THE SPES PROJECT AT LEGNARO NATIONAL LABORATORIES

M. Comunian

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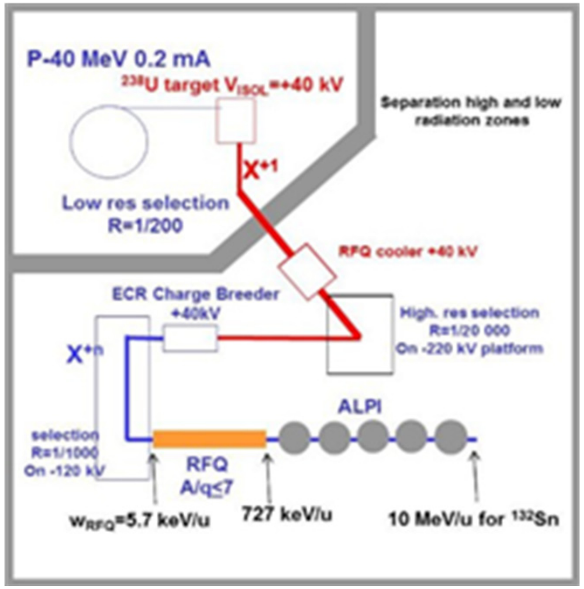
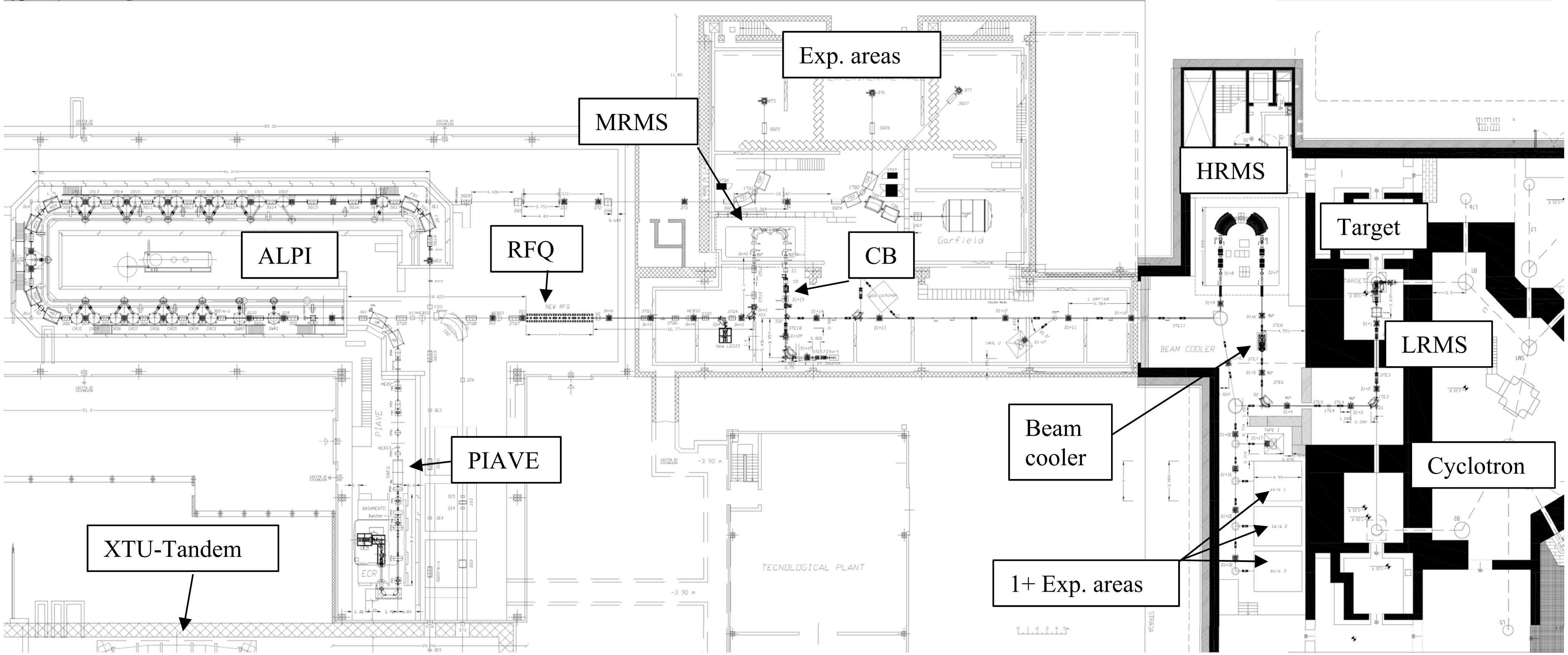
And all the SPES TEAM

Outline

- SPES Layout
- The SPES cyclotron
- The target
- The high resolution stage: RFQ Cooler and the HRMS
- The periodic transfer line.
- The post acceleration stage: charge breeder and the MRMS
- The MEBT matching line
- ALPI performances



The SPES Layout



General features

- The SPES facility may be divided in three stages: the RIB production, the magnetic isotope separation and the charge breeding with the post-accelartion.
- Low current beams (nA-fA) and transfer line with high dispersion require a careful manage of the beam optics.
- Several localised separation stages are needed for separate the nominal beam from the isotopes and fit the safety requirements.
- Very long transfer lines are needed in order to fit the new building with the existing linac ALPI.

Main stages

- The **cyclotron** accelerates 70 MeV proton beam of 750 μA onto a UCx **target**, heated at 2000 C°. The radioactive ions produced are extracted @ 20-40 keV, depending on the RFQ's β_s of the n+ beams.
- There are three separation stages: the **LRMS**, composed by a Wien filter and a 90° magnetic dipole 1/200 resolution in mass (isobar selection); the **HRMS**, with a capability of 1/20000 resolution (isotope separation) in mass and the **MRMS** of 1/1000, which removes the CB contaminants.
- The beam gains 1+ -> n+ charge and, after the removal of the **CB** contaminants is sent to an internal bunching **RFQ**, which accelerates the beam up to 727.3 keV/A (for A/q=7).
- The beam is longitudinally matched with the linac via a **MEBT** line (with two bunchers). The **ALPI linac** accelerates the beam up to 10 MeV/A .
- There are two experimental areas: the 1+ experimental areas down to the HRMS complex and the experimental areas down to ALPI for the post accelerated beams.

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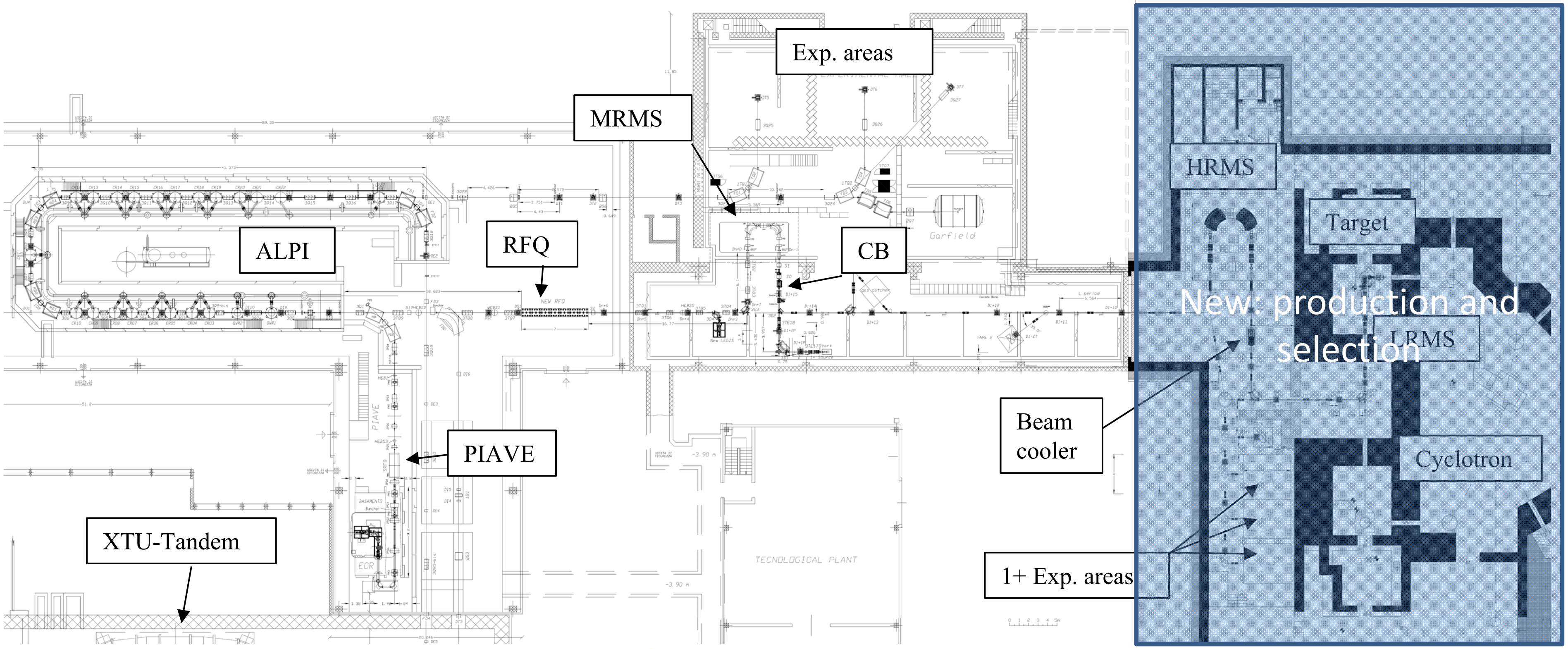

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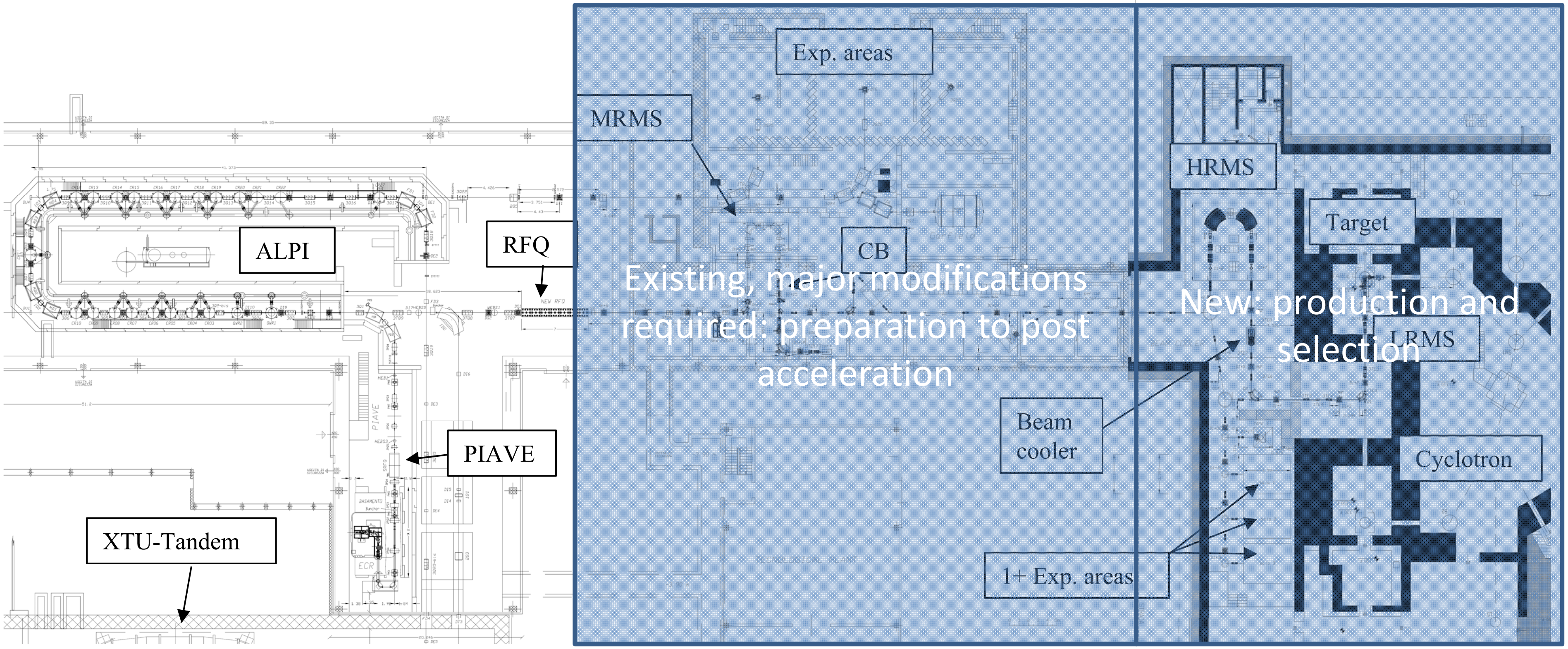

