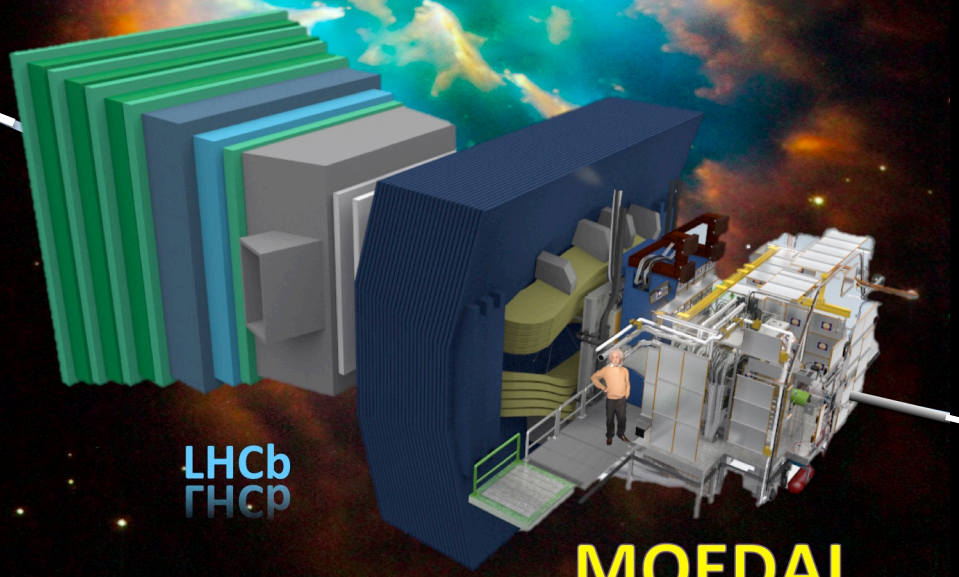
MoEDAL – Progress Report

James L. Pinfold (For the MoEDAL Collaboration)

LHCC Open Session

September 2016



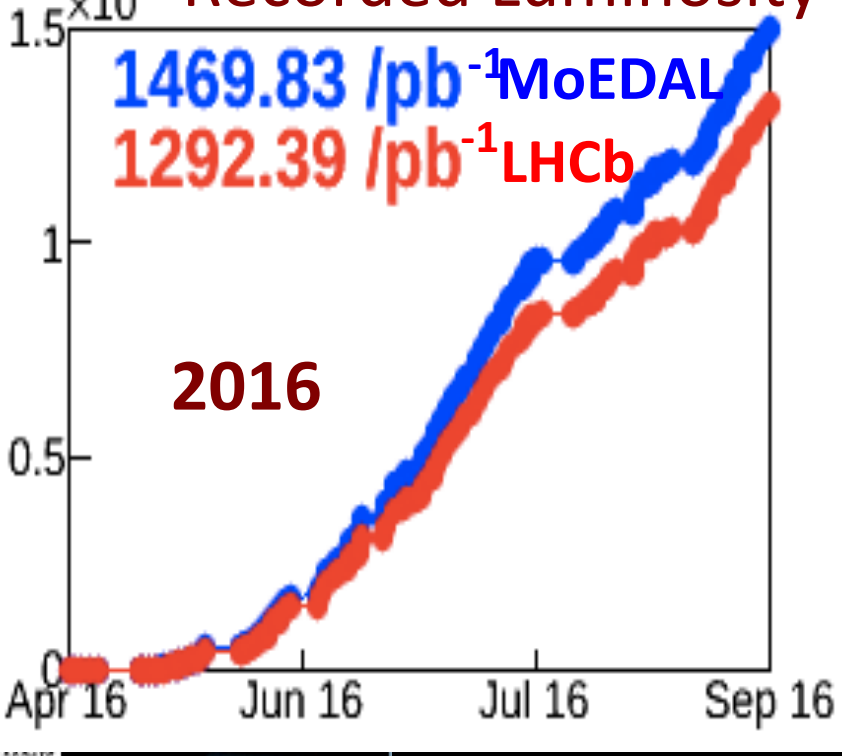
MoEDAL

MoEDAL in Run 2

LHC experiments are back in business at a new record energy 13 TeV

3rd June 2015

Recorded Luminosity



The luminosity delivered to MoEDAL in 2015 was 366 pb^{-1}

Despite "Sparky" the Field Martin – LHC is now on track

The MoEDAL Collaboration

66 physicists from 14 countries & 24 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., Simon Langton School UK, Tuft's.

The MoEDAL Collaboration

TWO NEW GROUPS JOINED SINCE OUR LAST REPORT (June 2015)

a) National University of Science and Technology (MISiS) Moscow

b) The University of Alabama

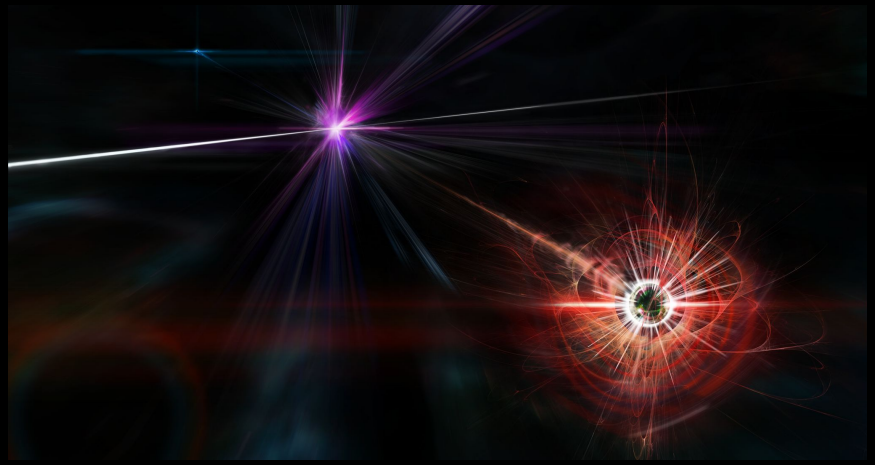
66 physic… …es. on 4 continents:

U. Alberta, U. … …a, U. Bologna, CAAG-Algeria, U. Cincinatti, Concordia U., … …angneung-Wonju Nat. U., U. Geneva, U. Helsinki, IEAP/ CTU Prague, IFI… …alencia, Imperial College London, ISS Bucharest, King's College London, Konkuk U., U. Montréal, MISiS Moscow, Muenster U., National Inst. Tec. (india),Northeastern U., Simon Langton School UK, Tuft's.

