nBLM detectors design

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nBLM CDR1.1

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OUTLOOK

- Description of slow and fast detector
- New detector design
- Results from tests
- Future plans for 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 n (shielding), X- and γ-rays (signal discrimination)
- 42 detector units will be delivered
- Each unit (FS) consists of 2 detectors: F (fast) and S (slow)

➢ 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 10 mW/m losses.

➢ Two types of detectors: slow and fast

- Different physical reaction to create the charged particles from the neutrons
- Different applications

NBLM DETECTORS

- *nBLM_CDR11_SlowvsFast_nBLM_Detector.pdf document*

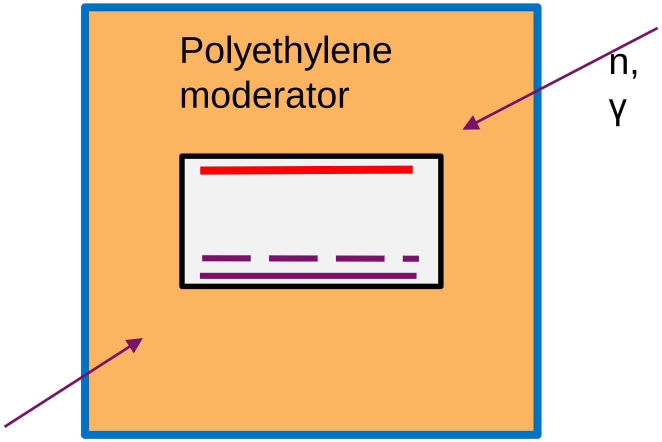
	SLOW	FAST
neutron-to-charged particle convertor	B_4C	Mylar or Polypropylene
Reaction	$(n,\alpha)^{10}B$	(n,p)
Signal produced by	Fast neutrons after moderation	Fast neutrons
Detected energy	~constant (1.4 MeV)	Continuum distribution of energies
Sensitivity	$10^{-6} < En < 100$ MeV	En > 0.5 MeV
Solid 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

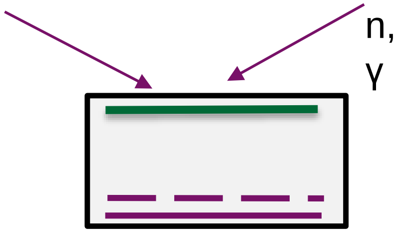
- ❑ Absorber shielding
- ❑ Detection of fast neutrons after moderation in polyethylene (~4cm)
- ❑ Gas chamber with layer of B4C
  - (n, α) ^{10}B reaction



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

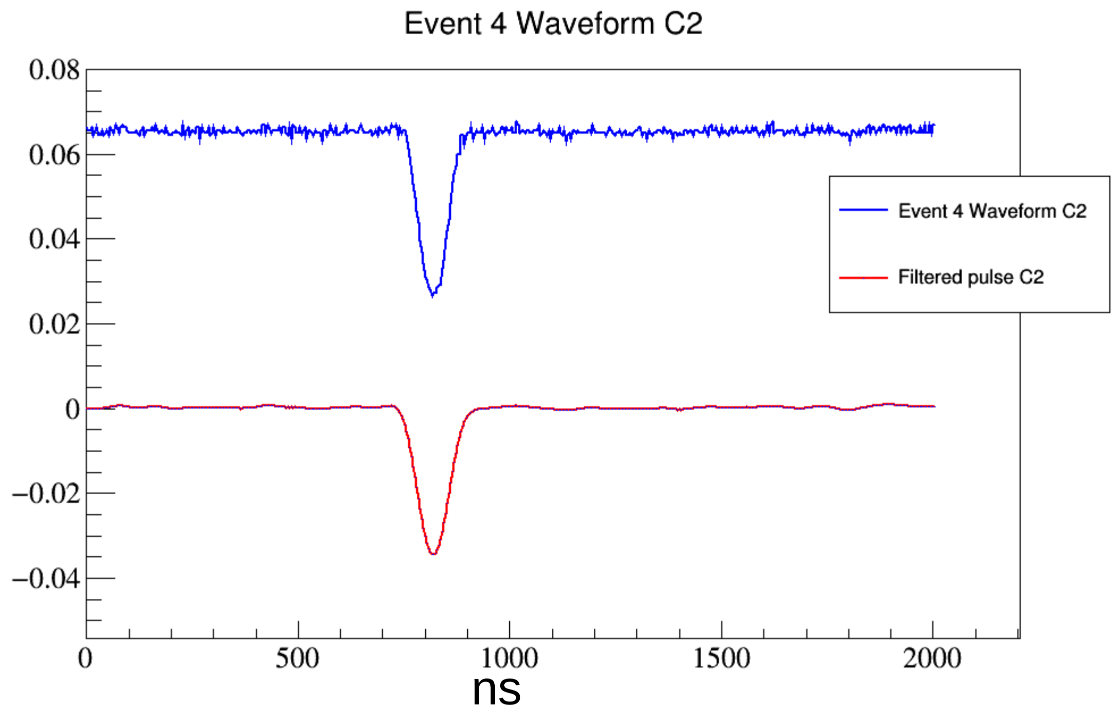
FAST

- ❑ Recoil protons produced by neutrons in polypropylene
- ❑ High flux high energy n's (>0.1 MeV)
- ❑ Faster response



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

NBLM SIGNALS



Obtained with a Cf-252 source in slow detector

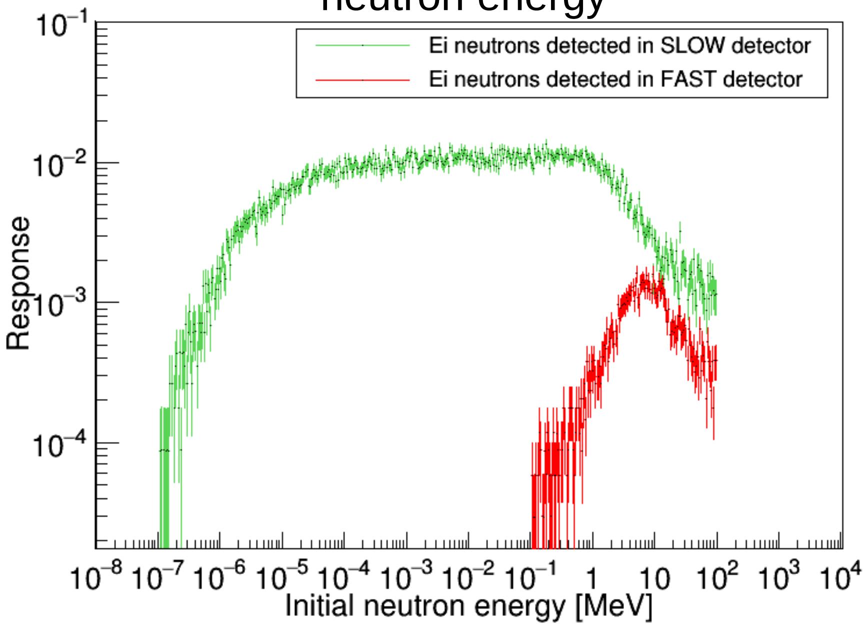
Typical neutron signal

- Rise Time 30-50 ns
- Pulse duration 100-200 ns
- Amplitude
  - Constant in slow
  - Distribution in fast

Response and deposited energy

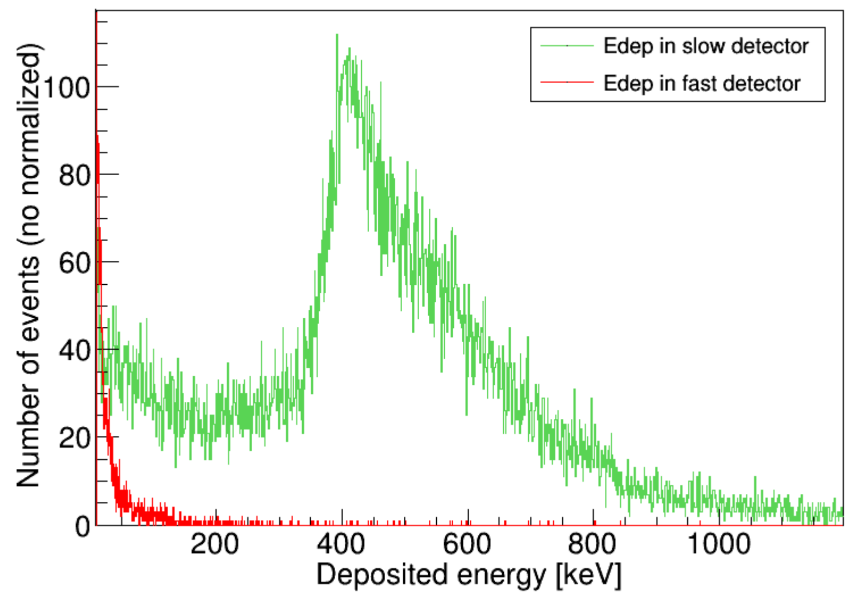
Slow
Fast

Efficiency with respect to initial neutron energy



- Slow: has a large dynamic range
- Fast: (n,p) starts at ~ 0.1MeV
- Differences in efficiency of factor 10-100

