Presentation of new groups

Ben Kilminster
U.Zürich

Darwin meeting
Dec. 9 2013

My background

- Experiments
  - Darwin
  - DAMIC (Dark Matter in CCDs) (2008 -)
  - CMS experiment (2011 -)
  - CDF experiment (1997 -)
- Positions
  - Associate professor, U. Zürich (2012 -
  - Scientist, Fermilab (2008-2012)
  - Post doc, Ohio State (2003-2008)
  - PhD, University of Rochester (2003)
    - advisor : Kevin McFarland

CDF experiment (1997 -)

- Physics
  - Higgs boson searches
    - Higgs convener 2008 - 2011
    - Searches for H $\rightarrow$bb
  - top quark properties
    - Search for right-handed top quark decay
- Hardware & software
  - as post doc, helped design, build 3D global track trigger at Level 1
  - as student, helped design, build Level 3 data logging and monitoring system
  - some work on controls for silicon pixel detector

CMS (2011-)

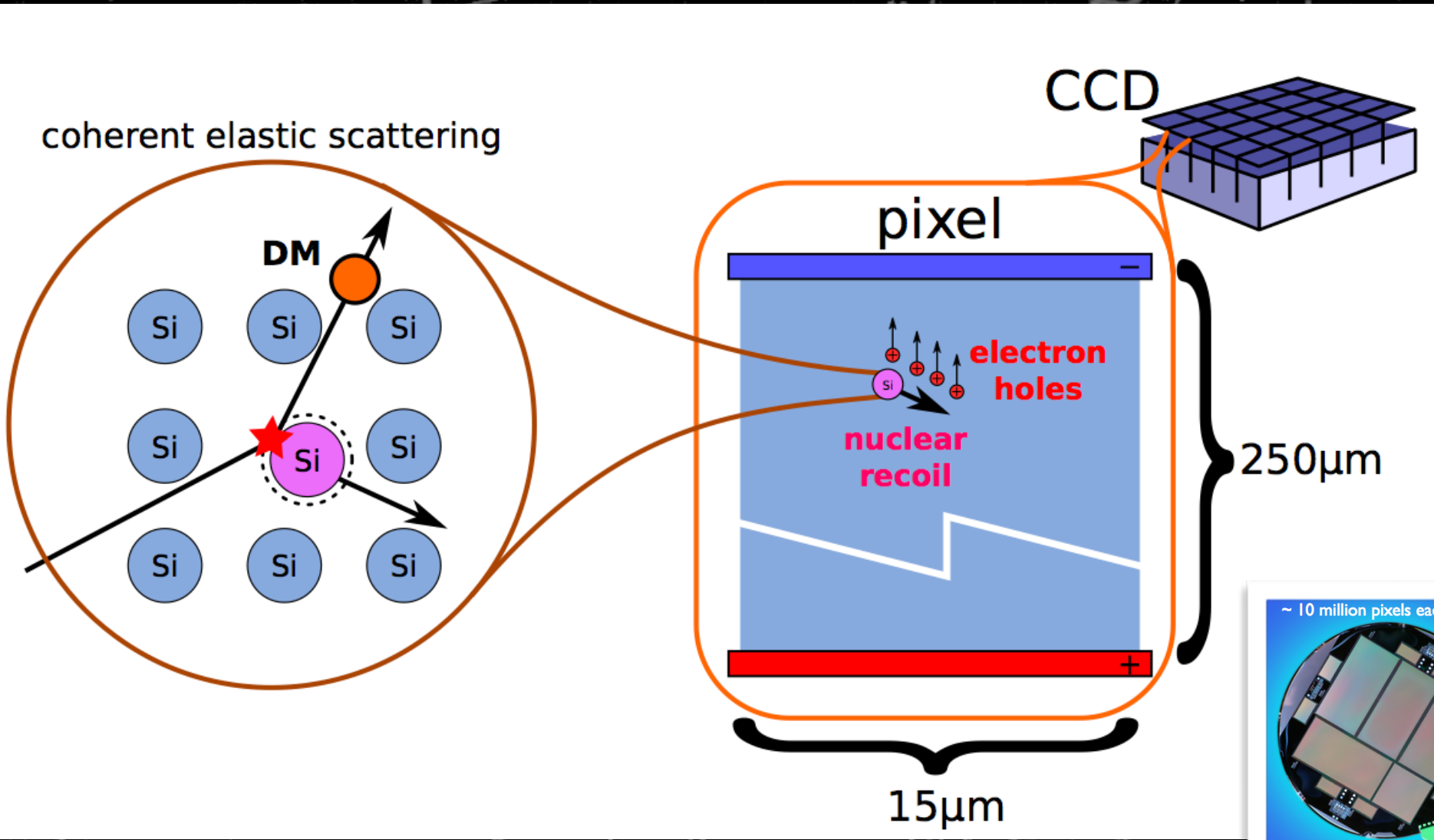
- Physics
  - Higgs combination
  - Now, exotic physics
    - Extra dimensions, supersymmetry
    - Especially, high mass particles in boosted boson-jets

- Hardware/software
  - Upgraded pixel detector (2016)
    - Building 2-phase CO_2 cooling system
    - Integrating pixel digital-optical signal/ control electronics, daq testing

