CMS BENCHMARKING OF THE RADIATION FIELDS

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Radiation effects at the LHC experiments and impact on operation and performance, CERN , 18’04’23-24

BRIL RadSim simulation tools and datasets

- We have an expert system to predict radiation field parameters & radiation effects
- ES includes:
  - Simulation software: **FLUKA** (and MARS for fast estimations)
  - Models (Database of models):
    - CMS model + Magnetic Field
    - CMS materials parameters
    - CMS Hall model
    - CMS/LHC interface
  - Generators and sources:
    - Initial event generators (DPMJET-III, PYTHIA…)
    - External normalization
    - External MIB sources (Beam Halo, Distant Gas, Local Gas, Accidental Losses)
- We need to use ES for simulations of radiation field and in the same time to control its stability with respect to the change or update of its constituents. We need to distinguish "improvements" and "real developments" and to keep "historic line" of models for benchmarking.

CMS benchmarking of the radiation fields

1. Simulations vs data (no induced RA here):
   1.1. Comparison of predictions with detector degradation.
   Degradation models based on specific studies, include many parameters and not too simple.
   1.2. Straight data.
   Usually subdetectors need special triggers & analysis to produce data, useful for comparison with simulations.
   1.3. BRIL detectors.
   1.4. LHC RadMons.
2. Internal cross-checks (codes, models, versions)
3. Some issues

1.1. Comparison of predictions with detector degradation

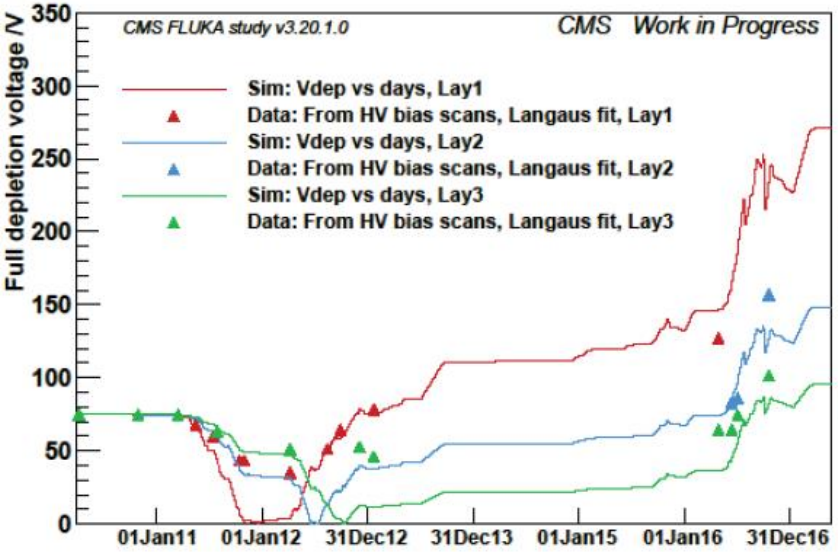
Pixel Phase-0: Depletion voltage simulation Work in progress

KIT Karlsruhe Institute of Technology

- Based on the **full temperature- and irradiation history** the expected full depletion voltages of the Pixel Tracker modules are simulated using the **Hamburg model*** for radiation damage
- The various plateaus in the simulation mirror long shutdown 1 and different technical stops of the LHC

* Hamburg model: M. Moll, Radiation Damage in Silicon Particle Detectors, Universität Hamburg, DESY-THESIS-1999-040, 1999
https://mmoll.web.cern.ch/mmoll/thesis/
(see also slide 14 in back-up slides)

Phase-0 Pixel -- Full depletion voltage vs days



Simulation input

FLUKA fluence simulation:
- High granular resolution
- Detector geometry
- Material - the different impact of charged and neutral particles on oxygenated silicon are taken into account

Hamburg model: **Hamburg parameter set** for oxygenated Si from RD48 3rd status report
http://rd48.web.cern.ch/RD48/status-reports/rd48-3rd-status-report.pdf

Actual temperature history from database
- Silicon temp. > measurement whenever LV on → added an offset

Data points: from HV bias scans
- Data is not expected to go to zero during type inversion

