Status of MLLTRAP

1. Status of MLLTRAP
2. Calculations for RFQCB
3. Emittance measurements

Sophie Morard
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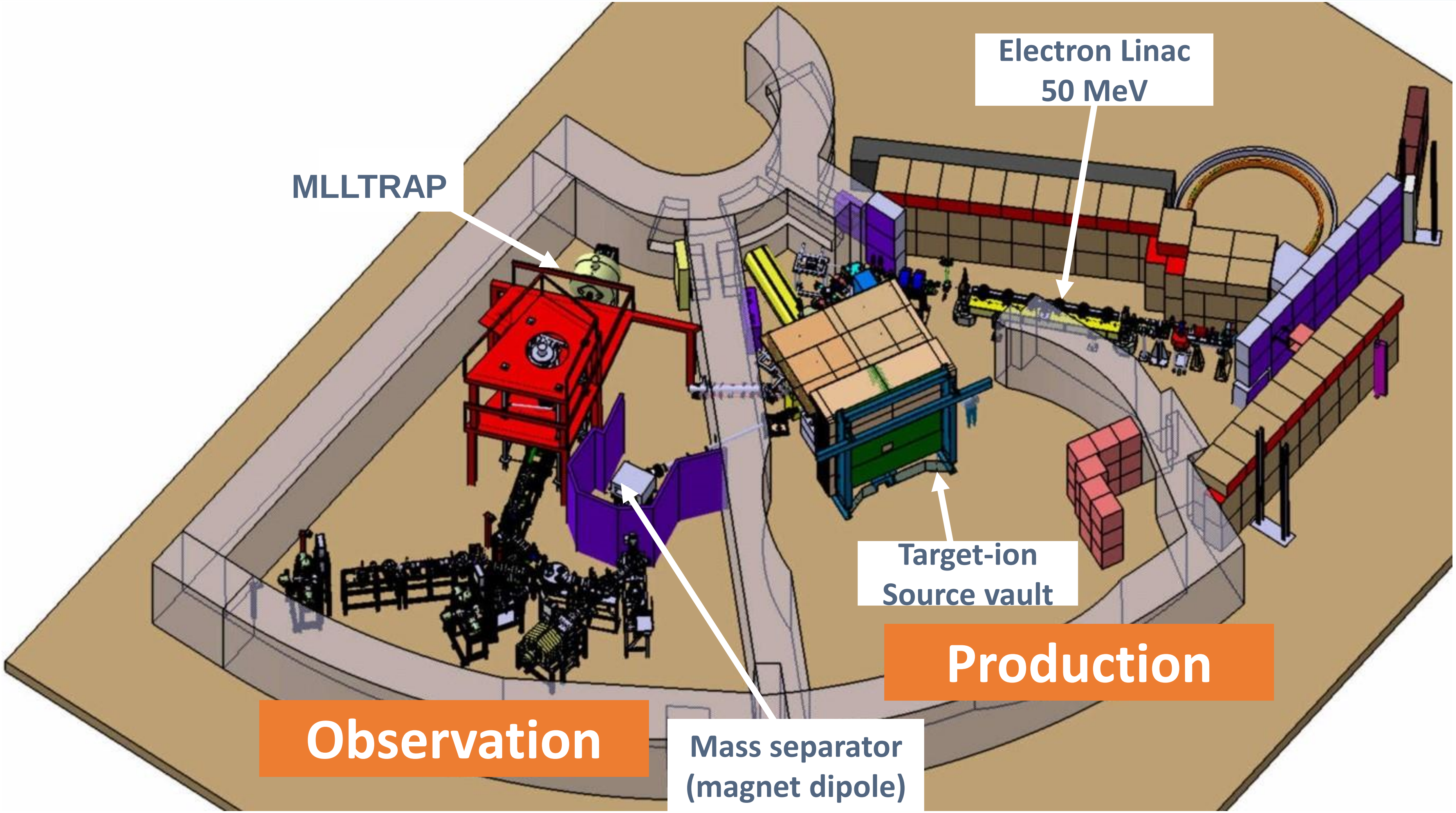
Supervisors :
Luc Perrot & Enrique Minaya Ramirez


Electron Linac
50 MeV
MLLTRAP
Target-ion
Source vault
Production
Observation
Mass separator
(magnet dipole)

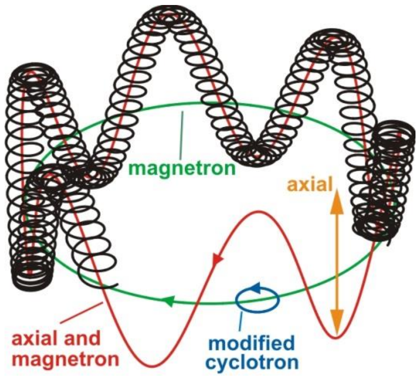
Double Penning trap spectrometer

- Penning trap : superposition of high magnetic field and low electrostatic field to confine in 3D
- Preparation trap : Isobaric separation with buffer gas cooling
- Measurement trap : Cyclotron frequency measurements

7T superconducting magnet

$$\nu_c = \frac{qB}{2\pi m}$$

Ion motion

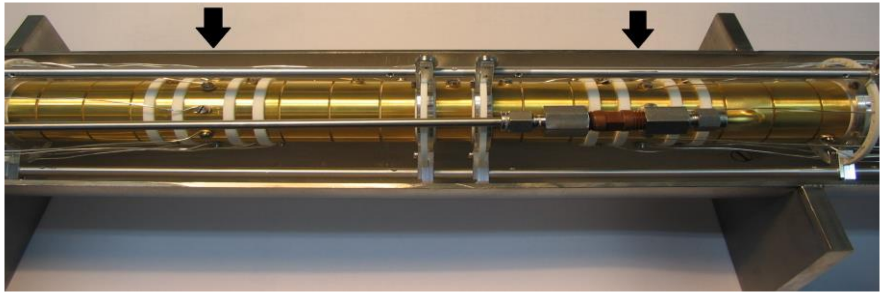


ν_+ : reduced cyclotron

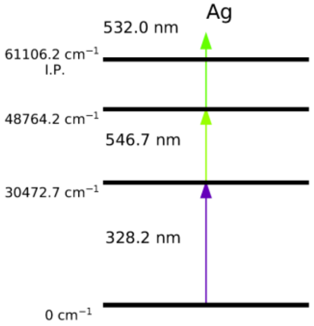
ν_- : Magnetron

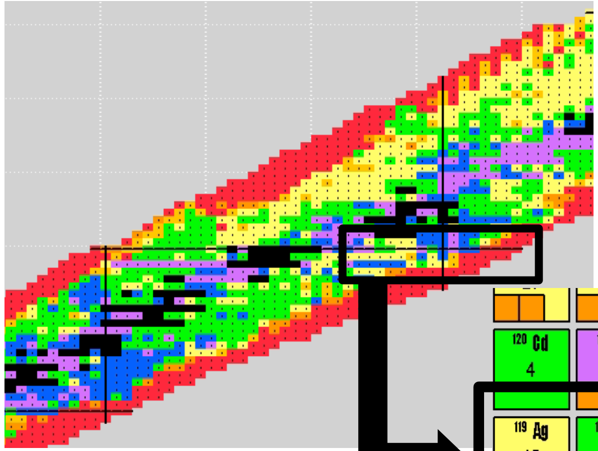
ν_Z : Axial

Measurement trap   Preparation trap



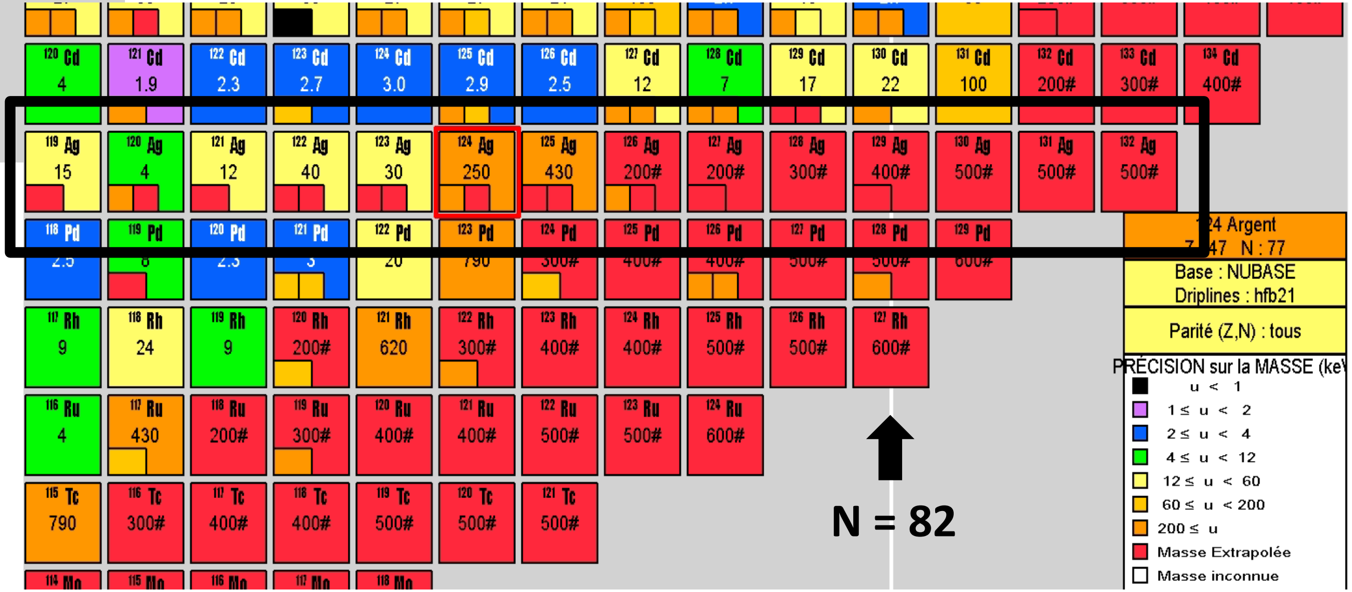
MLLTRAP – Physical case at ALTO-LEB

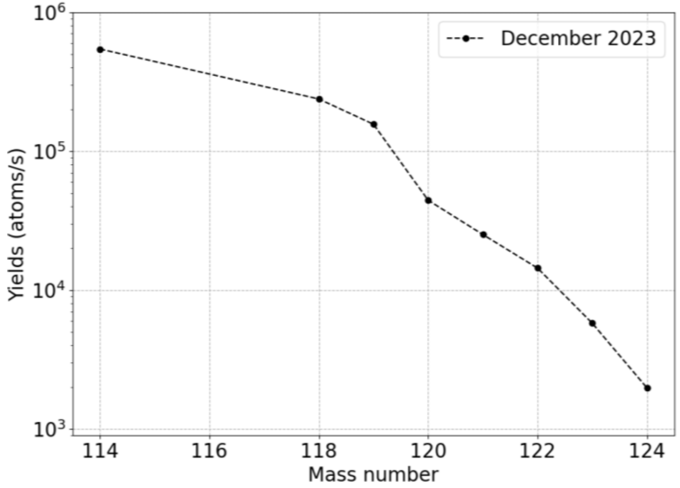




Study of Silver isotopes :

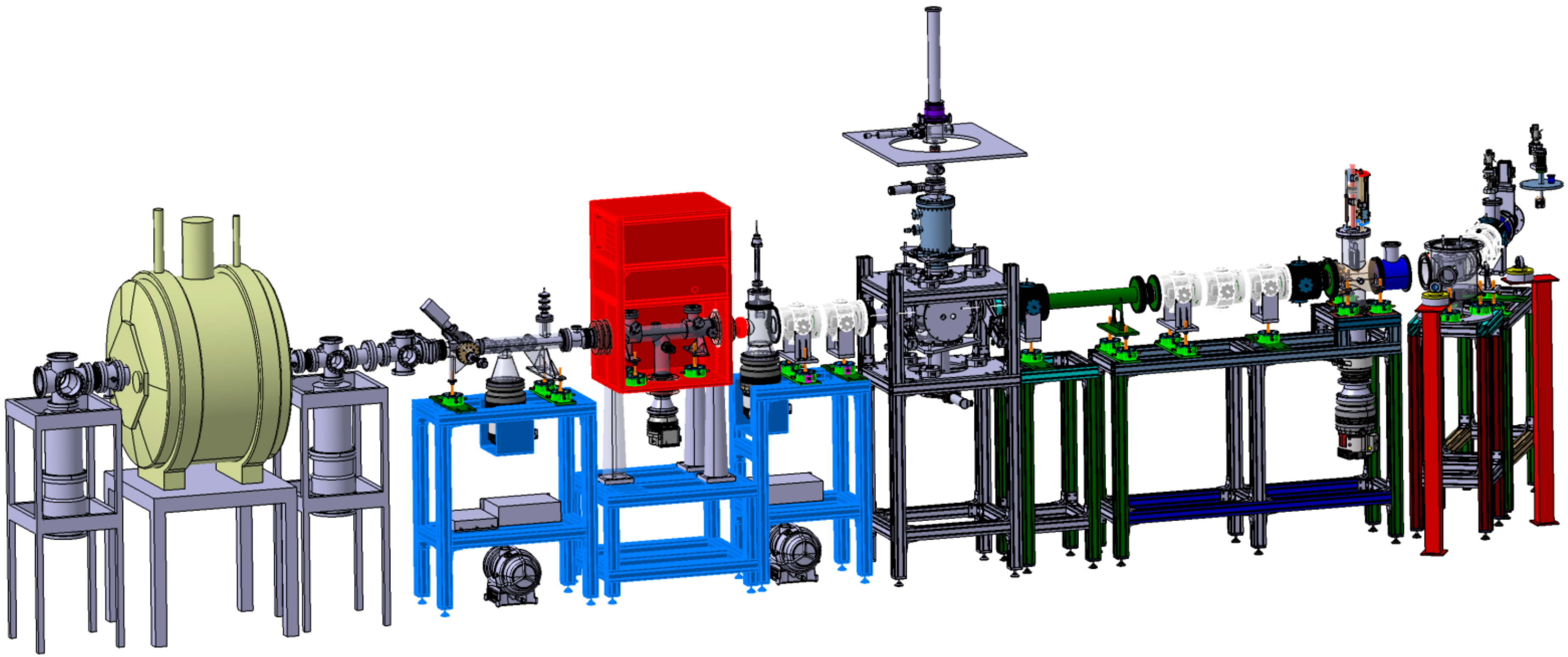
- N = 82 shell closure
- Access to binding energy
- Better understanding of nuclear structure





