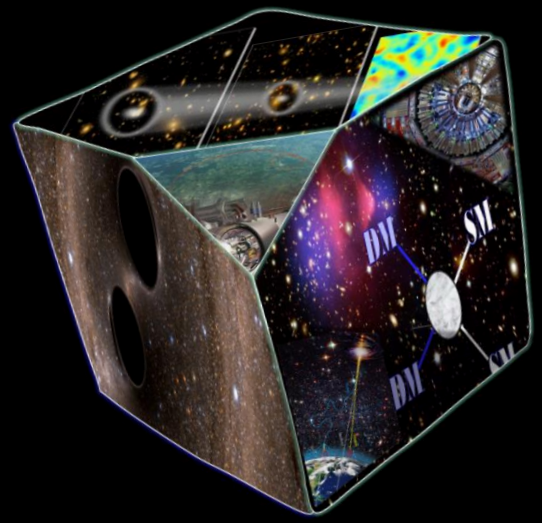
Interconnection between Collider and Dark Matter Physics



[Credits]

- Images of Baryon Acoustic Bscillations with Cosmic Microwave Background by E.M. Huff, the SDSS-III team, and the South Pole Telescope team. Graphic by Zosia Rostomian (Lawrence Berkeley National Laboratory)
- Image of Neutrino Astrophysics, taken from https://astro.desy.de/
- Image of the LHC by CERN Photo
- Image of Bullet Cluster by NASA/ Chandra X-ray Center
- Image of the merging black hole binary system into One by SXS, the Simulating eXtreme Spacetimes (SXS) project

Teruki Kamon

Mitchell Institute for Fundamental Physics and Astronomy, Texas A&M University

MI Workshop on Collider and Dark Matter Physics

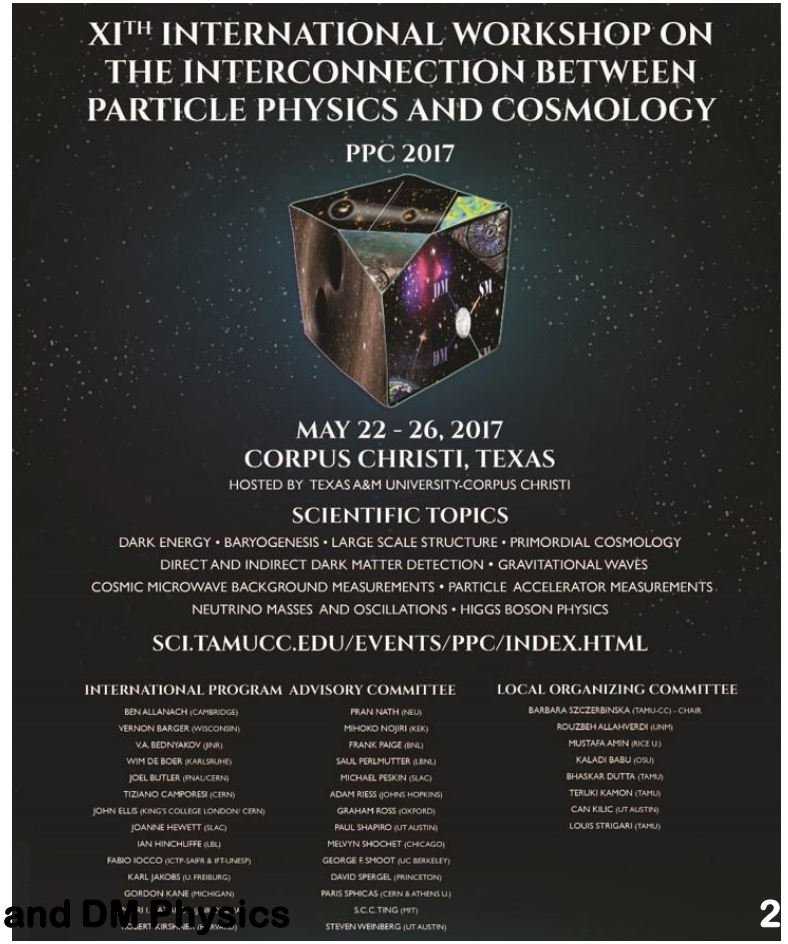
May 18, 2017

Welcome

https://indico.cern.ch/event/639901/timetable/#20170518
Mitchell Institute Workshop on Collider and Dark Matter Physics – 2-Day Program, instead of 4-Day, in 2017. The "collider" part is CMS-related talks, along with theory talks on dark matter from particle physics and cosmology.

