FLUKA benchmark study of radiation environment inside CMS cavern

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Introduction

Monte Carlo simulation study of radiation environment in CMS cavern

Comparison of selected results to measured data from 2010 and 2011

Overview

Definitions

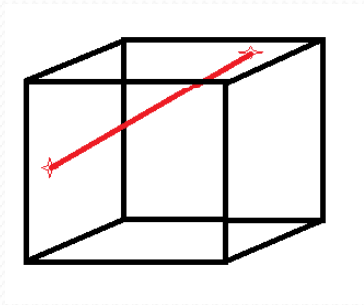FLUKA Monte Carlo Code

FLUKA results

Benchmark

Conclusion

Definitions:

Tracklength / [cm]:

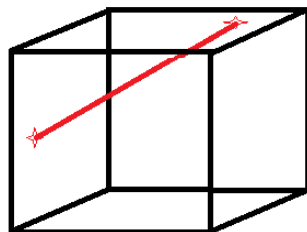   Distance, a particle covers in a certain volume

Fluence / [cm-2]:

        Tracklength density

Definitions:

Tracklength / [cm]:
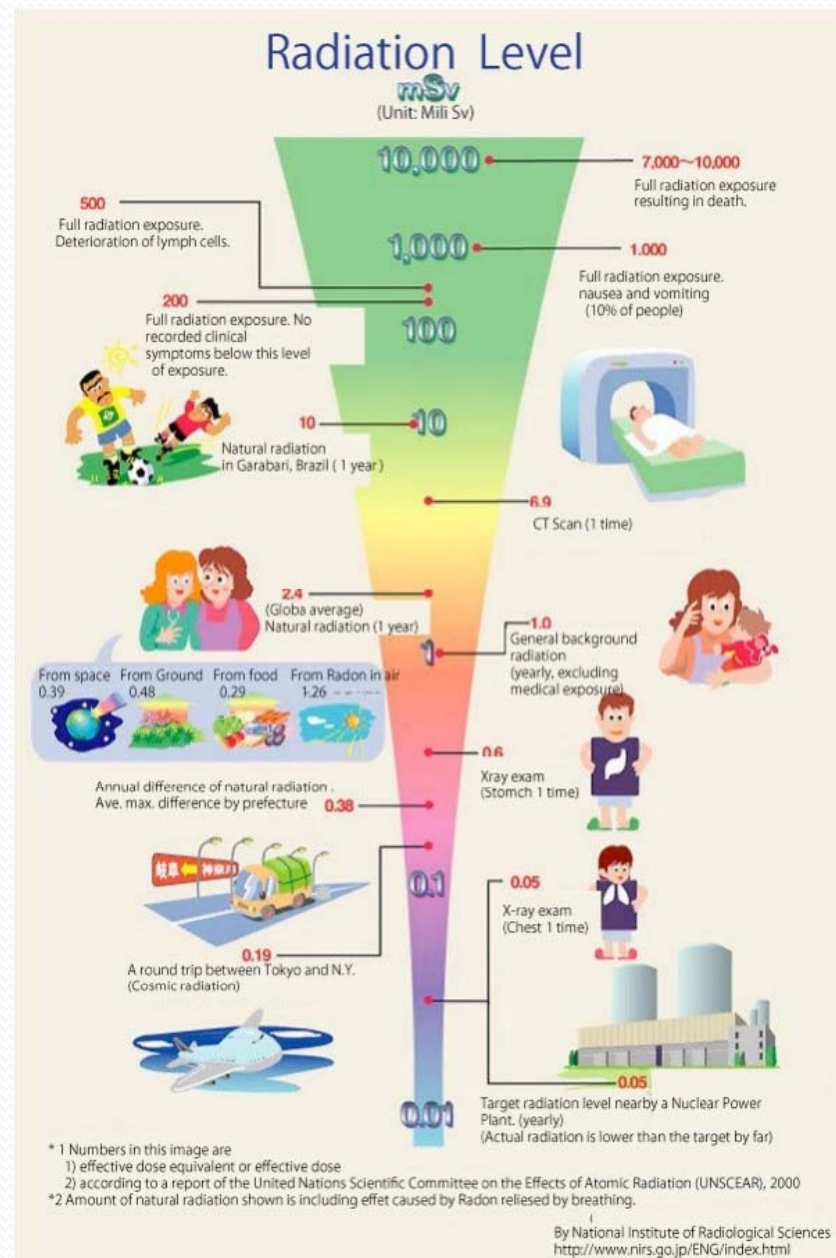
Distance, a particle covers in a certain volume

Fluence / [cm-2]:

Tracklength density

Dose equivalent / [Sv]:

Energy deposition in tissue weighted with biological damage factors depending on particle type and energy

FLUKA – a Monte Carlo code

- Fully integrated Monte Carlo code

- Applications
  - Shielding calculations
  - Prompt and residual radiation
  - Dosimetry
  - Medical physics
  - Etc.

Pictures by SimpleGeo

- Collaboration: CERN, DKFZ & HIT Heidelberg, NASA etc.
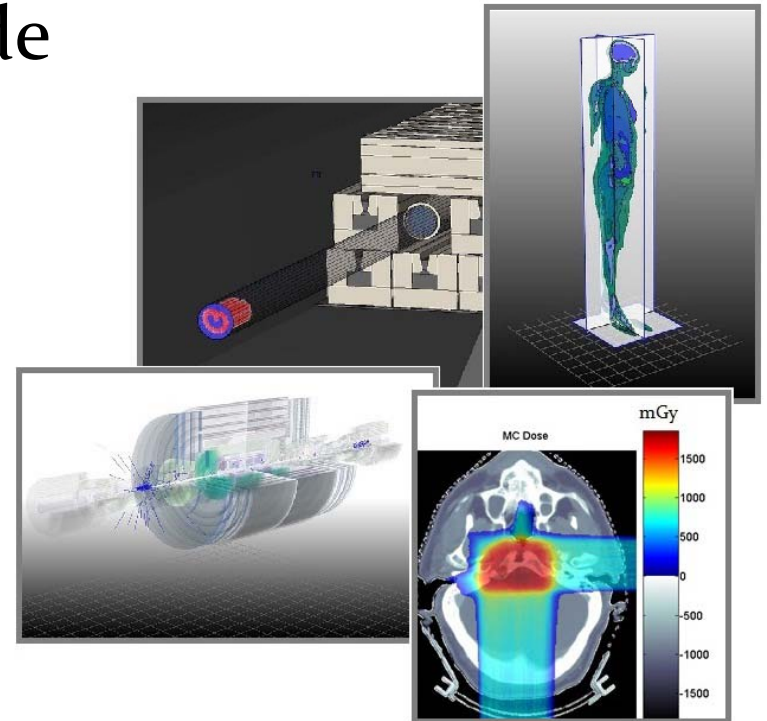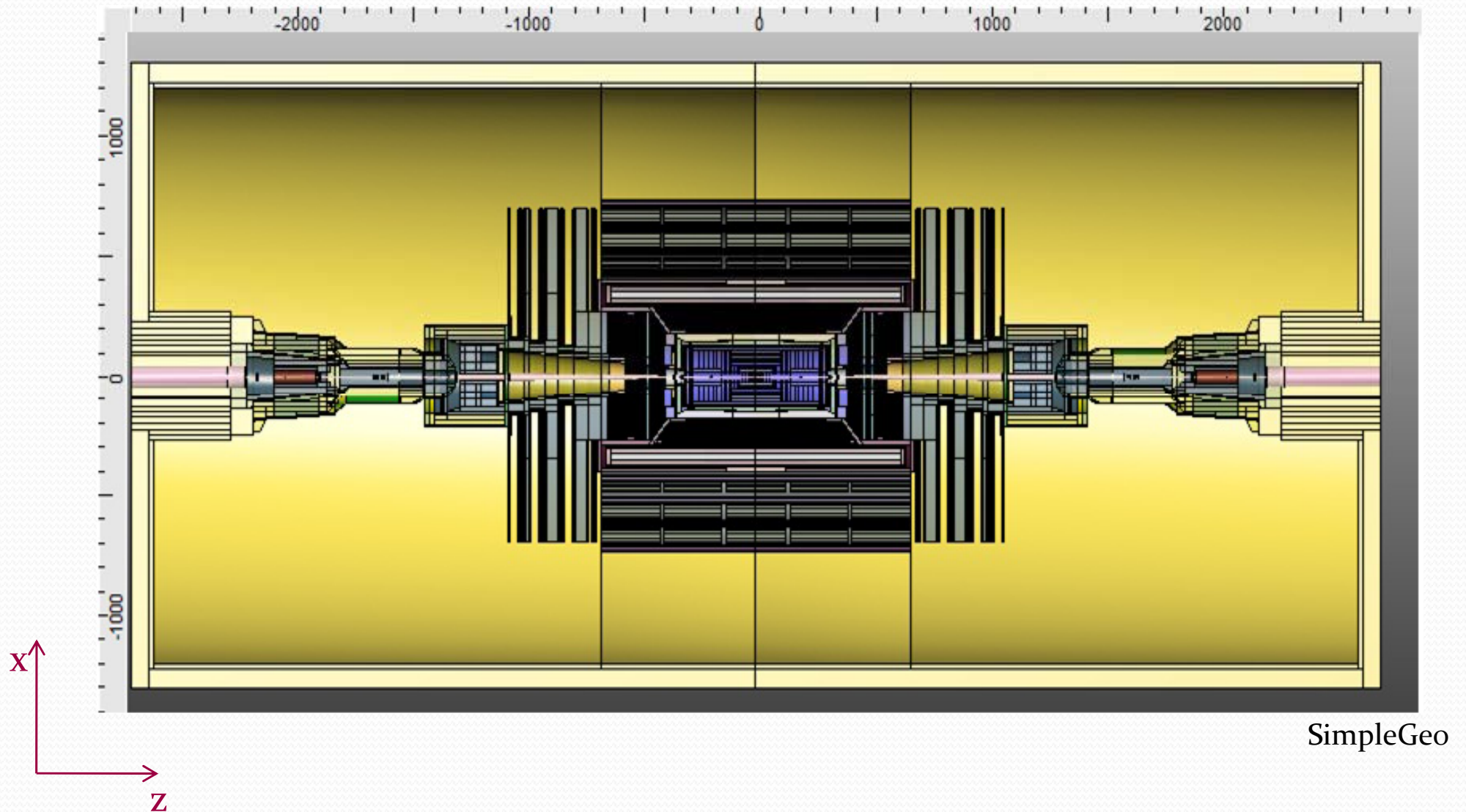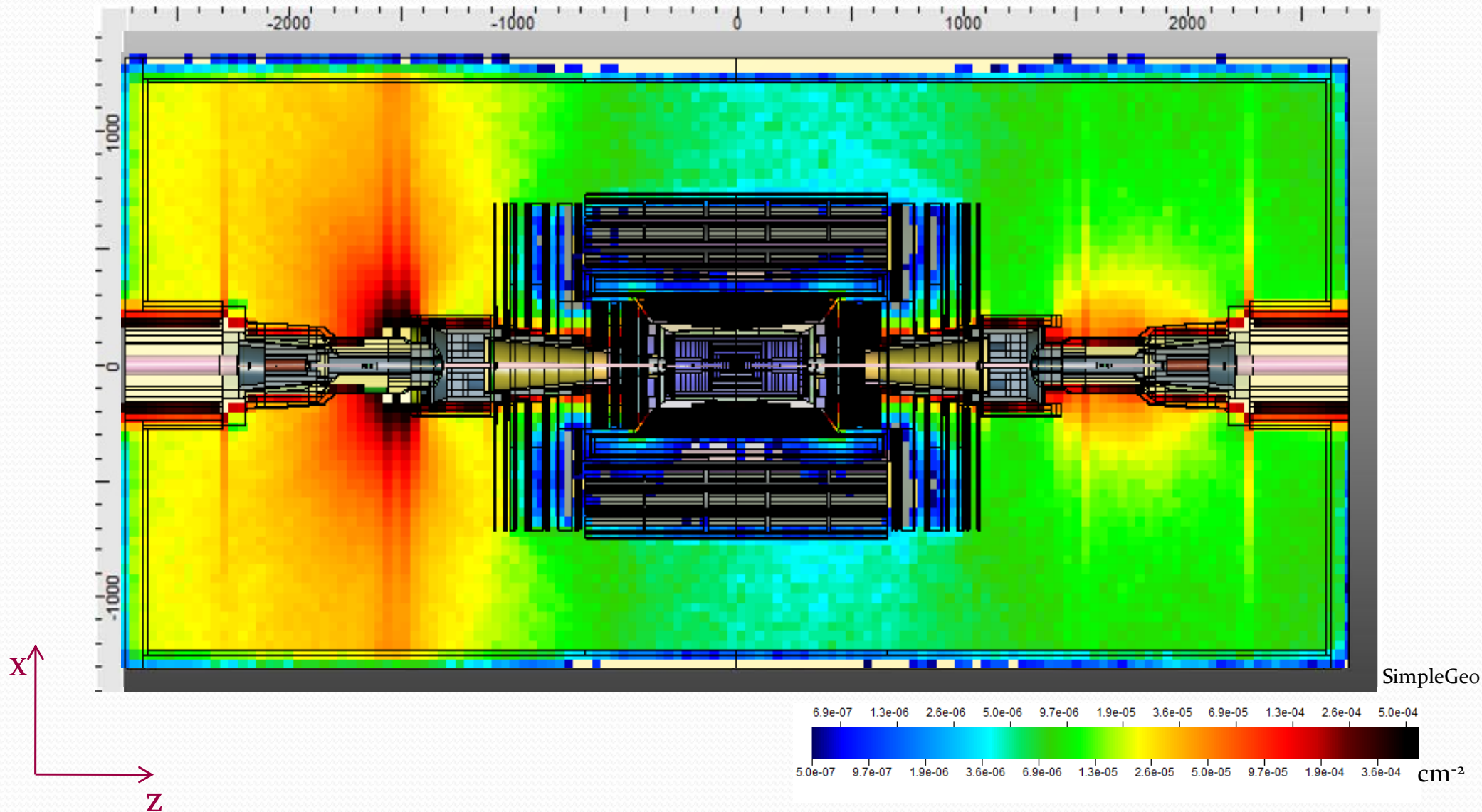
FLUKA calculation parameters

