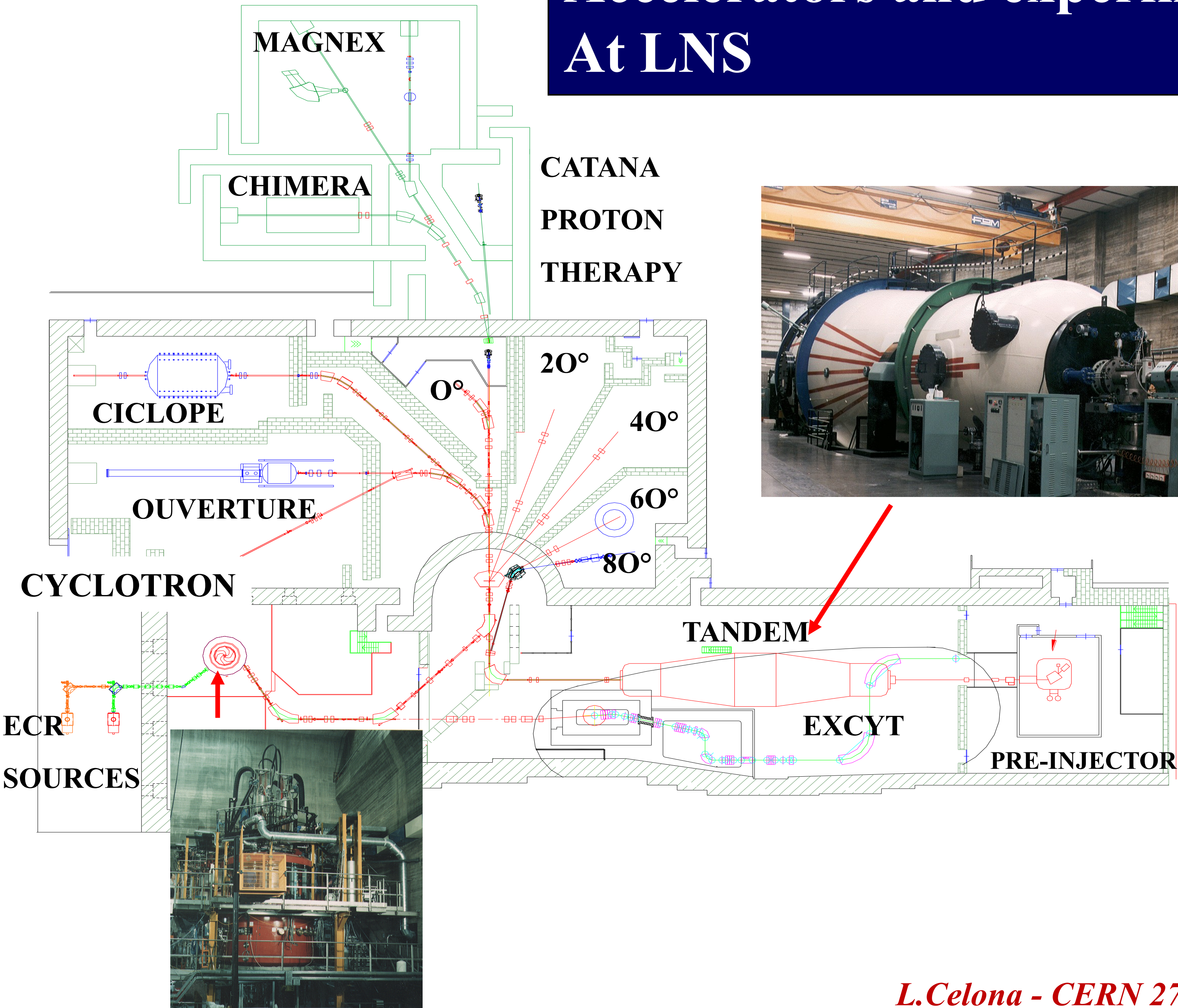
Radioactive beams at LNS

L. Celona

INFN - Laboratori Nazionali del Sud
Catania, Italy

EURISOL-NET (ENSAR/NA03) Working Group Meeting
CERN – Switzerland
27 June 2011

Accelerators and experimental hall At LNS



ISOL

↓

EXCYT
(CS+TANDEM)

In-Flight

↓

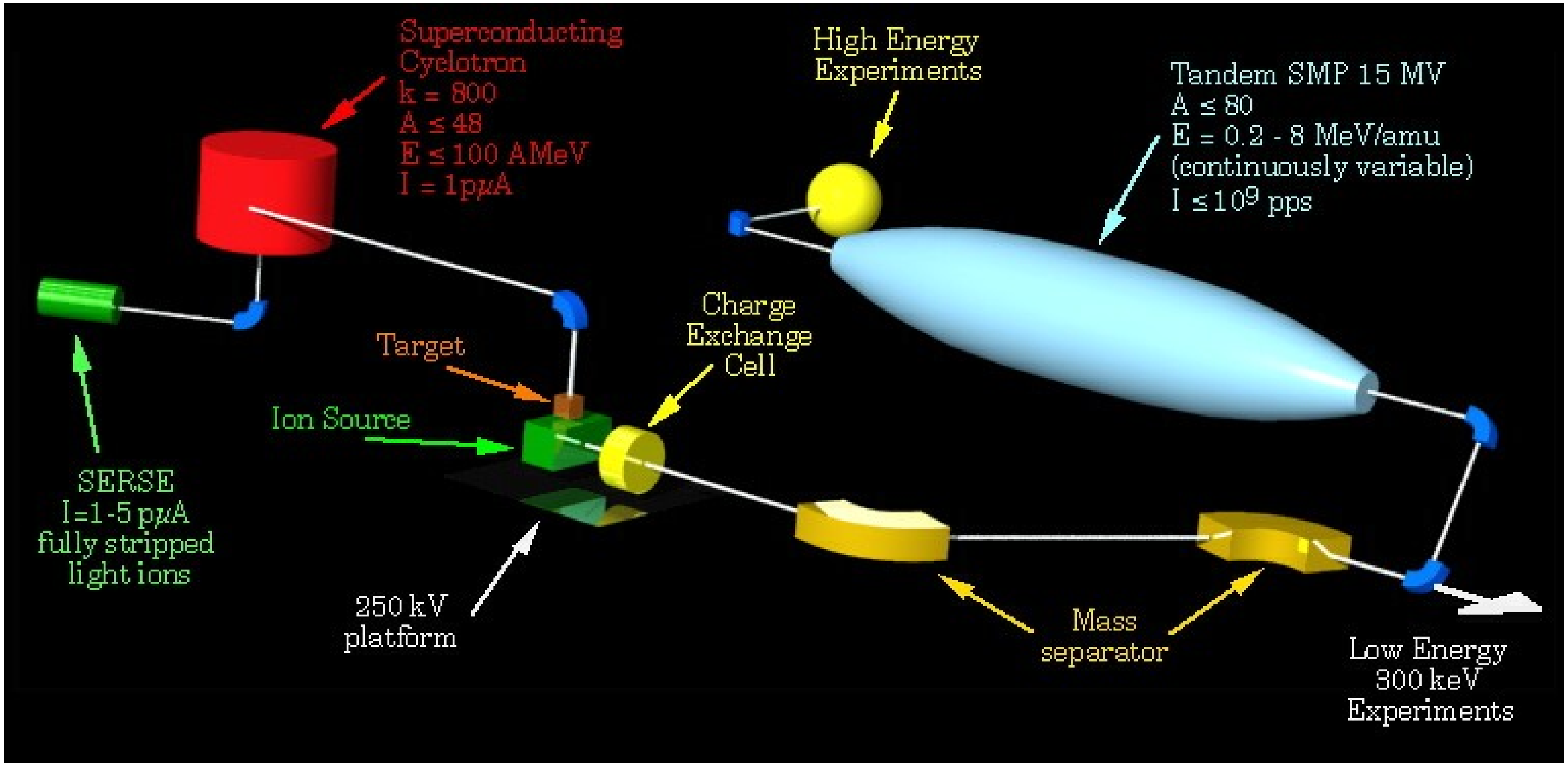
FRIBs
(CS+FRS)

The LNS 15 MV Tandem accelerator

The LNS K800 Superconducting Cyclotron

It's able to accelerate all the ions from hydrogen to uranium with energies up to 100 MeV/amu