News: XI International Workshop on the Interconnections between Particle Physics and Cosmology (PPC 2017), Corpus Christi, Texas, May 22nd – 26th, 2017

Goal: new PHENO projects to answer the question of how a model with cosmologically-consistent signals can be tested experimentally.

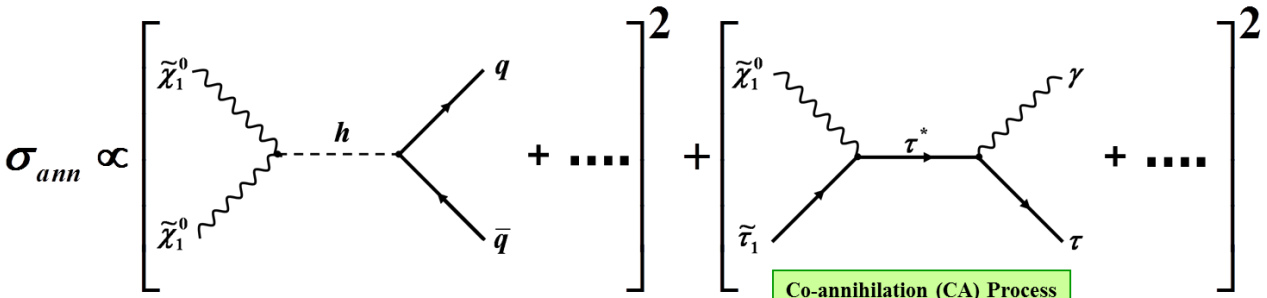


Cosmological Connection: $\Omega_{\chi_1^0} \stackrel{?}{=} \Omega_{DM}$

"Number" density (n_{DM}) → Ω_{DM}

$$\underbrace{\Omega_{\tilde{\chi}_1^0} h^2}_{0.23} \sim \int_0^{x_f} \frac{1}{\langle \sigma_{ann} v \rangle f(x)} dx$$

Cross section (σ)



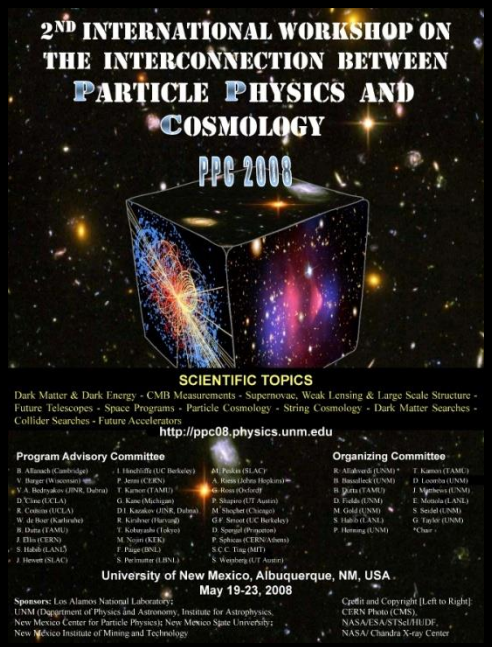
SUSY Masses

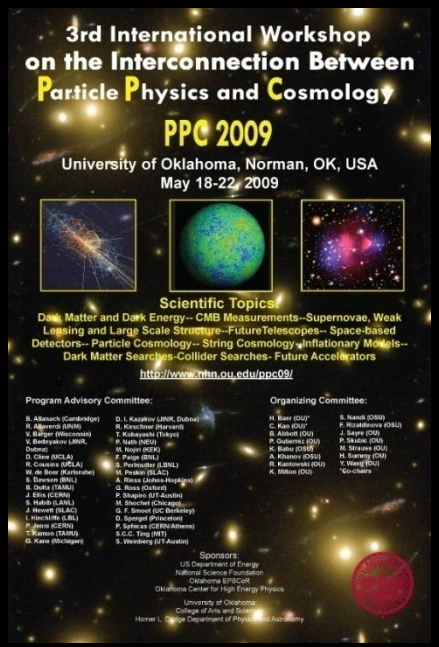
$$\Omega_{\tilde{\chi}_1^0} h^2 = \mathcal{D}(\text{SUSY masses})$$

