LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

IN2P3
INSTITUT NATIONAL DE PHYSIQUE NUCLÉAIRE ET DE PHYSIQUE DES PARTICULES

UNIVERSITÉ PARIS SUD

Overview of enhancement cavity work at LAL/Orsay

- **INTRO:**
  - **Optical cavity developments at LAL**
- **Results on optical cavity in picosecond regime**
- **Polarised positron source R&D effort**
- **Developments for compact Compton X-ray source (ThomX)**

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ECFA Linear Collider Workshop, Hambourg, may 2013

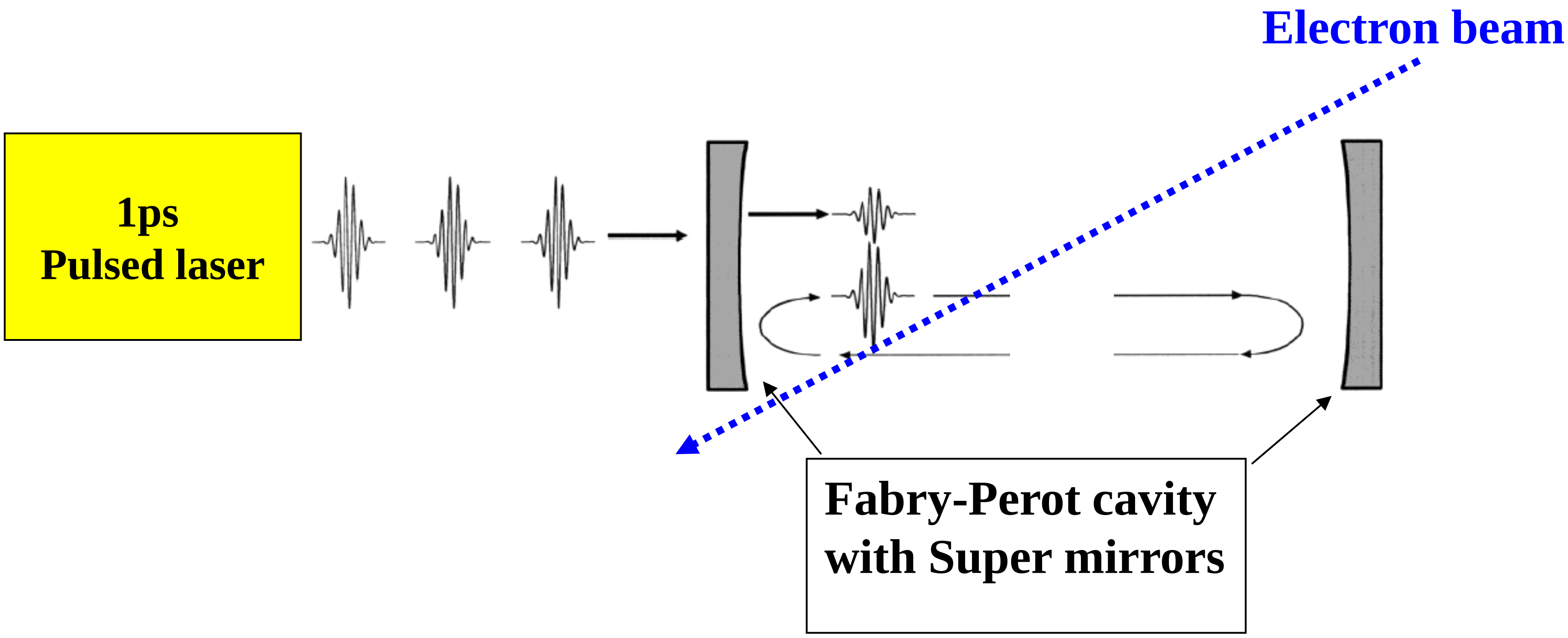
Introduction

- Instrumentation developments around laser-electron beam interaction at LAL since ~2000 (accelerator physics applications)
  - 2000: cw 30000 cavity finesse for the 30GeV electron beam at HERA/DESY (Coll. DESY, CEA)
  - ~2005 we started an R&D on Optical cavities in picosecond regime for a polarised positron source
    - 2006: start collaboration with ATF group of KEK
    - 2008: optical cavity for gamma-ray production on ATF/KEK
      - Coll. CELIA/KEK/LMA
  - 2011: optical cavity for X-ray production for the equipex ThomX/LAL

High Finesse Fabry-Perot cavity in 2ps & 200fs regime

Experiments at LAL
with E. Cormier & K. Osvay

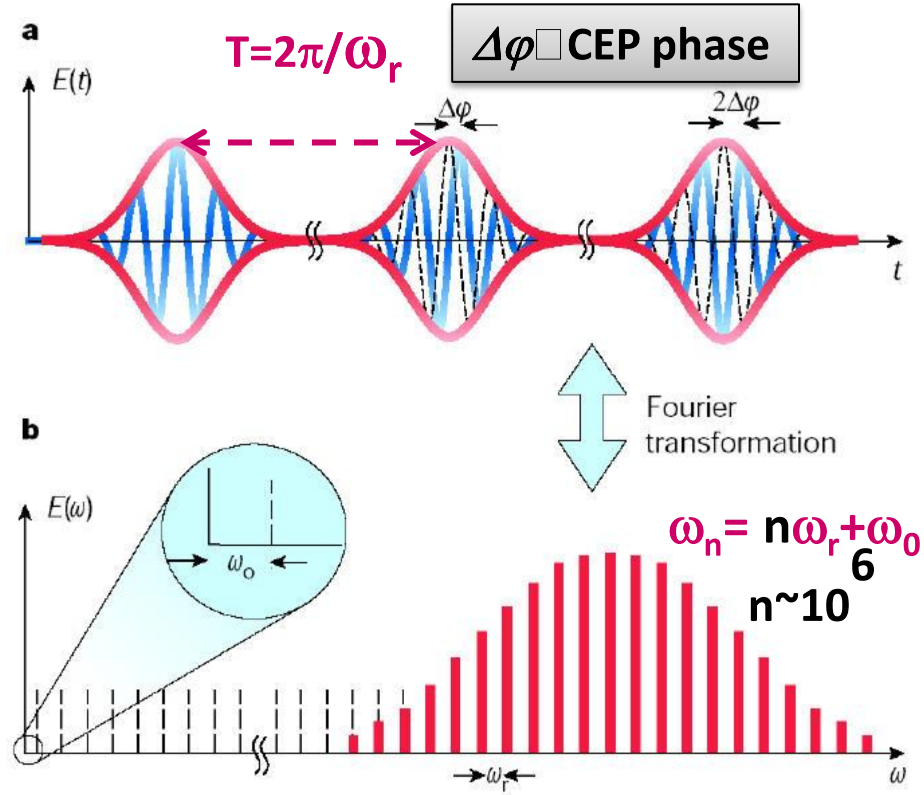
Fabry-Perot cavity in pulsed regime



Difference between continuous and pulsed regime

Pulsed_laser/cavity feedback technique

Specificity ➔ properties of passive mode locked laser beams



T. Udem et al. Nature 416 (2002) 233

Frequency comb ➔ all the comb must be locked to the cavity

➔ Feedback with

2 degrees of freedom :

