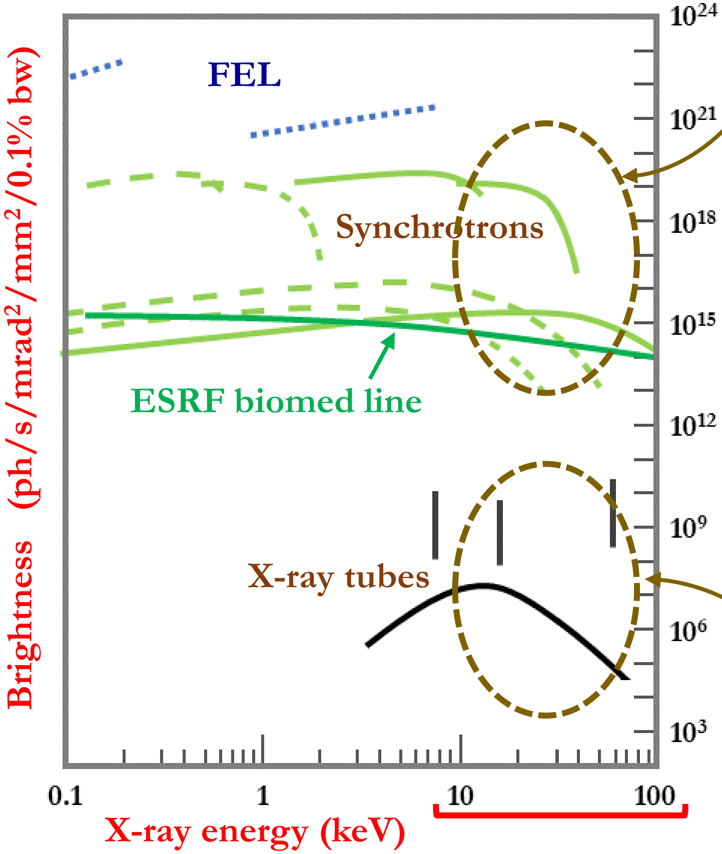
AG Pôle Accélérateur

23 septembre 2022 - IJCLab

ThomX

(a demonstrator)

ThomX: WHY ?



Synchrotrons

High power, monochromaticity, coherence

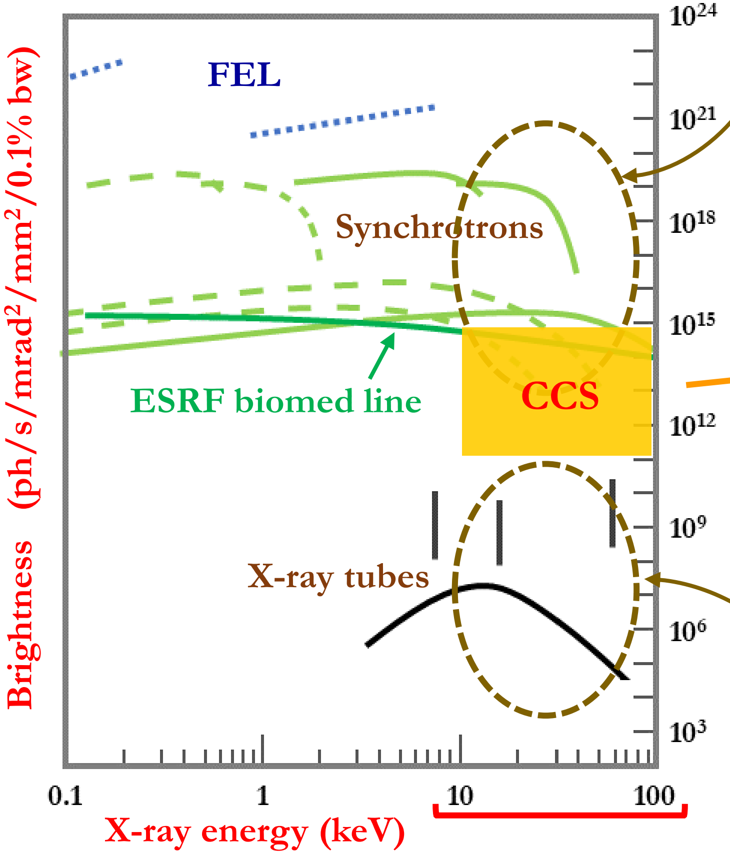
Large facilities
Not very practical
Limited access time

X-ray tubes

Lab-size sources

Lack of power, monochromaticity, coherence

ThomX: WHY ?



Synchrotrons

High power, monochromaticity, coherence

Large facilities
Not very practical
Limited access time

COMPACT installations (surface < 100 m^2)

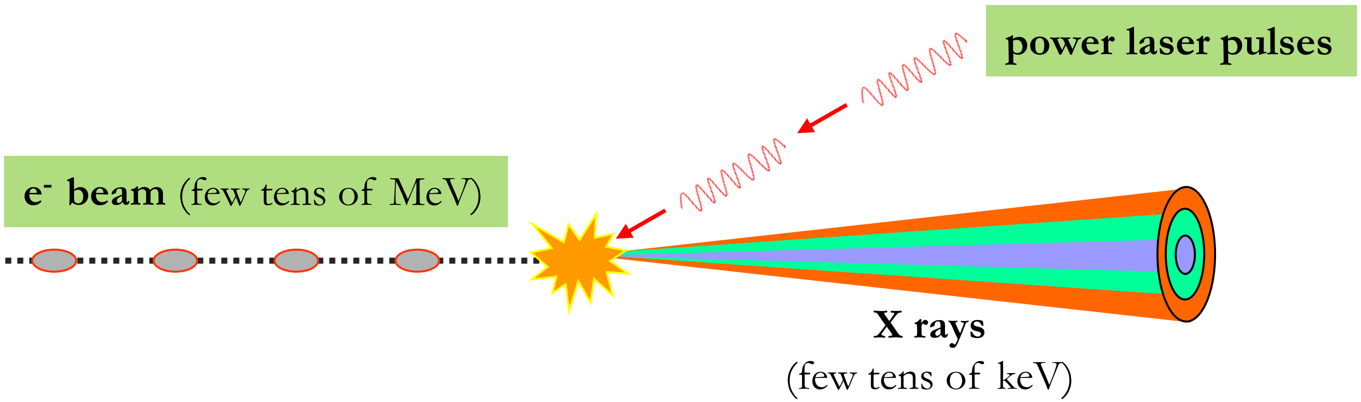
Some powerful analyzes currently realized at synchrotrons and requiring a high brightness beam could be developed in a lab-size environment (hospitals, labs, museums).

X-ray tubes

Lab-size sources

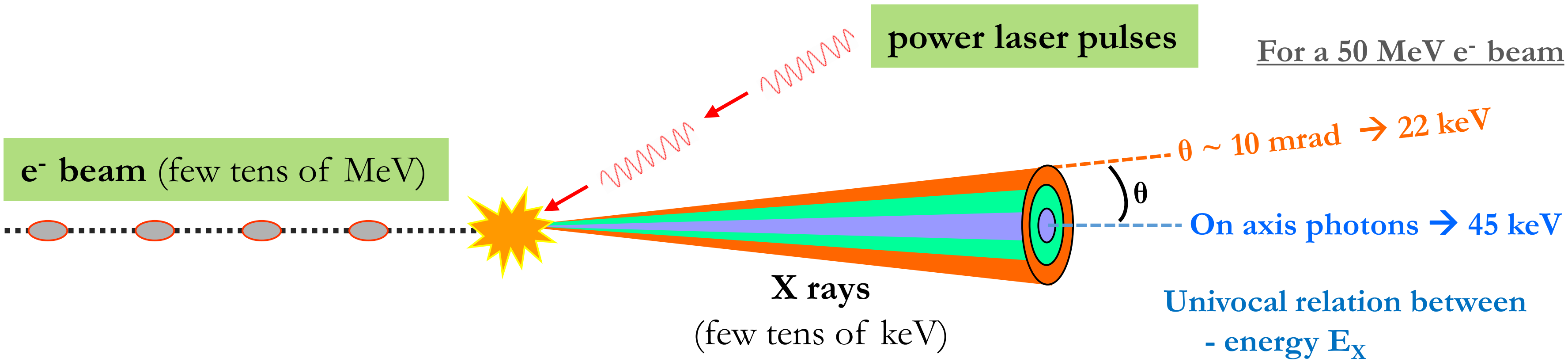
Lack of power, monochromaticity, coherence

ThomX: HOW ?



Conical X beam, Naturally divergent
(Compton effect)

ThomX: HOW ?

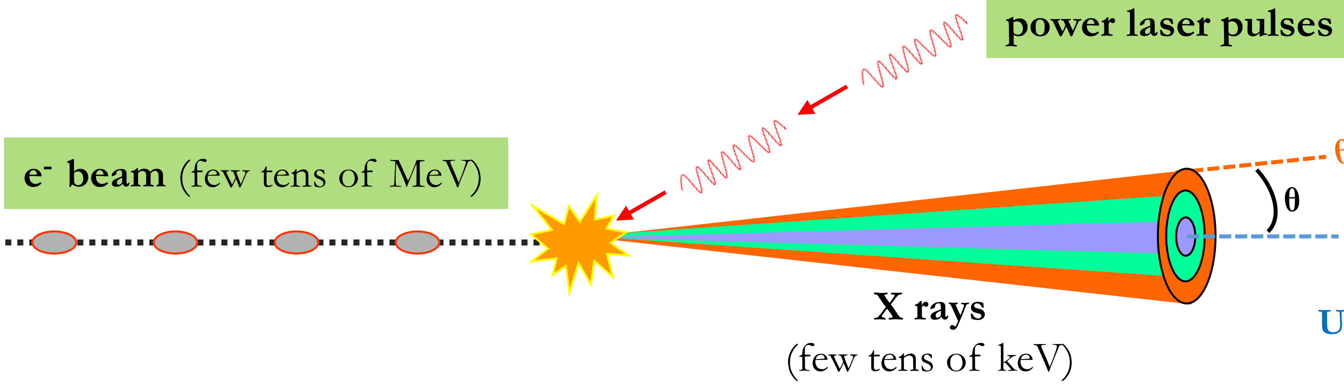


Conical X beam, Naturally divergent (Compton effect)

Univocal relation between
- **energy E_X**
- **and diffusion angle θ**

→ Quasi-Monochromatic beam with a simple diaphragm

ThomX: HOW ?



For a 50 MeV e$^-$ beam

Univocal relation between
- energy E_X
- and diffusion angle θ

→ Quasi-Monochromatic beam with a simple diaphragm

Conical X beam, Naturally divergent (Compton effect)

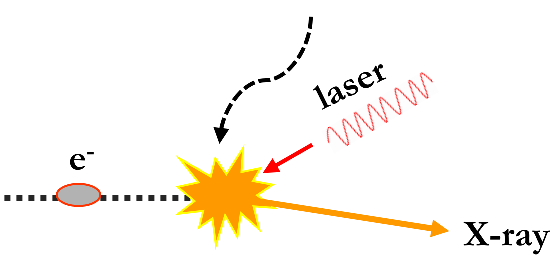
High flux HOW ?

