The MoEDAL Experiment

A Progress Report

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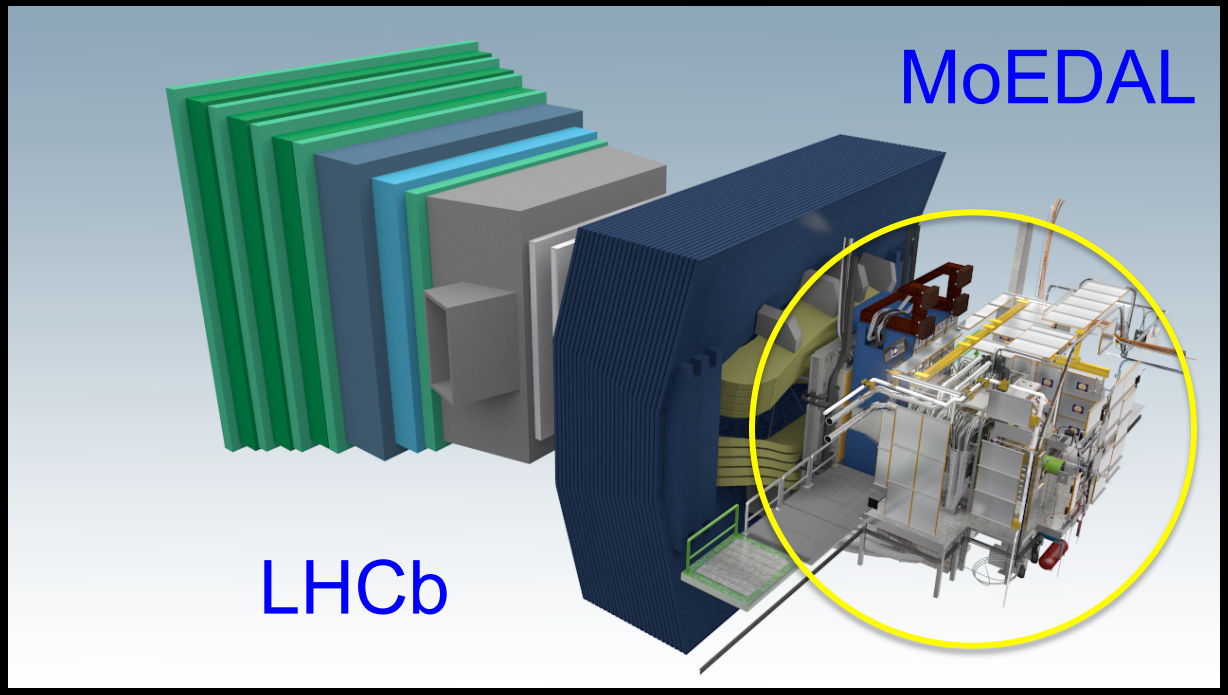
LHCC Open Session, June 2013

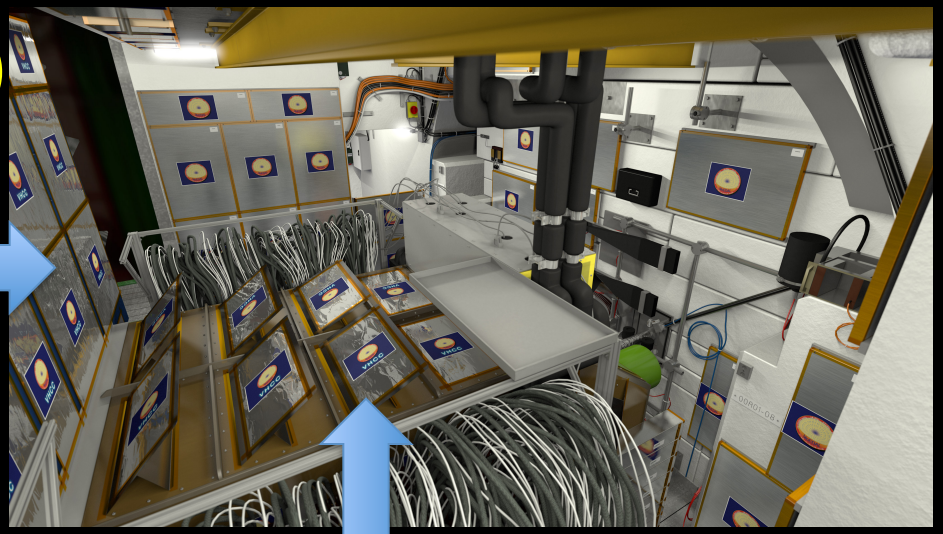
The MoEDAL Detector Today



- *The MoEDAL design consists of 4 detector subsystem:*
  - ***The TDR Nuclear Track Detector*** *(NTD) with low 5 x MiP threshold*
  - ***The Very High Charge Catcher (VHCC)*** *NTD array - 50 x MiP threshold*
  - ***The Magnetic Monopole Trapper (MMT)*** *– Al trapping volumes* NEW
  - ***The TimePix pixel chip (TMPX)*** *online radiation monitoring system*

