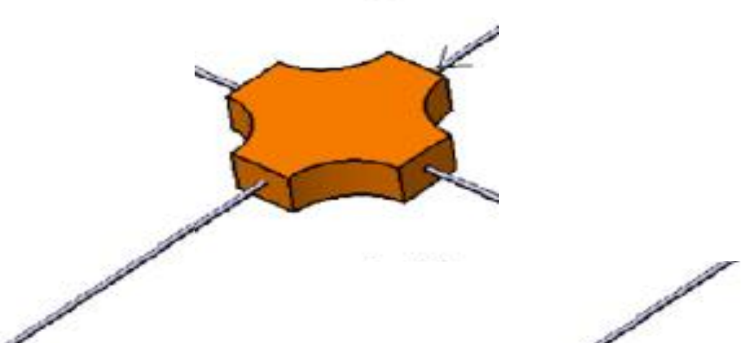
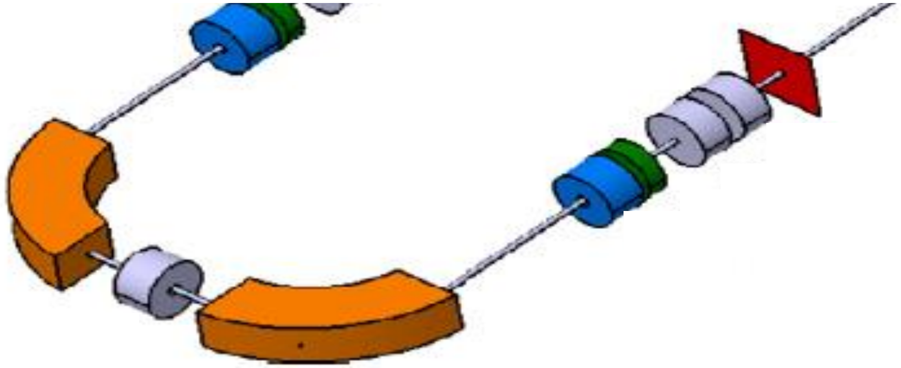


The DESIR High Resolution Separator



Speaker : **Julien Michaud**

CENBG CNRS IN2P3 Les deux infinis Spiral2 DESIR

Isol-France meeting March 15 2021

What is the HRS ?

*HRS : **H**igh **R**esolution mass **S**eparator*

Lattice and elements :

D : Two 90° *magnetic* dipoles (36° entrance/exit angles)
MQ : Matching quadrupoles
FQ : Focusing quadrupoles
FS : Focusing sextupoles
M : A multipole (up to 5th order)

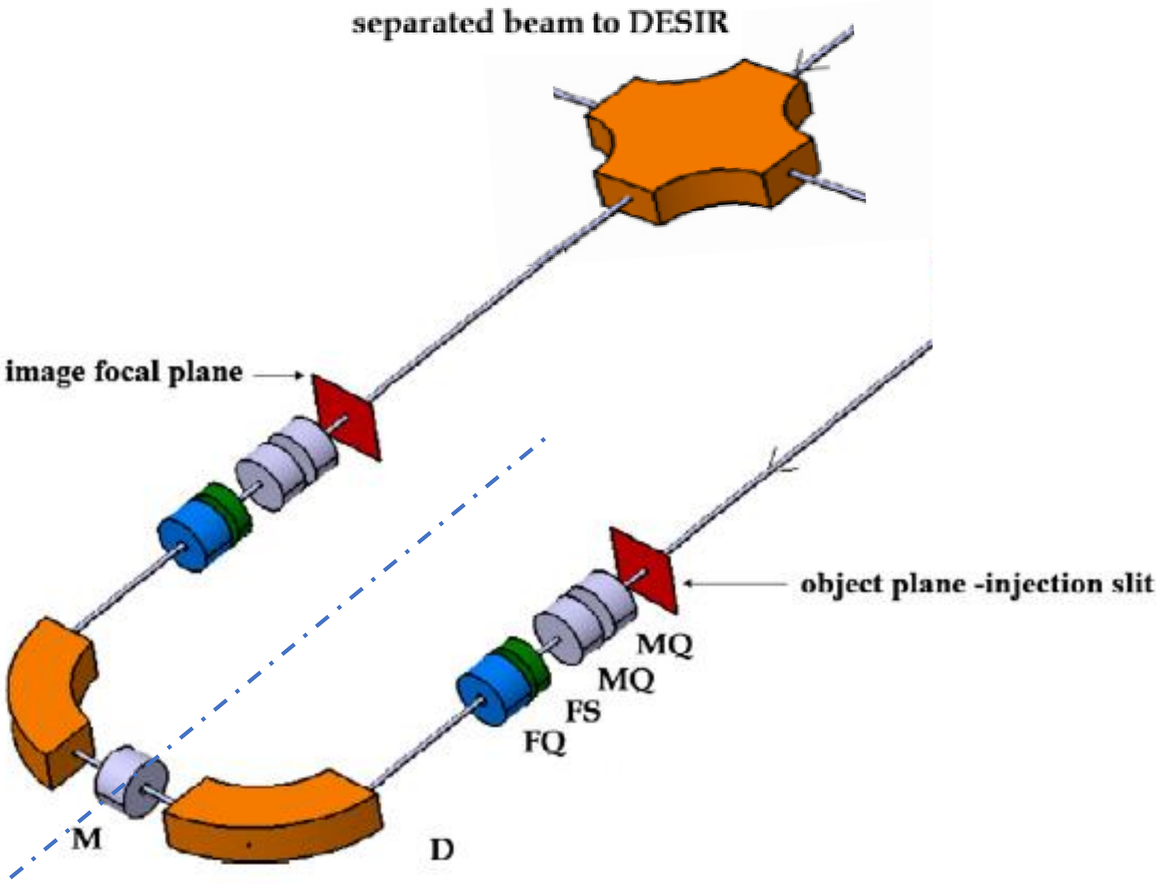
Electrostatic (MQ, FQ, FS, M)

Configuration: MQ-MQ-FS-FQ-D-M-D-FQ-FS-MQ-MQ

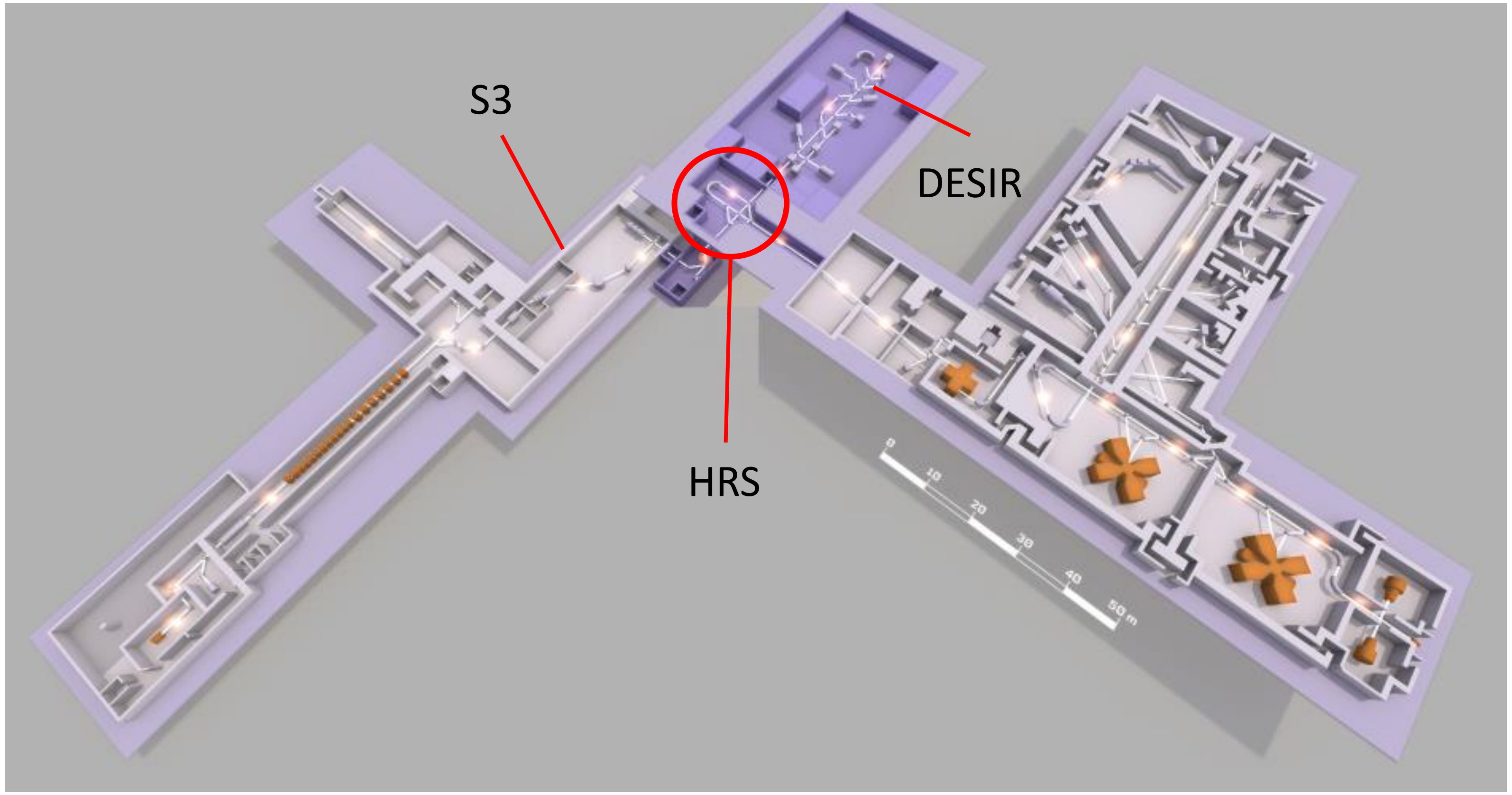
Mirror symetry is imposed to minimize aberrations

+ a transport section :

- Two quadrupole doublets
- Electrostatic benders



The HRS in DESIR



Located at the entrance of the DESIR hall, the HRS will purifiy the beam from the S3 and SP1 facilities and send it to the DESIR hall where it will be re-purified by the GPIB and Piperade setups, or send directly to the experiments.

