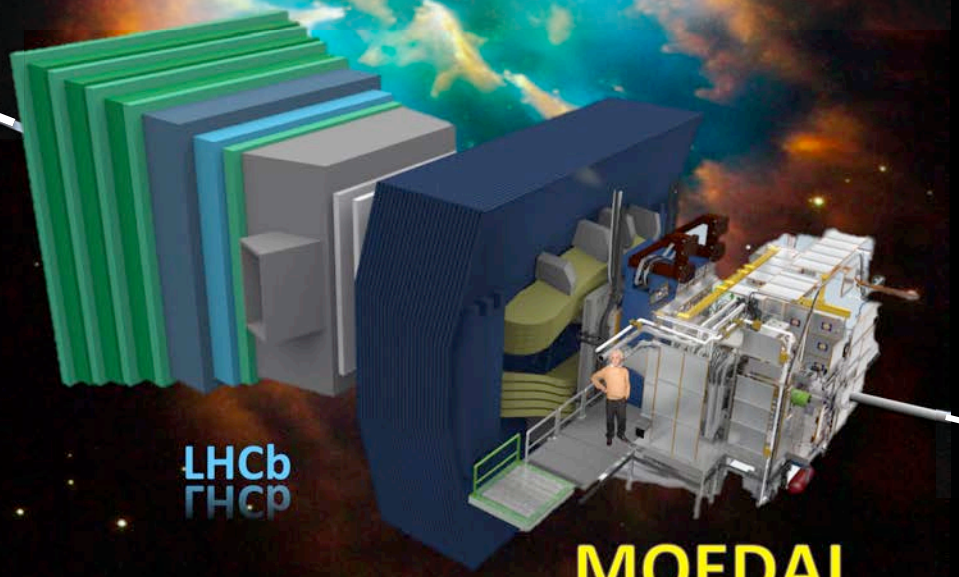
MoEDAL – Progress Report

James L. Pinfold (For the MoEDAL Collaboration)

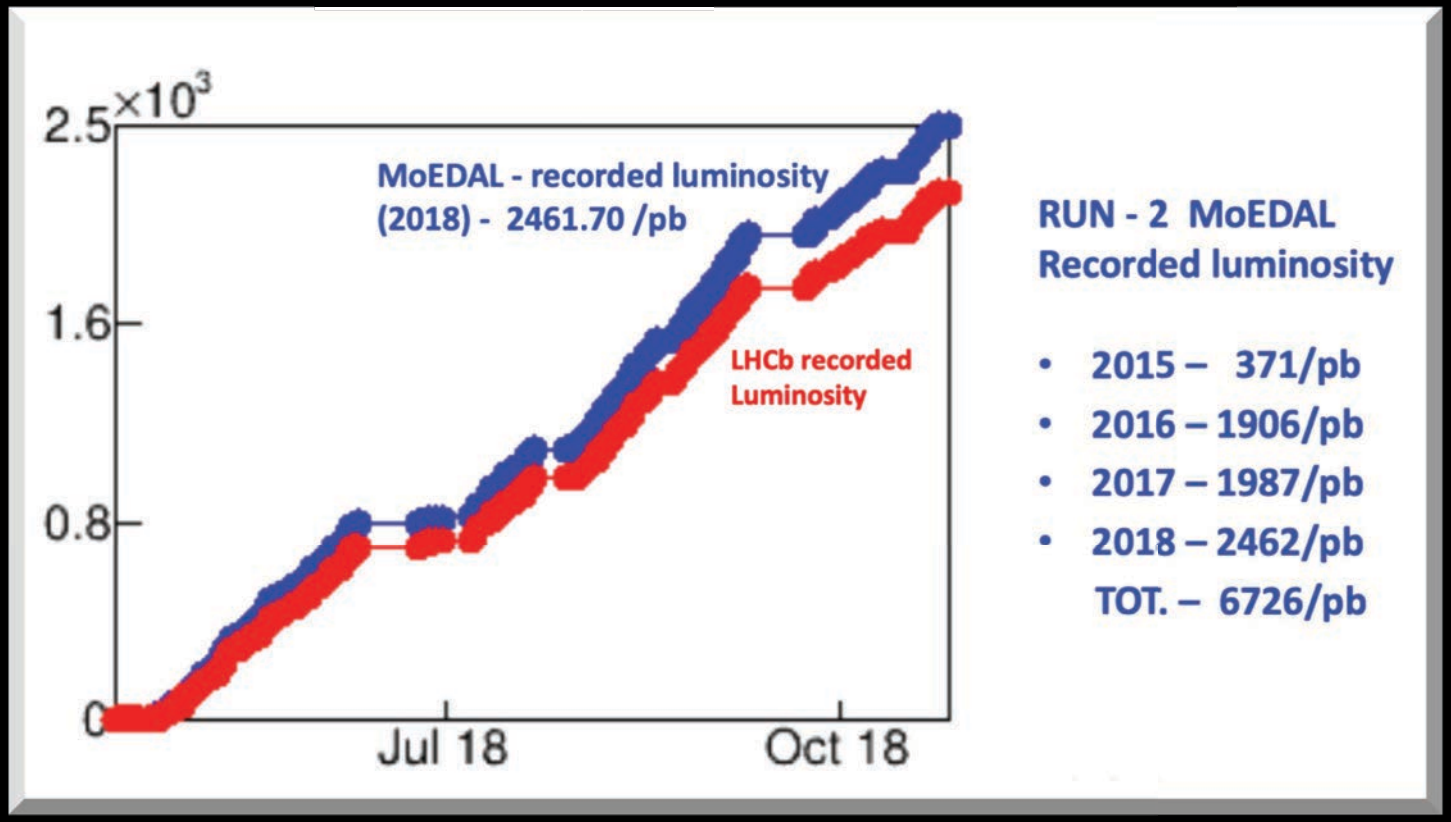
LHCC Open Session

February 2020 (Last Report November 2017)



MoEDAL

MoEDAL in Run 2



- *During RUN-2*
  - *The MoEDAL detector operated with 100% efficiency during RUN-2*
  - *MoEDAL collected a total of 6.73/fb of a requested 10 /fb*

The MoEDAL Collaboration

70 physicists from 13 countries & 30 institutes. on 4 continents:

U. Alberta,U. Alabama, UBC, INFN Bologna, U. Bologna, CAAG-Algeria, U. Cincinatti, Concordia U., CSIC Valencia, Gangneung-Wonju Nat. U., U. Geneva, U. Helsinki, IEAP/CTU Prague, IFIC Valencia, Imperial College London, ISS Bucharest, King's College London, Konkuk U., U. Montréal, MISiS Moscow, Muenster U., National Inst. Tec. (india),Northeastern U., IRIS UK, Tuft's, U. Vassa, Vassa U. App. Science, U.Umea.

The MoEDAL Collaboration

FOUR NEW GROUPS JOINED SINCE OUR LAST REPORT (Nov. 2017)

1) University of Vaasa (Finland)
2) Vaasa University of Applied Science
3) University of Umeå (Sweden)
4) National Institute of Technology (India)

70 p… …ntinents:

U. Albe… …CAAG-Algeria, U. Cincinatti, Concord… …Wonju Nat. U., U. Geneva, U. Helsinki, IEAP/CT… …Imperial College London, ISS Bucharest, King's College L… …Shkuk U., U. Montréal, MISiS Moscow, Muenster U., National Inst. Tec. (india),Northeastern U., IRIS UK, Tuft's, U. Vassa, Vassa U. App. Science, U.Umea.

