OPTIC AND BEAM DIAGNOSTICS FOR THE 100 MEV HEBT FOR THE MYRRHA PROJECT

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1. MYRRHA project.
2. HEBT beam optic conception
3. Beam diagnostics (Beam Position Monitor)

MYRRHA : Multi-purpose Hybrid Research Reactor for High-tech Applications
HEBT : High Energy Beam Transport

Thesis started the 03 April 2018 (~ 1 year)

1. MYRRHA: THE FIRST ADS IN EUROPE

MYRRHA project, Belgique / Möl :

- Burning long life nuclear wastes (Am and heavy isotopes).
- Transmutation studies and new isotopes production.

Need to reduce the thermic stress in the vessel of the reactor. After a beam trip longer than 3 seconds, 3 days are needed in order to restart.

Conception of a reliable LINAC-protons:

Minimise the trips.

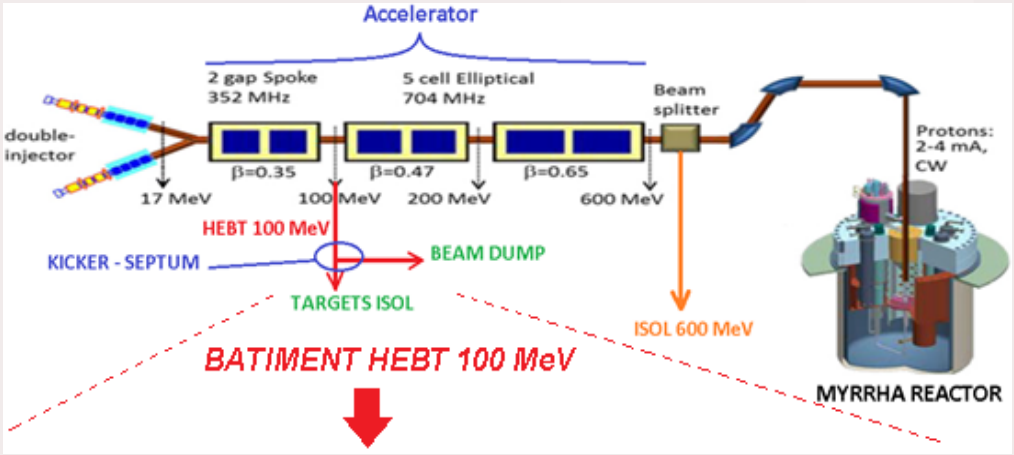
Less than 40 trips/year. → Double injector.

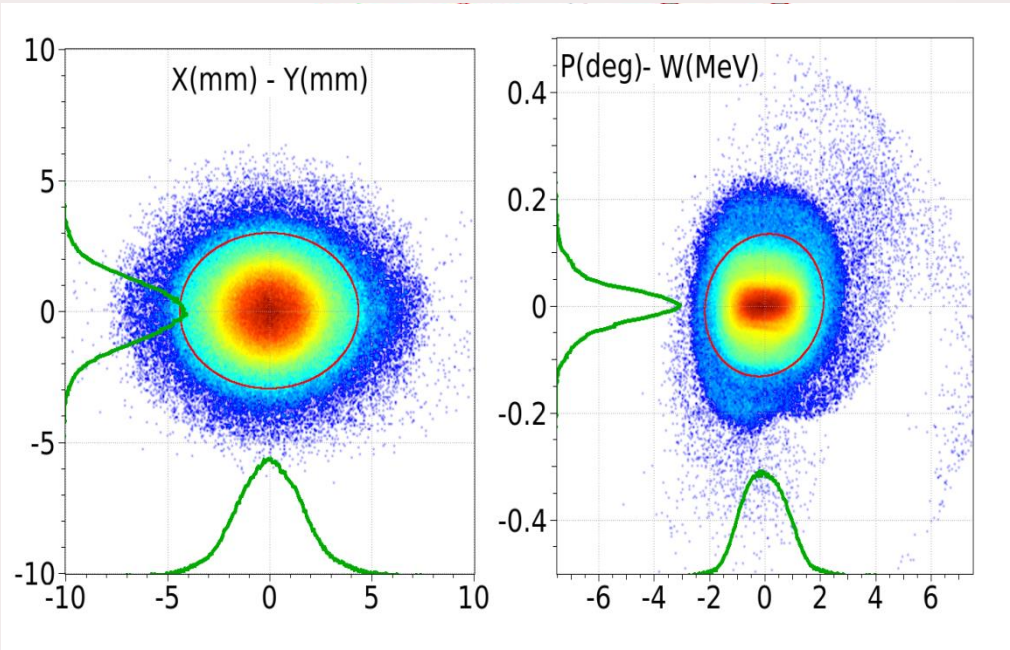
⇒ **Phase 1: Demonstrator LINAC 100 MeV protons.**

Nominal Beam characteristics :

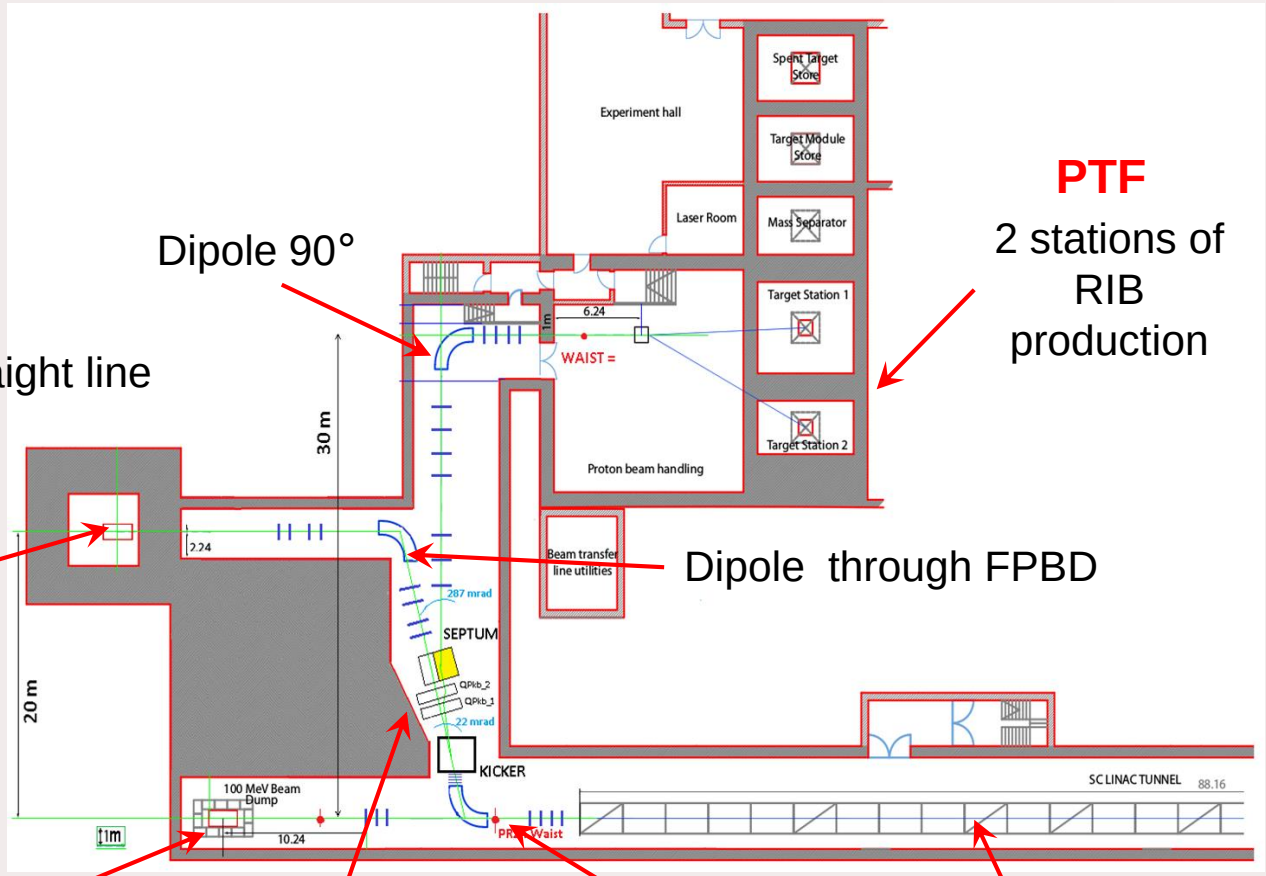
- Protons
- Output LINAC, E = 100 MeV
- Pulse Beam current = 4 mA (140 Mp/b)
- Bunch repetition 176 MHz
- Continuous (DC 100%)
- Transverse Emittance 0.25 π.mm.mrad

