Simulation of the MoEDAL-MAPP experiment at the LHC

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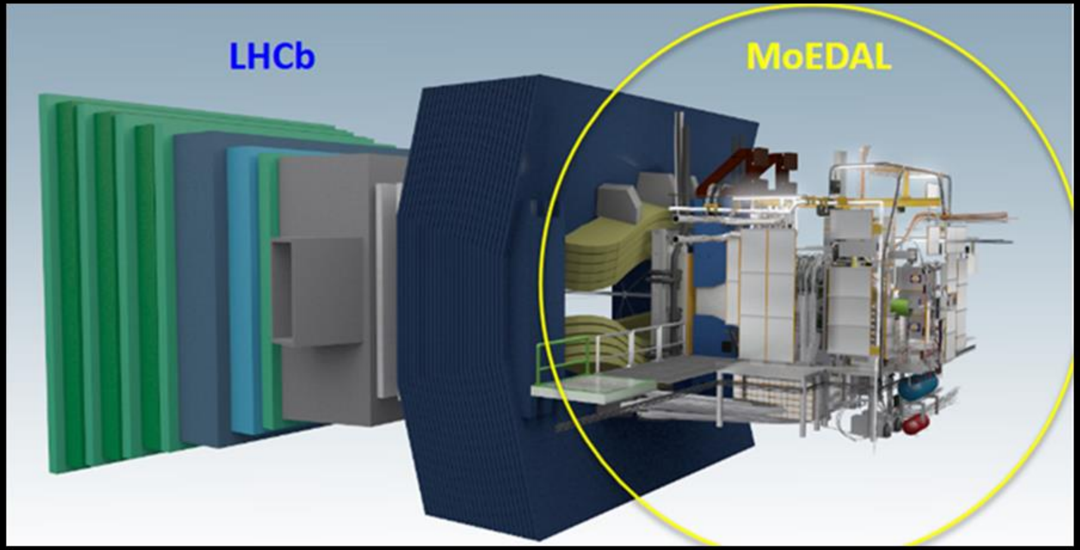
MoEDAL experiment

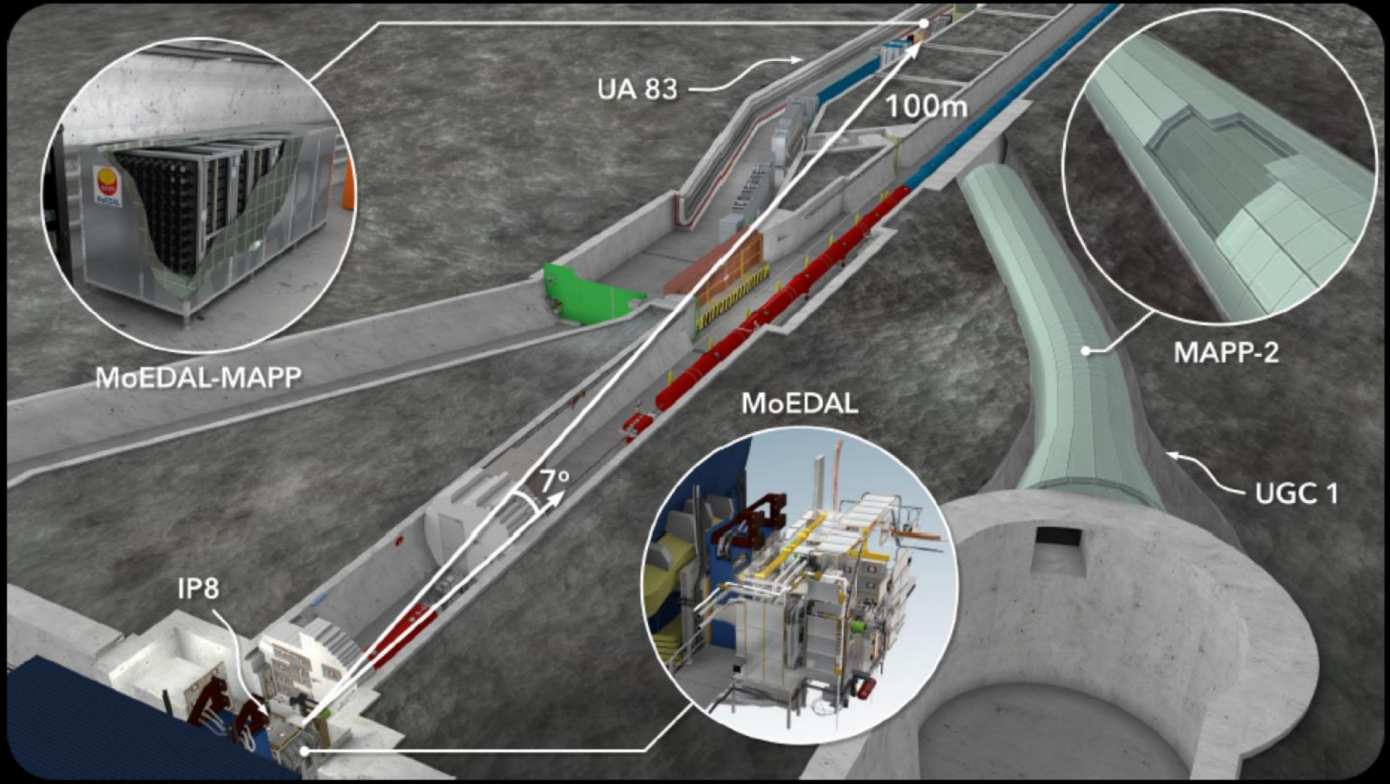
- The prime motivation of the experiment is to search directly for the magnetic monopole and other exotic particles that would indicate new physics beyond the Standard Model
- The experiment is installed in the same cavern with LHCb experiment at IP8
- The experiment consists of several mostly passive detector subsystems
  - Nuclear Track Detectors (NTD)
  - Monopole Trapping Detectors (MMT)
  - Timepix detectors



