Beam Loss Monitor (BLM) for SPIRAL2 linac

F. Negoita, R. Borcea, I Cruceru , L. Serbina, M. Petcu, L. Ciolacu, B. Savu, A. Buta, C. Petrone, S. Calinescu, M. Cruceru, G. Dumitru, M. Badea, D. Valica

IFIN-HH, Bucharest-Magurele, Romania

SPIRAL2 project team

The role of Beam Loss Monitor (BLM)

BLM systems aim to:

- to diminish activation
- protect accelerator components
  (in particular to avoid quenching of superconducting components)
- to help tuning/optimizing the beam

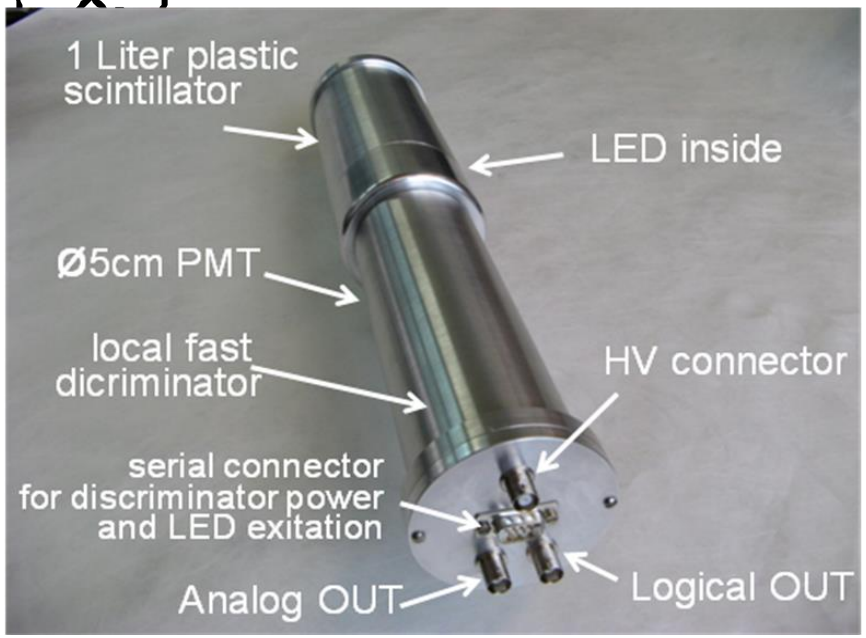
The BLM must provide:

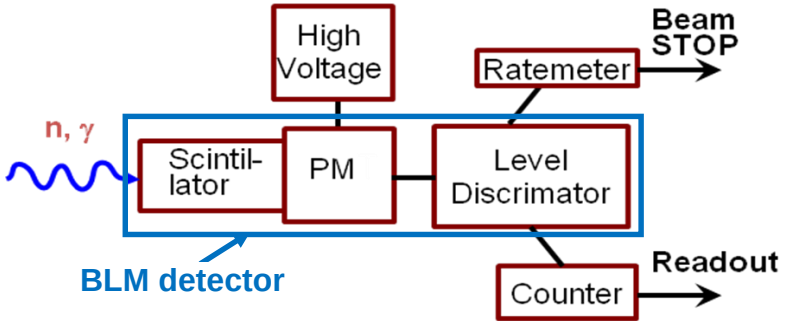
- the intensities of beam losses
- the positions where the losses occur
- a fast <Beam Stop> signal when allowed beam loss limits are exceeded

Worldwide, depending on beam nature and energy, BLM systems are composed of detectors of various types placed outside vacuum beam line:

- short or long ionisation chambers
- scintillators (liquid, plastic, crystals) coupled to photomultipliers
- solid state detectors (PIN diodes, Si detectors, etc.)

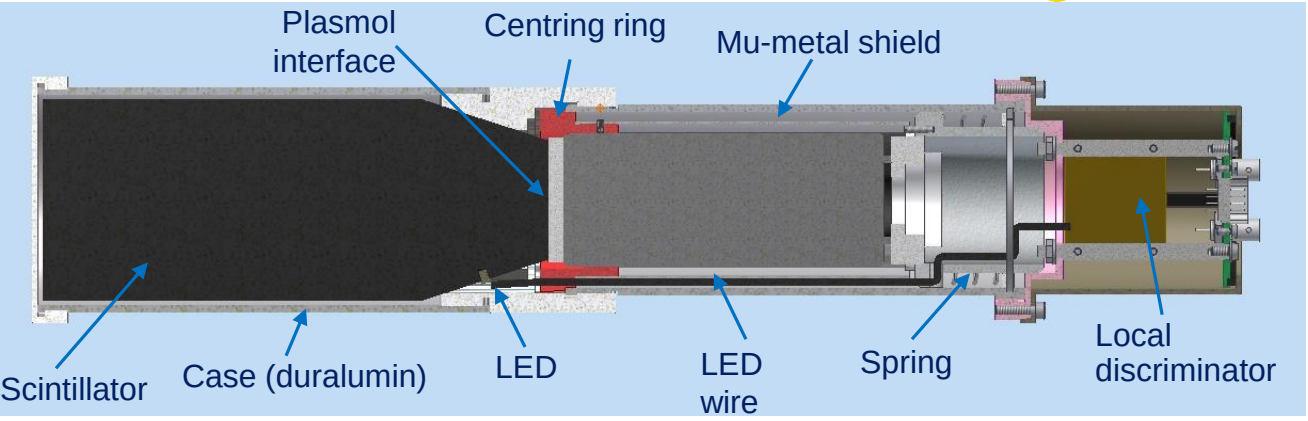
BLM detectors design

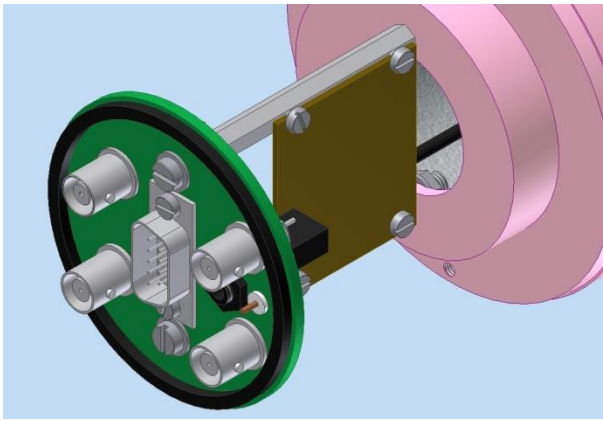




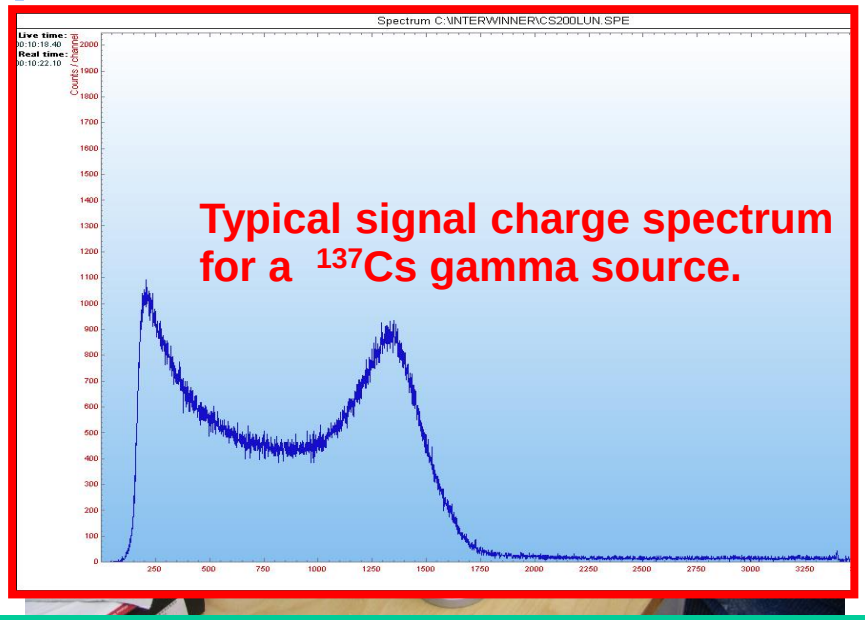
Radiation hardness tests at 10^{14} n/cm^2 (~ 1kGy) using d+Be reaction at Bucharest cyclotron:

- no effect on local discriminator
- strong effect on LED (30 times reduction)
- replacing the LED the pulse shape was recovered =>
  - no effect on PM amplification
  - no effect on optical transmission





BLM detectors are in individual characterization phase



The results are consistent with expectations and values used in simulations.

