Particle Physics Experiments

Stanford Physics Open House
Apr/1/2010

The Fundamental Questions

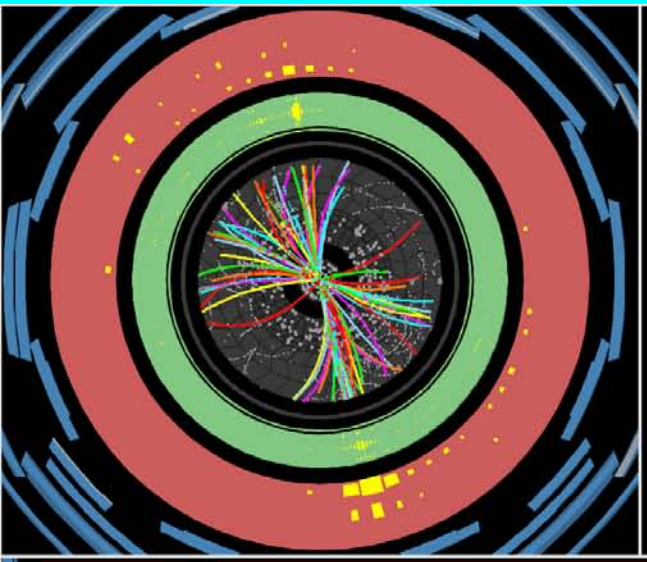
- Are there undiscovered principles of nature: new symmetries, new physical laws ?
- How can we solve the mystery of dark energy ?
- Are there extra dimensions of space ?
- Do all forces become one ?
- Why are there so many kinds of particles ?
- What is dark matter ?

  How can we make it in the laboratory ?
- What are neutrinos telling us ?
- How did the universe come to be ?
- What happened to antimatter ?

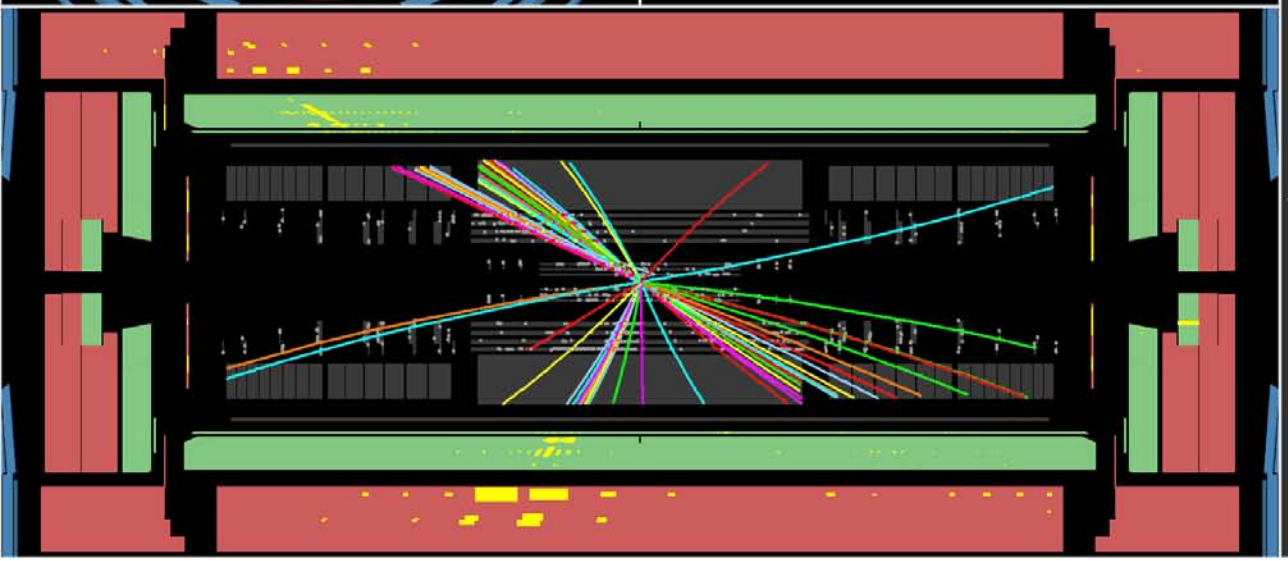
Particle Physics Programs

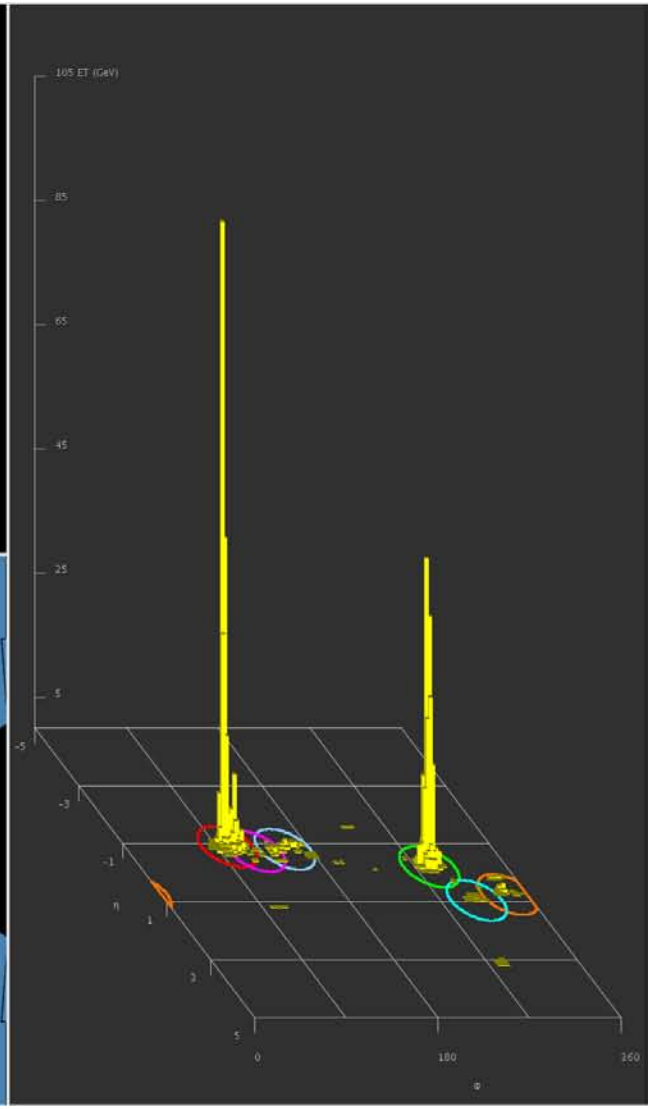
Expt	Description	Data Period
ATLAS	pp collision @7-14 TeV at LHC	2010-
BaBar/ superB	e+e- @10GeV at SLAC B-factory/ e+e- super B factory at Frascati	1999-2008/ ??
CDMS/ sCDMS	Dark Matter Search w/4.75Kg Ge@Soudan/ 15Kg Ge@Soudan / 100Kg Ge@SNOlab	2003-2009/ 2014-?? / ??
EXO200/ EXO	ν-less double β decay with Enriched Xe / 1T with Barium tagging	2010-2014 / ??
APEX/HPS	Heavy Photon Search at Jlab	2010/2012-
KamLand	Reactor neutrino	2002-present
MINOS	ν-oscillation at Soudan with NUMI	2005-present
SiD	Silicon Detector for ILC	??

