MoEDAL

Voyaging Beyond the Standard Model ...

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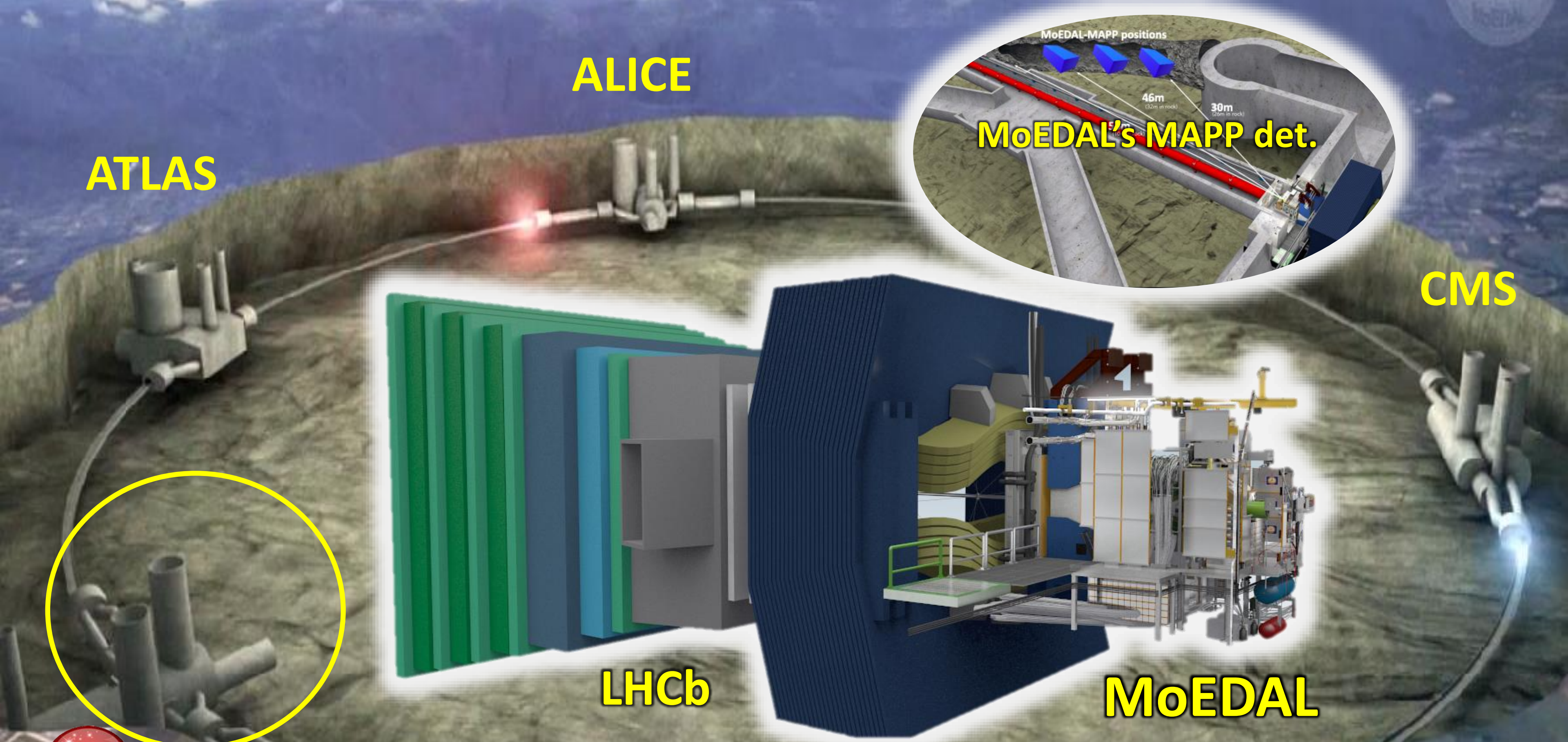
on behalf of the MoEDAL Collaboration

The MoEDAL Detector



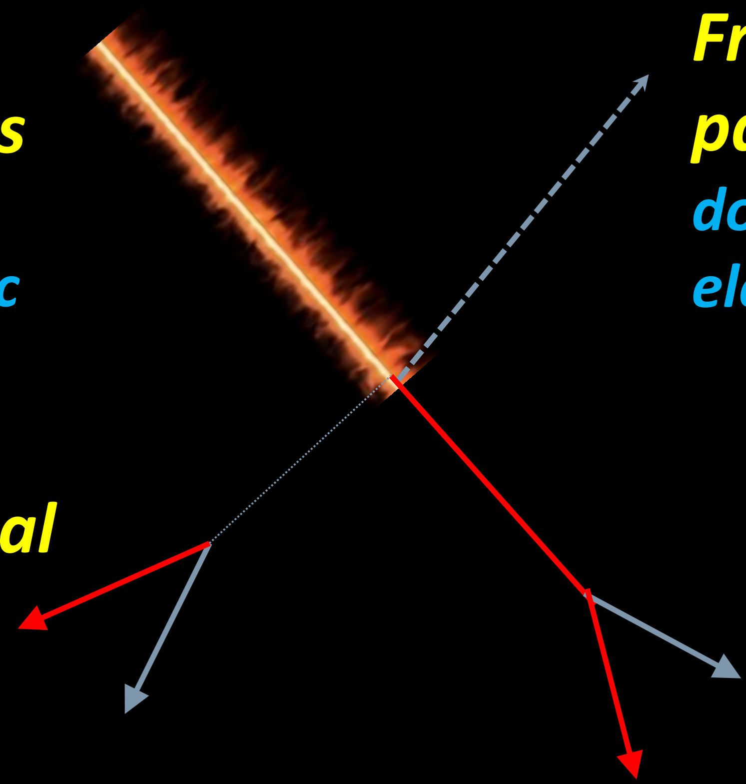
- *MoEDAL is a passive detector sensitive to new physics only.*
  - *It can track (with a permanent record) and trap highly ionizing avatars of new physics such as magnetic monopoles*
  - *MoEDAL's (proposed) Apparatus for Penetrating Particles (MAPP) will extend our reach to milli-charged particles & long-lived neutrals*