35 detectors are ready !

Four (4) detectors decided to installed in S3 area

⇒ **5 (smaller) detectors are under construction for mobile detector**

Threshold (mV)	Threshold (eekeV)	Background (cps)
50	25	411
100	50	313
200	100	246
300	150	167
400	200	139
500	250	119

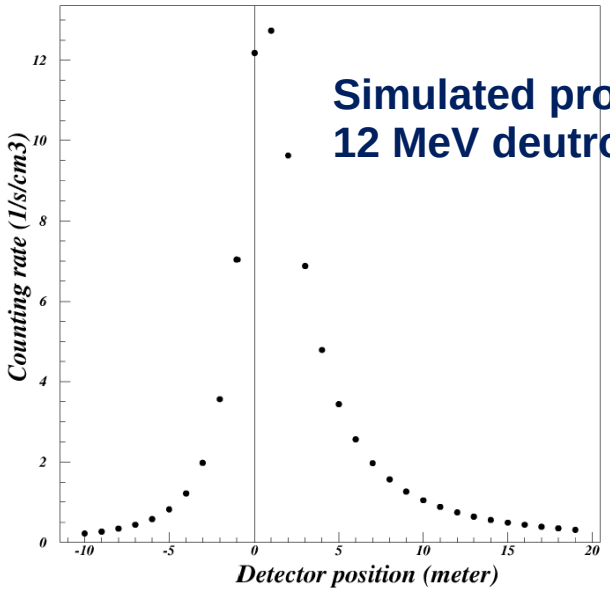
Background count rate at 1200 V as function of threshold.

BLM system configurations

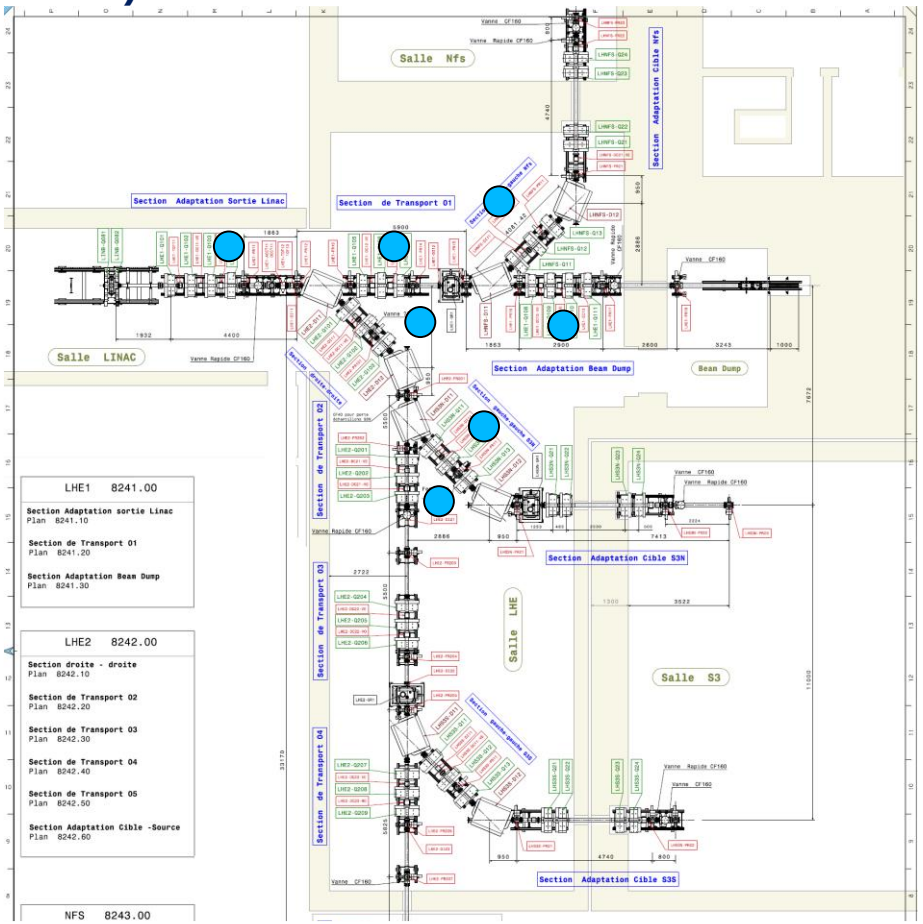
1 detector per cryomodule along linac (20 detectors) **+ 7 detectors in LHE**

(+5 mobile detectors)

Expected output:
longitudinal profile of counting rates



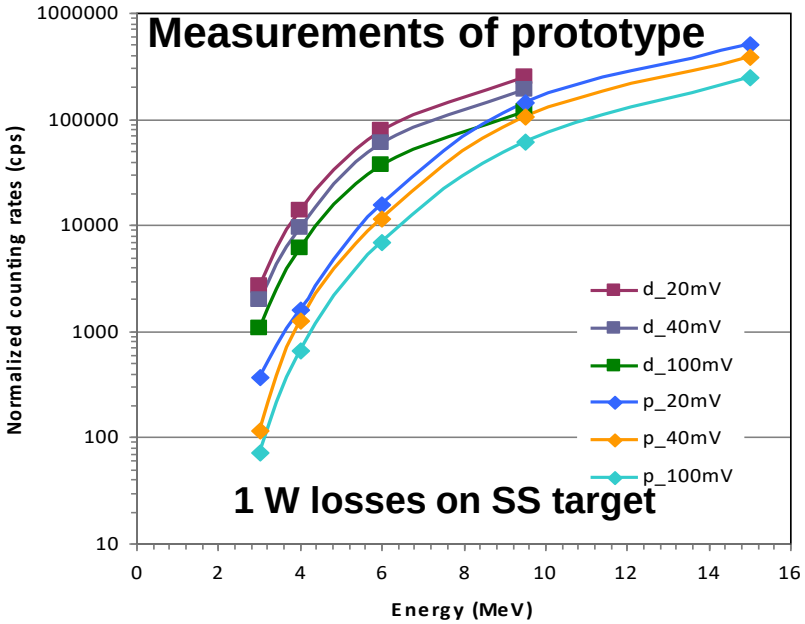
Simulated profile for 12 MeV deutrons

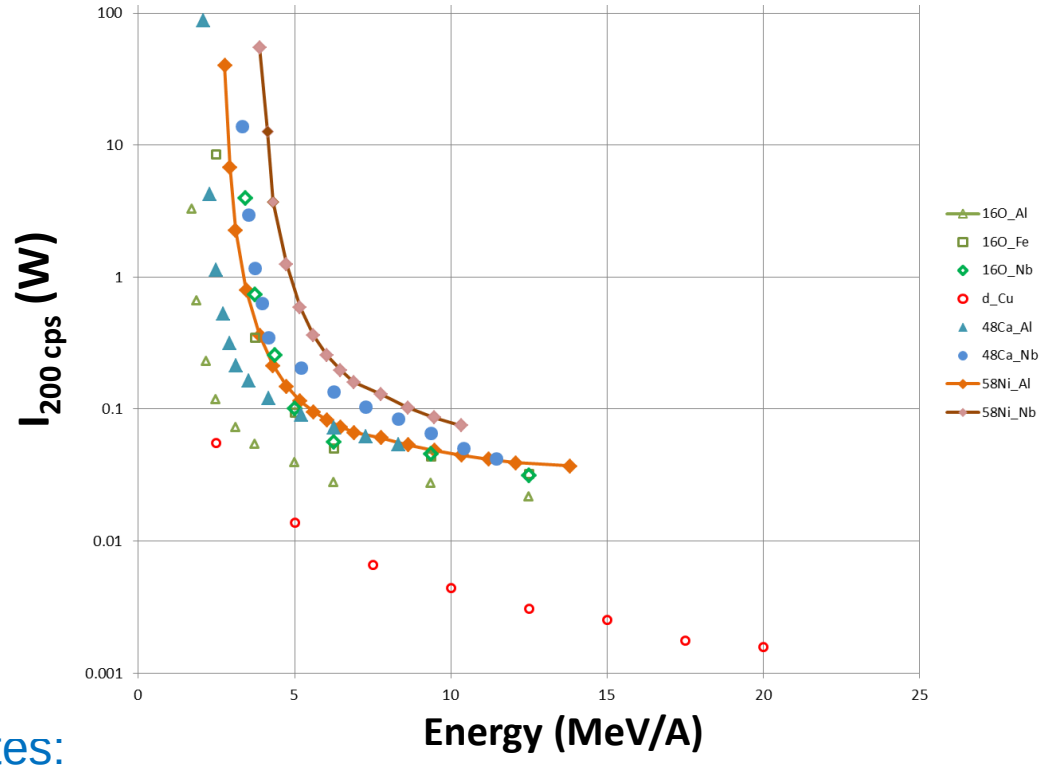


Distortions factors:

- **X-ray background**
- **activation build-up**
- **scattering/absorption on beam line elements**
- **complex profiles losses**

Response of detectors





Sources of background counting rates:

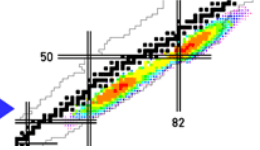
- Electronic noise is neglijable
- Natural radioactivity: 100-200 cps
- X-ray from cavities: 20 mSv/h + 5 cm Pb => ~10^3 cps @ 0.5 m
- activation built-up:

  10 min. of 1W of losses for deutons@15 MeV on Al

  => 28Al ($T_{1/2}$=2.2 min., Eγ=1.7 MeV)

  => ~10^5 cps w/o Pb; < 10^4 cps with 5 cm Pb

BLM functioning regime and performances



BLMs work for all beams ! The temporal structure of the beam is used only for displayed counting rates (and calculated losses), not for alarms.

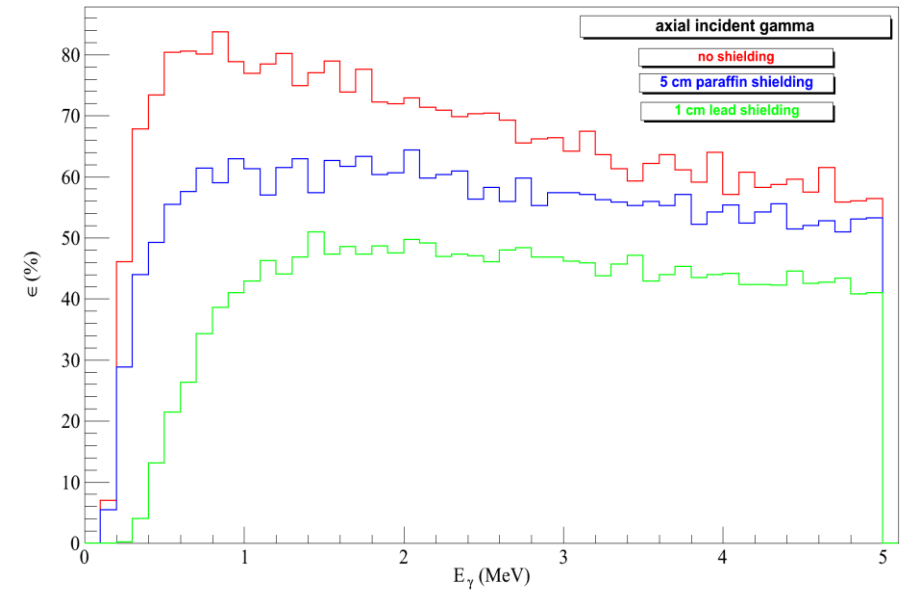
- Activation alarm thresholds:
  - correspond to the counting over one second of pulses induced by 1 W/m of losses for deuteron beam of 40 MeV
  - this counting threshold is not changed if the other beam or energy is accelerated
- Thermal alarm thresholds:
  - recalculated for each beam (ion type and acceleration law)
  - correspond to 50 W/m losses integrated over 140 ms.

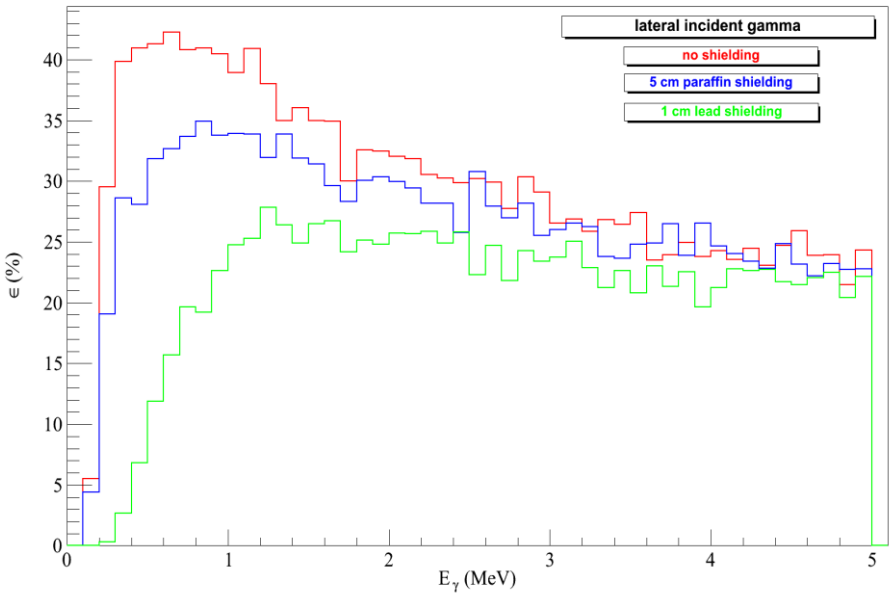
Sensitivity (minimal loss intensity that can be measured):

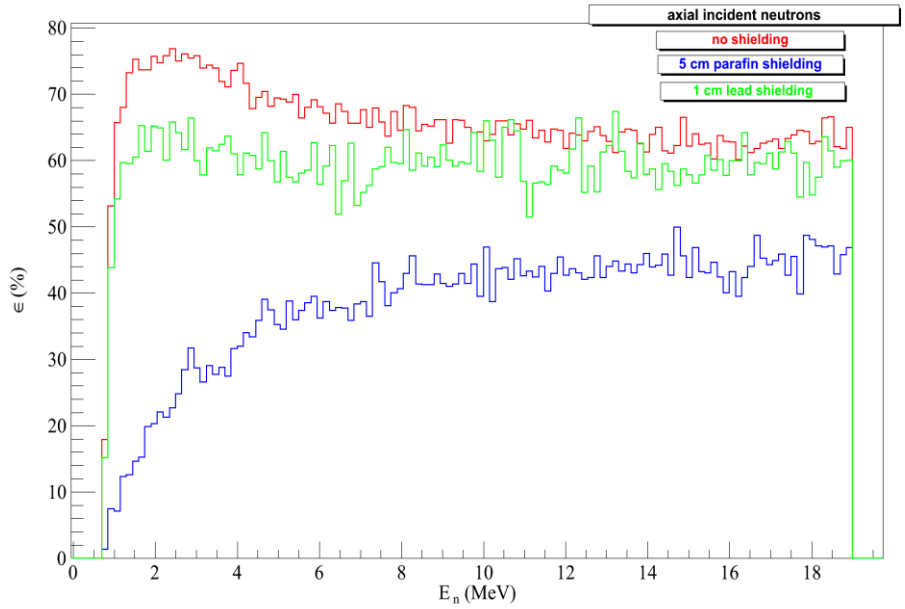
- is mainly due to background counting rates (expected $<10^3$ counts/second)
- depend strongly on ion type and improves with energy increase:
  - deuterons=> 0.1 W for 4-5 MeV; 0.01 W for higher energies
  - heavy ions=> 10 W for 3-4 MeV/A; 1 W for 4-5 MeV/A; 0.1 W for 6-8 MeV/A