Critical parameter:
The repetition frequency Frep of e-/laser interactions

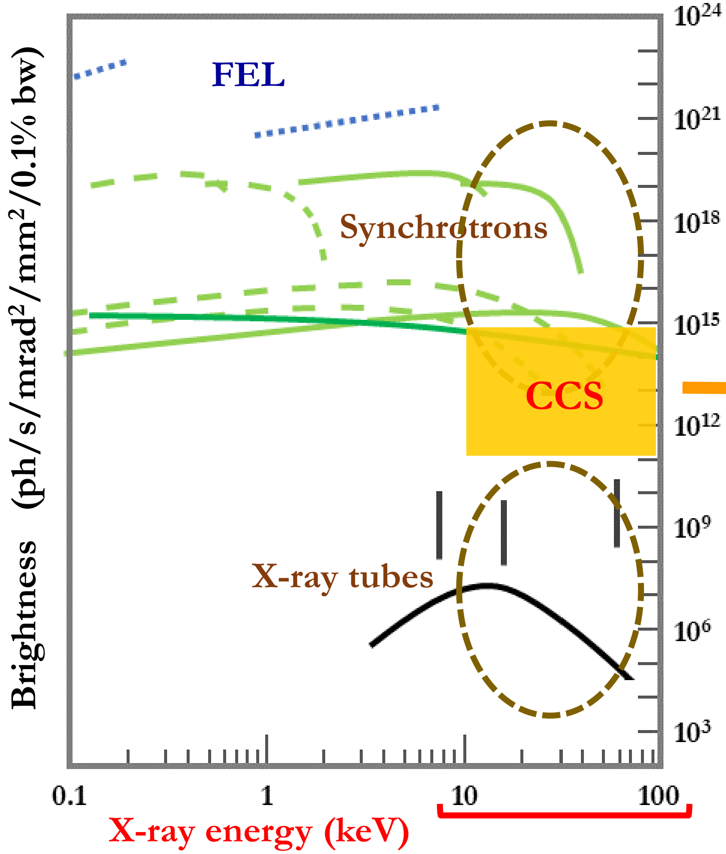
To obtain High Flux **(>10^{12} ph/s)**

→ e$^-$/laser Frep ~ few tens of MHz
Sine qua none condition

cross section is very small ($6.6\ 10^{-25}$ cm^2)



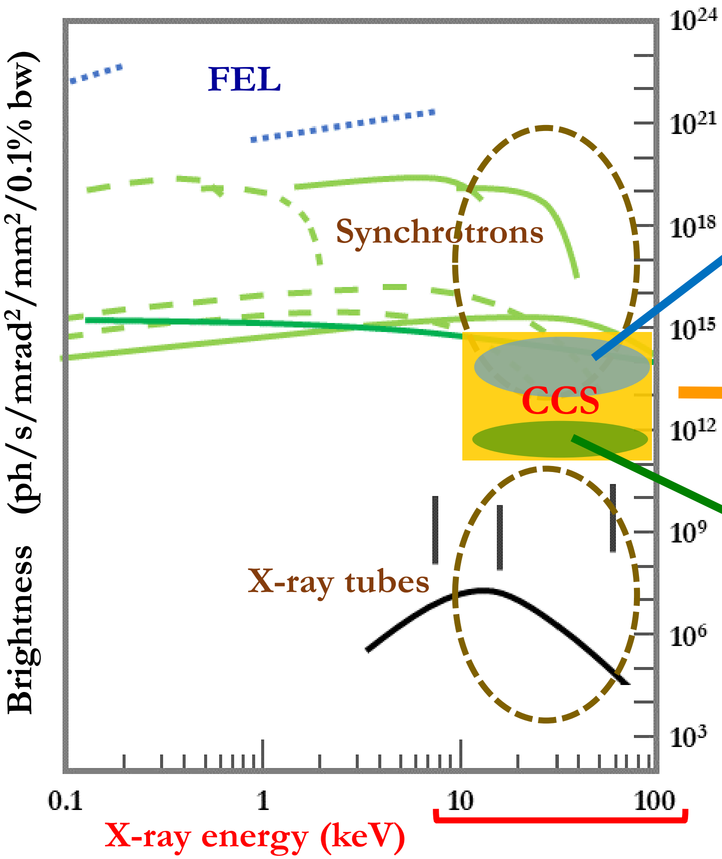
ThomX: HOW ?



Flux >10^{12} ph/s

(Frep ~ tens MHz)

ThomX: HOW ?



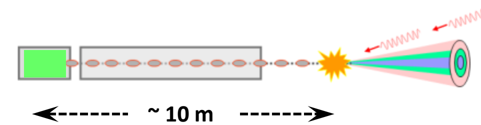
Not yet mature technology

Flux $>10^{12}$ ph/s
(Frep ~ tens MHz)

LINAC scheme
Superconducting electron gun

Frep = F_INJ ~ tens MHz

Intensity ~ mA

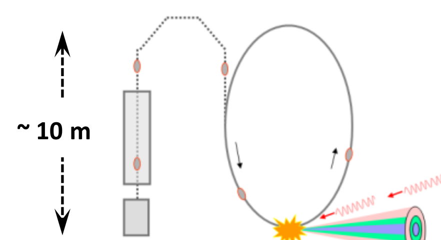


e- emittance: 0.1 - 0.5 mm.mrad

STORAGE RING scheme
Hot technology

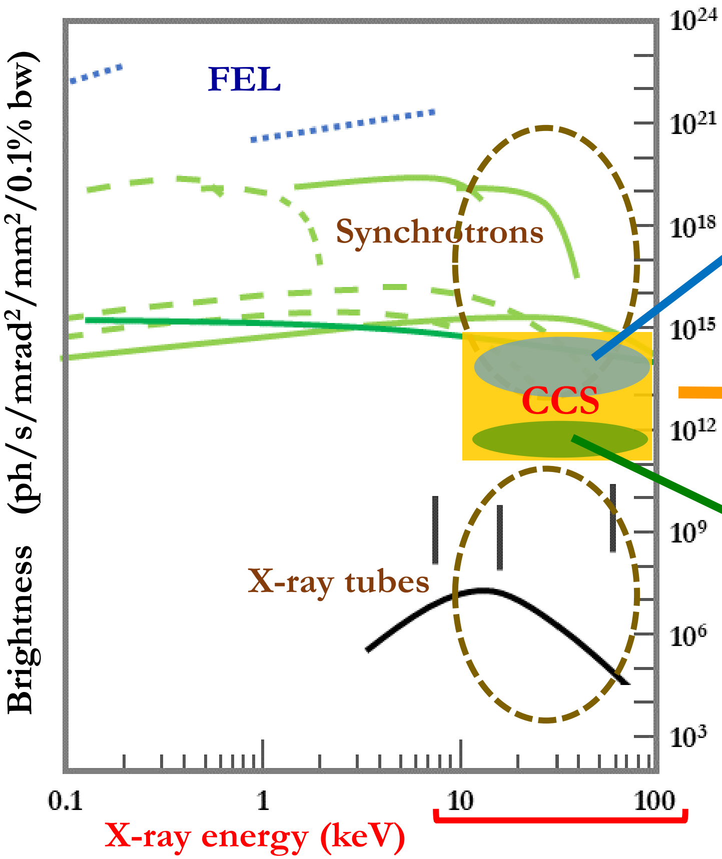
Frep = F_REV ~ tens MHz

Intensity ~ 10 mA



e- emittance: 1 - 10 mm.mrad

ThomX: HOW ?



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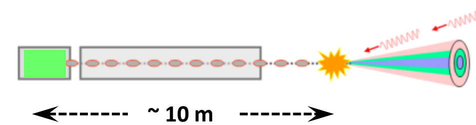

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STORAGE RING scheme
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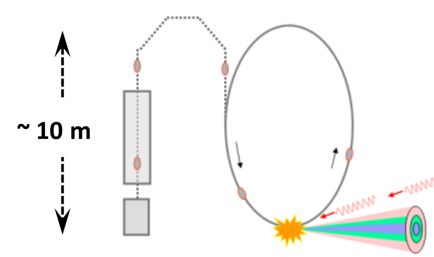
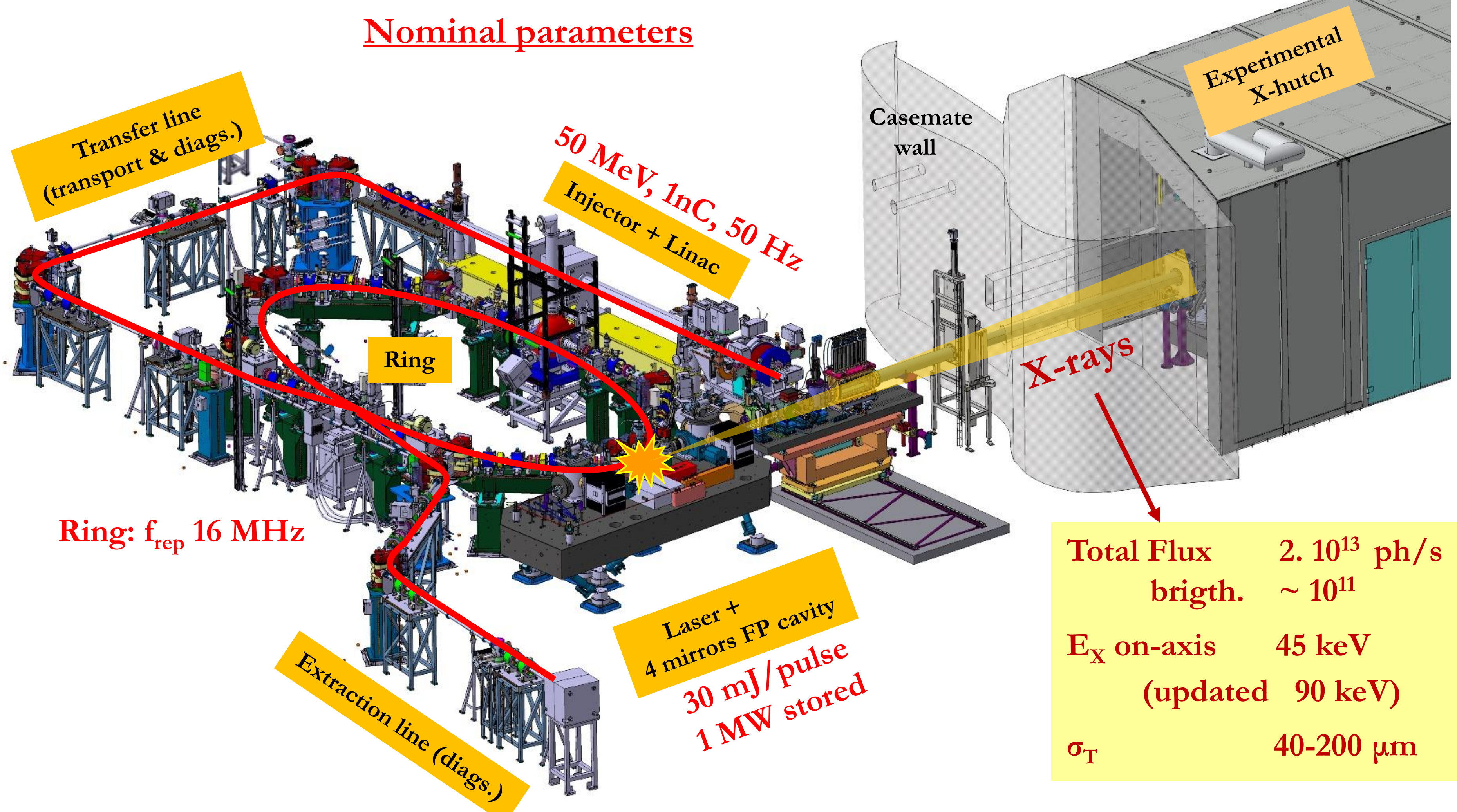
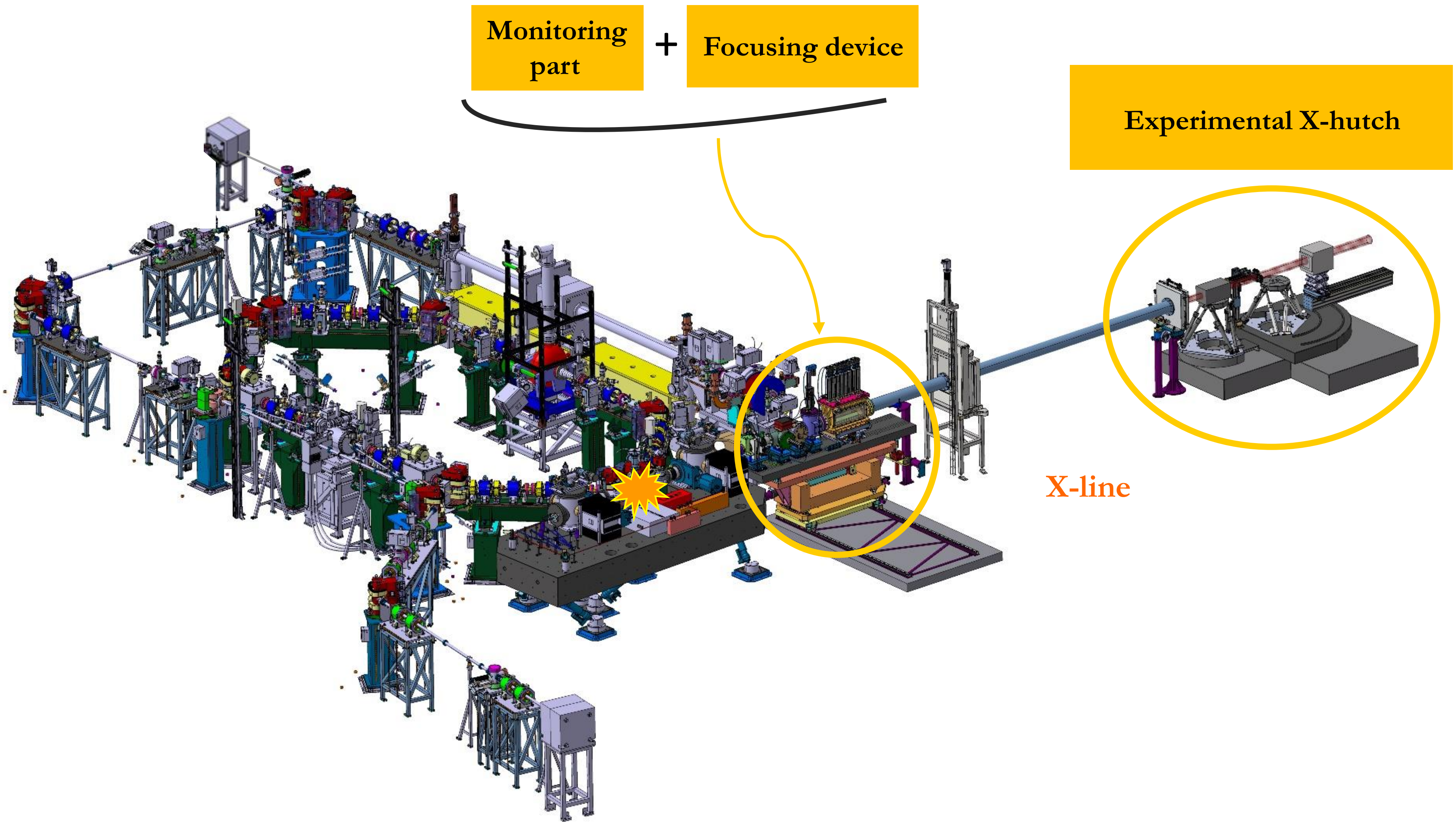