MoEDAL Collab. Meetings Since Last Report

MoEDAL Collaboration Meeting

CERN: 18th-19th June 2015



For all information regarding the meeting please check the link below

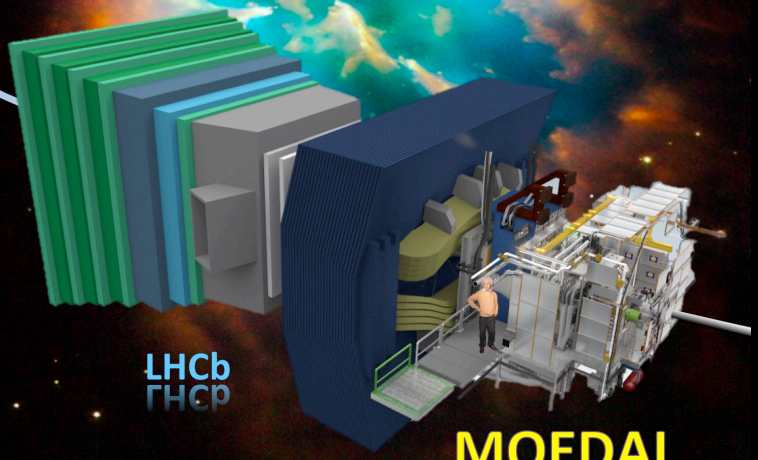
https://indico.cern.ch/event/389924/

Questions and/or problems please contact: jpinfold@ualberta.ca

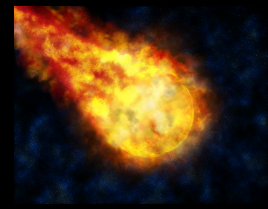
MoEDAL –LHC:
5th Collaboration Meeting

https://indico.cern.ch/event/493401/

28-29th June 2016
Valencia, Parque Cientifico



Highly Ionizing Particles – Avatars of New Physics



- **MoEDAL** – *Highly Ionizing Particles directly detected as messengers of new physics – no SM backgrounds*

- **Electric charge** - *ionization increases with increasing charge & falling velocity β (β=v/c) – use Z/β as an indicator of ionization*

$$-\frac{dE}{dx} = K z^2 \frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_e c^2\beta^2\gamma^2 T_{\max}}{I^2} - \beta^2 - \frac{\delta}{2}\right]$$

- **Magnetic charge** - *ionization increases with magnetic charge $g = ng_d$ and decreases with velocity β – a unique signature*

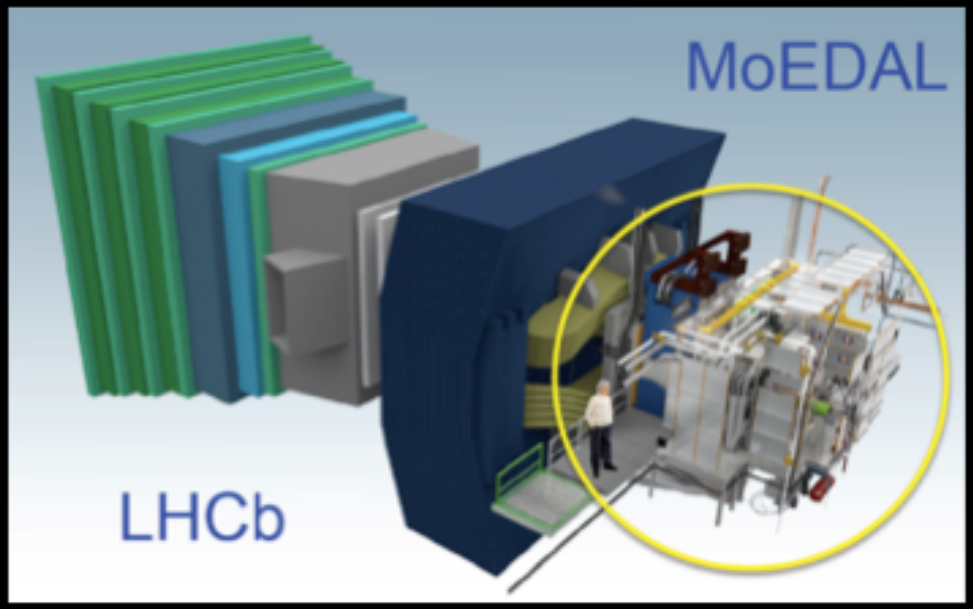
$$-\frac{dE}{dx} = K\frac{Z}{A}g^2\left[\ln\frac{2m_e c^2\beta^2\gamma^2}{I_m} + \frac{K|g|}{2} - \frac{1}{2} - B(g)\right]$$

The velocity dependence of the Lorentz force cancels $1/\beta^2$ term

- *As g = 68.5e the ionization of a rel. monopole is $4700n^2$!! n=1,2,3….In fact n ≥ 2 in many modern monopole theories*

