# IPAC11 Conference
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# The ThomX Project

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# The ThomX Project

## •Compton effect

- **ThomX is a light source based on Compton Back Scattering (CBS)**

- **Why CBS?**
- CBS is by far the most efficient photon energy amplifier : $\omega_{diff}=4\gamma^2\ \omega_{laser}$, ThomX => $\gamma$~100 => it is possible to have at one's disposal hard X rays with a relatively low energy electron machine.

- But for a light source: $\sigma \sim 6.6524\ 10^{-25}\ cm^2$, it is low!!!!!

  - Thomx target is a high AVERAGE flux so we need many electrons and photons colliding in a small volume at high frep => CHOICE:

  - Storage ring + high average power laser amplified in a Fabry Perot resonator (French collaboration among different kinds of expertise )

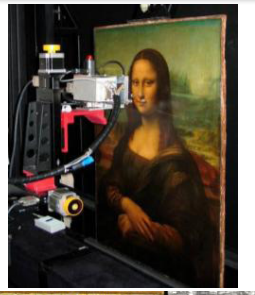
- CBS attractiveness :
- 1) Directivity (relativistic boost) = > f= 1/$\gamma$ around the electron direction
- 2) Energy angle dependence => monochromatic by diaphragm
- 3) Polarized if needed
- 4) Backscattered spectrum cut off => Energy dependence on collision angle

# Scientific Case

## •Cultural heritage and medical science

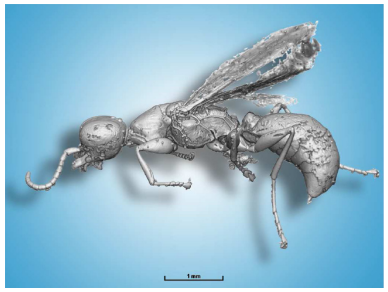
- Transfer of the SR techniques to these new machines. Many fields can be interested…
- At present two contributors: Medical field (ESRF, INSERM Grenoble)
  Cultural Heritage (C2RMF CNRS – Louvre Museum)

### •Painting analysis



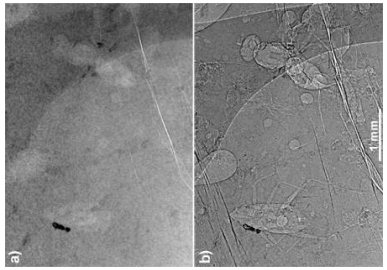

•*K-edge imaging* (Pb➔white, Hg➔ vermilion…) of a Van-Gogh's painting

•J. Dik et al., *Analytical Chemistry*, **2008**, *80*, 6436



•Paleontology

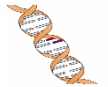
•Non-destructive analysis

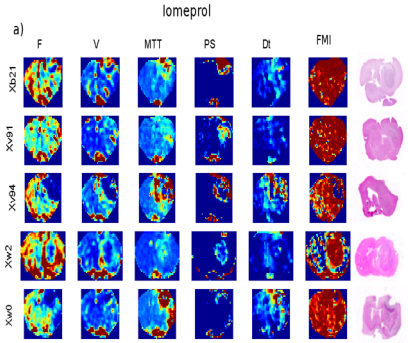


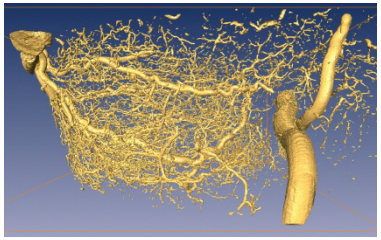
•Physiopathology and Contrast agents,

•Dynamic Contrast Enhancement SRCT

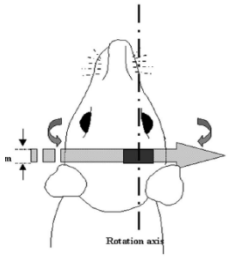
•Convection Enhanced Delivery =>Stereotactic Synchrotron RT

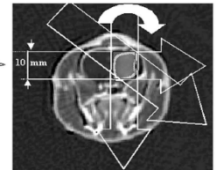




•J Cereb Blood Flow and Metab, 2007. 27 (2):292-303.



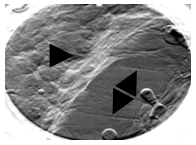



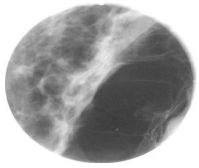

•Biston et al, Cancer Res 2004, 64, 2317-23

•Imaging,

•Mammography

•Microtomography





•Journal of Radiology 53, 226-237 (2005)

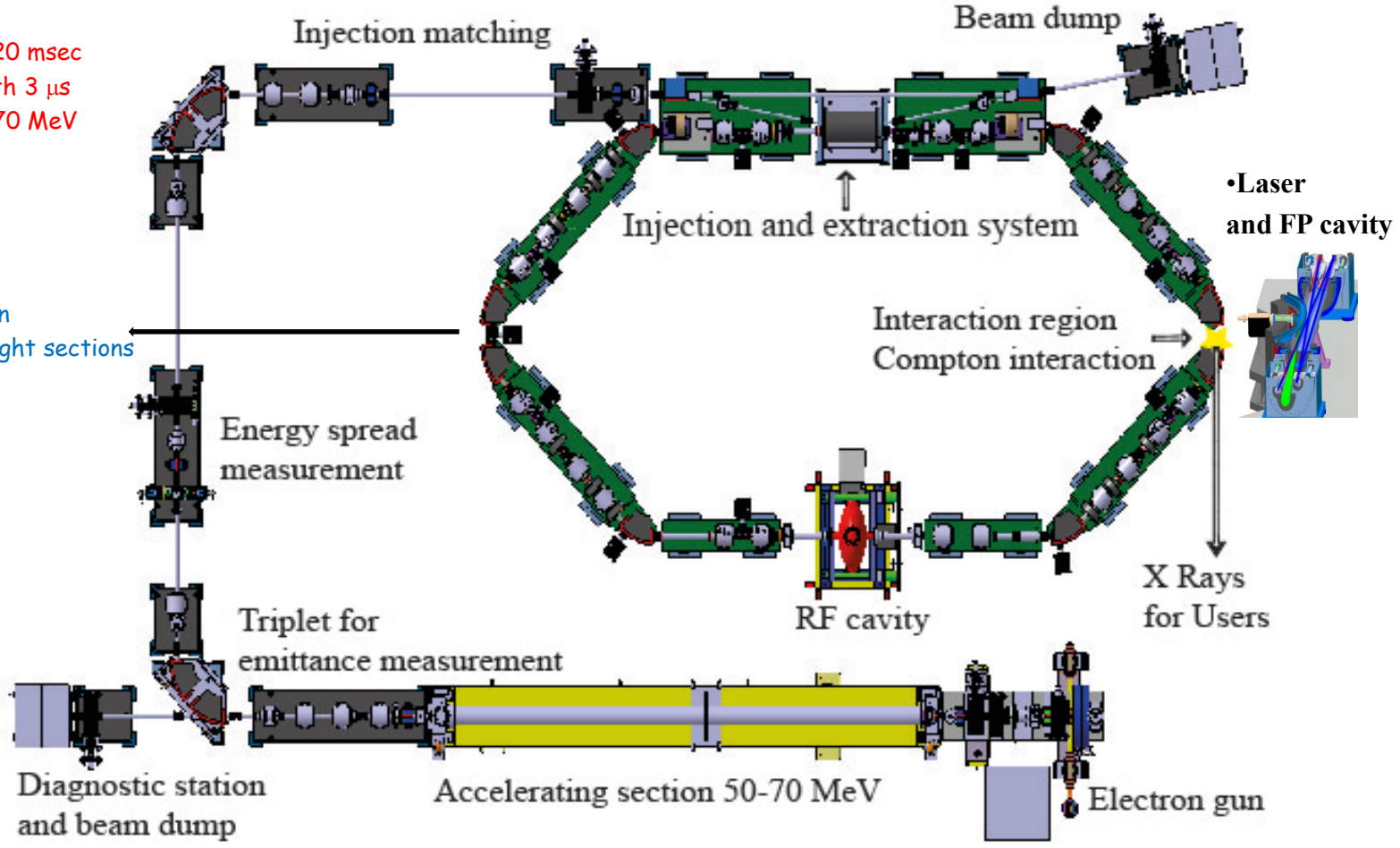
• Acknowledgments to G.Le Duc, P.Walter

# How it works

## •ThomX scheme and design

•Cycle Frep = 20 msec
•RF pulse length 3 μs
•Energy 50 - 70 MeV

•2 Ips
•Easy integration
•Frees the straight sections
•CSR line




• Acknowledgments to M.Jore, M Lacroix

# Expected beams characteristics

## •Injector, ring, laser, Fabry-Perot resonator and the source

| Injector | |
|---|---|
| Charge | 1 nC |
| Laser wavelength and pulse power | 266 nm, 100 μJ |
| Gun Q and Rs | 14400, 49 MW/m |
| Gun accelerating gradient | 100 MV/m @ 9.4 MW |
| Normalized r.m.s emittance | 8 π mm mrad |
| Energy spread | 0.36% |
| Bunch length | 3.7 ps |

