European Collaboration for the proposal of a Gamma-Beam System to the ELI-NP Project

ELI-NP-GBS

Extreme Light Infrastructure – Nuclear Physics – Gamma Beam Source

02/10/2014

LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

The 3 ELI's pillars

ELI-Beamlines

In **Czech Republic**:
Ultra-short and intense beams
for **interdisciplinary applications.**

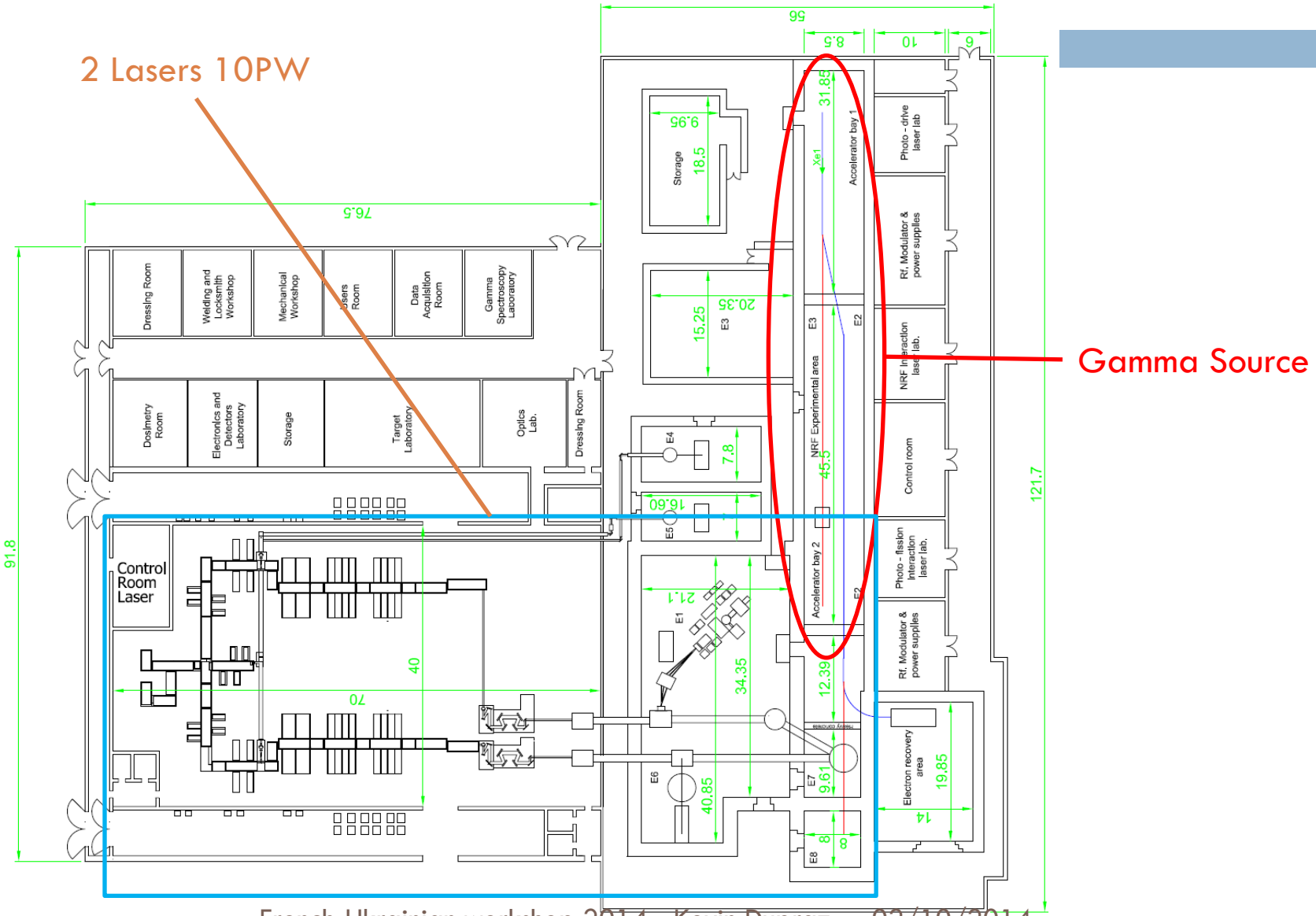
ELI-NP

In **Romania**:
Photonuclear physics
from **intense gamma-source** and **high-power laser beams**.

ELI-Attosecond

In **Hungary**:
physics of ultra-short laser pulses in attosecond order.

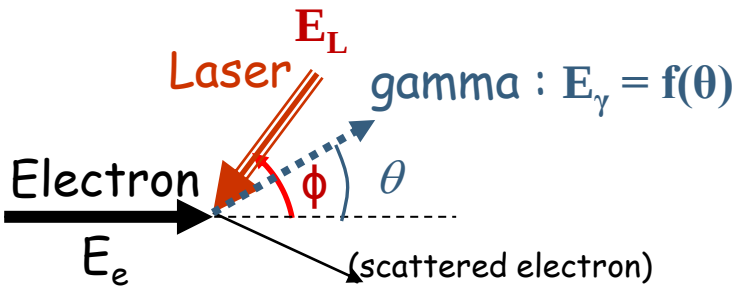
ELI-NP


2 Lasers 10PW
Gamma Source
Control Room Laser
Dressing Room
Welding and Locksmith Workshop
Mechanical Workshop
Lasers Room
Data Acquisition Room
Gamma Spectroscopy Laboratory
Dosimetry Room
Electronics and Detectors Laboratory
Storage
Target Laboratory
Optics Lab.
Dressing Room
Storage
Accelerator bay 1
NRF Experimental area
Accelerator bay 2
Photo - drive laser lab
Rf. Modulator & power supplies
NRF Interaction laser lab.
Control room
Photo - fission Interaction laser lab.
Rf. Modulator & power supplies
Electron recovery area
56
8.5
10
6
76.5
91.8
121.7
40
70
34.35
40.85
45.5
12.39
19.85
14