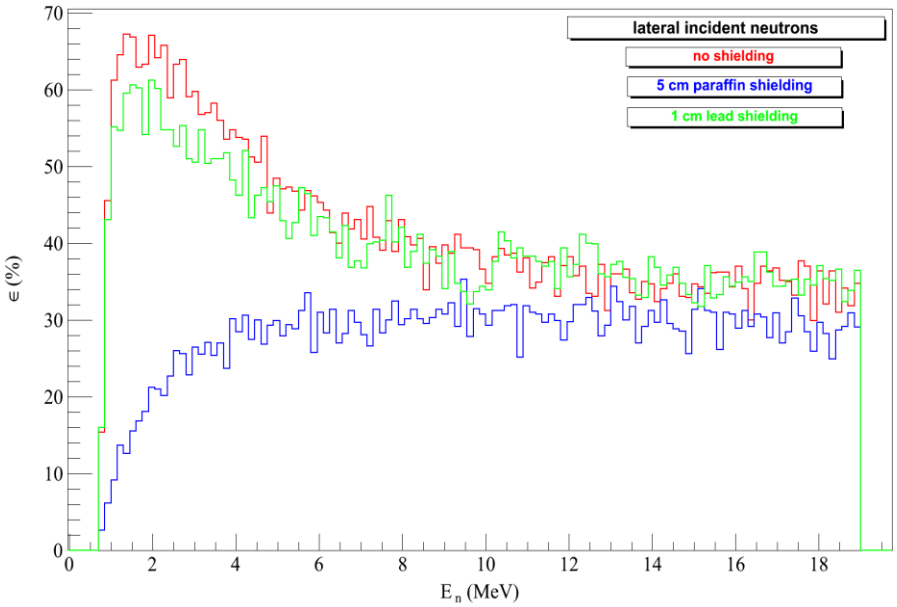
The range of measurements covers about 3 decades, limited by the thresholds that will stop the beam. Transitory higher losses can be measured, however if counting rates became higher than 10^6 counts/seconds will generate a very fast alarm (40 μs).

Gamma and neutron efficiencies with and without shielding





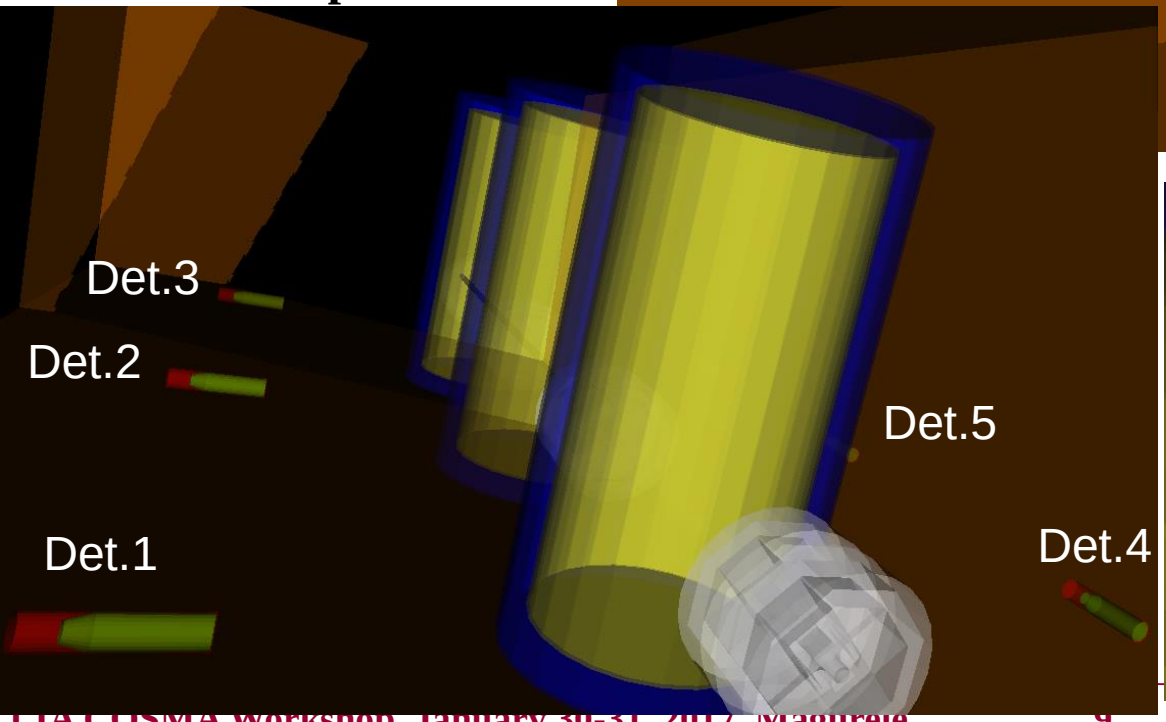


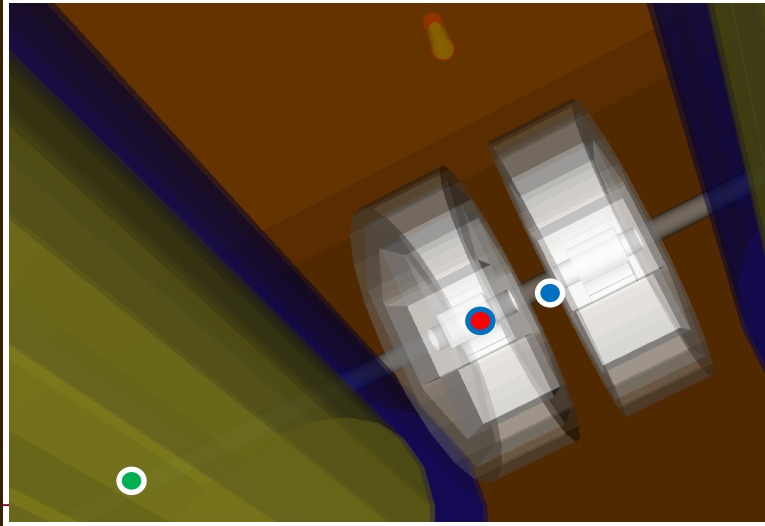


Simple, realistic simulations

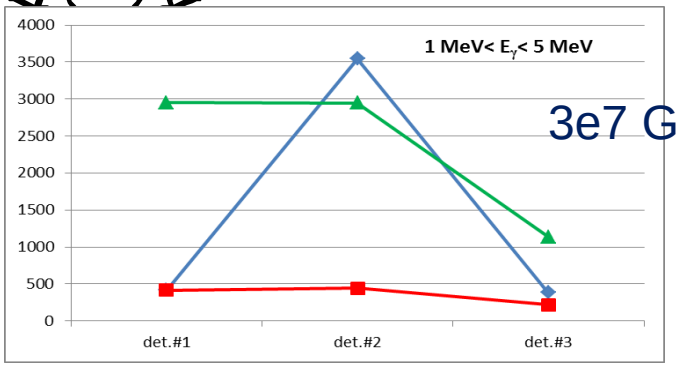
- 3 cavities (1 cm Nb)
- 3 cryomodules (1 cm Fe)
- 4 quad duoblets (Fe+Cu)
- 3+3 detectors

