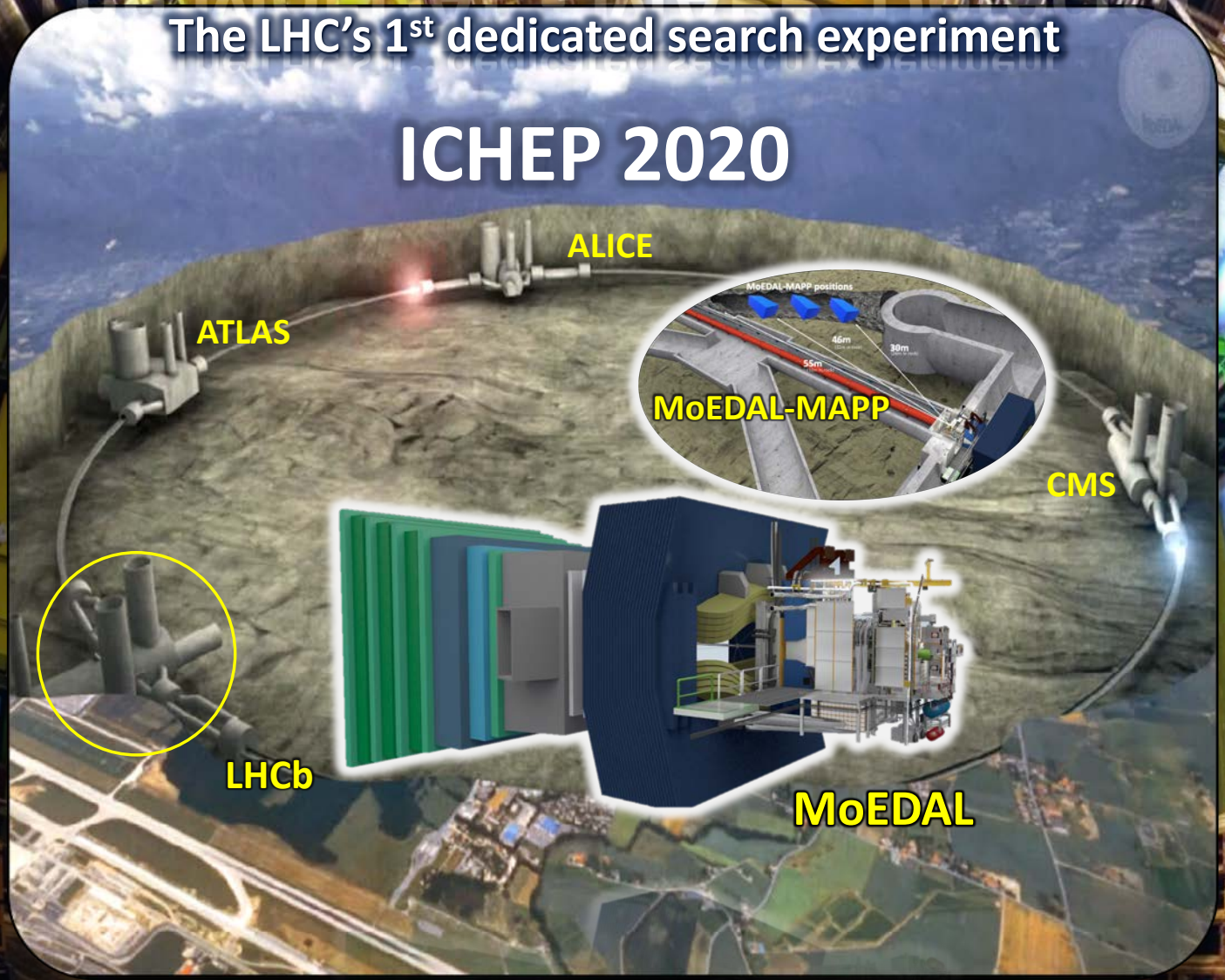
The MoEDAL - MAPP Detector

The LHC's 1st dedicated search experiment

ICHEP 2020



James L. Pinfold, University of Alberta
For the MoEDAL Collaboration

The MoEDAL Experiment

The LHC's First Dedicated Search Experiment

70 physicists – diverse group from 5 continents + India

CANADA-MoEDAL
4 inst. 6 fac. (FFTE 2.5)
4 grad students
1 postdoc

Spokesperson and Technical coordinator are Canadian

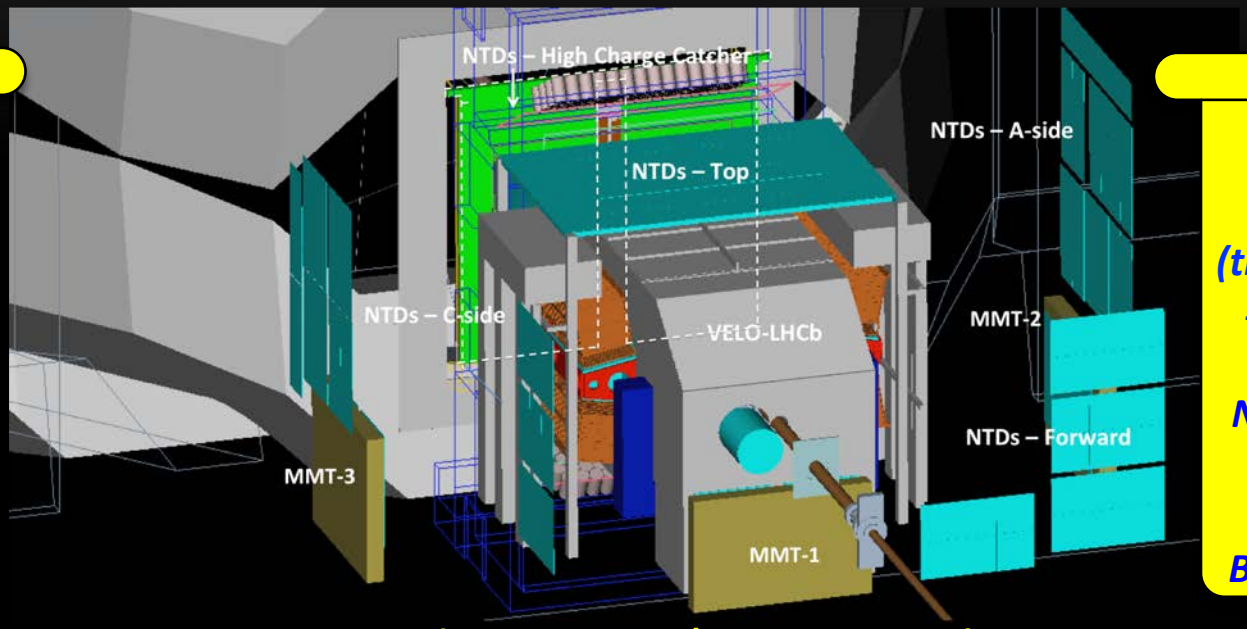
The MoEDAL Baseline Detector

Deployed for Run-2 (2015-2018) Ran with 100% efficiency taking 6.7 /fb

Canadian contribution: Design, installation and running of the detector, physics