e- emittance: 1 - 10 mm.mrad

ThomX DESIGN



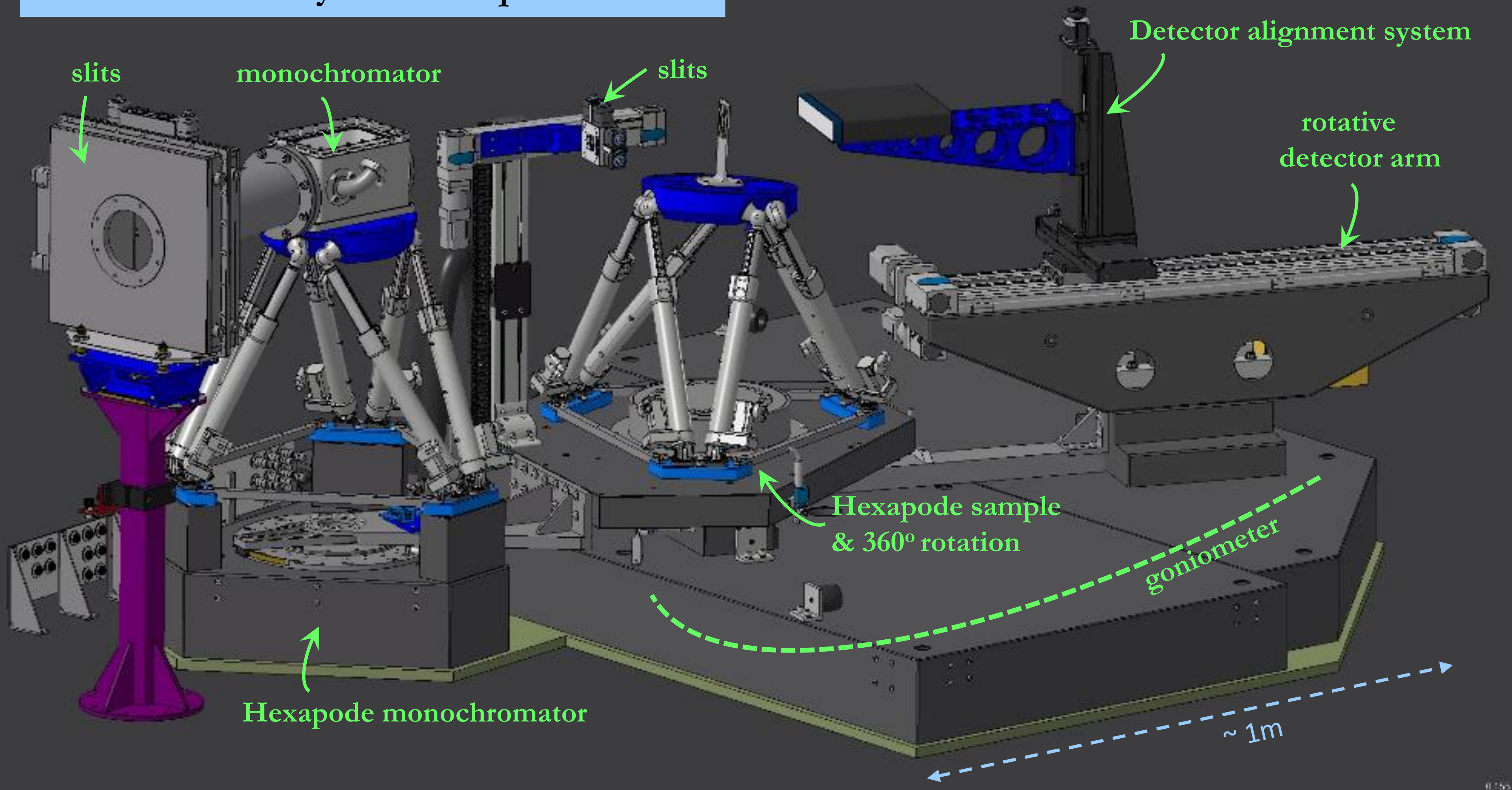
X-line INTEGRATION



X-ray experimental hutch

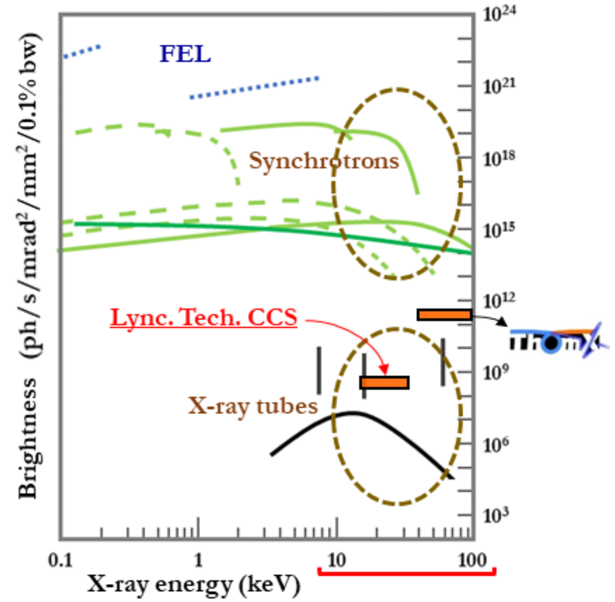
→ **Design a modulable equipment in order to be able to explore/qualify the main analysis techniques**

- Standard imaging
- Phase contrast imaging
- Tomography
- Fluo spectro
- Diffraction



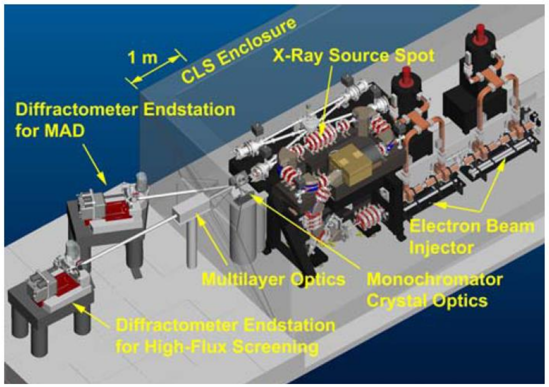
PROOFS of PRINCIPLE @ Lyncean Tech./Munich

(10^{10} -10^{11} ph/s)

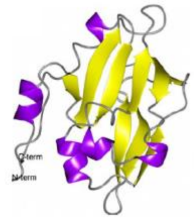


DIFFRACTION

3D structure determination Protein MytuGCSPH



- E = 15 keV
- 5. 10^6 ph/s, few % bw

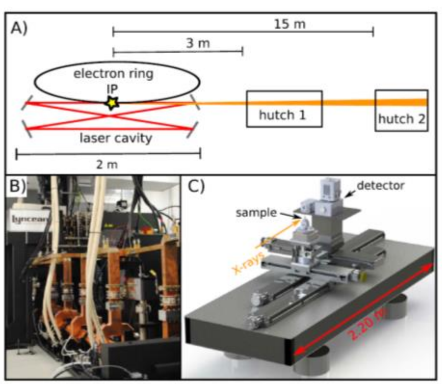


Flux and results comparable with the same analysis realized at a rotating anode

[J. Struct. Funct. Gen. 11, 2010, 91-100]

PHASE CONTRAST IMAGING

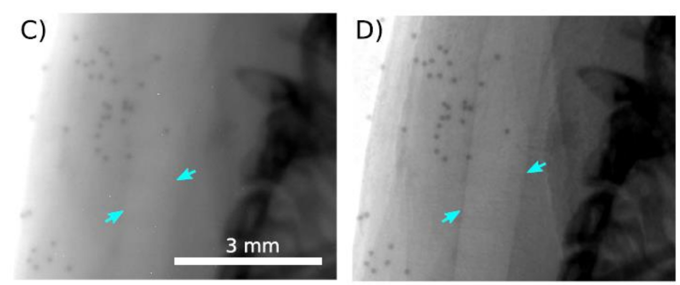
Mouse trachea region imaging



- E = 25 keV
- 10^8 - 10^9 ph/s, 3-4% bw
- 16 mm diameter beam

Exposure time = 1 sec

[Scientific Reports volume 7, 4908, 2017]



Standard imaging

Prop. based PCI

Air/tissue interfaces more visible

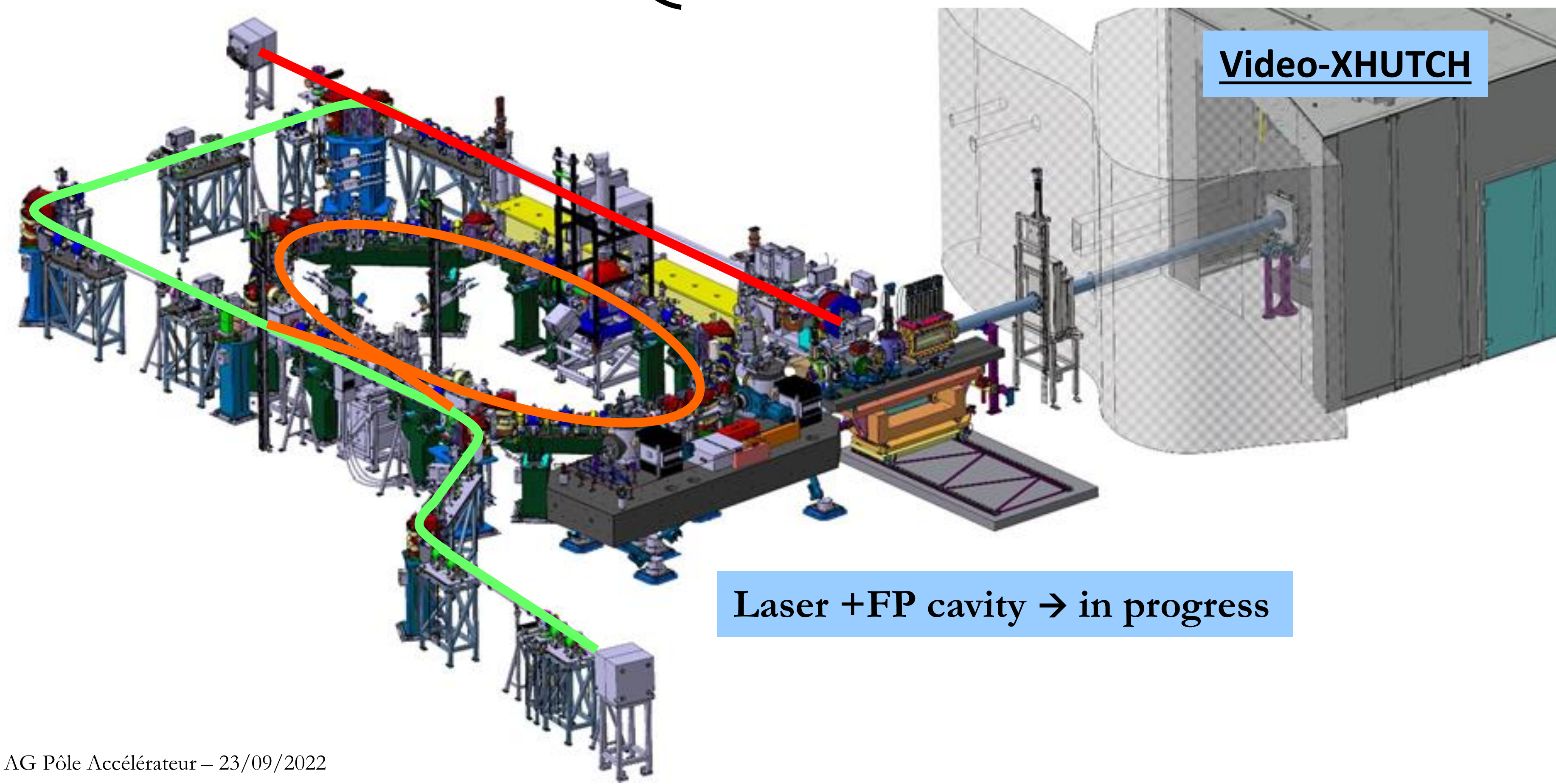
Where are we now ?