$$h \equiv H / [100 \text{ km} \cdot \text{s}^{-1} \text{Mpc}^{-1}]$$

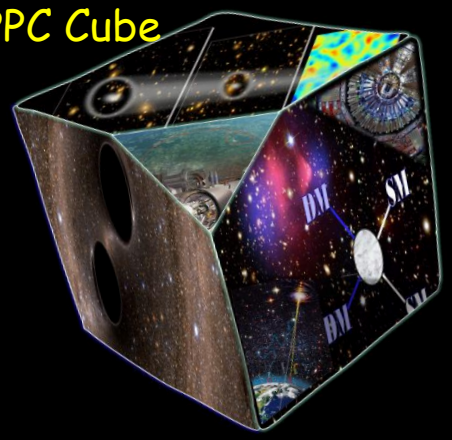
PPCs

Interconnection between Particle Physics and Cosmology



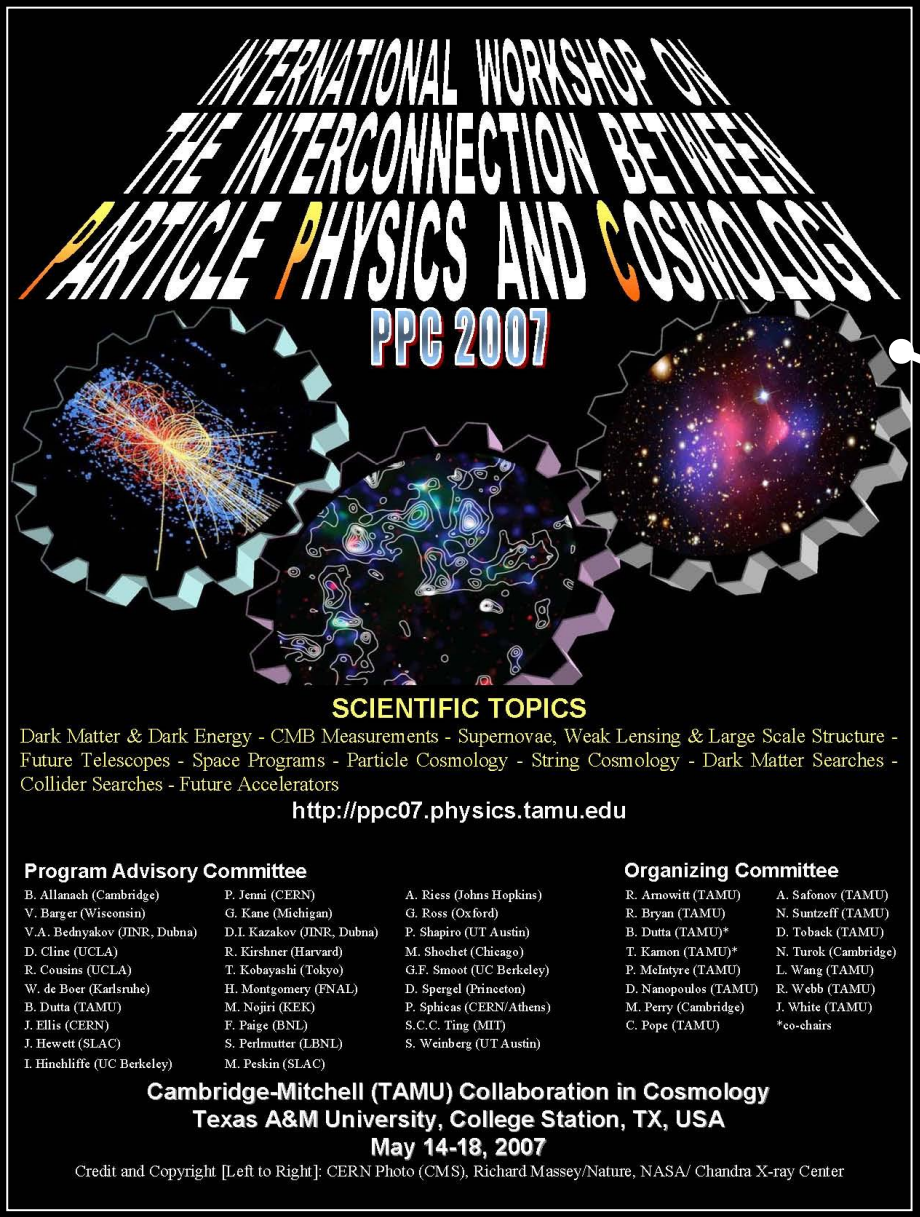


PPC Cube

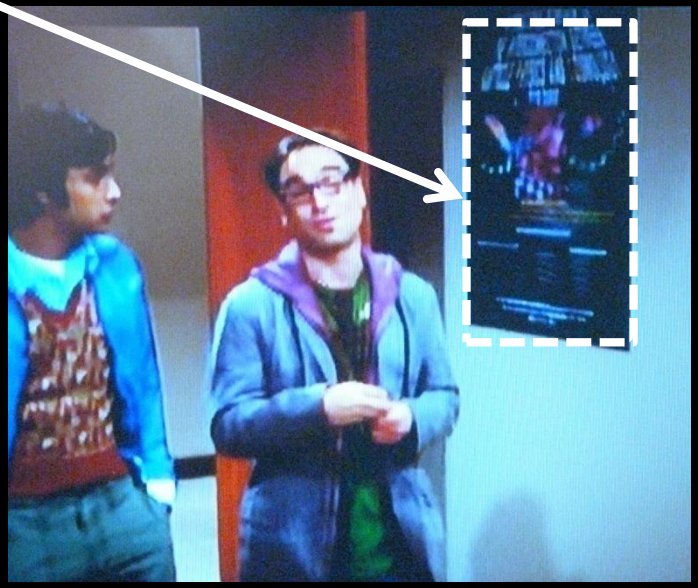


PPC 2011 at CERN, June 14-18
PPC 2012 at KIAS, Korea, Nov. 5-9
PPC 2013 at CETUP*, SD, USA, July 8-13