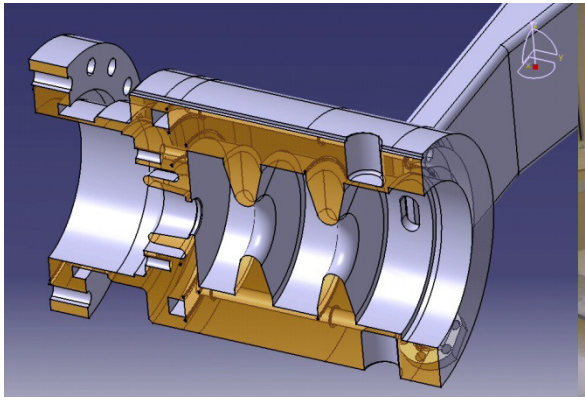
| Laser and FP cavity | |
|---|---|
| Laser wavelength | 1030 nm |
| Laser and FP cavity Frep | 36 MHz |
| Laser Power | 50 – 100 W |
| FP cavity finesse / gain | 30000 / 10000 |
| FP waist | 70 μm |

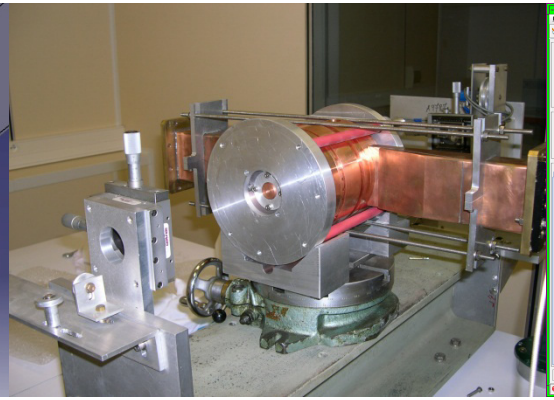
| Ring | |
|---|---|
| Energy | 50 MeV (70 MeV possible) |
| Circumference | 16.8 m |
| Crossing-Angle (full) | 2 degrees |
| $B_{x,y}$ @ IP | 0.2 m |
| Emittance x,y (without IBS and Compton) | $3\ 10^{-8}$ m |
| Bunch length (@ 20 ms) | 30 ps |
| Beam current | 17.84 mA |
| RF frequency | 500 MHz |
| Transverse / longitudinal damping time | 1 s /0.5 s |
| RF Voltage | 300 kV |
| Revolution frequency | 17.8 MHz |
| $\sigma_x$ @ IP (injection) | 78 mm |
| Tune x / y | 3.4 / 1.74 |
| Momentum compaction factor $\alpha_c$ | 0.013 |
| Final Energy spread | 0.6 % |

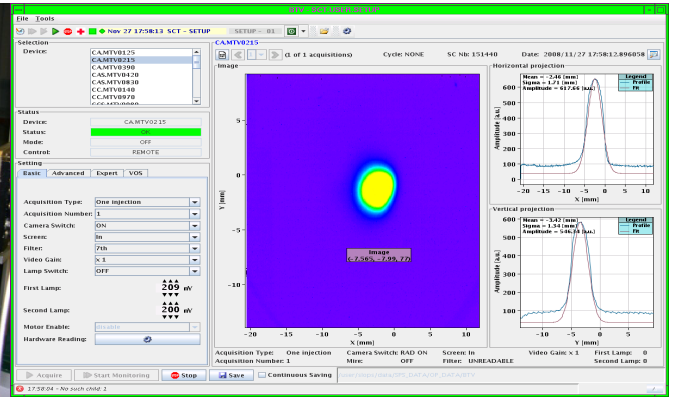
| Source | |
|---|---|
| Photon energy cut off | 46 keV (@50 MeV), 90 keV (@ 70 MeV) |
| Total Flux | $10^{11}$-$10^{13}$ ph/sec |
| Bandwidth (with diaphragm) | 1 % - 10% |
| Divergence | 1/γ ~ 10 mrad without diaphragm @ 50 MeV |

# Injector

## •Electron gun and accelerating section







- Probe Gun, LAL Design,
- Already tested in the CTF facility for high current

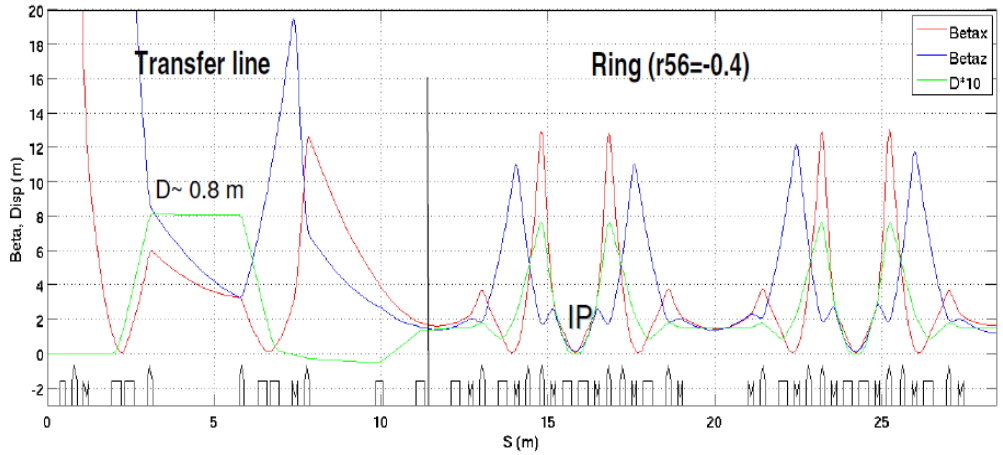
- Accelerating section => LIL type section
- 4.6 m, 135 cells, 2.998.46 MHz @ 31 C°, mode $2\pi/3$.
- Q = 14800, 12.6 MV/m for the 50 MeV case
- Entrance => 160 cm from the cathode
- Phase stability required $\Delta\phi \leq 1°$

• Acknowledgments to R.Roux, P.Marchand, J.P.Pollina

# Transfer line

## •Transport and diagnostics

- 4 correctors
- 4 stripline BPMs
- 3 screens
- 2 valves
- 2 ICT
- 1 scraper




Linac

Dump

•Emittance
•Beam size
•Steering

•Energy Spread
•Beam steering

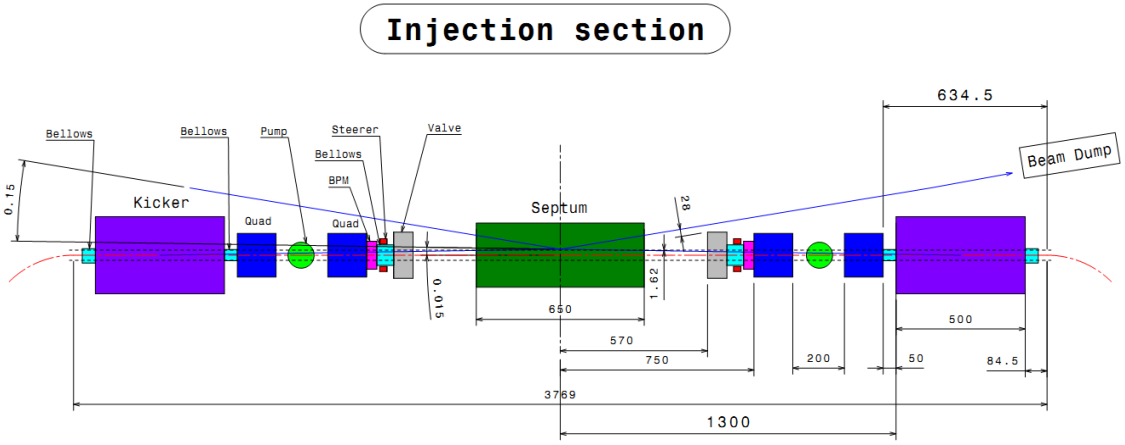
Injection

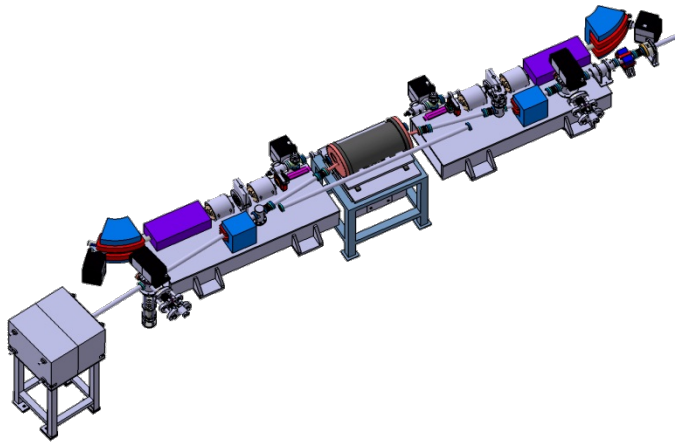
•Longitudinal and transverse emittance
•Dispersion matching (2 BPM)
•Orbit steering (2 coorrectors)