Design and objectives

Main objective : *Decrease isobaric contamination for high-intensity beams with a resolving power of $\frac{M}{\Delta M}$ up to 20 000*

Constrains and recquirements :

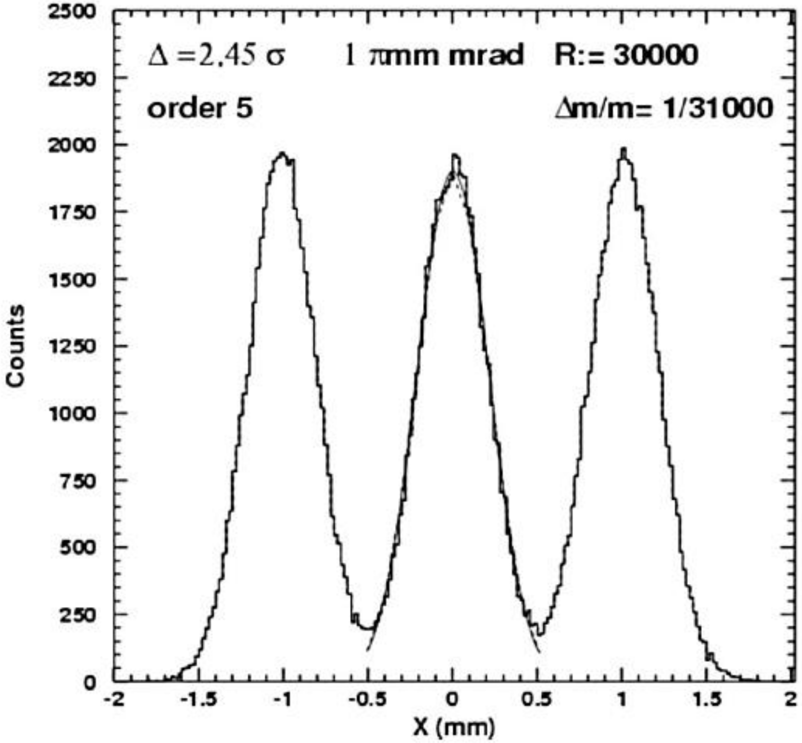
- High transmission (ideally close to 100%) and high resolving power (up to R = 20000) to provide monoisotopic beams of exotic nuclides
- Match beam emittance from RFQ cooler SHIRaC (ε<3π mm.mrad, ΔE<1 eV at 60 keV)
- Compact configuration (12 m x 8 m)

➔ Design by T. Kurtukian Nieto et al. [1] gives a maximal resolving power of 31 000 for the DESIR HRS (1π mm.mrad emmitance)

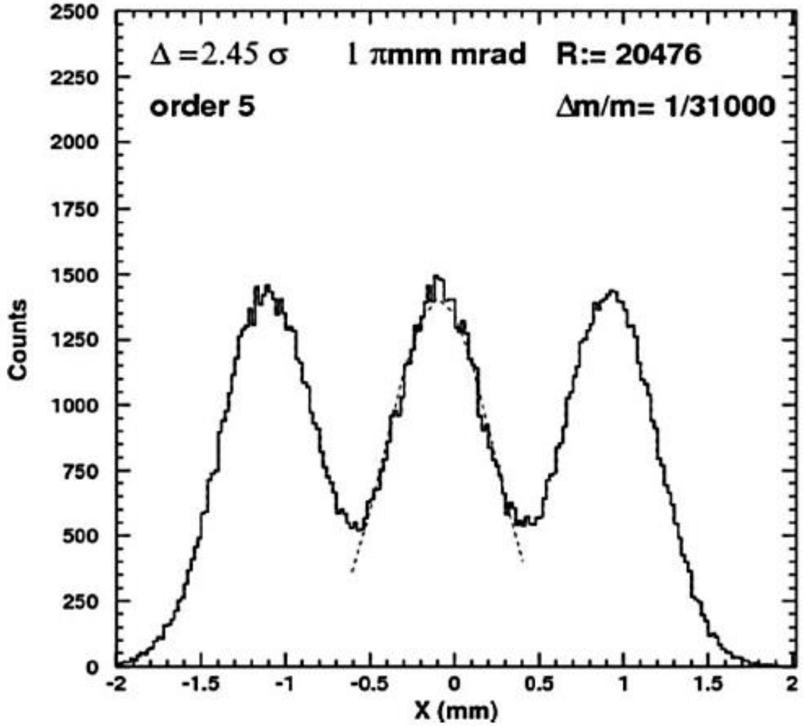
T. Kurtukian-Nieto et al. / Nuclear Instruments and Methods in Physics Research B 317 (2013) 284–289

Design and objectives - Misalignment

Mass spectrum – No misalignment



Mass spectrum – Maximal tolerance on misalignment



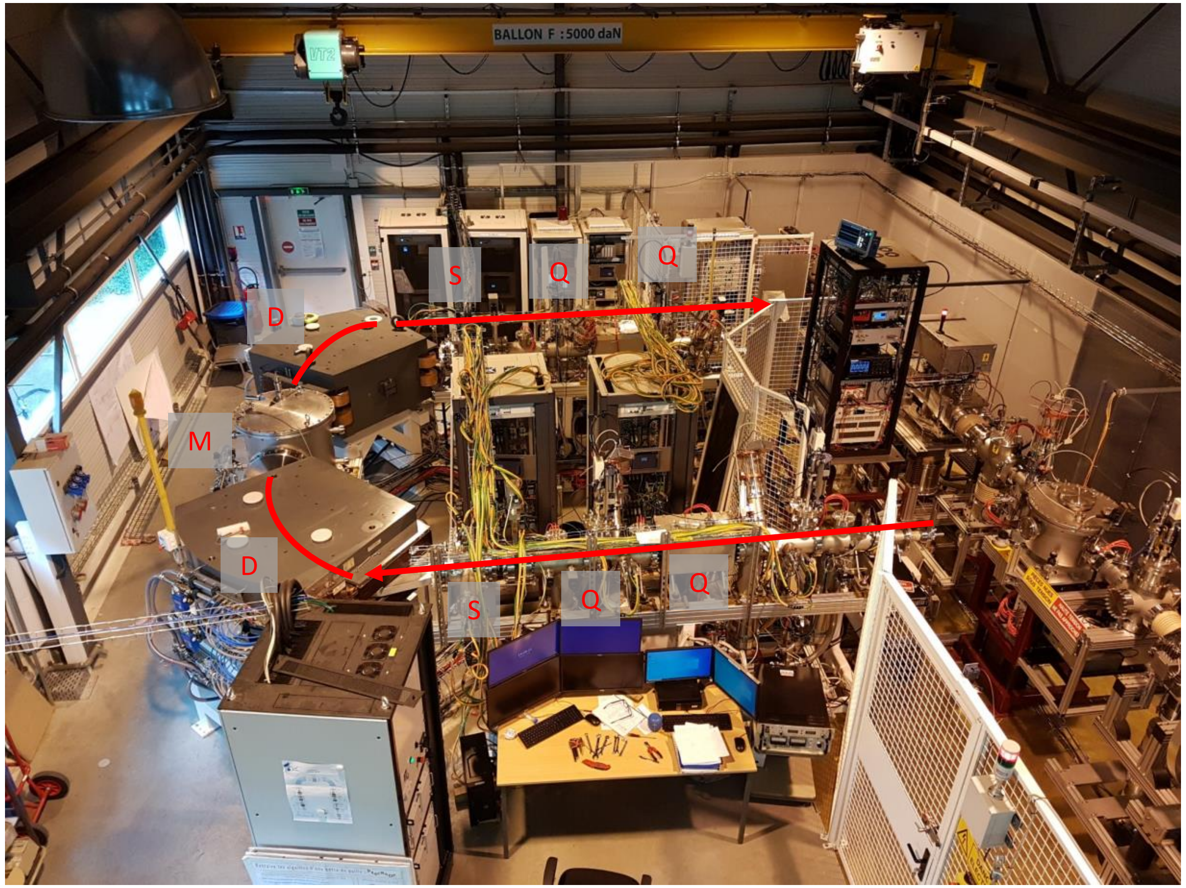
➔ A resolving power of ~20 000 can be achieved (for 1π mm.mrad , 60keV)

Positioning precision tolerances for the DESIR-HRS.

	X shift (mm)	Y shift (mm)	X tilt (mrad)	Y tilt (mrad)	θ(mrad)
MQ	± 0.1	± 0.1	± 3.5	± 3.5	± 3.5
FS	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
FQ	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
D	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
M	± 0.1	± 0.1	± 3.5	± 3.5	± 3.5

The HRS at CENBG

Mounting hall at CENBG

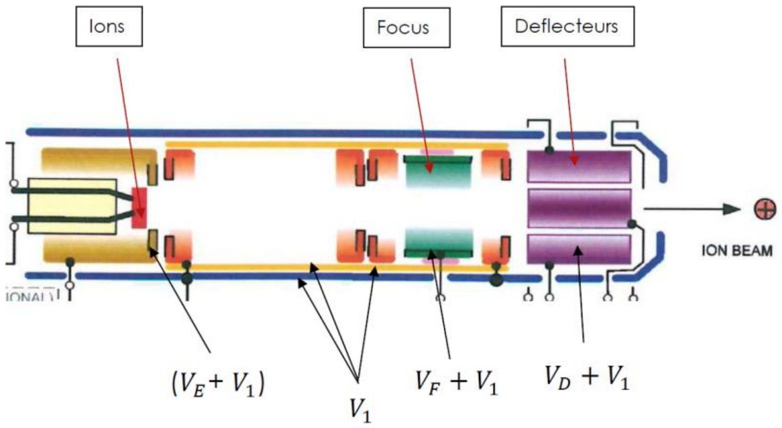


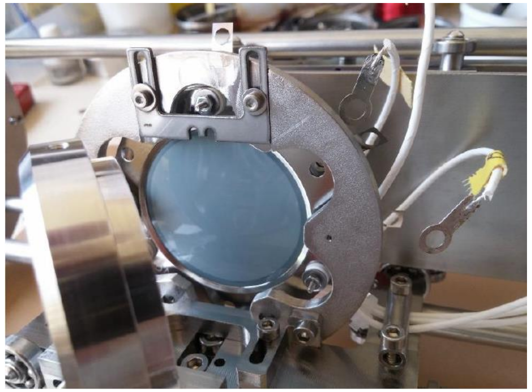
HRS

Current status – under commissionning

Two main tools are needed for the commissionning of the HRS :