Permanent physical record of new Physics

Able to directly detect magnetic charge



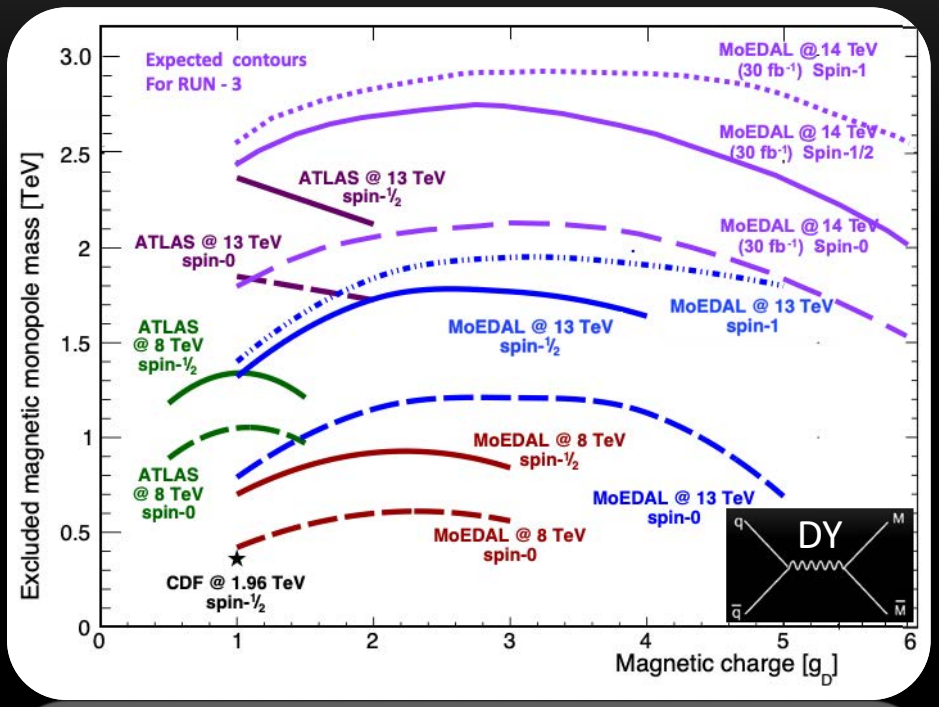
No trigger required (threshold $Z/\beta = v/c) \geqq .5$)

No Standard Model Physics Backgrounds

- *MMT - trapping detector: *1 tonne Al*
  - *Trap Highly Ionizing Particles (HIPs) for further study*
  - *Readout by MoEDAL SQUID facility at ETH Zurich*
- *NTD - Nuclear Track Detector system*
  - *320 stacks with 6 x (25 x 25 cm^2) MAKROFO/CR39 foils with*
  - *Readout by computer controlled optical rapid scanning microscopes devices at INFN Bologna and Helsinki University*

