nBLM detectors
Final design, production and 1st beam loss detection

Laura Segui on behalf or nBLM Team

(laura.segui@cea.fr)

nBLM CDR1.2

12/02/2019

OUTLOOK

- Description of slow and fast detectors
- Final detector design
- Production plan
- 1st beam losses detection at LINAC4

- Results from other tests

NBLM DETECTORS

As presented in Irena's talk

- Micromegas BLM detectors chosen for the MEBT and DTL sections.
- Detector sensitive to fast neutrons and not to thermal neutrons (shielding), X- and γ-rays (signal discrimination)
- 84 detectors will be delivered: 42F (fast) and 42S (slow), 8 of them in assembly SF

- System designed to be sensitive to small losses → to operate in counting mode with few n/cm2 sensitivity
  - ➔ Extension of the dynamic range to very low particle fluxes

- Current mode for higher rates, other observables can be measured (e.g. Q, ToT, …)

- For a section where other BLMs have low sensitivity

- The specific requirements for the system are:
  - Response in 5 μs
  - To be able to detect 100 mW/m losses.

- Two types of detectors: slow and fast
  - Different physical reaction to create the charged particles from the neutrons
  - Complementary function

- *nBLM_CDR11_SlowvsFast_nBLM_Detector.pdf document*

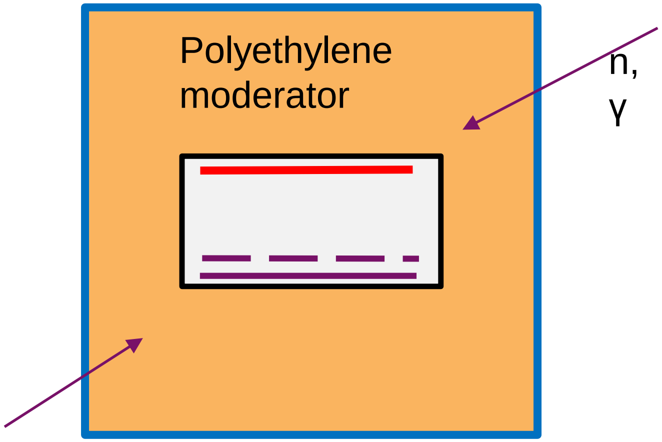
	SLOW	FAST
neutron-to-charged particle convertor	B_4C	Mylar or Polypropylene
Reaction	$^{10}B(n,\alpha)^7Li$	(n,p)
Signal produced by	Fast neutrons after moderation	Fast neutrons
Detected energy	~constant for all initial neutron energy	Depends on initial neutron energy
Sensitivity	10^{-4} < En < 100 MeV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

NBLM DETECTORS GEOMETRY

Detector chamber identical, differences on the:
convertor and the surrounding of the slow with absorber + moderator

SLOW

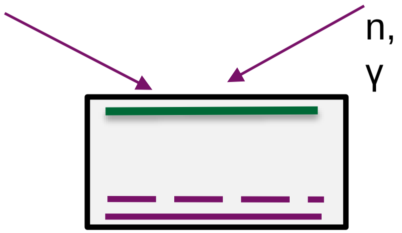
- Absorber shielding
- Detection of fast neutrons after moderation in polyethylene (~4cm)
- Gas chamber with layer of B4C
  - $^{10}B(n, \alpha)\,^{7}Li$ reaction



- Borated rubber (1mm)
- Polyethylene (4cm)
- Aluminium chamber
- B4C deposited on Al
- He+CO_2 gas
- MMs detector

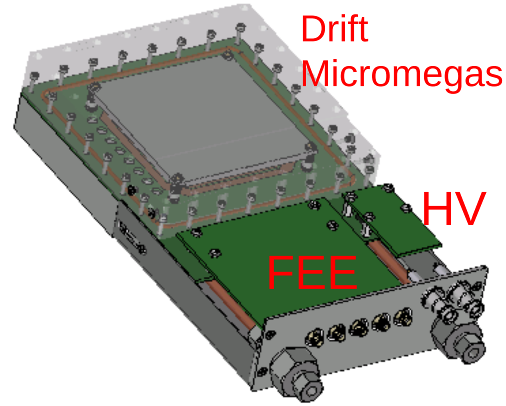
FAST

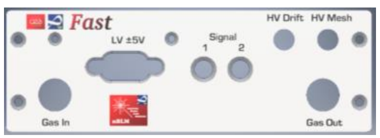
- Recoil protons produced by neutrons in hydrogen rich material (mylar)
- High flux high energy n's (>0.1 MeV)
- Faster response



- Aluminium chamber
- Plastic deposited on Al
- He+CO_2 gas
- MMs detector

THE NBLM FINAL CHAMBERS

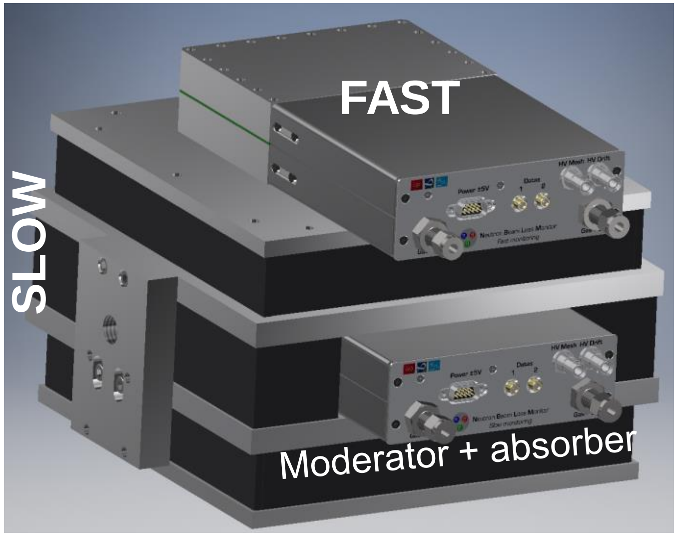




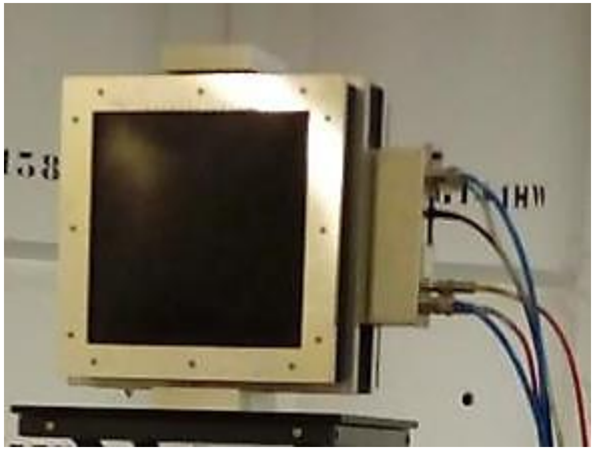
Same design for both modules

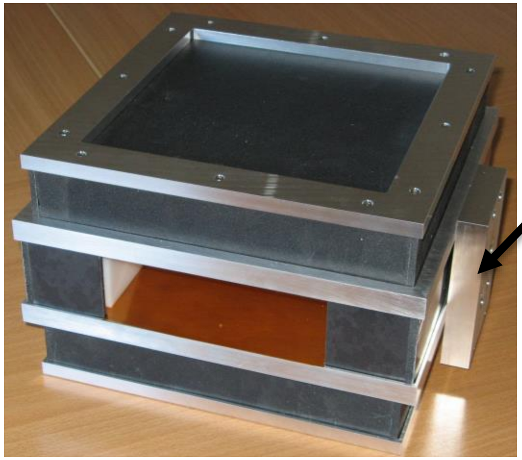
- Chamber
- Detector
- FEE & HV

Approved in July 2018



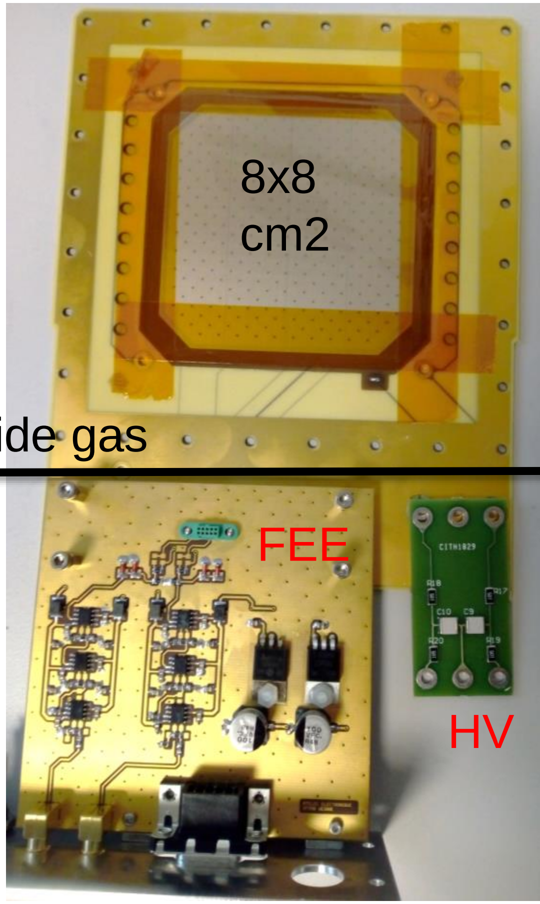
Assembly of a fast and a slow detector
size ≈ 20 × 25 × 25 cm^3 (~14 kg)





To be made in PEEK

Moderator + absorber



Final FEE design

- Bulk Micromegas detector
- Done at the MPGD workshopat CEA/Saclay
- Active surface 8x8 cm^2
- Segmented in 4 sectors to accommodate for final rates
- Only one signal output (from1 to 4 segments together)
- Operating in He+10% CO_2, 1 atm

- FEE card in P. Legou talk
- HV card designed also internally by M. Combet
  Includes the HV filters. The ground of the HV cables can be or not connected

EXPECTED SENSITIVITY

Presented during CDR1.1

From MC simulation studies in the DTLs

	Rates	
	1% 1W/m	Complete beam loss (rate in 1st µs)
Slow	0.1 – 68 kHz	10 MHz – 60 GHz
Fast	1 – 400 Hz	2-700 MHz

- The nBLM system originally conceived to operate in counting mode.
- Results from simulations using ESS scenarios as input have shown that rates up to GHz can be expected in cases of complete losses.
- The electronics chosen to be able to cope such rates and to be operative both in counting and in current mode.
- Each neutron pulse will have a duration of about 150 ns.
  - The requirement from ESS is to send a BIS flag to MPS in 5 µs.
  - If we monitor 1 µs window, taking into account the duration of each pulse, with ~6 events we start having pile-up (at 6 MHz)

NBLM – DETECTOR PRODUCTION

Pieces	Company	Status
Polyethylene (moderator)	Numeca	Delivered ✓
Neutron absorber	Mirrotron	Delivered ✓
Detector chamber	Numeca	Delivered ✓
Detector front face		To be ordered after CDR, 4 weeks after ordering
Detector chamber components	Swagelok, Numeca, …	Delivered ✓
Moderator support	CEA Workshop	For 12 detectors ready by March, rest TBD
PCB boards	Elvia	2 boards delivered Rest ordered, arriving in 4 weeks
Detectors support	TBD	3 months for MEBT and DTL Waiting final approval from ESS for the rest
Cathodes	Sermo	Delivered ✓
Boron convertors	ESS Detector Coatings Workshop (Linkoping)	Delivered ✓
Mylar (fast convertor)	Good Fellows	Delivered ✓
FEE cartes		5 delivered, Rest to be delivered by Mars 2019
HV cartes		Ordered, waiting for delivery

NBLM – DETECTOR PRODUCTION

Bulk	• Bulk of 9 detectors • In CEA MPGD Workshop
Detector integration	• Enclose Micromegas detector in detector chamber • In clean room
Soldering	• Solder connector into PCB and HV cables • In building 141 / external company
Final integration	• Final integration and Faraday cage installation • Integration laboratory
Verification	• Detector verification tests • In Verification laboratory

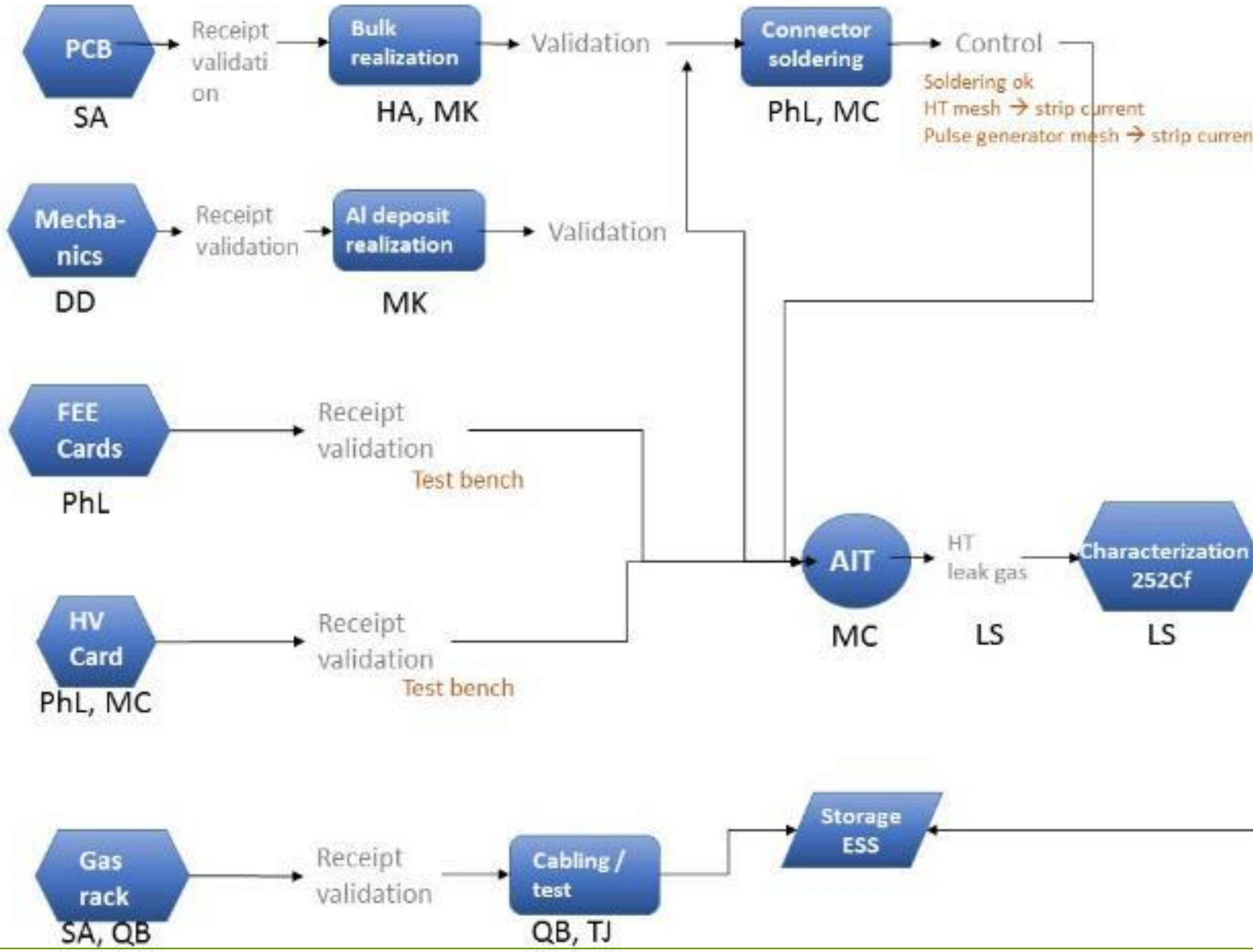
NBLM – DETECTOR PRODUCTION

	Process	Time	Where
1	Bulk of 9 detectors	1 week	MPGD Lab
2	Partial Integration of the 9 detectors	½ week	Clean room
3	Soldering of the connectors	½ week	Integration lab
4	Finalize Integration of the 9 detectors	1 week	Integration lab
5	Verification tests of the 9 detectors	1 week	Verification lab
	TOTAL for 9 detectors	**4 weeks**	

- First 18 detectors in 6-7 weeks from T0
- Then procedure start to overlap
- T0 may change 2-3 weeks, schedule precision 1 month
- Still 12 detectors can be ready in April

		2019																			
		February				March				April					Mai				June		
		week 6	week	wee	w	week 10	week 11	week 12	week 13	week 14	week 15	week 16	week 17	week 18	week 19	week 20	week 21	week 22	week 23	week 24	week 25
		4 to 8	*11to*	*18t*	*25*	*4to8*	*11 to5*	*18 to22*	*25to29*	*1to5*	*8to12*	*15to19*	*22to26*	*29to3*	*6to10*	*13to17*	*20to24*	*27to31*	*3to7*	*10to14*	*17 to 21*
Saclay nBLM AIT Operations	*Bulk*	CDR & TRAINNING				Det 1-9		Det 10-18		Det 19-27	Det 28 -36	Det 37 -45	Det 46-54	Det 55-63	Det 64-72	Det 73-81	Det 82-90	Contingency detectors			
	Soldering						Det 1-9		Det 10-18		Det 19 -27	Det 28-36	Det 37-45	Det 46-54	Det 55-63	Det 64-72	Det 73-81	Det 82-90	Contingency detectors		
	Integration							Det 1-9		Det 10-18		Det 19-27	Det 28-36	Det 37-45	Det 46-54	Det 55-63	Det 64-72	Det 73-81	Det 82-90	Contingency detectors	
	Gas leak								Det 1-9		Det 10 -18		Det 19-27	Det 28-36	Det 37-45	Det 46-54	Det 55-63	Det 64-72	Det 73-81	Det 82-90	Contingency detectors
	252Cf								Det 1-9		Det 10 -18		Det 19-27	Det 28-36	Det 37-45	Det 46-54	Det 55-63	Det 64-72	Det 73-81	Det 82-90	Contingency detectors