Production of Silver atoms at ALTO-LEB

MLLTRAP – Transfer Line



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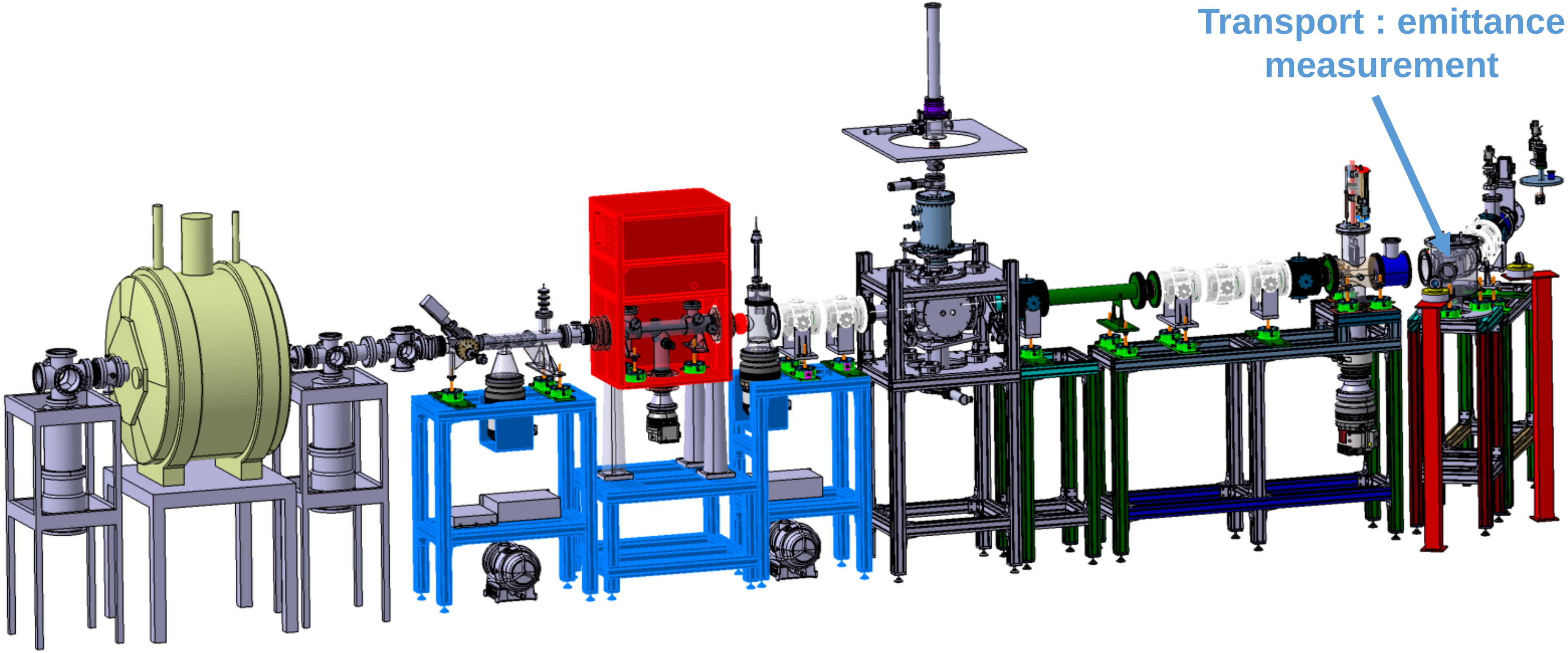

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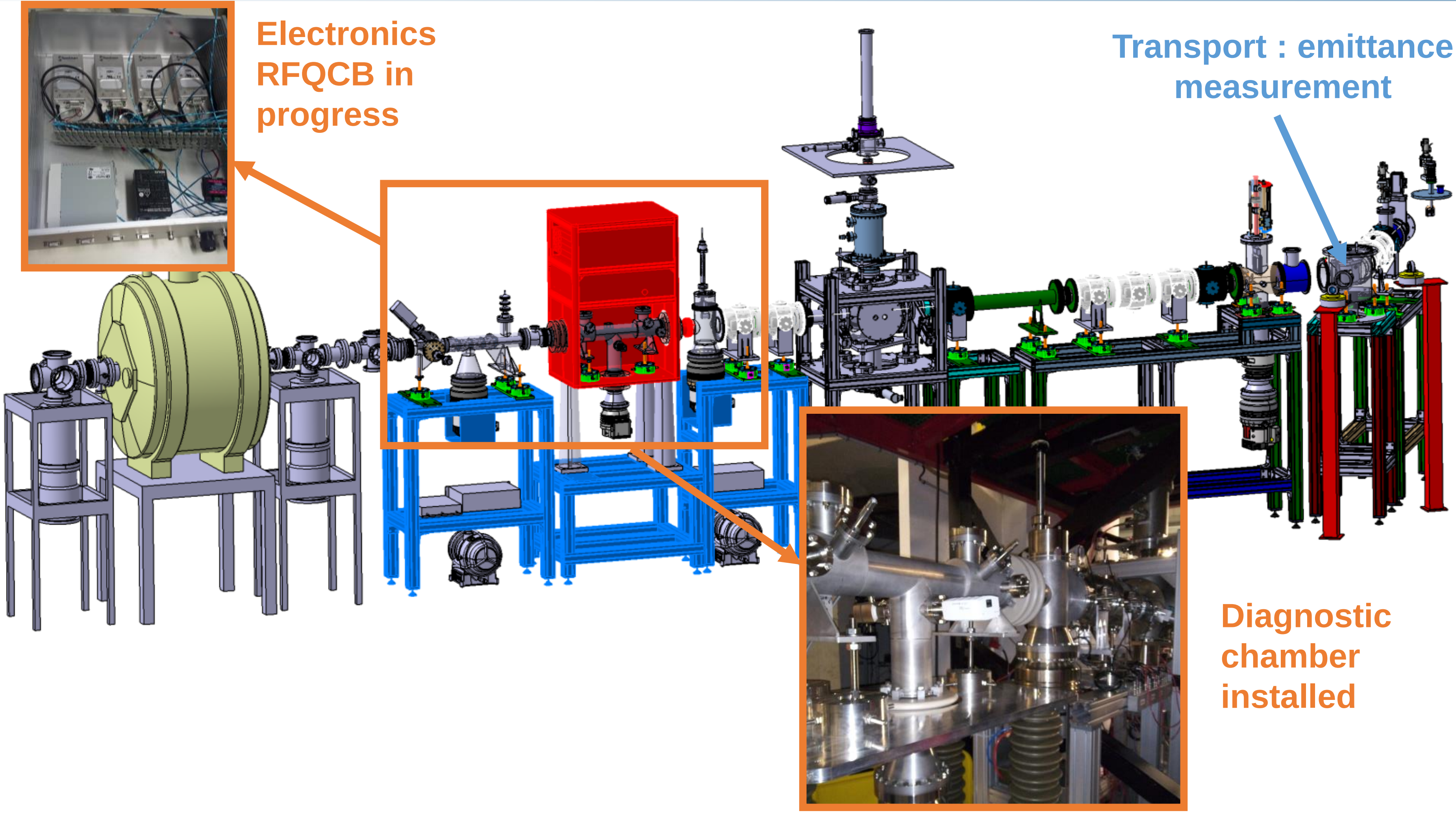
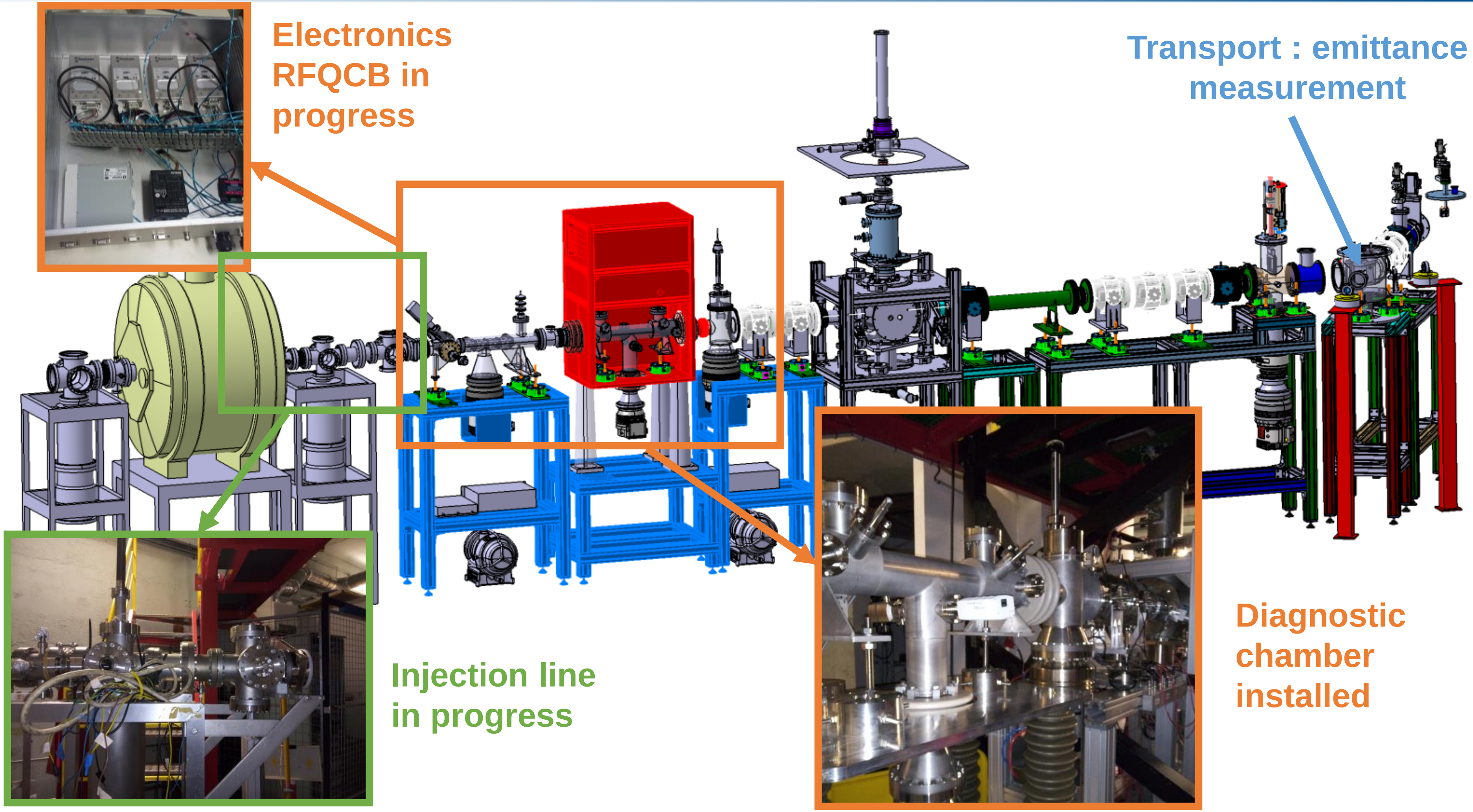