EXCYT (EXotics with CYclotron and Tandem)
A facility for the production of radioactive nuclei



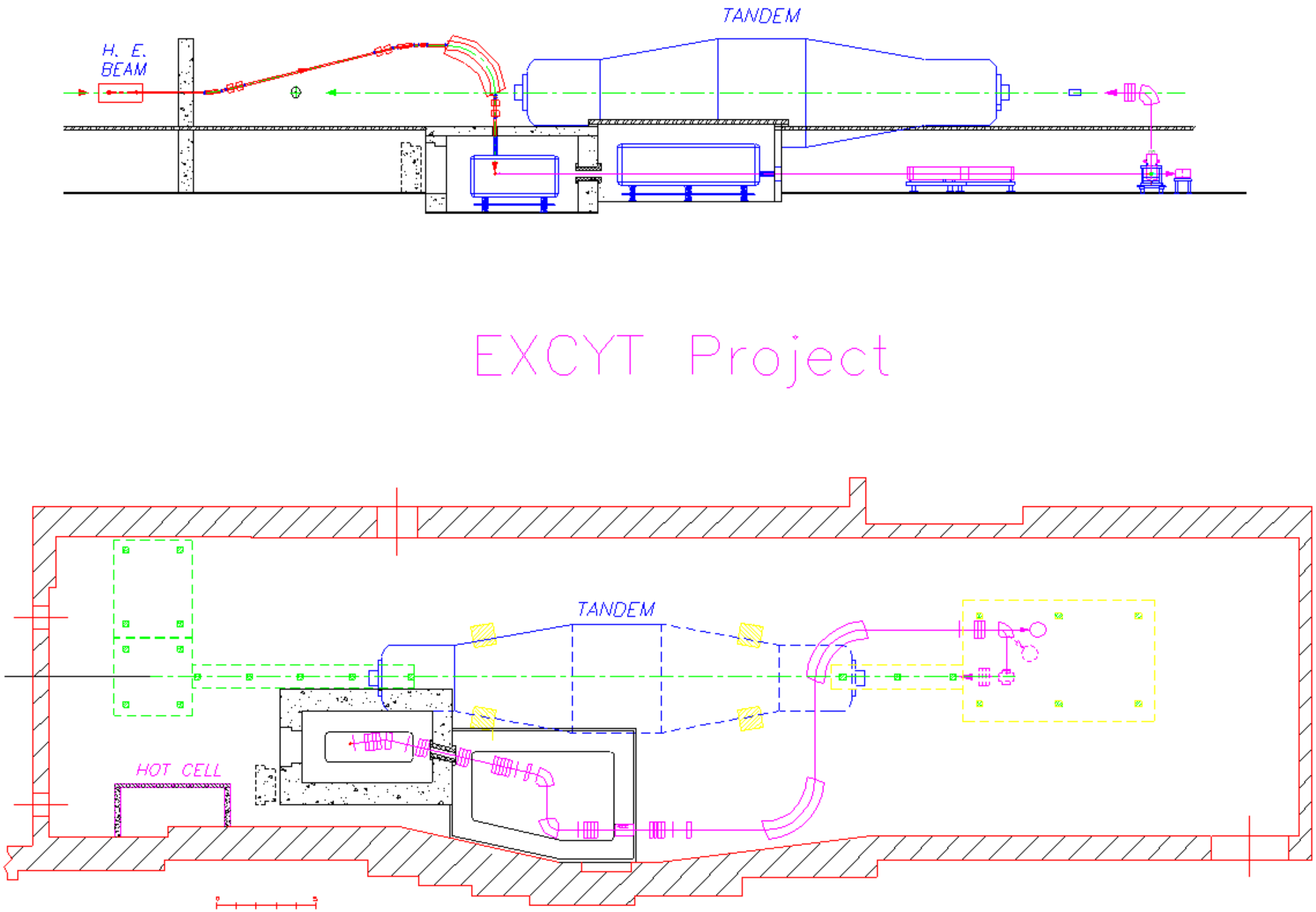
Maximun Energy: 2.5 ÷ 150 MeV (***preacceleration energy up to 300 keV***)

Low emittance (<0.5 π mm.mrad): clear-cut beam spot e low angular spread

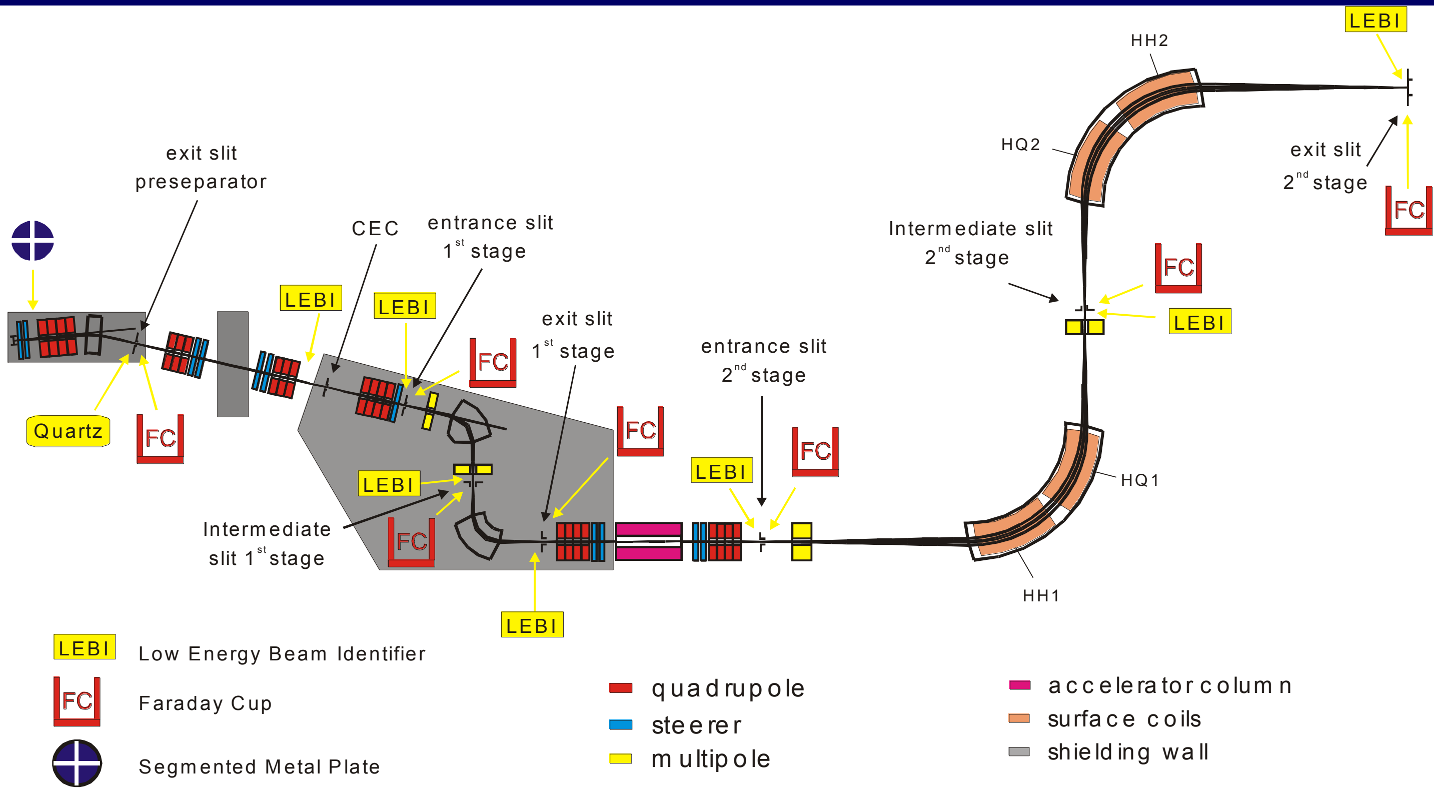
Easy variable beam energy (excitation function study)

