

MoEDAL – Expanding the LHC’s Discovery Frontier

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The Higgs Boson & the Magnetic Monopole



Dirac first hypothesized the monopole's existence



Higgs hypothesized the Higgs boson's existence

- **The main purpose of the general purpose LHC experiments ATLAS and CMS is to find and study the Higgs boson**
- **The main purpose of the MoEDAL- LHC Experiment is to search for the magnetic monopole, possibly a topological excitation in the Higgs field (eg. Yongmin Cho's Electroweak Monopole)**
- **But ATLAS, CMS and MoEDAL can do much more**

Motivation: Why should you care?!

$$\begin{aligned}\nabla \cdot \vec{E} &= 4\pi\rho \\ \nabla \cdot \vec{B} &= 4\pi\rho_m \\ -\nabla \times \vec{E} &= \frac{1}{c} \frac{\partial \vec{B}}{\partial t} + \frac{4\pi}{c} \vec{j}_m \\ \nabla \times \vec{B} &= \frac{1}{c} \frac{\partial \vec{E}}{\partial t} + \frac{4\pi}{c} \vec{j}\end{aligned}$$

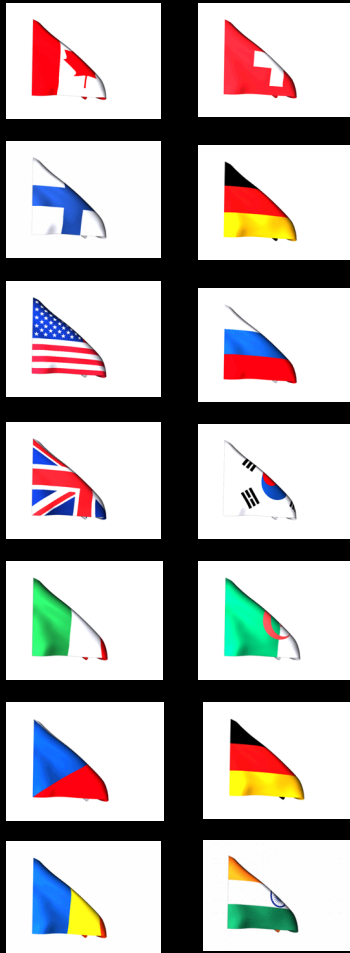
- Their inclusion in the theory of EM would restore the symmetry between E and B fields.
- Their existence would explain the quantization of electric charge.
- MM appear in many GUT theories, and we all want unification!

MoEDAL – the 7th and Newest LHC Exp.



- The MoEDAL experiment the 7th LHC experiment was officially approved by the CERN Research Board on March 3rd 2010
- MoEDAL started taking data at the LHC in the Spring 2015
- MoEDAL has taken data in p-p collisions at 8 TeV and 13 TeV Collision Energy as well as in heavy-ion collisions