Production of the gamma-beam

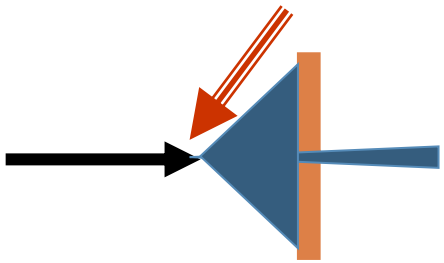
Compton Scattering + Collimation

- Gamma-ray production

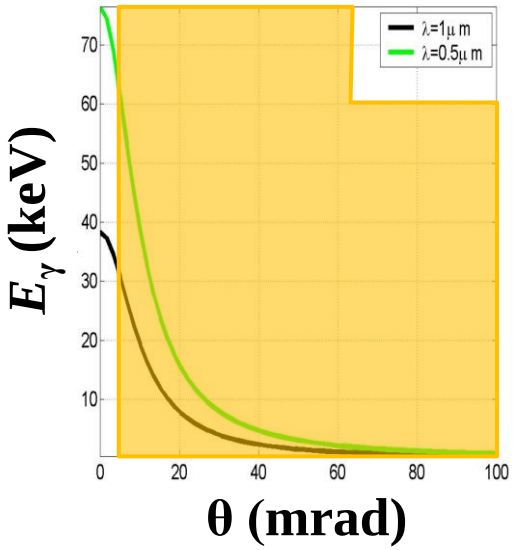


$$E_\gamma \simeq E_L \frac{4\gamma^2}{1+\gamma^2\theta^2+\frac{\phi^2}{4}}$$

- Energies selection



E_e = 50 MeV



Accelerator configuration

Gamma-beam specifications:

- Energies γ (E_γ) : 0.2 – 19.5 MeV
- Bandwidth ($\Delta E/E$) : <0.5%
- Spectral density (flux) : >5000 γ/(s.eV)
- Linear polarization: >95%

⇒ LINAC multi-bunch at 100Hz

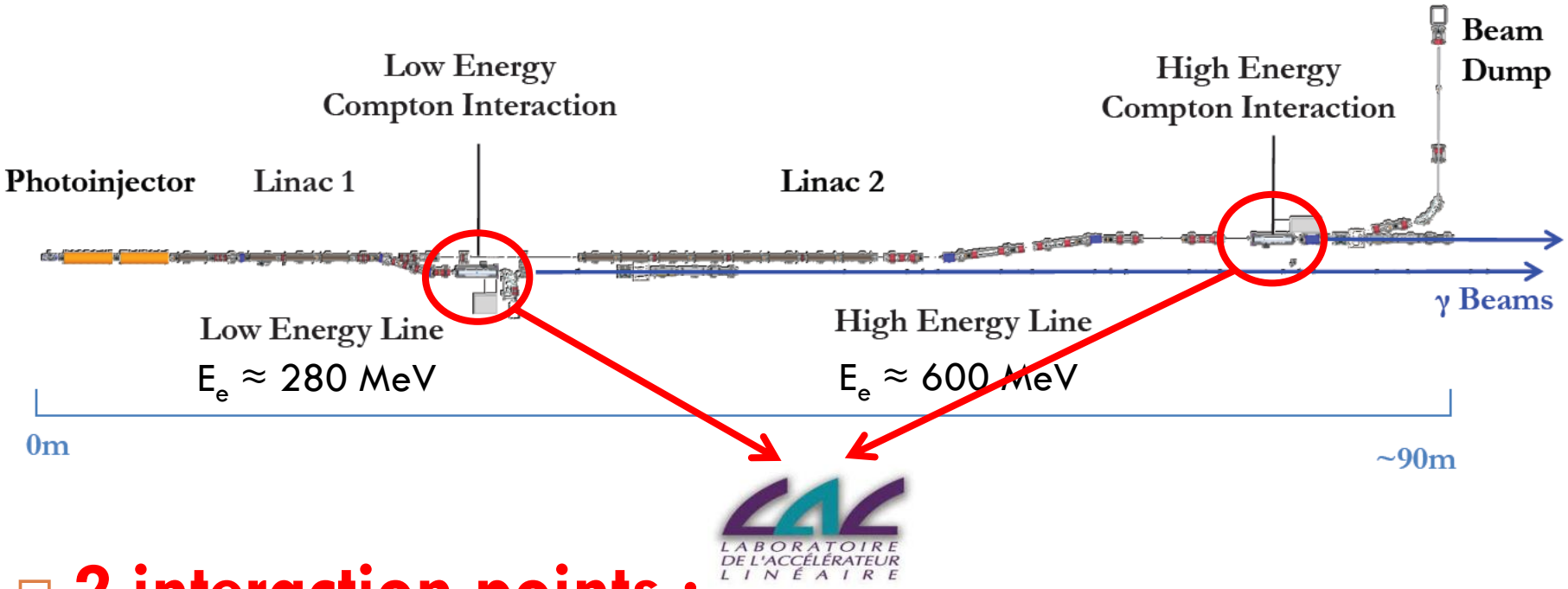
(space, cost and tunability)

+

Laser Beam optical Circulator

(efficiency, "robust")

Overview design



- **2 interaction points :**
  - 1 lasers 200mJ Yb@515nm (3.5ps) per interaction point (combined for the second: 400mJ)
  - Hybrid LINAC bands S and C (~100 – 720 MeV)

