ATLAS Muon Spectrometer cavern background

LPCC Simulation Workshop
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for the ATLAS Collaboration

Outline

- ATLAS Muon Spectrometer

- comparison of data and FLUGG simulation
  - … in the Inner Detector (before shielding)
  - … in the Muon Spectrometer

- modeling of the MDT hit rate

- comparison of …
  - … geometrical setups in Geant4 simulation
  - … FLUGG and Geant4 simulation

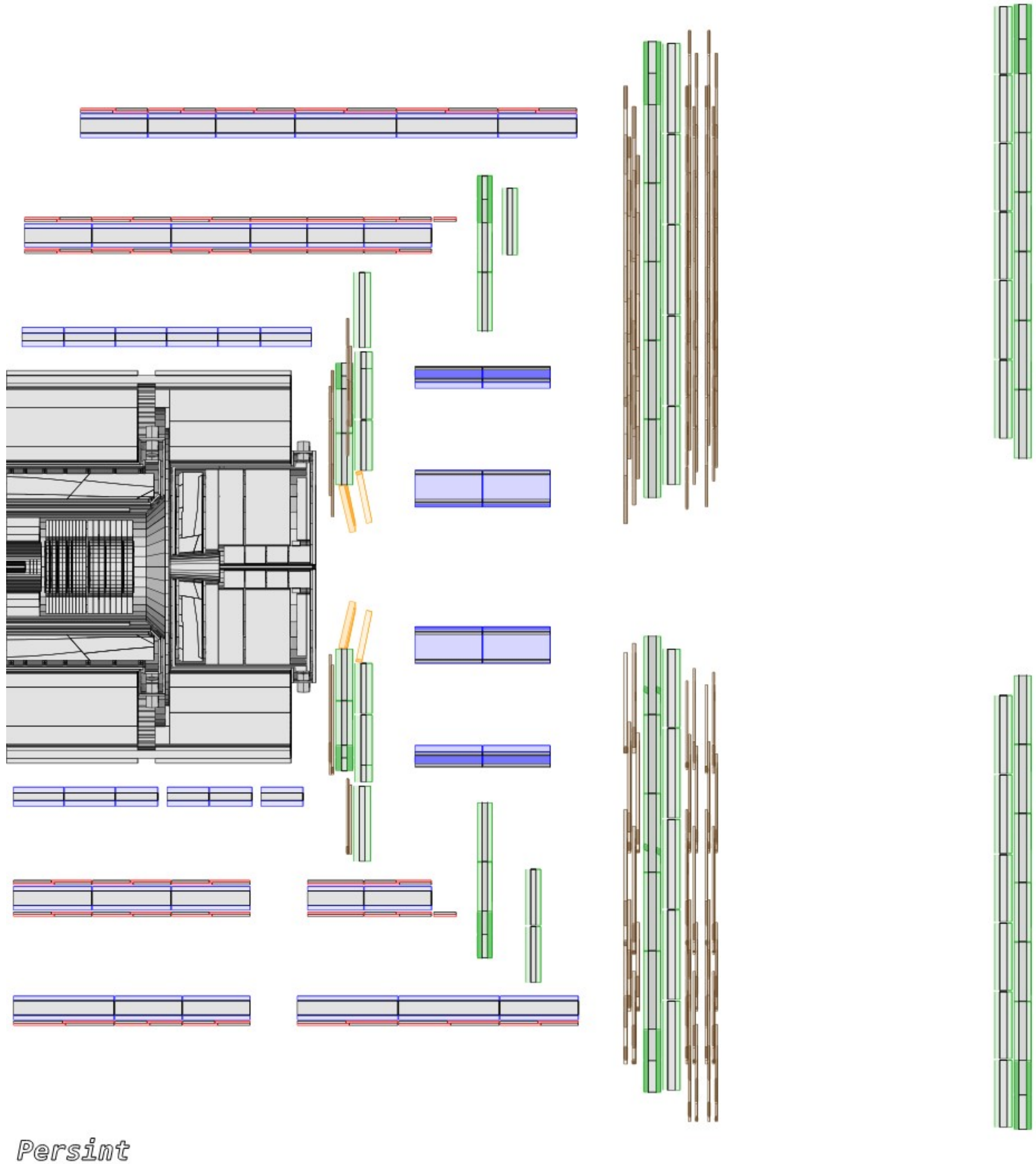
- FLUGG based study for 2015 beam-pipe

precision chambers:

- Monitored Drift Tubes:
  - MDT (barrel)
  - MDT (end cap)
- Cathode Strip Chambers CSC

trigger chambers:

- Resistive Plate Chambers RPC
- Thin Gap Chambers TGC



ATLAS Muon Spectrometer

toroidal magnets:

- barrel toroid coils
- end cap toroid

precision chambers:

- Monitored Drift Tubes:
  - MDT (barrel)
  - MDT (end cap)
- Cathode Strip Chambers CSC

trigger chambers:

- Resistive Plate Chambers RPC
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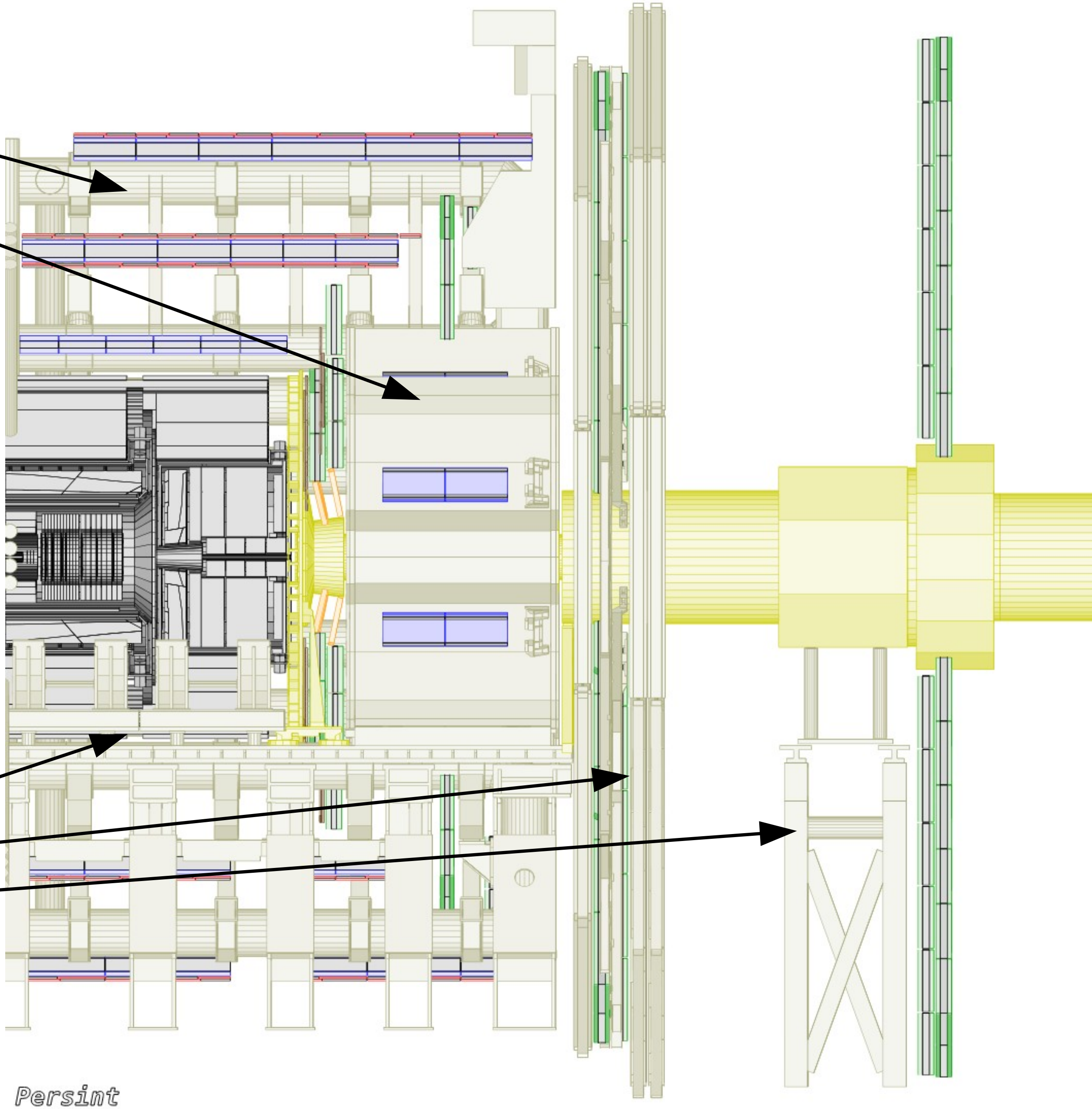
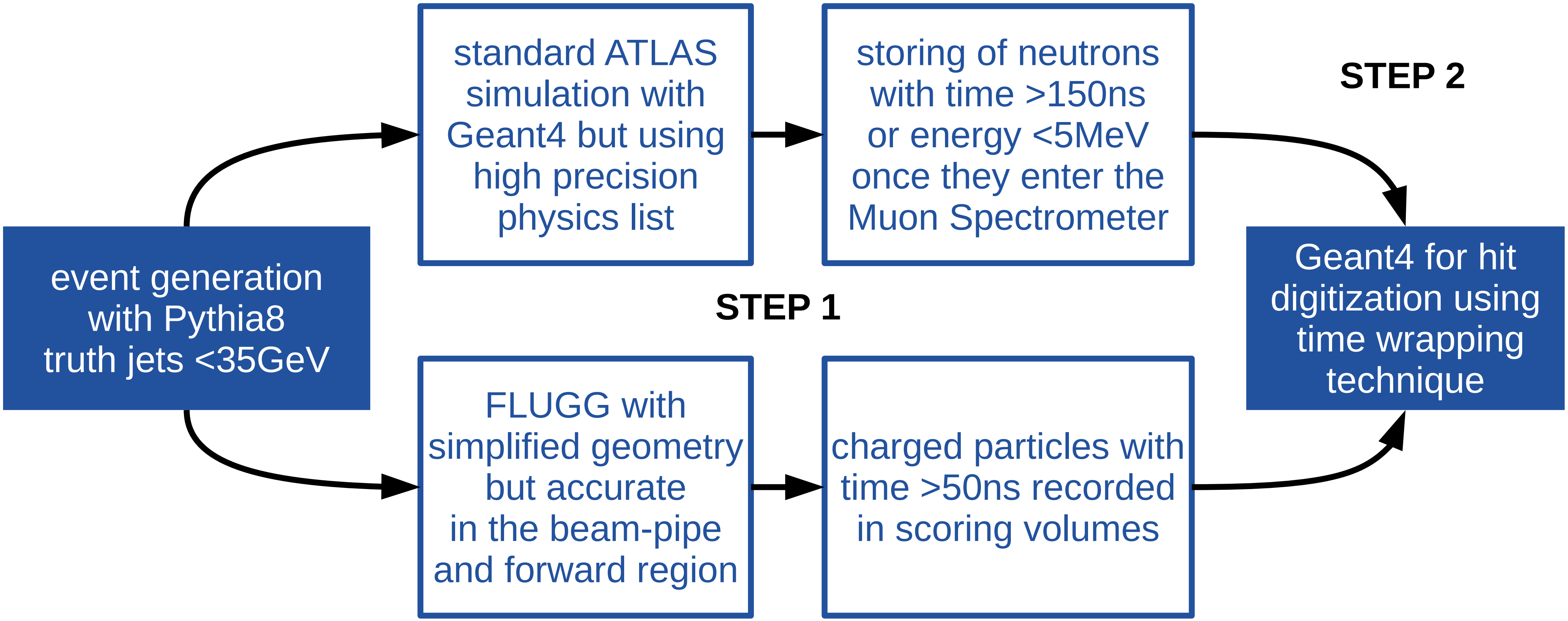
support structures

- feet with calorimeter saddle
- end cap chamber support
- shielding support
- …

shielding



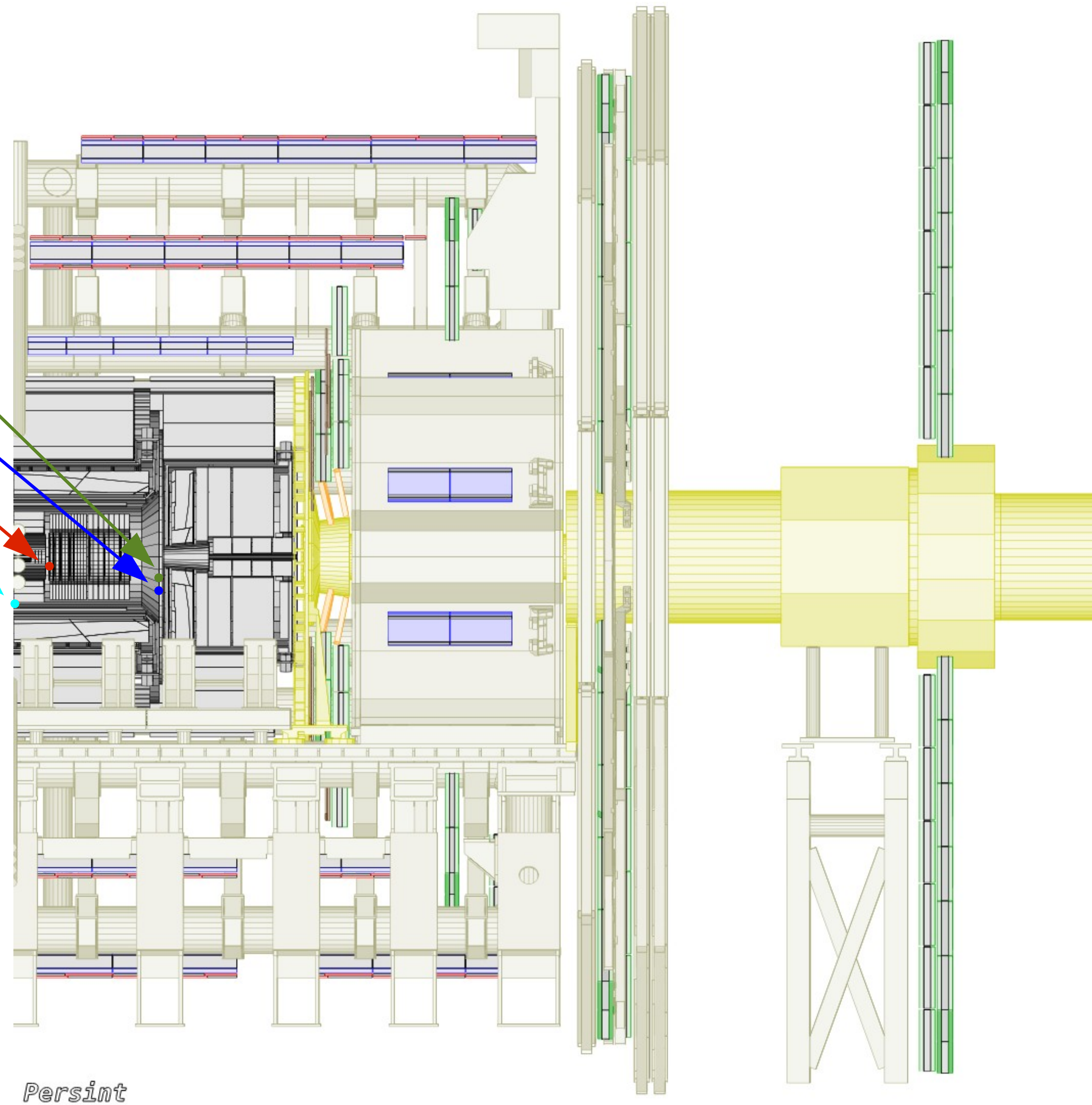
cavern background simulation approaches



- functionality is well understood and used for simulation of physics events
- alternative approach is overlay of real data (see talk by Andrew Haas)

comparison data and FLUGG simulation

- measurement of integrated radiation dose by 14 semi-conductor sensors in the inner detector region:
  - 4x at r=54cm, |z|=345cm
  - 4x at r=80cm, |z|=345cm
  - 4x at r=23cm, |z|=90cm
  - 2x at r=110cm, |z|=0cm



