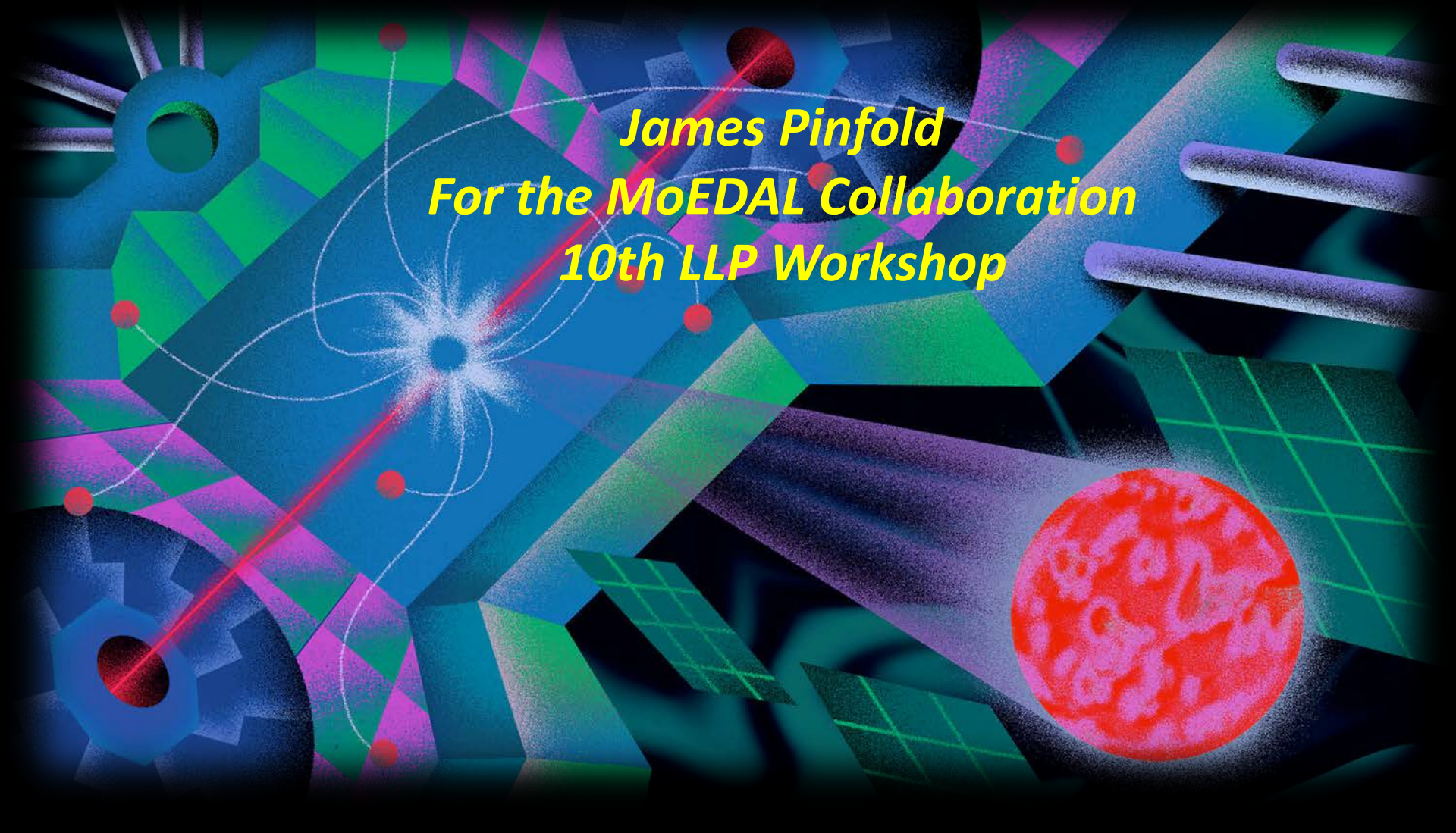
MoEDAL-MAPP Experiment – Status Report



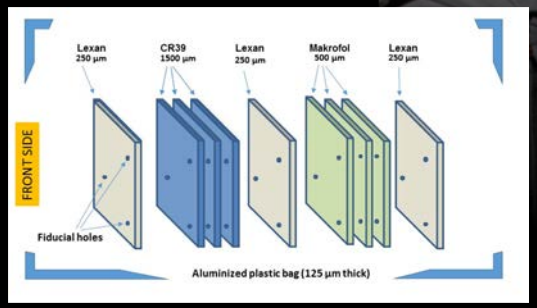
James Pinfold
For the MoEDAL Collaboration
10th LLP Workshop

The MoEDAL Detector – LHC's 1st dedicated Search Expt

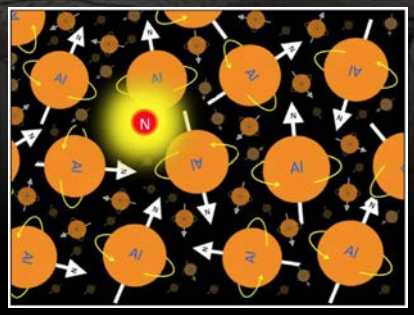
MoEDAL

Permanent Physical record of new physics

No Standard Model Physics Backgrnds



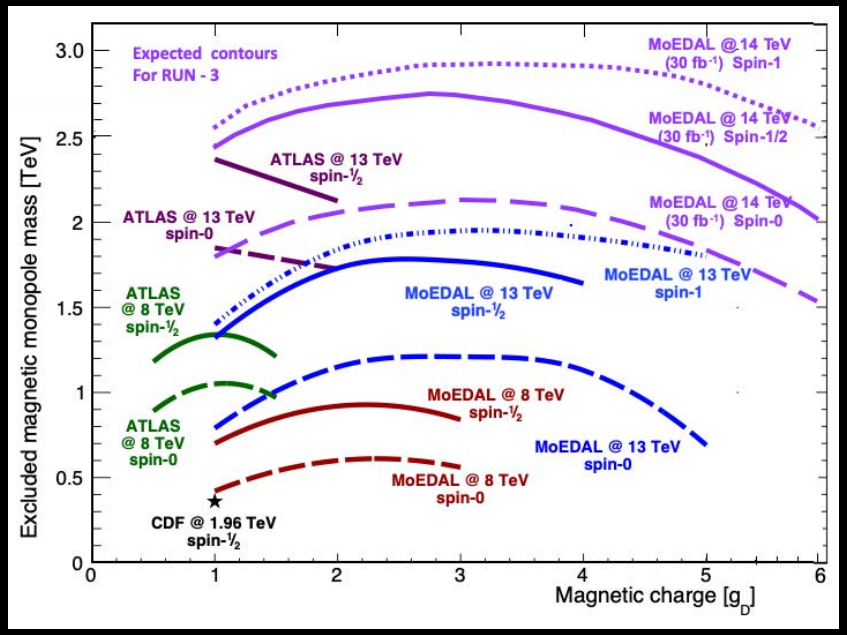
NUCLEAR TRACK DETECTOR Plastic array (185 stacks, 12 m^2) – Like a big Camera