Commissioning

Since September 2021, LINAC

Since September 2022,

TRANSFER Line
EXTRACTION Line
INJECTION + RING



THOMX

Retour sur le commissioning

Sophie Chance, Hayg Guler, Christelle Bruni

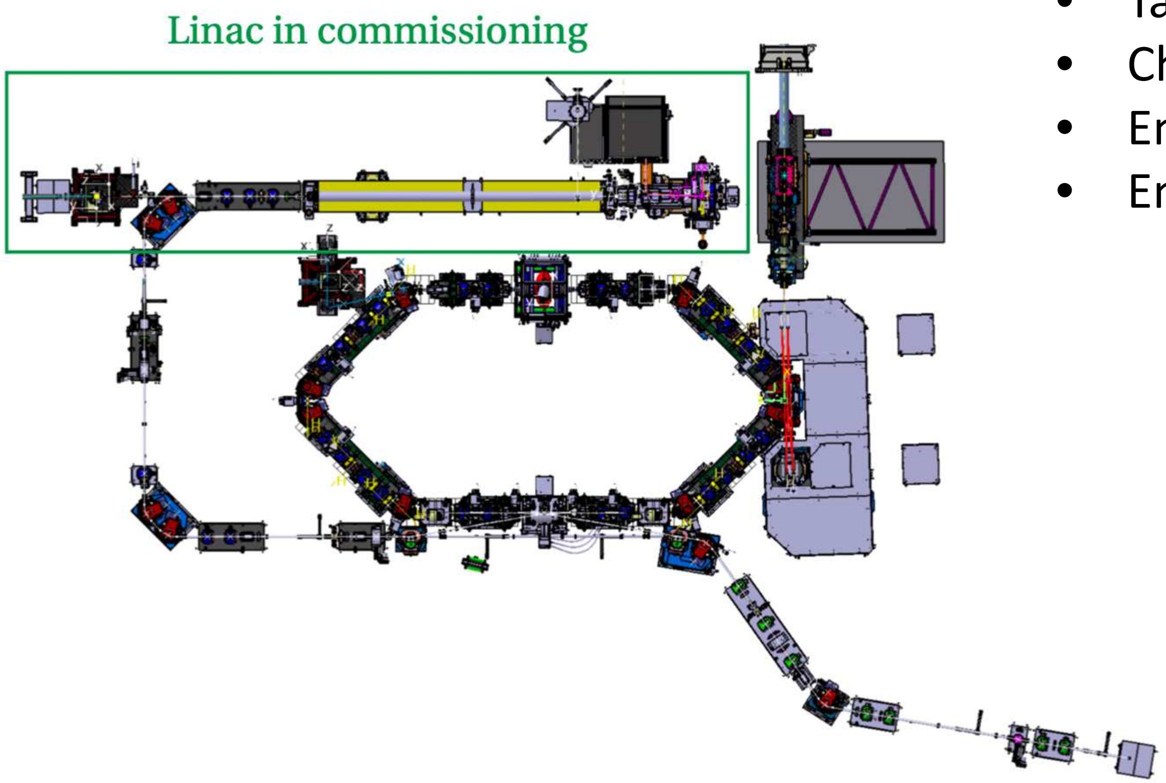
Pour

L'équipe ThomX

Quelques dates

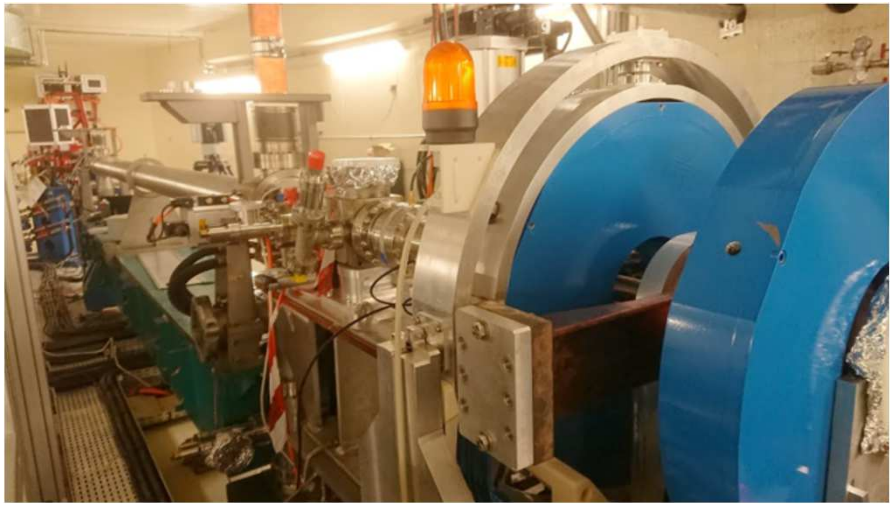
- 2021 :
  - Fermeture anneau
  - **Mai : autorisation ASN**
  - Juillet : conditionnement RF section
  - Septembre : conditionnement canon à 1Hz (nominal 50 Hz)
  - Lundi 4 Octobre : premier faisceau canon ~4 MeV (60 MV/m)
  - Mercredi 6 octobre : premier faisceau section 37 MeV (nominal 50 MeV)
  - 20 octobre : 10 Hz
  - 26 octobre : faisceau 50 MeV
  - 15 novembre : gradient canon 60 MV/m→ 80 MV/m
  - 25 novembre : 100pC, 10 Hz, 50 MeV

Commissioning du Linac



Paramètres nominaux phase I :

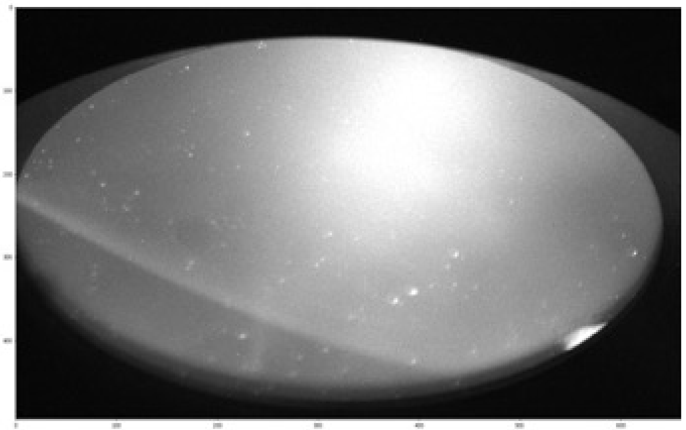
- Taux répétition : 10 Hz
- Charge : 100 pC
- Energie : 50 MeV
- Emittance transverse : 2 pi mm mrad



Conditionnement RF - linac

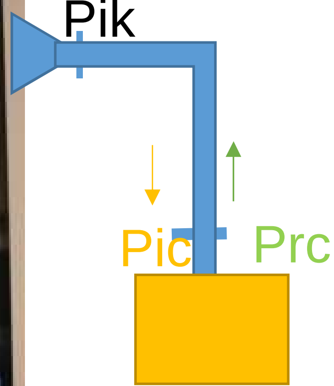
- Premier juillet : section conditionnée (9MW, 10Hz)
- Premier octobre : canon conditionné (5MW, 1 Hz)

Home made – RF gun 2.5cell

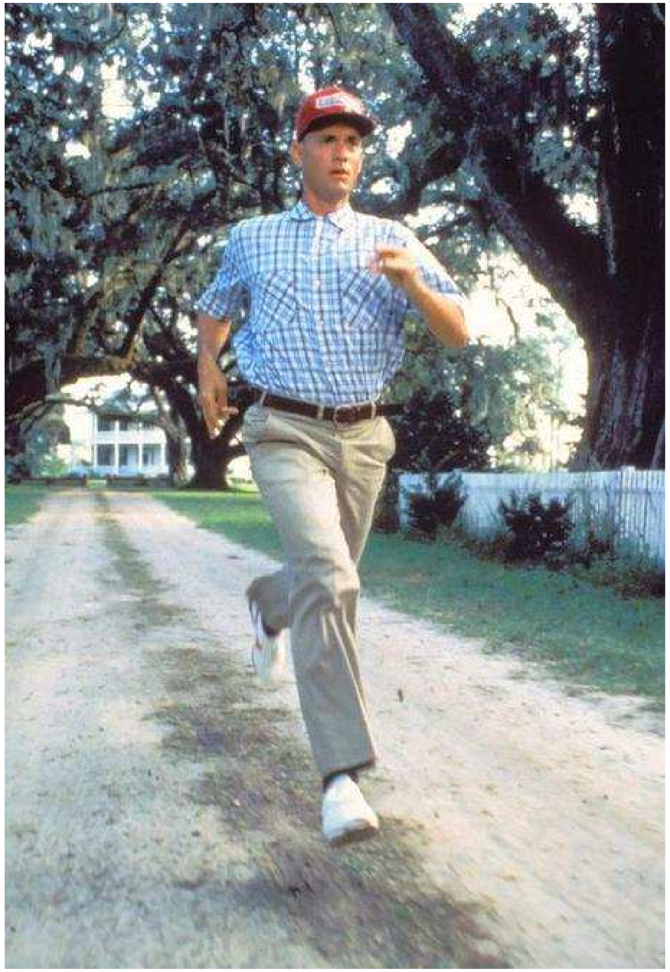


1ere image courant obscurité YAG1

6MW – 3,0 µs – 1 Hz , EZ = 60 MV/m

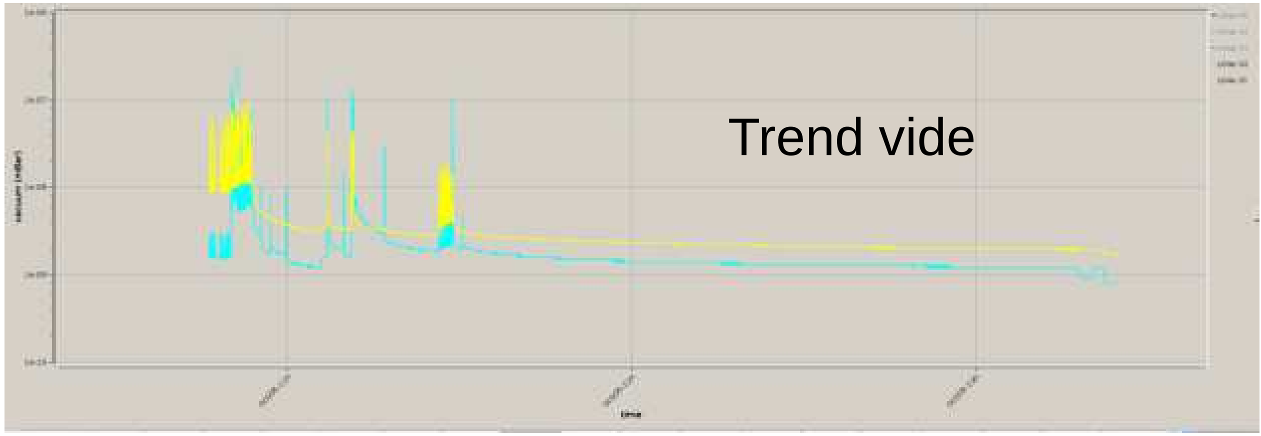


Premiers faisceau

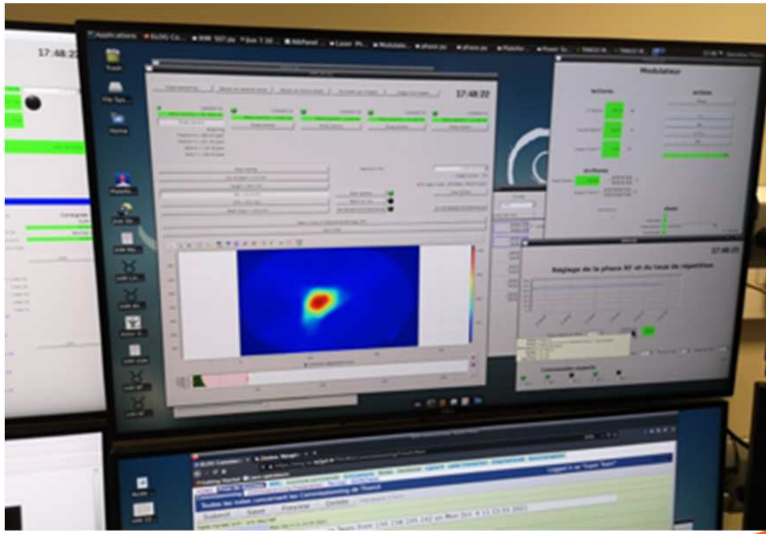


Premier faisceau canon

- Alignement laser
- Problème interlock vide
- Visualisation du faisceau sur le premier écran après recherche de la phase RF/laser