Electronics RFQCB in progress

Transport : emittance measurement

Diagnostic chamber installed

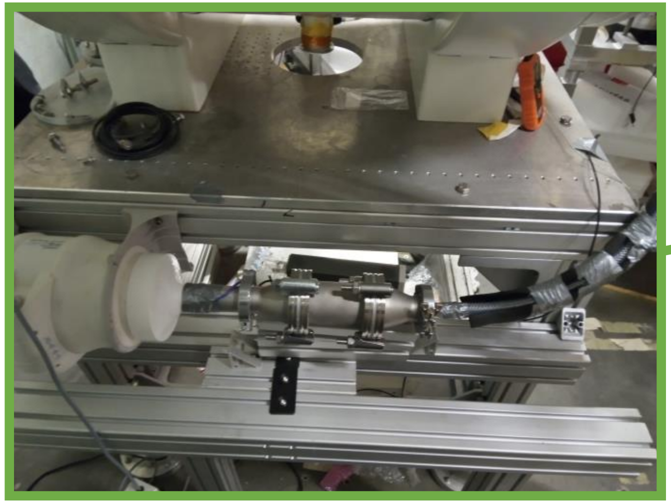
MLLTRAP – Transfer Line



MLLTRAP – Magnet

Temperature stabilisation

- First design failed
- Second one in progress



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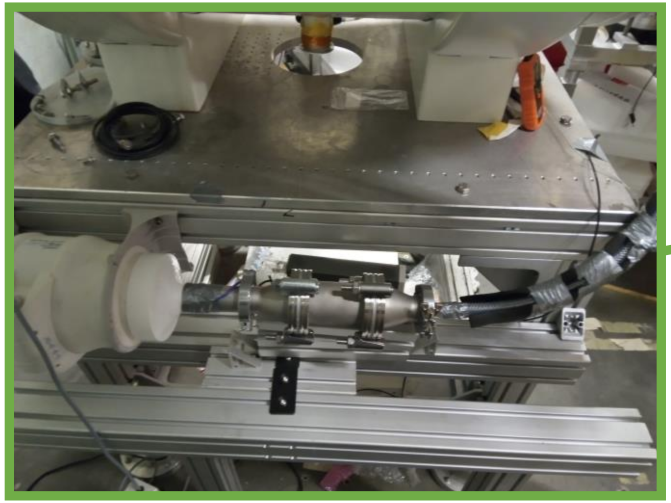
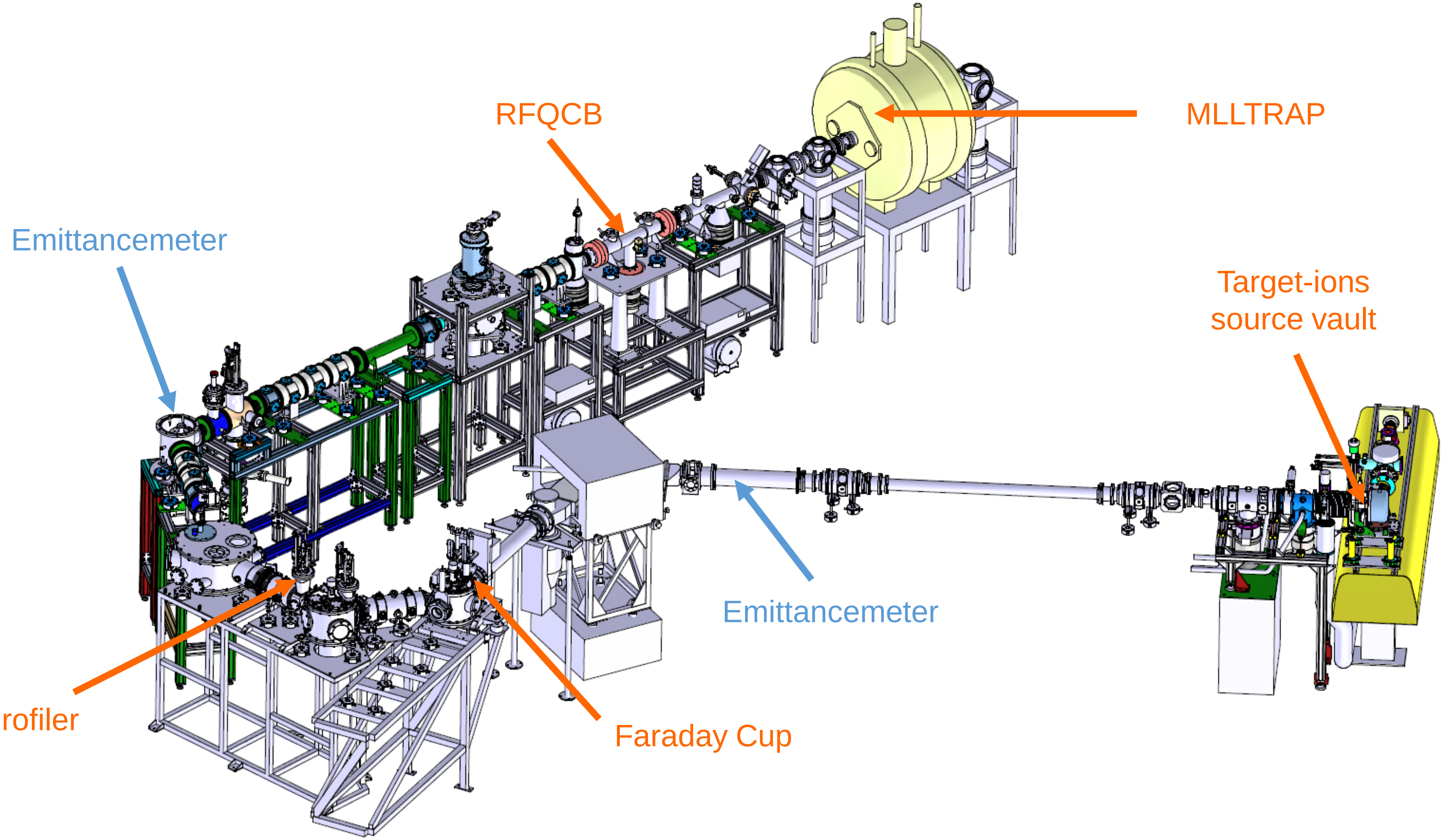


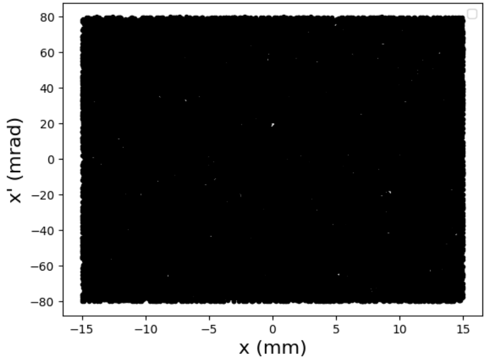
Helium recovery line

- Installed and tested in May with POLAREX
- Soon connected to MLLTRAP

Emittance measurements



- **Finding the acceptance**



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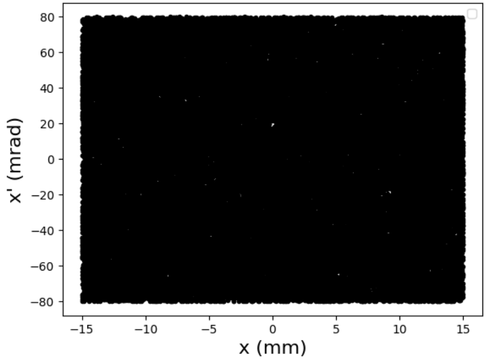

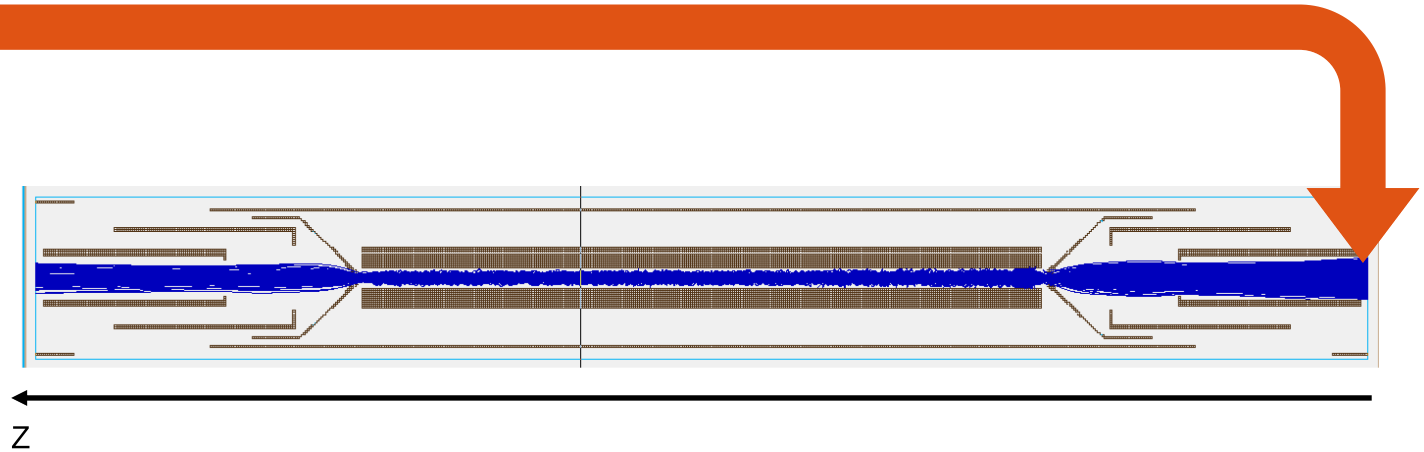

MLLTRAP – Calculations for RFQCB

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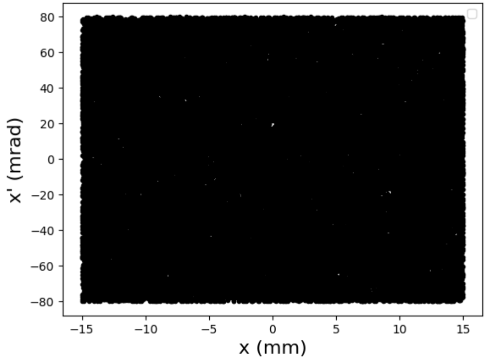
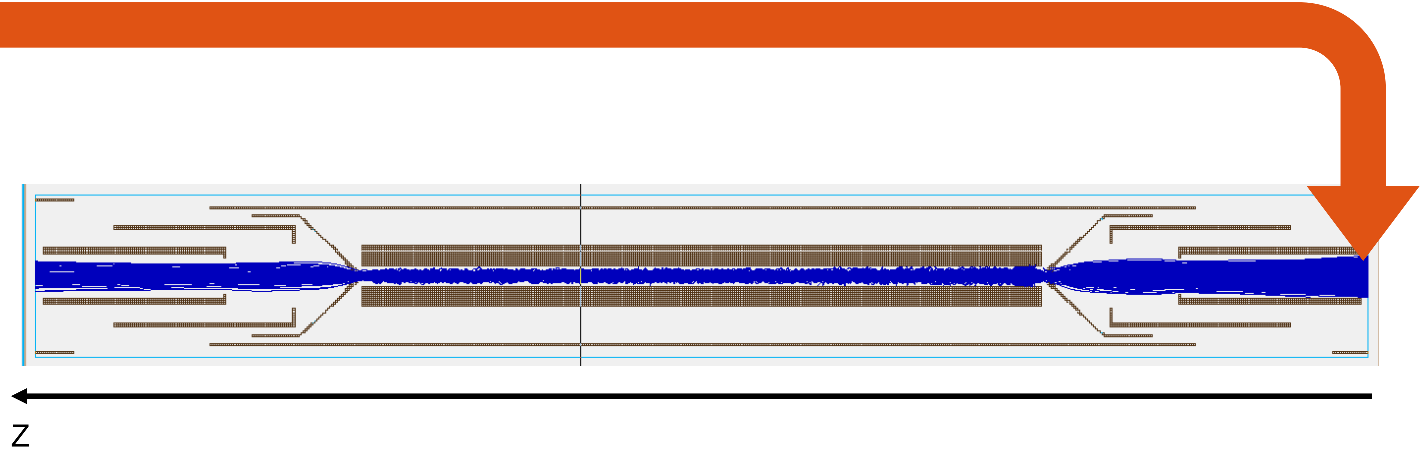
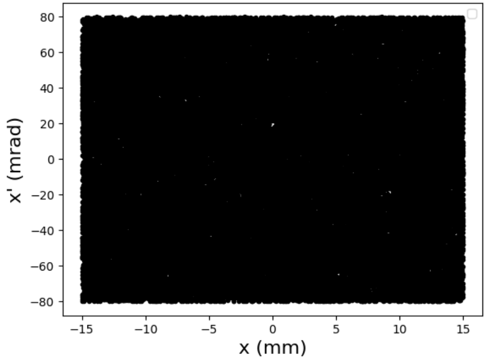
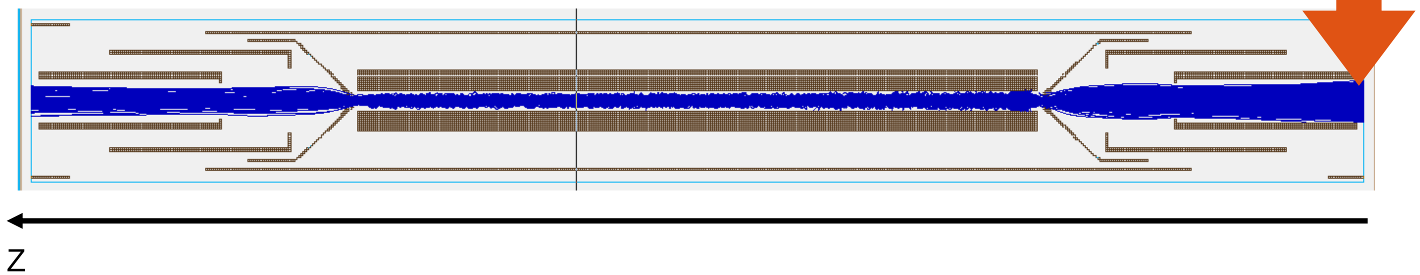




- **Applied voltage on injection and ejection (First electrode 29975 V)**

- **Finding the acceptance**





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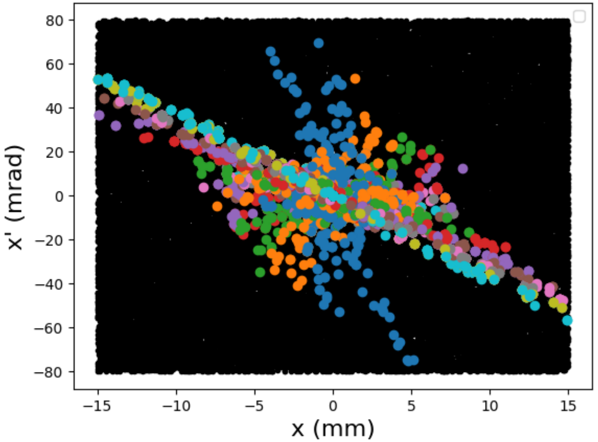
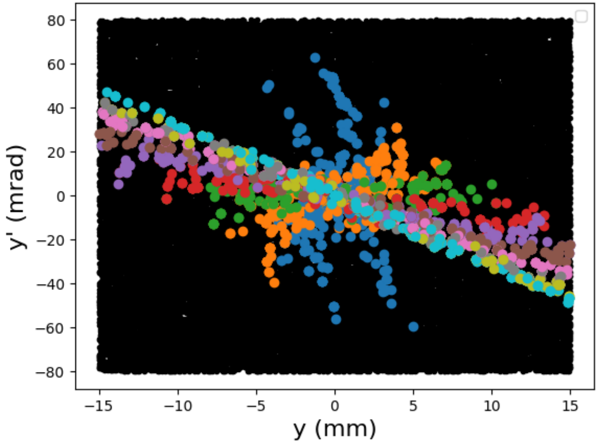
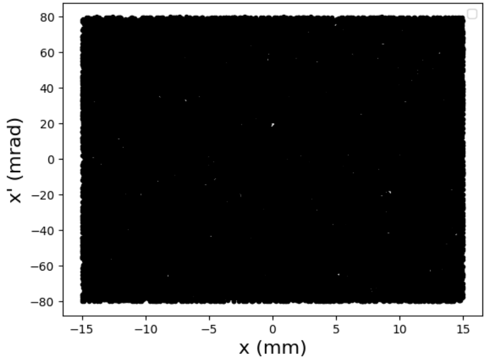
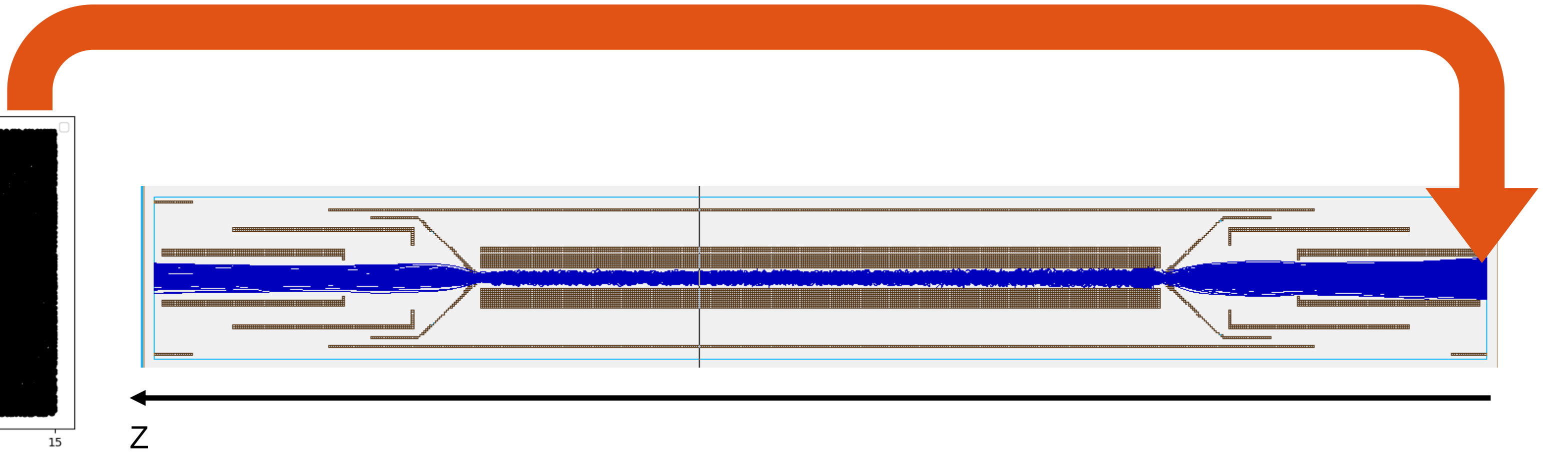