MoEDAL Meetings Since Last Report

7th International Conference on New Physics 2018, Crete, "Workshop on highly Ionizing avatars of new physics

Hooke Meeting (Royal Society London), March 2019. Topological Avatars of New Physics

Collaboration Meetings

Dec. 2017

CERN

June 2018

Vaasa, Finland

Dec.2018

CERN

June 2019

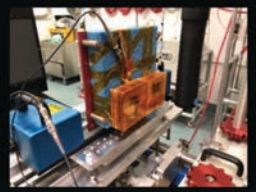
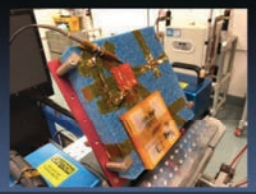
Prague

Dec.2019

CERN

NTD Calibration Campaigns in 2018

AT NSRL

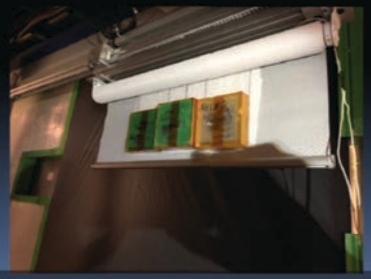




- BNL NASA Space Radiation Laboratory (NSRL)
- Performed run on Nov 22 2017 (with Igor Ostrovskiy)
- Four different ions used
  - O (z=8), Si (z=14), Fe (z=26) at 1000MeV/n
  - Kr (z=36) at 400 MeV/n
- Two additional angles used for Fe, one stack each at 15° and 30° from normal
- 12 stacks of plastic exposed
  - A mix of CR39 types used for O, Si and Fe
  - CR39 and makrofol exposed to Kr
- Stacks now in Bologna not yet etched

O, Si, Fe at 1GeV/N Kr at 0.4 GeV/N

AT NA61

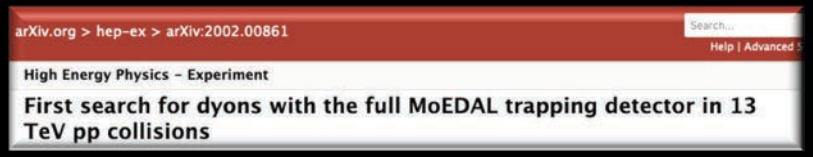
- Samples were irradiated at NA61
- 17 of 50 stacks of plastic exposed
- 150 GeV/n Pb beam
- Beam spot small so plastic remotely moved in x and y during the spill gate to expose the entire surface
- Assortment of CR39 and Makrofol
- Plastic at Bologna

150 GeV/N Pb beam

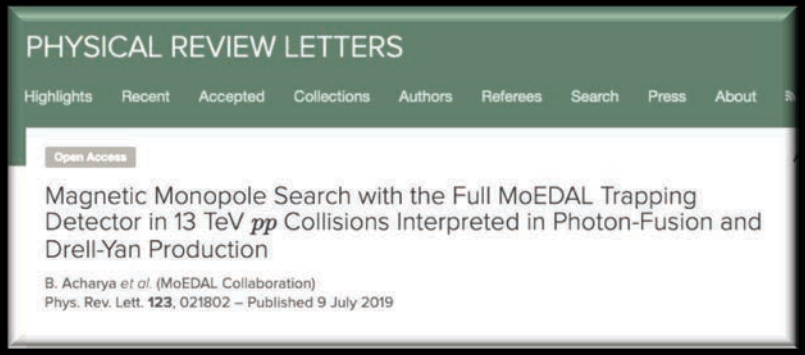
Data used to calibrate NTD plastic and also as training data for MoEDAL's Deep Machine Learning Group

MoEDAL Physics Papers Since Last Report

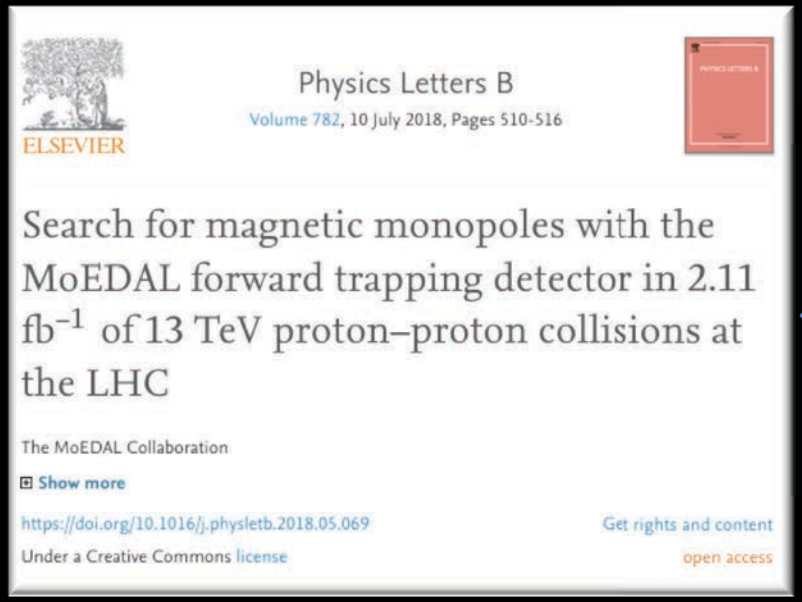


To be submitted to PRL

First ever search for dyons at an acc.

