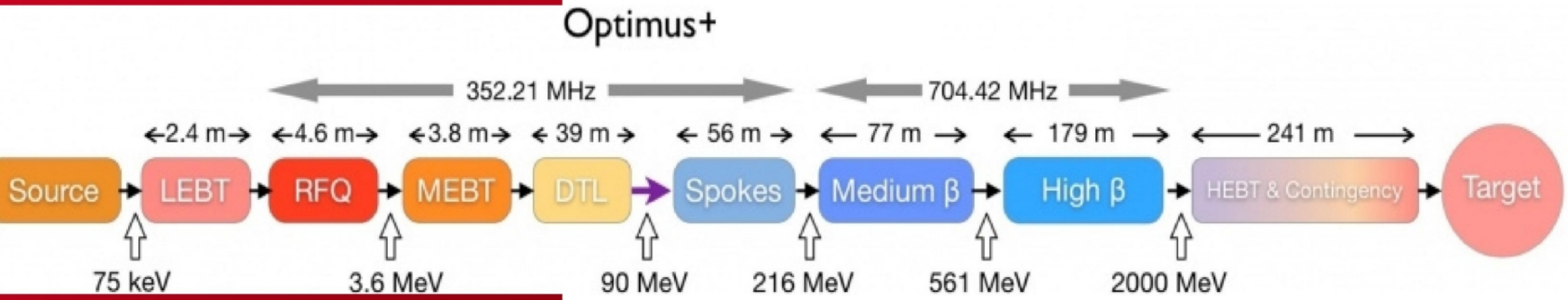
DE LA RECHERCHE À L'INDUSTRIE

Status of IPM and nBLM detectors



www.cea.fr

On behalf of the NPM & nBLM teams

NPMs

NPM project

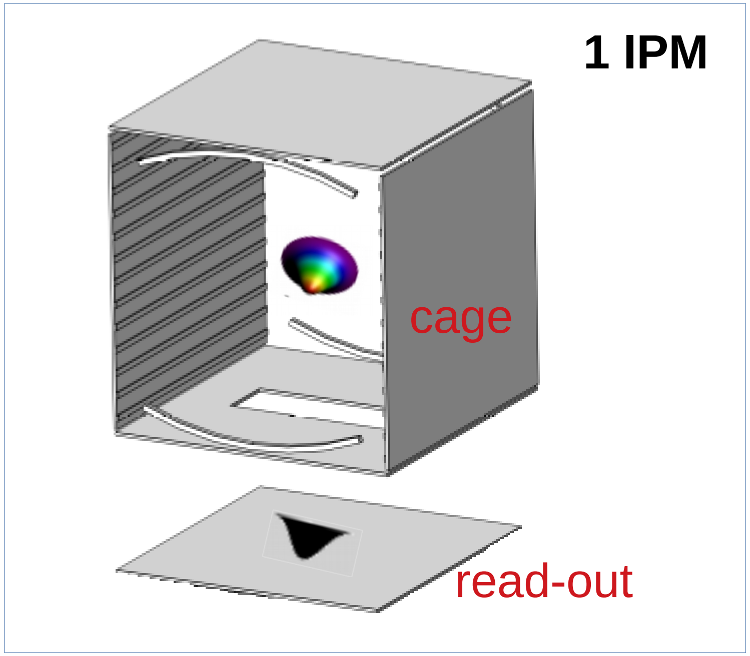
Since last BI Forum…

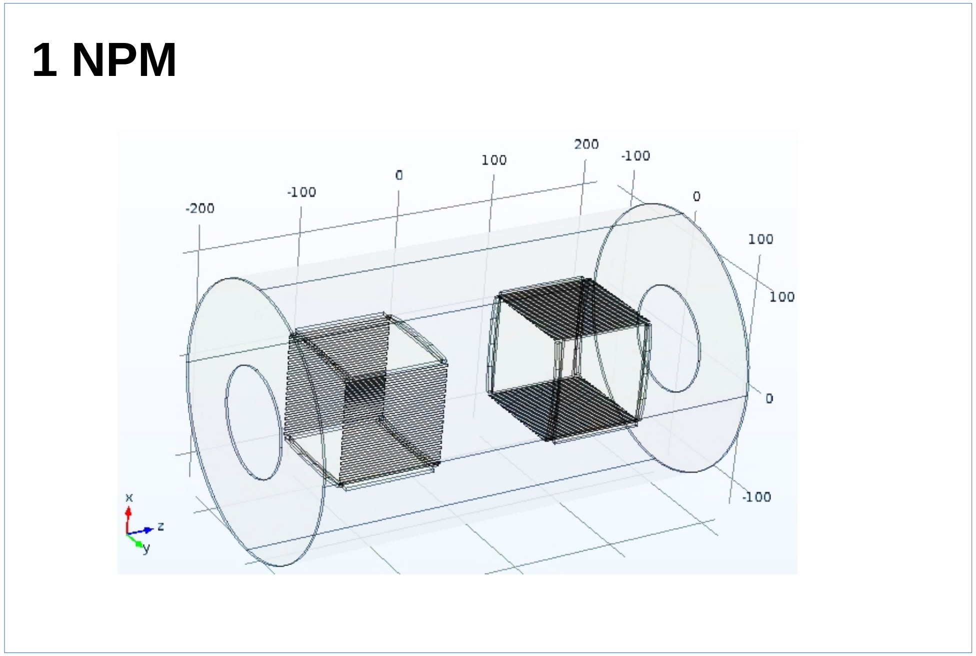
- ✓ Experimental tests for choosing the read-out (2018)
- ✓ Passed Final CDR (February 2019)
- ✓ Received (far) UV transparent windows
- ✓ Received vacuum valves
- ✓ Received support table for future tests
- ✓ Received ionic pump
- ✓ Problem with a vacuum chamber, now fixed
- ✓ 1 months internship
- ✓ Tests with UV lamp for monitoring the gain of the p-MCPs on-going
- ✓ Call for tender for p-MCPs
- ✓ Establishment of procedure for cleaning, assembling, testing and wrapping the cNPM

NPM : project reminding

NPMs

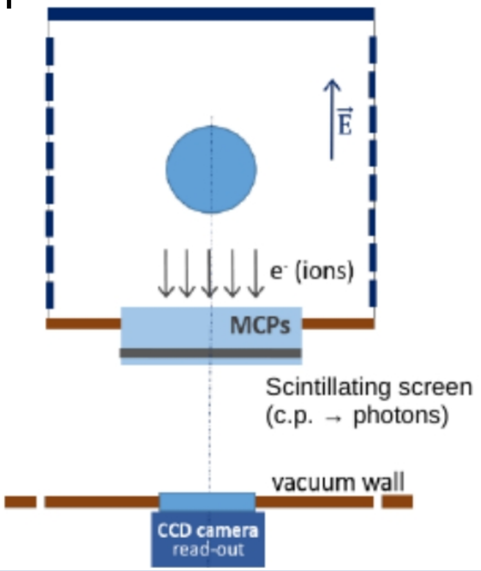
- 5 Non Interceptive (transversal) Profile Monitors
- To be installed in the Cold Linac → high vacuum and cleaniness (ISO 5)
- 1 in Spoke, 3 in Medium-β and 1 in High-β section → Proton energy $\in$ [90, 630] MeV
- Working principe : ionisation of the residual gas
- 1 IPM (Ionisation Profile Monitor) : 1 cage + 1 read-out
- 1 NPM : 2 IPMs



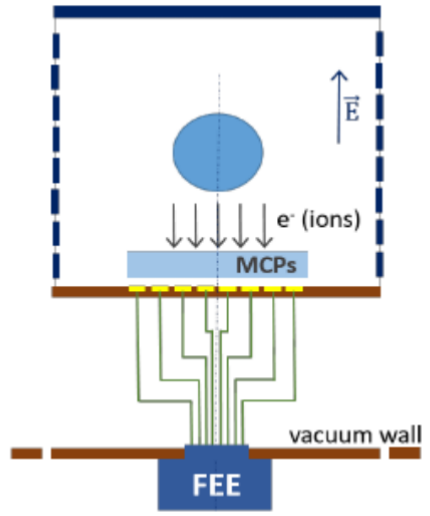


Chosen read-out : Optical

Optical

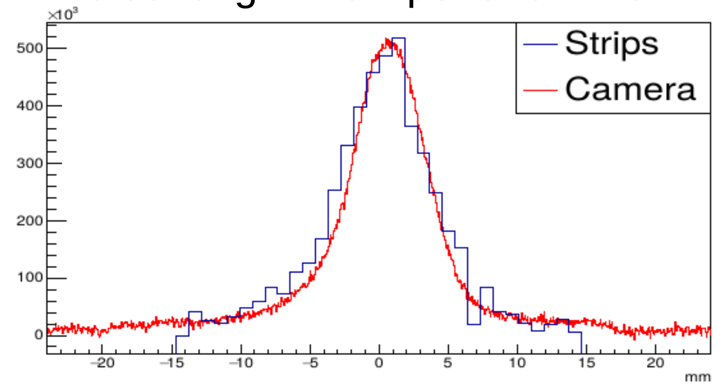


Strips

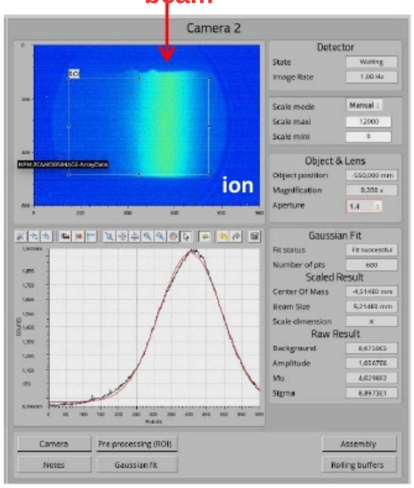


TESTS @ IPHI (02/2018 & 09/2018):

- 3 MeV proton beam
- Gas pressure : $10^{-6} \div 10^{-7}$ mbar
- Pulse length : few μs to few ms



beam



STRIPS

- High radiation resistant
- MCP necessary → it overthrows the radiation resistance
- Long developmento to integrate CS & on-line analysis under EPICS

- **OPTICAL READ-OUT**

- Camera lifetime can be increased by deporting it
- MCP lifetime can be increased by using double stage MCP
- No need of CS develoment

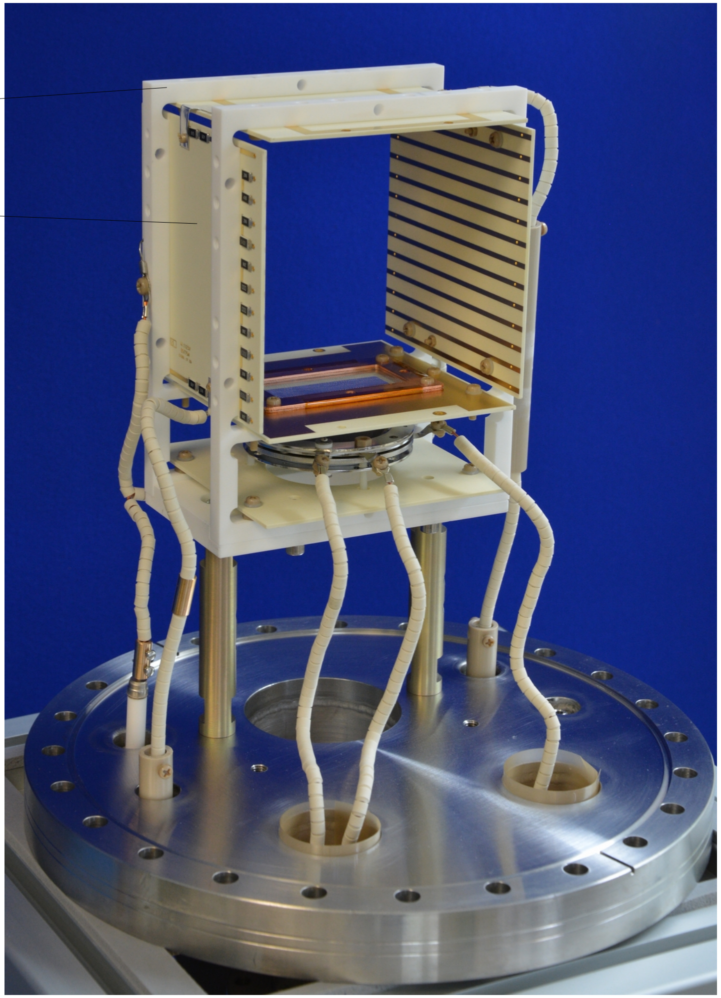
NPM : design

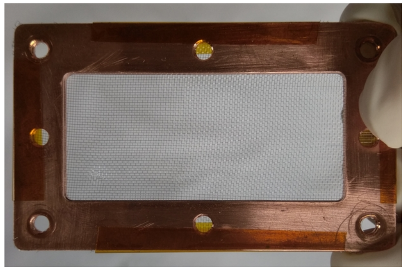
MATERIALS ISO 5 compatible:

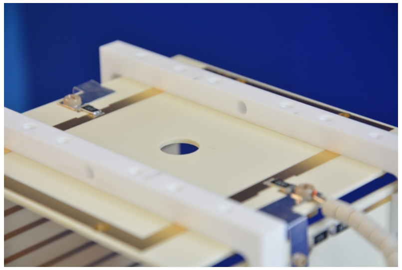
- MACOR frame
- PCB RO4350 (ceramic)
- Inox
- Peek (screews, nuts, washers)
- Al + Au metallisation
- Cu H.V. wires surroundend by ceramic insulators
- welded CMS resistors
- p-MCP

ADDITIONAL INFOs :

- grid for good field uniformity → to be replaced by wires
- Cage dimensions : 10 cm x 10 cm x 10 cm
- ***Symmetric HV configuration*** for IPM cage

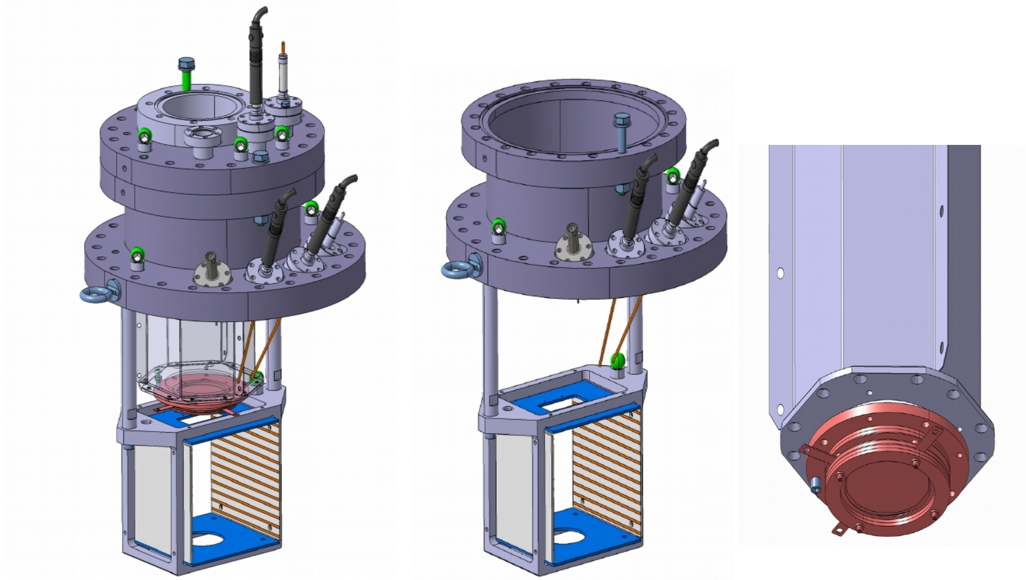




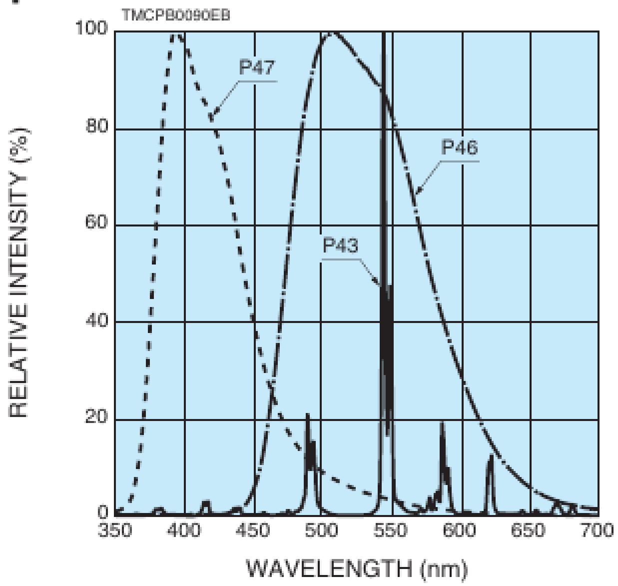


NPM : almost final design

- « Final » design of the system for extracting MCPs
- Number of connectors not up to date
- Launched call for tender for 10 double stack p-MCPs → soon decision => design finalisation

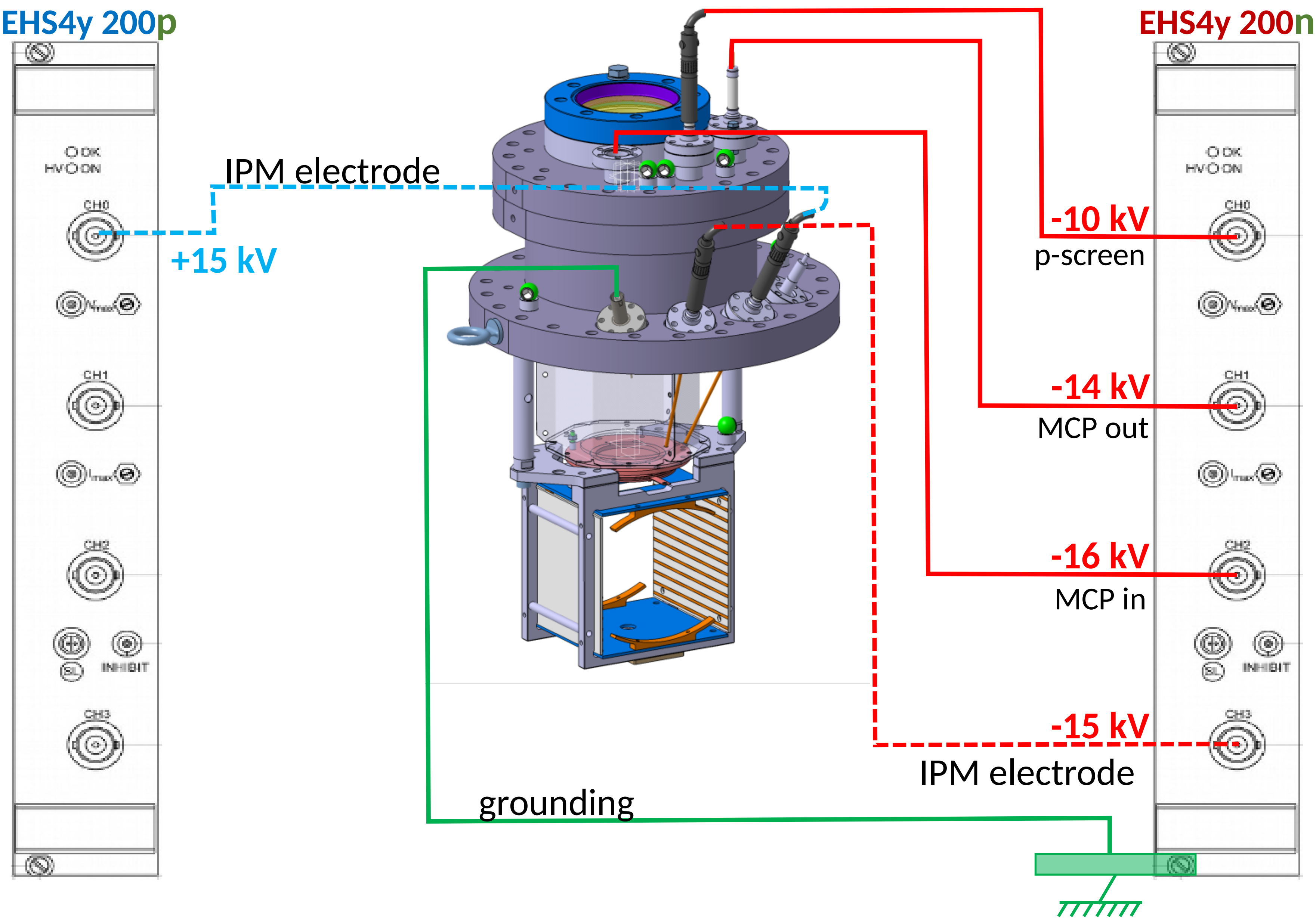


■Spectral emission characteristics



Screen type	Peak emission λ (nm)	Relative energy efficiency	10 % decay time
P43	545	1	1 ms
P46	510	0.3	0.2÷0.4 µs

NPM : almost final design



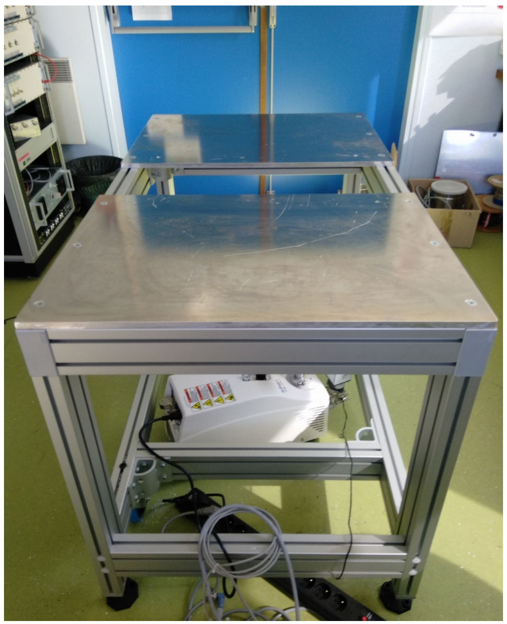
NPM : material inventory

August 2019 :

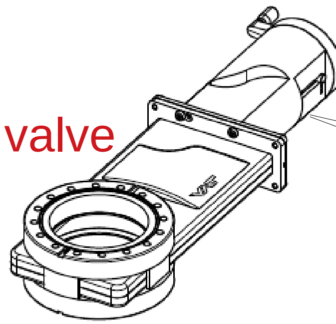
→ received table for test bench, now installed in our laboratory

→ received ionic pump

→ received vacuum valves



valve



Ionic pump

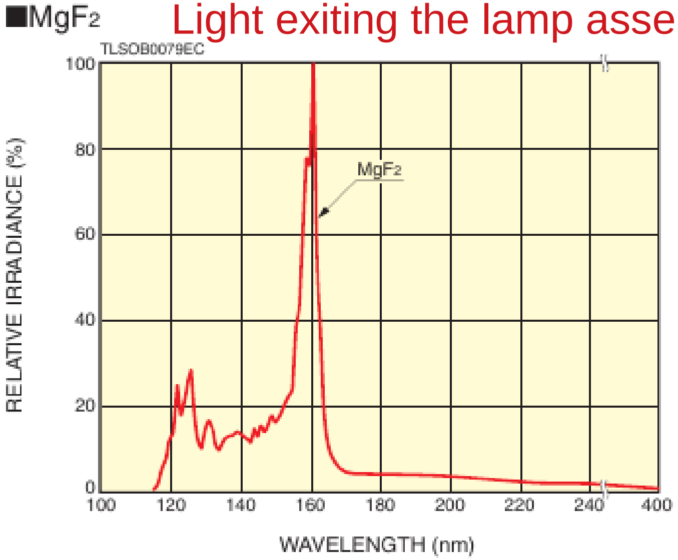
- Problem of vacuum chamber: a big leak appeared on a flange knife of the test chamber. This later was dropped on September 1st to Meca2000 to fix it. It came back fixed on September 15th

NPM : UV lamp tests

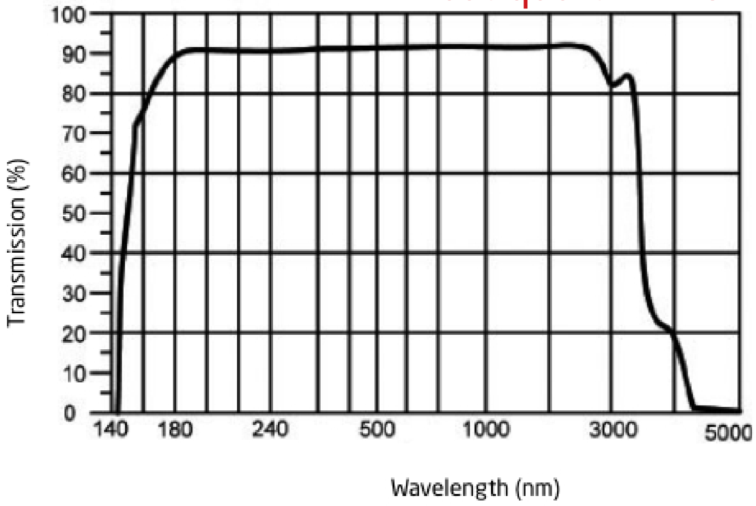
August 2019:

- 1 month internship of A. Marday
- LAMP :
  X2D2 L10904 lamp borrowed from a colleague
  → Lifetime 2000 hours
  → High stability
  → 9 years old
- In-house set-up => quite a few UV absorbed before the quartz window
- Z-cut quartz window
- P46 screen coupled to single stage MCP

