HELSINKI INSTITUTE OF PHYSICS

MAPP

MoEDAL

The MAPP-1 Detector at LHC’s Run-3

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The MoEDAL-MAPP Collaboration

25 Institutes in 13 countries
Around 70 physicists and engineers

NORTH AMERICA
University of Alabama
University of Alberta
University of British Columbia
Concordia University
University of Montreal
University of Regina
Tuft's University
University of Virginia

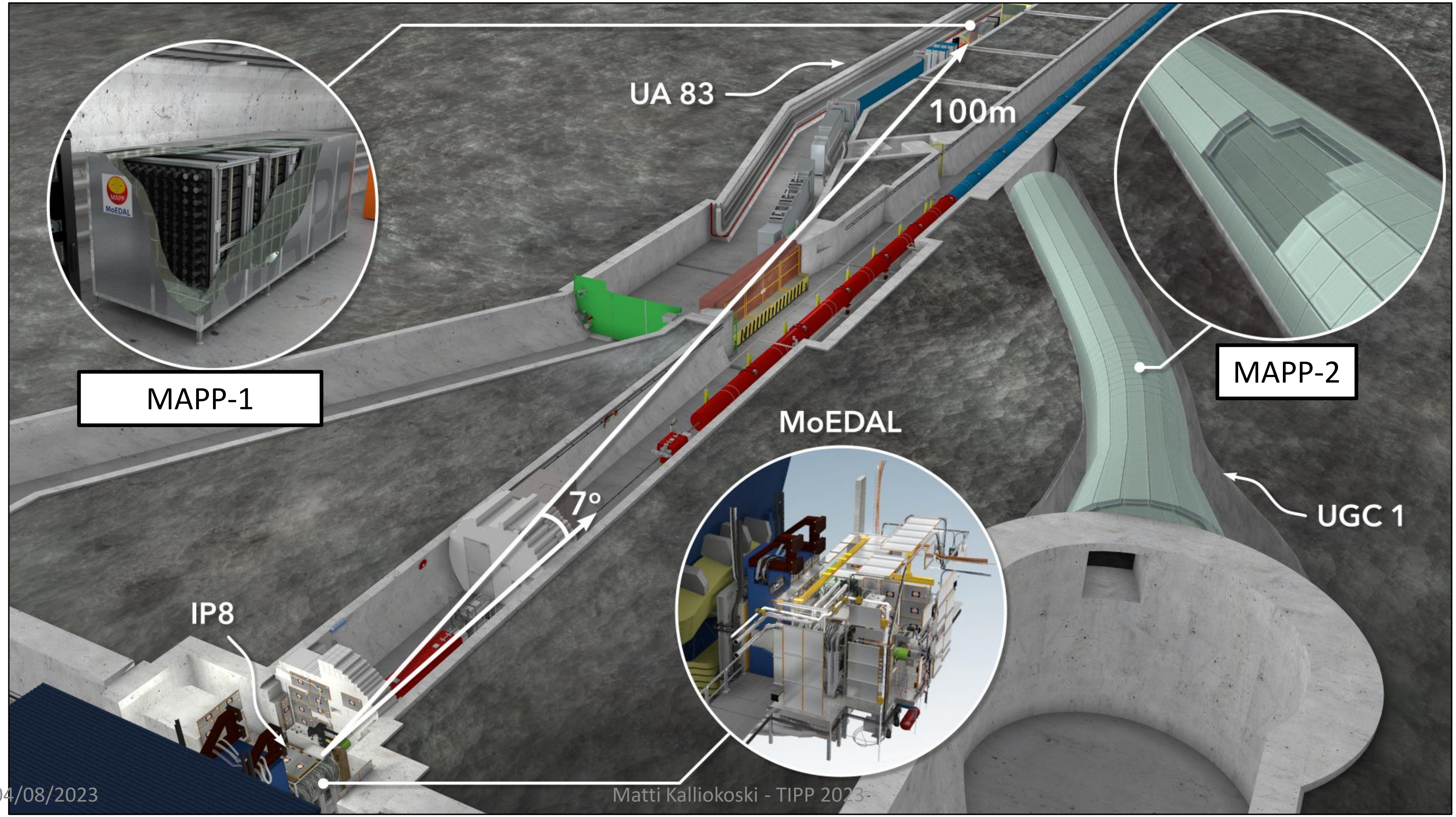
UNITED KINGDOM
Imperial College London
Kings College London
Queen Mary University
Track Analysis Systems Ltd
IRIS Canterbury

EUROPE
Technical University of Athens
University of Bologna & INFN Bologna
CERN, Switzerland
Czech Tech. University (IEAP)
Helsinki Institute of Physics
Institute of Space Sciences Romania
University of Valencia (IFIC)
University of Warsaw (Assoc.)

KOREA
Centre for Quantum Spacetime, Seoul

INDIA
University of Calcutta
National Institute of Technology, Kuruksetra (Assoc)

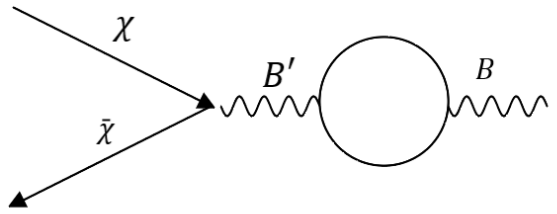
MAPP – MoEDAL Apparatus for Penetrating Particles



