Workshop

Radiation effects at the LHC experiments and impact on operation and performance – summary of **Radiation Background Simulation and Monitoring session**

CERN, 23-24 April 2018

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Session 3: Radiation Background Simulation and Monitoring

Two parts:

- simulation
- benchmark measurements

Introduction	*Sophie Mallows et al.*
6-2-024 - BE Auditorium Meyrin, CERN	09:00 - 09:10
ATLAS simulation overview	*Paul Miyagawa*
6-2-024 - BE Auditorium Meyrin, CERN	09:10 - 09:35
CMS simulation overview	*Sophie Mallows*
6-2-024 - BE Auditorium Meyrin, CERN	09:35 - 10:00
LHCb simulation overview	*Tomasz Szumlak*
6-2-024 - BE Auditorium Meyrin, CERN	10:00 - 10:25
Coffee break	
6-2-024 - BE	10:25 - 10:55
...EANT4 & GRID	*Sven Menke*
...eyrin, CERN	10:55 - 11:15
...MS benchmarking of the radiation fields	*Igor Azhgirey*
6-2-024 - BE Auditorium Meyrin, CERN	11:15 - 11:30
LHCb benchmarking of the radiation fields	*Matthias Karacson*
6-2-024 - BE Auditorium Meyrin, CERN	11:30 - 11:45
Inner detector radiation field measurements with RadMons	*Igor Mandic*
6-2-024 - BE Auditorium Meyrin, CERN	11:45 - 12:00
Measurement of composition of radiation fields in the ATLAS experiment with MPX/TPX	*Stanislav Pospisil*
6-2-024 - BE Auditorium Meyrin, CERN	12:00 - 12:15
Discussion on simulation uncertainties and safety factors	*Ian Dawson*
6-2-024 - BE Auditorium Meyrin, CERN	12:15 - 12:30

The main issue is to cross-check various tools and compare with benchmark measurements

Session 1: Sensor Measurements

Comparision of simulation with mesurements (see also the presentation of Aidan Grummer):

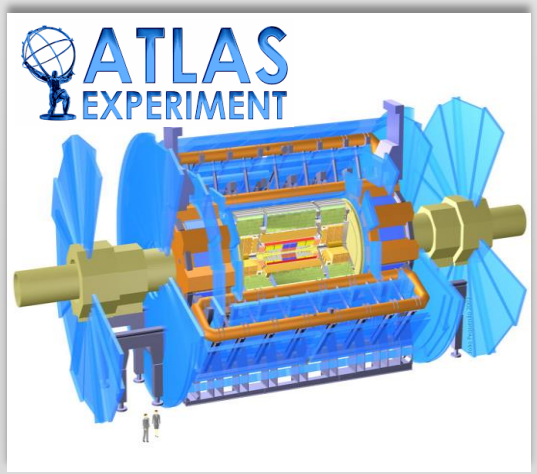
Session introduction	*Michael Moll*	
6-2-024 - BE Auditorium Meyrin, CERN	09:10 - 09:15	
Pixel Leakage Current Measurements from ATLAS (20'+5')	*Aidan Grummer*	
6-2-024 - BE Auditorium Meyrin, CERN	09:15 - 09:40	
Leakage Current Measurements from LHCb (20'+5')	*Vinicius Franco Lima*	
6-2-024 - BE Auditorium Meyrin, CERN	09:40 - 10:05	
CMS Pixel and Strip radiation damage measurements (20'+10')	*Julia Alexandra Hunt et al.*	
6-2-024 - BE Auditorium Meyrin, CERN	10:05 - 10:35	
Coffee Break		
6-2-024 - BE Auditorium Meyrin, CERN	10:35 - 11:00	
Pixel Depletion Voltage Measurements from ATLAS (15'+5')	*Julien-Christopher Beyer*	
6-2-024 - BE Auditorium Meyrin, CERN	11:00 - 11:20	
Depletion Voltage Measurements from LHCb (20'+5')	*William James Barter*	
6-2-024 - BE Auditorium Meyrin, CERN	11:20 - 11:45	
Measurements with the ATLAS strip detector (20'+5')	*Taka Kondo*	
6-2-024 - BE Auditorium Meyrin, CERN	11:45 - 12:10	

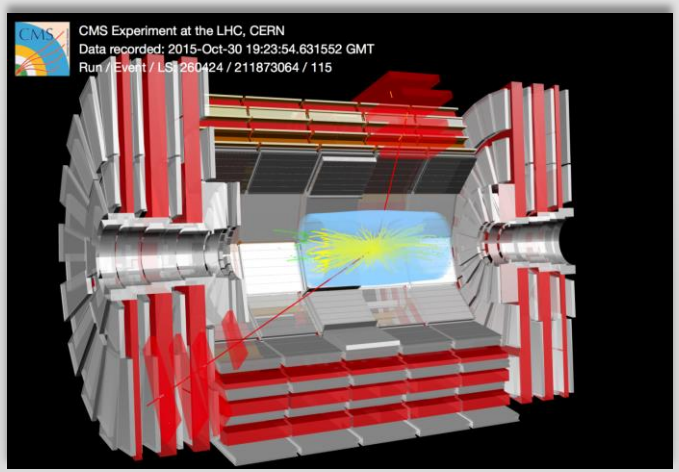
Session 3: Radiation Background Simulation and Monitoring

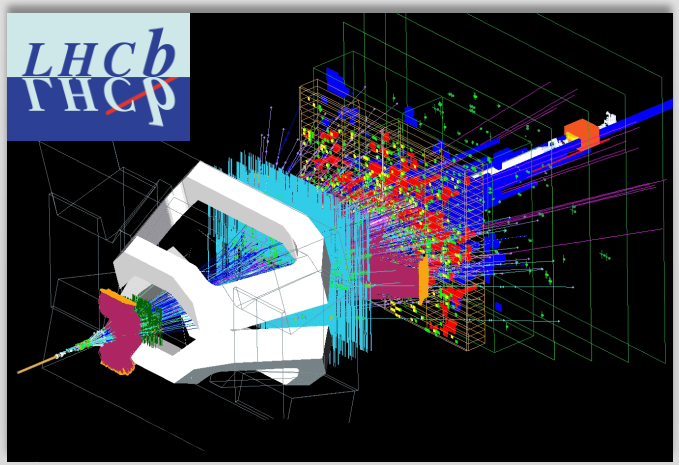
Outline:

1. Common simulation tools.
2. Experimental verification.
3. Benchmark measurements.
4. Web tools.
5. Summary

RD50

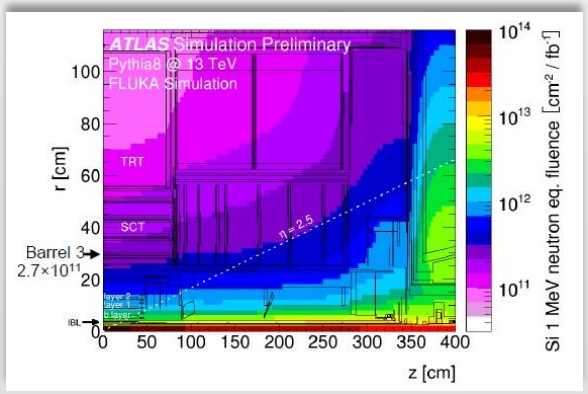


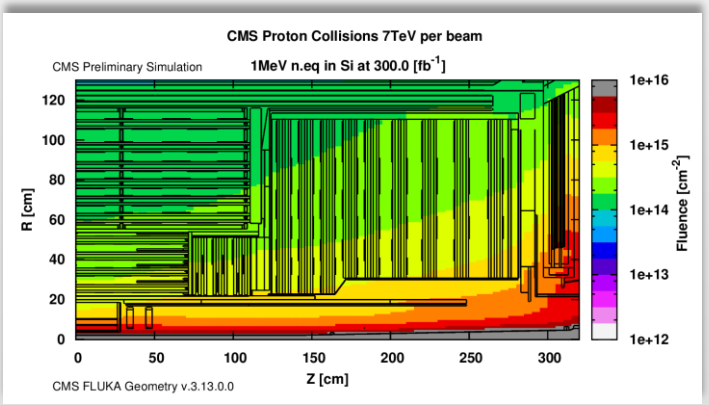


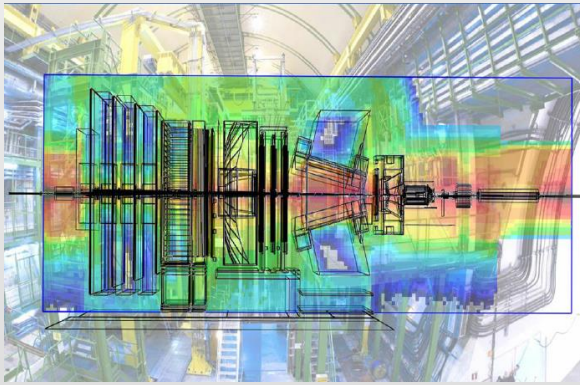


Simulation Tools

Which common tools are used in all experiments?







- tuned Pythia8 + FLUKA min bias proton-proton events (7-14 TeV),
- DPMJET used by CERN Radiation Protection,
- Particle transport with GCALOR, FLUGG, Geant4

- very detailed FLUKA (DPMJET3) simulation for fluence (n_{eq} and other charged hadrons), dose, activation studies
- MARS – independent geometry for part of the detector
- BRIL project focused on radiation issues coordinating/approving results

- FLUKA simulation for fluence and dose studies (Radiation Protection team),
- GEANT4 and full simulation used for RD studies,
- new FLUKA for VELO & Upgrade simulation

Experimental verification

Procedure:

- Simulation of fluence compared with the leakage current measurement.
- Dose simulation and measurement.

Delivered Luminosity (history)

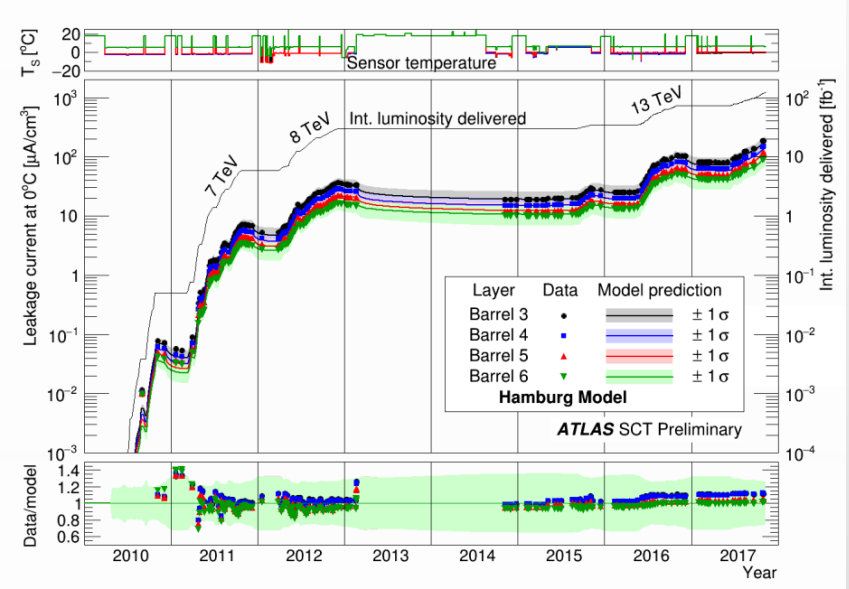
Full temperature history

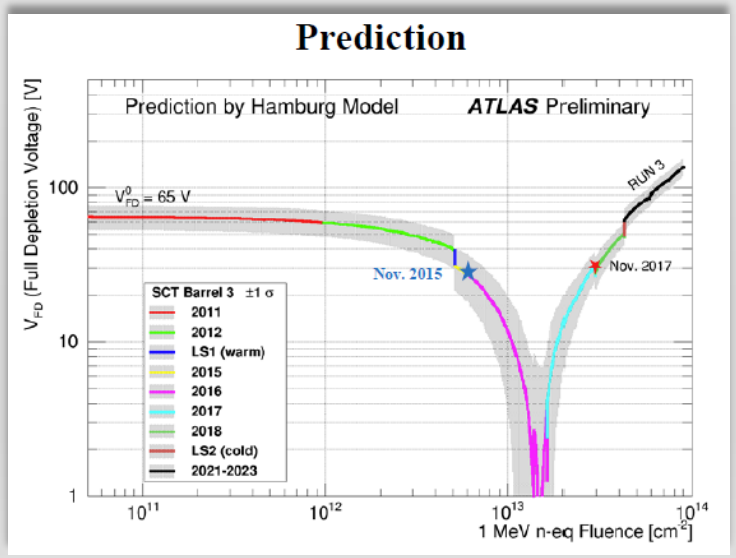
Radiation damage model:
- α and Hamburg model parameters.
- Fluence predictions (FLUKA).
- Geometry

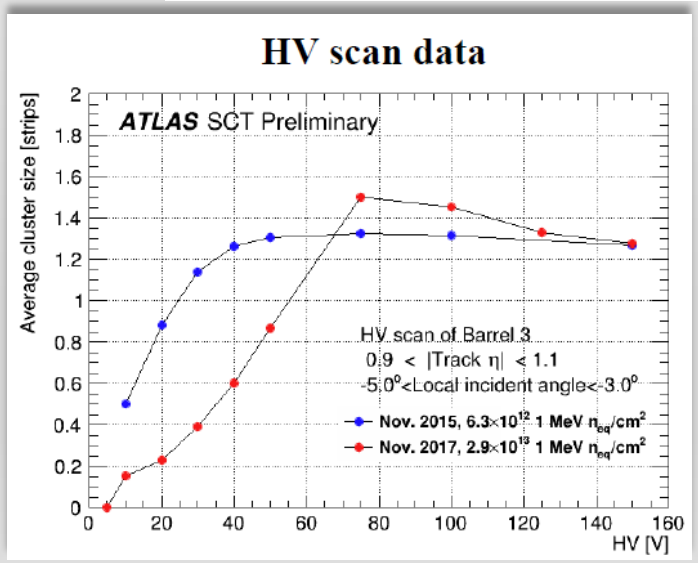
- leakage current,
- depletion voltage.

