MoEDAL-MAPP — The Monopole and Exotics Detector at the LHC: Progress, Plans & Prospects

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On Behalf of the MoEDAL Collaboration

IPP 50th Anniversary Symposium — Saturday, May 28, 2022

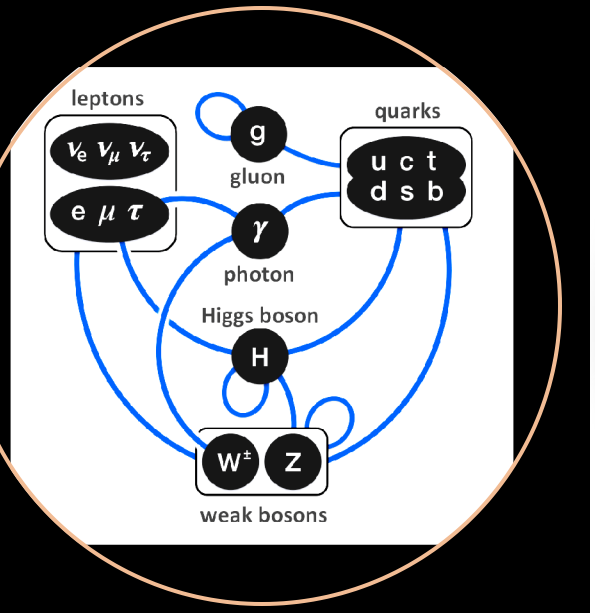
1

Dedicated Detectors at Accelerators/Colliders

The Origins of MoEDAL

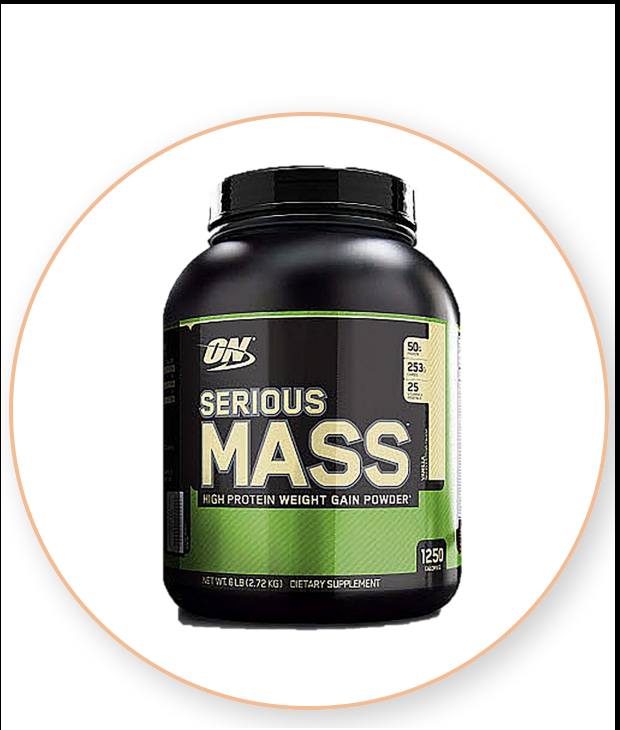
New Physics Remains Unseen at the LHC

What are the possibilities?

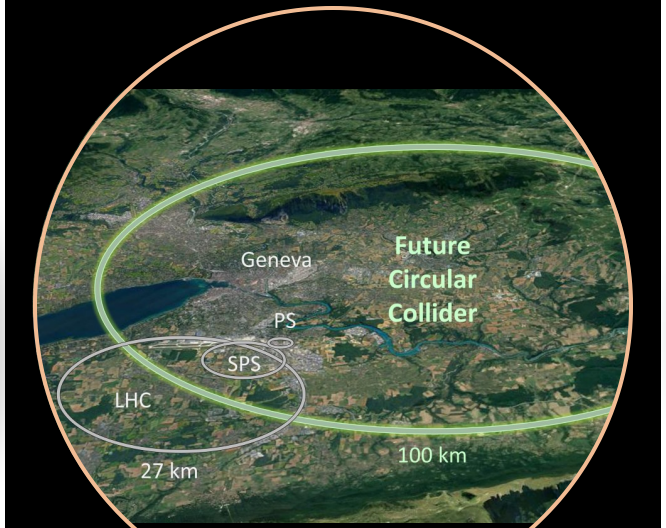


The Standard Model is it

There is no new physics



New physics exists but a mass scale we can't ever reach



New physics exists but we can only see something at a future collider

e.g., the FCC

$$\sigma << 1\,\text{ab}$$

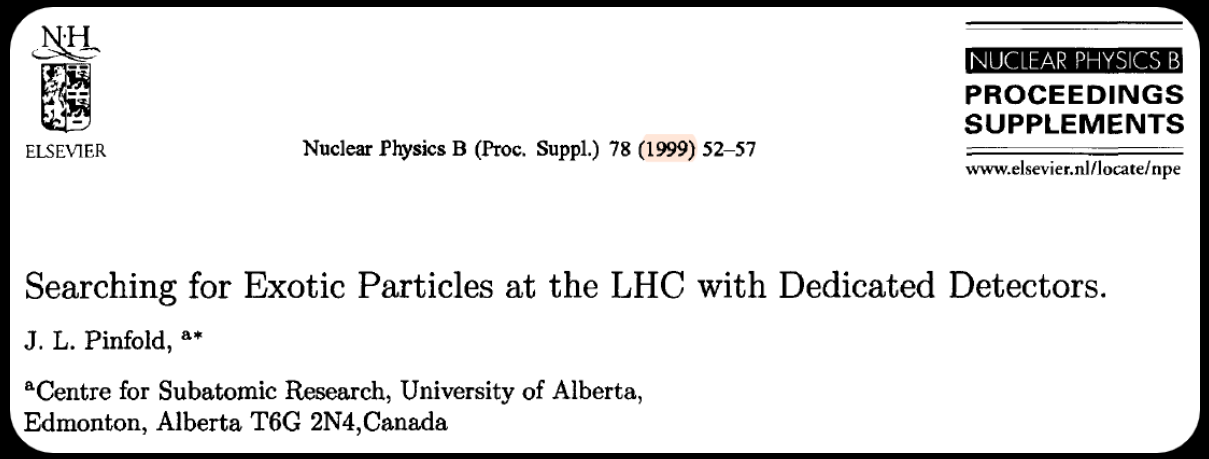
The physics exists at our mass scale but has an extremely small cross-section

...or, perhaps new physics is right under our noses — but we can't see it with our existing "standard" detectors

Dedicated Search Experiments at Colliders

Dedicated Search Experiments at Colliders

MoEDAL is the First Dedicated LHC Search Experiment



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Searching for Exotic Particles at the LHC with Dedicated Detectors.

J. L. Pinfold, [a*]

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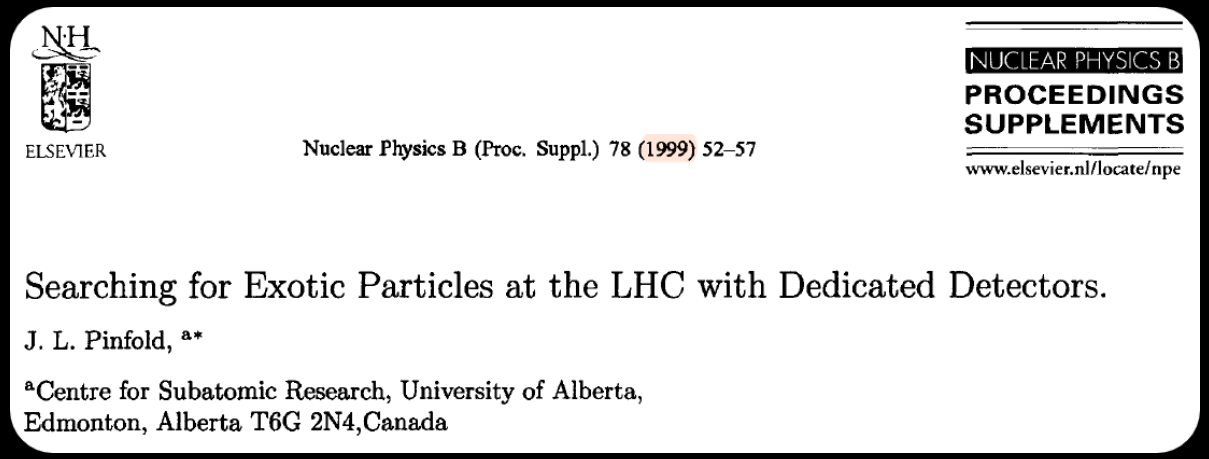

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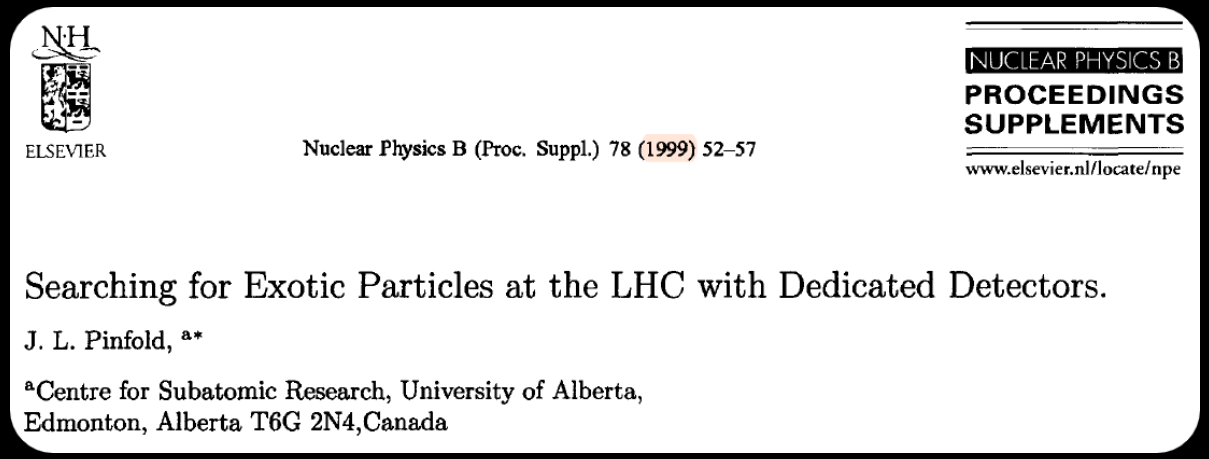

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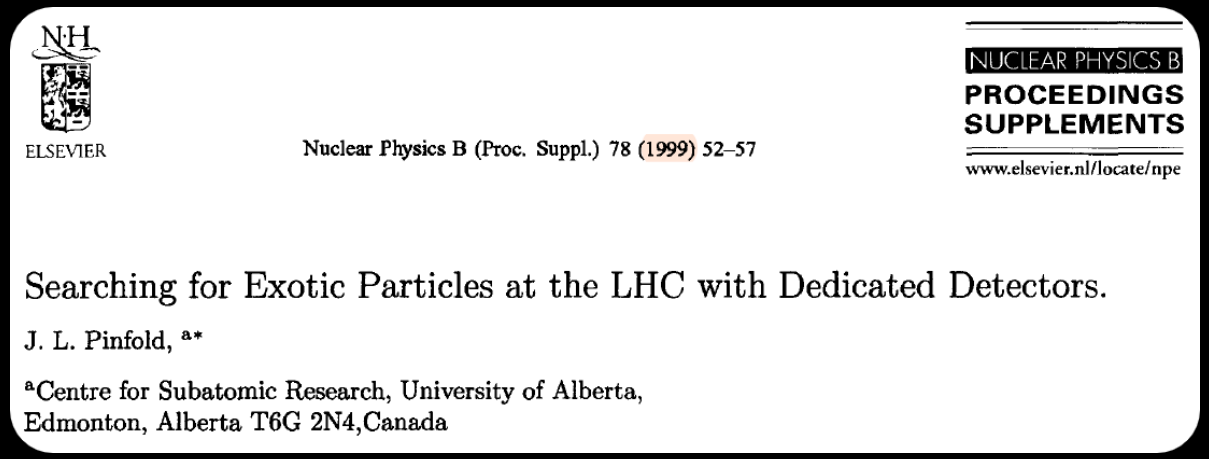

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  Typically stand alone, smaller, and lower cost w/ small teams

Dedicated Search Experiments at Colliders

MoEDAL was part of the 1st notice of intent (NOI) for dedicated detectors, which proposed searches for highly ionizing & long-lived particles at the LHC

MoEDAL is the First Dedicated LHC Search Experiment

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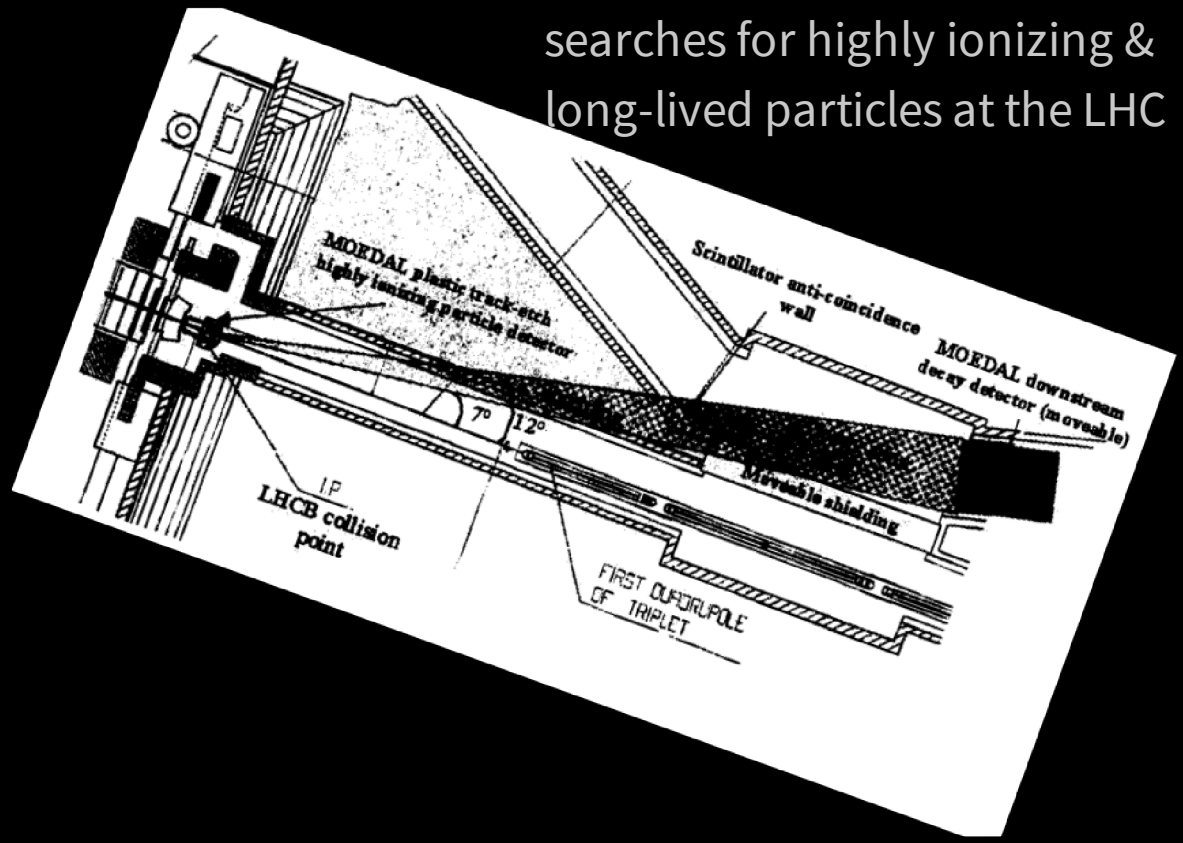

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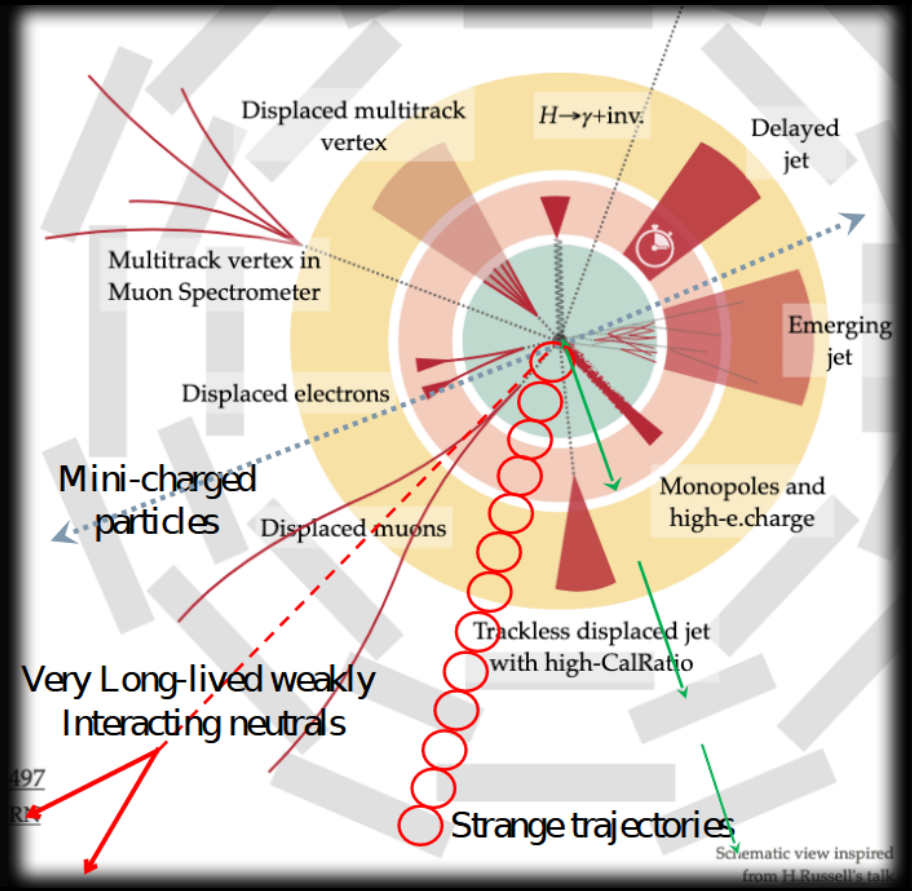
The Unconventional Signs of New Physics for which ATLAS & CMS are not Optimized



2

The Monopole and Exotics Detector at the LHC (MoEDAL) Experiment

Approved by the CERN Research Board in 2010! (CERN-LHCC-2009-006, MoEDAL-TDR-001)

MoEDAL Today

MoEDAL-MAPP Collaboration 26 Institutes

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

King's College London

Queen Mary University

Track Analysis Systems Ltd.

