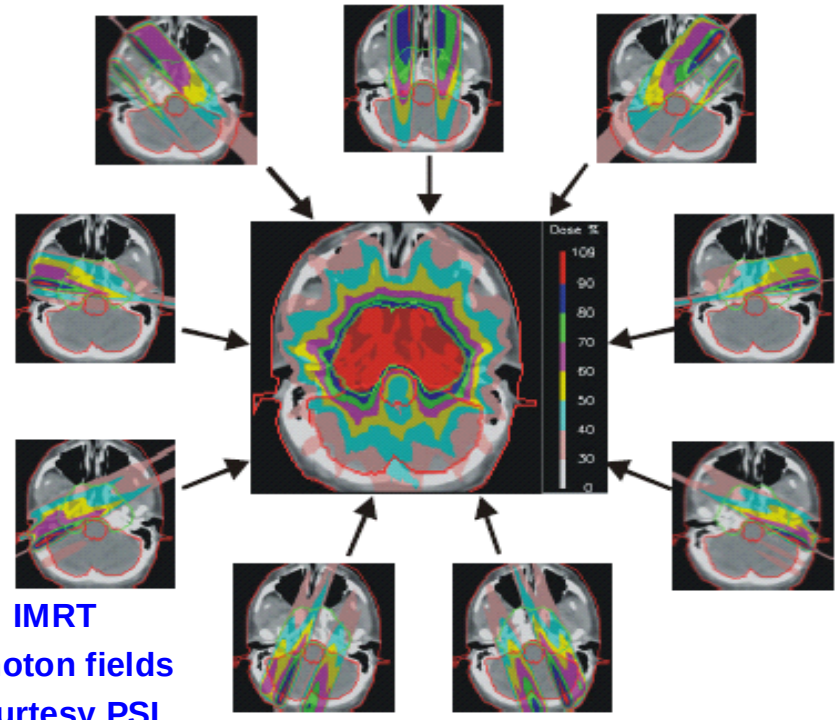
How to overcome failures?

- Physics & treatment technology: dose escalation
- Imaging: MRI, PET, image registration
- Biology: altered fractionation, radiosensitization

Ref. R. Miralbell 2007

Macroscopic distribution of the X ray dose

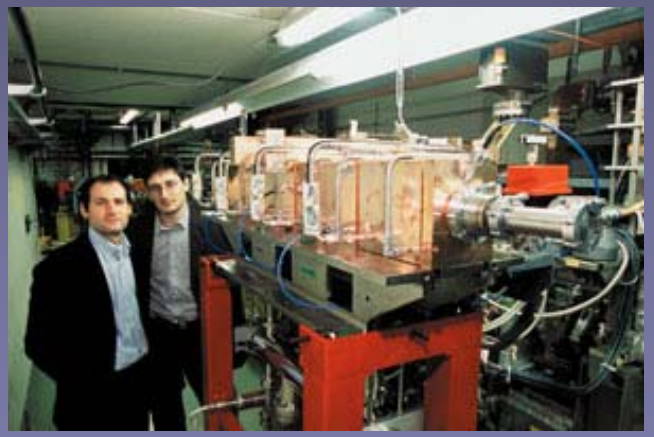


IMRT
9 photon fields
Courtesy PSI

At present the best is " Intensity Modulated Radiation Therapy" = IMRT
In future "Image Guided Radio Therapy" to follow moving organs

CERN e Hadrontherapy

- 1969 primi studi protoni e mesoni
- PIMMS (Rapporto publicato 2000)
- Collaborazione LIBO 3 GHz booster lineare Catania Ciclotrone



Oggi:
Collaborazione CNAO:
- Misure Campi magnetici, acquisizione dati e analisi
- Misure CNAO prototipo dipoli.
- Diagnostica e controllo

(Centro Nazionale di Adroterapia Oncologica), l'INFN (Istituto Nazionale di Fisica Nucleare).

Nuova collaborazione con TERA
ADAM
ENLIGHT

Hadrontherapy

Hadrontherapy:
a modern radiotherapeutic technique (mainly oncological) which uses hadronic beams (instead of “conventional” photonic radiation), i.e., beams of non-elementary particles made of quarks.

Most frequently used hadrons: charged particles, notably protons and carbon ions.

Hadrontherapy in Italy was proposed in 1991 by Ugo Amaldi and Giampiero Tosi with the support of the INFN.
The word “Hadrontherapy” was used by Ugo Amaldi and co-workers and the terms was increasingly accepted since the 1st Int. Symposium on Hadrontherapy held in 1993 at Como.

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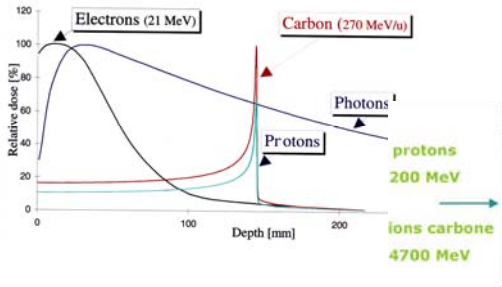
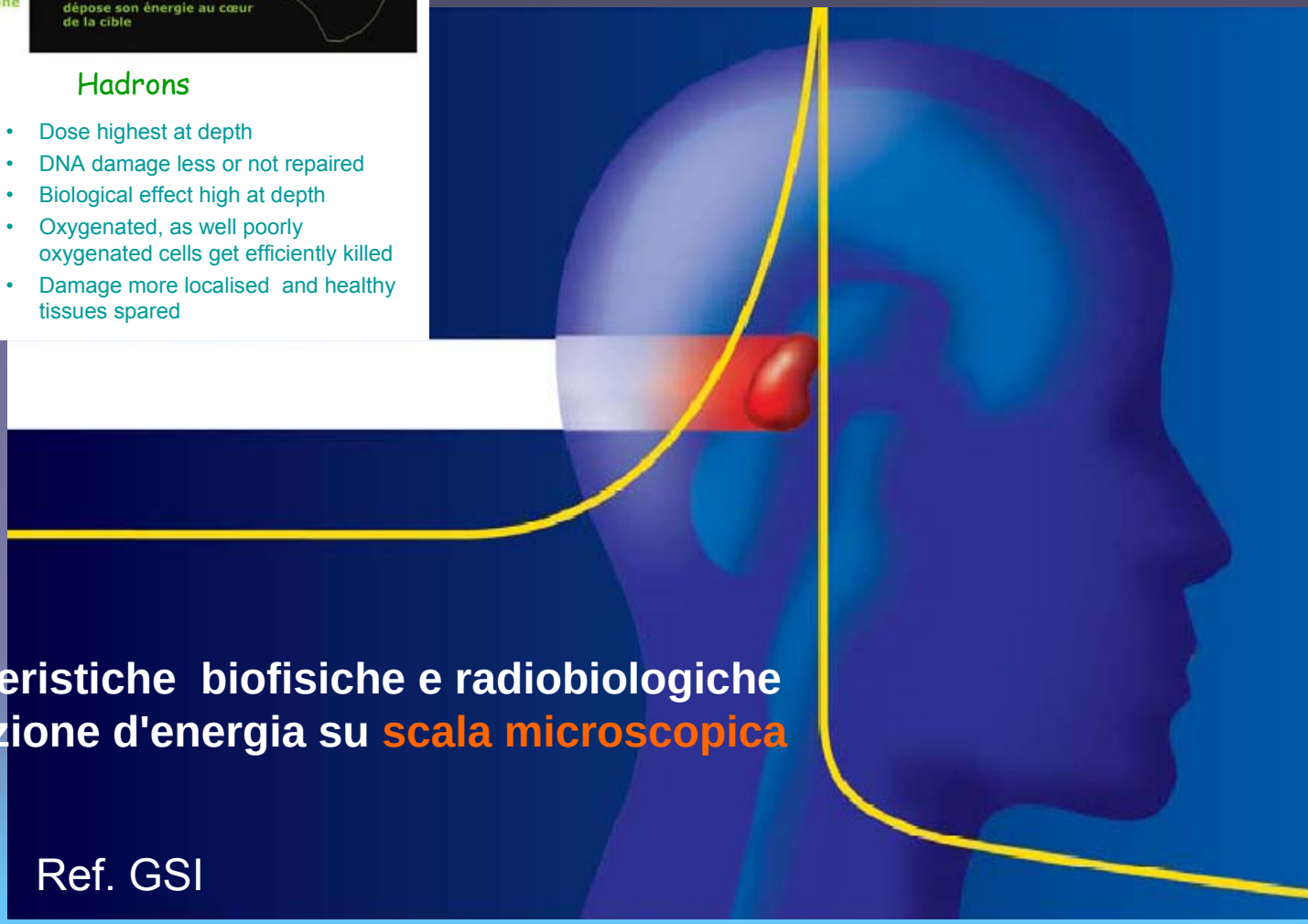
Hadron-therapy vs. radiotherapy



Ideal cancer treatment would be to eliminate all tumour cells without affecting any normal cells

Photons	vs.	Hadrons
• Physical dose high near the surface		• Dose highest at depth
• DNA damage easily repaired		• DNA damage less or not repaired
• Biological effect lower		• Biological effect high at depth
• Poorly oxygenated cells are less efficiently damaged		• Oxygenated, as well poorly oxygenated cells get efficiently killed
• Effect not localised		• Damage more localised and healthy tissues spared

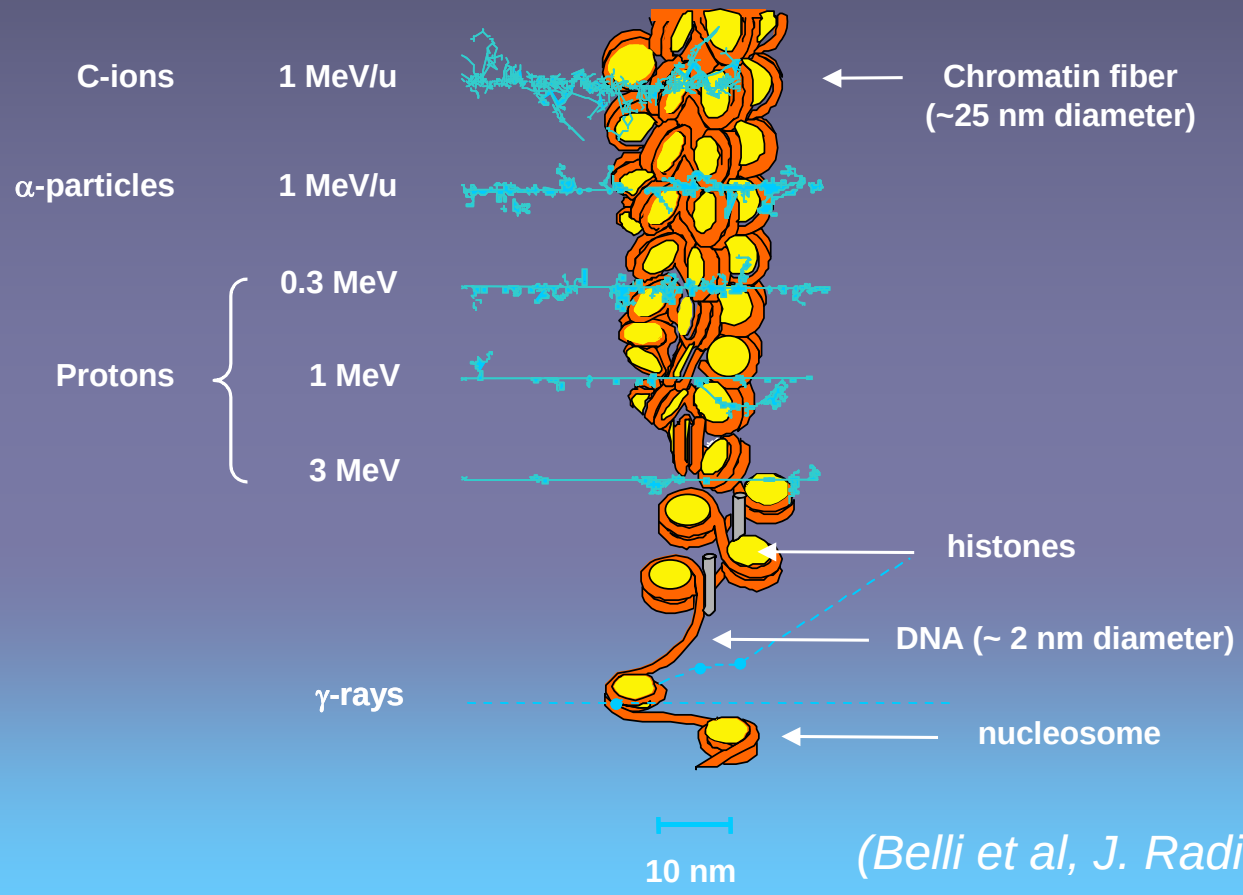


più selettiva
Vantaggiose caratteristiche biofisiche e radiobiologiche legate alla distribuzione d'energia su scala microscopica

Ref. GSI

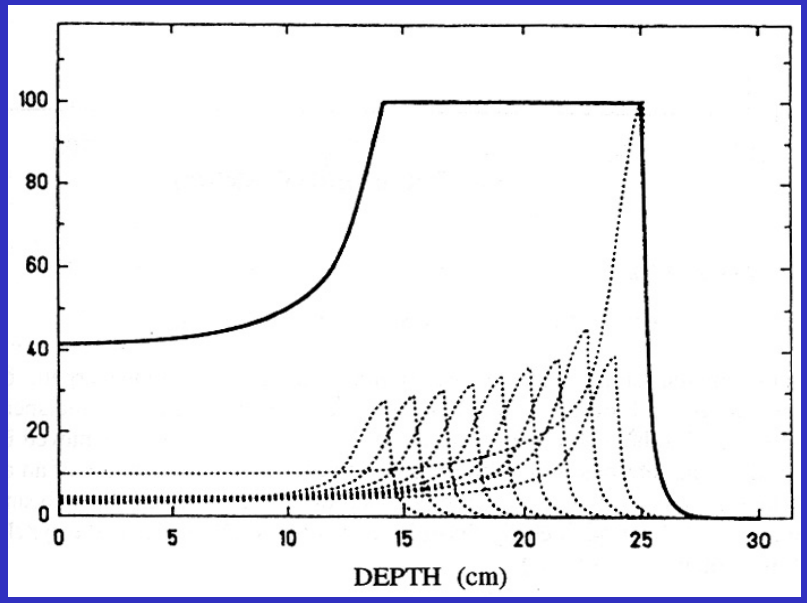
Distribuzione microscopica dell'energia: cluster di ionizzazioni nel bersaglio

INTERPLAY TRACK - CHROMATIN (at the nucleosome/fiber levels)
Clustered DNA damage - Reparability of DNA lesions



(Belli et al, J. Radiat. Res, 2002)

The Spread Out Bragg Peak (SOBP)



Superimposition of Bragg peaks with different energies to cover the tumour volume

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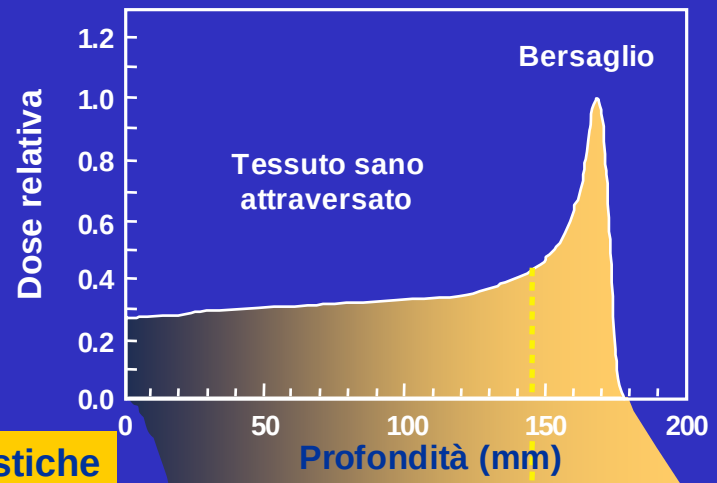
Potenziali vantaggi dell'adroterapia



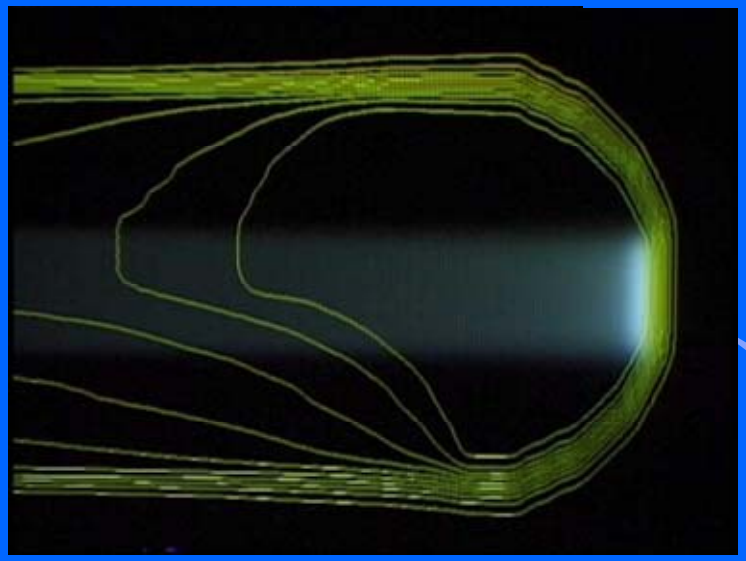
Caratteristiche		
E	"alta"	"bassa"
LET	"basso"	"alto"
Dose	bassa	elevata
RBE	≈ 1	> 1
OER	≈ 3 (X,γ)	< 3
Dipend. ciclo cell.	elevata	bassa
Dipend. dD/dt	si	scarsa

Potenziali Vantaggi

- Elevata D al tumore con risparmio tessuti circostanti
- Maggiore letalità nel bersaglio, efficacia per tumori radioresistenti
- Minore frequenza di recidive a causa di cellule ipossiche
- Maggiore letalità nel bersaglio per minor numero di cellule in fase resistente
- Possibilità di frazionamento per risparmiare tessuto sano

Mauro Belli 2007

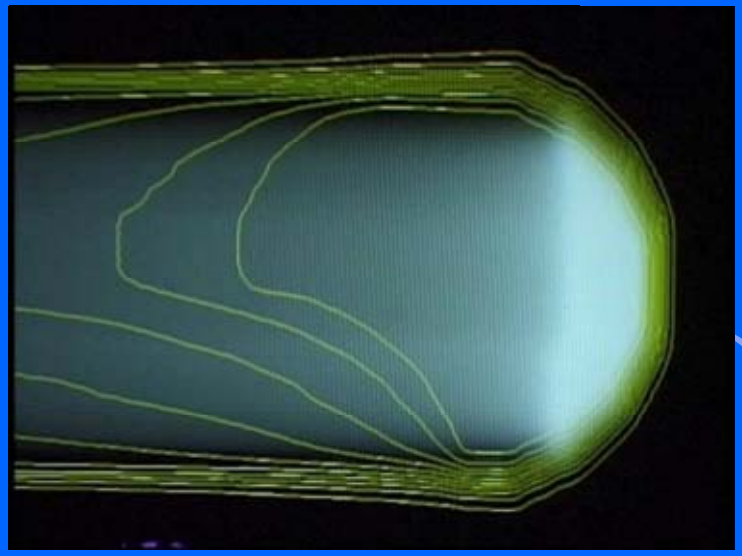
Macroscopic distribution of the proton dose



Active spreading : ‘spot scanning’ á la PSI

Longitudinal mouvement by varying the energy of the beam

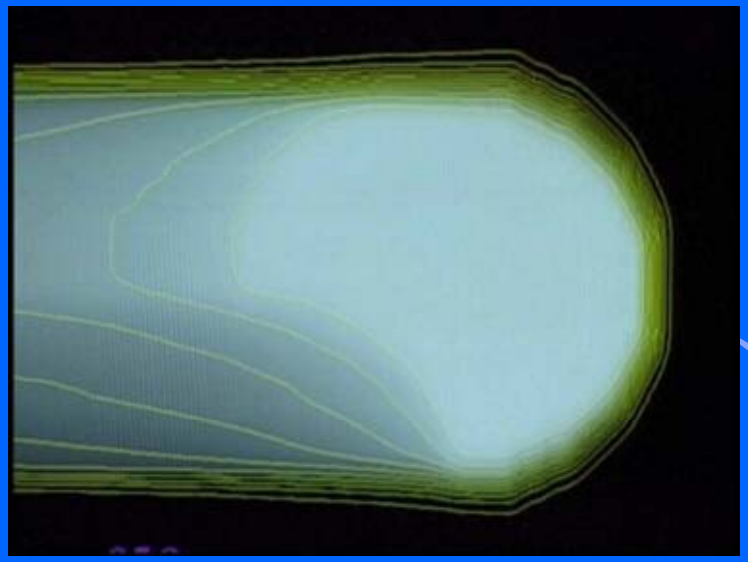
Macroscopic distribution of the proton dose



Active spreading : ‘spot scanning’ á la PSI

Longitudinal mouvement by varying the energy of the beam

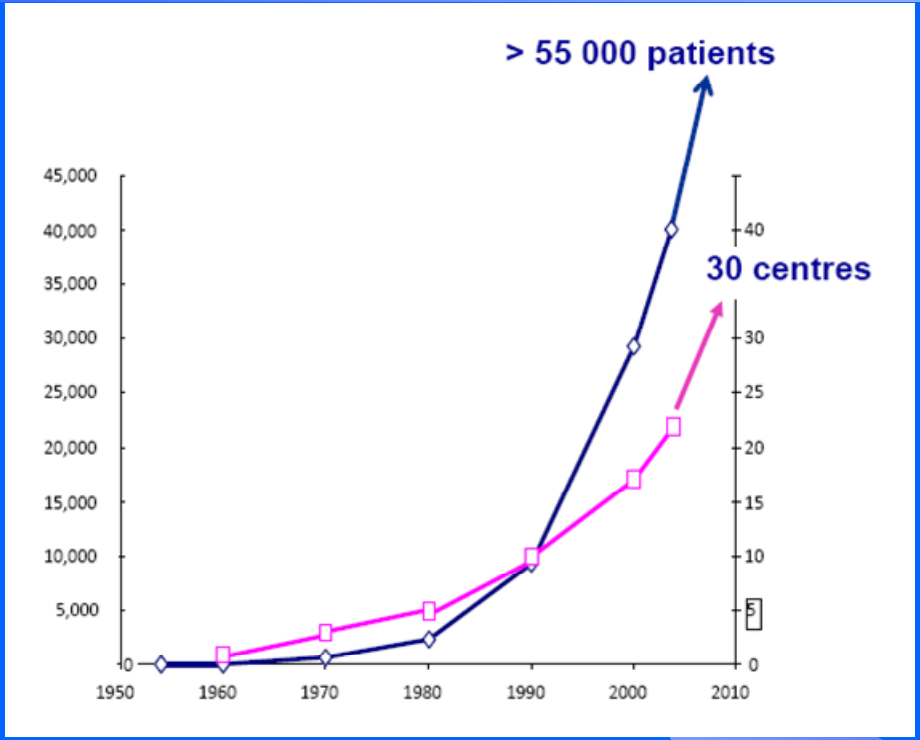
Macroscopic distribution of the proton dose



Active spreading : ‘spot scanning’ á la PSI

Longitudinal mouvement by varying the energy of the beam

For these reasons protontherapy is booming



20-25 sessions per patient

European cost of a full treatment:

IMRT: 7-8 k€

Protontherapy: 20-25 k€

Comparative planning (X-rays vs protons): virtual treatment referrals

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 47, No. 5, pp. 1449–1456, 2000

0360-3016/00/$–see front matter

PII S0360-3016(00)00544-7

PHYSICS CONTRIBUTION

THE EXCHANGE OF RADIOTHERAPY DATA AS PART OF AN ELECTRONIC PATIENT-REFERRAL SYSTEM

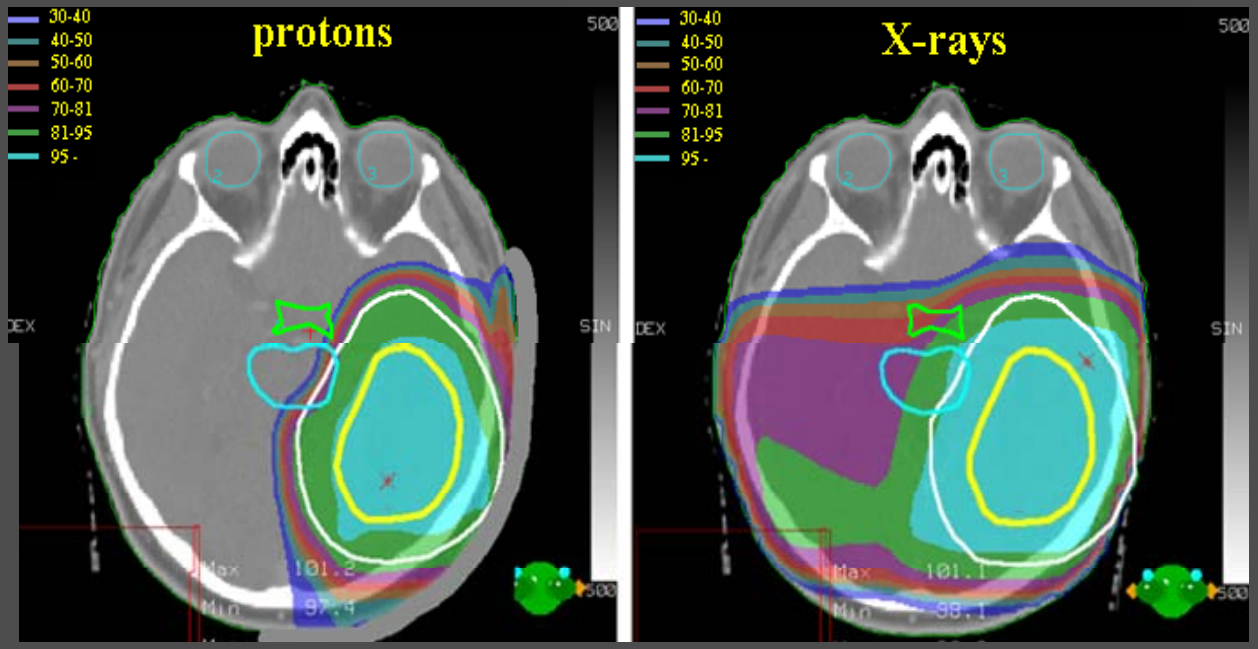
ANTONY LOMAX, PH.D.,* MARTIN GROSSMANN, PH.D.,* LUCA COZZI, PH.D.,† PIERRE-ALAIN TERCIER, PH.D.,‡ TERENCE BOEHRINGER, PH.D.,* UWE SCHNEIDER, PH.D.,§ MARIANNE LOGEAN, DIPL. ING.‖ WERNER VOLKEN, PH.D.,¶ OSMAN RATIB, M.D.,¶ AND RAYMOND MIRALBELL, M.D.#

*Department of Radiation Medicine, Paul Scherrer Institute, Villigen, Switzerland; †Department of Radiation Oncology, Ospedal San Giovanni, Bellinzona, Switzerland; ‡Department of Radiation Medicine, University Hospital of Lausanne, Lausanne, Switzerland; §Clinic for Radiation Oncology and Nuclear Medicine, Stadtspital Triemli, Zurich, Switzerland; ‖Digital Imaging Unit, Department of Medical Informatics, University Hospital of Geneva, Geneva, Switzerland; ¶Department of Medical Radiation Physics, Inselspital, Bern, Switzerland; #Department of Radiation Oncology, University Hospital of Geneva, Geneva, Switzerland

Purpose: To describe the implementation and use of an electronic patient-referral system as an aid to the efficient referral of patients to a remote and specialized treatment center.

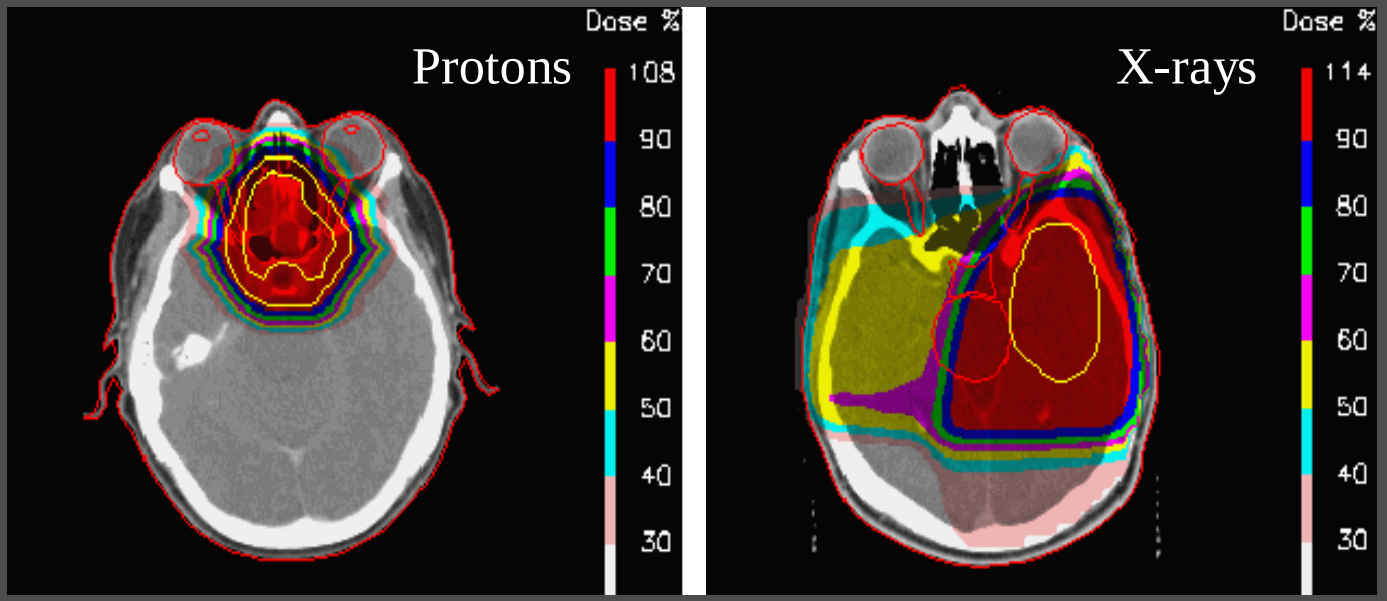
Ref. R. Miralbell 2007

Left temporo-parietal grade-II astrocytoma in a 36 years old male

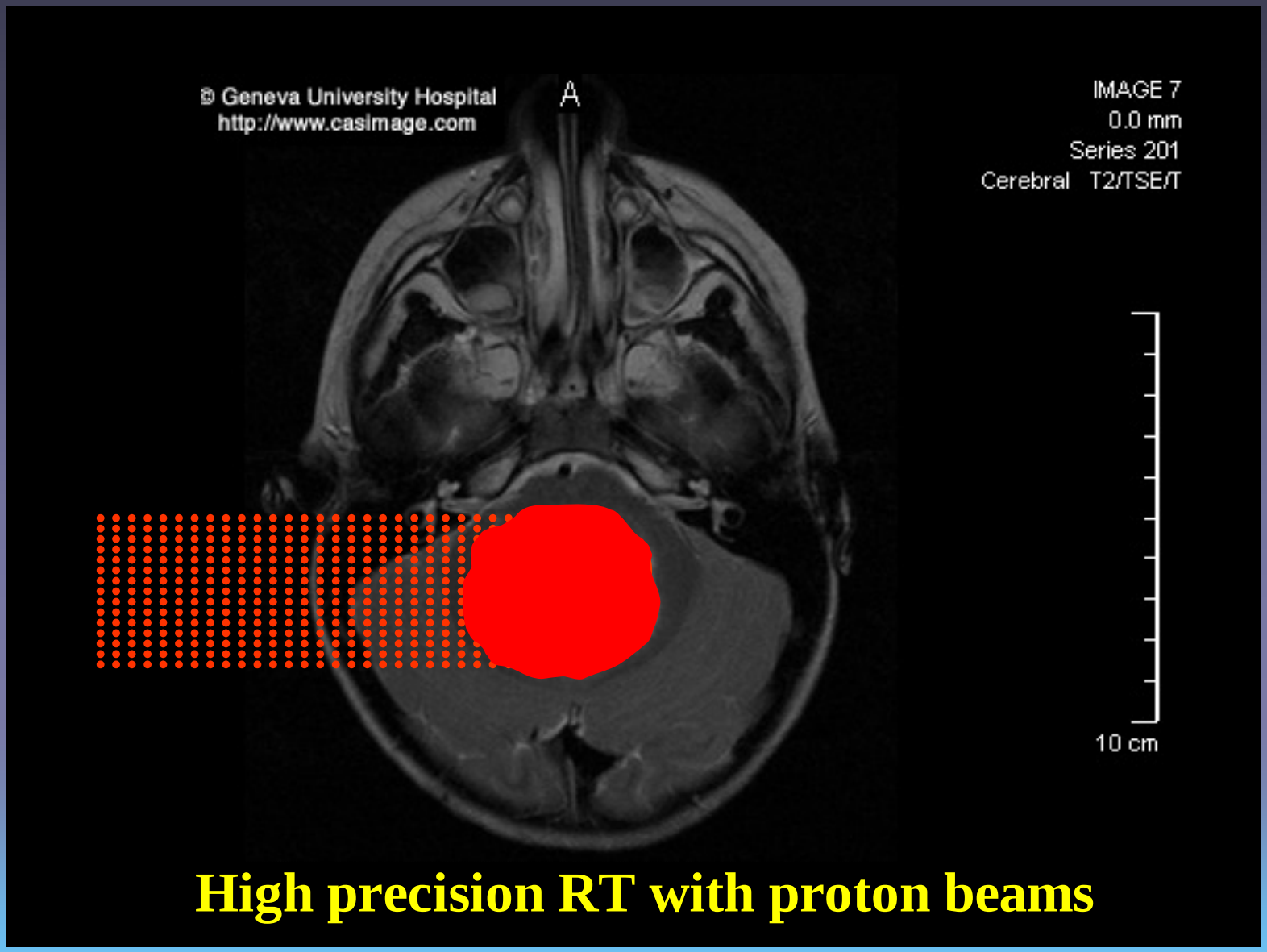


Ref. R. Miralbell 2007

Left temporal lobe brain tumor in a 28 year-old patient



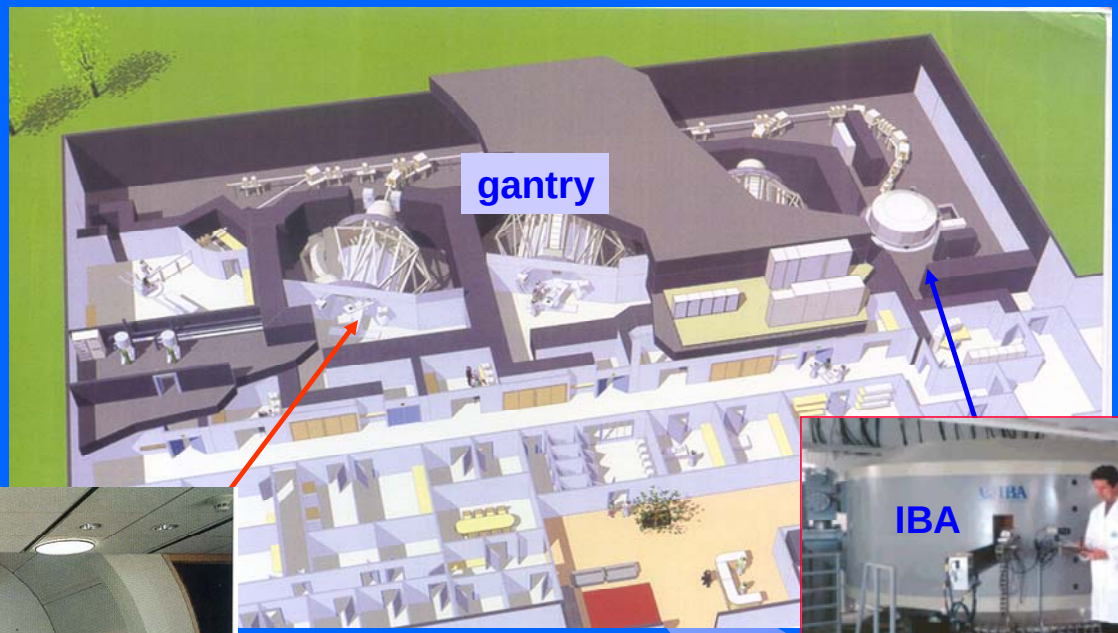
Ref. R. Miralbell 2007



High precision RT with proton beams

Ref. R. Miralbell 2008

Cyclotron for protons by Ion Beams Applications - Belgium



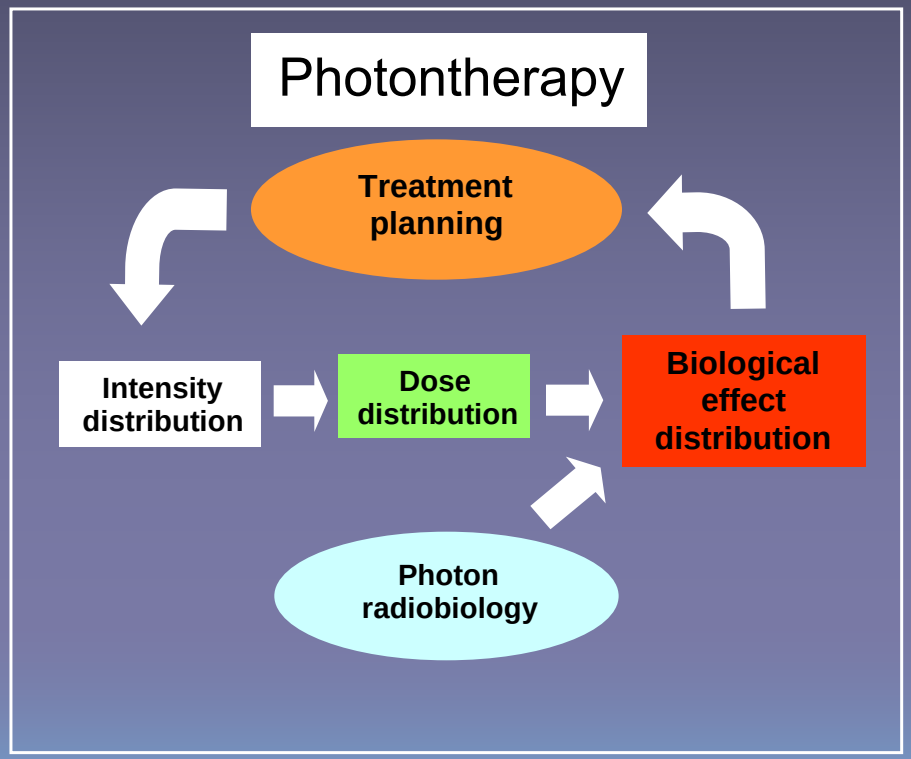
Five companies offer turn-key centres for 120-150 M€.
If proton accelerators were 'small' and 'cheap',
no radiation oncologist would use X rays.

