DE LA RECHERCHE À L'INDUSTRIE

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Kolympari, Crete
Greece

A Micromegas neutron detector as Beam Loss Monitor for the ESS Linac

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on behalf of the ***nBLM team***

www.cea.fr

WHY A NEW BLM

Why new Beam Loss Monitors (BLM)?

A need in the accelerator community:

- In **new high intensity hadron linear accelerators** even a beam loss at low energy could damage the accelerator or activate materials
  - Crucial to monitor **any small loss**
  - Keep the loss <~ 1 W/m to allow hands-on maintenance
    - ➔ *ESS 5MW → 2×10^{-5} /m of the total power (0.02 ‰)*
- Positioning of the BLM is important
  - Different beam lost signature in different areas of accelerator
  - At the **low energy part of the accelerator** only neutrons and photons can escape the beam pipe
  - Commonly used ionization chambers have little sensitivity in this area and are **affected by RF emission.**

> *"…the x-ray component is quite significant and can be even greater than the loss itself. A detector that is **sensitive to neutrons and not sensitive to x-rays** could be a possible solution. **Unfortunately it is hard to create such a detector** that would work in analog mode."*
>
> **A. Zhukov, WEYA2, PAC2013, Pasadena, CA USA**

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NEUTRON BEAM LOSS MONITORING

Signature of beam loss: **fast neutrons**

- ➔ Thermal neutrons can come from moderation inside the walls, so must be rejected
- ➔ Gamma's and X-rays present during normal operation, so the detector must be insensitive to them

Requirements:

- ➢ sensitive enough to *very small losses*
- ➢ fast enough to react on a *"catastrophic event"*
- ➢ appropriate for *high particle rates*
- ➢ reliable on long term
- ➢ radiation hard

nBLM (*neutron Beam Loss Monitor*) →

Micromegas detector equipped with a combination of neutron convertors and moderators

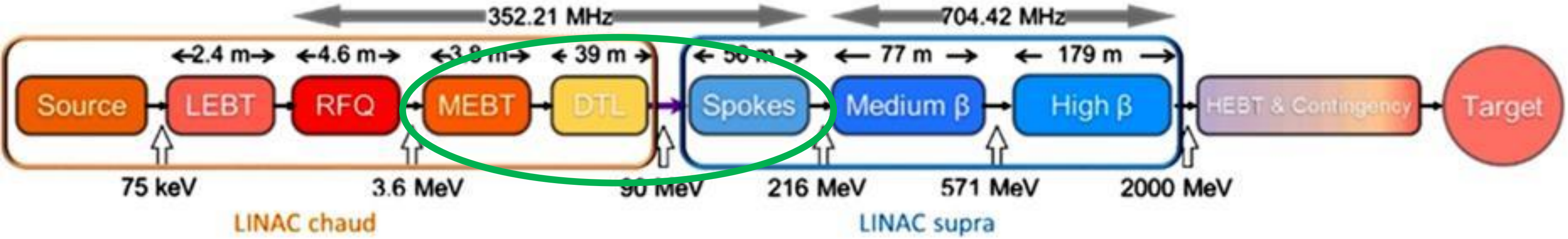
- ➔ *Detection of fast neutrons*
- ➔ *Low efficiency for thermal neutrons*
- ➔ *Strong suppression of gammas*
- ➔ *Fast system response (few µs)*

CONTEXT: ESS NBLM SYSTEM

In-kind contract between the European Spallation Source (ESS) & IRFU (CEA)
+ Lotz University (FPGA programming)

- Design, construction, test and commissioning of 84 detectors by Nov 2019
- Part of the Beam Instrumentation systems of the ESS Accelerator (Lund, Sweden)
- Dedicated mainly to the low energy region of the accelerator.

ESS BLM system lead: *I. Dolenc Kittelmann*
CEA coordinator: T. Papaevangelou



Pulse length (ms)	2.86
Energy (GeV)	2
Peak current (mA)	62.5
Pulse repletion freq. (Hz)	14
Max. average power (MW)	5

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ESS BLM system lead*: I. Dolenc Kittelmann*
CEA coordinator: T. Papaevangelou

nBLM-ESS System

- Req. & spec. develop. : ESS
- Concept: CEA + ESS
- Detectors: CEA
- Gas System: CEA
- DAQ firmware: LUT
- Control System: CEA
- Integration: ESS

Jul 2016: Kick-off

Dec 2016: PDR1.1

Jul 2017: PDR1.2 Start prototype tests

Dec 2017: CDR1.1

Feb 2019: CDR1.2 (**Final**)

July 2019: First detectors at ESS

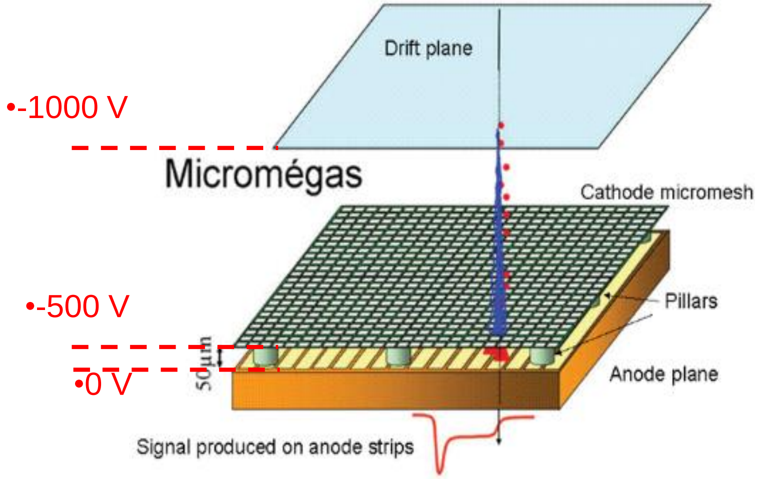
4th quarter 2019: SAR and vertical integration test

commissioning at ESS: end 2019

THE MICROMEGAS DETECTOR

The ***Micromegas*** *detector*

- Multi-Pattern Gaseous Detector, invented in 1995 at CEA Saclay[1]
- Parallel plate detector with a thin metallic mesh dividing the gas volume in 2 parts:
  - drift region (1 to 100 mm) → E ≈ 100 V/cm
  - amplification region (30 to 150 μm) → E ≈ 100 kV/cm
- Grounded read-out: conductive strips connected to FEE
- Pillars are used to reinforce the response uniformity



Small amplification gap:

- very strong and uniform electric field with low voltages → high gain / discharges non destructive
- single stage of amplification → fast signals
- fast ion collection → High rates (~10^6 s^{-1} mm^{-2})
- radiation hard

MPGD fabrication techniques → towards industrialization:

- Easy to manufacture at low cost & big surfaces

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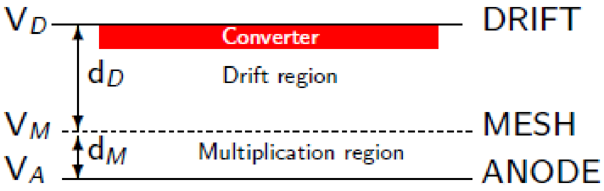
[1] Y. Giomataris, P. Rebourgeard, J.P. Robert and G. Charpak, "Micromegas: A high-granularity position sensitive gaseous detector for high particle-flux environments", Nuc. Instrum. Meth. A 376 (1996) 29.

NEUTRON DETECTION WITH MICROMEGAS

Neutron detection ➔ *neutron-to-charge converter*

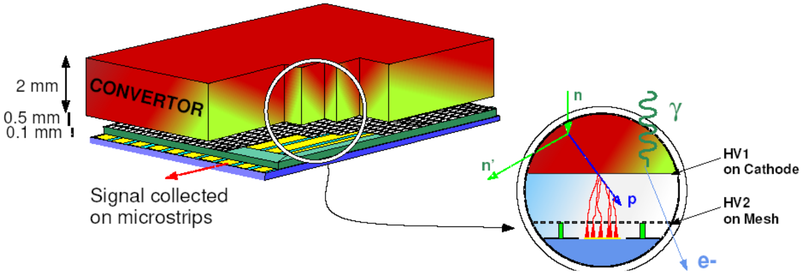
- Solid converter: thin layers deposited on the drift or mesh electrode (^{10}B, $^{10}B_4C$, ^{6}Li, ^{6}LiF, U, actinides…)
  - – Sample availability & handling
  - – Efficiency estimation
  - ✗ *Limitation on sample thickness from fragment range*
    ⇒ limited efficiency
  - ✗ Not easy to record all fragments



In use at nTOF, CERN, since 2001 for neutron beam flux and profile monitoring

- Detector gas (^3He, BF_3…)
  - – Record all fragments
  - – No energy loss for fragments ⇒ reaction kinematics
  - – No limitation on the size ⇒ high efficiency
  - ✗ *Gas availability*
  - ✗ Handling (highly toxic or radioactive gasses)

- Neutron elastic scattering
  - ➢ gas (H, He)
  - ➢ solid (paraffin etc.)
    - ✓ Availability
    - ✓ High energies
    - ✗ Efficiency estimation & reaction kinematics



DEMIN Micromegas for the MegaJoule program
https://doi.org/10.1016/j.nima.2005.11.184

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THE PROPOSED NBLM DETECTORS FOR ESS

Need for high sensitivity & fast response
*➔ 2 complementary types: “**slow**” & “**fast**”*

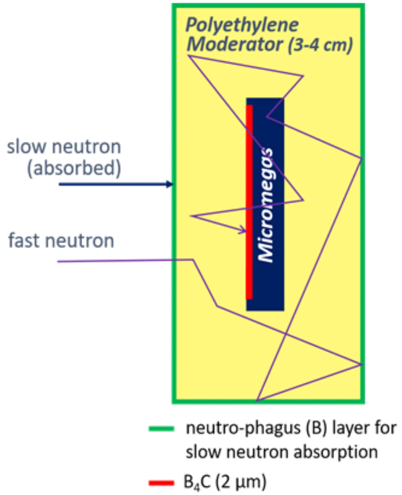
- detector chamber identical
- differences: neutron-to-charge particle convertor and the surrounding of the slow with absorber + moderator

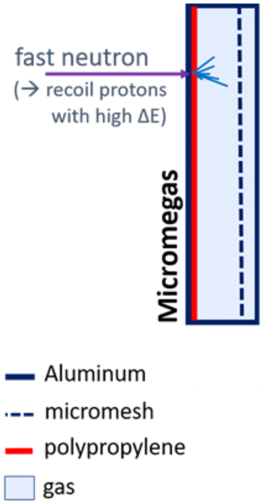
➔ “slow” detector (MM + B_4C) capable of monitoring fast neutron fluxes ~ few n · cm^{-2} s^{-1}

  - Neutron converter: 0.2 – 1.5 μm $^{10}B_4C$, $^{10}B(n, \alpha)^7Li$ reaction
  - Tuneable efficiency (converter thickness, segmentation, natural boron) max factor: 7×4×5 = 140
  - Detection of **fast neutrons after moderation** in polyethylene (5 cm)
  - Thermal neutron absorber (5 mm borated rubber)
  - 4π acceptance
  - Time response ~ 200 μs

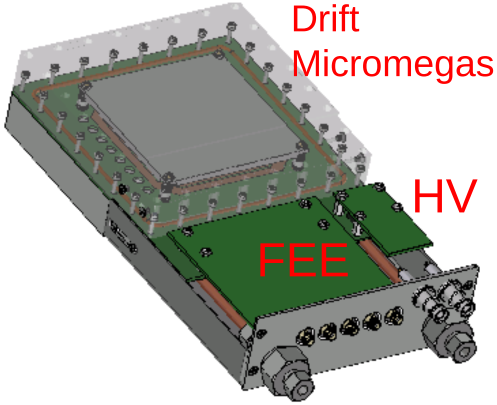
➔ “fast” detector (MM + H-rich target) appropriate for high flux - high energy neutrons

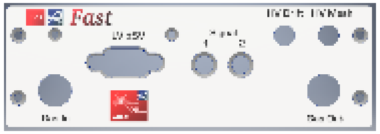
  - Neutron converter: 125 μm Mylar, aluminized (50 nm)
  - Insensitive to thermal neutrons
  - High particle fluxes
  - Fast time response ~0.01 μs
  - Directional
  - Lower detection efficiency (~100 times smaller)

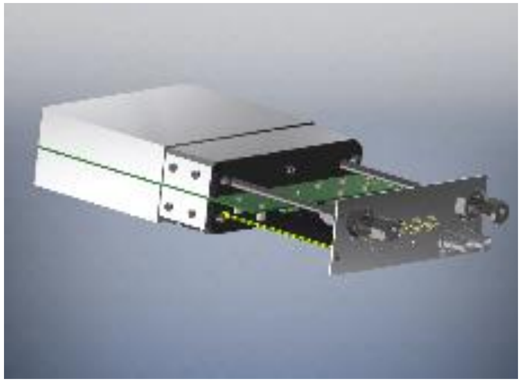




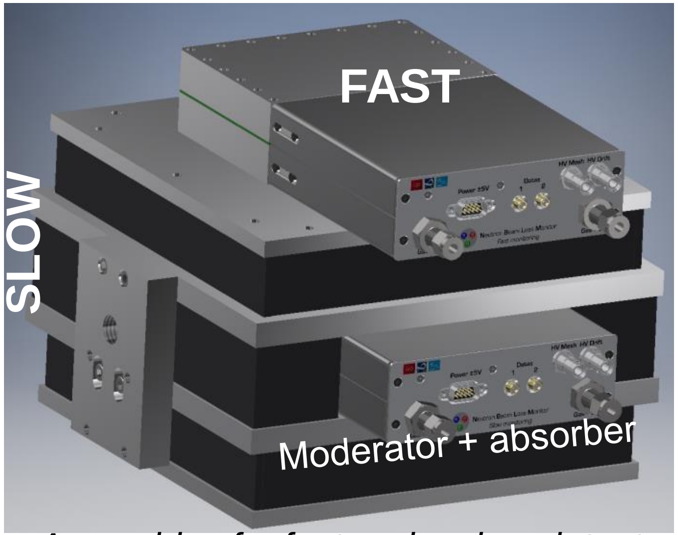
THE nBLM FINAL CHAMBERS







Chamber + Faraday Cage
~ 20 x 15 x 2 cm^3



Assembly of a fast and a slow detector
size ≈ 20 × 25 × 25 cm^3 (~14 kg)

Moderator + absorber

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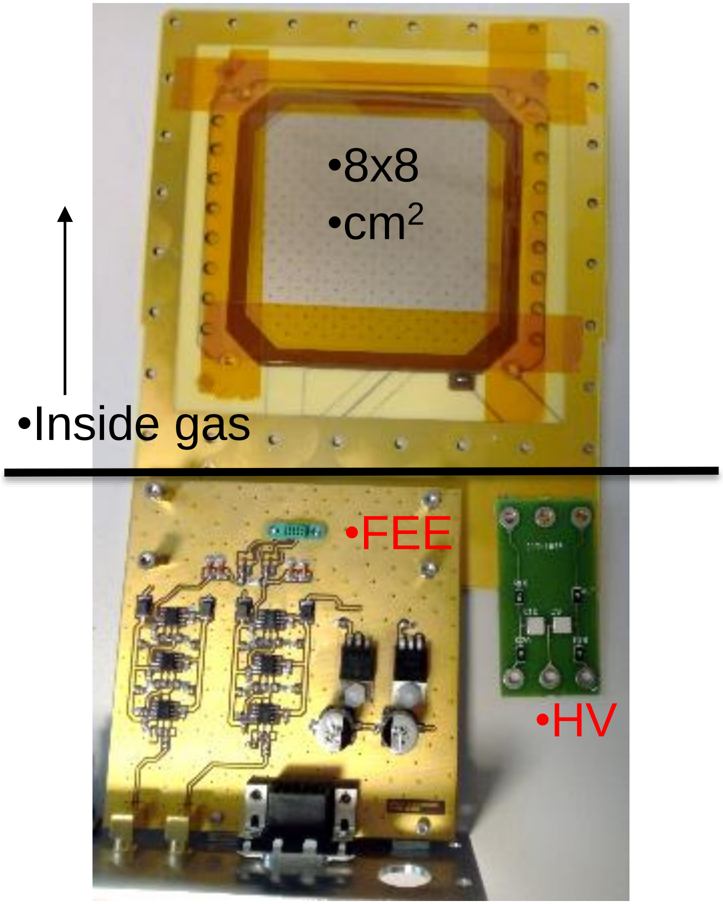
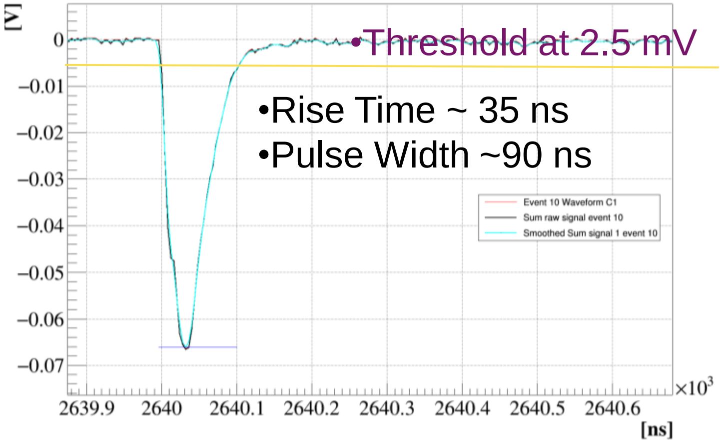
THE nBLM MICROMEGAS



- Bulk Micromegas (MPGD workshop at CEA/Saclay)
- Segmented in 4 sectors to accommodate for final rates
- Only one signal output (adding 1 to 4 segments together)
- Small drift gap: ~2 mm
- Operating in He+10% CO_2, 1 atm
- FEE card and amplifiers designed at CEA
- Can operate in counting and charge mode