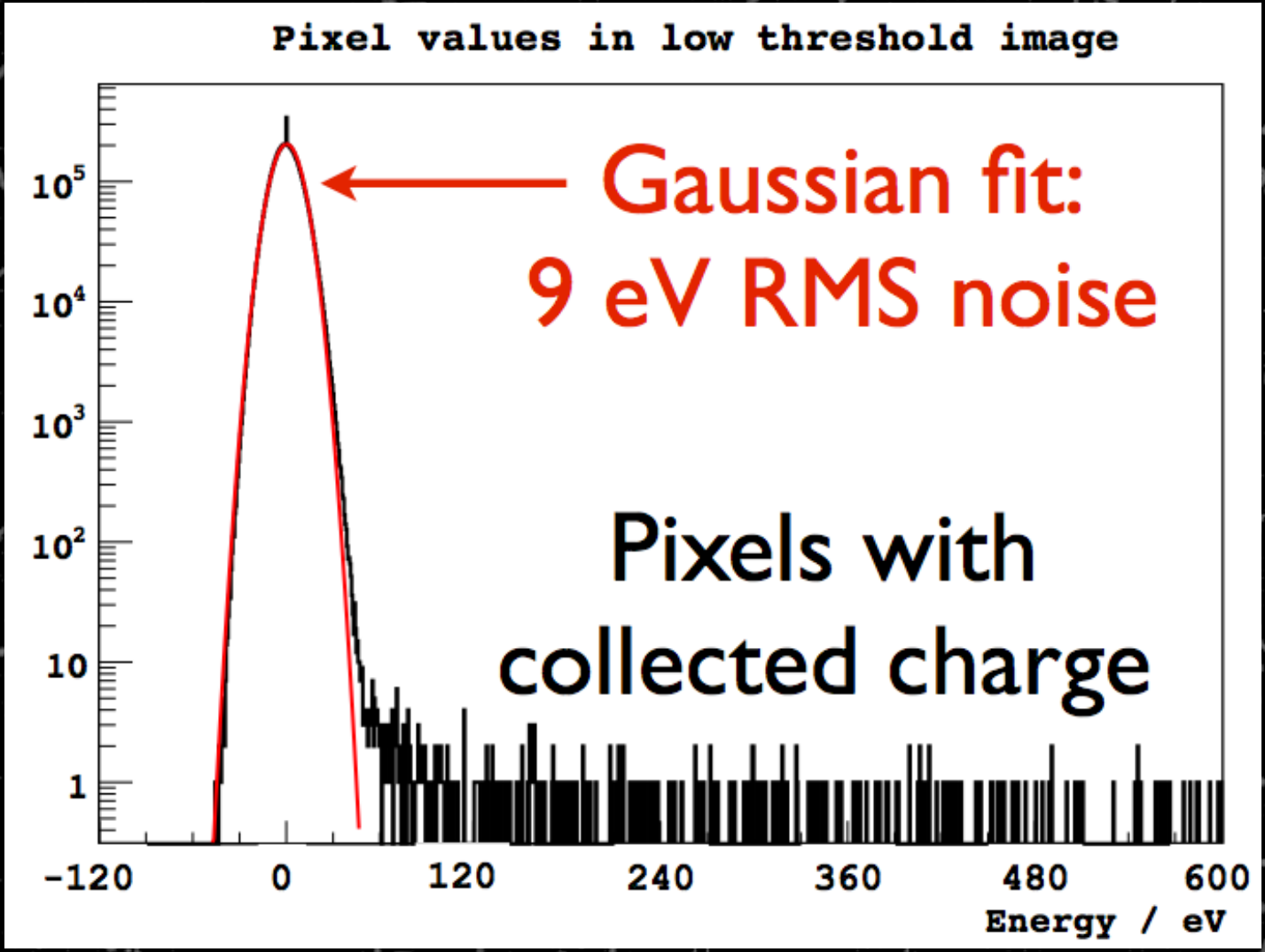
DAMIC

- Dark Matter in CCDs
- History
  - Design run 2009, T-987
  - Engineering run 2010
    - Best limits for DM < 4 GeV
  - Currently, running in SNOlab
    - Next phase begins summer 2014

Scientific CCDs for searching for DM



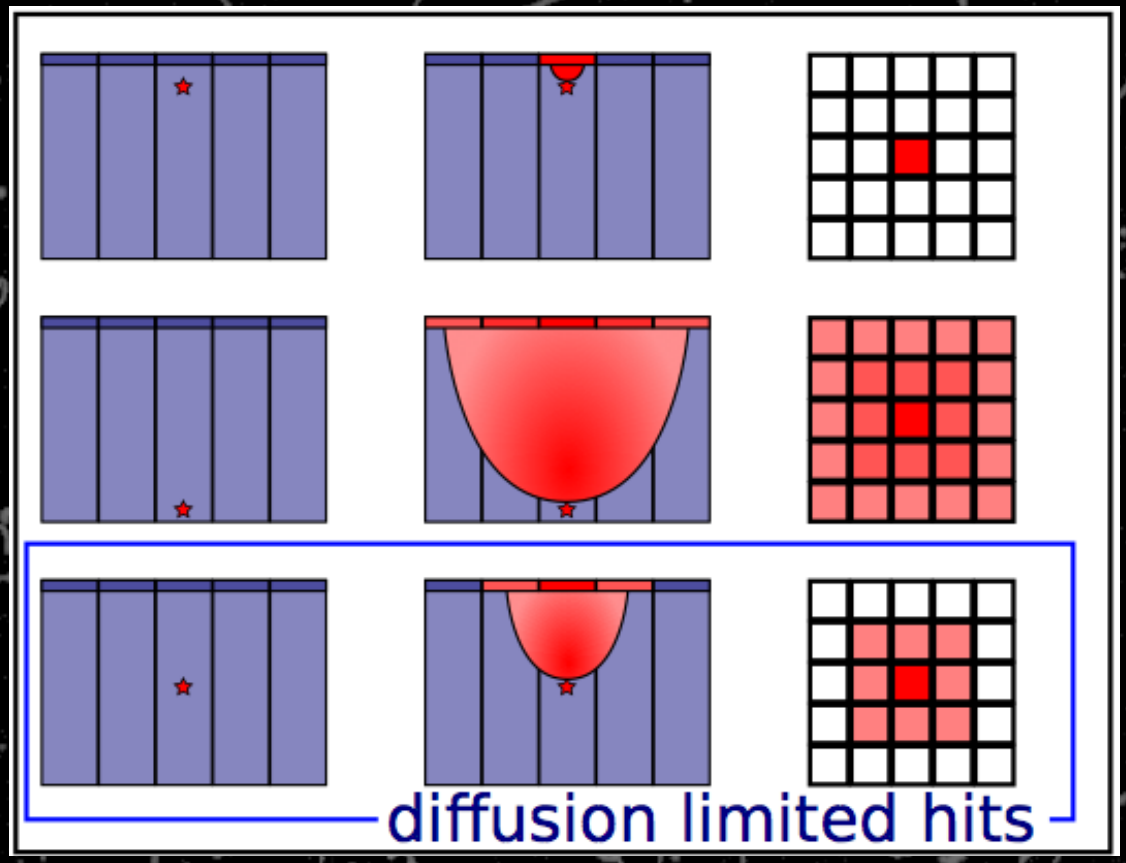
Noise measurement



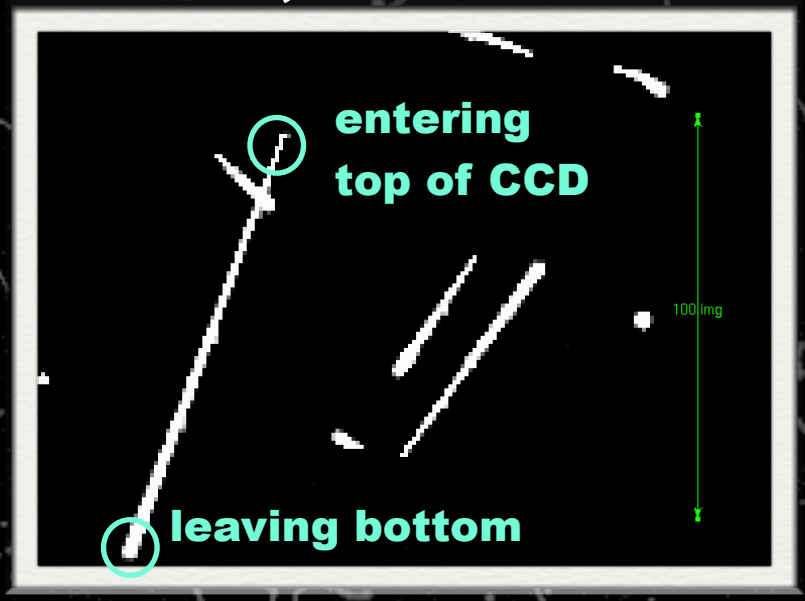
- **Allows lowest energy threshold of current dark matter experiments ~ 50 eV**

