Irfu - CEA Saclay
Institut de recherche sur les lois fondamentales de l'Univers

DE LA RECHERCHE À L'INDUSTRIE

15th RD51 Collaboration Meeting
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CERN

On the way to sub-100ps timing with Micromegas

T. Papaevangelou
IRFU / CEA Saclay

RD51 project

Title of project: **Fast Timing for High-Rate Environments: A Micromegas Solution**

Contact persons: *Sebastian White (co-PI), Rockefeller/FNAL swhite@rockefeller.edu*
Ioannis Giomataris (co-PI), Saclay ioa@hep.saclay.cea.fr

RD51 Institutes:

1. *IRFU-Saclay, contact person Ioannis Giomataris ioa@hep.saclay.cea.fr*
E. Delagnes, T. Papaevangelou, M. Kebbiri, D. Desforge, E. Ferrer Ribas, A. Peyaud

2. *NCSR Demokritos, contact person George Fanourakis gfan@inp.demokritos.gr*

3. *CERN, contact person, Leszek Ropelewsky Leszek.Ropelewski@cern.ch*
E. Olivieri, H. Muller, F. Resnati
+ RD51&Uludag University, Rob Veenhof veenhof@mail.cern.ch

4. *Universidad de Zaragoza, Diego González Díaz diegogon@unizar.es*

Ext. Collaborators:

1. *Rockefeller/FNAL, contact person Sebastian White swhite@rockefeller.edu*
+ Umesh Joshi (FNAL)

2. *Princeton University, contact person K.T. McDonald, kirkmcd@princeton.edu*
+ Changguo Lu

The project

- Current state of the art in fast timing for existing experiments is of the order of 100 ps (charged particles / EM shower)
- R&D on charged particle timing towards ~10 ps
  - ➔ high rates / high radiation environment (HL-LHC)
- *Purpose of this project:* to demonstrate this level of performance based on a **Micromegas photomultiplier** with **Cerenkov-radiator** front window
  - ✓ Single electron time jitter ~100 ps
  - ✓ produce sufficient photoelectrons to reach timing response ~ 10 ps

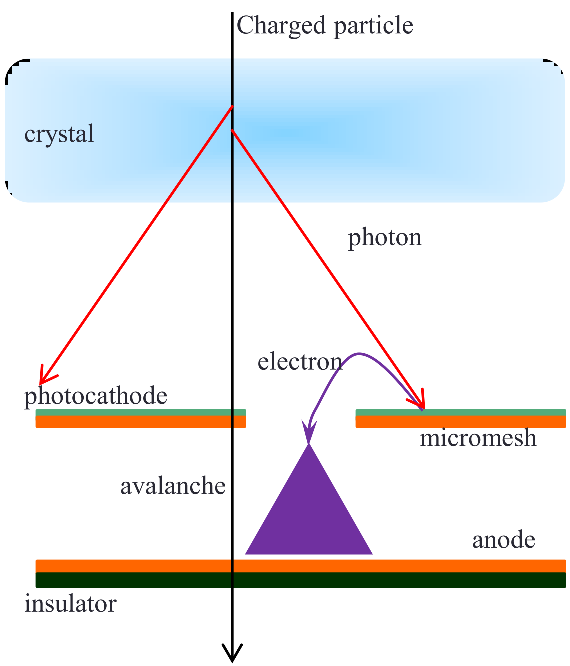
  ➔ Simultaneous production of primary electrons (time jitter for the Cherenkov light ~10 ps)

  ➔ Limited longitudinal diffusion

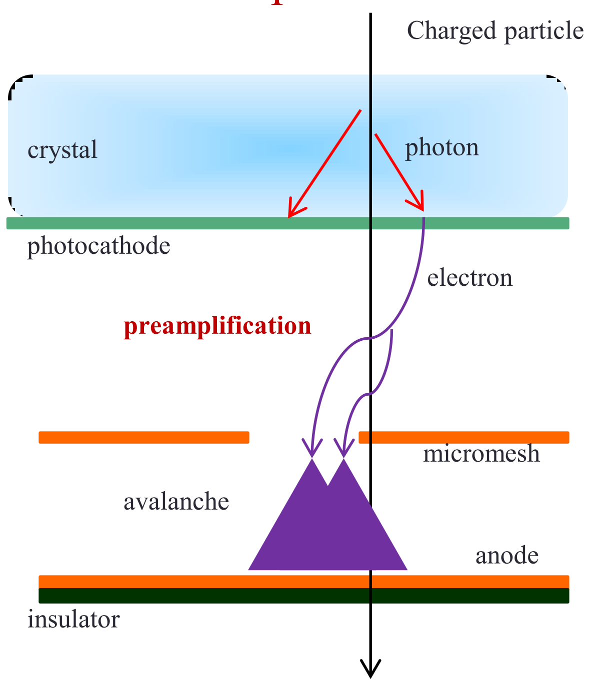
Primary ionization: photoelectrons

- Cherenkov light produced by charged particles crossing a MgF_2 crystal
- Photoelectrons extracted from a photocathode (CsI)
  - ➔ Simultaneous & well localized ionization of the gas