Trend vide



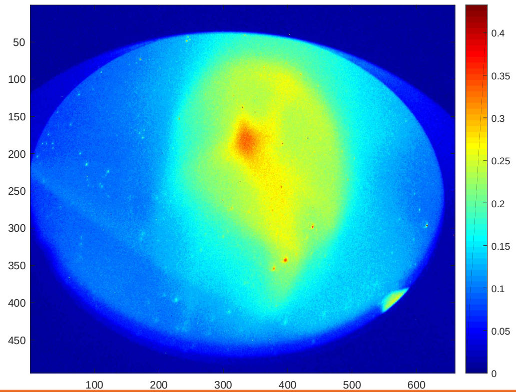
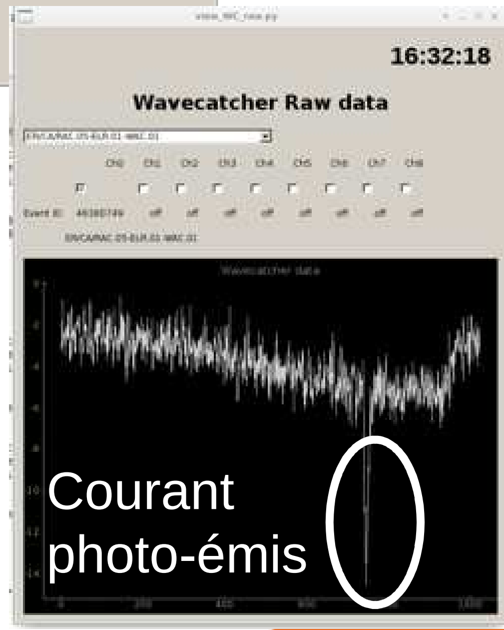
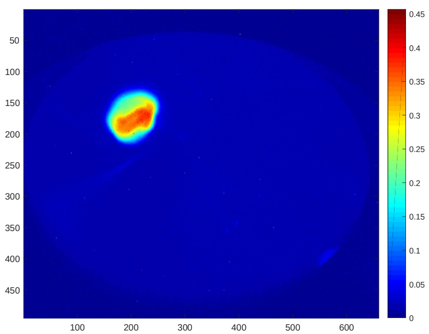


Image écran canon

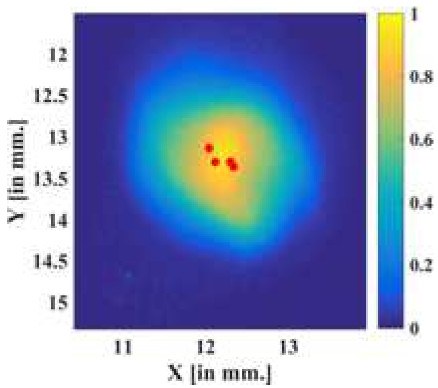
Mardi : premier faisceau canon focalisé

- Mardi :
  - Réglage des ICT
  - Montée progressive des champs des premier aimant (solénoides)



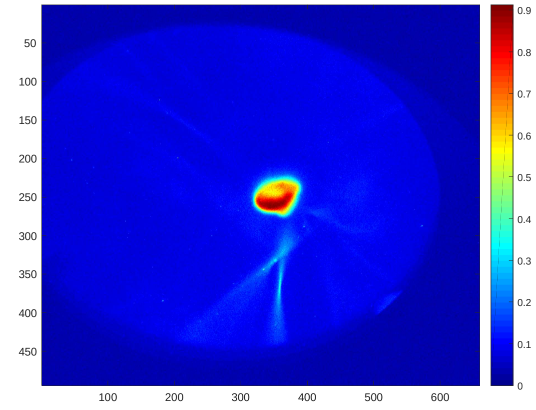


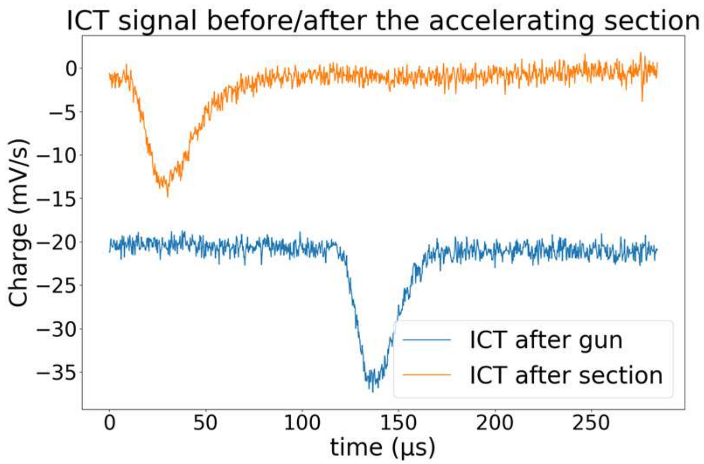
Faisceau canon focalisé



Mercredi : premier faisceau section

- Mercredi
  - Estimation énergie sortie canon 4 MeV
  - Mise en service de la section LIL
  - Mesures des puissances RF sur chaque voie avec voltmètre de crête
  - Faisceau transporté dans la section
    - Visualisé sur l’écran sortie section sans focalisation (3.2m)

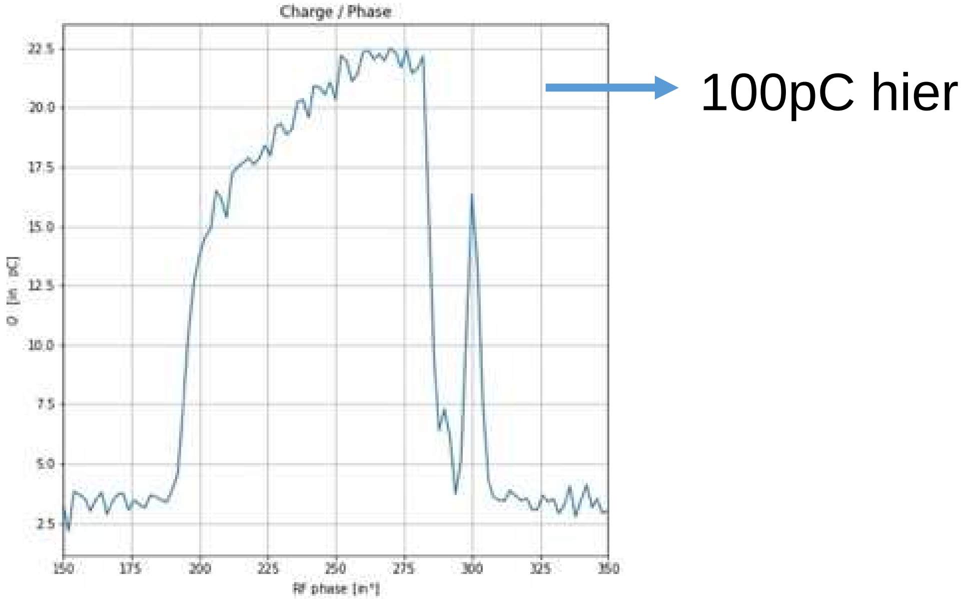




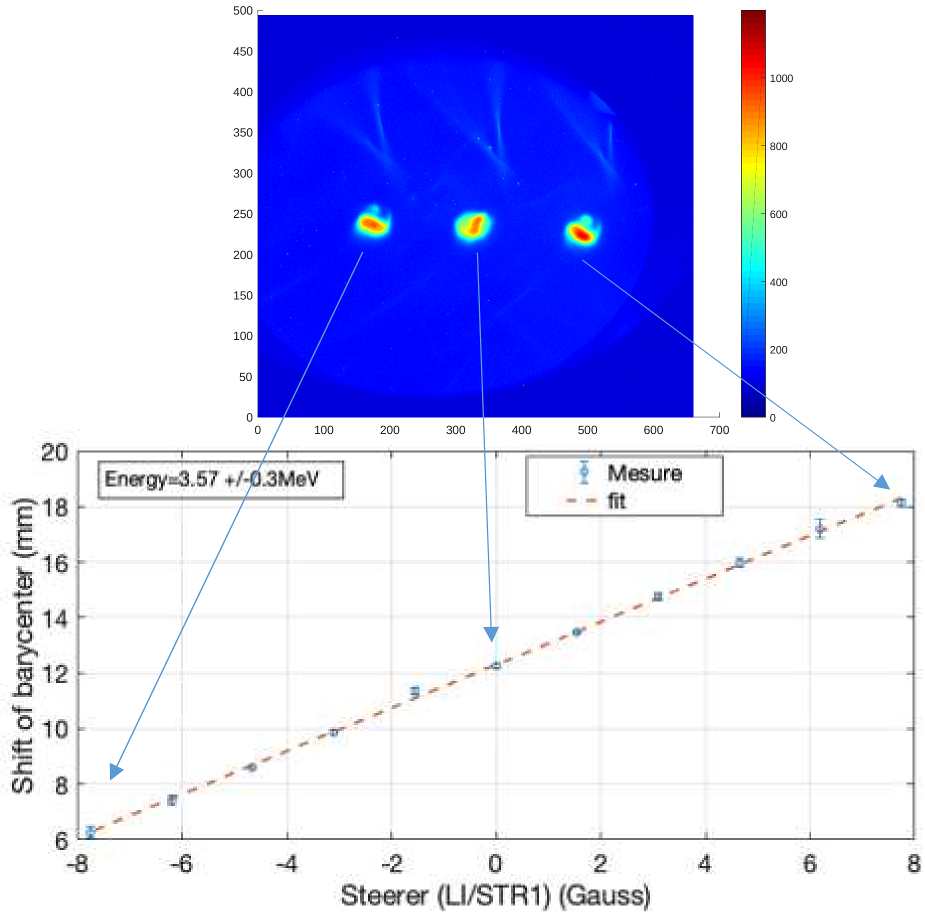
Faisceau canon accéléré par la section

Suite : automatisation des mesures et réglages

- Jeudi/vendredi
  - Début automatisation des mesures
  - Reprise de l'alignement en faisceau pas à pas

