

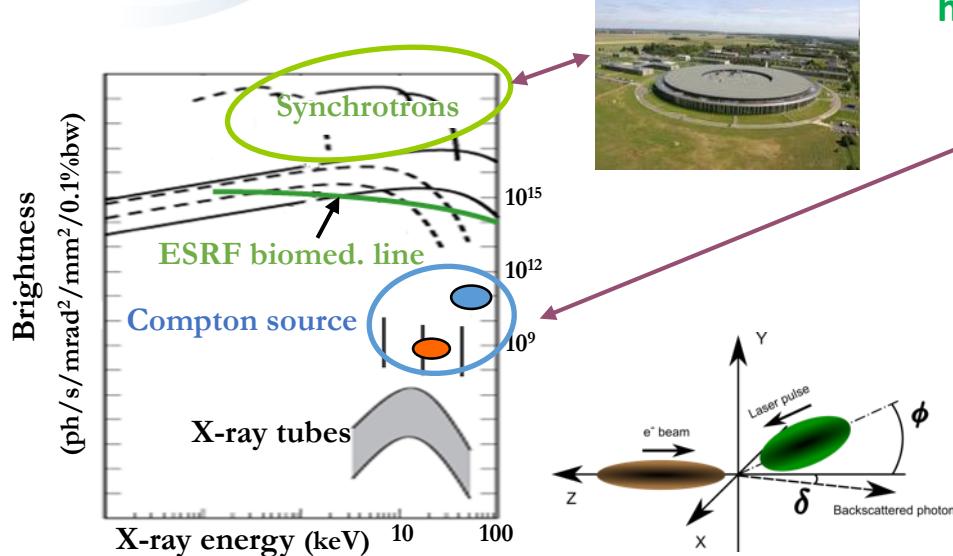
THOMX

Status

H. Monard

For ThomX Team

Project goals



**X ray compact source demonstrator,
high brilliance (hospital, lab, museum,...)**

ThomX : 45-90keV –
Flux $\sim 10^{12} - 10^{13}$ ph/s –
Brill $\sim 10^{10} - 10^{11}$ unit

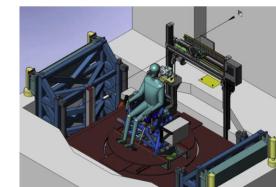
(a) Two tomographic views of the upper body of a mouse.
(b) Details of the head region. (c,d) 3D datasets see the Supplementary video file S2 and S3 online.



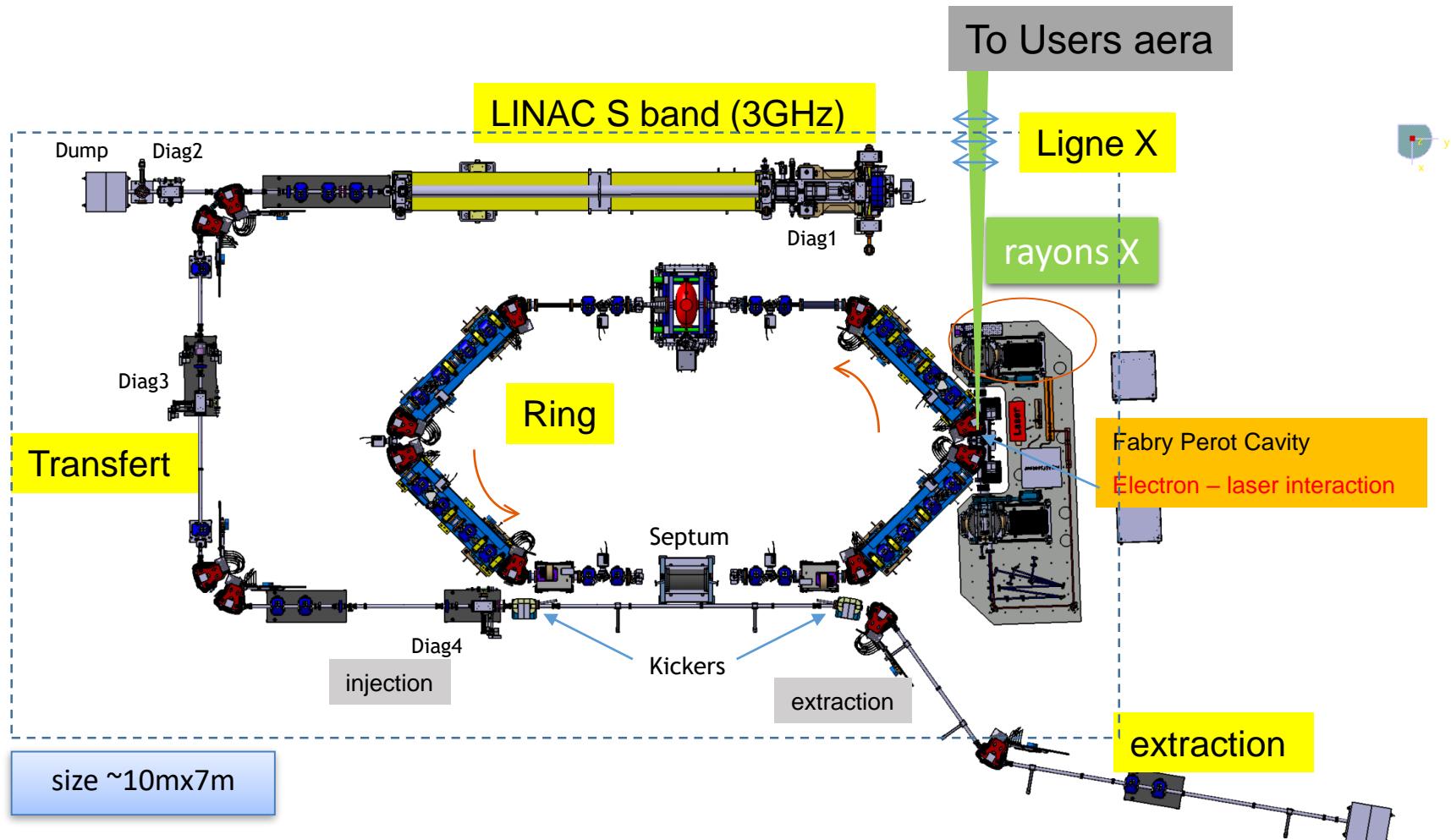
Buts scientifique :