- Production thresholds:
  - Neutrons: thermal energies (1E-5 eV)
  - Electrons, positrons: 1 MeV
  - Photons: 100 keV
  - Hadronic particles (except neutrons): 100 keV

- Biasing in certain parts of CMS

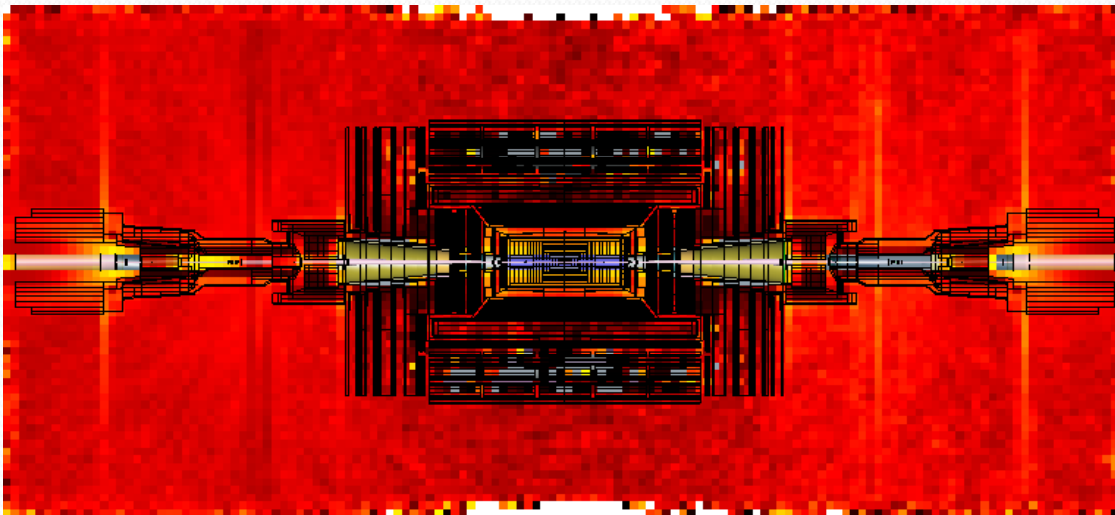- Calculation time: ~ 300 – 400 sec/pp-collision

CMS geometry in FLUKA

SimpleGeo

FLUKA results

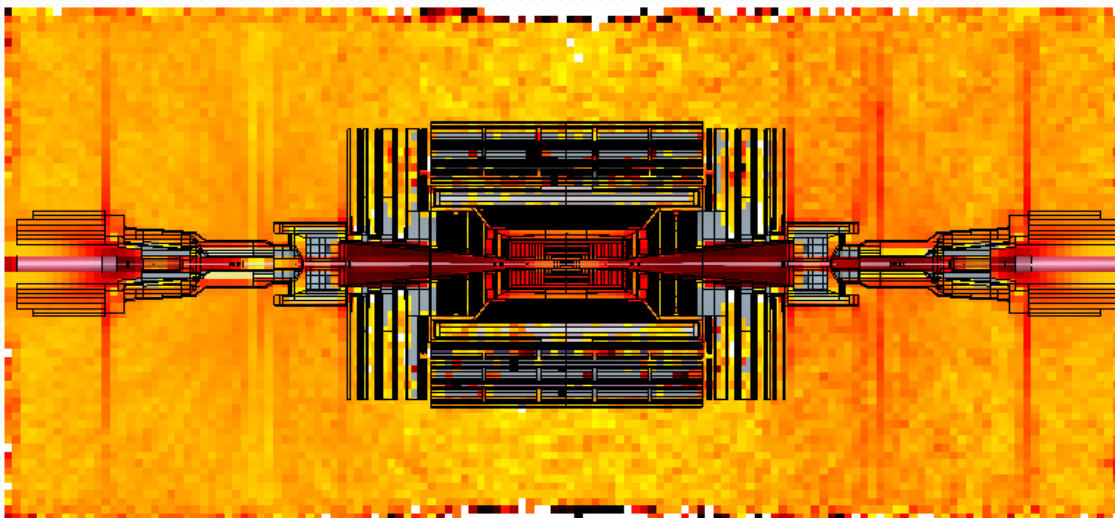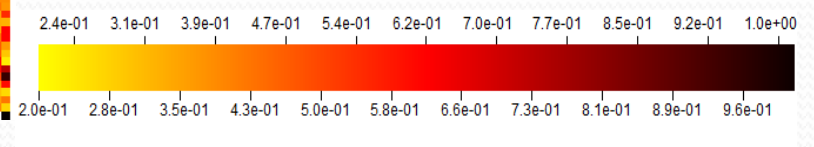## total integral fluence during LHC operation / [cm^{-2}]
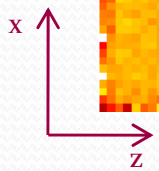
FLUKA results:

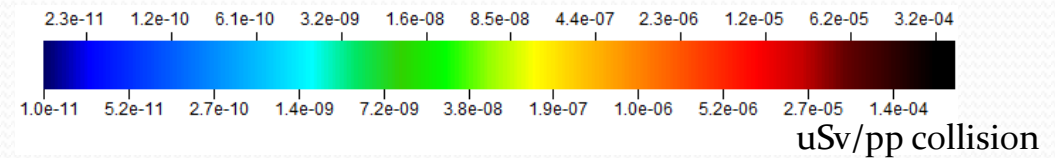Neutron and Photon relative contribution to total fluence
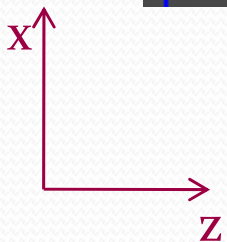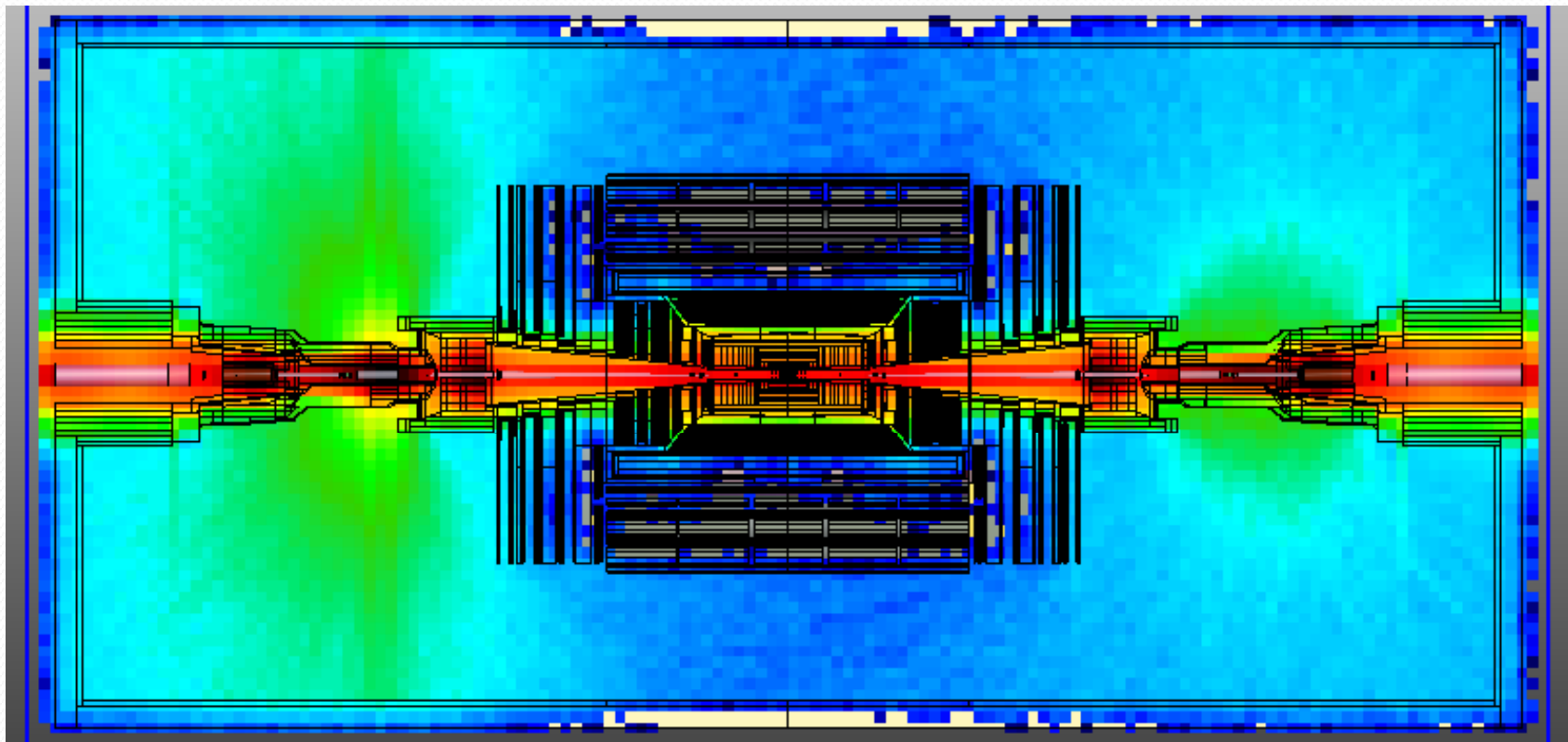

Neutrons / all particles

Photons / all particles

FLUKA results:

Dose equivalent rate during LHC operation / [uSv/pp-collision]

2.3e-11 1.2e-10 6.1e-10 3.2e-09 1.6e-08 8.5e-08 4.4e-07 2.3e-06 1.2e-05 6.2e-05 3.2e-04