→ Considering the high sensitivity to input data, the simulation matches the data well

11 10/04/18 Julia Hunt ETP – Institut für Experimentelle Teilchenphysik

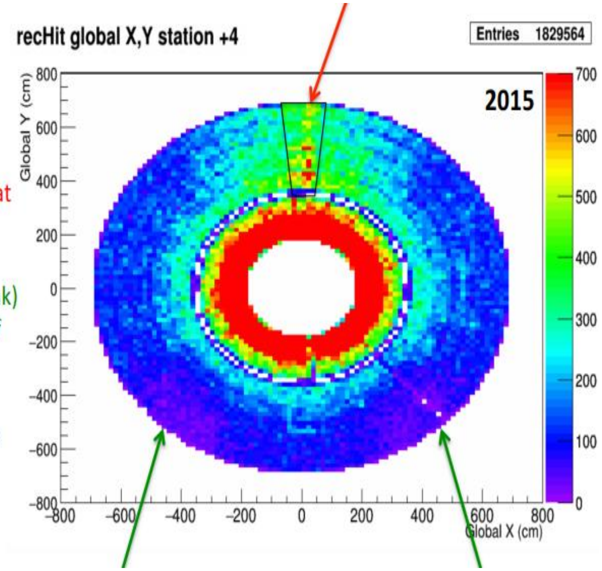
1.2. Straight data – ME4 background

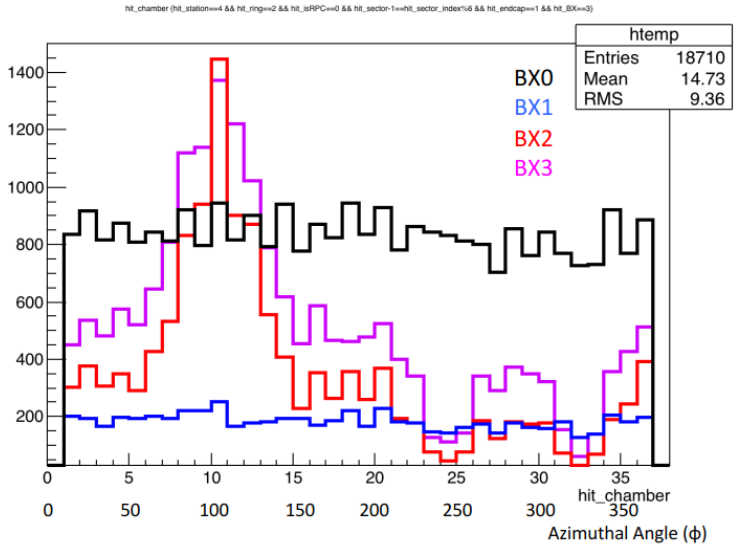
Single layer Rechit occupancy from late 2015.

High occupancy seen at top of the detector

Valleys (or second peak) seen on the bottom of the detector

Phi-asymmetry can be clearly seen in outer edges of ME4/2.



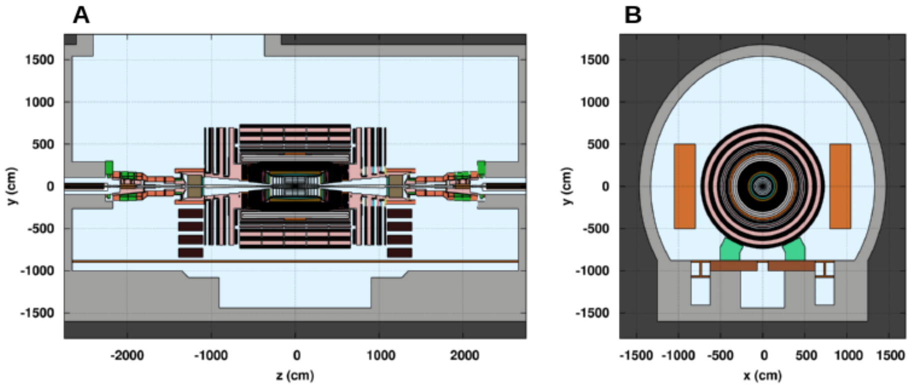


ZeroBias Dataset Isolated Bunches.