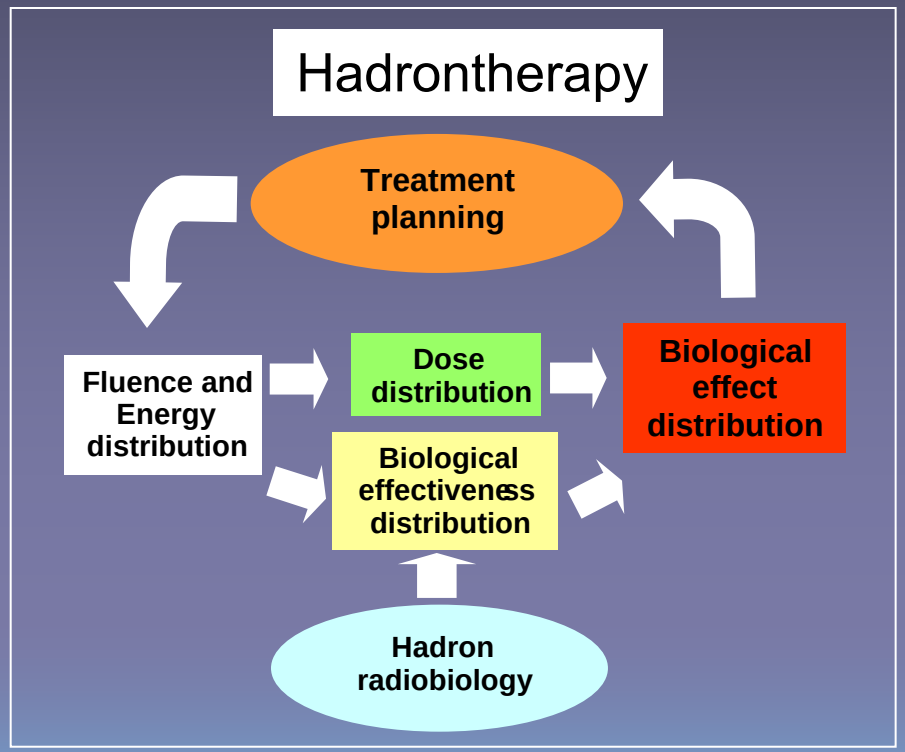
The GSI pilot project : 1997-2008

450 patients treated with carbon ions

J. Debus

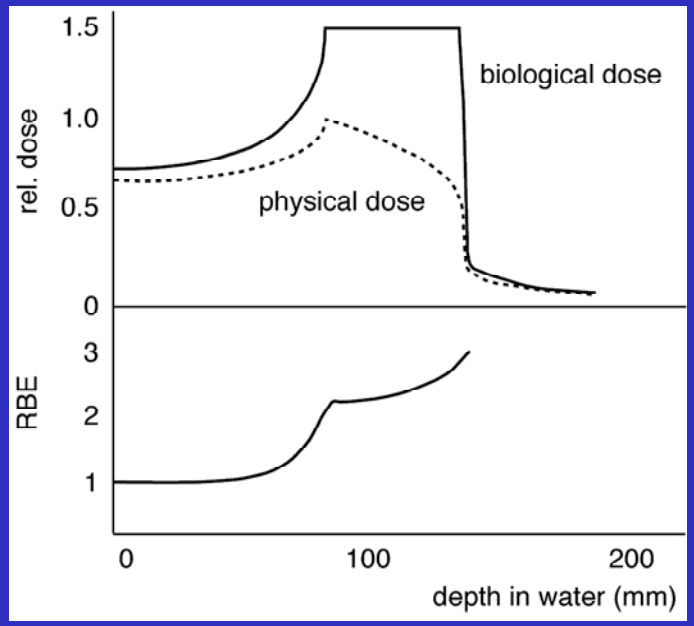
Treatment planning optimization in hadrontherapy





Ref. Mauro Belli 2007

Physical and biological doses



To obtain a homogeneous biological effect over the tumour volume the physical dose has to decrease towards the distal edge of the SOBP to take into account the RBE variations

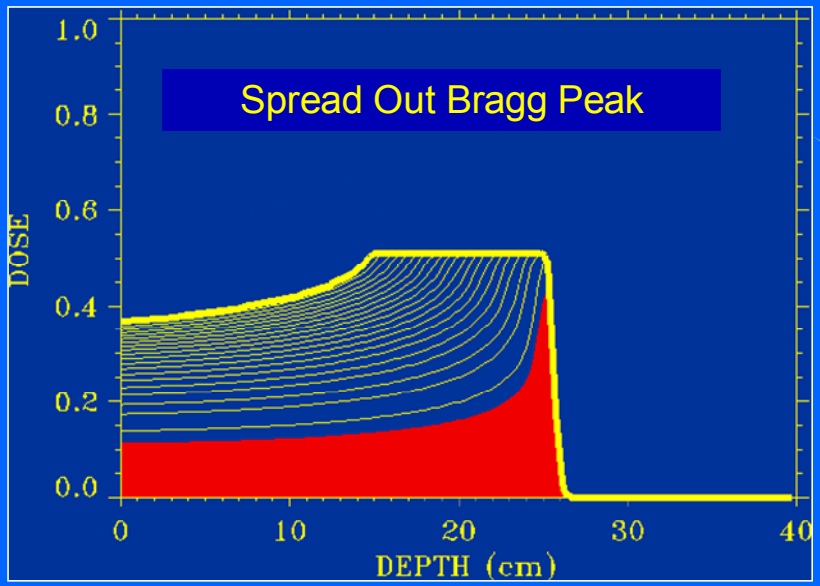
Mauro Belli 2007

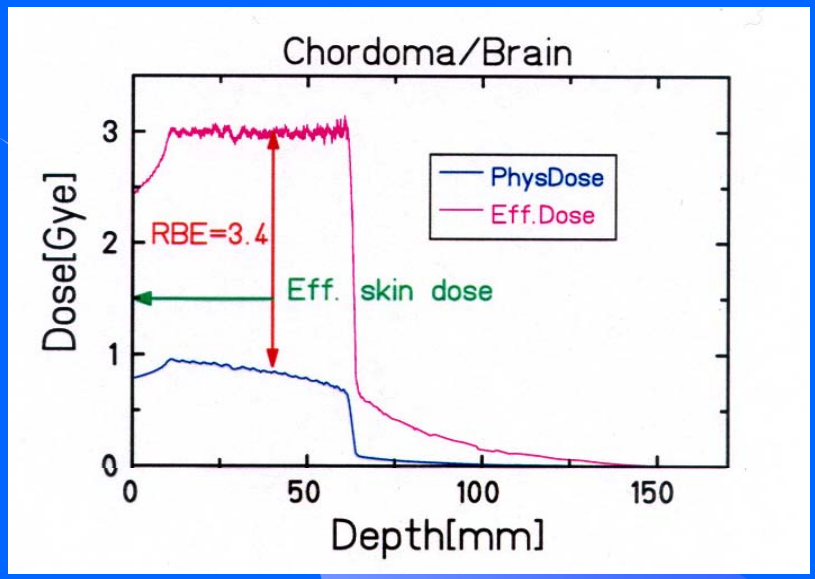
The effective "effective dose" in Gye is defined as Gy x RBE

At GSI the values of RBE are computed with X-ray cell survival data

by using the Local Effect Model (LEM) by G. Kraft el al.

To obtain a 'flat' dose in Gye the "physical dose" is not 'flat'





HIMAC in Chiba is the pioner of carbon therapy (Prof H. Tsujii)

Yasuo Hirao

[15] Hirao, Y. et al, "Heavy Ion Synchrotron for Medical Use: HIMAC Project at NIRS Japan" Nucl. Phys. A538, 541c (1992)

Hirohiko Tsujii

4500 pts 1994-2008

Since the cells do not repair. less fractions are possible

HIMAC: 4-9 fractions!

Numbers of potential patients (*)

X-ray therapy

every 10 million inhabitants: 20'000 pts/year

Protontherapy

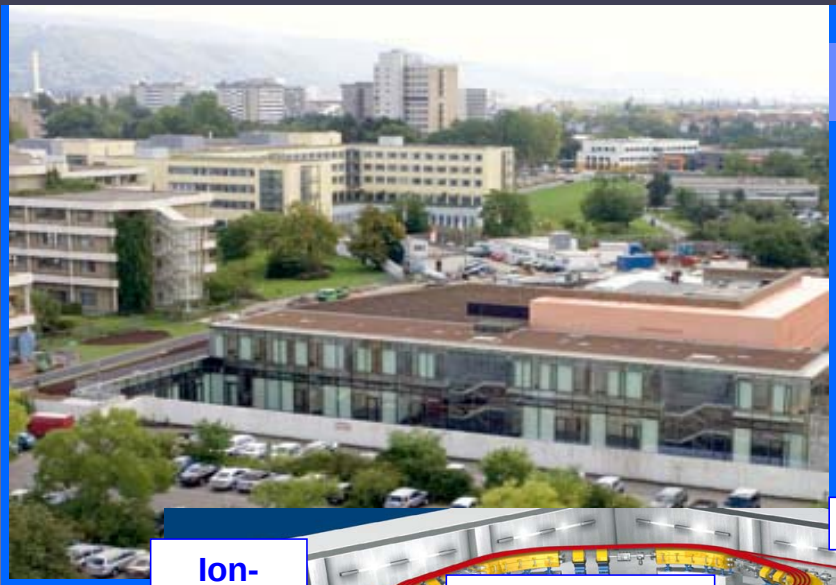
12% of X-ray patients 2'400 pts/year

Therapy with Carbon ions for radio-resistant tumour

3% of X-ray patients 600 pts/year

TOTAL every 10 M **about 3'000 pts/year**

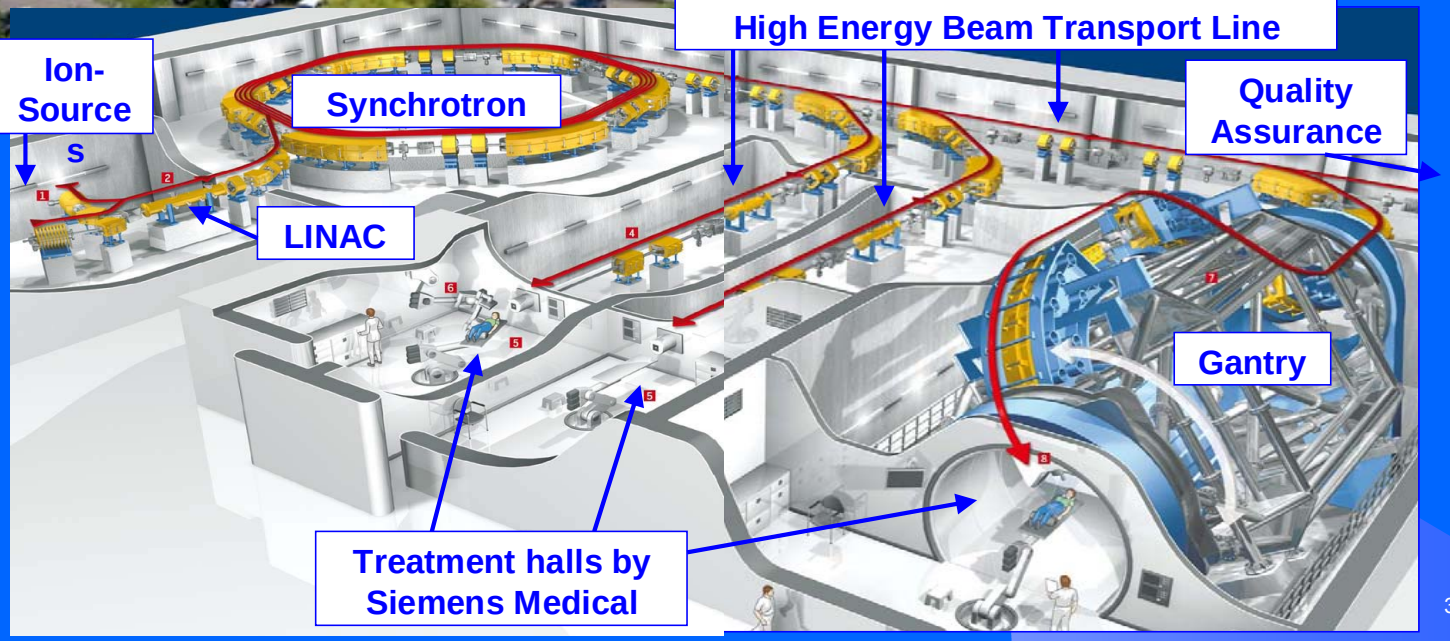
(*) Combining studies made in Austria, Germany, France and Italy in the framework of ENLIGHT - Coordinator: Manjit Dosanjh FP7 projects: ULICE , PARTNER, ENVISION



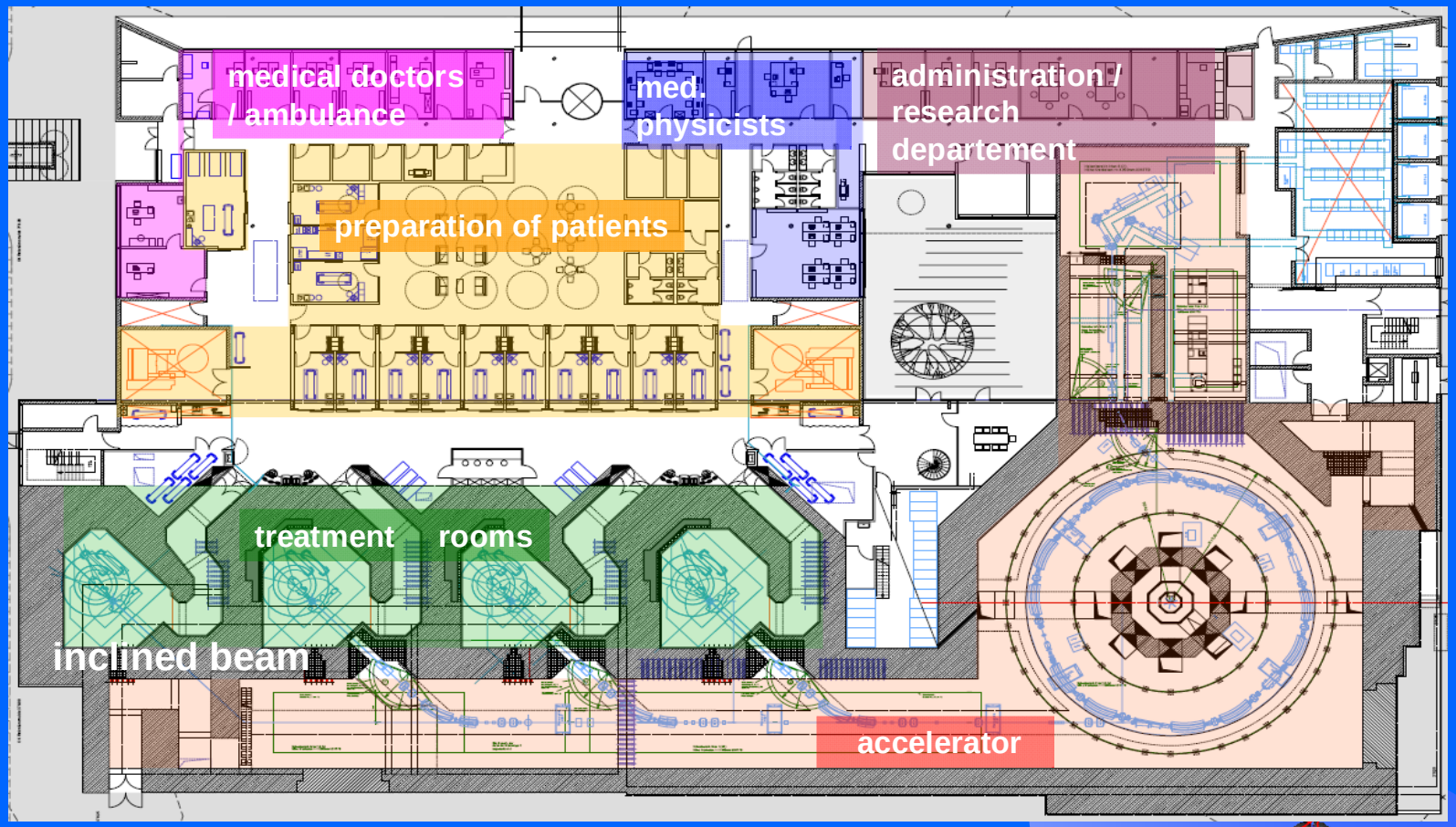
HIT at Heidelberg

First beam extracted in 2007

First patient: spring 2009



Siemens Medical is building for 2010 a 'dual' centre in Marburg



TERA programmes since 1992

TERA has proposed and designed the 'dual' National Centre for carbon ions and protons

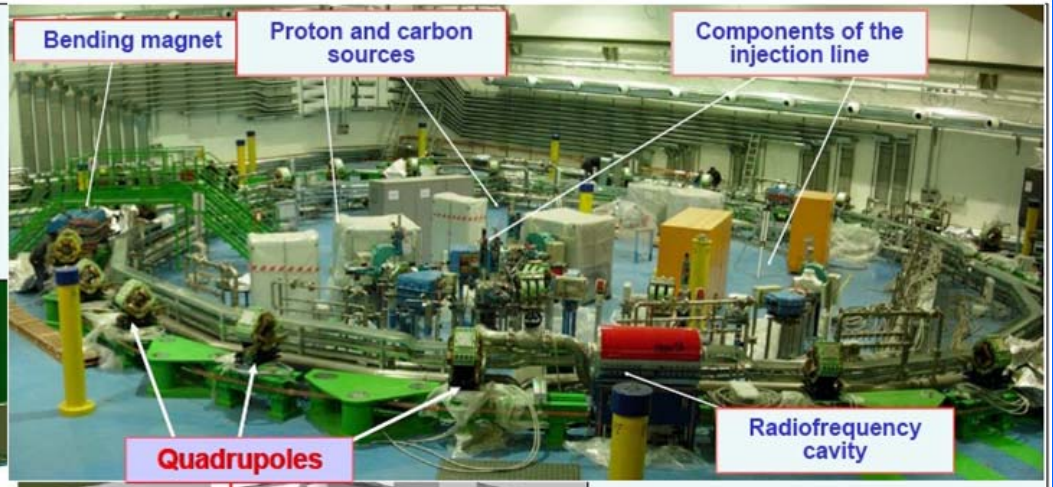
1. CNAO is being built in Pavia

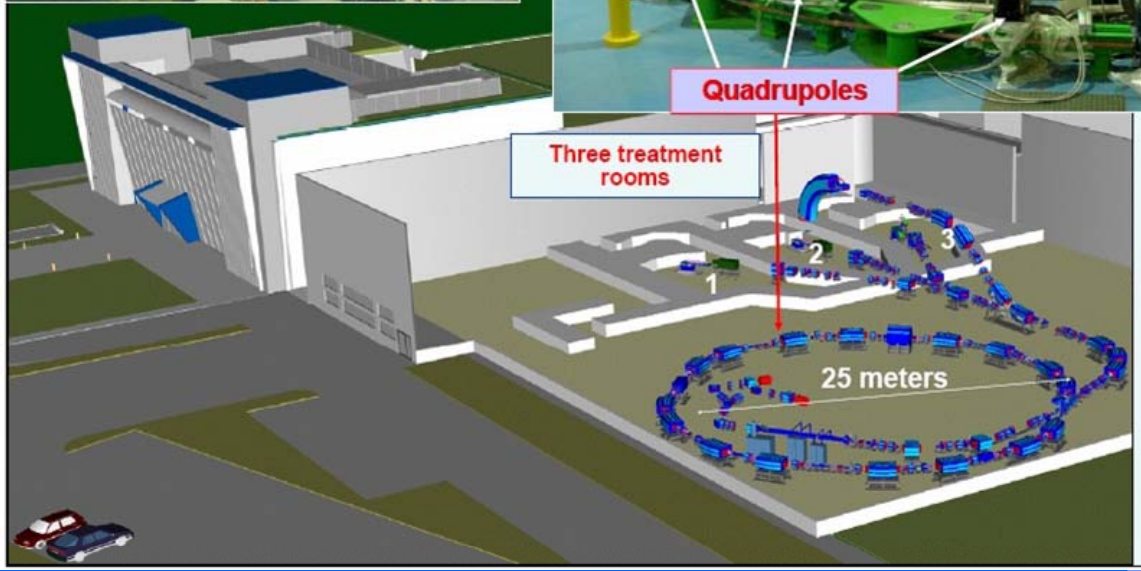
TERA has introduced and developed a novel type of accelerator:

the "cyclinac"

2. "cyclinacs" for protons and carbon ions

CNAO status in February 2007





CNAO
Centro Nazionale di Adroterapia Oncologica
Pavia

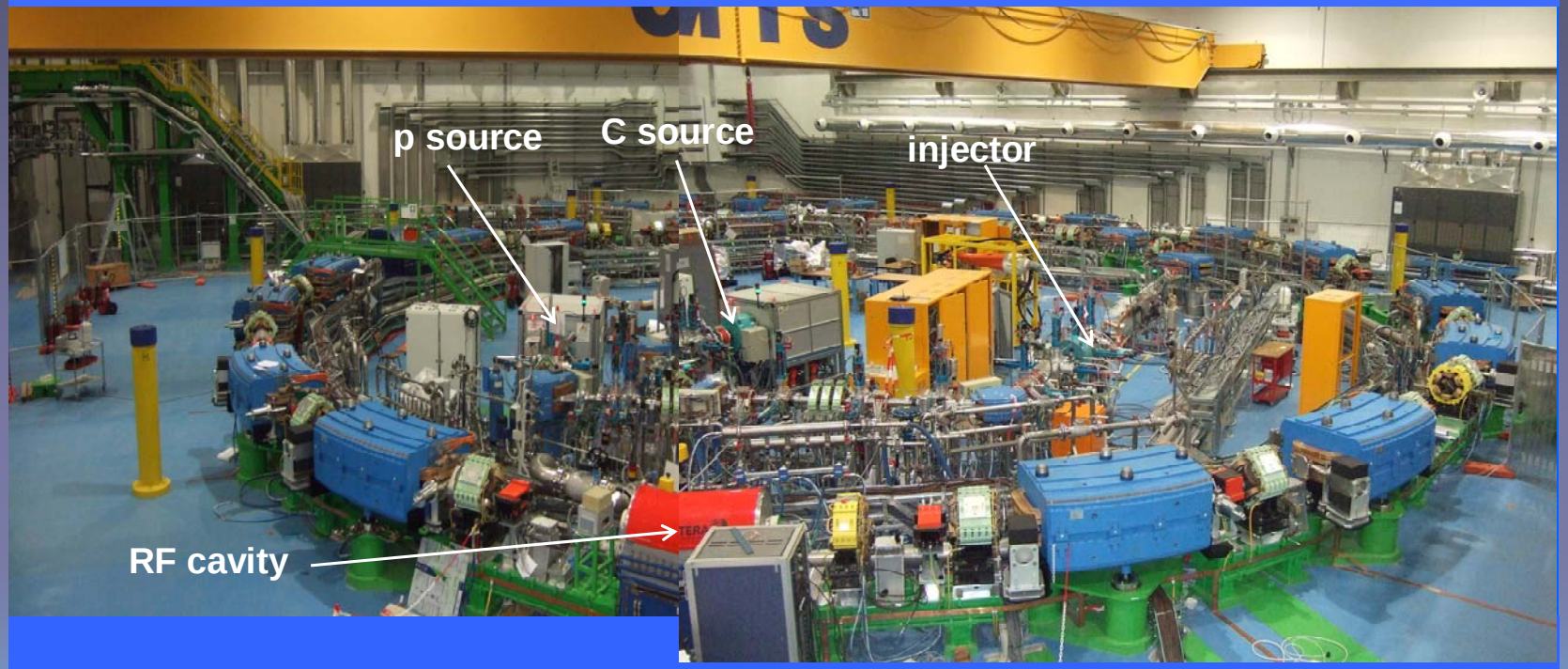
Beams ready:

summer 2009

CNAO status in October 2008

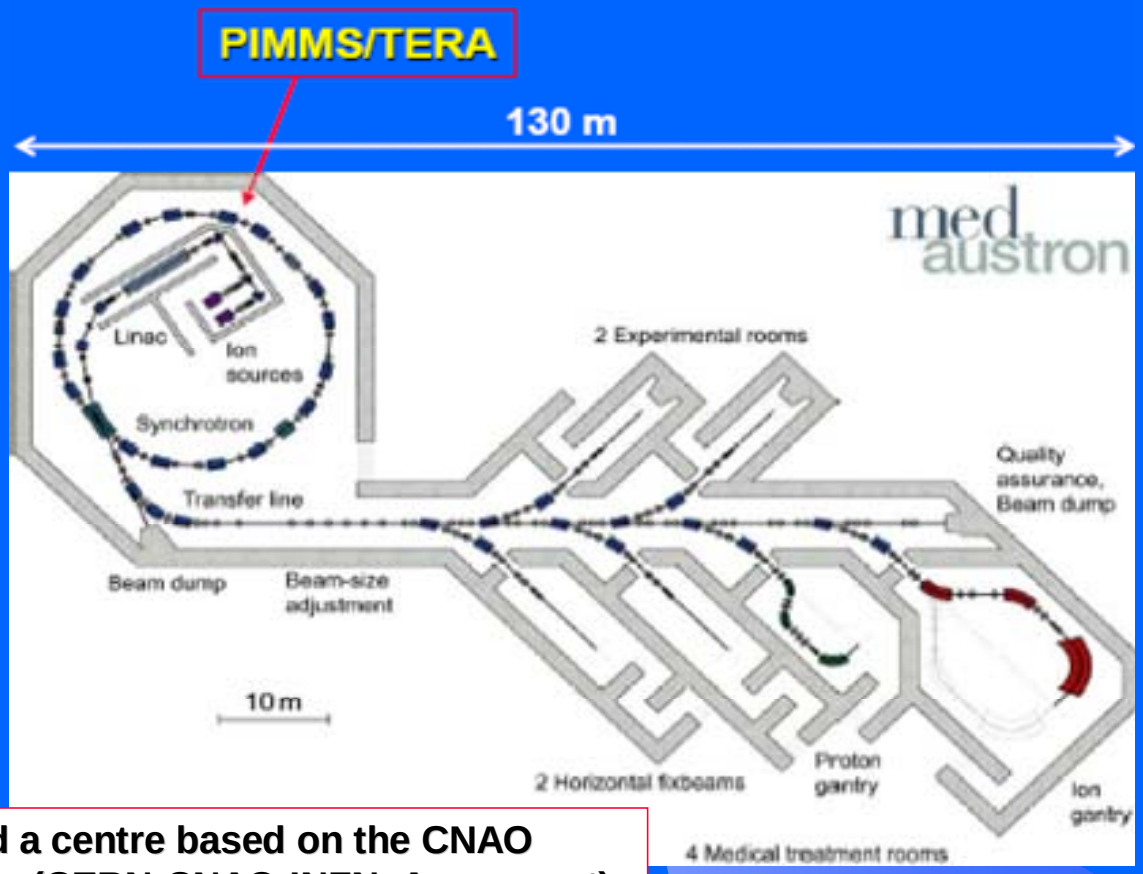
The Hospital Building

CNAO *The synchrotron area in October 2008*



In 2007 MedAustron has been approuved for Wiener Neustadt

Approved in 2007 by the Government of Lower Austria



MedAustron will build a centre based on the CNAO construction drawings (CERN-CNAO-INFN Agreement)

Projet ETOILE

Approuved in 2007 for construction in Lyon

Competitive tendering started in 2008

A Frech-Italian Consortium presents a project based on CNAO constructin drawings

www.projet-etoile.fr

Pr Jacques BALOSSO

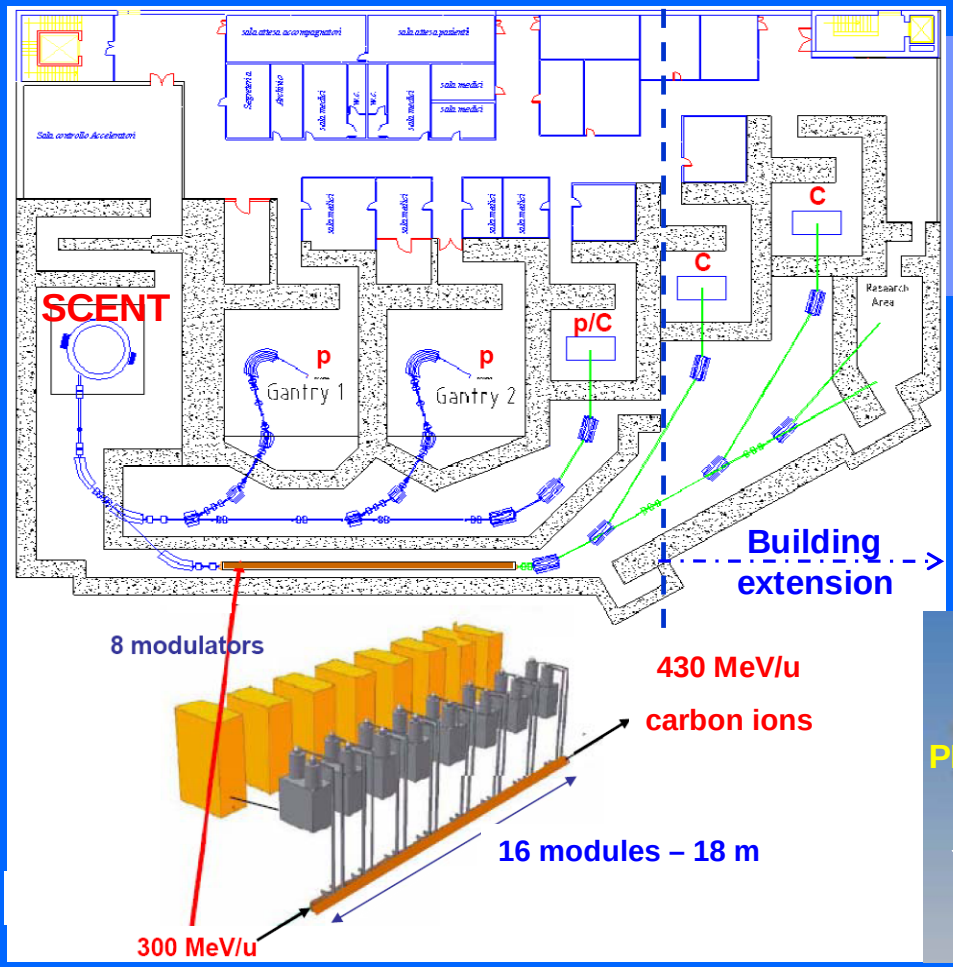
Medical director

CERN Colloquium - 5.2.09 - UA

In IDRA = Institute for Diagnostics and RAdiotherapy the proton beam can vary in energy and intensity every 5 ms

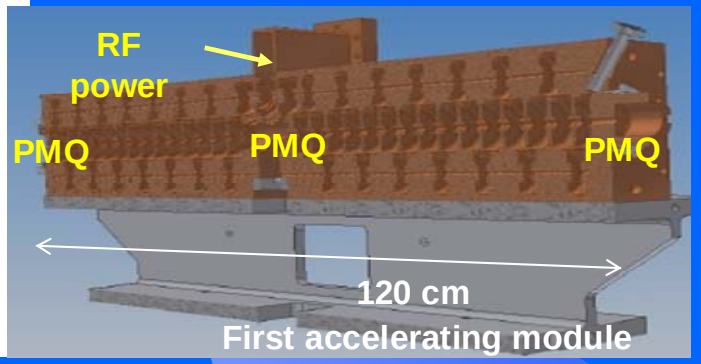
TERA passed the know-how to « Applications of Detectors and Accelerators to Medicine » - A.D.AM. - a CERN spin-off which has an agreement with CERN (President A. Colussi)

The TERA dual centre: SCENT + CABOTO



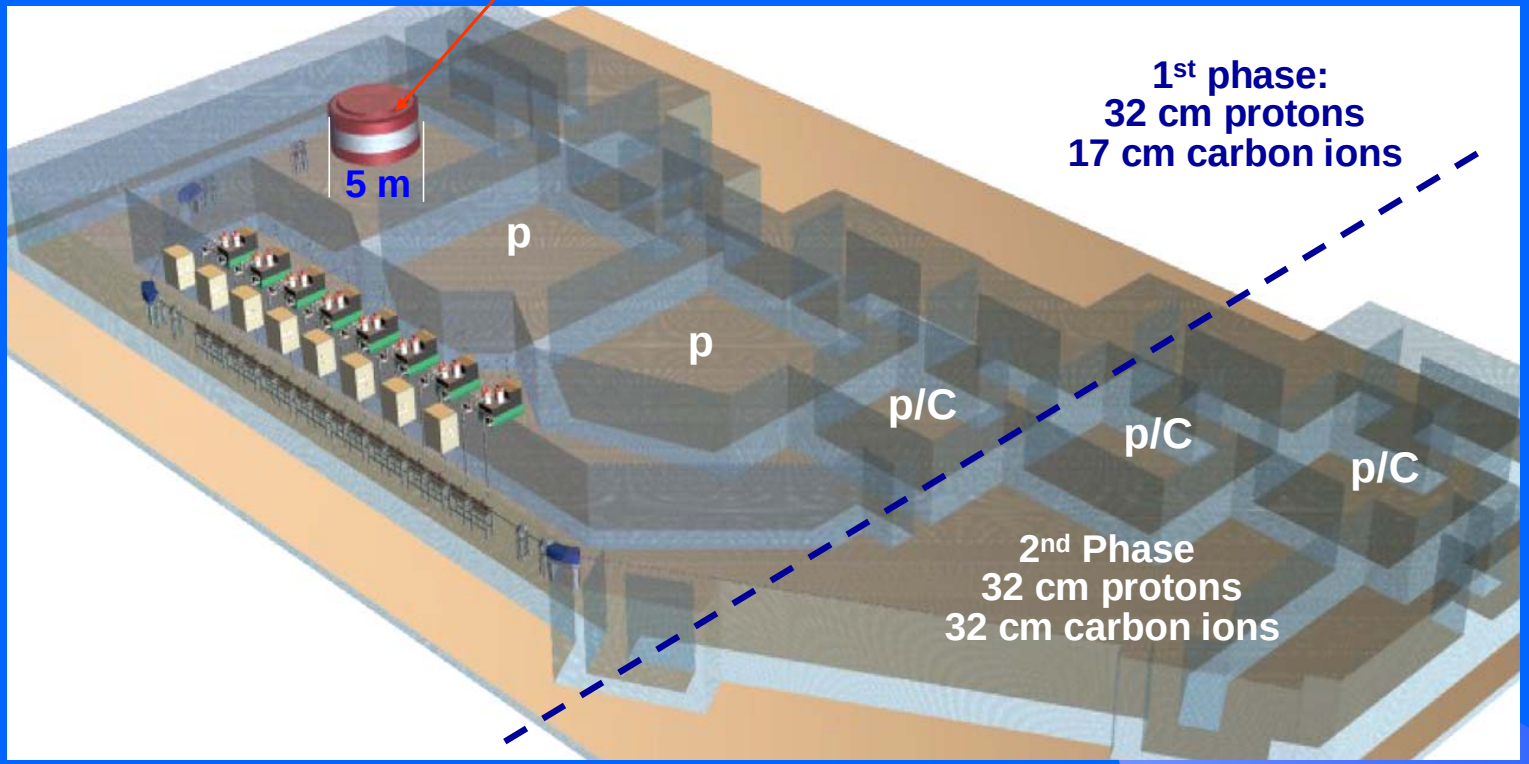
CArbon BOoster for Therapy in Oncology at 3 GHz

as IDRA



The TERA dual centre: SCENT + CABOTO

Superconducting cyclotron by LNS/IBA (250 MeV protons and 3600 MeV carbon ions) is now commercialized by IBA



INFN & Hadrotherapy

- In the 90th': INFN supported TERA in R&D project.
- INFN, in collaboration with University of Catania, realized in its laboratory (Lab. Naz. Del Sud) the first Italian protontherapy facility.
- INFN has UNIQUE capability in Italy in accelerators development.
- Considering its particular features, INFN was involved in CNAO to guarantee the necessary expertise.
- In 2005: INFN asked by Health Minister to produce a document about protontherapy in our country.

