

Title: DM-TPC: a novel approach to directional Dark Matter detection Denis Dujmic (MIT) on behalf of the DM-TPC collaboration

Date: Jun 06, 2008 11:45 AM

URL: <http://pirsa.org/08060182>

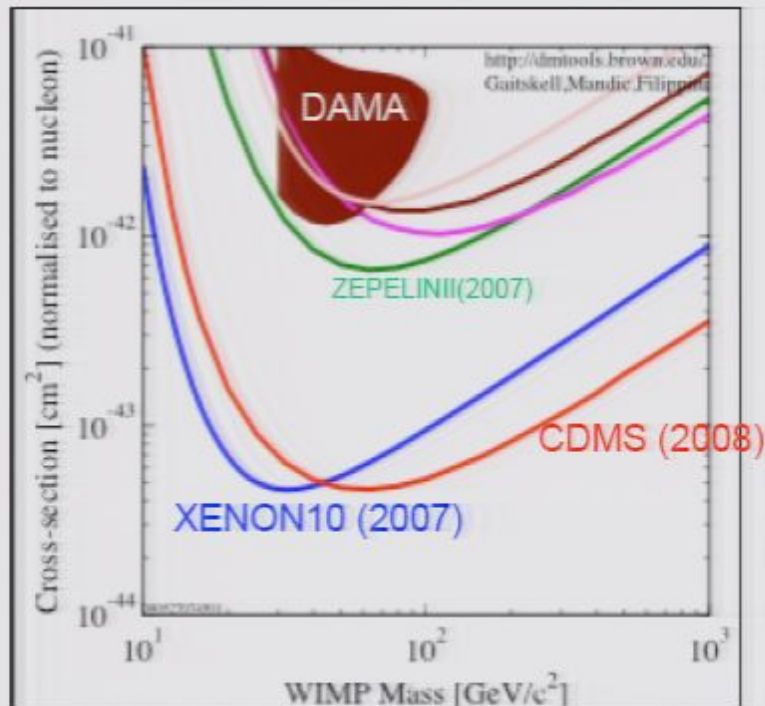
Abstract: Directional detection of dark matter can provide unambiguous observation of dark matter (DM) interactions even in the presence of insidious backgrounds. The DM-TPC collaboration is developing a detector with the goal of measuring the direction and sense ('head-tail') of nuclear recoils produced in spin-dependent DM interactions. The detector consists of a low pressure TPC with optical readout filled with CF₄ gas at low pressure. A collision between a WIMP with a gas molecule results in a nucleus recoil of 1-2 mm. The measurement of the energy loss along the recoil allows us to determine the sense and the direction of the recoil. Results from a prototype detector operated in a low-energy neutron beam clearly demonstrate the suitability of this approach to measure directionality. In particular, the first observation of the 'head-tail' effect for low-energy neutrons had been recently published by our Collaboration. A full-scale (1m³) module is now being designed. This detector, which will be operated underground in 2009, will allow us to set limits on spin-dependent Dark Matter interactions using a directional detector. The sensitivity of this experiment will be discussed in this talk.

WIMP Dark Matter

See plenary talk
by Uwe Oberlack

Direct search disagreement:

- Observation of annual oscillations by DAMA/LIBRA
- Limits on counting rates by others



Possible explanations:

Non-WIMP DM?

Local WIMP halo assumptions?

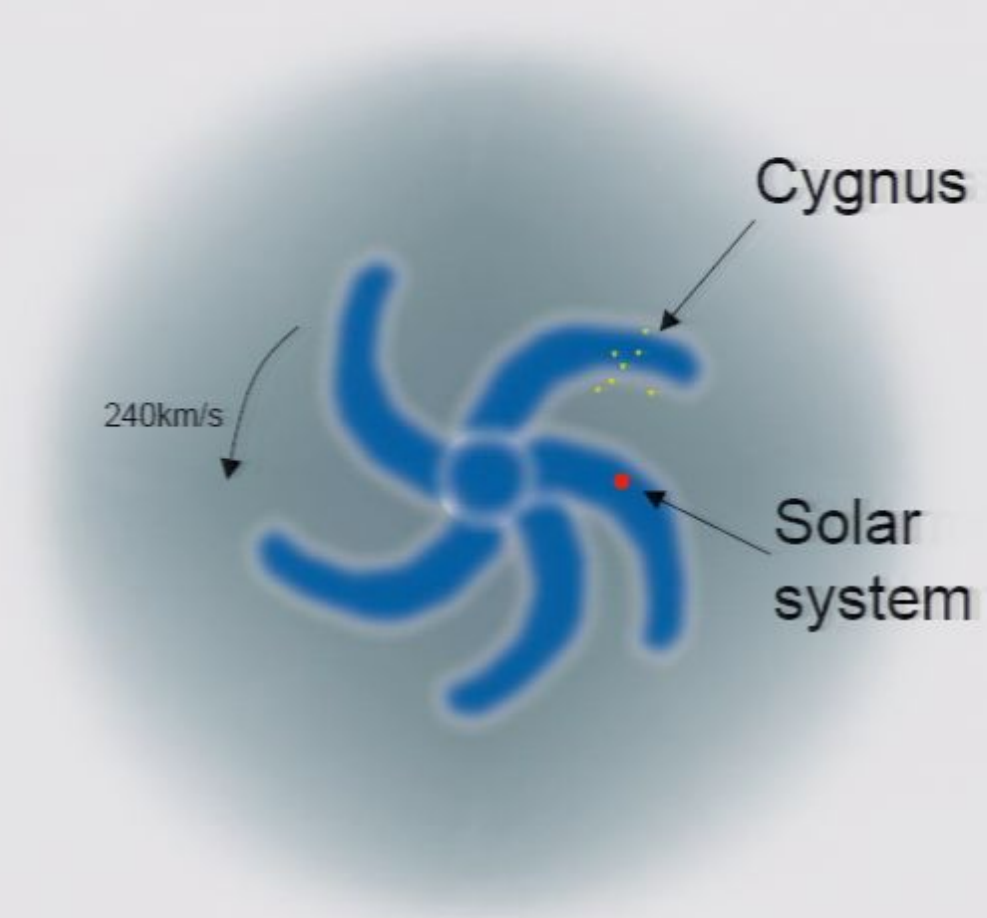
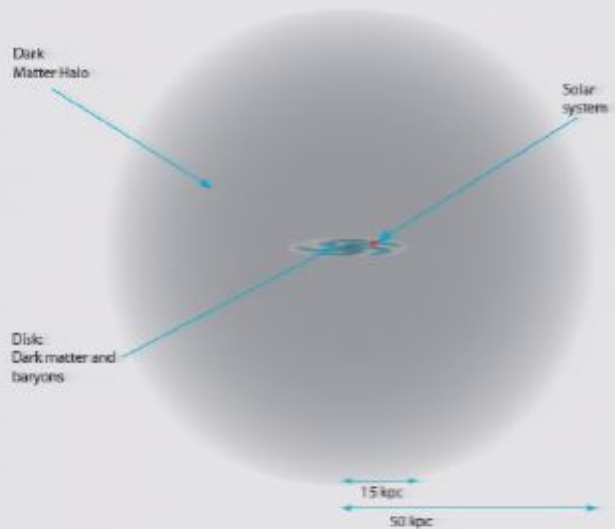
Interaction assumptions?