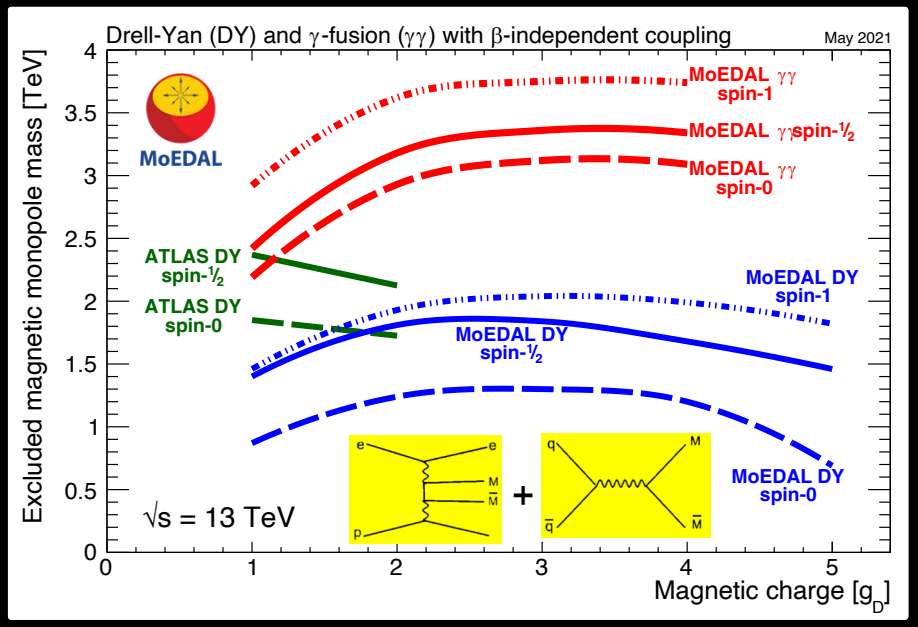


TRAPPING DETECTOR ARRAY A tonne of Al to trap Highly Ionizing Particles for analysis

TIMEPIX Array a digital Camera for real time radiation monitoring

Mass Limits on Magnetic Monopoles



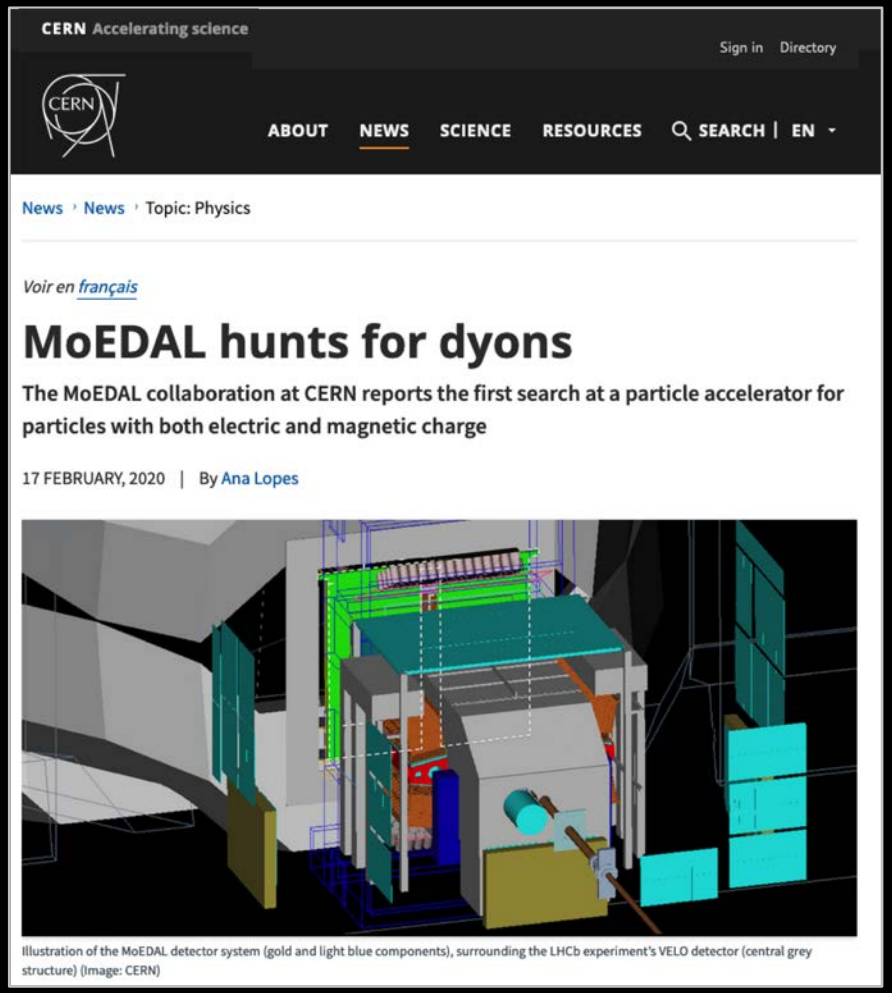


JHEP 1608 (2016) 067 PRL 118 (2017) 061801 Phys.Lett. B782 (2018) 510 PRL 123 (2019) 021802

- *So far MoEDAL has placed the world's best published direct limits on:*
  - *Multiply charged magnetic monopoles*
  - *Spin-1 monopoles*
  - *DY + Photon fusion production of monopoles*
  - *Dyons – electrically and magnetically charged particles.*

The Search for the Dyon

- *MoEDAL just completed the first direct search for Schwinger's Dyon – a particle with electric and magnetic charge*
- *We exclude dyons with:*
  - *A magnetic charge ranging up to $5g_D$ and an electric charge up to 200e with mass limits in the range 750–1910 GeV*
  - *And also monopoles with magnetic charge up to and including $5g_D$ with mass limits in the range 850 –2040 GeV.*



CERN Accelerating science

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Voir en français

MoEDAL hunts for dyons

The MoEDAL collaboration at CERN reports the first search at a particle accelerator for particles with both electric and magnetic charge