1 BX = 25 ns = 7.5 m path of relativistic particle.

50-75 ns delay means relativistic albedo from TAS.

270° structure is a result of scattering in HF and Collar support structures.



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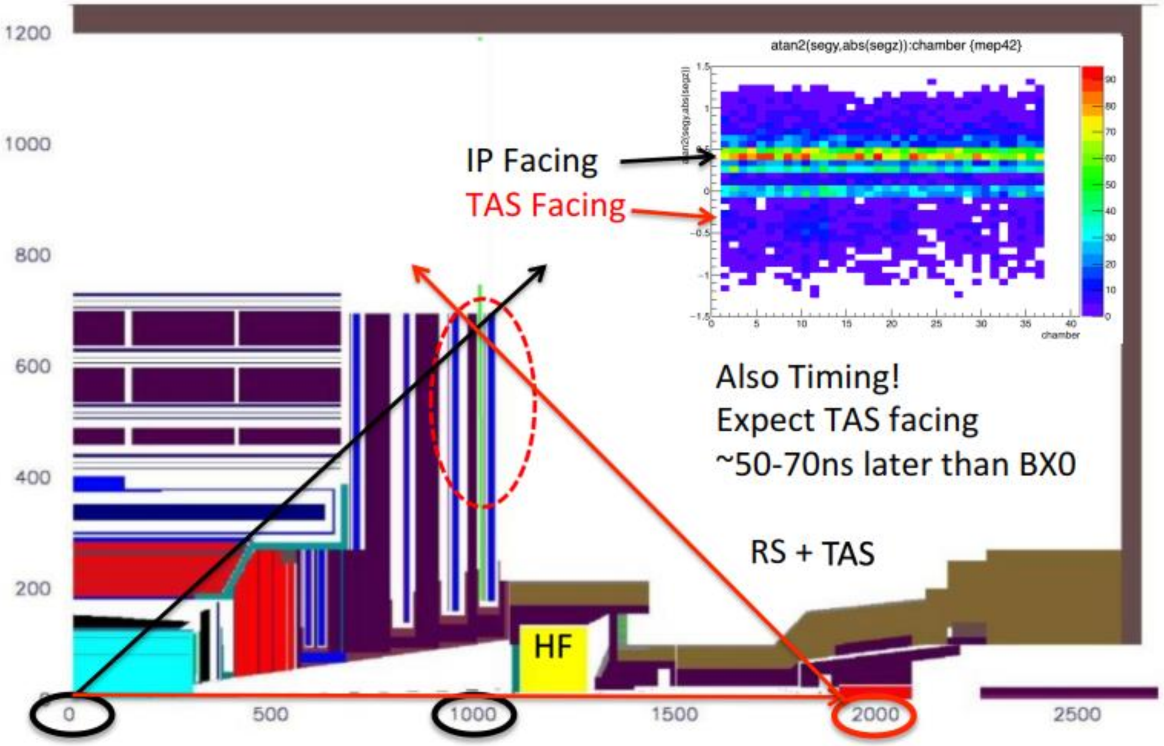
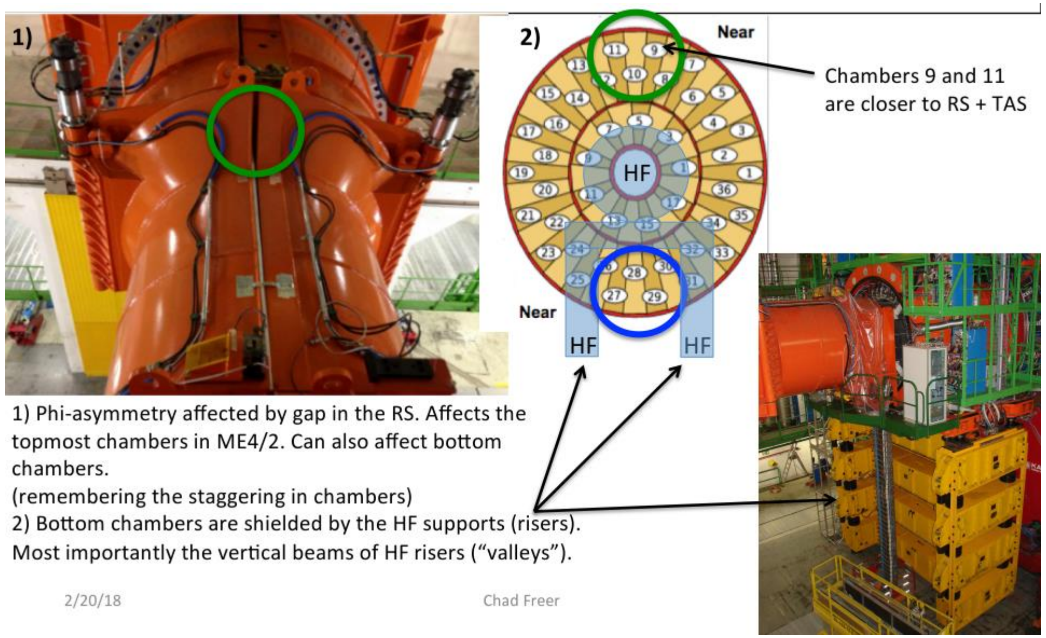