MoEDAL – a Unique Collider Detector

Permanent Physical record of new physics



No Standard Model Physics Backgrnds

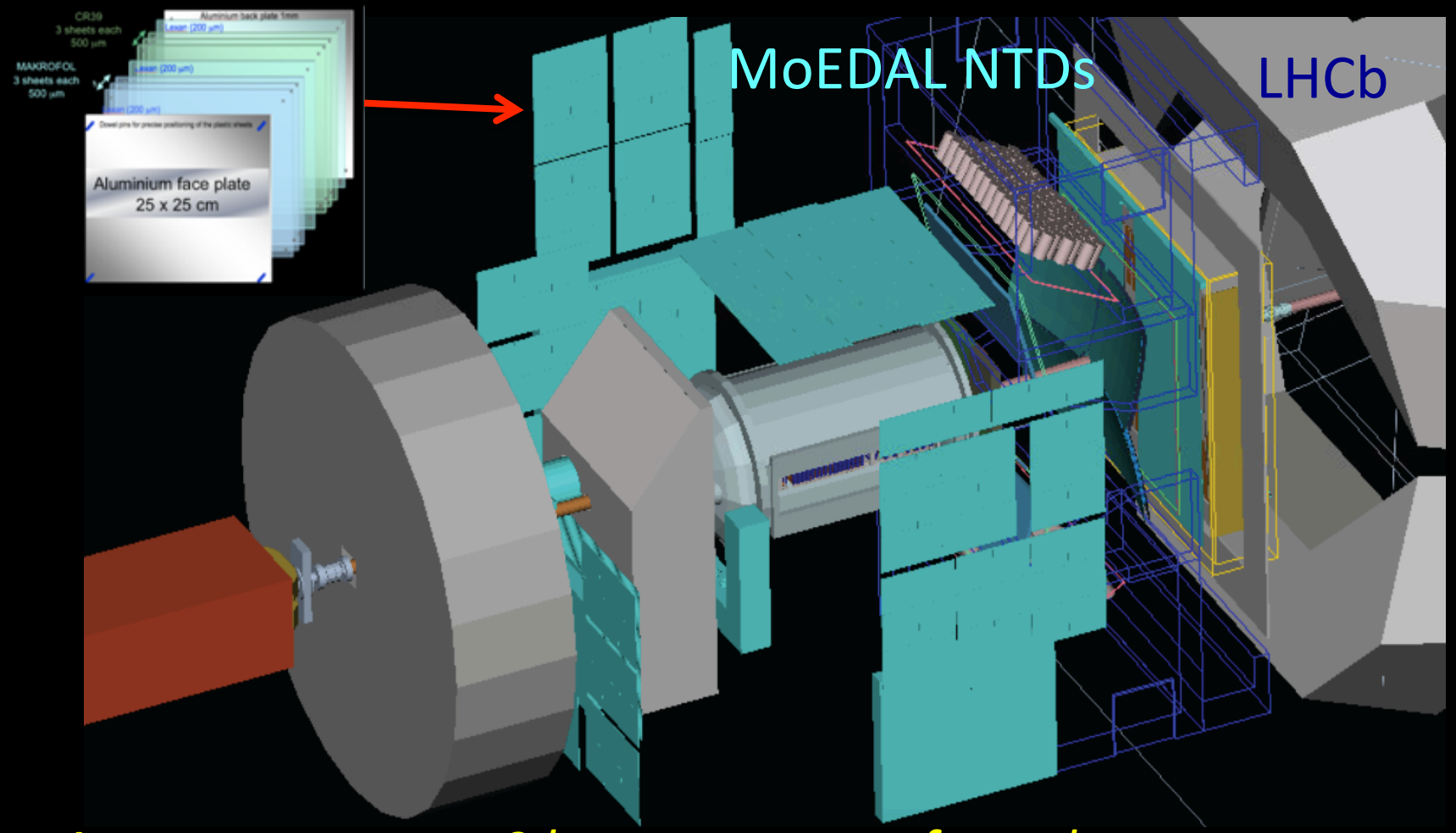
MoEDAL is largely passive made up of three detector system.

NUCLEAR TRACK DETECTOR
Plastic array (~200 sqm)
– Like a Giant 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

