MoEDAL – Monopole and Exotics Detector at the LHC

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Particle Physics Day 2021

16/11/2021

MAPP

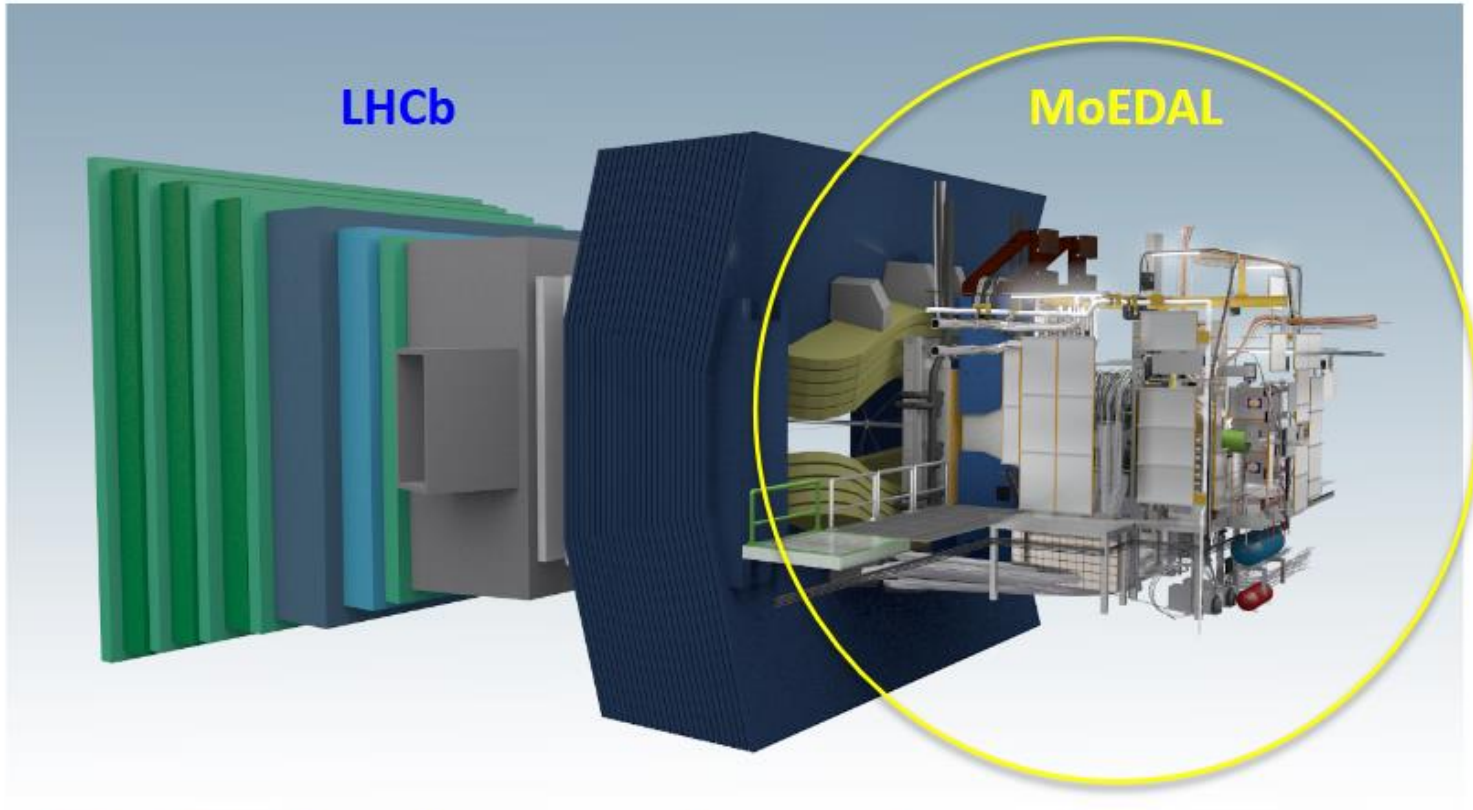
MoEDAL

HELSINKI INSTITUTE OF PHYSICS

MoEDAL Collaboration

- 19 institutes from 10 countries + India

MoEDAL detector



DETECTOR SYSTEMS

① Low-threshold NTD (**LT-NTD**) array
- $z/\beta > \sim 5 - 10$

② Very High Charge Catcher NTD (**HCC-NTD**) array
- $z/\beta > \sim 50$

③ **TimePix** radiation background monitor

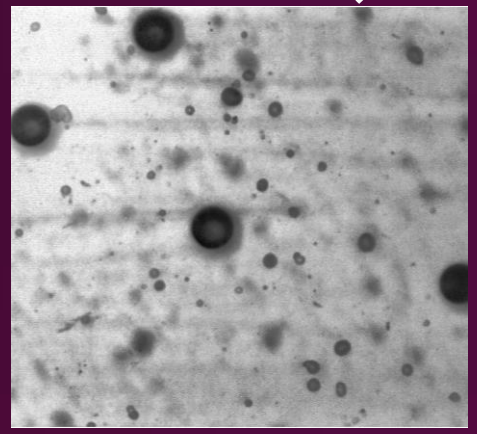
④ Monopole Trapping detector (**MMT**)

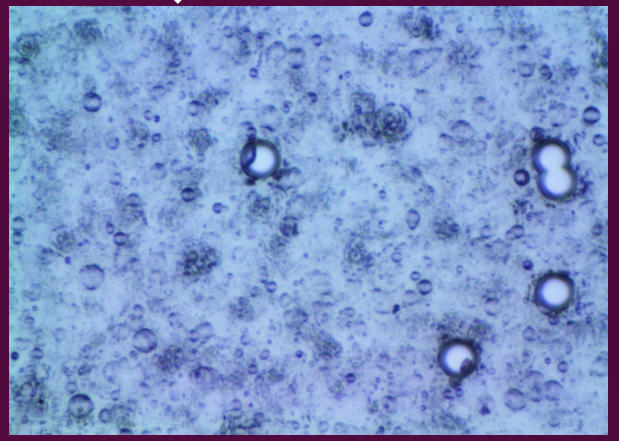
MoEDAL is unlike any other LHC experiment:

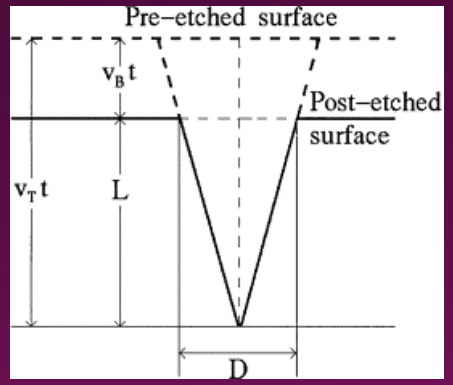
- mostly **passive detectors**; no trigger; no readout
- the largest deployment of passive **Nuclear Track Detectors (NTDs)** at an accelerator
- the 1st time **trapping detectors** are deployed as a detector

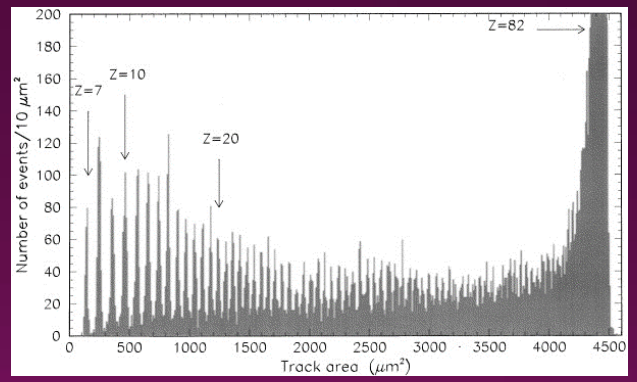
Nuclear Track Detectors (NTD)

- NTDs are samples of solid material that can be etched after they have been exposed to nuclear radiation
  - Photographic emulsion, crystal, glass, plastic …
- When the material is placed in etchant, the damage from the radiation makes the tracks of the particles to etch faster that intact material
- For a given type of particle, the track length gives the energy of a particle
- From the cone diameter and the penetration depth, the ions and their fragments can be identified





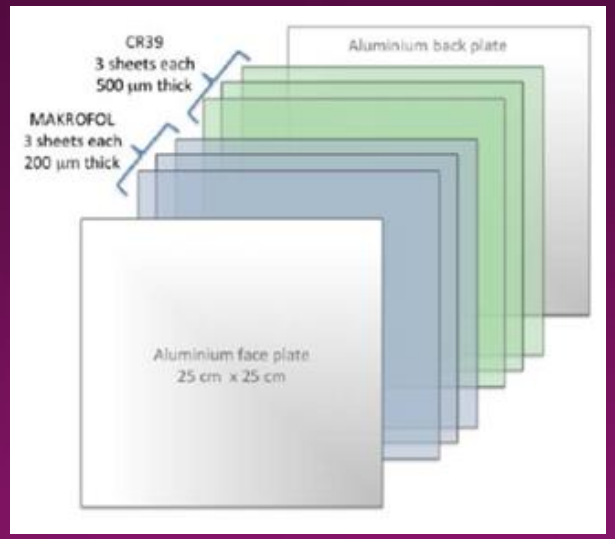


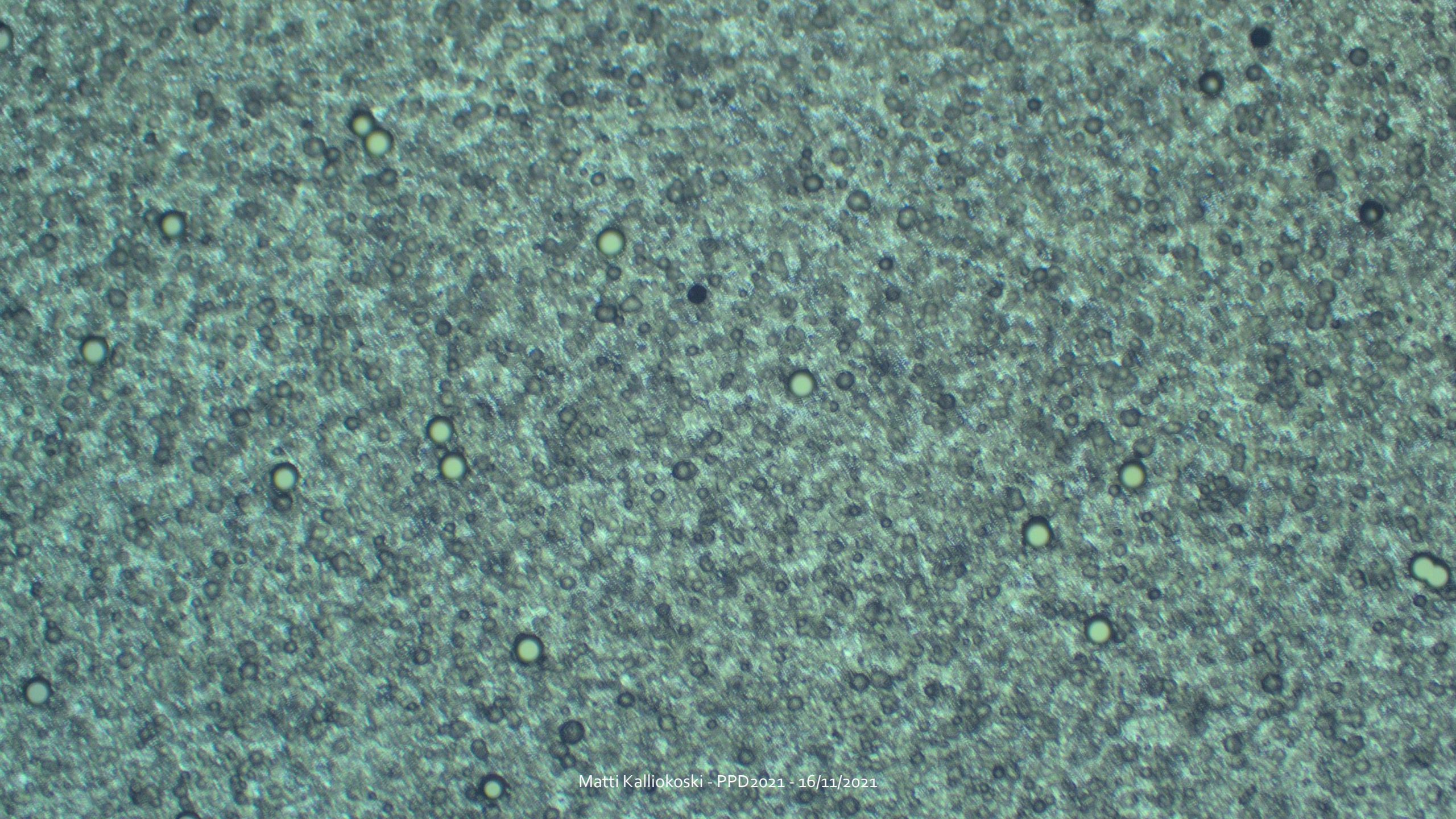


G. Giacomelli et al. "*Extended calibration of a Cr39 nuclear track detector with 158-A-GeV Pb-207 ions*" Nucl. Instrum. Meth. A 411 (1998) 173