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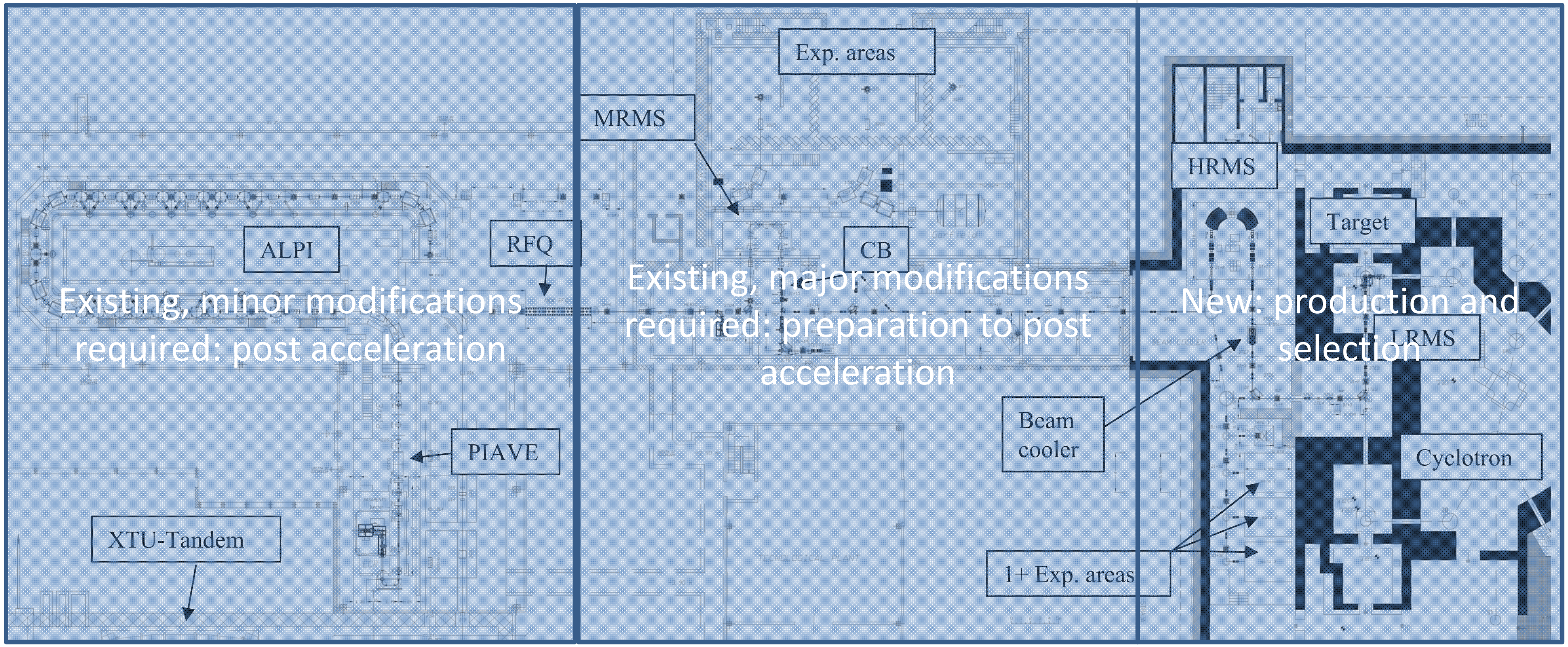

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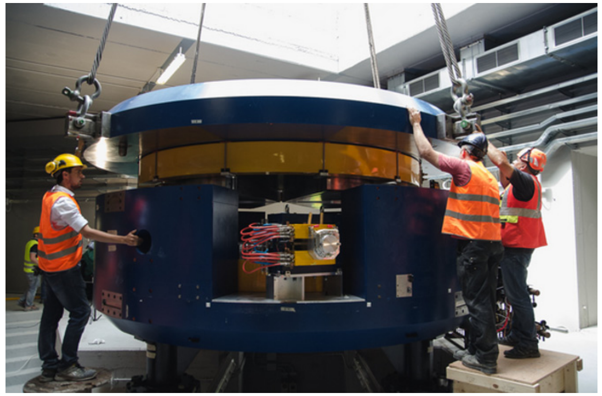
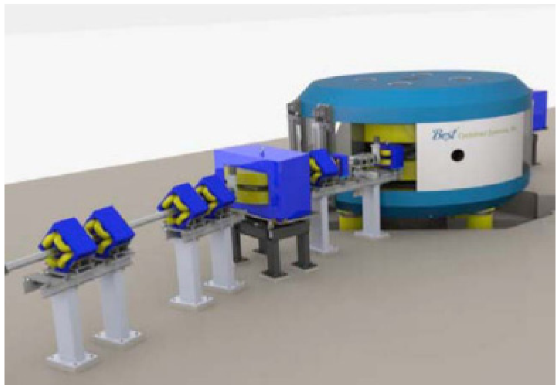
The SPES Cyclotron



BEST Cyclotron main characteristics:

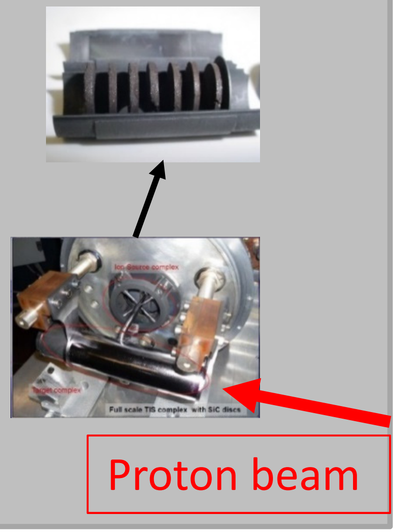
- 35-70 MeV, 750 μA of DC proton beam
- 40 keV H^- source (placed at the bottom of the magnet) 15-20 mA DC beam (neutralisation is achieved via a vacuum level of 10^{-6} mbar). The injection is by mean of a axial transfer line upwards to the spiral inflector which bends the beam 90° into the central region.
- Four straight sector machine (B_{max} of 1.6 T). Two independent extraction channels (2 stripping multi-foil carousels) which provides simultaneous two beams extractions.
- RF: two 4^{th} harmonics independent cavities @ 57-58 MHz.

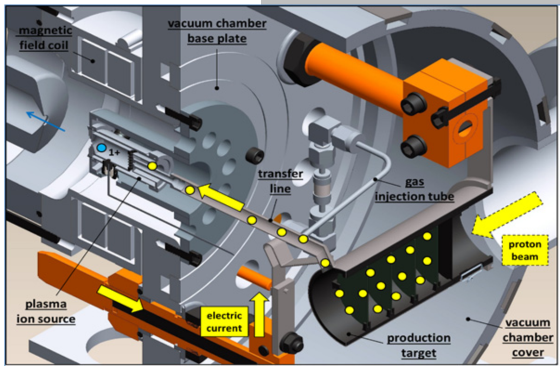


The cyclotron and the transfer lines are installed. The commissioning is going to start.

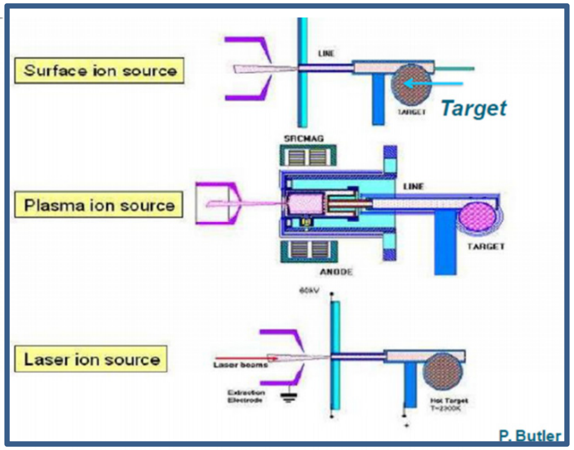
The SPES ISOL target

<u>**NEW CONCEPT**</u>
direct target
Multi-foil UCx
designed to
reach **10^{13} f/s**





SPES direct target-ion source
30g UCx
ISOLDE-type target/source



For more information, see the next talk (A. Andrighetto)

Main characteristics of the SPES target :

- Up to **10^{13} f/s.** Overall estimated current extracted up to 1 μA (plasma ion source) of neutron rich isotopes.
- Heated up to 2000°, diffusion of radioactive gas generated by induced fission between the UCx and the proton beam.
- Three kind of sources: **surface ion source**, **laser ion source** and the **plasma ion source**. Can be used in order to pre-discriminate the nucleus of interest.
- Offline test on the SIS shows a normalised rms emittance of 0.005 mm mrad.

PIS

Many isobars.

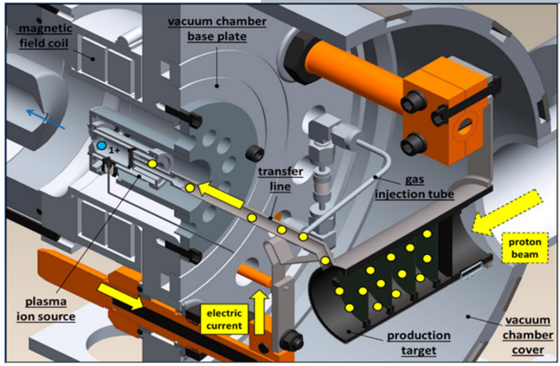
Z\A	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143
42	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47	1.91E+10	8.96E+09	3.68E+09	4.12E+08	2.55E+08	1.93E+07	1.25E+07	2.86E+04	1.23E+03	1.54E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	3.91E+10	4.32E+10	3.07E+10	2.27E+10	1.14E+10	8.06E+09	2.87E+09	1.44E+09	1.09E+09	1.38E+08	4.64E+05	2.81E+06	5.61E+03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49	3.22E+10	2.26E+10	3.76E+10	3.45E+10	3.75E+10	2.66E+10	2.26E+10	1.54E+10	1.12E+10	2.71E+09	1.54E+09	1.27E+09	2.07E+08	1.72E+07	1.75E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50	1.79E+10	3.31E+10	2.31E+10	3.77E+10	2.83E+10	4.24E+10	3.33E+10	4.36E+10	3.66E+10	4.37E+10	2.94E+10	3.34E+10	4.69E+09	4.54E+09	2.24E+09	3.77E+08	5.02E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51	1.13E+10	1.21E+10	2.02E+10	1.83E+10	2.73E+10	2.15E+10	3.08E+10	2.36E+10	3.28E+10	2.52E+10	3.31E+10	2.52E+10	3.02E+10	8.85E+09	1.08E+10	8.10E+09	3.32E+09	7.05E+06	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52	2.75E+09	5.94E+09	7.01E+09	1.31E+10	1.23E+10	2.20E+10	1.83E+10	2.95E+10	2.35E+10	3.42E+10	2.67E+10	3.85E+10	3.02E+10	4.49E+10	2.23E+10	3.02E+10	1.61E+10	1.09E+10	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53	6.88E+08	1.13E+09	2.58E+09	3.27E+09	6.73E+09	7.35E+09	1.36E+10	1.42E+10	2.19E+10	2.05E+10	3.05E+10	2.68E+10	3.97E+10	3.32E+10	4.43E+10	2.20E+10	2.76E+10	2.16E+10	2.38E+10	9.47E+09	2.57E+09	2.30E+08	3.67E+07
54	6.74E+07	1.75E+08	3.71E+08	8.77E+08	1.27E+09	2.98E+09	3.63E+09	7.49E+09	7.82E+09	1.43E+10	1.46E+10	2.43E+10	2.21E+10	3.53E+10	3.22E+10	4.50E+10	2.39E+10	3.30E+10	2.29E+10	2.05E+10	1.40E+10	1.11E+10	4.24E+09
55	0.00E+00	6.52E+06	4.04E+07	4.61E+07	2.56E+08	3.88E+08	1.04E+09	1.55E+09	2.91E+09	4.27E+09	7.75E+09	9.30E+09	1.56E+10	1.68E+10	2.66E+10	2.71E+10	3.86E+10	2.39E+10	2.98E+10	2.29E+10	2.75E+10	1.61E+10	2.34E+10
56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.72E+06	6.74E+06	7.41E+07	2.83E+08	4.52E+08	1.31E+09	1.78E+09	3.67E+09	4.69E+09	8.97E+09	9.57E+09	1.82E+10	1.93E+10	3.03E+10	2.15E+10	2.79E+10	2.00E+10	3.03E+10	1.38E+10
57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.37E+07	1.01E+08	3.24E+08	5.39E+08	1.19E+09	1.86E+09	3.99E+09	5.08E+09	9.24E+09	1.25E+10	2.00E+10	1.48E+10	2.15E+10	1.76E+10	2.07E+10
58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.37E+07	6.07E+07	3.78E+08	5.53E+08	1.51E+09	2.24E+09	4.42E+09	5.95E+09	1.08E+10	9.24E+09	1.46E+10	1.18E+10
59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	6.74E+06	3.37E+07	7.41E+07	4.38E+08	6.42E+08	1.50E+09	2.59E+09	4.85E+09	4.61E+09	8.02E+09
60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E+07	0.00E+00	1.08E+08	3.51E+08	7.35E+08	1.61E+09	1.99E+09
61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