Single neutron acquired with the nBLM electronics



•Threshold at 2.5 mV

•Rise Time ~ 35 ns

•Pulse Width ~90 ns

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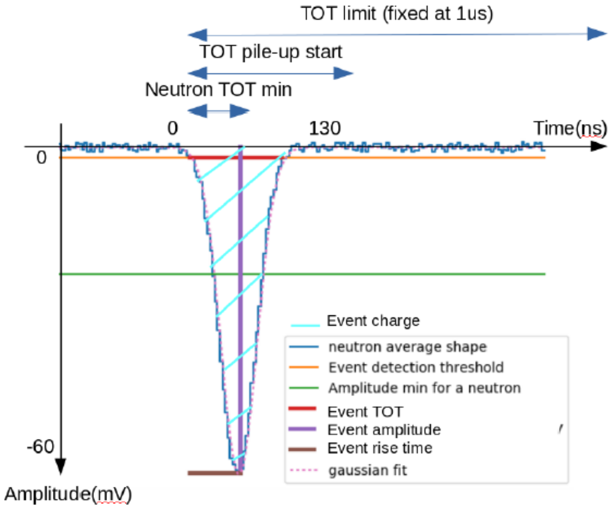
nBLM ACQUISITION: SINGLE NEUTRON COUNTING

Acquisition logic

- FMCs provide data continuously, every **4 ns**
- The algorithm compares the values to a threshold
- When trigger, pulse parameters are provided (TOT, amplitude)
- Neutron to gamma discrimination is based on **amplitude threshold**
- The number of neutrons per µs and the total charge (integral) is provided
- When pileup observed counting is based on charge

  ➔ The pulse charge distribution from neutron events has a constant shape. The mean value can be used to calculate the average number of neutrons
- Continuous integration is equivalent to current mode (1 reading per µs)
- Self - calibration of pulse amplitude and pedestal runs to check stability

BEE boards



DETECTOR PERFORMANCE

- The ESS nBLM is a system ***under development***
- The commissioning of the ESS linac is planned to start in 2019 and the actual condition (particle yields, background, E/M noise etc) are unknown
- As a result, the performance of the nBLM detectors is not known can only be estimated by:
  - MC simulations of loss scenario (ESS)[1] and of the detector response (Saclay)[2]
  - Detector characterization measurements in neutron and gamma ray facilities
  - Measurements at similar facilities for proof of principle and sensitivity estimation
    ➔ *Test at Linac4 at CERN*

[1] *I. Dolenc Kittelmann, "Report on the MC simulations for the ESS BLM", ESS, Lund, Sweden, Rep. ESS-0066428, Dec. 2016.29*

[2] *L. Segui, "Monte Carlo results: nBLM response to EES beam loss scenarios", CEA Saclay, France, Rep. CEA-ESS-DIA-RP-0023, July 2017*

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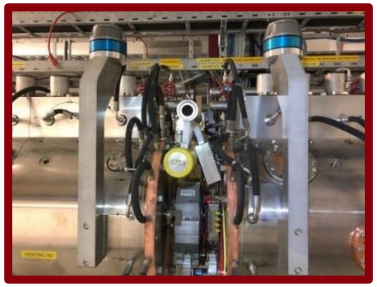
EXPERIMENTAL VALIDATION CAMPAIGN




July 2016

Kick-off

MC40- Cyclotron Birmingham, UK

Dec 2017

Correlation rate and intensity of the beam

IPHI, CEA, France

Jan. 2018

Time Response

AMANDE, IRSN France

Mar. 2018

Calibration n/γ discr.

ORPHEE, CEA France

Apr. 2018

Thermal neutrons

LINAC4 (CERN)

Nov-Dec. 2018

Real accelerator conditions

High intense n/γ sources, CEA France

Feb. 2019

n/γ discrimination

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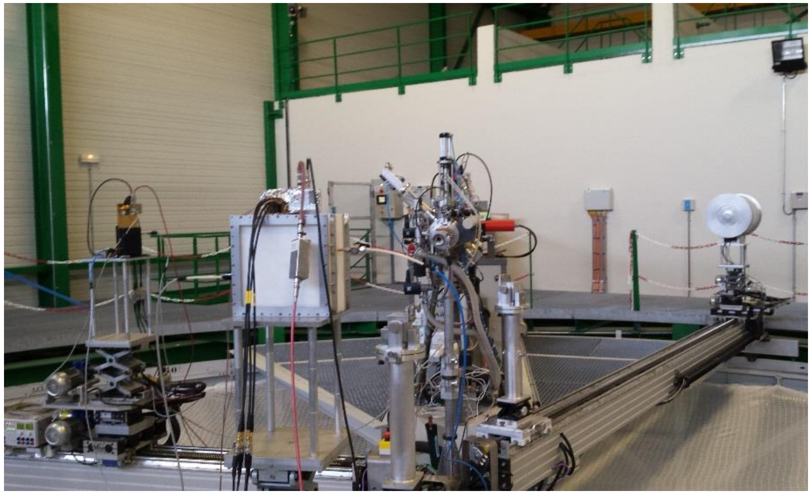
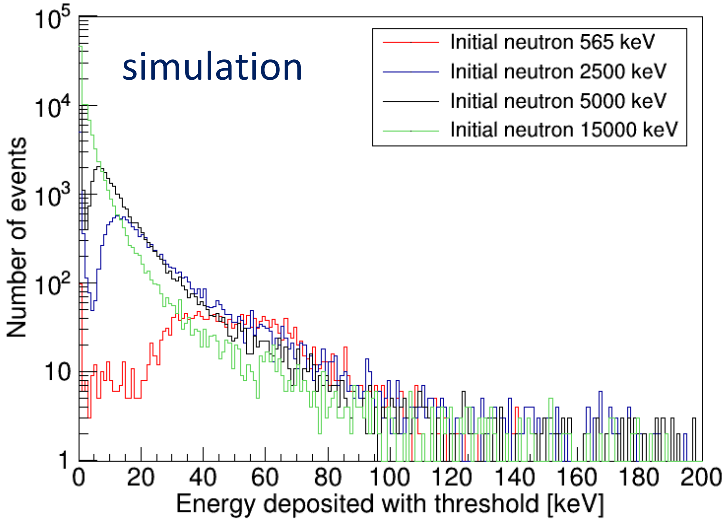
TESTS AT AMANDE

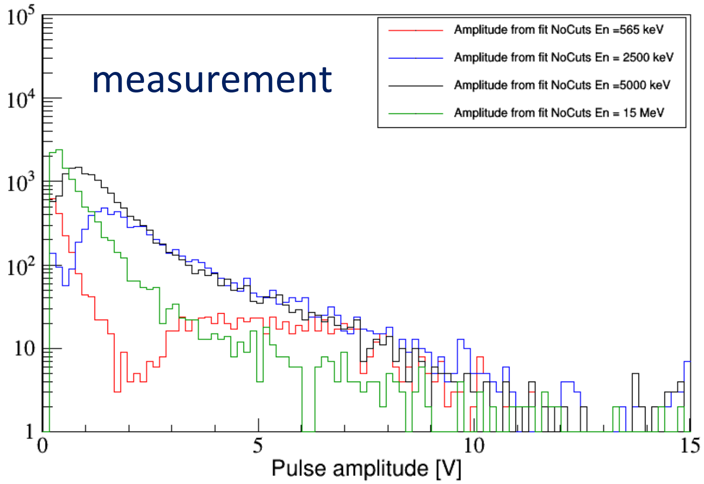
- Both slow and fast prototypes were tested at the following neutron energies: *565 keV, 1.2 MeV, 2.5 MeV, 5 MeV, 15 MeV*
- Varied the thickness of the polyethylene moderator of the **slow detector** between *3 – 7 cm*. The neutron convertor was *1.5 μm* $^{10}B_4C$, placed at *0.4 mm* from the mesh
- Tested two convertors for the **fast detector**: *100 μm Mylar* and *1 mm polypropylene*. Both samples had a layer of *50 nm Al* and were placed at *1.9 mm* distance from the mesh
- The 565 keV field is produced using a *LiF* target ➔ contamination by 6-7 MeV gammas from $^{19}F(p,\alpha\gamma)O^{16}$ of ~equal flux. Using an AlF_3 target instead only gamma field ➔ **measure γ/n suppression**.
- A shadow cone used for backscatter suppression. IRSN reference detectors for the flux.
- Acquisition with digital oscilloscope ➔ possible to detect beam fluctuations



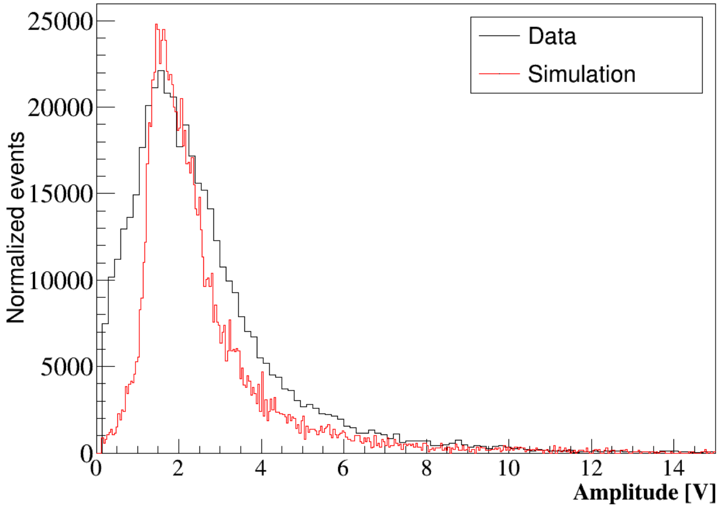
SIMULATION VALIDATION

Fast detector





Slow detector



- Good agreement with simulation
- Pulse amplitude spectrum of slow detector independent with neutron energy
- Energy calibration possible for both detectors thanks to the peaks

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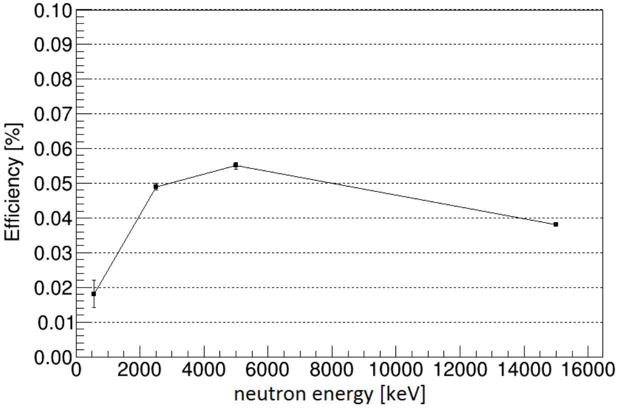
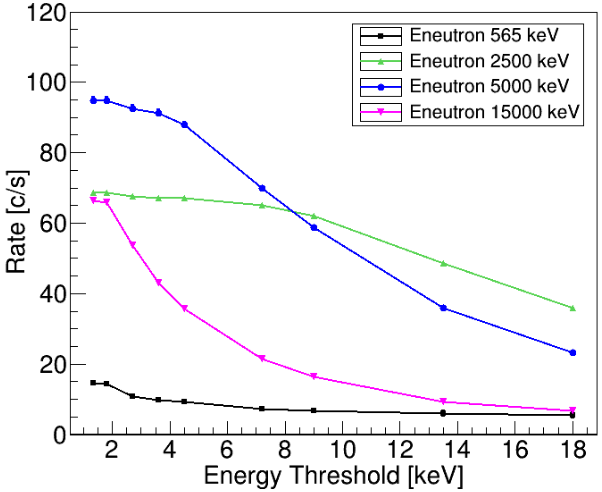
DETECTION EFFICIENCY

Fast detector

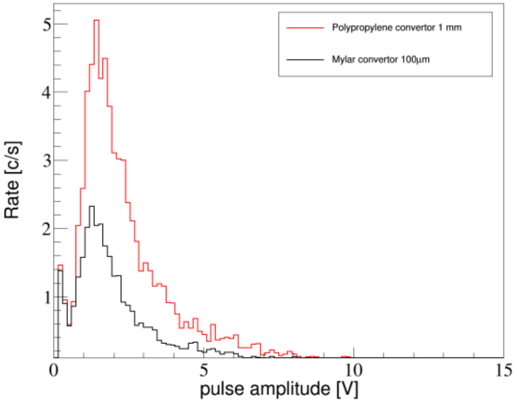
Dependence with neutron energy



Dependence with threshold



Mylar vs Polypropylene



Double efficiency when 1 mm polypropylene is used instead of 100 µm Mylar.

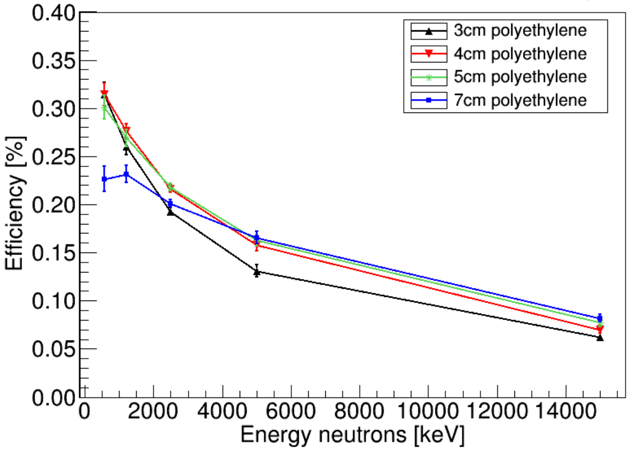
However, we choose the **Mylar** due to the **stability** of the metallization, sacrificing a factor 2 in count rate.

For the slow detector the area of the moderator is used for the calculation (25×25 cm²)

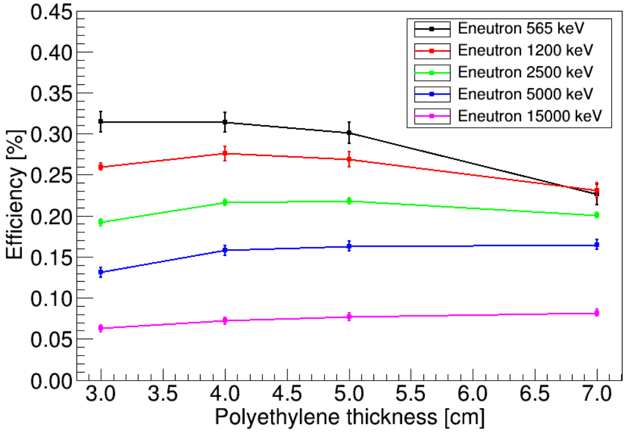
While for the fast the active zone (8×8 cm²) !

Slow detector

Dependence with neutron energy



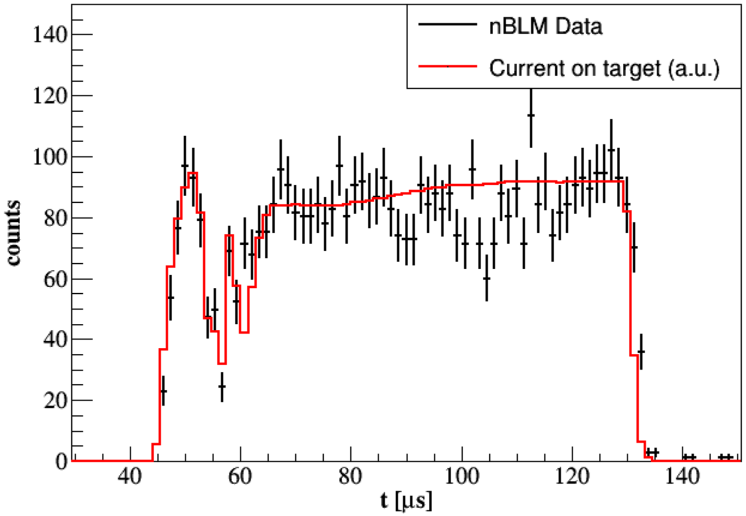
Dependence with polyethylene



Moderator thickness chosen for final detector: **5 cm**

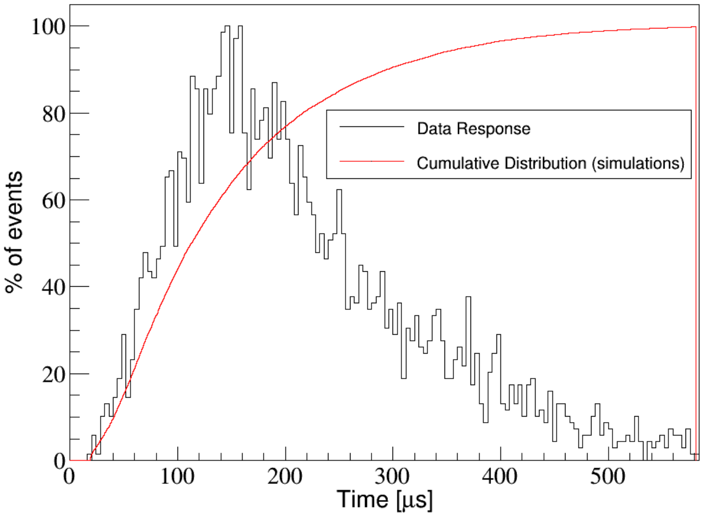
TIMING RESPONSE

Fast detector



- immediate response
- count rate in direct correlation with the intensity of the beam current

Slow detector



- due to moderation time most of the events are recorded with a delay of 100-200 µs.
- in agreement with simulation
- higher efficiency ➔ a significant number of the events (~5% of the total) will be register within the first 5 µs, so possible to use for early warning