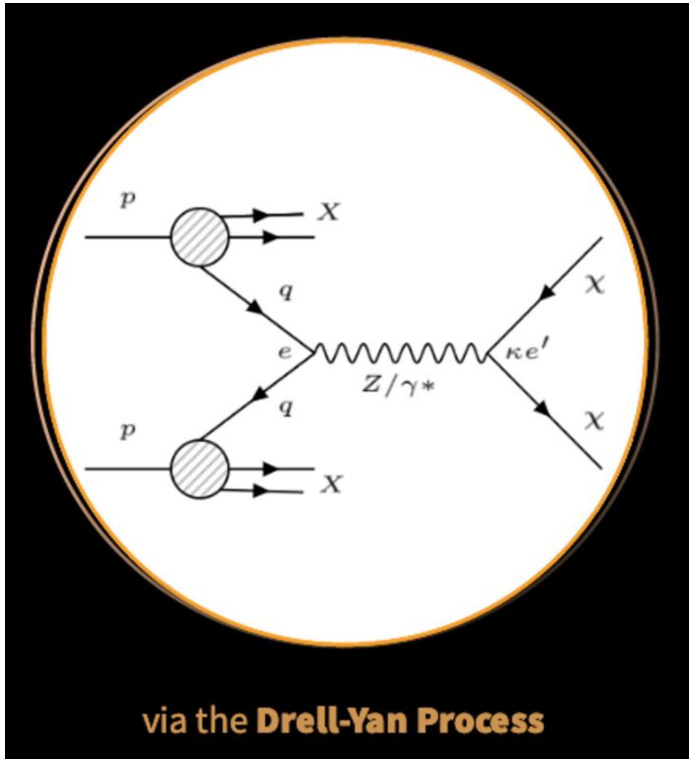
Millicharged Particles

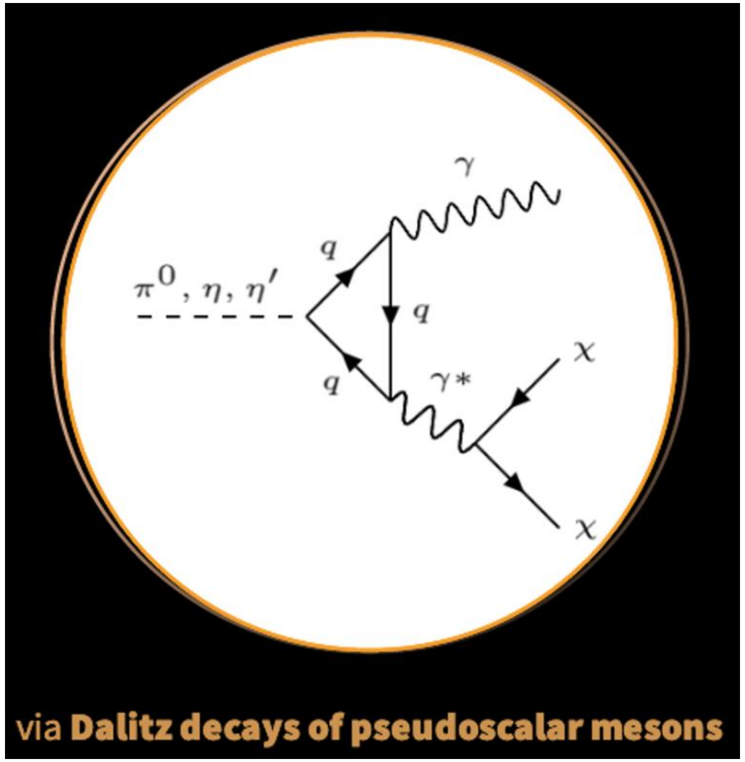
- Milli(or mini)charged particles, mCPs, are hypothetical free particles with electric charges below the elementary charge
- They are predicted by various models beyond the Standard Model
  - Charge quantization, dark sector models

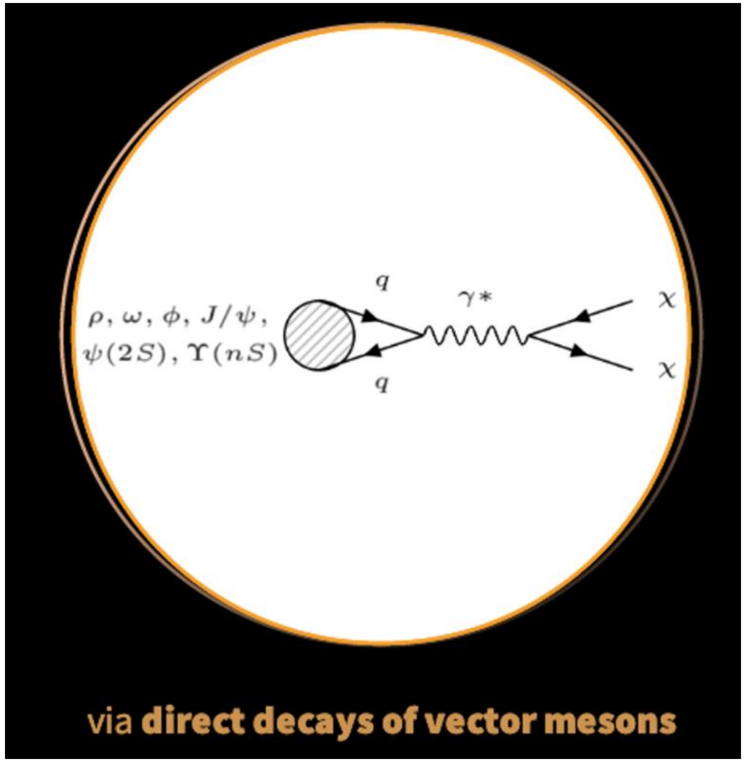
- $L = L_{SM} - \frac{1}{4} A'_{\mu\nu} A'^{\mu\nu} + i\bar{\chi}(\partial - ie'B' + iM_{MCP})\chi$