Diffusion of charge

- Size of hit depends on location within pixel



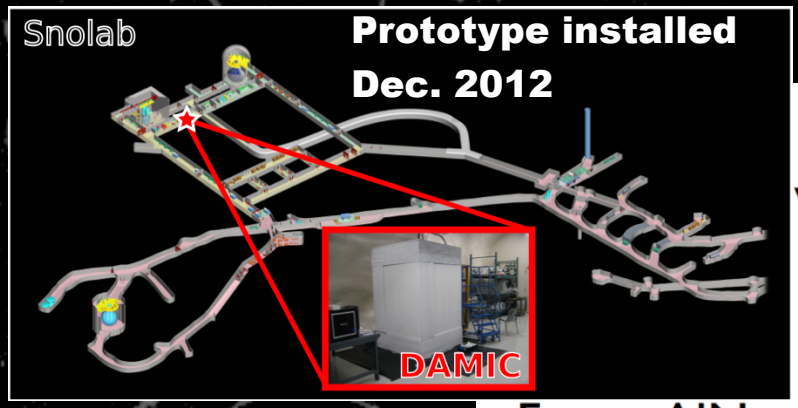
ie, muons

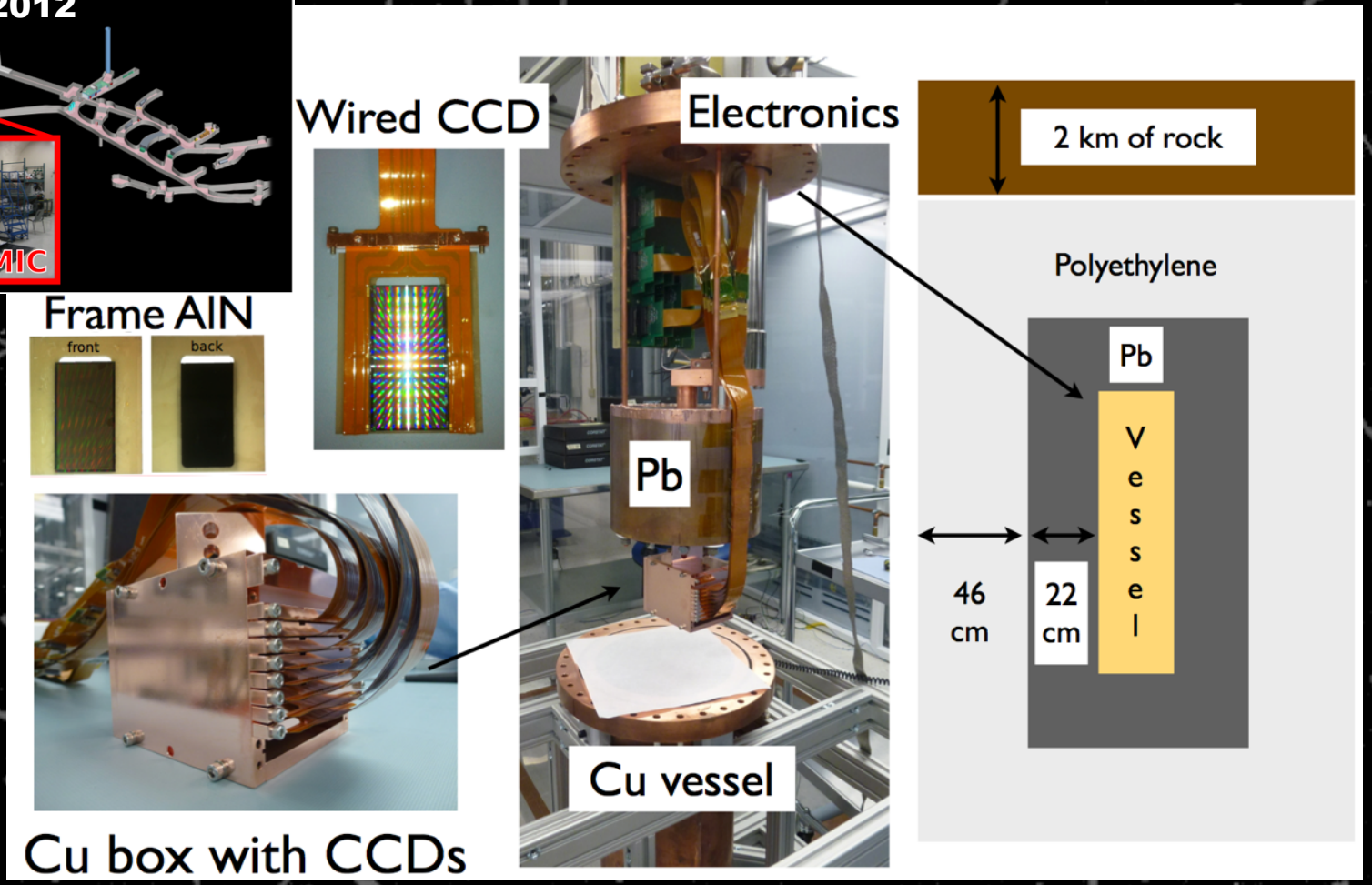


- Maximal (minimal) diffusion at bottom (top) of CCD

Experimental setup

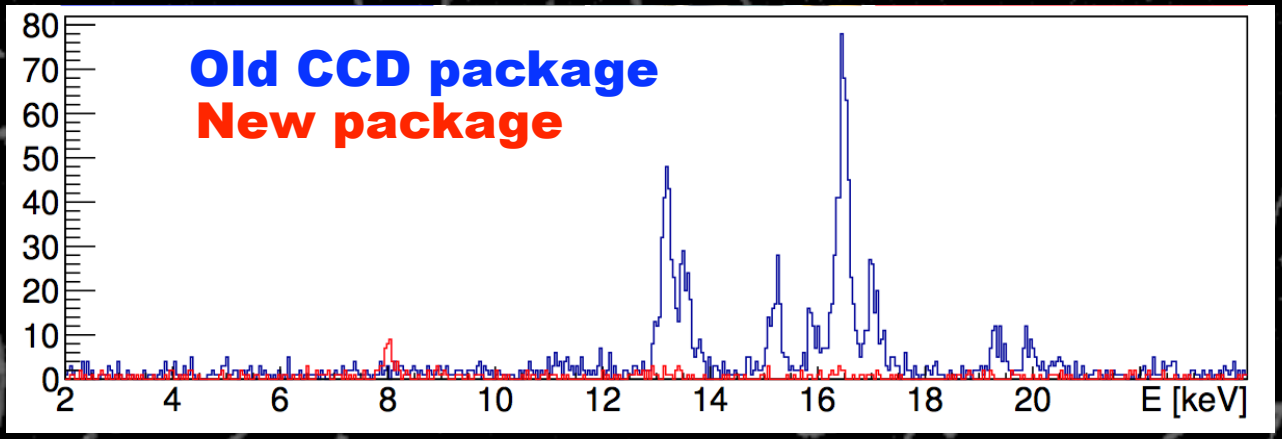
- **DAMIC prototype in operation at SNOlab**

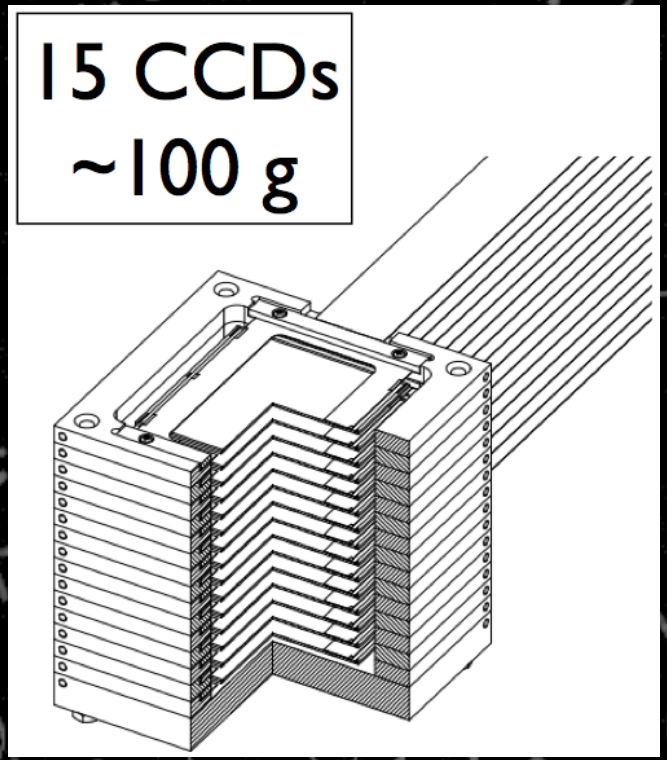




Upgrade to DAMIC 100

- LBNL CCD group is building us even thicker, fully depleted high resistivity CCDs (500 μm)
  - 4 times the mass
  - Can now reach 100 g of detector mass
- Prototype revealed dominant background from U^{238} in Al N substrate of CCD package ~ 3 Bq kg^{-1}
  - Solved in new CCD design
  - Also removed astronomy-related material additions