1.0e-11 5.2e-11 2.7e-10 1.4e-09 7.2e-09 3.8e-08 1.9e-07 1.0e-06 5.2e-06 2.7e-05 1.4e-04

uSv/pp collision

Benchmark results

Comparison of simulation results to measured data

Ionization Chamber (PMI) used in CMS

PE hull (4mm) / inside graphite coated

Active volume

Anode: PE / graphite coated

Connector to cathode

Connector to anode

Connector plug for power supply and signal outlet

15.8 cm

21.5 cm

28.5 cm

Response of a PMI chamber exposed to mixed high-energy radiation fields; H. Vincke et al.
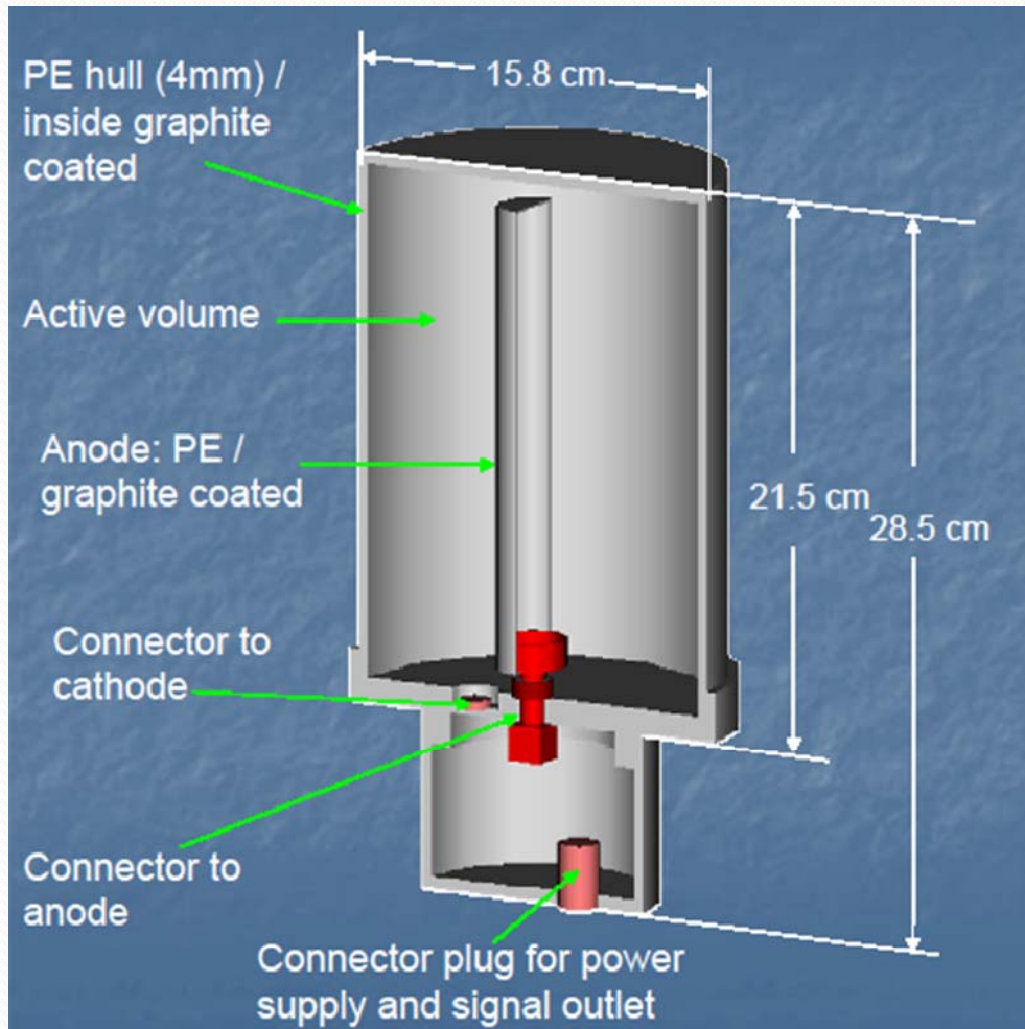
Filling gas:

air at atmospheric pressure

Active volume:

3 liter

Range:

5 uSv/h to 500 mSv/h

Location of ionization chambers (PMI) in CMS:

8 PMI chambers inside CMS cavern
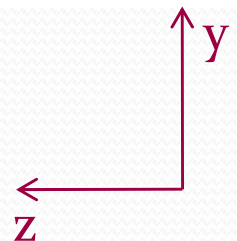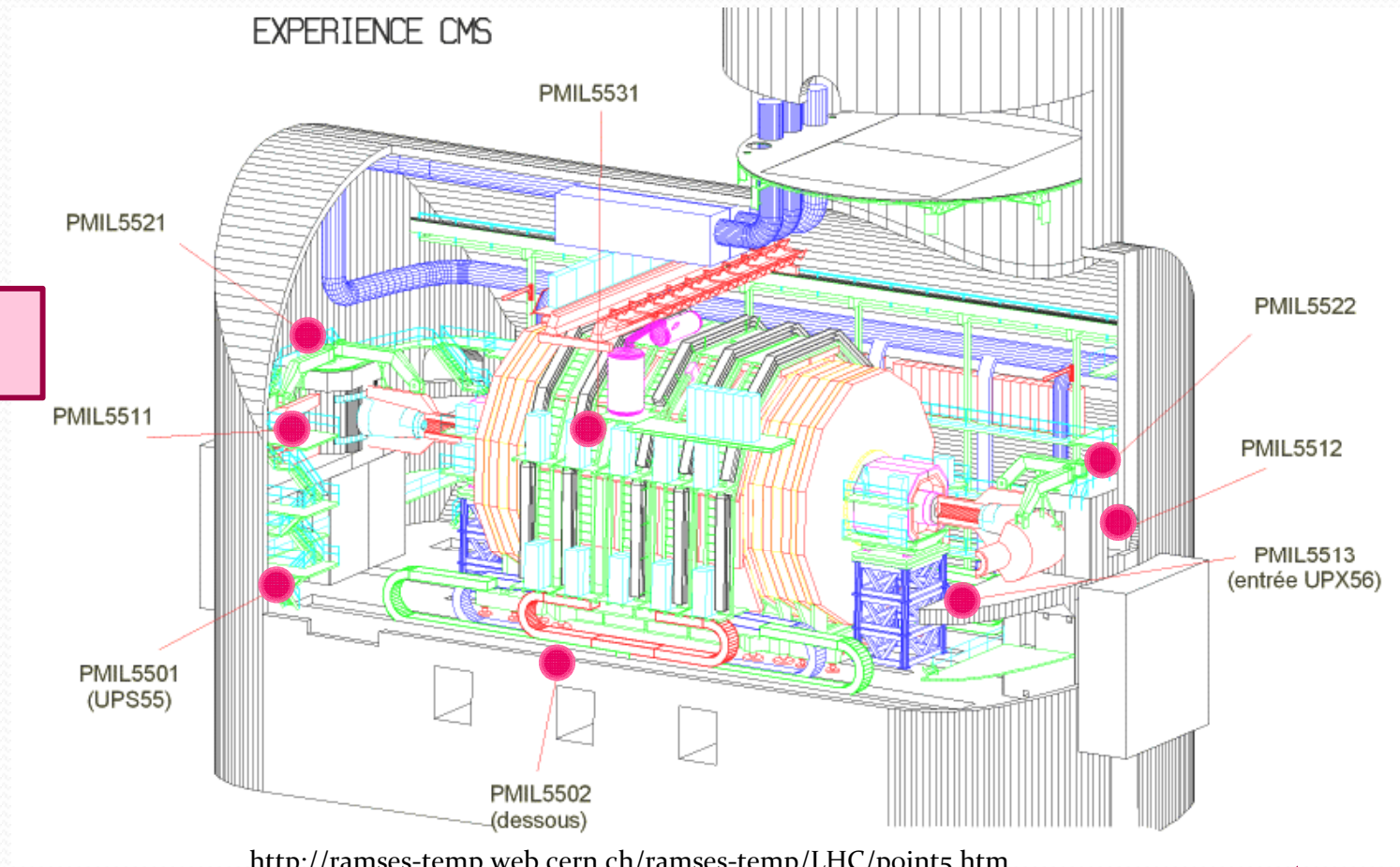
EXPERIENCE CMS

PMIL5531

PMIL5521

PMIL5511

PMIL5501
(UPS55)

PMIL5502
(dessous)

PMIL5522

PMIL5512

PMIL5513
(entrée UPX56)

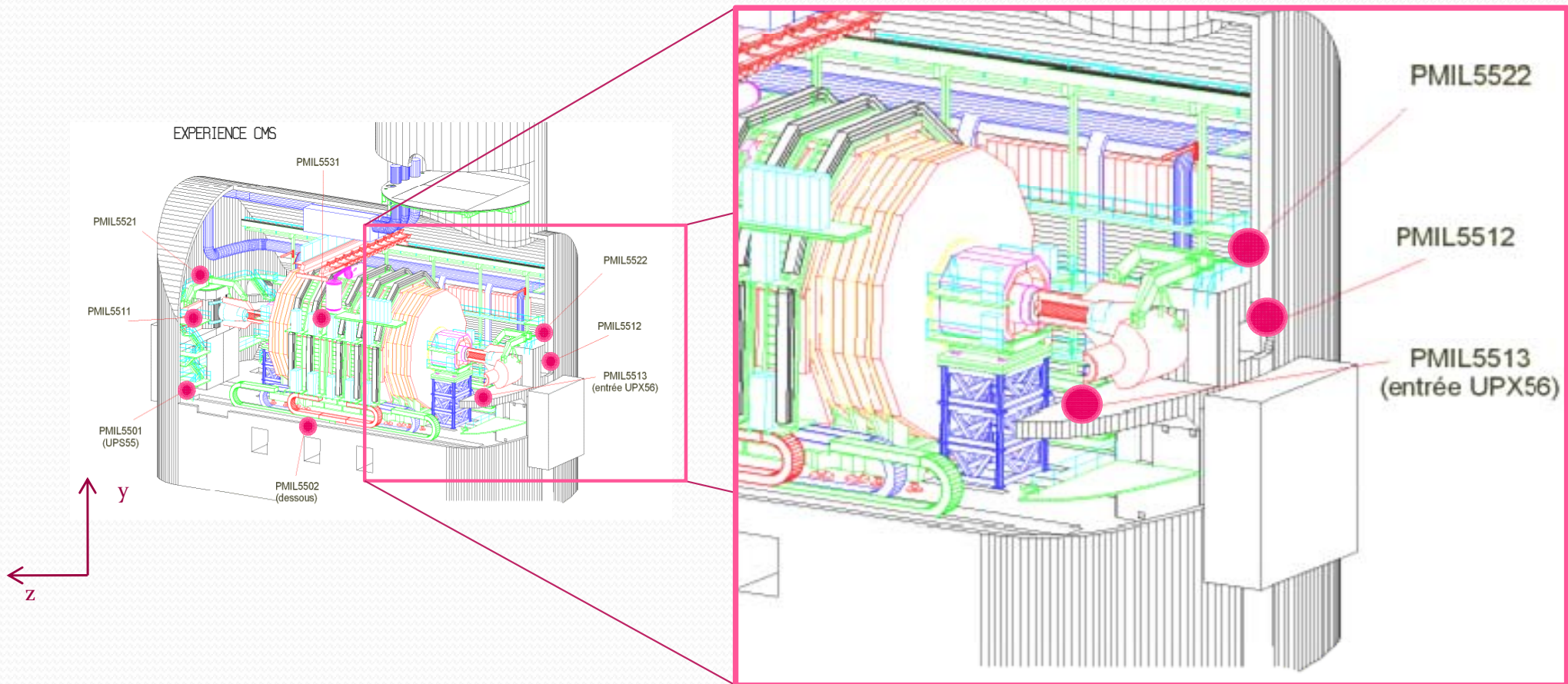http://ramses-temp.web.cern.ch/ramses-temp/LHC/point5.htm
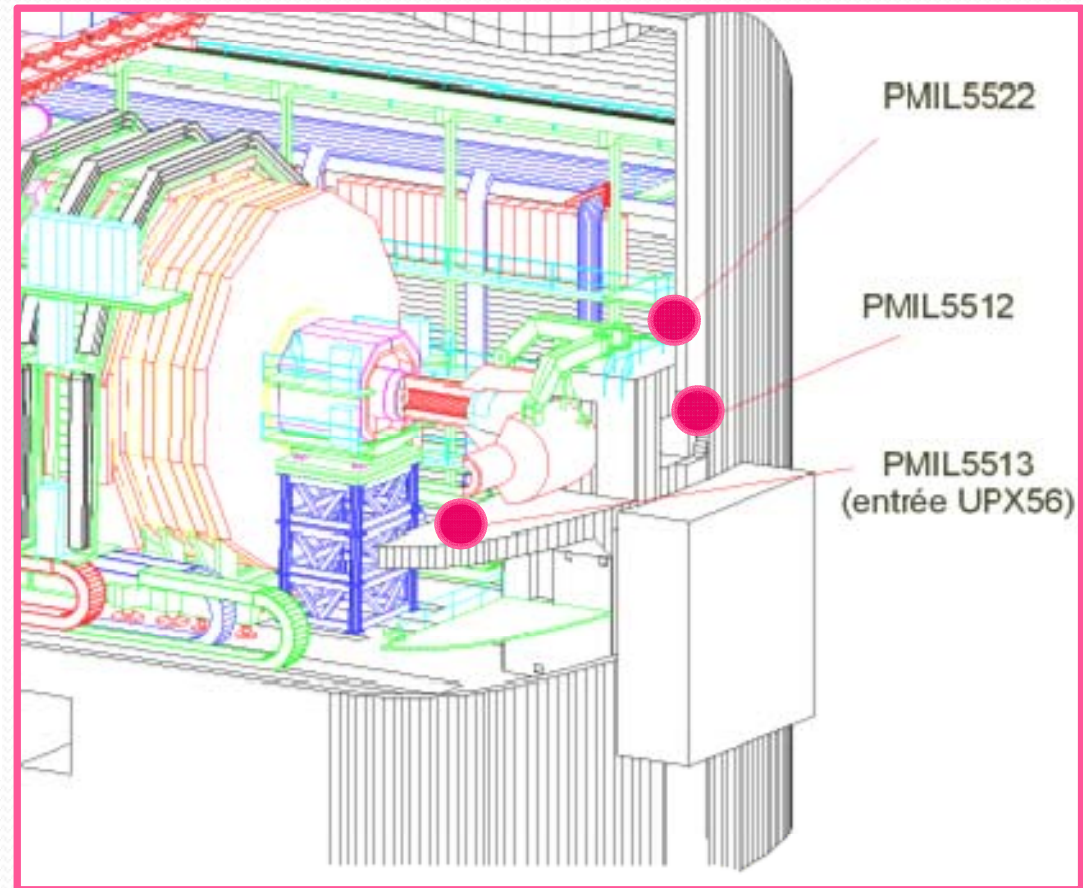
y