MoEDAL NTDs

- MoEDAL uses sheets of CR39 and Macrofoil as stacks as nuclear track detectors
- MoEDAL NTDs have a threshold of $Z/\beta \sim 5$
- In proton-proton collisions, the only source of known particles that can leave a track in MoEDAL NTDs are spallation products with range that is typically much less than the thickness of one sheet of the NTD
- Electrically or magnetically charged particles would traverse every sheet in a MoEDAL NTD stack, accurately demarcating a track that points back to the collision point



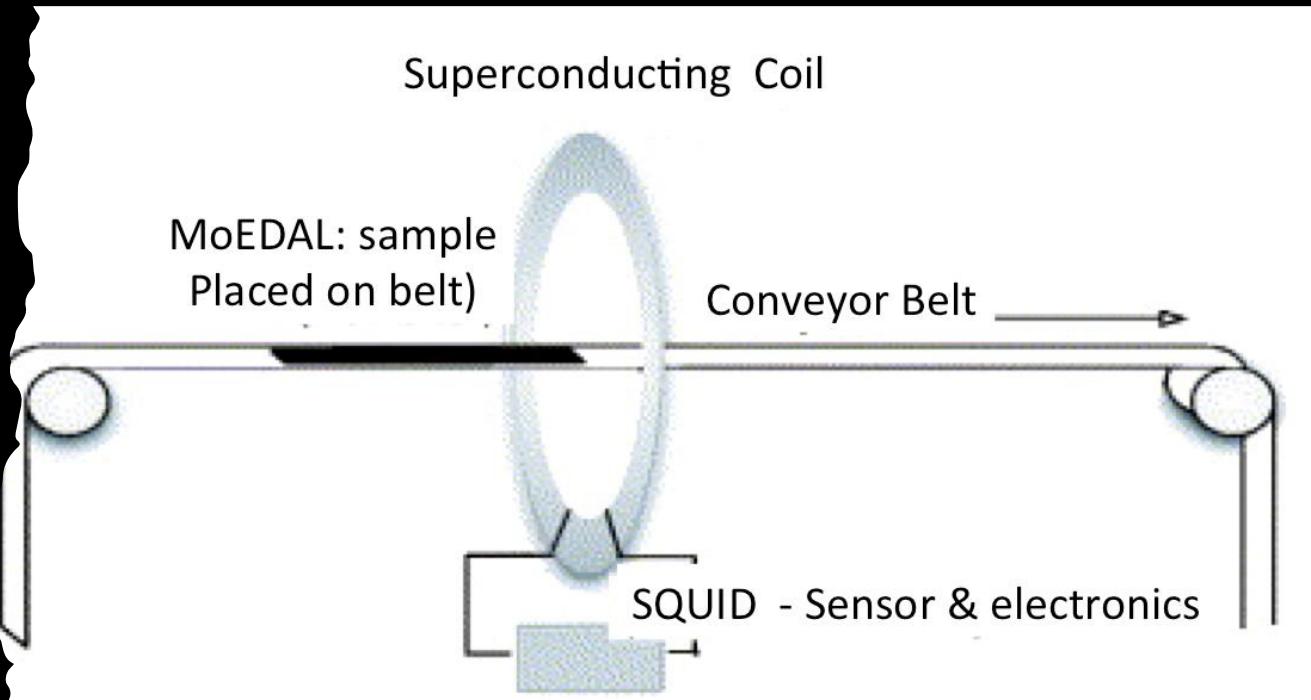


Magnetic Monopole Trappers (MMT)

- Aluminum has an anomalously large nuclear dipole moment (spin 5/2)
  - likely to bind monopoles
  - No activation, low magnetization, cheap
- Trapping detector prototype in 2012 consisted of 11 boxes, each containing 18 cylindrical rods of 60 cm length and 2.5 cm diameter
- For the 2015 run, the MMT was upgraded to an array consisting of 672 square aluminum rods with dimension 19×2.5×2.5 cm3 for a total mass of 222 kg in 14 stacked boxes

MMT Analysis

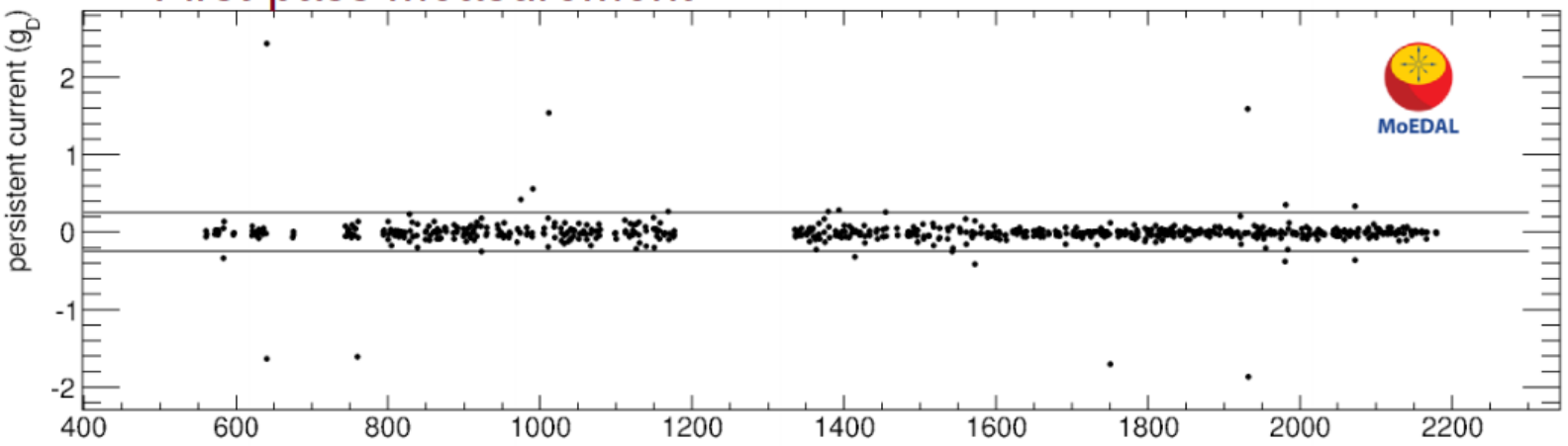
- Exposed aluminium bars are monitored by using the ETH SQUID magnetometer
  - Resolution around 0.1 g_d
- If a monopole is trapped in an aluminium bar it would be visible in the SQUID scans due to its anomalously large nuclear magnetic moment
- After the SQUID scan, the bars are sent to SNOLAB for monitoring of decays of very long lived electrically charged particles



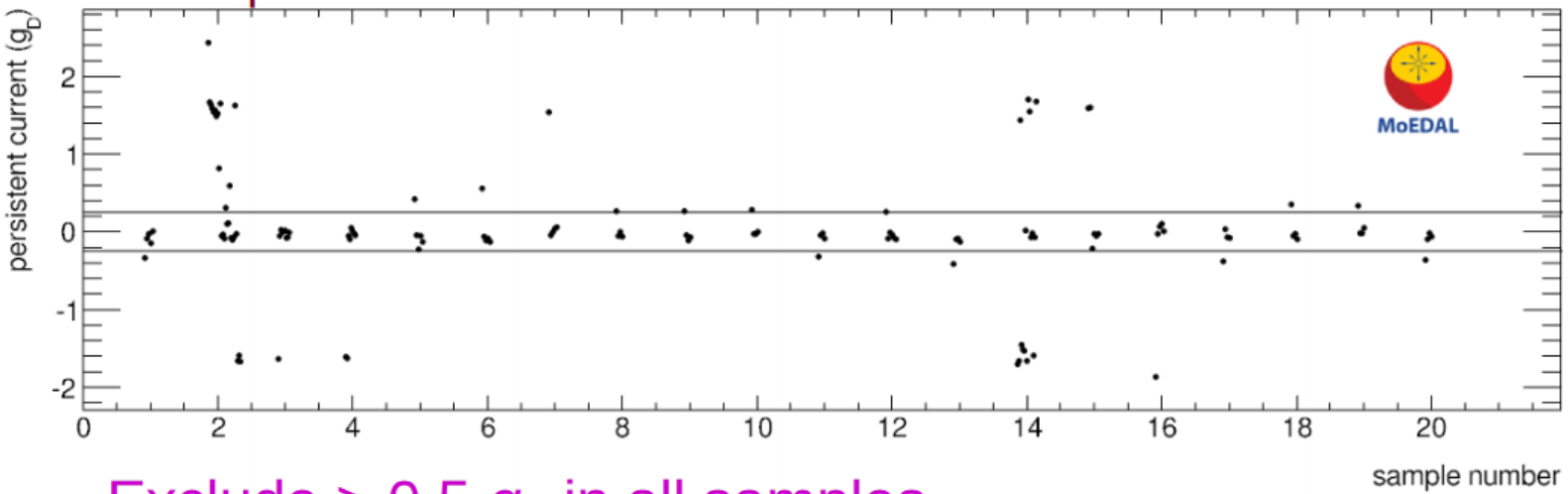
Magnetic charges in samples (13 TeV exposure in 2015)

PRL 118, 061801 (2017)