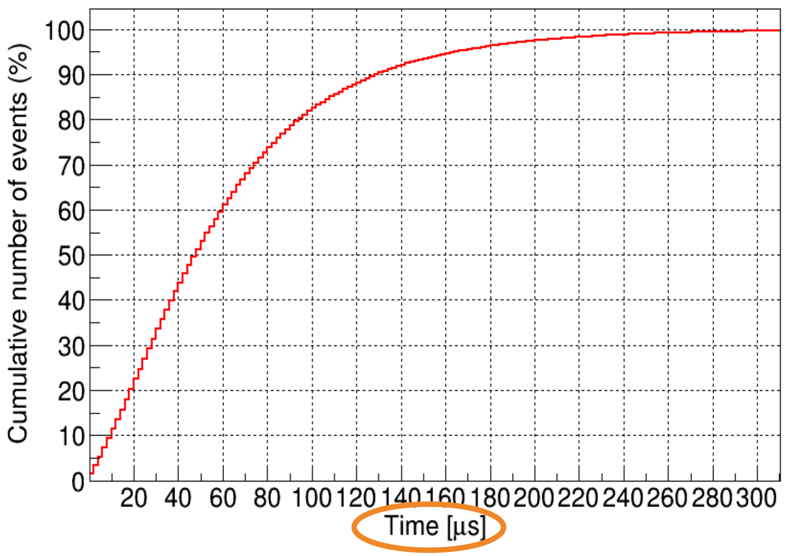
Spectrum of deposited energy



- Slow: peak from alpha energy
-

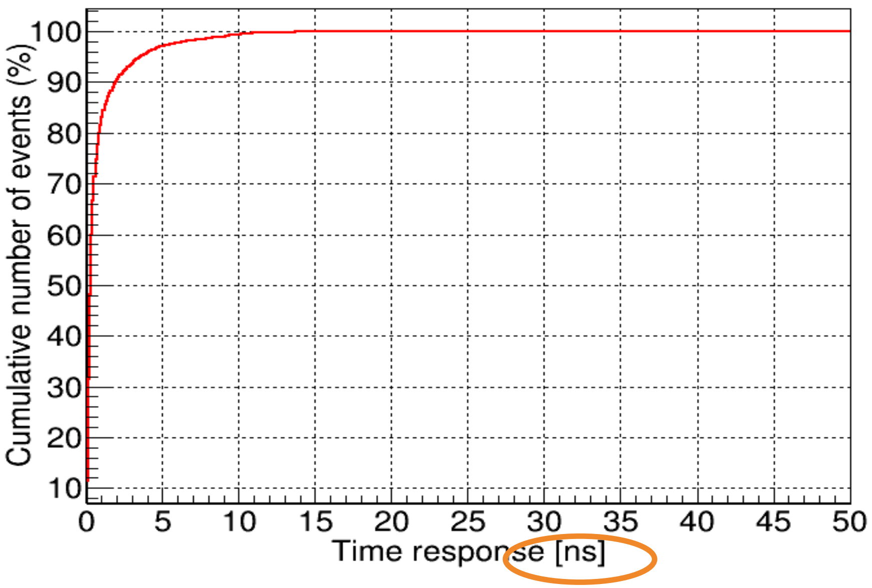
Time Response

SLOW



- ~5% detected in <1 µs
- All in ~200 µs

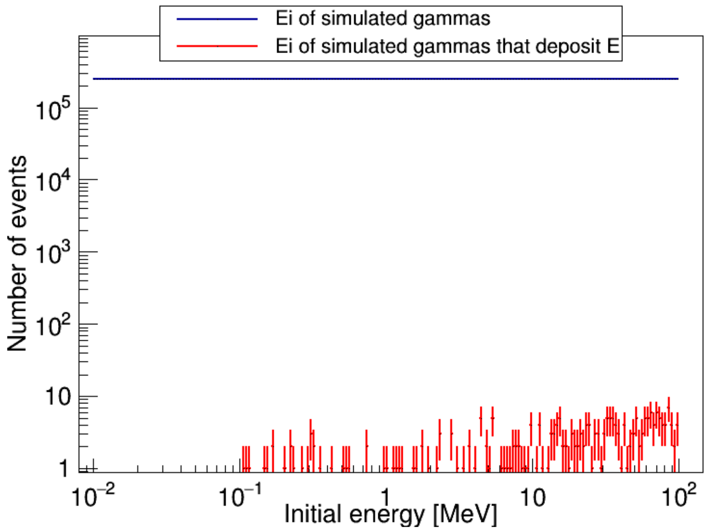
FAST



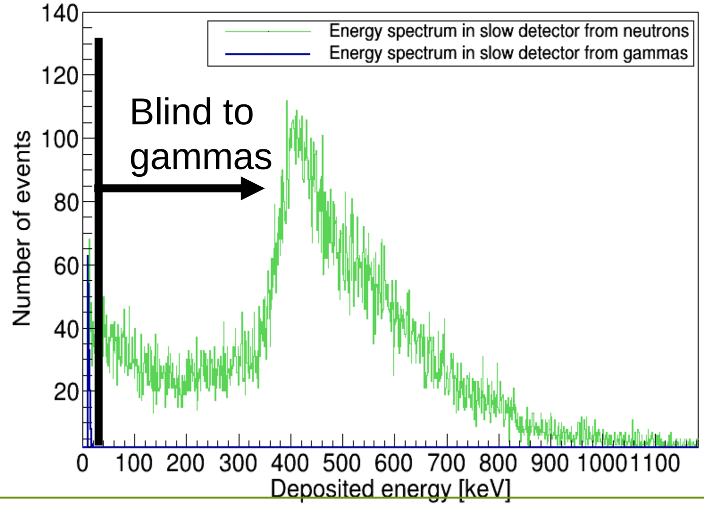
- All detected in 10ns

Gamma discrimination

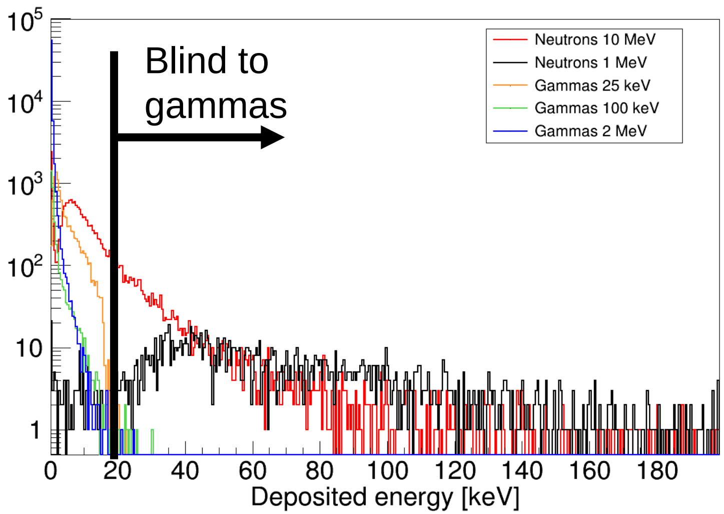
SLOW DETECTOR



- Only sensitive to high energy gammas
- with an energy threshold can be rejected



FAST DETECTOR



EXPECTED SENSITIVITY

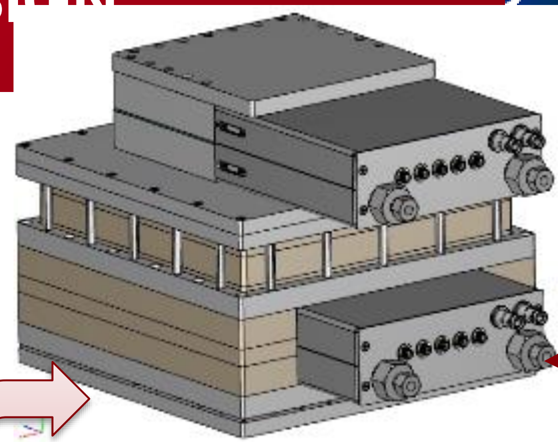
From MC simulation studies in the DTLs

	Rates	
	1% 1W/m	Complete beam loss (rate in 1st µs)
Slow	0.1 – 68 kHz	10MHz – 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 150ns.
  - The requirement from ESS is to send an BIS flag to MPS in 5µs.
  - If we monitor 1 µs window, taking into account the duration of each pulse, with ~6 events we start having pile-up (at 6MHz)
- The analysis in the FPGA will automatically change between counting and current mode when a rate of this order is obtained as we use ToT.

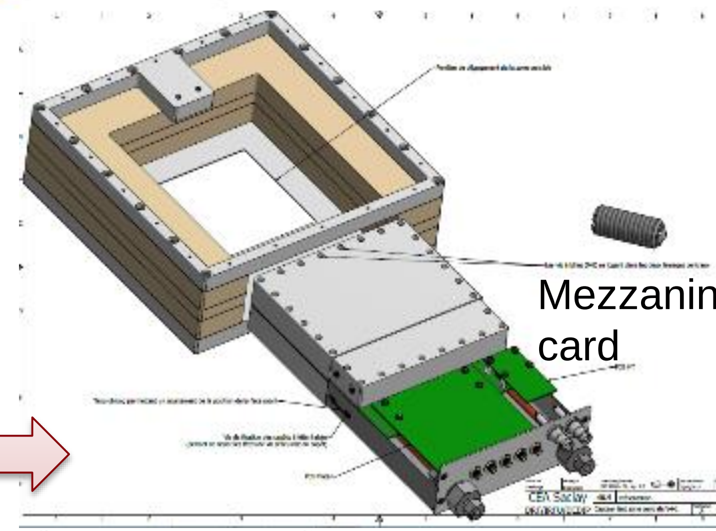
NBLM NEW DETECTORS DESIGN

- New mechanics to improve electronic shielding
  - Aluminium box of 1.5 mm thickness
  - More compact, easier for installation, more “industrialized”
  - All connections in front
  - Same mechanics for fast /slow chamber
- New electronics: mezzanine cards
  - One for FEE + LV; another for HV
  - More details in FEE’s talk