Reflective mode



Semitransparent mode



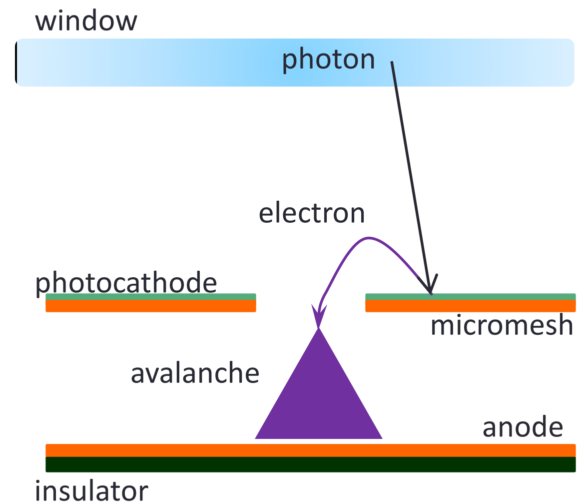
UV photon detection

- **Reflective photocathode:**

  Photosensitive material is deposited on the top surface of the micromesh.

  Photoelectrons extracted by photons will follow the field lines to the amplification region

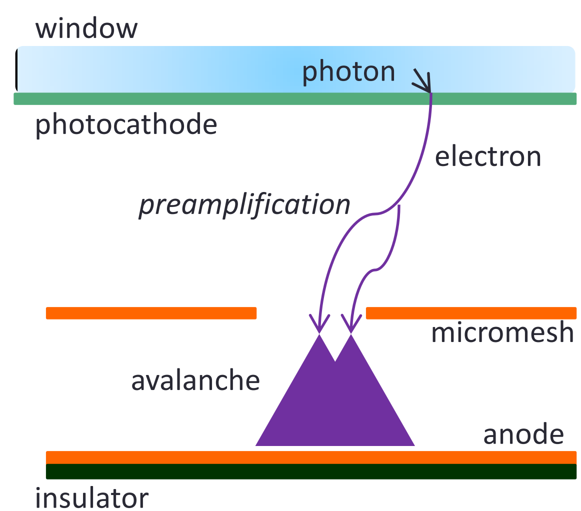
  - ✓ The photocathode does not see the avalanche ➔ *no ion feedback effect* ➔ *higher gain in single stage (> 10^5)*
  - ✓ High electron extraction & collection efficiency
  - ✓ Field on photocathode 10^4 V/cm



- **Semi-transparent photocathode:**

  Photosensitive material is deposited on an aluminized MgF_2 window (drift electrode)

  - ✓ Extra preamplification stage ➔ better long-term stability, higher total gain
  - ✓ Strong E_{drift}
  - × Lower photon extraction efficiency
  - × Fragility to sparks
  - × Ion feedback ➔ aging



Limited diffusion

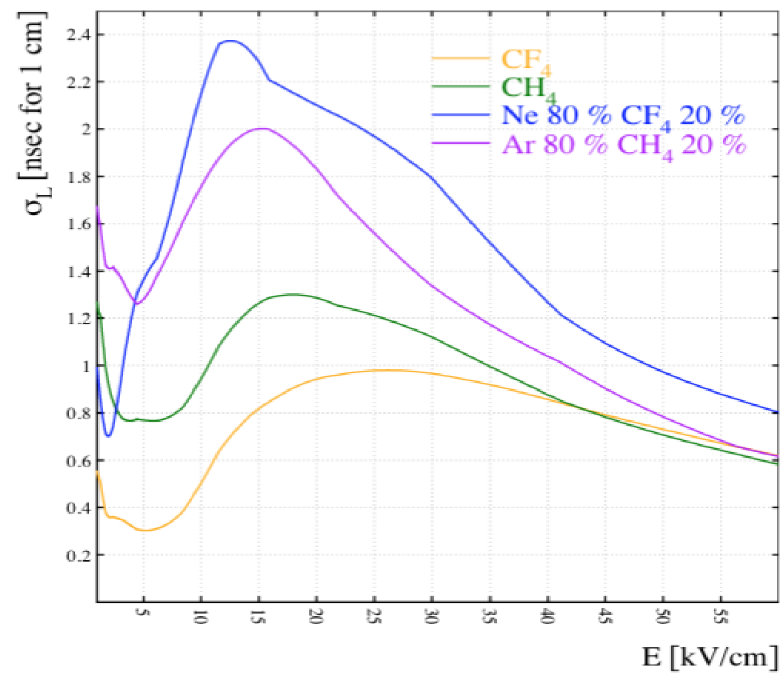
- Small drift gap (100-200 μM)
- strong electric field

  → Limited diffusion

Simulations:

- ✓ Few hundred μm drift field can provide time jitter per electron < 100 ps (Ed ~ 5kV/cm)
- ✓ Several gas mixtures possible
- ✓ Good performance for high amplification fields (>50 kV/cm)

  → preamplification!