IRIS Canterbury

Europe

Technical University of Athens

University of Bologna

INFN Bologna

CERN, Switzerland

Czech Technical University (IEAP)

University of Helsinki

Institute of Space Science (ISS) Romania

University of Valencia (IFIC)

Vaasa Universities

India

University of Calcutta

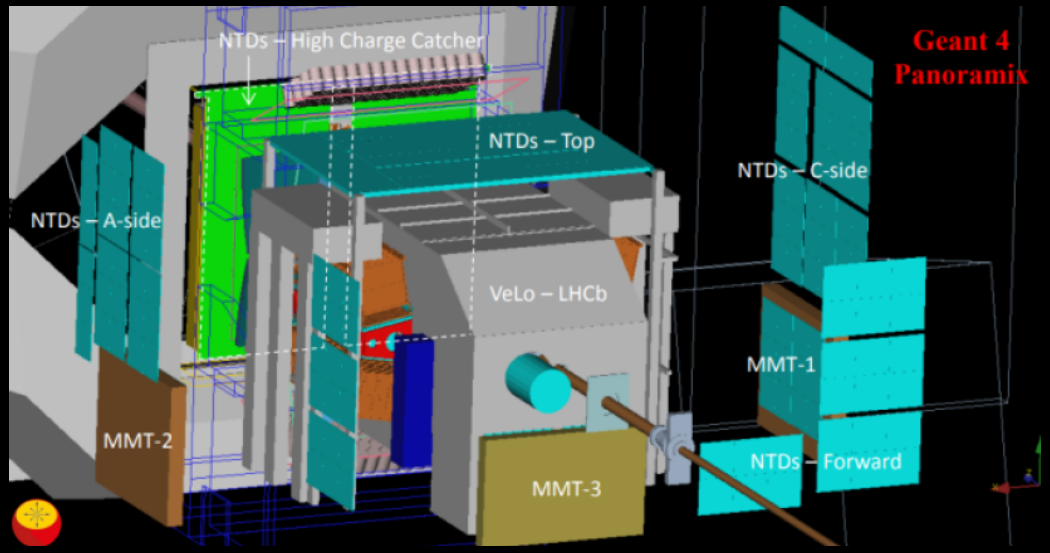
National Institute of Technology, Kurukshetra

Korea

Center for Quantum Spacetime, Seoul

The MoEDAL Detector

Started data taking in 2015 — the LHC's first dedicated search experiment designed to search for HIPs



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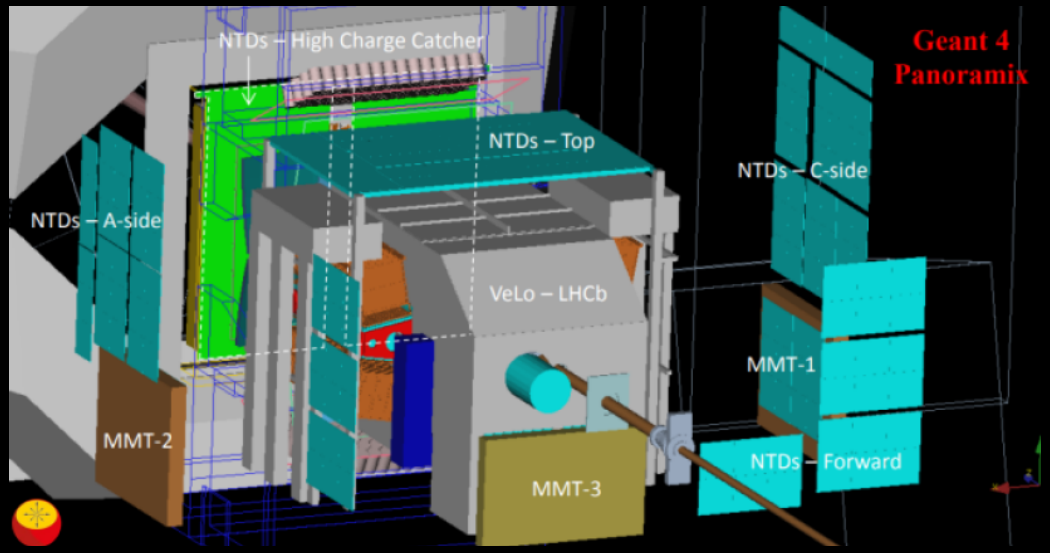

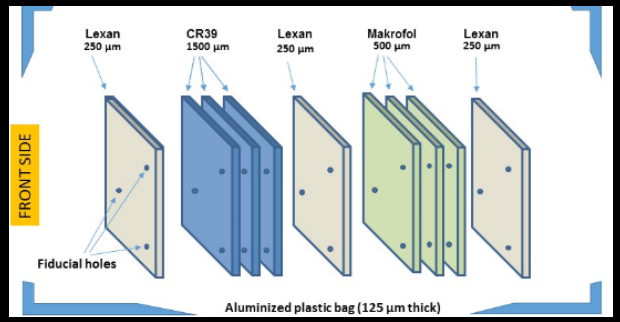

Nuclear Track Detector (NTD)

Plastic array (185 stacks, 12 sq. m)

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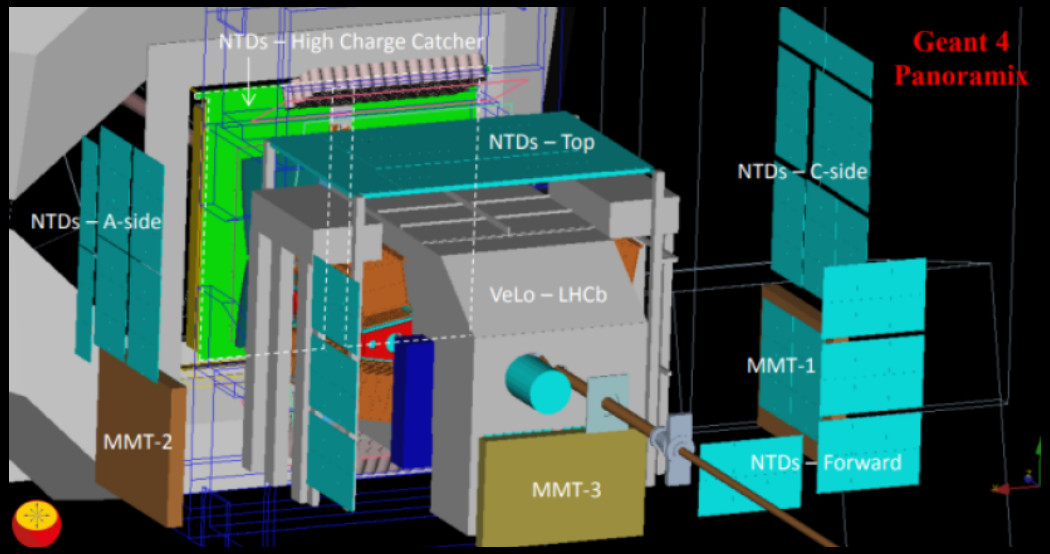

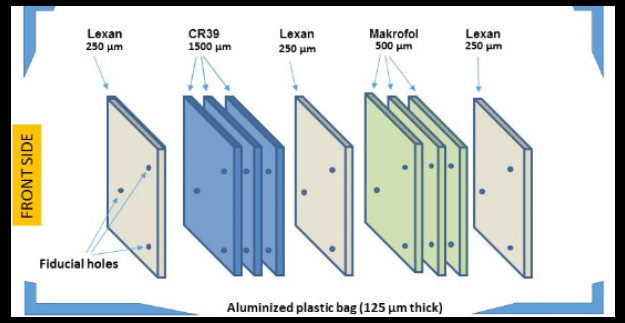

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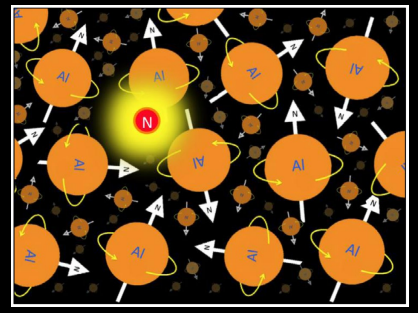

Trapping Detector Array (MMT)

A tonne of Al to trap HIPs for analysis

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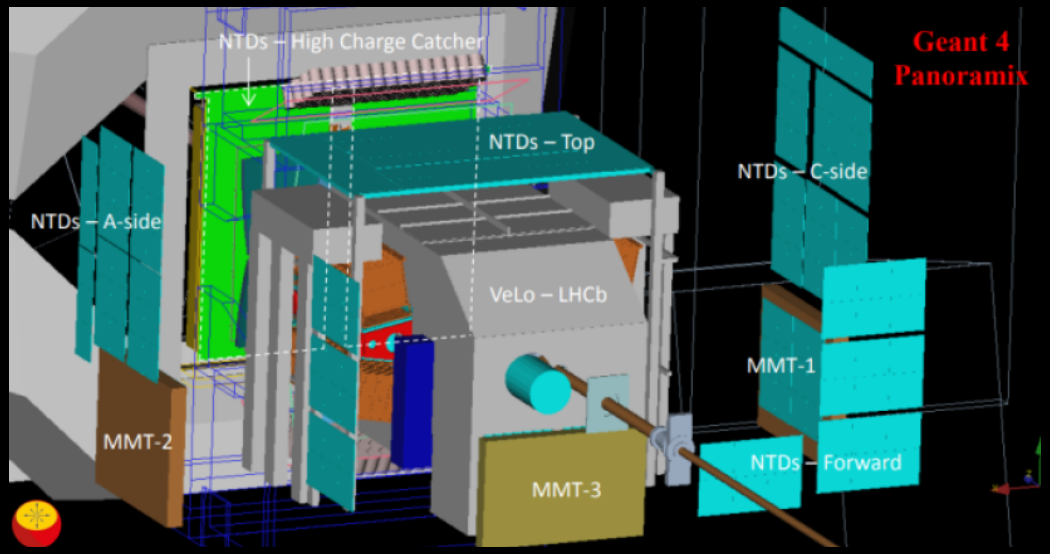

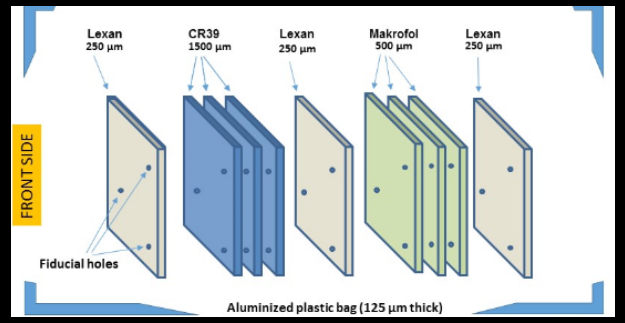

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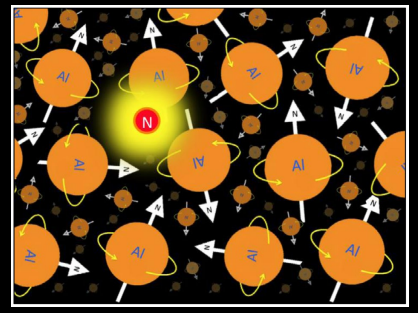

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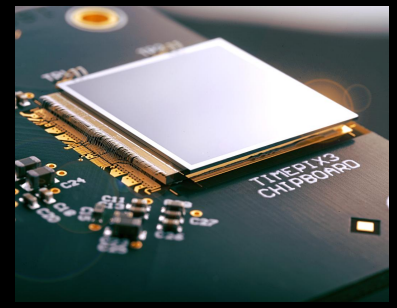

TIMEPIX Array

A digital camera for live rad. monitoring

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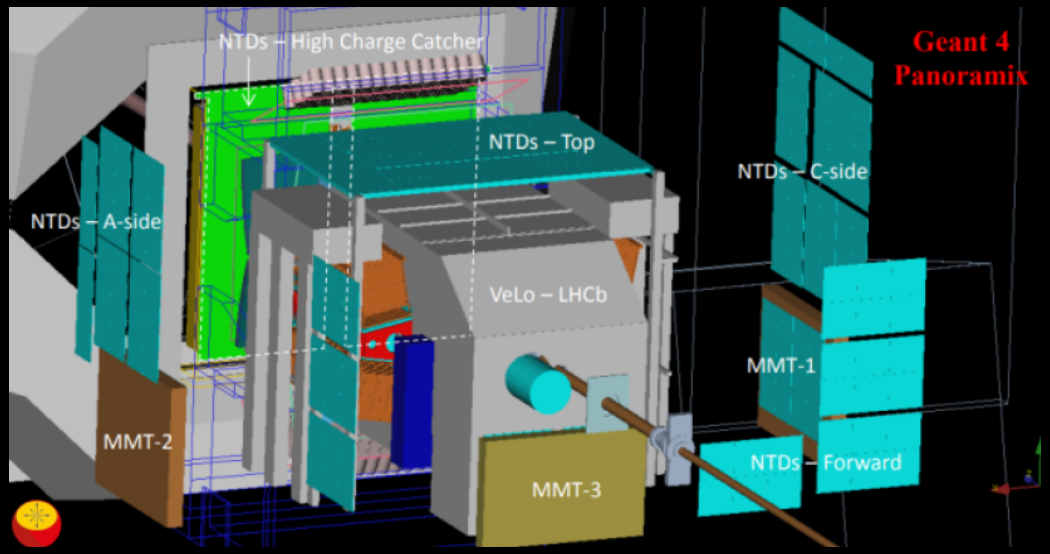
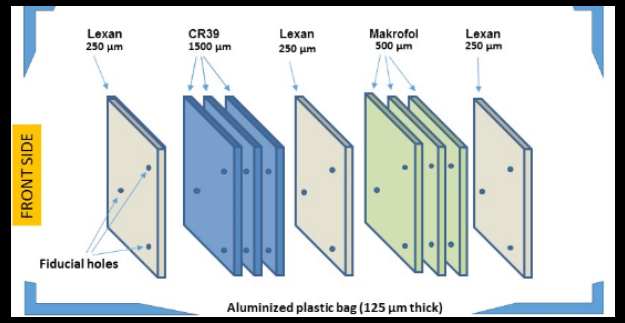
Permanent physical record of new physics!