"*MoEDAL physics program*", Int. J. Mod. Phys. A29 (2014) 1430050

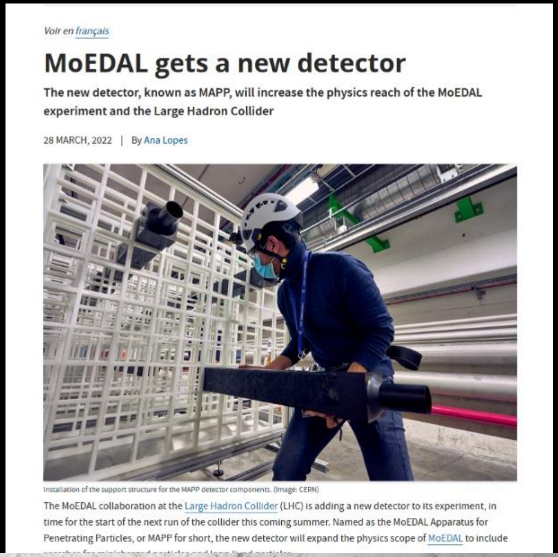
MoEDAL-MAPP

- 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



Voir en français

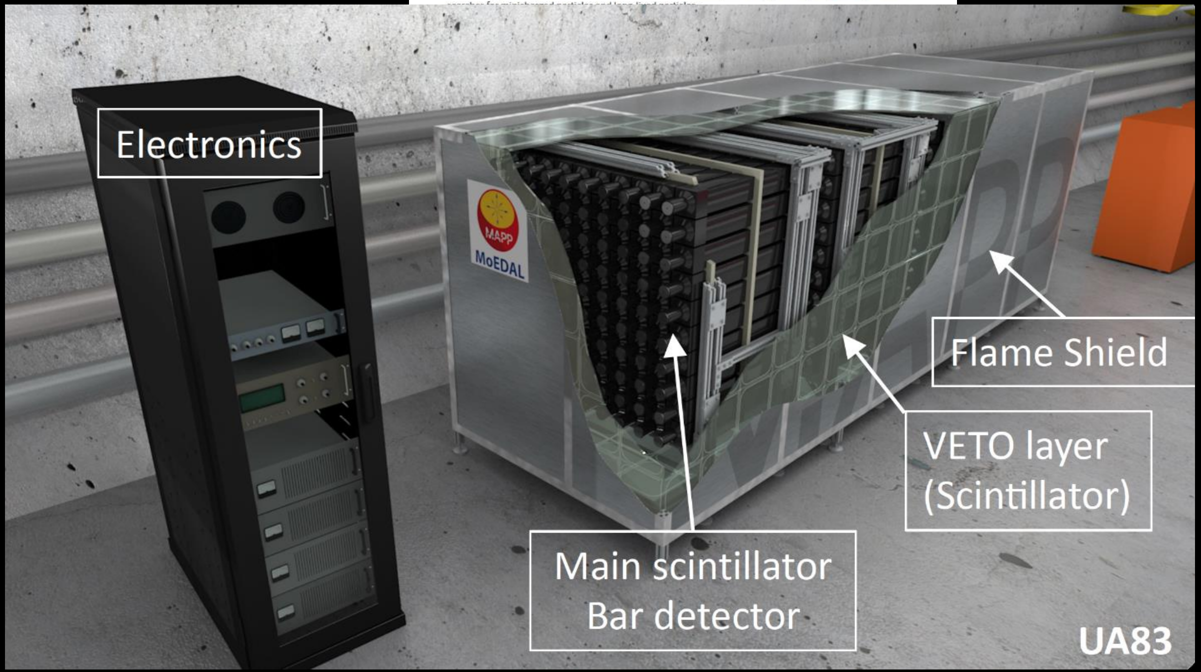
MoEDAL gets a new detector

The new detector, known as MAPP, will increase the physics reach of the MoEDAL experiment and the Large Hadron Collider

