

Emittance measurements for the characterisation of the target-ion source of ALTO-LEB

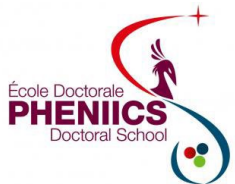
1. ALTO-LEB & Target-ion source
2. Analysis method
3. Results

Sophie Morard

Laboratoire de physique des 2 infinis Irène Joliot Curie

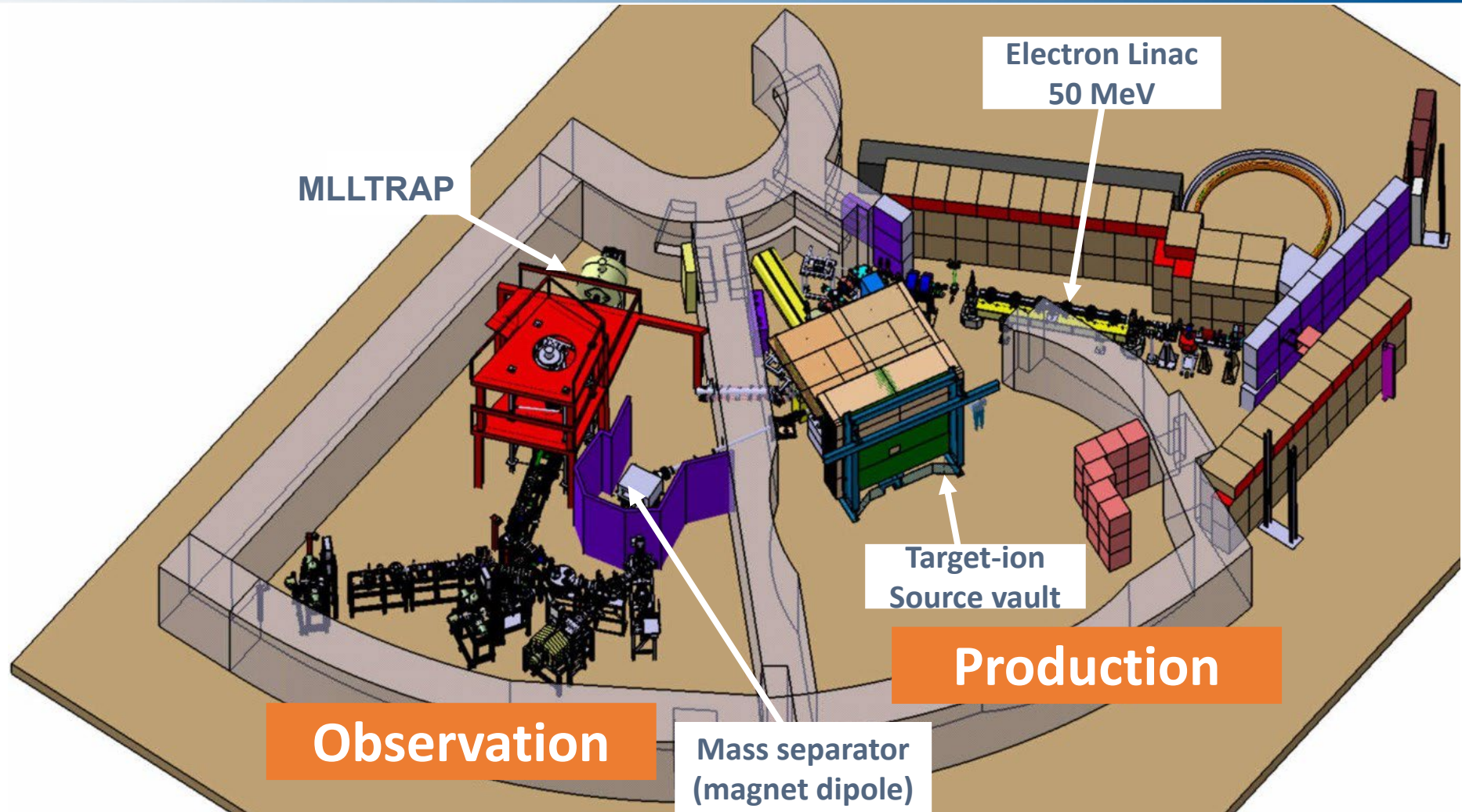
Supervisors :