Transfer experimental techniques from synchrotrons beam line to compact source

Add a new compact instrument in the landscape of X ray sources



ThomX layout

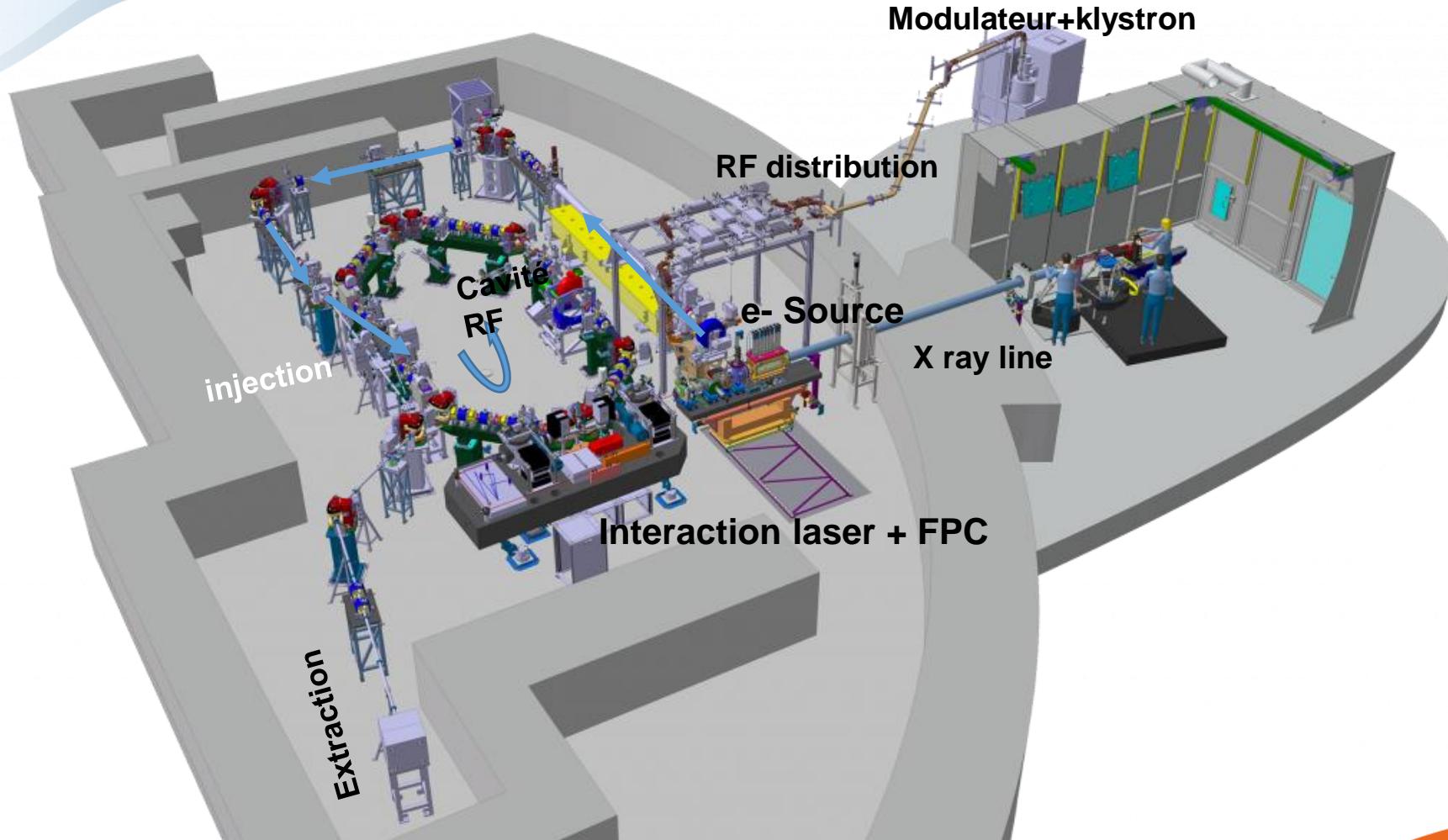


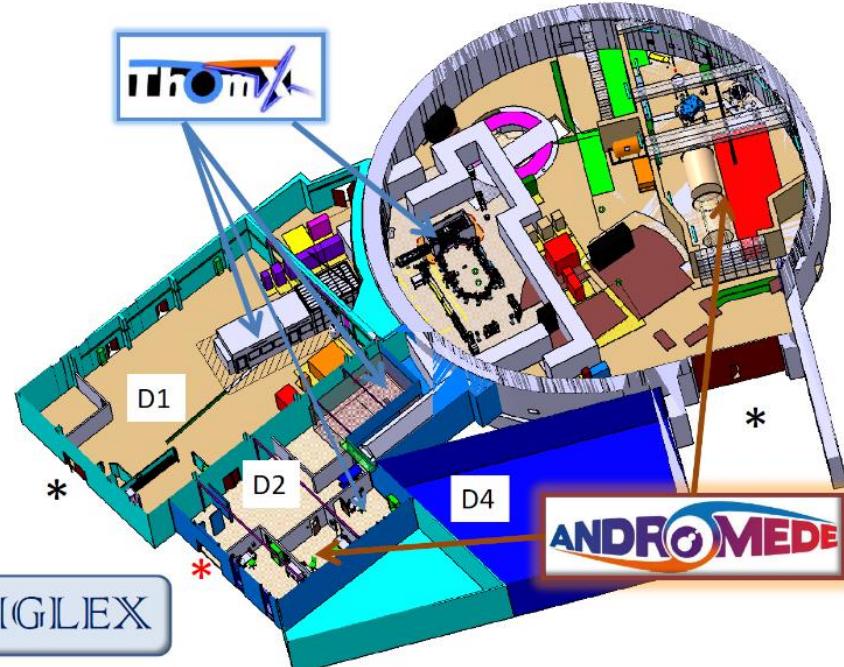
aiming $F = 50$ Hz, $Q = 1$ nC, $E = 50$ MeV (45 keV X ray) upgrade to 70 MeV possible (90 keV X ray)

Dump

0.0357 y
x

ThomX layout





Budget : National Research Agency
ANR /Equipex + **12 M€**
Installation and functioning (2012-2023)
With 2 delays + 2 years

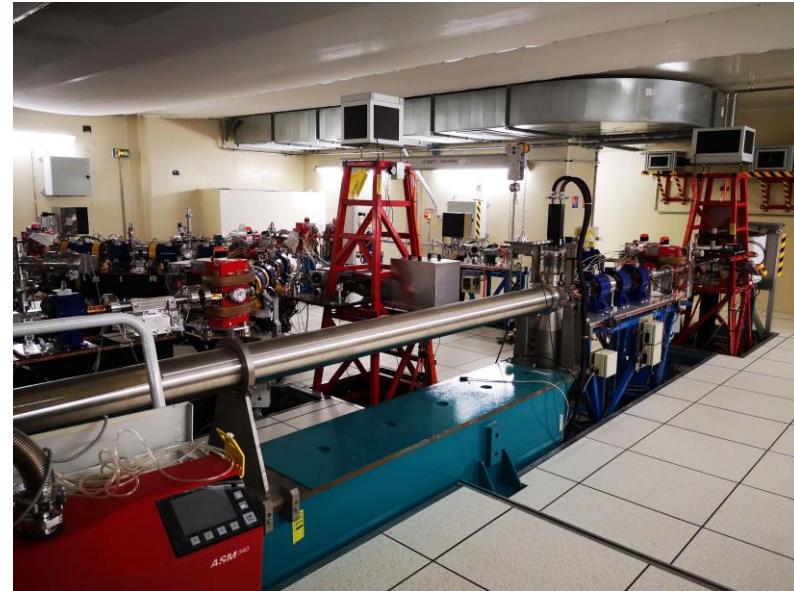
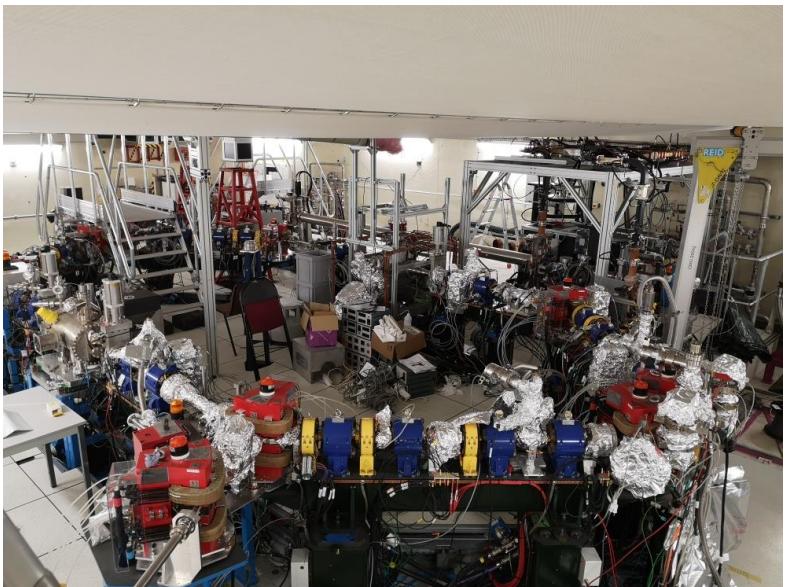
Civil engineering operation : 2,2 M€
(local Essonne funding)

8 french partners :
IJC Lab, Soleil, ESRF, CELIA, LAMS, NEEL, GIN, Thalès

Laboratoire de Physique
des 2 Infinis**Linac : working !**

(laser, RF gun, acceleration section , diags, vacuum,...)