MoEDAL Physics Results from Run-2

Complementary to main LHC experiments

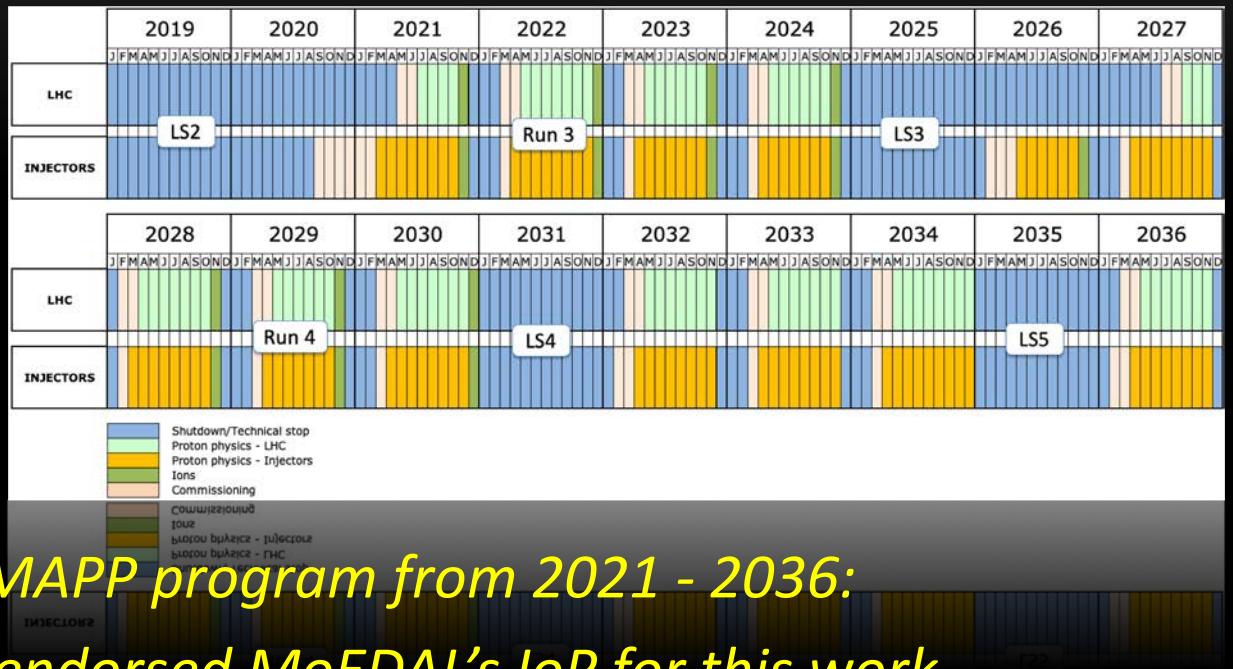


MoEDAL RUN-2 Papers In Progress

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

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

The MoEDAL-MAPP Plan for LHC's Run-3 and Beyond (2021-36)



- *MoEDAL-MAPP program from 2021 - 2036:*
- *LHCC has endorsed MoEDAL's IoP for this work*
  - *PHASE-1 (RUN-3 2021 –): The baseline MoEDAL detector will be reinstalled & the core MAPP (Moedal Apparatus for Penetrating Particles) mini-charged particle (mQP) detector will be installed (fully funded TDR in progress)*
  - *PHASE-2 (RUN3 2022 -) MAPP-1 Long-Lived Particle (LLP) detector, to be installed along with the MALL (MoEDAL Apparatus for extremely Long-Lived charged particles)*
  - *PHASE-3 (RUN4 2025 -) MAPP-2 Extended Long-Lived Particle (LLP) detector, will be installed for HL-LHC running*

MoEDAL LoI and TDR

Considered by LHCC in Feb. 2020

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

B. Acharya,[1,2] J. Alexandre,[1] P. Benes,[3] B. Bergmann,[3] J. Bernabéu,[4] A. Bevan,[5] H. Branzas,[6] P. Burian,[3] M. Campbell,[7] M. Campbell,[7] S Cecchini,[8] Y. M. Cho,[28], 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,[5] A. M. Hirt,[29] J. Janecek,[3] M. Kalliokoski,[18] D-W Kim,[13] A. Korzenev,[15] D. Lacarèrre,[7] S. C. Lee,[13] C. Leroy,[16] G. Levi,[8] A. Lionti,[15] A. S. Lobos, [9] J. Mamuzik,[4] A. Maulik,[8,9] A. Margiotta,[17] N. Mauri,[8] N. E. Mavromatos, [1] P. Mermod,[15] M. Mieskolainen,[18] L. Millward,[5] V. A. Mitsou,[4] R. Oravo,[18] I. Ostrovskiy,[19] P.-P. Ouimet,[9] J. Papavassilou,[4] B. Parker,[20] L Patrizii,[8] G. E. Păvălaș,[6] J. L. Pinfold,[9,*] L. A. Popa,[6] V. Popa,[6] M. Pozzato,[8] S. Pospisil,[3] A. Rajantie,[21] R. Ruiz de Austi,[4] Z. Sahnoun,[8,22] M. Sakellariadou,[1] A. Santra,[4] S. Sarkar,[1] G. Semenoff,[23] A. Shaa,[24] G.Sirri,[8] K. Sliwa,[25] R. Soluk,[9] M. Spurio,[8] M. Staelens,[9] M. Suk,[4] M. Tenti,[27] V. Togo,[8] J. A. Tuszynski,[9], A. Upreti,[19] V. Vento,[3] O.Vives,[4] A.Wall,[19]

Taken from LHCC minutes of the meeting

- The LHCC congratulates MoEDAL for the publication of several papers, documenting the search results for various exotic particles.
- The LHCC acknowledges the MoEDAL collaboration's experience with the baseline detector during Run 2, and finds the request to continue data taking in Run 3 justified
- The LHCC endorses the physics goals of the new detectors and the experimental approach, which complement well the existing LHC physics programme