Production of Millicharged Particles at the LHC

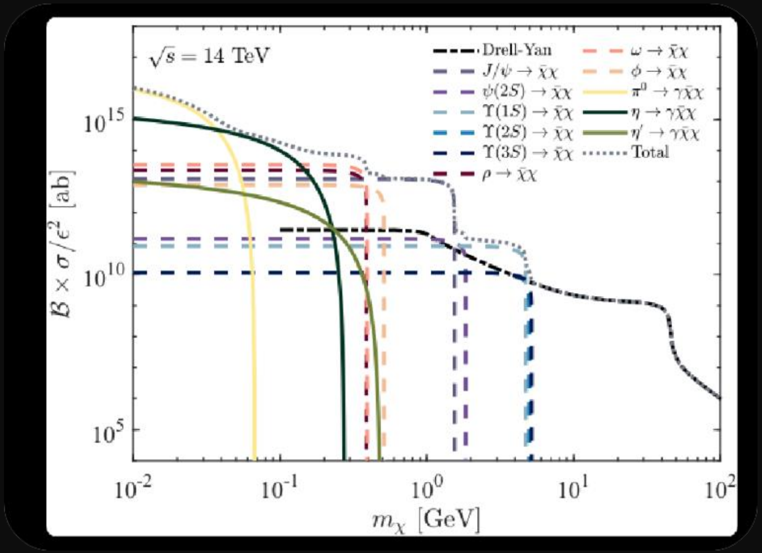


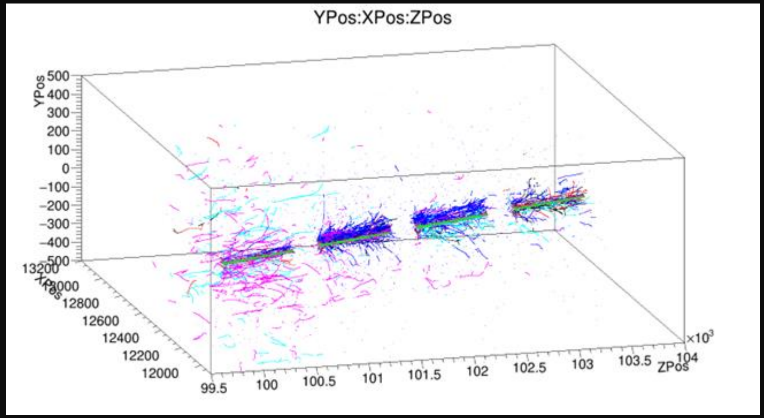




Signatures of millicharged particles

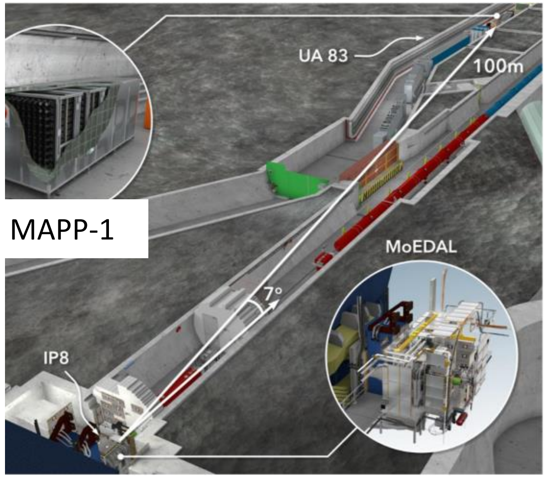
- mCPs with mass above 100 MeV will lose energy primarily through ionization and excitation
- Fractionally charged particles leave very little energy in standard particle detectors of the LHC
  - Tracking of missing energy
- In direct detection for particle with $Q<1e$, the energy deposition in reduced by factor Q^2