• Acknowledgments to A.Loulergue

# Injection

## One septum, two kickers

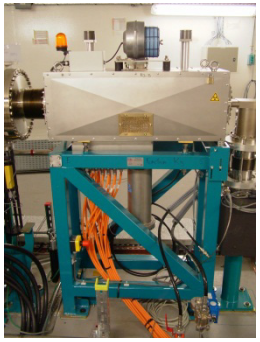


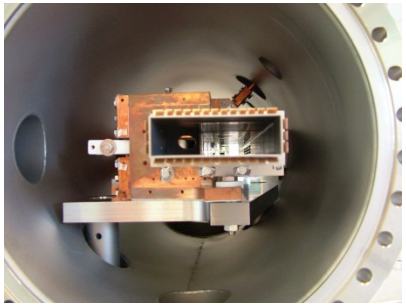



| Equipment | Active length | Overall length | Transverse Beam stay clear | | Septum thickness | Ceramic thickness |
|---|---|---|---|---|---|---|
| | (mm) | (mm) | H (mm) | V(mm) | (mm) | (mm) |
| Septum magnet | 250 | 650 | 30 | 12 | 3 | |
| Injection kicker | 250 | 450 | 40 | 28 | | 6 |
| extraction kicker | 250 | 450 | 40 | 28 | | 6 |

| Equipment | Deviation | Magnetic field length | Peak current | Charging voltage | Pulse shape | Pulse duration | Repetition rate (max) |
|---|---|---|---|---|---|---|---|
| | (mrad) | (mT) | (A) | (V) | | (μs) | (Hz) |
| Septum magnet | 150 | 100 | 960 | 150 | full sine | 130 | 50 |
| Injection kicker | 15 | 10 | 420 | 12500 | half sine | 0.050 | 50 |
| extraction kicker | 15 | 10 | 420 | 12500 | half sine | 0.050 | 50 |

•R&D => pulsed power supplies for the kicker magnets (ring revolution 56 ns) = > a very high di/dt (~20 kA/μs), fast rise time and fast blocking of the negative current, and a very small time jitter