1.3. CMS BRIL DETECTORS (current)

	Luminosity	Detector protection	MIB	Beam properties	Radiation monitoring
BCMF1	Yes		Yes		
PLT	Yes				
HF Lumi	Yes				
BCML		Yes	Yes		
BPTX				Yes	
BHM			Yes		
HFRM					Yes
MediPix					Yes
Passive Dosimetry					Yes

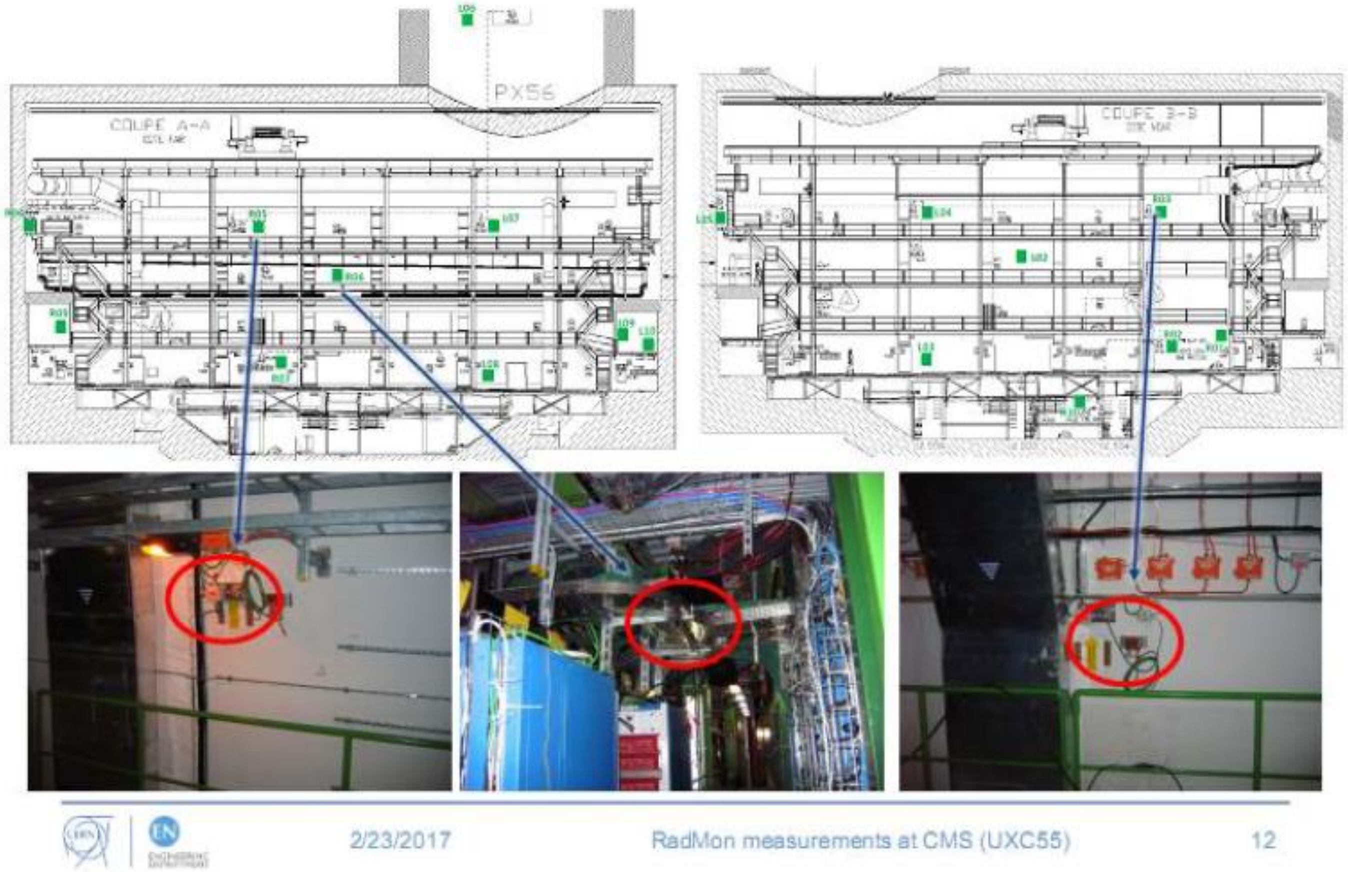
Work in progress!