Simulation – data comparision

- Comparisons with SCT leakage current show very good agreement between LC measured and Hamburg model prediction with increasing luminosity.
- No significant z-dependence.
- Ongoing work with pixel B layer 0, 1 and 2.

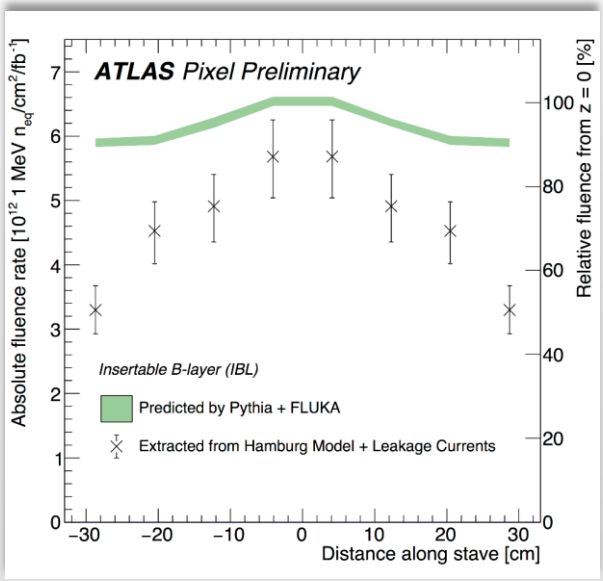


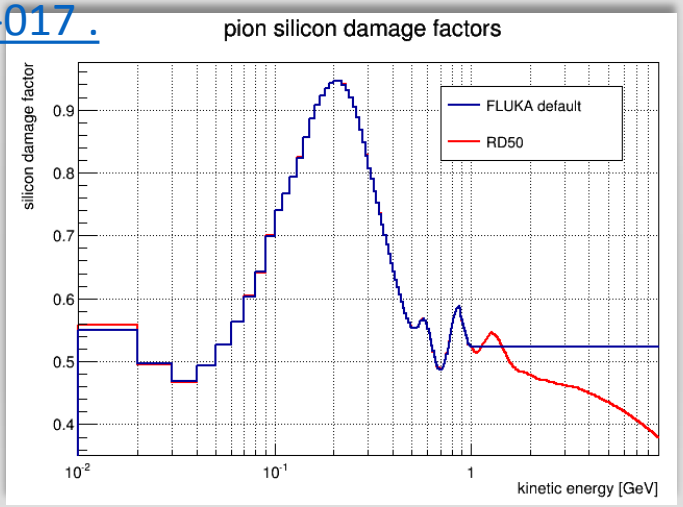


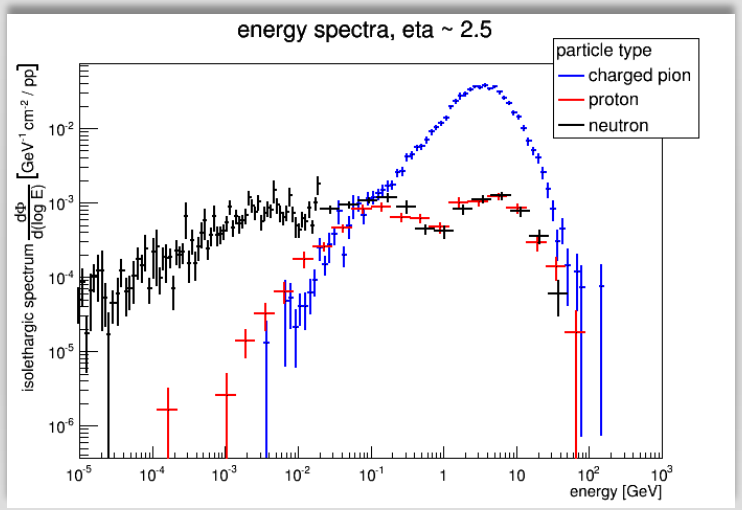


z-dependence of the leakage current

- Discrepancies observed between fluence prediction and IBL leakage current measurements.
- FLUKA simulation:
  - **overestimates** fluence rate by 15-40%,
  - **underestimates** the z-dependence (observed a 35% decrease, expected 10%).
- Corrections applied:
  - silicon damage function (above 1 GeV constant damage function)
  - absolute scale of min bias events (new Pythia 8 tuning) ATL-PHYS-PUB-2016-017 .







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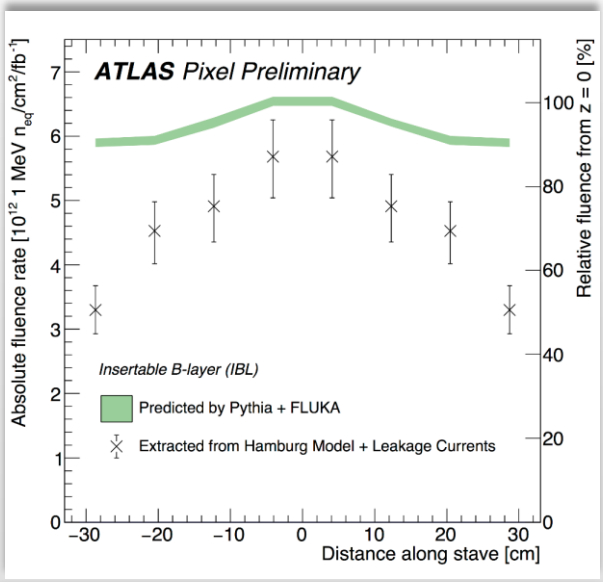
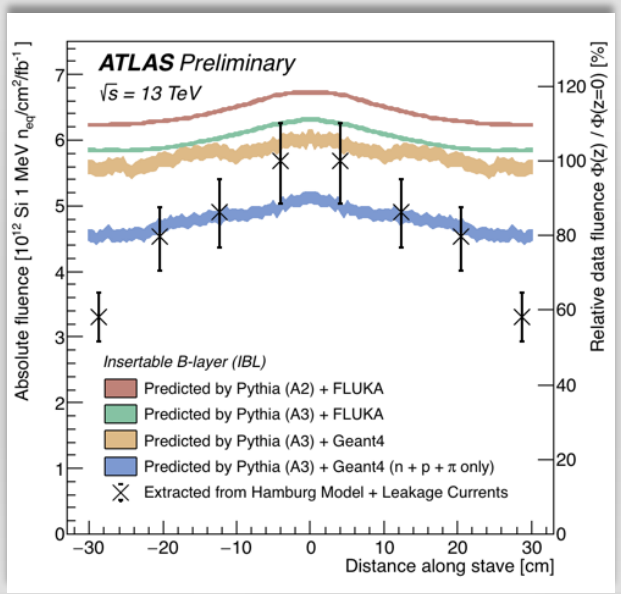
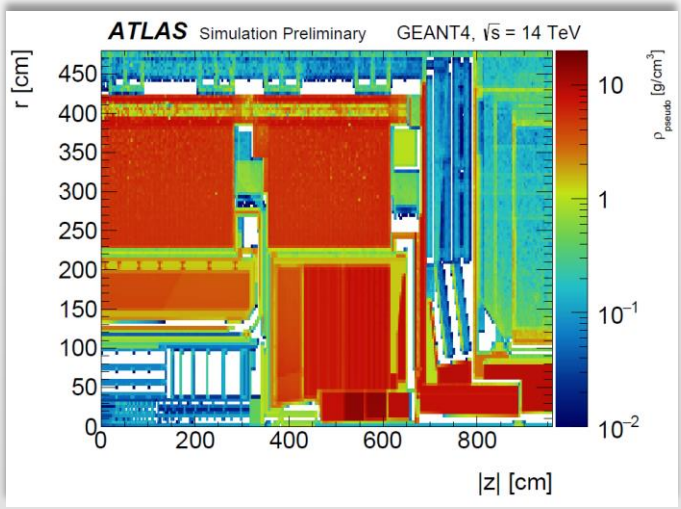
  - absolute scale of min bias events (new Pythia 8 tuning) ATL-PHYS-PUB-2016-017 .
- Result:
  - new user routine with new damage functions up to 9 GeV caused the increase of z-dependence to 12%.
  - n_{eq} fluence decreased of 5-7%