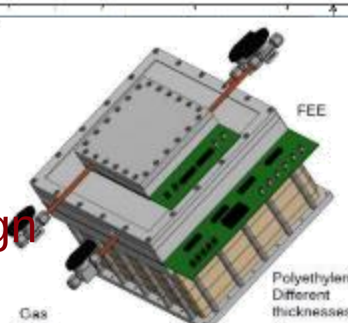
Signal, HV, LV, gas connectors

New Design



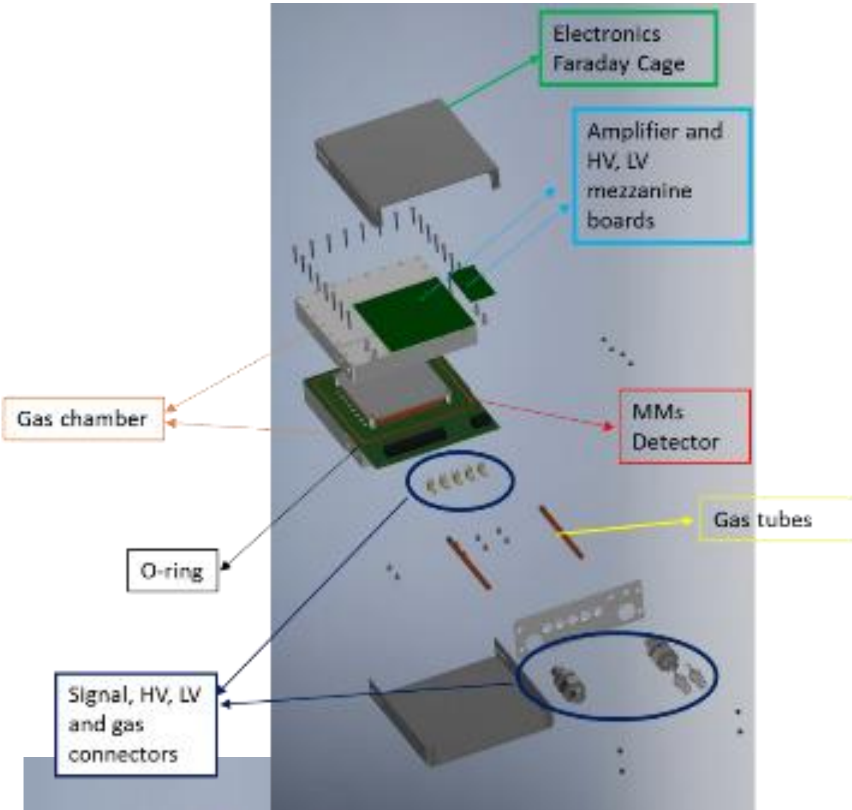
Mezzanine card

Old Design

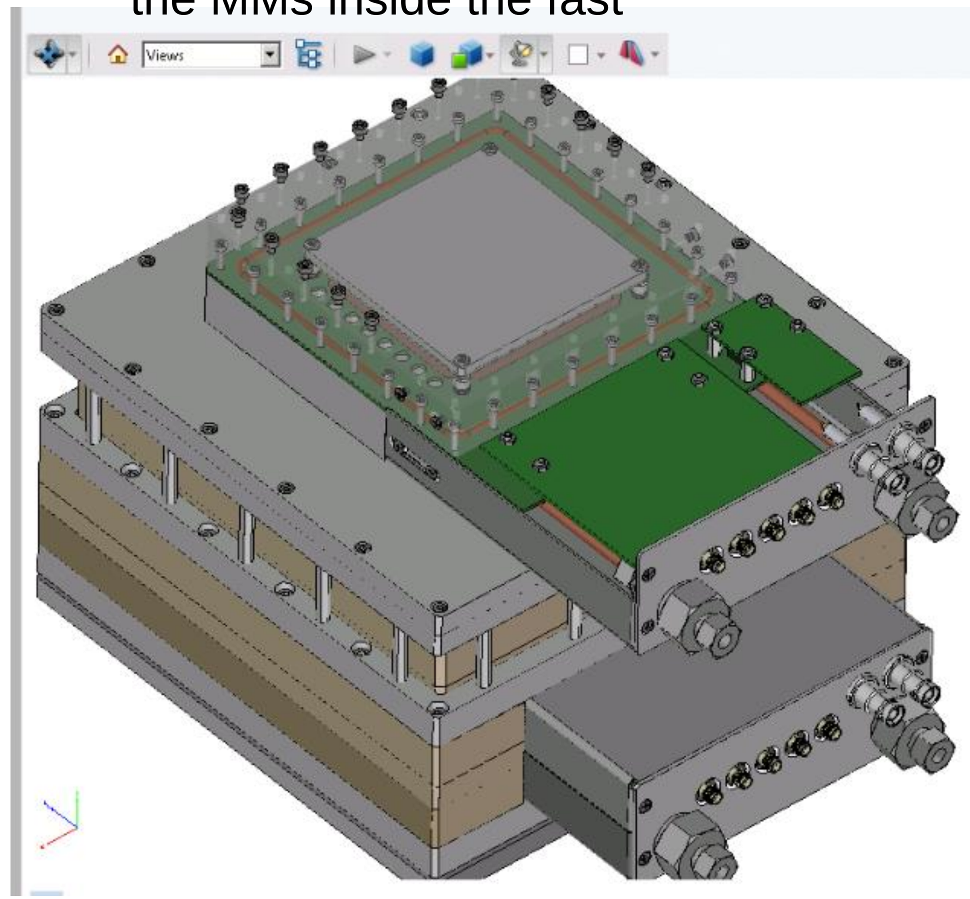


NBLM NEW DETECTORS DESIGN

Detail of gas chamber



Assembly of detectors showing the MMs inside the fast



NEW DETECTOR PRODUCTION

Mechanics

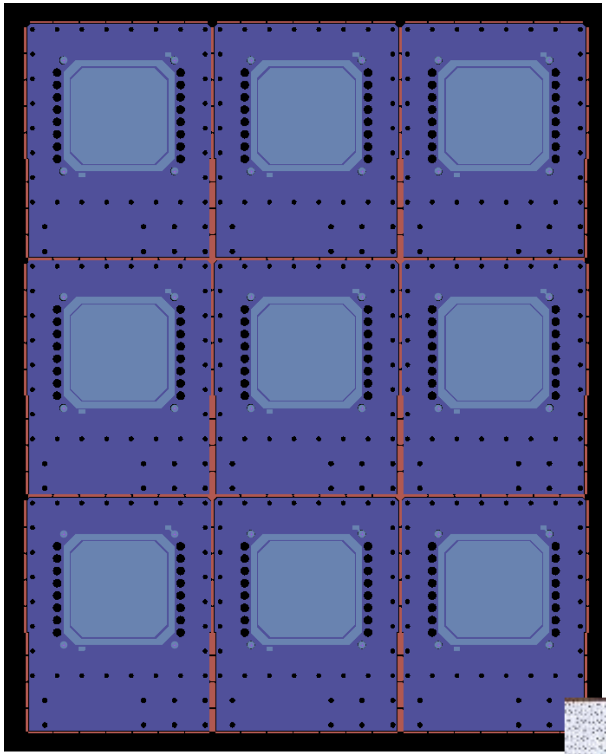
- Initially construct **4 chambers** → January 2017
- When finalized, ~**90 chambers**
- Production to start in ~June 2018
- Contact with several workshops for the production

Micromegas

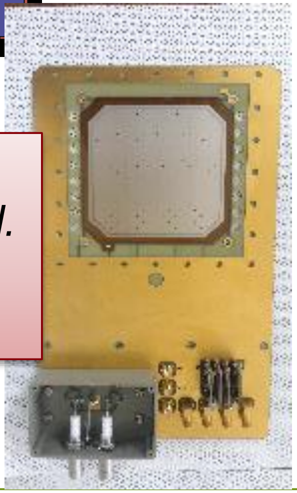
- 3x3 detectors per PCB
- **2 boards** initially to be order
  - Price offer received
  - Production for Dec 2017 – Jan. 2018
- Final production **12-15 boards** by June 2018
- Bulking at DEDIP lab ~20 working days
- Pre-series production to start immediately

FEE + HV boards

- Design on-going



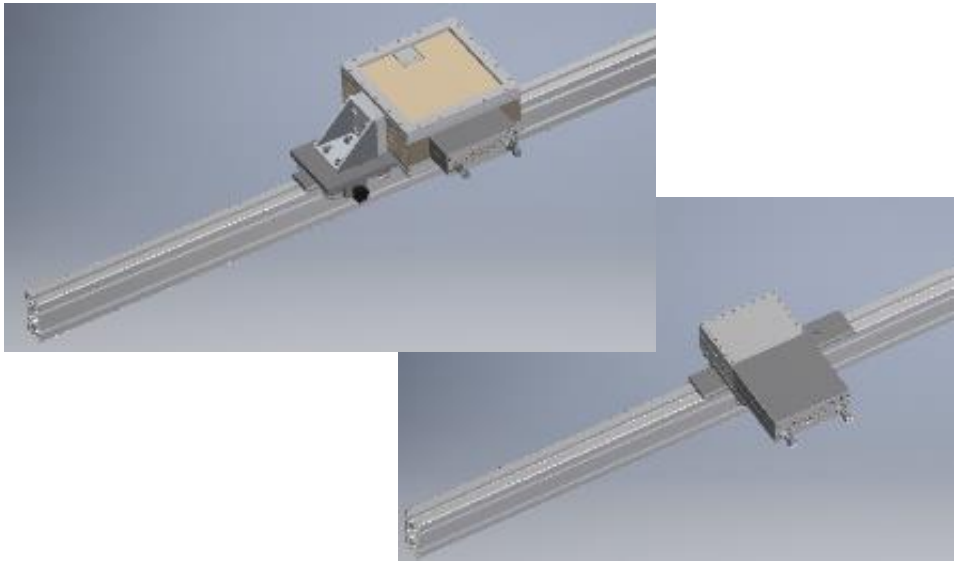
Gherber for 3x3 MMs board



Actual design with electronics on-board. The detector itself does not change

NBLM DETECTORS SUPPORTS 1ST PROPOSALS

- Rail along DTLs and MEBT
- Along SPK, under discussions
- Single support for the isolate detectors in MB, HB and PBW
- Along the rail, cable tray to pass the cables and gas tubes
- Flexible detector adaptor to move easily along rail during commissioning
  - Detector can also be placed with an angle