G. Cuttone 2009

CATANA collaboration

Centro di AdroTerapia e Applicazioni Nucleari Avanzate

INFN-Laboratori Nazionali del Sud

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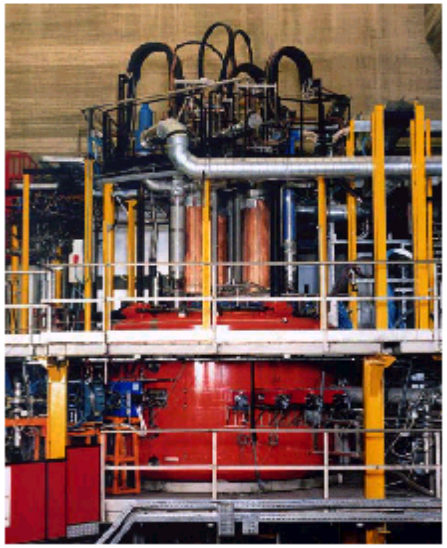
Radiologic Institute University of Catania

G. Privitera, V. Salamone, L. Raffaele, C. Spatola



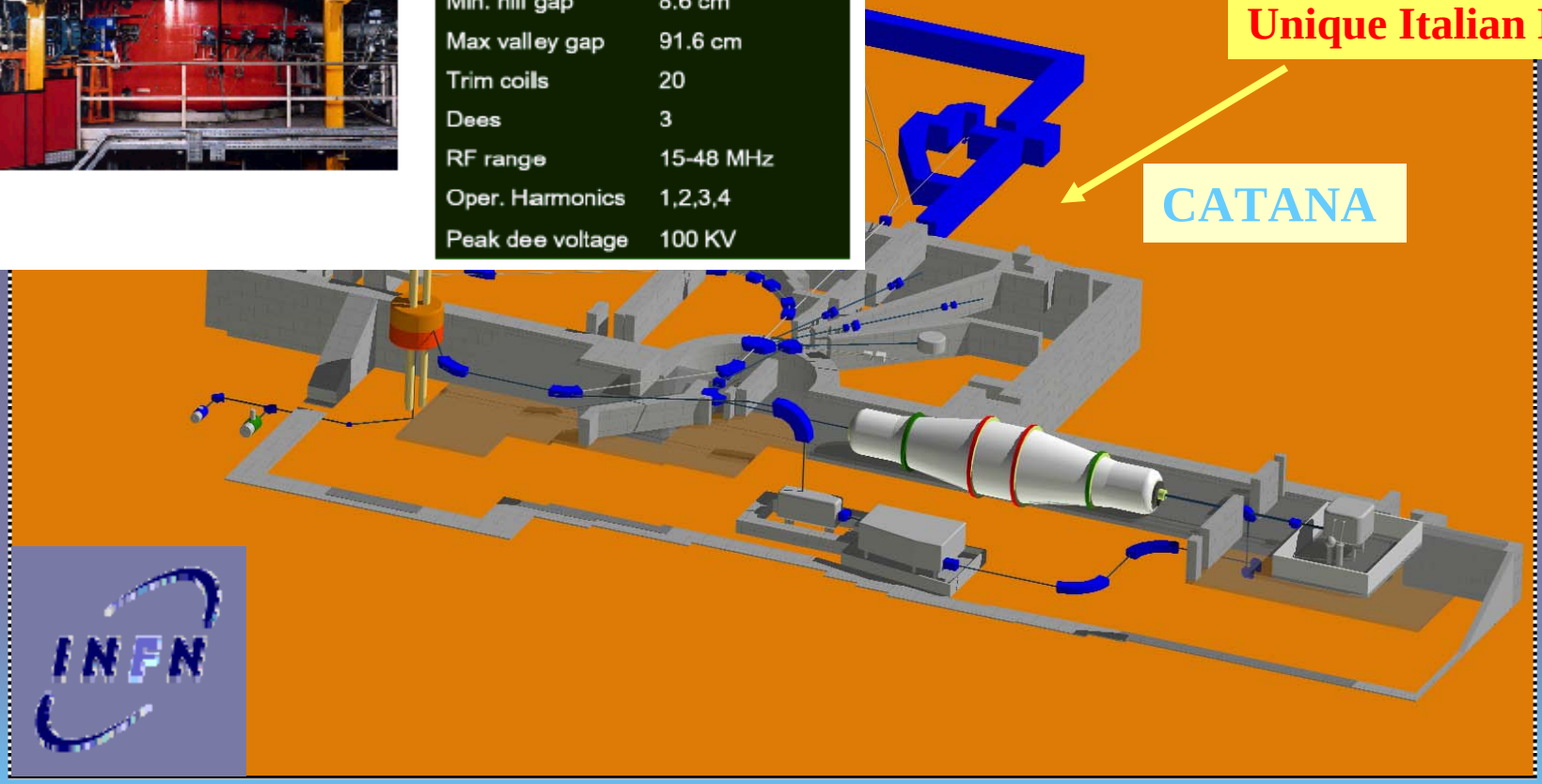
LNS Superconducting Cyclotron	
Bending limit	K=800
Focusing limit	Kfoc=200
Pole radius	90 cm
Yoke outer radius	190.3 cm
Yoke full height	286 cm
Total weight	176 tons
Min-Max field	2.2-4.8 Tesla
Main coil At	6.5 10^6
Sectors	3
Min. hill gap	8.6 cm
Max valley gap	91.6 cm
Trim coils	20
Dees	3
RF range	15-48 MHz
Oper. Harmonics	1,2,3,4
Peak dee voltage	100 KV

LNS Accelerator Layout

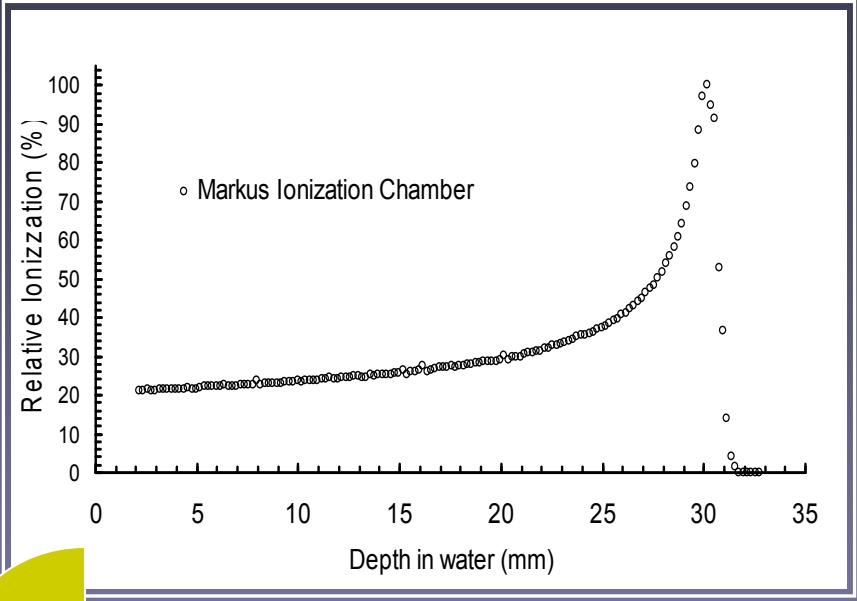
Ocular Protontherapy

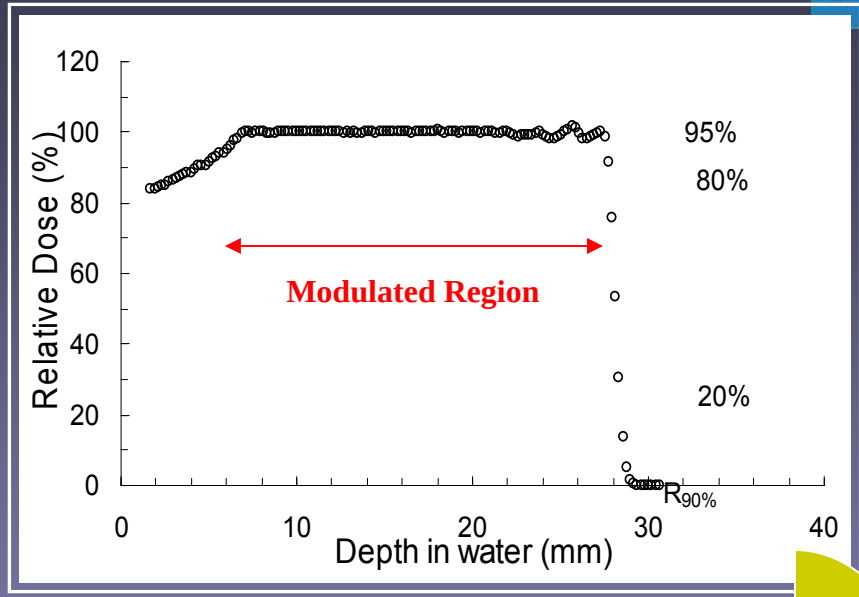
Unique Italian Facility

CATANA



Experimental SOBP curves

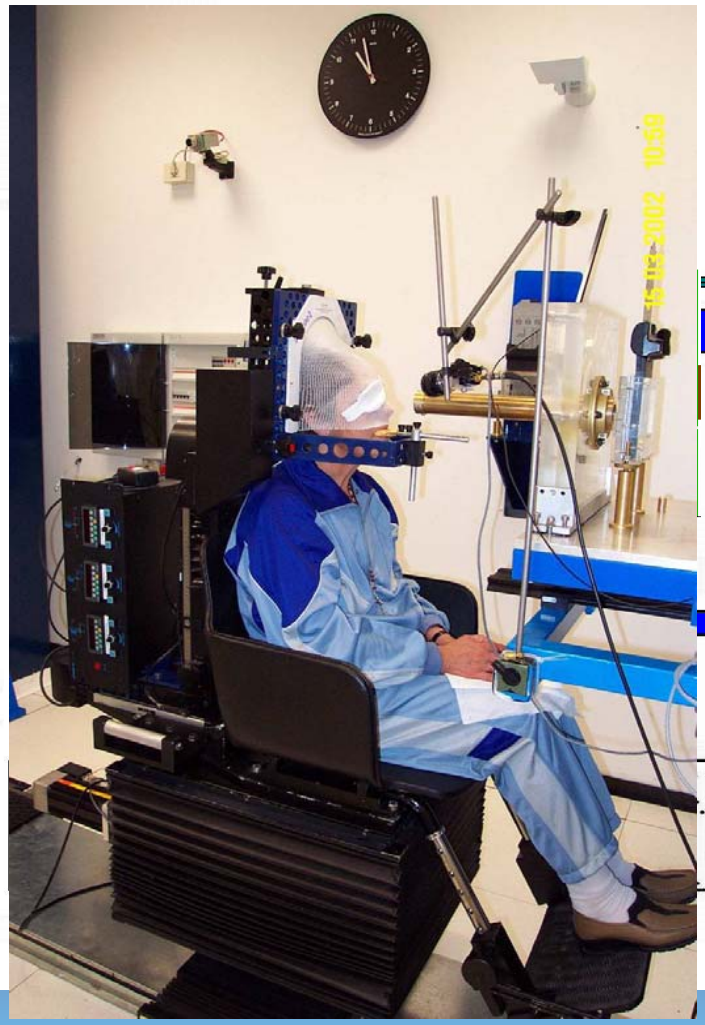


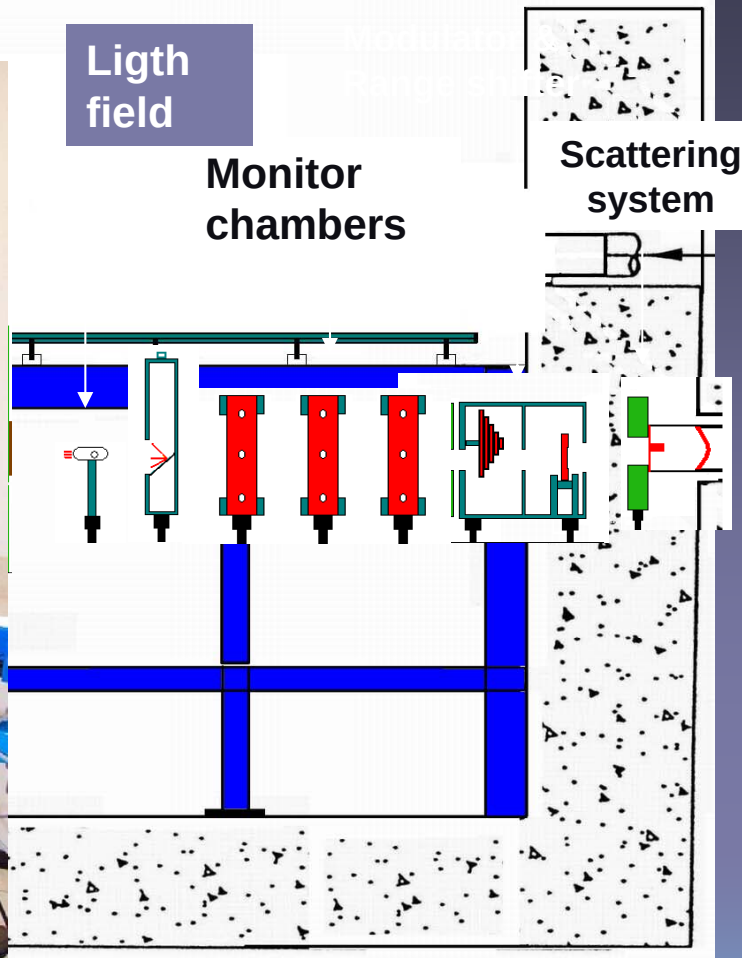


DETECTOR	Peak Depth	Peak-Plateu Ratio	F.W.H.M.	Distal - dose falloff $d_{80\%-20\%}$	Practical Range ($d_{10\%}$, ICRU 59)
MARKUS	30.14	4.68	3.19	0.50	31.15

DETECTOR	Modulation (SOBP)	Maximum Dose (%)	Distal - dose falloff $d_{90\%-10\%}$	Distal - dose falloff $d_{80\%-20\%}$	Beam Range (90% Distal)
MARKUS	21.31	103.9	0.84	0.57	28.39

CATANA proton therapy beam line





Patient Distribution by Pathologies

Uveal Melanoma	158 patients
Conjunctival Melanoma	4 patients
Conjunctival rhabdomyosarcoma	1 patient
Eyelid Carcinoma and metastases	2 patient
Conjunctival MALT-NHL	1 patient
Conjunctival Papilloma	2 patient

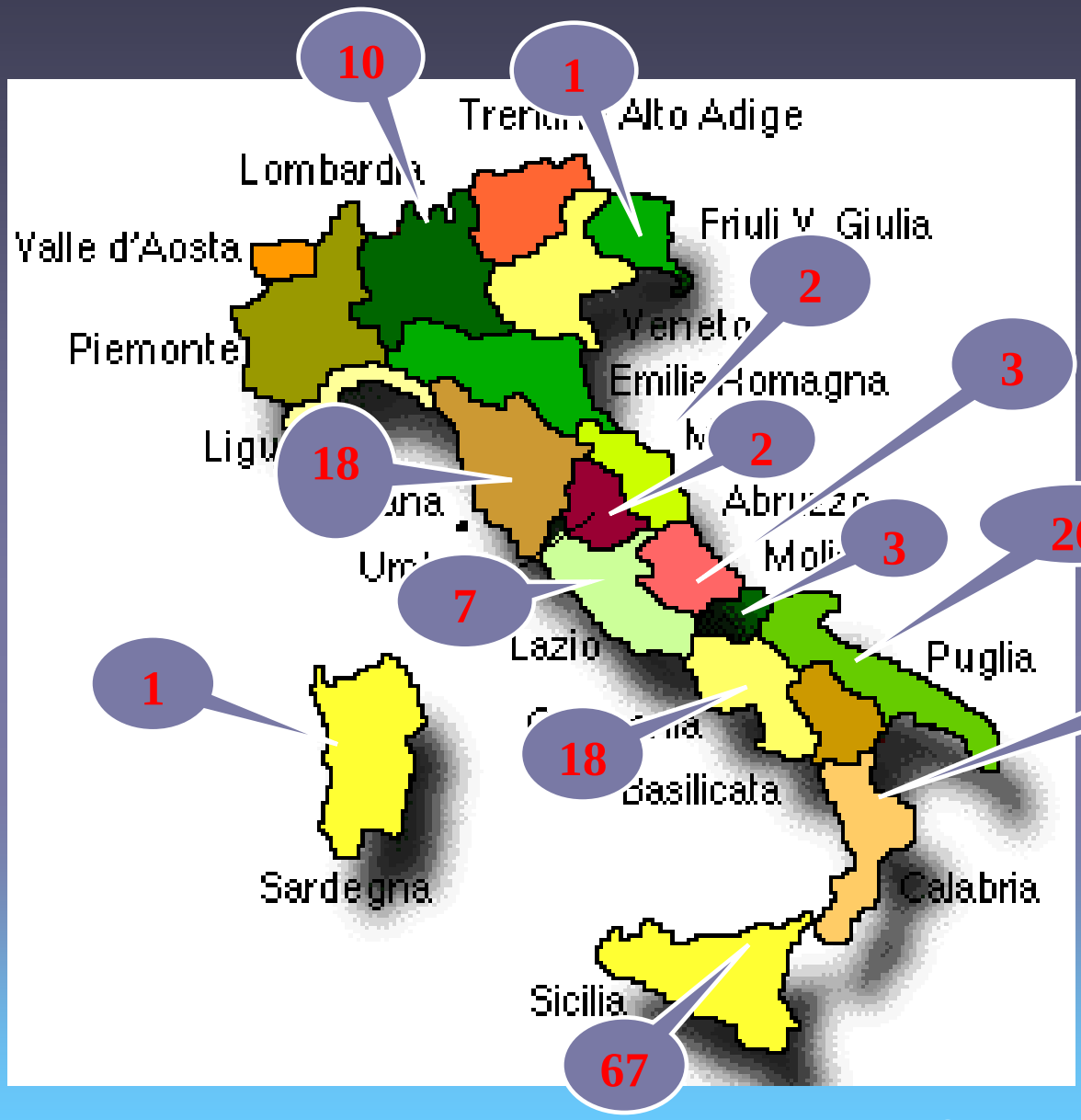
PAZIENTI TRATTATI 168

Patient Distribution by Origin Region

Since feb 2002

Total number of patients :

168



SURVIVAL RESULTS		
PatientsTotal Number (Feb. 2002- May 2008)	168	
Dead patients	4	
	Metastatis	3
	Other	1
Eye retention rate	95 %	
TOTAL SURVIVAL	98 %	
LOCAL CONTROL	95 %	

Proposal of LNS for Cannizzaro Hospital Catania

Available online at www.sciencedirect.com
SCIENCE DIRECT
ELSEVIER
Nuclear Instruments and Methods in Physics Research A 562 (2006) 1009–1012
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

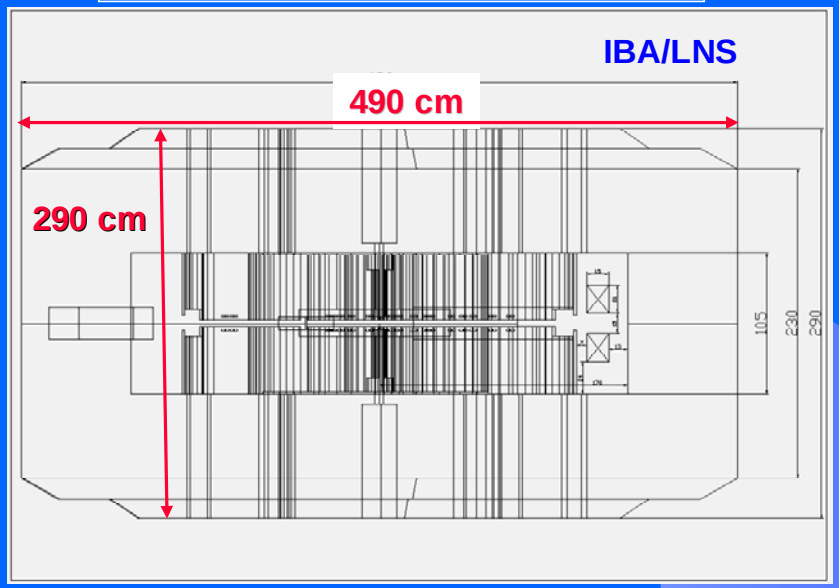
A novel superconducting cyclotron for therapy and radioisotope production

Luciano Calabretta[a,*], Giacomo Cuttone[a], Mario Maggiore[a,b], Maurizio Re[a], Danilo Rifuggiato[a]

[a]*LNS-INFN, Via S. Sofia 62, Catania 95123, Italy*
[b]*University of Catania, Via S. Sofia 64, Catania 95123, Italy*

Available online 6 March 2006

250 MeV/u H_2^{+1}, 300 MeV/u C^{+6}



- **Workshop on Hadron Beam Therapy of Cancer**

Erice, Sicily, Italy

April 24, 2009 - May 1, 2009

Hadron Therapy Challenge

Multidisciplinary and cutting-edge technologies:

- Clinical Studies
- Radiobiology
- Treatment planning for Intensity Modulated Particle Therapy
- Adaptive ion therapy and treating of moving organs
- Novel in-beam PET systems
- Feasibility study for innovative gantry designs
- Improved gantry design

ENLIGHT

Manjit Dosanjh, ENLIGHT Coordinator, 2009

ENLIGHT

Hadrontherapy complex undertaking, therefore ENLIGHT established to

- Create common multidisciplinary platform
- Share knowledge
- Share best practices
- Harmonise data
- Provide training, education
- Identify challenges
- → innovate

Manjit Dosanjh, ENLIGHT Coordinator, 2009

What happened?

ENLIGHT was established in 2002

Composed of: HIT, ETOILE, CNAO, CERN, ESTRO, GSI, Karolinska, MedAustron, TERA, Czech Rep, Spain

Funded as a network by the EC, 2002- 2005

Main achievements:

- Creation of a European Hadrontherapy Community
- Common multidisciplinary platform with a shared vision
- Helped to catalyse the transition from research to the clinical environment
- Served as a vehicle for education and dissemination

At the end of the funding:

ENLIGHT community showed clear desire for continuing the network focusing on new and on uncompleted research topics and helping new initiatives….

ENLIGHT

Manjit Dosanjh, ENLIGHT Coordinator, 2009

From ENLIGHT… to ENLIGHT++

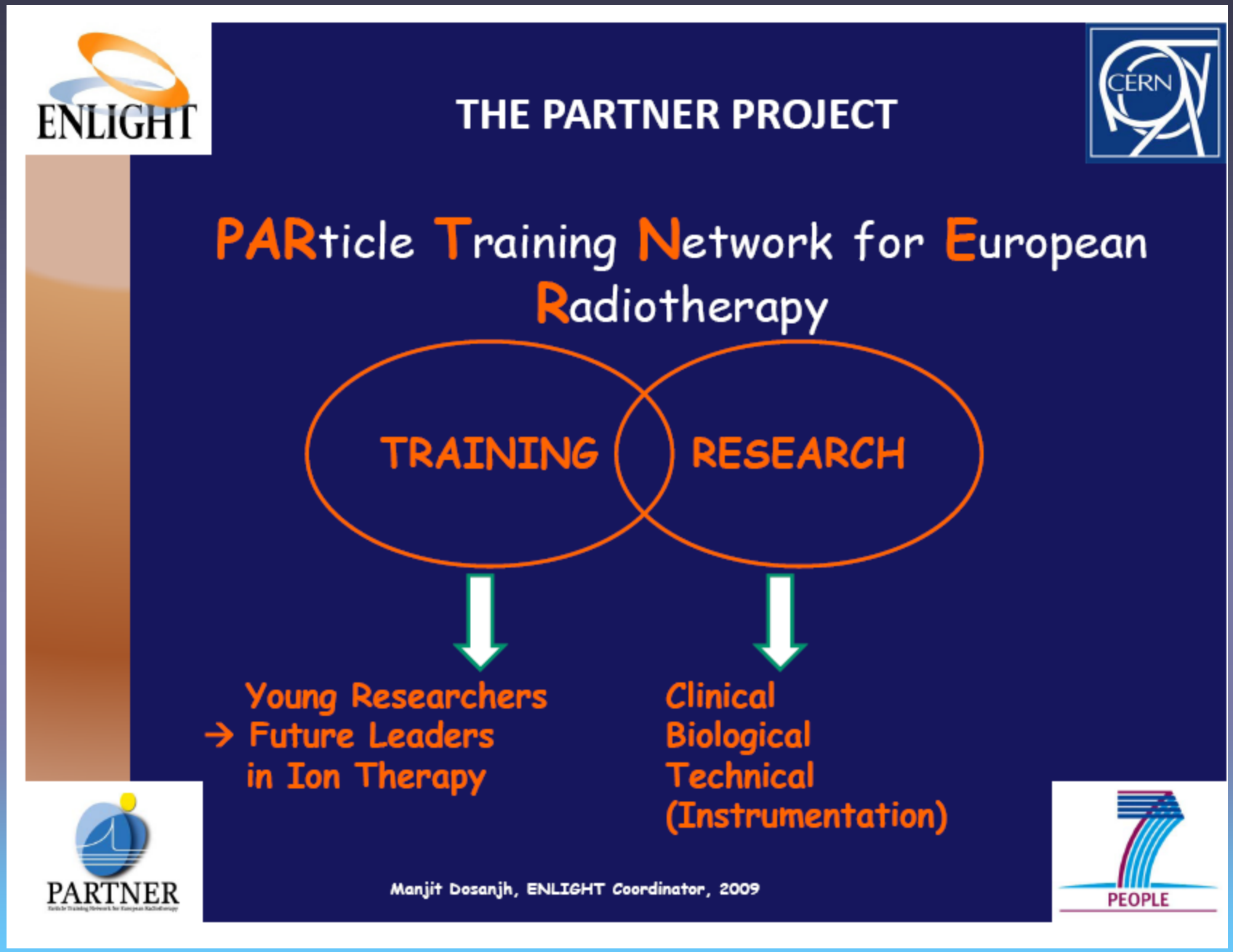
In 2006 ENLIGHT++:

+ one “plus” for more hadrons (specially protons),

++ the second “plus” refers to being more inclusive (15 countries, with 60 Institutions)

ENLIGHT++ goes beyond being a network:
Main Objective: Be more INCLUSIVE and become a RESEARCH network

Manjit Dosanjh, ENLIGHT Coordinator, 2009


ENLIGHT
THE PARTNER PROJECT
CERN
PARticle Training Network for European Radiotherapy
TRAINING
RESEARCH
Young Researchers
→ Future Leaders
in Ion Therapy
Clinical
Biological
Technical
(Instrumentation)
Manjit Dosanjh, ENLIGHT Coordinator, 2009
PARTNER
PEOPLE

THE PARTNER PROJECT

Joint Research & Training Programme

- Ten Institutes:
  CERN (Project Coordinator), CNAO, GSI, UKL-HD (HIT), KI, UNIS, TERA, MEDAUSTRON, ETOILE, IFIC
- Two leading companies in particle therapy:
  IBA, SIEMENS
- Multi-disciplinary research: Radiobiology, Dosimetry, Treatment Planning, Novel gantry design, Simulations, Clinical studies
- Mobility of researchers common network

Manjit Dosanjh, ENLIGHT Coordinator, 2009

ULICE

Union of Light Ion Centres in Europe

ULICE is a multidisciplinary initiative that involves all the major players in Europe in the field of hadrontherapy, integrating clinical, physical, biological, engineering and technological knowledge

ULICE is approved under the EC Infrastructure call for **8.4 M€** and is in the process of negotiation

ULICE structure :

- General coordination: Roberto Orecchia, CNAO & Milan University
- Joint research activities: Richard Poetter, Vienna University
- Networking activities: Manjit Dosanjh, CERN
- Trans-national access: Juergen Debus, HIT & Heidelberg Uni

ENLIGHT

Manjit Dosanjh, ENLIGHT Coordinator, 2009

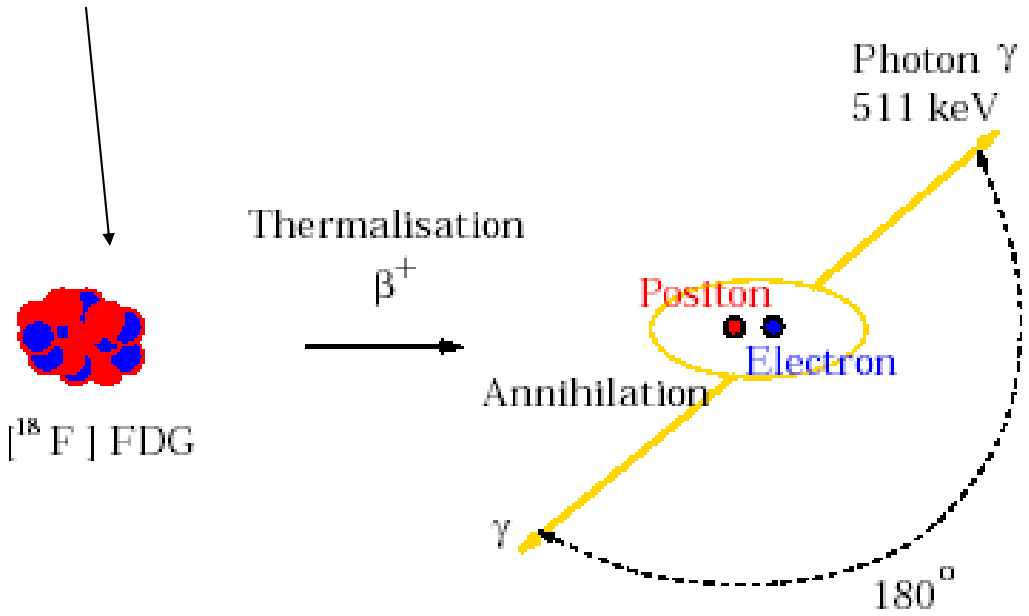
ULICE

The development of new instruments, the transnational European access to the existing facilities and the different communities (researchers, clinicians, patients) requires a broad network structure. The overall aims of ULICE are:

- to enable the full exploitation of all available resources
- open access to information
- improvement of the existing and upcoming facilities

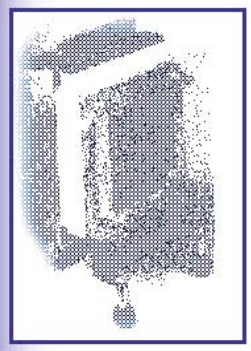
PET Basic Principles

Radioisotopes (Fluor)



1977

when PET started at CERN

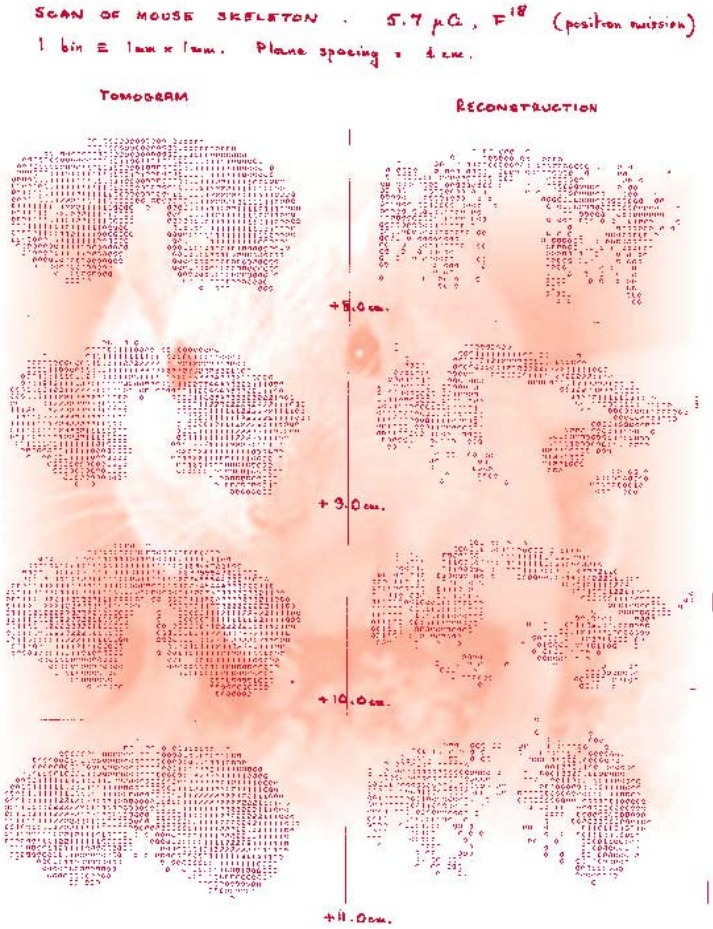


(Jeavons, Townsend et al.)