TDR Phase-1 Submitted in June 2020

MoEDAL -MAPP Phase-1 Technical Design Report

Version 1.1

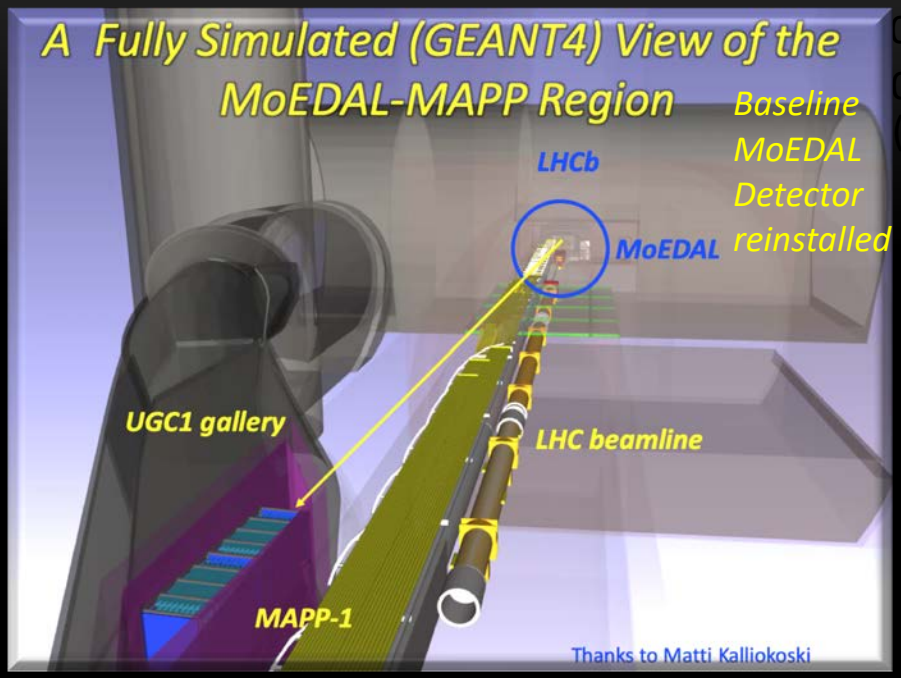
B. Acharya,[1,2] J. Alexandre,[1] P. Benes,[3] B. Bergmann,[3] J. Bernabéu,[4] A. Bevan,[5] H. Branzas,[6] P. Burian,[3] M. Campbell,[7] M. Campbell,[7] S Cecchini,[8] Y. M. Cho,[28], M. de Montigny,[9] A. de Roeck,[7] J. R. Ellis,[1,10] M. El Sawy,[7] M. Fairbairn,[1] D. Felea,[6] M. Frank,[11] J. Hays,[5] A. M. Hirt,[29] J. Janecek,[3] M. Kalliokoski,[18] D-W Kim,[13] A. Korzenev,[15] D. Lacarèrre,[7] S. C. Lee,[13] C. Leroy,[16] G. Levi,[8] A. Lionti,[15] A. S. Lobos, [9] J. Mamuzik,[4] A. Maulik,[8,9] A. Margiotta,[17] N. Mauri,[8] N. E. Mavromatos, [1] P. Mermod,[15] M. Mieskolainen,[18] L. Millward,[5] V. A. Mitsou,[4] R. Oravo,[18] I. Ostrovskiy,[19] P.-P. Ouimet,[9] J. Papavassilou,[4] B. Parker,[20] L Patrizii,[8] G. E. Păvălaș,[6] J. L. Pinfold,[9,*] L. A. Popa,[6] V. Popa,[6] M. Pozzato,[8] S. Pospisil,[3] A. Rajantie,[21] R. Ruiz de Austi,[4] Z. Sahnoun,[8,22] M. Sakellariadou,[1] A. Santra,[4] S. Sarkar,[1] G. Semenoff,[23] A. Shaa,[24] G.Sirri,[8] K. Sliwa,[25] R. Soluk,[9] M. Spurio,[8] M. Staelens,[9] M. Suk,[4] M. Tenti,[27] V. Togo,[8] J. A. Tuszynski,[9], A. Upreti,[19] V. Vento,[3] O.Vives,[4] A.Wall,[19]

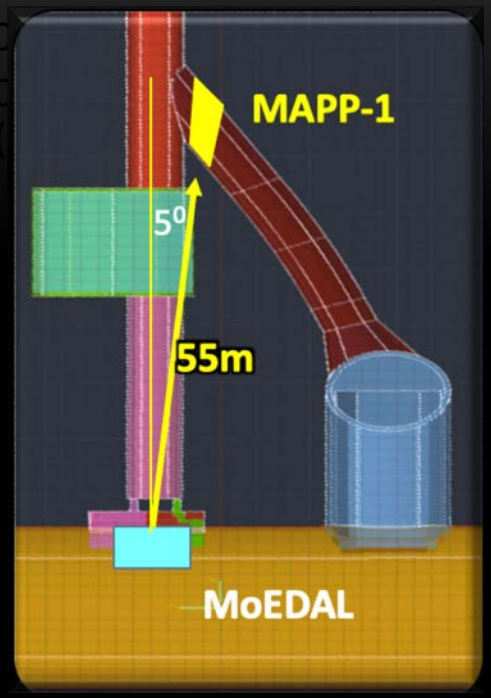
Minutes of LHCC meeting

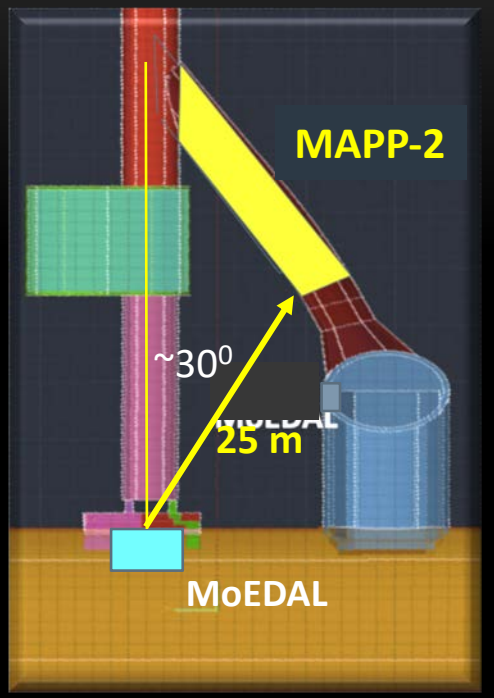
- The LHCC congratulates MoEDAL for the progress in the construction of the MAPP-mQP detector, and for securing the required financial support
- The LHCC encourages the MoEDAL and LHCb collaborations to continue they discussions, to complete the definition of the pending items in the design and planning of the MoEDAL projects. The MoEDAL experiment should also continue its interaction with CERN's safety and technical groups, to clear the path for the approval of the project.