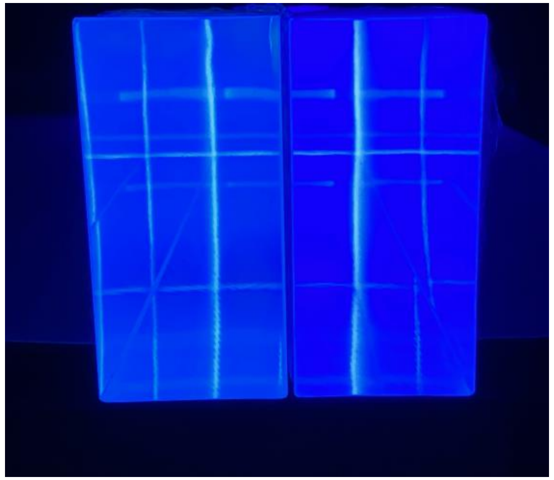


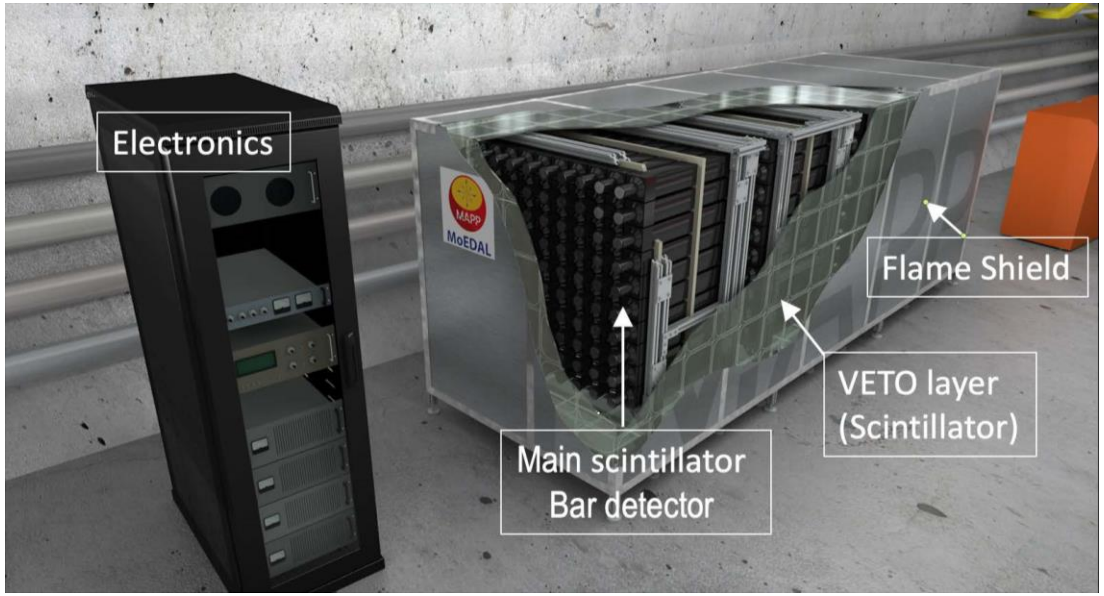


MAPP-1 Detector at UA83

- MAPP-1 mCP detector is placed in a service tunnel of the LHC at about 100 meters from the IP8
- The front face of the detector is pointing to the IP at about 7 degrees angle from the beam line
- 400 scintillator bars ($10 \times 10 \times 75$ cm^3) in four sections
- Scintillating VETO layers in all sides for background exclusion
- The location allows to connect the measurements directly to the LHC clock







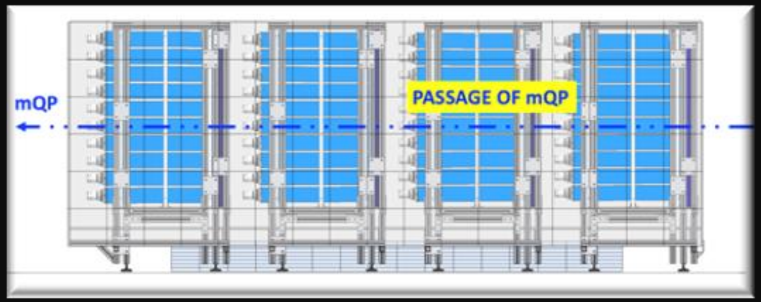
Installation in the UA83

- Since the detector is located in a side tunnel, the access to the location was simplified
  - However, no access during beam
- The scintillator detectors and PMTs have been installed in the location
- The readout electronics is being completed and will be installed during YETS starting in 2023
- The data-taking is expected to be started in spring 2024

Installation in the UA83

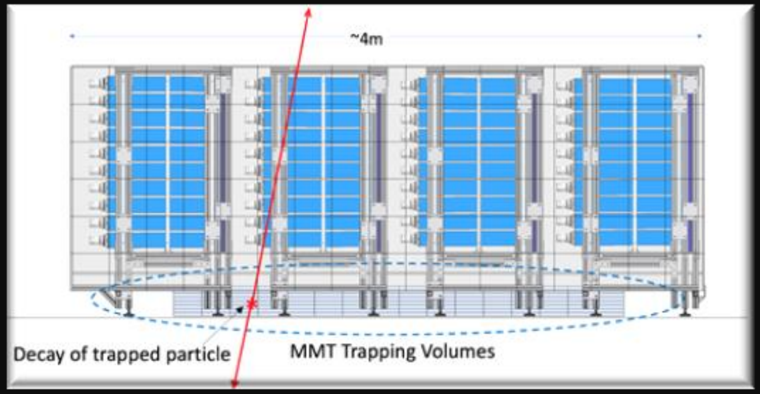
Detection of Millicharged Particles

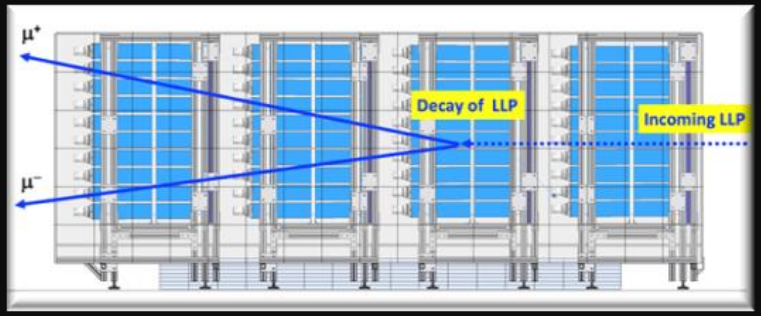
- Signatures of exotics can be identified from their signature in the mCP detector
- Millicharged particle would produce small number of photons in each of the scintillator bars
  - Q = 1e MIP deposits about 2 MeV / cm in scintillator => 2x10e6 photons / m
  - Q = 0.1e particle would produce 2x10e4 photons / m
  - Q = 0.01e particle 200 photons / m etc.
- True detection efficiency of a scintillator is about 10-20%
  - The signal that is generated is of the order of few photoelectrons