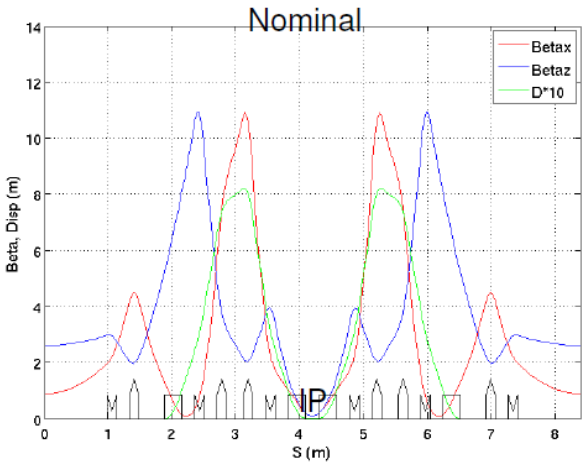


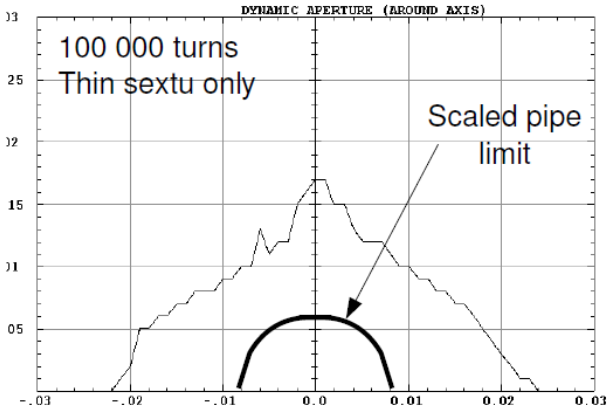


• Acknowledgments to P.Lebasque, T Vandenberghe

# Ring

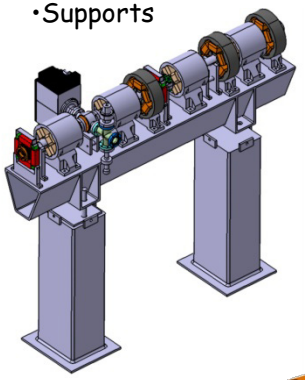
## Linear optics and mechanics



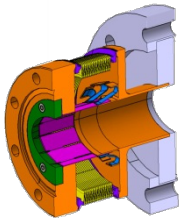




$\beta_x = \beta_z = 1.8$

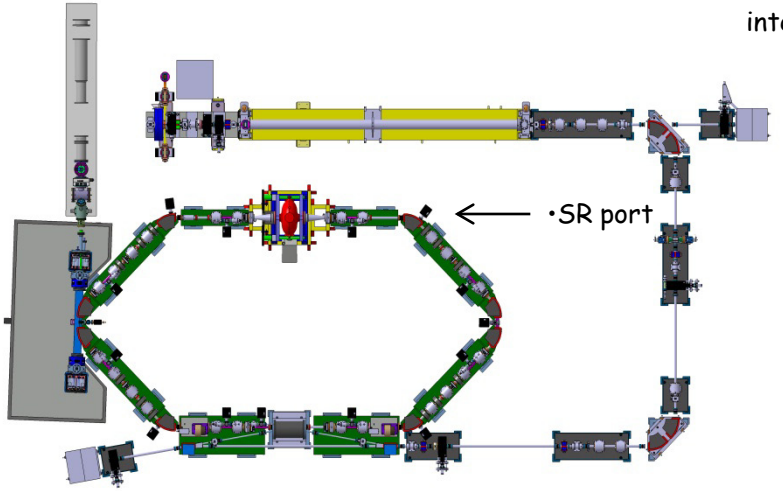
•Supports



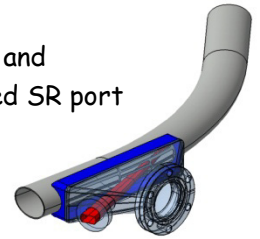
•Bellows



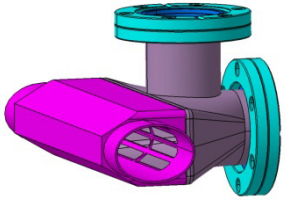
•X Line




•Pumping and integrated SR port



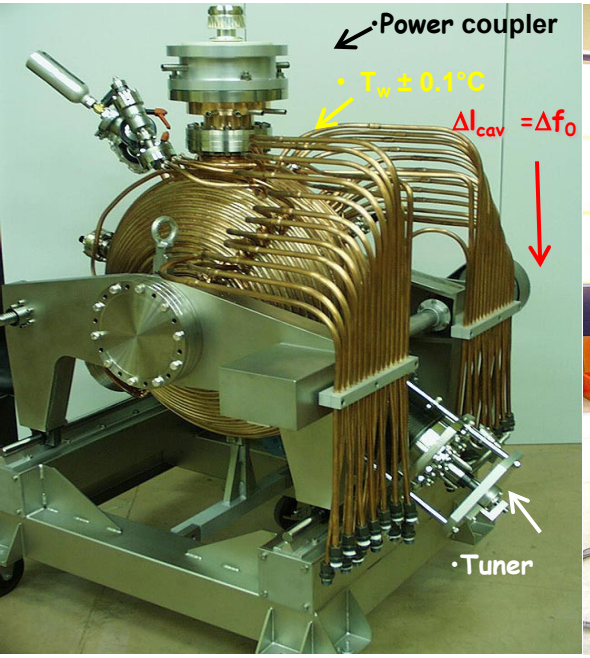
•Pumping ports

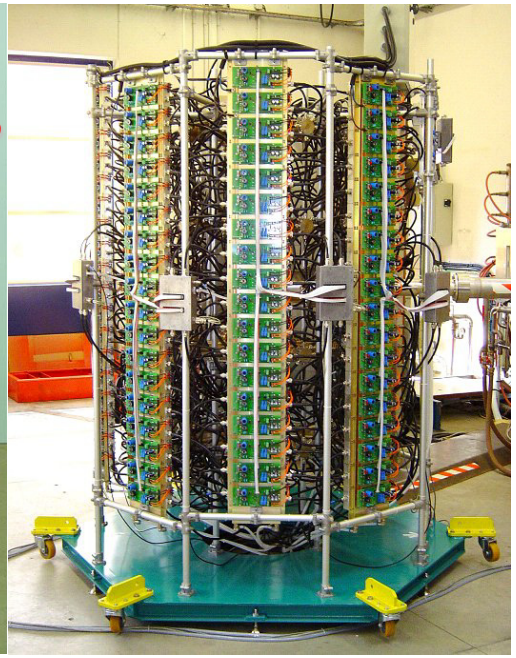


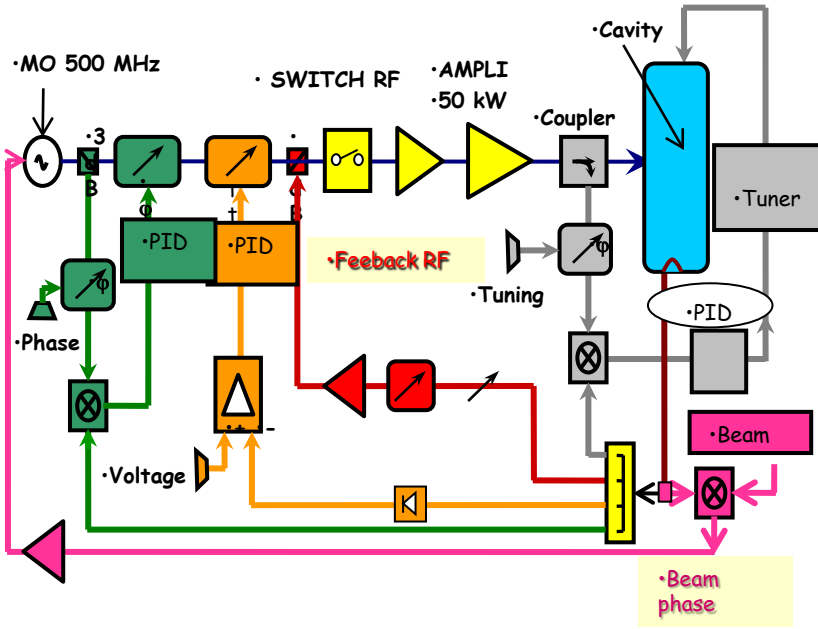
• Acknowledgments to A.Loulergue, T.Vandenberghe, C.Prevost, B Mericer, A. Gonnin, R.Marie

# Ring RF

## Cavity, Rf source and feedback






·'Elettra' type cavity
·3 different tuning knobs
·Temperature (30÷60 C°, ±0.05 C°)
·Mechanical length adjustment Δl
·Tuner on the equator

·'SOLEIL' type transistor amplifier
·No HT, modularity (easy to maintain)
·Tested (5 years, +25,000h of operation)
·Operational efficiency 99.995%
·1 Module @352 MHz 330W => Can be extended to 500 MHz

·'Slow and Fast feedback
·Slow Amplitude, phase , frequency loops
·Fast RF FB
· Phase loop => beam oscillations @ 500 kHz, $\Delta\Phi_{inj}$, HOM,...

· Acknowledgments to P.Marchand

# Beam Dynamics

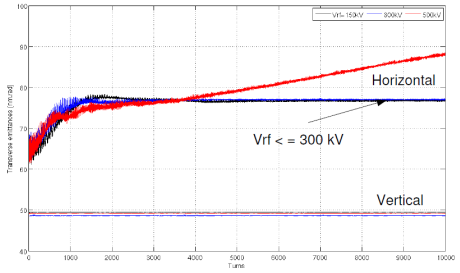
## Injection and instabilities. Compton effect

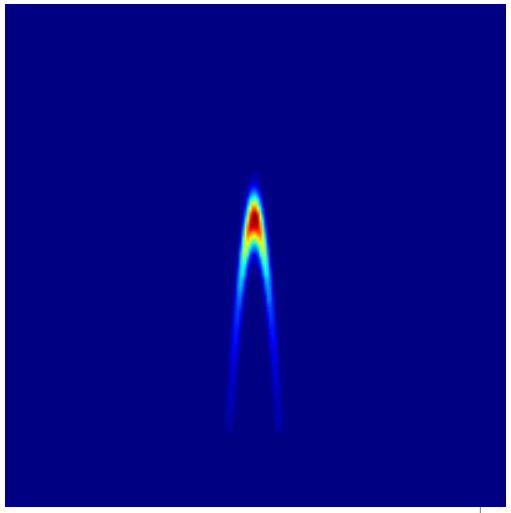
- Transient dynamics (no equilibrium)
- Compton recoil
- Collective instabilities
- CSR, Ions, Vacuum scattering, IBS…..
- Injection mismatching

- Feedbacks!!!!
- Ion clearing
- Simulations

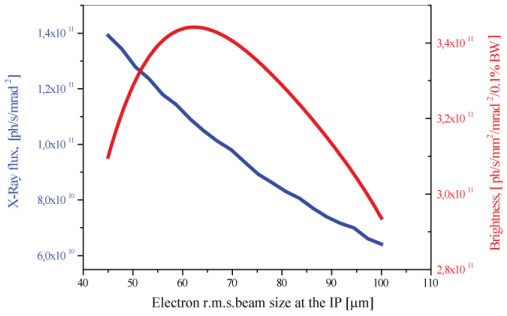
→

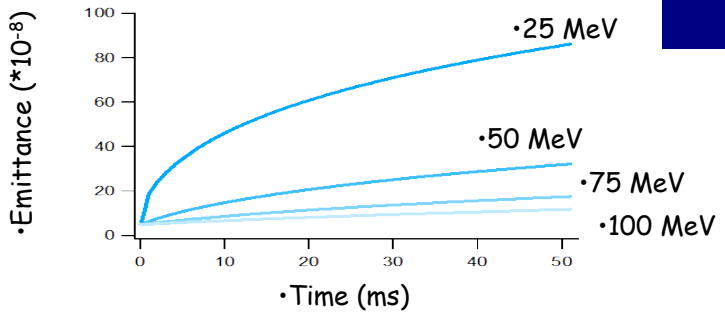
- 3 Phases
- Injection
- Turbulent regime
- Stabilization (thousand turns)

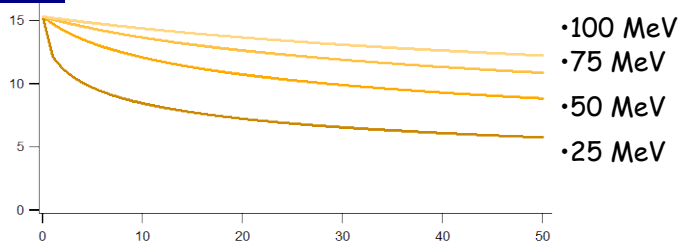


- Careful to the brillance !!!



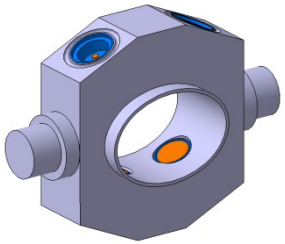

• Acknowledgments to A.Loulergue, C.Bruni

# Diagnostics

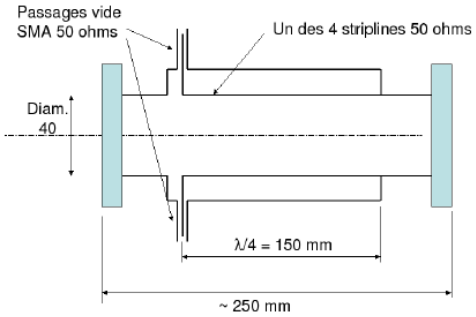
## Linac, transfer line and ring

- **In-flange Integrating Current Transformer**
- 5.0 Vs/C sensitivity
- Electronics: BCM-IHR with 2 ranges: 0.8 -2 nC
- Acquisition: ADC 12 bits 100kHz

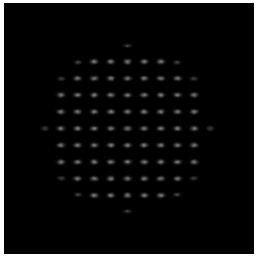
- 17 Button BPM in the ring.
- Absolute precision: < 50 μm
- Resolution: ~ 1 μm