Optical system: laser beam circulator

Circulator principle

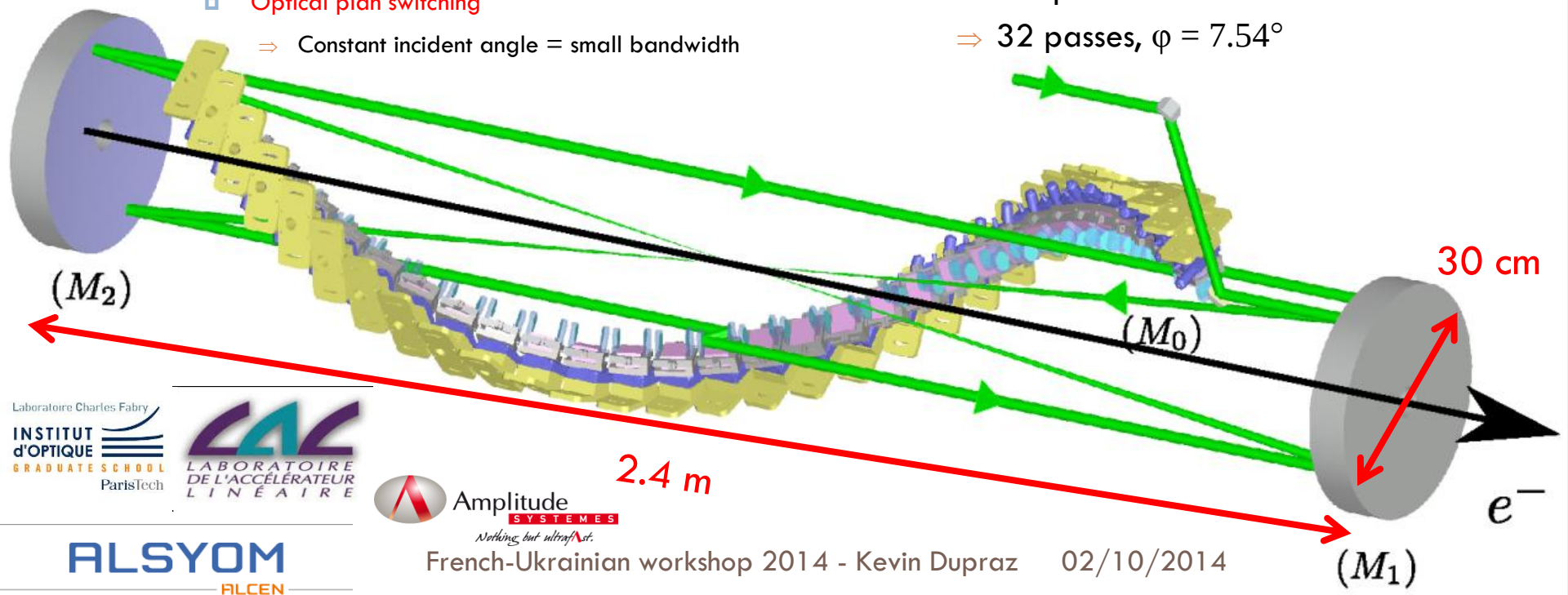
- 2 high-grade quality parabolic mirrors
  - Aberration free
- Mirror-pair system (MPS) per pass
  - Synchronization
  - Optical plan switching

⇒ Constant incident angle = small bandwidth

Free parameters = to be optimized on the gamma-ray flux

- Angle of incidence (Φ)
- Laser power = state of the art
- Waist size (ω_0)
- Number of passes

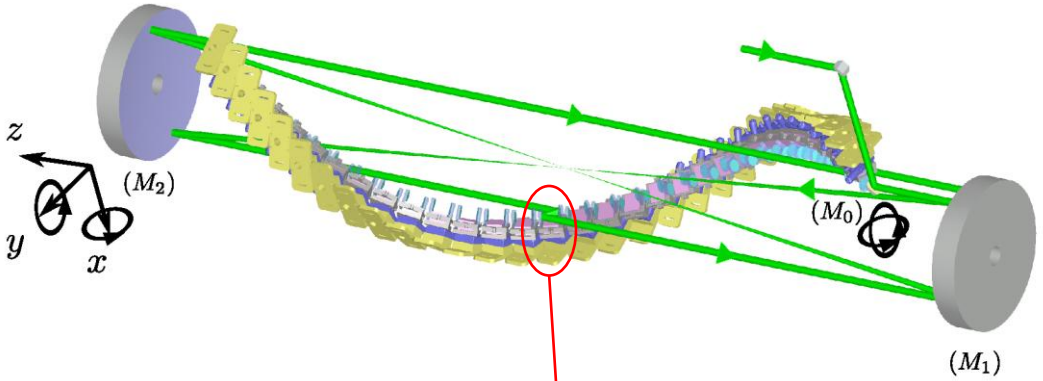
⇒ 32 passes, φ = 7.54°

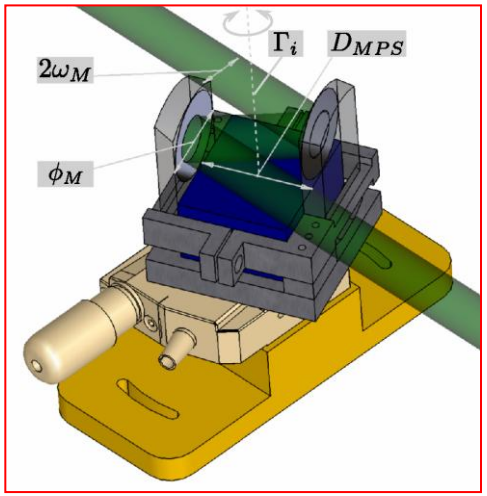


Circulator constraints

- Mirror surface quality (Code V)
- Frozen geometry (parabolic mirrors distance)

  => Tight alignment (few µm, µrad) with 7 degrees of freedom (see later)
- MPS parallelism (< 3 µrad)
- Synchronization (few 100fs)

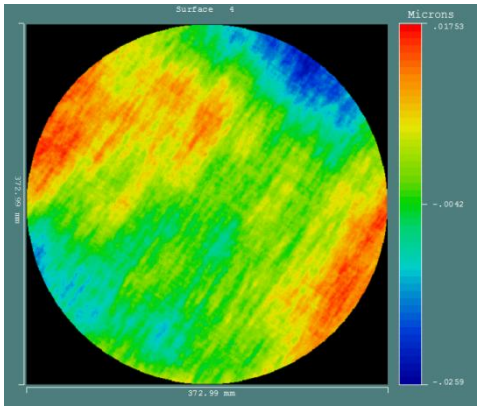




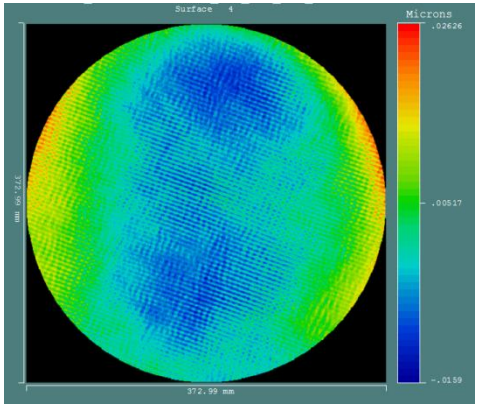
Optical Quality (in progress)

Surface deformations

- Simulated with proven method (same as Virgo)
- Parabolic mirrors deformations < λ/80 RMS
- MPS mirrors
- Difficult to relate surface quality to gamma-ray flux



