Role of the 1+ beam optics upstream the SPIRAL1 charge breeder

<u>L. Maunoury</u>[1], O. Kamalou[1], M. Dubois[1], S. Damoy[1], R. Frigot[1], S. Hormigos[1], and B. Jacquot[1]

[1]*Grand Accélérateur National d'Ions Lourds, bd Henri Becquerel, BP 55027, F-14076 Caen cedex 05, France*

GANIL spiral2

laboratoire commun CEA/DRF CNRS/IN2P3

ECRIS 2020

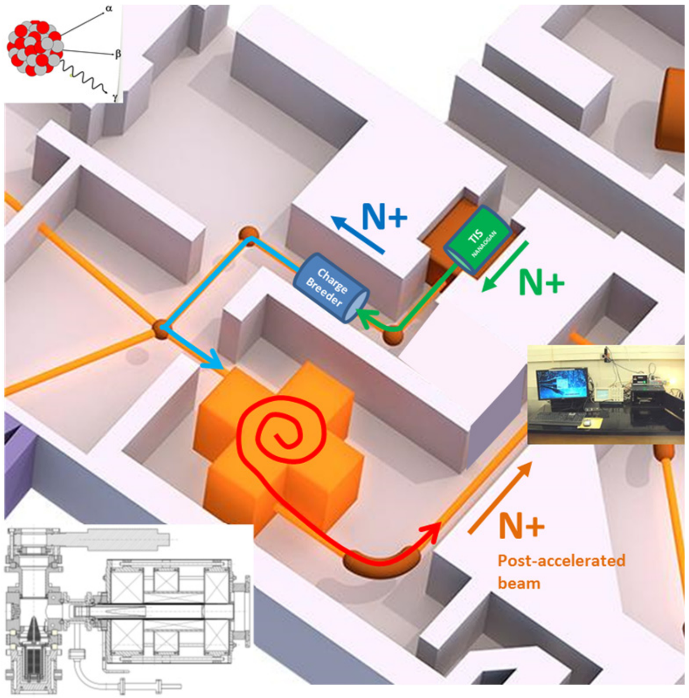
Outlines

- ✓ The SPIRAL1 facility
- ✓ The challenges
- ✓ The 1+ beam line
- ✓ ΔE Measurement
- ✓ Summary and perspectives

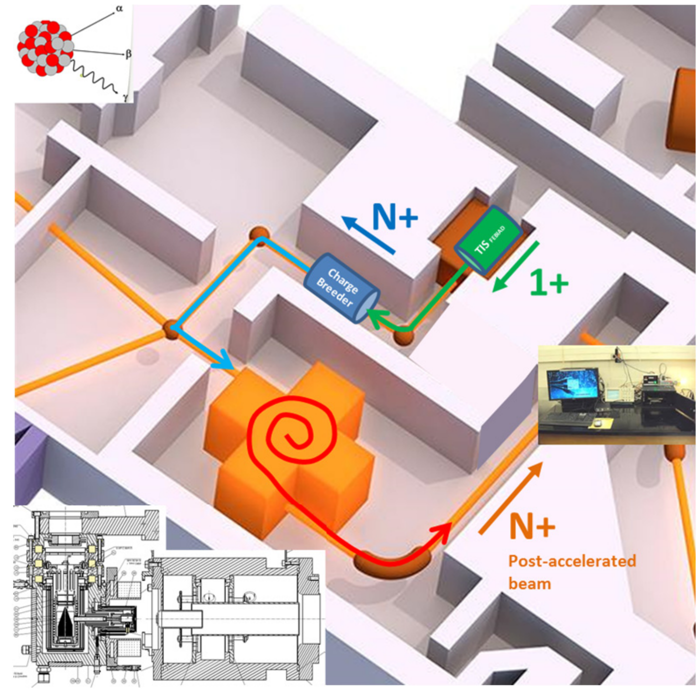
The SPIRAL1 facility

Two major modes

Shooting through (ST)

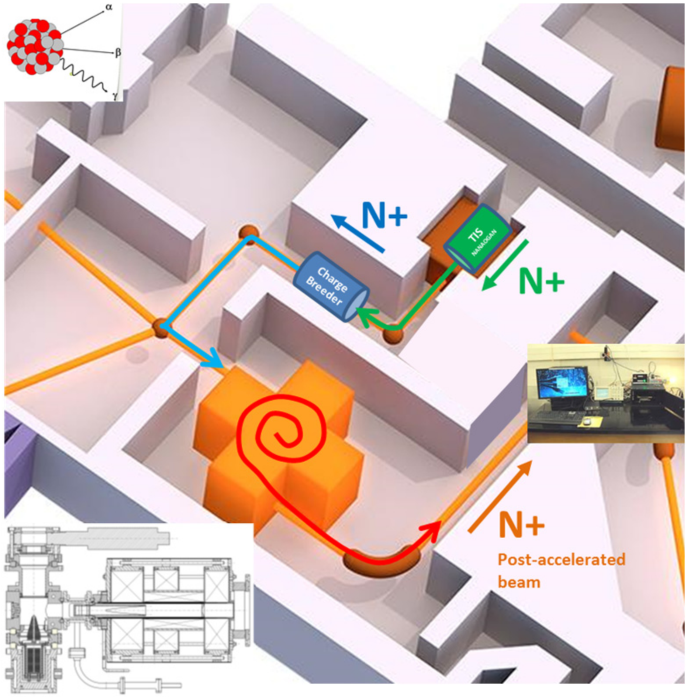


1+/N+

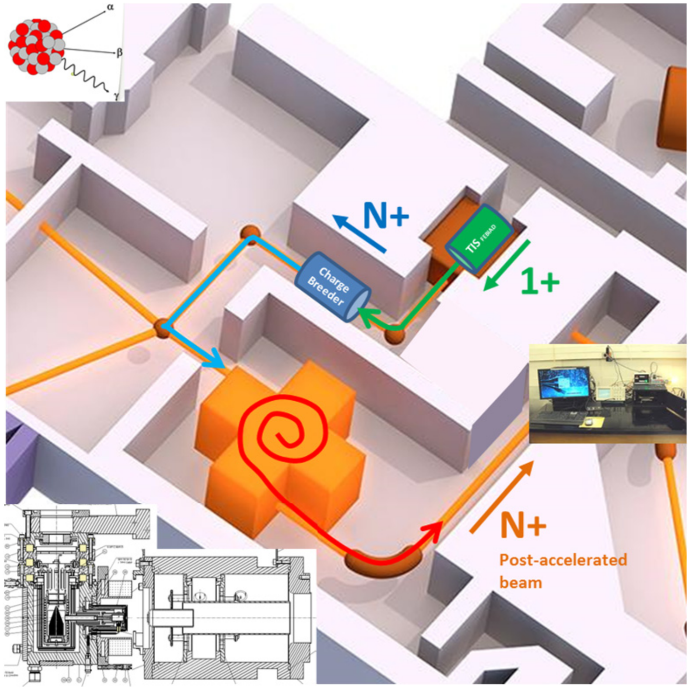


Two major modes

Shooting through (ST)



1+/N+

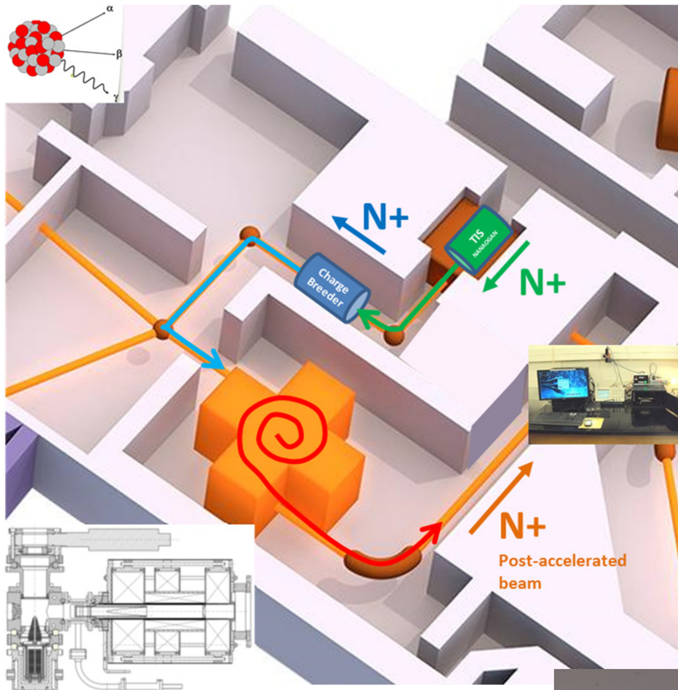


In operation mode

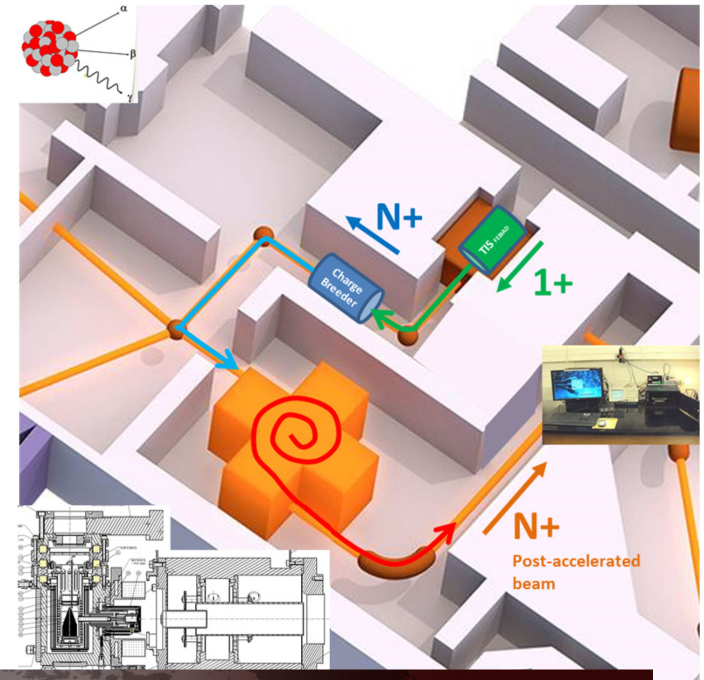
- ✓ 4 RIB's delivered in ST mode
- ✓ 1 RIB delivered in 1+/N+ mode

Two major modes

Shooting through (ST)