Cs_{133}



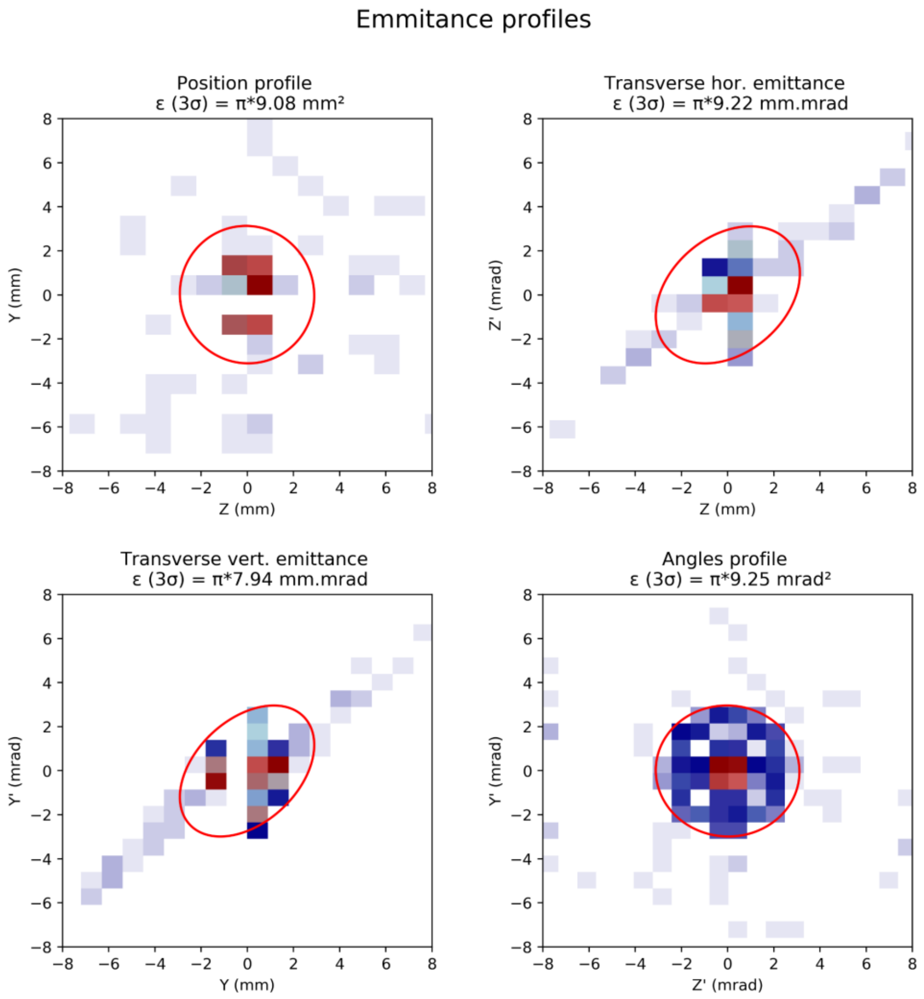


Ion source : - 0 – 30 keV
- $\Delta E \sim 0{,}1\ eV$
- $\varepsilon \sim 5 - 10\pi$ mm.mrad at 5keV

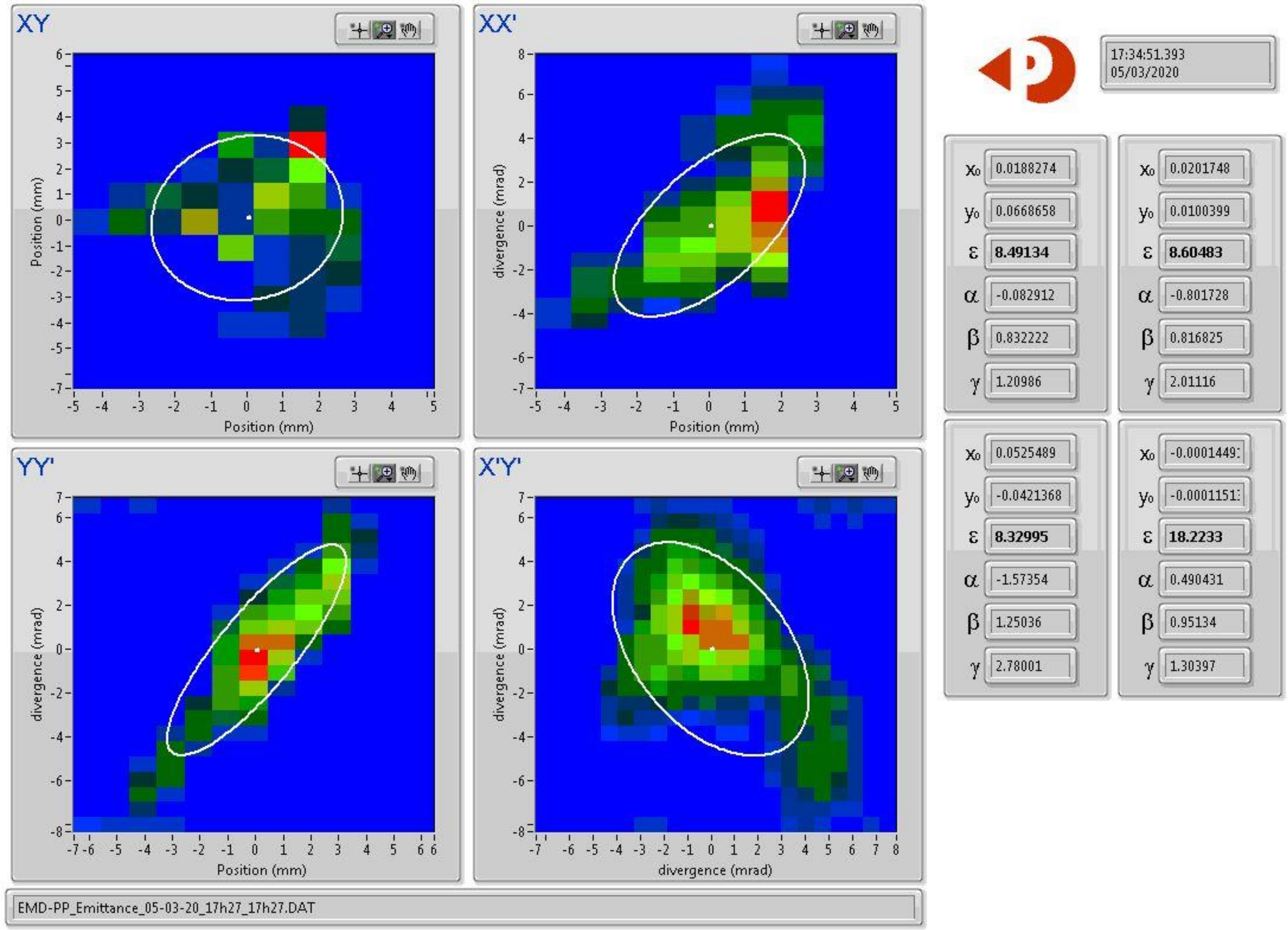
Emittancemeter: - pepperpot-like
- 40x21 holes
- 20 μm holes

➔ Necessity to understand these tools first (test bench) !