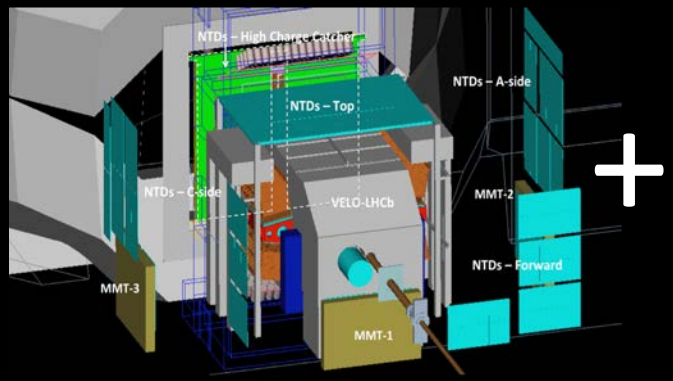
The MoEDAL-MAPP Detector

Canadian contribution: Design, installation and running of the detector, physics









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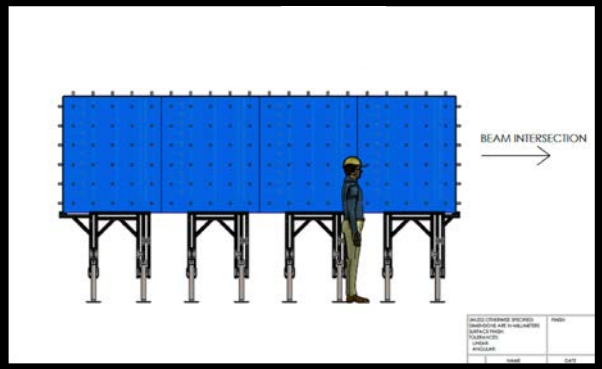

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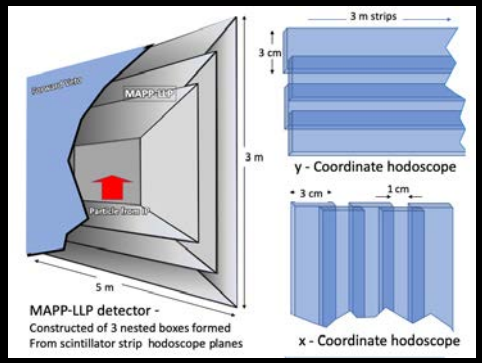
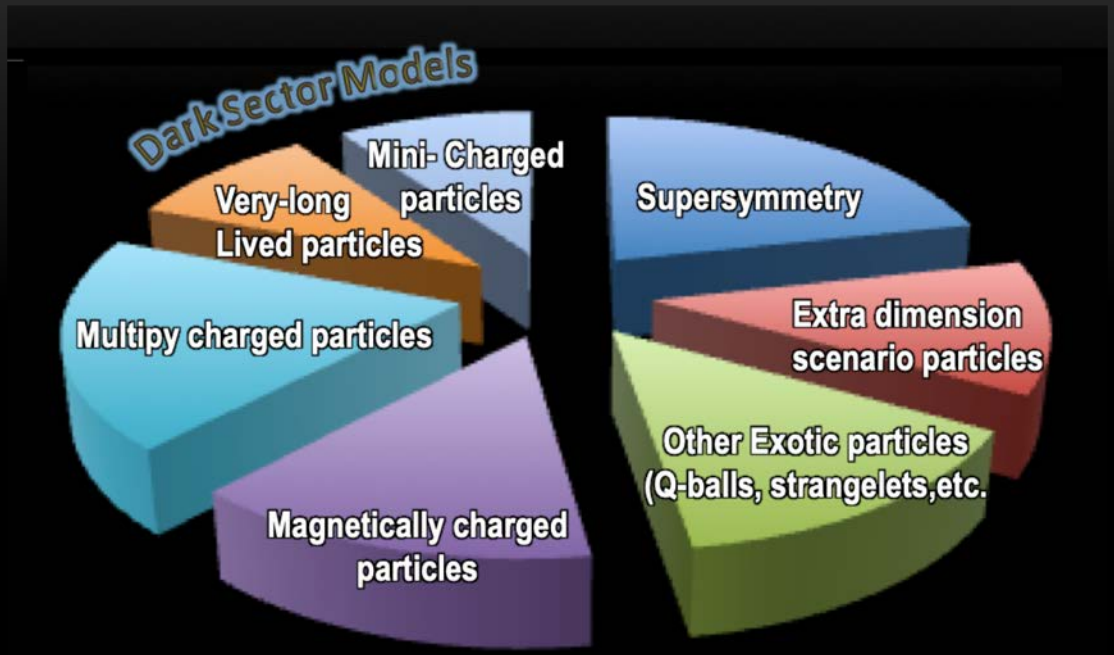


Reinstal MoEDAL (Phase-1)
Fully funded

MAPP-mQP (Phase-1)
Fully funded

MAPP-LLP detector concept (Phase-2)
fine grained scintillator hodoscopes

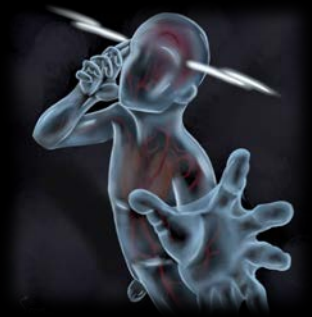
MoEDAL-MAPP – Physics Program



IJMPA, September 2014, Vol. 29, No. 23

Highly ionizing particles (HIPs)

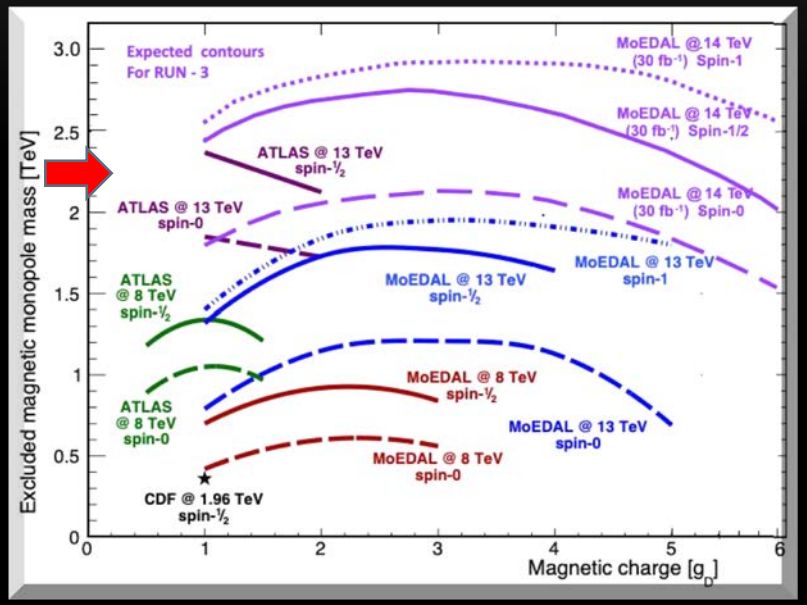
Long-Lived Particles (LLPs)