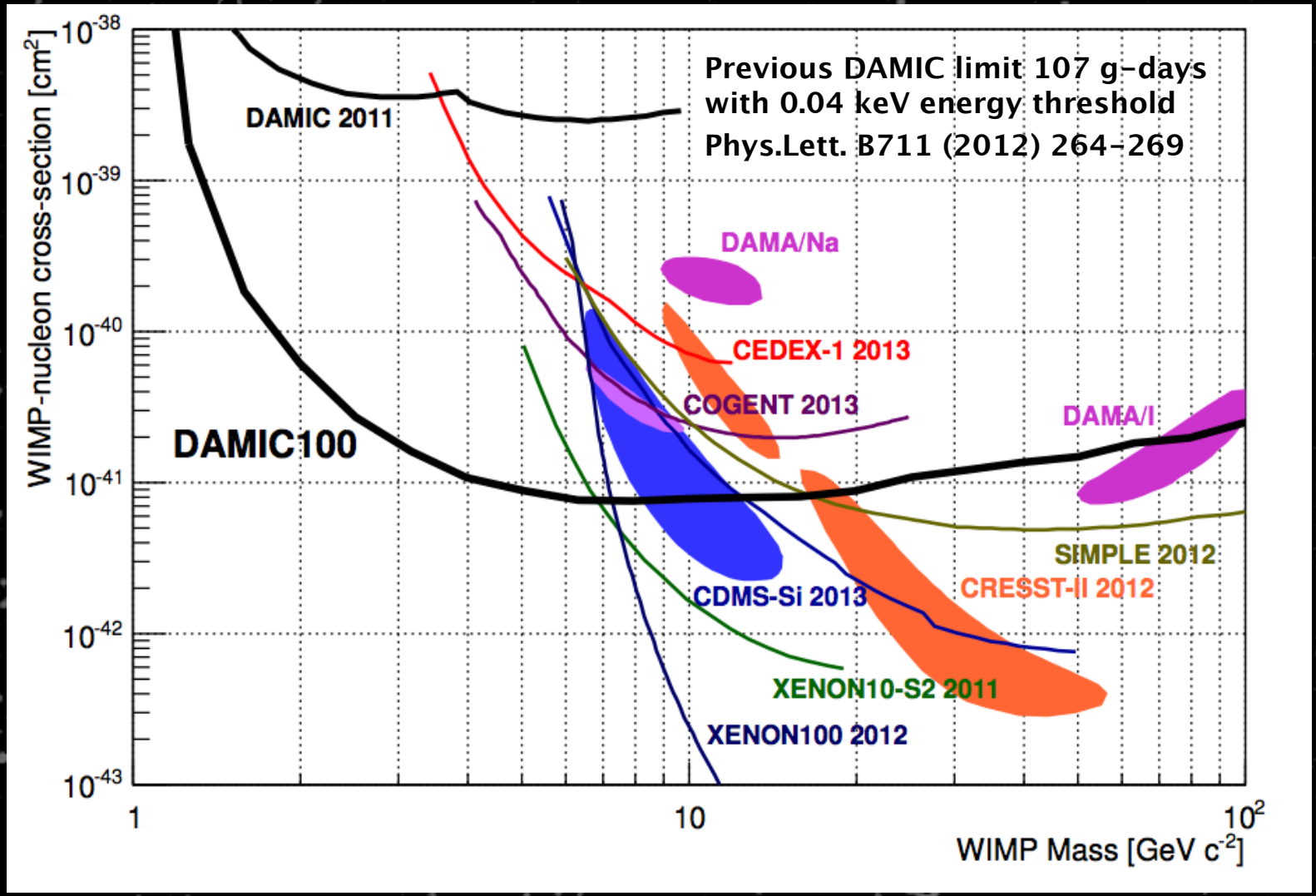




DAMIC100 : Fermilab, U. Chicago, U. Zürich, U. Michigan, UNAM, FIUNA, CAB

Projected sensitivity

- DAMIC 100 with 1 year of data



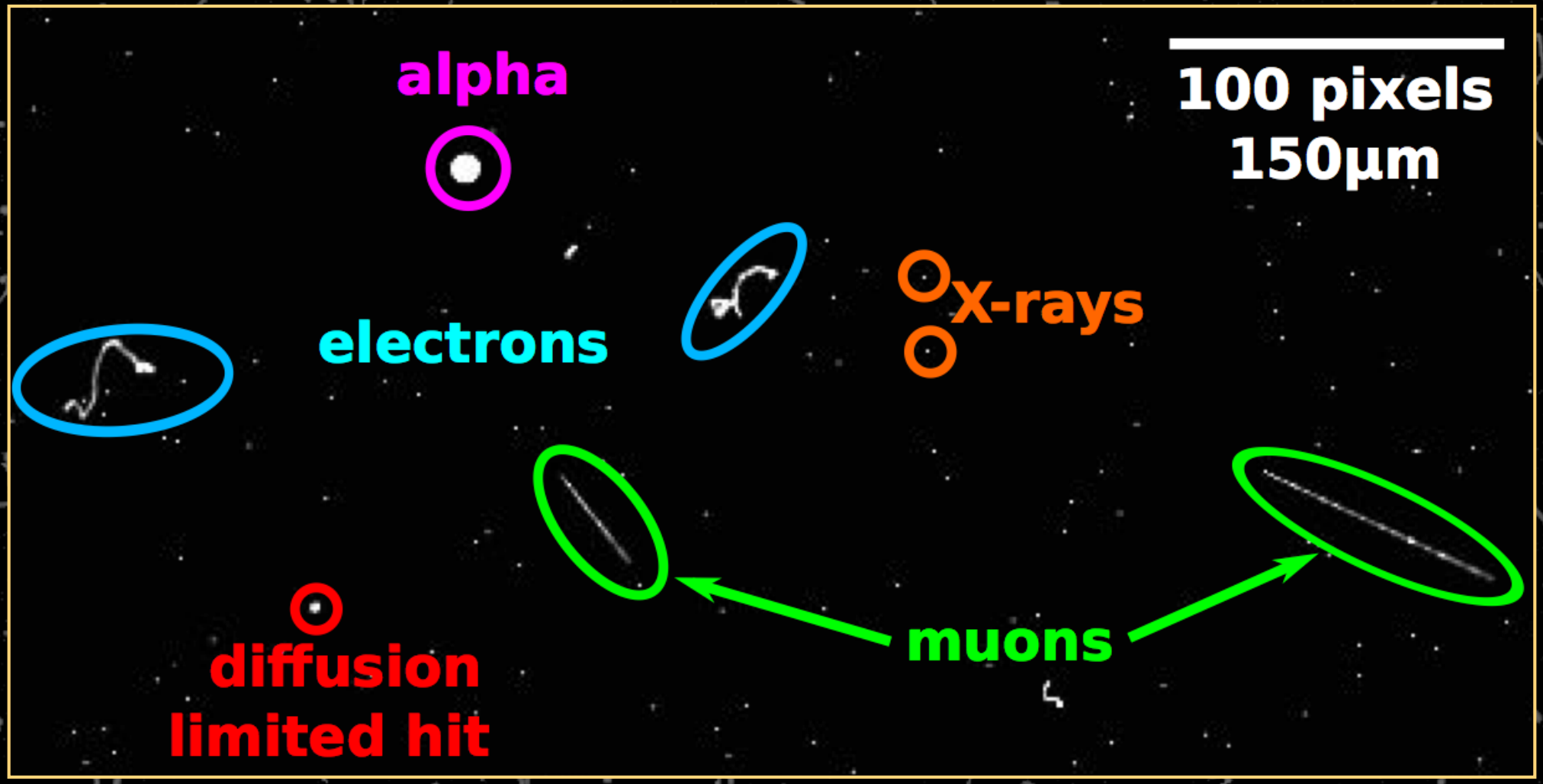
Previous results in Phys. Lett. B 711, 264-269 (2012)
arXiv:1105.5191