Test bench : source and emittance-meter

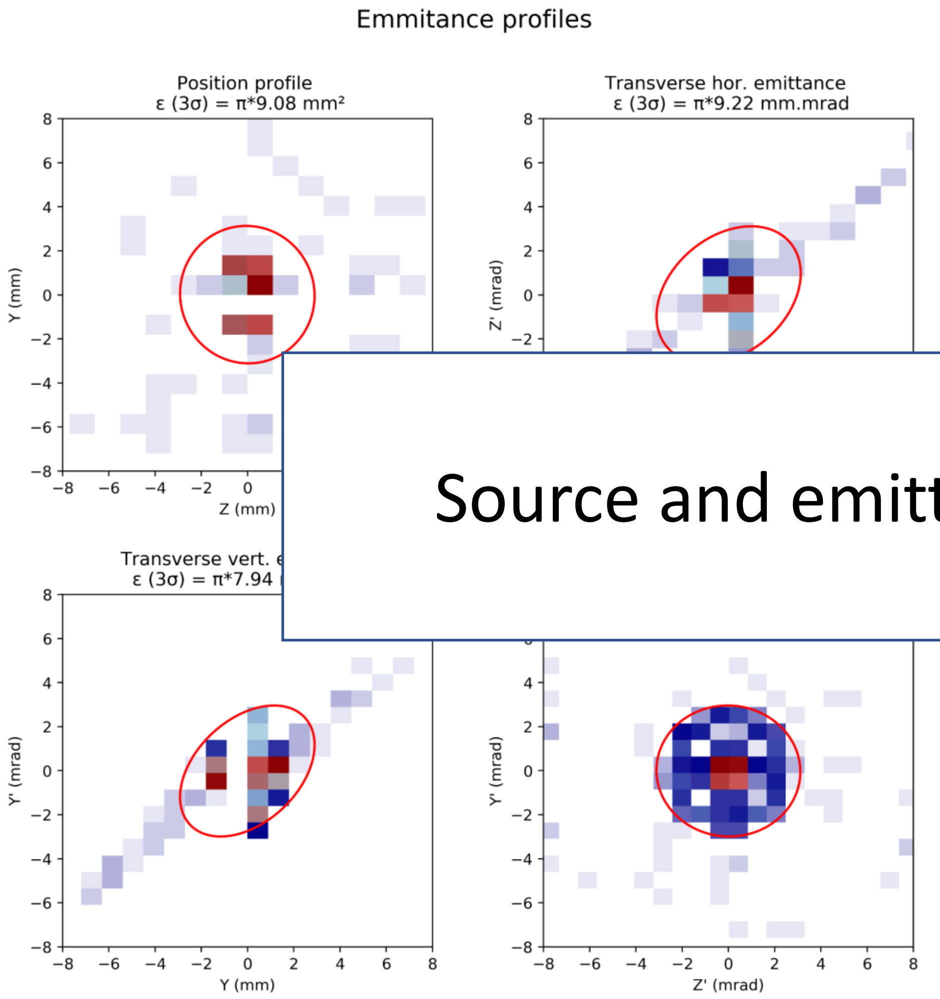


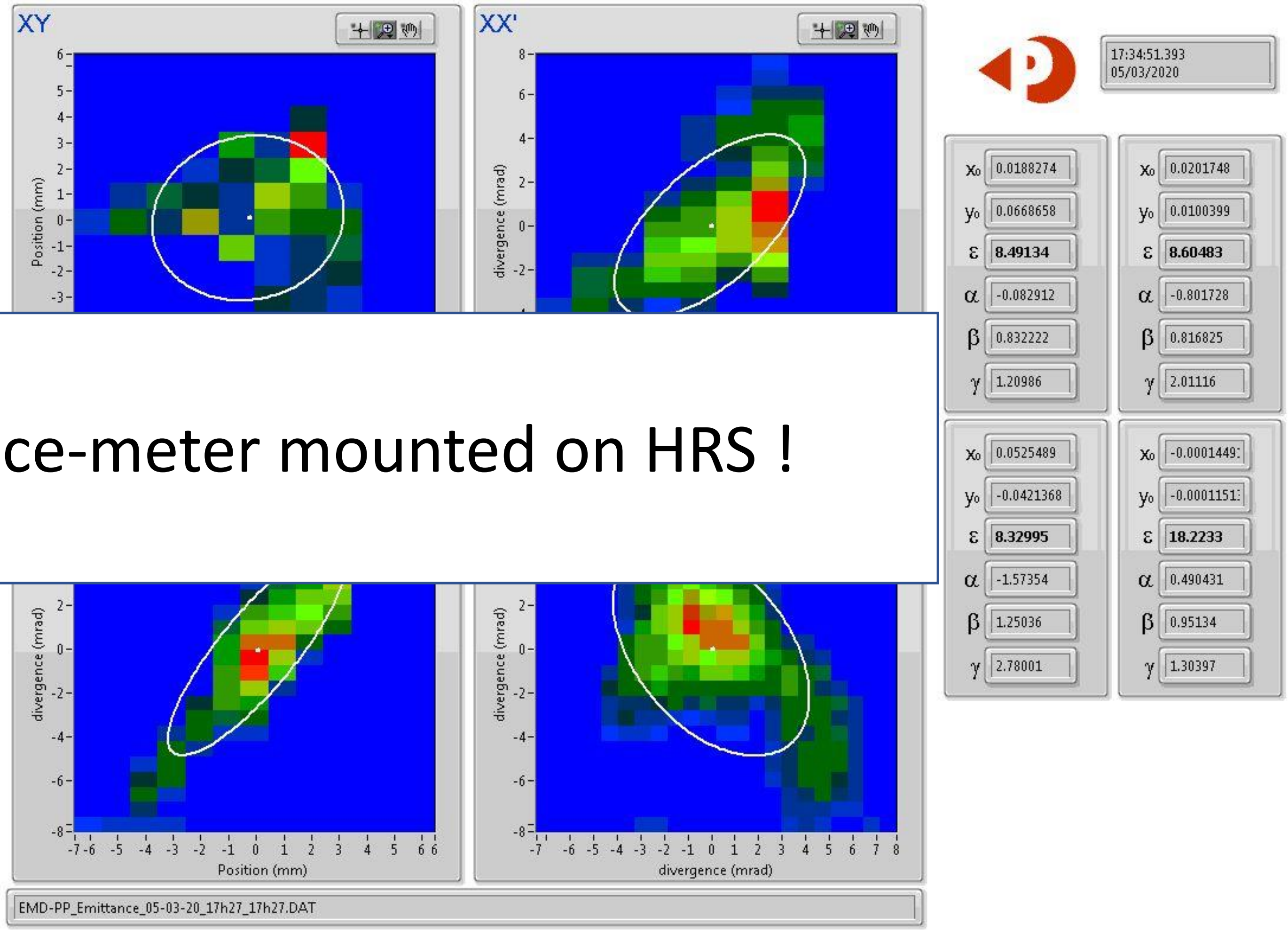
Simulation



Experiment

Test bench : source and emittance-meter





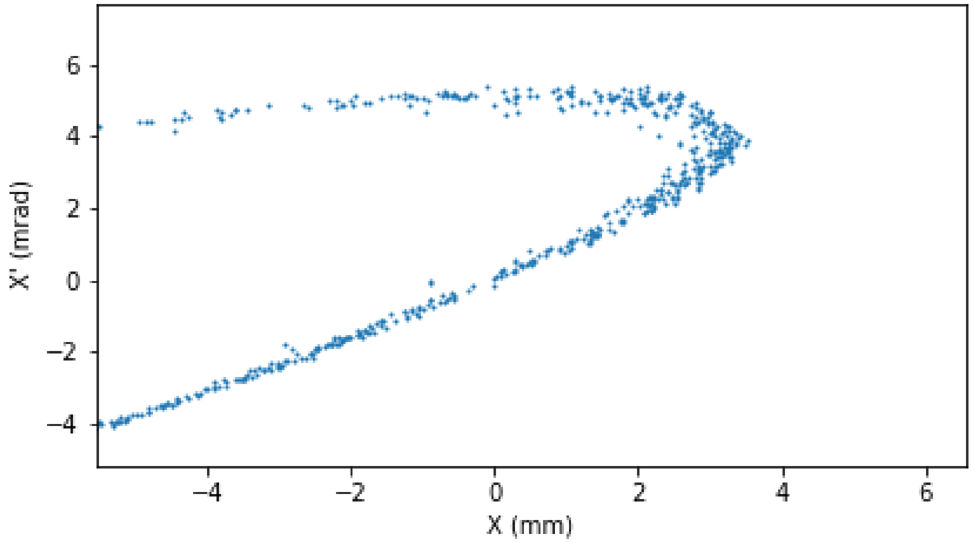
Source and emittance-meter mounted on HRS !

Simulation

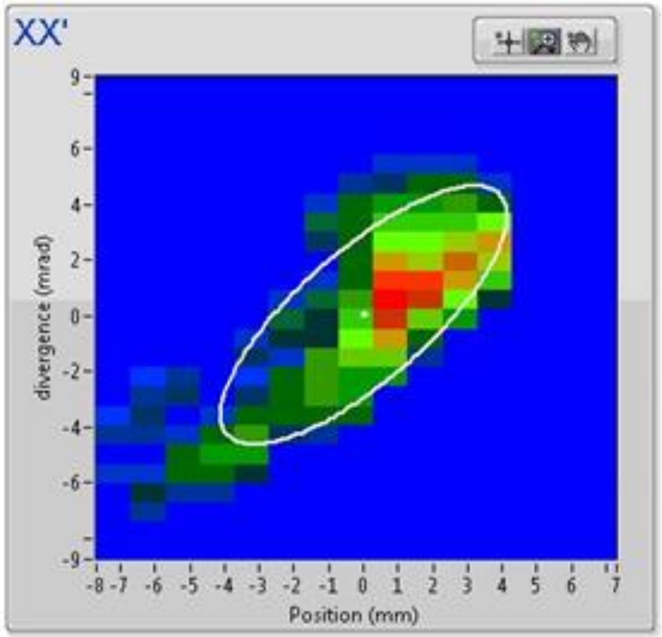
Experiment

Current work : correction of aberrations with the multipole

Higher order aberrations will lead to distorsions of the beam (spatial space or phase space)



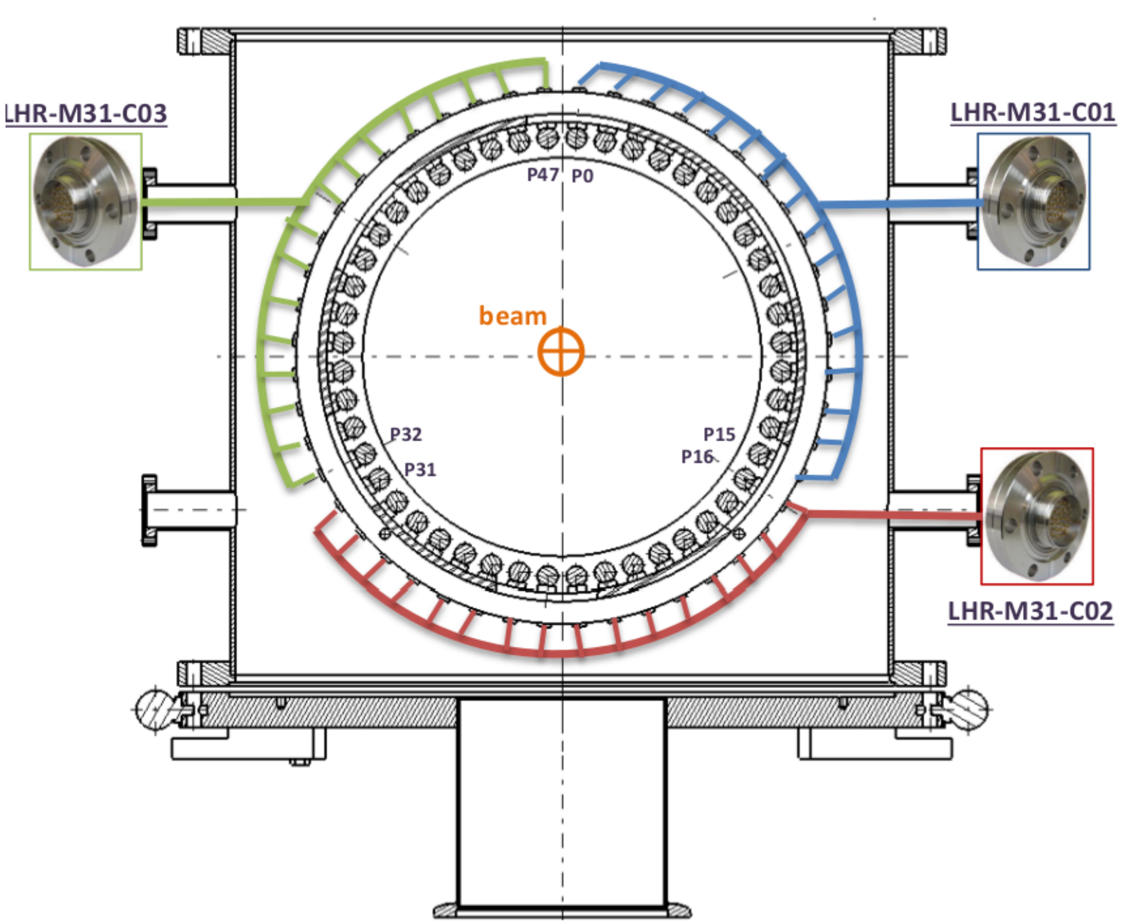
Simulated emittance with second order aberration (COSY)