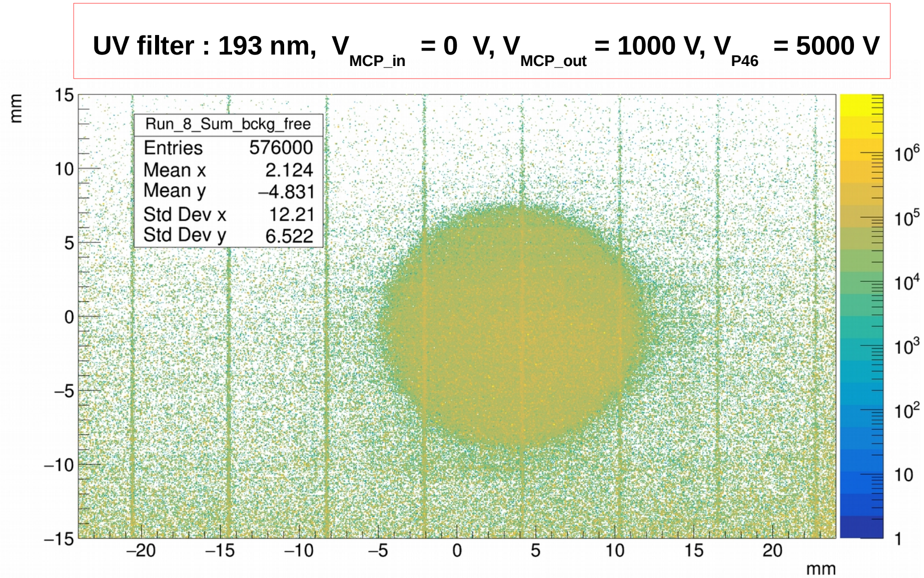
Light exiting the lamp assembly



Z-cut quartz winow



NPM : UV lamp tests



Details :

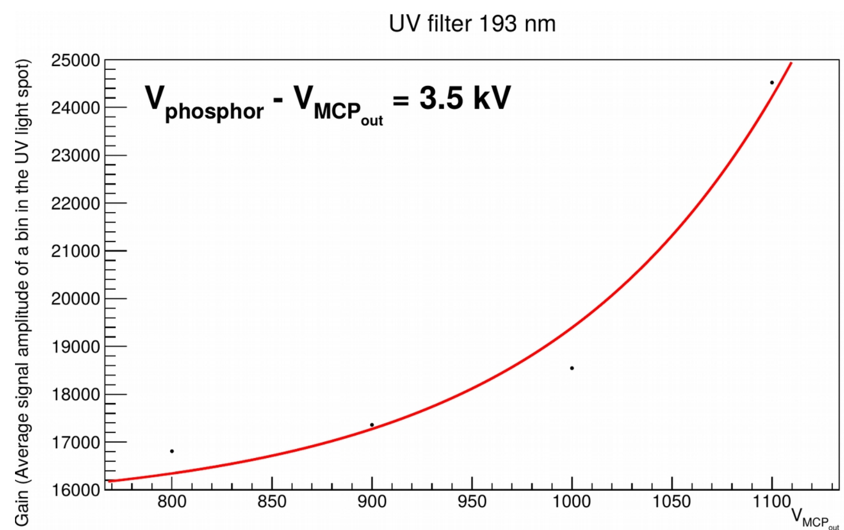
- V_{MCPin} = 0 V
- V_{MCPout} = varied
- V_{Screen} = V_{MCPout} + k
- a UV filter letting to pass only a specified wavelength ± 1 nm, was applied

GAIN calculation :

→ for every run 180 images were summed and the background subtracted(*)

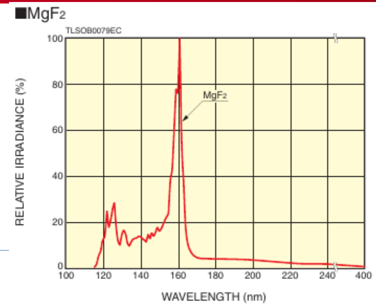
→ the sum of x pixels in the central spot was performed and divided by the number of pixels

(*) No background run. Pixels far away from the central spot were consider to calculate it

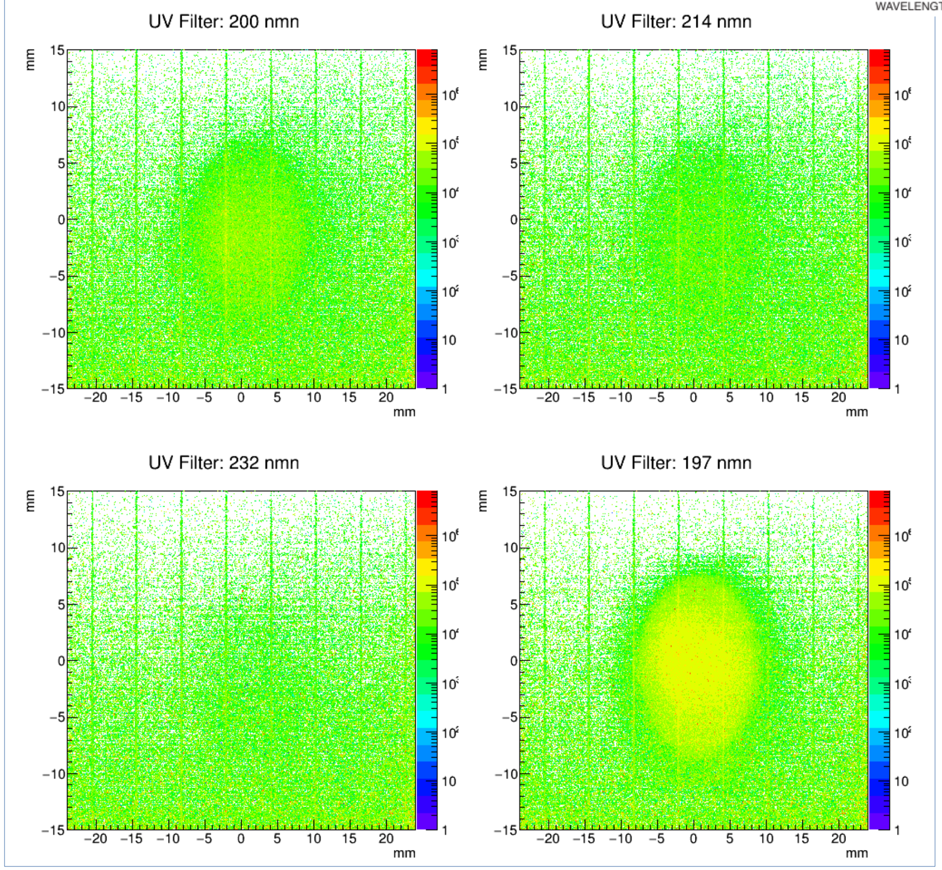


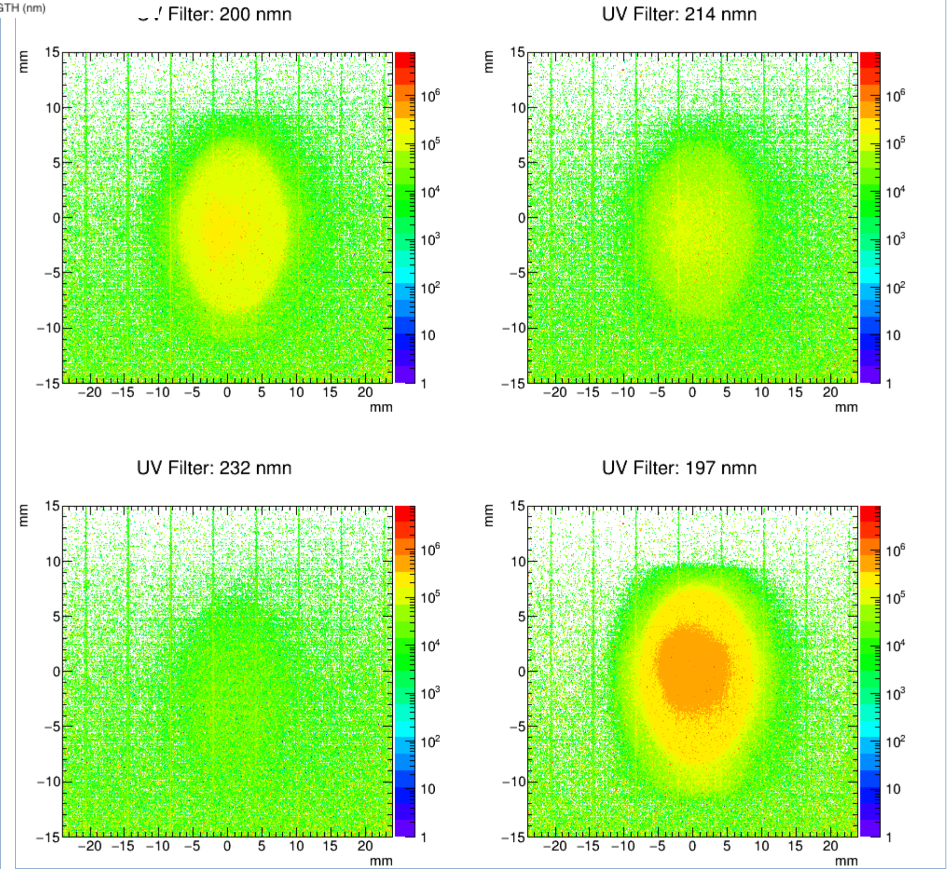
NPM : UV lamp tests

V(MCP_in) = 0 V
V(MCP_out) = 1 kV
V(screen) = 5 kV



V(MCP_in) = 0 V
V(MCP_out) = 1.1 kV
V(screen) = 5.1 kV

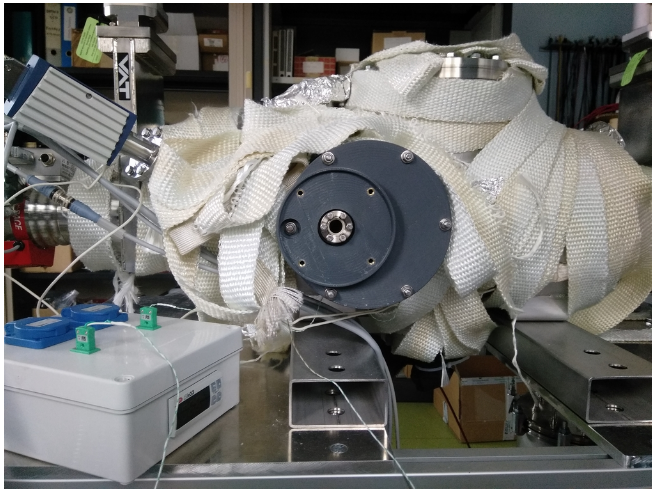




NPM : UV lamp tests

September 2019:

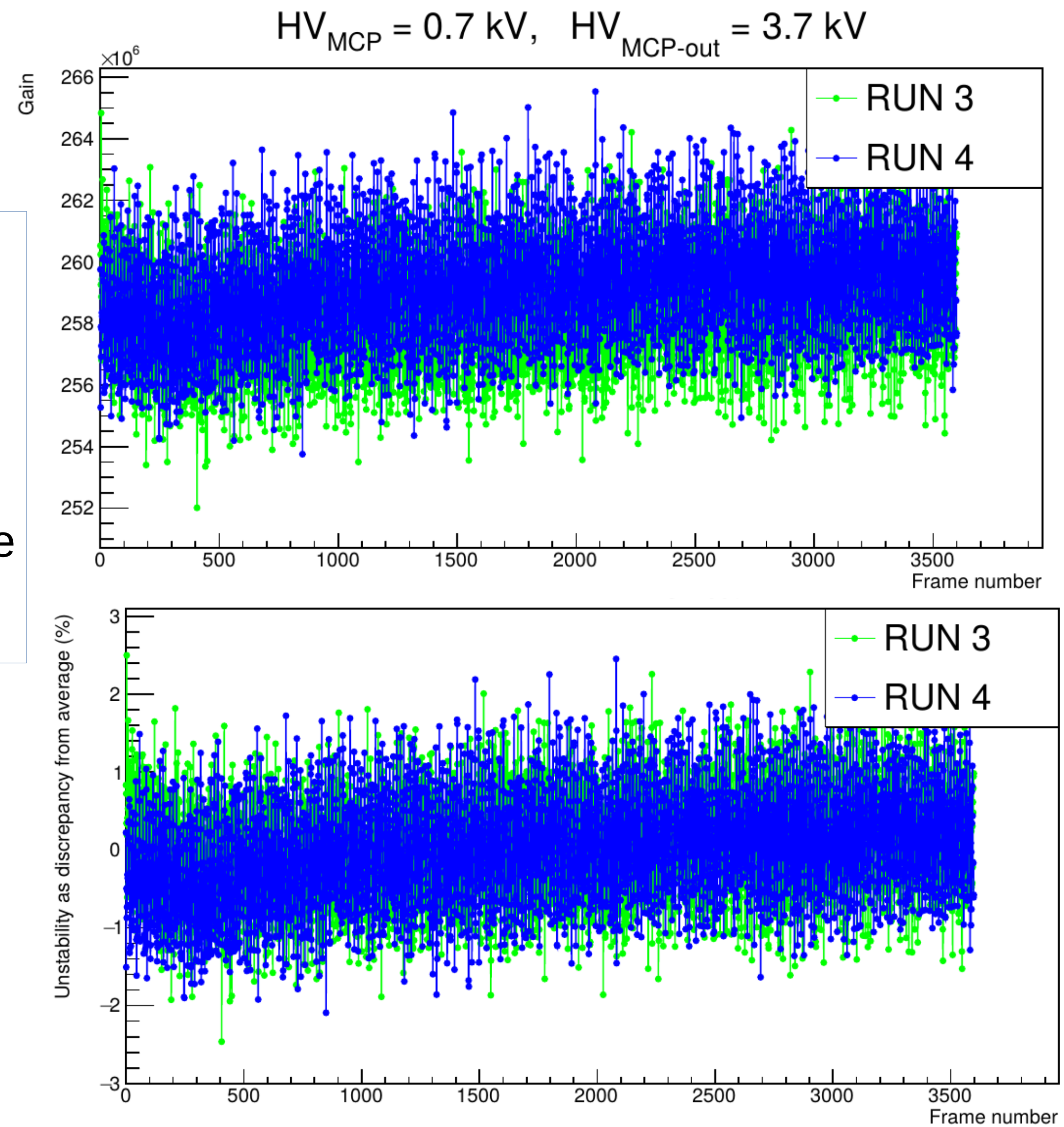
- LAMP :
- H2D2 L15094 lamp borrowed from Hamamatsu
  - → Lifetime 1000 hours
  - → High stability (0.05%)
  - → Used intensively few days before
- « Pro set-up » (L. Scola)
- Z-cut quartz window
- P46 screen coupled to single stage MCP
- P43 screen data are being analysed



