Theme Group 2 Experiment

→ fundamental physics

(EP/HEP, Nuclear, Particle Astrophysics, Gravity, Cosmic-Ray)

UMD Physics External Review

March 11-12, 2013

The Basic Science

The experimental theme group 2 (TG2E) is active in experimental observations of fundamental physics in search of a fuller understanding of the core properties of our universe. Some of the "Big Questions" addressed within the theme group include:

- Core principles: quantum physics + relativity
- Structure of spacetime
- Origins and evolution of the universe
- Fundamental constituents and forces of the universe
- Unity of forces and physical laws
- Origins of matter (vs. anti-matter)
- Understanding the mechanisms of high energy astrophysical objects
- Fundamental symmetries
- Understanding the nature of strongly interacting matter
- Origins of high energy cosmic-ray particles and their interactions

Program Summary

- 14 faculty (1 Assistant Professor)
- 4 research scientists
- 16 postdocs
- 26 graduate students
- ~24-30 undergraduates
- 10 Engineers & Technicians
- $6M/year in Base research funding (also substantial project funding)
  - >400k per faculty
  - $1.5M - $2M per year in IDC to University

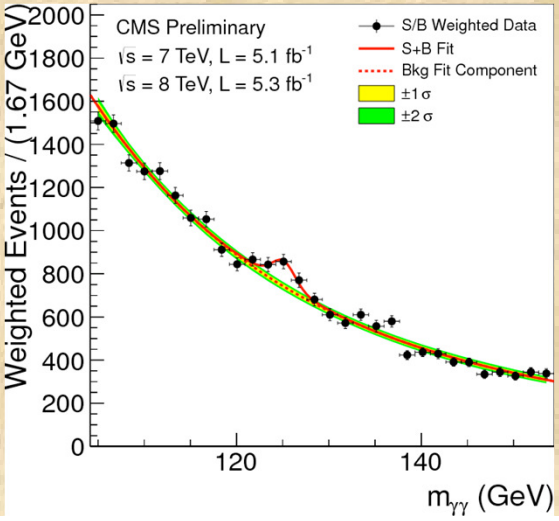
Program Breakdown by group

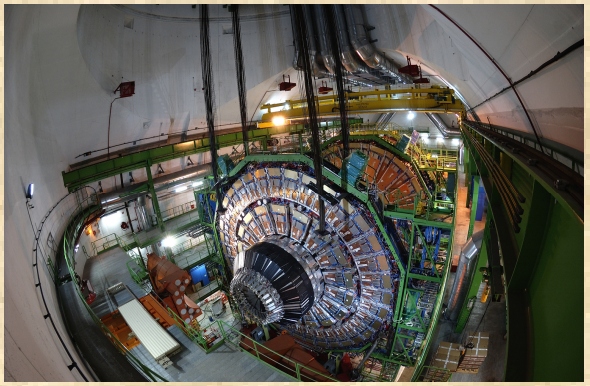
- Particle Physics / HEP – 7 faculty (1 Assistant)
  - *CMS at CERN – energy frontier (Skuja, Baden, Hadley, Eno, Belloni)*
  - *LHC-B flavor physics (previously BaBar) (Jawahery, Roberts)*
- Particle Astrophysics – 3 faculty
  - *IceCube - neutrino astronomy, particle physics(PINGU) (Sullivan, Hoffman)*
  - *Askarian radio Array - neutrino astronomy (Hoffman)*
  - *HAWC – gamma-ray astronomy (evolved from Milagro) (Goodman)*
  - *LBNE (neutrino oscillations) (Sullivan)*
- Nuclear/DM/beta decay – 2 faculty
  - *EXO & LuX – dark matter, neutrinoless beta decay (Hall)*
  - *QCD structure of nucleon, neutron detection (B. Beise)*
- Gravity (LIGO) – 1 faculty (plus 1 theorist) (P. Shawhan)
- Cosmic Ray/ Space Sciences – 1 faculty (E. Seo)
  - NASA funded Space and Balloon experiments

HEP

CMS

- 2012 was a big year! Evidence for a new particle!
- Faculty: Nick Hadley, Drew Baden, Andris Skuja, Sarah Eno, Alberto Belloni (New faculty hire last year)
- Postdocs: Matthieu Marionneau and Ted Kolberg, both at CERN
- Graduate Students: Chris Anelli (CERN), Kevin Pedro, Young Ho Shin, Brian Calvert (MD)
- Undergraduates: Ethan Cowan, Jon Wonders, Hannalore Gerling-Dunsmore, Noah Mandell, Michael Kossin, Ike Chukwu, Nick Zube, Julie Rose, Oliver Pierson, and Roland Jeannier.
- Engineering: Rob Bard and Tom O'Bannon





Papers with major contributions by MD group

- RPV-stop, 3rd generation leptoquarks
  - arXiv:1210.5629, accepted by PRL
- Stopped stops, stopped gluinos
  - Thesis, Ken Rosatto (now at Amentra)
  - Phys. Rev. Lett. 106 (2011) 011801, J. High Energy Phys. 08 (2012) 026.
- Leptoquark search in enujj, eejj
  - enujj Thesis, Dinko Ferencek (postdoc, Rutgers)
  - Phys. Lett. B703 (2011) 246-266
  - eejj Thesis, Ellie Twedt (now at Ventura Solutions)
  - Phys. Rev. Lett. 106 (2011) 201802
  - CMS-PAS-10-005
- Top cross section
  - Thesis, Malina Kirn (now at Palantir)
  - Phys. Rev. D84, 092044, Phys. J. C 71, 1721 (2011)
- MET
  - J. Instrum. 6 (2011) P09001, 24 Jun 2011)
  - CMS-PAS-JME-10-005, CMS-PAS-JME-10-004, CMS-PAS-JME-10-00, CMS-DP-2012-010

Leadership and Awards

- Coordination & Management
  - US CMS Collaboration Board Chair (Hadley)
  - CMS CB Career Committee Co-chair (Eno)
- Construction (all past efforts)
  - CMS HCAL Project Manager 2006-2009 (Skuja)
  - HCAL simulation for design choices (Kunori)
  - Level I Trigger Primitives (Baden, Bard, Grassi, Giganti + FNAL, BU & Princeton)
  - DAQ (Mans – now at Minnesota)
  - CERN Testing (Bat. 904) and Installation SX5, UX5, USC5 (Kellogg)
- Maintenance and Operations (M&O)
  - CMS Deputy HCAL Project Manager 2009-2011 (Skuja)
  - MTCC and H2 Test Beam in 2006 and H2 Test Beam in 2007
  - Commissioning and startup in 2007-2009
  - HCAL Operations Data Certification co-convener (Kolberg)
- CMS Achievement Awards
  - Pedro (upgrade), Twedt (HCAL), Rumerio (ECAL) and Temple (HCAL)
- Upgrade
  - CMS HCAL Upgrade Coordinator (Baden)

Physics Positions

- Sarah Eno co-head of “nonhadronic” subgroup of Exotica group 2013-present
- Matthieu Marionneau (MD postdoc) co-head of “MET” subgroup of JetMET group 2013-present
- Paulo Rumerio (while MD postdoc) co-head of “lepton+jet” subgroup of Exotica subgroup 2011-2012 (former MD postdoc Francesco Santanastatio has just replaced him)
- Sarah Eno was on the Exotica subgroup of the CMS publications committee 2012
- Sarah Eno was co-head of the MET subgroup of the JetMet group 2009-2010.
- Sarah Eno was co-head of the Exotica group 2006-2008

Flavor Physics and CP Violation
Current Status

- Faculty:
  - Hassan Jawahery
  - Doug Roberts
- Current Postdoctoral research associates:
  - Riccardo Cenci (2009-present)
  - Brian Hamilton (2012-present)
- Current Graduate Students:
  - Jack Wimberley (summer 2012-present)
  - Jason Andrews (summer 2012-present)
- Electronic Engineers: Rob Bard, Tom O'Bannon

History

- BABAR: since inception
  - Jawahery: 1993-present & Roberts: 1998-present
- INFN Super-B: 2008-2012
  - Program concluded fall 2012 after Italian government declined full funding
- LHCb
  - Member since Sept. 2012
  - Current program & development of LHCb upgrade
- Ancient:
  - B Physics with OPAL at LEP (1988-1995)
  - CLEO 1981-1999

Contributions to BABAR & Super-B

- Management of the Experiments:
  - Jawahery: Spokesperson (2006-2008)
  - Jawahery: Physics coordinator (2001-2002)
  - Jawahery: PI/Spokesperson for US Super-B groups
  - Roberts: SVT co-system manager (2003-2008)
  - Convenership of various working groups

- Design, Development of the detector and its reconstructions codes:
  - Particle Identification system, Drift Chamber, Silicon Vertex Tracker and tracking software

- Primary Physics focus of the group:
  - CP violation in B decays
  - CP violation in charm decays
  - Search for New Physics via rare loop-dominated processes

Summary of BaBar Physics papers led by Maryland group

- CPV violation in Charmless B decays and measurement of the angles α and γ :
  (6 published papers)

- The decays B→D(*)D(*): Measurement of rates, polarization and CPV effects. Deviations from SM could signal Physics beyond SM.
  (10 published papers)

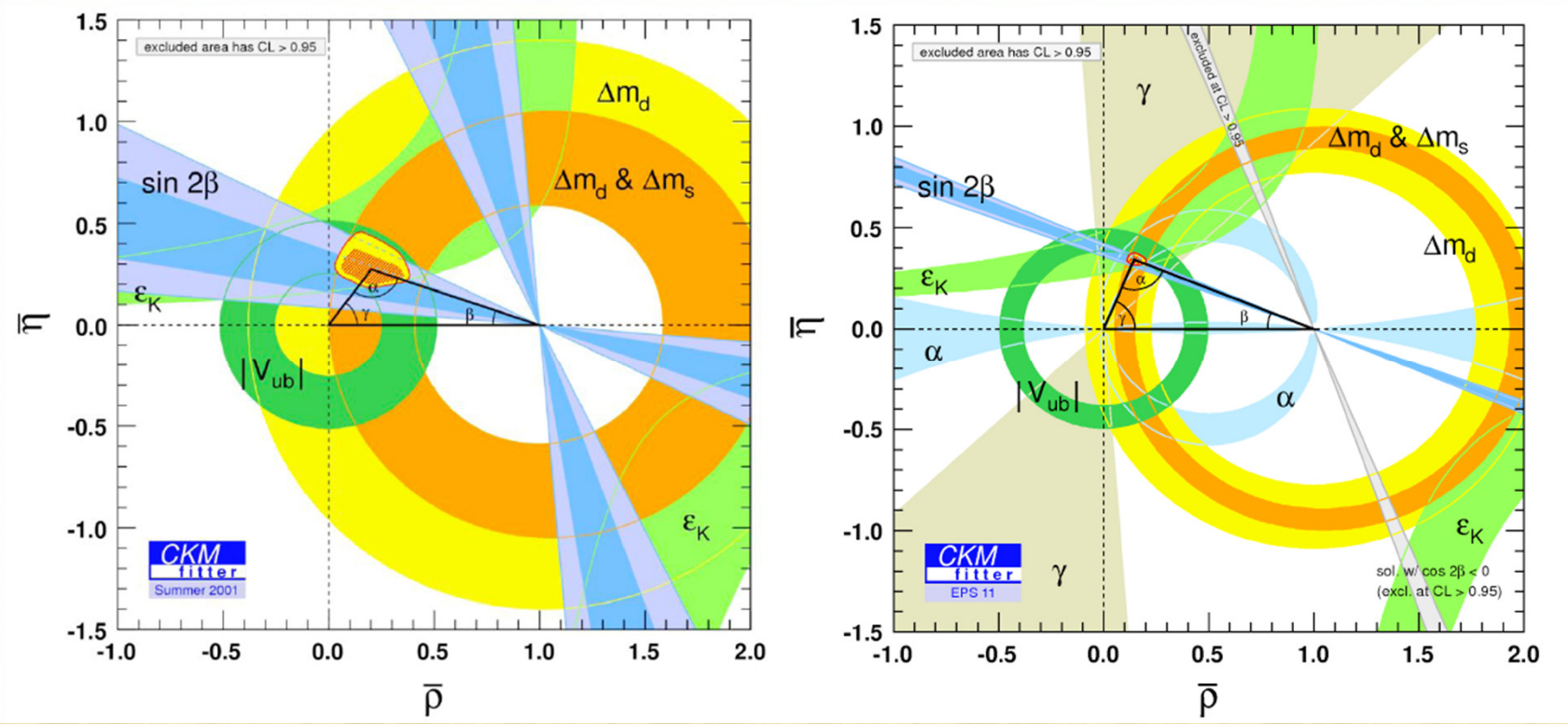
- Search for Physics Beyond the Standard Model via Loop peguin dominated B decays:
  (8 published papers)

- Rare Leptonic Charm decays: D→e^+ e^- & D→μ^+ μ^-, ..
  (1 published paper)
- Measurement of the decay Υ(1S)→D*+ X
  (1 published paper)
- Measurement of CP Asymmetry in charm decays
  (2 published paper)
- Measurement B^0_s Semileptonic Branching ratio
  (1 published paper)

The B Factory results verified the CP violating mechanism of the Standard Model and led to 2008 Nobel prize in Physics to Kobayashi and Maskawa (shared with Nambu.