MYRRHA: Accelerator + Reactor





2. BEAM DYNAMIC – HEBT BUILDING



PTF
2 stations of RIB production

Dipole 90°

~32m straight line

FPBD **Full Power Beam Dump**

Dipole through FPBD

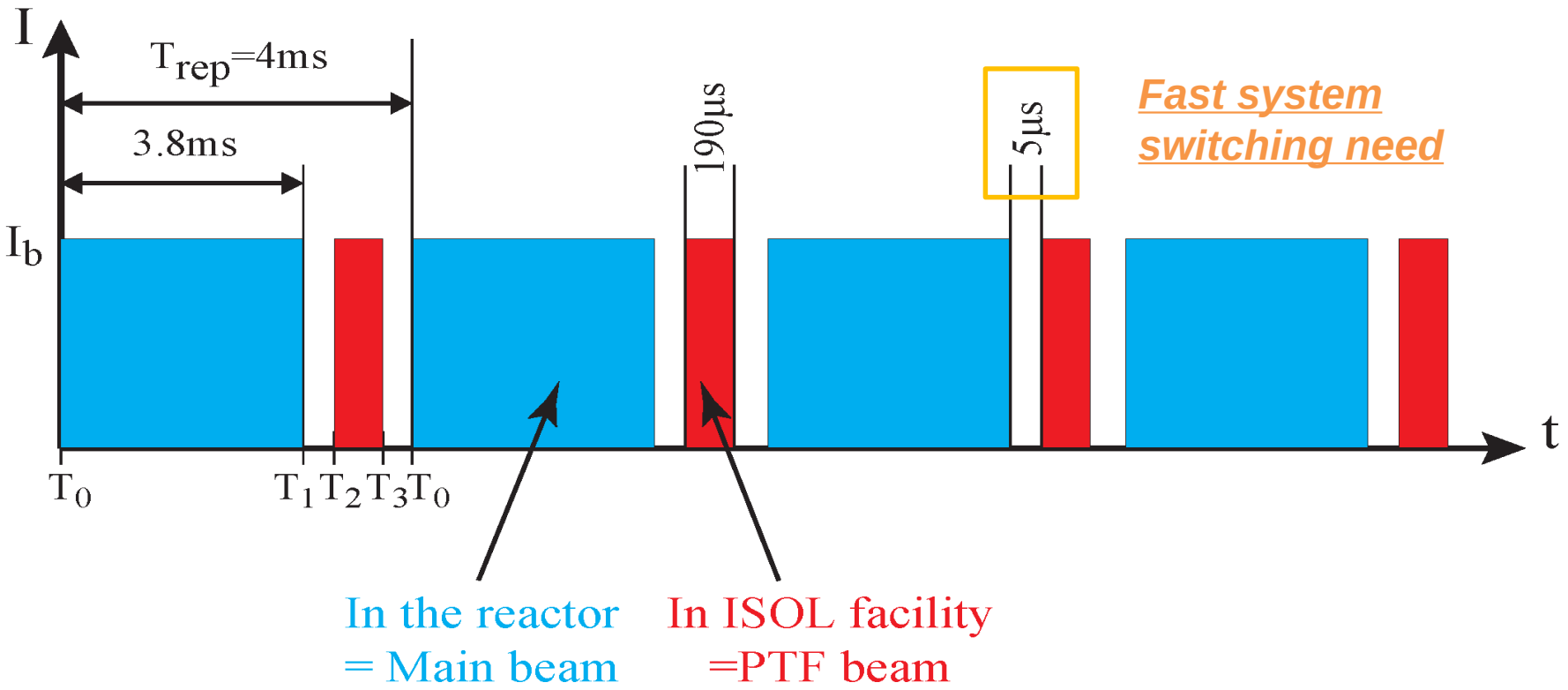
ETBD **Energy Tuning Beam Dump**

Kicker/Septum

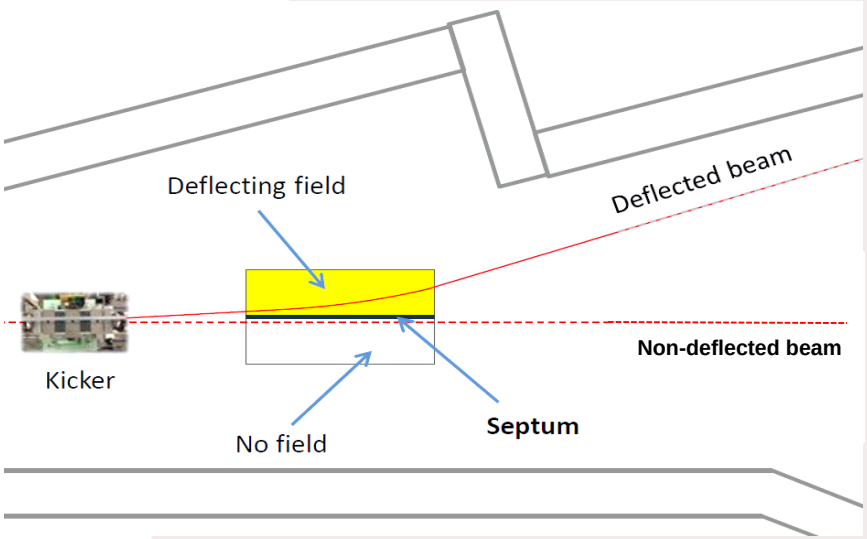
LINAC Adaptation
4 quad.
+ qualification

LINAC

2. BEAM TIME STRUCTURE



2. BEAM DYNAMIC – KICKER AND SEPTUM

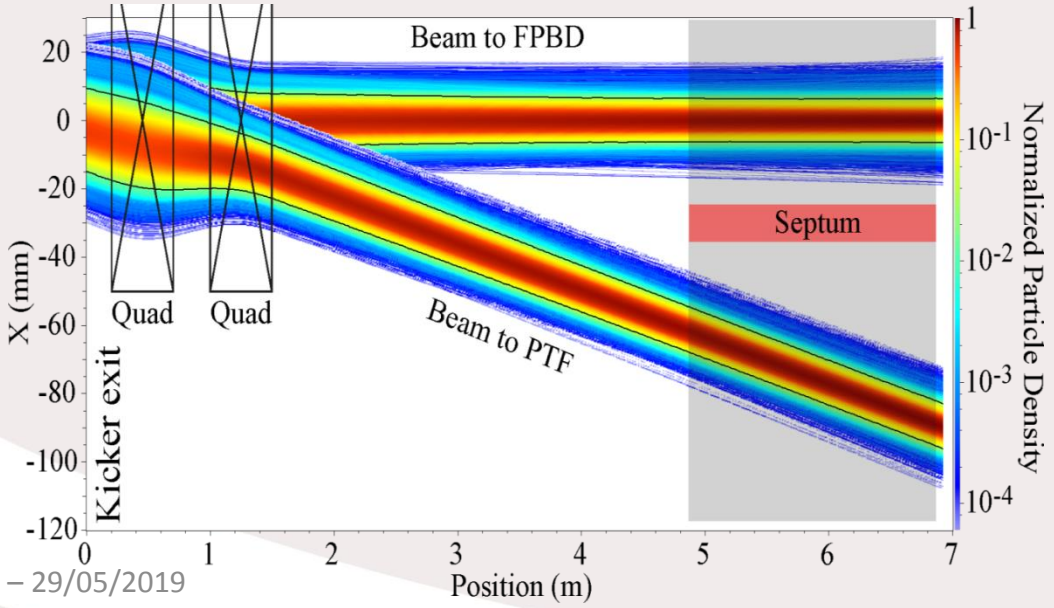


Kicker :

- Fast magnet : Rise field time ~ 5 µs
- Flat top ~ 200 µs
- Magnetic kick: very quick but weak (~20 mrad)
  → need to enhance the kick

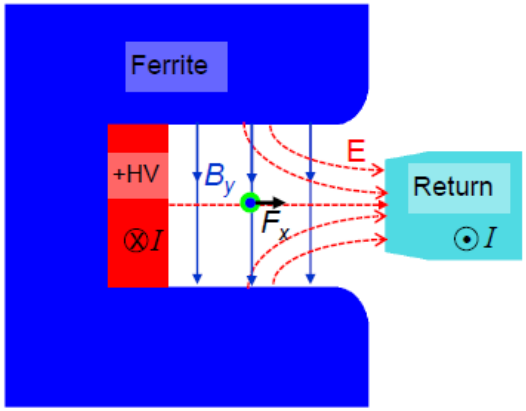
Septum :

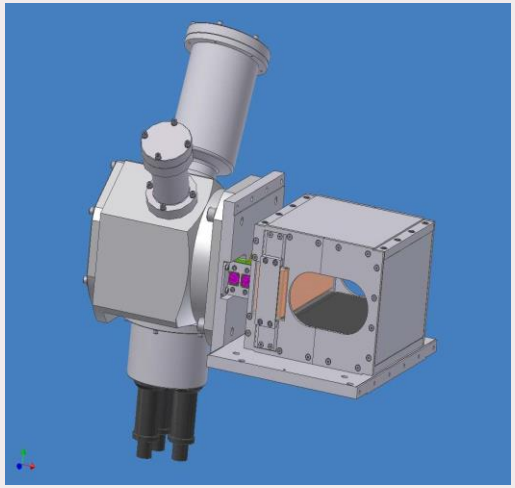
- 2 part magnet : DC field and No-field
- Magnetic screen ~10 mm
- Increase the magnetic kick / deviation