The MoEDAL Collaboration

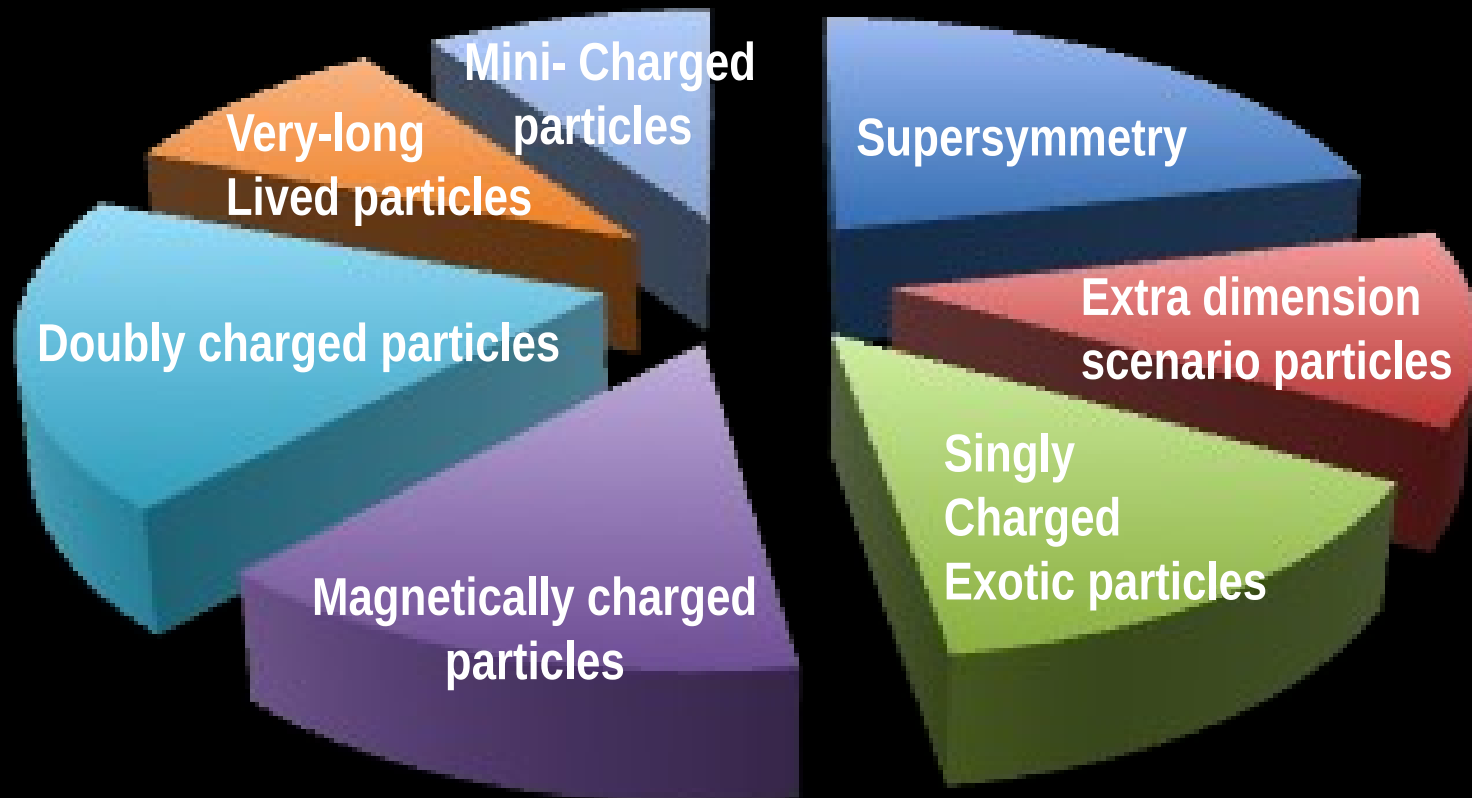


Now 66 physicists from 14 countries, 4 continents & 26 institutions:

U. Alberta, U. Alabama, UBC, INFN Bologna, U. Bologna, CAAG (Algeria), Algeria, U. Cincinnati, Concordia U., Gangneung-Wonju Nat. U., U. Geneva, U. Helsinki, ICTP Trieste, IEAP/CTU Prague, IFIC Valencia, Imperial College London, INP/PAS Cracow, ISS Bucharest, King's College London, Konkuk U., MiSIS U. Moscow, Muenster U., National Inst. Tec. (India), Northeastern U., Queen Mary University London, Simon Langton School UK, Tuft's.

MoEDAL is Sensitive to Many Other New Physics Scenarios

Sensitive to over 40 new physics scenarios



MoEDAL's Avatars of New Physics

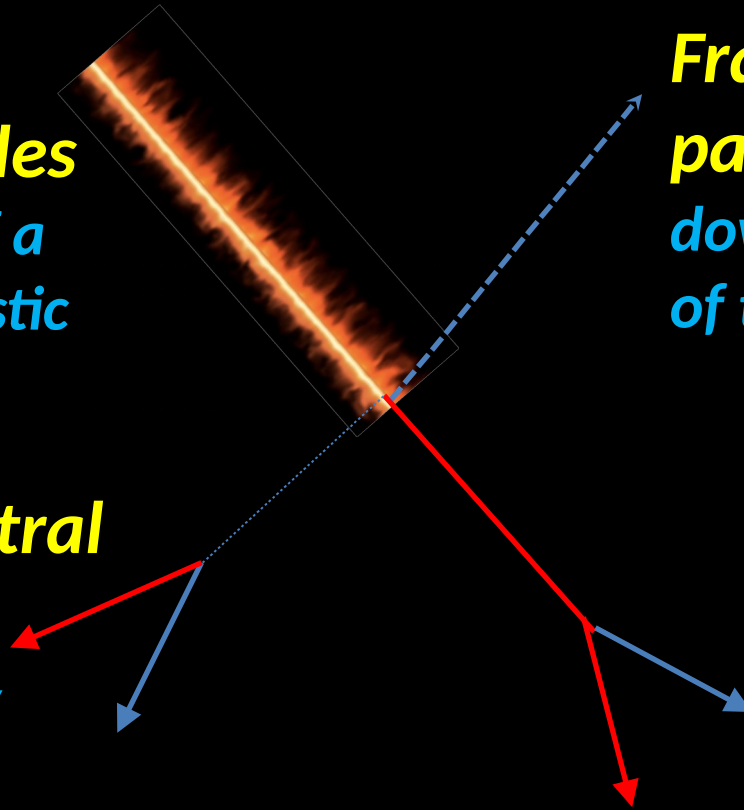
Avatar [av-uh-tahr]: An incarnation, embodiment, or manifestation of a person or idea:

Very Highly ionizing particles
(≥ 5 times that of a standard relativistic charged particle)

Fractionally charged particles (with charge down to less than $\sim 1\%$ of the electron's charge)