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 ~1/mille of the electron's charge)*

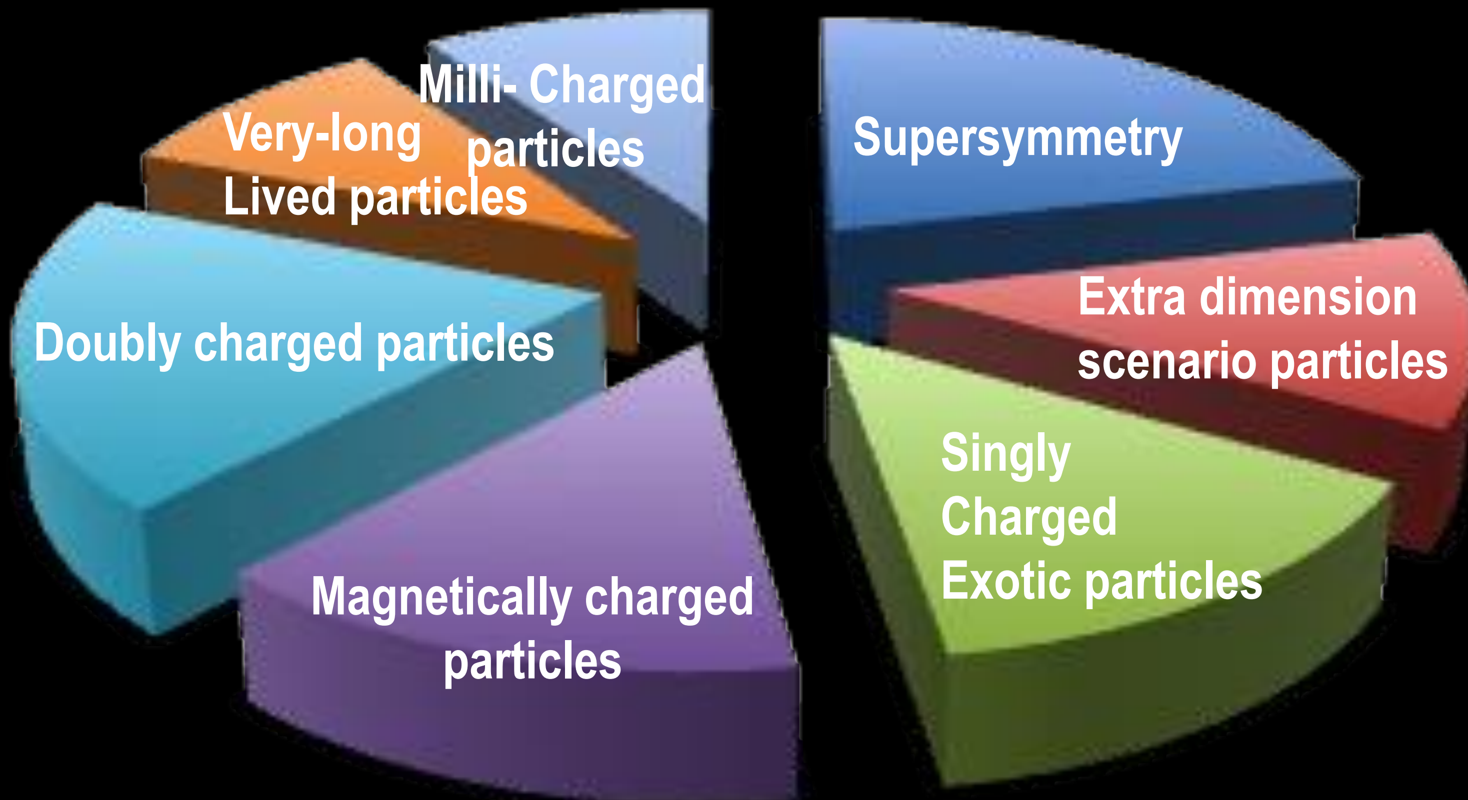


Long lived neutral particles –
(ofo ct ~10)