Experimental?

...

Unambiguous proof
of DM signal?

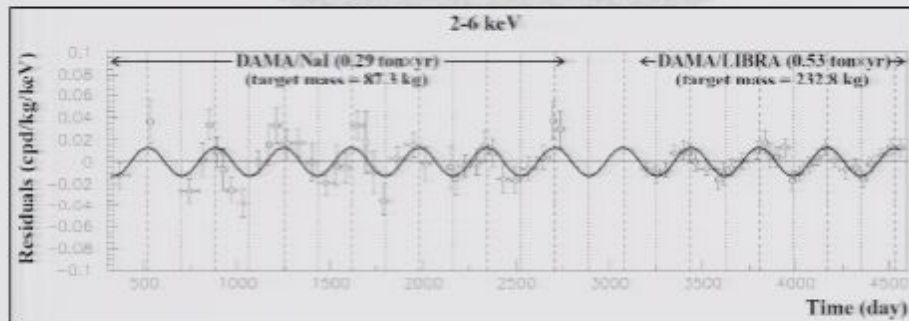
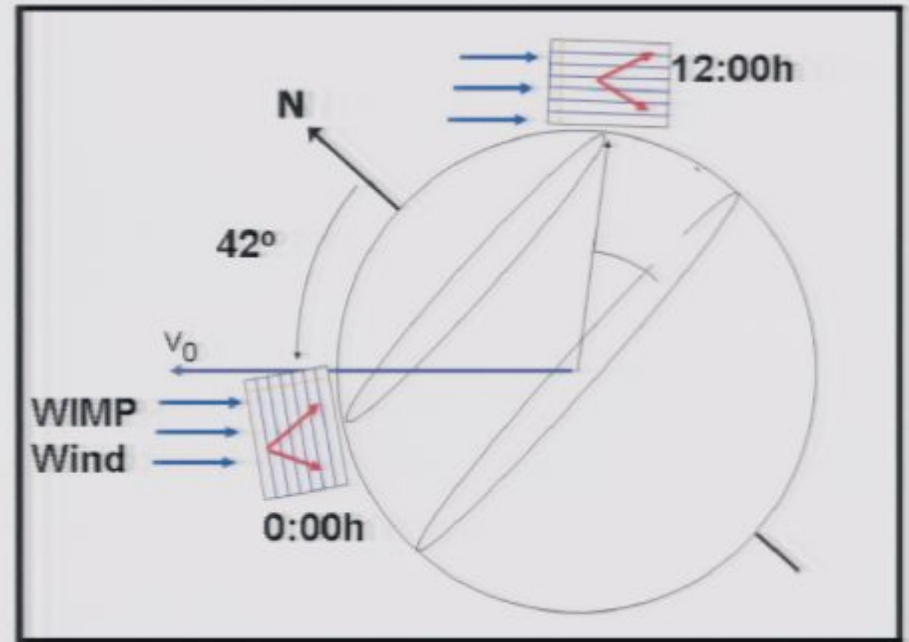
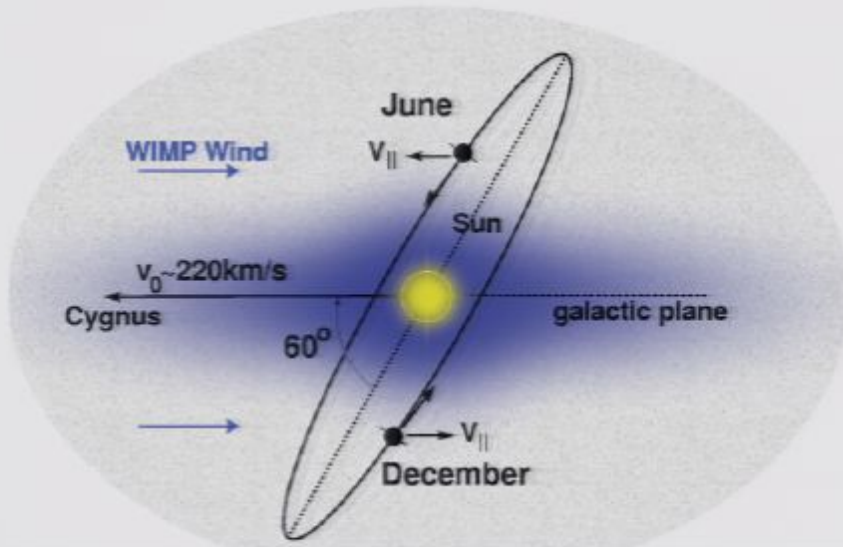
Dark Matter Wind



Direction-sensitive DM search

If DAMA annual oscillations (1-2%) due to DM wind...

