RESULTS OF THE RADIATION STUDY AROUND THE TESTED GEM MUON DETECTOR AT CMS

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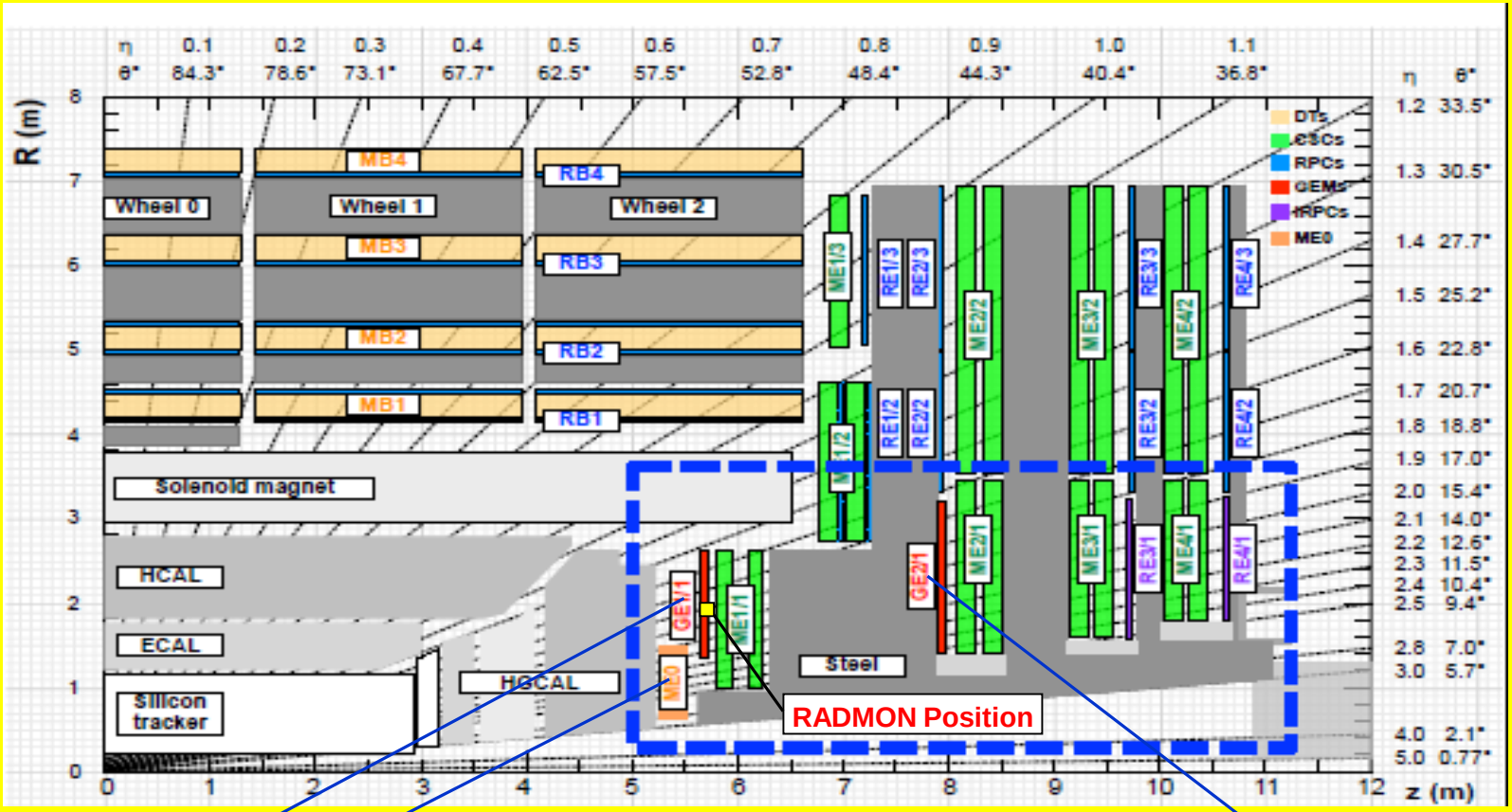
INTRODUCTION

The higher energy and luminosity of future HL-LHC imposed the development and testing of new type high-rate detectors as GEM (Gas Electron Multiplier) chambers. They are Micro-Pattern Gaseous Detectors that feature 50-100 microns spatial resolution, 4-5 ns time resolution, high detection efficiency, and proven high-rate capability and resilience against aging effects.

The very high time and spatial resolution of GEM enables their simultaneously application for triggering and tracking information. (instead of RPC + CSC). They are suitable also for the very forward region – 1,6 < |η| < 2,5 – a new region that have to be covered by CMS for the future research at HL-LHC.

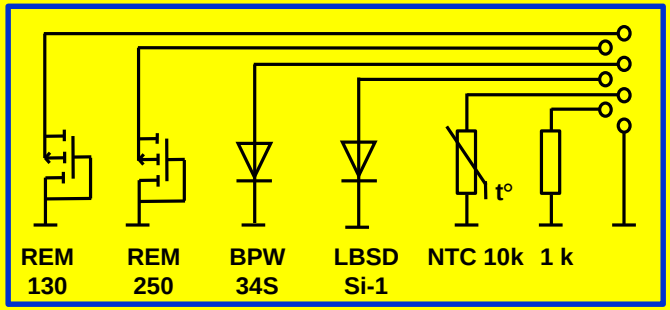
WORKPLACES OF THE GEMs in CMS

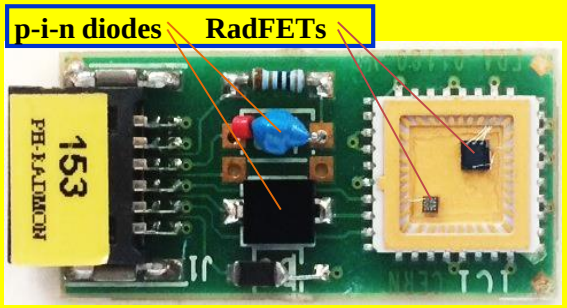


3 workstations are planed for GEM: GE1/1 – 2022, GE2/1 + MEO - 2026

One important task was to study the radiation level distribution around the GEM working places.