2001

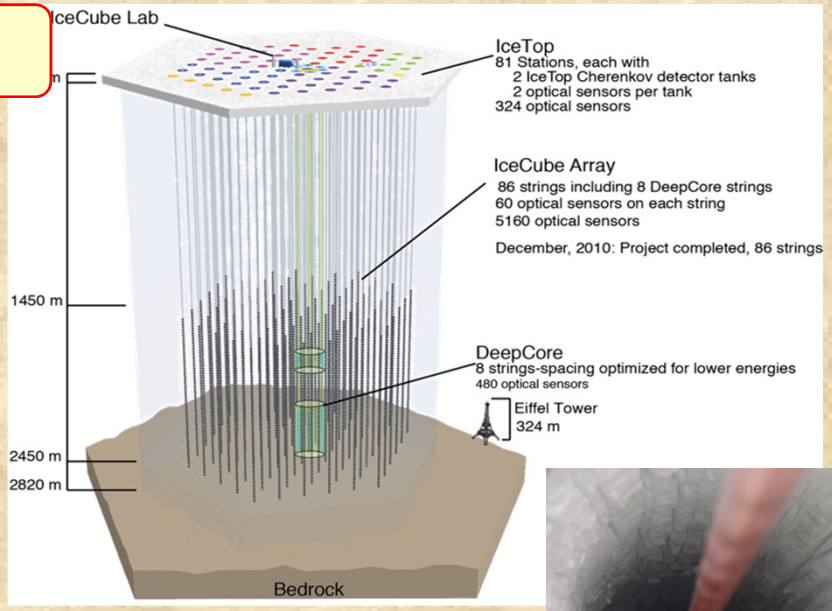
2011

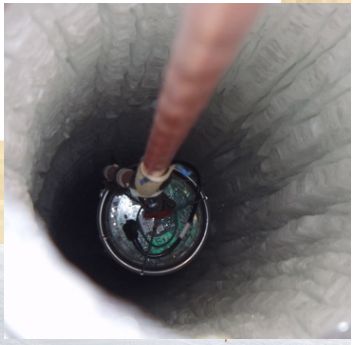


Particle Astrophysics

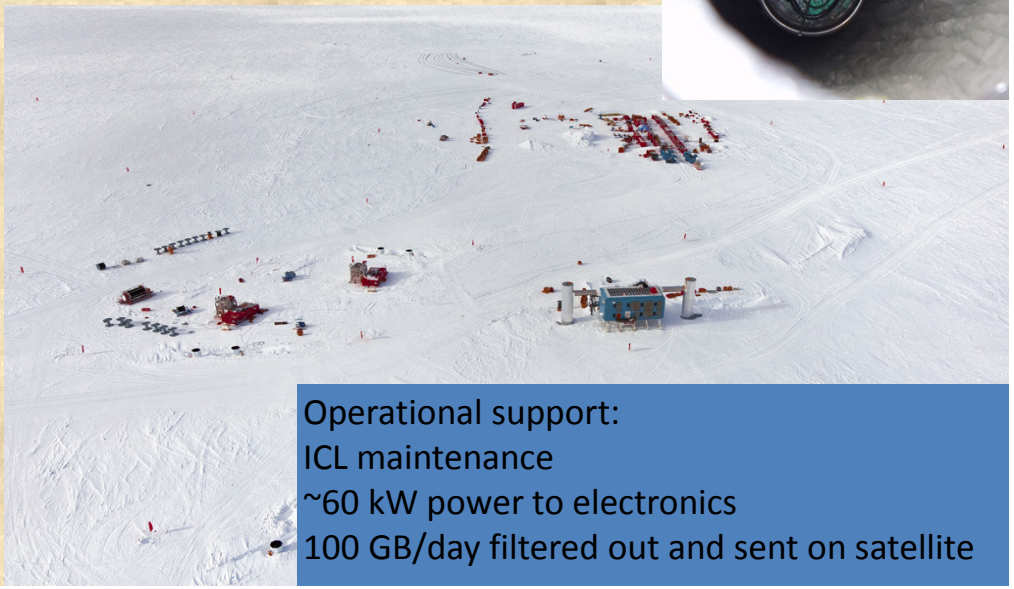
Neutrino Astrophysics - IceCube

Detector Completion Dec 2010



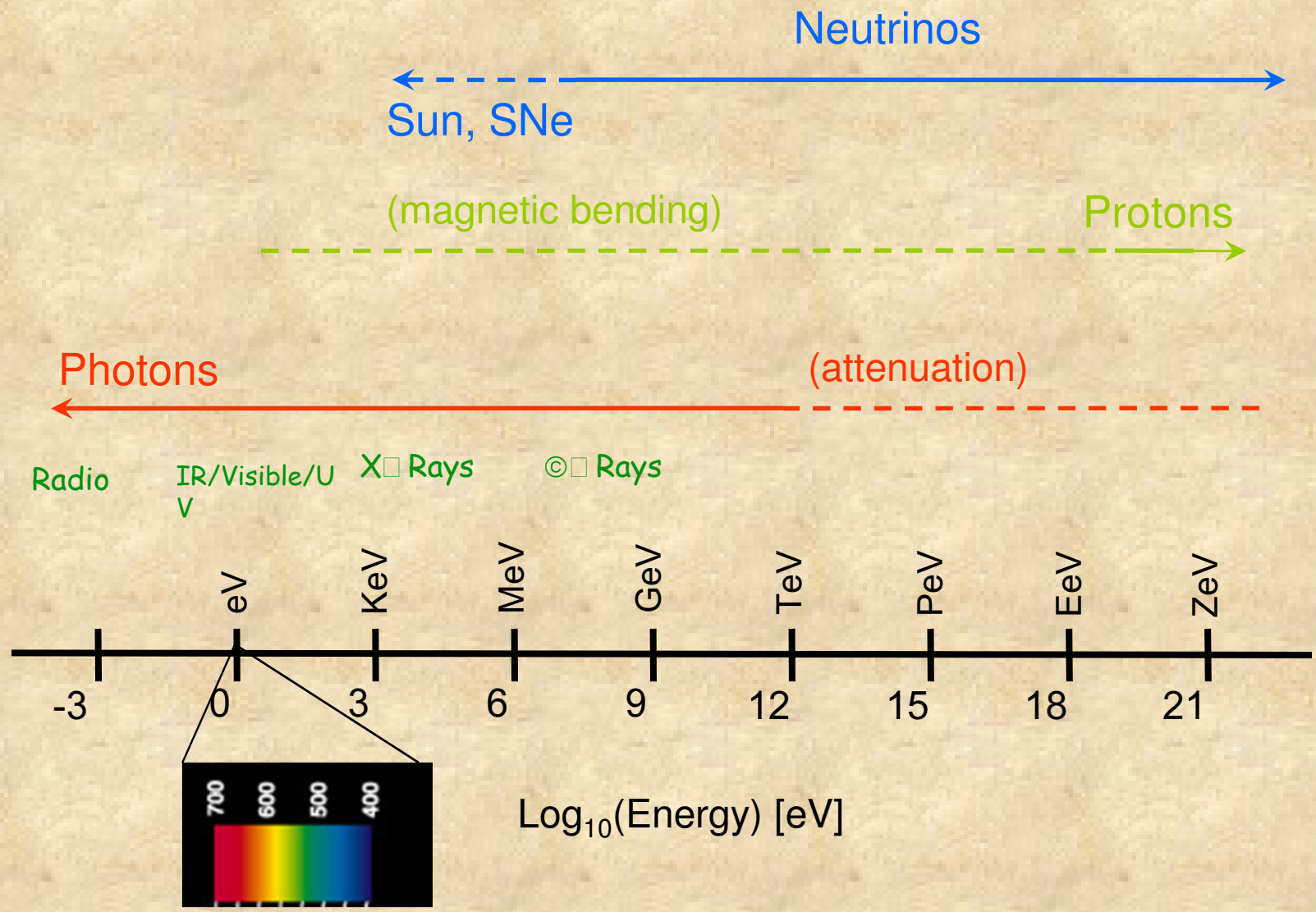


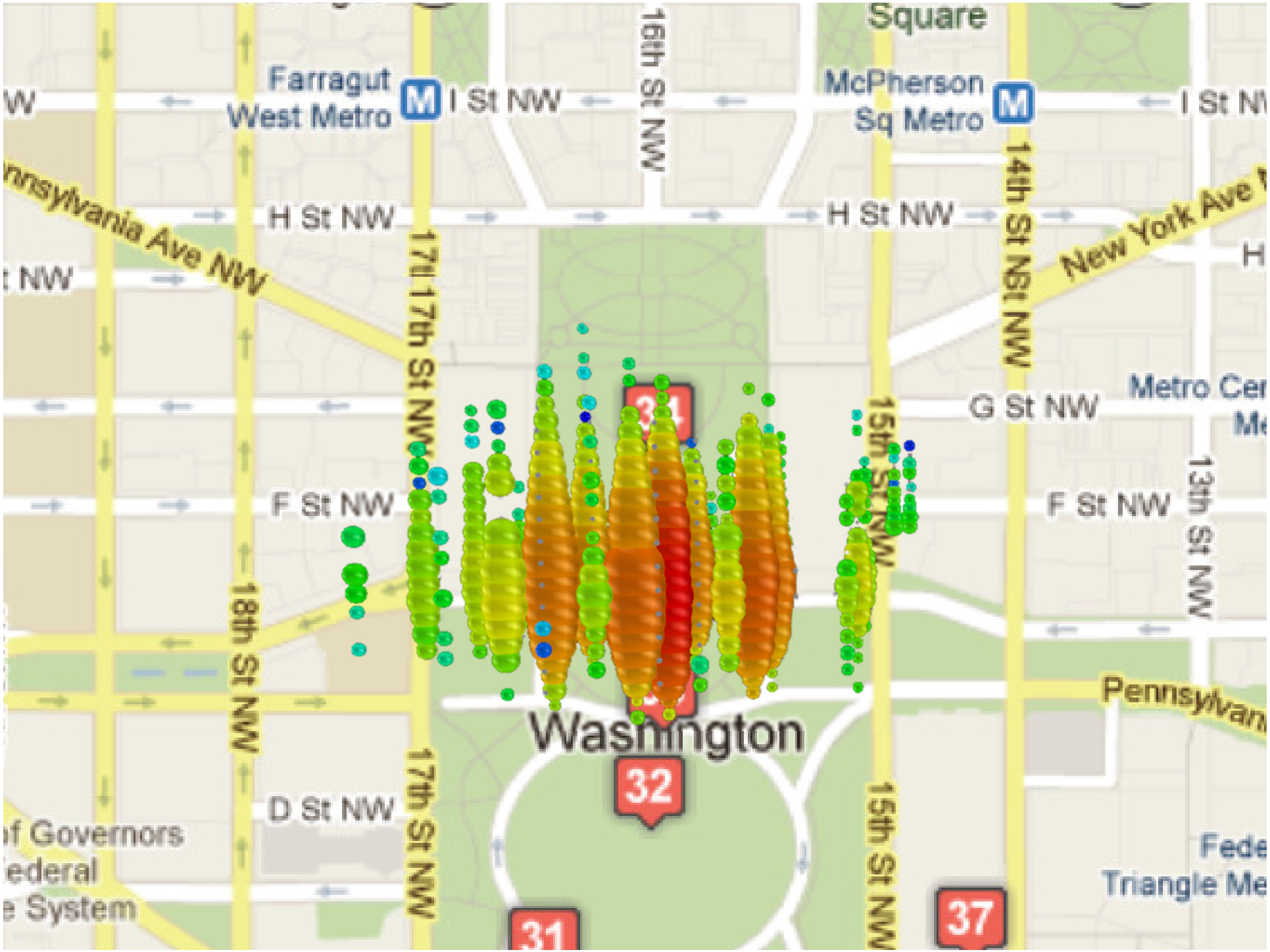
- Sullivan leading effort along with Research Scientist Erik Blaufuss
- Hoffman still plays a role → moving more to her own project ARA
- Two postdocs (both WG group leaders)
  - Olivas
  - Wissing
- Four graduate students
- 3 software professionals
  - UMD responsible for Onlinereconstruction and filter system, analysis software framework, code repository, multi platform build systems etc…
- $1.2M per year Science and M&O funding