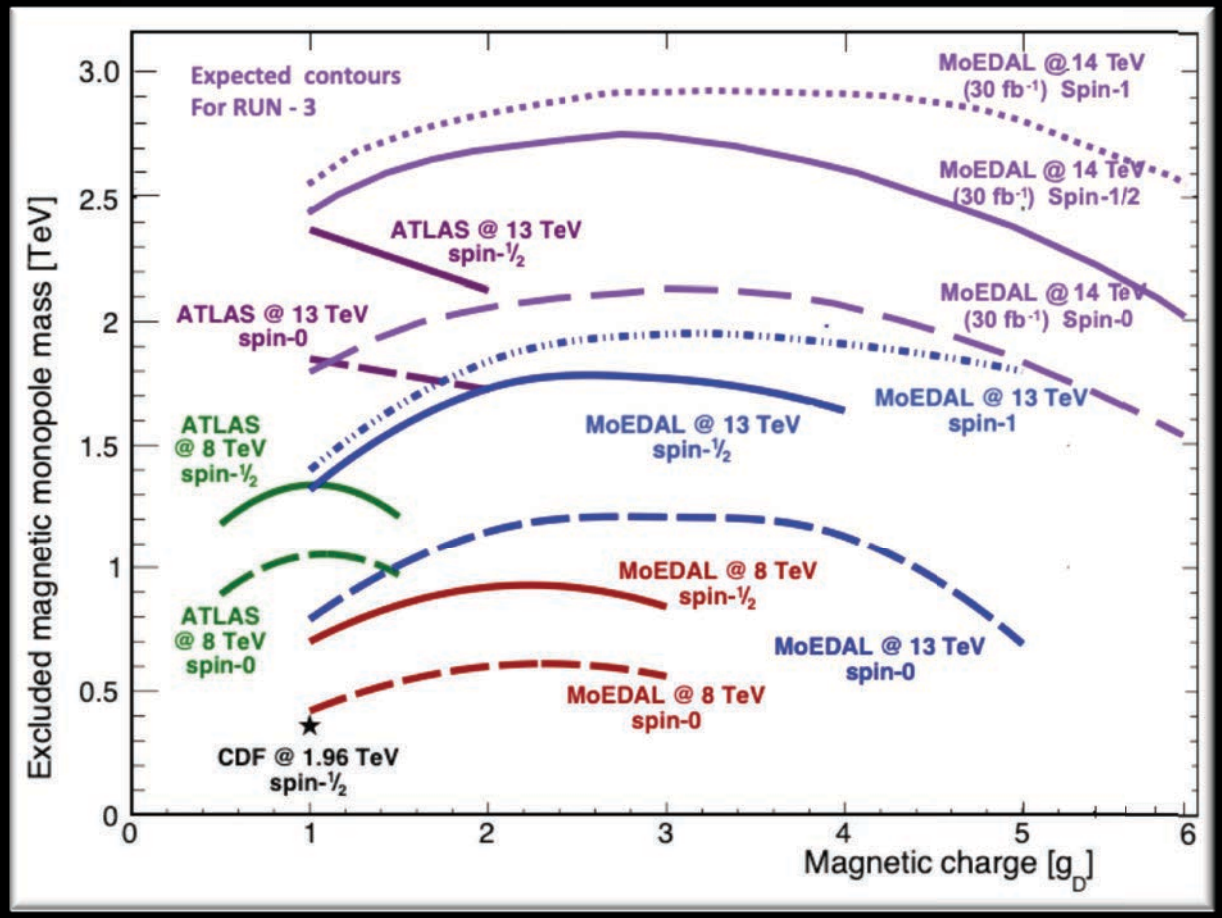


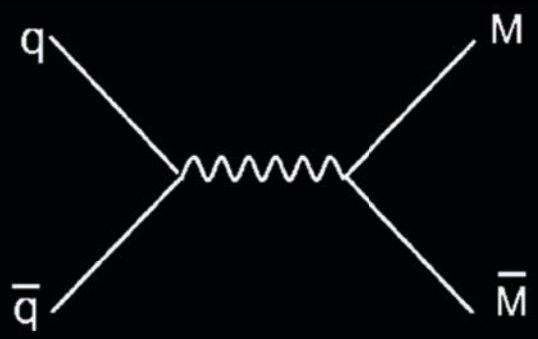
1st ever search for monopole production via γ- fusion at the LHC



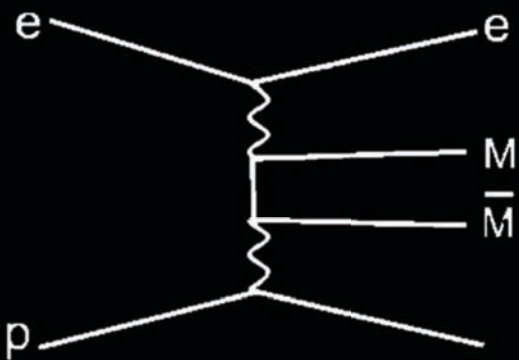
First ever limits on a spin-1 monopole

Summary of Run-2 Monopole Results





Drell Yan mechanism



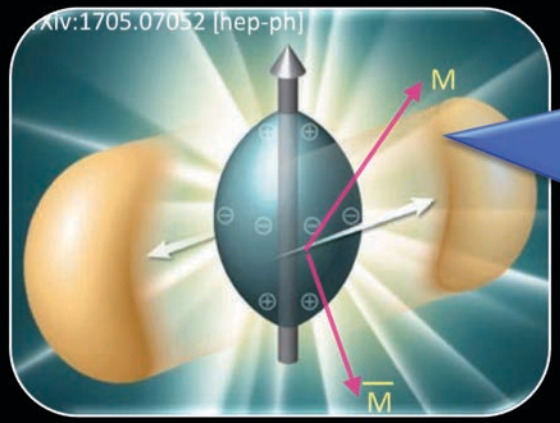
Photon fusion

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 direct on the direct search for magnetic charge (rather than its high ionizing signature)*

Other MoEDAL & Related Pubs Since Last Report

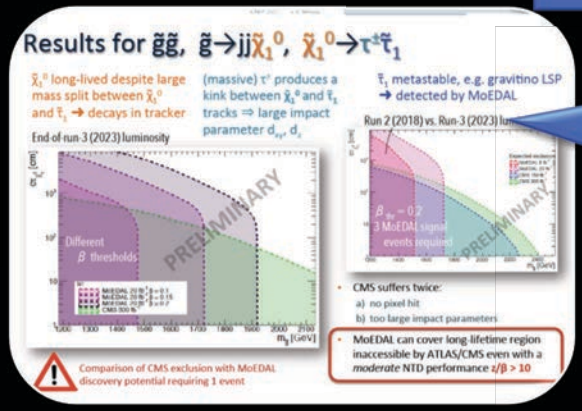
MoEDAL Results in the Pipeline



Search for Monopole Pair Production via the Schwinger Mechanism using HI Collisions at the LHC

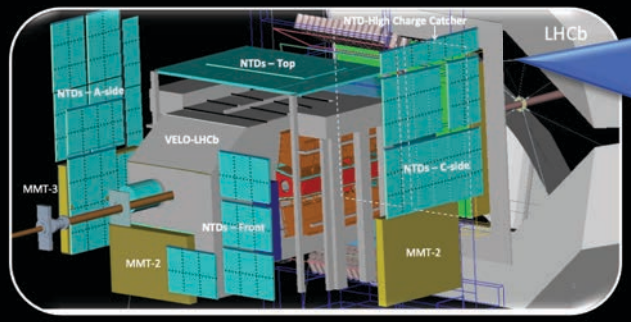
First use of the intense magnetic fields generated in heavy-ion collisions?

arXiv:1705.07052 [hep-ph]



Search for Long-lived Massive Charged Particles at the LHC

Explore SUSY scenarios where we are competitive with other LHC Expts?

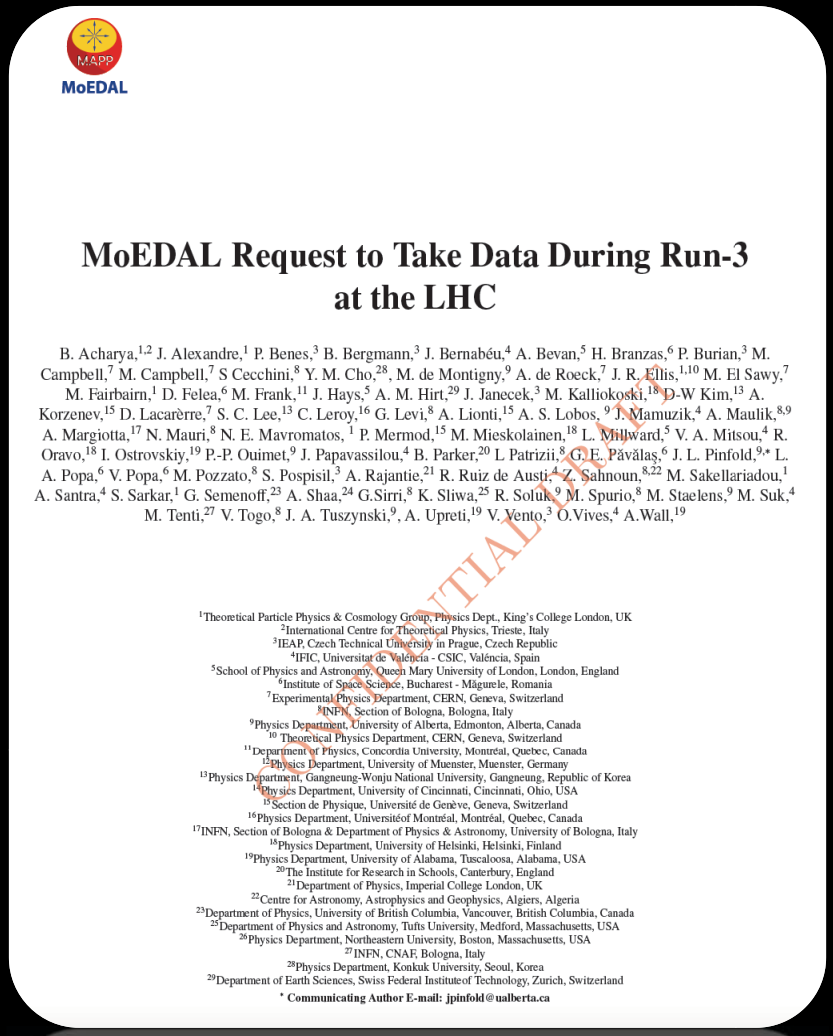


Search with Full MoEDAL Detector for Highly Ionizing Particles at 13 TeV

Use the full complement of MoEDAL trapping detectors and NTDs at Run-2

MoEDAL Request to Take Data at Run-3

- *Limited release Feb.13th 2020 and meant as a discussion document with LHCC, LHCb, etc.*
- *TDR in progress.*
- *Request ~30 fb^{-1} of lumi @Run-3*
  - *Continue to run baseline the MoEDAL detector at higher E_{cm} & luminosity (x 5 at IP8) - request to install for Run-3*
  - *Run-3 upgrade (a) - Deploy the MAPP (MoEDAL Apparatus for Penetrating Particles) detector in UGC1 - request for staged installation during Run-3*
  - *Run 3 upgrade (b) – Deploy the MALL (MoEDAL Apparatus for extremely Long Lived particles) detector in the UGC1 gallery- request installation after MAPP*