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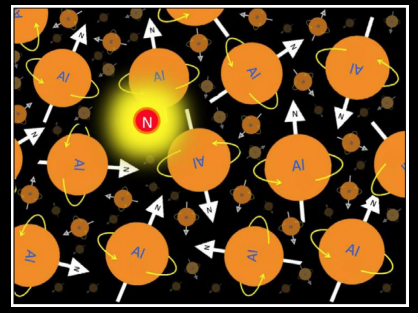

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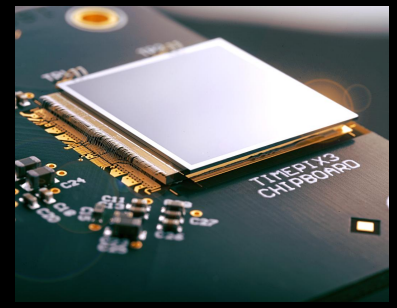

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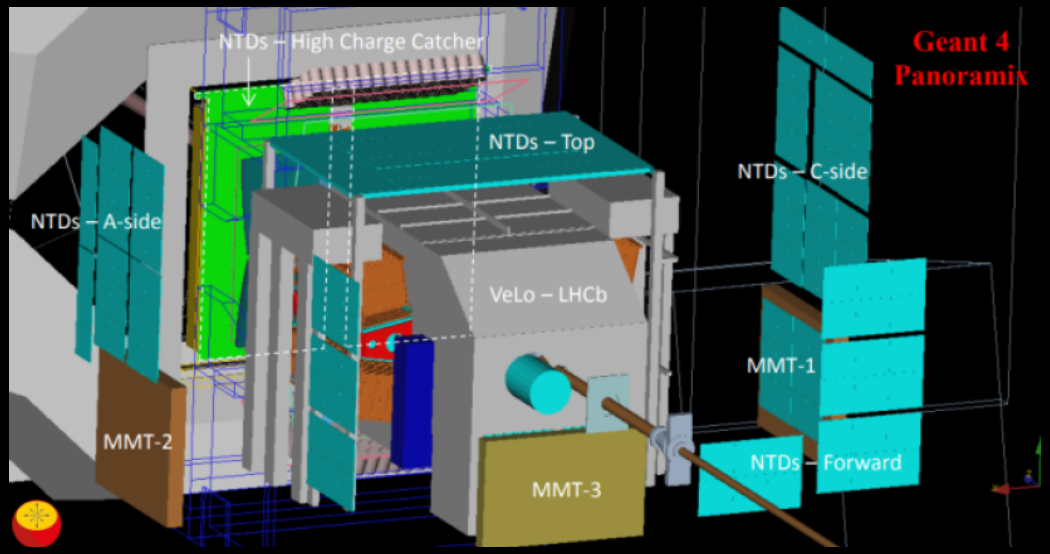
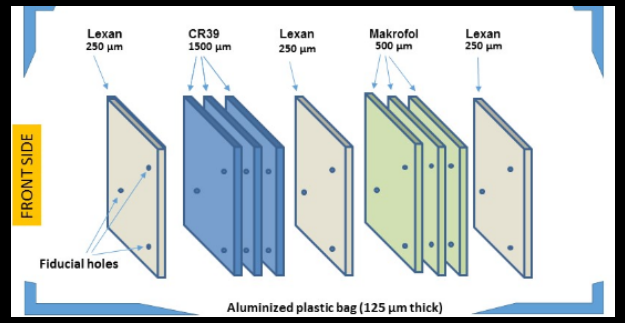


No Standard Model physics BGs!



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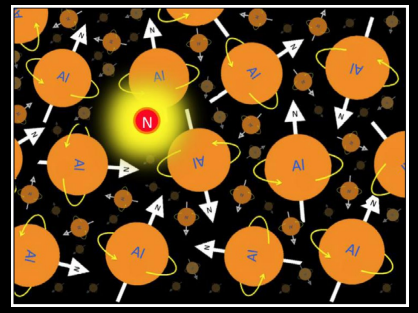

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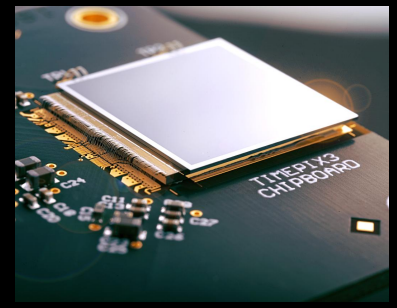

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MoEDAL's Magnetic Monopole Searches

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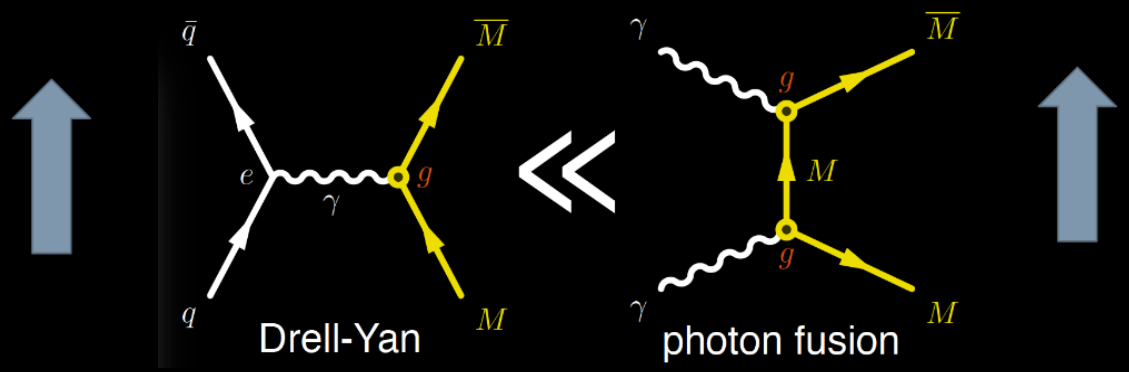

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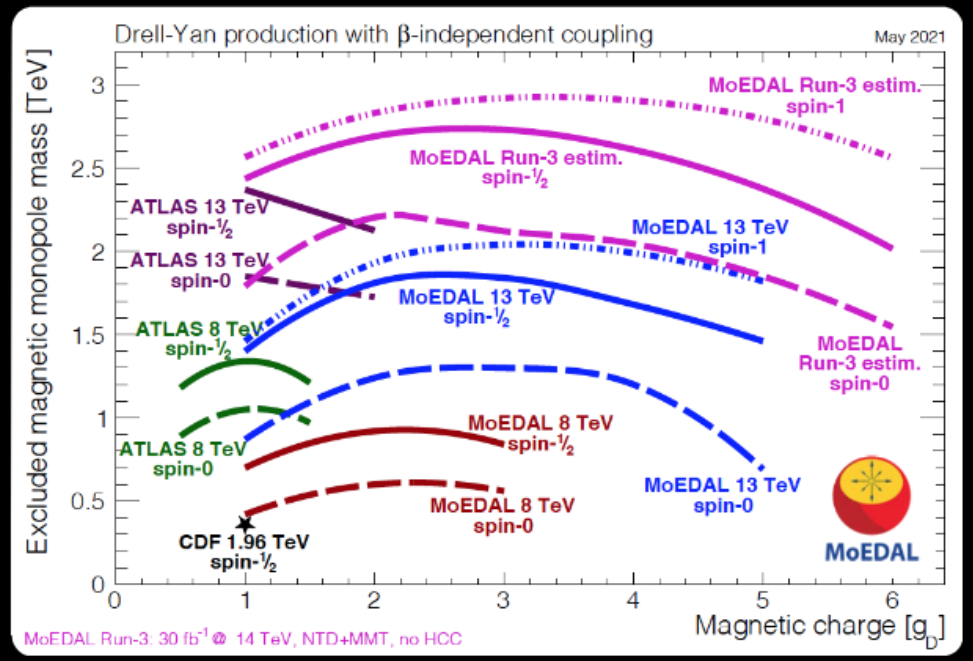

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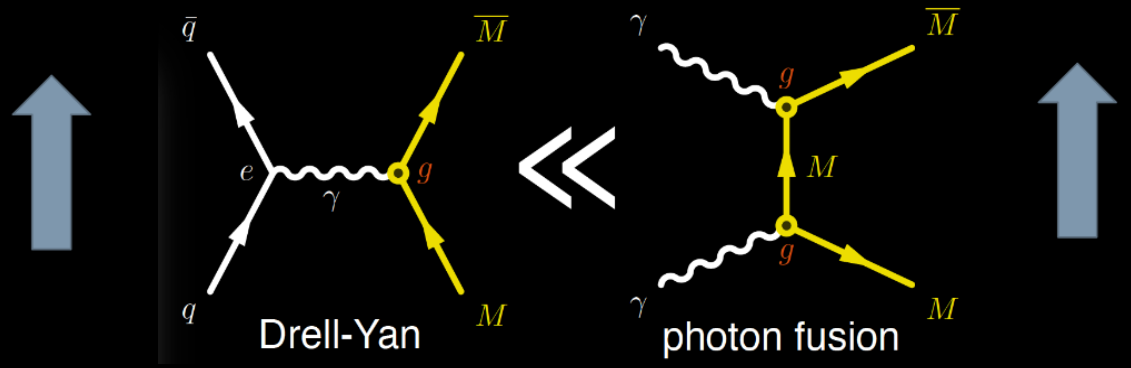

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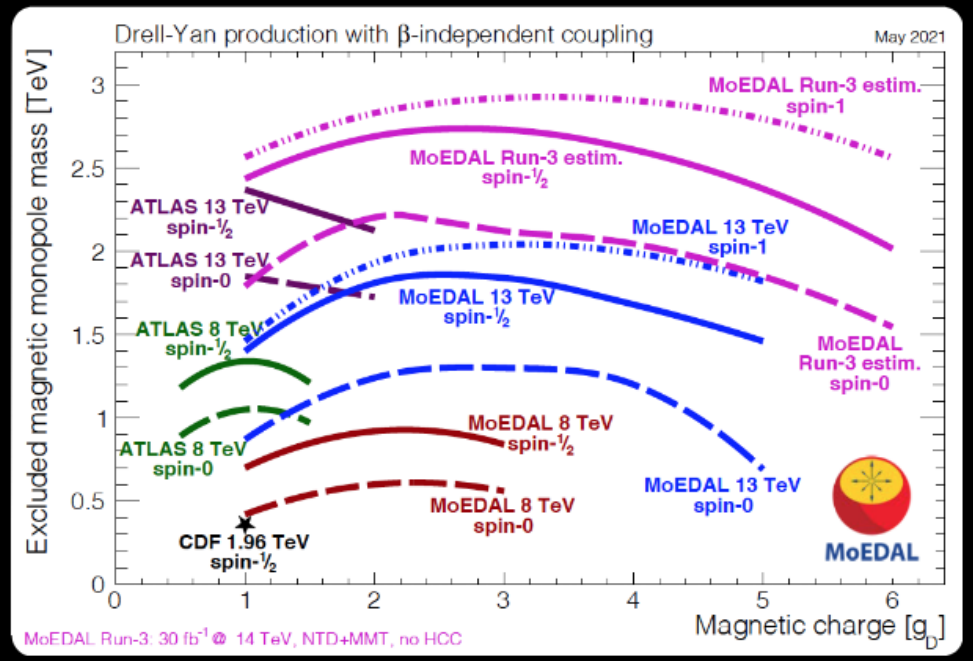

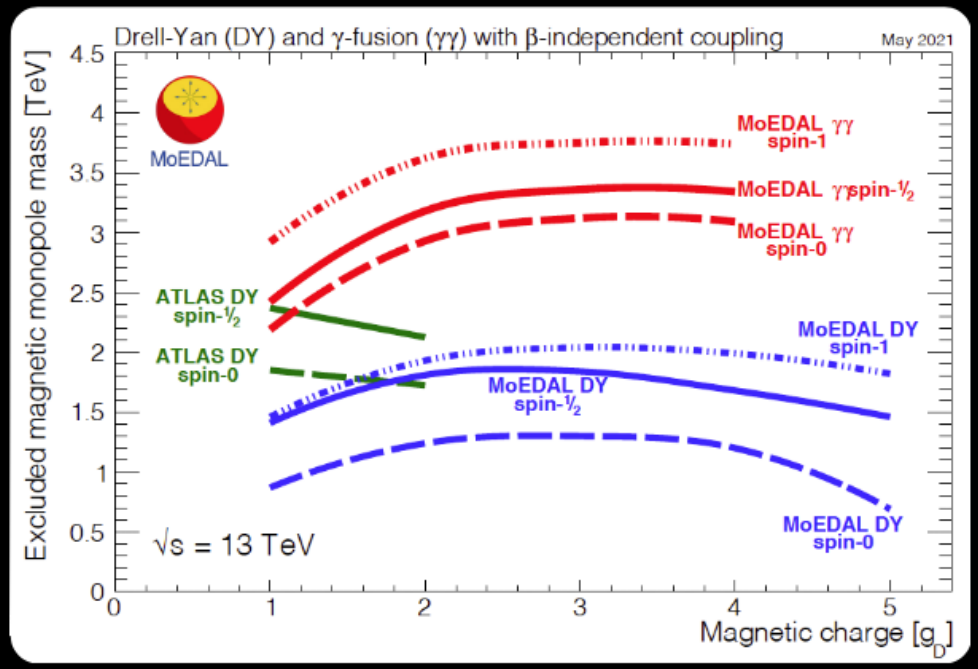

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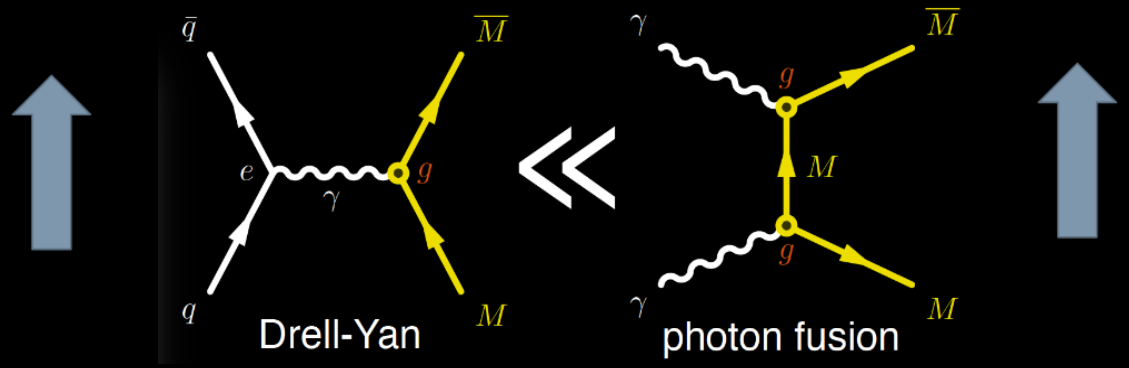

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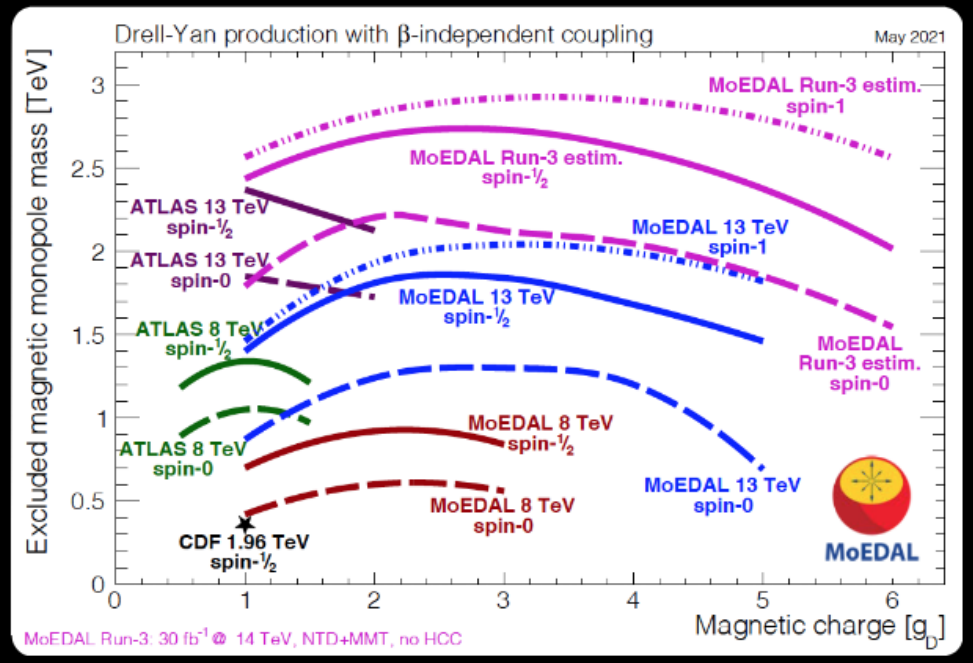

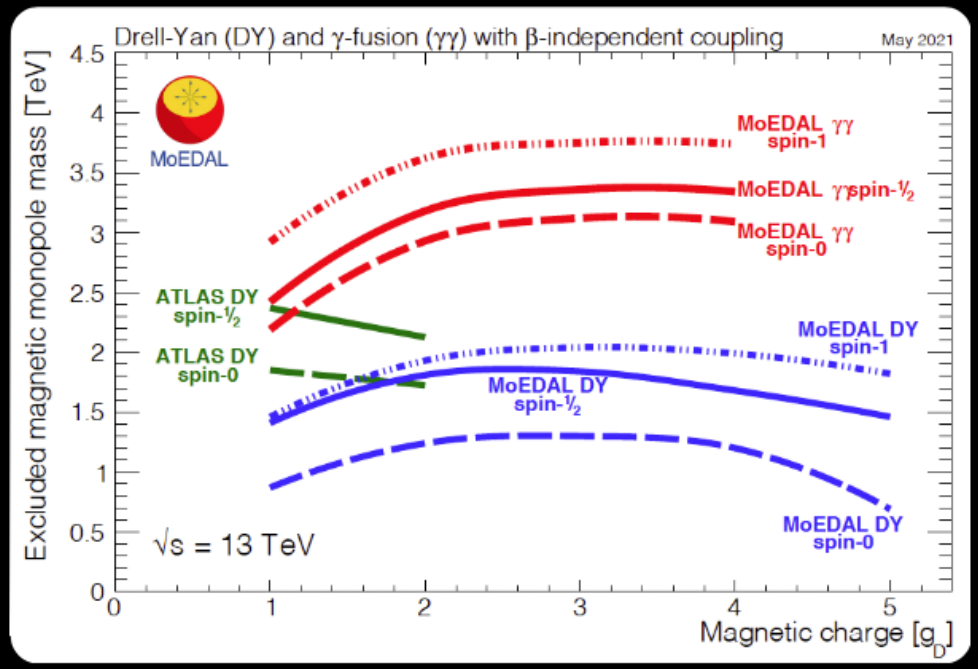

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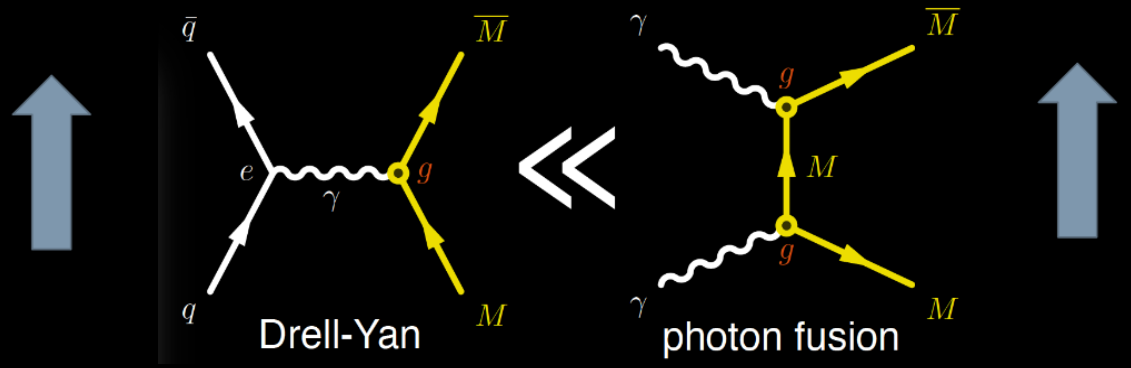

First search for spin-1 MMs!