Luc Perrot & Enrique Minaya Ramirez



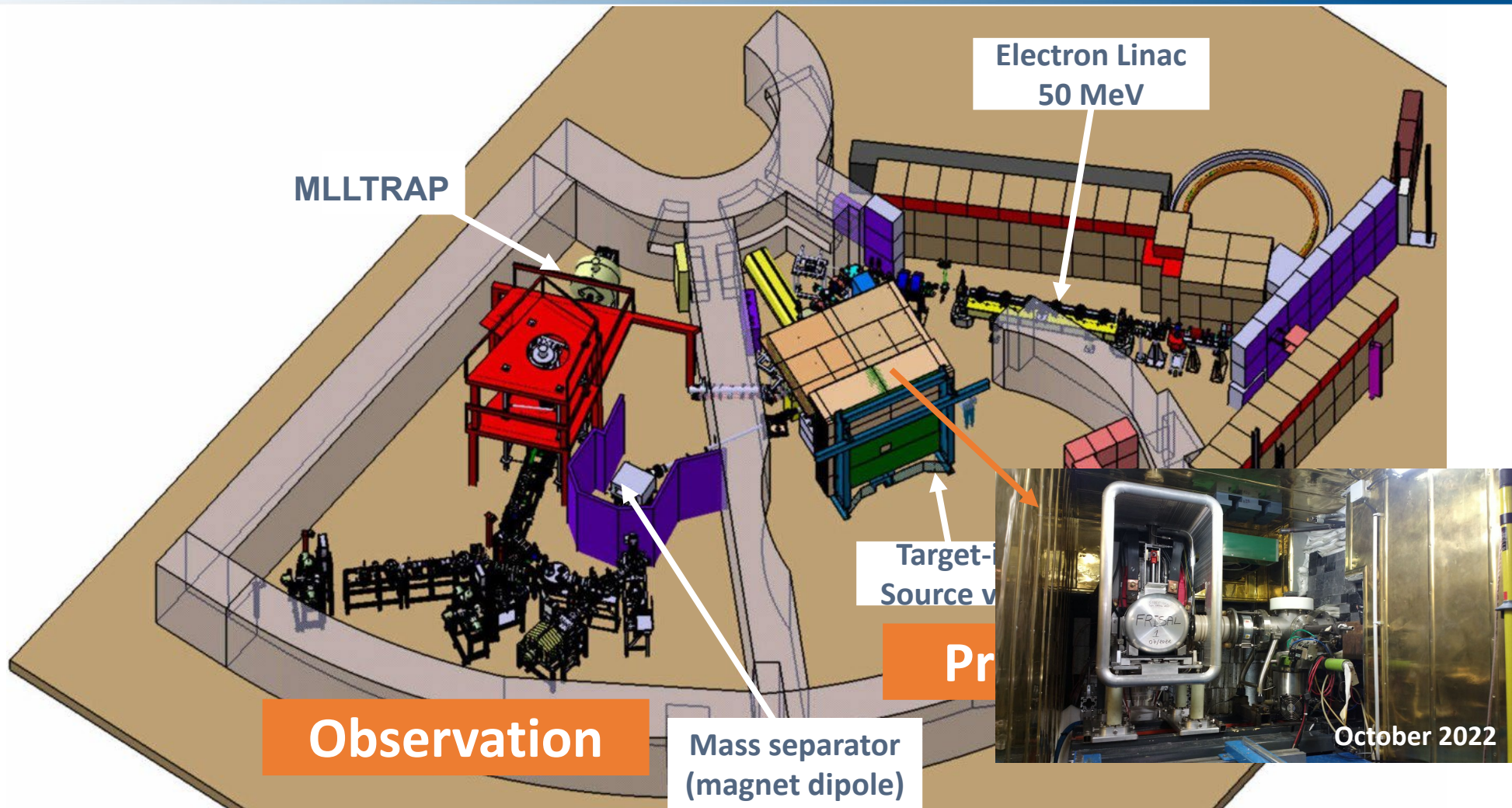


ALTO-LEB : Accélérateur Linéaire & Tandem d'Orsay – Low Energy Beam



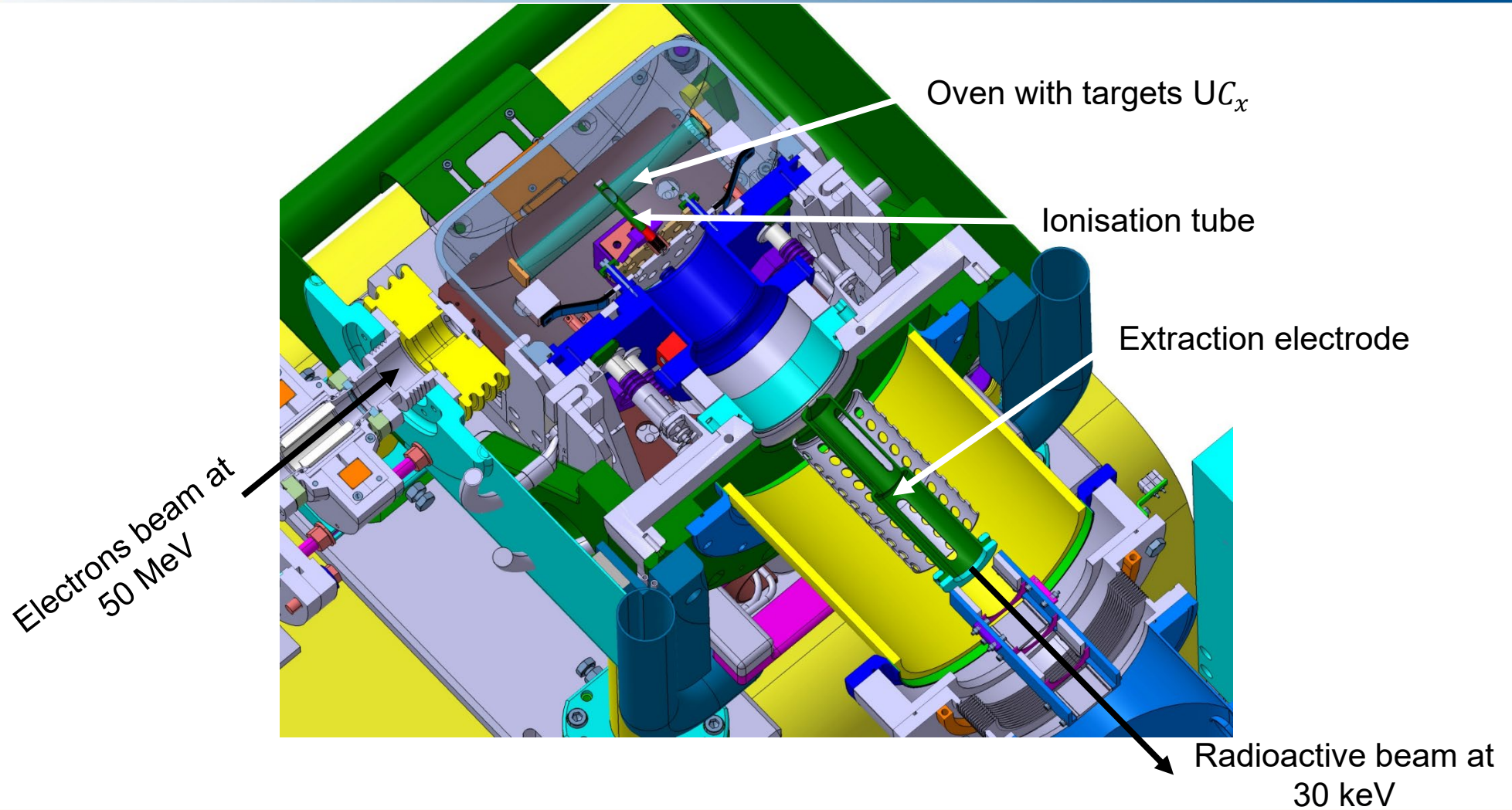


ALTO-LEB : Accélérateur Linéaire & Tandem d'Orsay – Low Energy Beam





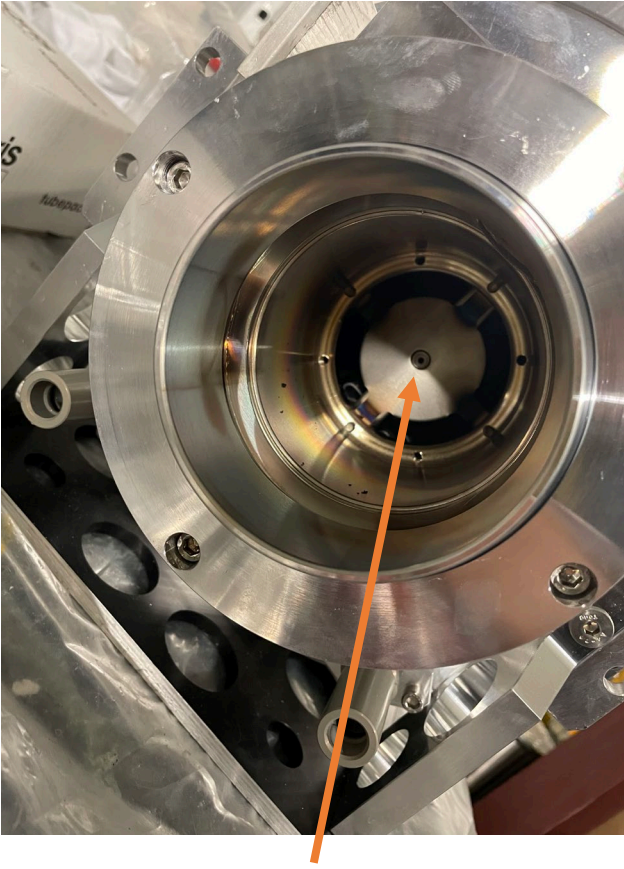
Target-ion source



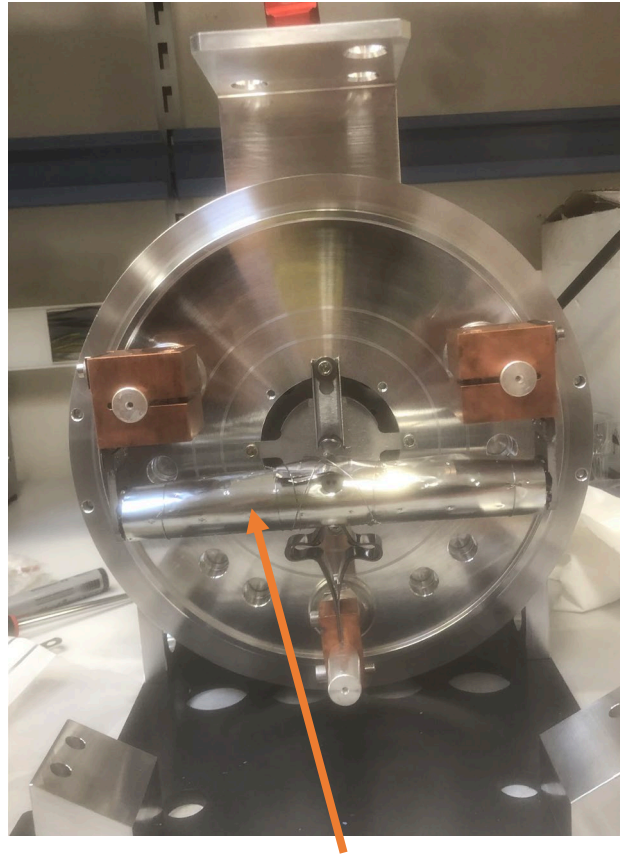


Target-ion source

Production of radioactive beam :



Exit ionisation tube

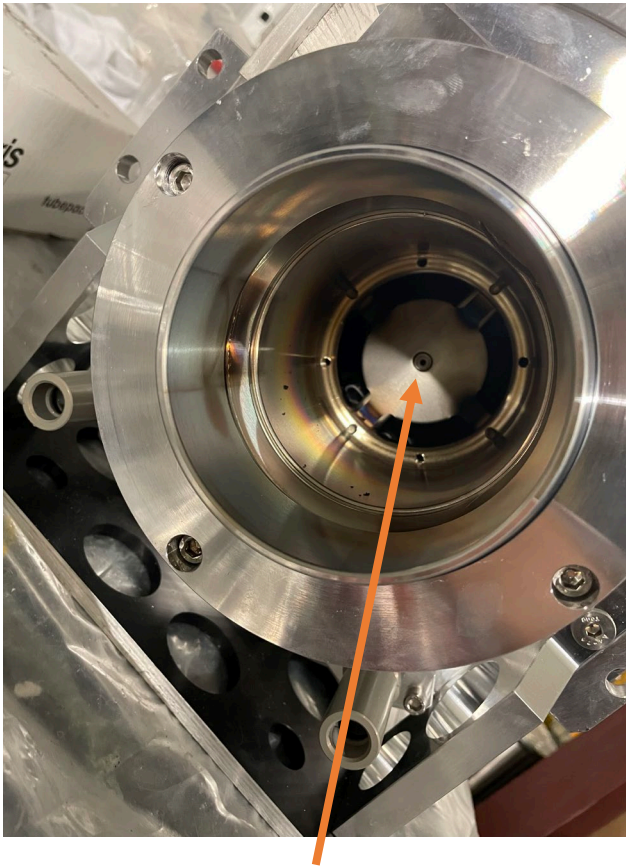


Oven

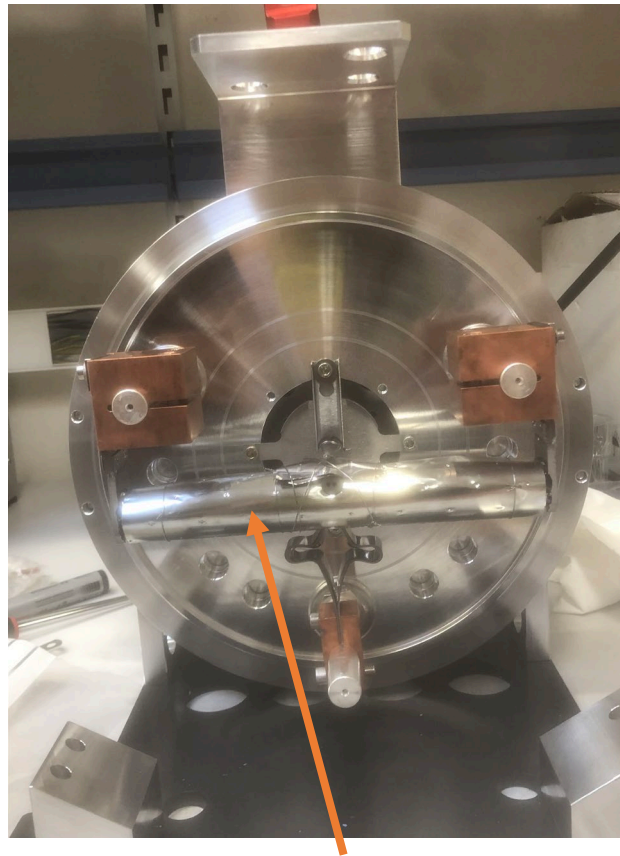


Target-ion source

Production of radioactive beam :