NBLM – DETECTOR PRODUCTION FLOW

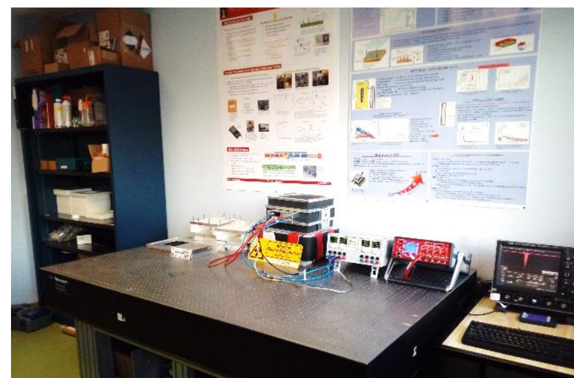


NBLM – DETECTOR PRODUCTION


Polyethylene


Mirrobor


Integration laboratory



Detectors Verification laboratory



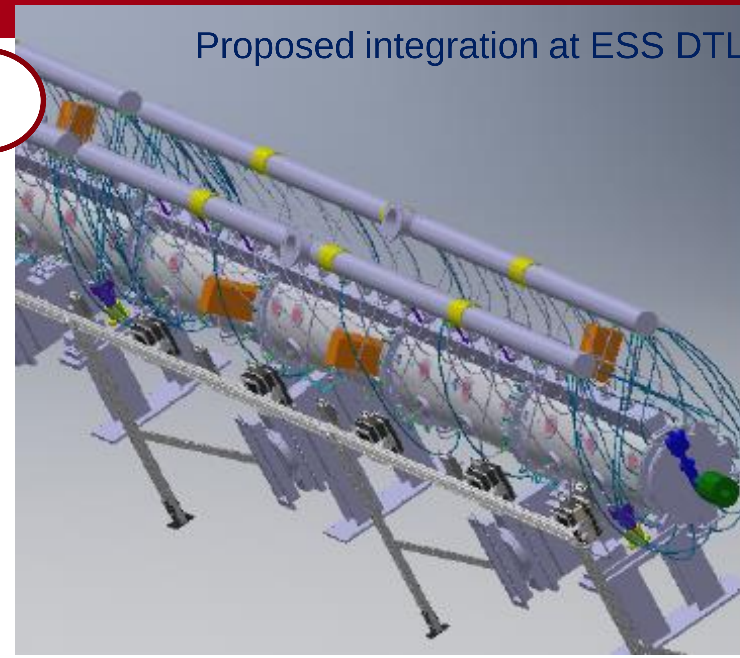
Mechanics of the nBLM detector chambers (for 84 modules) at CEA

NBLM DETECTORS SUPPORTS

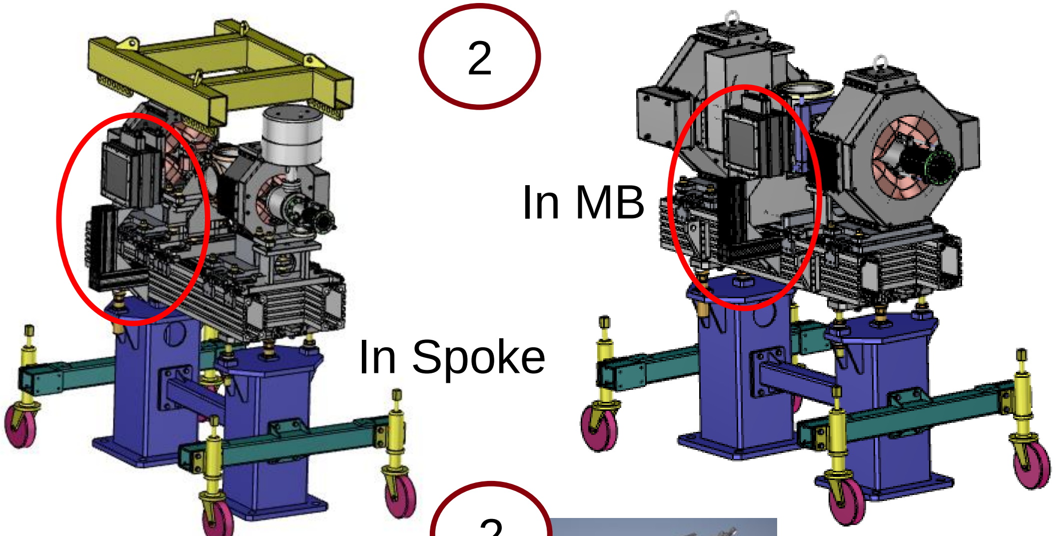
Three designs based on same principle

1. For DTL Region
    - Integrated at ESS 3D model
2. For Spokes and high energy regions
3. For MEBT

1



2



2

3

NBLM TESTS

Installation	Date	Goal of test	Results
MC40 (Birmingham)	Nov-17	First test in an accelerator	Linear response with beam current
IPHI (Saclay)	Jan-18	First test in a beam pulsed accelerator First test of FEE in accelerator First test of fast module with big neutron flux	Time Response Neutron identification (FEE test) Algorithm development
AMANDE (Cadarache)	March-18	Calibration of detectors Moderator optimization Fast module tested at high energies First gamma/neutron discrimination	Response curves as a function of moderator thickness and neutron energy
ORPHEE (Saclay)	March-18	Response to thermal neutron B4C thickness studies	Response to thermal neutrons Signal characteristics B4C thickness studies
LINAC4 (CERN)	Oct/ Dec-18	Test in real accelerator conditions Test the FEE, the DAQ and the detectors	Response to beam losses Response to gammas from RF
Saclay	Feb-19	Detailed study neutrons vs gamma Test of one final nBLM module	Gain curves Discrimination n/gamma

All details in document *nBLM_CDRfinal_ReportTests.pdf*

NBLM TESTS

Presented in July 2018

Installation	Date	Goal of test	Results
MC40 (Birmingham)	Nov-17	First test in an accelerator	Linear response with beam current
IPHI (Sacl…	…18	…rst test in a beam pulsed accelerator First test of FEE in accelerator First test of fast module with big neutron flux	Time Response Neutron identification (FEE test) Algorithm development
…ANDE (Cadarache)	March-18	Calibration of detectors Moderator optimization Fast module tested at high energies First gamma/neutron discrimination	Response curves as a function of moderator thickness and neutron energy
ORPHEE (Saclay)	March-18	Response to thermal neutron B4C thickness studies	Response to thermal neutrons Signal characteristics B4C thickness studies
LINAC4 (CERN)	Oct/ Dec-18	Test in real accelerator conditions Test the FEE, the DAQ and the detectors	Response to beam losses Response to gammas from RF
Saclay	Feb-19	Detailed study neutrons vs gamma Test of one final nBLM module	Gain curves Discrimination n/gamma

All details in document *nBLM_CDRfinal_ReportTests.pdf*

NBLM TESTS

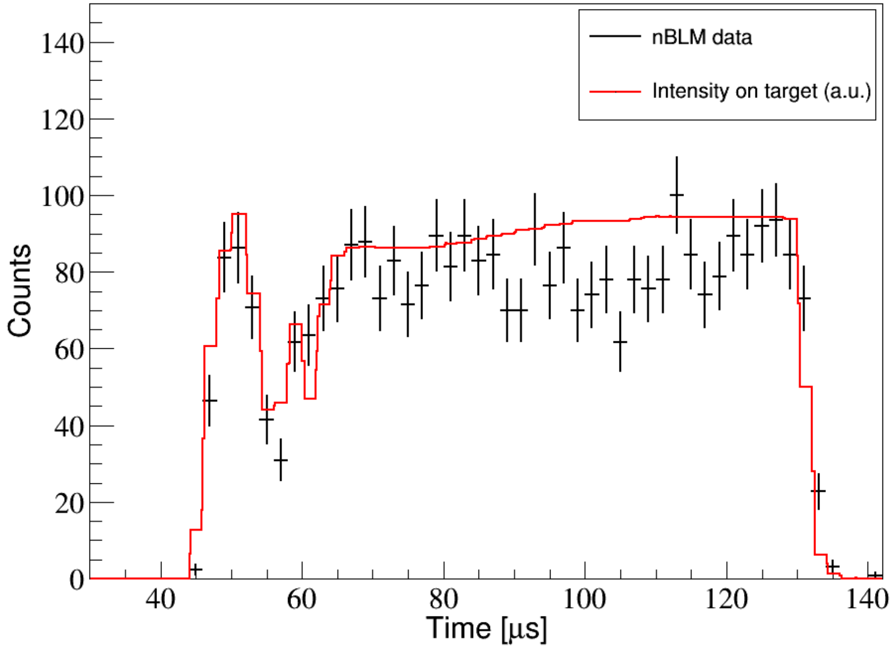
Installation	Date	Goal of test	Results
MC40 (Birmingham)	Nov-17	First test in an accelerator	Linear response with beam current
IPHI (Saclay)	Jan-18	First test in a beam pulsed accelerator First test of FEE in accelerator First test of fast module with big neutron flux	Time Response Neutron identification (FEE test) Algorithm development
AMANDE (Cadarache)	March-18	Calibration of detectors Moderator optimization Fast module tested at high energies First gamma/neutron discrimination	Response curves as a function of moderator thickness and neutron energy
ORPHEE (Saclay)	March-18	Response to thermal neutron B4C thickness studies	Response to thermal neutrons Signal characteristics B4C thickness studies
LINAC4 (CERN)	Oct/ Dec-18	Test in real accelerator conditions Test the FEE, the DAQ and the detectors	Response to beam losses Response to gammas from RF
Saclay	Feb-19	Detailed study neutrons vs gamma Test of one final nBLM module	Gain curves Discrimination n/gamma

All details in document *nBLM_CDRfinal_ReportTests.pdf*

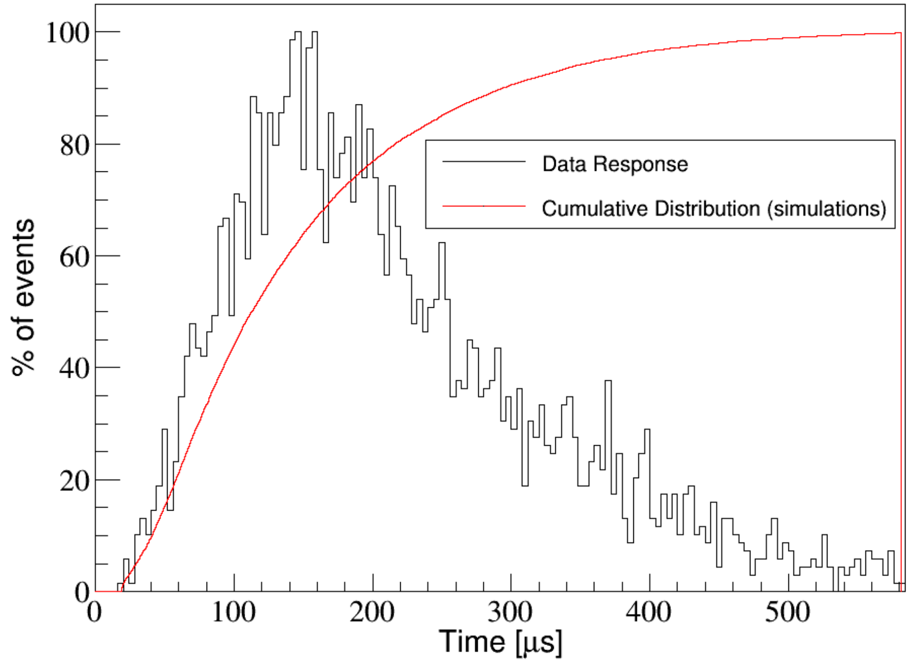
IPHI – NBLM TIME RESPONSE

Presented in July 2018

Fast detector



Slow detector

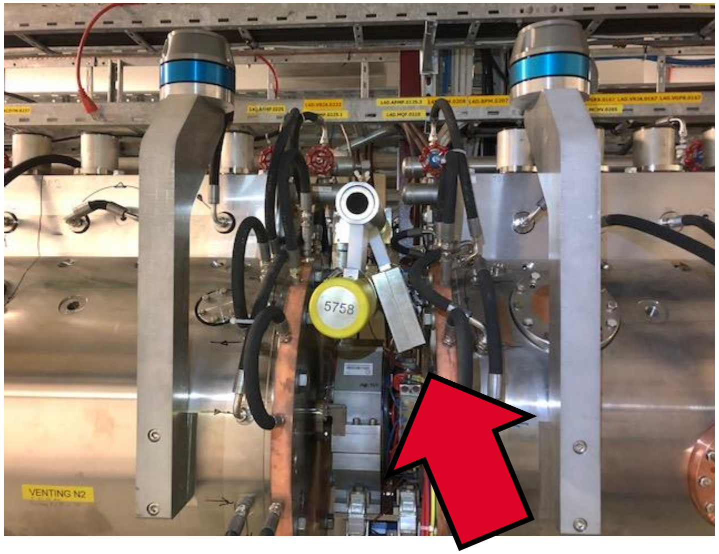


- Immediate response
- Count rate in direct correlation with beam current intensity

- Moderation time → delay of 100-200µs.
- In agreement with simulation
- Higher efficiency

  ~5% of the total in the first 5µs so possible to use for early warning. To verified during commisioning

- **Fast nBLM module** installed between two DTLs at ~13 MeV proton region
- Final mechanics and electronics (pre-series)
- Gas: He + 10% CO2
- Two data campaigns
  - November 2018
    - Understanding the detector, test the FMC for first time, test FEE in accelerator conditions…
  - December 2018
    - Losses were produced
    - Second test of FMC with newer version



- Data taking with a fast oscilloscope
  - 250 Ms/s
  - Full bandwidth
  - With trigger of Linac4 also recorded
- CEA Analysis based on C code integrated with ROOT (details in the backup)
- Benchmark for results obtained with FMC

LINAC4 DATA

Nov 2018

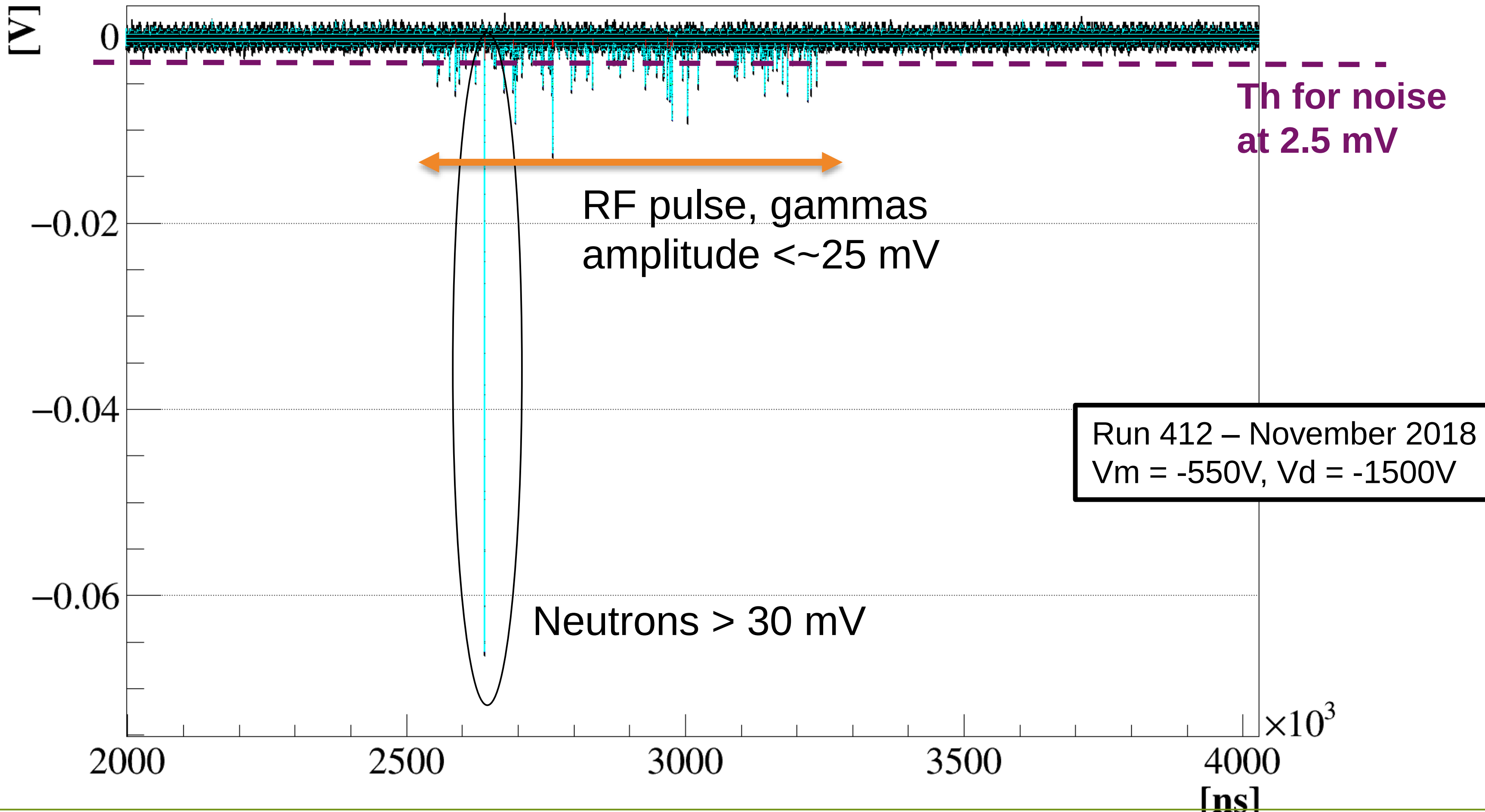
Run	Vm	Vd	ext trigger	Comments
412	550	1650	no	autotrigger in ”neutrons"

Dec 2018

Run	Vm	Vd	ext trigger	Comments
413	550	1500	yes	Losses
414	525	1000	yes	No losses
415	525	1000	yes	Losses
416	550	1500	no	Autotrigger, no losses
417	550	1500	no	Autotrigger, no losses, signal shared with Strucks
418	550	1500	yes	No losses signal shared with IOxOS
419	525	1000	yes	Losses
420	550	1500	no	Autotrigger signal shared with IOxOS