Full NTD Deployment in 2015/16

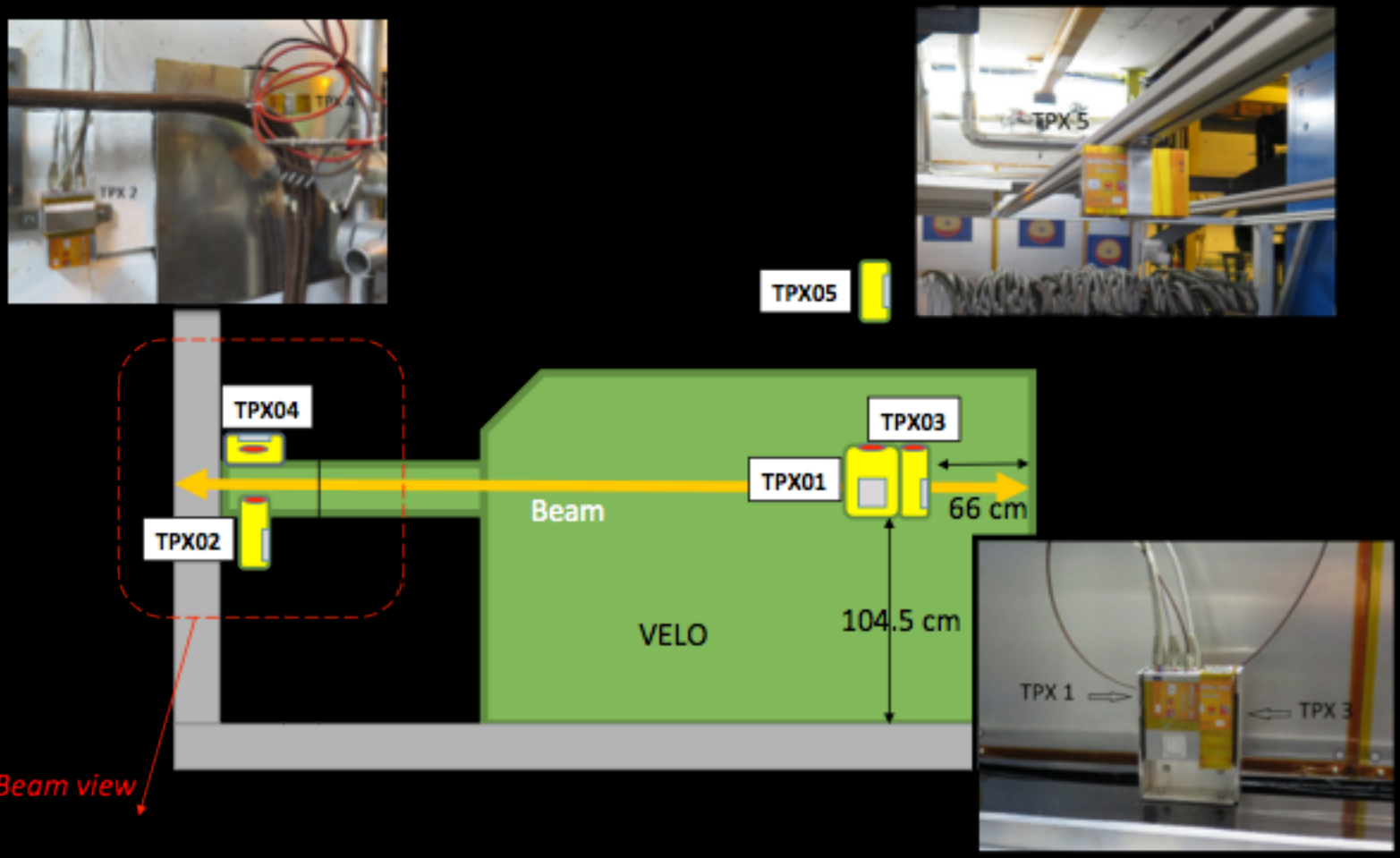


- *Acceptance at $\eta = 0$ but acceptance for at least one monopole from monopole pair production to hit NTDs ~70%*
  - *Detection efficiency essentially 100%*
  - *Detection threshold $Z/\beta \geq 5$ (CR39) and 50 (MAKROFOL)*

Full MMT Deployment in 2015/16

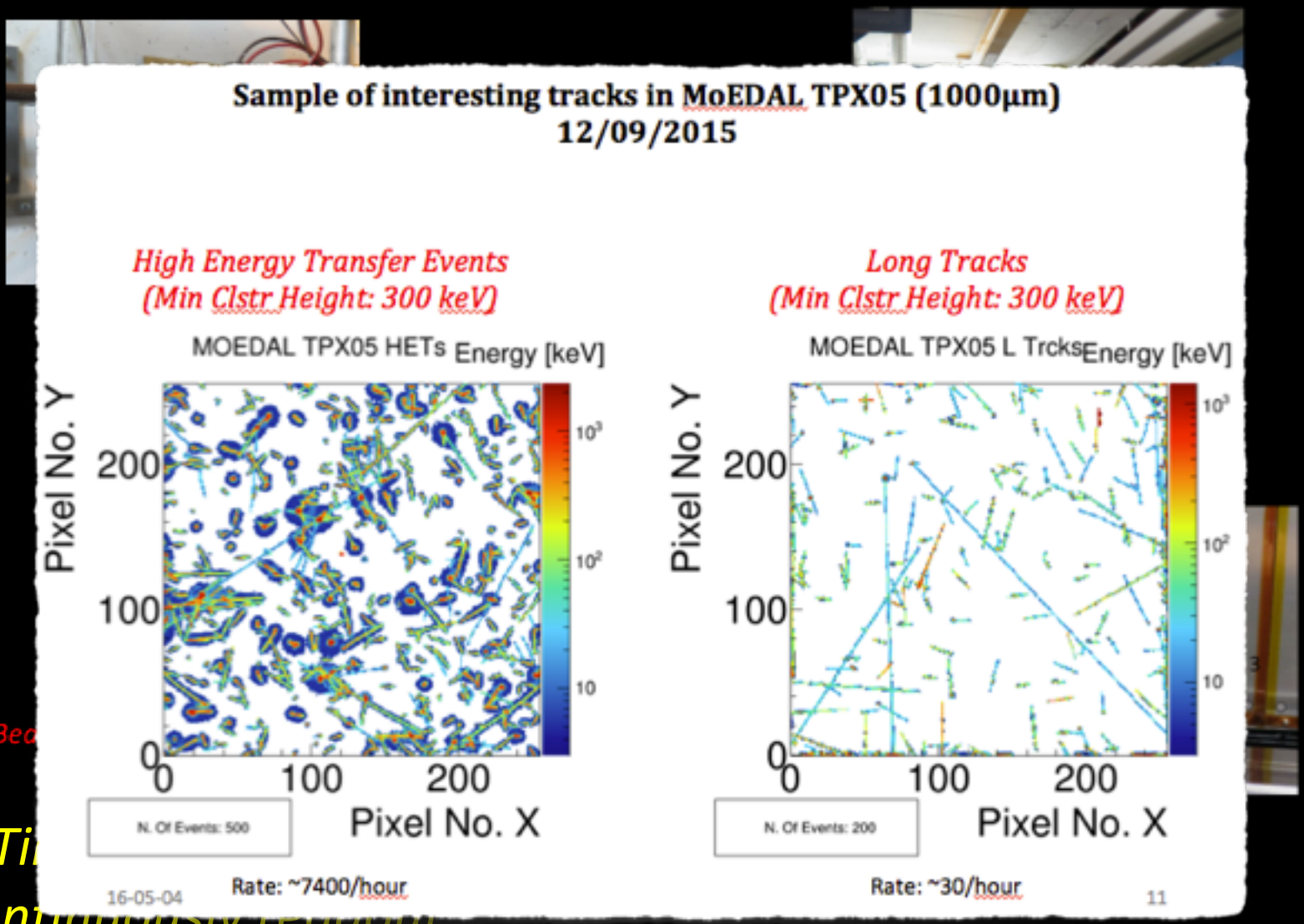
- *Total mass of trapping detectors ~ 800 kg of Al (~2400 bars)*
  - *Read out by a SQUID magnetometer calibrated with special solenoids*
  - *First time a purpose built trapping detector has ever been deployed*
  - *After scanning for monopoles Al will be monitored undergound for very slow decays,*

TimePix Deployment in 2015/16



- *5 TimePix chips deployed around the cavern and being continuously readout*
  - *Studies if HI particle backgrounds at IP8 underway,*