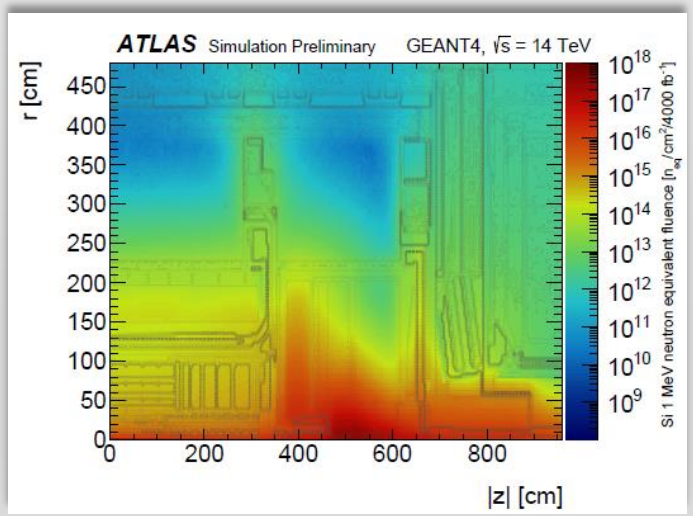




GEANT 4 simulation

- ATLAS uses Geant 4, especially for the upgrade electronics estimation for Si-NIEL, TID and SEE.
  - Geant 4 is the basing architecture of the detector simulation software,
  - Allows to add user-defined code in ROOT framework.
- Parameters for simulation – the same as FLUKA.
- Results in agreement with FLUKA simulation.
- 3D radiation map available.



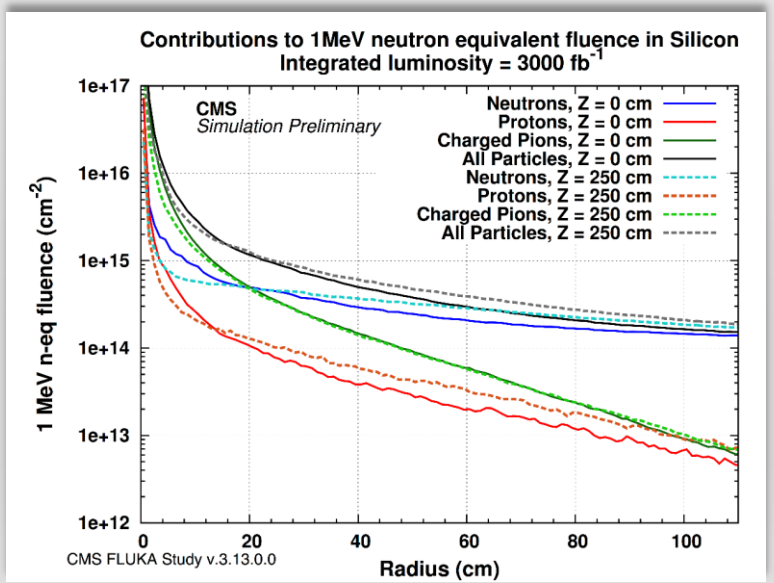


Next steps

- Propagate uncertainties from Si-NIEL damage weights
- Compare to Rad-Mon measurements
  - Knowledge of exact location in 3D of the Rad-Mons is crucial!!!!