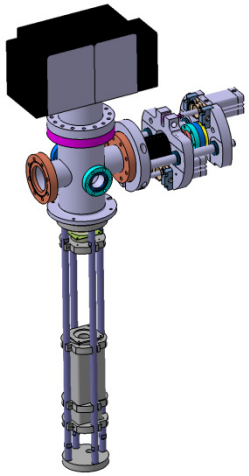


- Linac Stripline BPMs: λ/4,
- 500 MHz, resolution = 100 μm for 1 nC




- 1 Pepper pot

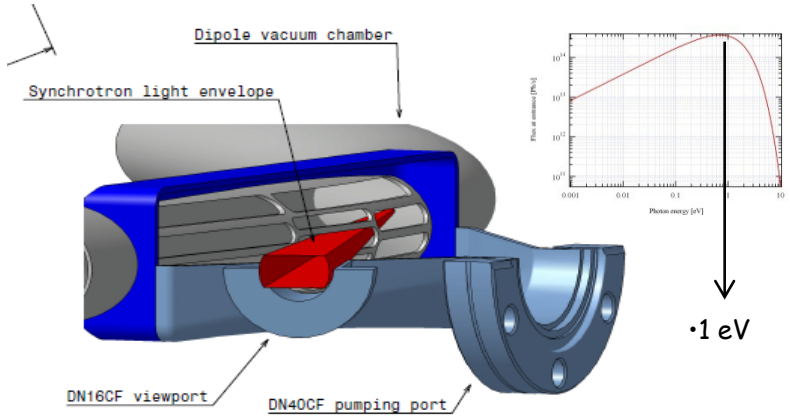




- Diagnostic Station:
- 1 design for a set of diagnostics at 4 different locations
- Elements: 2 or 3 screens
- 1 OTR : 25 mm diameter, 100 μm aluminized silicon wafer
- 1 YAG(Ce) : 25 mm diameter, 100 μm thick,
- Crystals: 1 sapphire screen
- Stepper motor to mount the screens
- View port: Fused Silica DN 60 CF
- 1 CCD: Basler with gigabit ethernet
- 1or 2 objective (s)

- Beam losses => fiber system

- 1 SR light port
- Extraction @ 15 ° - 63 mrad x 32 mrad aperture
- Dipole BM5

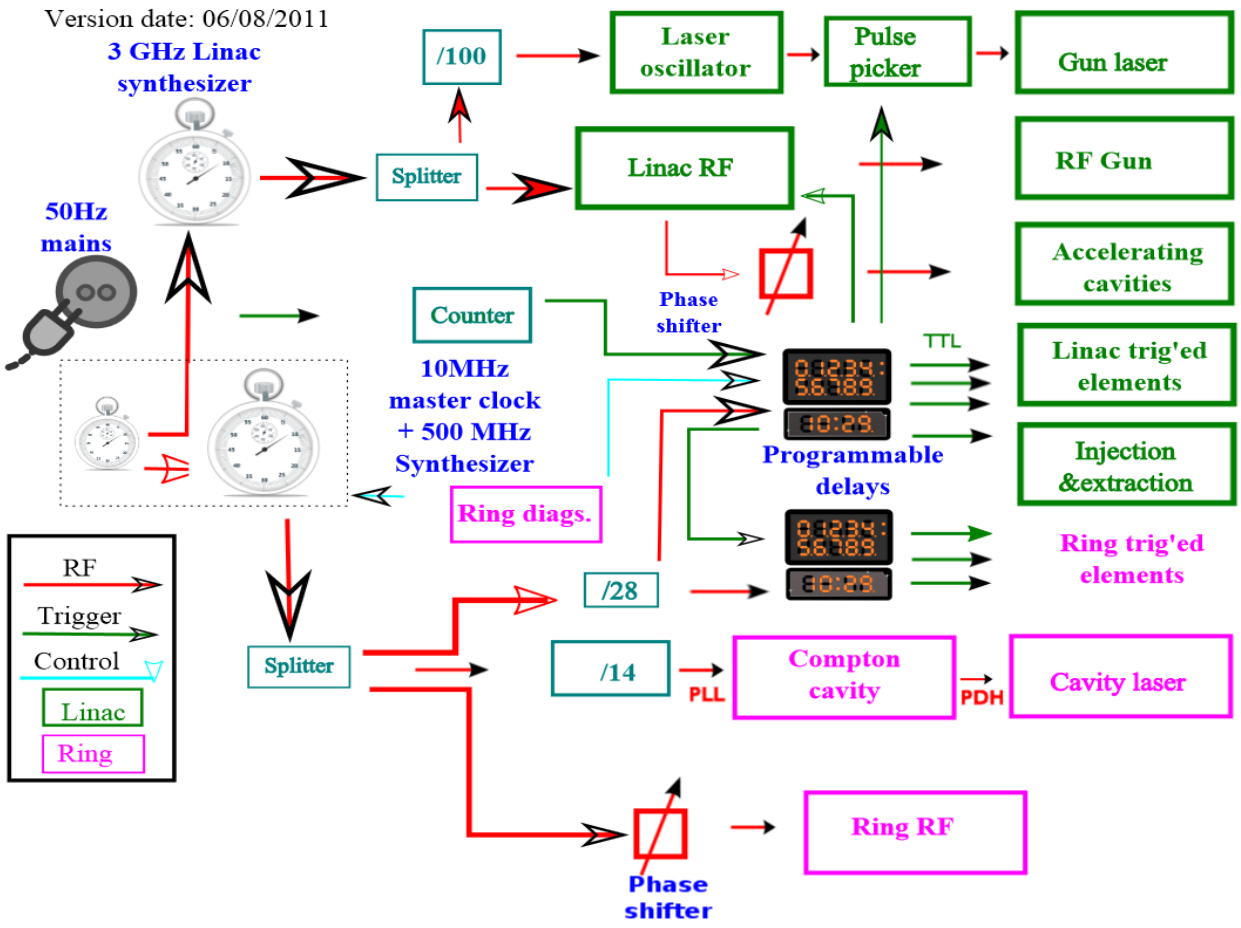



- 1 eV

• Acknowledgments to J.C Denard, M.Labat, N Delerue, M.Jore, L.Cassinari, N.Hubert