MLLTRAP – Calculations for RFQCB

- **Finding the acceptance**





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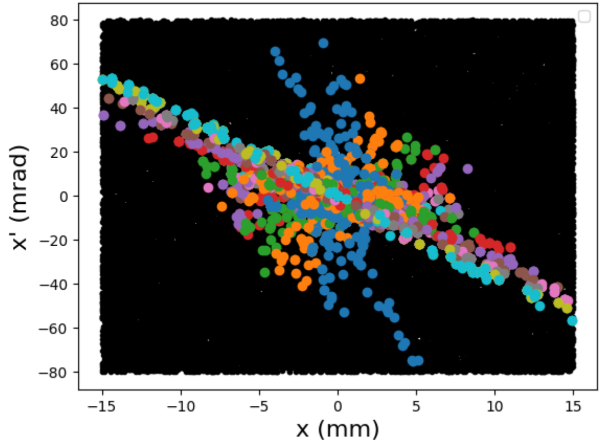
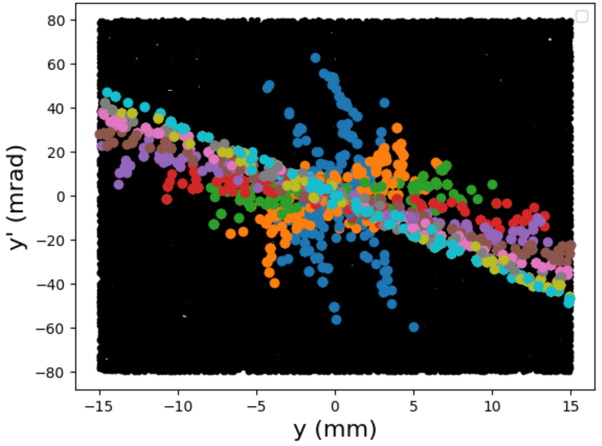
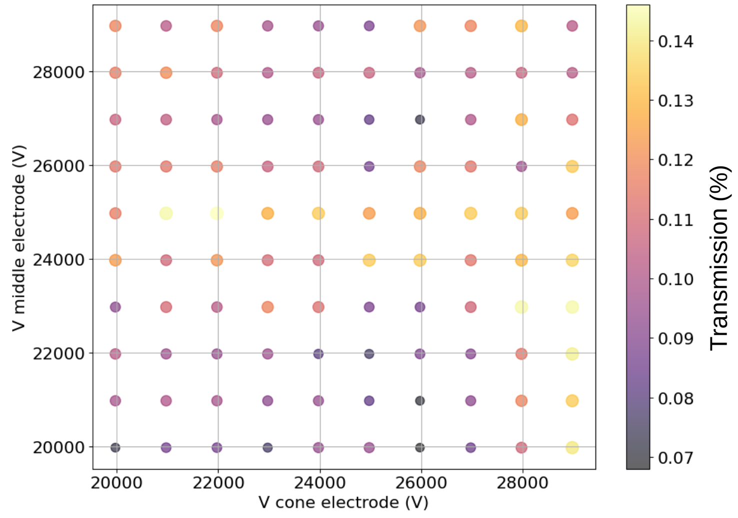
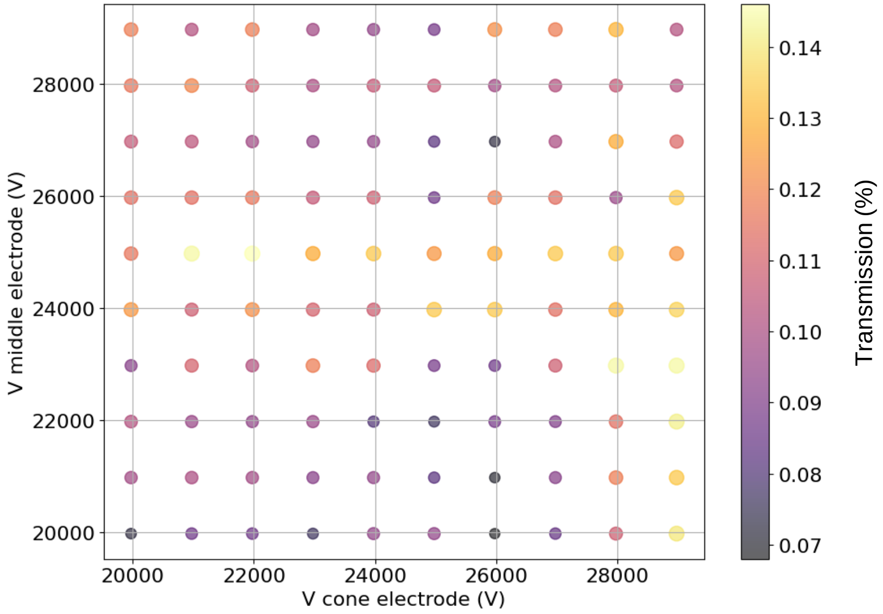






Gas pressure optimisation :

- 5 cases studied : best transmission
- Initial distribution : Ellipse of acceptance of 50000 particles



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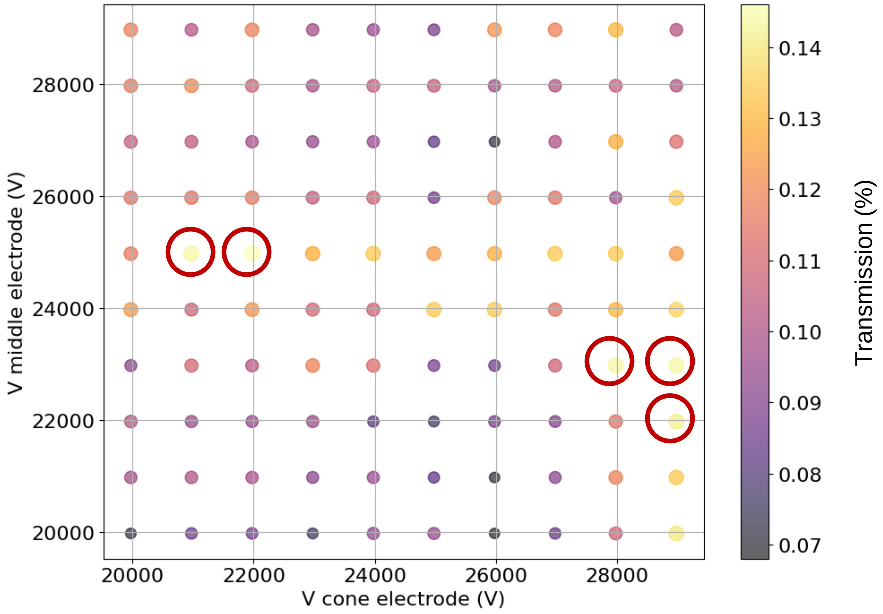

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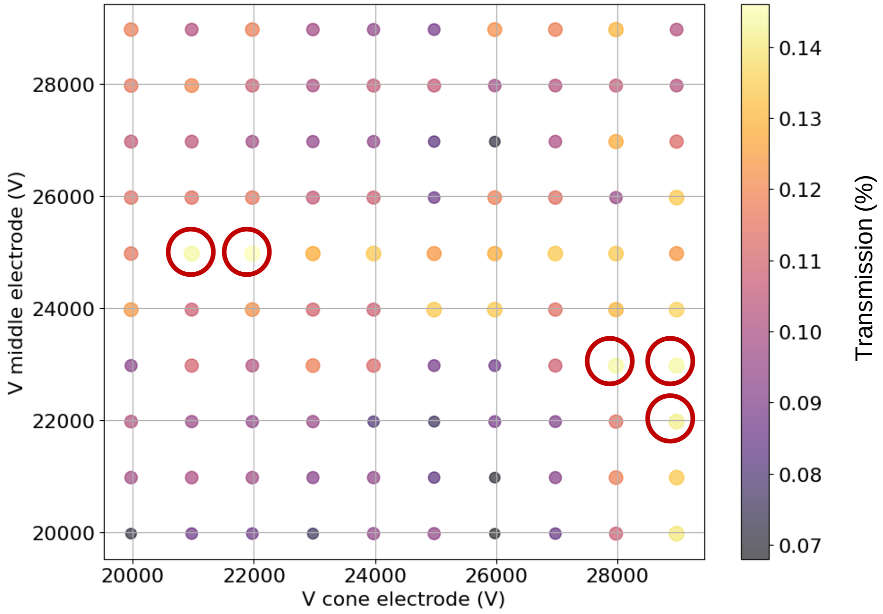
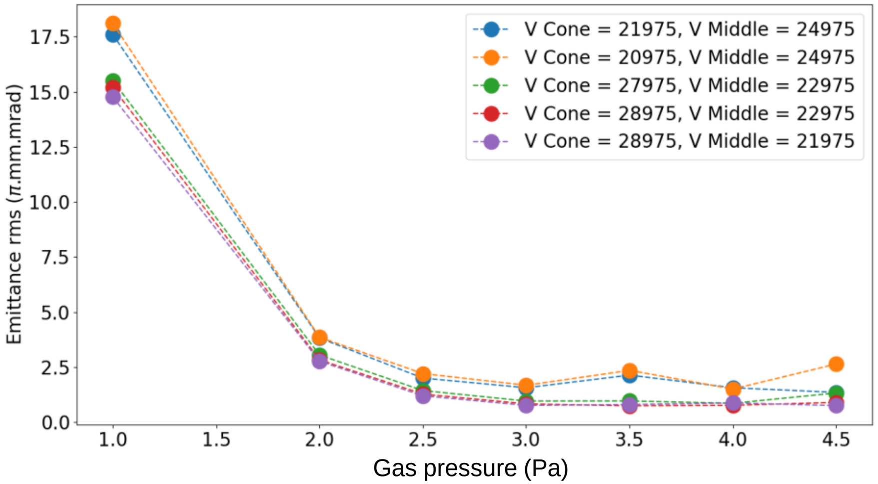
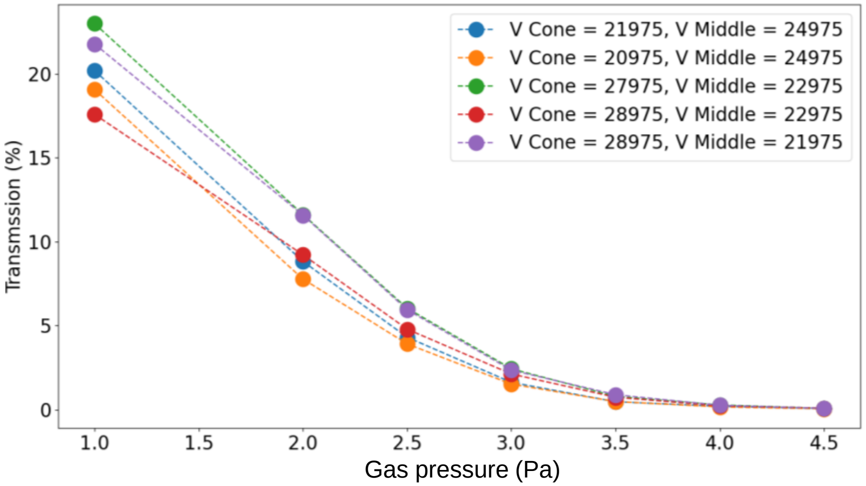
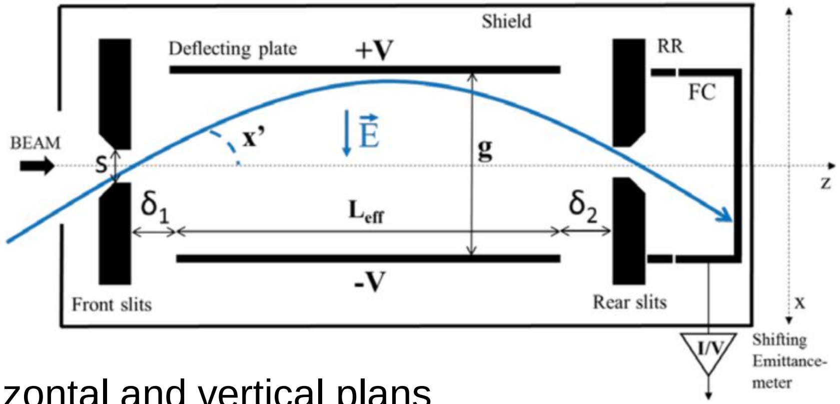