RADIATION MONITORING SYSTEM - RADMON



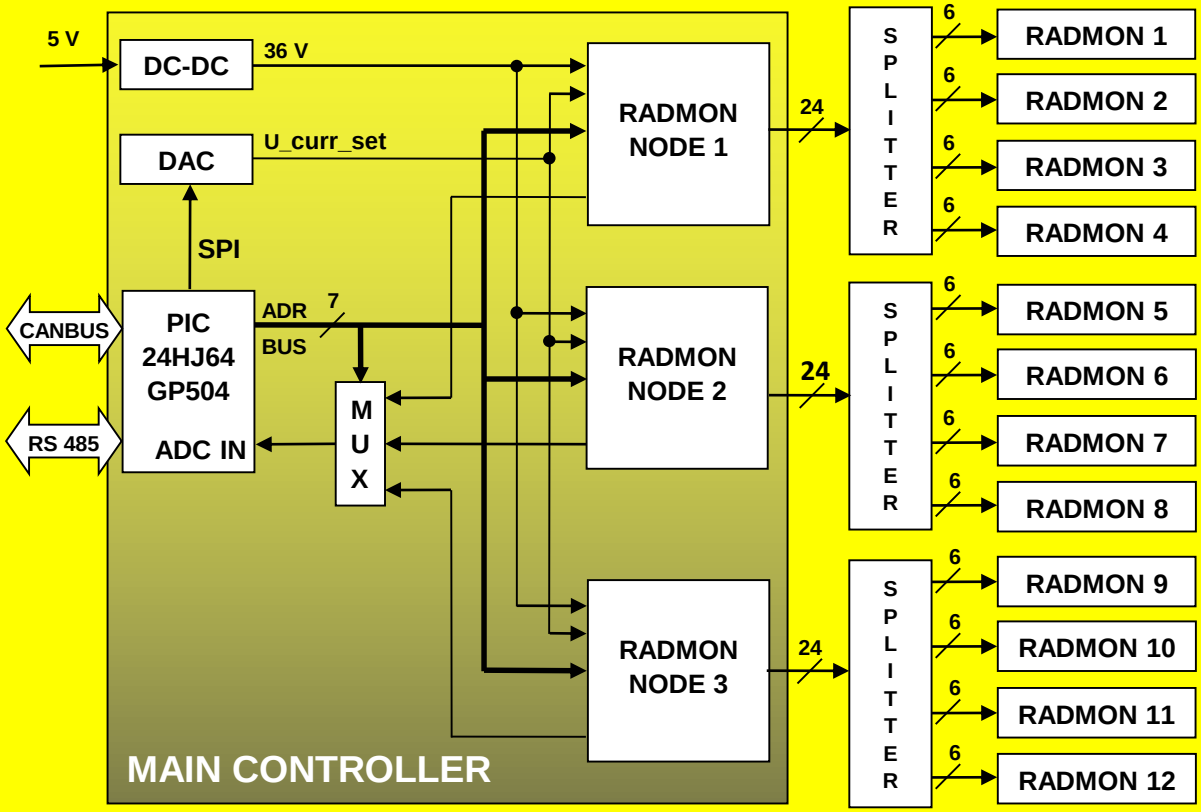


4 SENSORS:
2 RadFETs – the total absorbed dose
2 p-i-n diodes – 1 MeV neutron equivalent fluence

Function	Type	Device	Operating range	Sensitivity / Resolution	I_{read}
Total Dose Sensor (high doses)	RadFET	REM 250	A few 10^{-1} Gy to > $2x10^{4}$ Gy	~ 20 mV/Gy (initial)	160 µA
Total Dose Sensor (very high doses)	RadFET	REM 130	A few Gy to > $2x10^{5}$ Gy	~ 3 mV/Gy (initial)	160 µA
1 MeV n eq. Fluence Sensor (high sensitivity)	p-i-n diode	LBSD Si-1	10^{10} cm^{-2} to ~ $2x10^{12}$ cm^{-2} (almost linear)	~ $2.1x10^{8}$ cm^{-2}/mV	10 mA
1 MeV n eq. Fluence Sensor (low sensitivity)	p-i-n diode	BPW34S	~2.10^{12} cm^{-2} to ~ $4x10^{14}$ cm^{-2} (linear)	~ $1x10^{10}$ cm^{-2}/mV	1 mA
Temperature sensor	Thermistor	NTC 10 k	-55 ^{0}C to 125 ^{0}C	0.1 ^{0}C	10 µA
Line checking	Resistor	1 k		1%	1 mA