"Near-beam" detectors (sitting on the beam pipe)

PASSIVE MONITORING

- Films (need photometer). Didn’t studied in mixed high E field.
- Foils (need gamma-analyzer). Not enough data for high E.
- TLDs (need reading machine). Didn’t studied in mixed high E field. Narrow dynamical range.
- Lessons: use of passive monitors needs understanding of its limits and dynamical ranges. It is clear that one needs to do special calibration (on CHARM facility, e.g.) for specific irradiation conditions (spectra, hadron/EMS ratio e.t.c.) Factory calibration in the soft gamma-field can not be used at LHC!!!

1.4. LHC RadMons in CMS Hall



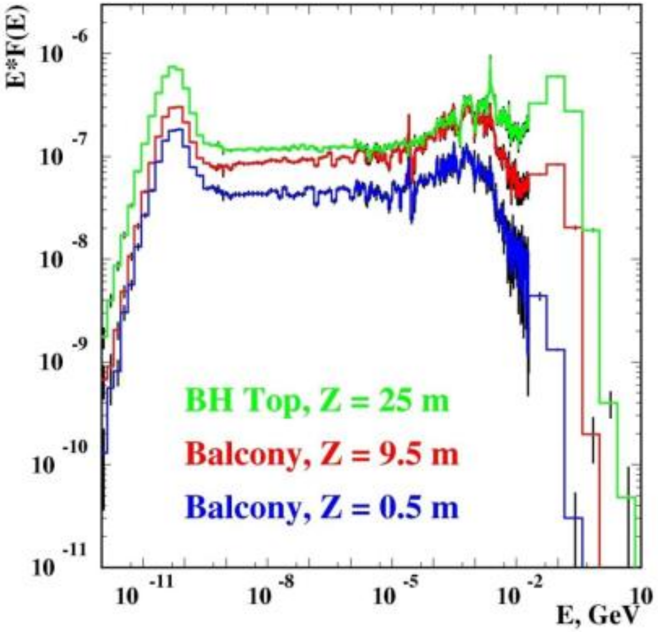
19 units (near 500 for all LHC)

Measures TID in Silicon Dioxide by Radiation-sensing Field Effect Transistors, Displacement Damage by p-i-n diodes and high E hadrons and thermal n fluence by SEU in SRAM memory

For us up to now – works as a passive monitor (and not Independent from Fluka)

Rather low sensitivity

Neutron Spectra in CMS Hall



Hard (~ R04, Rth = 1.5)

Intermediate (~ R05, Rth = 5.5)

Soft (~ L02/R06, Rth near 20)

Spectra of all particles were simulated by FLUKA for all LHC RadMons locations In the CMS Hall.