MoEDAL

MoEDAL Request to Take Data During Run-3 at the LHC

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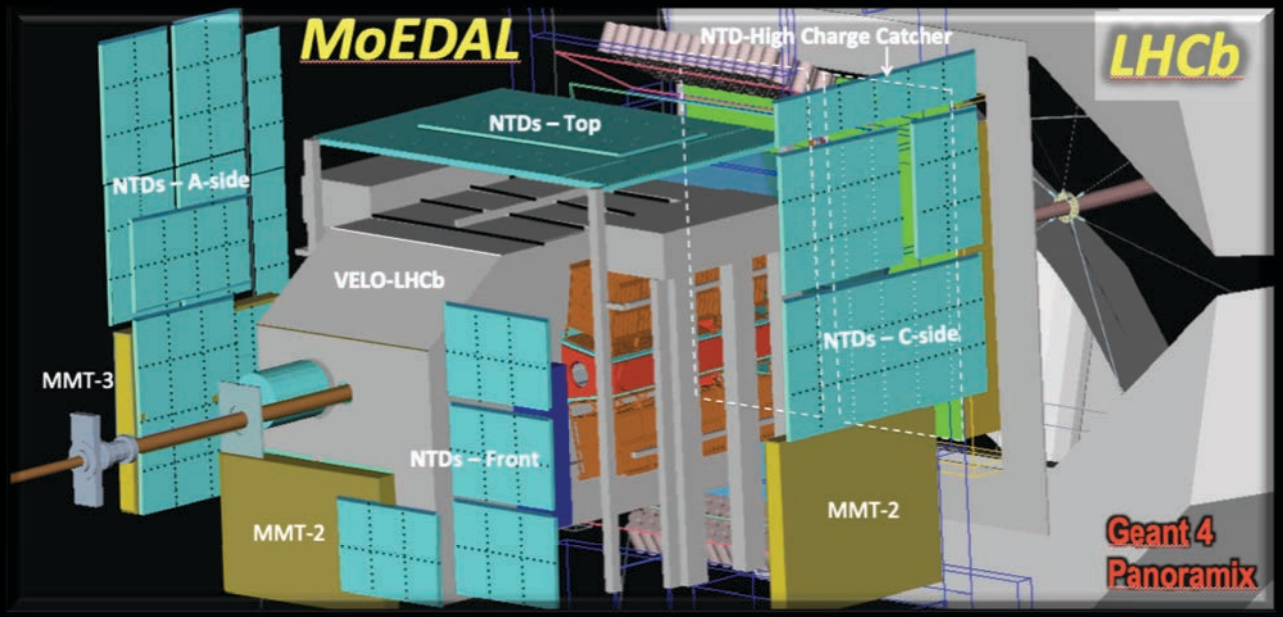
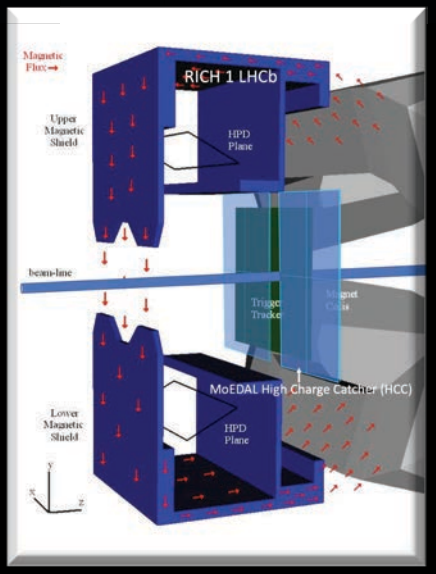
CONFIDENTIAL DRAFT

Redeploying the Baseline MoEDAL Detector

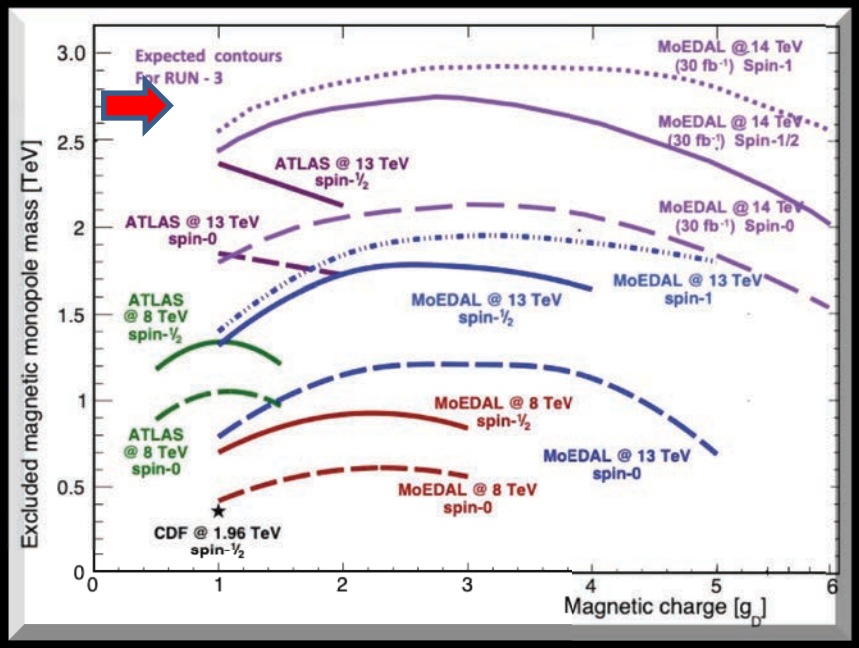


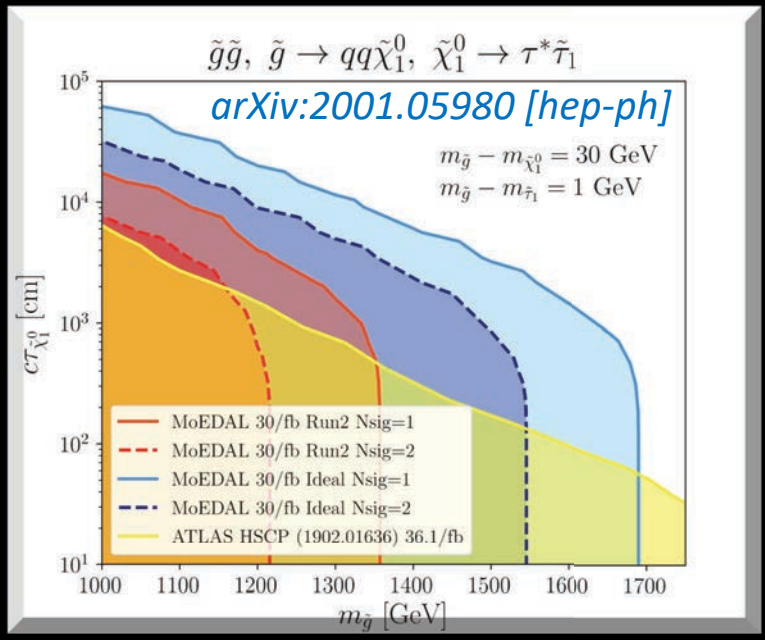


High Charge Catcher (HCC)