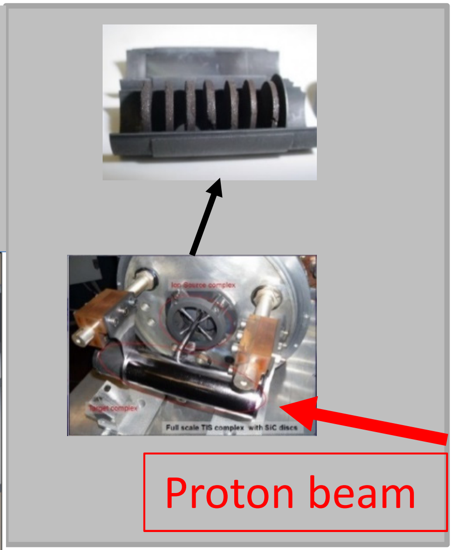
example of ^{132}Sn production.

The SPES ISOL target

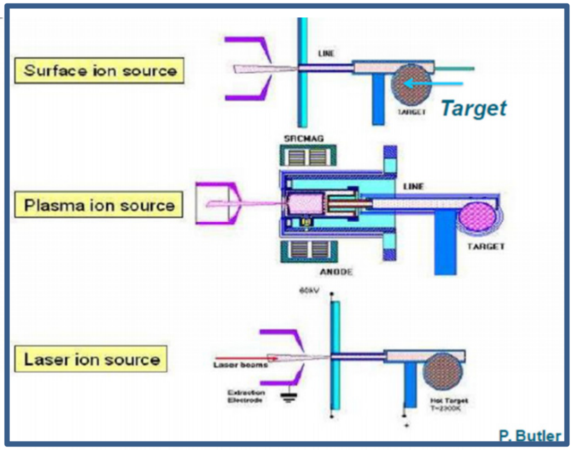
NEW CONCEPT

direct target
Multi-foil UCx
designed to reach 10^{13} f/s





SPES direct target-ion source
30g UCx
ISOLDE-type target/source



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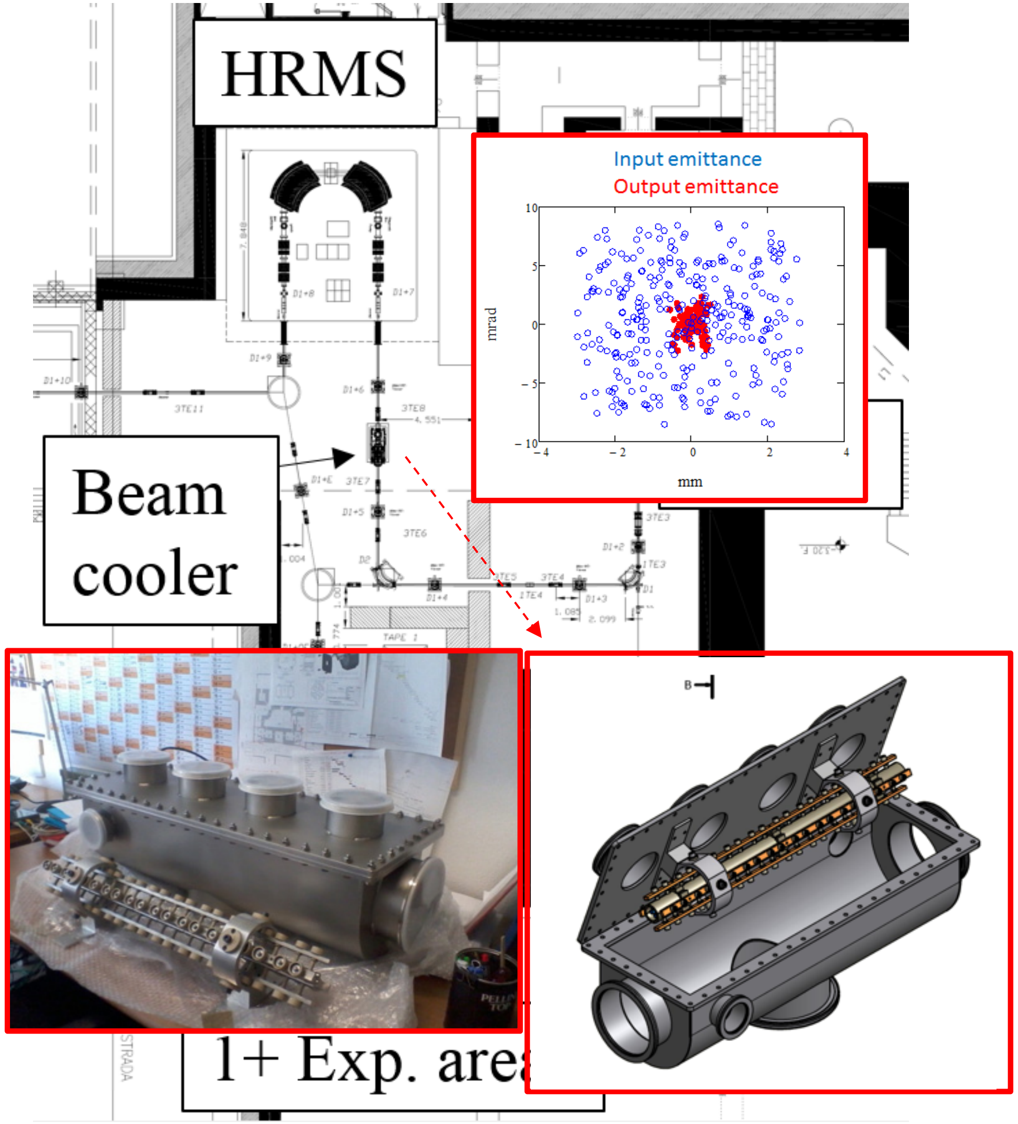
43	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
44	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
45	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
46	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
47	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
48	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
49	3.60E+09	2.52E+09	4.20E+09	3.85E+09	4.19E+09	2.98E+09	2.52E+09	1.72E+09	1.26E+09	3.03E+08	1.73E+08	9.94E+07	2.31E+07	1.93E+06	1.96E+05	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
50	9.96E+09	1.84E+10	1.29E+10	2.10E+10	1.57E+10	2.36E+10	1.85E+10	2.42E+10	2.03E+10	2.43E+10	1.63E+10	1.30E+10	2.60E+09	2.52E+09	1.25E+09	2.09E+08	2.79E+07	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
51	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
52	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
53	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
54	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
55	0.00E+00	3.15E+06	1.95E+07	2.23E+07	1.24E+08	1.88E+08	5.05E+08	7.47E+08	1.40E+09	2.06E+09	3.75E+09	3.15E+09	7.56E+09	8.11E+09	1.29E+10	1.31E+10	1.87E+10	1.16E+10	1.44E+10	1.10E+10	1.33E+10	7.76E+09	1.13E+10
56	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.50E+06	1.51E+06	1.66E+07	6.34E+07	1.01E+08	2.93E+08	3.98E+08	5.74E+08	1.05E+09	2.01E+09	2.14E+09	4.07E+09	4.33E+09	6.79E+09	4.82E+09	6.24E+09	4.48E+09	6.78E+09	3.08E+09
57	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.77E+06	1.13E+07	3.62E+07	4.22E+07	1.33E+08	2.09E+08	4.46E+08	5.68E+08	1.03E+09	1.40E+09	2.23E+09	1.66E+09	2.41E+09	1.96E+09	2.32E+09
58	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
59	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
60	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
61	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

example of ^{132}Sn production.