First-pass measurement

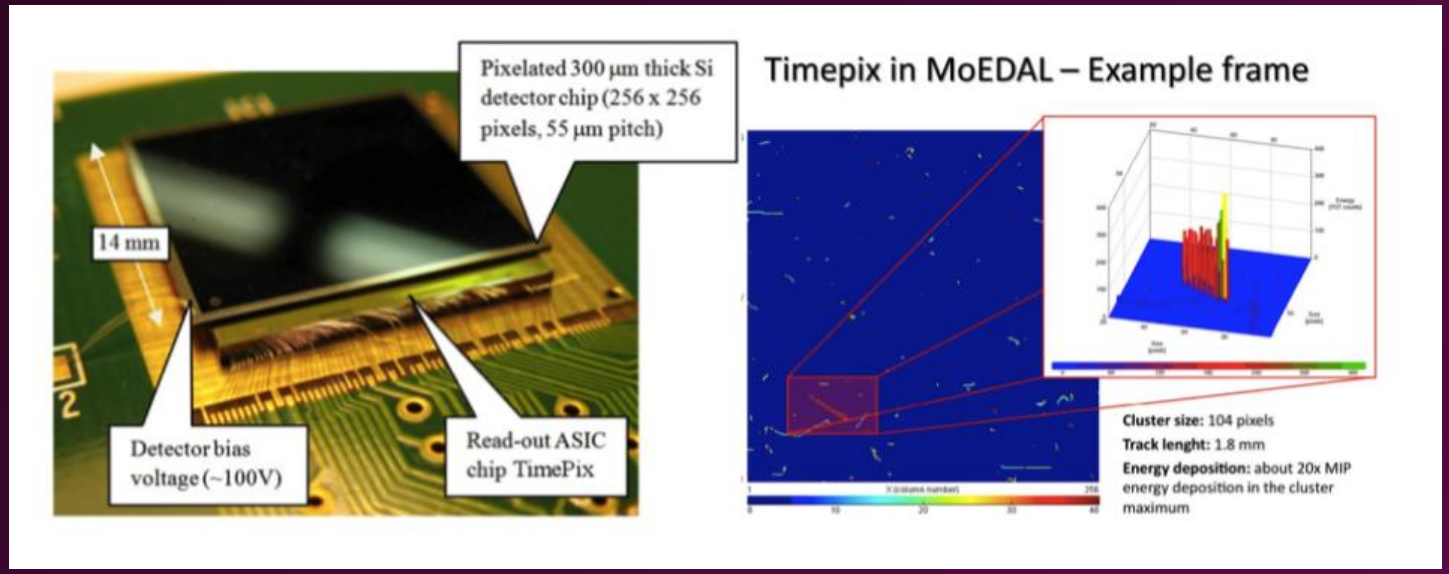


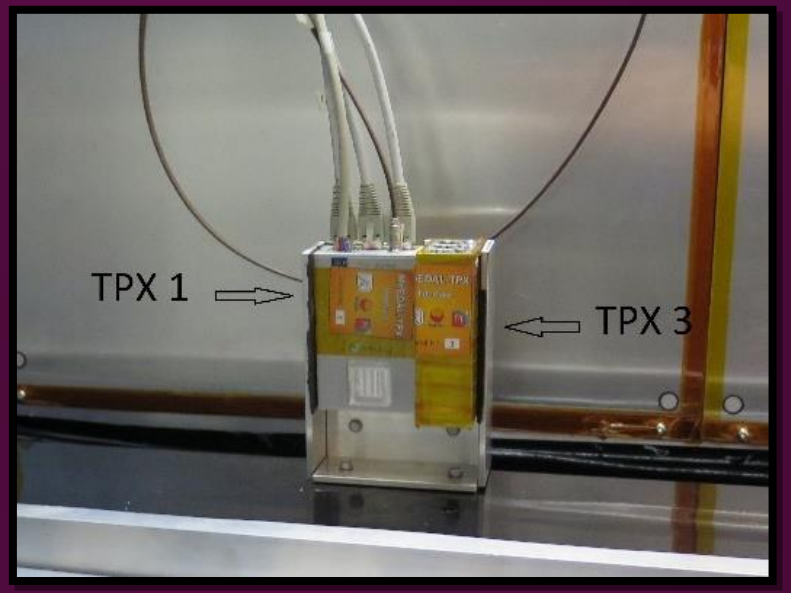
Multiple measurements of candidates



➔ Exclude > 0.5 g_D in all samples

Timepix detectors



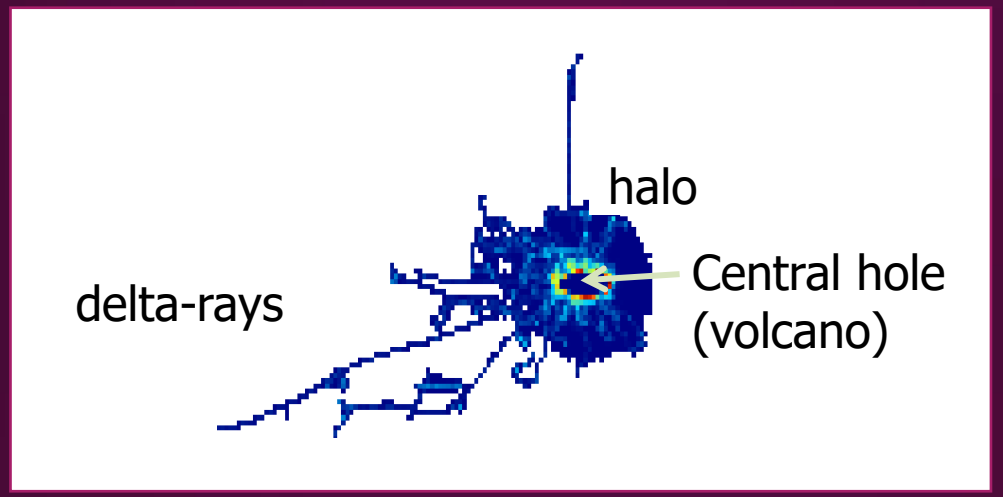


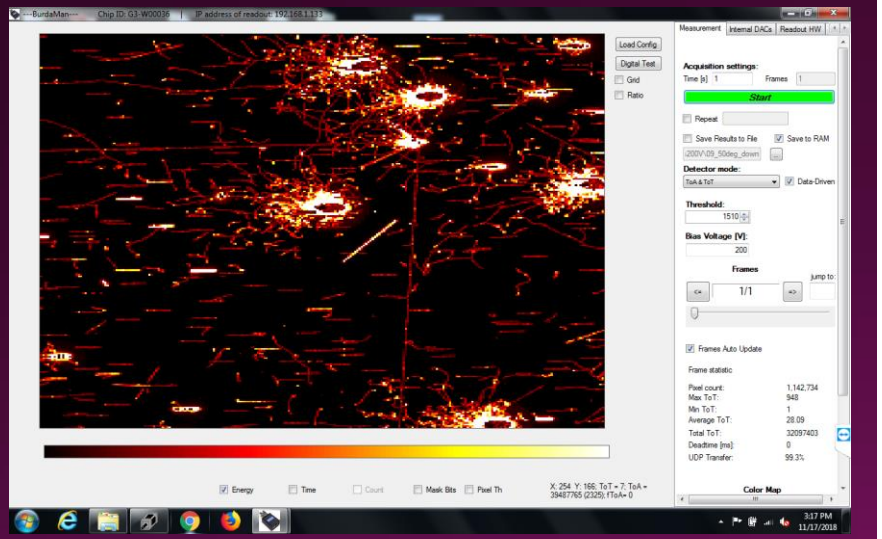
- Measurements of radiation background
- Can be used to directly measure and identify particles from the IP

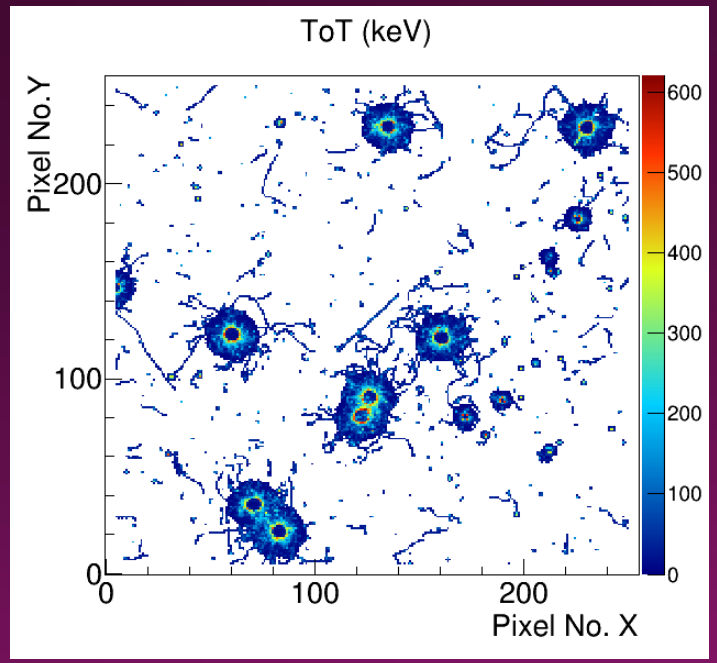
Timepix detectors

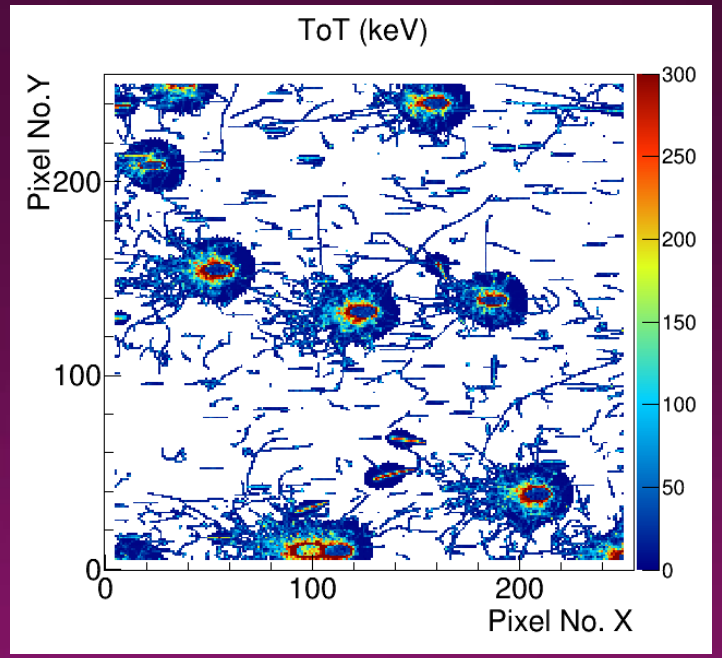
Extending the range of measured responses to high-Z.

- Pb ions ~150 GeV/c
- Timepix3 500 µm thick silicon
- Data-driven mode with 0.01 s acquisition time