***Low energy spread*: $\Delta E/E = 10^{-4}$.**

EXCYT layout



The mass separator

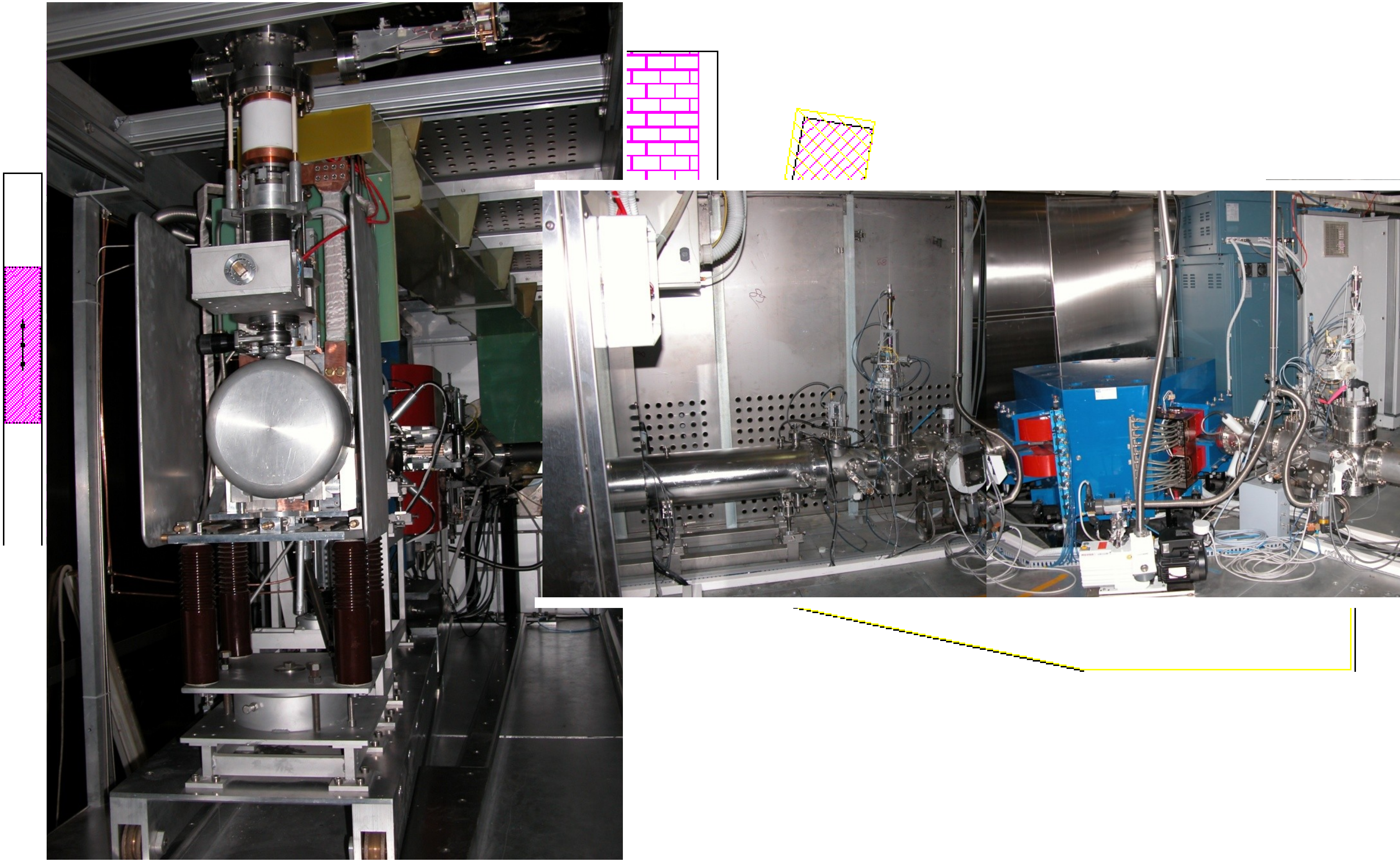


The mass separator system consists of a pre-separator and 2 main stages, the pre-separator and the first stage being assembled on two 250 kV platforms

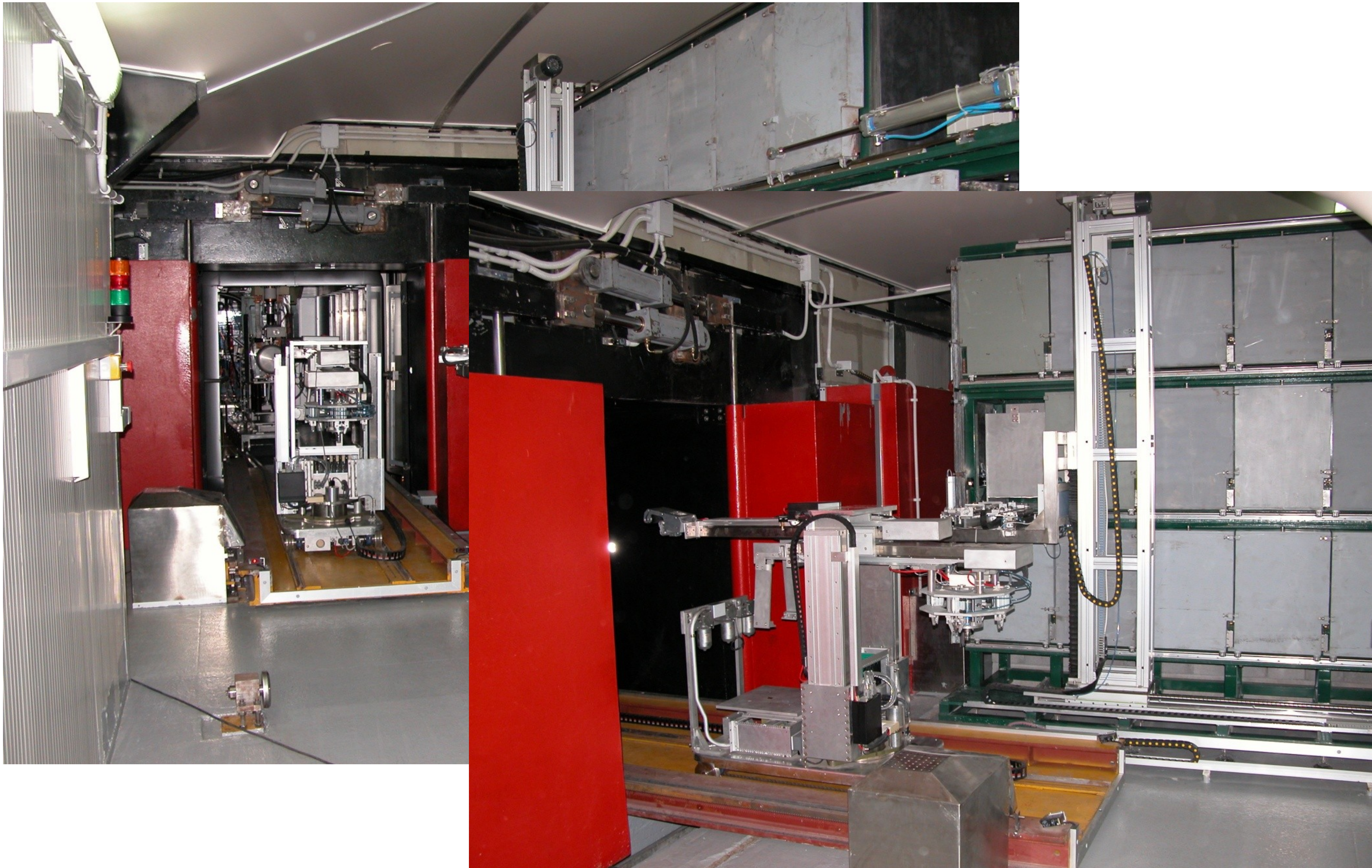
Assuming a beam with $\varepsilon_x=\varepsilon_y=4\pi$ mm•mrad ($x_0=y_0=\pm0.2$ mm, $a_0=b_0=\pm20$ mrad), the mass resolution of each stage is:

$(M/\Delta M)_{Pre} \approx 180$ (pre-separator : 18° magnet and a set of 4 electrostatic quadrupoles)
$(M/\Delta M)_{1st} \approx 2000$ (I stage: 2 magnets (77°, 90°) and 2 sets of 4 electrostatic quadrupoles)
$(M/\Delta M)_{2nd} \approx 20000$ (II stage: 2 magnets (90°) and a set of 4 electrostatic quadrupoles)