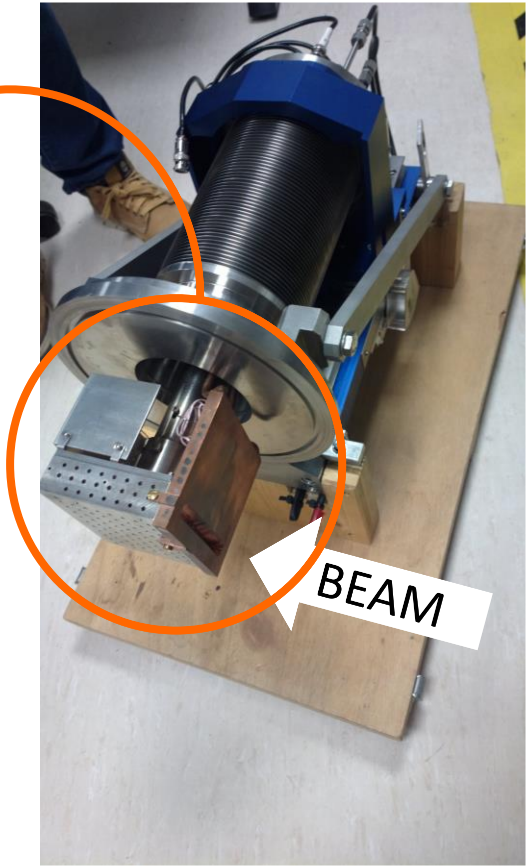




Allison emittancemeter

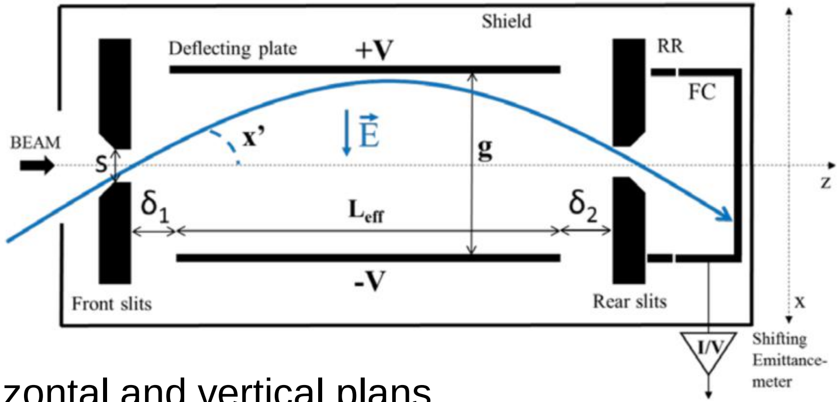
$$x' = \frac{\Delta V}{4Ug} \frac{L_{eff} + 2\delta_2}{\delta_1 + L_{eff} + \delta_2}$$



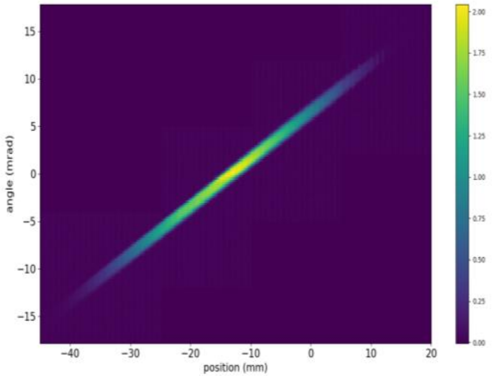


- 2D measurements in horizontal and vertical plans

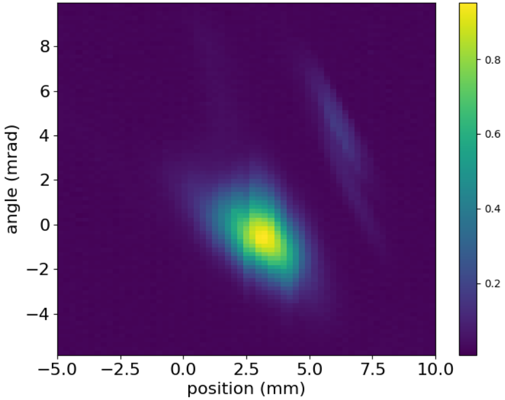
Allison emittancemeter



Measurement of horizontal phase space



Measurement of vertical phase space



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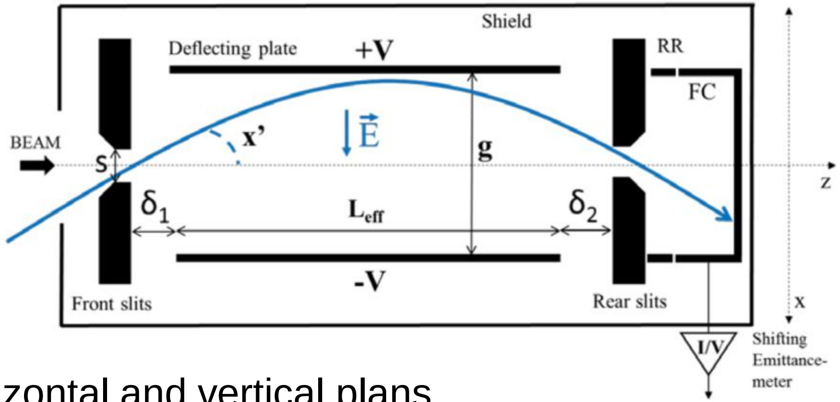
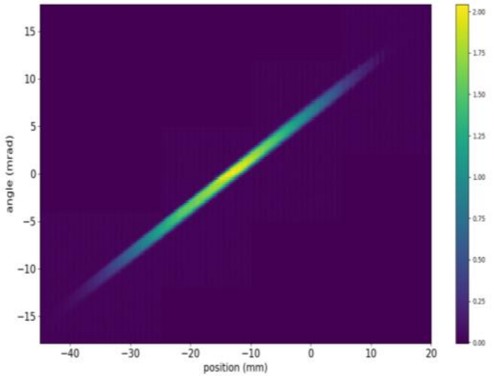
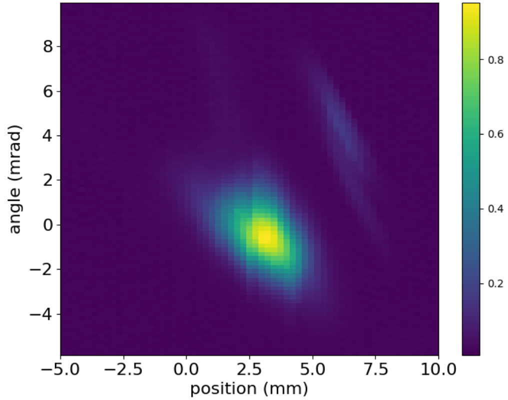


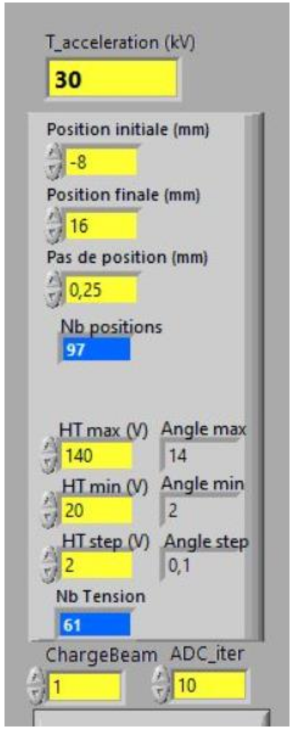
Measurement of horizontal phase space



Measurement of vertical phase space

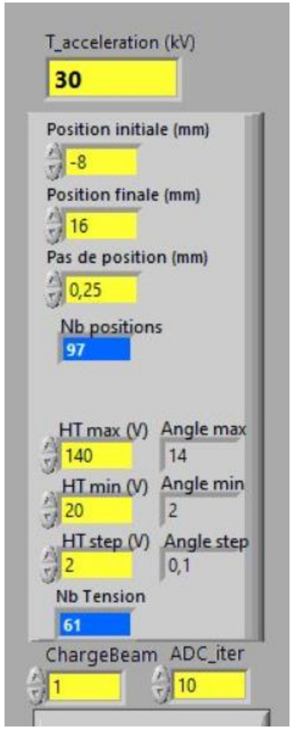


- 2D measurements in horizontal and vertical plans
- Parametric studies:
  - Error of emittancemeter : Measurement steps
  - Focusing effect : Quadrupoles voltage
  - Sensitivity of target-ions source vault : Position of extraction electrode and temperature of oven



Part of control command interface of Emittancemeter

Results of parametric studies : Step of measurements



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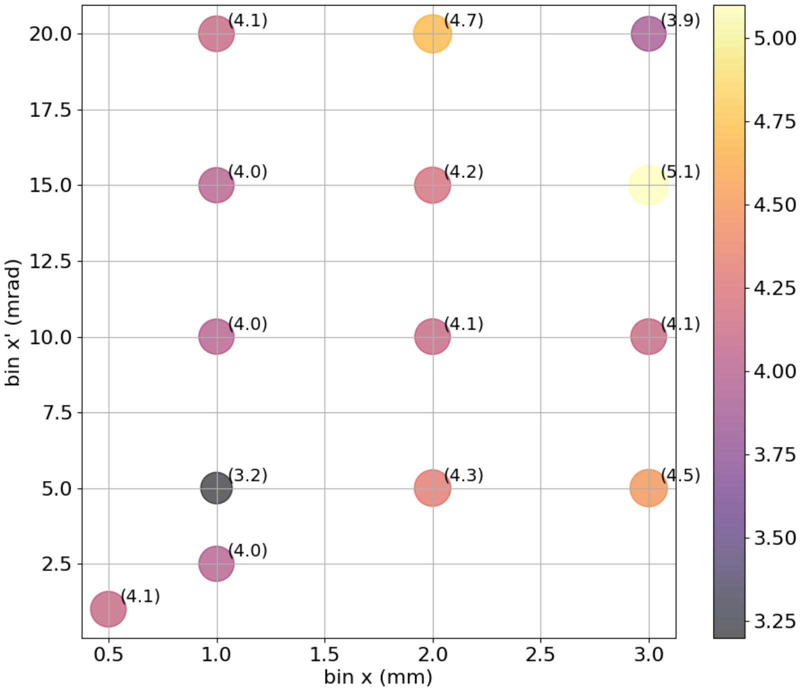

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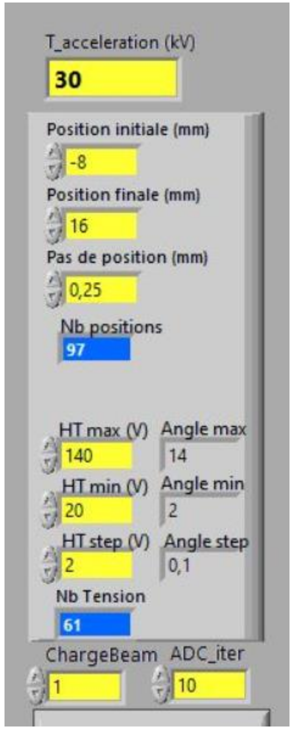

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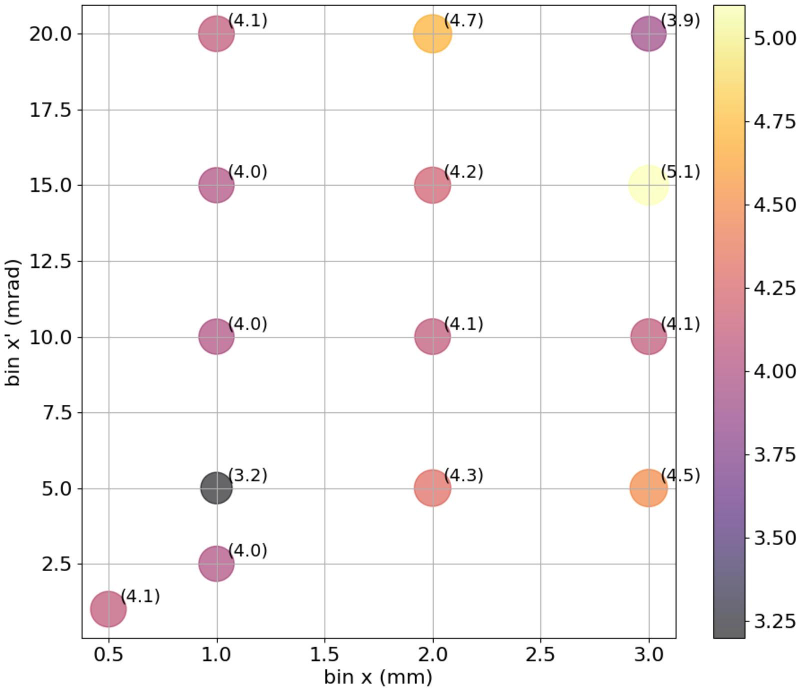