PPC 2014 at Univ. de Guanajuato, Mexico, June 23-27
PPC 2015 at CETUP*, SD, USA, June 28 - July 3
PPC 2016 at CTP-SAIFR/IFT-UNESP, São Paulo, Brazil, July 11-15
PPC 2017 at TAMU Corpus Christi
PPC 2018 at (TBD)

Outreach: Big Bang Theory



CBS comedy "Big Bang Theory" (Season 1 Episode 15)



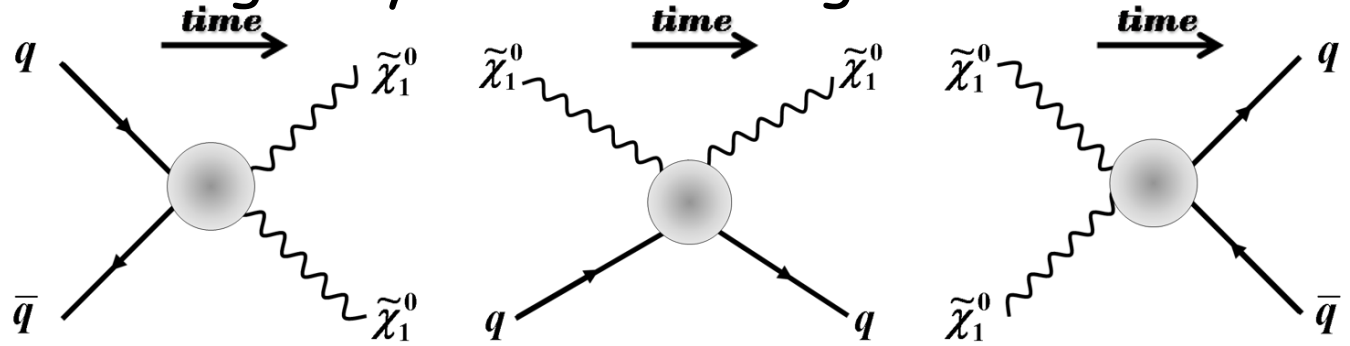
The poster was designed during lunch meetings …