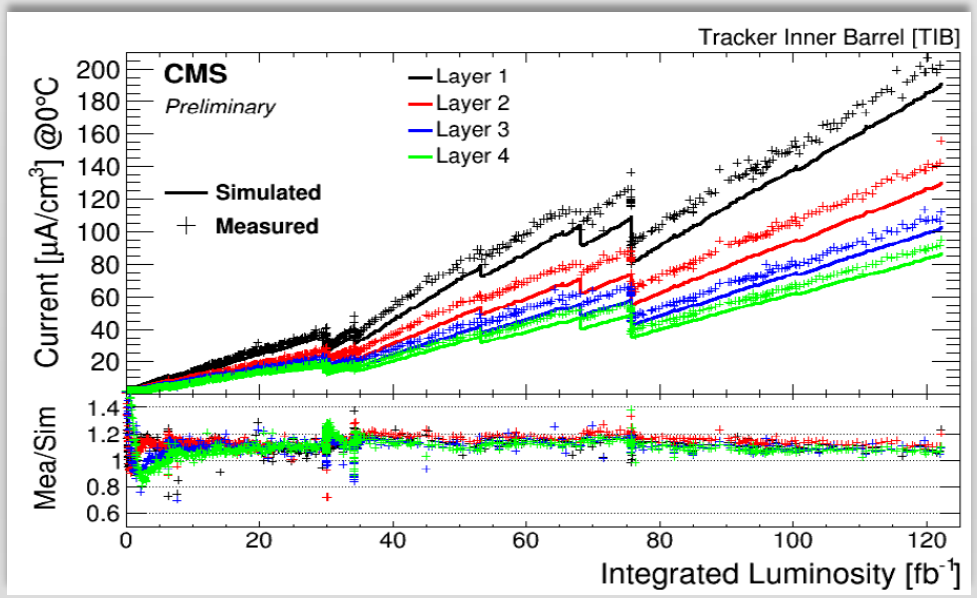
Simulation vs measurement

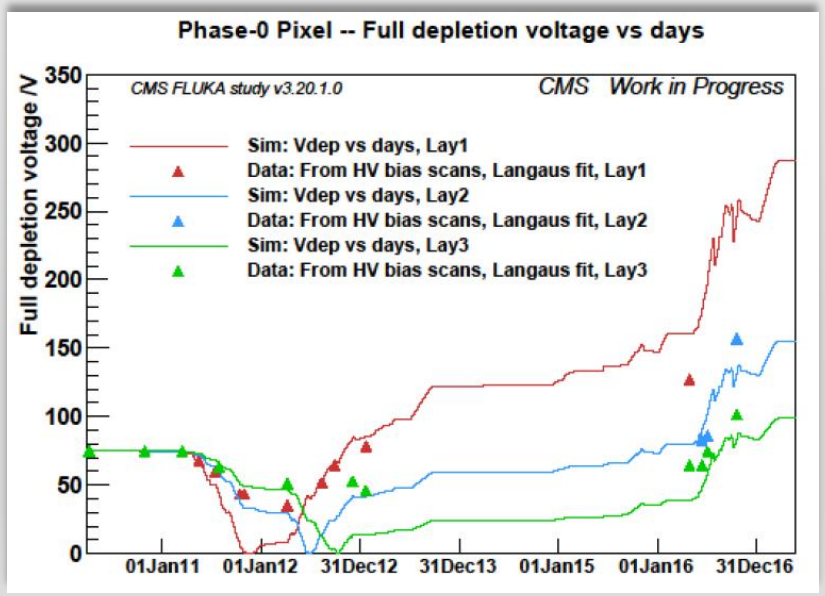
- Simulation, measurements, tools for analyses under BRIL project.
- Main simulation tool for radiation simulations is FLUKA for prompt radiation in central detectors.
- Use standard FLUKA weighting factors to directly score 1 MeV n_{eq} on Si.
- Simulations occasionally performed with MARS code for quick turnaround which used independent, lower resolution geometry.
- FLUKA with SESAME tool for activation studies. When appropriate other tools (Actiwiz, Nucleonica) are used in place of full detector simulation to save time.



Simulation vs measurement

- Leakage current in the strip tracker:
  - Calculations with the self-heating term (possible thermal runaway).
  - Good agreement with ~20% of **underestimation.**
- Depletion voltage in Pixel tracker:
  - The simulation matches the data.



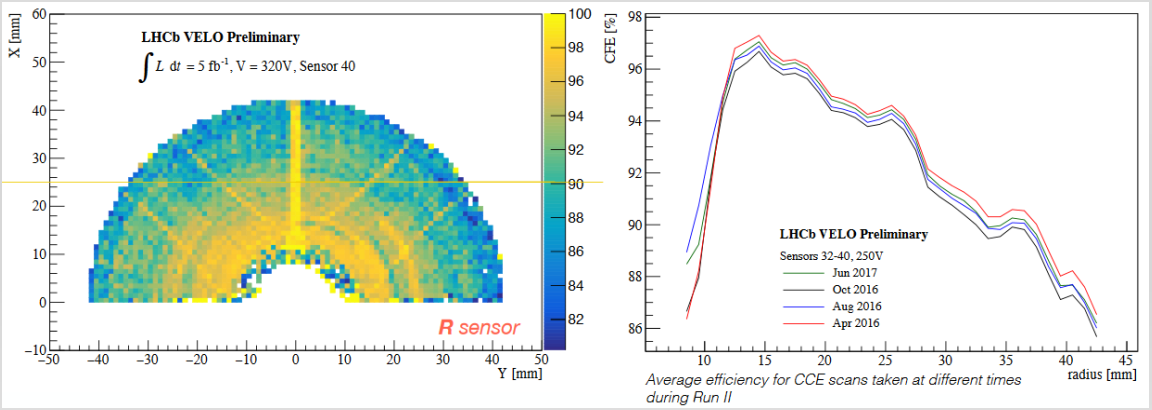


Radiation damage simulation

- Currently FLUKA is used mainly for the purposes of radiation protection.
- New FLUKA simulation for VELO is done.

see the next slides

- Effects of RD (second metal layer effect) are **simulated** in LHCb software.
  - dedicated tool implemented to **modify the detector response** (fraction of charge that is leaked to the inner strips are parametrized as a function of sensor pitch and pseudorapidity),
  - the final simulation tuning assumes both the charge diffusion width and strips capacitive coupling to be free parameters
  - we also adjusted the simulation code to **reproduce the observed cluster spectrum distribution;** the final simulation tuning assumes both the charge diffusion width and strips capacitive coupling to be free parameters.

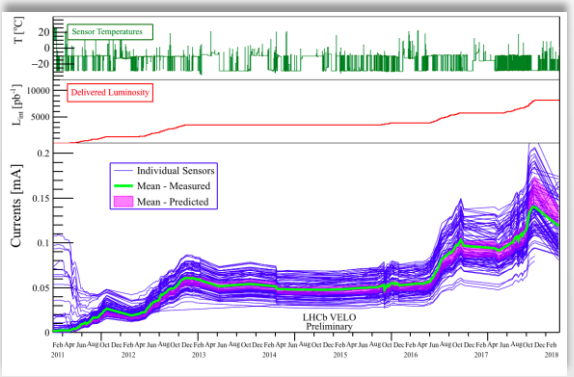


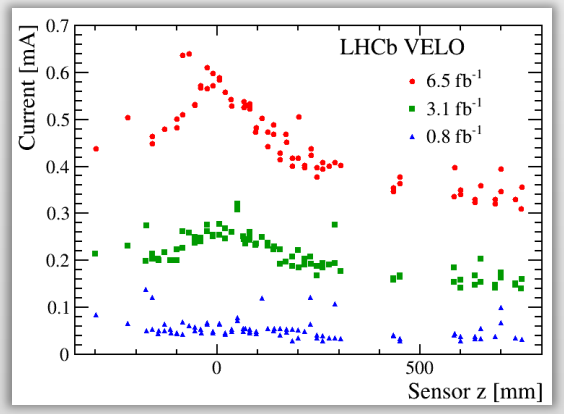
Average efficiency for CCE scans taken at different times during Run II

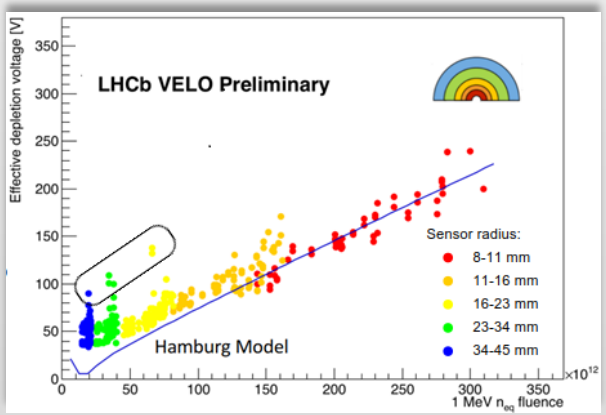
- Preliminary results look promising, we are in process of validating them with dedicated large simulated samples

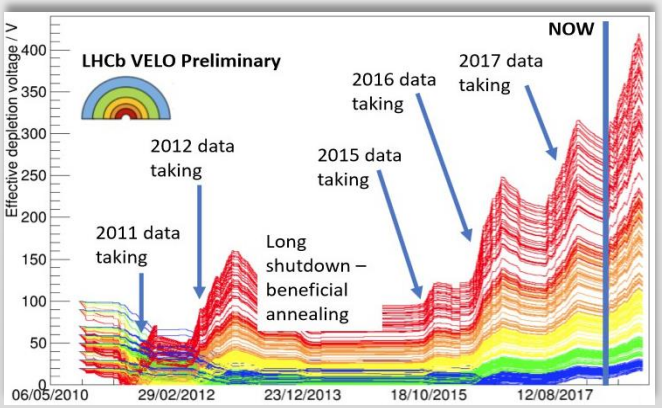
Simulation vs measurements

- The evolution of leakage current and effective depletion voltage are based on Hamburg model.
- Fluence is determined by Geant4 and FLUKA (comparison is ongoing),
  - the z-dependence of the fluence reflects the shape of the leakage current.