Operational support:
ICL maintenance
~60 kW power to electronics
100 GB/day filtered out and sent on satellite

Messenger Particles & Astronomy




Square
Farragut West Metro
I St NW
16th St NW
McPherson Sq Metro
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Pennsylvania Ave NW
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G St NW
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18th St NW
Washington
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31

Leadership Roles at UMD

- Collaboration & Science
  - Sullivan (prof) Spokesperson
  - Blaufuss (res sci) GRB WG leader, Online systems leader, analysis software leader
  - Hoffman (prof) first muon WG leader
  - Wissing (postdoc) EHE WG leader
  - Olivas (postdoc) Simulation program leader
- Construction (completed 2010), M&O
  - Sullivan L2 for all data systems
  - Blaufuss L3 for online system and analysis framework
  - Maryland largest M&O responsibility outside UW
  - Run the weekly call on detector and software systems

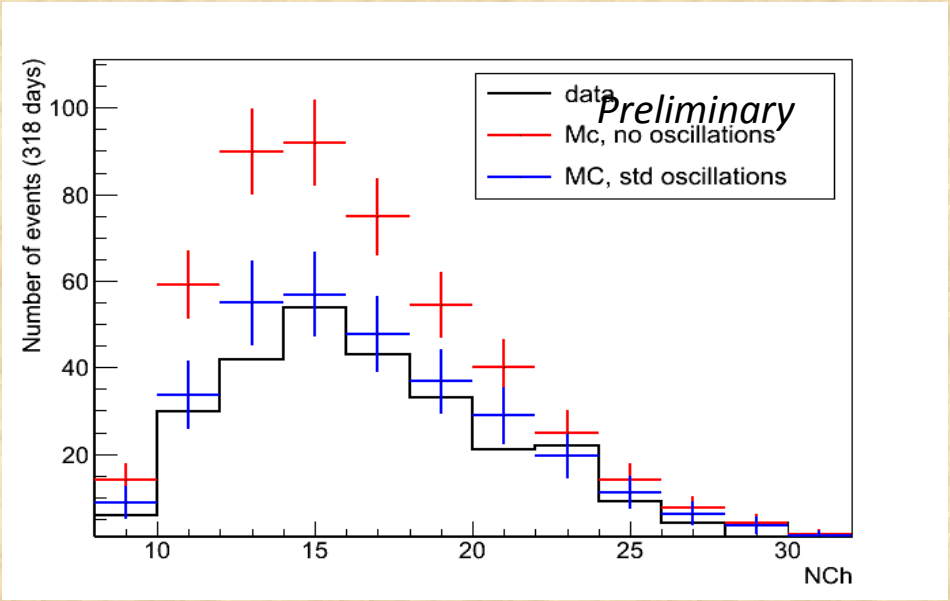
IceCube Publications from UMD

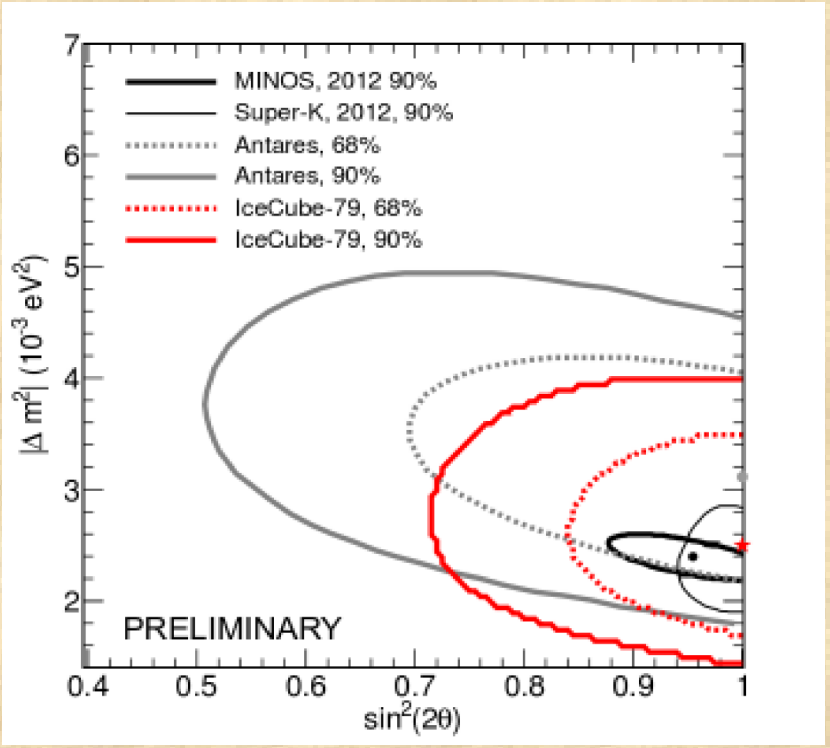
- Search for Relativistic Magnetic Monopoles with IceCube. Phys.Rev. D87:022001, 2013.
- *An absence of neutrinos associated with cosmic-ray acceleration in γ-ray bursts. Nature 484:351-353, 2012.*
- Limits on Neutrino Emission from Gamma-Ray Bursts with the 40 String IceCube Detector. Phys.Rev.Lett.106:141101,2011.
- Measurement of the atmospheric neutrino energy spectrum from 100 GeV to 400 TeV with IceCube, Phys. Rev. D 83, 012001 (2011)
- Search for a Lorentz-violating sidereal signal with atmospheric neutrinos in IceCube Phys.Rev.D82:112003, 2010. [arXiv:1010.4096]
- Search for muon neutrinos from Gamma-RayBursts with the IceCube neutrino Astrophys.J.710:346-359, 2010. [arXiv:0907.2227]
- Detection of Atmospheric Muon Neutrinos with the IceCube 9-String Detector, Phys. Rev. D *76*, 027101 (2007).
  - The first IceCube paper.

All from PhD theses of UMD students

Cross Check and oscillation parameter fit

Distribution of the number of hit DOMs for vertical events (cos(theta)<-0.55) of the low-energy event selection. *Errors are statistical only.*





- IceCube DeepCore has now explored the energy region where standard neutrino oscillation are expected with IC79
- the non-oscillation hypothesis is rejected with high statistical significance.
- Data are in good agreement with standard oscillation expected from global best fit mixing parameters available from the literature.
- Systematic effects have been investigated and factorized in normalization, correlated and uncorrelated terms.

Neutrino Oscillations in PINGU?

PINGU is a concept for even higher density infill to DeepCore that lowers the energy range of IceCube to several GeV range with MT's effective volume

Ref: E. Kh. Akhmedov, S. Razzaque, A. Y. Smirnov arXiv:1205.7071 [hep-ph]

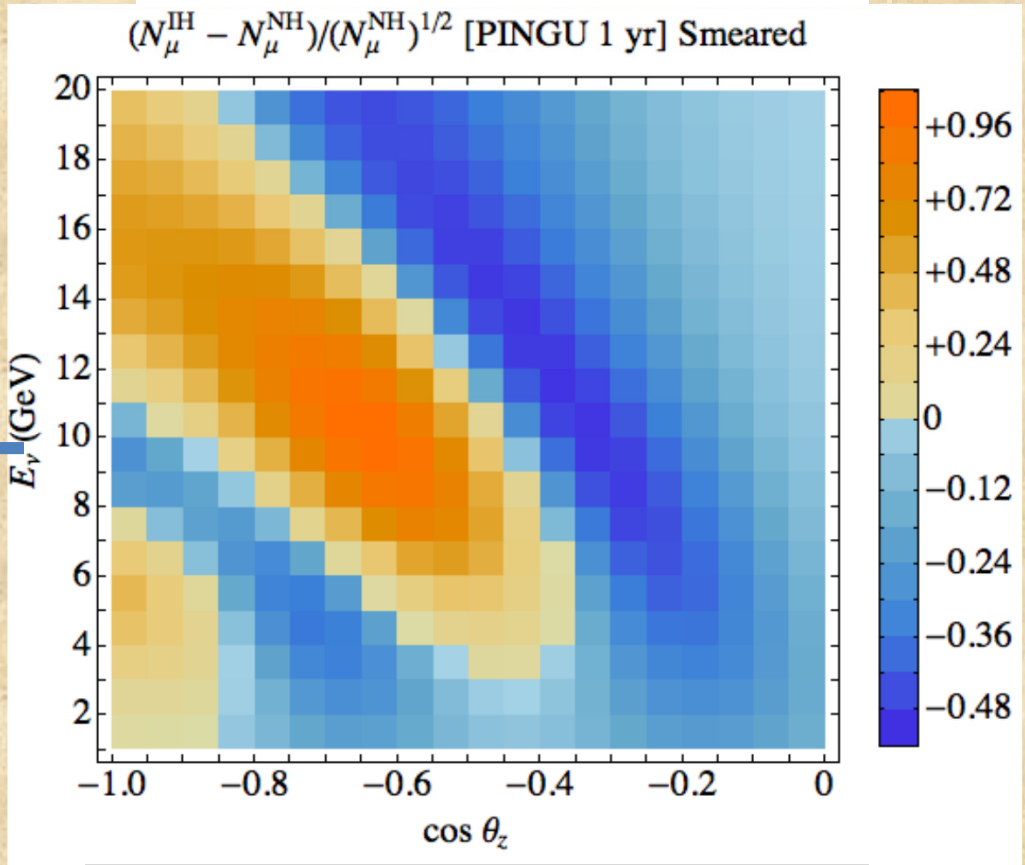
Statistical significance of Normal versus Inverted Mass Hierarchy.

Sets PINGU requirements on:

1) Energy Resolution
2) Angular Resolution
3) Systematic Errors

We are currently studying the feasibility of reaching the needed requirements.