ATLAS @ LHC



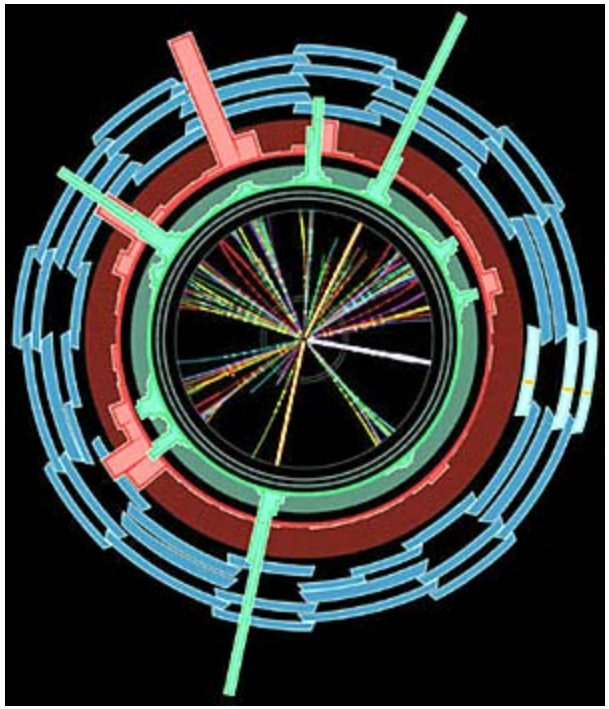

ATLAS
EXPERIMENT
Run Number: 152166, Event Number: 810258
Date: 2010-03-30 14:56:29 CEST
Di-jet Event at 7 TeV





Physics Opportunities

- Higgs particle
- SuperSymmetry
- Large extra-dimensions
- *The unexpected…*



SLAC physics strategy:

Initial emphasis on physics signature tools (b-tag,jet/missingEt) and trigger. Use Standard Model measurements with early data to validate these tools to prepare for searches of new physics beyond Standard Model.

Current SLAC physics analyses

- New physics search and top cross section measurement with b-tag and missing E_t
- Search for long lived new particles
- Lepton jets
- Heavy fermions->same sign dileptons
- Boosted W

Close collaboration with SLAC theory group

SLAC Involvement in ATLAS

2 Faculty + 1 Panofsky fellow
17+ Staff physicists & professionals
7 Postdocs
6 Grad students
& Tier2 computing center staff

Experimental Involvement

- Pixel vertex detector and tracking
- High Level Trigger and DAQ
- Simulation
- Tier-2 computing center
- ATLAS Detector Upgrades

Contact Info

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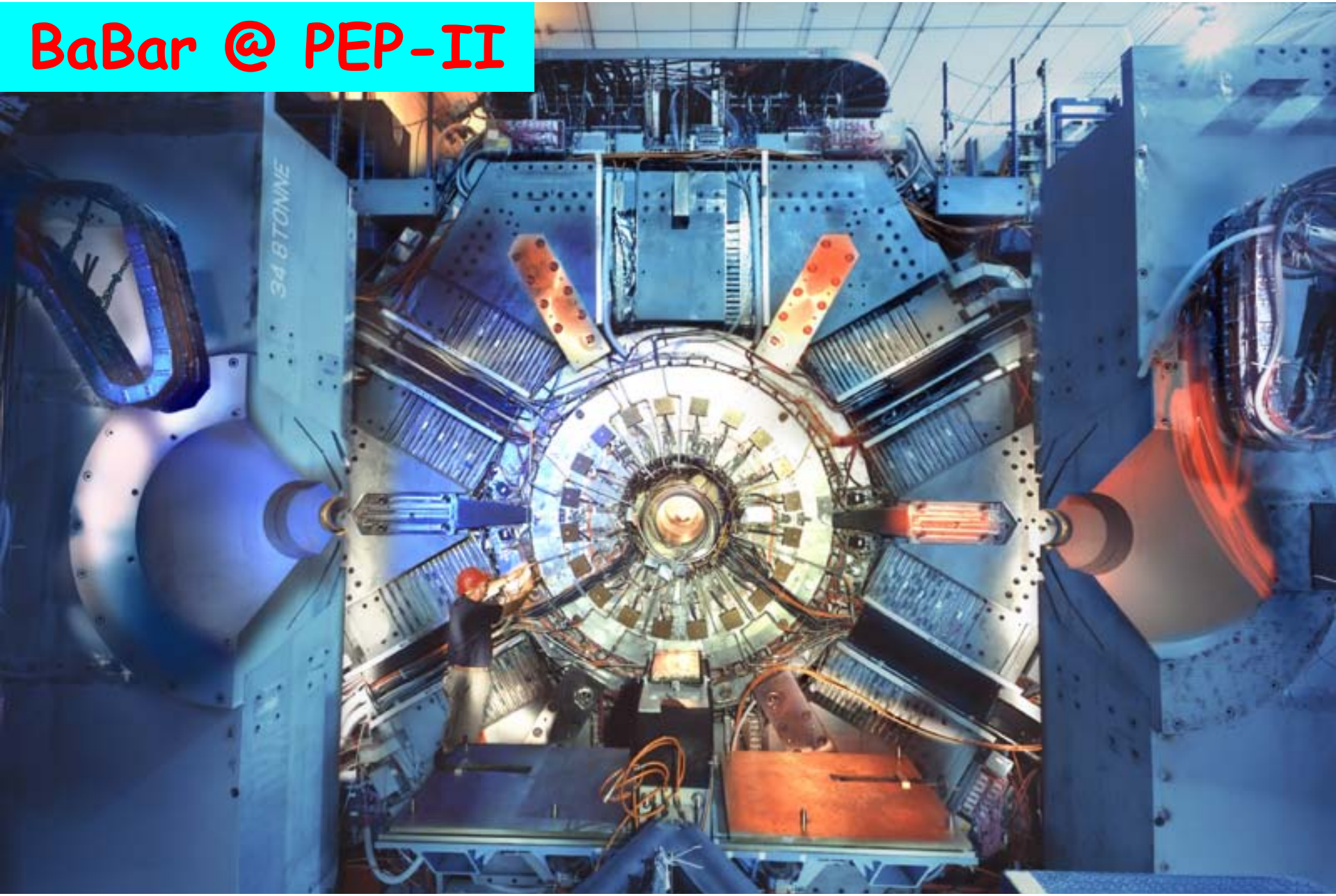
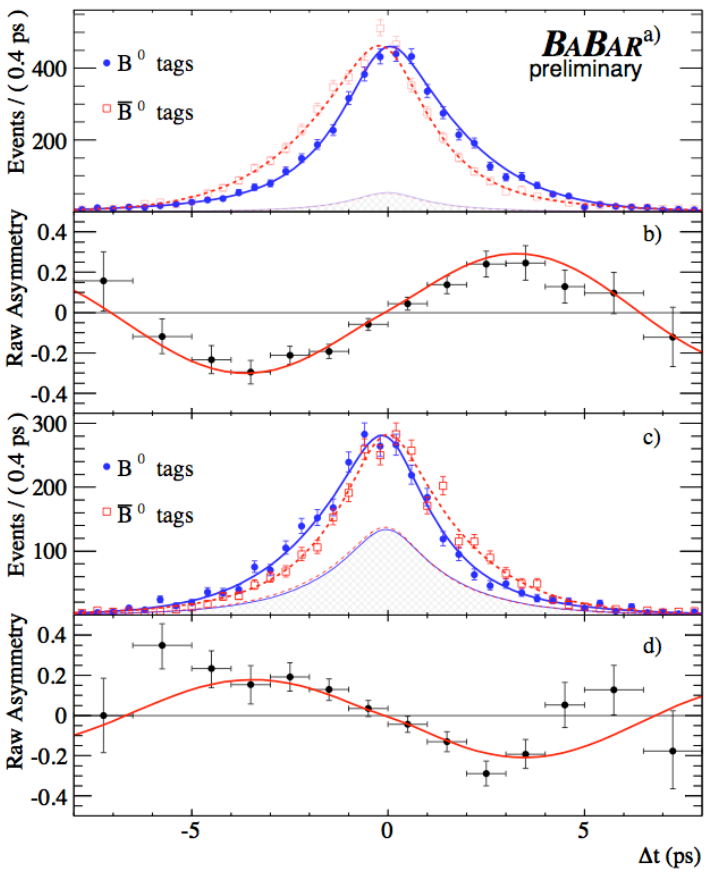
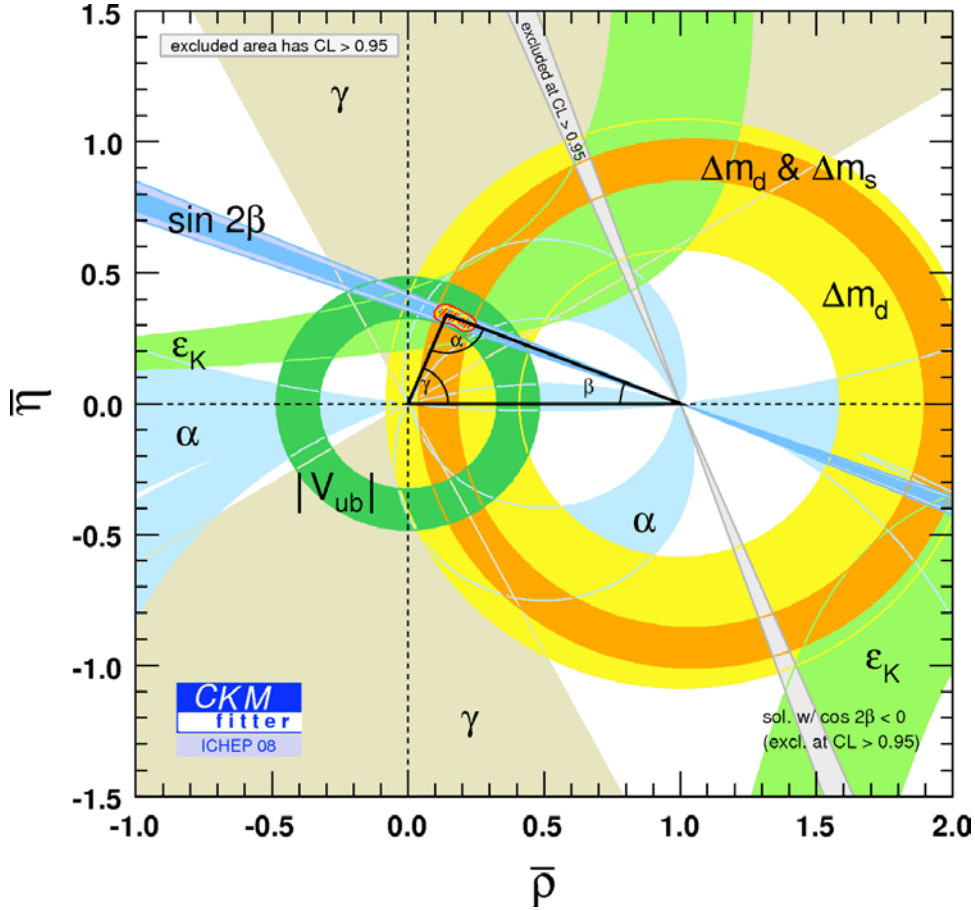
Detailed info on ATLAS@SLAC for students:
http://www.slac.stanford.edu/exp/atlas/students/

