Operational experience with the Excyt facility

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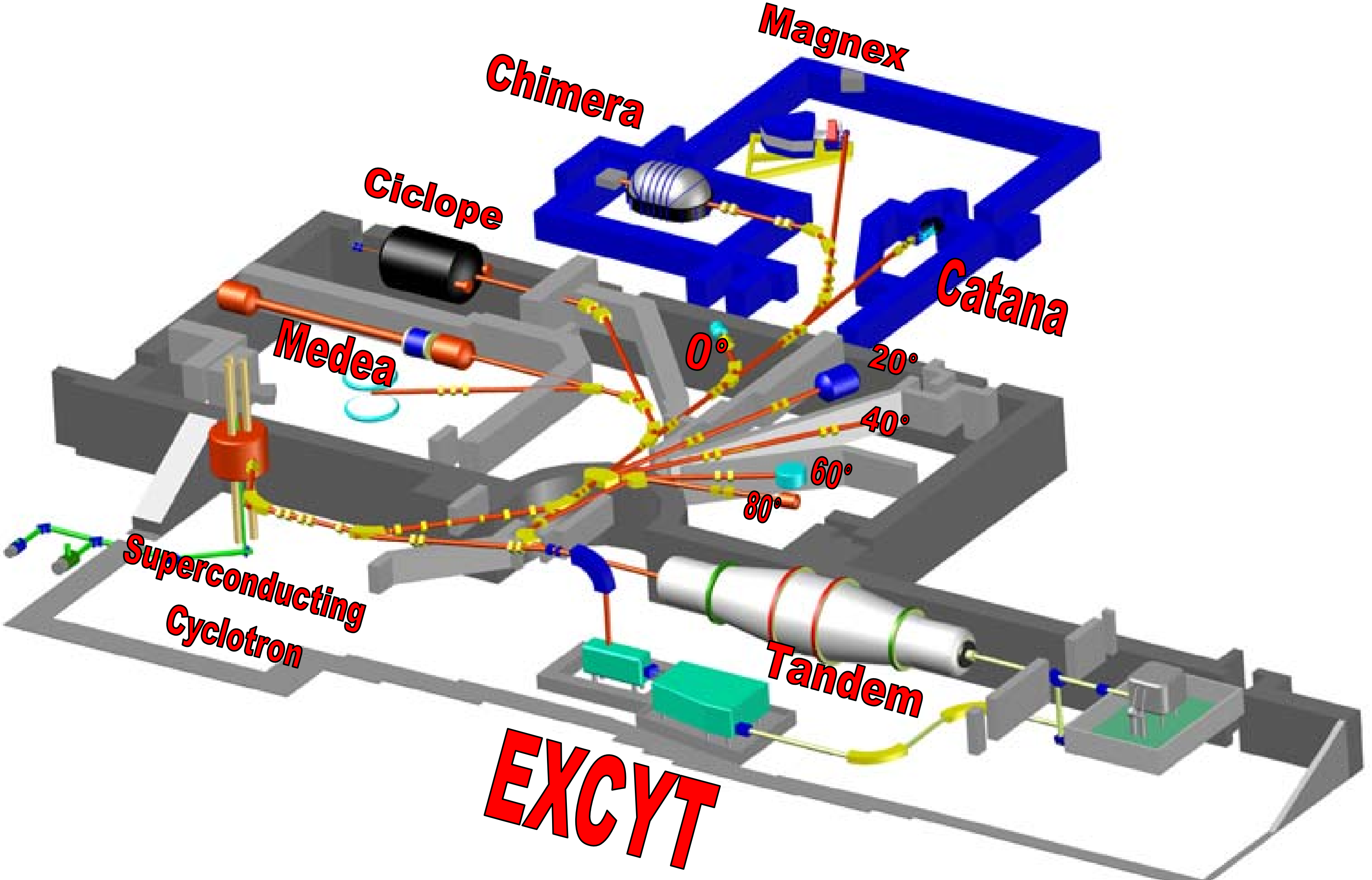
Heavy Ion Accelerator Technology HIAT09

Venice, Italy, June 8-12 2009

LNS lay-out : accelerators and experimental hall



The LNS Accelerators

Superconducting Cyclotron

Compact (and complex) machine designed for acceleration of ions with variable mass and energy ($0.01<q/A<0.5$, $8\ \text{AMeV}<E<100\ \text{AMeV}$)

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

Applications (beam interaction with biological matter, radiation hardness (presentation by A.B. Alpat on Wednesday morning), 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=14 MV)

Nuclear Physics (nuclear structure)

Nuclear astrophysics

Applications (cultural heritage, radiation hardness, superconducting materials)

Post-accelerator of radioactive beams

Ion sources

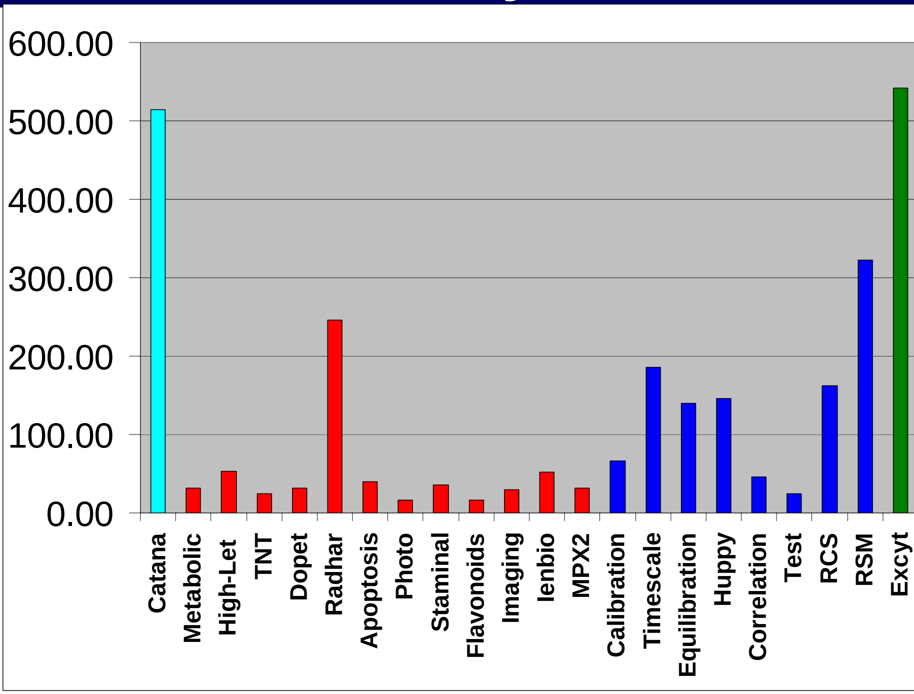
2 ECR sources (one superconducting) for the Superconducting Cyclotron