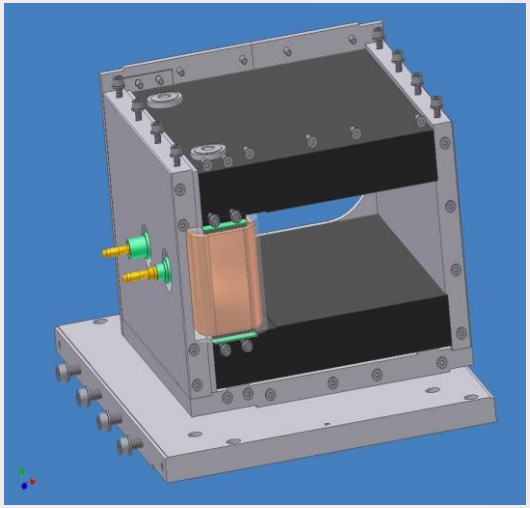


2. PRINCIPLE KICKER-SEPTUM

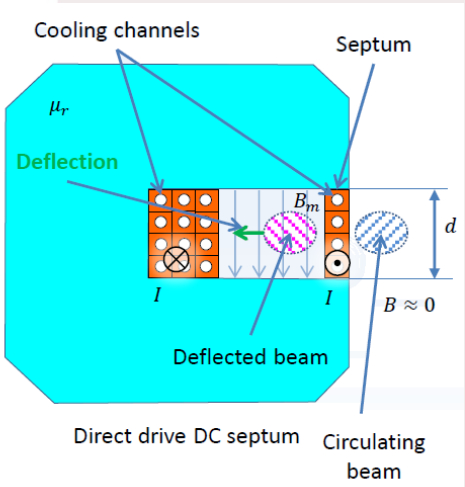
Kicker

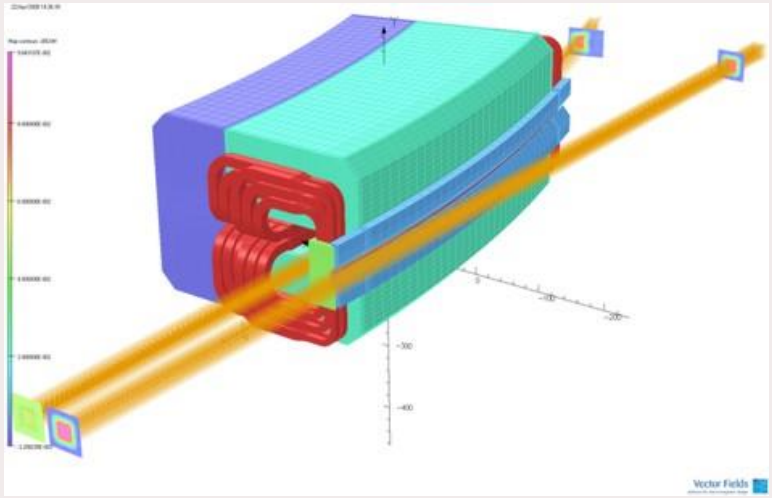






Septum





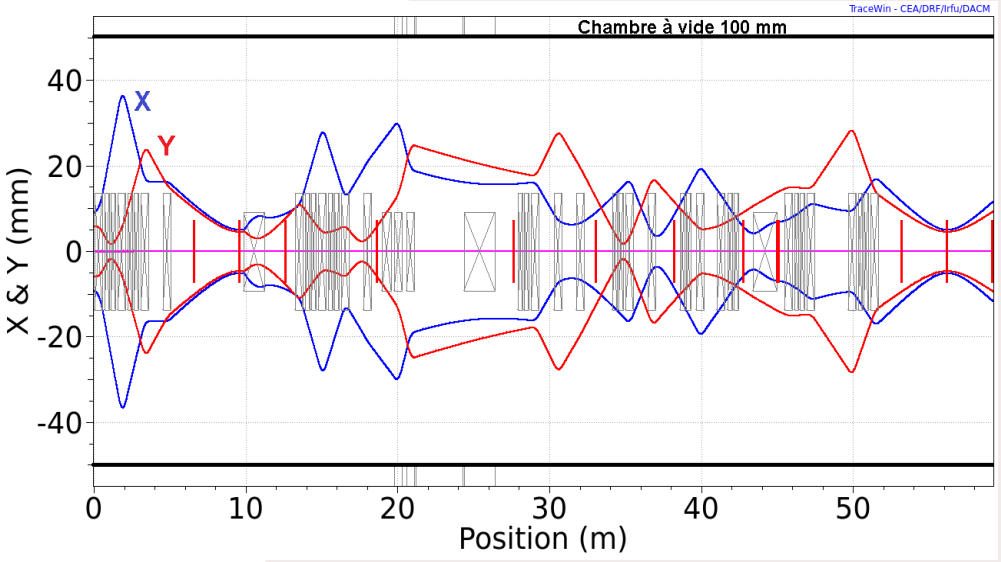
2. BEAM DYNAMIC – KICKER AND SEPTUM

MYRRHA's Kicker specifications	
Effective magnetic length (m)	0.6
100 MeV Protons beam rigidity (T.m)	1.483
Maximum field B (Tesla)	0.0209
Deflection angle (mrad)	8.47
Aperture w × h (m^2)	0.12 x 0.12
Nominal current for the maximum field (A)	200
Maximum voltage (V)	2000
Number of turns N	10
Estimated inductance (µH)	75.4
Fall time (µs) ≈ Rise time	12.592
Impedance estimation (Ohm)	10

Septa parameters	
Curvature radius (mm)	*7420*
Equivalent magnetic length (mm)	2022
Deflection angle (mrad)	273
Septum thickness + screen (mm)	10 + 1
Gap (mm)	120
Horizontal width in field (mm)	630
B nom (Tesla)	0.2

- Discussion with CERN kicker experts
- Specifications based on existing kicker and septum
- Safer specifications as possible to avoid possible breakdowns
- First specifications enough realistic to use it in beam dynamic simulations

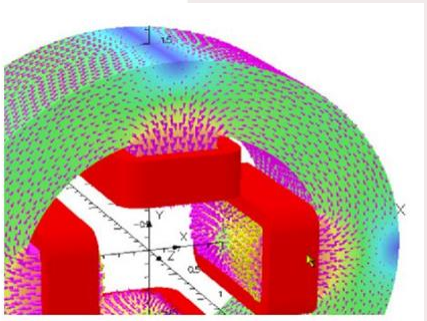
2. BEAM DYNAMIC



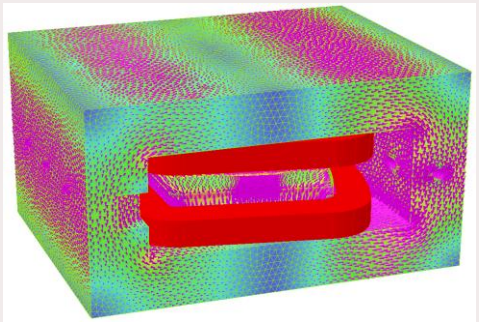
X , Y Beam envelops : from Output LINAC up to Proton Target Facility

Beam dynamic studies with Tracewin :

- **Implantation of magnetic elements:** Quadrupoles, Dipoles, Sterrers according building specifications.
- **Adjust gradients** of optic elements
- **Errors Study**: Consider uncertainties on the beam and of the elements. The beam lines have to be robust.



Field map of a Quadrupole



Field map of a dipole

Magnetic Conception of optic elements :

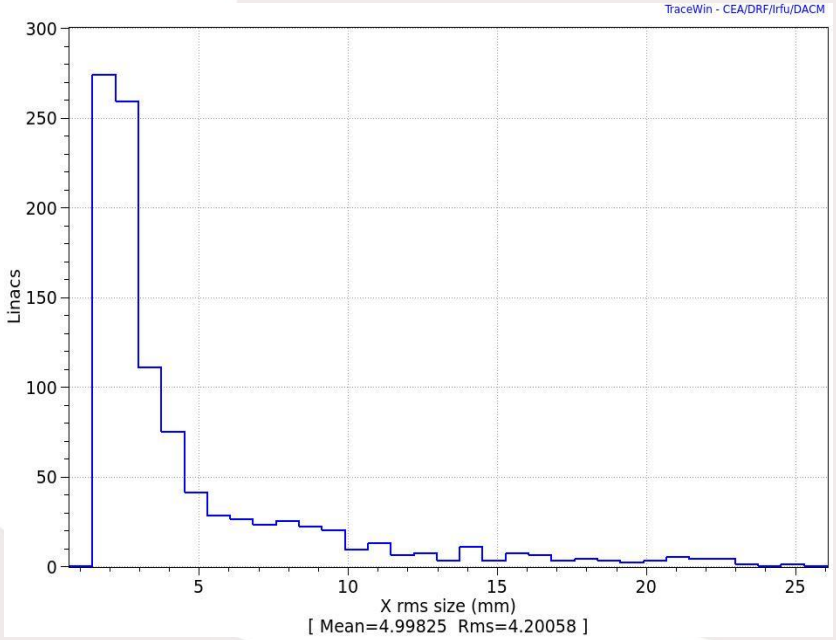
- **Magnetic specifications** of fast magnets as « Kicker » and « Septum » → Separate the beam between the 2 main beam lines.
- **Field Calculations** using CST and OPERA–3D
- Field map → Increase beam dynamic **accuracy** withTracewin.

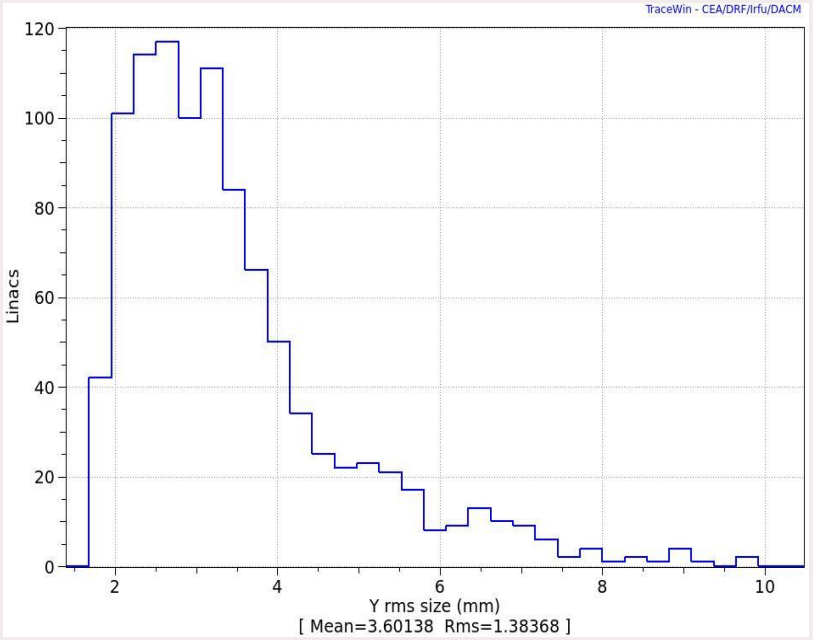
2. BEAM DYNAMIC : ERRORS

Error study considering:
- Diag accuracy
- Errors on the beam characteristics
- Optical elements.

