Status of the INFN-LNS accelerator facility

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ECOS Facility Meeting

Orsay, France, May 16, 2013

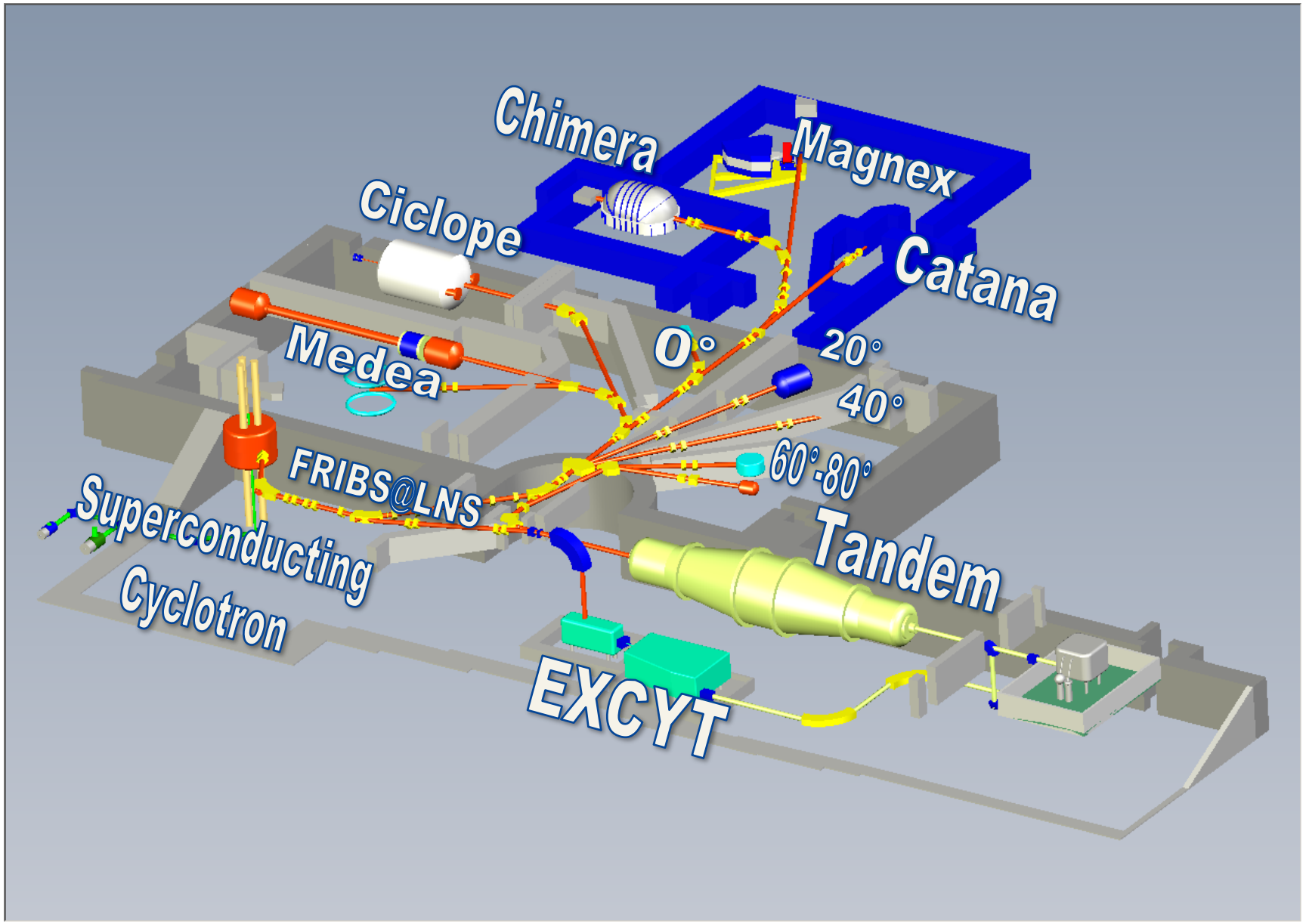
INFN Laboratori Nazionali del Sud

INFN ISTITUTO NAZIONALE DI FISICA NUCLEARE

LNS LABORATORI NAZIONALI del SUD - CATANIA

- Personnel : 109
- Associated (University) : 110
- Users : 220 per year (110 foreigners)
- Budget: 10 M€ per year (excl.salaries)

LNS lay-out: accelerators and experimental halls



The LNS Accelerators

Superconducting Cyclotron

Compact (and complex) isochronous cyclotron designed for acceleration of ions with variable mass and energy (0.01<q/A<0.5, 8 AMeV<E<100 AMeV)

Nuclear Physics (multifragmentation with 4π detectors): good timing quality

Applications (beam interaction with biological matter, radiation hardness, superconducting materials)

Protontherapy: reliability

Primary accelerator for production of radioactive beams (ISOL and IFF):high intensity

Tandem

Electrostatic accelerator for ions with variable mass and energy (Vmax=13 MV)

Nuclear Physics (nuclear structure)

Nuclear astrophysics

Applications (cultural heritage, radiation hardness, superconducting materials)

Post-accelerator of radioactive beams (ISOL)

Ion sources

2 ECR sources (one superconducting) for the Superconducting Cyclotron

2 Negative sources for the Tandem

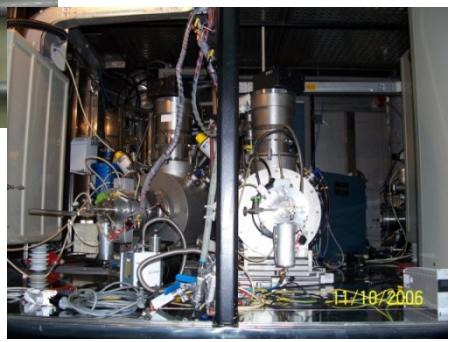
EXCYT

ISOL facility for production and acceleration of radioactive beams at the Tandem energies

FRIBS@LNS

In flight facility for production and acceleration of radioactive beams at the Cyclotron energies