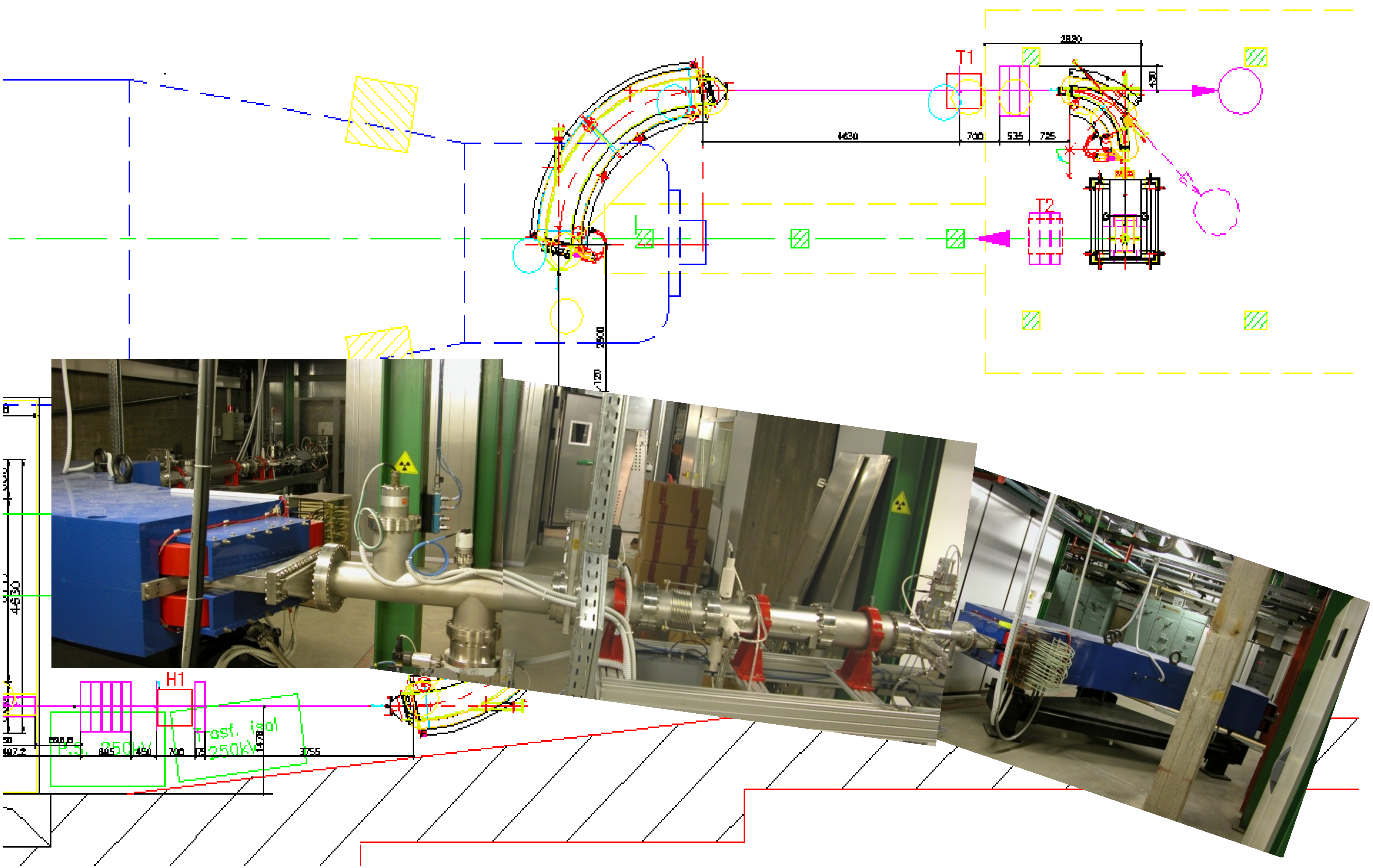
EXCYT layout



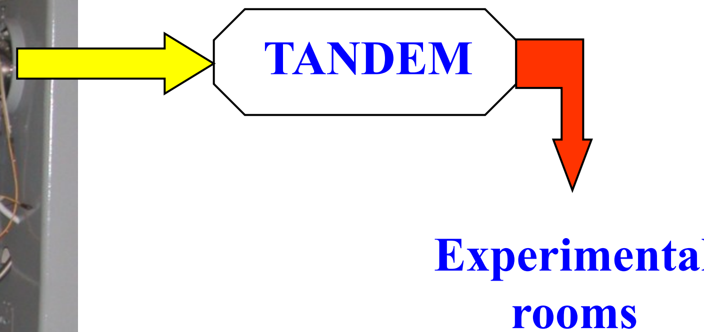
Remote handling



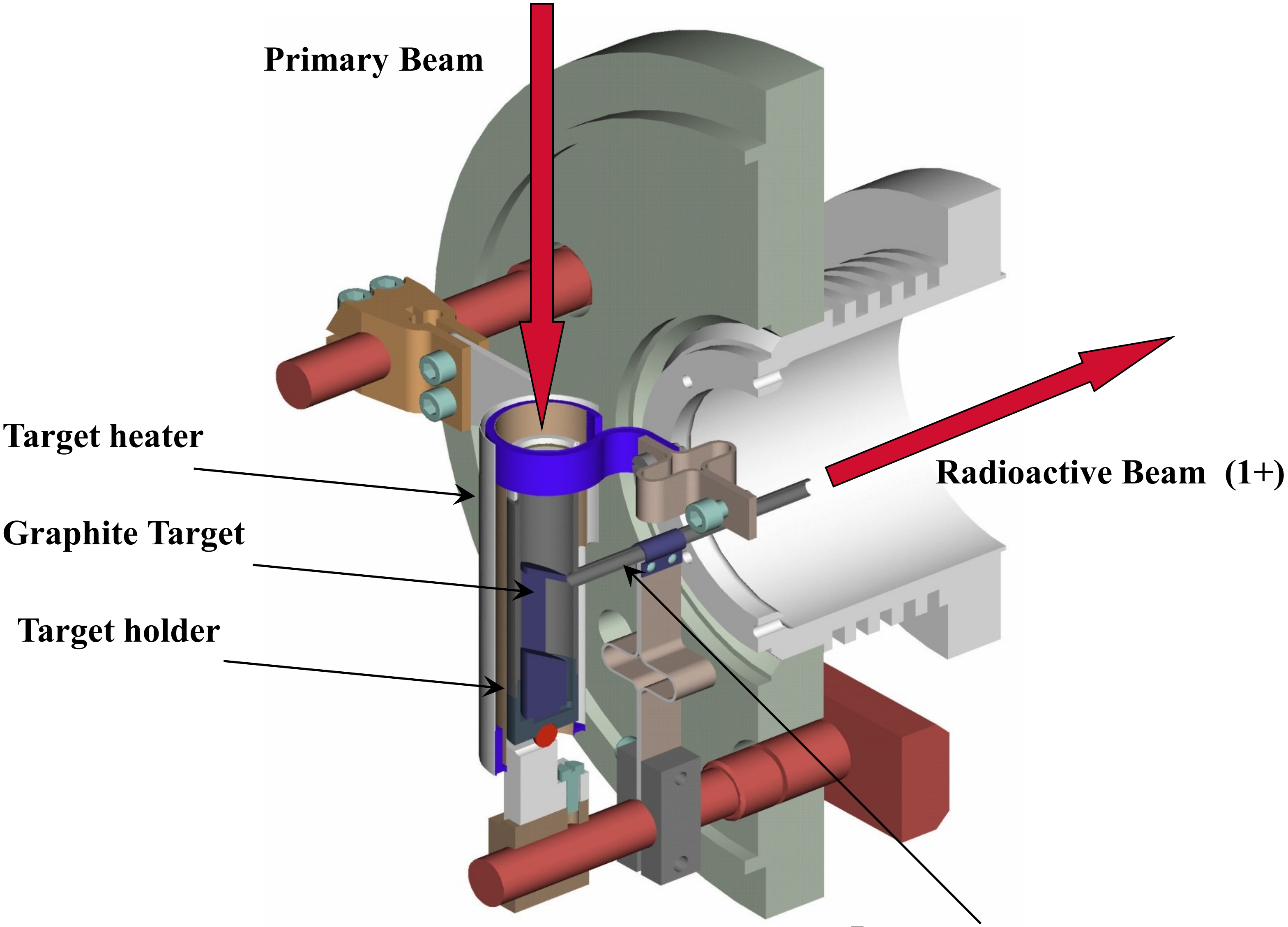
EXCYT layout



Beam lines to the Tandem



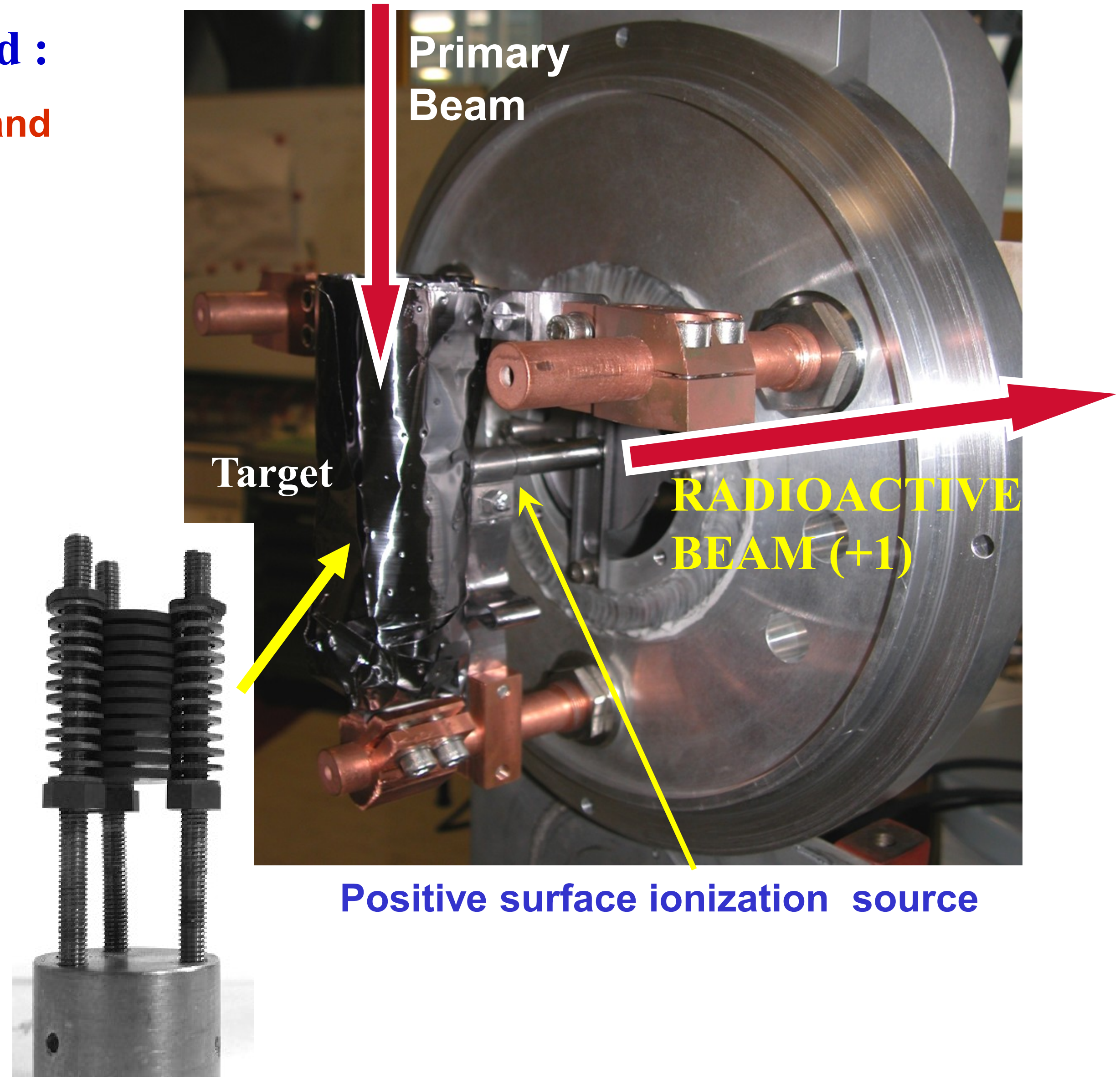
The Target-ion source complex

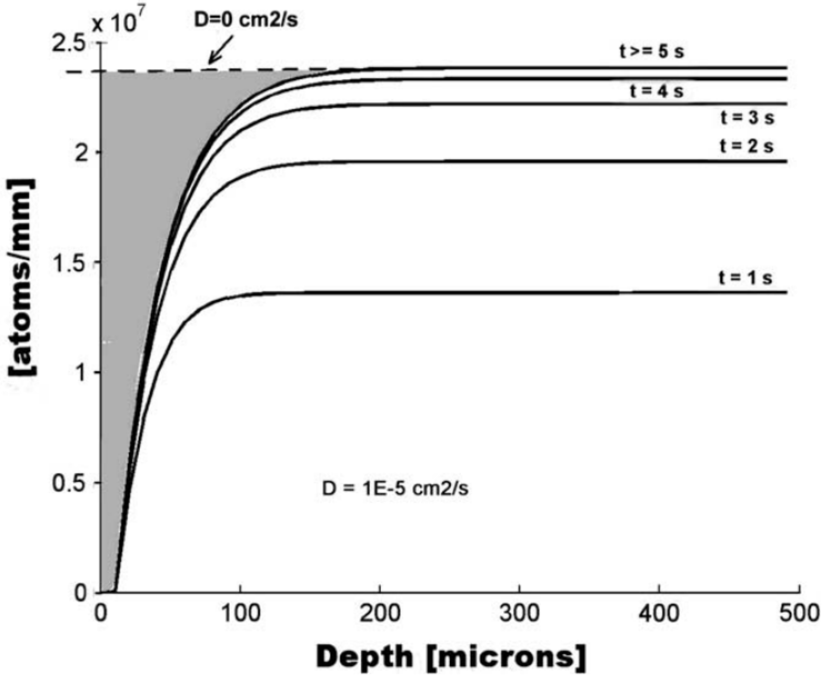