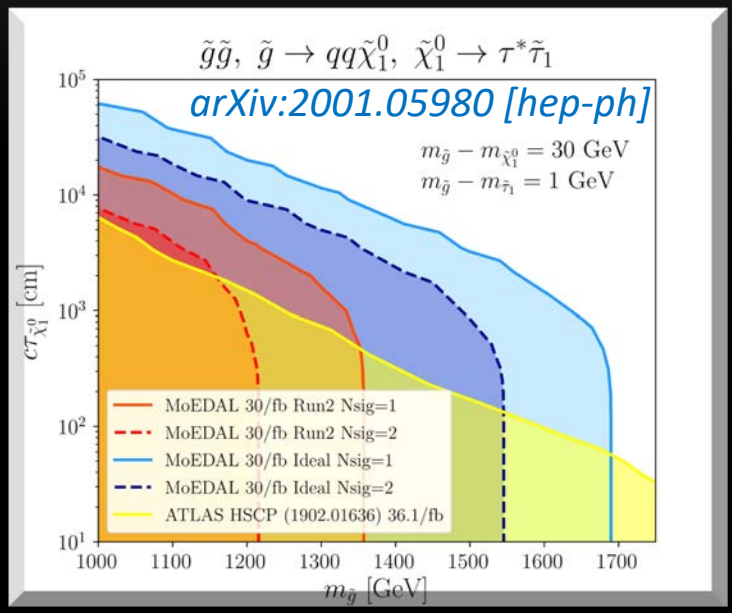


Mini-charged particles (mQPs)

- *With MAPP the MoEDAL Experiment will be sensitive to 3 clear avatars of new physics: HIPs, mQPs and LLPs.*
- *MAPP allows us expand the physics reach of our existing program to include dark sector models, hidden valley models, etc.*

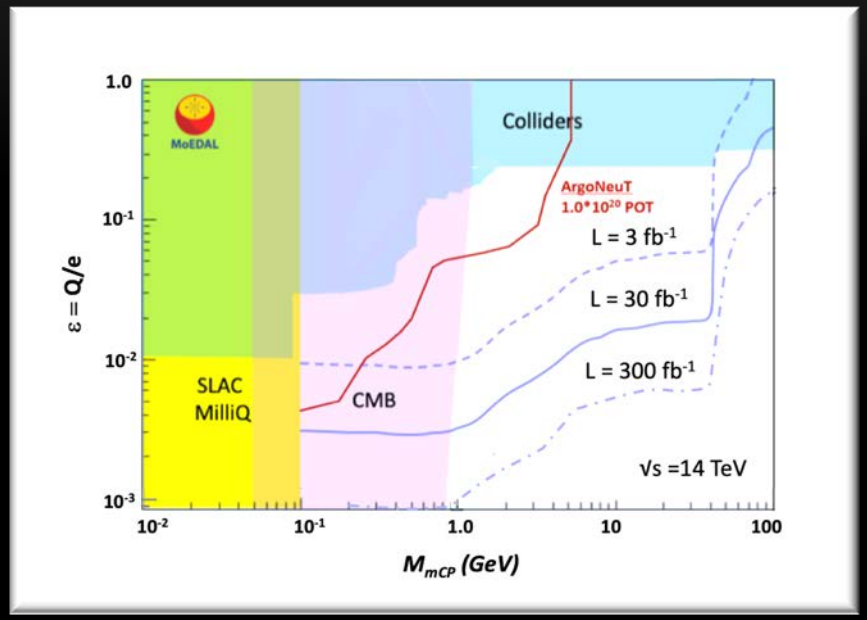
Physics Goals with the Baseline MoEDAL Detector at Run-3



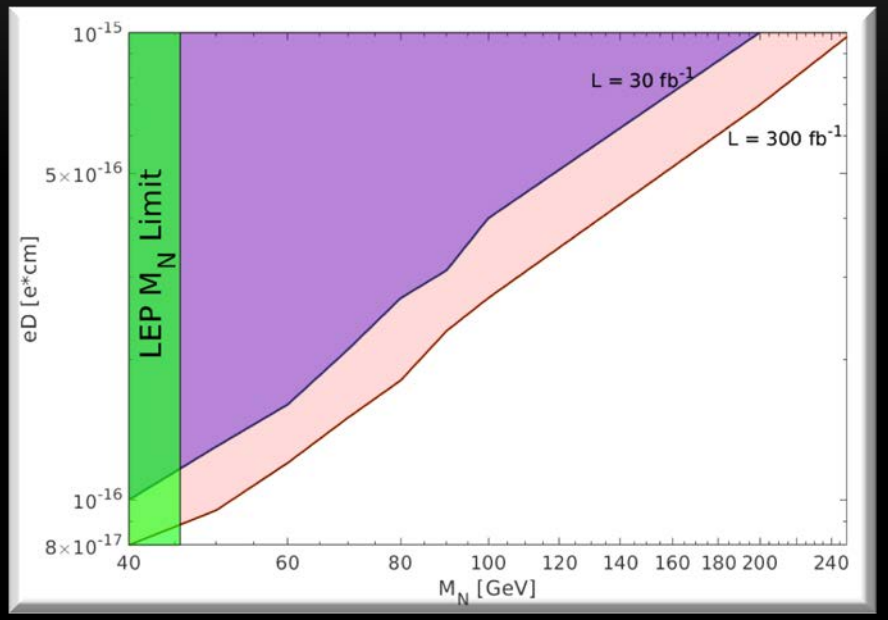


- *Pursue the hunt for magnetic charge using NTD & MMT detectors (see above left) to higher energy (14 TeV) and luminosity.*
- *Search for massive electrically charged objects with low threshold NTD detectors (CR39) from a number of new physics scenarios*
  - *EG complementary sensitivity to long-lived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