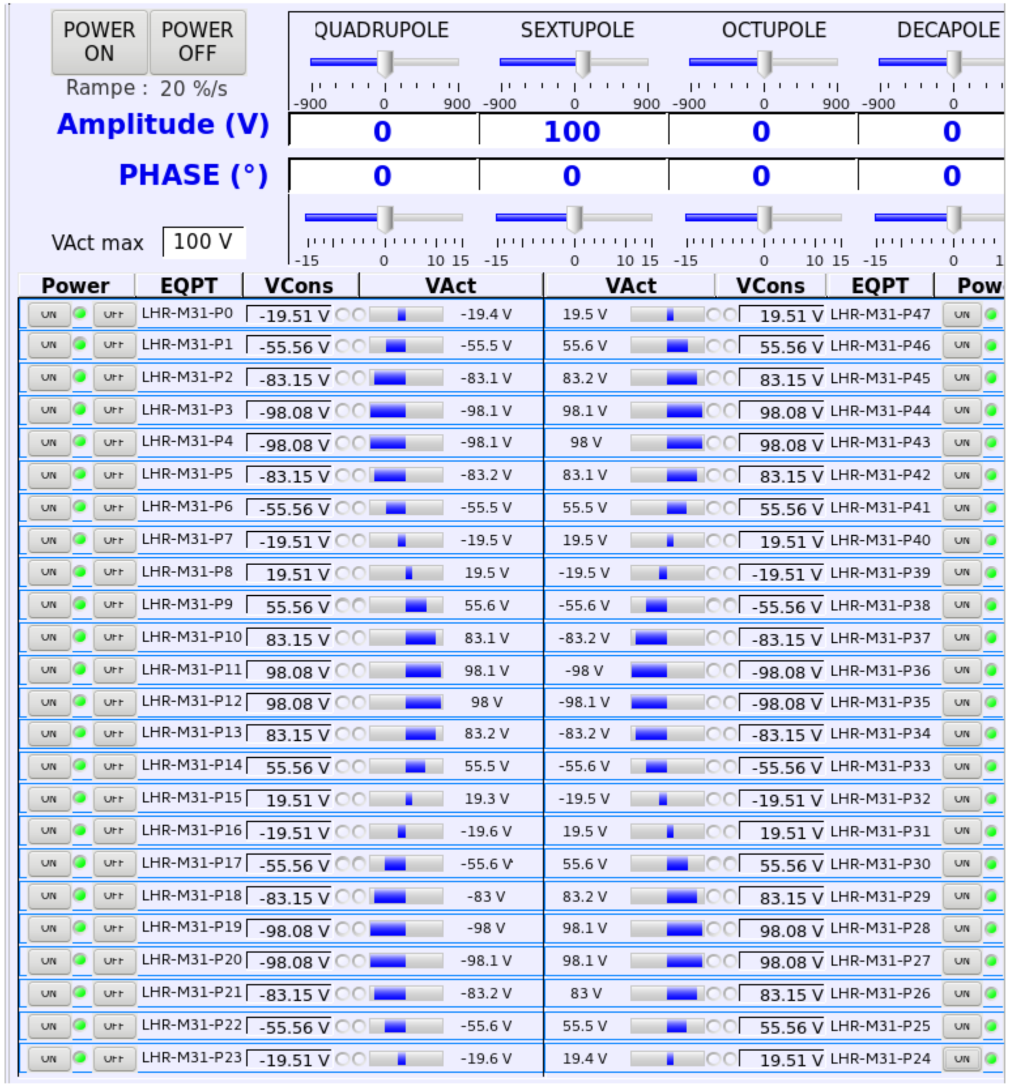


Measured emittance

One solution : cancel totally or partially the aberrations with the multipole

Current work : correction of aberrations with the multipole

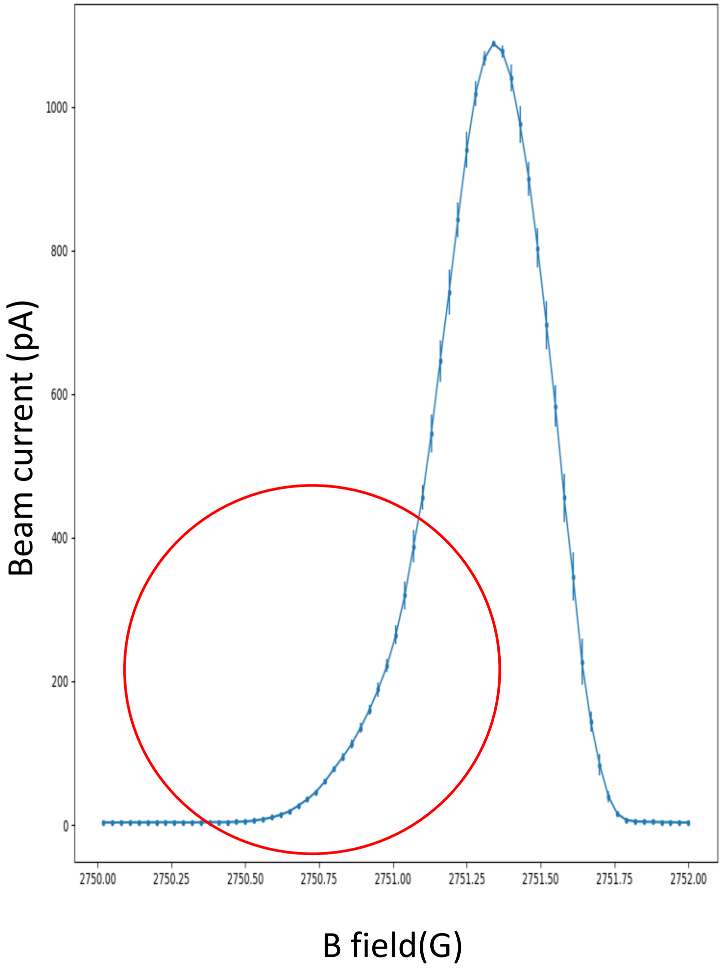




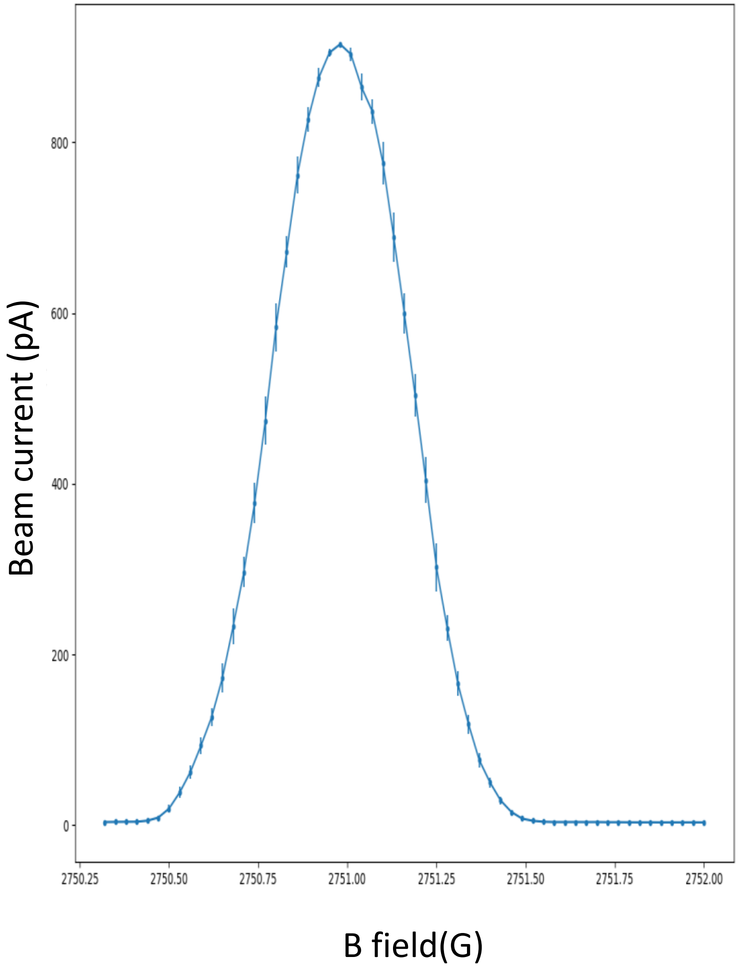
Power	EQPT	VCons	VAct	VAct	VCons	EQPT	Pow
ON OFF	LHR-M31-P0	-19.51 V	-19.4 V	19.5 V	19.51 V	LHR-M31-P47	ON
ON OFF	LHR-M31-P1	-55.56 V	-55.5 V	55.6 V	55.56 V	LHR-M31-P46	ON
ON OFF	LHR-M31-P2	-83.15 V	-83.1 V	83.2 V	83.15 V	LHR-M31-P45	ON
ON OFF	LHR-M31-P3	-98.08 V	-98.1 V	98.1 V	98.08 V	LHR-M31-P44	ON
ON OFF	LHR-M31-P4	-98.08 V	-98.1 V	98 V	98.08 V	LHR-M31-P43	ON
ON OFF	LHR-M31-P5	-83.15 V	-83.2 V	83.1 V	83.15 V	LHR-M31-P42	ON
ON OFF	LHR-M31-P6	-55.56 V	-55.5 V	55.5 V	55.56 V	LHR-M31-P41	ON
ON OFF	LHR-M31-P7	-19.51 V	-19.5 V	19.5 V	19.51 V	LHR-M31-P40	ON
ON OFF	LHR-M31-P8	19.51 V	19.5 V	-19.5 V	-19.51 V	LHR-M31-P39	ON
ON OFF	LHR-M31-P9	55.56 V	55.6 V	-55.6 V	-55.56 V	LHR-M31-P38	ON
ON OFF	LHR-M31-P10	83.15 V	83.1 V	-83.2 V	-83.15 V	LHR-M31-P37	ON
ON OFF	LHR-M31-P11	98.08 V	98.1 V	-98 V	-98.08 V	LHR-M31-P36	ON
ON OFF	LHR-M31-P12	98.08 V	98 V	-98.1 V	-98.08 V	LHR-M31-P35	ON
ON OFF	LHR-M31-P13	83.15 V	83.2 V	-83.2 V	-83.15 V	LHR-M31-P34	ON
ON OFF	LHR-M31-P14	55.56 V	55.5 V	-55.6 V	-55.56 V	LHR-M31-P33	ON
ON OFF	LHR-M31-P15	19.51 V	19.3 V	-19.5 V	-19.51 V	LHR-M31-P32	ON
ON OFF	LHR-M31-P16	-19.51 V	-19.6 V	19.5 V	19.51 V	LHR-M31-P31	ON
ON OFF	LHR-M31-P17	-55.56 V	-55.6 V	55.6 V	55.56 V	LHR-M31-P30	ON
ON OFF	LHR-M31-P18	-83.15 V	-83 V	83.2 V	83.15 V	LHR-M31-P29	ON
ON OFF	LHR-M31-P19	-98.08 V	-98 V	98.1 V	98.08 V	LHR-M31-P28	ON
ON OFF	LHR-M31-P20	-98.08 V	-98.1 V	98.1 V	98.08 V	LHR-M31-P27	ON
ON OFF	LHR-M31-P21	-83.15 V	-83.2 V	83 V	83.15 V	LHR-M31-P26	ON
ON OFF	LHR-M31-P22	-55.56 V	-55.6 V	55.5 V	55.56 V	LHR-M31-P25	ON
ON OFF	LHR-M31-P23	-19.51 V	-19.6 V	19.4 V	19.51 V	LHR-M31-P24	ON

Effect of the multipole on final beam size (hexa only)