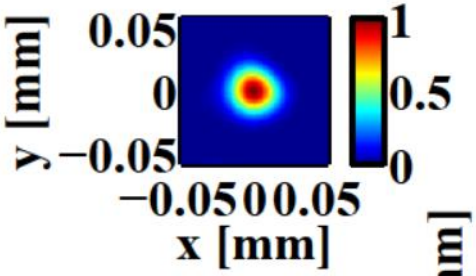
Good



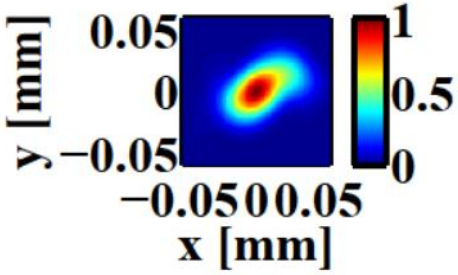
Bad

IP beam profile

Good



Bad

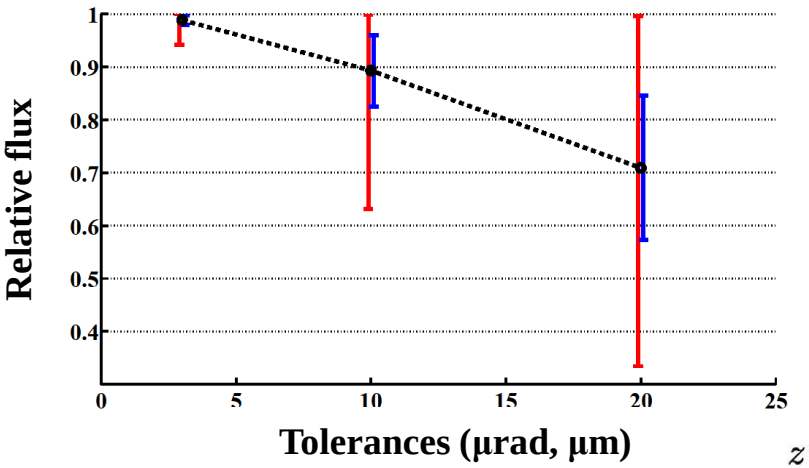


- System with **nonlinear behavior**

  => **everything** have to be **simulated**

Alignement

Alignment = overlap of 32 passes

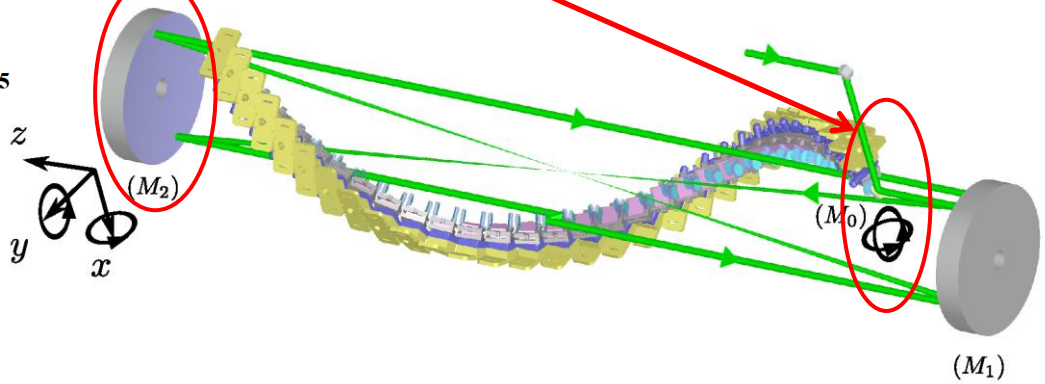


⇒ Dedicated alignment algorithm necessary

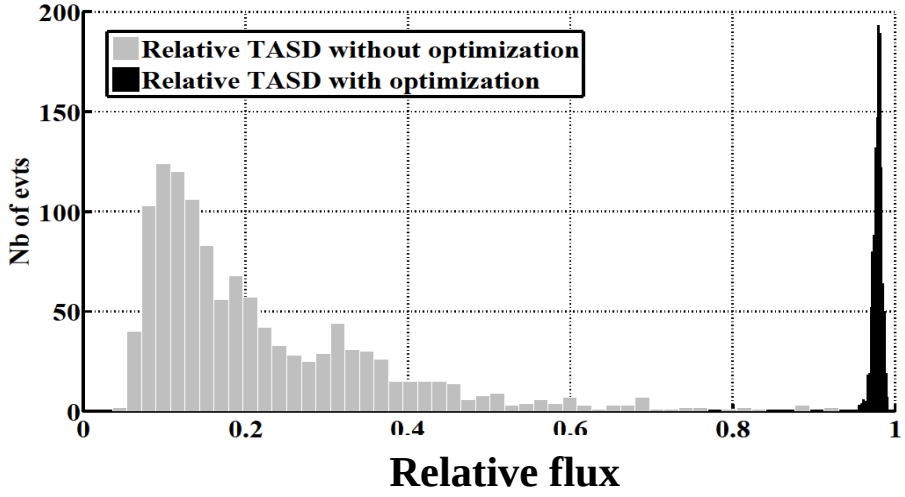
Degrees of freedom

- Injection Tilts (M0)
- Tilts + translations (M2)