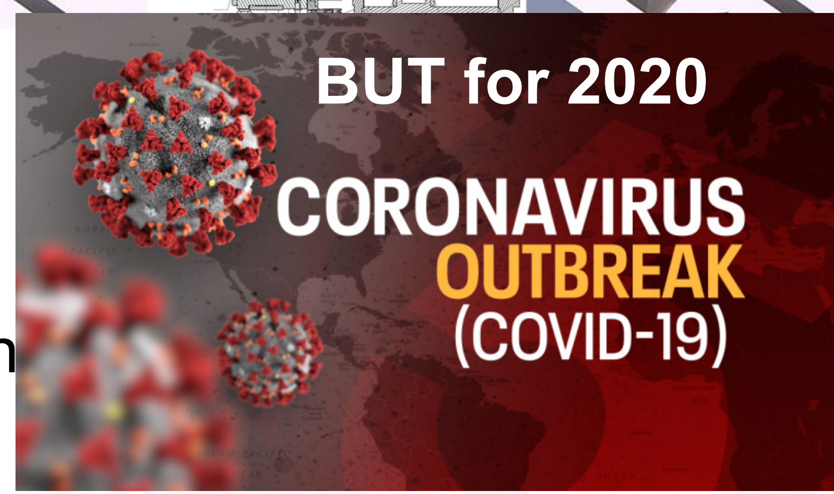


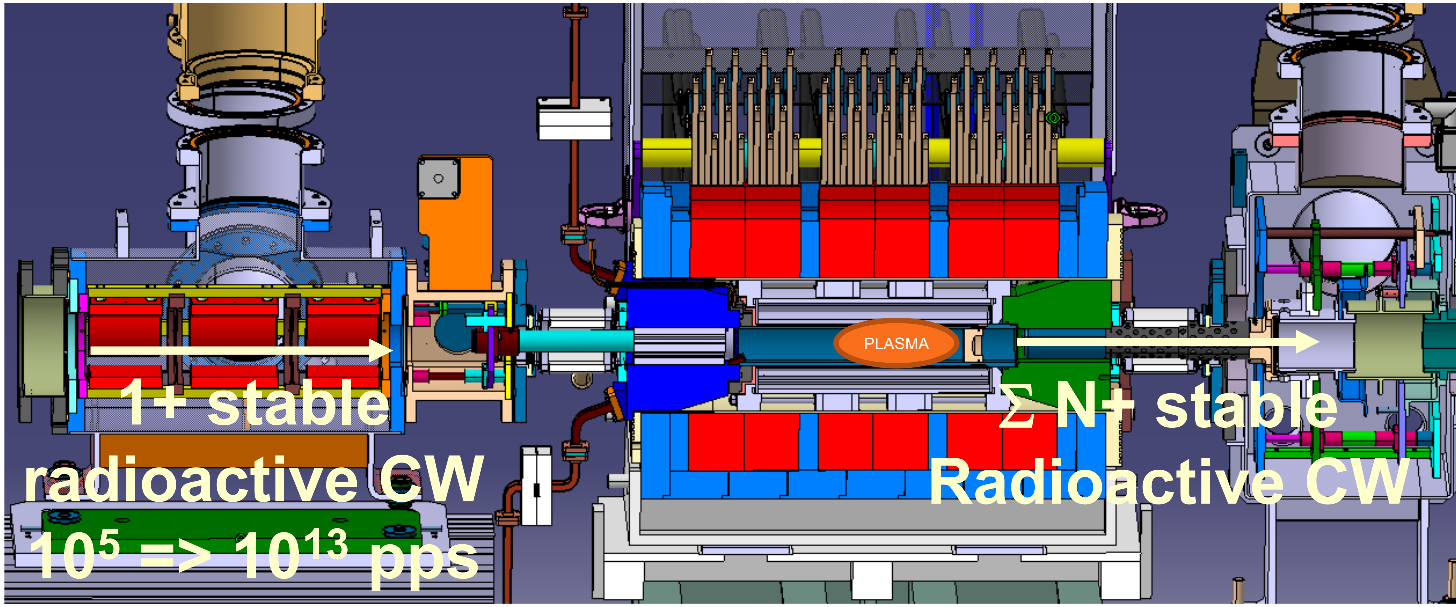
1+/N+

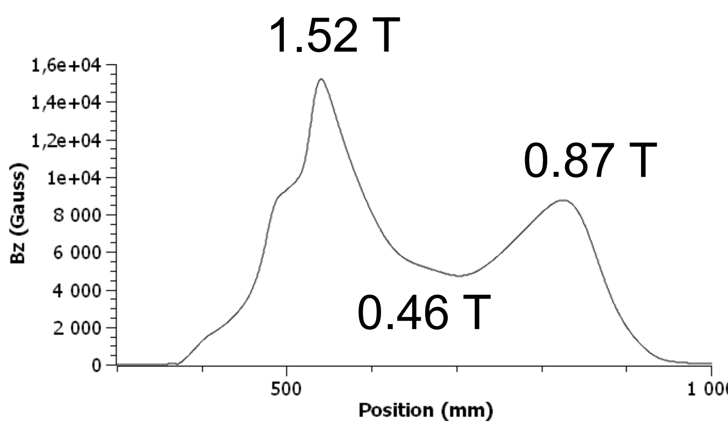


In operation mode

✓ 4 RIB's delivered
✓ 1 RIB delivered in







Axial magnetic field

Stable Species: Li => Cs
Radioactive Species: All
Efficiency / Q: 5 - 15%
Σ Efficiency: 40 - 70%
CB time: 5 - 20 ms/Q
Energy: 10 - 30 Q.keV

The challenges

Two main goals

For operation

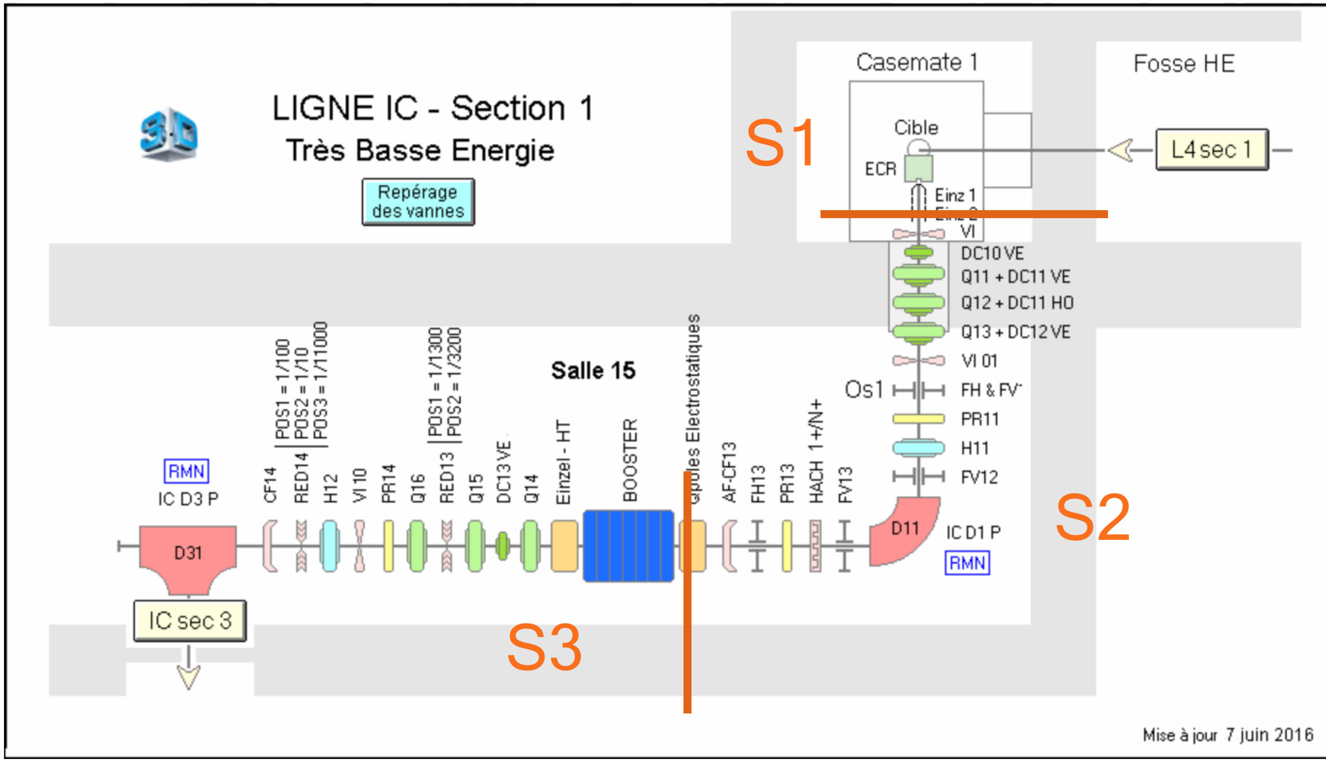
- Fast tuning (~ ½ day)
- One set of beam parameters
- Blind tuning with RIB
- High transmission (ST mode)

For R&D

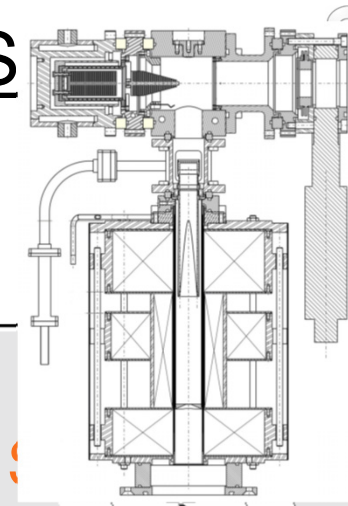
- What are the beam key points?
- What are the beam characteristics?