Accelerator equipment for stable beams

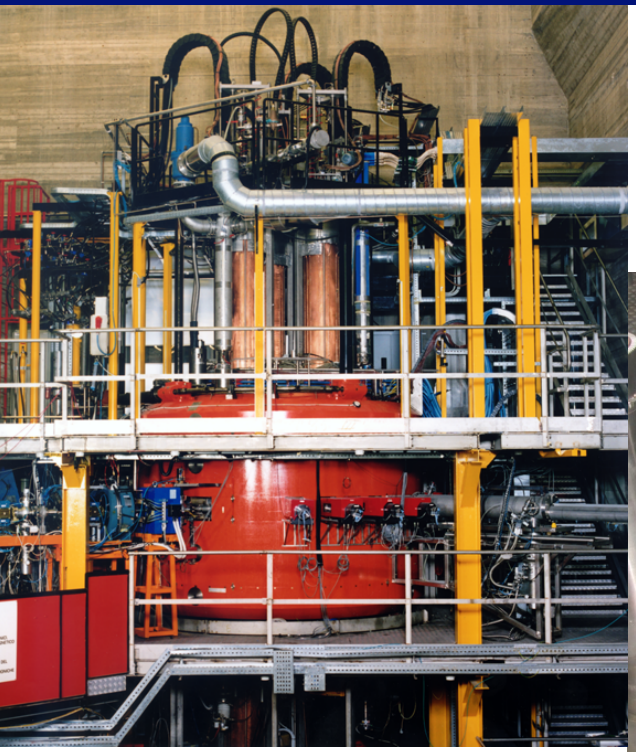


450 KV injector
2 sputtering sources

Normal conducting ECR source CAESAR

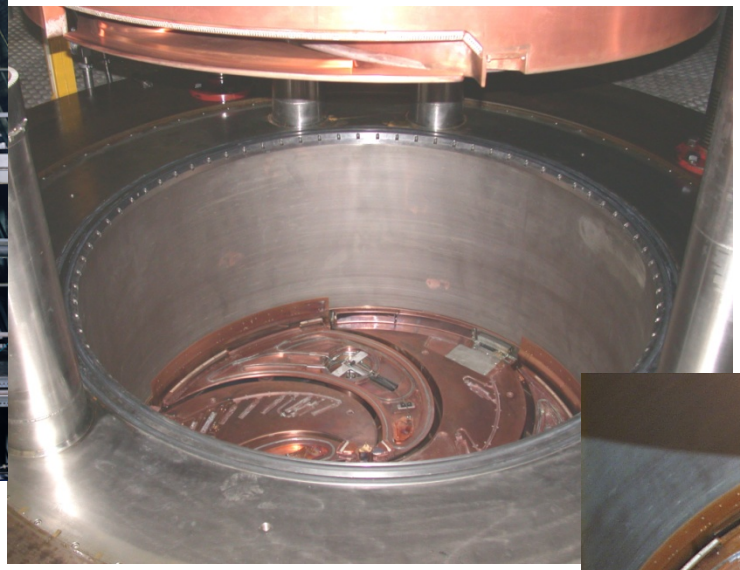
Superconducting ECR source SERSE

The LNS Superconducting Cyclotron



$(T/A)_{max} = K_{bending} (Q/A)^2$ ~ 25 AMeV Au36+

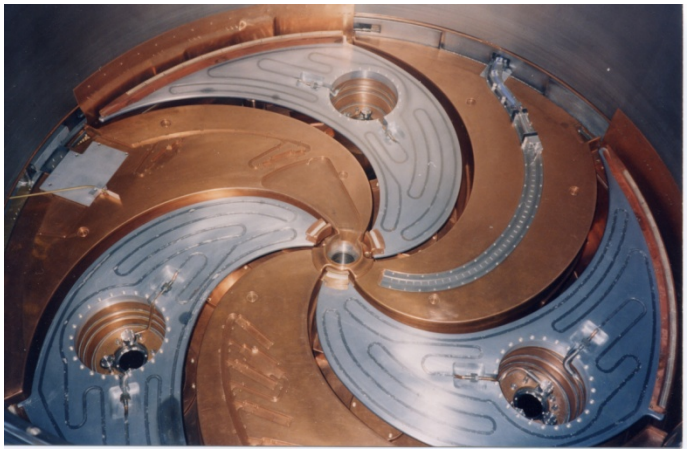
$(T/A)_{max} = K_{focusing} (Q/A)$ 100 AMeV fully stripped

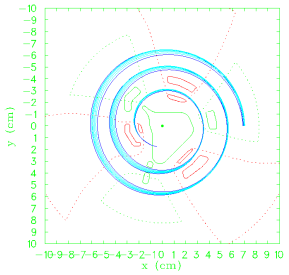


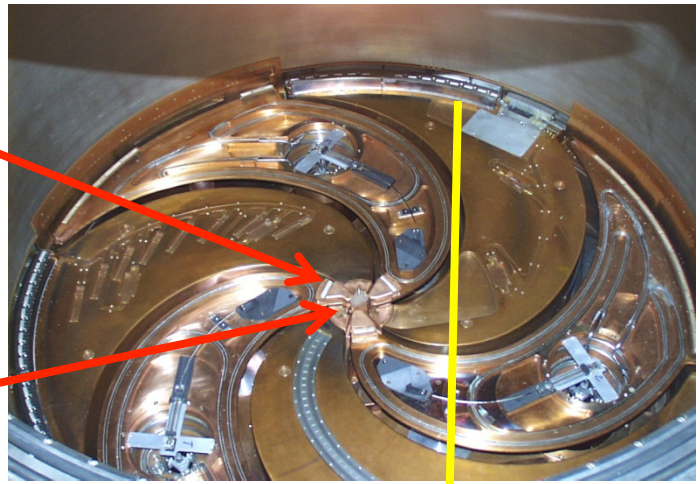
Bending limit	**K=800**
Focusing limit	**Kfoc=200**
Pole radius	**90 cm**
Yoke outer radius	**190.3 cm**
Yoke full height	**286 cm**
Min-Max field	**2.2-4.8 T**
Sectors	**3**
RF range	**15-48 MHz**