Status and plan

- Received stp file of DTL, SPK and MEBTfrom T. Grandsheart
- Daniel Desforges (mechanical designer at CEA) to integrate rail in ESS-3D model
- Meeting on Tuesday to discuss more details with installation group
- Several interactions foreseen
  - Where to attach them, how, height?
- Designed finalized and integrated in model for CDR1.2

NBLM PLANNED TESTS

- Different tests planned in order to fully characterize nBLM performance
- First beam test done between the 26th -29th November 2017 (next slides)
- Next year with new prototypes
- DAQ probably not available until March-June

NBLM PLANNED TESTS

Test Facility	Particle	Energy Max	Test	Date
Birmingham MC40	Protons to material target	28 MeV	- Study response under different loss scenarios - Electronics ageing	Nov-17 + in 2018
LINAC-4	Protons	160 MeV	RF backgrounds and response to losses	January 2018 Summer 2018
ORPHEE CEA/Saclay	Thermal neutrons	Few keV	Response to thermal neutrons	Q1 2018
Amande (CEA/Cadarache)	Mono-energetic neutrons	From 250 keV to 15 MeV	Efficiency studies. Different poly and convertors thickness	March 2018 (6 days)
IPHI	Neutrons	1MeV	Response study for different energies	March 2018
Upssala	Testing the ESS cryo-modules		Response to RF backgrounds	From January 2018

NBLM PERFORMED TESTS AND LESSONS LEARNED

Tests at DEDIP Lab

- With a Cf-252 source, very weak
- Both detectors tested with first prototypes
- To tune gain in preamplifiers
- To understand better the noise and to improve shielding
- Helpful to develop algorithm
  - Test it with real data

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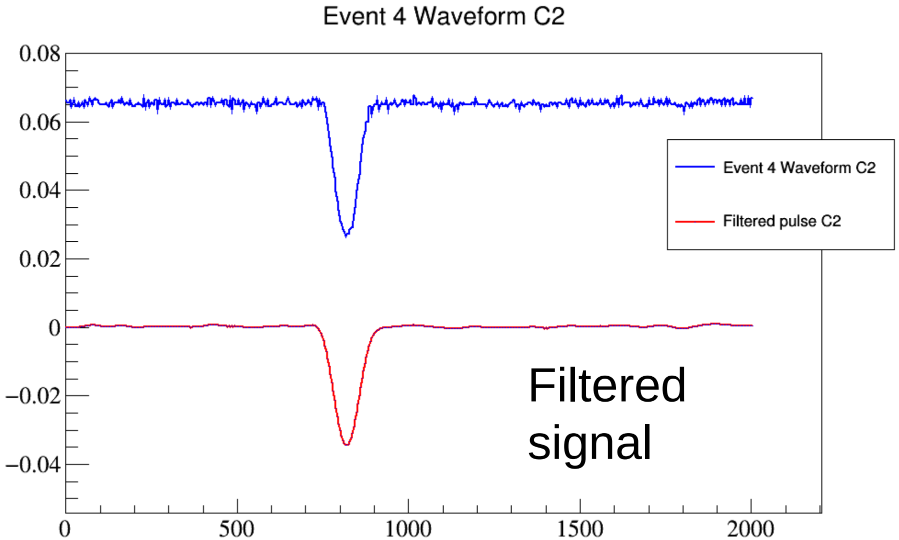
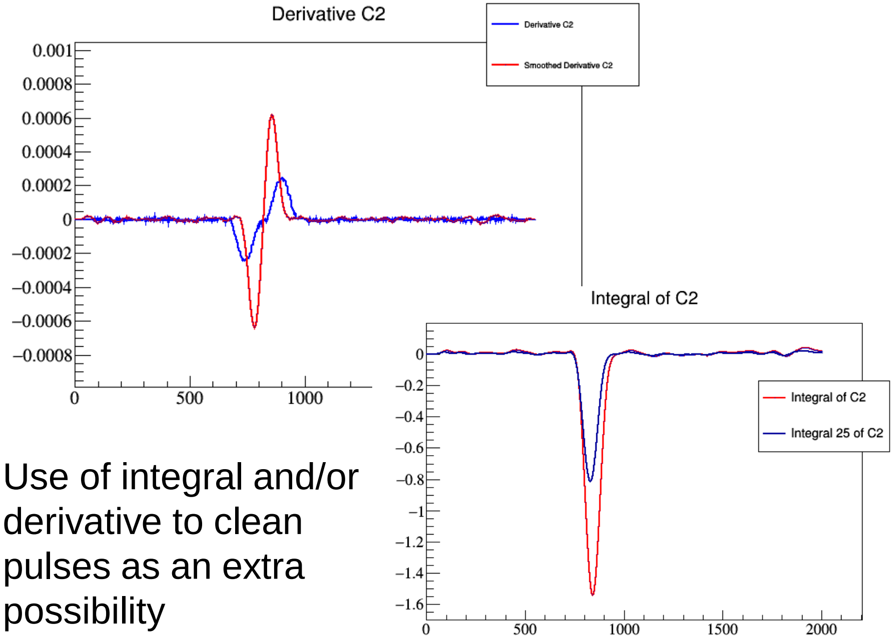




Use of integral and/or derivative to clean pulses as an extra possibility

NBLM TESTS PERFORMED AND LESSONS LEARNED

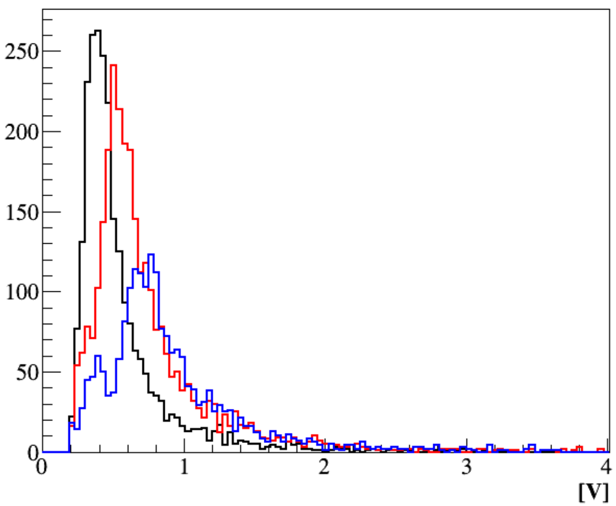
Tests at DEDIP Lab

SLOW DETECTOR

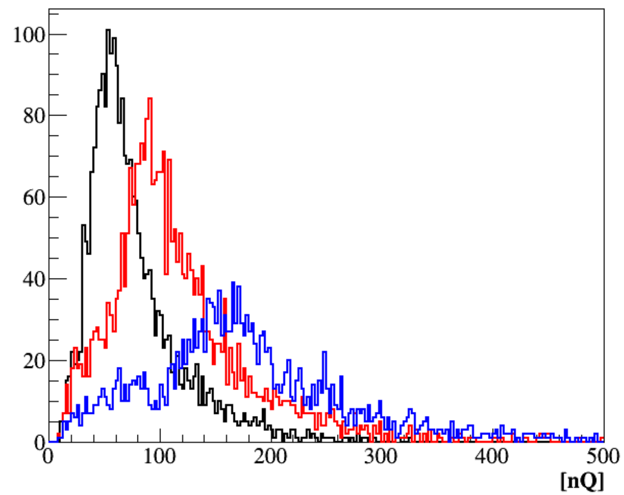
Analysis by G. Tsiledakis

- With a Cf-252 source very weak

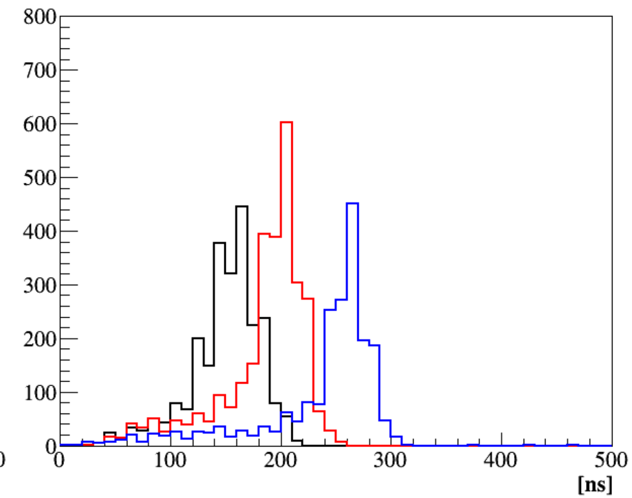
Amplitude



Charge



ToT



- Changing the amplification voltage
- Drift constant

- Studies also changing the drift cross-checked with simulations

(black) Vm = -450V, Vd = -575
(red) Vm = -500V, Vd = -575
(blue) Vm = -475V, Vd = -575