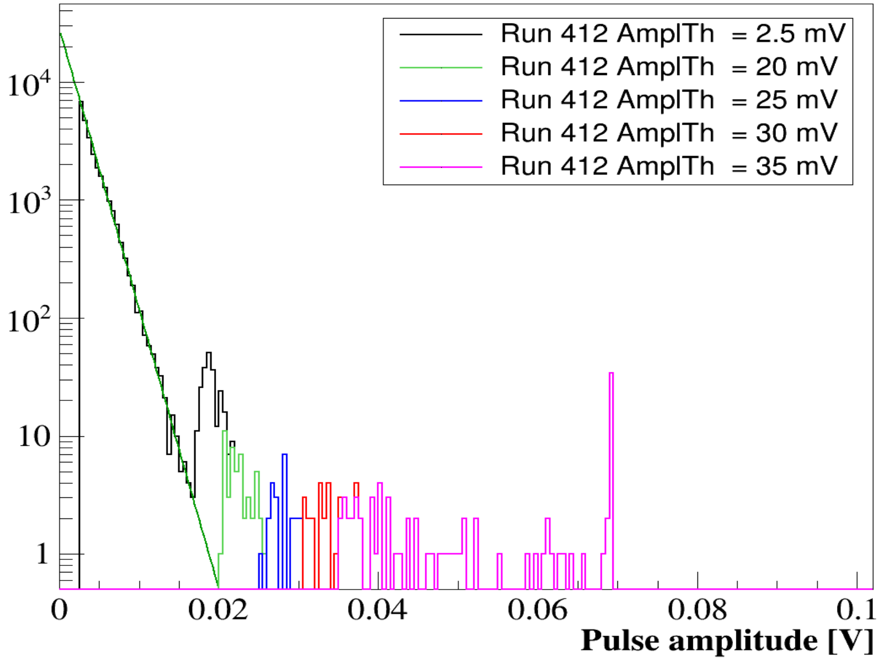
LINAC4 DATA

- 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

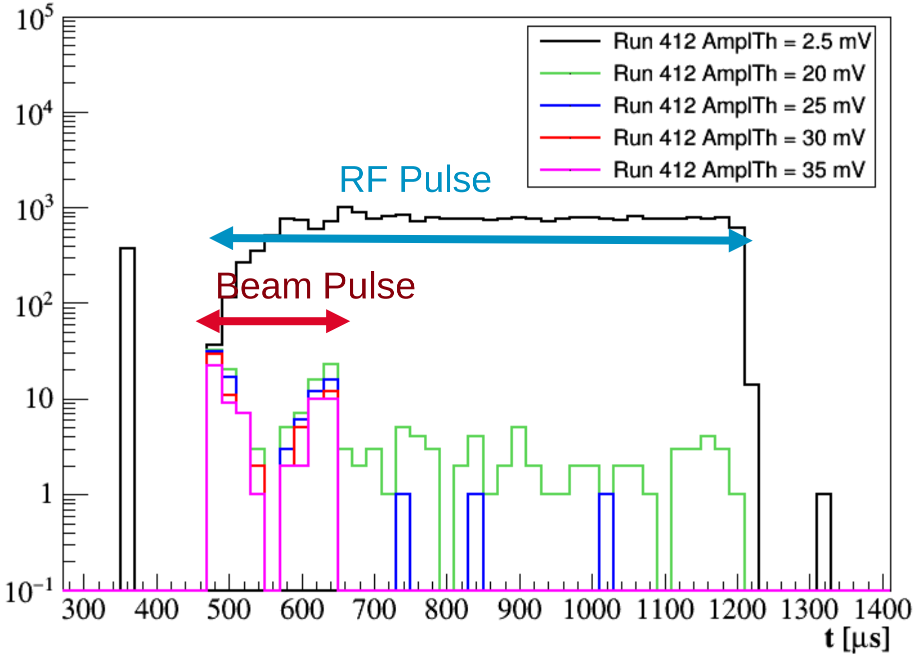


Run 412 – November 2018
Vm = -550V, Vd = -1500V

Amplitude



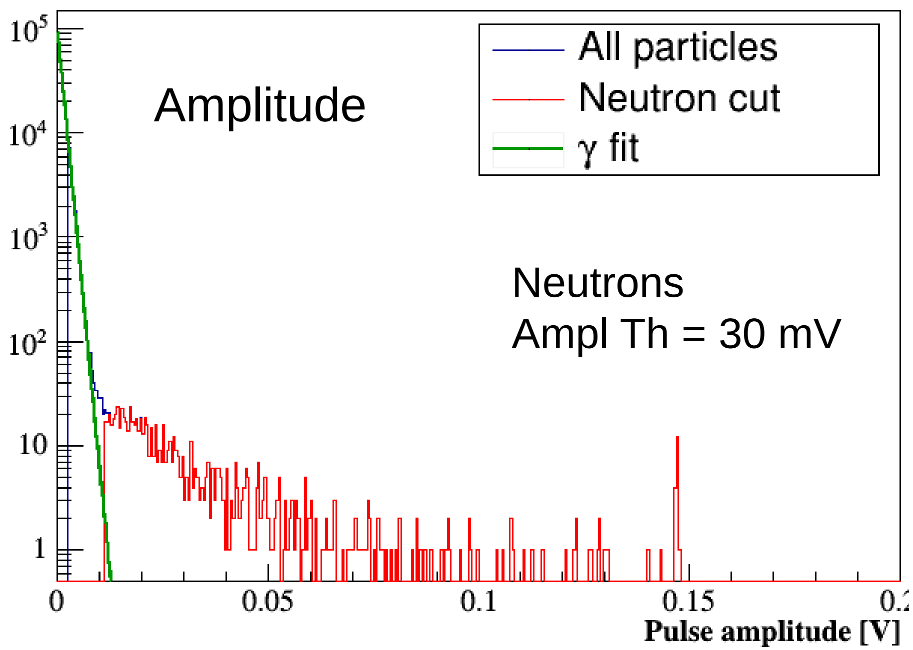
Beam Structure

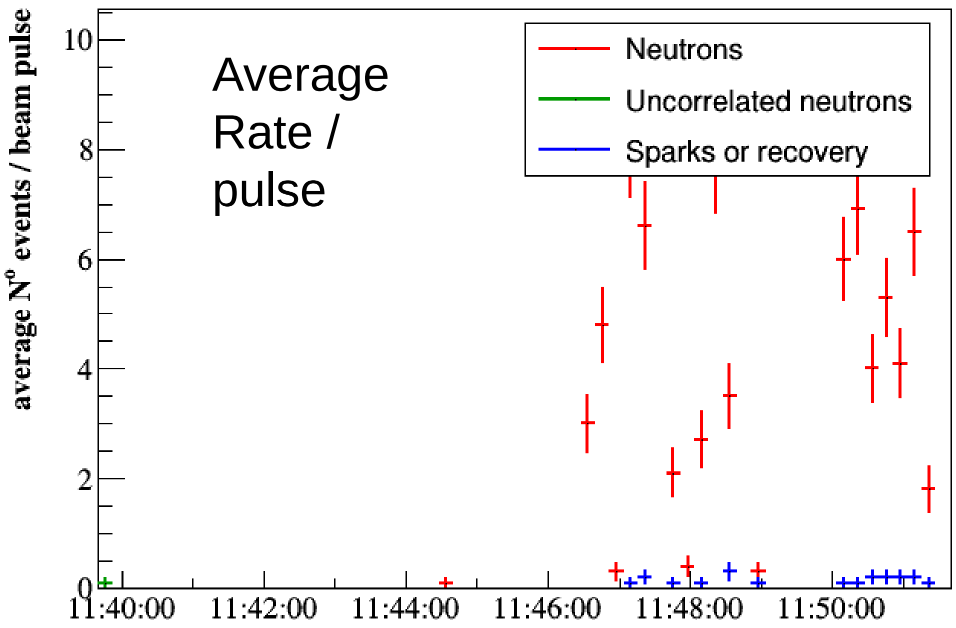


Applying amplitude cut, we recover the beam duration
→ Neutrons produced by beam
→ Gammas distributed all along RF pulse

LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

Run 413 – December 2018
Vm = -550V, Vd = -1500V





- Sparks appear at high gain
- Produced by the neutrons

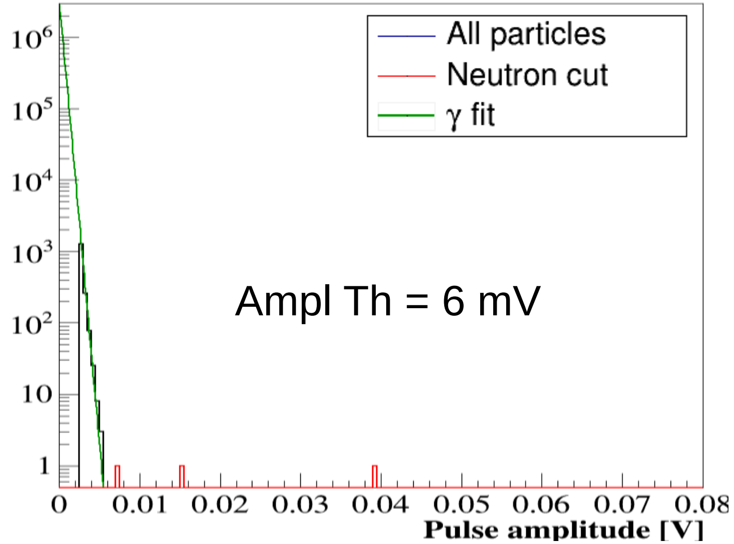
LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