⇒ N° degrees of freedom = 7

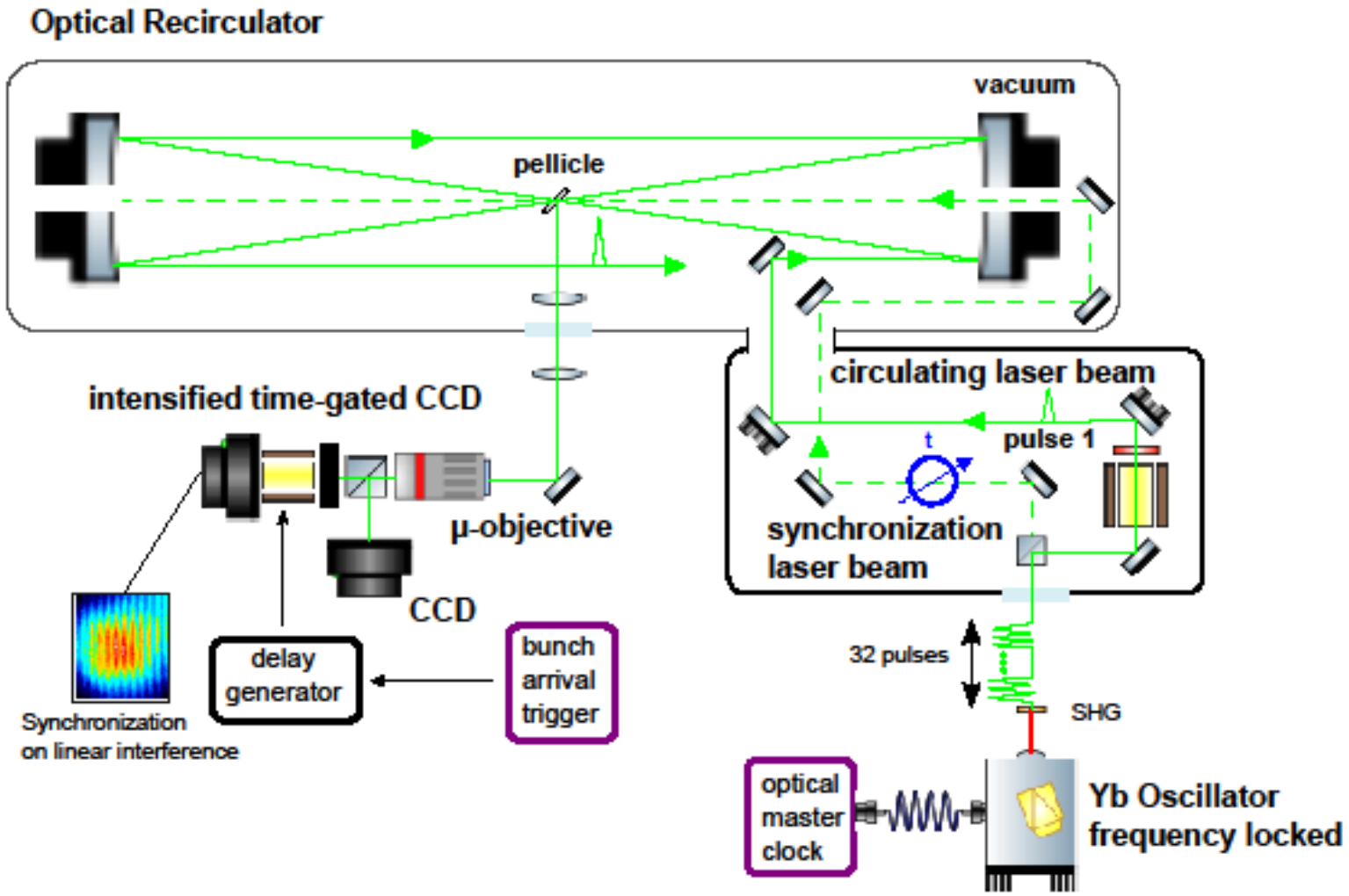


Expected performances



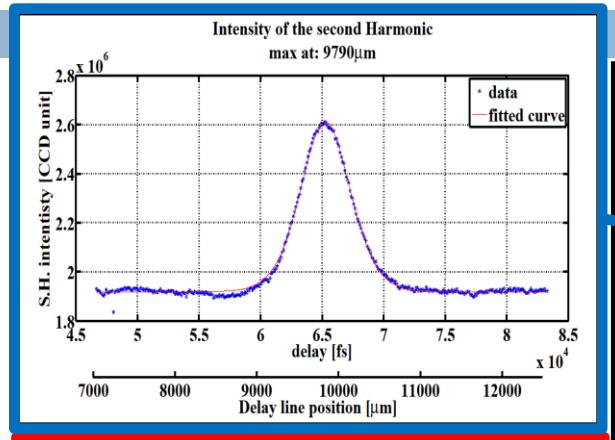
- Relative flux (>95%)
- Simulation of the alignment algorithm
  => Flux maximization
- **Circulator gain** VS simple pass (loss from mirror surface not taken into account) ≈ **30**