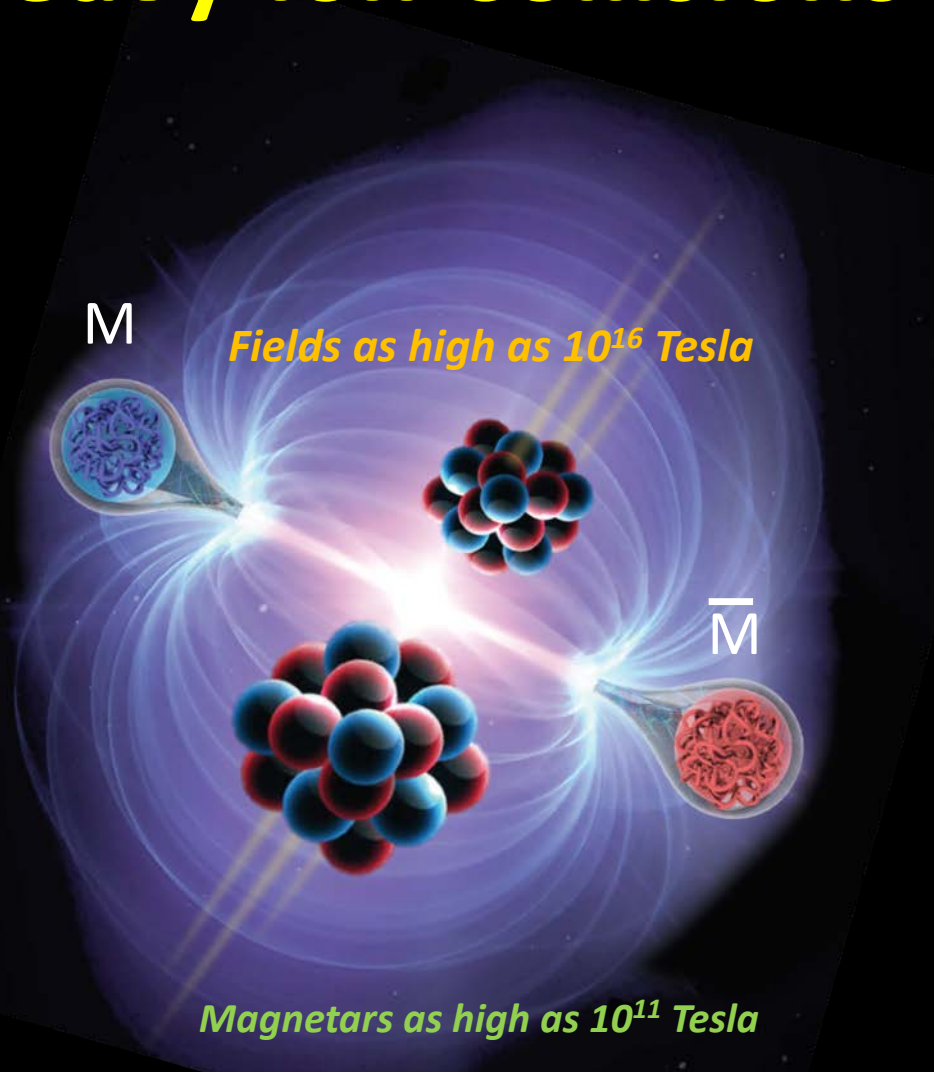
17 FEBRUARY, 2020 | By Ana Lopes

Illustration of the MoEDAL detector system (gold and light blue components), surrounding the LHCb experiment's VELO detector (central grey structure) (Image: CERN)

Phys. Rev. Lett. 126 (2021) 7, 071801

Schwinger Production of Monopoles in Heavy-ion Collisions

- *Schwinger mechanism originally described spontaneous creation of e^- - e^+ pairs in presence of an extremely strong electric field.*
- *Important benefits:*
  - *No exponential suppression for finite sized monopoles*
  - *X-sec calculation does not suffer from non-perturbative couplings as in DY*
- *MMs with Dirac charges $1g_D$, $2g_D$, $3g_D$ and masses up to 75 GeV were excluded by the analysis.*
- *This provides the first mass limit for finite-size MMs from a collider search*



arXiv:2106.11933v1 [hep-ex] 22 Jun 2021

The Search for HECOS

Watch this space

Search for High Ionizing Particles in *pp* Collisions at the LHC's Run-1 Using the Prototype MoEDAL Detector

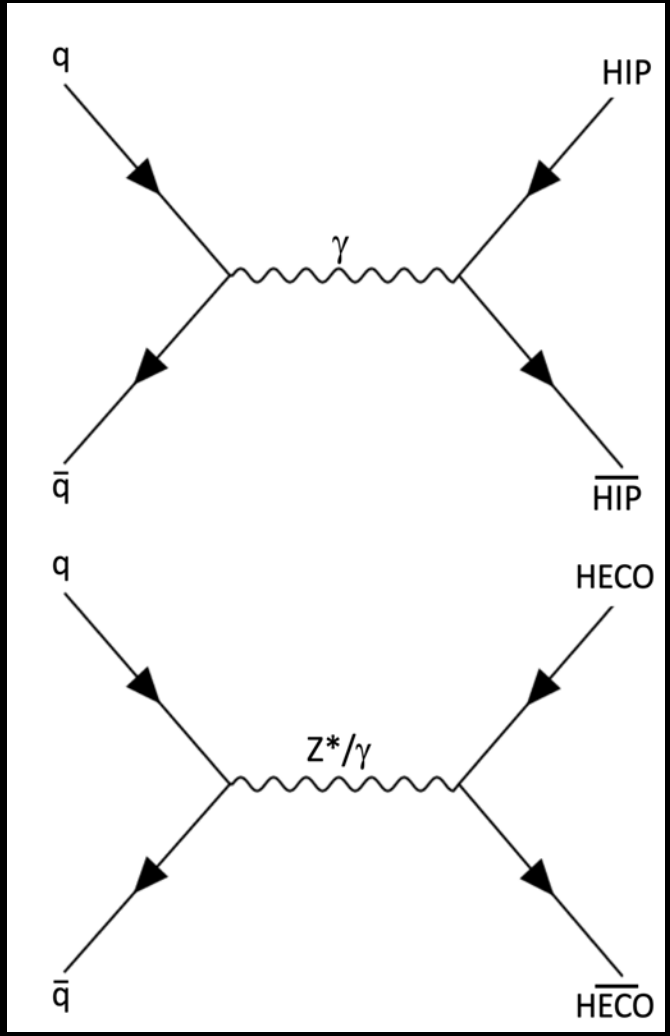
B. Acharya,[1,*] J. Alexandre,[1] P. Benes,[2] B. Bergmann,[2] S. Bertolucci,[3] A. Bevan,[4] R. Bhattacharyya,[3,†] H. Branzas,[5] P. Burian,[2] M. Campbell,[6] S. Cecchini,[3] Y. M. Cho,[7] M. de Montigny,[8] A. De Roeck,[6] J. R. Ellis,[1,9,‡] M. El Sawy,[6,§] M. Fairbairn,[1] D. Felea,[5] M. Frank,[10] J. Hays,[4] P. Q. Hung,[11] A. M. Hirt,[12] J. Janecek,[2] M. Kalliokoski,[13] A. Korzenev,[14] D. H. Lacarrère,[6] C. Leroy,[15] G. Levi,[16] P. Li,[8] A. Lionti,[14] R. Maselek,[17] A. Maulik,[3,8] A. Margiotta,[16] N. Mauri,[16] N. E. Mavromatos,[1,¶] P. Mermod,[14,**] M. Mieskolainen,[13] L. Millward,[4] V. A. Mitsou,[18] R. Orava,[13] I. Ostrovskiy,[19] P.-P. Ouimet,[20] J. Papavassiliou,[18] B. Parker,[21] L. Patrizii,[3] G. E. Păvălaş,[5] J. L. Pinfold,[8,††] L. A. Popa,[5] V. Popa,[5] M. Pozzato,[3] S. Pospisil,[2] A. Rajantie,[22] R. Ruiz de Austri,[18] Z. Sahnoun,[3,‡‡] M. Sakellariadou,[1] K. Sakurai,[17] A. Santra,[18] S. Sarkar,[1] G. Semenoff,[23] A. Shaa,[8] G. Sirri,[3] K. Sliwa,[24] R. Soluk,[8] M. Spurio,[16] M. Staelens,[8] M. Suk,[2] M. Tenti,[25] V. Togo,[3] J. A. Tuszyński,[8] A. Upreti,[19] V. Vento,[18] and O. Vives[18]
(THE MoEDAL COLLABORATION)

Analysis finished, to be submitted to EPJC

Search for High Ionizing Particles in *pp* Collisions at the LHC Using the Full LHC MoEDAL Detector