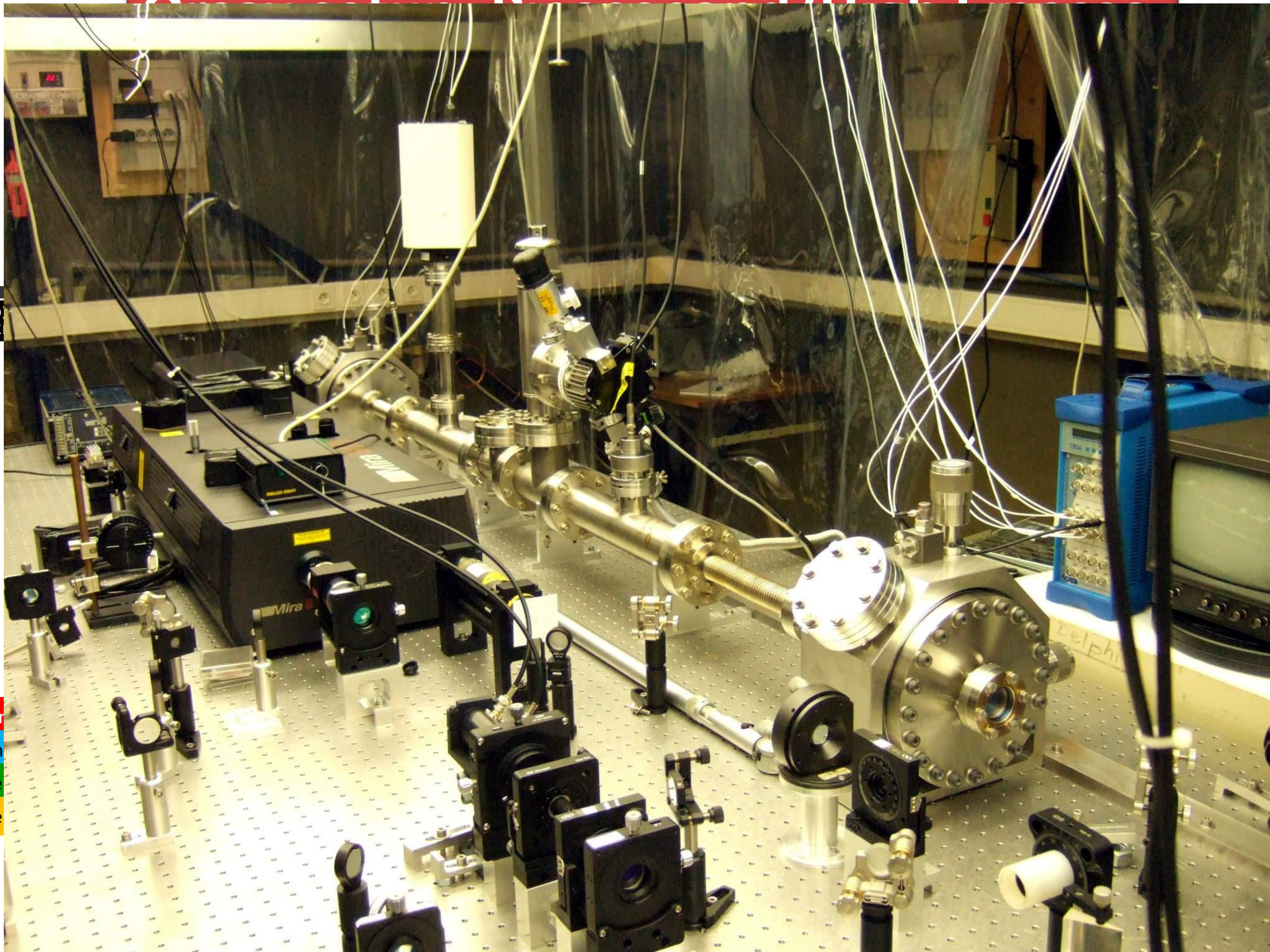
control of the

Dilatation (frep) & translation (CEP phase)

State of the art (Garching MPI) : **~70kW,** 2ps pulses @78MHz, stored in a 6000 finesse cavity

(O.L.35(2010)2052) **~20kW,** 200fs pulses @78MHz

VERDI
532

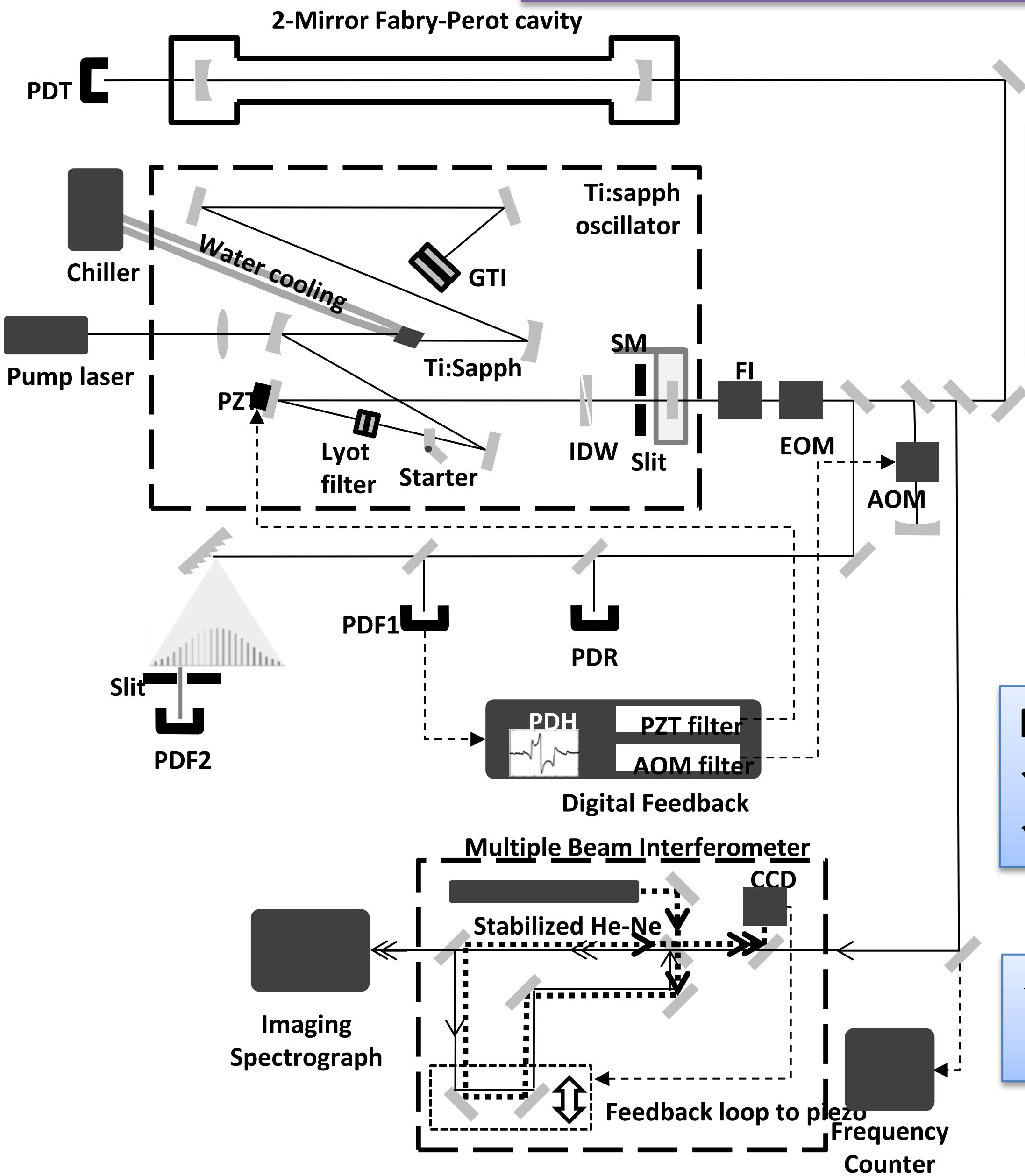


t cavity
0

RANS
ont-end

Pour
Tran
Lase
Lase

CEP effects measurement in picosecond/high finesse regime
CELIA, LAL, SZEGED Univ.



