Mighty laser update
4 mirrors cavity at the ATF

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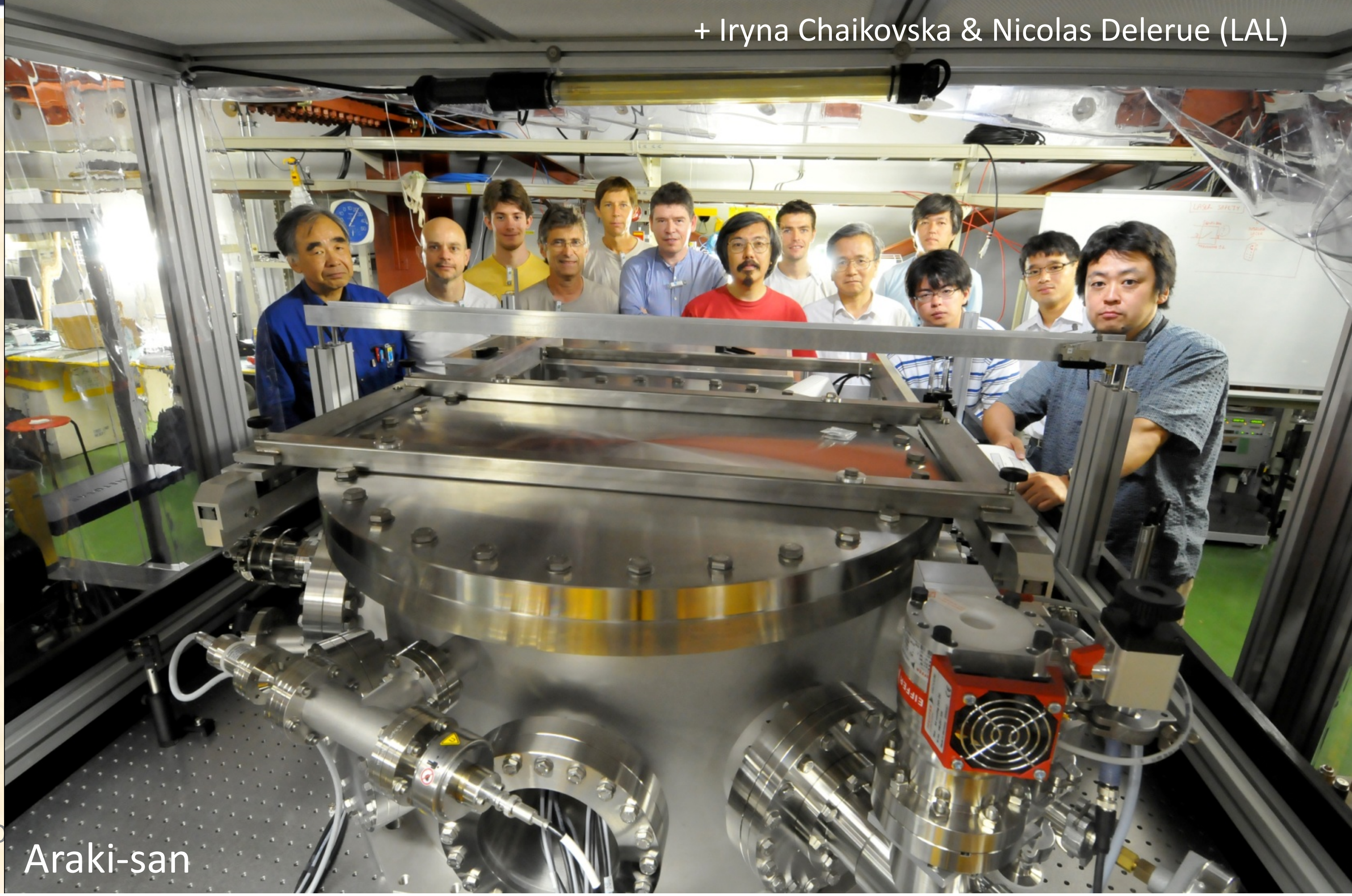
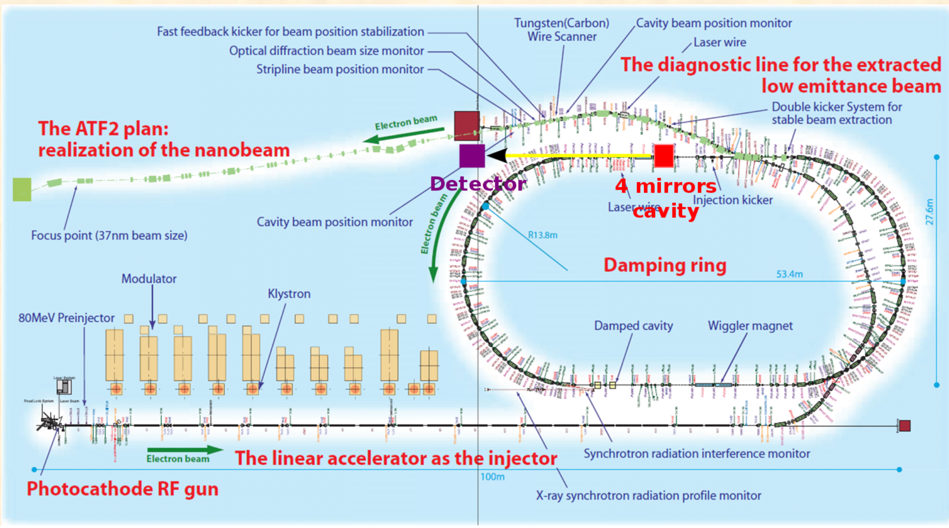
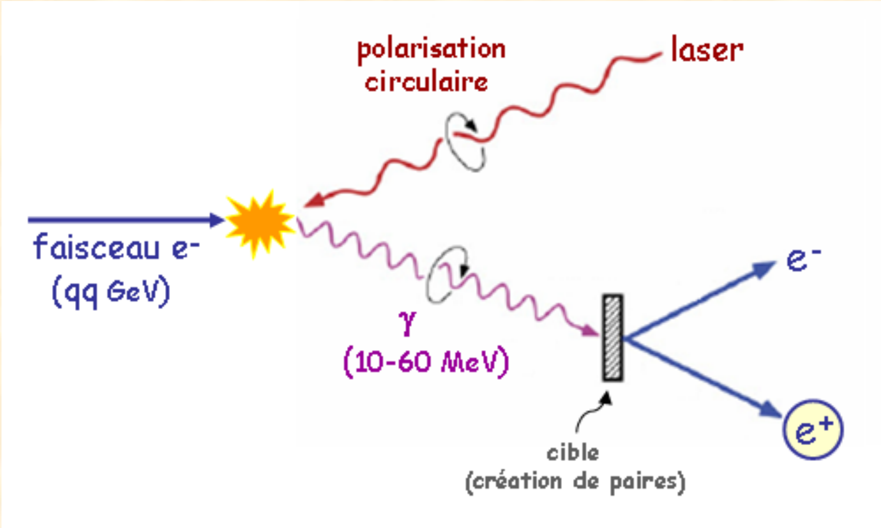