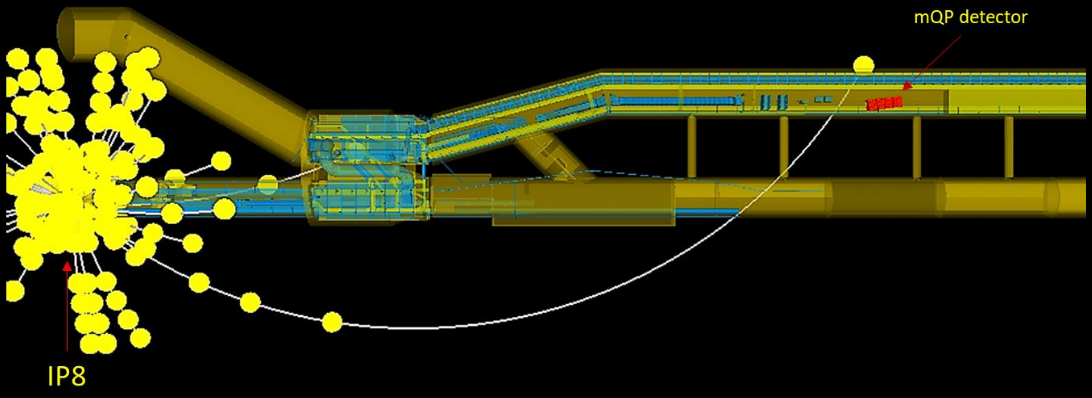
28 MARCH, 2022 | By Ana Lopes

Installation of the support structure for the MAPP detector components. (Image: CERN)

The MoEDAL collaboration at the Large Hadron Collider (LHC) is adding a new detector to its experiment, in time for the start of the next run of the collider this coming summer. Named as the MoEDAL Apparatus for Penetrating Particles, or MAPP for short, the new detector will expand the physics scope of MoEDAL to include



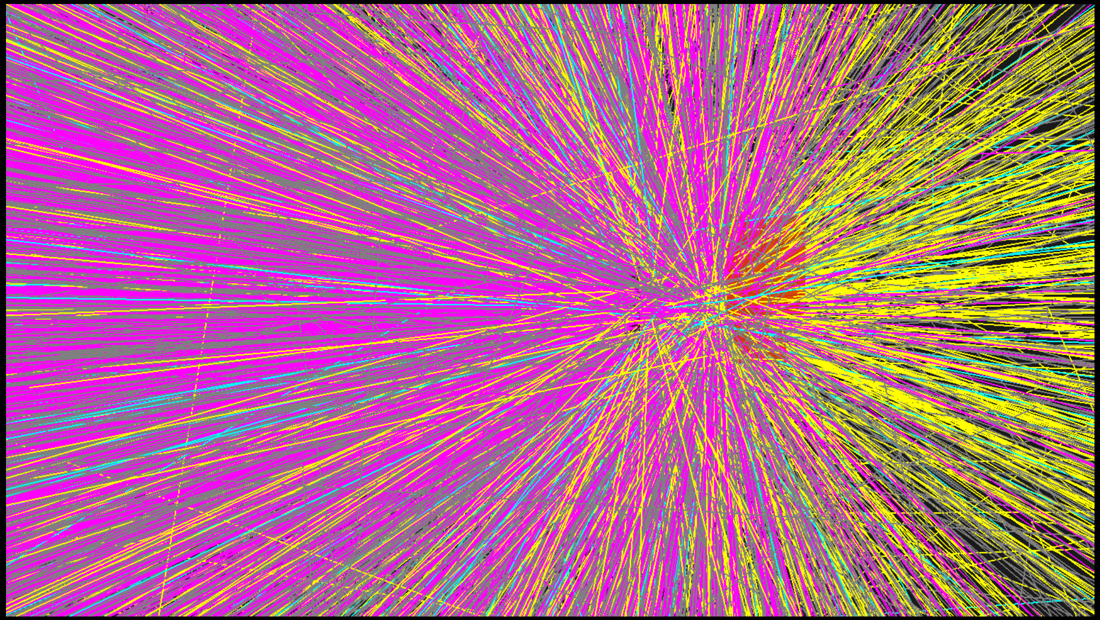
Simulation of the UA83, MoEDAL, MAPP-mCP Arena (SUMMA)