- ✓2ps Ti:Sapph (75MHz) Locked to a ~30000 finesse cavity
- ✓No control of the CEP drift in the feedback loop

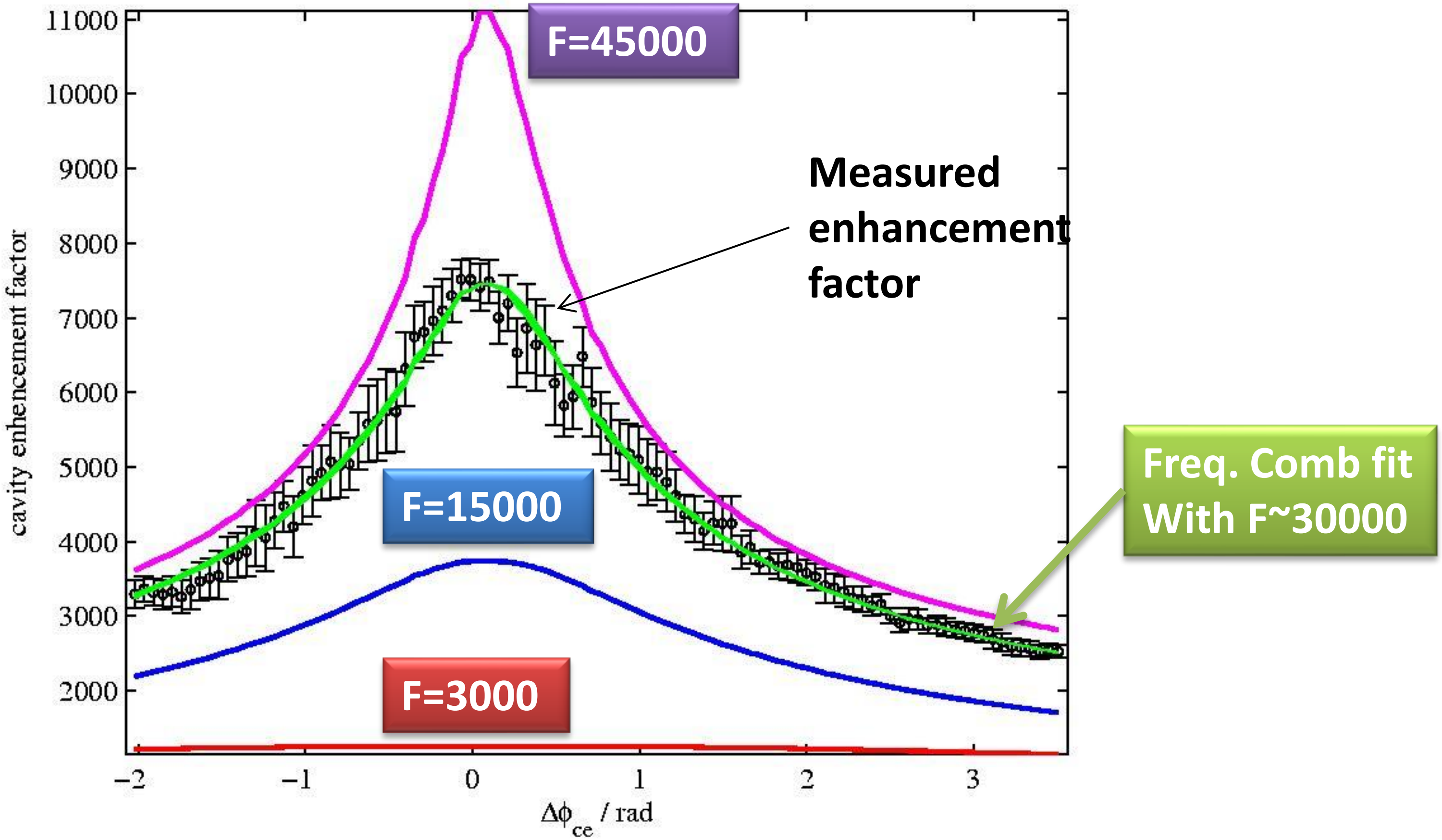
Numerical feedback loop
- ✓BW=100-200kHz
- ✓BW ~1MHz under development

- ✓CEP measured with Karoly's interferometer

November 1, 2007 / Vol. 32, No. 21 / OPTICS LETTERS 3095

Variation of the pump power

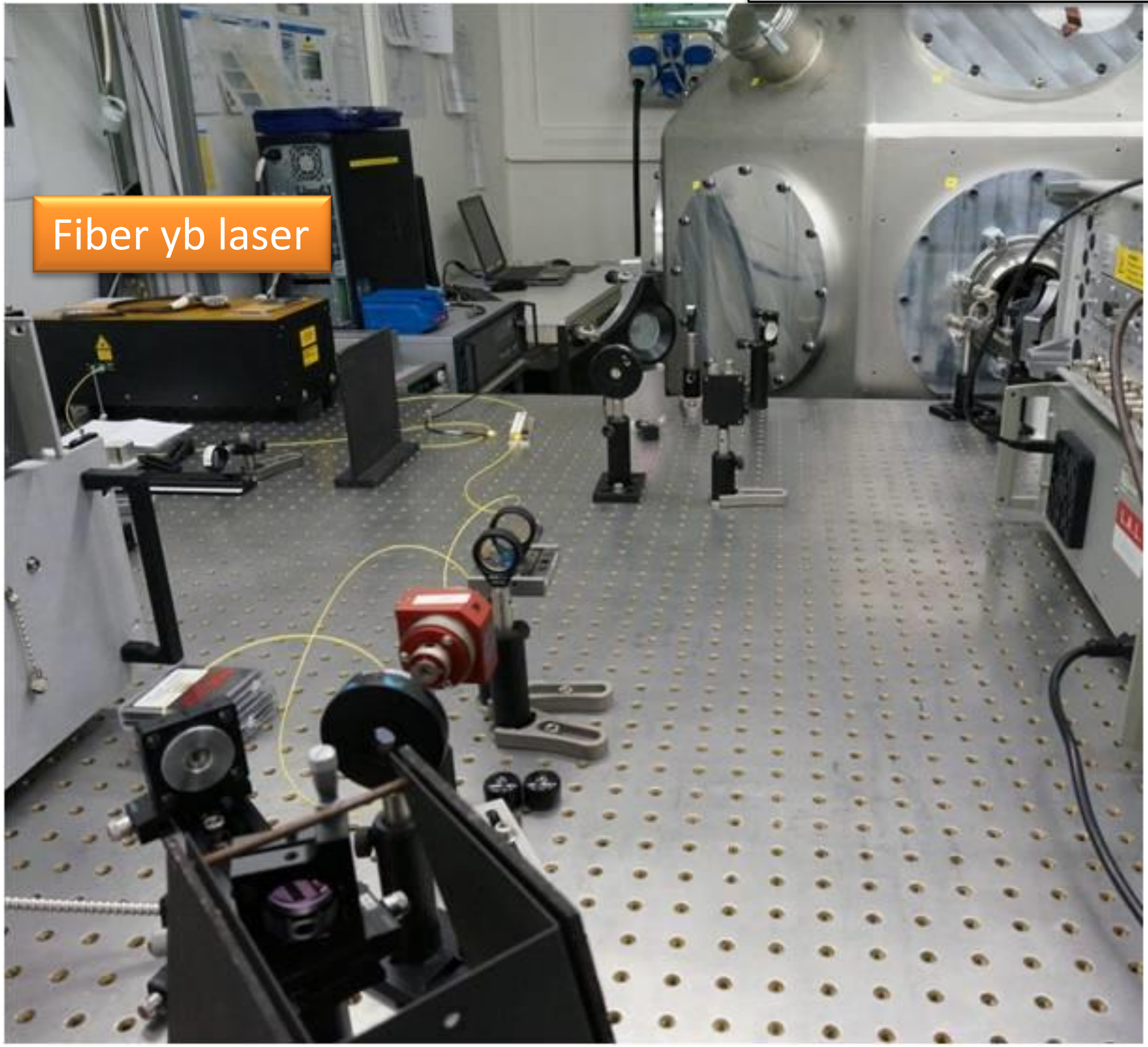
➔laser/cavity coupling measurement➔effective enhancement factor
➔CEP measurement