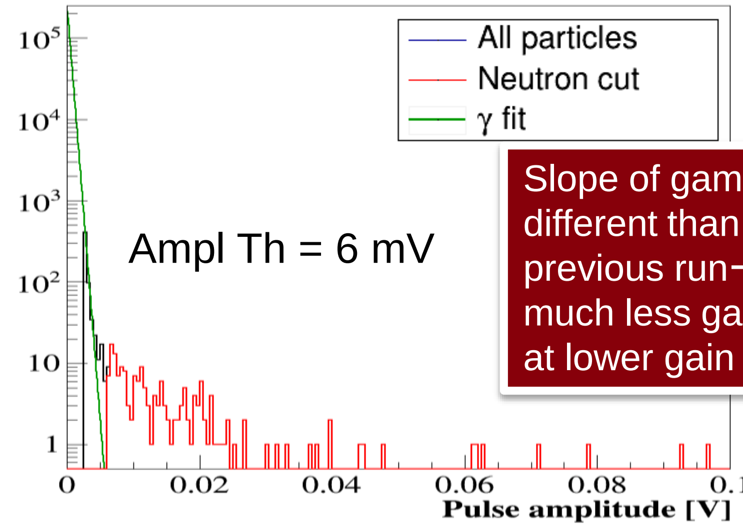
Vmesh = 525 V
Vdrift = 1000 V

Run 414
No losses

Run 415
Losses

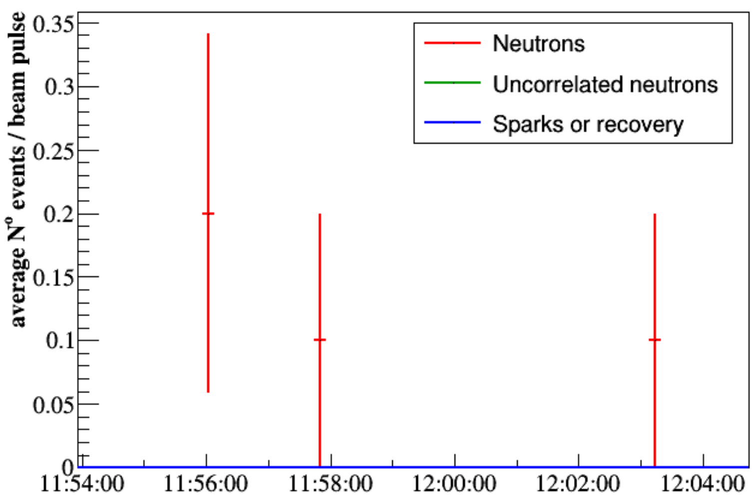
Amplitude

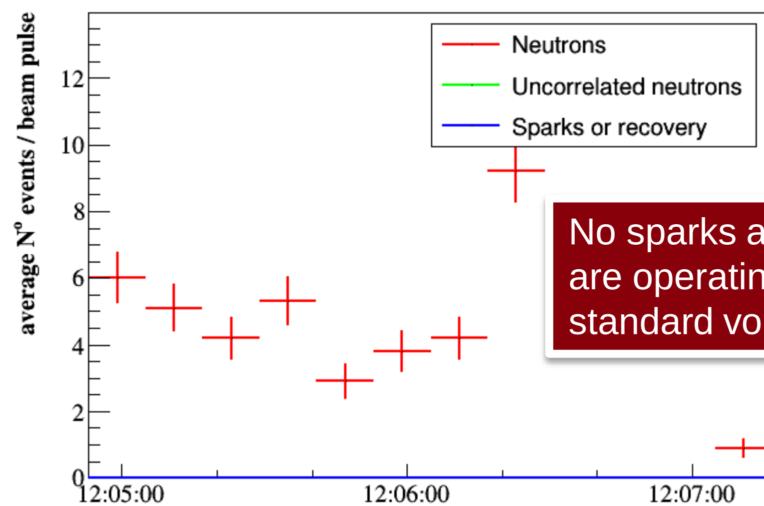




Slope of gammas different than in previous run→ much less gammas at lower gain

Average rate



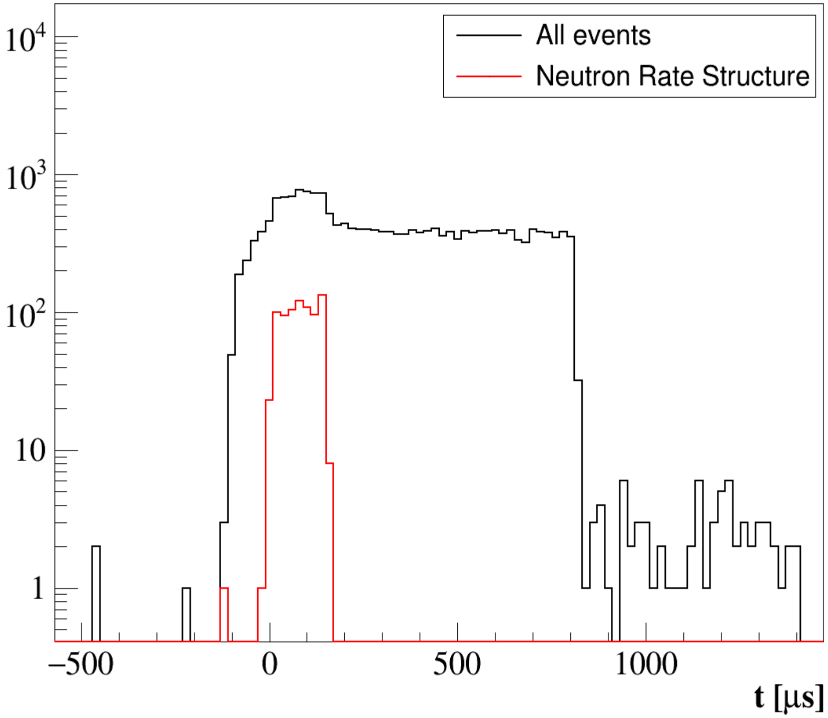


No sparks as we are operating at standard voltages

LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

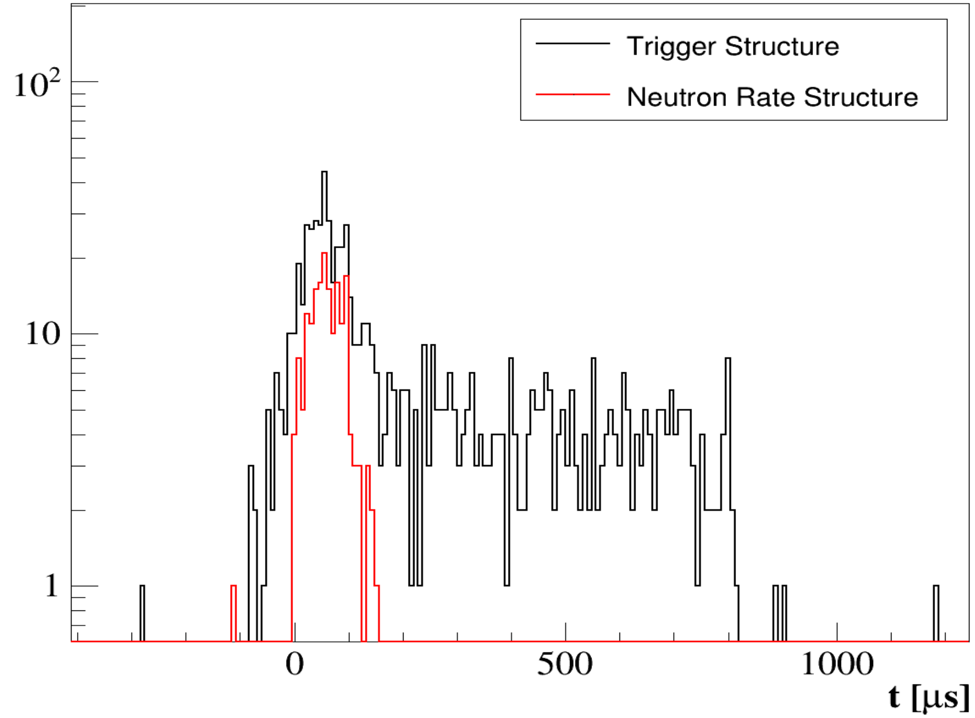
Beam Structure

Run 413



Vmesh = -550V
Vdrift = -1500V

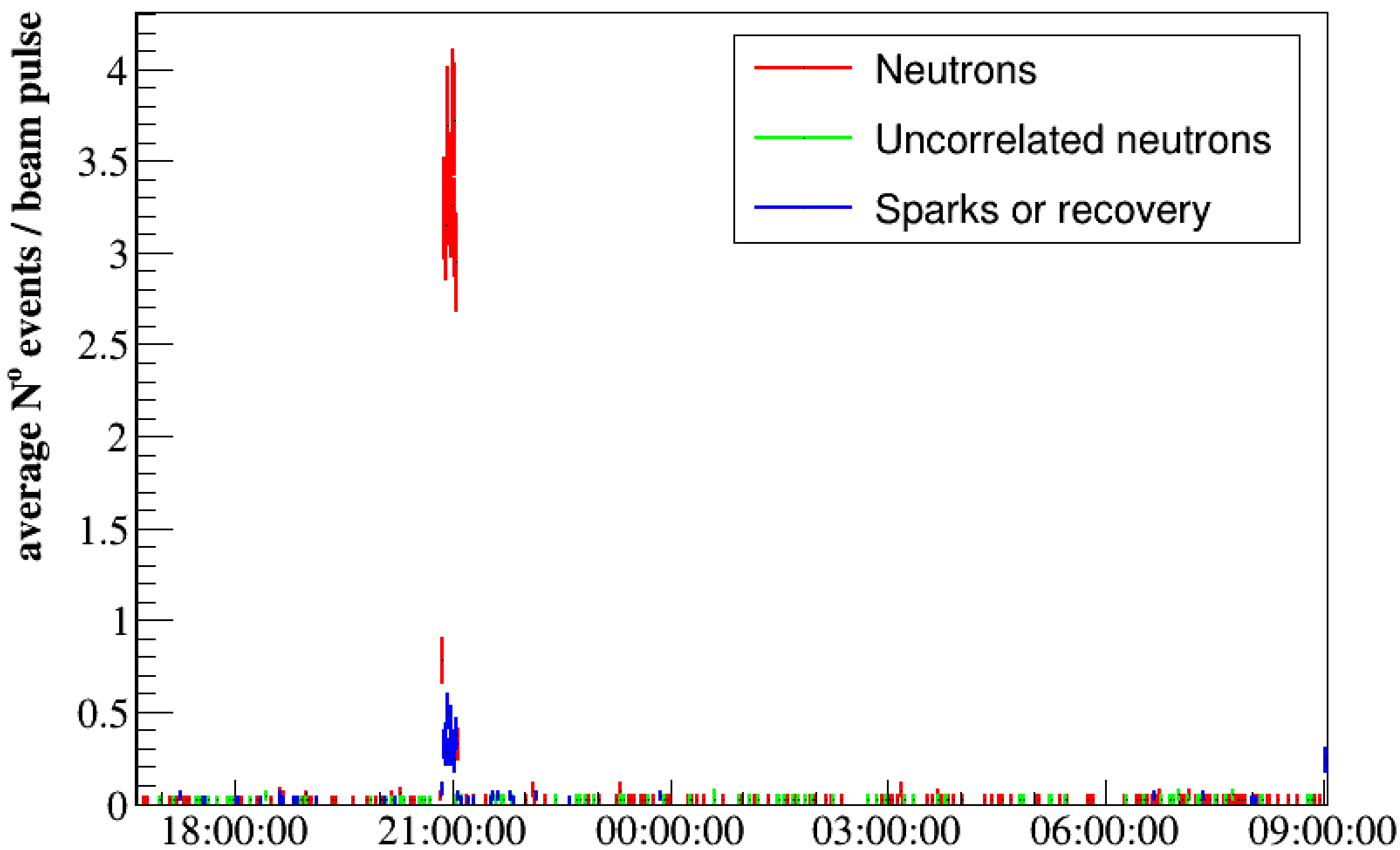
Run 415



Vmesh = 515 V
Vdrift = 1000 V

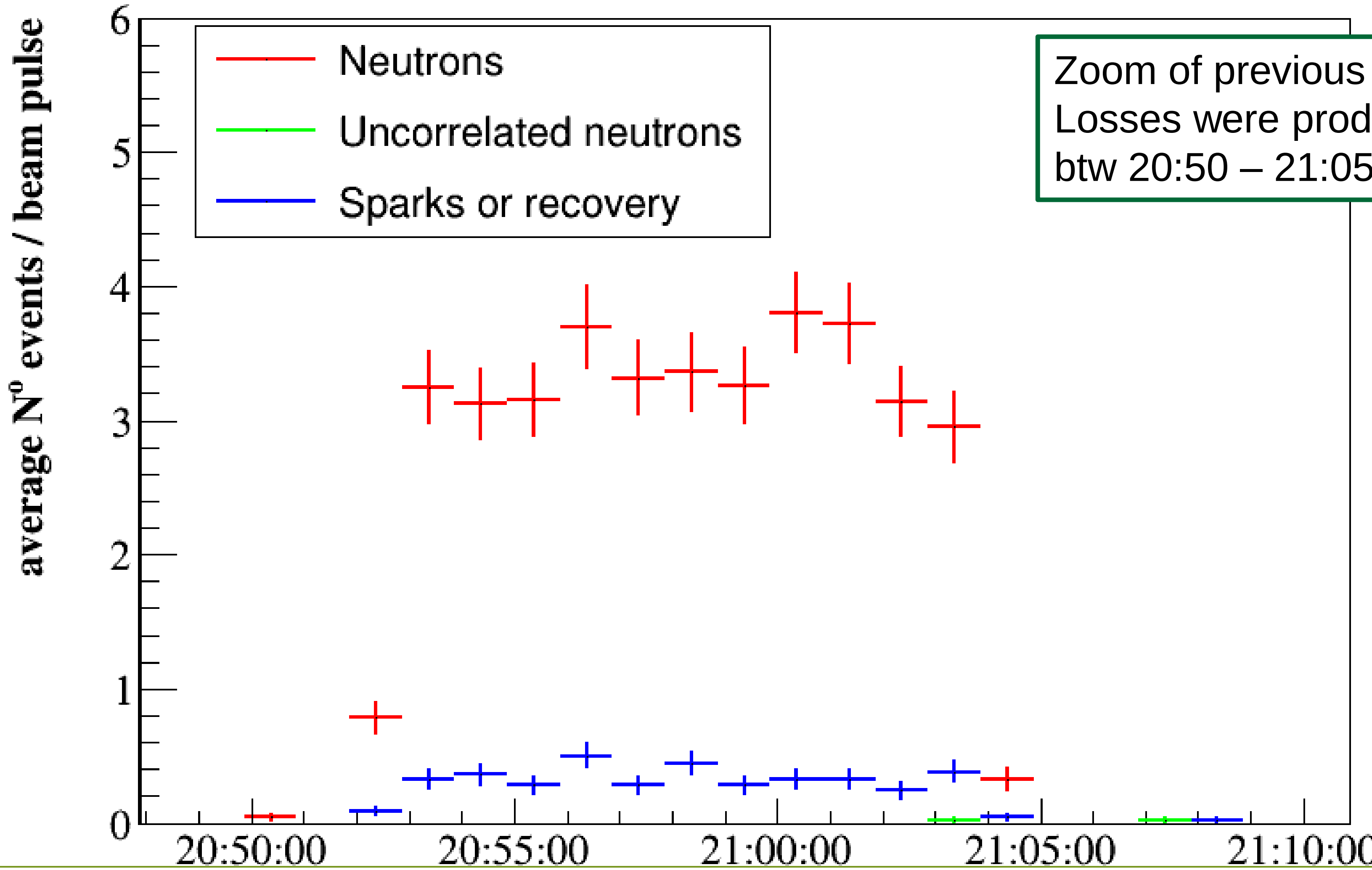
LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

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



LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

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

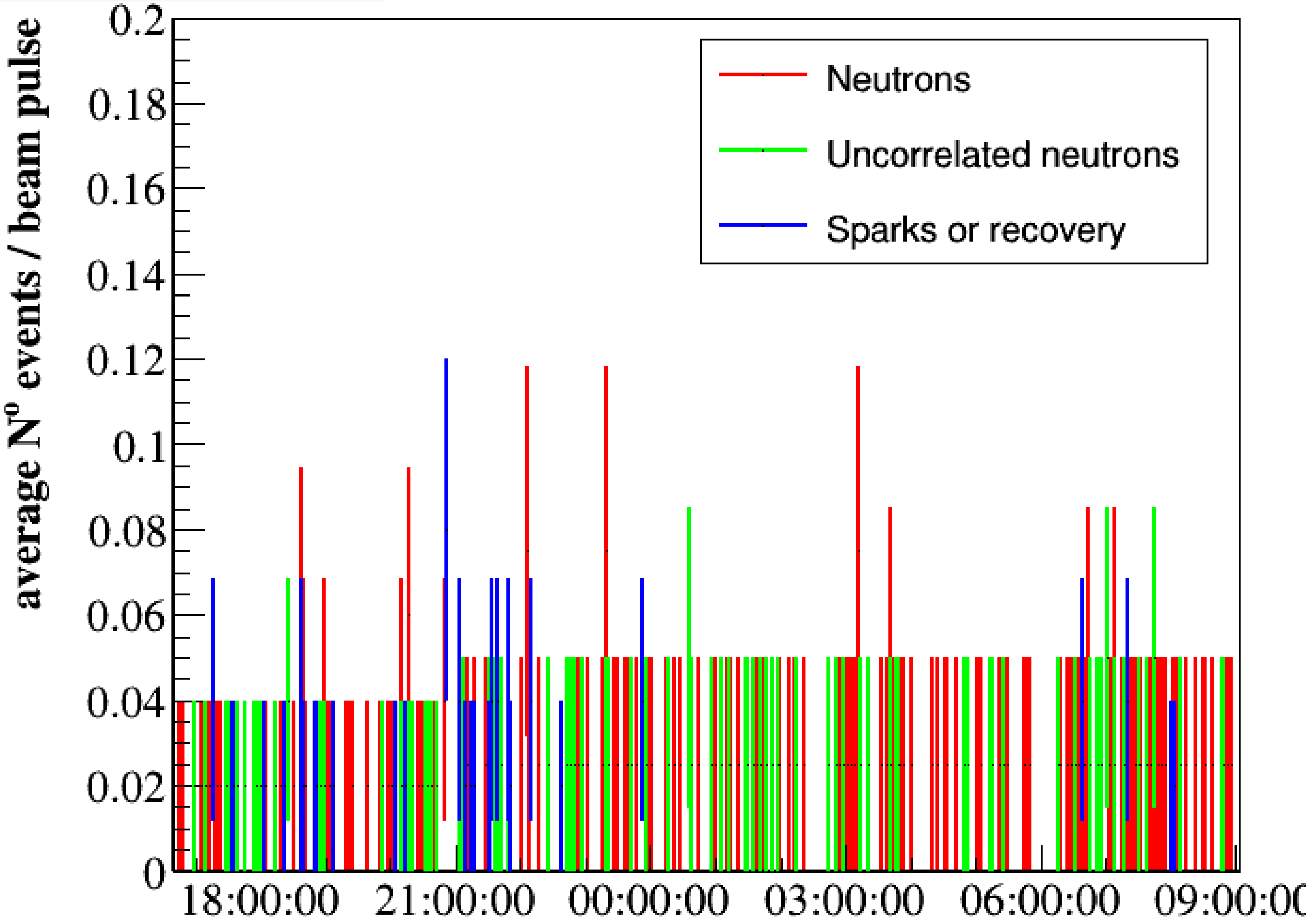


Zoom of previous slide
Losses were produced btw 20:50 – 21:05

LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

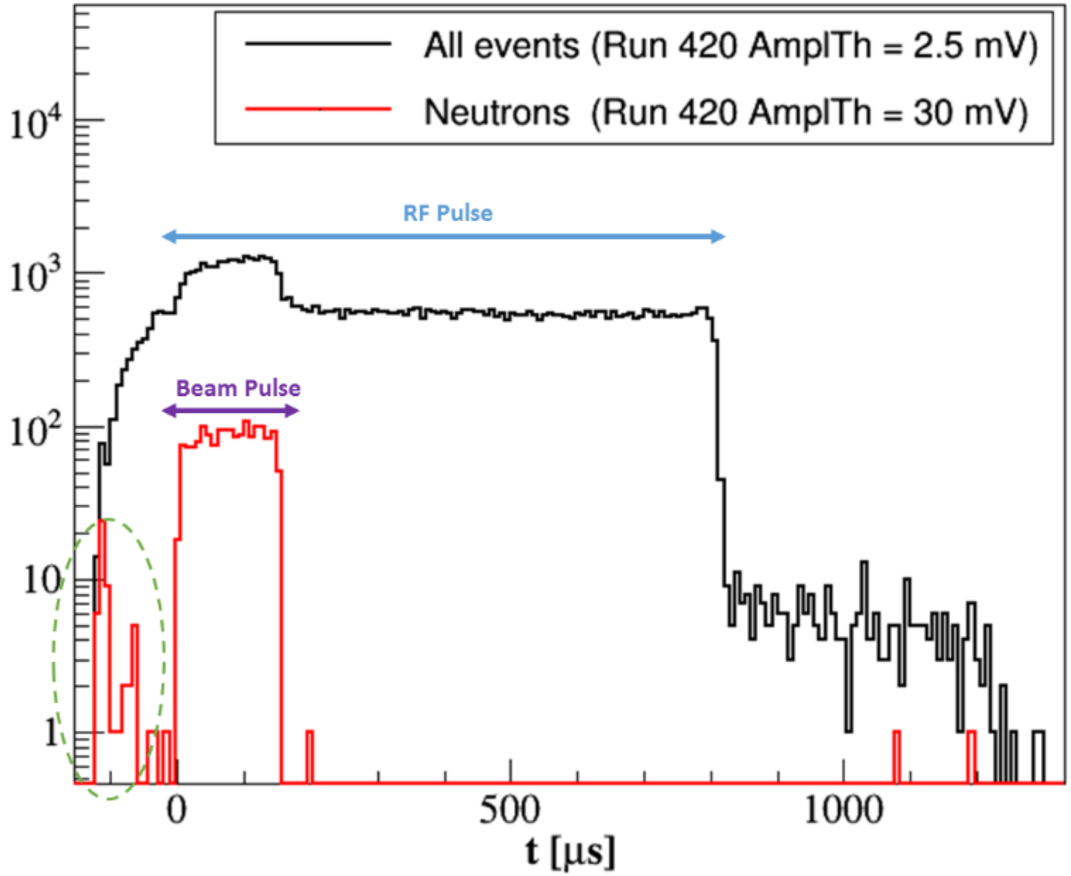
Zoom of previous slide in vertical axis

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



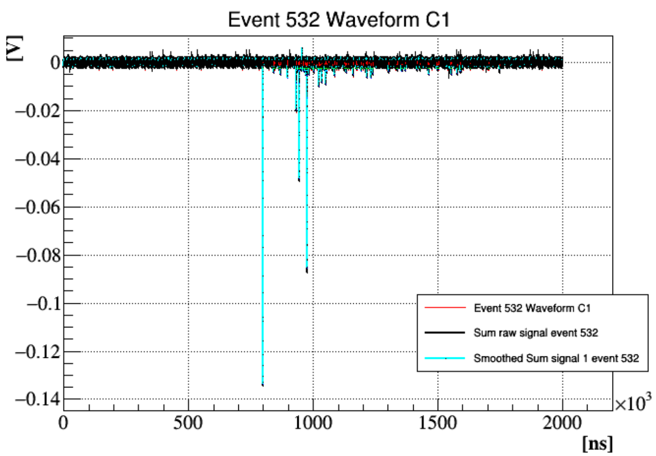
LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

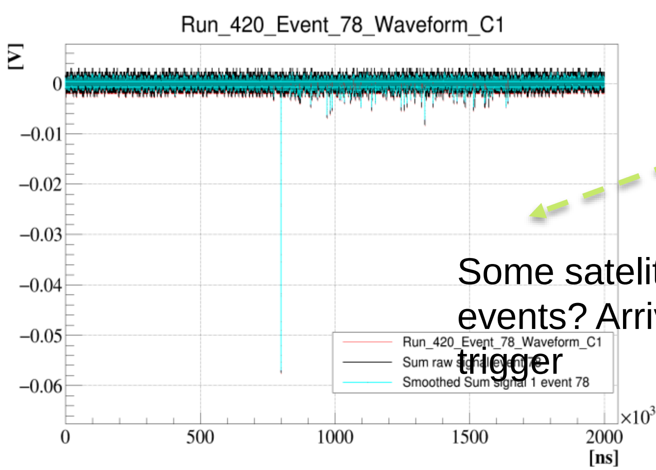
Run 420 – December 2018
Vm = -550V, Vd = -1500V

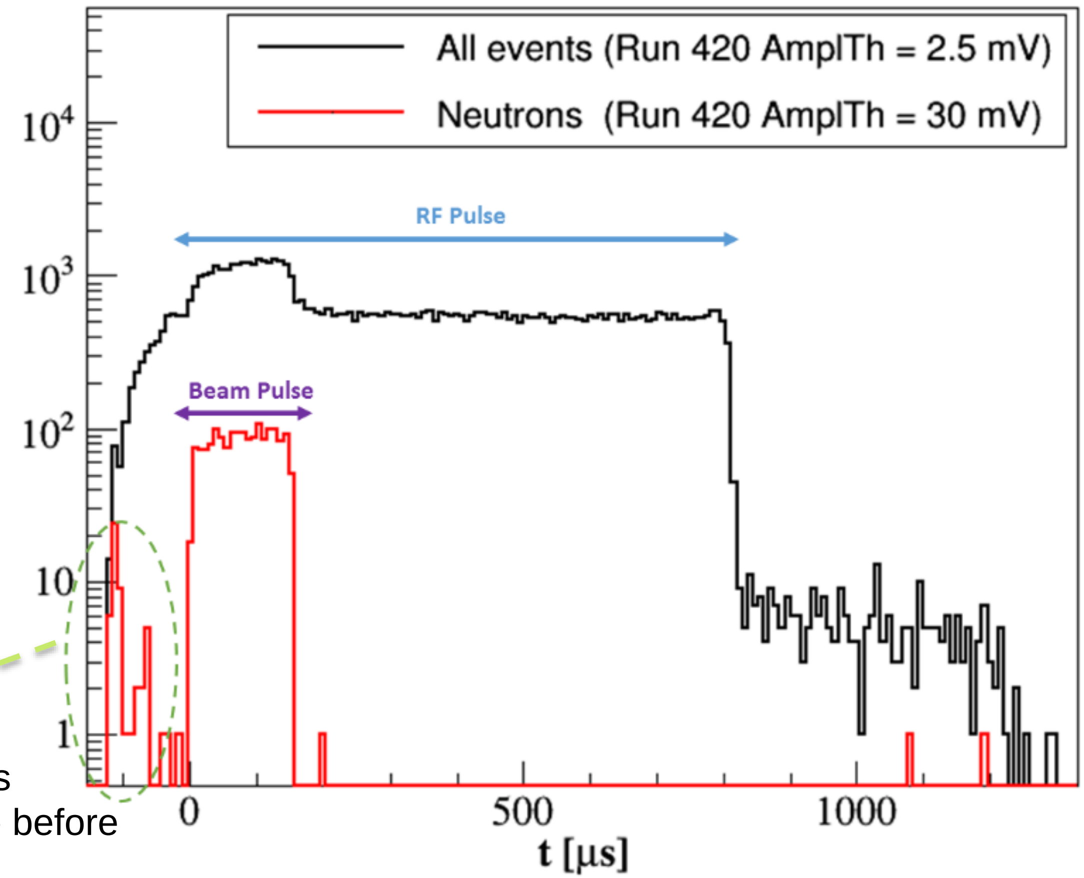


LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES

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



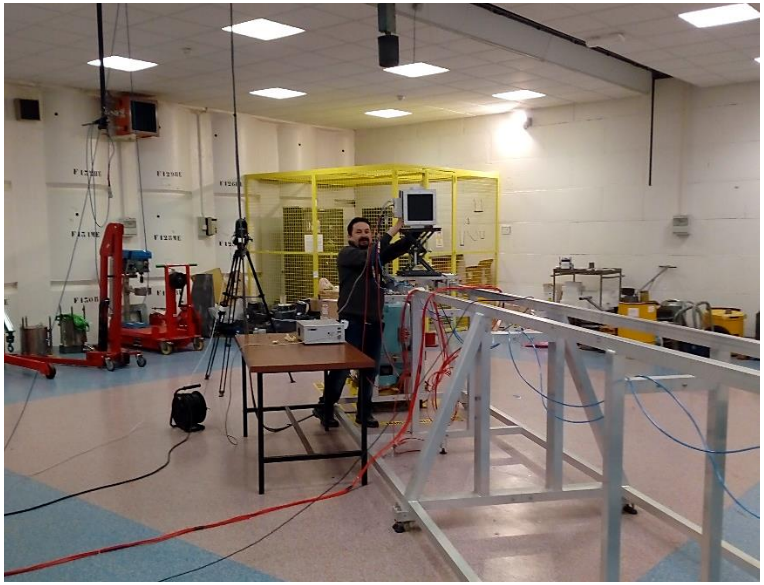




Some satelites events? Arrive before trigger

NBLM DATA – NEUTRON AND GAMMA SOURCES

- High intensity neutron and gamma sources available from the CEA radioprotection department
- Data taken with slow module on the 6/02 – 08/02
- Gain curves for gammas and neutrons to determine operational point