- isotropic angular distrib.
- flat energy distrib.
- 3 emission points

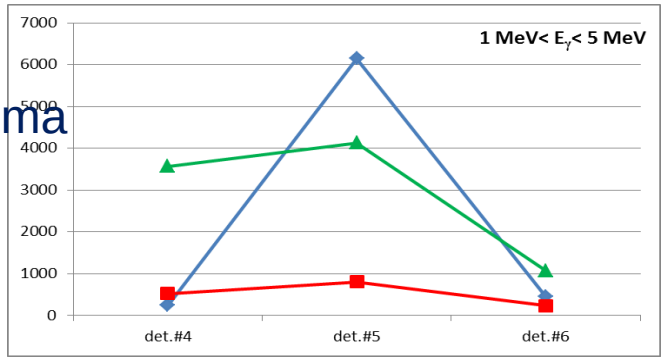


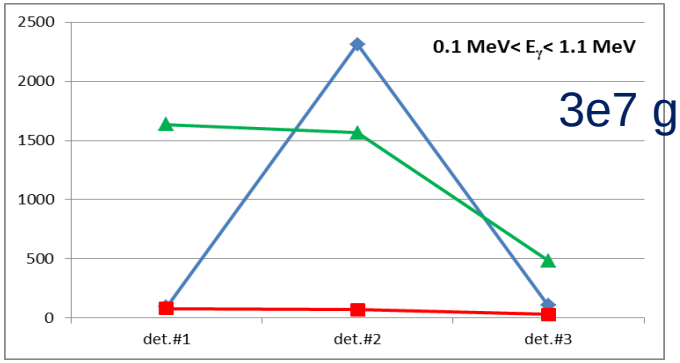


Precision of measurement

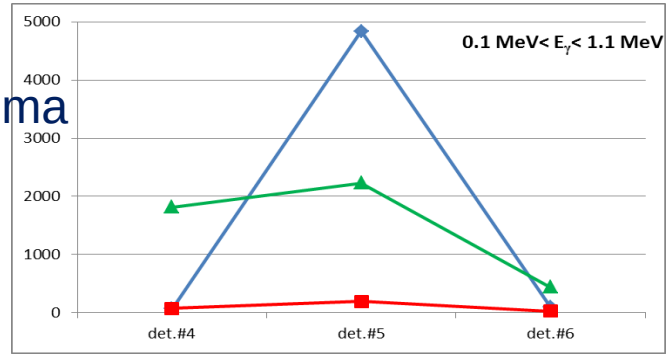


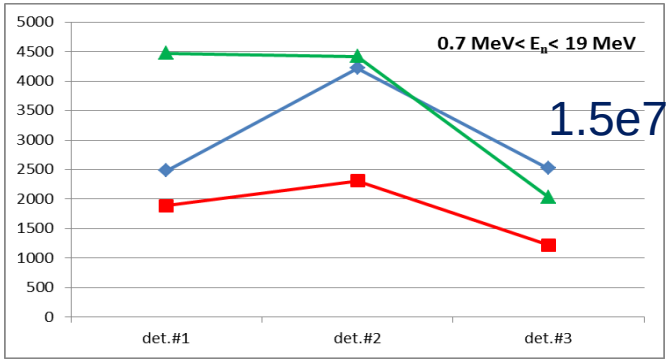
3e7 Gamma



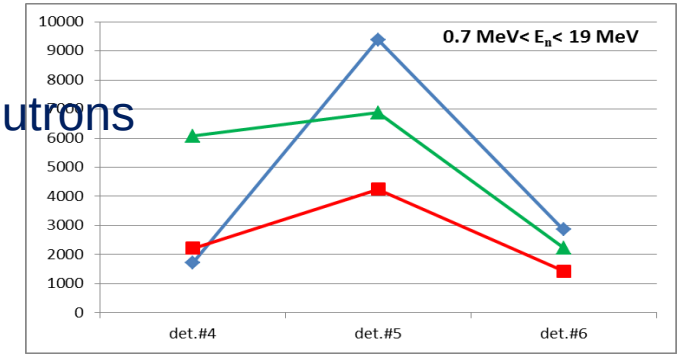


3e7 gamma





1.5e7 neutrons



Detectors perpendicular with beam axis

Detectors parallel with beam axis

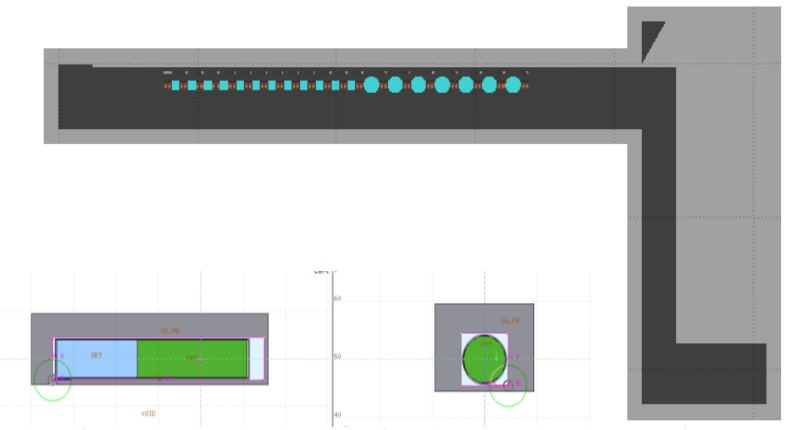
- Middle doublet
- Middle cavity
- Inside q-pole

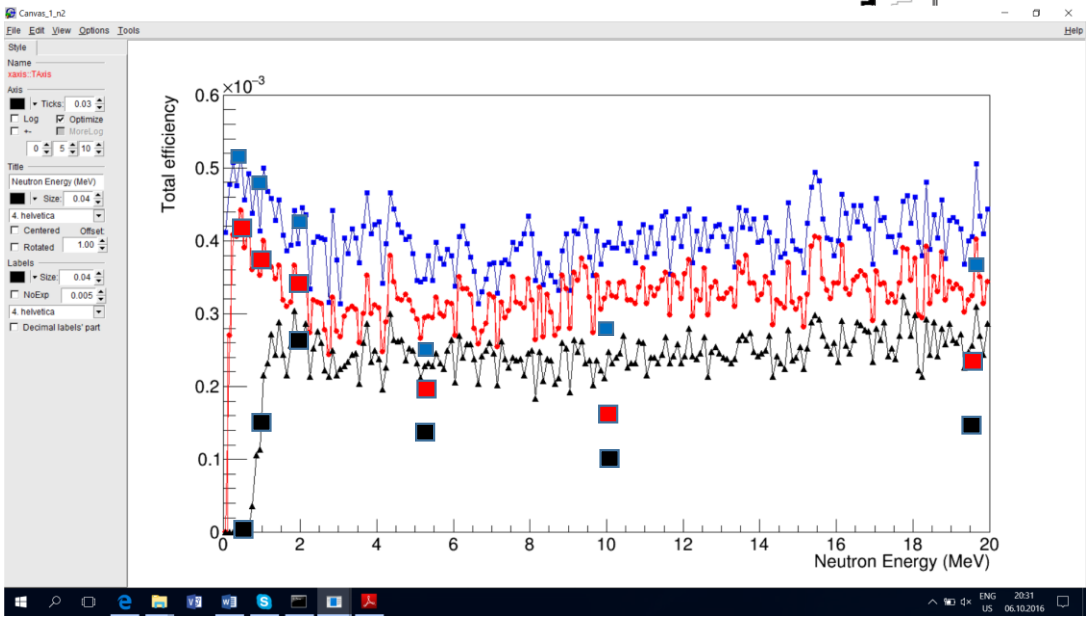
Attenuation factor with Pb:
5-8 for Gamma
10-20 for X-rays
2-3 for neutrons

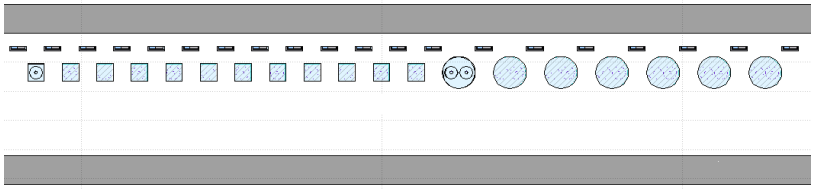
Precision in the intensity measurement with Pb: ~200%