Negative sources for the Tandem

EXCYT

Production and acceleration of radioactive beams at the Tandem energies

Use of the Cyclotron and Tandem beams in 2008



Cyclotron

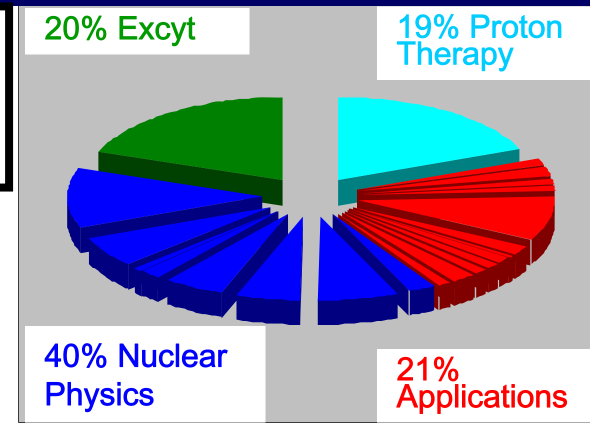
2757 h

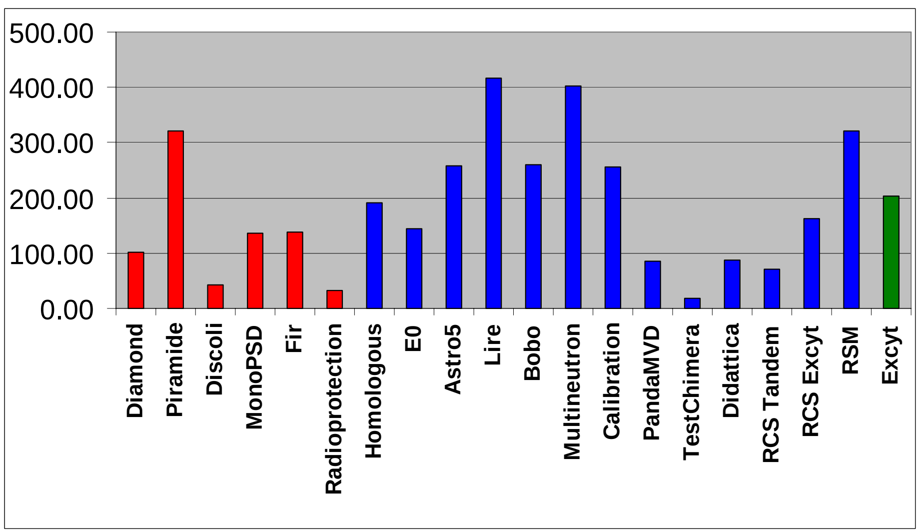
40% Nuclear Physics

19% Proton-Therapy

21% Applications

20% Excyt





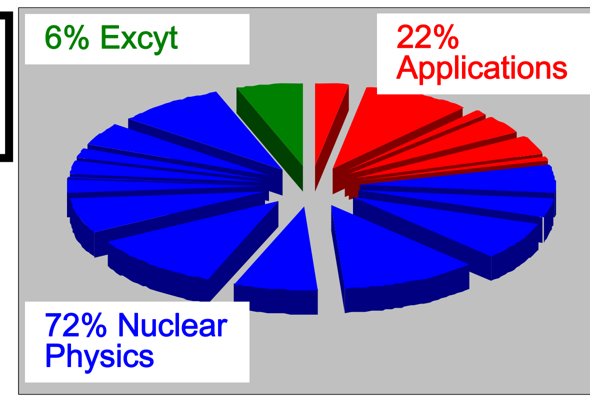
Tandem

3651 h

72% Nuclear Physics

22% Applications

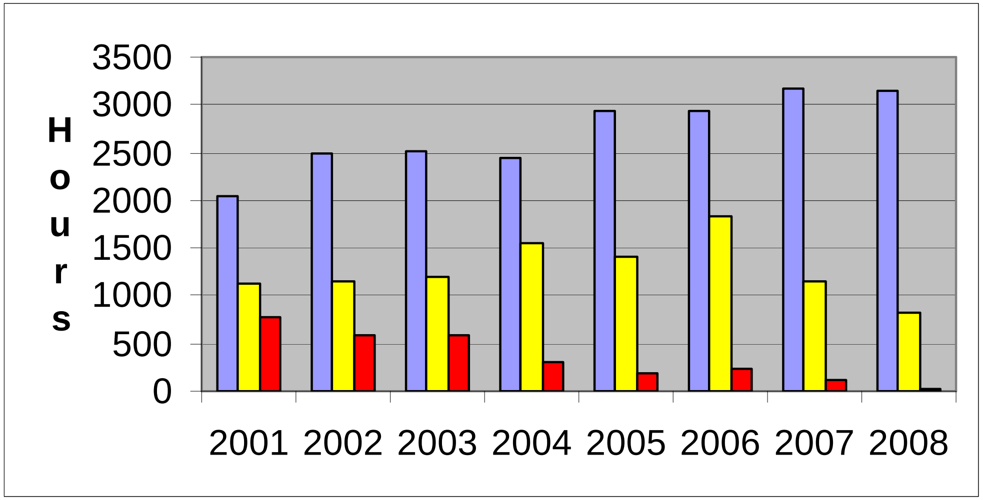
6% Excyt



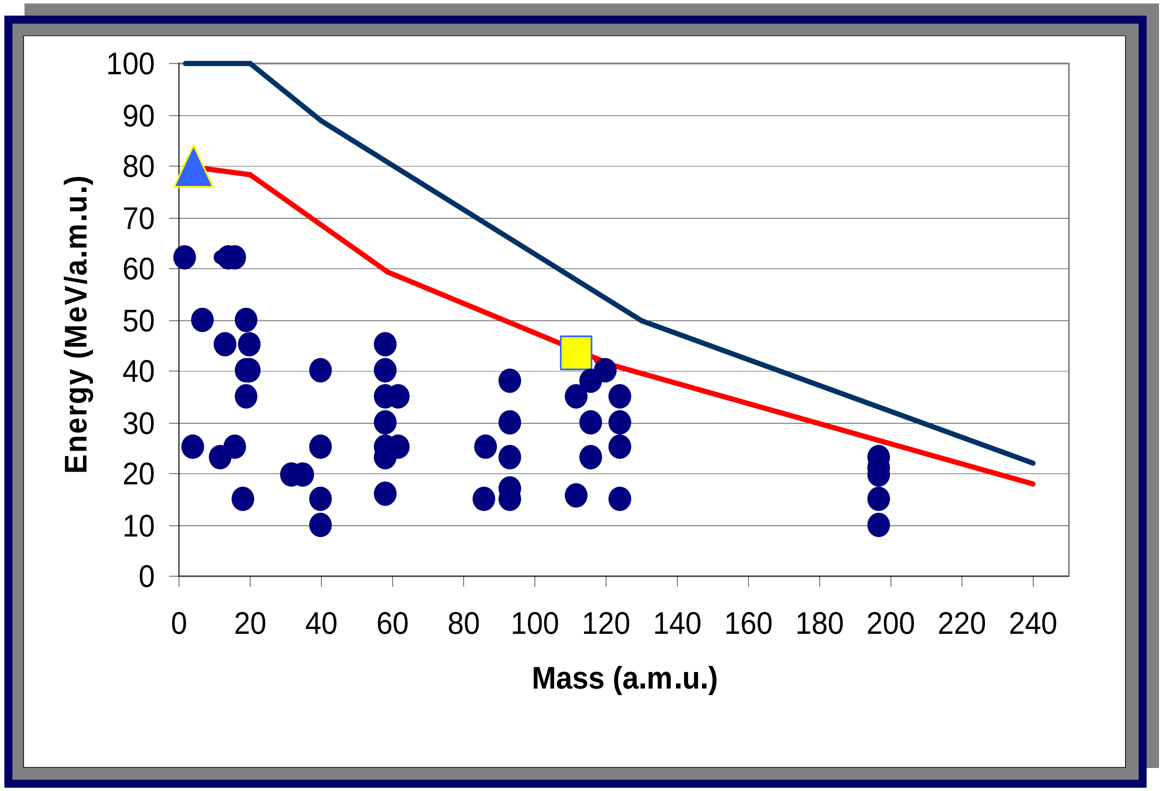
Cyclotron beam statistics 2001-2008: reliability

		Delivered	Setting	Failures
2001	10 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

Data scaled for 8 months →



Beams developed at the Cyclotron

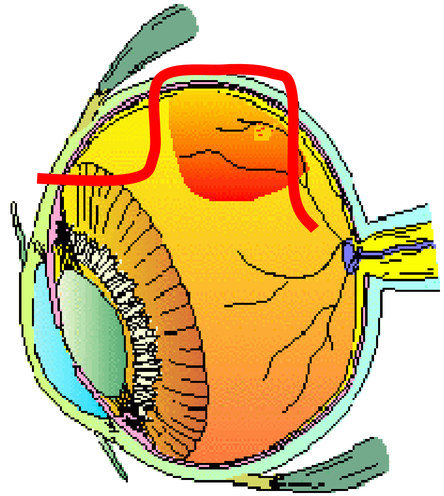


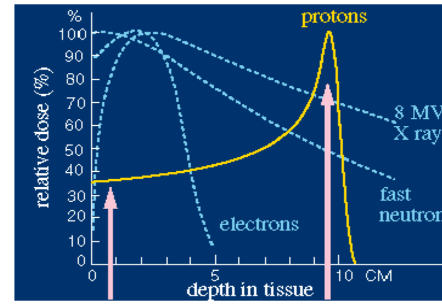