➔60% enhancement factor variation if CEP phase □[0,2π] for 2ps & ~30000 Finesse
➔CEP phase must be also controled in high Finesse/picosecond regime
➔Feedback loop BW must be>200kHz (on Frep at least)

Same experiment with Yb fiber laser at Orsay (8nm spectrum)

4 mirror non planar cavity



Cavity mirrors: T~20ppm
➔Finesse~25000

Fiber laser
➔frequency noise issues
➔feedback bandwidth>1MHz
Very stable laser/cavity Locking

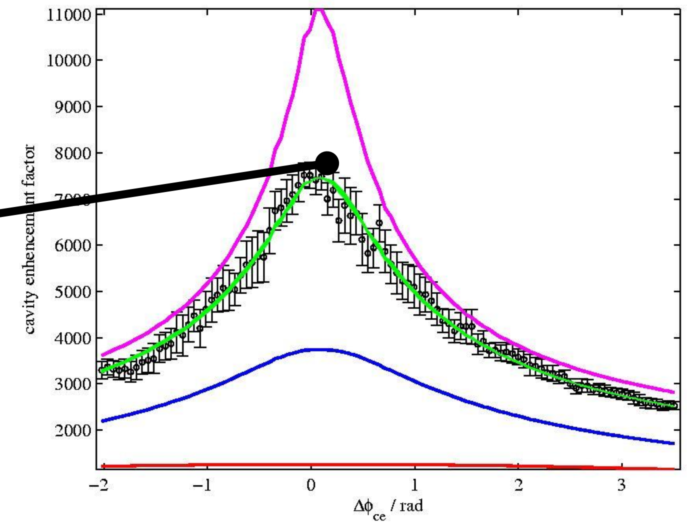
'Secondhand' vacuum vessel
➔We had dust issued
➔laser/cavity coupling ~50%
(➔Net power gain ~7500*50%)

Next week:
➔new mirrors T~8ppm (➔F~43000)
➔fiber amplifier (CELIA) : 50W

Summer 2013
➔installation of ATF at KEK

Towards 1 MW average power

G = 10000



150 W fiber laser

CELIA

F = 30 000

FP cavity

LAL

Stored average power of 100 kW to 1 MW

Polarised positron source

Experiment at KEK

Collaboration with ATF/KEK and CELIA to provide Yb fibre amplifier

(10W→60W average power)

KEK cavity
French Japanese Collaboration

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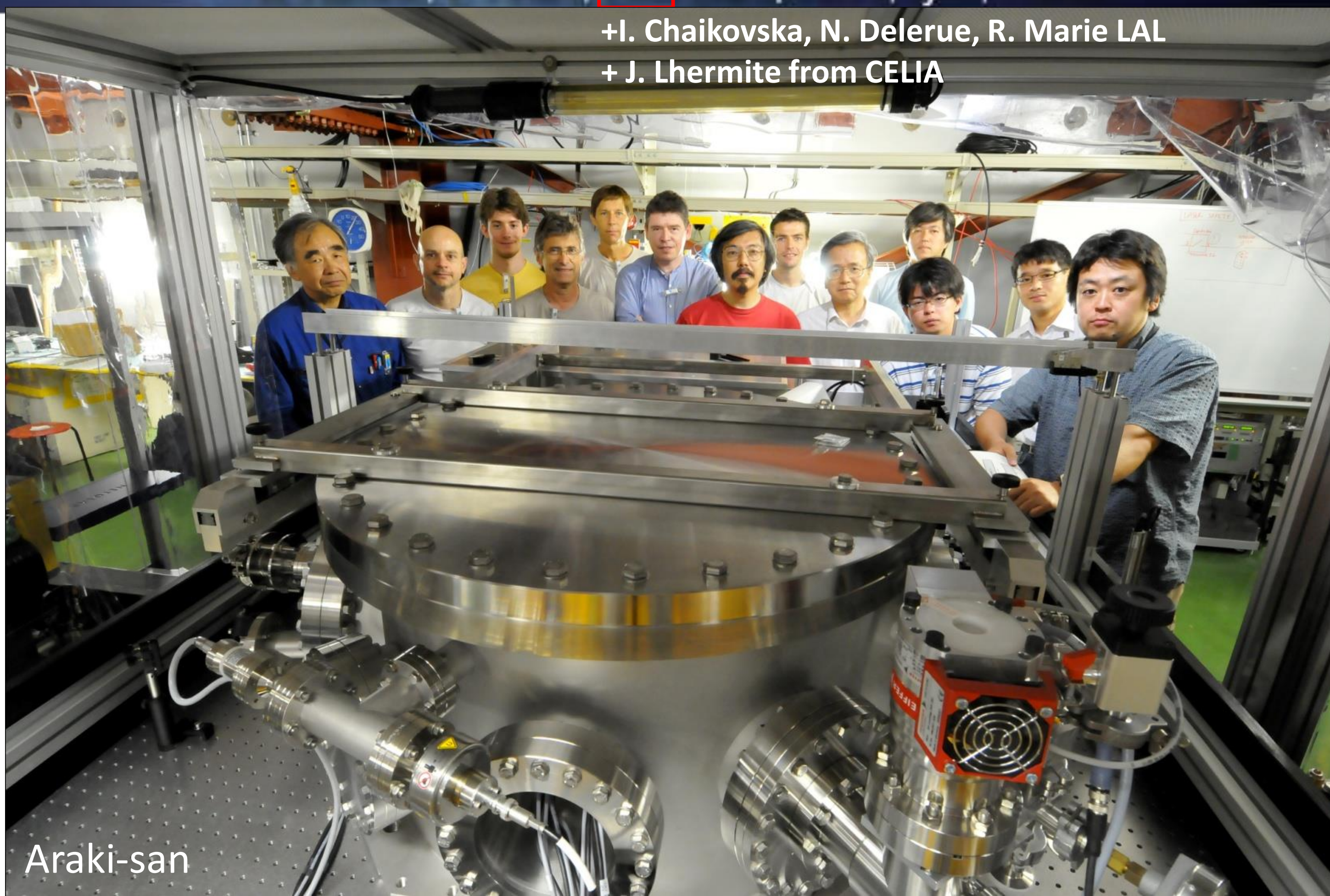
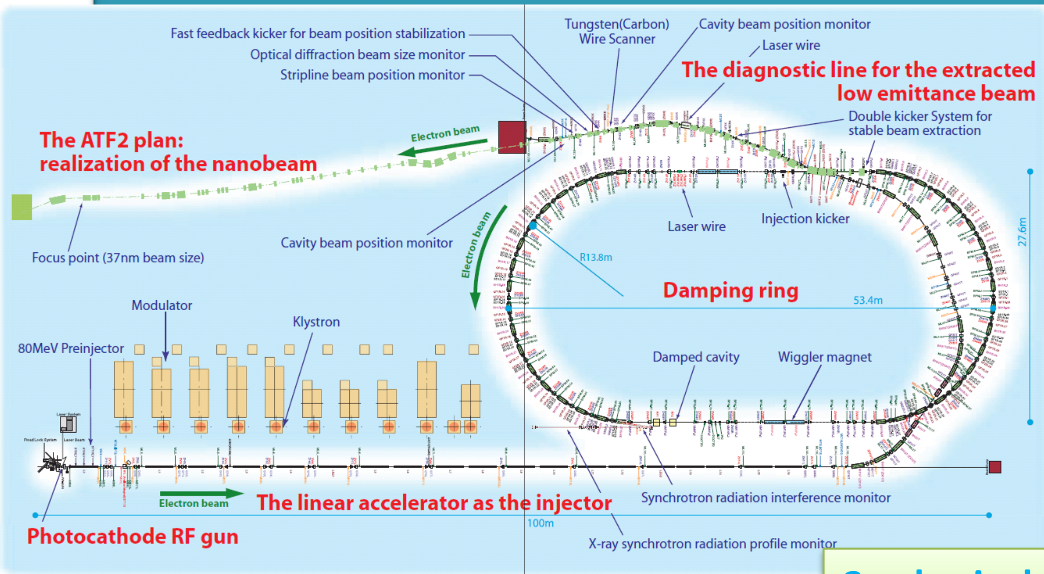
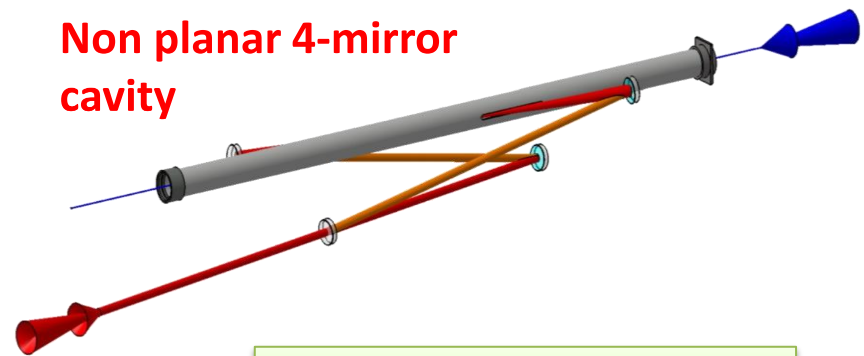
T. Akagai, S. Miyosohi, S. Nagata, T. Takahashi, Hishoshima University, Hiroshima, Japan
S. Araki, S. Funahashi, Y. Honda, T. Omori, H. Shimizu, T. Terunuma, J. Urakawa, KEK, Tsukuba, Japan
J. Bonis, R. Chiche, R. Cizeron, M. Cohen, J. Colin, E. Cormier, P. Cornebise, D. Jehanno, F. Labaye, M. Lacroix, Y. Peinaud, V. Soskov, A. Variola, F. Zomer, LAL CNRS/IN2P3 Université Paris-Sud 11, Orsay, France
R. Flaminio, L. Pinard, LMA CNRS/IN2P3, Lyon, France