The MoEDAL NTD Detectors

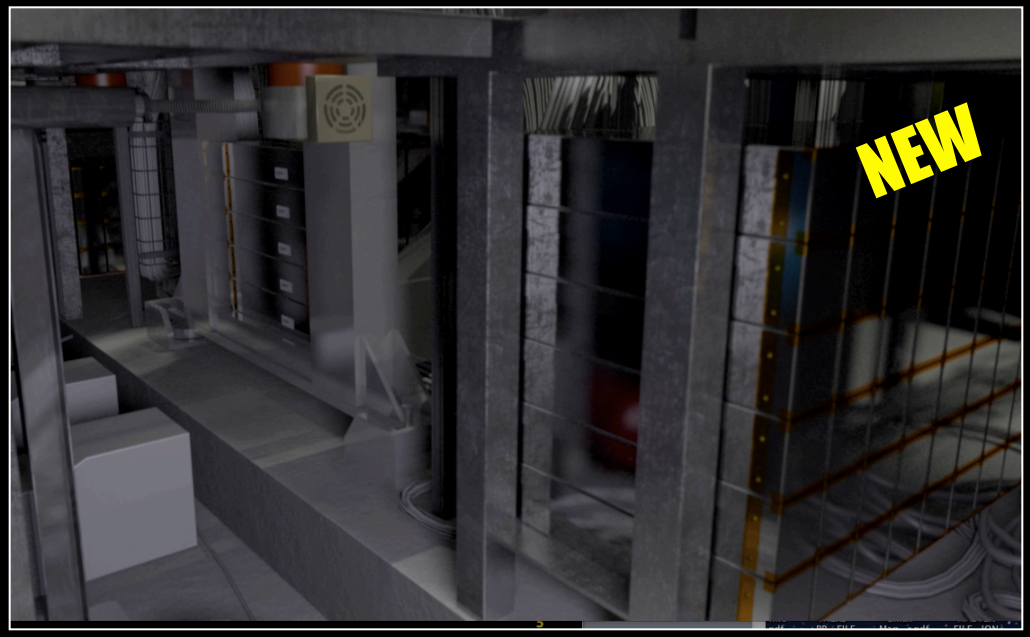
- *"TDR" NTD stacks (10 layers)*
  - *Placed on VELO cavern walls*
  - *Low threshold ~50 MIP*
  - *Very large area ~250 sqm of plastic (CR39+Makrofol)*
  - *20 precise measurements/track*



- *"VHCC" NTDs (3 layers)*
  - *Light flexible NTDs (Makrofol) placed adjacent to VELO*
  - *Higher 50 MIP threshold*
  - *Purpose to increase acceptance for VHIP's to ~70%*
  - *6 precise measurements/track*

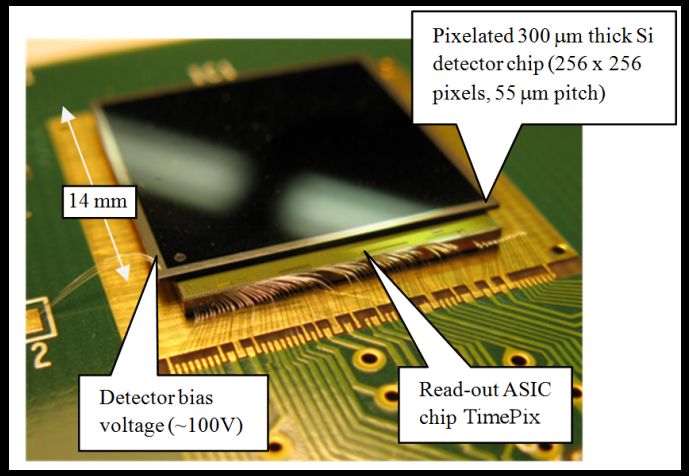
***** 20 NTDs calibrated using heavy ions****