Spatial resolution 2.4 mm FWHM
Maximum data rate: 3000 c.p.s

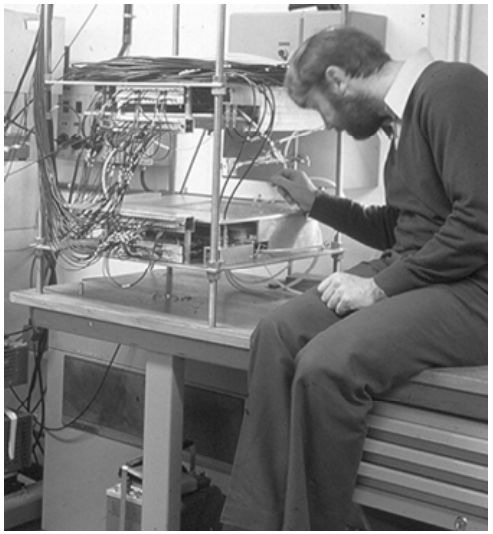
Sensitivity: 25 c.p.s / μCi

1 μCi=3.7 10^4Bq

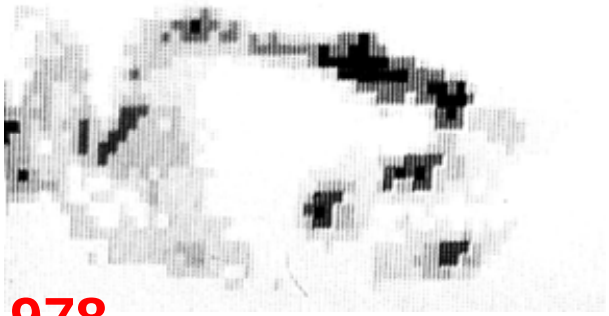


CERN Technology Transfer http://cern.ch/TTdb

The HIDAC Camera: 25 years later…..



Quad HIDAC small animal scanner



1978

2003

by courtesy D. Townsend IEEE Oct.2008

- Articolo di D.W. Townsend e T. Beyer “ Combined image fusion” British Journal of Radiology 75 (2002), 824-830

Future developments in combined PET/CT scanners will be exciting, attaining a higher level of integration and anatomical and functional imaging performance than ever before. By playing an important role, not only in diagnosis and staging of cancer, but in designing and monitoring appropriate therapies, the combined PET/CT scanner will have a significant impact on patient care, survival and quality of life.

Townsend defined PET-CT as a highly powerful tool to diagnose and stage disease, monitor the effects of treatment, and potentially design much better, patient-specific therapies .

TIME Magazine : **the Medical Invention of the Year 2000**.

In 2004, D. Townsend received the Academy of Molecular Imaging Distinguished Clinical Scientist Award and in 2006 has been elected Fellow of the IEEE.

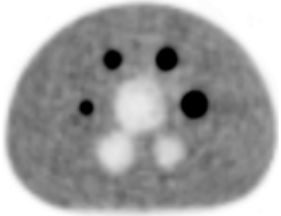
- Il successo dell' applicazione di modalità combinate PET–CT per il monitoraggio, trattamento e il controllo periodico in campo clinico ha fatto si che tali tecniche siano estese a scanners per piccoli animali

- La possibilità di ripetere le analisi, piu' volte ed in maniera non invasiva, nello stesso animale o nei pazienti, facilitano lo sviluppo e lo studio di farmaci ad effetto mirato e nuovi approcci nella cinetica farmacologica

Aspetti da migliorare

Advancing medical imaging

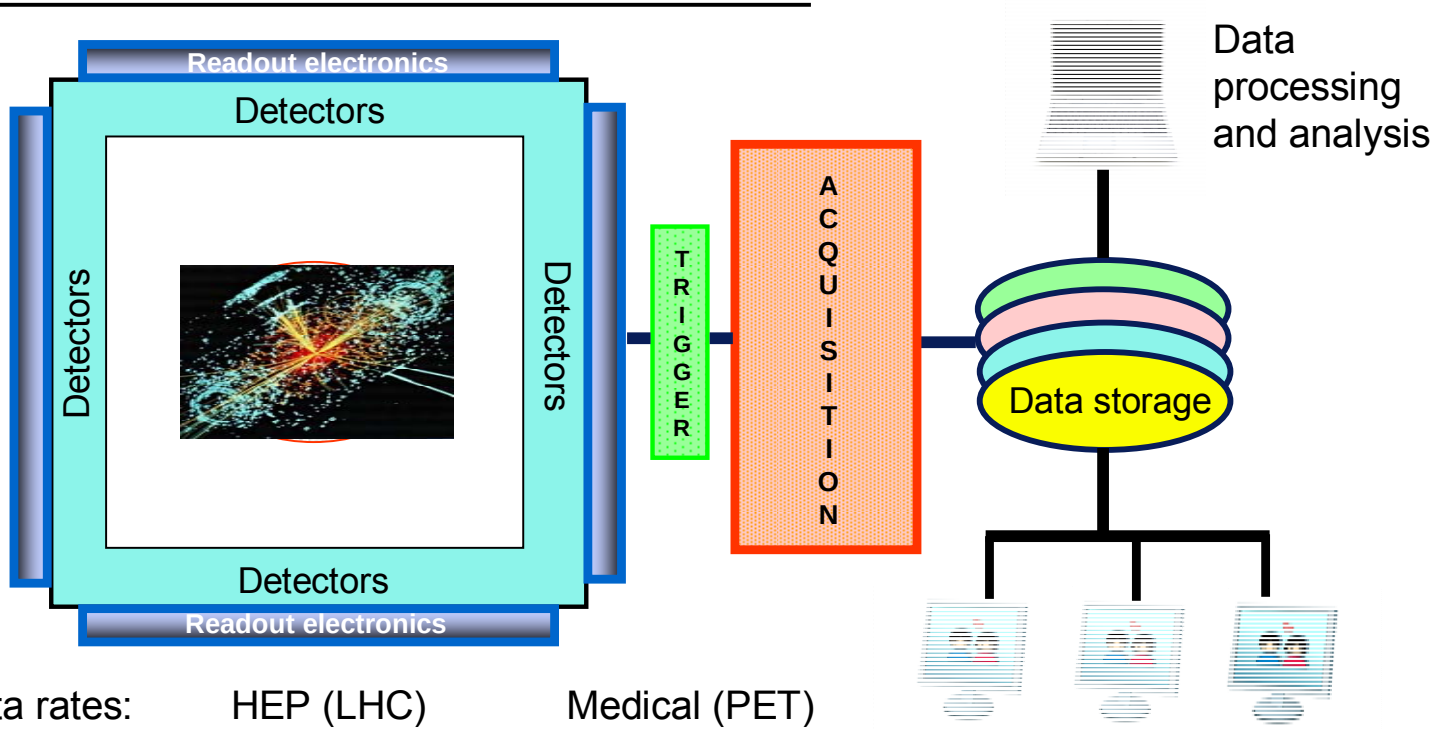
- Spatial resolution
- Sensitivity
- Count rate
- Timing resolution
- Signal-to-noise



- Reduced scan time
- Motion correction
- Dynamic scanning
- Improved quantitation
- Reduced radiation
- Increased integration
- Reduced cost

Dalle imagini LHC alla PET

Basic schematic for imaging

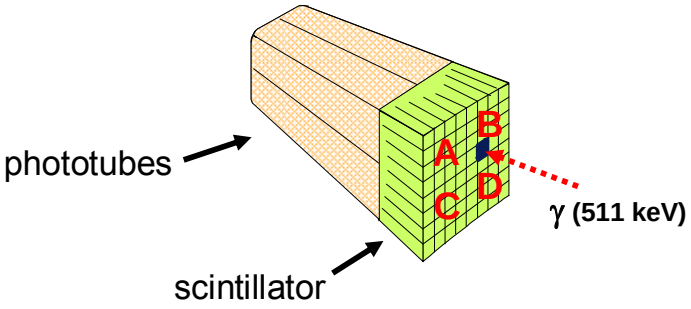


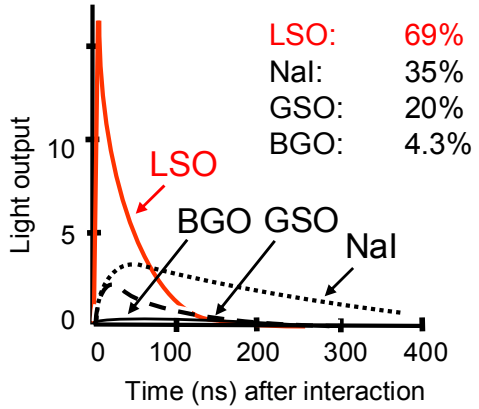
Data rates:	HEP (LHC)	Medical (PET)
Events (/s)	~ 6.5 x 10^8	3 x 10^7
Trigger (/s)	10^2	3 x 10^5
Acquired (B/s)	X x10^2	10^7

CERN
(P. Lecoq)
e
Cristal Clear
Coll.

Studi sulle caratteristiche dei cristalli (collaborazione Crystal Clear)

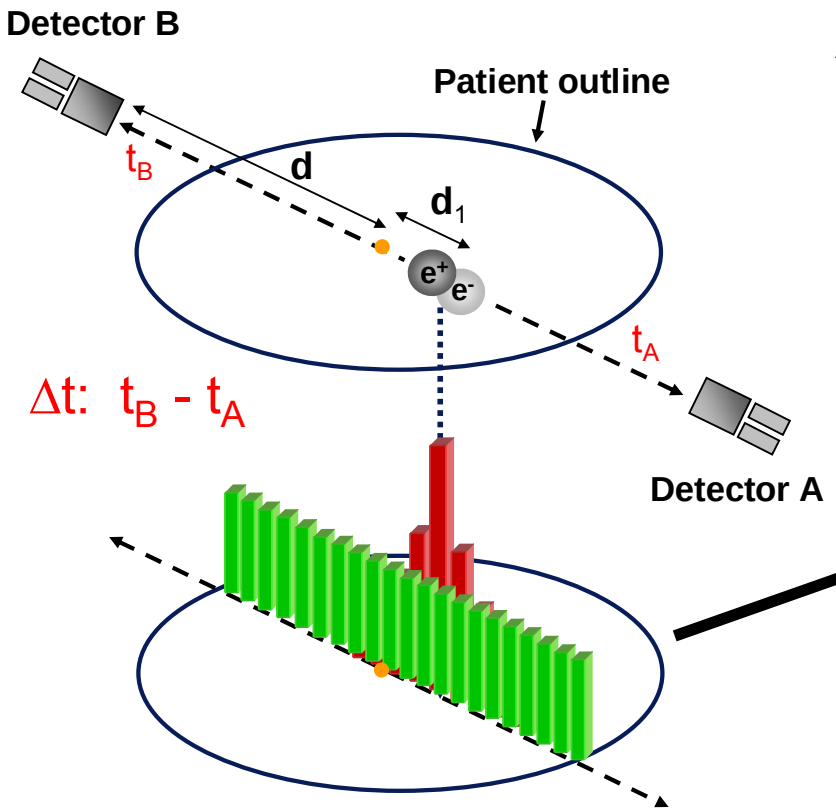
Advances in scintillators (Crystal Clear)





	NaI	BGO	GSO	LSO	LYSO	$LaBr_3$	LuAP
Density (g/ml)	3.67	7.13	6.7	7.4	7.1	5.3	8.3
Effective Z	51	74	59	66.4	65.4	64	65
Decay (ns)	230	300	30-60	35-45	42	35	17
Rise time (ps)				500	585	375	
Light (ph/MeV)	41,000	8,200	10,000	30,000	30,000	61,000	11,400
% NaI	100	15	25	80	80	150	28

Improving signal-to-noise: ultraHD·PET (Time-of-Flight)



$\Delta t = [(d+d_1) - (d-d_1)]/c$; $d_1 = c\,\Delta t/2$

$SNR_{TOF} = \sqrt{(D/\Delta d)} \cdot SNR_{non\text{-}TOF}$

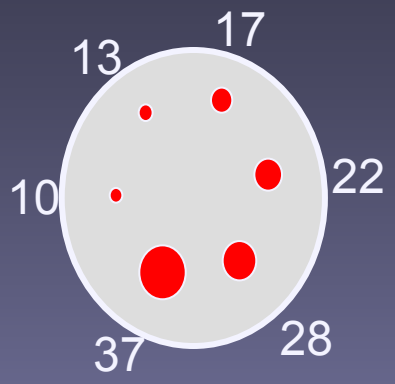
δt (ps)	Δd (cm)	SNR*
100	1.5	5.2
300	4.5	3.0
500	7.5	2.3
600	9.0	2.1

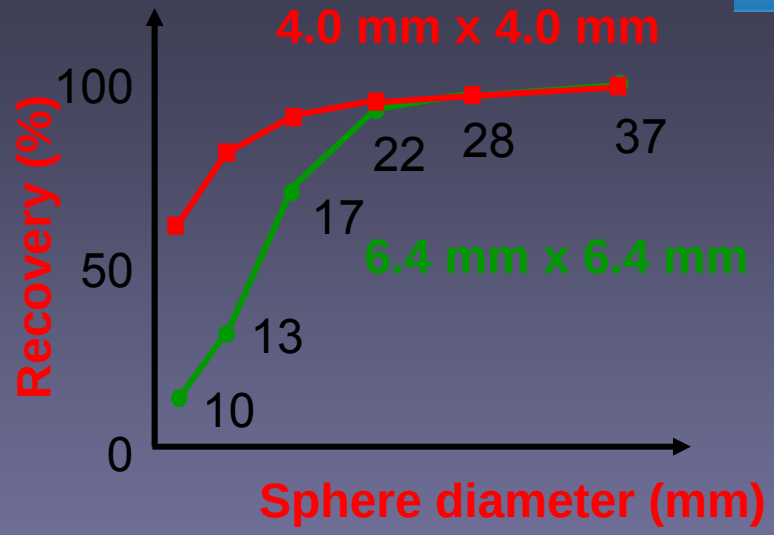
**** SNR gain for 40 cm phantom***
= SNR_{TOF} / $SNR_{non\text{-}TOF}$

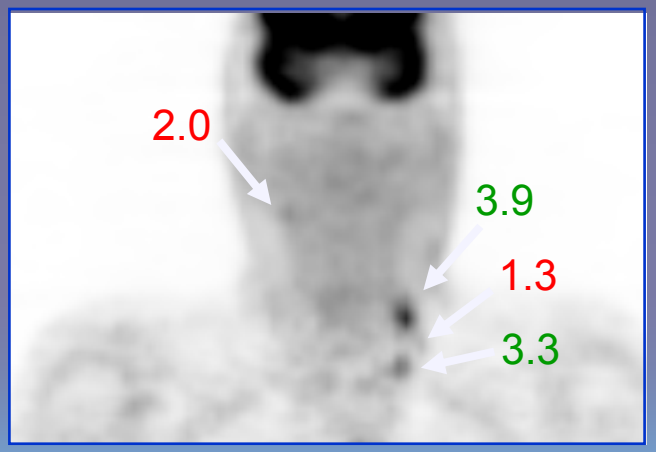
by courtesy D. Townsend IEEE Oct.2008

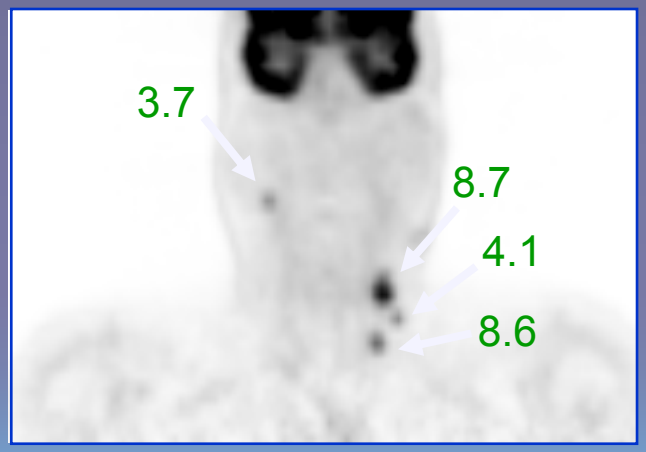
Improving intrinsic spatial resolution

13 x 13 LSO detectors
4 mm x 4 mm x 20 mm
48 detector blocks/ring







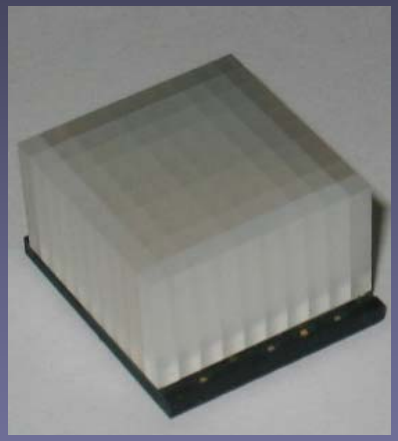


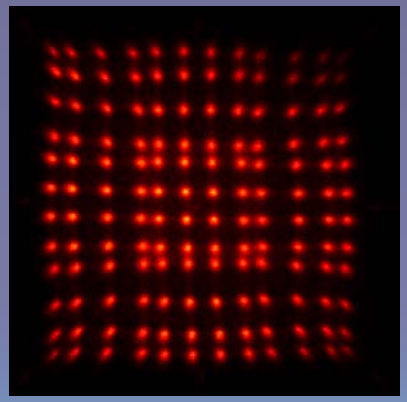
8.6 mCi; 60 min uptake

11.2 mCi; 90 min uptake

6.4 mm x 6.4 mm **7/05** *4 mm x 4 mm* **3/08**

Avalanche Photodiodes (APDs)





APD-LSO block readout

- 3 x 3 APD array
- individual APD: 5 x 5 mm²
- 12 x 12 LSO array (1.5 x 1.5 x 10 mm³)
- Energy resolution ~ 12% (individual)
- Energy resolution ~ 23% (block)
- Timing resolution ~ 2.5 ns (individual)
- Timing resolution ~ 4 ns (block)

by courtesy D. Townsend IEEE Oct.2008

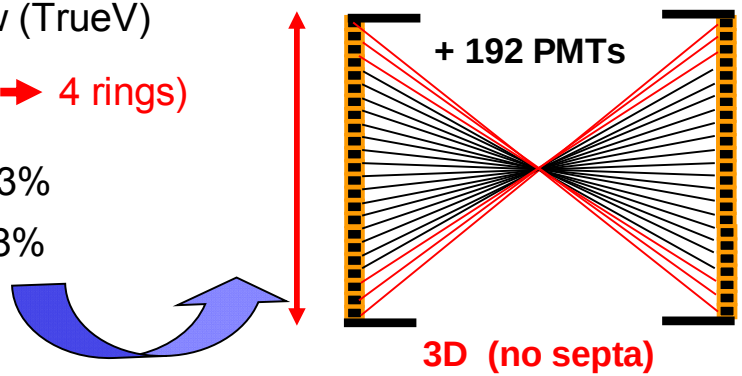
Come migliorare la sensibilità

Improving intrinsic sensitivity

Increasing the axial field-of-view (TrueV)

16.2 cm ➔ 21.8 cm (3 rings ➔ 4 rings)

- LSO volume increase: 33%
- sensitivity increase: 78%

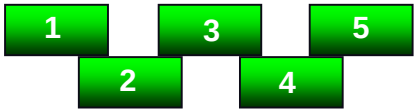


3D (no septa)

7 beds x 3 min/bed (16.2 cm)

21 min

5 beds x 2 min/bed (21.8 cm)



10 min

28 min (8/05)

10.6 mCi, 115 min pi
4 min/bed, 7 beds
3i / 8s; 6f
16.2 cm

15 min (5/06)

10.5 mCi, 104 min pi
3 min/bed, 5 beds
3i / 8s; 6f
21.8 cm

by courtesy D. Townsend IEEE Oct.2008

rivelatori RPC PET (proof of principle)

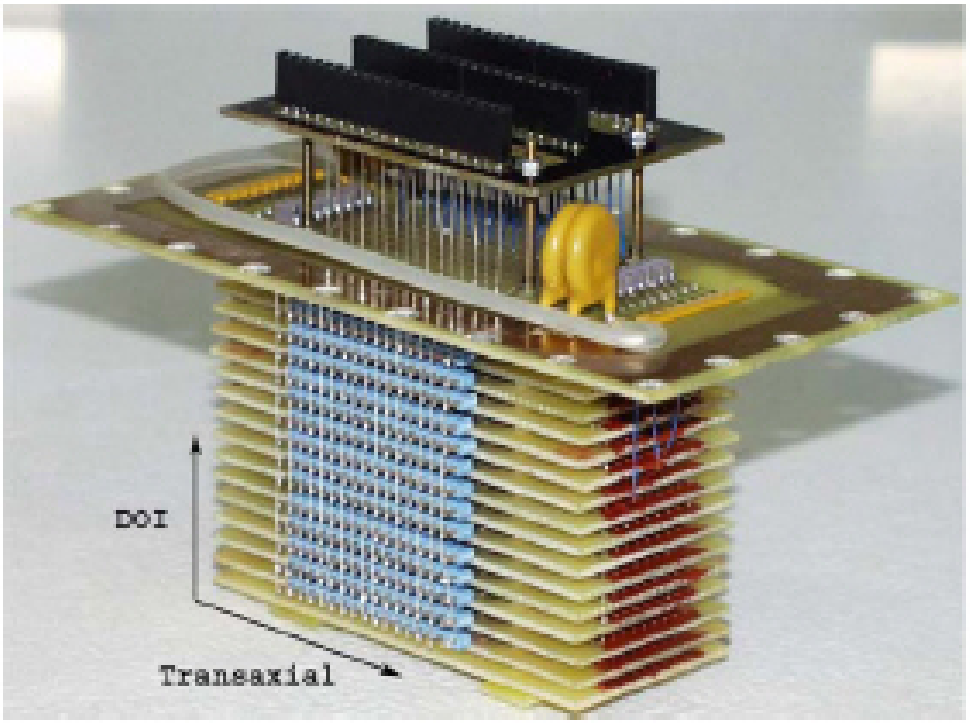


Fig. 2. Each of the counting heads, built of 16 stacked RPCs, is able to measure the photon interaction point in two dimensions, the transaxial dimension and the DOI.

- 22% efficiency for 140 layers
- LLD cutoff at 300 keV
- time resolution of 300 ps
- 380 mm FWHM spatial resolution
- 200 cm axial length
- peak NECR: 10 x LSO system
- TOF PET capability

PET RPC

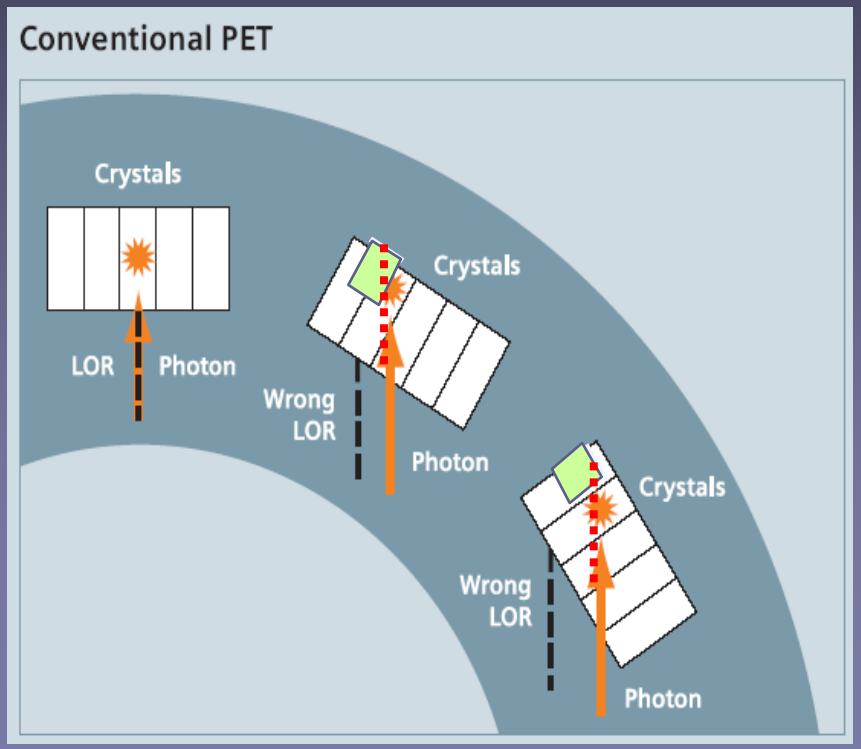
HV ~11 kV , $C_2H_2F_4$ 85% , SF_6 10% , i-C_4H_{10} 5%

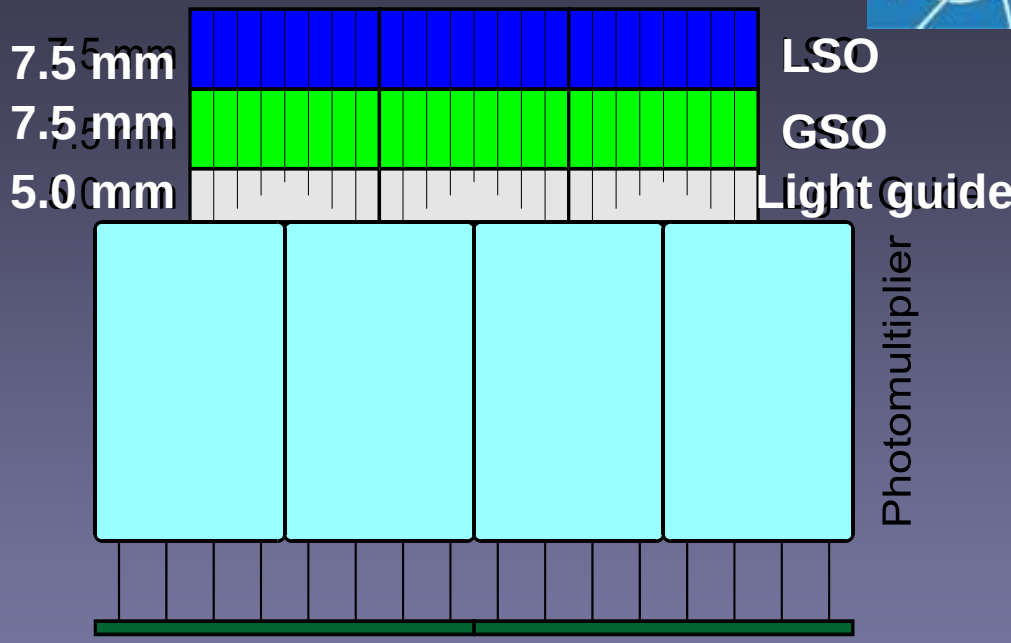
Area of RPC element is approx. 10 x 32 mm^2

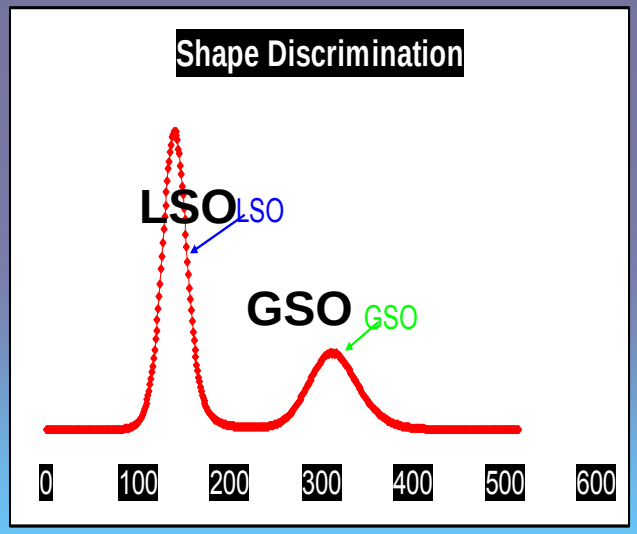
A. Blanco et al. / Nuclear Instruments and Methods in Physics Research A 533 (2004) 139–143

by courtesy D. Townsend IEEE Oct.2008

Depth of Interaction (DOI)







Without depth-of-interaction (DOI), LORs are mispositioned for incident photons that are detected in the back of the crystal

by courtesy D. Townsend IEEE Oct.2008

From Particle Physics to Medical Imaging: the impact of LHC technologies

What the LHC needs:

Radiation hard, fast and high precision measurement of:

- **Energy**
- **Momentum**
- **Time**

Detector and electronic technologies

	Examples
Solid State detectors	Microstrip Pixel A-Si:H
Gaseous detectors	MWPC FGLD GEM
Calorimeter	Scintillating crystals Scintillating fibers
Photo detectors	HPDs Pixel SiPM
Readout electronics	Single photon counting HPTDC timing Discriminators

Applications in Medical and Molecular Imaging:

- **PET**
- **CT**
- **X-Ray**
- **SPECT**
- **MRI**

Performance

- **High sensitivity for small lesion detection**
- **High specificity to avoid unnecessary invasive procedures and incorrect staging**
- **High spatial resolution to resolve details**

and in addition:

- **Compact**
- **Low cost**
- **Reliable**
- **Flexible**

The Clear-PEM (positron-emission mammogram)

- **The device has been developed by a Portuguese consortium in collaboration with CERN and laboratories participating in the Crystal Clear collaboration, will detect even the smallest tumours and thus help avoid unnecessary biopsies.**
- The system consists of two 16 x 18 cm plates constituted by a matrix of crystals, inserted together with the associated electronics into an automated rack. During the scan, the device rotates about the breast. ClearPEM is endowed with crystals that scintillate as the high-energy photons (gamma rays) emitted by the body pass through them. The 6,000 crystals in ClearPEM are far more sensitive than those in CMS, however, as they need to detect much weaker signals, they are also much smaller as the energies of the gamma rays to be detected are approximately 100,000 times weaker. The crystals were characterised at CERN using a device similar to the one used to characterise the CMS crystals.

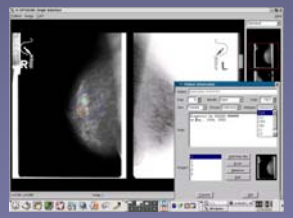
- One of the keys to achieving a compact device was the use of **avalanche photo-diodes (APD)**, which transform the light signal into an electrical one. These very compact silicon cubes, affixed to the ends of the crystals, were developed for CMS. Development of very compact, very low-background electronics, and read-out electronics, based on the CMS trigger system.