... search for much larger (30-100%) diurnal oscillations in WIMP *direction*



Spergel, PRD37

Directional detector needed!

DMTPC@Boston



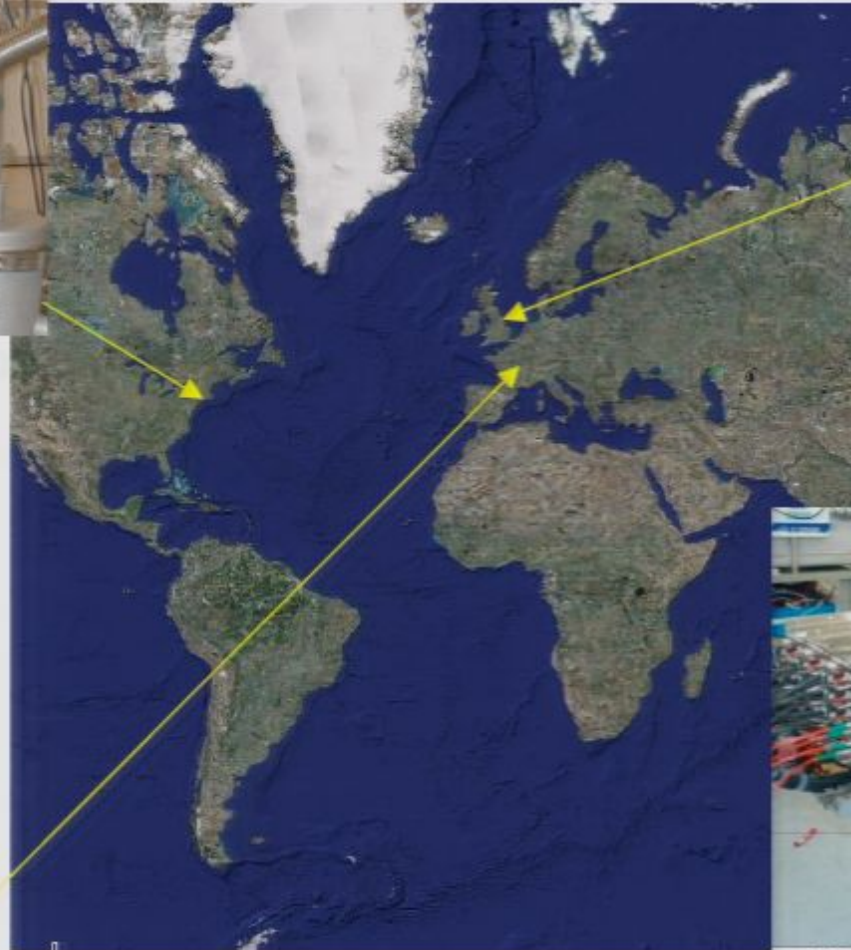
CF4 gas, micromesh+CCD readout, direction tag; D. Dujmic, et al., NIM A 584:337 (2008)

Directional DM Detectors

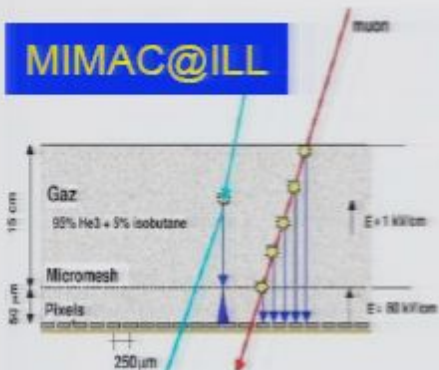
DRIFT@Boulby



wire readout, CS₂ gas, negative ion drift, 16 kg-day exposure S. Burgos et al., Astropart. Phys. 28, 409 (2007)



MIMAC@ILL



μ -TPC, charge readout, He3 gas, D. Santos, et al., J. Phys. Conf. Ser. 65, 021012 (2007)

NEWAGE@Kamioka



μ -TPC charge readout, CF₄ gas; 3mo surface run; K. Miuchi, et al., Phys.Lett.B654:58-64 (2007)

Denis Dujmic, PASCOS08

DMTPC Collaboration

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A. Roccaro



Boston University

N. Skvorodnev, H. Wellenstein
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Massachusetts Institute of Technology



Note:

* indicates undergraduate students

¹ also Harvard University

Denis Dujmic, PASCOS08

DMTPC

← WIMP-induced elastic recoil

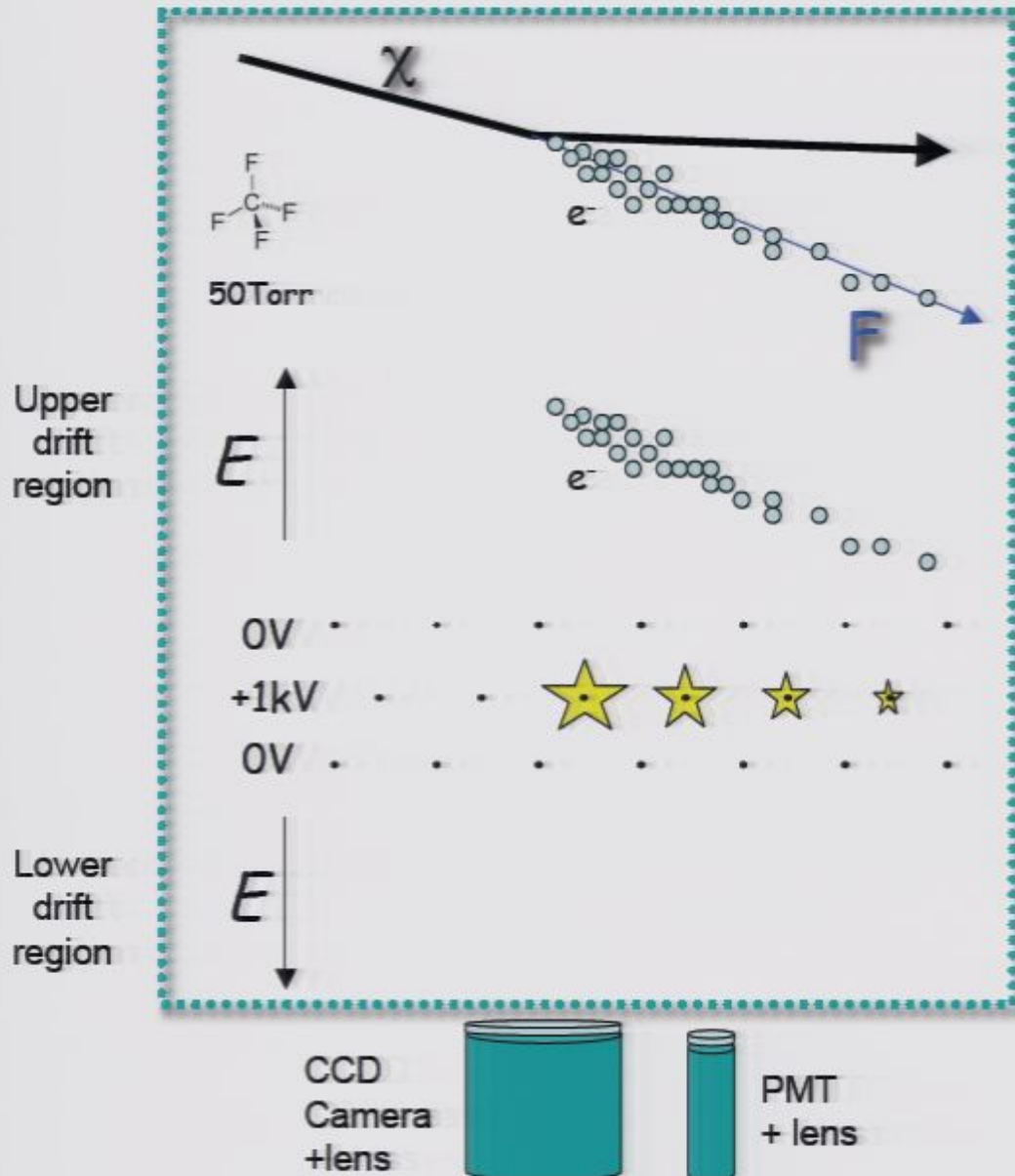
- F recoil $\sim 1-2\text{mm}$
- CF_4 50-100 Torr
- F(86%): $\lambda^2 J(J+1) \sim 0.65$
- Low diffusion
- Non flammable, non toxic

← Mesh amplification plane

- scintillation photons produced in avalanche
- $n(\gamma)/n(e^-) \sim 1/3$

← Optical readout

- CCD: 2D plane
- PMT: Δz , trigger



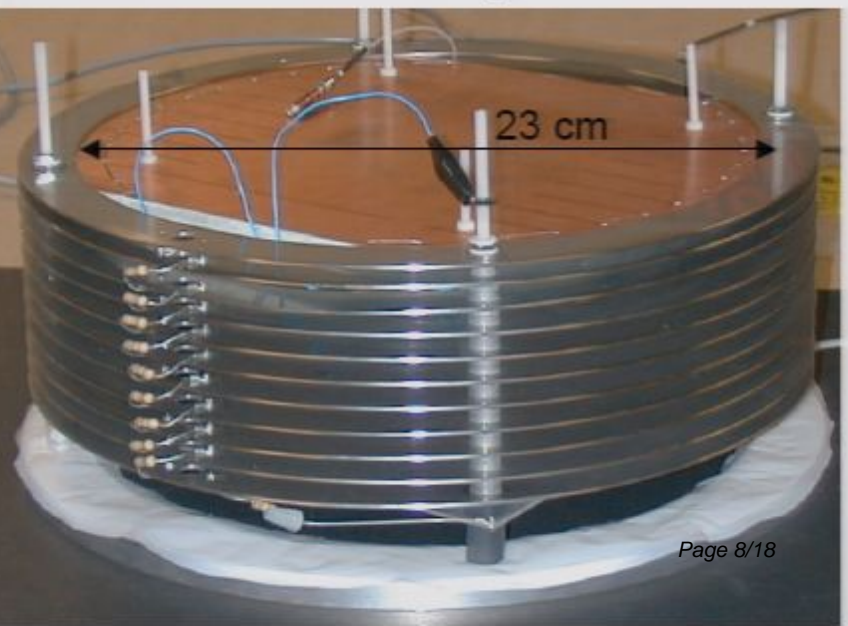
DM-TPC Prototype ($\sim 5\text{ l}$)



