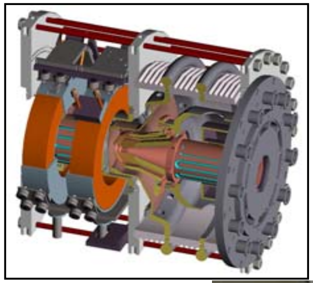
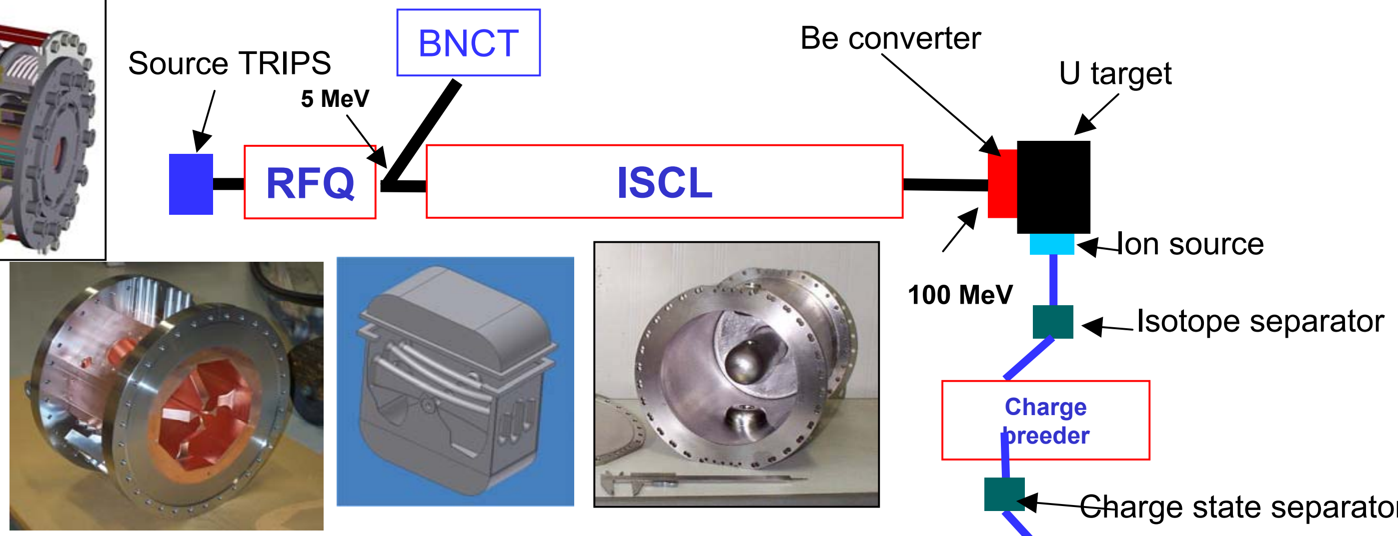




SPES Conceptual Design Report

TECHNICAL COMMITTEE

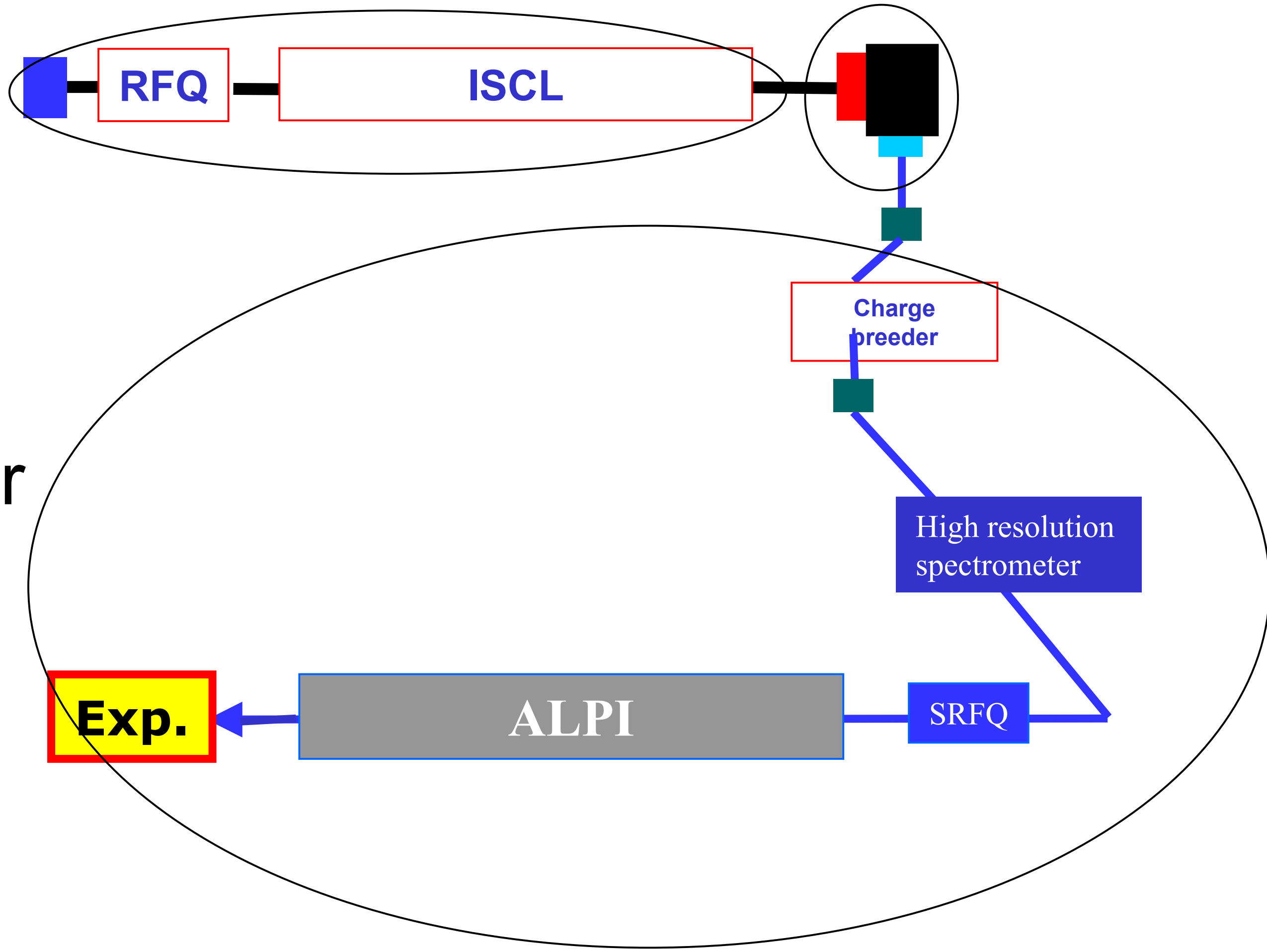
A. Pisent (Technical Coordinator)
M. Comunian (Injector and Normal Conducting Driver Linac)
A. Facco (Superconducting Driver Linac)
L. Tecchio (Production of Exotic Beams)
A. Lombardi (Reacceleration of Exotic Beams)
P. Favaron (Civil Engineering, Infrastructure and Safety)
G. Bisoffi (Costs and Schedule)

Outlook

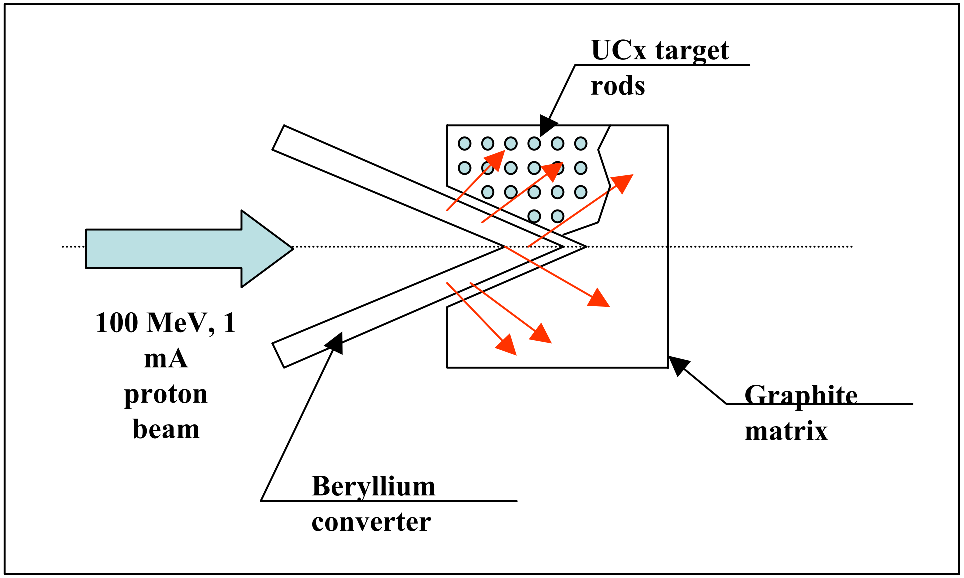
RIBs production

Driver accelerator

Reacceleration

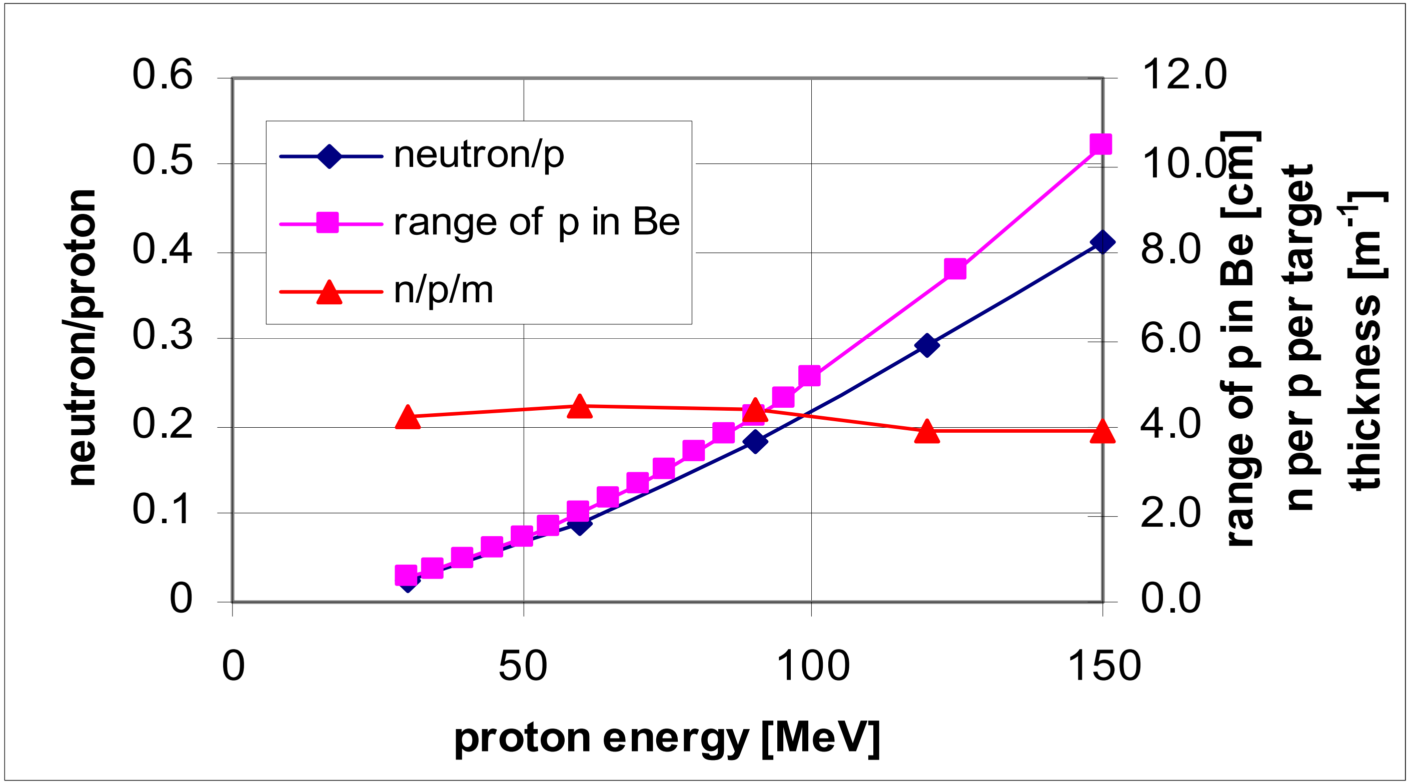


Production of neutron reach RIBs in SPES



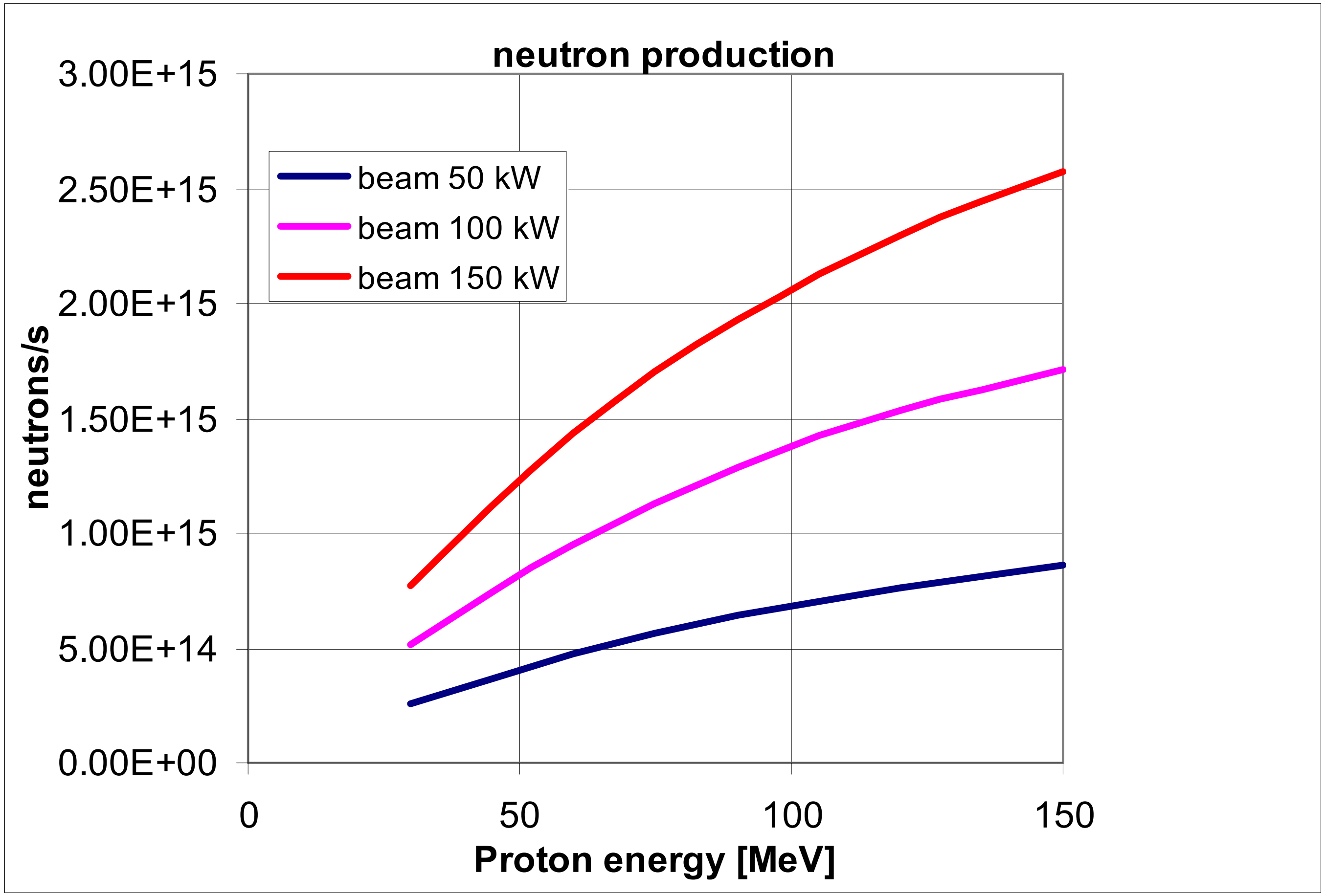
- Fission induced by fast neutrons
- 3 10^{13} fissions per second.
- The p beam power (~ 100 kW) is dissipated in the first target (converter), while the second target (production target) only withstands the fission power (few kW).
- The **production target** consists of ^{238}U, in the UCx form.
- The (p/n) **converter** is a thick **Be** target