- provided information is the non-ionizing energy loss (NIEL) and the total ionizing dose (TID)

- precision of installed measurement system is about 20%

comparison to FLUGG based stand-alone simulation:

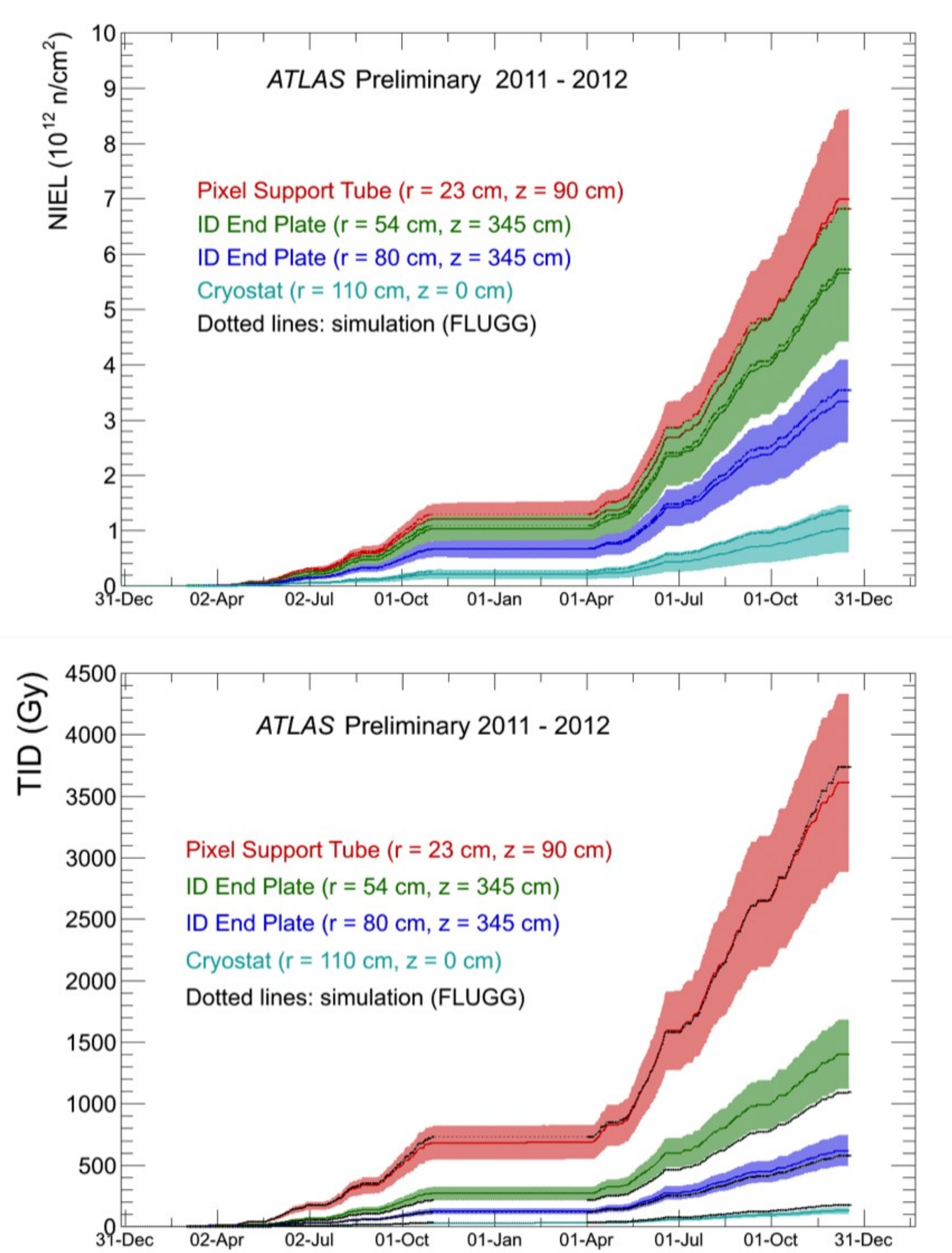
- 7TeV and 8TeV center of mass energy
- 10x 10000 events samples per energy

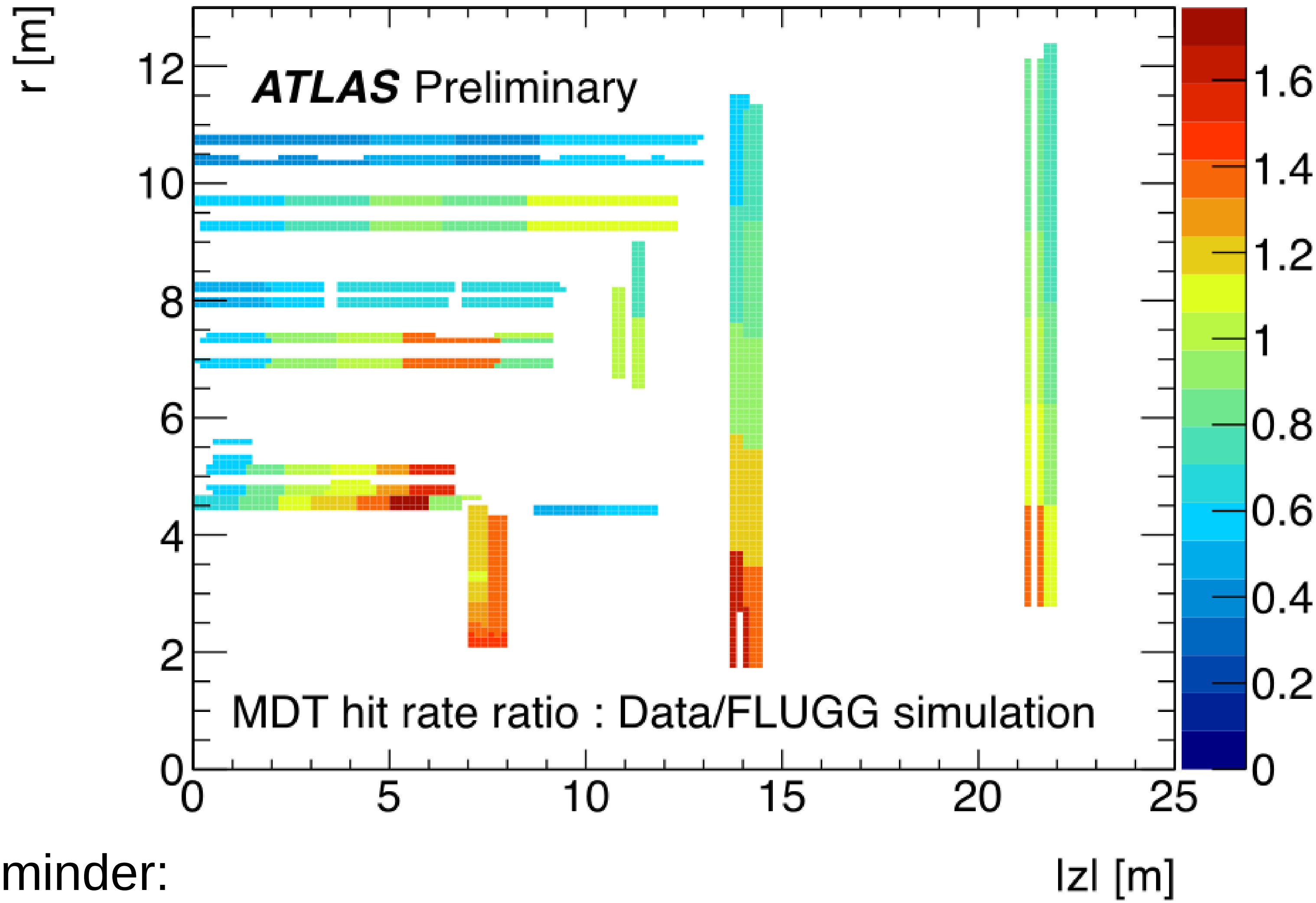
first checks interior of any shielding:

