



UNIVERSITÀ DEGLI STUDI
DI NAPOLI FEDERICO II



Workshop on basic research and interdisciplinary applications
with small accelerators

**Storia e possibili applicazioni dell'acceleratore Tandem
dell'Universita' Federico II di Napoli**

Luigi Campajola

17-18 January 2018

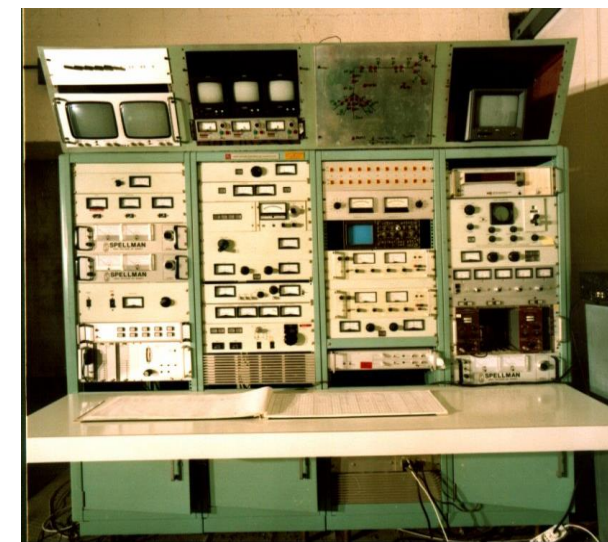
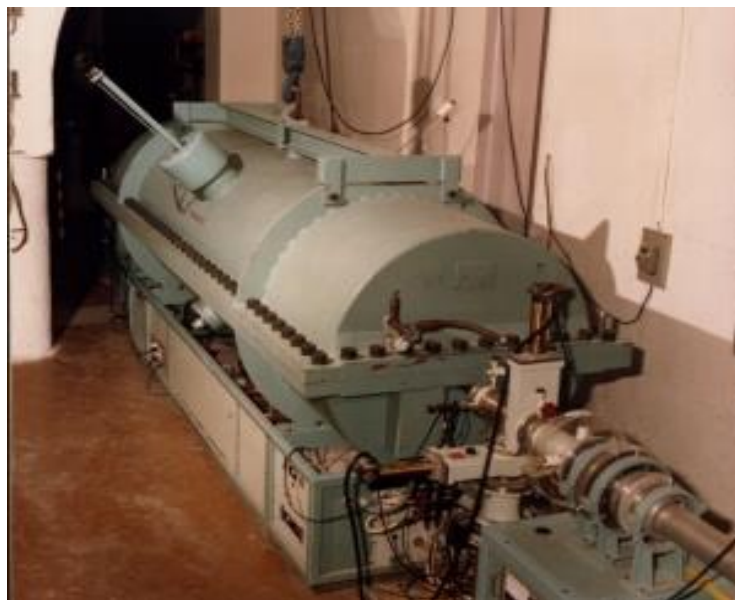
Univ. Federico II, Compl. Monte S. Angelo



LABORATORIO ACCELERATORE



The accelerator is an HVEC TTT3 Tandem with a nominal maximum voltage of 3 MV.



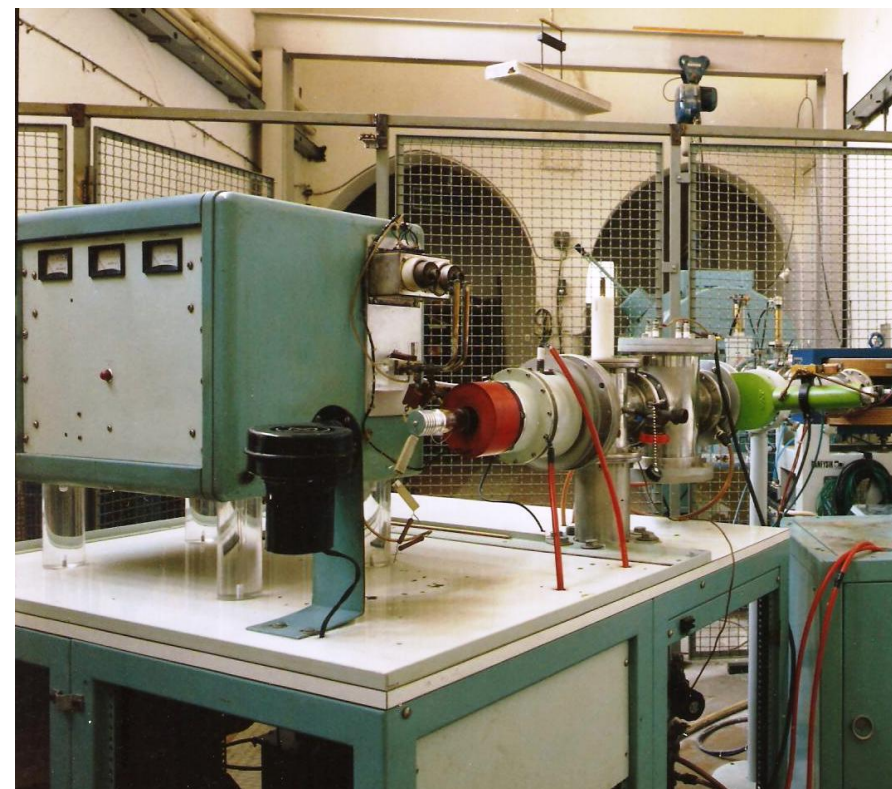
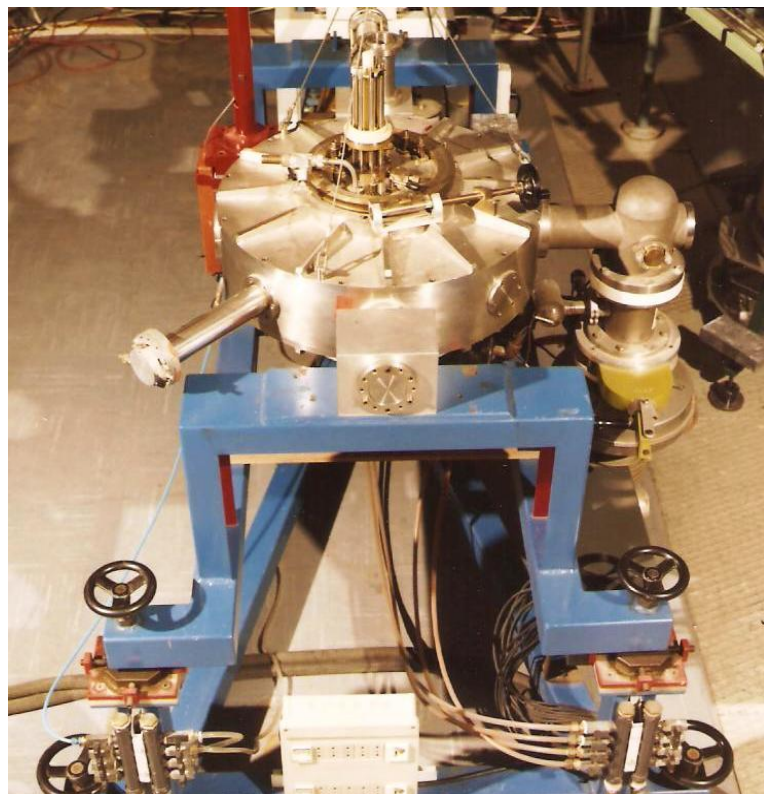
Operations in the “Padiglione Rodi” started in 1977



LABORATORIO ACCELERATORE



It was equipped with a RF source, a 90° analysing magnet and a general-purpose scattering chamber.



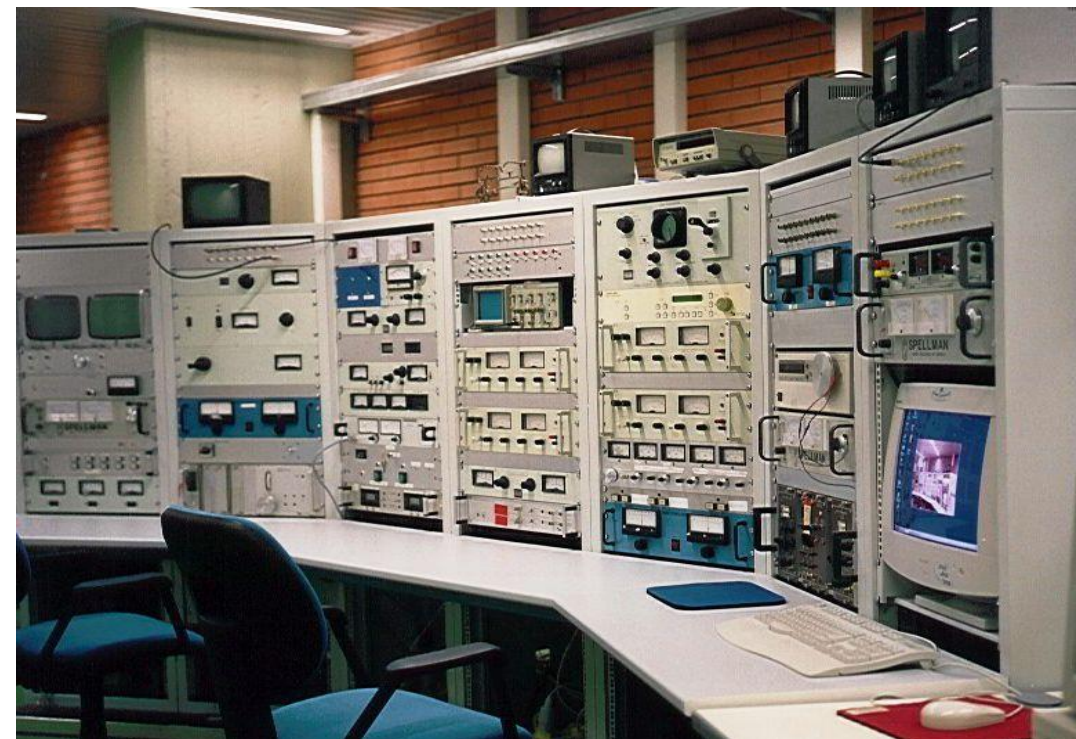
H and He beams were available



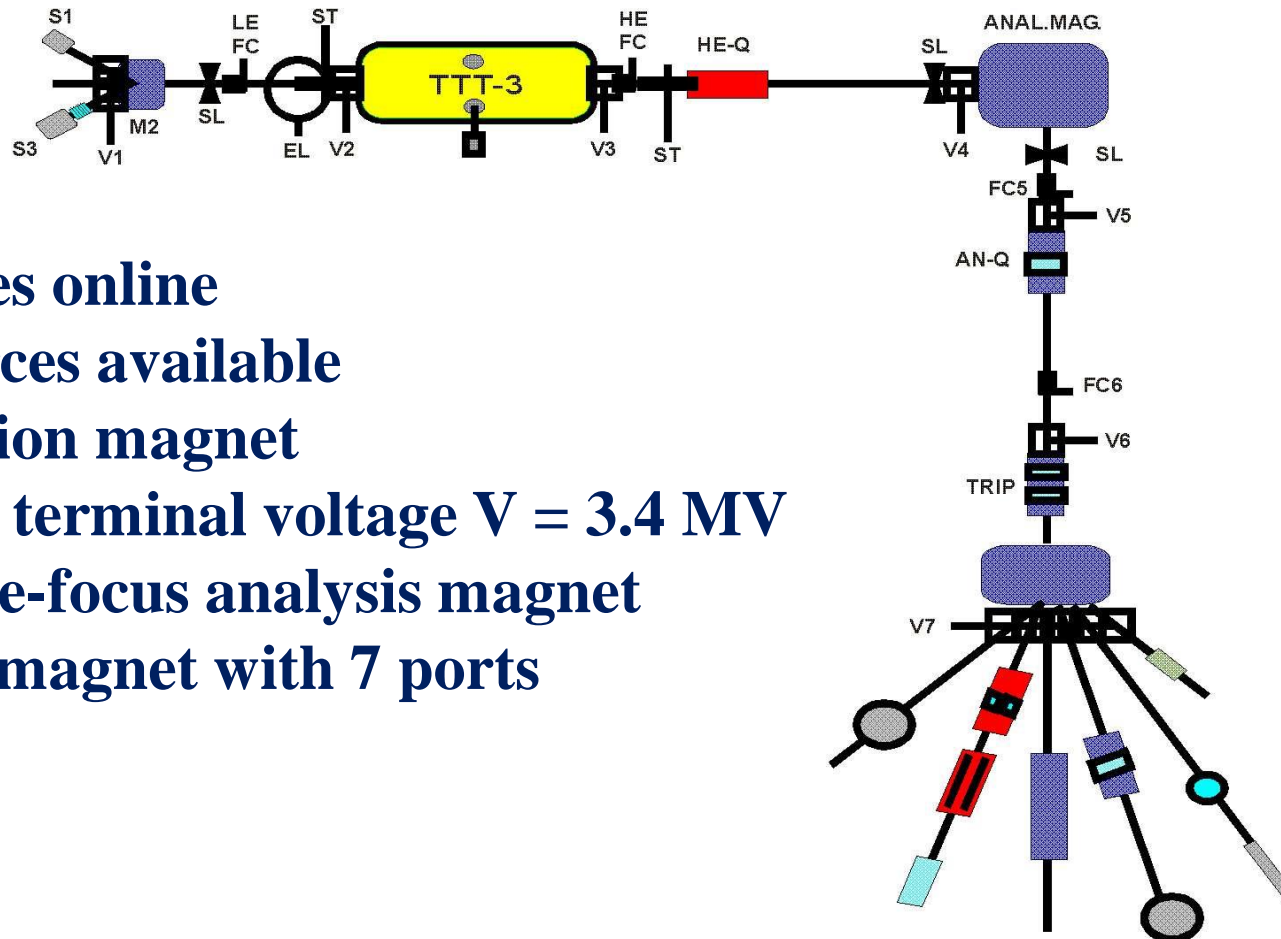
The new LABORATORIO ACCELERATORE



In 1997 the accelerator moved to the new campus.