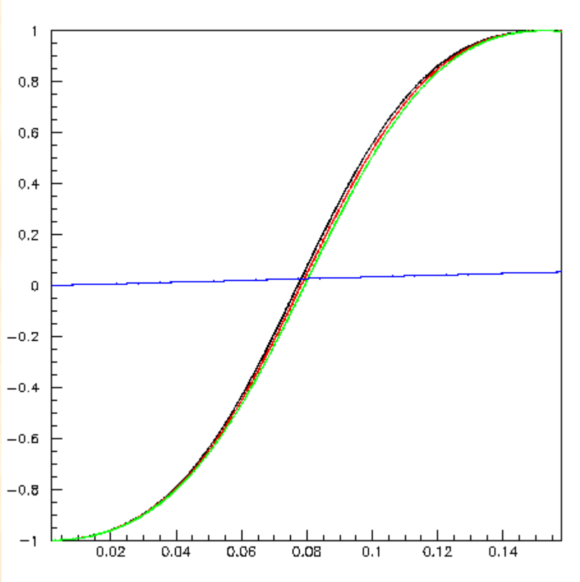
Mighty laser overview

- The aim of mighty laser is to demonstrate that high flux of gamma rays can be produced by Compton scattering.
- This can be applied to the production of polarised positrons for a linear collider but also to compact gamma-ray sources such as the ThomX project in France.
- This experiment is done in the damping ring of the KEK ATF (1.28 GeV electrons).
- Laser power is enhanced by stacking in a cavity.
- Collisions occur at about 1MHz.



Compton scattering for polarised positrons





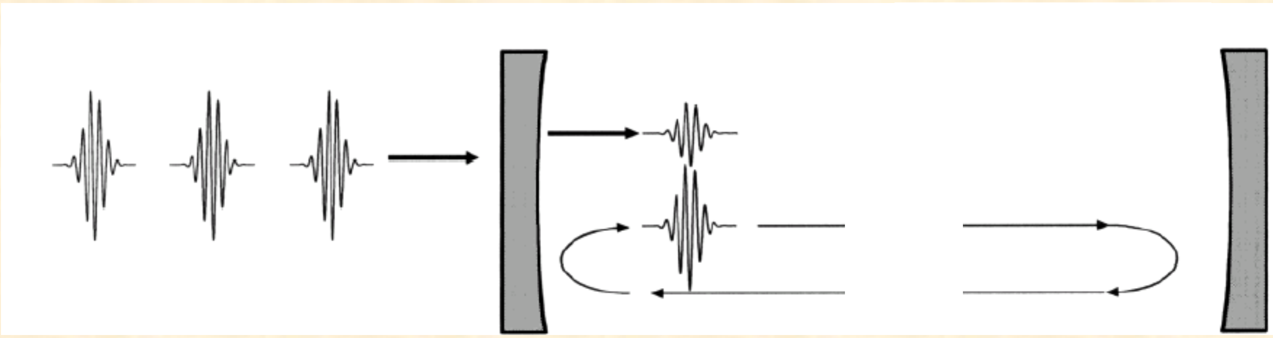
- Circularly polarised gammas can be sent on a target to produce polarised e+/e- pairs.
- The high energy gammas produced in Compton scattering have the same polarisation than the incident laser.
- The angular distribution of the gammas depends on their energy.
- Hence Compton scattering can be used to "transfer" the polarisation from the laser to positrons.