NPM : UV lamp tests

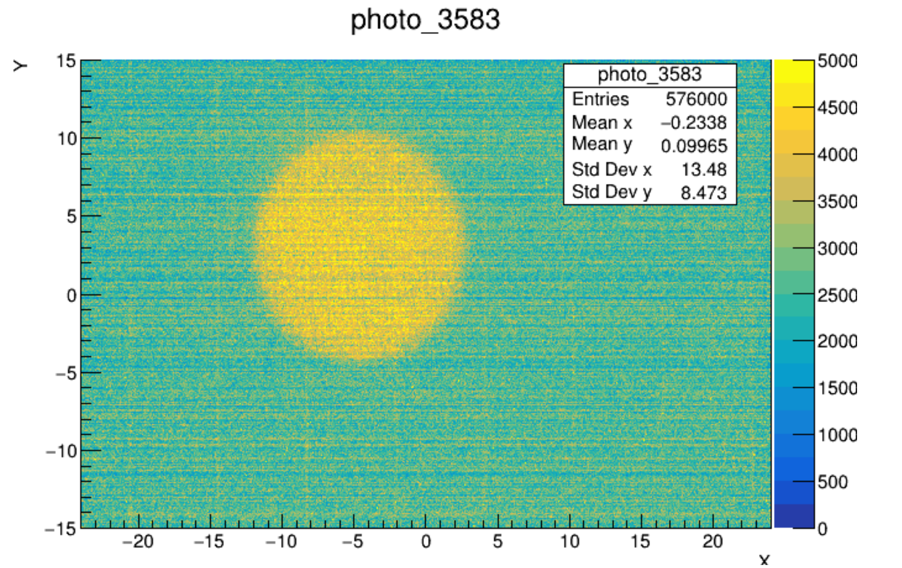
- No change in behaviour is seen if the UV lamp is extracted from its holder and reput in position

- Data are not corrected for the heating up of the camera nor the current in the MCPs

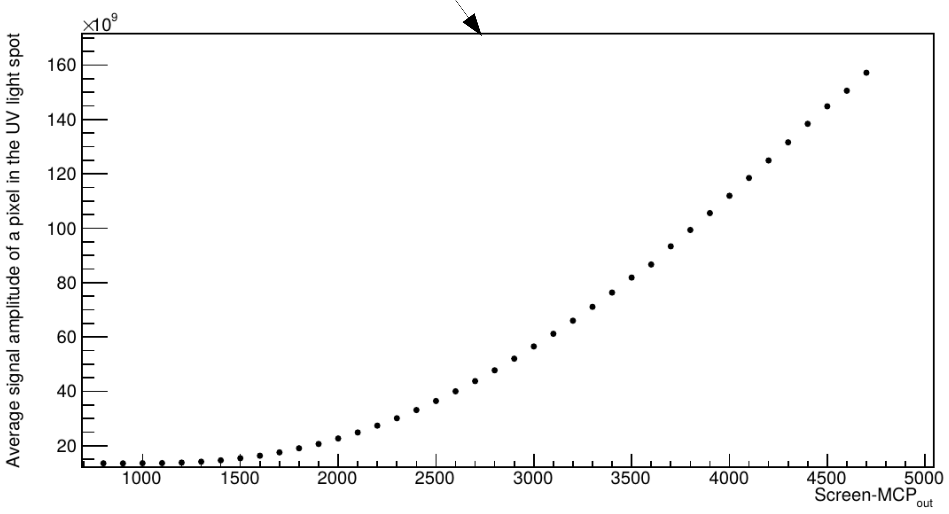


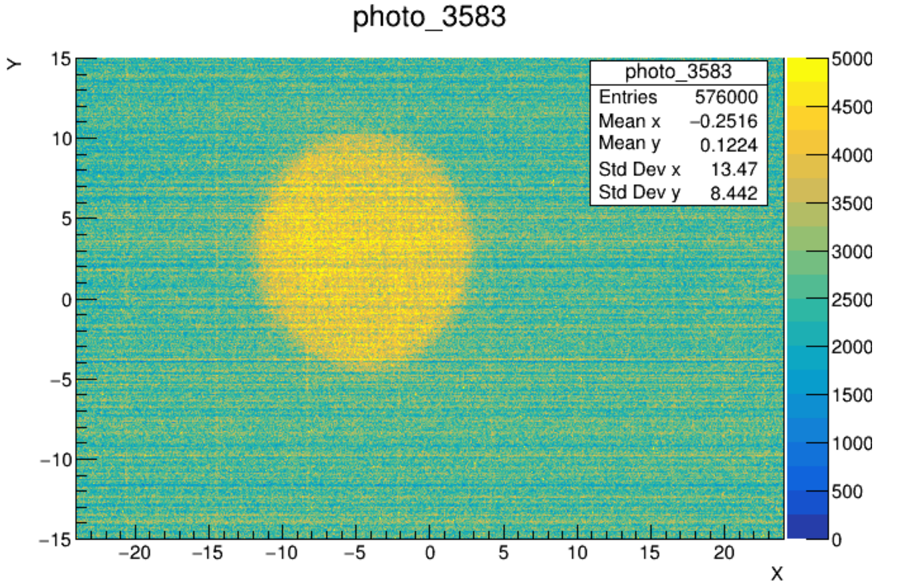
NPM : UV lamp tests

- No displacement is seen if the UV lamp is extracted from its holder and reput in position
- A more quantitative analysis is on-going



- Test of P43 screen linearity





Cleaning/assembling/testing/wrapping :

US bath for cleaning
+ filtered water [1]

clean tent for
drying + US
bath [1]

test bench [2]

Dédip “North”

Building 534

Dédip : **D**épartement d’**é**lectronique des **d**étecteurs et d’**i**nformatique pour la **p**hysique

DEDIP: **D**epartment of **E**lectronics for **D**etectors and **C**omputing for **P**hysiques

Cleaning/assembling/testing/wrapping :

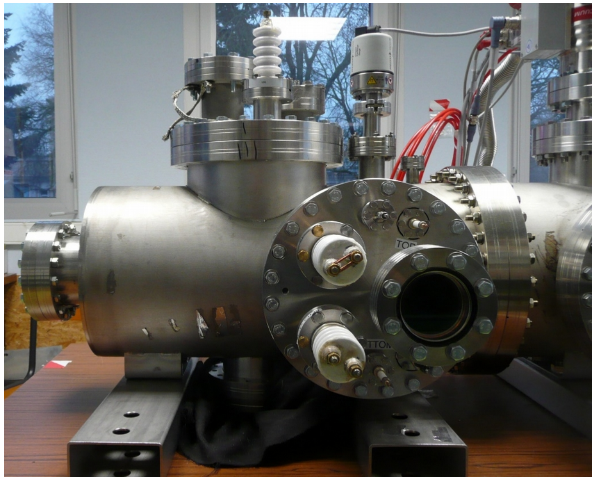
Phase 1: Sorting pieces for an IPM pair, cleaning, drying and assembling

- All necessary pieces including screws (except MCP) to assemble 2 IPMs will be sorted and cleaned in an ultrasonic bath with a specific detergent (EC260, pH 7.1) and rinsed with demineralized water18MΩ (B.534/R.1 and B.534/40).
- Then, all of them are gathered into B.534/R.40 (20m) where they are dried in a laminar flux. Once dried, there are assembled under the air laminar flux to built the 2 IPMs. The goal is to work on one IPM pair after each other.
- Finally brought to B.534/R.43C (10m) where there are mountings, with their MCPs.

A- ultrasonic bath for cleaning
+ filtered water
+ pure N_2 gas
534/1

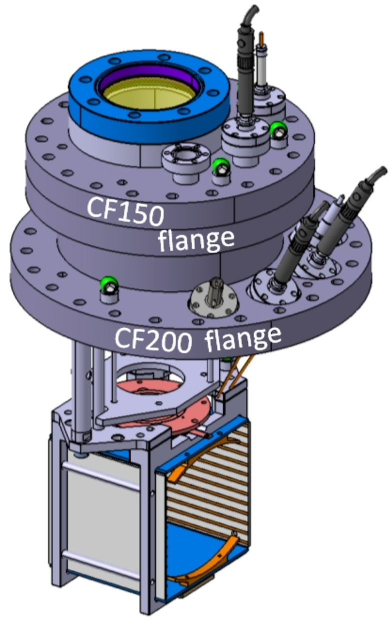
B- clean tent for drying
+ large US bath 534/40

C- test bench in 534/43C laboratory



Cleaning/assembling/testing/wrapping :

Phase 2: IPM tests (B.534/R.43)



- Both IPMs are mounted on the vacuum chamber
- Start to pumping (down to 10^{-7} – 10^{-6} mbar)
- HV test to check sparking, goal is to reach ±15 to ± 20 kV
- MCP test with a UV light source
- Then, pumping down, with the help of ionic pump (goal: reaching 10^{-8}-10^{-9} mbar) and make a RGA measurement.

Qualification

- Test pressure
- HV reached
- MCP gain curve (UV source)
- Very low pumping down pressure achieved
- RGA spectrum and vacuum leakage rate
- Alignment coordinates (next step)

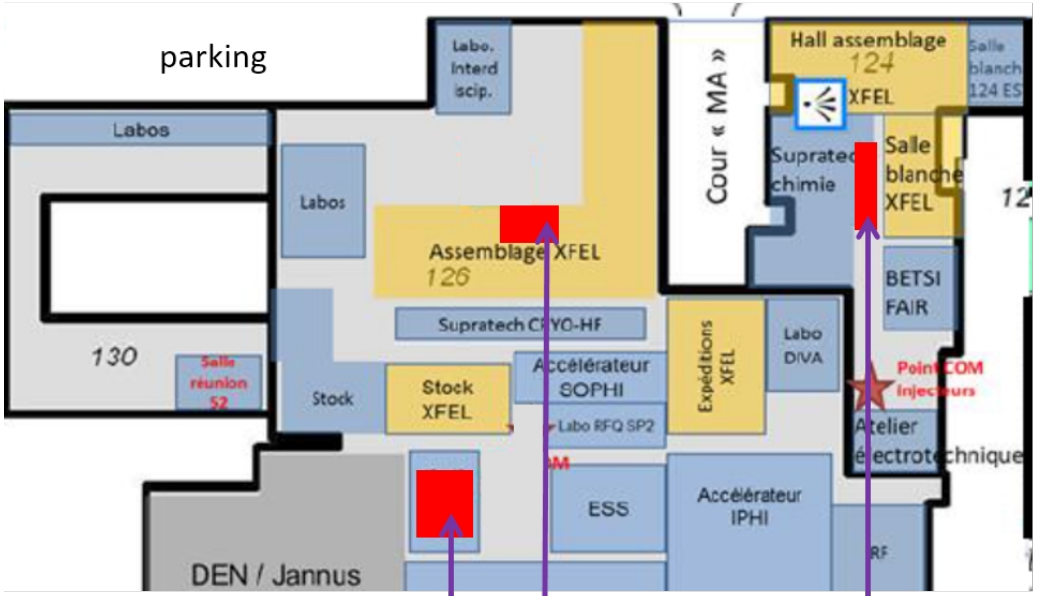
DACM

Buildings 124 & 126

DACM : **D**épartement des **A**ccélérateurs, de **C**ryogénie et de **M**agnétisme

DACM: **D**epartment of **A**ccelerators, of **C**ryogenic and of **M**agnetism

DACM – B.124 & 126



Optical bench [3]

Clean tent [5]-[6]

[4] large US baths + pure water rinsing station

Note: locations of clean tent and optical bench are supposed to move.