The lay-out of the accelerator



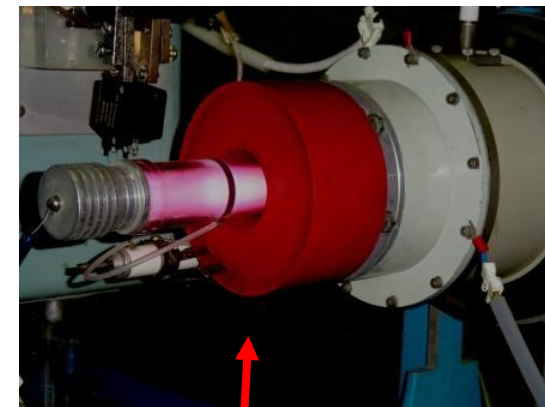
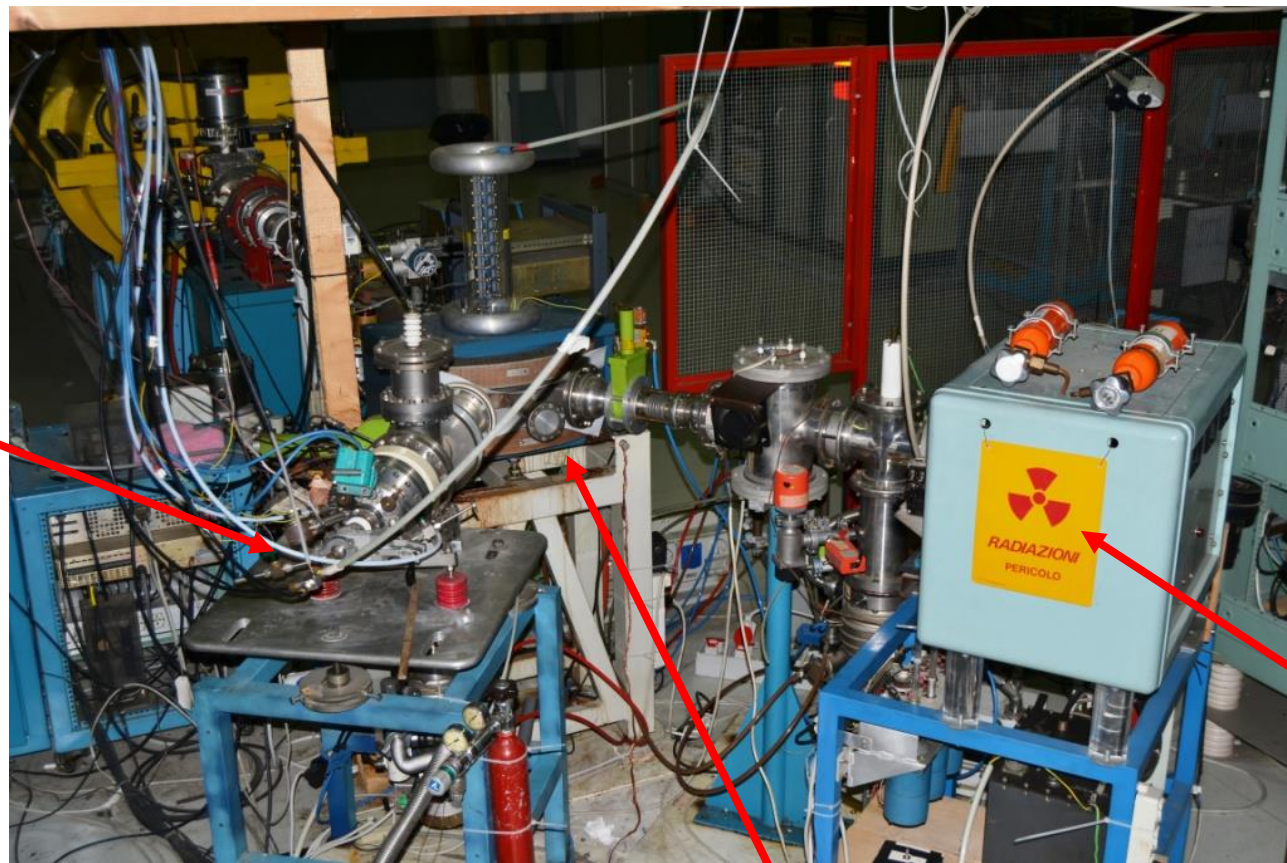
- two sources online
- other sources available
- 35 ° injection magnet
- maximum terminal voltage $V = 3.4$ MV
- 90 ° double-focus analysis magnet
- switching magnet with 7 ports



The Injector



Sputtering source

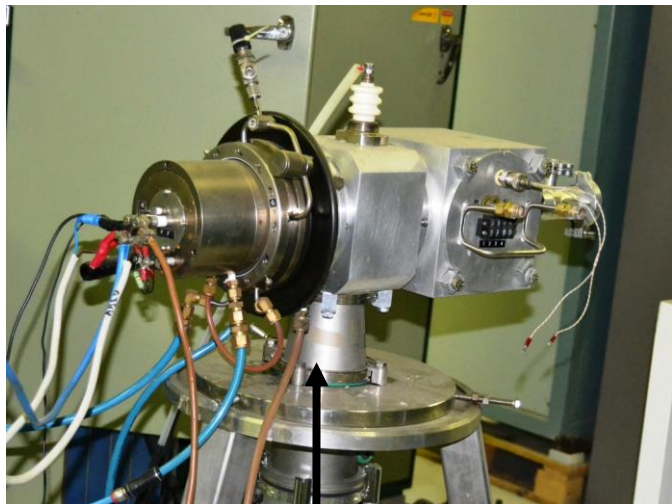


RF source

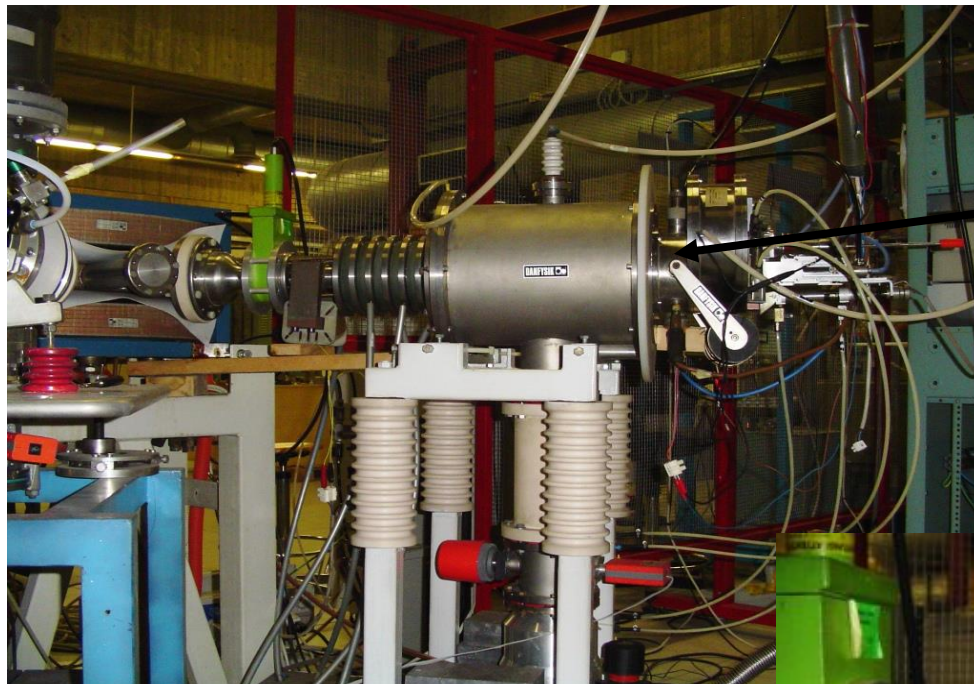
35° Injection Magnet



Off-line sources

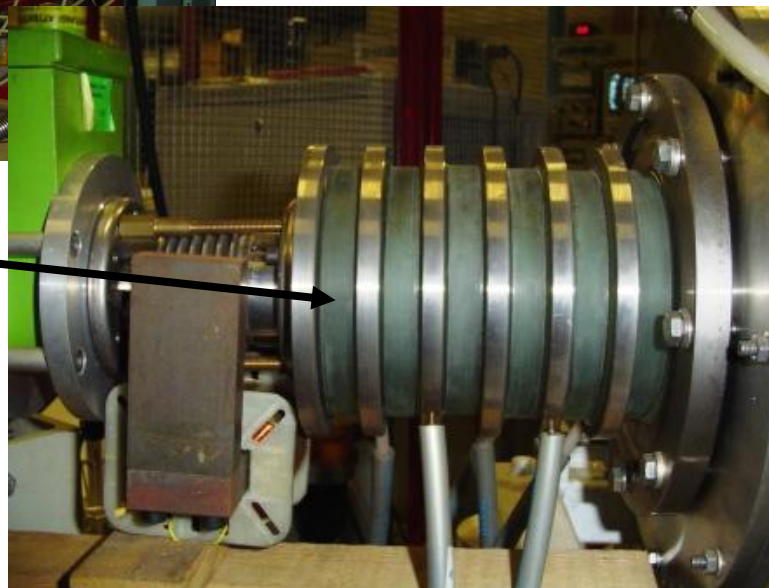


Duoplasmatron source



Multisample sputtering source with a home made 90 kV preacceleration

90 kV preacceleration: gain in transmission efficiency up to 75% for heavy ions

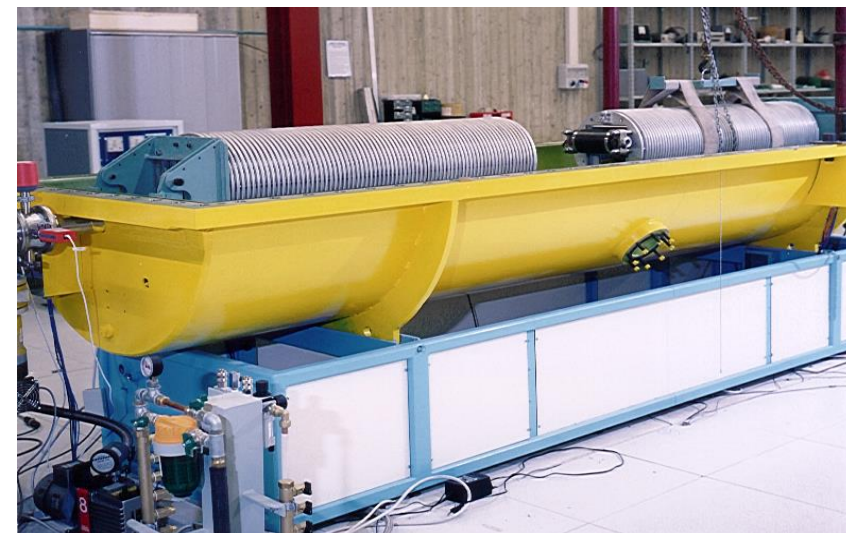
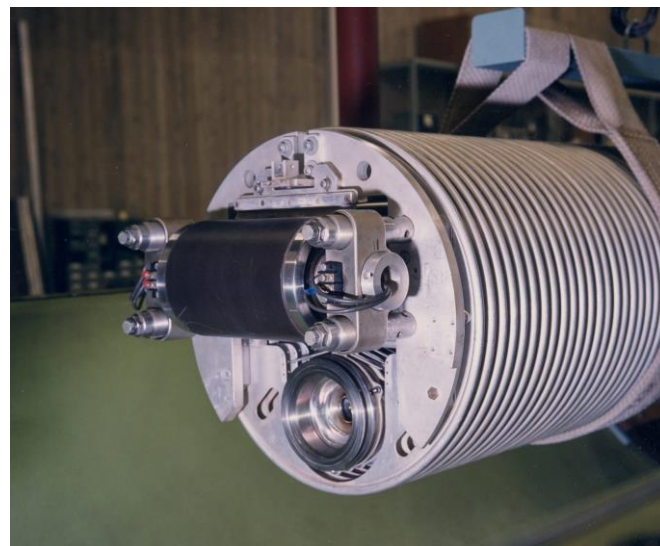
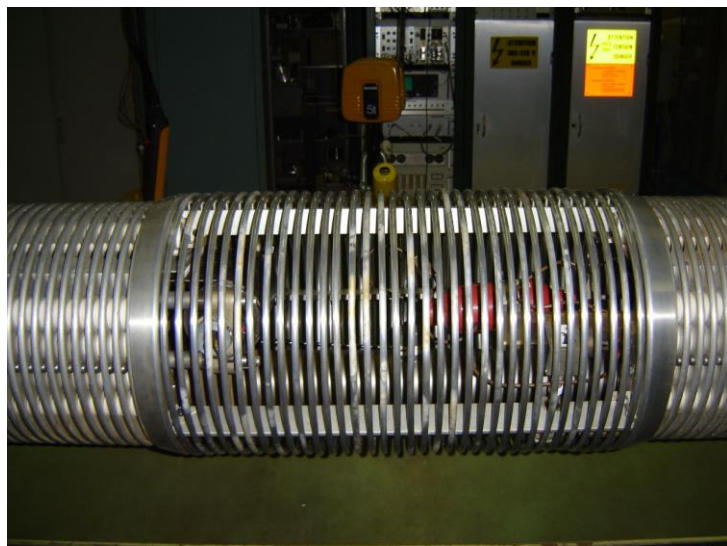