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

MoEDAL is Sensitive to Many Other New Physics Scenarios

Sensitive to over 40 new physics scenarios



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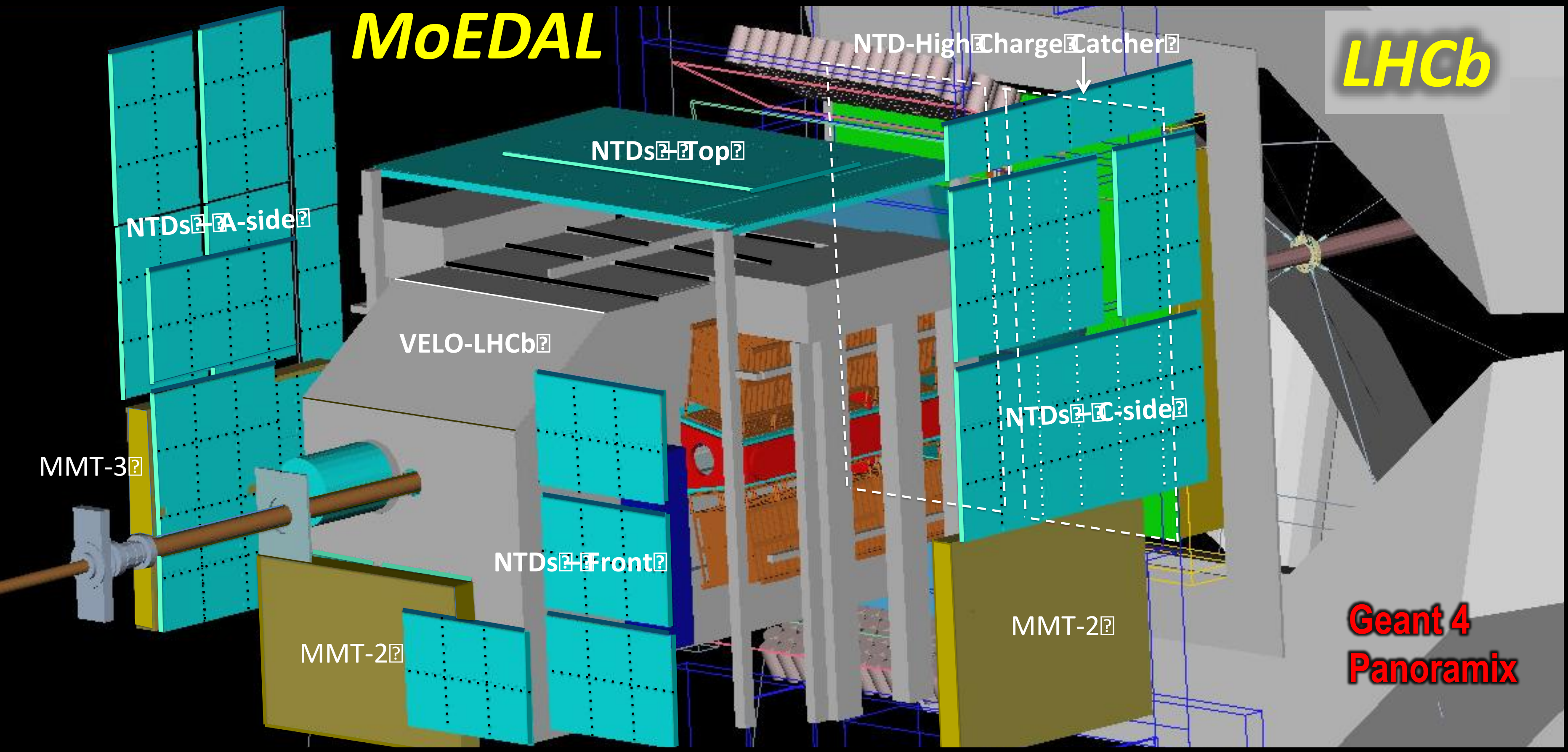
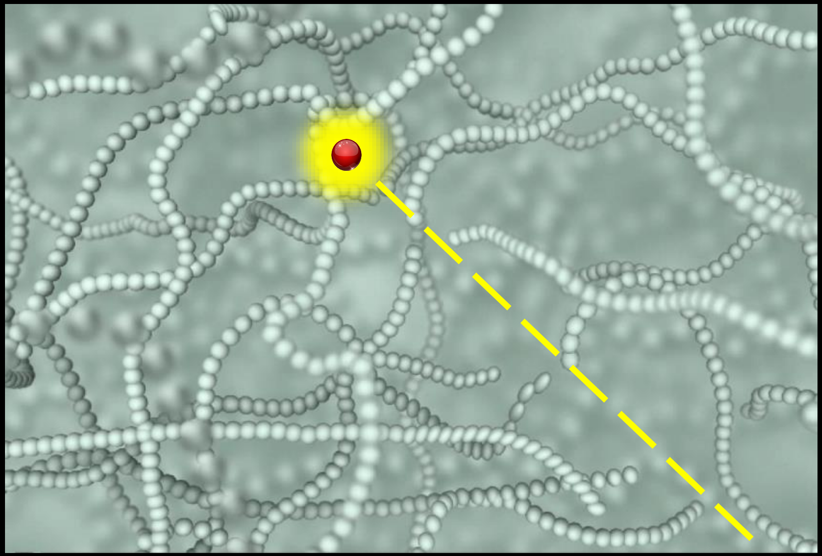
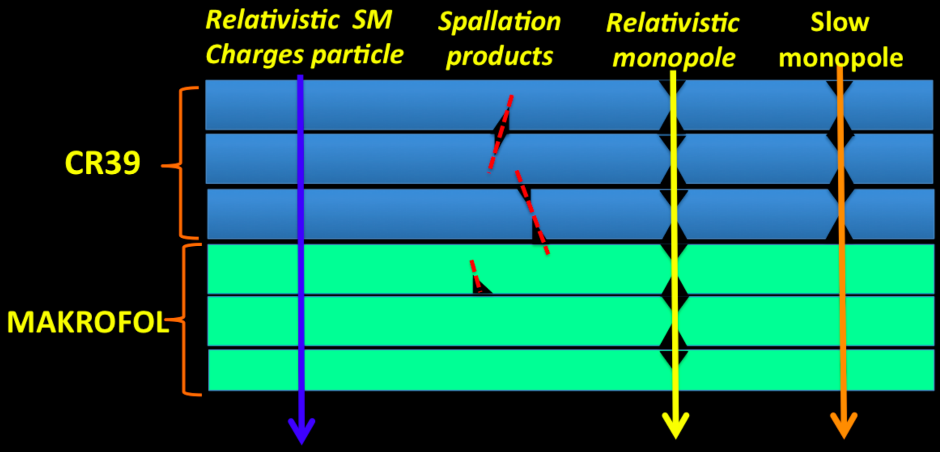
The MoEDAL Detector Today



- *Acceptance for at least one monopole from monopole pair production to hit NTDs ~70% (120 m² of plastic)*