Other particles

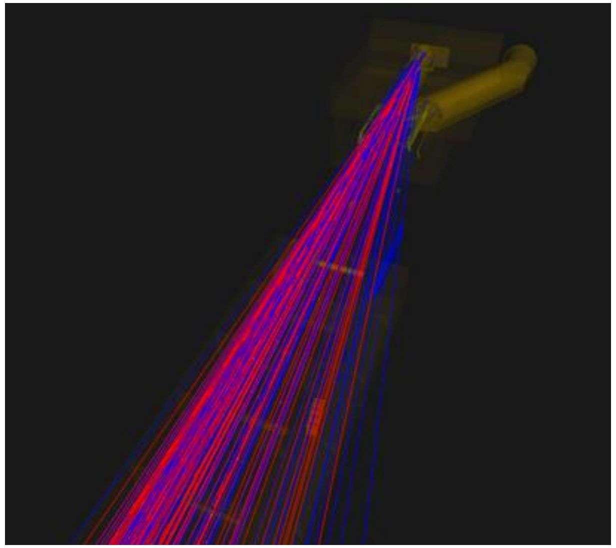
- In addition to millicharged particles, the MAPP detectors are designed to search for other exotic particles
- Long lived particle decays could be identified based on the decay modes
- The detector can also be used to identify and to detect trapped particles from MoEDAL MMTs
  - The aluminium bars can be stored under the mCP detector for long measurements
  - The analysis can run even outside the LHC operation times

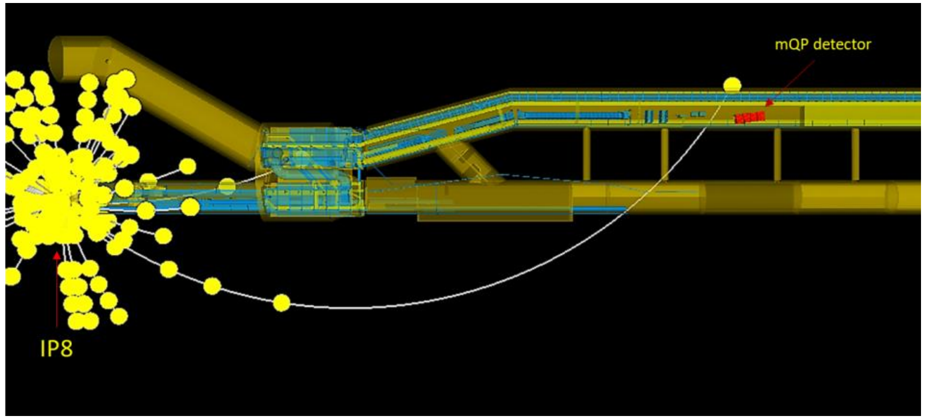




Simulation of the UA83, MoEDAL, MAPP Arena (SUMMA)

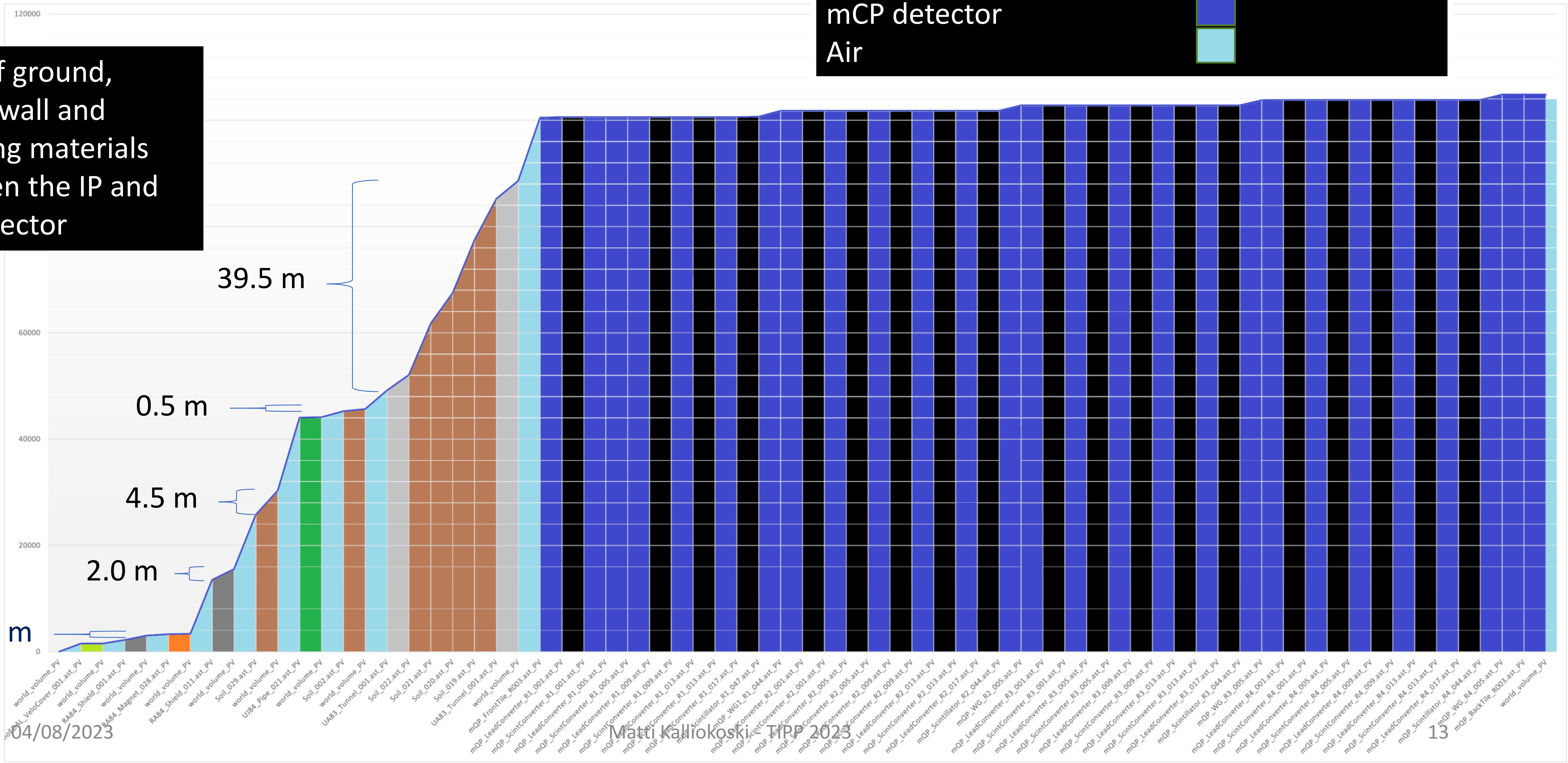
- The simulation model is build on standard Geant4 classes
  - Version 11.0 and above is used
- The model depends only on few external packages
  - All within default installations
  - xerces-c (gdml parser), ROOT (for the analysis of the ntuples), Pythia8 (primary interactions)
- Import of external data through HEPEvt format
- New particle properties and decays are implemented as new classes and modifications to the physics lists