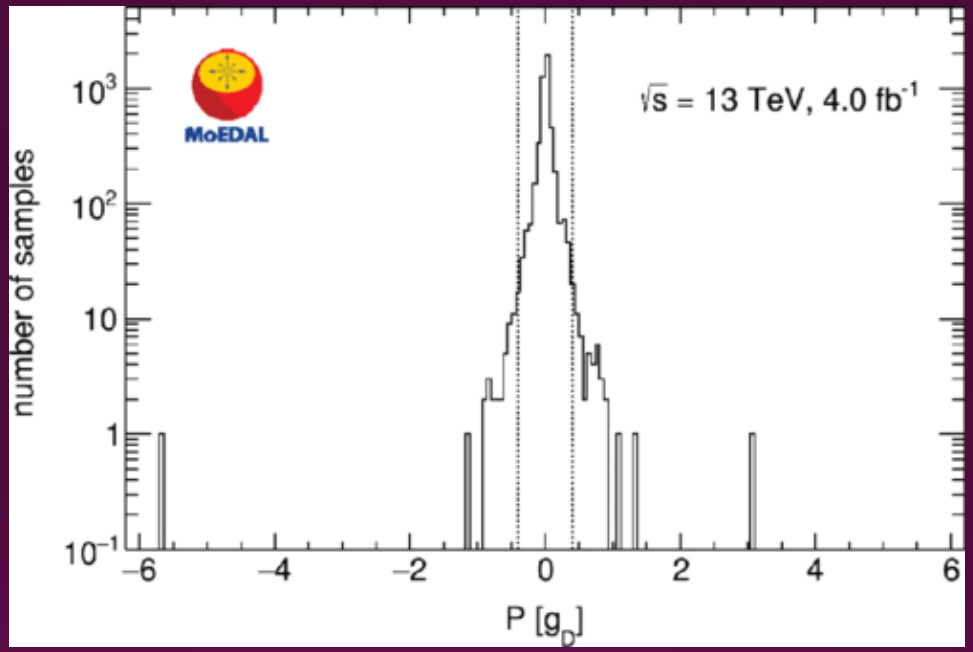




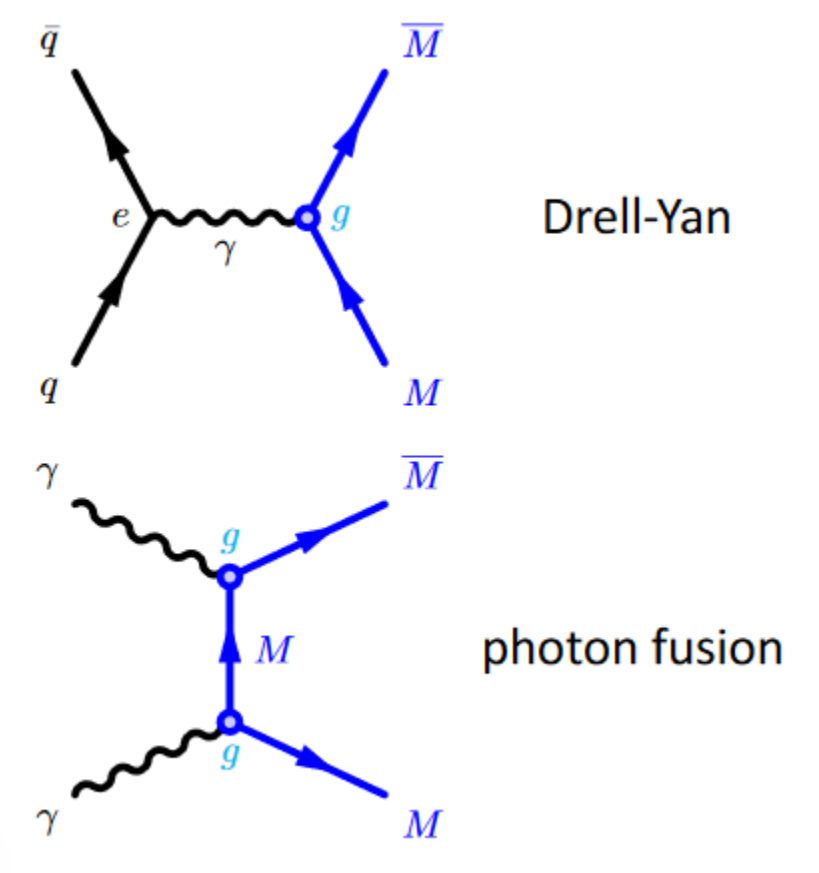
B. Bergmann, P. Manek - Radiation field characterization with the MoEDAL Timepix network

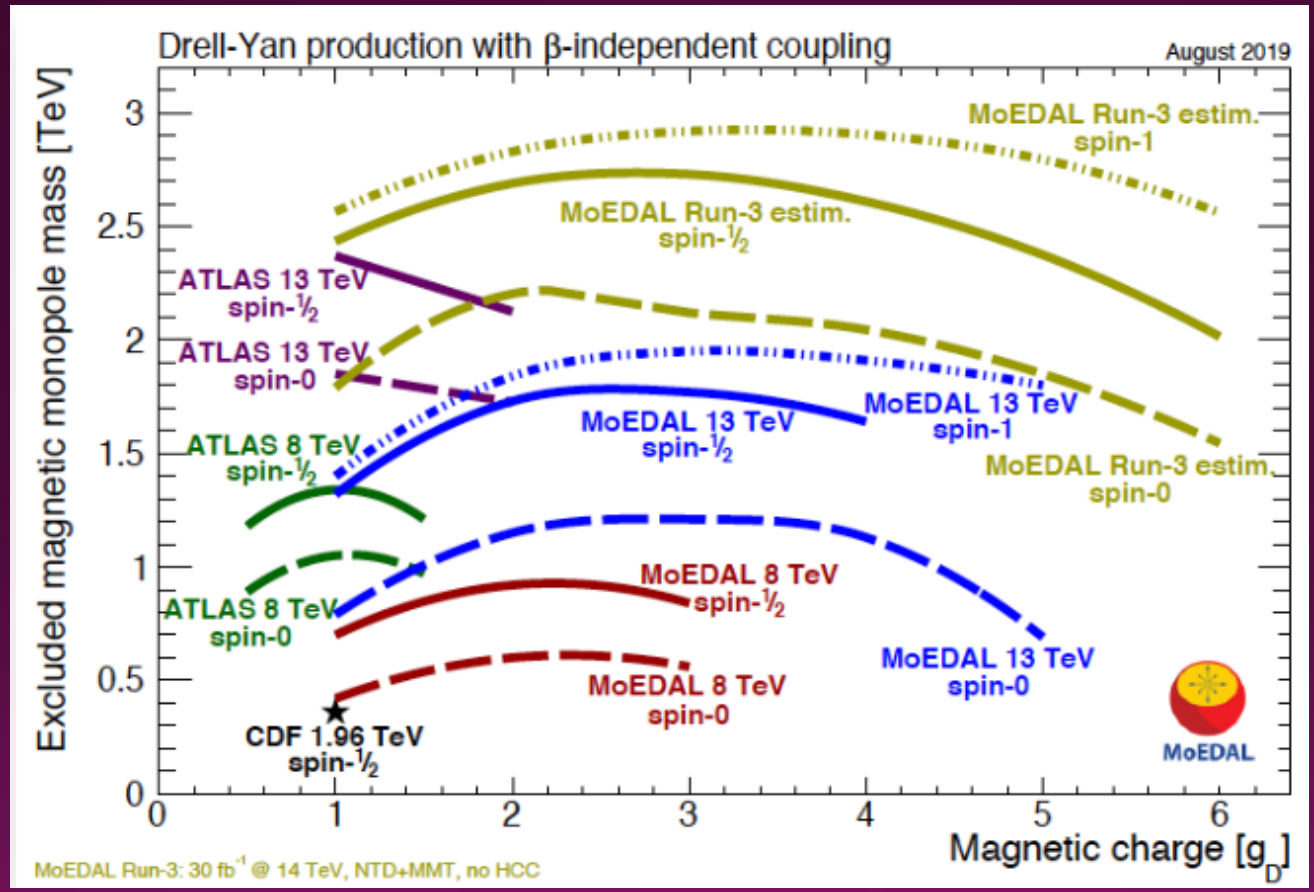
MoEDAL Physics Results

- First results from Run1 at 8 TeV
  JHEP 1608 (2016) 067
- First results from Run2 at 13 TeV
  Phys. Rev. Lett. 118 (2017) 061801
- MMT results with spin-1 monopoles and with β-dependent coupling
  Phys. Lett. B 782 (2018) 510-516
- MMT results with full MMT detector with 2 times more integrated luminosity and with photon fusion interpretation
  Phys. Rev. Lett 123 (2019) 021802
- MMT results for dyon searches
  Phys. Rev. Lett. 126 (2021) 071801



Limits on Magnetic Monopoles



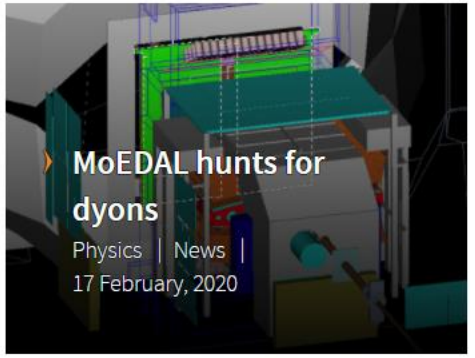


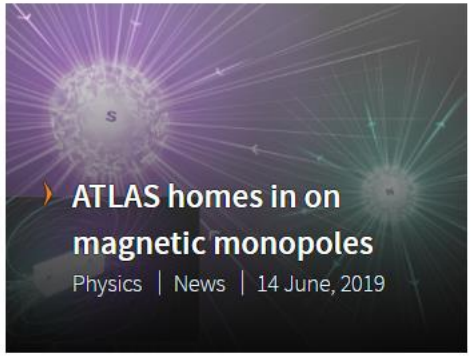
MoEDAL bags a first

The MoEDAL experiment has conducted the first search at a particle collider for magnetic monopoles produced through the Schwinger mechanism

2 JULY, 2021 | By Ana Lopes

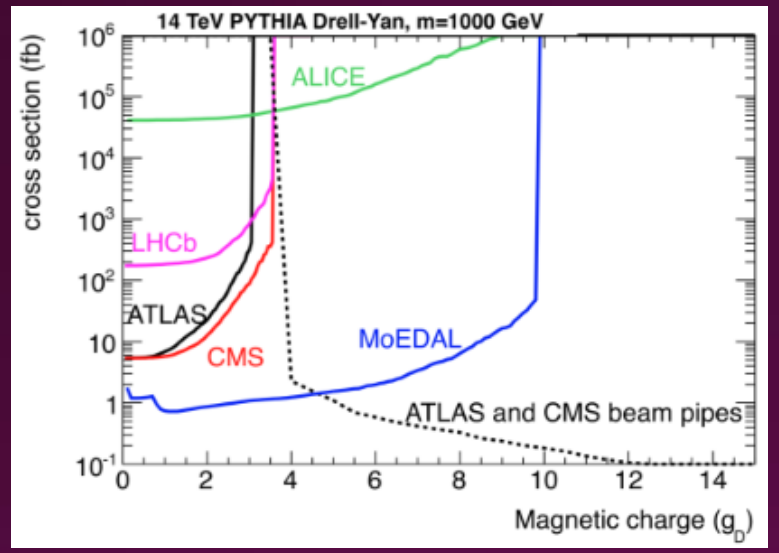
Related Articles





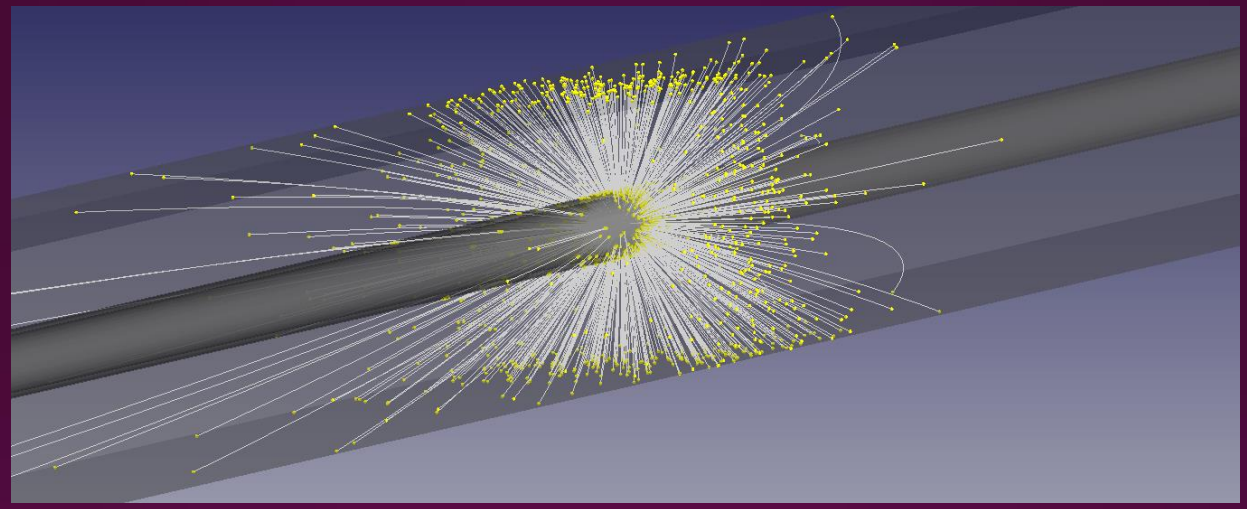
Trapping of Monopoles in Beam Pipes

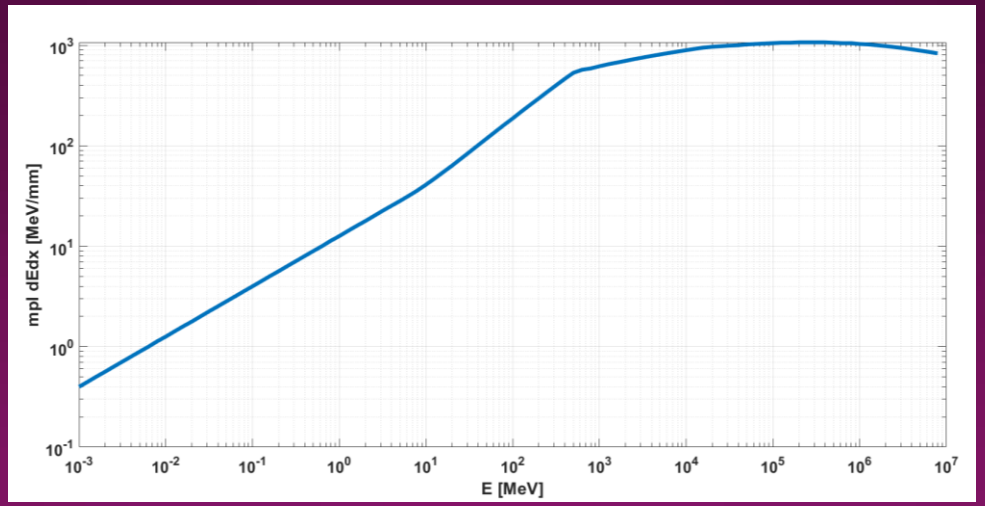
- Feb 2019: CMS and MoEDAL collaborations signed agreement transferring ownership of the Run-1 CMS beam pipe to MoEDAL
- CMS beam pipe was shipped to Alberta and cut into smaller pieces and put into plastic coverings
- Using SQUID-facility in Zurich the samples were scanned