Contributions to DARWIN

- Possible contributions ?
  - Previous experience points to :
    - data acquisitions
    - triggering
    - logging
    - monitoring
  - Simulations
  - Or wherever most help is needed
- Open to suggestions new ideas
- Person-power
  - still building up CMS, DAMIC groups
  - estimate student or post doc on DARWIN sometime in 2014
  - ramp up over next few years

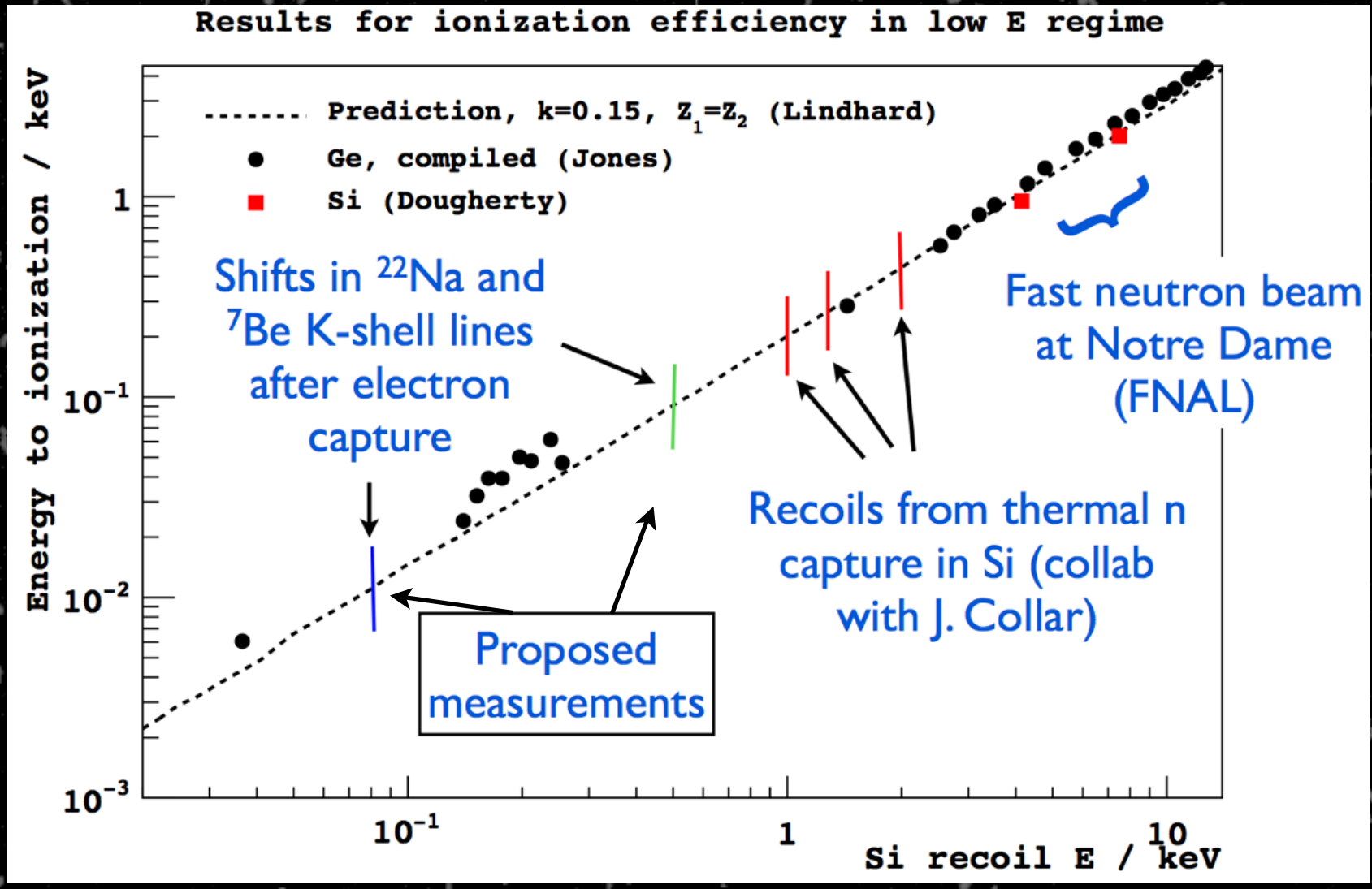

BACKUPS

Particle identification in CCD



Ionization efficiency for nuclear recoils

- Challenge is to provide dependable calibration down to 50 eV energy threshold



Ongoing R & D

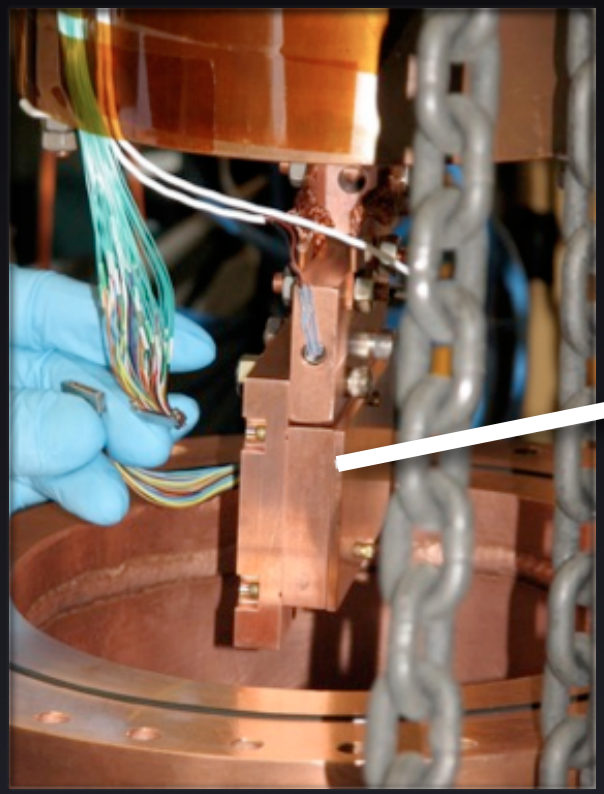
- Neutron energy response at low energy
  - Electron Capture from irradiated silicon (calibration at ~ 100 eV) : could be done at PSI
  - Lower energy calibrations still needed
- Improved readout - multiple sampling (skipper) of CCD data can yield sub-eV noise
- CCD limitation is long exposure time : 1000s of seconds - no timing to reject triggerable backgrounds
  - Other types of silicon detectors with fast readout and low background noise can be investigated