Source	Activity (Bq)	H^*_{10} at 0.5 m
AmBe (Neutrons)	10^{11}	275 µSv/h
Co-60	10^{8}	1 mSv/h
Co-60	10^{8}	100 mSV/h

Slow detector

Sources

NBLM DATA – NEUTRON AND GAMMA SOURCES

- Big matrix of data to analyze
- **n** = neutrons, γ = gammas
- Preliminary observations

Vm	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV
440	n	n	n	n	n	n
450	n	n	n	n	n	n
460	n	n	n	n	n	n
470	n	n	n	n	n	n
480	n	n	n, γ	n, γ	n, γ	n, γ
490	n	n	n, γ	n, γ	n, γ	n, γ
500	n	n	n, γ	n, γ	n, γ	n, γ
510	n	n	n, γ	n, γ	n, γ	n, γ
525		γ	γ	γ	γ	γ
550	γ	γ	γ	γ	γ	γ

NBLM DATA – NEUTRON AND GAMMA SOURCES

- Big matrix of data to analyze
- **n** = neutrons, γ = gammas
- Preliminary observations

Vm	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV
440	n	n	n	n	n	n
450	n	n	n	n	n	n
460	n	n	n	n	n	n
470	n	n	n	n	n	n
480	n	n	n, γ	n, γ	n, γ	n, γ
490	n	n	n, γ	n, γ	n, γ	n, γ
500	n	n	n, γ	n, γ	n, γ	n, γ
510	n	n	n, γ	n, γ	n, γ	n, γ
525		γ	γ	γ	γ	γ
550	γ	γ	γ	γ	γ	γ

Above this value the neutrons produce sparks

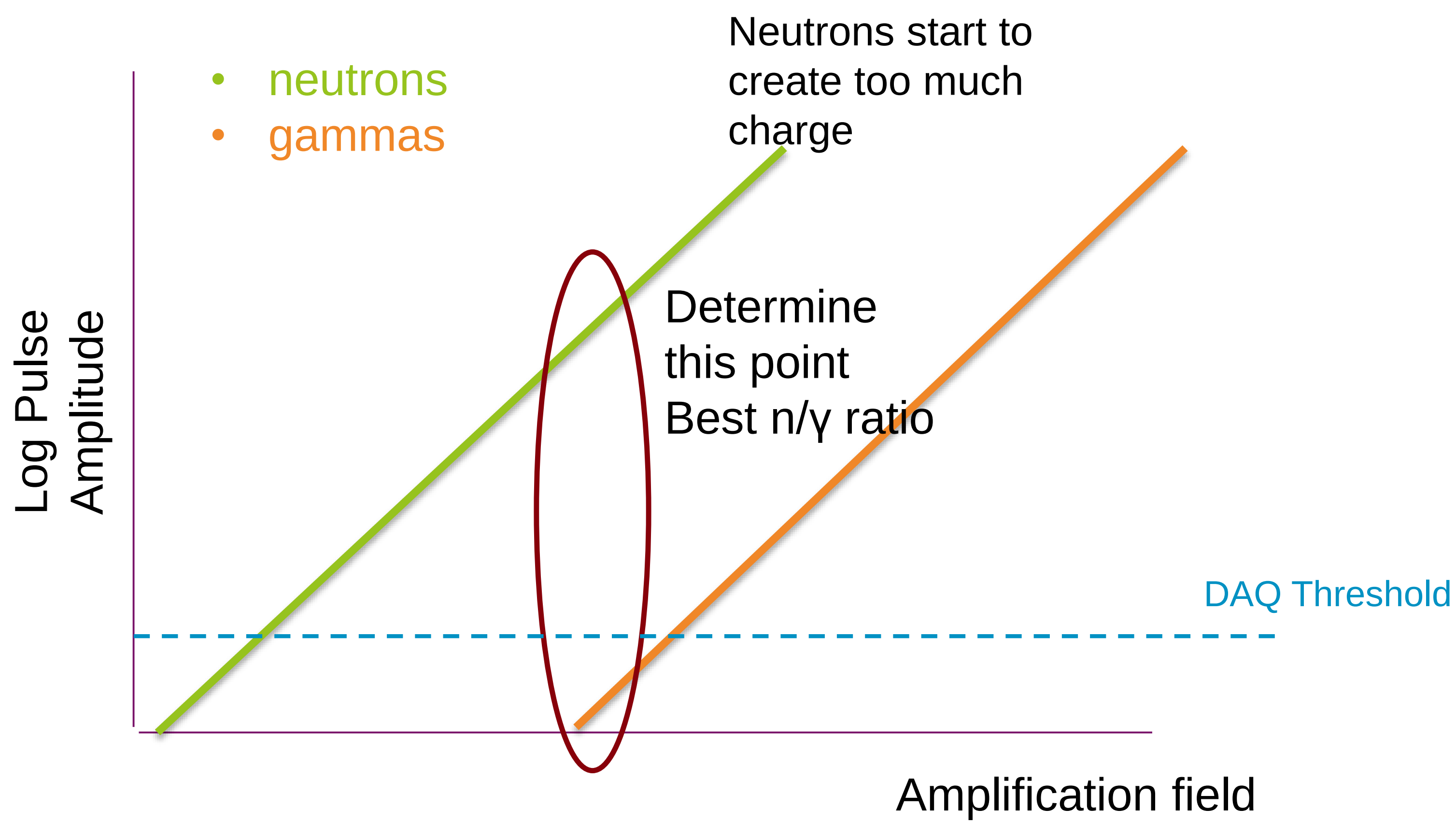
NBLM DATA – NEUTRON AND GAMMA SOURCES

- Big matrix of data to analyze
- **n** = neutrons, γ = gammas
- Preliminary observations

Vm	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV	Vd = Vm+25mV
440	n	n	n	n	n	n
450	n	n	n	n	n	n
460	n	n	n	n	n	n
470	n	n	n	n	n	n
480	n	n	n, γ	n, γ	n, γ	n, γ
490	n	n	n, γ	n, γ	n, γ	n, γ
500	n	n	n, γ	n, γ	n, γ	n, γ
510	n	n	n, γ	n, γ	n, γ	n, γ
525		γ	γ	γ	γ	γ
550	γ	γ	γ	γ	γ	γ

Below this value the gammas not visible

NBLM DATA – NEUTRON AND GAMMA SOURCES



Thank you!

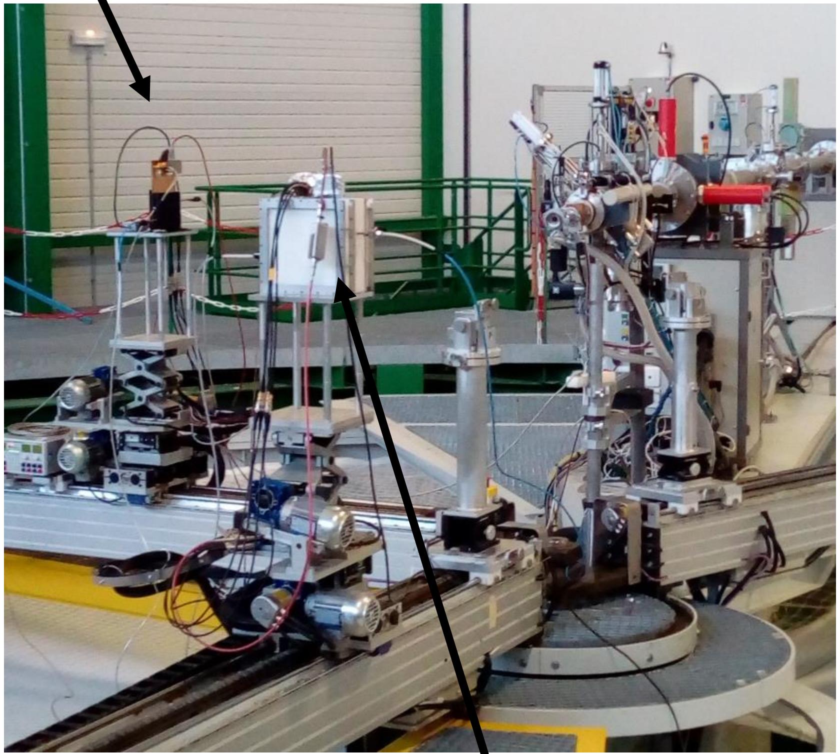
Full characterization of detector in next slides

NEUTRON BLM: CHARACTERISATION AT DIFFERENET IRRADIATION FACILITIES

AMANDE FACILITY (IRSN-Cadarache): monoenergetic neutron reference fields

- Metrology
- Testing and calibrating neutron sensitive devices (between 2 keV -20 MeV).

Fast module
2mm drift

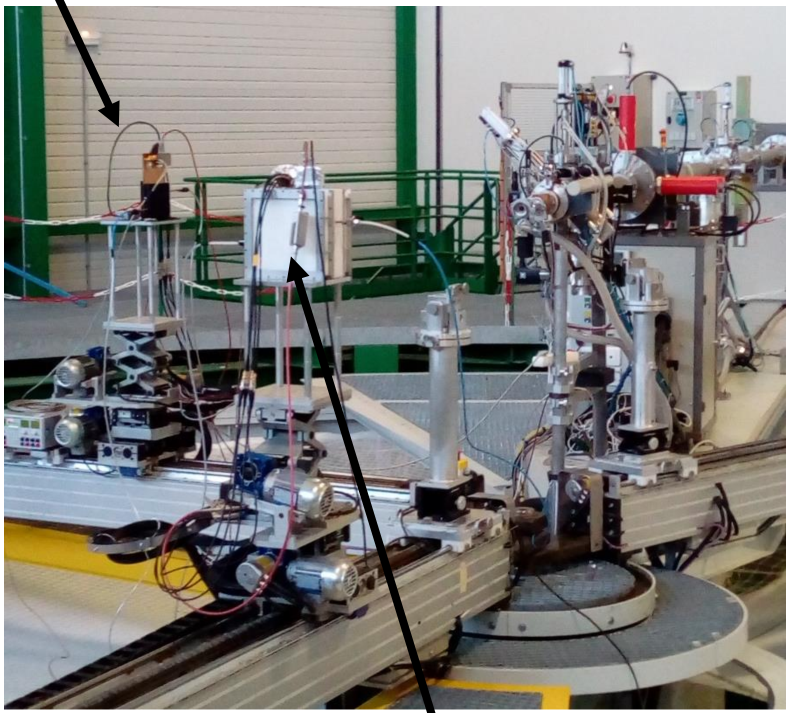


Slow module
0.4 mm drift,
1.5µm B_4C

- Data campaign in March 2018
- Slow and fast module tested, He+10%CO_2
- At diff neutron energies:
  - 565, 1200, 2500, 5000 and 15000 keV

AMANDE FACILITY (IRSN-Cadarache): monoenergetic neutron reference fields

Fast module
2mm drift

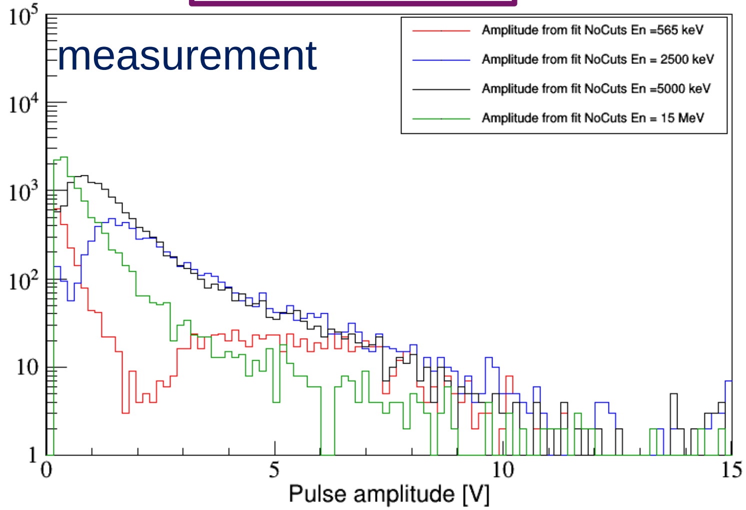


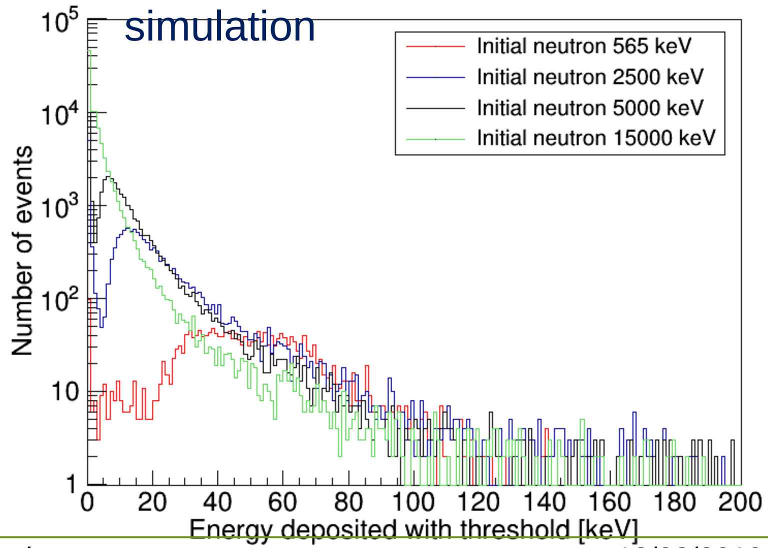
Slow module
0.4 mm drift,
1.5µm B_4C

- nBLM Goal:
  - Efficiency measurements
  - Comparison with Geant4 simulations
  - Slow module
    - Polyethylene thickness optimization
  - Fast module:
    - Convertor comparison
  - Extra: gamma rejection proof
- Use charge preamplifier + Amplifier
- Acquisition with digital oscilloscope
- A shadow cone used for backscatter suppression.
- IRSN reference detectors for the flux

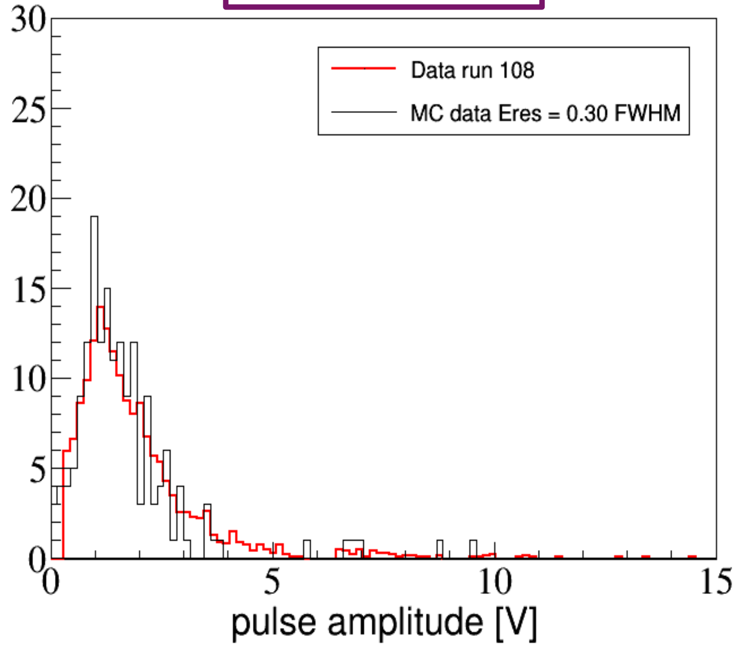
SIMULATION COMPARISON

FAST



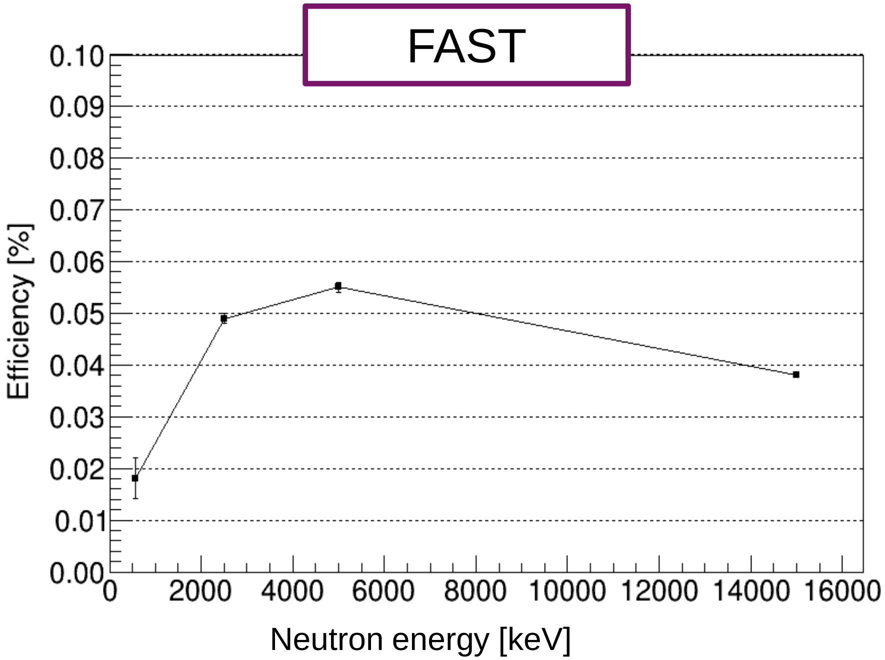


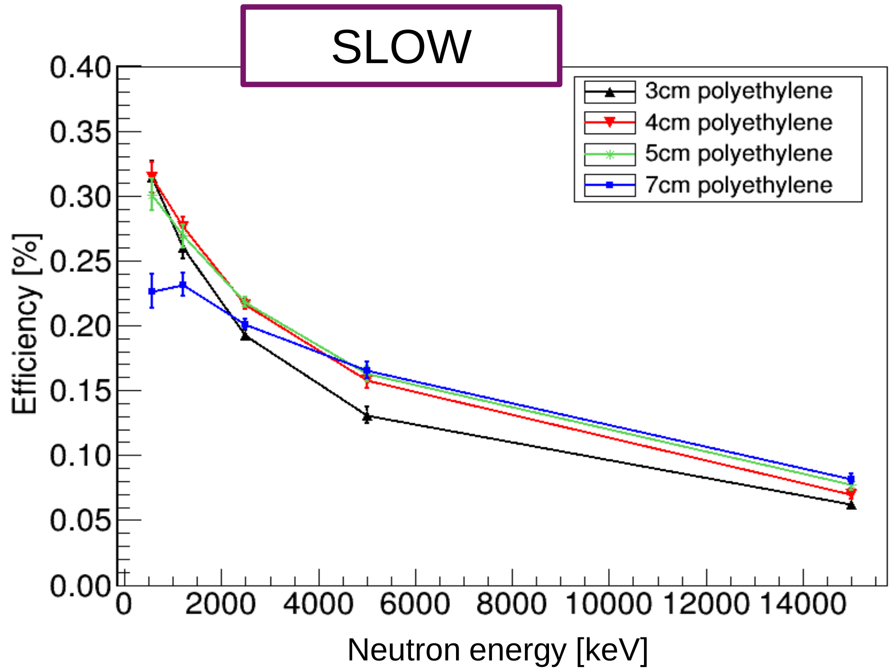
SLOW



- Good agreement with Geant4 simulation
  - Still few details under revision
- Pulse amplitude spectrum of slow detector independent with neutron energy
- Energy calibration possible for both detectors thanks to the peaks