- shaded area shows the RMS with 20% systematic error added in quadrature
- comparison of the NIEL (top) and TID (bottom)

good agreement between data and simulation

- significantly better than 20% systematic uncertainty
- outlayer is the TID for r=54cm with a difference of about 30%



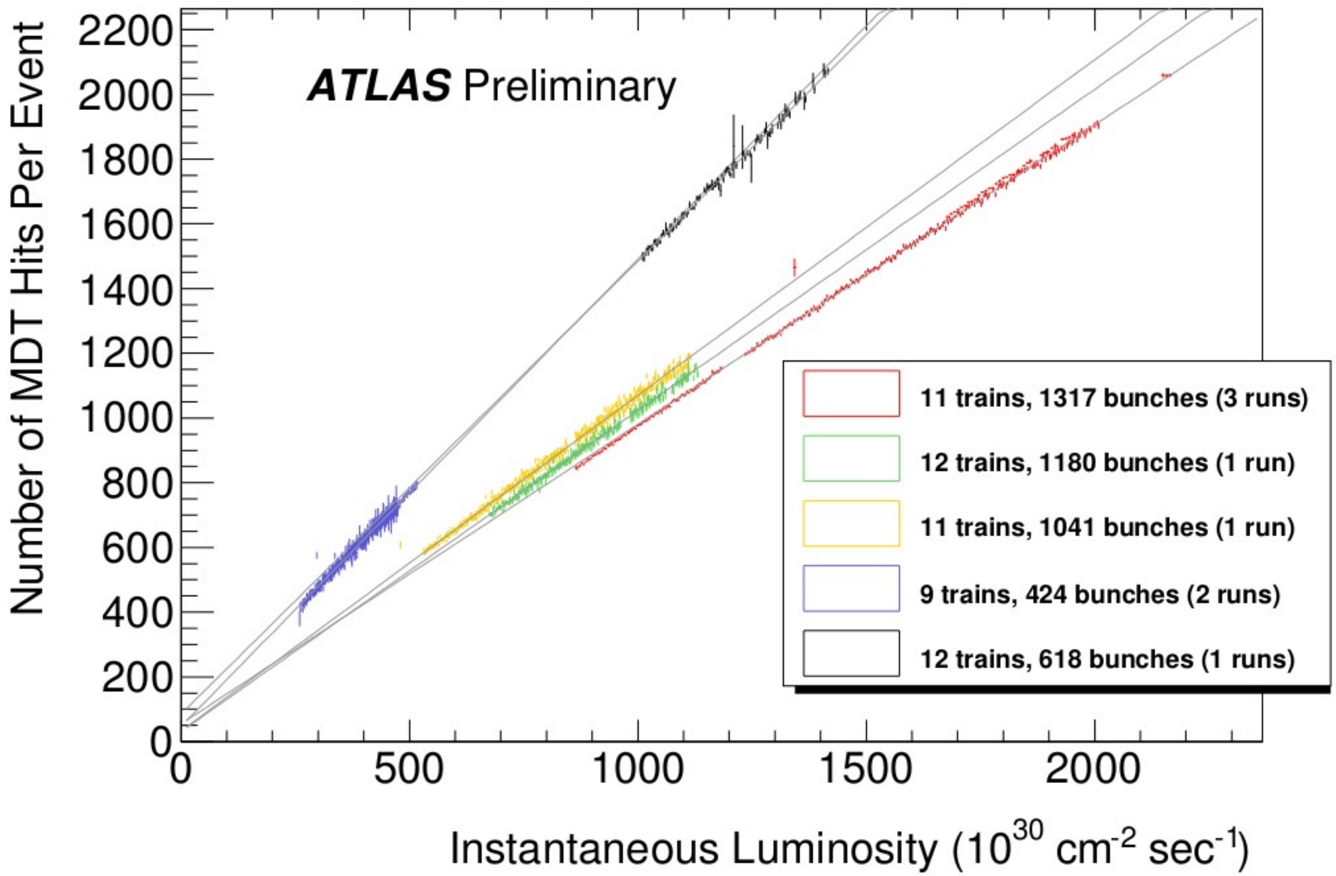


Reminder:

- MDT hit rate (= flux ⊗ sensitivity) in data compared to FLUGG based simulation (sensitivity is assumed from data)
- agreement within a factor of 2 everywhere in MDT chambers

MDT hit rate modeling

- for runs with same bunch structure the MDT hit rate grows linearly with the instantaneous luminosity
- accordingly hit rates of different runs with the same bunch structure line up
- once the hit rate for a run with a certain filling is known it is possible to predict the rate for any instantaneous luminosity for this particular filling



- for higher number of bunches the lines become more flat because more than one collision is recorded by one MDT readout cycle which takes place every 2500ns function to model a single collision

$$N_{hits}(t) = C \cdot \left(\underbrace{B_1 \cdot \frac{1}{\tau_s} \cdot exp\left(-\frac{t-t_i}{\tau_s}\right)}_{\text{short-lived component}} + \underbrace{B_2 \cdot \frac{1}{\tau_l} \cdot exp\left(-\frac{t-t_i}{\tau_l}\right)}_{\text{long-lived component}} \right)$$

C → normalization factor depending on instantaneous luminosity

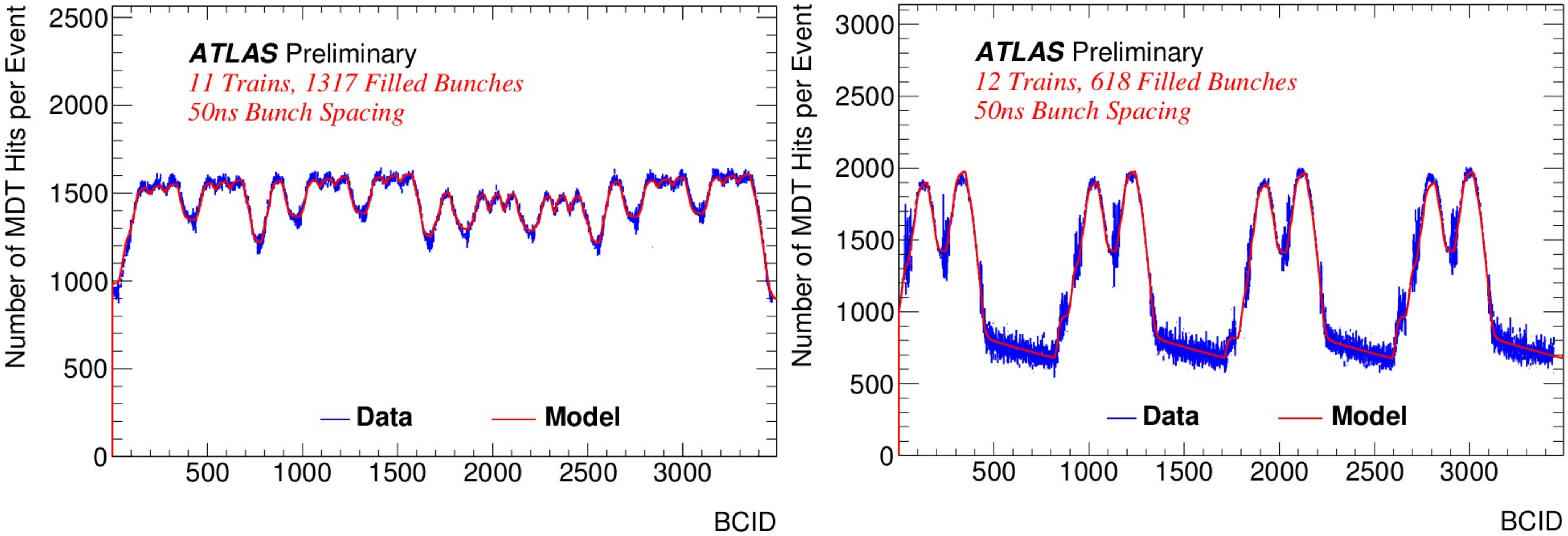
parameters fixed by fit to data

- short-lived component: $\tau_s = 300\text{ns}$ $B_1 = 36\%$
- long-lived component: $\tau_l = 50\mu\text{s}$ $B_2 = 64\%$ ← cavern background

summing over the hits made by each filled bunch the MDT hit distribution vs time can be predicted

after convoluting the result with a 2500ns step function (MDT readout cycle) a distribution vs BCID can be derived