Longitudinal time jitter in 1-cm drift gap as function of the drift field for several gas mixtures. *(R. Veenhof)*

Detector design

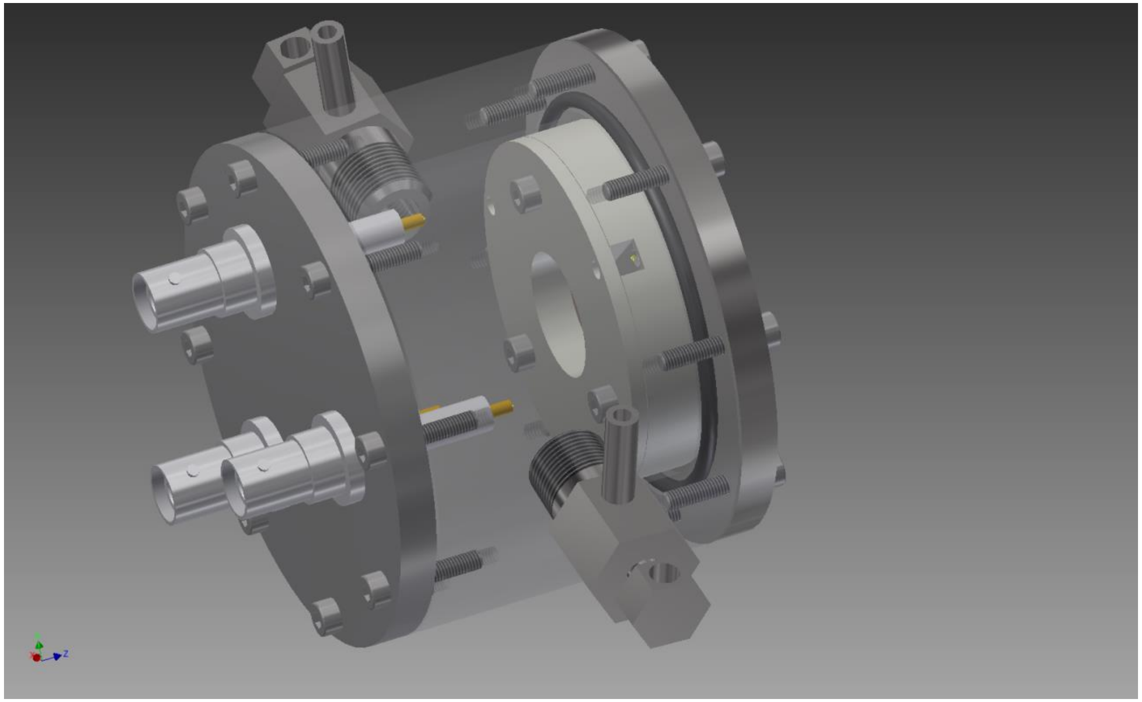
First tests with UV lamp / laser ➔ quartz windows

Microbulk Micromegas ø 1cm

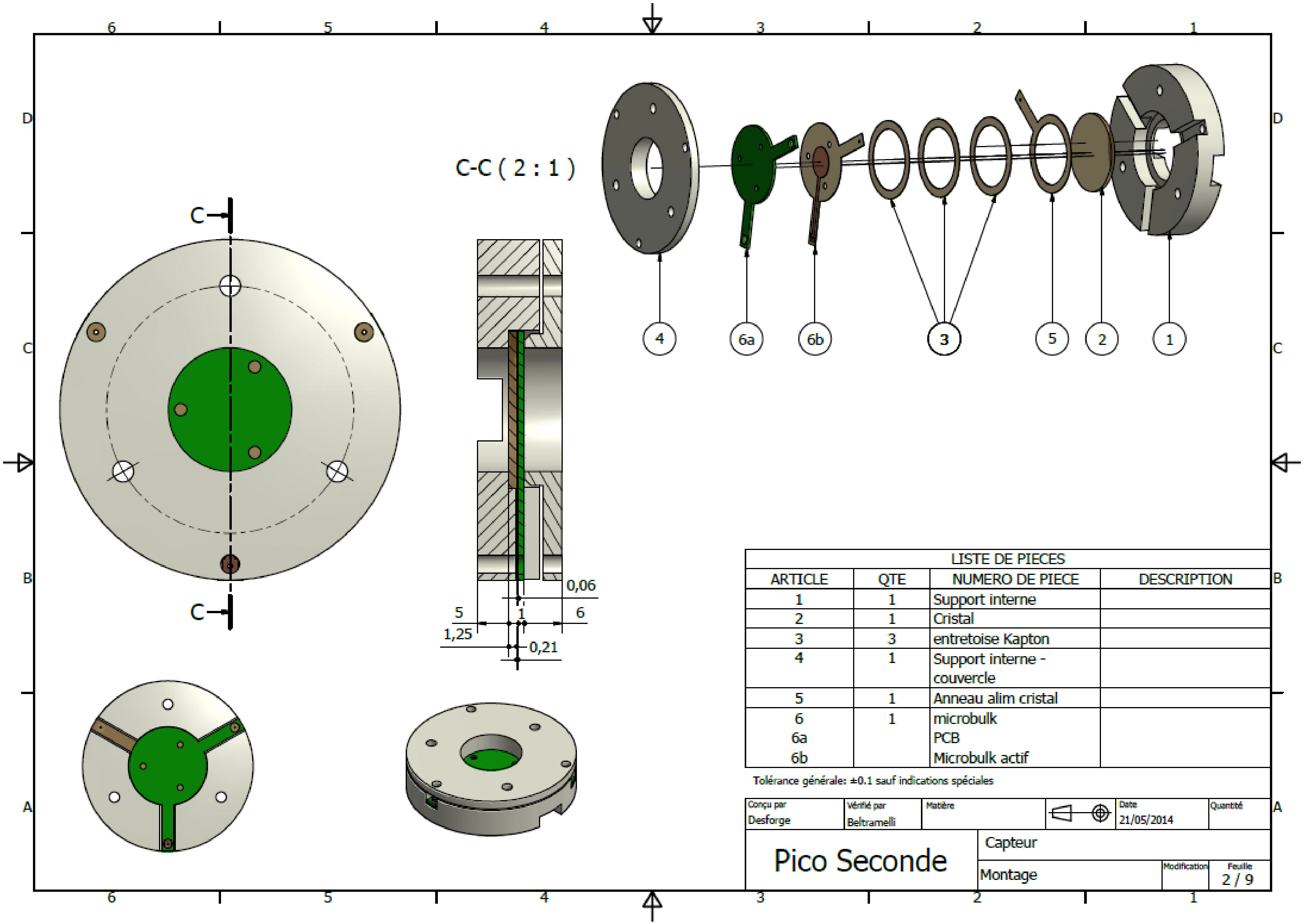
- ✓ Possibility to deposit CsI on the mesh surface
- ✓ Capacity ~ 35 pF