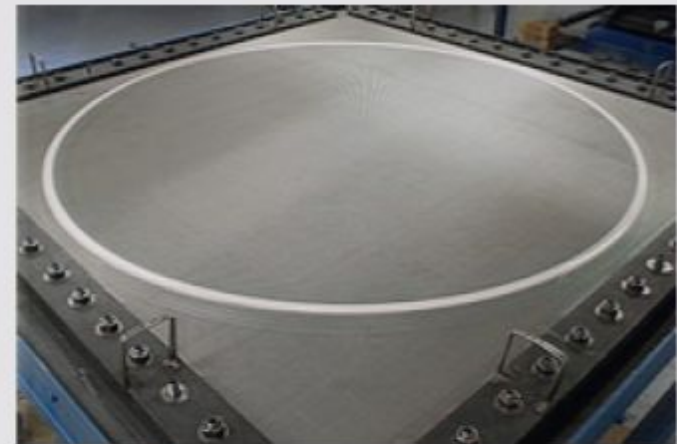
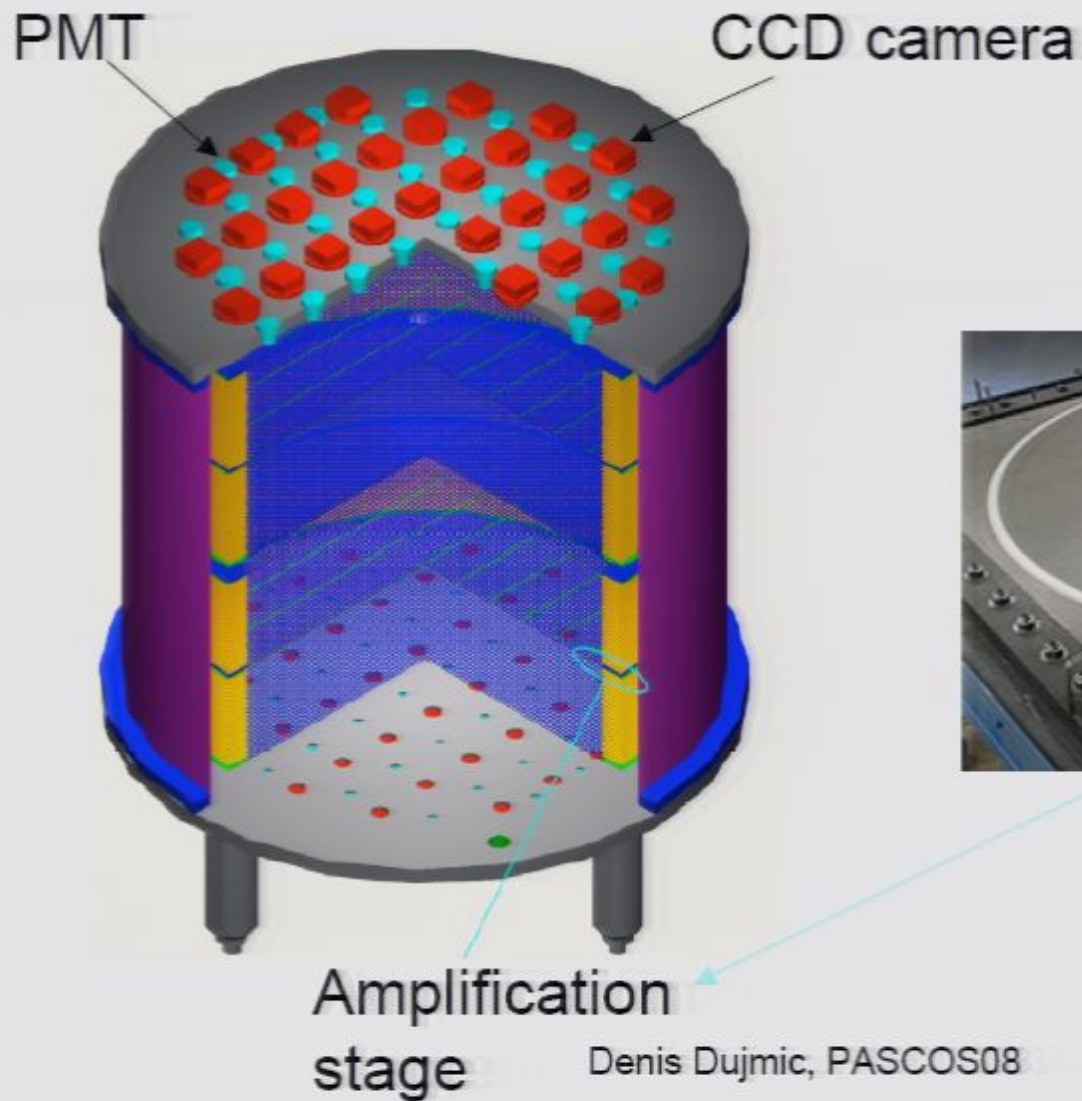
Surface operation at BU:



- 256 μm pitch
- 30 μm wire diameter
- 79% transparency
- Gain > 10,000
- Inexpensive



Next Stage: 1m³ Module

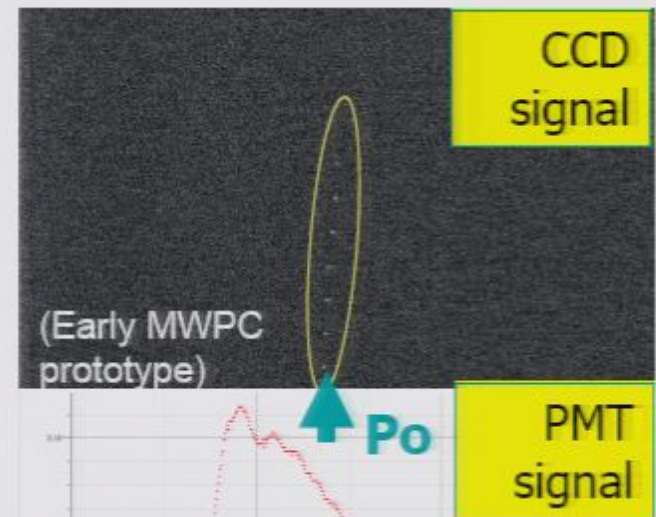
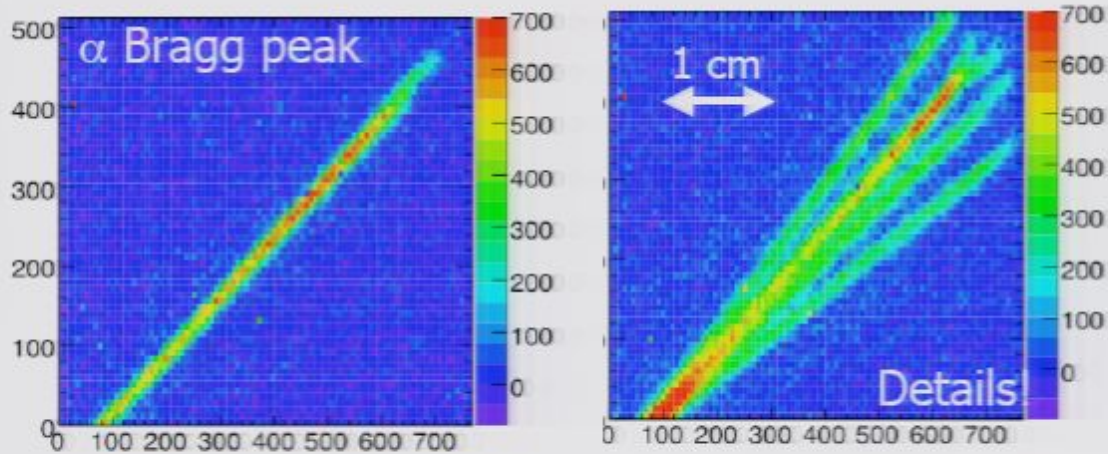


