MOEDAL AT THE LHC

A NEW LIGHT ON THE TEV FRONTIER

DISCRETE 2014

KING'S COLLEGE LONDON

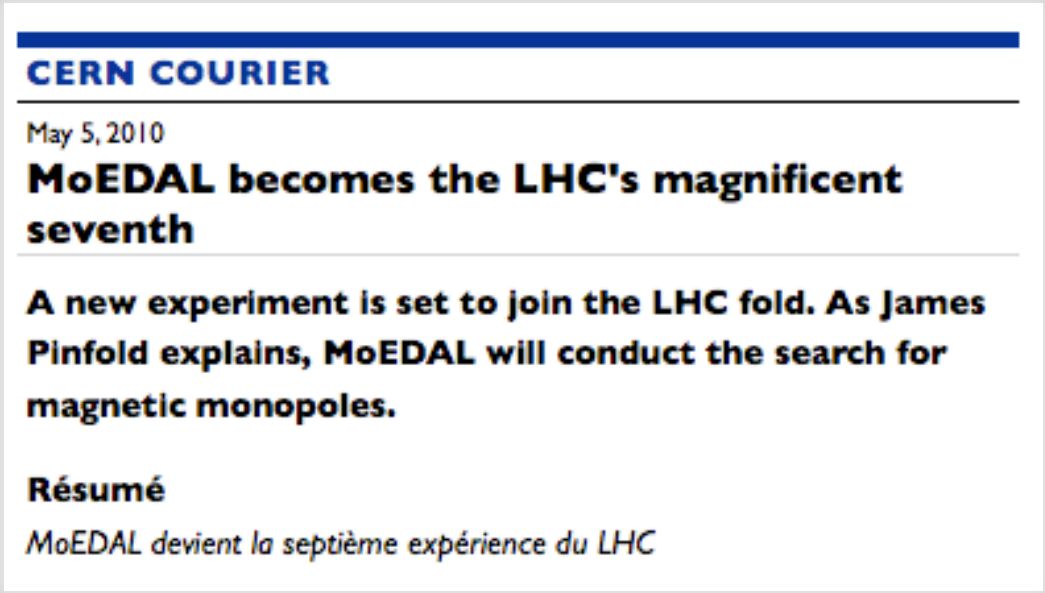
JAMES PINFOLD

UNIVERSITY COLLEGE LONDON

Talk is Not Specifically About Discrete Sym.

MoEDAL the 7th LHC Experiment

AIM: The search for the highly ionizing particle avatars of New Physics with magnetic and/or electric charge



CERN COURIER

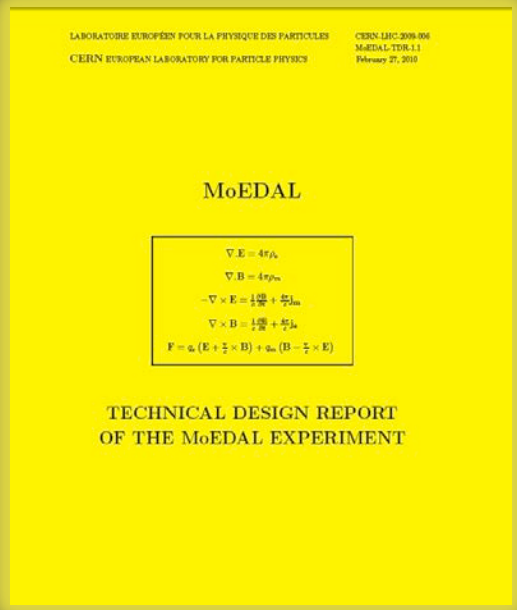
May 5, 2010

MoEDAL becomes the LHC's magnificent seventh

A new experiment is set to join the LHC fold. As James Pinfold explains, MoEDAL will conduct the search for magnetic monopoles.

Résumé

MoEDAL devient la septième expérience du LHC



LABORATOIRE EUROPÉEN POUR LA PHYSIQUE DES PARTICULES
CERN EUROPEAN LABORATORY FOR PARTICLE PHYSICS

CERN-LHC-2009-006
MoEDAL-TDR-1.1
February 27, 2010

MoEDAL

$$\nabla \cdot E = 4\pi\rho_e$$
$$\nabla \cdot B = 4\pi\rho_m$$
$$-\nabla \times E = \frac{1}{c}\frac{\partial B}{\partial t} + \frac{4\pi}{c}j_m$$
$$\nabla \times B = \frac{1}{c}\frac{\partial E}{\partial t} + \frac{4\pi}{c}j_e$$
$$F = q_e\left(E + \frac{v}{c} \times B\right) + g_m\left(B - \frac{v}{c} \times E\right)$$

TECHNICAL DESIGN REPORT
OF THE MoEDAL EXPERIMENT

- *In September 2009 the Large Hadron Collider Committee (LHCC), accepted the MoEDAL Technical Design Report.*
  - *The CERN Research Board (CRB) unanimously approved the MoEDAL during their 190th meeting on December 3rd 2009.*

THE MAGNIFICENT SEVENTH

They fought on the high energy frontier

ATLAS
STEVE MCQUEEN

JAMES COBURN
"BRITT"
CMS

LHCb
HORST BUCHHOLZ
"CHICO"

YUL BRYNNER
"CHRIS ADAMS"
ALICE

TOTEM
BRAD DEXTER
"HARRY LUCK"

ROBERT VAUGHN
"LEE"
LHCf

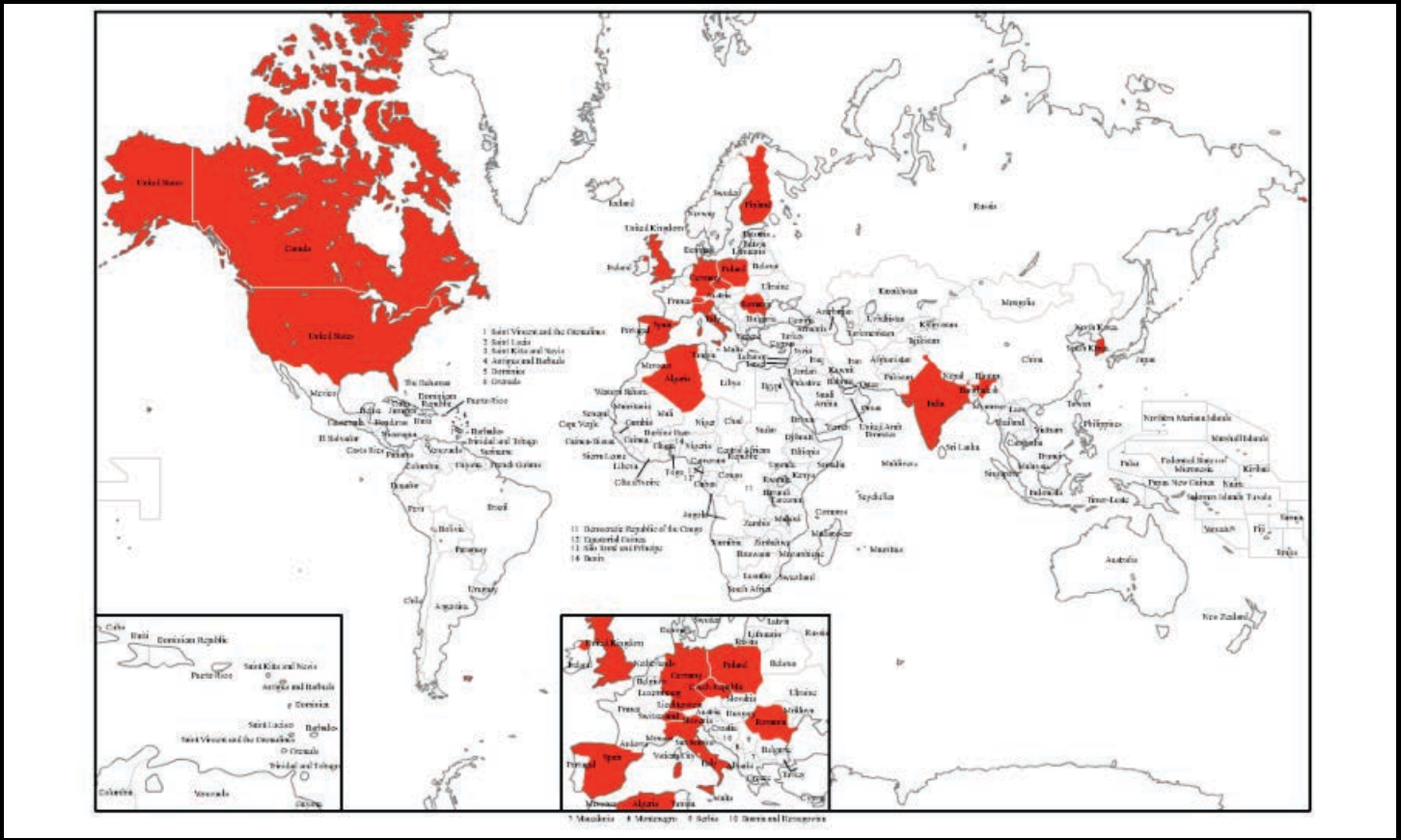
MoEDAL
CHARLES BRONSON
"BERNARDO O'REILLY"

MoEDAL: The Magnificent 7th LHC Experiment

Extensive data from test deployments has already been taken and being analyzed

MoEDAL is now being installed and will start to take data in p-p and p-A running at 13-14 TeV in 2015

The MoEDAL Collaboration

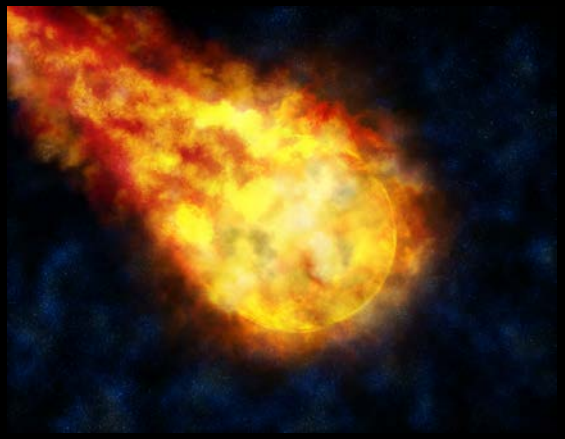


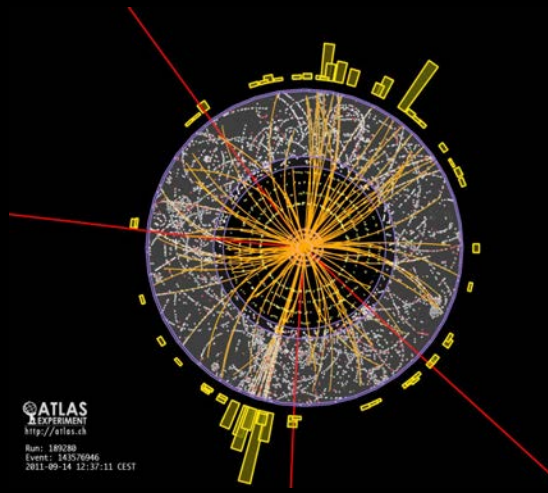
66 physicists from 14 countries & 23 institutions on 4 continents:

U. Alberta, UBC, INFN Bologna, U. Bologna,CAAG (Algeria), Algeria U. Cincinatti, Concordia U., CSIC Valencia, DESY, Gangneung-Wonju Nat. U., U. Geneva, U. Helsinki, ICTP Trieste, IEAP/CTU Prague, IFIC Valencia, Imperial College London, INP/PAS Cracow, ISS Bucharest, King's College London, Konkuk U., Muenster U., National Inst. Tec. (india),Northeastern U., Simon Langton School UK, Tuft's. (Stanford University is the latest (associate) member of MoEDAL)

Highly Ionizing Particles – Avatars of New Physics

Avatar [av-uh-tahr]: An incarnation, embodiment, or manifestation of a person or idea:





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

ATLAS & CMS – New physics largely reconstructed from SM particles – large SM backgrounds