p energy

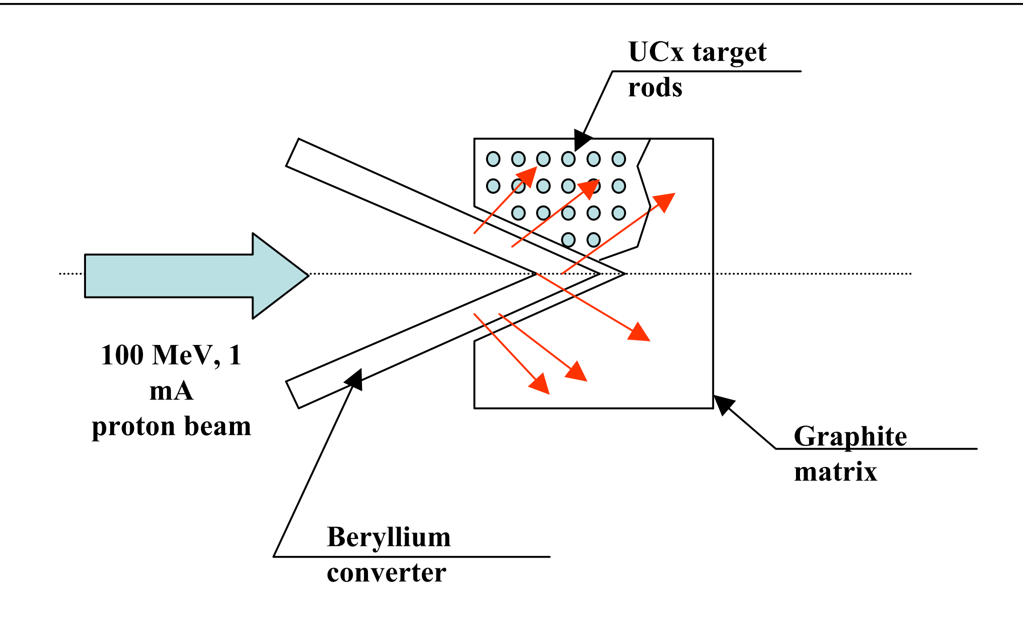


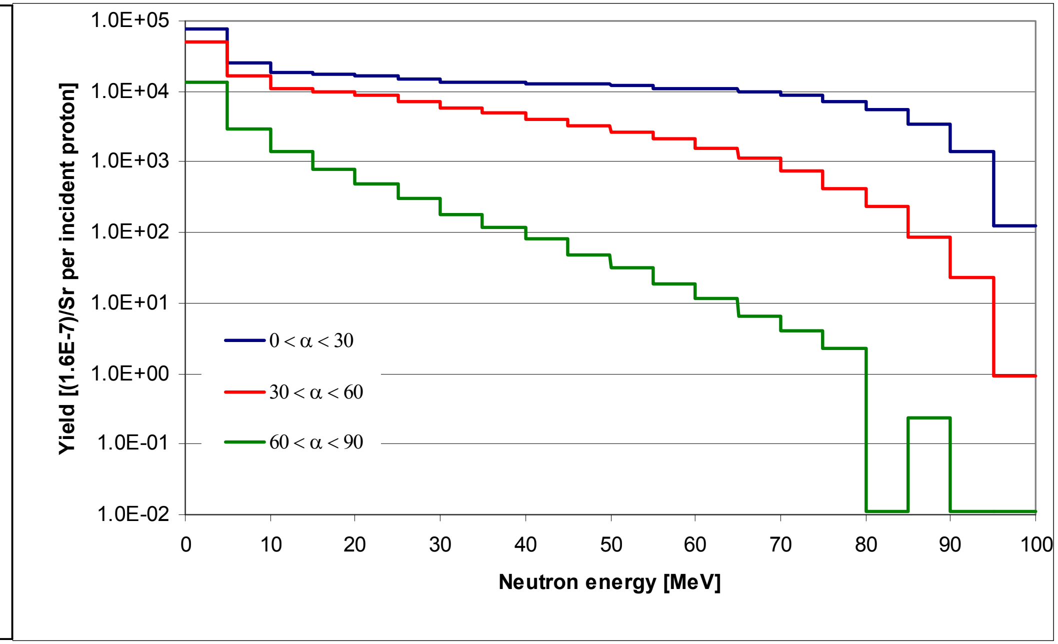
Number of neutrons (above 2 MeV) produced for each proton in the whole solid angle

Neutron production@different beam power



Flux of neutrons (above 2 MeV) in the whole solid angle for a thick beryllium target as function of p energy.

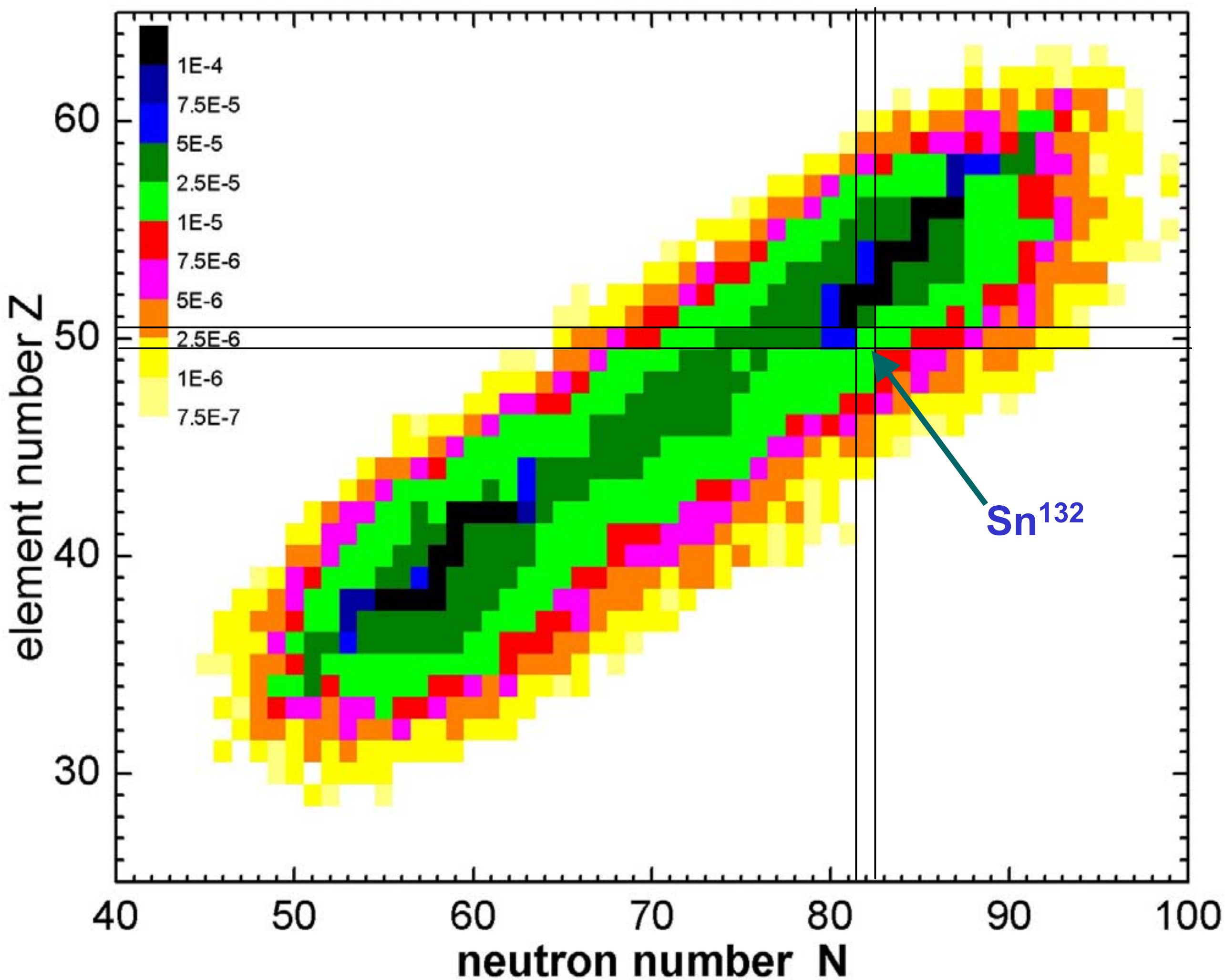




n spectrum (100 MeV p on thick Be target)

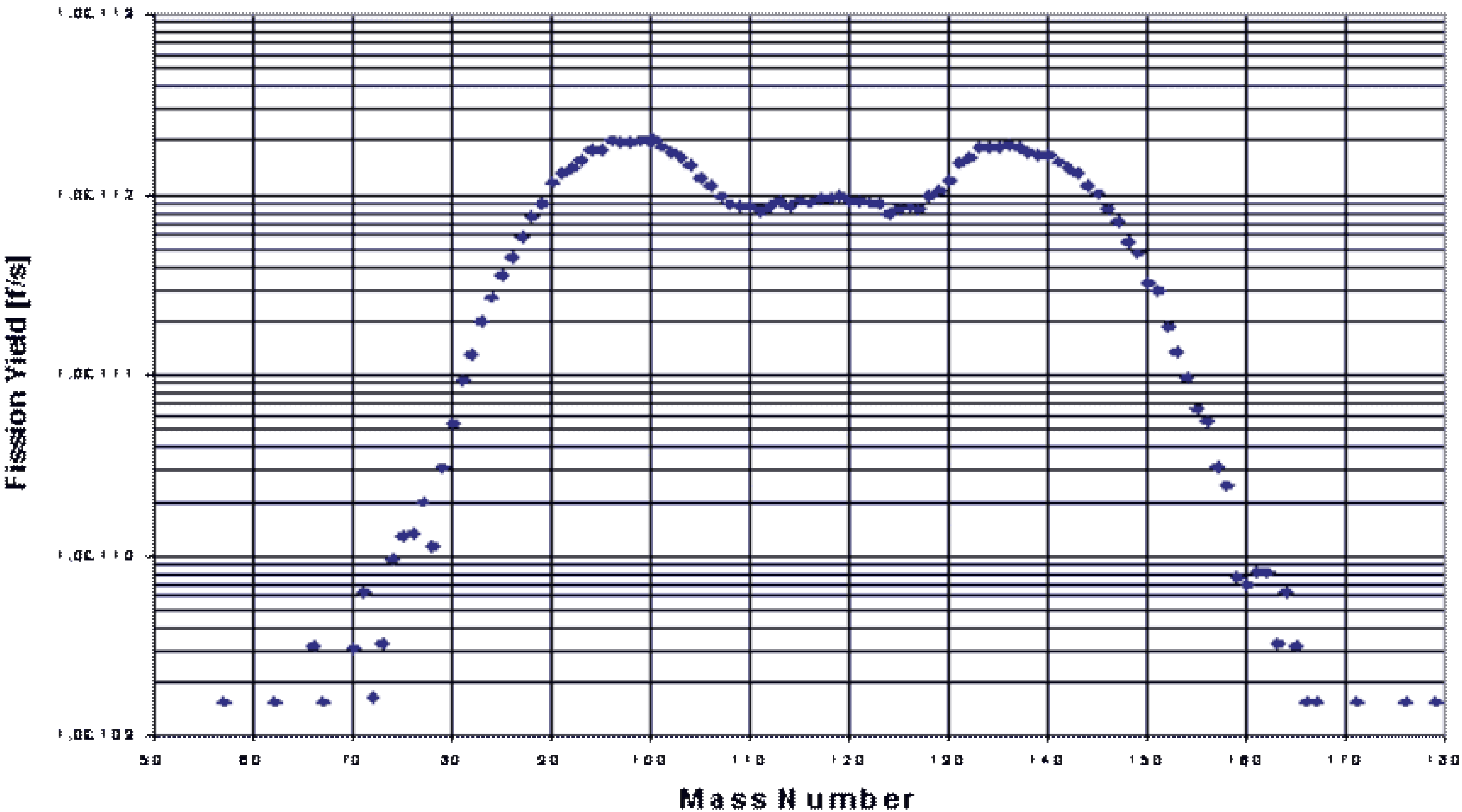
- **Production target 4 kg UCx** , nuclear graphite containing UCx rods (ϕ = 10 mm, δ = 2.5 g cm^{-2}) uniformly distributed.
- A tungsten container encapsulates the target that can be heated to high temperatures (2000-2500^{0}C).
- This latter is connected by a tube to an ion source and both stand to a potential of 60 kV, respect the ground.
- The calculated total fission rate is about 3 x 10^{13}/s

Fragments produced by each proton
(in 4 kg of Ucx)

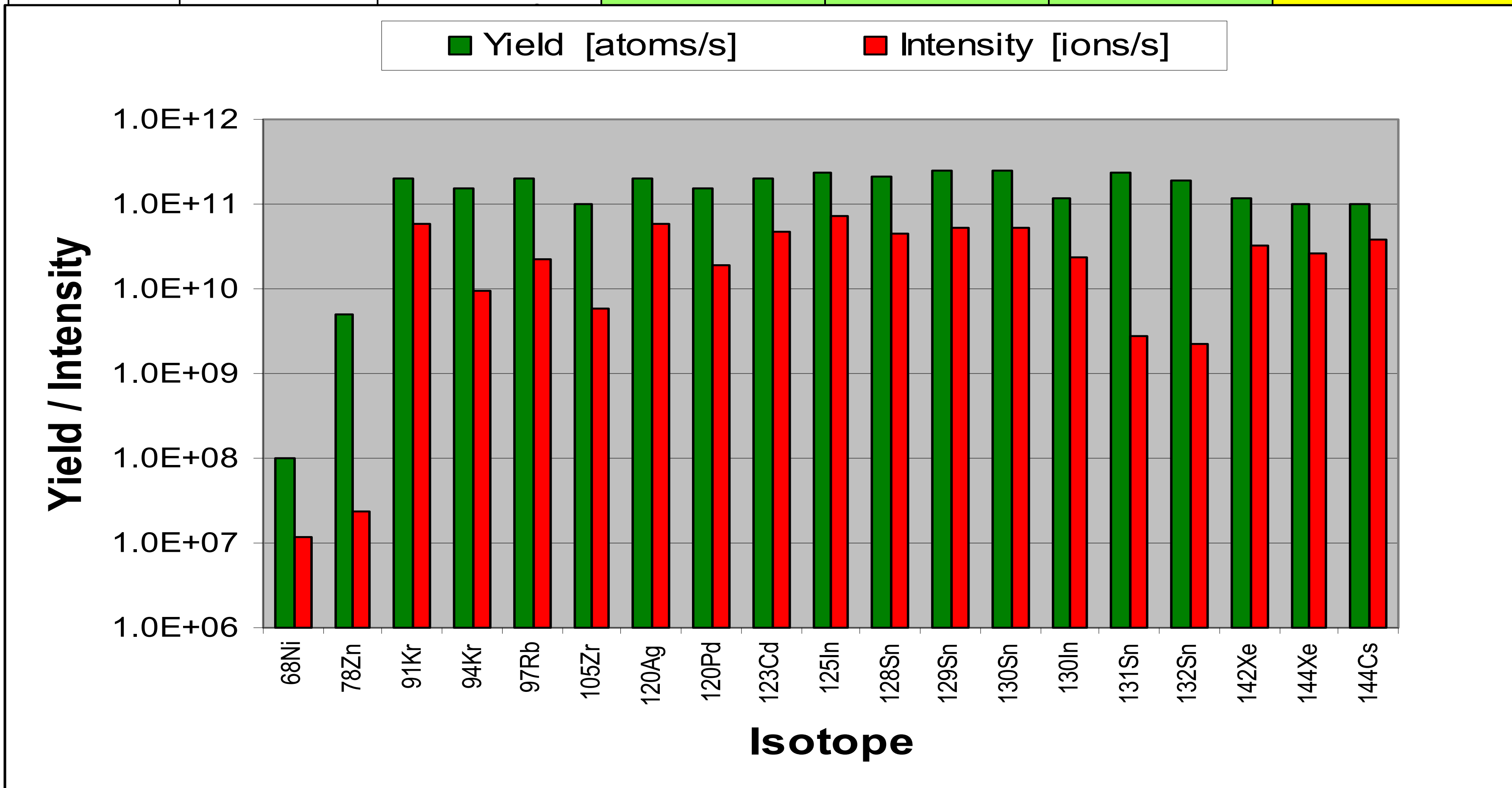


The nominal beam is of 1.7 x 10^{16} p/s.