But for a given point of loss: 10%-20%

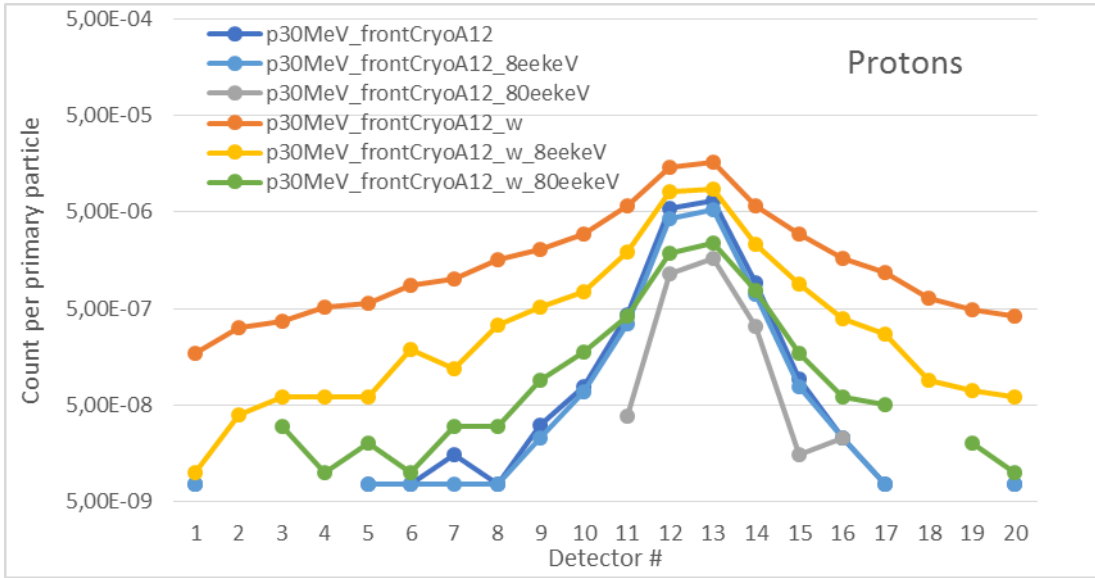
Fluka simulations





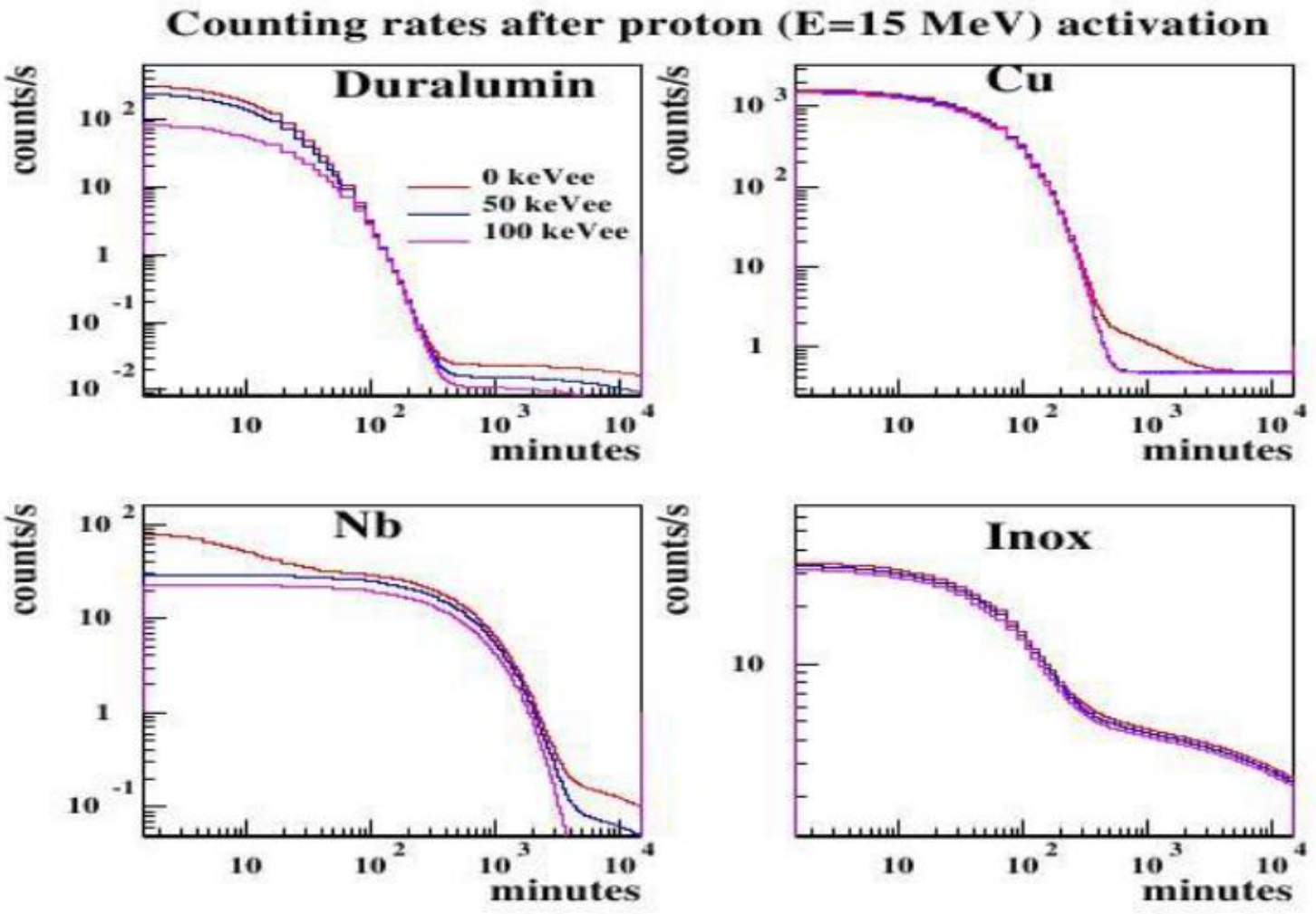


Full BLM system response in simplified geometry under implementation.

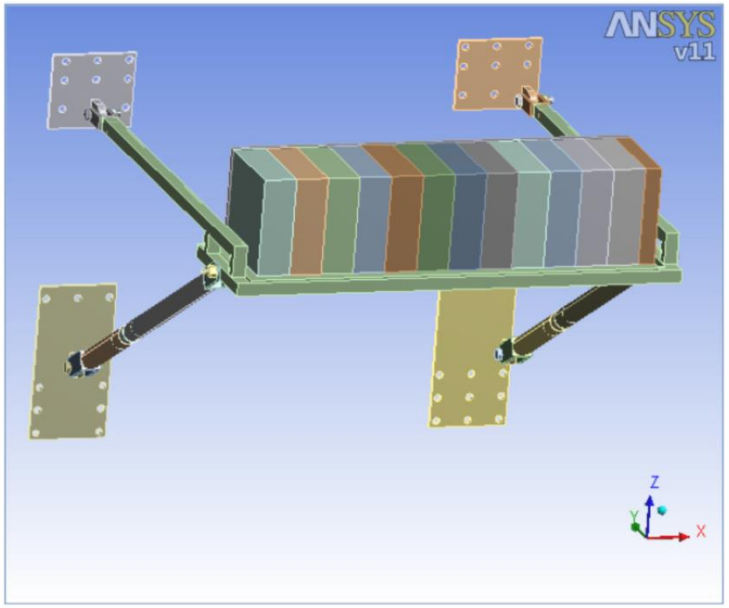


+Y. Zafar, S.Tabbassum (PINSTECH, Nilore, Pakistan)

Beam OFF counting rates



Detector implantation



In LHE the detectors are placed on the floor.

Les fonctions du système BLM

Sous-système EPS

n, γ → Détecteurs → Comptage

Fonction: Protection contre l'exposition externe
Surveillance seuils activation
=> Alarme BLM Activation

Fonction: Protection thermique
Surveillance seuils thermique
=> Alarme BLM thermique

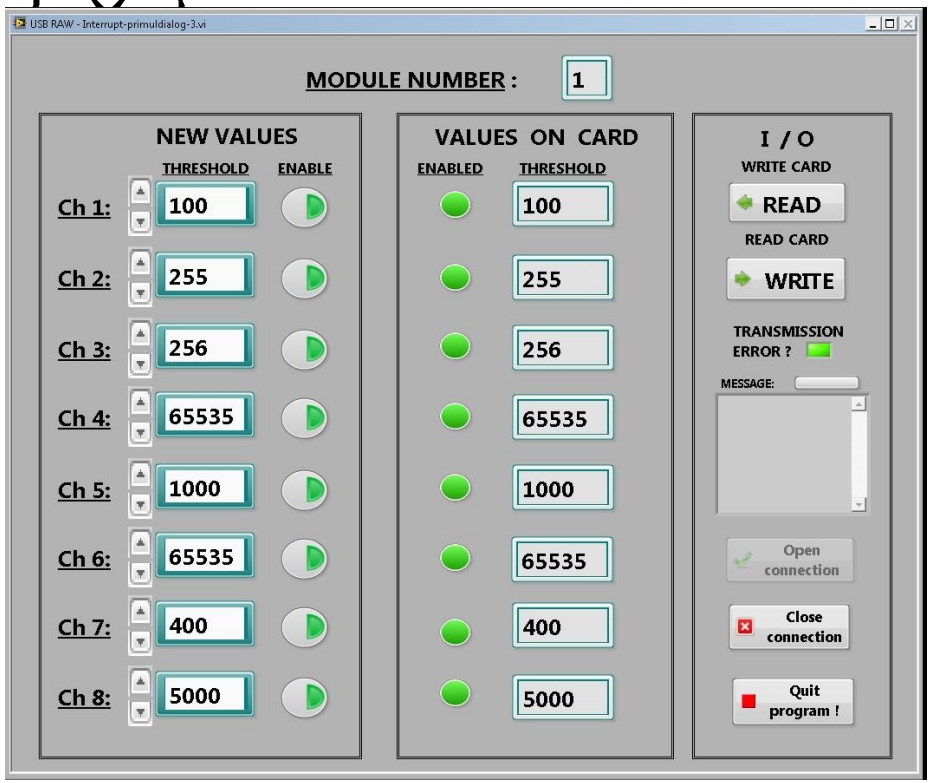
Fonction: Réglage accélérateur
Visualisation taux comptage

