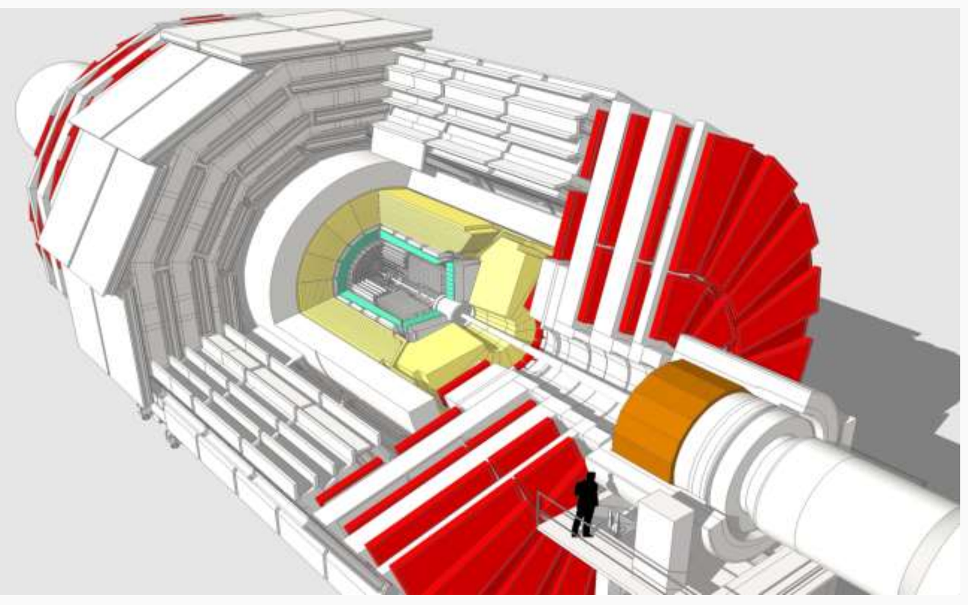


Monte Carlo simulations of the radiation environment for the CMS Experiment

I.Azhgirey[1], I. Bayshev[1], I.Bergstrom[2], T.Cooijmans[2], A.Dabrowski[2], L.Glöggler[2], M.Guthoff[2], I.Kurochkin[1], S.Mallows[3], S.Tadeja[2], H.Vincke[2]