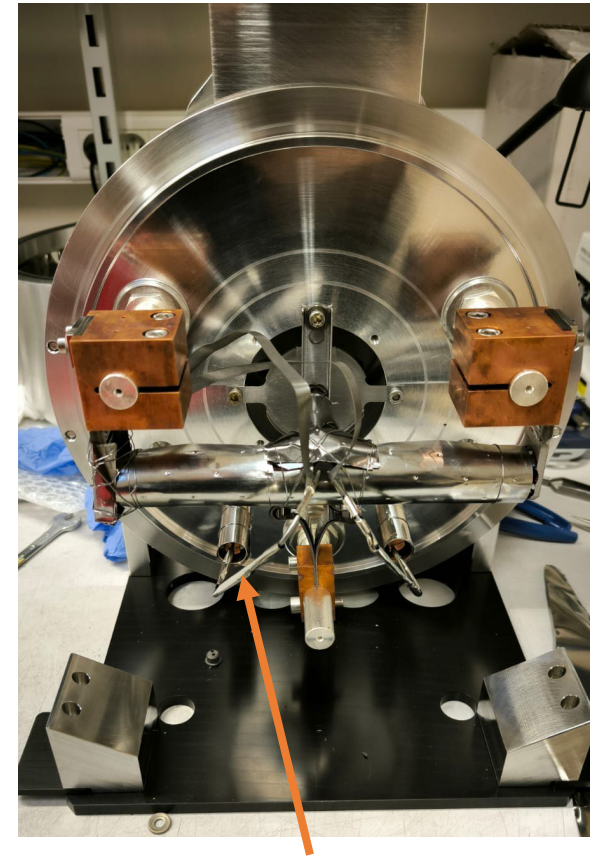


Exit ionisation tube



Oven

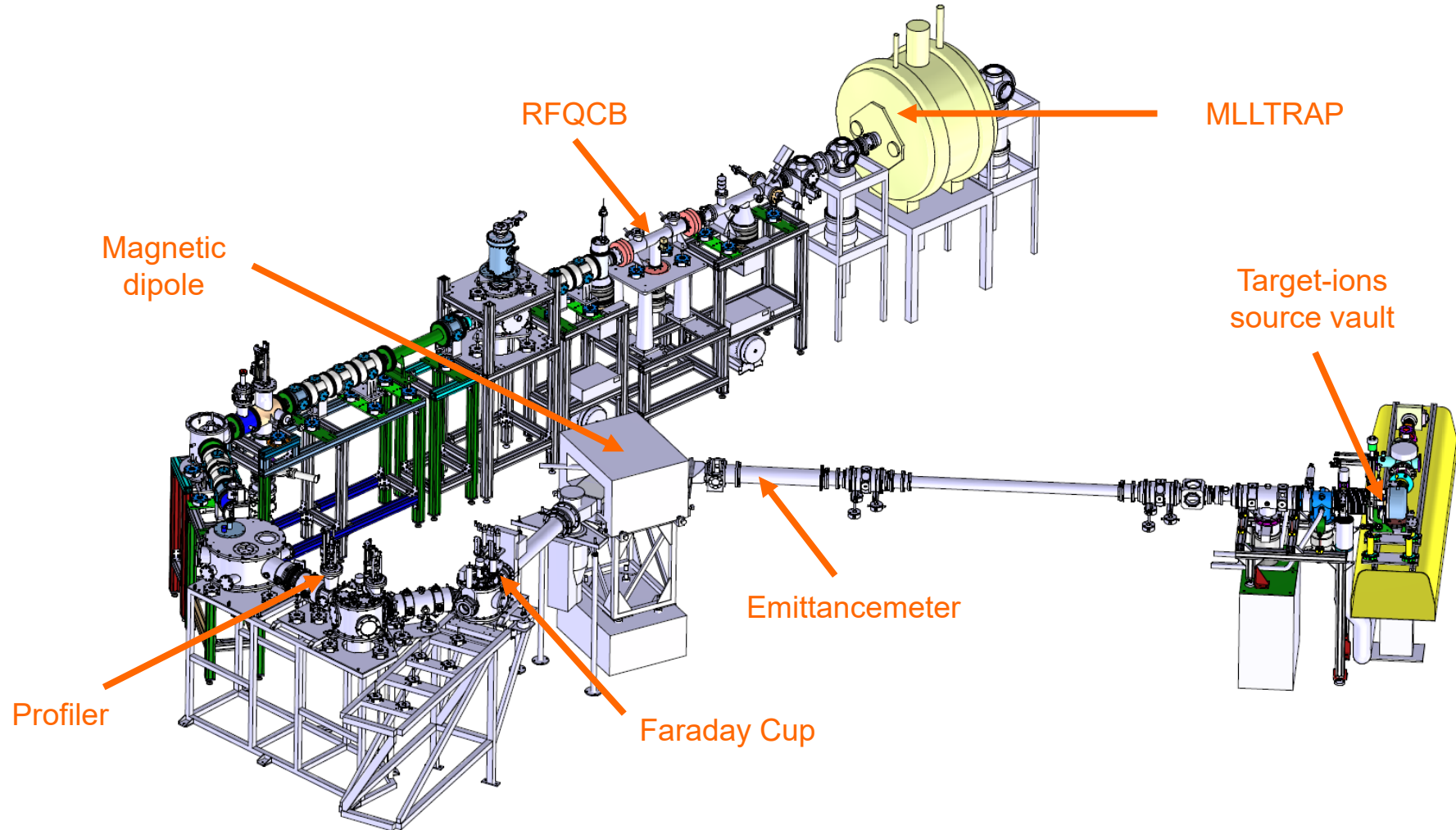
Production of stable beam :



Additional oven



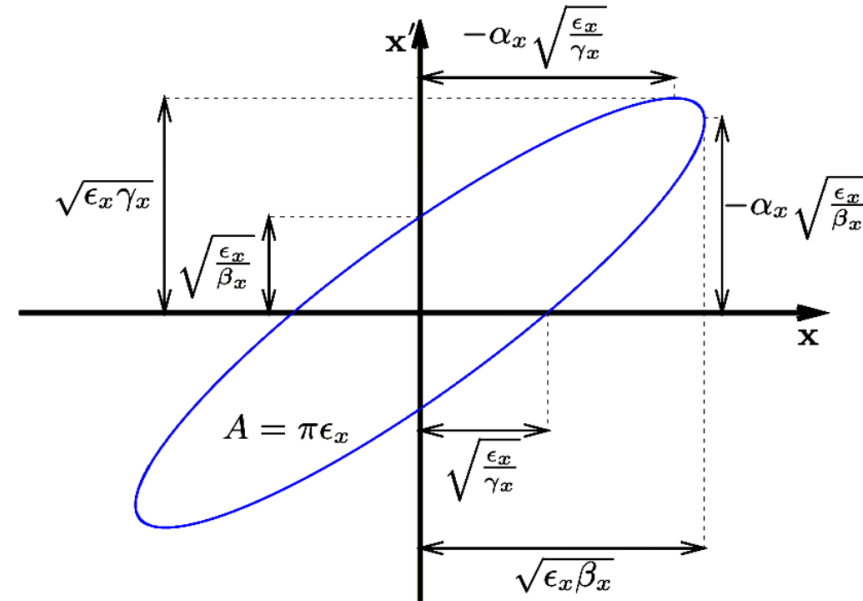
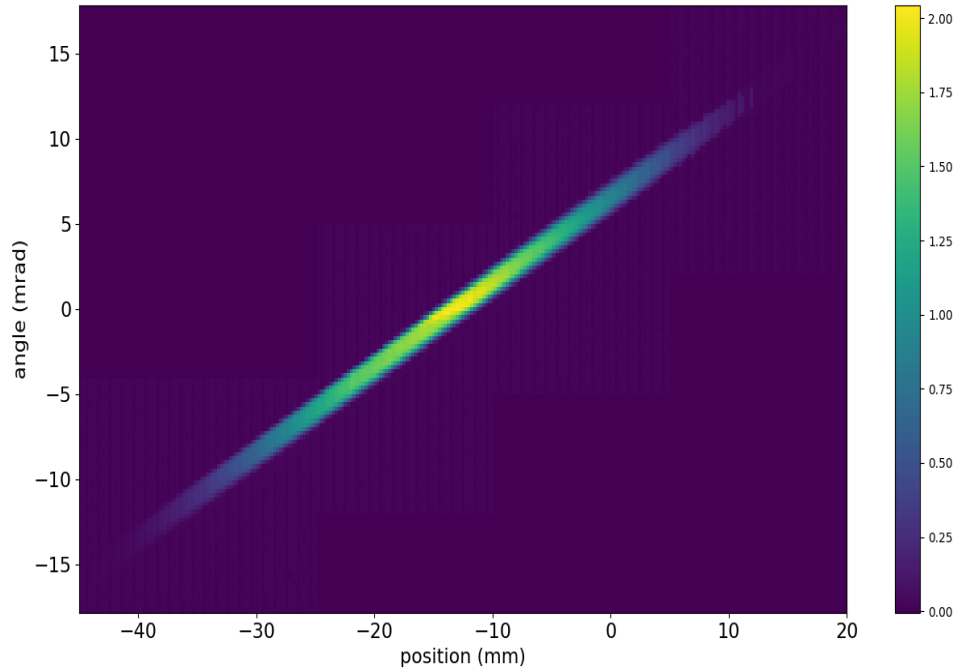
ALTO-LEB : Accélérateur Linéaire & Tandem d'Orsay – Low Energy Beam





Emittance

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



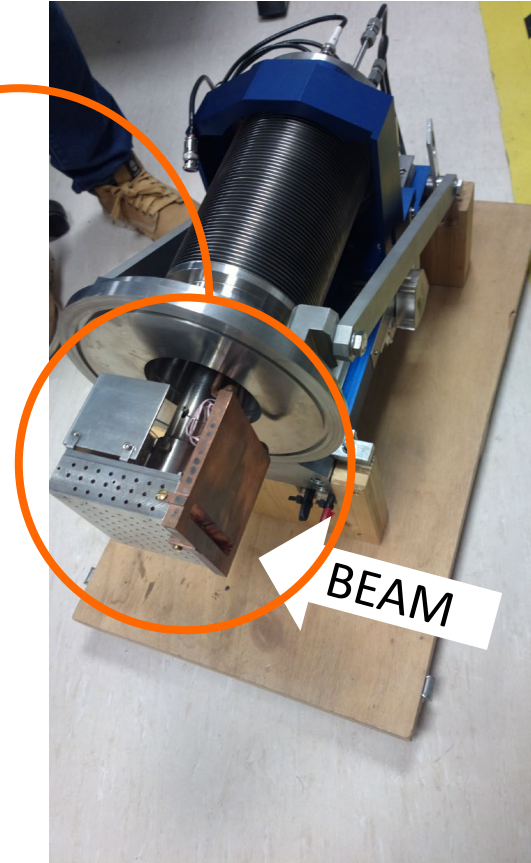
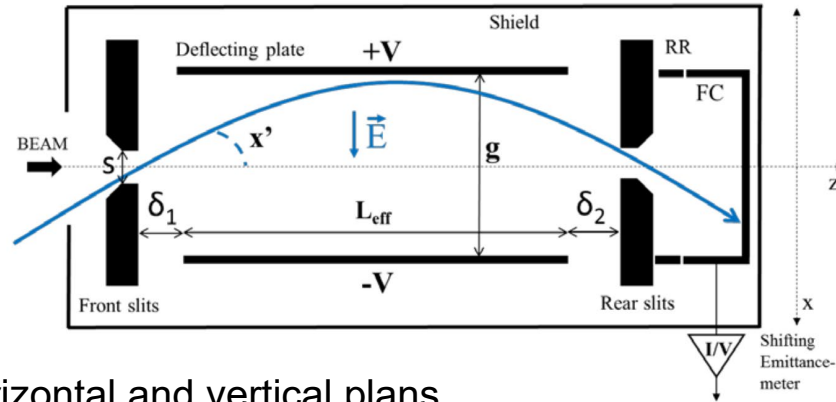
Emittance is conservative