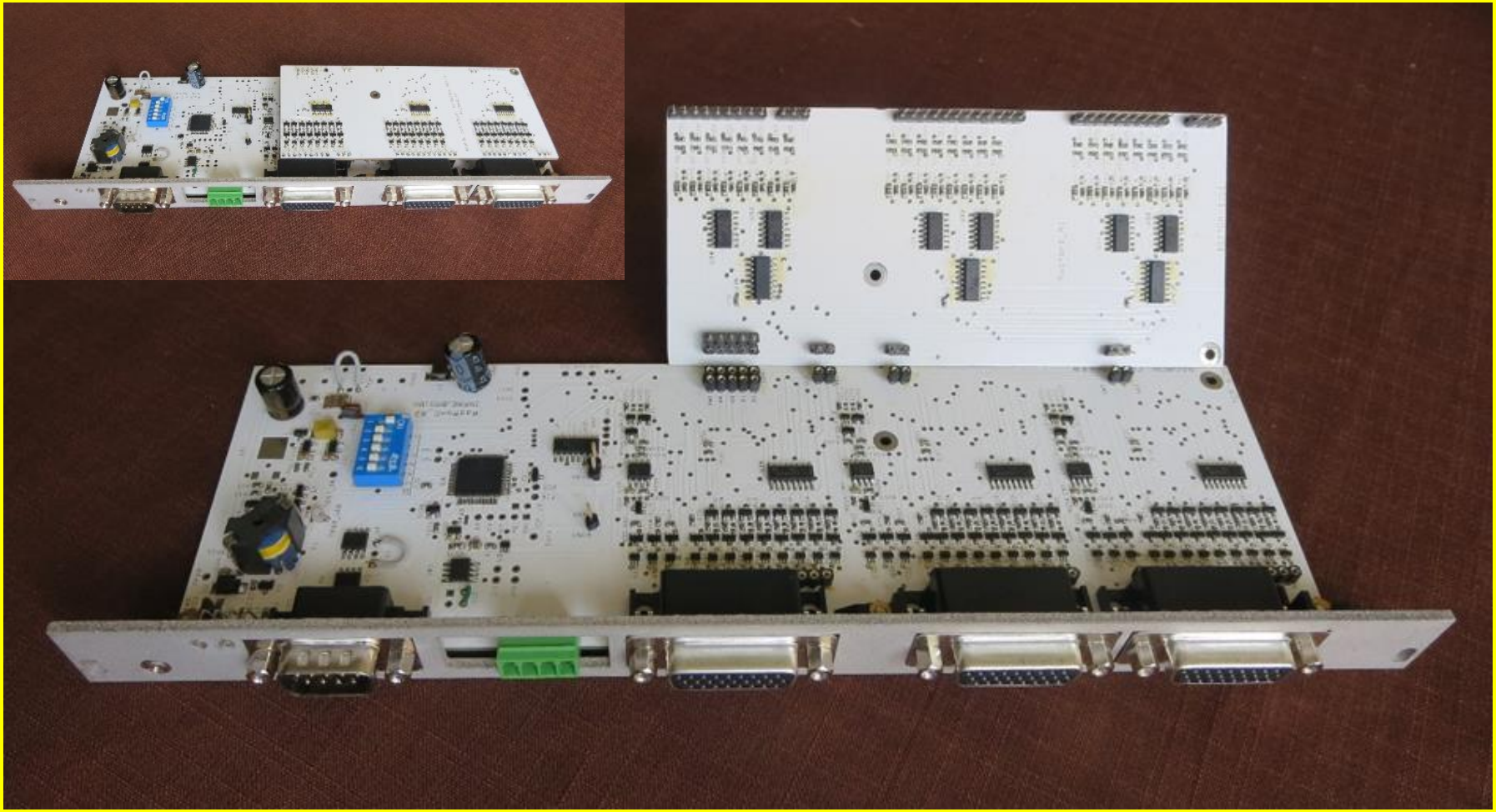
RADIATION MONITORING SYSTEM - STRUCTURE

A monitoring system is designed to control the radiation absorbed by the GEM detectors during their operation.