σ_E = 2 GeV, σ_θ = 11.25°



3σ – 11σ in 5 Years of running

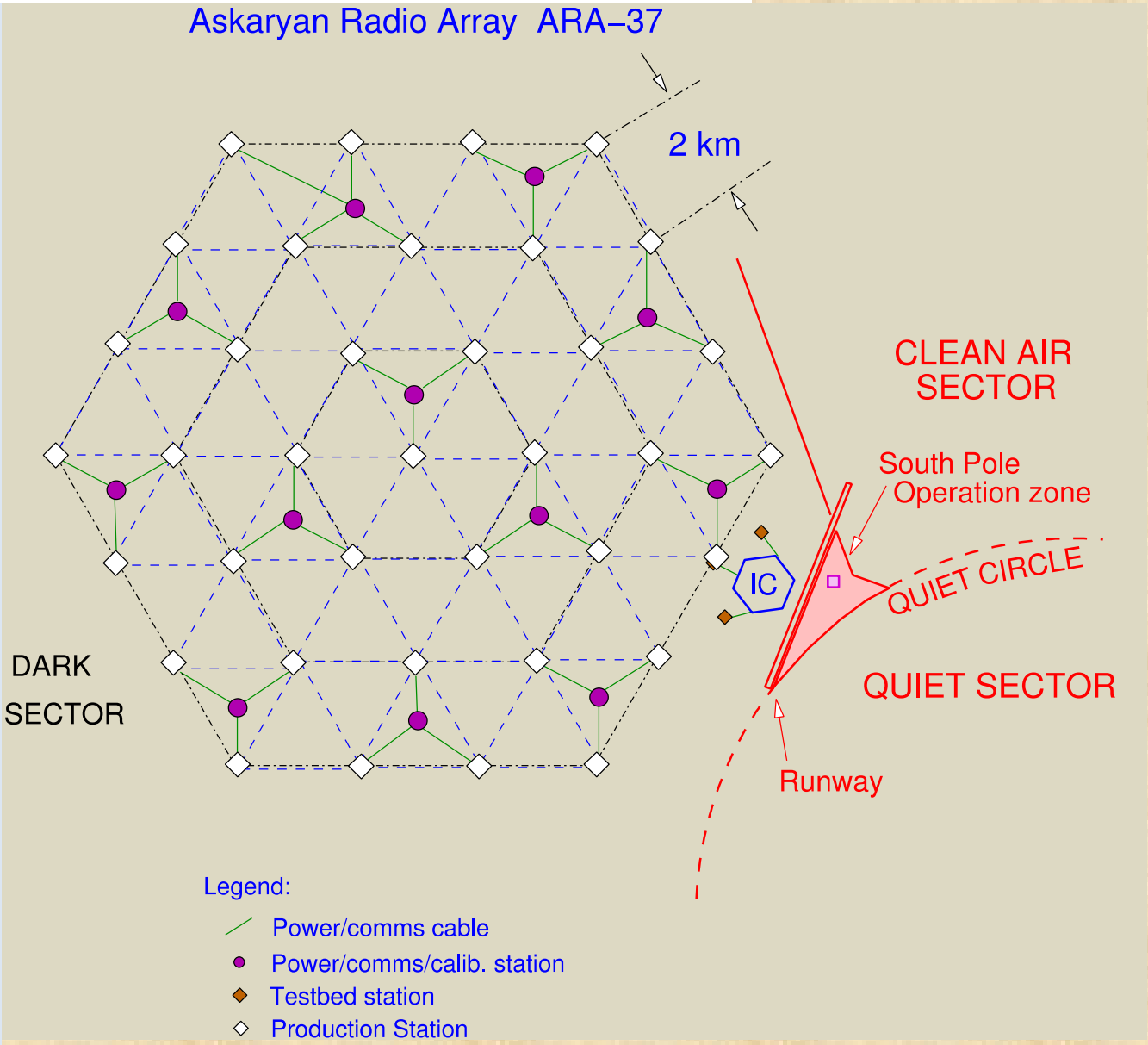
Includes systematic error ≤ 10%

Neutrino Astronomy - ARA

- Kara Hoffman leading effort
  - NSF CAREER award for R&D
  - PI on a successful MRI grant for R&D and prototype detector deployment
- Currently searching for new postdoc
- two graduate students
  - One with a split between ARA and IceCube
  - Gives new IceCube students hardware experience!

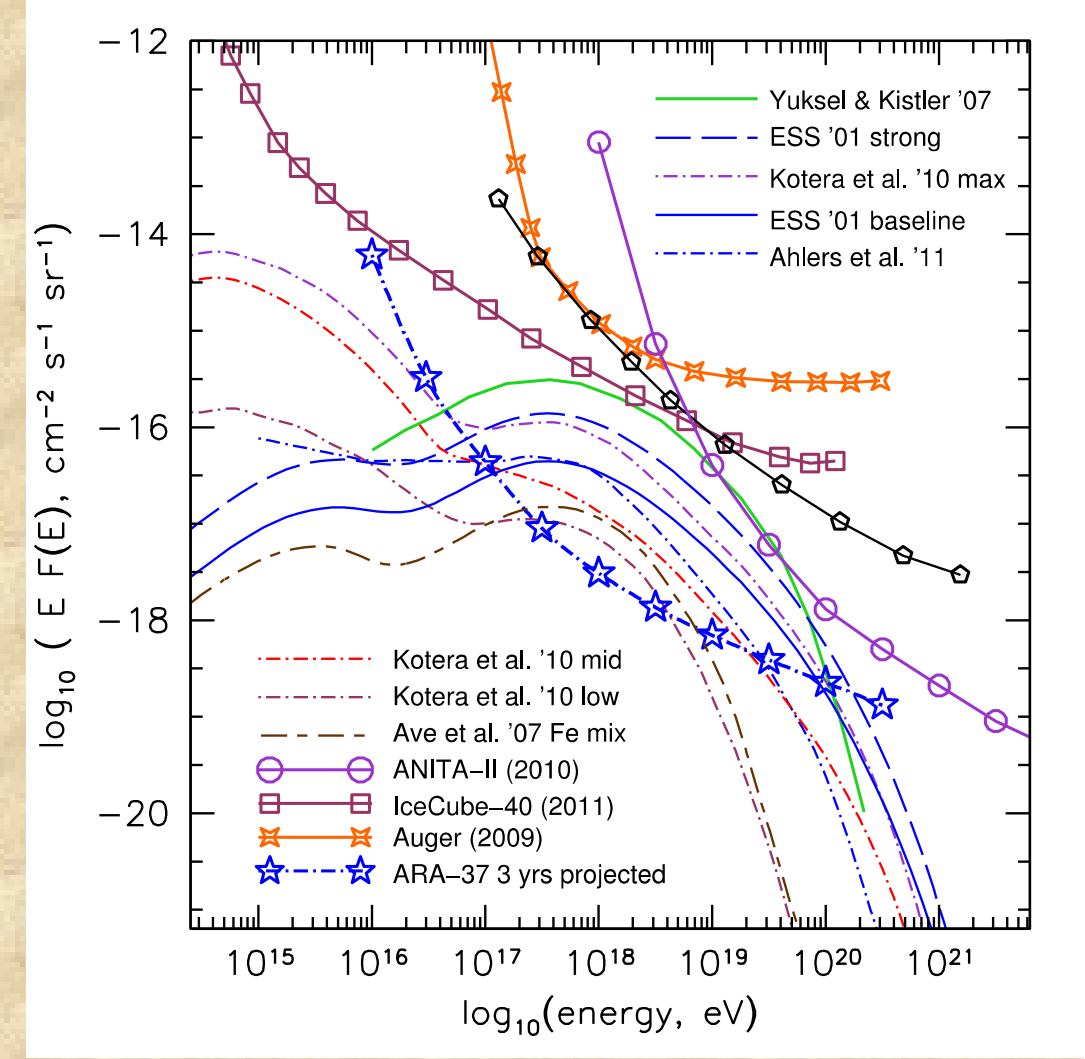
ARA 37 layout

- Goal is to count events, not reconstruct the angles as would be needed for observatory class instrument, so a clustered design was adopted.
- A single station can provide a stand alone trigger -> trigger locally.
- Spacing increased to 2 km from 1.33 km in original proposal due to recent indications of a possibly heavier nuclear spectrum.



ARA Sensitivity

Model & references	N_ν:	ANITA-II, (2008 flight)	ARA, 3 years
Baseline cosmogenic models:			
Protheroe & Johnson 1996 [27]		0.6	59
Engel, Seckel, Stanev 2001 [28]		0.33	47
Kotera,Allard, & Olinto 2010 [29]		0.5	59
Strong source evolution models:			
Engel, Seckel, Stanev 2001 [28]		1.0	148
Kalashev *et al.* 2002 [30]		5.8	146
Barger, Huber, & Marfatia 2006 [32]		3.5	154
Yuksel & Kistler 2007 [33]		1.7	221
Mixed-Iron-Composition:			
Ave *et al.* 2005 [34]		0.01	6.6
Stanev 2008 [35]		0.0002	1.5
Kotera, Allard, & Olinto 2010 [29] upper		0.08	11.3
Kotera, Allard, & Olinto 2010 [29] lower		0.005	4.1
Models constrained by Fermi cascade bound:			
Ahlers *et al.* 2010 [36]		0.09	20.7
Waxman-Bahcall (WB) fluxes:			
WB 1999, evolved sources [37]		1.5	76
WB 1999, standard [37]		0.5	27



See ArXiv: 1105.2854 for flux references

ARA Status

- Prototype phase funded by linked collaborative NSF MRI's to UM and UW (Hoffman and Karle PI's) Each institution was awarded 1.5 million plus cost share from UM, UW and collaborating foreign institutions.
- 3 prototype stations installed by the end of 2012-2013 austral summer, plus a "testbed" to measure noise profile, and 3 deep, high voltage calibration sources (installed on final IceCube strings)
- A collaborative proposal was submitted to the NSF in 2011 to fund the balance of the array ($7M requested from the NSF, the rest would come from foreign agencies). It's still pending. A "site visit" was finally convened in Washington in February 2013.
- It is likely that the pending proposal will be only partially funded, and another proposal will be required.
- Estimated construction time is 5 years, once full funding is secured.

Gamma-Ray Astronomy - HAWC

- Jordan Goodman (Prof) – PI
- Andrew Smith (Research Scientist) – Project Manager
- Two Post-docs
- Two Grad Students

The HAWC Observatory

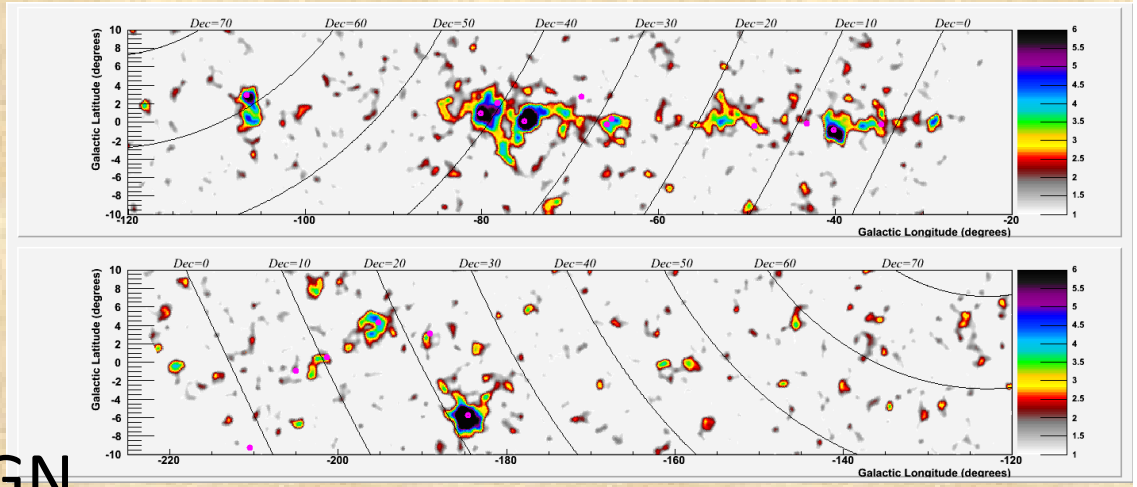
- HAWC (High Altitude Water Cherenkov)
  - 2nd generation water Cherenkov gamma-ray telescope
  - Under Construction at 4,100M asl in Mexico
  - 300 large Water Cherenkov Detectors
  - Follow-on to the Milagro observatory
  - Being built by NSF, DOE and CONACyT (Mexico)
- Maryland has the leadership role
  - Goodman is the PI
  - Smith is the Project Manager
  - $13M Project total - $6.5M through UMD since Feb 2011