Cleaning/assembling/testing/wrapping :

Phase 3: ESS CM test bunker:

- After the tests in the laboratory (building 534), the MCPs are extracted and stored in a vacuum chamber.
- An IPM pair is transported to the DACM in order to start alignment work i.e. IPM measurement with a kind of optical bench (X, Y).
- Tools and brackets need to be designed and perhaps fixed.

Phase 4: in the huge assembling vault B.124 of DACM (4 cleaning rooms…)

Gateway to access to big ultrasonic tank:

The entire IPMs (except MCP) will be plunged in the bath and cleaned with specific detergent (TDF4, pH 13.5).

Rinsing station with its duckboard floor:

Filtered and demineralized water flushed on IPMs.

Cleaning/assembling/testing/wrapping :

Phase 5: XFEL vault (B.126): mobile clean tent (about 2 × 3 m²)

Clean tent interior (ISO 5):
vacuum pipe and more important, laminar air flux.
Cleaned IPMs and storage VC are brought inside a box, drawn in pure water. They are dried in the laminar flux hung on specific brackets (to be designed). Free particles are measured and items are flushed with pure filtered nitrogen until reaching the requested value.
Then, IPMs are mounted on both sides of the storage box.
Slow vacuum can be started.

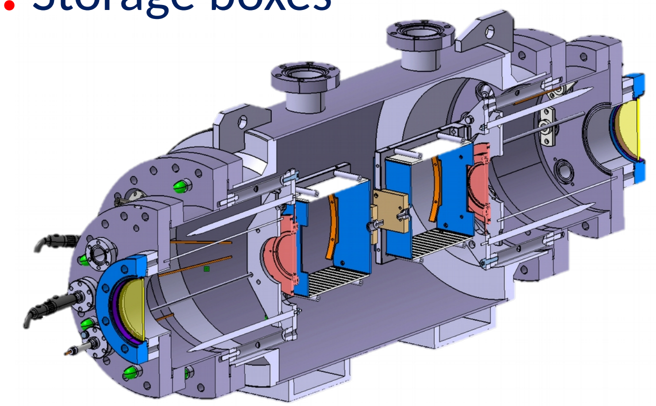
Cleaning/assembling/testing/wrapping :

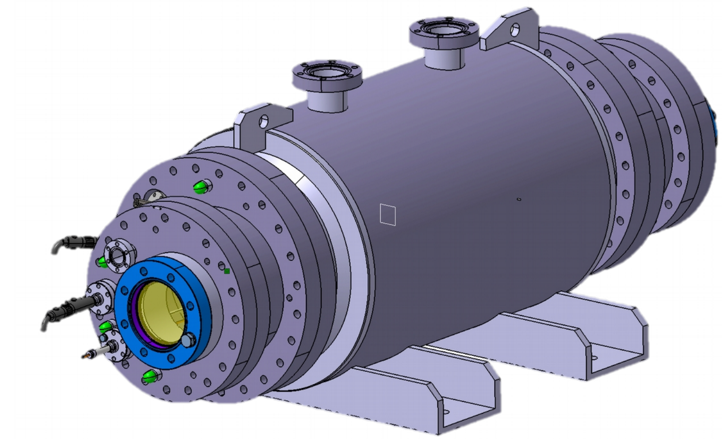
Phase 5: slowing pumping down and up system of DACM (B.124)

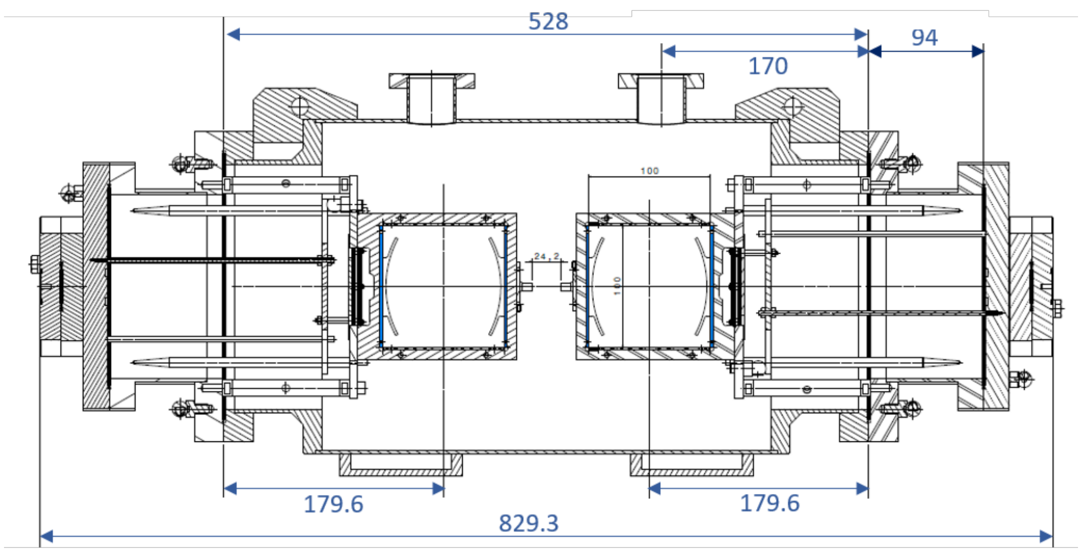
Slow pumping system and slow N_2 filling up to atmospheric pressure developed by DACM staff member for compliance with free particle requirement.
This kind of system is goig to be used for the last process phase, meaning the insertion of the both IPMs in the storing and transporting VC.

Cleaning/assembling/testing/wrapping :

Phase 6: Storage boxes







Cleaning/assembling/testing/wrapping :

Phase 7: reproducibility test

- After all this 1 IPM is extracted from the storage box and mounted on the test bench (Phase 2)
- Re-test
  → HV
  → Vacuum
- Bring the IMP back to DACM and re-test
  → Alignment
  → Re-clean the IPM and re-put it in the storage box
- If everything is ok, repeat the procedure (Phase 1-6, but not Phase 7) for all IPMs

Cleaning/assembling/testing/wrapping :

Rough planning

1st IPM pair (Spoke)
- Dédip nord → 2-3/2020
- DACM → 4-5/2020

2nd IPM pair (MBL)
- Dédip nord → 5-6/2020
- DACM → 6/2020

3rd IPM pair (MBL)
- Dédip nord → 6-7/2020
- DACM → 7/2020

4th IPM pair (MBL)
- Dédip nord → 8-9/2020
- DACM → 9/2020

5th IPM pair (HBL)
- Dédip nord → 10-11/2020
- DACM → 12/2020

Note
- DACM expert to be foreseen at least for the 1st IPM pair operations.
- To save time, we can also imagine to have 2 teams, one working on B.534 and at the same time the other one on DACM building.

Report :

A report for each IPM will be provided with the following listed items:

- The highest achieved HV IPM with the consumption current and the pressure
- MCP gain curve using VUV lamp
- The RGA spectrum
- The vacuum leakage rate
- The alignment coordinates of IPM marks wrt the external sight targets

Miscellaneous :

SPACE CHARGE EFFECT

- Comparison with code from GSI on-going, forseen comparison with Kenichirou's code

BACKGROUND

- We implemented the geometry of the chamber + optical IPMs in GEANT4,
- we received info about

→ protons (Yngve)

→ TO WHOM SHOULD WE ASK ABOUT OTHER PARTICLES ?

nBLMs

NBLM STATUS

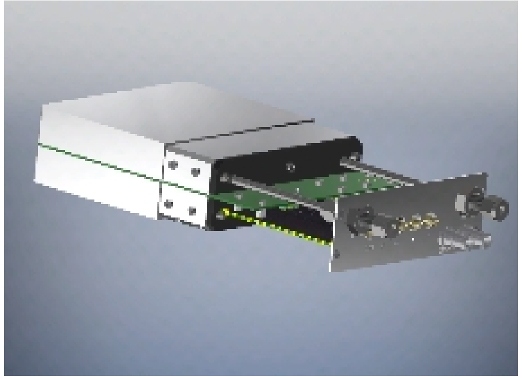
Since last BI Forum…

- ✓ Passed Final CDR (February 2019)
- ✓ Manufactured of gas crates and purchase of HV elements, FMC, etc
- ✓ Production of detectors started
  - September 2019
    - Send first 4 detectors to ESS (to be installed around MEBT)
    - Send also gas crates, HV crate and several cables, patch panels, etc…
- ✓ Beam losses detection at LINAC4 (end of 2018 and now!)
- ✓ FPGA development (Lodz UT) very well advanced
  - Tested also at LINAC4 (2018)
- ✓ Passed Vertical Integration Test for Control System contract (September 2019)
  - Minor changes required
- ✓ Data with neutrons and gammas source (April 2019)
- ✓ Irradiation of the electronics (September 2019)

NBLM IN A NUTSHELL

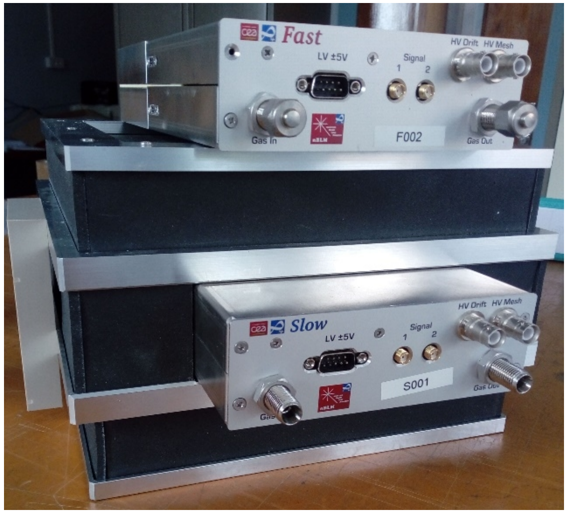
ESS-nBLM System

- 84 neutron Beam Loss Monitors
- Dedicated mainly to the low energy region of the accelerator
- Detectors based on gaseous Micromegas (amplification and readout of the signals)
- Losses measured by detecting fast neutrons
- Detectors will operate in counting mode
- Transition to current mode in case of high flux (pile-up)
- Detectors designed to have low sensitivity to gammas (can be produced by RF) and thermal neutrons
- Two complemantary modules
- Fast response – high sensitivity



Chamber +
Faraday Cage ~ 20 x 15 x 2 cm³

Moderator + absorber

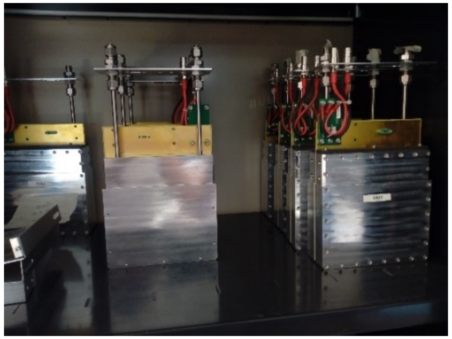


Assembly of a fast and a slow detector
size ≈ 20 × 25 × 25 cm³ (~14 kg)

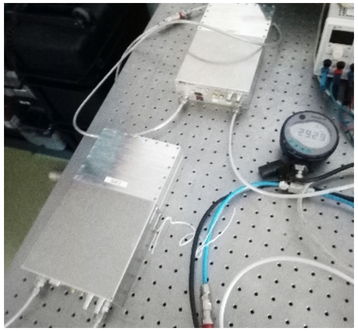
PRODUCTION INSTALLATIONS

- Production of the detectors has started
- First 4 fully characterized and send to ESS
- First extra 8 modules expected before end 2019
- Control System and FPGA development almost finalized