Allison emittancemeter



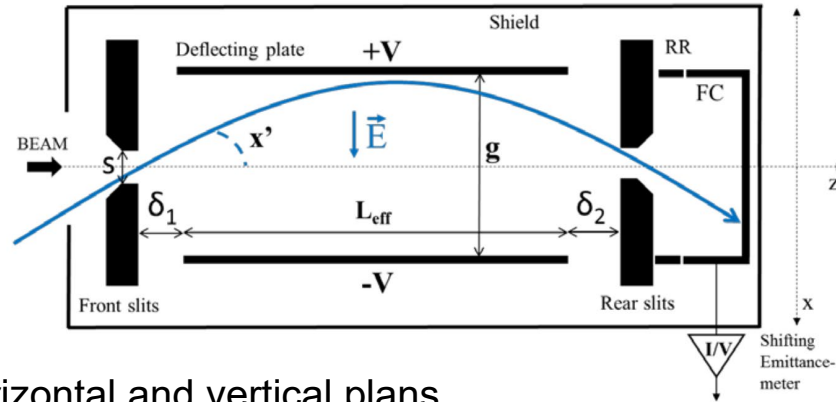
$$x' = \frac{\Delta V}{4Ug} \frac{L_{eff} + 2\delta_2}{\delta_1 + L_{eff} + \delta_2}$$



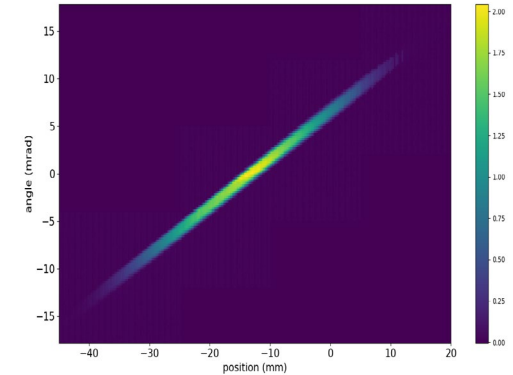
- 2D measurements in horizontal and vertical plans
- Measurements of position x and angular x' distributions, and for each couple (x,x') its intensity, amplified and converted in tension by electronics



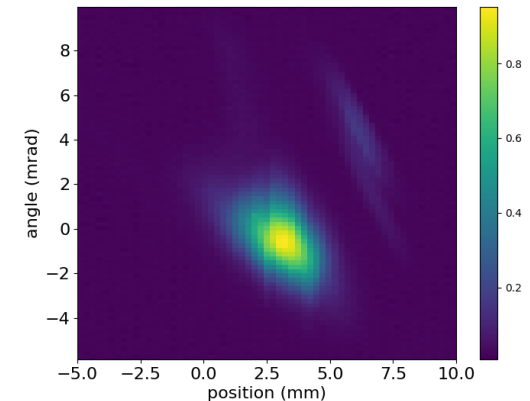
Allison emittancemeter



Measurement of horizontal phase space



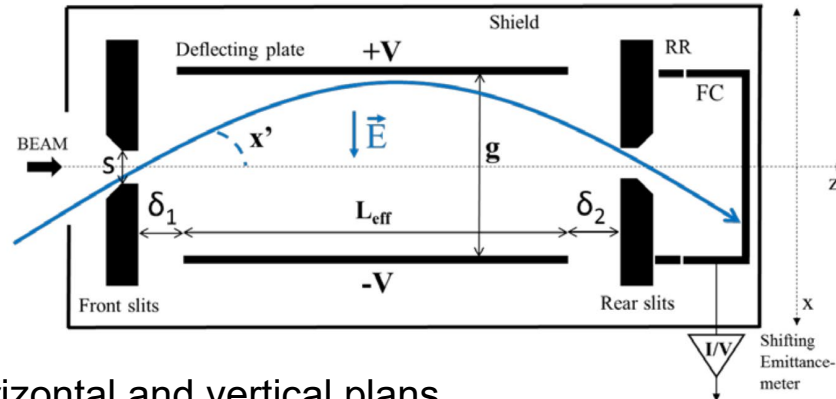
Measurement of vertical phase space



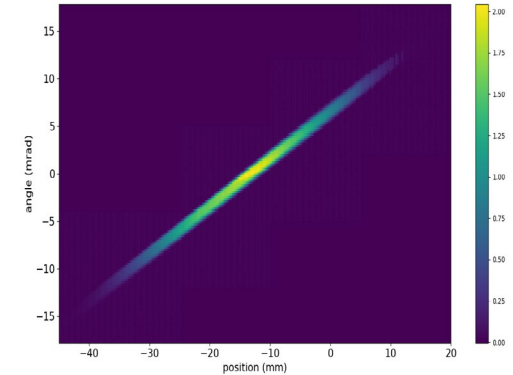
- 2D measurements in horizontal and vertical plans
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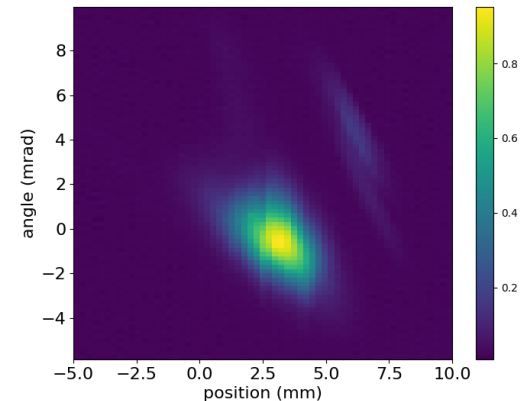
Allison emittancemeter



Measurement of horizontal phase space



Measurement of vertical phase space



- 2D measurements in horizontal and vertical plans
- Measurements of position x and angular x' distributions, and for each couple (x, x') its intensity, amplified and converted into tension by electronics
- 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



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:

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

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

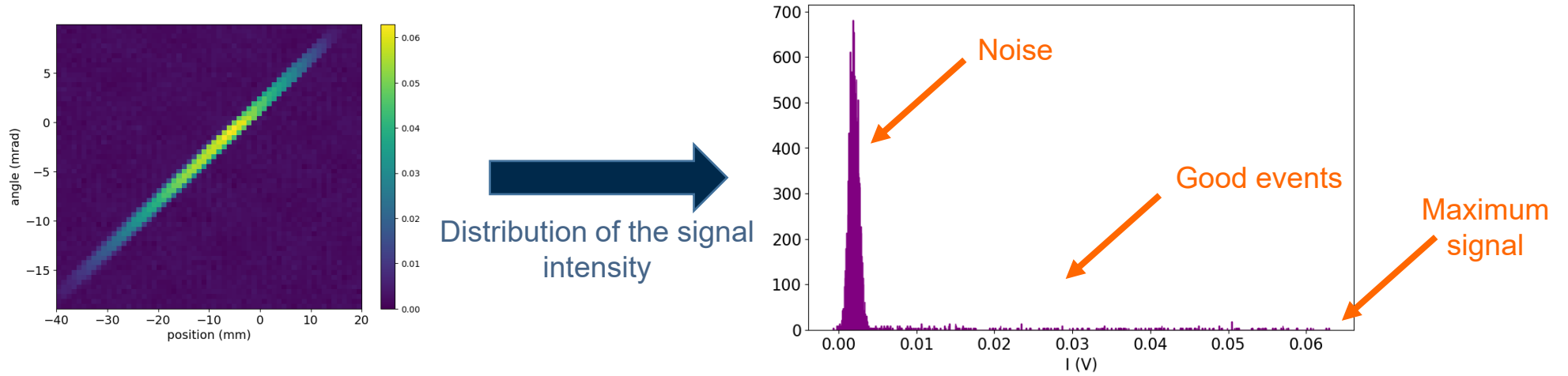
$$\delta\sigma_x = \sqrt{\left(\frac{1}{2\sigma_x}\right)^2 \delta w^2(x^2) + \left(\frac{w(x)}{\sigma_x}\right)^2 \delta w^2(x)}$$

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

$$\begin{aligned} \delta x &= 10 \mu\text{m} \\ \delta x' &= 0,025 \text{ mrad} \\ \delta I &= 9 \cdot 10^{-6} \text{ V} \end{aligned}$$

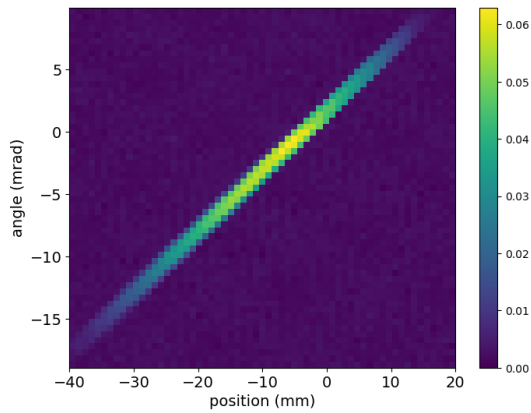


Emittance measurements analysis

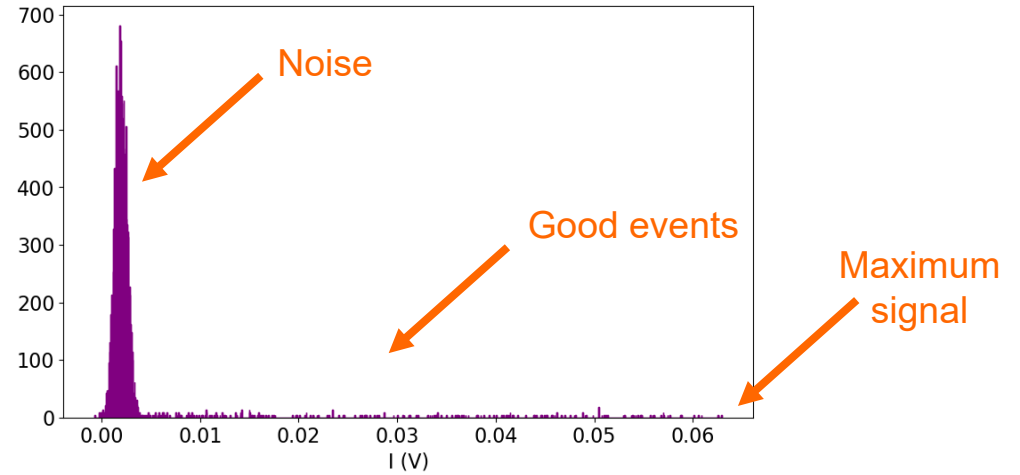




Emittance measurements analysis



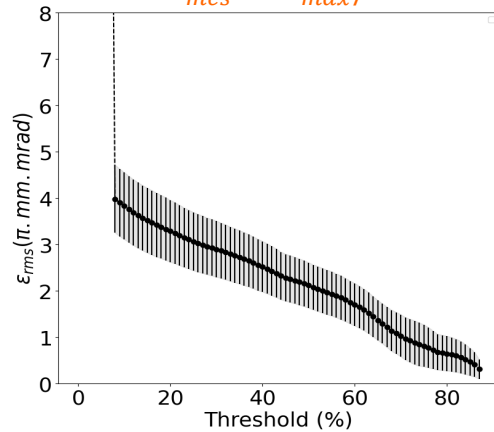
Distribution of the signal intensity



Noise substraction :