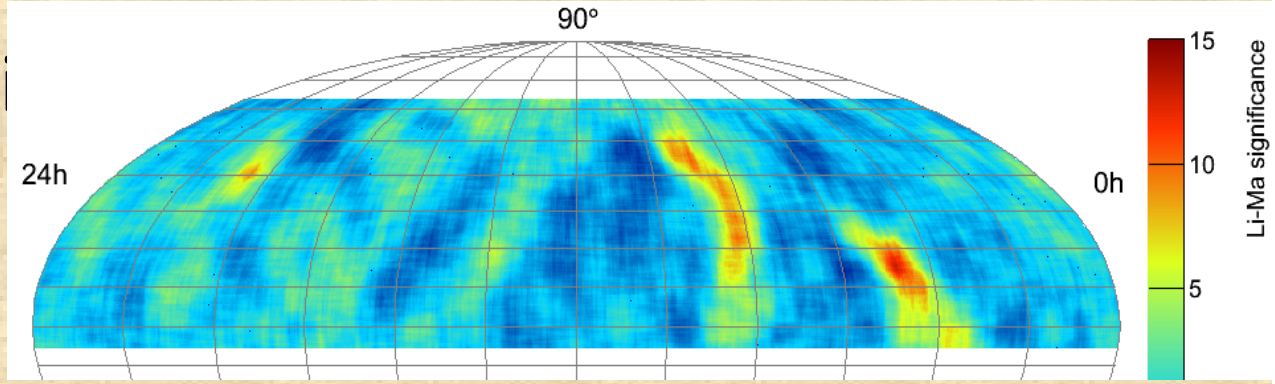
HAWC

- The only new start in the PA field in the US in the last few years
  - Scheduled to be completed in 2014
  - Already taking data with a partially completed array

HAWC Science

- TeV Gamma-ray sources
  - Galactic – SNR
  - Extragalactic – AGN
- Transients - GRBs
- Diffuse emissi
- Dark Matter
- Anisotropy





Long Baseline Neutrino Experiment

- Developed out of our experience on Super-Kamiokande
  - Sullivan recruited early on for the water option
    - Co-authored original white paper on depth requirement coupled with DUSEL lab
    - Member of first LBNE exec committee
    - UMD wrote section of CDR for online filter systems, monitoring, run control
  - Technology choice by project manager selected LAr detector
    - Remain involved in LBNE and helped prepare CDR for CD-1 review
    - Responsibilities for Lar detector in online systems and run control.
  - Have returned significant funding over past years (100's k$)
    - Need more faculty support at UMD → Busy with IceCube
    - Tried to recruit a young assistant professor from another university last year. Unsuccessful recruitment (two body problem, and university couldn't quite come through for her husband)
  - Well placed for continuing opportunity here!

Experimental Nuclear Physics

- Faculty (since 2005)
  - Betsy Beise – Professor and Associate Provost (2009)
  - Carter Hall – Associate Professor (tenured 2012)
  - Herbert Breuer – Associate Research Scientist (retired 2012)
  - 4 departures in 2005/2006 (Chang, Roos, Chant, Kelly)
- Current and recent postdocs and research scientists
  - Kazutaka Nakahara (2009-current) – UMD Asst. Res. Sci. since 2012
  - Lisa Kaufman (2007 - 2010) - now Asst. Prof. at Indiana University
  - Doug Leonard (2009 - 2011) - now Asst. Prof. at Univ. of Seoul
  - Fatiha Benmokhtar (2006-2008) – now Asst. Prof. at Christopher Newport University

Current and Recent Students

Current grad students

- Tom Langford (neutrons, 2013)
- Yung-Ruey Yen (EXO, 2013)
- Atilla Dobi (LUX, 2014)
- Clayton Davis (EXO, 2014)
- Richard Knoche (LUX, 2017)
- Jon Balajthy (LUX, 2018)

Recent grad placements

- Simon Slutsky (EXO, 2013) – now postdoc at Caltech
- Jon Miller (Jlab, 2009) - now faculty at Universidad Tecnica Federico Santa Maria , Chile
- Colleen Ellis (G0, 2009) -now at Lockheed Martin
- Tanja Horn (G0, 2006) - now faculty at Catholic University
- Jianglai Liu (G0, 2006) – now faculty at Shanghai Jiao Tong University, China

Undergrads

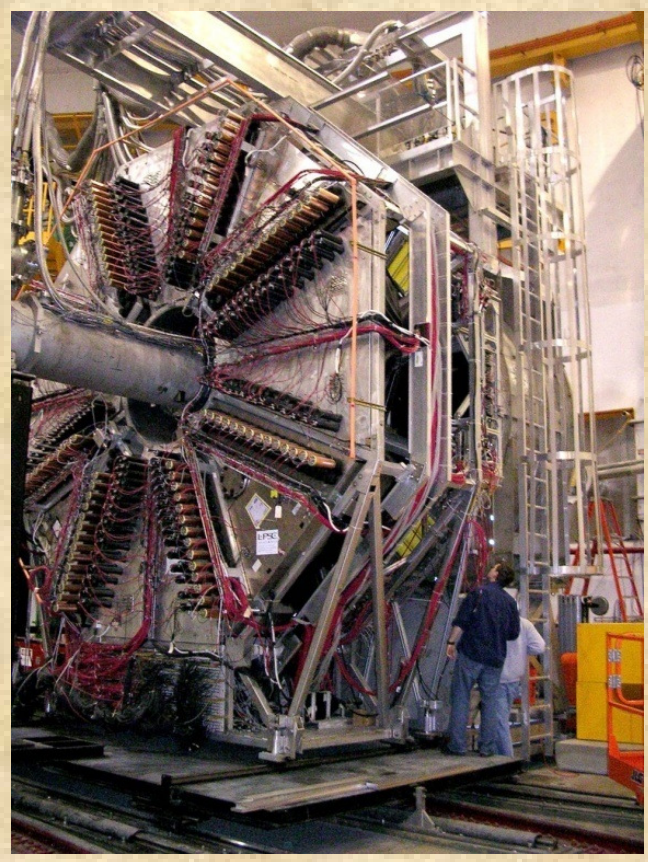
- Typically supervise 3 – 6 undergrads per year (currently 3)
- Recent students have gone to Caltech, UCLA, BU, UC Boulder, and UMD.
- Several winners of the Monroe-Martin award for best undergraduate thesis (Richardson and Szamotula, 2011, Erwin 2010).
- Philip Merrill Distinguished Scholar (Kiriluk)
- High Honors (Kiriluk, Erwin)

QCD structure of the nucleon

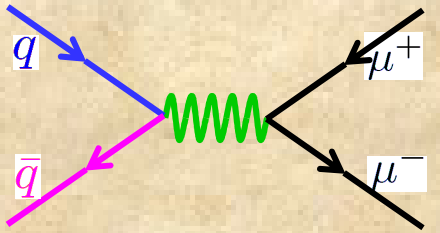
Parity-violating electron scattering at Jefferson Lab

Places stringent limits on the contribution of strange quarks to proton's charge and magnetism distributions.

D. Androić et al. (G0 Collaboration) Phys. Rev. Lett. ***104*** *(2010) 012001*



Drell-Yan in pp and pd scattering at Fermilab



Sensitive test of antiquark distributions in nucleon, important to understand role of antiquark sea in non-perturbative QCD description of nucleon

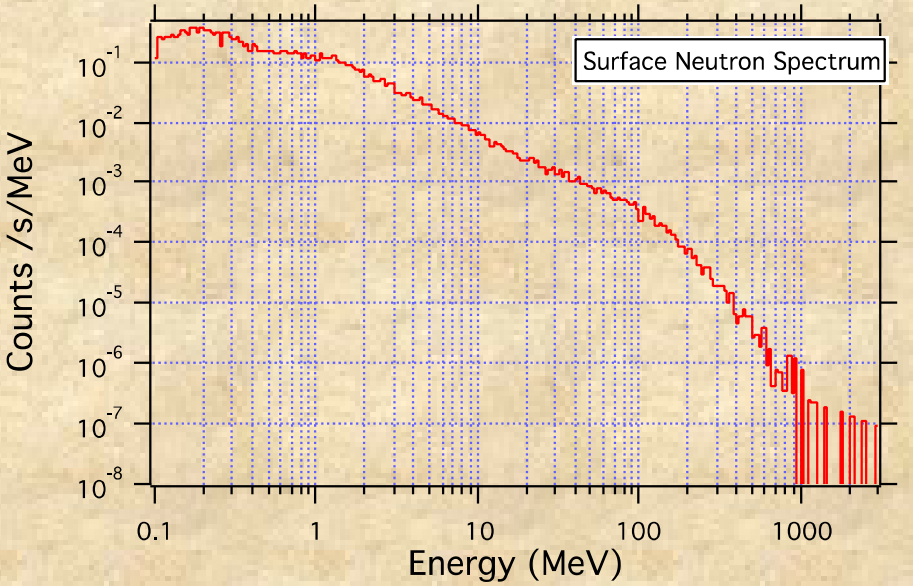
Experiment E906 installed and in progress at Fermilab

UMD role – DAQ, cryogenic targets (K. Nakahara is on-site at FNAL)

High Sensitivity Neutron Detection

UMD-NIST collaboration
Ph.D. thesis, Tom Langford

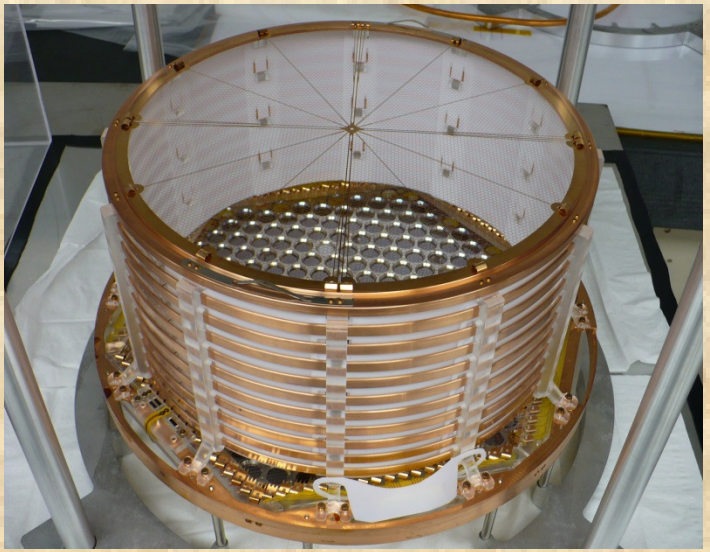
- Fast neutron detection for deep underground experiments, based on "capture gated spectroscopy". Funded by DUSEL R&D award and by NIST.
- Prototype operated in Kimballton Underground Research Facility (KURF) for 2 years.