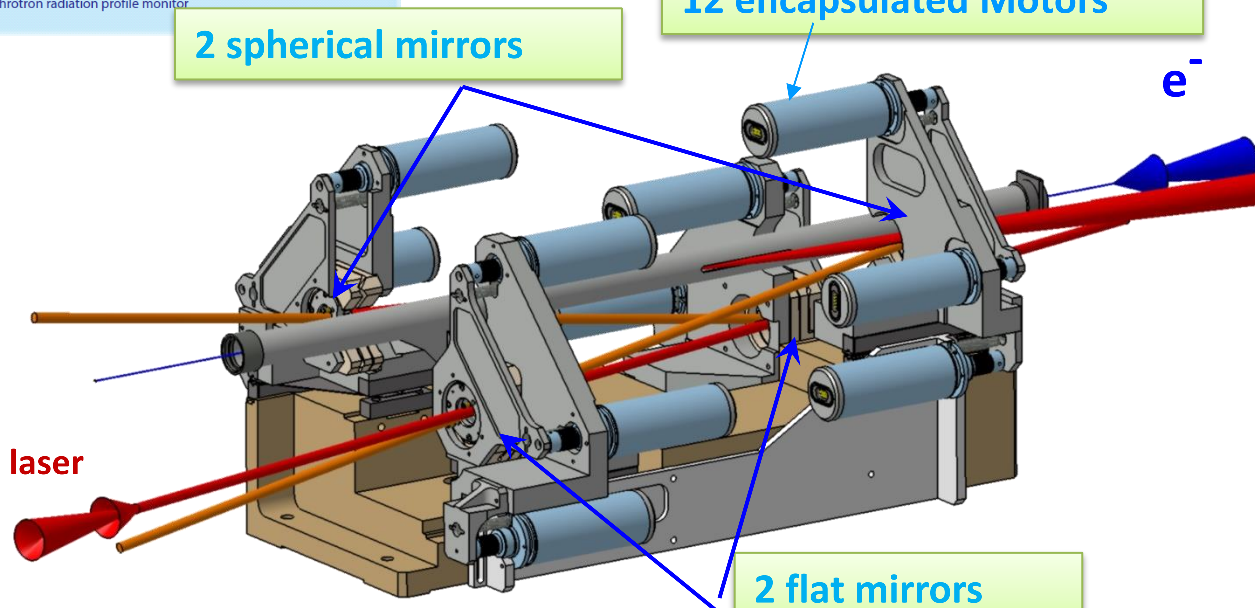


Results at KEK



Non planar 4-mirror cavity





mechanical stability

➔ **4-mirror cavity**

circularely polarised eigenmodes

➔ **Non-planar geometry**

Four mirror non-planar cavity

Results before the earthquake
✓ Finesse 3000 & 10W incident laser power
✓Detection of ~30MeV gamma-rays