Conclusions

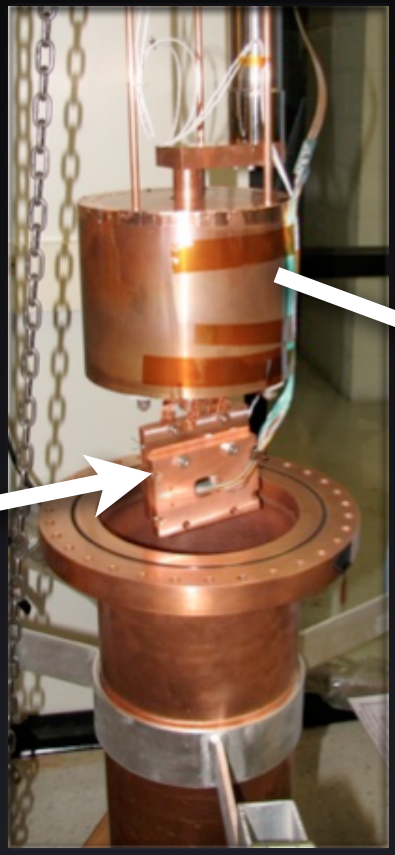
- CCDs are a viable particle detector for low mass dark matter
  - Can provide useful constraints on an exciting mass range for dark matter
  - Relatively cheap (DAMIC 100 ~ 400 kCHF)
- Detector R&D advancing with thick, high resistivity, low noise scientific CCDs
- U. Zürich is playing a leading role in this experiment
  - Building a CCD lab for testing and calibrations