Ensure homogeneous small drift gap + contacts

Stainless steel chamber for sealed mode operation



Detector design



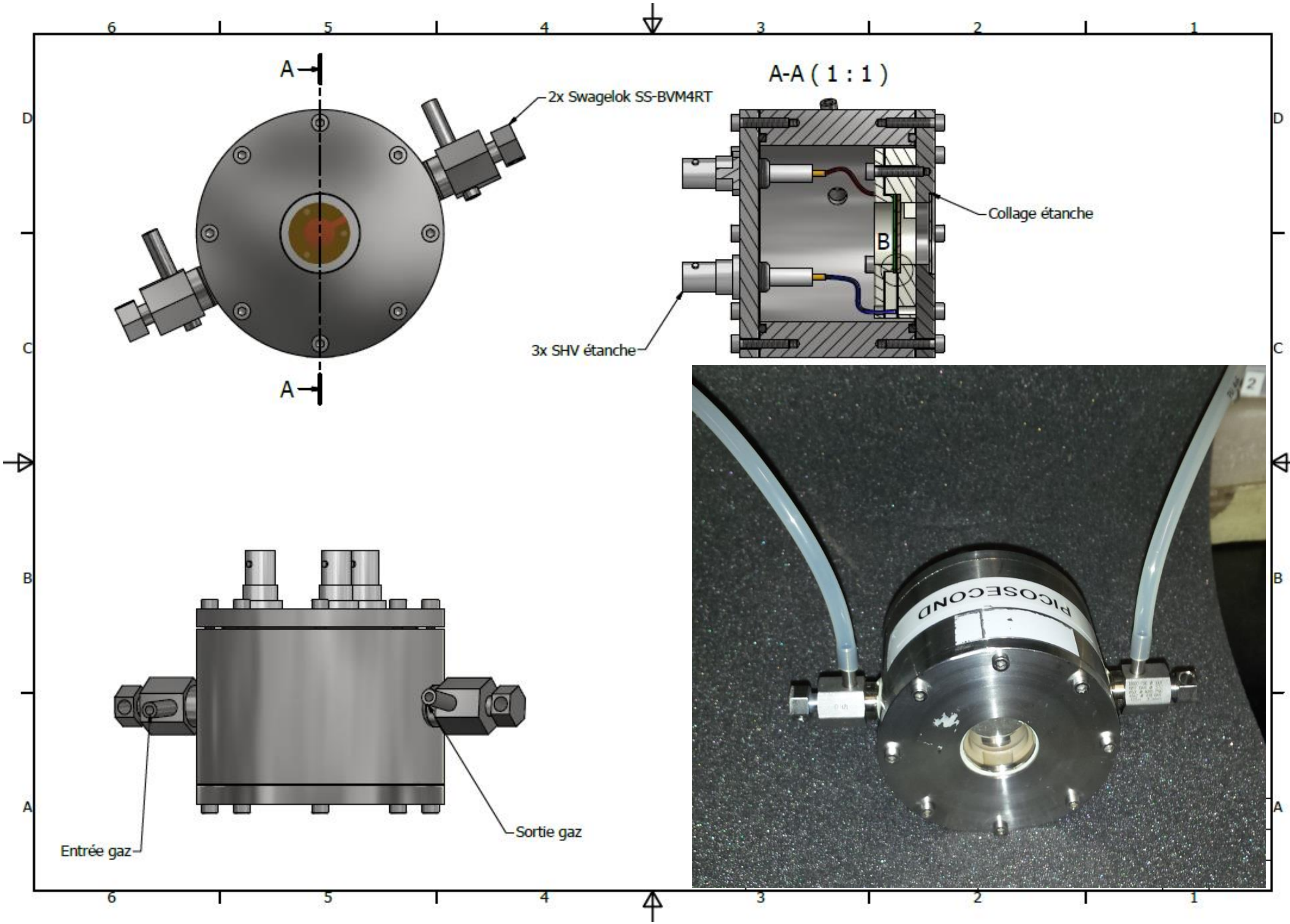
LISTE DE PIECES			
ARTICLE	QTE	NUMERO DE PIECE	DESCRIPTION
1	1	Support interne	
2	1	Cristal	
3	3	entretoise Kapton	
4	1	Support interne - couvercle	
5	1	Anneau alim cristal	
6	1	microbulk	
6a		PCB	
6b		Microbulk actif	