Target-Ion Source

Total RIB Production yield :

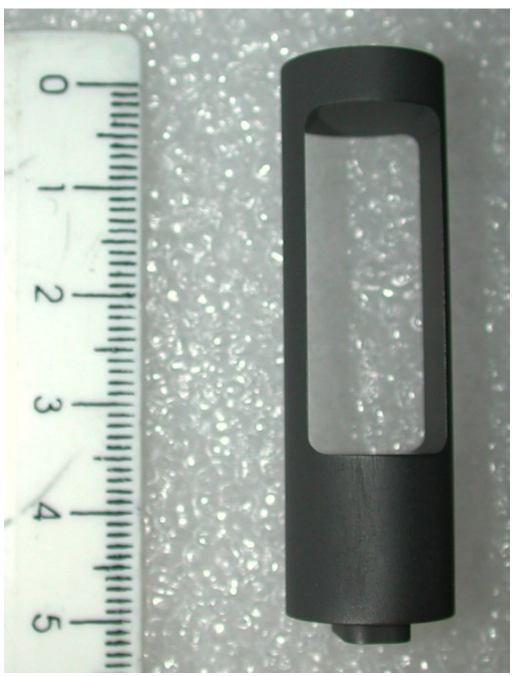
- -Primary ion beam intensity and energy
- -Cross-section of production
- -Diffusion through the target bulk
- -Effusion to ionizer
- -Ionisation efficiency
- -Charge exchange efficiency
- -Transport, Separation and Post-acceleration efficiency