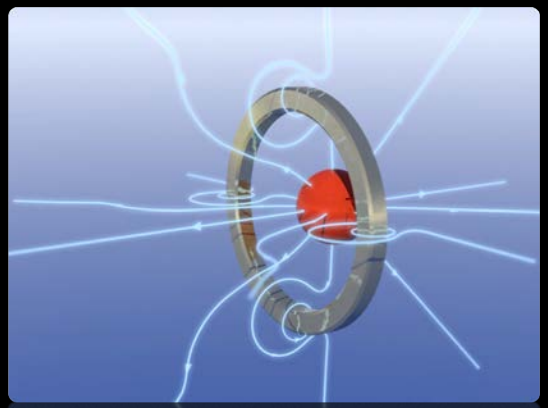
B. Acharya,[1,*] J. Alexandre,[1] P. Benes,[2] B. Bergmann,[2] J. Bernabéu,[3] A. Bevan,[4] R. Bhattacharyya,[5,†] H. Branzas,[6] P. Burian,[2] M. Campbell,[7] S. Cecchini,[5] Y. M. Cho,[8] M. de Montigny,[9] A. De Roeck,[7] J. R. Ellis,[1,10,‡] M. El Sawy,[7,§] M. Fairbairn,[1] D. Felea,[6] M. Frank,[11] J. Hays,[4] A. M. Hirt,[12] J. Janecek,[2] M. Kalliokoski,[13] A. Korzenev,[14] D. H. Lacarrère,[7] C. Leroy,[15] G. Levi,[16] P. Li,[9] A. Lionti,[14] J. Mamuzic,[3] A. Maulik,[5,9] A. Margiotta,[16] N. Mauri,[16] N. E. Mavromatos,[1] P. Mermod,[14,¶] M. Mieskolainen,[13] L. Millward,[4] V. A. Mitsou,[3] R. Orava,[13] I. Ostrovskiy,[17] P.-P. Ouimet,[9,**] J. Papavassiliou,[3] B. Parker,[18] L. Patrizii,[5] G. E. Păvălaş,[6] J. L. Pinfold,[9,††] L. A. Popa,[6] V. Popa,[6] M. Pozzato,[5] S. Pospisil,[2] A. Rajantie,[19] R. Ruiz de Austri,[3] Z. Sahnoun,[5,‡‡] M. Sakellariadou,[1] A. Santra,[3] S. Sarkar,[1] G. Semenoff,[20] A. Shaa,[9] G. Sirri,[5] K. Sliwa,[21] R. Soluk,[9] M. Spurio,[16] M. Staelens,[9] M. Suk,[2] M. Tenti,[22] V. Togo,[5] J. A. Tuszyński,[9] A. Upreti,[17] V. Vento,[3] O. Vives,[3] and A. Wall[17]
(THE MoEDAL COLLABORATION)

Analysis underway



MoEDAL's Search for Monopoles Trapped in CMS Beampipe

- *MoEDAL searched for highly charge magnetic monopoles trapped in the Run1 CMS beampipe*
- *We used the MoEDAL's SQUID detector based at ETH Zurich*



- *No evidence was seen for trapped magnetic charge*
- *Publication in preparation*

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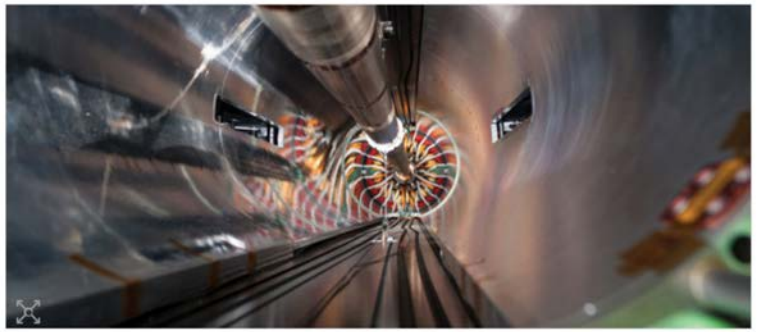
CMS beam pipe to be mined for monopoles

8 March 2019

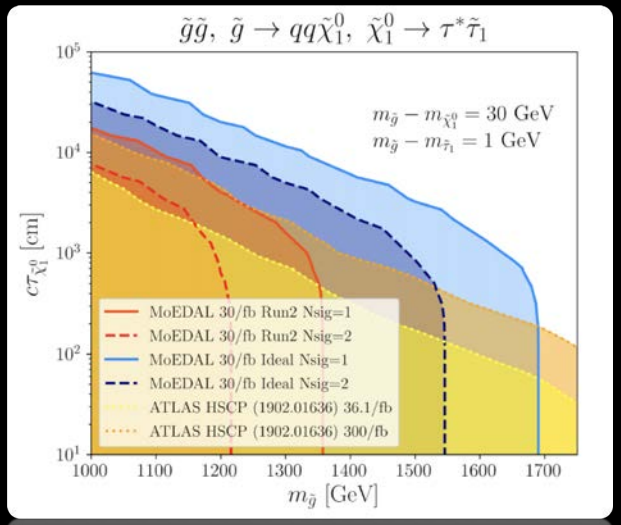


Pipe dreams: The original CMS beampipe, in use during LHC Run 1. (Credit: CERN-PHOTO-201611-288-4)

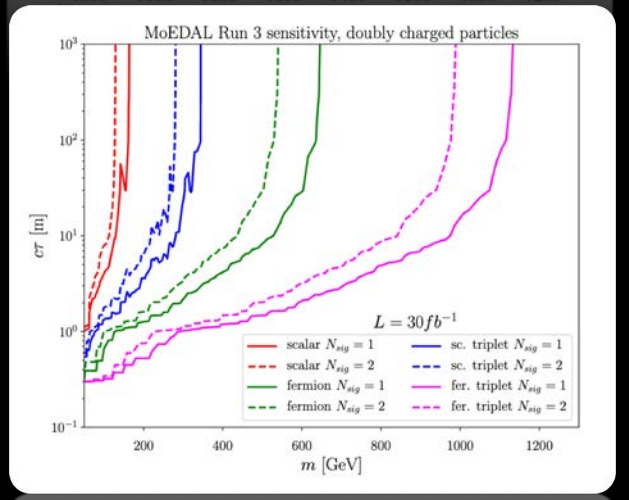
On 18 February the CMS and MoEDAL collaborations at CERN signed an agreement that will see a 6 m-long section of the CMS beam pipe cut into pieces and fed into a SQUID in the name of fundamental research. The 4 cm diameter beryllium tube – which was in place (right) from 2008 until its replacement by 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.

Sensitivity to Long-lived Massive Singly & Double Charged Particles

- *MoEDAL can cover the challenging long-lifetime region with lifetime, ct ≥ 100 m*
  - *MoEDAL sensitivity to p p → $\tilde{g}\tilde{g}$ production*
    - *Mass splitting between the gluino & neutralino = 30 GeV + splitting between the neutralino & stau =1 GeV.*
- *The opposite figure shows the expected MoEDAL sensitivities for four types of doubly-charged particles, assuming a Run 3 in-integrated luminosity of 30 fb^{-1}. :*
  - *a scalar singlet (red),*
  - *a scalar triplet (blue),*
  - *a fermion singlet (green)*
  - *afermion triplet (magenta),*