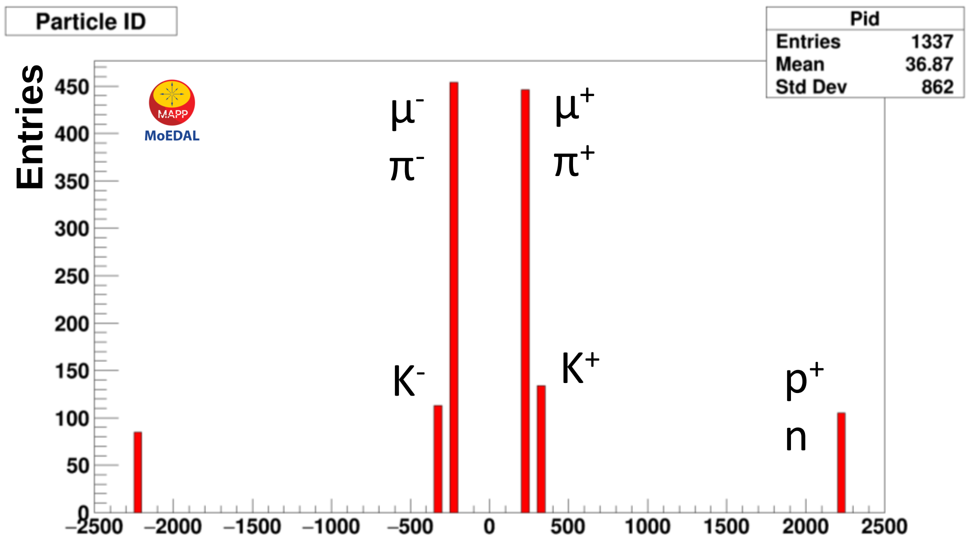
Material Budget

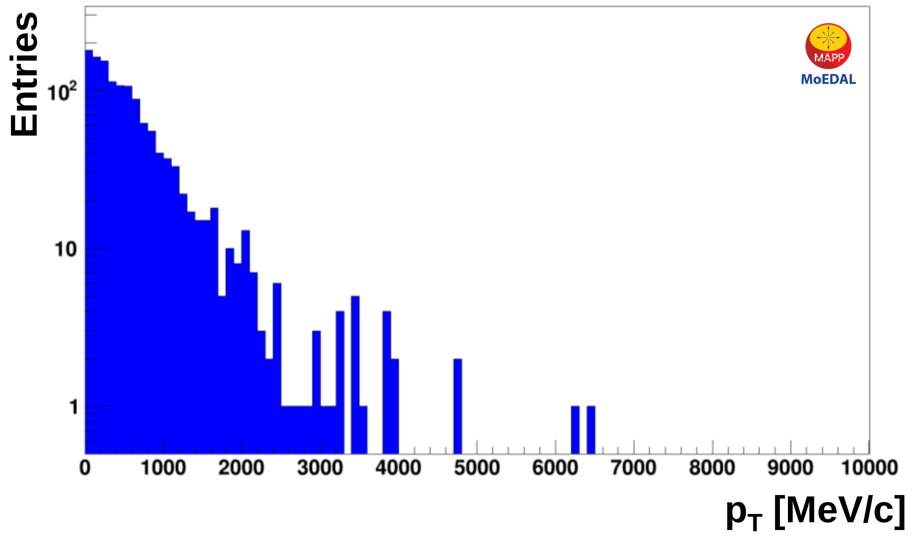
47 m of ground, tunnel wall and shielding materials between the IP and the detector