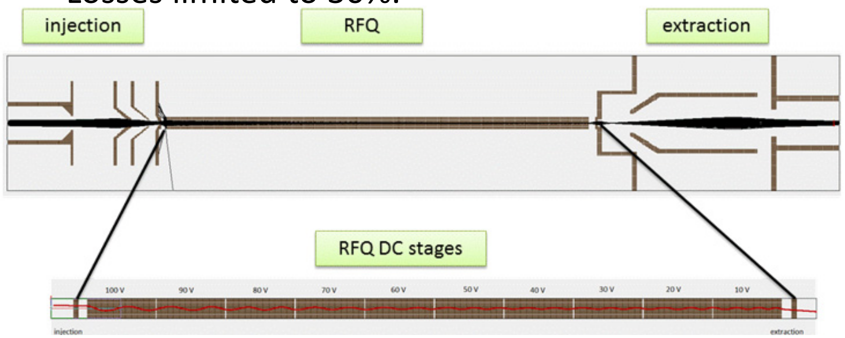
The High Resolution Section



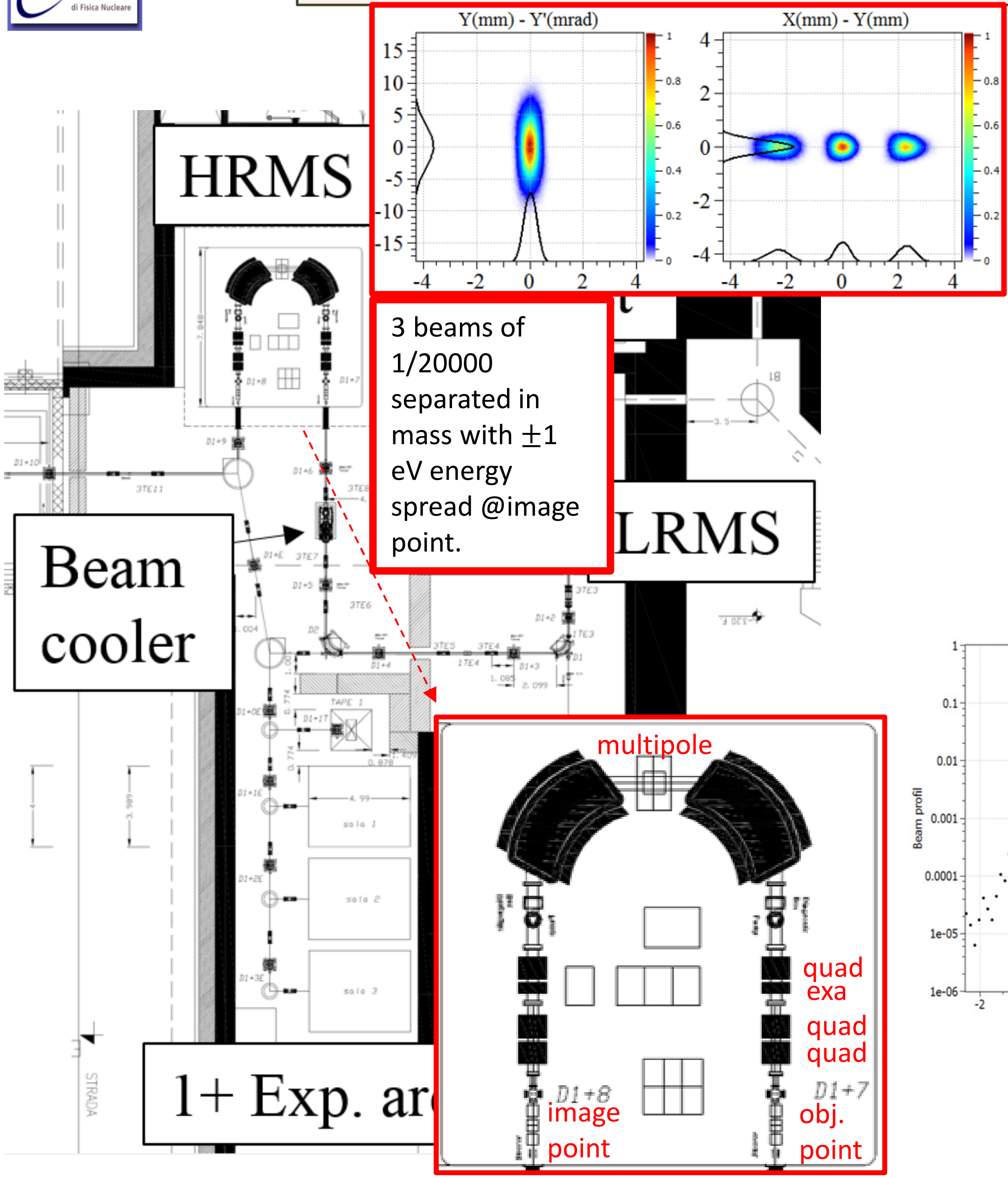
- The beam is prepared by the beam cooler:

Mass Range	5-200 amu
Transverse Emittance Injected beam	30 π mm mrad @ 40 keV
Emittance Reduction factor	10 (max)
Buffer Gas	He @ 273 K
Beam Intensity	50-100 nA → x10^{11} pps
Energy spread	< 5 eV <1 eV for input I< 50 nA
RF Voltage range	0.5 – 2.5 kV (1 kV at q=0.25)
RF Frequency range	1 -30 MHz (3.5 – 15 MHz at q=0.25)
RFQ gap radius (ro)	4 mm
RFQ Length (total)	700 mm
Pressure Buffer Gas (He) range	0.1 – 2.5 Pa
Ion energy during the cooling	100 -200 eV

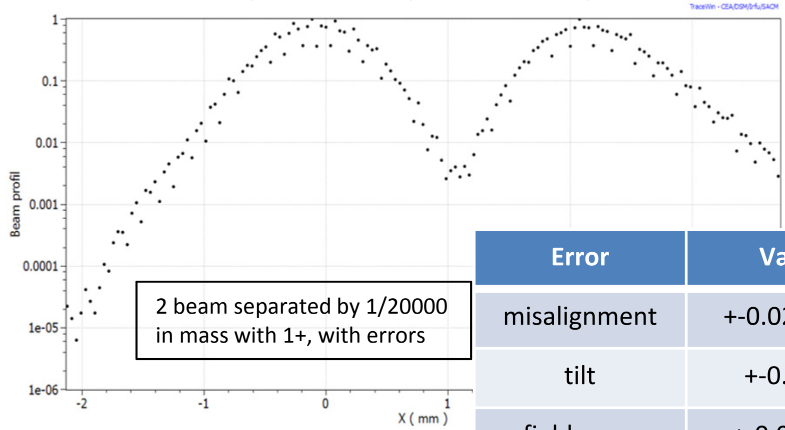
- Crucial for the separation and injection to the CB (low emittance and energy spread).
- 10 times lower emittance and +-1eV energy spread. Losses limited to 30%.



The High Resolution Section

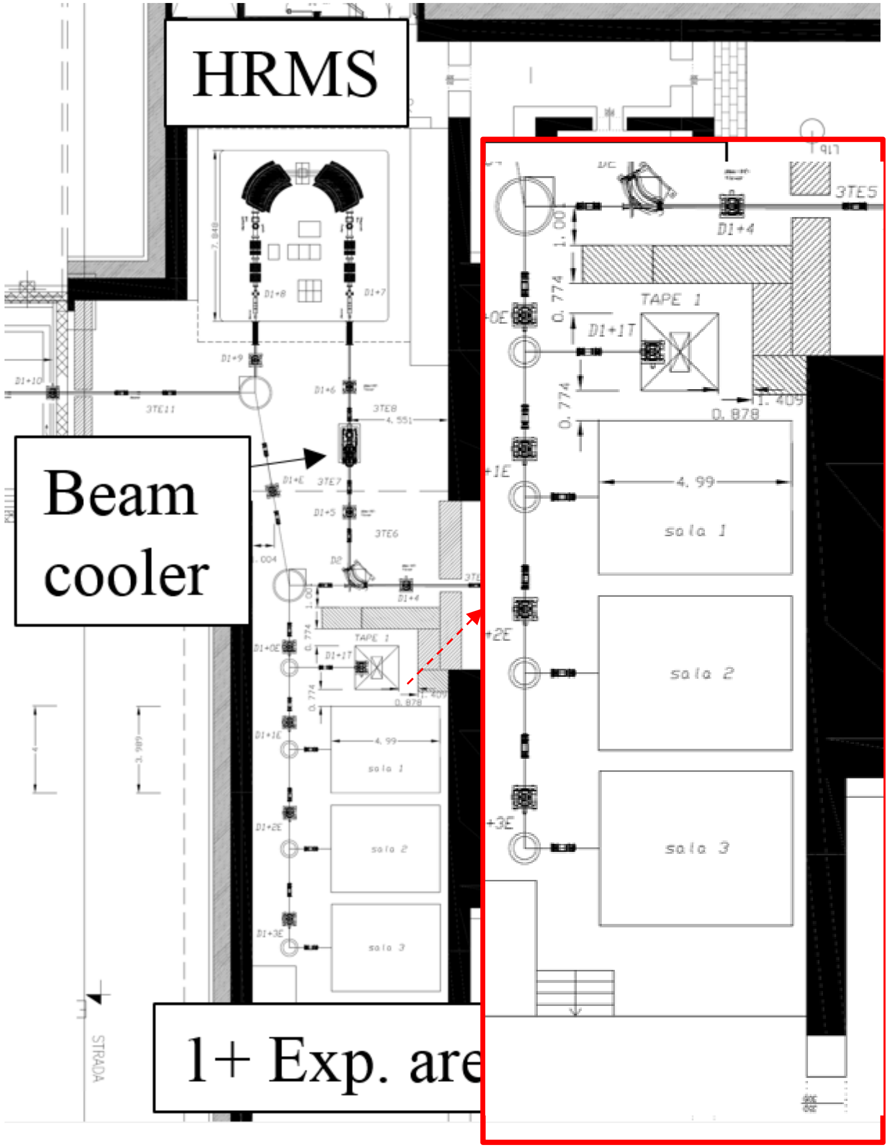


- The HRMS is composed by 2 90° (overall 180°) dipoles of R=1.5 m. There are 3 electric quadrupoles at the entrance and at the exit, with an external hexapoles. Between the two dipoles a multipole (12° order) ensures the correction of curvature aberrations.
- The HRMS is placed onto a HV platform (@-220 kv) because of the effect on the relative energy spread term $\Delta E/E$ which reduces the resolution. This system is also used for the MRMS.
- The optimisation and engineering design is still ongoing.
- A preliminary error study was done.



Error	Value
misalignment	+-0.025 mm
tilt	+-0.005°
field error	+-0.0025%

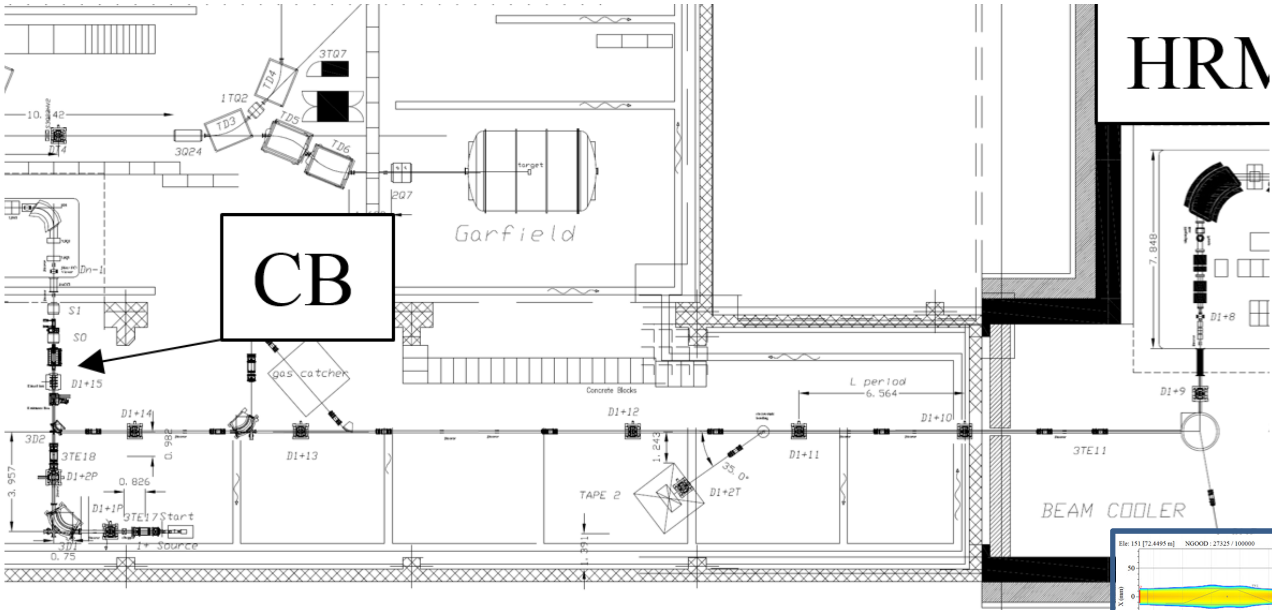
The High Resolution Section

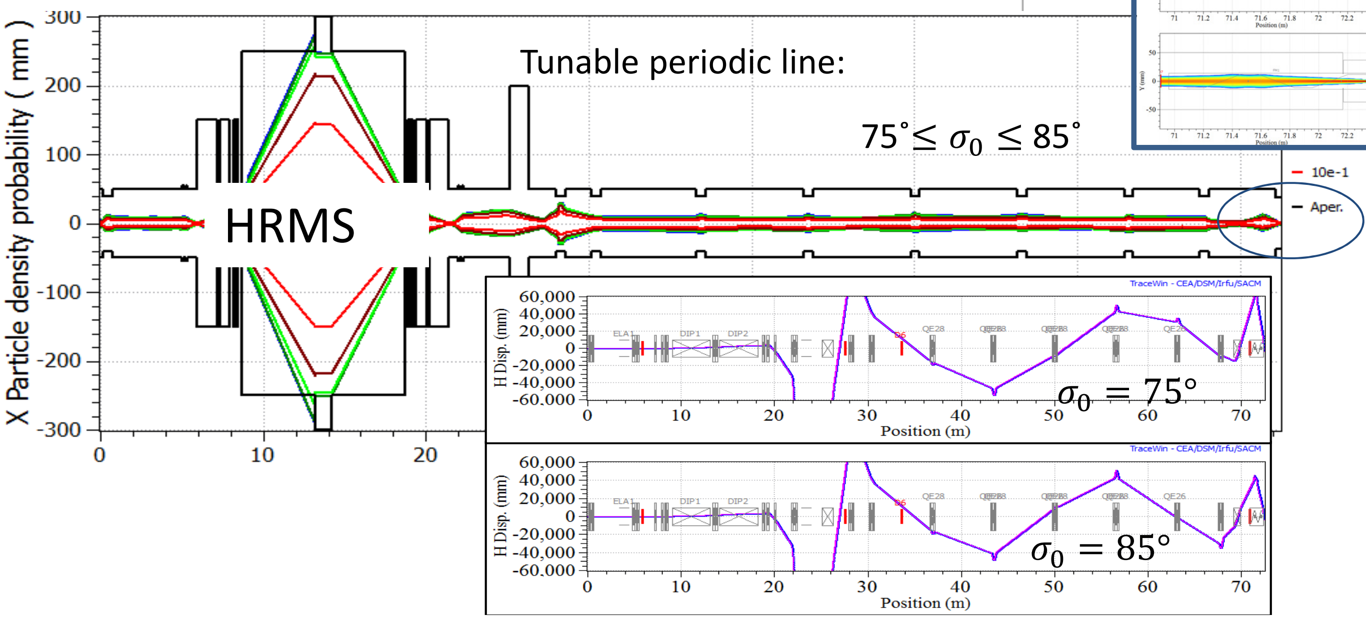


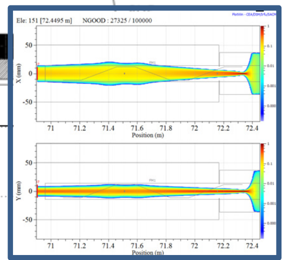
- Three 1+ experimental halls. Electrostatic deflectors under study.
- The beam cooler performances are crucial for: the beam separation and the charge breeding process
- Tape system foreseen after the LRMS in order to first characterise the target beam.
- Electrostatic deflectors under study: mass independent, but little aperture.