- *Continue with MoEDAL baseline detector & program to higher energy (E_{cm}=14 TeV) and luminosity (lumi – up by 5x at IP8)*
  - *Only minor changes to the detector planned*
  - *May need to redesign/relocate HCC to accommodate redesign of LHCb's TT (UT)*
- *Major improvements to our NTD system is on track for Run-3 , they are:*
  - *New large-bed computer controlled optical scanning microscopes*
  - *New deep learning SW developed by our Machine Learning group for automated scanning in the presence of large beam induced backgrounds*

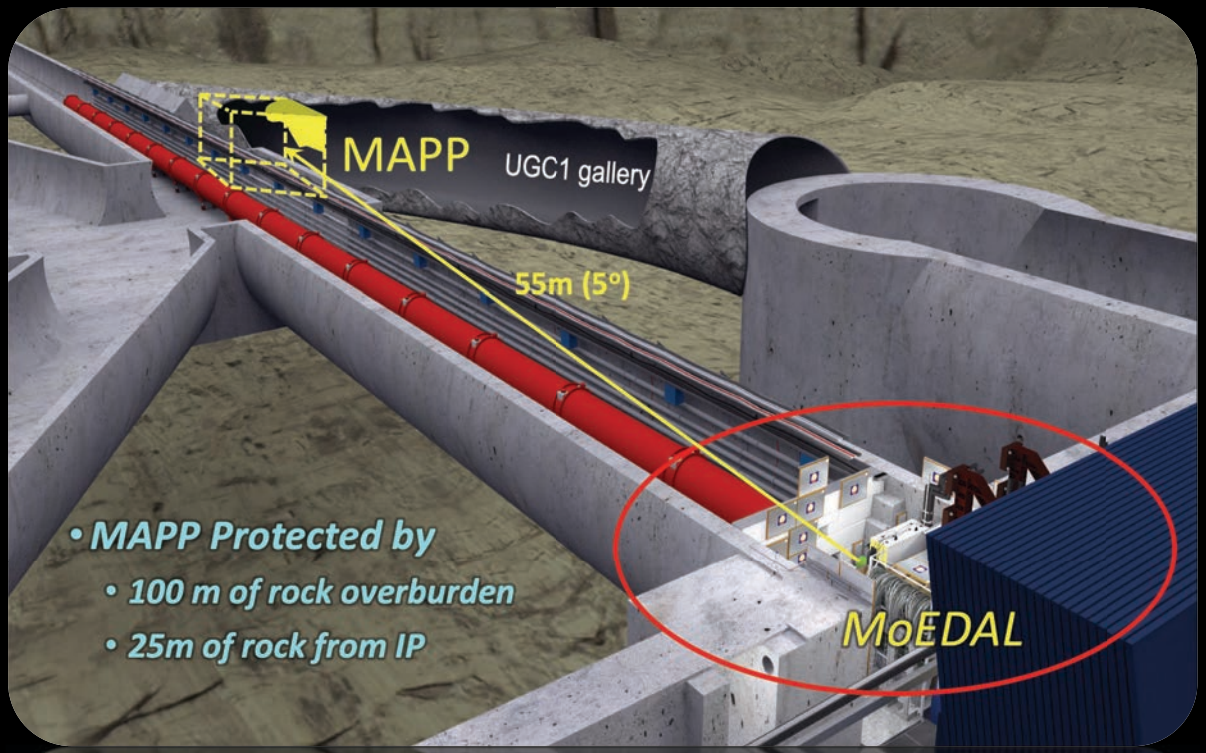
MoEDAL Detector at Run-3 – Physics aims

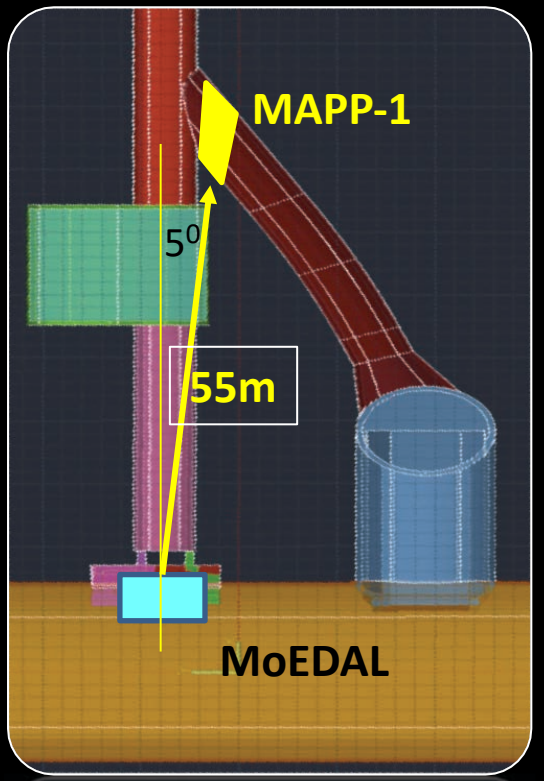




- *Pursue the hunt for magnetic charge using NTD & MMT detectors (see above left) to higher energy (14 TeV) and luminosity.*
- *Search for massive electrically charged objects with low threshold NTD detectors (CR39) from a number of new physics scenarios*
  - *EG complementary sensitivity to long-lived massive SUSY particles (see above right)*

MoEDAL's MAPP Upgrade for Run-3



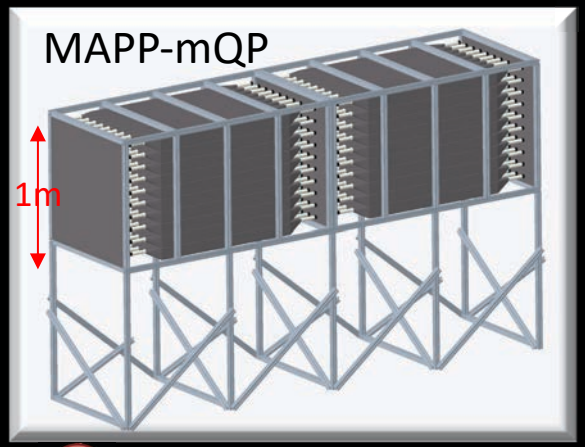


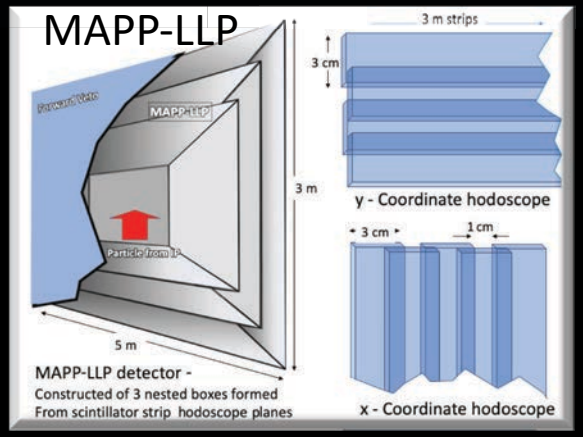
- *MAPP (to be installed for Run-3 of the LHC) has 2 motivations*
  - *To search for particles with charges <<1e (ATLAS & CMS limited to searches with particles of charge around e ≥ 1/3) with MAPP-mQP*
  - *To search for new weakly interacting neutrals with very long lifetime with MAPP-LLP.*