The Ways to get High Ionization

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

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

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

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

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

- *The ionization of a relativistic monopole is $(ng)^2$ times that of a relativistic proton i.e $4700n^2$!! (n=1,2,3…)*

The MoEDAL Physics Program

Physics Program (34 Scenarios)

arXiv:1405.7662v3 [hep-ph] 26th Jul 2014

arXiv.org > hep-ph > arXiv:1405.7662

Search or Article-id

High Energy Physics - Phenomenology

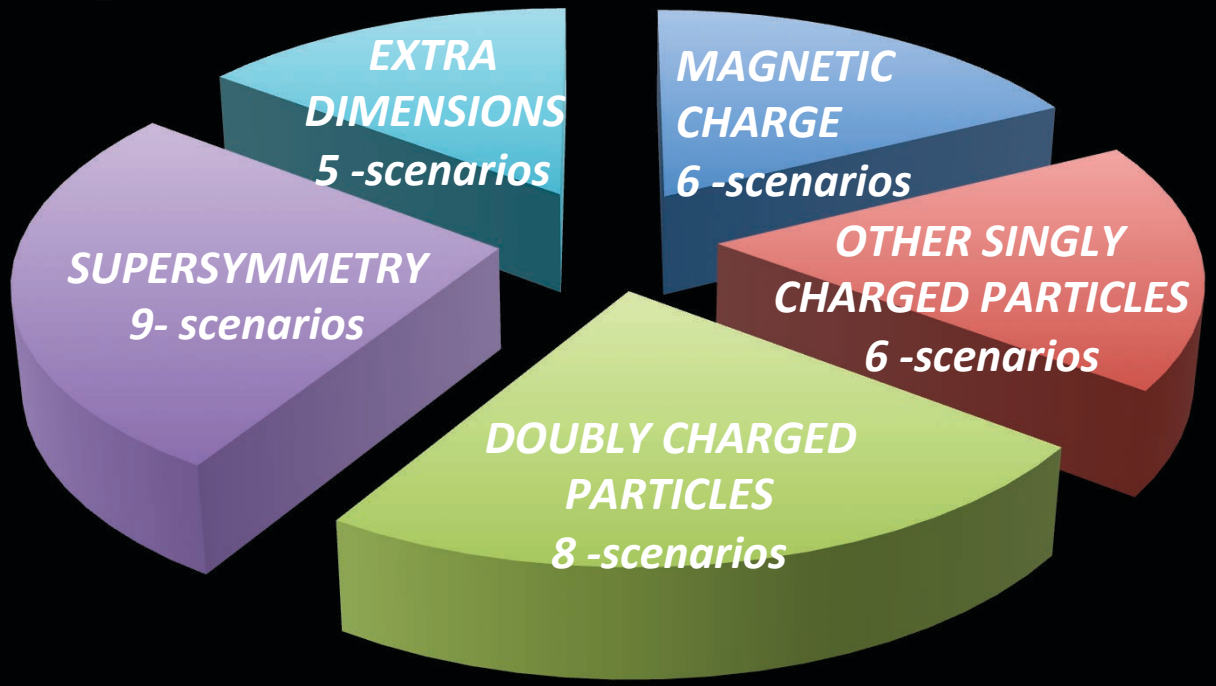
The Physics Programme Of The MoEDAL Experiment At The LHC

B. Acharya, J. Alexandre, J. Bernabéu, M. Campbell, S. Cecchini, J. Chwastowski, M. De Montigny, D. Derendarz, A. De Roeck, J. R. Ellis, M. Fairbairn, D. Felea, M. Frank, D. Frekers, C. Garcia, G. Giacomelli, M. Giorgini, D. HaŞegan, T. Hott, J. Jakůbek, A. Katre, D-W Kim, M.G.L. King, K. Kinoshita, D. Lacarrere, S. C. Lee, C. Leroy, A. Margiotta, N. Mauri, N. E. Mavromatos, P. Mermod, V. A. Mitsou, R. Orava, L. Pasqualini, L. Patrizii, G. E. Păvălaş, J. L. Pinfold, M. Platkevč, V. Popa, M. Pozzato, S. Pospisil, A. Rajantie, Z. Sa... M. Sakellariadou, S. Sarkar, G. Semenoff, G. Sirri, K. Sliwa, R. Soluk, M. Spurio, Y.N. Srivastava, R. Staszewski, J. Swain, M. Tenti, V. Togo, M. Trzebinski... Vykydal, A. Widom, et al. (1 additional author not shown)

(Submitted on 29 May 2014 (v1), last revised 15 Jul 2014...

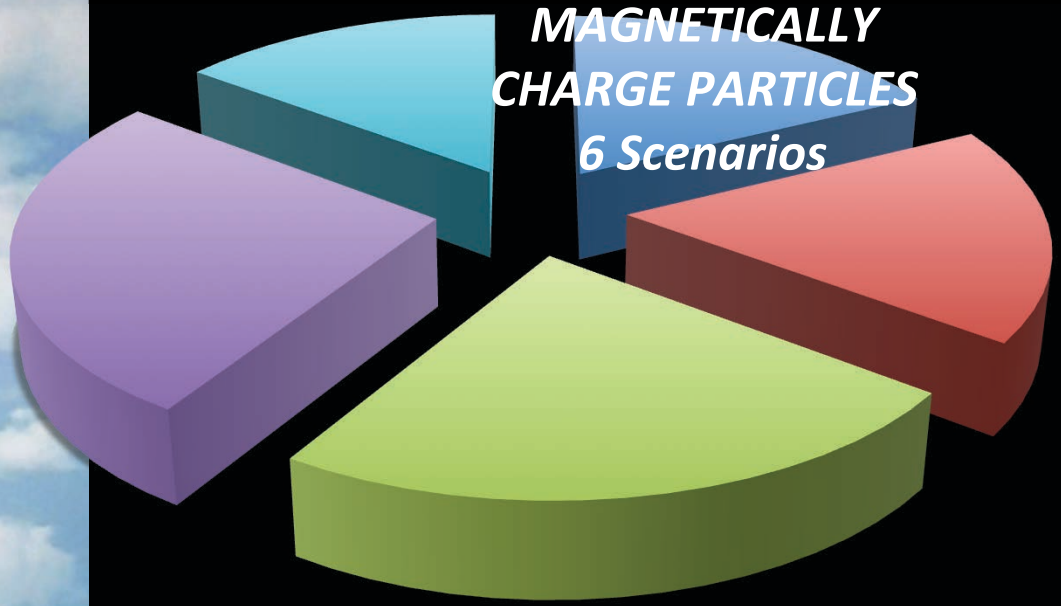
The MoEDAL experiment at ... the Standard Model, extending significantly the di... MoEDAL is an unconventional and largely passive LHC dete... on the LHC ring. Another novel feature is the use of p... includes an array of TimePix pixel devices for mo... a trigger system, electronic readout, or online computerized data acquisitio... complementary to the programs of the large multi-purpose LHC detectors ATLAS and CMS.

JUST PUBLISHED (September 9th 2014)
International Journal of Modern Physics A Vol. 29, No. 23 (2014) 1430050 (91pages)



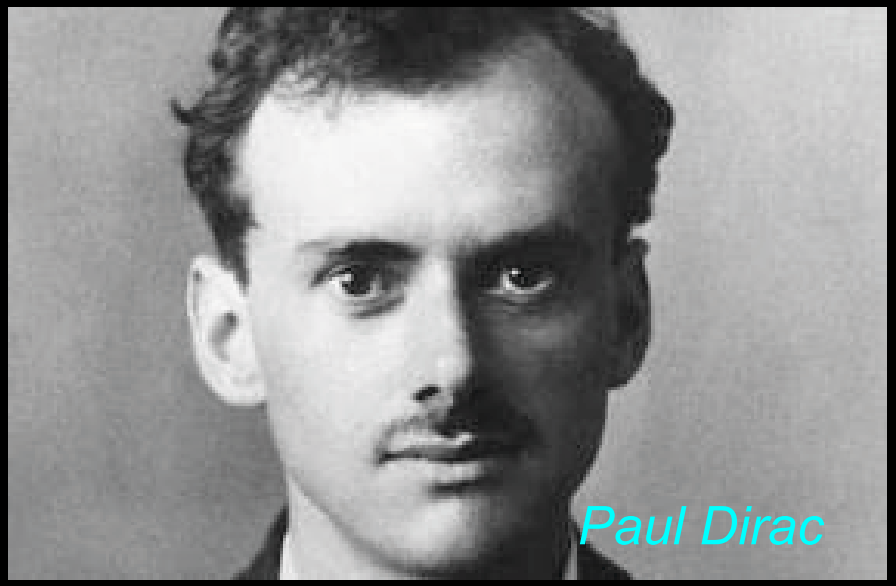
Massive "Stable" Electrically Charged Particles

6 SCENARIOS



- *Dyons/Monopoles in general*
- *Electroweak Monopole*
- *Electroweak strings*
- *Light 't Hooft-Polyakov monopoles*
- *Monopolium*
- *D-particles*

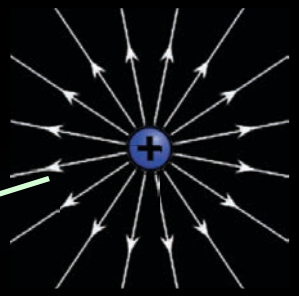
The Monopole is MoEDAL's Higgs



- *Just as the general purpose experiments ATLAS & CMS have as their prime physics purpose the discovery and elucidation of the Higgs……*
- *….Then the equivalent "benchmark" physics process for MoEDAL is the magnetic monopole production – thus we shall concentrate more on this topic due to time constraints*
- *But ATLAS, CMS and MoEDAL can do much more!*

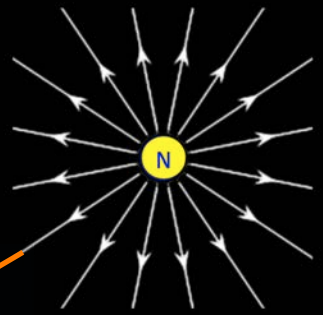
Monopoles Symmetrize Maxwell's Eqns

$$\vec{\nabla}\cdot\vec{E} = \rho_{\mathrm{E}}$$
$$\vec{\nabla}\cdot\vec{B} = 0$$
$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t}$$
$$\vec{\nabla}\times\vec{B} = \frac{\partial\vec{E}}{\partial t} + \vec{j}_{\mathrm{E}}$$



ELECTRIC CHARGE

$$\vec{\nabla}\cdot\vec{E} = \rho_{\mathrm{E}}$$
$$\vec{\nabla}\cdot\vec{B} = \rho_{\mathrm{M}}$$
$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} - \vec{j}_{\mathrm{M}}$$
$$\vec{\nabla}\times\vec{B} = \frac{\partial\vec{E}}{\partial t} + \vec{j}_{\mathrm{E}}$$

