ATLAS Muon Spectrometer cavern background

LPCC Simulation Workshop
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• 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
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
- Thin Gap Chambers TGC

support structures
- feet with calorimeter saddle
- end cap chamber support
- shielding support
- ...

shielding
cavern background simulation approaches

- event generation with Pythia8 truth jets <35GeV
  - standard ATLAS simulation with Geant4 but using high precision physics list
  - FLUGG with simplified geometry but accurate in the beam-pipe and forward region

STEP 1

- storing of neutrons with time >150ns or energy <5MeV once they enter the Muon Spectrometer
  - charged particles with time >50ns recorded in scoring volumes

STEP 2

- Geant4 for hit digitization using time wrapping technique

- functionality is well understood and used for simulation of physics events
- alternative approach is overlay of real data (see talk by Andrew Haas)
measurement of integrated radiation dose by 14 semiconductor sensors in the inner detector region:
- 4x at \(r=54\text{cm}, |z|=345\text{cm}\)
- 4x at \(r=80\text{cm}, |z|=345\text{cm}\)
- 4x at \(r=23\text{cm}, |z|=90\text{cm}\)
- 2x at \(r=110\text{cm}, |z|=0\text{cm}\)

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 $\otimes$ sensitivity) in data compared to FLUGG based simulation (sensitivity is assumed from data)
- agreement within a factor of 2 everywhere in MDT chambers
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

\[ N_{\text{hits}}(t) = C \cdot \left( B_1 \cdot \frac{1}{\tau_s} \cdot \exp\left(-\frac{t-t_i}{\tau_s}\right) + B_2 \cdot \frac{1}{\tau_l} \cdot \exp\left(-\frac{t-t_i}{\tau_l}\right) \right) \]

short-lived component

long-lived component

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: \( \tau_l = 50\mu\text{s} \) \( B_2 = 64\% \)

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
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
The first realizations 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.

Collateral efforts in comparing Geant4 geometry to information from 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 \(|z|\approx 9\)m and \(|z|\approx 13\)m and \(r\approx 1\)m
- reimplemented end cap support (brown) at \(|z|\approx 14\)m
- calorimeter crates at \(|z|\approx 3.5\)m and \(r\approx 6.5\)m
- shielding installed during winter shutdown 2011/2012 at \(|z|\approx 6.5\)m and \(r\approx 1\)m
- 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 $|z|\approx 6.5$ m 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
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