Remarks on PHENO Projects

PHENO projects … Experiment-Theory collaboration, usually beginning with simple questions:

(a) how well a model can be tested experimentally;

(b) how cosmologically-consistent signals can be determined.



The choice of PHENO project topics has been evolving as major scientific events occurred:

i) SSC was cancelled in 1993

ii) WMAP results were out in 2002.

iii) The Higgs boson was discovered in 2012.

iv) ???

Hopefully, a new project, a new collaboration, …

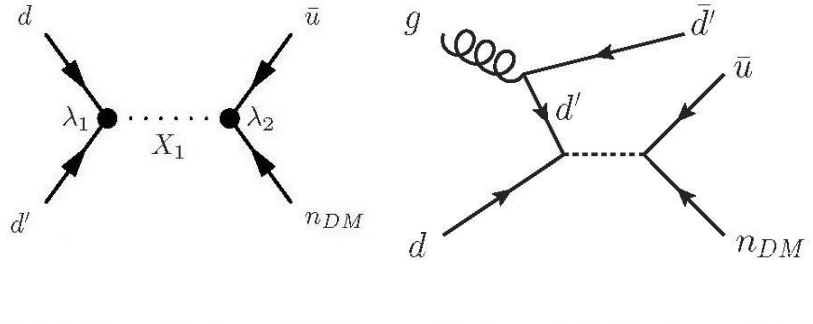
Example: PHENO to CMS

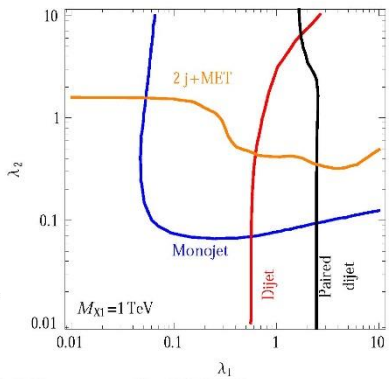
CMS PAS EXO-16-048 (May 2017)

Search for new physics in final states with an energetic jet or a hadronically decaying W or Z boson using 35.9 fb^{-1} of data at $\sqrt{s} = 13$ TeV

Abstract

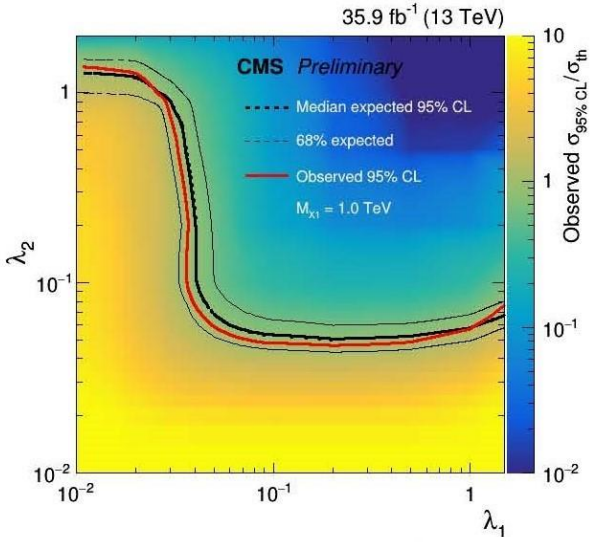
A search for dark matter and extra dimensions are presented using events containing an imbalance in transverse momentum and one or more energetic jets. The data of proton-proton collisions at the LHC were collected with the CMS detector, and correspond to an integrated luminosity of 35.9 fb^{-1}. Results are presented in terms of limits on the dark matter production in association with jets or vector bosons in a simplified models, nonthermal dark matter models, and fermion portal dark matter models. Results are also interpreted in terms of the decay of the standard model Higgs boson to invisible particles and as limits on the Planck scale in the ADD model with large extra spatial dimensions.