Machine Background

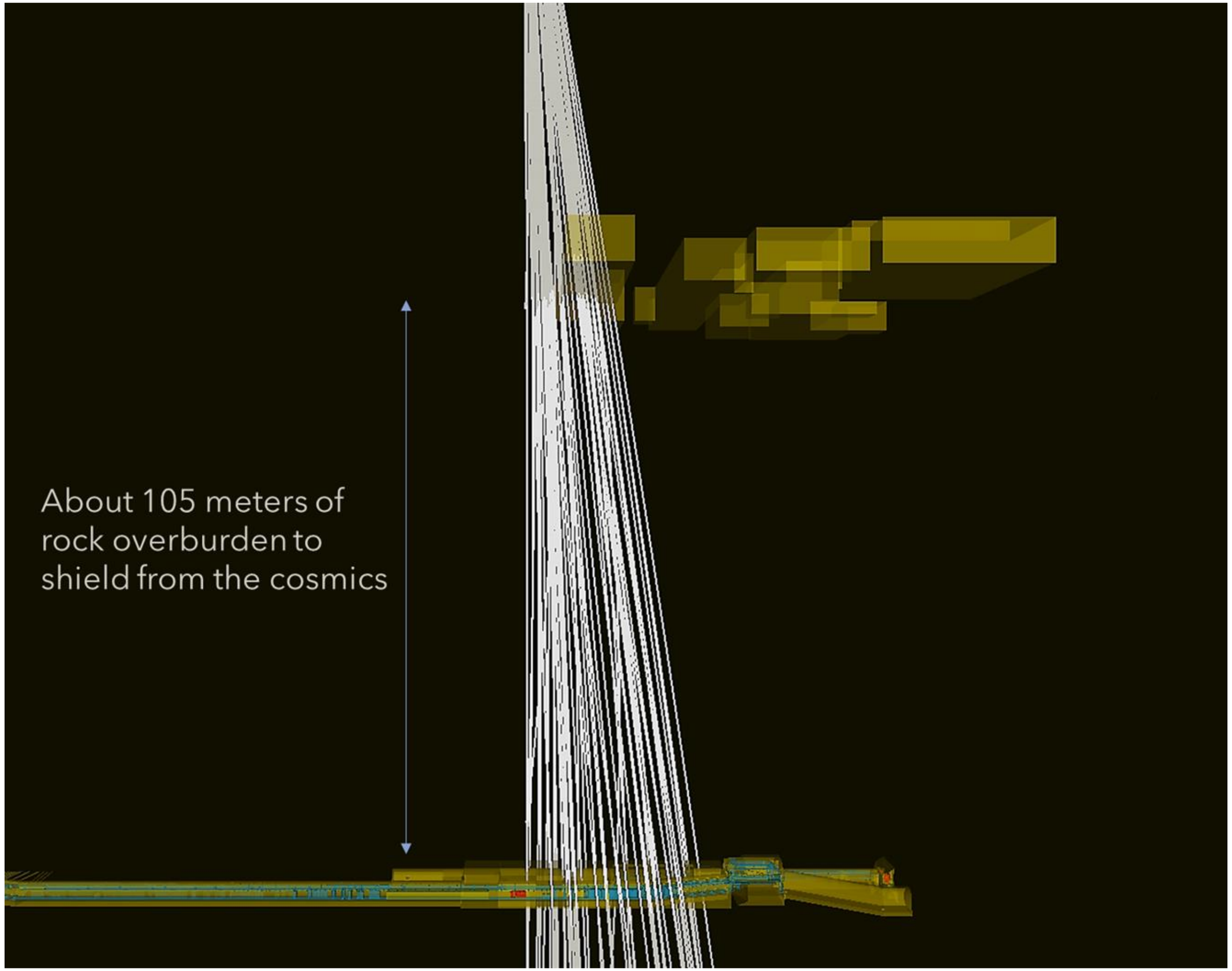
- The main contribution for the background are muons, kaons and pions from proton-proton collisions at the IP
- Also some secondary neutrons and protons are produced in the material between the detector and the IP
- By using Pythia8 to model 1×10^7 SoftQCD processes in the SUMMA simulation model, we measure 1337 events in mCP detector





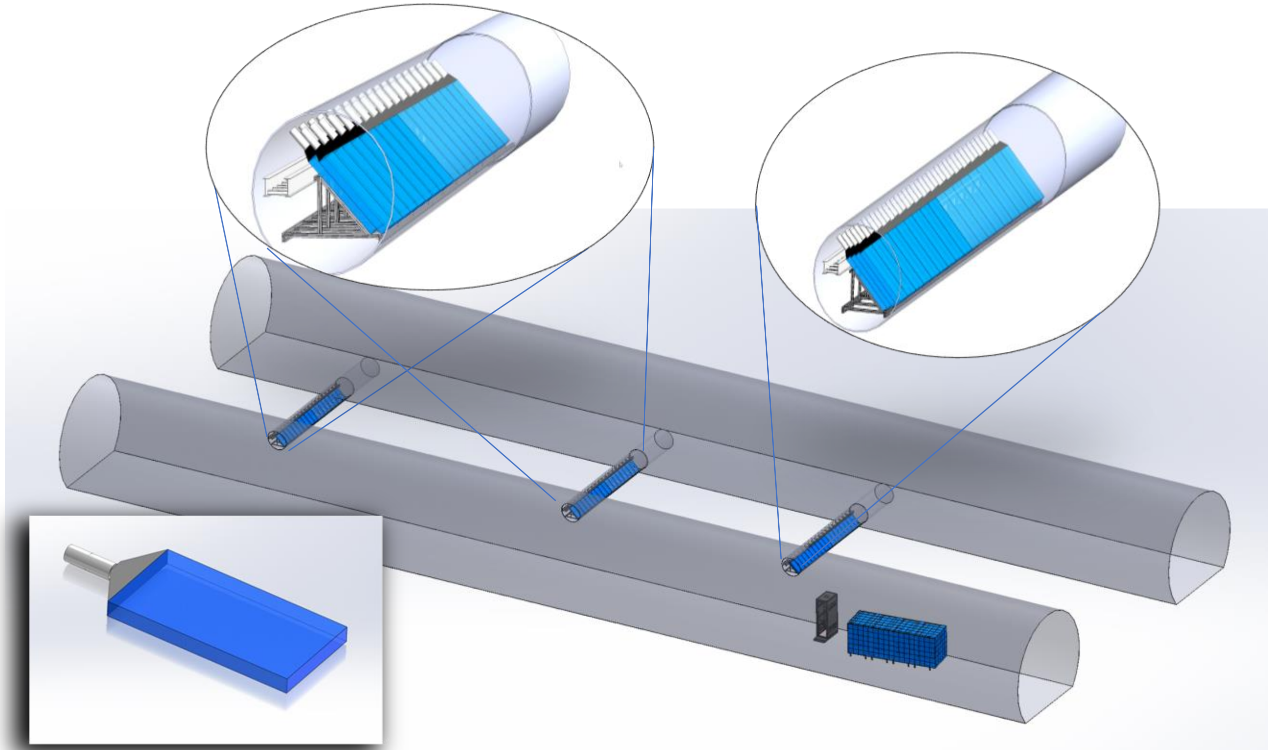
Background from Cosmics

- For the rare decays, information about the rate of cosmic background radiation is important
  - Cosmic muons are not misidentified as signatures since their angle and charge deposition does not match the signature of rare decay
  - However, the dead time of the detector increases with each event
- MAPP is protected by over 100 meters of rock overburden
  - Reduces the background but is not sufficient to stop high energy muons