^{4}He 80 MeV/a.m.u.

^{112}Sn 43.5 MeV/a.m.u.

^{A}X	E (MeV/a.m.u.)
H_2^+	62,80
H_3^+	45
$^{2}D^{+}$	35,62,80
^{4}He	25,80
He-H	21
^{9}Be	45
^{12}C	23,62,80
^{13}C	45
^{14}N	62,80
^{16}O	21,25,62,80
^{18}O	15
^{19}F	35,40,50
^{20}Ne	21,40,45,62
^{32}S	19.5
^{35}Cl	19.5
^{36}Ar	16,38
^{40}Ar	15,21,40
^{40}Ca	10,25,40,45
^{48}Ca	10,45
^{58}Ni	16,23,25,30,35,40,45
^{62}Ni	25,35
^{86}Kr	15,21,25
^{93}Nb	15,17,23,30,38
^{112}Sn	15.5,35,43.5
^{116}Sn	23,30,38
^{120}Sn	40
^{124}Sn	15,25,30,35
^{129}Xe	21,23
^{197}Au	10,15,20,21,23

CATANA : a facility for protontherapy of the eye tumors





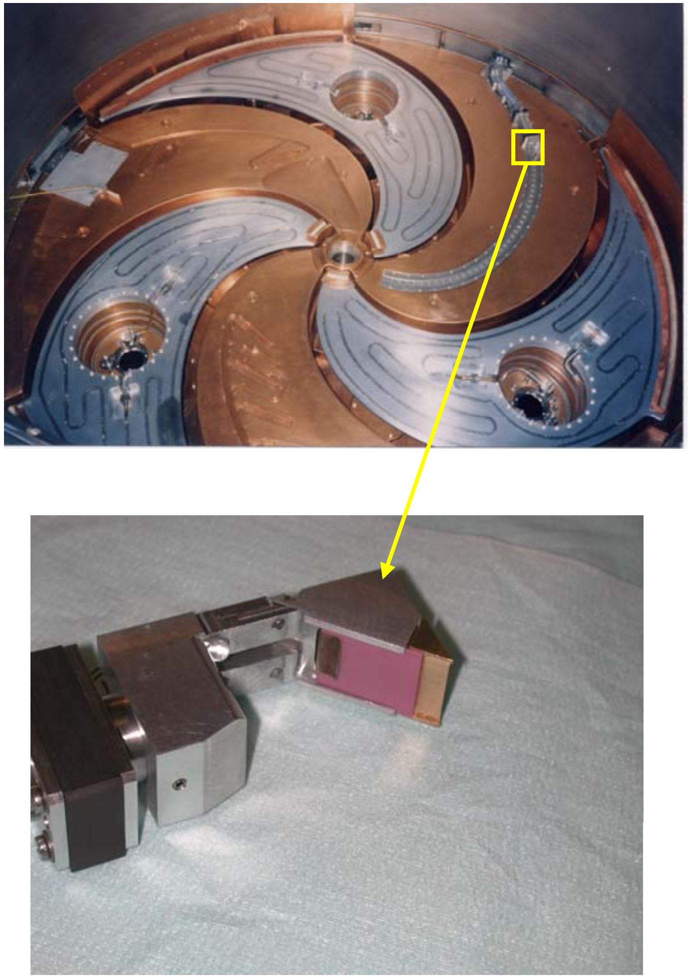
2002:	750 h	23 patients
2003:	600 h	34 patients
2004:	350 h	19 patients
2005:	420 h	16 patients
2006:	492 h	31 patients
2007:	197 h	18 patients
2008:	290 h	32 patients
2009:	110 h	5 patients