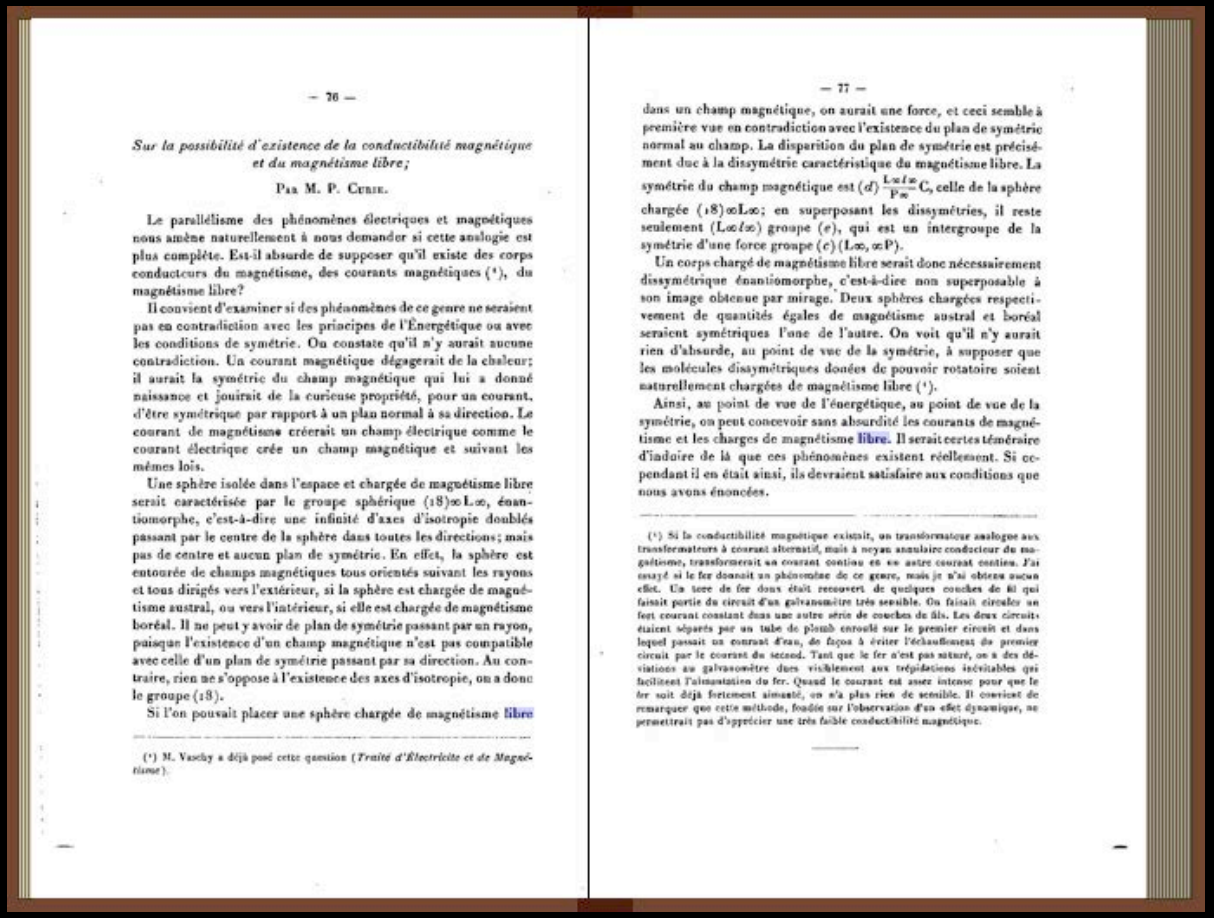


MAGNETIC CHARGE

- *The symmetrized Maxwell's equations are invariant under rotations in the plane of the electric and magnetic field*
- *This symmetry is called Duality - the distinction between electric and magnetic charge is merely one of definition*
- *SEE VERY NICE TALK BY ARTTU RAJANTIE ON THE FIELD THEORY OF MAGNETIC MONOPOLES (Thursday parallel-9)*

150th Anniversary of Maxwell's Equations

Maxwell's Asymmetric Equations



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Sur la possibilité d'existence de la conductibilité magnétique et du magnétisme libre;

PAR M. P. CURIE.

Le parallélisme des phénomènes électriques et magnétiques nous amène naturellement à nous demander si cette analogie est plus complète. Est-il absurde de supposer qu'il existe des corps conducteurs du magnétisme, des courants magnétiques (1), du magnétisme libre?

Il convient d'examiner si des phénomènes de ce genre ne seraient pas en contradiction avec les principes de l'Énergétique ou avec les conditions de symétrie. On constate qu'il n'y aurait aucune contradiction. Un courant magnétique dégagerait de la chaleur; il aurait la symétrie du champ magnétique qui lui a donné naissance et jouirait de la curieuse propriété, pour un courant, d'être symétrique par rapport à un plan normal à sa direction. Le courant de magnétisme créerait un champ électrique comme le courant électrique crée un champ magnétique et suivant les mêmes lois.

Une sphère isolée dans l'espace et chargée de magnétisme libre serait caractérisée par le groupe sphérique $(18)\infty L\infty$, énantiomorphe, c'est-à-dire une infinité d'axes d'isotropie doublés passant par le centre de la sphère dans toutes les directions; mais pas de centre et aucun plan de symétrie. En effet, la sphère est entourée de champs magnétiques tous orientés suivant les rayons et tous dirigés vers l'extérieur, si la sphère est chargée de magnétisme austral, ou vers l'intérieur, si elle est chargée de magnétisme boréal. Il ne peut y avoir de plan de symétrie passant par un rayon, puisque l'existence d'un champ magnétique n'est pas compatible avec celle d'un plan de symétrie passant par sa direction. Au contraire, rien ne s'oppose à l'existence des axes d'isotropie, on a donc le groupe (18).

Si l'on pouvait placer une sphère chargée de magnétisme libre

(1) M. Vaschy a déjà posé cette question (*Traité d'Électricité et de Magnétisme*).

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dans un champ magnétique, on aurait une force, et ceci semble à première vue en contradiction avec l'existence du plan de symétrie normal au champ. La disparition du plan de symétrie est précisément due à la dissymétrie caractéristique du magnétisme libre. La symétrie du champ magnétique est $(d)\ \frac{L\infty I\infty}{P\infty}C$, celle de la sphère chargée $(18)\infty L\infty$; en superposant les dissymétries, il reste seulement $(L\infty I\infty)$ groupe (e), qui est un intergroupe de la symétrie d'une force groupe (c) $(L\infty, \infty P)$.

Un corps chargé de magnétisme libre serait donc nécessairement dissymétrique énantiomorphe, c'est-à-dire non superposable à son image obtenue par mirage. Deux sphères chargées respectivement de quantités égales de magnétisme austral et boréal seraient symétriques l'une de l'autre. On voit qu'il n'y aurait rien d'absurde, au point de vue de la symétrie, à supposer que les molécules dissymétriques douées de pouvoir rotatoire soient naturellement chargées de magnétisme libre (1).

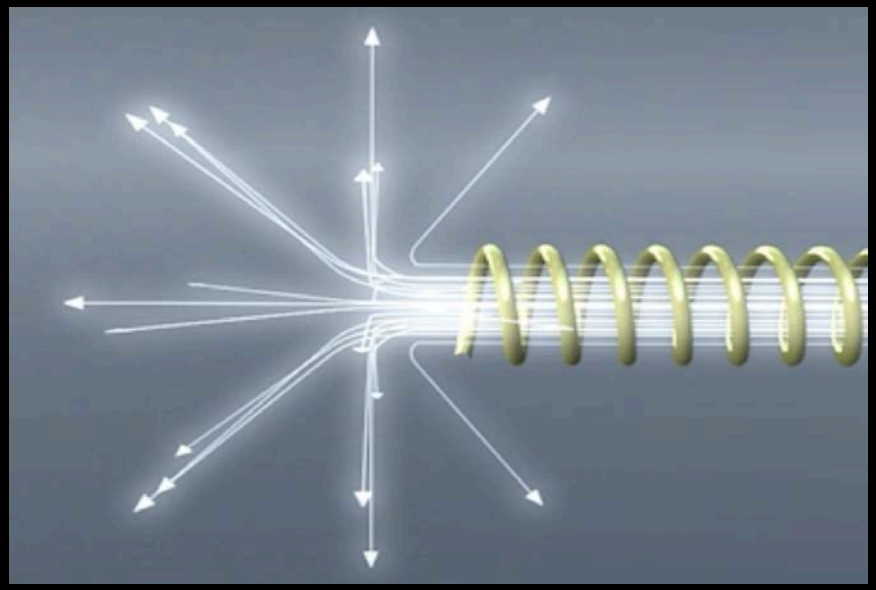
Ainsi, au point de vue de l'énergétique, au point de vue de la symétrie, on peut concevoir sans absurdité les courants de magnétisme et les charges de magnétisme libre. Il serait certes téméraire d'induire de là que ces phénomènes existent réellement. Si cependant il en était ainsi, ils devraient satisfaire aux conditions que nous avons énoncées.

(1) Si la conductibilité magnétique existait, un transformateur analogue aux transformateurs à courant alternatif, mais à noyau annulaire conducteur du magnétisme, transformerait un courant continu en un autre courant continu. J'ai essayé si le fer donnait un phénomène de ce genre, mais je n'ai obtenu aucun effet. Un tore de fer doux était recouvert de quelques couches de fil qui faisait partie du circuit d'un galvanomètre très sensible. On faisait circuler un fort courant constant dans une autre série de couches de fils. Les deux circuits étaient séparés par un tube de plomb enroulé sur le premier circuit et dans lequel passait un courant d'eau, de façon à éviter l'échauffement du premier circuit par le courant du second. Tant que le fer n'est pas saturé, on a des déviations au galvanomètre dues visiblement aux trépidations inévitables qui facilitent l'aimantation du fer. Quand le courant est assez intense pour que le fer soit déjà fortement aimanté, on n'a plus rien de sensible. Il convient de remarquer que cette méthode, fondée sur l'observation d'un effet dynamique, ne permettrait pas d'apprécier une très faible conductibilité magnétique.

- *Pierre Curie was the 1st to suggest that we should search Monopoles (Seances, Société Française de Physique, 1894)*

120th Anniversary of the Magnetic Monopole

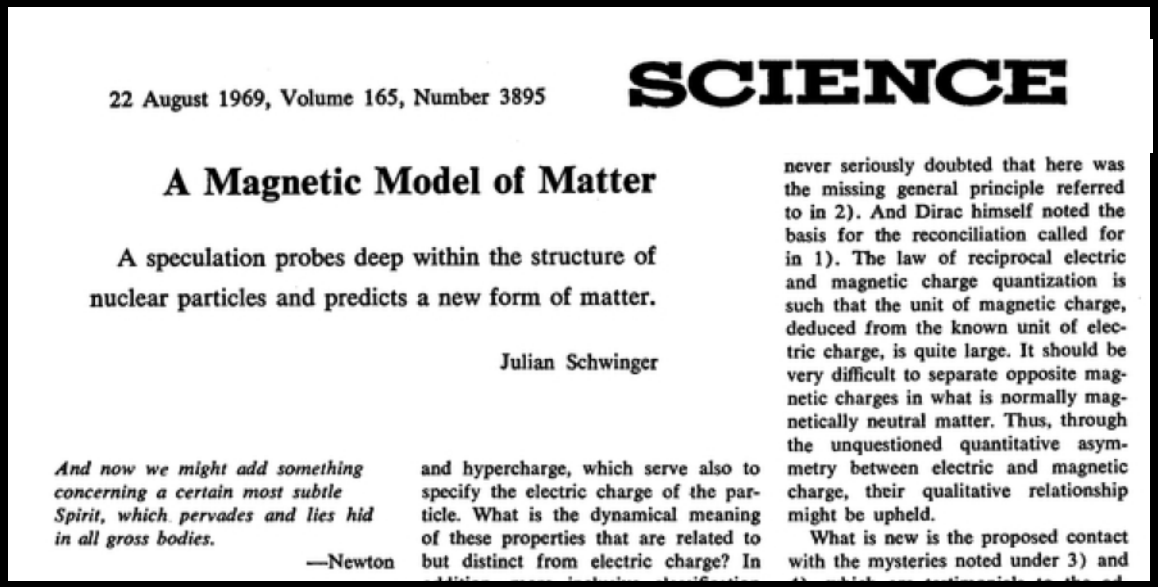
Dirac's Monopole



- *In 1931 Dirac hypothesized that the Monopole exists as the end of an infinitely long and thin solenoid - the "Dirac String"*
- *Requiring that the string is not seen gives us the Dirac Quantization Condition & explains the quantization of charge!*

$$ge = \left[\frac{\hbar c}{2}\right] n \quad OR \quad g = \frac{n}{2\alpha} e \quad (from \quad \frac{4\pi eg}{\hbar c} = 2\pi n \quad n = 1,2,3..)$$

Schwinger's Dyon



22 August 1969, Volume 165, Number 3895 **SCIENCE**

A Magnetic Model of Matter

A speculation probes deep within the structure of nuclear particles and predicts a new form of matter.

Julian Schwinger

And now we might add something concerning a certain most subtle Spirit, which pervades and lies hid in all gross bodies.