TimePix Deployment in 2015/16



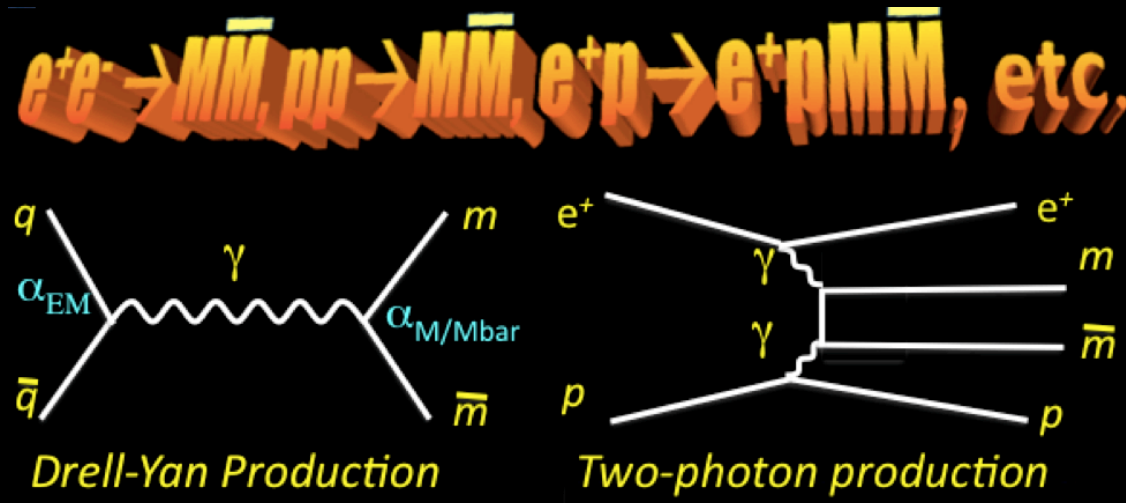
- *5 Ti*
  continuously readout

MoEDAL's 1st Physics Paper (1)

Journal of High Energy Physics
August 2016, 2016:67

Search for magnetic monopoles with the MoEDAL prototype trapping detector in 8 TeV proton-proton collisions at the LHC

The MoEDAL collaboration, B. Acharya, J. Alexandre, K. Bendtz, P. Benes, J. Bernabéu, M. Campbell, S. Cecchini, J. Chwastowski, A. Chatterjee, M. de Montigny, D. Derendarz, A. De Roeck, J. R. Ellis, M. Fairbairn, D. Felea, M. Frank, D. Frekers, C. Garcia, G. Giacomelli, D. Hasegan, M. Kalliokoski, A. Katre, D.-W. Kim, M. G. L. King, K. Kinoshita, D.H. Lacarrère, S. C. Lee, C. Leroy, A. Lionti, A. Margiotta, N. Mauri, N. E. Mavromatos, P. Mermod ✉, D. Milstead, V. A. Mitsou, R. Orava, B. Parker, L. Pasqualini, L. Patrizii, G. E. Păvălas, J. L. Pinfold, M. Platkevič, V. Popa, M. Pozzato, S. Pospisil, A. Rajantie, Z. Sahnoun, M. Sakellariadou, S. Sarkar, G. Semenoff, G. Sirri, K. Sliwa, R. Soluk, M. Spurio, Y. N. Srivastava, R. Staszewski, M. Suk, J. Swain, M. Tenti, V. Togo, M. Trzebinski, J. A. Tuszynski, V. Vento, O. Vives, Z. Vykydal, T. Whyntie, A. Widom, G. Willems, J. H. Yoon … *show less*



MoEDAL's 1st Physics Paper (1)

Journal of High Energy Physics
August 2016, 2016:67

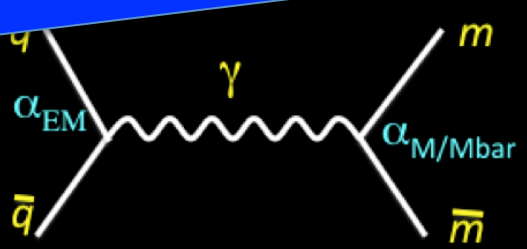
Search for magnetic monopoles with the MoEDAL prototype trapping detector

MoEDAL's first (of many) PhD Thesis

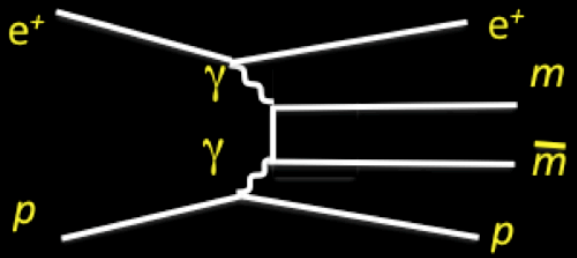
Searches for Magnetic Monopoles and Highly Ionising Particles at √s = 8 TeV at the LHC