Main technical features of the TTT3 accelerator

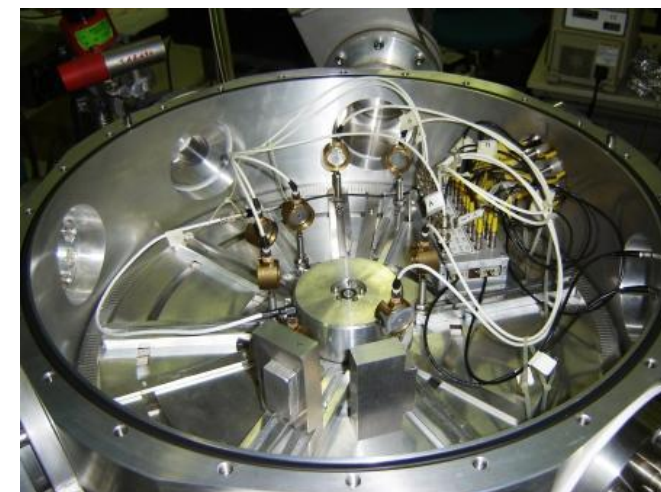
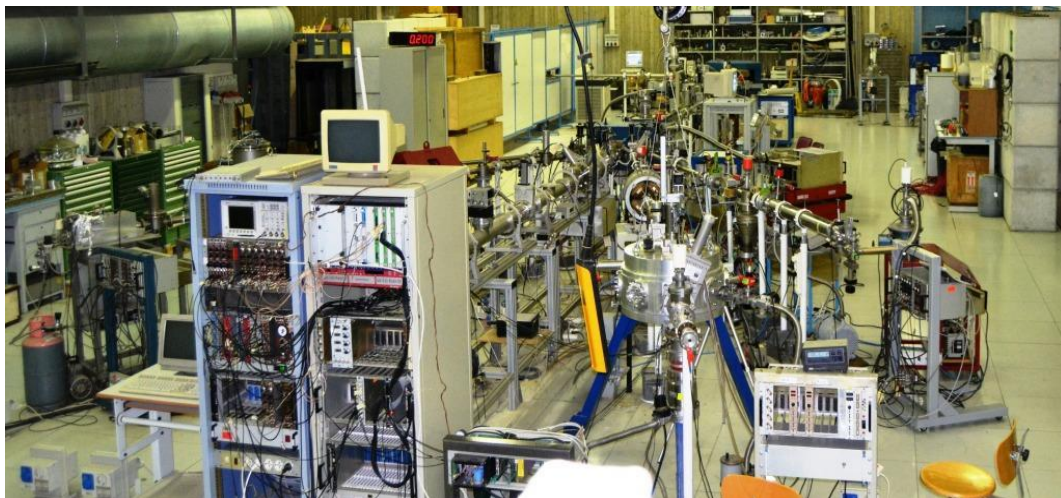


- Electrostatic accelerator, Van de Graaff type
- Double stage, belt charging system
- Two stripper systems: foil and gas
- Maximum terminal voltage: 3,4 MV (nominal 3 MV)





Beam lines



Up to 7 beam lines available

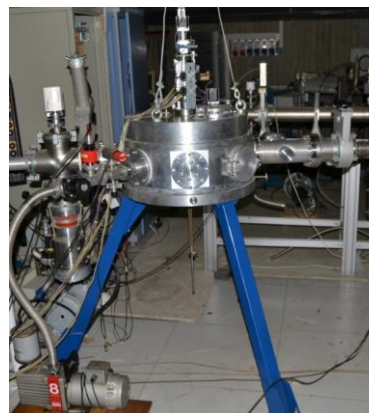
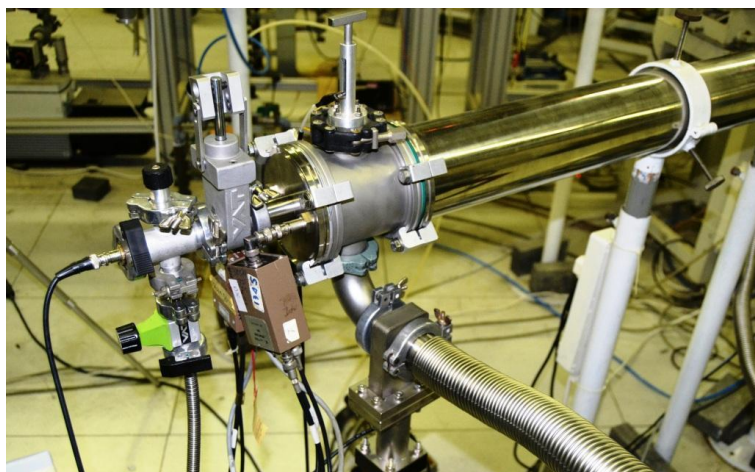
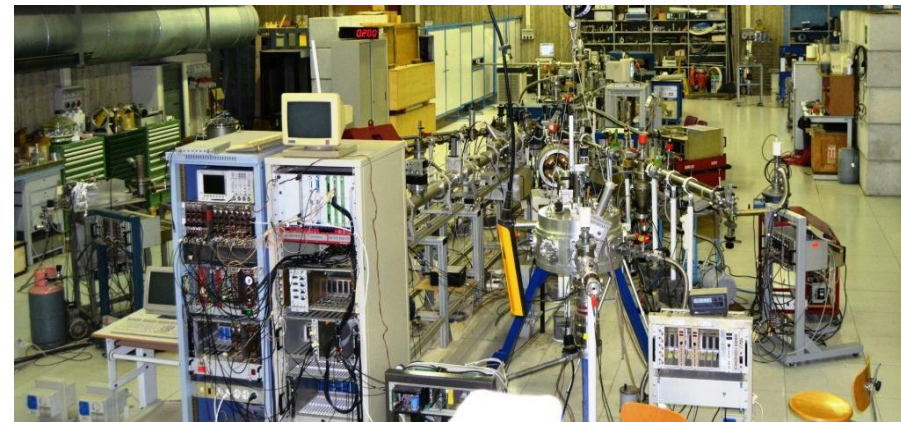
- Scattering chamber (IBA & Nuclear Reactions)
- Ion implantation with extracted beam
- Radiation Biophysics
- Neutron production

Available:

- AMS beam line equipped with Wien Filter and E-DE Ionization Chamber
- X-Y scanner for ion implantation under vacuum



Gallery







Ions

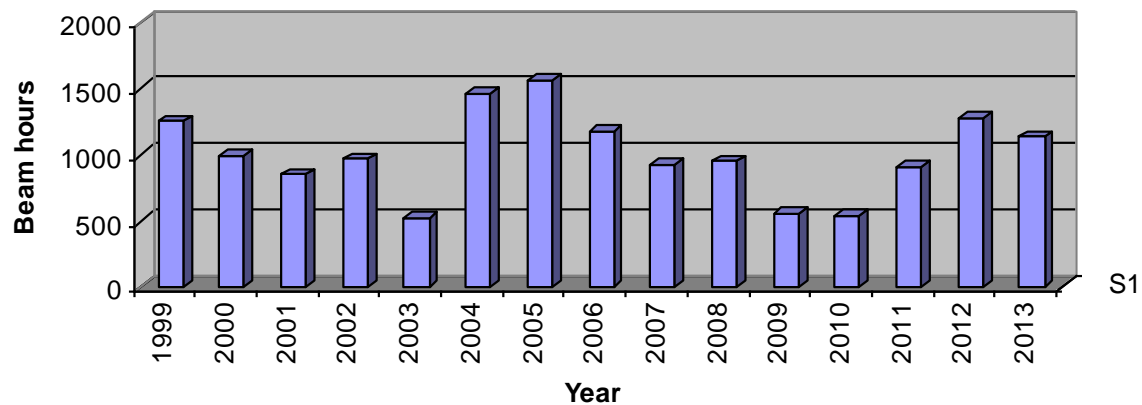
Ion	E MeV	I _{analysed} nA	E _{max} MeV
¹ H	6,5	100	6,5
² H	6,5	10	
³ He	10	20	10
⁴ He	10	20	10
⁶ Li	13		13
⁷ Li	13	20	13
⁹ Be	13		16
¹⁰ B	13		20
¹¹ B	13		20
¹² C	16	100	20
¹³ C	16		20
¹⁴ N	13		16
¹⁶ O	16	100	23
¹⁹ F	19	50	23



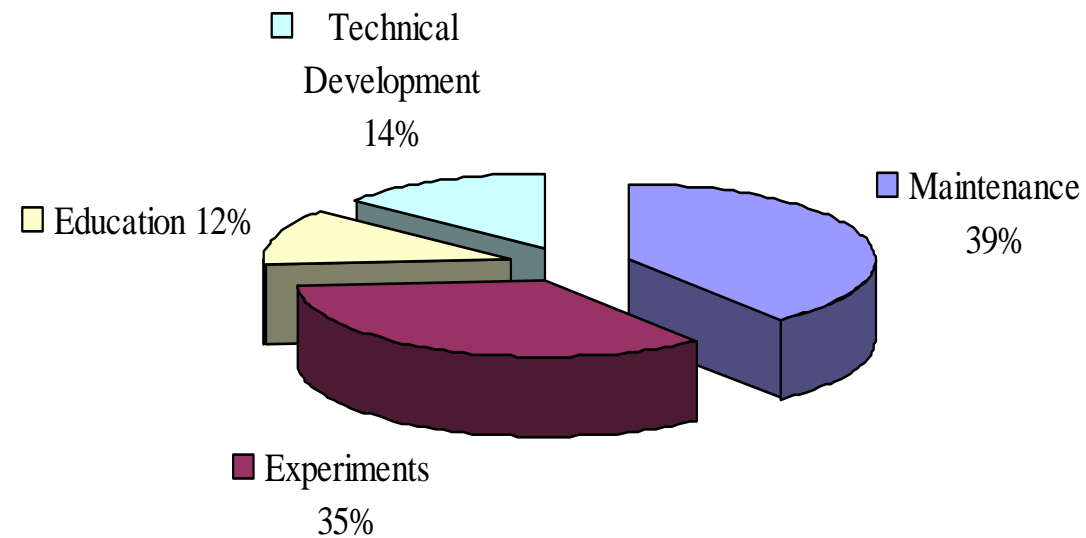
Statistiche



Beam statistics



S1





Finanziamenti



anno	Università k€	Dip. k€	INFN k€	Tot k€
1999	12,5 (25 ML)		6,5 (13 ML)	19
2000				
2001	12,9		6,7	19,6
2002	12,9		6,7	19,6
2003	12,6		6,7	19,3
2004	12,3		6,7	19
2005		-0,4	6,7	6,3
2006		3,3	6,7	10
2007		0,3	6,7	7
2008		0,3	6,7	7
2009		6	8	14
2010			8	8
2011			8	8
2012			8	8
2013			8	8
2014				



Computer monitoring and automatic operations



Monitoring:
LE and HE column current,
Corona Current, Terminal
Voltage, Radiations, ...