Upgrading of the Cyclotron: beam intensity

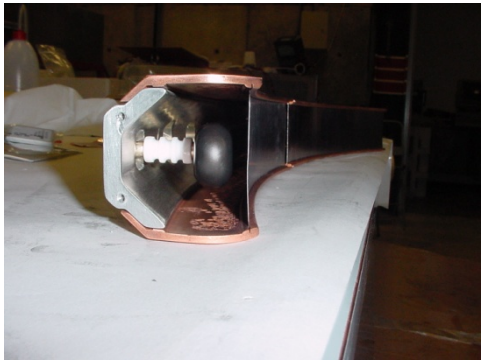
Axial injection allows for intensity enhancement





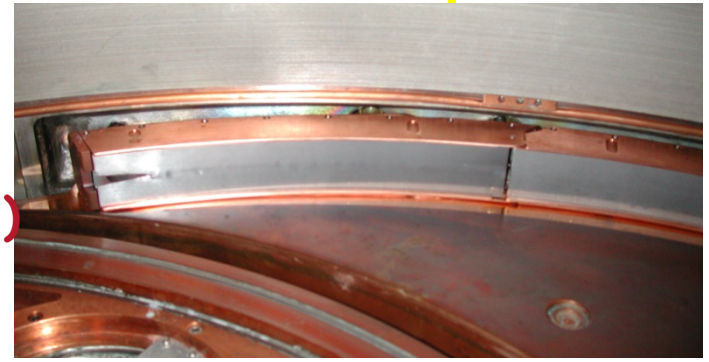


Compactness makes extraction a critical process : ε≈ 50%

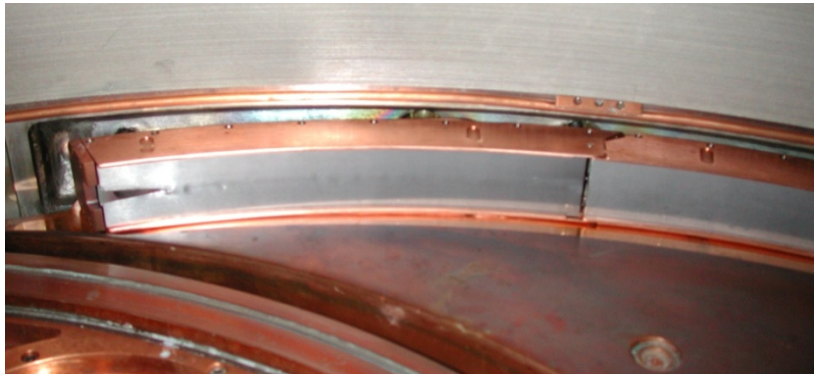


Inter-turn separation

$$\Delta R = R \cdot (\Delta E/E) \cdot (1/\nu_r^2) \cdot \gamma/(\gamma+1)$$



Increasing the Cyclotron beam intensity



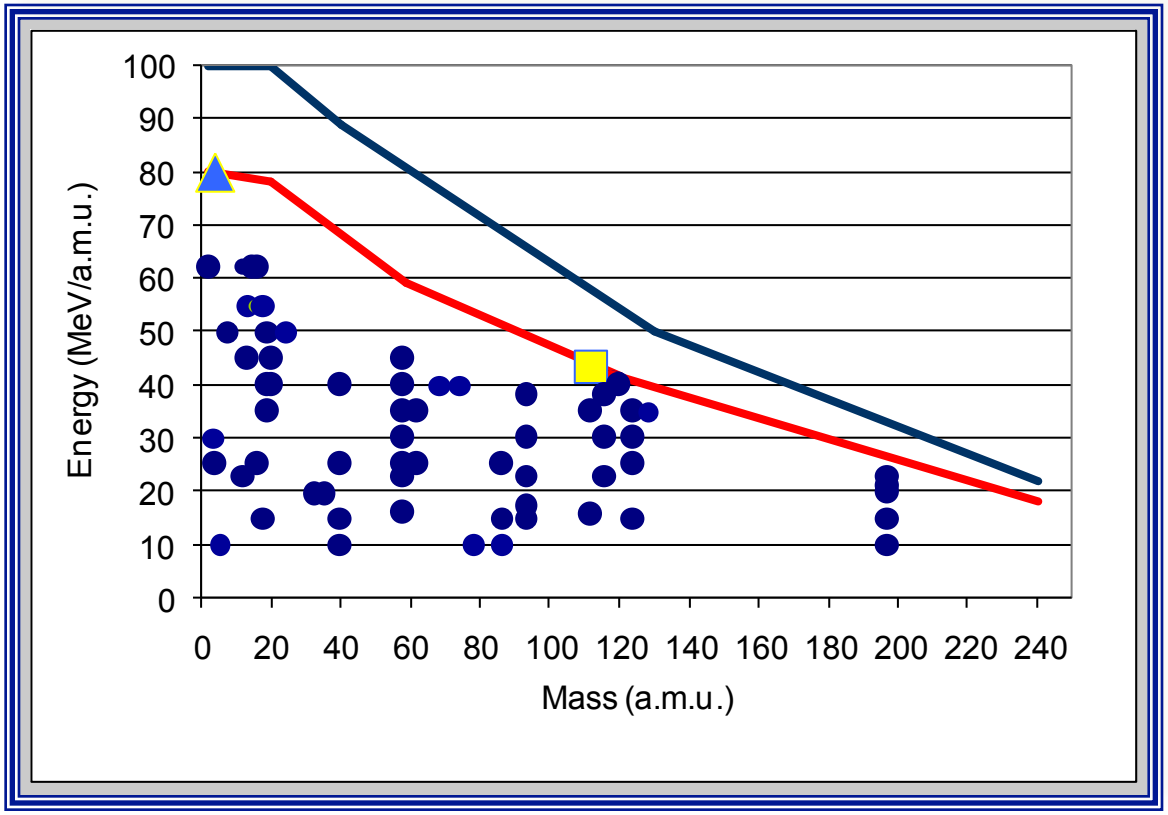
Septum: directly cooled
New septum material: W vs. Ta
Bigger thickness: 0.3 vs. 0.15 mm
⇨extraction efficiency 63% vs. 50%