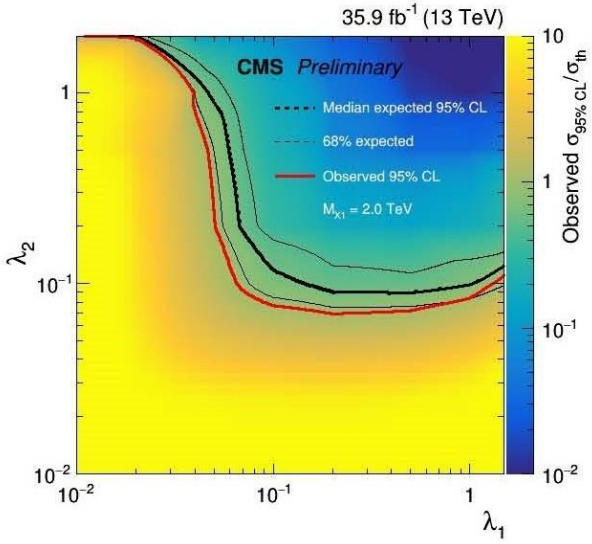




[12] B. Dutta, Y. Gao, and T. Kamon, "Probing Light Nonthermal Dark Matter at the LHC", *Phys. Rev. D* **89** (2014), no. 9, 096009, doi:10.1103/PhysRevD.89.096009, arXiv:1401.1825.

[13] R. Allahverdi and B. Dutta, "Natural GeV Dark Matter and the Baryon-Dark Matter Coincidence Puzzle", *Phys. Rev.* **D88** (2013), no. 2, 023525, doi:10.1103/PhysRevD.88.023525, arXiv:1304.0711.