More for FLUKA/LHC RM Comparison

Location	HEH-2016	FLUKA	R factor	FLUKA/HEH
L03	4.65+08	5.61+08	3.0	1.2
L04	2.64+08	4.29+08	4.4	1.6
L07	7.03+08	1.29+09	1.9	1.8
L08	7.11+08	9.90+08	2.4	1.4
R02	8.37+08	1.29+09	2.3	1.5
R03	7.06+08	1.06+09	2.5	1.5
R05	2.35+08	3.63+08	5.5	1.5
R07	9.04+07	2.05+08	6.6	2.3

Location	HEH-2016	FLUKA	R factor	FLUKA/HEH
L05	1.34+09	3.23+09	1.2	2.4
L09	1.93+09	7.26+09	0.7	3.8
L10	3.79+09	4.62+09	1.2	1.2
R04	1.35+09	3.14+09	1.5	2.3
R09	1.84+09	7.26+09	0.7	3.9
L02	1.72+07	6.93+07	19	4.0
R06	1.06+07	6.60+07	20	6.2

- Good agreement for the first comparison.
- LHC RadMons coordinates were promised.
- 3W/5W switch will be done for some RM in 2017 for independent R factor measurement.
- CMS Hall geometry should be more detailed.
- It would be good to know more about hall concrete.

2016 data are presented.

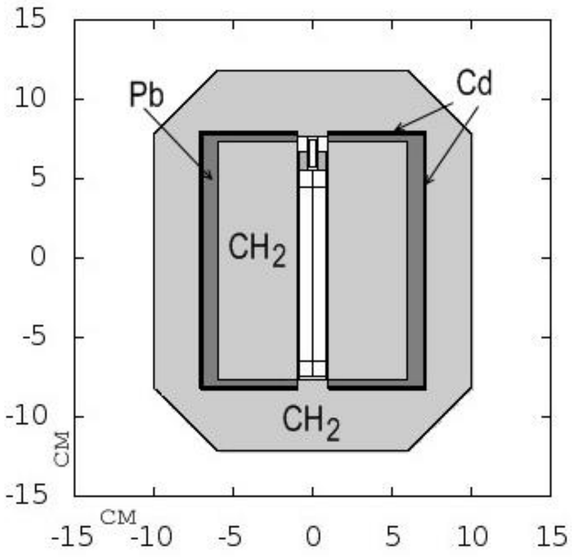
2017 data – work in progress.

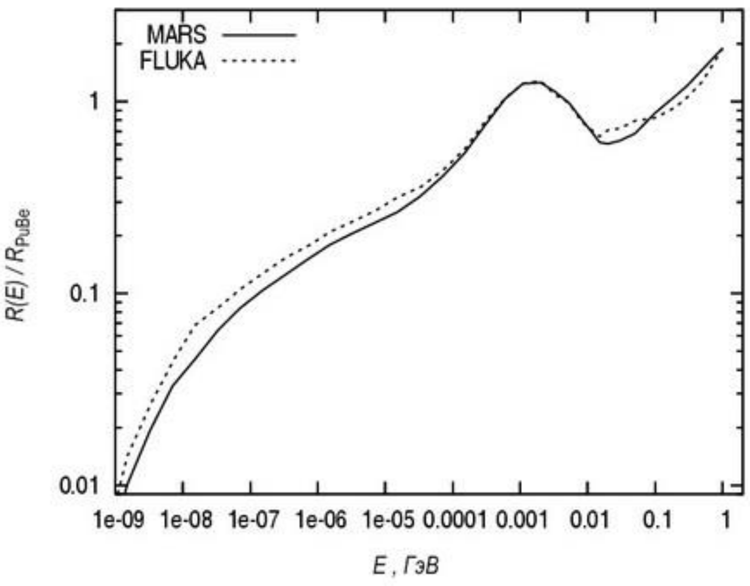
Lesson: we need good geodesy for all non-CMS detectors, because original use of these devices didn't Provide it.