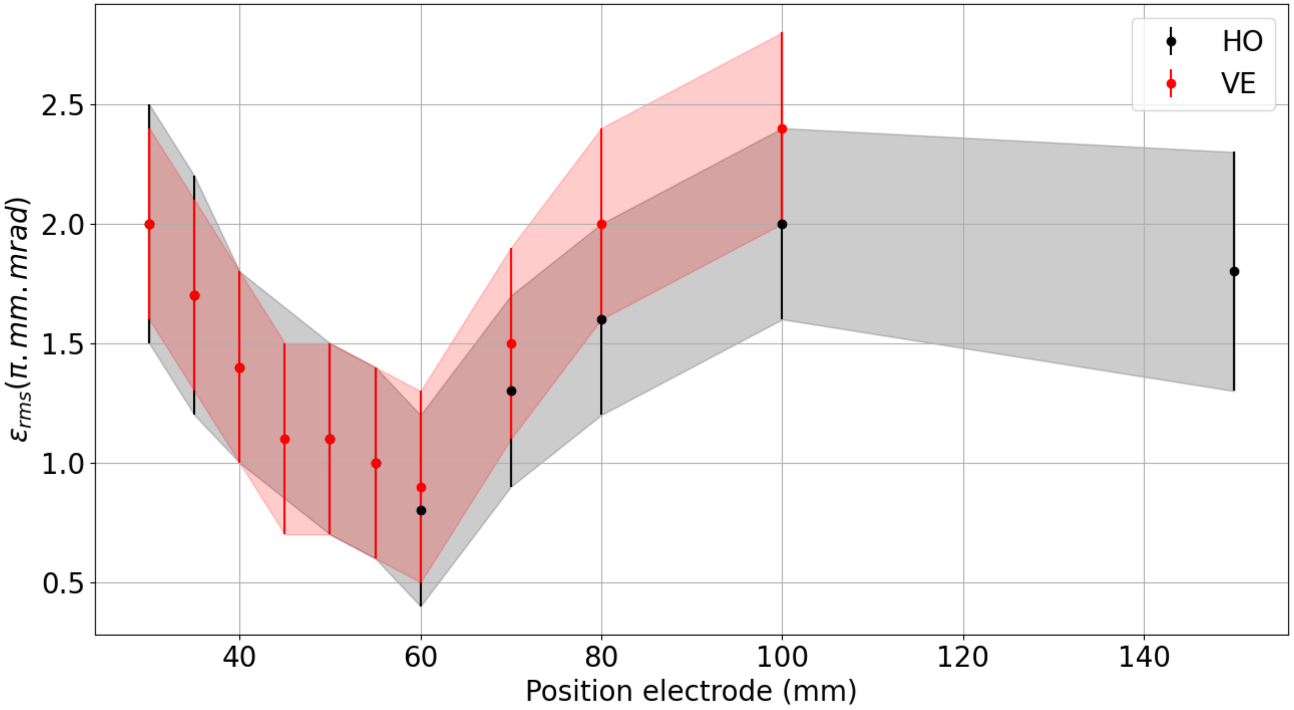
Mean = $4.2\ \pi.mm.mrad$

Standard deviation = $0.4\ \pi.mm.mrad$

→ Error due to step of measurement

Final error : $\delta\varepsilon = \sqrt{\delta_{fit}^2 + \delta_{step}^2}$

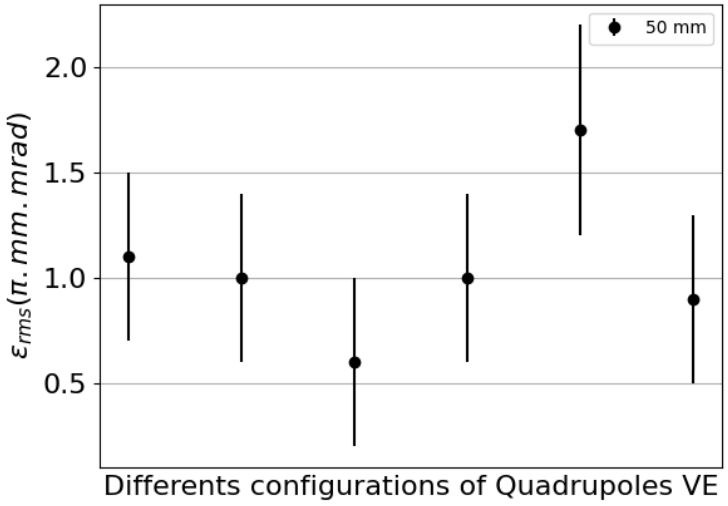
Results of parametric studies : Position of extraction electrode



➡ Minimum of emittance at position 60 mm in both plans

Results of parametric studies : Voltage on quadrupoles

Vertical plane



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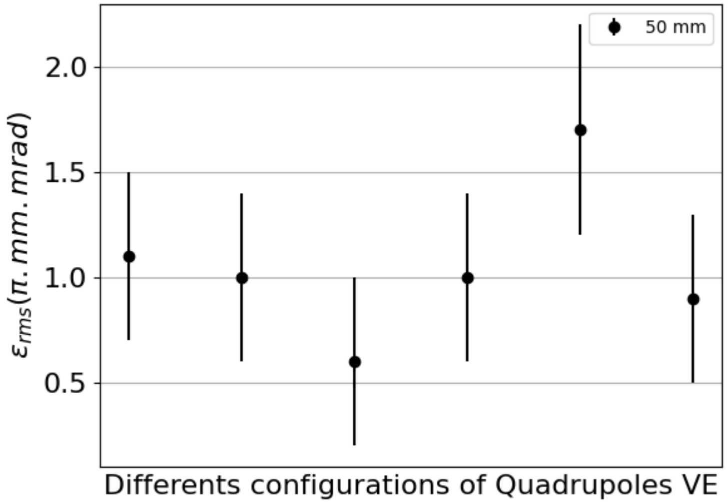

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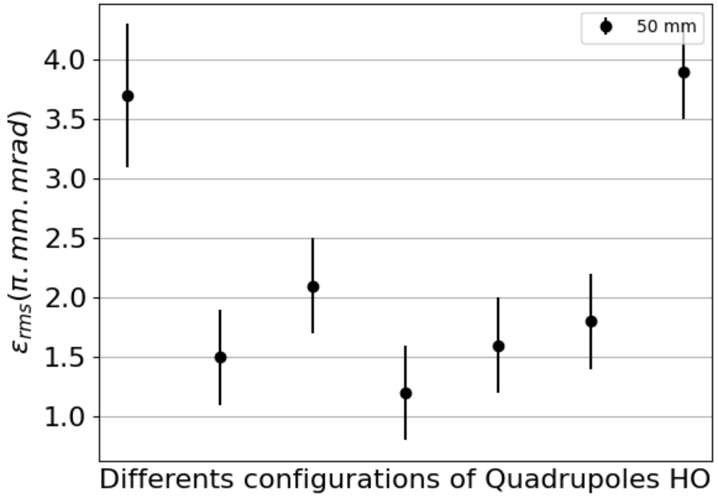

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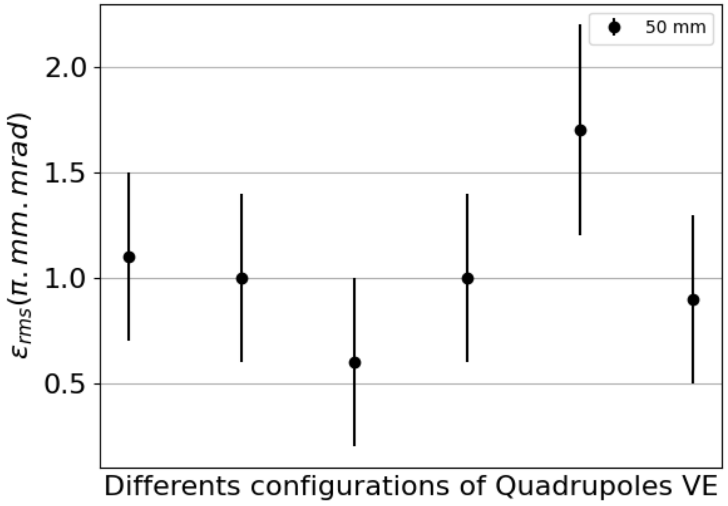
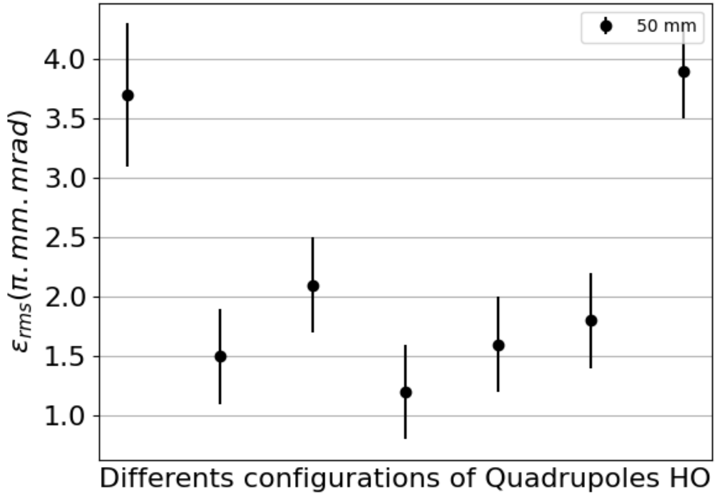


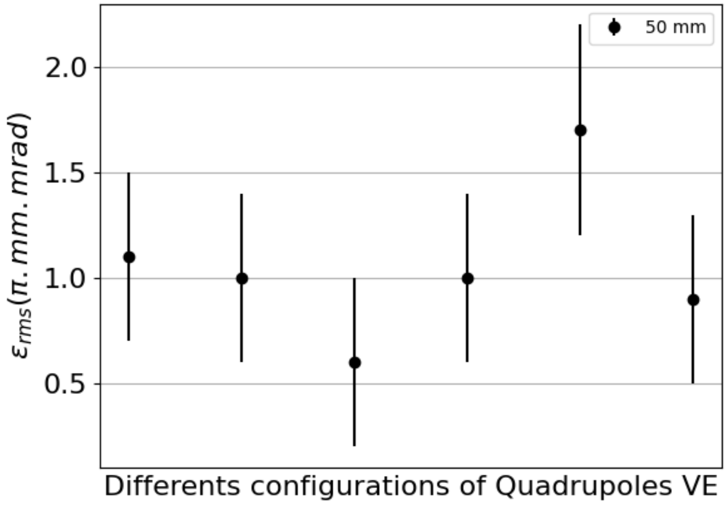
Horizontal plane



Problem : Emittance not conservative

Results of parametric studies : Voltage on quadrupoles

Vertical plane



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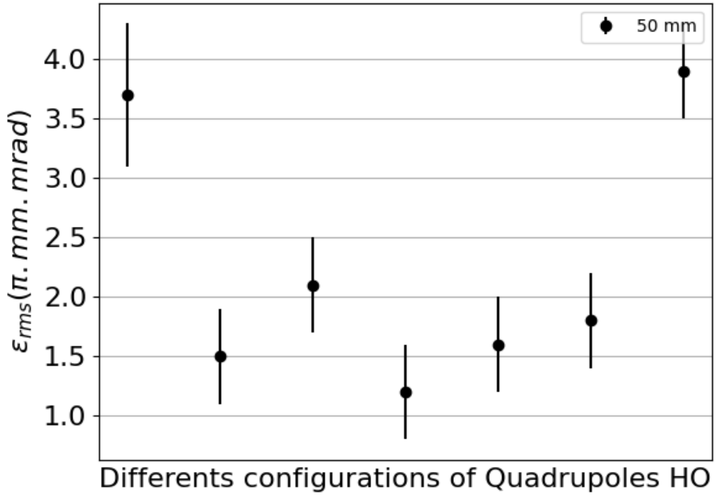
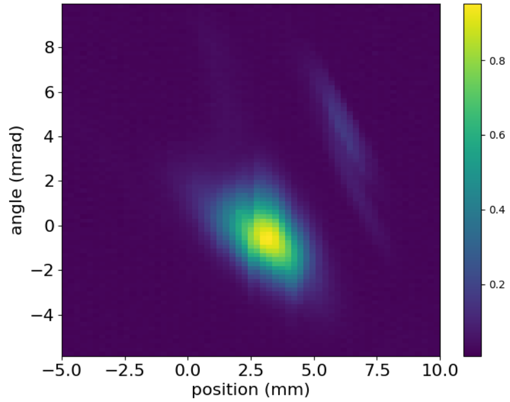
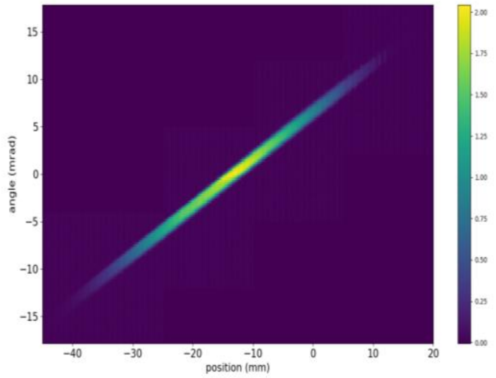




Problem : Emittance not conservative

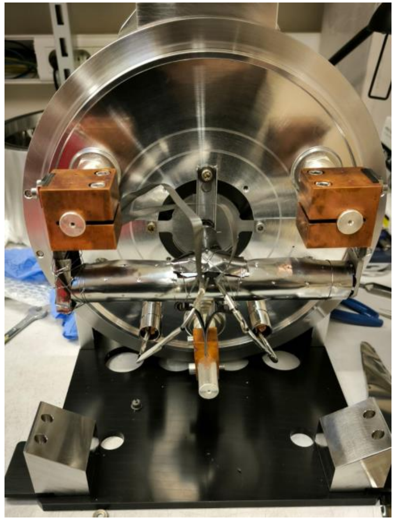
Influence of the shape of the beam on the analysis ?



Results of parametric studies : Oven current

Study of target-ion source different :

- Additional oven withdraw
- Target of C doped with Cs used in oven to simulate radioactive beam



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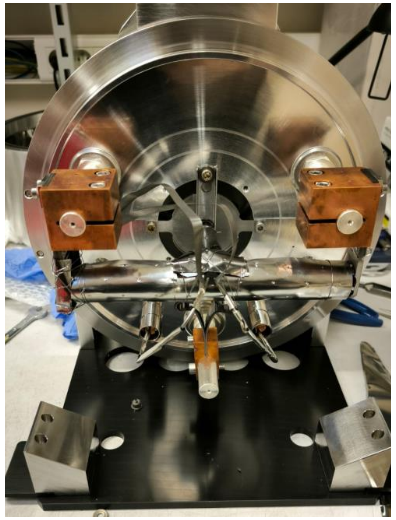
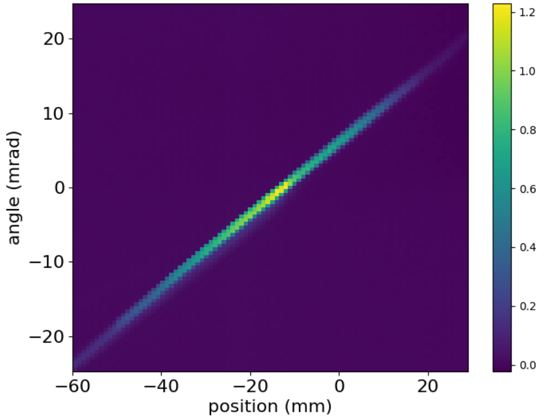


« Large » beam
in Horizontal plan



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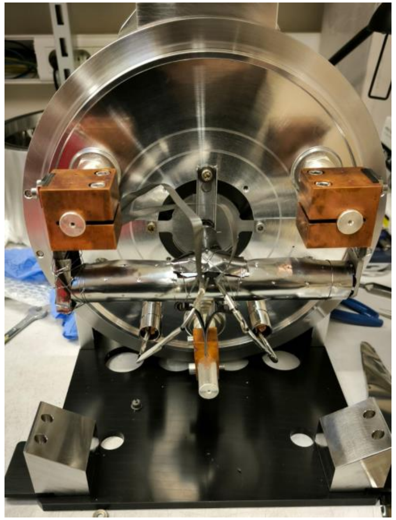
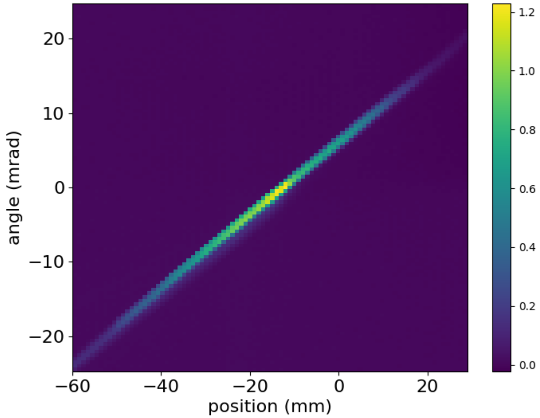
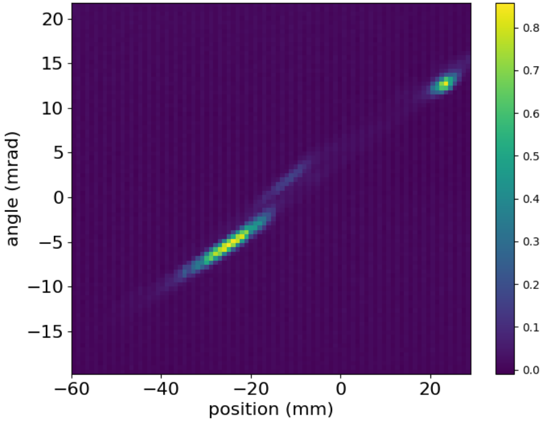