NBLM TESTS PERFORMED AND LESSONS LEARNED

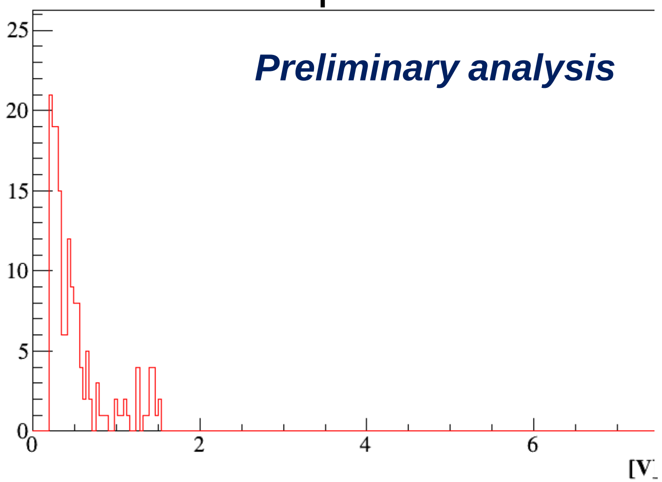
FAST DETECTOR

Analysis by G. Tsiledakis

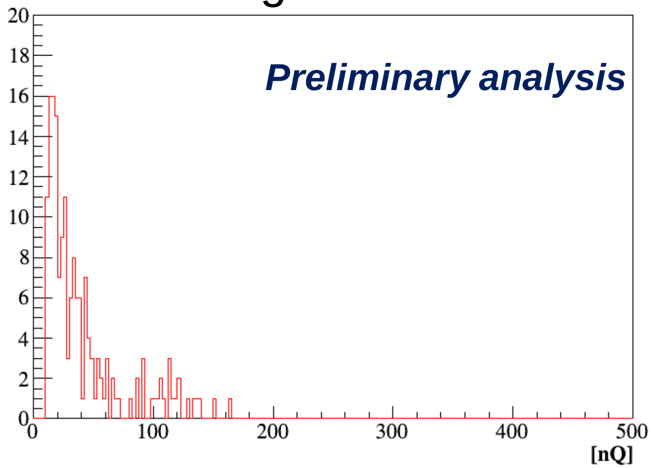
Tests at DEDIP Lab

- With a Cf-252 source very weak

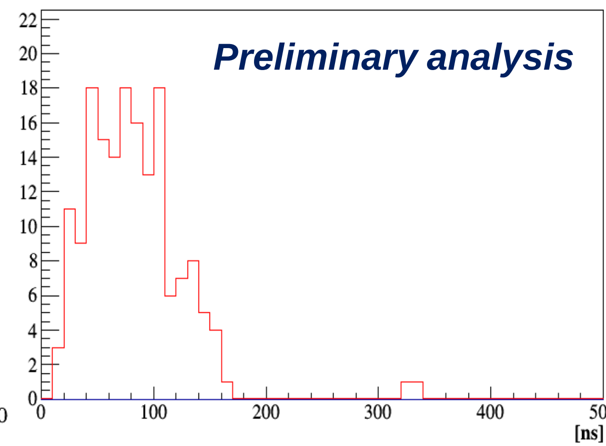
Amplitude



Charge



ToT

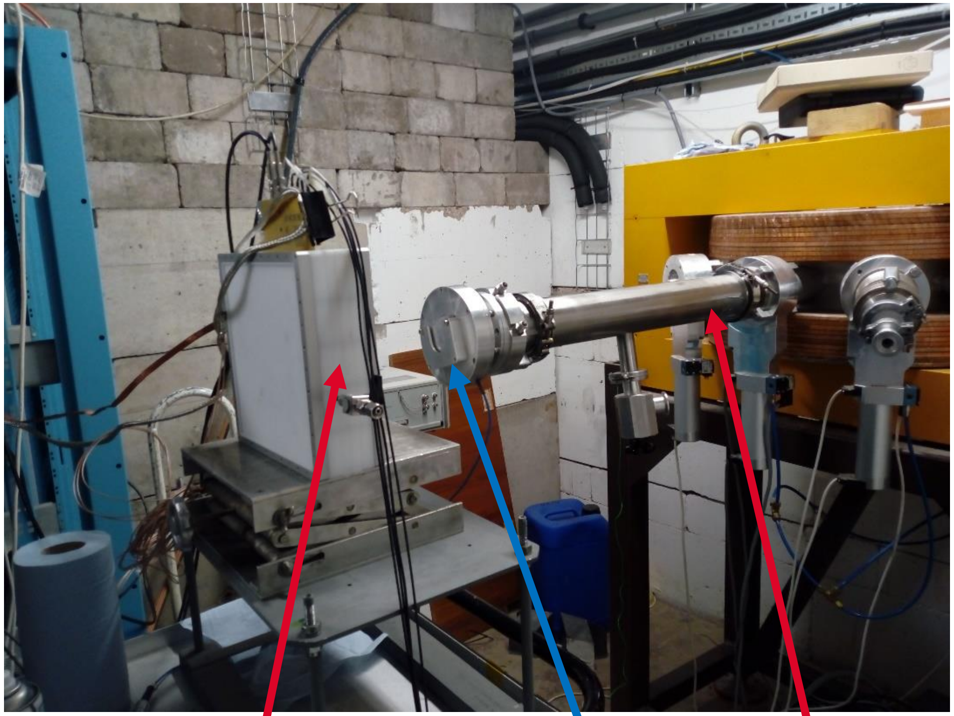


- Only *one run taken so far*
- No peak in amplitude as expected
- But ToT can be used instead

Tests at MC40 Birmingham Irradiation Facility

Thanks to Kostas Nikolopoulos

- MC40 medical synchrotron
- Protons up to 30 MeV
- Beam diameter ~1cm
- Continuum pulse
- Data taken at 28 MeV and
  - 0.017, 0.025, 0.044, 0.051, 0.08, 0.10 nA
- Proton beam into Al plate ϕ=1cm



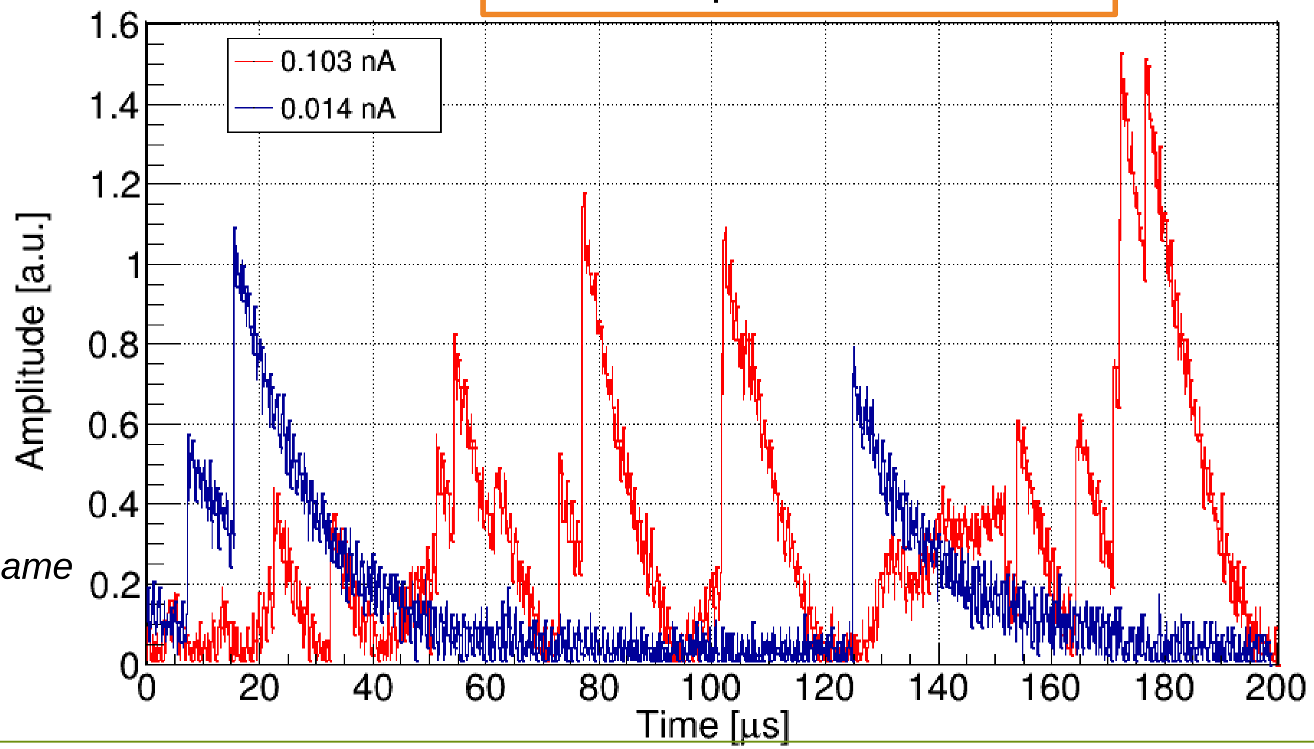
Tests at MC40 Birmingham Irradiation Facility

Thanks to Kostas Nikolopoulos

First observations

- Detect rates between 1-10 kHz
- See difference in rate when changing the intensity
- Analysis on-going

First signals in a test beam
Proof of operation



Data taken in same time window

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.