Hard spectra: geometry factor importance (high gradient for HEH)
Soft spectra: concrete humidity (H content) → n thermalisation accuracy

2. Internal cross-checks (codes, models, versions)

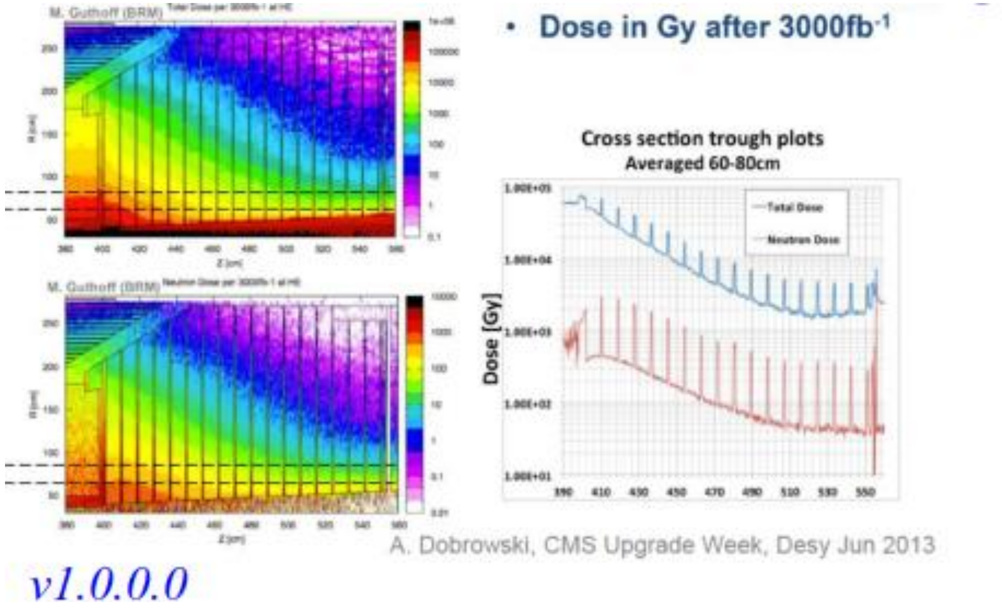
- 2.1. Codes comparison: FLUKA vs MARS. New n monitors response function.

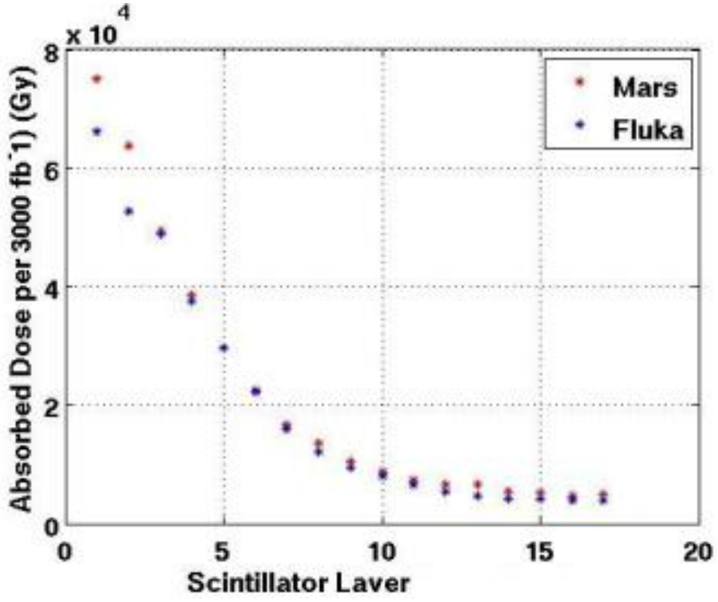




Agreement is very good, despite of different neutron constant systems: 28 groups in MARS and 260 – in FLUKA.

2.1. FLUKA vs MARS: D_a in endcap HCAL





Absorbed dose integrated in PS layers for radial regions [60., 80.] cm

3. Issues: simulation codes hierarchy

- Support of the detailed geometry model is the main manpower consuming task; it needs FLUKA+CMS expert in one person.
- If we really need to optimize CMS hall periphery (X0 hall, for example), a combined model should be built: FLUKA as a central source generator + MARS for a fast long distant transport tool.
- GEANT is good for separate detector unit response function standalone simulations; results can be coupled with the FLUKA simulations of “input” into this detector (under development for CMS Muon System studies).

Thank you for your attention!