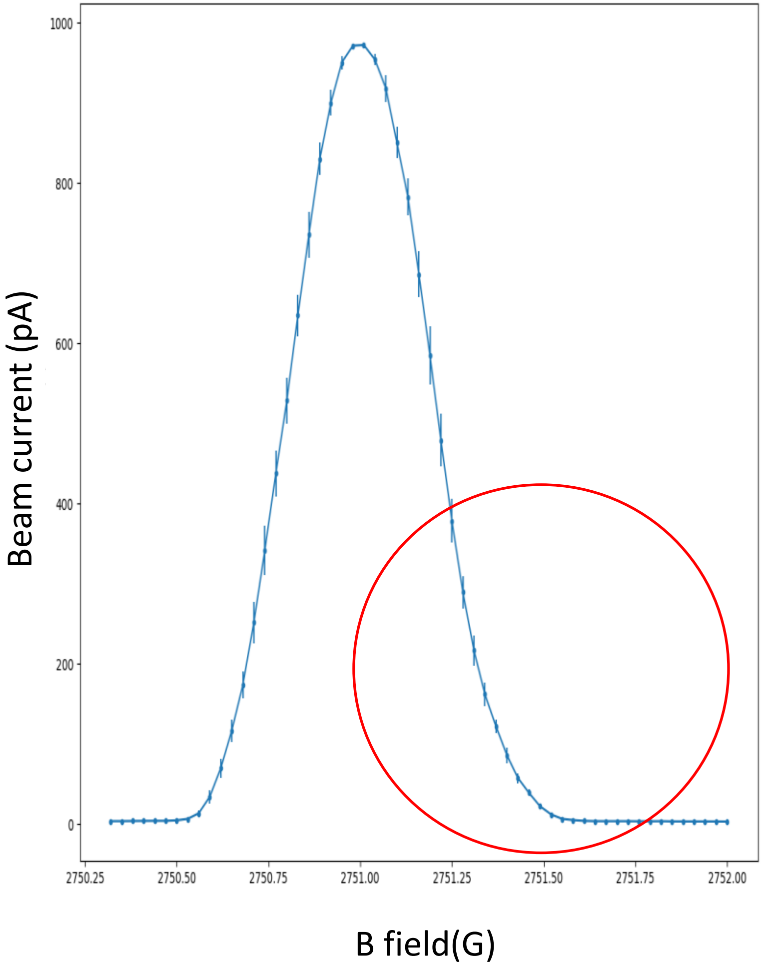
$H_{mult} = 100\ V$



$H_{mult} = 160\ V$

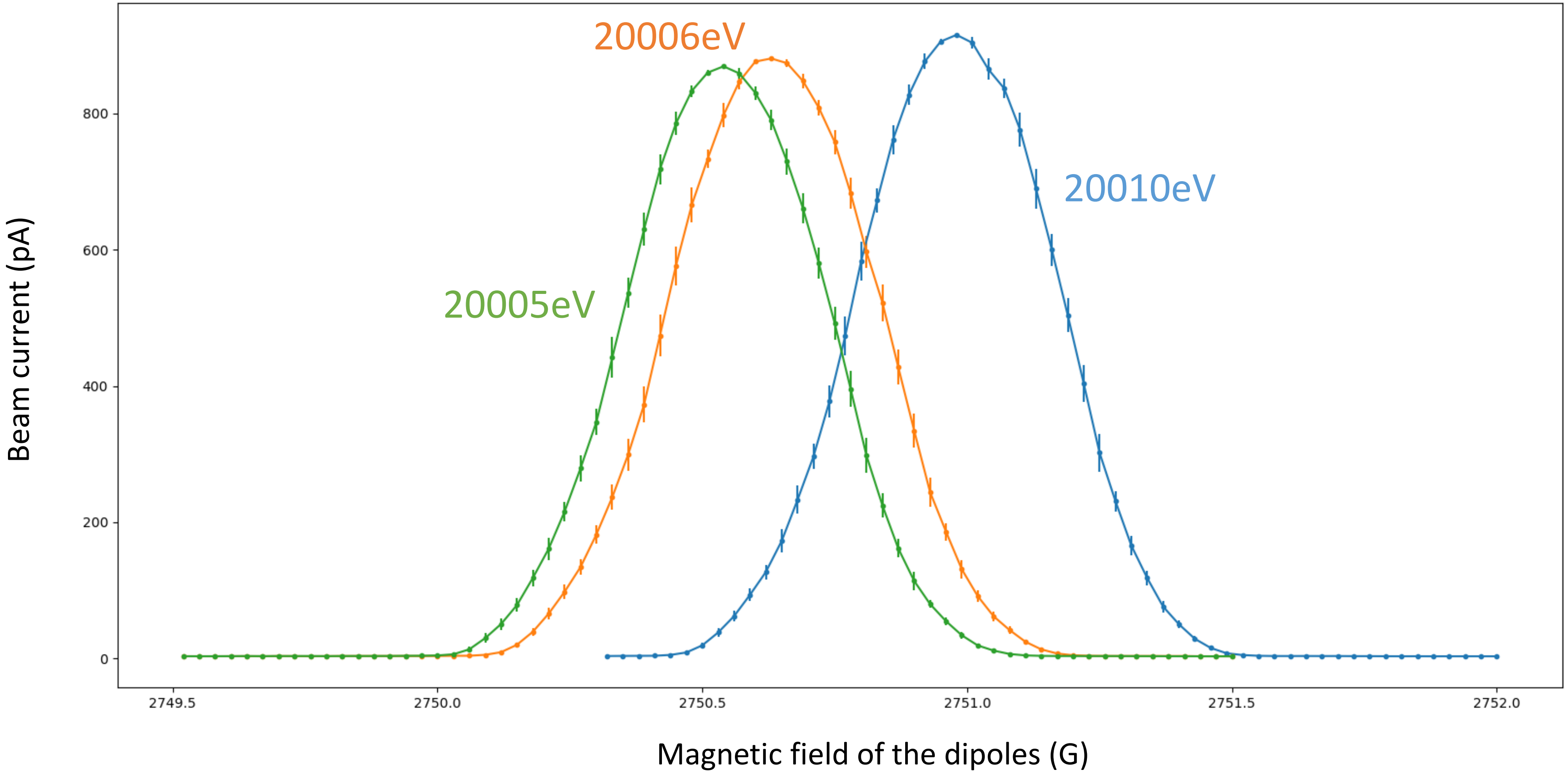


$H_{mult} = 180\ V$



Latest resolution measurement : 2mm beam

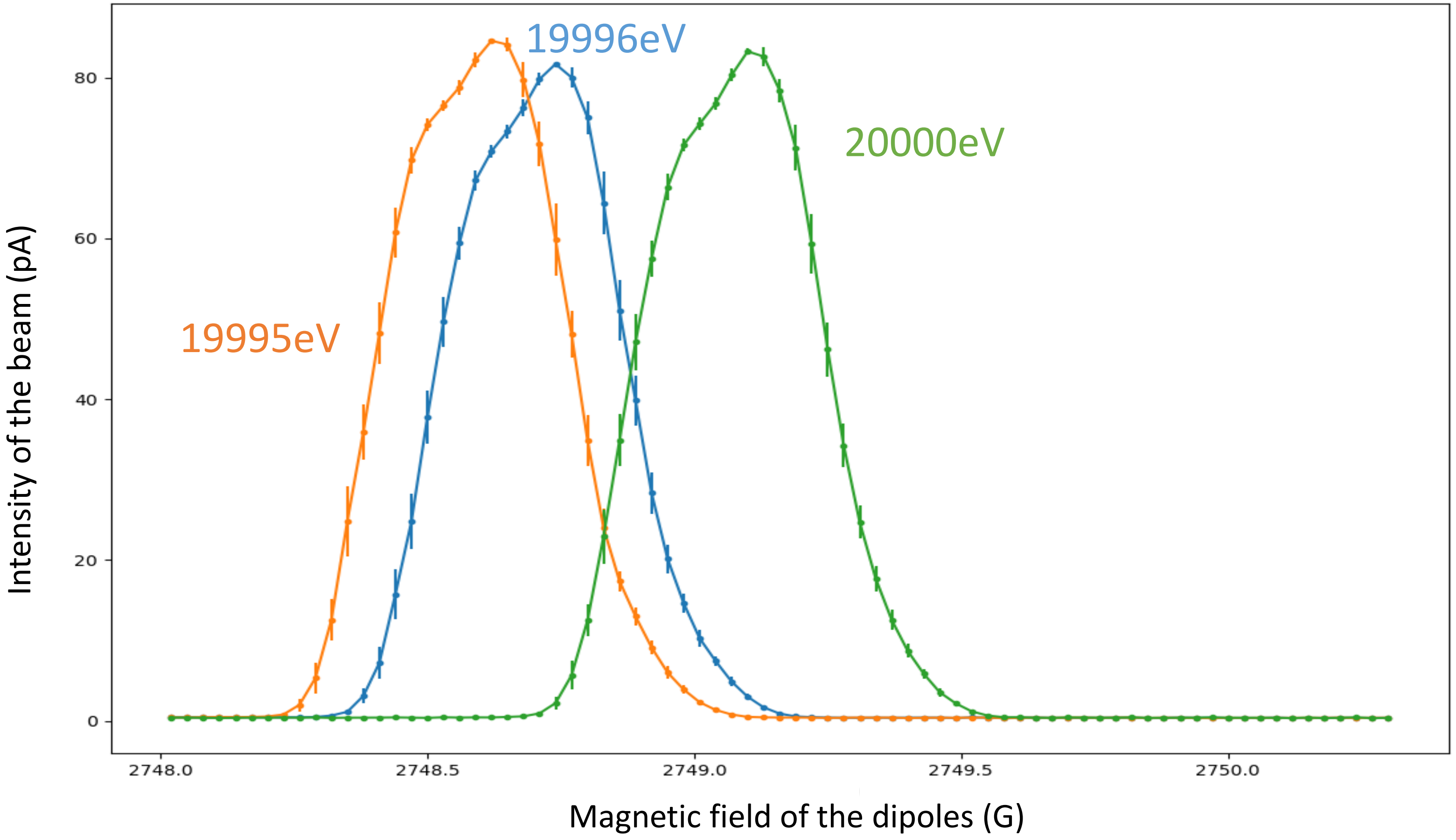
- Transfer functions of the spectrometer are identic for $\frac{\Delta M}{M}$ and $\frac{\Delta E}{E}$
- ➔ We can estimate the resolution of the HRS by measuring two beams with close energy



Measurement done for :

- 133 Cs 1+
- E : 20keV
- Slits : $\pm 1mm/\pm 1mm$
- $\epsilon_{source} \sim 5\pi\ mm.mrad\ (1\sigma)$
- Transmission : > 95%

Latest resolution measurement : 1mm beam



Measurement done for :

- 133 Cs 1+
- E : 20keV
- Slits : $\pm 0{,}5mm / \pm 0{,}5mm$
- $\epsilon_{source} \sim 5\pi\ mm.mrad\ (1\sigma)$
- Transmission : $\sim$ 45%

Next steps

- Better understand the effect of the multipole on the emittance figure
  - ➔ Identifying patterns (code in development)
  - ➔ Find the tuning of the multipole that correct these patterns

- Build/reshape entrance poles (dipoles) to compensate most of the natural hexapolar aberration

- Include Octupole, decapole… fields in the multipole to correct more aberrations
  - ➔ Should in principle reduce the final beam spots

- Reduce initial energy spread of the beam to minimize beam dispersion (HV supply $\sim 10^{-4}$)
  - ➔ Increase measured resolution

Thank you

Thank you!

References :
[1] : T. Kurtukian-Nieto et al, SPIRAL2/DESIR high resolution mass separator, Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms,Volume 317, Part B,2013,Pages 284-289,ISSN 0168-583X,https://doi.org/10.1016/j.nimb.2013.07.066.
[2] : J.R. Beene et al., J. Phys. G. Nucl. Part. Phys. 38 (2011) 024002.
[3] : T.J. Giles et al., Nucl. Instr. B 204 (2003) 497.
[4] : Tsviki Y. Hirsh et al,First operation and mass separation with the CARIBU MR-TOF,Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms,Volume 376,2016,Pages 229-232,ISSN 0168-583X,https://doi.org/10.1016/j.nimb.2015.12.037.