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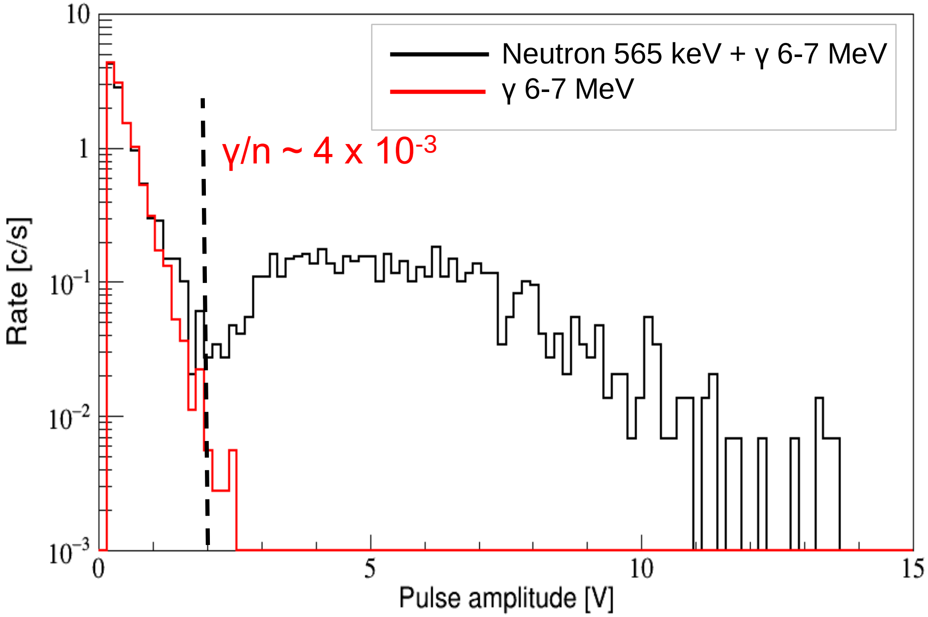
GAMMA TO NEUTRON SUPPRESSION

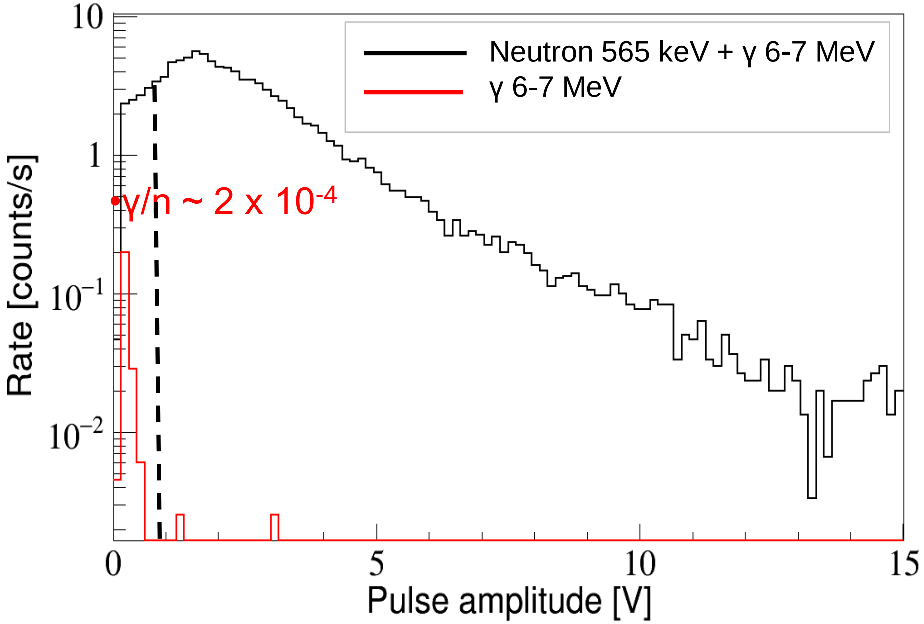
Vm = - 500 V
Vd = - 700V

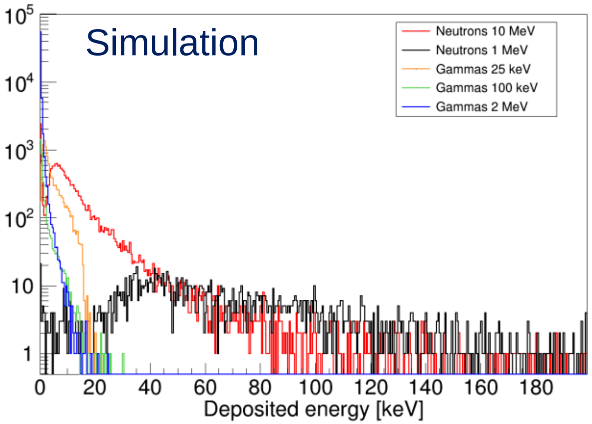
Fast detector



Slow detector

Vm = - 500 V
Vd = - 540V





- The lower efficiency to gammas is due to the difference in the **ionization power between ions and electrons.**
- The choice of **He gas enhances the suppression**
- In the case of the slow detector the suppression is stronger due to :
  - α or ^{7}Li ions instead of protons of fixed energy
  - Smaller drift gap (0.4 vs 1.9 mm) for this measurement

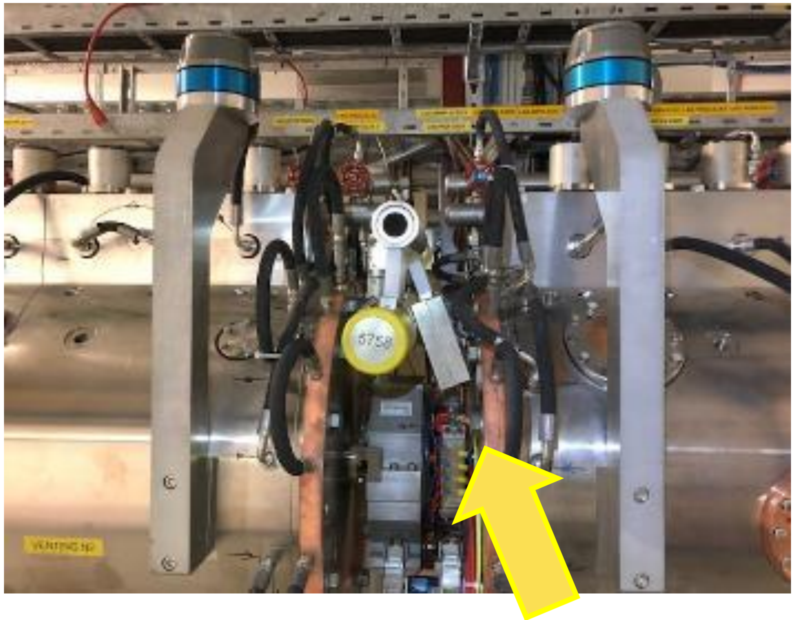
TEST @ LINAC4

Fast nBLM module installed between two DTLs at ~13 MeV proton region

- Final mechanics and electronics (*pre-series*)
- Gas: He + 10% CO_2
- Two data campaigns
  - November 2018

    Understanding the detector, test FEE in accelerator conditions…
  - December 2018

    Losses were produced



Data taking with a 2.5 GHz oscilloscope
- 250 Ms/s
- Full bandwidth
- Possibility to use trigger from Linac4

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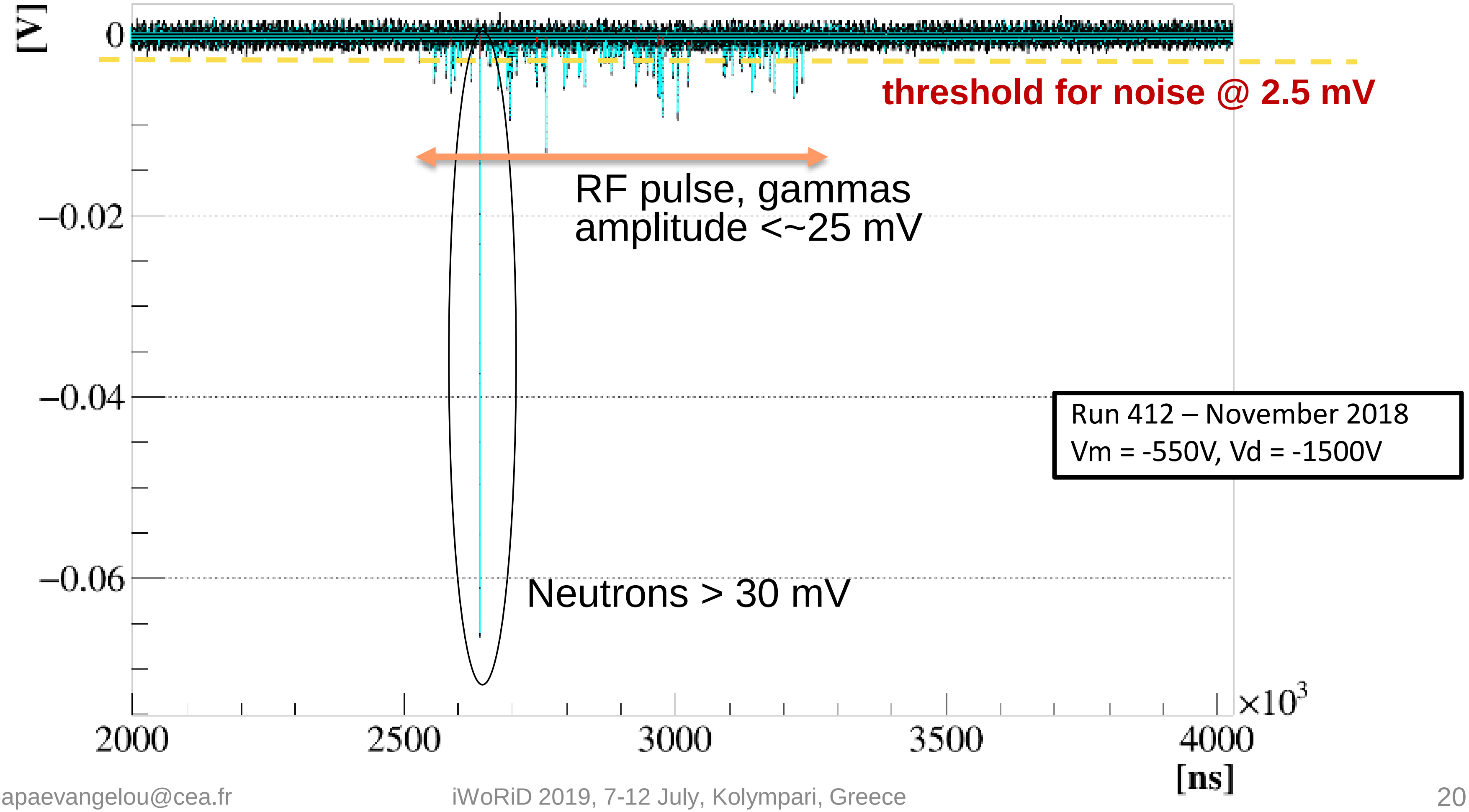
LINAC4 DATA

- *Some history…* Initially nBLM @ Linac4 shown no signal ➔ increase gain of the detector to force sparks to check detector was alive
- At 550V… ~50 -75 V higher gain than nominal, we started having events…