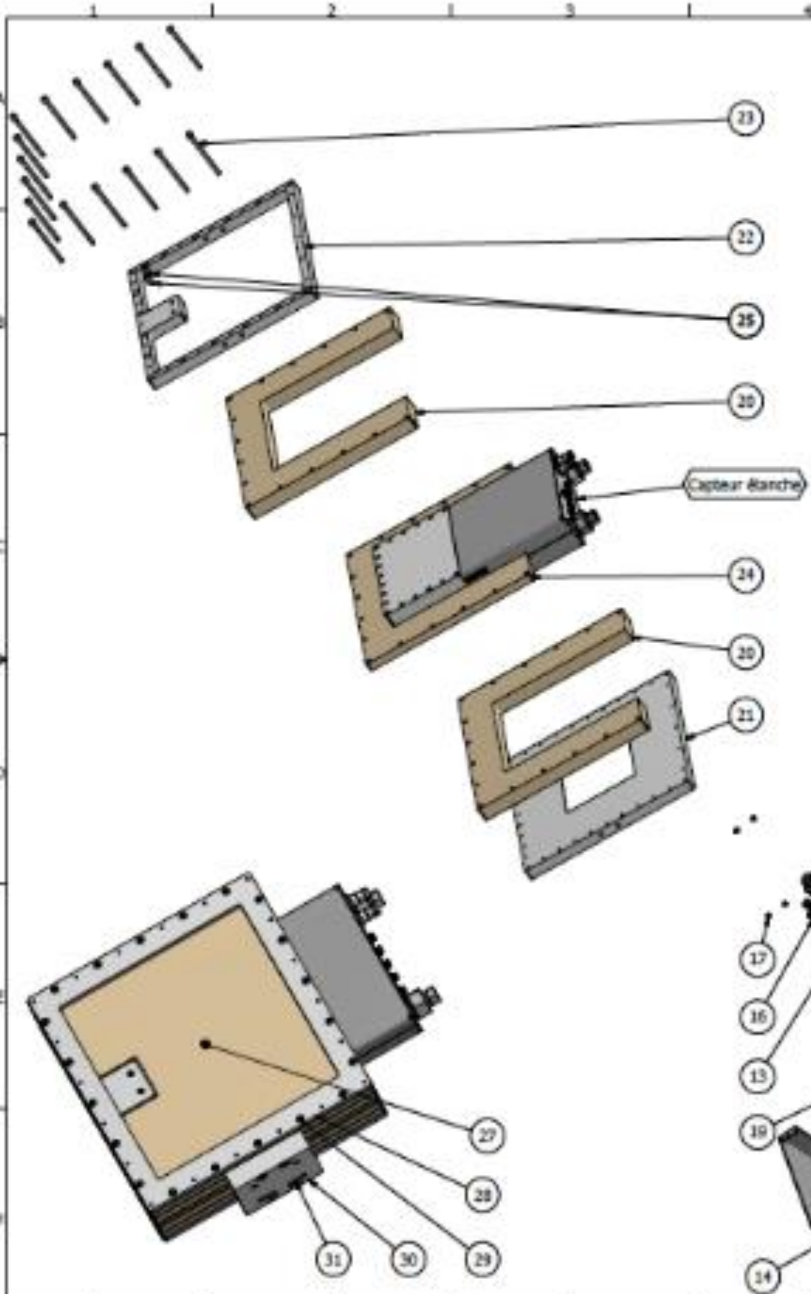
NBLM PLANNED TESTS

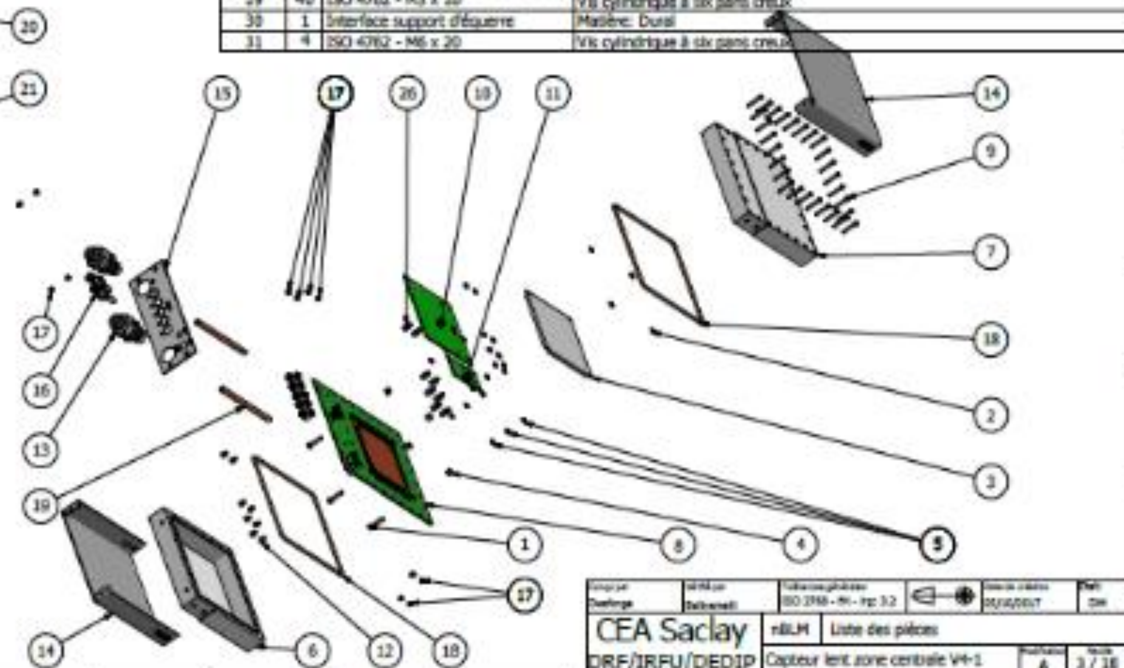
	Nov. 2017				Dec. 2017				Jan. 2018				Feb. 2018				March 2018				April 2018			
Test Facility	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Birmingham																								
LINAC-4										Installation			Operation											
ORPHEE																								
CEA/Cadarache					Ask for time								Time will be allocated here (6days)											
IPHI n																								
Cryo. at Upssala																								

- Other test we are looking for is a gamma irradiation facility. One has been identified in CEA/Saclay but at a high budget. Irena mentioned the possibility to use a source here in Lund University.

SLOW nBLM

ARTICLE	QTE	NUMERO DE PIECE	DESCRIPTION
1	4	Entretoises M3 - V4	Laiton
2	8	ISO 4035 - M3	Ecrous hexagonaux bas (avec chanfrein) - Produit de classes A et B
3	1	Plaque d'alu boré V4	
4	4	Rondelle céramique 3x5	
5	12	Rondelle céramique 3x2	
6	1	Demi boite interne inférieure V4	Matière: Dural
7	1	Demi boite interne supérieure V4	Matière: Dural
8	1	PCB central V4 (capteur inclus)	
9	28	ISO 4762 - M2,5 x 20	Vis cylindrique à six pans creux
10	1	PCB Datas	
11	1	PCB HT	
12	8	ISO 4762 - M3 x 4	Vis cylindrique à six pans creux
13	2	Passe paroi pour tube de 6mm	Swagelok - SS-6PKD-61
14	2	Capot interne électronique	Tole d'aluminium épaisseur 1.5mm
15	1	Face avant	Tole d'aluminium épaisseur 1.5mm
16	2	r317580000 - SHV étanche - corps	High voltage BNC solder bulkhead jack
17	12	ISO 7046-1 - M3 x 4 - 4.8 - H	Vis à tête fraisée plate (type de tête standard) avec empreinte cruciforme
18	2	Joint torique interne	Silicone
19	2	Tube cuivre	Diamètre 6 externe / 4 interne
20	2	Cadre blindage polyéthylène 40-20	épaisseur 20
21	1	Cadre externe inférieur	Matière: Dural
22	1	Cadre externe supérieur	Matière: Dural
23	16	ISO 4762 - M4 x 70	Vis cylindrique à six pans creux
24	1	Cadre blindage polyéthylène 40-12	épaisseur 12
25	2	Vis à bille M6	HPC - BPM6
26	8	Entretoises Male Femelle M3x10	Standard RS
27	1	Couvercle 15 à échancrure	Polyéthylène
28	2	Cadre de maintien des couvercles	Matière: Dural
29	40	ISO 4762 - M3 x 16	Vis cylindrique à six pans creux
30	1	Interface support d'équerre	Matière: Dural
31	4	ISO 4762 - M6 x 20	Vis cylindrique à six pans creux

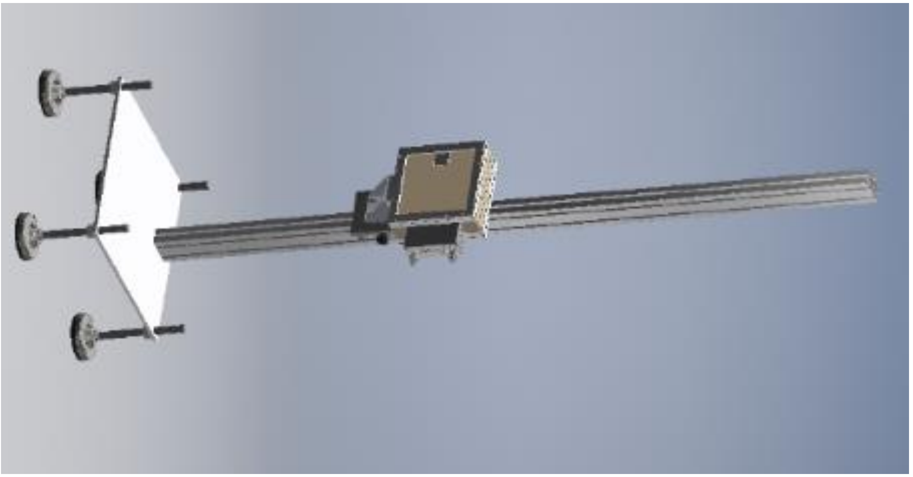




CEA Saclay
DRF/IRFU/DEDIP
nBLM | Liste des pièces
Capteur lent zone centrale V4-1
A | 3 / 18

NBLM DETECTORS INTEGRATION IN ESS (I)