Experimental proof at ATF

- Omori et al. PRL 96(2006)114801

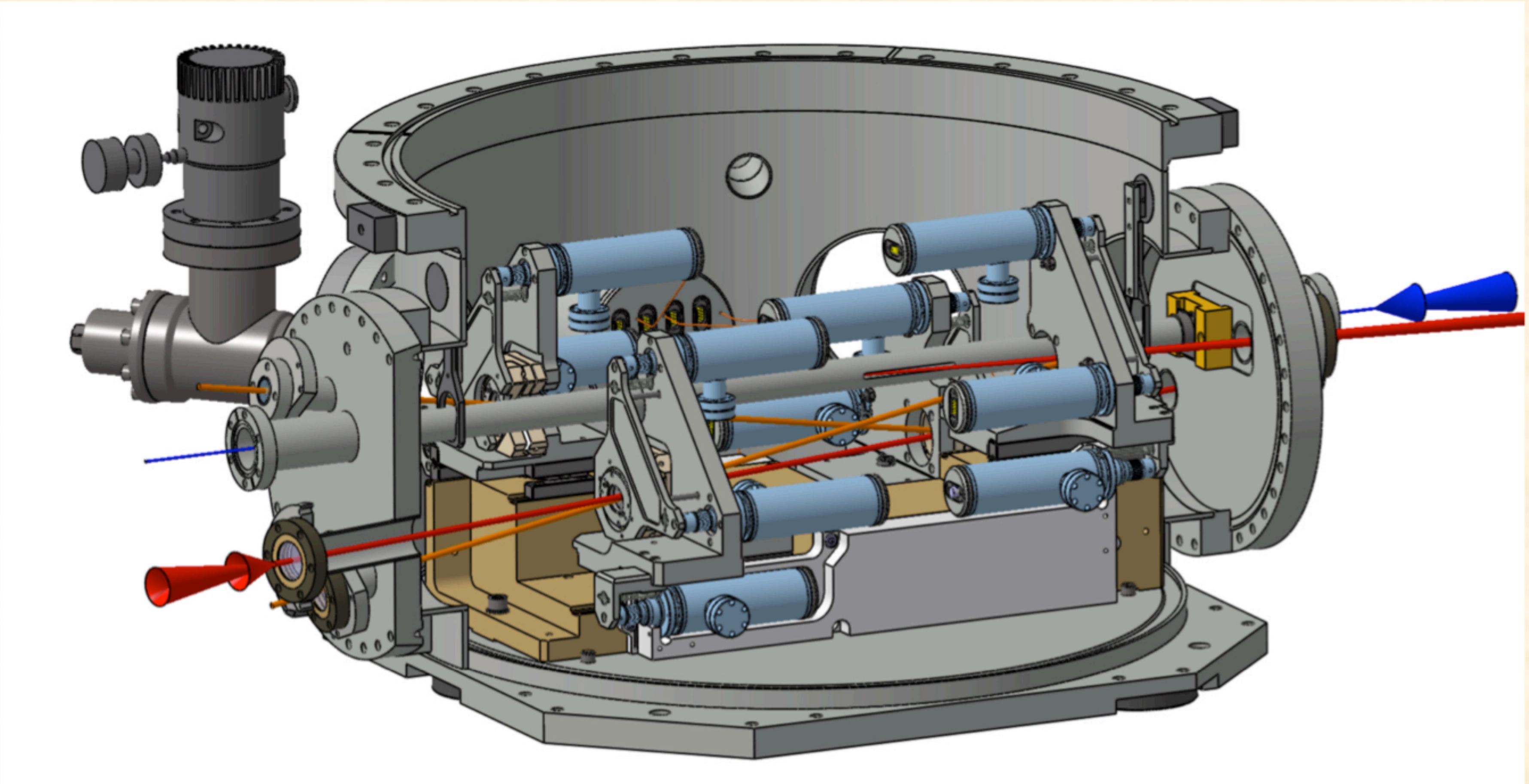
Laser pulses stacking

- Compton cross-section is very small
  => important to recycle laser and electrons (laser cavity and electron ring) .
- However this requires that each laser pulse arrives in phase with those already stacked in the cavity
  => feedback system needed between the seed laser and the cavity.
- Furthermore the laser pulse must cross the IP at the same time than the electrons
  => second feedback loop needed.

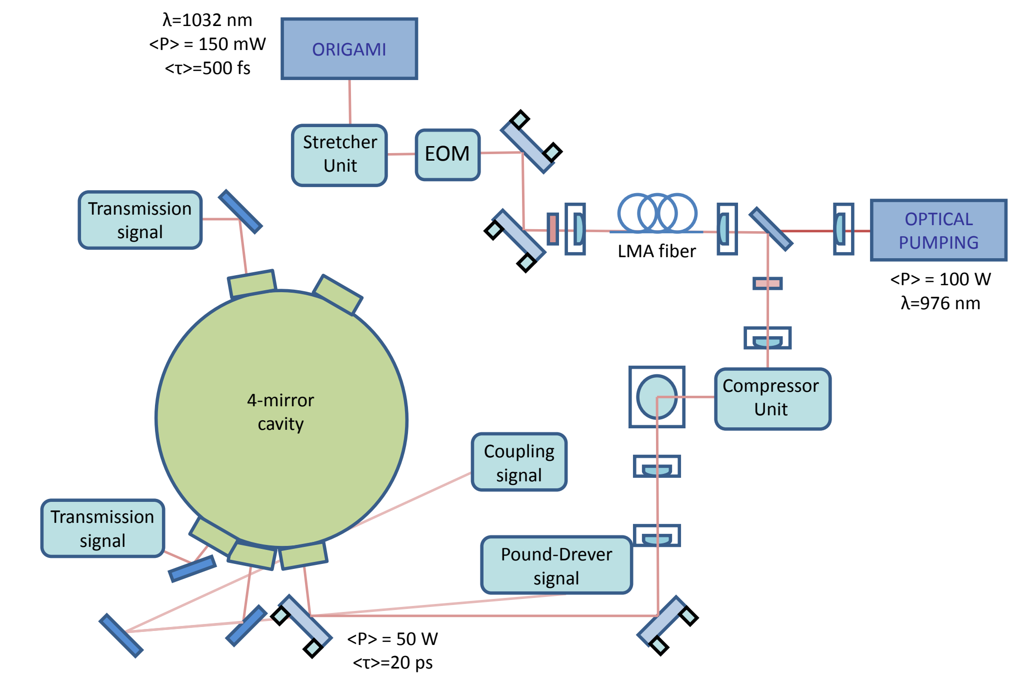


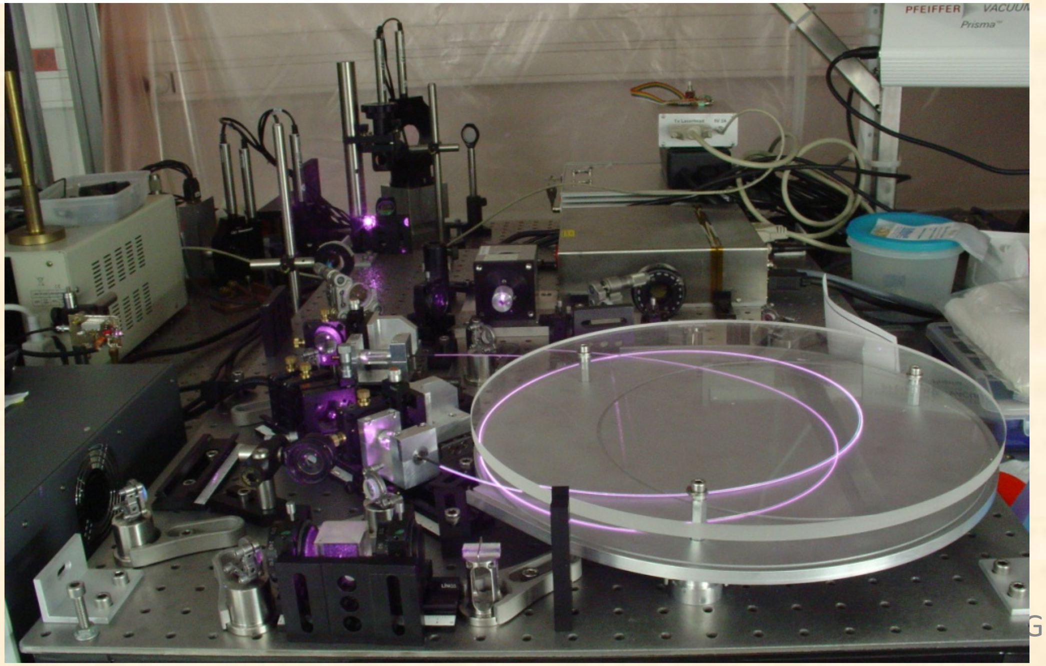
The cavity

- A 4-mirrors non planar cavity is used to stack laser pulses.
- Length: 1.68m => f=178.5MHz (fATF/2)
- A non-planar geometry ensures that the laser pulses are polarised circularly.
- The current finesse (stacking power) of the cavity is about 3000 but an upgrade to 30 000 is foreseen.