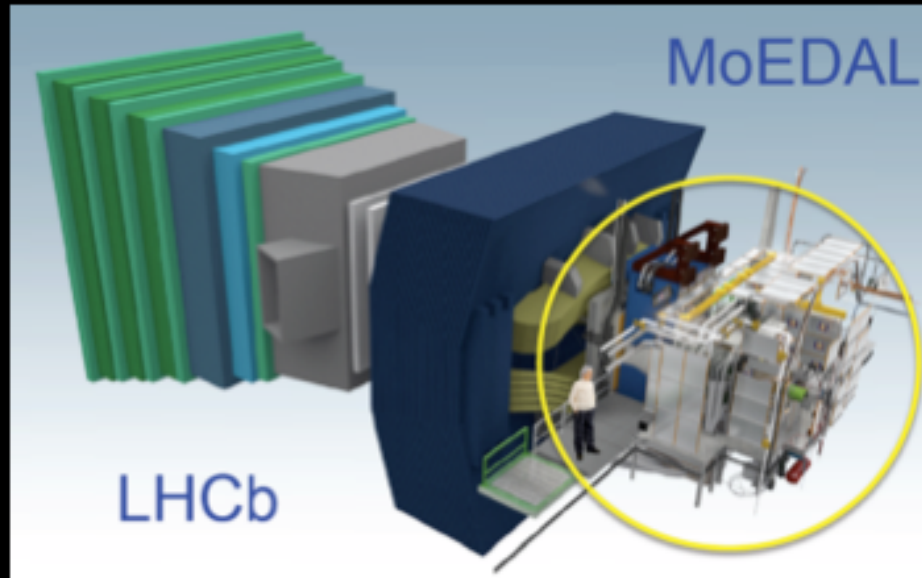
Long lived neutral particles –
(of 100m decay length or more)

Very long-lived charged particles
(with lifetimes up to ~ 10 years)



The MoEDAL Detector in a Nutshell

**Permanent
Physical
record
of new
physics**



**No
Standard
Model
Physics
Backgrnds**

MoEDAL is largely passive and made up of three detector systems



NUCLEAR TRACK DETECTOR
Plastic array (~200 sqm)
– Like a Giant Camera

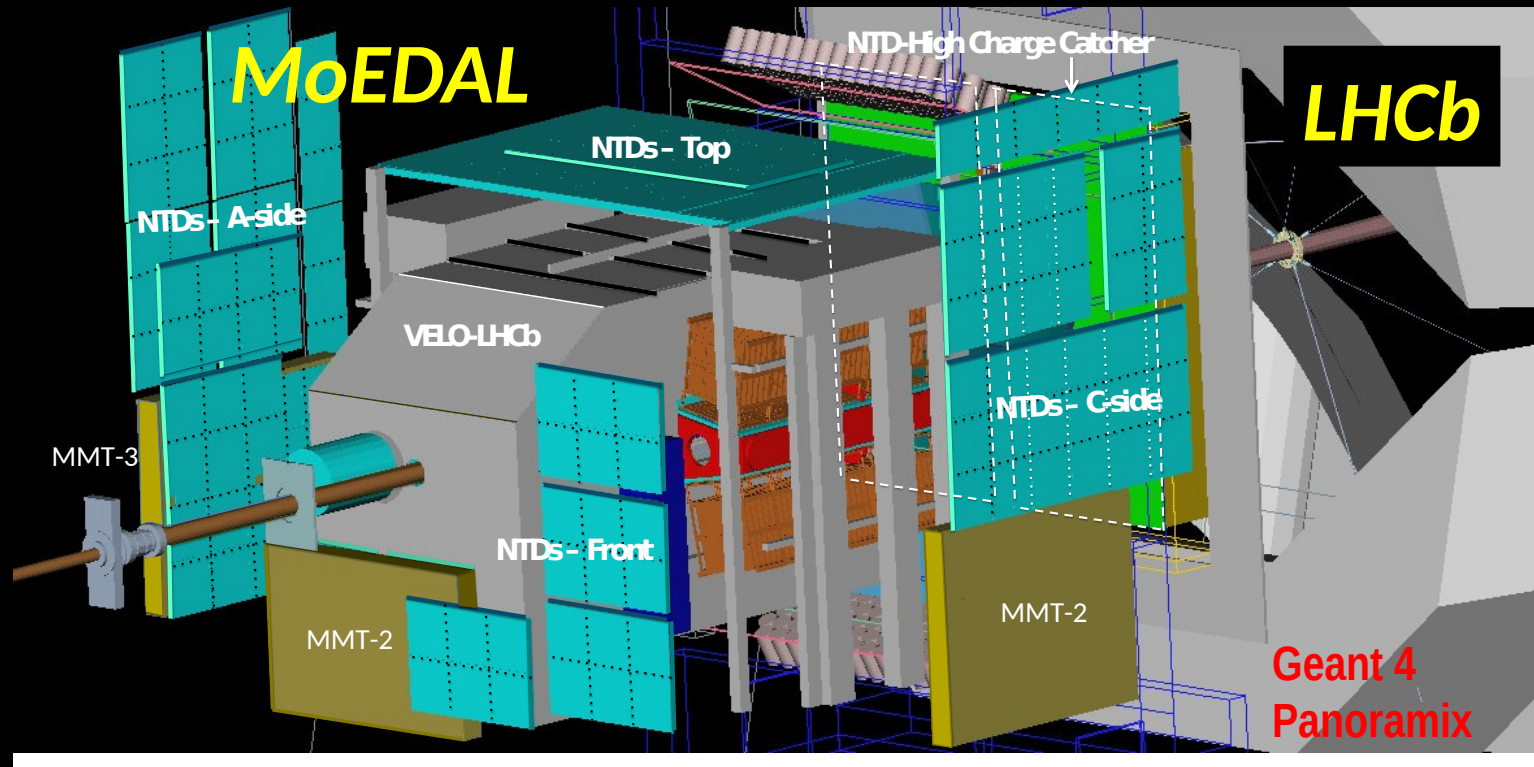


TRAPPING DETECTOR ARRAY
A tonne of Al to trap Highly
Ionizing Particles for analysis