Trapping of Monopoles in Beam Pipes

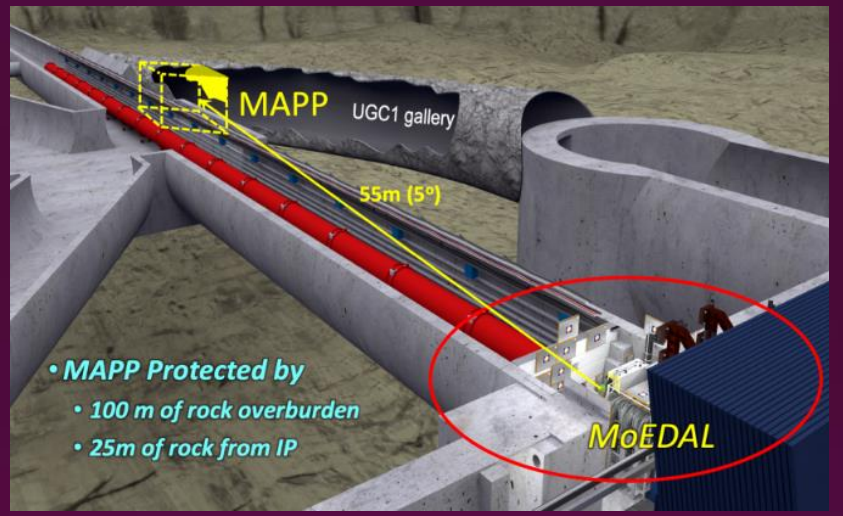
- The measurement results are compared to Geant4 simulations
  - Question whether monopoles can be trapped with beryllium
  - Simulations show that the monopoles slow down in the material, but the trapping condition is unclear
    - Depends on model of the nuclei

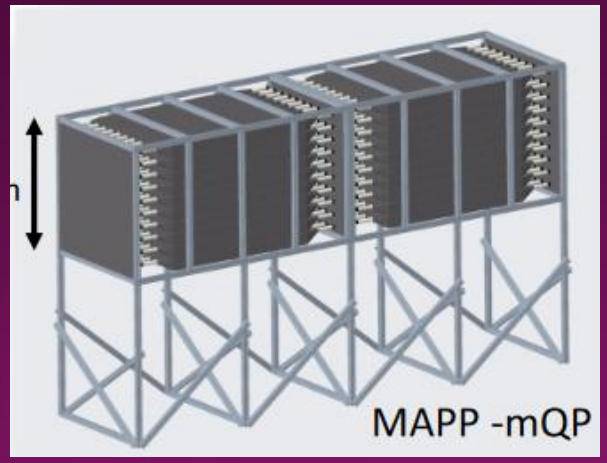


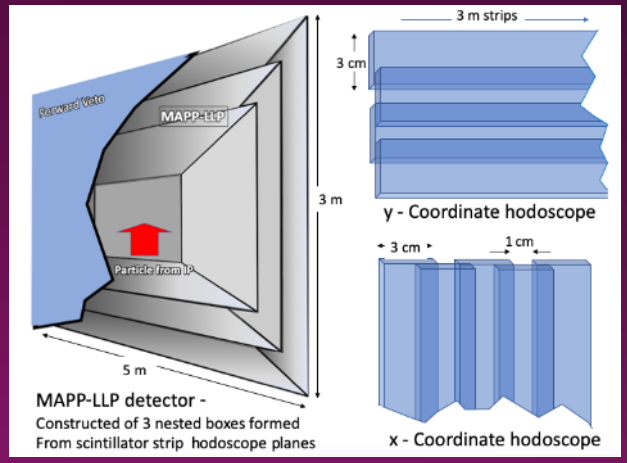


MAPP – MoEDAL Apparatus for Penetrating Particles

- MAPP detector consists of basic subdetectors
  - Mini (milli)-charged particle (mQP) detector
    - 100 ×(10 cm ×10 cm ×75 cm) scintillator bars in 4 lengths, 2 lengths/section readout by 4 low noise 3.1" PMTs, in coincidence
  - Very long-lived weakly interacting neutral particle detector
    - "Box-within-a-box" or "Russian Doll" structure from scintillator strips in an x-y configuration readout by SiPMs







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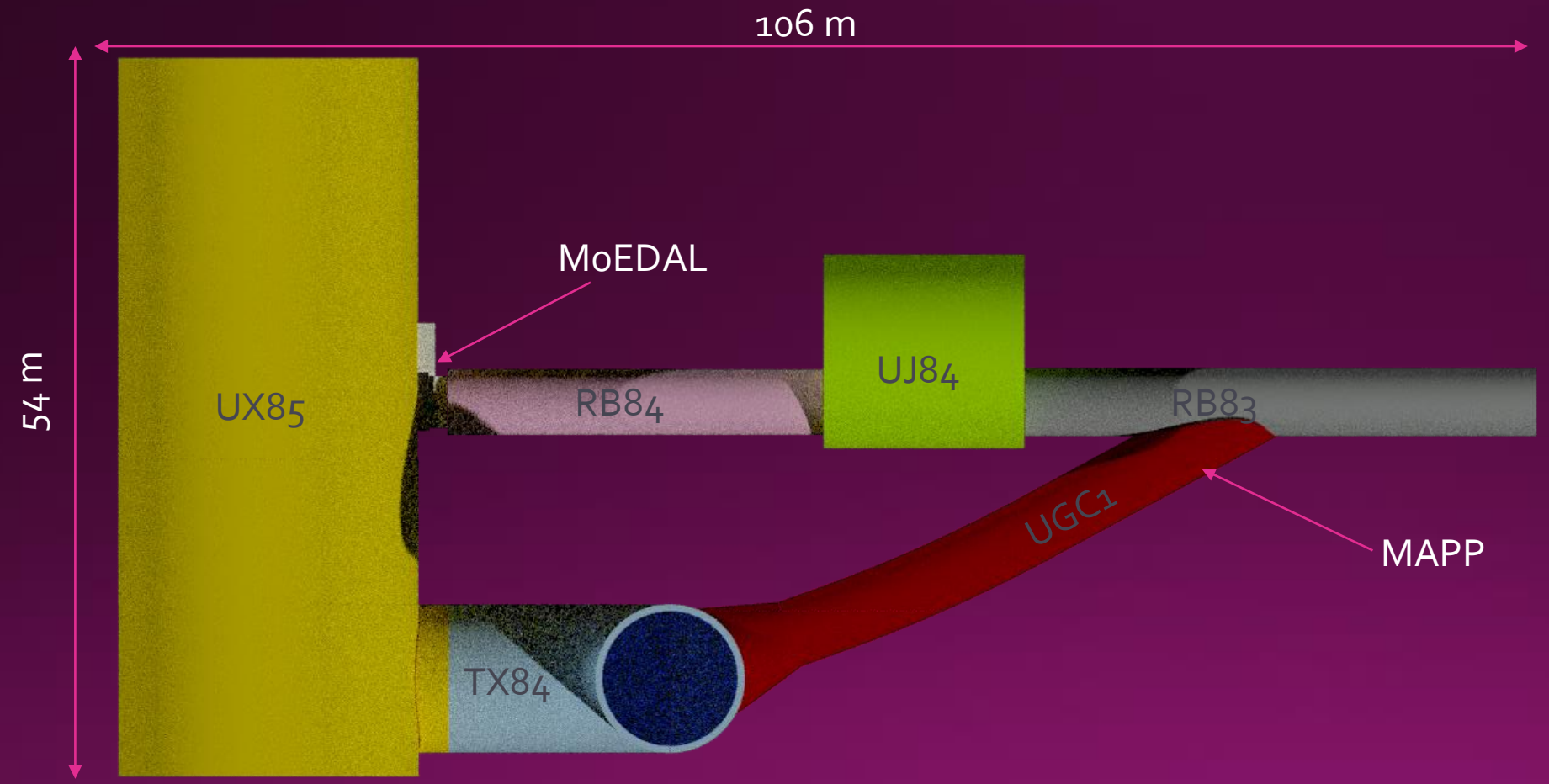

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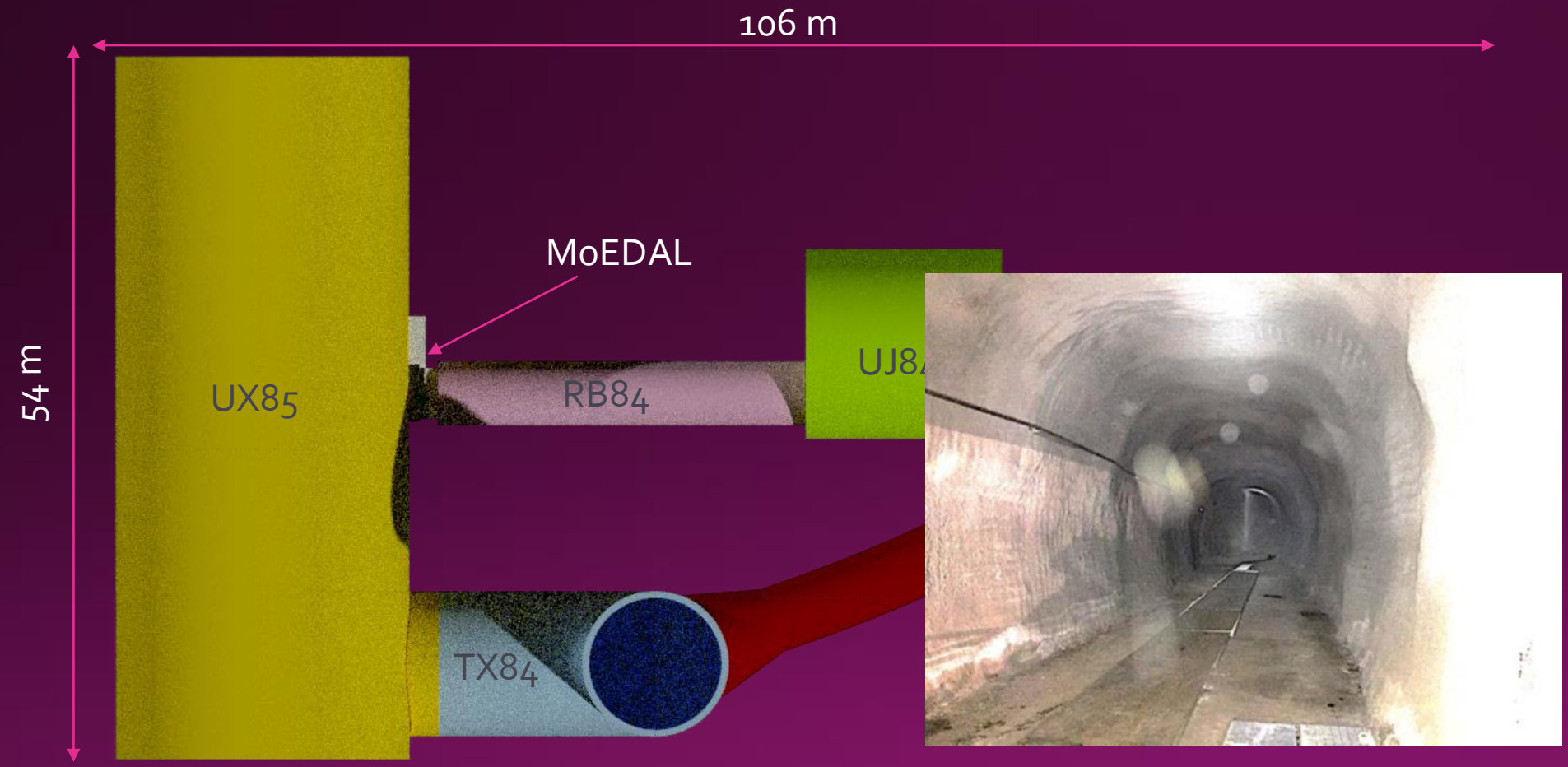