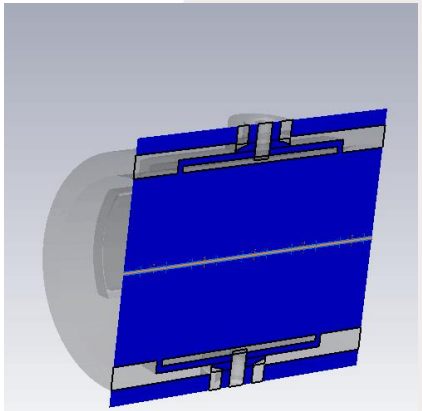
→ validation of beam optic robustness
→ Fixing the operations ranges

Statistical Results examples :



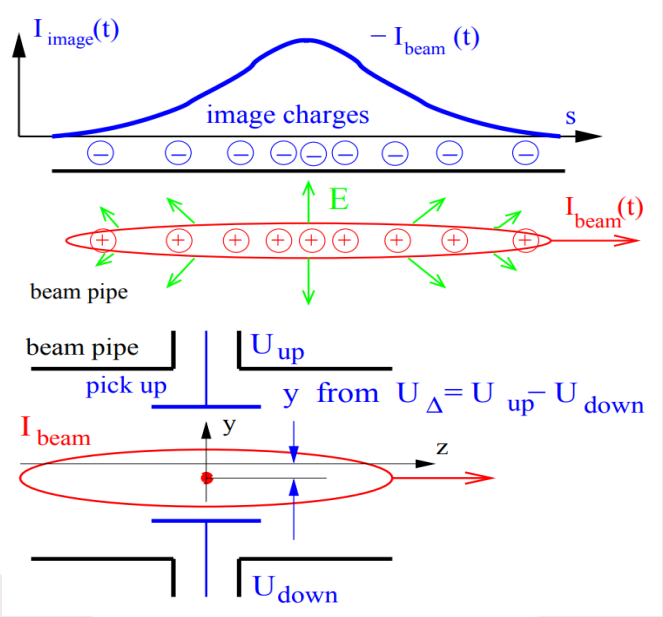


3. BEAM DIAGNOSTIC : BEAM POSITION MONITOR



Electrostatic study of the BPM with CST :

- BPM development for HEBT at 100 MeV.
- Simulate the bunch going through a BPM.
- Electrostatic field map in the BPM.
- Signal induction → Output Voltage.
- Parametric Study: BPM geometry , beam characteristics.
- Compare to analytic and real beam measurement.



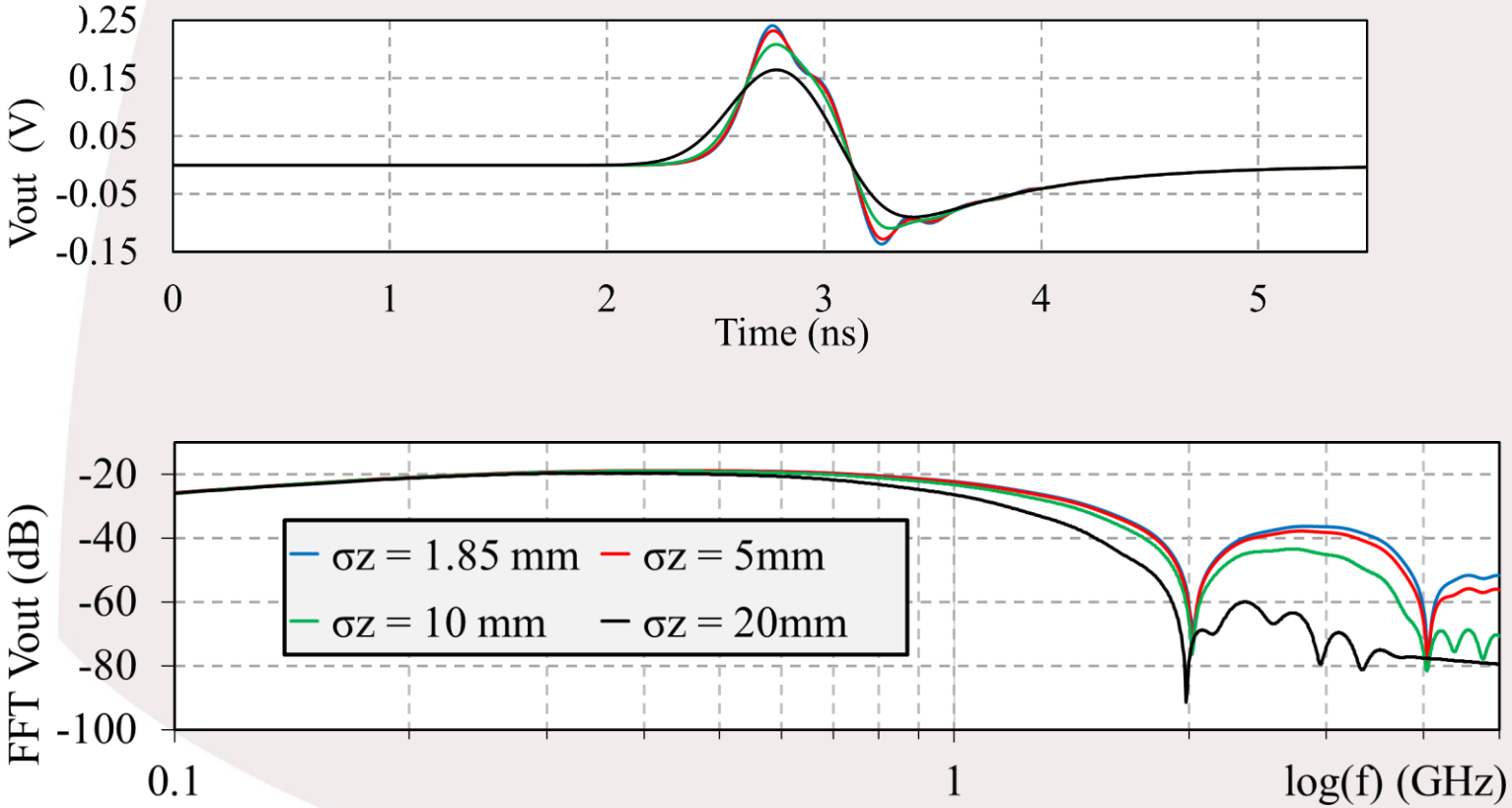
Imbalance of Charges → Beam position

Mesures:

- Real beam measurements (IPHI, SPIRAL2)
- Measures on the Test IPN's bench

3. DIAGNOSTIQUES FAISCEAU : BEAM POSITION MONITOR

- Temporal → FFT→ frequency domain → data analyzing
- Digitalization around a specific harmonic (frequencies) → Noise reduction → position information

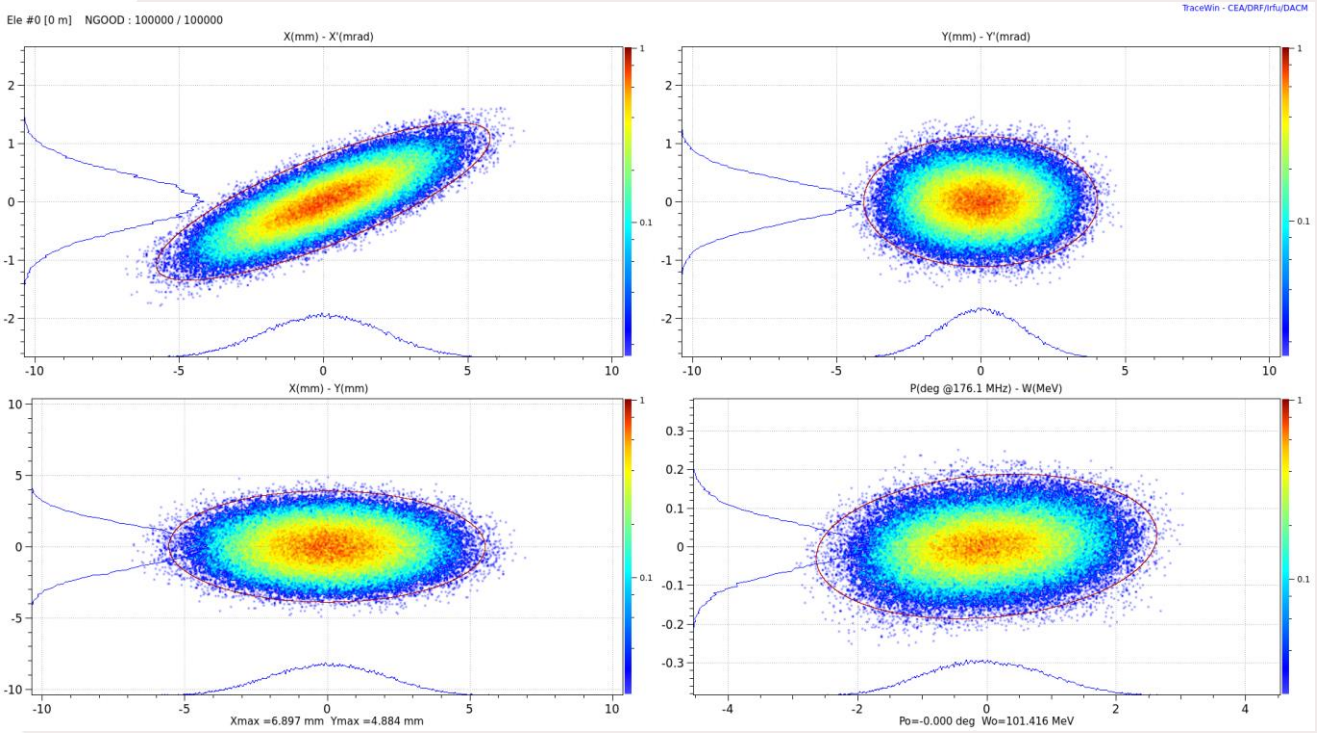


CONCLUSIONS - PERSPECTIVES

- MYRTE report contribution: first complete study of the HEBT.
- Update beam lines conceptions of HEBT→ Future plans
- Magnetic conception of optic elements.
- Continue BPM studies with CST and analyze the measurements at IPHI
- Extract data measurements from BPM of SPIRAL2 (winter 2020)