BaBar @ PEP-II



BaBar Physics





CP violation in B^0 decays

BaBar Analysis Opportunities

- Data taking ended Apr/08.
- 465M BB events
- 630M cc events
- 460M $\tau\tau$ events
- Largest sample of Upsilon resonance data
- 2-photon, ISR

Analysis topics:

- ISR->hadronic final states
- B/D decay Dalitz analysis
- Radiative B decays
- f_{Ds}
- Charmonium like resonances

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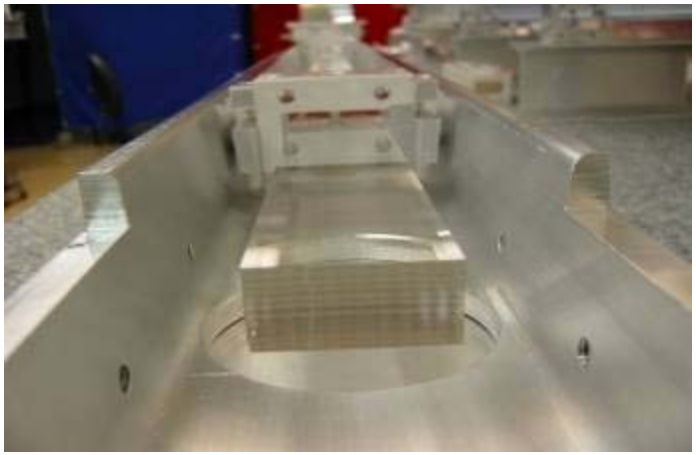
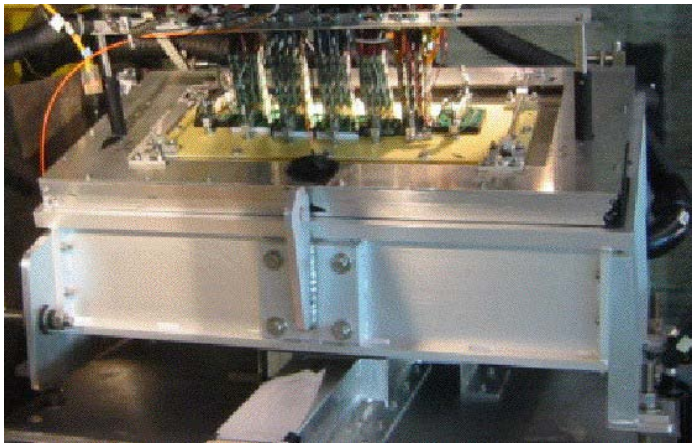
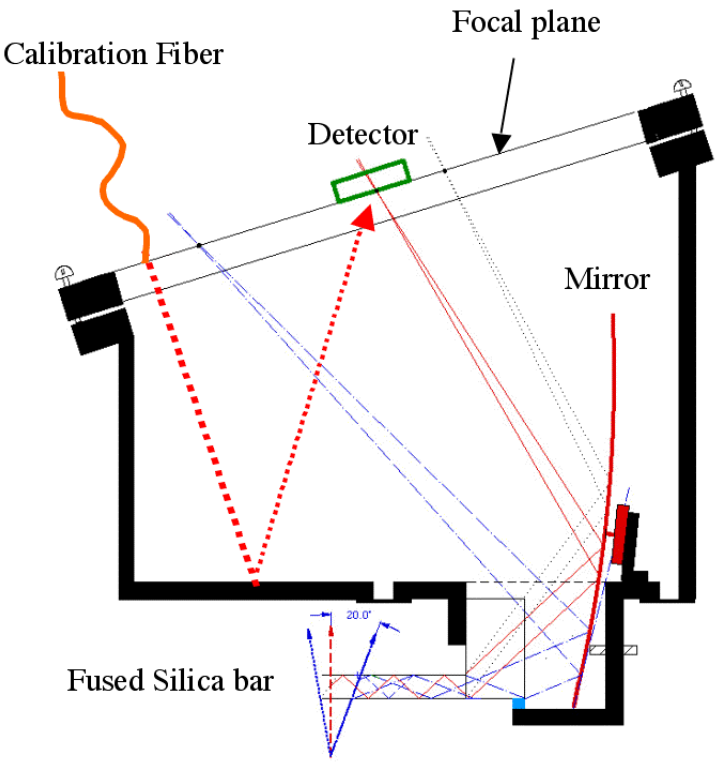
superB @ Frascati