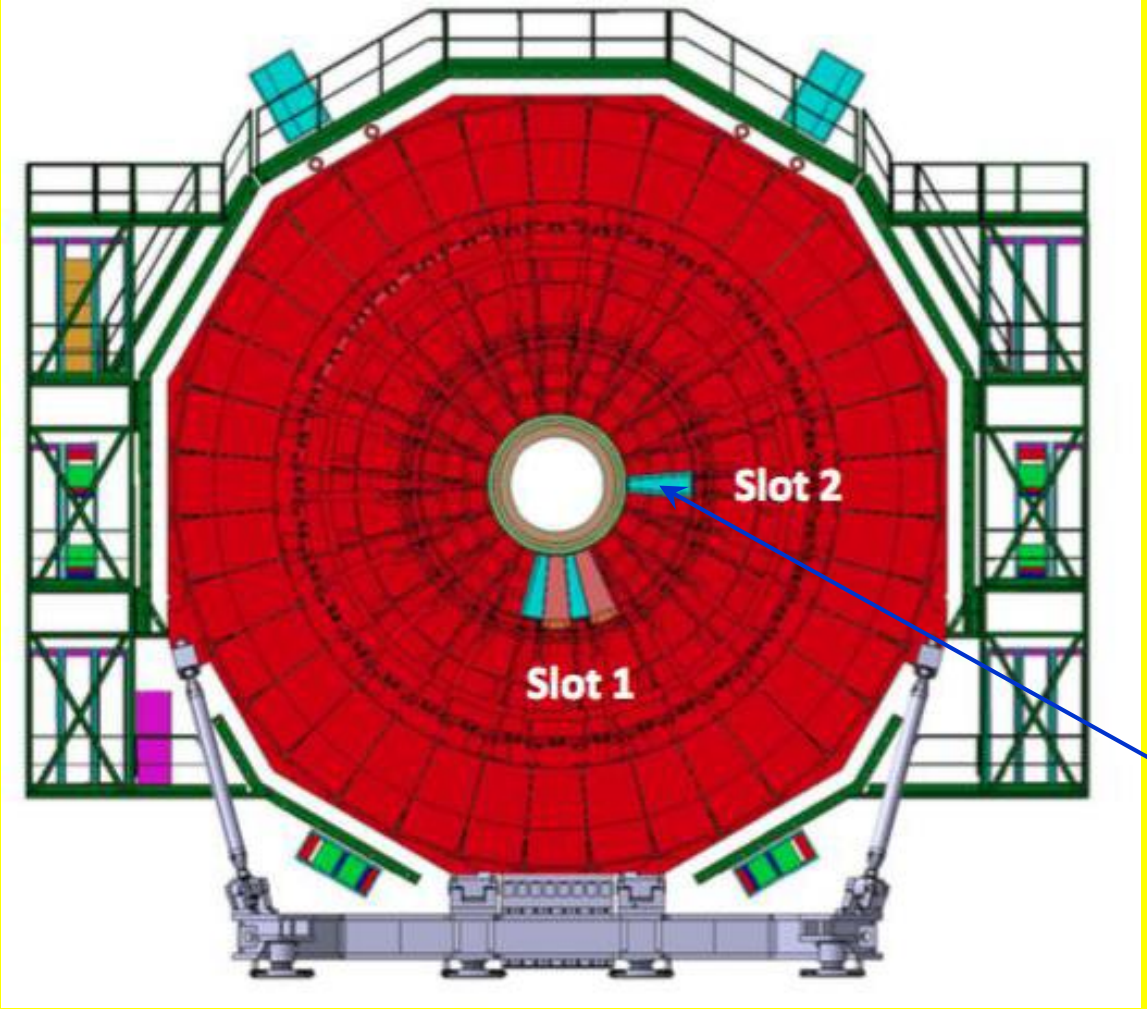


The system consists of a Main Controller and a basic radiation sensor unit, called RADMON. Up-to 12 RADMONs can be connected to the main controller.

RADIATION MONITORING SYSTEM – MAIN CONTROLLER



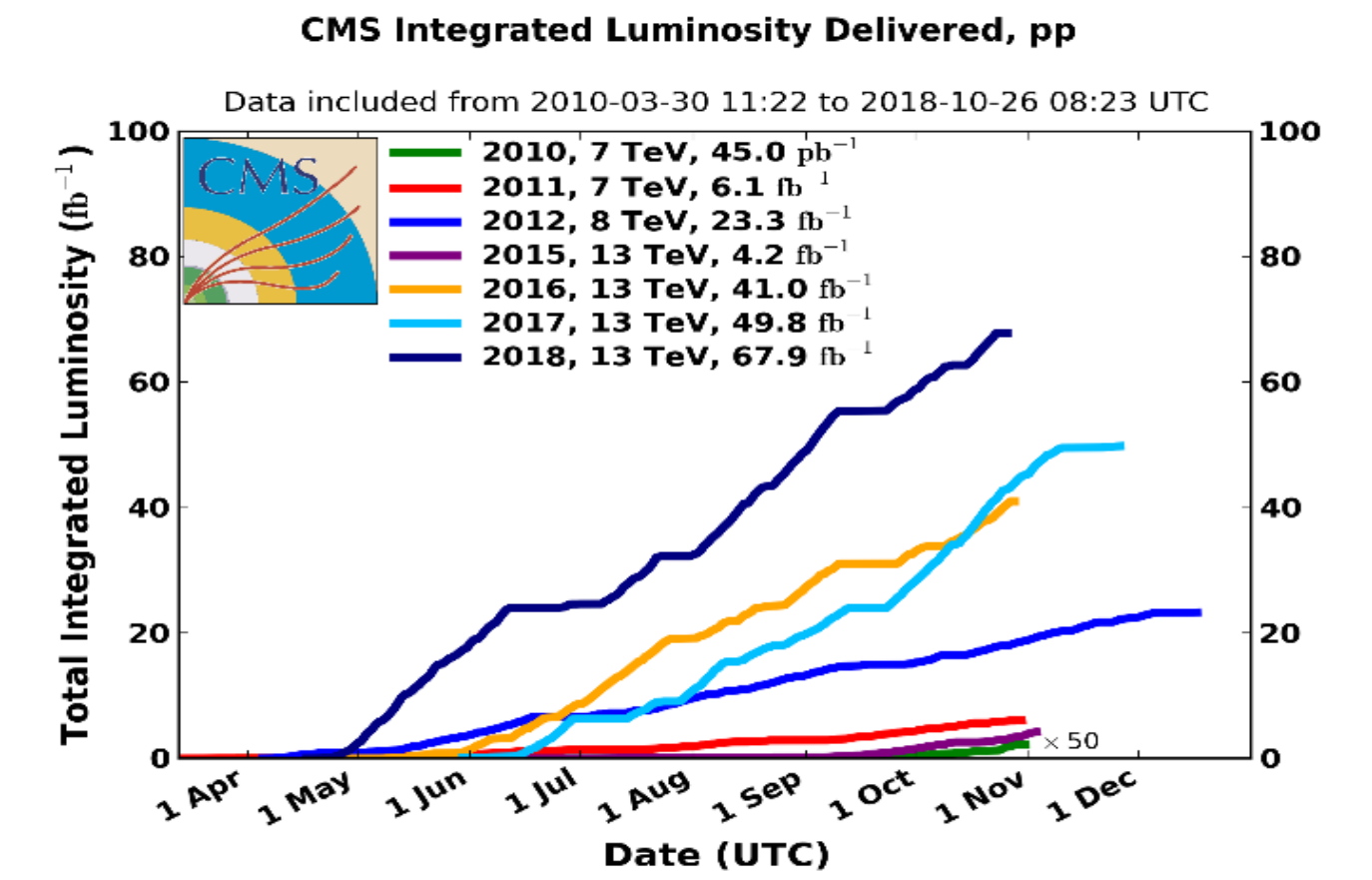
GEM SLICE TEST: 2017-2018



Three GEM detector prototypes were installed in March 2017 insight two slots of the GE1/1 station in inner endcap of CMS for a slice test