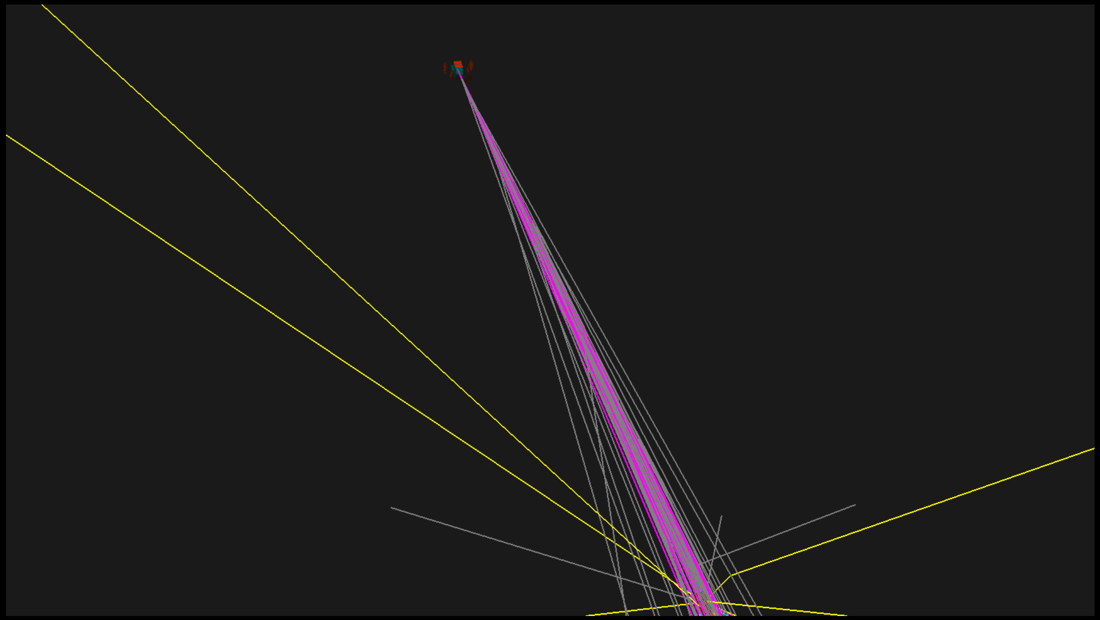


- The simulation model is build with standard Geant4 classes
  - Version 11.0 and above is used
- The model depends only on few external packages
  - All within default installations
  - xerces-c (gdml parser), ROOT (for the analysis of the ntuples), Pythia8 (primary interactions)