THANK YOU

CONCLUSIONS - PERSPECTIVES



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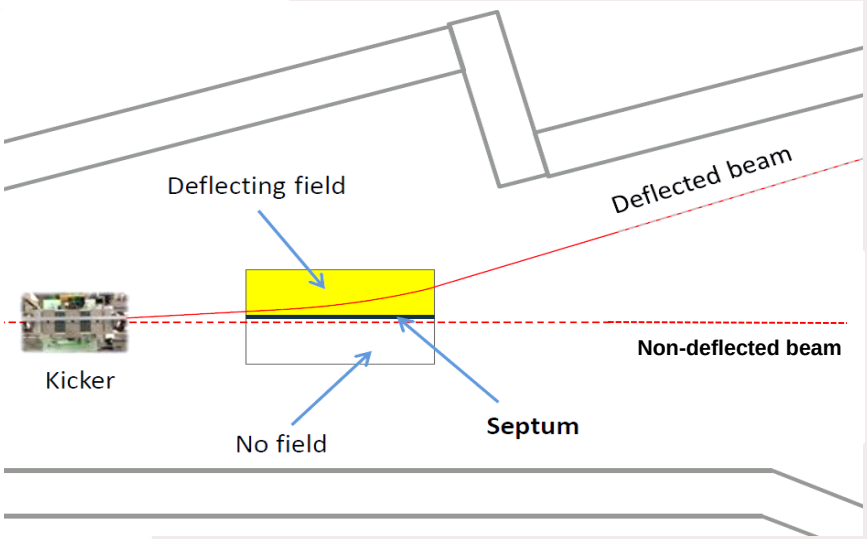

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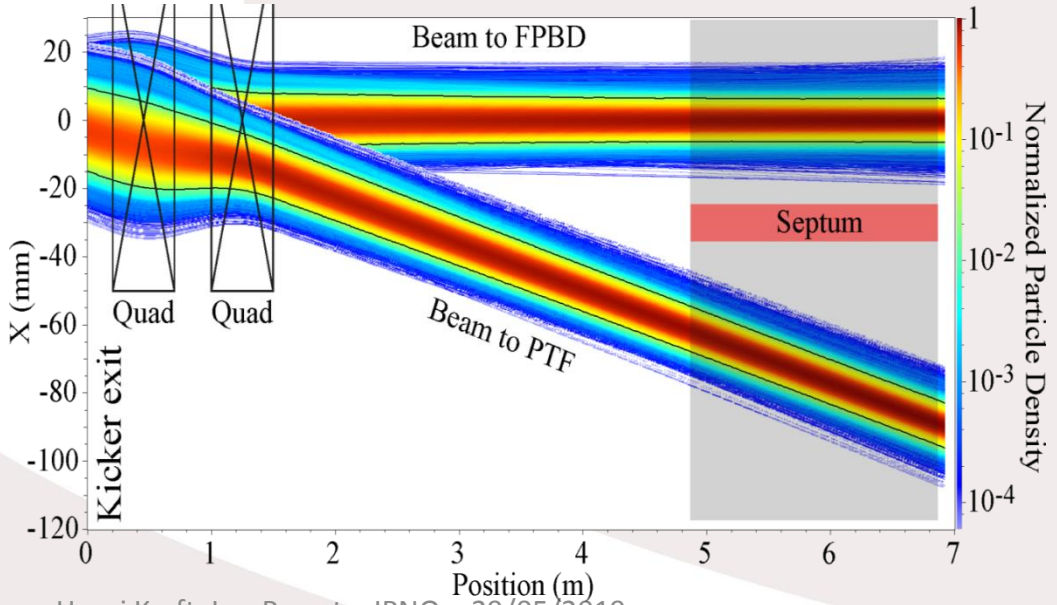
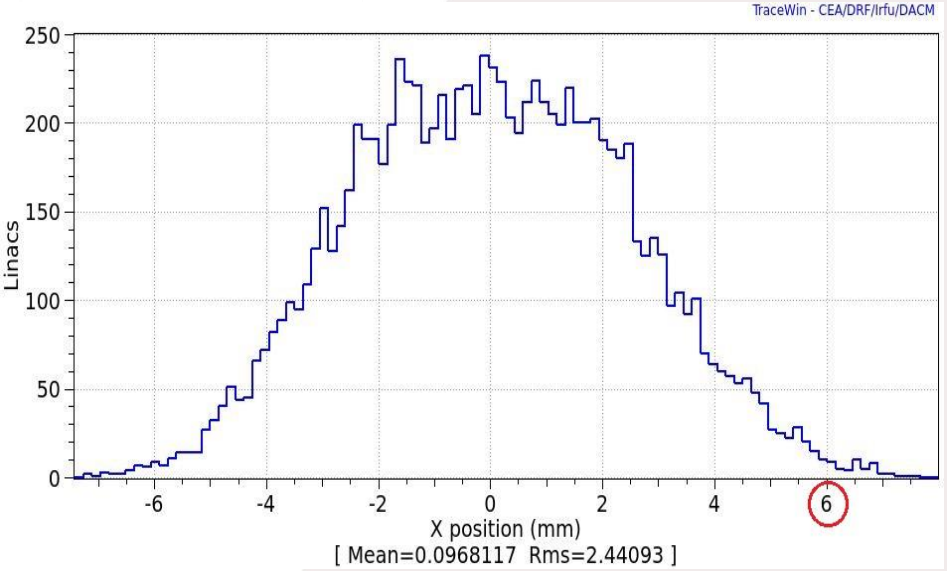


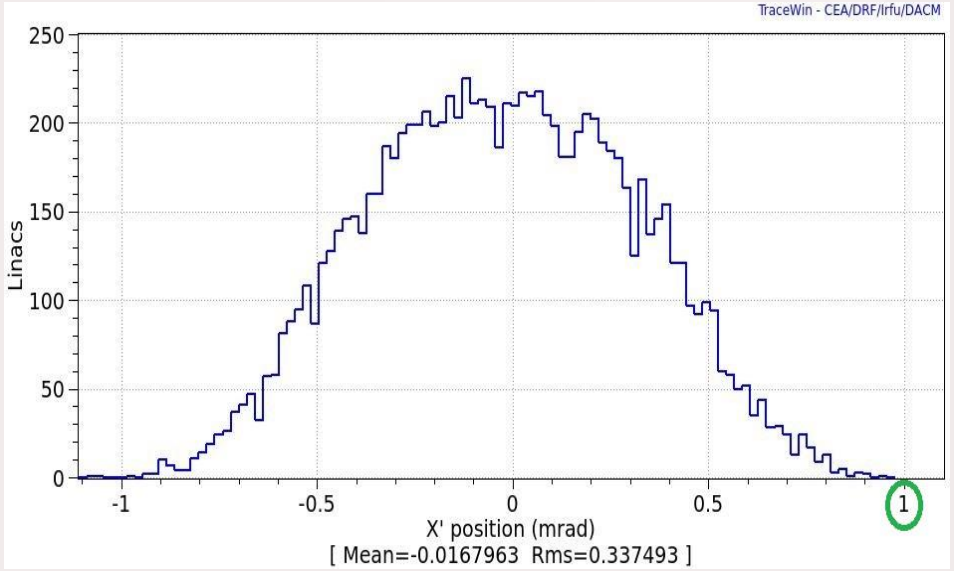
2 magnetic quadrupoles :

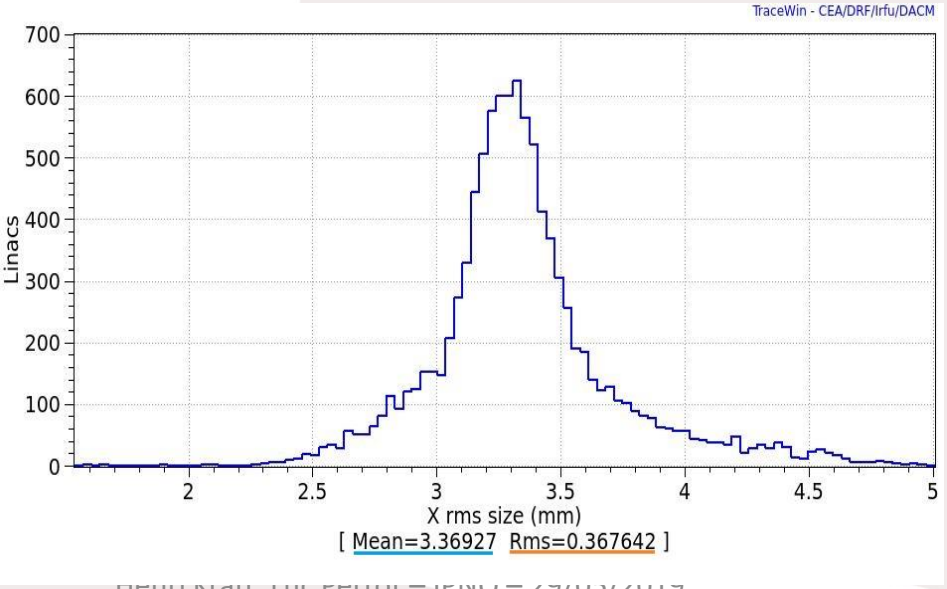
- Keep focusing effects
- Slightly enhance the kick before the septum.
- Simulation of Off-centered quadrupoles.