Control&command, PSS, MPS : operational



<- Ring : all installed and tested, under vacuum 10^{-9} mbar
(magnets, pulsed magnets, vacuum,
BPM, beam loss monitors, RF cavity, ...)

- Fabry-Perot cavity : installed in the bunker

results on prototype : **200 kW pdt 30 min**

(see A. Martens presentation)

final version of cavity installed in bunker (10^{-9} mbar)

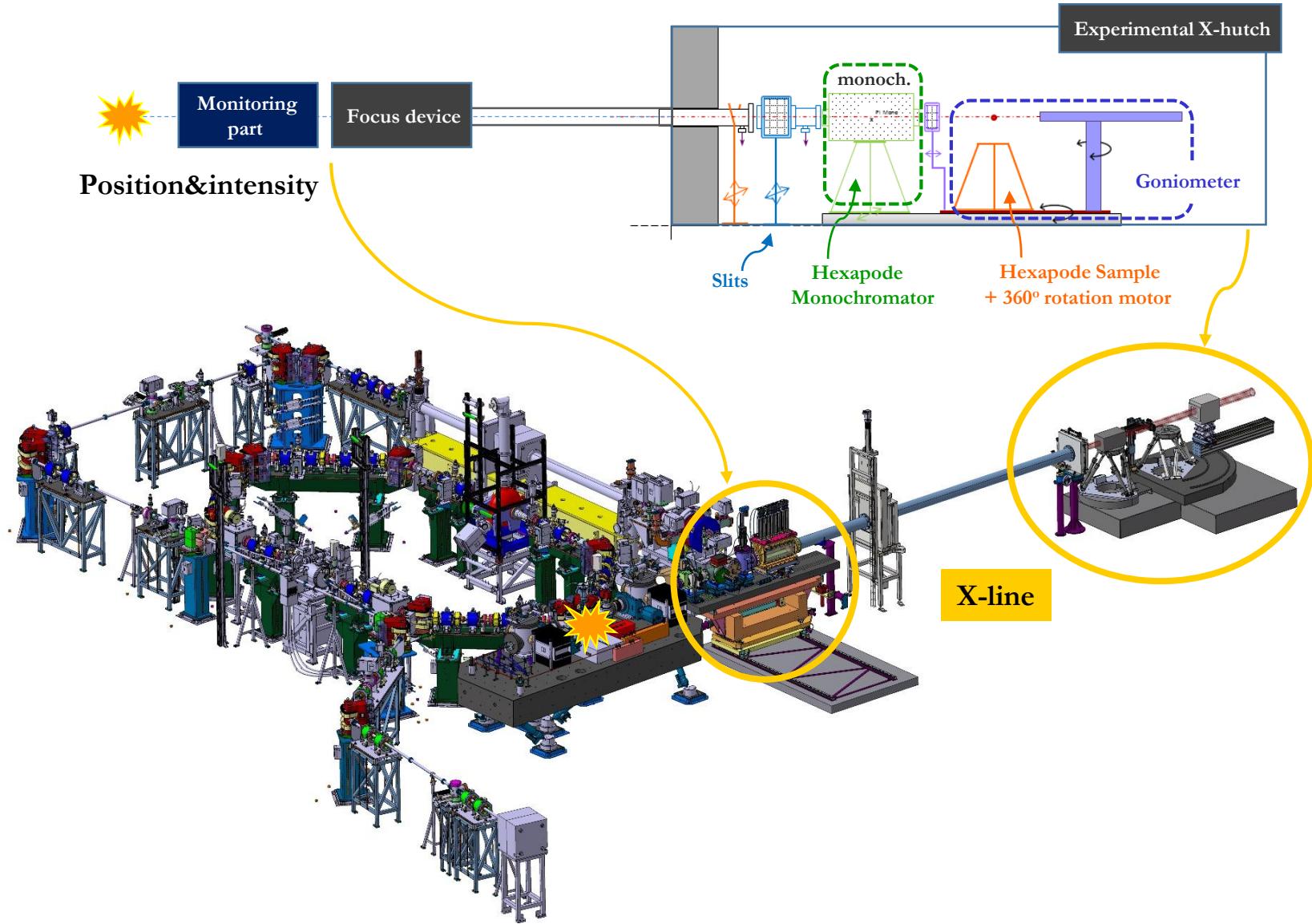
wait for laser+ amplification installation