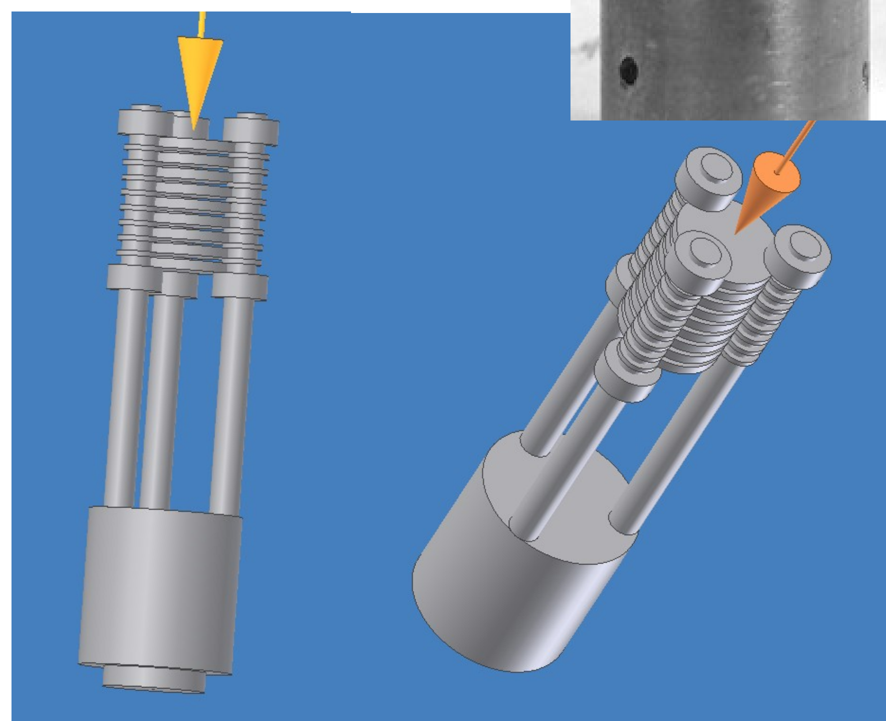




8Li concentration plot versus time, near the target surface

TARGET material UTR146 graphite

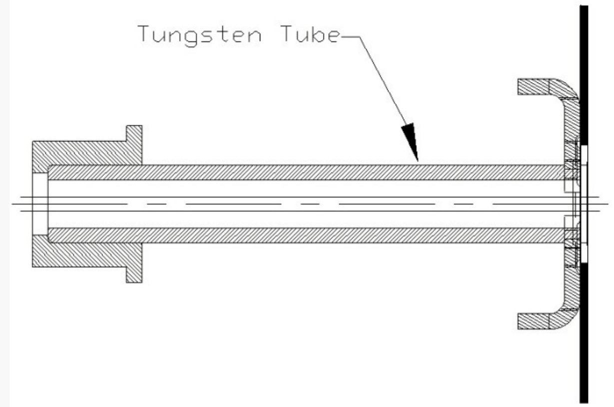


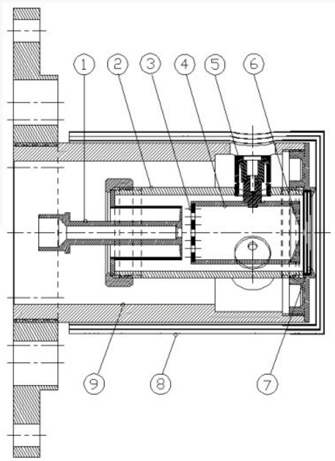


EXCYT Ion sources

- PIS : Positive Ion Source by
  surface ionisation
  High efficiency for Li:
  Suitable for alcalines (Li, Na, K)

- HPIS : Hot Plasma Ion Source

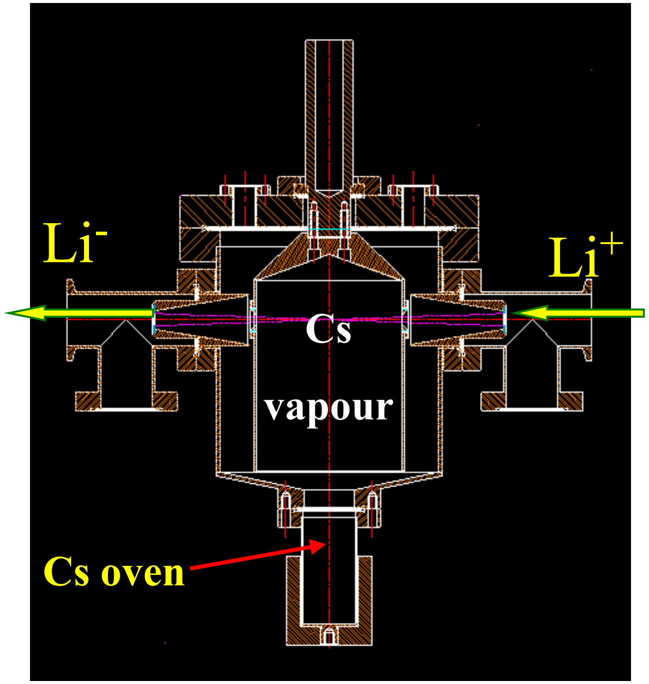


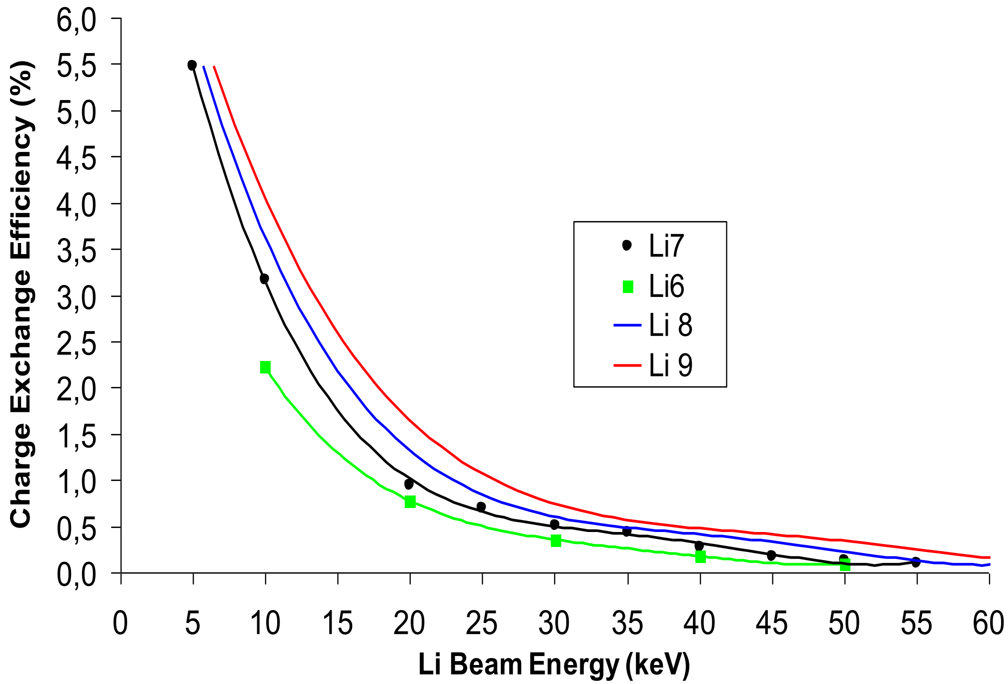


ITEM	NAME
1	Cathode
2	Cathode Support
3	Anode Grid
4	Anode Body
5	Anode Isolator
6	Outlet
7	Thermal Screen
8	External Thermal Screen
9	Support Assembly

•NIS : Negative Ion Source by surface ionisation.
High efficiency for halogens (Cl , Br ..) except F

Charge-exchange cell





$$Li^{+} + Cs \rightarrow Li + Cs^{+}$$

$$\Delta E = E_i(Cs) - E_i(Li) = 3.89\,eV - 5.39\,eV = -1.5\,eV$$

$$Li + Cs \rightarrow Li^{-} + Cs^{+}$$

$$\Delta E = E_i(Cs) - E_a(Li) = 3.89\,eV - 0.62\,eV = 3.27\,eV$$

@10 keV 7Li- Eff=2.7%
@10 keV 8Li- Eff=3.4%

@5 keV 7Li- Eff=4.5%
@5 keV 8Li- Eff=5.5%

EXCYT transmission factors

October 2008

Primary beam power	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	$5.4 \cdot 10^{6}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$1.5 \cdot 10^{5}$	$7.0 \cdot 10^{4}$	$5.0 \cdot 10^{4}$

Production: at least 3 times the value found at Ganil (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

Experiments with EXCYT approved by the LNS PAC

BIGBANG

Measurement of the $^{8}Li(\alpha,n)^{11}B$ cross section in the c.o.m. energy range from about 1.5 MeV down to the Gamow peak (~0.5 MeV). Key reaction in the inhomogeneous Big-Bang model

Published on Physics Letters B 664 (2008) 157-161

RCS

Measurement of the $^{8,9}Li$ + ^{28}Si reaction cross section at near barrier energies to determine the size of the unstable Li isotopes

RSM

Measurement of the α -$^{8,9}Li$ elastic scattering excitation functions in reverse kinematics, aimed at studying backward angle resonances associated with cluster configurations of $^{12,13}B$