$^{13}C^{4+}$ @ 45 AMeV (EXCYT primary beam)
Pextr = 150 watt I=1020 enA= $1.5x10^{12}$ pps

The source-cyclotron transmission needs to be improved, the injection efficiency being ~15%

Beam transport along the injection line is now being considered

Superconducting Cyclotron status: beams developed



^{4}He 80 AMeV

^{112}Sn 43.5 AMeV

In red beams with intensity 10^{12} pps

^{A}X	E (AMeV)
H_2^+	62,80
H_3^+	30,35,45
$^{2}D^+$	35,62,80
^{4}He	25,62,80
He-H	10, 21
^{9}Be	45
^{11}B	55
^{12}C	23,62,80
^{13}C	45,55
^{14}N	62,80
^{16}O	21,25,55,62,80
^{18}O	15,55
^{19}F	35,40,50
^{20}Ne	20,40,45,62
^{24}Mg	50
^{27}Al	40
^{36}Ar	16,38
^{40}Ar	15,20,40
^{40}Ca	10,25,40,45
^{48}Ca	10,45
^{58}Ni	16,23,25,30,35,40,45
^{62,64}Ni	25,35
^{68,70}Zn	40
^{74}Ge	40
^{78,86}Kr	10
^{84}Kr	10,15,20,25
^{93}Nb	15,17,23,30,38
^{107}Ag	40
^{112}Sn	15.5,35,43.5
^{116}Sn	23,30,38
^{124}Sn	15,25,30,35
^{129}Xe	20,21,23,35
^{197}Au	10,15,20,21,23
^{208}Pb	10

Improvements on ECR sources: cryogenics of Serse and new injection system of Caesar

Limited availability of SERSE due to cryogenic problems

Autonomous system based on Helium recondensation and replacement of current leads with high Tc ones

1) **Design : the new system has been dimensioned and designed by a French company close to CEA Grenoble, who made the source – done**
2) **Realization : Cost defined to be around 300 k€ : a call for tender is starting based upon the executive drawings of 1)**

New beams with CAESAR new injection system

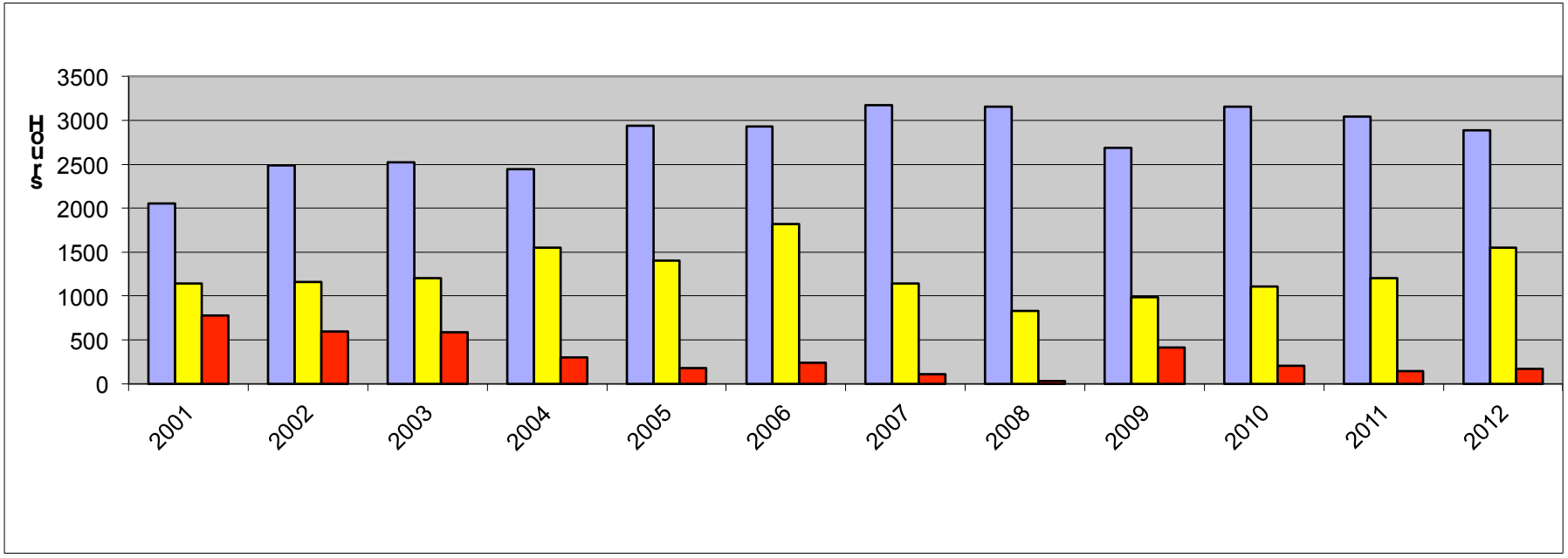
Assembled at the beginning of 2012

New beams will be available:

1) **metallic species through the implementation of an oven in 2013**
2) **The MIVOC technique will be exploited for production of "difficult beams", i.e. ^{11}B for production of ^{8}He with FRIBS@LNS tests done – feasibility demonstrated**

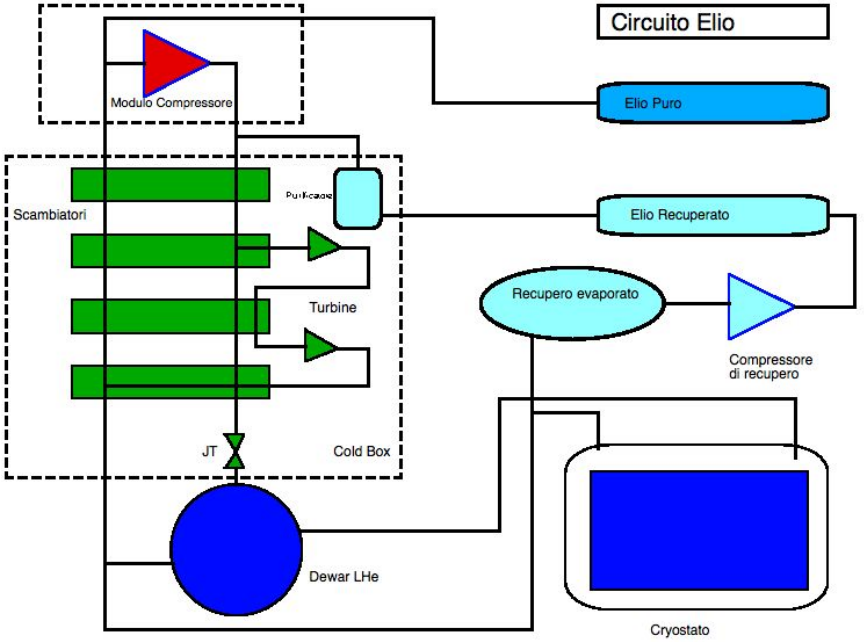
Superconducting Cyclotron status: beam statistics 2001-2012