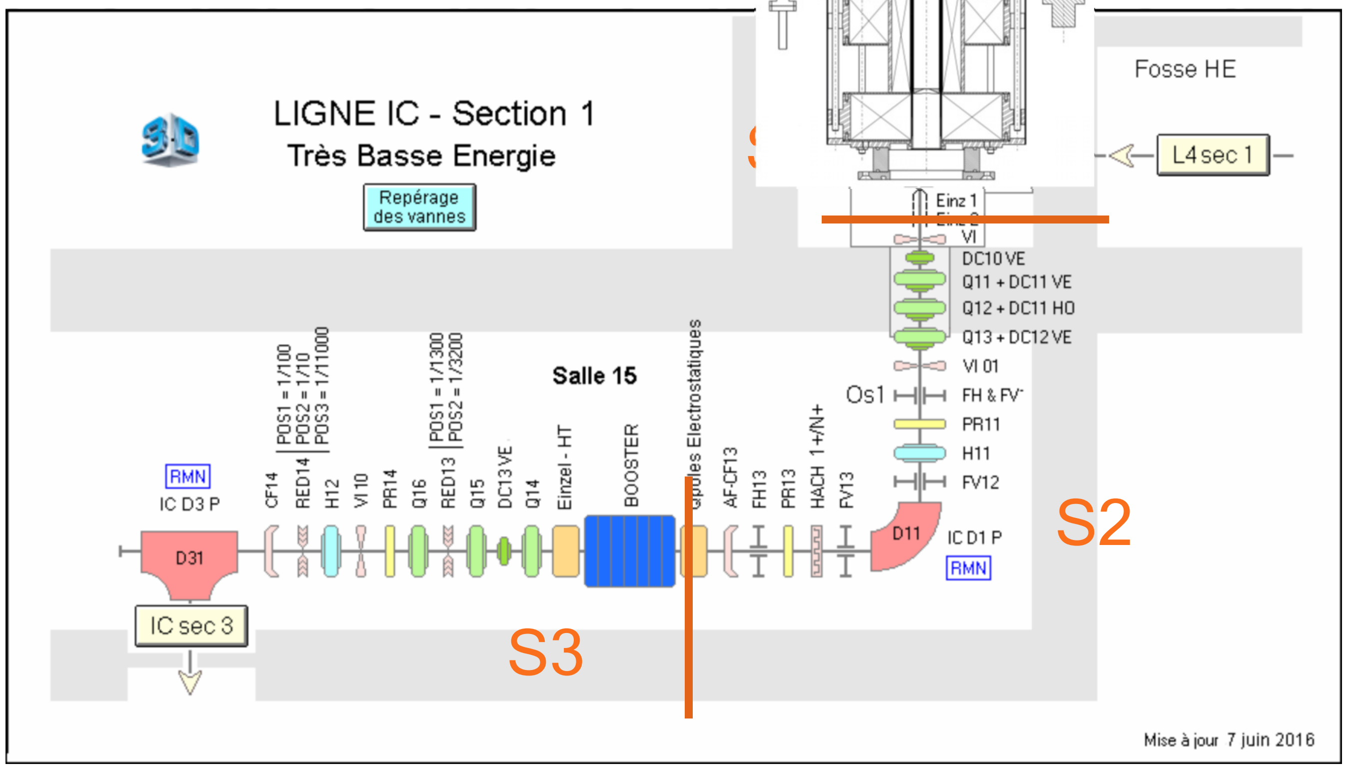
The 1+ beam line

SPIRAL1 beam line : ST mode

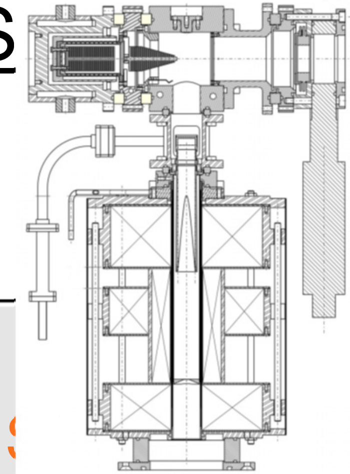


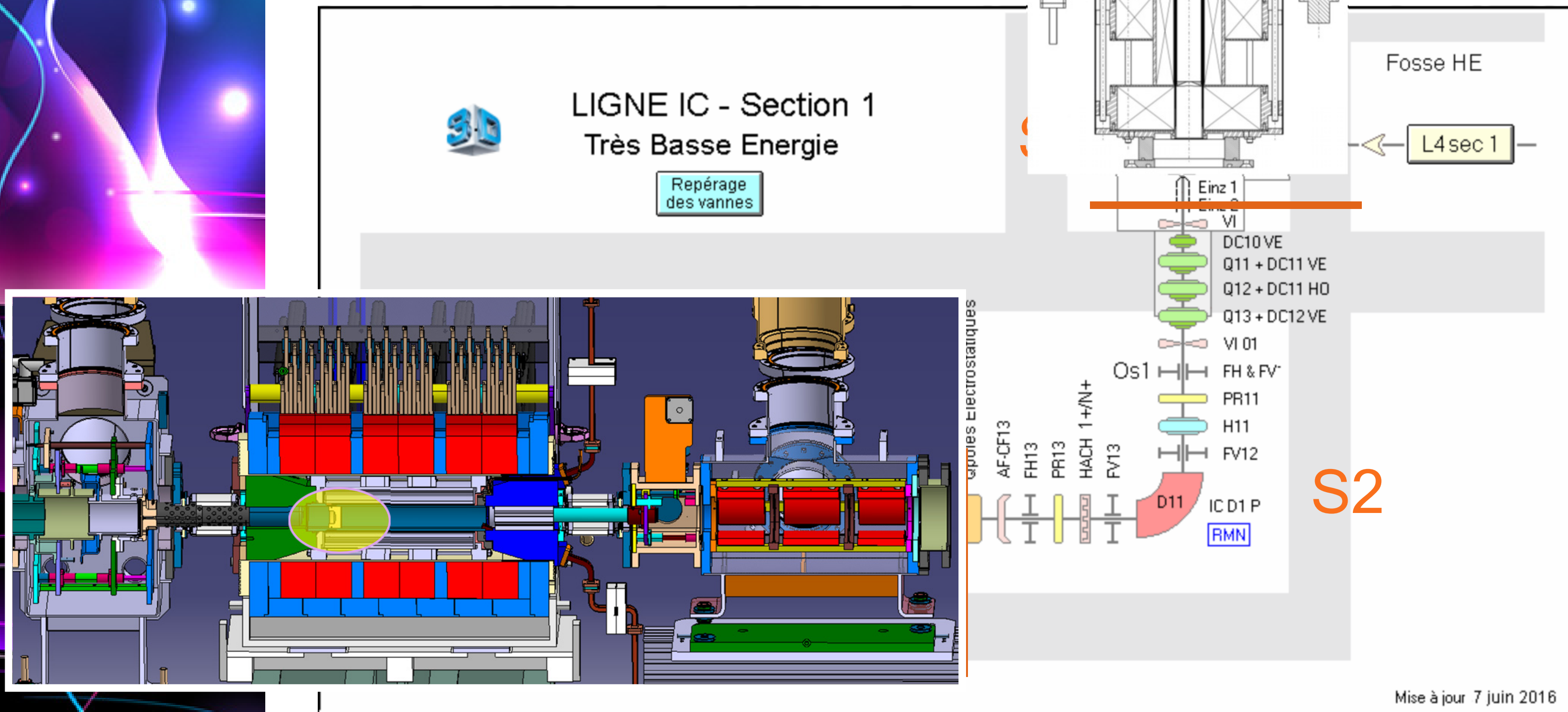
SPIRAL1 beam line : S





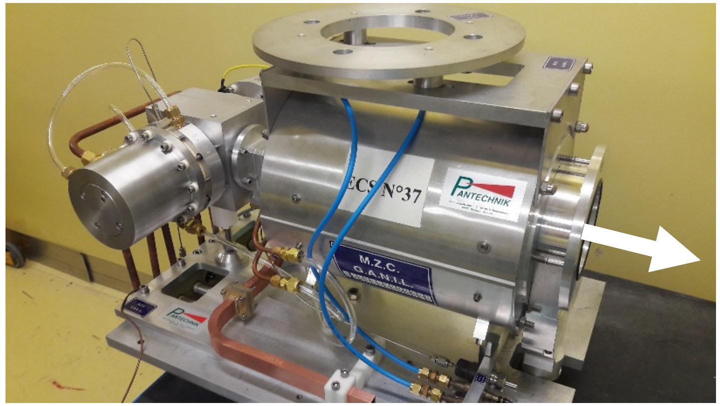
SPIRAL1 beam line : S



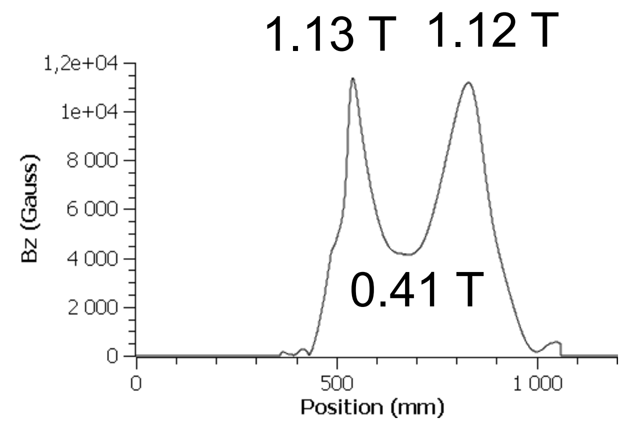


SPIRAL1 CB switched off !

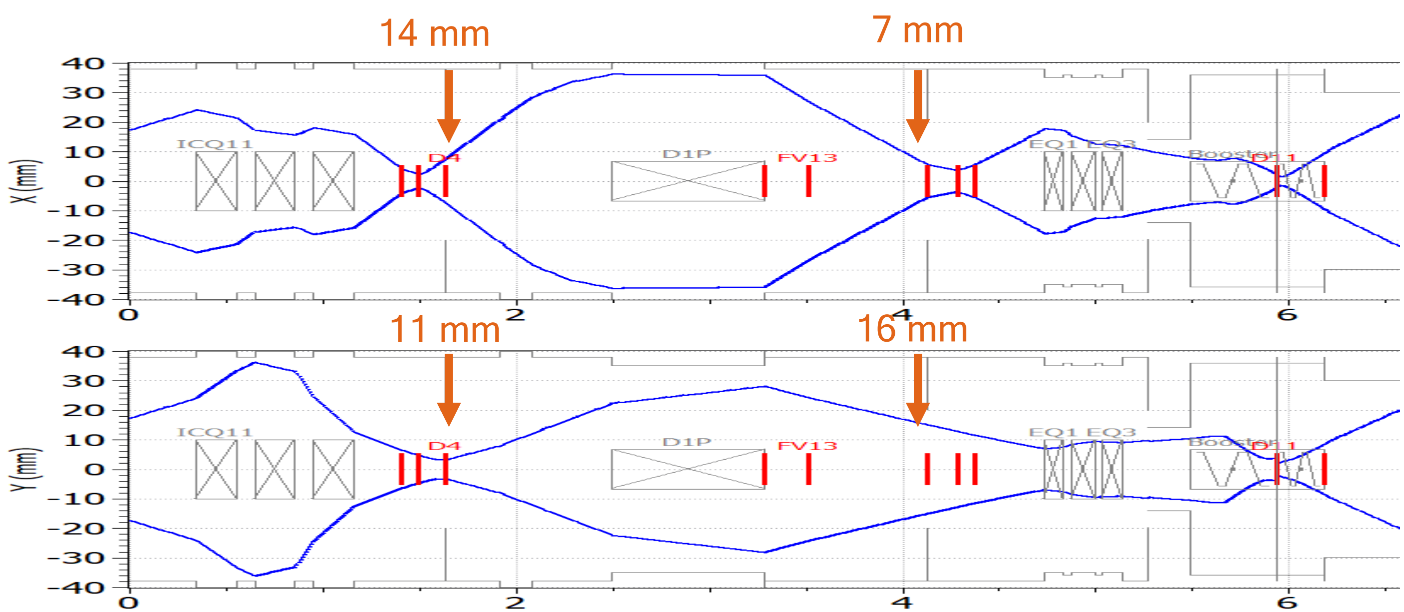
Shooting Through: $^{14}N^{3+}$@19.751kV



TISS NanoganIII



SPIRAL1 Charge Breeder

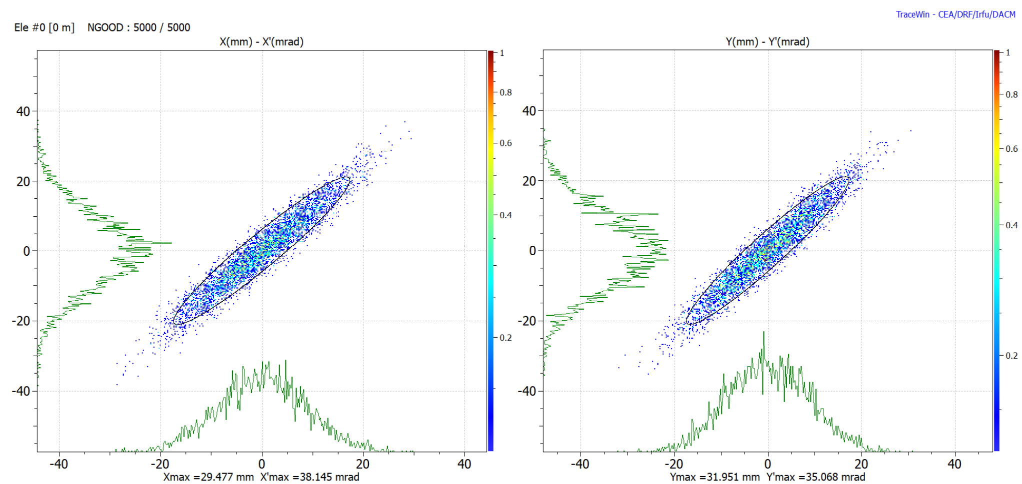


Shooting Through: $^{14}N^{3+}$@19.751kV

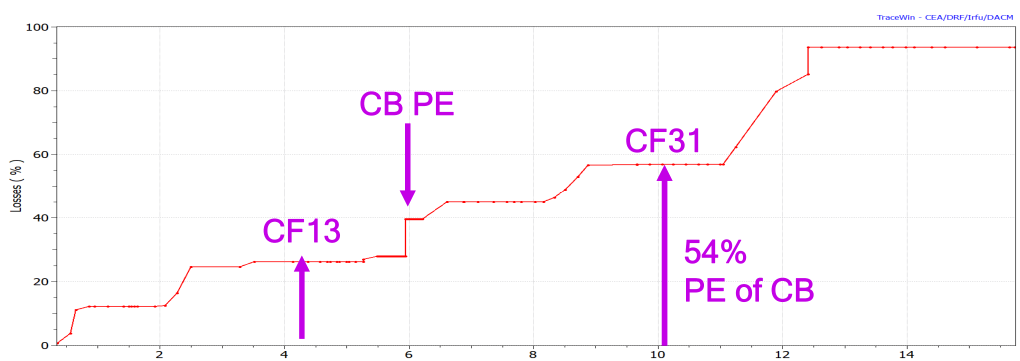
Input emittance = free parameter

Constraints =>

- ✓ Measured transmission of 54%
- ✓ Measured beam profiles PR11 and PR13



Emittance X - X'
106 π.mm.mrad
α = -3.31
β = 2.84 mm/π.mrad
γ = 4.21 mrad/π.mm
Emittance Y - Y'
106 π.mm.mrad
α = -3.31
β = 2.84 mm/π.mrad
γ = 4.21 mrad/π.mm