~1m mesh frames

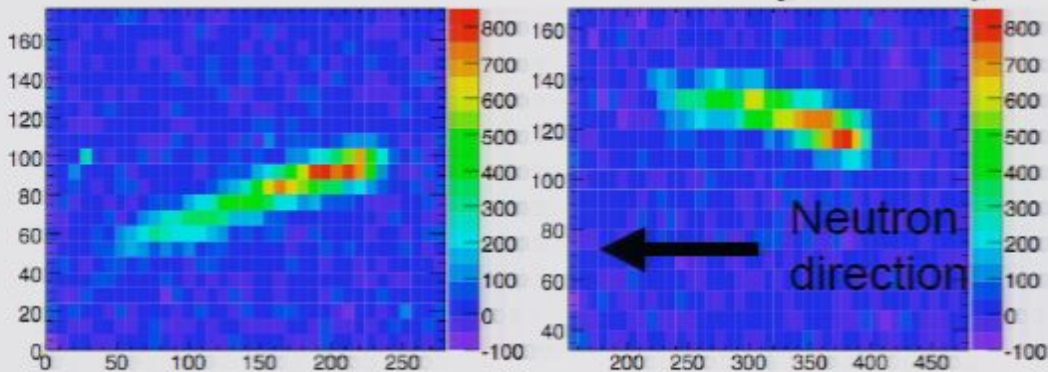
2D (CCD) + 1D (PMT)

Alpha tracks (Am-241)

(Po background)



Nuclear recoils (Cf-252 exposure):



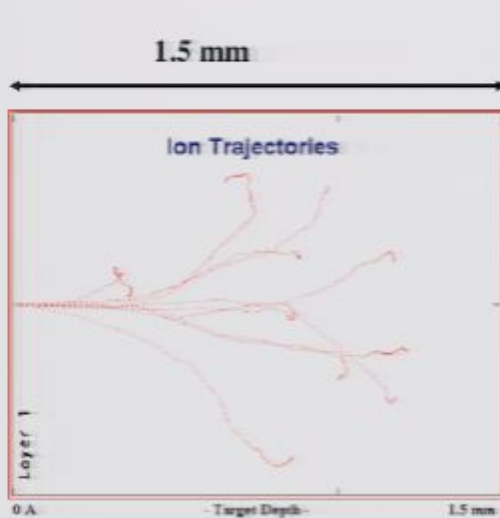
arXiv:0804.4827

arXiv:0803.2195

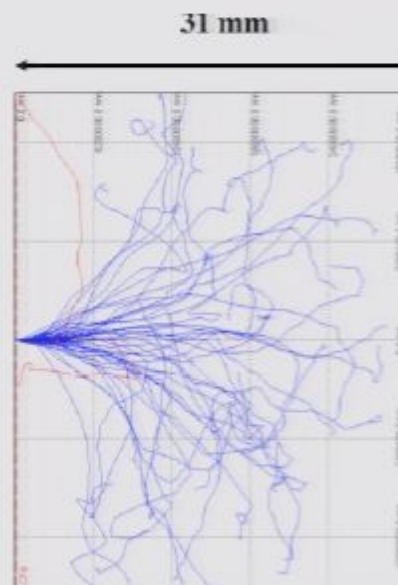
NIMA584,327 (arXiv:0708.2370)

Denis Dujmic, PASCOS08

Background Rejection: Energy-Range

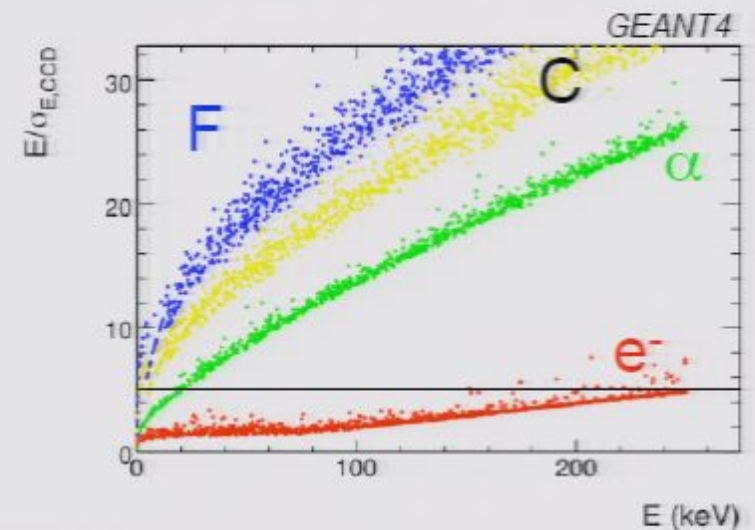


30keV F ions in 50mbar CF4. Typical ion range is about **1mm**. These produce same ionization as 15 keV electrons.