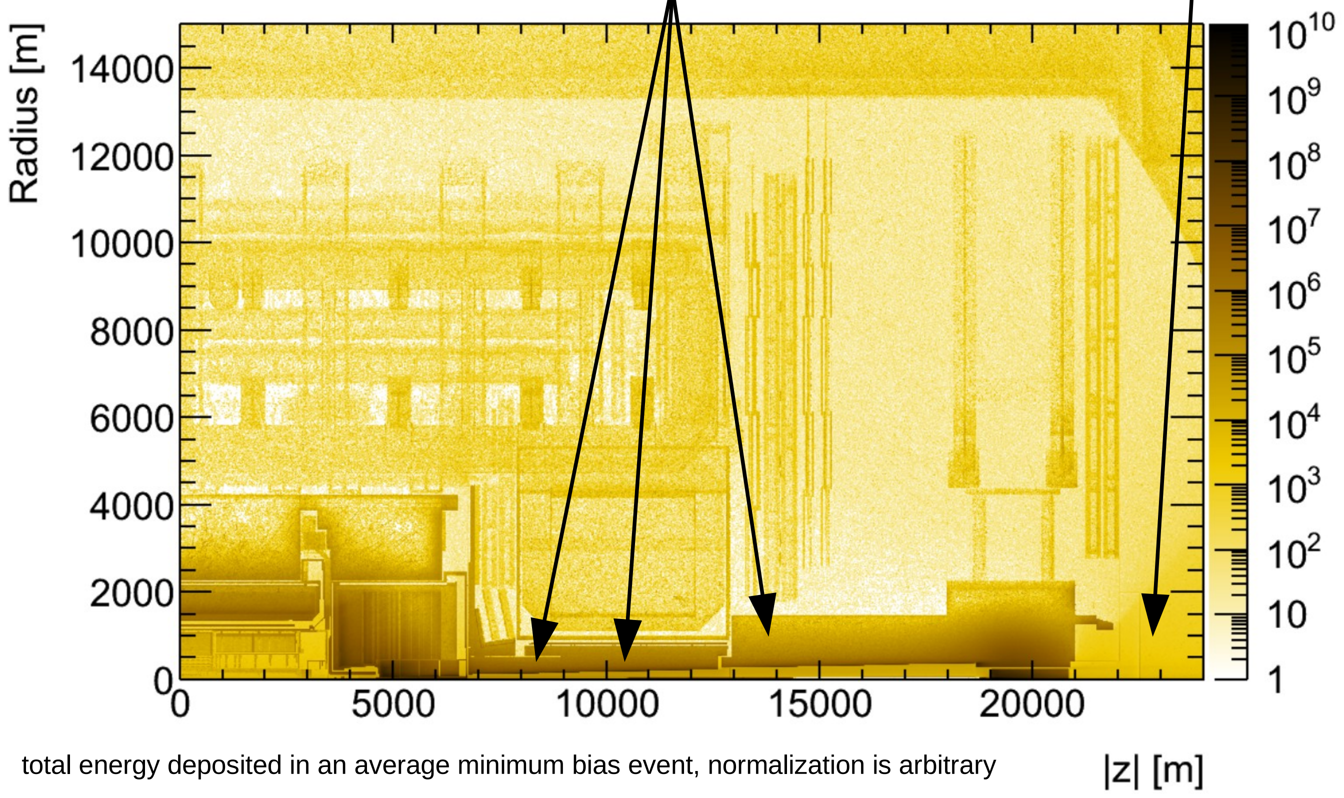
MDT hit rate modeling



- figures above show the model fitted to two runs of 2011 data with different bunch configurations (on the left half the LHC ring is empty)
- with a known peak hit rate the model can predict hit rates from one bunch structure to another with an accuracy of 8% in the MDT chambers with highest rates (inner end cap chambers closest to beam pipe) and even better for remaining chambers
- it can be predicted how much the lines on slide 9 differ

comparison of FLUGG and Geant4

- first realizings of comparing Geant4 to FLUGG geometry :
  - unrealistic gap between shielding and cavern wall has to be closed
  - uniform material used in shielding system has to be changed to iron with polyboron/lead cladding



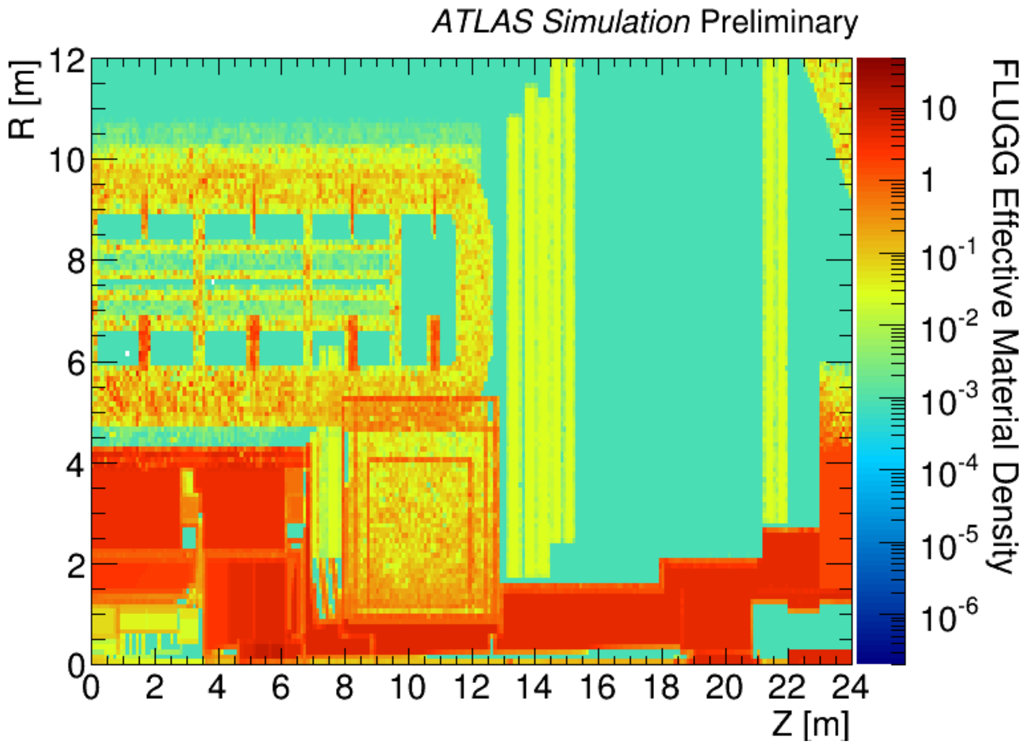
total energy deposited in an average minimum bias event, normalization is arbitrary