« Large » beam in Horizontal plan



« Small » beam in Horizontal plan



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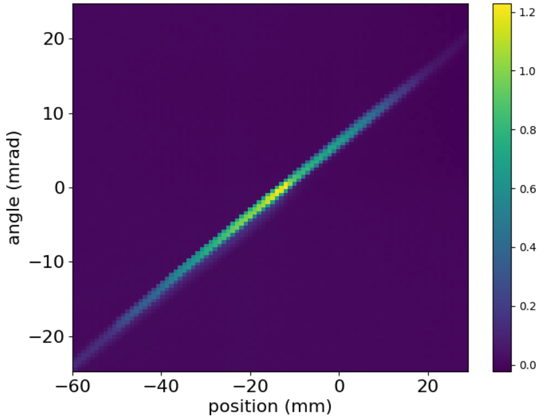
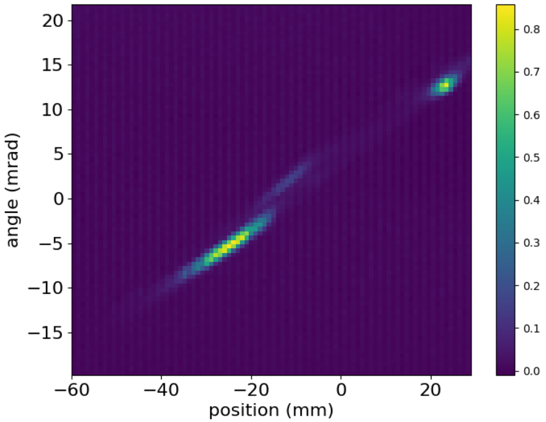
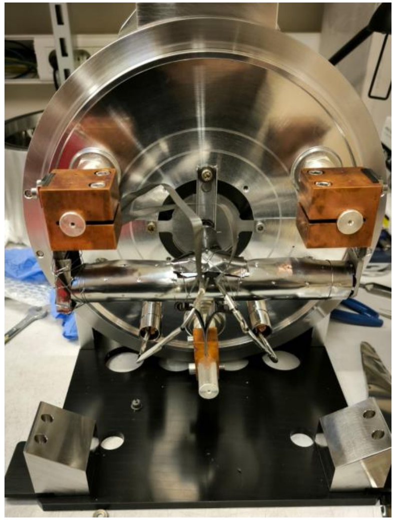
« Large » beam in Horizontal plan

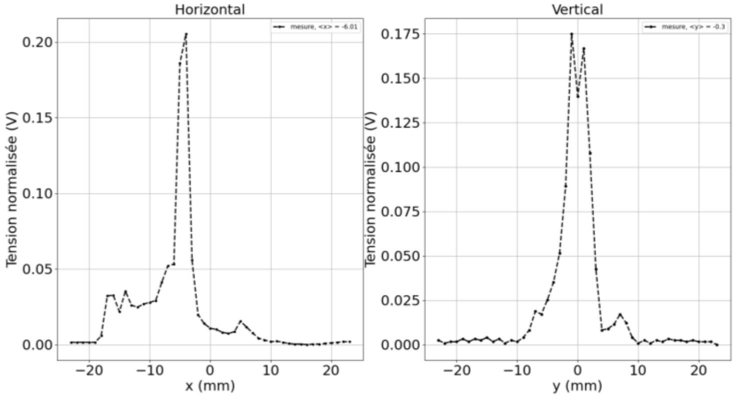


« Small » beam in Horizontal plan





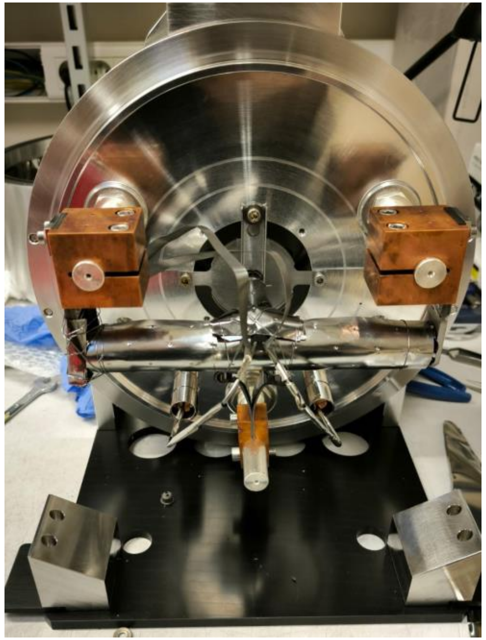
Profile measurement



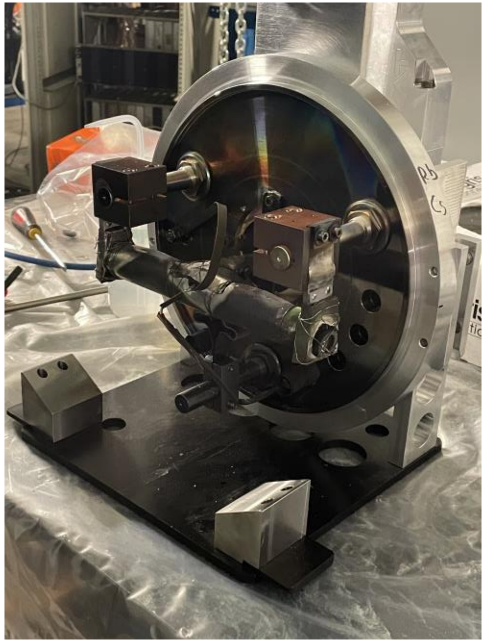
Results of parametric studies : Oven current

Study of target-ion source different :

- Additional oven withdraw
- Target of C doped with Cs used in oven to simulate radioactive beam



After 1 week



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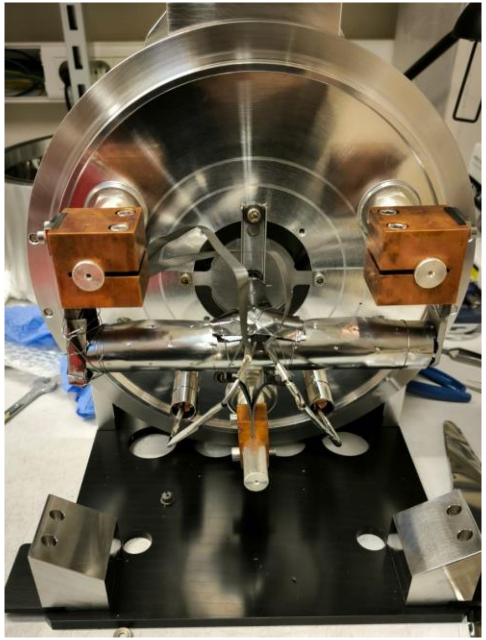

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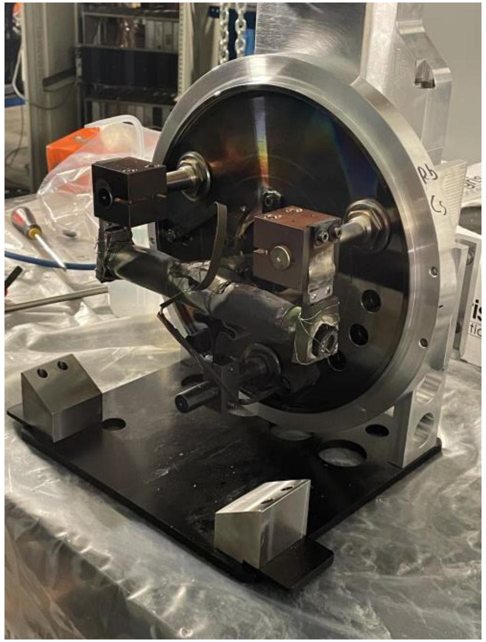
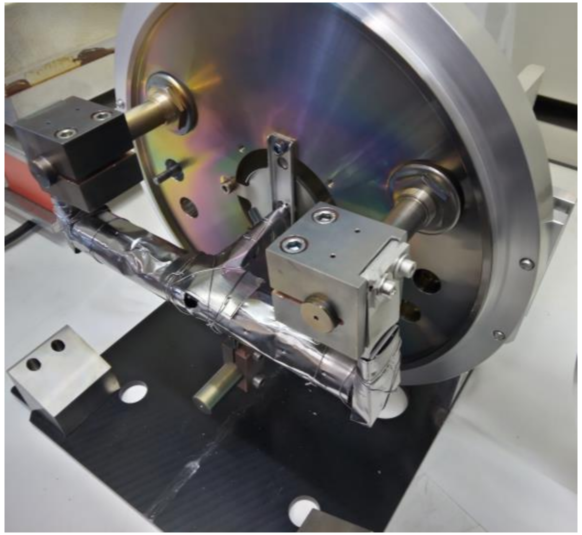


Last Friday



Conclusion

- **MLLTRAP** :
  - Beam line soon connected to the traps
  - Helium recuperation still has to be tested with MLLTRAP
  - Stabilisation of magnet temperature

- **RFQCB** :
  - Electronics needed to start testing
  - Calculations :
    - Decoupling of injection and extraction
    - Effect of q parameter
    - Effect of grouped particles
    - Buncher

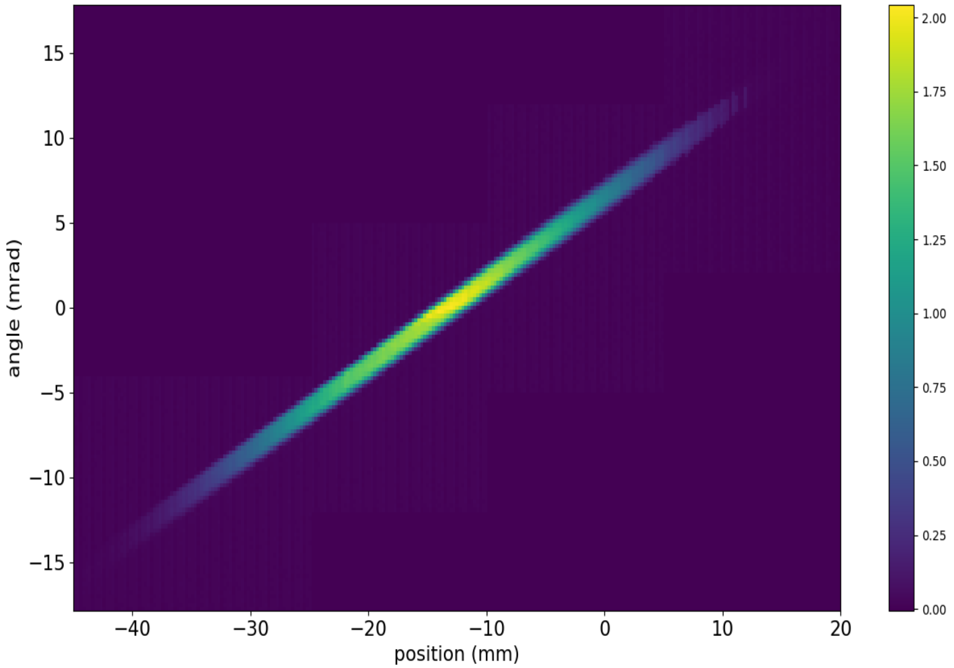
- **Emittance analysis** :
  - Influence of beam shape to study further
  - Checking errors

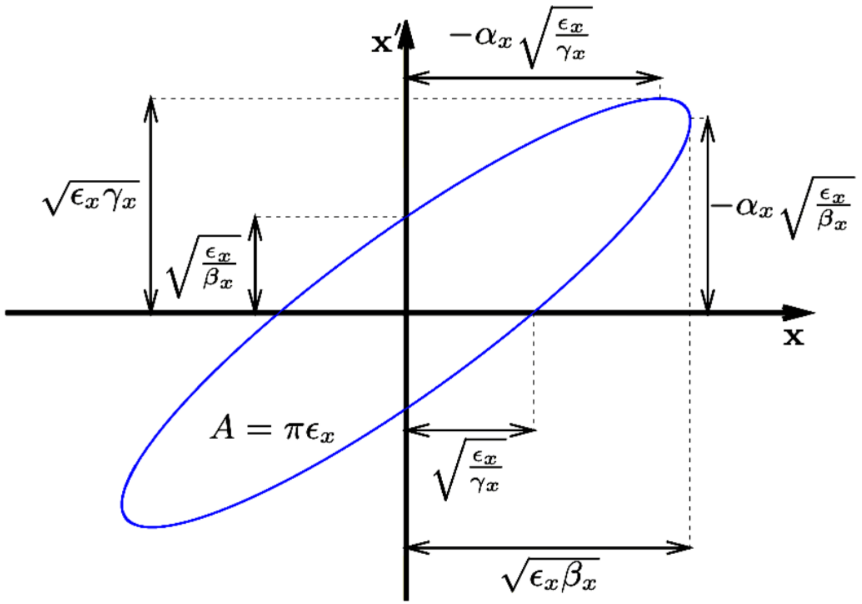
- **Perspectives** : Transport calculations from target-ion source to exit of RFQCB