The Search for Schwinger's Dyon

The **first ever** explicit accelerator search for a dyon!

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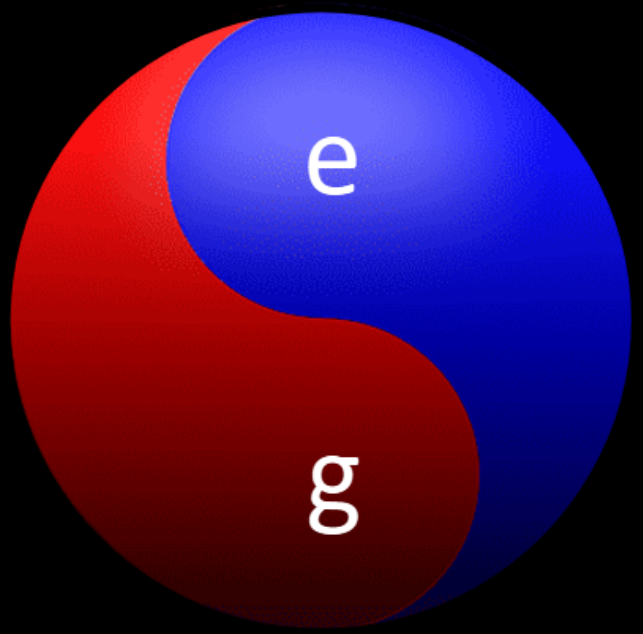

A dyon has both electric and magnetic charge

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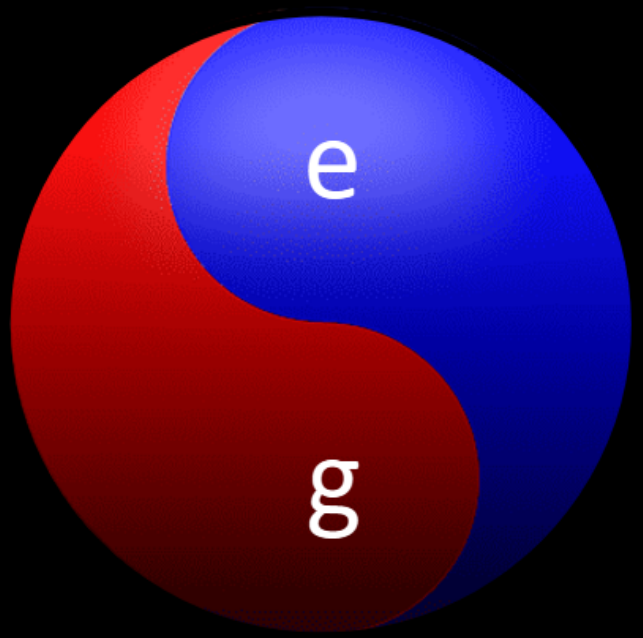

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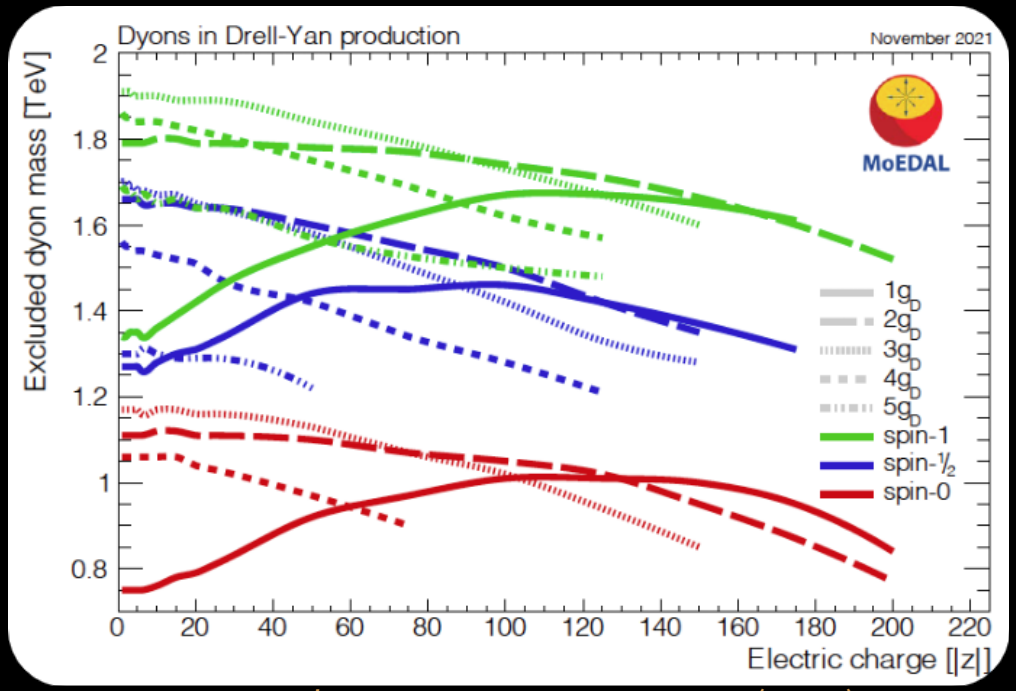

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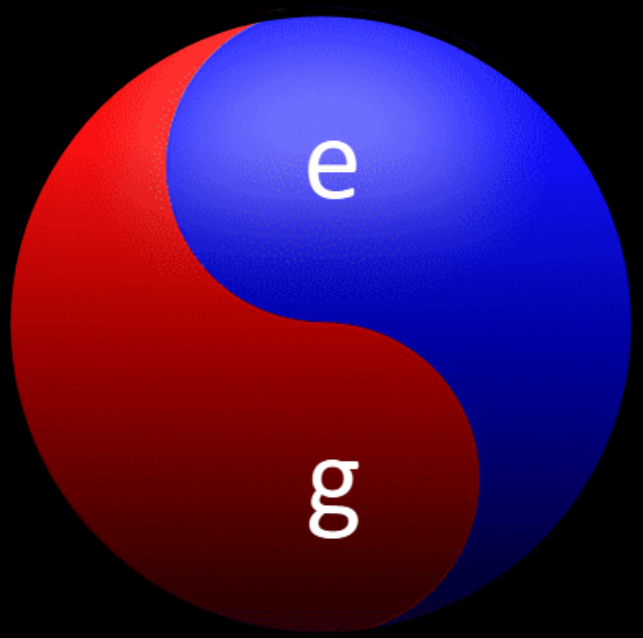

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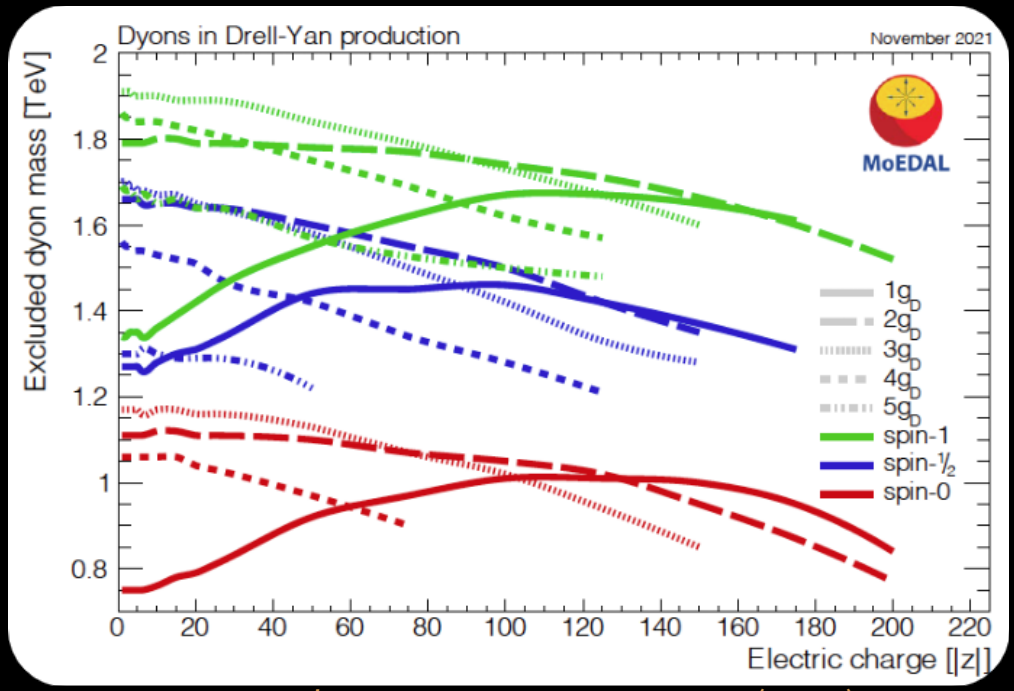

Phys. Rev. Lett. **162**, 071801 (2021)

- *Spin-dependent mass limits were set for dyons w/ up to 5 Dirac magnetic charges and electric charges as large as 200e.*

  Search was exclusively based on analyses of the MoEDAL MMT exposed to pp collisions at Run-2 (13 TeV, 6.46 fb-1)

Monopole Production via the Schwinger Mechanism

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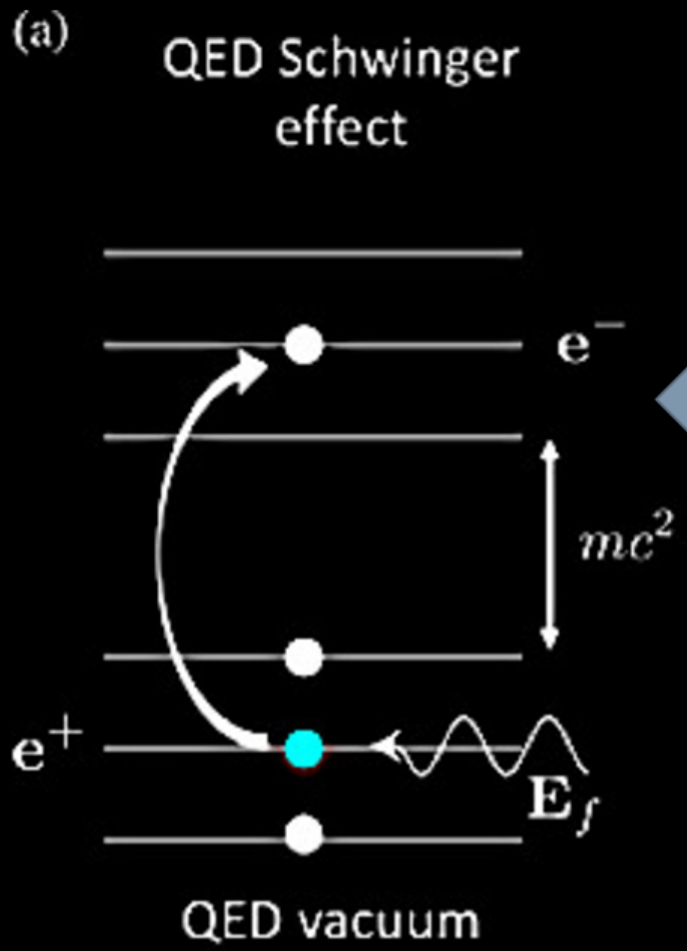
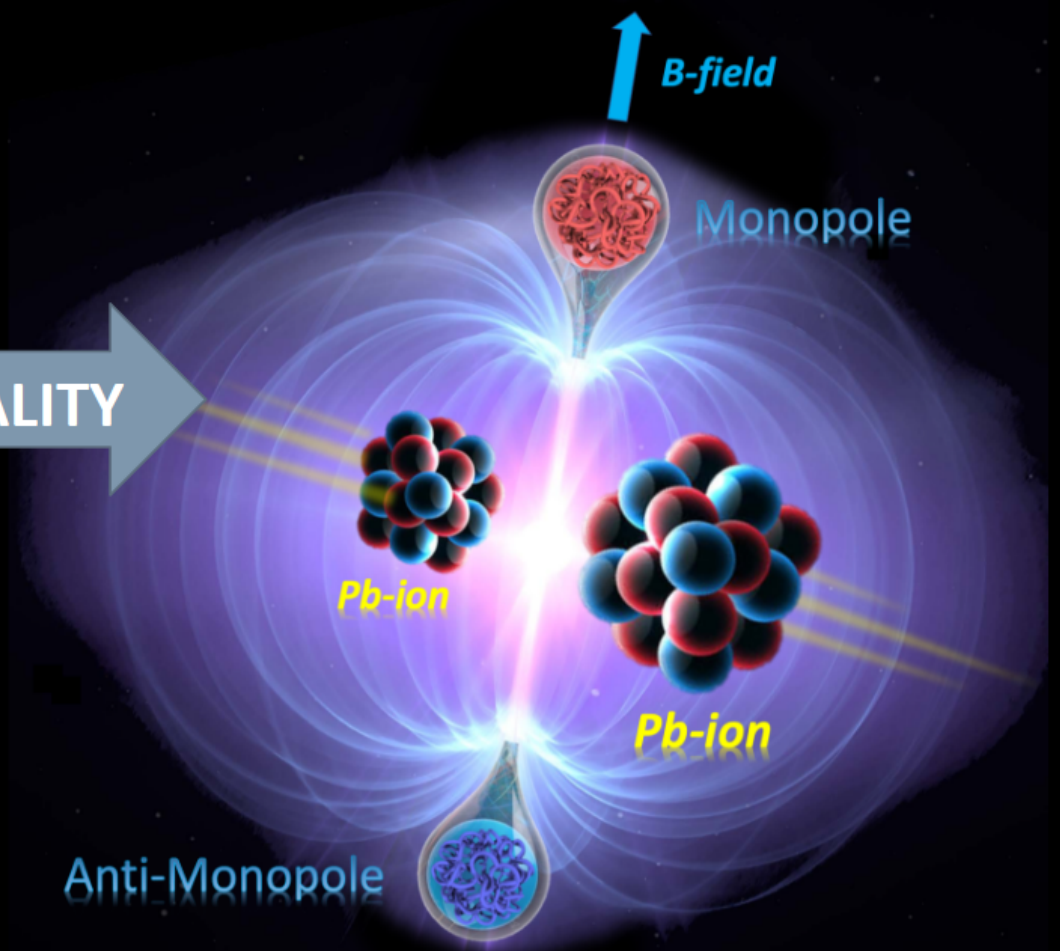


DUALITY



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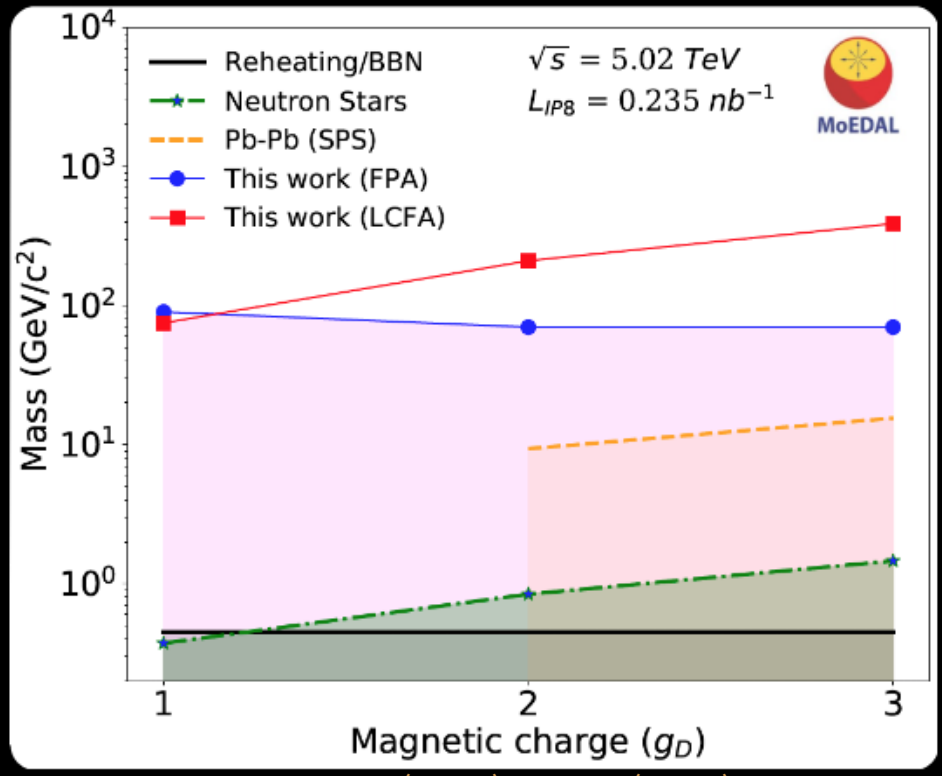