Tolérance générale: ±0.1 sauf indications spéciales

Conçu par	Vérifié par	Matière	Date	Quantité
Desforge	Beltramelli		21/05/2014	

Pico Seconde — Capteur — Montage — Modification — Feuille 2 / 9

Detector design



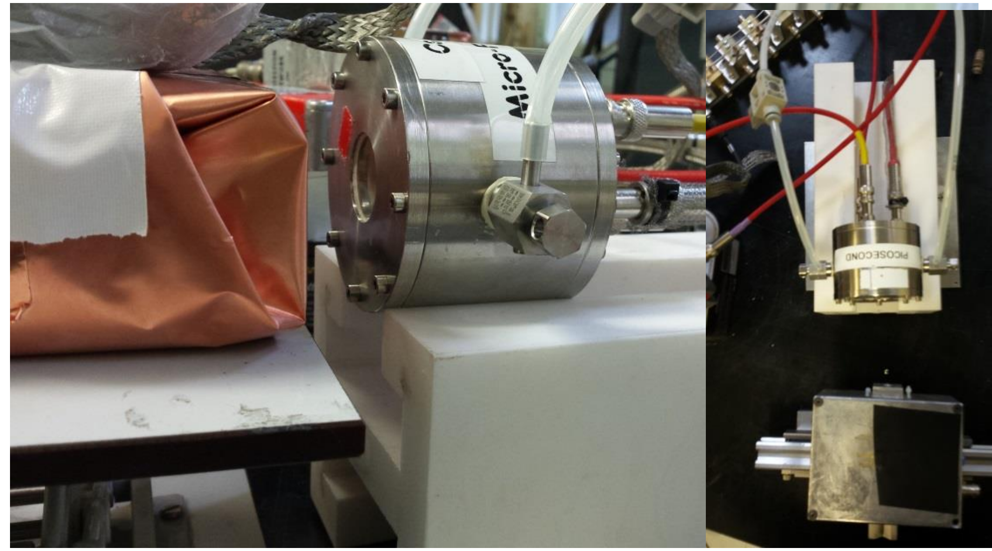
First tests

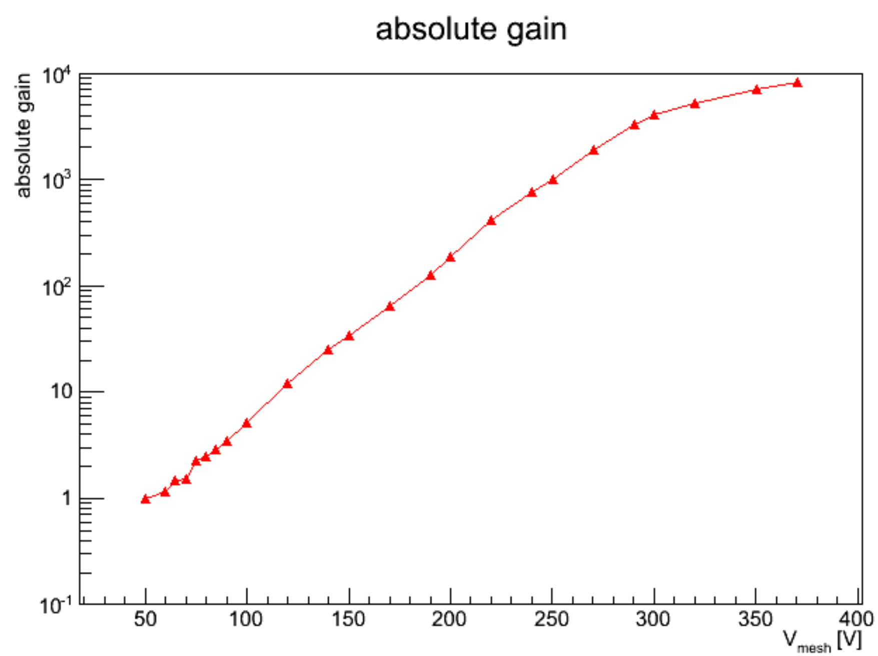
- Detector operating *with / without gas circulation* & standard electronics (ortec 142B preamp, microcircuit current preamp)
- Ne – 10% ethane @ 1 bar
- No CsI, only 15 nm aluminum on Quartz window, 15 % transparent < 200 nm
- Tests with a deuterium flash lamp