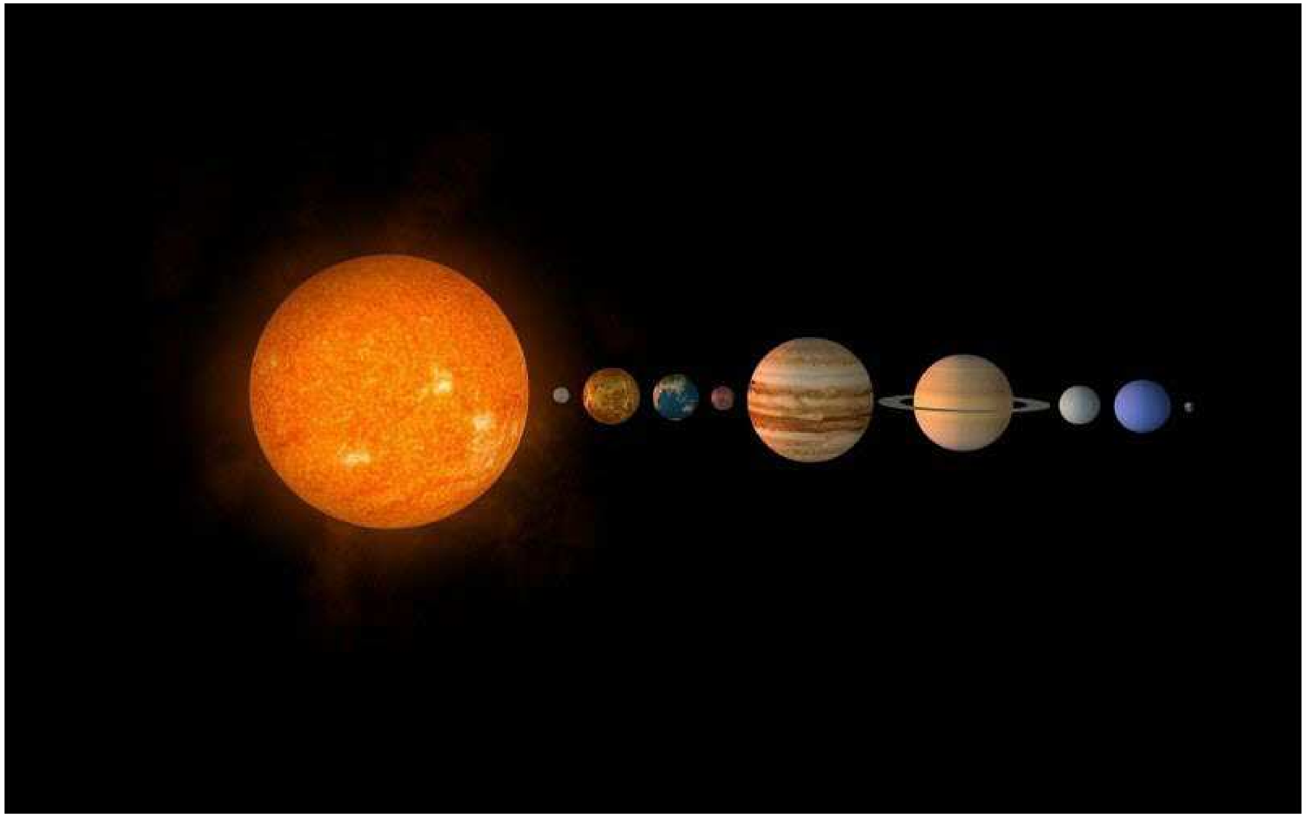


Charge en fonction de la phase laser/RF

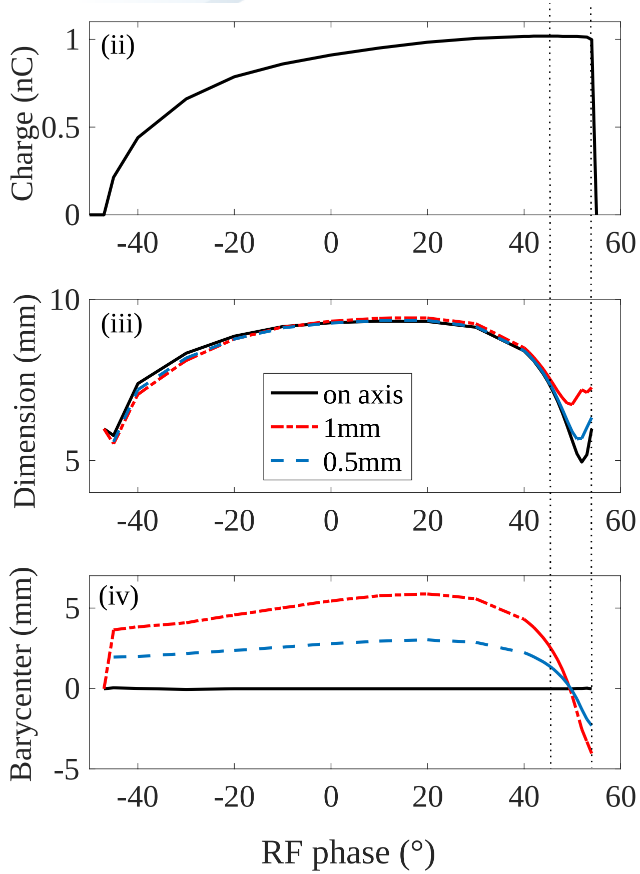


Mesure énergie avec correcteur

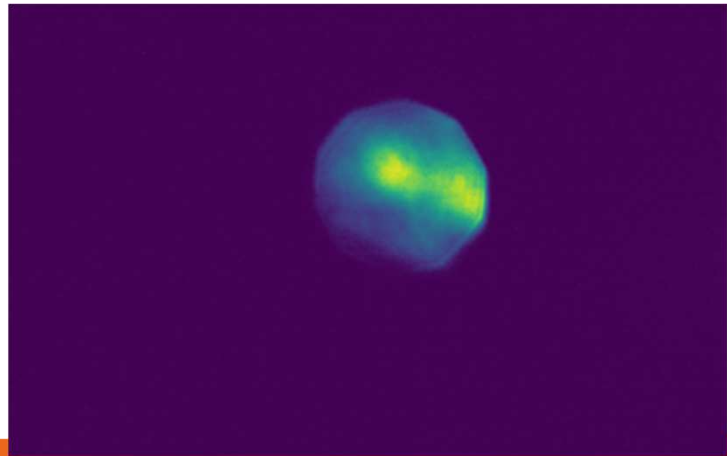
Alignement de la tête de machine



Alignement laser

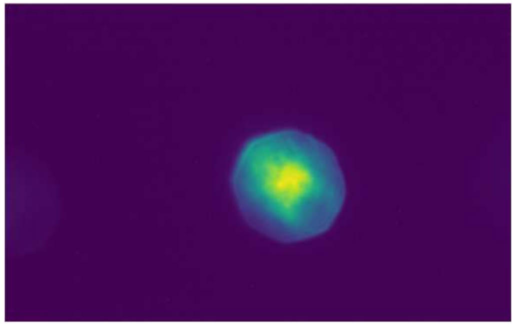


- Discrimine les effets, canon seul + faisceau photoémis
- Comportement du faisceau avec la phase relative entre la RF et le laser sur la photocathode

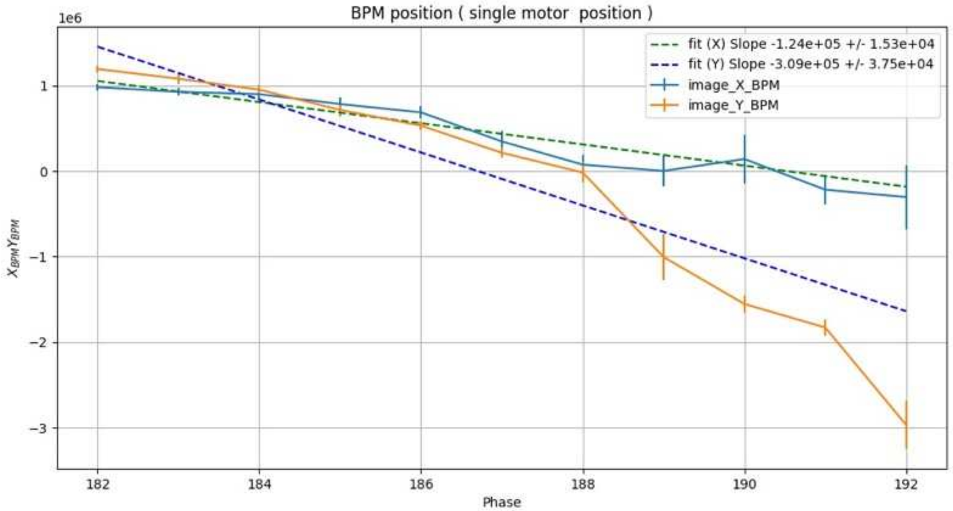


Alignement du laser sur la photocathode

Laser, iris ouverture variable

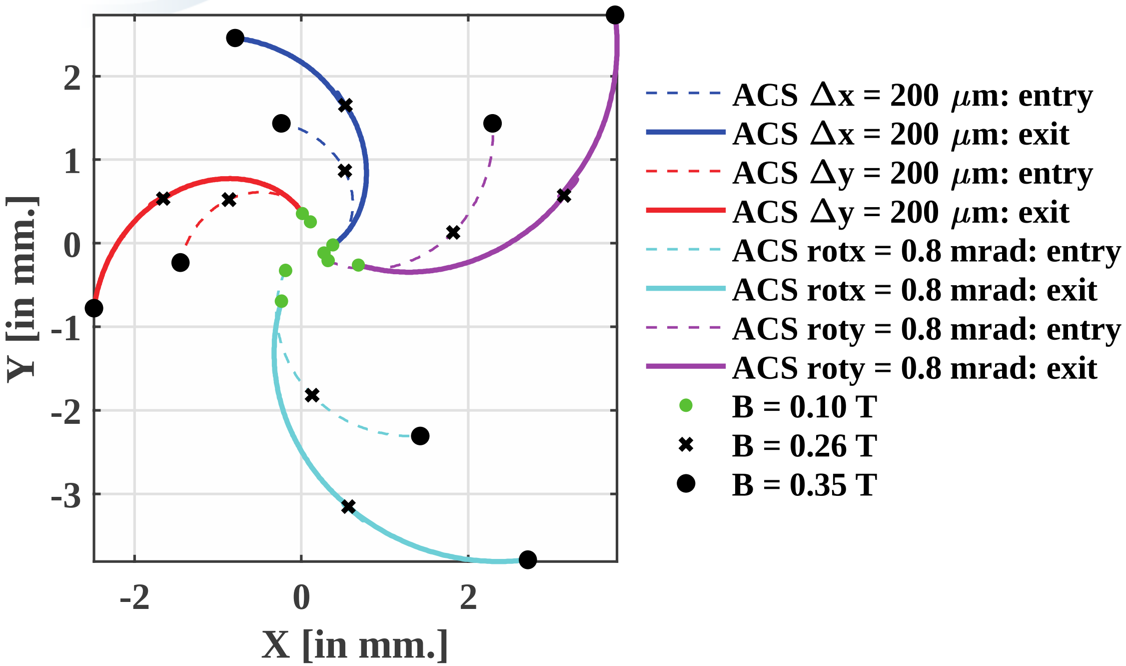


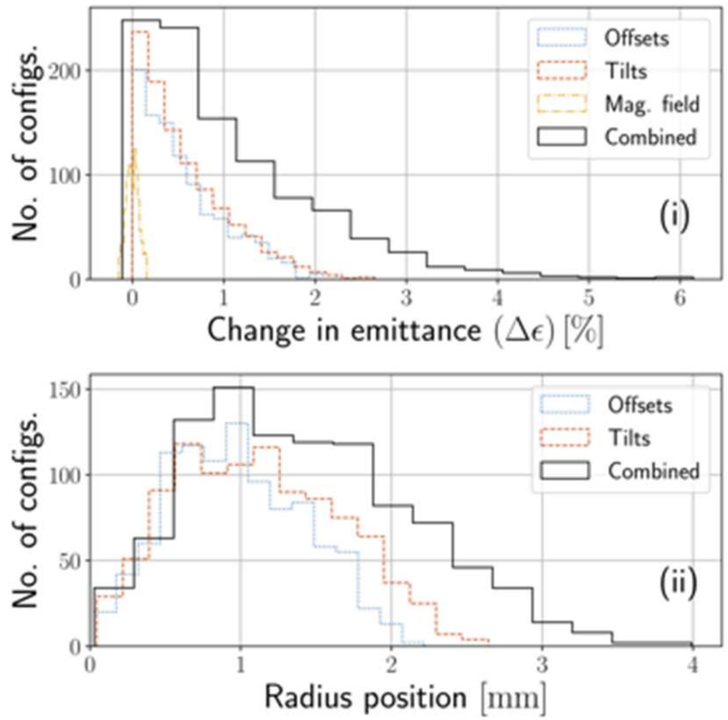
Alignement avec miroir polotable



Correction automatique (Pid) des derives de la position du spot laser dans l'Iris.