One RADMON sensor was placed at the center of the GEM chamber in Slot 2

CMS INTEGRATED LUMINOSITY 2017-2018



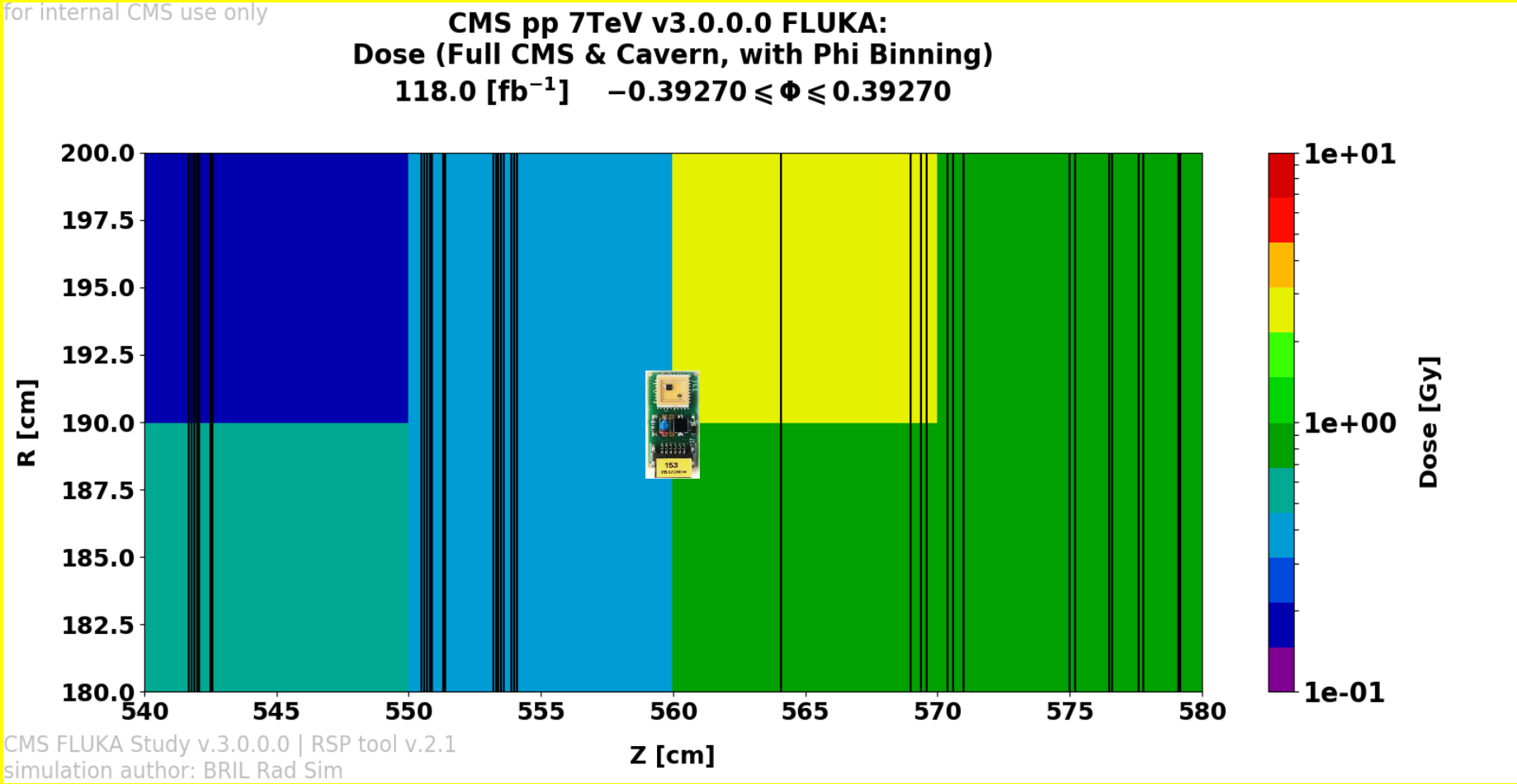
Full luminosity during the slide test –
49,8 + 67,9 = 117,7 fm^{-1}

ALL EXPERIMENTAL AND SIMULATED DATA

Date of measurement	Integrated luminosity	Dose		Fluence	
		REM 250	FLUKA v.3.0.0.0	LBSD Si-1	FLUKA v.3.0.0.0
	fb^{-1}	Gy	Gy	cm^{-2}	cm^{-2}
07.08.2017	14,5	0,132	0,15	4,42E+09	3,10E+09
15.08.2017	17,3	0,134	0,15	4,63E+09	4,00E+09
05.09.2017	21,7	0,218	0,20	6,50E+09	5,00E+09
18.10.2017	39,3	0,361	0,35	1,13E+10	1,00E+10
01.11.2017	46,0	0,448	0,45	1,43E+10	1,20E+10
31.07.2019	117,6	1,073	1,1	3,52E+10	3,40E+10