- BACKUPS

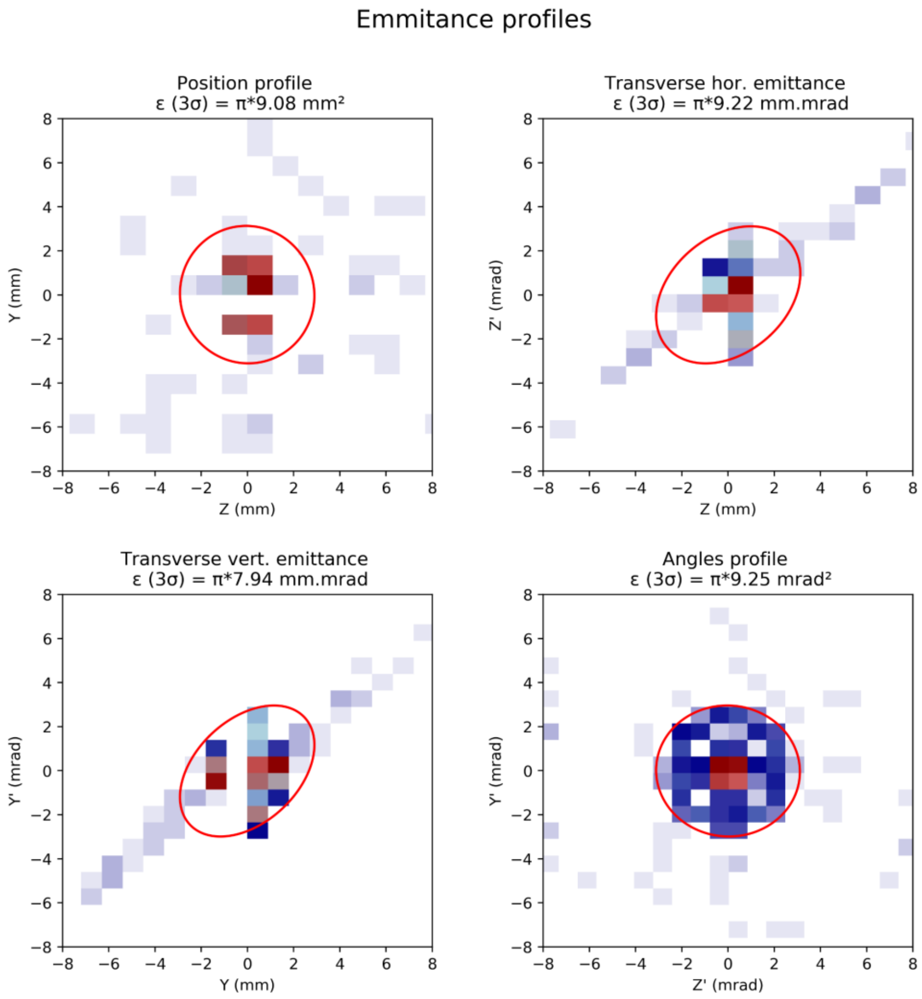
Table 3
Positioning precision tolerances for the DESIR-HRS.

	X shift (mm)	Y shift (mm)	X tilt (mrad)	Y tilt (mrad)	θ(mrad)
MQ	± 0.1	± 0.1	± 3.5	± 3.5	± 3.5
FS	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
FQ	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
D	± 0.1	± 0.1	± 0.35	± 3.5	± 3.5
M	± 0.1	± 0.1	± 3.5	± 3.5	± 3.5

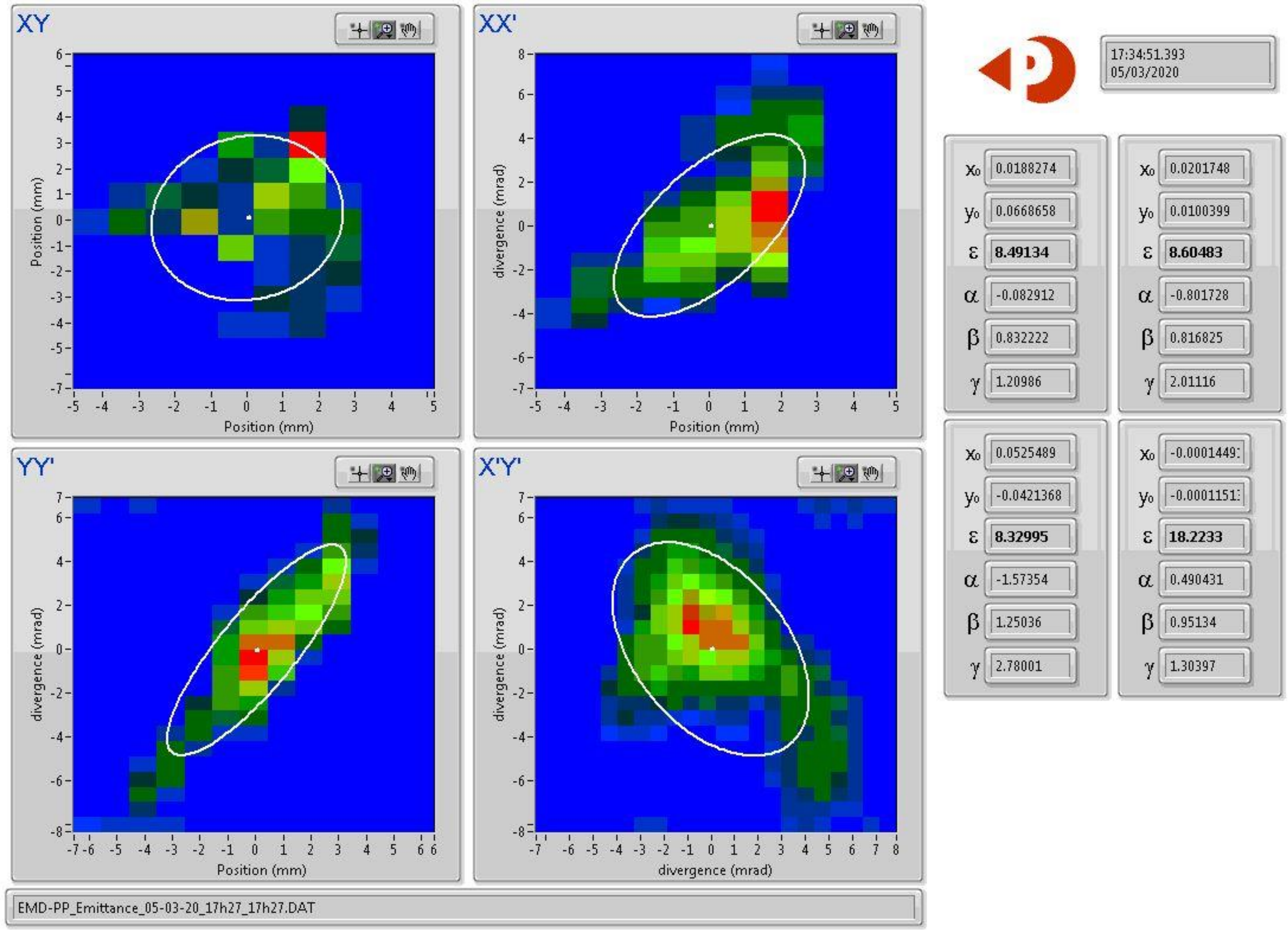
The mass resolving power of a separator is given by

$$R = \frac{D_M}{2x_0|M_x| + \delta_{\text{aberrations}}}$$

Matching: 15 keV (3sigma)