Detector R&D on focusing DIRC for particle ID

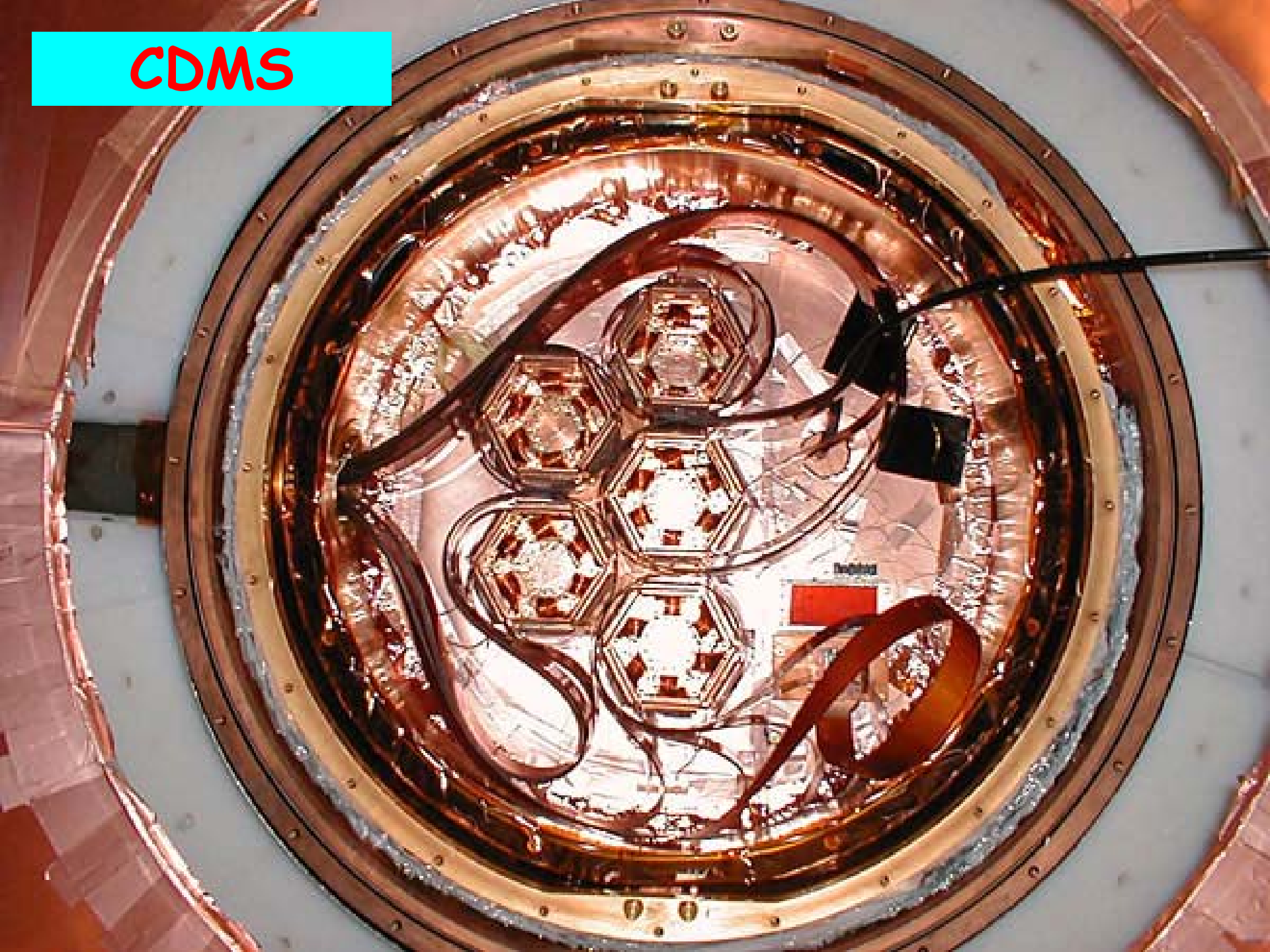
Detection of
Internally
Reflected
Cherenkov light







CDMS

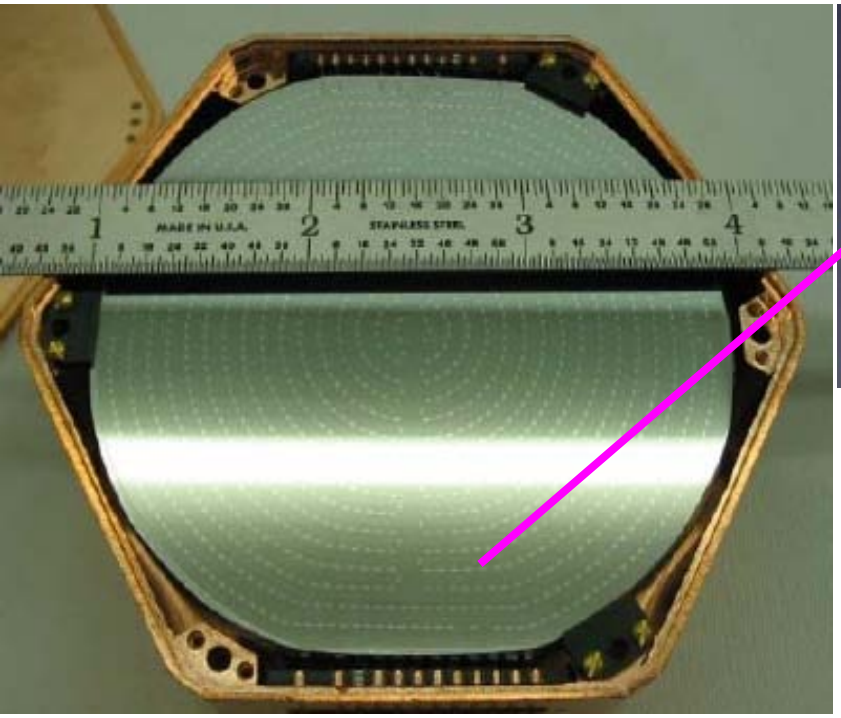


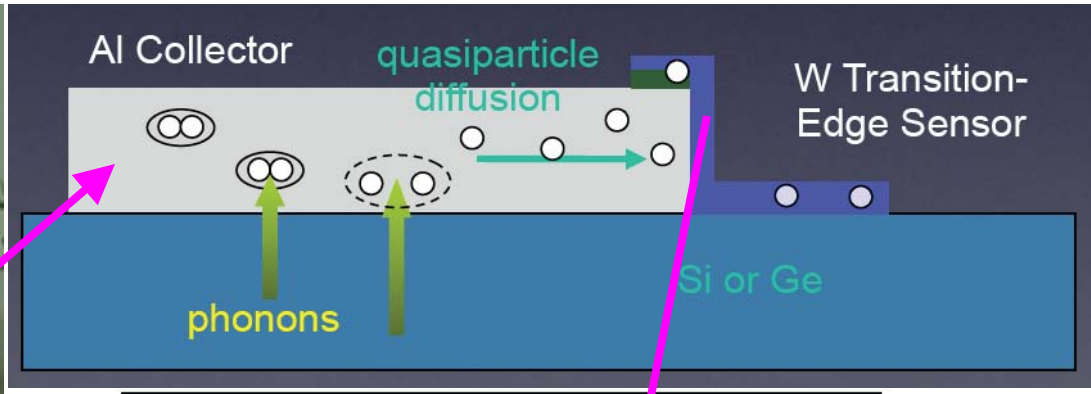
Cryogenic Dark Matter Search (CDMS)