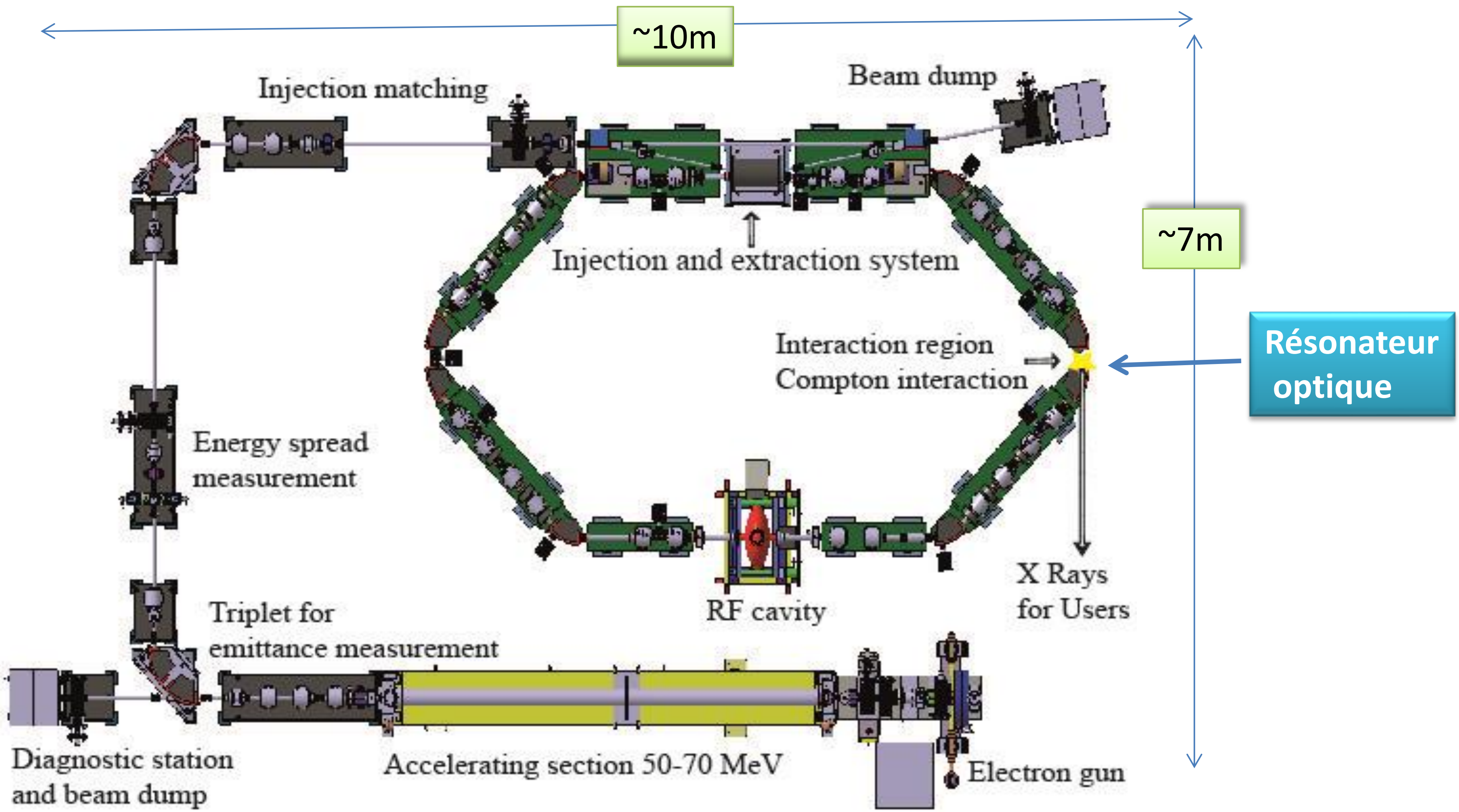
Re installation during summer 2013
New fiber Laser
•Cavity Finesse 25000→45000
•Laser power 50W→100W

Monochromatic X-ray source ThomX

Experiment at Orsay

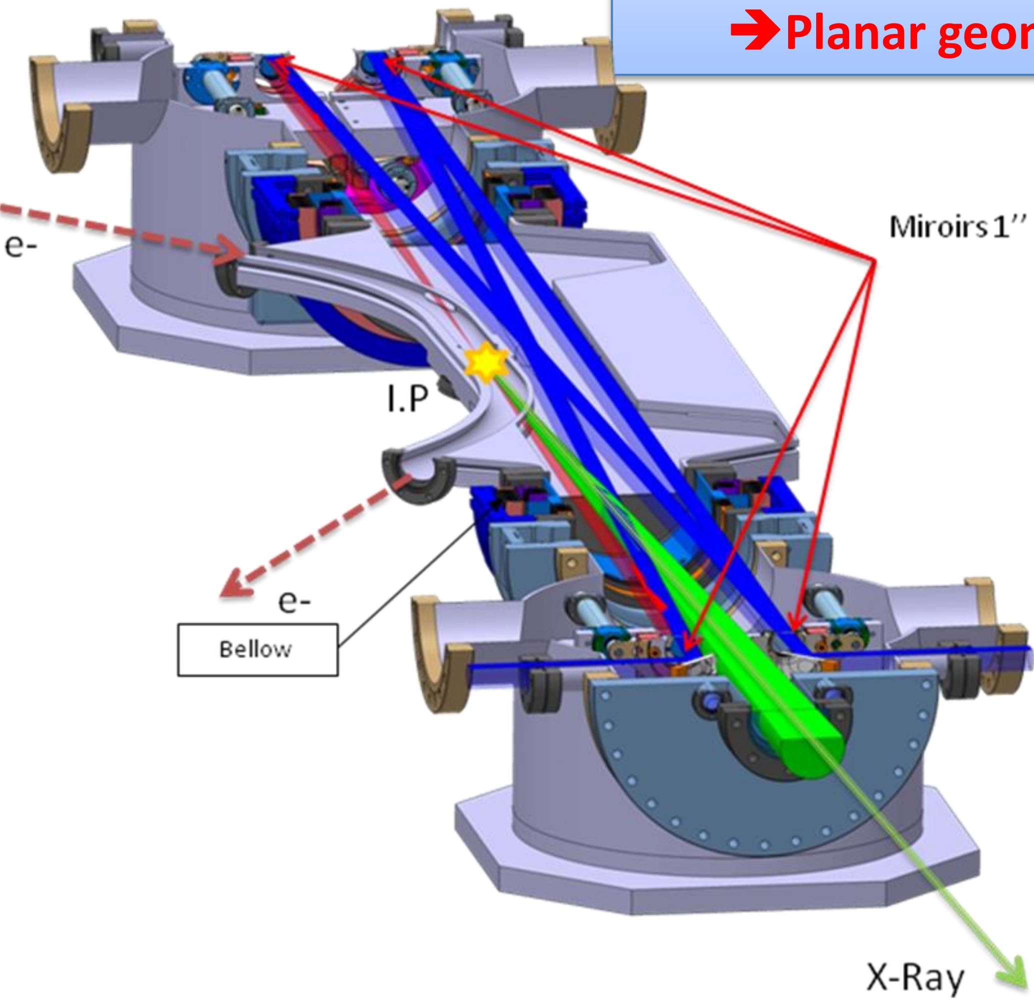
CELIA in charge of high average power amplifier