threshold for noise @ 2.5 mV

RF pulse, gammas amplitude <~25 mV

Neutrons > 30 mV

Run 412 – November 2018
Vm = -550V, Vd = -1500V

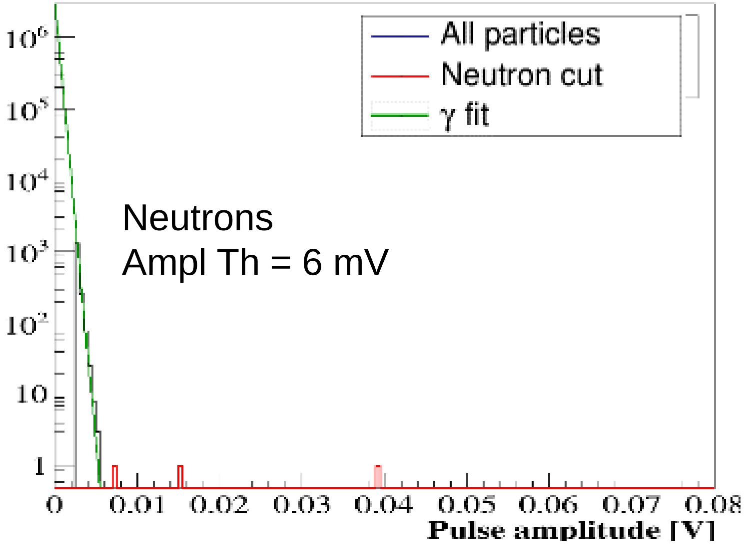
LINAC4 DATA – PROVOKED LOSSES

Vmesh = - 525 V
Vdrift = - 1000 V

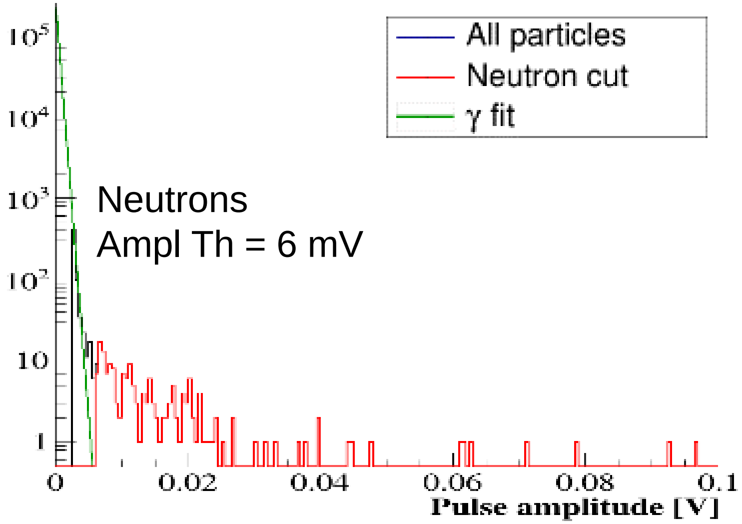
Run 414
No losses

Run 415
Losses

Amplitude

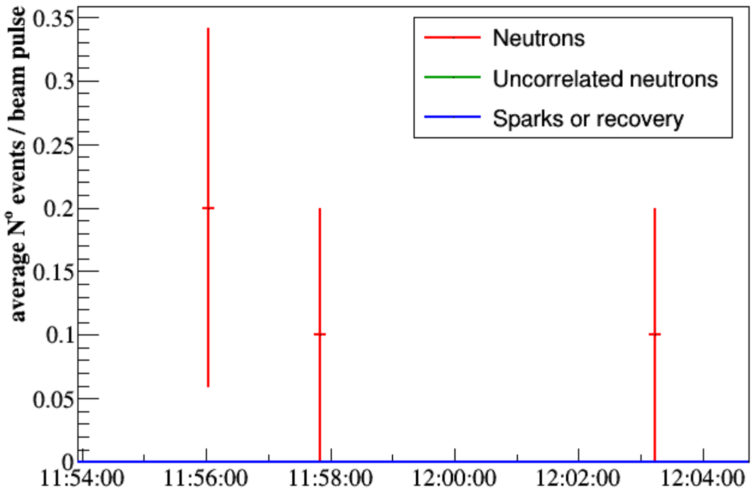


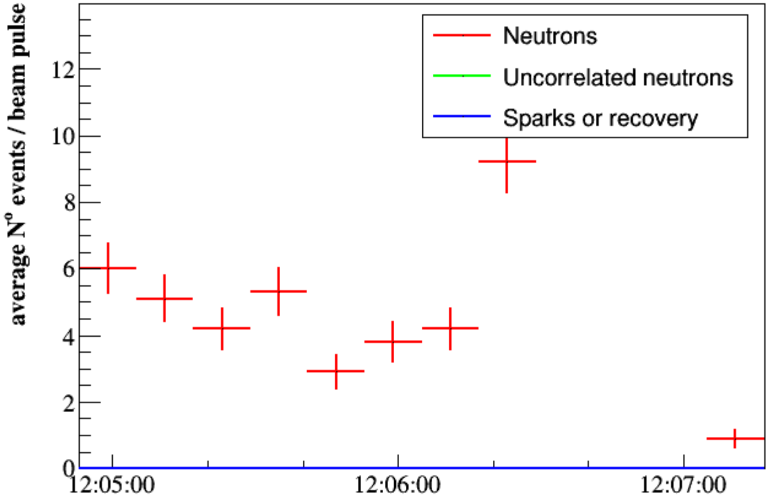
Neutrons
Ampl Th = 6 mV



Neutrons
Ampl Th = 6 mV

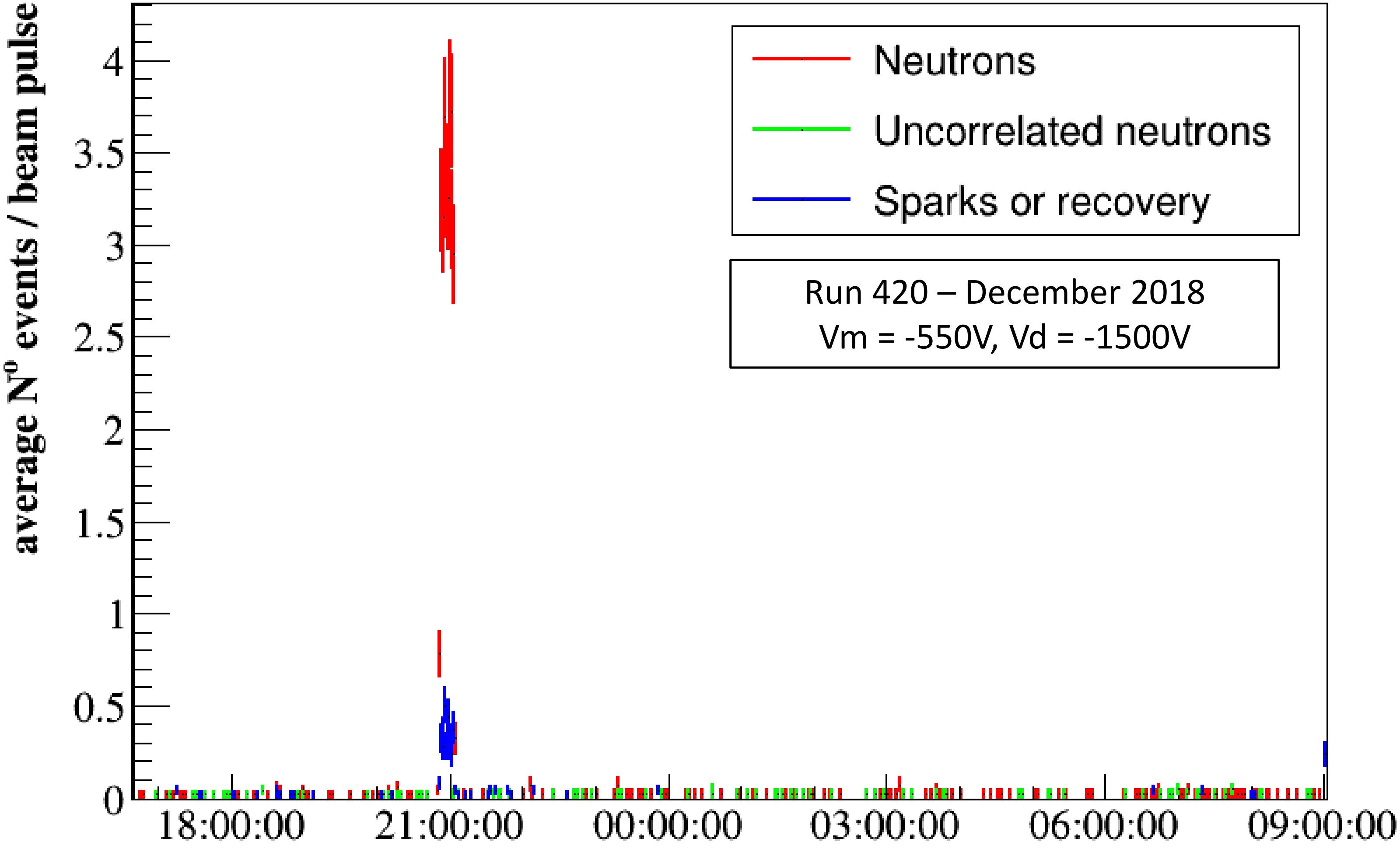
Average rate





LINAC4 DATA – PROVOKED LOSSES

1st proof of the expected functionality of the nBLM



Run 420 – December 2018

Vm = -550V, Vd = -1500V

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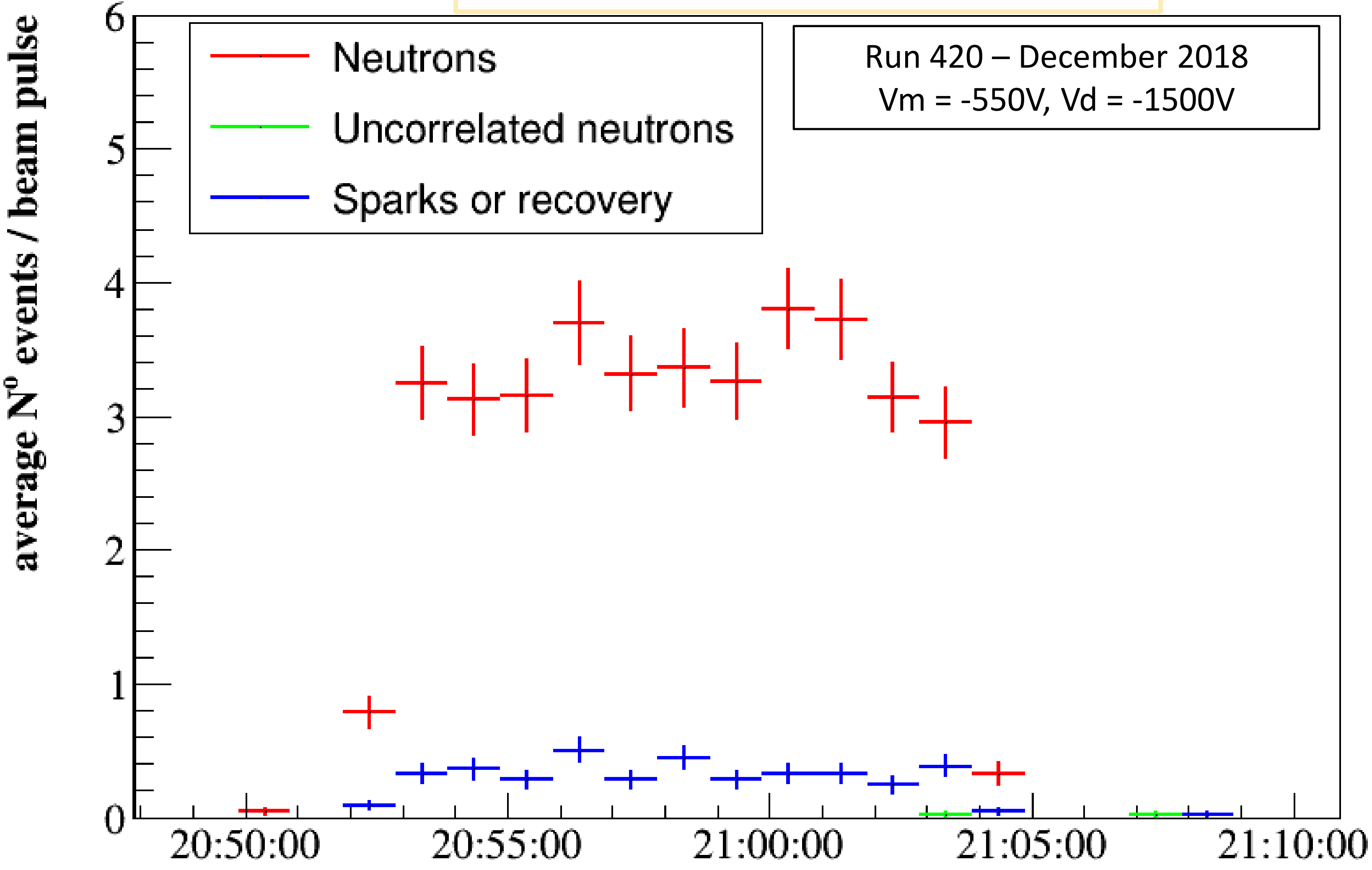
LINAC4 DATA – PROVOKED LOSSES

Zoom of previous slide
Losses were produced btw 20:50 – 21:05



CONCLUSIONS

- A new application of Micromegas detectors in Accelerator Beam Instrumentation
- A lot of interest from the accelerator community (SARAF…)
- Detector concept, design, first prototypes and proof of concept in irradiation facilities in ~2 years
- Proof of fast response, n/g rejection, efficiency and FEE performance
- Proof of principle with ***clear detection of beam losses at LINAC4***
- Production of 84 detectors system with ESS started

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Thank you very much
for your attention!

THE nBLM TEAM

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F. Gougnaud, T. Joannem, M. Kebbiri, C. Lahonde-Hamdoun, P. Legou, Y. Mariette, A. Marcel,
J. Marroncle, V. Nadot, **T. Papaevangelou, L. Segui**, G. Tsiledakis,
IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France

E. Bergman, **I. Dolenc-Kittelmann**, F. Dos Santos Alves, S. Grishin, K. Rosengren, **T. J. Shea**
European Spallation Source ERIC, SE-221 00, Lund, Sweden

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Department of Microelectronics and Computer Science. Lodz University of Technology. Poland

neutron
Beam
Loss
Monitor
nBLM

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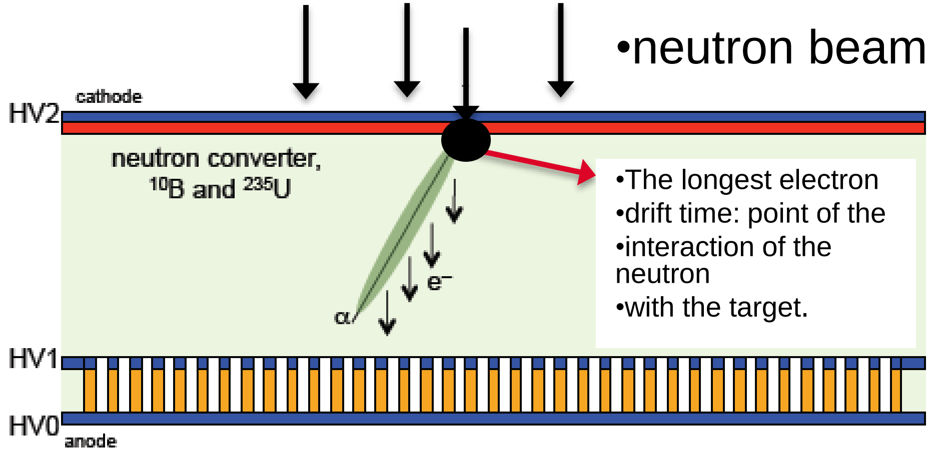
Back up

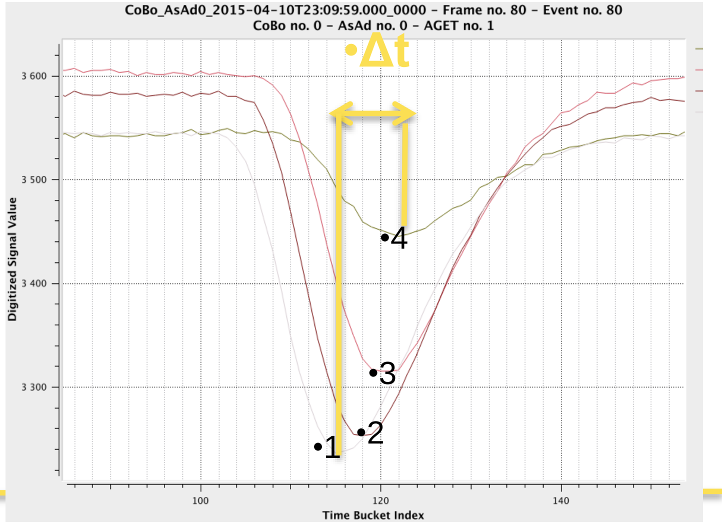
MICROMEGAS PERFORMANCE WITH NEUTRON BEAM

Successfully used as a neutron beam profiler at GELINA, n_TOF, Orphee reactor.



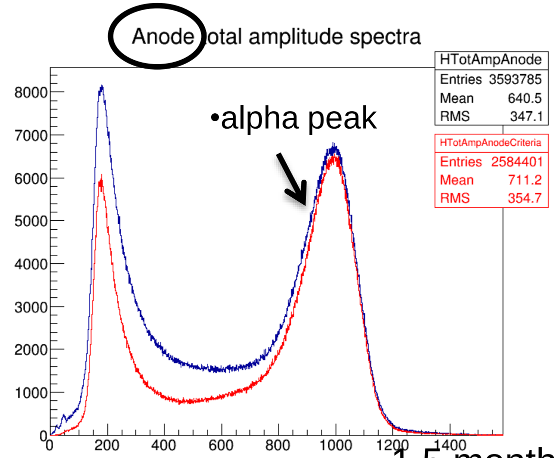
- neutron beam

- The longest electron
- drift time: point of the
- interaction of the neutron
- with the target.

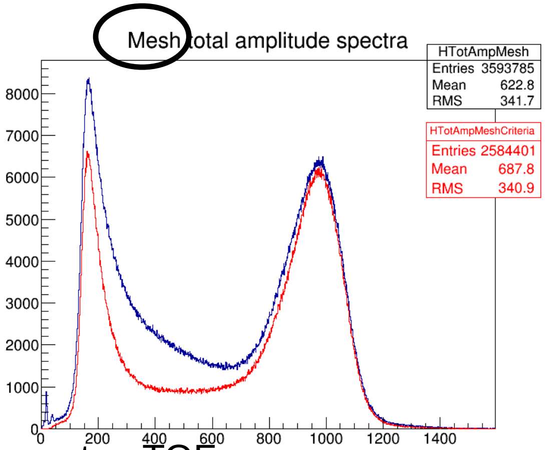


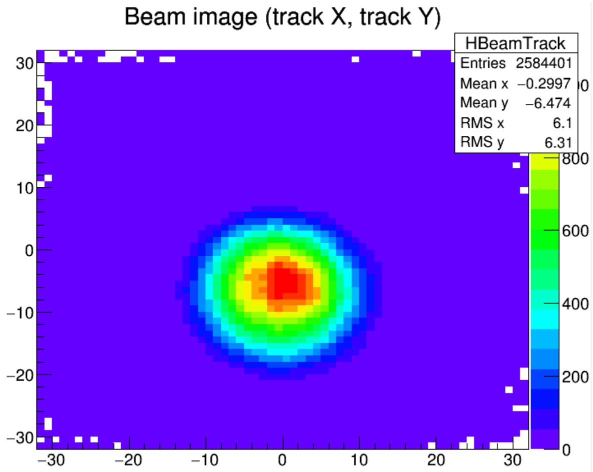
Criterias applied : 1) Δt <= (drift space)/(drift velocity), 2) Total amplitude ratio ~1, 3) consecutive strips

Fit of the track with a straight line=> better spatial resolution



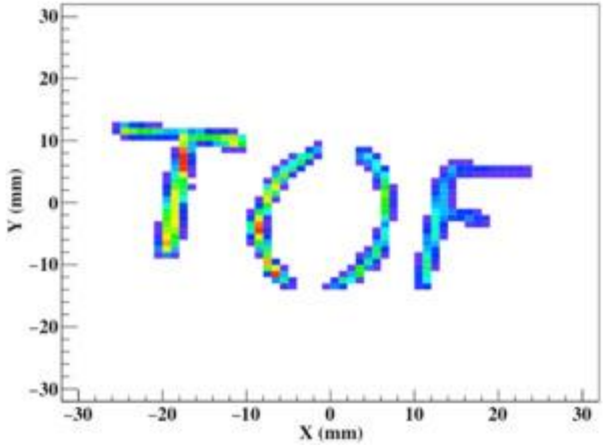
- alpha peak

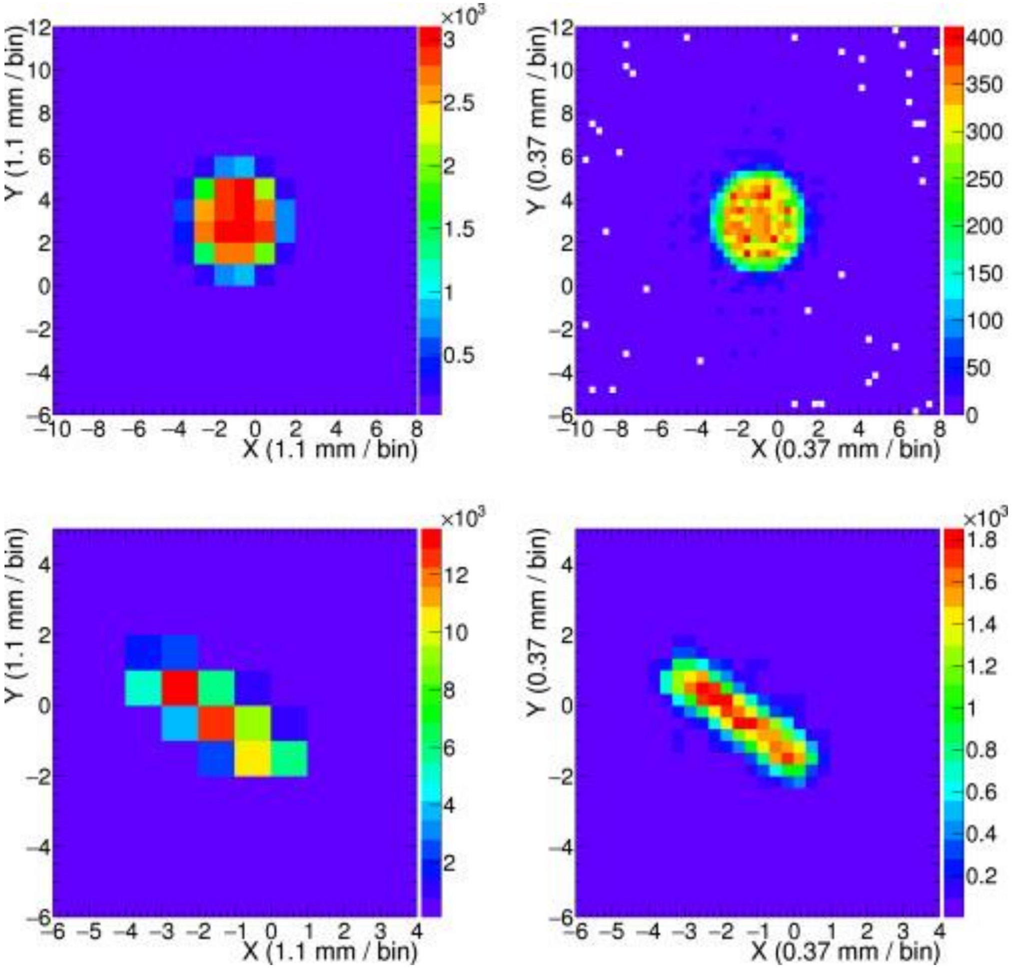




1.5 months run at n_TOF

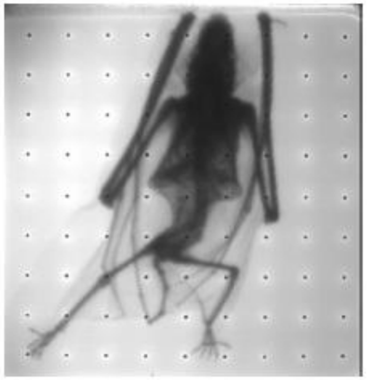
IMAGING CAPABILITIES





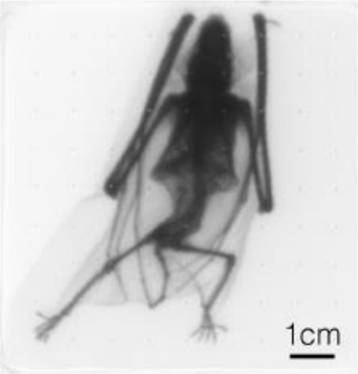
M. Diakaki et al, https://doi.org/10.1016/j.nima.2018.06.019

IMAGING WITH OPTICAL READOUT



Background substracted

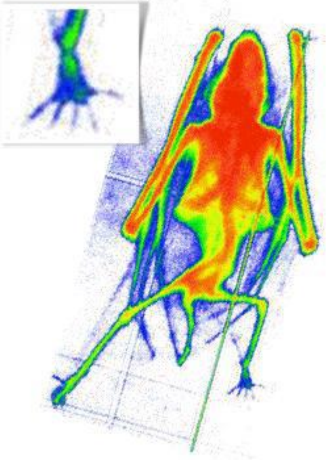
"White" image



Flat-field corrected

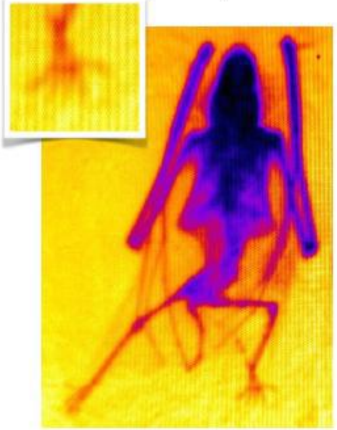
- Images acquired by averaging several 10s exposure times.
- Beam profile shape removed by dividing by "white" image.
- High resolution images are obtained.