Nature **602**(7895), 63–67 (2022)

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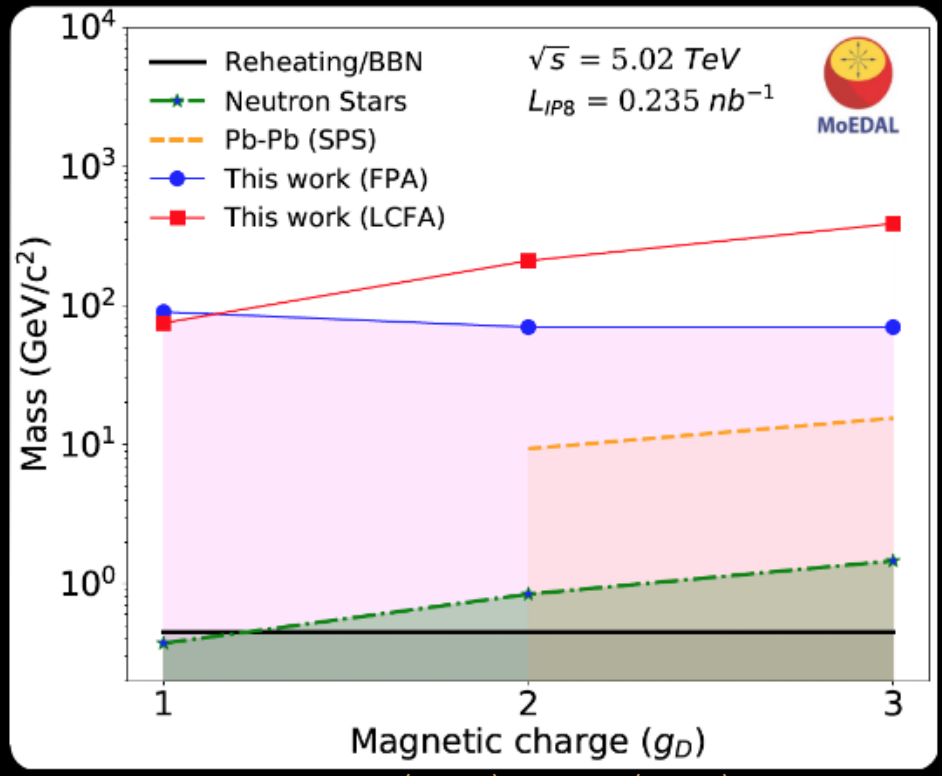

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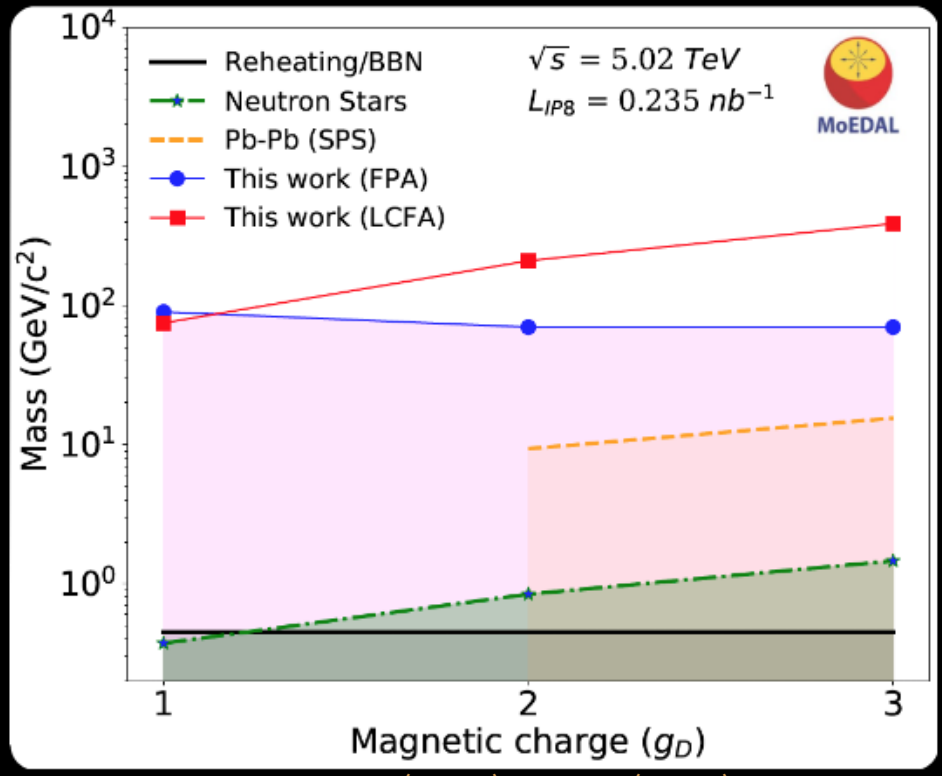

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Probably the first time that finite sized monopoles would have been detectable!

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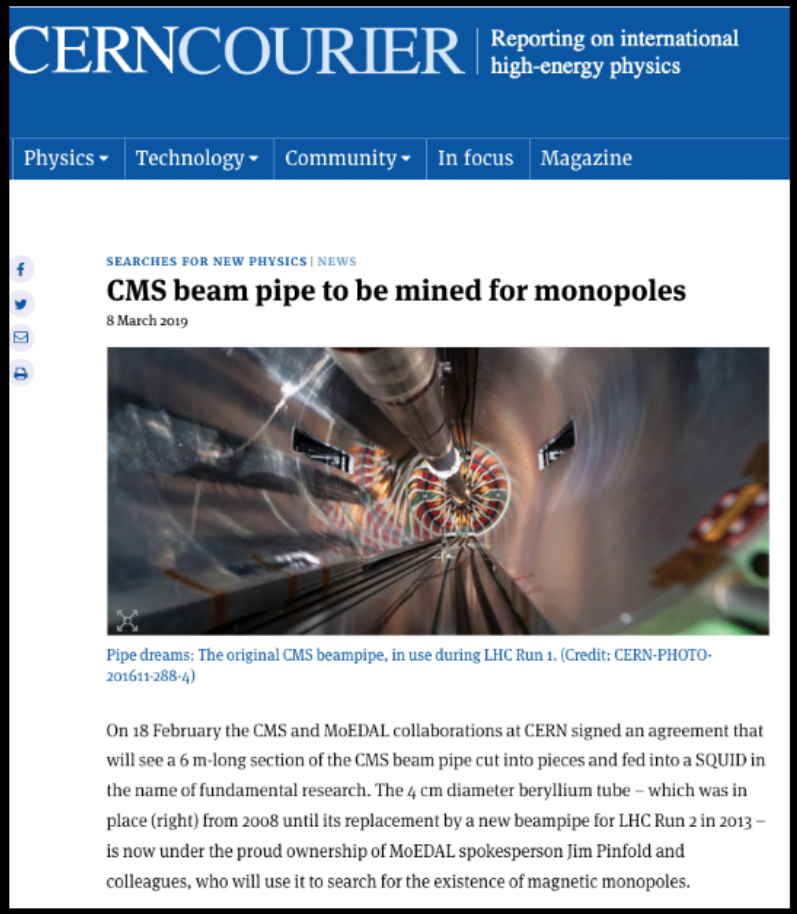
A search for MMs trapped in the Run-1 CMS beampipe is also currently underway!



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CMS beam pipe to be mined for monopoles

8 March 2019

Pipe dreams: The original CMS beampipe, in use during LHC Run 1. (Credit: CERN-PHOTO-201611-288-4)

On 18 February the CMS and MoEDAL collaborations at CERN signed an agreement that will see a 6 m-long section of the CMS beam pipe cut into pieces and fed into a SQUID in the name of fundamental research. The 4 cm diameter beryllium tube – which was in place (right) from 2008 until its replacement by a new beampipe for LHC Run 2 in 2013 – is now under the proud ownership of MoEDAL spokesperson Jim Pinfold and colleagues, who will use it to search for the existence of magnetic monopoles.

3

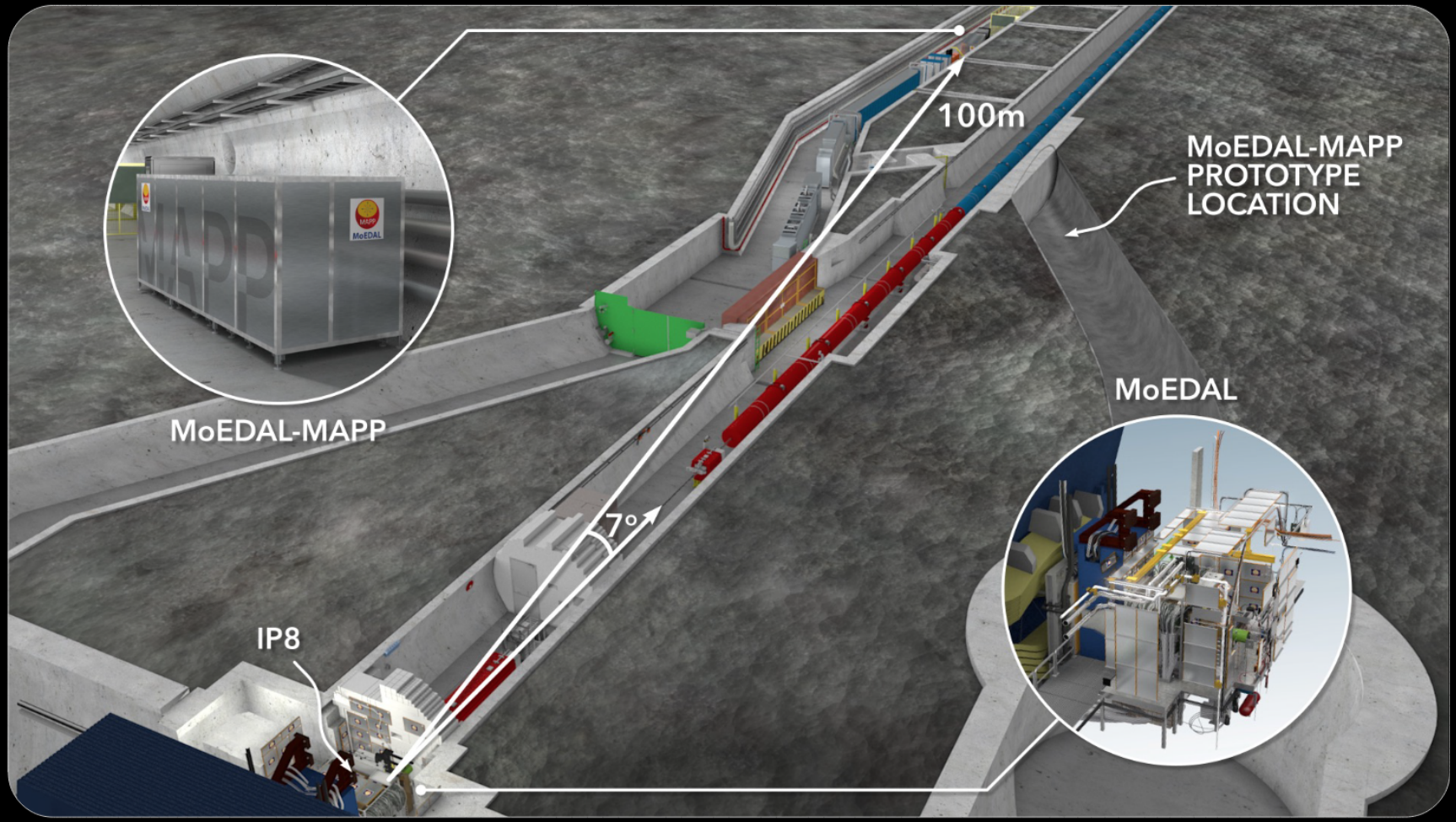
Phase-I: MoEDAL-MAPP (MoEDAL's Apparatus for Penetrating Particles)

Approved Dec. 2021 by the CERN Research Board! (CERN-LHCC-2021-024, LHCC-P-022)

Run-3 Plans & Prospects

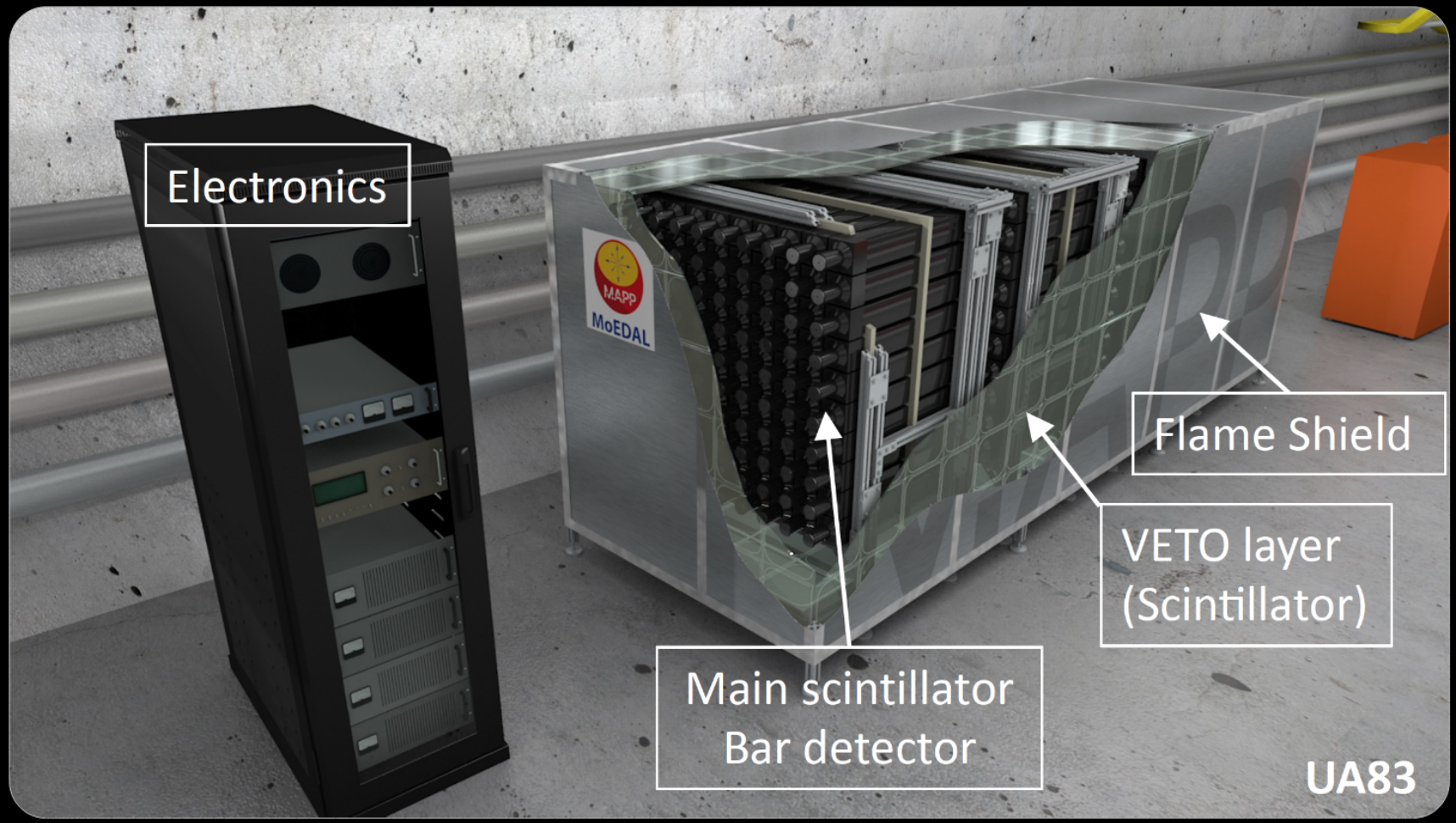
MoEDAL & MAPP Phase-I

Expanding the Physics Reach of MoEDAL Beyond HIPs to Include Feebly-Interacting Particles (FIPs)



The Phase-I MAPP Detector

400 scintillator bars (10 x 10 x 75 cm) in 4 sections readout by coincidental PMTs protected by a hermetic VETO system