The Magnetic Monopole Trapper

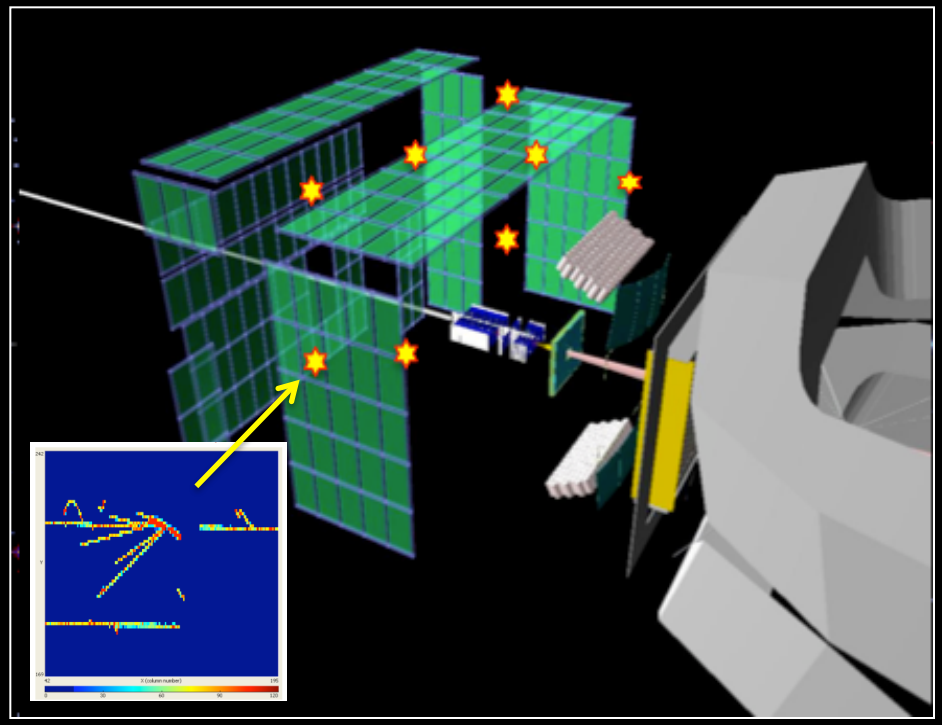


- *The MMT - an array of Al trapping volumes deployed to stop magnetic monopoles and other very highly ionizing objects*
  - *The exposed volumes will be scanned at the ETH Zurich SQUID facility*
  - *And after to an underground facility (eg SNOLAB) to be monitored for the decays of trapped particles.*
- *This gives MoEDAL the ability to detect magnetic charge and monitor for the decays of pseudo-stable particles.*