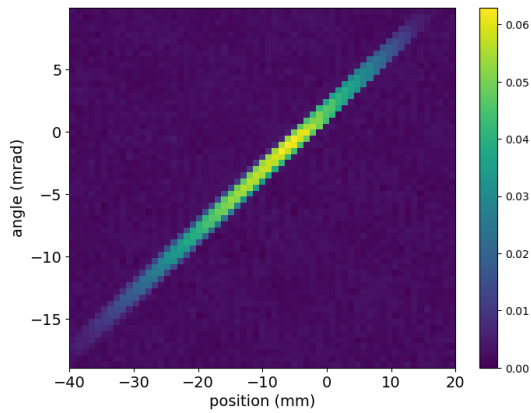
Threshold of maximum signal :

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

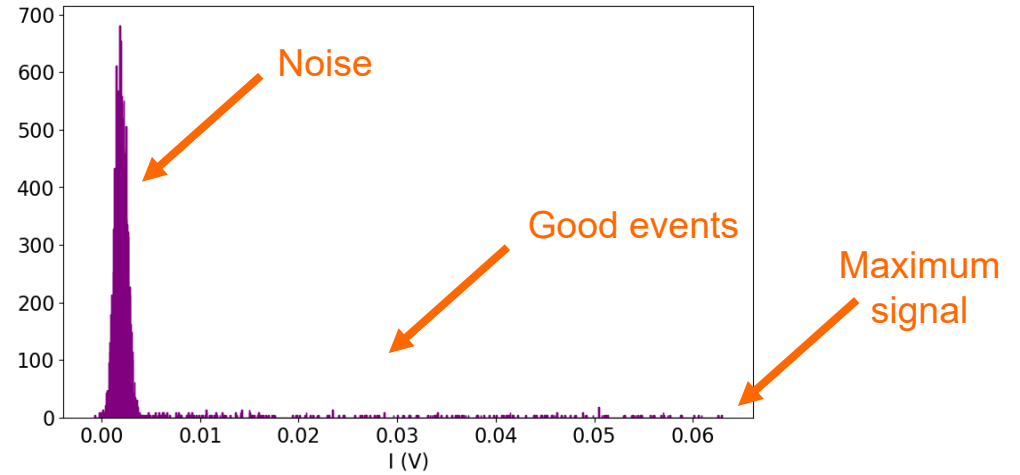




Emittance measurements analysis



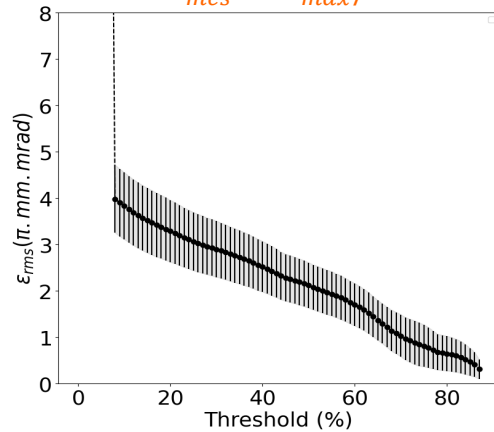
Distribution of the signal intensity



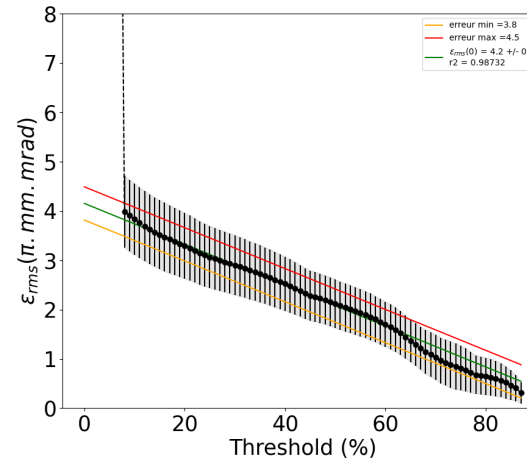
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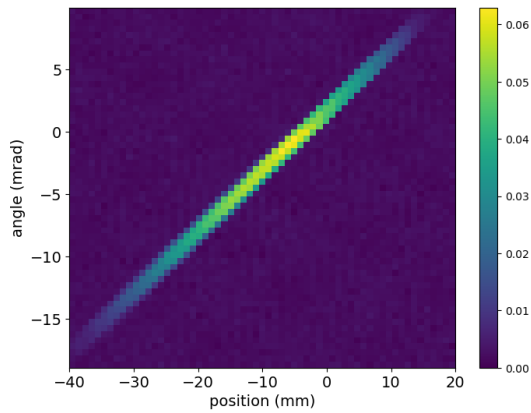


Linear regression

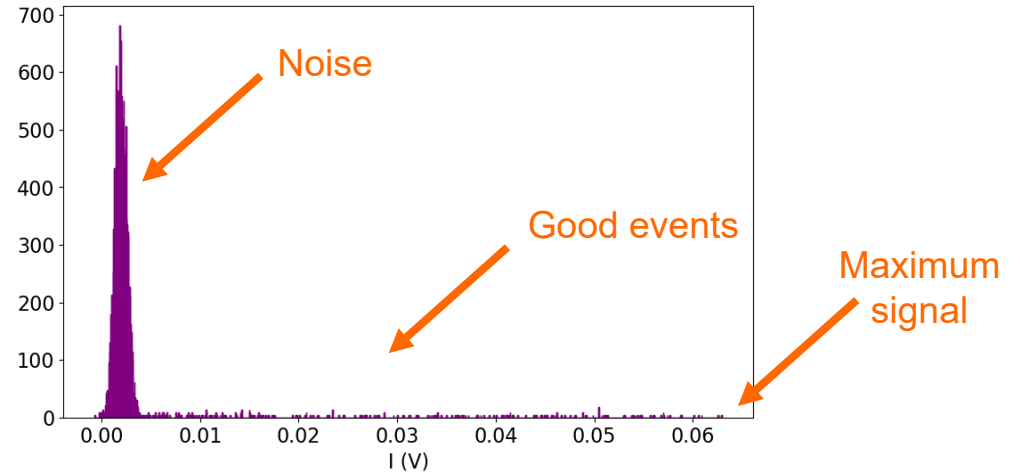




Emittance measurements analysis



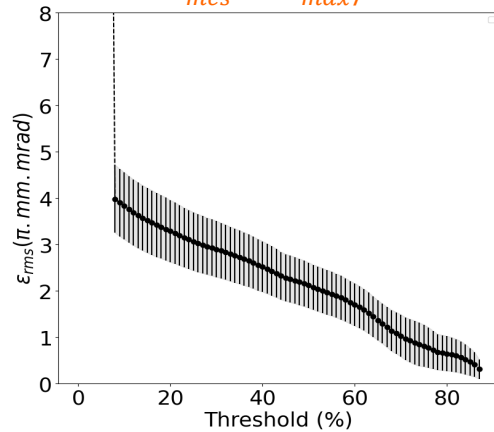
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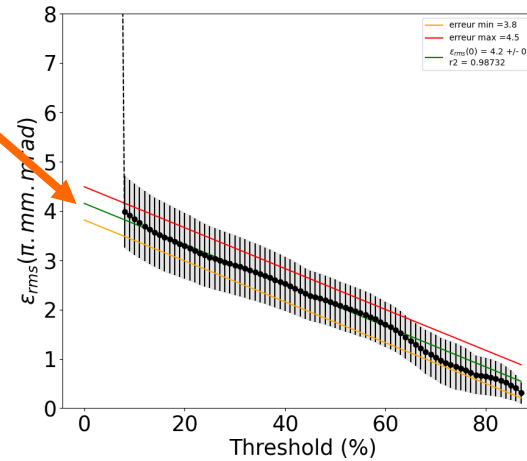
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Linear regression

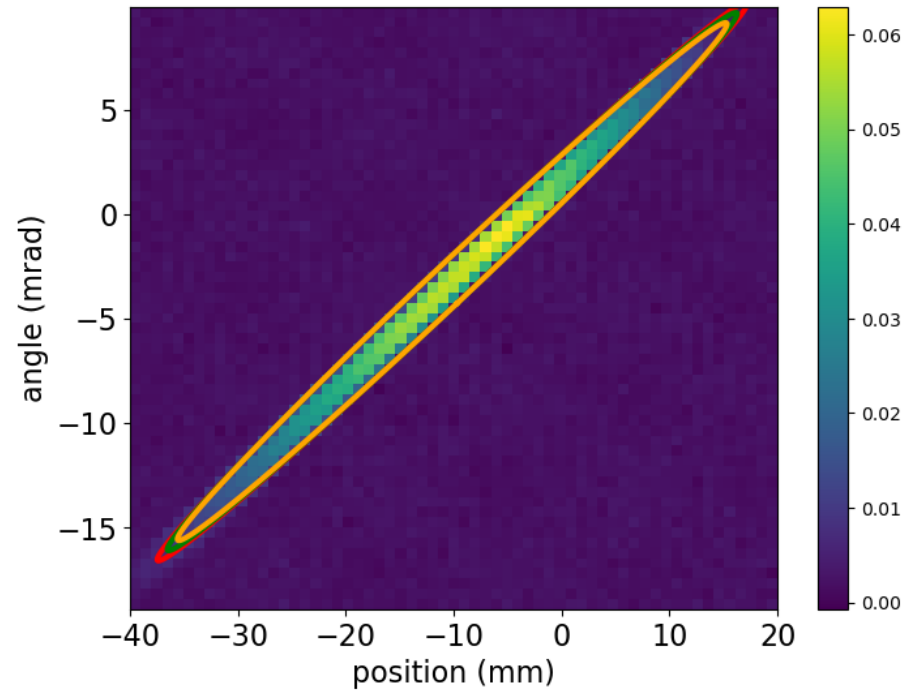
Value of emittance





Reconstitution of phase ellipse ($6 \epsilon_{\text{rms}}$):