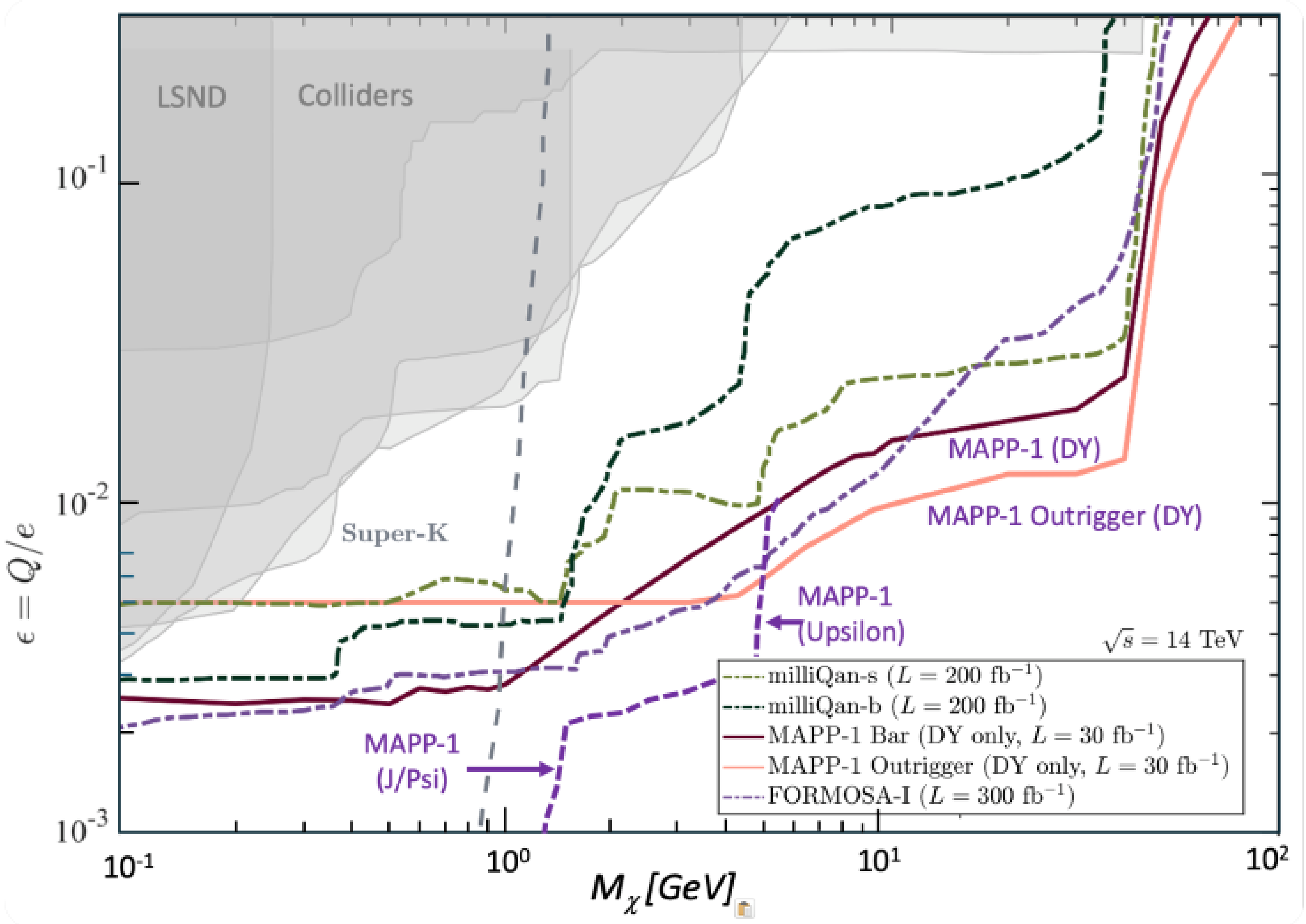
MAPP Outrigger Detectors

- Increases the acceptance of MAPP-1 at higher mass and at larger fractional charge we proposed to utilize the old LEP magnet powering vents for additional detector installations
- Stacked scintillator detectors can be used to study exotic decays coming for the IP
    - Compared to the mCP detector, the background event rate is about 100 times smaller
    - However, the vents are closer to the machine
        - Background directly from the beamline can be expected



MAPP-1 mCP Physics sensitivity

- The physics reach of the MAPP-1 detectors are expected to be enhanced further by the Outrigger detectors
- The distributions assume 100% detection efficiency
    - Will be adjusted with results from SUMMA simulations and with first measurements



Summary

- MoEDAL-MAPP mCP detector is installed in the UA83 corridor of the LHC
- It will be starting its data taking in 2024
- With the detector we will be able to study exotic decays
- The outrigger extensions allows to increase the dynamic range of the MAPP-1 stage