AMANDE FACILITY (IRSN-Cadarache): EFFICIENCY STUDIES





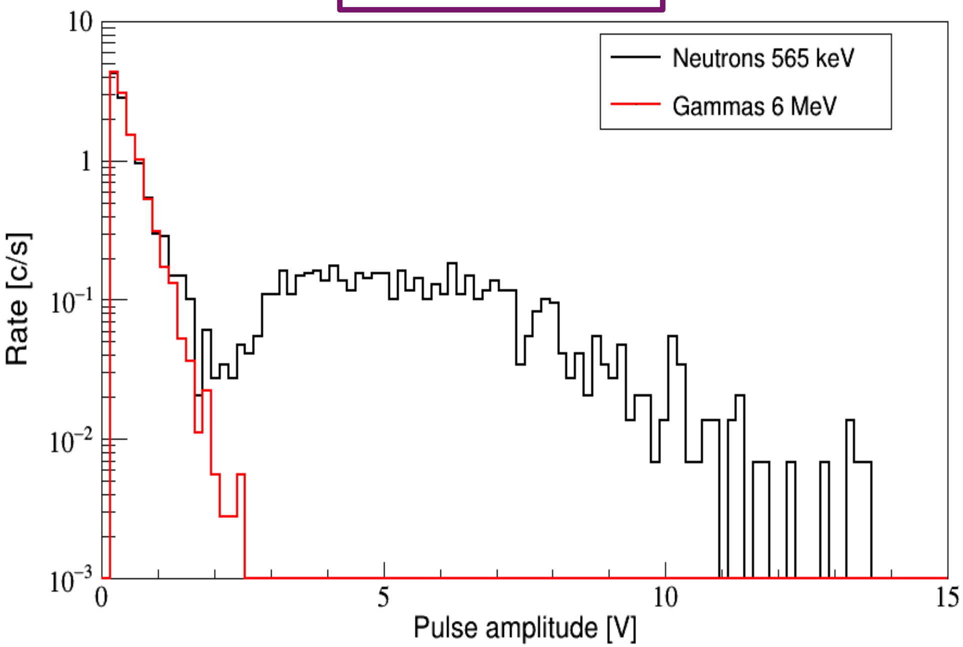
- Efficiency strongly dependent
  - on threshold
  - on initial energy
- Efficiency between factor 5-20 smaller than slow module (as expected)

- Count rate of few /s for a neutron fluence rate of 1/s/cm2
- Polyethylene thickness fixed at 5cm

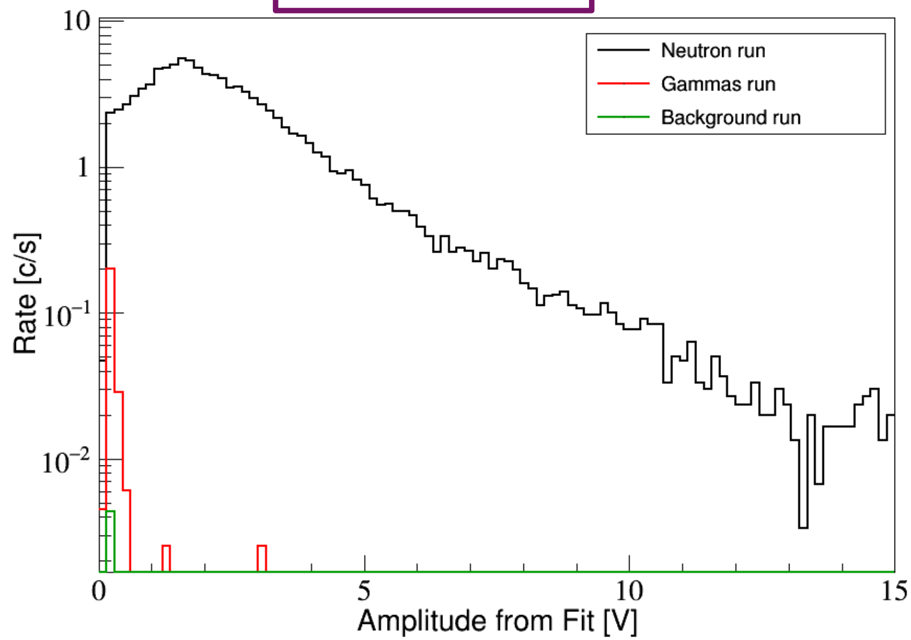
NBLM: CHARACTERISATION AT DIFFERENT IRRADIATION FACILITIES

AMANDE FACILITY (IRSN-Cadarache): GAMMA REJECTION

FAST



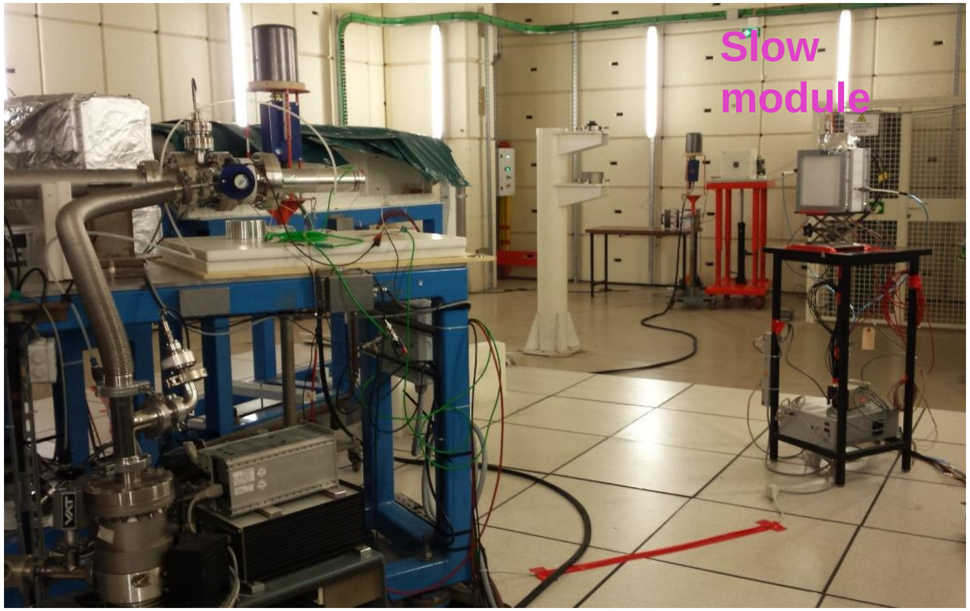
SLOW



- Rejection possible to difference in the ionization power between ions and electrons.
- The choice of He gas enhances the suppression
- With a energy threshold we can totally reject the gamma contribution
- The difference in rate observed between fast and slow due to different drift distance (1.9 mm in fast / 0.4 in slow)

nBLM: CHARACTERISATION AT DIFFERENT IRRADIATION FACILITIES

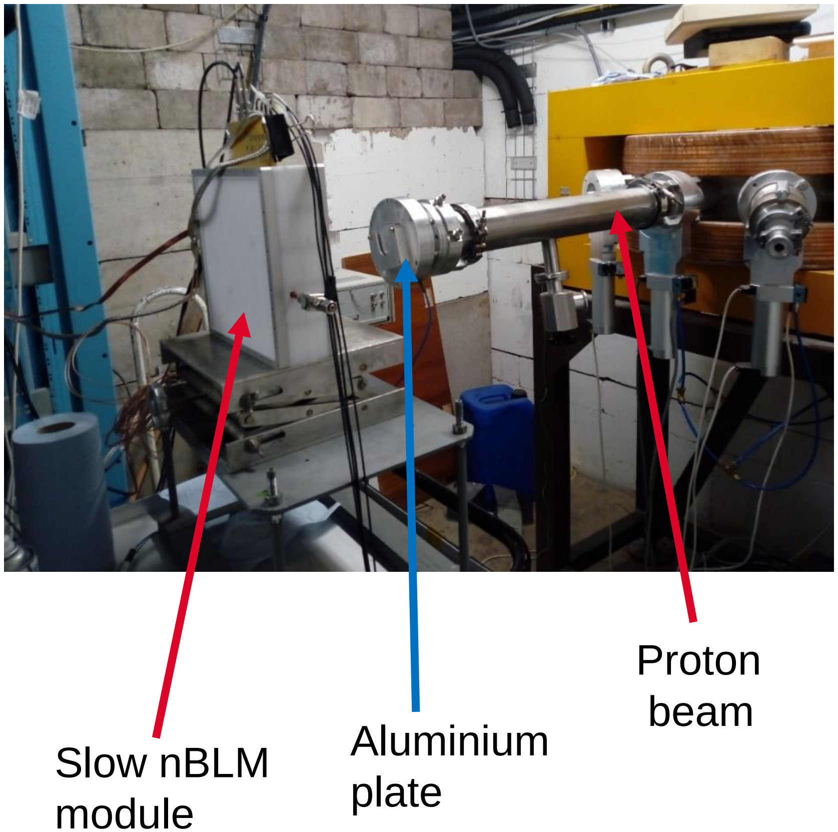
IPHI, Injecteur de Protons à Haute Intensité (CEA/Saclay):



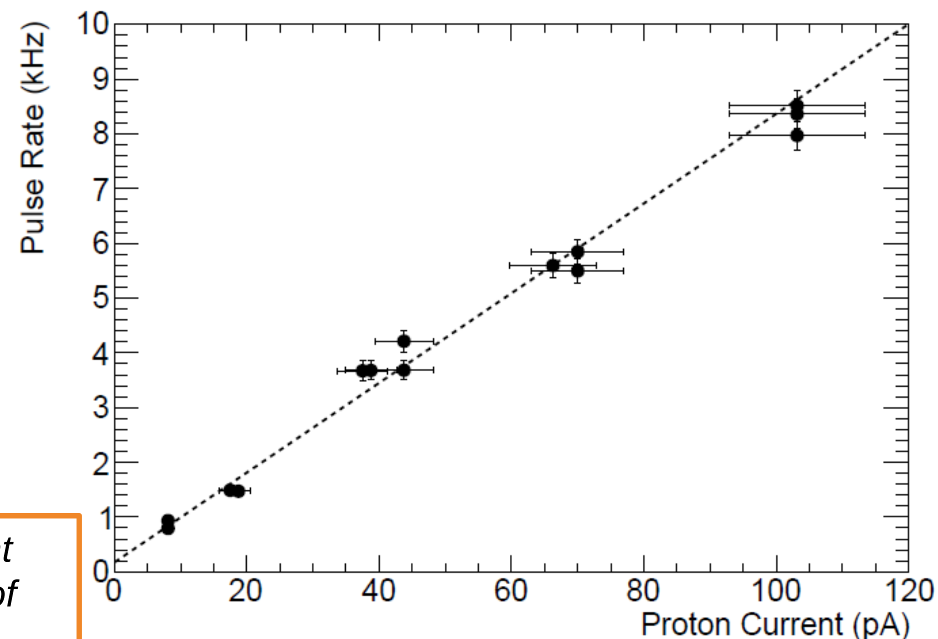
With 5 mm borated rubber outside

- 3 MeV proton beam
- Pulsed beam 90 µs, 1Hz repetition frequency
- Use of a Be target to produce neutrons during January-February 2018
- Goal:
  - Neutron flux measurement and characterisation
  - Test of detectors under pulsed beam
  - Time response study
  - Analysis development
- Test both slow and fast modules

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

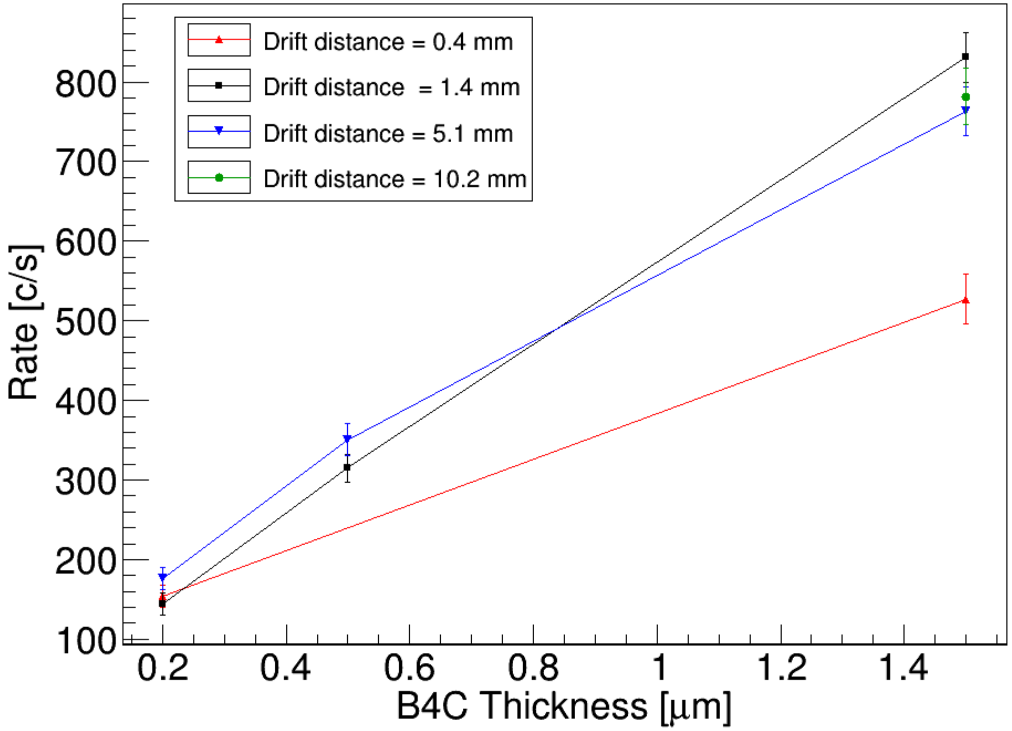


Correlation of the count rate with the intensity of the proton beam

nBLM: CHARACTERISATION AT DIFFERENT IRRADIATION FACILITIES

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

- Stable operation with high current (up to 600 nA), no discharges
- Verified that 5 mm borated rubber absorbs the thermal neutrons a reduction factor of $\sim2.5\times10^{-4}$ + polyethylene → $>10^{-5}$
- Study the detector operation parameters (B_4C thickness, drift gap, operating voltages) to optimize signals (duration, amplitude etc.)