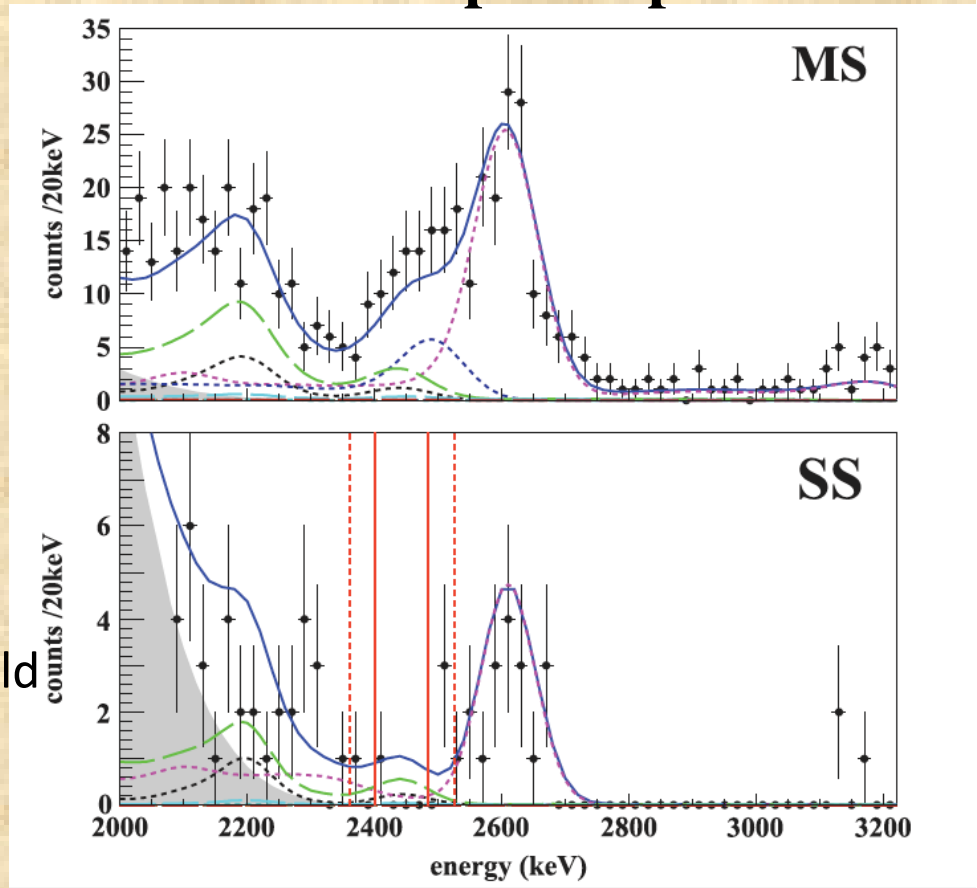
- 2nd generation detector complete and currently being calibrated at NIST
- Measuring the surface neutron spectrum and to be deployed in a "modestly deep" underground location (DC metro?).

T. J. Langford, et al., arXiv:1212.4724: use of pulse-shape discrimination in ^{3}He counters
C.D. Bass, et al., arXiv: 1206.4036: performance of ^{6}Li loaded scintillator

Neutrinoless double beta decay with EXO-200



^{136}Xe Endpoint spectrum



- World's most sensitive search for Majorana neutrino masses.
- First experiment to check a ten-year old discovery claim in this field.
- First observation of two-neutrino double decay decay in ^{136}Xe.
- Data taking will continue until 2015.
- UMD group is one faculty (Hall) and three grad students (Slutsky, Yen, Davis). Hall is analysis coordinator and software coordinator.

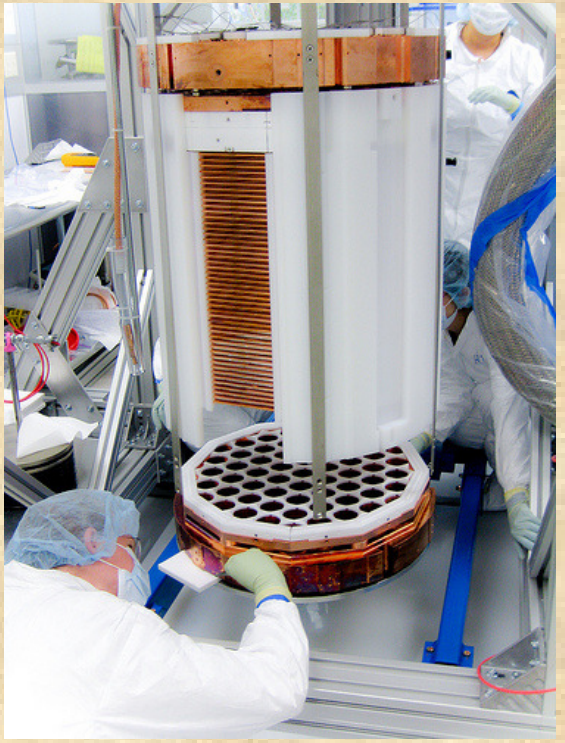
$T_{1/2} > 1.6 \times 10^{25}$ years (90% C.L.)

$m(\nu) < 140 - 380$ meV

Phys. Rev. Lett. 109 032505 (2012)

Search for WIMP dark matter with LUX

- 350 kg liquid xenon dark matter detector located in the former Homestake Gold Mine in South Dakota (SURF).
- Operations began in February 2013; physics results expected this year.
- One of the largest experiments of its type.



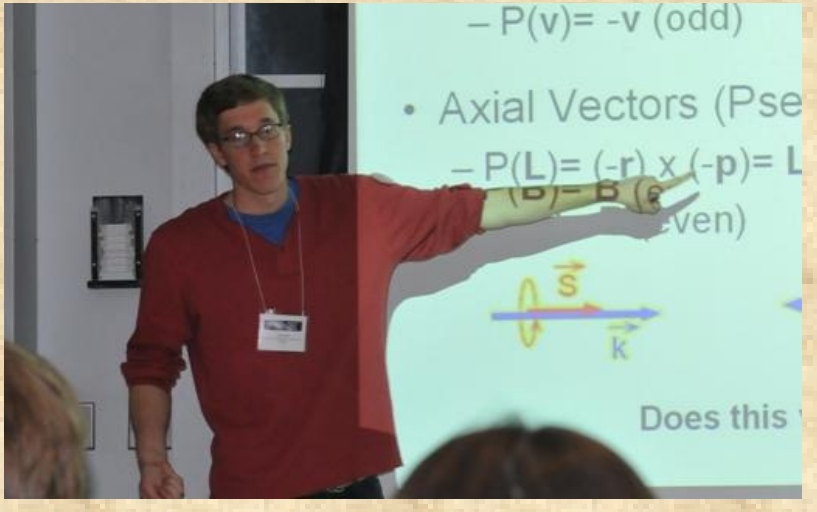
- UMD group is 1 faculty (Hall) and 3 grad students (Dobi, Knoche, Balajthy).
- Planning underway for next generation 8-ton experiment (LZ).
- Hall is Level 2 manager for LZ xenon purification and an elected member of the executive board.

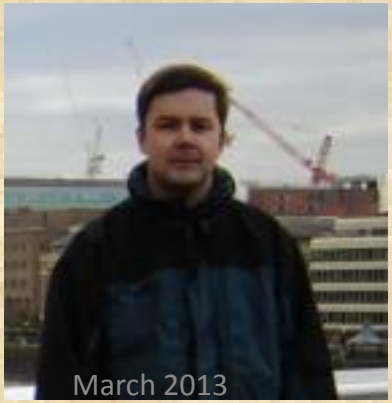
Experimental Nuclear Physics

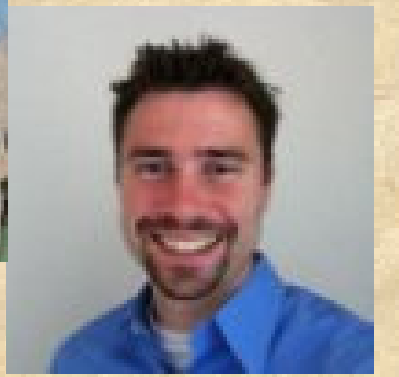
- **Awards, Recognition, External service, and Leadership**
  - Beise
    - UMD Distinguished Scholar Teacher, 2012
    - AAAS Fellow 2000
    - APS Fellow 2001
    - Maria Goeppert-Mayer Award 1998
    - NSF Program Director, Nuclear Physics, 2004-2006
    - Active on APS committees (Exec Board 2009-2010)
    - Jefferson Lab Science Council (2013-)
  - Hall
    - DOE- HEP Early Career Award (2011)
    - Richard Ferrell Young Faculty Award - UMD (2011)
    - LZ experiment executive board (2012 – 2013)
    - LZ experiment Level 2 manager for xenon handling (since 2012)
    - Analysis coordinator for EXO-200 (2012 – 2013).

Experimental Nuclear Physics

- **Funding**
  - EXO-200 (double beta decay): $170k/year (NSF)
  - LUX (dark matter): $190k/year (DoE)
  - E906 (Drell-Yan): $100K/year (NSF)
  - Neutron spectroscopy: grant completing: $480K total (NSF)
- **Opportunities:**
  - US is planning large new experiments in both dark matter and double beta decay.
  - Discovery potential is outstanding.
  - Student interest is very high (6 students supervised by Hall).
- **Challenges**
  - With Beise serving as Associate Provost, most group activity is due to a single faculty member (Hall)
  - Not all interested students can be accommodated.


– P(v)= -v (odd)
• Axial Vectors (Pse
– P(L)= (-r) x (-p)= L
ven)
Does this





Experimental Gravity Research

Two research areas:

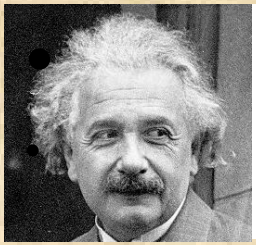
Gravitational wave searches with LIGO and other detectors

- GW signal searches, multimessenger astrophysics, tests of gravity theory
- One faculty (Shawhan), ½ postdoc, 1–2 grad students
  - Complemented by Buonanno's more theoretically focused GW group
- Funded by NSF, currently $120k/year
- Direct contributions to many LIGO data analysis results papers, and leadership roles within the LIGO Scientific Collaboration

Precision laboratory tests of gravity

- Superconducting gravity gradiometer tests of inverse-square law, precision seismometry
- Retired faculty (Paik), lab manager (Moody), 2 postdocs, 1 grad student
- Funded by NASA, industry partnership

Closing in on Direct Detection of Gravitational Waves



Wave solutions to the equations of general relativity

Emitted by a massive object or system with a rapidly varying shape or orientation

- Astrophysical sources include:
  - Binary black hole / neutron star systems
  - Stellar core collapse (supernova engine)
  - Rapidly spinning neutron stars
- Typical strain at Earth: **~ 10^{-21} !**
  - No signals directly detected yet, but close

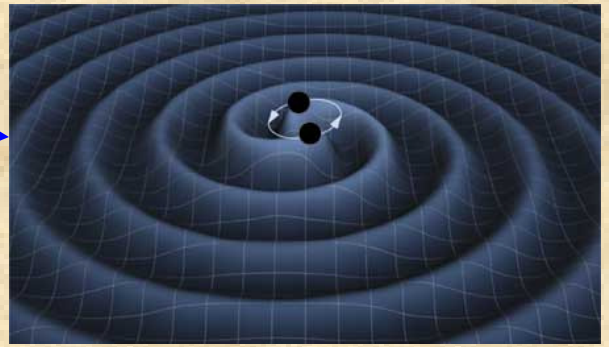
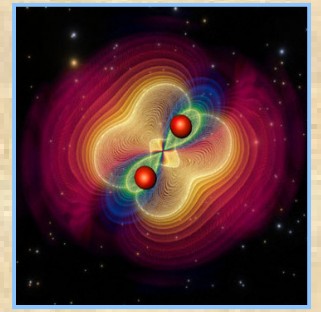


Image Credit: K. Thorne (Caltech), T. Carnahan (NASA GSFC)

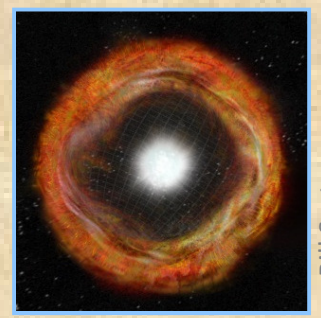
Maryland focus areas

Gravitational-Wave Science

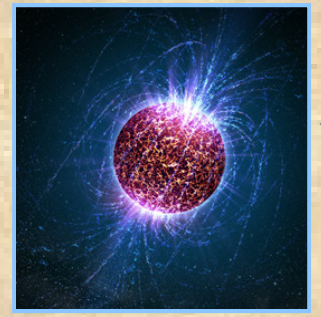
- Astronomy with gravitational waves
  - Populations of neutron stars and black holes
  - Core-collapse supernovae and other “burst” sources
  - Cosmic strings, other exotica?
- Multi-messenger astronomy
  - Deep searches following gamma-ray bursts, magnetar flares, …
  - Joint analysis with high-energy neutrinos, radio bursts
  - Rapid EM follow-up observations of GW event candidates
- Testing the theory of gravity – was Einstein right ??
  - Verify that gravitational waves exist !
  - Test wave properties: alternative theories predict different polarization states and/or propagation speeds
  - Study source dynamics driven by strong-field gravity
- Astrophysics of GW sources
  - Neutron star equation of state, material properties
  - Black hole formation, mergers, ringing, spin distributions
  - Physical mechanisms of core-collapse supernovae
  - Cosmic gravitational wave backgrounds