Charge readout
(1998)



https://gdd.web.cern.ch/GDD/
gemreadout.htm

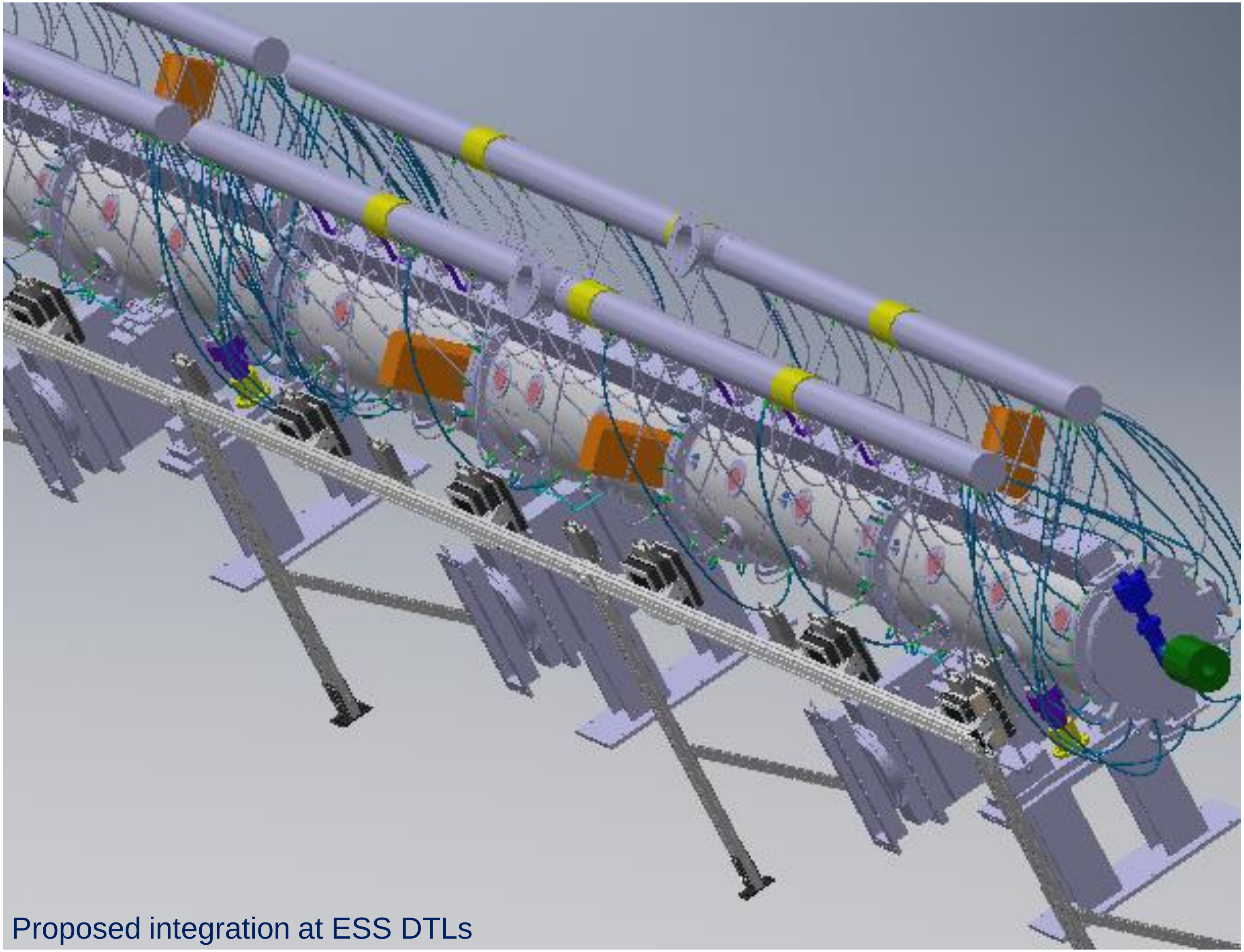
Optically read out GEMs
(2016)



Optically read out MMs
(2018)

F. Brunbauer (CERN), PhD Thesis

THE nBLM CHAMBERS



Proposed integration at ESS DTLs

TESTS AT IPHI

Tests for future neutron facility SONATE: *3 MeV protons on Be* target

Use of polyethylene and borated plastic blocks for beam moderation and / or collimation

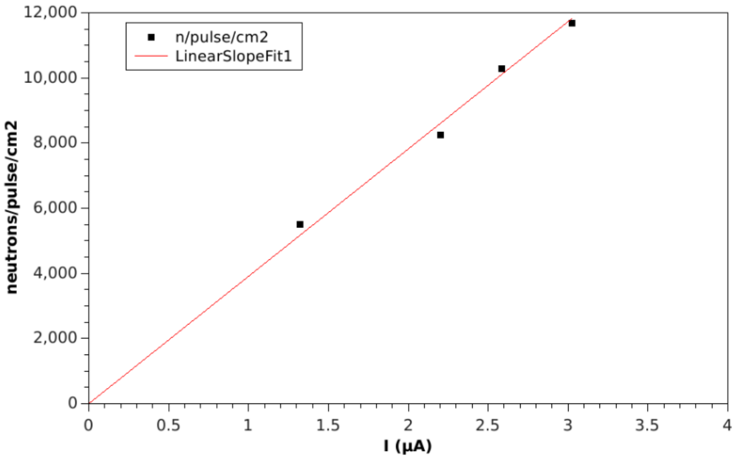
Pulsed beam, duration *90 ns*, repetition rate *1Hz,* intensity *1.3 – 3.2 μA*

Tested both detectors with same configuration as in AMANDE

Data also taken when Be was replaced by a Ni Faraday cup for other experiments (drop in neutron flux by factor 100). Main goals:

- Study the neutron yield
- Test of Front-End Electronics
- Develop the analysis algorithm for the FPGA
- Study the timing response

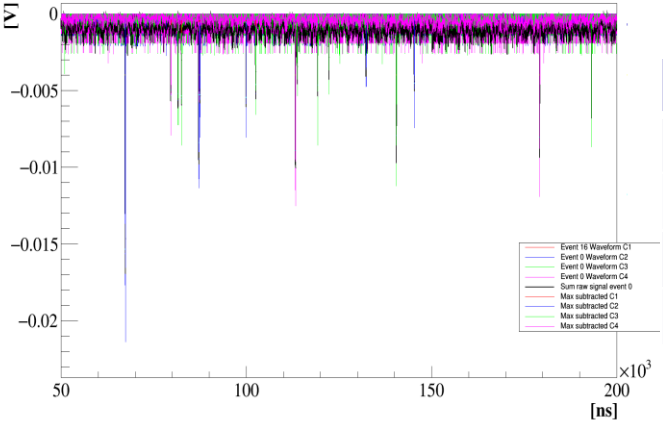
Count rate vs beam current



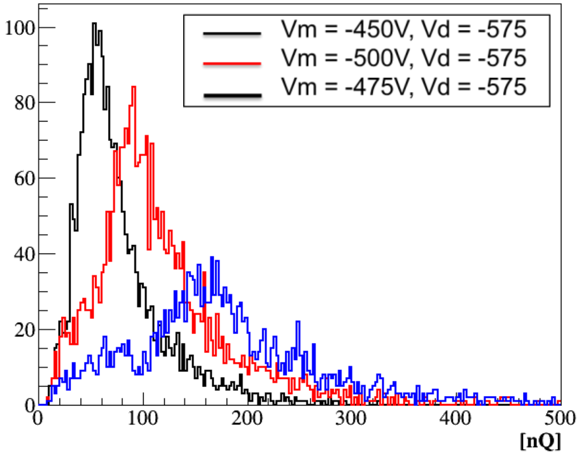
PASSING FROM COUNT RATE TO CURRENT MODE

- The 4 segments were recorded independently by a digital oscilloscope at 250 MS/s
- Instantaneous rate high enough to reach the limit of **current mode.** *Detector stable*.

Run with Ni

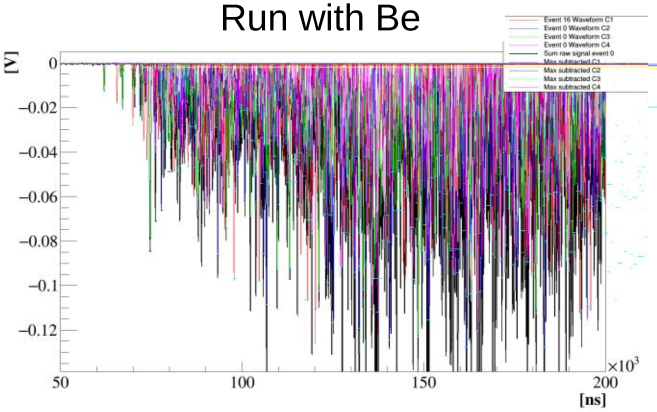


	Rate [c/p]	RateQ [c/p]
Sum	34.	34
C2	12.	11.
C3	10.	10.
C4	7.	6.

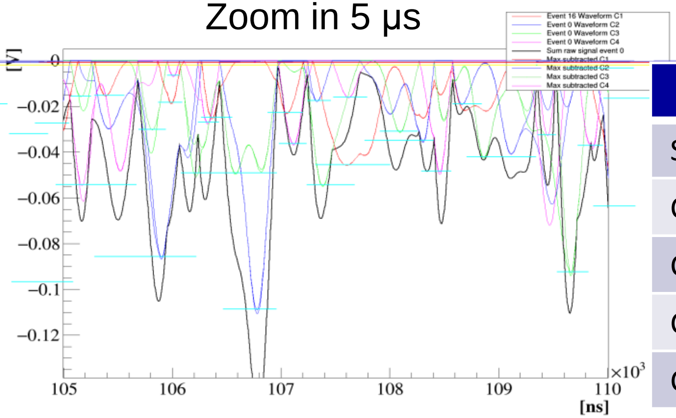


Pulse Charge from low intensity run

Run with Be



Zoom in 5 µs



	Rate [c/p]	RateQ [c/p]
Sum	241	2318
C1	511	794
C2	518	783
C3	521	730
C4	473	816

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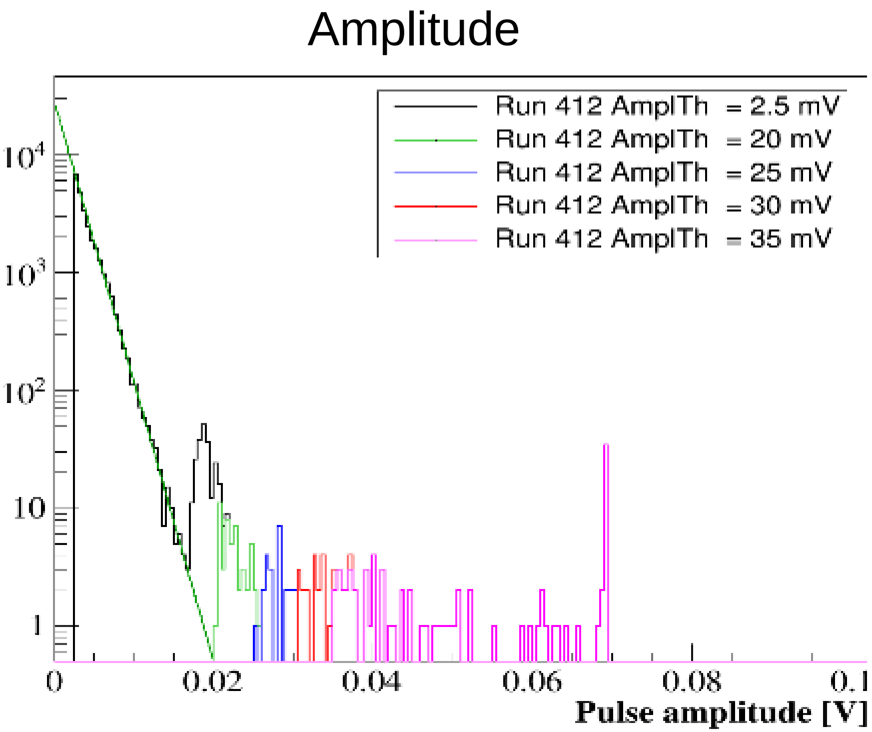
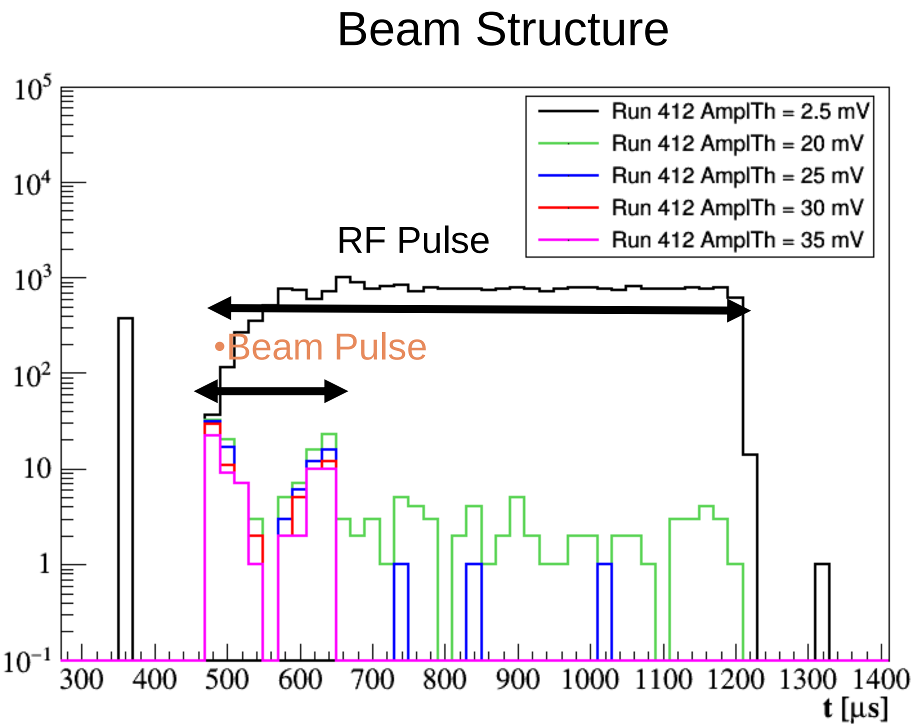
LINAC4 DATA