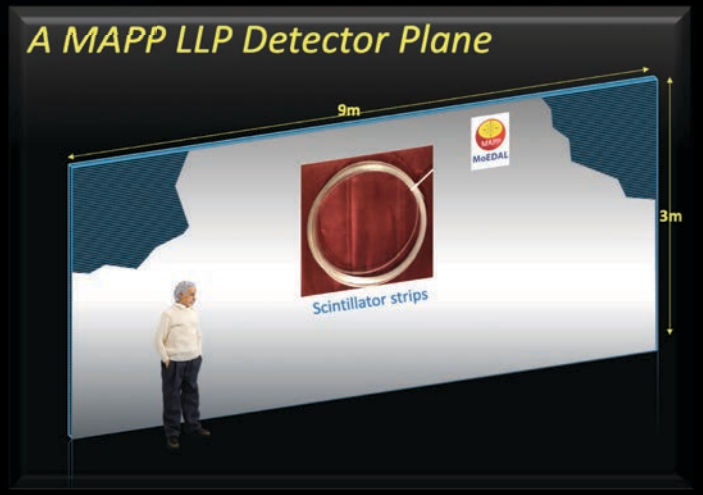
MAPP-mQP Detector Prototype

- *A small prototype of the MAPP-mQP detector deployed in Dec. 2017*
  - *It consists of 9 x (10cm x 10cm) scintillator bars of length 1.2m complete with readout system*
  - *Studies of this system informed the final design of the MAPP-mQP detector.*

MAPP- Detector

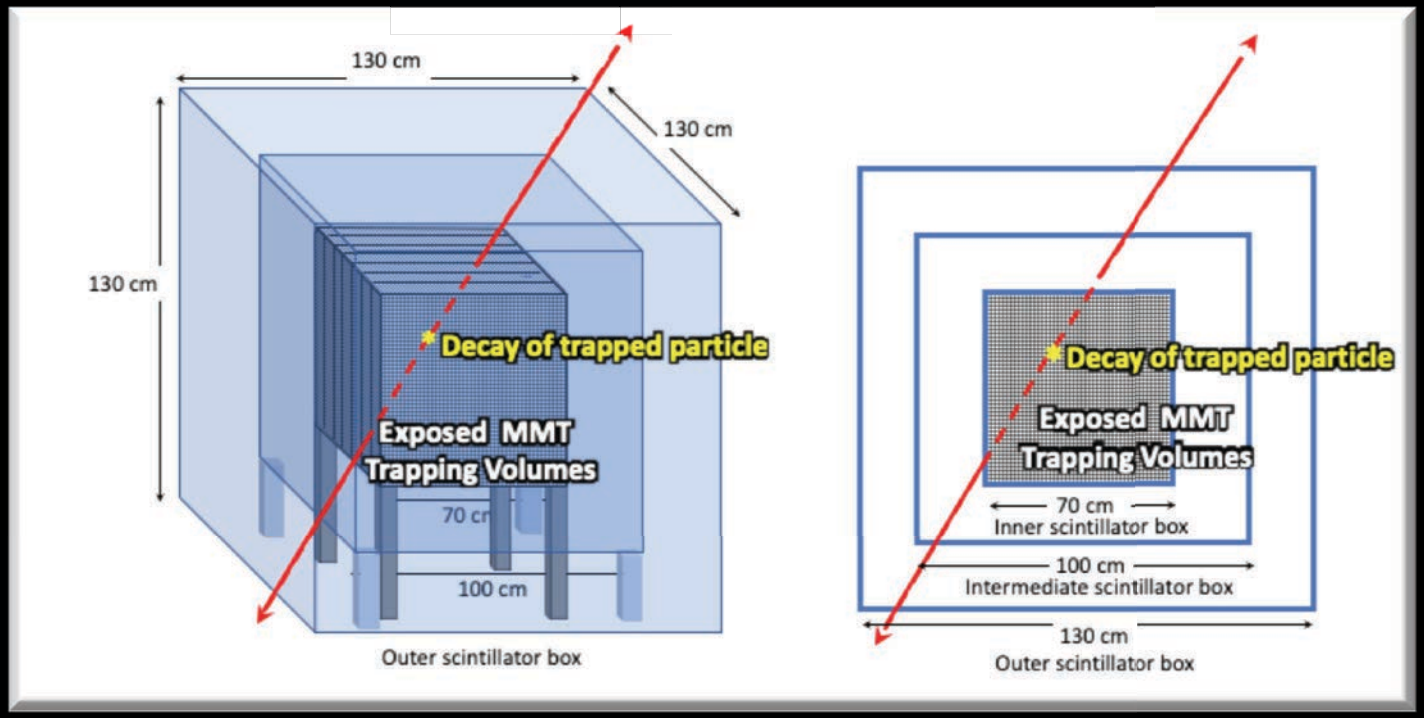






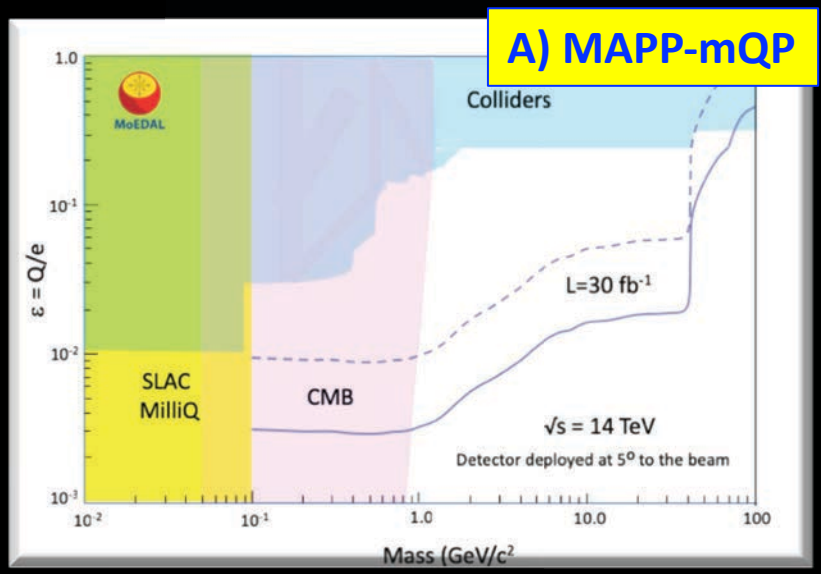
- *MAPP Detector:*
  - *Protected from cosmics by 100m of rock overburden + active veto system*
  - *Protected by 25-26m of rock/concrete (~65 Nuclear Interaction Lengths) + forward veto from SM particles from SM particles from IP8)*
- *MAPP-MQP Detector:*
  - *100 x (10cm x 10cm x 75cm) scintillator bars in 4 lengths, readout by 4 low noise 3.1" PMTs, in coincidence + hermetic veto detector system*
- *MAPP-LLP Detector*
  - *Fine grained scintillator hodoscope planes with 1cm X/Y resolution readout by SiPMs and picoTDC chips with timing resolution ~500 ps.*