- X line : ready to start



FPC installation in bunker

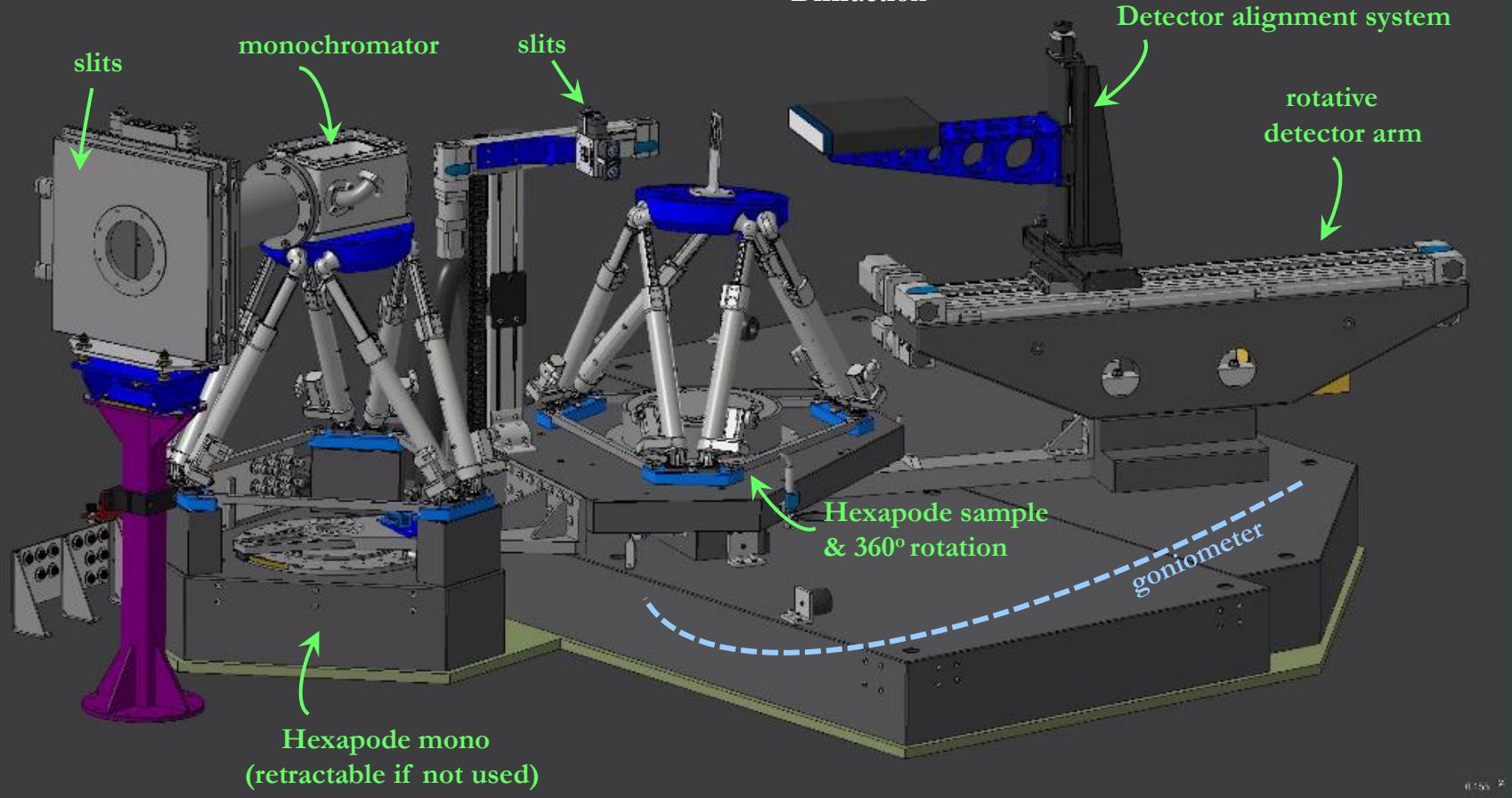
X-line integration



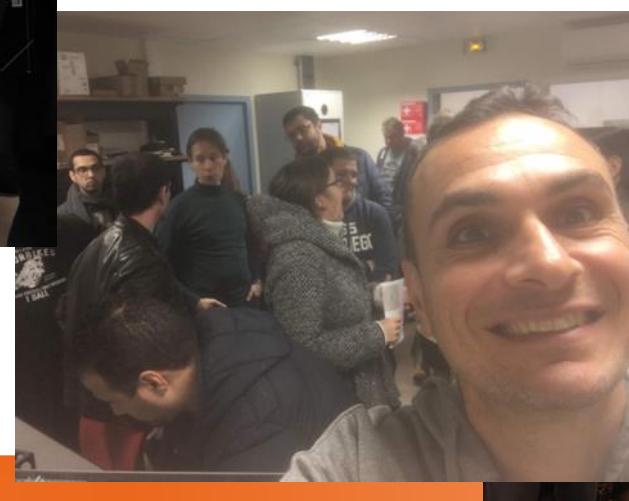
X-ray experimental hutch

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

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

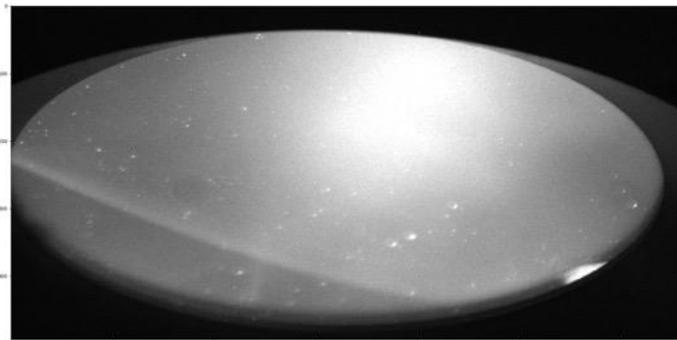


- Electrons out of RF gun : october 2021 !



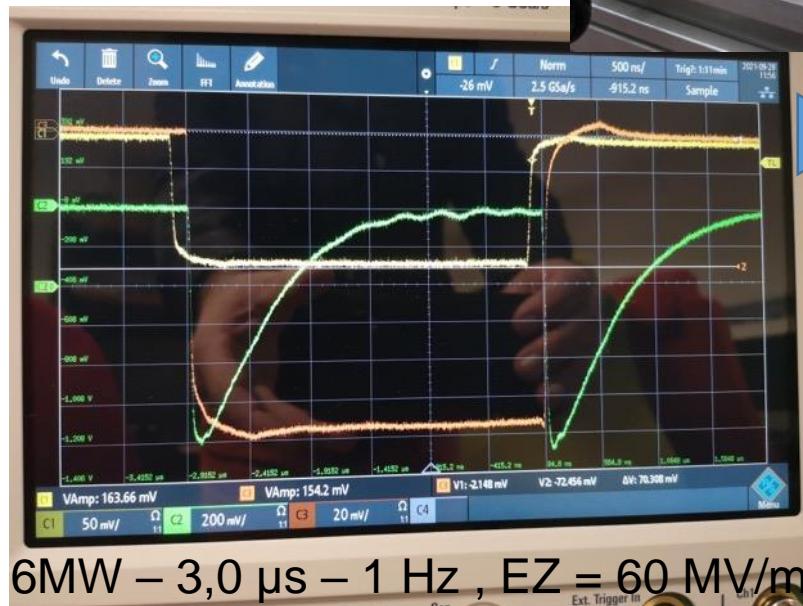
- Touching the real start with the hand !
- Still a long way to go ...

- july : LIL section conditionning (10 MV/m, 10Hz, 3 μ s)
- october : RF gun conditioning (80 MV/m, 10 Hz, 3 μ s)