—Newton

and hypercharge, which serve also to specify the electric charge of the particle. What is the dynamical meaning of these properties that are related to but distinct from electric charge? In never seriously doubted that here was the missing general principle referred to in 2). And Dirac himself noted the basis for the reconciliation called for in 1). The law of reciprocal electric and magnetic charge quantization is such that the unit of magnetic charge, deduced from the known unit of electric charge, is quite large. It should be very difficult to separate opposite magnetic charges in what is normally magnetically neutral matter. Thus, through the unquestioned quantitative asymmetry between electric and magnetic charge, their qualitative relationship might be upheld.

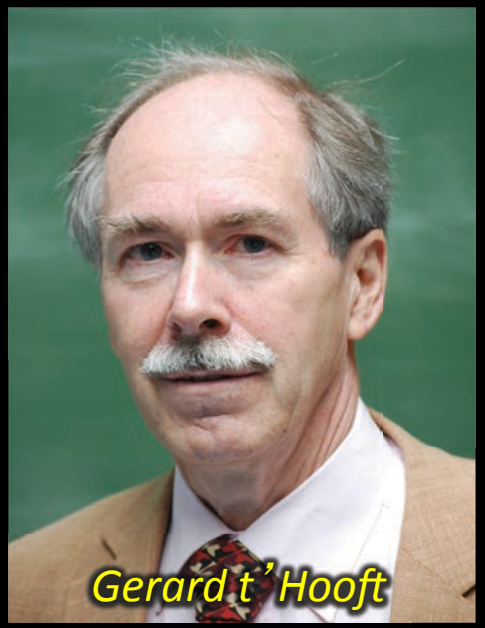
What is new is the proposed contact with the mysteries noted under 3) and

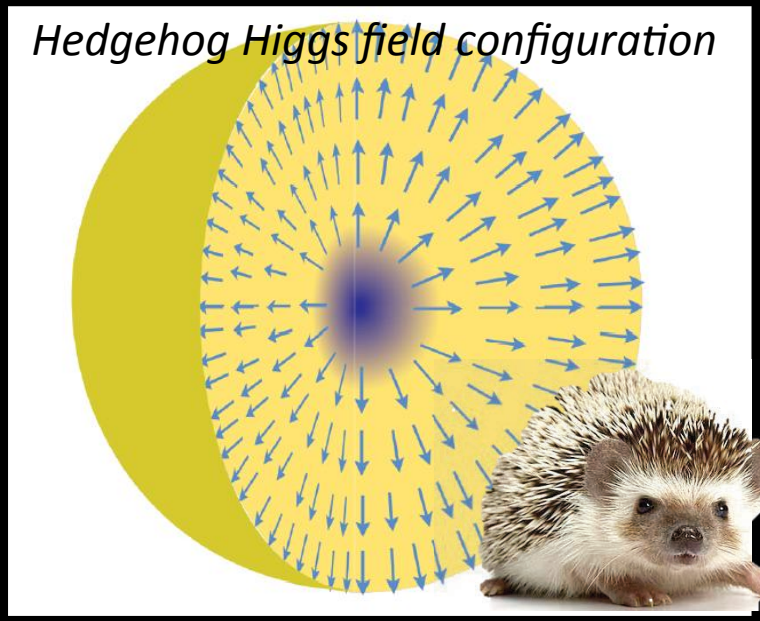
- *Postulated a "dyon" that carries electric & magnetic charge*
- *Quantisation of angular momentum with two dyons (q_{e1},q_{m1}) and (q_{e2},q_{m2}) yields*

$$(q_{e1}, q_{m1}) - (q_{e2}, q_{m2}) = 2nh/m_0 \quad (n \text{ is an integer})$$

- *Fundamental magnetic charge is now $2g_D$*
  - *If the fundamental charge is 1/3 (d-quark) as the fundamental electric charge then the fundamental magnetic charge becomes $6g_D$*

The ‘t Hooft-Polyakov Monopole

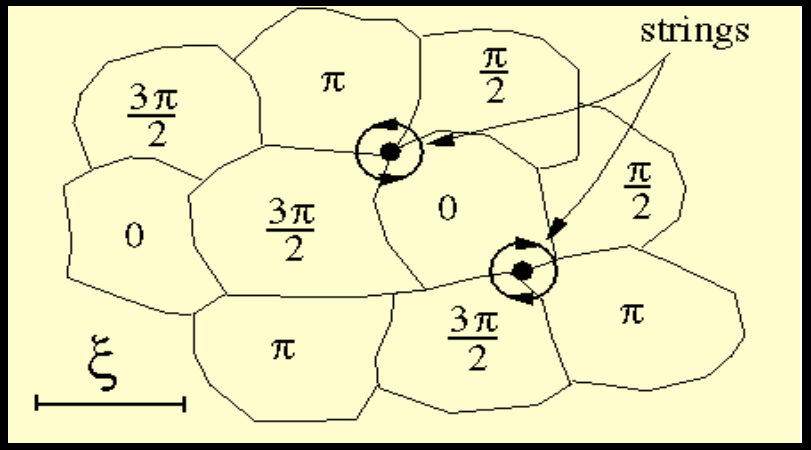


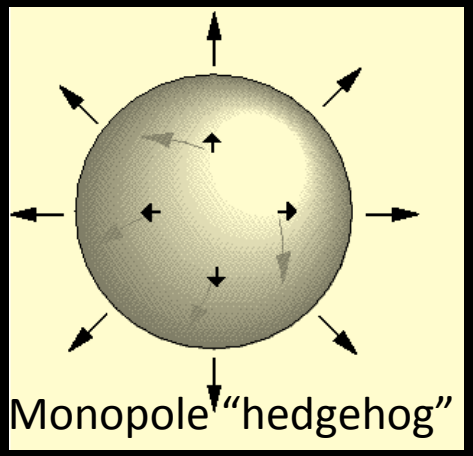


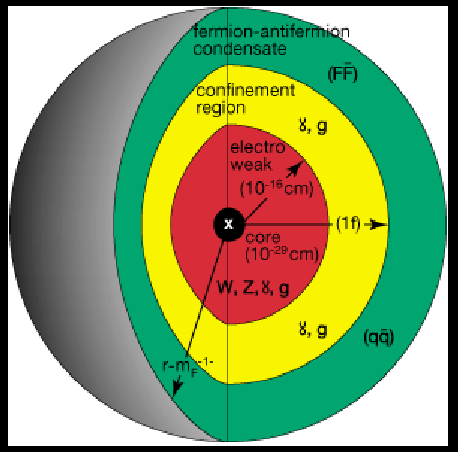
- *In 1974 ‘t Hooft and Polyakov showed that monopoles exist with the framework of Georgi-Glashow with an SO(3) gauge symmetry broken to the U(1) of EM – with charge $2g_d$*
  - *The 't Hooft and Polyakov monopole arises when the Higgs field vector points away from the origin everywhere - the “hedgehog” configuration*
  - *Such monopoles are topological solitons (stable, non dissipative, finite energy solutions) - Like a knot in the Higgs field configuration*

‘t Hooft’s & Polyakov’s Monopole 40th Birthday

The GUT Monopole



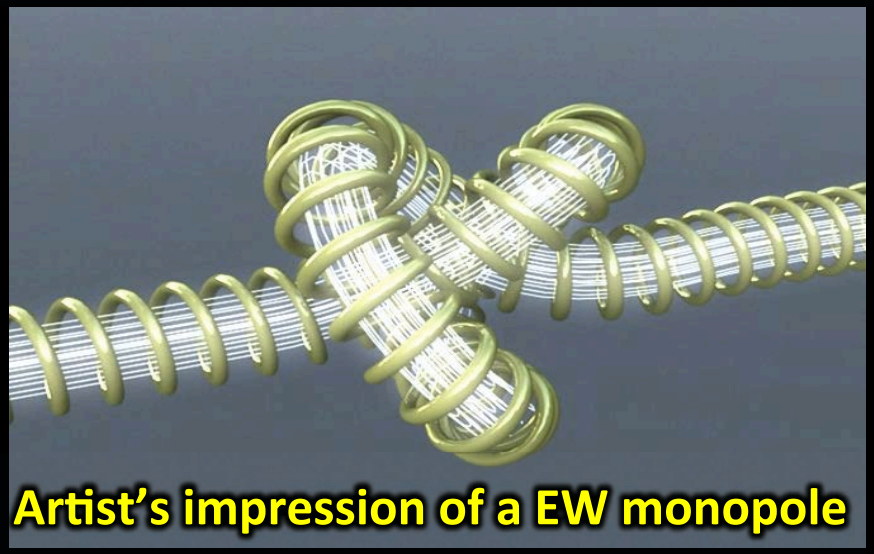




- *The structure of the SU(5) GUT is similar to the Georgi-Glashow EW theory – thus it also predicted 't Hooft-Polyakov with mass around 10^{16} GeV (or 10 ng in SI units).*
- *A symmetry-breaking GUT phase transition triggered the creation of topological defects (domain walls cosmic strings, monopoles) when the universe froze out at the GUT transition (Kibble-Zurek mechanism)*
- *GUTS+ standard cosmology leads to a monopole glut that enouraged Guth to introduce inflation to dilute their density*
- *They are obviously much too heavy to be produced on Earth*

As Usual the Greeks Were There First

The Cho-Maison Magnetic Monopole



Artist's impression of a EW monopole

Yongmin Cho

- *Yongmin Cho's pioneering paper in 1986 envisioned a spherically symmetric Electroweak Monopole, with:*
  - *Magnetic charge $2g_D$ & mass potentially in the range 4→7 GeV/c^2*
- *The Cho monopole is a non-trivial hybrid between the Dirac monopole & the 't Hooft-Polyakov monopole*
  - *His monopole arises from the Weinberg Salam model*
- *The Cho-Maison monopole would be detectable by MoEDAL*

Magnetic Monopole Properties

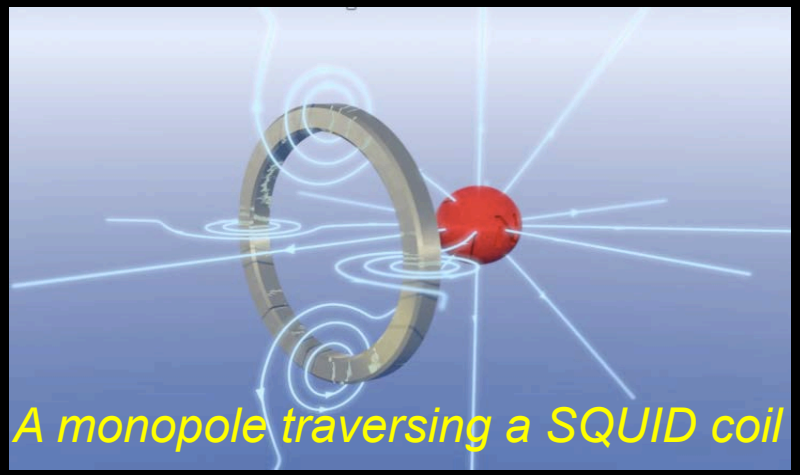
Magnetic charge = ng = n68.5e (if e→1/3e; g→3g) HIGHLY IONIZING

Coupling constant = g/ħc ~ 34. Spin ½?

Energy acquired in a magnetic field =2.06MeV/gauss.m = 2TeV in a 10m, 10T solenidal field

The monopole mass is not predicted within the Dirac's theory, ~ 4-7 TeV EW monopole

Induction Experiments - Evidence?



