Simulation of the MoEDAL-MAPP experiment at the LHC

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MoEDAL experiment

• The prime motivation of the experiment is to search directly for the magnetic monopole and other exotic particles that would indicate new physics beyond the Standard Model

• The experiment is installed in the same cavern with LHCb experiment at IP8

• The experiment consists of several mostly passive detector subsystems
  • Nuclear Track Detectors (NTD)
  • Monopole Trapping Detectors (MMT)
  • Timepix detectors
MoEDAL-MAPP

• For the Run 3 of the LHC, the experiment is upgraded to MoEDAL-MAPP (MoEDAL Apparatus for Penetrating Particles)

• This extends the physics programme to searches for minimally ionizing and long-lived particles
mCP Detector

• The first new implementation of the MAPP detectors will be the mCP detector

• This is a scintillator detector which would respond to mCP particles traversing the sensitive volume

• The detector consists of 400 (10 x 10 x 75 cm) scintillator bars in four sections

• The detector is placed at about 100 meters from the interaction point and it is shielded by tens of meters of rock
Simulation of the UA83, MoEDAL, MAPP-mCP Arena (SUMMA)

- The simulation model is built with standard Geant4 classes
  - Version 11.0 and above is used
- The model depends only on a few external packages
  - All within default installations
  - xerces-c (gdml parser), ROOT (for the analysis of the ntuples), Pythia8 (primary interactions)
Primary particles

• Primary particles can be produced either with Geant4 native particle gun and general particle source generators, or with Pythia8 interpreter by using LHE event files

• Position of the sensitive volumes is used to select the primary particles for tracking
  • Particles heading to ”wrong” direction are killed

• A cone of particles is generated
Exotic particles

- MAPP is designed to search for millicharged, long lived and other exotic particles
- Geant4 allows to create new particles with unique properties which can be used as primary particles coming from the IP
- However, the MAPP region behaves as a beam dump experiment, and thus there will be an additional source of exotics coming from the collisions between the ground layer and the detector
  - Will create a boost to millicharged particle production via bremsstrahlung and decays of secondary mesons
  - Similar tracking to primary particles is required
  - If the decay product or the secondary particle is of interesting type, the trajectory is calculated
    - If it points to sensitive detectors, track is created

Geometry

- All elements of the model are imported from CAD drawings with CAD to GDML converter and read in with the G4gdmlparser
- The geometry model is divided in subsections based on the LHC naming conventions
- In total, over 5000 elements are included in the full model
- Direct conversion would result in file sizes over 100 MB with total size of over 6 GB
  - Time and memory consuming to pass to simulations
  - Lot of optimization is required
• The geometry holds a modular structure.
• The detectors are defined in standalone modules, while the machine components are placed under their locations.
Geometry model

47 m of ground, tunnel wall and shielding materials between the IP and the detector.

- 39.5 m
- 0.5 m
- 4.5 m
- 2.0 m
- 0.5 m
Detector response and extensions

• The detector response is based on the sensitive volumes
  • By default, only the scintillator bars of the mCP-detector are set sensitive
  • Array of detectors with individual ntuples for each bar
  • Optical physics is not applied by default
  • Can use output files as an input for light yield calculations
• More elements can be set sensitive through macros or by default
• The sensitive detectors can be set with the GDML files
  • The sensitive detectors are created automatically when the geometry is built
• New ROOT files are generated for each sensitive detector with hits
Cosmic background radiation

- For the rare decays, the rate of the cosmic background radiation is important
- MAPP is protected by over 100 meters of rock overburden
  - Reduces the background but is not sufficient to stop high energy muons
- Additional volume with the material properties of the overburden can be switched on
Summary

• SUMMA simulation model is developed to study exotic physics in the MoEDAL-MAPP detectors
• The model utilizes modular geometry structure and allows adding new elements from CAD design
• Interfacing to different particle generators is done with LHE files, but might be changed to direct calls in the future
• The secondary particles are tracked by selection of the user
• Detector response can be selected with use