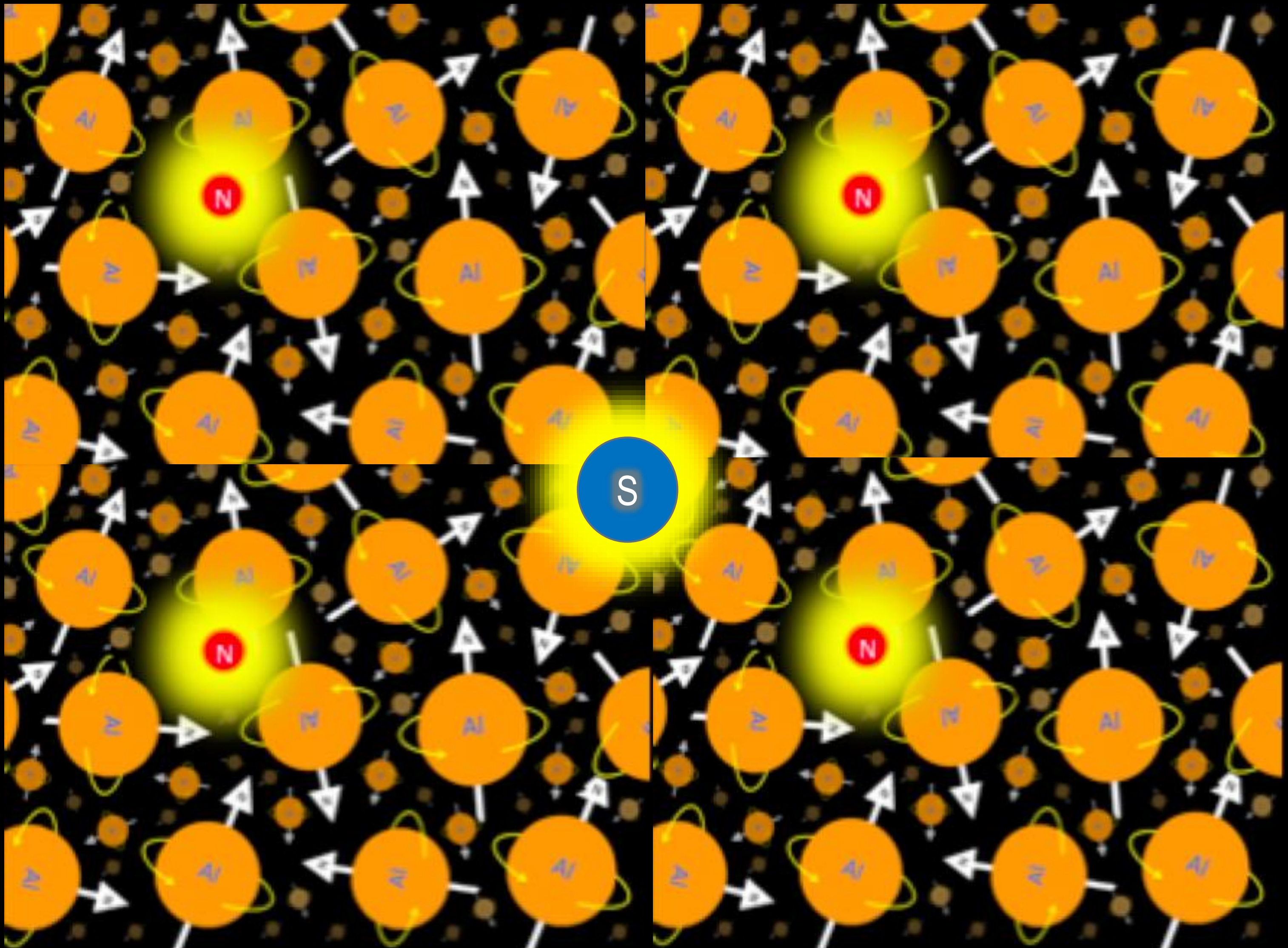
The Signal in the NTDs





- Largest NTD array (120m^2) ever deployed at an accelerator
  - NTD stacks consist of CR39 (Thr. 5 mip) & Makrofol (Thr. 50 mip)
  - Damage revealed by controlled etching - etch pits are formed
  - Charge resolution is ~|0.1|e, where |e| is the electron charge
  - Precision of each etch a pit measurement ~20-50 microns
- NTDs are calibrated at heavy-ion beams at NSRL & NA61

The Principle of the Trapping Detector



- ***Highly ionizing particles lose energy quickly, slow down stop and are captured in the trapping detectors***