IJMPE 4 (2011) 1026-1029 – J.Phys.Conf. Ser. 267 012011

MAGNEX-RIB

Exploratory attempt to investigate ^{8}He states using the (^{8}Li,^{8}Be) charge exchange reaction

2.10^{5} pps required, now feasible – Beam lines equipped with diagnostics

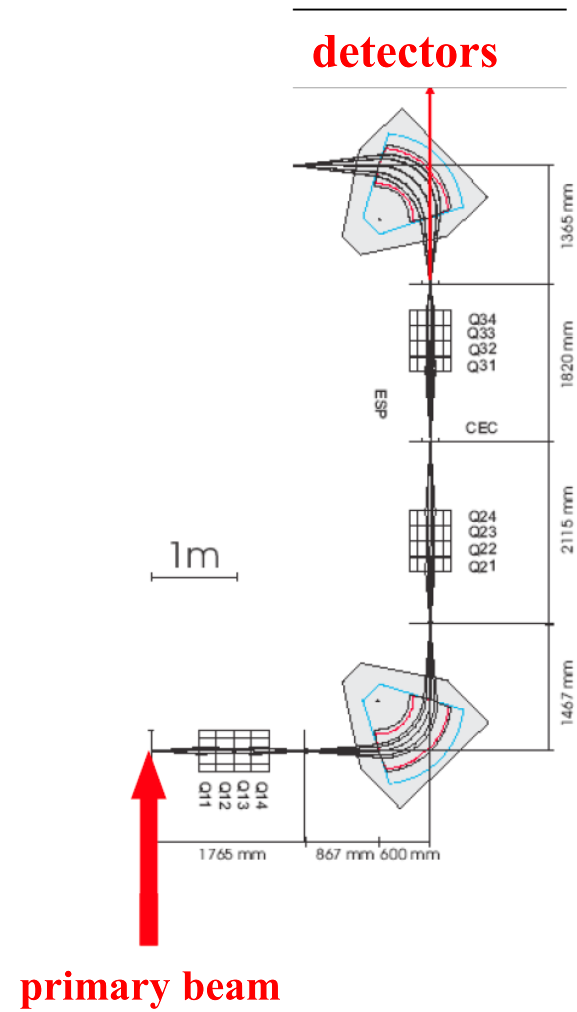
EXCYT: next steps

- ◆Optimization of transmission through preseparator and tandem.
- ◆Increase of primary beam power to reach the design value of 500 W.
- ◆Cold Testbench installation for Ion Source developments.
- ◆ “Warm” Testbench installation for target characterisation in collaboration with LNL staff of SPES project.

EXCYT & SPES Testbench

R&D activities on the Target – Ion source complex

- **Better undestanding of diffusion-effusion models (improve target design)**
- **New target materials (e.g. Foams, Fibers, Ta foils,…)**
- **New container geometry to increase the transport efficiency (effusion) to the ioniser.**
- **New PIS surface materials**
- **Sources development (HPIS, negative, microwave)**



To be installed in the Magnex hall

EXCYT possible future beams

A primary beam power of 500 watt is assumed

$^{8,9}Li$	Positive Ion Source	$3{\cdot}10^5$ pps ^{8}Li	$3{\cdot}10^7$ @ 300 KeV
$^{20,21}Na$	Positive Ion Source	$3{\cdot}10^4$ pps ^{21}Na	$6{\cdot}10^6$ @ 300 KeV
^{15}O	Hot Plasma	$2.5{\cdot}10^6$ pps	$3{\cdot}10^7$ @ 300 KeV
$^{25,26}Al$	Hot Plasma		
$^{26,27}Si$	Hot Plasma		
$^{7,11}Be$	Hot Plasma		
$^{10,11}C$	Hot Plasma		
$^{38,39,40}Cl$	Negative Ion Source, no CEC		
$^{17,18}F$	KENIS ion source, no CEC		

Increasing the Cyclotron beam intensity

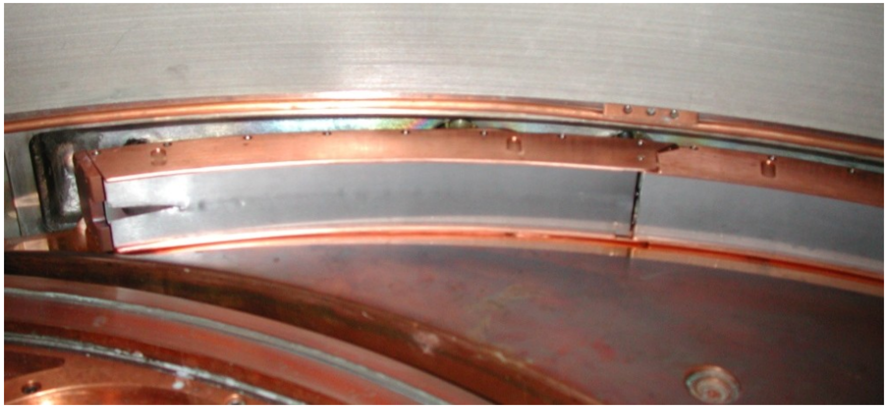
100 ⟶ 500 watt

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

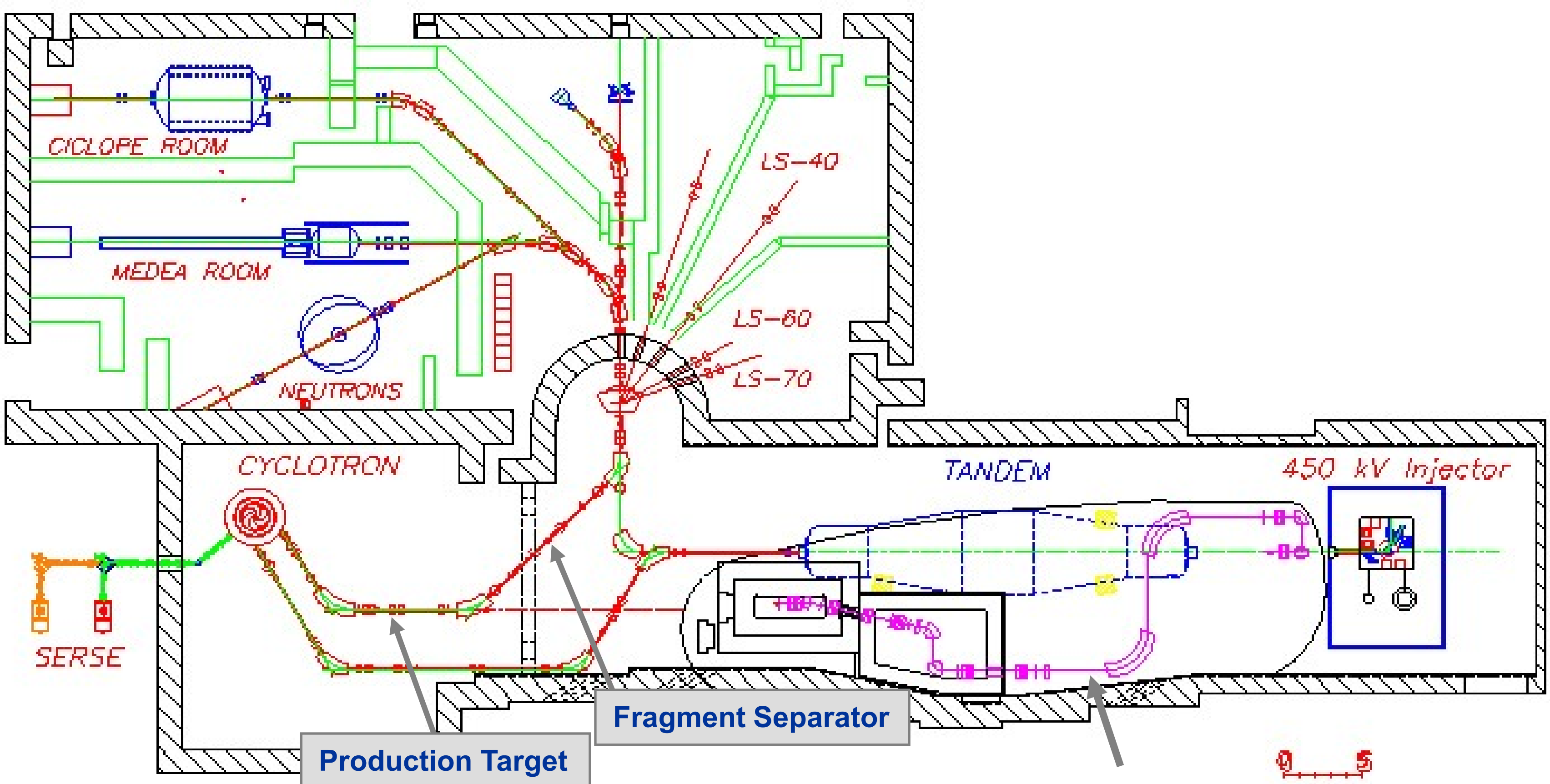
ε = 63%

Pdiss = 87 watt

F R I Bs (In Flight Radioactive Ion Beams)