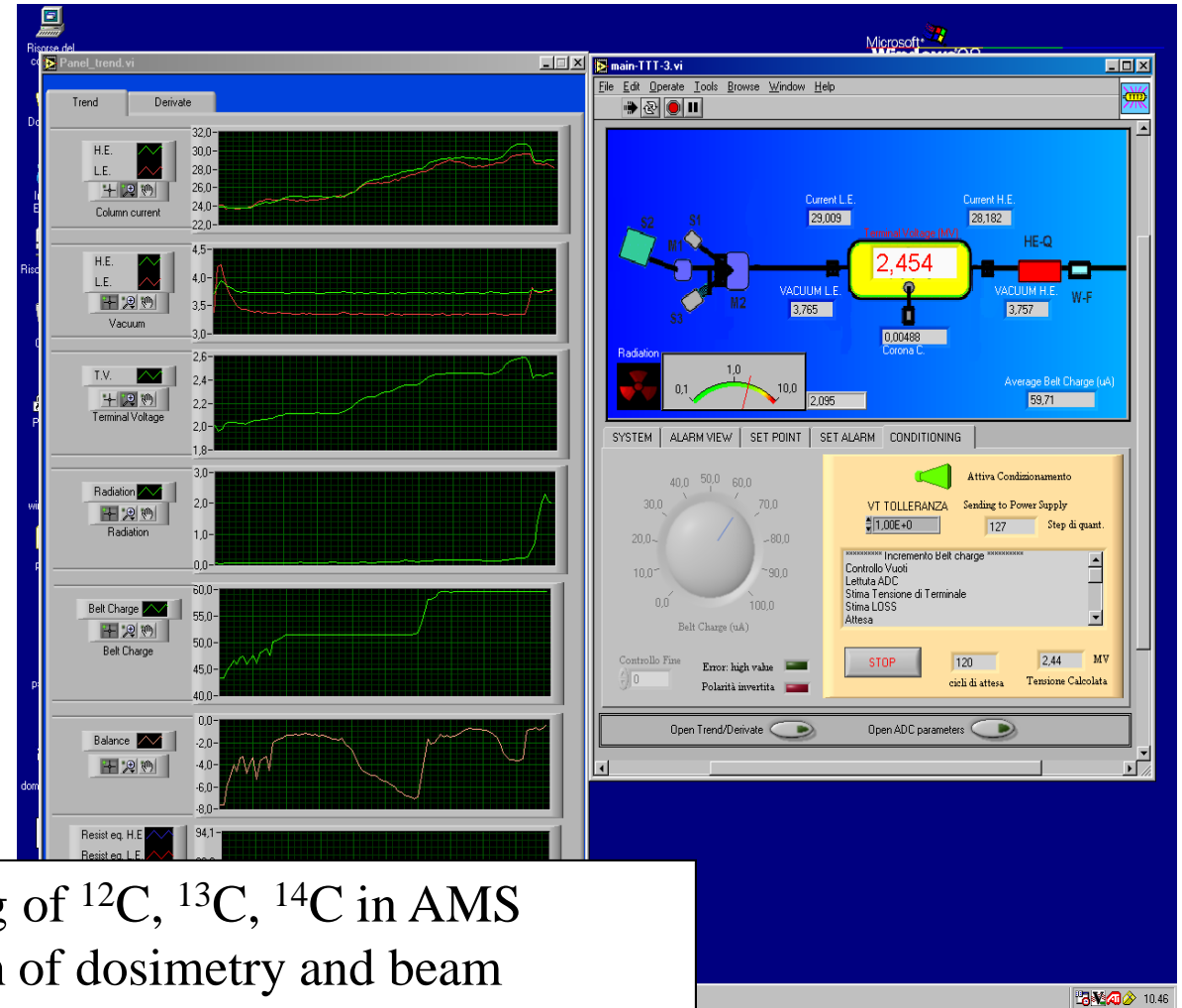
Automatic management:
Pumping systems (pumps,
gauges, valves ...), Van de
Graaff
Automatic shutdown
...

Automatic conditioning
and setting of Term.Volt.

Automatic measurements



- Fast cycling of ^{12}C , ^{13}C , ^{14}C in AMS
- Automation of dosimetry and beam uniformity in biophysics and implantation





Main improvements

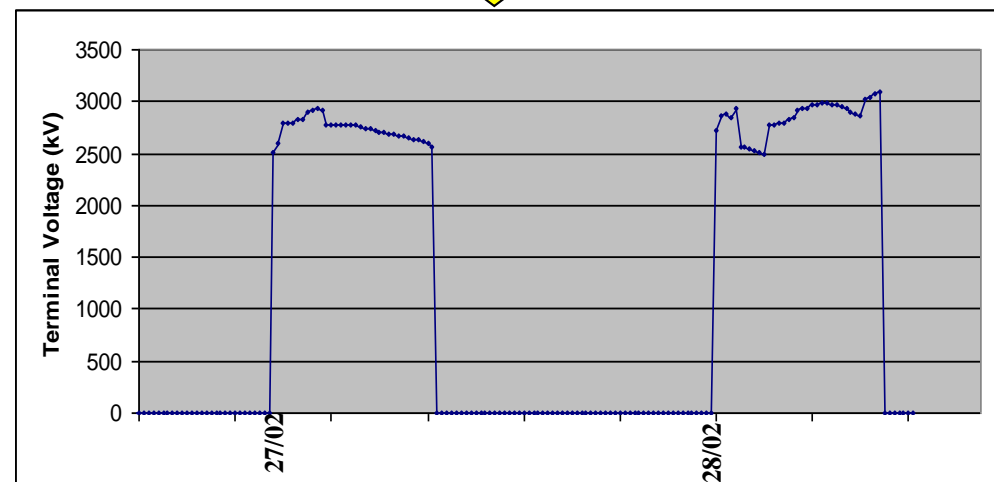
- Very accurate alignment of the tubes within the columns.
- Modification of the spark gaps and of electrical configuration of the first electrodes.
- Improved handling of SF₆

- Life time of the belt charge: > 11 y
- Long duration of the strippers
- Reduced ripple (< 300 V P-P)

Two days working after half a day of conditioning

$$TV_{\max} = 3,4 \text{ MV}$$

Improvement of the maximum terminal voltage
Reduced conditioning time





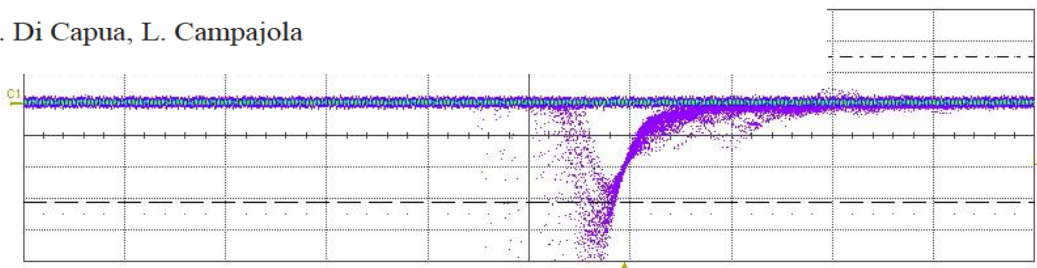
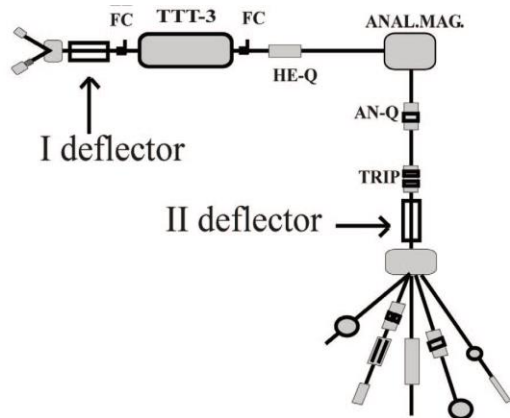
Beam Pulser



978-1-5090-1642-6/16/\$31.00 ©2016 IEEE

A Beam Pulser at the TTT-3 Tandem Accelerator of the University of Naples

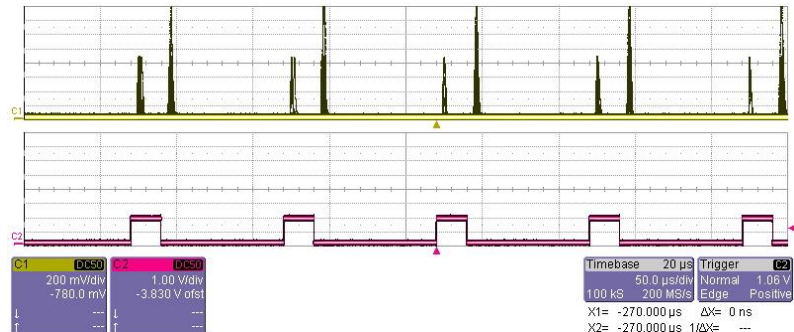
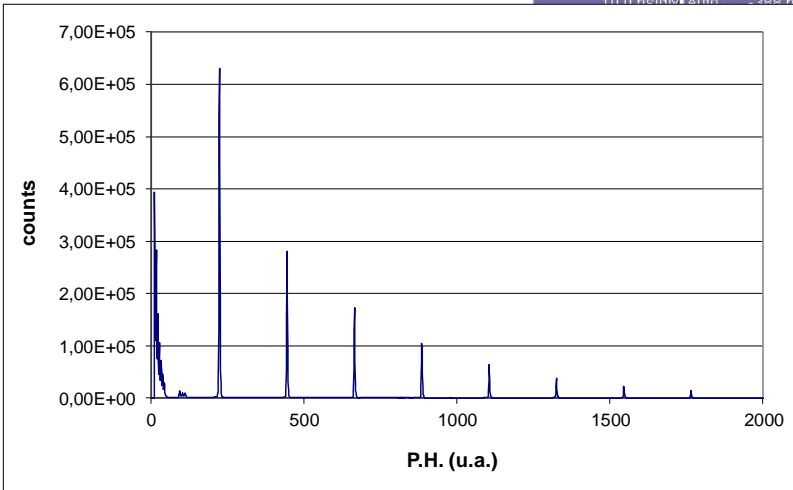
F. Di Capua, L. Campajola



Measure	P1:max(C1)	P2:freq(C2)	P3:freq@v(C1)	P4:freq(F1)	P5:width(C1)	P6:--	P7:--	P8:--
value		91.125 MHz			3.339 ns			
status		OK			OK			

C1	DC50
200 mV/div	200.0 mV
-----	298 mV
-----	-626 mV

Timebase	9.4 ns	Trigger	C1
	10.0 ns/div	Auto	298 mV



Luigi Campajola

A beam pulser at the TTT-3 tandem accelerator of the University of Naples

L. Campajola^{1,2}, F. Di Capua^{1,2}

¹Dipartimento di Fisica E. Pancini, Università di Napoli Federico II, ²Istituto Nazionale di Fisica Nucleare (INFN), Italy

Introduction

The continuous beam provided by the TTT-3 accelerator of Naples has been pulsed with five long bunches to allow some experiments in many fields of the fundamental and applied physics. A beam pulser is designed to produce bunches of particles in a wide range of masses and energies. The pulse length can be varied from about 5 ns to 100 ns and the pulse repetition rate is stable in a large range from few Hz to 100 kHz. The beam pulser is based on two electrostatic deflector, one located before the accelerator and one after the analyzing magnet. The main features of the deflector are the physical flexibility in use and the cool for the system. It is based on standard low-cost electronic line technology. The characteristics of the low energy chopper prototype and the results obtained during preliminary tests with a proton beam are presented.

The Naples 3 MV tandem accelerator, manufactured by High Voltage Engineering Corporation, is in operation since 1977. At the beginning it was equipped with a RF source, a 50° analyzing magnet and a general purpose scattering chamber. Over the years the number of ion sources and beam lines, the increased and several improvements have been made to the accelerator system to overcome the needs of experiments: nuclear physics, radiocarbon dating, ion beam analysis, biophysics, ion implantation, electron microscopy, etc.

The Naples Tandem Accelerator: the beam and the control room.

The beam pulser is obtained through two electrostatic deflectors. To get very intense beam and of short duration pulses concerning the limitation of the loading of the tubes a test deflector is placed in the low energy section, before the entrance of the beam in the accelerator. In this way it is possible to inject many beams in the accelerator but of short duration. The average load is hereby reduced and capacitance of the terminal of the accelerator is sufficient to deliver the required current without leading to a significant voltage drop. A second deflector, synchronized with the test deflector, is placed in the high energy section and provides to clean up the beam pulse from the time-lagging produced by acceleration and beam transport.

The operating principle consists in deflecting the beam coming from the source transversally across a slit producing on the way a bunch processing through the slit for a short time lapse. The duration of the bunch does not depend, on its way, on the size of the applied high voltage.

A constant voltage V_1 is applied to one of the electrodes while the other electrode is applied a square wave of amplitude $V_2 = 2 \cdot V_1$. The beam is deflected a half in position B when the voltage of the square wave is $V_2/2$ and no beam is transmitted through the slit. When $V_2 = 2 \cdot V_1$ the voltage difference is maximum and the beam is directed toward the position A. In this way the beam is transmitted through the slit as a pulse. The beam depends only on the width of the slit and the distance A-B, that is from the voltages V_1 and V_2 . The duration of the bunch does not depend, therefore, on the rise time of the high voltage applied, provided that the distance A-B is greater than the opening of the slit.