Same method to obtain Twiss parameters





Results of parametric studies : Step of measurements

T_acceleration (kV)
30

Position initiale (mm)
-8

Position finale (mm)
16

Pas de position (mm)
0,25

Nb positions
97

HT max (V) Angle max
140 14

HT min (V) Angle min
20 2

HT step (V) Angle step
2 0,1

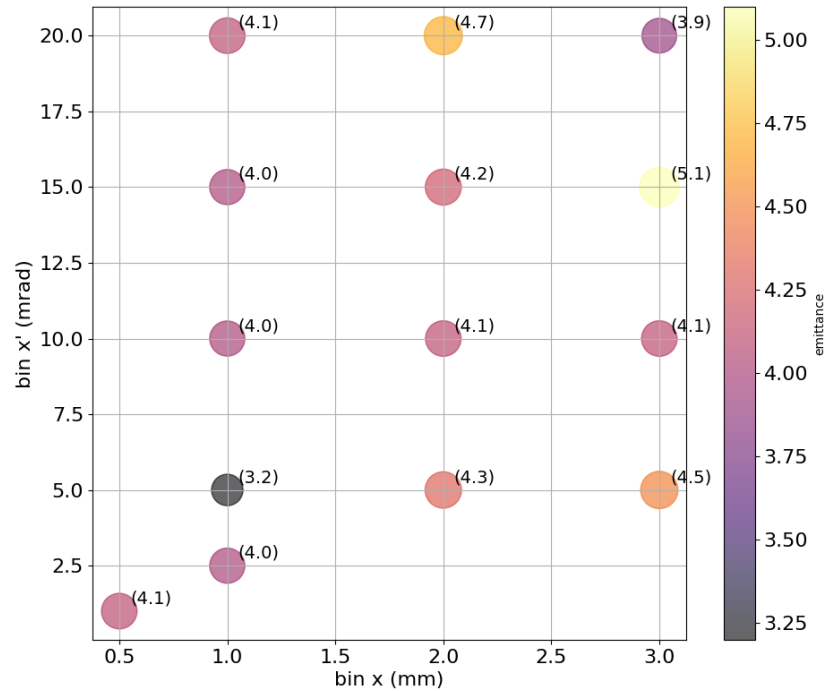
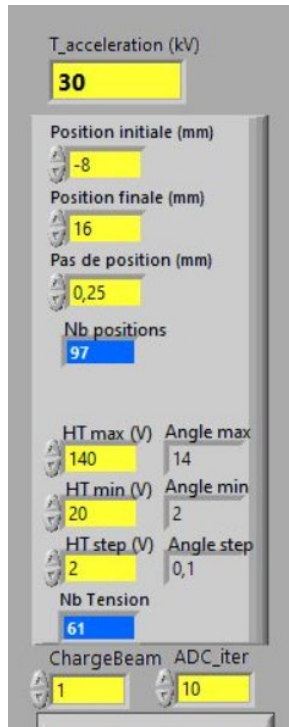
Nb Tension
61

ChargeBeam ADC_iter
1 10

*Part of control command
interface of Emittancemeter*



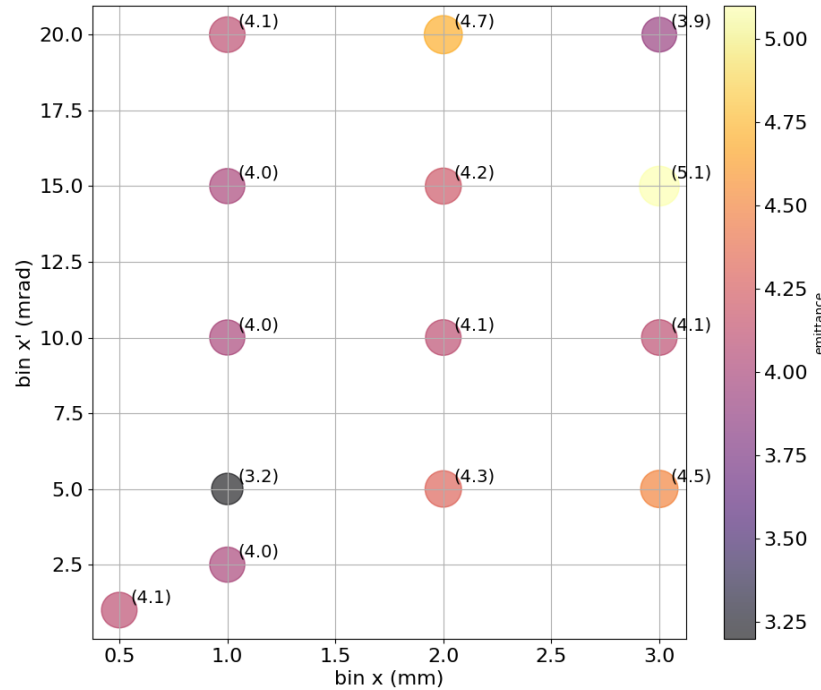
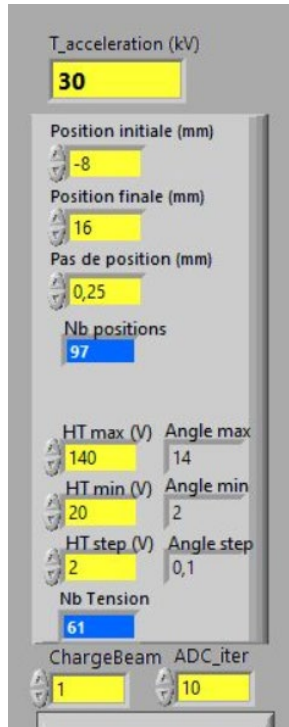
Results of parametric studies : Step of measurements