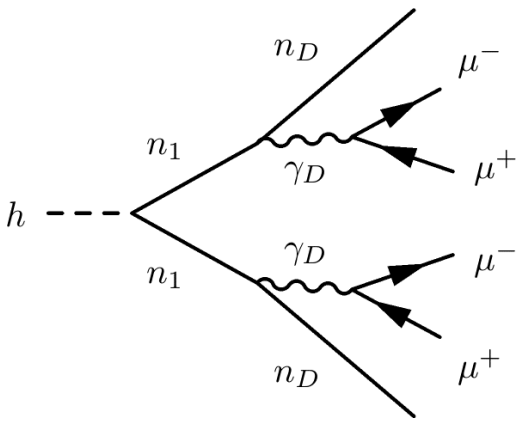
See Rouzbeh's talk and Sonaina's talk

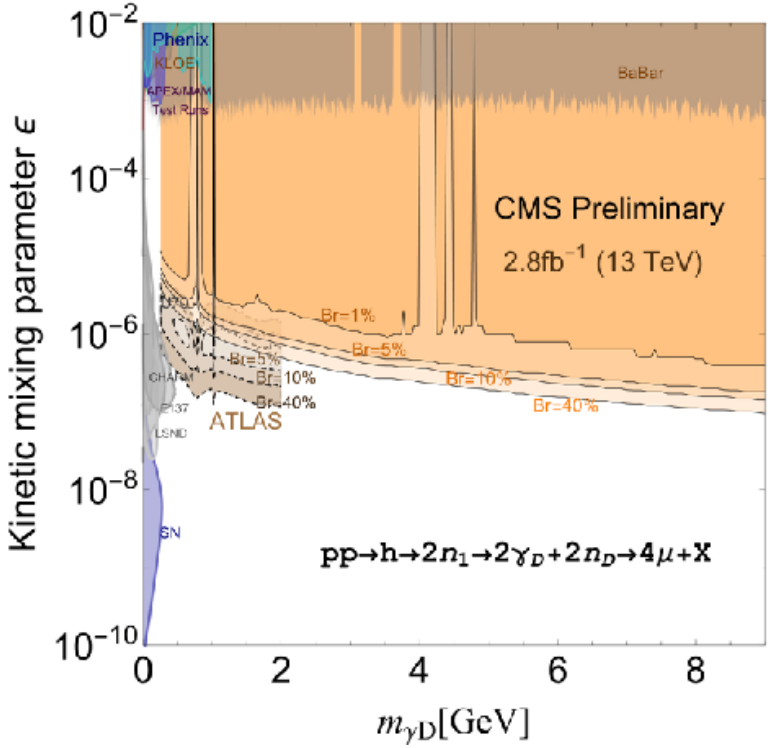
Example: PHENO to CMS

Hidden Sectors – Rich phenomenology depending on mediators (e.g., dark photon,..) → Long-lived particles. See *Flashes of Hidden Worlds at Colliders*, D. Curtin and R. Sundrum, Submitted to Physics Today, arXiv:1702.02524

Texas A&M and Rice University involved in displaced muons searches

CMS HIG-16-035





GEM technology for Muon Detector Upgrade at the CMS experiment: Triggering displaced muons with excellent position resolutions

See Luca's talk

Example: PHENO to superCDMS

[3-prong approach]

Louis E. Strigari, "Neutrino Floor at ultra-low threshold", Phys. Rev. D 93 (2016) 103534 **…** Theoretical calculation of neutrino floor to connect with low energy threshold detector for the dark matter detection experiment.

J. Dent, B. Dutta, J. Newstead, and L. Strigari, "Dark matter, light mediators, and the neutrino floor", Phys. Rev. D 95 (2017) 051701 (R); B. Dutta, Y. Gao, R. Mahapatra, N. Mirabolfathi, L. E. Strigari, and J. Walker, "Sensitivity to oscillation with a sterile fourth generation neutrino from ultra-low threshold neutrino-nucleus coherent scattering", Phys. Rev. D94 (2016) 093002 … interconnecting particle physics and dark matter detection experiment, and developing unique physics case for the Mitchell Institute Neutrino Experiment at Reactor (MINER) experiment

MINER collaboration, "Background Studies for the MINER Coherent Neutrino Scattering Reactor Experiment", Nucl. Inst. Meth. 853 (2017) 53 … Development of low energy threshold detector for the dark matter detection experiment:

PHENO to Experimental Ph.D

Table 1: Experimental Ph.D. students who carried (or are carrying) out their Ph.D projects based on the PHENO papers.

	PHENO Paper	Experimental Paper	Student (Ph.D)
(1)	http://arxiv.org/abs/hep-ph/0203069 (PLB 538 (2002) 121 on $B_s \to \mu^+\mu^-$ decays in SUSY)	PRL 93 (2004) 032001 PRL 95 (2005) 221805 PRL 100 (2008) 101802 PRL 107 (2011) 191801 PRD 87 (2013) 072003	Slava Krutelyov (TAMU, 2005)
(2)	http://arxiv.org/abs/0802.2968 (PRL 100 (2008) 231802 on SUSY Stau-Neutralino Co-annihilation)	EPJC 73 (2013) 2493 (or CMS SUS-12-004)	Roy Montalvo (TAMU, 2013) Friederike Nowak (Hamburg, 2013)
(3)	http://arxiv.org/abs/1104.2508 (PLB 703 (2011) 475 on a precision measurement of top-quark mass using Bi-Event Subtraction Technique (BEST))	CMS Physics Analysis Summary TOP-14-011 (Nov 2015), unpublished.	EunHyang Kwon (Sungkyunkwan University, Korea, 2015)
(4)	http://arxiv.org/abs/1210.0964 (PRD 87 (2012) 035029 on search for chargino-neutralino production in VBF)	JHEP 11 (2015) 189 (or CMS SUS-14-005)	Will Flanagan (TAMU, 2014) Denis Rathjens (Hamburg, 2015) Amandeep Kaur Kalsi (Panjab, 2018)
(5)	http://arxiv.org/abs/1304.7779 (PRL 111 (2013) 061801 on search for the lightest neutralino production in VBF); https://arxiv.org/abs/1507.01001 (PRD 92 (2015) 095009 on SUSY compressed mass spectra in VBF)	PRL 118 (2017) 021802 (or CMS SUS-14-019)	Andrés G. Delannoy (Vanderbilt, 2016)
(6)	http://arxiv.org/abs/1401.1825 (PRD 89 (2014) 096009 on search for mono-jet events in non-thermal DM scenario)	CMS EXO-16-048 (13 TeV)	Sonaina Undleeb (Texas Tech, 2017)
(7)	http://arxiv.org/abs/1210.0964 (PRD 87 (2012) 035029 on search for chargino-neutralino production in VBF) … same as (4)	New analysis with 13-TeV data.	Andres Cabrera (los Andes, 2017?) Ali Celik (TAMU, 2017?) Priyanka Kumari (Panjab, 2017?)
(8)	http://arxiv.org/abs/1507.02271 (JHEP 12 (2016) 046 on search for mono-top events in non-thermal DM scenario.)	New analysis with 13-TeV data.	Ryan Mueller (TAMU, 2018?)
(9)	?	??	???