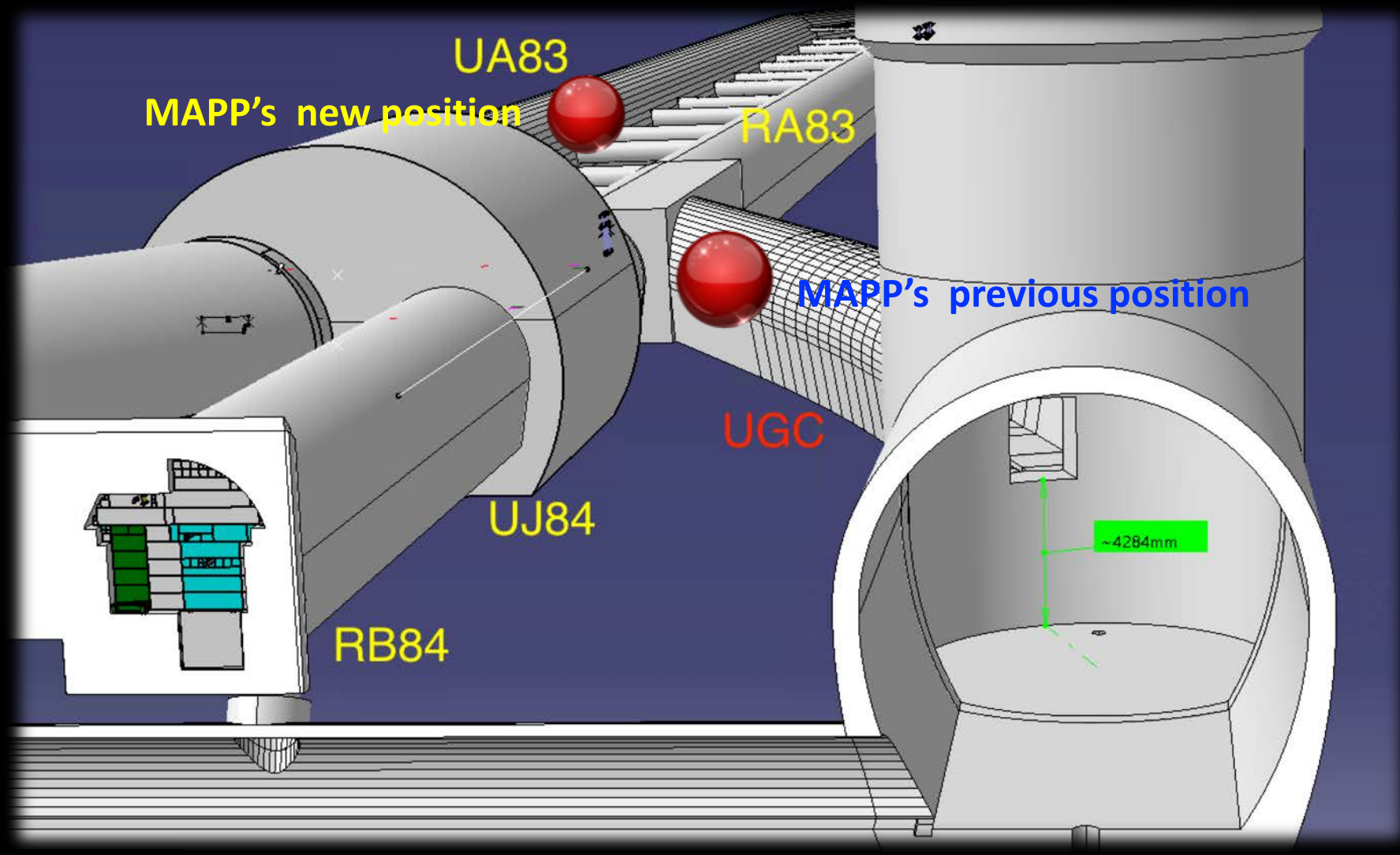


•*Eur.Phys.J.C* 80 (2020) 5, 431



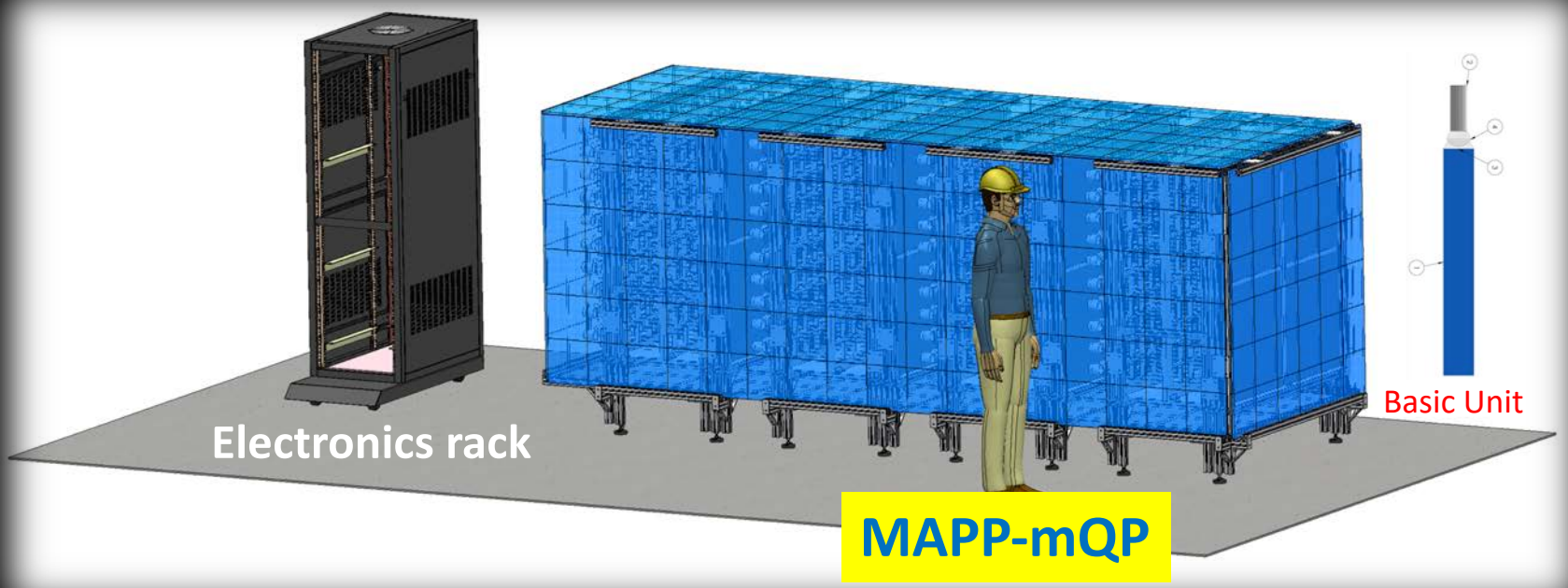
•*Eur.Phys.J.C* 80 (2020) 6, 572

MAPP – Status



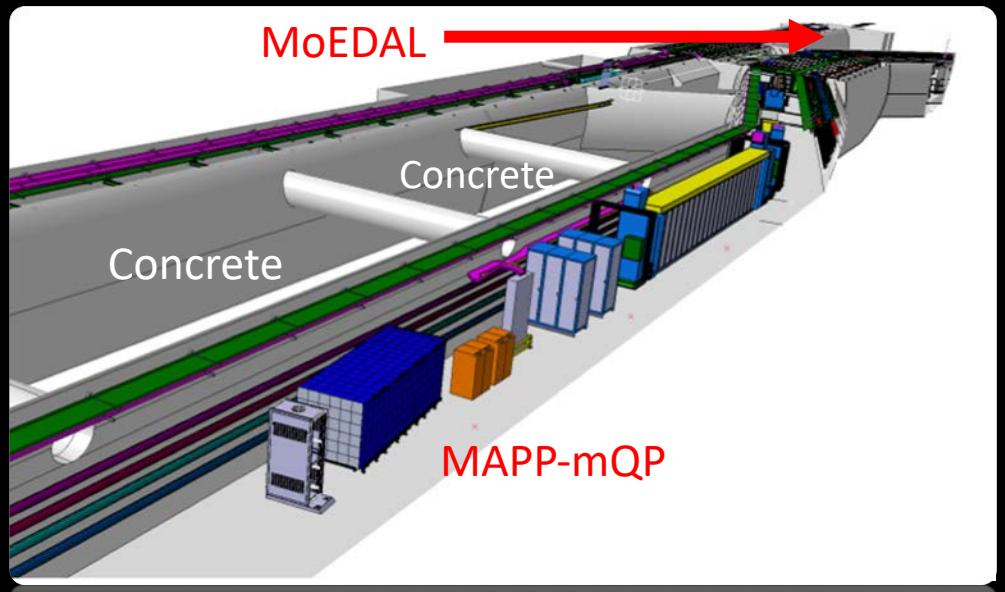
MAPP's New Home for Run-3

The MAPP-mQP in UA83



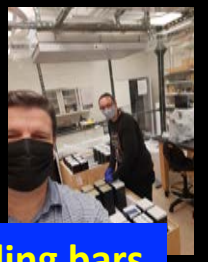
- *The MAPP-mQP detector will be deployed in UA83 for RUN-3.*
  - *It weighs 4-5 tonnes with size (veto layer) ~1.3 x 1.8 x 4.0 m^3*
  - *It is surrounded by a veto layer to help eliminate cosmic ray backgrounds.*
  - *Consists of 400 scint. bars (10x10x75 cm^3) in 4 sections readout by 400 PMTs*
  - *Uses FPGA-based software trigger, readout over the internet in standalone mode*
  - *Calibration using blue LEDs (in each bar) + neutral density filter absolute calibration*