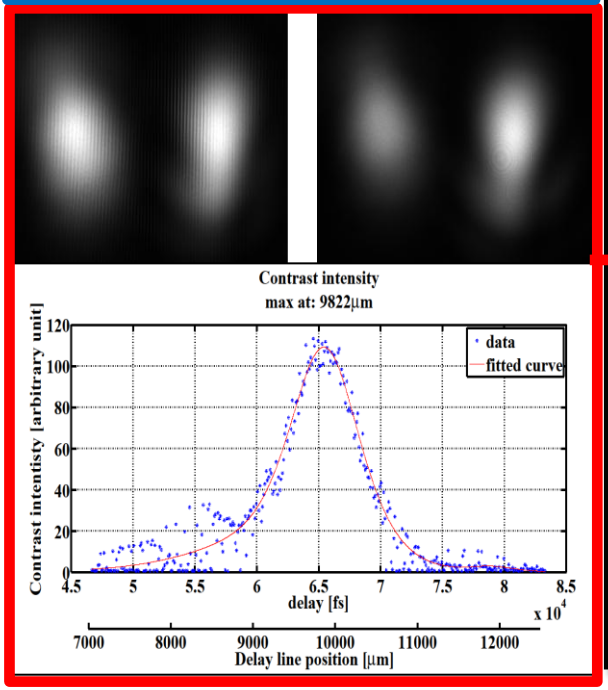
Synchronization tool

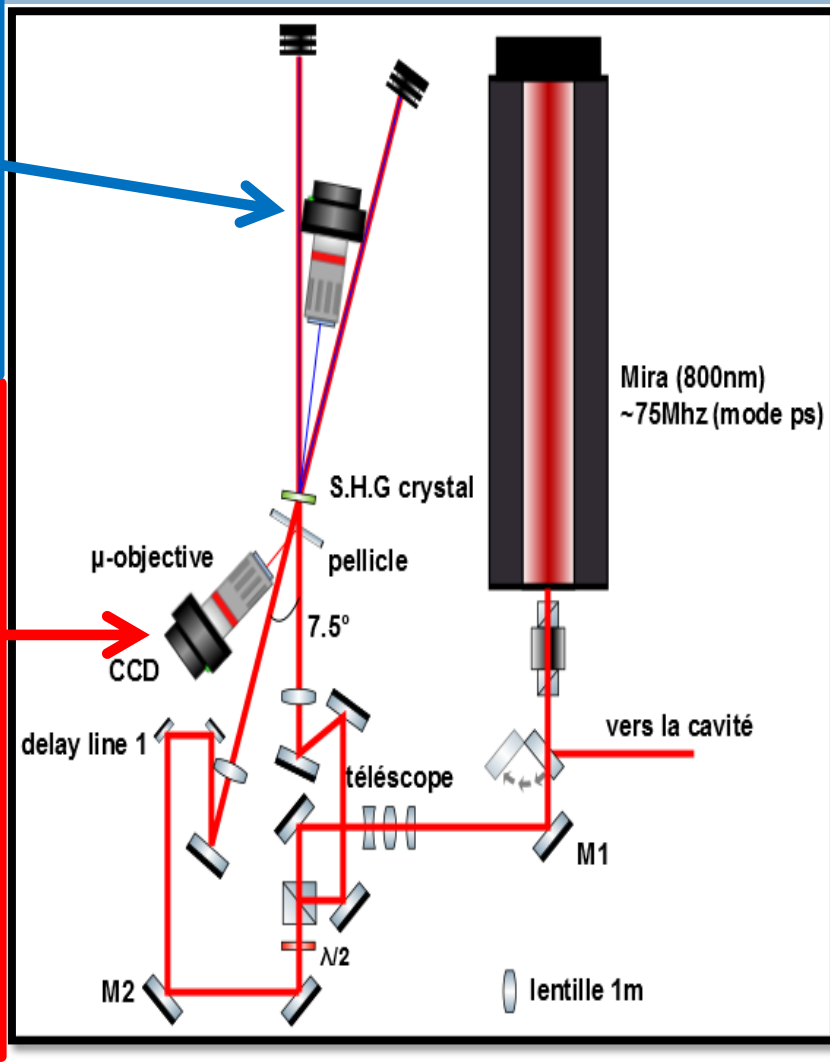


Synchronization (Proof of principle)

Synchronization repeatability = **100fs**





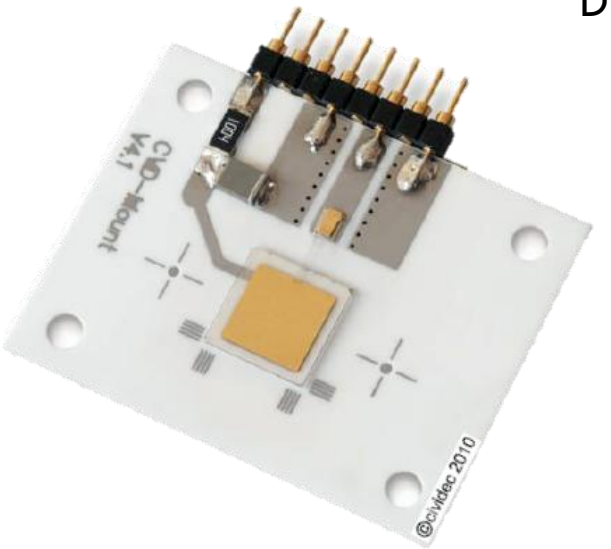


Synchronization online

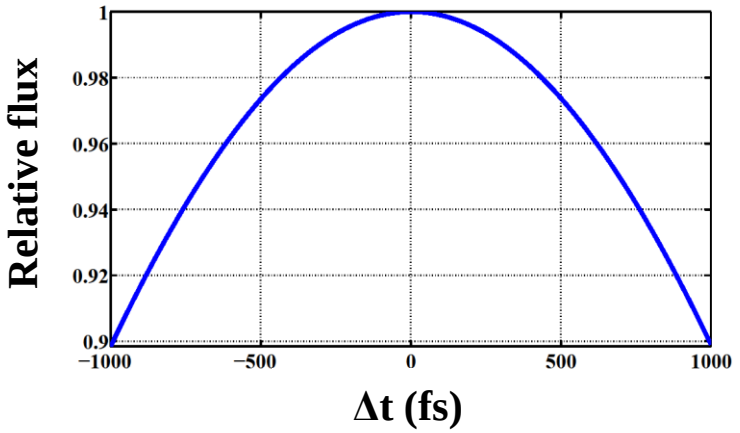
- Diamond detector

Located in the gamma beam line before collimation

=> Synergy with superkekB



Diamond detector
$5x5mm^2$
+
Preshower
+
DAQ



Cheikh Ndiaye

Outlook

- New optical system under development:
  - LAL: design and tool development
  - ALSYOM: opto-mechanics
  - AMPLITUDE: lasers

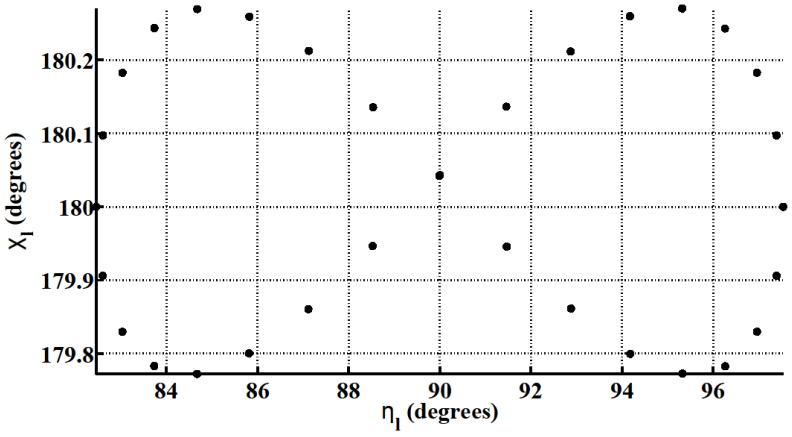
- Laser Beam Circulator is not as easy as it was thought (challenging optics)

- Required performances reachable
  - Flux > 5000γ/(s.eV)
  - Degree of polarization > 99%
  - Bandwidth < 0.5%