Absolute gain calibration non trivial

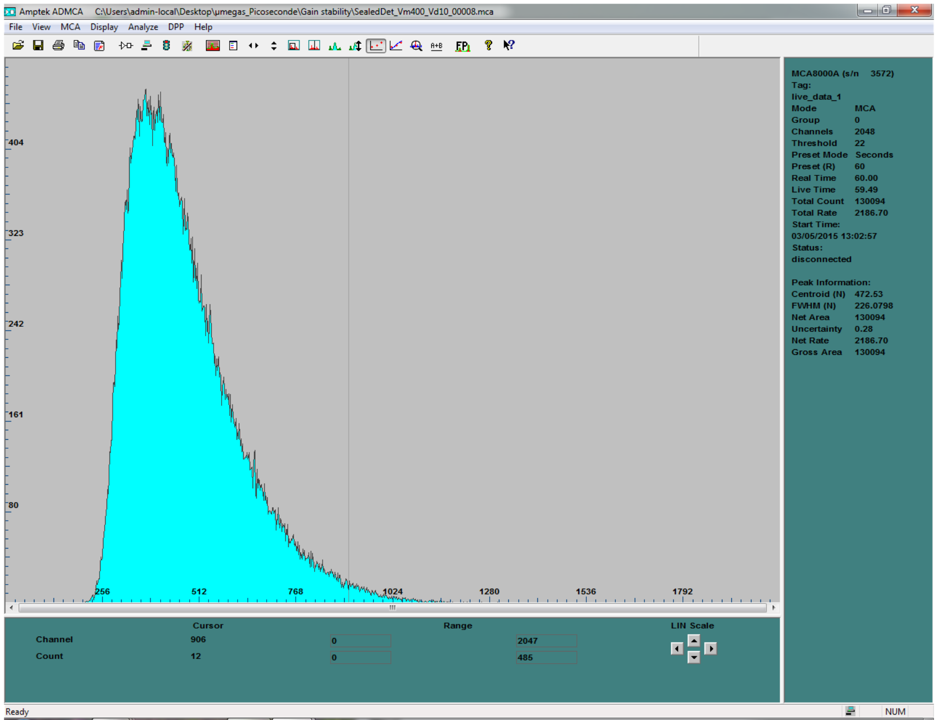
➔ Preamplification

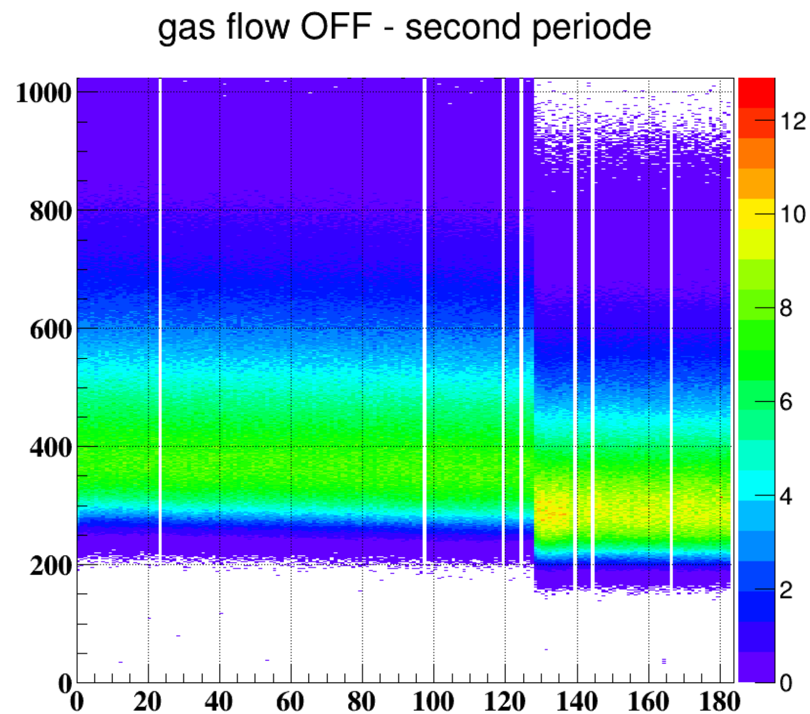
➔ Lamp stability





Tests with deuterium flash lamp

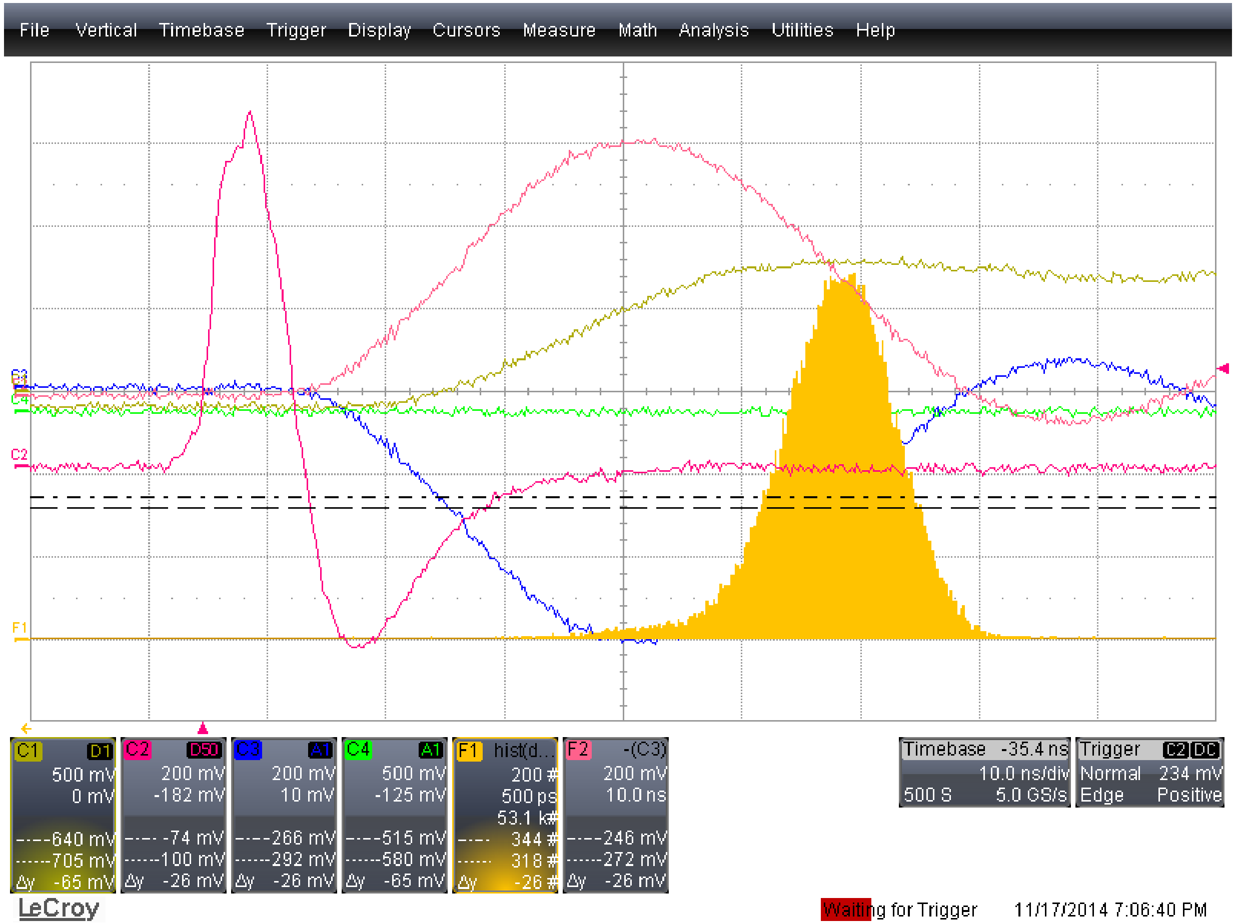




Estimated ~20 photoelectrons per pulse by comparing with the amplitude of the signal from a candle