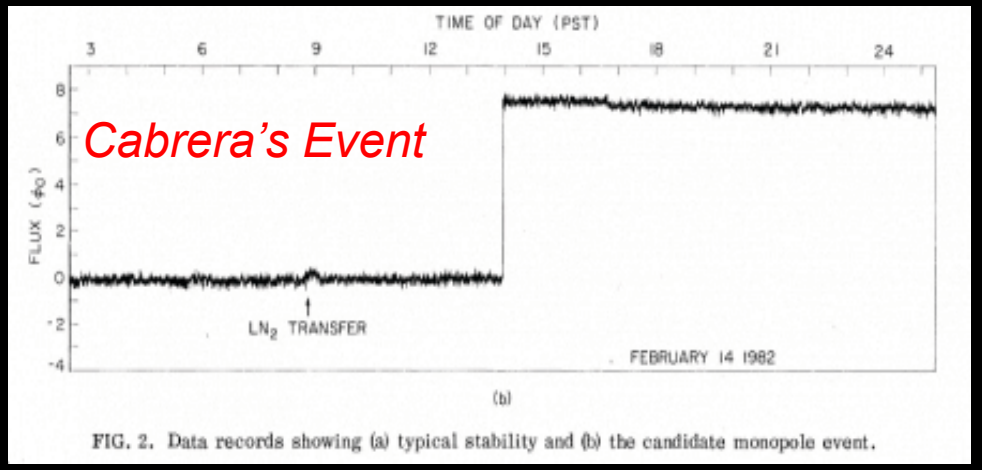
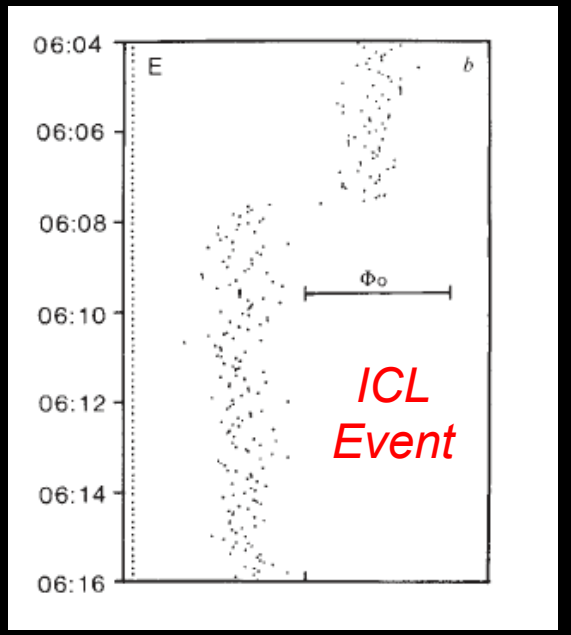


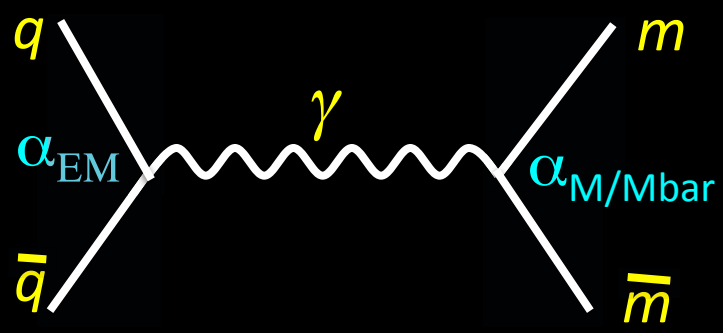
FIG. 2. Data records showing (a) typical stability and (b) the candidate monopole event.

- *Data from Cabrera's apparatus taken on St Valentine's day in 1982 (A=20 cm^2).*
  - *The trace shows a jump – just before 2pm - that one would expect from a monopole traversing the coil.*
- *In August 1985 a groups at ICL reported the:"observation of an unexplained event" compatible with a monopole traversing the detector (A= 0.18 m^2*
- *SAME TECHNOLOGY IS UTILIZED BY MoEDAL*

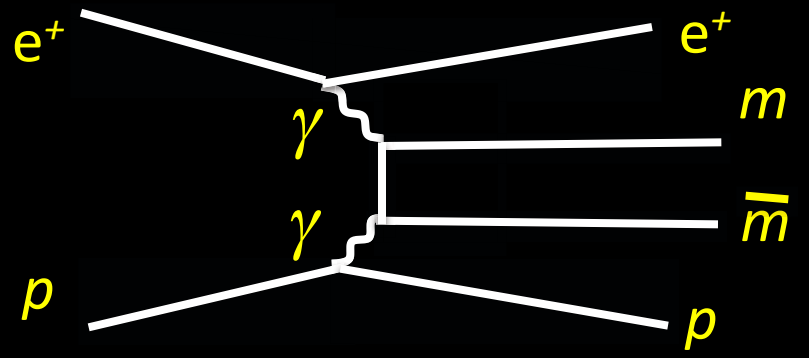


Monopole Production at Colliders

$e^+e^- \to M\bar{M}$, $pp \to M\bar{M}$, $e^+p \to e^+pM\bar{M}$, etc.

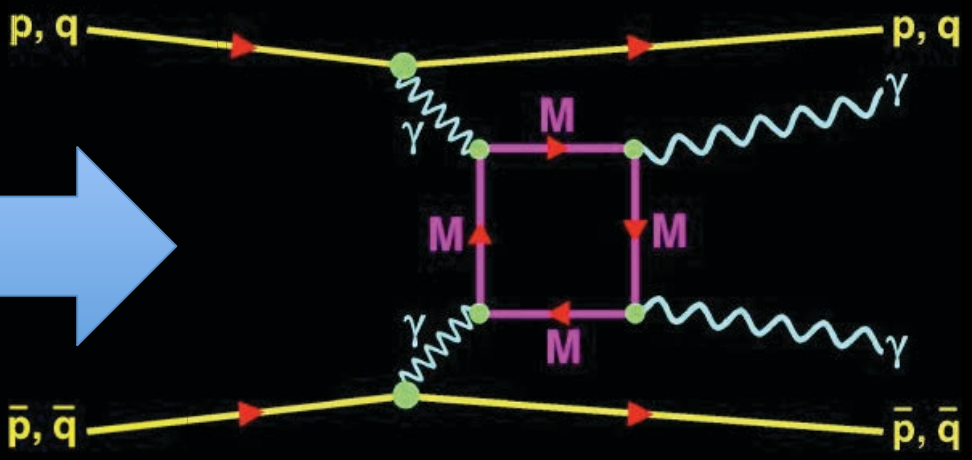


Drell-Yan Production

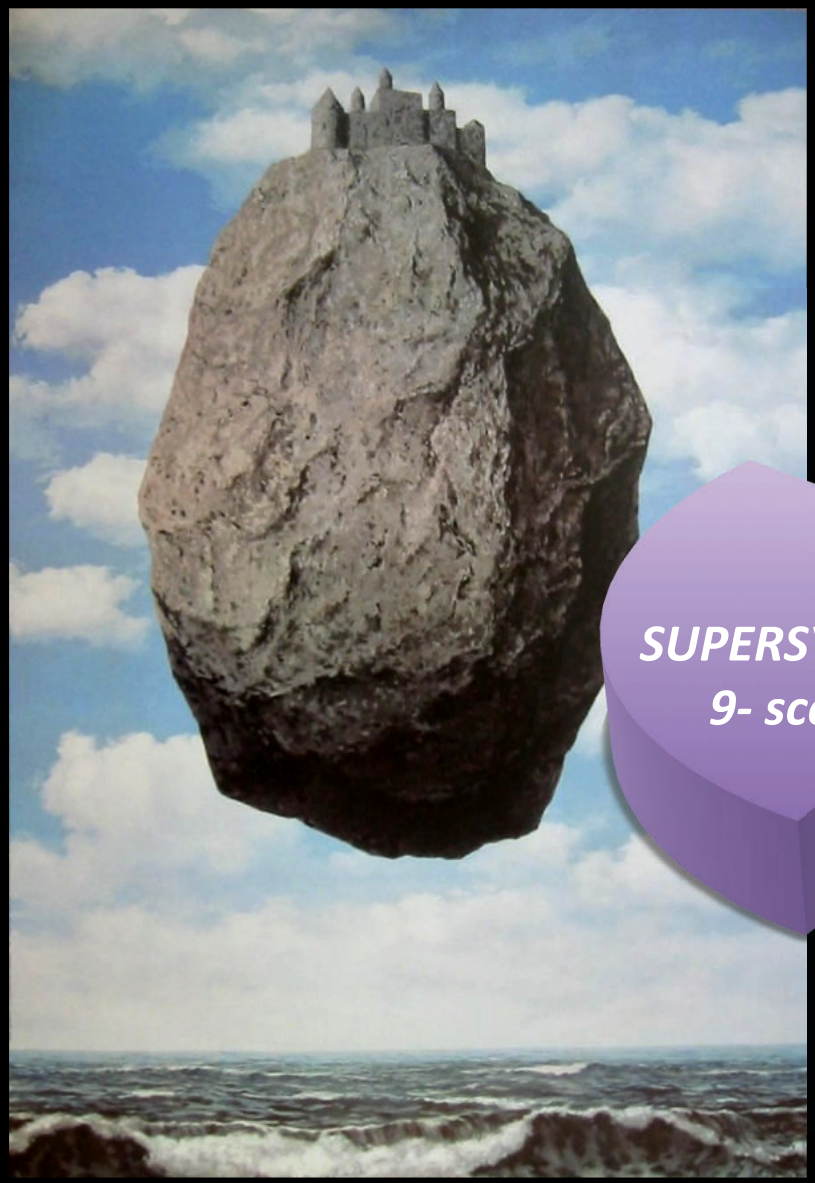


Two-photon production

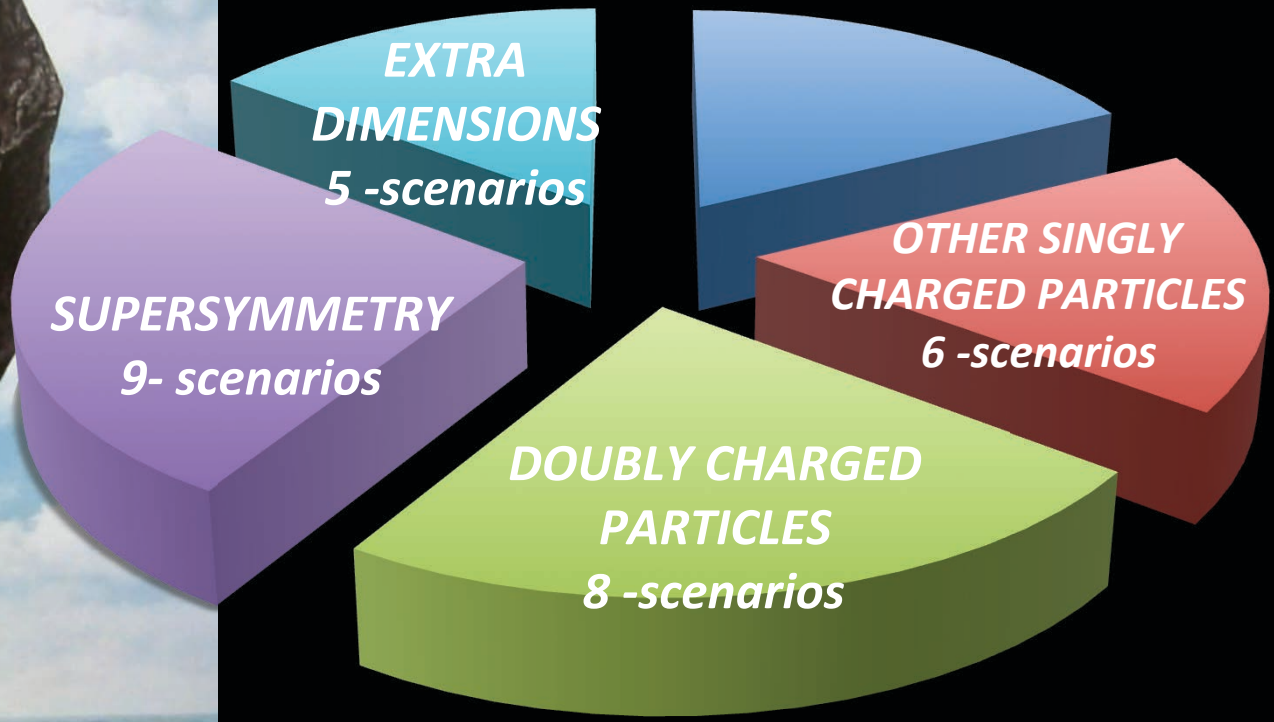
Indirect search using virtual monopole box diagrams allow – observable two high energy gammas.