z

Benchmark results

PMI responses *on CASTOR side* / [10^{-21}C/pp-collision] :
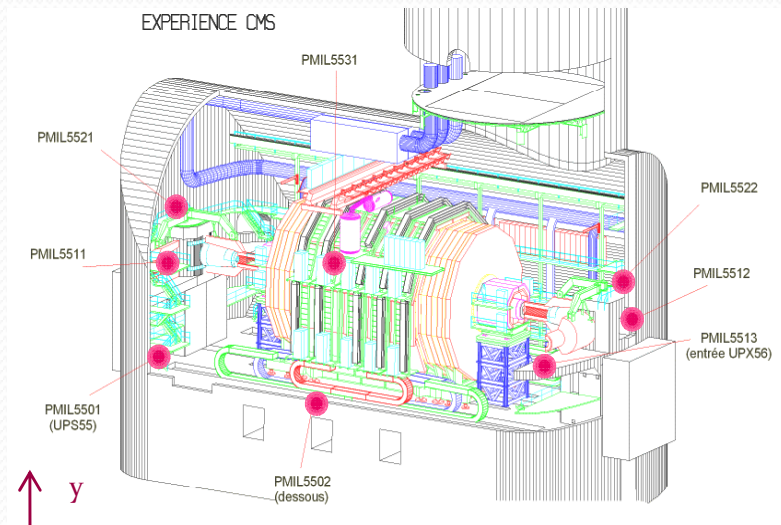
Benchmark results

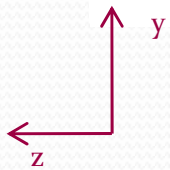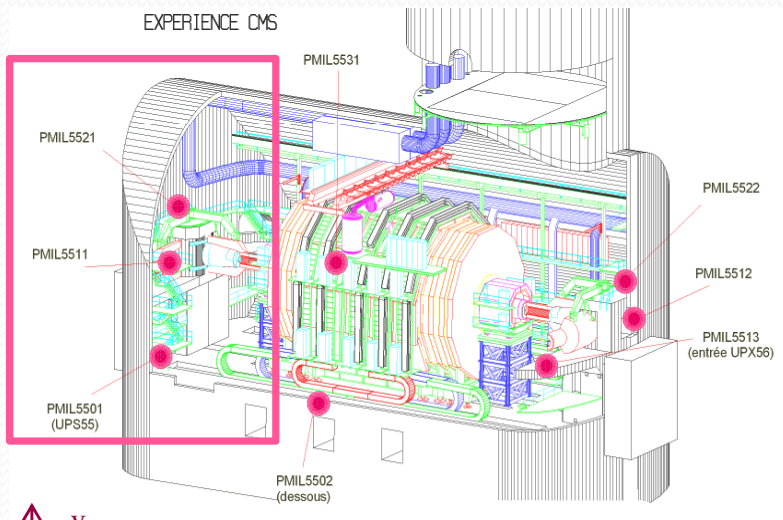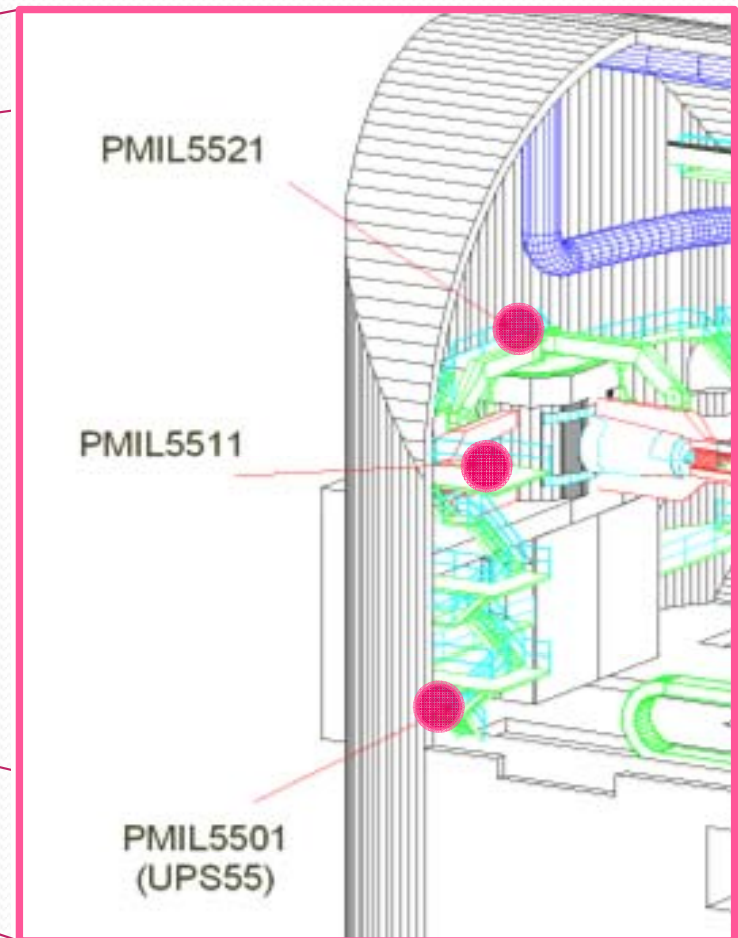PMI responses *on CASTOR side* / [10^{-21}C/pp-collision] :

Benchmark results

PMI responses *on CASTOR side* / $[10^{-21}C/pp\text{-collision}]$:

PMI	Ratio Sim. / Meas.	FLUKA prediction $(10^{-21}\,C/pp)$	Measured Data $(10^{-21}\,C/pp)$
5513	1.4	17.4 +- 4%	12.1 +- 3%
5512	2.4	14.8 +- 2%	6.1 +- 10%
5522	1.8	15.0 +- 3%	8.3 +- 2%

Benchmark results

EXPERIENCE CMS

PMIL5531

PMIL5521

PMIL5511

PMIL5501
(UPS55)

PMIL5502
(dessous)

PMIL5522

PMIL5512

PMIL5513
(entrée UPX56)