The MAPP-mQP Disposition & Status



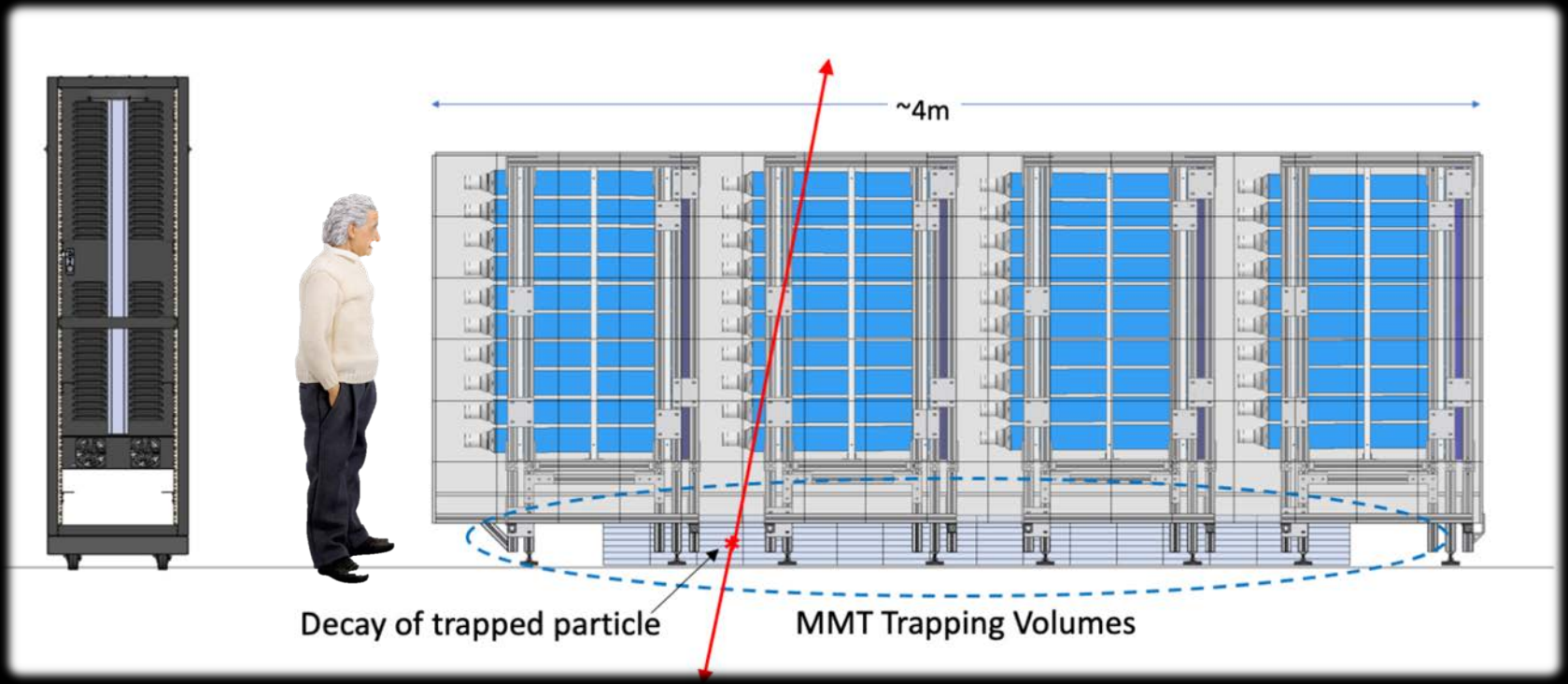

A Completed section


LED Calibration light


Assembling bars

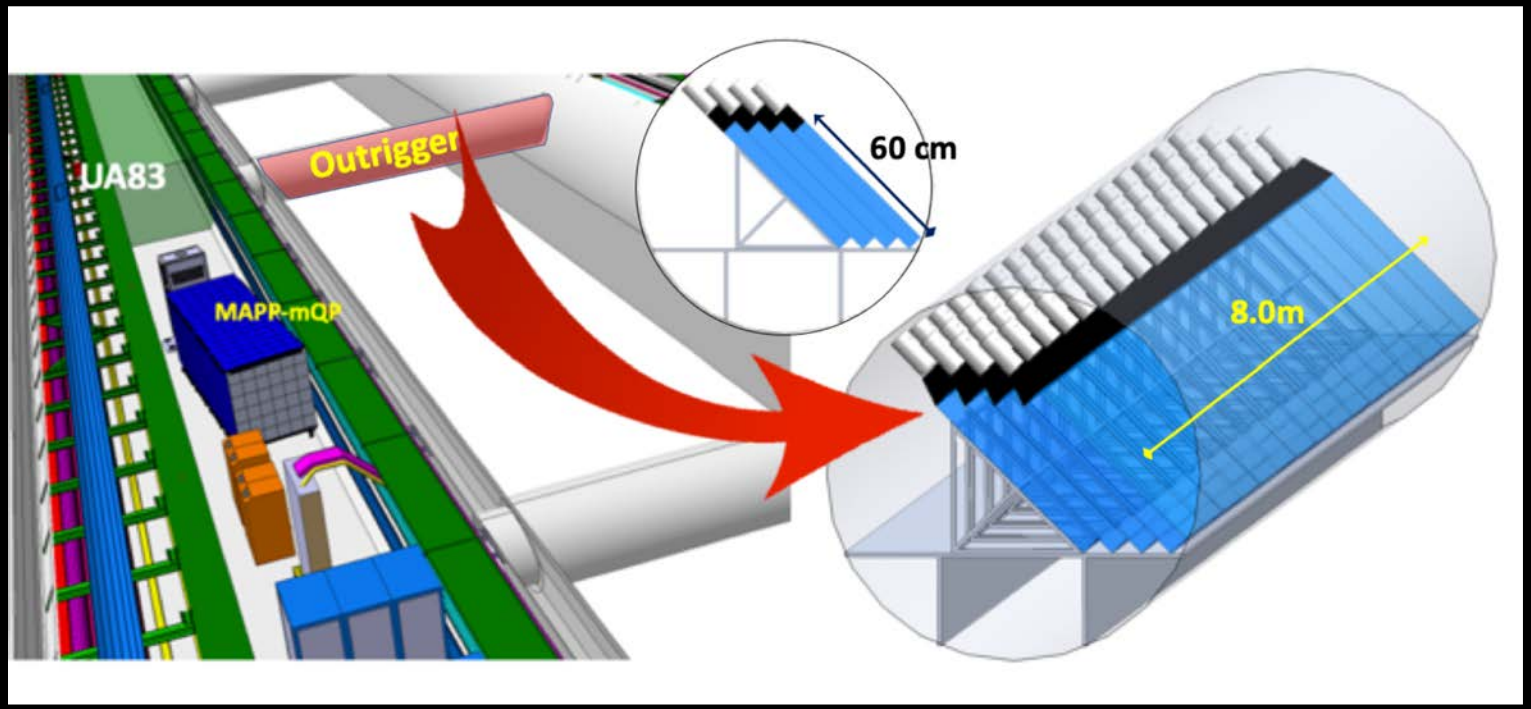
- *The MAPP-mQP detector is deployed 100m from IP8 at 6.5 deg. to the beam*
- *It is shielded by ~35 m of rock from SM backgrounds from the IP and protected from CR backgrounds by 110m rock overburden.*
- *The TP for the MoEDAL-mQP detector in UA83 has been submitted:*
  - *The Safety Derogation Request has been accepted*
  - *The Engineering Change Request for MAPP-mQP in UA83 has been accepted by the LHC Machine Committee (LMC)*
- *INSTALLATION IS PLANNED TO START IN DECEMBER 2021*