Massive "Stable" Electrically Charged Particles



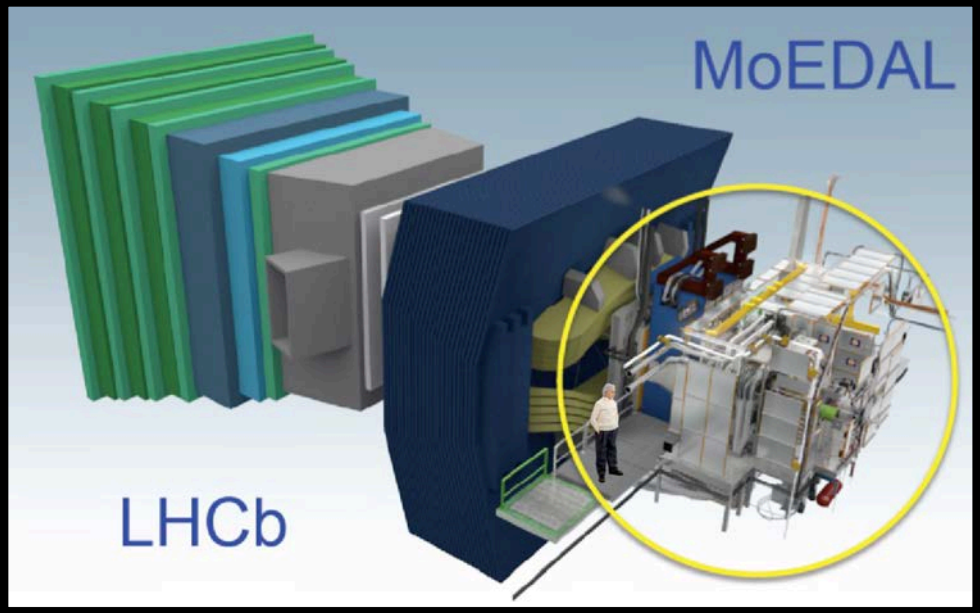
~30 SCENARIOS



Examples: Massive "Stable" Charged Particles

The MoEDAL detector

MoEDAL - Very Different from Other LHC Expts



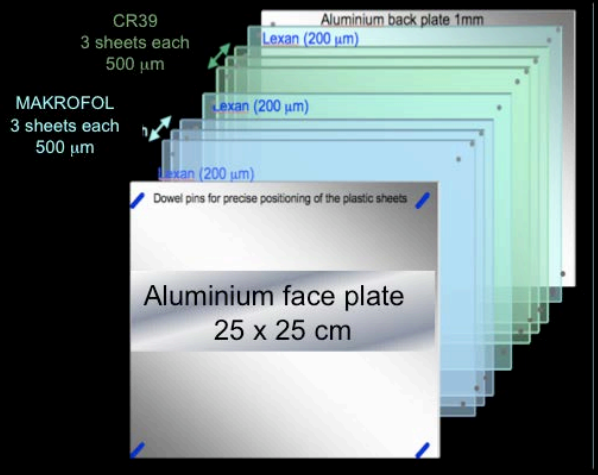
MoEDAL is largely passive made up of three detector system.

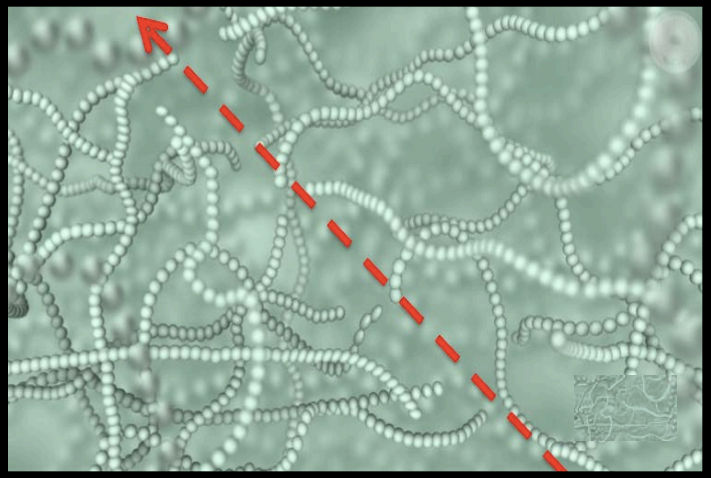
NUCLEAR TRACK DETECTOR
Plastic array (~100 sqm)
– Like a Giant Camera

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

TIMEPIX Array a digital Camera for real time radiation monitoring

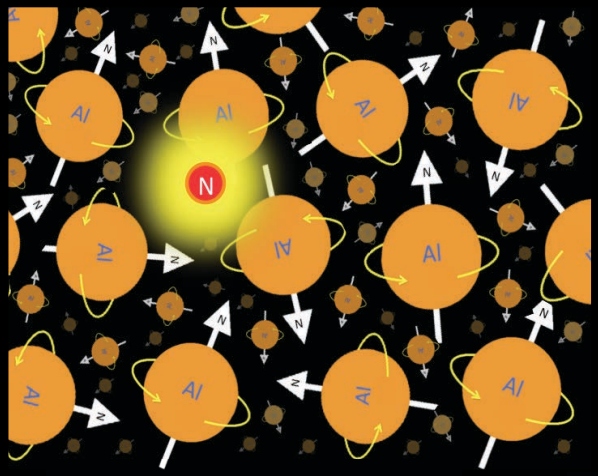
The Nuclear Track Detector System





- *Largest array (150 m^2 of NTDs every deployed at an accelerator*
  - *Plastic NTD stacks consist of CR39 (threshold 5 MiPs) and Makrofol (50 MiPs) – that are "damaged" by the highly ionizing particle*
  - *The damage is revealed by controlled etching in a hot Sodium Hydroxide solution – etch pits are formed*
  - *Charge resolution is ~0.1|e|, where |e|is the electron charge*
- *NTD system acts like a giant camera that is only sensitive to new physics - no known SM backgrounds*

The Trapping Detector System



Trapped monopole

SQUID magnetometer (ETH Zurich)

Search for trapped quasi-stable decays at SNOLAB

- We will deploy trapping volumes (~1 tonne) in the MoEDAL/VELO Cavern to trap highly ionizing particles
  - The binding energies of monopoles in nuclei with finite magnetic dipole moments are estimated to be hundreds of keV
- After exposure the traps are removed and sent to:
  - The SQUID magnetometer at ETH Zurich for Monopole detection
  - Underground lab (SNOLAB) to detect decays of electrically charged MSPs