1. Institute for High Energy Physics 2. CERN 3. Karlsruher Institut für Technologie

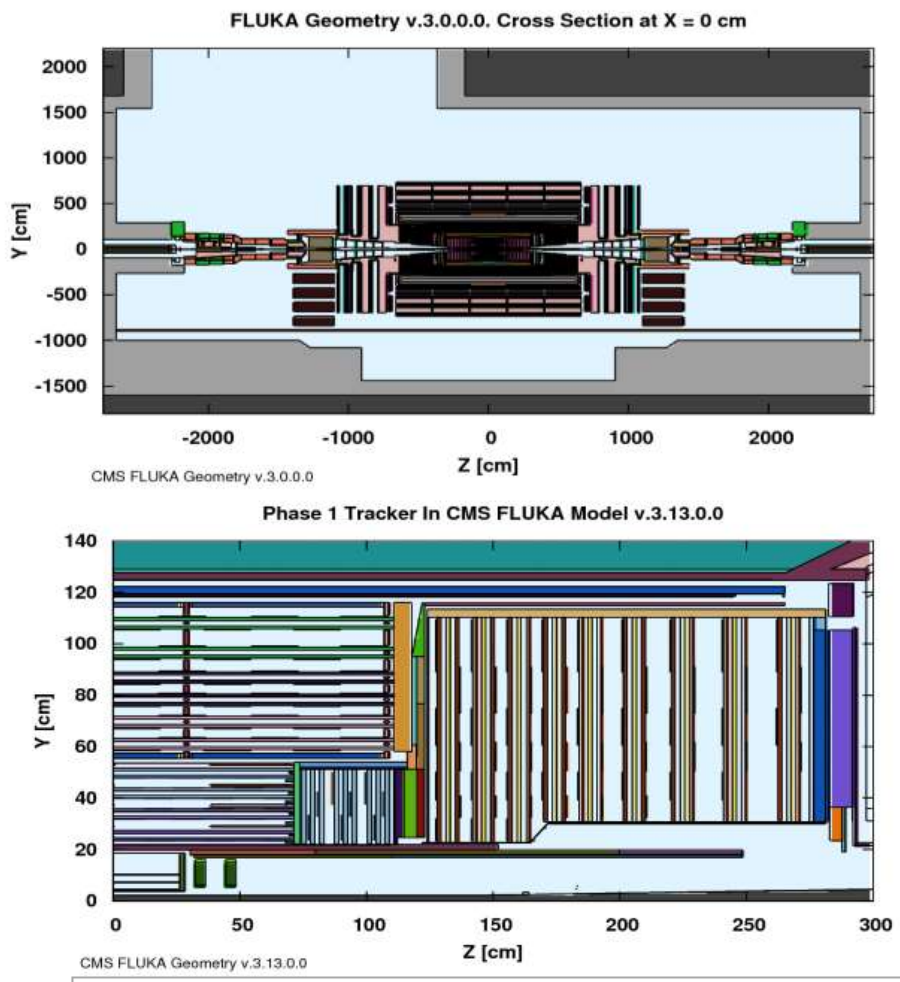
Introduction

It is important to predict the radiation levels for the CMS experiment at the LHC to determine the detector performance, longevity of materials and expected dose to personnel. Estimations, made with the use of Monte Carlo particle transport codes FLUKA [1],[2], and MARS [3], are made by the CMS Beam Radiation Instrumentation and Luminosity (BRIL) project. The simulation work highlighted for LHC Run II includes:

- Maintenance of the FLUKA & MARS CMS Models, including extensive geometry updates
- Development of tools to enable sharing of BRIL results and to enhance CMS FLUKA work
- Estimates of radiation levels due to collision induced and machine induced background
- Activation studies for planned interventions, which are made in collaboration with the CERN DGS/RP group.

Updates to the CMS FLUKA Model

- A version scheme was introduced by BRIL, for CMS FLUKA models, where new tag is given for every change to the input files that influences a result (simulation parameters and geometry updates, etc.).
- Geometry for latest 'Run II' CMS model includes:
  - Representation of upgrades during long shutdown: central beampipe and the newly installed fourth muon endcap disk
  - Recent improvements to the nominal model such as introduction of phi-asymmetric cavern elements, better modelling of gaps in the forward rotating shielding, detailed model of tracker
- A full list of updates with details can be found on the BRIL webpage [4].



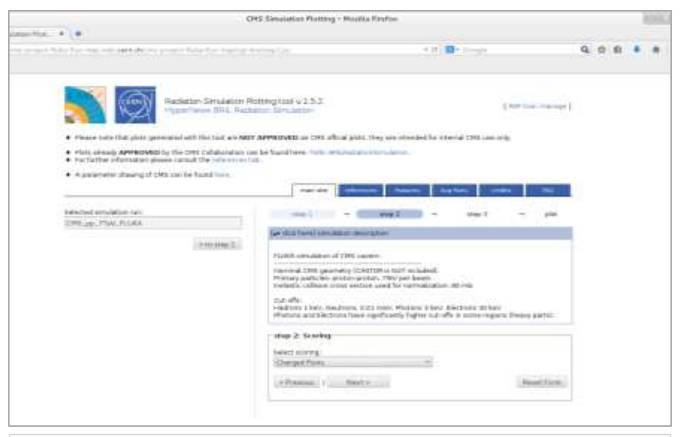
Example cuts through FLUKA model of the full CMS experiment and recently updated tracker region

Tools Developed by BRIL

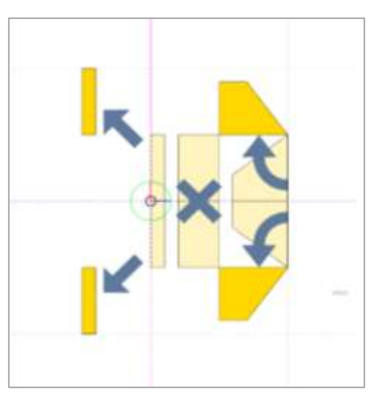
1. Web-based 'radiation simulation plotting tool' was created to enable CMS members to access BRIL simulation data and generate their own corresponding 2D 'flux maps' according to user-specified region, particle type, simulation parameter, [5].

2. FOCUS allows CMS users not familiar with FLUKA to perform simulations of proton-proton collisions and output a list of particles and their properties (time of arrival, coordinate, momentum, etc.) at a user specified boundary, [6].

3. SESAME is a tool for **FLUKA** that enables the separation of the prompt and decay simulation steps, and the transformation of the geometry model in between. This includes the ability to rotate, translate, remove and add (shielding) components, [7].