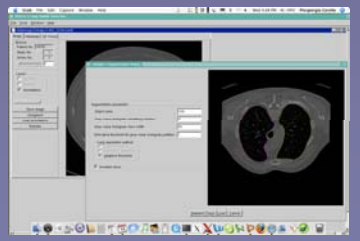
- **The prototype is now being used to perform 100-200 clinical trials at the Porto Institute of Oncology. (Cern weekly March 2009)**

MAGIC-5

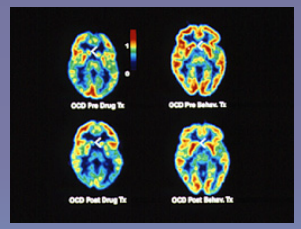
Medical (Imaging) Applications on a GRID Infrastructure Connection

Computer Assisted Detection (CAD) & Distributed Computing Infrastructure (GRID)

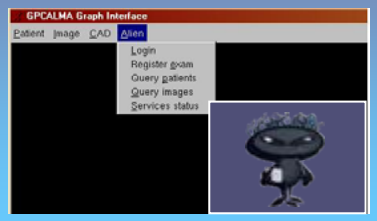




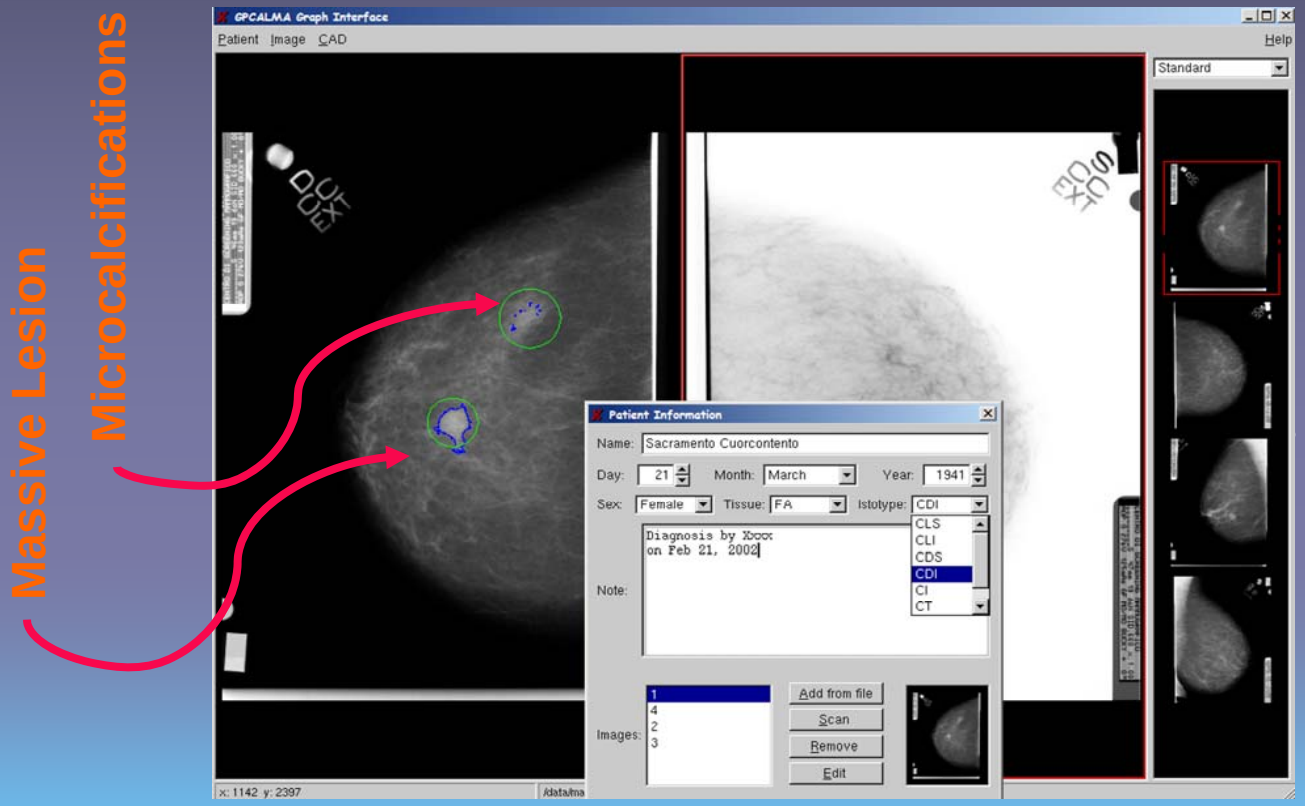
- Medical (Imaging) Applications
  - Analysis of Digital Images
    - **the beginning: Mammography**
    - **the present: Lung CTs**
    - **the future: NeuroImages**



- GRID
  - Why Medical ***Imaging*** Applications?
  - Grid use cases: (mammographic) screening
  - Interface to GRID Services



stazione CAD per la mammografia



[P. Cerello *et al*, Methods Inf Med 44, 244-248 (2005)]

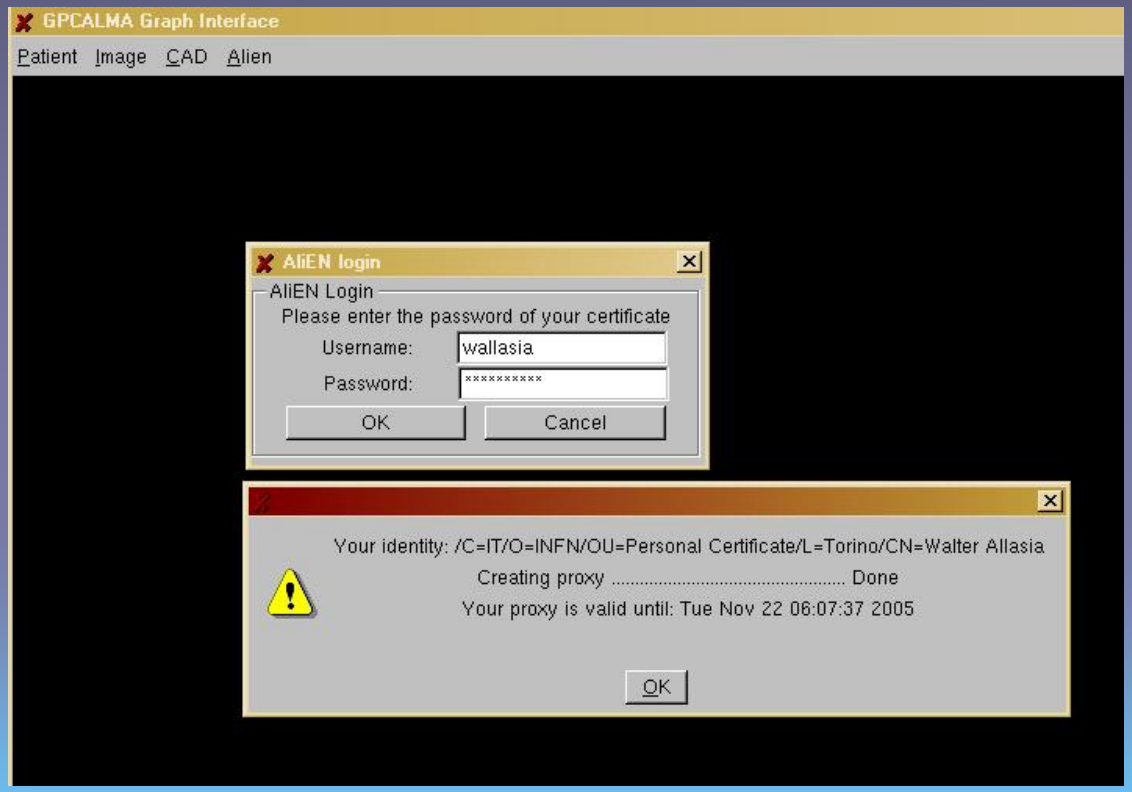
- Image Acquisition & Manipulation (DICOM)
- Metadata & Diagnosis insertion
- CAD execution
- Data storage & retrieve through the GRID

Operating Installations:

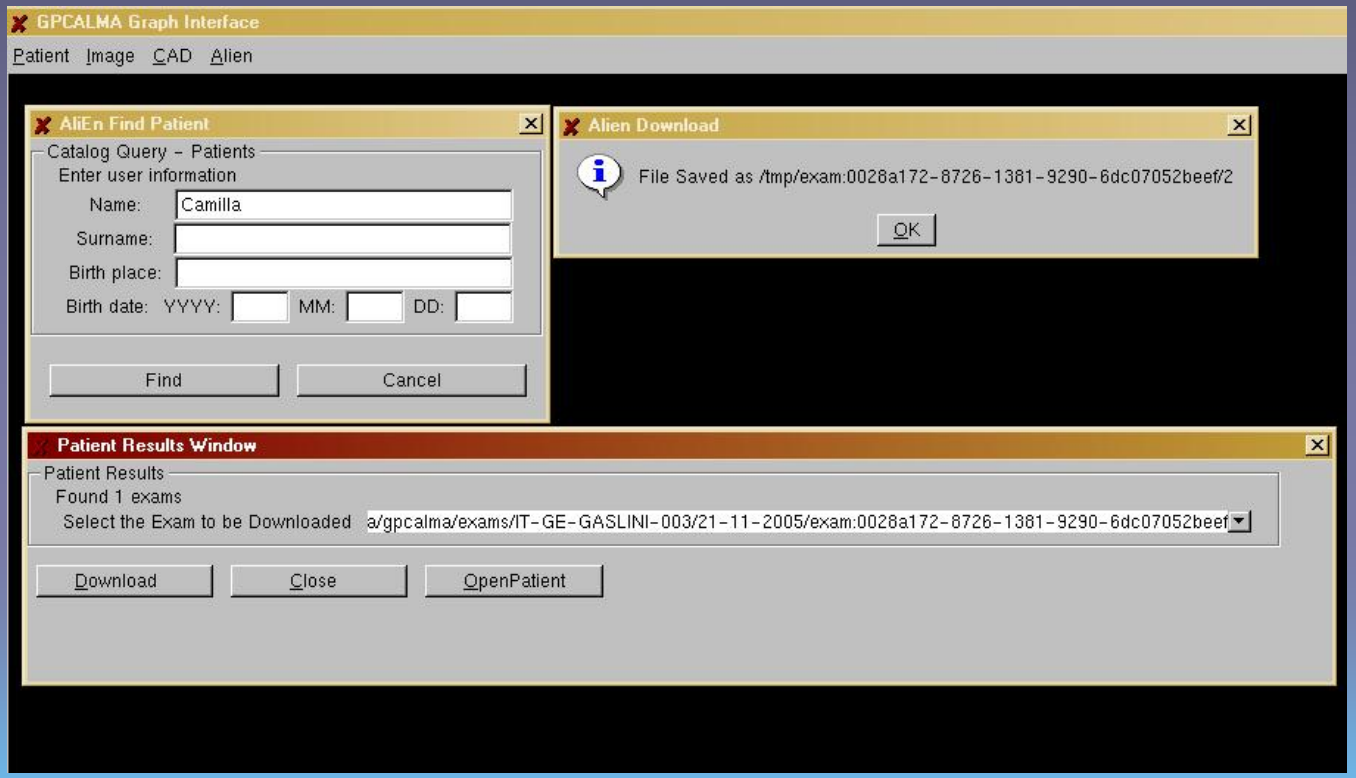
- Torino (Valdese), Lecce, Bari Hospitals
- *Suzanne Mubarak Centre for Women's Health and Development*, Alexandria (EGY)

Analysis Station

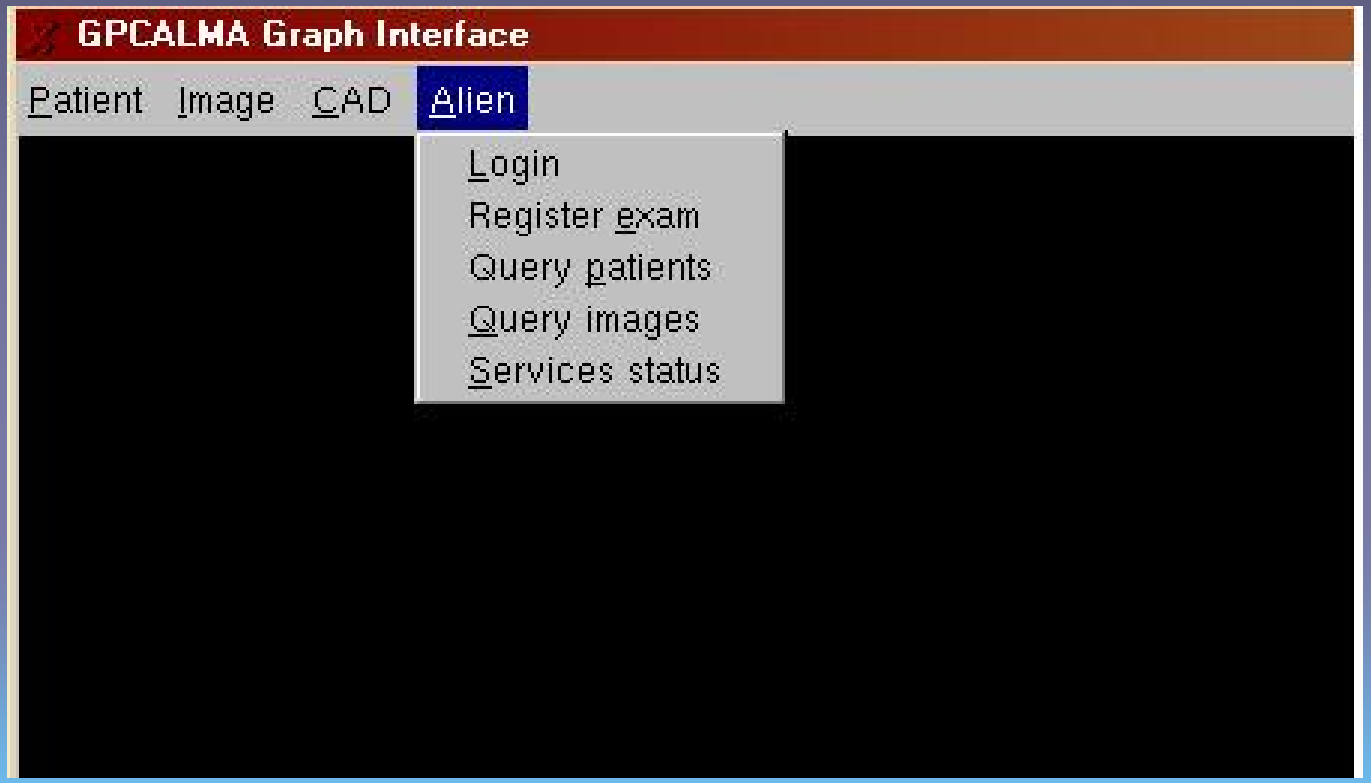
Login: User Authentication



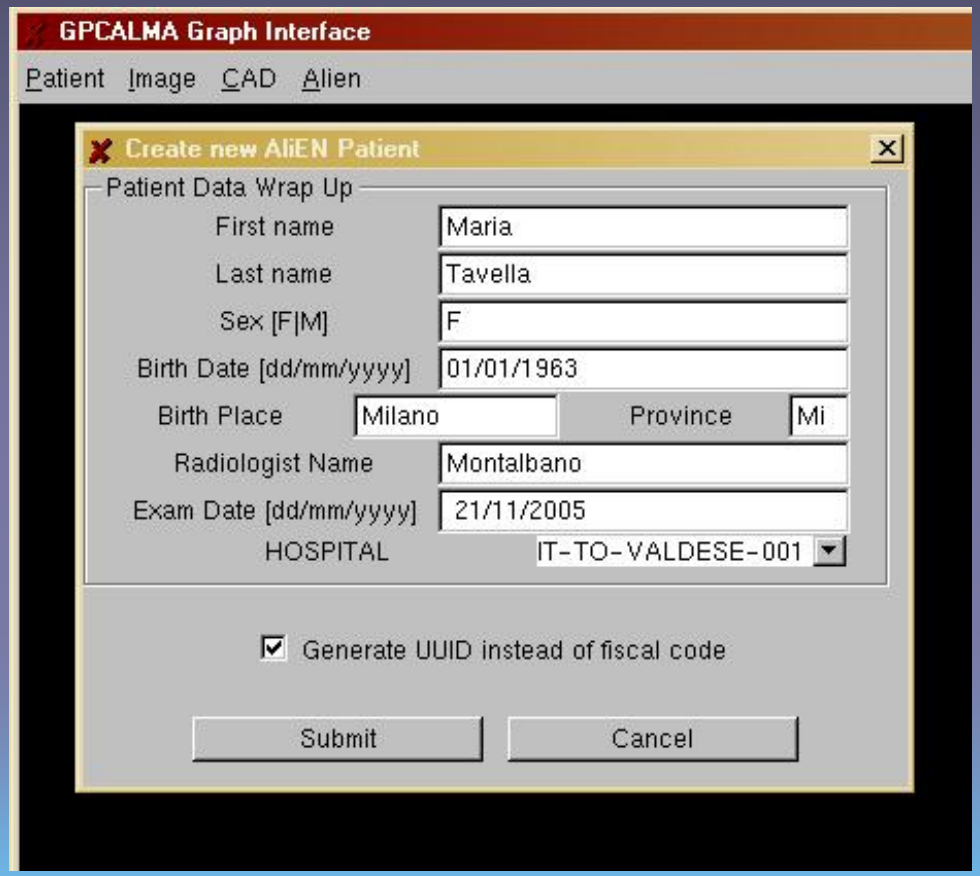
Query on Patient Data
Find (& Retrieve) Exams



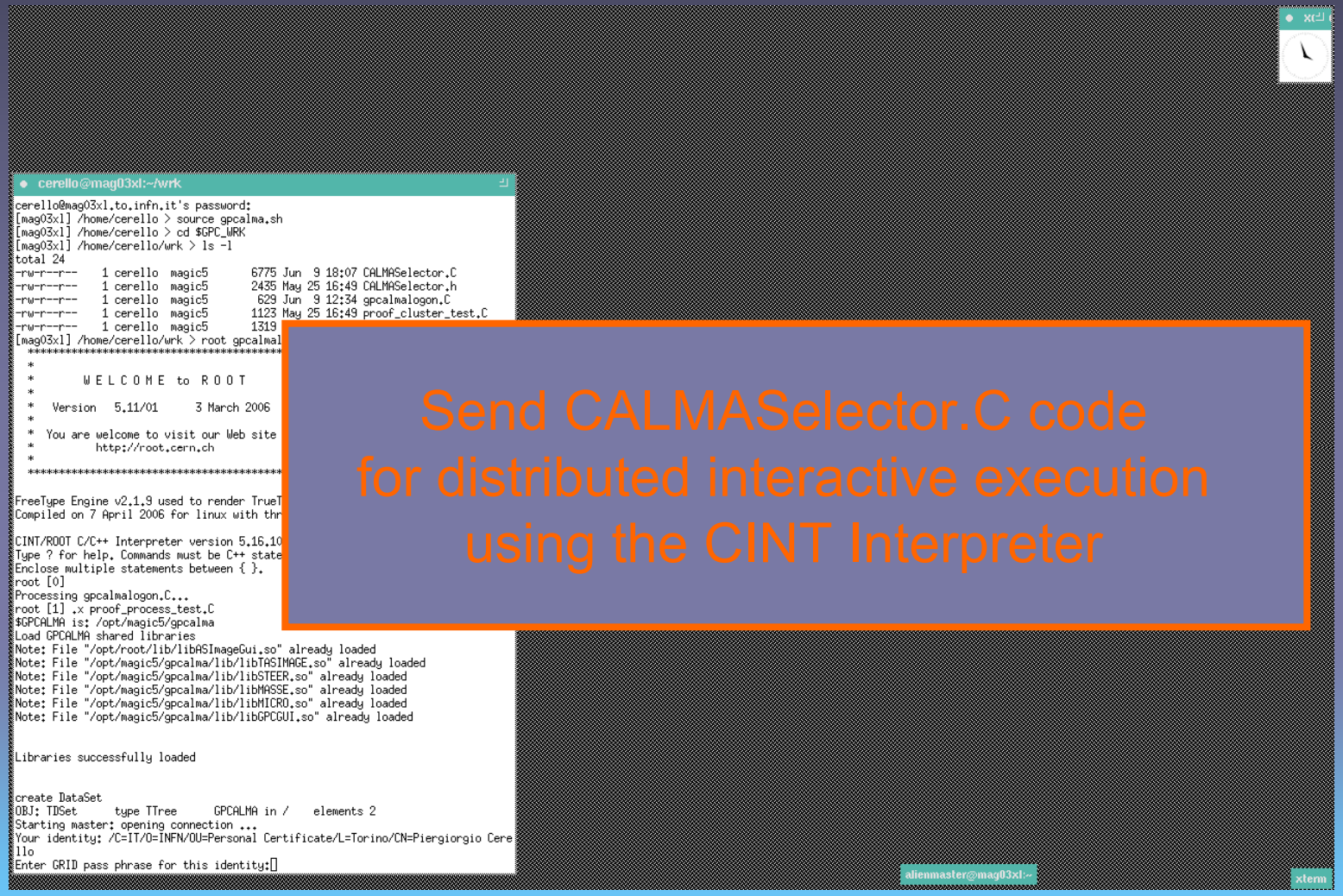
The GPCALMA GUI to Grid Services



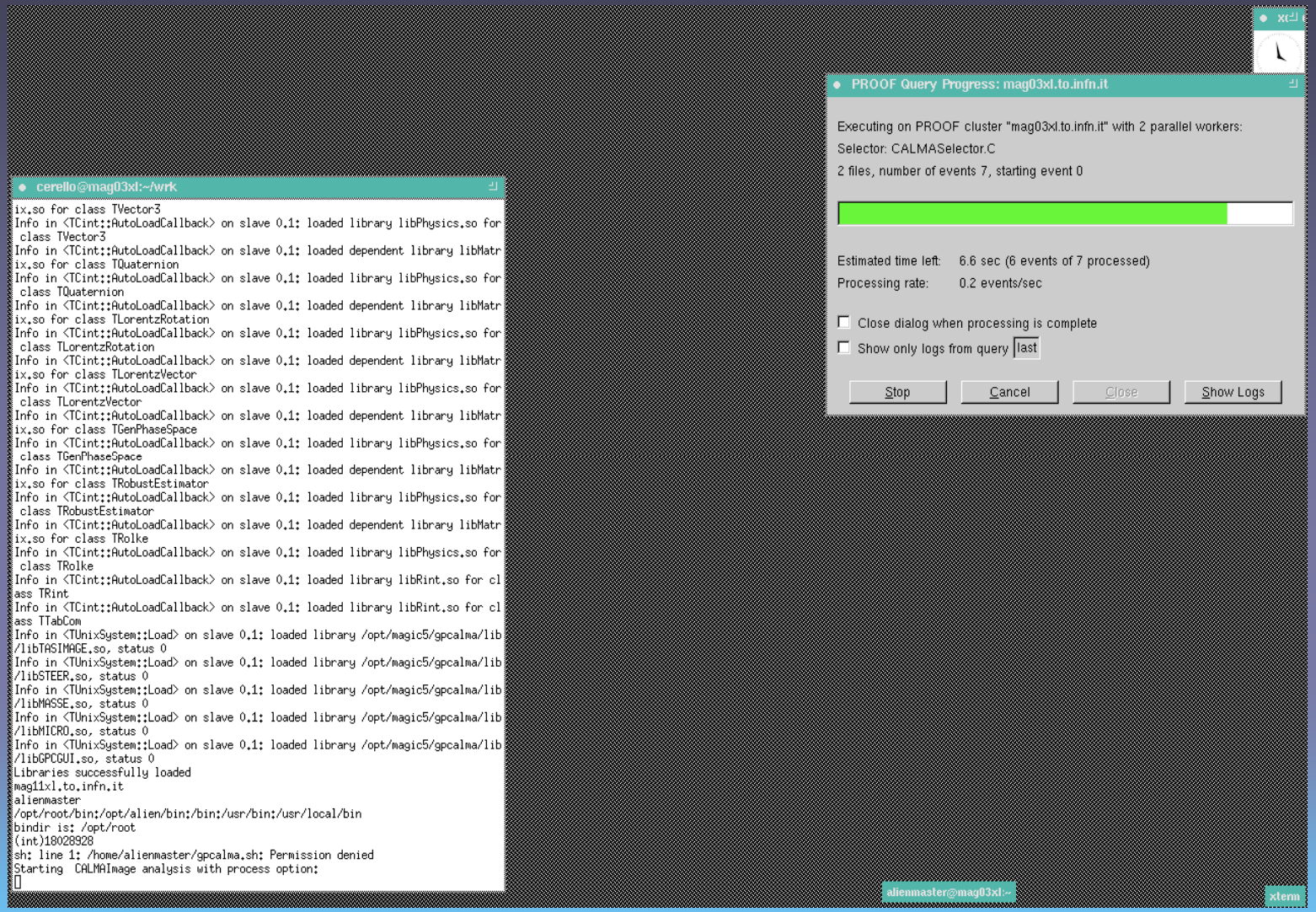
Register a new Exam (& Patient) in the Data Catalogue



Start PROOF Cluster
for interactive distributed analysis

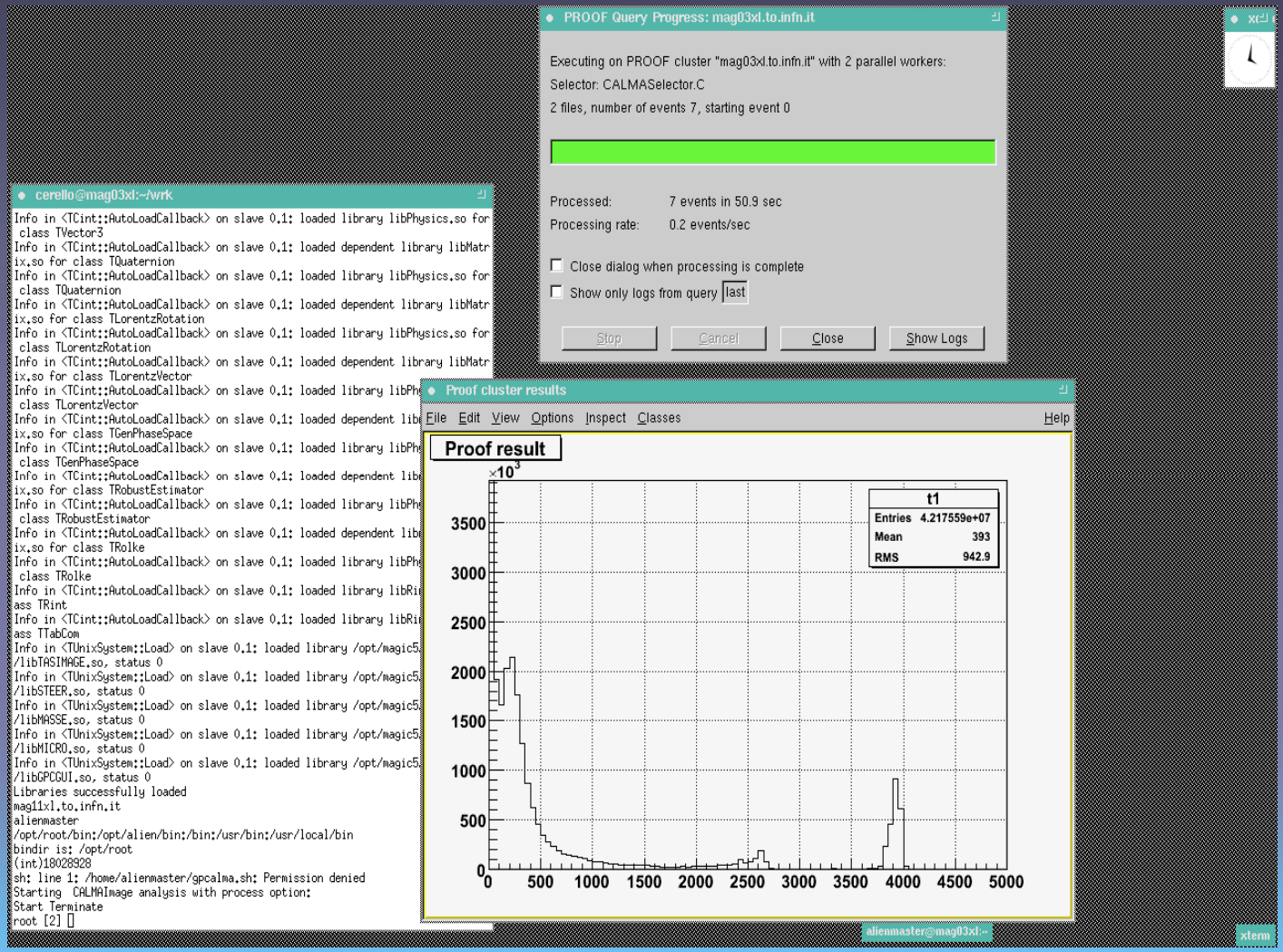


Working PROOF Cluster
Ongoing Analysis



The GPCALMA Mammogram Analysis Station

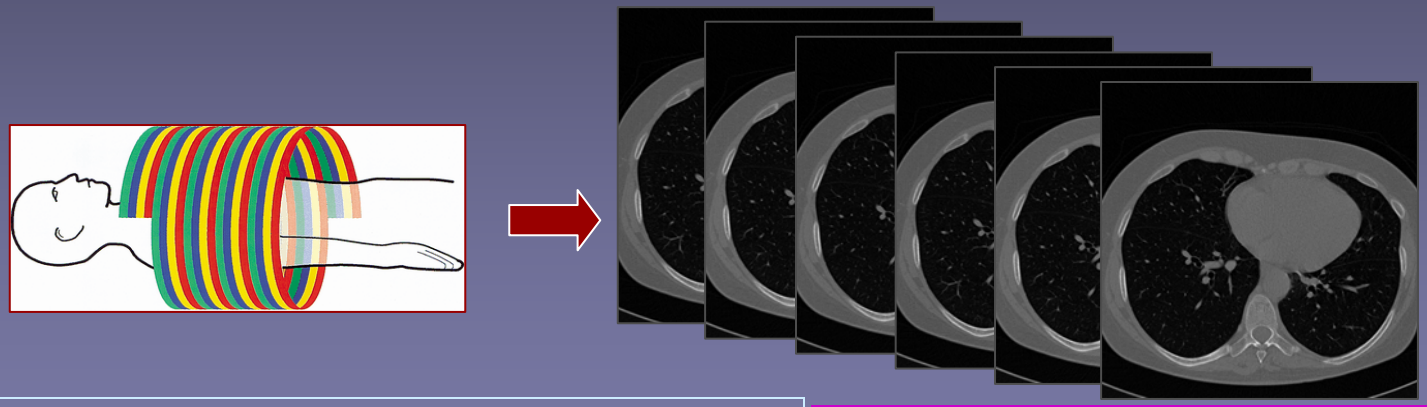
PROOF Cluster - End of Task
Display (or Save) Results



Lung CT Screening and Computer-Aided Detection (CAD)

Non-calcified small pulmonary nodules are considered as the primary signs of early-stage lung cancers

Nodules with diameter ≥ 3 (5) mm have to be detected



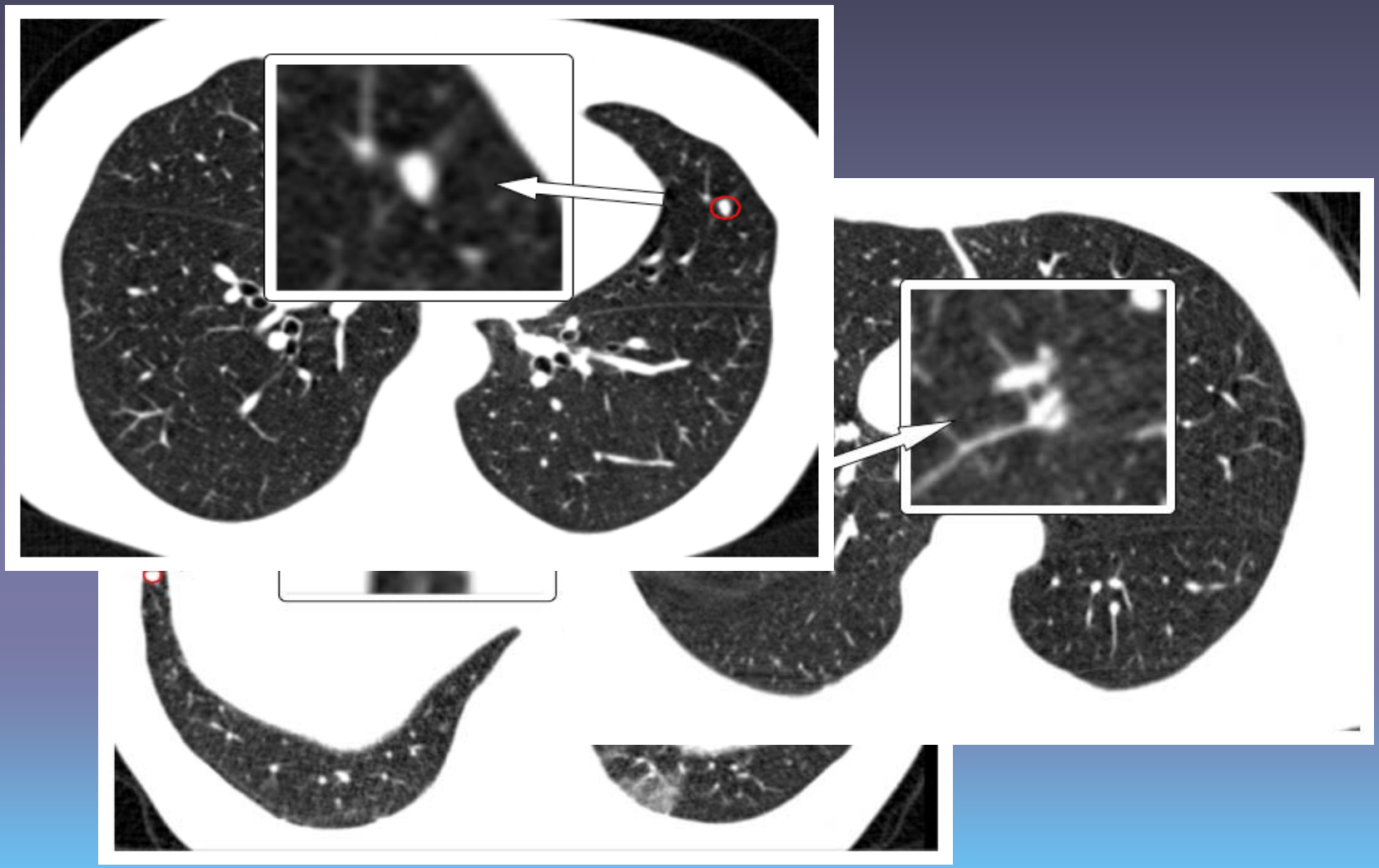
Thin-slice CT:
Reconstructed slice thickness ~1mm →
~300 slices/scan

Low-dose helical multi-slice CT 0.6 mSv
Low-dose helical single-slice CT 1.2 mSv
Standard dose helical CT 5.0 mSv
Rx torax 2 views 0.1 mSv

A CAD system could be useful as first or second reader
It should be characterized by:

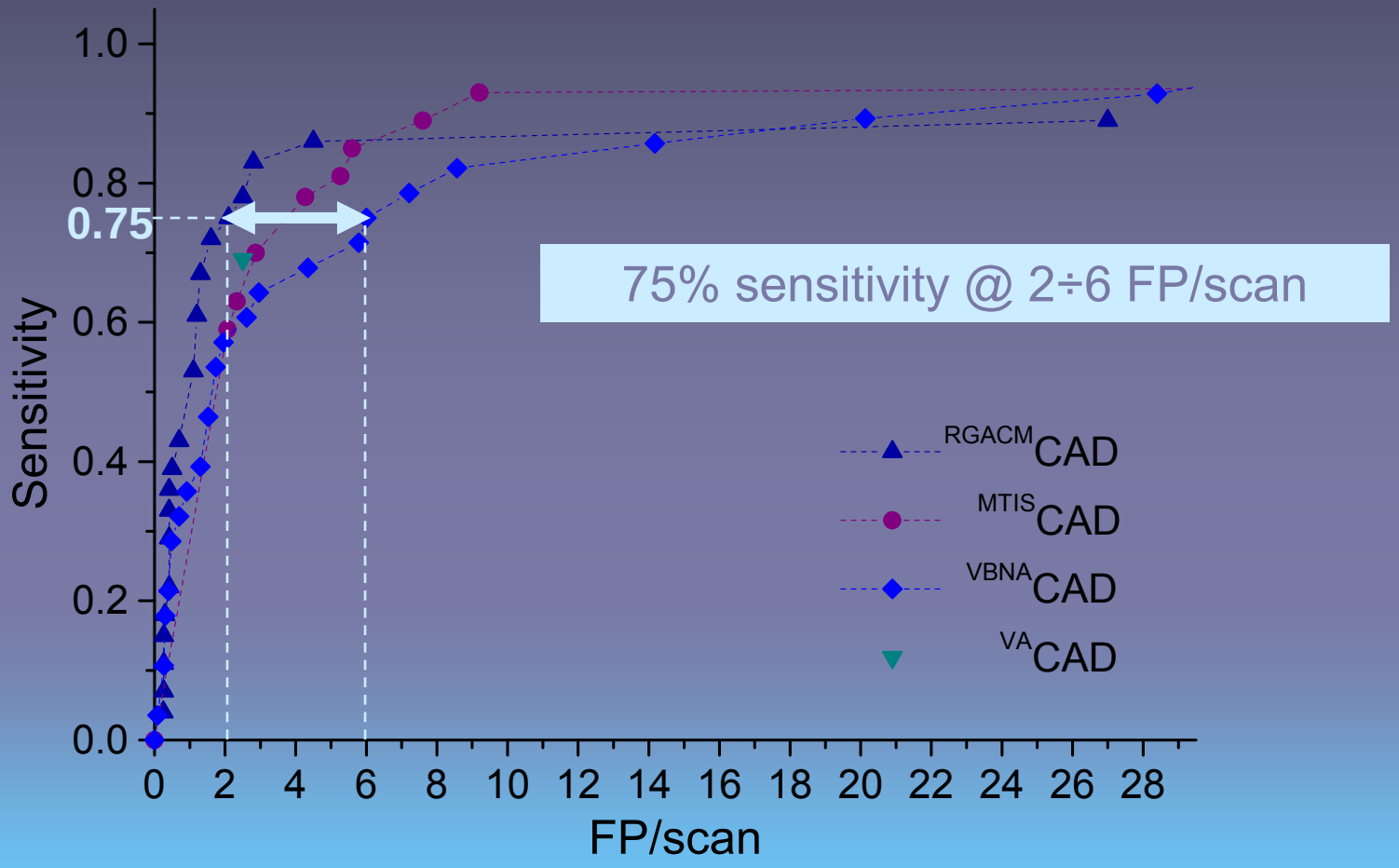
- high sensitivity
- low number of false-positive findings (FPs) per scan

Noduli nel polmone: esempi

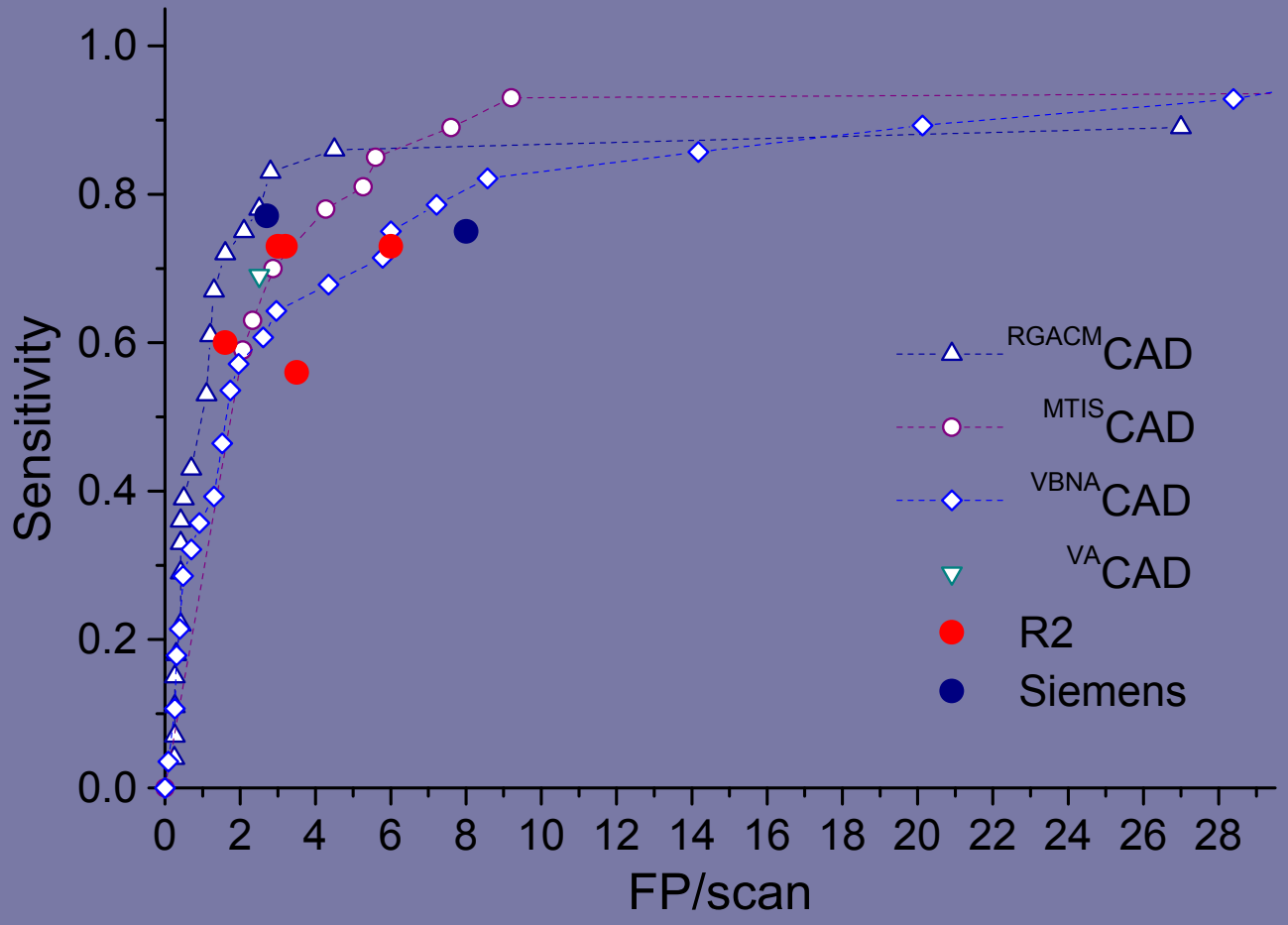


Polmone CAD FROC curve

Validation dataset: 24 CT (28 noduli di diametro ≥ 5mm)



Confronto con sistemi commerciali



Diagnosis precoce della malattia di Alzheimer

- Analisi di imagini NMR del cervello
- Valutazione della atrofia dell'ippocampo

Marilena Streit-Bianchi

Diagnostica della malattia di Alzheimer (AD)

Alzheimer's disease diagnostic tools:

- Cognitive performance tests (Minimental State Examination [MMSE], Global Dementia Scale, etc…)
- Clinical history
- Follow-up examinations (progressive loss of motion and space abilities, memory, etc…)
- Cerebrospinal fluid (CSF) protein fraction dosage, MRI and PET

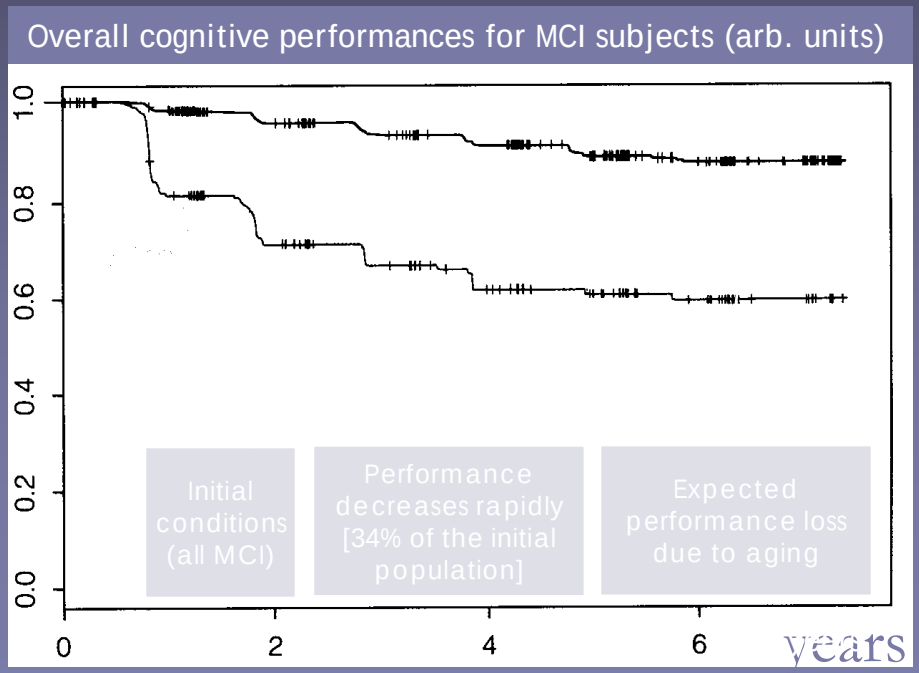
However:

"…there are no definite means of diagnosing AD without a brain biopsy or an autopsy…"

Quale informazione interessa i neurofisiologi?