Fission mass distribution for 100 MeV, 1 mA proton beam on beryllium converter and 4 kg UCx production target

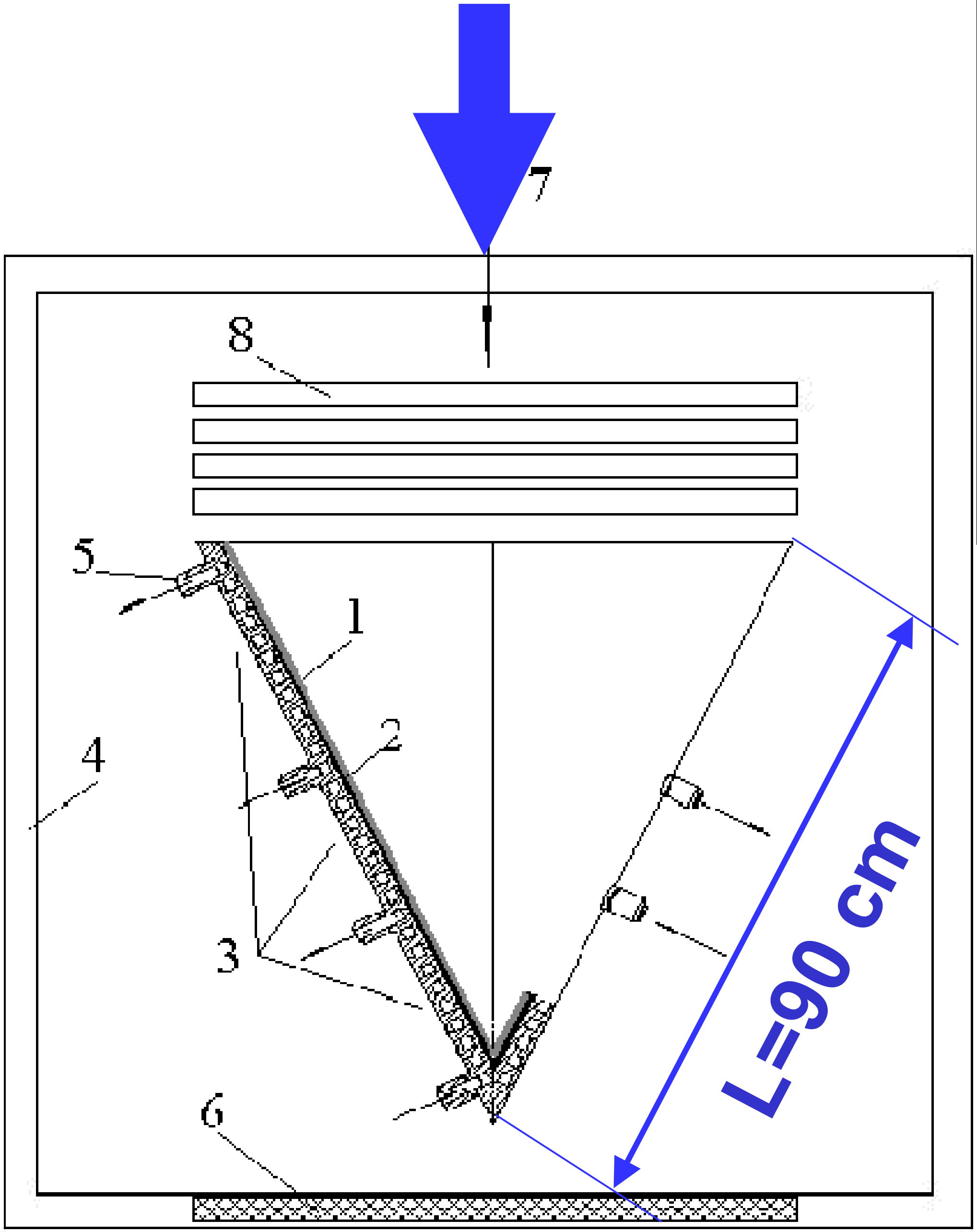


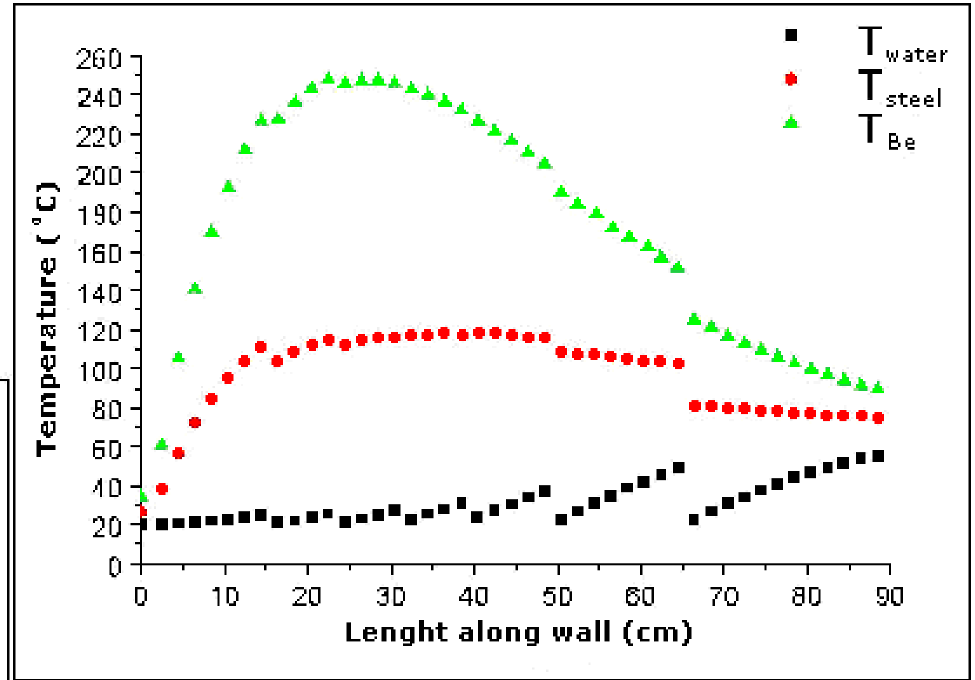
Element	Lifetime [s]	Yield [atoms/mC]	Total eff. [%]	Release &delay eff. [%]	Ioniz. eff. [%]	Ion source Intensity [ions/s]
132Sn	**34.9**	**1.9 10^{11}**	**1.2**	**2.4**	**50**	**2.28 10^{9}**
142Xe	1.24	1.2 10^{11}	26.4	44	60	**3.17 10^{10}**
144Xe	1.15	1.0 10^{11}	26.4	44	60	**2.64 10^{10}**
144Cs	1	1.0 10^{11}	38	40	95	**3.80 10^{10}**



At experiments for Sn^{132} typically 10^{8} ions/s (0.02 pnA)

10 MeV 30 mA

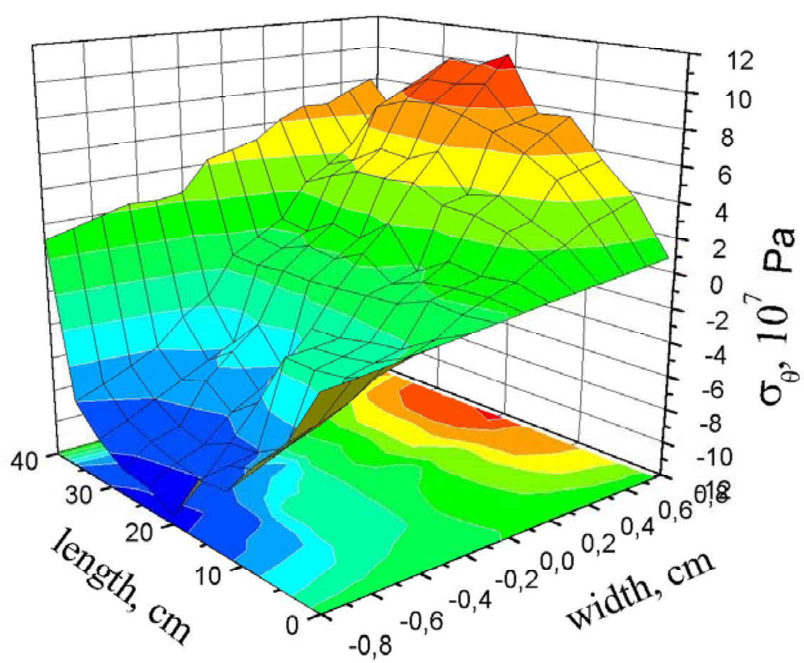


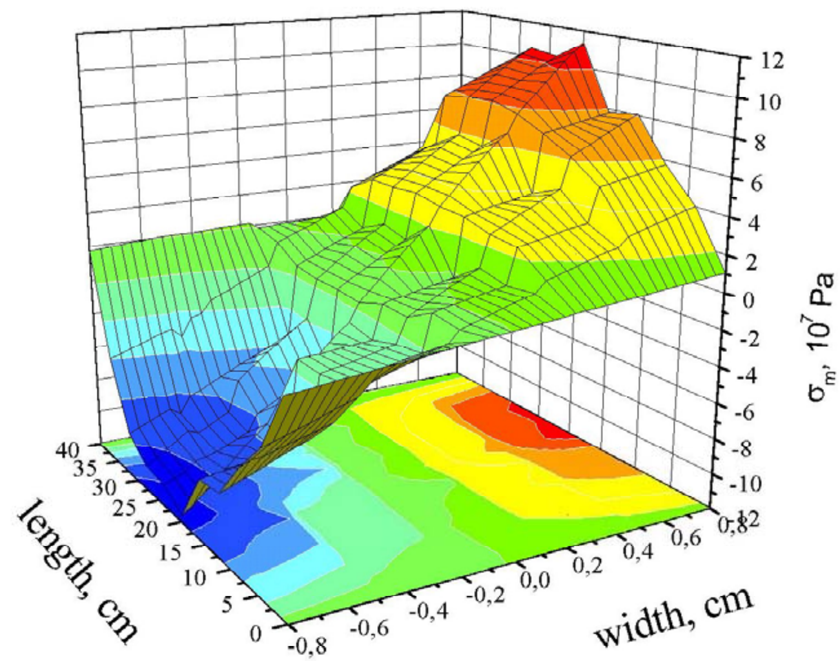


Be converter

300 kW water cooled
to be prototyped

Thermal stress calculations (10 MeV, 30 mA)

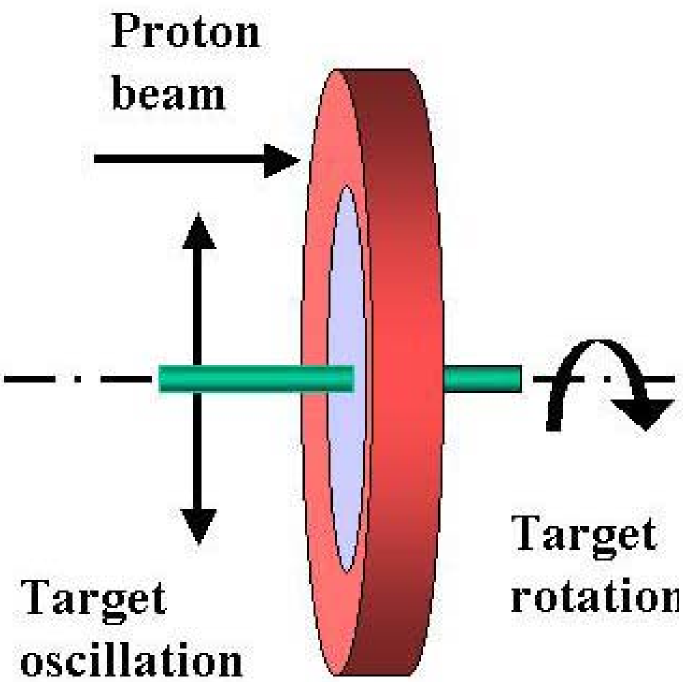




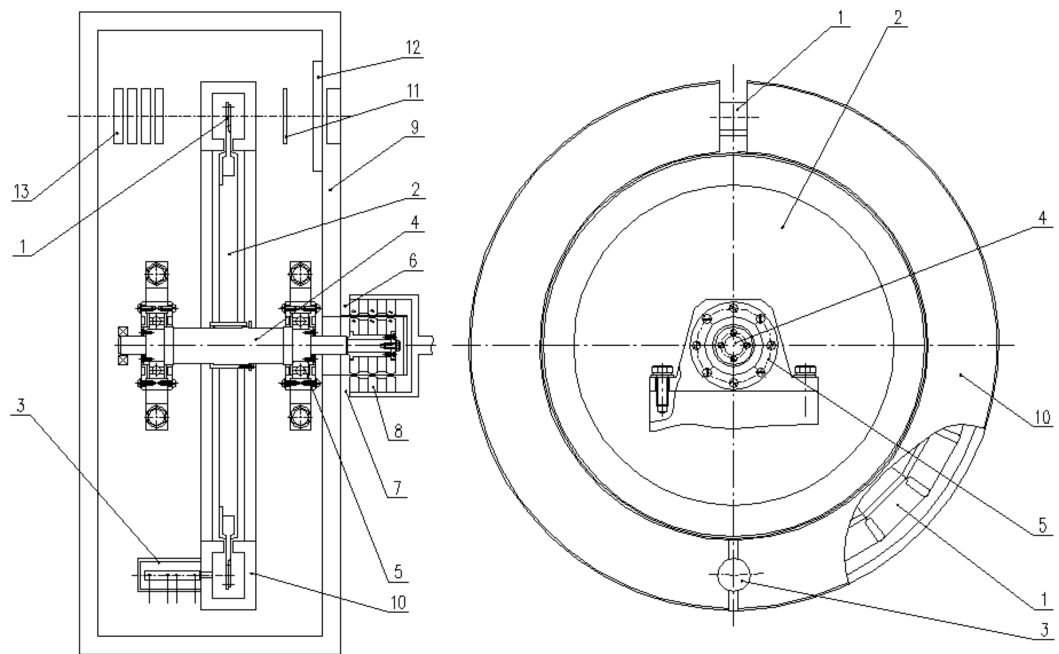
Maximum thermo-mechanical stress [10^7 Pa]

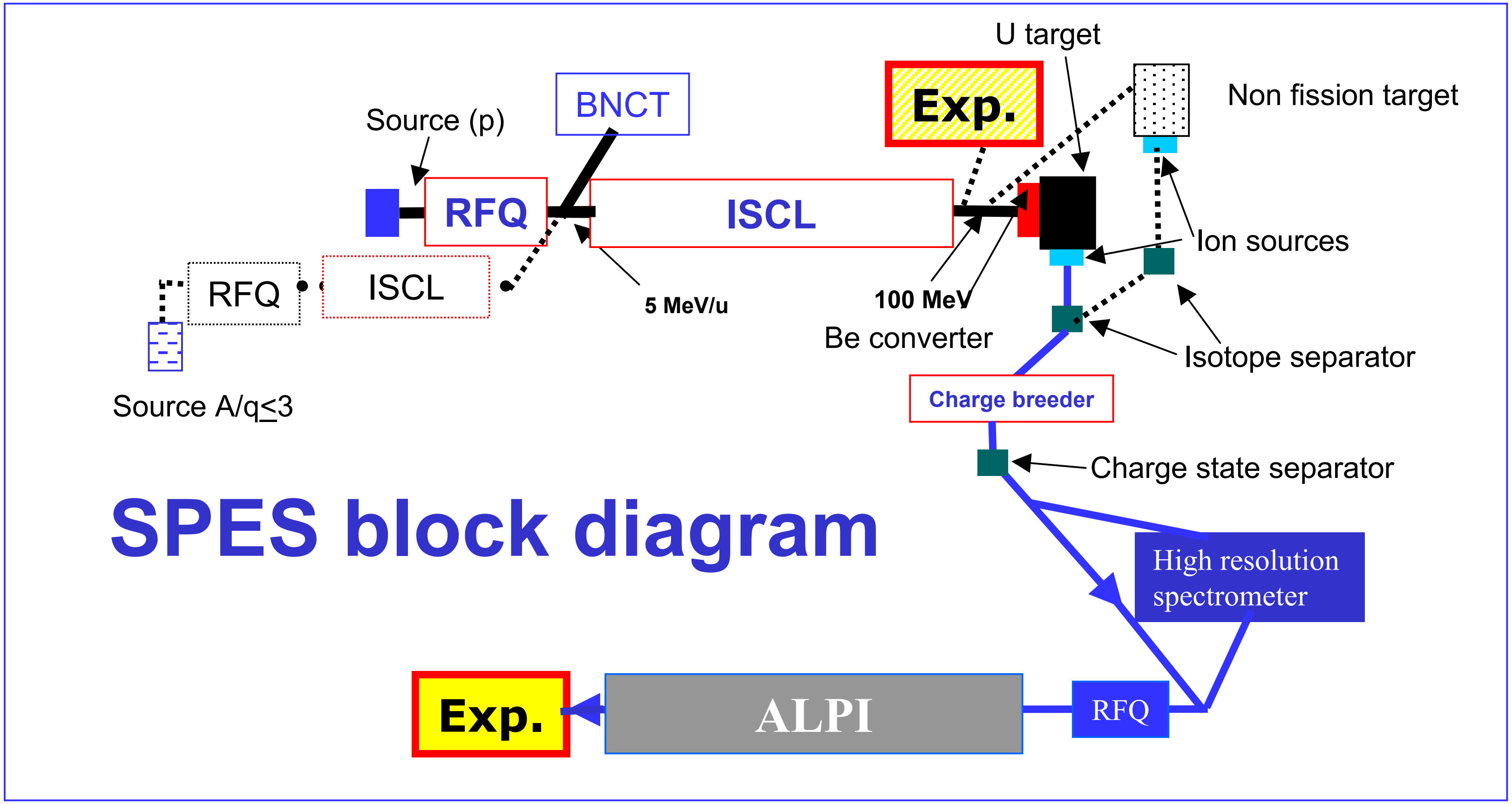
σ_m Be	σ_θ Be	σ_{ult} Be / σ_{fl} Be	σ_m Fe	σ_θ Fe	σ_{ult} Fe / σ_{fl} Fe
8.76	10.96	27 - 37 / 25.5	12.71	15.90	32.4 / 20.5