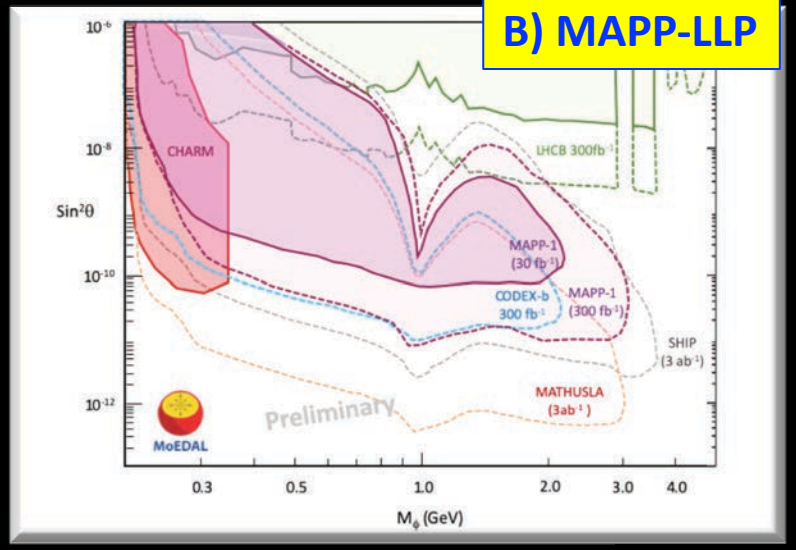
MALL- Detector



- *After exposure MoEDAL trapping volumes will be monitored in the UGC1 gallery, for the decays of trapped extremely long-lived particles using the MALL scintillator-based detector*
- *Lifetimes as long as ~10 years can be probed.*
  - *The planned detector has a low threshold (eg ~1 GeV muons) and is sensitive to electrons, muons, hadrons and photons.*

MAPP & MALL Physics Examples

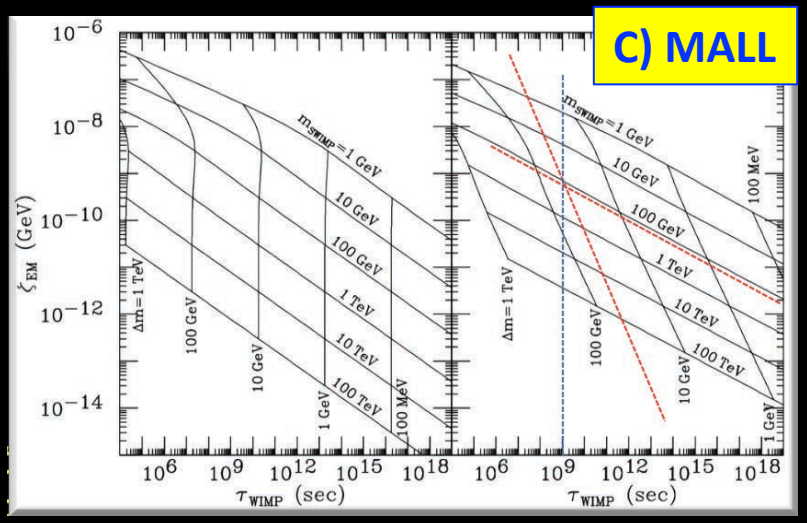




A. *DY production of mQPs in a Dark-EM scenario*

B. *Inclusive B → $X_s\phi$ decays, where φ is a light CP-even long-lived scalar (Higgs portal Dark Sector)*

C. *Superwimp model for CDM – Eg the lifetime of a 150 GeV stau →100 GeV gravitino is about 10^9 s*



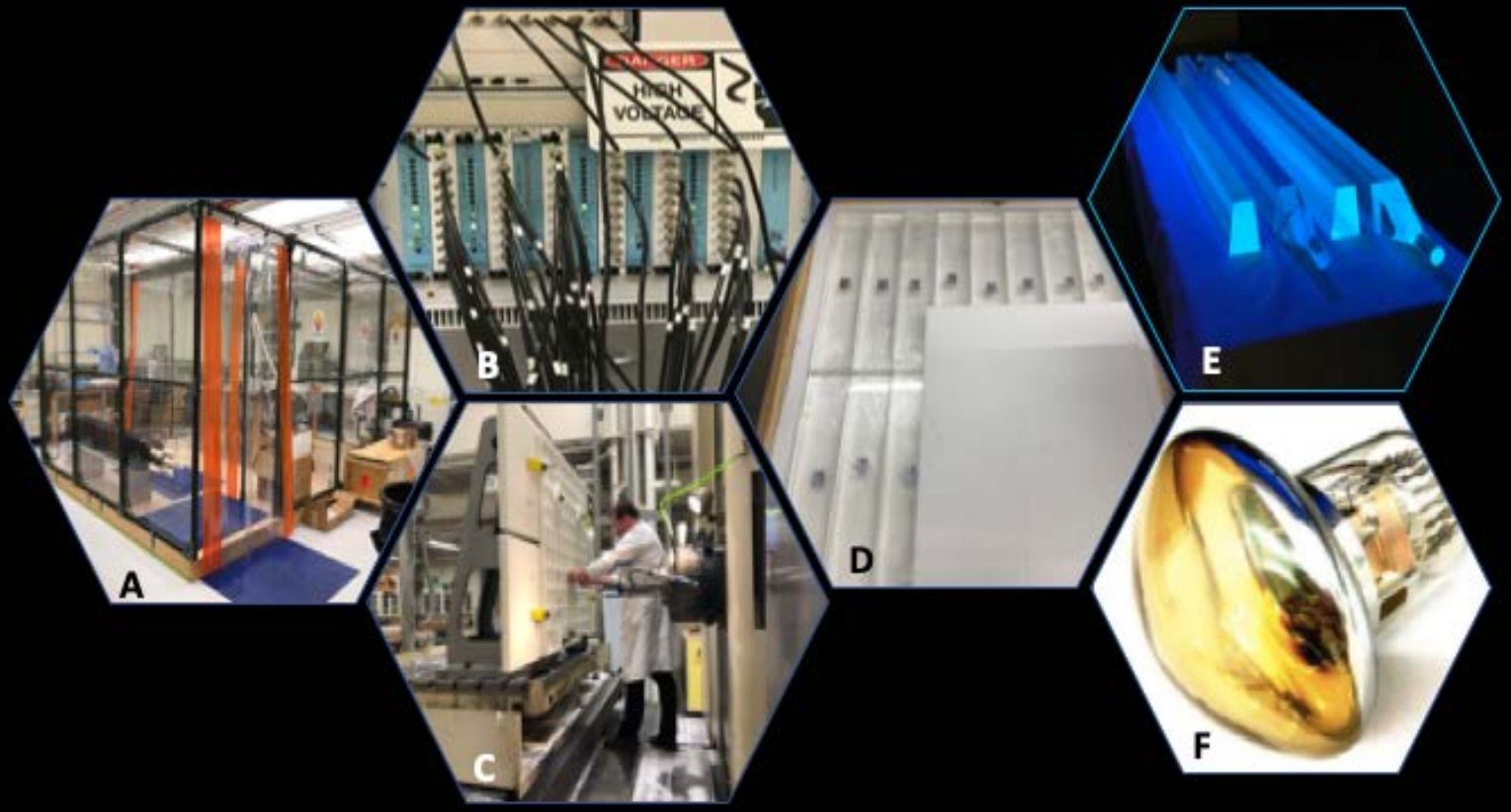
Summary

- *Analysis of Run-2 data still underway*
- *MoEDAL has an Exciting Run-3 Program planned that would significantly expand is physics reach.*
- *Program Planning Underway :*
  - *Redeploy MoEDAL Baseline Detector for Run-3*
  - *Install MAPP detector:*
    - *MAPP-mQP aiming to installed in Winter 2020/21 for Run-3*
    - *MAPP-LLP aiming to stage installation in first two years of Run-3*
  - *MAPP detector planned for installation after MAPP*
- *Discussion document issued: "MoEDAL Request to Take Data at Run-3".*
  - *Discussions with LHCb & LHC machine/safety to start forthwith*
- *TDR in preparation*