Installation of MAPP Phase-I in UA83

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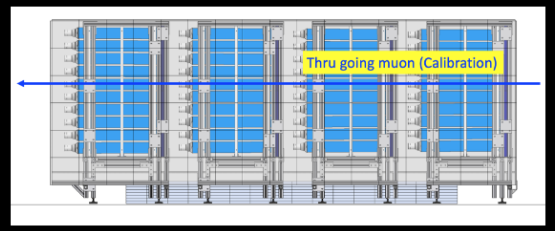
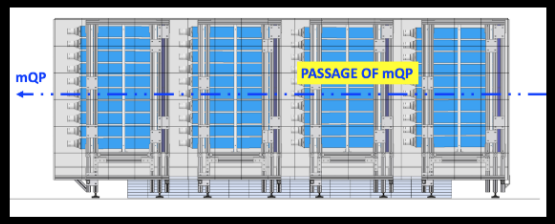
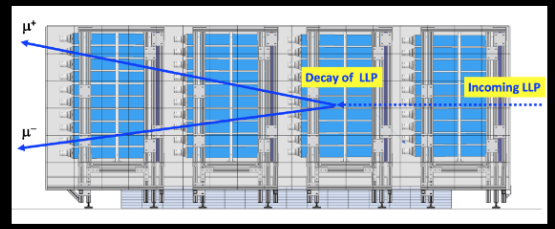
MAPP — Modes of Detection



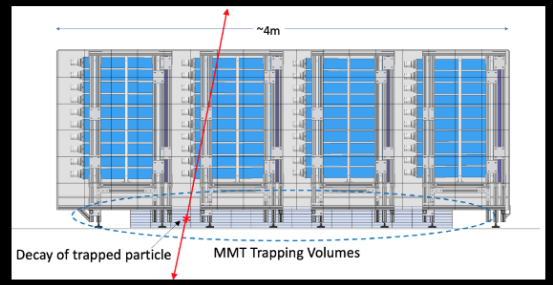
Muons from IP (Calibration)



Millicharged particle detection



Neutral LLP Detection

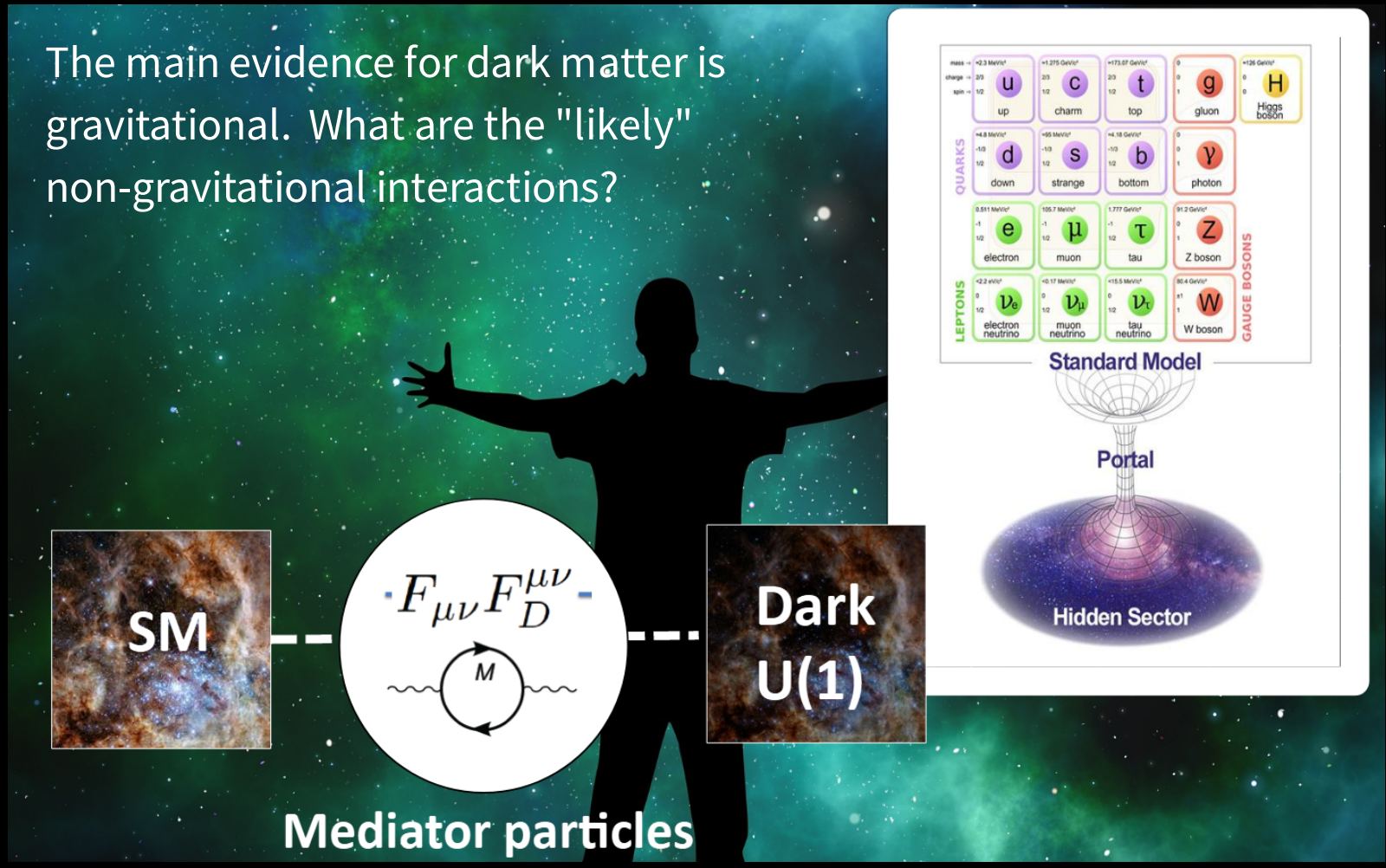


Charged LLP Detection
(In conjunction with MoEDAL)

MAPPing the Dark Sector

The main evidence for dark matter is gravitational. What are the "likely" non-gravitational interactions?

MAPPing the Dark Sector



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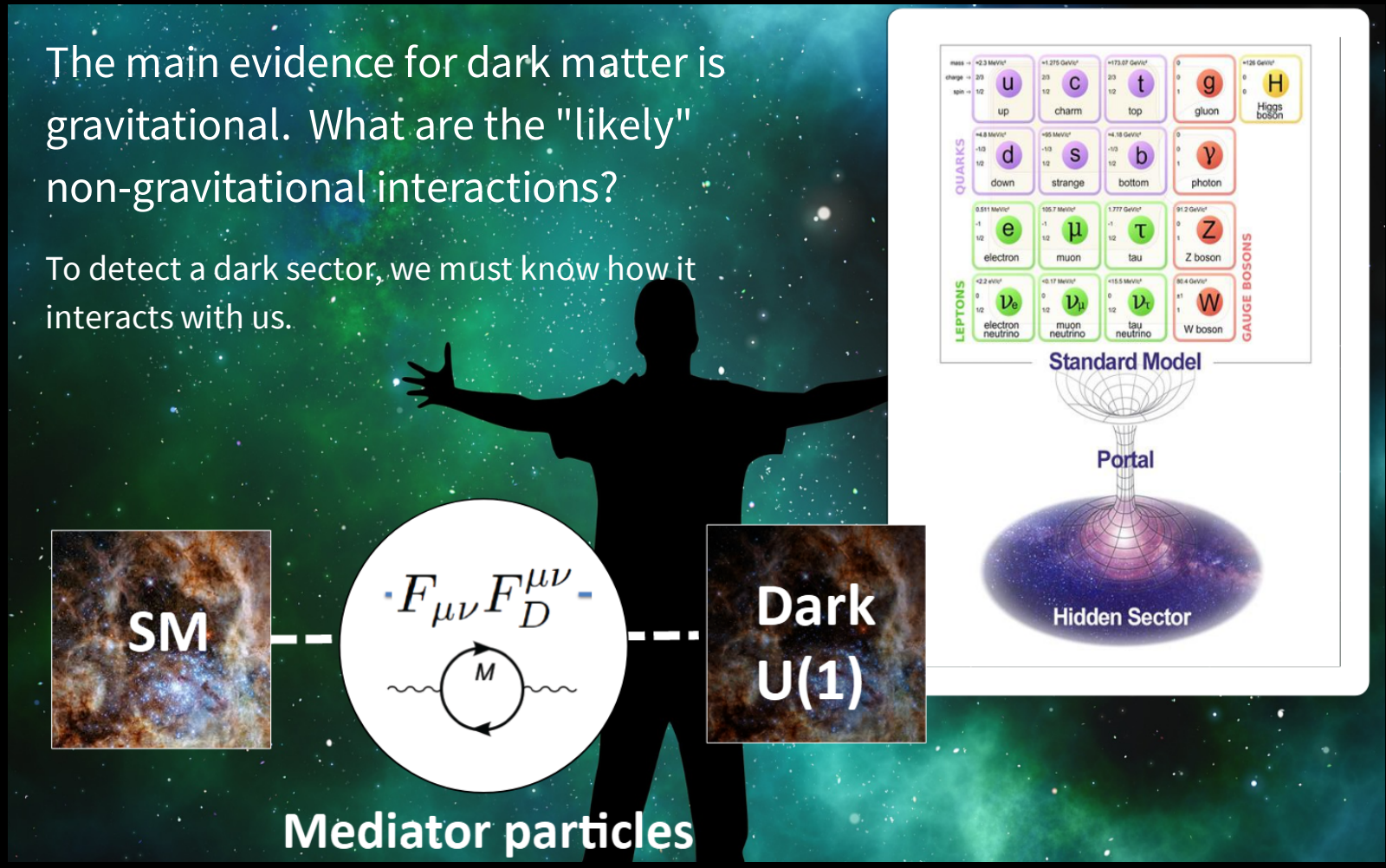

MAPPing the Dark Sector

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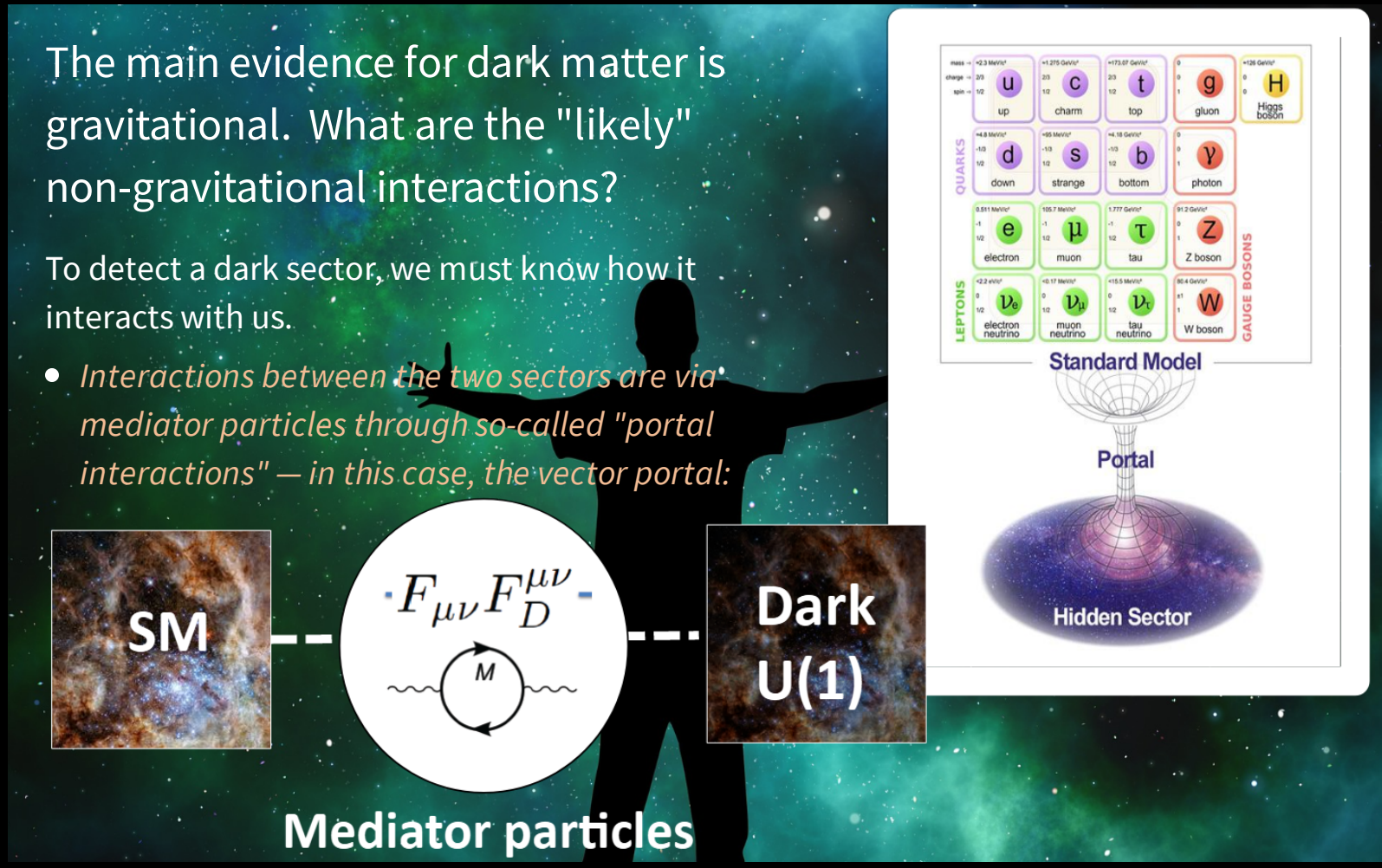
To detect a dark sector, we must know how it interacts with us.

- *Interactions between the two sectors are via mediator particles through so-called "portal interactions" — in this case, the vector portal:*



The Physics Program of MAPP-1 (A Couple Examples)

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Minicharged Particles (mCPs)

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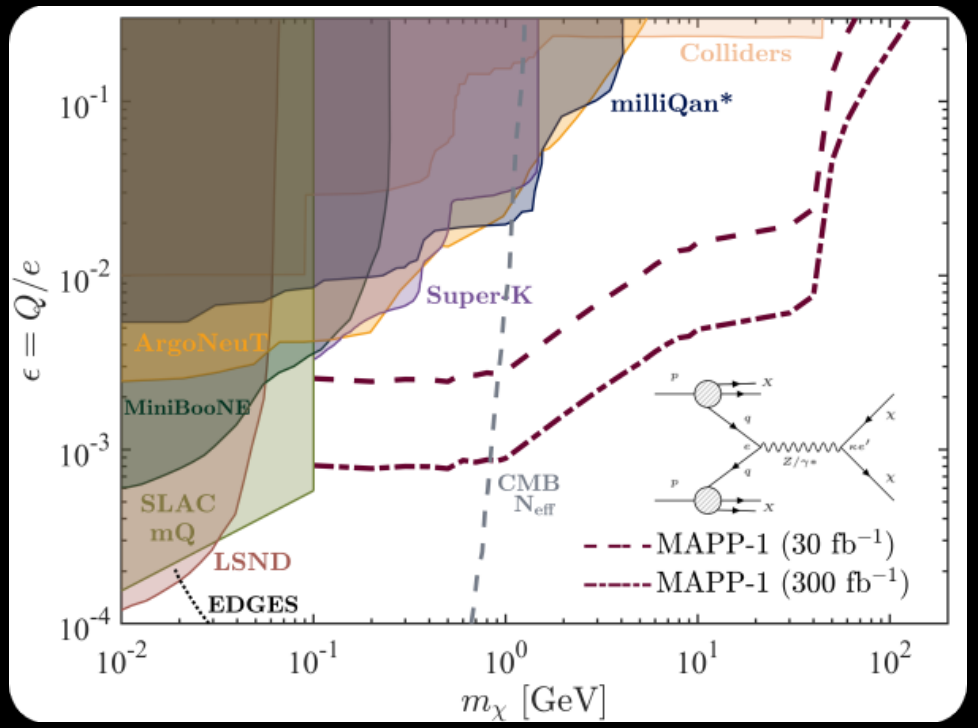
95% C.L. for DY pair-produced mCPs in 14 TeV *pp* collisions



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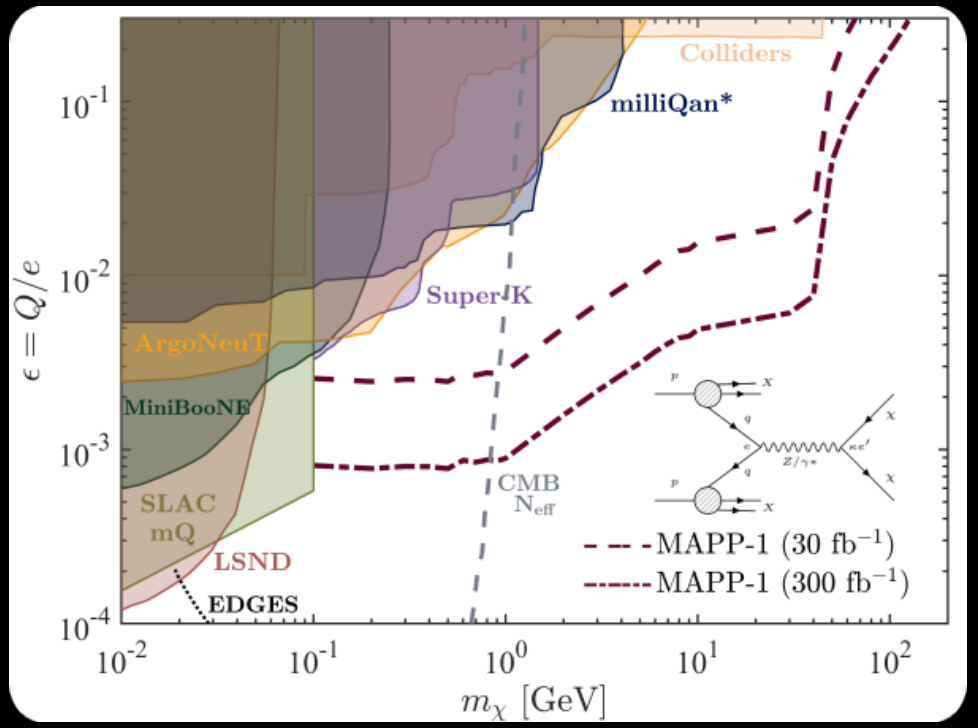