The Signal from the Trapping Detectors

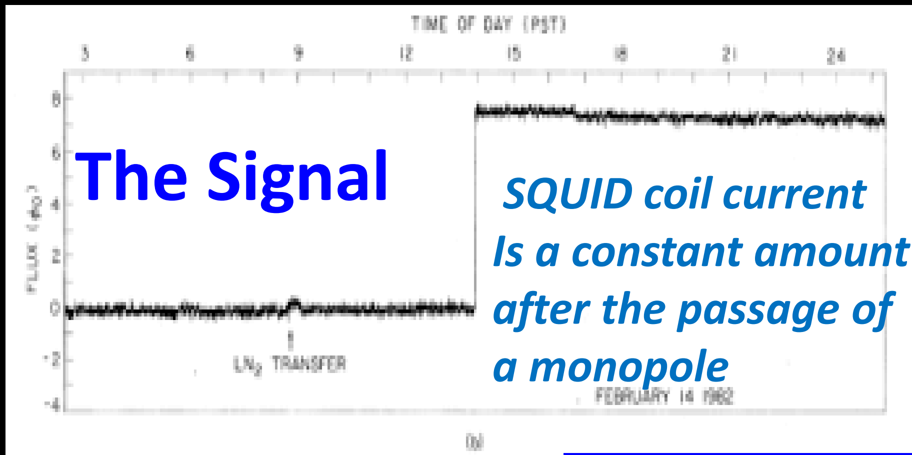
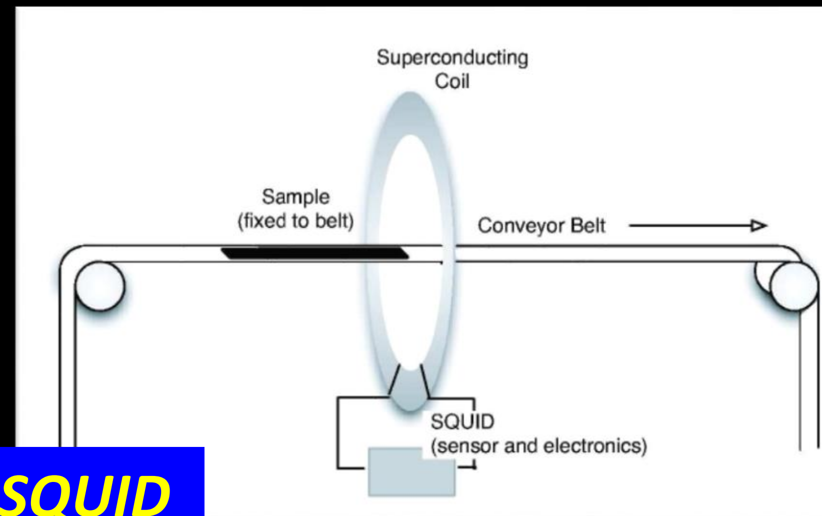


FIG. 2. Data records showing (a) typical stability and (b

The Signal

SQUID coil current Is a constant amount after the passage of a monopole



The Zurich DC-SQUID magnetometer

- ***The trapping detector can identify magnetic charge***
- ***This detector can also trap new massive electrically charged particles***

MoEDAL's Latest Monopole Mass Limits

Submitted to PRL in April 2019

Magnetic monopole search with the full MoEDAL trapping detector in 13 TeV *pp* collisions interpreted in photon-fusion and Drell-Yan production

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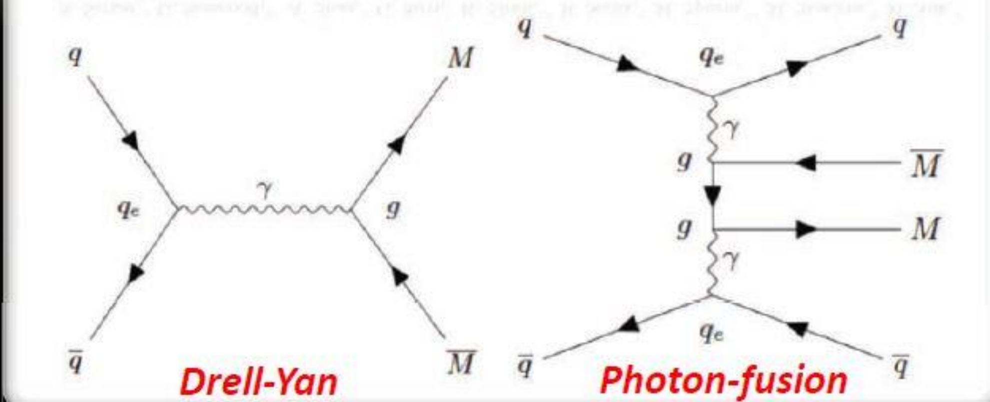
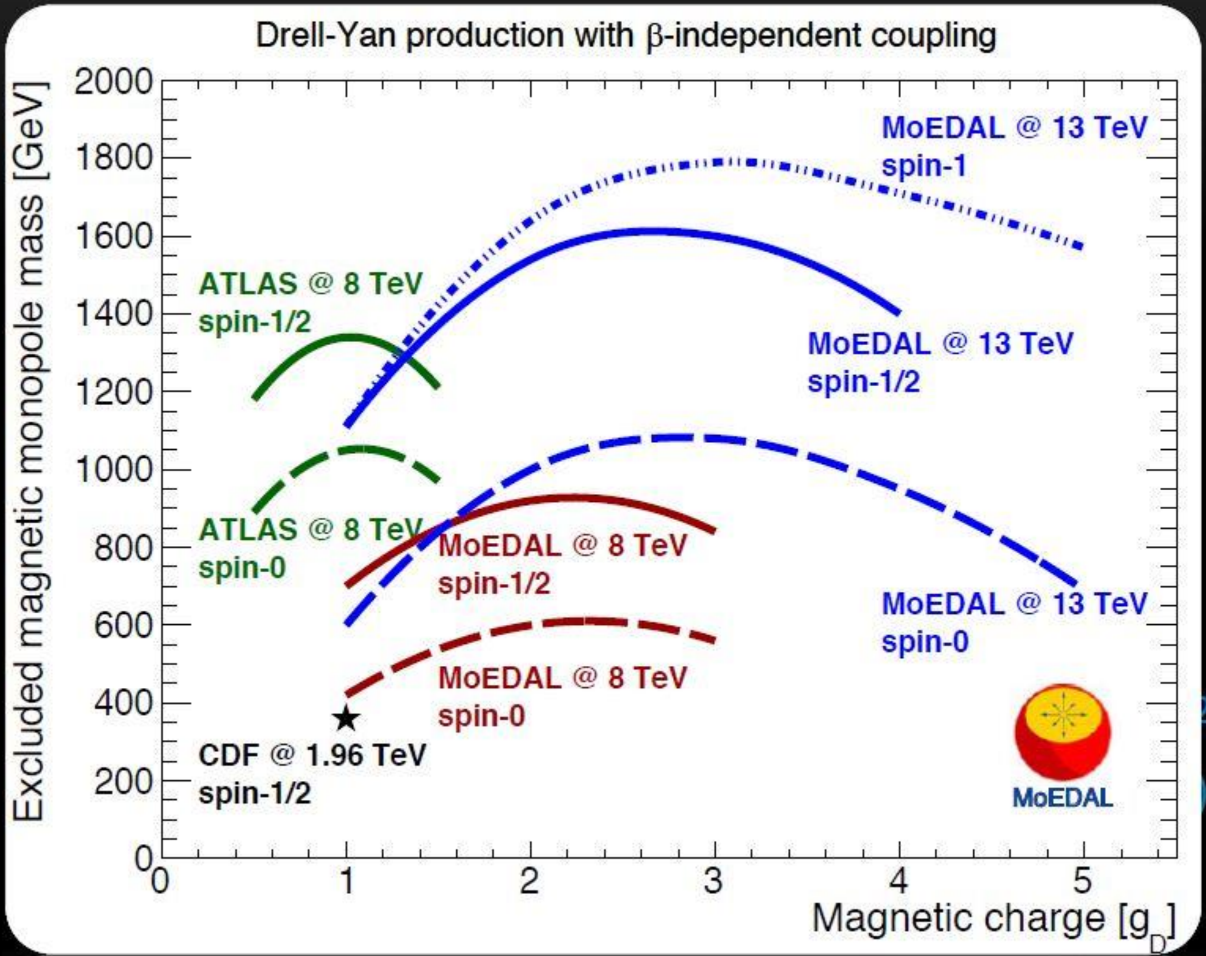
(THE MoEDAL COLLABORATION)