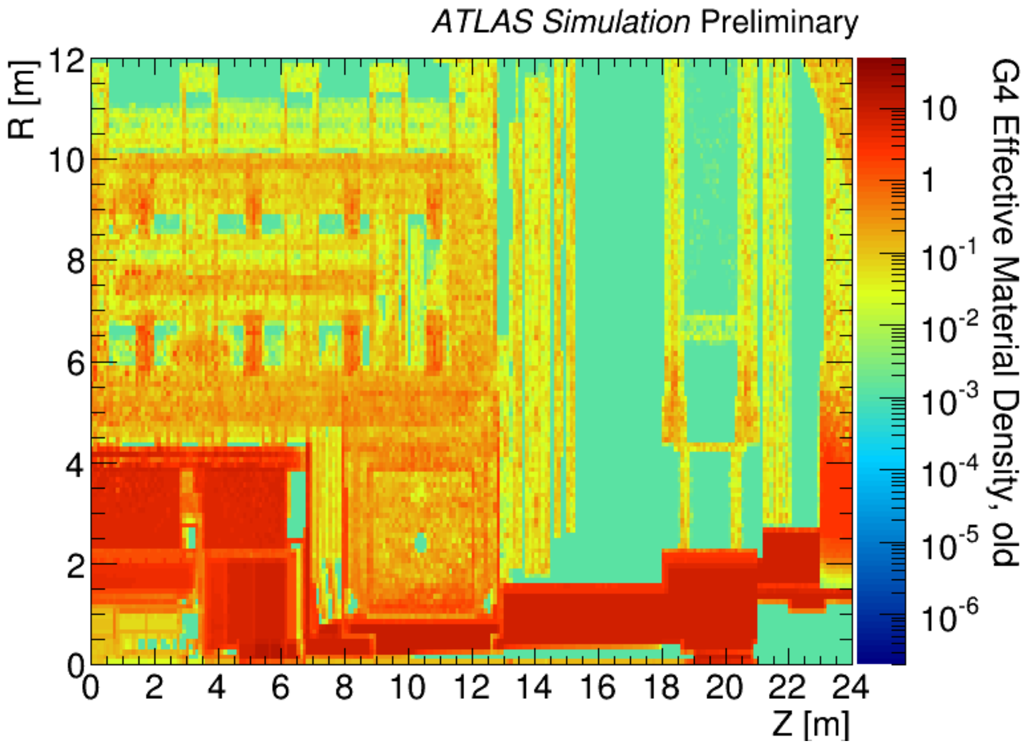
- collateral efforts in comparing Geant4 geometry to information form engineers
- use of high precision physics list (QGSP_BERT_HP) is essential for Geant4

- comparison of simplified FLUGG geometry and Geant4 geometry used in simulation of physics events
- studied quantity is

$$\text{effective material density [mass/volume]} = \frac{\text{energy deposition [energy/volume]}}{\text{dose [energy/mass]}}$$

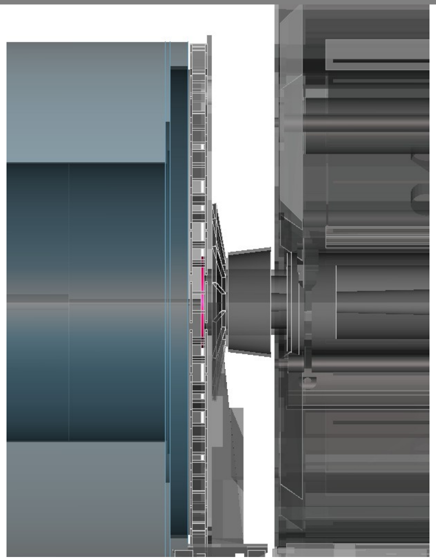
- remaining differences are missing feet, shielding support and further small structures inside the Muon Spectrometer of the FLUGG geometry

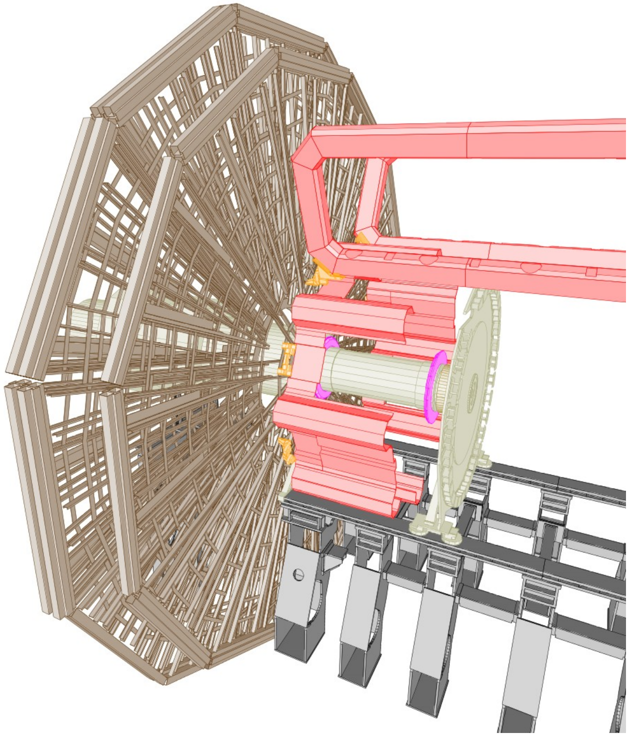


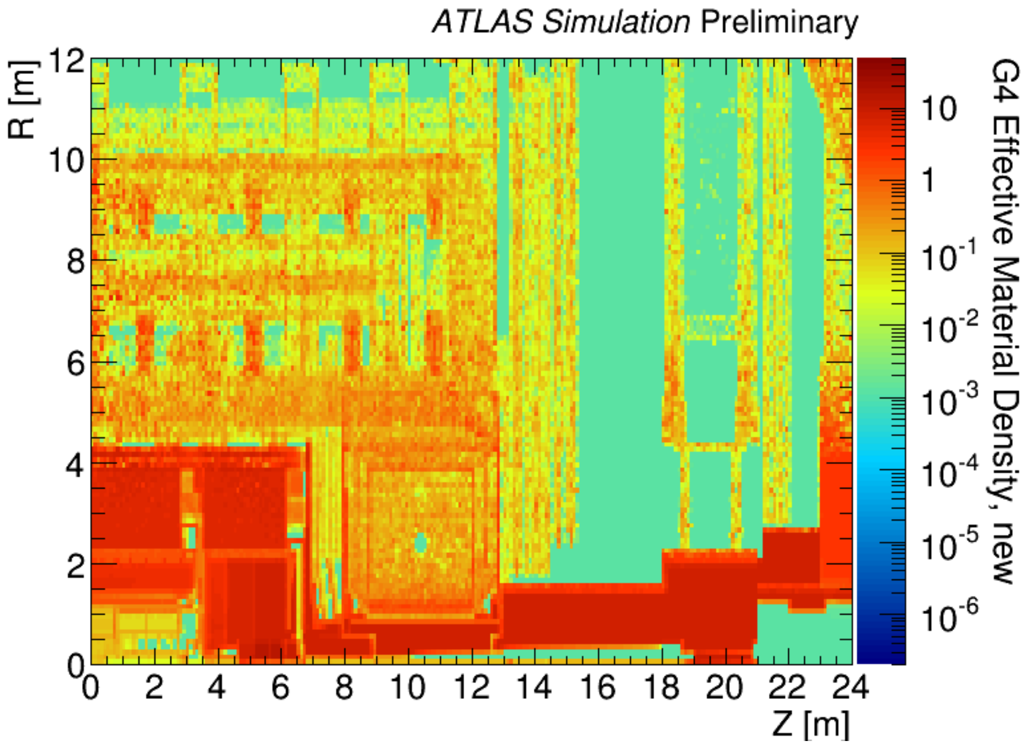


major updates of the Geant4 geometry:

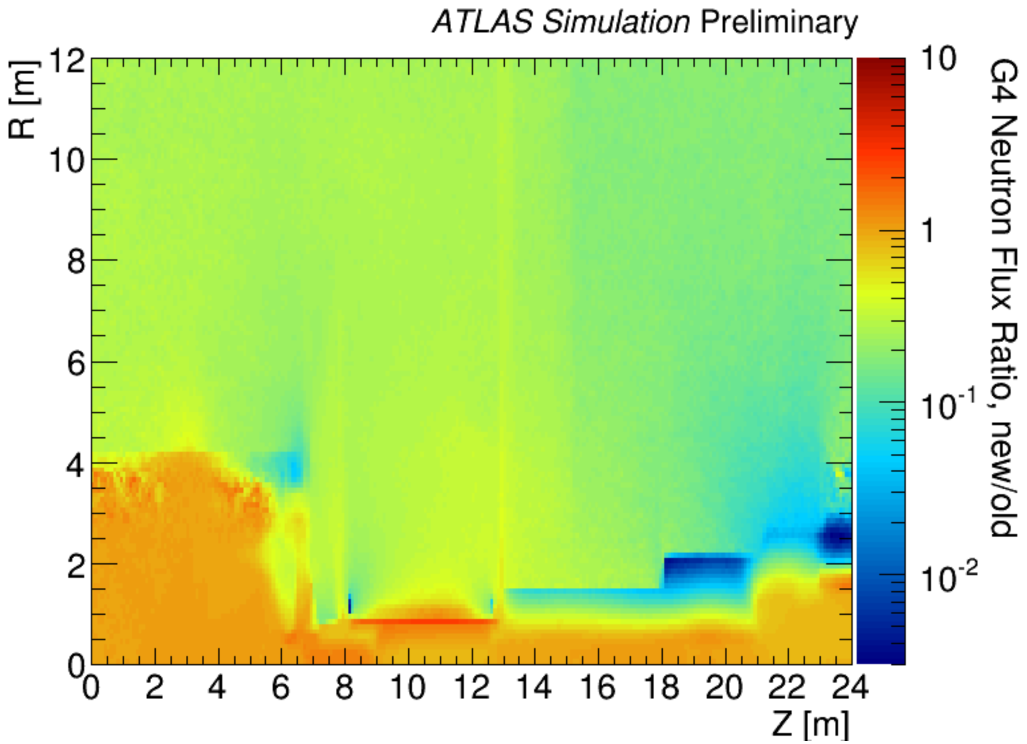
- thermal shielding for all toroid coils (red)
- additional shielding inside end cap toroid (magenta) at |z|≈9m and |z|≈13m and r≈1m
- reimplemented end cap support (brown) at |z|≈14m
- calorimeter crates at |z|≈3.5m and r≈6.5m
- shielding installed during winter shutdown 2011/2012 at |z|≈6.5m and r≈1m