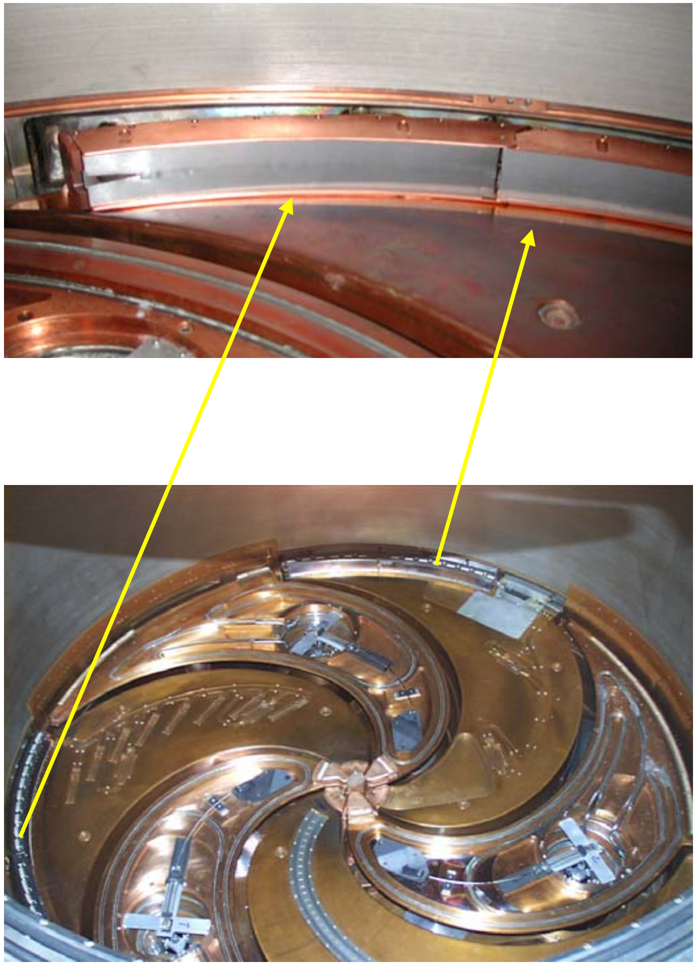
Total : 178 patients

5 sessions on average per year

Increasing the Cyclotron beam intensity

Critical features: beam diagnostics and extraction ($\varepsilon \approx 50\%$)





Increasing the Cyclotron beam intensity

100 ⟶ 500 watt

Septum: directly cooled

New septum material: Tungsten vs. Tantalum

Bigger thickness: 0.3 vs. 0.15 mm

⇨ extraction efficiency 63% vs. 50%

$^{13}C^{4+}$ @ 45 AMeV (EXCYT primary beam)

Pacc = 237 watt

Pextr = 150 watt I=1020 enA= 255 pnA

ε = 63%

Pdiss = 87 watt

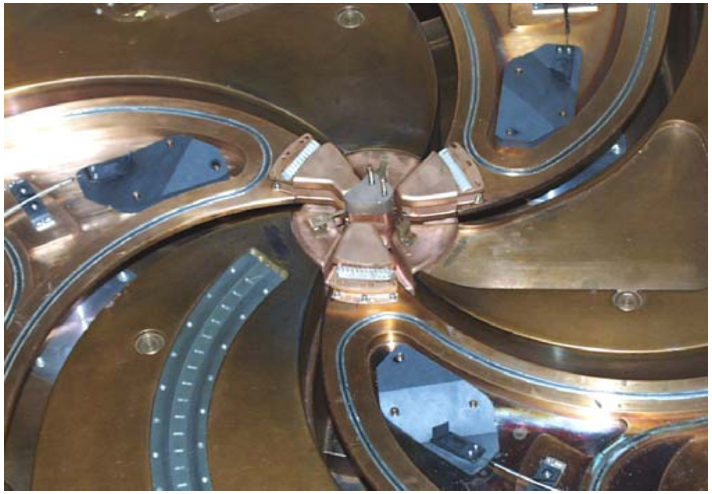
Increasing the Cyclotron beam intensity

200 → 500 watt

<u>Short term upgrading</u>: a primary beam power of 500 watt

Before going beyond 150 watt it is wise to look for a further increase of the extraction efficiency

Use of phase slits exploiting the phase-radius correlation given by $\Delta E = -\Delta\phi \int \sin\phi \, dE$

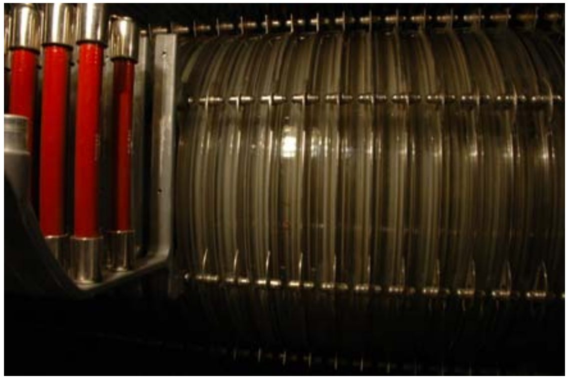


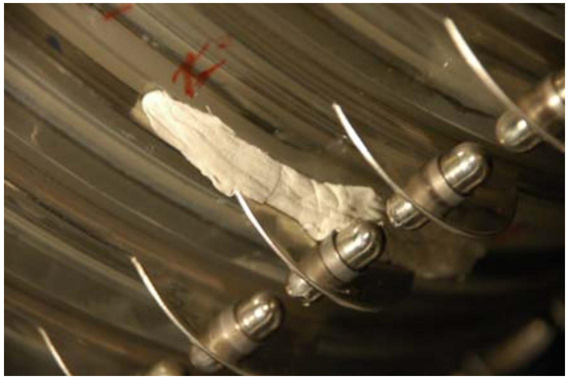
The source-cyclotron transmission needs to be improved, the injection efficiency being ~15%

Beam transport along the injection line is now being considered

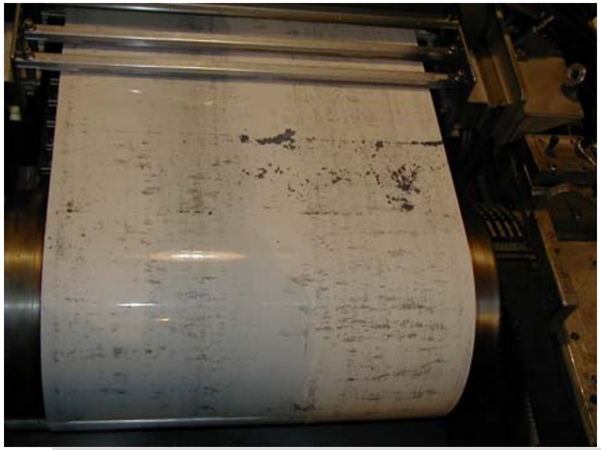
Tandem status

Leaks have been detected in the 1° and 8° accelerating tubes





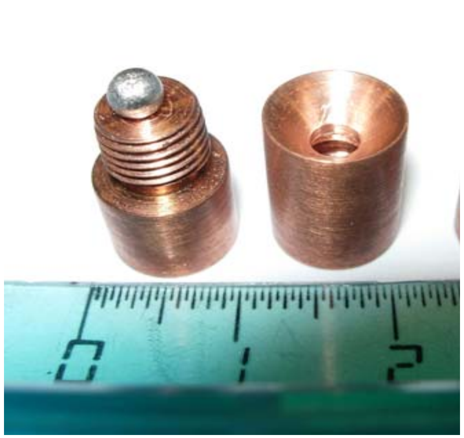
Alternatives to High Voltage belts have not been found