Run 412 – November 2018
Vm = -550V, Vd = -1500V





Applying amplitude cut, we recover the beam duration

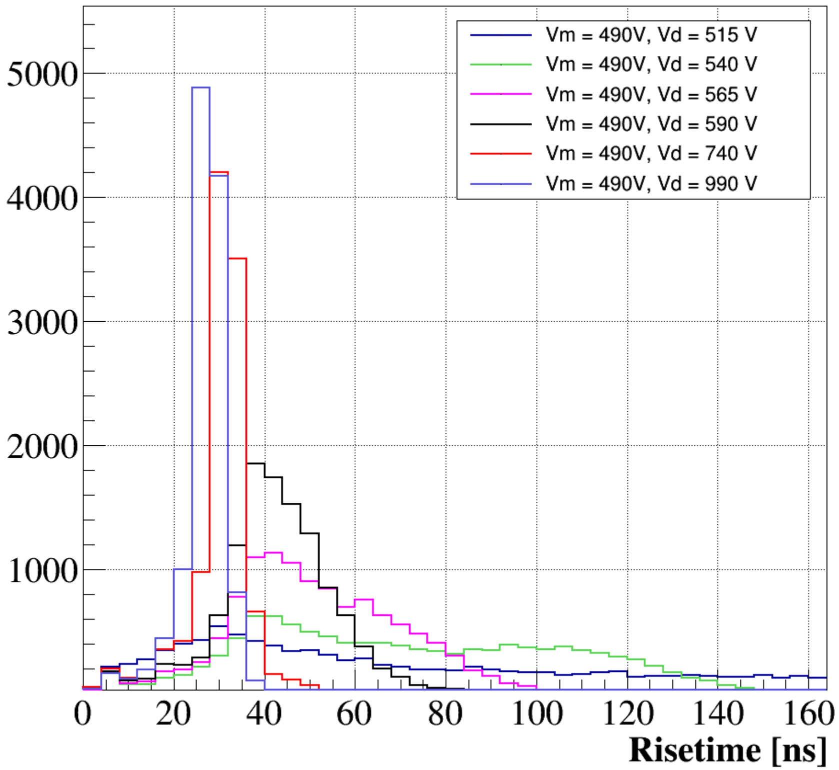
→ Neutrons produced by beam

→ Gammas distributed all along RF pulse

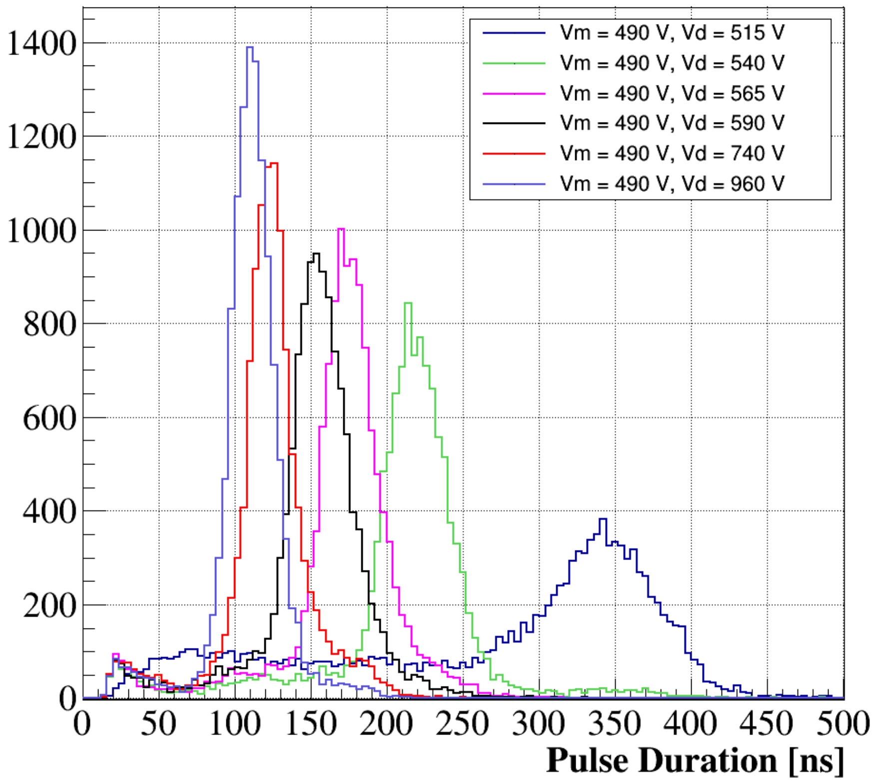
NBLM DATA – SIGNAL CARACTERISTICS

Dependency with drift voltage

Rise Time



Pulse width

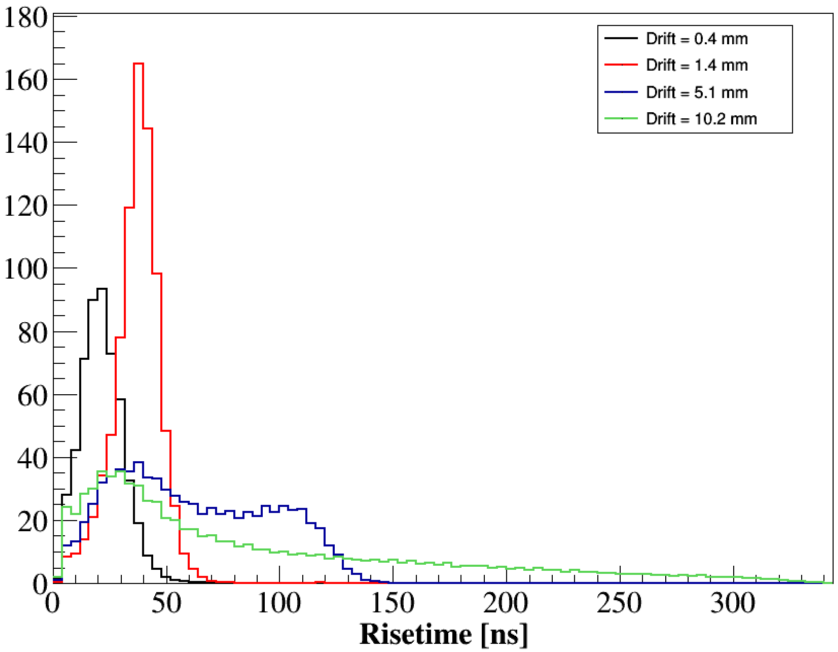


nBLM DATA – SIGNAL CARACTERISTICS

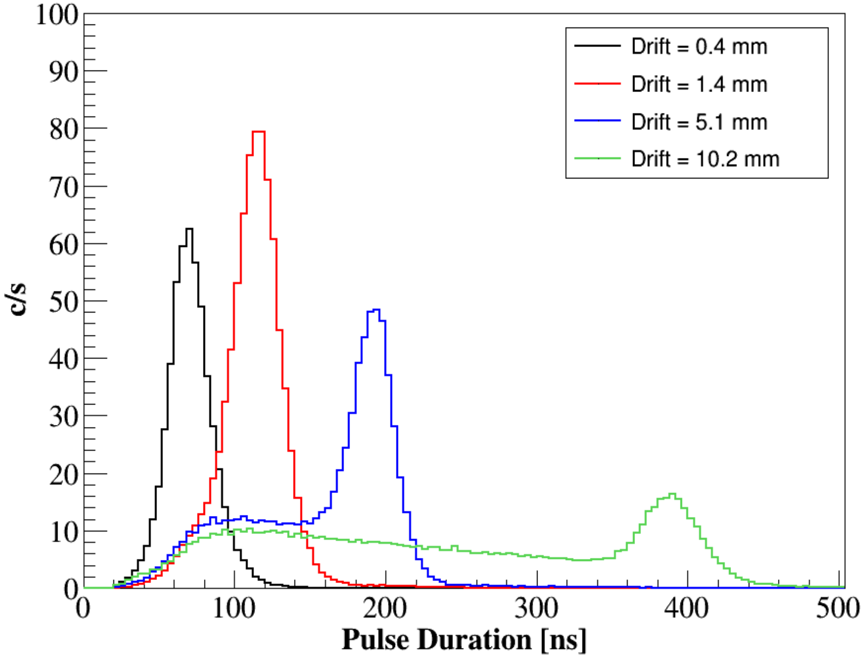
ORPHEE nuclear reactor LLB, CEA Saclay: 0.01 eV neutrons, flux 2×10^{6} s^{-1} cm^{-2}

Dependency with drift distance

Rise Time



Pulse width

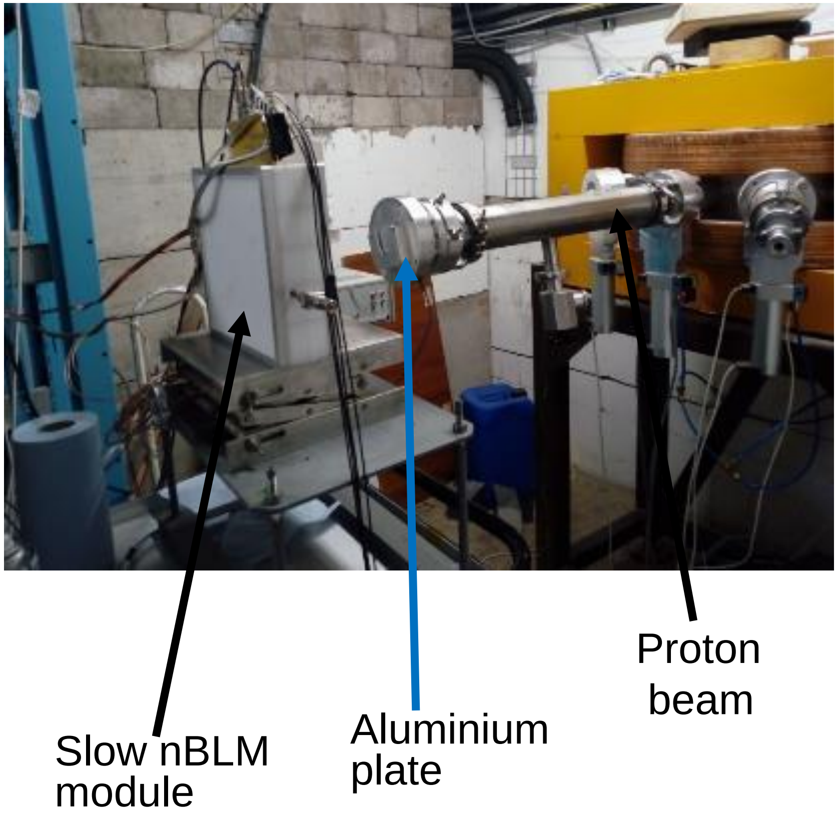


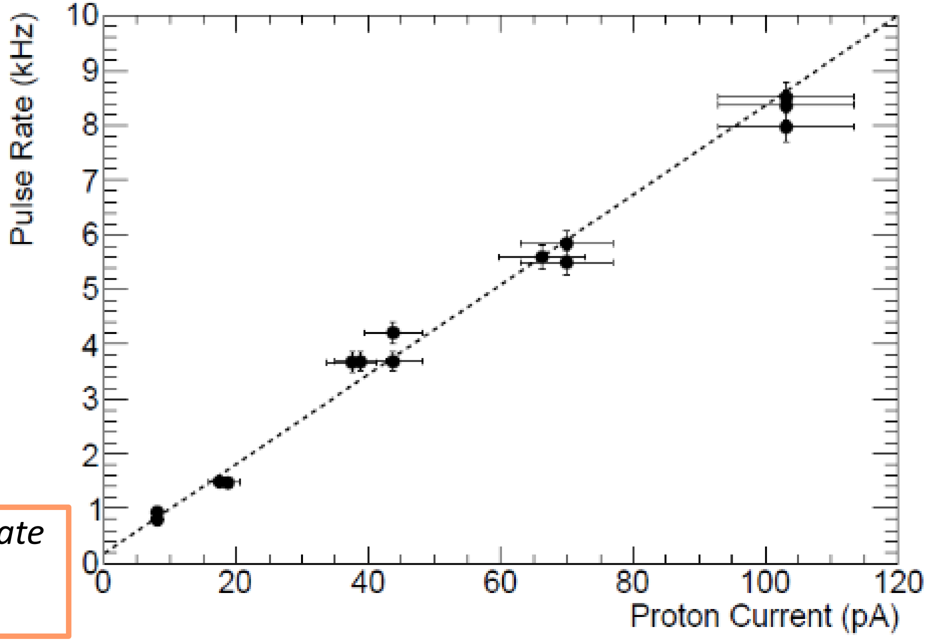
- Optimum **value ~2 mm**
  - Rise Time ~ 45 ns and very stable
  - Pulse duration ~ 60 ns → in 1µs ~ >10 pulses/window before pile-up (~10 MHz)
- Optimized to avoid also to be very close to sparking point

NBLM: CHARACTERISATION AT DIFFERENET IRRADIATION FACILITIES

MC40 Cyclotron (Birmingham University, UK):

- Medical synchrotron
- Protons up to 30 MeV
- Beam diameter ~1cm
- Continuum pulse
- Data taken at 28 MeV and different intensities
- Proton beam into Al plate ϕ=1cm





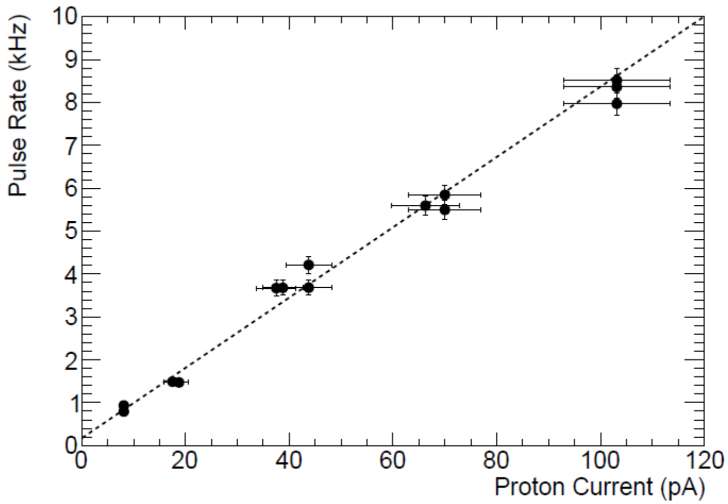
Correlation of the count rate with the intensity of the proton beam

OTHER TESTS

MC40 cyclotron , Birmingham Un. UK

28 MeV p on Al plate. To follow:

- *More materials relevant to the ESS linac*
- *FEE irradiation*



ORPHEE nuclear reactor LLB, CEA Saclay

0.01 eV neutrons, flux $2\times10^{6}\ s^{-1}\ cm^{-2}$

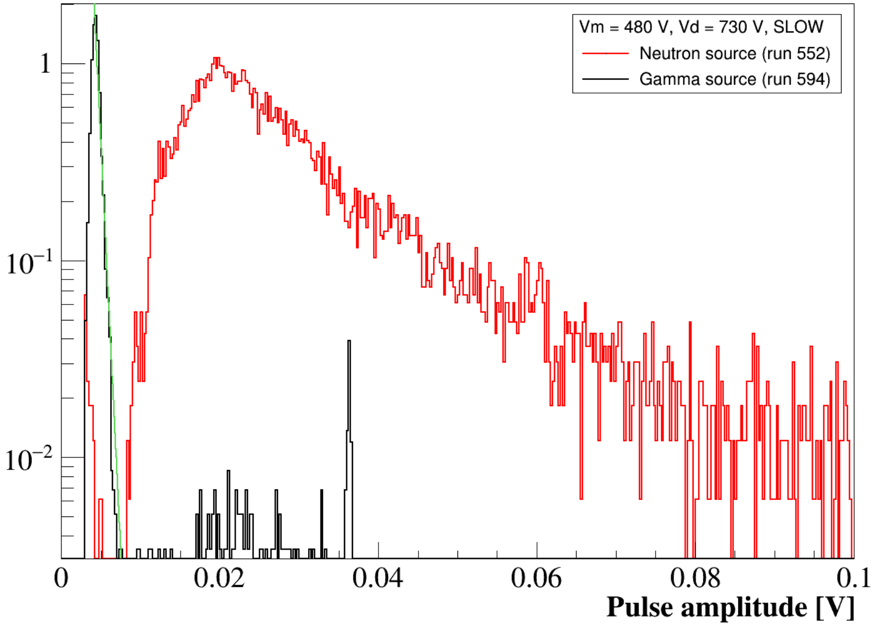
- *Analysis ongoing*
- *Stable operation with high current (up to 600 nA), no discharges*
- *Verified that 5 mm Borflex absorbs completely the thermal neutrons*
- *study the detector operation parameters (B4C thickness, drift gap, operating voltages) to optimize signals (duration, amplitude etc.)*

Planning

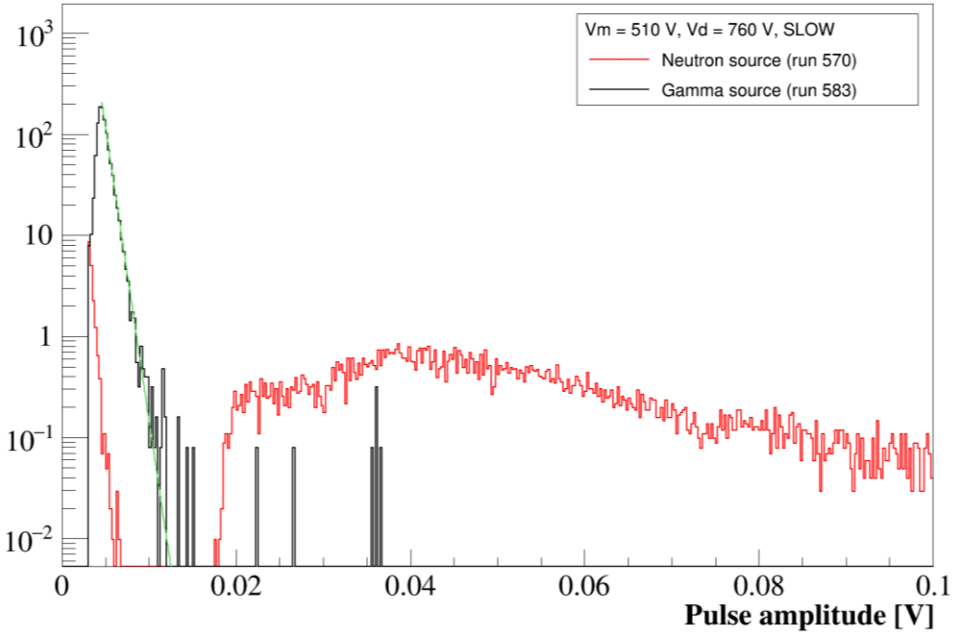
- ***CEA Saclay SPR:** 110 GBq AmBe, Co, Cs sources*
- ***CERN GIF++:** gamma irradiation*
- ***CERN Linac4:***
  - ➔ *Install a detector in the hall (without interfering!) in Aug 2018.*
  - ➔ *Profit from September's run to test response, backgrounds, BEE (possible) in most similar(?) conditions available to the ESS linac*

NBLM DATA – NEUTRON AND GAMMA SOURCES

SLOW



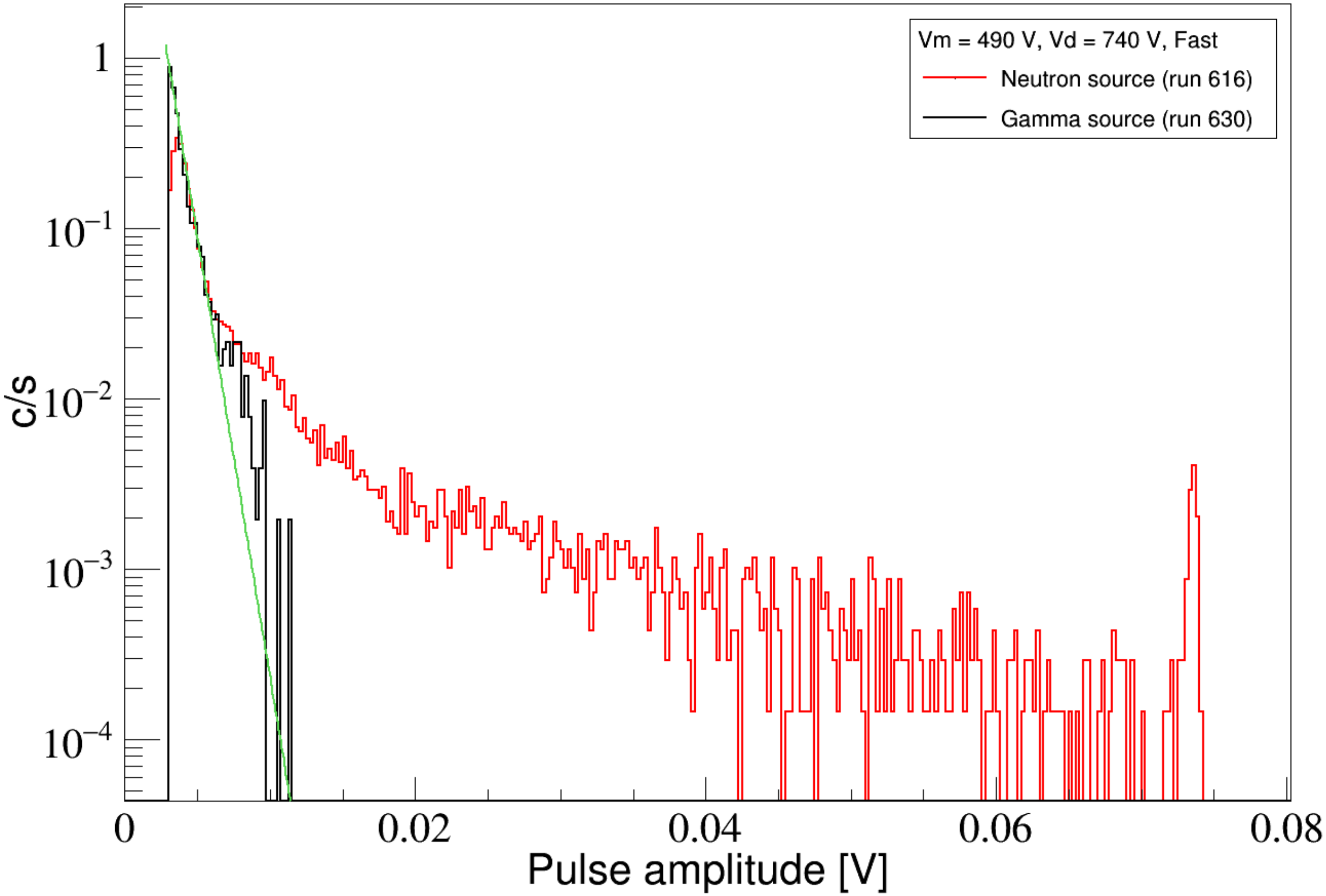
Lower gain (480 V)