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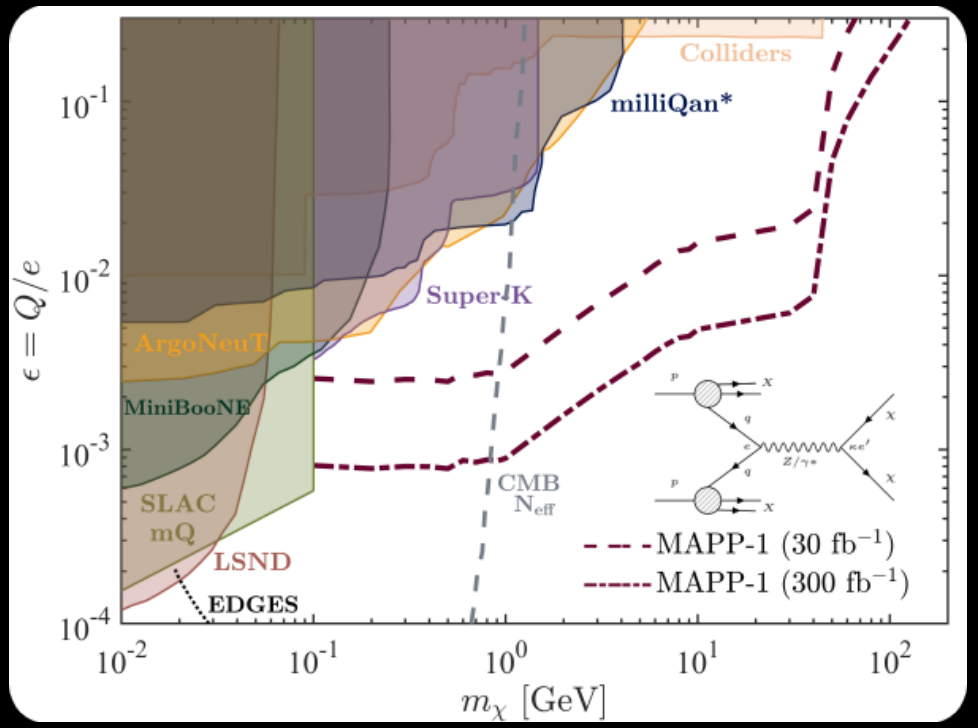

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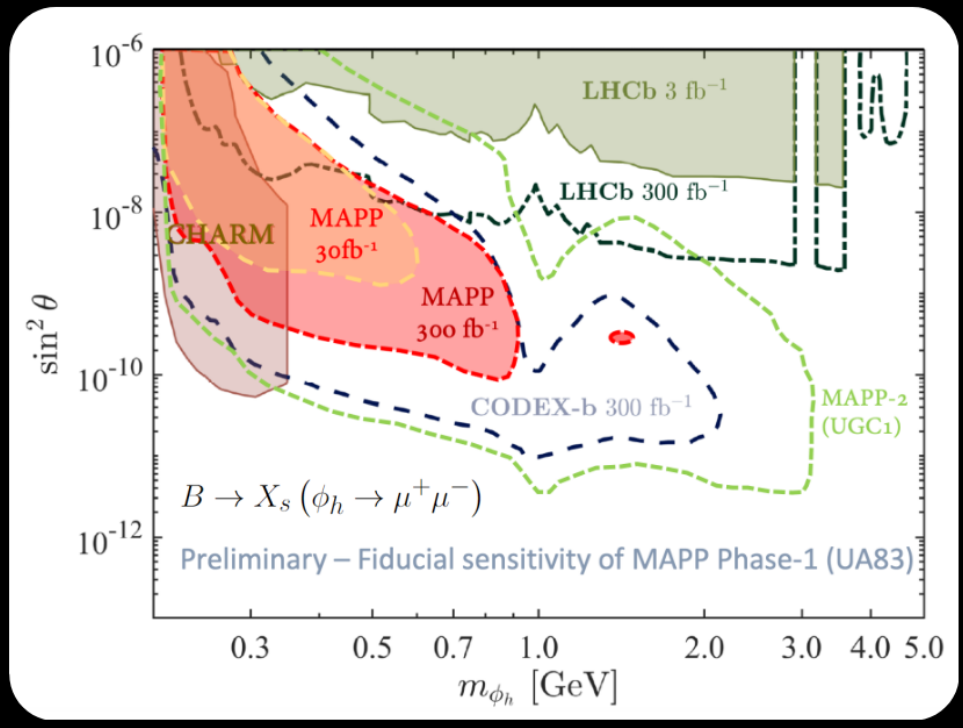
95% C.L. for a light CP-even dark scalar produced via rare B decays



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4

The Future of the MoEDAL-MAPP Experiment

The HL-LHC & Beyond

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Results based on 14 TeV *pp* collisions

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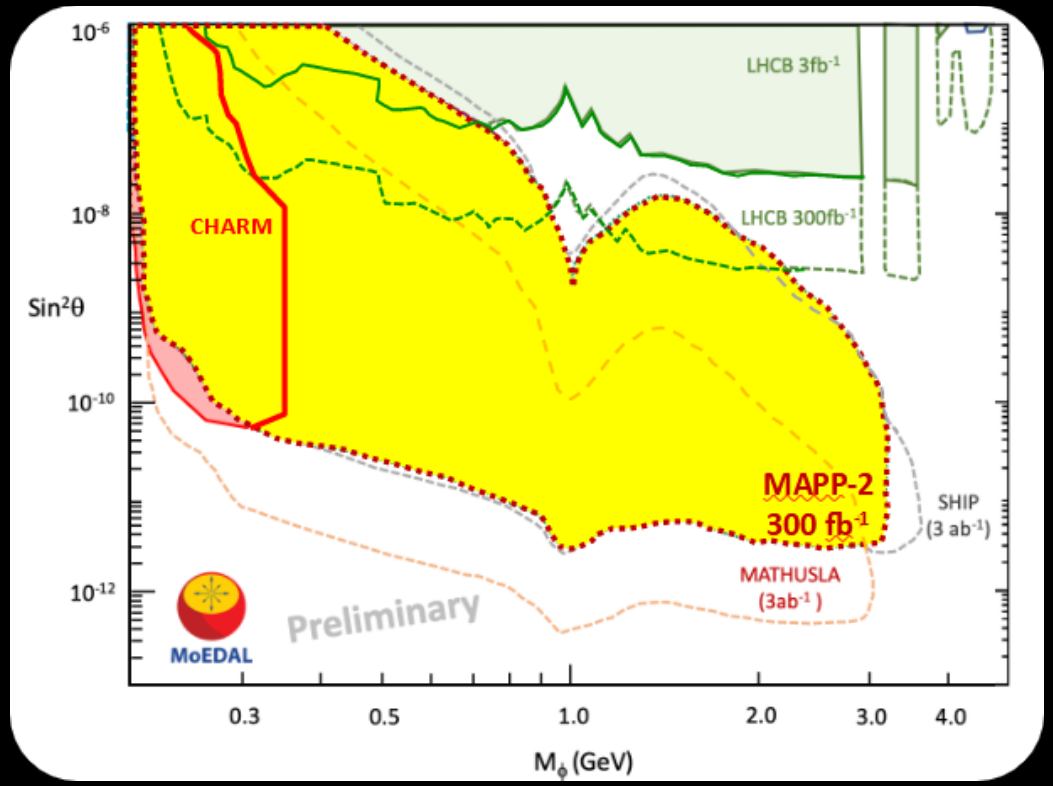

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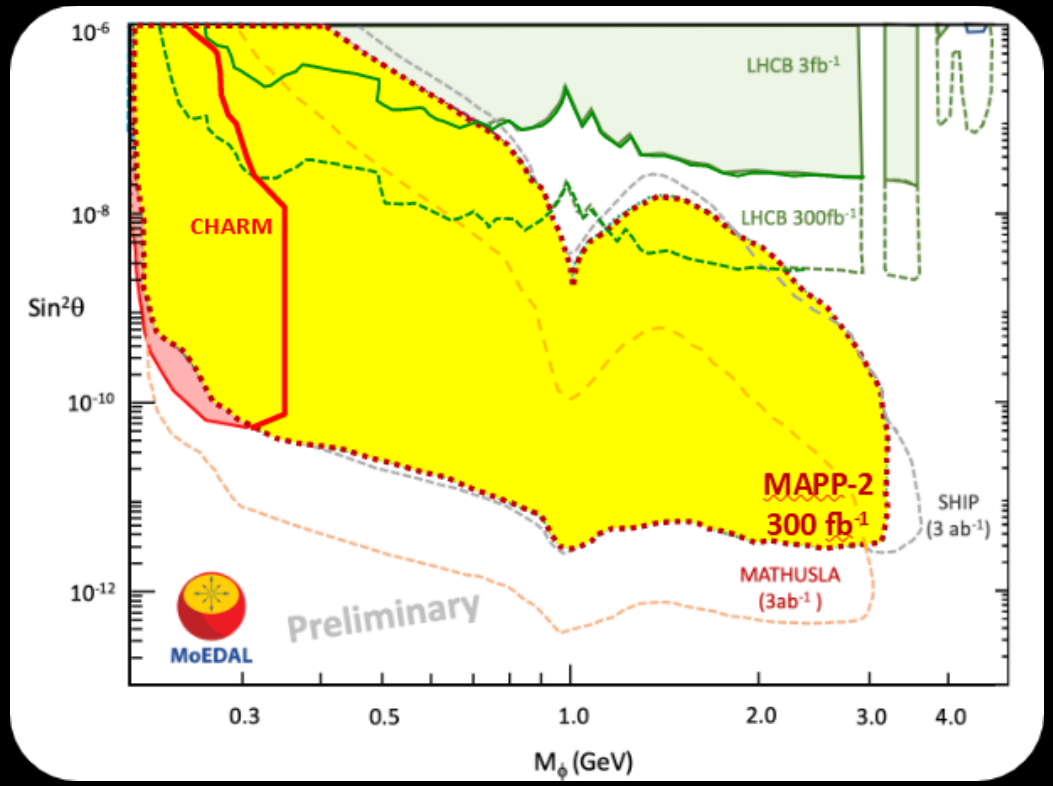

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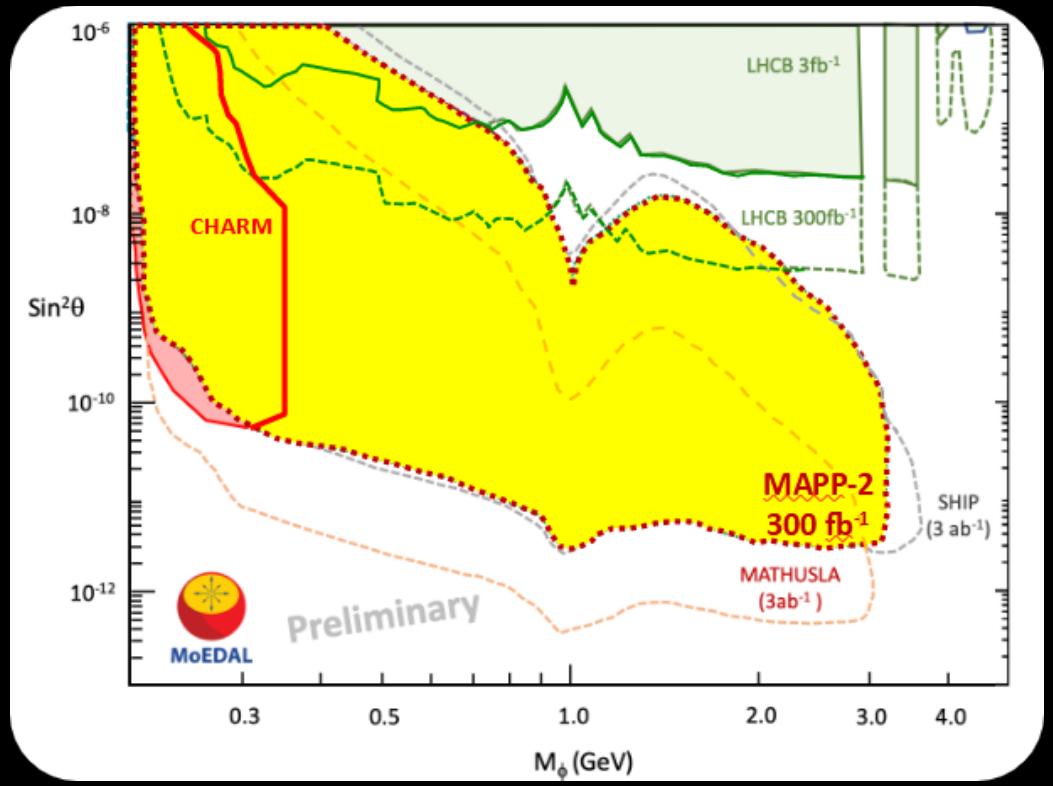

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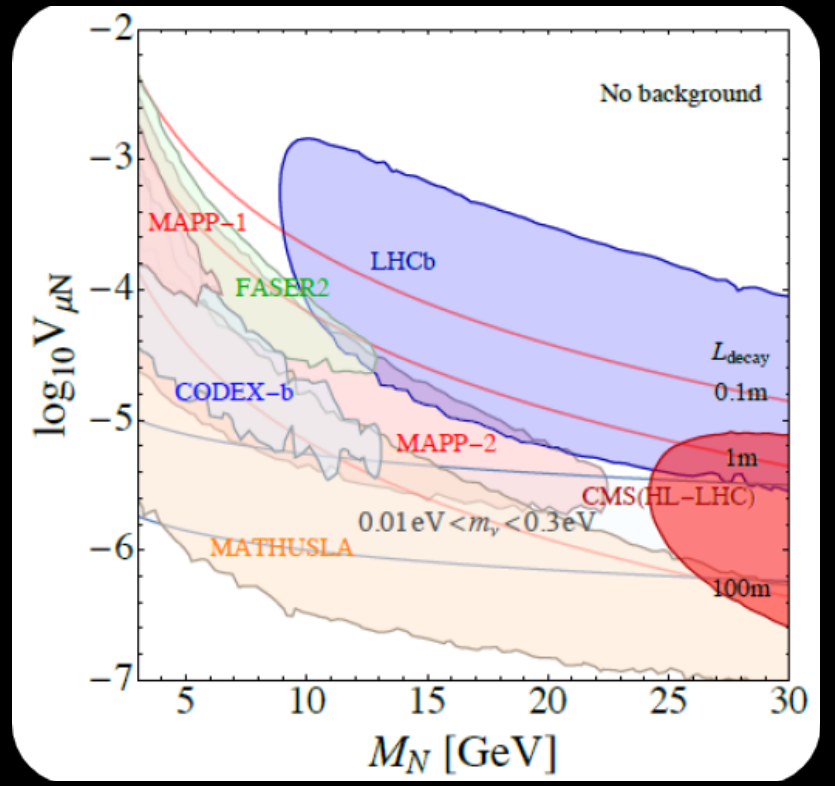

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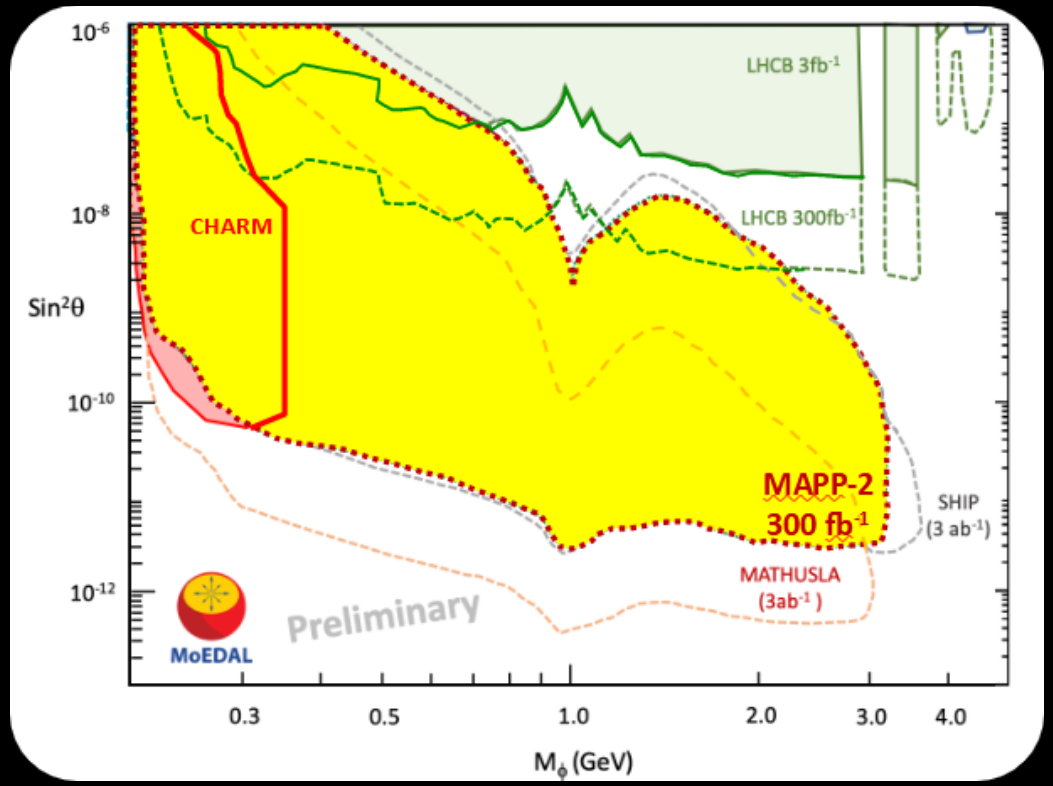