Phase-1 MAPP-mQP – Feebly Interacting Particles



Dark photon decays to mQPs



Heavy neutrino with large EDM

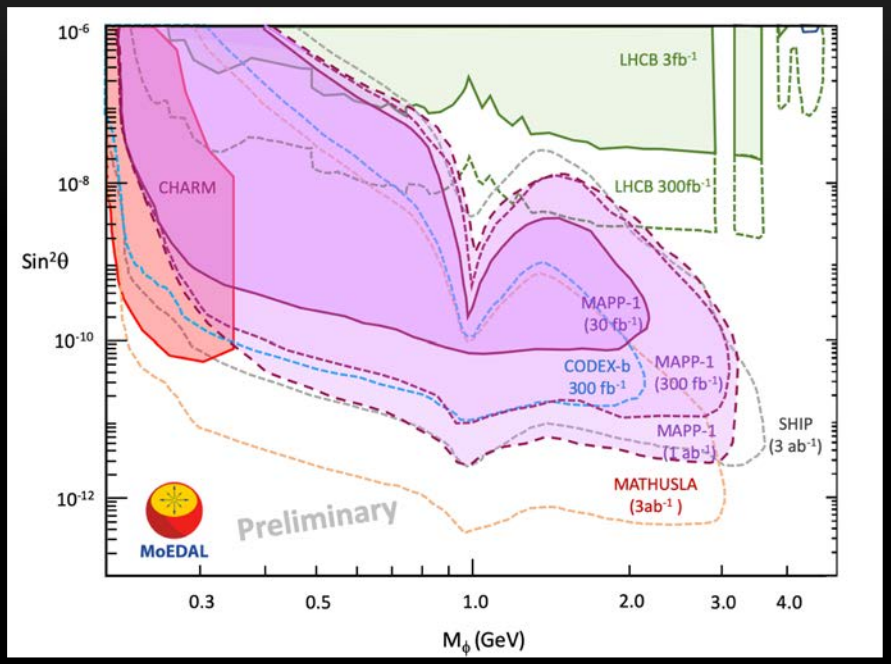
- *(LEFT) Limits that can be placed in Run-3 for the decay of a dark photon to mQP pairs (Phys. Lett. B746 (2015) 117-120)*
- *(RIGHT) Limits that MAPP can place of heavy neutrino production with large EDM at Run-3 and HL-LHC at IP8 (Phys. Lett. B802 (2020) 135204).*

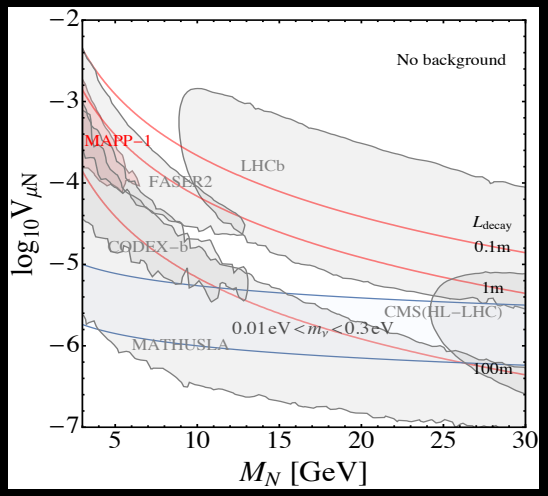
MAPP-LLP – Example Physics Studies

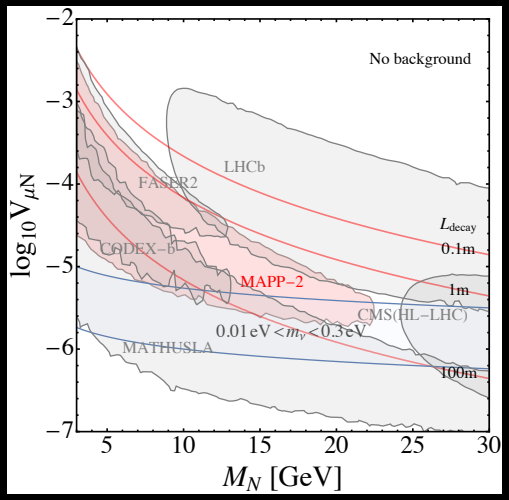
- *TOP: Reach for 30 fb^{-1}/300 fb^{-1} for the scenario where the Higgs mixing portal admits inclusive B → $X_s\phi$ decays, where φ is a light CP-even scalar that mixes with the Higgs, with mixing angle $\vartheta \ll 1$.*

- *BOTTOM: Pair production of right-handed neutrinos from the decay of an additional neutral **Z^0** boson in the gauged **B-L** model – Phys. Rev. D100 (2019), 035005.*

See Phys. Rev. D97 (1) (2018) 15023 for CODEX-b results.