W. Benger, LSU



Bill Saxton, NRAO/AUI/NSF



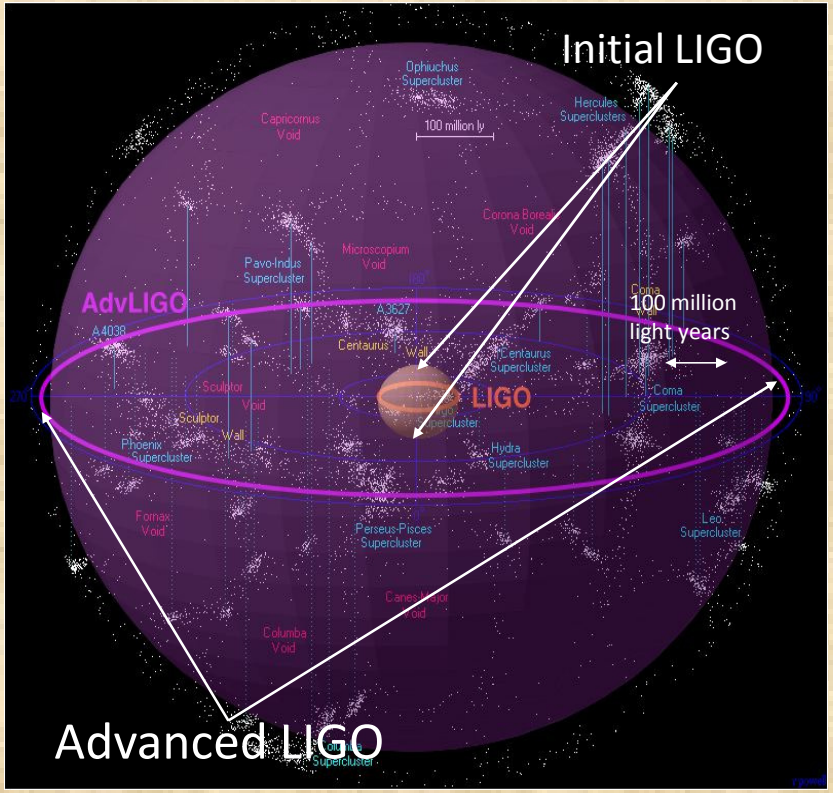
Casey Reed/PSU

Advanced LIGO Status

- Project is fully funded, on budget and on schedule
  - ~$200 million upgrade, mostly complete
  - Interferometer components currently being installed and tested !
  - Will increase range by an order of magnitude
  - Commissioning over next few years
  - First science run planned for **2015**

Advanced Virgo (Italy), KAGRA (Japan), LIGO-India [pending final approval of funding from Indian government] will round out global network of advanced detectors

- Preparing now for Advanced detector operations, data analysis, discoveries, physics tests and astrophysics !



Reaching further into the universe

Gravity Research – Notes, Concerns

Gravitational wave searches with LIGO and other detectors

- Currently few students – should grow as Advanced LIGO starts up
- Growing ties to mainstream astronomy and astrophysics – opportunities and challenges
- Benefits from Joint Space Science Institute

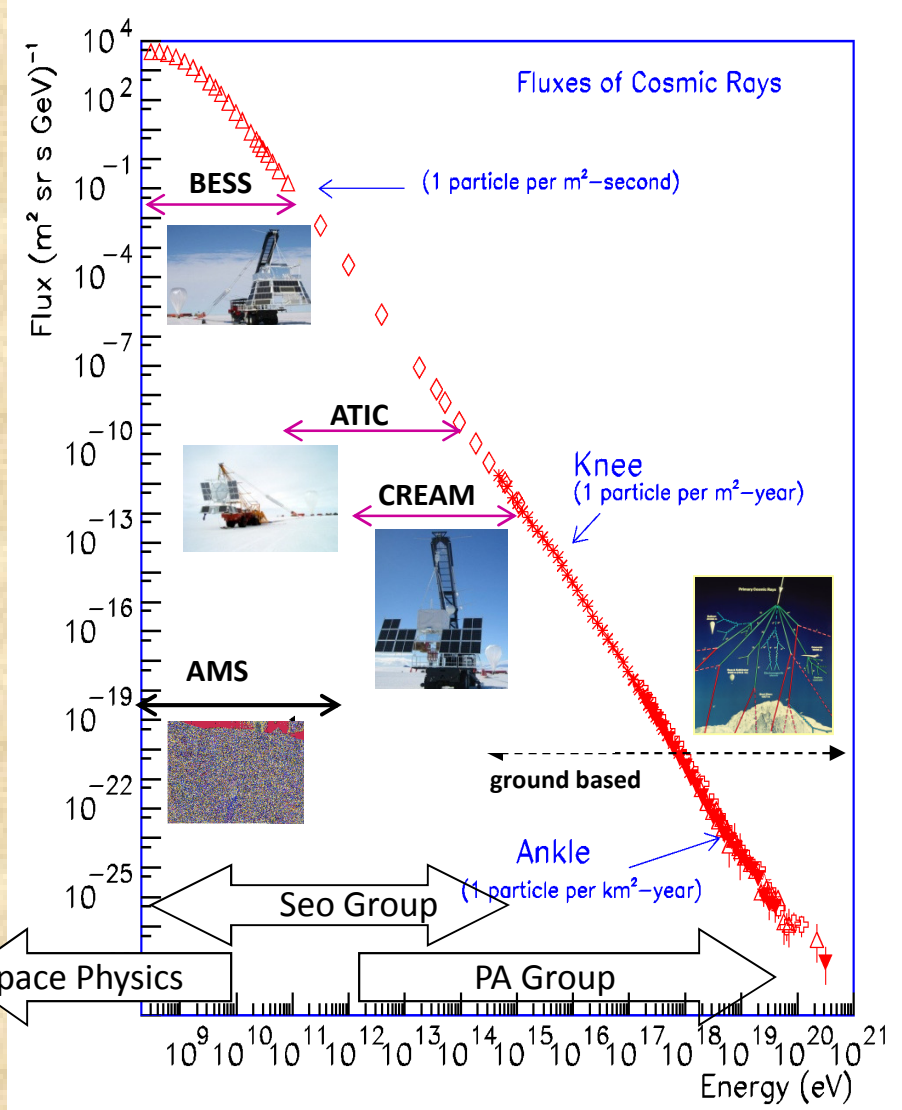
Precision laboratory tests of gravity

- Department has leading heritage in gravity research
- Paik directs laboratory remotely since his retirement

Cosmic Ray Physics Group

http://cosmicray.umd.edu/

- This group's precision measurements fill the gap between space- and ground-based research activities of other groups on campus.
- The AMS, ATIC, BESS, and CREAM instruments are based on particle detectors like those used at accelerators, but they are flown in space for cosmic ray measurements
- The instruments are for the most part **built in-house by students** and young scientists, many of them currently working in the on-campus laboratory.
- The CREAM Science Operation Center at UMD remotely controls the instruments flying in Antarctica by sending commands and receiving data via satellite.



Cosmic Ray Physics Group

~30 members led by one professor

Annual research funding ~$1.5 M for more than 10 years

- Faculty (1)
  - Eun-Suk Seo
- Research Scientist (1)
  - Moo Hyun Lee
- Postdoctoral Research Associates (5)
  - Alexander Malinin
  - Hyun-Gue Huh
  - Kichun Kim
  - Munhwa Kim
  - Nicholas Picot-Clemente
- Graduate Students and Lab Assistants (6)
  - David Angelaszek, Jihye Han, Mike Copley, Brian Fields, Kenny Kwashnak, Oluchi Ofoha
- Undergraduate Students (13)
  - Harry Arnold, Daniel Bae, Kevin Cheriyan, Christiane Ebonque, Jon Frys, Raymond Guerci, Paul King, James Meade, Ashley Seto, Justin Tevala, Peter Weinmann, Bret Yon, David Zukerman
- Engineers and technicians (5)
  - Mayank Gupta, Larry Lutz, Azzi Haque, Steve Derdeyn, Hendrik Wats

- NASA Group Achievement Award, 2006 and 2011.
- 2012 KWiSE (Korean-American Women in Science and Engineering) Woman Scientist Award, August 2012.
- APS fellow 2010.

Balloon–borne Experiment with a Superconducting Spectrometer (BESS)

- Original BESS instrument was flown 9 times between 1993 and 2002.
- New BESS-Polar instrument flew from Antarctica in 2004 and 2007
  - Polar–I: 8.5 days observation
  - Polar–II 24.5 day observation: 4.7B events collected and ~8,000 antiprotons detected: **no evidence of primary antiprotons from exotic sources (e.g., evaporation of primordial black holes, dark matter annihilation etc.).**

Abe et al. PRL, 108, 051102, 2012

Search for the existence of Antimatter in the Universe

Search for Antihelium with the BESS-Polar Spectrometer

K. Abe *et al.*

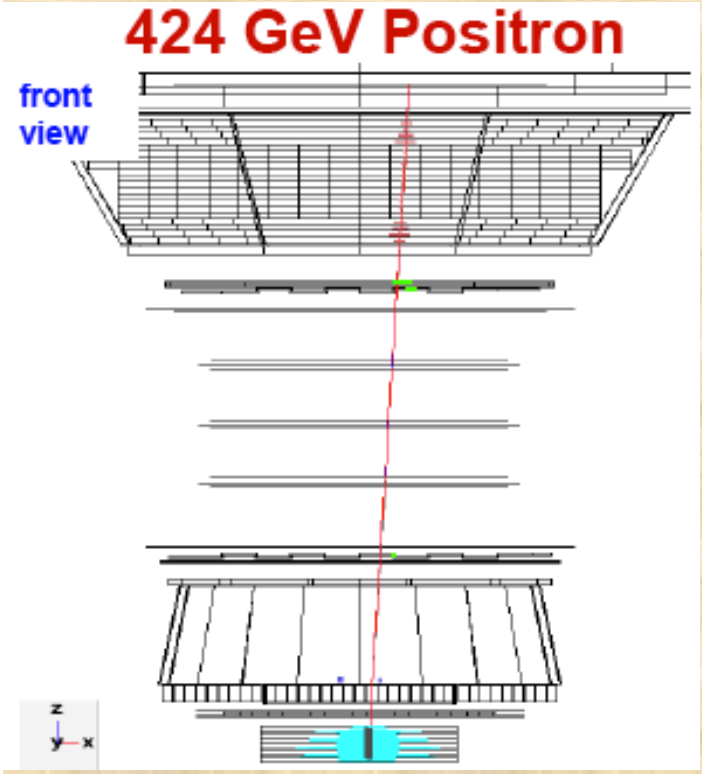
Phys. Rev. Lett., 108, *131301*, 2012

- No single anti He has been measured
- BESS has provided the lowest upper limit to date on the relative antihelium-to-helium ratio 6.9×10^{-8}
- This limit is *three orders of magnitude* improvement over data (results) prior to BESS.