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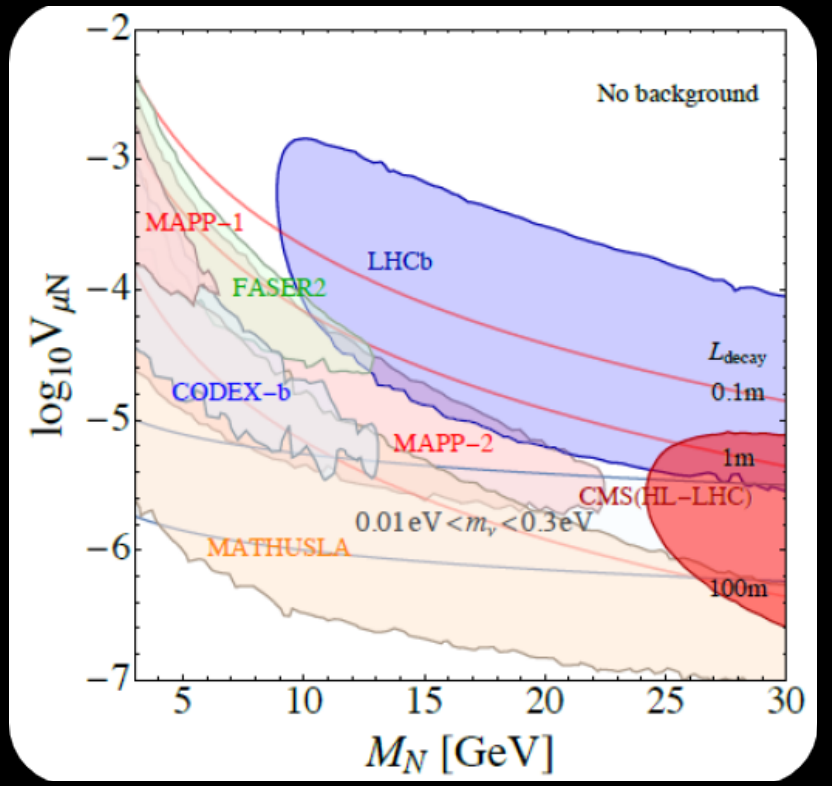

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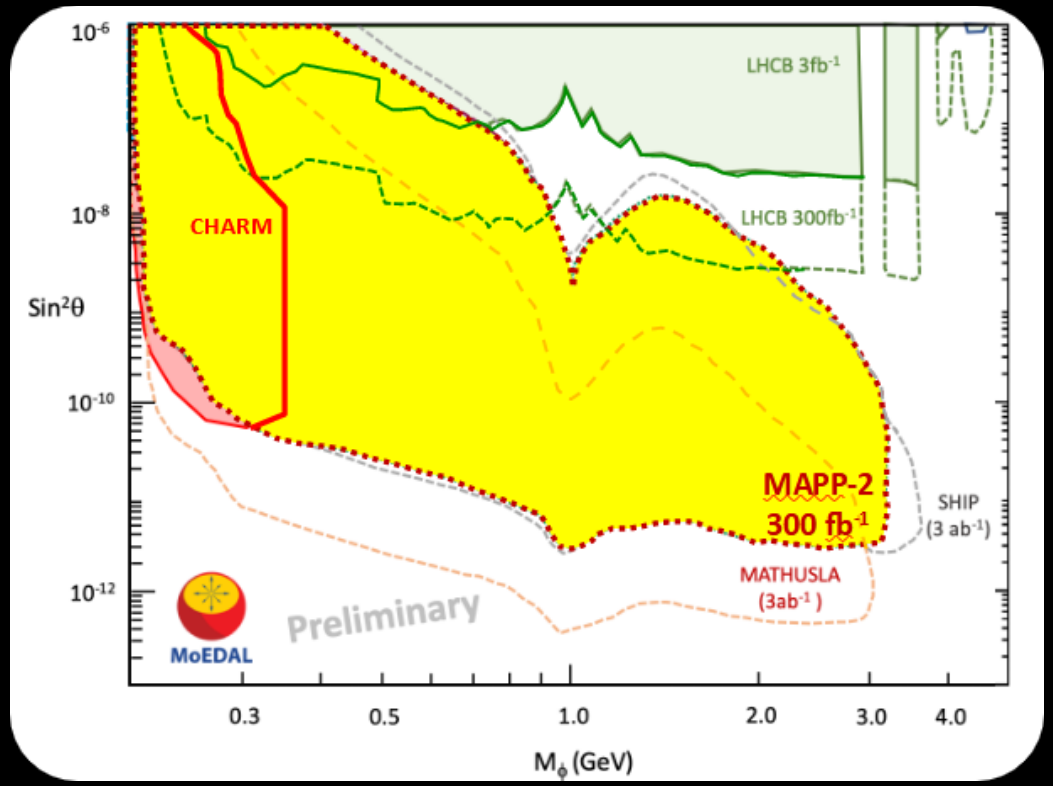

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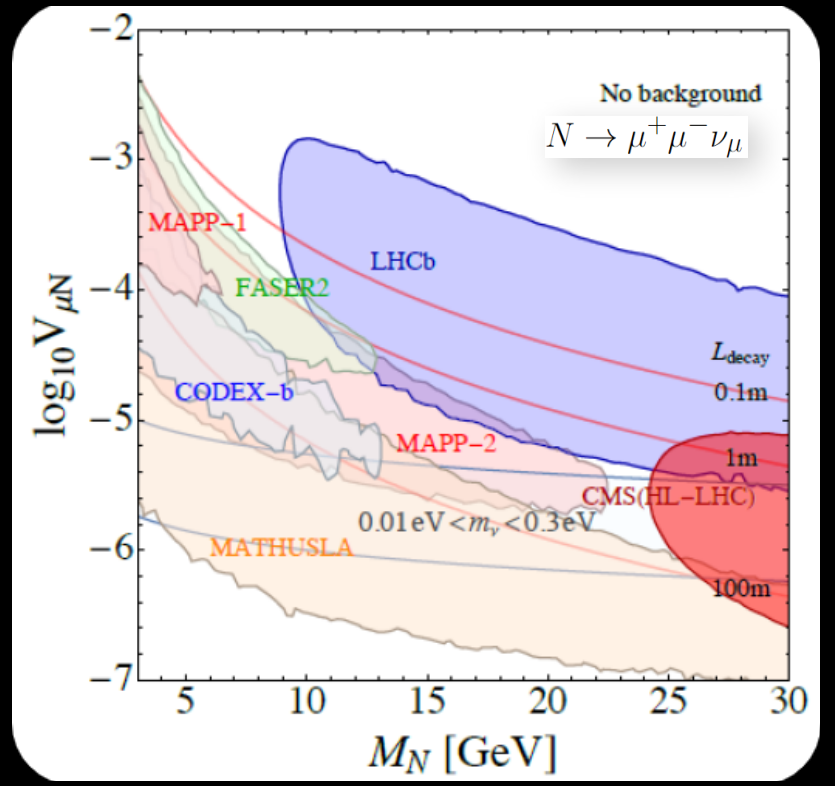

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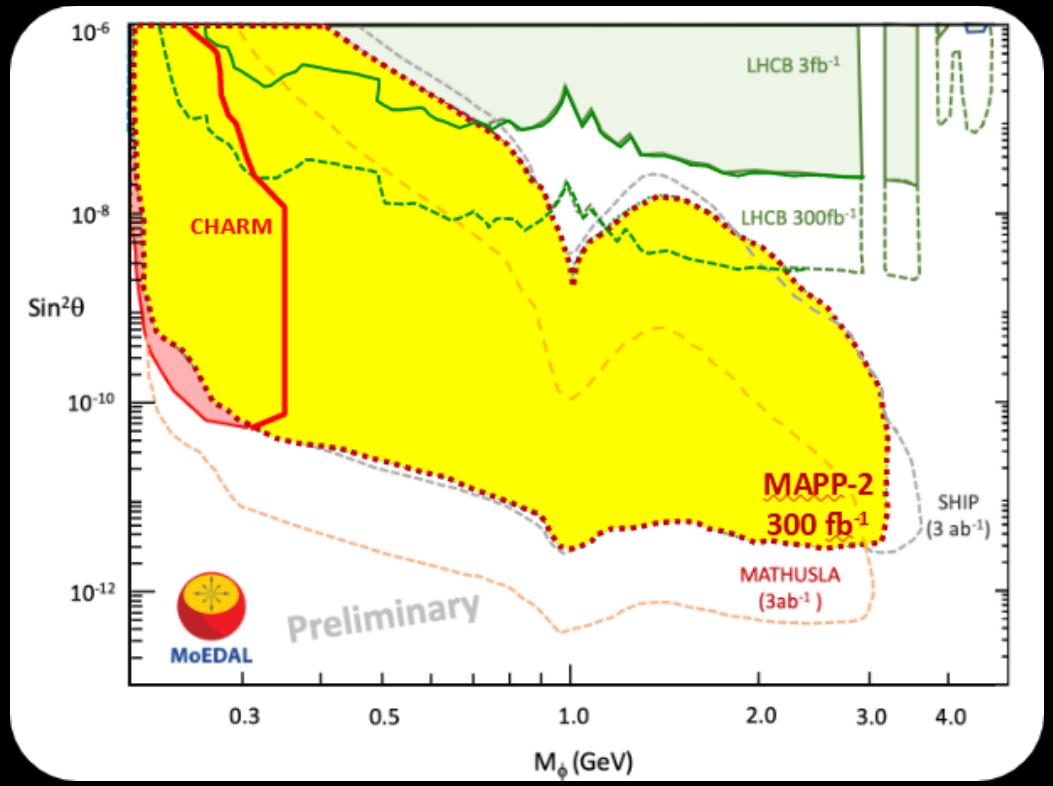

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Phys. Rev. Lett. **115**, 161802 (2015); *Phys. Rev. D* **95**, 071101 (2017); *Phys. Rev. D* **99**, 015018 (2019)

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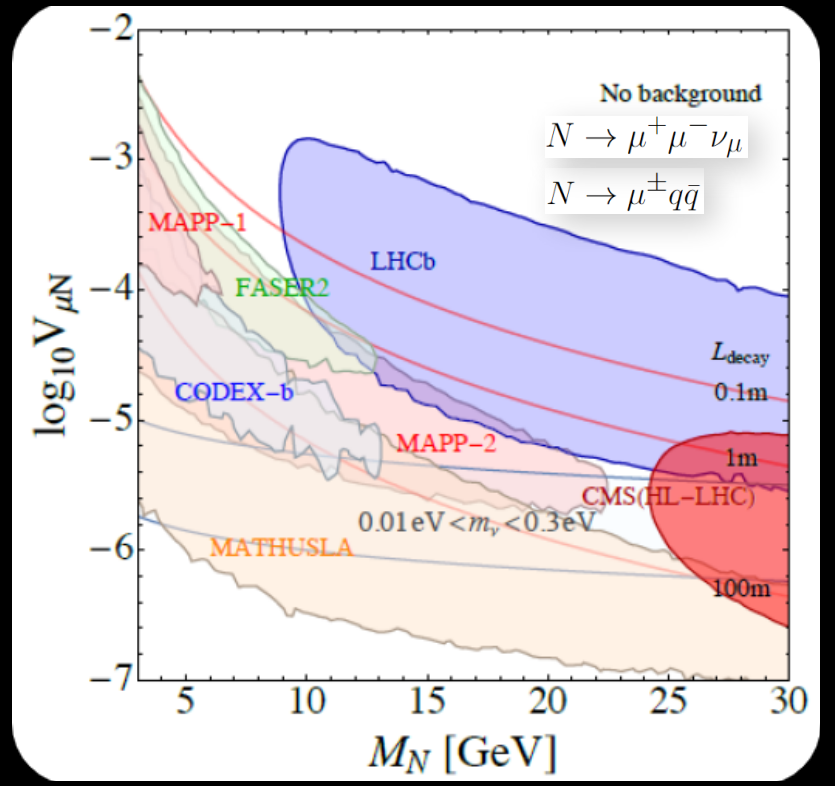
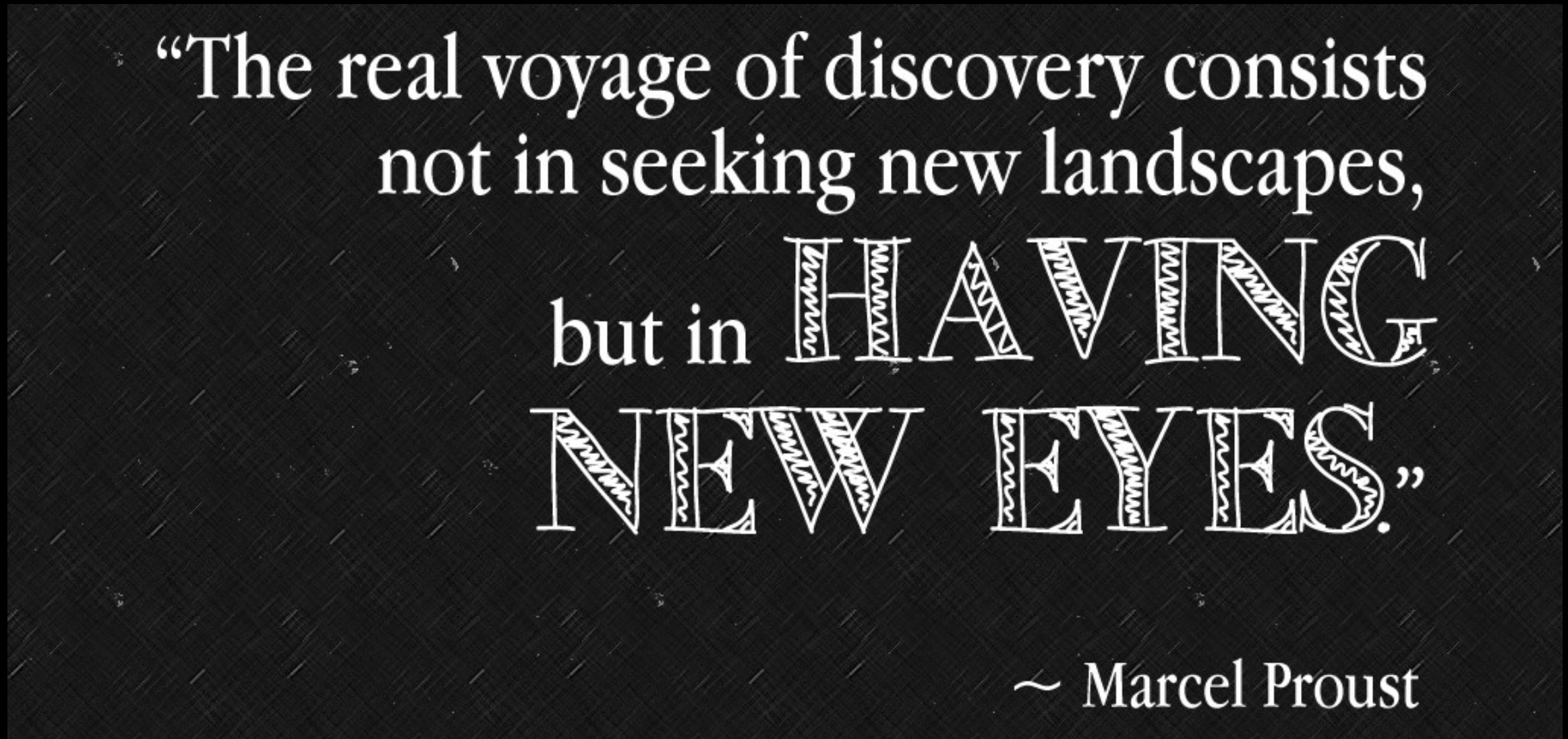


Long-Lived Heavy Neutral Lepton (Neutrino Portal)

Phys Rev. D **100**, 035005 (2019); *J. High Energy Phys.* **2018**, 181 (2018). MAPP-1 → 30 fb-1; MAPP-2, CODEX-b & LHCb → 300 fb-1; FASER2, CMS & MATHUSLA → 3 ab-1

Concluding Remarks



Thank you!

Questions?