Higher gain (510 V)

NBLM DATA – NEUTRON AND GAMMA SOURCES

FAST



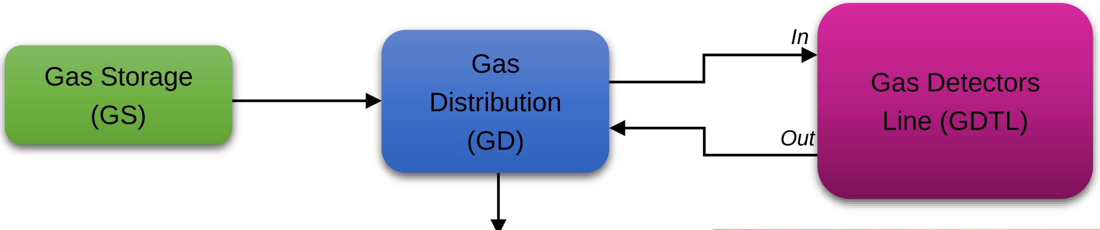
nBLM GAS SYSTEM

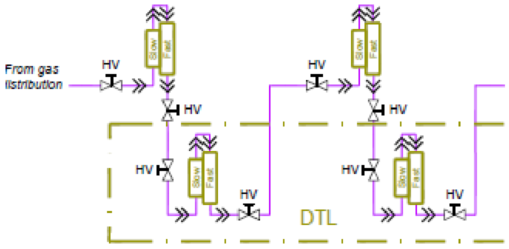
*Detectors are designed to operate in **semi – sealed mode**, however for long term stability some gas recirculation is necessary. The nBLM Gas System:*

- Provide a constant flow of 0.2 - 2 l/h of **He + 10% CO_2** @ 1bar in 6 independent gas lines
- Each line feeds a group of detectors in series
- PLC Control / Monitoring of flow IN – flow OUT of each line ➔ assure tightness & gas quality
- Report system health status to EPICs GUI

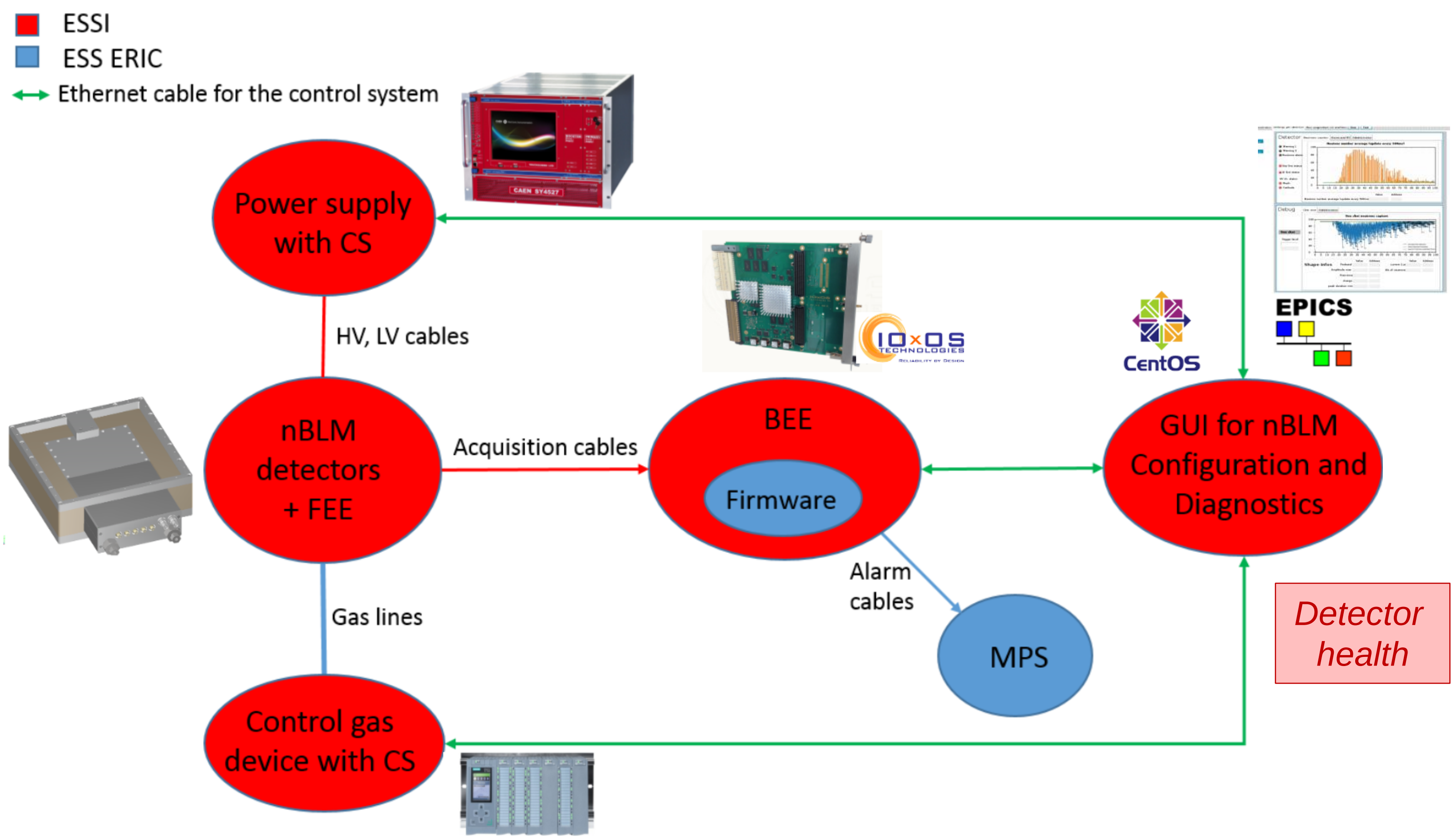
The need for gas recirculation complicates the system. However:

- The detectors can keep operating stably for hours if gas recirculation has stopped
- Gas is non flammable, redundant gas storage design
- Manual bypass for all controllers is possible in case necessary





CONTROL SYSTEM ARCHITECTURE



🟥 ESSI

🟦 ESS ERIC

↔ Ethernet cable for the control system

Power supply with CS

HV, LV cables

nBLM detectors + FEE

Acquisition cables

BEE

Firmware

GUI for nBLM Configuration and Diagnostics

Alarm cables

MPS

Gas lines

Control gas device with CS

Detector health

THE ACQUISITION SYSTEM

- **Fast acquisition**

ICS standardisation for fast acquisition is based on:

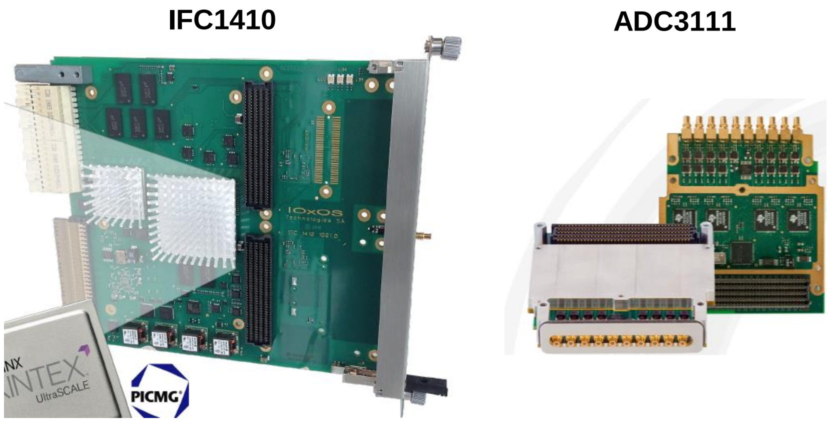
- µTCA.4
- IOxOS CPU IFC_1410
- IOxOS ADC_3111 FMC boards
    - Total 16 cards (128 channels)
    - Input voltage range is -0.5V to 0.5V
    - Sampling frequency of 250 MSamples/s

- **FPGA firmware**

The FPGA will have the following tasks:

- Detection of neutrons and counting. Automatic switch to current mode.
- Beam Permit signal to the Beam Interlock System
- Acquire post-mortem data
- Provide debug and diagnostic data
- Provide oscilloscope functionality
- Generate warnings/health status of subsystems

BEE boards



- Only one ADC3111 FMC per IFC1410 board
- Pairs of fast and slow acquisition for software architecture convenience.
- Cross detector pairs on different ADC3111 modules to avoid blind regions in case of card failure

NBLM DETECTORS CHARACTERISTICS

	SLOW	FAST
neutron-to-charged particle convertor	B_4C	Mylar or Polypropylene
Reaction	$^{10}B(n,\alpha)^{7}Li$	(n,p)
Signal produced by	Fast neutrons after moderation	Fast neutrons
Detected energy	~constant for all initial neutron energy	Depends on initial neutron energy
Sensitivity	10^{-4} < En < 100 MeV	En > 0.5 MeV
Solid angle	4π	2π, n coming from the front only
Efficiency	~few n·cm^{-2}·s^{-1}	~10-100 times smaller
Response time	~200 µs	~0.01 µs
Objective	Monitoring of small losses	Alarm (in 5 µs) Fine structure of the lost
Shielding	Yes, for thermal neutrons	Not needed

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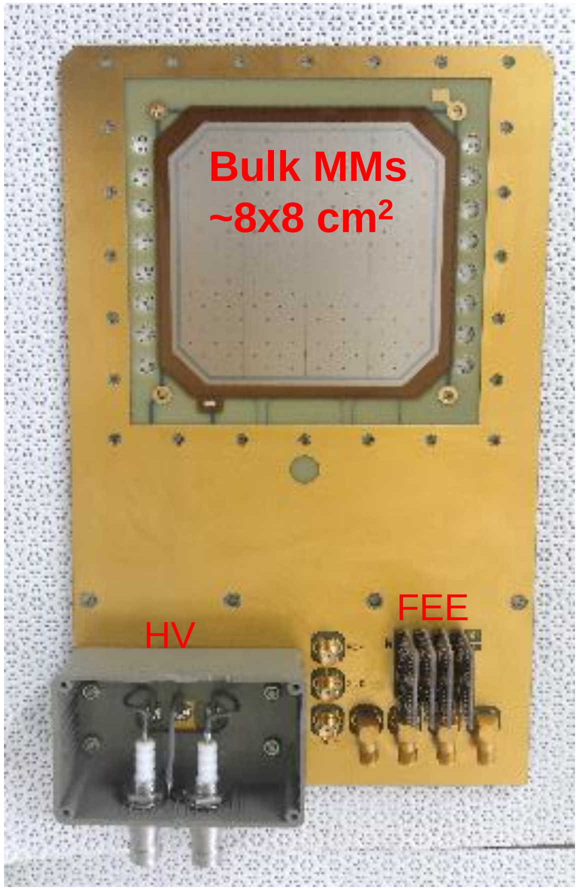
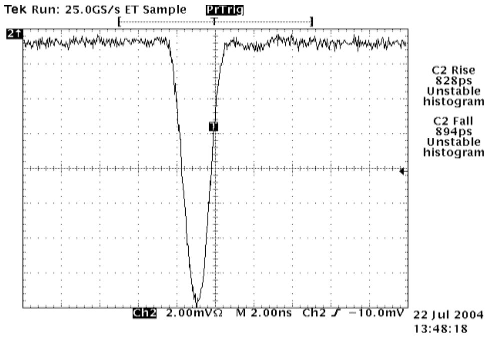
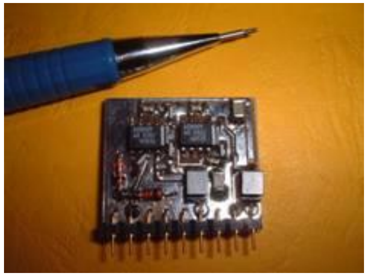
THE FIRST PROTOTYPES

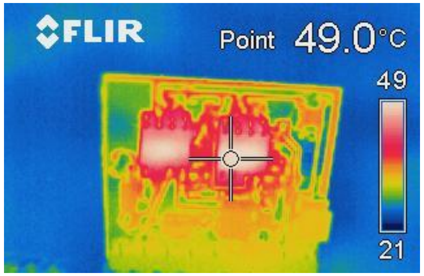


- Common design for fast and slow detectors
  - ➔ Different convertors, the slow surrounded by moderator
  - ➔ Standard "Bulk" Micromegas, segmented in 4 pads (can be read individually or as one)
- FEE electronics: FAMMAS[1] preamplifiers (*Fast Amplifier Module for Micromegas ApplicationS*)
  - ➔ integrated on the board for the prototypes
  - ➔ as mezzanine card for the production
  - ➔ Radiation hardness: test planned @MC40 cyclotron Birmingham U.
    - LV : + 5V -5V
    - Consumption ≅ 50 mW
    - Noise: 600 µV rms
    - Risetime: < 1ns



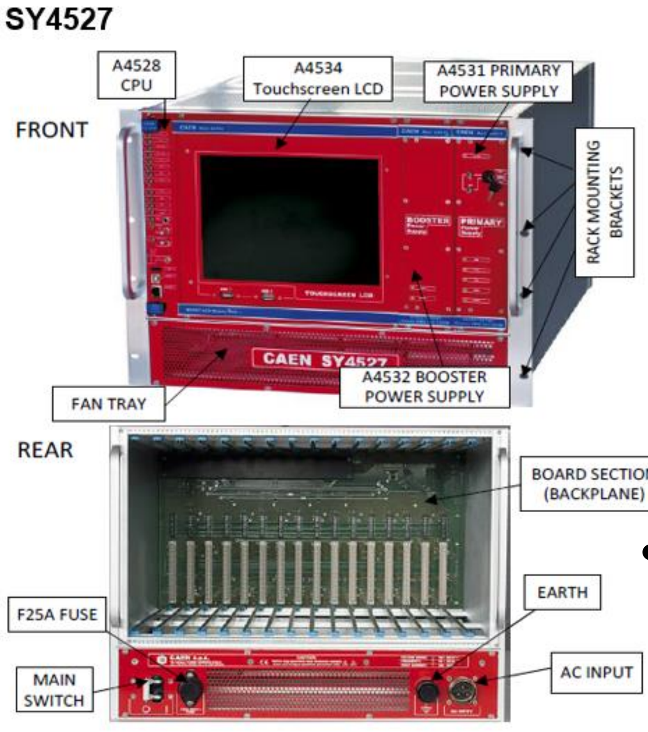
[1] P. Legou, "Beam Spectrometers using Micromegas in Time Projection Chamber mode", in Proc. HB2006, Japan 2006.