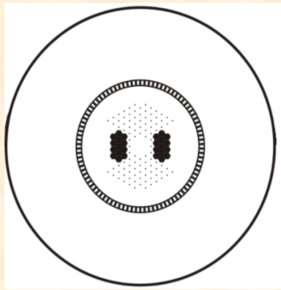
Setup MigthyLaser

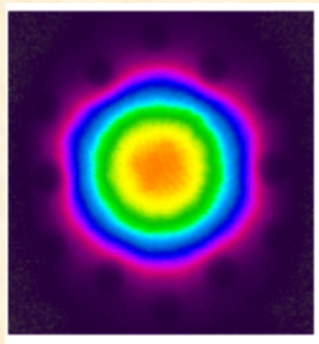




The laser

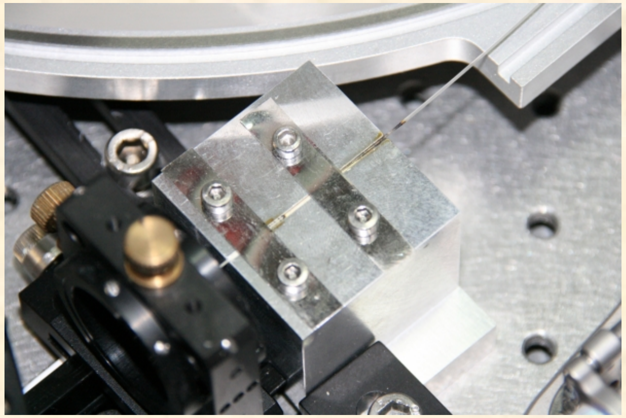
- Seed purchased commercially with low noise specifications.
- Amplification in Yb doped fibre for better performances.
- Double stabilisation system:
  - laser on cavity
  - cavity on accelerator
  => low noise is critical for our operations.
- Design power: 50W
- So far we obtained only 10W at the ATF under data taking conditions.



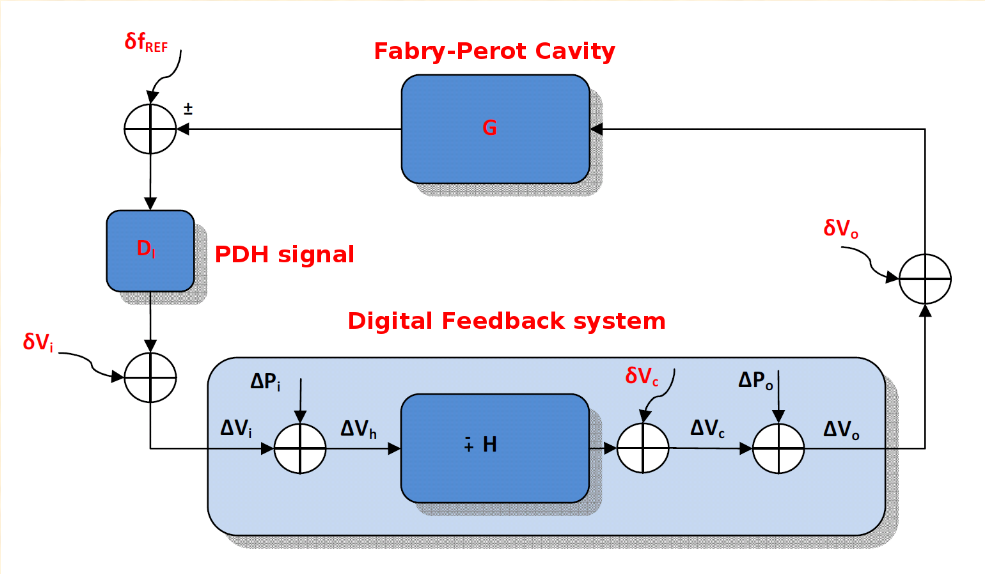


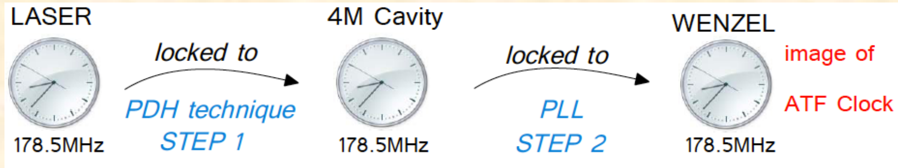
Laser amplification issues

- So far we have not yet reached our design performances.
- Several factors:
  - We experienced difficulties injecting the pump radiation in the core of the fibre
  => need pump with smaller numerical aperture
  - Heating of the fibre limits the power we can inject (we damaged several fibres)
  => improved cooling system
  - Our EO modulator has been damaged
  => need replacement.
- We are currently working on an improved design to make operations more reliable.