- System of 82 detectors will be installed
  - 164 HV cables + 82 signal cables + 3x82 LV cables + gas lines
- Detectors will be grouped for the gas lines and amplifiers low voltage cables
- Two type of patch panels (2x6):
  - Gas
  - Cables connectors
- Start design of detectors support
  - Rail along linac
  - Flexibility to move the detector in order to optimize the beam losses detection



Detectors in	Gas line	# of detectors
MEBT-DTL1	Line 1	12
DTL2	Line2	8
DTL3	Line 3	8
DTL4	Line4	8
DTL5	Line 5	8
SPK1-4	Line6	8
SPK5-8	Line 7	8
SPK9-13	Line8	10
MB-HB	Line 9	4
Bend Magnet	Line 10	6

FAST nBLM

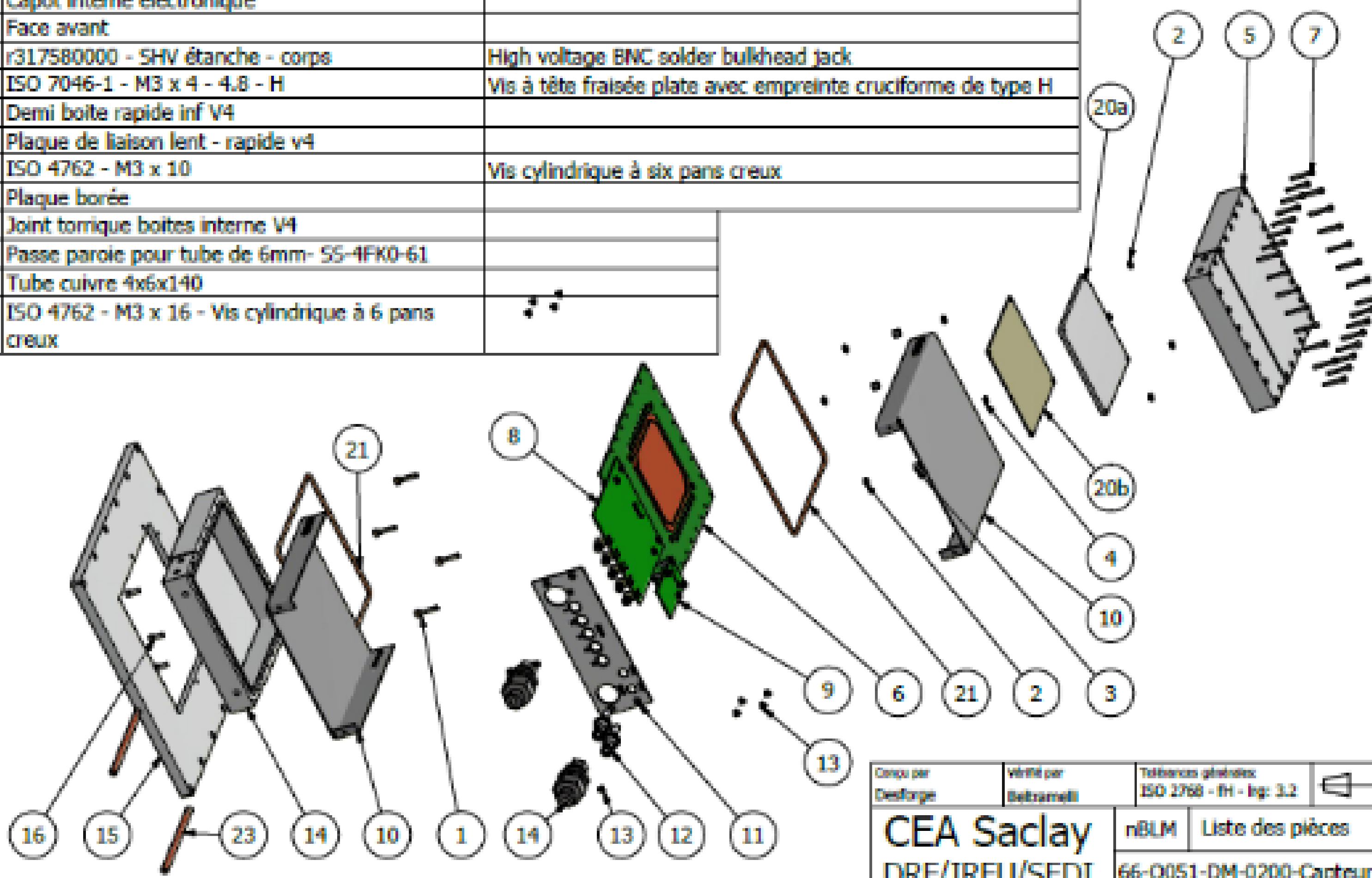
LISTE DE PIECES

ARTICLE	QTE	NUMERO DE PIECE	DESCRIPTION
1	4	Entretoises M3 - V4	
2	8	ISO 4035 - M3	Ecrous hexagonaux bas (avec chanfrein)
3	4	Rondelle céramique 3x5	
4	4	Rondelle céramique 3x2	
5	1	Demi boite interne supérieure Rapide V4-1	
6	1	Assemblage PCB central	
7	28	ISO 4762 - M2,5 x 20	Vis cylindrique à six pans creux
8	1	PCB Datas	
9	1	PCB HT	
10	2	Capot interne électronique	
11	1	Face avant	
12	2	r317580000 - SHV étanche - corps	High voltage BNC solder bulkhead jack
13	12	ISO 7046-1 - M3 x 4 - 4.8 - H	Vis à tête fraisée plate avec empreinte cruciforme de type H
14	1	Demi boite rapide inf V4	
15	1	Plaque de liaison lent - rapide v4	
16	15	ISO 4762 - M3 x 10	Vis cylindrique à six pans creux
20	1	Plaque borée	
21	2	Joint torique boites interne V4	
22	2	Passe paroie pour tube de 6mm- SS-4FK0-61	
23	2	Tube cuivre 4x6x140	
24	20	ISO 4762 - M3 x 16 - Vis cylindrique à 6 pans creux	

Note: La plupart des pièces sont communes avec le capteur lent. les principales différences se portent sur la pièce [14] ainsi que sur les pièces spécifiques [15] et [20].

Les PCB et leurs composants font l'objet d'un second dossier de plans

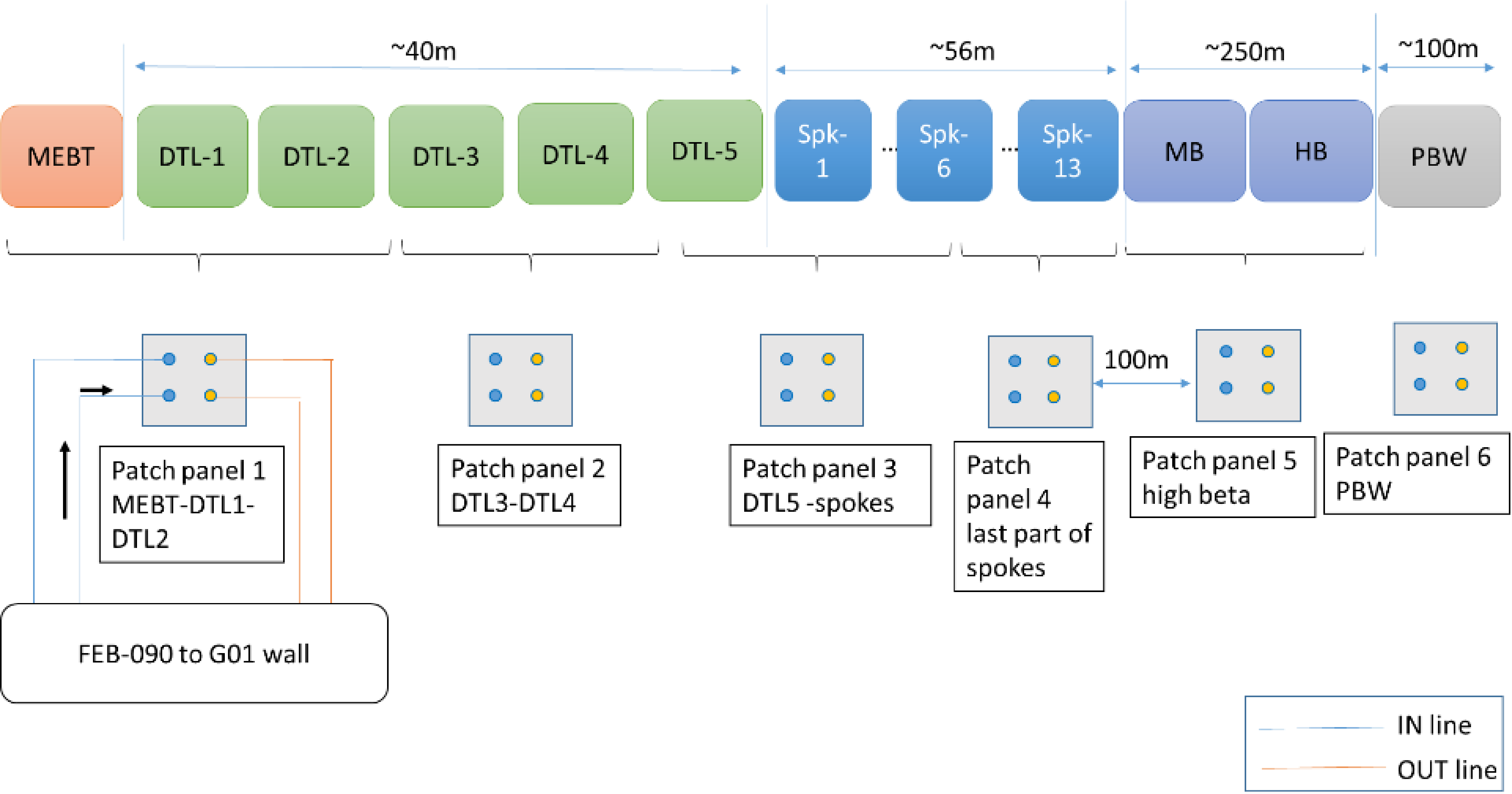
Les pièces [17] à [19] concernant le blindage plomb ne sont plus utilisées (Modification A)