→Equivalent to Dipoles with index

Impact des erreurs en entrée septum







- Simulations jusqu'à l'entrée du Septum

- Spécifications du septum : la taille faisceau

- Extension à 6 RMS du faisceau PTF et FPTB avec la marge de sécurité:

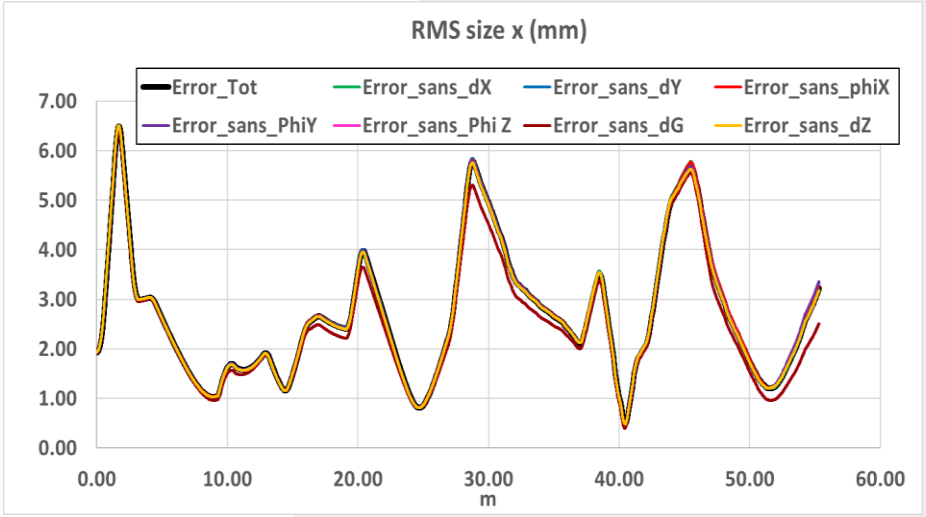
$$\mathbf{Size_{SFx}} = 6 + 6 * (3.369 + 3 * 0.368)$$

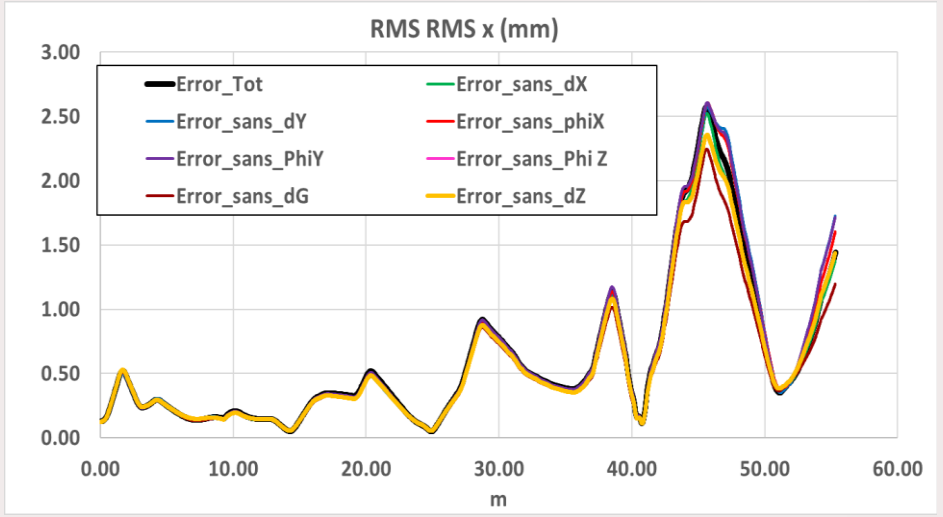
$$\mathbf{Size_{SFx}} = \mathbf{32.7\ mm}$$

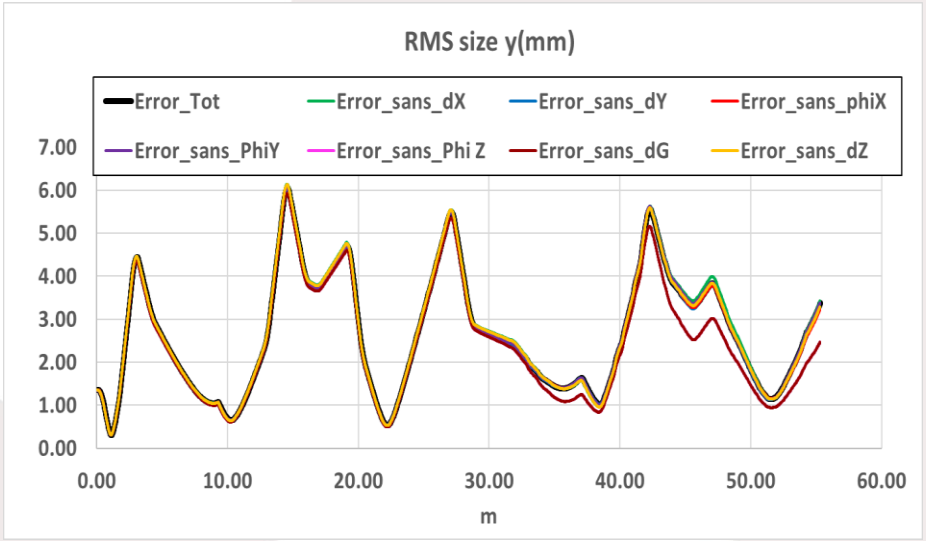
- Contribution de la divergence: +/- 1 mrad
  2mm de Shift faisceau en sortie du septum ($L \sim 2m$)