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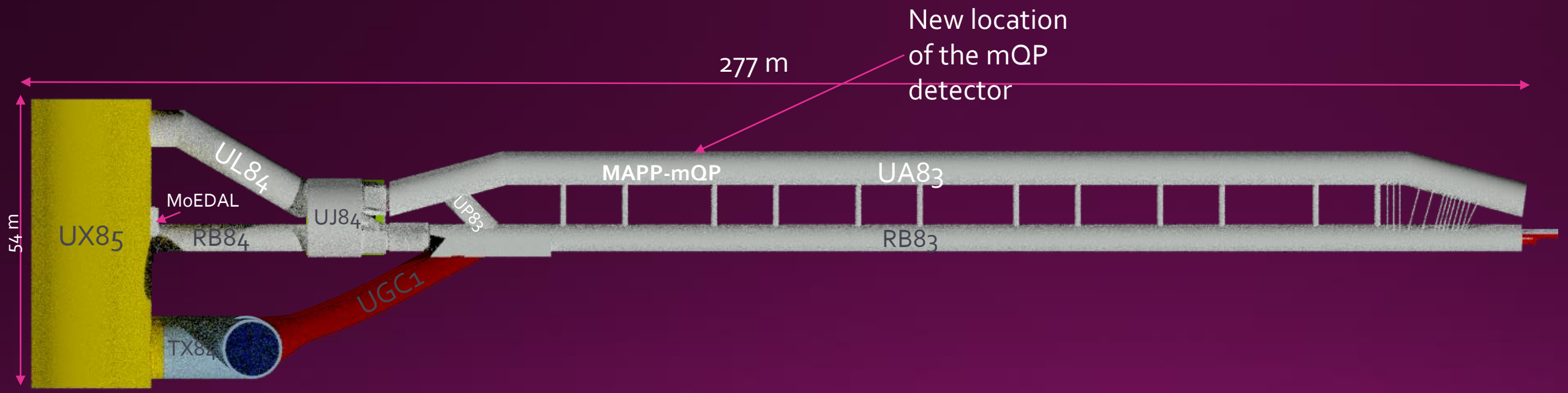

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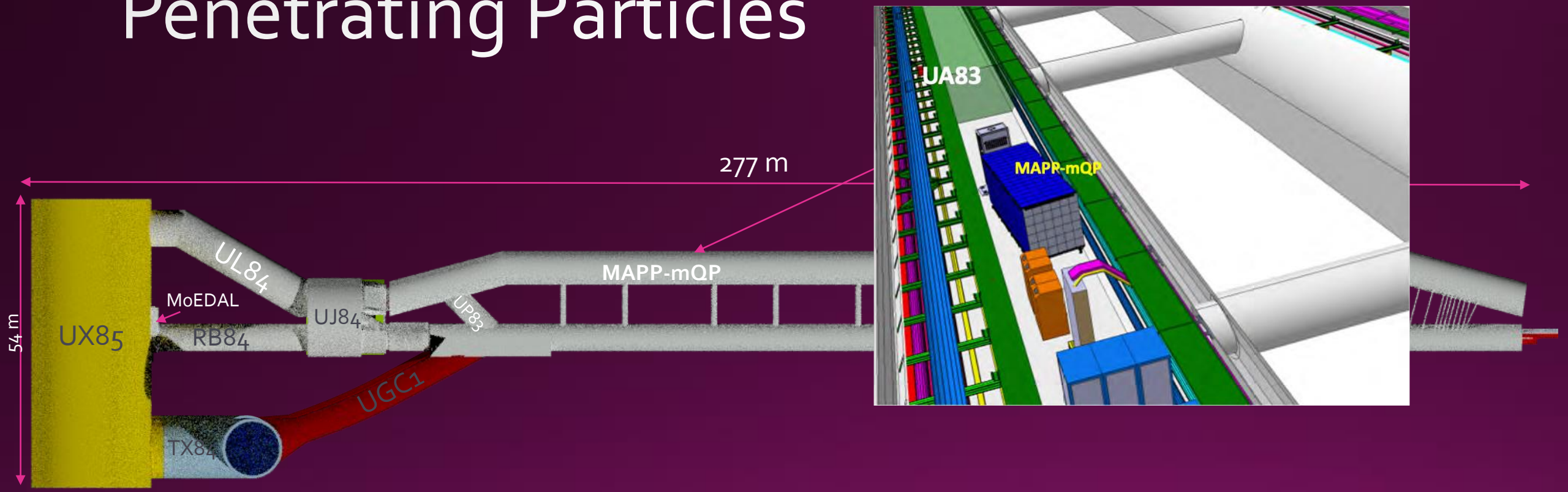
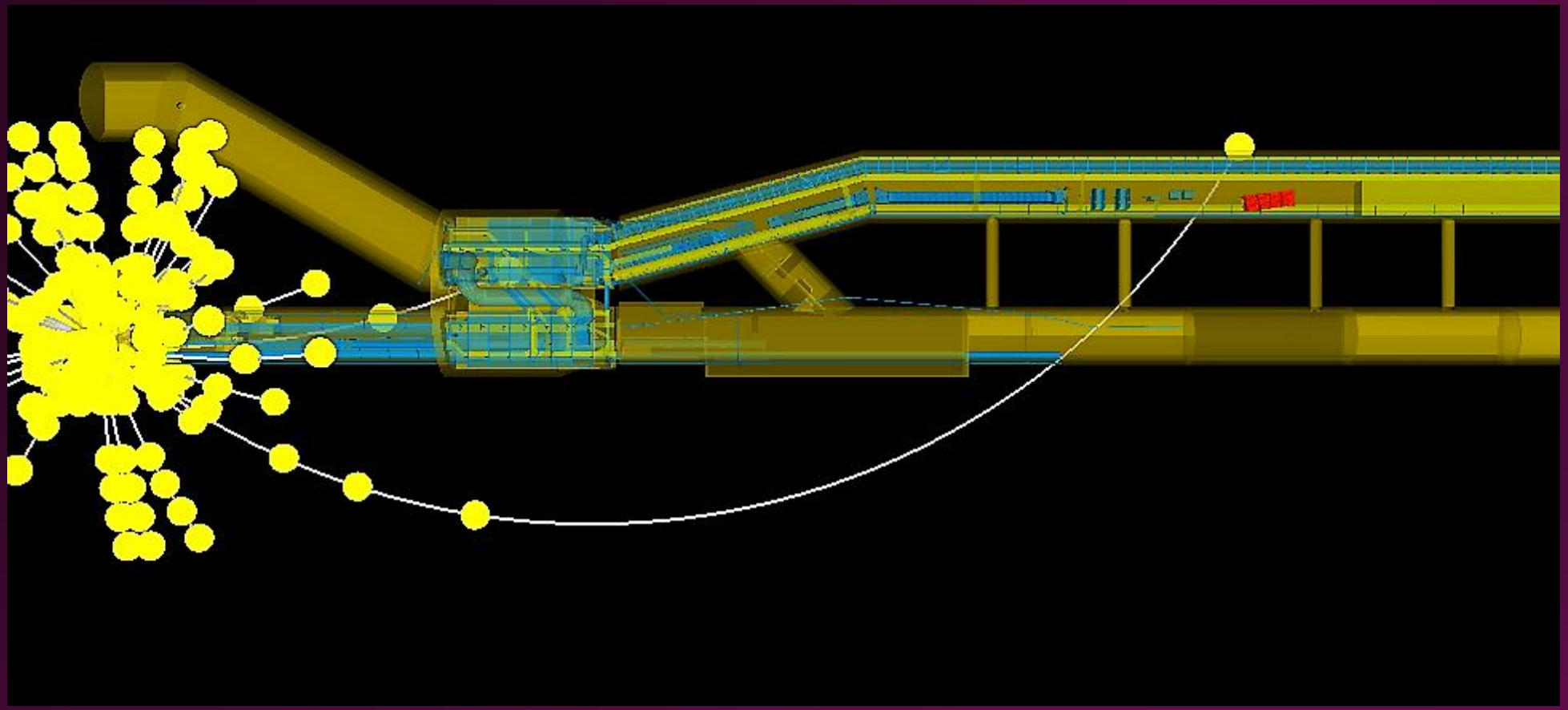
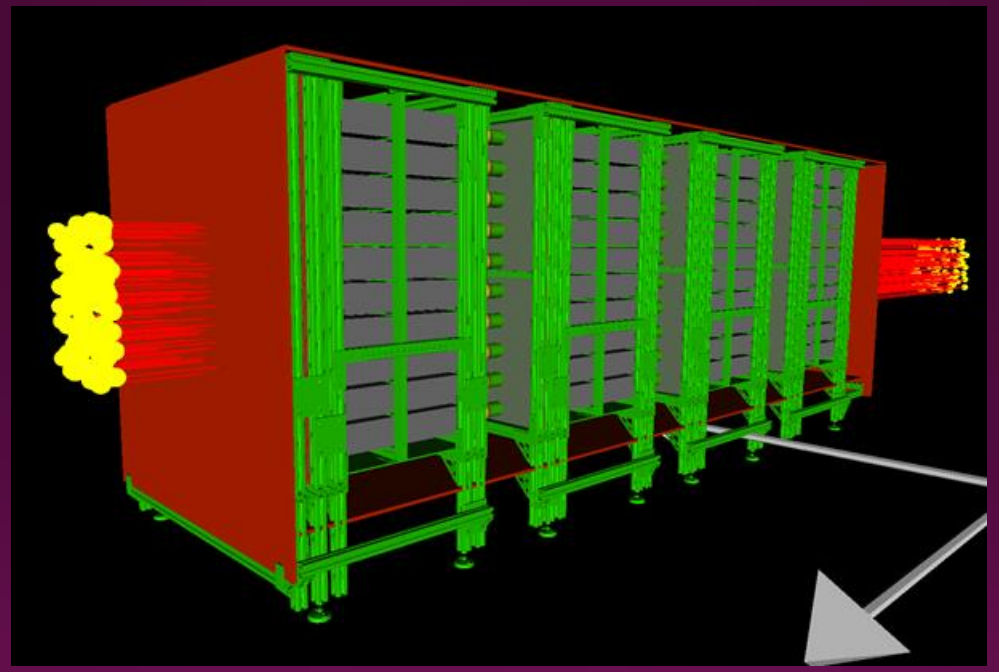




- In the new location the beam background is reduced
  - About 35 meters of rock/concrete between the IP and the detector location
- The rock overburden is about 110 meters
  - Only small contribution from cosmics
- UA83 tunnel is further away from the accelerator tunnel
  - Reduced machine background