Detectors Integration

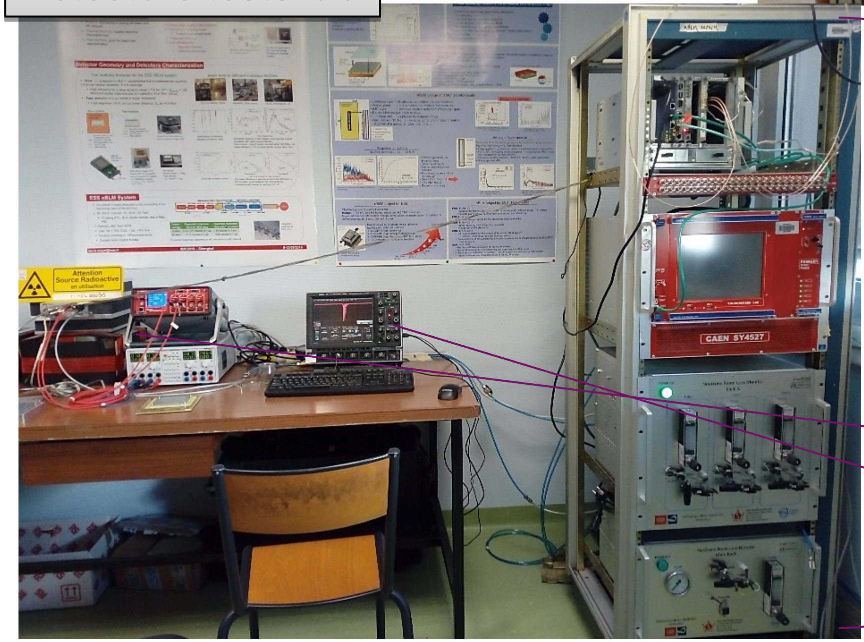


Detectors mounted



Gas tests

Detectors tests lab



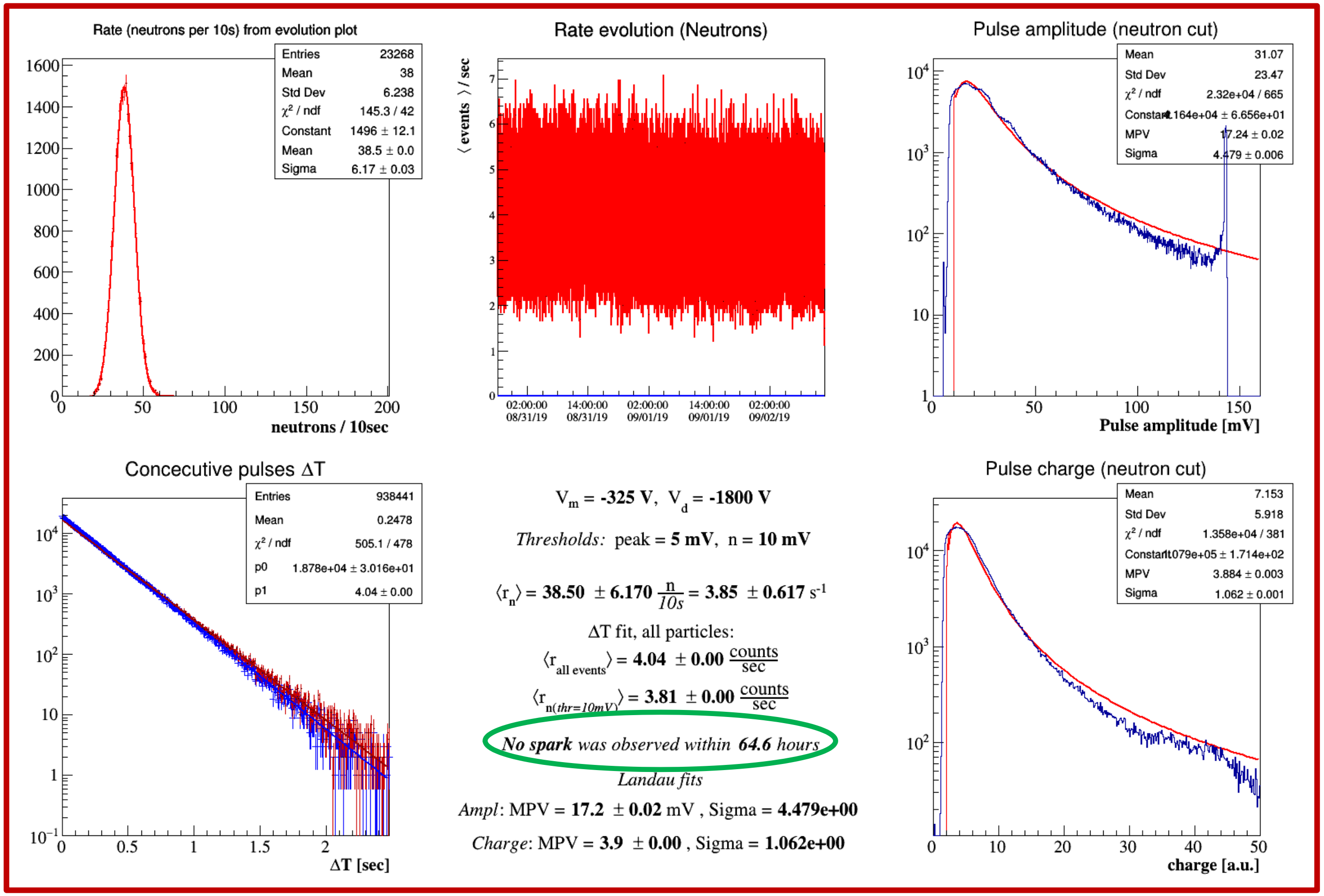
Rack with (from top to bottom)
1. MTCA+FMC card
2. SY4527 CAEN Crate with the HV A7030 and LV A2519
3. Gas distribution chassis
4. Gas main control chassis

Slow module S002 under tests

Neutron pulses

DETECTOR VERIFICATION

- Strict QA/QC of each detector



One of the outputs of the **verification tests**:

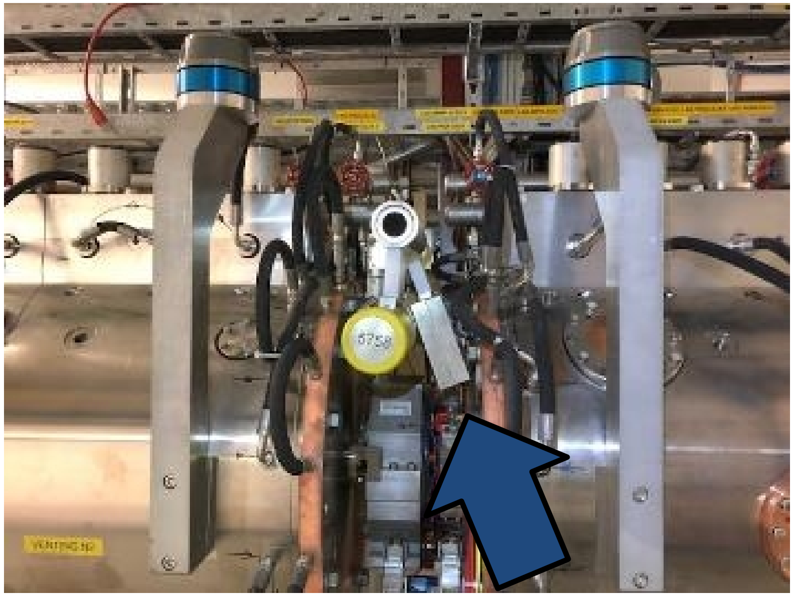
- Rate
- Rate evolution
- Amplitude distribution
- Charge distribution

Other include

- Amplitude stability
- Pedestal stability
- ToT, rise time, …

NBLM @ LINAC4

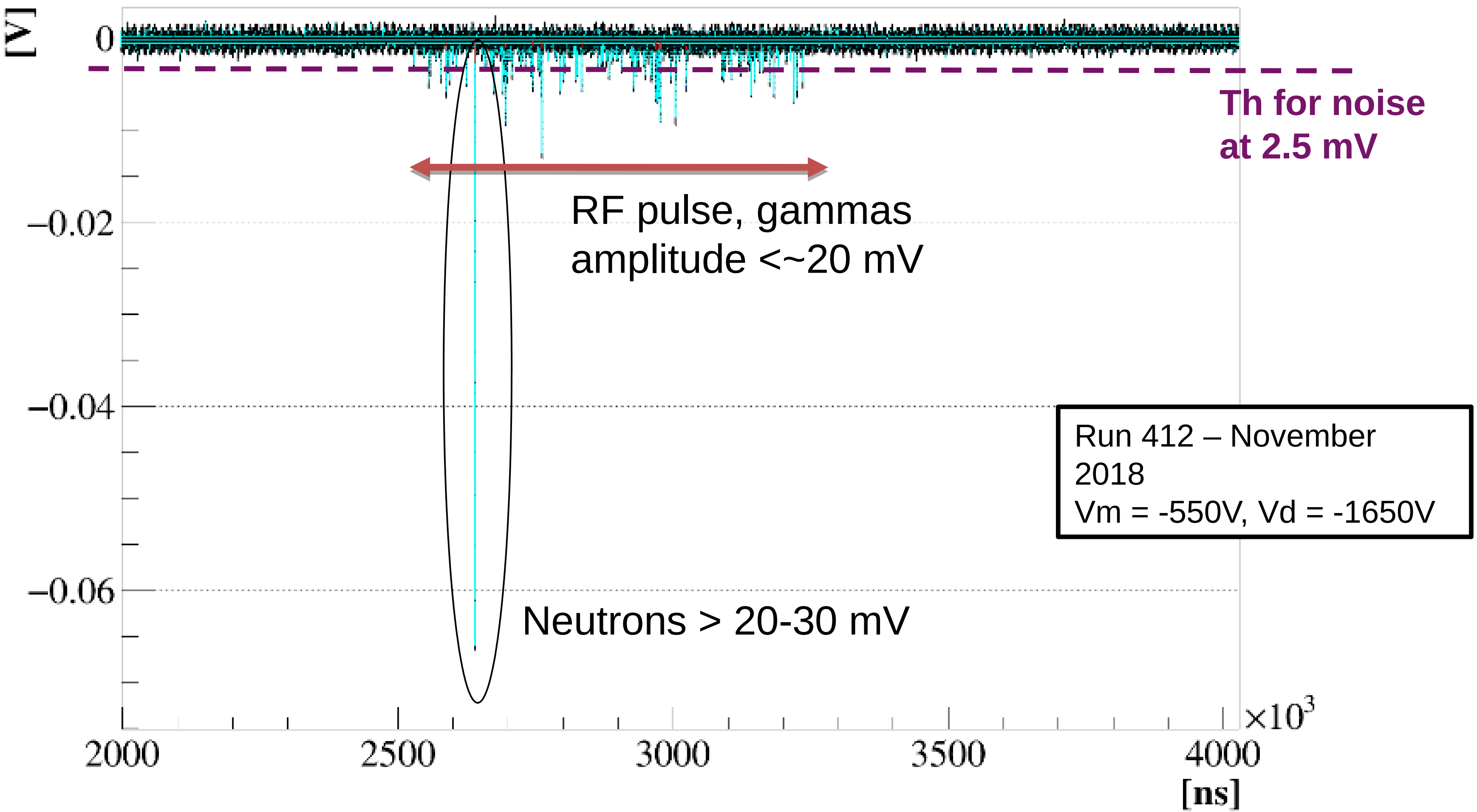
- **Fast nBLM module** installed between two DTLs at 13 MeV proton region
- Final mechanics and electronics (*pre-series*)
- Gas: He + 10% CO_2
- Installation in August 2018
- Three data campaigns
  - November 2018
    - Understanding the detector
    - Testing the FMC card
  - December 2018
    - Losses were produced
    - Data with oscilloscope and FMC
    - First version of FPGA code
  - Fall 2019 (NOW!)



- Data taking with a fast oscilloscope
  - 250 Ms/s
  - Full bandwidth
  - With trigger of Linac4 also recorded

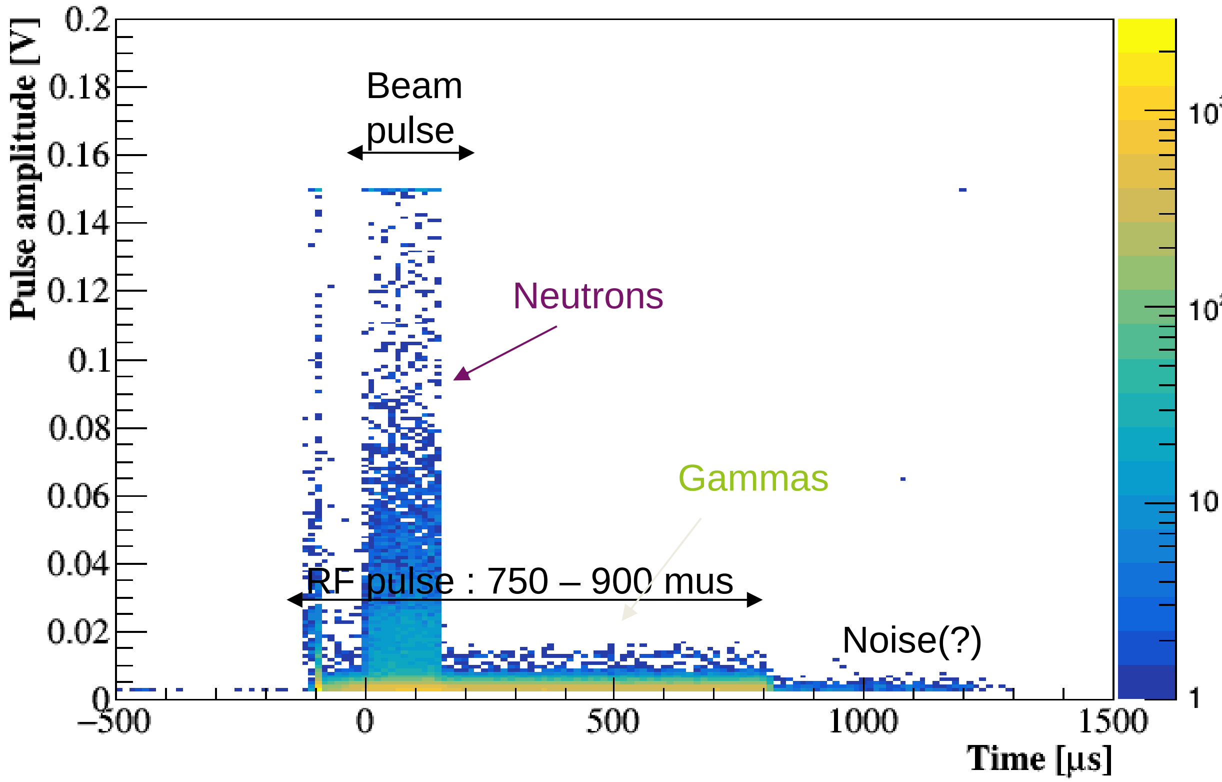
LINAC4 DATA

- Some history… Initially at Linac 4 we were detecting nothing so we increase the gain of the detector to force sparks to check detector was alive
- We start having events at 550V… ~50 -75 V higher gain than nominal