- **Diagnosi precoce mediante tests di basso costo e affidabili**

- Mild Cognitive Impairment (MCI) predictors:
  only a fraction of the MCI population evolves in AD
- *Evaluation of AD developers*



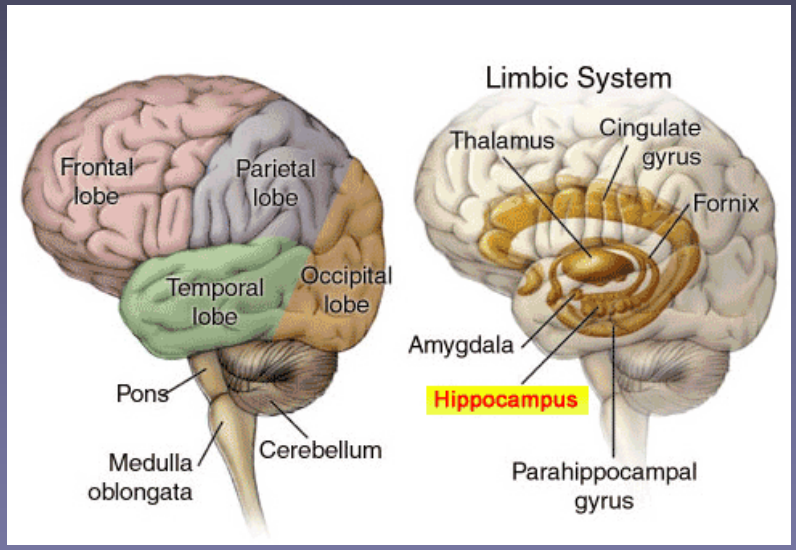
[Neurology 2002;59:198-205]

"… a highly sensitive and specific diagnostic method for early detection of the disease is of the utmost importance for overall patient management and outcome."

Ruolo dell'ippocampo

- Hippocampus plays an important role in several researches
  - Hippocampal atrophy is known to occur early in the course of AD on a spatial scale large enough to be detectable with MR images

    [NeuroImage 28 (2005) 1033–1042]



Manual segmentations are labor-intensive

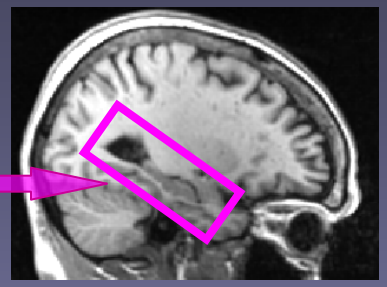
- Typically, segmenting both hippocampi take between 1 and 2 hours by hand

Manual segmentation of a large number of hippocampi for broad studies of atrophy effects is not feasible

Algoritmi per estrarre e analizzare l'informazione nelle aree dell'ippocampo e in vicinanza dell'ippocampo

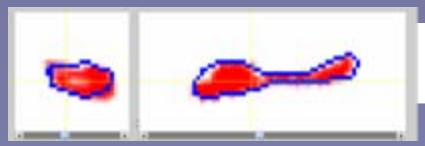
The MAGIC-V neuroimage analysis

- Algorithm for the automated localization of MTL ROIs (containing the Hippocampus) from MR images



- Automatic segmentation of the hippocampus starting from few manually segmented templates

- Validation of the segmentation method by comparison with shapes manually segmented by expert readers



- Extraction of features and their analysis

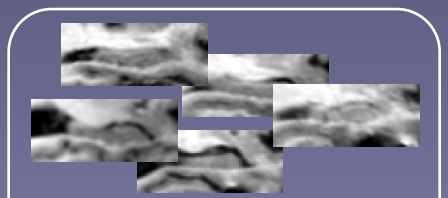
  Identification of a *physical observable* allowing for a reliable prediction on MCI patients

Physical observables

The goal is to find one (or more) *observable*, whose distribution:

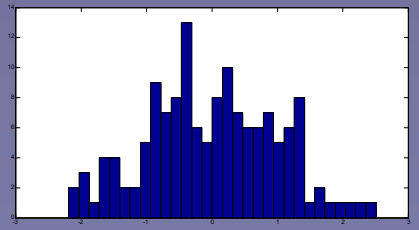
- maximizes the separation between Controls and AD population
- is able to predict the evolution of a MCI patient

Significant information is supposed to be encoded in the hippocampal ROI

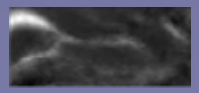


Scalar product

135 Controls
247 MCI
150 AD



Median HB Controls



CSF/GM/WM Histogram equalization

Median HB AD

Δ

Database provided by:
• Ospedale S. Martino, Genova
• the Alzheimer's Disease Neuroimaging Initiative (ADNI)

A. Chincarini *et al*, Computational Vision and Medical Image Processing, Taylor & Francis, 121-126 (2007)

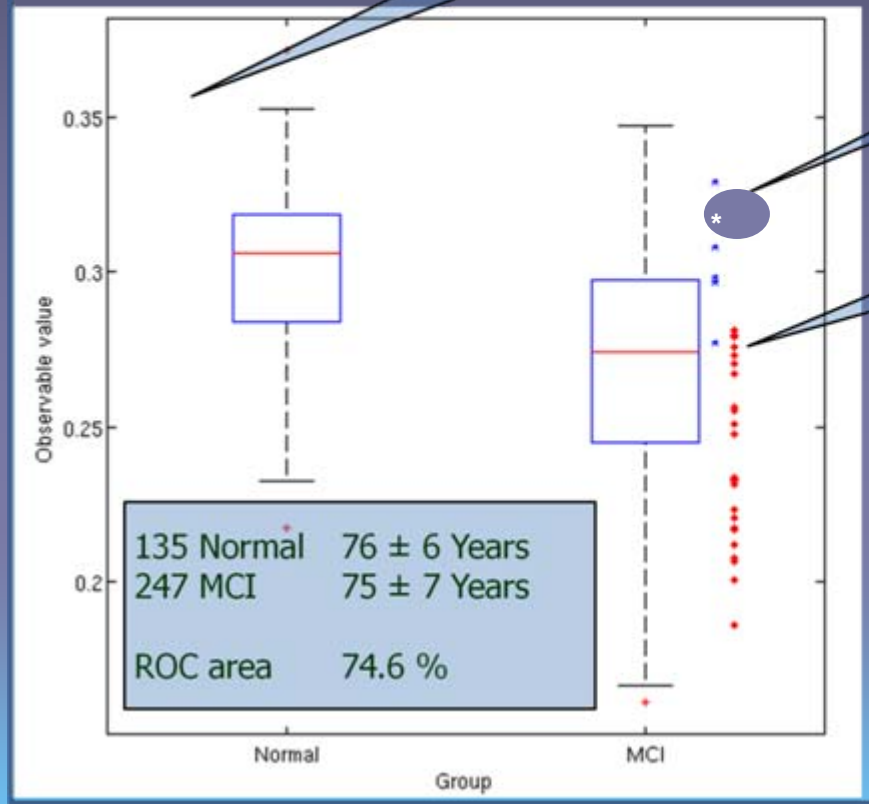
Analysis of MTL ROIs

MTL Analysis

MTL Observable corrected with age detrend performed on Normal cohort

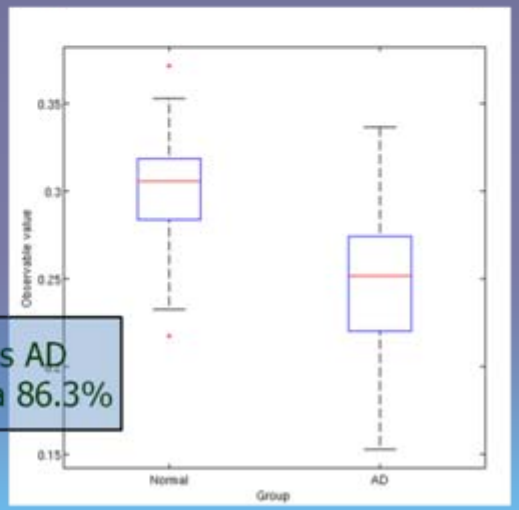
Initially classified as AD turned up to be misplaced

25 AD converters [red]
5 revert to normal [blue]
after 3 years followup



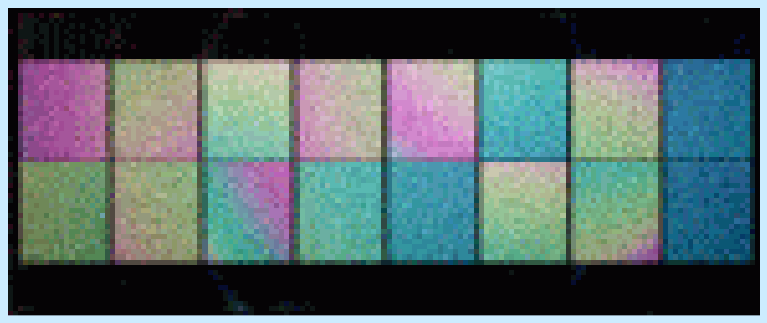
135 Normal 76 ± 6 Years
247 MCI 75 ± 7 Years

ROC area 74.6 %

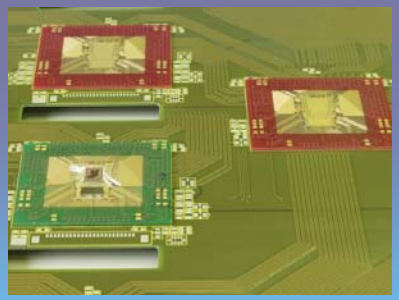


Normal vs AD
ROC area 86.3%

Detector technologies



ATLAS Pixel detector, 50x100μ/pixe
140million channels



ALICE 3 multi chip modules of TRD

Crystals for CMS
EM calorimeter

two Ring Imaging Cherenkov
detectors of the LHCb

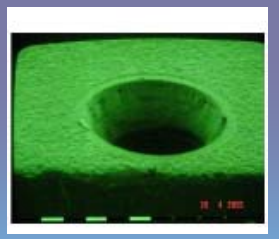
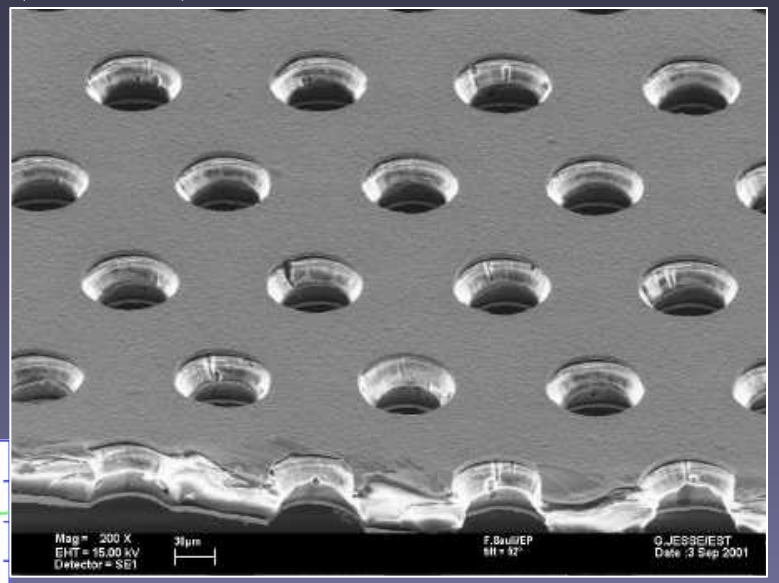
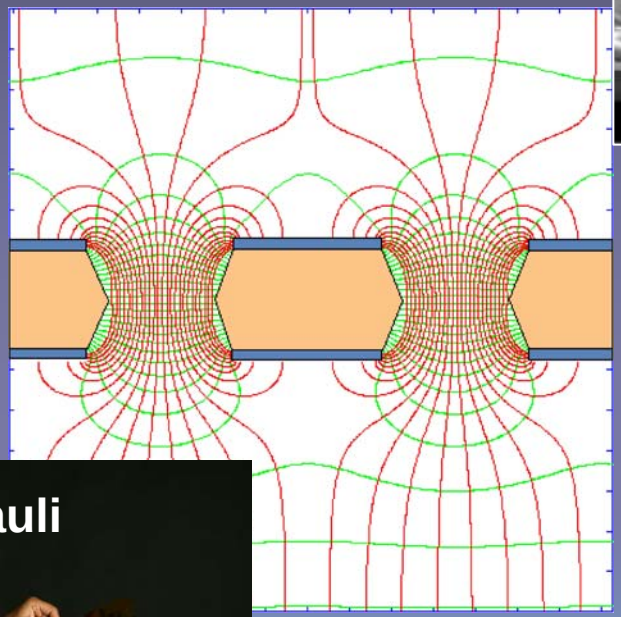


Image of a light GEM
for TOTEM detector

GAS ELECTRON MULTIPLIER (GEM)

Thin, metal-coated polymer foil with high density of holes. On application of a voltage difference, each hole acts as an individual proportional counter, multiplying the electrons entering from the drift region. The amplified electrons leave the hole; most of the ions are collected by the upper electrode:





Typical geometry:
5 µm Cu on 50 µm Kapton
70 µm holes at 140 mm pitch

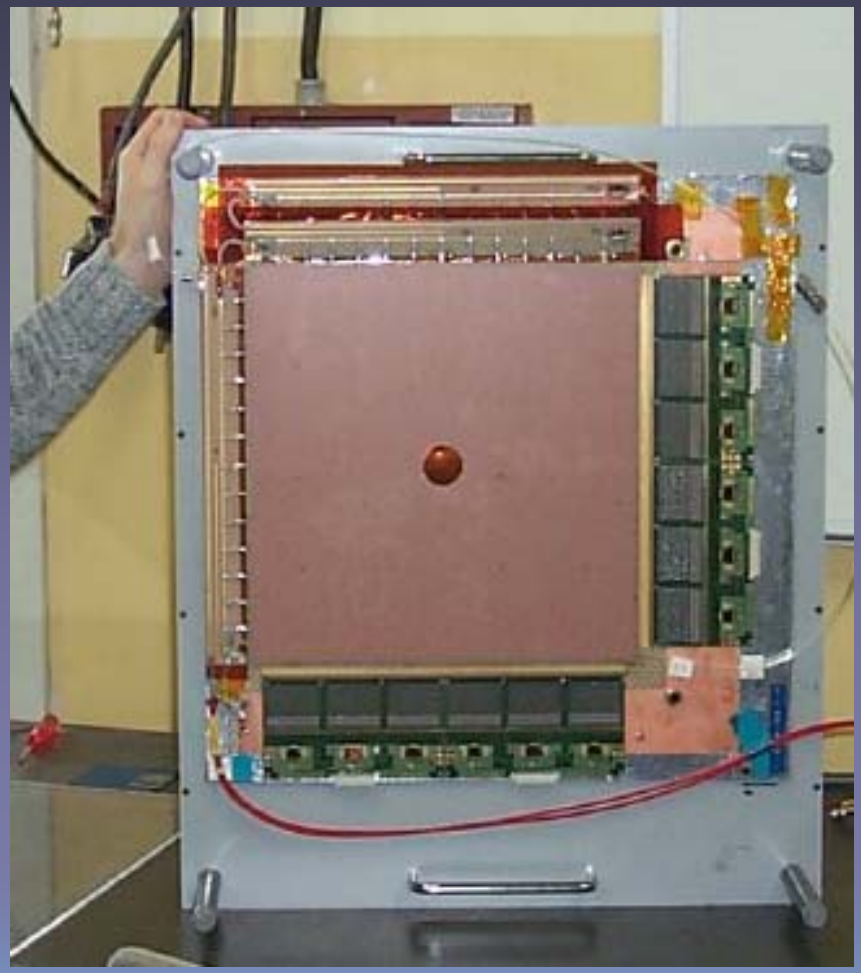
5-10,000 INDEPENDENT PROPORTIONAL COUNTERS per cm^2

F. Sauli, Nucl. Instrum. Methods A386(1997)531

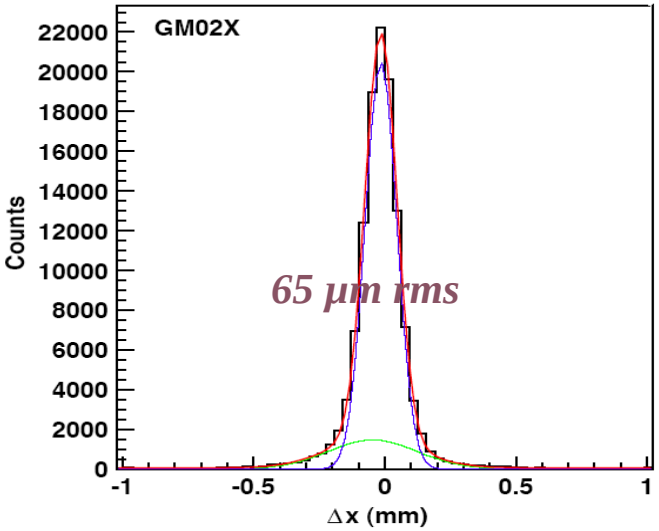
GEM, l'alta densità dei fori permette di raggiungere una sensibilità tale da rilevare il passaggio di singoli elettroni

COMPASS GEM

Active Area 30.7 x 30.7 cm²
2-Dimensional Read-out with remotely controlled Beam Killer 5 cm Ø
Total Thickness: 15 mm
Honeycomb support plates
Low mass: 0.7% X_0



POSITION ACCURACY

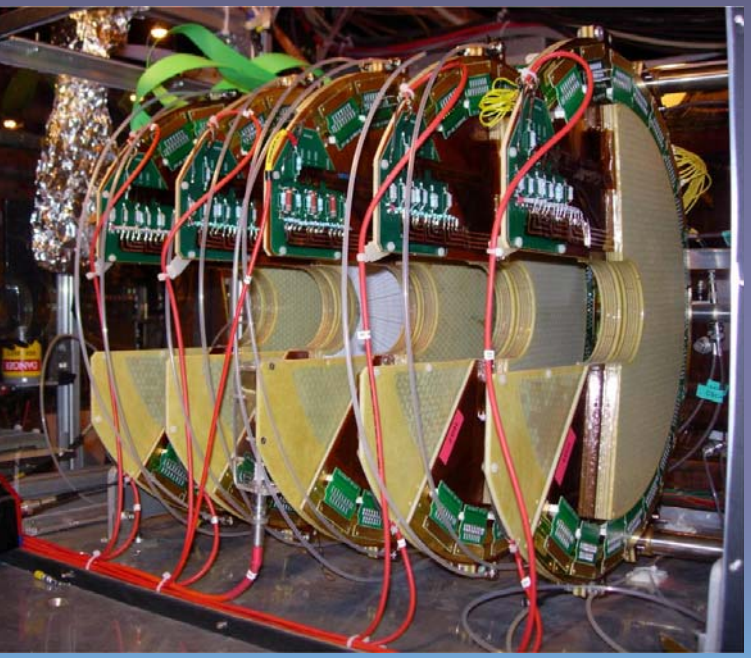


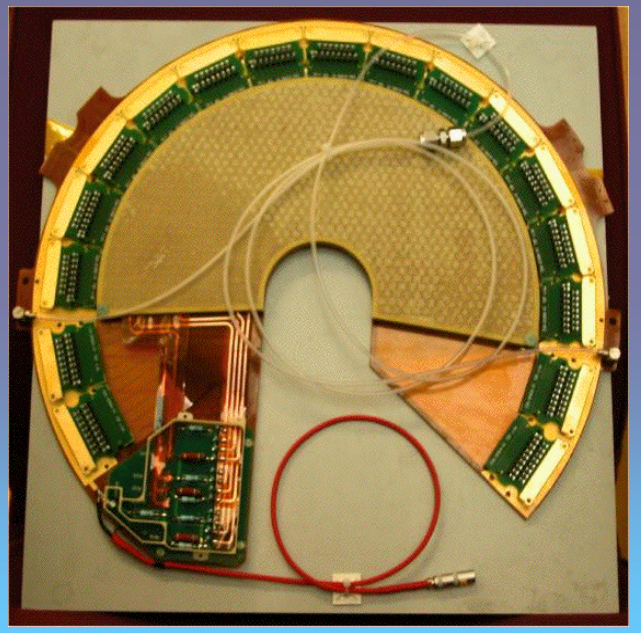
C. Altumbas et al, Nucl. Instrum. Methods A490(2002)177
B. Ketzer et al, Nucl. Instr. and Meth. A535(2004)314

GEM DETECTOR FOR TOTEM (CERN-HELSINKI)

HALF-MOON GEM FOR TOTEM

10-CHAMBERS TOTEM SETUP



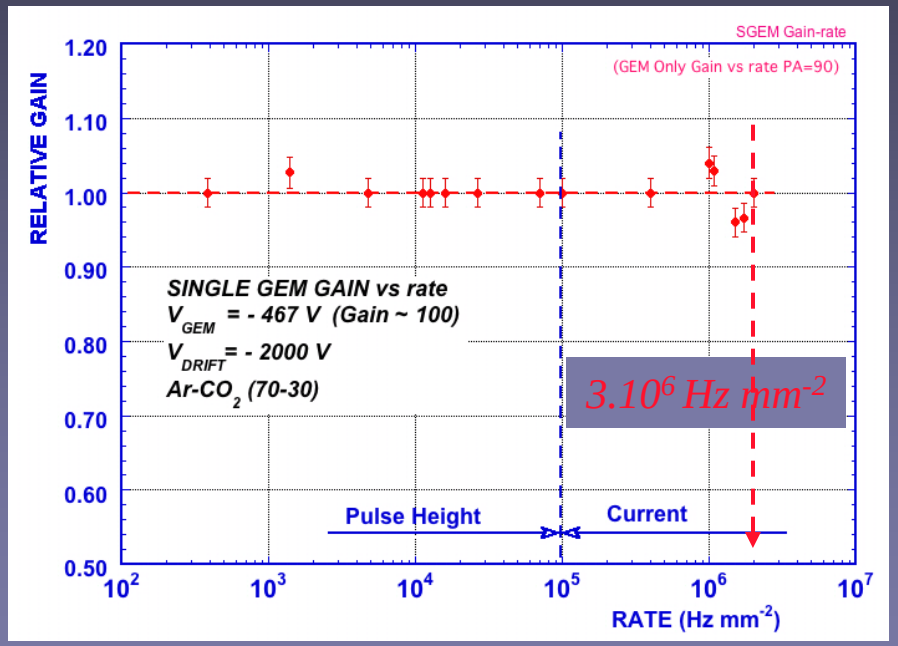


FORWARD TRACKER IN CMS

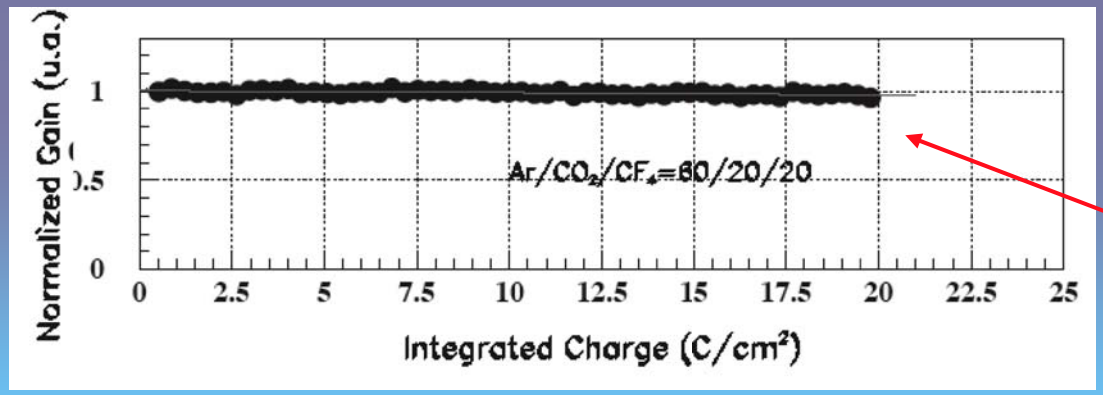
S. Lami et al, arXiv:physics/0611178v1 (nov. 2006)

RATE CAPABILITY

Each GEM hole acts as an independent proportional counter; due to the high density of holes (50÷100 mm^{-2}) space charge effects appear only at extreme rates (> 3 10^6 mm^{-2}):



RADIATION HARDNESS

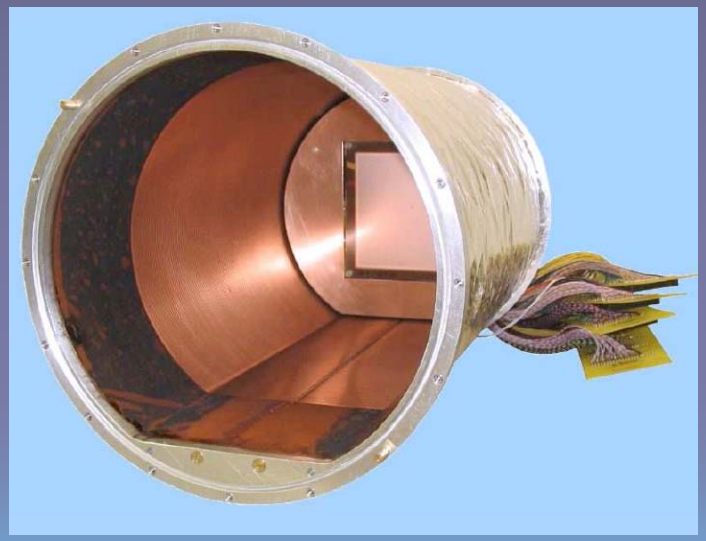


J. Benlloch et al, IEEE NS-45(1998)234

~ 4 10^{14} MIPS cm^{-2}

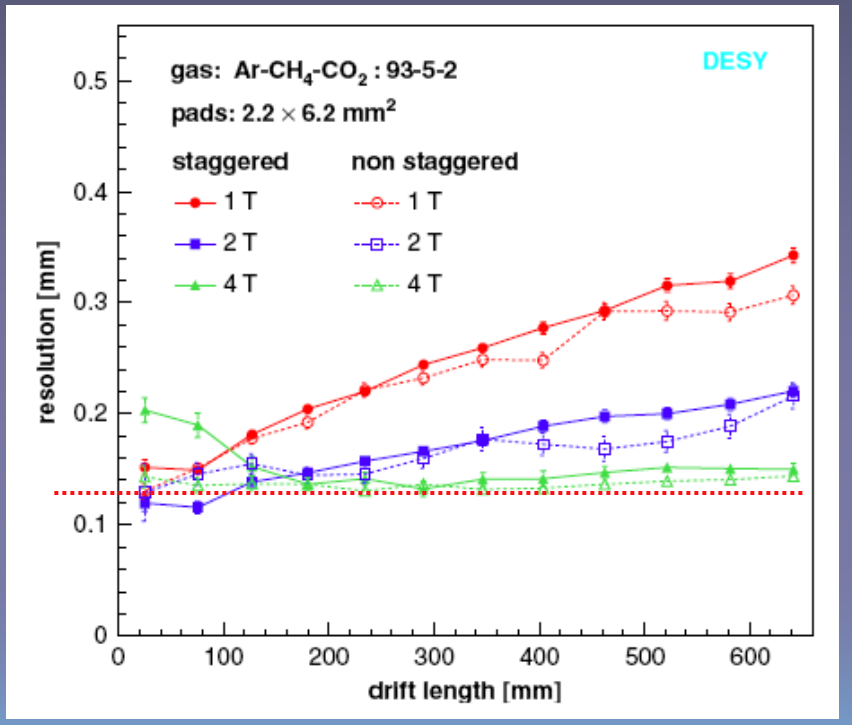
M. Alfonsi et al, Nucl. Instr. and Meth. A518(2004)106

PROTOTYPE TPC WITH GEM READOUT (DESY-AACHEN)



130 μm

POSITION RESOLUTION

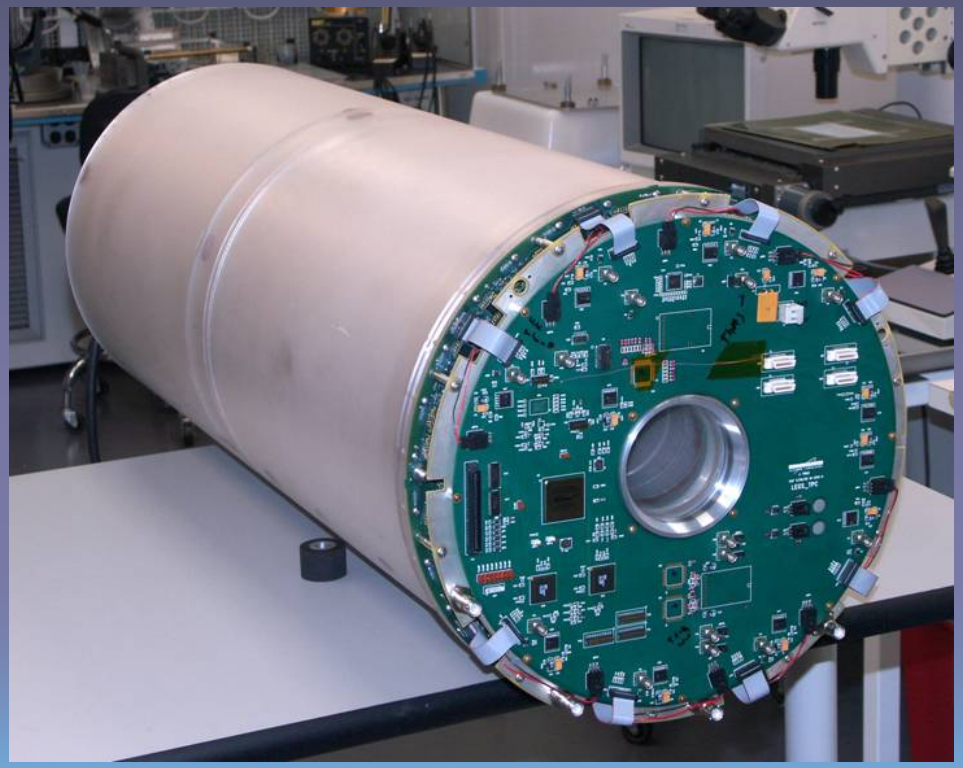


M. Killenberg et al, Nucl. Instr. and Meth. A530(2004)251

M. Janssen et al, Nucl. Instr. and Meth. A566(2006)75

GEM TPC FOR LEGS (LASER ELECTRON GAMMA SOURCE) AT BNL

RADIAL TPC
Double GEM with pads readout
35 cm Ø, 50 cm drift



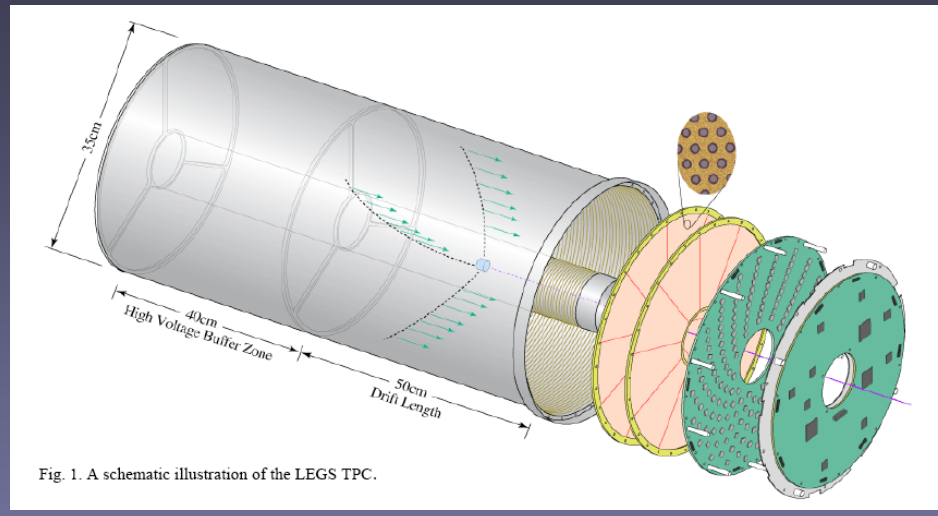
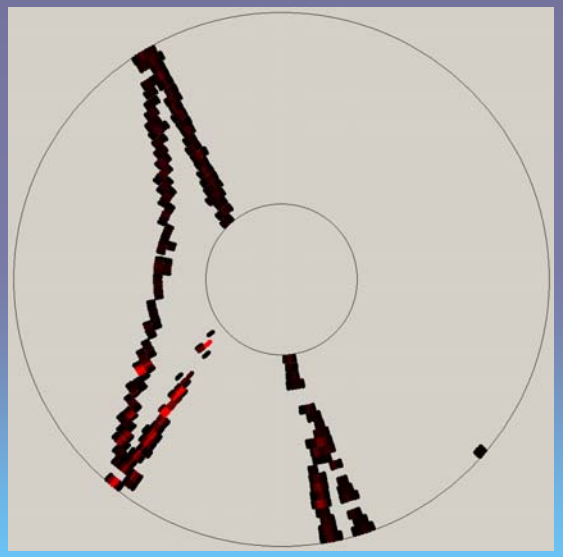


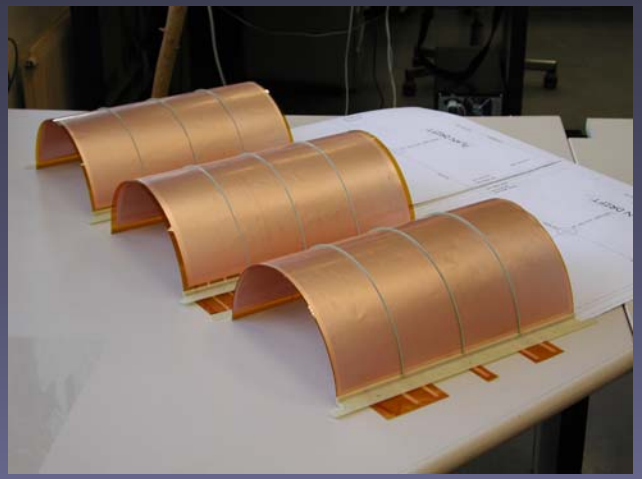
Fig. 1. A schematic illustration of the LEGS TPC.