MoEDAL's Complementarity

Designed & Optimized for highly ionizing particles

Insensitive to SM particles

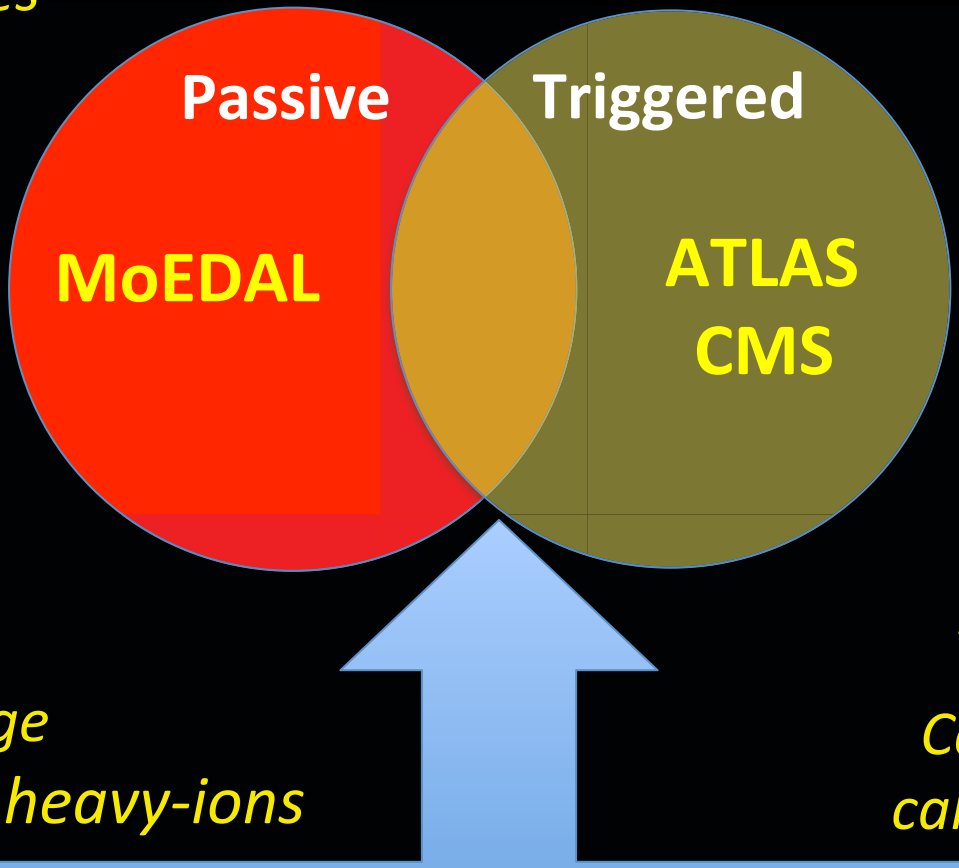
Mass ~ 1 ton

Size ~ 5 m^3

Thickness in RL ~ 0.002 X_0

Can directly detect & trap magnetic charge

Calibrated by heavy-ions



Designed & optimized for SM relativistic MIPs & photons

Mass ~10K tons

Size ~ 25m diam. x 46 m length

Thickness in RL ~ 25 X_0

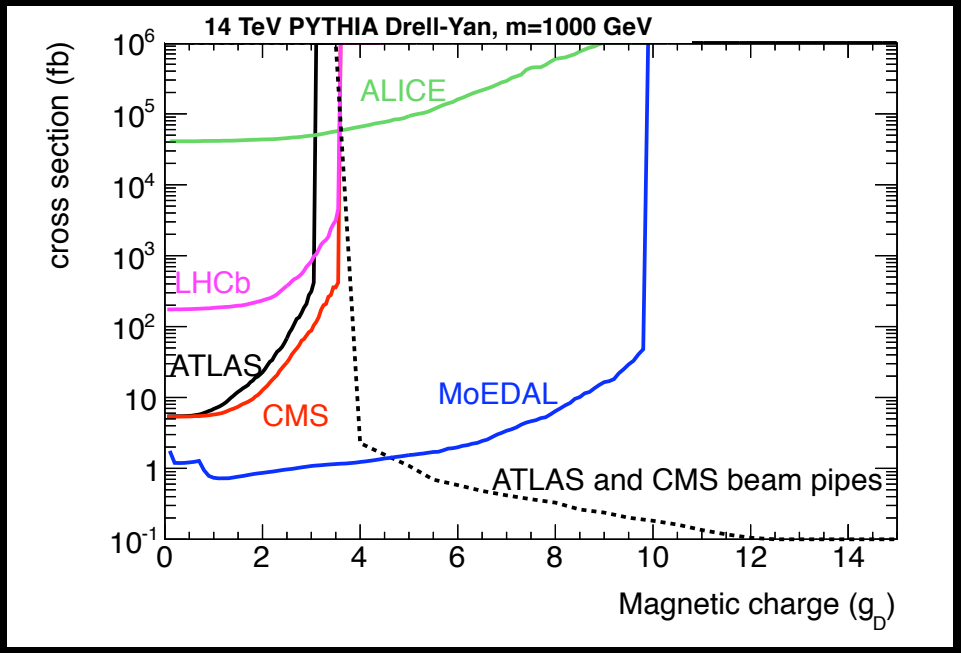
Cannot detect magnetic charge

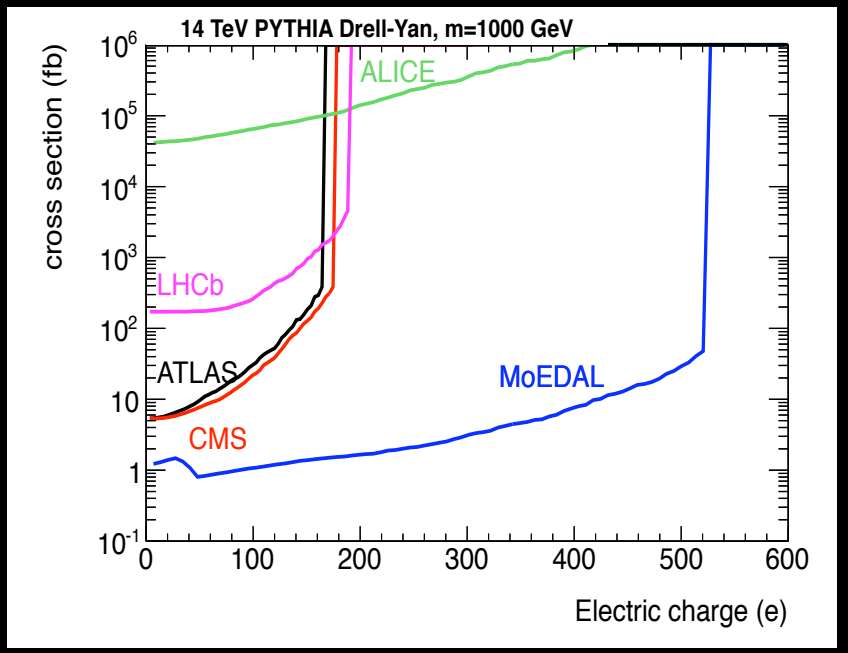
Cannot be directly calibrated for HIPs

The totally different systematics and mode of detection of MoEDAL compared to the ATLAS/CMS experiments → important validation of and insights into a joint observations

MoEDAL's Sensitivity

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 ✔



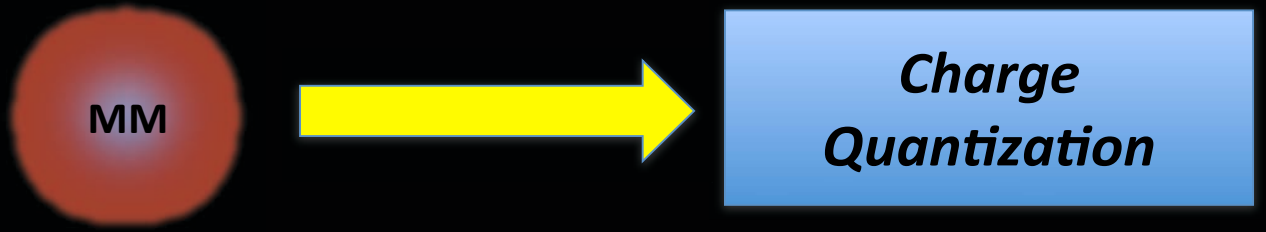


- *Cross-section limits for magnetic (LEFT) and electric charge (RIGHT) (from **arXiv:1112.2999V2** [hep-ph])*

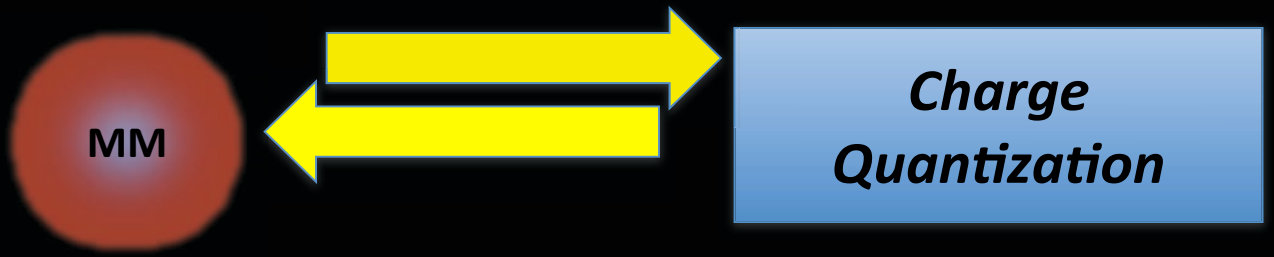
Closing Remarks

The Polchinski Conjecture

- *Dirac showed that the existence of at least one magnetic monopole would explain charge quantization*



- *Thus, Polchinski conjectured, any theory requiring charge quantization must have a monopole*



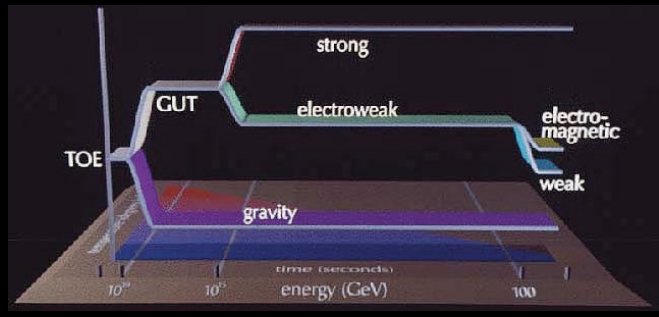
- *He also maintains that in any fully unified theory, for every gauge field there will exist electric and magnetic sources.*

On the Existence of the Monopole (1)

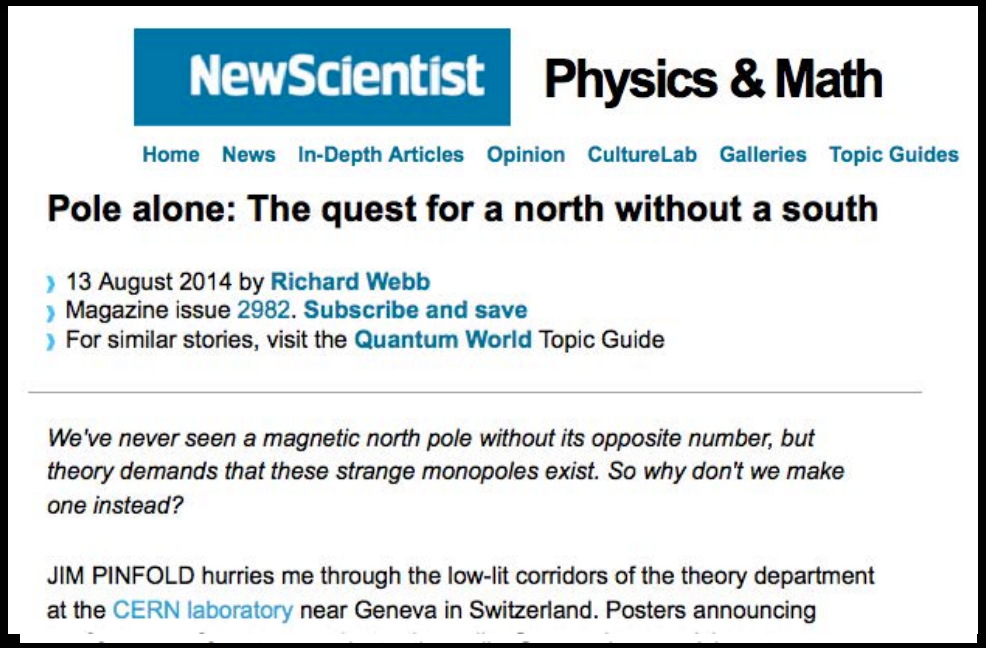
- *The existence of magnetic monopoles is suggested by Electromagnetic theory. But, Grand unified and superstring theories, predict the existence of the monopole.*

- ***Dirac** felt that he "would be surprised if Nature had made no use of it". It, being the Magnetic Monopole.*

- ***Ed Witten** once asserted in his Loeb Lecture at Harvard, "almost all theoretical physicists believe in the existence of magnetic monopoles, or at least hope that there is one."*



On the Existence of the Monopole (2)



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Pole alone: The quest for a north without a south

- 13 August 2014 by Richard Webb
- Magazine issue 2982. Subscribe and save
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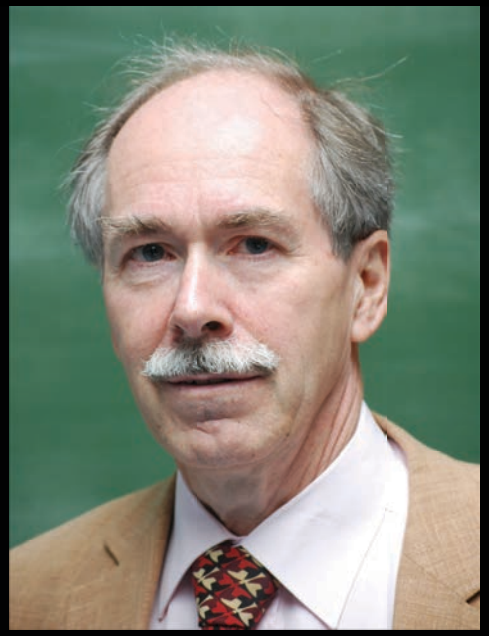
We've never seen a magnetic north pole without its opposite number, but theory demands that these strange monopoles exist. So why don't we make one instead?

JIM PINFOLD hurries me through the low-lit corridors of the theory department at the CERN laboratory near Geneva in Switzerland. Posters announcing



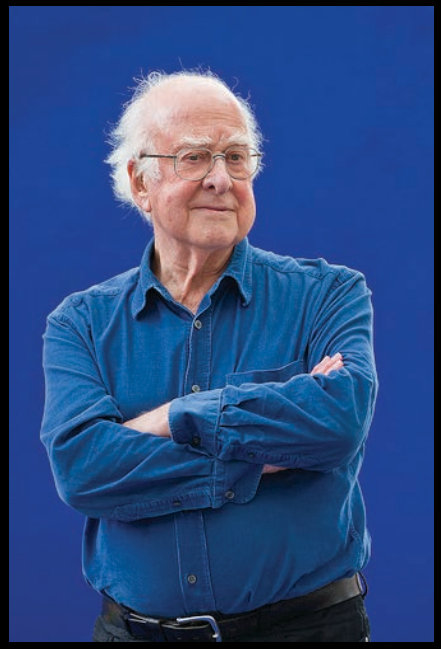
- *Gerard 't Hooft a father of the GUT was quoted in the recent New Scientist article on MoEDAL:*

"Many attempts to improve on the standard model have emerged in recent years. Some of these exotic theories, such as ones that predict the existence of extra dimensions, predict a significantly lighter monopole too….Their energy would be much closer to where the LHC or its future descendants can reach, so the prospects look brighter".

On the Existence of the Monopole (3)

- *The discovery at the LHC of what looks like the SM Higgs boson has reinforced the case for the electroweak(EW) monopole.*
- *Yongmin Cho the discoverer of the EWM had this to say on the topic:*

"Only the electroweak, monopole is consistent with the theoretical framework of the standard model. It has twice the magnetic charge of a Dirac monopole and I estimate that its mass would be in the TeV range – making it ideally suited to be detectable by MoEDAL.