Results and conclusions

Each detector consists of a pair of copper electrodes parallel to the beam line: the first is 25 cm wide × 4 cm with electrodes spaced 2.5 cm, while the second is 35 cm long with 2 cm gap.

A constant voltage V_1 is applied to one of the electrodes while the other electrode is applied a square wave of amplitude $V_2 = 2 \cdot V_1$. The beam is deflected a half in position B when the voltage of the square wave is $V_2/2$ and no beam is transmitted through the slit. When $V_2 = 2 \cdot V_1$ the voltage difference is maximum and the beam is directed toward the position A. In this way the beam is transmitted through the slit as a pulse. The beam depends only on the width of the slit and the distance A-B, that is from the voltages V_1 and V_2 . The duration of the bunch does not depend, therefore, on the rise time of the high voltage applied, provided that the distance A-B is greater than the opening of the slit.

The test deflector is 100 cm from the low energy slit.



Main activities



Fisica nucleare



Studio di reazioni nucleari a bassa energia

Biofisica



**Irraggiamento di matrici biologiche con ioni
Studio del danno cellulare**

Analisi di materiali con fasci ionici



**Caratterizzazione di superfici
Misura di elementi in traccia
Studio di nuovi rivelatori
Datazioni archeologiche**

AMS



Impiantazione ionica



Elettronica e nuovi materiali

Radiation hardness



Elettronica e nuovi materiali

Produzione e rivelazione di neutroni



Fisica nucleare di base ed applicata

Didattica



**Diffusione Rutherford
Reazioni nucleari
Misure di stopping power**



Nuclear physics



Z. Phys. A 356, 107–109 (1996)

ZEITSCHRIFT
FÜR PHYSIK A
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Short note

Production of an 8.0 MeV ^7Be ion beam at the Naples TTT-3 accelerator

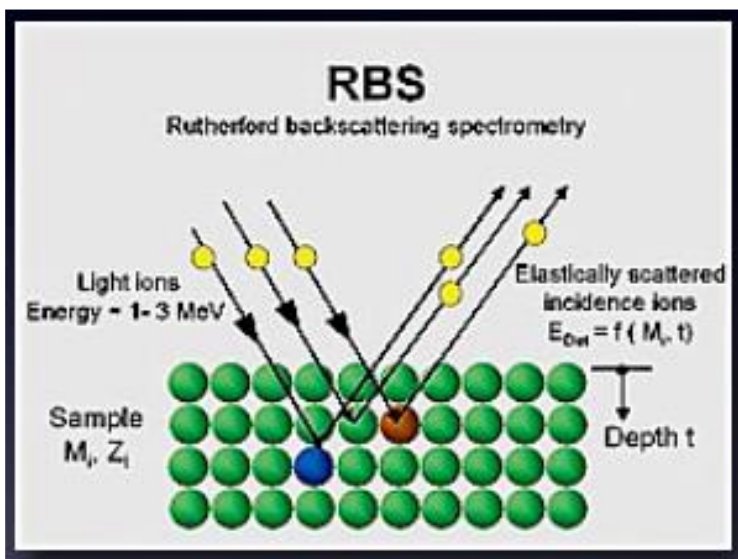
L. Campajola¹, L. Gialanella^{1,2}, K. Brand³, A. D'Onofrio⁴, U. Greife², E. Huttel⁵, R. Kubat⁵, G. Oliviero¹,
H. Rebel⁶, V. Roca¹, C. Rolfs², M. Romano¹, M. Romoli¹, S. Schmidt², W.H. Schulte², F. Strieder², F. Terrasi⁷,
H.-P. Trautvetter², D. Zahnow²

PHYSICAL REVIEW C **78**, 064001 (2008)

Off-energy-shell p - p scattering at sub-Coulomb energies via the Trojan horse method

A. Tumino,^{1,2,3,*} C. Spitaleri,^{1,2} A. Mukhamedzhanov,⁴ G. G. Rapisarda,^{1,2} L. Campajola,⁵ S. Cherubini,^{1,2} V. Crucillá,^{1,2}
Z. Elekes,⁷ Z. Fülöp,⁷ L. Gialanella,⁶ M. Gulino,^{1,2} G. Gyürky,⁷ G. Kiss,⁷ M. La Cognata,^{1,2} L. Lamia,^{1,2} A. Ordine,⁶
R. G. Pizzone,^{1,2} S. Romano,^{1,2} M. L. Sergi,^{1,2} and E. Somorjai⁷

In an elastic collision of a particle with a nucleus of the target, the particle is deflected.



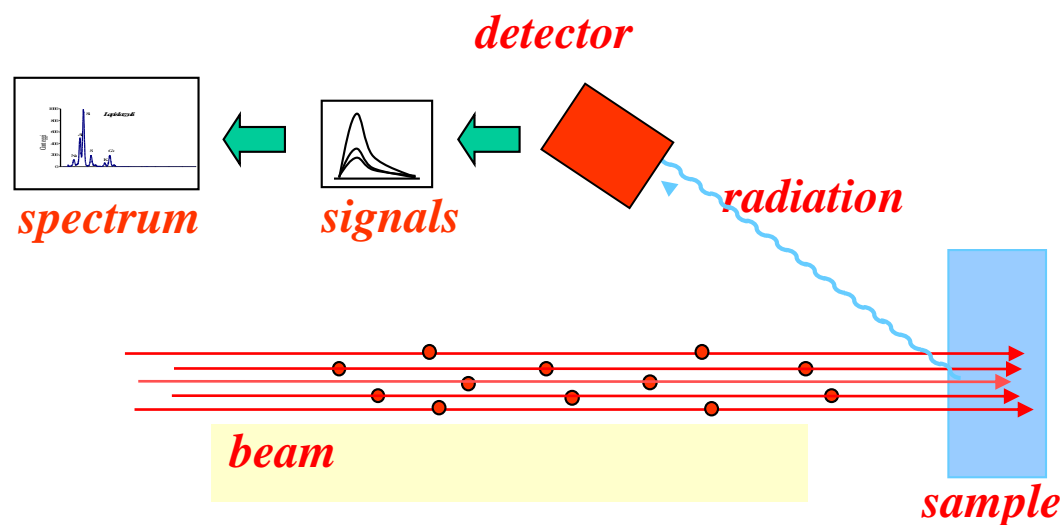
In collisions with nuclei of a given mass M , as the impact parameter decrease:

→ the scattering angle grows

→ the residual energy of the particle decreases



Elemental Analysis: RBS



By the detection of the energy of the particle elastically scattered backward from the nuclei of the target can be determined:



the elemental composition of the sample

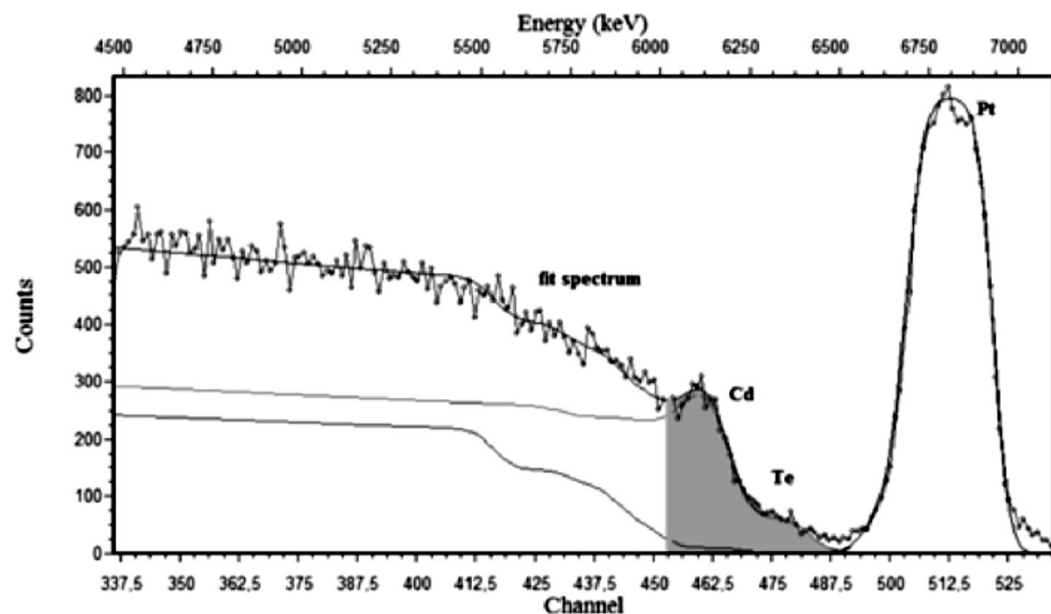


the concentration profile of the elements as a function of depth in the sample



Pt-CdTe Detectors Spectroscopic Performances and RBS and XRF Interface Composition Analysis

A. Raulo, M. Sowinska, G. Hennard, L. Campajola, D. Marano, G. Paternoster, and E. Perillo



La caratterizzazione è stata effettuata mediante la tecnica RBS utilizzando fasci di Li^{3+}



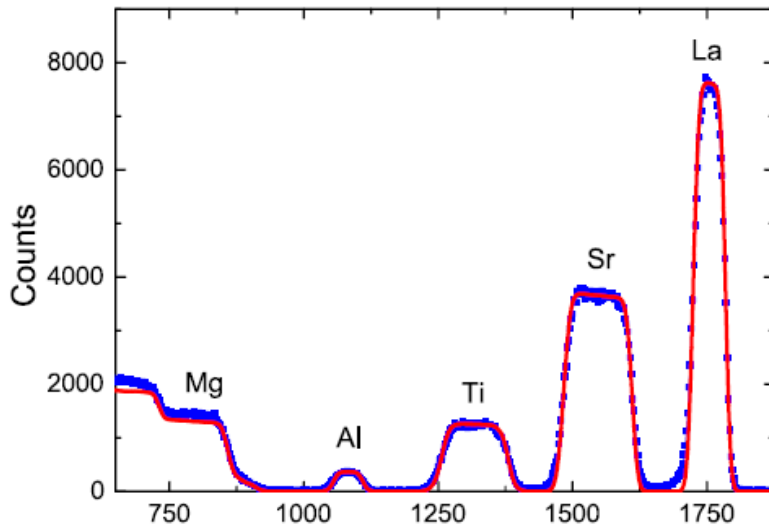
Elemental Analysis: RBS



JOURNAL OF APPLIED PHYSICS **120**, 225306 (2016)



Plasma dynamics and cations off-stoichiometry in LaAlO₃ films grown in high pressures regimes



A. Sambri,^{1,2,a)} Amit Khare,³ S. Mirabella,⁴ E. Di Gennaro,⁵ Akif Safeen,⁶ F. Di Capua,⁵ L. Campajola,⁵ U. Scotti di Uccio,⁵ S. Amoroso,⁵ and F. Miletto Granozio²

¹NEST, Istituto Nanoscienze-CNR, Piazza San Silvestro 12, 56127 Pisa, Italy

²CNR-SPIN, Complesso Universitario di Monte Sant' Angelo, Via Cintia, I-80125 Napoli, Italy

³Department of Physics, Indian Institute of Science Education and Research (IISER), Bhopal 462 066, India

⁴MATIS IMM-CNR and Dipartimento di Fisica e Astronomia, Università di Catania, Via Santa Sofia 64, 95123 Catania, Italy

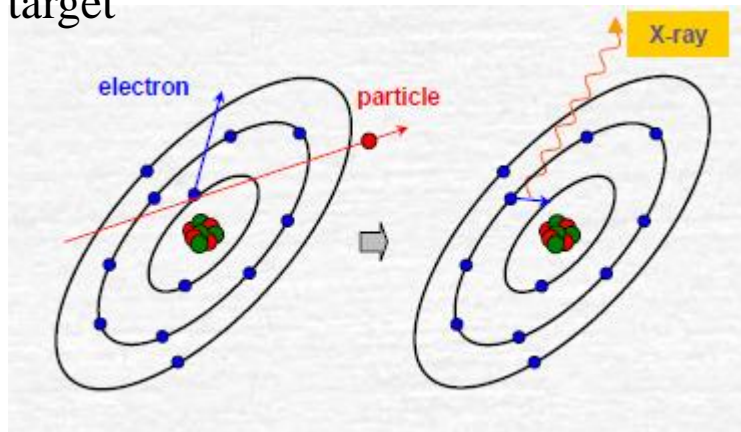
⁵Dipartimento di Fisica, Università di Napoli Federico II, Via Cintia, I-80125 Napoli, Italy

⁶Departments of Physics, Abdul Wali Khan University, Mardan, Pakistan

La caratterizzazione dei rapporti La/Al è stata effettuata mediante la tecnica RBS utilizzando fasci di C³⁺