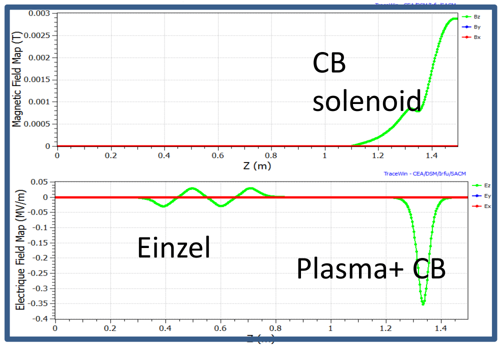
The periodic transfer line to CB

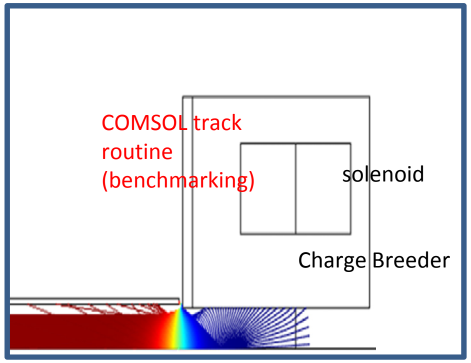
- The periodic transfer line is composed by electrostatic triplets.
- The phase advance of the periodic line can be tuned from $75^{\circ} \leq \sigma_0 \leq 85^{\circ}$ (drive by dispersion).
- Phase advance influences the maximum modulus of D_x along the periodic line
- Triplet after the image point on HV HRMS platform help to control dispersion at HRMS exit.





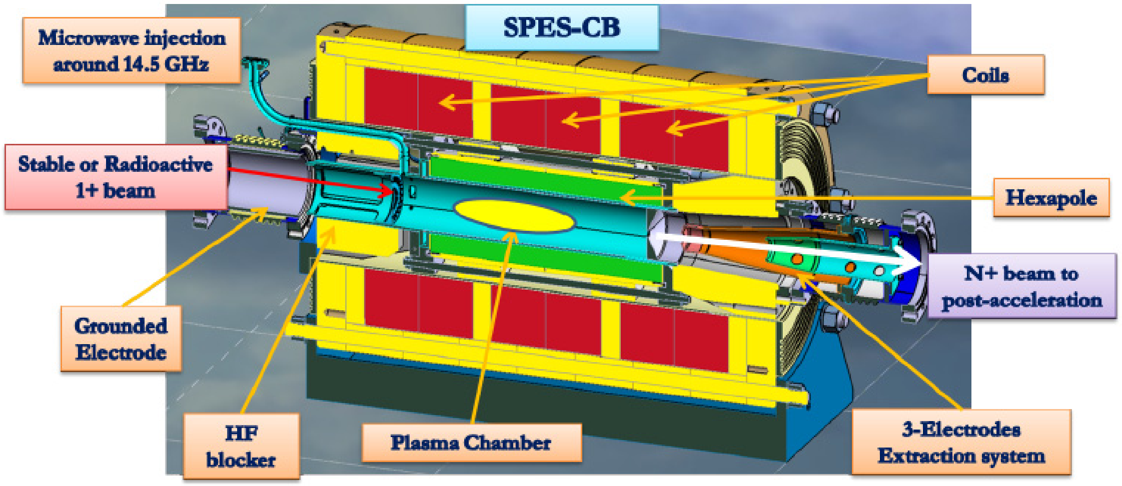


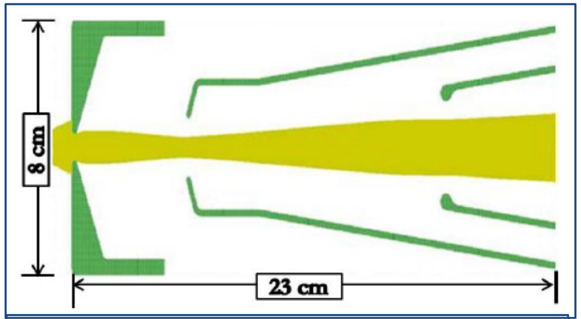




The CB

- 2^{nd} generation ECR source
- 3 coils for axial magnetic field (1.2 T at the injection, 0.42 T minimum and 0.82 T at extraction). 14.5 GHz microwave with a maximum power of 600 W
- Three electrode extraction system: from 40 kV to 20 kV depending on the a/q ratio.
- $\varepsilon_{rms,n} = \mathbf{0.0486\ mm\ mrad}$ **measured during the test bench @LPSC in March 2015 [1]**



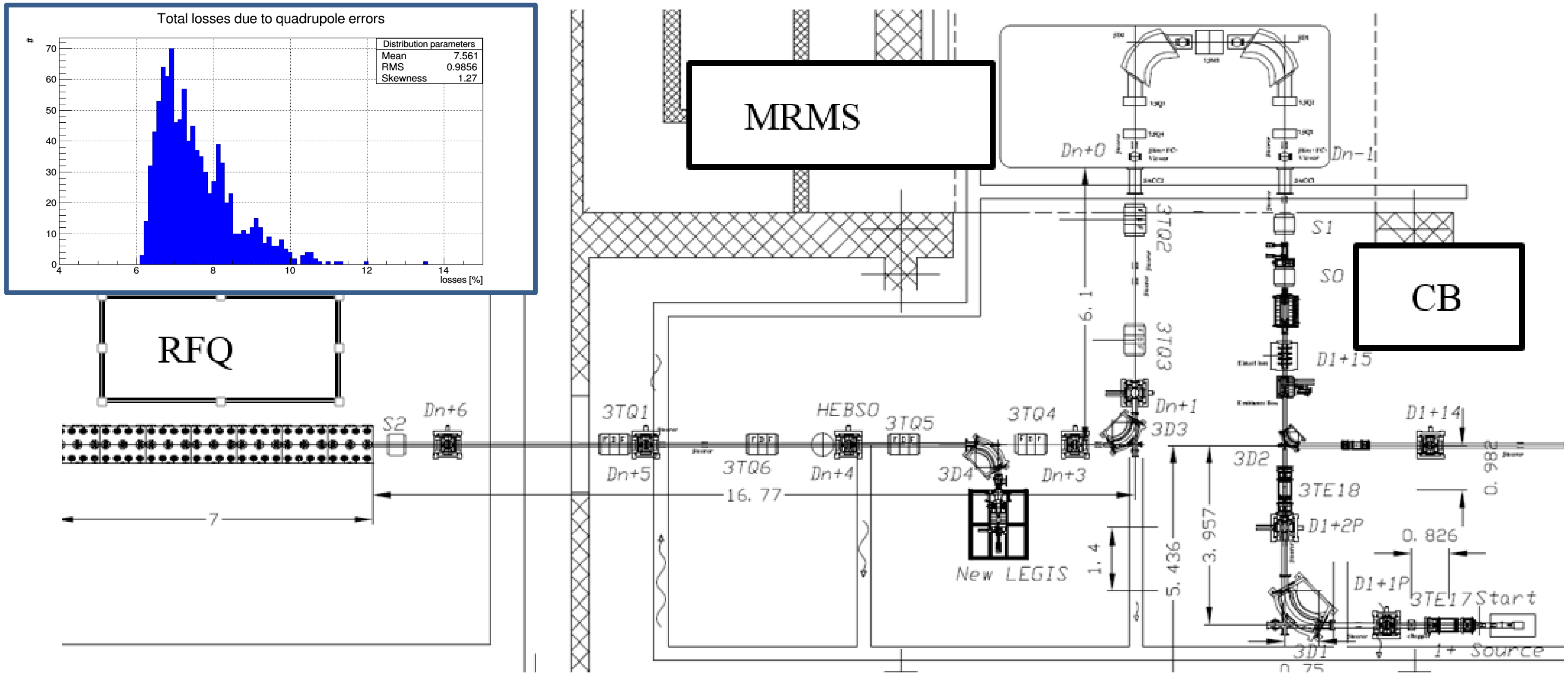


Kobra 3D simulations benchmarked by the test bench within 10%. [1]

Mass Range			ION	Q	Efficiency [%]	Year Data Source	(M/q)_min	(M/q)_max
		138	Xe	20+ (21+)	10,9 (6,2)	2012 (2005)	6.57	6.90
130	132	134	Sn	21+	6	2005	6.19	6.38
		98	Sr	14+	3.5	2005	7	7
		94	Kr	16+(18+)	12(8,5)	2013	5.22	5.88
90	………..	99	Y	14+	3.3	2002	6.43	7.07
74	………..	80	Zn	10+	2.8	2002	7.40	8.00
	81	82	Ga	11+	2	2002	7.36	7.45
90	91	92	Rb	17+	7.50	2013	5.29	5.41
		34	Ar	8+(9+)	16,2(11,5)	2012 (2013)	3.78	4.25

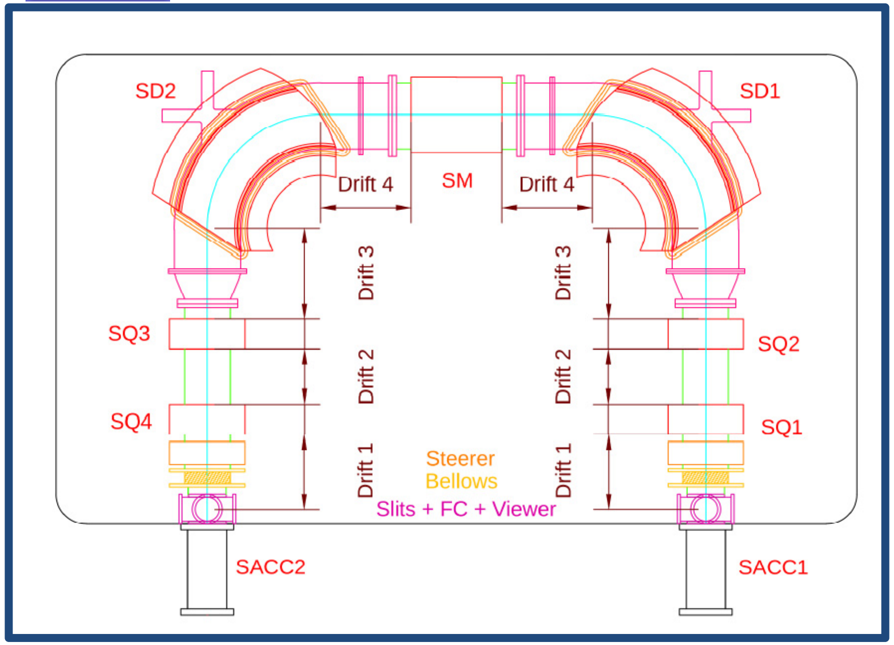
[1] The SPES-Charge Breeder (SPES CB) and its beam line INFN-LNL, Alessio Galatà et Al. EMIS15 under publication