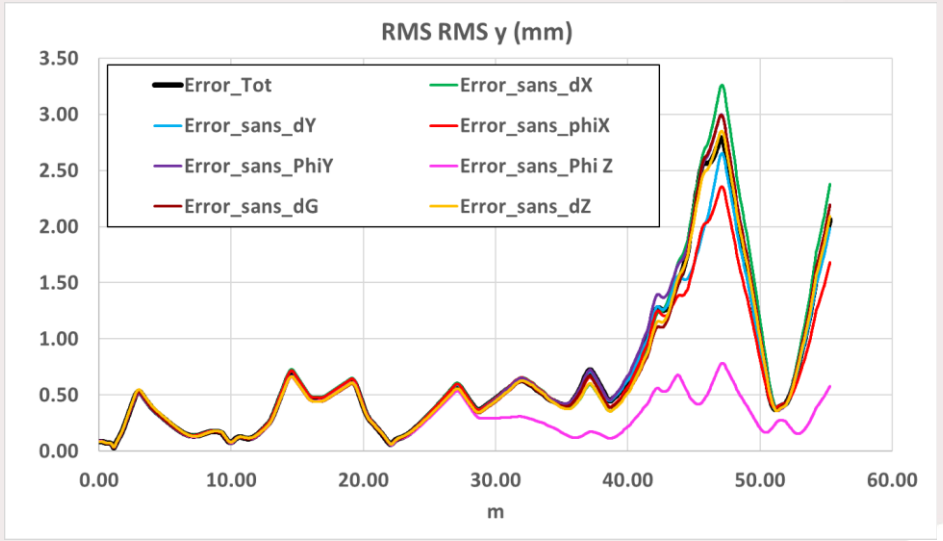
PTF LINE

Sensibilité de la ligne liées aux erreurs QUAD - RMS X,Y ; ΔE = 0.2 MeV



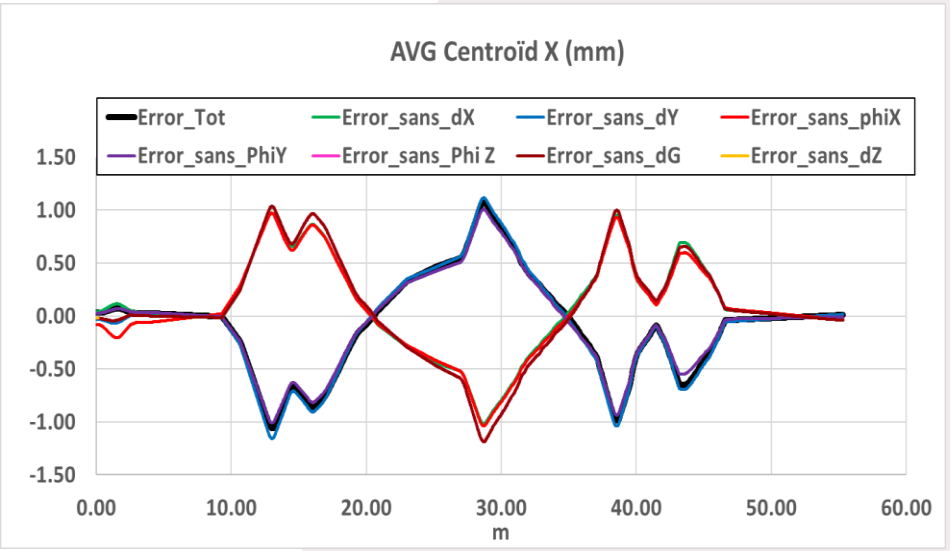


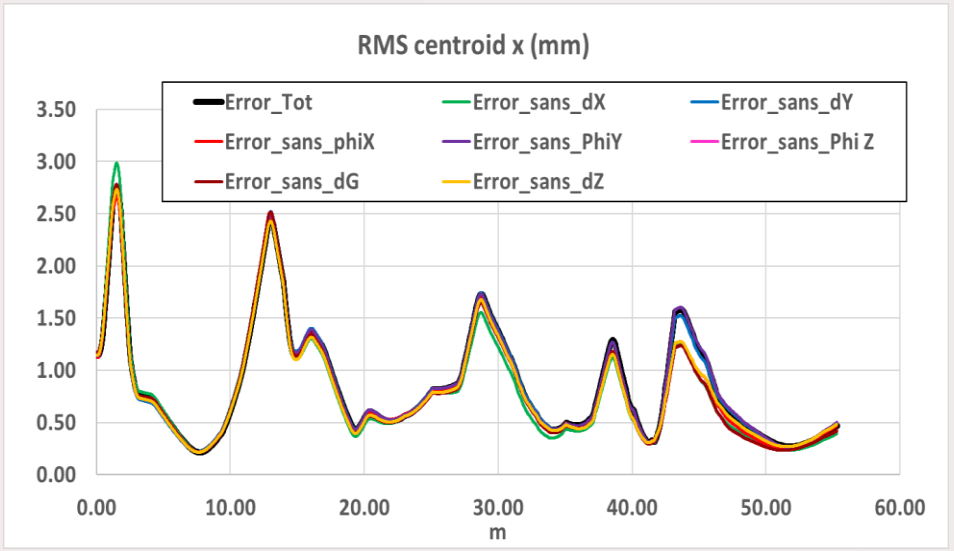


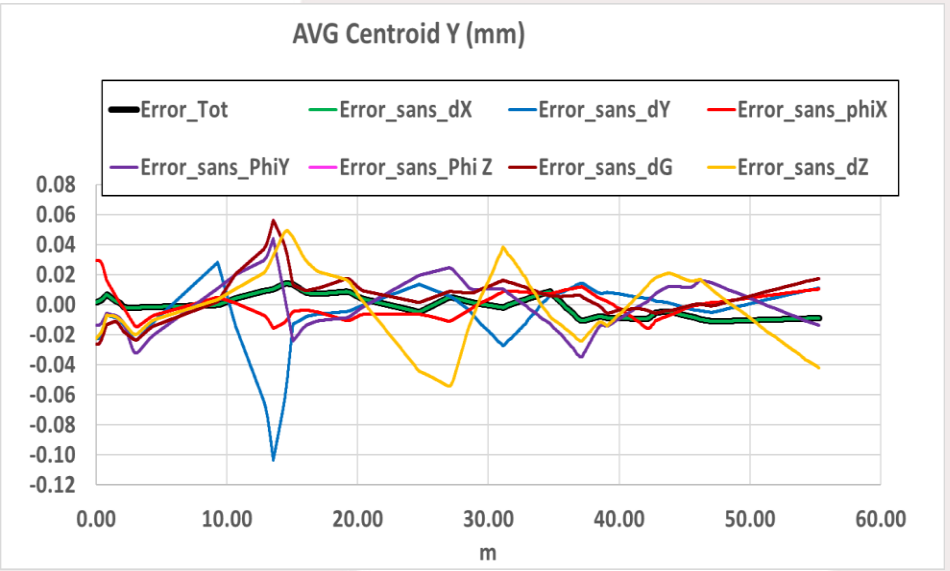


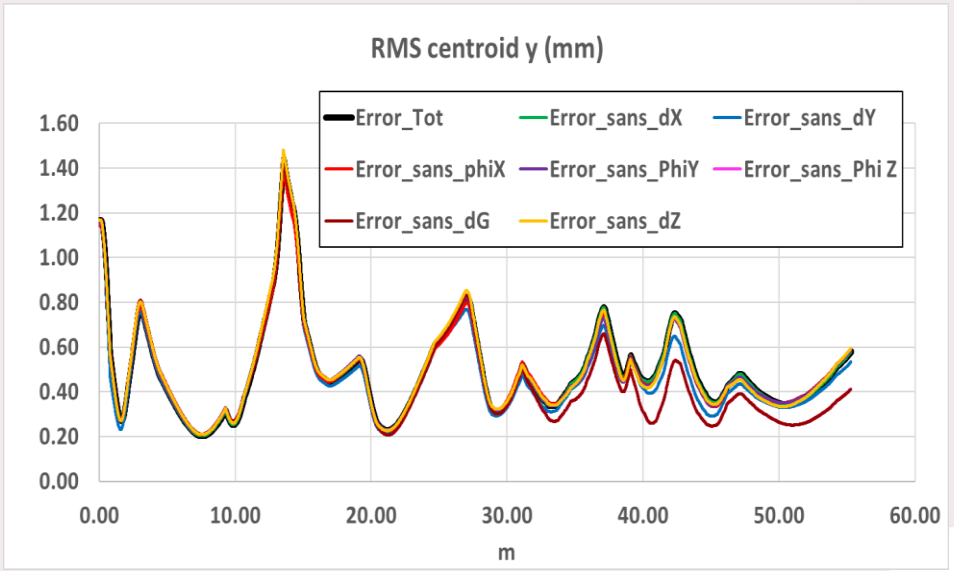
PTF LINE

Sensibilité de la ligne liées aux erreurs QUAD - Centroid X,Y ; ΔE = 0.2 MeV

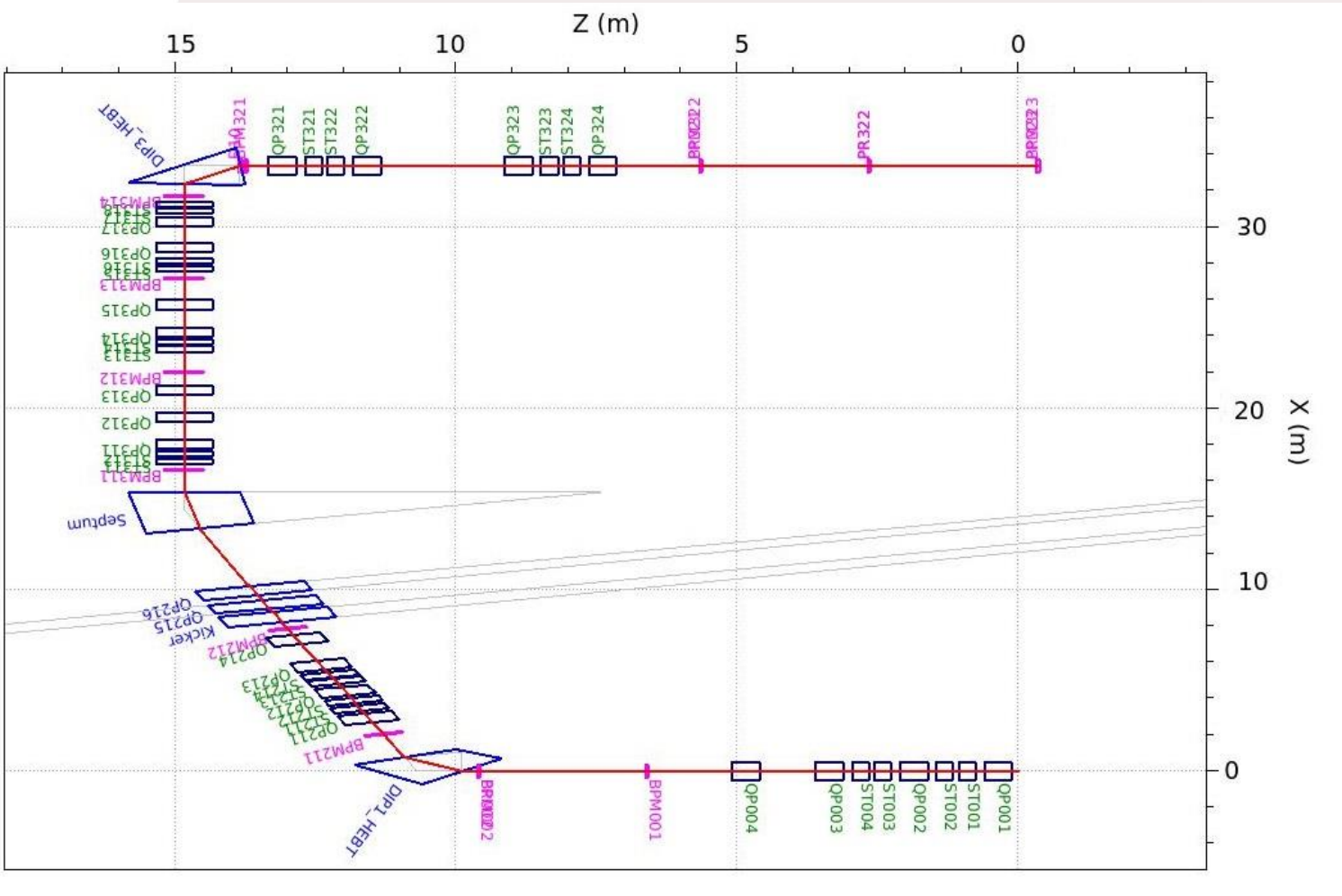






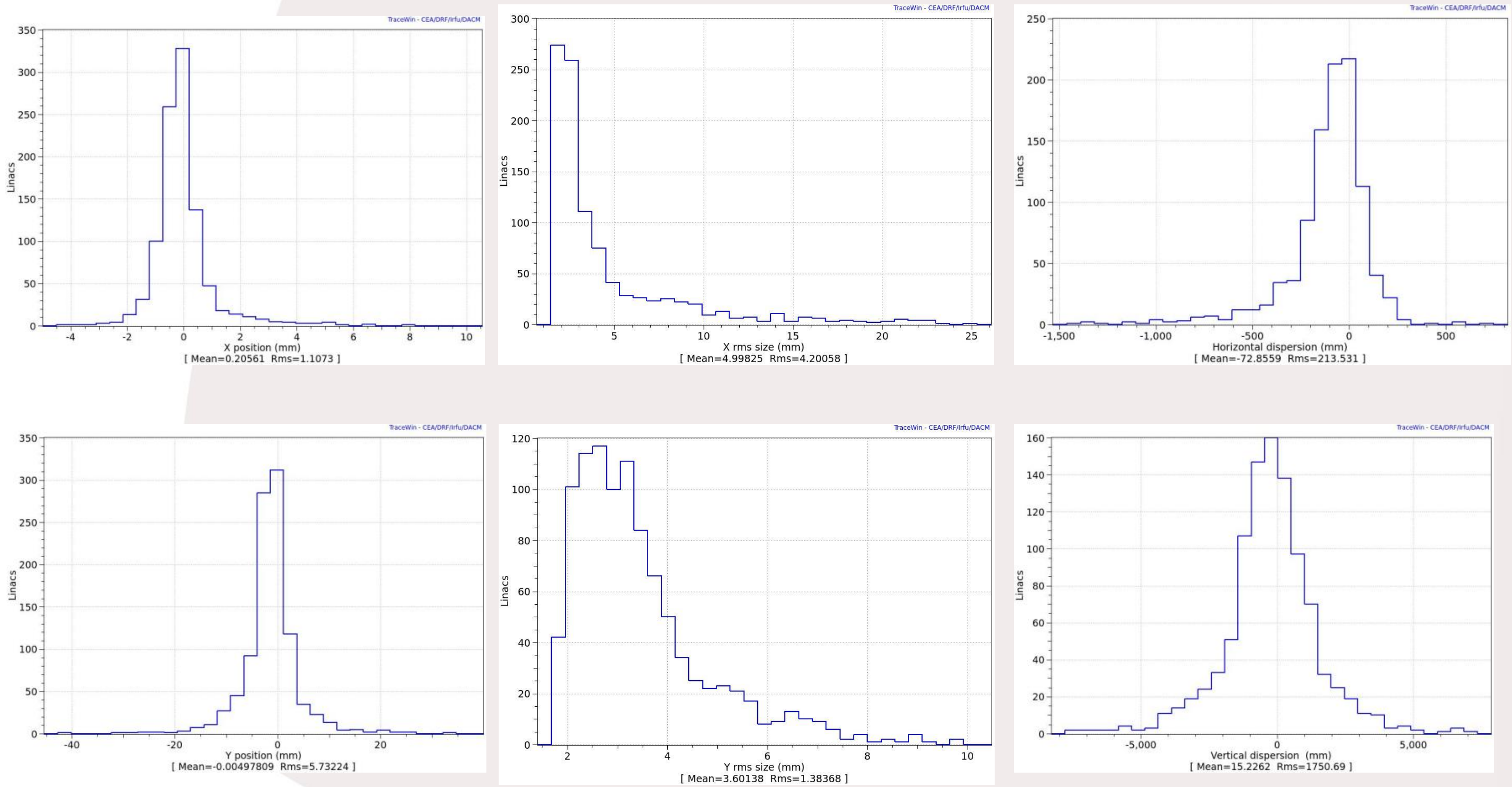


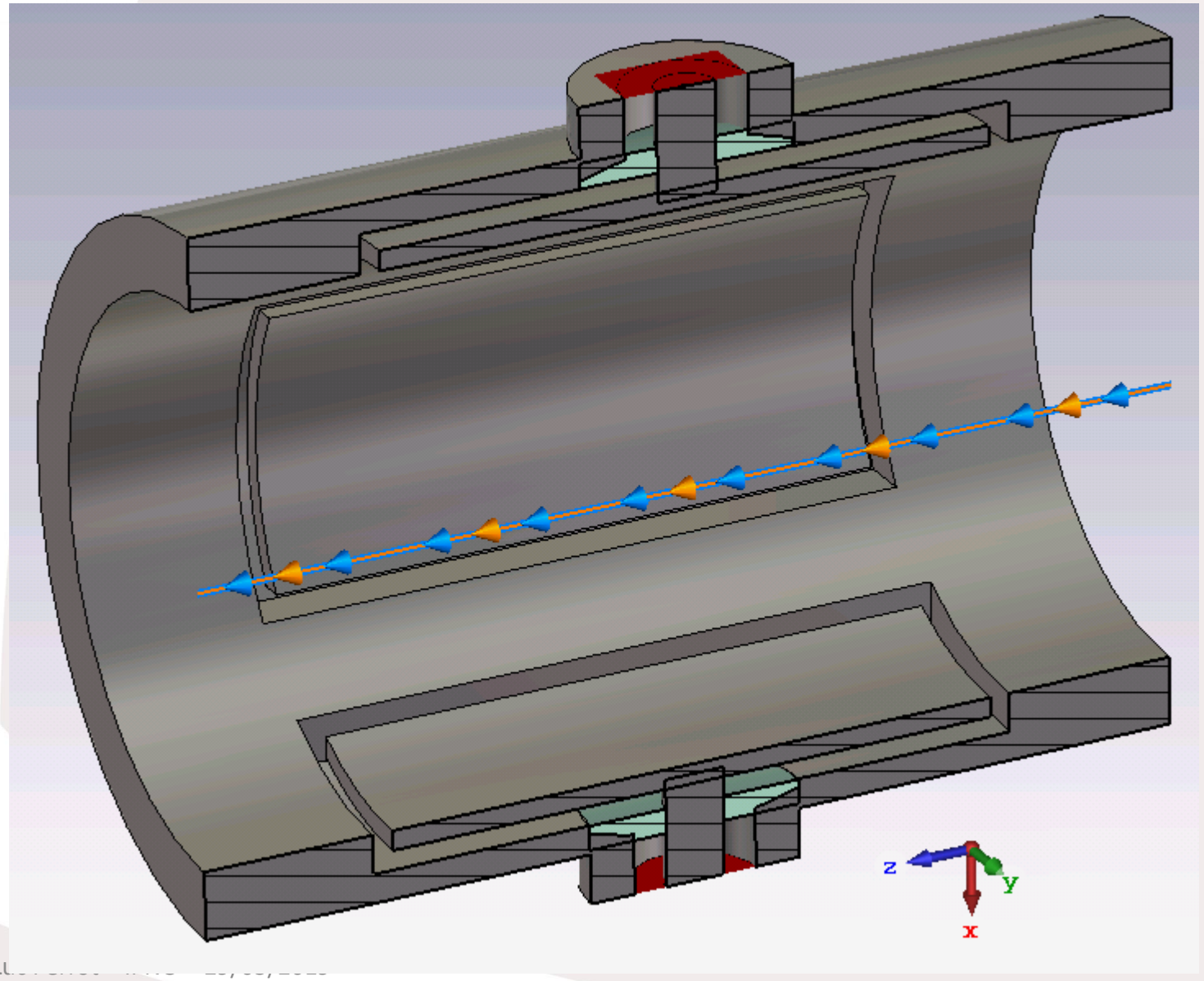
CONCLUSIONS - PERSPECTIVES



INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

STATISTIQUES D'ERREURS TRACEWIN – SORTIE HEBT CALCUL D'ERREURS EN ENVELOPPE (POSITION, RMS, DISPERSION)




z
y
x

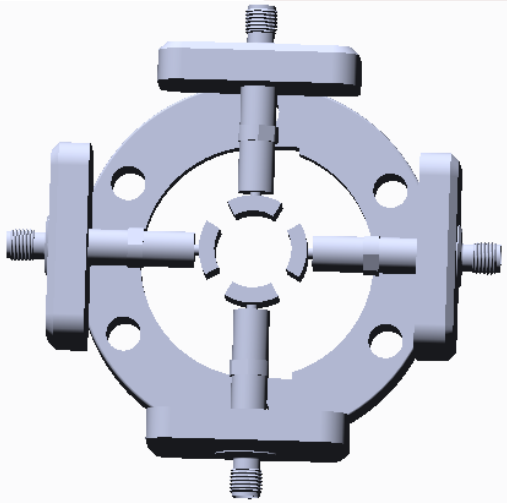
DIAGNOSTICS