The PIXE technique is used for analysis of low concentrations (trace elements)

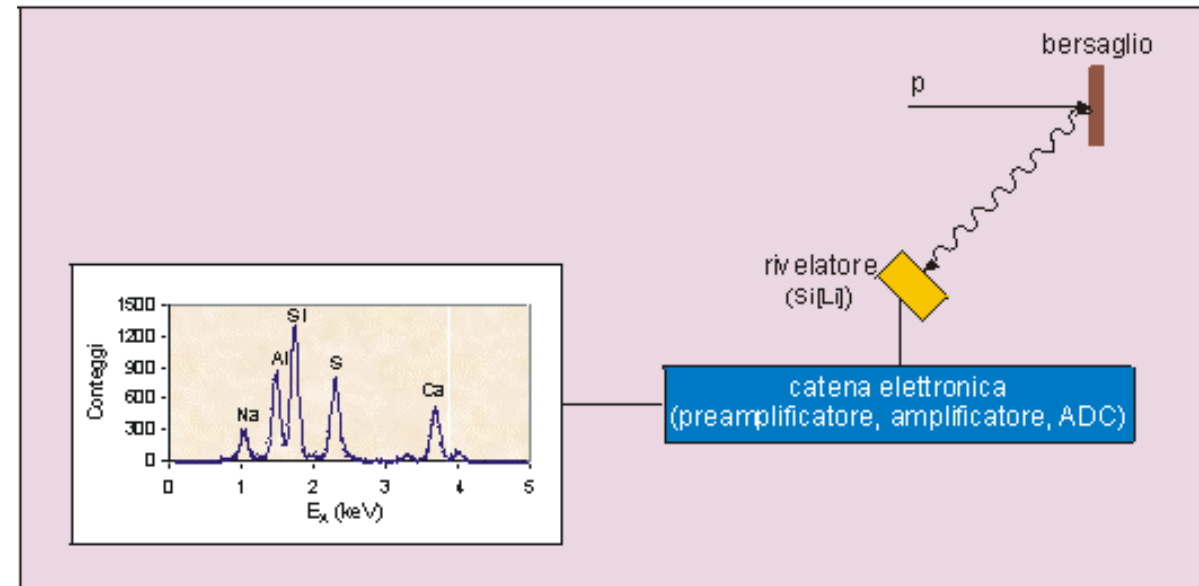
It is based on the process of X-ray emission that occurs when a beam of charged particles causes the ionization of one of the inner shell (K or L) of the atom target



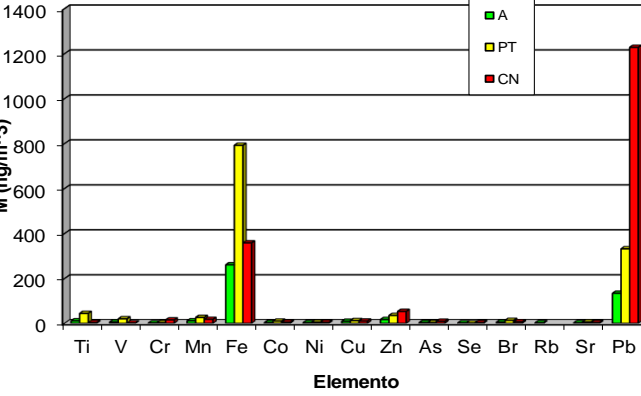
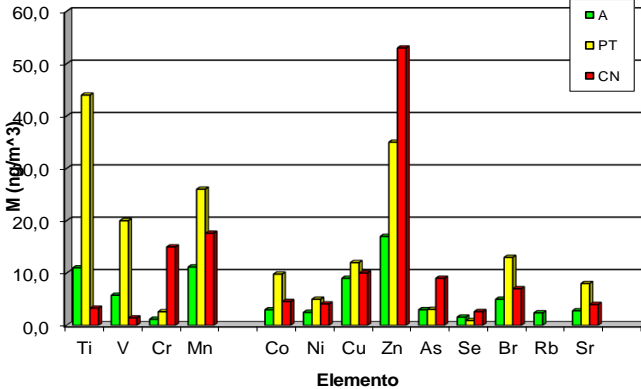
With characteristic times of the order of 10^{-15} s the atom returns to its stable state by filling the gap with an electron from an outer shell

The energies of electrons in different atomic levels are characteristic of each atomic species.

The energies of electrons in different atomic levels are characteristic of each atomic species.



Confronto tra il contenuto degli elementi in traccia nel particolato atmosferico campionato in tre siti

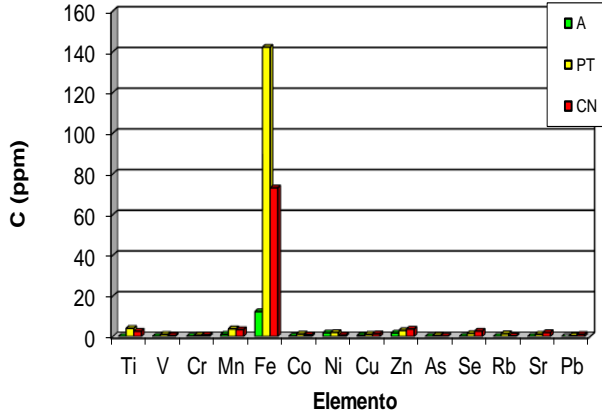
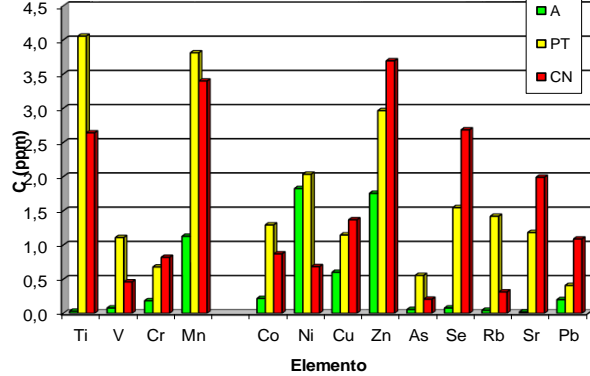


**Astroni
Piazzale Tecchio
Corso Novara**



La correlazione esistente tra i contenuti nel particolato atmosferico e nelle foglie di Leccio (alberi cittadini) permette di definire procedure di misura semplici senza la necessità di attrezzature complesse.

Confronto tra i contenuti degli elementi in traccia in foglie di Leccio di tre siti

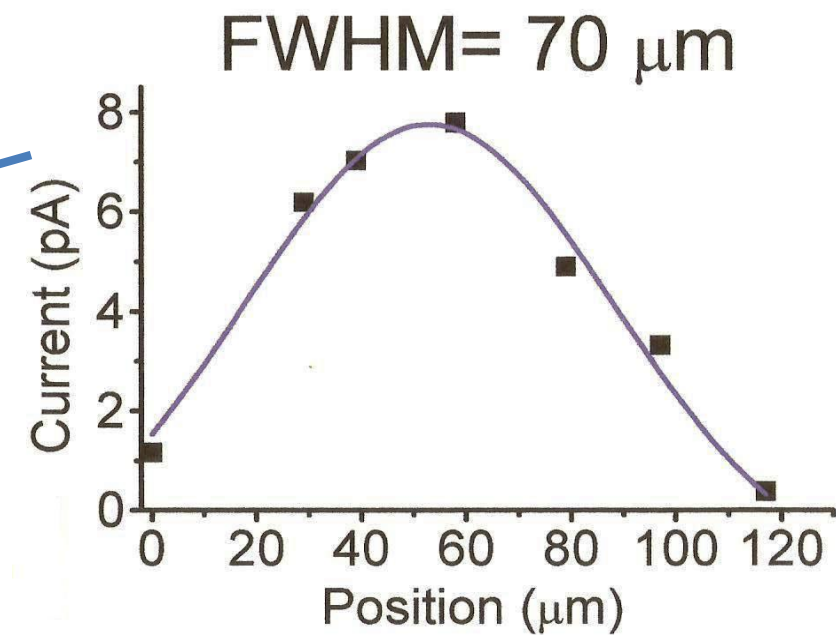
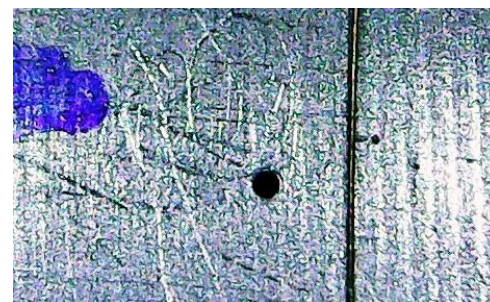
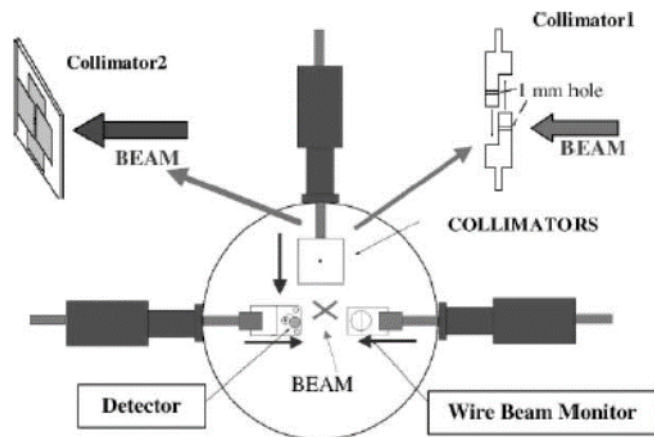


Response of semi-insulating GaAs detectors to low energy protons

P. Russo^{a,b,*}, L. Campajola^{a,b}, C. Carpentieri^a, E. Bertolucci^{a,b}

^a Dipartimento di Scienze Fisiche, Università Federico II, Napoli, Italy

^b I.N.F.N., Napoli, Italy





AMS: ^{14}C



Notizie Storiche

In un antico codice del 9° secolo che narra del martirio di S.Emiliano (o Miliano), primo vescovo di Trevi, si legge che “lo legarono ad una giovane pianta d’olivo” per decapitarlo. Correva l’anno 304 d.C; di origine armena, Emiliano fu inviato a reggere la chiesa locale, ma in seguito all’editto di Diocleziano, fu preso e dopo numerosi supplizi, fu legato ad un olivo novello e poi messo a morte.





AMS: ¹⁴C



Magia rossa

Da domani la mostra di preziosi a Palazzo Vallelonga di Torre del Greco

STELLA CERVASIO

IN OCCIDENTE approdavano spezie. In cambio verso l'Oriente, percorrendo le stesse strade carovaniere, viaggiava una gemma color del sangue, capace di guarire tremende malattie, di salvare i lattanti dai mali oscuri, e di ornare le donne facendole belle come nessuna: il corallo. Torna la biennale di Natale nella capitale dell'Oro rosso, Torre del Greco. La rinno-va, come un appuntamento fisso, la passione dei dirigenti della Banca di Credito Popolare (in ca-po il presidente Antonino De Si-mone), che si sono rivolti a un'an-tropologa, Cristina Del Mare, anch'essa presa dalla magia del corallo, per realizzare ad anni alter-ni una mostra e un libro. Il 2002 è la volta della mostra, che accende le luci sul corallo etnico del nuo-vo paese «visitato» per ricostruire la storia degli scambi tra Oriente e Occidente: lo Yemen, regno del-la regina di Saba, che forse prop-rio con un collier di sanguigno gemme addosso sedusse Salo-mone. Oggi alle 18 nel settecente-

PEZZI D'ARTE

IN ARGENTO
Una collana di manifattura yemenita

IN ORO
Un'Agd dell'800 in corallo mediterraneo

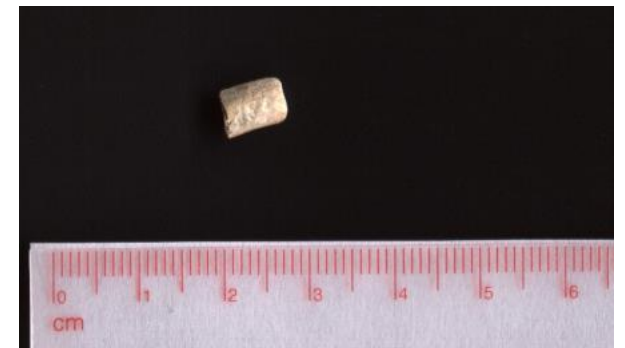
**“Le vie del corallo”
la gemma che lega
l'Asia all'Occidente**



Ornamento in elementi di corallo ritrovato in un sito archeologico della regione dello Yemen centrale

Ornament with coral elements from an archaeological site in central Yemen

**Campione di corallo dal quale è stato prelevato il frammento utilizzato per la datazione:
circa 200 mg
2880 BC – 2440 BC**



Aperta fino al 19 gennaio a Palazzo Vallelonga a Torre del Greco

Una mostra unica al mondo con un corallo di 4500 anni fa

di Felice Cavallaro

È un pezzo di corallo etnico, quello che si trova in un sito archeologico in un villaggio di nome Agd, in provincia di Tarso, in Arabia Saudita. È un pezzo di corallo che si trova in un sito archeologico in un villaggio di nome Agd, in Arabia Saudita. È un pezzo di corallo che si trova in un sito archeologico in un villaggio di nome Agd, in Arabia Saudita.