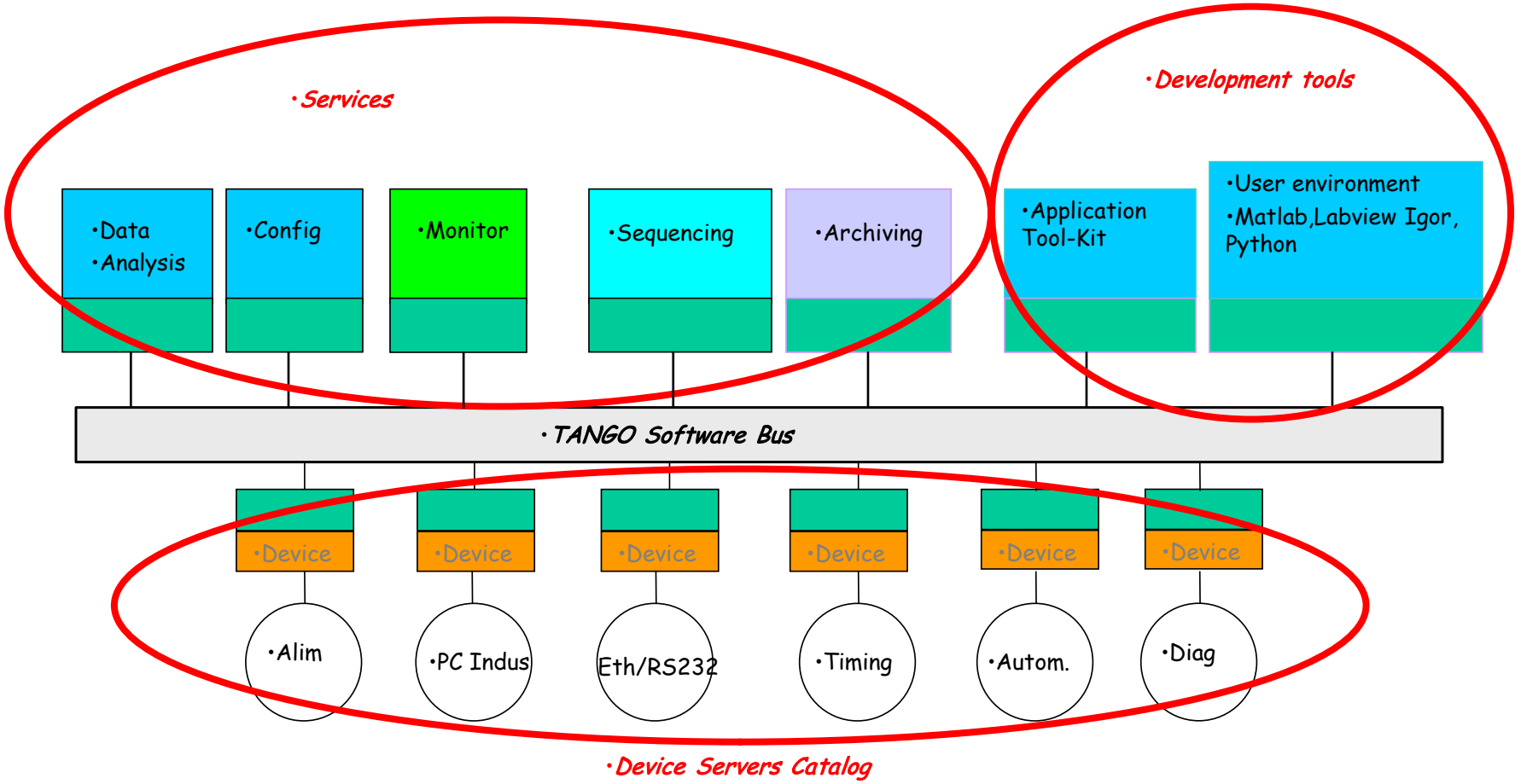
# Syncronisation

## MightyLaser (KEK ATF) experience




• Acknowledgments to N.Delerue

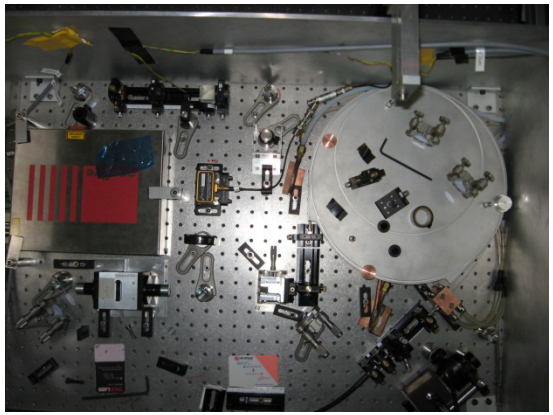
# Controls

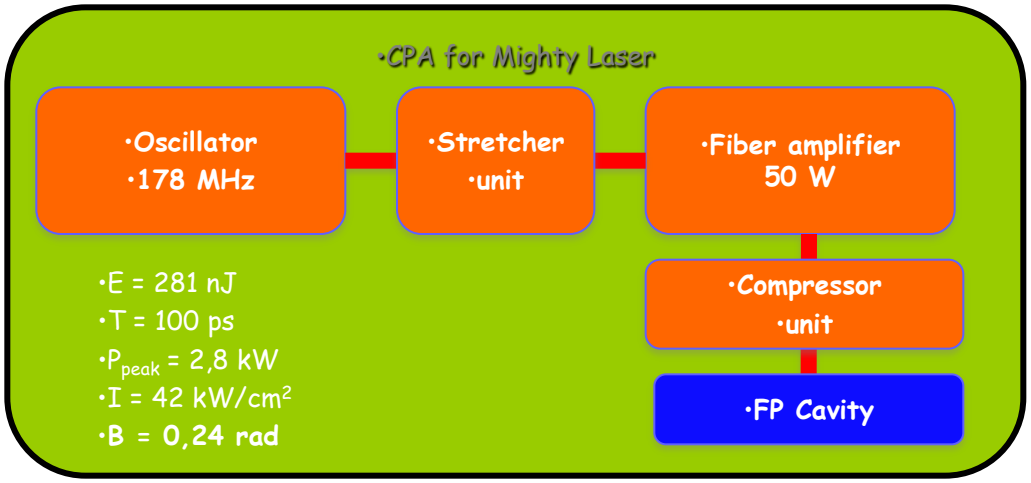


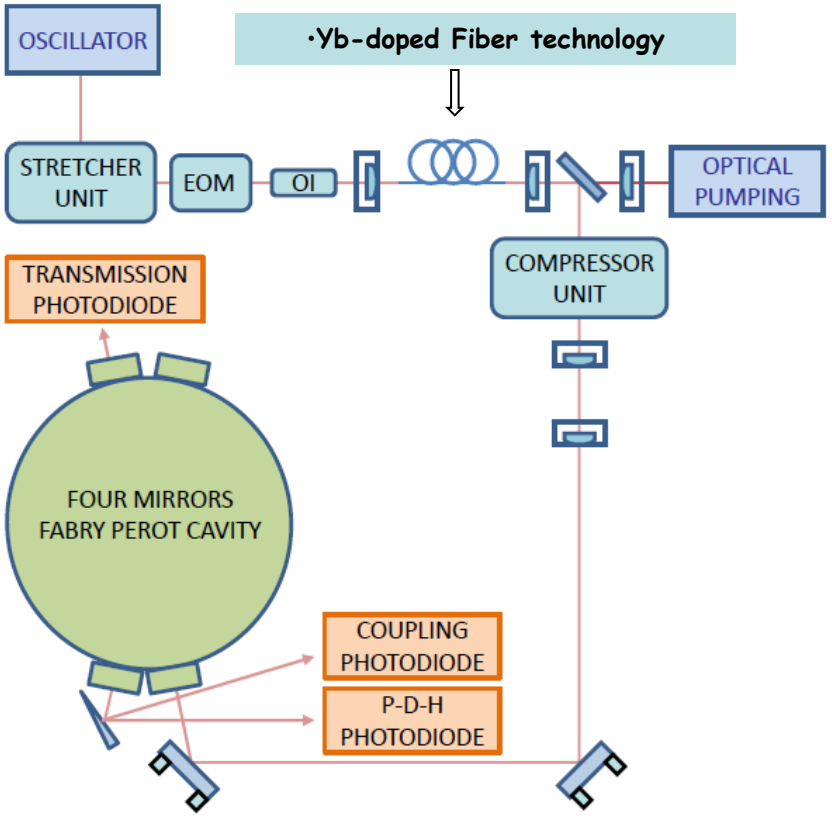

· Acknowledgments to X.Renon

# Laser

## •The MightyLaser experience






•**Compatible with low noise amplification**

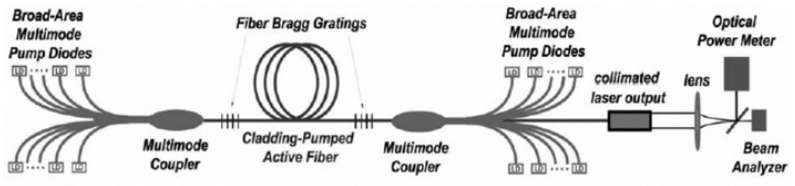
• Acknowledgments to E.Cormier, V.Soskov, F.Labaye

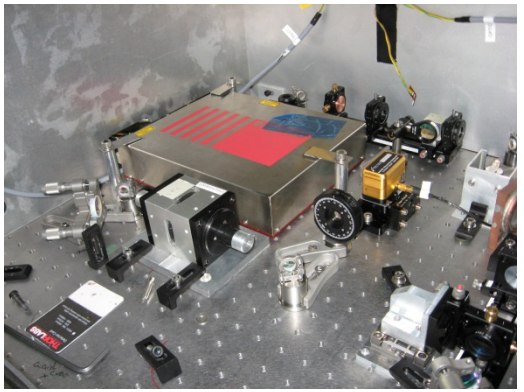
# Laser

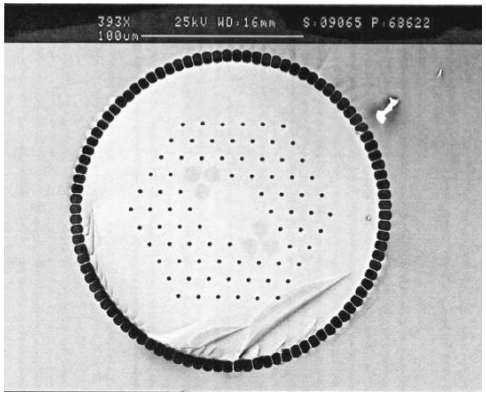
•Towards ThomX, (178 => 35 MHz)

•**New developments:**

- **Integration (all-fibered)**
  - **Mode adaptors (tapers)**
  - **Fiber connectorization**
  - **Specialty fiber splicing**
  - **Integrated optics**
  - **(EOM, CVBG, Isolators, …)**
  - **High power beam combiners**
  - **Fiber end facet preparation**
  - **(sealing, polishing, endcap, ….)**
  - **Tests (heat management, losses,**
  - **mode quality, reflections, …**
  -
- **•Architecture (fiber or hybrid)**
  - **Design of new large core fibers**
  - **Design of integrated**
  - **stretcher-compressor units**
  - **Evaluation of hybrid architectures**
  - **Fiber + Bulk**