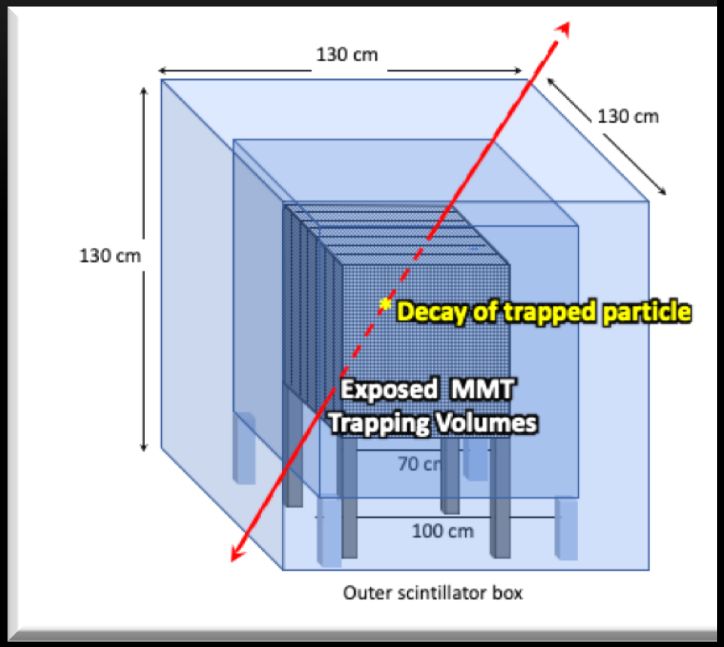


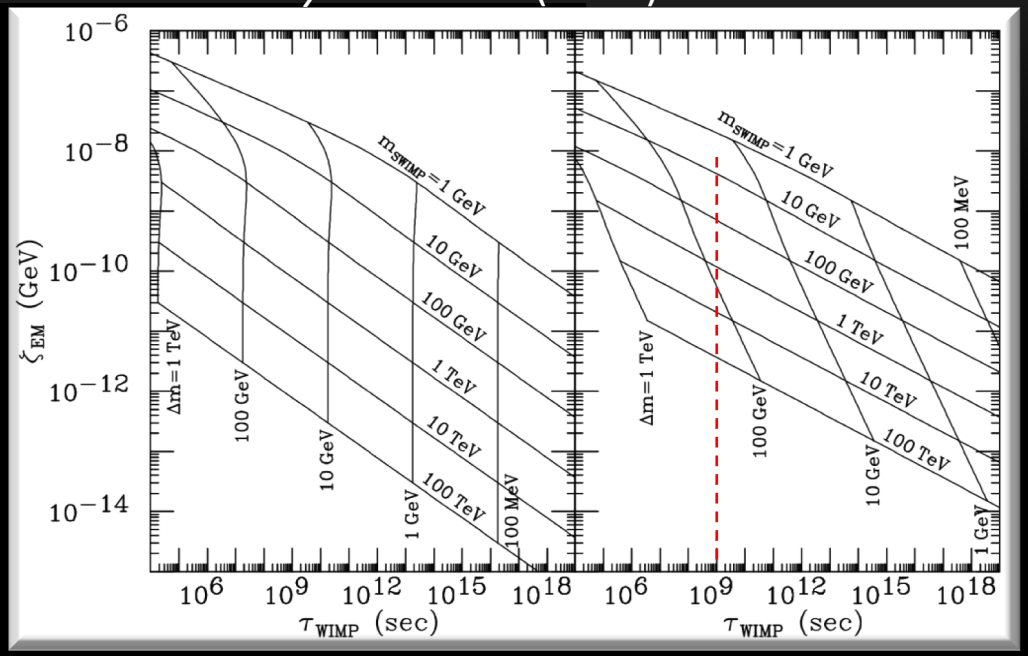


MAPP-1 → 30fb^{-1} MAPP-2 → 30 fb^{-1} CODEX-b → 300 fb^{-1} FASER-2 → 3Ab^{-1} MATHUSLA → 3 Ab^{-1}

The MoEDAL-MALL Detector

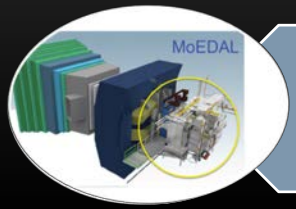
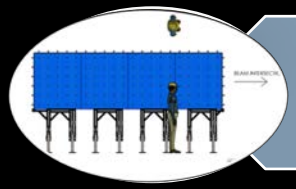
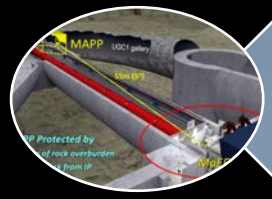
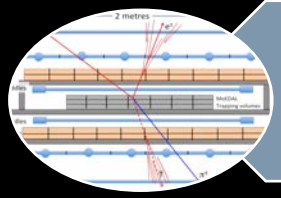
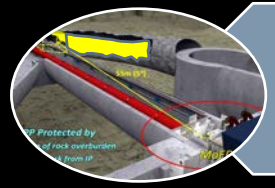
Phys.Rev.D 68 (2003) 063504





- *After exposure MoEDAL trapping volumes will be monitored in the UGC1 gallery for the decays of trapped ultra long-lived particles using the MALL (MoEDAL Apparatus for ultra Long Lived particles) detector*
  - *The massive SuperWIMP particles are naturally bequeathed the desired relic density from the late decays of metastable WIMPs. EG a charged slepton NSLP in this scenario the lifetime of a 150 GeV stau decaying to a 100 GeV gravitino is about 10^9 s or around 10 years*

MoEDAL-MAPP: Run-3 and Beyond

	Highly Ionizing Particles *(HIPs)*	Weakly Ionizing Particles *(mQPs)*	Long-lived Particles *(LLPs)*	APPROVED	START
 MoEDAL	✓	✗	✗	TDR Phase-1	≥ 2015
 MAPP-mQP	✗	✓	✗	TDR Phase-1	≥ 2021
 MAPP-1	✗	✗	✓ *LLP-neutral*	TDR Phase-2	≥ 2022
 MALL	✗	✗	✓ *LLP-charged*	TDR Phase-2	≥ 2022
 MAPP-2	✗	✗	✓ *LLP-neutral*	TDR Phase-3	≥ 2025
OVERALL	✓	✓	✓		