The TimePix Radiation Monitor



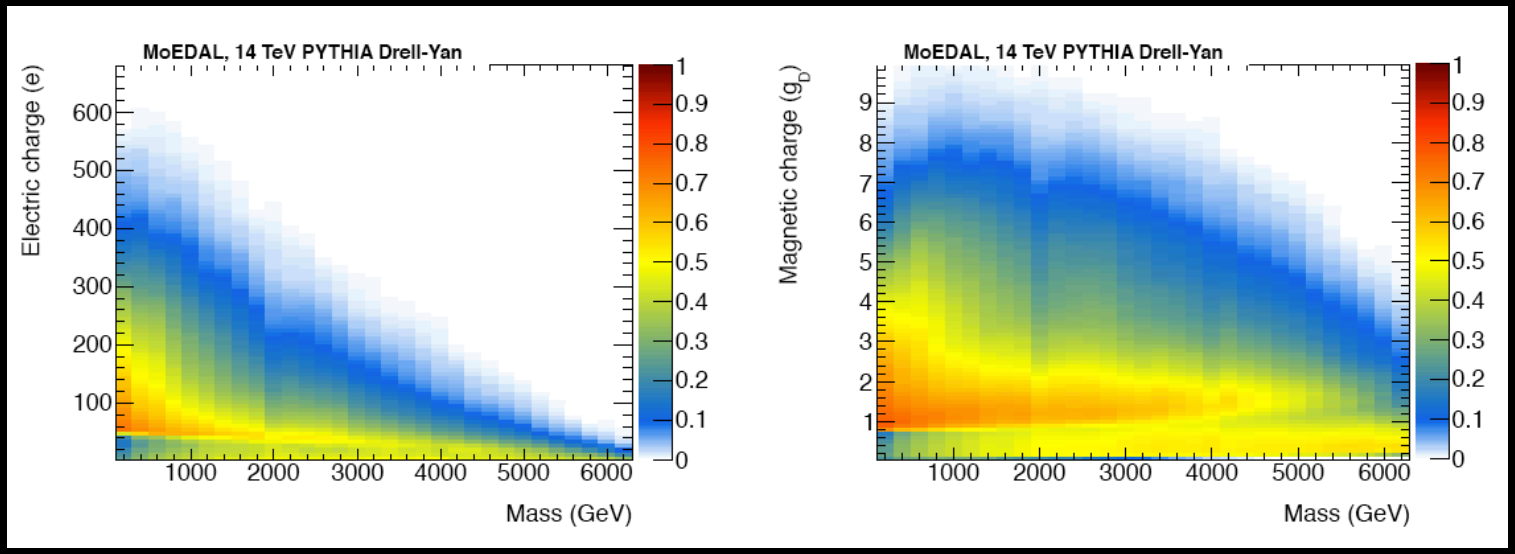
The Timepix chip



- *Timepix (MediPix) chips will be used to measure the radiation/spallation background in real-time*
- *The TimePix chip pixels are instrumented with an amp. + comparator + counter + timer (allows TOT E- measurement)*
- *The TimePix chip is a petite electronic bubble chamber*

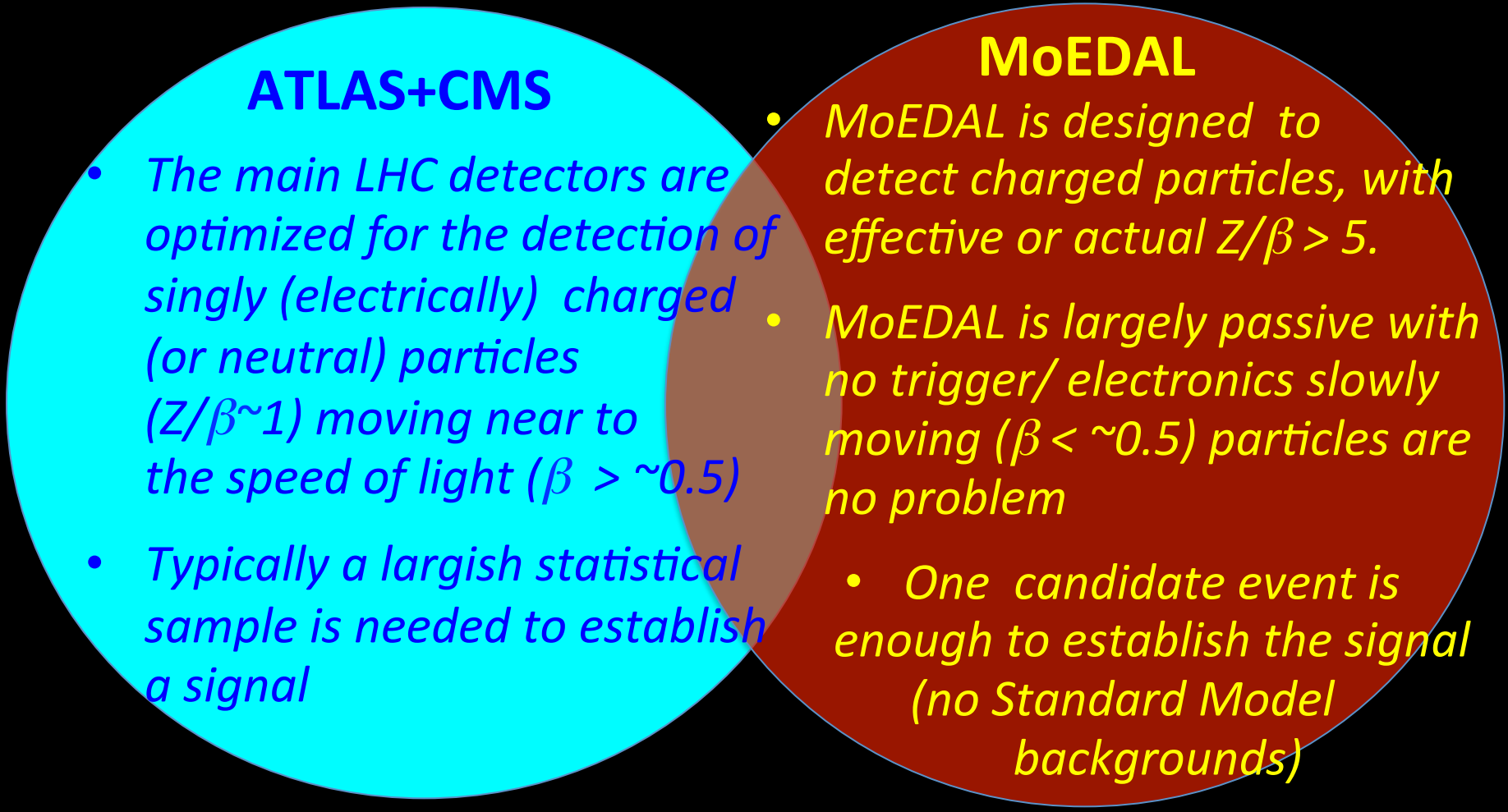
MoEDAL Coverage (With the VHCC)