Part of control command interface of Emittancemeter



Results of parametric studies : Step of measurements



Mean = $4.2 \pi. mm. mrad$

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



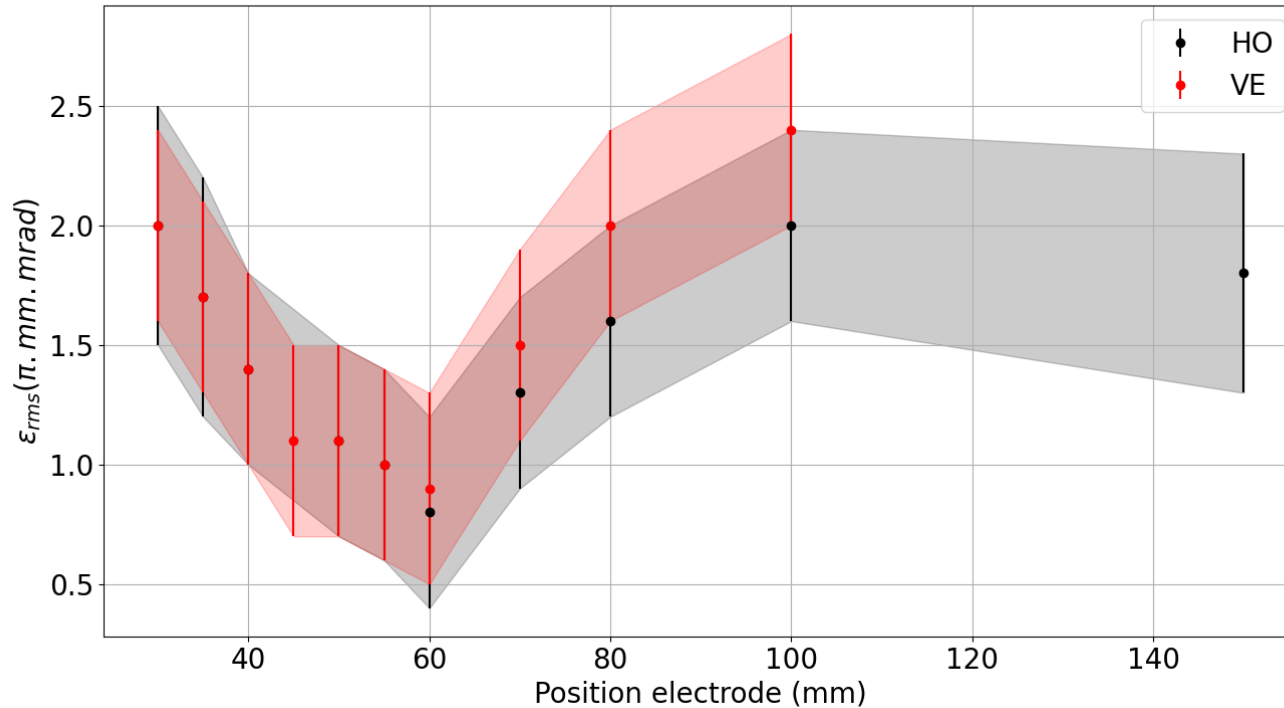
Error due to step of measurement

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

Part of control command interface of Emittancemeter



Results of parametric studies : Position of extraction electrode

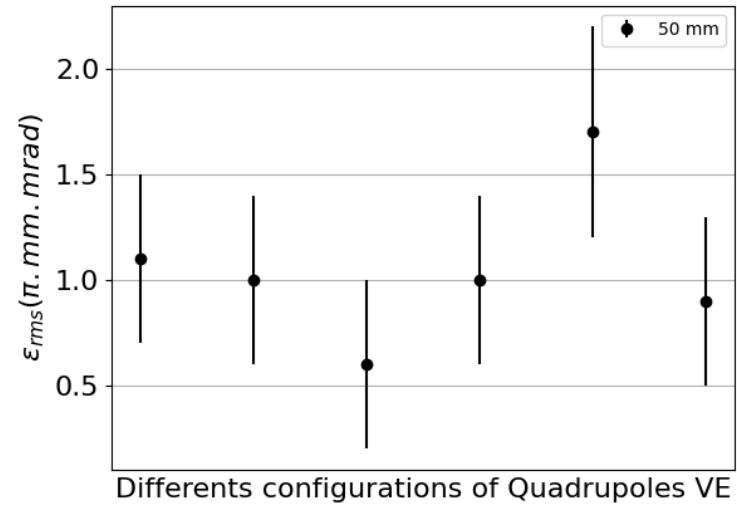


➔ Minimum of emittance at position 60 mm in both plans



Results of parametric studies : Voltage on quadrupoles

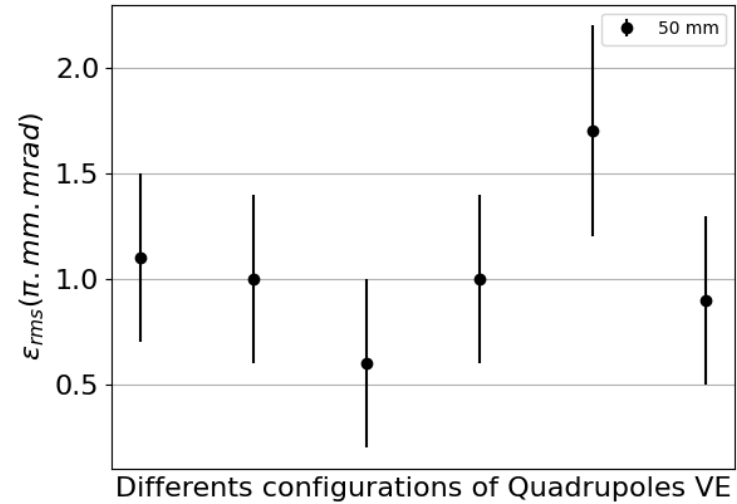
Vertical plan



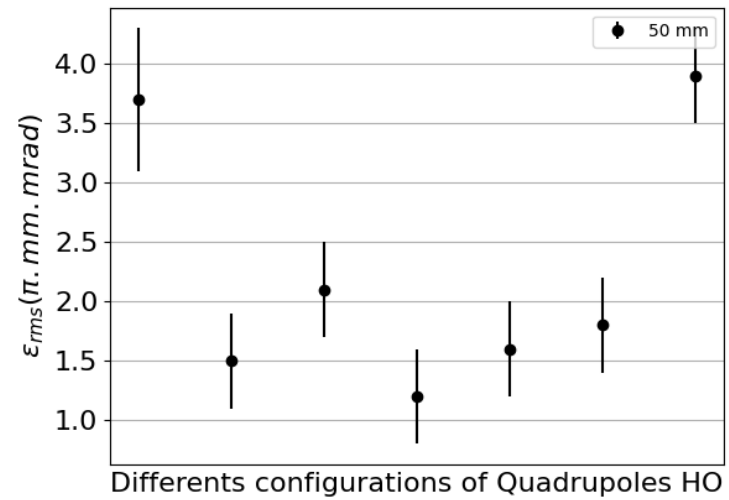


Results of parametric studies : Voltage on quadrupoles

Vertical plan



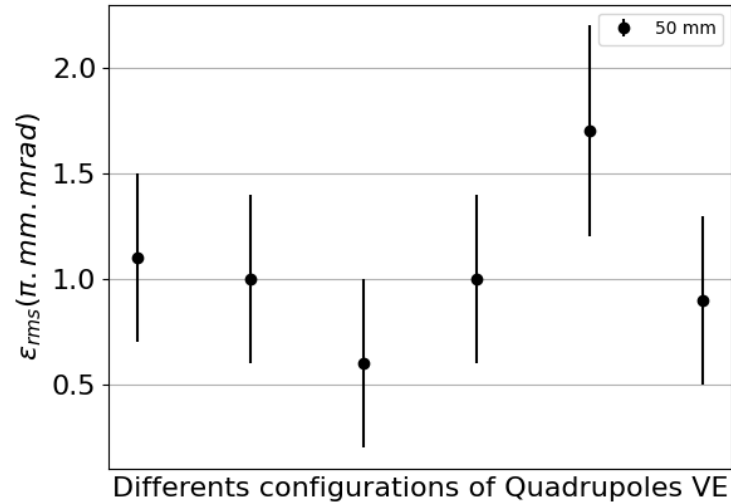
Horizontal plan



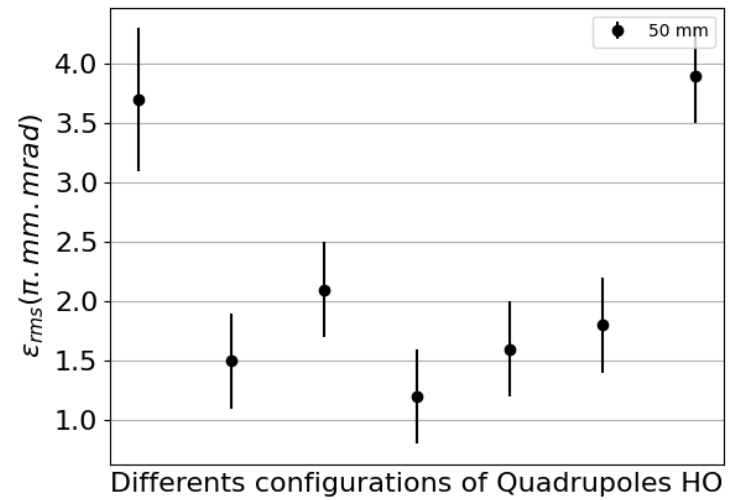


Results of parametric studies : Voltage on quadrupoles

Vertical plan



Horizontal plan

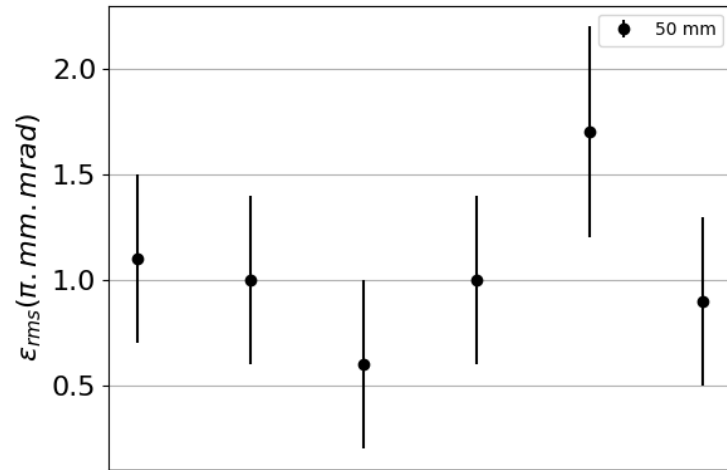


Problem : Emittance not conservative



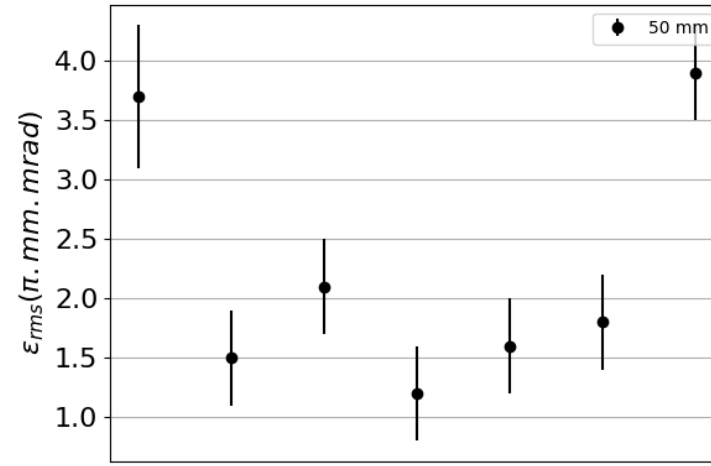
Results of parametric studies : Voltage on quadrupoles

Vertical plan

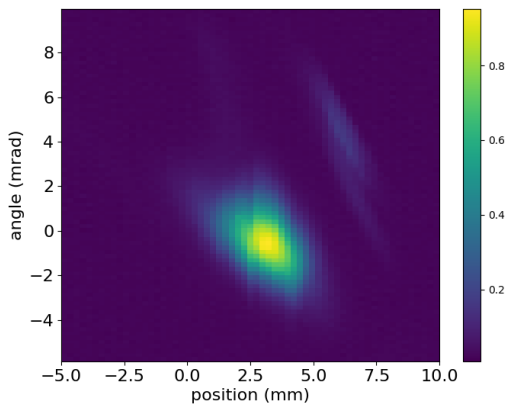


Differents configurations of Quadrupoles VE

Horizontal plan

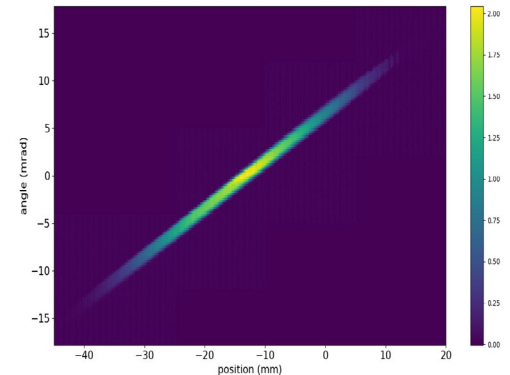


Differents configurations of Quadrupoles HO



Problem : Emittance not conservative

Influence of the shape of the beam on the analysis?