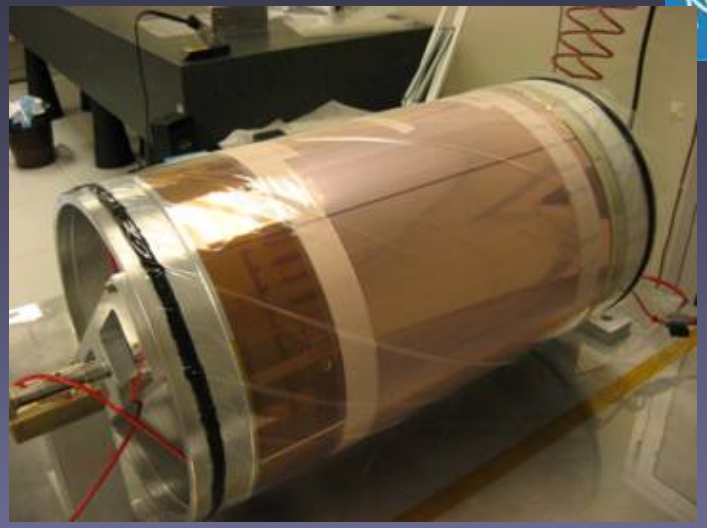
COSMIC TRACKS



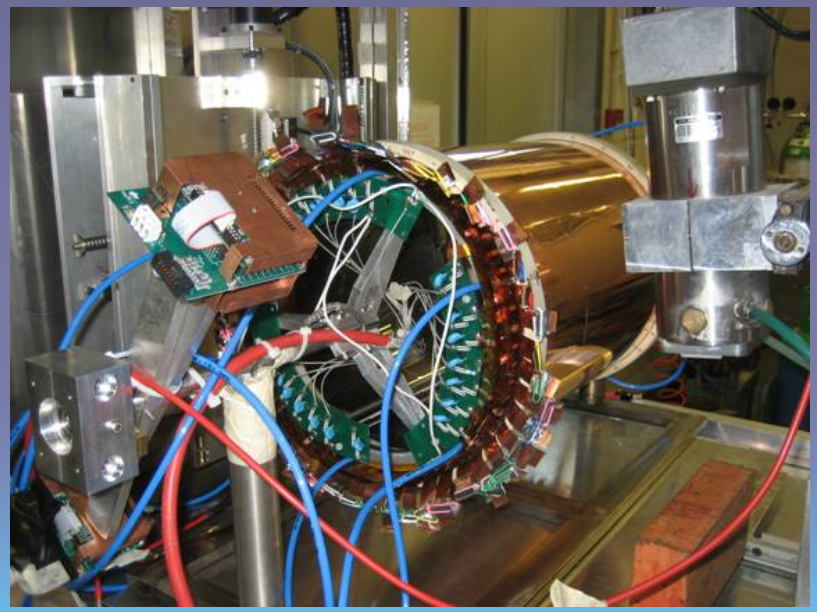
Bo Yu, LBL TPC Workshop (Berkeley 7-8 April 2006)

CYLINDRICAL GEM DETECTORS





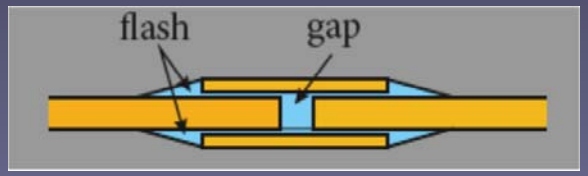
L. Ropelewski, Vienna Instr. Conf. 2007

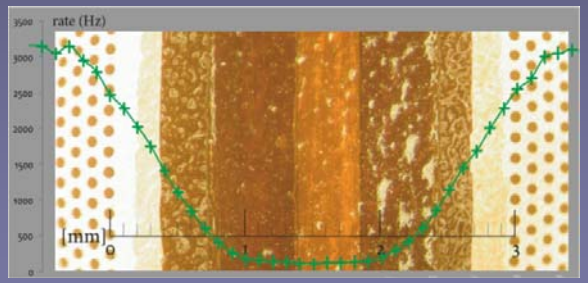


G. Bencivenni, RD51 Paris

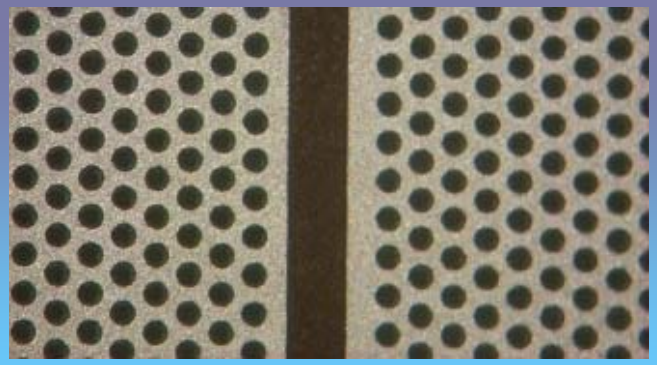
LARGE SIZE GEMS

The limit in width (~40 cm) due to the available material (Cu-clad polymer) is overcome "splicing" together two foils, with a ~3 mm wide local efficiency loss.

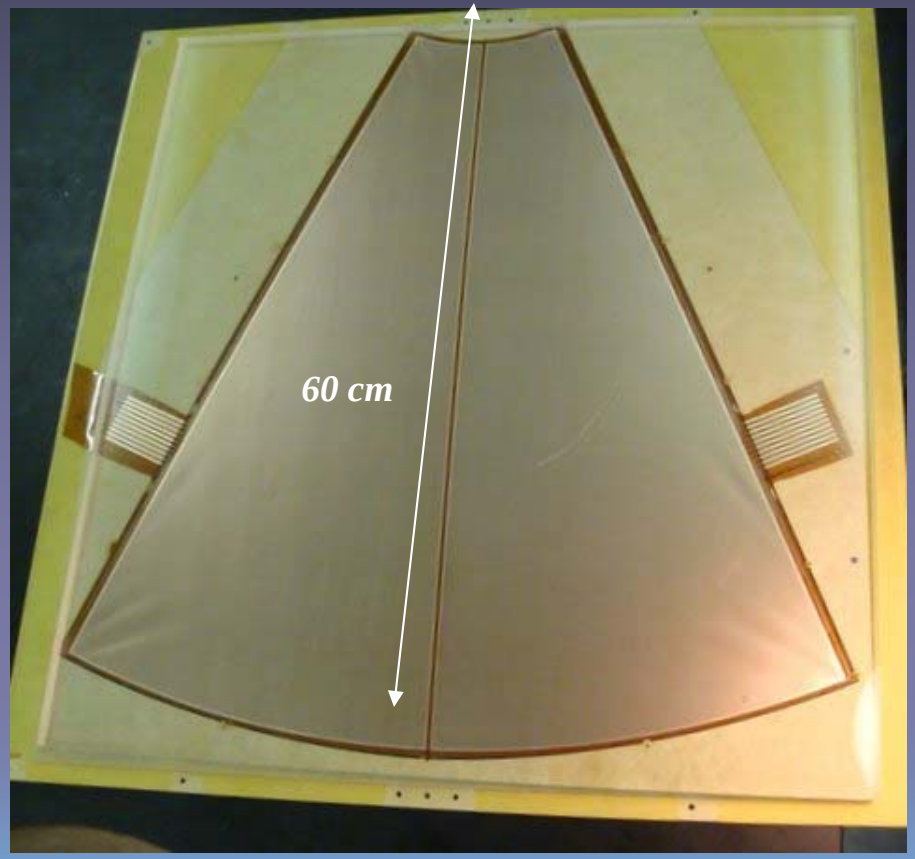




Sectoring one side of the GEM foils limits the capacitance (discharge energy)



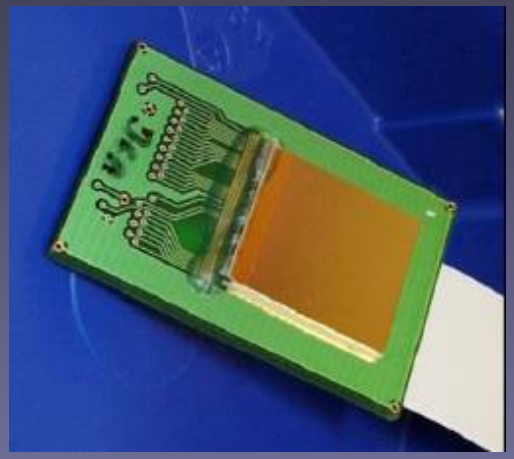
TWO-SECTORS TRIPLE-GEM PROTOTYPE FOR TOTEM T1 UPGRADE (60x60 cm^2)

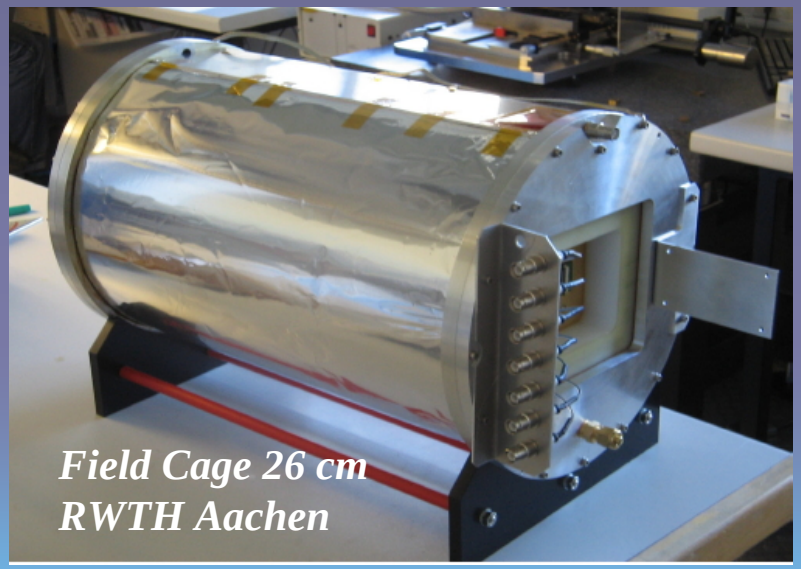


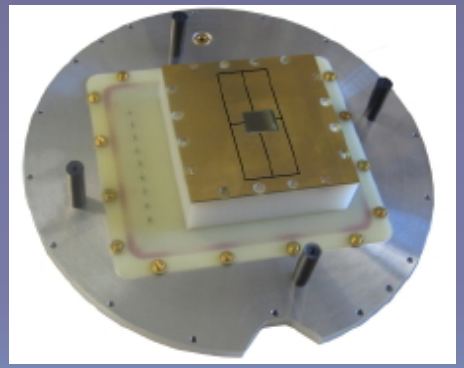
S. Duarte Pinto et al,
IEEE Nucl. Sci. Symp. Conf. Rec. (Dresden, Oct. 2008)

GEM TPC WITH TIMEPIX READOUT

TIMEPIX
Improved version of the MEDIPIX chip, adding a time measurement for each pixel
256x256 pixels, 55x55µm^2
14x14 mm^2 active area
Triple GEM amplifier

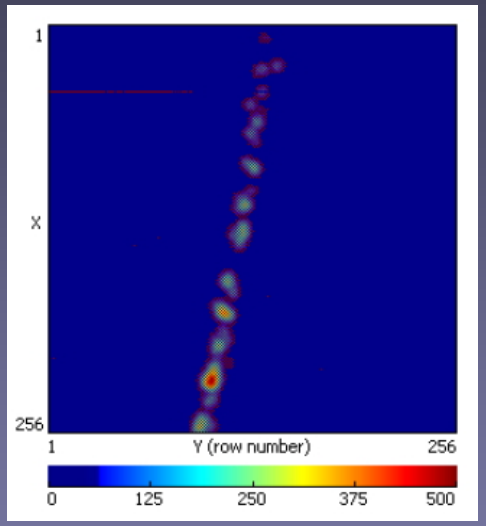




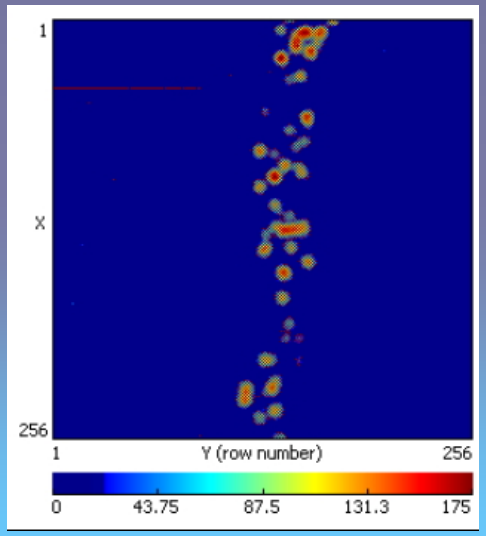


J. Kaminski, RD51 Workshop, Paris (October 2008)
Bonn University ILC-TPC

Cosmic track: short Drift



Cosmic track: long Drift



GEM Applications

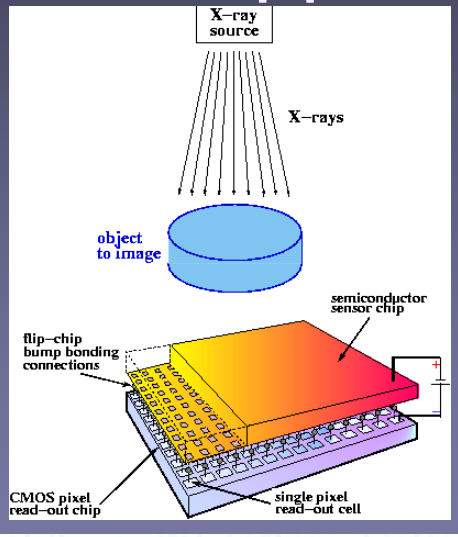
- Ultra-fast Soft X-Ray plasma diagnostics
- Neutron Detection
- X-RAY Polarimetres for astrophysics
- Position sensitive photomultipliers
- Portal imaging

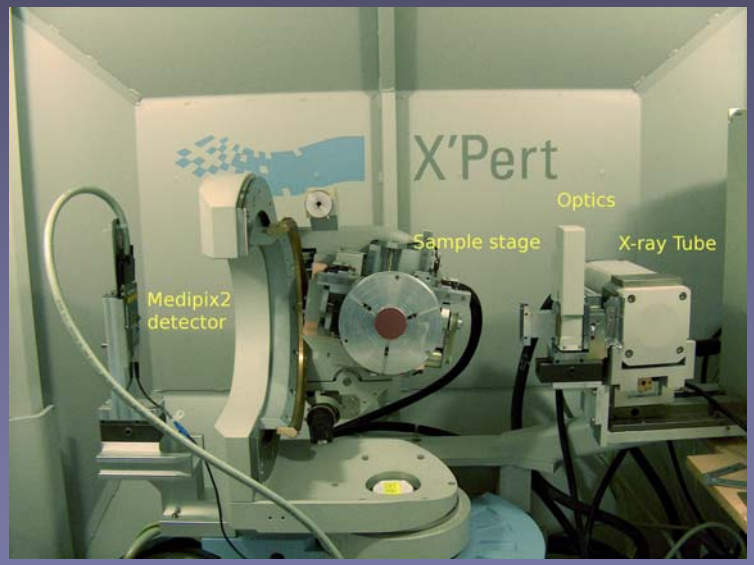
GEM

- For more information: http://gdd.web.cern.ch/GDD/

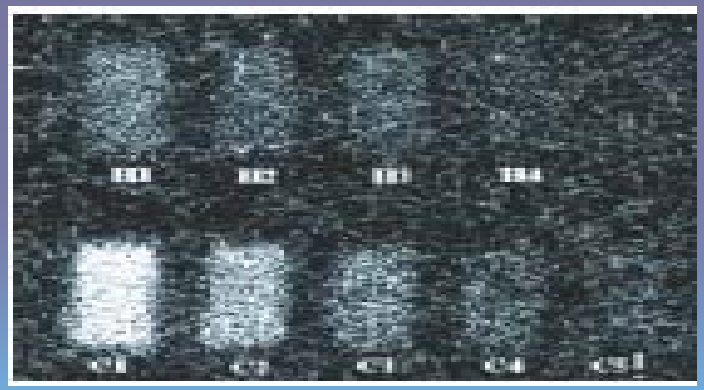
- M. Titov, New developments and future perspectives of gaseous detectors, NIMA 581(2007)25

Medipix 2 sviluppo di pixel chips capaci di contare singoli fotoni per applicazioni mediche e industriali





PANalytical's X'Pert strumento a diffrazione a raggi X per analisi dei materiali, prototipo commerciale che incorpora la tecnologia MEDIPIX (Ref. PANalytical).



Autoradiogramma ^{14}C tracciante (Ref. INFN Napoli)

PANalytical introduces its second generation solid state detector technology. With PIXcel, PANalytical adds a high-end companion to the renowned X'Celerator, with specific benefits for advanced materials research in high tech applications. PIXcel is the result of a collaboration with CERN and others as part of the Medipix2 project.

Marilena Streit-Bianchi

The Medipix2 ASIC is a high spatial, high contrast resolving CMOS pixel read-out chip working in single photon counting mode. It can be combined with different semiconductor sensors which convert the X-rays directly into detectable electric signals. Hybrid pixel technology is used for pattern recognition in vertex detectors of the LHC

Characteristics

- Count of photons within a given energy region. Noise-free.
- High intensity illumination up to the order of 0.4 GHz/mm².
- High sensitivity, large dynamic range and low contrast detection.
- No sensitivity to dark currents, allowing for long exposure times under very low intensity illumination.
- High speed imaging and readout - 20 frames per second.
- The chip is limited to 256x256 pixels (1.4x1.4 cm). The chip is 3-side buttable and a four Medipix2 chips detector gives an active area of 2.8x2.8 cm.

Applications

- Life Sciences.
- Digital Autoradiography.
- Astrophysics.
- Various X-ray and gamma-ray imaging applications.
- Neutron imaging.
- Diffraction analysis.

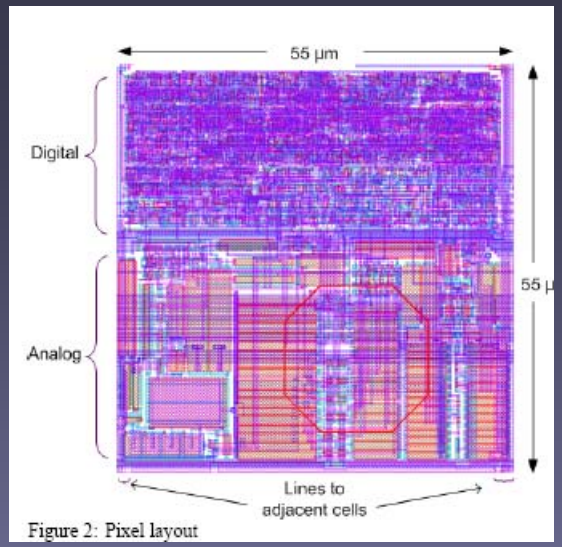


Figure 2: Pixel layout

Development on going

Medipix 3

a CMOS pixel detector readout chip designed to be connected to a segmented semiconductor sensor

The Medipix3 architecture allows pixels to operate either in single pixel mode or in charge summing mode.

- Each Medipix3 pixel have 2 thresholds and 2 counters the user may configure the chip to work either in simultaneous read/write mode (one counter is read out while the other counts) or in sequential read/write mode with 2 different thresholds.
- It is also possible to bump bond only 1 pixel in 4 increasing the sensor pixel pitch from 55 µm to 110 µm while having 8 counters per pixel. This is called spectroscopic mode and permits either 4 separate thresholds in simultaneous read/write mode or 8 thresholds in sequential read/write mode.

Due to the complexity of the Medipix3 processing circuits, there are almost 1600 transistors in each pixel, which is three times the number of transistors in the Medipix2 pixel.

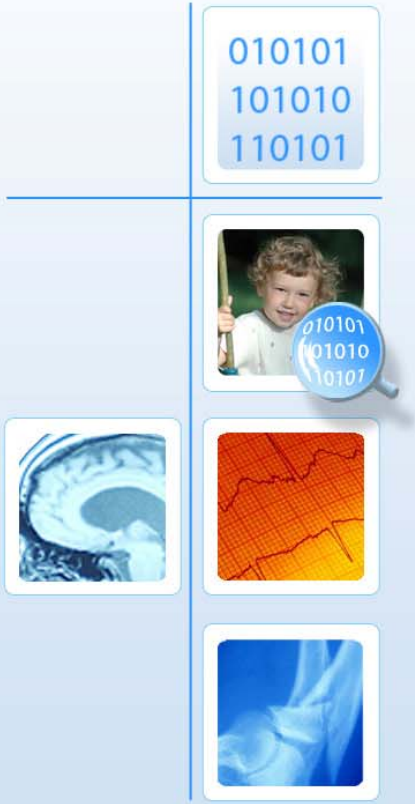
Ref. W. Wong et al. 2008

La rete al servizio della salute

- Le tecnologie informatiche permettono di sviluppare un ambiente intelligente capace di:
  - Gestire l'informazione relativa alla salute del paziente
  - Assistere gli operatori sanitari nell'affrontare nuove tematiche lavorative
  - Integrare gli ultimi sviluppi tecnico scientifici nella pratica clinica

from V .Hernandez & I. Blanquer - U.P. Valencia - Spain

Introduction to Health-e-Child



Marilena Streit-Bianchi

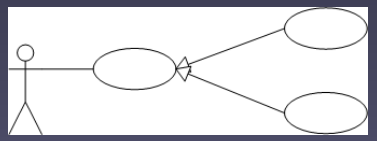
Motivation

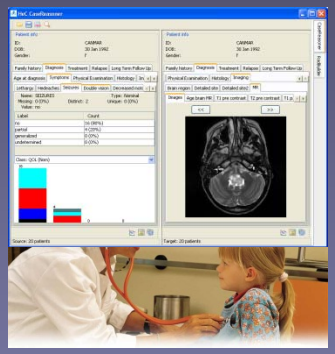
- **Clinical demand for integration and exploitation of heterogeneous biomedical information**
  - vertical dimension – multiple data sources
  - horizontal dimension – multiple sites
- **Need for generic and scalable solutions**
  - integrate traditional and emerging sources
  - offer decision support in diagnosis, therapy and follow-up
  - provide complex integrated disease models
  - ubiquitous access to knowledge repositories in clinical routine
  - connect stakeholders in clinical research
- **Specific Needs in Paediatrics**
  - Many medical disorders in children are little understood and some diseases are rare
  - Incentives to invest in research are low

Health-e-Child
Europe-wide Information Platform for Pediatrics

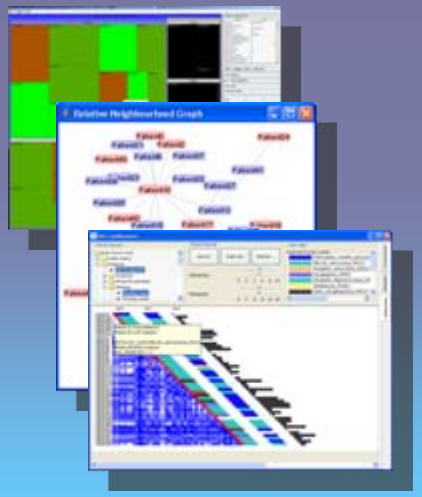
- Four peadiatric hospitals
  - Gaslini, Genoa, Italy
  - GOSH, London, UK
  - Necker, Paris, France
  - OPBG, Rome, Italy
- Strong interdisciplinary team across
  - Countries and languages
  - Technical and clinical fields
- Research on three peadiatric disease areas:
  - Arthritis
  - Cardiac Disorders
  - Brain Tumours

Top Use Cases:





- **“Aiding the Clinician in Decision Making”**
  - Defines the HeC system from the point of view of **evidence-based medicine**
  - Primary concern is associated with a **single patient** in relation to cohorts of diagnosed patients
- **“Clinical Studies”**
  - Defines the HeC system from the point of view of accessing, manipulating and using information collected about **many patients**
  - Primary concern is searching for **new medical knowledge**
  - Basic scenario is that of running **clinical studies** on a large, heterogeneous, distributed data sample.



Research Focus in Rheumatology

Improve current classification of JIA subtypes

- **Identify homogeneous groups of clinical features**
- **Find early predictors of poor outcome**
- **Identify sensitive markers of joint damage progression**

Develop MRI and US paediatric scoring system

- **Joint space width varies with age – studies performed on adult are not applicable on children.**

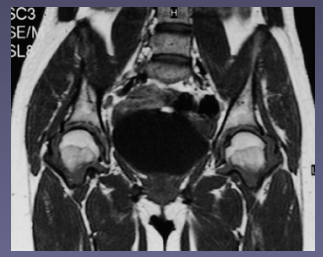
Robust Information Fusion

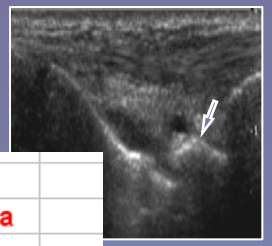
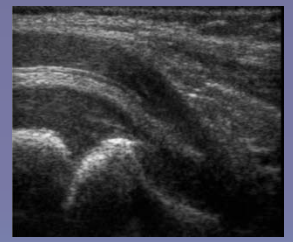
- **Pattern discovery in multimodal data, correlation between genomic, clinical and image data**

Rely on the collaboration with PRINTO:

Pediatric Rheumatology

INternational Trials Organization

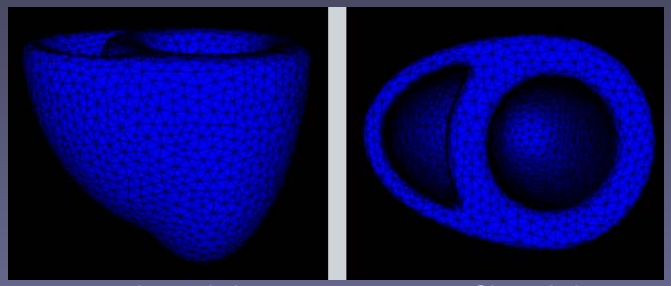
Wrist Hip

Clinical Data
Lab Data, Familial Data
Imaging Data
Wrist & Hip X-Rays
Ultrasound, wrist
Ultrasound, hip
MRI, wrist
MRI, hip
Biological Samples
Blood
Synovial and Serum Levels
Genetic Data

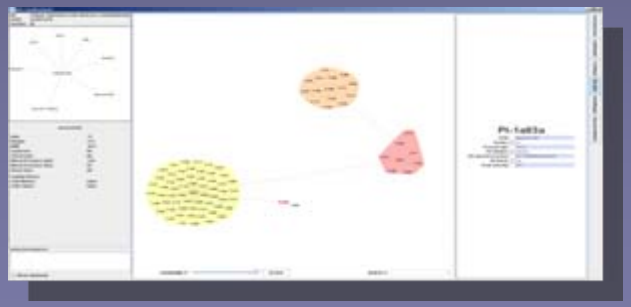
Marzo 2009 131 patients enrolled (Target – 300)

Research Focus in Cardiology

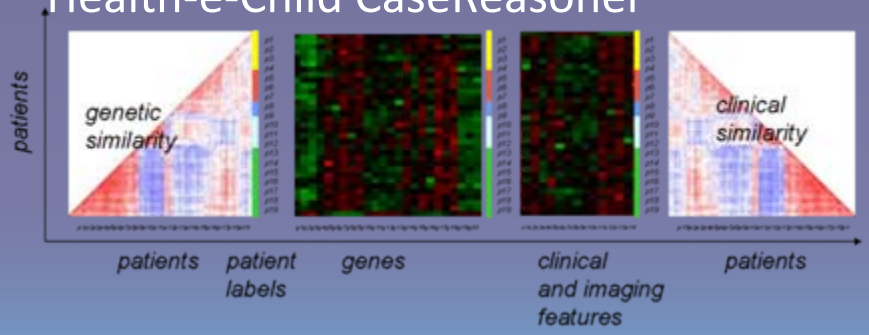
- Concentrating on Right Ventricular Overload and Cardiomyopathies
- Computational electromechanical models of the heart
- RVO monitoring and decision support based on similar cases – similarity search on complex, multimodal data
- Decision Support based on semi-automatic feature extraction from cardiac MR



Long Axis Short Axis



- Health-e-Child CaseReasoner



Clinical Data
History
Physical Examination
Exercise Testing
ECG
Imaging Data
Echo 2D/3D
MRI
Genetic DataDNA sequencing, Chromosomal Analysis
Karyotyping
CGH
FISH
Sequencing of 3 candidate genes

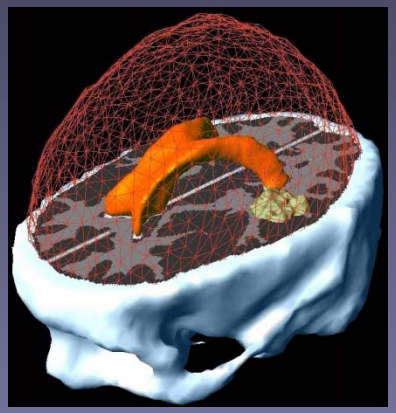
- Visualizing integrated biomedical data for patient cohorts using treemaps and neighborhood graphs

194(RVO)+38(CMP) patients enrolled (Target – 300)

Research Focus in Neuro-oncology:

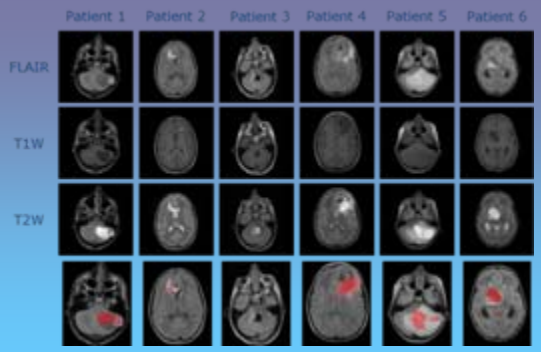
Glioma growth model:

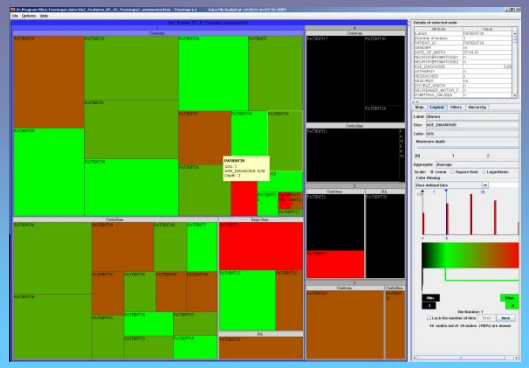
- Interpolating growth between two time instances
- Using proliferation and diffusion of tumor cells
- Including high speed of tumor invasion in white vs. grey matter



Knowledge Discovery, Finding Prognostic Markers:

- Classification of low vs. high grade
- Sub-typing of pilocytic astrocytomas (e.g. regarding tumour site, age)
- Regression analysis of factors (clinical, imaging, genetics) that affect treatment outcome
- Prediction of prognosis (survival rate and quality of life)