Shooting Through: $^{14}N^{3+}$@19.751kV

Input emittance = free parameter

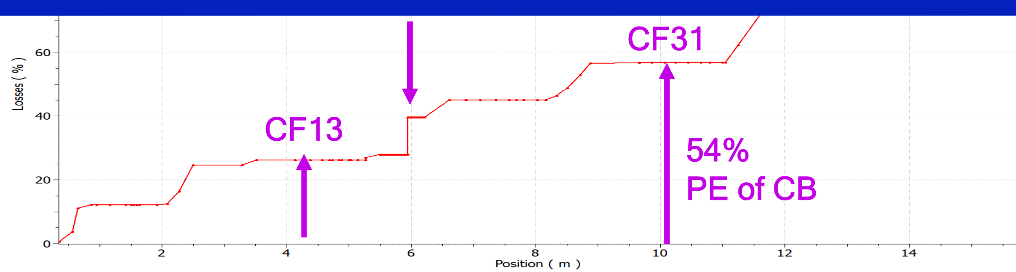
Constraints =>

- ✓ Measured transmission of 54%

Reproduce the beam profile PR11 and PR13 as well as the over-all transmission

BUT…

Booster magnetic field = coefficient applied 0.6



Shooting Through: $^{14}N^{3+}$@19.751kV

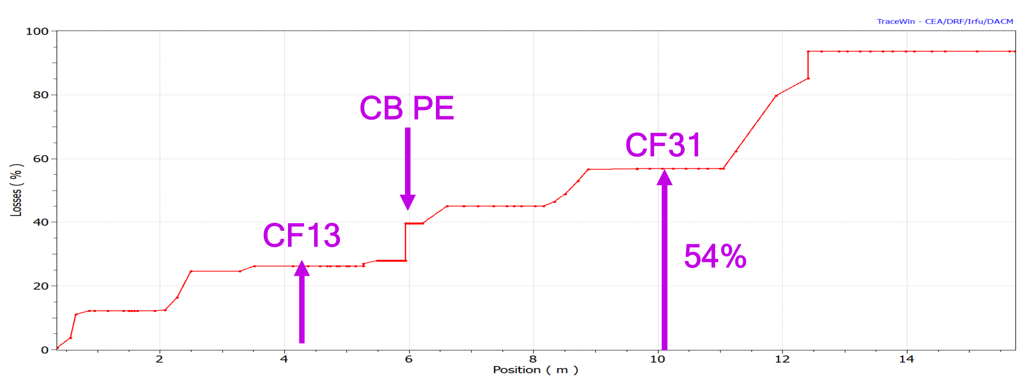
Input emittance = free parameter

Constraints =>

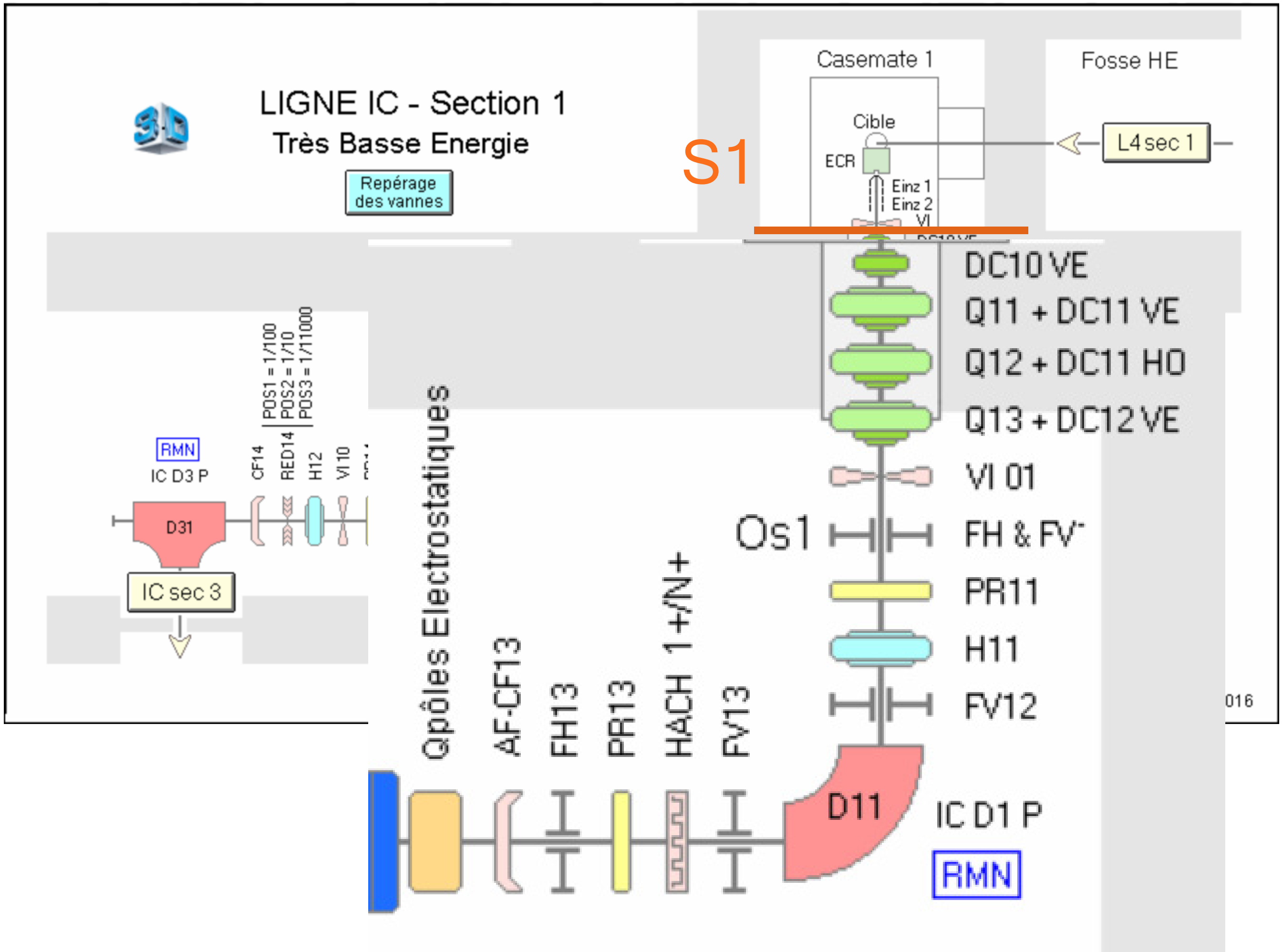
- ✓ Measured transmission of 54%
- ✓ Measured beam profiles PR11 and PR13

A new constraint is requested =>

Beam emittance measurement!