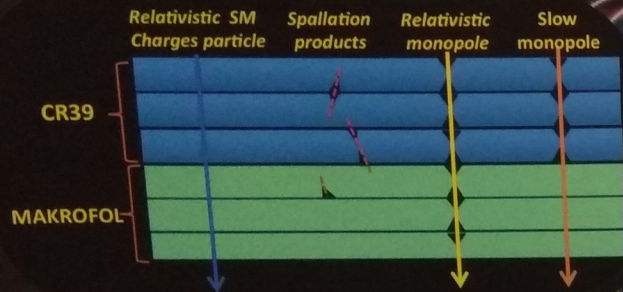
TIMEPIX Array a digital
Camera for real time
radiation monitoring

The MoEDAL Detector Today



Acceptance for at least one pair produced monopole $\sim 70\%$ (NTD)

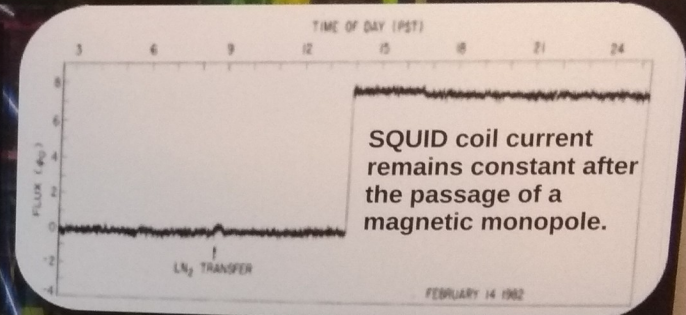
NTD Signal



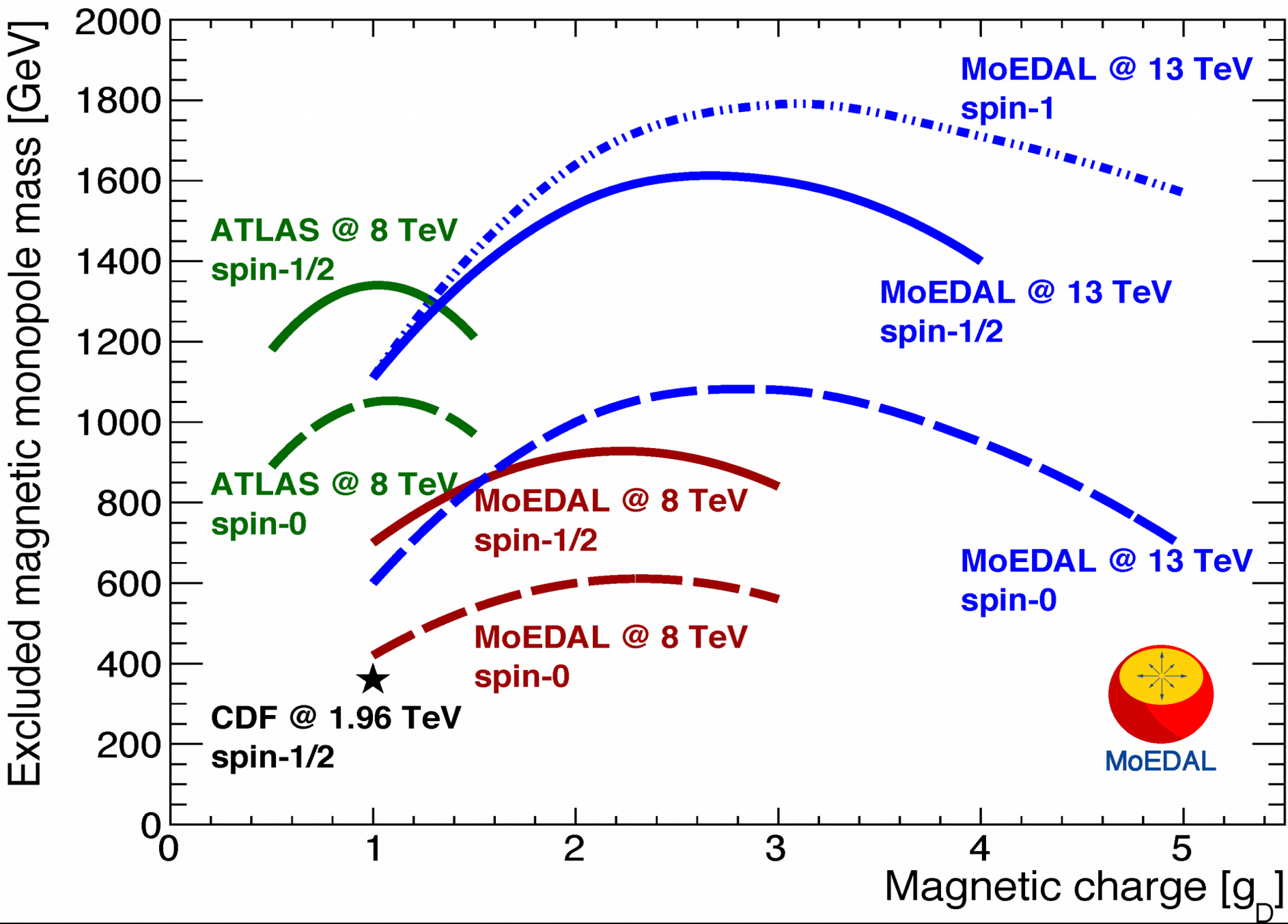
Signal & Analysis

Monopole path through an NTD stack is unique and forms conical etch pits, revealed by etching NTD sheets in a caustic NaOH solution. The trapping detector can identify magnetic charge as well as trap new massive electrically charged particles.