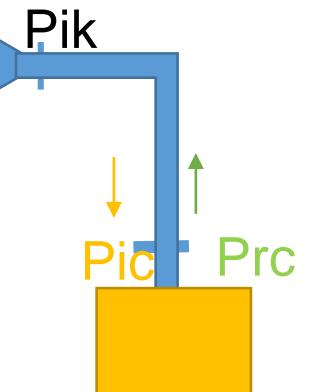


Dark current on YAG1

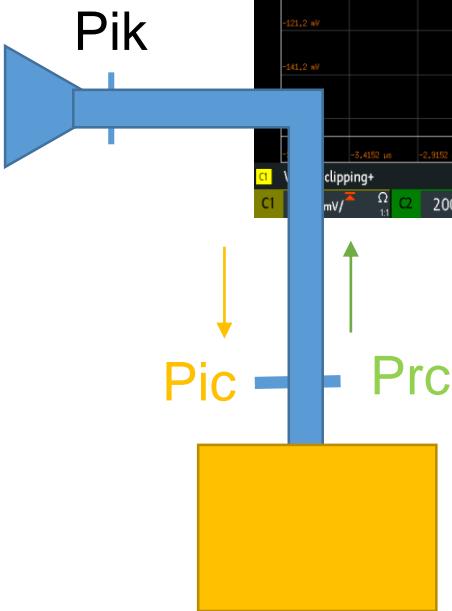
RF signals



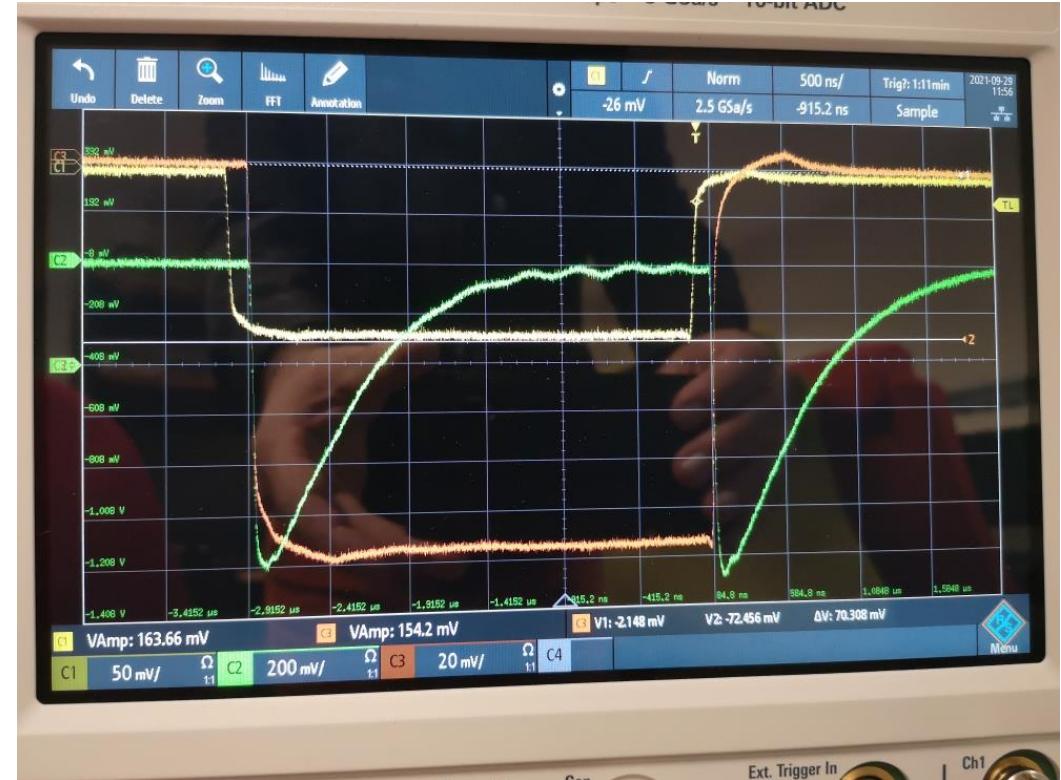
Home made – RF gun 2.5cell



RF gun conditioning



5MW – 2,0 μ s – 1 Hz



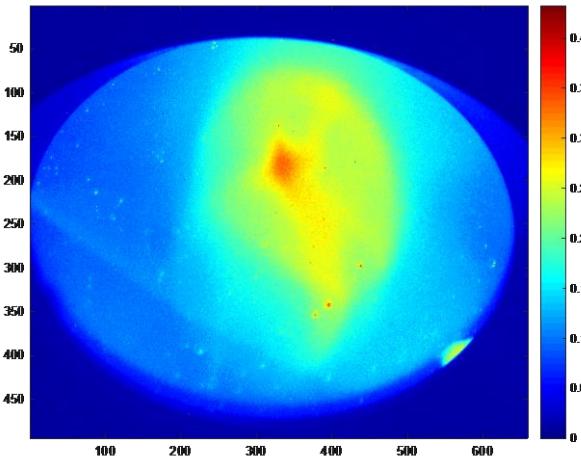
6MW – 3,0 μ s – 1 Hz

EZ = 80 MV/m

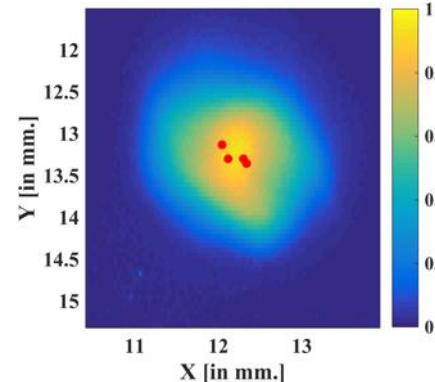
First photocurrent

Laboratoire de Physique
des 2 Infinis

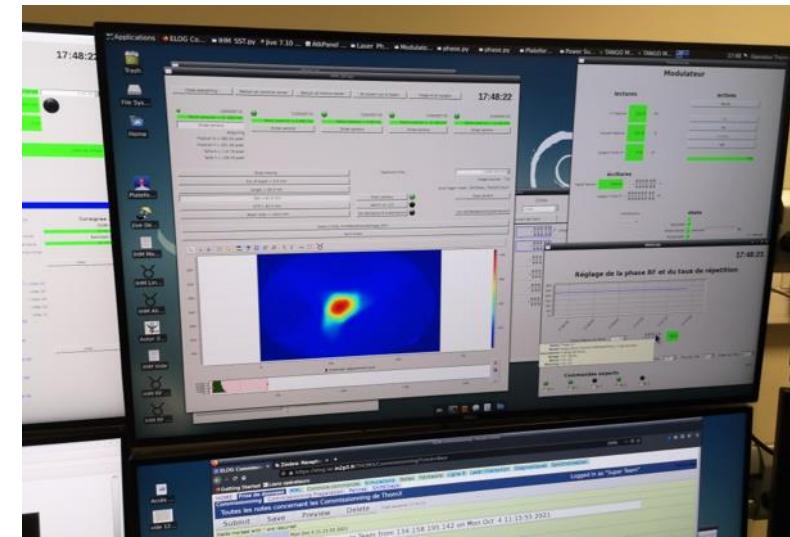
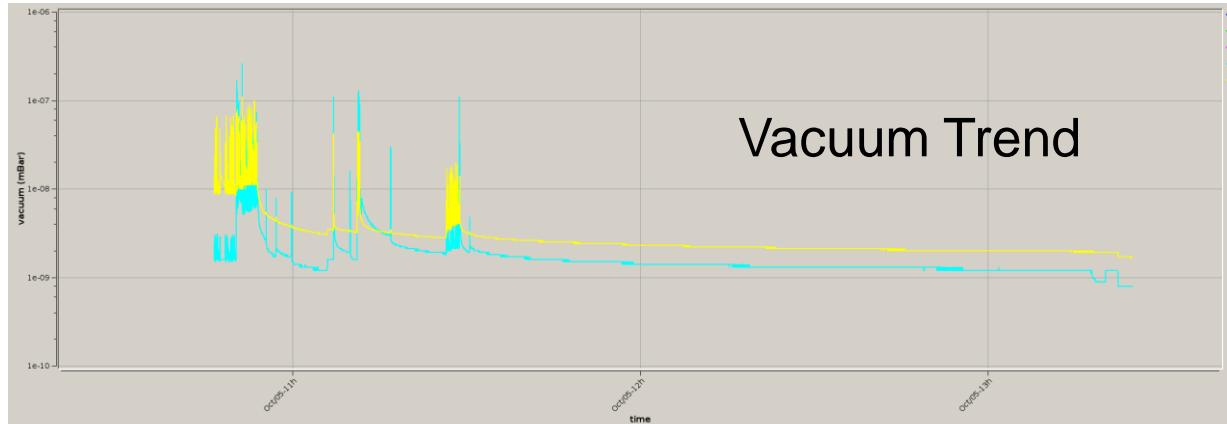
- Vacuum interlock at the begining
- Photocurrent on YAG1