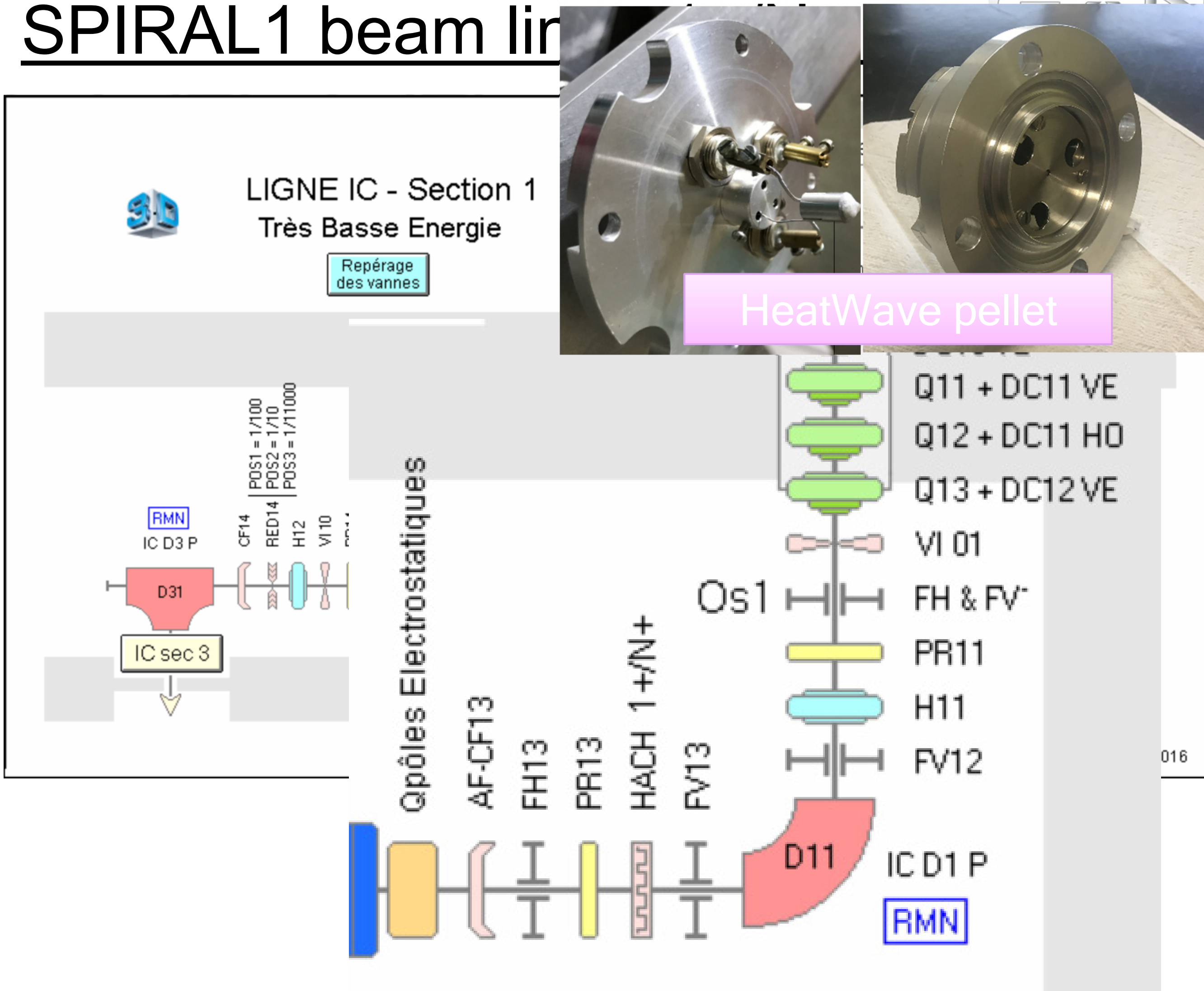


SPIRAL1 beam line : 1+/N+ mode

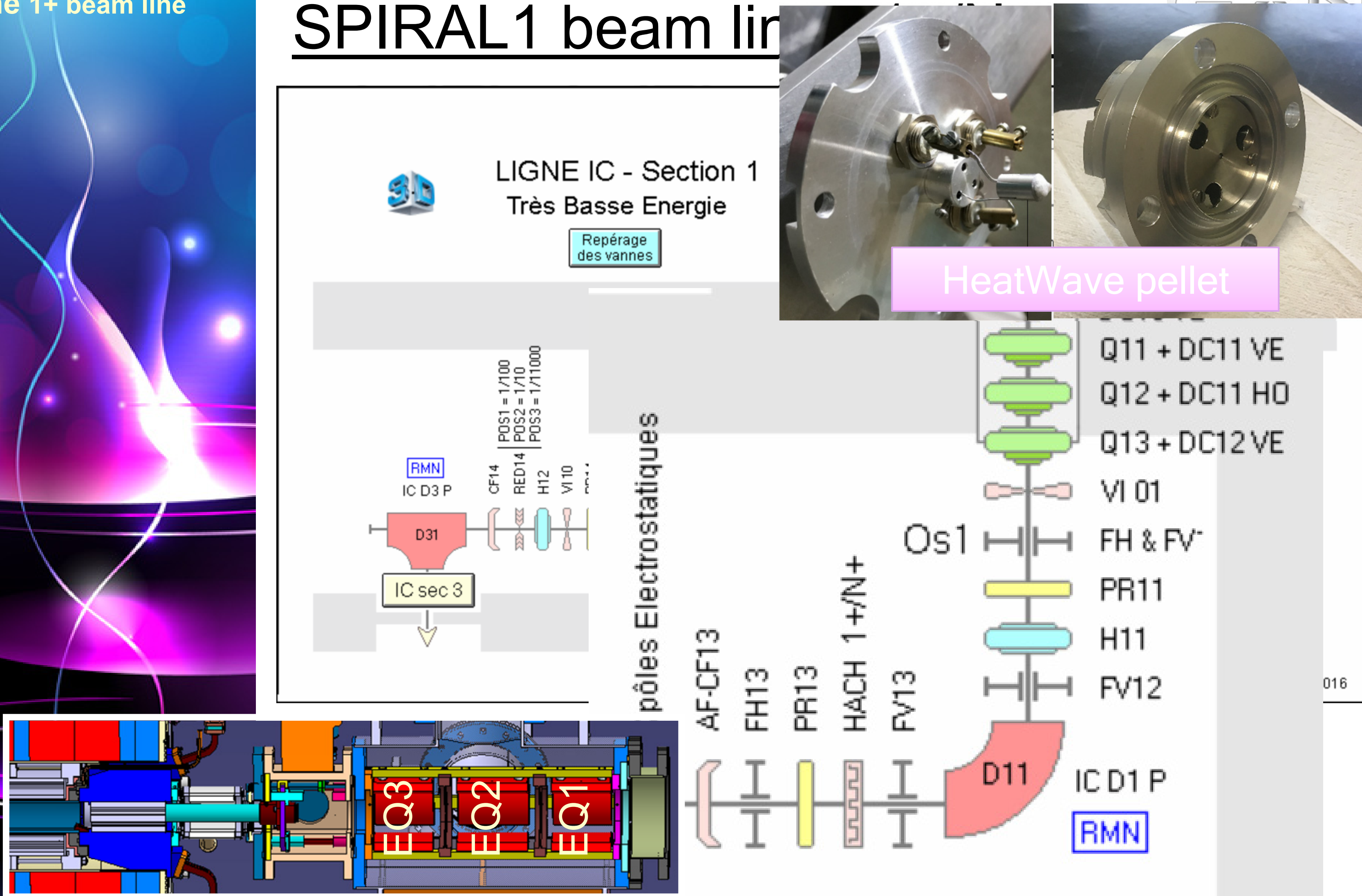


The 1+ beam line

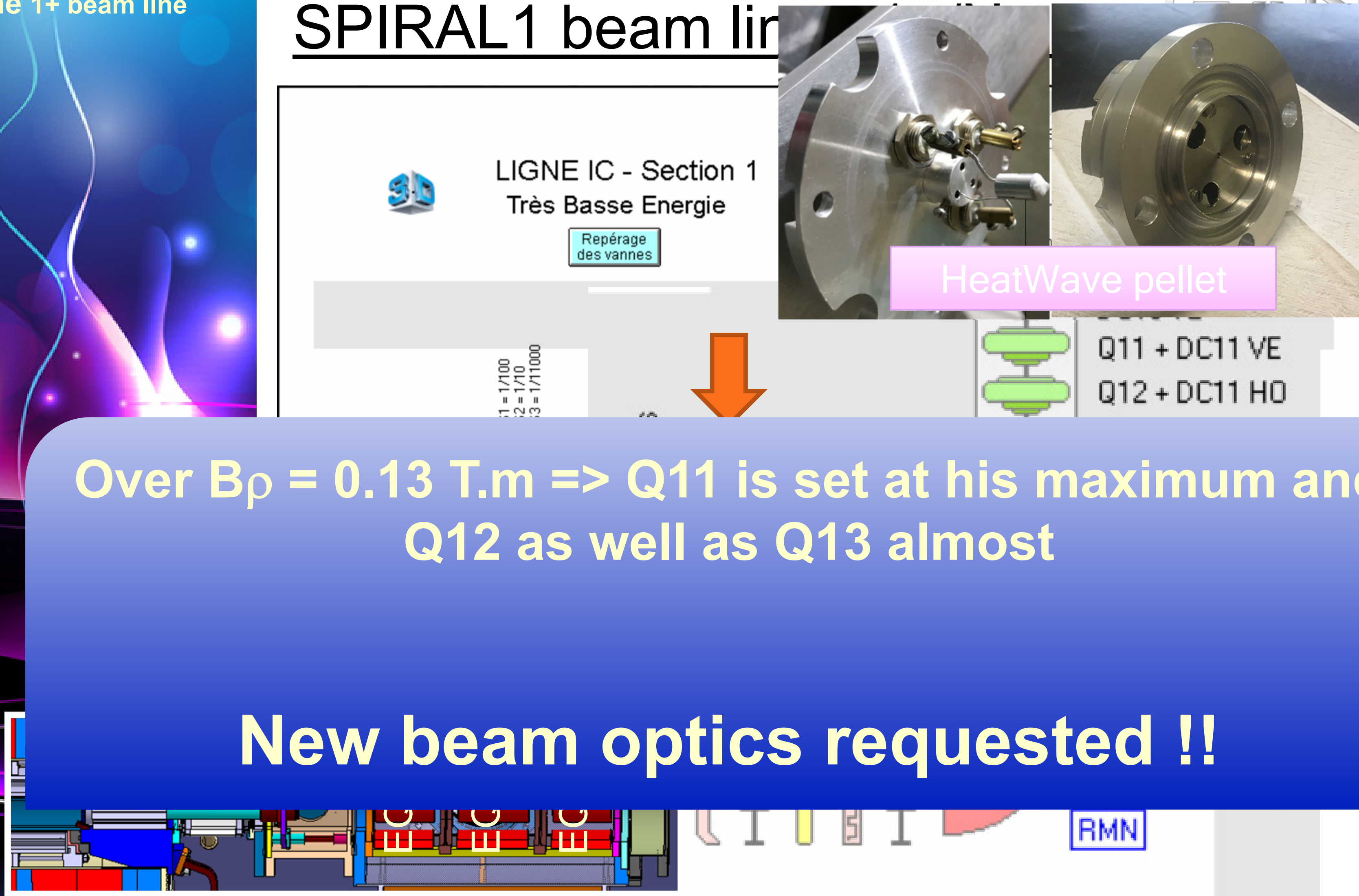
SPIRAL1 beam lin



SPIRAL1 beam lin



SPIRAL1 beam lin

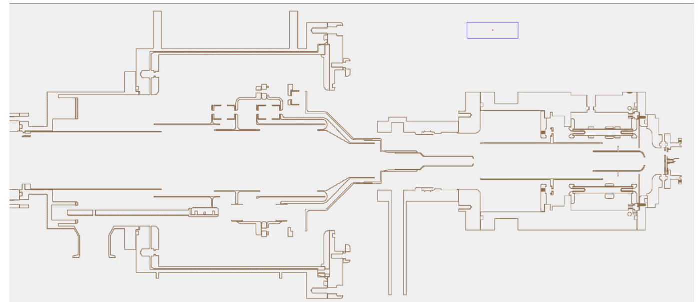


Over Bρ = 0.13 T.m => Q11 is set at his maximum and Q12 as well as Q13 almost

New beam optics requested !!

The method

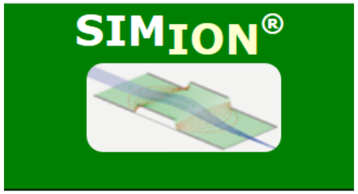
SIMION®

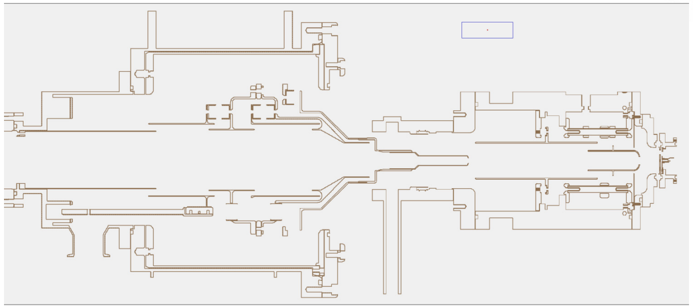


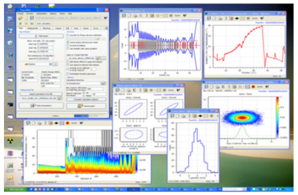
Input: geometry, voltages, ion distribution

Output: Twiss parameters (α, β, γ, ε)

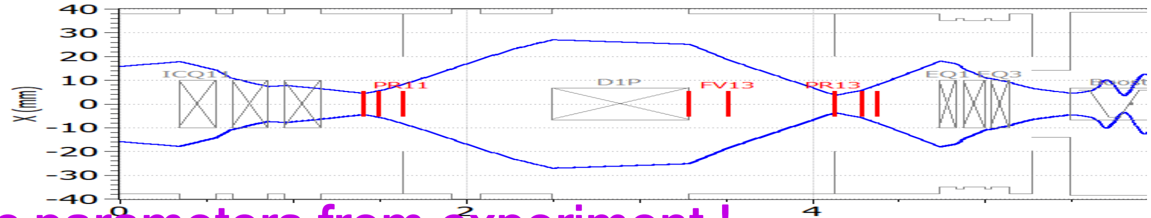
The method





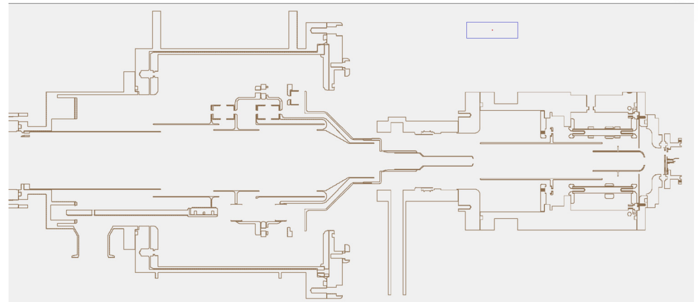


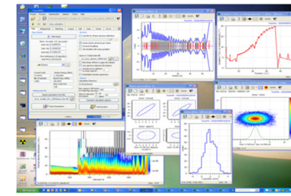
Input: geometry, voltages, ion distribution
Output: Twiss parameters (α, β, γ, ε)



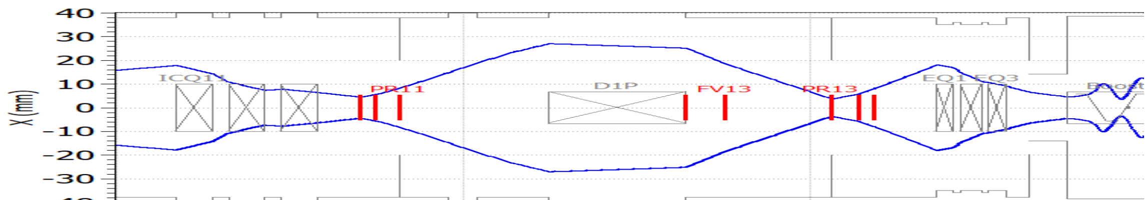
Using optic parameters from experiment !

The method





Input: geometry, voltages, ion distribution
Output: Twiss parameters (α, β, γ, ε)



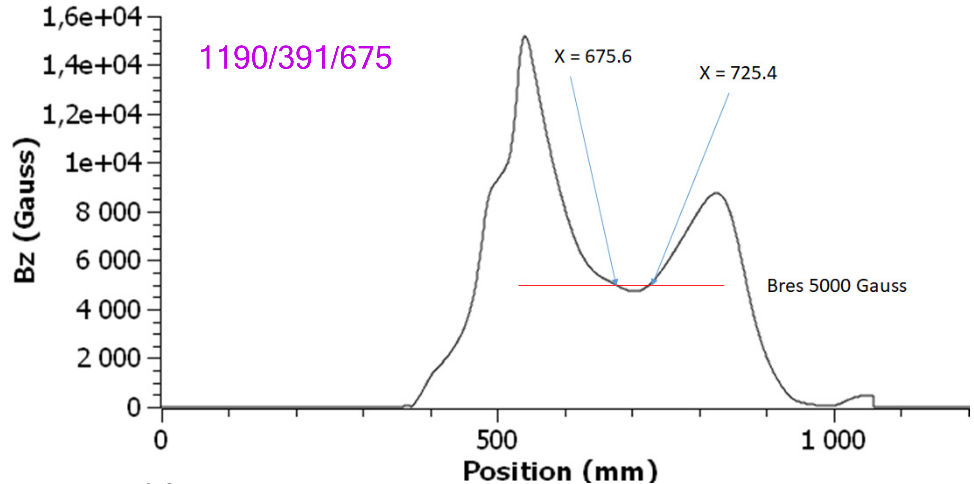
Using optic parameters from experiment !

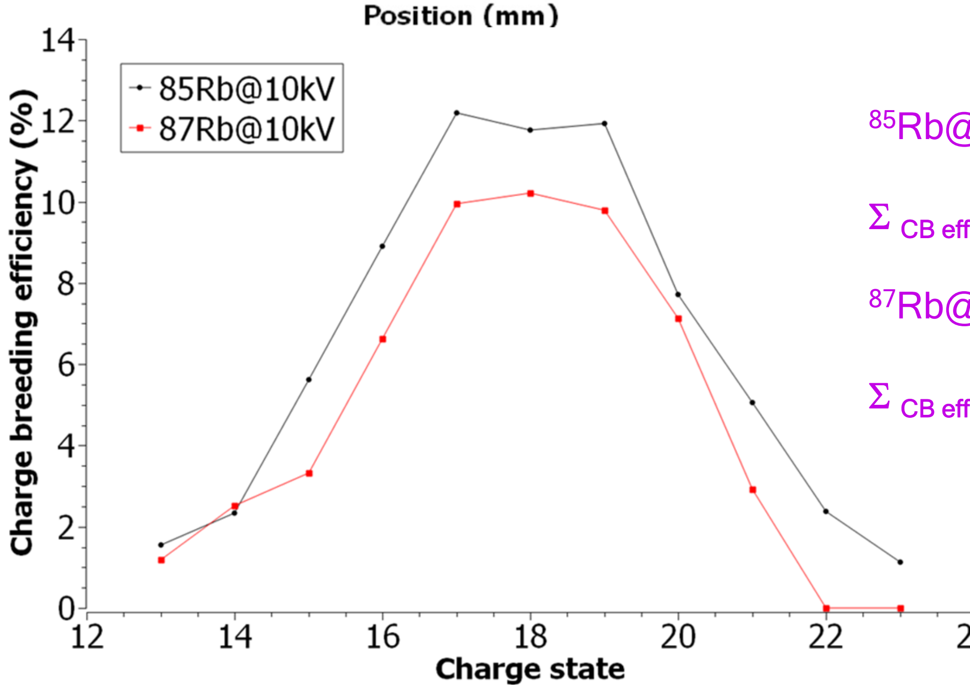
Input: Twiss parameters
Output: Twiss parameters (α, β, γ, ε)

No plasma model implemented

1+/N+: $^{85}Rb^{+}$@10kV / $B\rho$ = 0.133 T.m

Beam optics used until now….