***1** RSP Tool which enables CMS users to produce their own plots*



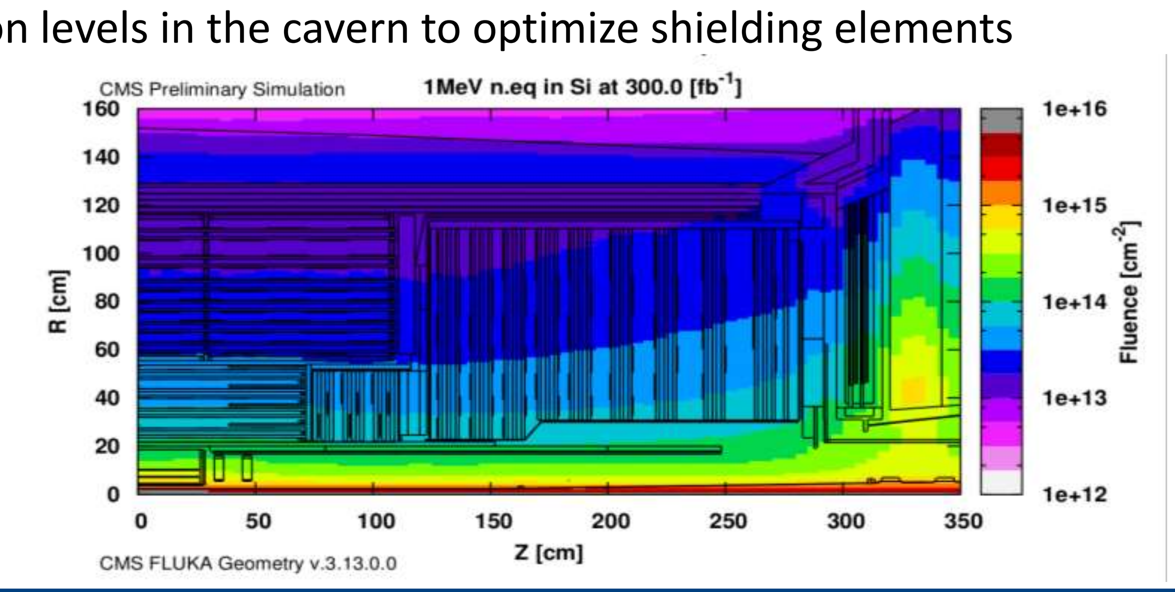
***3** SESAME enables the movement of components between FLUKA prompt and decay radiation steps*

a ;;

Collision Induced Radiation Levels

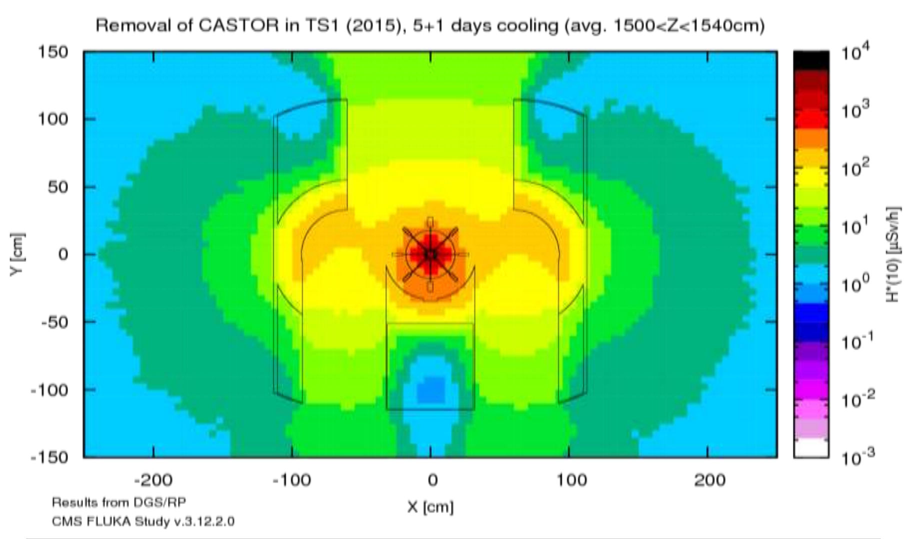
- Particle transport and collisions simulated with FLUKA to determine absorbed dose and particle fluxes over whole CMS cavern and particle spectra in specific regions.
- Examples of data applications:
  - Estimation of background particle rates on muon detectors
  - Prediction of radiation damage to pixel and strip tracker (1 MeV n-eq in silicon)
  - Estimation of particle flux and spectra at BRIL detector locations
  - Dose to various detector parts to predict radiation damage, such as optical fibers in the HF detector or scintillators in the hadronic calorimeter
  - Estimates of radiation levels in the cavern to optimize shielding elements