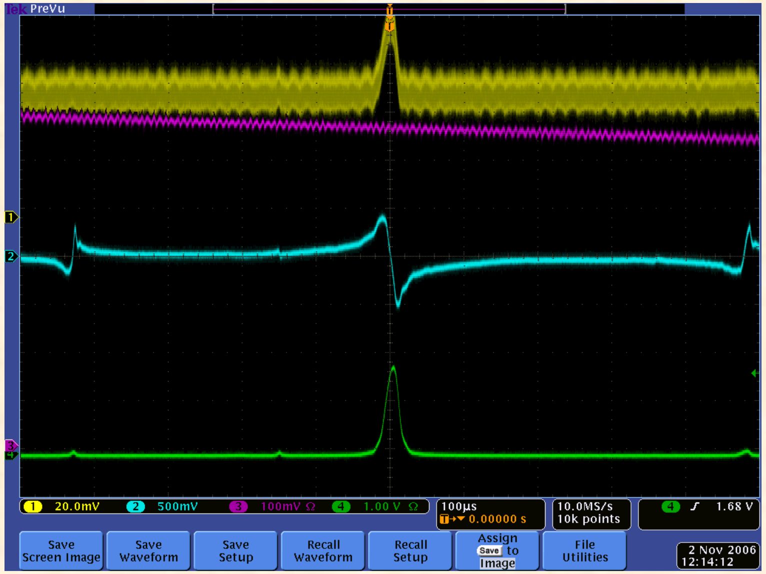
Digital feedback system





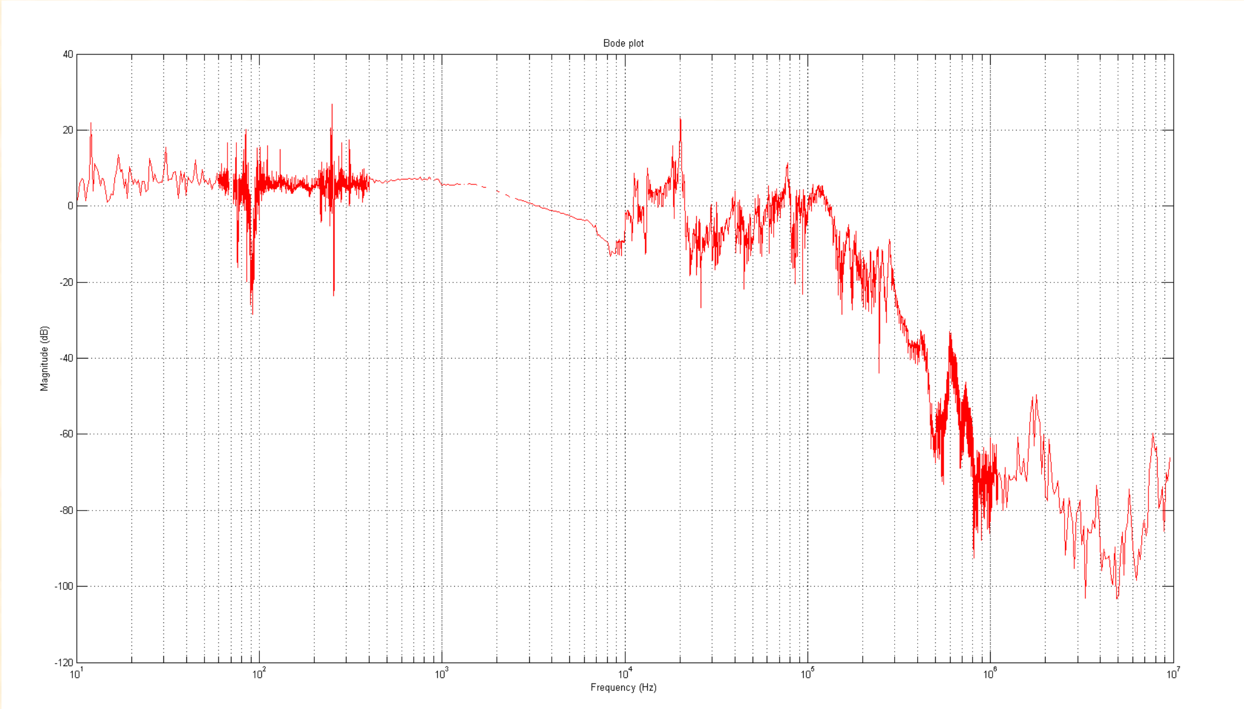
- To ensure that the laser pulses are properly stacked in the cavity we use a digital feedback system.
- Such system gives us more flexibility than an analogue one.
- Based on a FPGA Virtex II board.
- The laser is locked on the cavity using the Pound Drever Hall technique.
- The cavity is locked on the ATF clock using a phase lock loop.

Cavity stabilisation: Pound Drever Hall technique



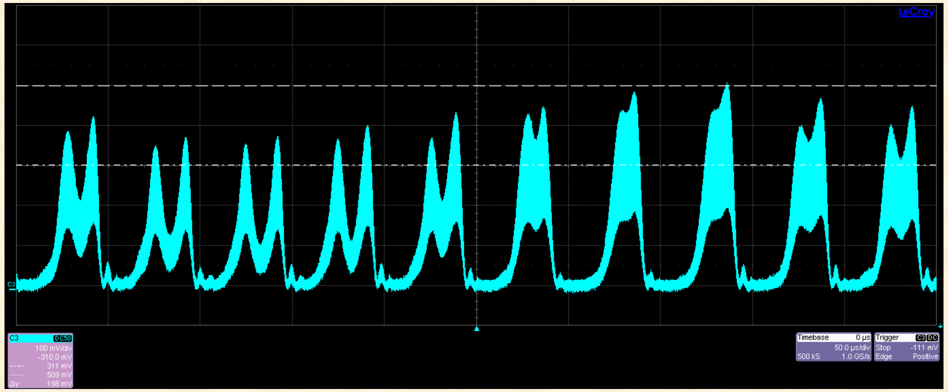
- We use the Pound Drever Hall technique to stabilise the cavity.
- The laser signal is modulated before being injected in the cavity.
- When close from the correct cavity length the signal “reflected” on the coupling port of the cavity is proportional to the correction to be applied on the piezo stack to adjust the laser cavity length.

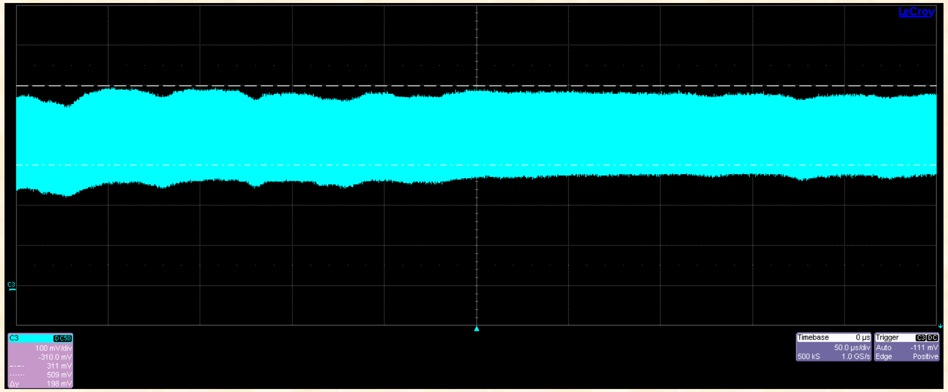
Feedback resonances

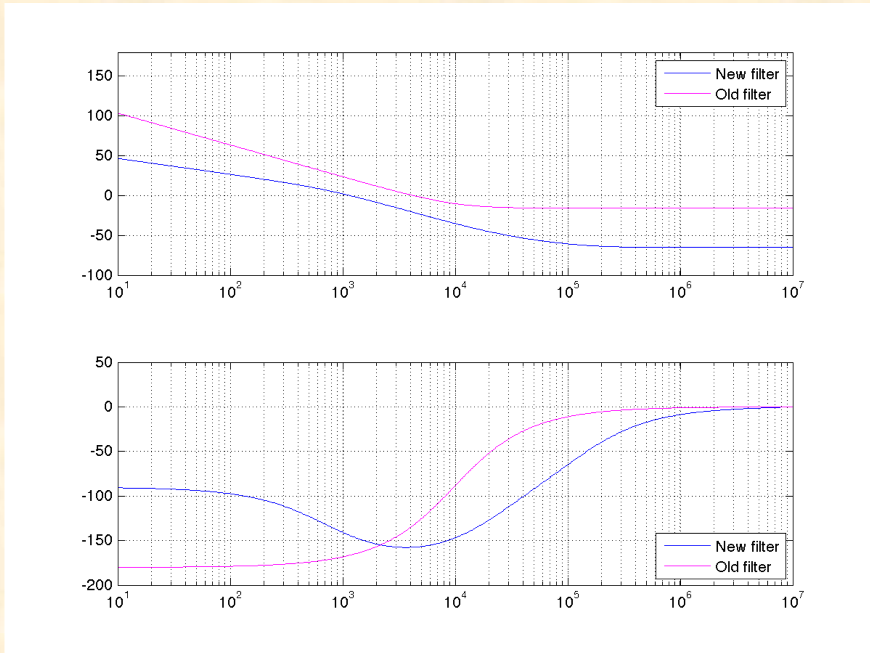


- To optimize the locking of the laser on the cavity, the transfer function of the system (cavity, piezo,…) must be measured.
- This allows to adjust the gain and the bandwidth of the feedback system to avoid resonances.