Process / coupling	Spin	Magnetic charge [g_D] 1	2	3	4	5
		95% CL mass limits [GeV]				
DY	0	790	1150	1210	1130	–
DY	½	1320	1730	1770	1640	–
DY	1	1400	1840	1950	1910	1800
DY β-dep.	0	670	1010	1080	1040	900
DY β-dep.	½	1050	1450	1530	1450	–
DY β-dep.	1	1220	1680	1790	1780	1710
DY+γγ	0	2190	2930	3120	3090	–
DY+γγ	½	2420	3180	3360	3340	–
DY+γγ	1	2920	3620	3750	3740	–
DY+γγ β-dep.	0	1500	2300	2590	2640	–
DY+γγ β-dep.	½	1760	2610	2870	2940	–
DY+γγ β-dep.	1	2120	3010	3270	3300	3270

- ***MoEDAL has now improved its lead and placed the LHCs first limits on monopole production via photon fusion.***

Mass Limits for ng_D Monopoles

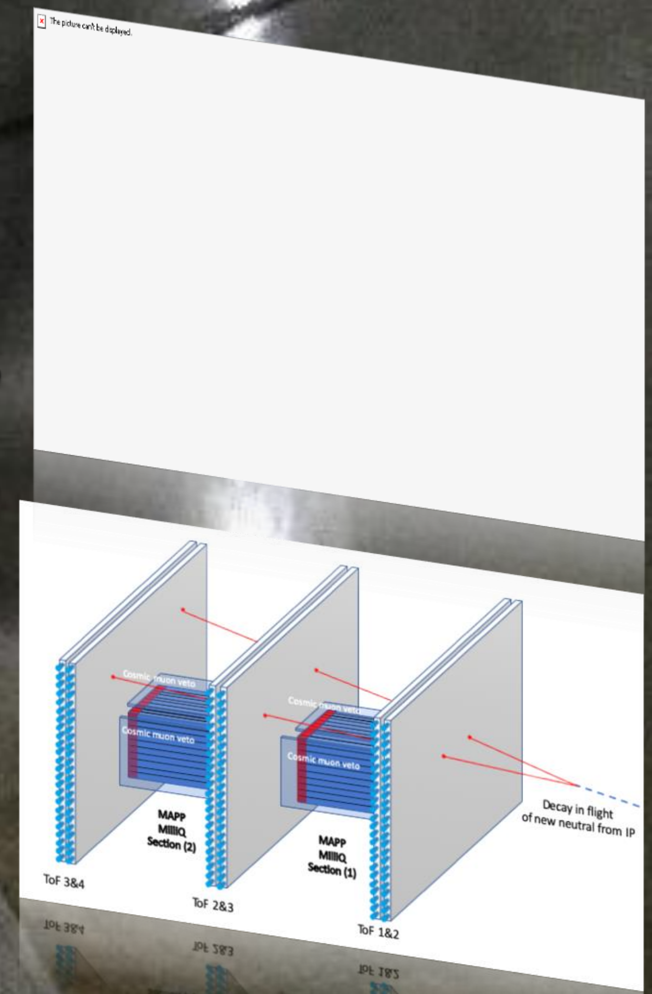


- ***MoEDAL has the world's best limits on multiply charge monopoles and has placed the first limits ever on Spin-1 monopoles***

MAPP* MoEDAL's Upgrade for RUN-3

*(MoEDAL Apparatus for Penetrating Particles)