detector	energy threshold	angular coverage	luminosity	robust against timing	robust efficiency
ATLAS	medium	central	high	no	no
CMS	relatively low	central	high	no	no
ALICE	very low	very central	low	yes	no
LHCb	medium	forward	medium	no	no
MoEDAL	low ✔	full ✔	medium ✔	yes ✔	yes ✔



- *MoEDAL acceptance for electric (left) and magnetic (right) charges, assuming a Drell-Yan pair production with 14 TeV pp collisions (From Ref.* ***arXiv:1112.2999V2*** *[hep-ph]).*

MoEDAL's Complementarity



MoEDAL is complementary to the main LHC experiments and expands the physics reach of LHC

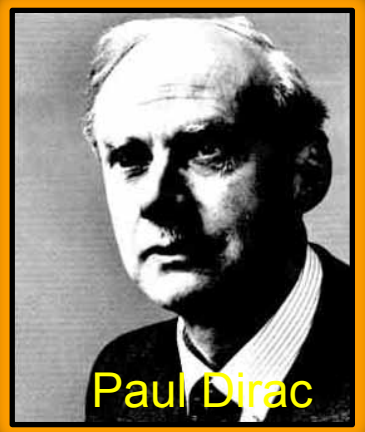
The MoEDAL Physics Program (1)

- Search for magnetic Monopole/Dyon (a singly charged relativistic monopole has ionization ~4700n times that of a MIP) - with mass up to ~7 TeV and magnetic charge (ng) of up to n=8-9
- Search for exotic, massive (pseudo-)stable, single or multiply charged particles (SMPs) with $Z/\beta \geq 5$, with mass up to 7 TeV and charge as high as ~400, for example:
  - Charged black hole remnants from ADD models of LEDs
  - Universal Extra dimensions - KK-particles
  - Higgs bosons: H^{++} (L-R symmetric models) & H^{o} → N-Nbar
  - R-hadrons (Split SUSY, GMSB, SUSY5D)
  - Very heavy stable SUSY particles (sleptons, etc.)
  - Techni-baryons & Mirror fermions
  - Q-balls (extended balls of electric charge), Quirks, etc

The MoEDAL Physics Program(2)


Gerard 't Hooft


Yongmin Cho


Paul Dirac

- *Cho & Maison predicted in 1996 an Electroweak "Standard Model" Monopole with charge twice the Dirac Charge*
- *The Cho monopole is a hybrid between the Dirac monopole and the 't Hooft-Polyakov monopole*
- *Recently the mass of this monopole has been estimated (Y.M. Cho, Ky. Kimm, J.H. Yoon. Dec 2012. 4 pp. e-Print: arXiv: 1212.3885 [hep-ph]) to be detectable at the LHC.*
  - *Mass in the range 4→7 GeV/c^2*

The First MoEDAL Physics Workshop

International Journal of High-Energy Physics

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Aug 23, 2012

MoEDAL looks to the discovery horizon

't Hooft

MoEDAL, the "magnificent seventh" LHC experiment, held its first Physics Workshop in CERN's Globe of Science and Innovation on 20 June. This youngest LHC experiment is designed to search for the appearance of new physics signified by highly ionizing particles such as magnetic monopoles and massive long-lived electrically charged particles from a number of theoretical scenarios.

Philippe Bloch of CERN commenced the meeting, stressing CERN's support for the MoEDAL programme. He spoke of the key role that smaller, well motivated "high-risk" experiments such as MoEDAL play in expanding the physics reach of the LHC and reminded the audience that "one cannot predict with certainty where the next discovery will