Akshay Katre, Université de Genève

Summer 2016



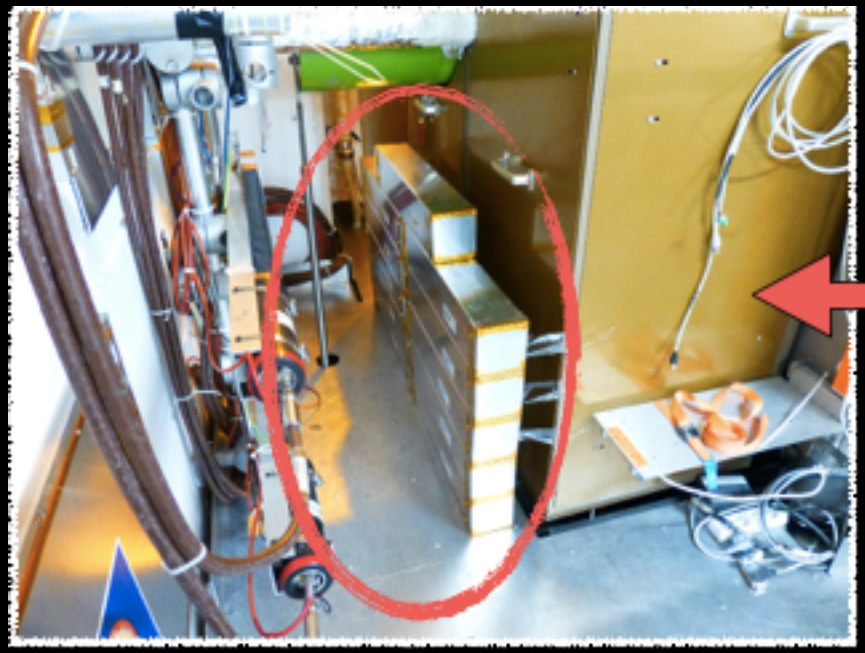
Drell-Yan Production



Two-photon production

MoEDAL's 1st Physics Paper (2)

- *Search was carried out using the prototype trapping detectors (MMTs) shown on the left, deployed for 0.75 fb^{-1} at 8 TeV E_{cm}.*



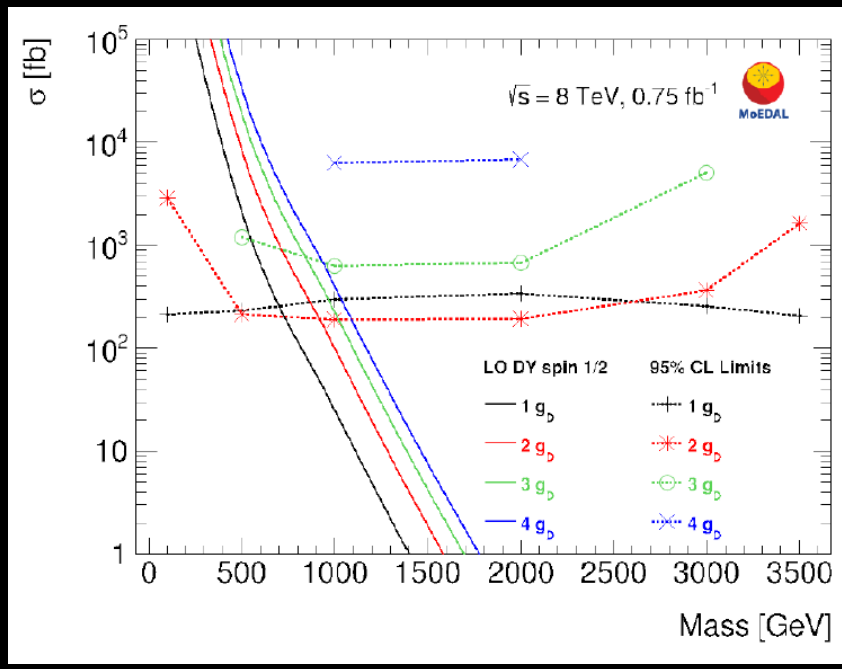
Prototype trapping detector~ 160 kg

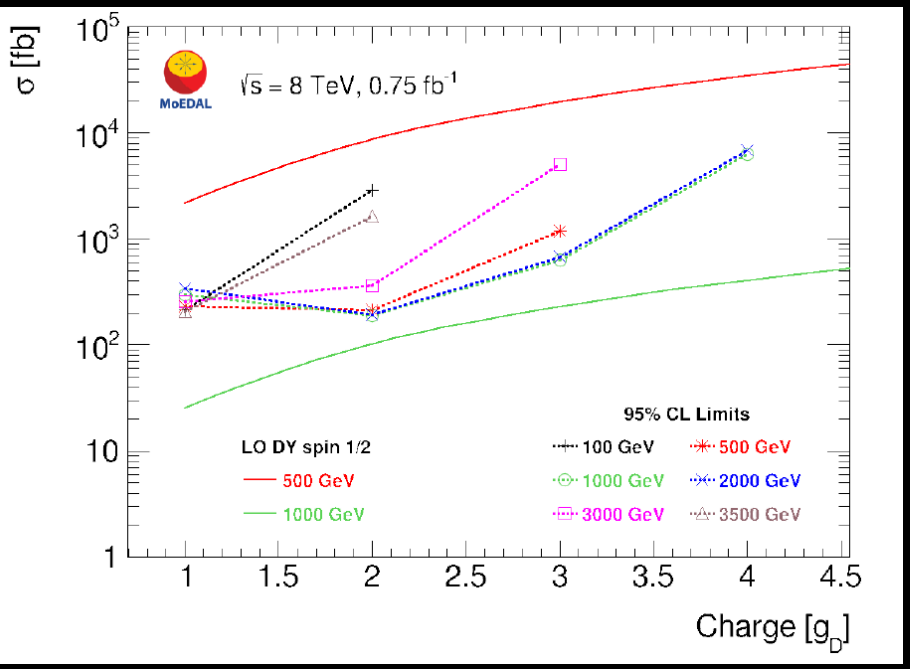
The challenge

New forward trapping Detector- 270 of 800 kg

- *Trapping criterion if the monopole $\beta \leq 0.001$ in the MMT volume then the monopole is captured.*

Cross-section Limits vs Mass + Magnetic Charge





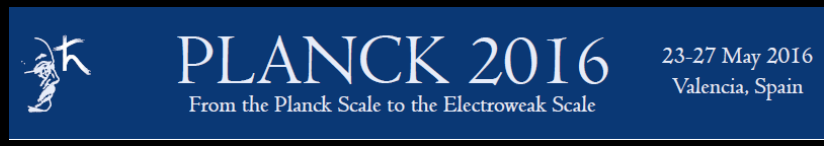
DY Lower Mass Limits [GeV]	$\|g\| = g_D$	$\|g\| = 2g_D$	$\|g\| = 3g_D$
spin-1/2	700	920	840
spin-0	420	600	560

- *Probe monopole mass > 2.5 TeV for the 1st time at the LHC*
  - *Even with low lumi (0.75 pb^{-1}) and a small prototype detector*
  - *World' best limits for $|g| > g_D$ - probe up to $4g_d$*