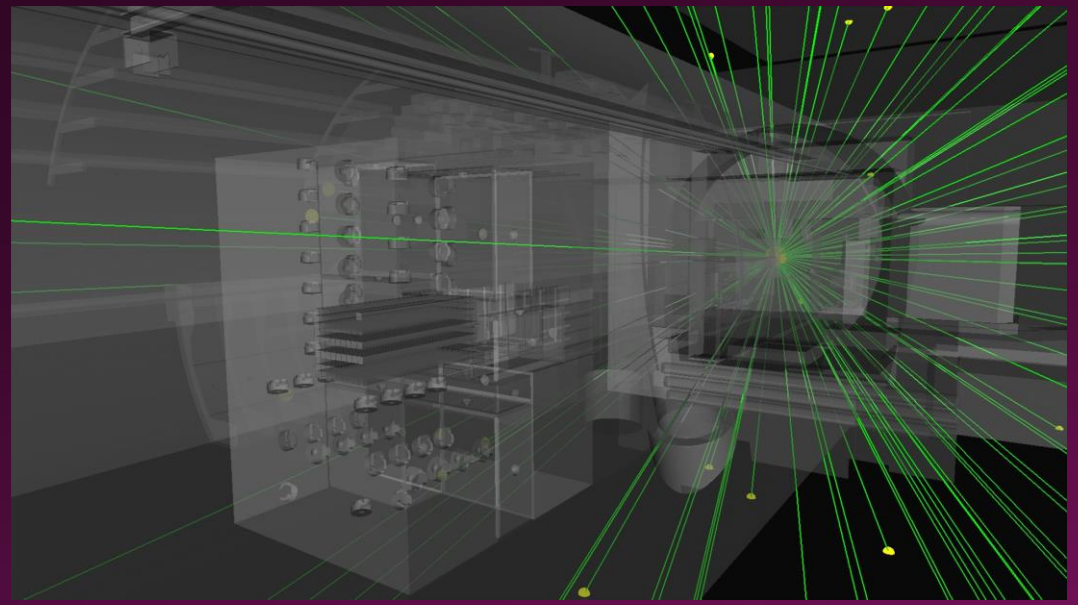
MAPP mQP-detector

- Consists of 4 collinear sections
  - 100 scintillator bars in 10x10 array in each
- Veto system in each section
  - Combination of scintillator layers and radiator layers

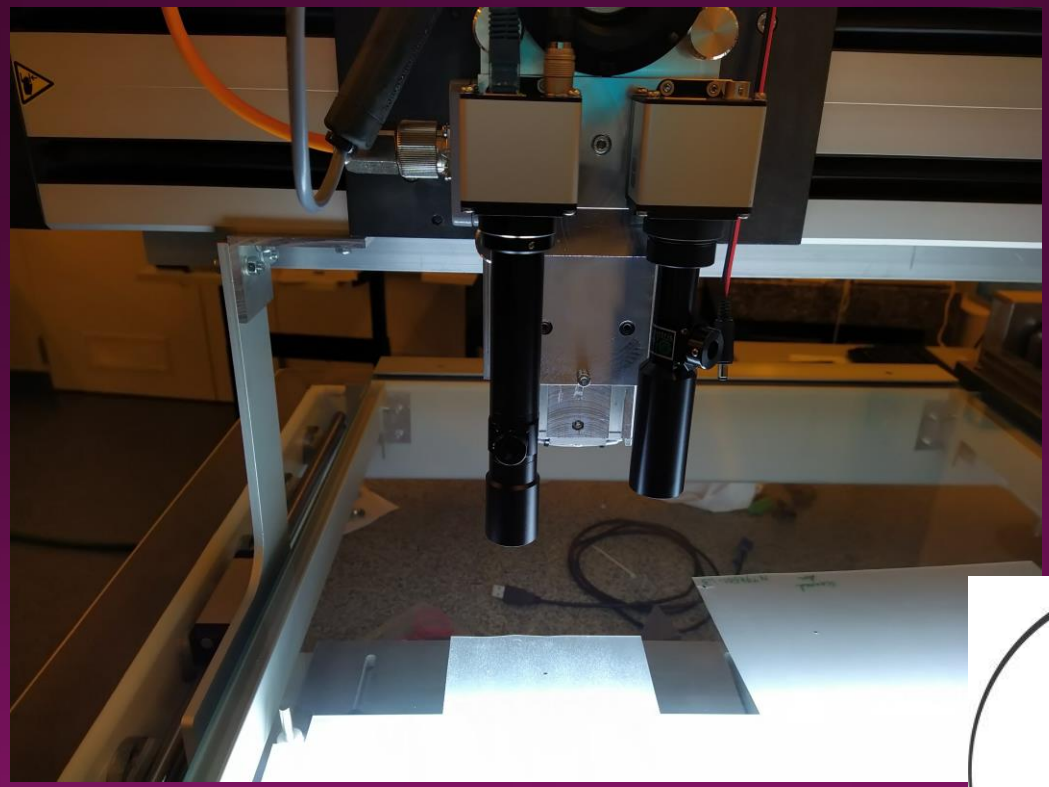


HIP in MoEDAL-MAPP

Simulations



Optical scanning of NTD foils



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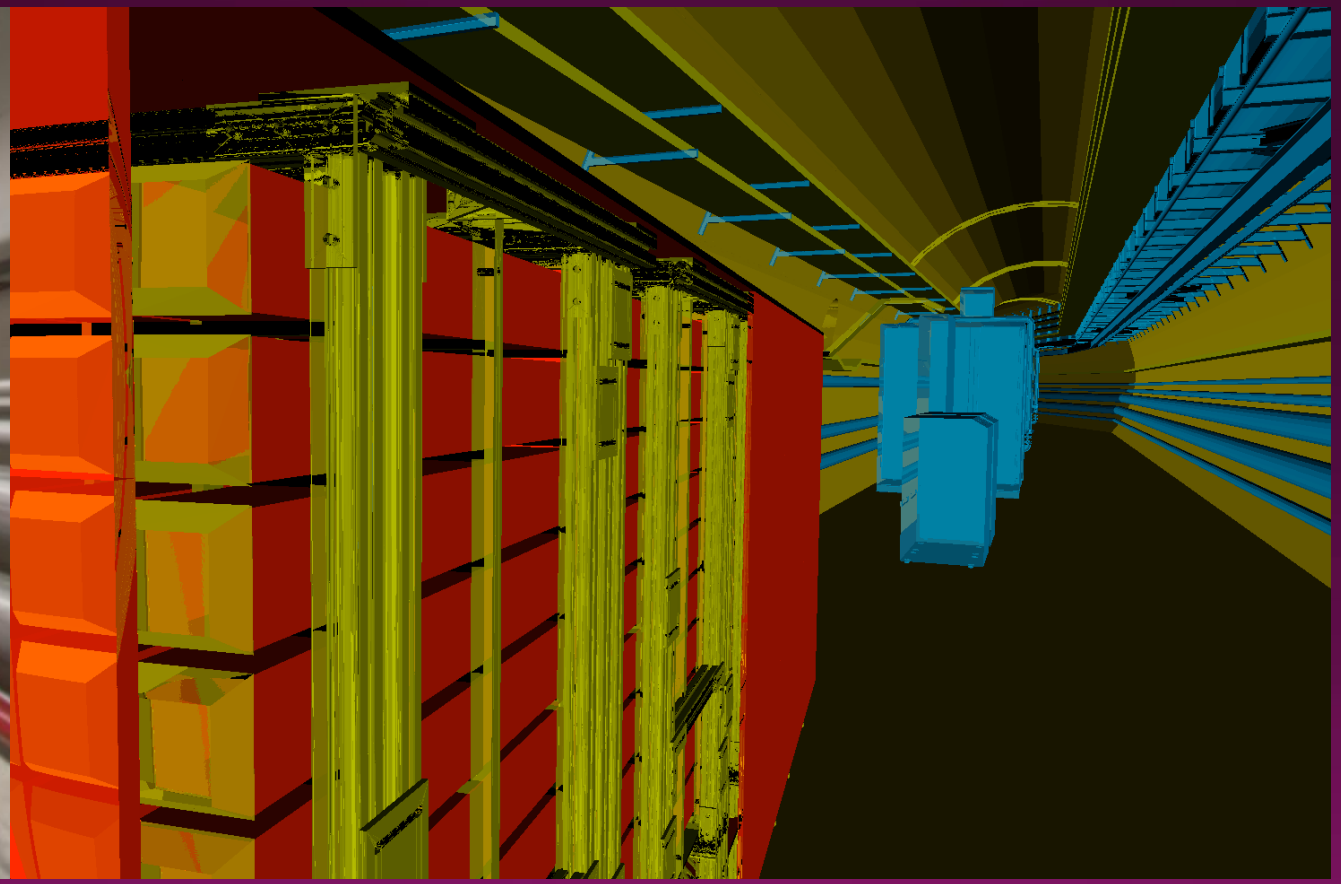
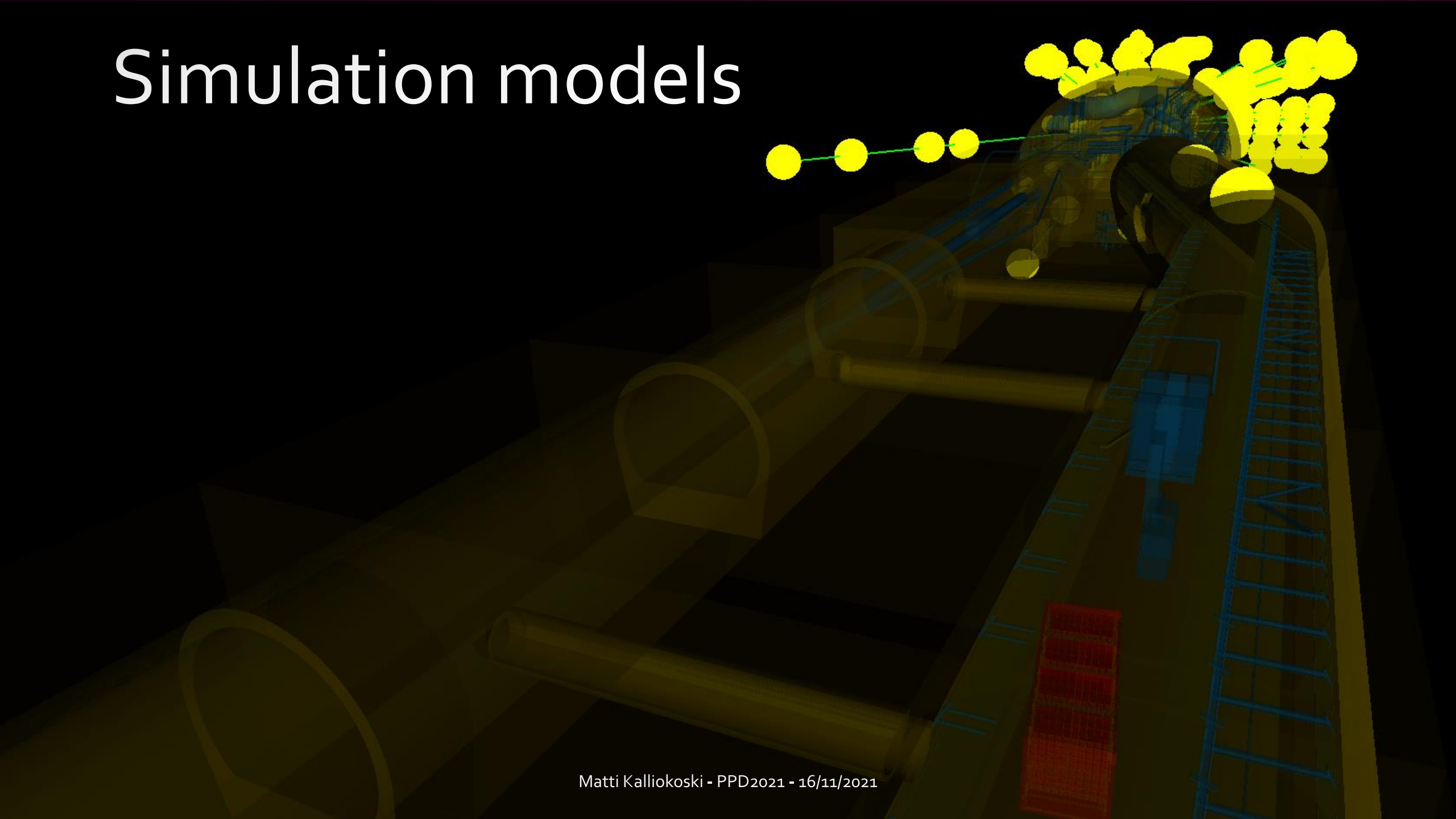
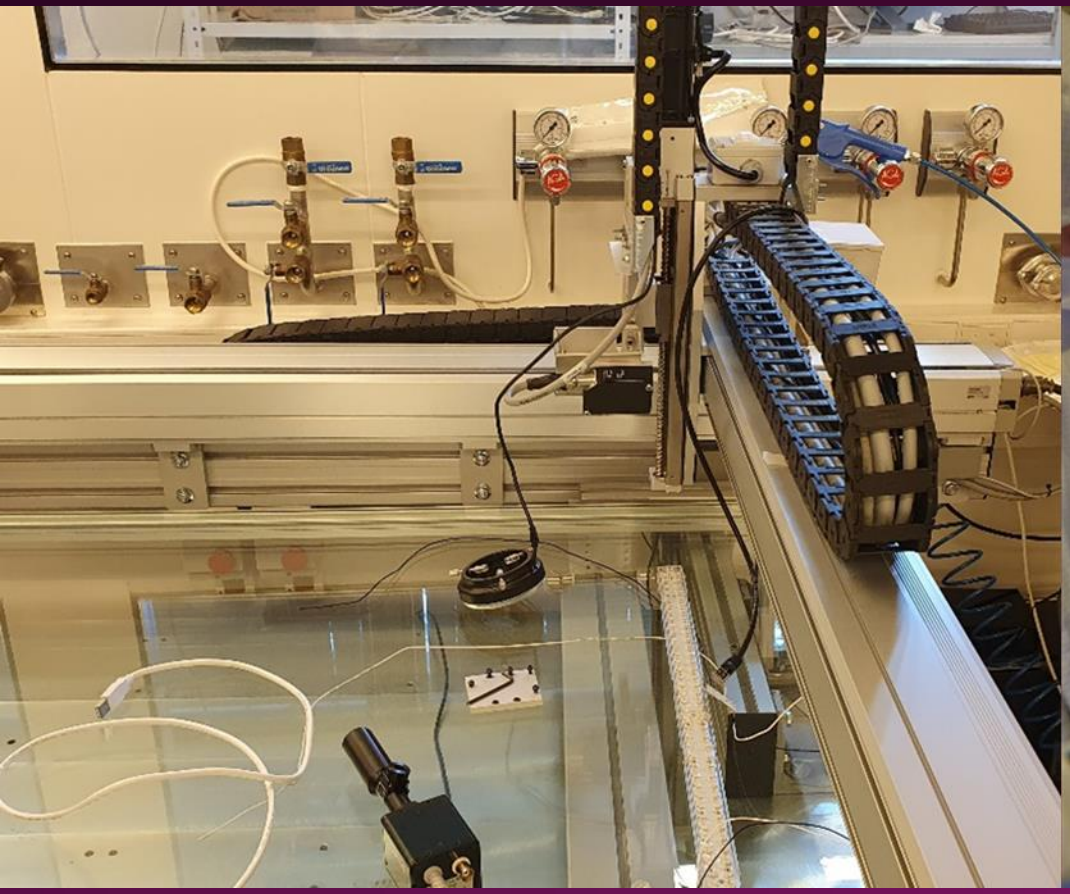
Simulation models