Goal: New PHENO Projects

J. Ellis, SUSY07

"Supersymmetrists, Beware!"

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN-EP/84-42
29 March 1984

Experimental Observation of Events with Large Missing Transverse Energy Accompanied By a Jet or Photon(s) in ppbar Collisions at /s = 540 GeV

UA1 Collaboration, CERN, Geneva, Switzerland

Aachen[1]-Annecy(LAPP)[2]-Birmingham[3]-CERN[4]-Harvard[5]-Helsinki[6]-Kiel[7]
Queen Mary College, London[8]-NIKHEF, Amsterdam[9]-Paris(Coll.de France)[10]-Riverside[11]
Roma[12]-Rutherford Appleton Lab.[13]-Saclay(CEN)[14]
Vienna[15]-Wisconsin[16] Collaboration

Abstract

We report the observation of five events in which a missing transverse energy larger than 40 GeV is associated with a narrow hadronic jet and of two similar events with a neutral electromagnetic cluster (either one or more closely spaced photons). We cannot find an explanation for such events in terms of backgrounds or within the expectations of the Standard Model.

(submitted to Phys. Lett. B)

CERN-TH.3968/84

IS SUPERSYMMETRY FOUND?

John Ellis
CERN — Geneva

and

Marc Sher **)
University of California, Irvine

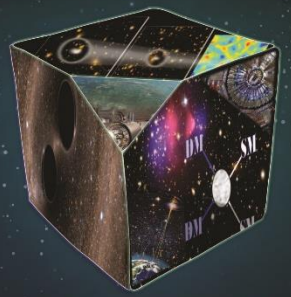
ABSTRACT

Monojet events seen recently by the UA1 collaboration at the CERN $p\bar{p}$ Collider may be due to squarks or gluinos with masses O(40) GeV. The thinness of the observed jets favours the squark interpretation. In this case, we predict that sleptons should have masses between 20 and 30 GeV and that the photino should have a mass between 5 and 10 GeV. Such masses are close to the experimental lower limits and sparticles could soon be detectable in e^+e^- → $(\tilde{\gamma}\tilde{\gamma})\gamma$ experiments and $W^\pm$ and Z^0 decay. We demonstrate that such light sparticle masses are consistent with models whose weak gauge symmetry breaking is driven by a t quark weighing O(40) GeV as recently reported, and even with no-scale models in which the supersymmetry breaking scale is also determined dynamically.

CERN-TH.3968/84
July 1984

XITH INTERNATIONAL WORKSHOP ON THE INTERCONNECTION BETWEEN PARTICLE PHYSICS AND COSMOLOGY

PPC 2017



MAY 22 - 26, 2017
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HOSTED BY TEXAS A&M UNIVERSITY-CORPUS CHRISTI

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DIRECT AND INDIRECT DARK MATTER DETECTION • GRAVITATIONAL WAVES
COSMIC MICROWAVE BACKGROUND MEASUREMENTS • PARTICLE ACCELERATOR MEASUREMENTS
NEUTRINO MASSES AND OSCILLATIONS • HIGGS BOSON PHYSICS

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