Conçu par	Vérifié par	Tolérances générales:		Date de création	Etat:
Desforge	Beltramelli	ISO 2768 - fH - Rug: 3.2		05/10/2017	

CEA Saclay DRF/IRFU/SEDI	nBLM	Liste des pièces		
	66-Q051-DM-0200-Capteur rapide		Modification A	Feuille 2 / 11

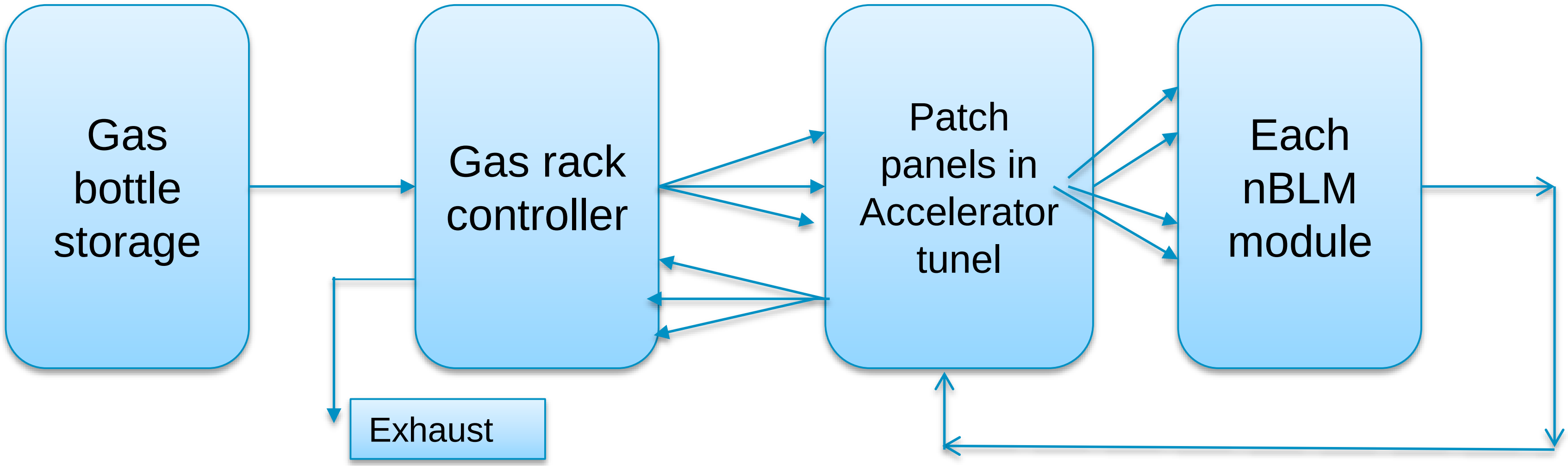
NBLM DETECTORS INTEGRATION IN ESS (II)



NBLM GAS SYSTEM

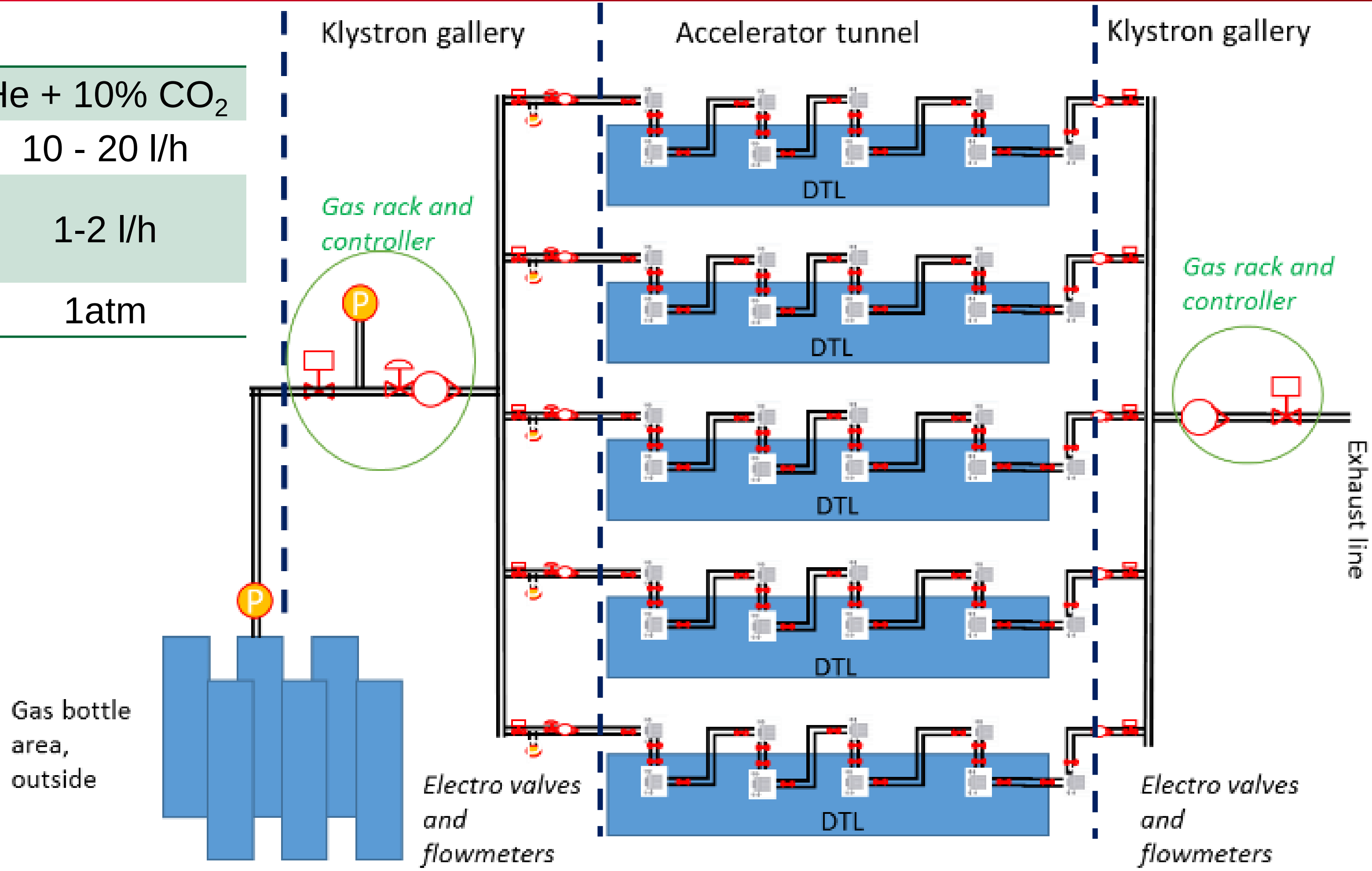
General design

- The gas system consists in 3 parts:
  1. The bottle storage area outside the building
  2. Gas distribution system
     1. Distribution and return lines from (to) the rack to (from) the accelerator tunnel
     - 10 distribution + 10 return lines
  3. Gas Line system fo group of detectors



NBLM GAS SYSTEM

Gas	He + 10% CO_2
Total flow	10 - 20 l/h
Flow per line	1-2 l/h
Pressure	1atm



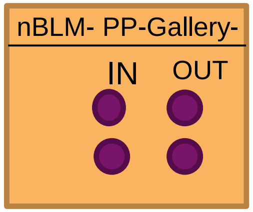
- Micromegas are gaseous detectors. Work in circulation with open circuit
- High reliable system for the 84 detectors

NBLM GAS SYSTEM

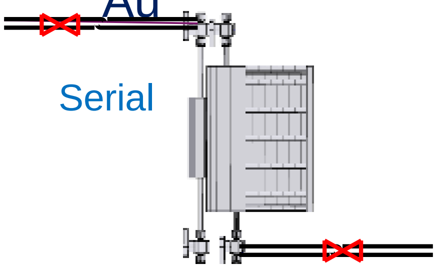
- Gas: He + 10% CO_2
- Flow: ~ 5 l/h, in recirculation
- P ~ 1 atm
- Volume/detector ~ 0.25 l
- Leak tight and low outgassing
- Gas bottle storage: 6-12 rack premix
  - ~200 bar/bottle, 50 l →
  - 2 IN/2 OUT lines (1 in use, 1 spare)
  - Outside gallery
- From gas bottle to gas rack to patch panel to tunnel
  - Distribute in 5 lines → one per DTL, in parallel
    - 5 IN/5 OUT Lines going to tunnel (+ spares)
  - Electrovalve in/out in Klystron gallery
    - Isolate system
  - Flowmeter in/out in Klystron gallery
    - Leak monitoring
- Gas in serial for detectors in DTL

Bottle rack

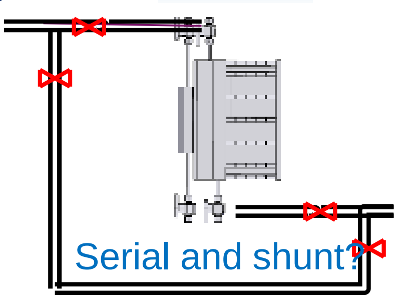
Gas controller



Designed by Stephan Au



Serial



Serial and shunt?

NBLM DETECTORS INTEGRATION IN ESS (III)

Detail of one nBLM gas distribution patch-panel