Refereed MoEDAL Pubs Since Last Report

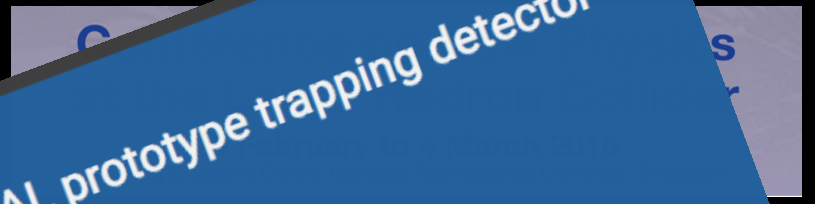
The Price of an Electroweak Monopole	Phys. Lett. B756 (2016),29	Published
Search for magnetic monopoles with the MoEDAL protype trapping detector in 8TeV proton-proton collisions at the LHC	JHEP 1608 (2016), p.067	Published
MoEDAL a new light on the high energy frontier	Contemporary Physics	Accepted TBP
Search for magnetic monopoles with the MoEDAL trapping detector in 13TeV proton-proton collisions at the LHC	To be submitted to PRL In October 2016	Paper in prep.
The MoEDAL LHC detector	To be submitted to JINST	Paper in prep.
NTD analysis for the MoEDAL experiment using mass participation methodologies	To be submitted to NIMA	Paper in prep.
An analysis of the highly ionizing particle background at IP8 (using TimePix tech.)	To be submitted to NIMA	Paper in prep.
Search for magnetic monopoles using the (full) Moedal detector in p-p collisions at the LHC	To be submitted to Phys. Rev. D	Start paper in March 2017
Search for massive electrically charged particles using MoEDAL	To be submitted to PRL	Start paper in May 2017

MoEDAL Presentations Since June 2015



- *18 invited MoEDAL talks since the last report*

MoEDAL Presentations Since June 2015



- *18 invited MoEDAL talks since the last report*

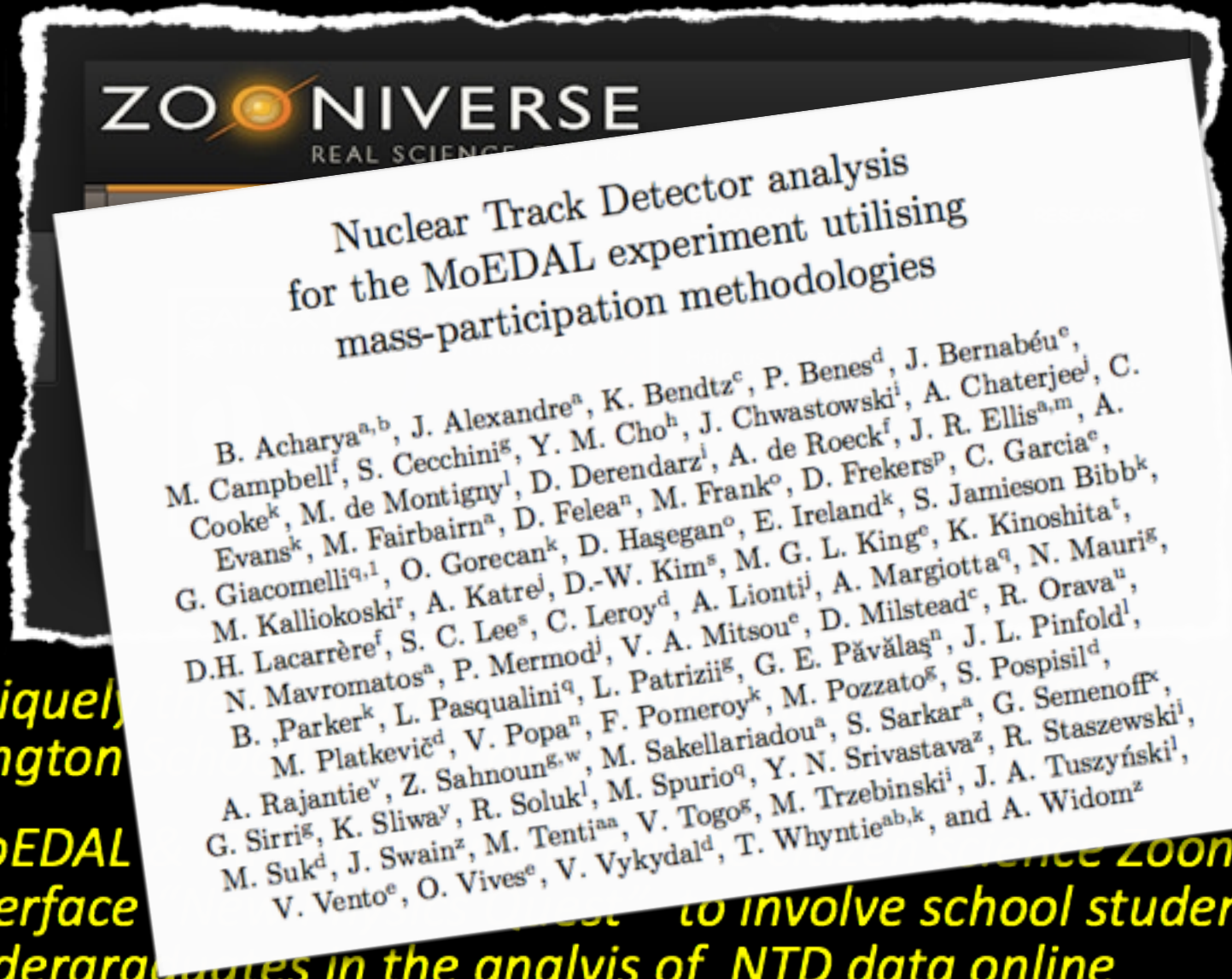
MoEDAL and the Royal Society

- ***MoEDAL chosen to exhibit at the Royal Society (RS) Summer Exhibition in 2015 & "Behind the Scenes at the RS" in 2016***