Improved gain

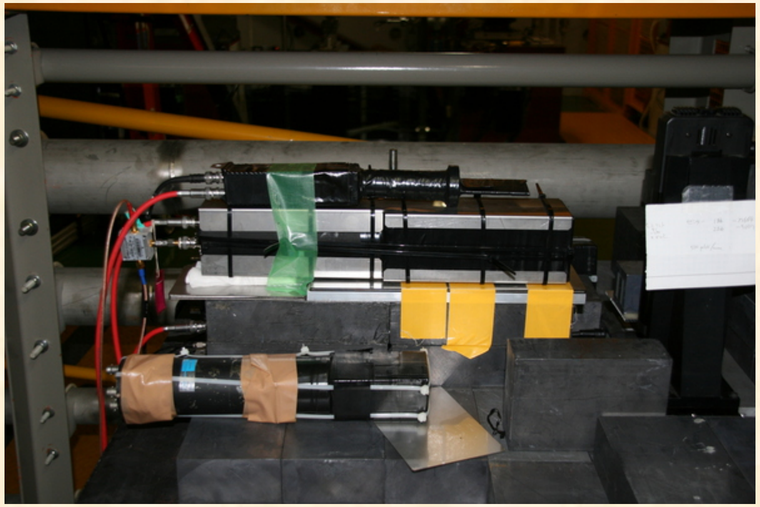




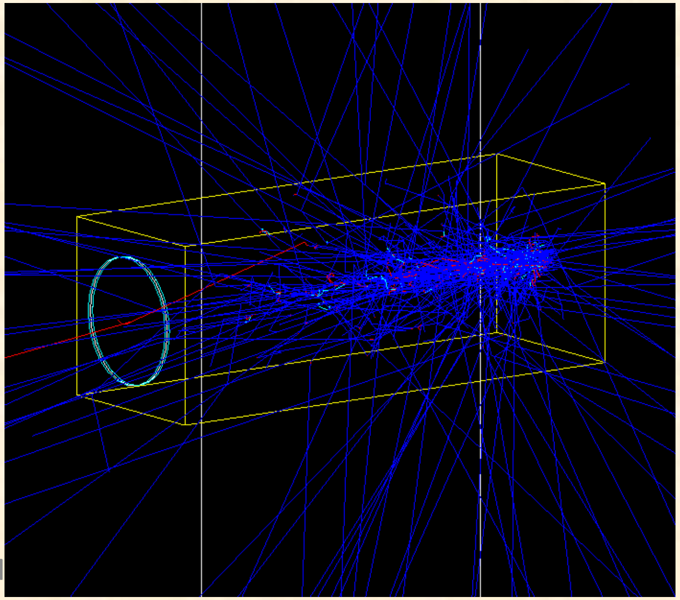


- Optimizing the filters in the feedback system can significantly improve the stability of the laser power stored in the cavity and therefore the flux of Compton produced.

Compton Flux measurements

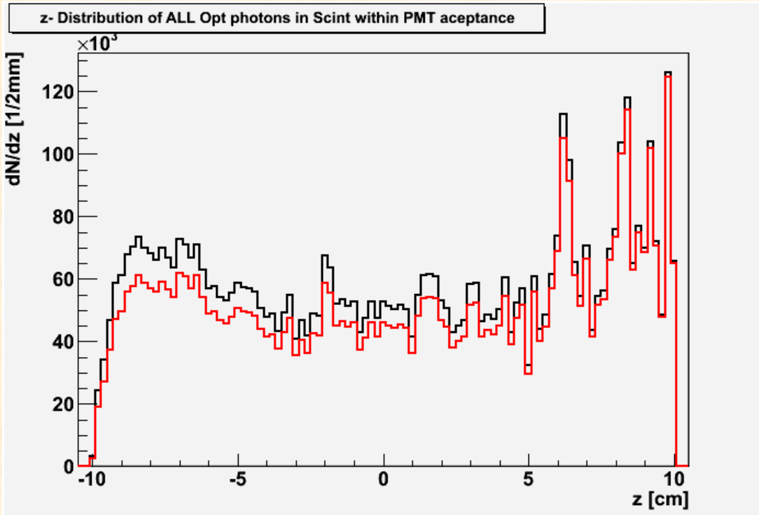


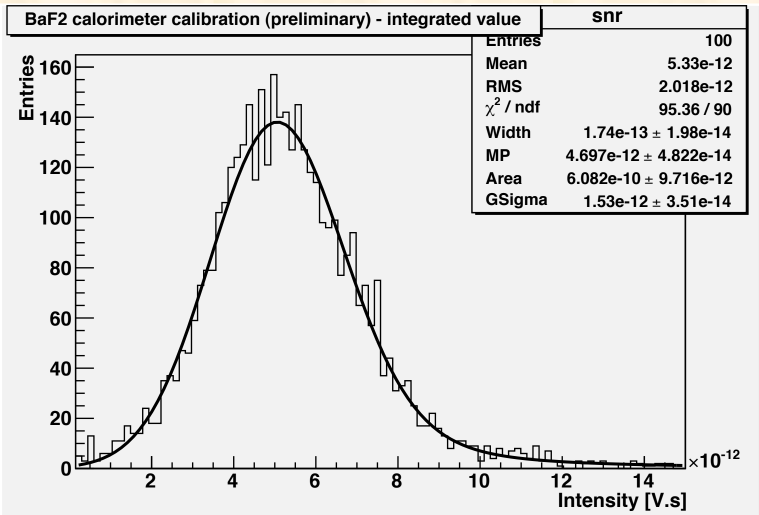
- The flux of Compton gamma rays is measured by a BaF2 scintillating crystal read out by a fast photomultiplier tube.
- This calorimeter has been simulated using Geant4.