y

z

Benchmark results

Benchmark results

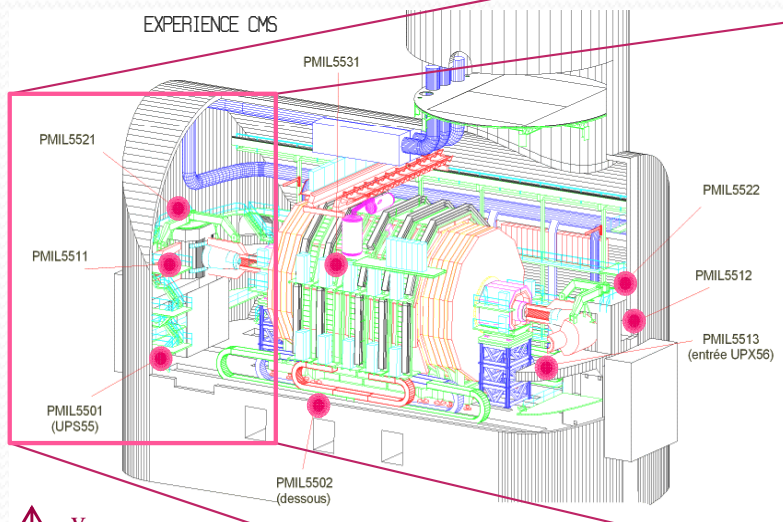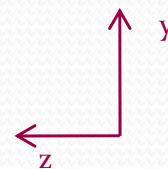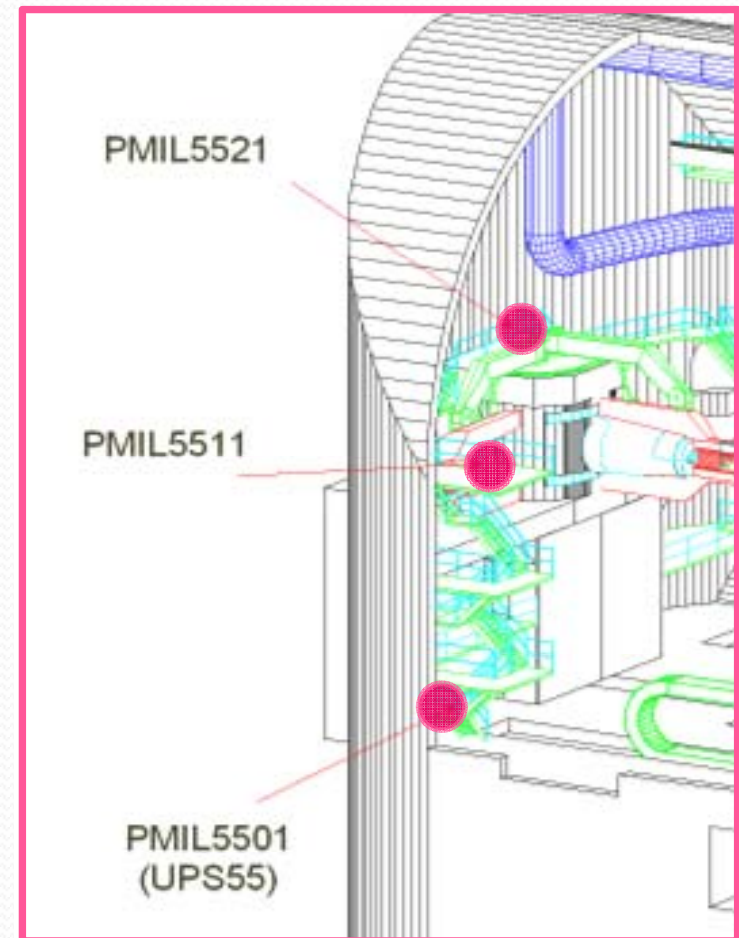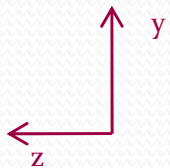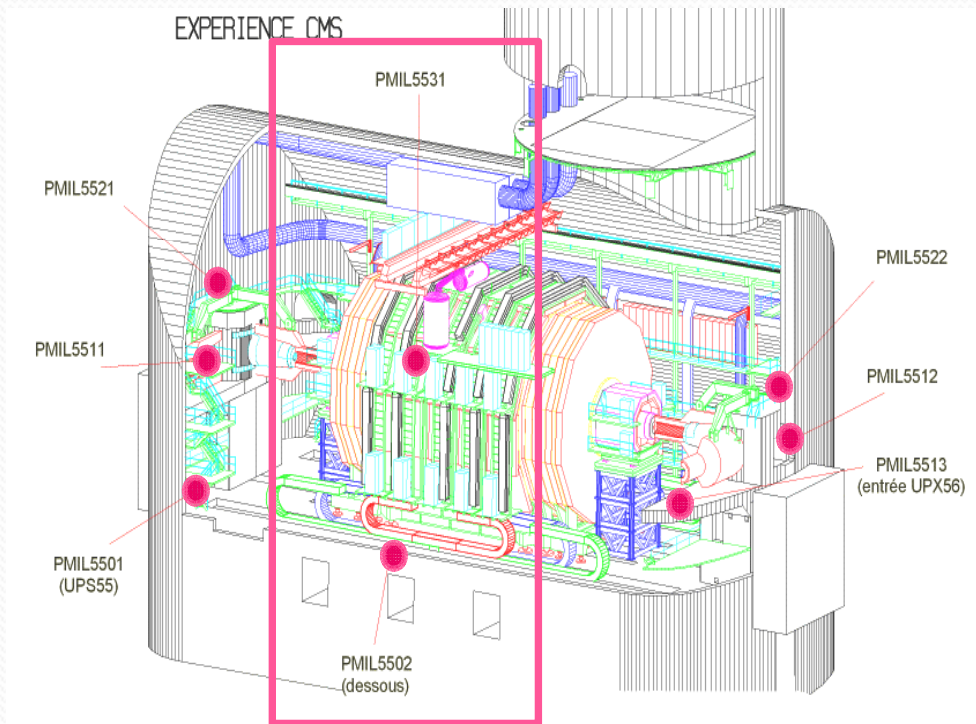PMI responses *non CASTOR side* / [10^{-21} C/pp-collision] :

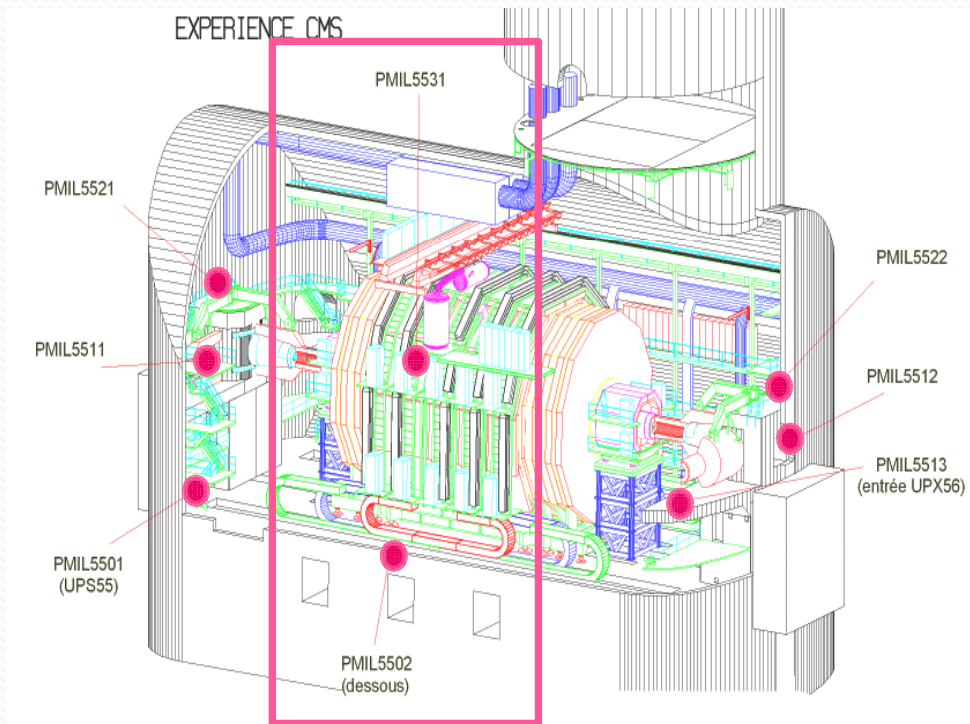| PMI	Ratio Sim. / Meas.	FLUKA prediction (10^{-21} C/pp)	Measured Data (10^{-21} C/pp)
5501	1.3	7.3 +- 4%	5.5 +- 4%
5511	1.8	10+- 2%	5.6 +- 4%
5521	1.3	8.9 +- 2%	6.7 +- 2%

Benchmark results

PMI responses *at interaction point* / [10^{-21} C/pp-collision] :

PMI	Ratio Sim. / Meas.	FLUKA prediction (10^{-21} C/pp)	Measured Data (10^{-21} C/pp)
5502	–	3.0 +- 3%	100% error
5531	4.4	3.0 +- 5%	0.7 +- 70%

Benchmark results

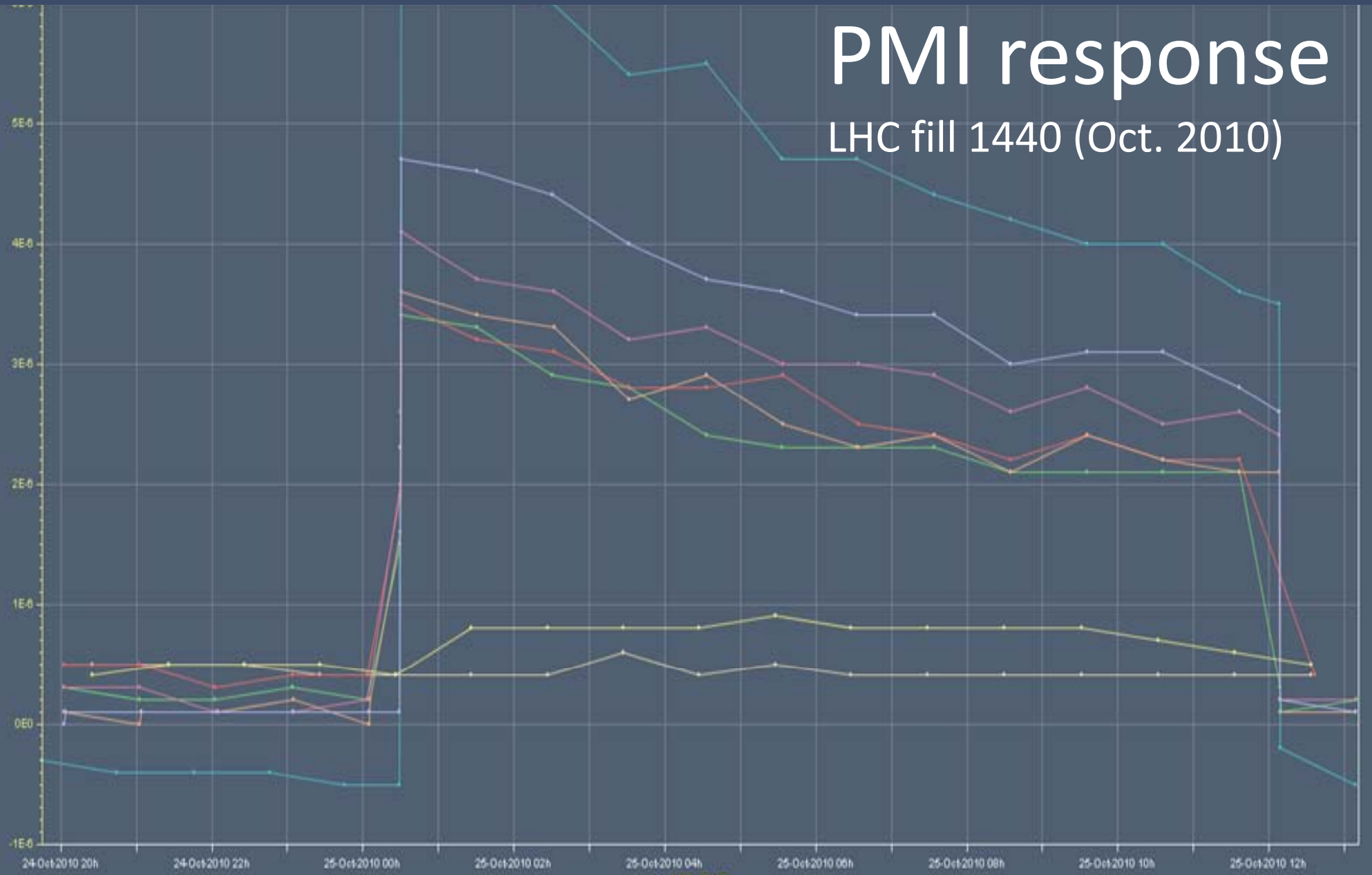PMI responses *at interaction point* / [10^{-21} C/pp-collision] :

Measured data not reliable due to large errors!