Contacts with VIVIRAD (France) to face both the belt question and the tubes problems

^{14}C beam at the Tandem

The project started: many initiatives have been realised

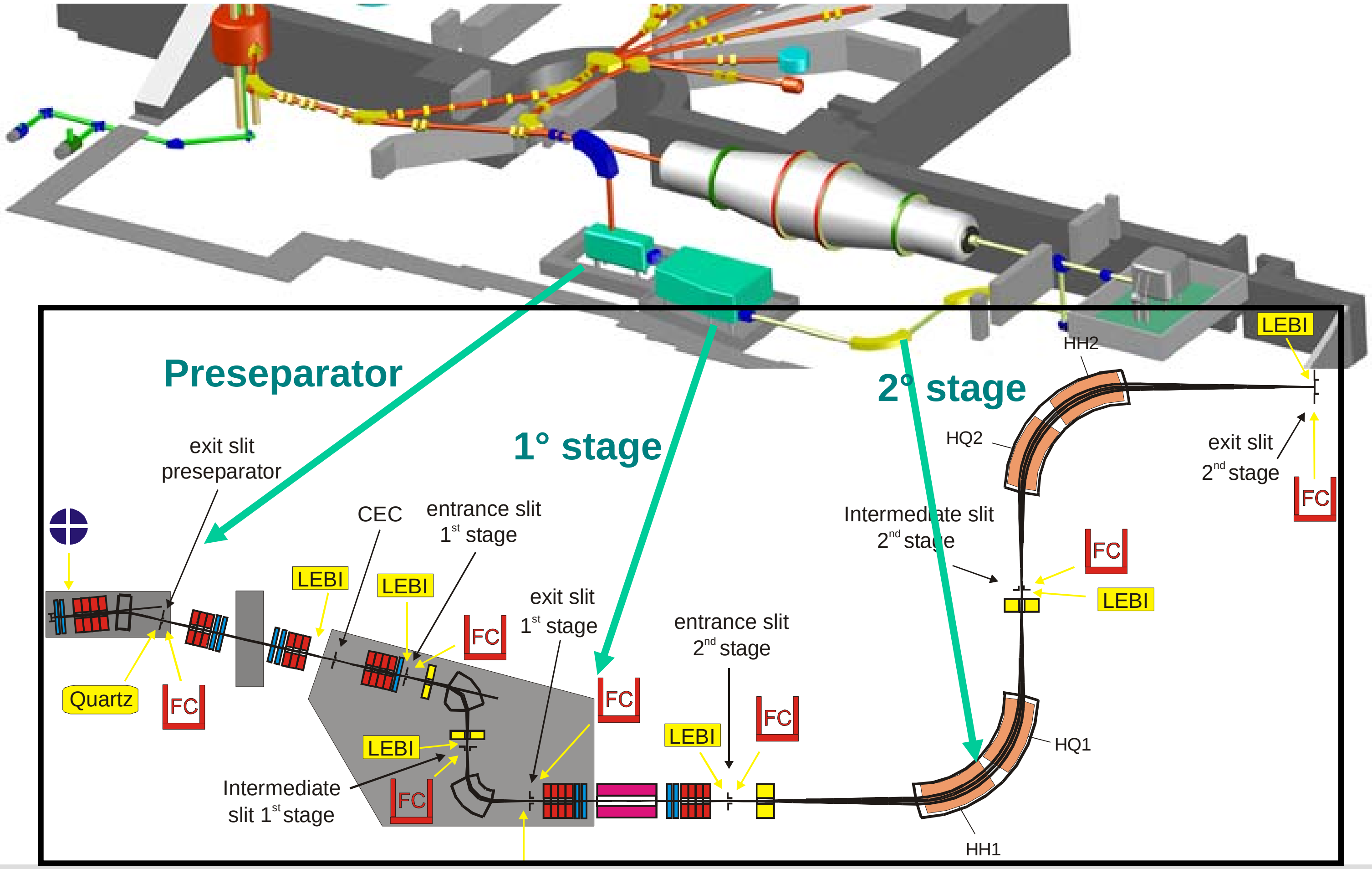


Contacts with Dr. Hans Joerg Maier (Munich) to produce $Fe_3{}^{14}C$ pellets

BUT…………

^{14}C elemental powder is not easy to be available with the required chemical characteristics