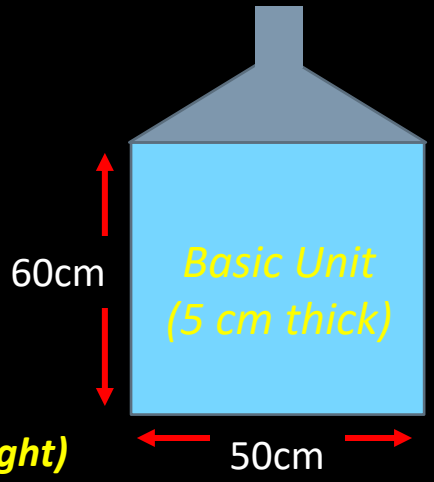
Searching for Extremely Long-Lived Charge Particles with MAPP-MQP



- *The MAPP-mQP can be used to monitor MoEDAL's exposed trapping detector for the decays of electrically charged trapped particles.*
  - *Exposed trapping volumes moved directly underground to UA83*
  - *Lifetimes longer than 10 years can be probed.*

The MAPP-MCP Outrigger



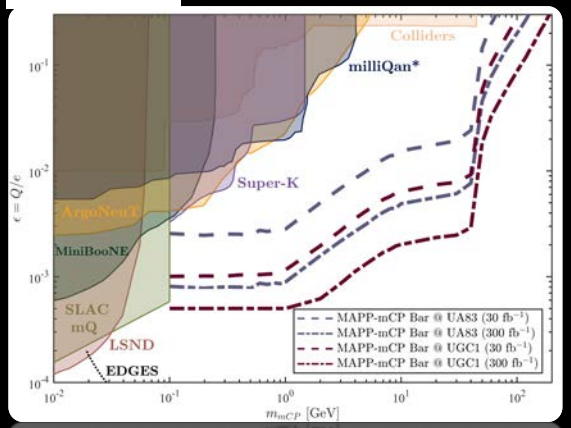


Delivery of EXO-200 donated scintillator in April 2019 (LEFT) & June 2021 (Right)

Physics Program – Examples

MoEDAL

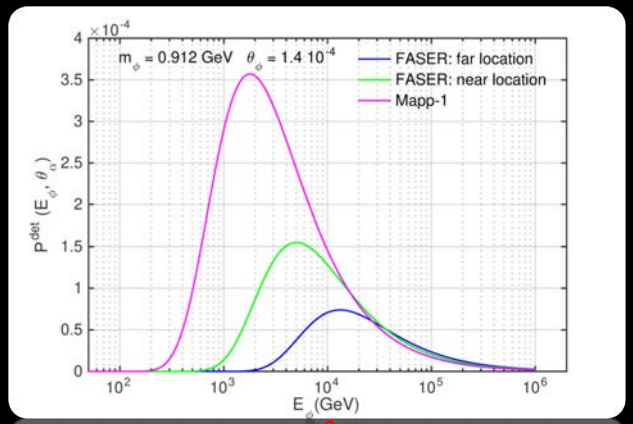
mQPs



Phys.Lett.B746,117 2015.

Run-3 sensitivity for the decay of a dark photon to mQP pairs (assume 100% efficient detector and no background)

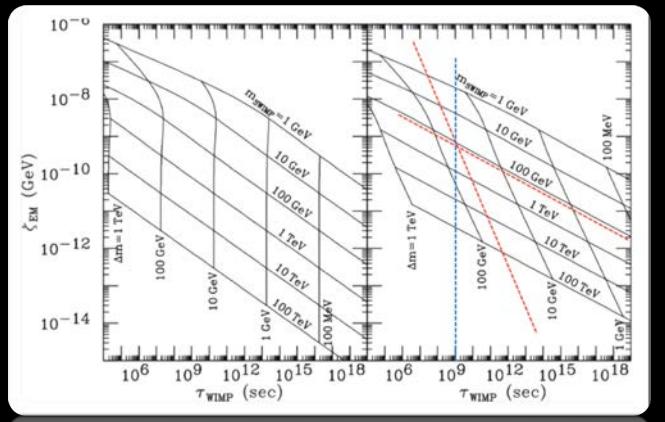
Neutral LLPs



arXiv:2110.09392v1 [hep-ph] 18 Oct 2021

The dependence on the dark Higgs energy of the normalised detection probability. The long-lived dark Higgs bosons are mainly produced through K and B meson decays.

Charged LLPs

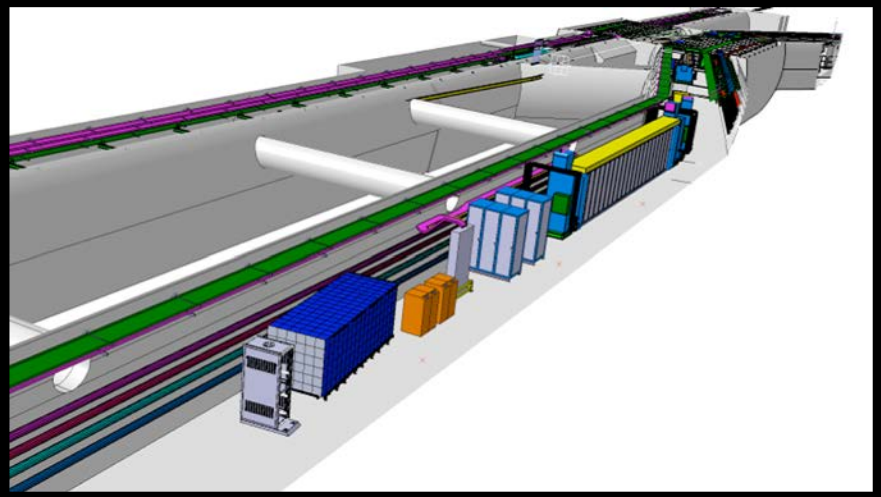


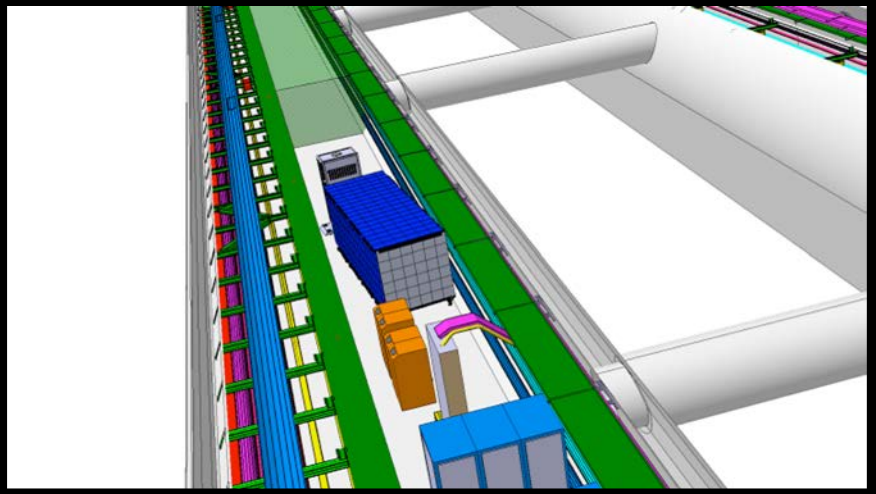
J. L. Feng, A. Rajaram Phys. Rev. D 68, 063504 (2003).