The MoEDAL Collaboration Today

1) *UNIVERSITY OF ALBERTA, CANADA - M. de Montigny, J. L. Pinfold, R. Soluk, J. Soukup*
2) *UNIVERSITY OF BOLOGNA, ITALY - S. Cecchini, G. Giacomelli, M. Giorgini, L. Patrizii, G. Sirri, V. Togo*
3) *UNIVERSITY OF BRITISH COLUMBIA, CANADA - G. Semenoff*
4) *CERN, SWITZERLAND - M. Campbell, D. Lacarrére, Albert de Roeck*
5) *THE UNIVERSITY OF CINCINNATI, Ohio, USA - K. Kinoshita*
6) *CONCORDIA UNIVERSITY, Montreal, Quebec, CANADA – M. Frank*
7) *CZECH TECHNICAL UNIVERSITY IN PRAGUE (IEAP) - Jakůbek, M. Platkevič, Stanislav Pospíšil, Z. Vykydal*
8) *UNIVERSITÉ DE GENÈVE, Geneva, Switzerland - P. Mermod, A. Katre*
9) *DESY, Hamburg, GERMANY - T. Hott*
10) *UNIVERSITY OF HELSINKI, Helsinki, Finland - R. Orava*
11) *IMPERIAL COLLEGE LONDON, England, UK - A. Rajantie*
12) *KING'S COLLEGE LONDON, England, UK - J. Ellis, N. Mavromatos, M. Fairbairn*
13) *KONKUK UNIVERSITY, Seoul, Korea - Y. Cho, J K Yoon*
14) *UNIVERSITY OF MÜNSTER, Münster, Westphalia, Germany - D. Frekers*
15) *NORTHEASTERN UNIVERSITY, Boston, Mass., USA - J. Swain, A. Widom*
16) *INSTITUTE FOR SPACE SCIENCES, Bucharest ROMANIA - D. Felea, D. Haşegan, G. E. Păvălaş, V.Popa*
17) *TUFT'S UNIVERSITY, Boston, Massachusetts, USA - K. Sliwa*
18) *IFIC VALÈNCIA, SPAIN - José Bernabéu, Vasiliki A. Mitsou, Vicente Vento, Oscar Vives*
19) *YORK UNIVERSITY, Toronto, Ontario, CANADA - V. Sanz*

The New Faces Since 2012 Report

Imperial Coll., UK.

Concordia, Canada

York U., Canada

UBC, Canada

Konkuk U., Korea

Tuft's U. USA

Alberta U., Canada

Helsinki U. Finland

----------IFIC Valencia----------

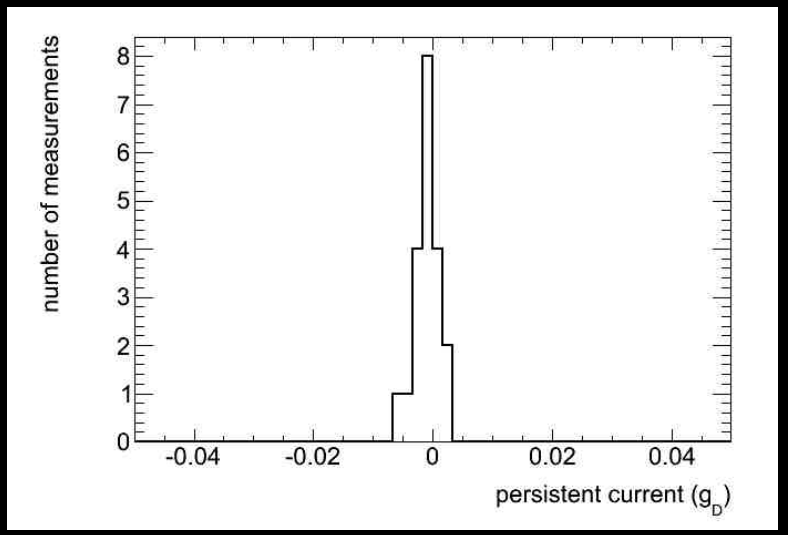
*****12 new physicists and 8 new institutes*****