R&D for C^{13} rotating target



R&D program for the production of C^{13} with graphyte mechanical properties





Beside fast fission, p for direct reactions

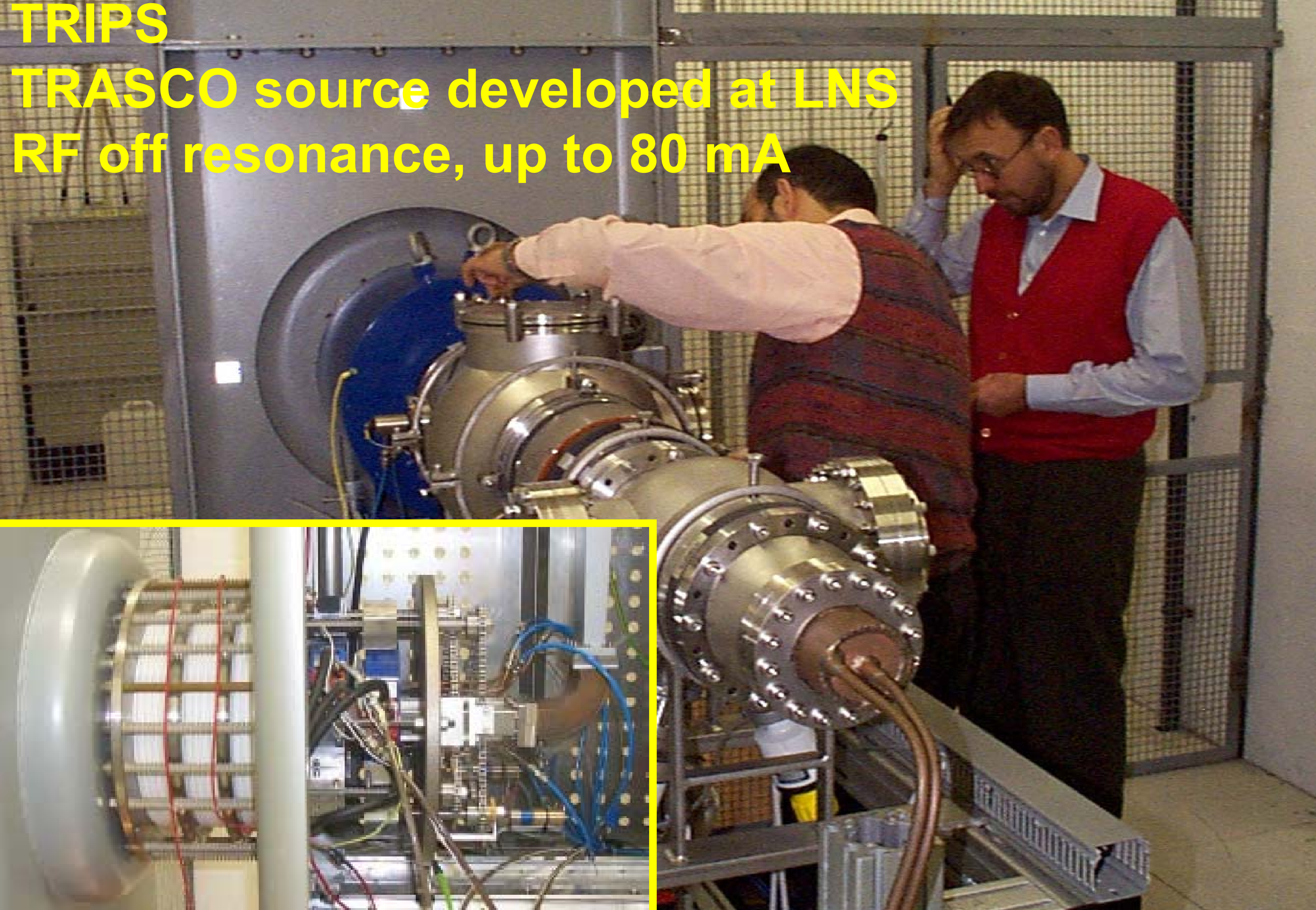
- **A/q≤3 (~100MeV/q):fusion-evaporation or multinucleon transfer reactions.**
- **deuterons increased production of neutrons (*2 on the whole solid angle, * 8 in the forward direction) getting to 10^{14} Fission/s.**
- **with d is much more difficult the linac operation (activation of the structure including the RFQ).**
- **this high intensity ion beam can be directly used by experiments.**

The driver linac

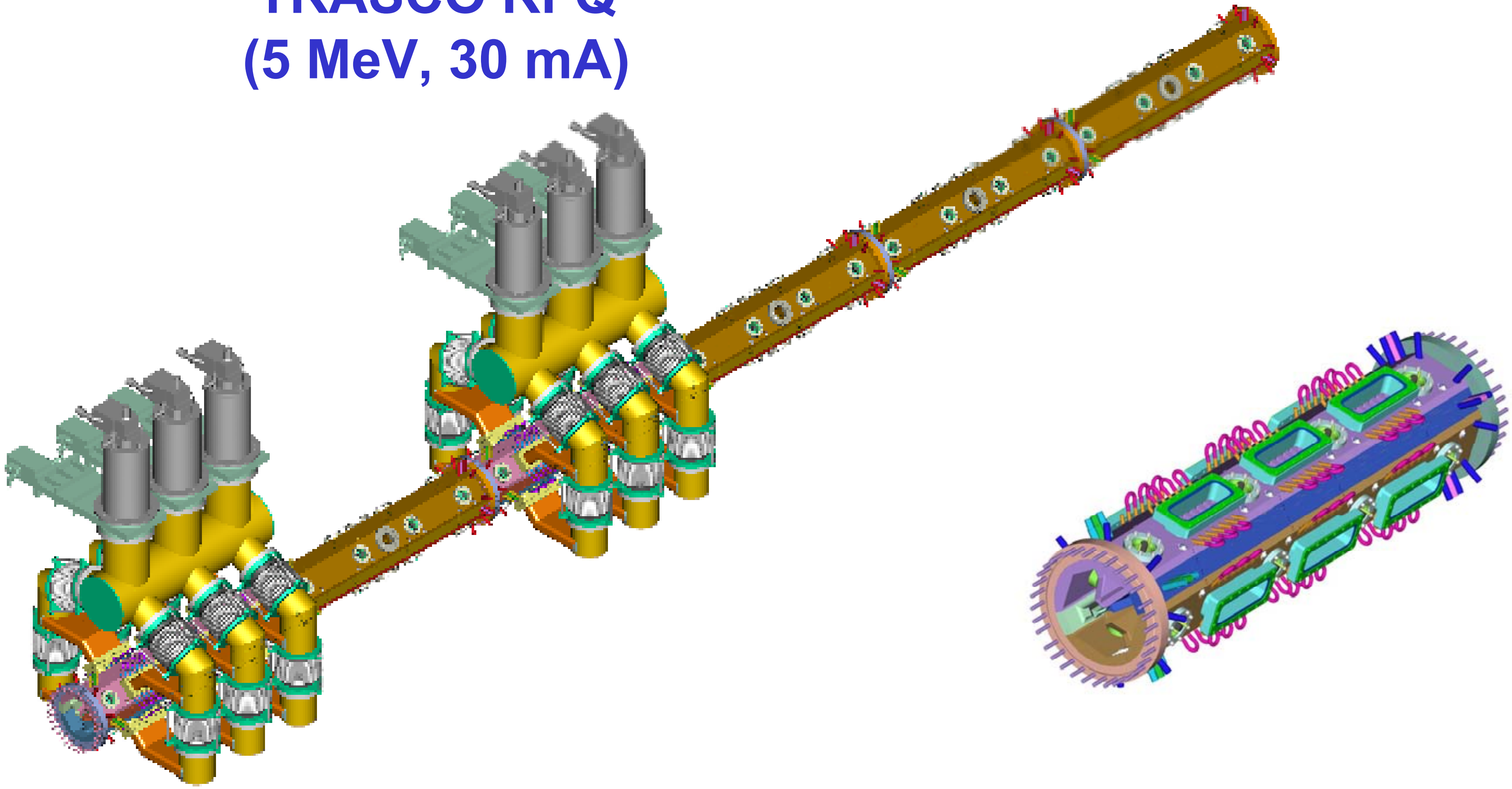
The main linac parameters are:

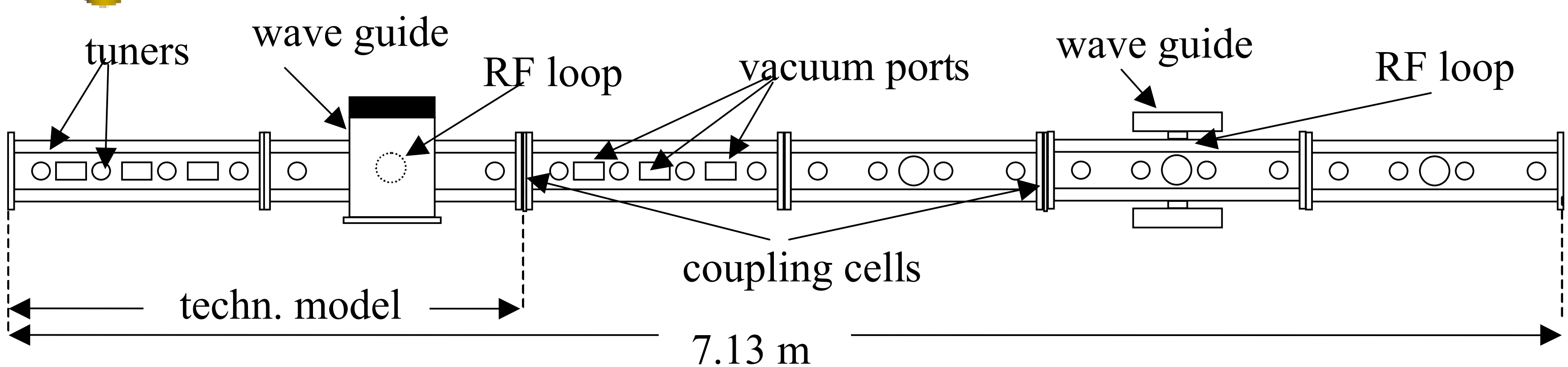
- Beam energy: ~100 MeV
- Beam current : 5 mA (like Eurisol driver)
- rf installed for 3 mA
- Duty cycle: 100% (cw), compatible with pulsed operation
- Beam losses below 1 W/m
- RF frequency: 352 MHz
- A/q≤3 ions accelerated

- The driver construction will include two stages.
  - In the first stage the proton injector and the main linac will be built.
  - In the second stage, the ion injector will be built.

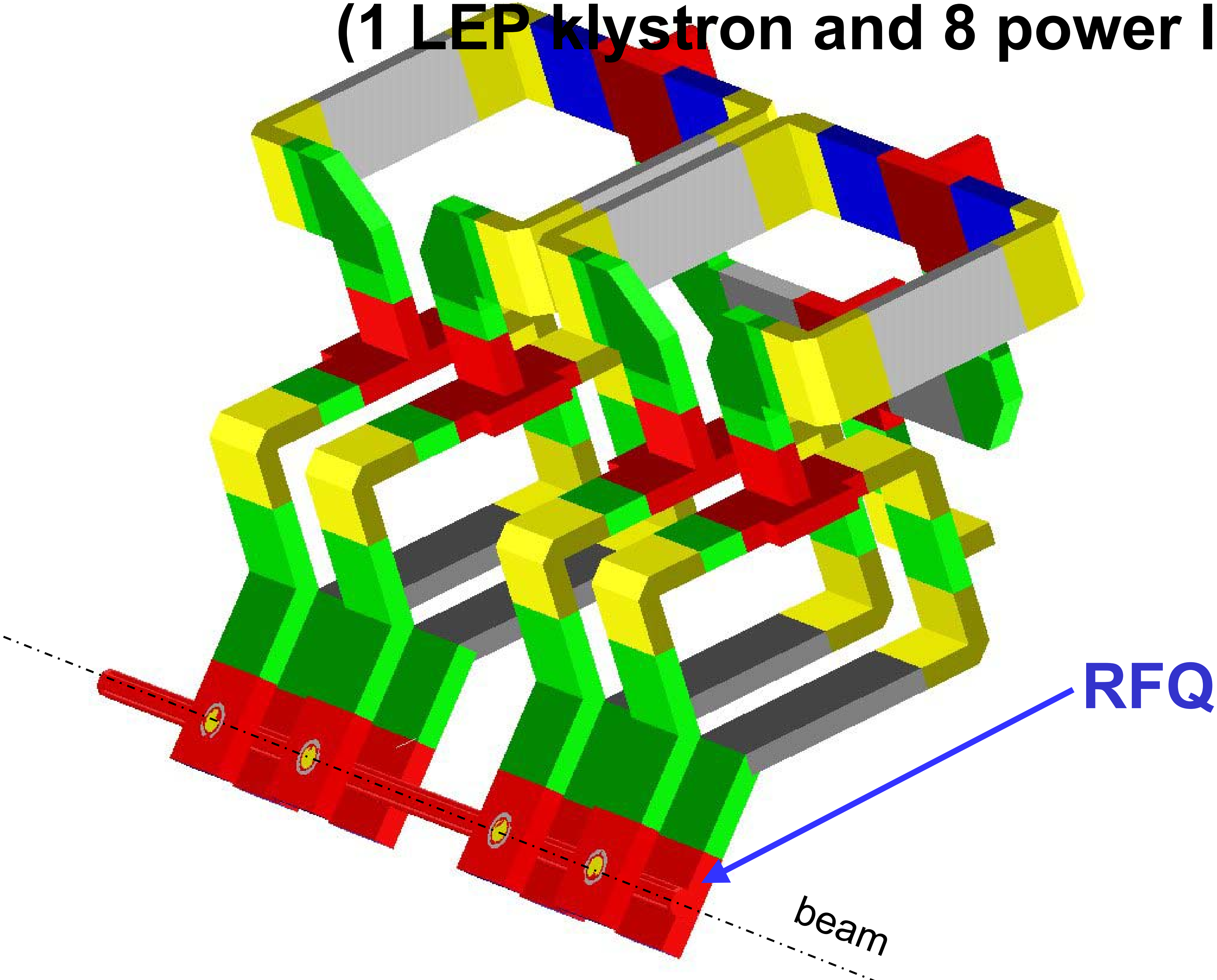

TRIPS
TRASCO source developed at LNS
RF off resonance, up to 80 mA

TRASCO RFQ
(5 MeV, 30 mA)