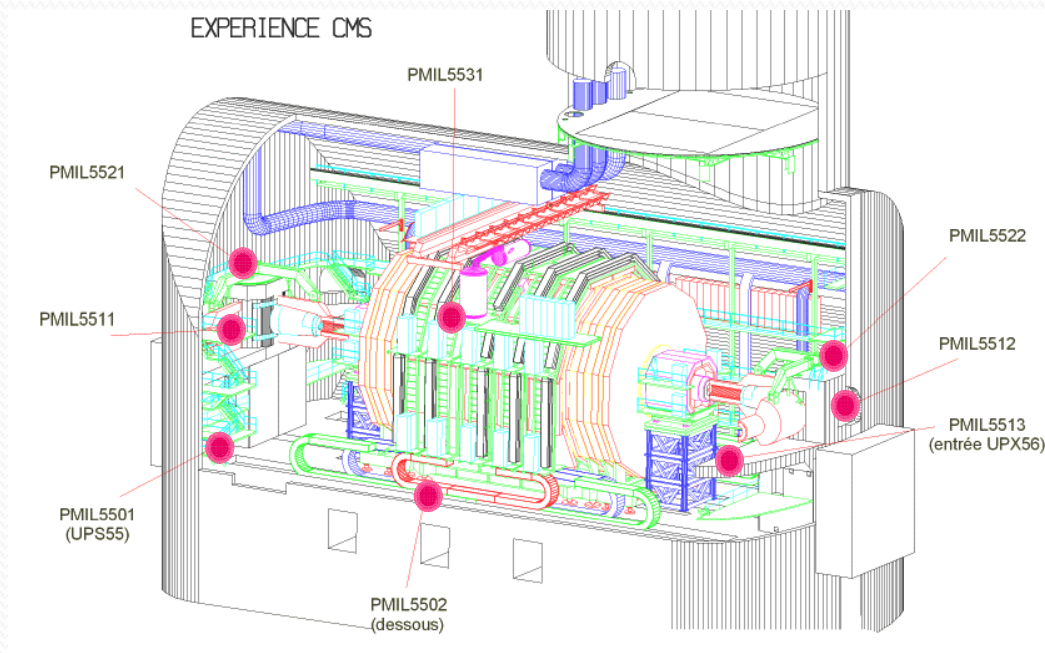| PMI	Ratio Sim. / Meas.	FLUKA prediction	Measured Data
5502	–	3.0 +- 3%	100% error
5531	4.4	3.0 +- 5%	0.7 +- 70%

PMI response
LHC fill 1440 (Oct. 2010)

RAMSES database

Data 2011 Simulation Results / Data 2010 resp. 2011

|	PMI5501	PMI5511	PMI5512	PMI5513	PMI5521	PMI5522	PMI5531
Ratio 2010	**1.3** +- 6%	**1.8** +- 4%	**2.4** +- 10%	**1.4** +- 5%	**1.3** +- 3%	**1.8** +- 3%	**4.4** +- 71%
Ratio 2011	**1.2** +- 4%	**1.7** +- 2%	**2.1** +- 4%	**1.2** +- 6%	**1.1** +- 3%	**1.5** +- 6%	**3.5** +- 6%

Conclusion

- Radiation field in CMS cavern is dominated by neutrons and photons
- MC simulation shows substantial influence of castor on the radiation field in CMS cavern
- Benchmark shows a general overestimation of ionization chamber response by MC simulation
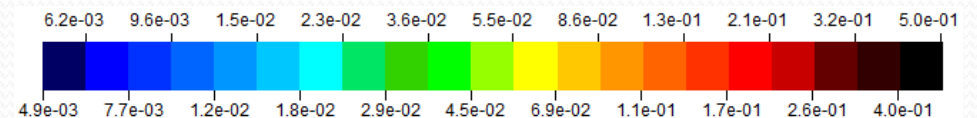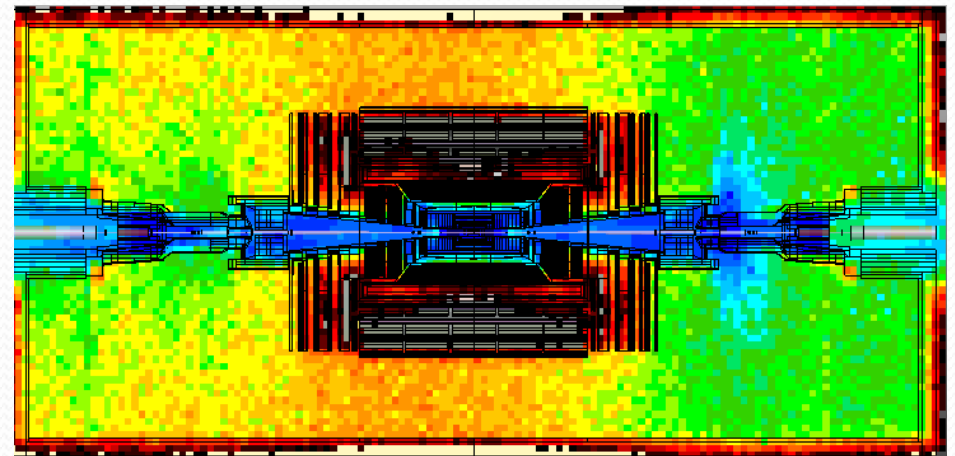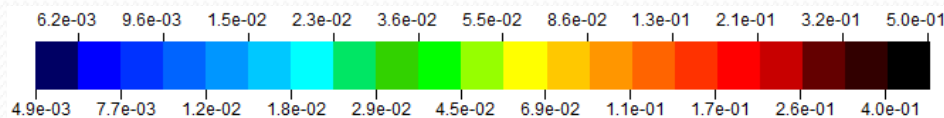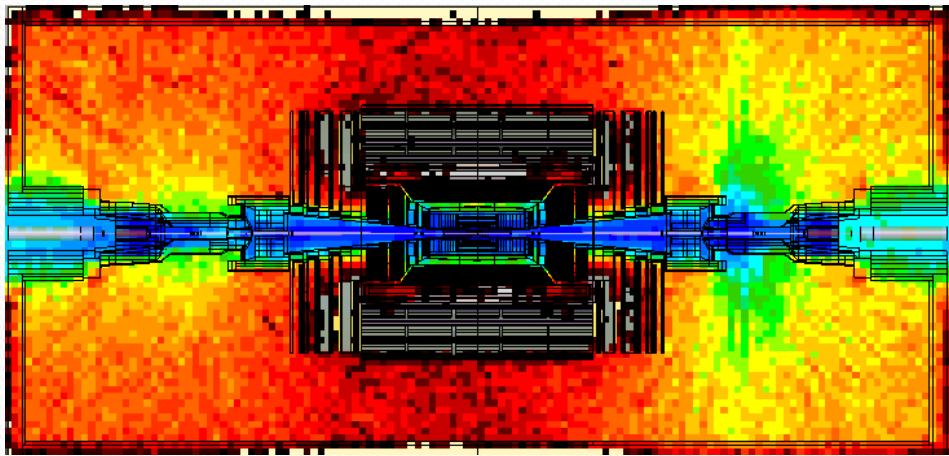
BACKUP SLIDES

- Contribution of neutrons and photons to total particle track length in CMS cavern
- Error maps
- particle spectra at different PMI positions
- integrated response by each particle at different PMI positions

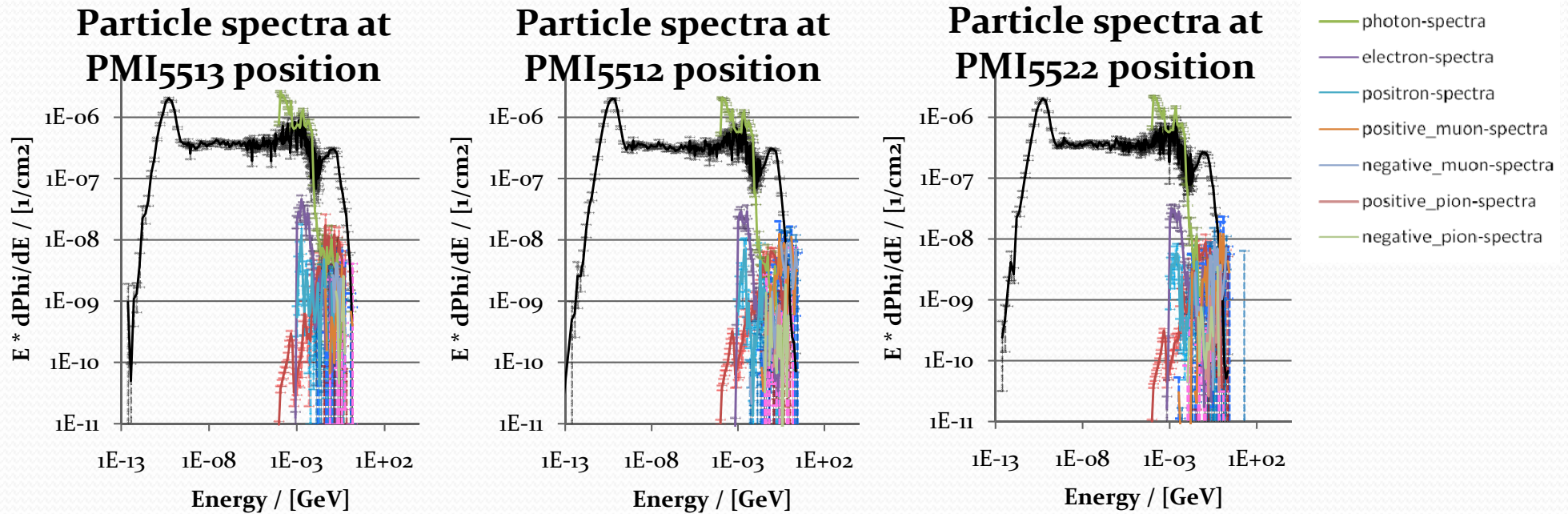# Ratio total track length / Sum(Neutron + Photon TL)
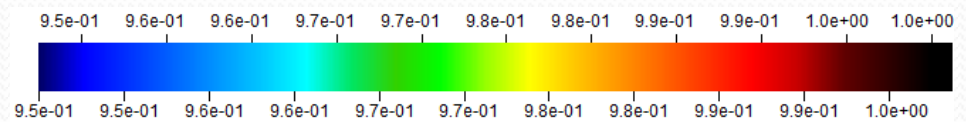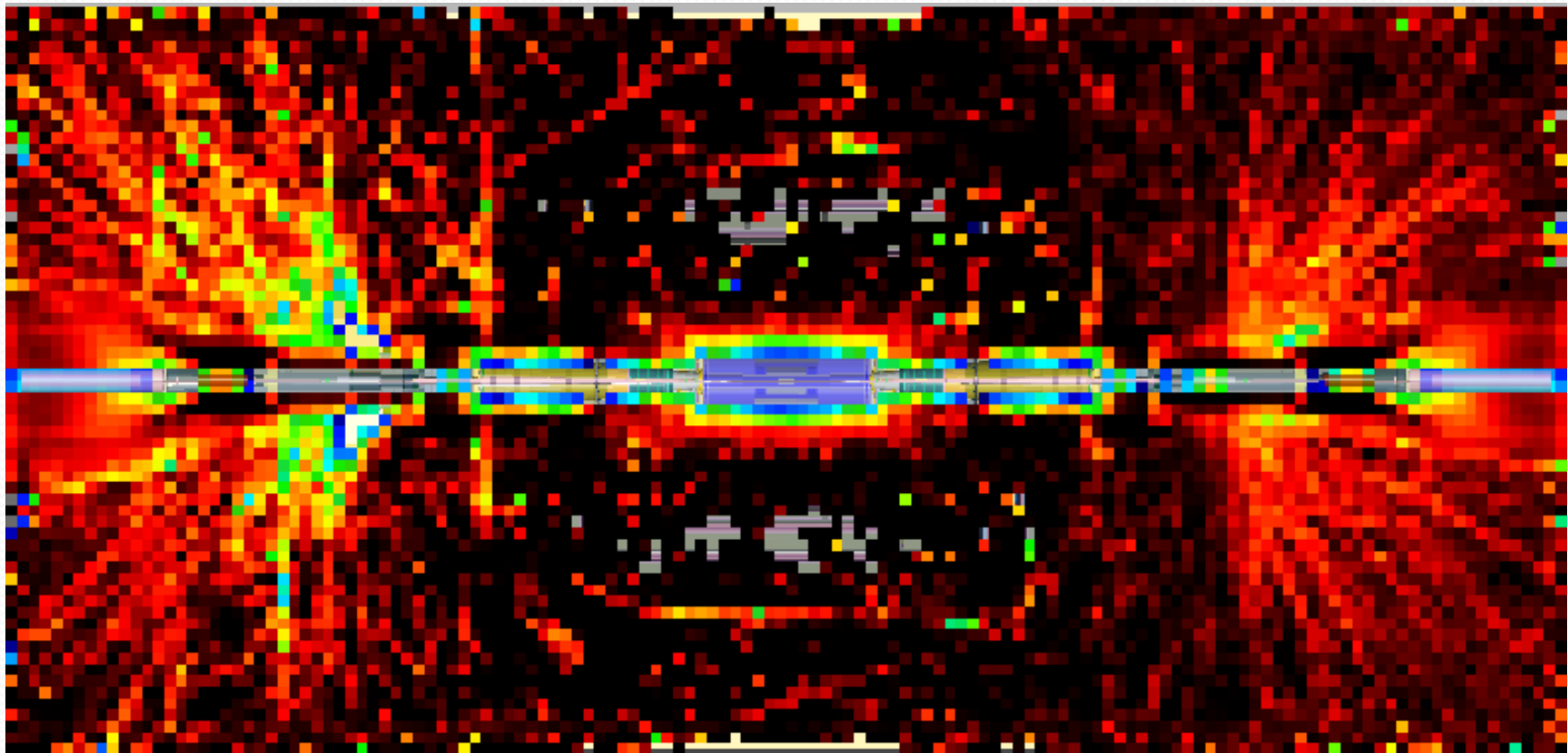
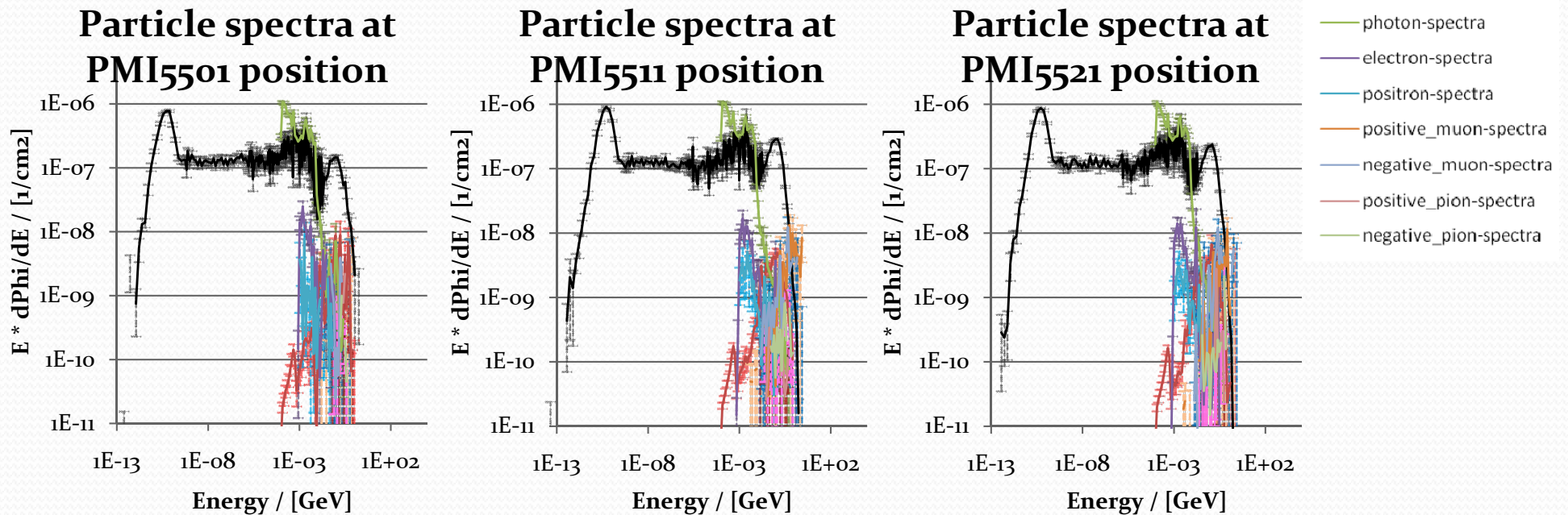# Relative Errors on integral fluence and dose equivalent rate