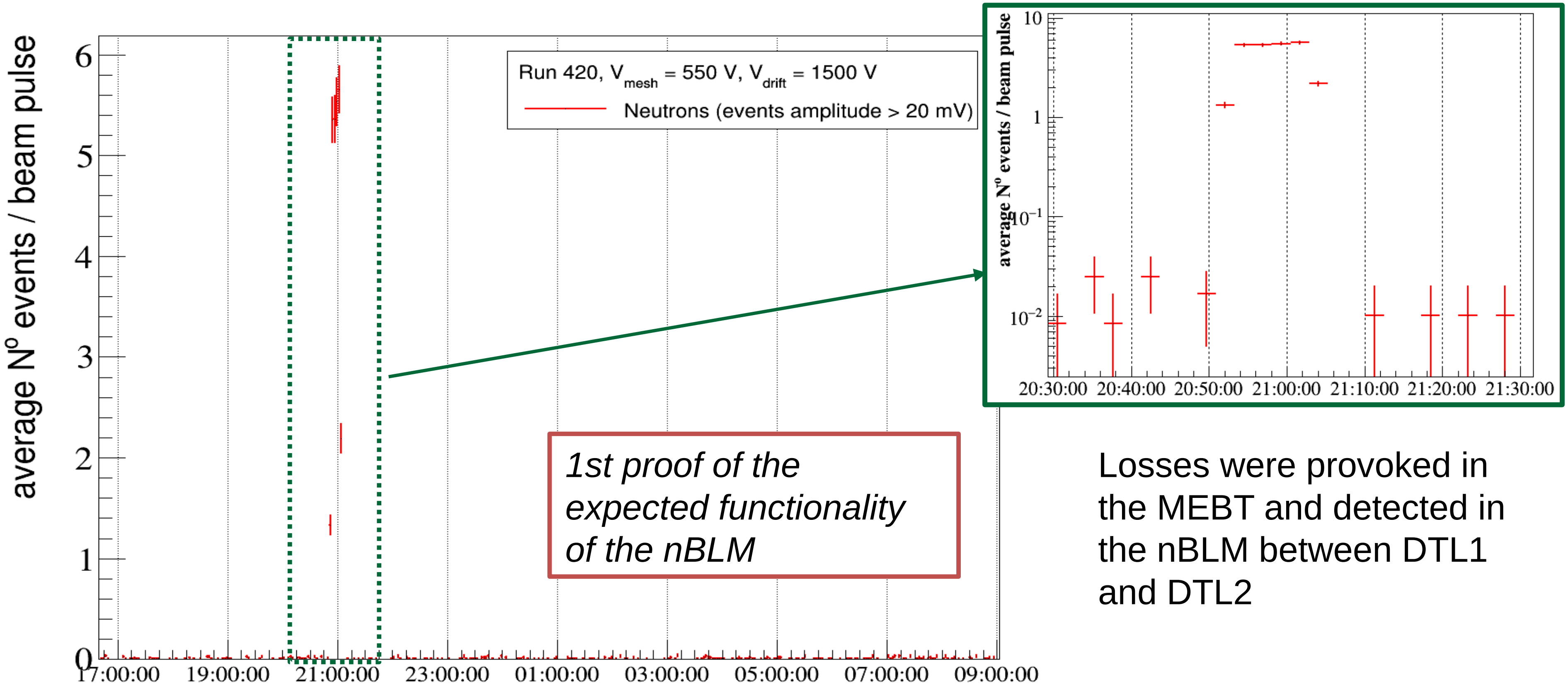
LINAC4 DATA

- Low amplitude events (gammas)distributed along the duration of the RF pulse ~750µs
- High amplitude events (neutrons) distributed along beam pulse (150µs)
- Same results in independent data set acquired with the FMC with FPGA integrated.



LINAC4 DATA – PROVOKED LOSSES

Run 420 – **December 2018**
Vm = -550V, Vd = -1500V

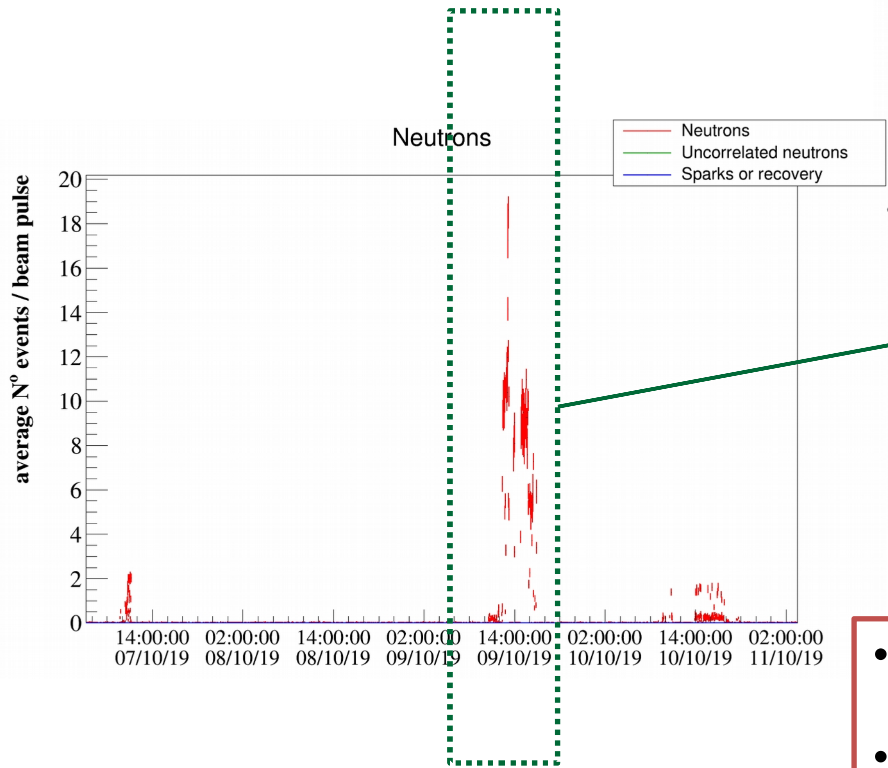


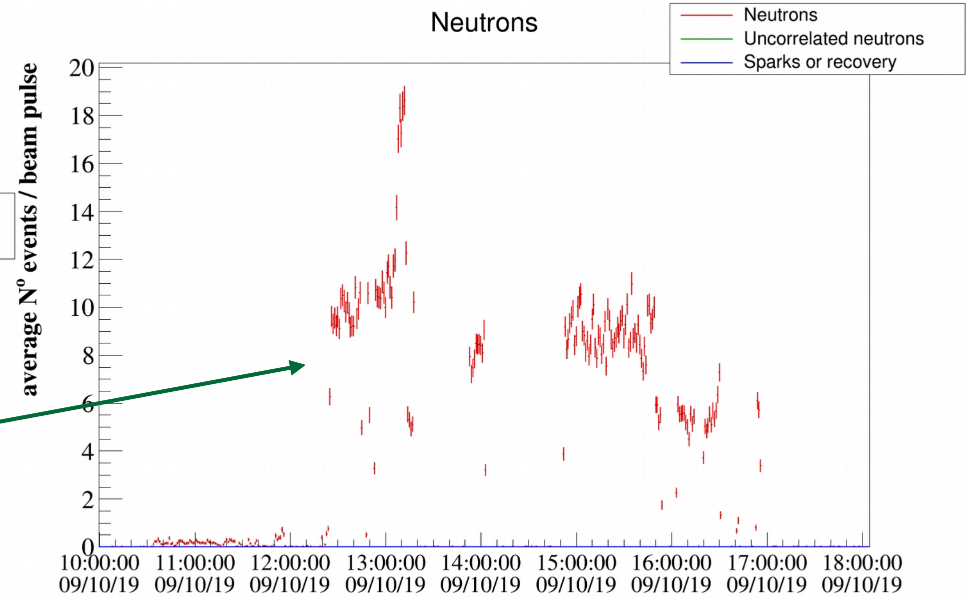
1st proof of the expected functionality of the nBLM

Losses were provoked in the MEBT and detected in the nBLM between DTL1 and DTL2

LINAC4 DATA – LOSS DETECTION DURING COMMISSIONING

Run 433 – **October 2019**
Vm = -525V, Vd = -1475V

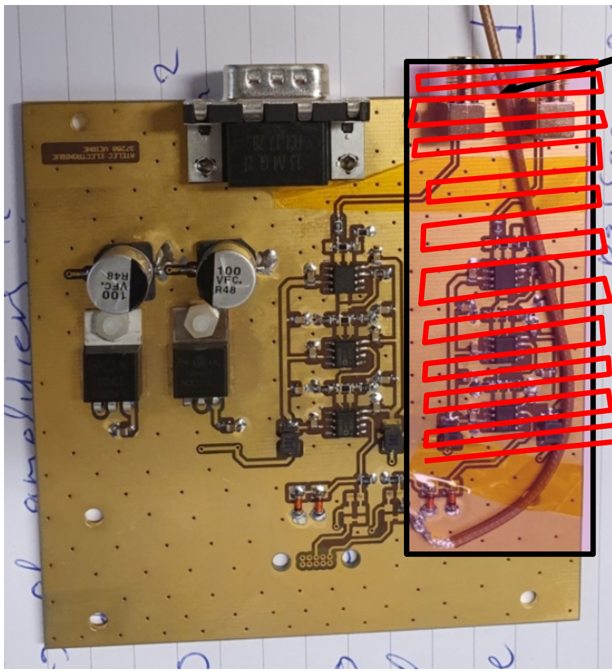




- *After one year installed detector operates in perfect conditions*
- *A fast analysis already show losses*
- *In principle that week they were producing losses in the quadrupoles*
- *Full Analysis on-going to integrate info from the trigger*

The losses were not produced by purpose. nBLMs saw them, the icBLM no.