Réglage en locale
Seuils fixes : 1 W/m deutons (* 5 mètres)
=> ~ 0.1 MHz * 1 s temps d'intégration

Contrôle: stabilité HV
taux comptage minimale

Protections: dépassement curent
taux comptage > 5 MHz
saturation
} alarme 35 μs

Settings of NIM Alarm Ratemeter



Snapshot of the interface to change the parameters from a PC (laptop).

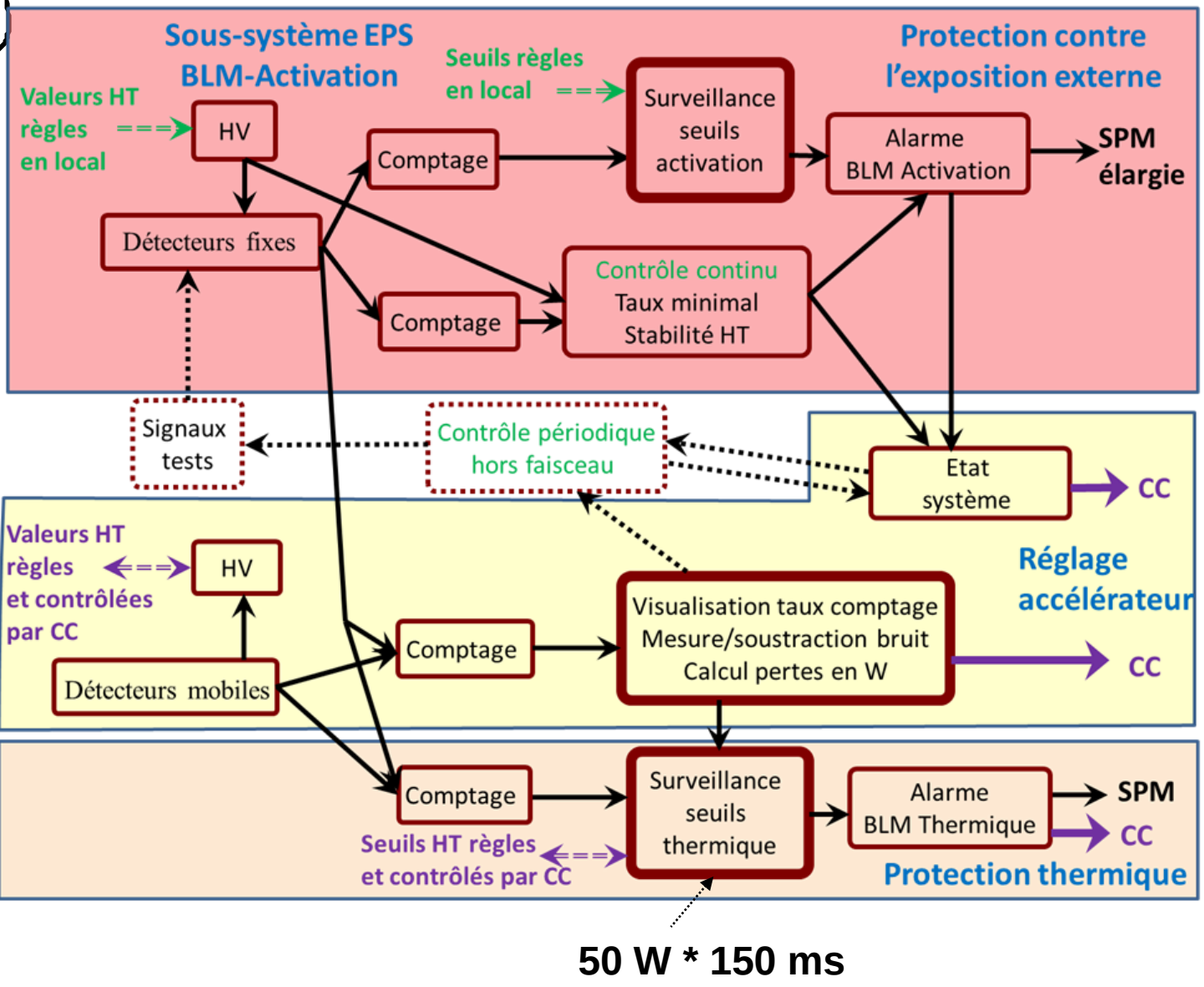
The programing of both the microcontroller and interface are completed (work of B.Savu/IFIN-HH).

Alarm function are implemented using ICs (Integrated Circuits) (work of M.Petcu/IFIN-HH)

Parameters are input through a microcontroller with USB interface.

Microcontroller is involved only in (re)initialiazation of the module. The values of parameters can be checked independently (and periodically) using the LED on detectors.