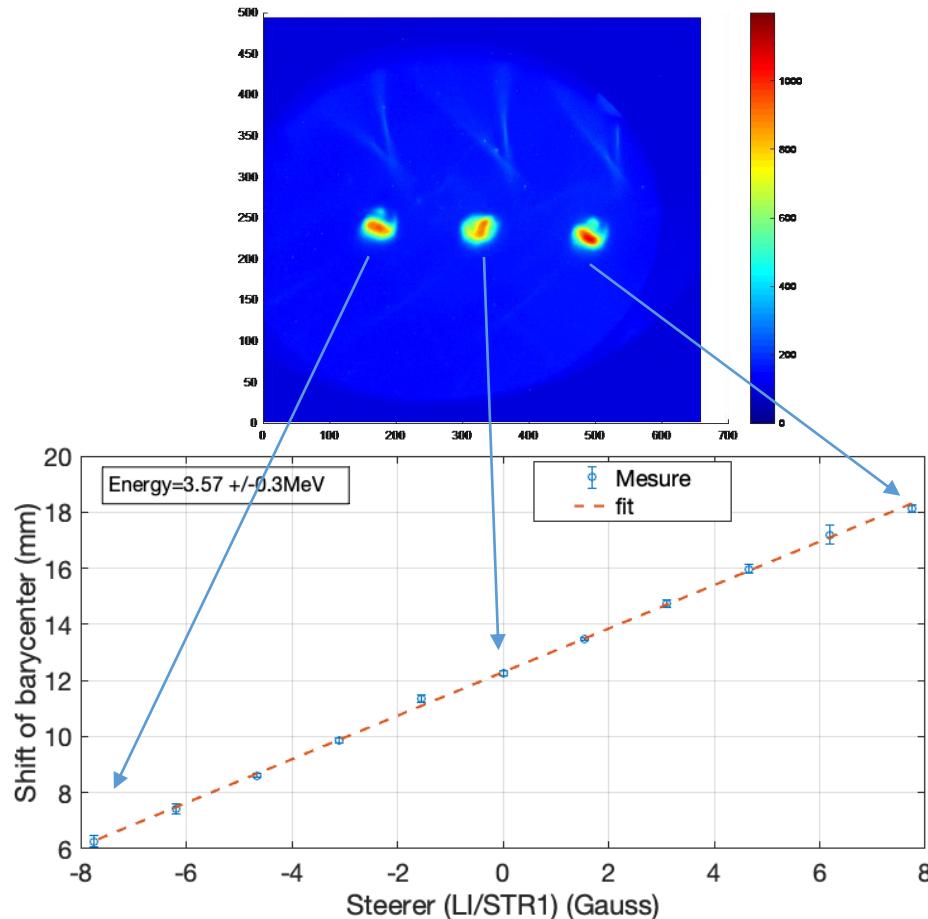
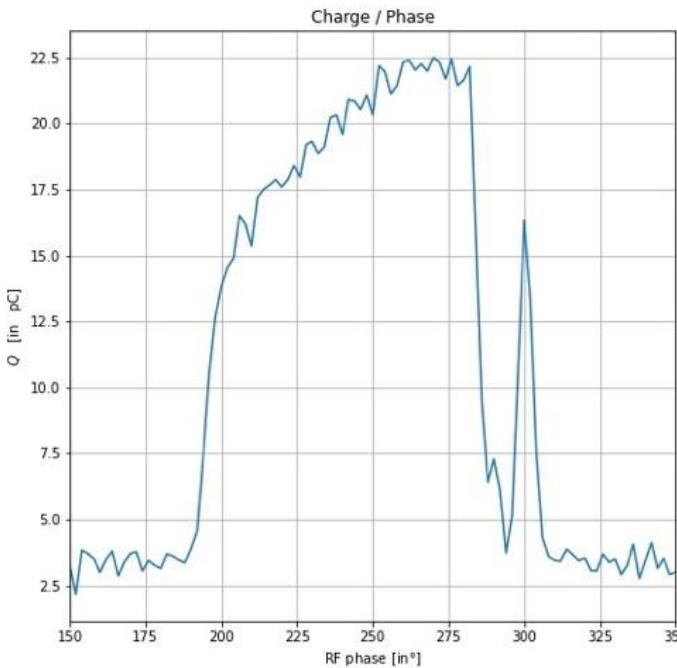
No Solenoid current



Current = 100A

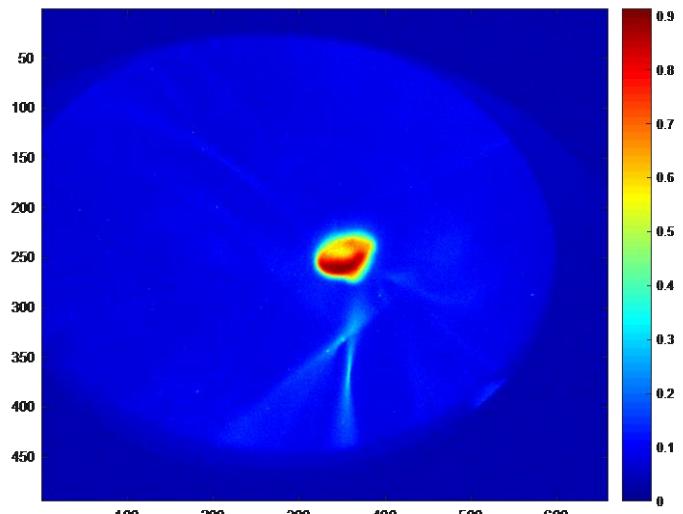
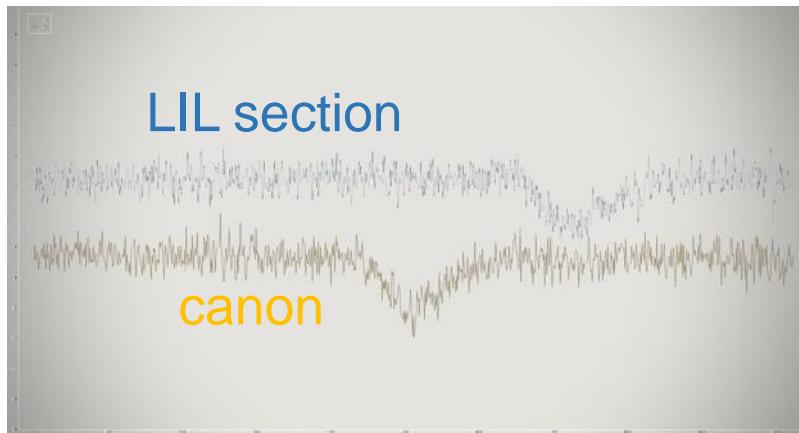


- Charge=f(phase) : preliminary results



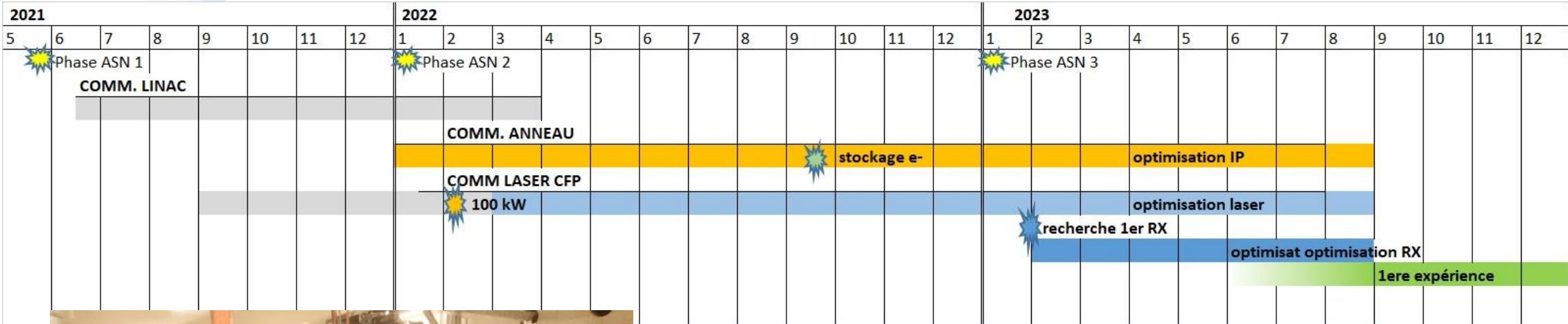
Energy measurement with steerers

- measurement of energy out of RF gun 3.6 MeV
- start LIL section
- Beam out of LIL section : 37 MeV



- Forseeing to go to 50 MeV with full RF power (klystron > 30 MW)

Planning of commissionning



ASN phases to manage

- 1) LINAC : 50 MeV, 100 pC, 10 Hz
 - 2) RING : id.
 - 3) RX production : 50 MeV, 1 nC, 50 Hz