DAMIC 2011

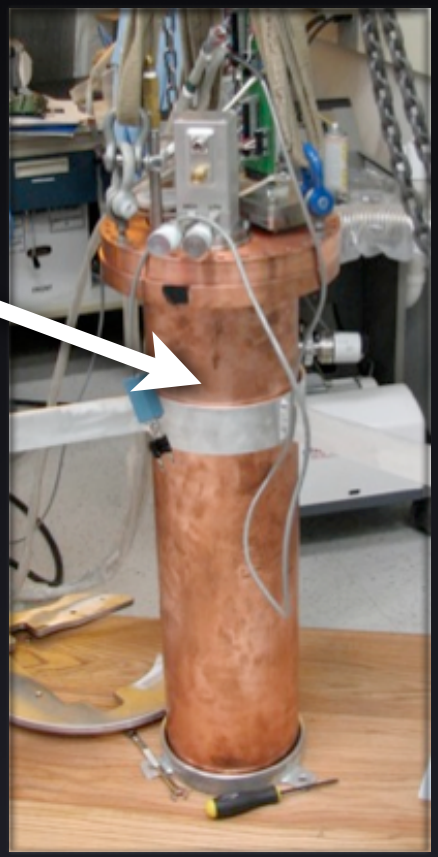
CCD Inside a cold Cu box



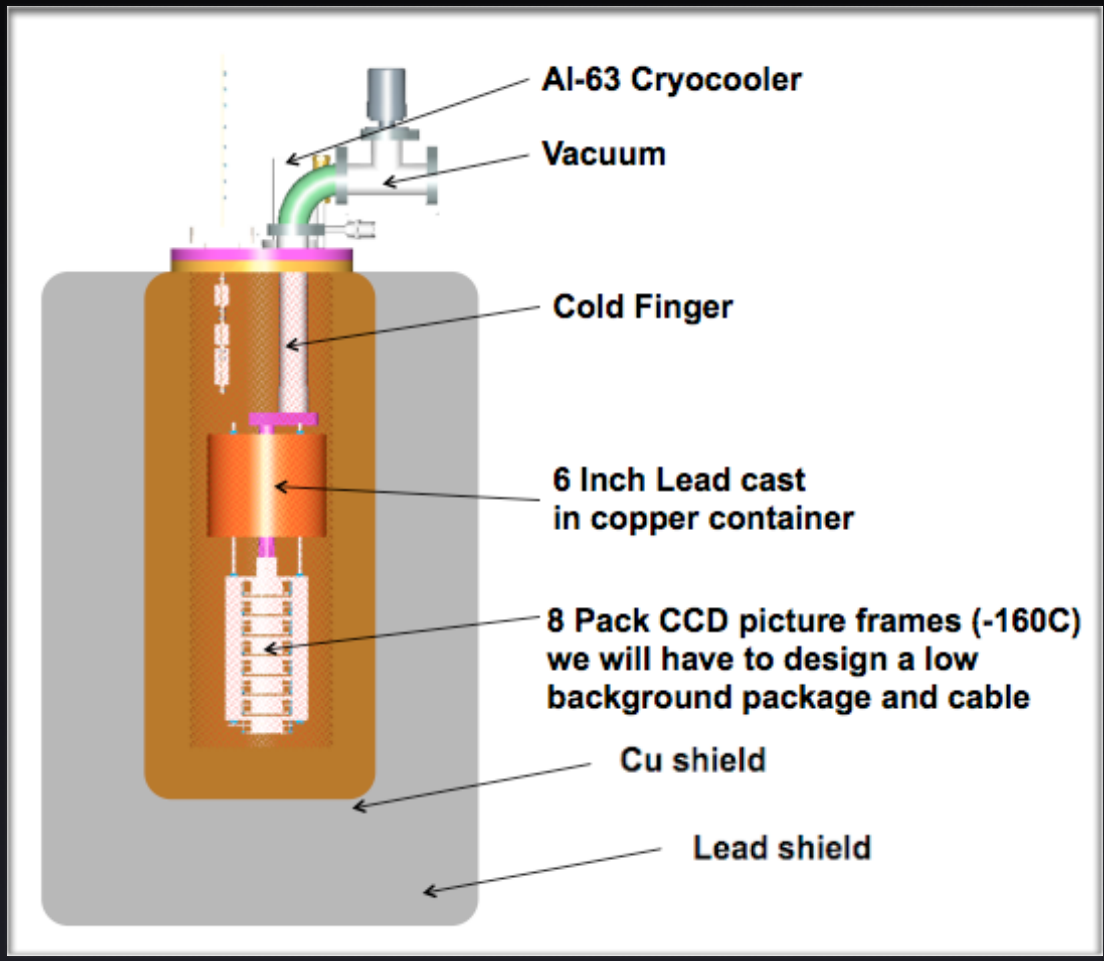
Lead Bucket



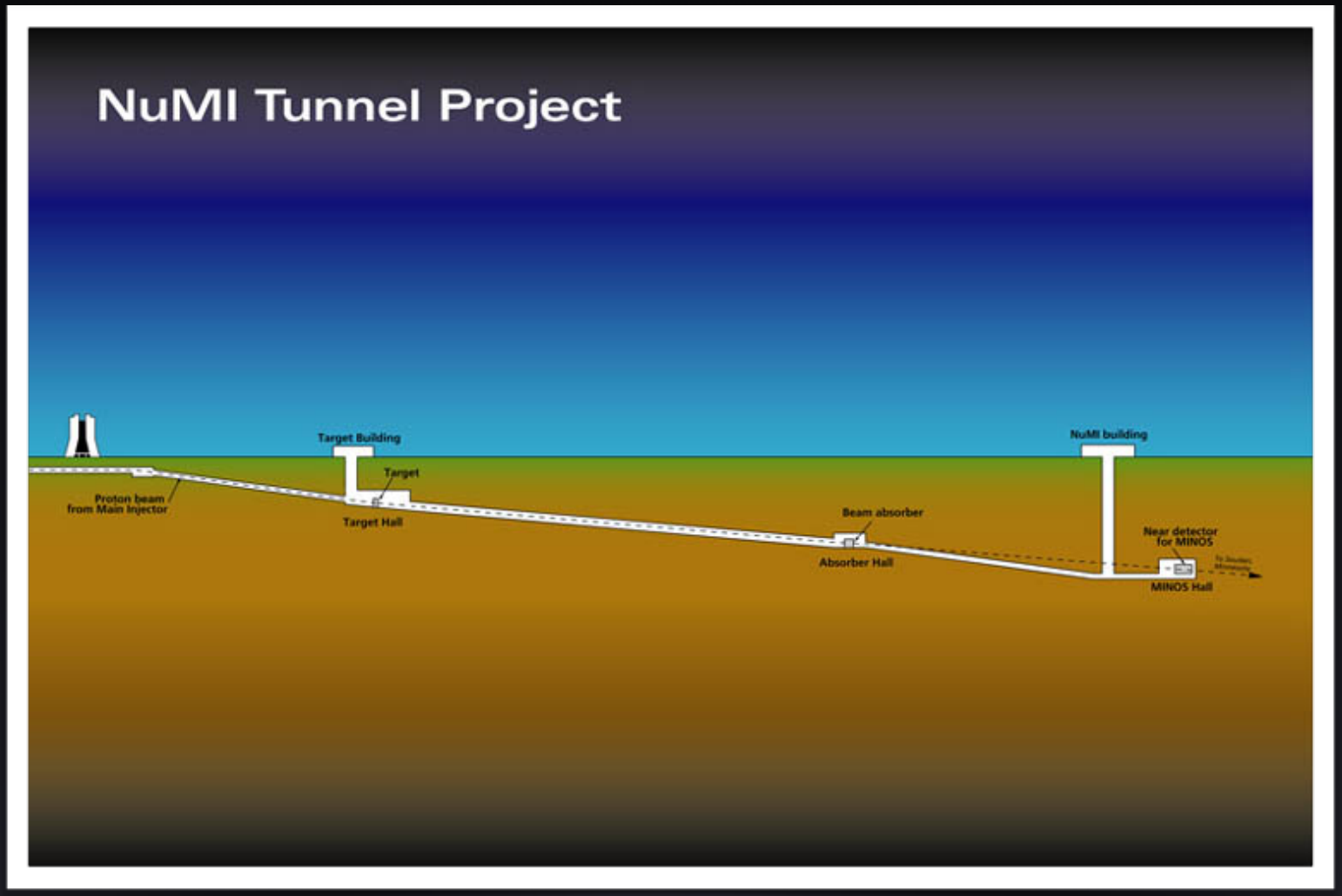
Cylindrical Cu Dewar



DAMIC 2011

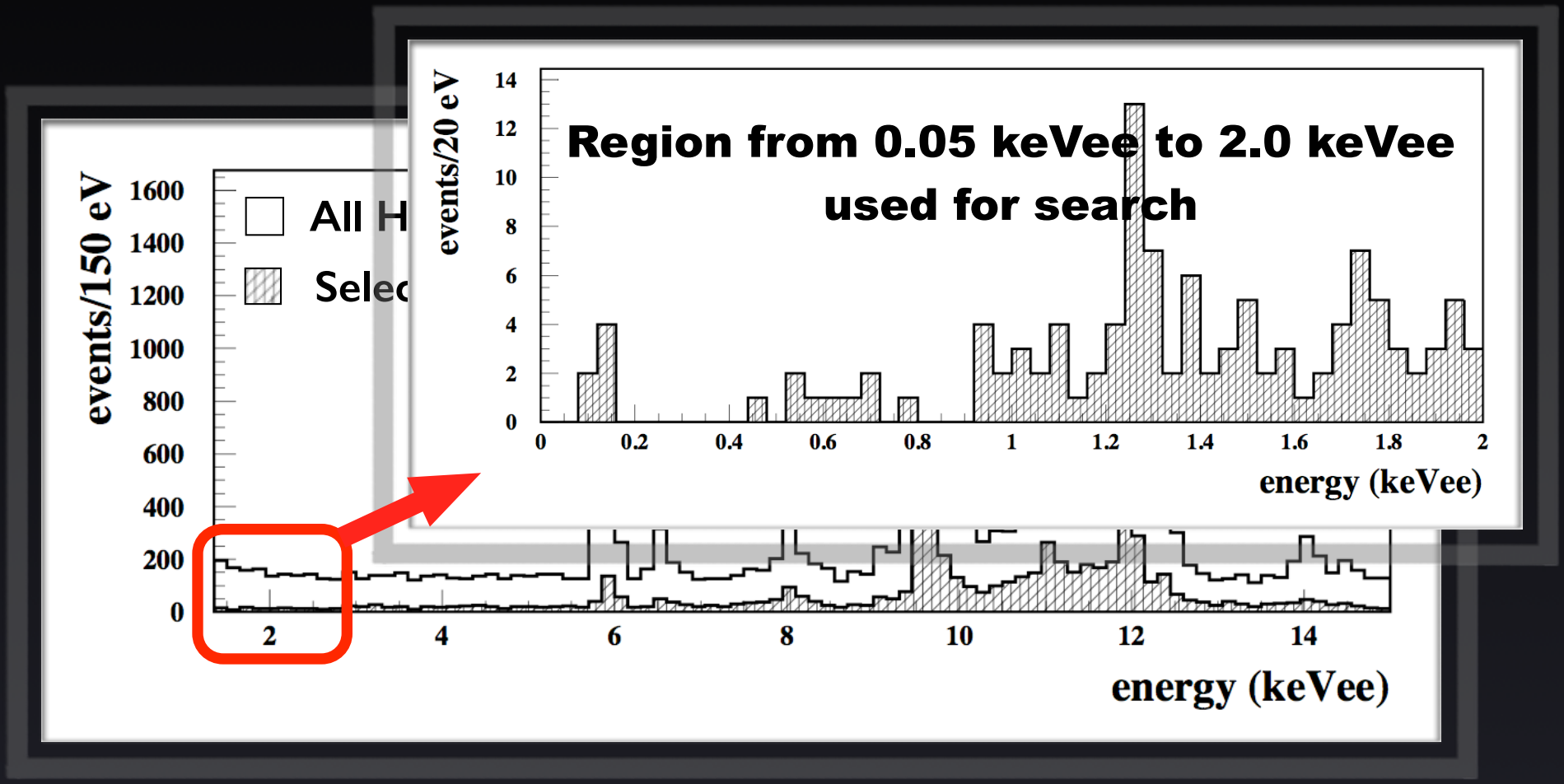

Al-63 Cryocooler
Vacuum
Cold Finger
6 Inch Lead cast
in copper container
8 Pack CCD picture frames (-160C)
we will have to design a low
background package and cable
Cu shield
Lead shield

DAMIC 2011


NuMI Tunnel Project
Target Building
Target
Proton beam
from Main Injector
Target Hall
Beam absorber
Absorber Hall
NuMI building
Near detector
for MINOS
MINOS Hall