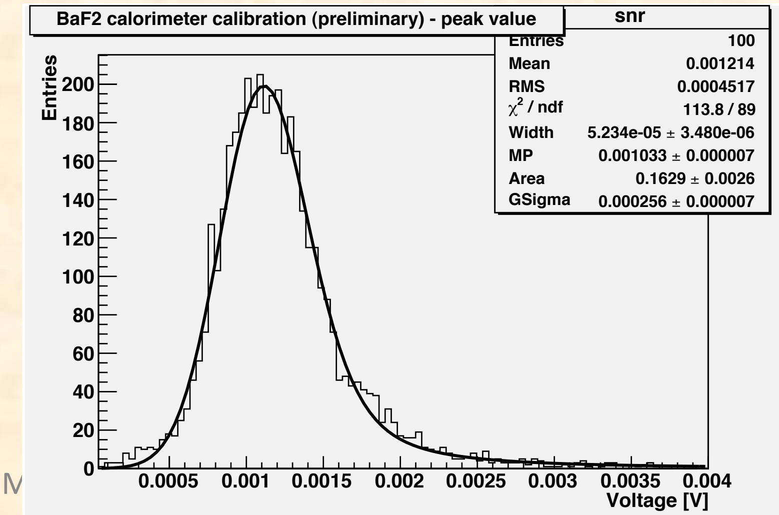


Calorimeter simulations and calibration

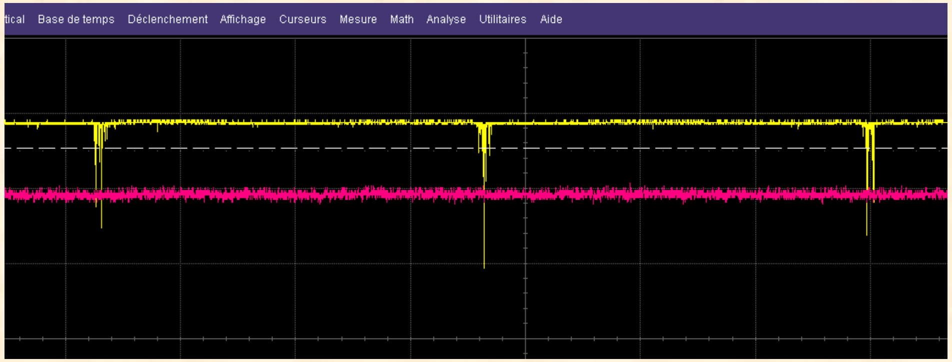
- The calorimeter is calibrated using cosmic rays (MIPs).
- Correction factors for the acceptance have been calculated using Geant4.