- Rel. Err of dose equivalent rate:
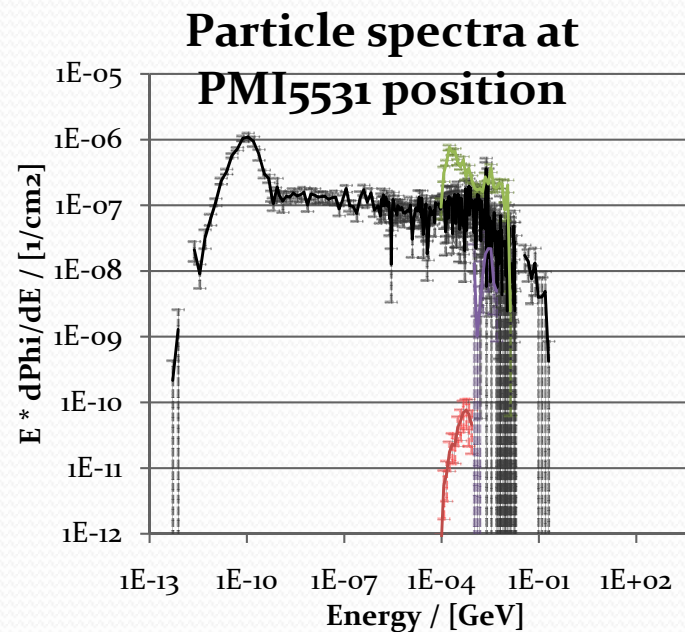
- Rel. Err of integral fluence:

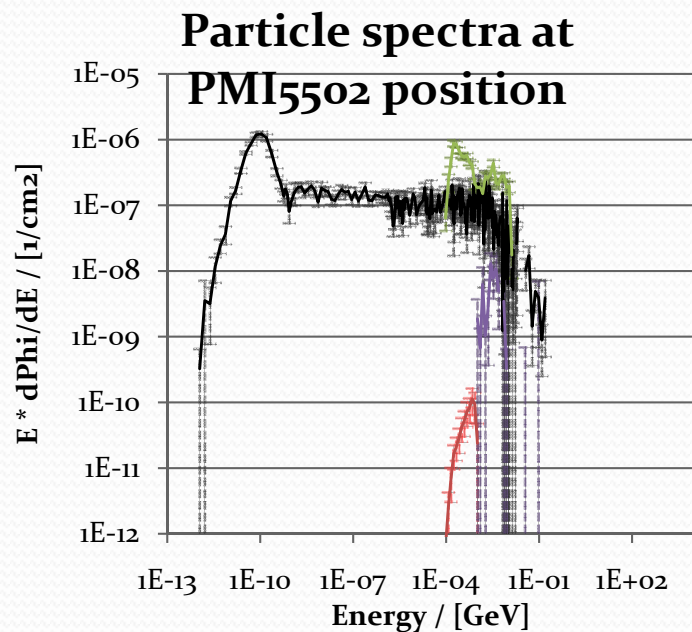# Particle Spectra @ Castor side

Particle spectra at PMI5513 position

Particle spectra at PMI5512 position

Particle spectra at PMI5522 position

Legend:
- neutron-spectra
- proton-spectra
- photon-spectra
- electron-spectra
- positron-spectra
- positive_muon-spectra
- negative_muon-spectra
- positive_pion-spectra
- negative_pion-spectra

Particle Spectra @ non Castor side

Particle spectra at PMI5501 position | Particle spectra at PMI5511 position | Particle spectra at PMI5521 position
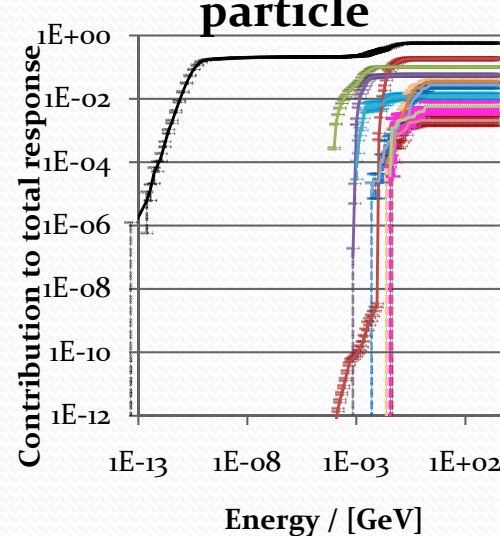
Legend:
- neutron-spectra
- proton-spectra
- photon-spectra
- electron-spectra
- positron-spectra
- positive_muon-spectra
- negative_muon-spectra
- positive_pion-spectra
- negative_pion-spectra
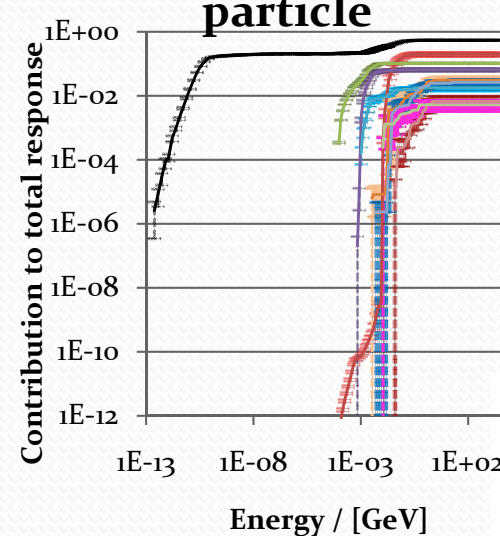
Particle Spectra @ IP

Integral Response @ Castor side

Integral responses from PMI5513 by particle
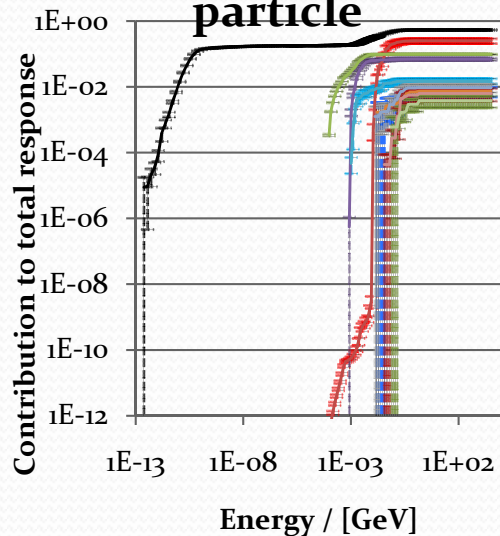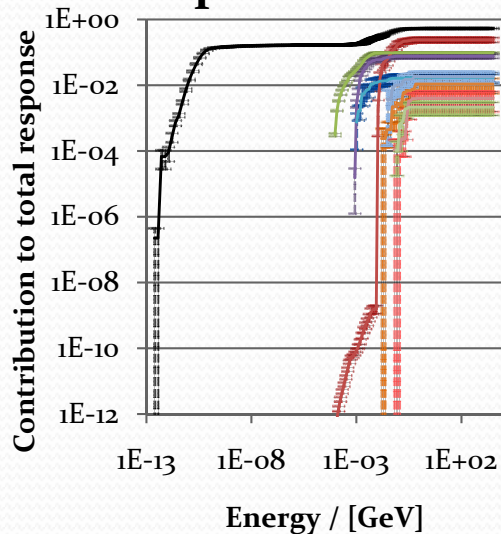
Integral responses from PMI5512 by particle

Integral responses from PMI5522 by particle
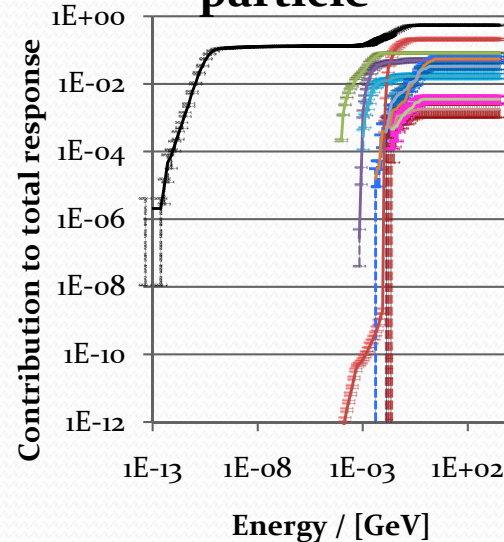
Contribution to total response

Energy / [GeV]