^{85}Rb@10kV

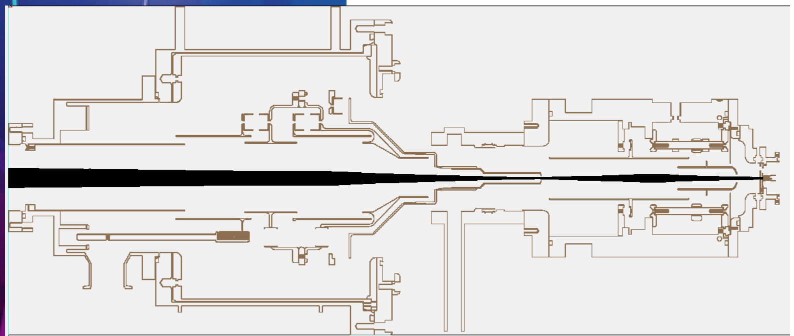
Σ $_{\text{CB efficiency}}$ = 70.6%

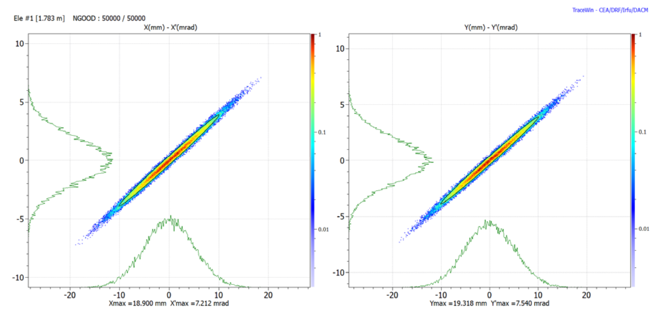
^{87}Rb@10kV

Σ $_{\text{CB efficiency}}$ = 53.7%

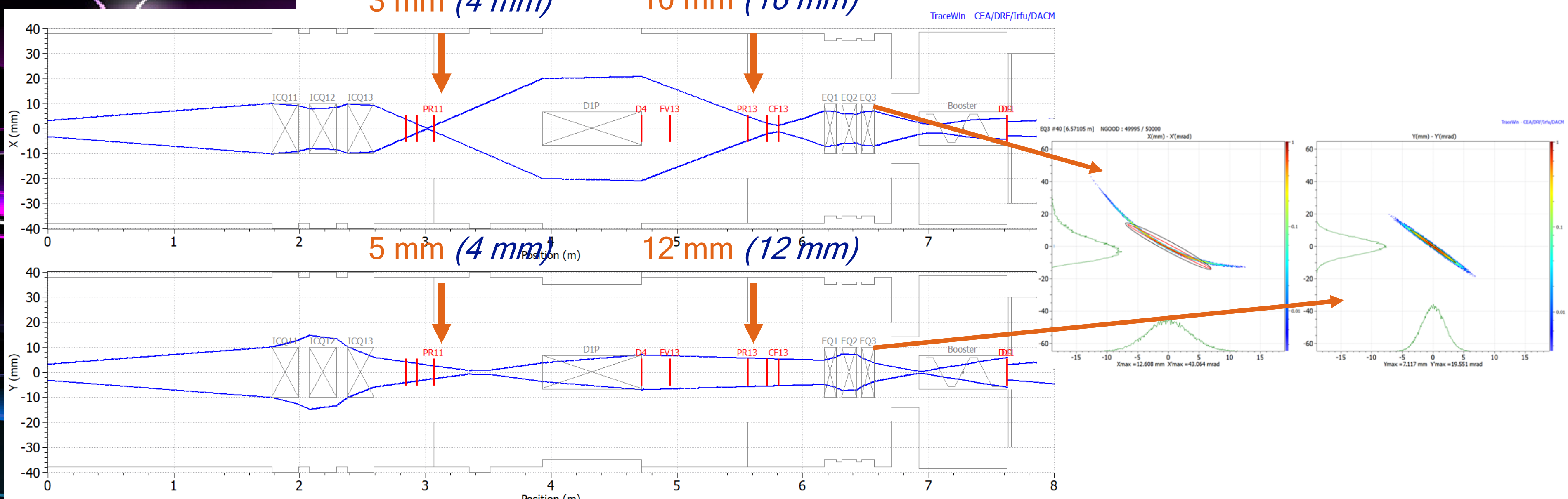
1+/N+: $^{85}Rb^{+}$@10kV / $B\rho$ = 0.133 T.m

laboratoire commun CEA/DRF CNRS/IN2P3

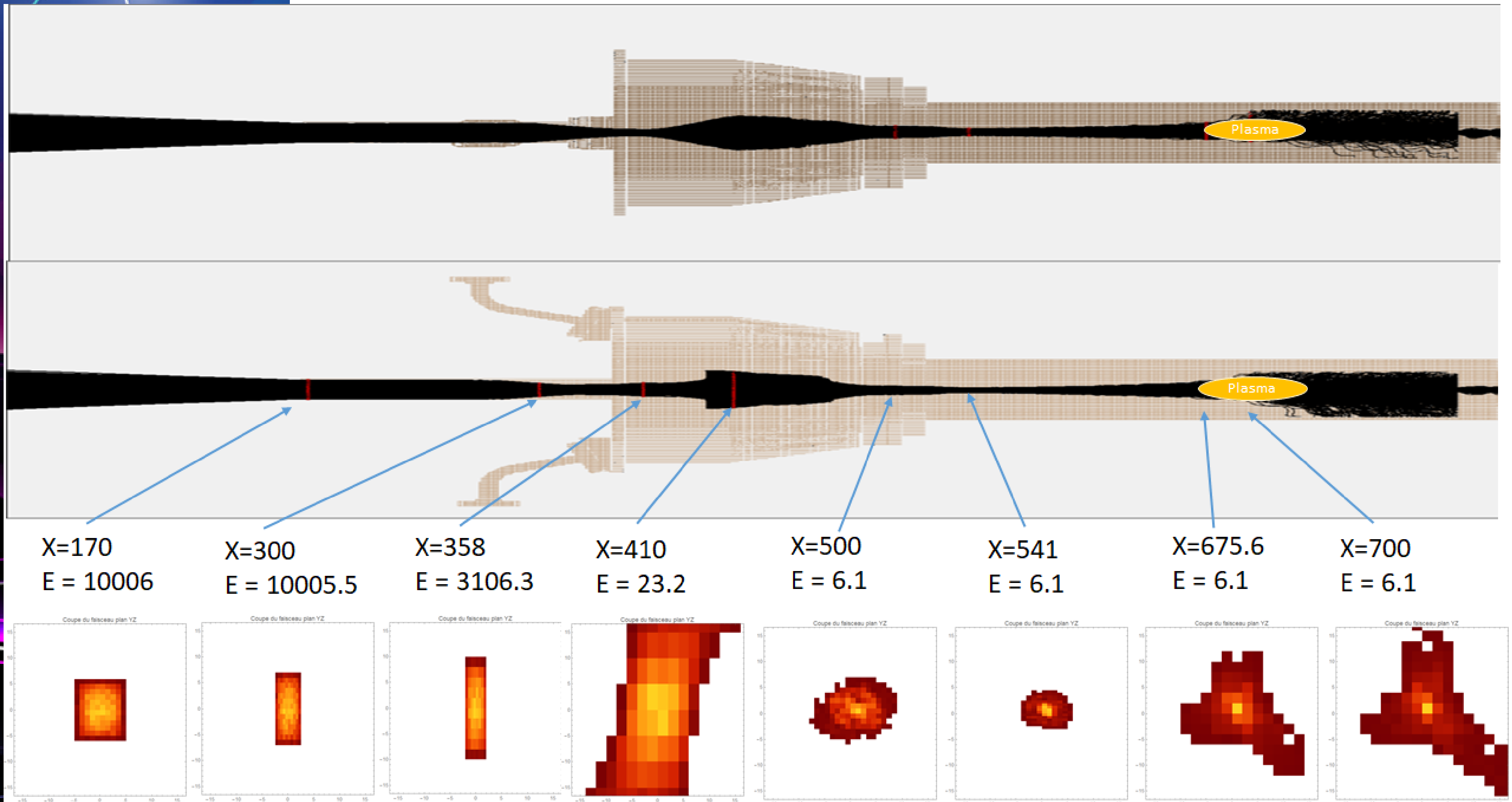




Emittance X - X'
4 π.mm.mrad
α = -9.9
β = 25.5 mm/π.mrad
γ = 3.9 mrad/π.mm
Emittance Y - Y'
4 π.mm.mrad
α = -9.9
β = 25.5 mm/π.mrad
γ = 3.9 mrad/π.mm

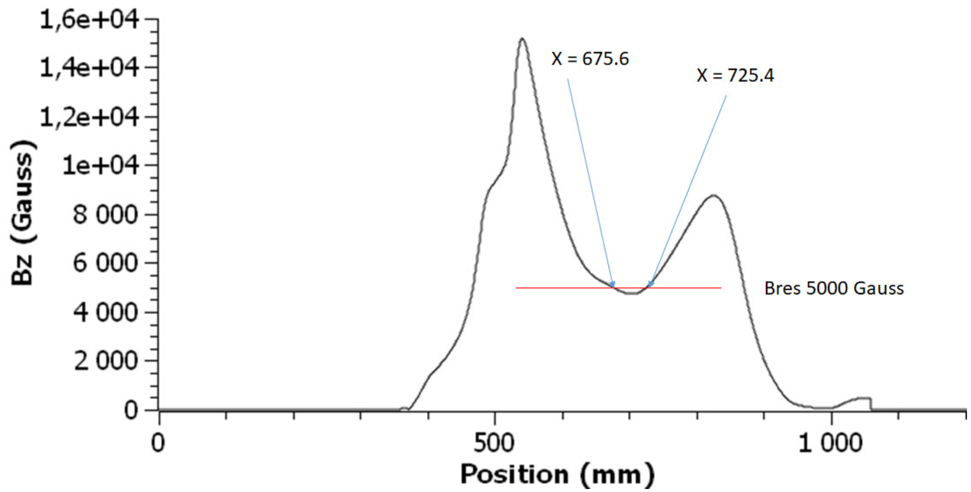


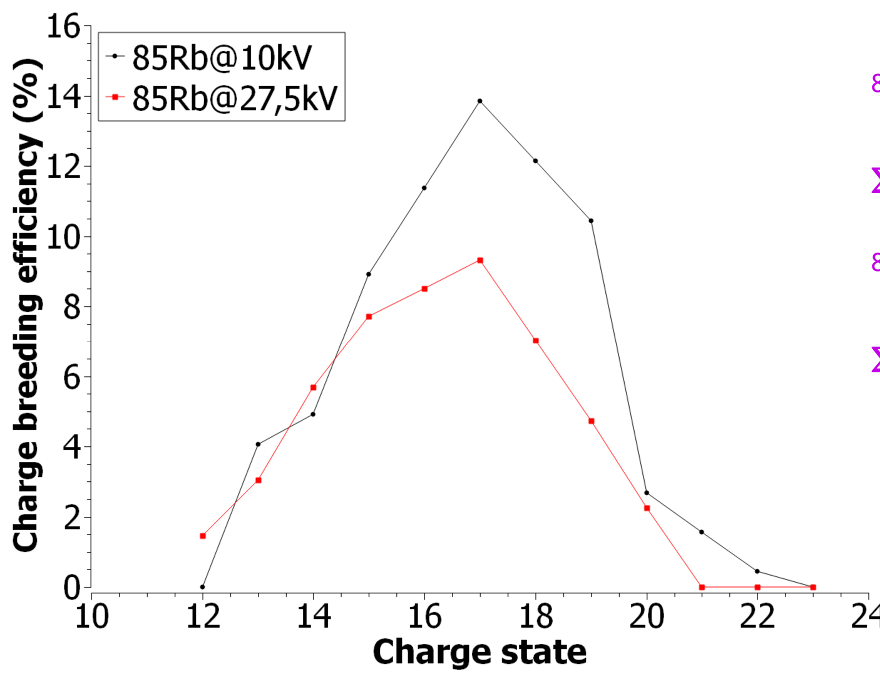
1+/N+: $^{85}Rb^{+}$@10kV / Bρ = 0.133 T.m