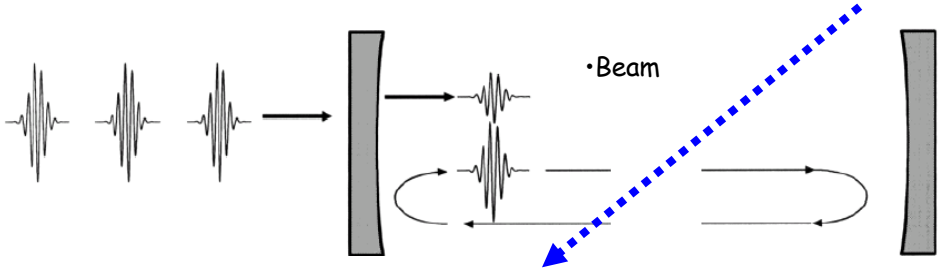





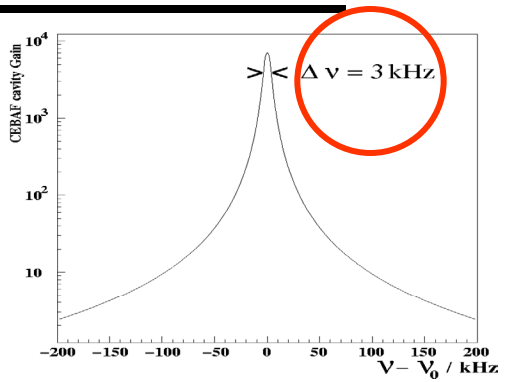

• Acknowledgments to E.Cormier, V.Soskov

# Fabry-Perot cavity

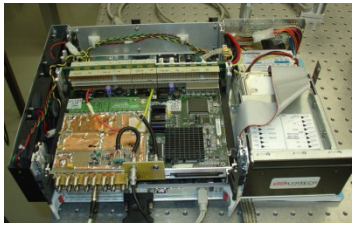
## MightyLaser and PLIC experience

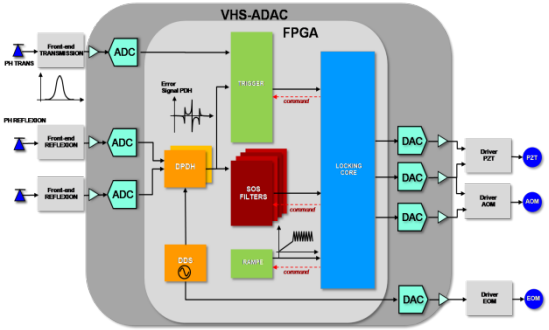



•Gain=1/(1-R)~10000

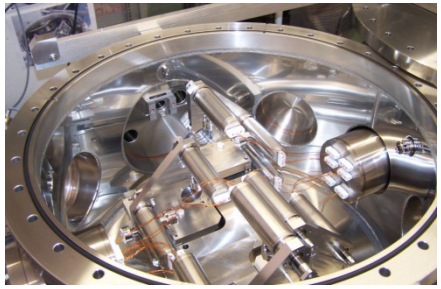


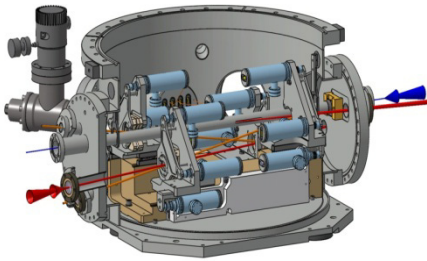

•Digital Pound-Drever-Hall feedback






•Vacuum and mechanics : MightyLaser experience



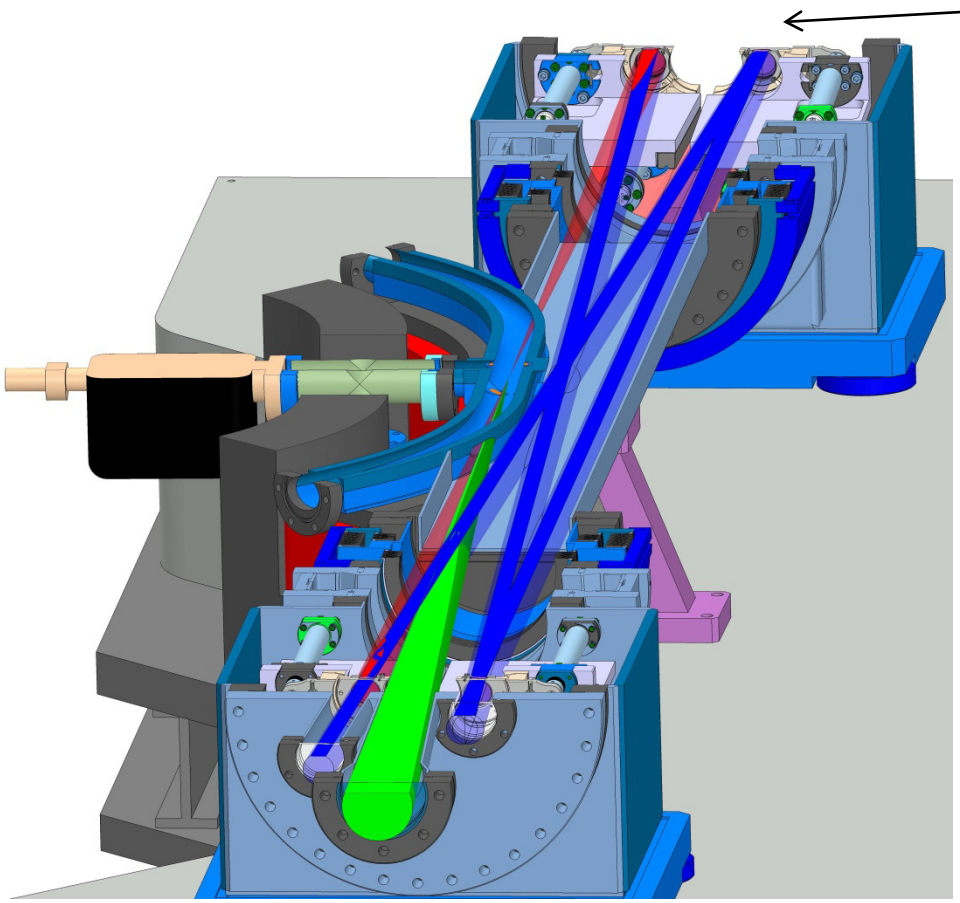


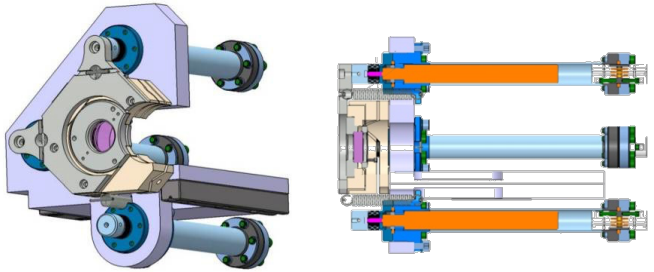
•PLIC and MightyLaser : record in stable finesse locking (30000).