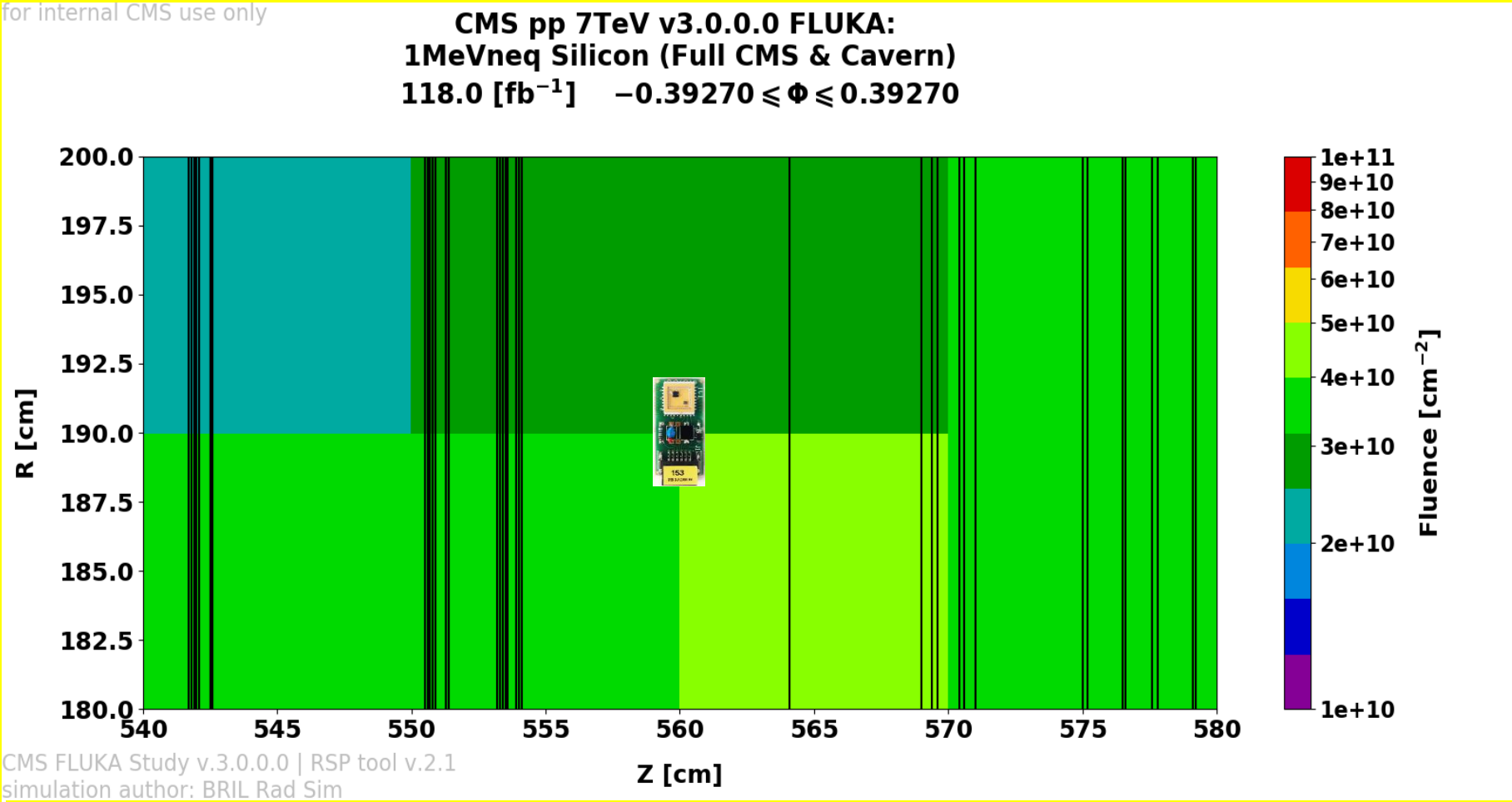
No real data from REM 130 and BPW34S – low sensitivity