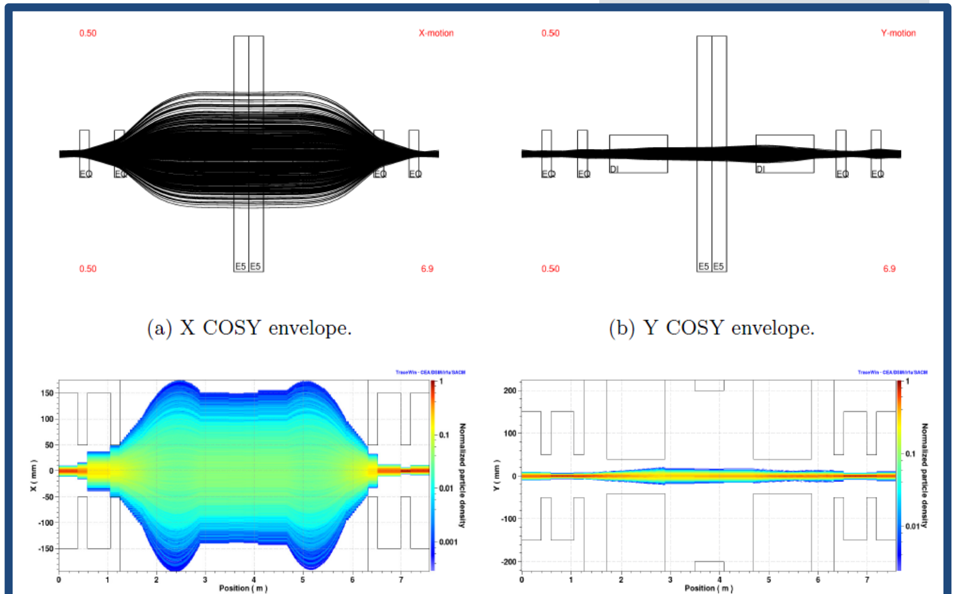
The CB-RFQ line



- The CB to RFQ line is composed by the Medium Resolution Mass Separator of 1/1000 in A/q which cleans the contaminants coming from the CB, and a matching line for the RFQ.
- The 1+ pilot beam line is composed by a low resolution mass separator 1/150.
- The MRMS is placed onto a HV platform like the HRMS in order to decrease the geometric emittance and to decrease the term $\frac{\Delta E}{E}$ which would decrease the resolution.
- The line is design for a beam of $\varepsilon_{rms,n}$ of 0.1 mm mrad which is twice the measured emittance from the CB test bench. The assumed energy spread is ± 15 eV.
- The RFQ is a CW RFQ with internal bunching at 80 MHz specifically designed for a low longitudinal emittance. A 5 MHz buncher is forseen for the experiments which will require pulsed beam

The MRMS





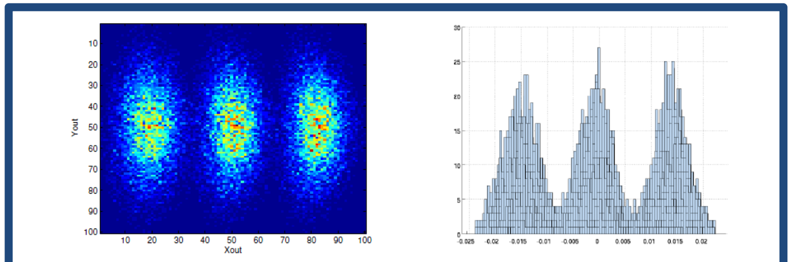
(a) X COSY envelope.

(b) Y COSY envelope.

(c) X TraceWin envelope.

(d) Y TraceWin envelope.

- The optics is composed by 4 electrostatic quadrupoles, 2 dipoles and a 12° order multipole.
- Dipole characteristics: 0.750 m bending radius, 90° bending angle. External edge curvature: 2.6 m. Edge angles β=33.35°. Horizontal aperture 0.4 m. Vertical aperture 0.08 m.
- Both the four quadrupoles are x defocusing.
- BD Benchmarking with COSYINFINITY.
- Required Platform stability of the order of 0.01% in voltage.

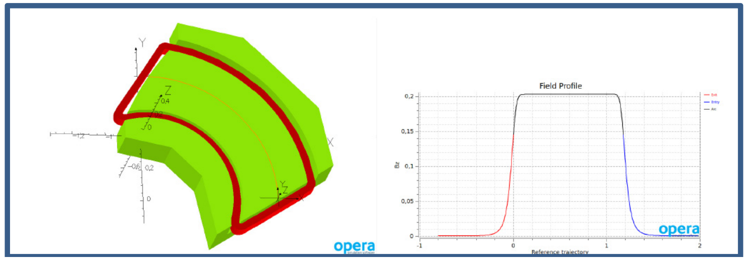


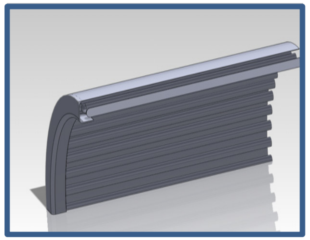
(a) X-Y COSY distribution.

(b) X COSY distribution.

(c) X-Y TraceWin distribution.

(d) X TraceWin distribution.





The four-vane SPES RFQ

Parameter (units)	Design Value
Operational mode	CW
Frequency (MHz)	**80.00**
Injection Energy (keV/u)	5.7 (β=0.0035)
Output Energy (keV/u)	727 (β=0.0395)
RF power dissipation (kW)	100

Table 2: RFQ design parameters

Parameter (units)	Design
Inter-vane voltage V (kV, A/q=7)	63.8 – 85.84
Vane length L (m)	6.95
Average radius R_0 (mm)	5.33 – 6.788
Vane radius ρ to average radius ratio	0.76
Modulation factor m	1.0 – 3.18
Min small aperture a (mm)	2.45
Total number of cells	321
Synchronous phase (deg.)	-90 – -20
Focusing strength B	4.7 – 4
Peak field (Kilpatrick units)	1.74
Transmission (%)	95
Input Tr. RMS emittance (mmmrad)	0.1
Output Long. RMS emittance (mmmrad) / (keVns/u)/(keVdeg/u)	0.055 / 0.15 / 4.35

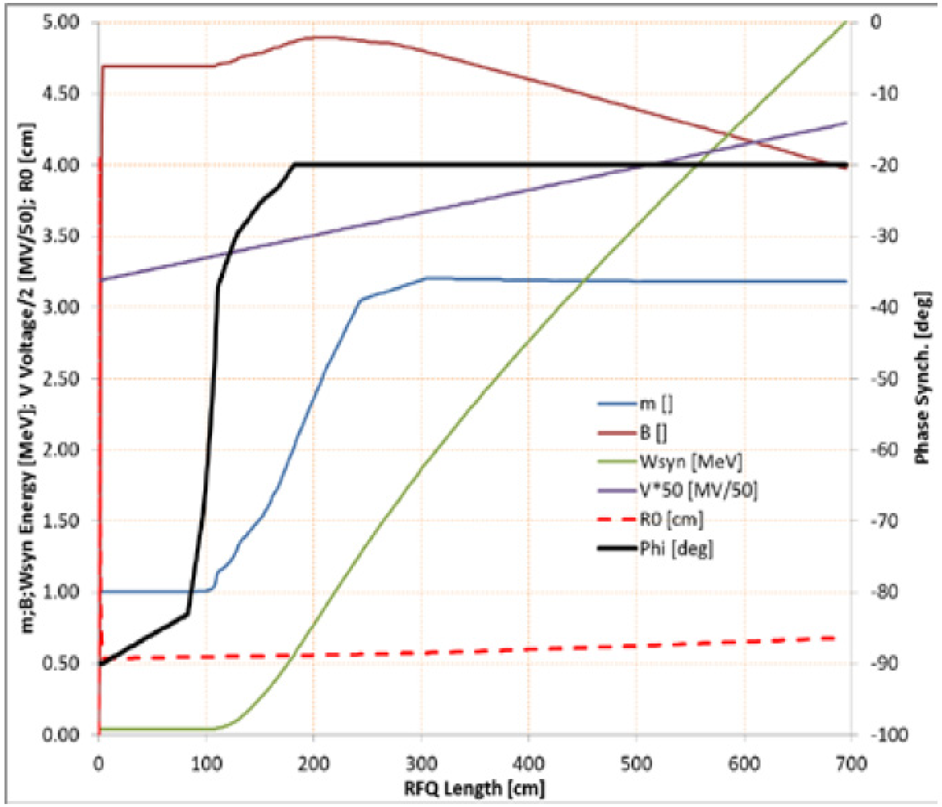
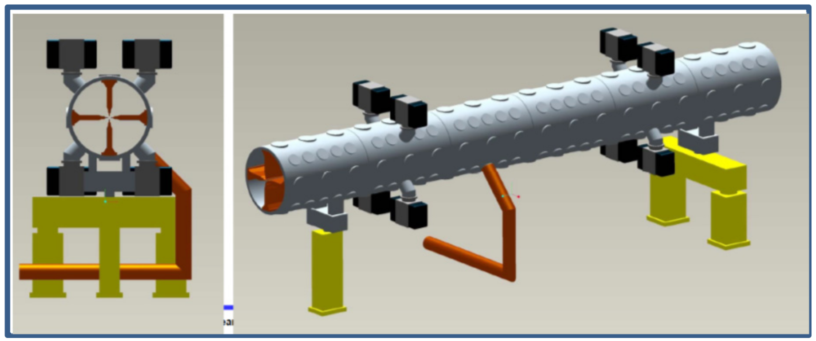
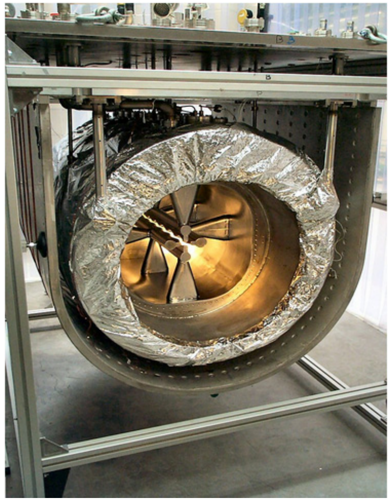


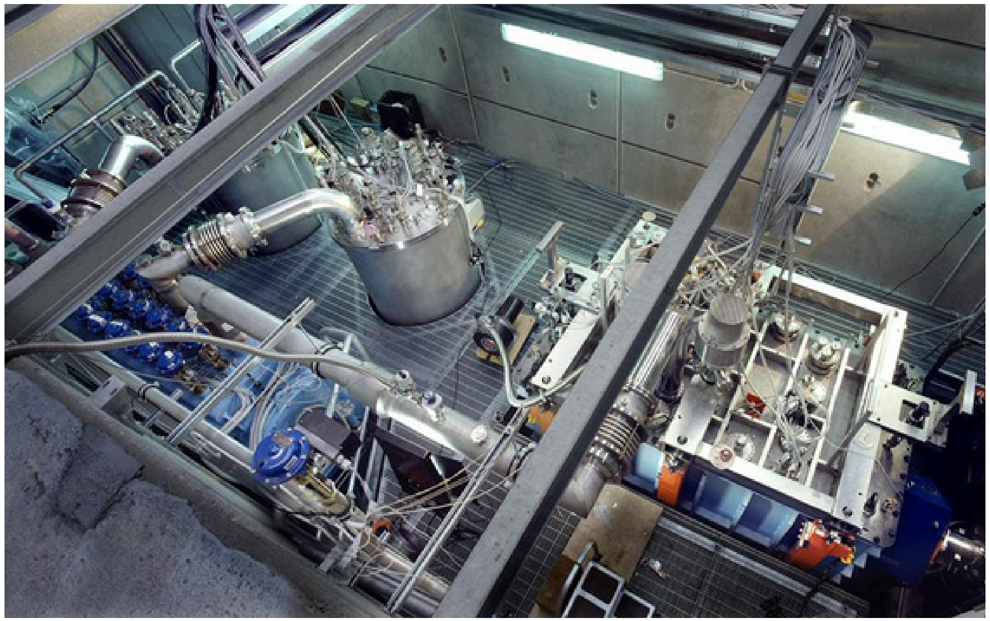
Figure 1: The main RFQ parameters vs. length.