EXCYT: the mass separator



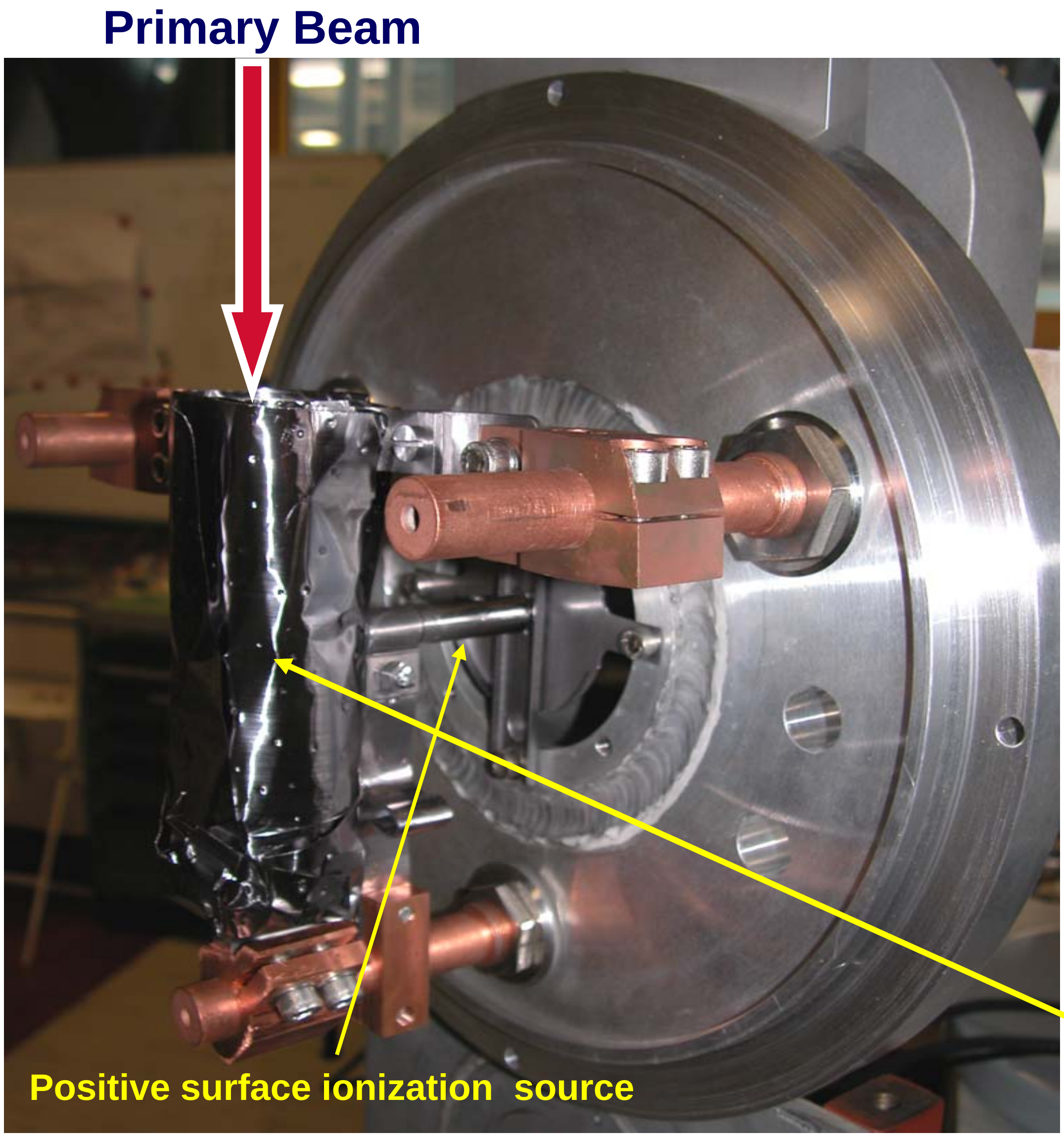
The mass separator system consists of a pre-separator and 2 main stages, the pre-separator and the first stage being assembled on two 250 kV platforms

$(M/\Delta M)_{Pre} \approx$ 180 (pre-separator : 18° magnet and a quadruplet of 4 electrostatic quadrupoles)

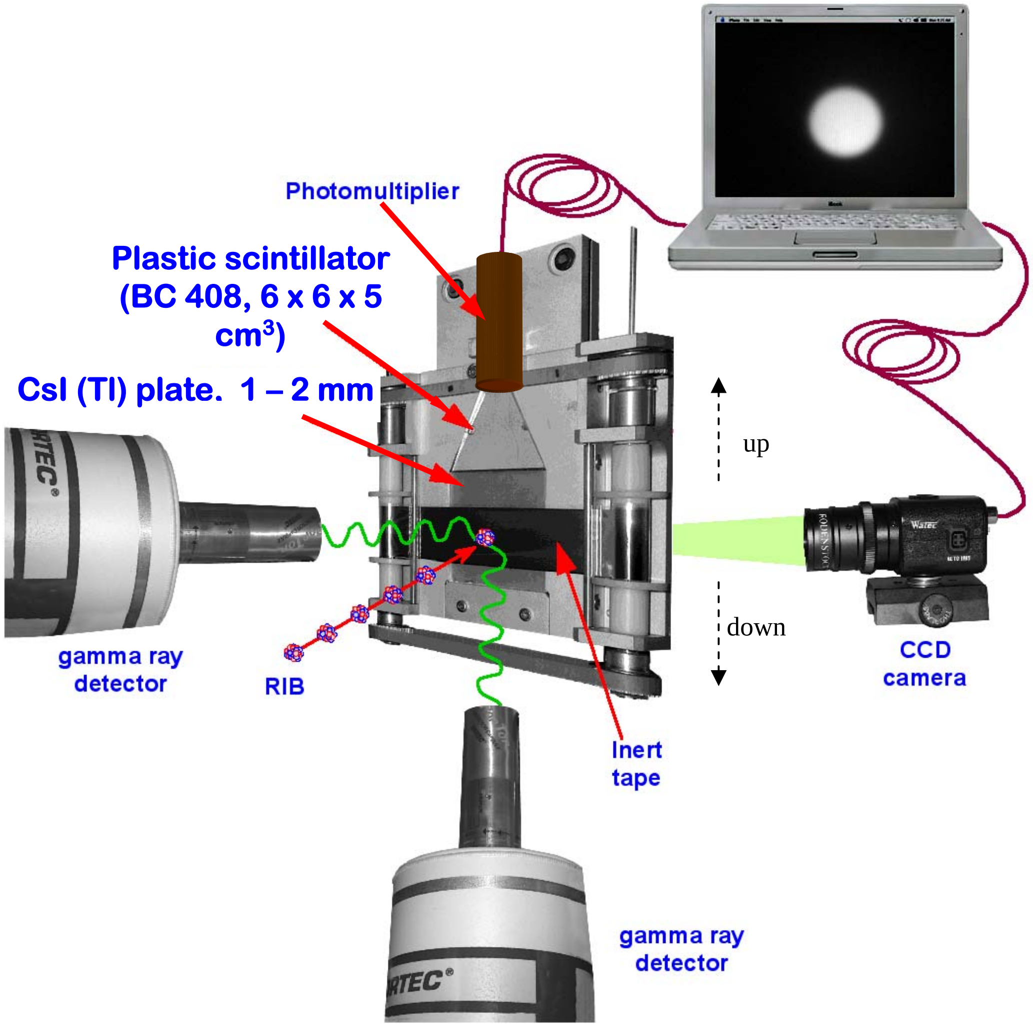
$(M/\Delta M)_{1st} \approx$ 2000 (I stage: 2 magnets (77°, 90°) and 2 quadruplets of 4 electrostatic quadrupoles)