Estimation of the expected 1 MeV neutron equivalent fluence in Silicon in the Tracker Region for a total integrated luminosity of 300 fb^{-1}, Collisions from 7 TeV proton beams were simulated



Residual Radiation

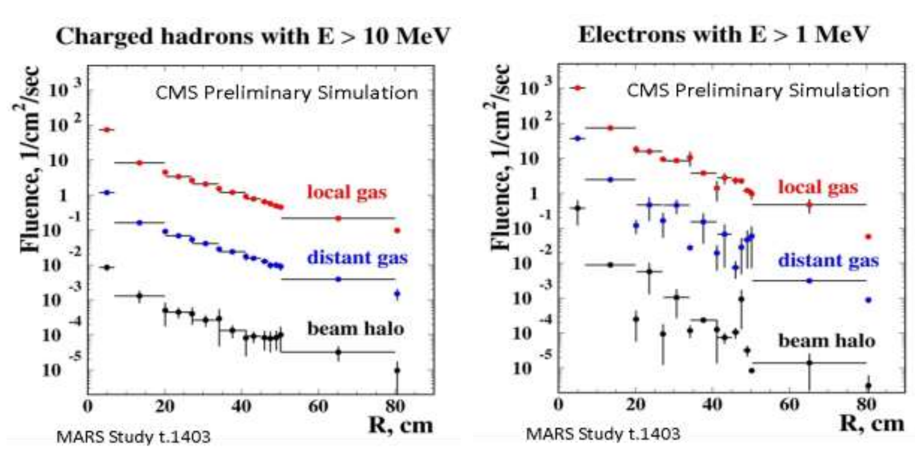
- Estimates of the residual radiation are an important part of the planning process for interventions.
- Activation simulations have been performed with FLUKA for several LHC Run II scenarios, for both closed (standard FLUKA) and open (with SESAME) CMS configurations.
- E.g. The predicted residual ambient dose equivalent rates were compared considering various CASTOR removal and reinstallation dates in 2015.



Simulation by DGS/RP: The plot shows the ambient dose equivalent rates, H(10), across the CASTOR detector with open rotating shielding and open collars after 6 days cooling in technical stop 1, TS1.. Results are based on an 'irradiation profile' with 1 fb^{-1} before Technical Stop 1, at 75% of peak luminosity 10^{34} cm^{-2}. Collisions from 6.5 TeV proton beams are simulated and an 80 mb inelastic cross section is assumed.*

Radiation Levels: Machine Induced Background

- Particle transport through CMS has been performed with the MARS code.
- The machine induced background MIB sources for local, distant and beam halo were calculated by various codes (Six Track, STRUCT, MARS and FLUKA). Local gas profiles are from [8] and normalizations from [9].
- The figures below show an example of the fluxes due to MIB in the region of the BRIL BCM1 detector.



Estimation of the MIB flux for nominal Run 2 LHC conditions (L = 10^{34} cm^{-2} s^{-1}, 7 TeV beams) at Z = 1.8 m from IP5 based on Monte Carlo simulations. MIB from Beam 2 is considered.

References

[1] A. Ferrari, P.R. Sala, A. Fasso`, and J. Ranft, "FLUKA: a multi-particle transport code", CERN 2005-10 (2005), INFN/TC_05/11, SLAC-R-773
[2] T.T. Böhlen, F. Cerutti, M.P.W. Chin, A. Fassò, A. Ferrari, P.G. Ortega, A. Mairani, P.R. Sala, G. Smirnov and V. Vlachoudis, "The FLUKA Code: Developments and Challenges for High Energy and Medical Applications", Nuclear Data Sheets 120, 211-214 (2014)
[3] I.Azhgirey & V.Talanov, in: Proc. of XVIII Workshop on the Charged Particles Accelerators, Protvino, 2000
[4] https://cern.ch/bril/SitePages/FLUKAstudies.aspx
[5] https://cern.ch/cms-fluxmap
[6] https://espace.cern.ch/cms-project-bril/SitePages/Radiation%20Simulation.aspx
[7] https://espace.cern.ch/cms-project-bril/SitePages/Sesame.aspx
[8] A. Rossi, Residual gas density estimations in the LHC IR1 & IR5 for different beam operations, LHC PR 783
[9] R. Bruce et al., NIM A 729 (2013) 825-840

Acknowledgments

We would like to thank CMS Technical Coordination, CMS Engineering Integration Office, the CMS ECAL and Tracker projects for their support of BRIL Radiation Simulation. We acknowledge H. Burkhardt, R. Bruce and A. Lechner for their assistance with the machine induced background studies. We would also like to thank C. Theis for his useful feedback on the SESAME tool.