MMT Signal

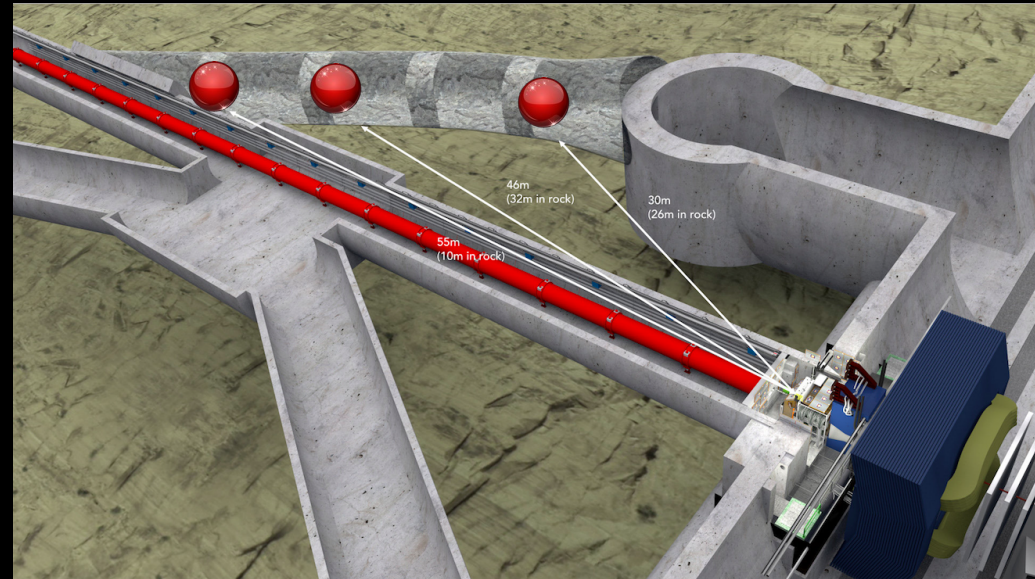
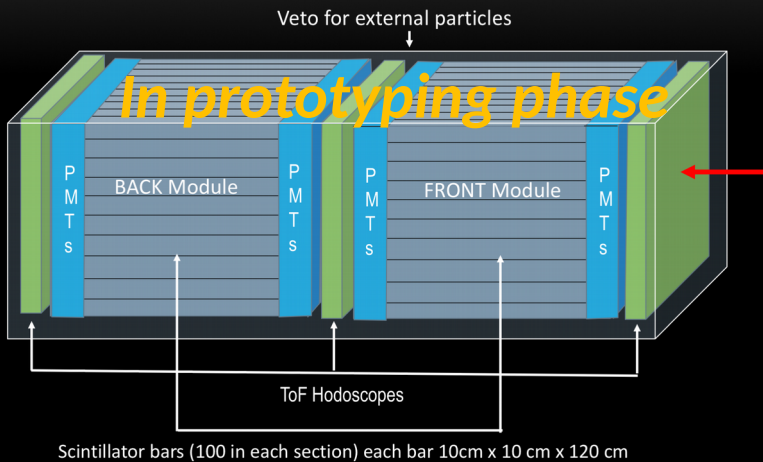


Drell-Yan production with β -independent coupling



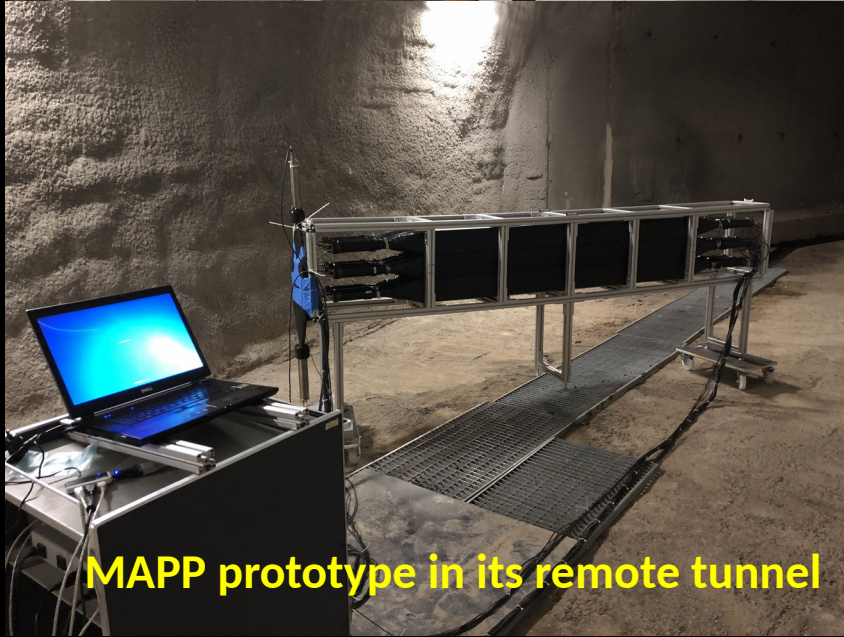
MAPP – MoEDAL Apparatus for Penetrating Particles