Intermediate Energy RIBs @ LNS

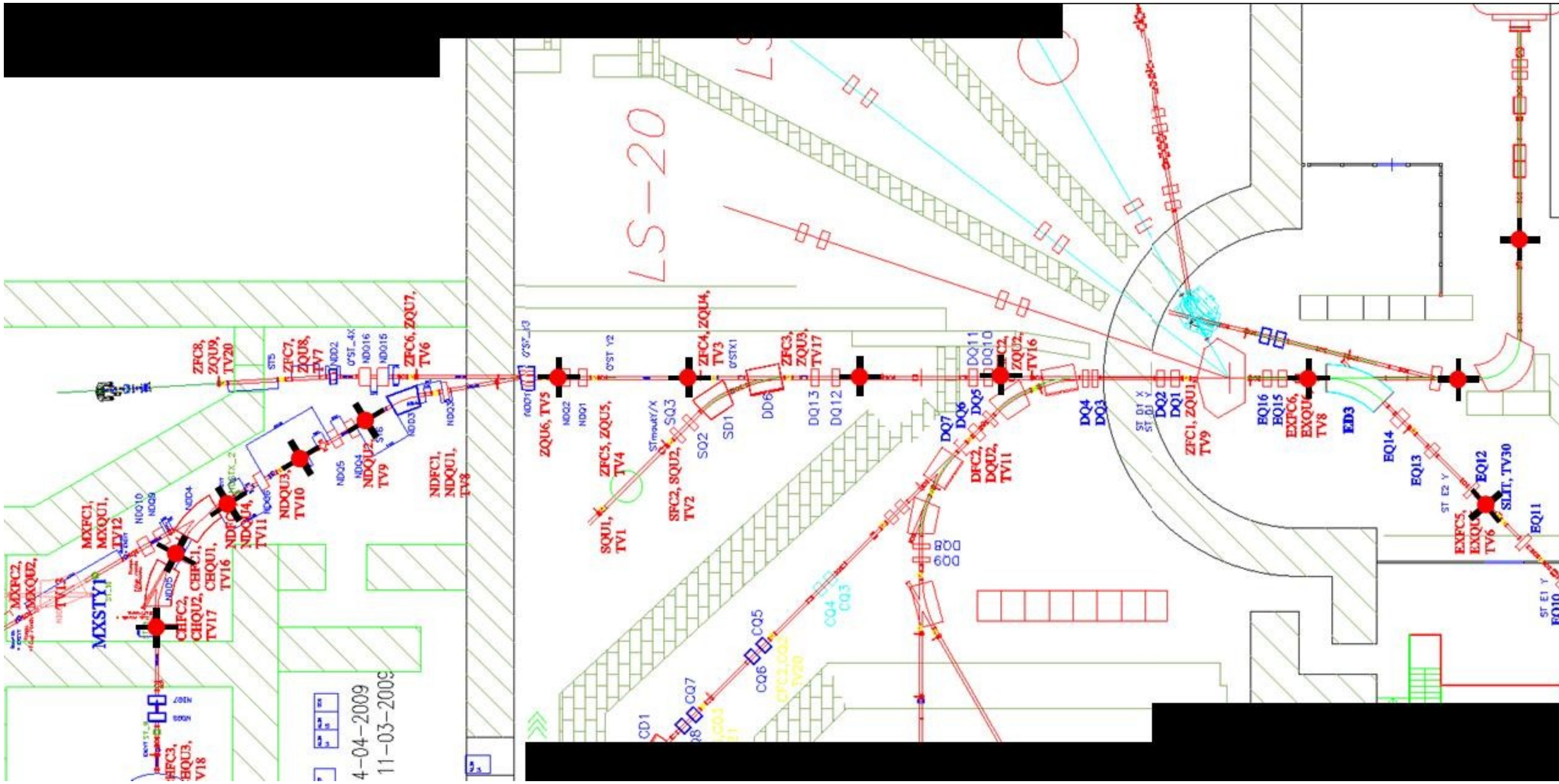
LNS - Layout



FRIBs

EXCYT

FRIBS@LNS experimental setup

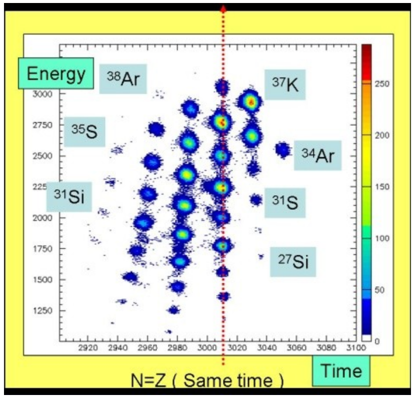


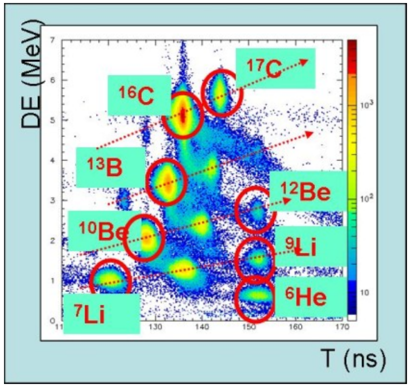
Successfully tested in March 2011 with 36Ar and 18O primary beams at 42 and 55 MeV/A respectively.

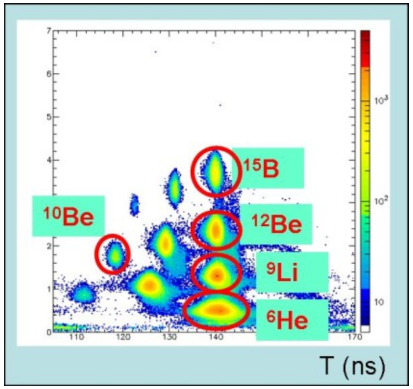
The beam transport was greatly improved due to the availability of the new EXCYT beam diagnostic system, distributed along all the beam line in 13 points, all equipped with a plastic scintillator for beam counting and a silicon position sensitive detector for the measurement of the beam profile and in the future also for identification pourposes.

FRIB@LNS yields

preliminary results data analysis going					
beam	primary beam	setting	intensity with old FRIBS (kHz/100W)	intensity (kHz/100W) March 2011	foreseen yield (kHz/100W) END 2011
16C	18O 55MeV/A	11Be	9	59	>120
17C	18O 55MeV/A	11Be		6	>12
13B	18O 55MeV/A	11Be	4.5	37	>80
11Be	18O 55MeV/A	11Be	2	11	>20
10Be	18O 55MeV/A	11Be		31	>60
8Li	18O 55MeV/A	11Be	3	9	>20
14B	18O 55MeV/A	12Be		1.2	>3
12Be	18O 55MeV/A	12Be		2	>5
9Li	18O 55MeV/A	12Be		2.7	>6
6He	18O 55MeV/A	12Be		4.7	>12
11be	13C 55 MeV	11Be	10		>50
12B	13C 55 MeV	11Be	20		>100
37K	36Ar 42 MeV	34Ar		50	>100
35Ar	36Ar 42 MeV	34Ar		35	>70
36Ar	36Ar 42 MeV	34Ar		50	>100
37Ar	36Ar 42 MeV	34Ar		12	>25
33Cl	36Ar 42 MeV	34Ar		6	>10
34Cl	36Ar 42 MeV	34Ar		25	>50
35Cl	36Ar 42 MeV	34Ar		26	>50
18Ne	20Ne 35 MeV	18Ne	9		>50
17F	20Ne 35 MeV	18Ne	3		>20
21Na	20Ne 35 MeV	18Ne	20		>100







Thanks for your attention