Determination of the simulated absorbed dose by FLUKA v3.0.0.0 at 118 fb^{-1}



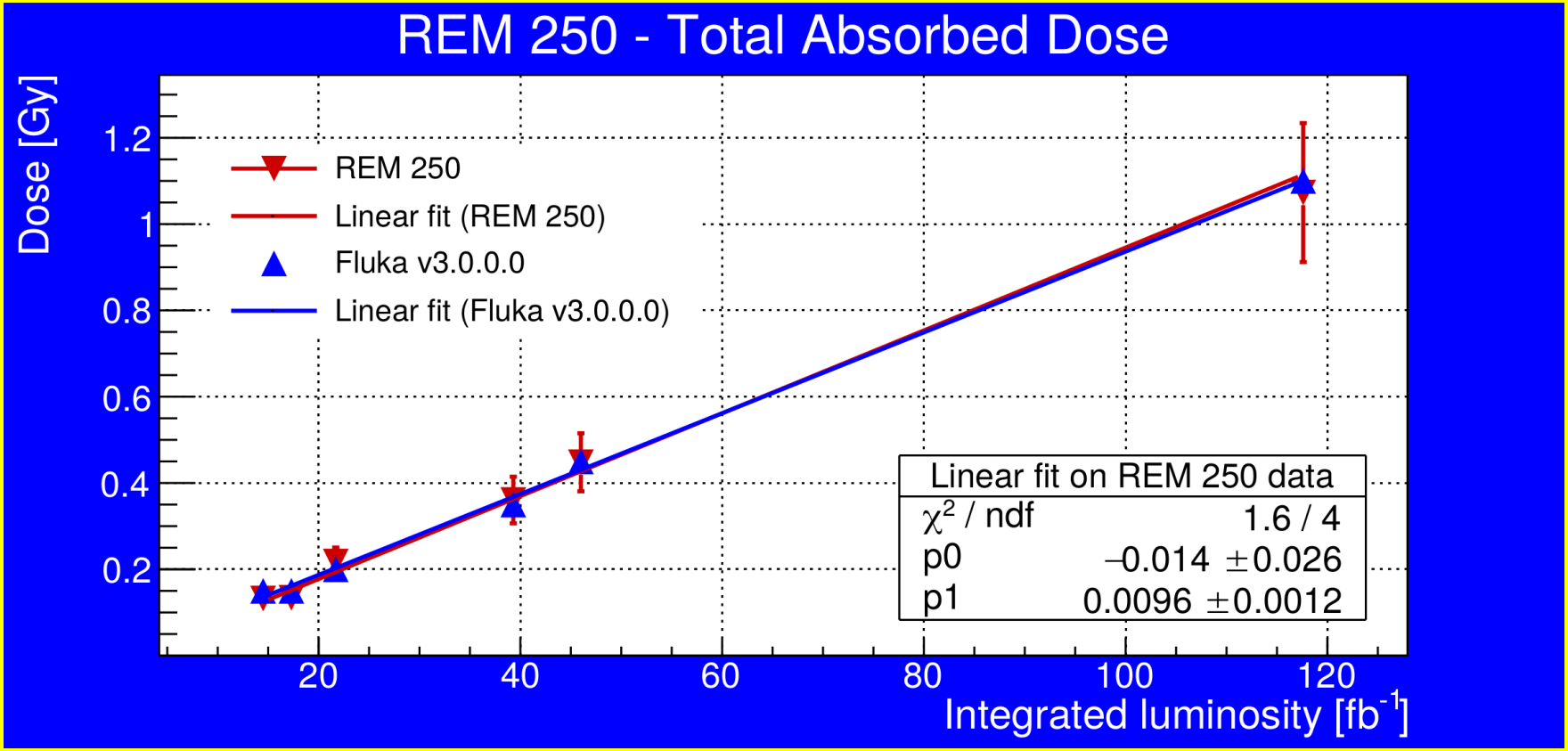
D ≈ 1,05 Gy

Determination of the simulated 1 MeV neq fluence by FLUKA v3.0.0.0 at 118 fb^{-1}