• Acknowledgments to F.Zomer, R.Chiche, D.Jheanno, M.Lacroix, R.Cizeron

# Fabry-Perot cavity

- Towards ThomX



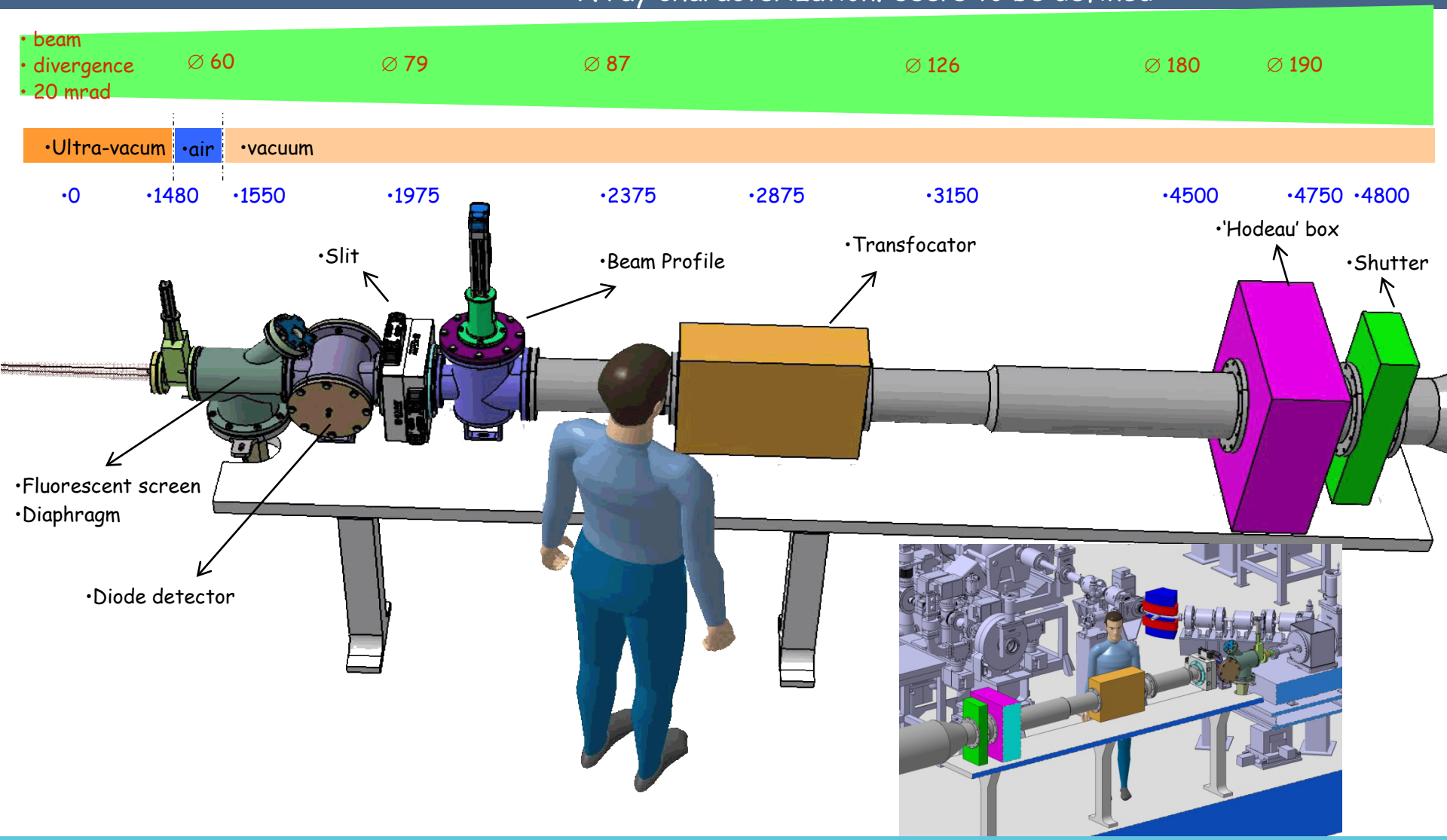


- Too long => Two monoblocks
- Dipoles Integration
- Dedicated BPM
- Bakable
- Easy to access, mounting
- 2 degrees collisions
- Laser insertion
- MightyLaser stabilization, adjustment

• Acknowledgments to M.Lacroix, Y.Peinnaud

# X ray line

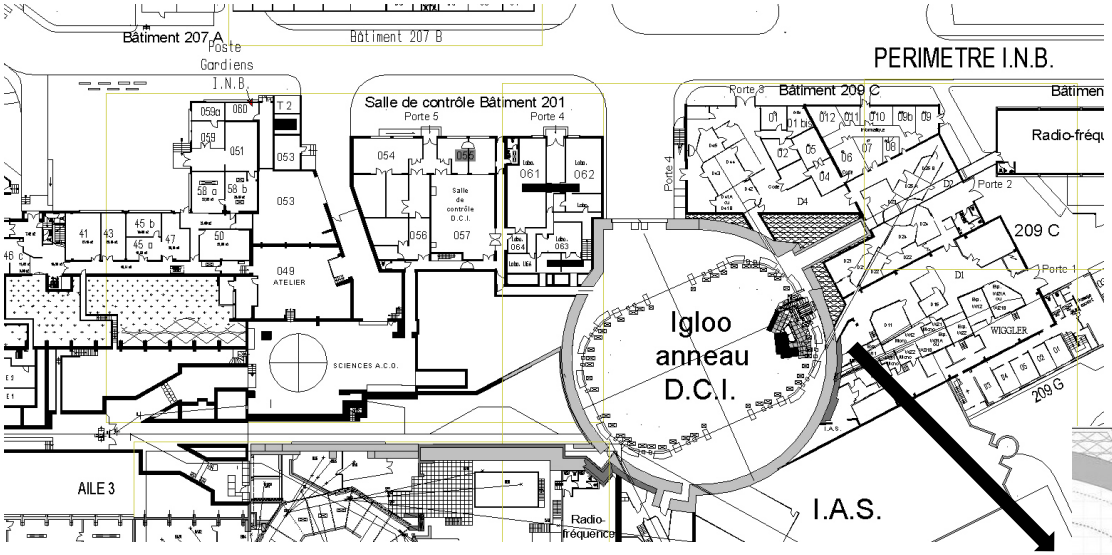
•X ray characterization. Users to be defined



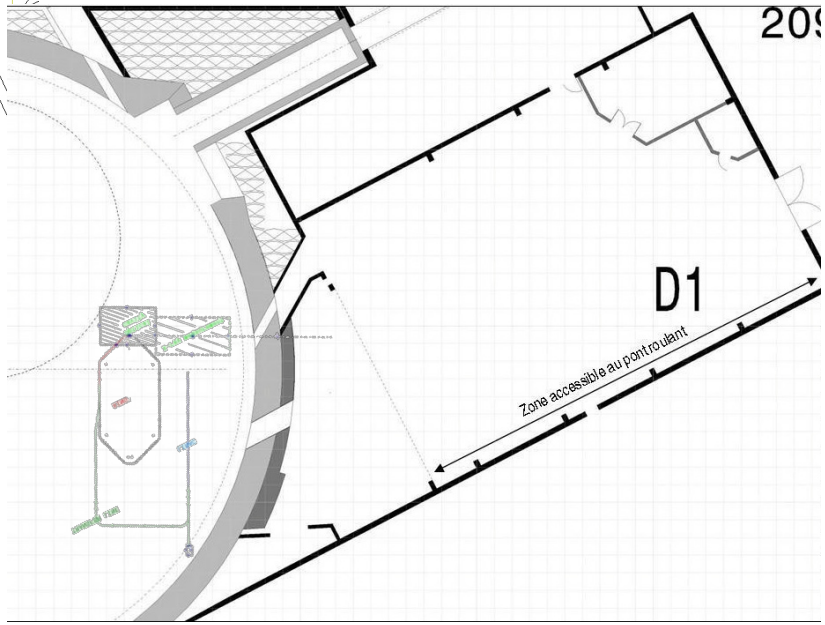

• Acknowledgments to M.Jacquet, J.L Hodeau, J.L Hazemann, P.Jeantet

# Integration and Site

## Paris-Sud University Campus



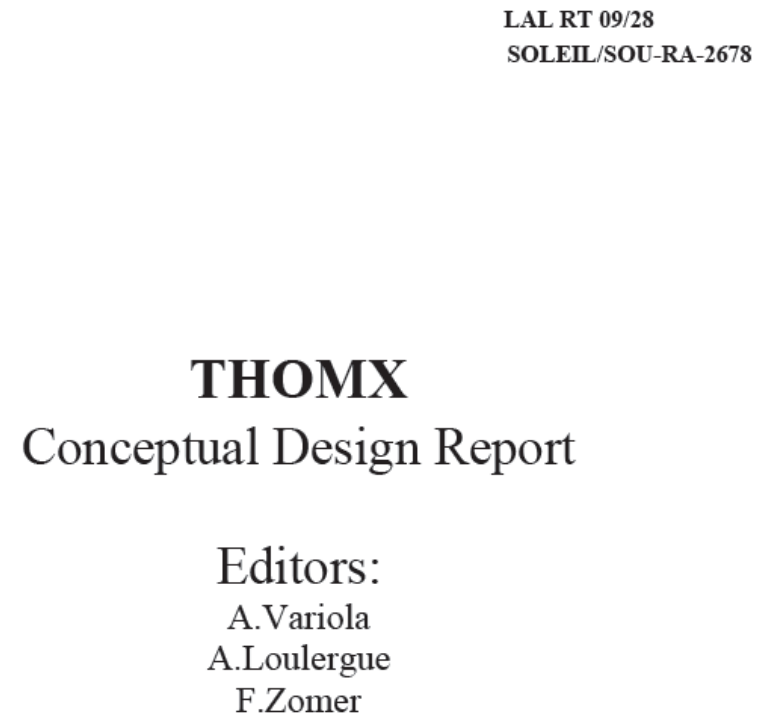

- OLD Orsay IGLOO





- Acknowledgments to A.Pichot, M .Tran

- 42 Contribtors
- 7 Research partners/ 1 Company
- 136 pages / 7 chapters
- Internal review committee. Eight international experts
- Published as a note:
- **LAL RT 09/28**
- **SOLEIL/SOU-RA-2678**


LAL RT 09/28
SOLEIL/SOU-RA-2678

THOMX
Conceptual Design Report

Editors:
A.Variola
A.Loulergue
F.Zomer

# Conclusions

- Different kinds of expertise in French Labs => Compton X Rays source
- Collaboration established, CDR published
- Financing!!!! Equipex (French minister), Ile-de-France Region, CNRS-IN2P3, Université Paris Sud XI
- TDR phase close to the end
- Very nice accelerator and laser physics
- Beam dynamics and technology R&D
- Industrial collaboration and user access expected
- Education!!!
- Construction starts in 2012

- Other IPAC Conference papers and posters correlated with ThomX
- C.Bruni et al MOPS050
- I.Chaikovska et al. WEPC051
- N.Delerue et al. TUPO002
- P.Marchand et al. MOPS127

- Thanks for your attention !!!!!!!

- Thanks to all the ThomX staff (unfortunately I cannot mention everybody……). They all contributed to the design and the study of the machine