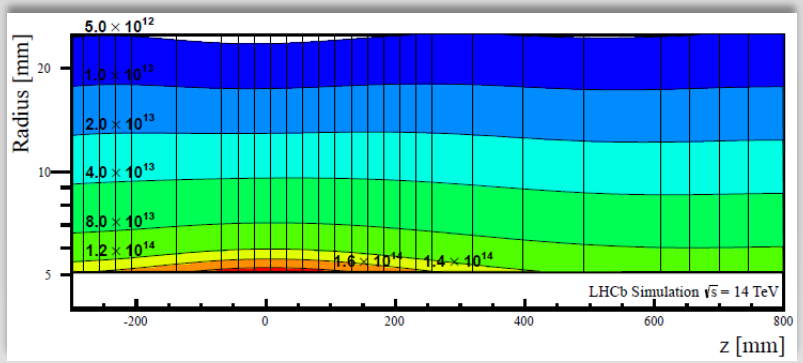








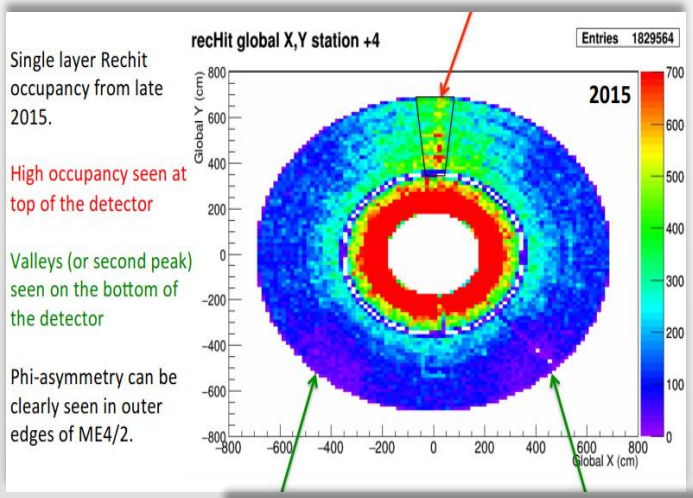
- Simulation for the VELO Upgrade shows that the inner tip of the sensors will be irradiated up to 7×10^{15} n_{eq} per 50 fb^{-1}.

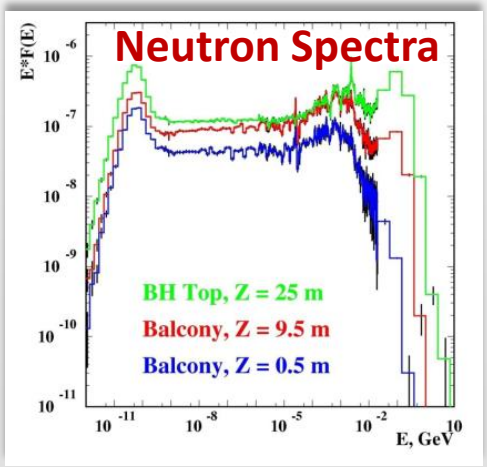


Benchmarking of the radiation fields

- Expert system to predict radiation field parameters & radiation effects (FLUKA for simulation, model of detector and experimental hall).

- Sources of data for benchmarking:
  - straight data from subdetectors,
  - BRIL detectors,
  - LHC RadMons (measures TID, rather low sensitivity).



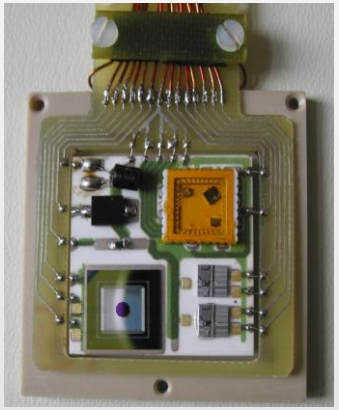


- Good agreement with FLUKA simulation (would be better if only the position of monitor were known more precisely).
- Work ongoing with GEANT inclusion.

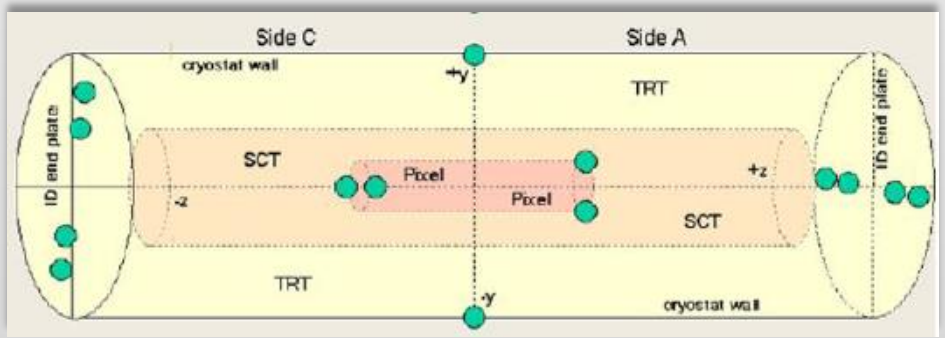
Benchmarking of the radiation fields

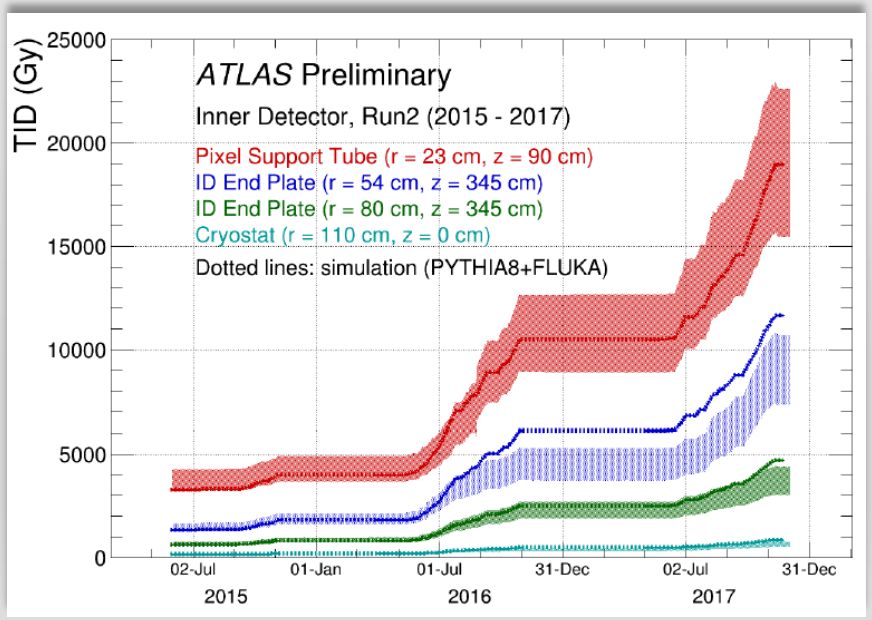
Monitoring of radiation damage in detectors and electronics:

- Online radiation dose monitoring measures accumulated ionizing dose (TID) in SiO_2 and displacement damage in silicon.
- Doses are monitored at 14 locations in the Inner Detector, sensors read out every 60 minutes.
- Good agreement between TID and neq fluence with online integrated dose monitoring in ATLAS ID.



RMSB





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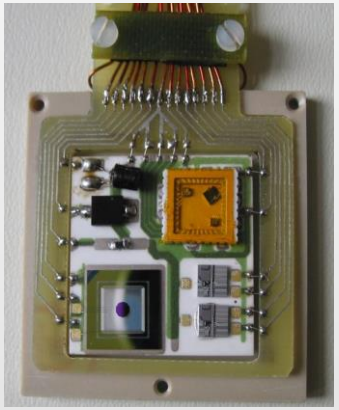
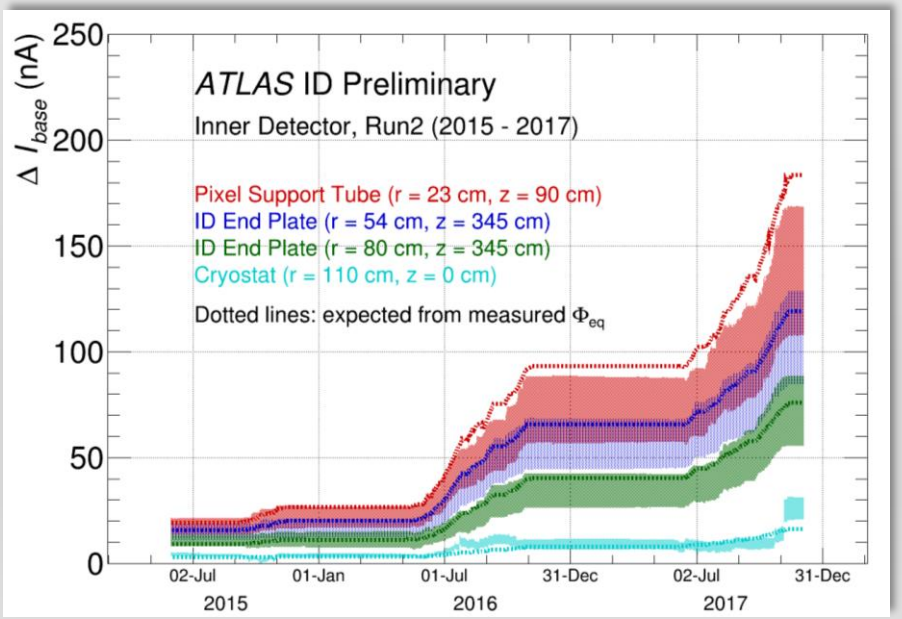
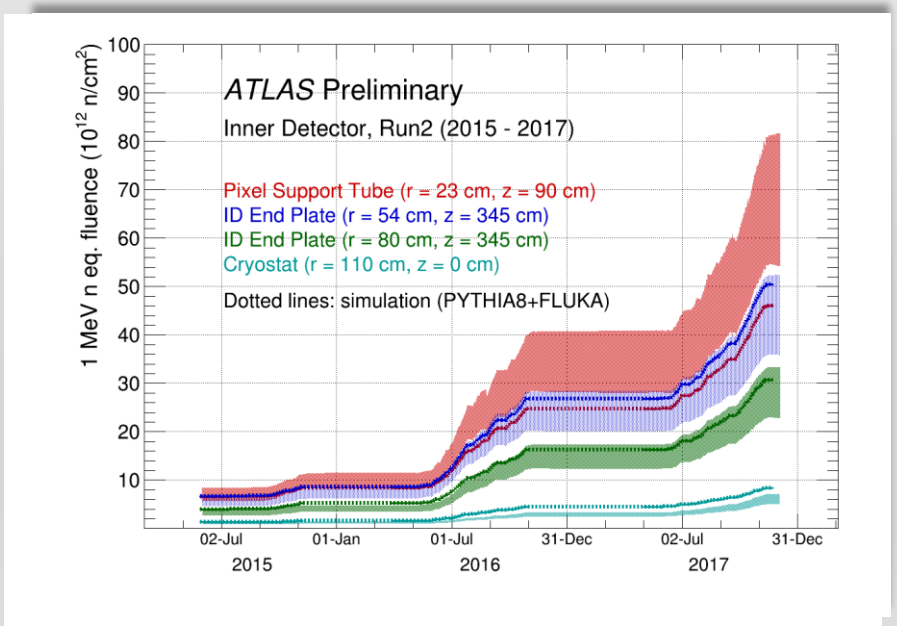