1+/N+: $^{85}Rb^{+}$@27.5kV / Bρ = 0.221 T.m (Bρ max)

New beam optics to overcome quadrupole restrictions





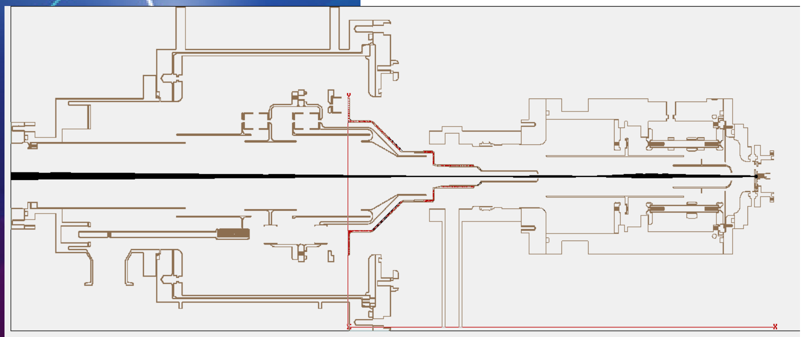
^{85}Rb@10kV

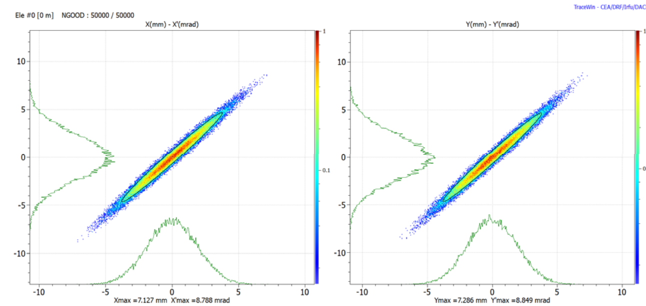
Σ CB efficiency = 72.3%

^{85}Rb@27.5kV

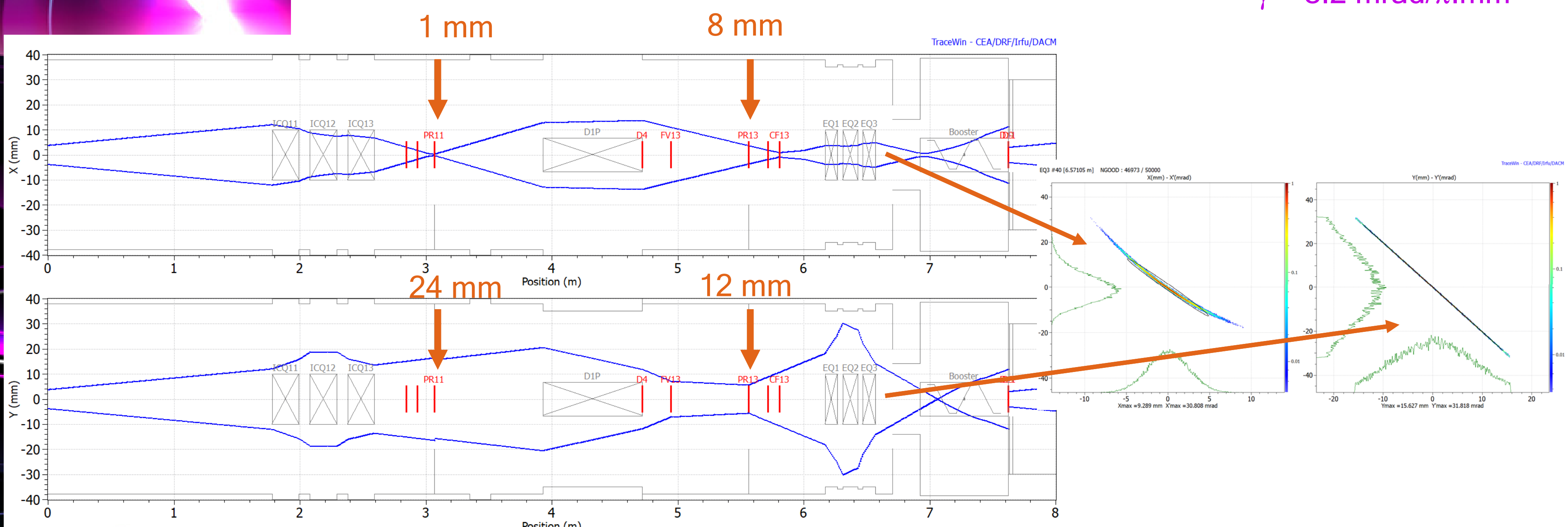
Σ CB efficiency = 48.3%

1+/N+: $^{85}Rb^{+}$@27.5kV / Bρ = 0.220 T.m

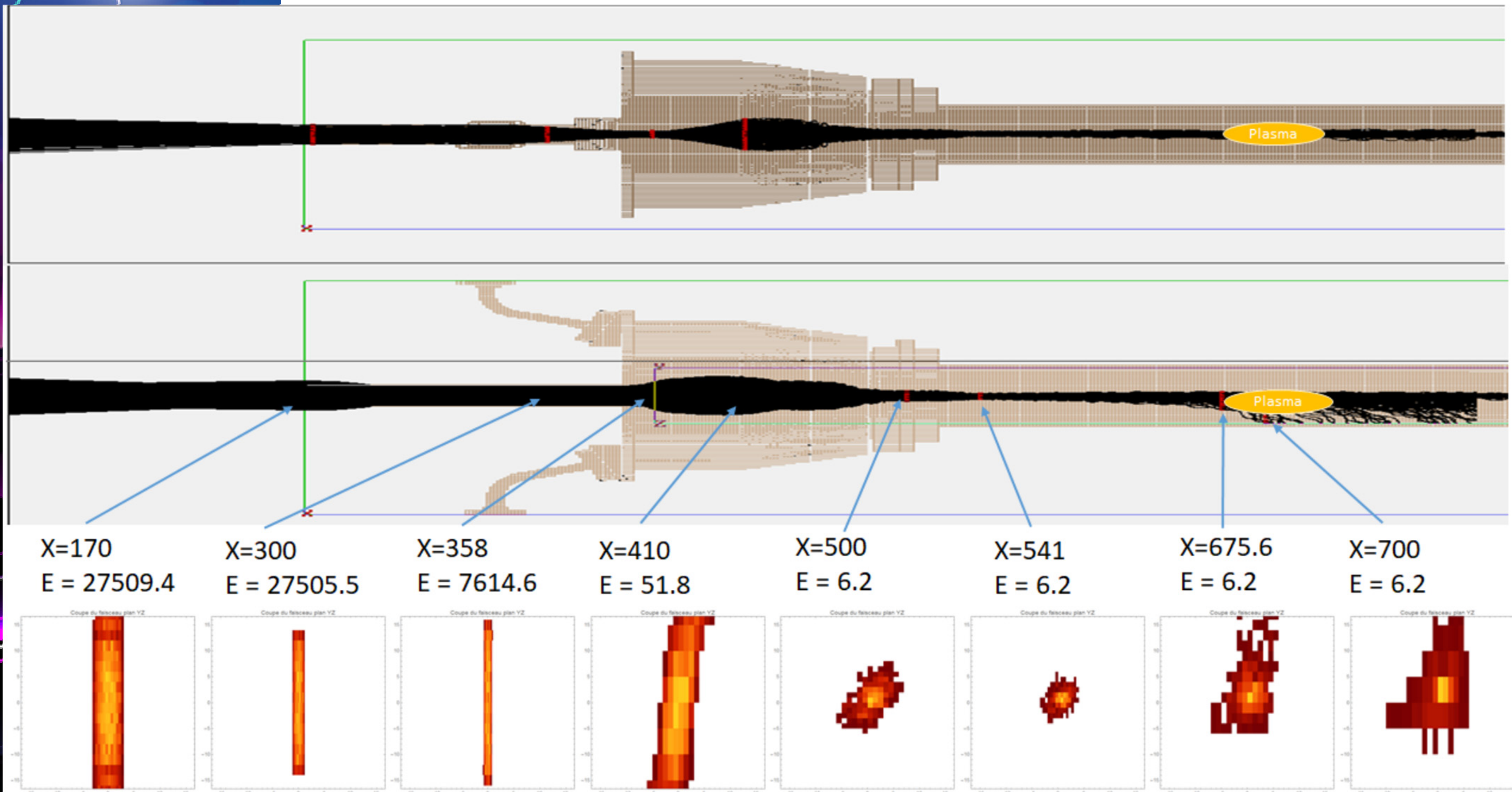




Emittance X - X'
2.6 π.mm.mrad
α = -6.5
β = 5.3 mm/π.mrad
γ = 8.2 mrad/π.mm
Emittance Y - Y'
2.6 π.mm.mrad
α = -6.5
β = 5.3 mm/π.mrad
γ = 8.2 mrad/π.mm



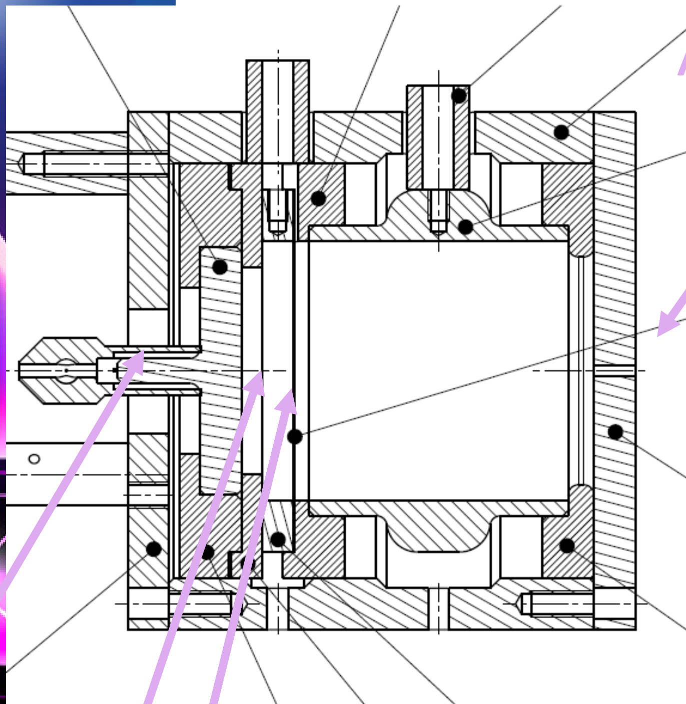
1+/N+: $^{85}Rb^{+}$@27.5kV / Bρ = 0.221 T.m



ΔE measurement

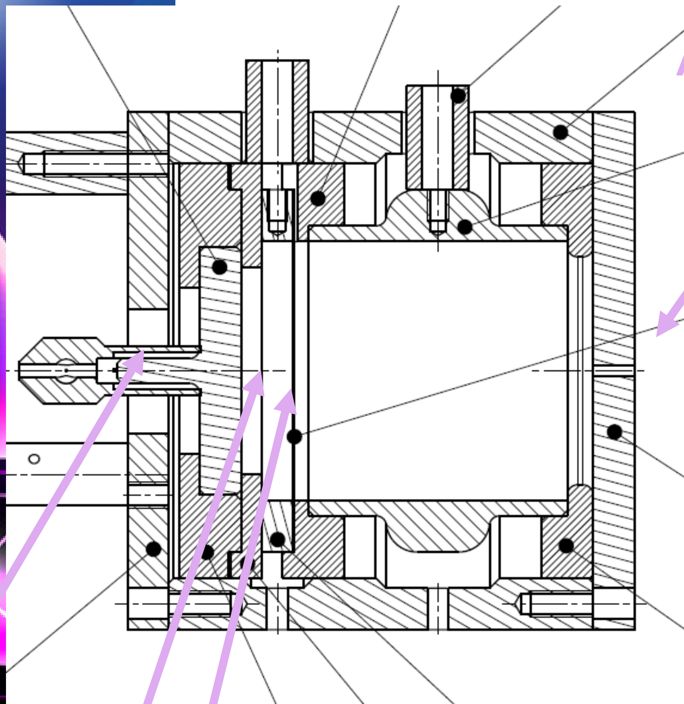
Energy dispersion measurement

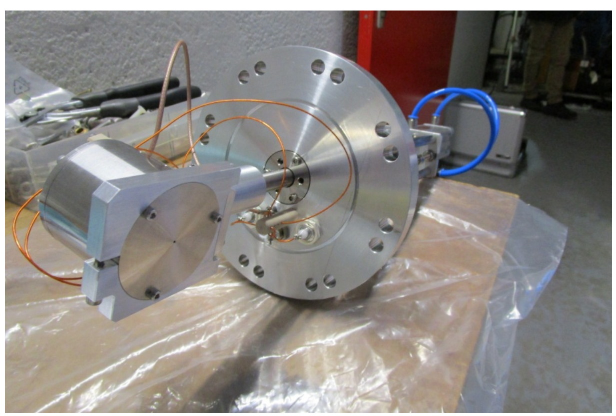
Measure done using a Retarding Field Analyzer