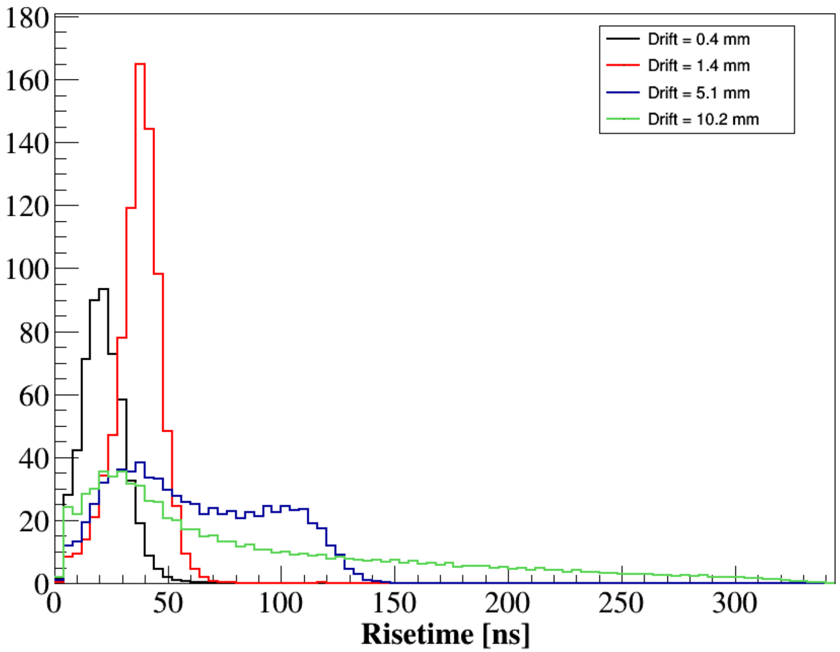


- No corrected by different gain
- Small gap
  → no full ionization
- Factor ~5 between 0.2 – 1.5 µm

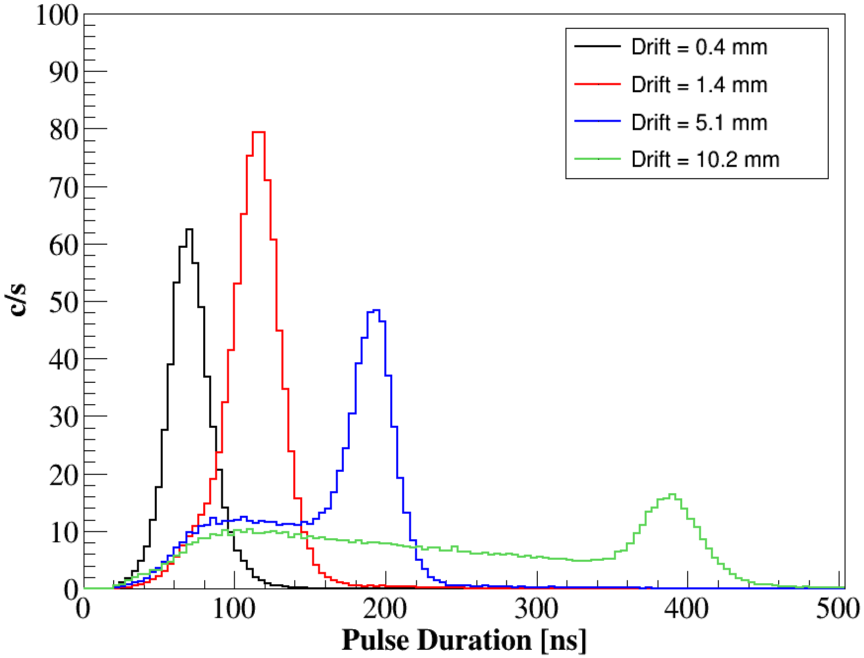
nBLM: CHARACTERISATION AT DIFFERENT IRRADIATION FACILITIES

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

Rise Time Distributions for different drift distances



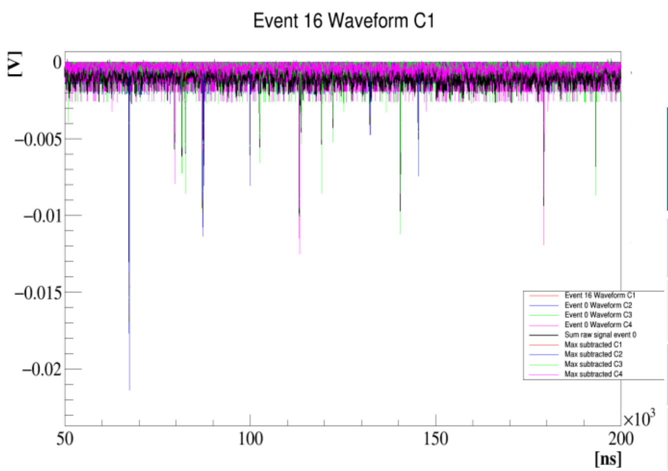
Pulse duration for different drift distances



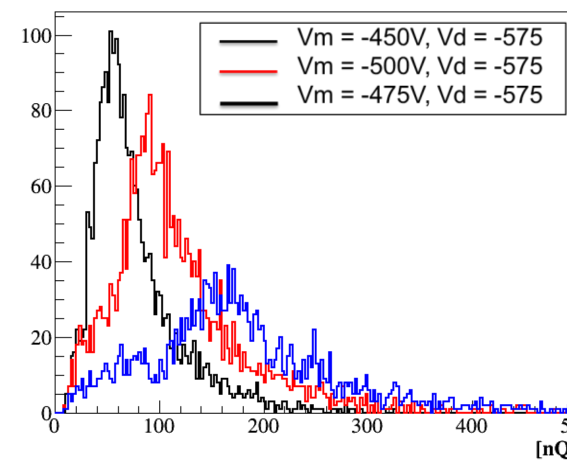
- Optimum **value ~2 mm**
  - Rise Time ~ 45 ns and very stable
  - Pulse duration ~ 60 ns → in 1µs ~ >10 pulses/window before pile-up (~10 MHz)
- Optimized to avoid also to be very close to sparking point

PASSING FROM COUNT RATE T
CURRENT MODE

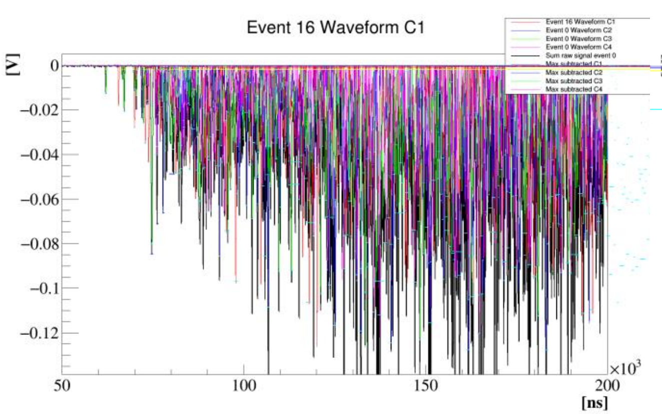
- The 4 segments were recorded independently by a digital oscilloscope at 250 MS/s
- Instantaneous rate high enough to reach the limit of **current mode.** *Detector stable*.

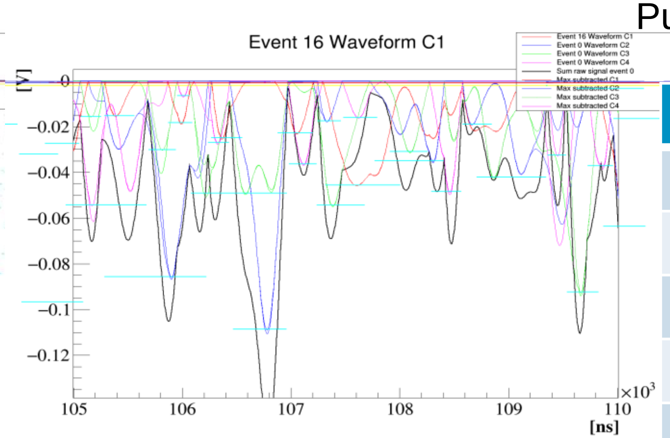


	Rate [c/p]	RateQ [c/p]
Sum	34.	34
C2	12.	11.
C3	10.	10.
C4	7.	6.



Pulse Charge from low intensity run





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

BACK-UP

NBLM DETECTORS SIGNALS

SLOW

- Neutron converted at the drift entrance
- Convertor: B-10
- (n, α) reaction. The α has always the same energy.
- The produced α enters the gas volume ionizing it.
- The amplitude is almost constant as the energy is always the same. It will have a certain distribution as it depends on the angle of the emitted alpha
- Efficiency ~1% for all neutron energies
- Time response is ~150µs
  - About 10% of events detected in 4µs
  - The delay is introduced by the moderation time of the neutrons in the moderator
- Each event detected (alpha ionizing the gas) has, more or less, same pulse duration ~100-200ns

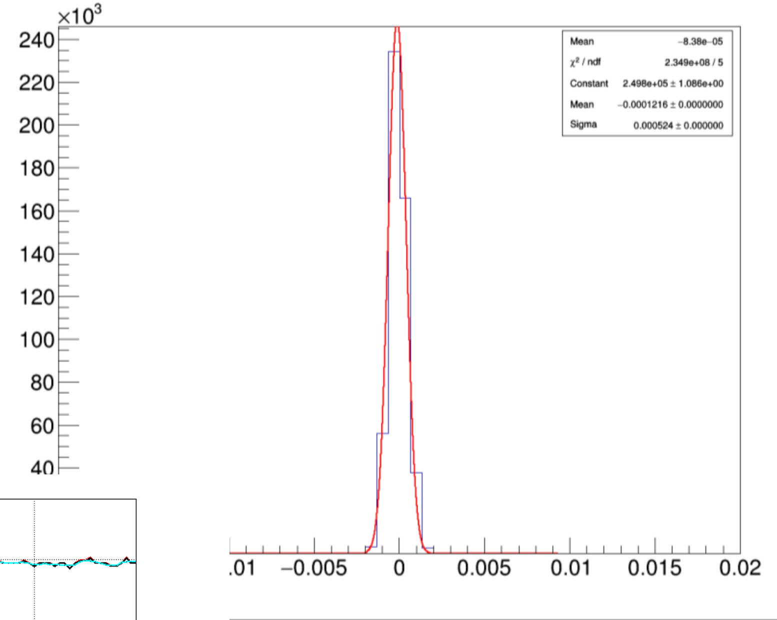
FAST

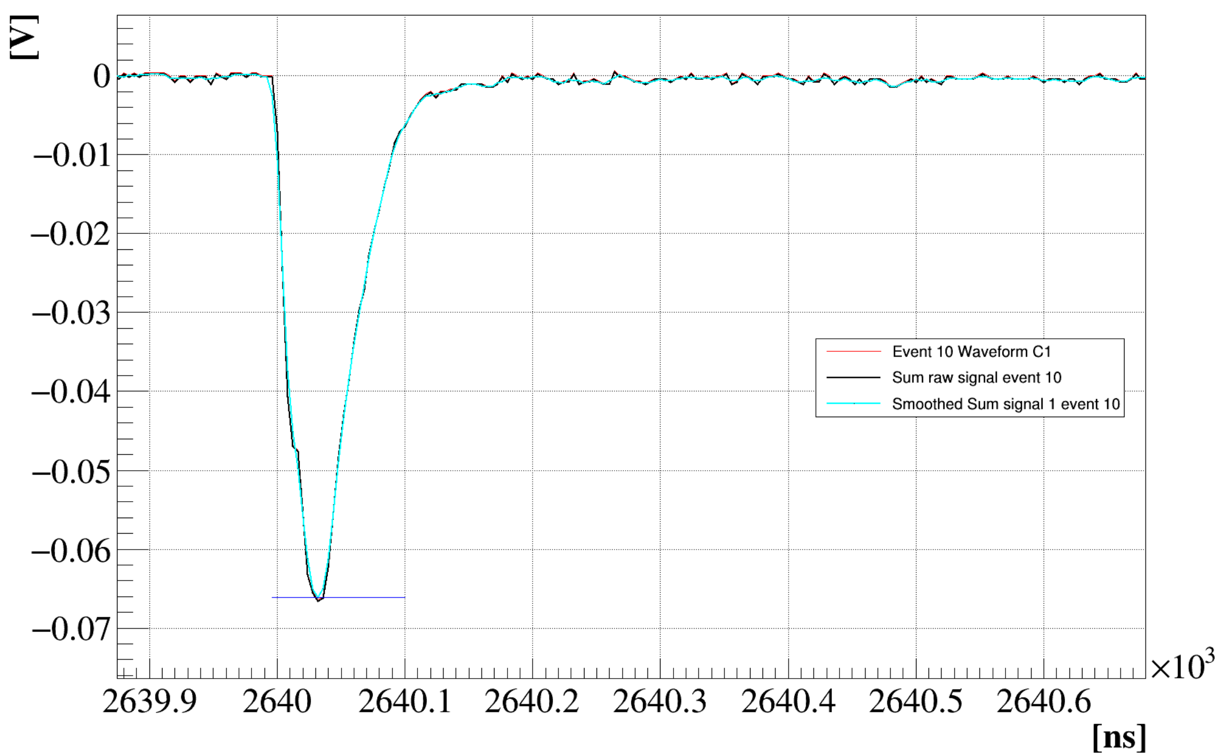
- Neutron converted at the drift entrance
- Convertor: plastic
- (n,p) reaction. P with continuum of energies
- Emitted in the opposite direction of the arrival of the neutron.
- Reaction threshold at ~0.1MeV
- The efficiency is much lower in this detector
- However, as there is no moderator the time response is very fast, of ~10ns.

NBLM CEA ANALYSIS

1. Baseline subtraction

2. Smooth raw data





NBLM CEA ANALYSIS

3 Calculate derivative and integral
(Integral is never used)

4 The derivative is only used to help defining end of pulse

5 Peak identification over Noise Threshold

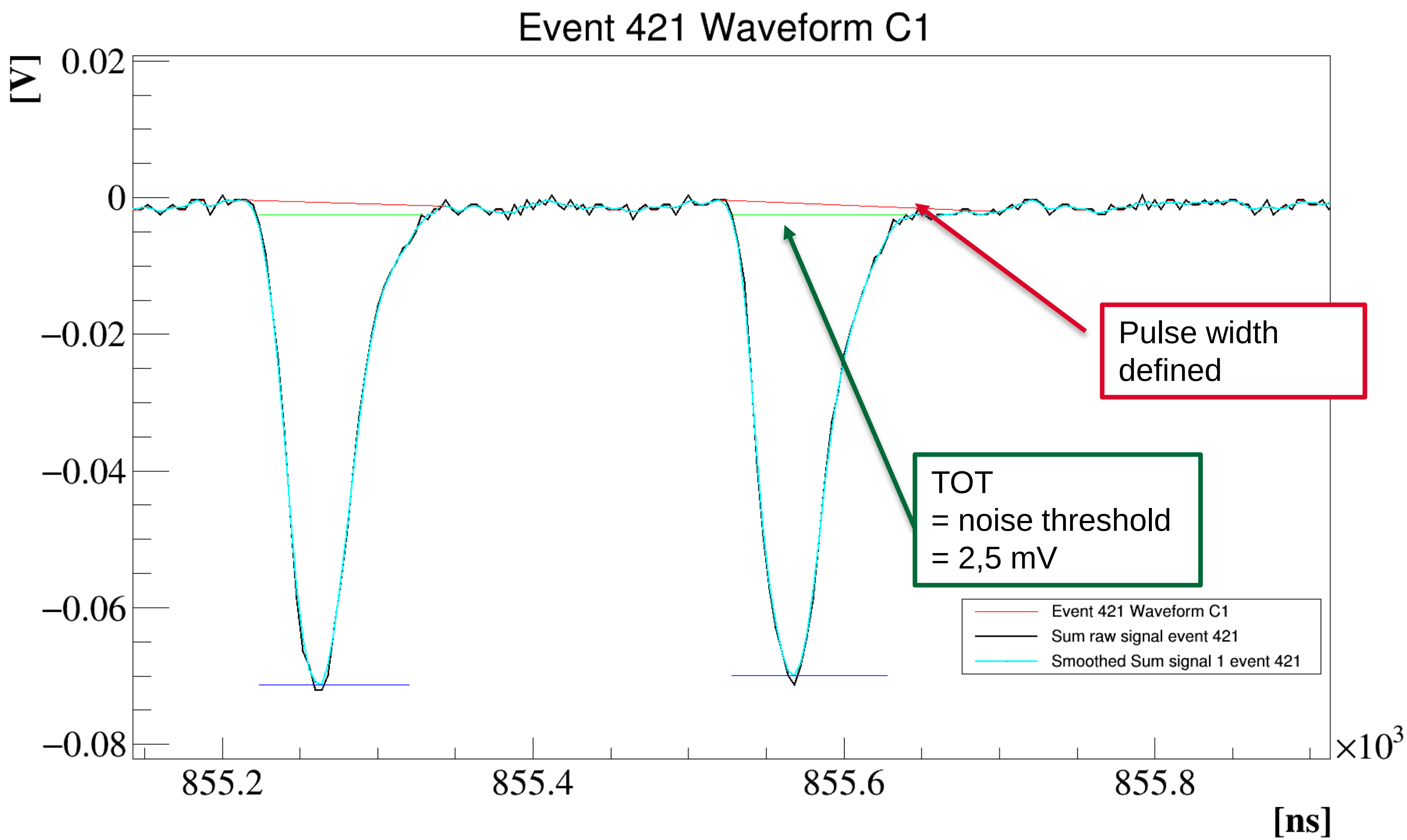
For each peak identified calculate

- Rise Time : from 10%ampl max to 90% ampl max
- Pulse Width: find end and beginning of pulse requiring ampl to be < than a certain factor of noise threshold and using also the derivative (derivative < than a very small value~0).
- TOT

6 Neutron selection

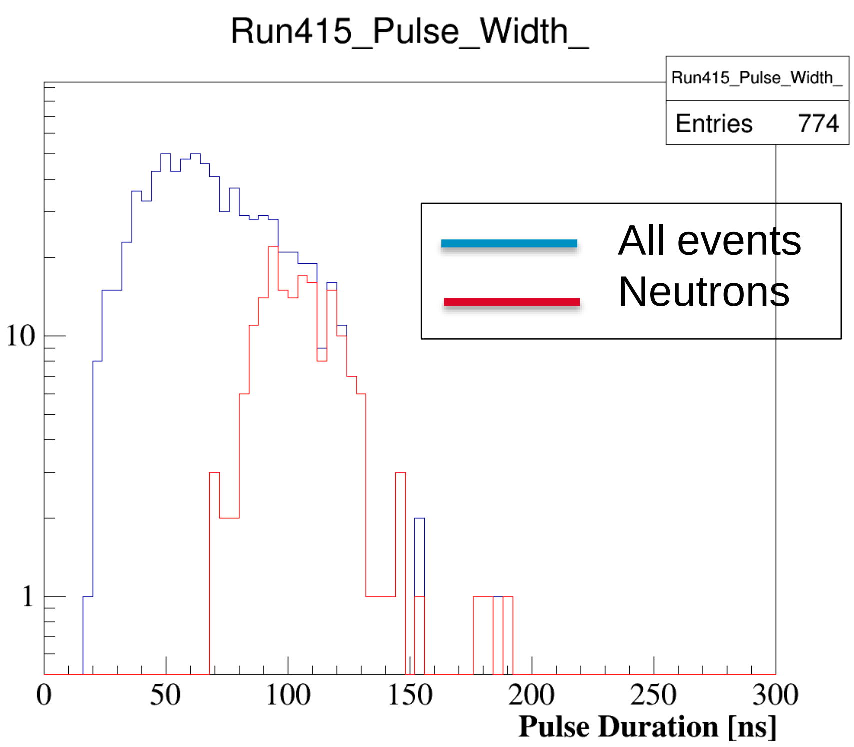
- Cut in amplitude to tag neutron events.
- All variables have been calculated before, when the pulse was identified as a pulse because ampl > Noise threshold