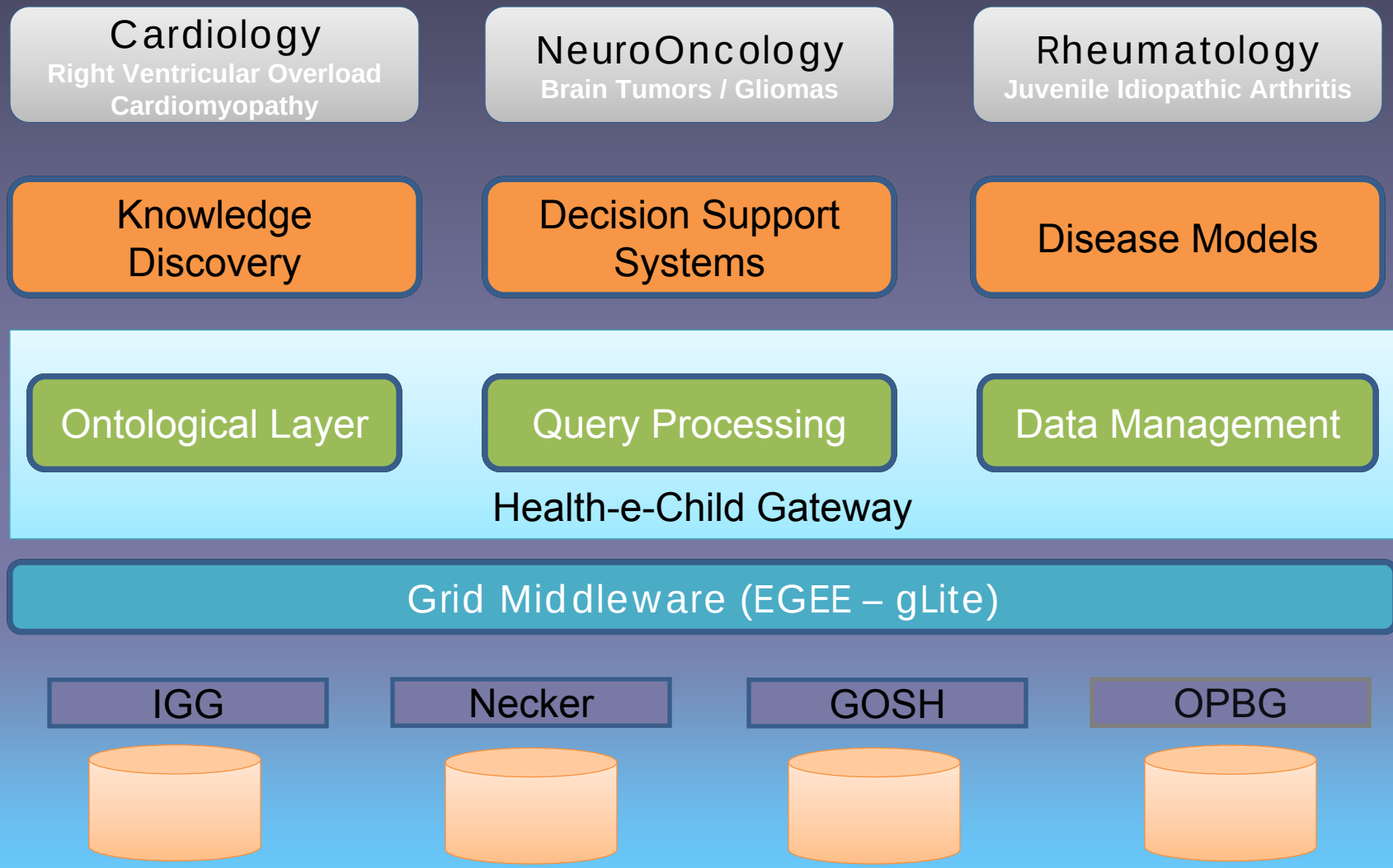


Clinical Data
Imaging Data
MRI
Tissue Samples
Tumor Gene Expression Data (Microarray)
Sequence Analysis PTEN, CDKN2A, PTPN11 an
Longitudinal Data (Treatment, Outcome)

49 Studies Collected (Target – 78)

Marilena Streit-Bianchi

Health-e-Child Platform Overview



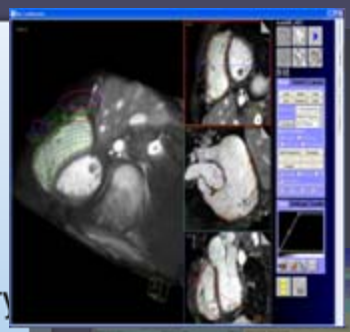
Health-e-Child Demonstrator

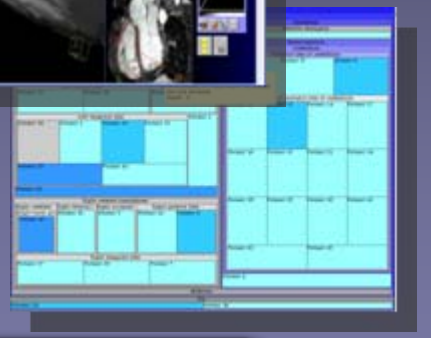
Domains

- Cardiology
- Rheumatology
- Oncology

Scenarios

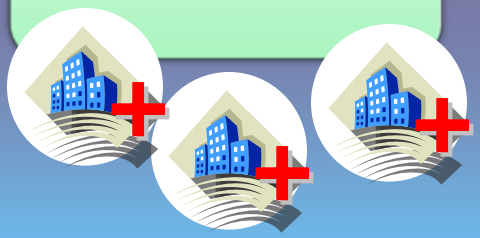
- Personalized Decision support
- Similarity Search
- Knowledge Discovery





Sites

- Gaslini, Italy
- Necker, France
- GOSH, UK



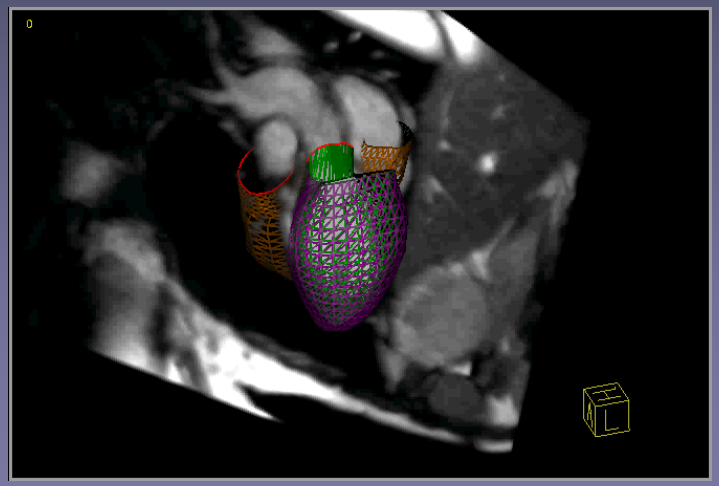
Integrated Demonstrator

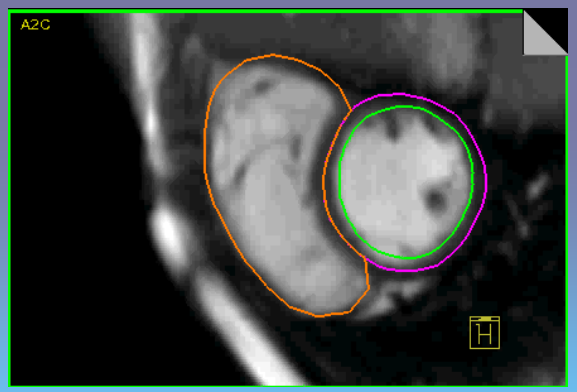
IT Innovation

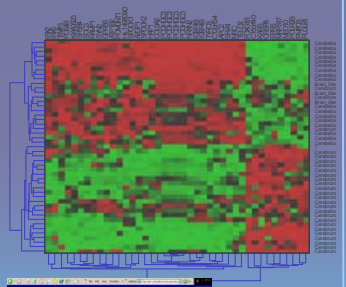
- Machine Learning
- Imaging
- Data Integration
- Grid
- ...

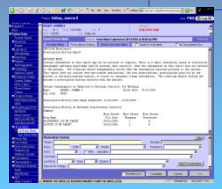
Platform at Work

Current Patient Data

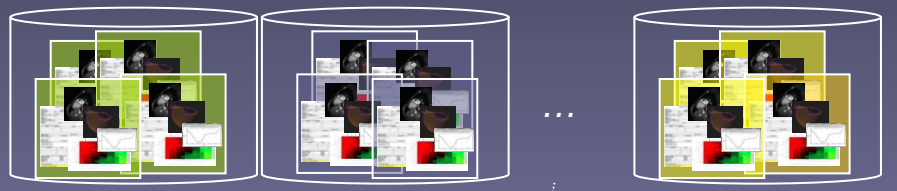






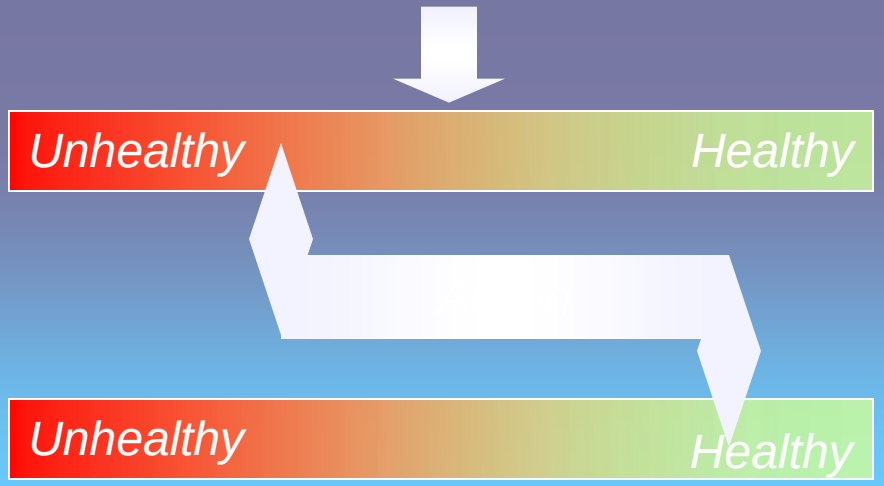


Hospital 1 *Hospital 2* ... *Hospital N*



"Do I Operate"

Knowledge Base



Marilena Streit-Bianchi

2008 Awarded Presentations

- Exhibit Grand Prize, ICT 2008, Lyon, France
- Best Poster and Demo Award (Health-e-Child Gateway and Case Reasoner), HealthGrid Conference, Chicago, USA, 2008
- Best Poster Award (Visualization of Patient Proximity), Medical Informatics Europe, Goeteborg, Sweden, 2008

- Annual Award of the French Society of Pediatric Research (Disease Modeling for Tetralogy of Fallot), France, 2008
- Best Live Demo Award (Health-e-Child Gateway), EGEE User Conference, Clermond Ferrand, France, 2008

More information

- Project Coordinator: Jörg Freund (Siemens)
  - joerg.freund@siemens.com
- Website:
  - http://www.health-e-child.org

GRID e le sue molteplici applicazioni

- The BioinfoGRID European project promoted the Bioinformatics applications for life science and carried out research based on the Grid networking technology. Applications in the fields of Genomics, Proteomics, Transcriptomics and Drug Discovery, reducing data calculation times by distributing the calculation using the Grid infrastructure network created by the EGEE Project (6th Framework Program).

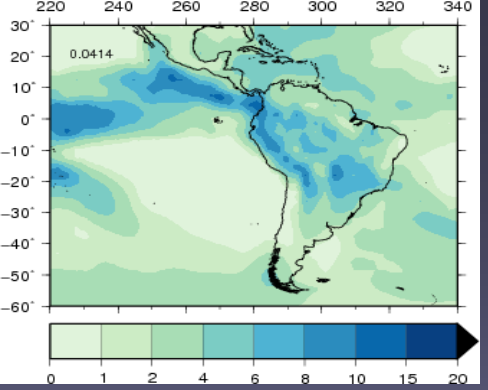
Consortium coordinated by Dott. Luciano Milanesi, CNR-ITB

CNR-ITB, INFN, DKFZ, CNRS, UCAM, CILEA, STW

- Project end Dec. 2007

BioinfoGRID White Paper: guidelines and recommendations for the scientific community based on the experience and the results gained from the BioinfoGRID project download at :

http://www.biomedgrid.it/bioinfogrid/bioinfogrid-white-paper-now-available-for-download



Application for Climate study

Climate modelling of El Niño impact on the GRID

Experiences in the EU-project EELA

University of Cantabria Santander, Spain; Universidad de Concepción, Concepción, Chile; SENAMHI, Lima, Perú

El Niño phenomenon is a key factor for Latin-American climate prediction. El Niño has a special interest due to its direct effects in the Pacific coast of South America and in particular in Peru and Chile. Moreover, research institutes from Peru and Chile (EELA LA partners) run global and regional climate models and need to compare their results with other simulations performed by international centres in the El Niño area.

- Climate applications in EELA designed around this phenomenon with the main objective of developing a simulation and analysis tool especially useful for LA partners. 3 different applications were selected to cover the typical cascade required for regional climate studies:
  - simulation of models (CAM and WRF)
  - efficient data access (middleware)
  - data analysis and mining applications (SOM).

  The 10-year simulation showed a slight but clear precipitation response to El Niño conditions.

More research is still needed to minimize the job failure.

Consorzio COMETA – Open Middleware Enabling Grid Applications

The Grid for Industry, Commerce, and Public Administration

A Consortium coordinated by INFN

INFN, DATAMAT, EUROTECH, ANSALDO Ricerche, SPACI Consortium

GRID INFN LABORATORY for GILDA DISSEMINATION ACTIVITIES

(Grid INFN Laboratory for Dissemination Activities) Launched in 2004 by INFN, GILDA is a fully working Grid testbed devoted to dissemination activities, and allows both users and system administrators access to first hand experience with Grid systems. GILDA acts as a crucial component of EGEE's t-Infrastructure (training infrastructure) program, helping to pass on knowledge and experience, as well as computing resources, to the scientific community and Industry.

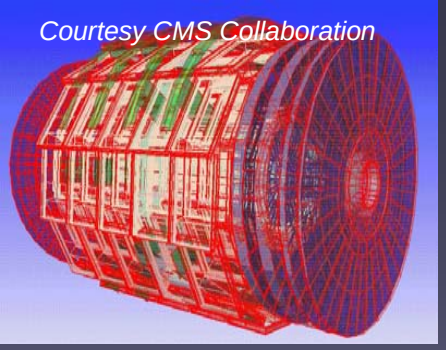
Biomed **Grid**school

10-15 May 2009 **10-15 May 2009, Varenna, Italy**

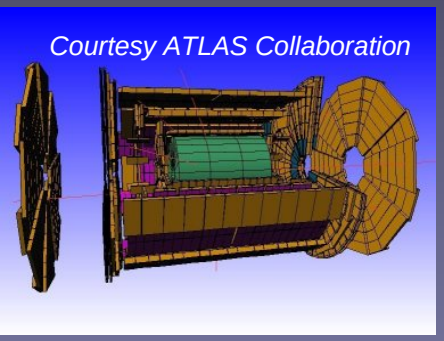
The aim of the school is to provide bioinformatics and biomedical developers the opportunity:

- to learn to use new services and functionalities made available by new middleware releases
- to implement applications in the EGEE Grid environments
- to build high level interfaces for Grid and Web Services for data provision and management
- to improve skills in Web Services, Workflow technology and Grid services for Bioinformatics e Biomedical applications
- to learn how to generate complex workflows of Bioinformatics and System Biology analysis

http://www.biomedgrid.it/

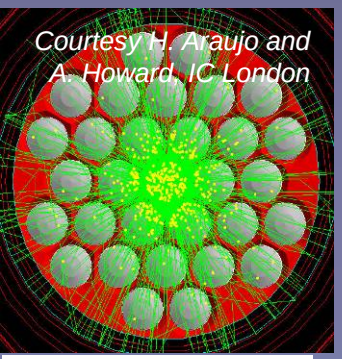


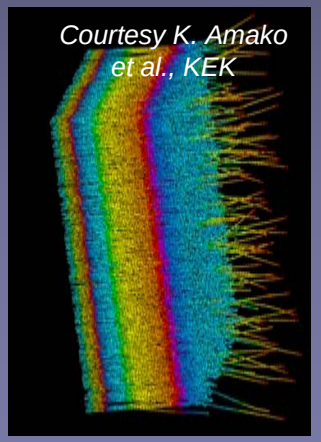
Geant 4

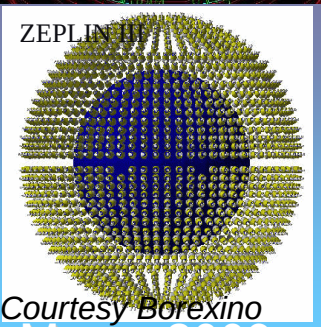


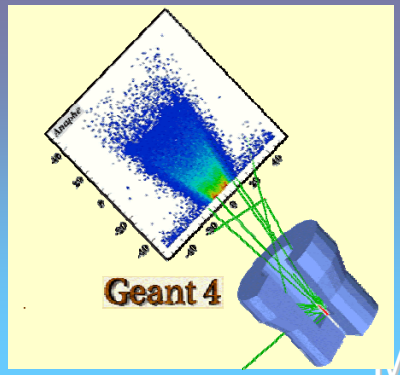
Sistema di simulazione delle interazioni di particelle con la materia

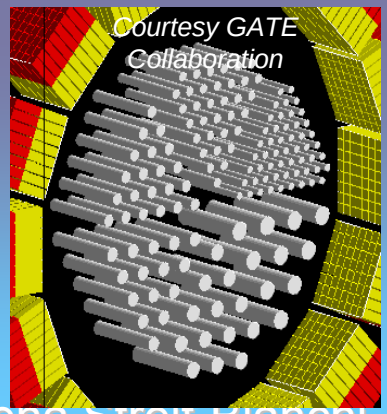
- Geometria e materiali
- Processi fisici
- Proprietà delle particelle
- Trasporto nella materia
- Visualizzazione grafica
- Interfaccia utente
- etc.











Geant 4

Nato dalle esigenze degli esperimenti di fisica delle particelle ad alte energie

Ampiamente usato in svariati ambiti sperimentali

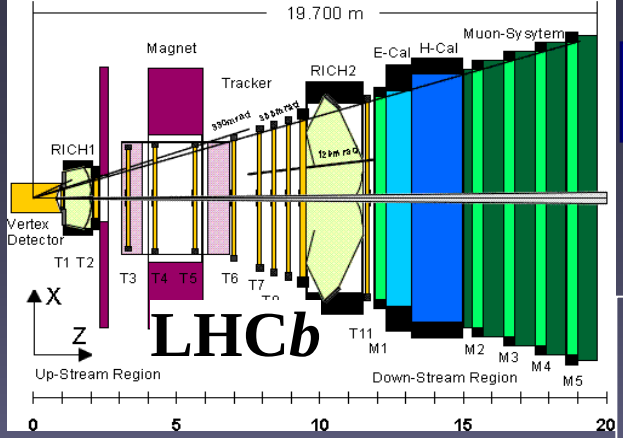
S. Agostinelli et al.
GEANT4 - a simulation toolkit
NIM A 506 (2003) pag. 250-303

È la pubblicazione **piú citata** nella storia dell'intera categoria **"Nuclear Science and Technology"**

(>140000 articoli)

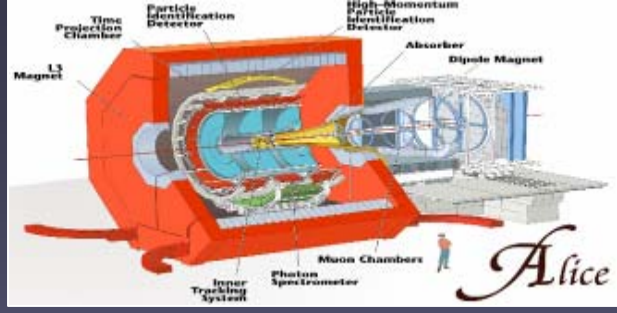
2° articolo piú citato del **CERN** e dell'**INFN**

Most recent reference paper on Geant4: Allison et al. "Geant4 developments and applications" *IEEE Transactions on Nuclear Science* 53 No. 1 (2006) 270-278.

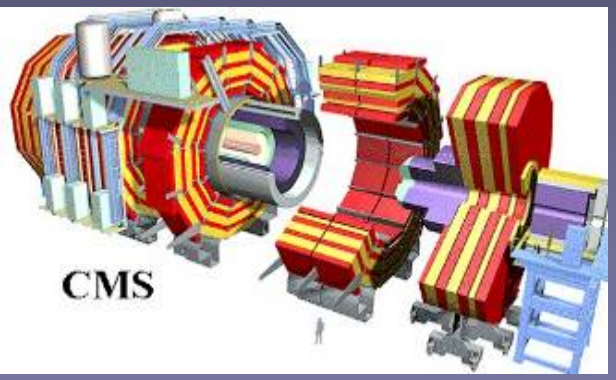


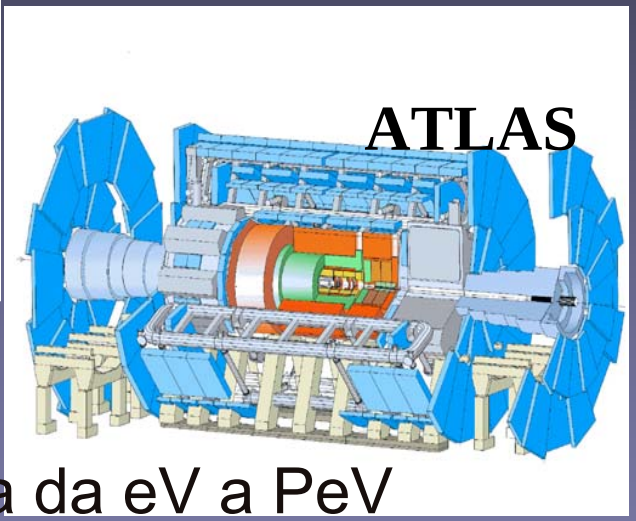
Fisica delle particelle

LHC



Fisica complessa
Rivelatori complessi
Software in uso sull'arco di ~20 anni





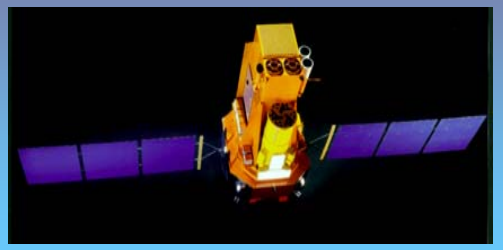
Simulazione su scala da eV a PeV

Esprimenti in profondità (terra, mare)

Astronomia, Fisica di astroparticelle

Esperimenti con raggi cosmici

Esperimenti su satelliti

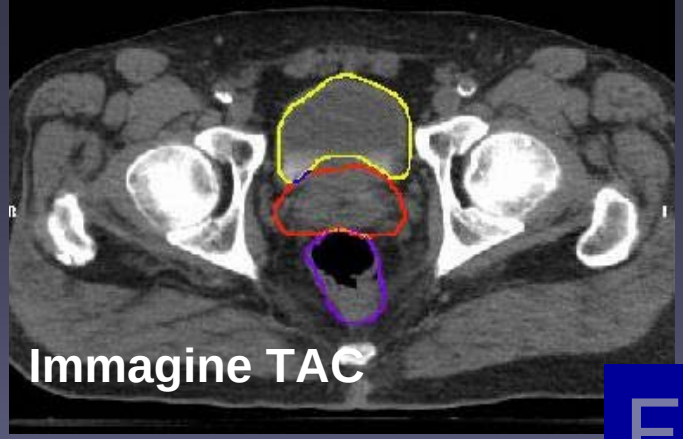


Technology transfer

Particle physics software aids space and medicine

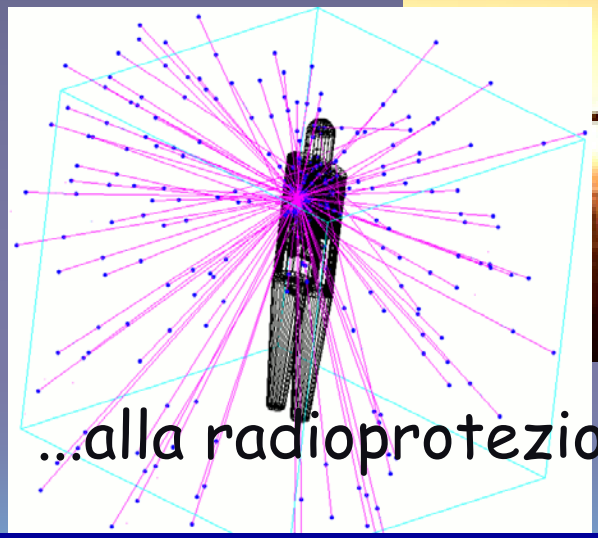
"Geant4 is a showcase example of technology transfer from particle physics to other fields such as space and medical science […]".

CERN Courier, June 2002
Cover article by M.G. Pia and J. Knobloch

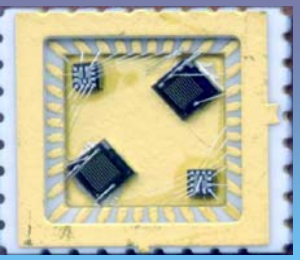


Dalla radioterapia oncologica…

Fisica medica e radioprotezione



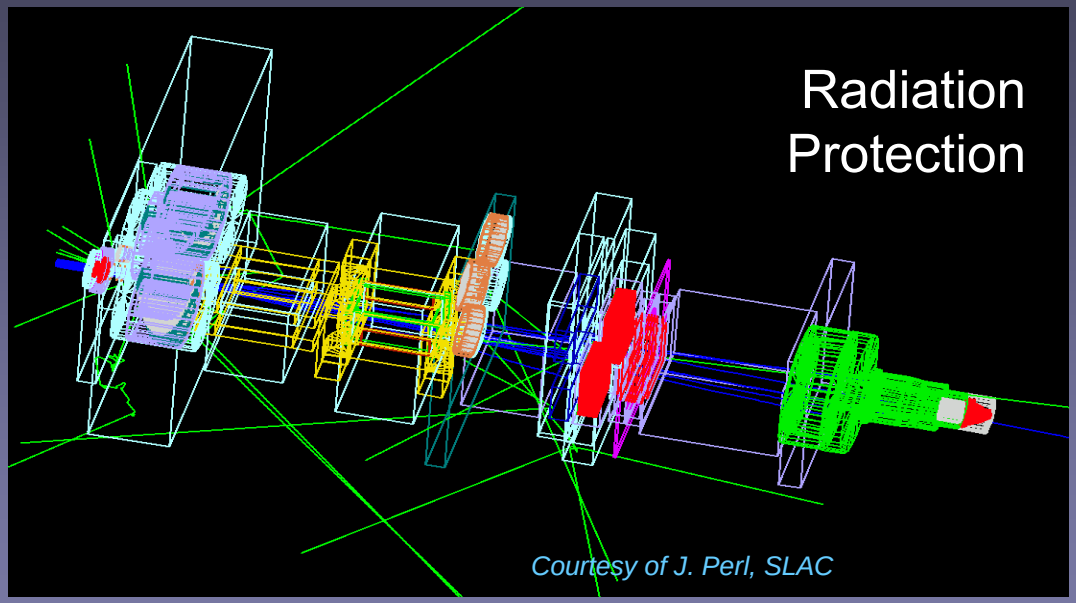
…alla radioprotezione di astronauti

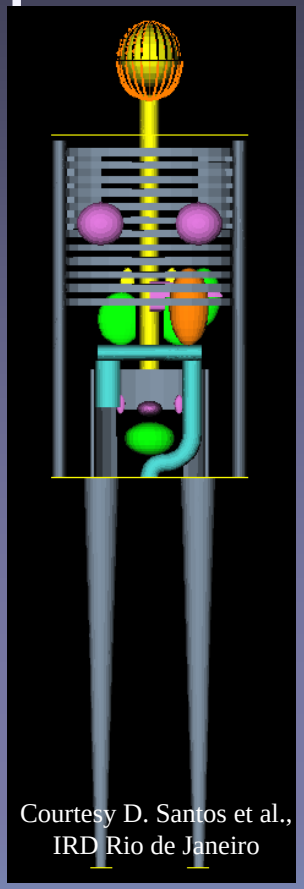


Courtesy of CERN

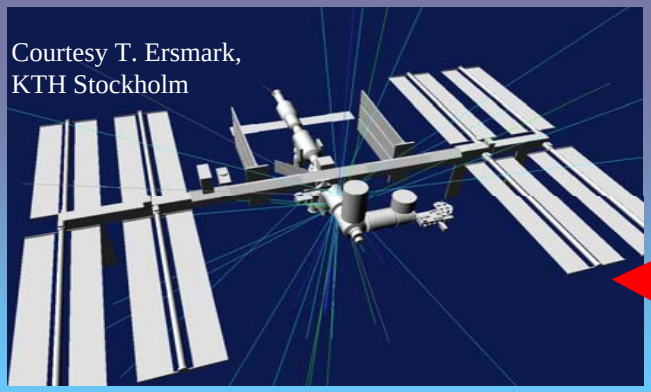
Effetti di radiazioni su componenti elettronici

Potenti strumenti di modellizzazione di geometrie e materiali





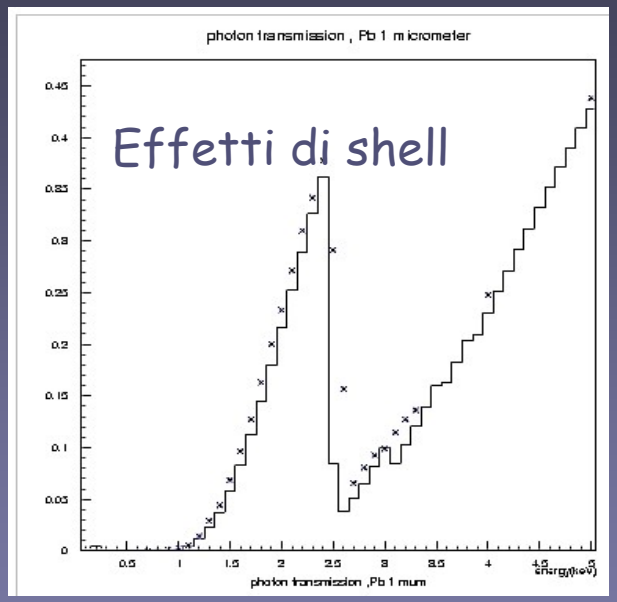
Linee di fascio
Rivelatori
Anatomia umana etc.

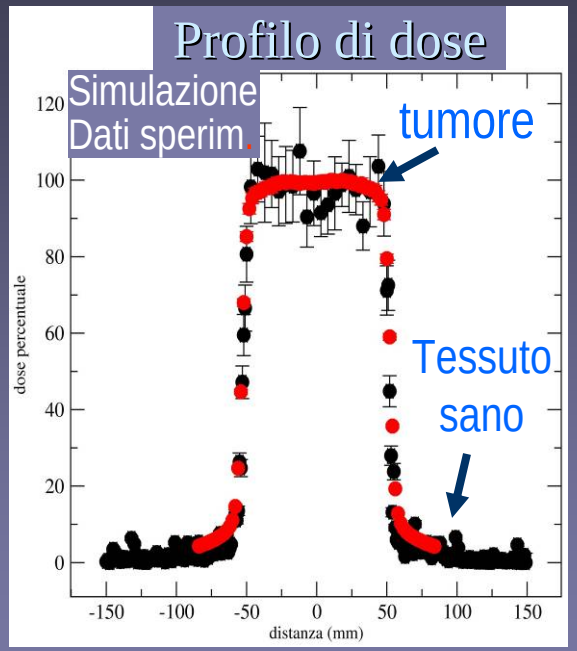


International Space Station

riprodotta con Geant4

Fisica elettromagnetica e adronica





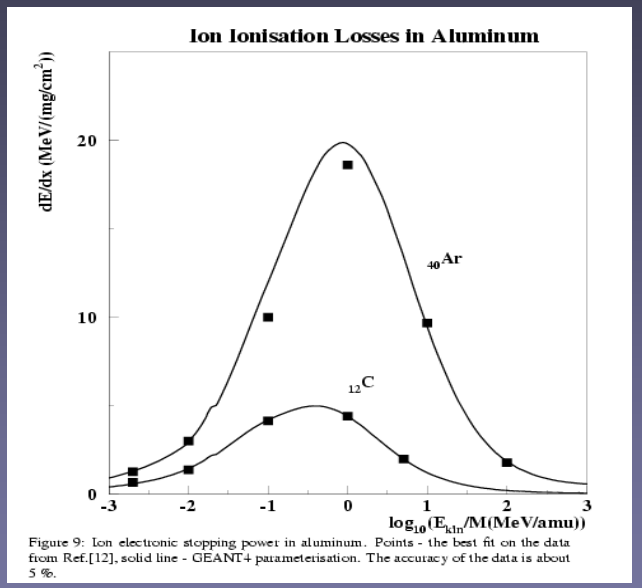
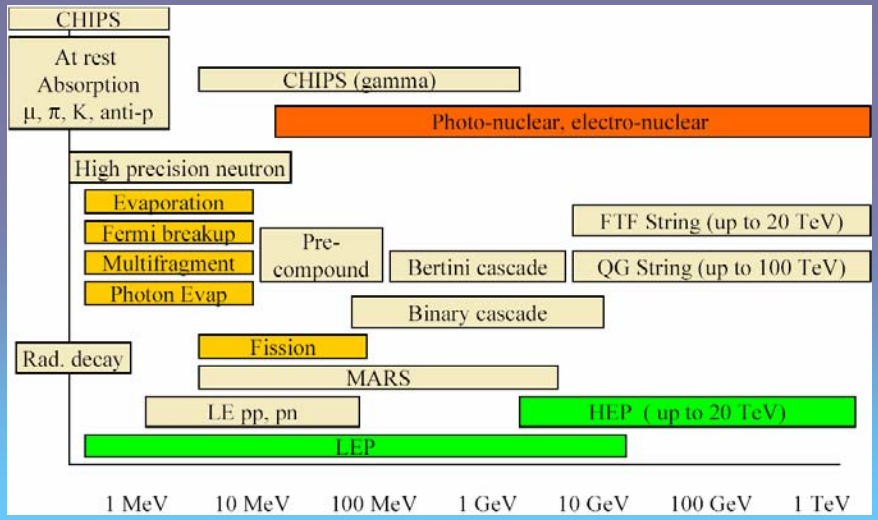
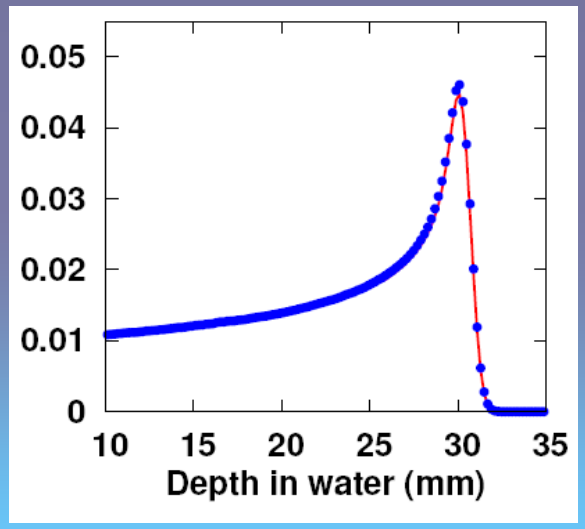


Figure 9: Ion electronic stopping power in aluminum. Points - the best fit on the data from Ref.[12], solid line - GEANT4 parametetisation. The accuracy of the data is about 5 %.





Miglioramenti ed estensioni
della versione attuale…

Prospettive future

NANO5

Nuovo progetto associato a Geant4
lanciato dall'INFN nel 2009

Metodi di trasporto → **Condensati**
Discreti

Metodi di trasporto → **Monte Carlo**
Deterministici

nello stesso ambiente di simulazione

Simulazione multi-scala

Es. Rivelatori a nanotecnologie, radiobiologia, fisica del plasma, reattori a fusione etc.

APPLICATIONS FROM QUANTUM PHYSICS

- **QUANTUM TELEPORTATION**

based on EPR [1930] and John Bell [1960] theories. 1989

C. Bennet from IBM says it is possible only if the original is destroyed further studies followed

all this is today an experimental reality

Group of Nicolas Gisin at Geneva University:

1993 First trial

2003 Validated over more than 120 km with dedicated optic fibers and 16 km in air.

2008 Developed a "quantum memory", capturing a single particle of light (a photon) in a crystal and then reproducing and retransmitting it.

Quantum cryptography enables two parties to produce a shared random-bit string known only to them, which can be used as a key to encrypt and decrypt messages.
Commercial applications already exist in the banking sector and for secure e-voting (Company idQuantique in Geneva)

QUANTUM TELEPORTATION

Gisin N and Thew R. "Quantum Communication" ***Nature Photonics*** **1**, 165 - 171 (2007)

D. Salart et al. "Testing the speed of 'spooky action' at a distance", **Nature 454 - 14/08/2008**

We performed a Bell test over more than 24 hours between two villages separated by 18 km and approximately east–west oriented, with the source located precisely in the middle. We continuously observed two-photon interferences well above the Bell inequality threshold. Taking advantage of the Earth's rotation, the configuration of our experiment allowed us to determine, for any hypothetically privileged frame, a lower bound for the speed of the influence. For example, if such a privileged reference frame exists and is such that the Earth's speed in this frame is less than 10^{-3} times that of the speed of light, then the speed of the influence would have to exceed that of light by at least four orders of magnitude.

The speed of propagation of information must be more than 100,000 times the speed of light