-Lol's from: Upsala, Sweden; NIT, India; Langton Star Centre, UK-

Analyzing & Calibrating the NTDs

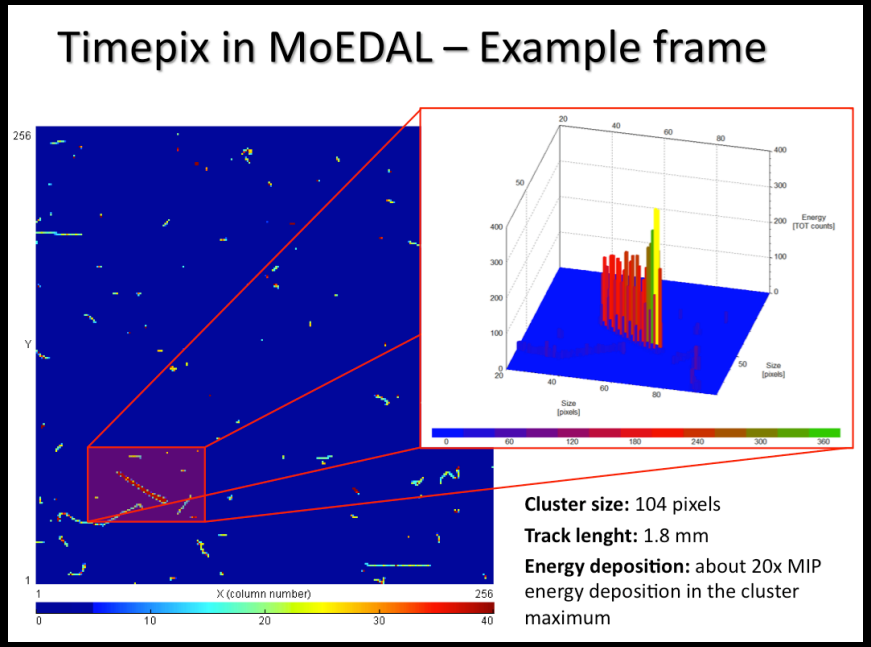
- *We exposed MoEDAL plastic in 2012 & 2013 at BNL's NSRL facility using a heavy ion (Fe) beam of 1 GeV/nucleon.*
  - *The exposures were used to calibrate plastic and to make test samples for the study of signal extraction in the presence of background.*
- *The Jan 2011 test deployment (~80m^2) of NTDs, was removed prior to the p-Pb run in 2013 This plastic is now being analyzed.*
- *Fresh plastic was deployed for the 2013 p-Pb run.*

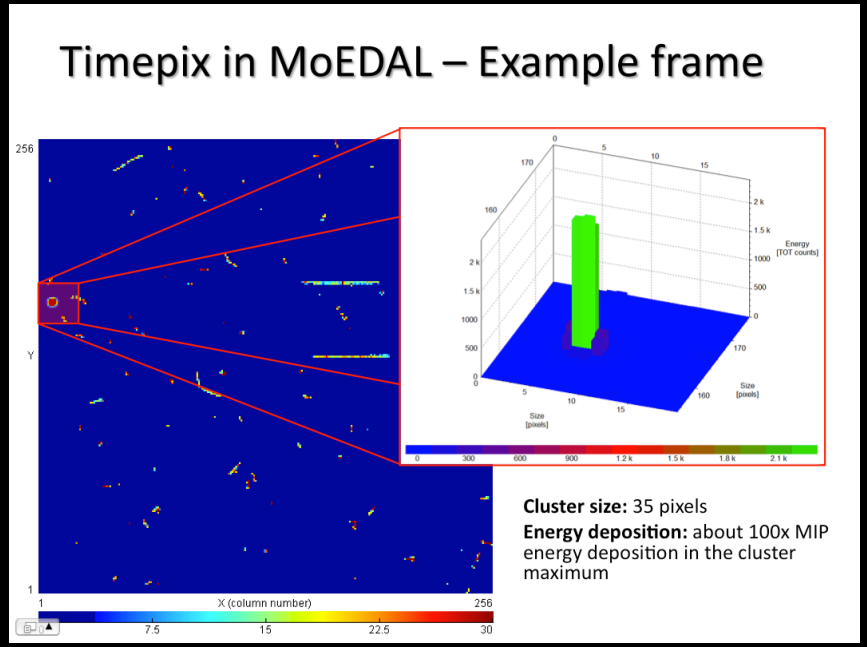
Analyzing the MMT Exposure



- *Test Deployment of 11 boxes of MMT sub-detector were made in Sept. 2012*
  - *Test samples we made and analyzed using the ETH SQUID magnetometer to ascertain the sensitivity of the SQUID – found to be better than ± 0.01 g_d (g_d - Dirac magnetic charge) – see above.*
  - *All of the boxes of the test MMT detector were exposed and have now been removed – in July 2013 the whole sample will be cut and passed through the SQUID*

The TimePix Radiation Monitor Test Deployment – Data Being Analyzed





- *Interesting 1st results from the test TimePix chip deployment in Feb. 2012*
- *Many interesting pictures of highly ionizing "blobs" & "tracks"*
- *Scanning and calibration studies are in progress.*