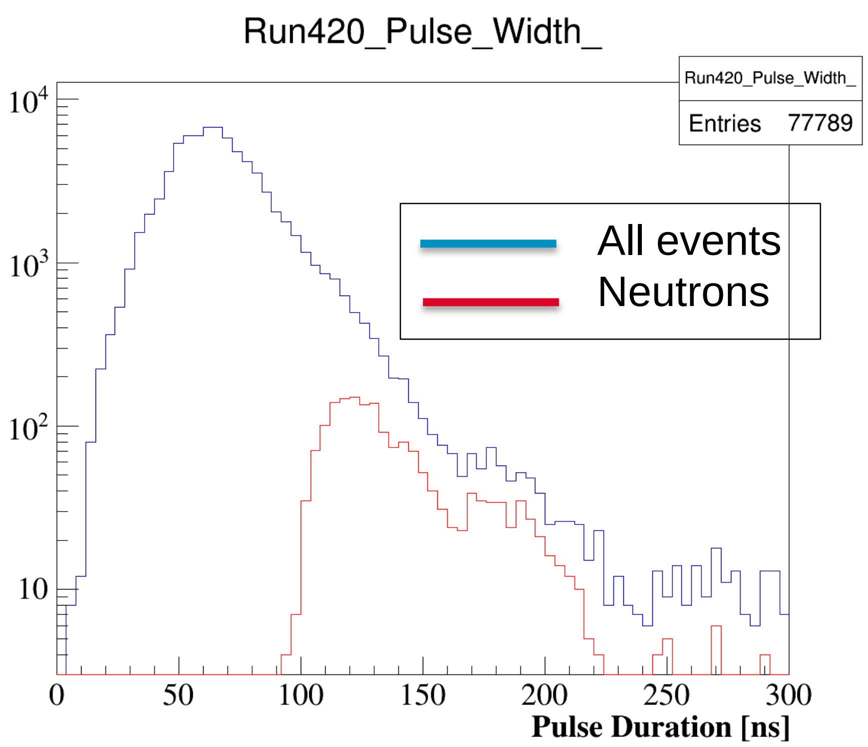
NBLM CEA ANALYSIS



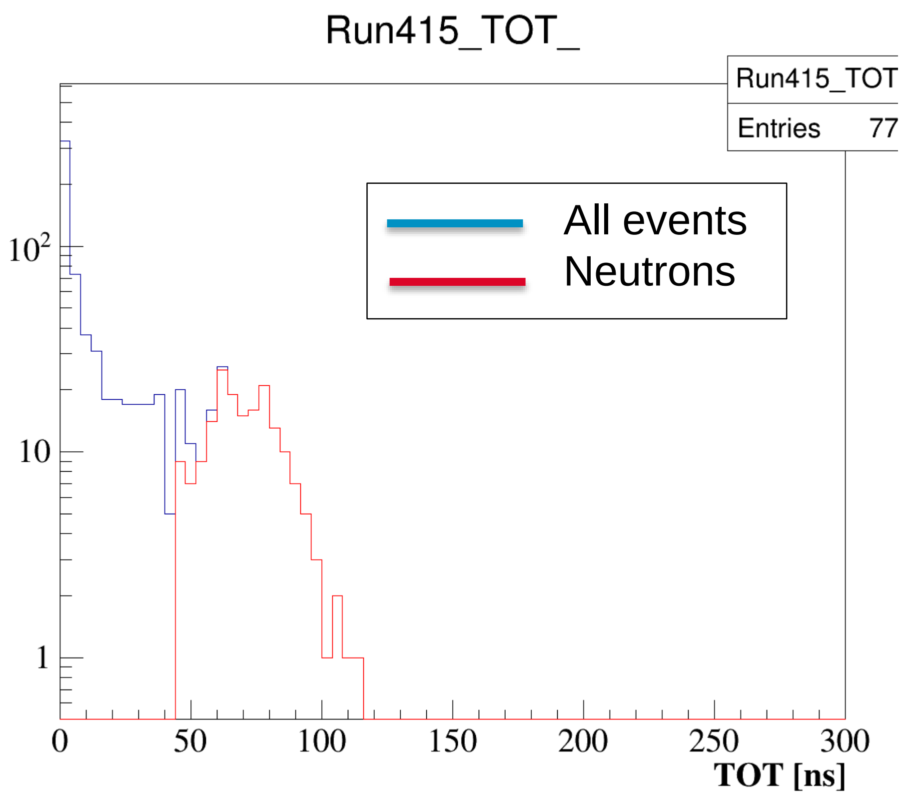
NBLM CEA ANALYSIS

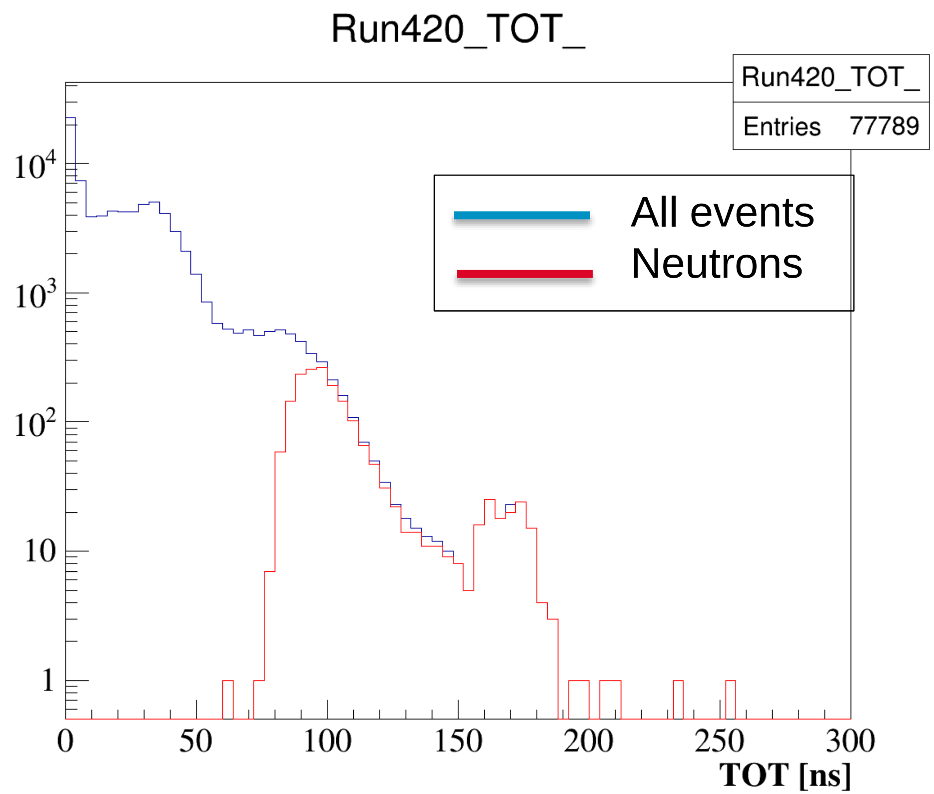
Low gain	High gain





Low gain	High gain





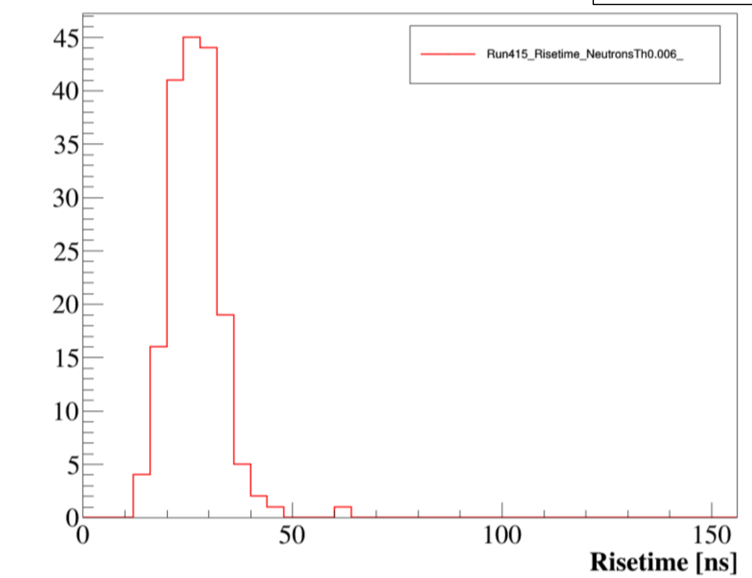
NBLM CEA ANALYSIS

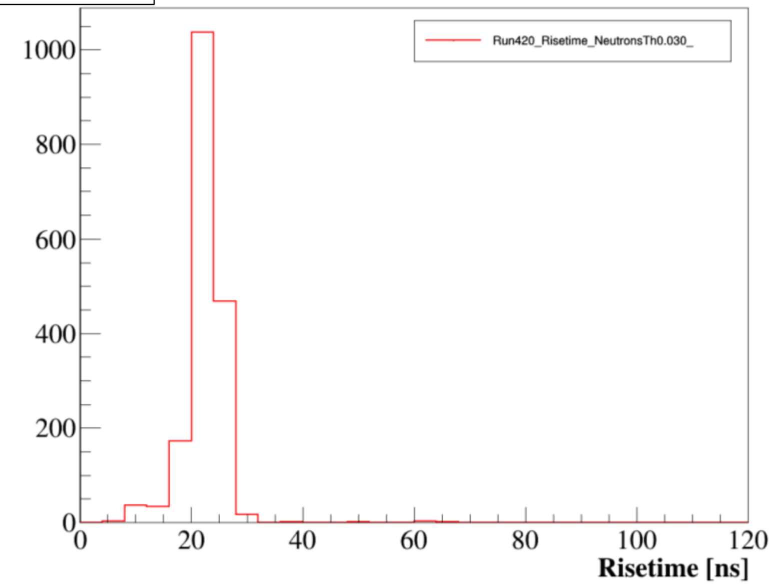
Neutrons

Low gain

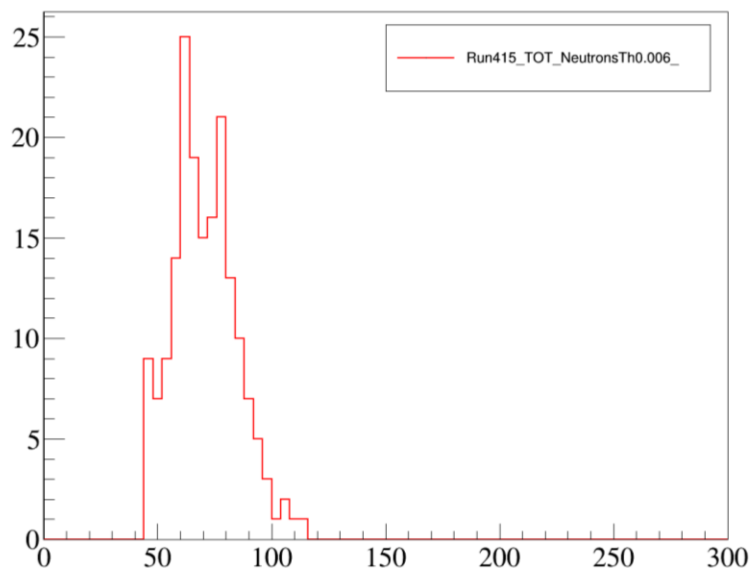
High gain

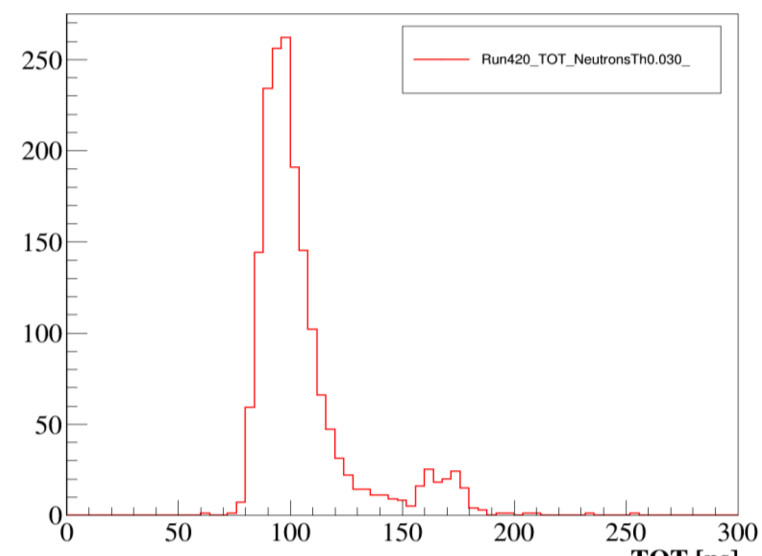
Rise Time



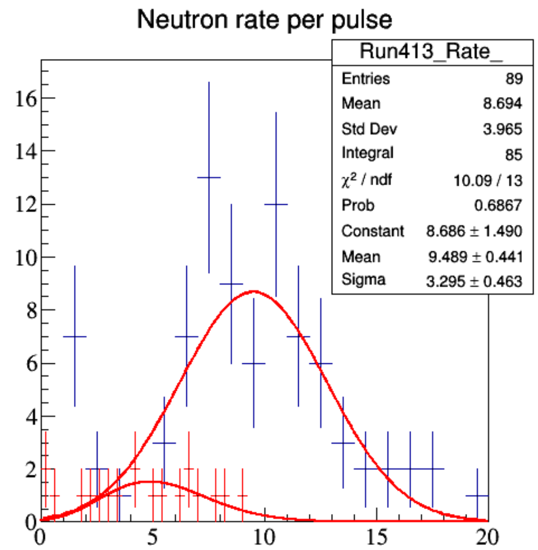


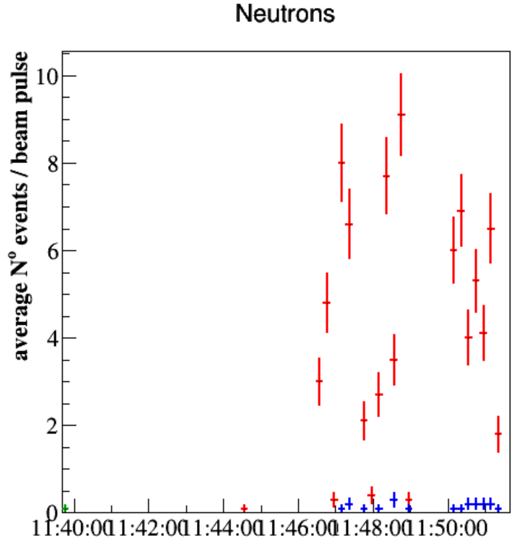
TOT

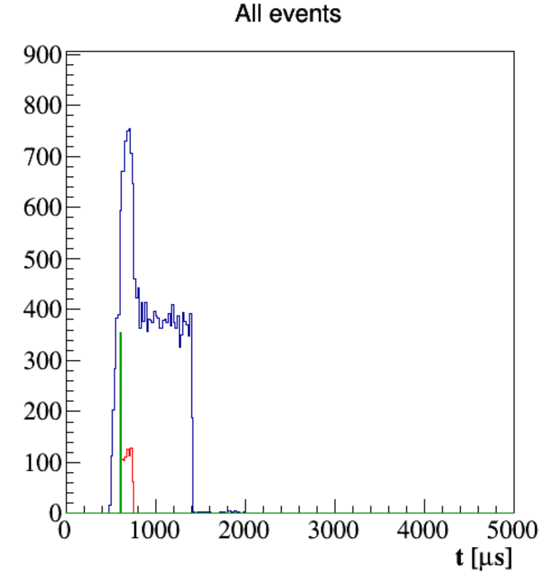


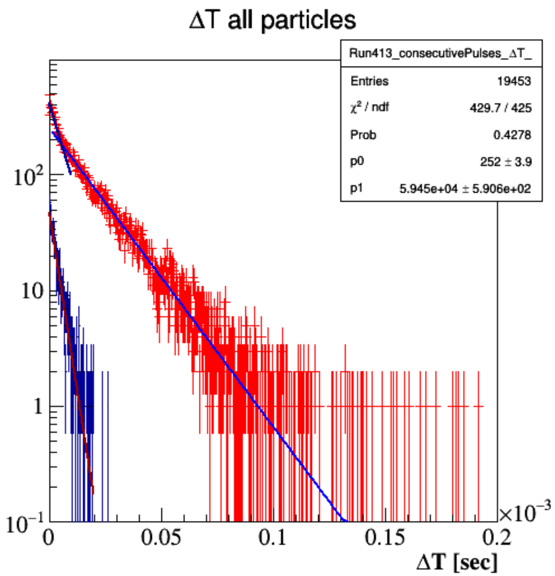


LINAC4 DATA – DEC. 2018 – PROVOQUED LOSSES









V_m = **-550 V**, V_d = **-1500 V**

Thresholds: peak = **2.5 mV**, n = **11 mV**

$\langle r_{n(\Delta t=12s)} \rangle = \mathbf{5.41} \pm \mathbf{1.071} \ \frac{n}{pulse}$

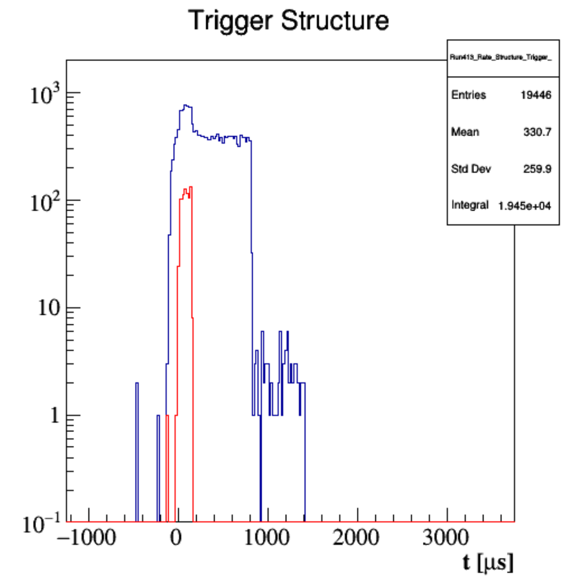
$\langle r_{n(loss\ events)} \rangle = \mathbf{9.49} \pm \mathbf{3.295} \ \frac{counts}{pulse}$

ΔT fit, all particles:

$\langle r_{\text{all events}} \rangle = \mathbf{59446} \pm \mathbf{591} \ \frac{counts}{sec}$

$\langle r_{\text{loss events}} \rangle = \mathbf{146402} \pm \mathbf{8909} \ \frac{counts}{sec}$

$\langle r_{n(loss\ events)} \rangle = \mathbf{283447} \pm \mathbf{16159} \ \frac{counts}{sec}$



SPARK IDENTIFICATION

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