Thank you for your attention

Emittance

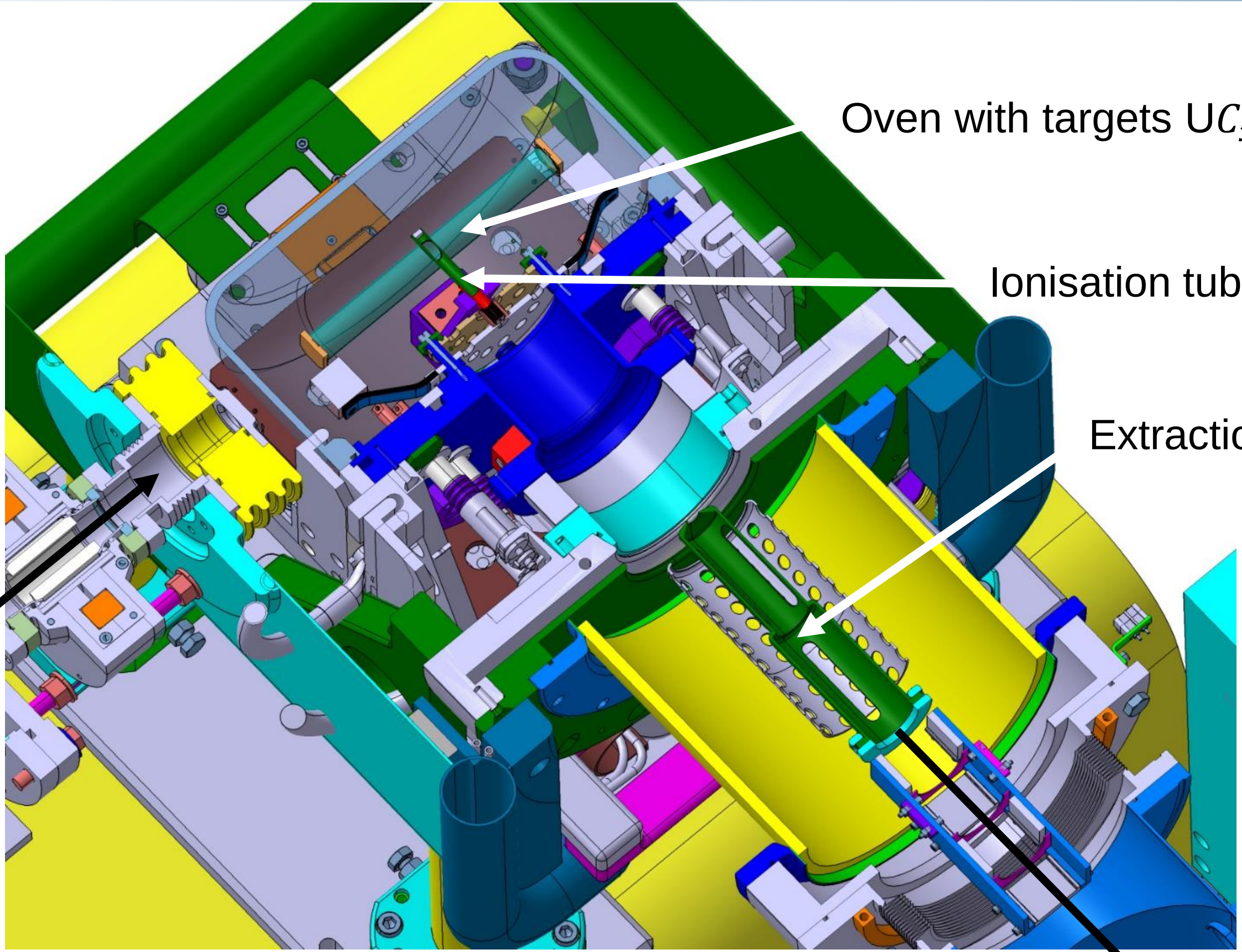
- **Emittance** : surface representing all the points in the phase space of the particles of the beam, with a factor of π.
- **Twiss parameters** : $\epsilon = \gamma x^2 + 2\alpha x x' + \beta x'^2$





Emittance is conservative

Target-ion source



Emittance measurements analysis

Used definitions:

$$\epsilon_{rms} = \sqrt{\sigma_x^2\sigma_{x'}^2 - \sigma_{xx'}^2}$$

$$\sigma_x = \sqrt{w(x^2) - w(x)^2}$$

$$\sigma_{x'} = \sqrt{w(x'^2) - w(x')^2}$$

$$\sigma_{xx'} = w([x - w(x)][x' - w(x')])$$

$$w(x) = \frac{\sum_i x_i I_i}{\sum_i I_i}$$

Associated errors calculations:

$$\delta\epsilon = \sqrt{\left(\frac{\sigma_x\sigma_{x'}^2}{\epsilon}\right)^2\delta\sigma_x^2 + \left(\frac{\sigma_{x'}\sigma_x^2}{\epsilon}\right)^2\delta\sigma_{x'}^2 + \left(\frac{\sigma_{xx'}}{\epsilon}\right)^2\delta\sigma_{xx'}^2}$$

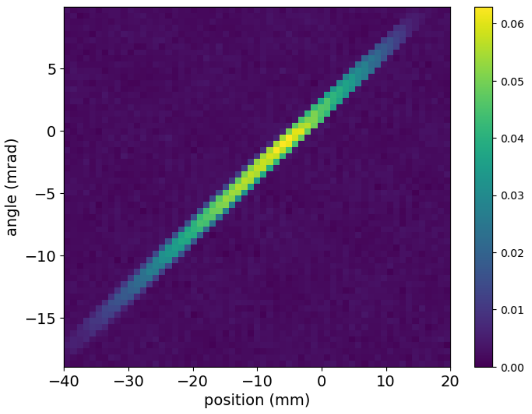
$$\delta\sigma_{xx'} = \sqrt{\sum_i\left(\frac{\partial\sigma_{xx'}}{\partial x_i}\right)^2\delta x^2 + \sum_i\left(\frac{\partial\sigma_{xx'}}{\partial x'_i}\right)^2\delta x'^2 + \sum_i\left(\frac{\partial\sigma_{xx'}}{\partial I_i}\right)^2\delta I^2}$$

$$\delta\sigma_x = \sqrt{\left(\frac{1}{2\sigma_x}\right)^2\delta w^2(x^2) + \left(\frac{w(x)}{\sigma_x}\right)^2\delta w^2(x)}$$

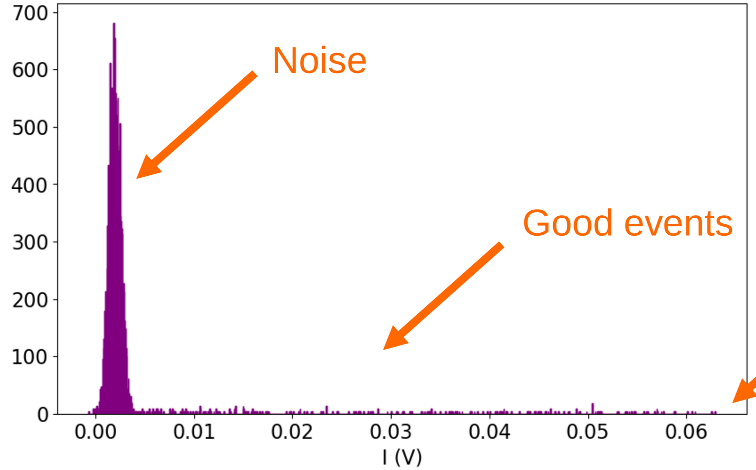
$$\delta w = \sqrt{\sum_i\left(\frac{\partial w}{\partial x_i}\right)^2\delta x^2 + \sum_i\left(\frac{\partial w}{\partial I_i}\right)^2\delta I^2}$$

$\delta x = 10\ \mu m$
$\delta x' = 0{,}025$ mrad
$\delta I = 9.10^{-6}$ V

Emittance measurements analysis



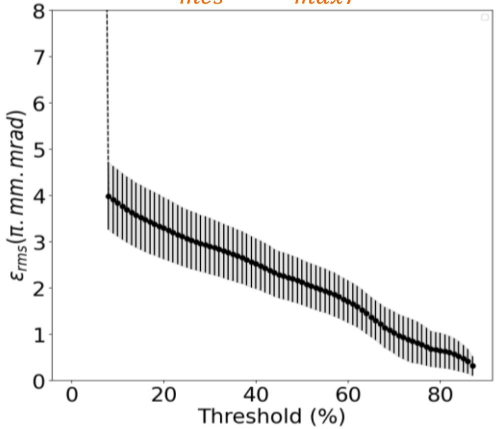
Distribution of the signal intensity



Noise substraction :

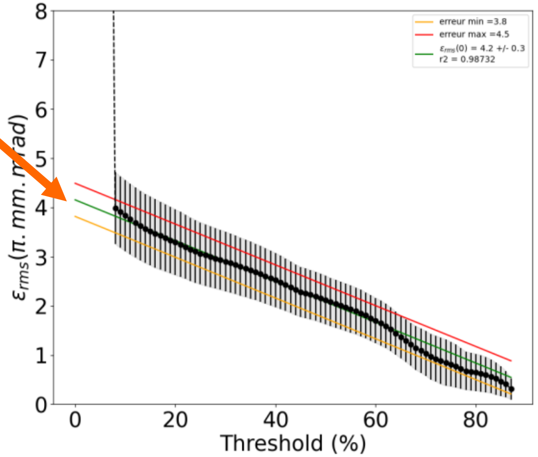
Threshold of maximum signal :

$I = I_{mes} - nI_{max}/100$



Linear regression

Value of emittance

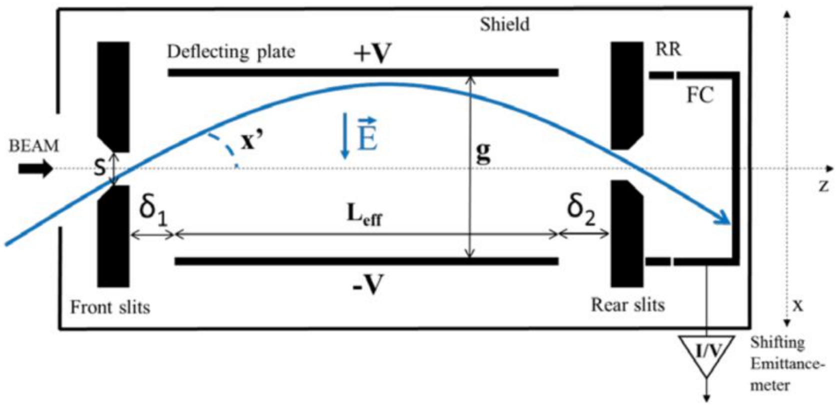


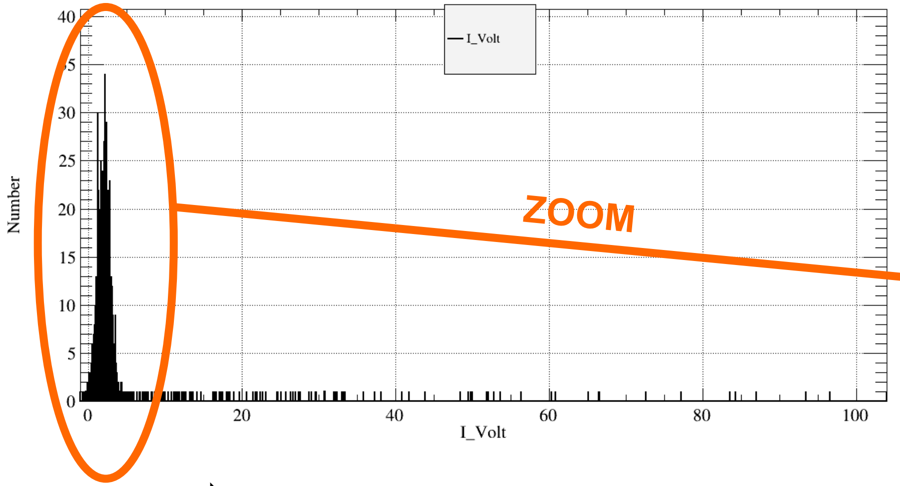
Emittance measurements errors

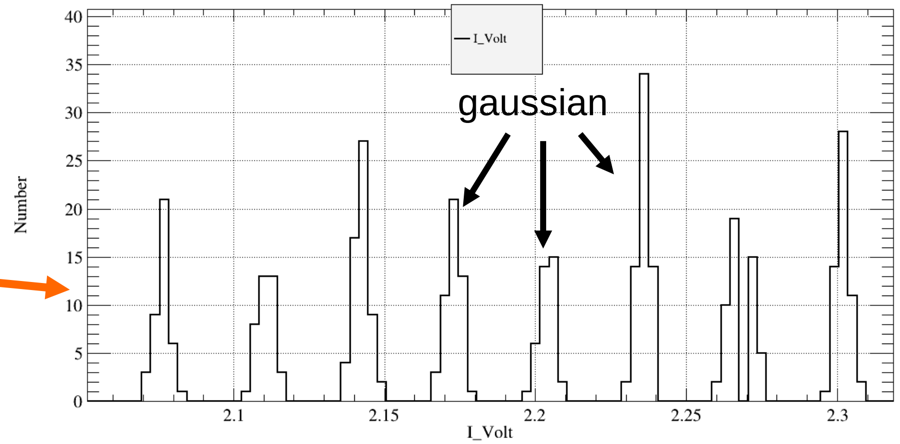
- Position error: stepper motor precision
  ➡ δx = 10 µm

- Angular error: voltage supplier precision
  ➡ δx' = 0,025 mrad

- Measured intensity error: electronics precision

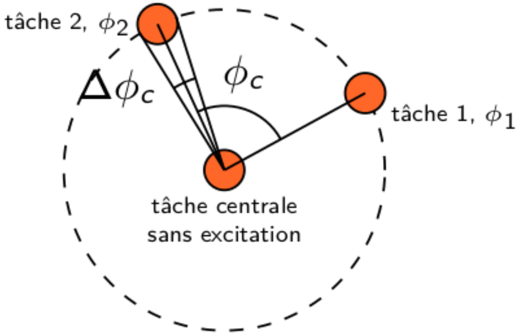






➡ δI = 3×3.10^{-6} V

- Projection des mouvements propres des ions sur un détecteur sensible à la position transverse, une galette à microcanaux avec des lignes à retard
- $\phi_c + 2\pi(n_+ + n_-) = 2\pi\nu_c t$
- Pouvoir de séparation : $\Delta\nu_c = \frac{\Delta\phi_c}{2\pi t_{acc}}$



S. Eliseev et al., Appl. Phys. B, 114 (2014) 107-128