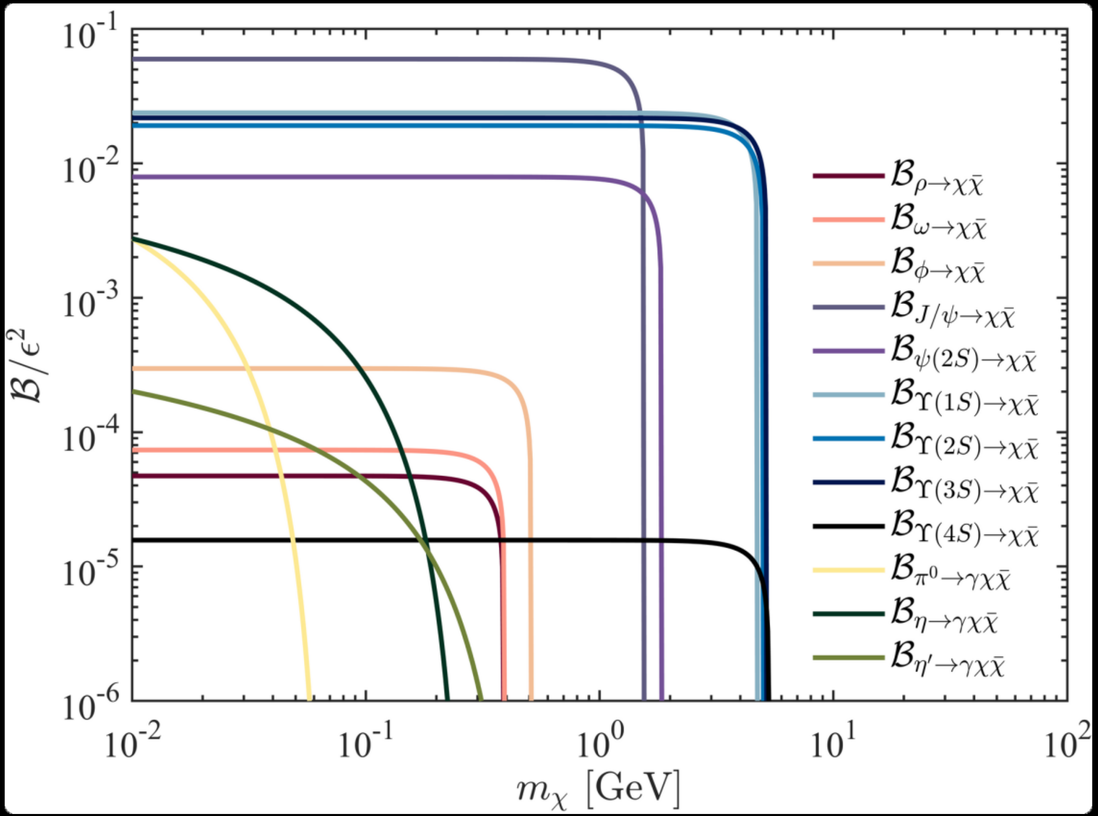
Primary particles

- 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



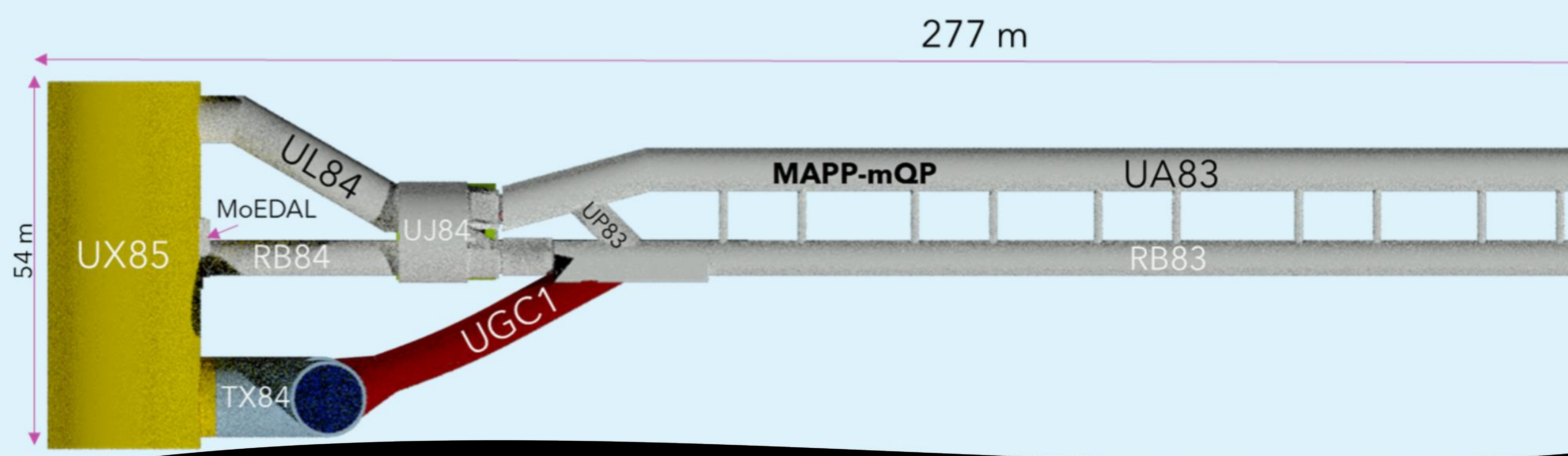


Exotic particles



M. Staelens from *Phys. Rev. D* 104, 035014 (2021)
& *Phys. Rev. D* 100, 095010 (2019)

- 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