RMSB

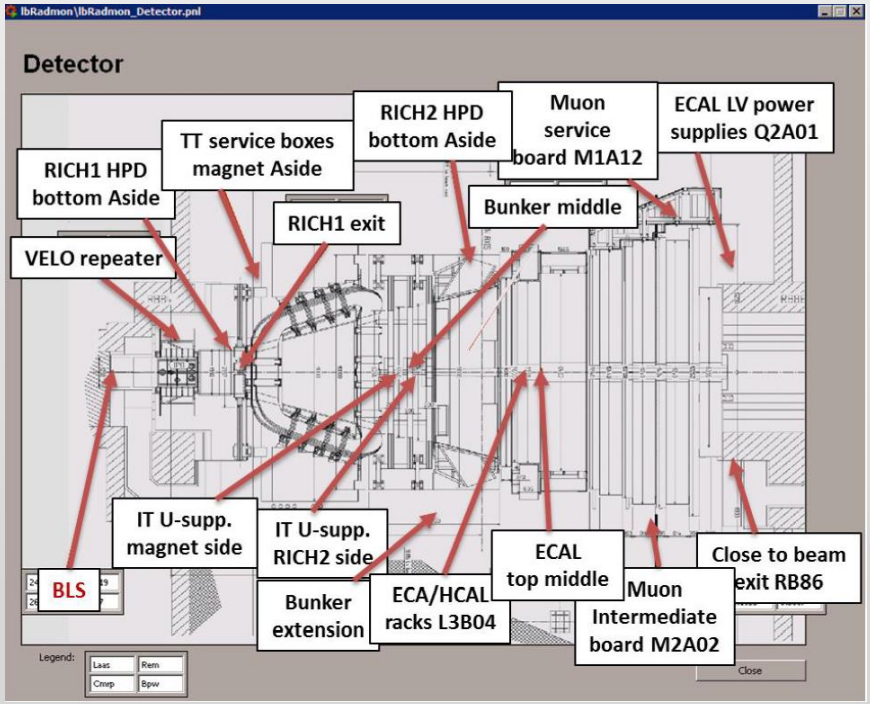




Benchmarking of the radiation fields

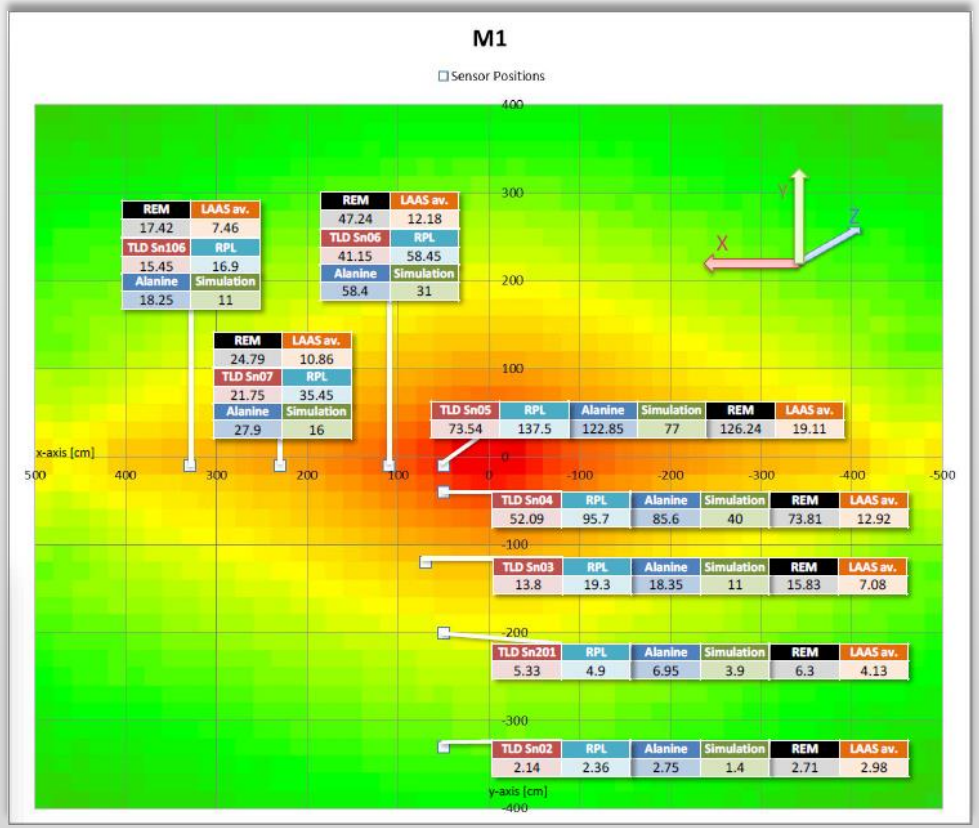
- FLUKA simulation of TID and neutron equivalence fluence in 3D grid (and many other simulations, like energy spectra and detailed binning in various places of spectrometer).
- More than 100 active and passive dosimeters in various places inside and around the spectrometer.

- Reliability of dosimeters in mixed field was established within reasonable parameters. Higher precision would require analysis in well-defined radiation fields.



Benchmarking of the radiation fields

- Comparison between methods and simulation showed that simulation results are lower than measurement but measurements agree among one another.
  - better agreement is in areas that are closer to the outer edge of the acceptance, worse in the central areas around the beam.
- The read outs of passive sensors are performed every YETS.
- Active sensor measurements are performed online every 23 minutes.



Active sensors are still under study – high level dose (REM) and both fluence (PiN) sensors look promising

Web tools

ATLAS radiation simulation results

This interface allows you to access the results of three different simulations of the ATLAS radiation background in Phase 2 (based on FLUGG, FLUKA, GCALOR, and GEANT4).

Note on geometries in the simulations: FLUGG, FLUKA, GCALOR, and GEANT4 all use a model of the Phase 2 geometry with the ITk.

Step 1: Choose the quantity you're interested in:

Total Ionizing Dose (Gy)

Step 2: Input the region of interest

388 ≤ r ≤ 424 cm

616 ≤ |z| ≤ 652 cm

Step 3 (optional): Set the integrated luminosity

Integrated luminosity : 4000 fb^{-1}

Submit

Radiation Simulation Plotting tool v.1.5.2

HyperNews BRIL Radiation Simulation

[RSP tool: manage]

- Please note that plots generated with this tool are **NOT APPROVED** as CMS official plots, they are intended for internal CMS use only.
- Plots already **APPROVED** by the CMS Collaboration can be found here: TWiki: BRILRadiationSimulation.
- For further information please consult the references tab.
- A parameter drawing of CMS can be found here.

main site | references | features | bug fixes | credits | FAQ

» plot generated in: 20.800000 [sec]

step 1 → step 2 → step 3 → plot

Selected simulation run: CMS_pp_7TeV_FLUKA

« to step 1

Selected scoring: Charged Particles

« to step 2

Selected plot options:

R min [cm]:	R max [cm]:	R rebin:
0.00	1300.00	1
Φ min [rad]:	Φ max [rad]:	Φ rebin:
-3.14159	3.14159	1
Z min [cm]:	Z max [cm]:	Z rebin:
-2750.00	2750.00	1

Normalization form & value:

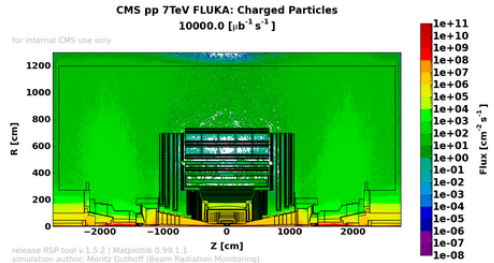
instantaneous: 10000.0 [$\mu b^{-1} s^{-1}$]

« to step 3

[▲▼ click here] simulation description

step 5: PLOT

Please use **[RIGHT_CLICK]** and save the picture as "PNG" to store the plot or open in new browser tab.



[▲▼ click here] data download

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[▲▼ click here] 1D plot menu

Summary

- ATLAS recommends the safety factor 1.5 for future predictions of neutron equivalence fluence and dose.
- CMS and LHCb rather consider predictions on a case by case basis.
- FLUKA is currently the basic simulation tool, CMS and LHCb use the FLUKA implementation of DPMJET3, whereas ATLAS generates events separately using tuned PYTHIA8. Basically, simulation agrees with the leakage current and TID measurements;
  - but it is critical to have an updated database of damage factors to see what the uncertainties are and where maybe some of these could be updated if possible.
  - it is also very important to keep on studying the z-dependence of the fluence predictions wrt leakage current measurements.

Thank you for your attention!
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