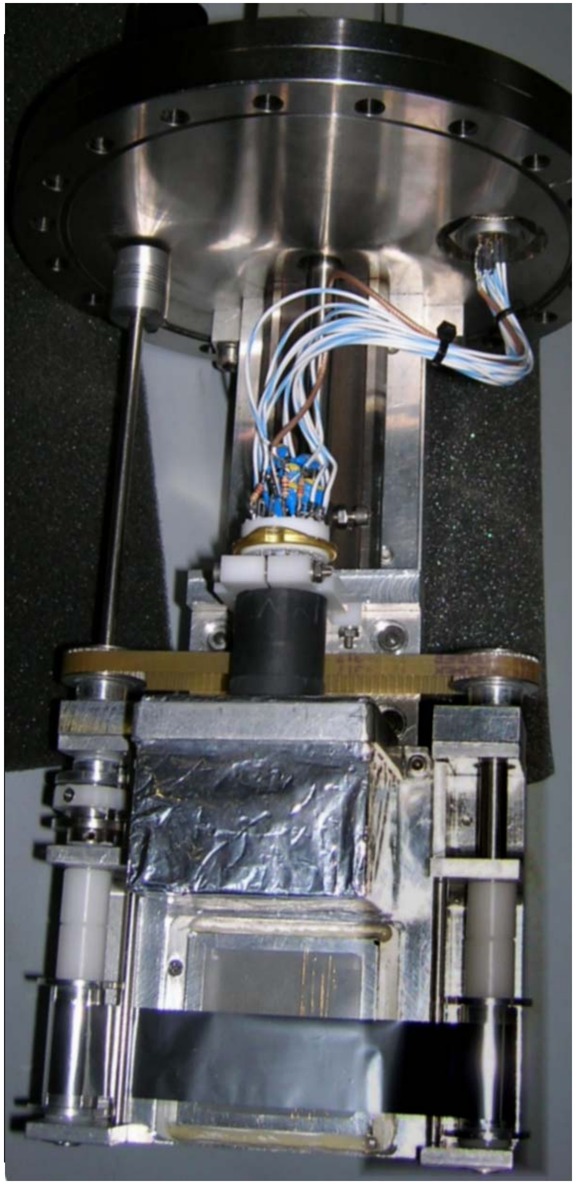
$(M/\Delta M)_{2nd} \approx$ 20000 (II stage: 2 magnets (90°) and a quadruplet of 4 electrostatic quadrupoles)

The Target-ion source complex

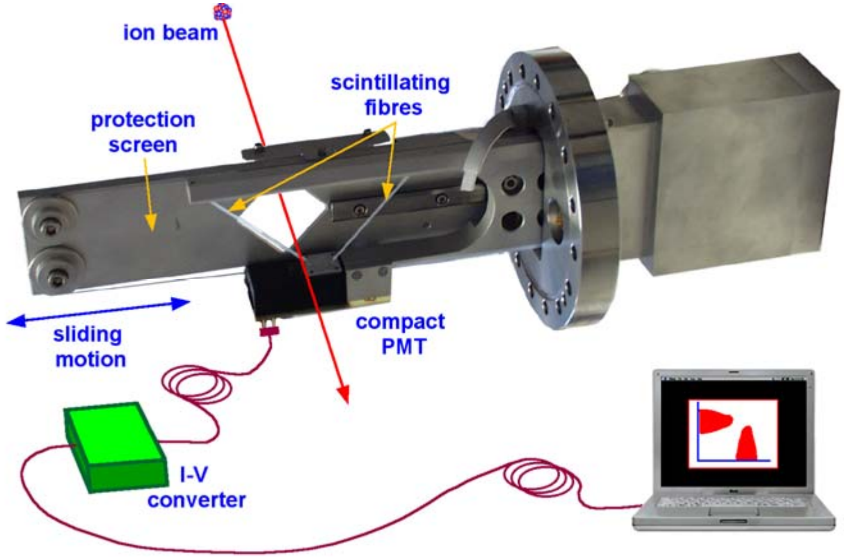


Diagnostics of Low Energy Beams : LEBI





Diagnostics for High Energy (Tandem) RIBs

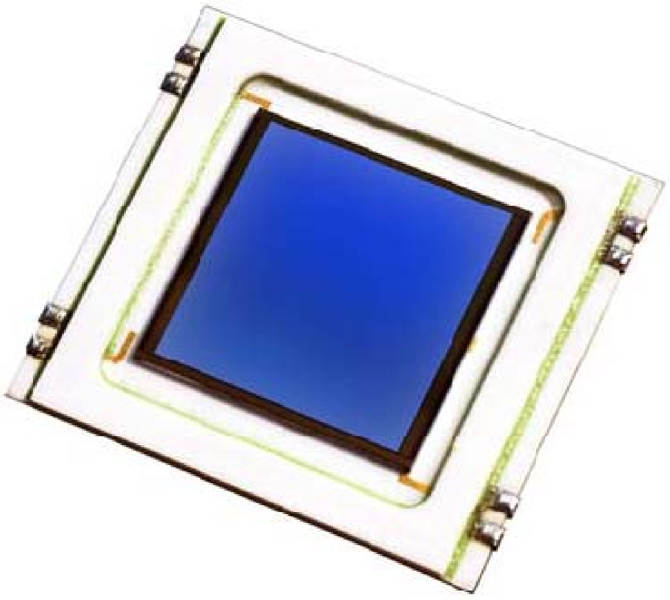


Position sensitive silicon detectors

- beam intensity measurement
- beam energy spectra
- 2D beam profile monitor
- identification of the beam particles (ΔE – E) by adding a thin silicon detector to obtain a telescope configuration

Beam profile monitor based on a pair of scintillating fibres scanning the beam

Fibres diameter: 300 ÷ 500 µm
Plastic fibres for low intensity



size: 50 x 50 mm^2

EXCYT transmission factors

October 2008

Primary beam ^{13}C 45AMeV	LEBI1 (pps) $^{8}Li^{+}$	CEC (10 keV) $^{8}Li^{-}$	Through platforms $^{8}Li^{-}$	Through 2nd stage	Tandem entrance	Through Tandem @7MV	On target $^{8}Li^{3+}$
		2.8%	100%	100%	100%	47%	70%
100watt	$5.4 \cdot 10^{6}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$7.0 \cdot 10^{4}$	$5.0 \cdot 10^{4}$

New triplet needed

Production: at least 3 times the value found with the cylinder target

A factor 1.4 after the Charge Exchange Cell (CEC)

The Tandem transmission could be increased by a factor 1.3

With a primary beam power of 200 watt, $1.8 \cdot 10^{5}$ pps might be expected on target

EXCYT status and prospects

- **The facility has been commissioned and 3 experiments have been carried out**
- **For ^{8}Li an intensity of $5 \cdot 10^{4}$ pps is available on target**

Safety and reliability:

- **Revision of the source remote handling**
- **Air and water treatment**
- **Shielding of the primary beam line (troubles on hard disks, CPU, electronics)**
- **Upgrading of plants (especially dehumidification)**