(RE-)IRRADIATION OF 1ST CARD 24-25 / 09 / 2019

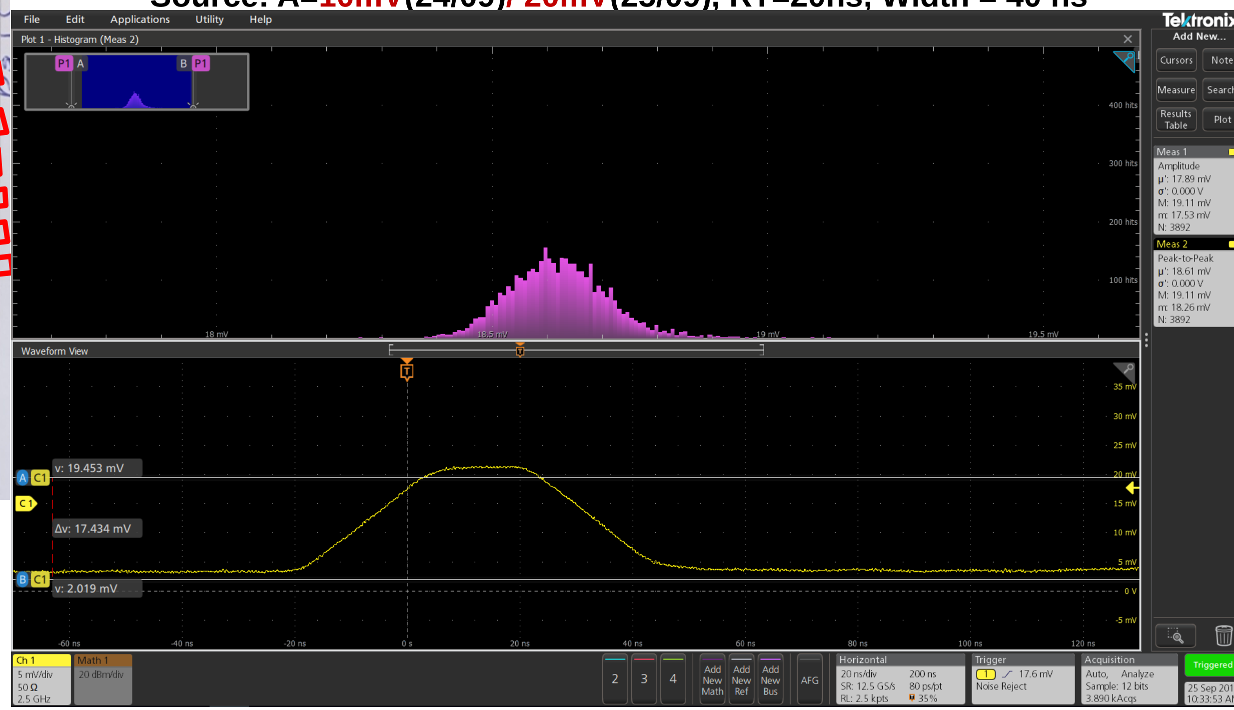


Irradiation zone
Scan from bottom left → up right
in steps of ~3 mm

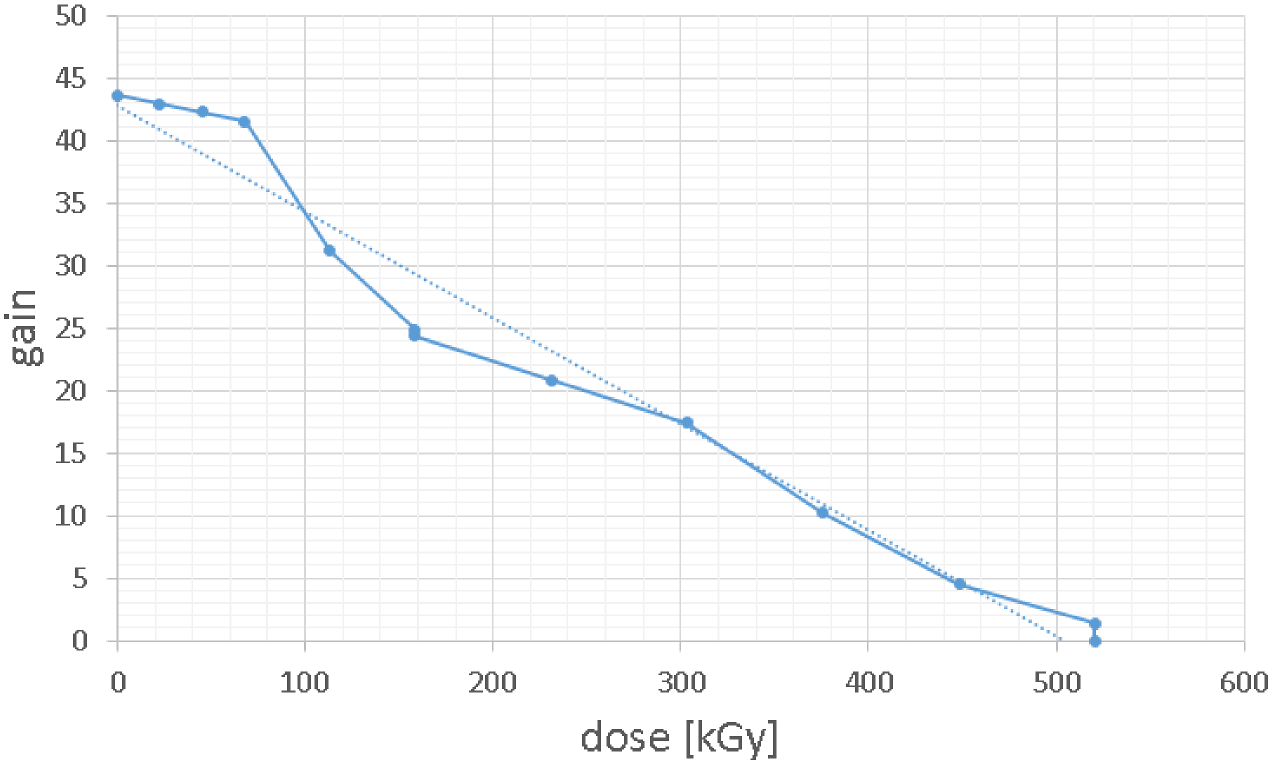
1 cycle = 2 passages (1 up + 1 down)

Beam: 1x1 cm²
E: 27 MeV
E @ the card: 24 MeV
Intensity: 50 nA

Source: A=10mV(24/09)/ 20mV(25/09), RT=20ns, Width = 40 ns



CARD 2: GAIN CHANGE



- Change in gain observed as a function of integrated dose
- Chain in gain seen in the pulse shape too
- Card already irradiated in July 2019 with 180 kGy
- Report under preparation

- In MC40 Cyclotron (Birmigham, UK)
- Protons 28 MeV
- Three cards were irradiated
- Report on-going

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FROM NOW ON…

- Production continues
  - Next 8 detector for DTL1 by the end of this year
- Waiting to receive new FEE cards with teflon-free SMA for the next detectors
  - However during the irradiation tests no damage was observed (in first cards, the others not accesible yet for investigation due to activation)
- Second and spare distribution crates ordered
- Experimental Tests
  - Want to repeat more neutron/gamma studies at a different operation point
  - Slow detector may be installed at ISIS in UK or at FERMILAB to see the response to losses as well

DE LA RECHERCHE À L'INDUSTRIE

Thank you for your attention

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Etablissement public à caractère industriel et commercial | R.C.S Paris B 775 685 019

Direction de la Recherche Fondamentale
Institut de recherche
sur les lois fondamentales de l'Univers
Service

Extra slides

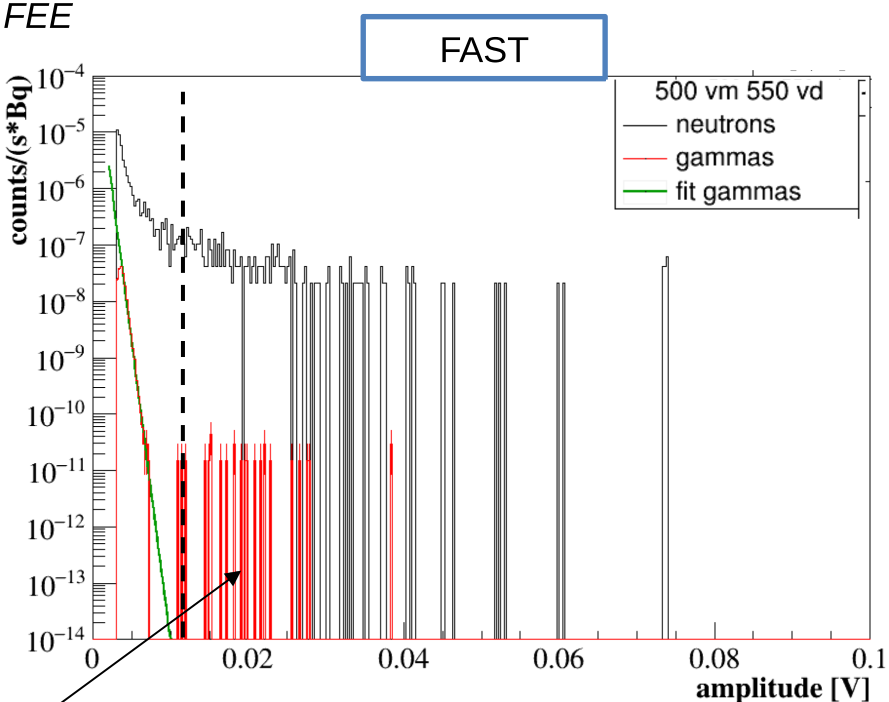
GAMMA/NEUTRON SUPPRESSION (II)

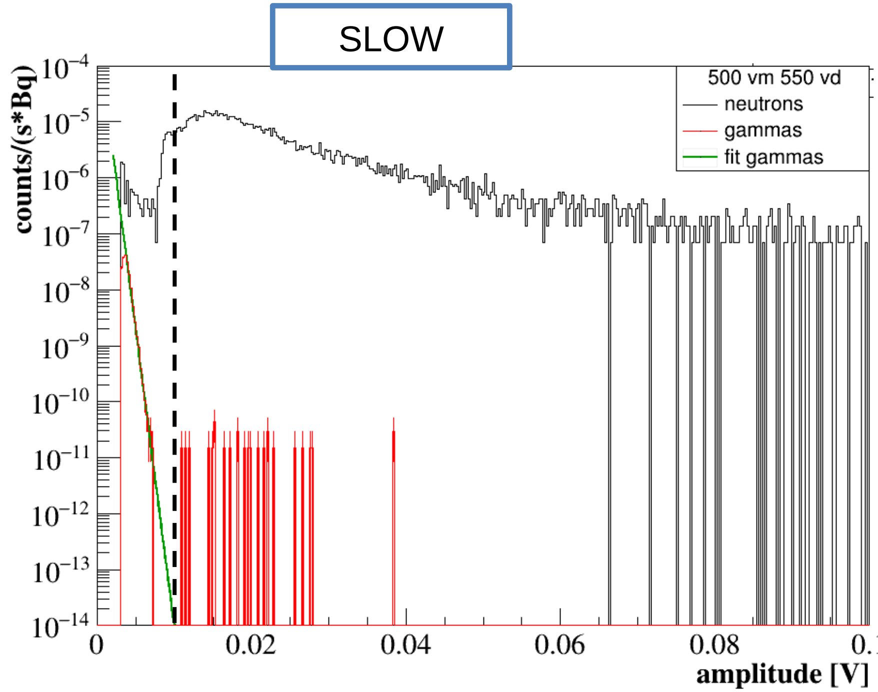
CEA Radioprotection Service

AmBe (n up to 10 MeV)

^{60}Co (1.17, 1.33 MeV gammas)

Using the final FEE card





Background from neutron source stored close by

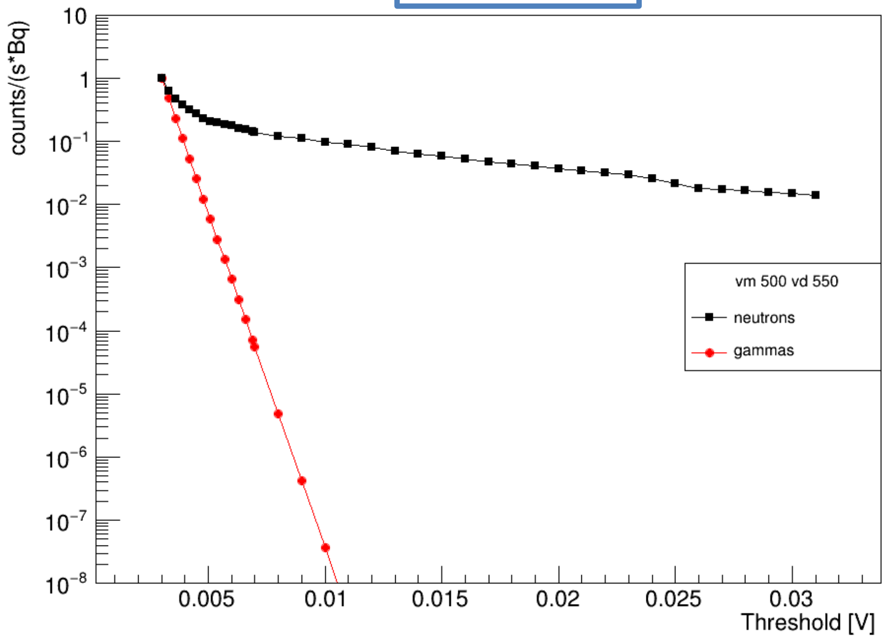
- The gammas follow an exponential decay also observed in the simulations
- For an initial neutron spectrum with several energies the separation for the fast worsen
  - And for the fast is strongly dependent on the energy threshold

GAMMA/NEUTRON SUPPRESSION (II)

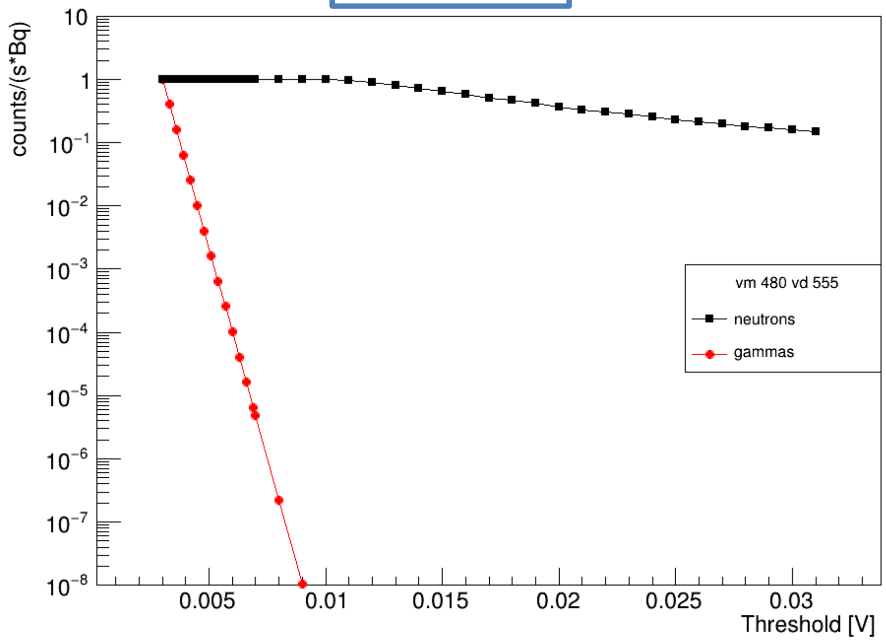
CEA Radioprotection Service

- In the case of the fast the discrimination is strongly dependent on the energy threshold
- A relative efficiency is computed for a range of energy thresholds

FAST



SLOW



QA/QT: OTHER VARIABLES