Polchinski on MoEDAL

I would like to express my strong support for the MoEDAL experiment. Although monopoles do not get as much press as dark energy and other hot topics, in fact they are the most certain prediction of theory beyond the Standard Model - more so than supersymmetry, strings, extra dimensions, modified gravity, or many other widely discussed ideas. As I have discussed in my Dirac Centenary Talk, their existence seems inevitable in any framework that explains the quantization of electric charge. Of course their mass scale and abundance are highly uncertain, but the same can be said for almost any other form of new physics

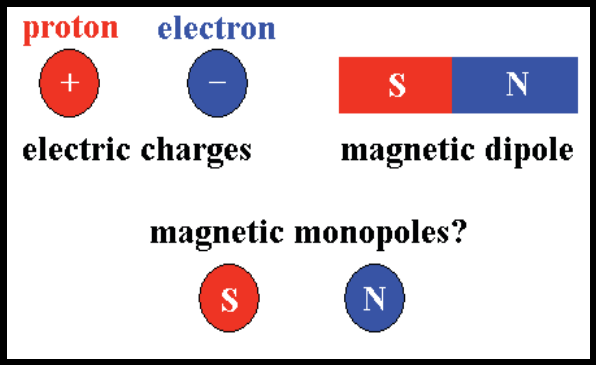
Ed Witten

Joseph Polchinski

MoEDAL Addresses Fundamental Questions:

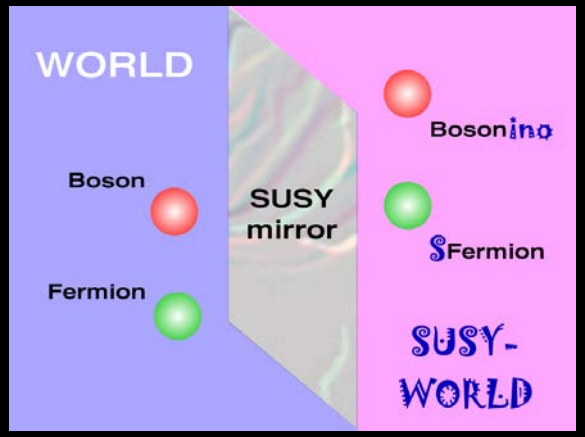
Are there extra dimensions?

What happened just after the big bang?



Does magnetic charge exist?

What is the nature of Dark matter?



Are there new symmetries of nature?

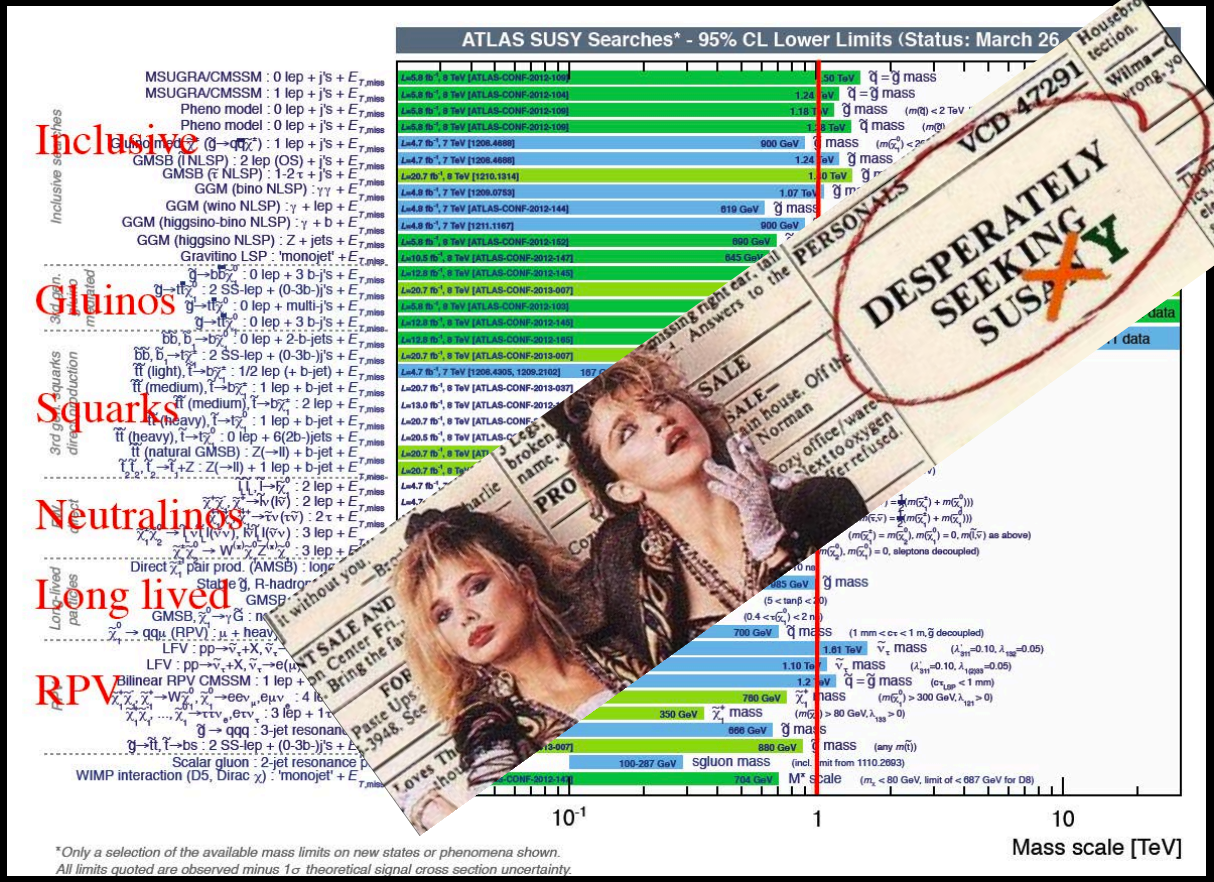
The Importance of High Risk Research

"So many centuries after the Creation, it is unlikely that anyone could find hitherto unknown lands of any value." - Spanish Royal Commission, rejecting Christopher Columbus' proposal to sail west.

The MoEDAL experiment will set sail on a voyage of discovery when the new LHC high energy frontier opens at 13-14TeV in 2015 - stay tuned

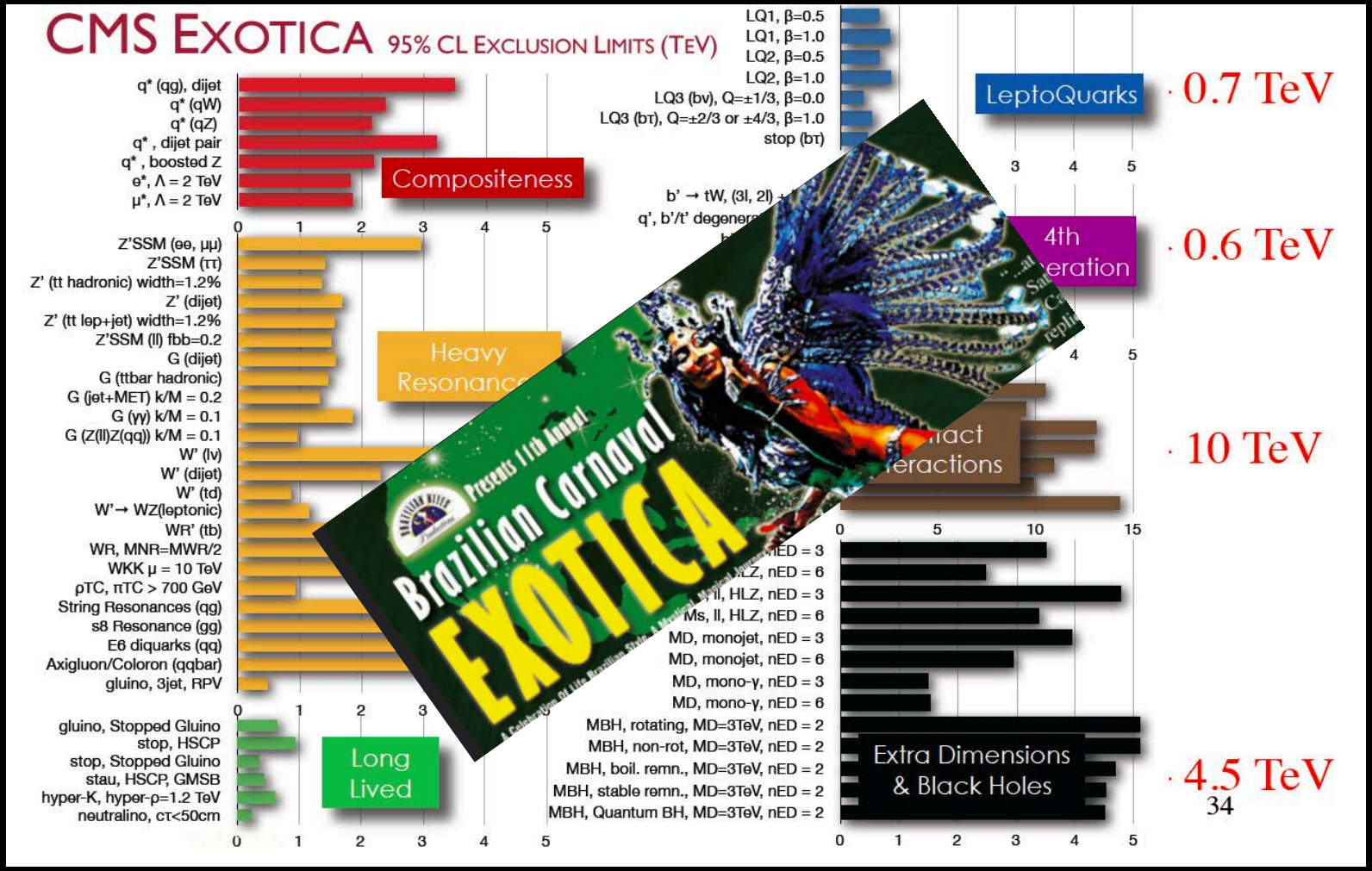
EXTRA SLIDES

Seeking Supersymmetry



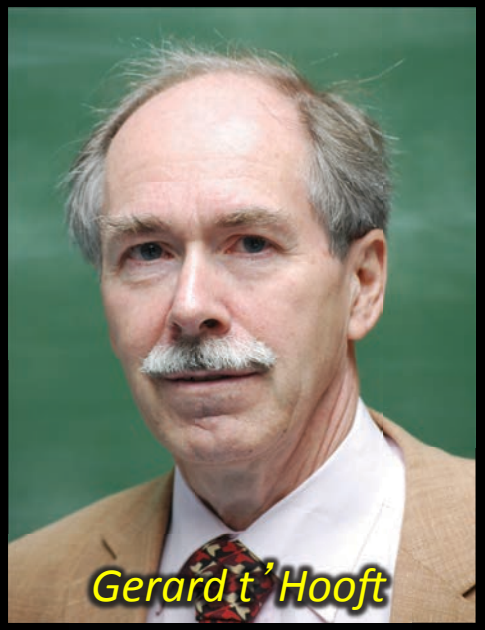
- *No evidence for SUSY at the LHC as yet but we should not despair - the search will continue in 2015 at 13.8 TeV and higher luminosity. MoEDAL will throw a new light on this search*

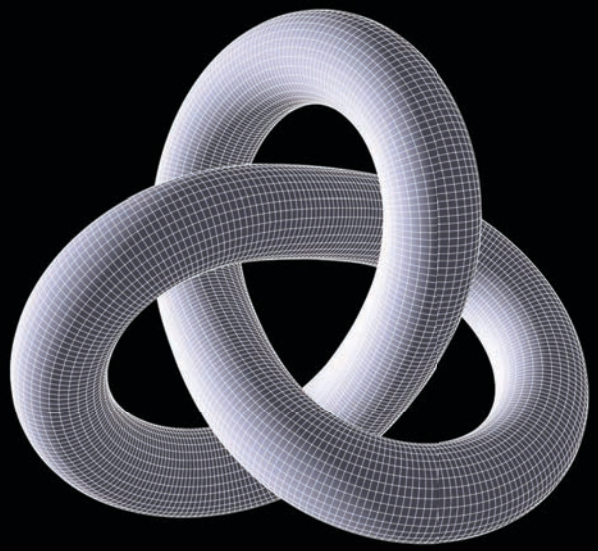
Other Searches Beyond the Standard Model



- *The search for physics beyond the Standard Model will continue at the LHC – MoEDAL expands this discovery horizon*

The ‘t Hooft-Polyakov Monopole


Gerard t’Hooft


Topological soliton


Alexander Polyakov

- *In 1974 ‘t Hooft and Polyakov showed that monopoles exist with the framework of Georgi-Glashow with an SO(3) GS broken to the U(1) of electromagnetism – with charge $2g_d$*
  - *The 't Hooft and Polyakov monopole arises when the Higgs field vector points away from the origin everywhere - the “hedgehog” configuration*
  - *Such monopoles are topological solitons with a topological charge*
  - ***Like a knot in the Higgs field configuration***