Commissionning steps

Labo des 2	RP	Phase système	Goals	livrables	Internal prerequisite	durée (j)	corrigée
		ASN	ASN Autorisation phase1				1,2
	1 A1a	LINAC	conditioning preparation			2	
	1 A1b	LINAC	LIL section conditionning	10 MV/m, 3 µs, 10 Hz	P=20MW F=1, 5 10Hz	5	6
	1 A1a	LINAC	RF gun conditionning	80 MV/m, 3 µs, 10 Hz	P=7MW	10	12
	1 A2	LINAC	1st electron beam 5 MeV, Q=10% Qn = 100 pC, 10 Hz	5 MeV, 100 pC, 10 Hz	laser	9	11
	1 A3	LINAC	1st electron beam 50 MeV straight line	50 MeV, 100 pC, 10 Hz	5 MeV, 100 pC, 10Hz RF gun	5	6
	ASN		ASN Autorisation phase2a			10	12
	1 A4	LINAC	Electron transport to extraction line	100 pC to EL dump	deviation dipole OFF	11	13
	1 A5	LINAC	Optimisation faisceau pour injection	100 pC, 5 ps, 10 Hz entrance Pulsed	deviation dipole ON	30	36
2a	AB0	LIN+RING	Pulsed magnets commissioning with e- beam	signal on 1st BPM Ring	PM comm. Without beam	4	5
2a	B1	RING	1st turns : injection+beam instrum+threading	100 pC, 1 turn, ring diags	diags tested	12	14
2a	AB1	LIN+RING	optimisation linac+ring	100 pC, N > 1000 turns		4	5
2a	B2	RING	machine physics : LOCO, beta dispersion, dynamic studies	measurements e- dynamics	MML ok	20	24
2a	AB2	LIN+RING	optimisation linac+ring			4	5
2a	B3	RING	stored beam and extraction (EL), BBA, precise measurement: Nt > 10 000		Nt > 10 000	40	48
2a	B4	RING	machine physics : LOCO, beta dispersion, dynamic studies			40	48
2a	C1	CFP	alignment of the Fabry-Perot cavity and the laser		laser 33MHz @ ijc lab	4	5
2a	C2	CFP	P=100 kW stored & stable for 30 min	P= 100 kW, stability = x %	Pin=100W	10	12
	ASN		ASN Autorisation phase3			10	12
3	C3	CFP+LX	Search of the first X-ray production	synchro, alignment ok	spatial&synchro locked	10	12
3	C4	CFP+LX	Nph > 10 ^9 ph/s	10^9 ph/s, spatial profile meas	spatial&synchro locked	20	24
3	C5	EXP	1st experiment			40	48

- 2021 :

- Ring : baking
- May : **authorization from ASN** (phase 1 : linac 50 MeV, 100 pC, 10 Hz)
- July : RF acc. section (LIL) (10 MV/m, 10 Hz)
- September : RF gun conditionning 1Hz
- October : **4/10 first beam out of RF gun 4 MeV, 20 pC**
6/10 first beam@ 37 MeV (nominal 50 MeV)
18/10 conditionning RF gun @ 10 Hz
20/10 first beam 100 pC

....

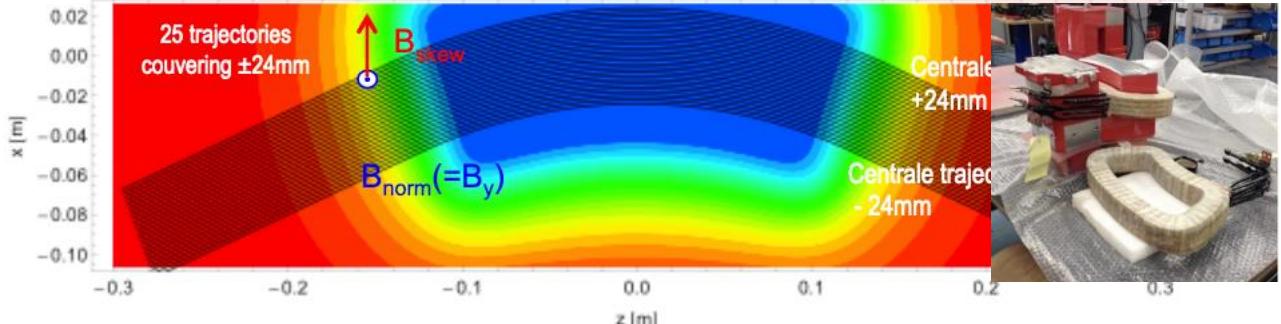
- First electron beam in 2021
 - > focus put on going to phase 2 (Ring)
 - > full characterization of linac beam
- Electron in RING in 2022
- First X ray expected end of 2023
- ANR budget ends end of 2023.
 - What is becomming THOMX after 2023 ?
 - new project, new budget, new WP
 - Becoming a user platefrom ?

- 2012 : Equipex budget : 10 + 2 M€
- 2015 : Igloo building declassified as NBI (Nuclear Base Inst)
- 2016 : infrastructure civil engineering starts
- 2019 : démarrage sans RF des équipements à distance





DP : 12 ; QP : 30; SP : 12 ; ST : 12 total 70
+ Pulsed Magnets



2014 : choice SigmaPhi
2015 : delay
2016 : measurements @ALBA
@LAL & Soleil
2017 : mounting @LAL
2018-2019 : bunker integration
2020 : pulsed magnets @SOLEIL
+integration



More dates

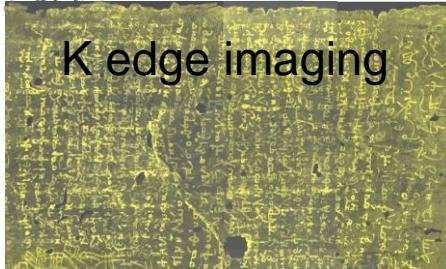
- 2011 : Equipex
- 2016 : travaux de lancement de l'infrastructure iglex
- 2017 : start integration
- 2018 : sending autorisation demand to NSA (Nat. Secur. Agency)
- 2019 : Linac ready , missing Pulsed magnets on ring
- simulations of starting the machine without RF
- (no ASN autorisation yet)
- 2020 :
 - Fermeture anneau
 - Mai : autorisation ASN
 - Juillet : conditionnement RF section
 - Septembre : conditionnement capteurs
 - Lundi 4 Octobre : premier faisceau
 - Mercredi 6 octobre : premier faisceau



REX : Delays on the project

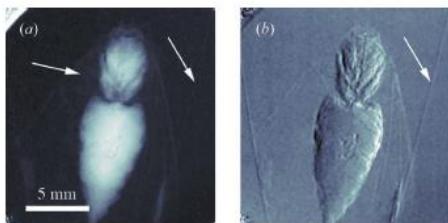
Main delay origin :

- Déclassification (NBI) of bulding : **4,5 y**
- Call for tender global duration + integration: **3 y**
- authorisation ASN delay : **1 y 8 m**
- COVID19 : **~6 m**

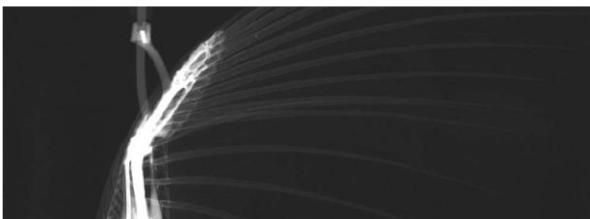


K edge imaging

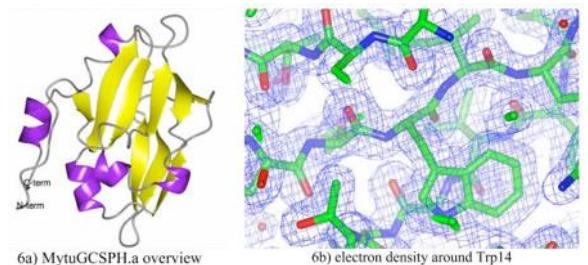
[Synch. Rad. 16, 2009, 43-47]