EXTRA SLIDES

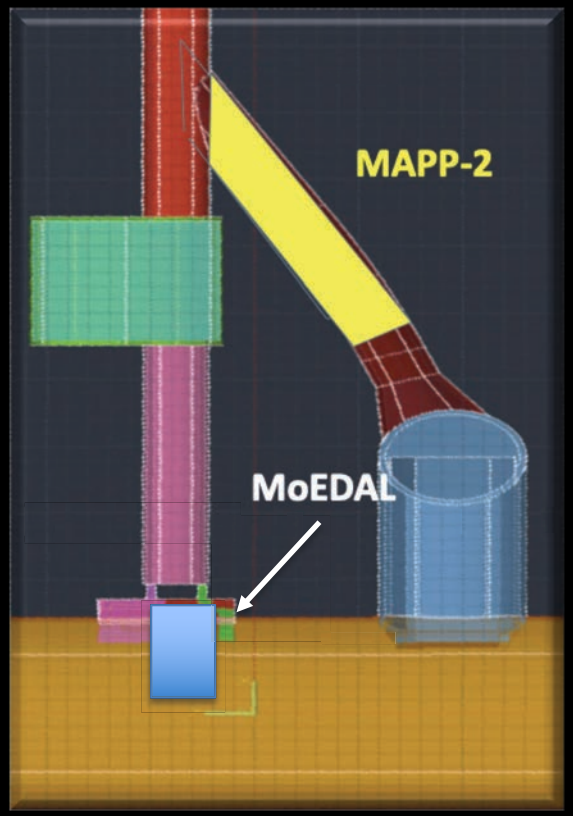
MAPP & MALL Installation Plans

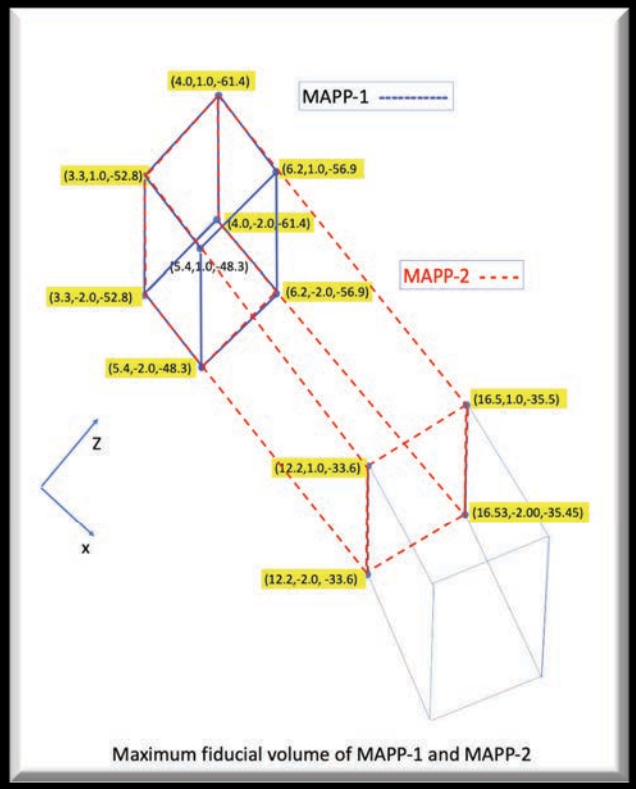
a) MAPP assembly room
b) MAPP electronics test
c) MAPP-mQP support structure being machined
d) MAPP-mQP sci. bars
e) MALL sci bars
f) PMTS for MAPP-mQP



- *The construction of the MAPP-mQP and forward veto wall is underway at the UofA.*
  - *We are looking at installation in the Fall->Winter of 2020/21.*
  - *The MAPP-LLP detector will be deployed in the Winter of 2021/22 and 22/23*

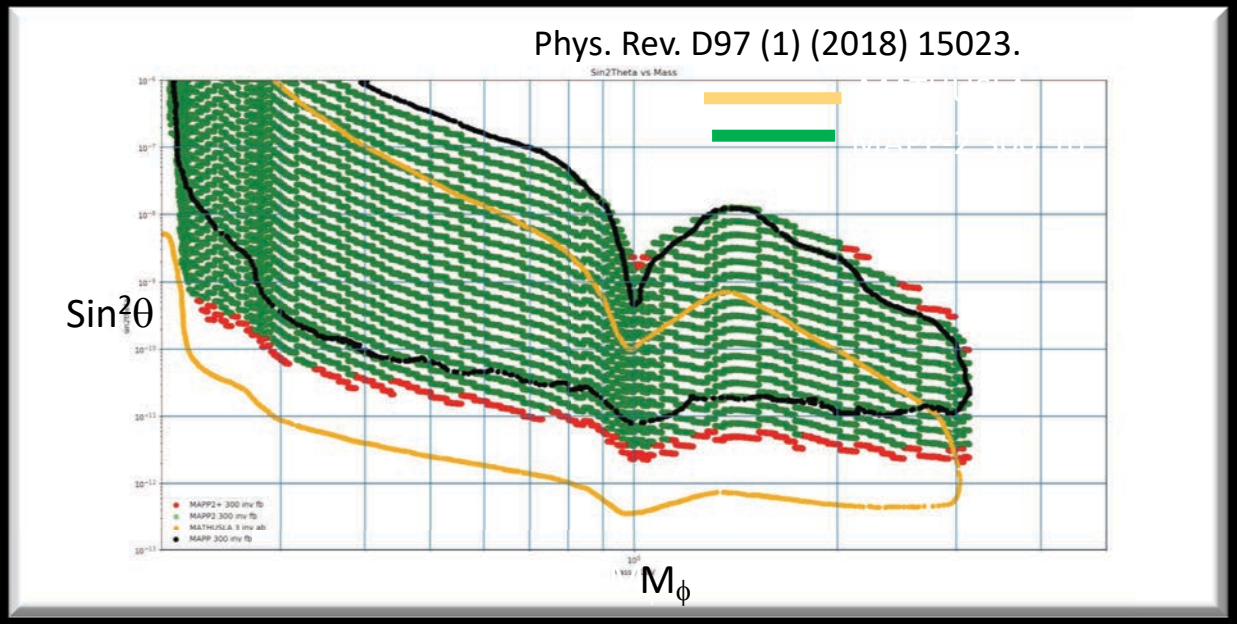
MAPP-2 – For Hi Lumi HLC (HL-LHC)

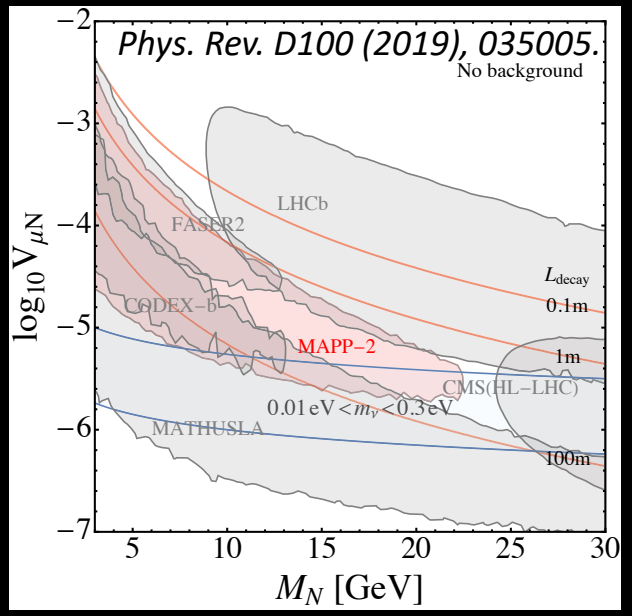




- *We are planning for the HL-LHC run (300 fb-1) to install the MAPP-2 detector.*
- *Here the existing MoEDAL-LLP detector is extended along the UGC1 gallery as shown above..*

MAPP-2 – Some Physics Examples





- *LEFT: Reach for 300 fb^{-1} for the scenario where the Higgs mixing portal admits inclusive B → $X_s\phi$ decays, where φ is a light CP-even scalar that mixes with the Higgs, with mixing angle $\vartheta \ll 1$.*
- *RIGHT: Pair production of RH neutrinos from the decay of an additional neutral Z^0 boson in the gauged B-L model – for HL-LHC (300fb^{-1})*