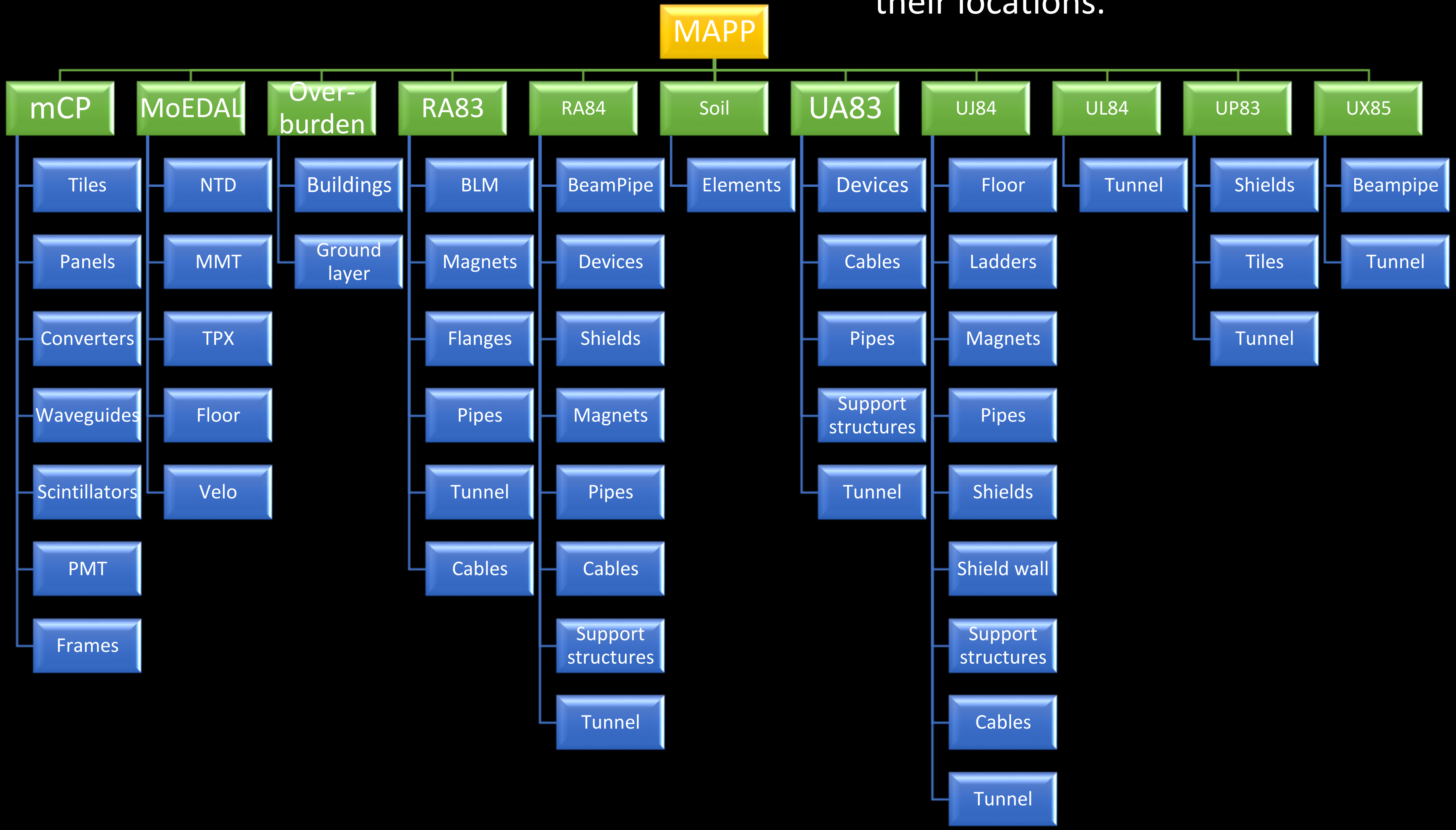


Geometry

- 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

Geometry

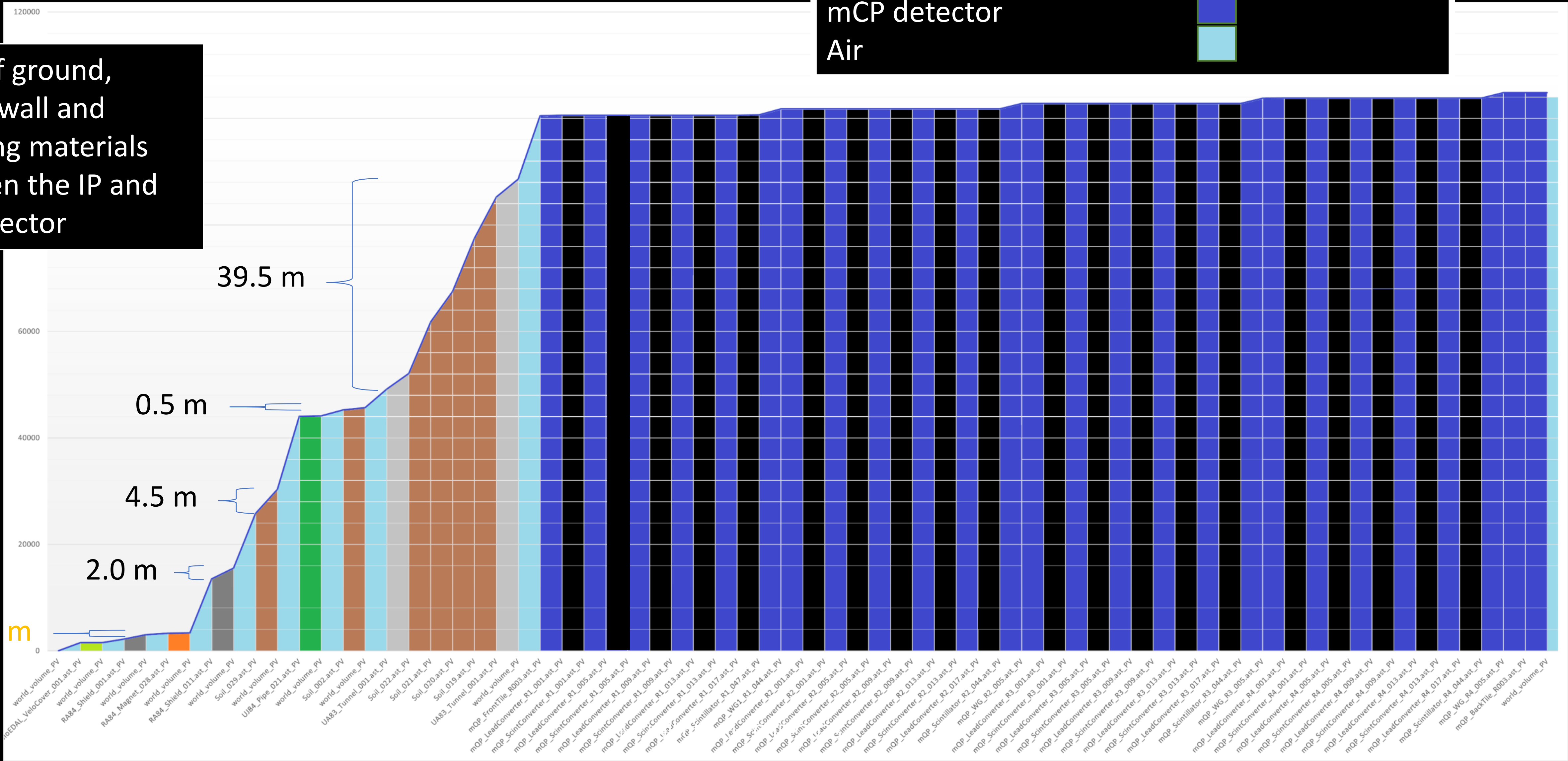
- The geometry holds a modular structure.
- The detectors are defined in standalone modules, while the machine components are placed under their locations.