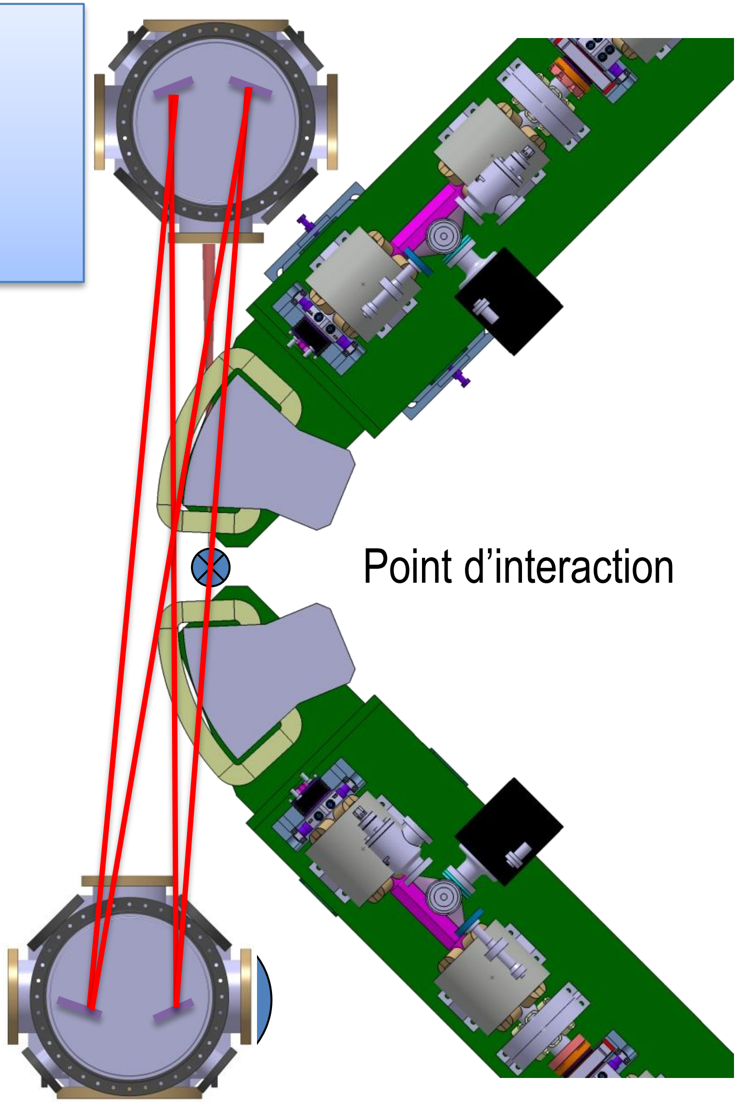
ThomX


~10m
~7m
Injection matching
Beam dump
Injection and extraction system
Interaction region
Compton interaction
Résonateur optique
Energy spread
measurement
Triplet for
emittance measurement
RF cavity
X Rays
for Users
Diagnostic station
and beam dump
Accelerating section 50-70 MeV
Electron gun

Geometry for ThomX

Mechanical stability
➔**4-mirror cavity**
Linear polarised modes
➔**Planar geometry**