5 mm

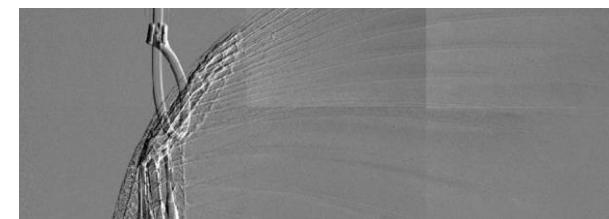
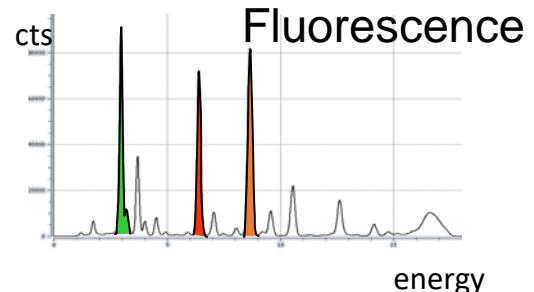


absorption



Lyncean 15 KeV, 1.4% bw
 5.10^6 ph/sec
 $\sigma = 120 \mu\text{m}$

[J Struct Funct Genomics. Mar 2010; 11\(1\): 91–100](#)



Dark field (scattering)

JOURNAL OF APPLIED PHYSICS 105, 102006 2009

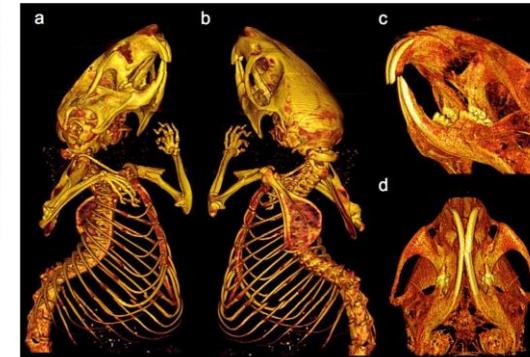
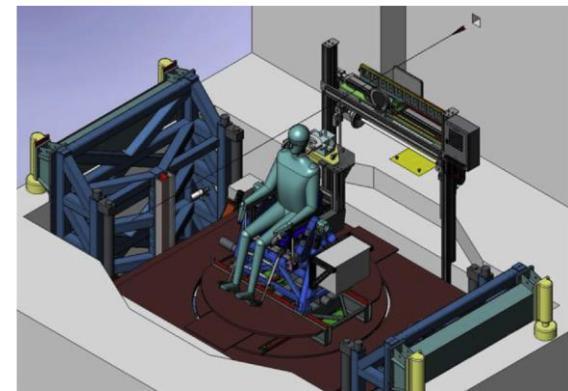
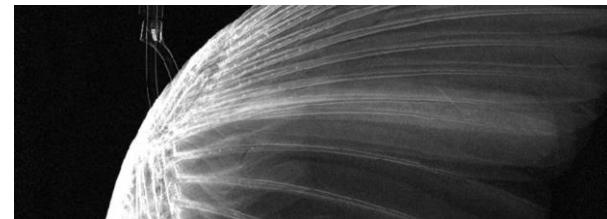


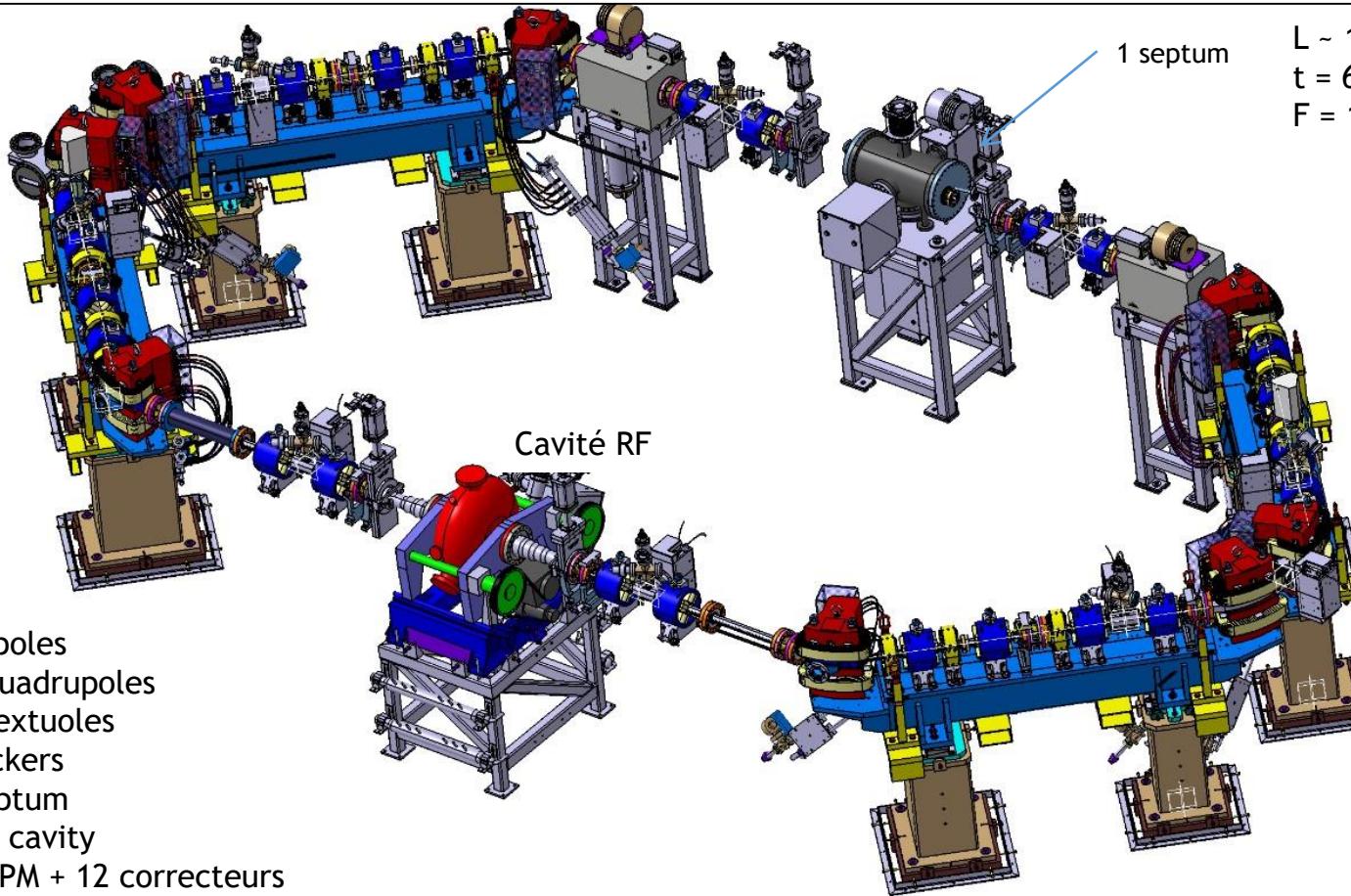
Figure 6 | Absorption computer tomography of a mouse. (a),(b) Two tomographic views of the upper body of a mouse. (c),(d) Details of the head region. For 3D datasets see the Supplementary video files S2 and S3 online.



[Physica Medica 31 \(2015\) 596-600](#)



Back up



Conditionnement RF

Durée* : 16 jours
 80MV/m canon,
 12 MV/m section

Cathode (1) → entrée section (2)

Durée : 9 jours
 Charge :100 pC,
 Energie 5 MeV,
 emittance < 5 pi mm mrad
 Orbite invariante

Entrée section (2)→ Dump Section Droite (3)

Durée : 5 jours
 Charge :100pC,
 Energie : 50 MeV,
 emittance < 5 pi mm mrad,
 twiss sortie linac : beta< 60m,
 alpha < -15

Entrée Section (2)→ Dump EL(4)

Durée : 11 jours
 Charge :100pC,
 Energie : 50 MeV, emittance 5 pi mm mrad,
 espread 300keV ,

Optimisation

Durée : 32 jours
 Charge :100pC,
 Energie : 50 MeV, emittance 2 mm mrad,
 espread 120 keV,

*Durée : nombre de jours ouvrables estimé sans arrêt ni problème technique
 Ex : 16 j = 4 x 4 semaines (4j/sem)