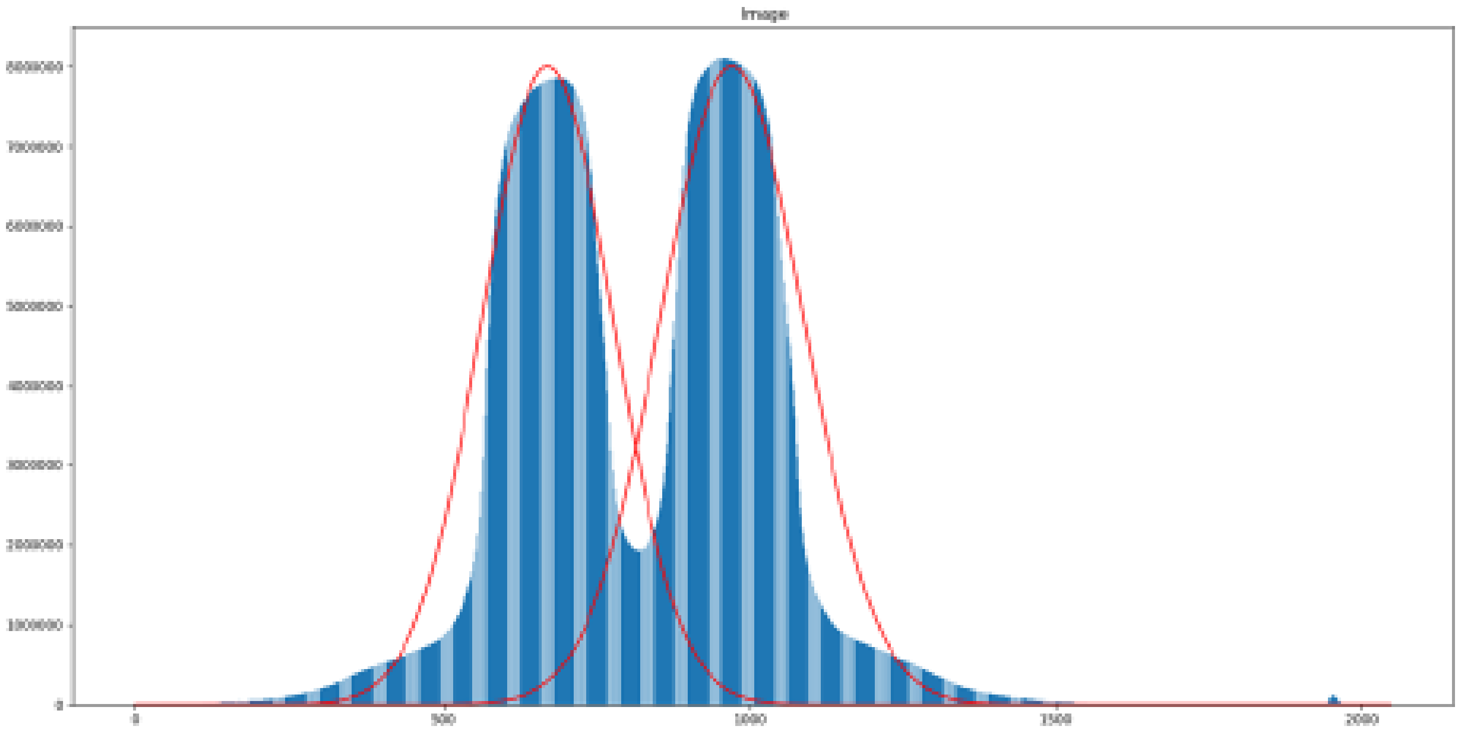


Simulation

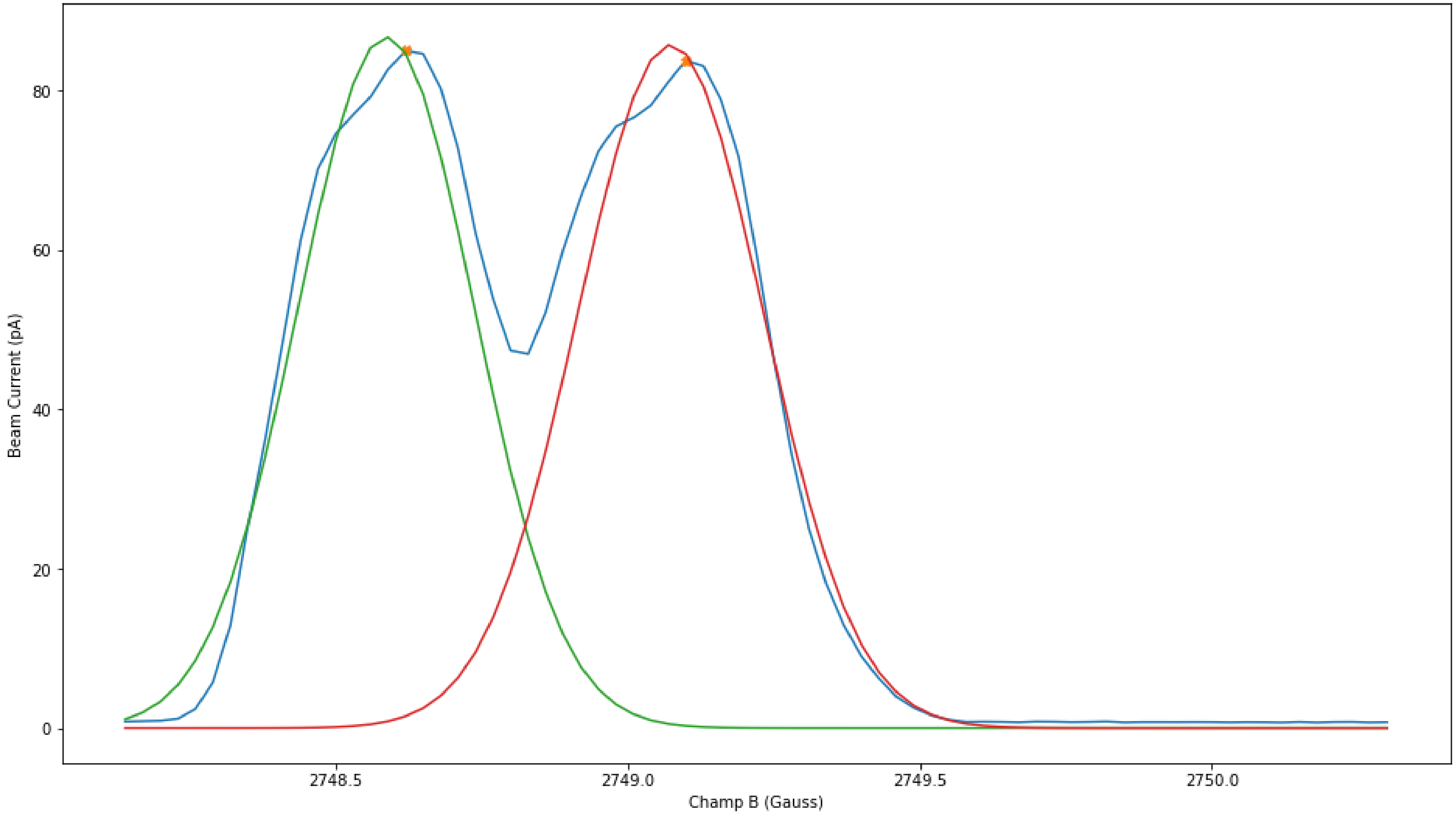


Experiment

Resolution using the camera



First resolution check

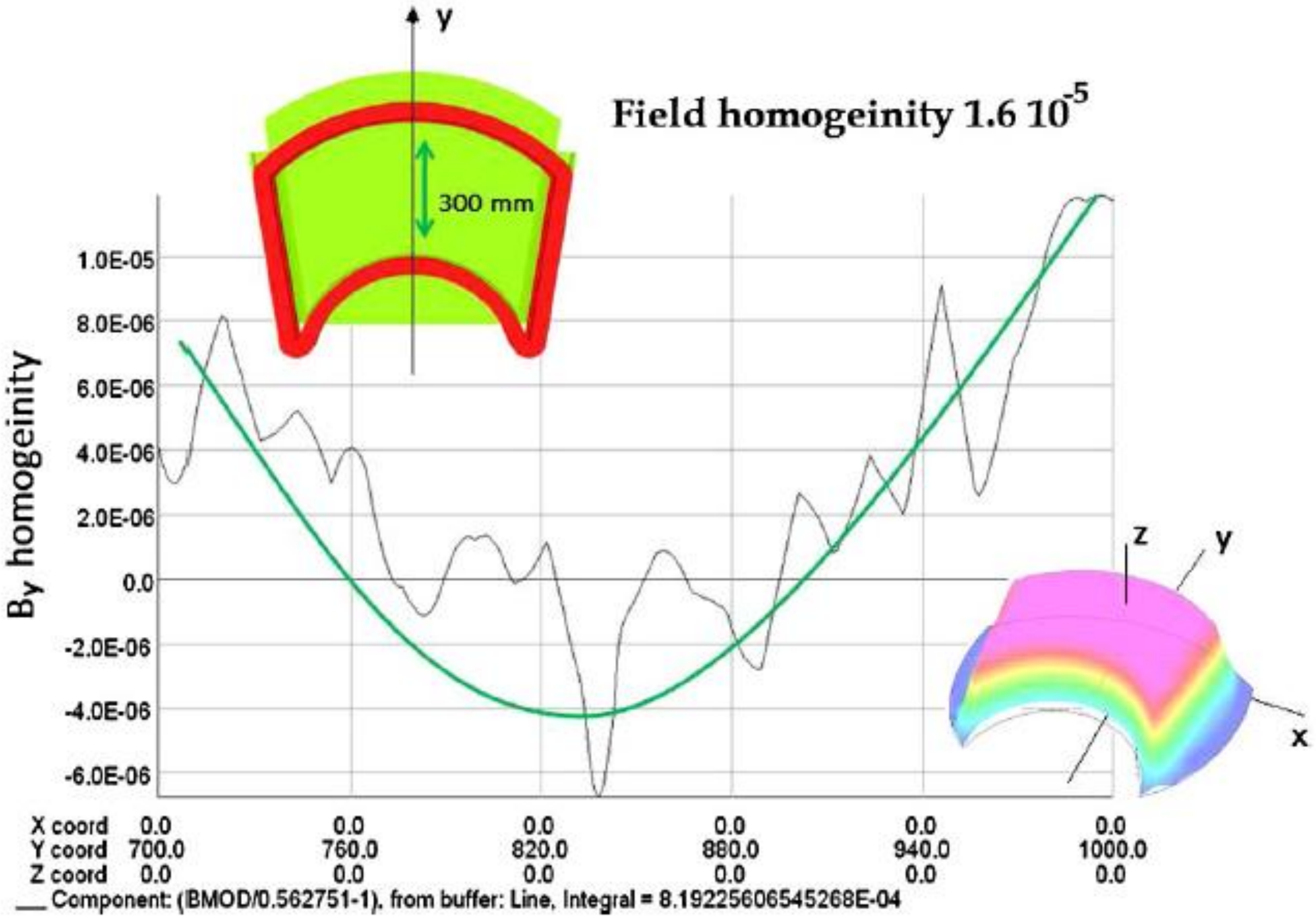


Design and objectives – Field homogeneity

Field transverse homogeneity : 10^{-5} over $\pm 150\ mm$ around central beam

Beyond this zone : 10^{-4}

Design includes the possibility to change magnetic edges to refine the minimization of aberrations



High Resolution Separators in the World

The ISAC facility at TRIUMF : - R = 25 000 for 8 mm.mrad with no aberrations
- R = 10 000 for 8 mm.mrad with energy spread and systematics

Oak Ridge Holifield ISOL facility [2] : Resolving power up to R = 10 000

ISOLDE HRS [3] : - Routinely achieves R = 5000

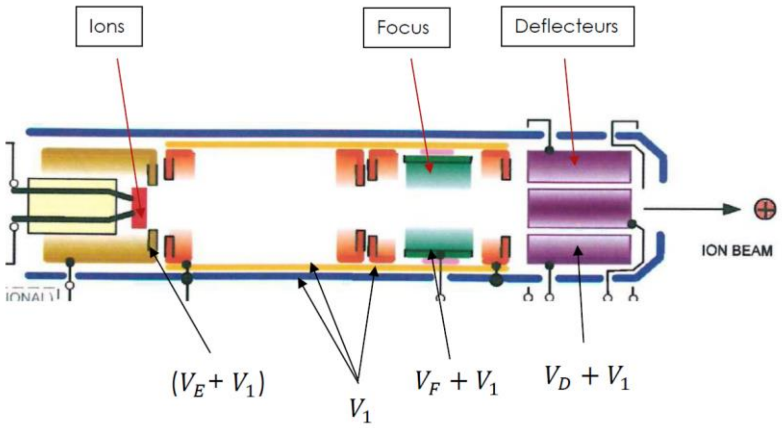
CARIBU project at ANL [4]: - Design goal of R = 20 000
- R = 14 000 after tests

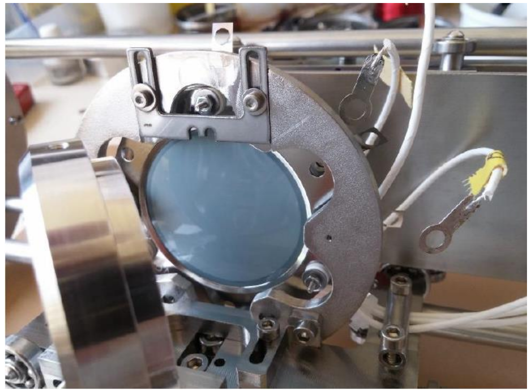
DESIR HRS: - Design goal of R= 31,000 for 1 π mm.mrad with no aberrations
- Simulated R = 20 000 including energy spread and misalignments

Current status – under commissionning

Two main tools are needed for the commissionning of the HRS :

Cs_{133}





Ion source : - 0 – 30 keV
- $\Delta E \sim 0,1\ eV$
- $\varepsilon \sim 5\pi$ mm.mrad at 5keV

Emittancemeter: - pepperpot-like
- 40x21 holes
- 20 μm holes

➔ Necessity to understand these tools first (test bench) !