		Delivered	Setting	Failures
2001	9 months	2569	1424	975
2002	8 months	2485	1161	597
2003	8.5 months	2679	1204	587
2004	5 months	1529	944	187
2005	5.5 months	2020	964	122
2006	5.5 months	2017	1252	166
2007	4.5 months	1783	643	65
2008	7 months	2757	740	28
2009	8 months	2683	983	411
2010	5 months	1970	690	128
2011	7 months	2665	1269	125
2012	7.5 months	2710	1549	171



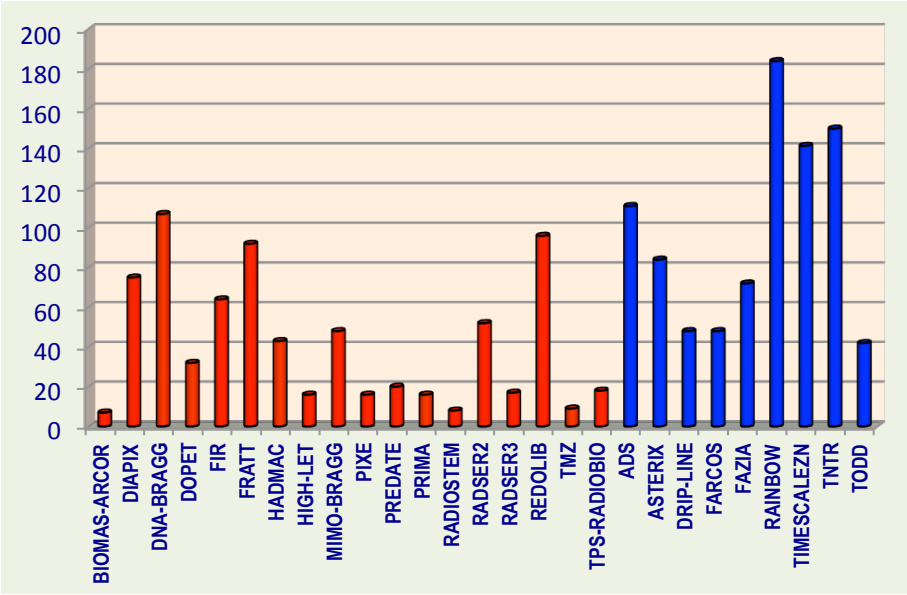
Superconducting Cyclotron status: Cryogenic problems in 2013

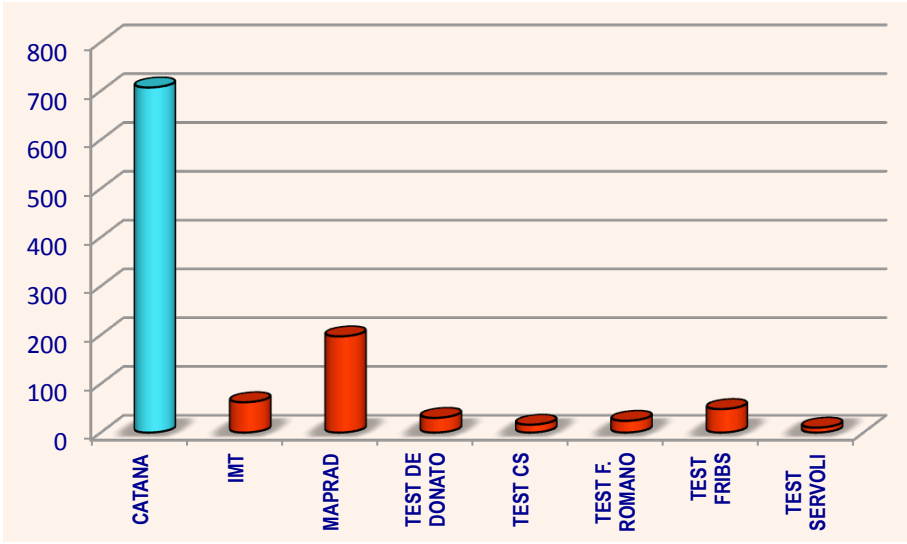
1. **January 1st 2013 h 5:00**
   Breakdown of the helium liquefier: turbine found broken due to impurities – restart on January 15
   Cyclotron operating on January 25
2. **May 2nd 2013**
   a new failure!



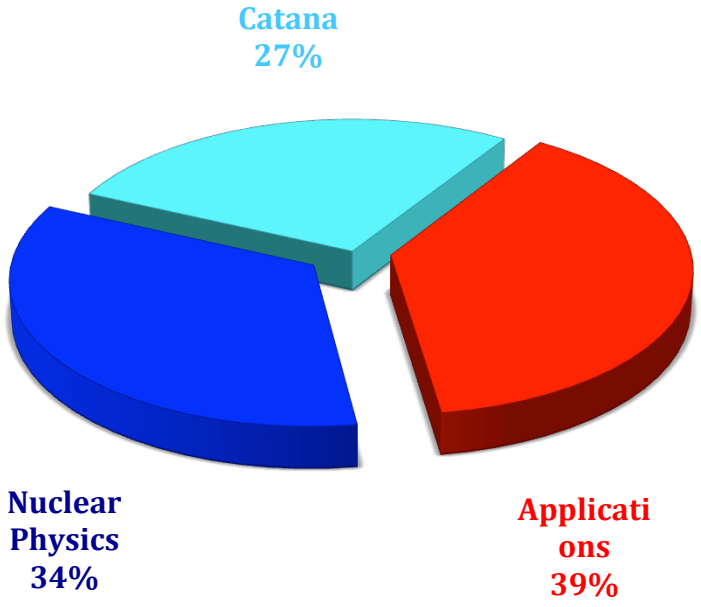
A deep revision of the helium liquefier is necessary – audit of Air Liquide