15keV electrons in 50mbar CF4. Typical electron range is about **30mm**.

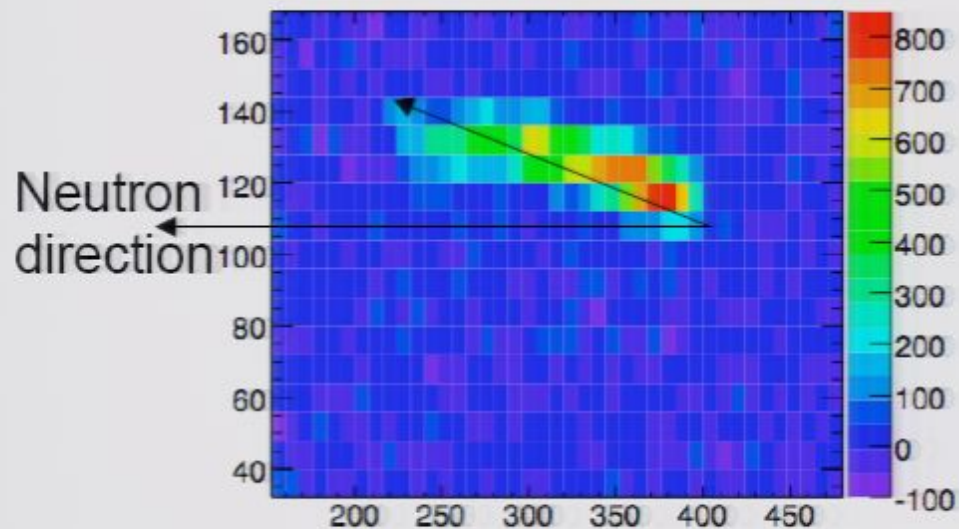
Energy/readout noise



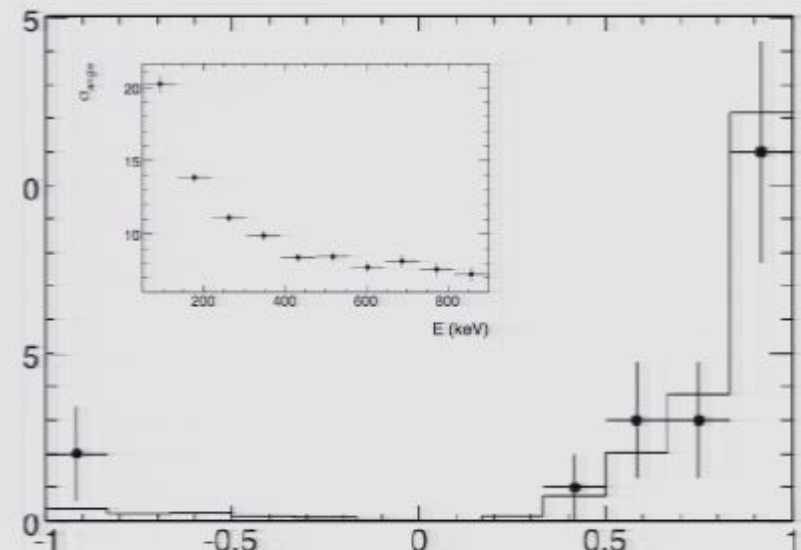
- e^- rejection ($>10^6$ from previous study with Cs137)

Direction + Sense (head-tail)

2D angle + head-tail
from light asymmetry



Signed cosine of
2D recoil angle:



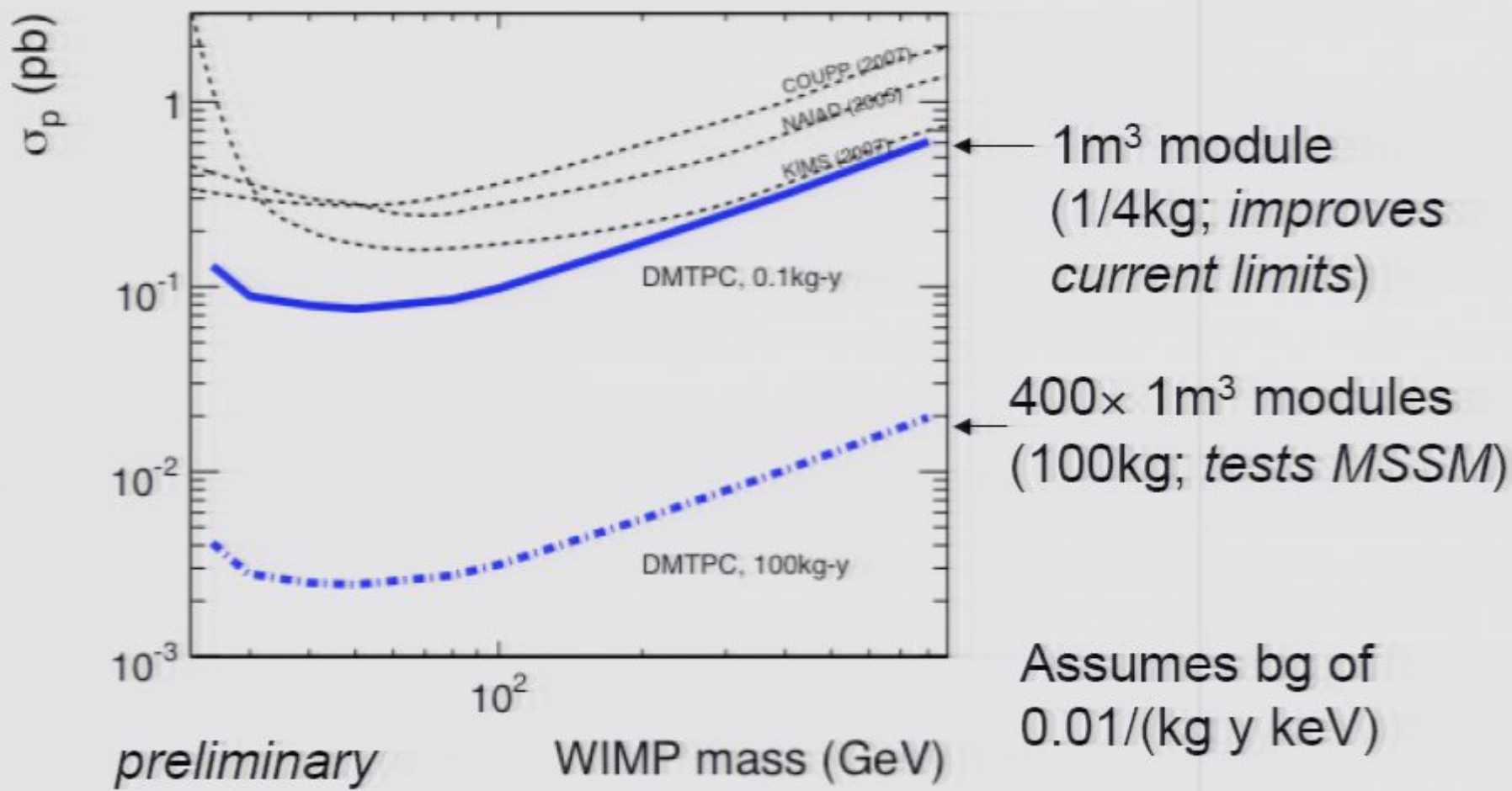
Cf-252, 75 Torr $\text{CF}_4^{\cos(\theta_{\text{Recoil}})}$