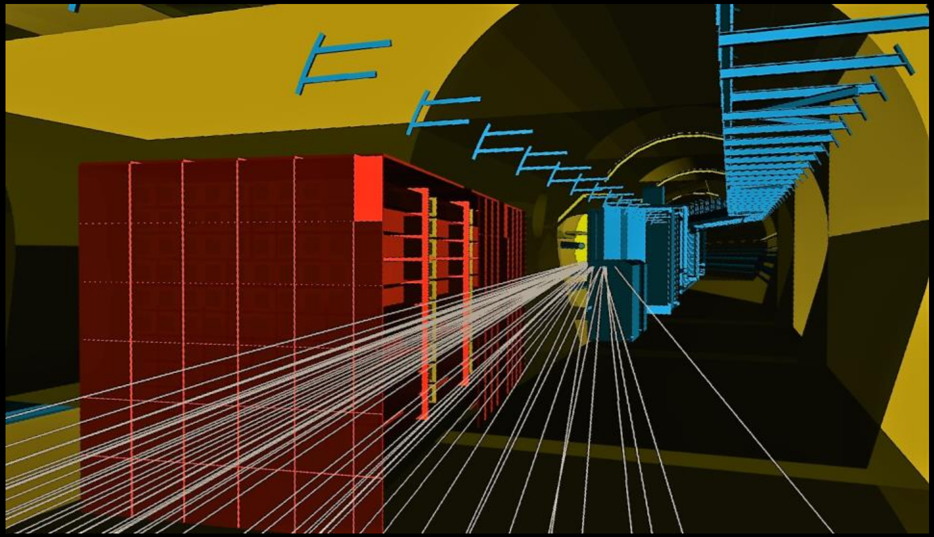
Geometry model

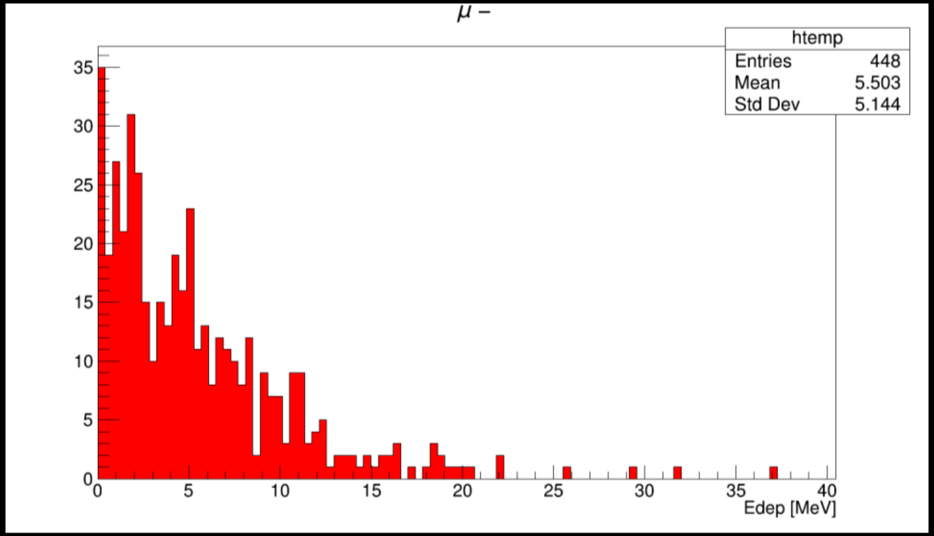
Accelerator components
Shielding
Tunnel wall
Ground layer
mCP detector
Air