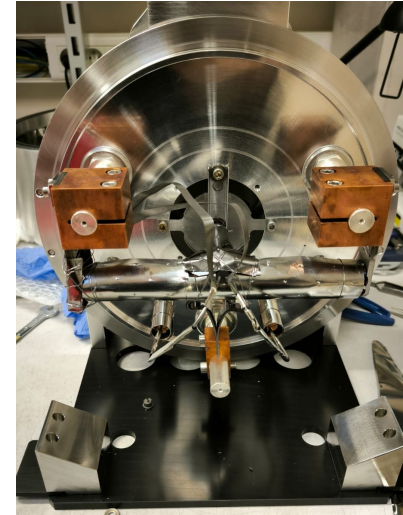




Results of parametric studies : Oven current

Study of target-ion source different :

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



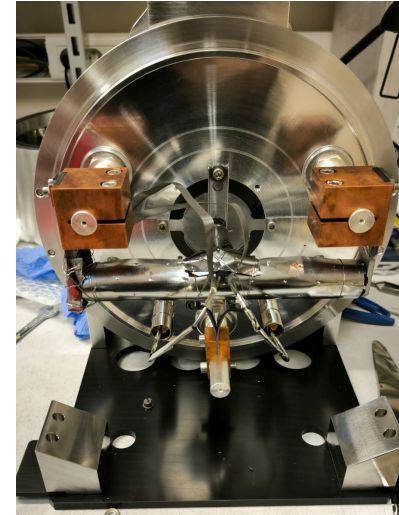
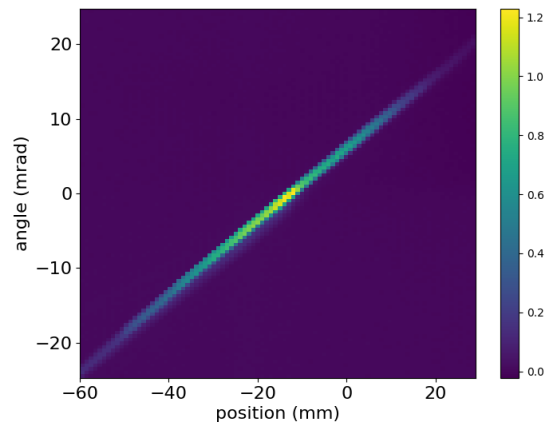


Results of parametric studies : Oven current

Study of target-ion source different :

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*« Large » beam
in Horizontal plan*



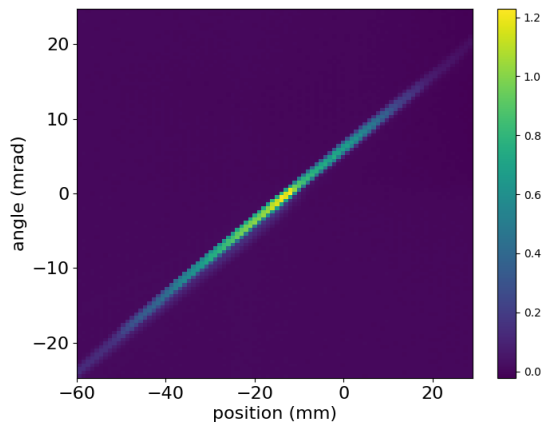


Results of parametric studies : Oven current

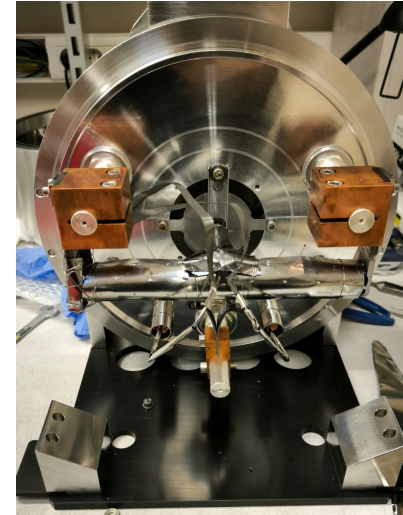
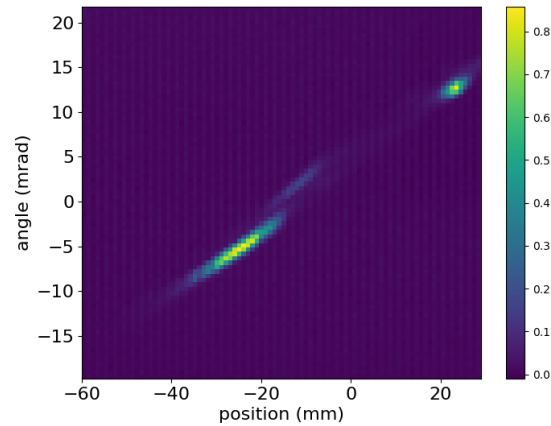
Study of target-ion source different :

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*« Large » beam
in Horizontal plan*



*« Small » beam
in Horizontal plan*



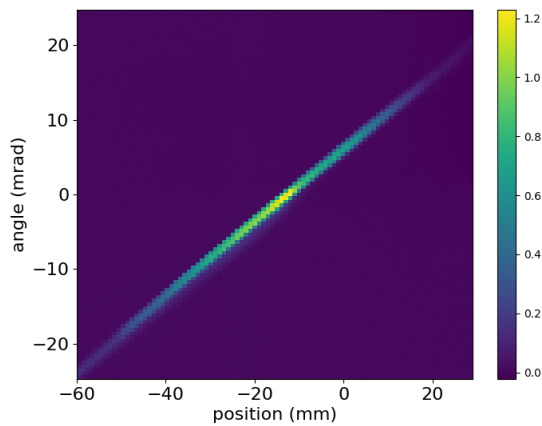


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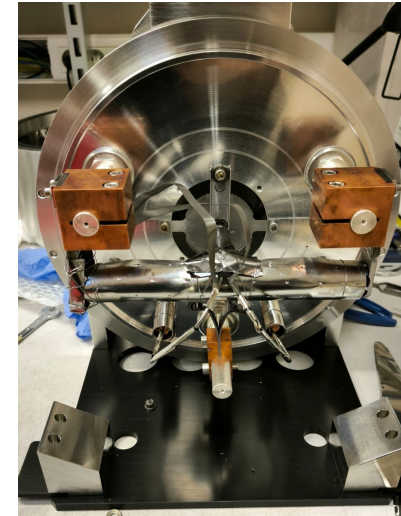
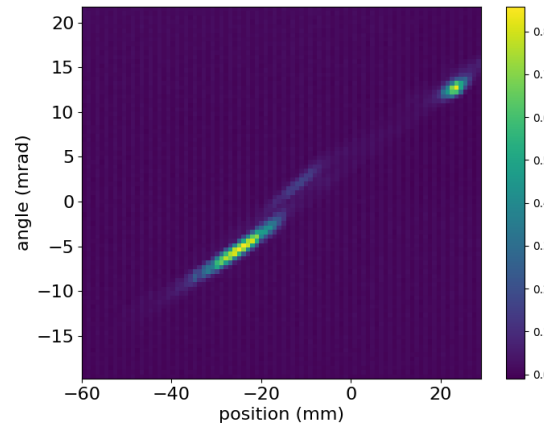
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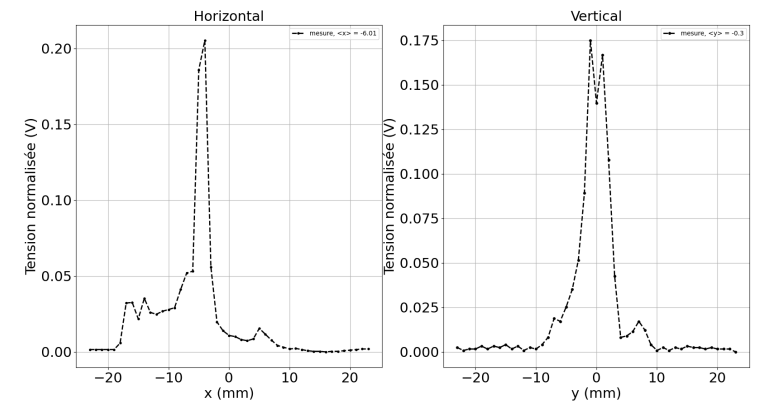
« Large » beam
in Horizontal plan



« Small » beam
in Horizontal plan



Profile measurement

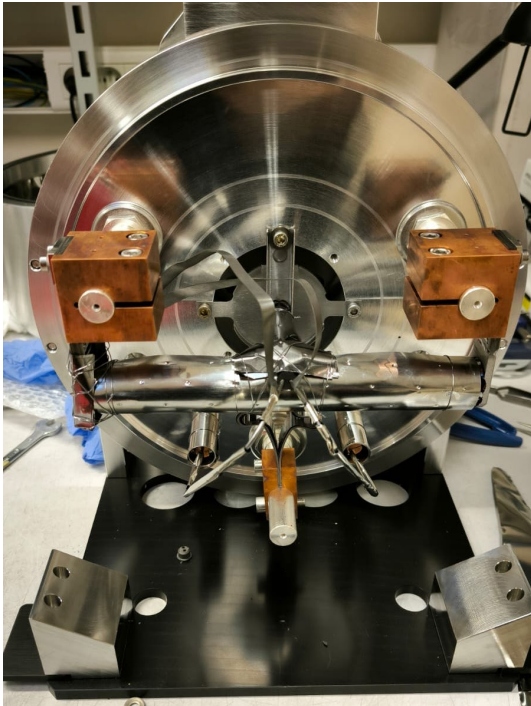




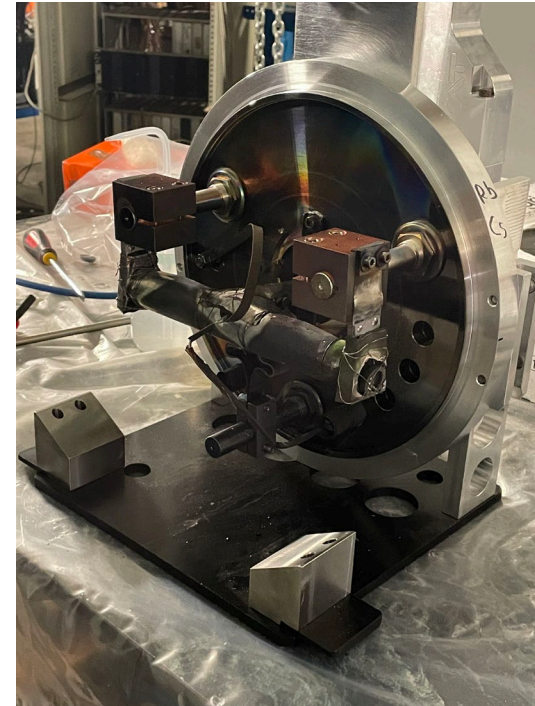
Results of parametric studies : Oven current

Study of target-ion source different :

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



After 1 week





Conclusion

- Emittance data analysis still ongoing
 - Influence of beam shape to study further
 - Have we forgotten some errors ?
 - Additional oven

- Target-ion source need to be studied
 - Ionisation inside ionisation tube
 - Heating of source

- Characterisation of the target-ion source
 - Inverse transport of the beam to the exit of the extraction electrode



Thank you for your attention



ALTO : Accélérateur Linéaire & Tandem d'Orsay