MoEDAL's FULL MAPP SUB-DETECTOR

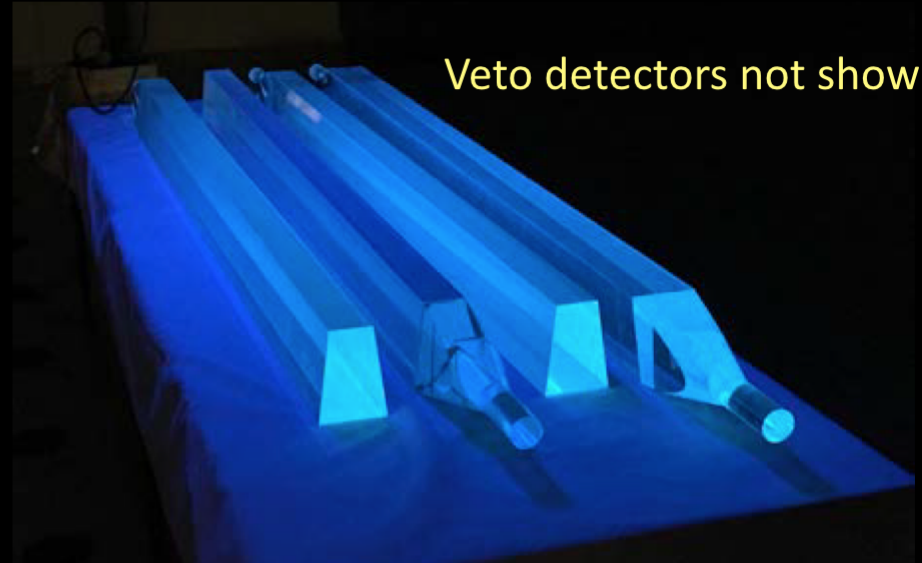


- **MAPP (MoEDAL Apparatus for Penetrating Particles) has 3 motivations:**
 - To search for “millicharged “ particles with charge $\ll 1e$
 - To search for new neutral particles with very long lifetimes
 - To search for anomalously penetrating particles
- **Detector is protected from SM backgrounds by 20m-30m of rock/concrete and can be moved from 5° to 25° to the beam**
- **Plan for deployment at LHC-RUN3 (2021)**

The MAPP Prototype Installed in 12/2017

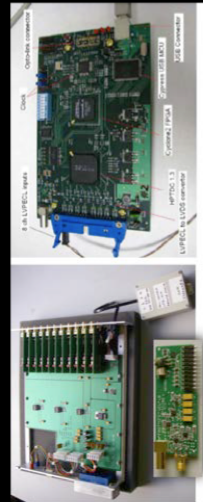
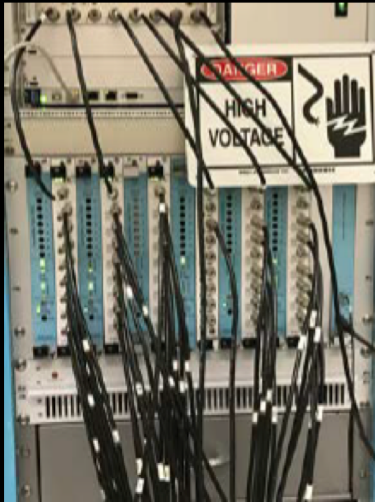