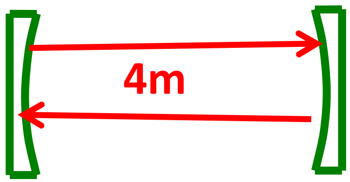




Summary

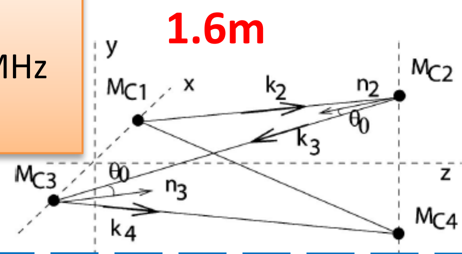
ORSAY

Ti:sapph
76 MHz
1ps



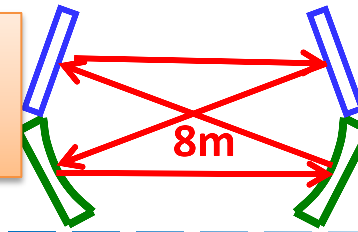
KEK cavity

Yb
180 MHz
0.2ps



ThomX

Yb
35.7MHz
~15ps



Achieved

Gain~10000
Laser coupling ~80%
Low laser power <1W

Achieved at ATF in 2011-2012

Gain~1000
Laser coupling ~60%
laser 10W-50W
Laser amplification stability

Achieved at Orsay with new laser

Finesse 25000
Coupling ~50%
Laser power<100mW

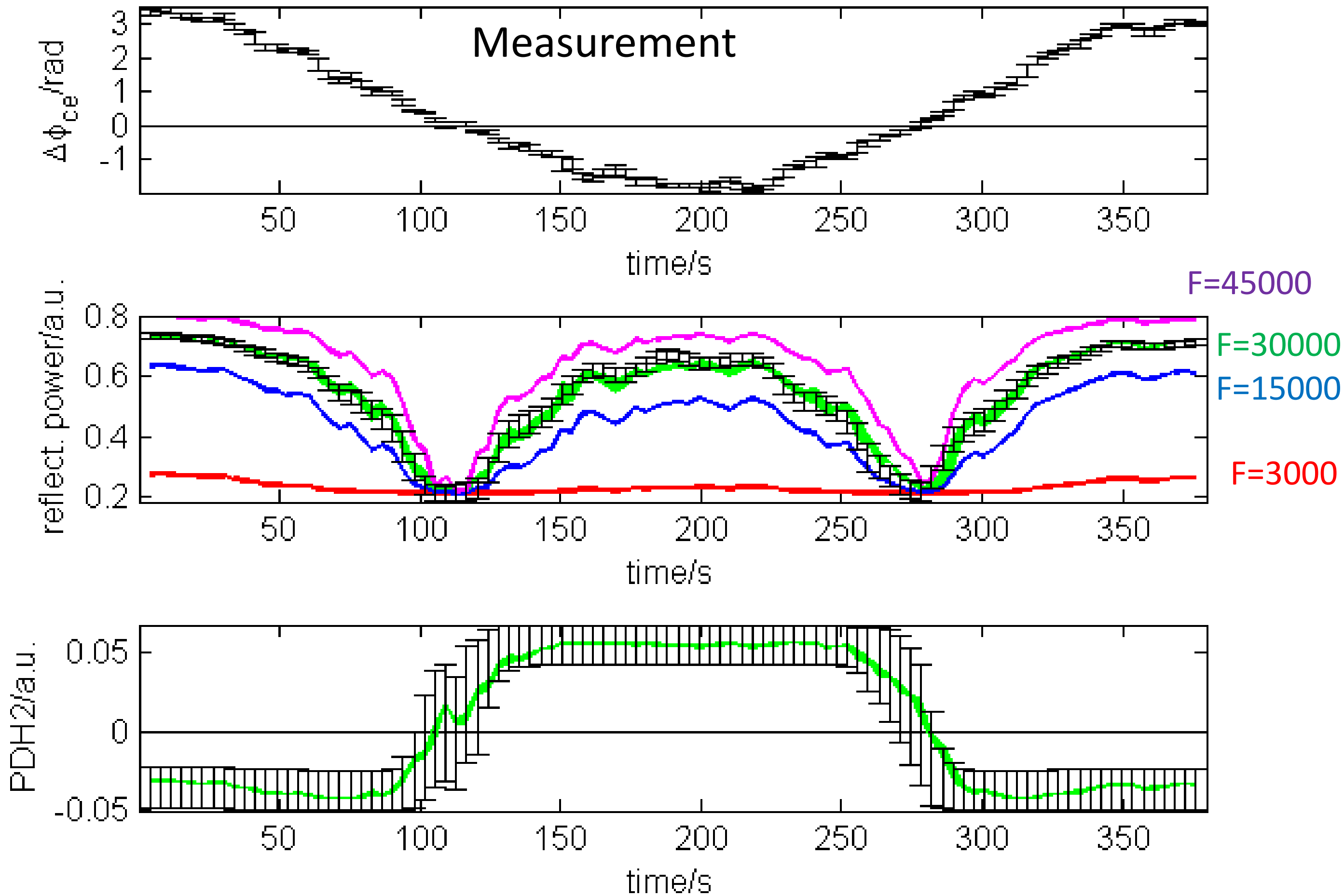
Immediate improvement

Finesse 43000
Coupling >50%
Laser power>50W
➔ Expected stored power>300kW

Foreseen end 2013-2014

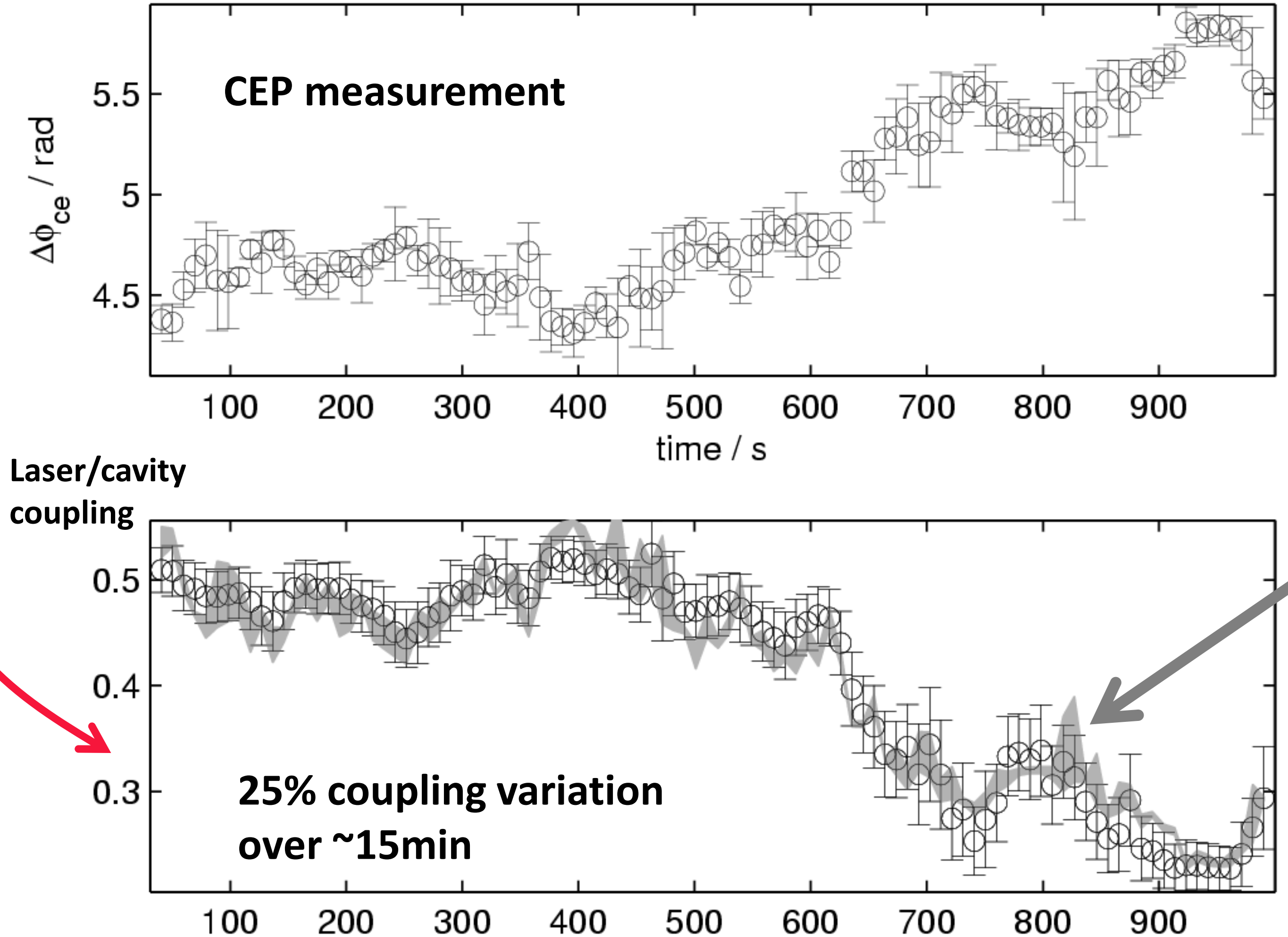
Gain ~10000
Laser coupling ~80%
Laser power 50-100W
➔400kW

results



Only 3 free parameters in the fit:
a normalisation factor, an offset and the Finesse

We observed strong free running laser/cavity coupling variations (Finesse~30000)

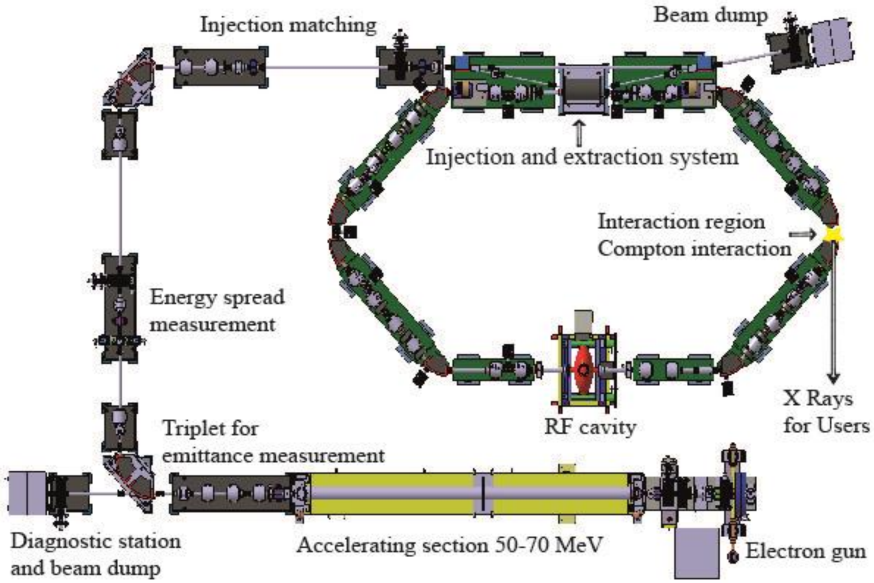


Fit:
Frequency comb +$\Delta\phi_{ce}$ variations

Only 3 free parameters in the fit:
a normalisation,
an offset
the Finesse

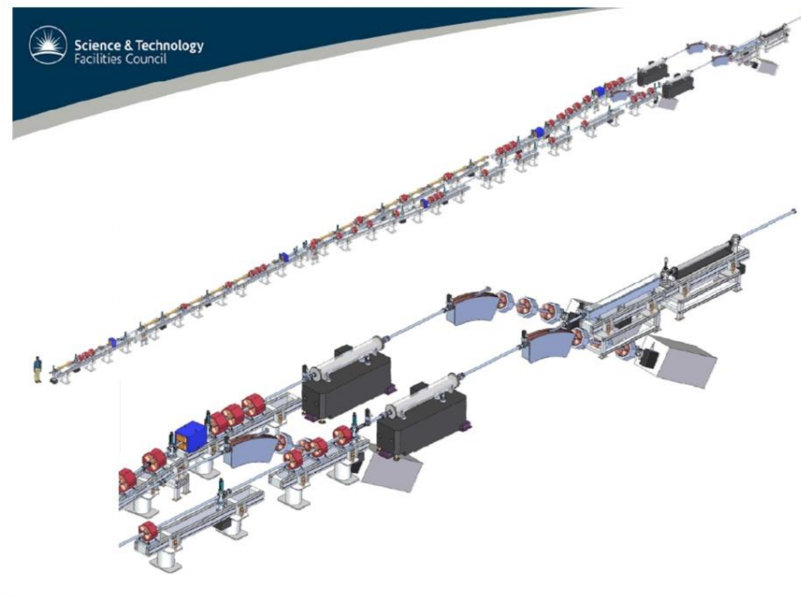
A technological issue: huge requested laser power

Priority : High X/g ray Flux (spectral purity ~few %)
➔ Electron ring (ThomX)



~20MHz e-beam/laser collision frequency
➔Optical resonator to increase the laser power
➔**High cavity gain & High laser average power**

Priority : High X/g ray spectral purity <1% (φν applications)
➔LINAC (ELI-NP)



~100Hz e-beam/laser collision frequency
➔Optical recirculator of a high peak power laser pulse
➔**High laser peak power & high nb of passes**