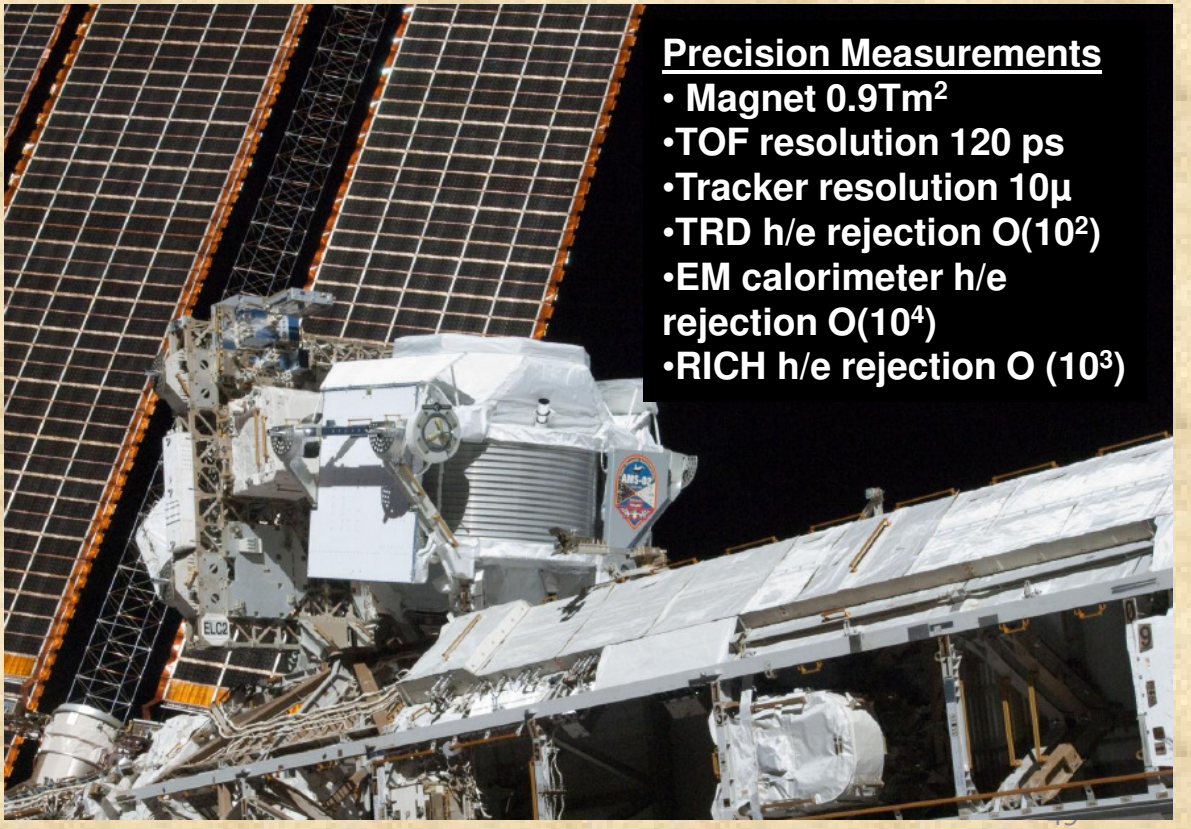
Alpha Magnet Spectrometer (AMS)

Taking data ~16 billion events per year since its launch to ISS in May 2011
Plan to operate for the ISS lifetime (>2021)

- Search for dark matter by measuring positrons, antiprotons, antideuterons and γ-rays with a single instrument
- Search for antimatter on the level of < 10^{-9}



Flight data example



Advanced Thin Ionization Calorimeter (ATIC)

Discovery of excess of high energy electrons

"All the News That's Fit to Print"

The New York Times

National Edition

VOL. CLVIII . . . No. 54,505 TUESDAY, NOVEMBER 25, 2008 $1.50

Detecting a Whisper, Perhaps, From the Dark Side of the Universe

From First Science Page

Searching for Dark Matter High Above the Antarctic

Are anomalies in the sky signs of dark matter, or something simpler?

Chang et al., Nature, **456**, 362-365 (2008)

Cited > 500 times

nature
international weekly journal of science

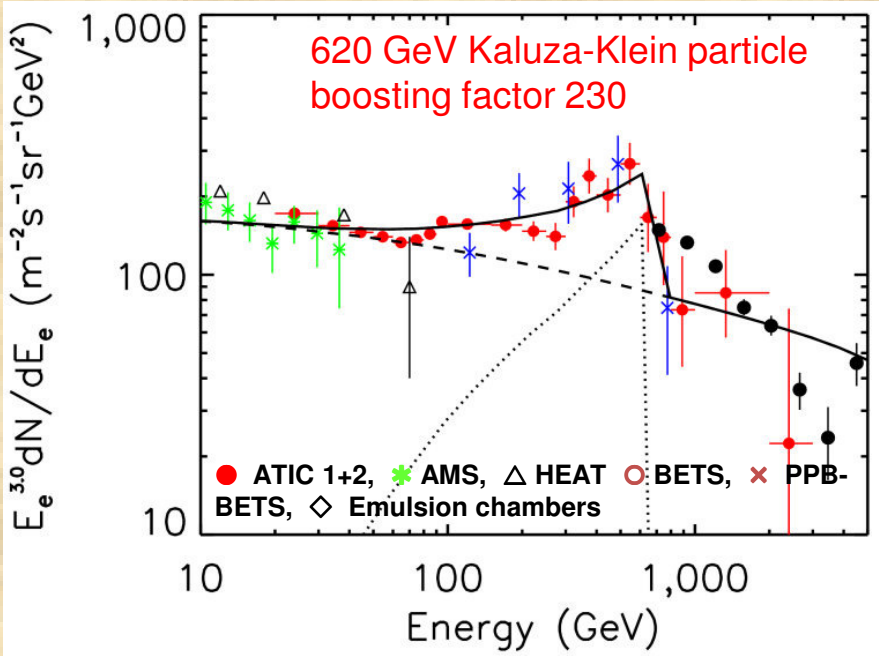
Letter

Nature **456**, 362-365 (20 November 2008) | doi:10.1038/nature07477; Received 23 May 2008; Accepted 1 October 2008

An excess of cosmic ray electrons at energies of 300–800 GeV

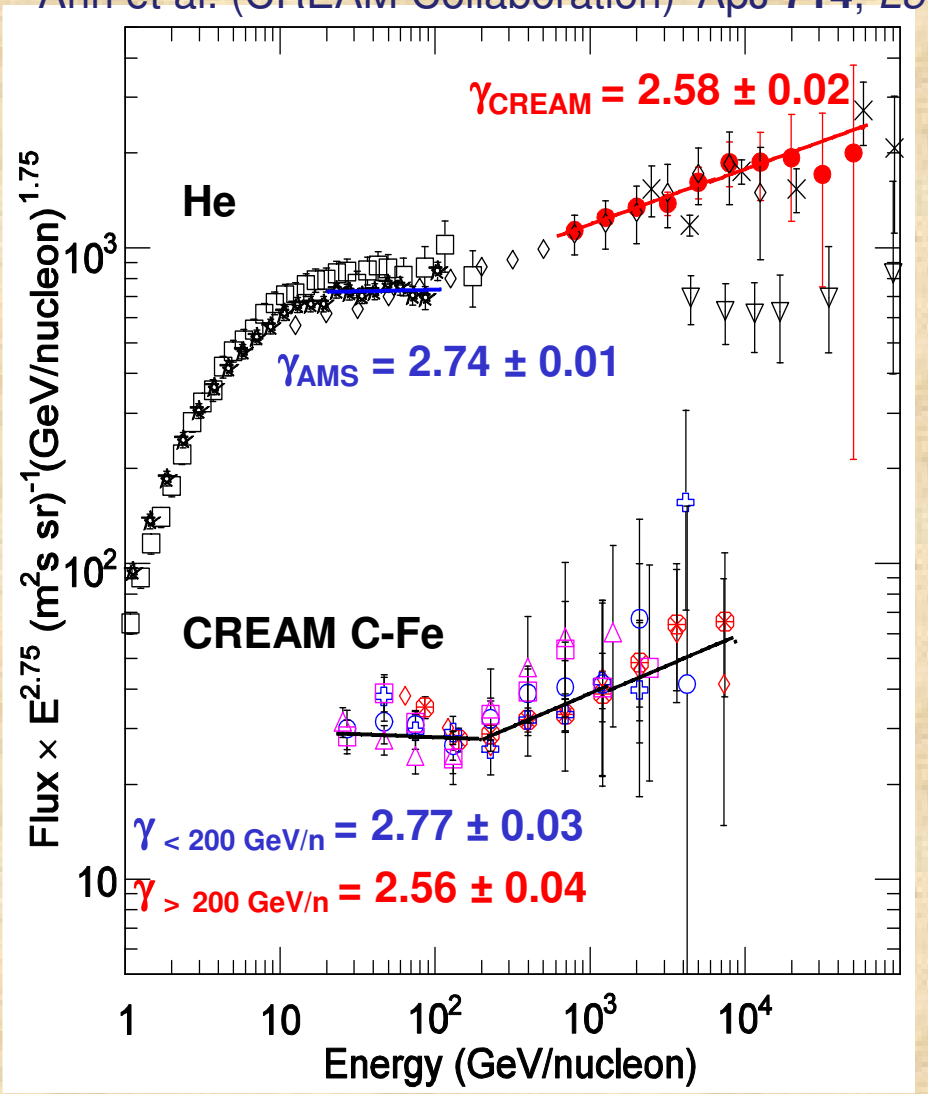
J. Chang[1,2], J. H. Adams[3], H. S. Ahn[4], G. L. Bashindzhagyan[5], M. Christl[3], O. Ganel[4], T. G. Guzik[6], J. Isbert[6], K. C. Kim[4], E. N. Kuznetsov[5], M. I. Panasyuk[5], A. D. Panov[5], W. K. H. Schmidt[2], E. S. Seo[4], N. V. Sokolskaya[5], J. W. Watts[3], J. P. Wefel[6], J. Wu[4] & V. I. Zatsepin[5]

1. Purple Mountain Observatory, CAS, 2 West Beijing Road, Nanjing 210008, China
2. Max Planck Institute for Solar System Research, 2 Max Planck-Strasse, Katlenburg-Lindau 37191, Germany
3. Marshall Space Flight Center, Huntsville, Alabama 35812, USA
4. University of Maryland, Institute for Physical Science & Technology, College Park, Maryland 20742, USA
5. Skobeltsyn Institute of Nuclear Physics, Moscow State University, Leninskie gory, GSP1, Moscow 119991, Russia
6. Louisiana State University, Department of Physics and Astronomy, Baton Rouge, Louisiana 70803, USA



Cosmic Ray Energetics And Mass (CREAM)

Ahn et al. (CREAM Collaboration) ApJ **714**, *L89*, 2010



- CREAM results contradict the traditional view that a simple power law can represent cosmic rays without deviations below the "knee" around 3 x10^{15} eV.
  - It provides important constraints on cosmic ray acceleration and propagation models, and it must be accounted for in explanations of the electron anomaly and mysterious cosmic ray "knee."

These spectra will provide experimental measurements of the assumptions that go into calculating the background in searching for Dark Matter, i.e., p + C → e+, pbar, …

CREAM for the International Space Station (ISS-CREAM)

Seo is the PI and international spokesperson

building on the success of balloon-borne experiments

Six Balloon Flights in Antarctica :
~ 161 days Cumulative Exposure

The longest known flight time for a single balloon project

- Space-X launch in 2014
- Plan to operate until ISS end-of-life (> 2021)
- Science operation center must operate continually

Opportunities, Concerns & Issues

- TG2E has developed into a premier set of groups with leadership positions in many of the high profile experiments in our field.
  - Number of Spokespeople, leadership positions and Construction project PIs
  - Funding well over $400k per faculty
  - Fundamental science questions → synergy with MCFP
- Opportunity exists to leverage the position we have worked toward in the last decade, with support from the university
  - More state support from IDC return for engineering and technical support closer to the level of our top competitors
  - Faculty positions to exploit opportunities that have developed (e.g. neutrino oscillations LBNE/PINGU, Dark matter, LHC upgrades…)
- Concern on the flip-side
  - Age profile of faculty is a concern
  - Possible that our success has resulted in complacency by the university?
- We are at a cross-roads:
  - opportunity of leveraging the success into a truly exceptional group, or
  - leave opportunities on the table and let group continue to age.