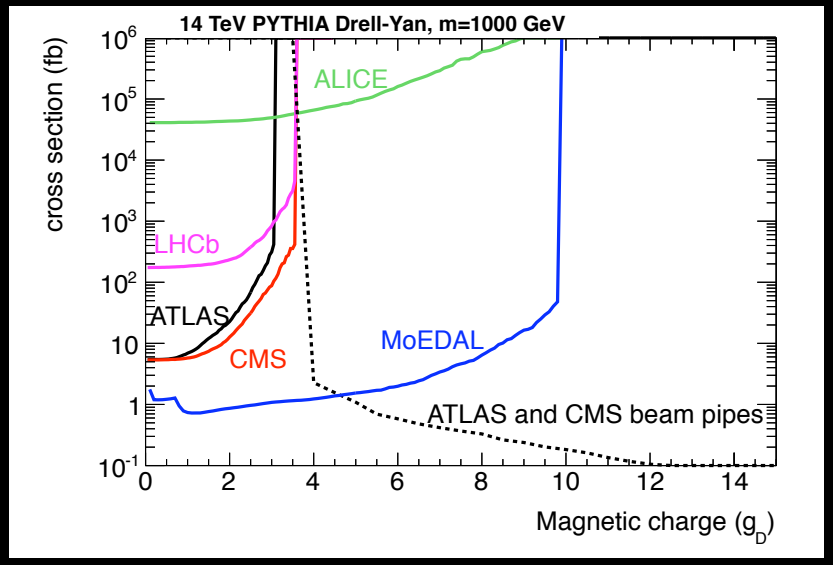
Publications in Progress for 2013

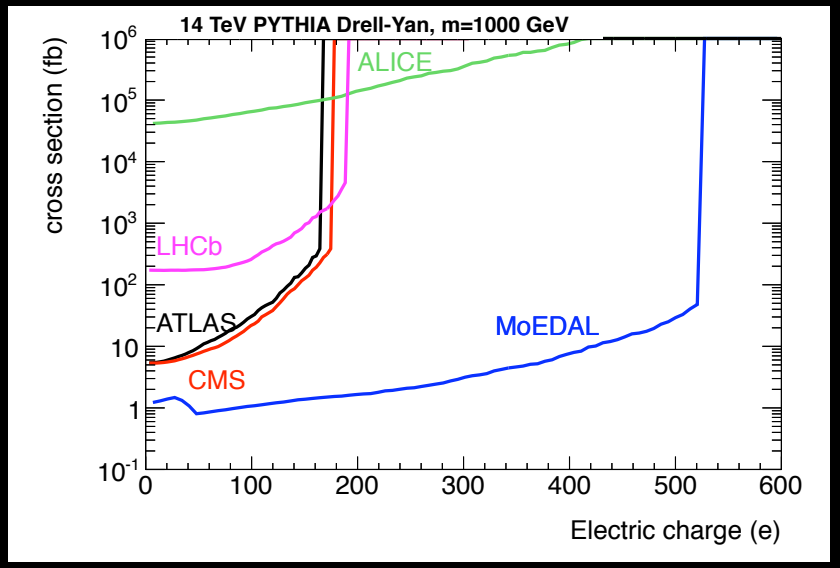
1. *The MoEDAL Physics Program (IJMPA) – nearing completion, The MoEDAL Experiment at the LHC (Contemporary Physics) – in draft, ready in 2013*
2. *Search for Magnetic Monopole Production at Ecm 7-8 TeV obtained from MoEDAL NTD Test Deployment - data collected*
3. *Search for on Magnetic Monopole Production at Ecm 7-8 TeV obtained from MoEDAL MMT Test Deployment – data collected*
4. *The MOEDAL Detector (NIMA) – in preparation*

The MoEDAL Summary & Timescale

- *First detectors (10 sqm of plastic) deployed in Nov. 2009)*
- *VHCC detector concept introduced in Dec 2011 to improve acceptance for VHIPs*
- *We deployed ~80 m^2 of plastic in Jan. 2011 – removed for analysis late 2012*
- *Test deployment of TimePix detectors in Feb. 2012 – data under study*
- *Test Deployment of MMT sub-detector in Sept. 2012 - removed for analysis late 2012*
- *Placing of plastic in Dec. 2012 for p-Pb run*
- *Full MoEDAL detector deployment will take place in 2014*
- *In 2015 expect to have our first "official" run to be continued until we reach a ΣL of ≥ ~10fb^{-1} at 14 TeV.*

MoEDAL Sensitivity





- *Cross-section limits for magnetic (LEFT) and electric charge (RIGHT) (**arXiv:1112.2999V2** [hep-ph]) assuming:*
  - *One MoEDAL event only needed for discovery & precise calibrated measurement of effective charge (<0.01e) with 20 (NTD)/6(VHCC) measurements for each candidate*
    - *As the other LHC detectors are not calibrated or optimized for VHIPS assume at least 100 events required to make similar claim.*
  - *Only MoEDAL has the facility to measure magnetic charge directly*