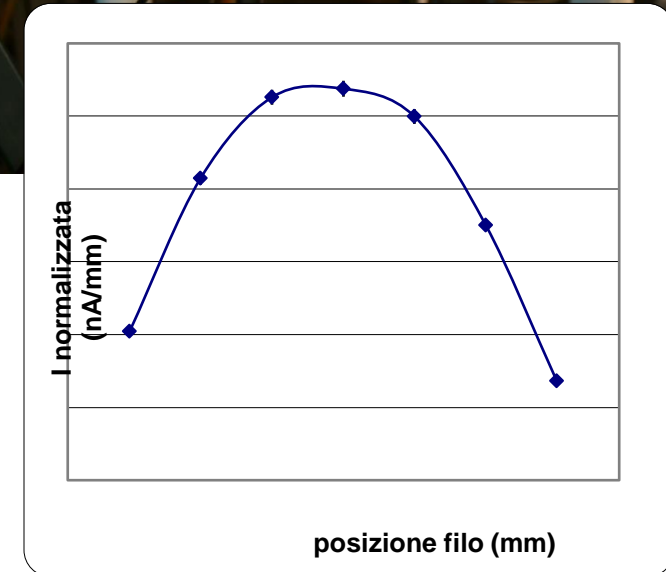
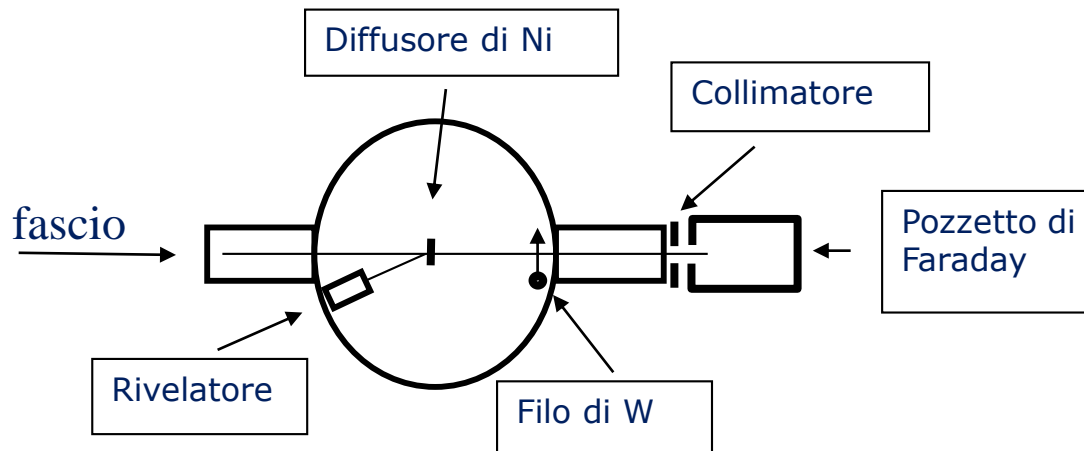
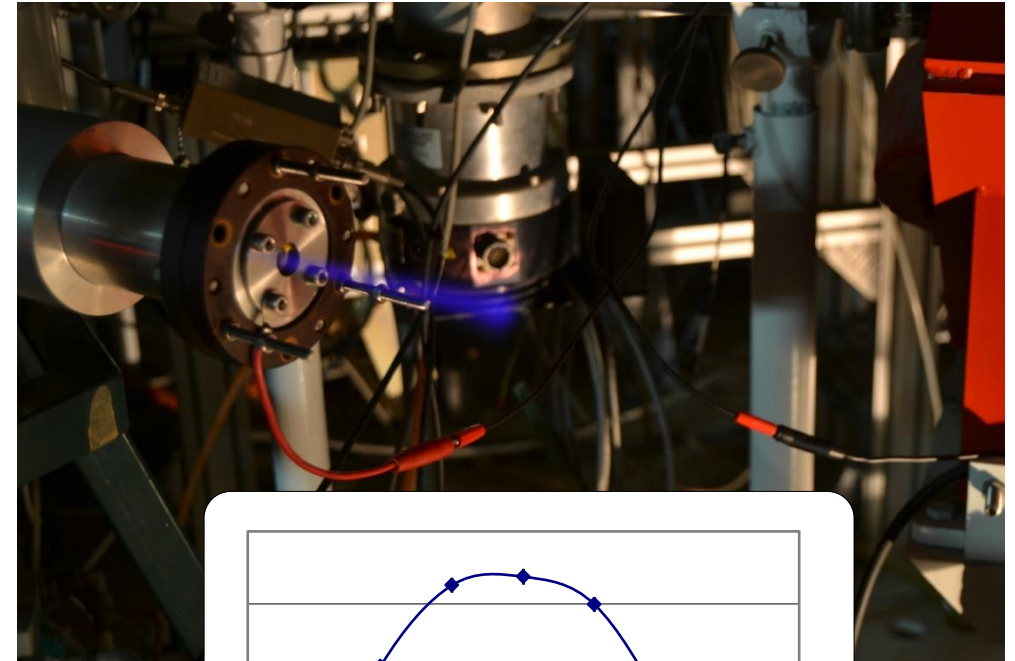
La mostra è unica al mondo perché è la prima volta che un corallo di 4500 anni fa viene esposto in Italia. Il corallo è un materiale prezioso che viene utilizzato per la produzione di gioielli e per la medicina tradizionale.

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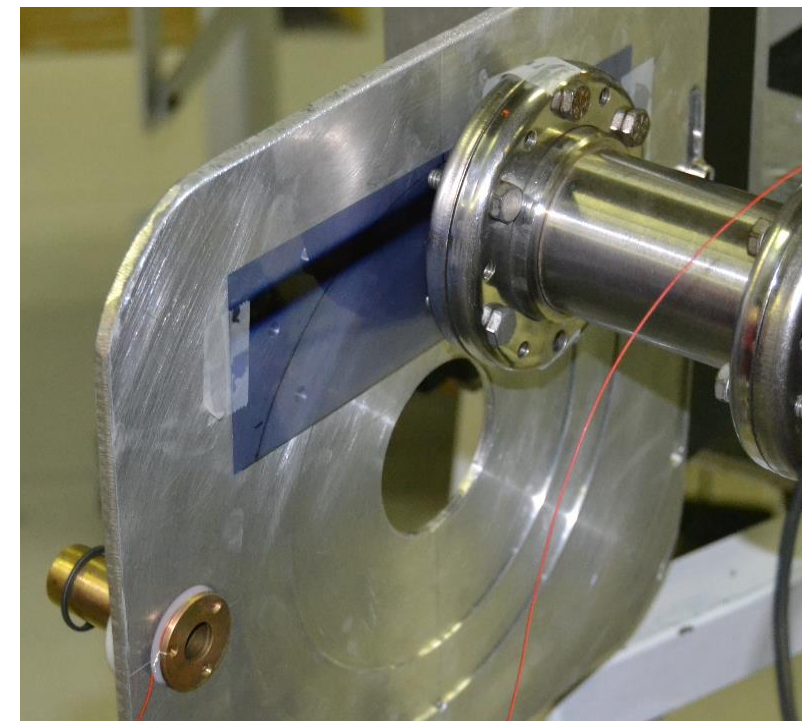
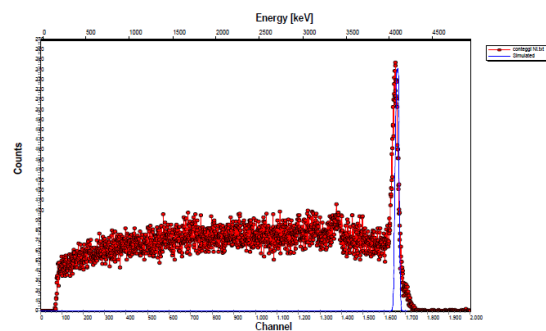
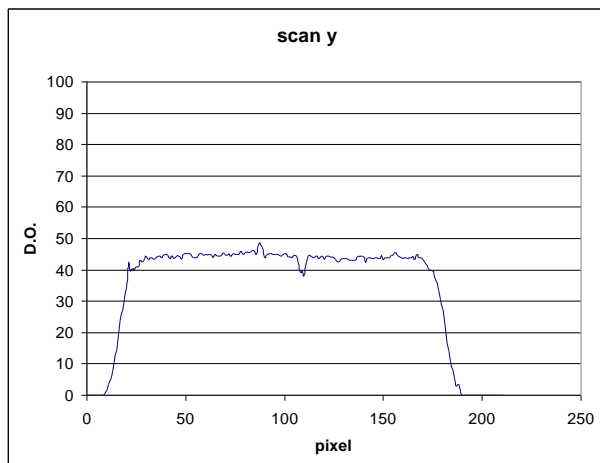
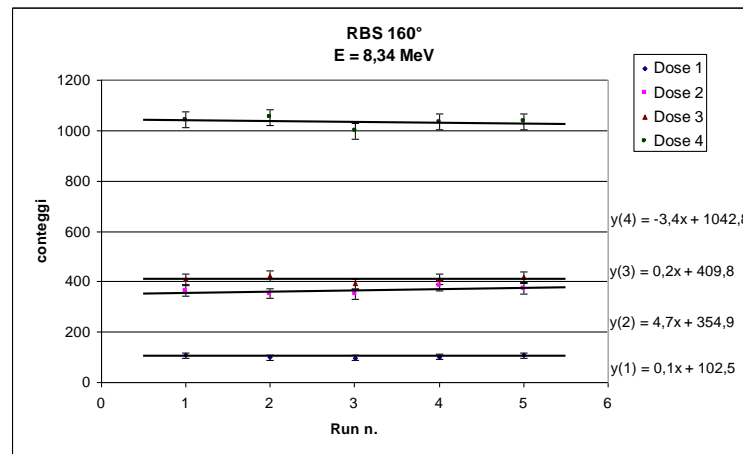
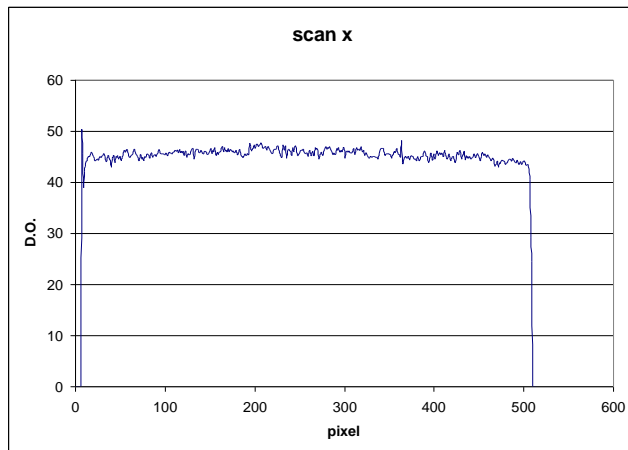
Controllo di uniformità del fascio, flusso e fluenza:

- RBS su foglio sottile di Ni impiegato anche come diffusore
- Scanning con filo di tungsteno
- Faraday Cup con lettura periodica
- Pellicole radiocromiche (GAF) per uniformità e dose





Ion implantation





Absolute dosimetry



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Absolute dose calibration of EBT3 Gafchromic films

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Via Cinthia, Napoli, 80126 Italia

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Napoli, Italy



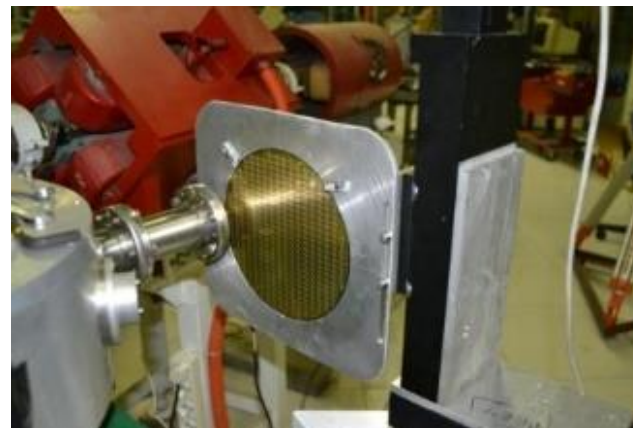
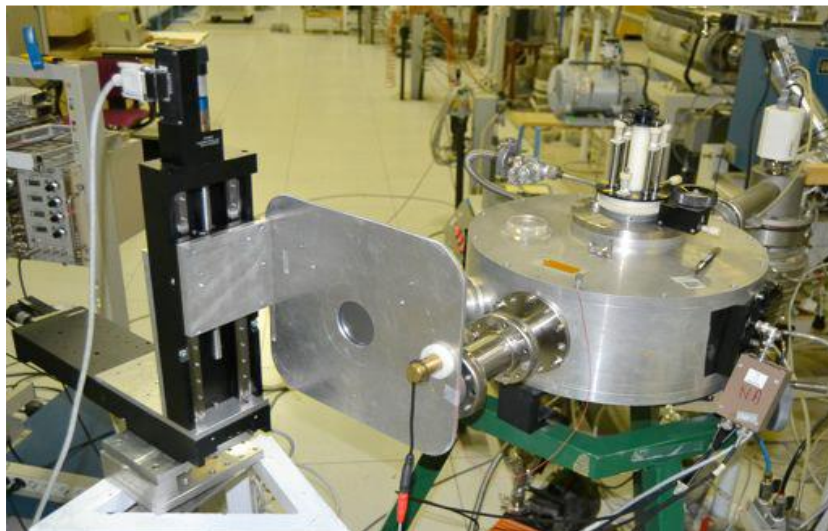
Ion implantation



Struttura dei MOSFET e IGBT.