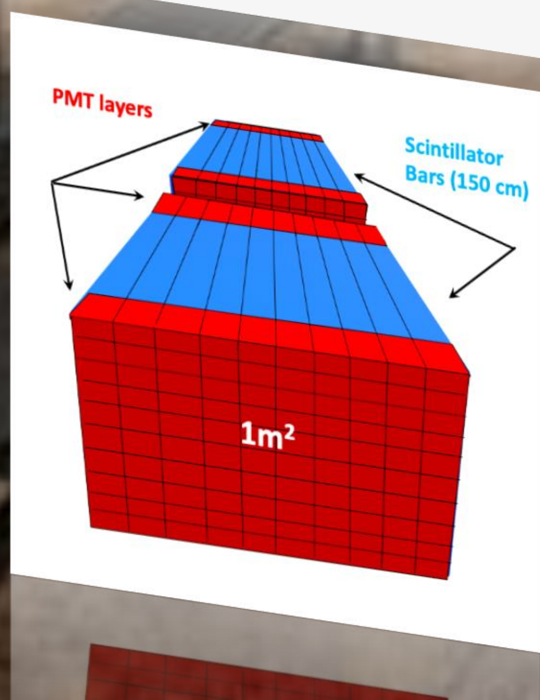
- The Long Lived Particle (LLP) detector is formed from 3 pairs of 3m x 4m scintillator hodoscopes , pointing to IP, in well shielded area of LHC IP8 (LHCb)
  - Placed in UGC8 gallery ~100m underground Positioned at 55m from IP, 50m through rock, in horizontal beam plane)
  - Deployed from 5º to the beam (at 55m) to 25º to the beam (at 26 m)
  - 7-10m decay zones in front of first plane
  - Veto detector on tunnel face defining decay zone
- Under construction during the current LHC shutdown
- Due to start data taking in LHC's RUN-3



MAPP* MoEDAL's Upgrade for RUN-3

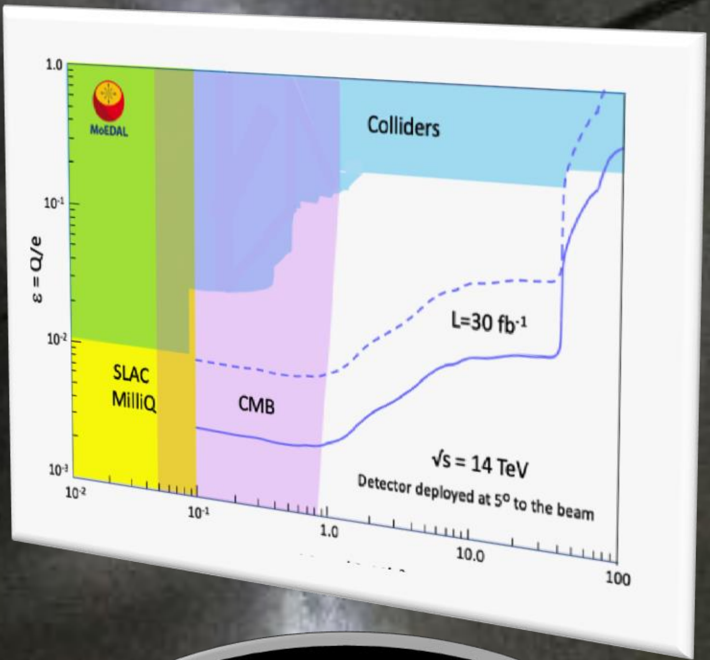
*(MoEDAL Apparatus for Penetrating Particles)

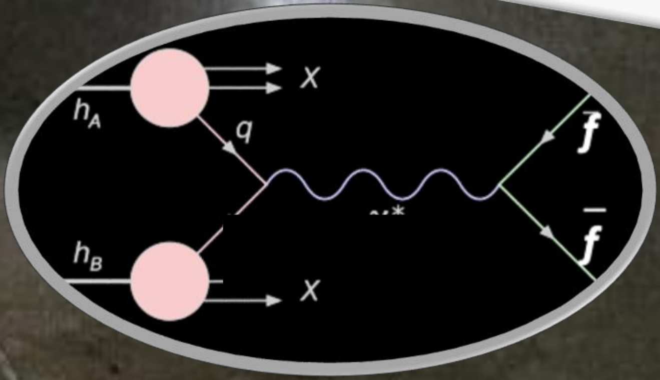
- The Milli-charged particle (mQP) detector is a 1m x 1m x (2 x 1.5m) scintillator array, pointing to IP, in well shielded area of LHC Point 8 (LHCb)
  - Placed in UGC8 gallery ~100m underground Positioned at 55m from IP, 50m through rock, in the horizontal beam plane
  - Deployed from 5^o to the beam (at 55m) to 25^o to the beam (at 26 m)
  - 7-10m decay zones available in from of
  - Uses quadruple coincide between the two scintillator bars) sections (2 PMTs per bar)
  - Active veto against showers in rock
- Under construction during current shutdown
- Due to start data taking in LHC's RUN-3



MAPP Sensitivity

- *MAPP will enable the search for particles with charge as low as ~.001e and masses above ~100 MeV.*
- *Simulations indicate that with 30 fb^{-1}:*
  - *We will have sensitivity to a charge of $\mathcal{O}(10^{-2})$ e to $\mathcal{O}(10^{-3})$e can be achieved for masses of $\mathcal{O}$ (1) GeV, and charge $\mathcal{O}(10^{-2})$ e for masses of $\mathcal{O}(10)$ GeV.*
- *For RUN-3 lumi delivered to MoEDAL (& LHCb) will rise by a factor of ~5 reducing the lumi disadvantage at IP8 to a factor of ~10 compared to ATLAS and CMS*
  - *But, the forward stance of MAPP (at 5° to the beam) can roughly cancel the lumi benefit – for "forward-backward" biased physics signals – of centrally placed detectors*



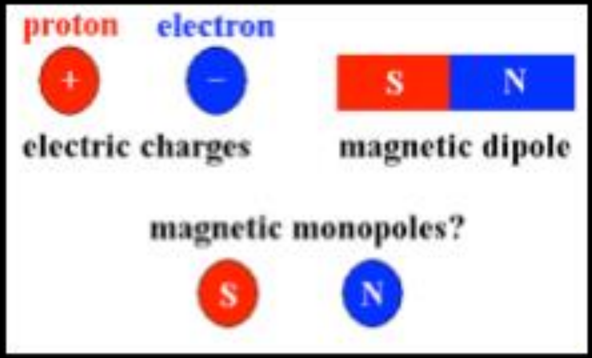


The direct and indirect bounds on mQPs for models with a massless dark photon qnd the projected reach of MAPP for RUN-3 (---line 10% overall MAPP eff.)