Use of the Cyclotron beams in 2012

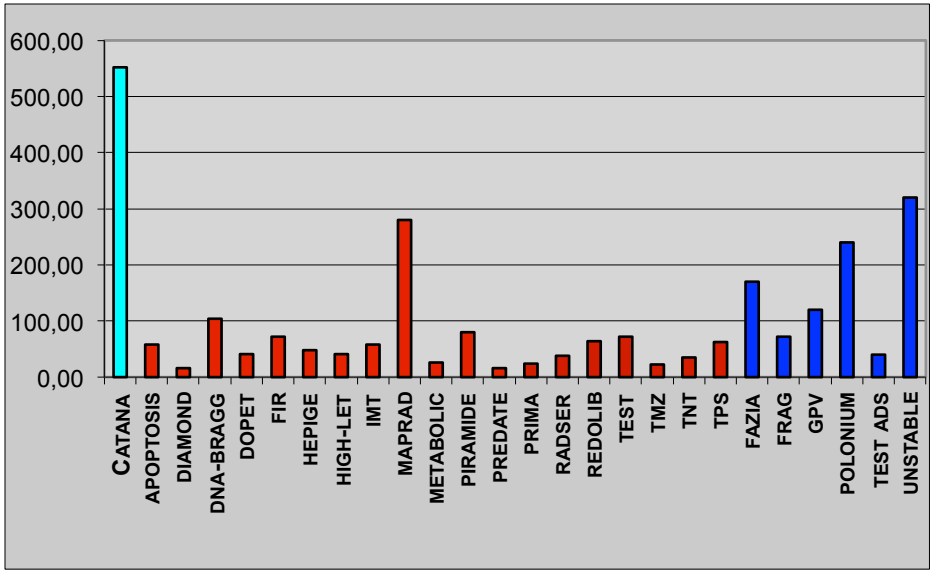




Cyclotron
2710 h



Use of the Cyclotron and Tandem beams in 2011

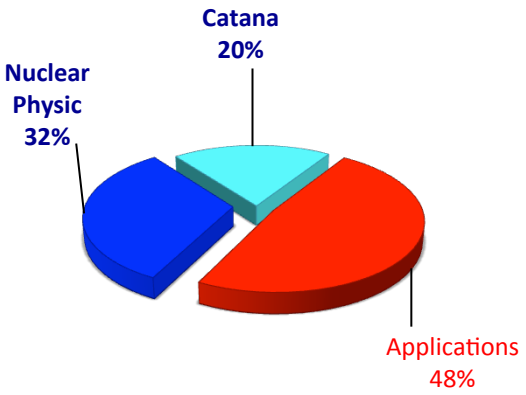


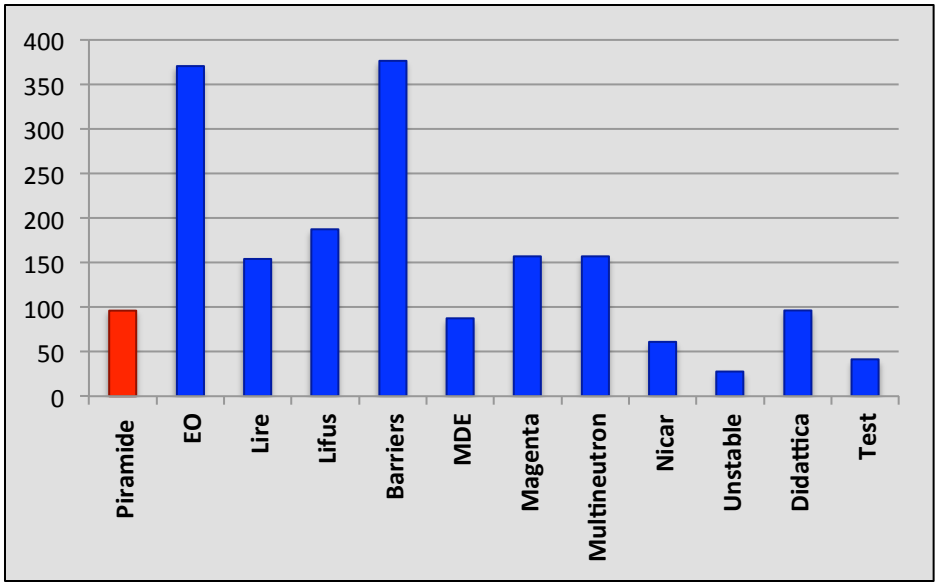
Cyclotron 2665 h

32% Nuclear Physics

20% Catana

48% Applications

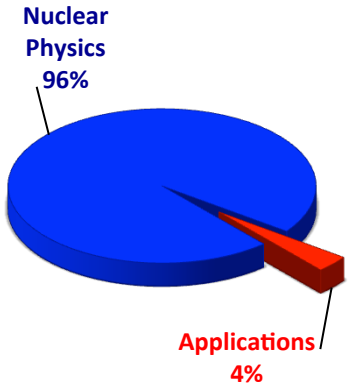




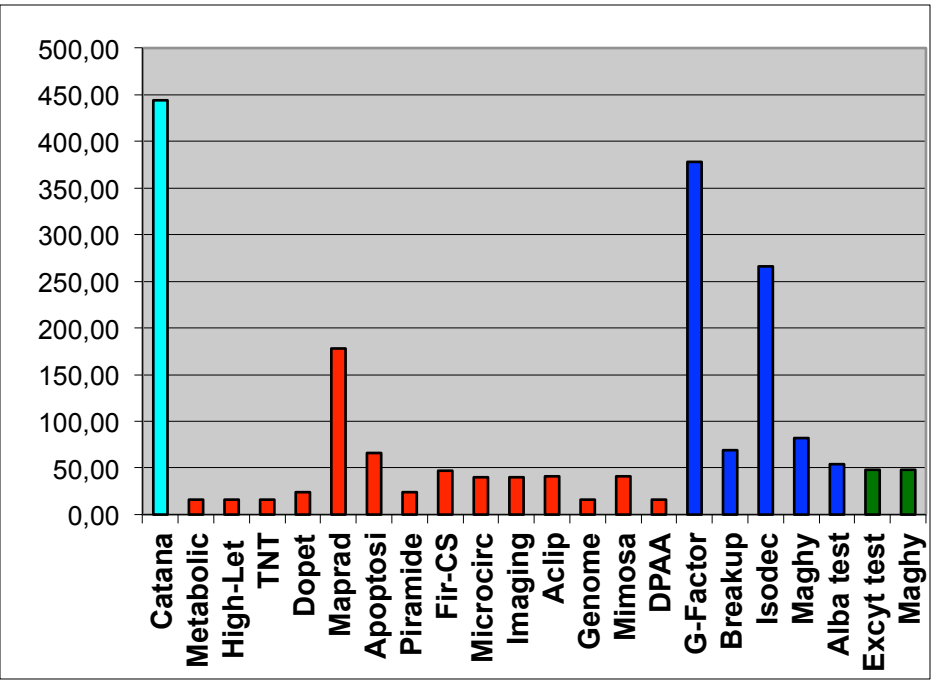
Tandem 1810 h

96% Nuclear Physics

4% Applications

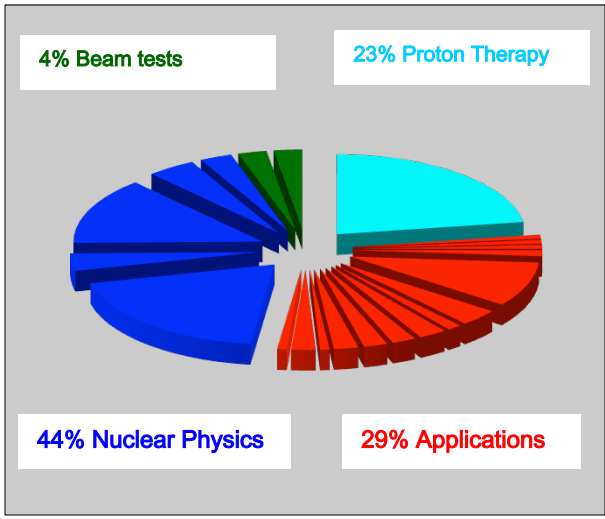


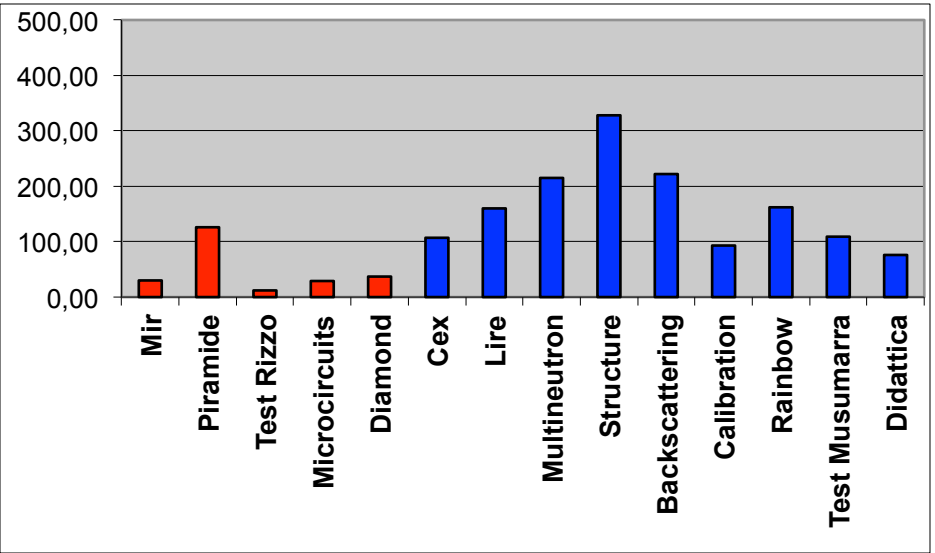
Use of the Cyclotron and Tandem beams in 2010



Cyclotron
1970 h

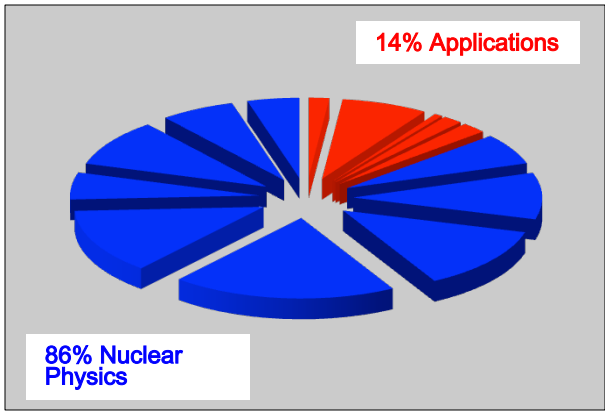
- 44% Nuclear Physics
- 23% Proton-Therapy
- 29% Applications
- 4% Beam tests





Tandem
1706 h

- 86% Nuclear Physics
- 14% Applications



Beams developed at the Tandem source

The HVEC MP Tandem has been operating since 1984

Negative ions	Intensity (nA)
^{1}H	1500
^{2}D	1500
^{6}Li	250
^{7}Li	250
^{9}Be (as BeO)	200
^{10}B	300
^{11}B	300
^{12}C	700
^{13}C	150
^{14}N (as CN)	400
^{16}O	700
^{17}O	700
^{18}O	700
^{19}F	700
^{27}Al	200
^{28}Si	400
^{29}Si	300
^{32}S	400
^{34}S	200
^{35}Cl	400
^{37}Cl	300
^{40}Ca (as CaH_3)	150
^{58}Ni	700
^{60}Ni	300
^{63}Cu	400
^{65}Cu	400
^{70}Ge	500
^{79}Br	200
^{93}Nb (as NbC)	200
^{116}Sn	200
^{120}Sn	250
^{127}I	300
^{197}Au	700