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



Detector response and extensions

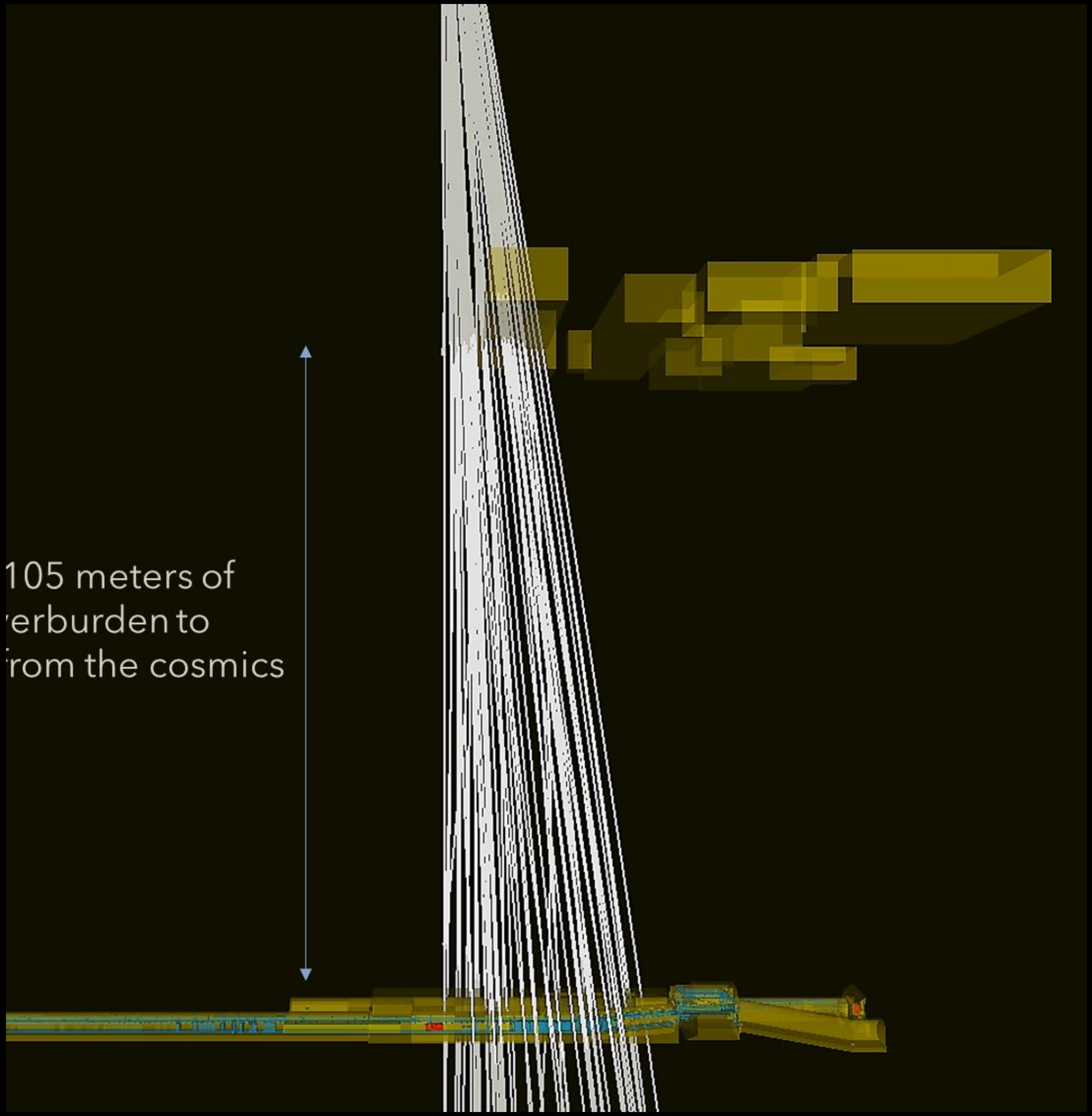




- The detector response is based on the sensitive volumes
  - By default, only the scintillator bars of the mCP-detector are set sensitive
    - Array of detectors with individual ntuples for each bar
  - Optical physics is not applied by default
    - Can use output files as an input for light yield 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