CONTROL DEVICES

- HV and LV crate

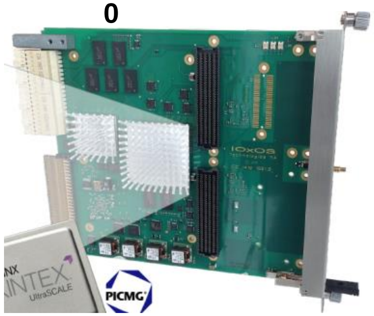


- A7030 + A2519

- +

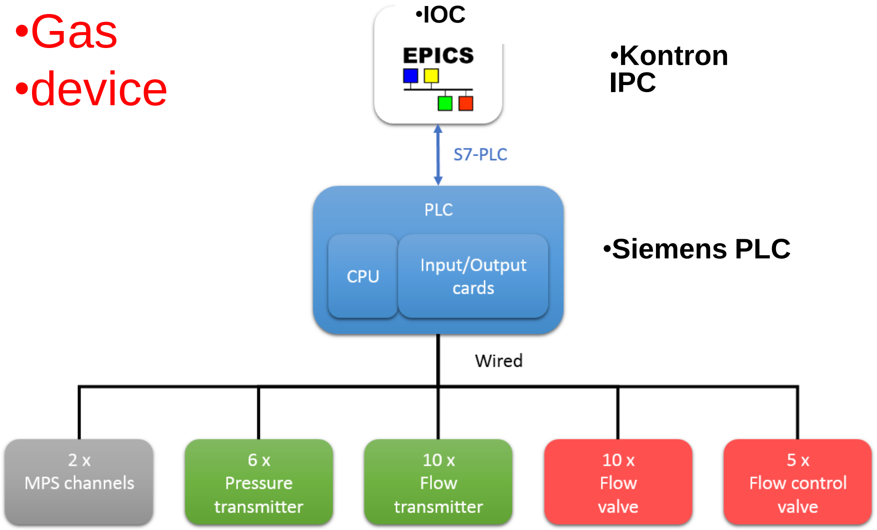
- BEE boards

- IFC1410



- ADC3111

- Gas
- device



- IOC

EPICS

- Kontron IPC

S7-PLC

PLC

CPU

Input/Output cards

- Siemens PLC

Wired

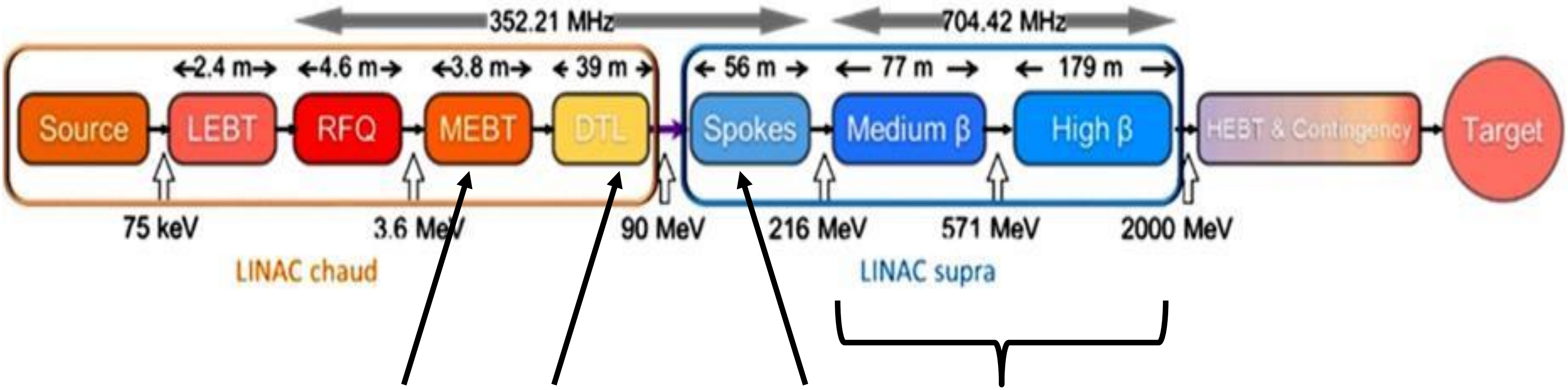
2 x MPS channels

6 x Pressure transmitter

10 x Flow transmitter

10 x Flow valve

5 x Flow control valve



4 detectors   42 detectors   26 detectors   10 detectors

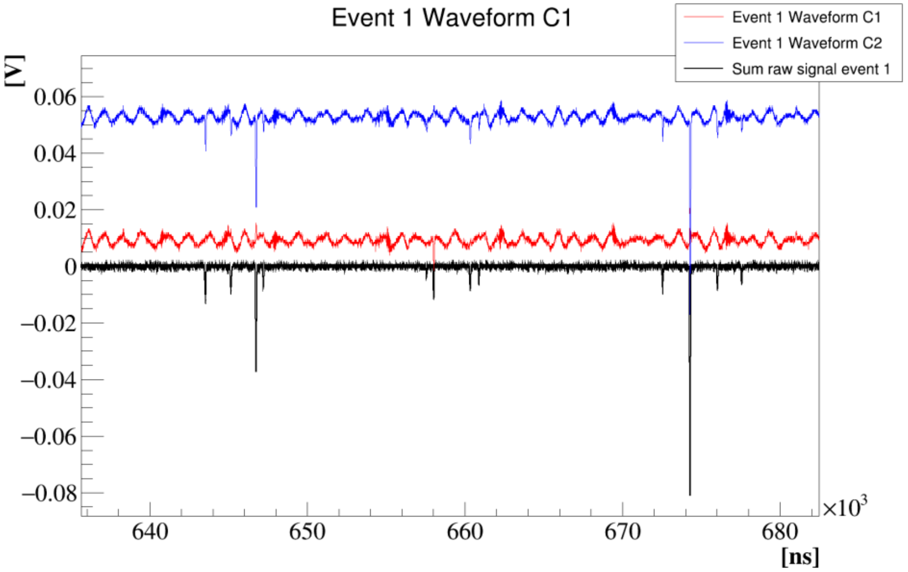
NOISE REJECTION

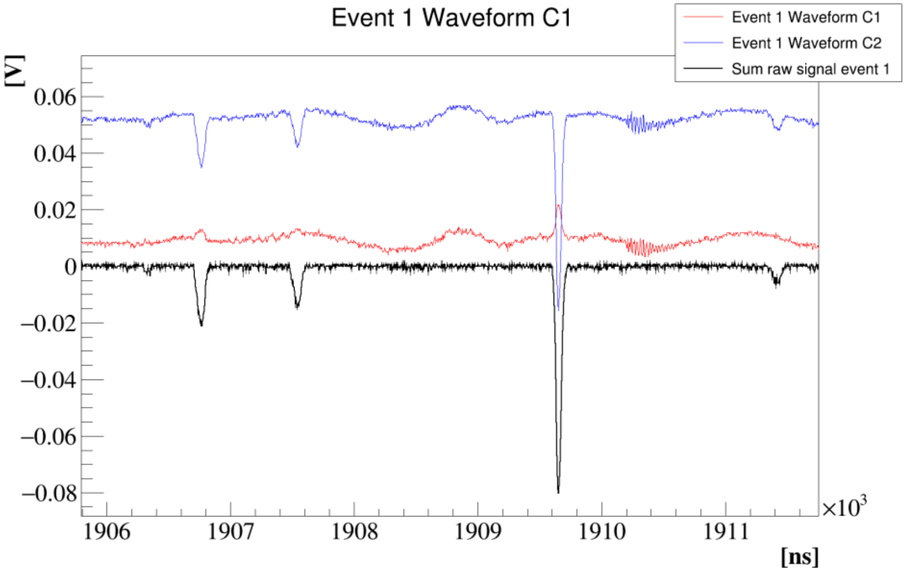
Special care is taken for the design of the detector grounding, Faraday shielding and cabling.

FEE with low noise components and proper choice of power supplies, filters and buffers.

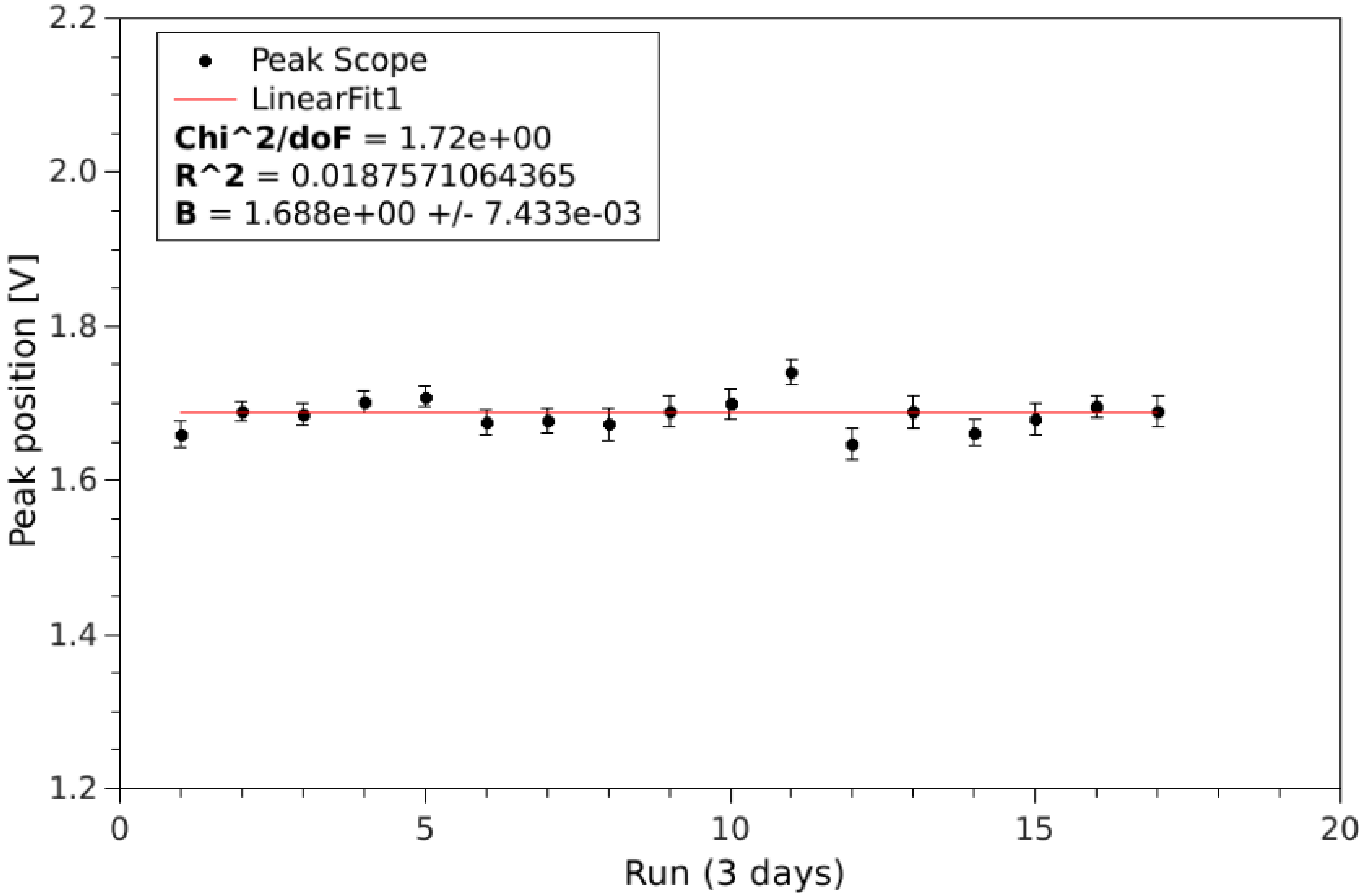
Furthermore: FEE cards equipped with 2 identical amplifiers each, with all channel connection combination possible. This could allow in case of extreme conditions:

- ➢ Common mode noise suppression in-flight by subtraction channel by channel at the same FMC (double amount of signal cables and FMC channels)
- ➢ In case gamma background too high ➔ continuous signal, no threshold discrimination: Possible to mask part of the converter: this part of the detector will be sensitive only to gammas and subtraction of the gamma continuous can be done channel by channel



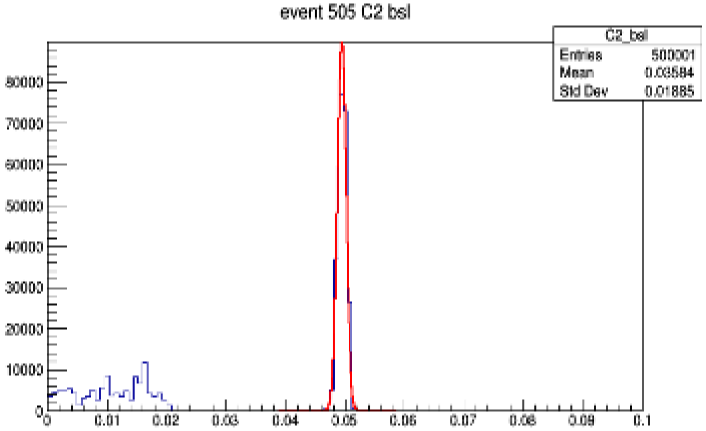


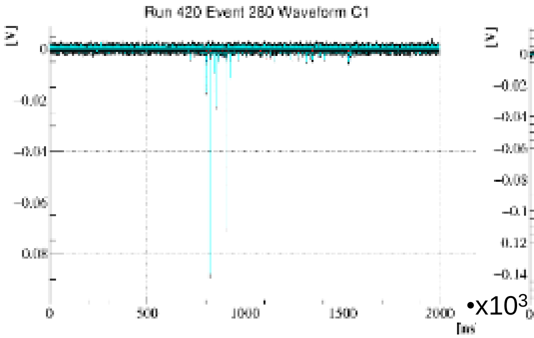
GAIN STABILITY

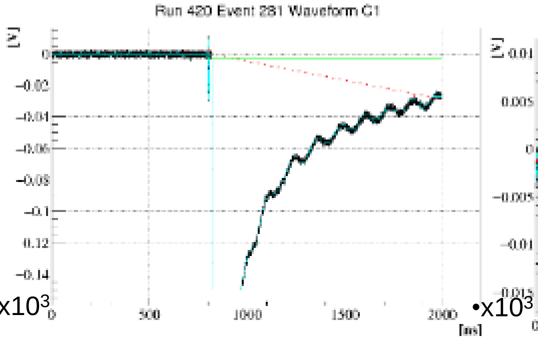


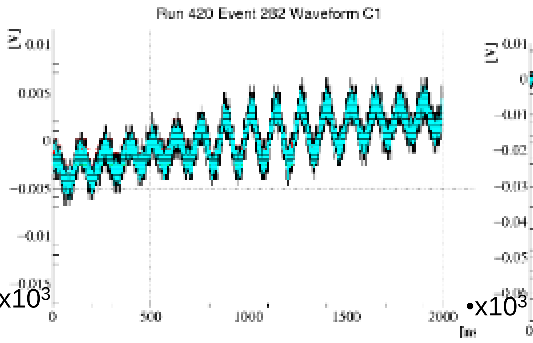
SPARK IDENTIFICATION

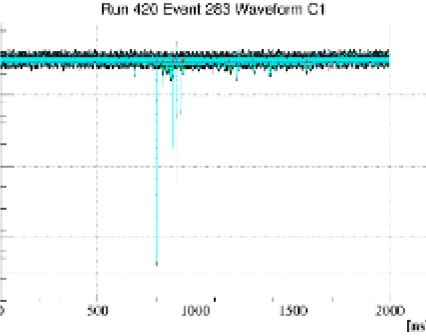
- Identified pulse by pulse if
  - Sigma of baseline too large
  - Charge of pulse too large







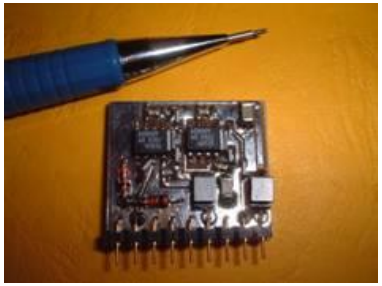


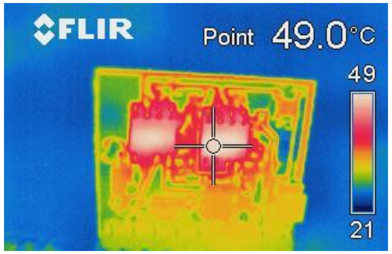


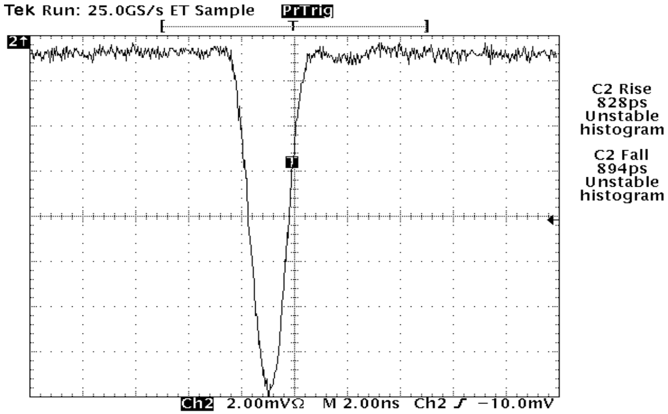
FRONT END ELECTRONICS FOR NBLM PROTOTYPE

- Designed by Philippe Legou

- FAMMAS front-end module
- (Fast Amplifier Module for Micromegas ApplicationS)



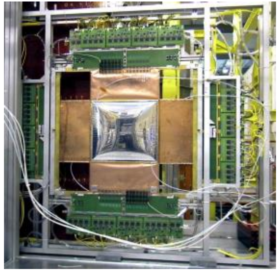




- *In few figures …*

- *Power supply : + 5V -5V*
- *Consumption ≅50 mW*
- *Input: positive or negative*
- *Noise: **600 µV rms***
- *Rise time : **< 1ns***
- *Bandwidth adjustable up to few GHz*
- *Configurable gain, in these results 40dB*
- *(equals x 100)*
- *Very robust to sparks*

MICROMEGAS APPLICATIONS: PARTICLE & NUCLEAR PHYSICS EXPERIMENTS AND MORE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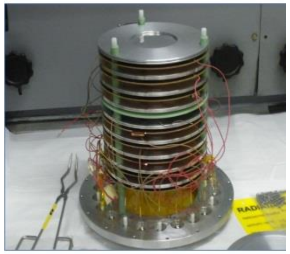
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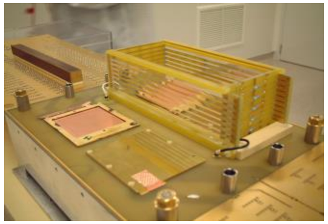
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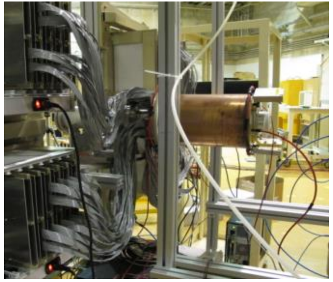
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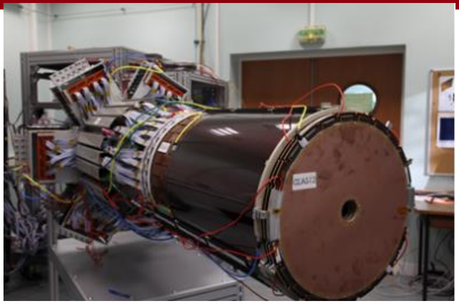
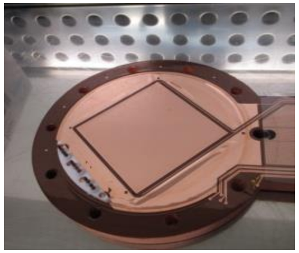

CLAS12

1996 2000 2001 2003 2009 2014 2015 2017 2018

Micromegas Invention

CAST



T2K

ScanPyramids

ATLAS-NSW

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