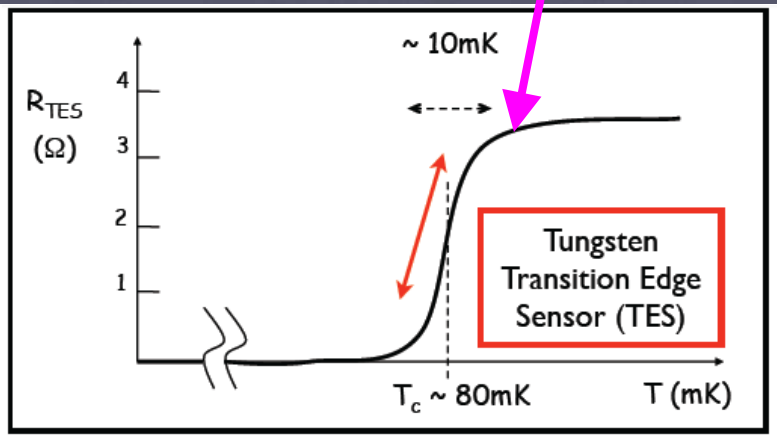
- Stanford and SLAC are taking lead roles in the CDMS experiment, which seeks to directly detect the Dark Matter that makes up ~25% of the universe
  - Modest sized experiment with 18 institutions, ~80 collaborators
  - Complementary to LHC – sensitive to stable particles produced in early universe, which may or may not be observable at the LHC
- Focus for new graduate students will likely be the SuperCDMS experiment in the Sudbury nickel mine
  - ~100 kg of Ge crystals cooled to 10 mK
  - 6800 feet underground to minimize backgrounds
  - Data taking expected to begin in 2014
- For further information, contact us:
  - Blas Cabrera (Stanford) – cabrera@stanford.edu
  - Eduardo Do Couto E Silva (SLAC) – eduardo@slac.stanford.edu
  - Richard Partridge (SLAC) – richp@slac.stanford.edu

SuperCDMS Technology

- Identify Dark Matter by simultaneously measuring phonons and ionization produced in Ge crystals
  - Phonons signal acts as a “calorimeter” in the traditional sense
  - Ionization signal helps distinguish electron recoils (highly ionizing - largely background) from nuclear recoils from Dark Matter interactions