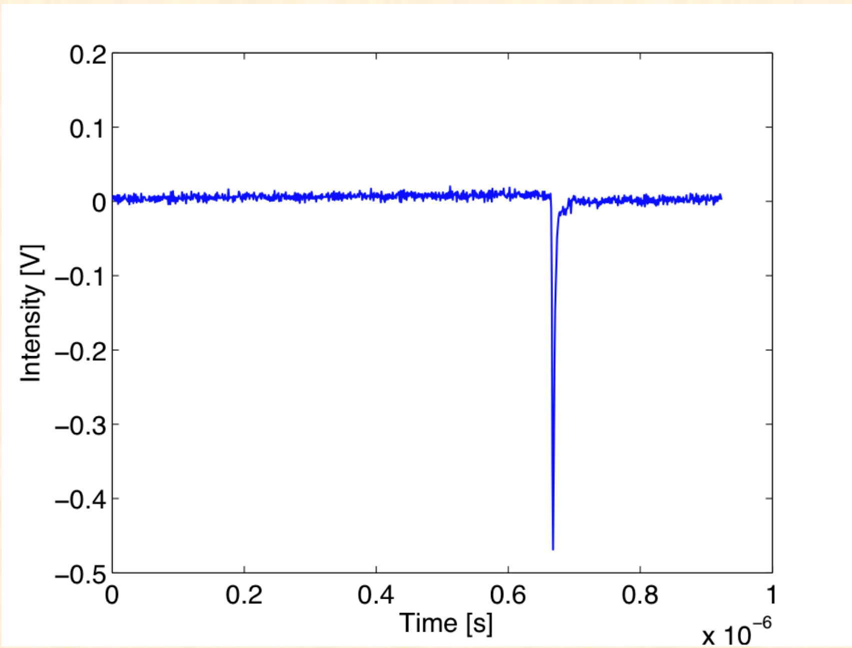


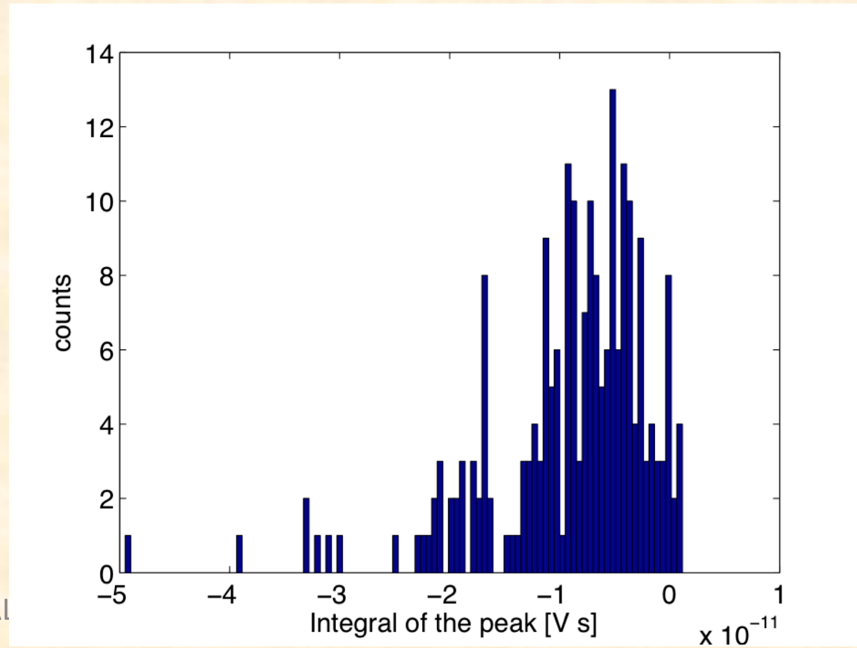


First data taking



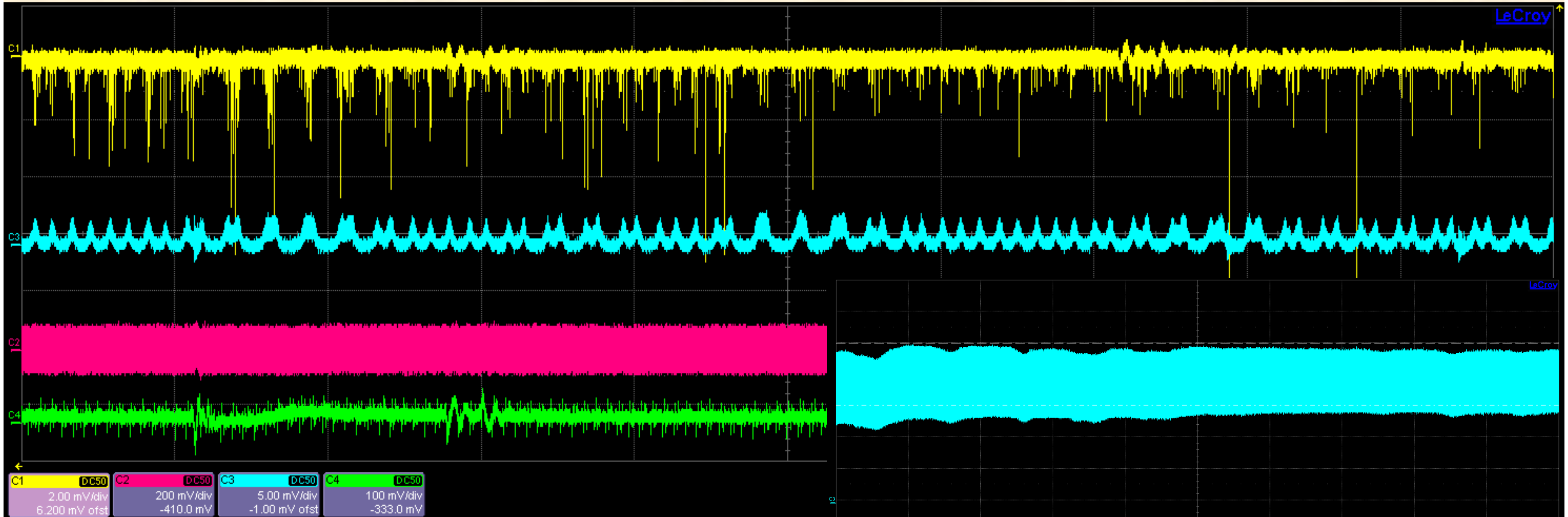
- We achieved electron-laser collision during our first data taking shift and during each data taking run after.



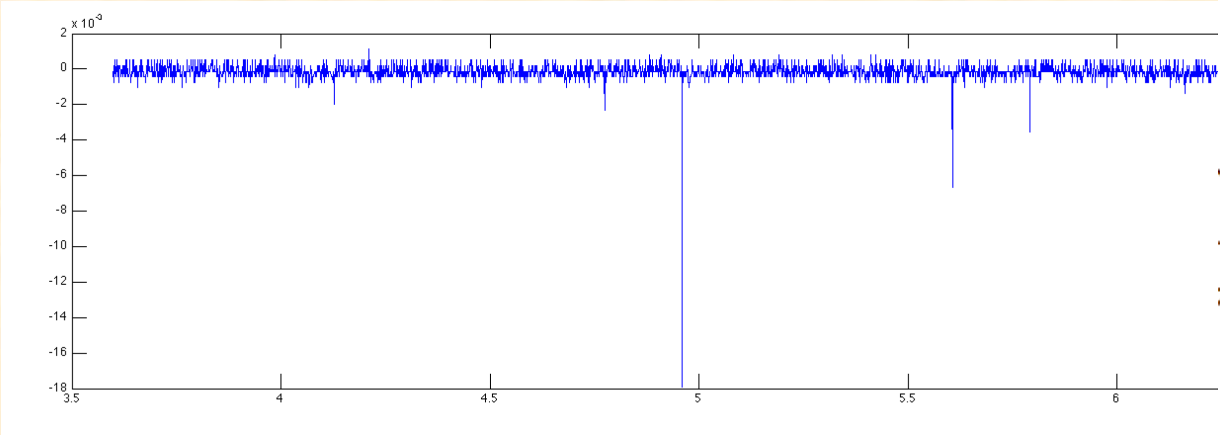


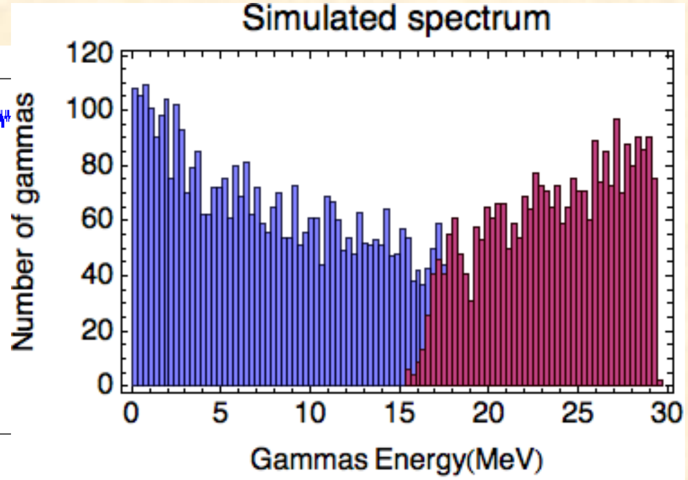
Cavity stability & Power fluctuations

- During our data taking shifts at the end of 2010 we noticed significant fluctuations of the power stored in the cavity (blue trace) and consequently of the gamma ray yield (yellow trace).
- This issue was resolved in February by changing the filters in the digital feedback (but no Compton data have been taken with these filters yet).



High luminosity data





- On several occasions in December and January we observed peaks in our data around 18-20mV.
- We are still analysing these data but for some of them we have confirmed that the timing and the shape was compatible with a Compton signal.
- According to our calibration this would correspond to about 600MeV deposited in our calorimeter.
- Given the expected gamma spectrum this would correspond to about 25 photons/turn in the calorimeter.

Current status

- In February we upgraded the laser to allow runs at higher power.
- We achieved 10W amplified power with a 30% coupling efficiency so the power stored in the cavity was about 3kW.
- We also improved the filters on the digital feedback system and we found a technique to improve the coupling efficiency.
- However our data taking run in February/March was postponed due to an incident on modulator 0 at the ATF.
- Following the recent earthquake in Japan the ATF is currently shut down.

Future work

- We are planning to replace our data acquisition system with a faster one to be able to resolve individual bunches (separated by 5.6ns).
- A second piezo has been added in the laser to give us a better control on the feedback.
- To increase the luminosity we intend to upgrade our mirrors to reach a finesse of 30000.
- We plan to upgrade our laser to reach 100W before injection.
- In the literature there is no record of a high power stored in a cavity for a long duration (several minutes) => significant effort will be required to achieve this.

Outlook

- We have used a high finesse cavity in an electron ring to produce polarised high energy gammas.
- Our best luminosity so far is about 25 gammas per interactions. In multibunch mode this could be repeated at about 10-15MHz.
- We have not yet taken data at full laser power.
- We are working on improvements to the stability of our cavity.
- During our next data taking run we expect to increase our luminosity (instantaneous and integrated).
- Future operations will depend on the extent of the damages done to the ATF by the recent earthquake.