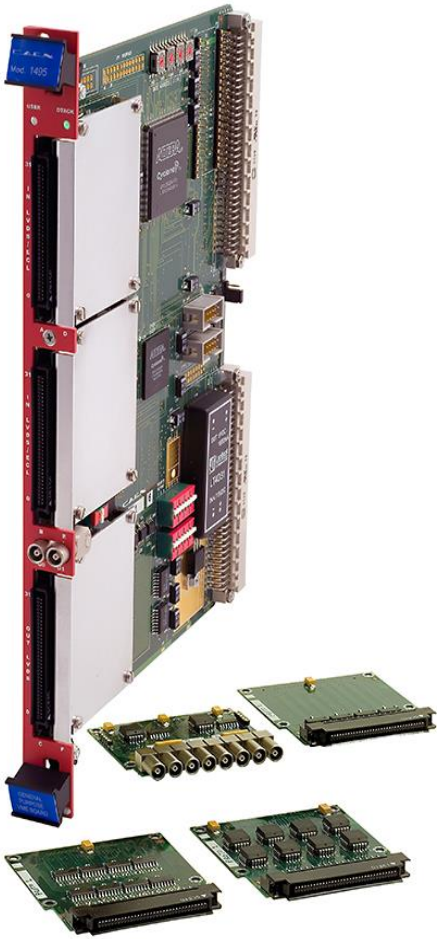
BLM System Configuration



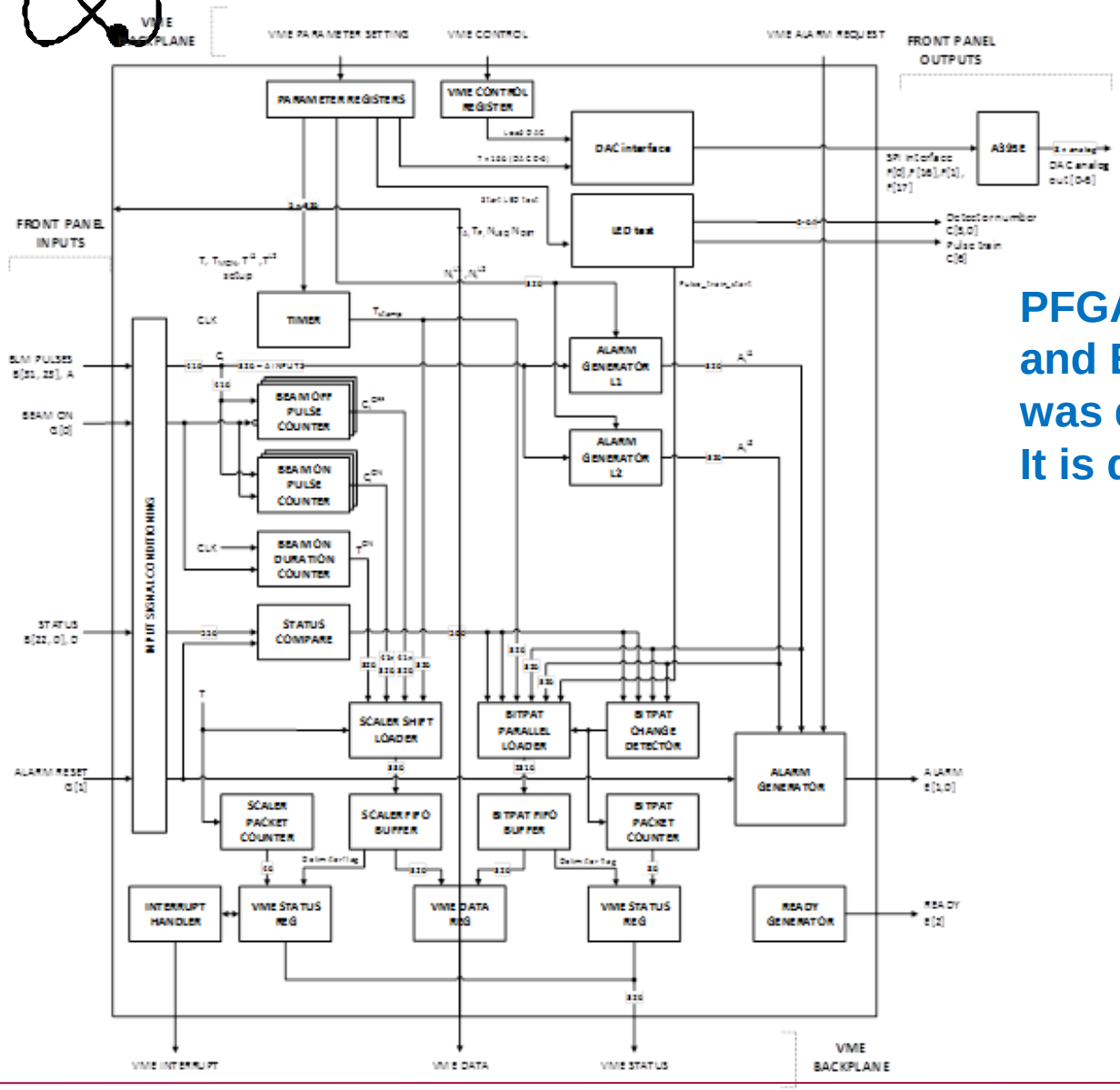
Non-EPS functions implemented in VME cards

Commercial FPGA card (V1495 from C.A.E.N.):
- fast thermal alarms
- counting separated on Beam ON/OFF
- monitoring status/individual alarms
- control the HV of mobile detectors
- control the LED tests (signal trains generation)
- ~~generate software alarms (SPM-T)~~

CPU-VME:
- setting parameters on FPGA card
- readout FPGA card with 1 ms period
- transform raw rates in beam losses intensities (W)
- ~~slow (software) alarms~~

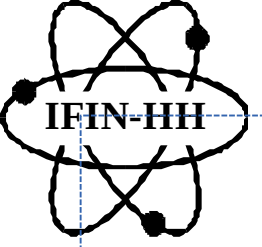


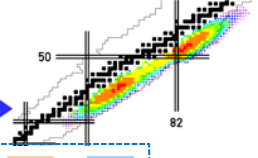
FPGA architecture and BLM EPICS driver



PFGA firmware programing and EPICS driver development was done by Cosylab (Slovenia). It is delivered and tested.

Synoptic of BLM System





Salle accélérateur

LINA-BLM01

LINA-BLM02

LHE2-BLM23

BLM-MOB1

BLM-MOB5

3294 Chassis Haute Tension

3295 Module Base Tension

3296 Module Impulsion LED

3293 Sorties Analogiques

3292 Module Alarm Activation

DdeC_BLM-SPME/NO

DdeC_BLM-SPME/NF

acquittement BLM SPME

Limande

3912

6165

Module VME a FPGA

Sorties Analogiques

Module Base Tension

Chassis Haute Tension

DdeC_BLM-SPMT

acquittement BLM SPM T

Système de protection élargi

Système de protection thermique

Baie A/28-4/008

Baie A/28-4/007

Baie A/166/001

Ethernet

6165 A/28-4/007

6166 A/28-4/007

6167 A/28-4/007

6168 A/28-4/007

Seulement un de ces 4 câbles sera utilisé

Baie A/27-2/007

PF linac 3912 A/28-4/007

SF LHE 1101 A/28-4/007 (non-utilisé)

BLM costs

- 280 kEuro equipment (excluding VAT and overheads)
- 450 kEuro manpower (including travels)

[SPIRAL2 contributions estimated to ~ 40 kEuro]

	Item		Qty	Unit Price (EUR)	Price (EUR)	Remarks
1.	BLM detectors					
	1.1.	Scintillators and optical consumables	38	371	14523	
	1.2.	Photomultipliers + mu-metal shield + sockets	40	938	37510	
	1.3.	PCBs, electronic components and connectors	40		3000	
	1.4.	Mechanical components and materials	35	200	7000	
2.	Detector supports and Pb shielding		33		14839	
3.	Supports for mobile detectors		5	300	1500	
4.	HV Supply with 4 boards (4*12 channles)		1	23336	23336	
5.	High Voltage power supply for mobile and S3 detectors		3	4984	14952	
6.	IFIN-HH built electronics modules					
	6.1.	Blank NIM cases	24	234	5616	
	6.2.	Electronics components			4750	
	6.3.	Connectors			2800	
7.	Commercial electronics modules					
	7.1.	N405	3	2797	8391	
	7.2.	N638	3	1580	4740	
	7.3.	N454	3	1335	4005	
	7.4.	N844	1	2000	2000	
8.	Cables and connectors					
	8.1.	Long cables for fixed detectors	200			GANIL Contribution
	8.2.	Long cables for mobile detectors	25			GANIL Contribution
	8.3.	Extension cables for mobile detectors	35		3500	
	8.4.	Electronics interconexion cables and adaptors			8160	
9.	Crates					
	9.1.	NIM crates	4	6658	26632	
	9.2.	VME crate	1			GANIL Contribution
10.	Lockable ventilated racks		2	2000		GANIL Contribution
11.	VME General purpose board					
	11.1.	VME board with mezzanine cards and controllers	1	9500	9500	
	11.2.	FPGA software for basic functionalities			14985	
	11.3.	FPGA software for enhanced functionalities			24975	
12.	BLM EPICS Software					
	12.1.	Motorola CPU				GANIL Contribution
	12.2.	EPICS software for basic functionalities			14985	
	12.3.	EPICS software for enhanced functionalities			28800	
				TOTAL:	280499	

Status of BLM System

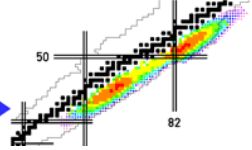
- More than 95% of the hardware is ready
- Installation of supports along linac + 5 detectors done in Dec. 2016
- Software developed by Cosylab (FPGA firmware + EPICS drivers) currently under test at GANIL
- Documents for BLM long term (4 years) custody signed
- Next work:
  - Mobile detectors with their supports → Q2/2017
  - Cables (~ 200 pcs with various lengths and connectors) → Q2/2017
  - Software for parameter calculations and on-line data treatment
  - Complete installation, testing, commissioning → Q4/2017
  - Full documentation, operation and maintenance manual → Q4/2017
- Long term collaboration:
  - Simulations of full BLM system response
  - Assistance/support for operation and data interpretation
  - Assistance/support for maintenance and improvements/upgrades

Conclusions

- BLM system has a robust (and rather simple) sub-system responsible for activation diminishing.
- BLM is a versatile (and rather complex) system taken as whole
- The use of information provided by BLM system for linac tuning will be learned and improved during first few years of operation

IFIN-HH

Spiral2



Thank you for attention