Energy dispersion measurement

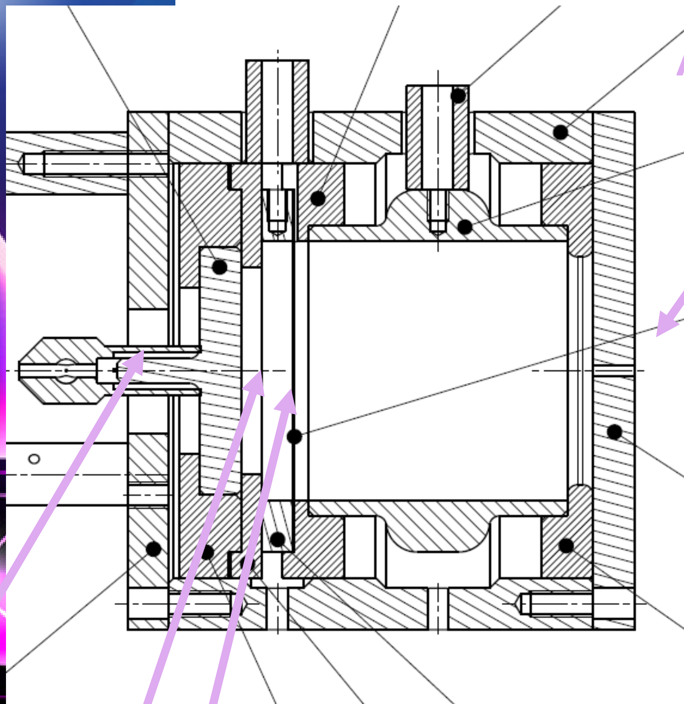
Measure done using a Retarding Field Analyzer

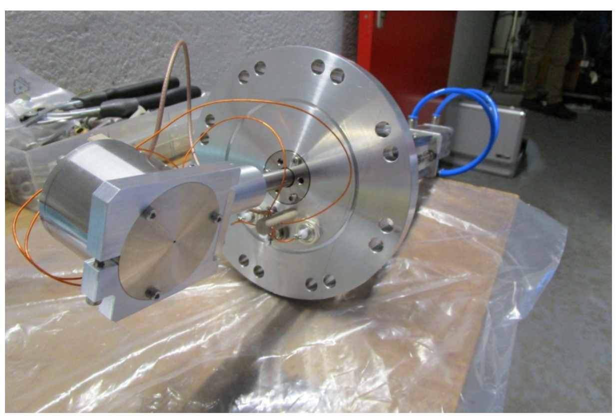


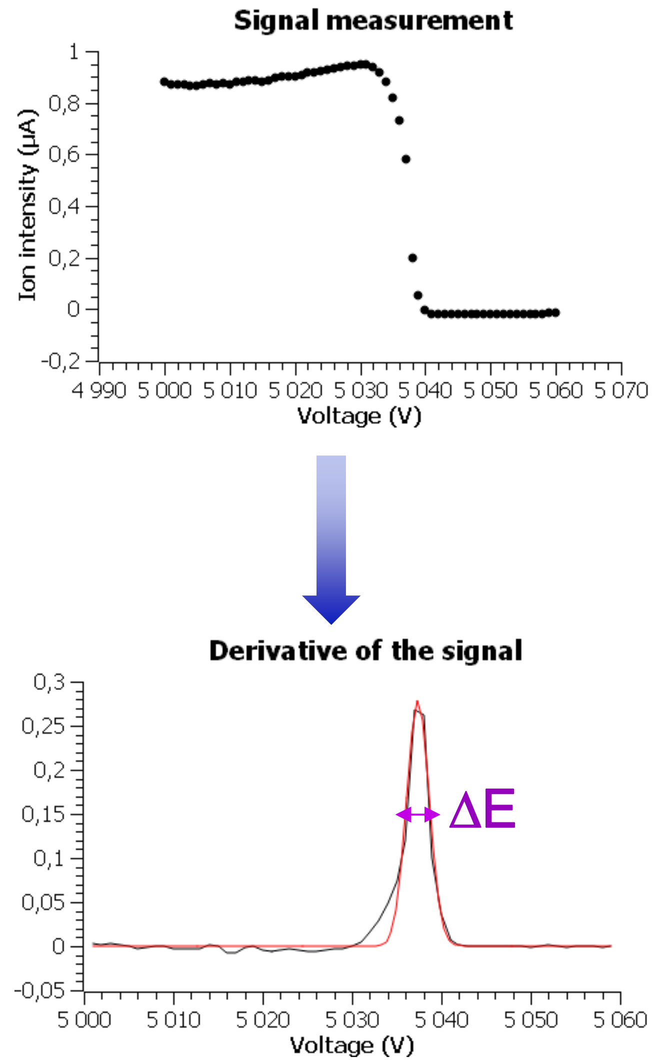


Energy dispersion measurement

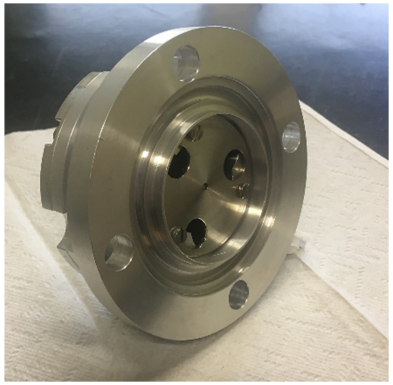
Measure done using a Retarding Field Analyzer



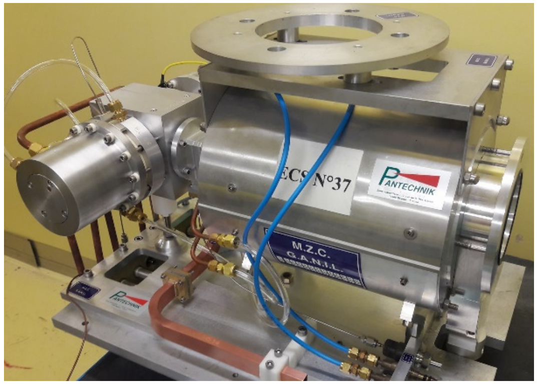




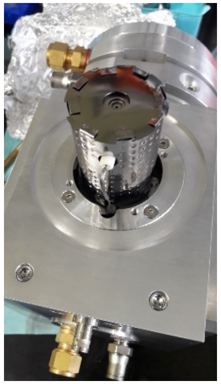
Measure done with two TISS's and Ion gun



Ion Gun

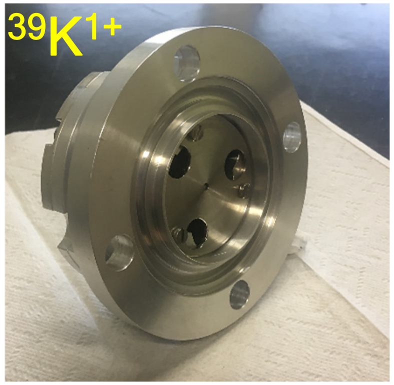


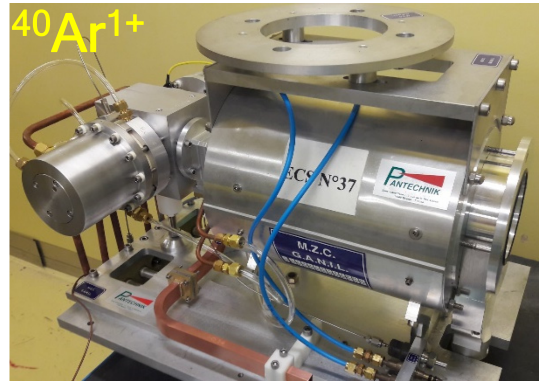
TISS NanoganIII

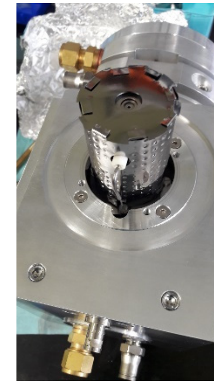


TISS FEBIAD

Measure done with two TISS's and Ion gun





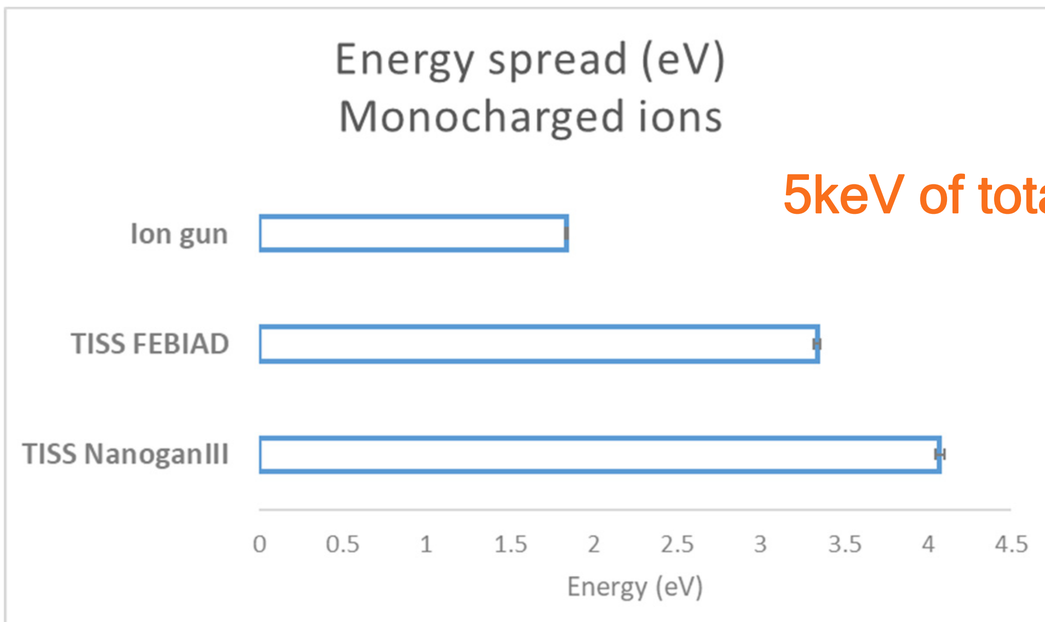


$^{23}Na^{1+}$

Ion Gun

TISS NanoganIII

TISS FEBIAD



5keV of total energy

Measure done with two TISS's and Ion gun

Open question:

The energy window acceptance for a CB is ~ 4-8 eV

- ✓ Ion gun = tiny emittance, low ΔE
  => **high CB efficiency (up to 15% for $^{85}Rb^{19+}$)**
- ✓ TISS FEBIAD = tiny emittance, medium ΔE
  => **not so good CB efficiency for $^{38}K^{8+}$ (~2-3%)**
- ✓ TISS NanoganIII => large emittance, highest ΔE
  => **bad CB efficiency for S^+ and F^+ (~1%)**

More investigation is needed to evaluate the effect of ΔE on the CB efficiency

Summary and perspectives

Actual results

ST Mode =>

- ✓ Emittance measurements with a pepperpot type emittance meter
- ✓ Optimization of beam optics between EQ's and CB coils

1+/N+ mode =>

- ✓ Same behavior inside the charge breeder whatever the beam optics
- ✓ One set of beam optics: to be tested with Na and K for several Bρ's
- ✓ Preparation of the next run in 2021

ΔE versus Emittance => more data are needed to decorrelate the both parameters

Mid-term R&D

- ✓ Double frequency heating => control of the CSD, stability, CSD shift for heavy elements
- ✓ Contamination reduction => collaboration LPSC - INFN - GANIL (J. Angot talk)
- ✓ Development of a new radioactive diagnostic => on-line control and survey of the RIB


THANK YOU