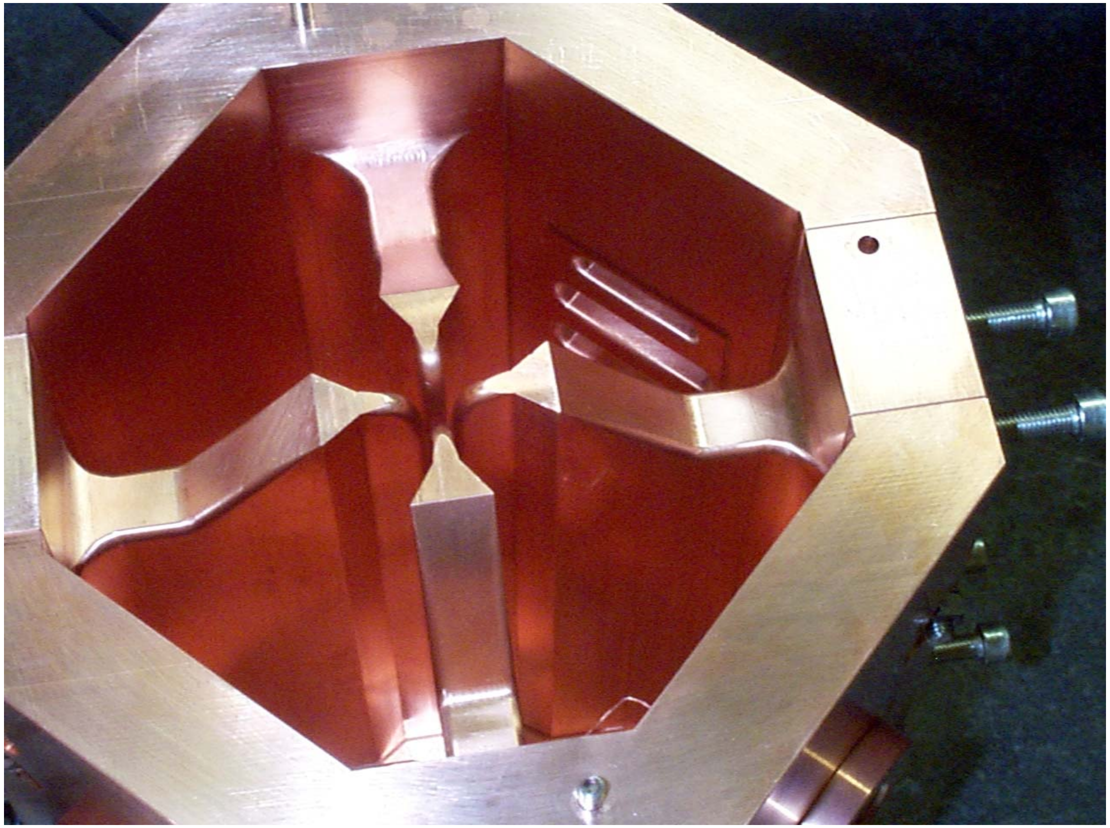


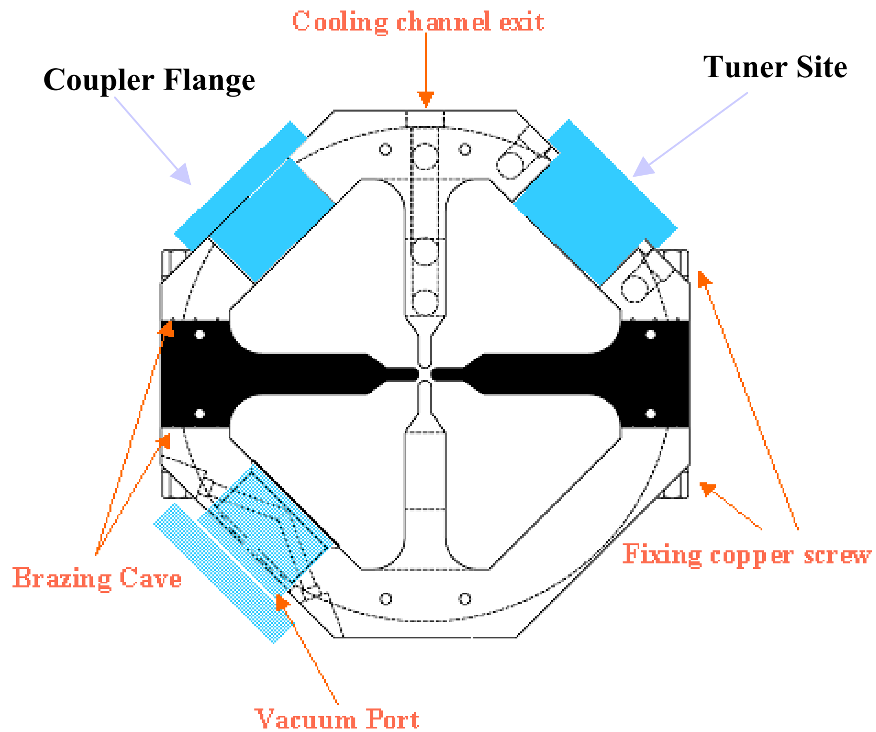


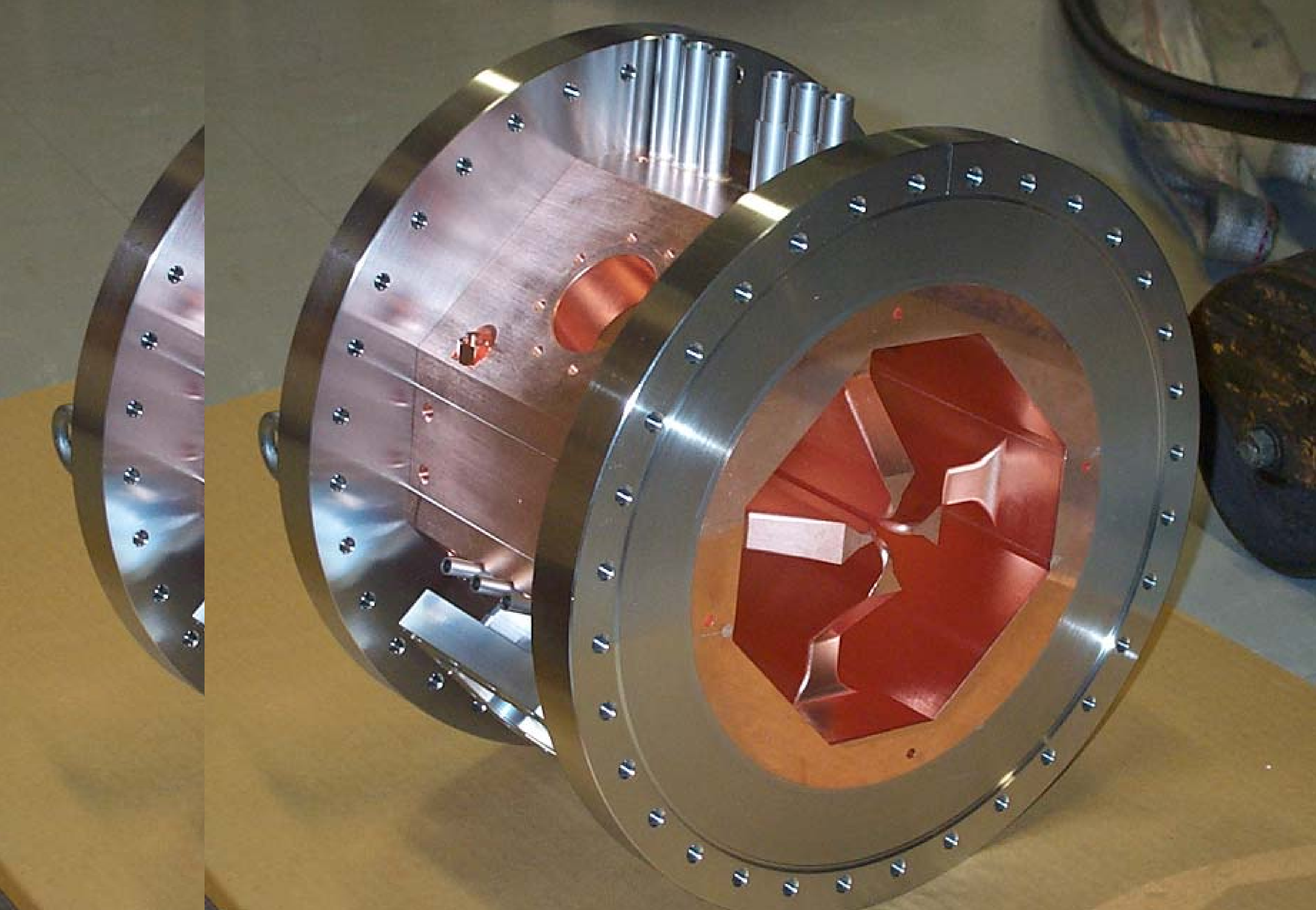
Wave guides
(1 LEP klystron and 8 power loops)



RFQ Test Model







RFQ construction

- In the 220 mm long technological model all construction steps have been tested
- First 1200 mm segment under construction

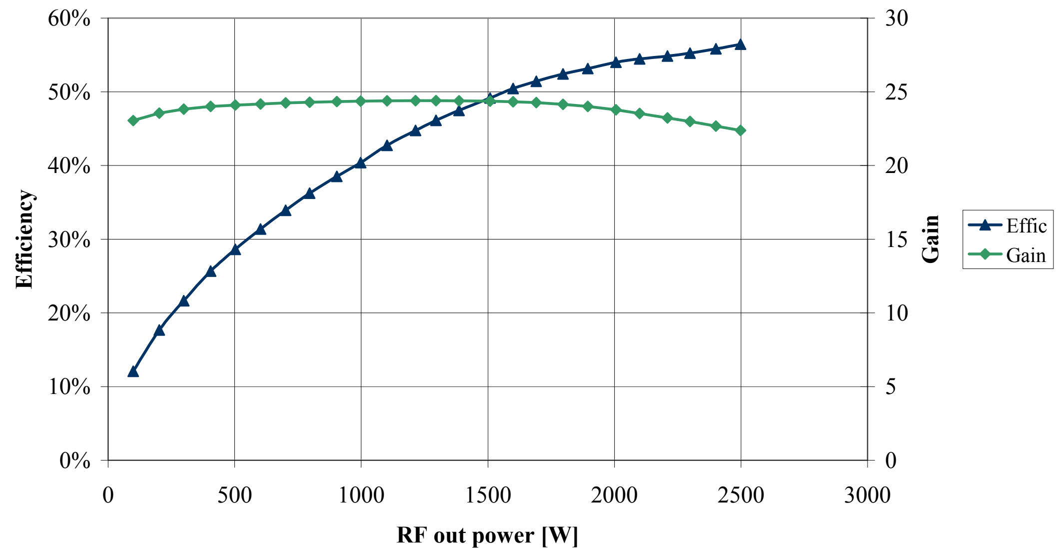
Proton Superconducting driver

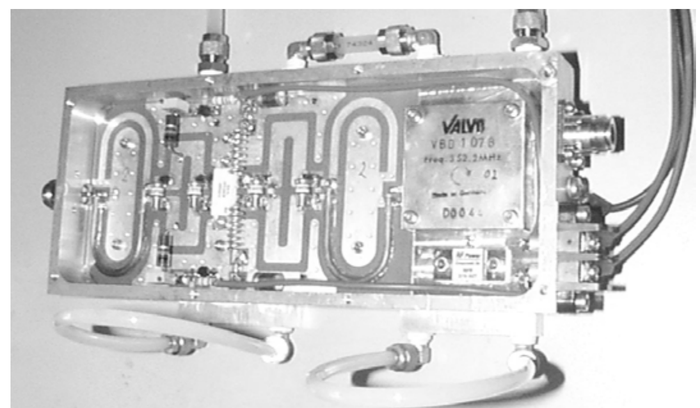
Moderate current, CW like heavy ion boosters
.....but.....
beam loading dominated

352 MHz solid state RF amplifiers

2.5 kW prototype

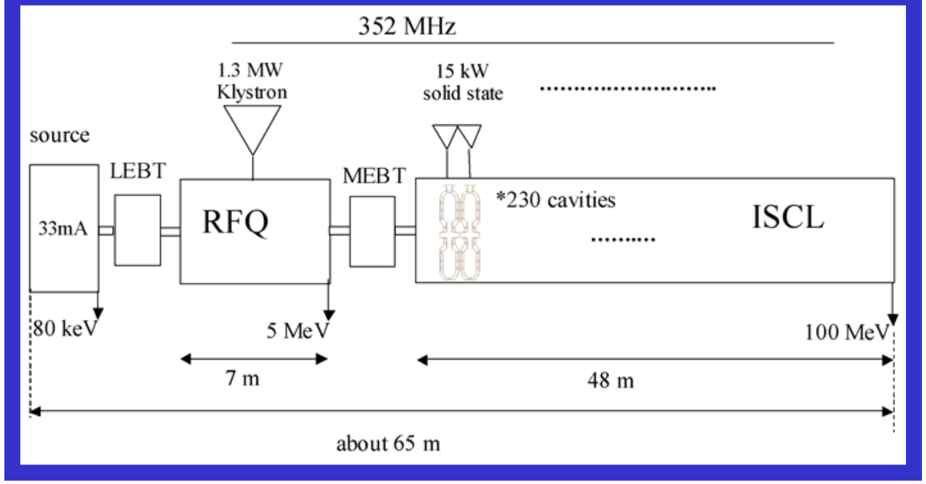
2.5 kW RF Amplifier





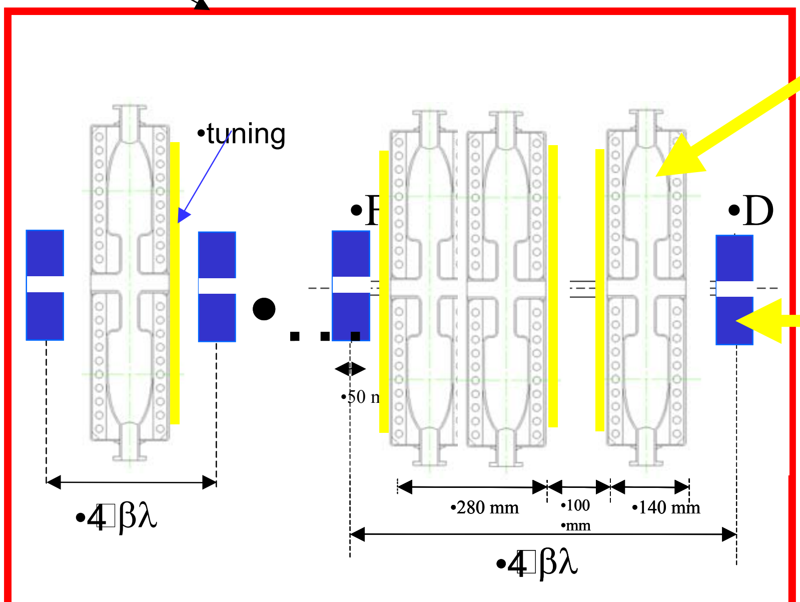
330 W basic unit

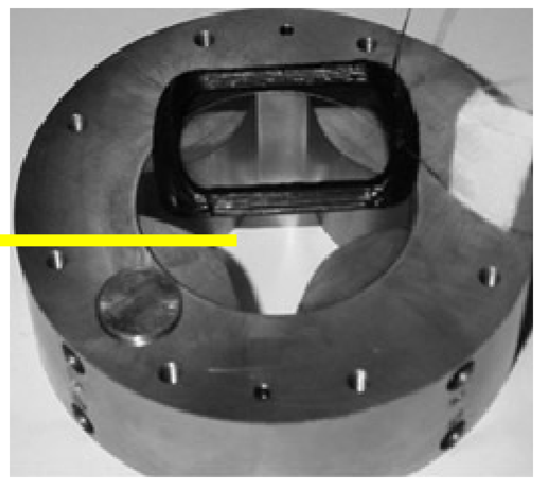
100 MeV TRASCO



•Cryostat (4.5 K)