Désalignement du solénoide - principe





- Variation de l'orbite avec le champ du solenoide

Objectif : orbite invariante pour l'optimisation future pour l'injection dans l'anneau

Mesures

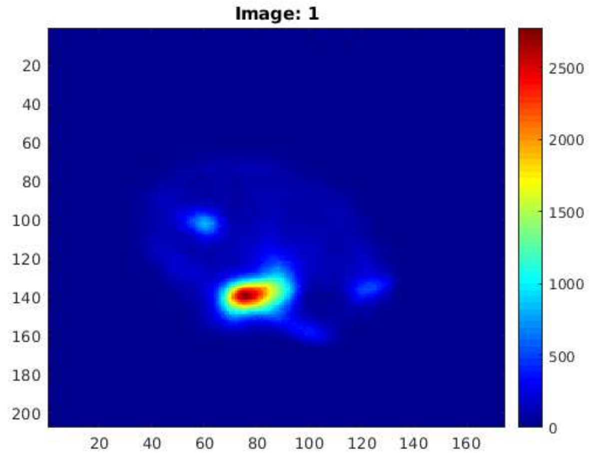


Image: 1
20
40
60
80
100
120
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200
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40
60
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140
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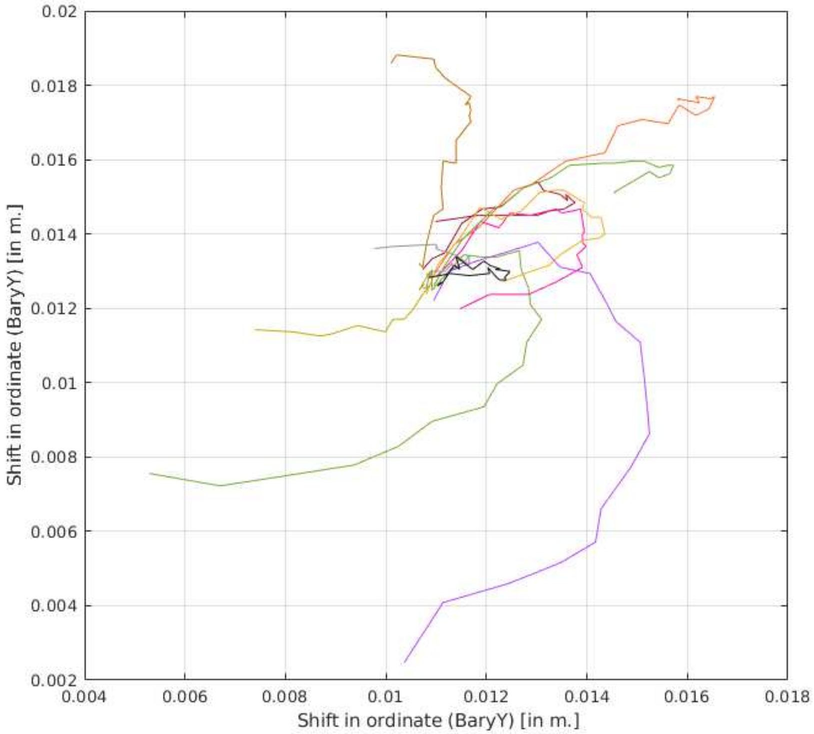
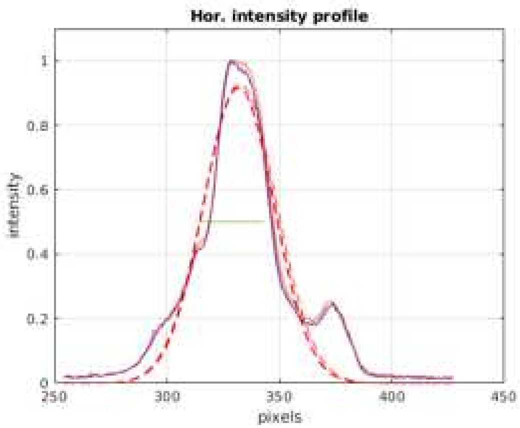
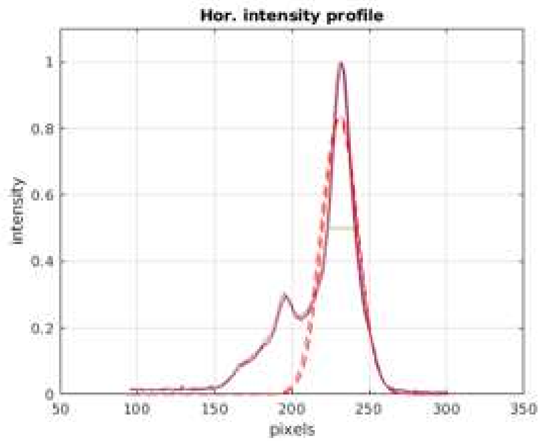
2000
1500
1000
500
0


0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0.004
0.006
0.008
0.01
0.012
0.014
0.016
0.018
Shift in ordinate (BaryY) [in m.]
Shift in ordinate (BaryY) [in m.]

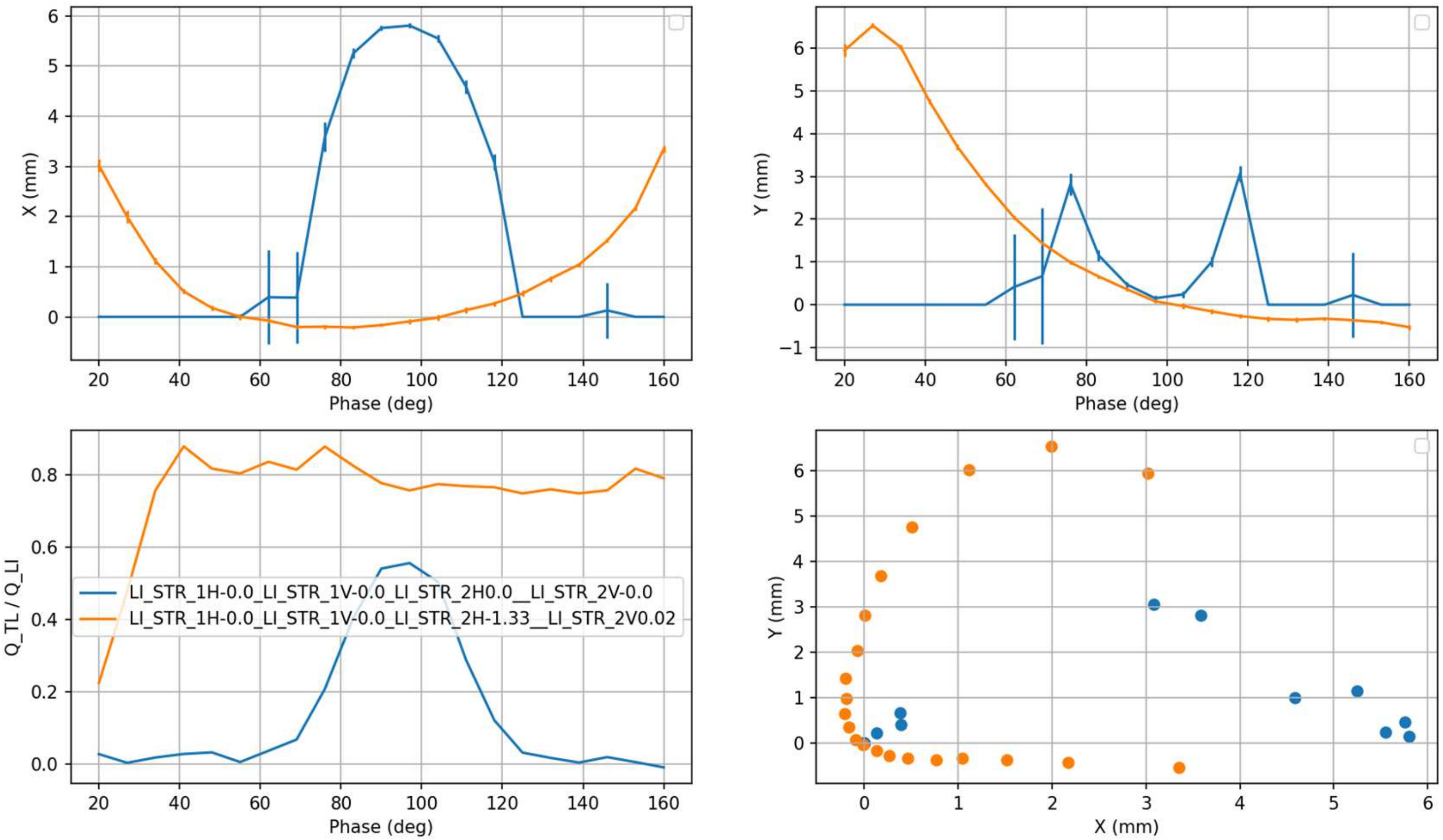

Hor. intensity profile
intensity
pixels
1
0.8
0.6
0.4
0.2
0
250
300
350
400
450


Hor. intensity profile
intensity
pixels
1
0.8
0.6
0.4
0.2
0
50
100
150
200
250
300
350