SPES RFQ and PIAVE

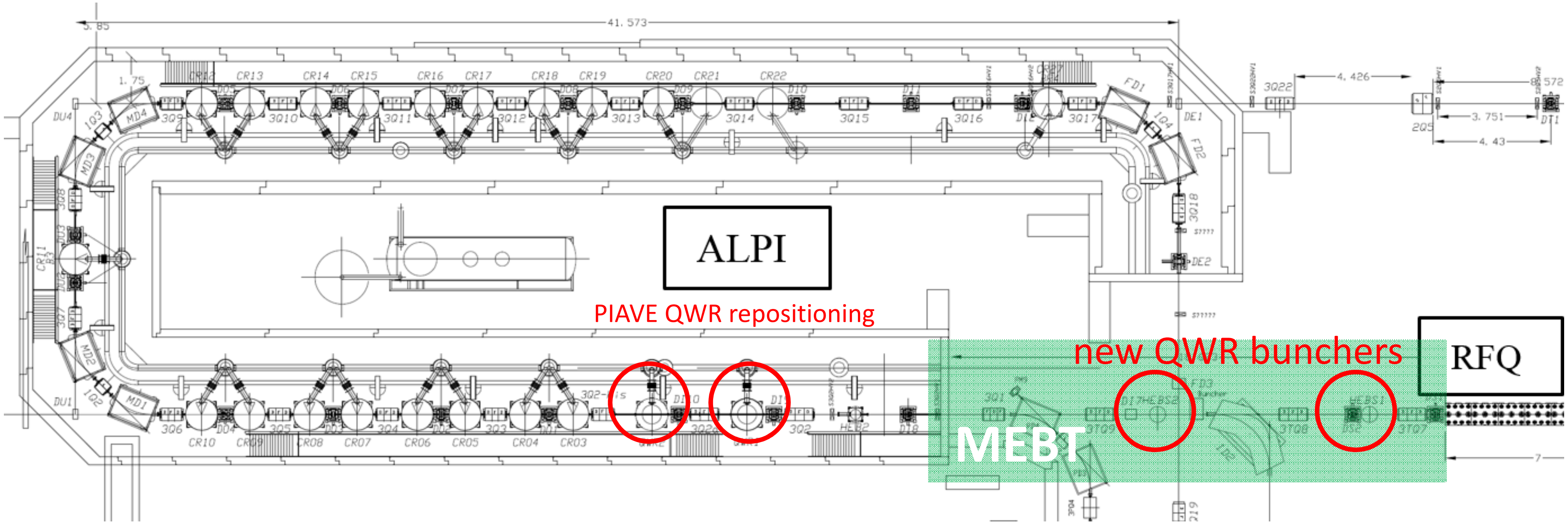


Parameter	SPES RFQ	PIAVE SRFQ
Input energy	5.7 keV/u	37.1 keV/u
Output Energy [keV/u]	727 (β=0.0395)	587 (β=0.0355)
Mass to charge ratio	3-7	2-8.5
Input Tr. Norm. RMS emittance [mmmrad]	0.071	0.1
Output RMS Long. emittance [degkeV/u]	4.5	4.8
Output 90% Long. emittance [degkeV/u]	29.3	26
Transmission [%]	75	95
QWR 0.047 TTF	0.85	0.95
QWR 0047 DY’ [mrad]	-0.48	-0.32

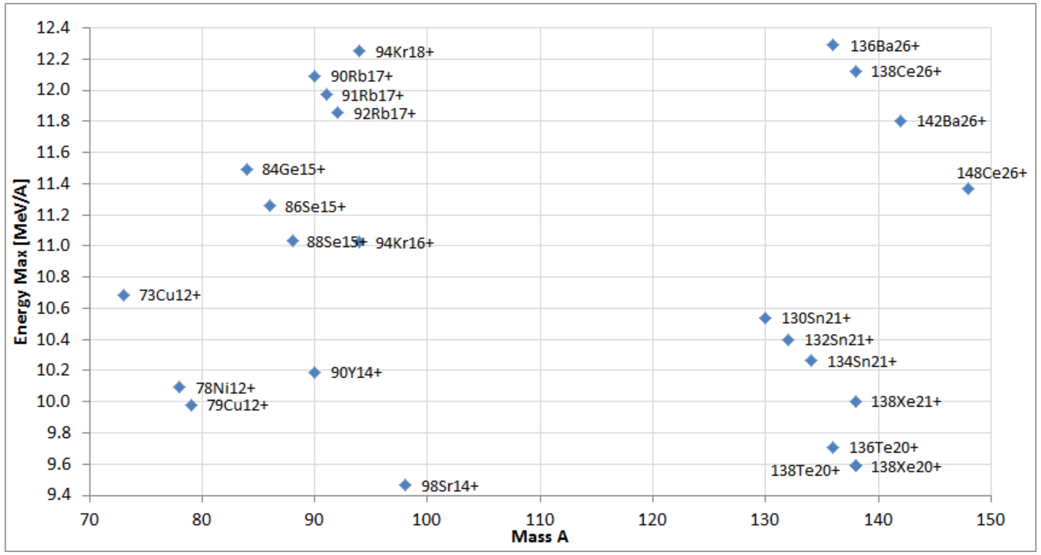


- The PIAVE accelerator is a superconductive injector (up to 8 MeV) composed by two superconductive RFQ in Nb, decoupled functions, and 8 QWR cavities.
- The cryo-cooling of the superconductive RFQ is key parameter for the stability.
- Transmission of 70% by External 3H buncher.

ALPI accelerator

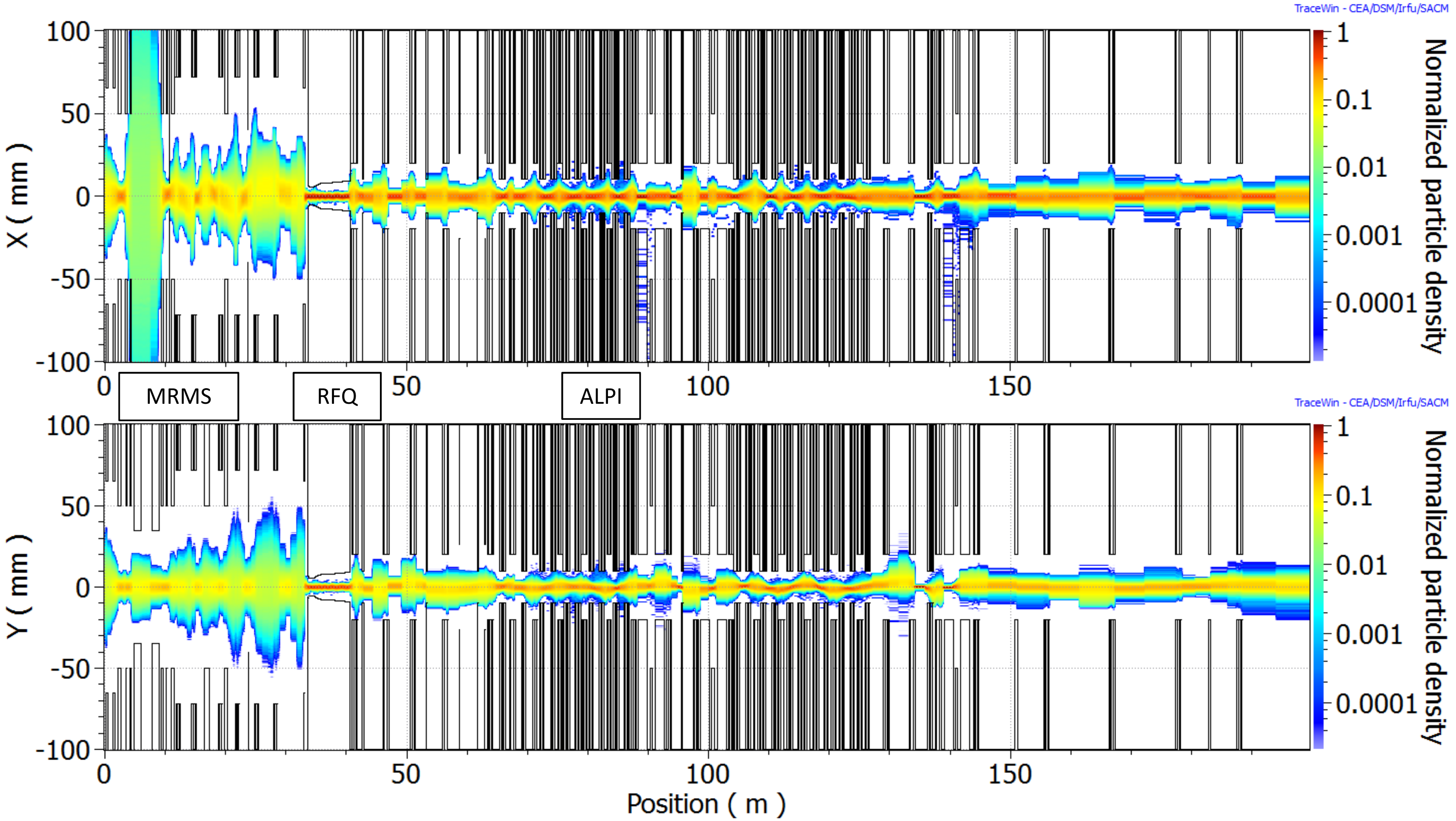


RIB energy as a function of mass



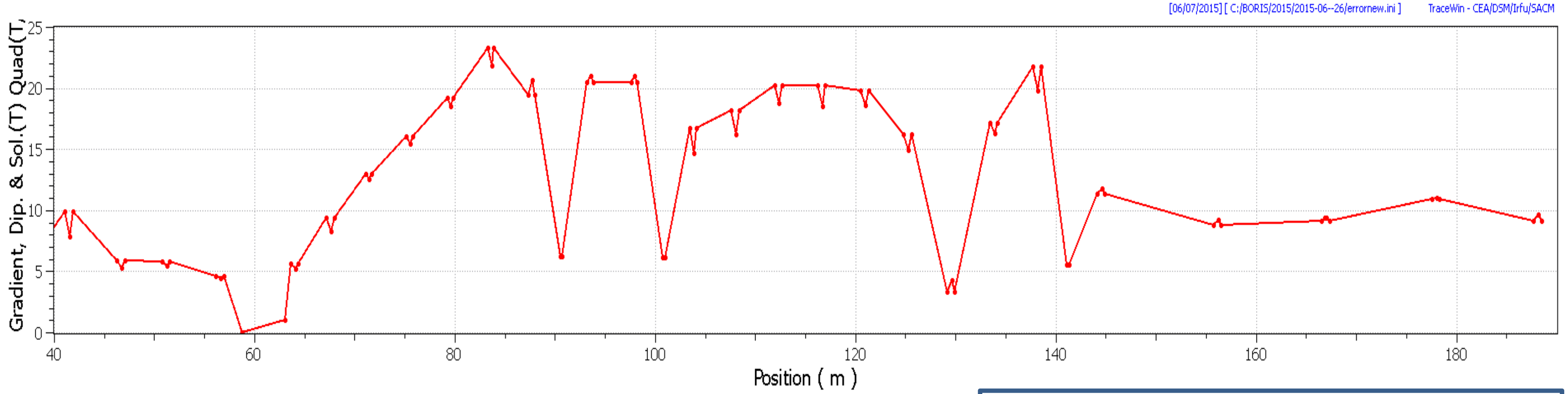
- Independent cavity LINAC
- New quads with higher gradient (20→25 T/m) to optimize T
- MEBT will ensure longitudinal matching from the RFQ to ALPI
- Acceleration up to 10 MeV/u depending on the A/q ratio.