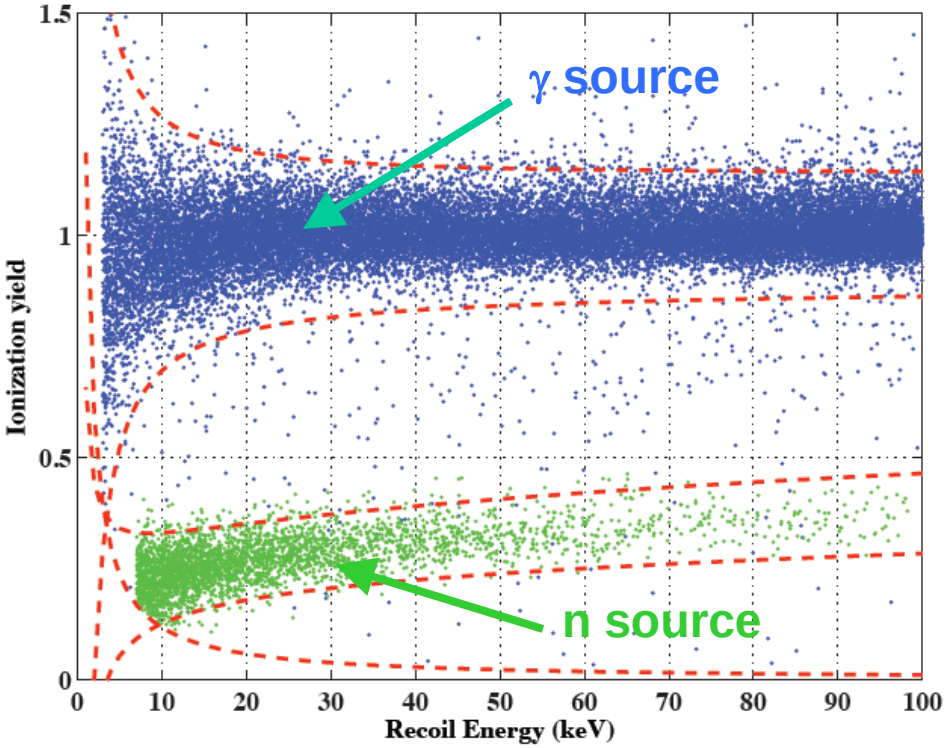


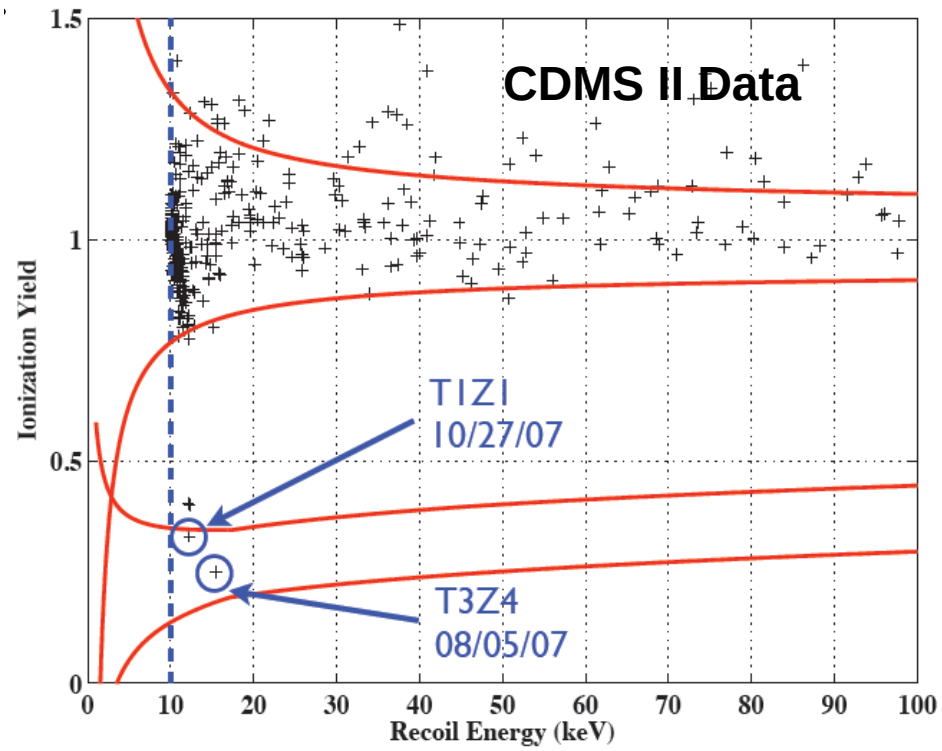




CDMS Results To Date

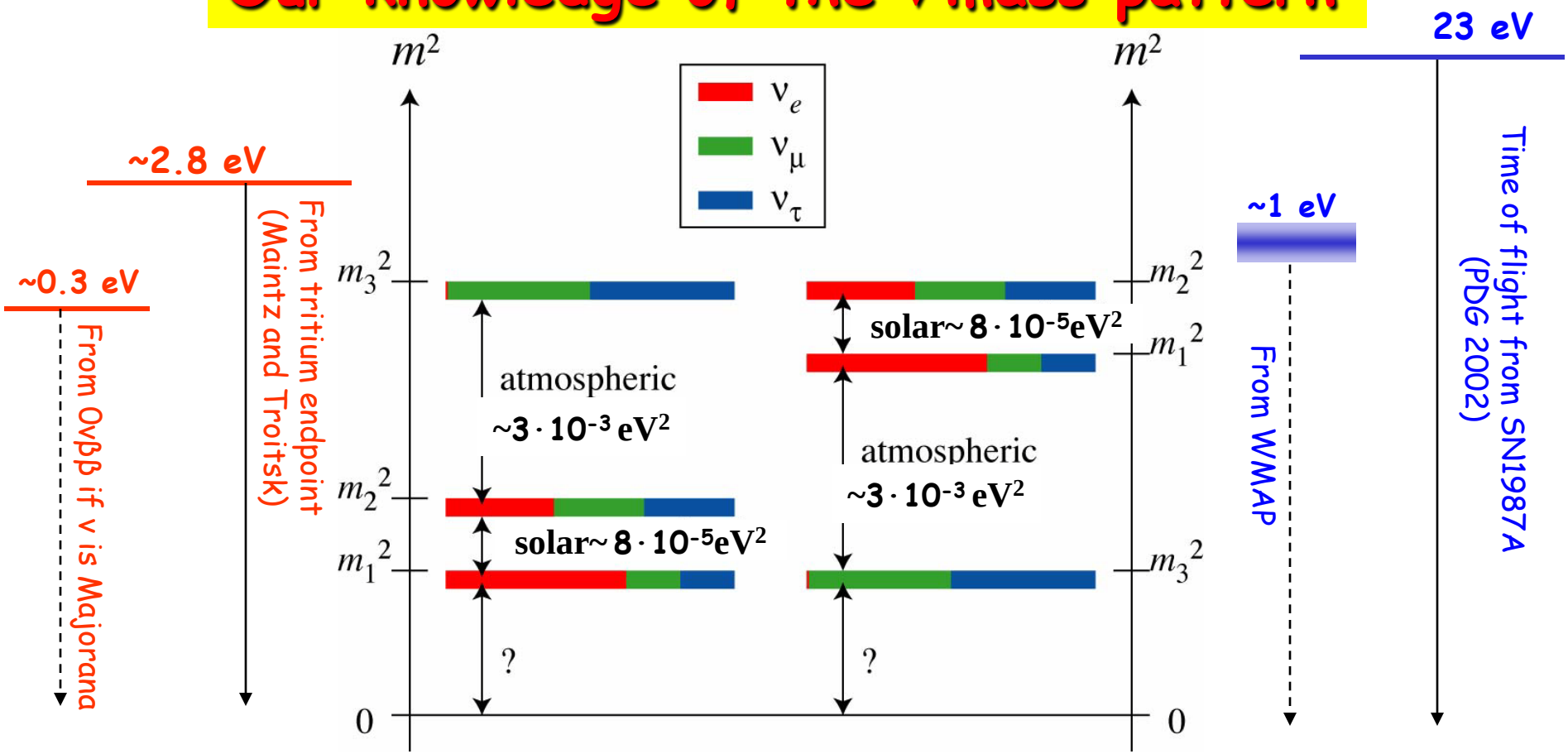
- In December, CDMS II presented results from ~600 kg-days of exposure
- Two candidate events observed with an





EXO

Our knowledge of the ν mass pattern



The measurement of the absolute mass scale,
θ_{13} and the choice of hierarchy
are the next big challenges in neutrino physics

EXO: measuring the neutrino masses with ββ decay

Prof. G.Gratta (Physics) and M.Breidenbach (SLAC)
(rotation positions / theses available)

0ν mode: a hypothetical process can happen only if:

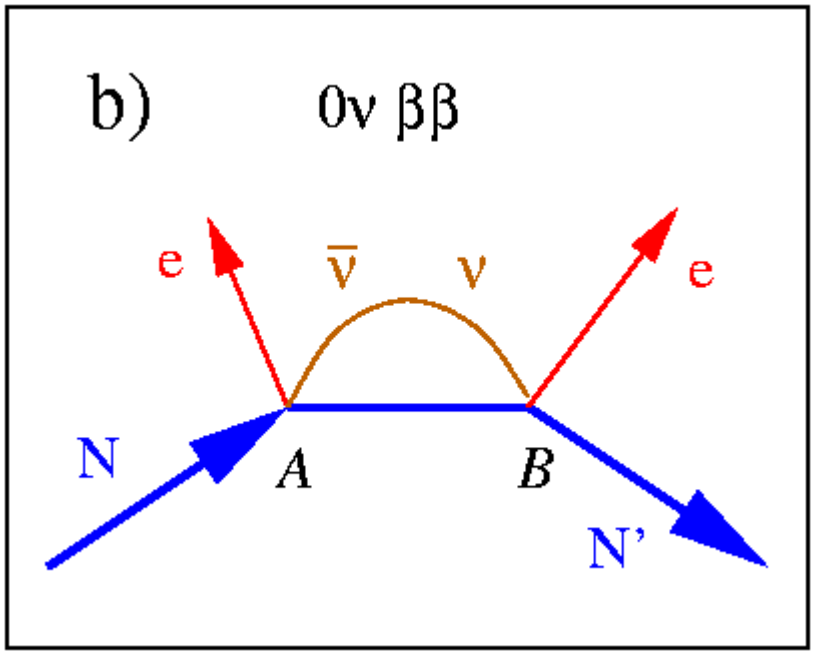
$M_\nu \neq 0$

$\nu = \nu$

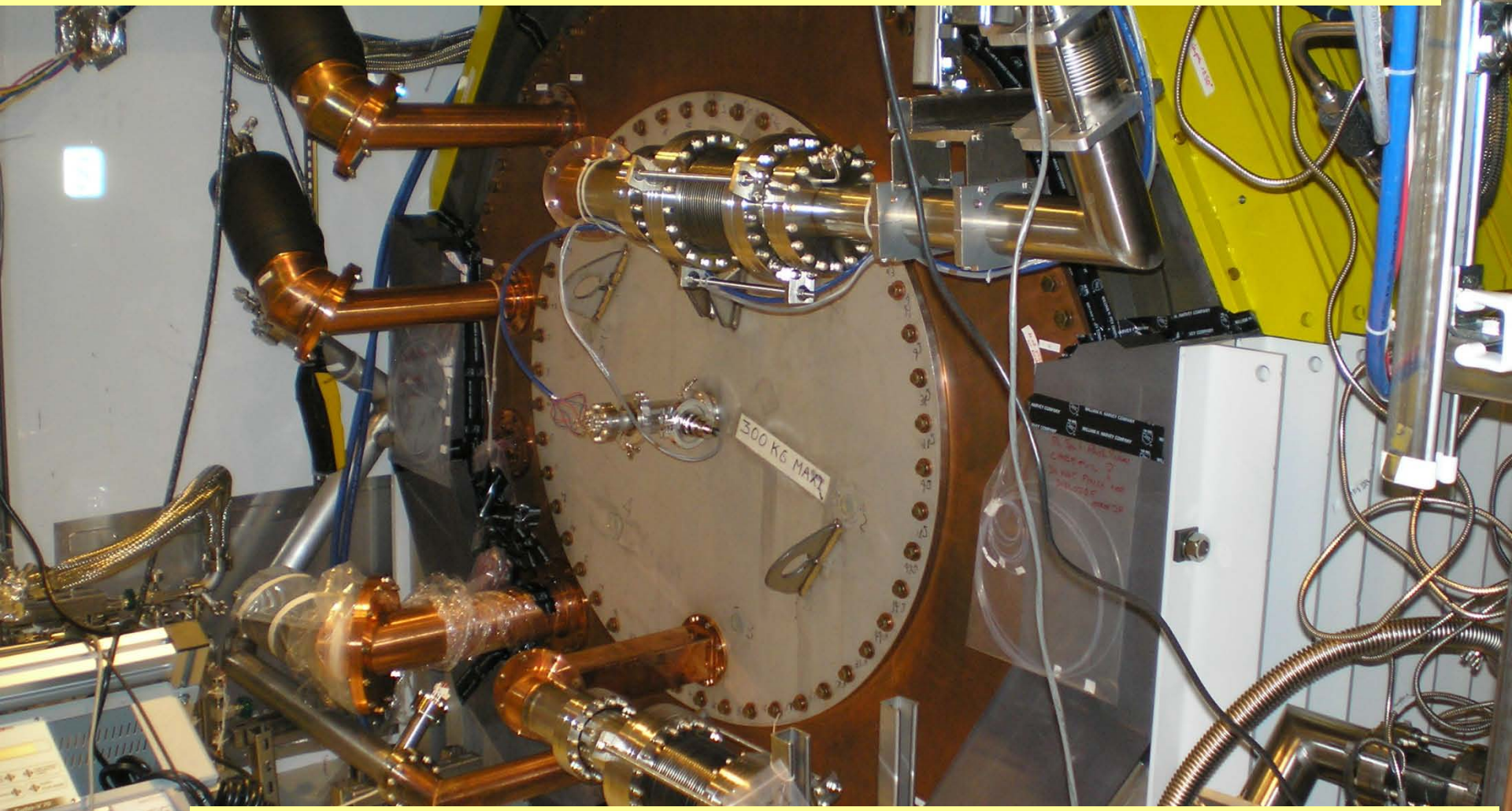
$|\Delta L|=2$

$|\Delta(B-L)|=2$

Since helicity has to "flip"



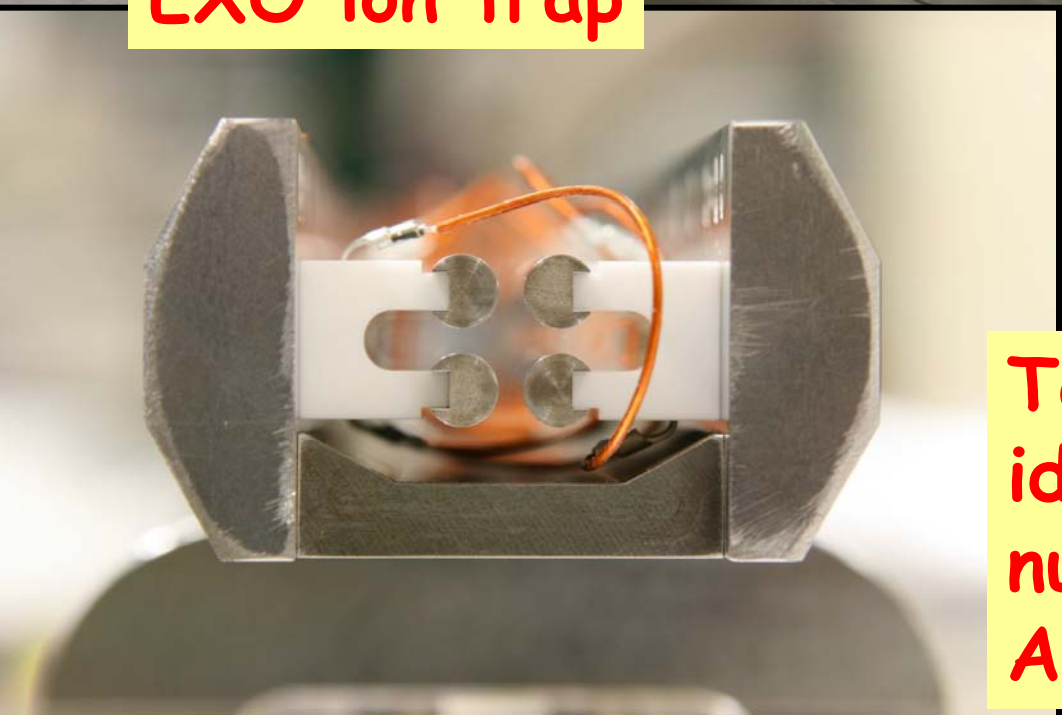
EXO-200 will soon start data taking at the WIPP underground site (New Mexico) and will reach a neutrino mass sensitivity of ~125 meV



Will also test lepton number conservation and check wheather Majorana particles exist in nature

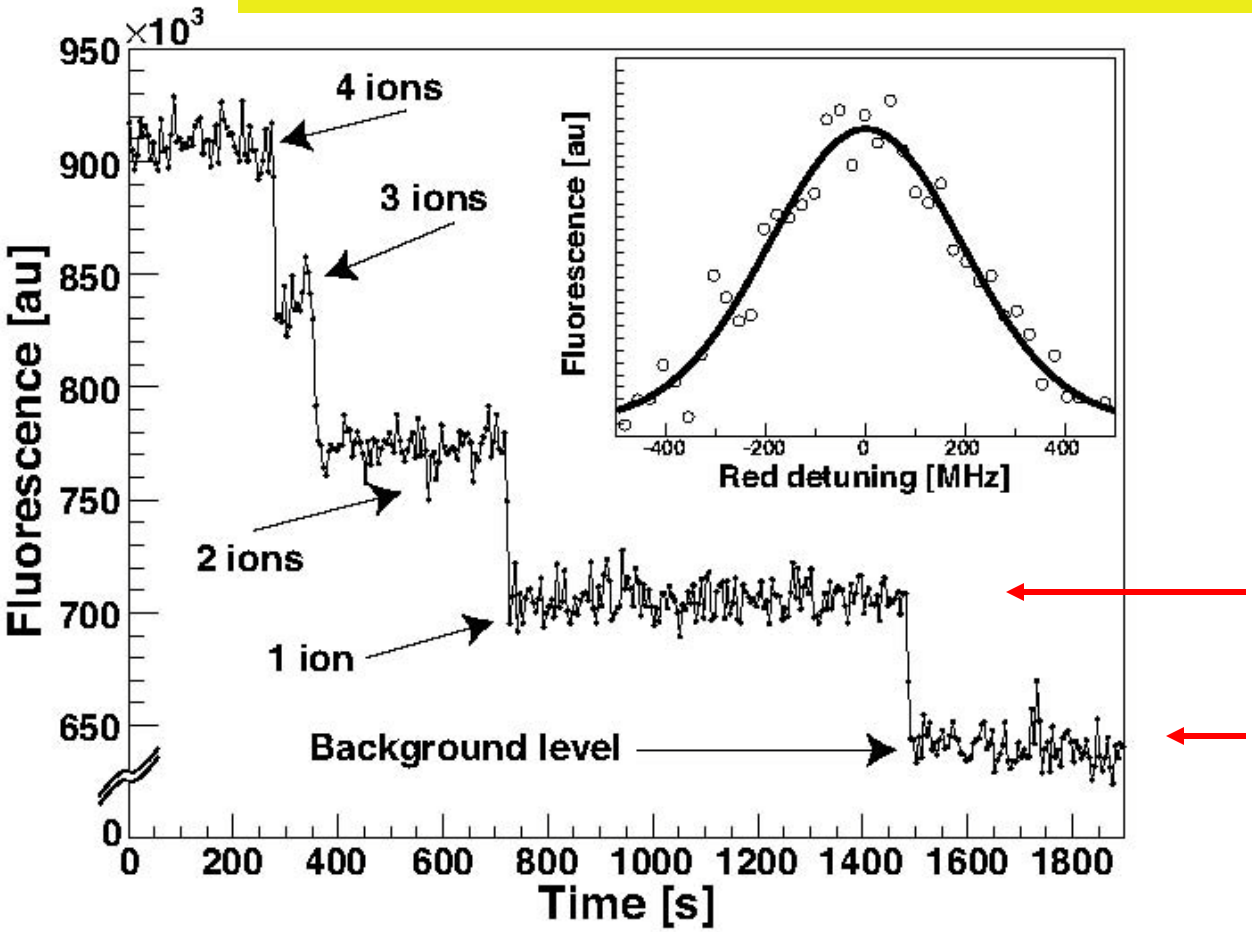
A larger version of EXO will use up to 10 tons of ^{136}Xe and reach a neutrino mass sensitivity of <10 meV