The MoEDAL "Zooinverse" Project

- *Uniquely the Institute for Research in Schools (IRIS) (Simon Langton School) Canterbury, UK is a full member of MoEDAL*
- *MoEDAL & IRIS are working on the citizen science Zooniverse interface "New Physics Quest" to involve school students and undergraduates in the analyis of NTD data online*

The MoEDAL "Zooinverse" Project



Nuclear Track Detector analysis for the MoEDAL experiment utilising mass-participation methodologies

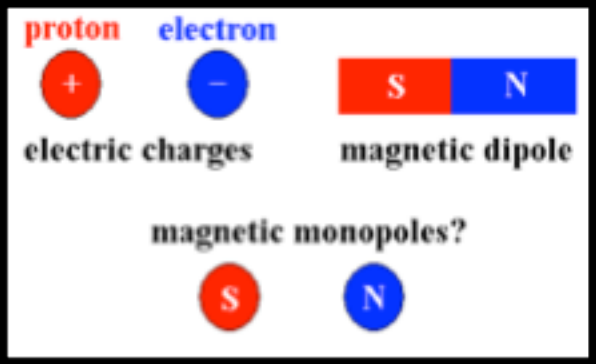
B. Acharya[a,b], J. Alexandre[a], K. Bendtz[c], P. Benes[d], J. Bernabéu[e], M. Campbell[f], S. Cecchini[g], Y. M. Cho[h], J. Chwastowski[i], A. Chaterjee[j], C. Cooke[k], M. de Montigny[l], D. Derendarz[j], A. de Roeck[f], J. R. Ellis[a,m], A. Evans[k], M. Fairbairn[a], D. Felea[n], M. Frank[o], D. Frekers[p], C. Garcia[e], G. Giacomelli[q,1], O. Gorecan[k], D. Haşegan[o], E. Ireland[k], S. Jamieson Bibb[k], M. Kalliokoski[r], A. Katre[j], D.-W. Kim[s], M. G. L. King[e], K. Kinoshita[t], D.H. Lacarrère[f], S. C. Lee[s], C. Leroy[d], A. Lionti[j], A. Margiotta[q], N. Mauri[g], N. Mavromatos[a], P. Mermod[j], V. A. Mitsou[e], D. Milstead[c], R. Orava[u], B. ,Parker[k], L. Pasqualini[q], L. Patrizii[g], G. E. Păvălaş[n], J. L. Pinfold[l], M. Platkevič[d], V. Popa[n], F. Pomeroy[k], M. Pozzato[g], S. Pospisil[d], A. Rajantie[v], Z. Sahnoun[g,w], M. Sakellariadou[a], S. Sarkar[a], G. Semenoff[x], G. Sirri[g], K. Sliwa[y], R. Soluk[l], M. Spurio[q], Y. N. Srivastava[z], R. Staszewski[i], M. Suk[d], J. Swain[z], M. Tenti[aa], V. Togo[g], M. Trzebinski[i], J. A. Tuszyński[l], V. Vento[e], O. Vives[e], V. Vykydal[d], T. Whyntie[ab,k], and A. Widom[z]

- *Uniquel… …on Langton …DAL*
- *MoEDAL … …Zooniverse interface … …to involve school students and undergraduates in the analyis of NTD data online*

MoEDAL Addresses Fundamental Questions:

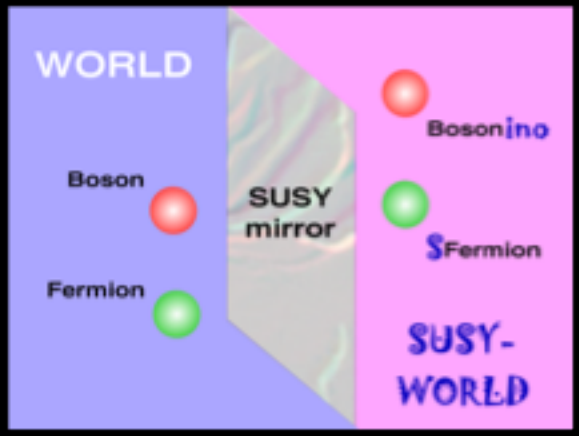
Are there extra dimensions?

What happened just after the big bang?



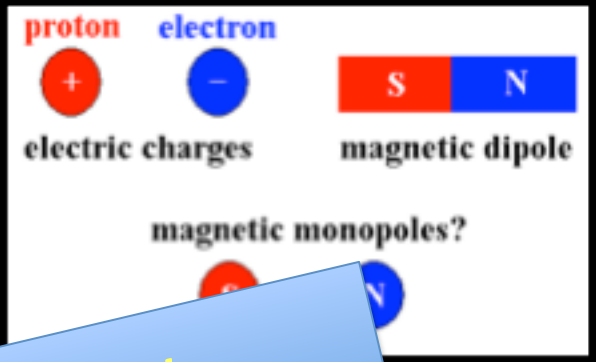
Does magnetic charge exist?

What is the nature of *Dark matter?*



Are there new symmetries of nature?

MoEDAL Addresses Fundamental Questions:



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Are there extra di

Stay tuned for many, potentially revolutionary, MoEDAL results to come

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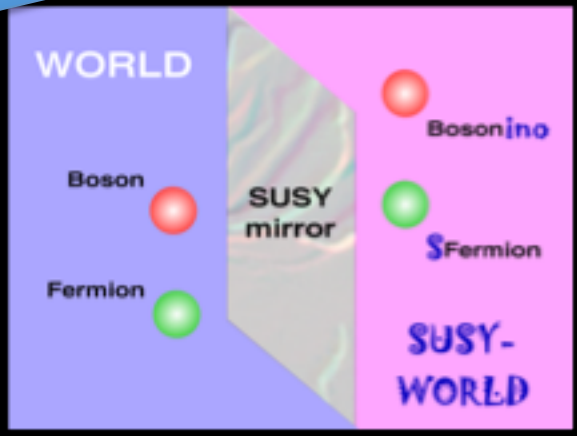

Are there new symmetries of nature?