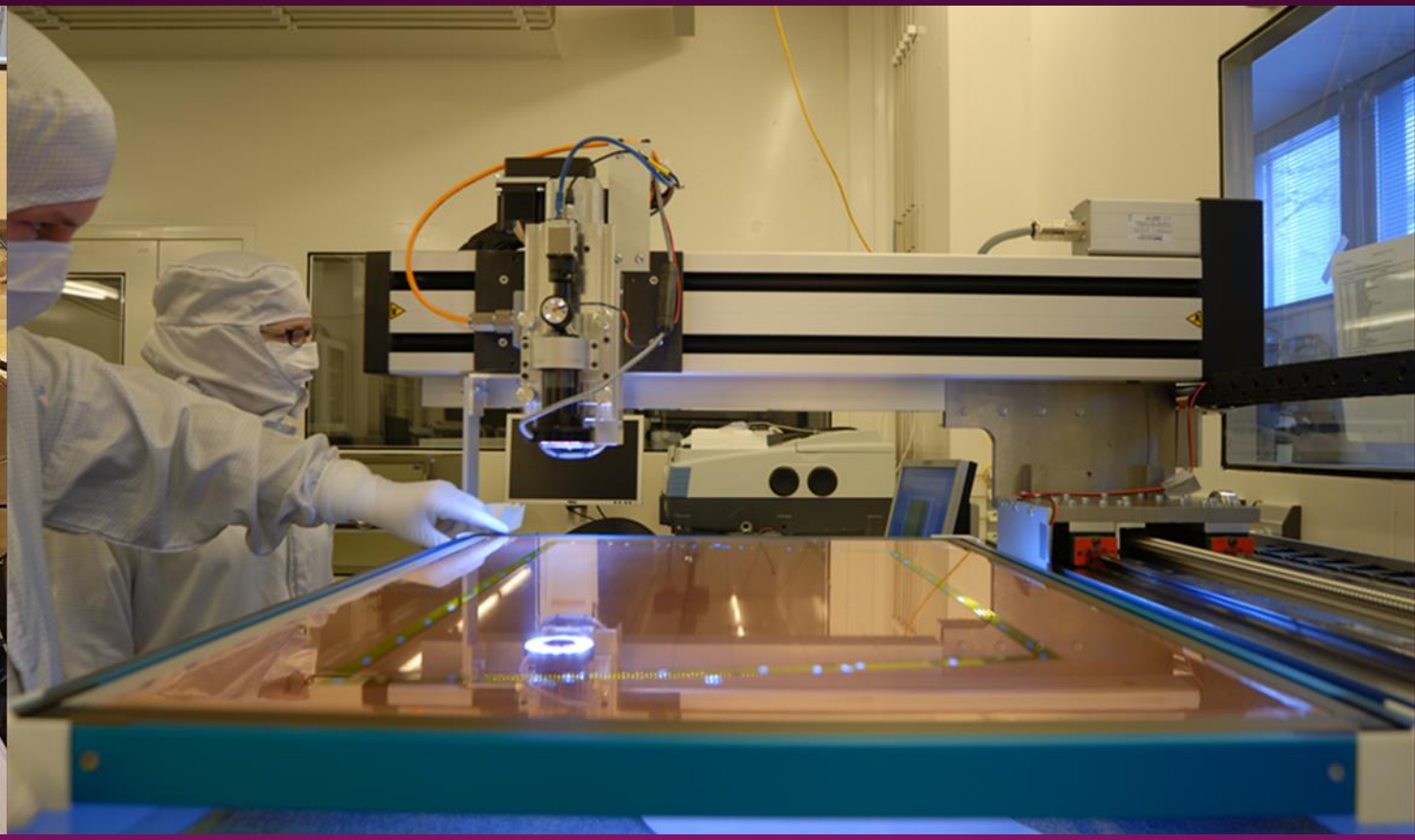


Simulation models



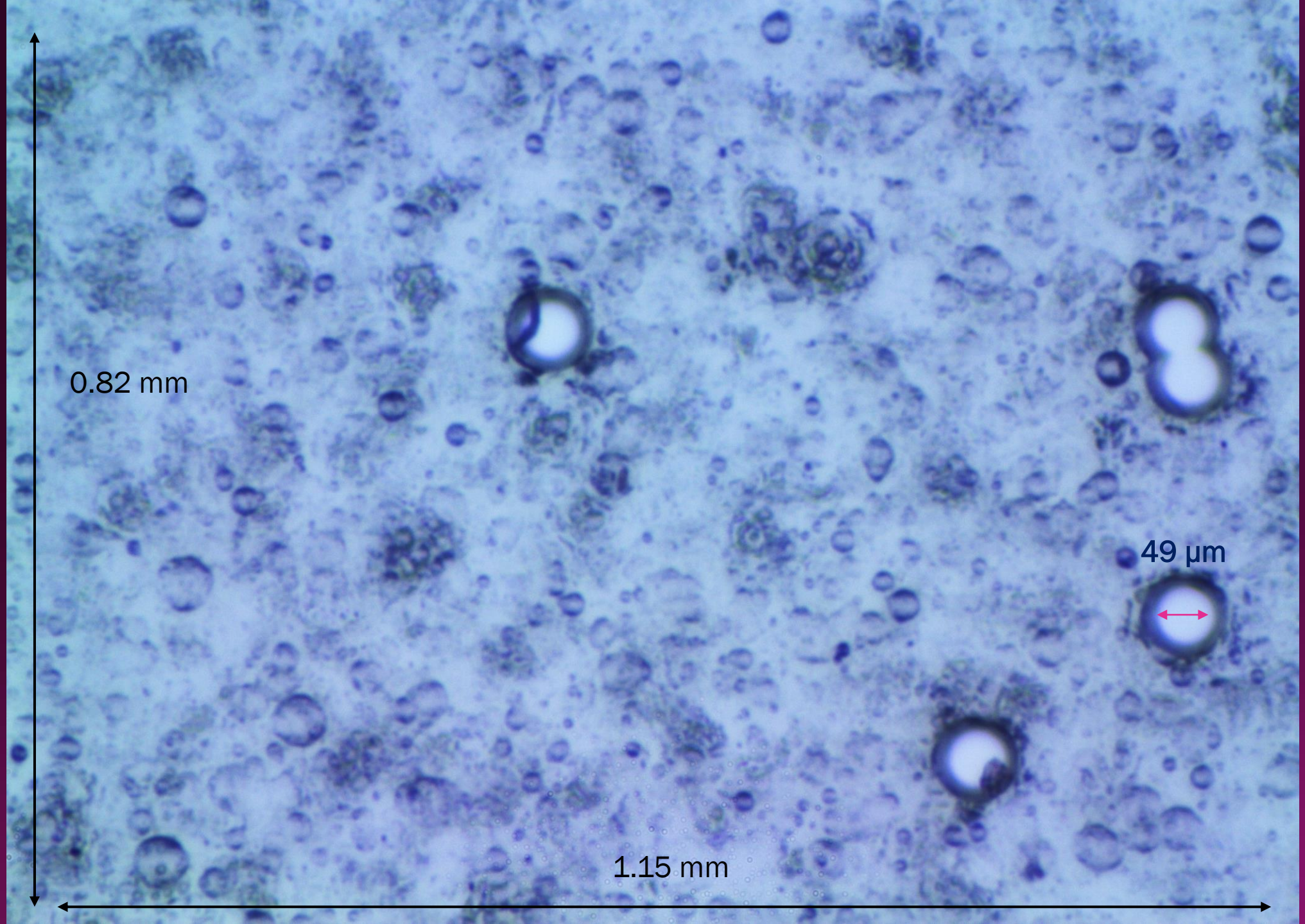
Optical scanning





Optical scanning

- C-mount cmos cameras
  - 5.2, 9.0 and 10.5 Mpix
  - Lenses are interchangeable between cameras
  - Different magnification and field of view options
- Bi-telecentric lenses with no coaxial light
  - Magnifications of 0.5 and 1.0
- Telecentric lenses with coax light
  - Magnifications of 0.5, 1.0 and 6.0


0.82 mm
49 µm
1.15 mm

Conclusions

MoEDAL is prepared for data taking during Run3

Due to increase in luminosity, unprecedented amount of NTD foils will be required for measurements

New update for the experiment will be an active mQP detector at UA83

- The detector will extend the search capabilities of MoEDAL to millicharged and exotic particles