Définition des détécteurs et electronique d'acquisition :

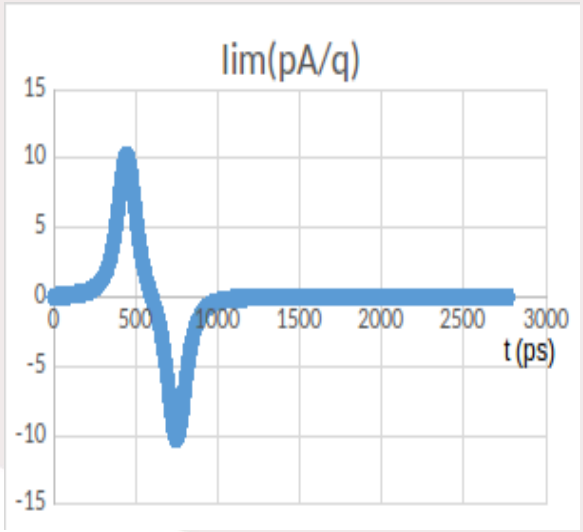
Beam position monitor (BPM) , Beam Current Monitor (BCM) , Beam loss Monitor (BLM), Phase monitor, Profile monitor , Beam Emittance monitor (BEM), etc …

Dans l'idée d'un fonctionnement à long terme, le choix de détécteurs non destructif est le plus pertinent, par exemple , BPM-Button type.

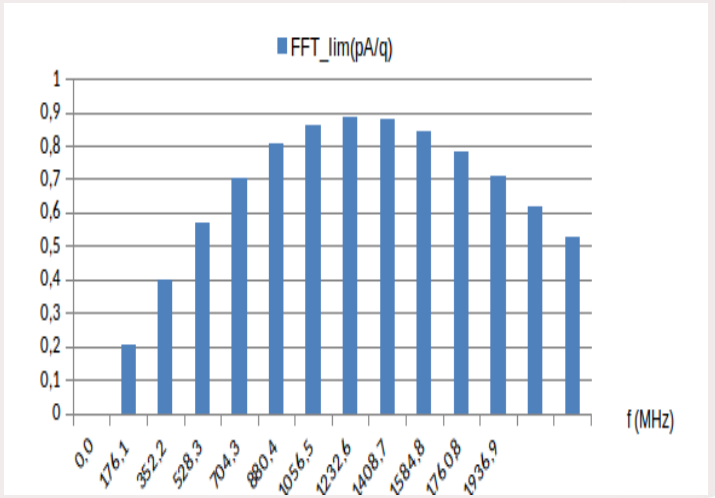
Discrétisation du signal analogique => analyse des datas. Une FFT du signal permet de représenter les harmoniques du signal, permettant de designer l'électronique du numériseur qui filtrera sur 1 ou 2 harmonique pour réduire un maximum le bruit de mesure



BPM button type



Output 1 electrode BPM



FFT - Harmonics of the signal