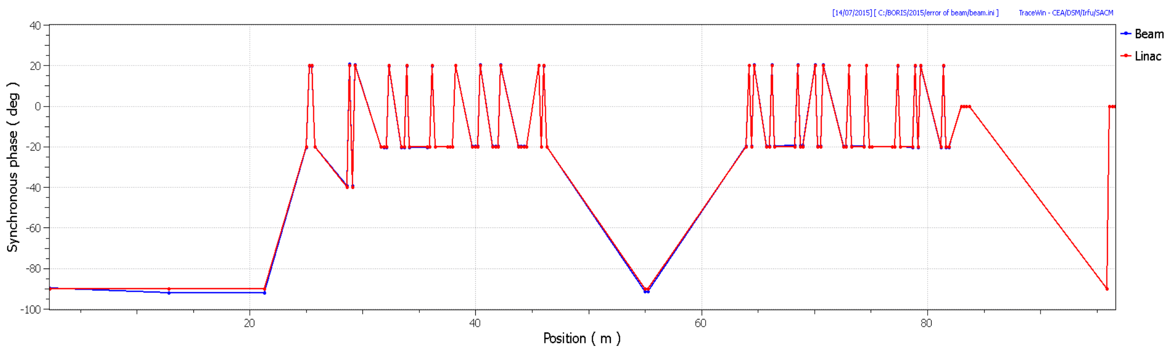
End to end simulation from the CB to end of ALPI

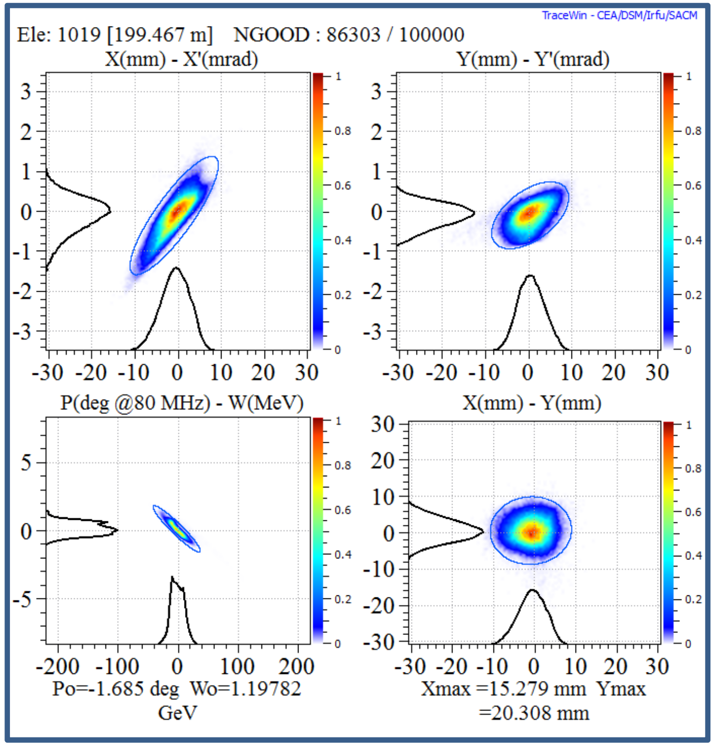


- Case of $^{132}Sn^{19+}$ @ 0.76 MeV with 0.1 mm mrad from the CB and +-15 eV of energy spread.
- The total losses in the nominal case are less than 14%, the final energy is 1200 MeV

End to end simulation from the CB to end of ALPI

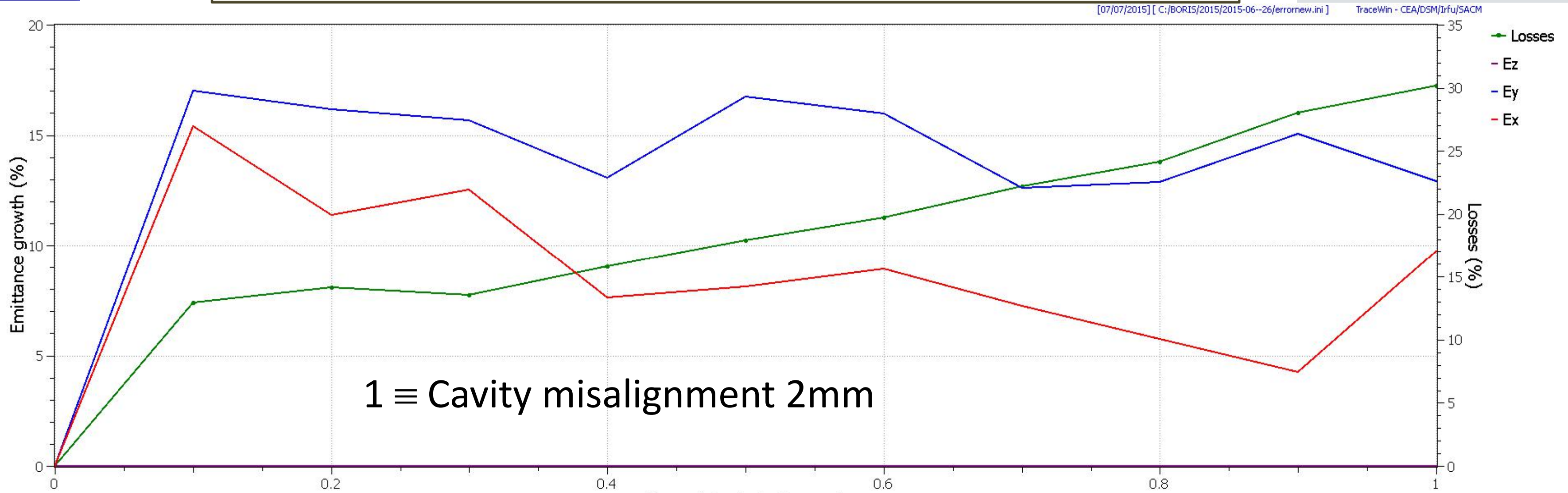


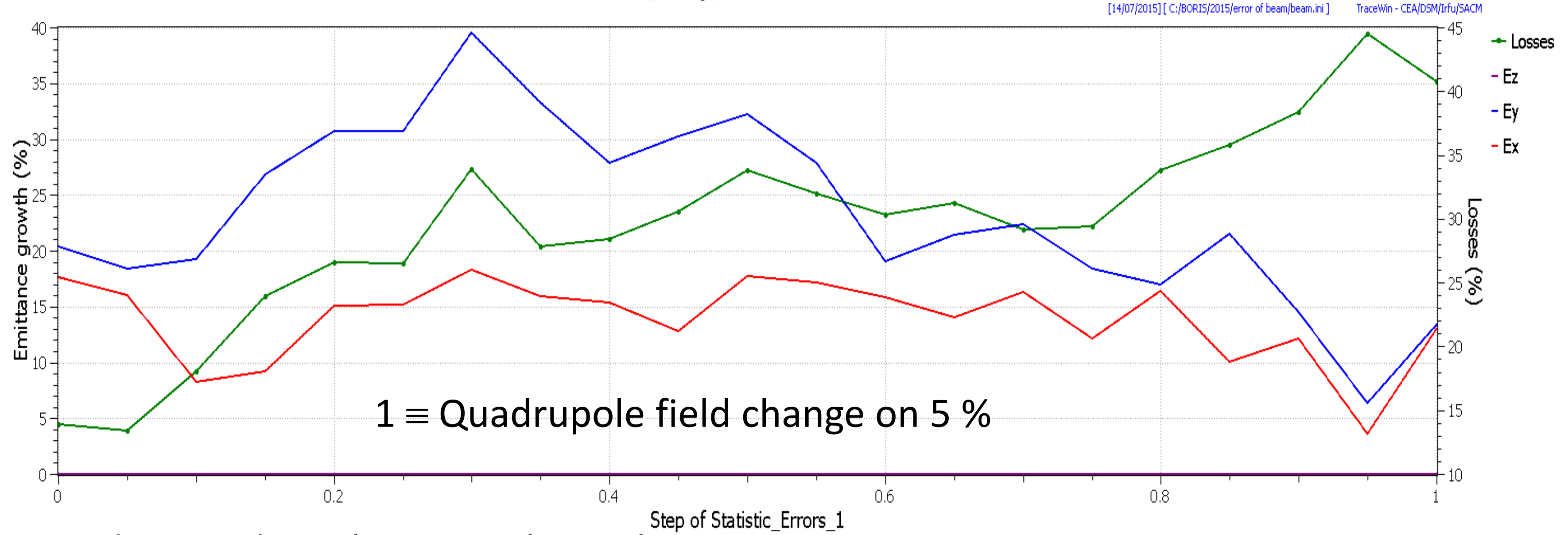




- Gradient and synchronous phase along ALPI
- Output beam with energy spread of about 1/1000

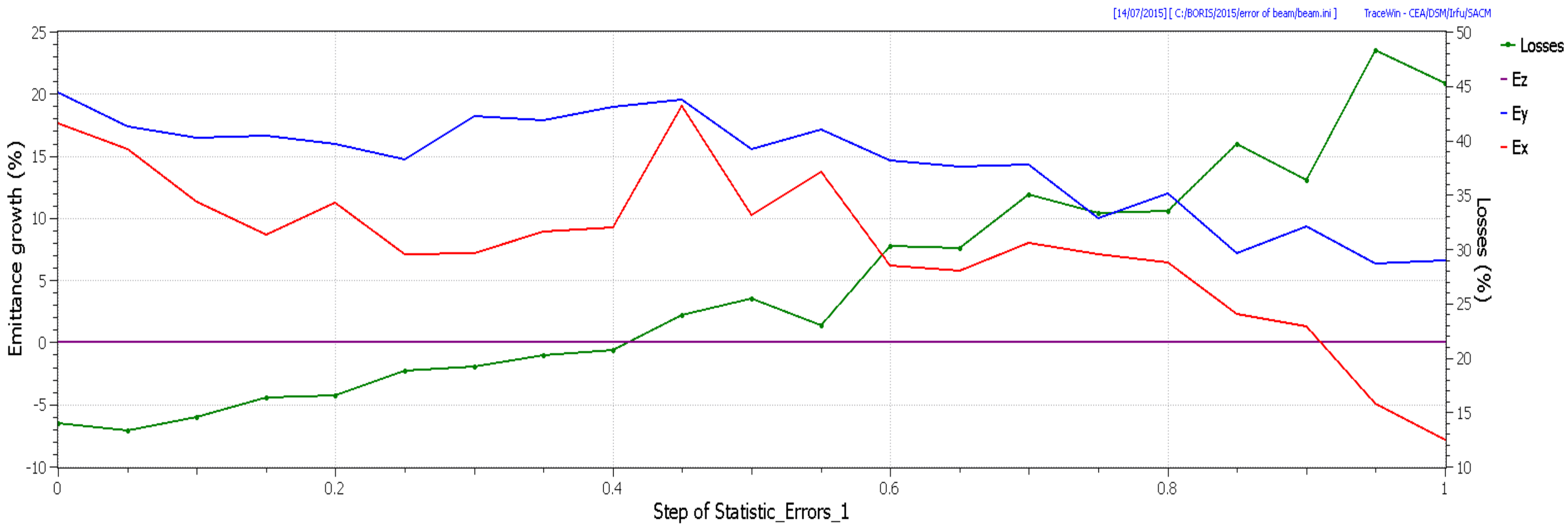
Preliminary error study





- Gradient and synchronous phase along ALPI

Preliminary error study



1 ≡ Quadrupole position 0.1 mm

Parameter	Value	Average losses
Cavity displacement	±1 mm	30%
Phase error	±1°	15%
Input beam phase error	±2°	10%
Quadrupole displacement	±0.05 mm	22%

Conclusions

- The Layout of SPES has been fully defined.
- The cyclotron commissioning is about to begin.
- The line between the CB to the RFQ is on procurement.
- The HRMS is on the final physics design.
- ALPI will be upgraded with new magnets and control system.

	2012	2013	2014	2015	2016	2017	2018	2019
Authorization to operate and safety	UCx 5microA							
ISOL Target-Ion Sources development								
ISOL Targets construction and installation								
ISOL on-line commissioning								
Building Construction	Executive project	raw building construction						
Cyclotron Construction & commissioning				Cyclotron at LNL				
RFQ development and Alpi up-grade								
Design of RIB transport & selection (HRMS, Charge Breeder, Beam Cooler)								
Construction and Installation of RIBs transfer lines, CB and spectrometers								
Stepwise commissioning and first exotic beam (2018), HRMS in 2019								