EXO ion trap



Tools being developed to identify the final state nucleus (nuclear and AMO techniques)

First single ion detection in high pressure gas (He, Ar)



~9σ discimination in 25s integration

M. Green et al. arXiv:0702122, Phys Rev A 76 (2007) 023404
B. Flatt et al. arXiv:0704.1646, NIM A 578 (2007) 409

Discovering 0νββ decay:

→ *Discovery of the neutrino mass scale down to <10meV*

→ *Discovery of Majorana particles*

→ *Discovery of lepton number violation*

Heavy Photon Searches at J Lab
APEX HPS

HPS is a small experiment which offers the thesis student exposure to all aspects of experimental particle physics, from experiment design and optimization, to hardware and data acquisition implementation, to commissioning, and eventual data analysis.

SLAC
R. Essig
C. Field
M. Graham
J. Jaros
C. Kenney
T. Maruyama
K. Moffeit
T. Nelson
R. Partridge

A. Odian
P. Schuster
C. Spencer
N. Toro
D. Walz

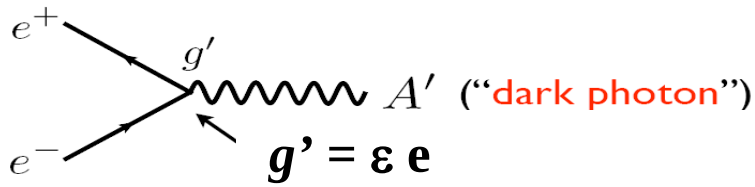
JLab
S. Stepanyan
L. Weinstein

FNAL
M. Demarteau
B. Cooper

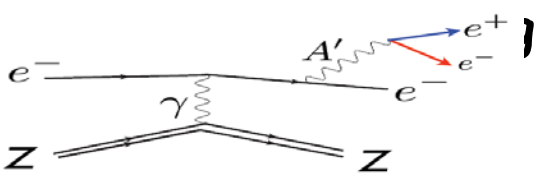
UCSC
A. Grillo

What is a "Heavy Photon"?

- A heavy photon (A') is a new, ~100 MeV spin one, force-carrying particle that couples to an analogue of electric charge. Because it will mix with "our" photon, it couples to electrons, all

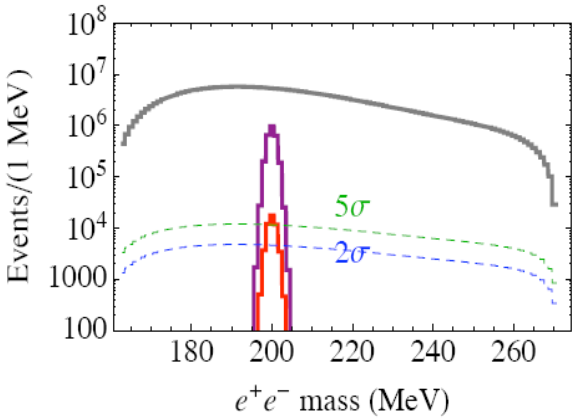


- Heavy photons can be produced by el
off heavy targets and they decay to



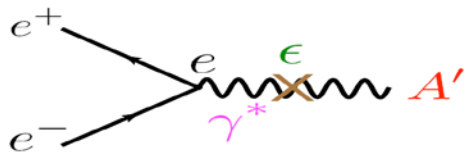
- A heavy photon appears as an e^+e^- r
background of QED tridents.

- Heavy photons will travel detectabl
distances before decaying, providin
a unique signature.



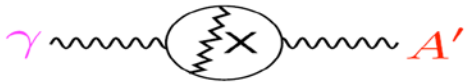
Why Consider Heavy Photons?

- **Are there are additional U(1)'s in Nature?** If so, they'll show up by mixing with "our" photon, inducing weak couplings to electri



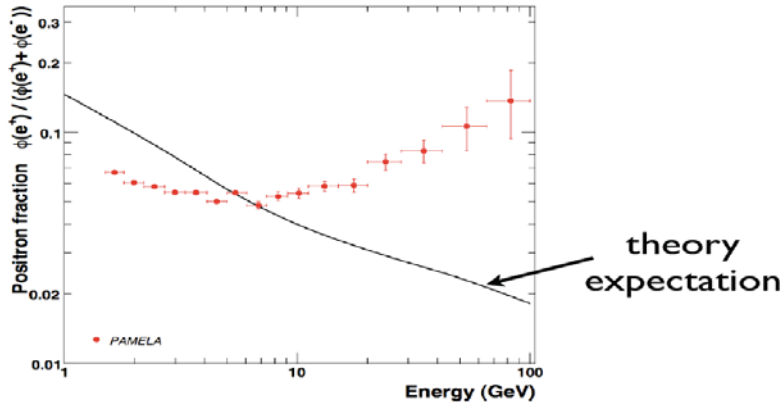
$$\Delta\mathcal{L} = \frac{\epsilon}{2} F^{Y,\mu\nu} F'_{\mu\nu}$$

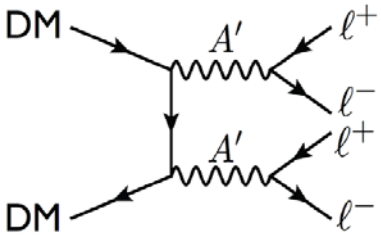
$\epsilon \sim 10^{-4} - 10^{-2}$



$\epsilon \sim 10^{-5} - 10^{-3}$
(if SM unifies in a GUT)

- **Heavy Photons could cause Dark Matter annihilations** and explain current cosmic ray puzz





For $m_{A'} \lesssim 1\,\mathrm{GeV}$: $A' \to \ell^+\ell^-, \pi^+\pi^-$

SLAC Activities on APEX and HPS

SLAC Heavy Photon Group is engaged in two projects:

Heavy Photon Search is a new Jlab experiment being proposed

- Design and simulation underway
- Proposal by mid-May
- Hope for review and funding by Summer
- Hope to construct, test, install by Fall 2011

APEX (A Prime Experiment) utilizes two large existing spectrometers in Jlab's Hall A to search for heavy photons

- Conditionally approved, test run this June
- SLAC is designing and building targets for test run
- SLAC will help run experiment
- SLAC will help analyze data

Students wanted ASAP! This summer or next year's Rotations.

Contact: John Jaros john@slac.stanford.edu