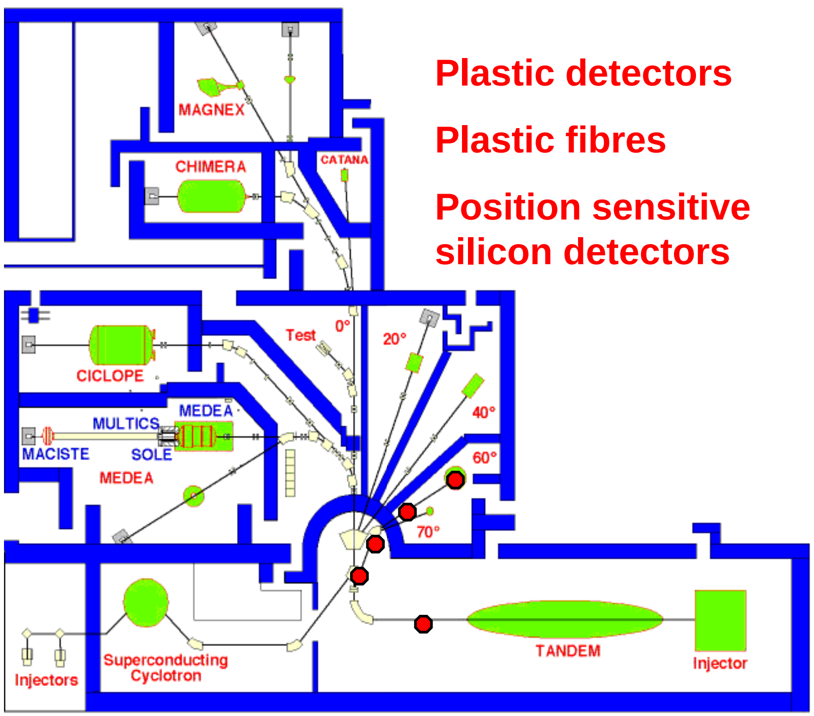
Optimization:

- **A new focusing element in the Tandem injection line to improve the acceleration efficiency**
- **Mechanical re-design of the target (ioniser) to improve the electric contacts**
- **Hall probes to be implemented on the separator**

EXCYT status and prospects

Short term upgrading:

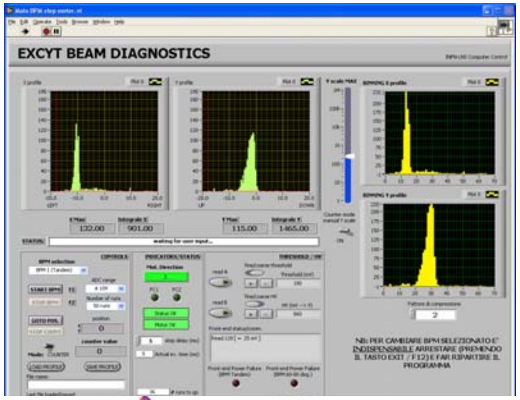
- **Provide the long beam lines (Magnex and Chimera) with low intensity diagnostics**
- **Provide the platforms with services to install different sources**
- **Gain a factor 3 in the primary beam intensity**

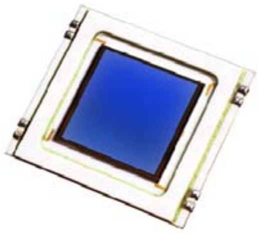


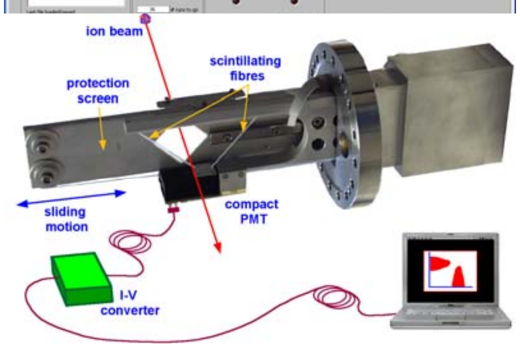
Plastic detectors

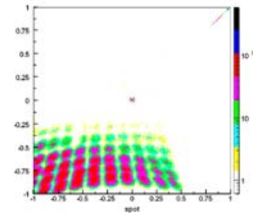
Plastic fibres

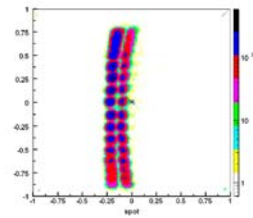
Position sensitive silicon detectors











EXCYT status and prospects

Short term upgrading: possible future beams

$^{8,9}Li$	Positive Ion Source	$2 \cdot 10^5$ pps ^8Li	($2 \cdot 10^7$ @ 300 KeV)
^{21}Na	Positive Ion Source	$3 \cdot 10^4$ pps	($3 \cdot 10^6$ @ 300 KeV)
^{15}O	Hot Plasma	$2.5 \cdot 10^6$ pps	($3 \cdot 10^7$ @ 300 KeV)
	ε_{CEC}=30%, present target		
$^{25,26}Al$	Hot Plasma Target: SiC		
$^{26,27}Si$	Hot Plasma Target: SiC		
$^{7,11}Be$	Hot Plasma		
$^{10,11}C$	Hot Plasma		
$^{38,39,40}Cl$	Negative Ion Source, no CEC		
$^{17,18}F$	KENIS ion source, no CEC		

EXCYT prospects

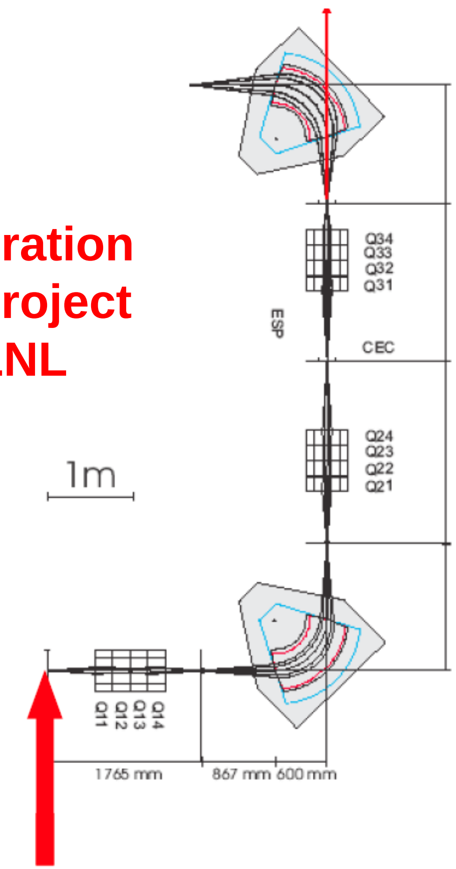
R&D activities:

- **Test bench installation**
- **Target ion source complex**

R&D activities on the Target – Ion source complex

- **Better undestanding of diffusion-effusion models**
- **New target materials (e.g. Foams, Fibers, Ta foils) and geometry**
- **New PIS surface materials**
- **Sources development (negative, microwave)**

In collaboration with the project SPES at LNL



Thank you for your attention

INFN-LNS

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Etna
20 km

Ionian sea 2 km