MoEDAL Addresses Fundamental Questions

Are there extra dimensions?

What happened just after the big bang?



Does magnetic charge exist?

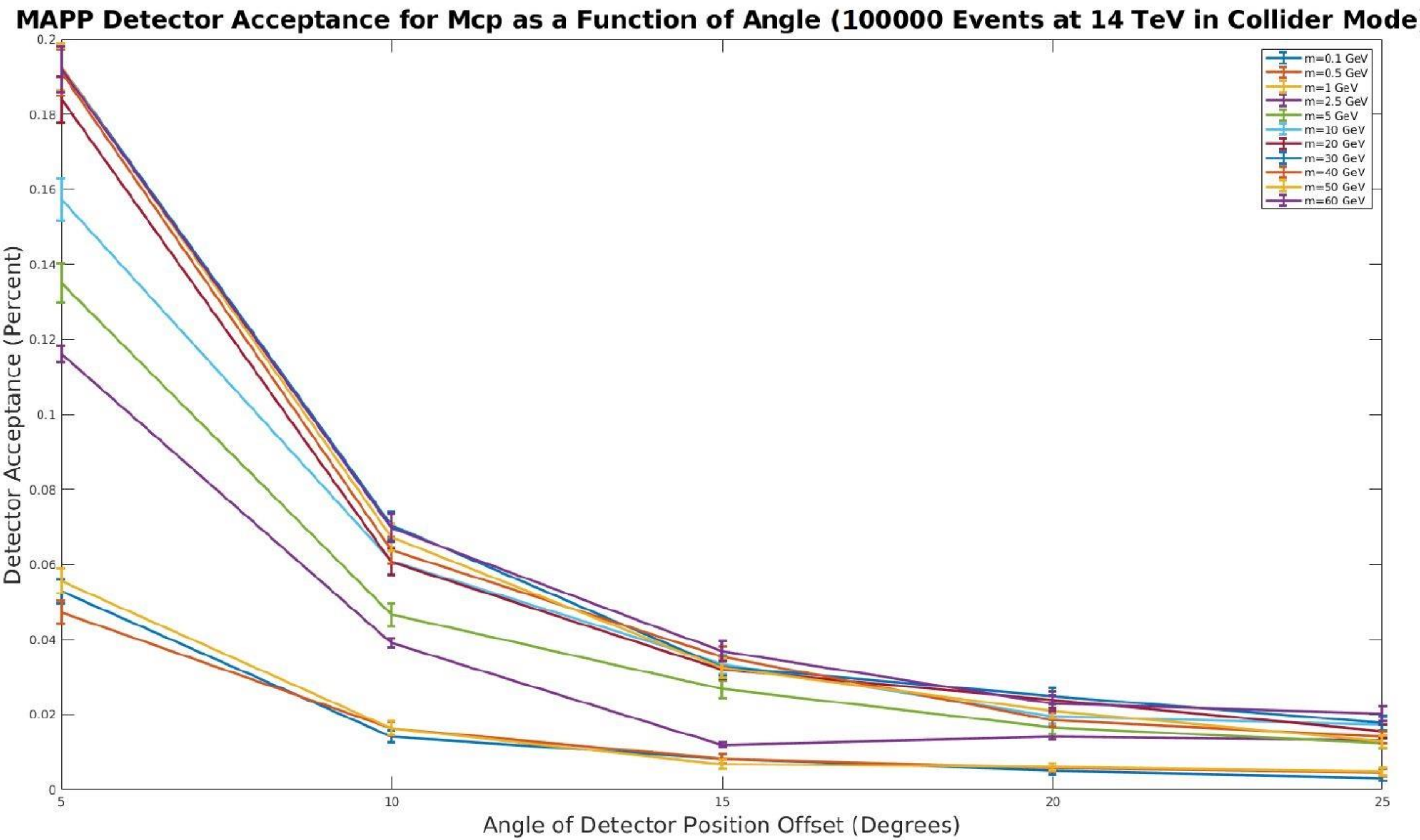
What is the nature of Dark matter?

Are there new symmetries of nature?

Backup Slides

MoEDAL's In Progress

- ***Limits on highly electrically charged objects (using NTDs)***
- ***Limits on Dyons (using MMTs)***
- ***Limits on Monopoles (using NTDs)***
- ***Limits on Dyons (using NTDs)***


MAPP Detector Acceptance for Mcp as a Function of Angle (100000 Events at 14 TeV in Collider Mode)
Detector Acceptance (Percent)
Angle of Detector Position Offset (Degrees)
0
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
5
10
15
20
25
m=0.1 GeV
m=0.5 GeV
m=1 GeV
m=2.5 GeV
m=5 GeV
m=10 GeV
m=20 GeV
m=30 GeV
m=40 GeV
m=50 GeV
m=60 GeV

- At a 45 degree angle, we get an acceptance of 0.01% for a mCP of mass 5 GeV (same as Haas et al. Phys.Lett. 746B (2015))
- However, at a 5 degree angle, we get an acceptance of 0.135% for a mCP of mass 5 GeV (10 times more)
- All things remaining equal, this higher acceptance negates any increase in luminosity other experiments might have (for this particular model)