•Reentrant cavity

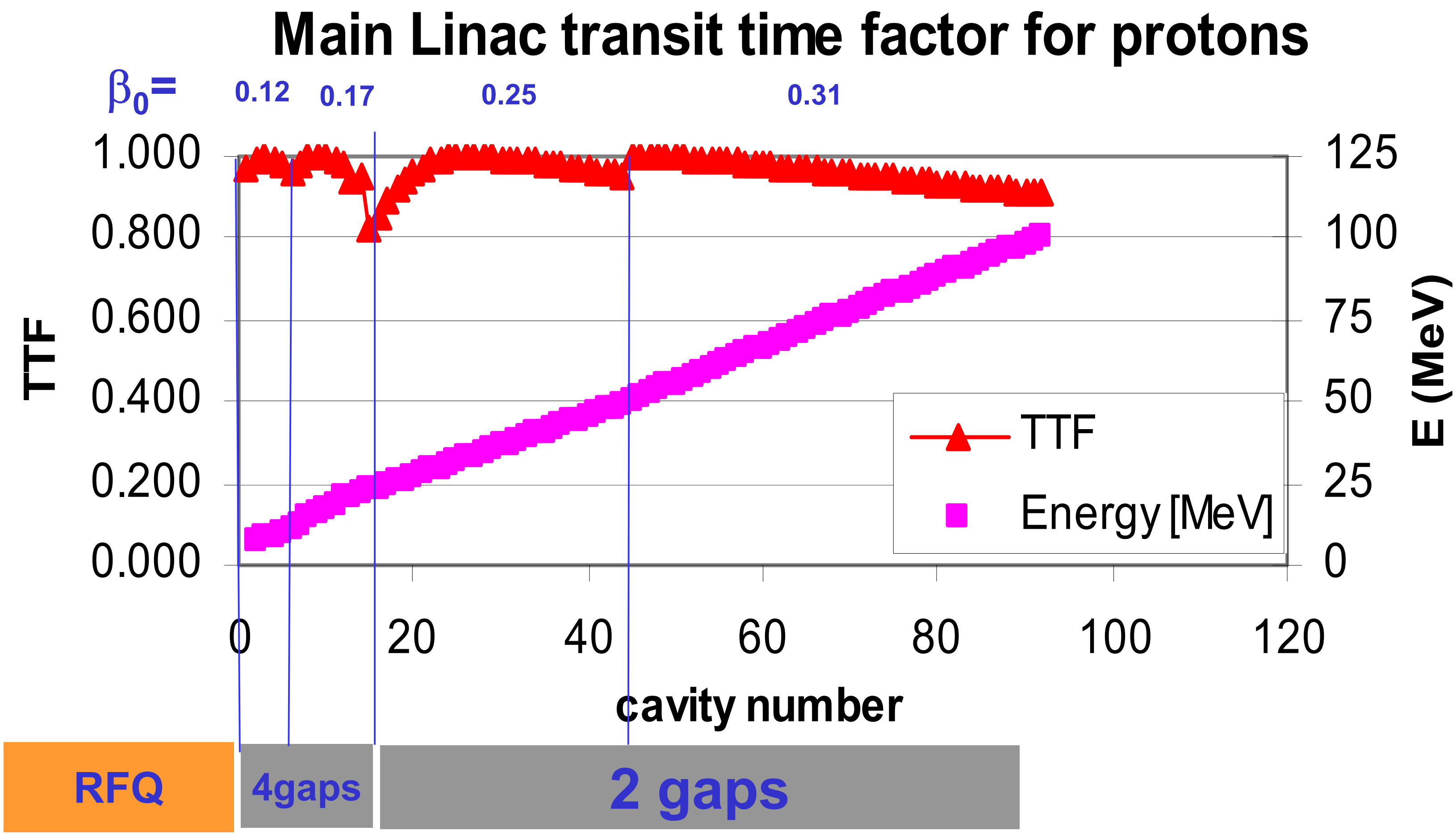




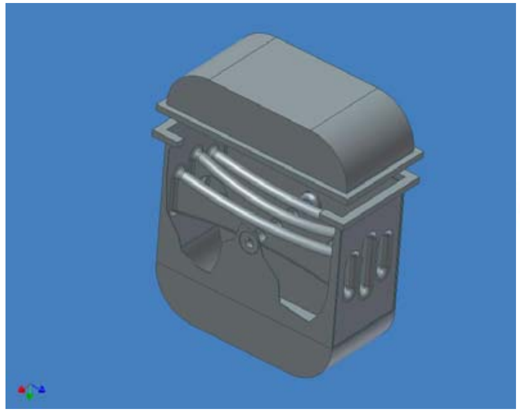
•Superferric qudrupole

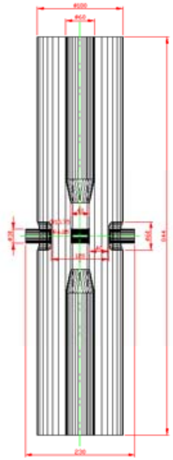
Fig. 4. The yoke and coil with a penny shown for size.

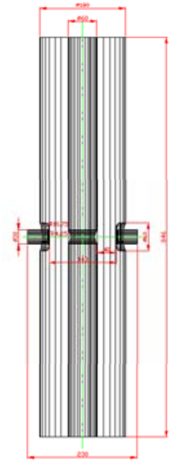
Driver structure (Φ_s=-30^0)



Cavities (352 MHz)





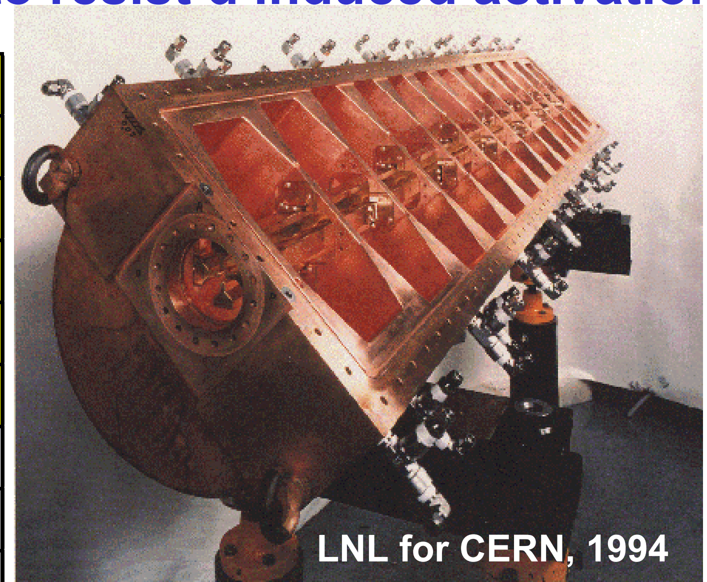


Cavity type	4-gap	4-gap	HWR	HWR	units
β_0	0.12	0.17	0.25	0.31	
n. of gap	4	4	2	2	
E_p/ E_a	**~3.**	**~3.**	**~4**	**~4**	
H_p/E_a	**102**	**87**	**95**	**106**	**Gauss/(MV/m)**
$R_s \times Q$	45	62	54	66	Ω
Eff. length	0.2	0.28	0.18	0.214	m
Design E_a	6	6	6	6	MV/m
Design energy gain	**1.2**	**1.7**	**1.08**	**1.284**	**MeV/q**
n. required	6	6	32	48	

Ion Linac A/q<3

RFQ to be developed cw!
Able to resist d induced activation!

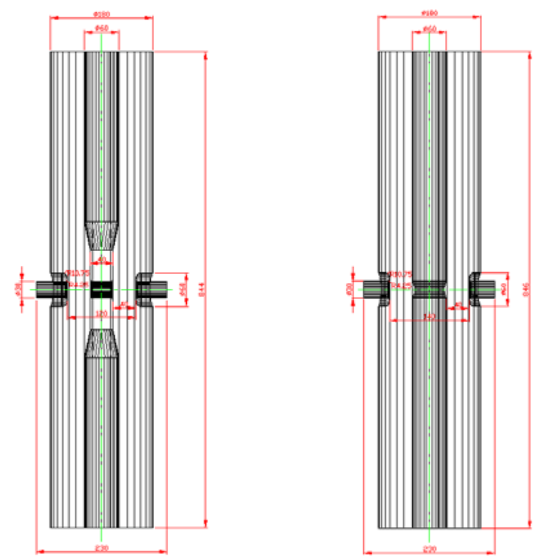
RFQ Energy Range	0.023 ÷ 1.7	MeV/u
Frequency	176	MHz
Beam Current	3	mA
Transmission	96	%
Length	**7.2**	**m (4.2 λ)**
Approx. RF power	**500**	kW
Parameters of the SPES ion injector linac		
beam energy	18.5	MeV
Beam current	3	mA
Number of cavities	**18**	
Approx. Length of the ISCL	**7.5**	**m**
avg. cryogenic power in operatio	217	W
total AC power in operation	**201**	kW



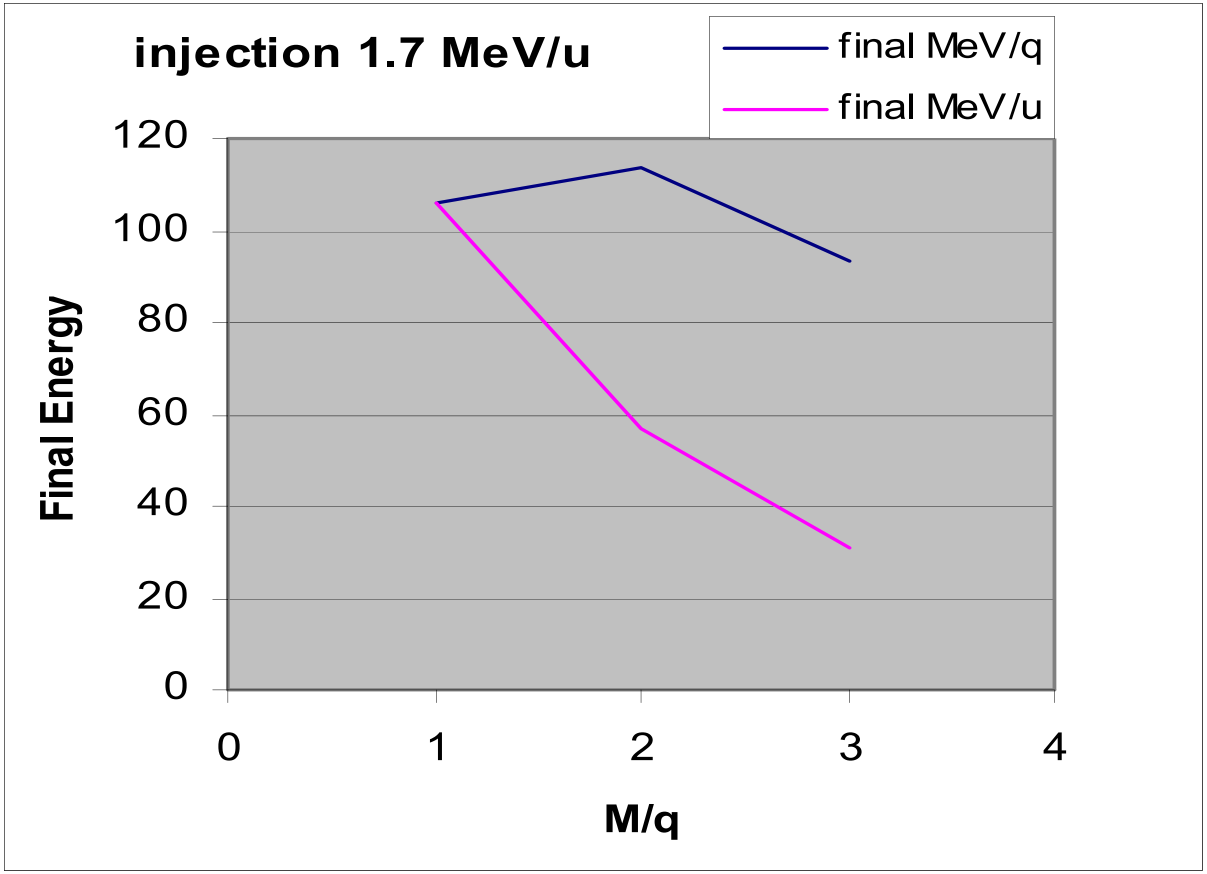
RFQ | 2gaps | 4gaps | 2 gaps

176 MHz

Main linac 352 MHz

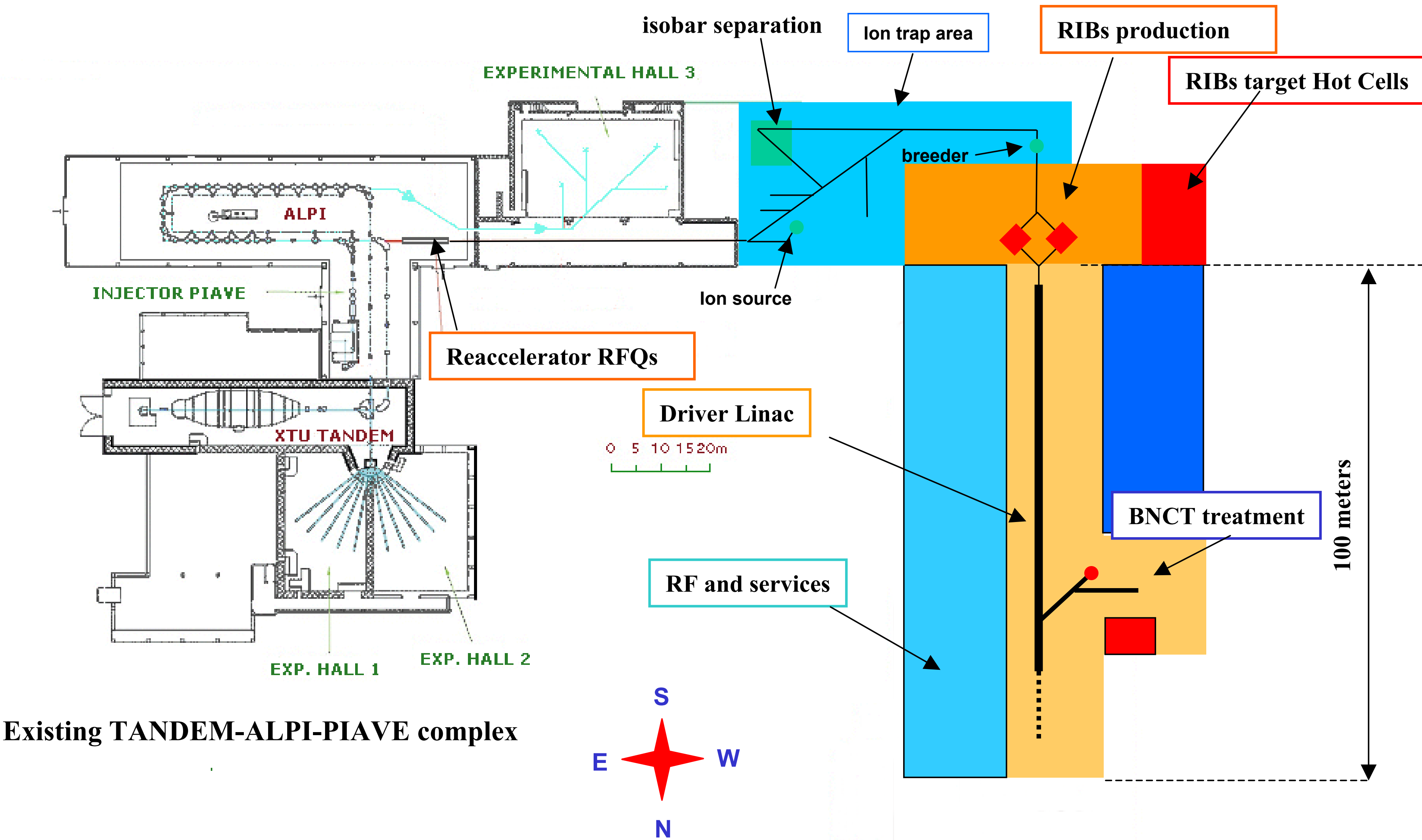


Linac acceptance

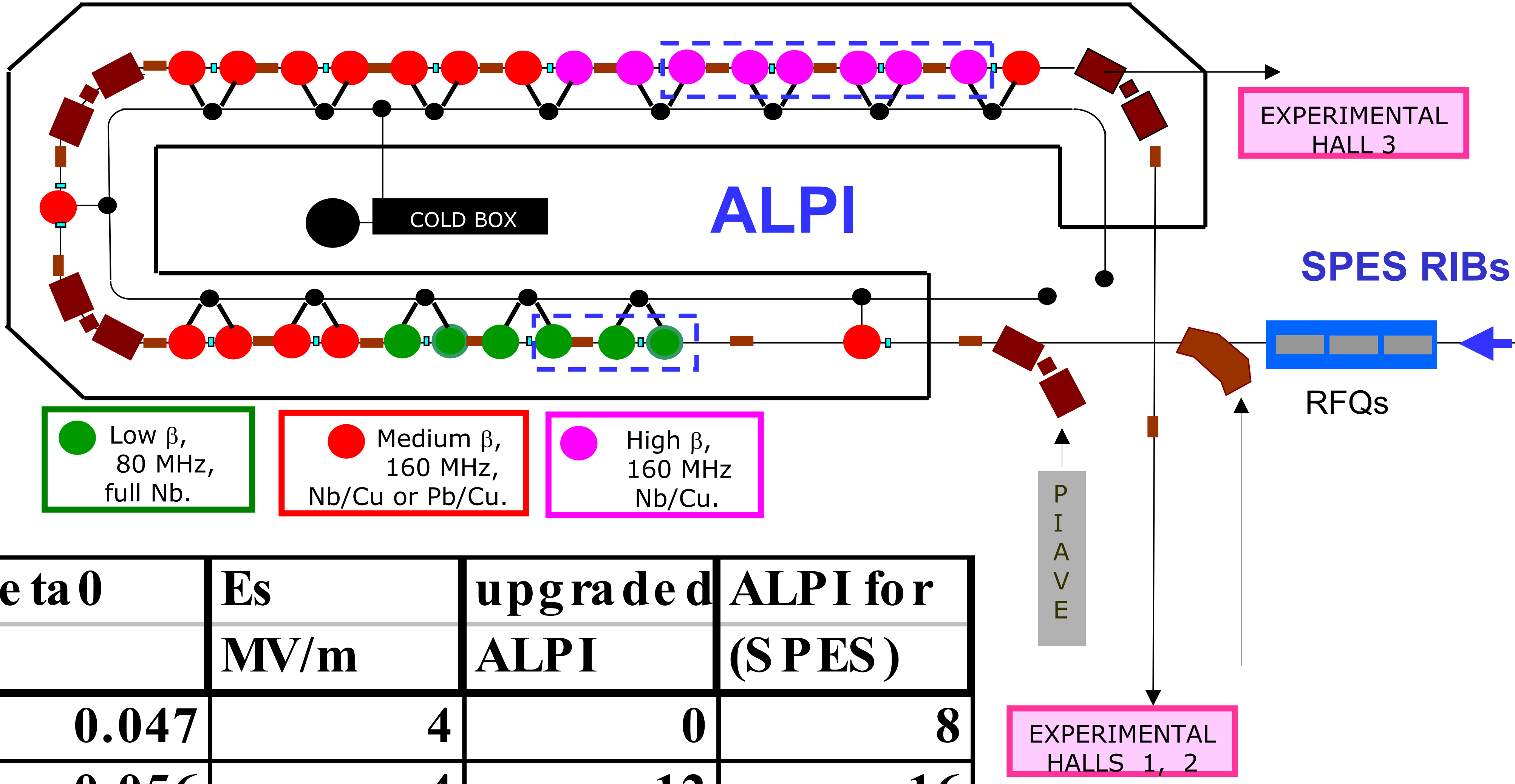


Reacceleration with ALPI

SPES lay-out



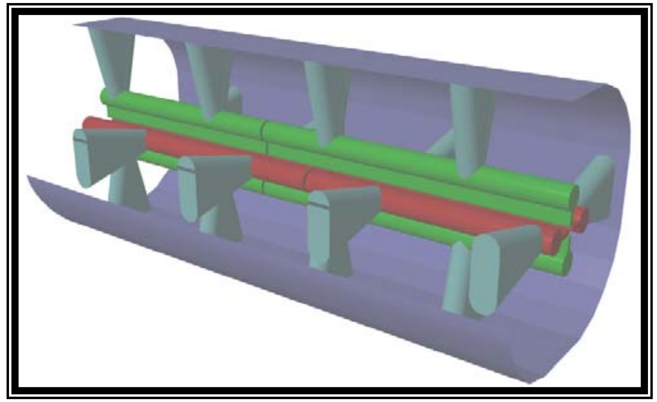
isobar separation
Ion trap area
RIBs production
RIBs target Hot Cells
EXPERIMENTAL HALL 3
breeder
ALPI
INJECTOR PIAVE
Ion source
Reaccelerator RFQs
Driver Linac
XTU TANDEM
0 5 10 15 20m
BNCT treatment
100 meters
RF and services
EXP. HALL 1
EXP. HALL 2
Existing TANDEM-ALPI-PIAVE complex
S
E
W
N