MAPP prototype in its remote tunnel



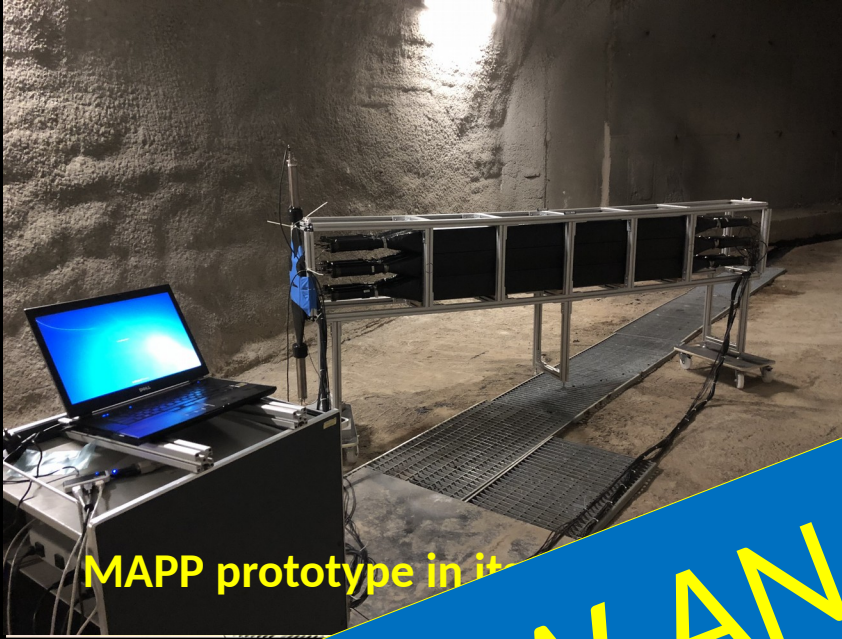
Veto detectors not shown

Electronics

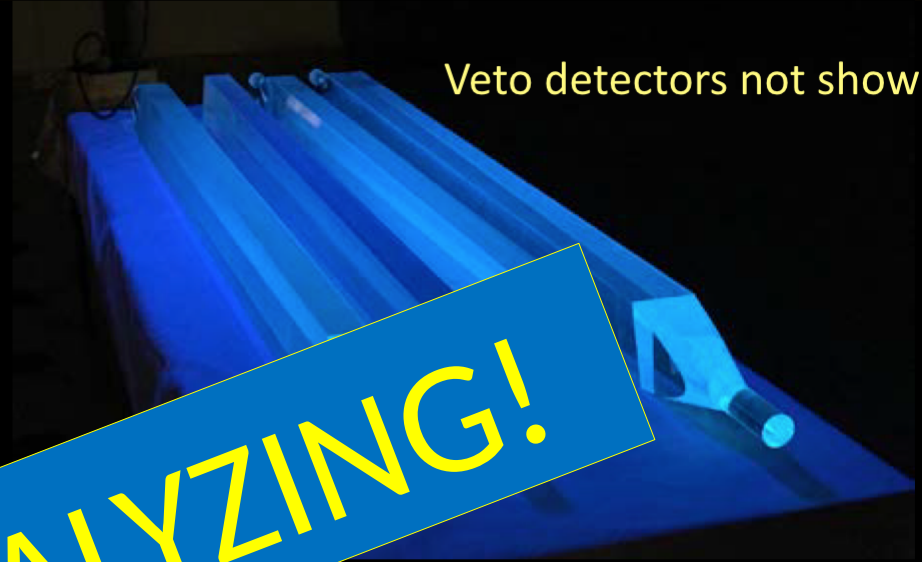


MAPP prototype in its remote tunnel

The MAPP Prototype Installed in 12/2017



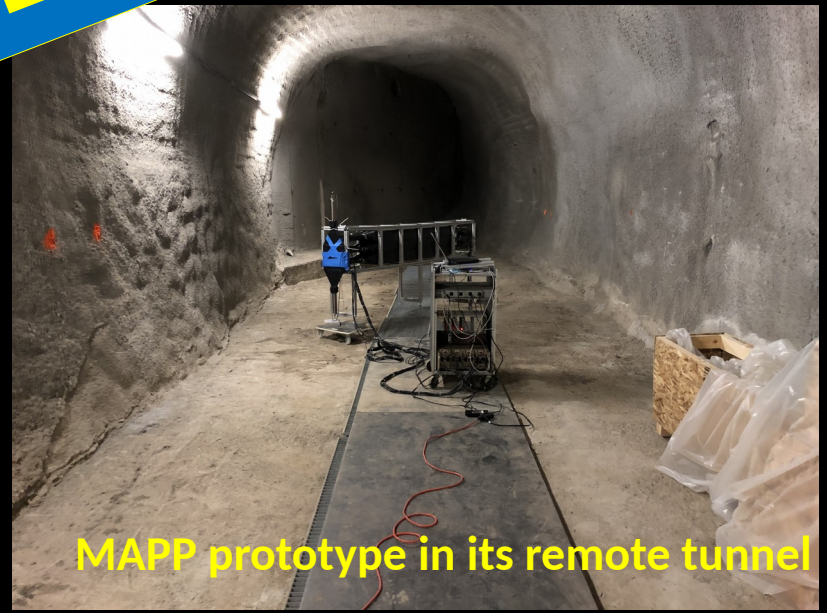
MAPP prototype in its remote tunnel



Veto detectors not shown

NOW ANALYZING!