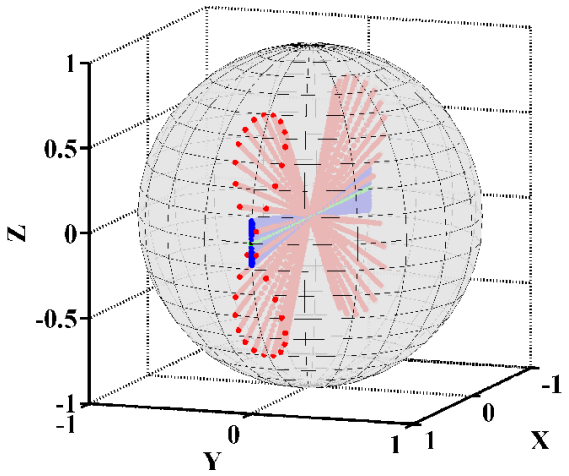
- Prototype delivery date: June 2015

Thank you for your attention

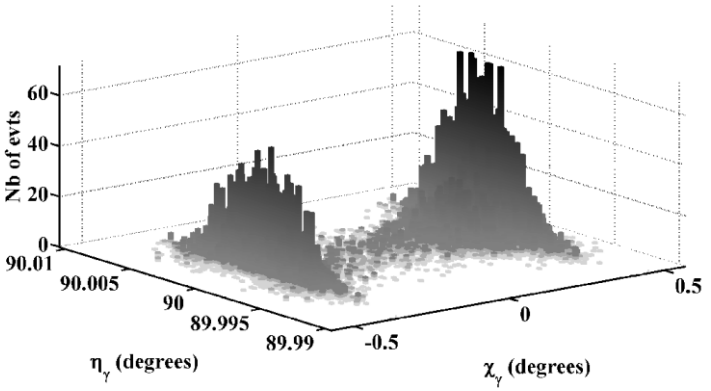
Polarisation



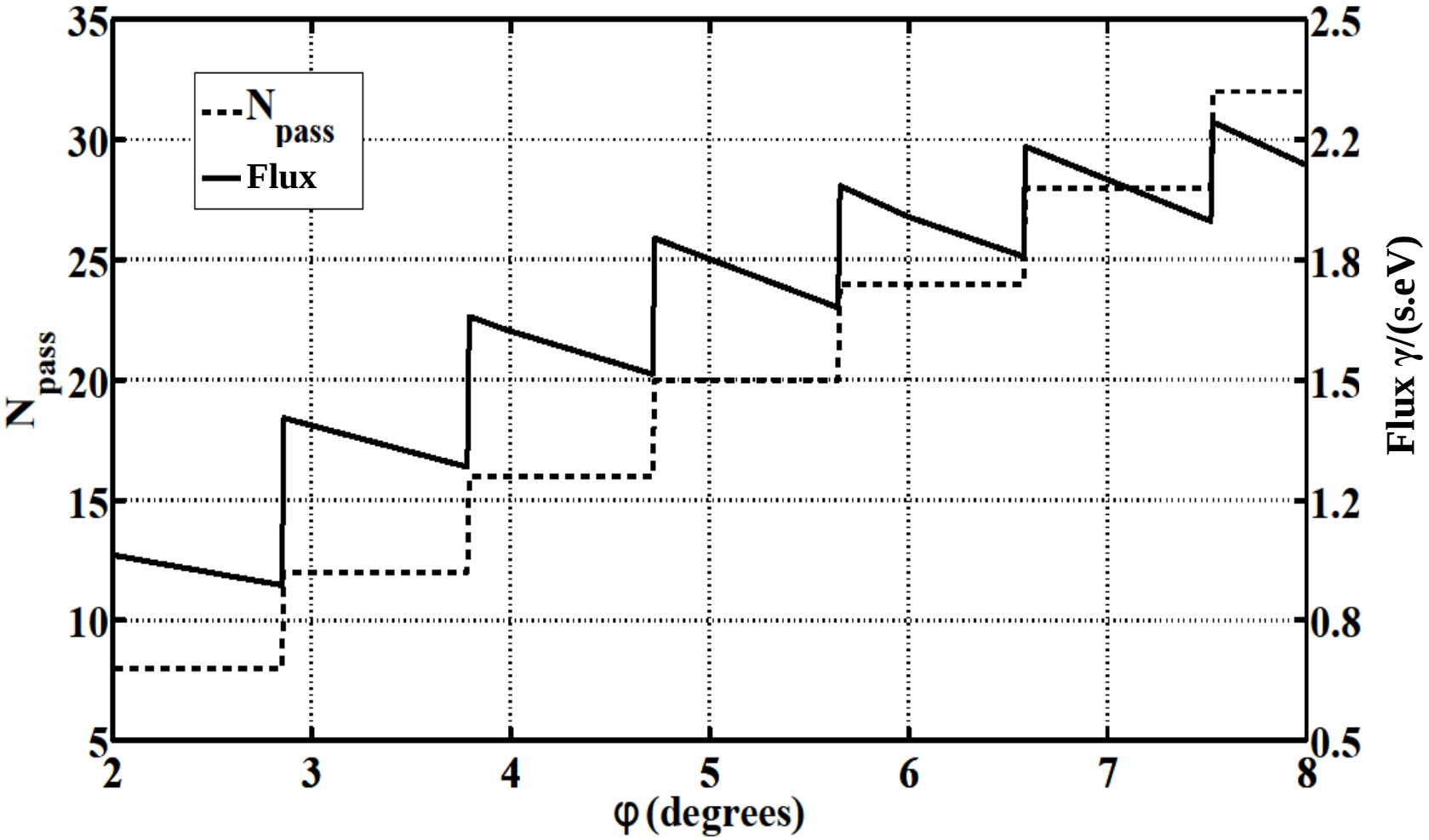
Interaction Point polarisation orientation



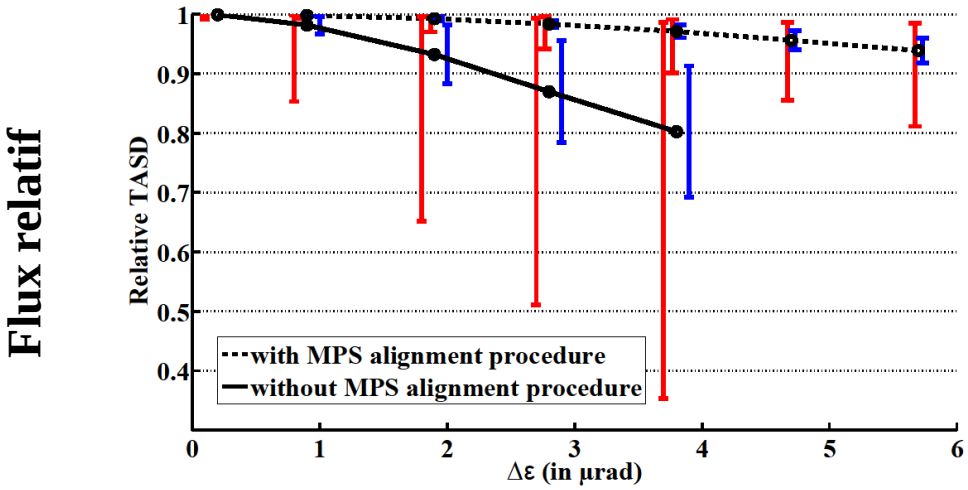
- Simulation with multilayer coatings and coating birefringence
- Polarization preserved during circulation (>99%)
  - Linear
  - Circular