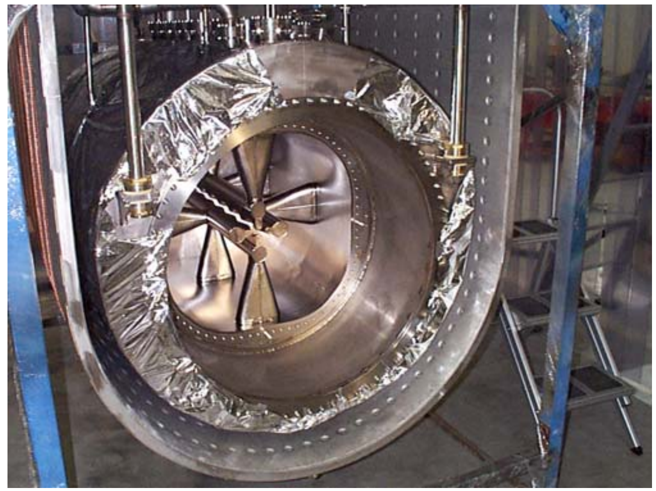


beta0	Es MV/m	upgraded ALPI	ALPI for (SPES)
0.047	4	0	8
0.056	4	12	16
0.11	4	44	44
0.13	4	8	32

Injector

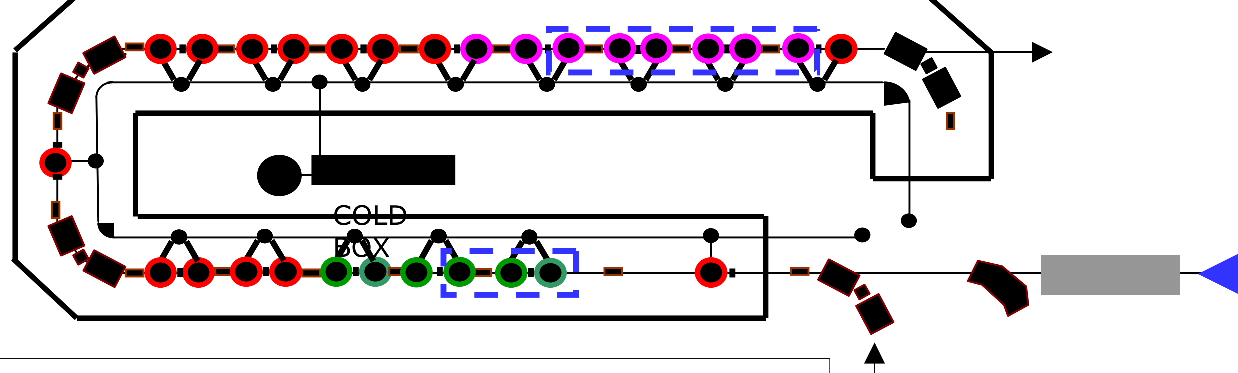
- **Charge breeder** (ECR or EBIS): from results of EU RTD Network a charge state +18 for Sn^{132} is feasable.
- **High resolution separator**, either:
  - ISAC like magnetic structure before the breeder
  - Mixed magnetic TOF using the long transfer lines
- RFQ will accept A/q=10, **three SRFQ**
- Only the first RFQ needs important R&D (and could be normal conducting)

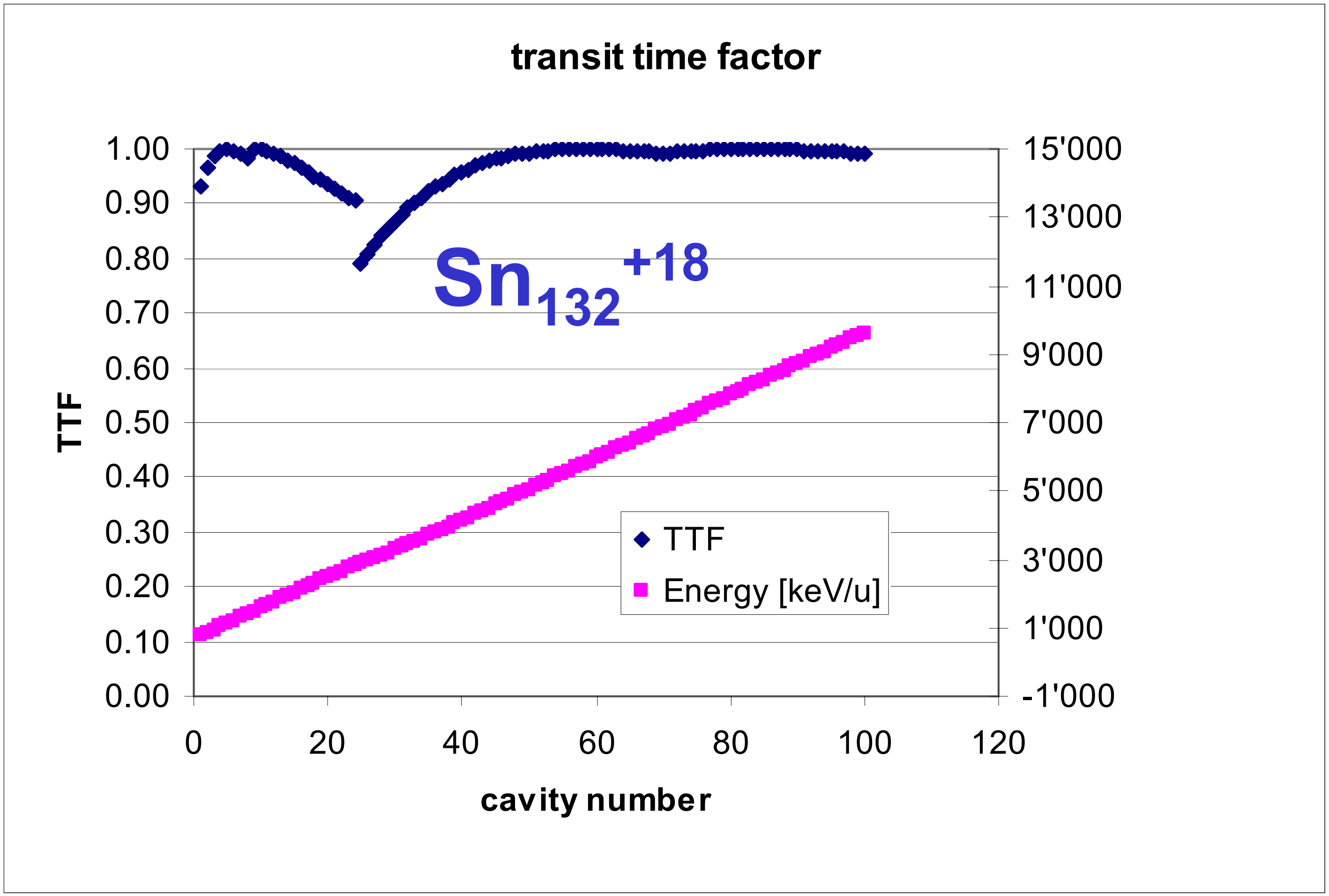




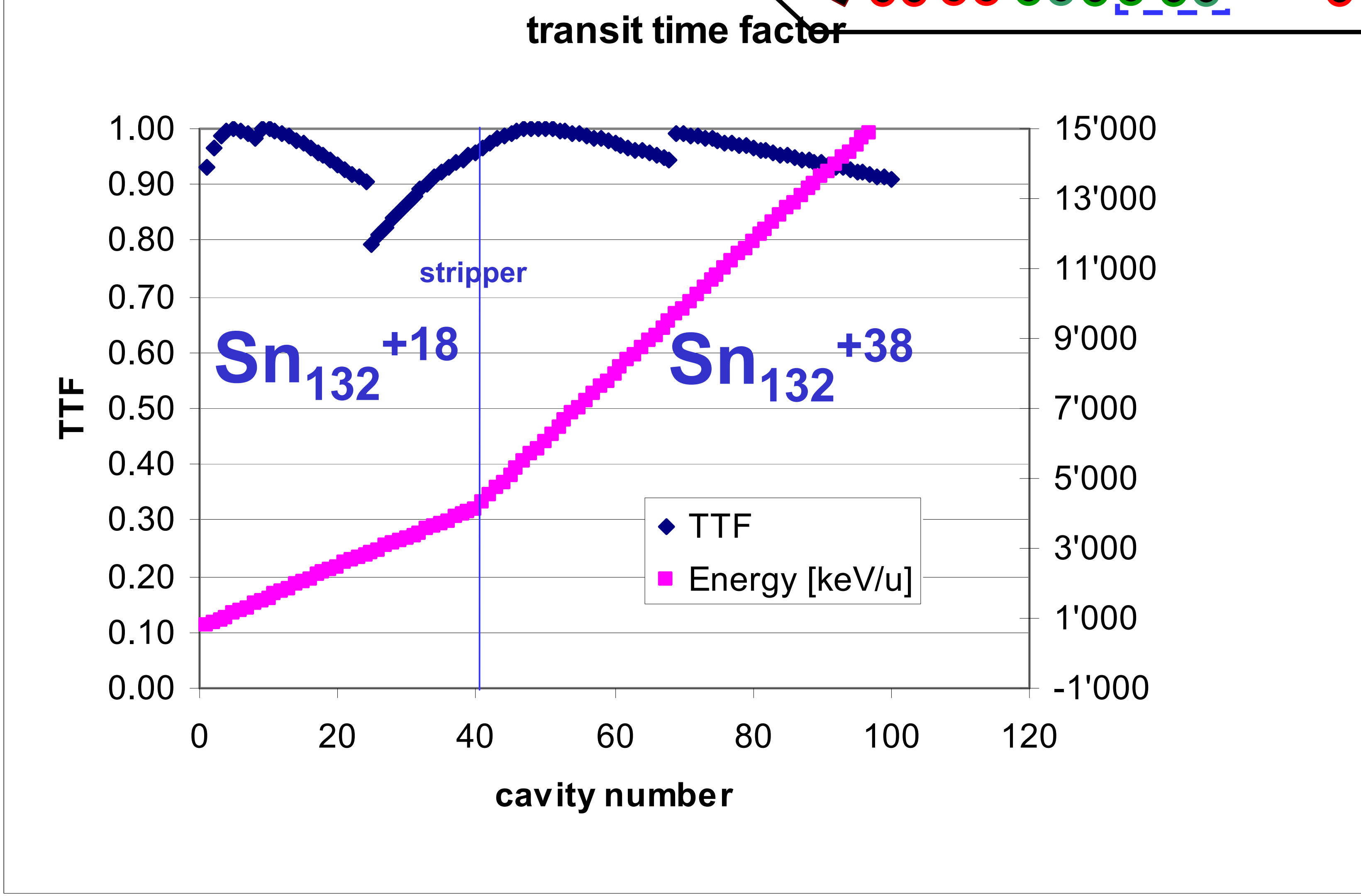
EBIS source “BRIC” developed at INFN Bari
(Tested with low solenoid field)

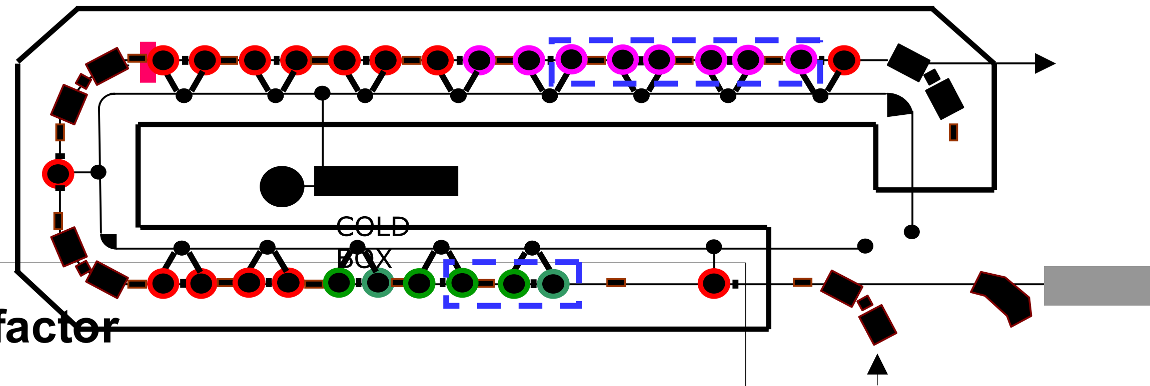
Sn_{132}^{+18} in ALPI (up to 9.6 MeV/u)



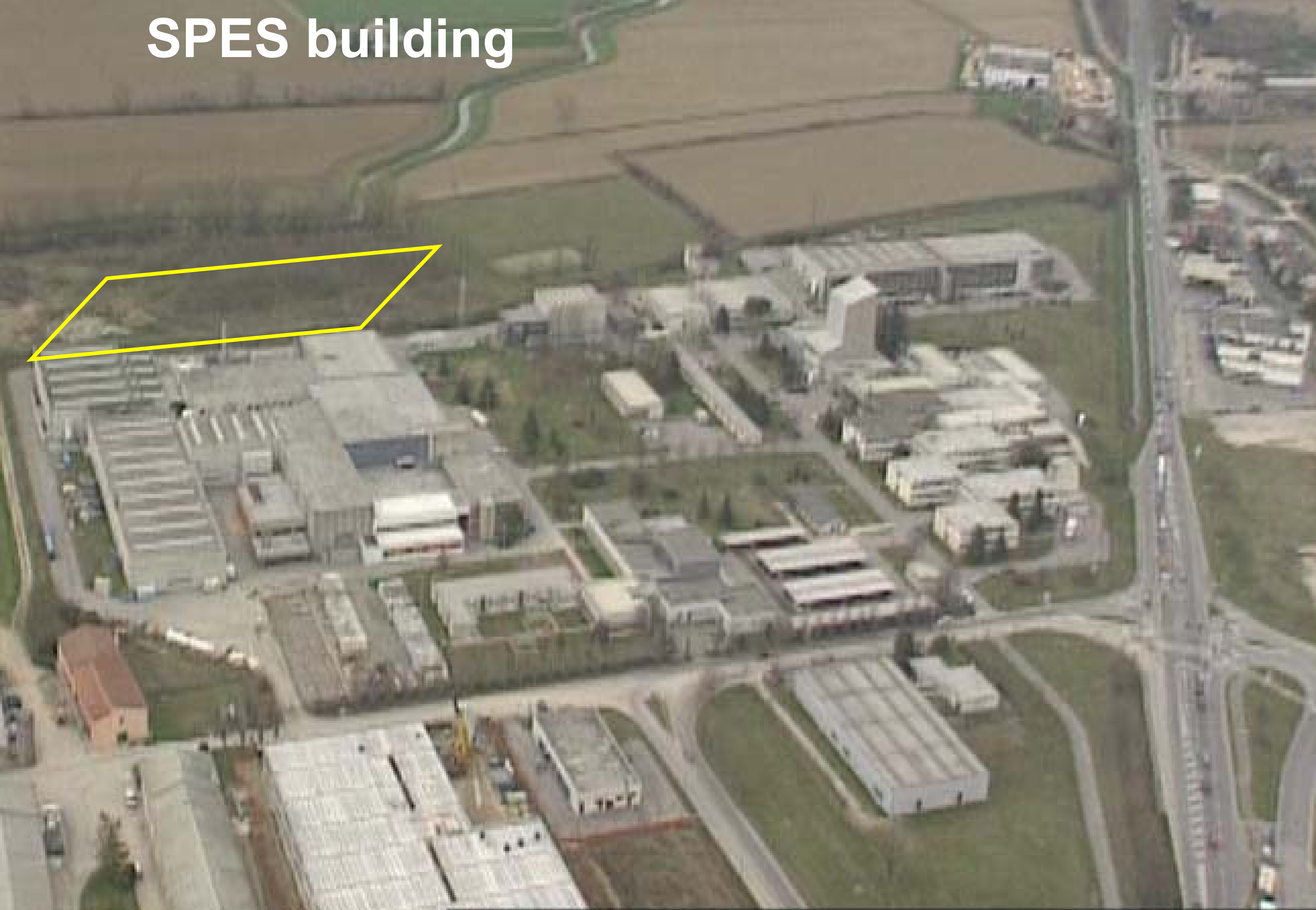


Sn_{132}^{+18} in ALPI with stripper (up to 15.7 MeV/u)