Mesures alignement LIL

Sans steerer

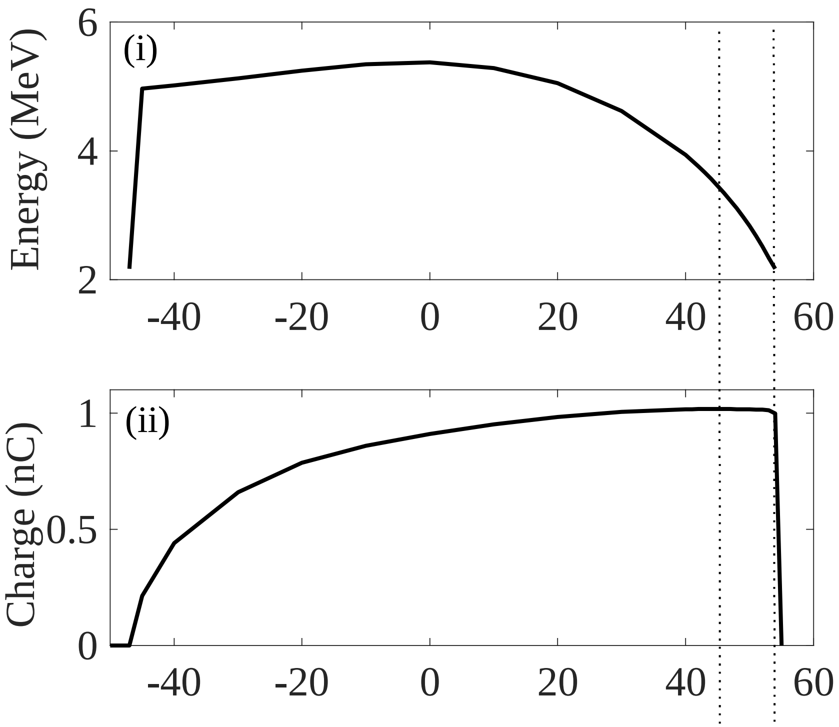
Steerer horizontal

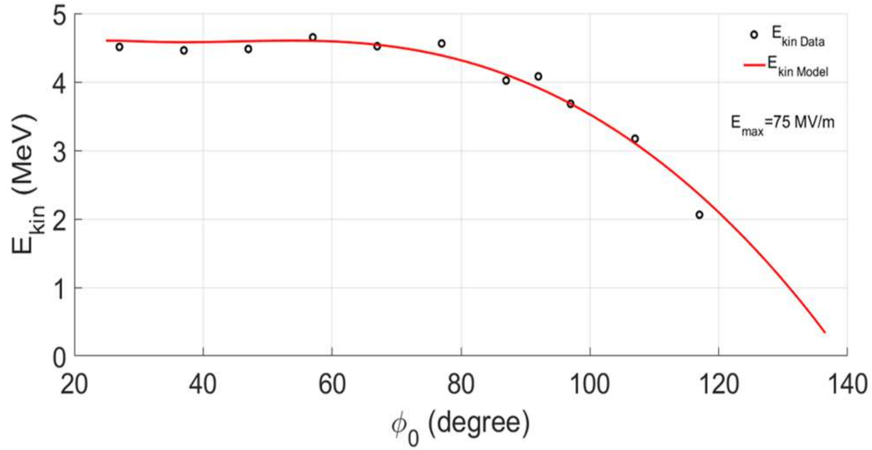


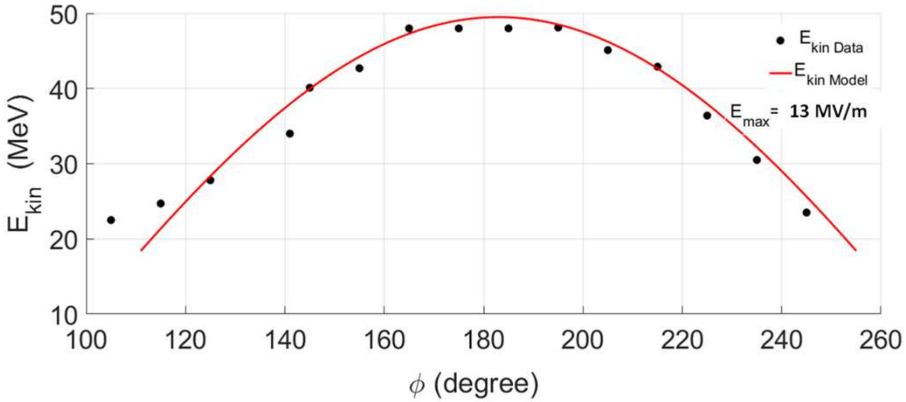
→ Section désalignée

Mesures des caractéristiques du Linac

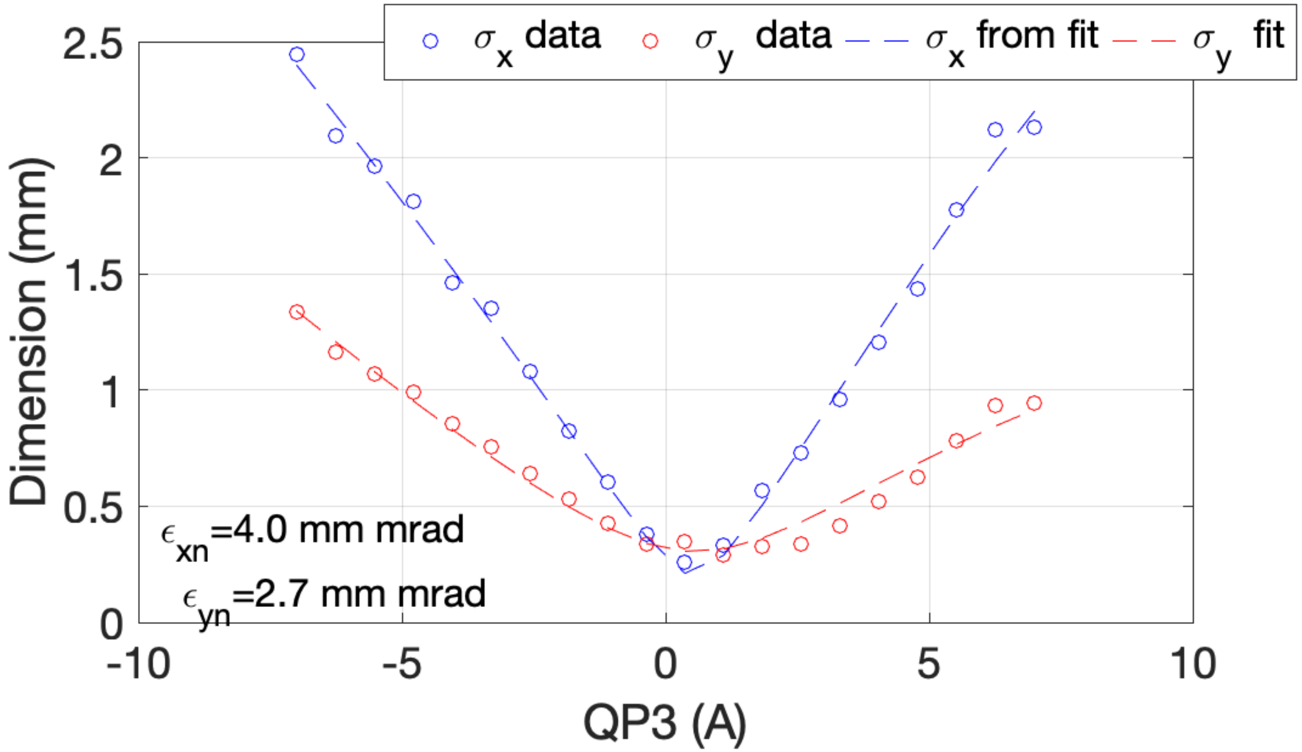
Mesure d’énergie : Steerer + Yag







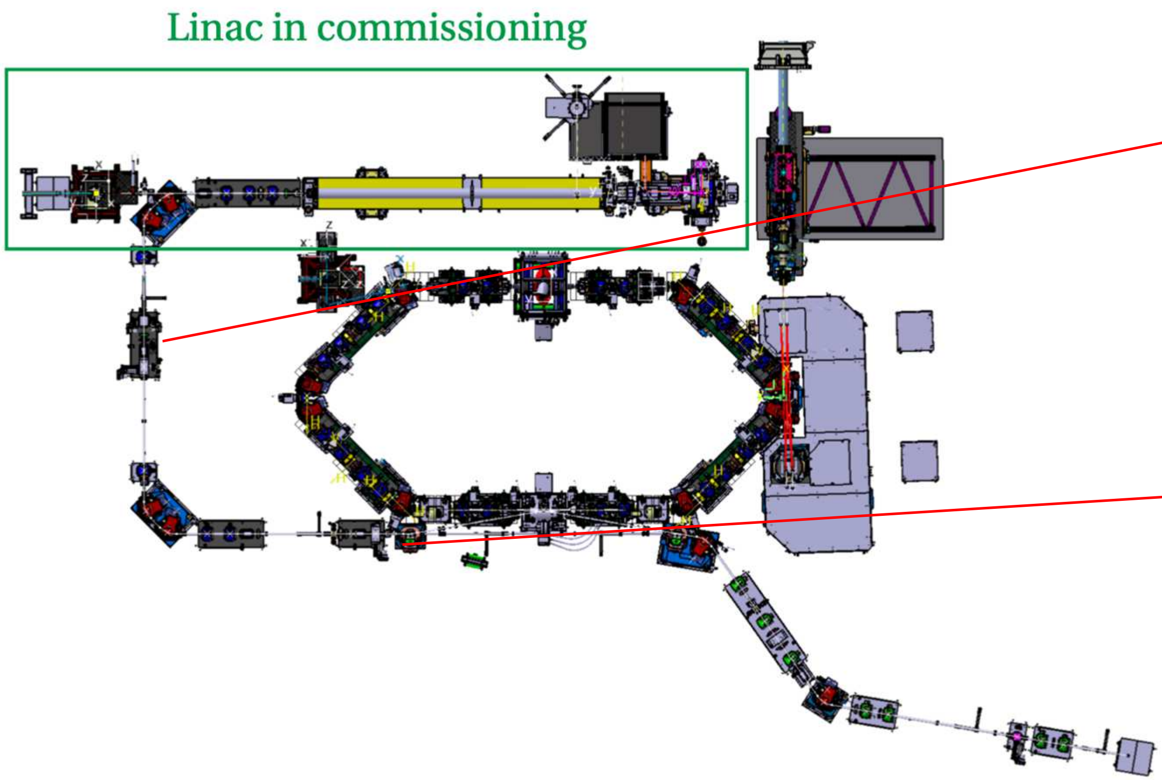
Mesure d'émittance

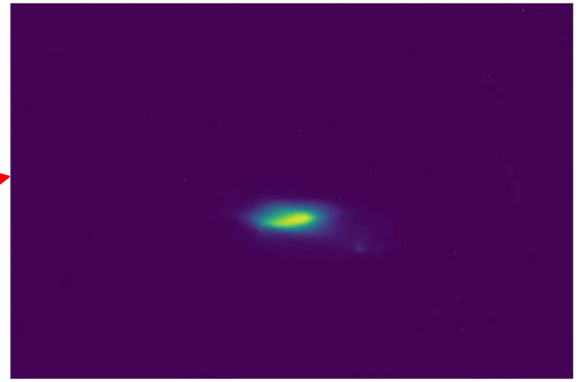


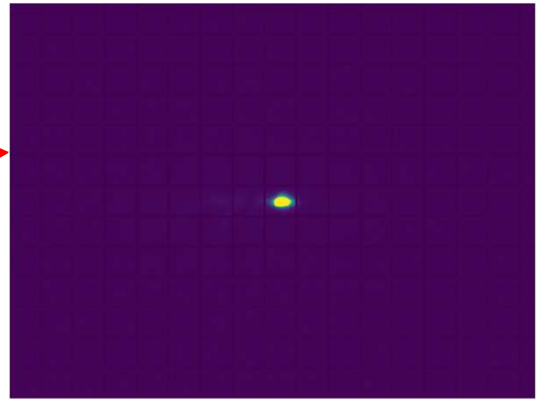
Phase II : Linac, LT, LE, Ring

- Aout 2021
  - 24 aout : premier faisceau TL
  - 26 aout : faisceau TL pour une première injection dans l'anneau
  - 9 septembre : première détection dans l'anneau
  - 20 septembre : premier tour dans l'anneau

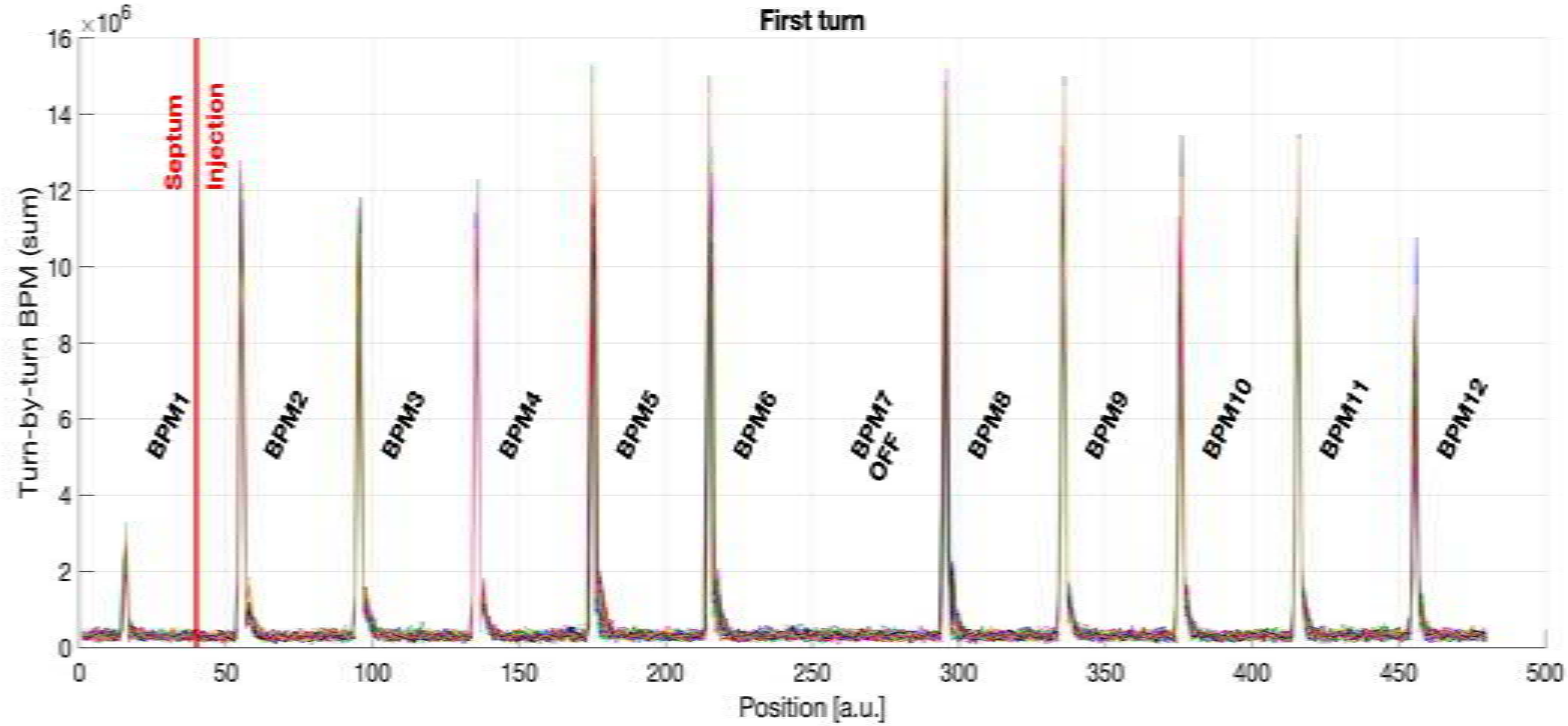
Phase II : Linac, LT, LE, Ring







Ring : 1er tour



Encore beaucoup de chemin ☺