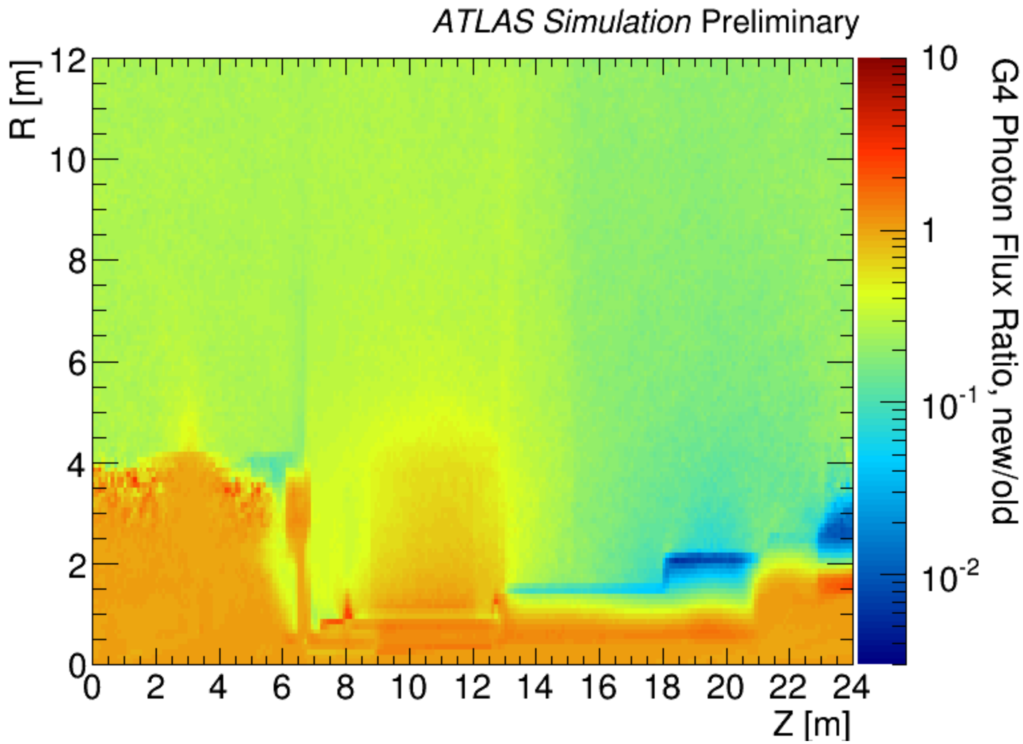




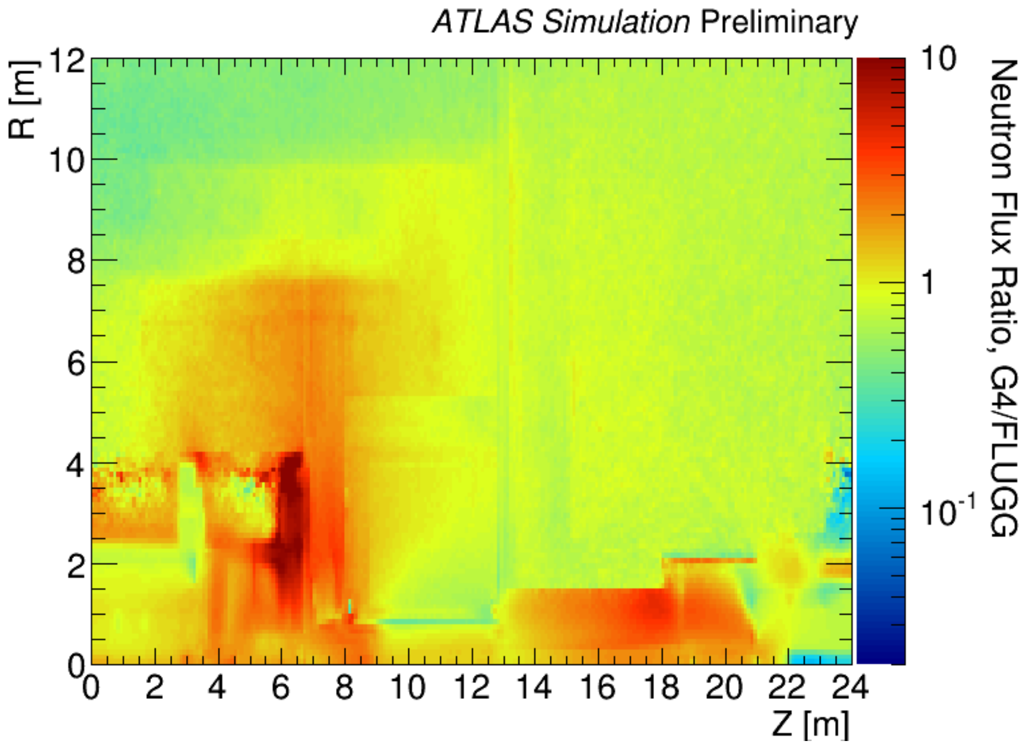


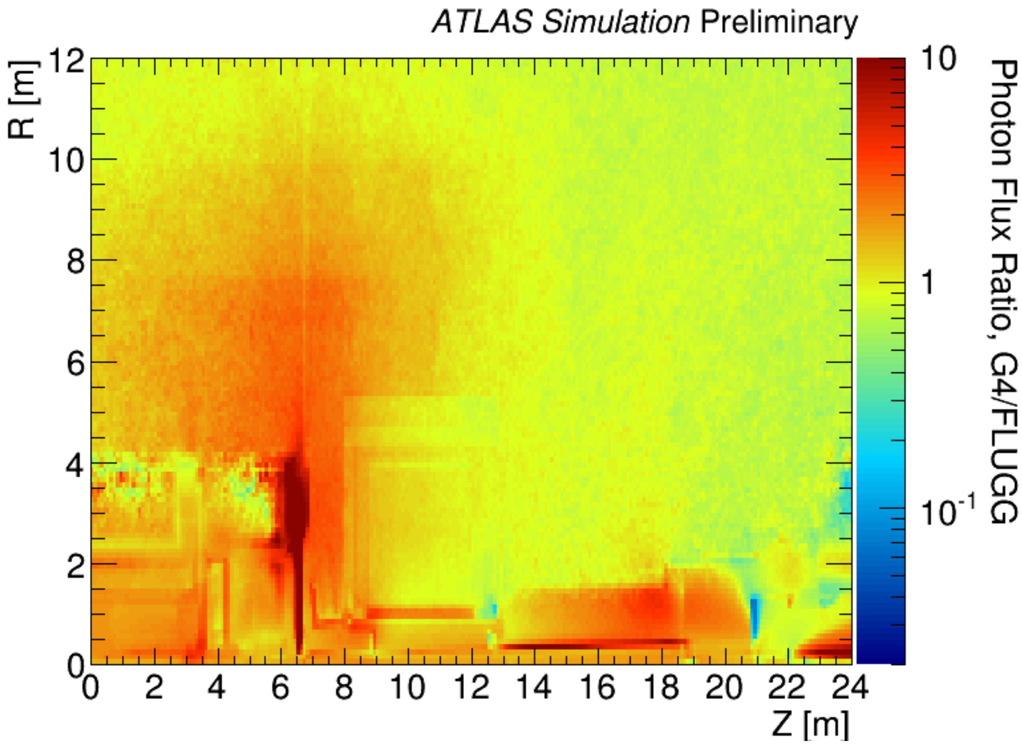
- ratio of neutron flux (left) and photon flux (right)
- significantly reduced flux in the Muon Spectrometer due to updated shielding system which now includes polyboron cladding
- reduction of photon flux at |z|≈6.5m caused by the additionally Installed shielding well visible





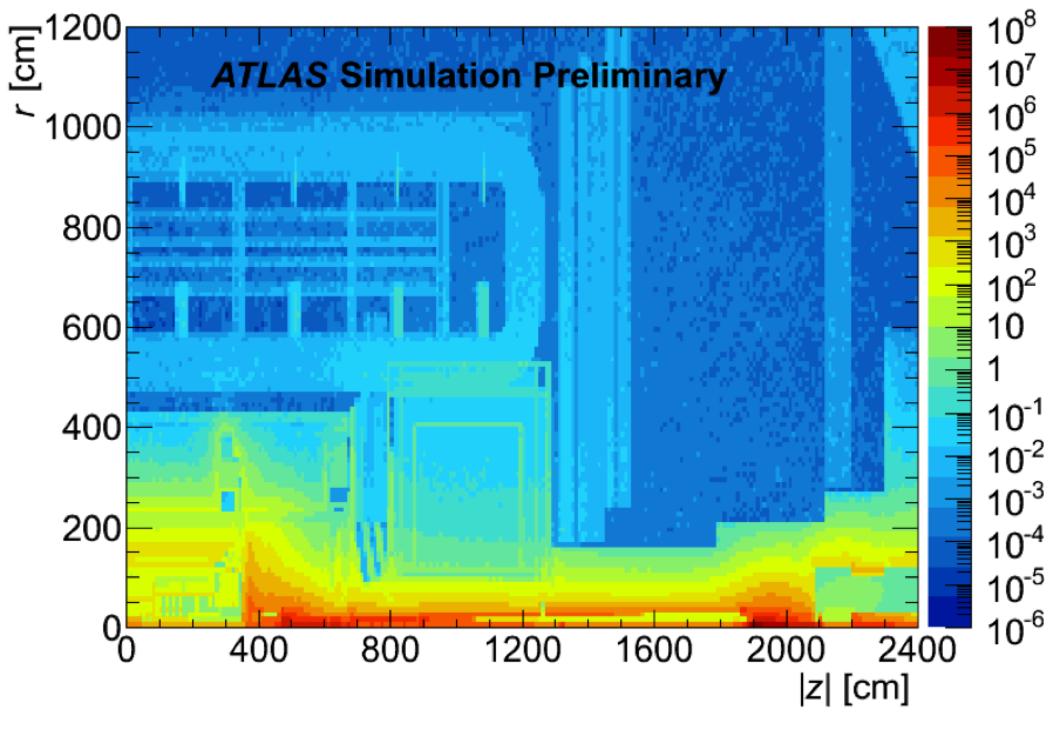
- neutron flux (left) and photon flux (right) simulated with Geant4 divided by corresponding flux simulated with FLUGG
- fairly good agreement in the bulk of the muon system where FLUGG differs from data at a factor of 2 (slide 7)

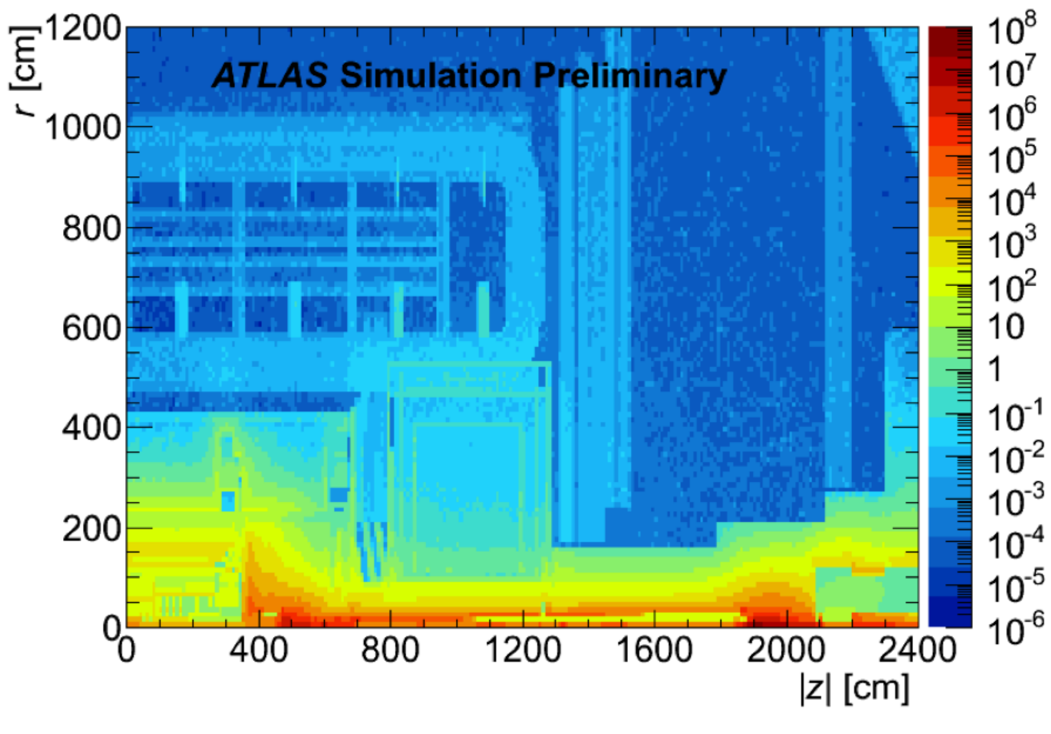




FLUGG based study of 2015 geometries

- FLUGG based simulation of current energy deposition (left) and energy deposition with new beam-pipe to be installed with the insertable *B*-layer (right) in units of Gy/cm^3/s
- energy deposition is reduced by 30-40% visible all over the displayed volume





Summary

- agreement of FLUGG based simulation and data in the Inner Detector region is of the same size like the uncertainty of the measurement

- existing models to describe the MDT hit rate depending on the instantaneous luminosity and the time structure can reproduce actual data with good accuracy

- updates of the Geant4 geometry reduced fluxes sizable (modified geometry has also visible impact on simulated resolution in the Muon Spectrometer due to additional multiple scattering – not shown here)

- agreement of FLUGG based predictions of cavern background in the Muon Spectrometer and corresponding predictions by Geant4 are of the size of agreement between FLUGG and data

- studies of 2015 geometrical setup using FLUGG