DAMIC 2011

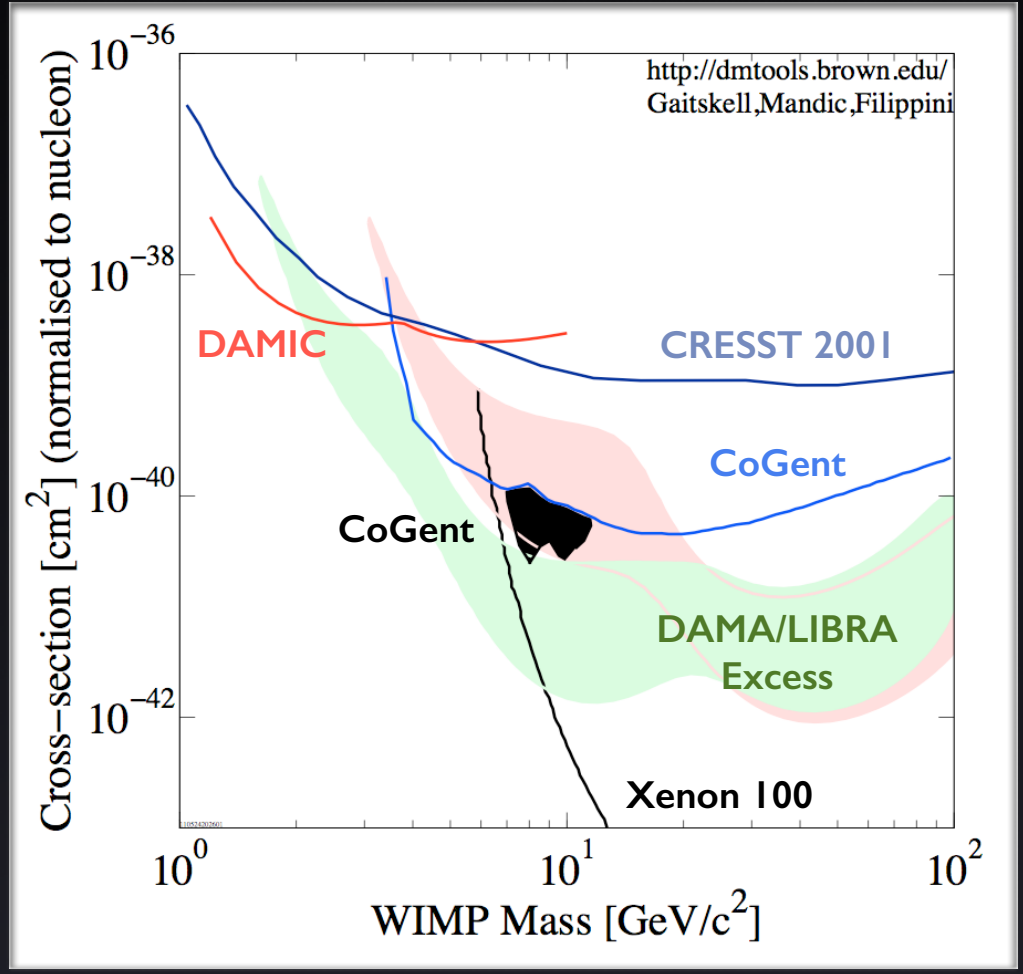
Energy Spectrum



Results from 2011 Run

- **Wimp density → 0.3 GeV/cm**
- **V_{earth} = 244 km/s**
- **V_{escape} = 650 km/s**

Assumes Lindhard quenching factor for conservative limits



Results from First Run

Direct Search for Low Mass Dark Matter Particles with CCDs

J. Barreto[1], H. Cease[2], H.T. Diehl[2], J. Estrada[2], B. Flaugher[2], N. Harrison[2] J. Jones[2], B. Kilminster[2], J. Molina[3], J. Smith [2] , T. Schwarz[4] and A. Sonnenschein[2]
[1] *Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil*
[2] *Fermi National Accelerator Laboratory, Batavia, Illinois, USA*
[3] *Facultad de Ingenieria, Universidad Nacional de Asuncion (FIUNA), Asuncion, Paraguay*
[4] *University of California at Davis, USA.*

(Dated: August 17, 2011)

A direct dark matter search is performed using fully-depleted high-resistivity CCD detectors. Due to their low electronic readout noise (RMS∼7 eV) these devices operate with a very low detection threshold of 40 eV, making the search for dark matter particles with low masses (∼ 5 GeV) possible. The results of an engineering run performed in a shallow underground site are presented, demonstrating the potential of this technology in the low mass region.

PACS numbers: 93.35.+d, 95.55.Aq

I. INTRODUCTION

There have been several direct-detection experiments searching for dark matter (DM) performed in recent years, and several more in development.[1]. Most of these

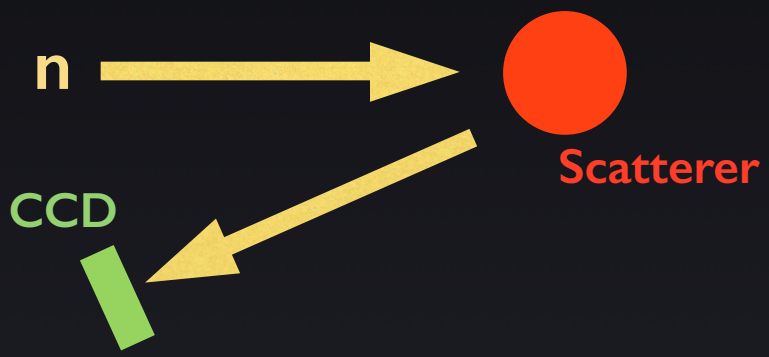
of their very low fiducial mass. The re
of thick, fully-depleted CCDs
than conventional CCDs
Dark Matter in C
DM sear
ology.

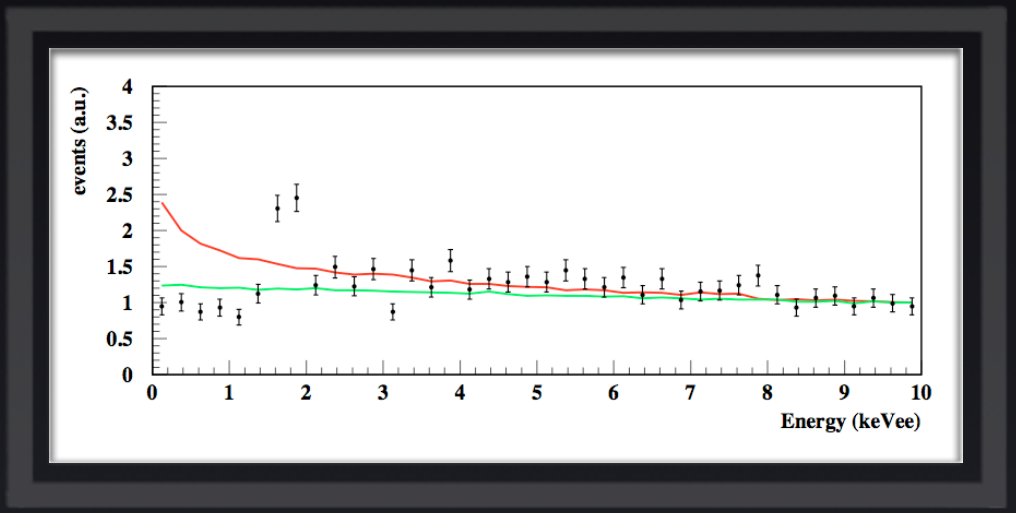
Phys. Lett. B 711 (2012) 264-269

Ramping Up!

Calibrating to Lower Energy

- **Using a mono-energetic beam of neutrons to calibrate quenching factor to very low energies**





Naturalness of Dark Matter Mass scale

1. "Wimp miracle" scale :
   - Why do SUSY cross-sections provide correct relic DM density ?

     $M_{DM} \sim 100$ GeV

2. "Baryon-DM coincidence" scale :
   - Why is the DM abundance so close to matter ?

     $\rho_{DM} \sim 5 \cdot \rho_M$
   - What if dark matter is more baryon-like ?
   - Assume $N_{DM} \sim N_{baryon}$ in early universe

     $M_{DM} \sim 5$ GeV

Asymmetric DM hep-ph/1111.0293