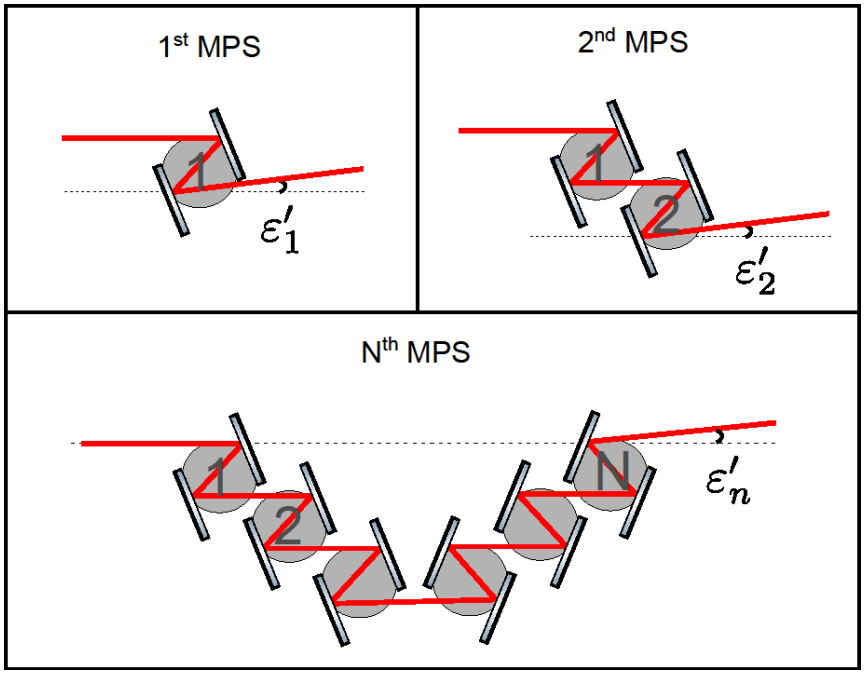


Optimization No. passes

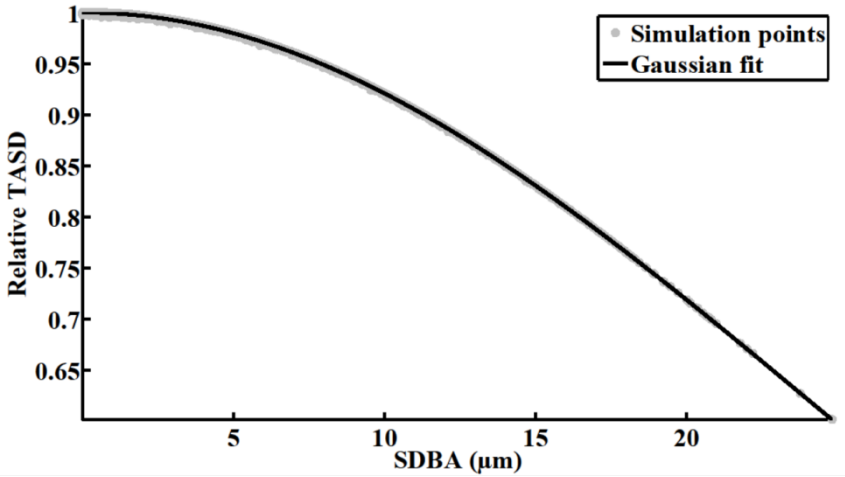


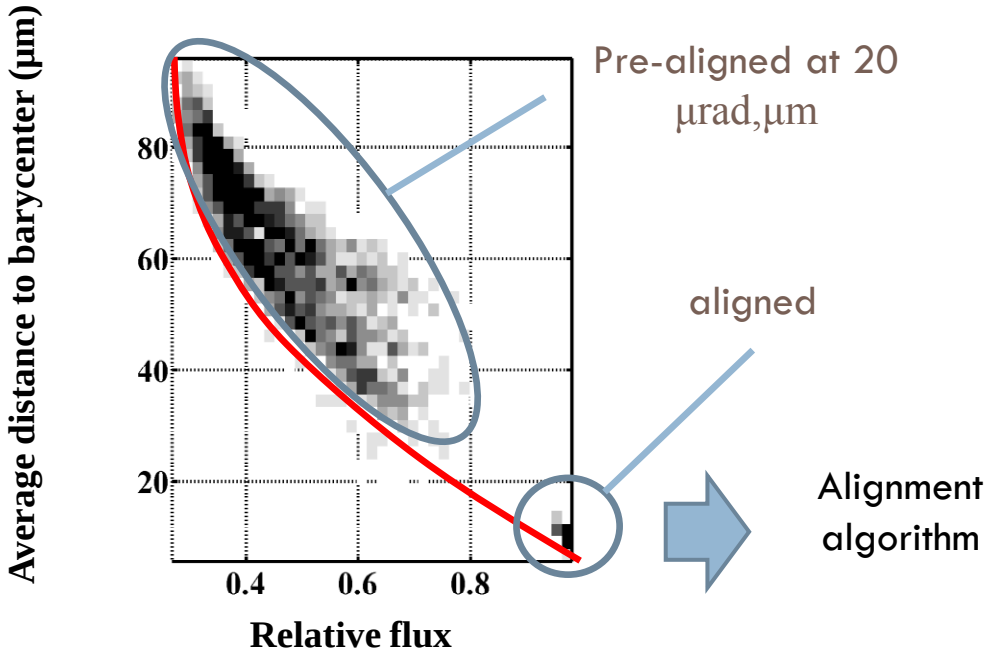
MPS parallelism





Alignment


Simulation points
Gaussian fit
Relative TASD
SDBA (µm)
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
5
10
15
20


Average distance to barycenter (µm)
Relative flux
80
60
40
20
0.4
0.6
0.8
Pre-aligned at 20 µrad,µm
aligned
Alignment algorithm