24 hour run in sealed mode.
Lamp not very stable

Tests with deuterium flash lamp



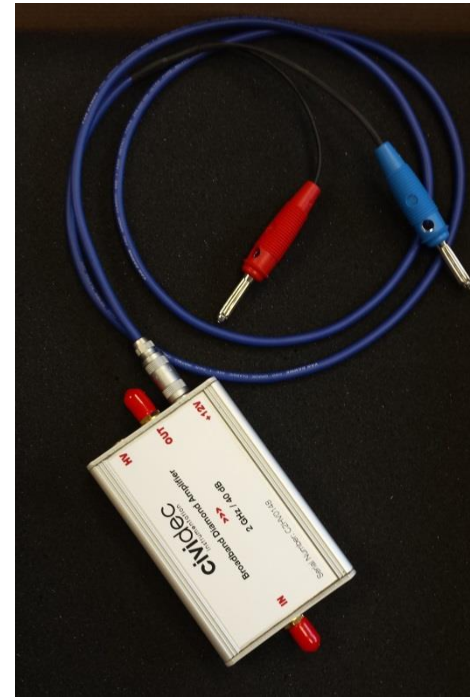
Time jitter of deuterium lamp ~ 100s ps

Result very promising!! FWHM ~ 600 psv

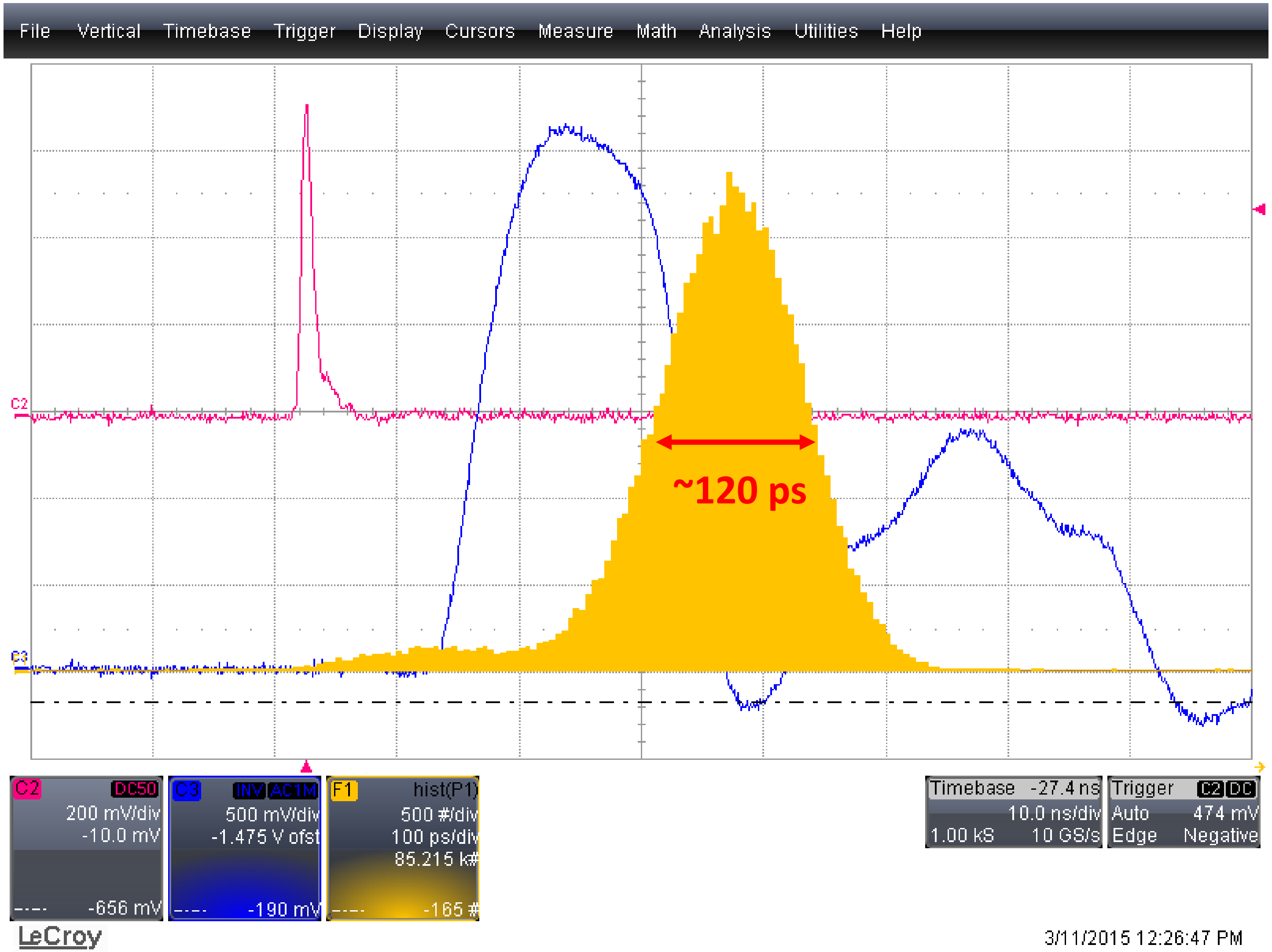
Tests with femtosecond laser

IRAMIS facility @ CEA Saclay
(thanks to Thomas Gustavsson!)

- UV laser with σ_t ~ 100 fs
- λ = 285 nm after doubling
- intensity ~ 3 mW
- Repetition 5 MHz (!!) - limitation on gain
  - ➔ Reduced to 8 kHz on the second day
- Sealed mode
- Trigger from fast PD
- Cividec 2 GHz current preamplifier

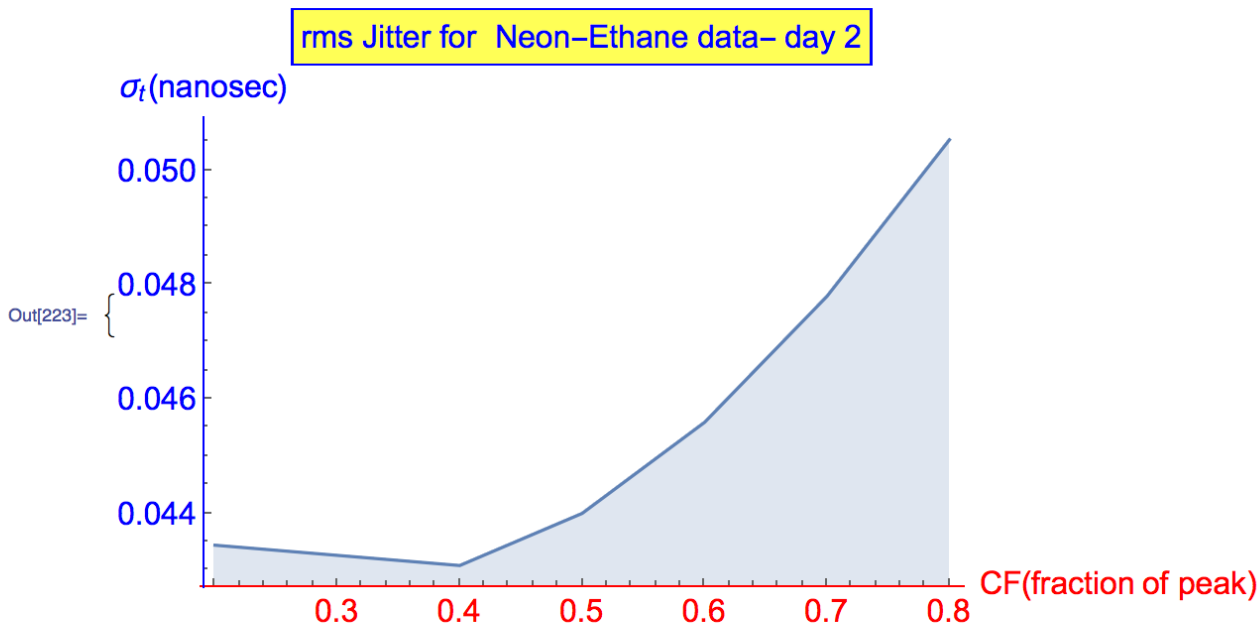


Tests with femtosecond laser



Vm = -440V / Vd = -650V (preamplification / signal ~ 3V !!!)

Tests with femtosecond laser



0.2	0.0434365
0.4	0.0430806
0.5	0.043993
0.6	0.0455856
0.7	0.0477906
0.8	0.0505277

Analysis by Sebastian White ➔ **σ_t = 43 ps**

Detector gain to be estimated

➔ *number of photoelectrons?*

Conclusions - outlook

A Micromegas photodetector has been constructed in order to study the potential for sub-picosecond timing

First tests are positive.

- **43 ps time resolution** has been measured in **semi-transparent** & sealed mode, with **preamplification**
  - ➔ *Must estimate number of pfotoelectrons!!!*

Next steps

- Detailed calibration with / without preamplification
- Laser tests with attenuators ➔ *direct measurement of single electron jitter*
- Reflective mode
- Electric field dependence study
- Other gasses (CF_4)
- CsI photocathode
- Bulk detectors (64/128/192 μm gaps)
- Other meshes (high LPI nickel / kapton meshes / bulk / clasic detectors)

Other issues:

- Electronics
- Test with BaF2 / alpha source
- Beam tests

Thank you!