Tandem status

In 2012 two technical problems have been faced:

1) **Vacuum losses in the first accelerating tube**
2) **Belt charging system**

After several tests, and a stop of 1 year, our conclusion is:

The Tandem needs to be upgraded

1) **Alternative to the belt : Pelletron (NEC)**

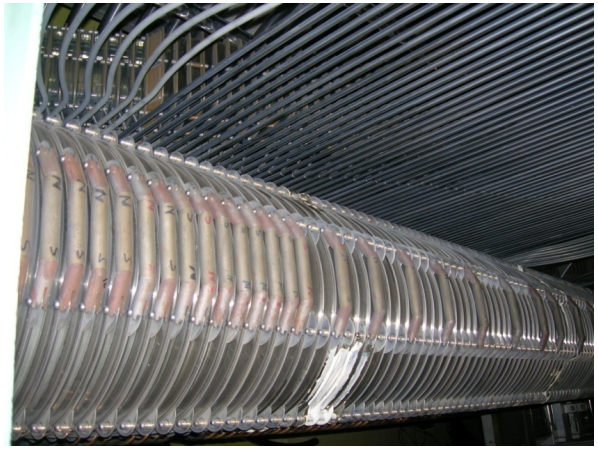
2) **Replacement of the first and eighth (damaged) accelerating tubes**

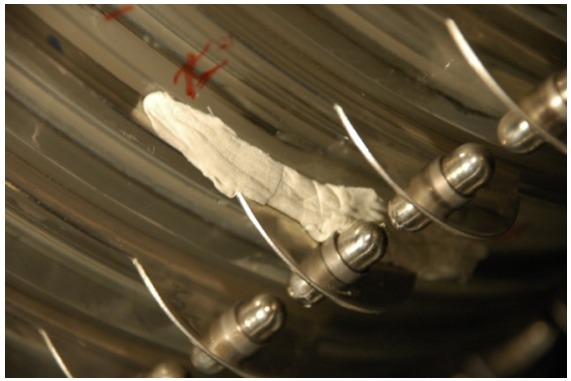
We are proceeding with these two big operations - funds are available through a special project for Nuclear Astrophysics at LNS

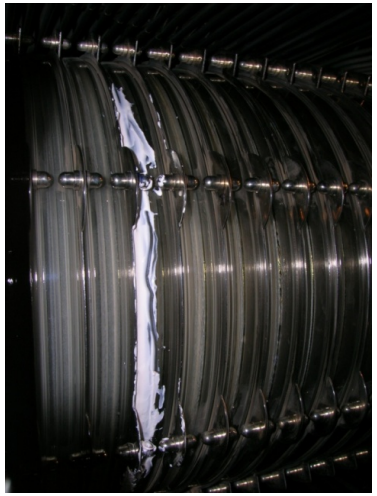
Tandem status

Vacuum losses in the first accelerating tube

- difficult to be located <5.10^{-5} mbar lt/s
- but due to the high SF6 pressure cause a high residual pressure in the Low Energy section: 4.10^{-6} mbar due to the high SF6 pressure
- once roughly located, they have been fixed by means of a vacuum sealant
- this has been done twice







After few months the problem appears again

Replacement of the first and eighth accelerating tubes

Cost 200.000 € - Offer received from VIVIRAD

Tandem status

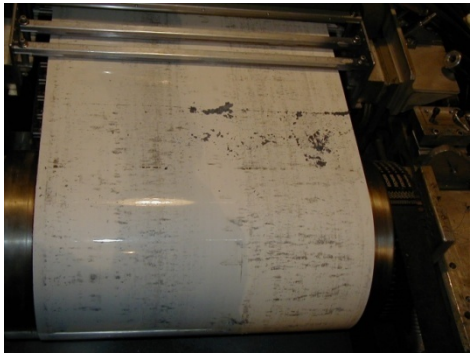
Charging system: the belt

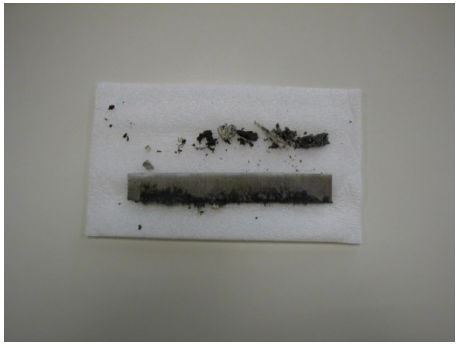
Tandem status

Charging system

Original (HVEC) belts are not any longer available

Several attempts have been done with belts produced by different companies to find a new belt with good mechanical and electrical properties





Another attempt ……

Tandem status

Charging system

our conclusion is that the new belts need to be improved : the insulating material does not resist to temperature and discharges
No company available to do that

Alternative to the belt : Pelletron

Offer received from NEC: 465.000 €

Time needed for installation: 2 months, but not before september 2014

Conversion Kit for Installation in the LNS-INFN HVEC Model 15MV MP Tandem Accelerator of a Pelletron Charging System, consisting of three (3) charging chains, one (1) motor, suitable sheaves and mounting hardware and four (4) regulated high voltage power supplies.

Supervision of installation and test by one (1) experienced engineer

Beam availability at LNS

Proposals are submitted to the PAC once per year

Financial support within the ENSAR TNA project is available

Cyclotron: the amount of available beam time is 270 BTU per year after subtracting the time to be allocated for :

- protontherapy 5 sessions: 85 BTU
- companies working in the field of rad. hardness: 60 BTU

450 BTU have been requested in the last two years

Tandem: during 2013 will be operated with an old belt so as to let the experimental activity to be carried out, in particular the approved experiments running with low – medium voltage

In 2014 the upgrade program will start : at the beginning of the year the accelerating tubes will be replaced, while in the second half of the year the pelletron will be installed

Thank you for your attention