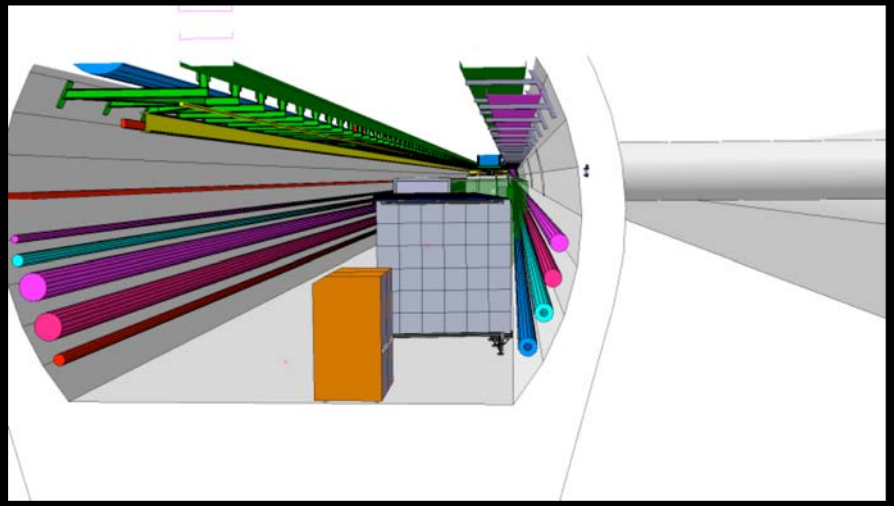
CDM made of super WIMPs, that inherit the desired relic density from late decays of metastable WIMPs. Predicted values of WIMP lifetime and EM energy release

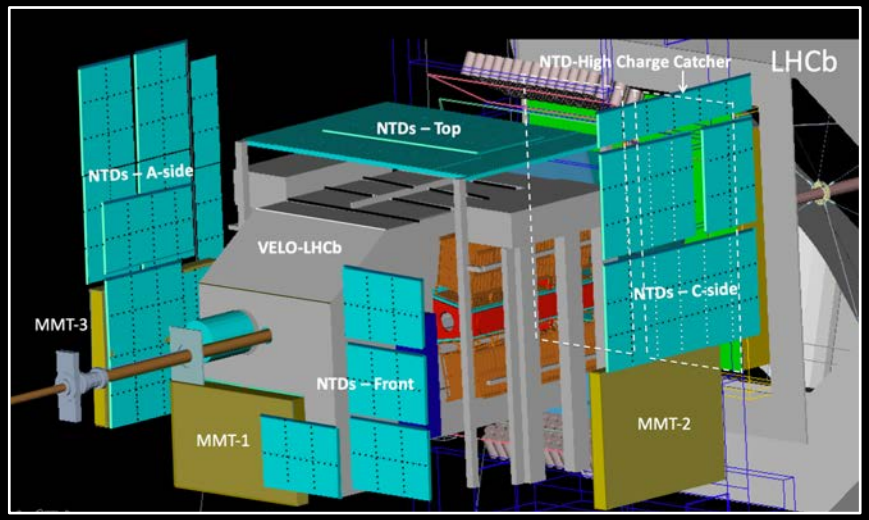
MALL REGION SIMULATION (MARS)

The MARS GEANT-4 simulation covers the whole MoEDAL-MAPP region and involves over 2500 elements. This will allow the full assessment of the sensitivity of the MAPP detector – ready soon

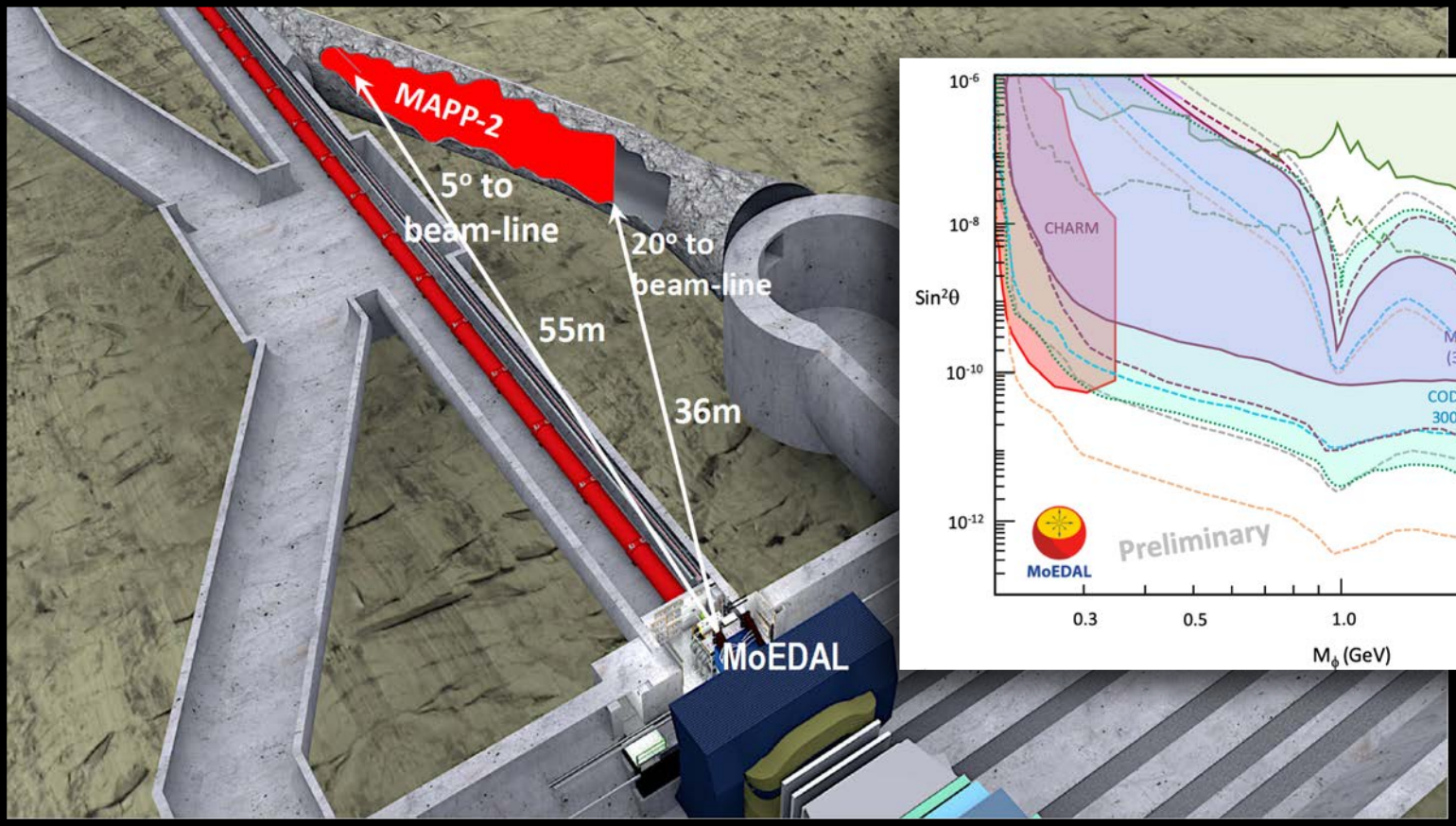








Phase-2: MAPP-2 for HL-LHC



- *MAPP-2 utilizes the renovated UGC1 gallery.*
- *The UGC1 Gallery would be updated for experiental use in LS3.*

Concluding Remarks

"The real voyage of discovery consists, not in seeking new landscapes, but in having new eyes." Marcel Proust

Dedicated search experiments such as MoEDAL-MAPP are the "new eyes" of the LHC