- neutron-response
- proton-response
- photon-response
- electron-response
- positron-response
- positive_muon-response
- negative_muon-response
- positive_pion-response
- negative_pion-response
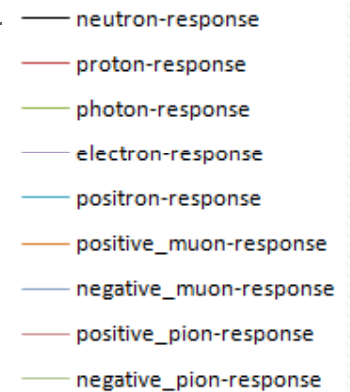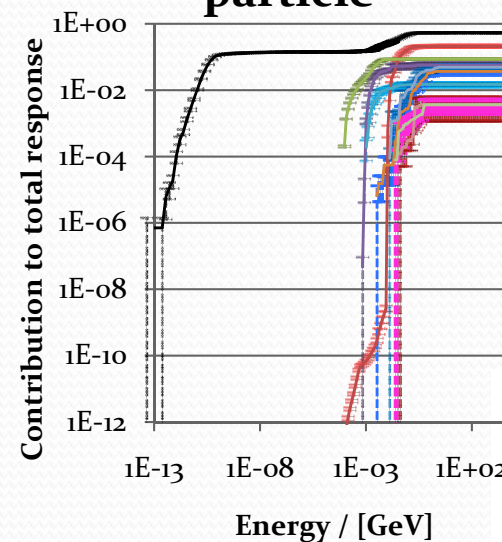
Integral Response @ non Castor side

Integral responses from PMI5501 by particle
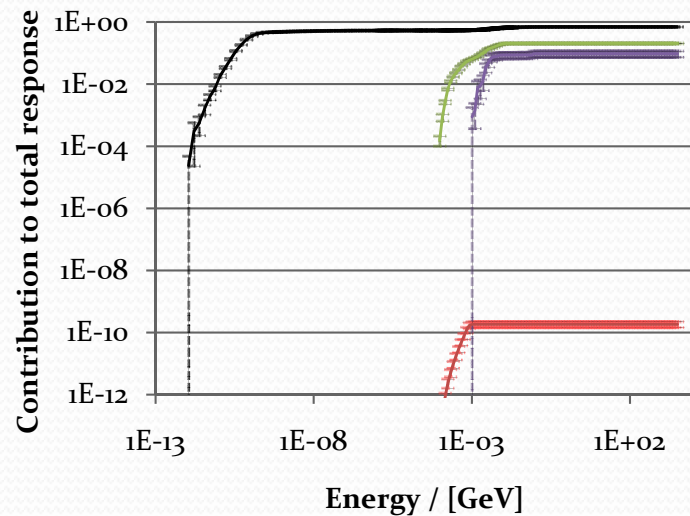
Integral responses from PMI5511 by particle

Integral responses from PMI5521 by particle

Contribution to total response

Energy / [GeV]

- neutron-response
- proton-response
- photon-response
- electron-response
- positron-response
- positive_muon-response
- negative_muon-response
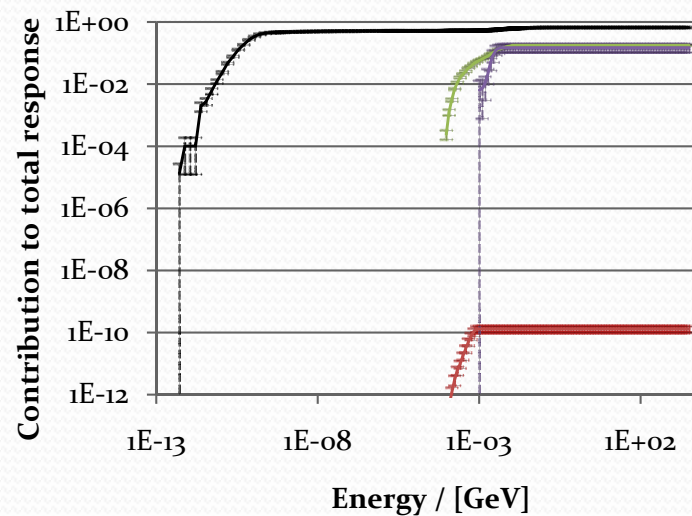- positive_pion-response
- negative_pion-response

Integral Response @ IP
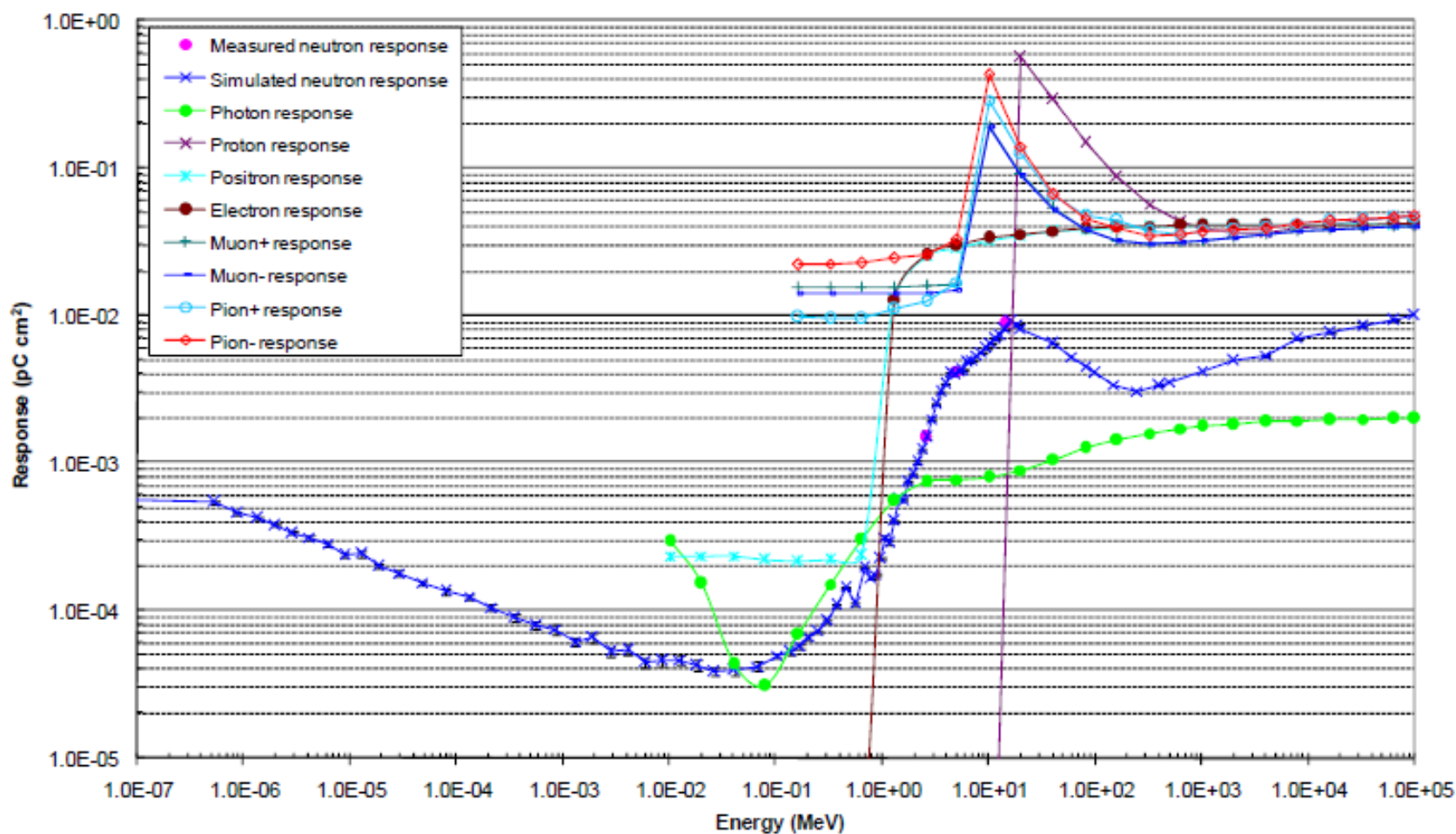

Integral responses from PMI5502 by particle

Integral responses from PMI5531 by particle

Legend:
- neutron-response
- proton-response
- photon-response
- electron-response
- positron-response
- positive_muon-response
- negative_muon-response
- positive_pion-response
- negative_pion-response
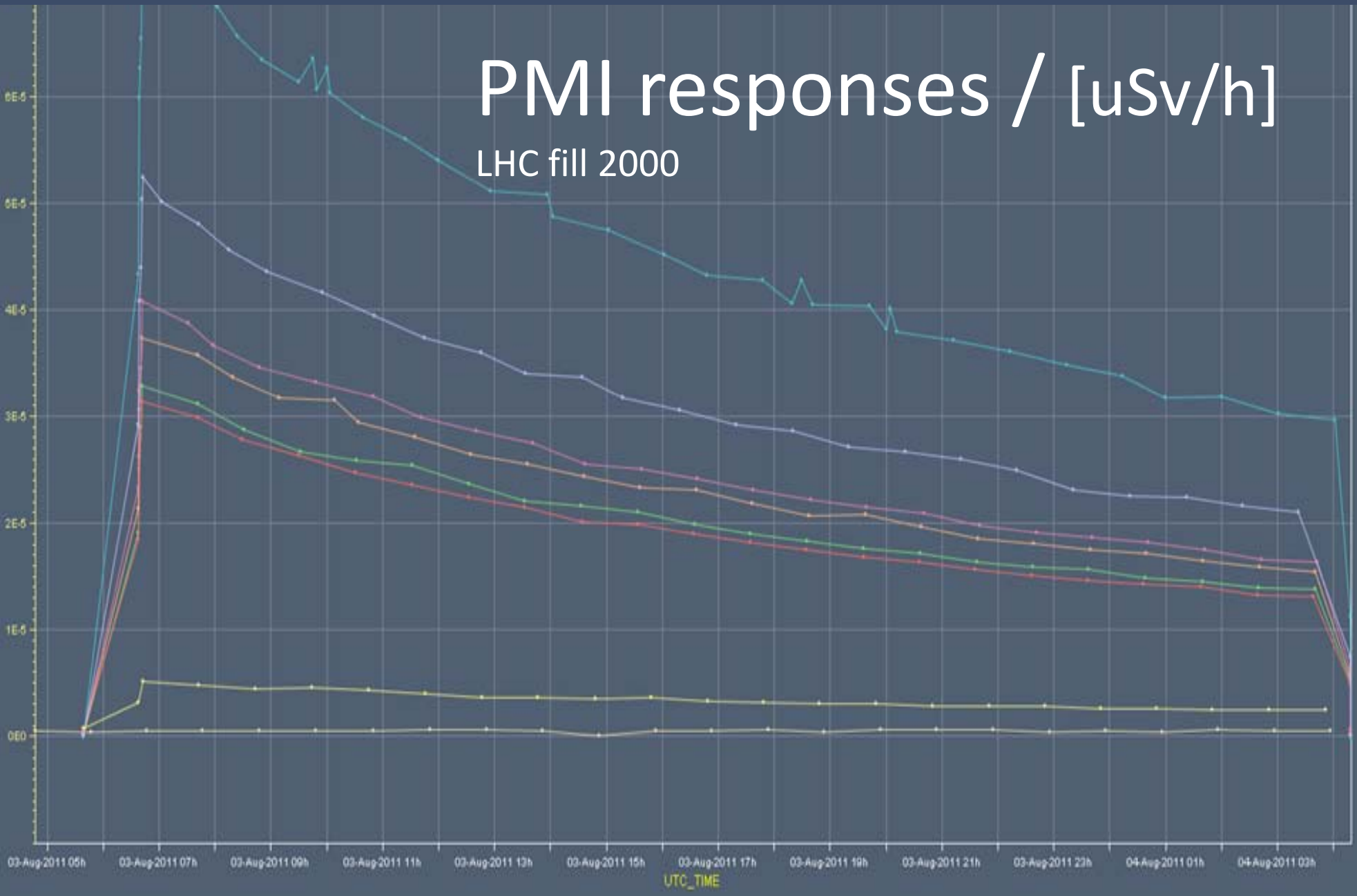
Calculated response function of PMI detector

Field calibration studies of the PMI ionization chambers in the UX85 cavern; Ch. Theis et al.

PMI responses / [uSv/h]

LHC fill 2000

Location of ionization chambers (PMI):

8 PMI chambers inside CMS cavern