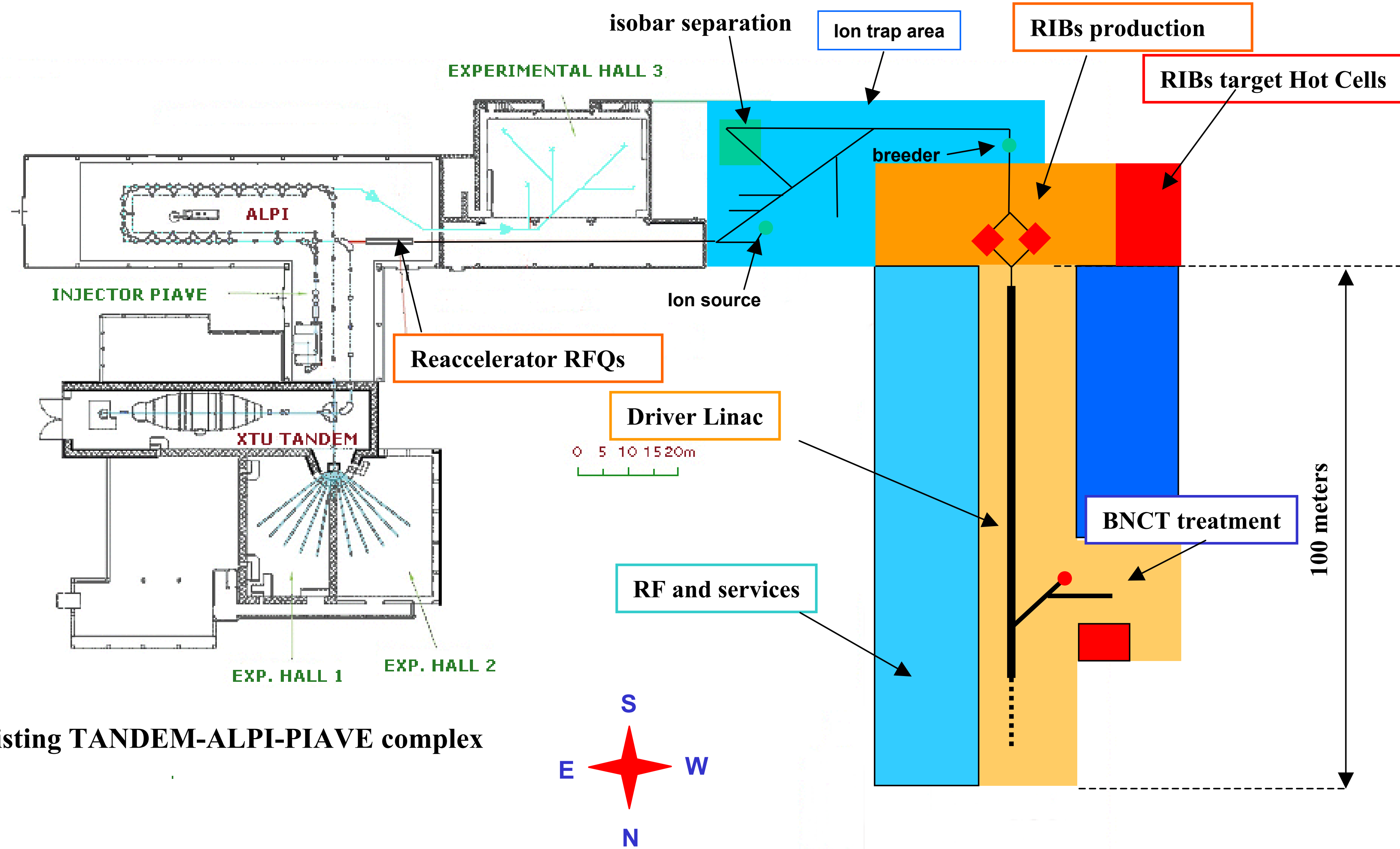




SPES building



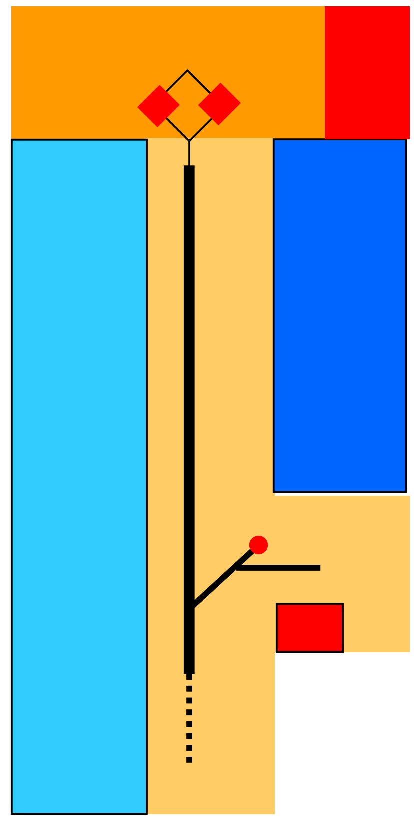
SPES Building



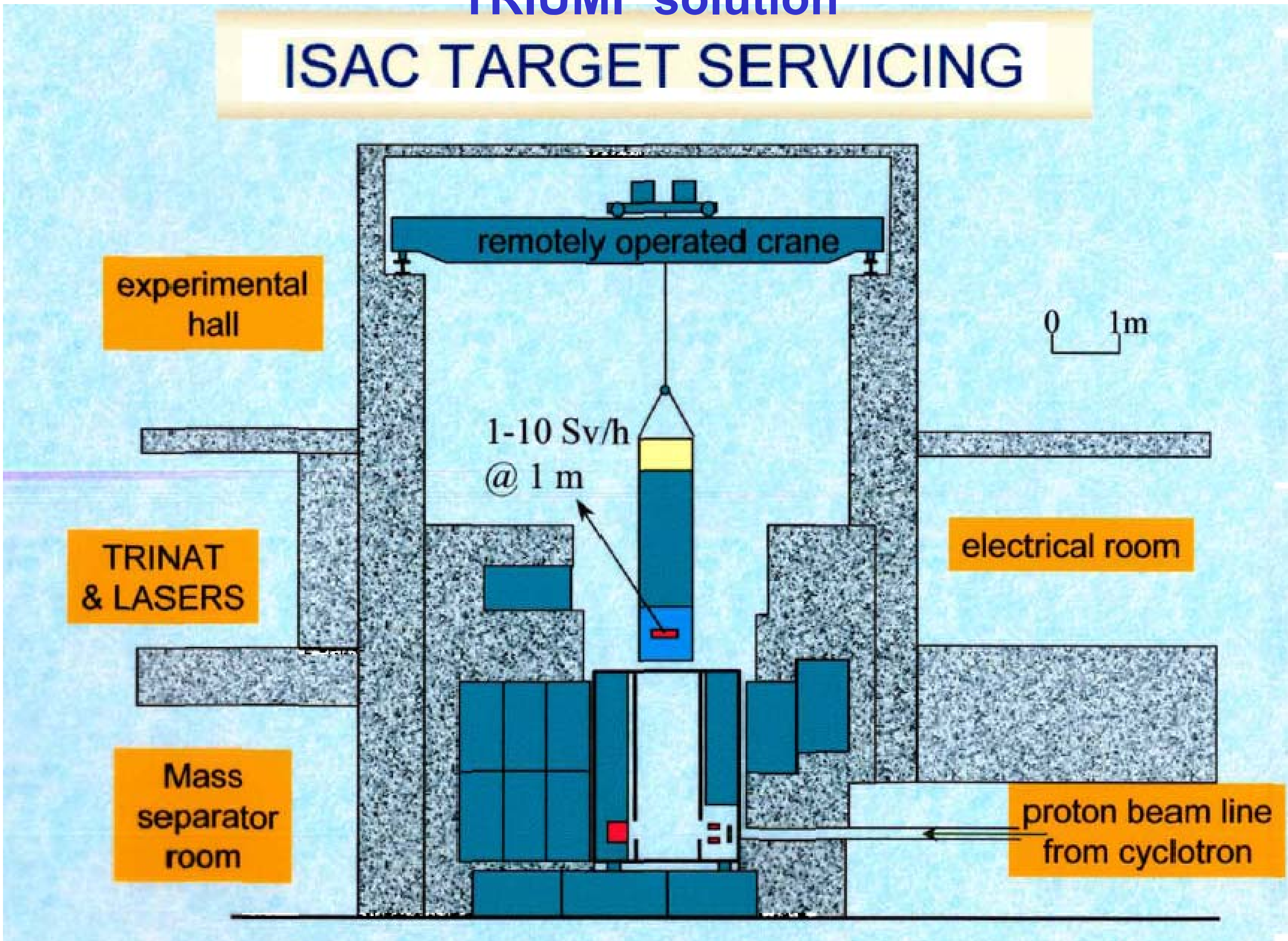
Existing TANDEM-ALPI-PIAVE complex

SPES Building

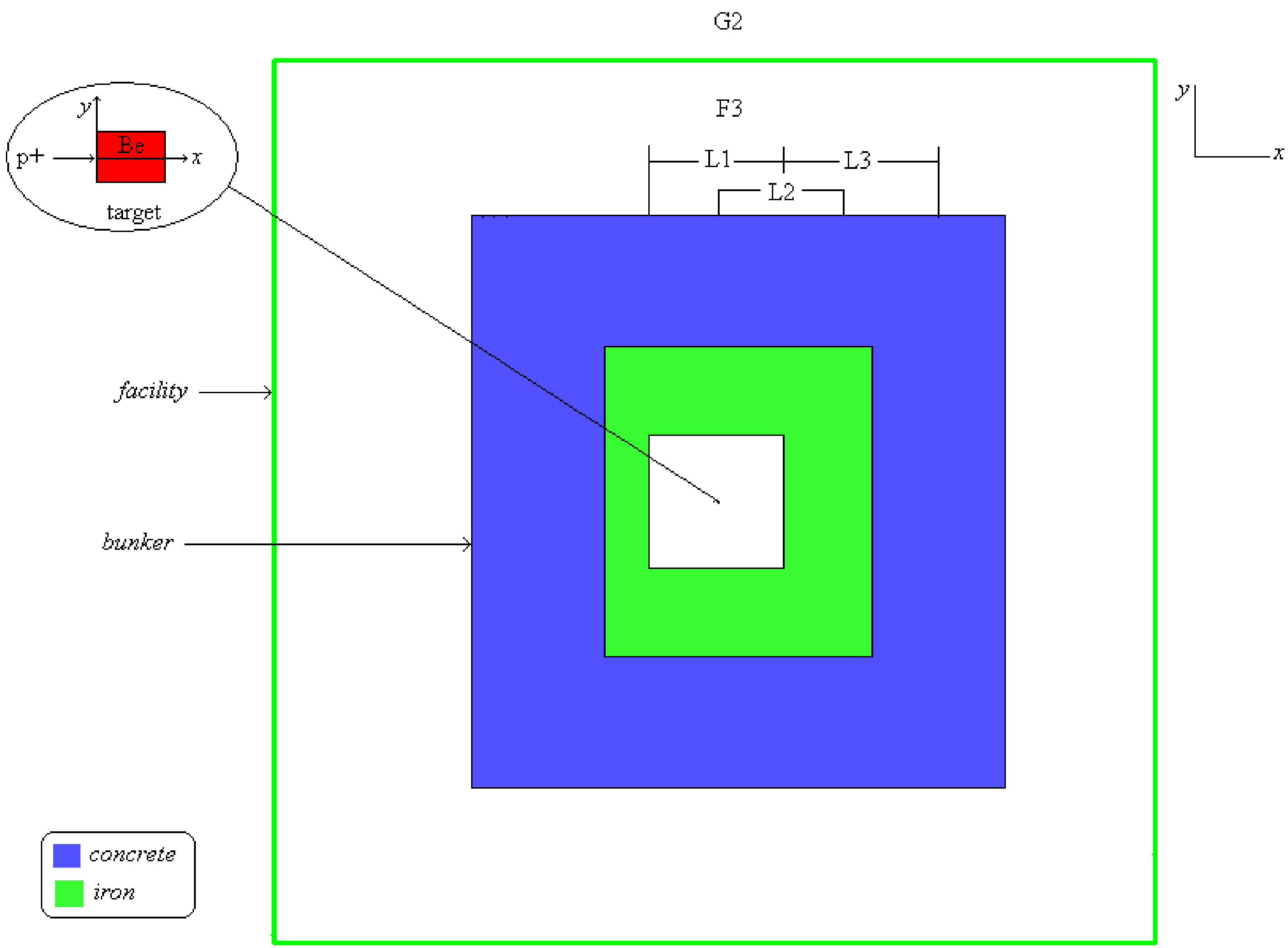
- A sled with light external structures, but with a floor sitting on a thick concrete bed in the regions where ionizing radiation is produced, so to exclude water contamination;
- The floor must be able to sustain a thick shielding walls, with the possibility to add concrete blocks.
- The building has to maintain the alignment of linac and beam lines.
- In a preliminary study it has been checked the feasibility of this solution, using in the central part of the building a linac tunnel 8 m wide and 4.6 m height, an 8 m thick concrete bed below the linac tunnel, 6 m lateral shielding and 5 m concrete roof.
- A core boring of the ground showed various layers of clay, silt and sand, with the water layer at –2.5 m from ground level. A specific proposal for the construction of the building under these geological conditions has been done.



TRIUMF solution

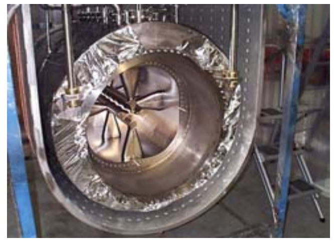


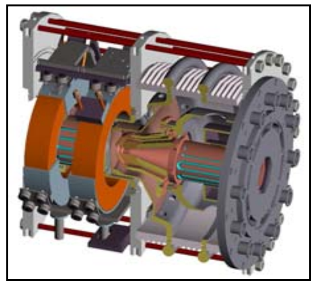
Shielding the target area (100 MeV 30 mA)



Conclusions

- The facility will reach its physics goal making the maximum use of
  - existing installations
  - developed accelerators and other high technology components
  - out come of already launched R&D programs
- In this sense, the need for R&D is minimized.





R&D

In the immediate future, the R&D needs to be intensified, so to arrive to engineered and proven systems for all the components of SPES. The most relevant points are:

1. Completion of the RFQ
2. Construction of a prototype of Be converter (and possibly beam measurement at PSI) and development of C^{13} targets.
3. UCx target development.
4. Construction of a ISCL cryomodule (HWR, ladder cavities) and related RF.
5. Development of the bunching RFQ for the reacceleration.
6. Charge breeder and isobar separation.
7. Waste management and safety.

For ion acceleration there is need for an additional point, namely

8. Development of the 176 MHz RFQ for A/q=3 ions.

These programs have to be implemented, making the best use of the resources of LNL and of possible synergies with other projects and institutions.