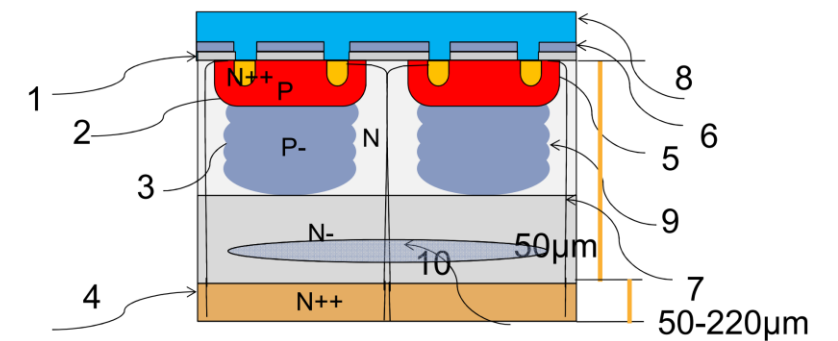
Fronte	Al	SiO ₂	Si	Si	Retro
	4,5 mm	1 mm	0,5 mm	274 mm	

Fronte	Si	Si	Al	Ni-V00	Ag	Retro
	100 mm	30 mm	100 0 A	0 A	150 0 A	



Luigi Campajola

SECTION VIEW OF A SJ POWER MOSFET

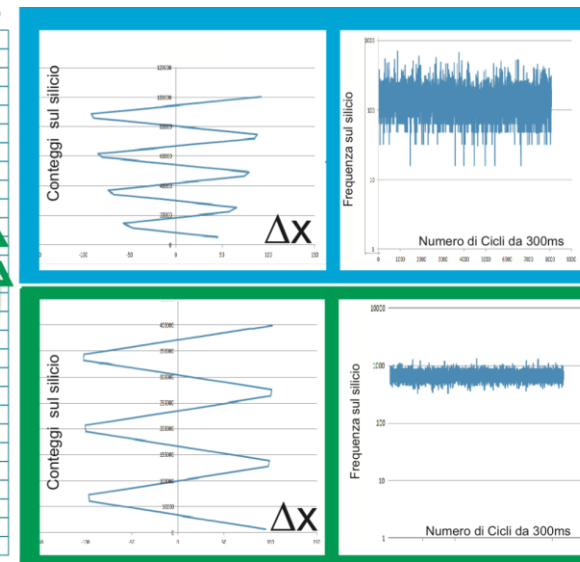
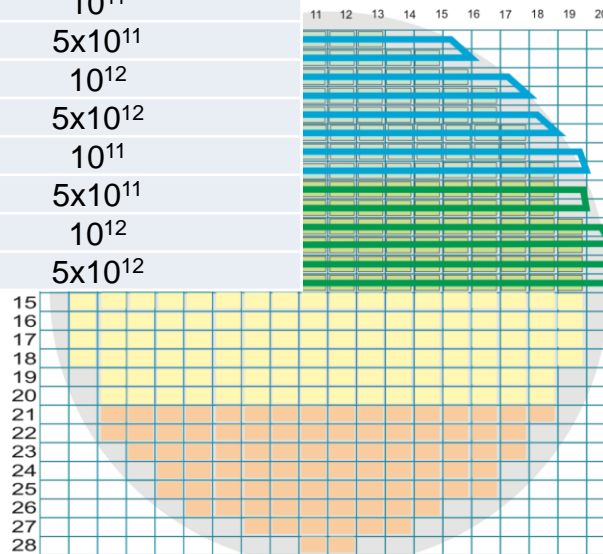




Ion implantation



Waf. ID	E (MeV)	Irradiat. side	Depth (mm)	Reg.	Beam Int. (nA)	Dose (protons/cm ²)
5240335-14H0	5.74	Back	240	1	2.5	10^{11}
				2	13	5×10^{11}
				3	25	10^{12}
				4	34	5×10^{12}
5240335-15G3	5.60	Back	230	1	2.5	10^{11}
				2	13	5×10^{11}
				3	25	10^{12}
				4	50	5×10^{12}
5240335-13A2	2.17	Front	40	1	2.5	10^{11}
				2	13	5×10^{11}
				3	25	10^{12}
				4	38	5×10^{12}
5240335-16F6	2.41	Front	50	1	2.5	10^{11}
				2	13	5×10^{11}
				3	25	10^{12}
				4	36	5×10^{12}





Radiation hardness application with low-energy protons



esa

A Novel Method for SEE Validation of Complex SoCs Using Low-Energy Proton Beams

Gianluca Furano, T. Szewczyk, S. Di Mascio, M. Ottavi, A. Menicucci, L. Campajola, F. Di Capua, A. Fabbri

ESA-ESTEC Data System Division

DFT 2016 UCONN - 18 September 2016

European Space Agency

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2016 11th International Conference on Design & Technology of Integrated Systems in Nanoscale Era
(DTIS)

Qualitative techniques for system-on-chip test with Low-Energy Protons

Stefano Di Mascio^{*†}, Marco Ottavi^{*}, Gianluca Furano[†], Tomasz Szewczyk[†], Alessandra Menicucci[‡], Luigi Campajola[§] and Francesco Di Capua[§]

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campajo@na.infn.it, dicapua@na.infn.it



Radiation hardness





Neutrons



Produzione di neutroni attraverso le reazioni:



- Produzione del fascio di deutoni mediante sorgente RF e/o sorgente sputtering modificata
- Realizzazione del canale dedicato con camera di scattering per la rivelazione della particella associata ^3He



Neutrons

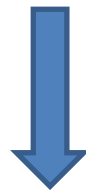




Educational Activity



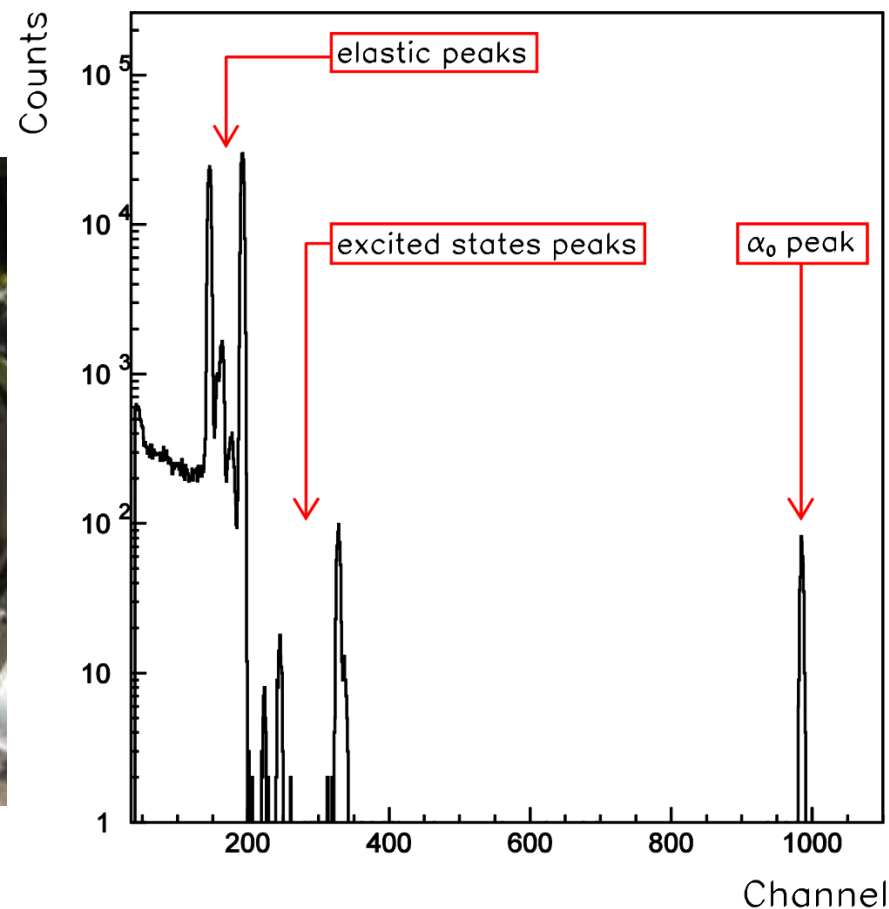
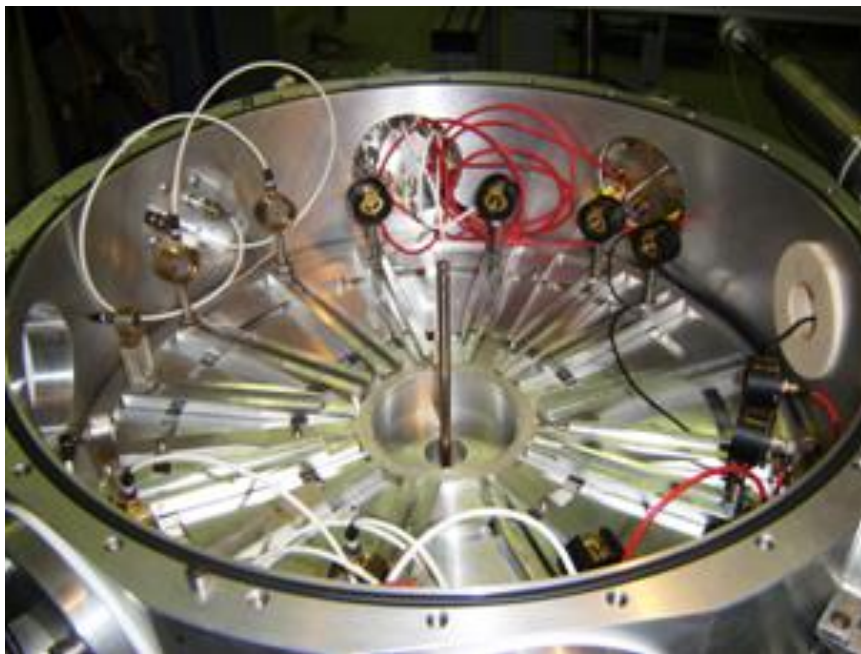
- Tesi di laurea magistrale
- Attività sperimentali connesse al corso di «Particle Accelerators» del dottorato in Fisica
- Laboratorio del I anno del corso di Laurea Magistrale in Fisica



3 gruppi/anno (3 studenti/gruppo)

- Diffusione Rutherford
- Reazioni Nucleari
- Misure di perdite di energia
- Spettroscopia nucleare
- AMS

Studio della reazione $^{19}\text{F}(p,\alpha)^{16}\text{O}$



- Diffusione elastica del protone su ^{12}C , ^{16}O , ^{19}F , ^{137}Ba
- Stati eccitati dell' ^{16}O (α_3 , α_2 , α_1 , α_π)
- Picco $\alpha_0 \rightarrow E_{\alpha_0} = 6.96\text{MeV}$?

Cosa si può fare con una reazione nucleare ?

- Analisi elementare: RBS
- Spettroscopia nucleare
- Modelli atomici
- Meccanica quantistica
- ...



Educational Activity



Studio della reazione $^{19}\text{F}(p,\alpha)^{16}\text{O}$

- Verifica sperimentale del principio di equivalenza massa-energia
- Verifica delle leggi di conservazione (energia, impulso, momento angolare)
- Verifica del modello di Rutherford
- Analisi composizionale
- Spettroscopia nucleare (^{16}O)
- Meccanica quantistica
- Confronto tra formule classiche e formule relativistiche

The image shows the cover of the European Journal of Physics. It features a red header bar with the URL 'www.ejop.org'. Below the header is a globe icon and the title 'European Journal of Physics' in a large, bold font. Underneath the title is the subtitle 'For physics teachers in university-level education' in a smaller, red font. The background is a light blue gradient.

Educational activities with a tandem accelerator

Pierluigi Casolaro, Luigi Campajola, Emilio Balzano, Eliana D'Ambrosio, Rodolfo Figari, Emanuele Vardaci and G La Rana

Fine