$\Phi \approx 3{,}4 \times 10^{10}\ cm^{-2}$

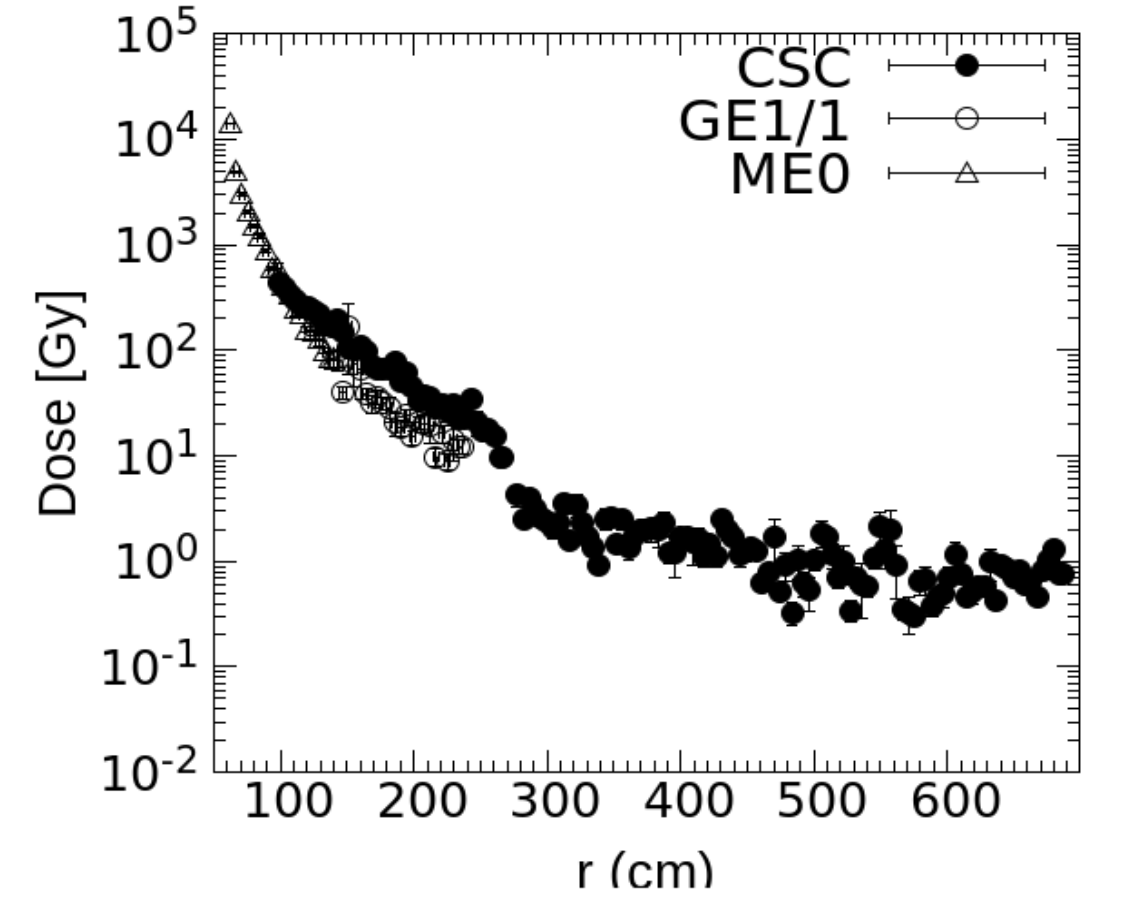
DATA OF REM 250



1. Good linearity of the experimental data – R-squared = 0,9974.

2. Almost identical experimental data and data of FLUKA 3.0.0.0 simulation.

ADEQUATE CHOICE OF THE DOSE SENSORS FOR RUN 3

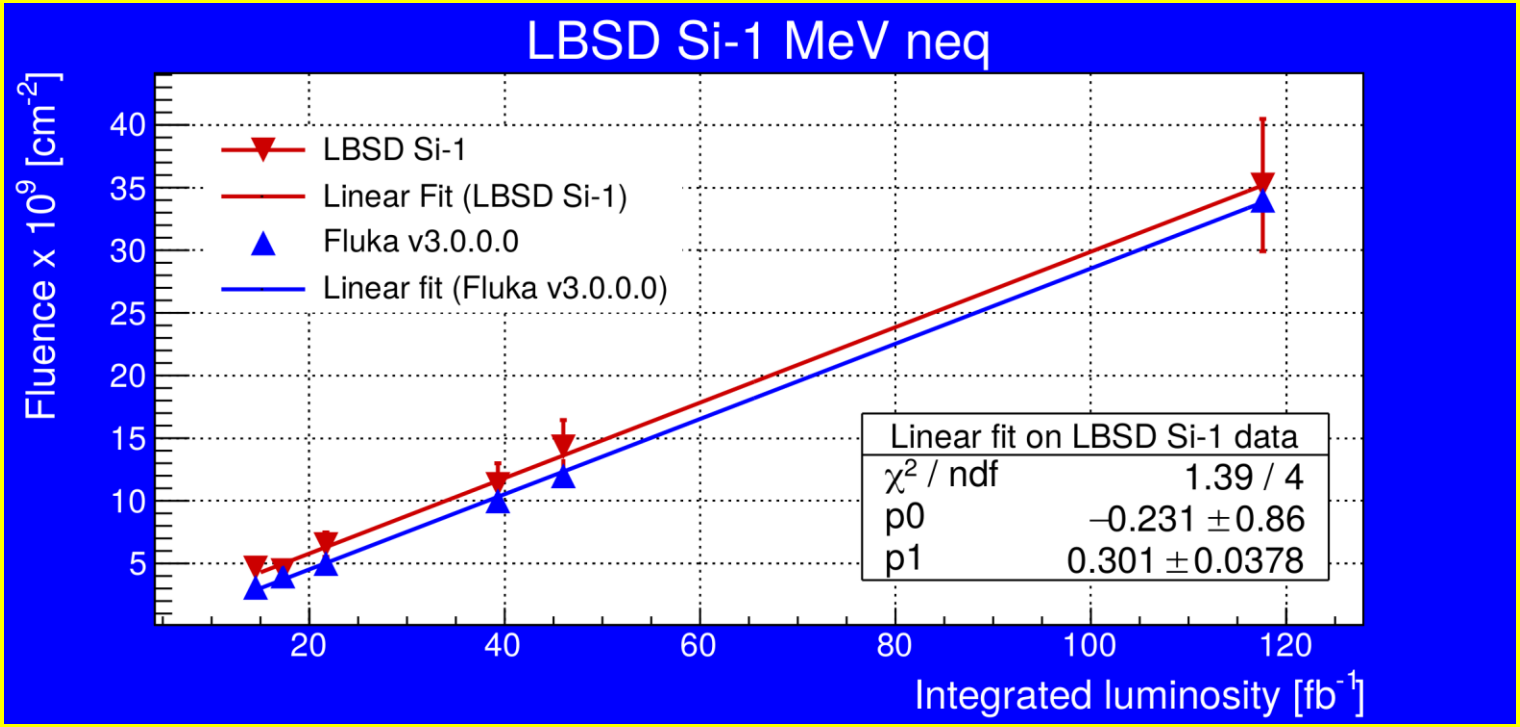


FLUKA v3.7.7.0 PHASE 2 DOSE SIMULATION AT 3000 fb^{-1}

FLUKA SIMULATION SHOW AN AVERAGE ABSORBED DOSE OF 20 Gy FOR THE PHASE 2 (AT 3000 fb^{-1})

REPLACING REM 130 BY A SECOND REM 250?

DATA OF LBSD Si-1



1. Good linearity of the experimental data – R-squared = 0,9984.
2. Minimal difference between the experimental and the simulated data – about 2% of the lowest values.

CONCLUSIONS

- The experimental results obtained confirm the good qualities of the selected radiation sensors for the control of the total absorbed dose and the 1 MeV neutron equivalent fluence. However, more accurate estimation of the expected dose and fluence during the Run 3 of LHC will be useful to select the sensors with most appropriate sensitivity.
- Our results show also that for this region of CMS (around the slot GE1/1) the BRILL simulations by FLUKA v. 3.0.0.0 estimates well the dose and fluence distribution.
- We rely on the GEM DAQ and DCS for all data in Run3.

ACKNOWLEDGEMENTS

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