Electronics



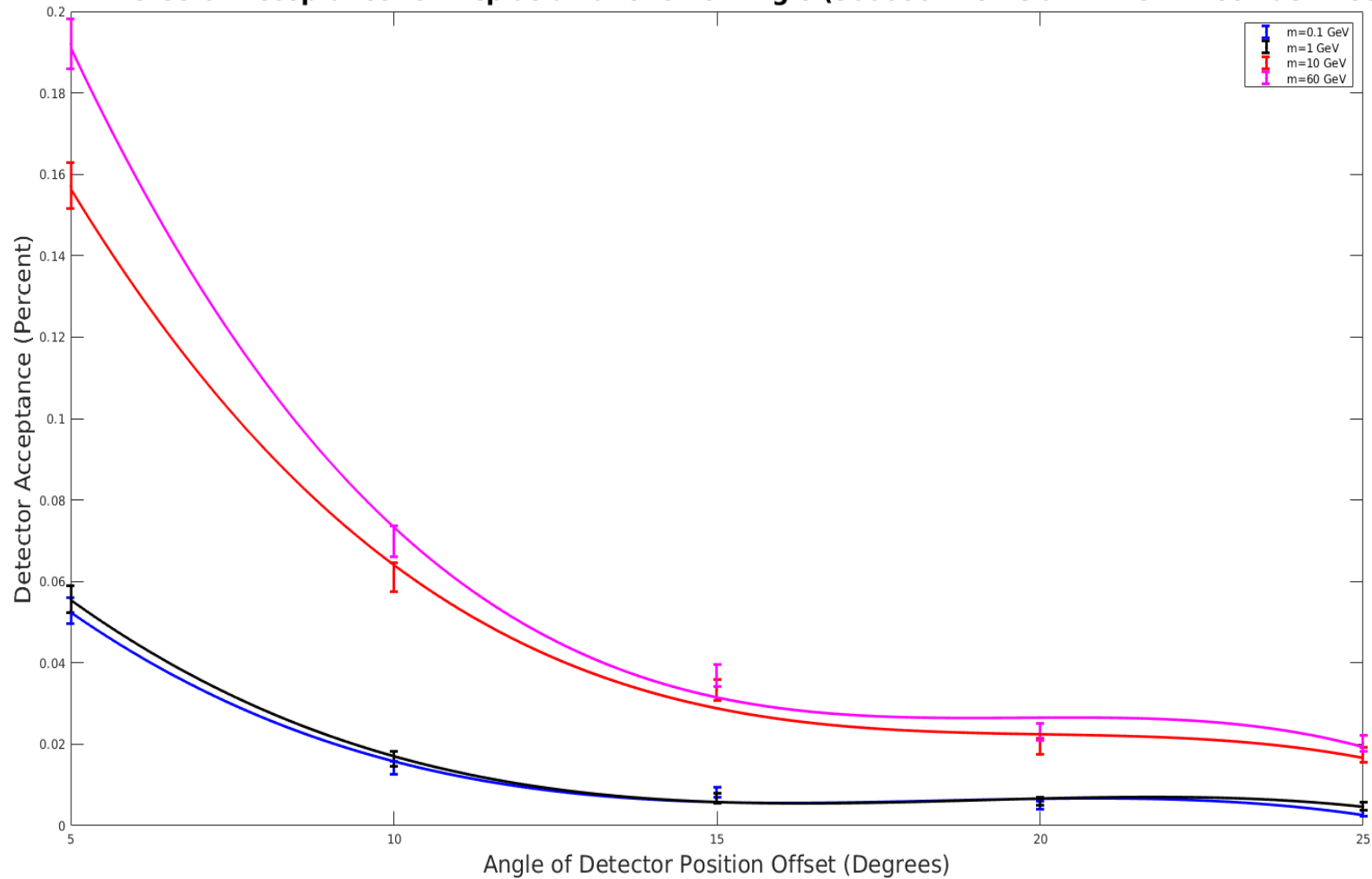
MAPP prototype in its remote tunnel

MAPP: Physics Processes

- Explore BSM scenarios from various theories, which have signatures that MAPP could be sensitive to
- Use Feynrules + Mathematica to create Madgraph models
- Validate models using the literature, analytic calculations, and numerical calculations.
- Generate Monte-Carlo events w/ MG5
- Write, test, and run simulations of MAPP to get detector acceptance.
- Establish MAPP's sensitivity to each of these processes.

Milli-Charged Particles in Dark QED ($0.1e$)

MAPP Detector Acceptance for M_{CP} as a Function of Angle (500000 Events at 14 TeV in Collider Mode)

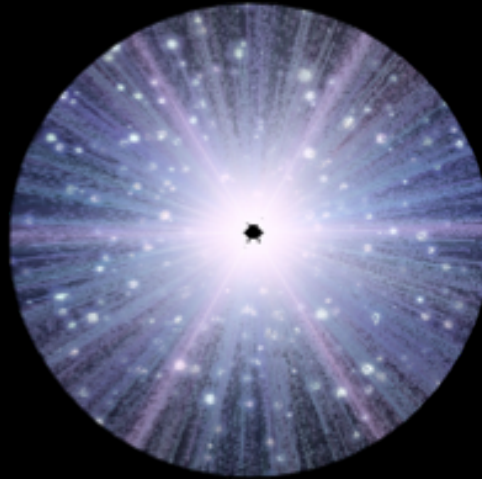


MAPP is sensitive to m_{CP} ($\sim 0.1-0.01e$) with $M \sim 0.1-100$ GeV

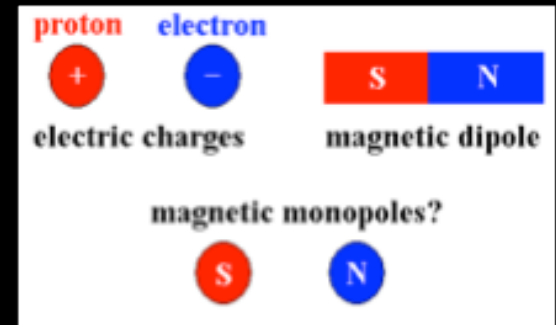
MoEDAL HELPS THE LHC TO ADDRESS FUNDAMENTAL QUESTIONS SUCH AS:



Are there extra dimensions?



What happened just after the big bang?

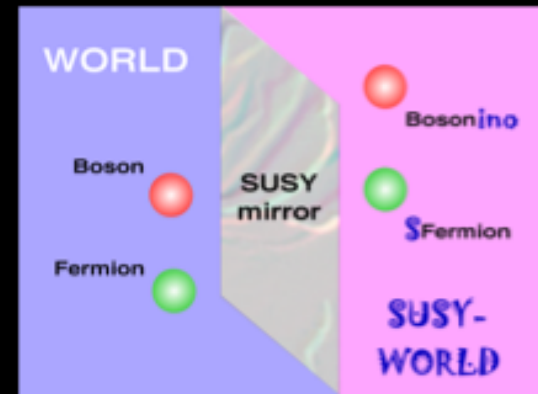


Does magnetic charge exist?



What is the nature of Dark matter?

19-2-11



Are there new symmetries of nature?