arXiv:0804.4827

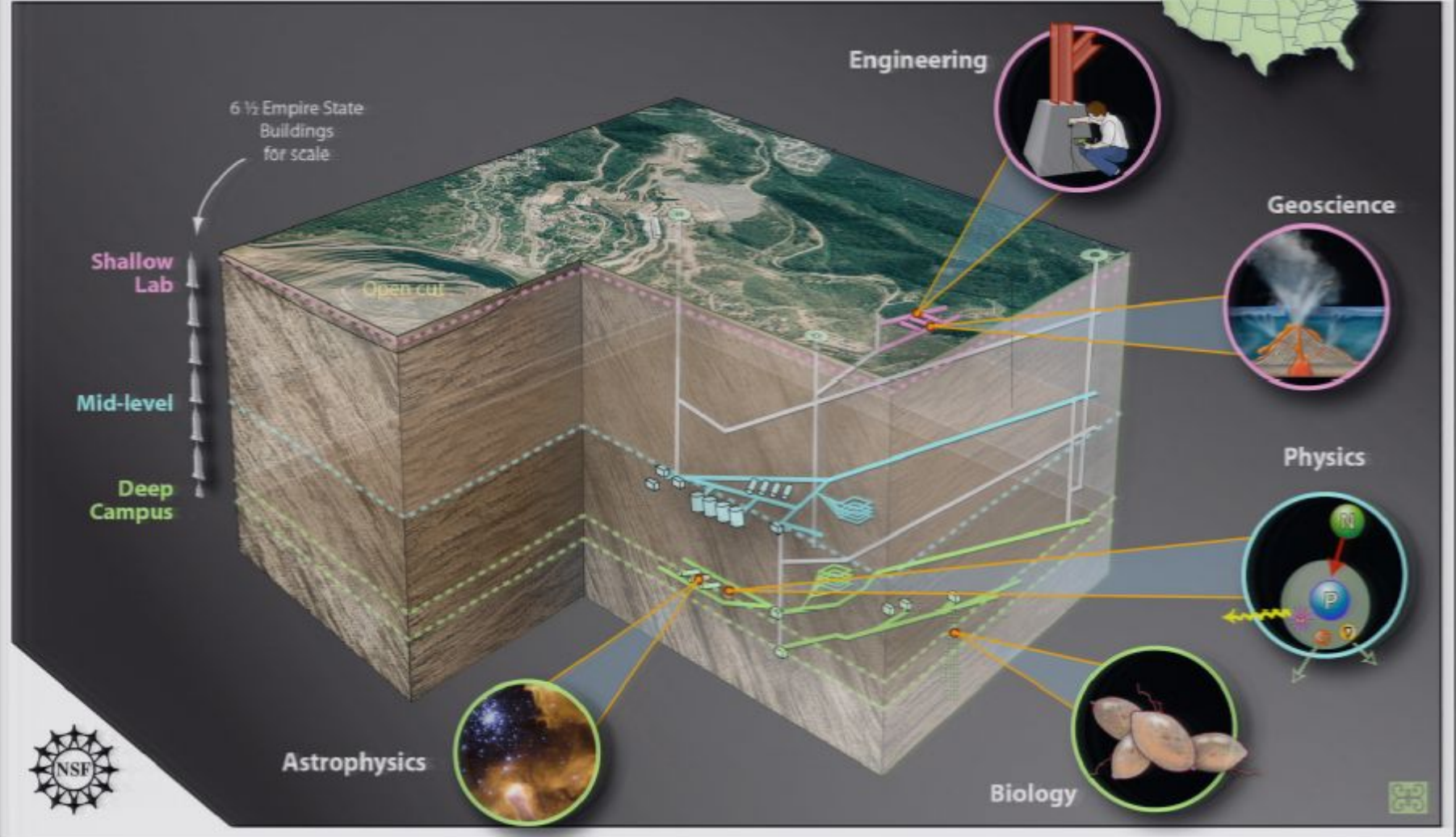
~100keV head-tail threshold

Physics Reach

Spin-dependent:

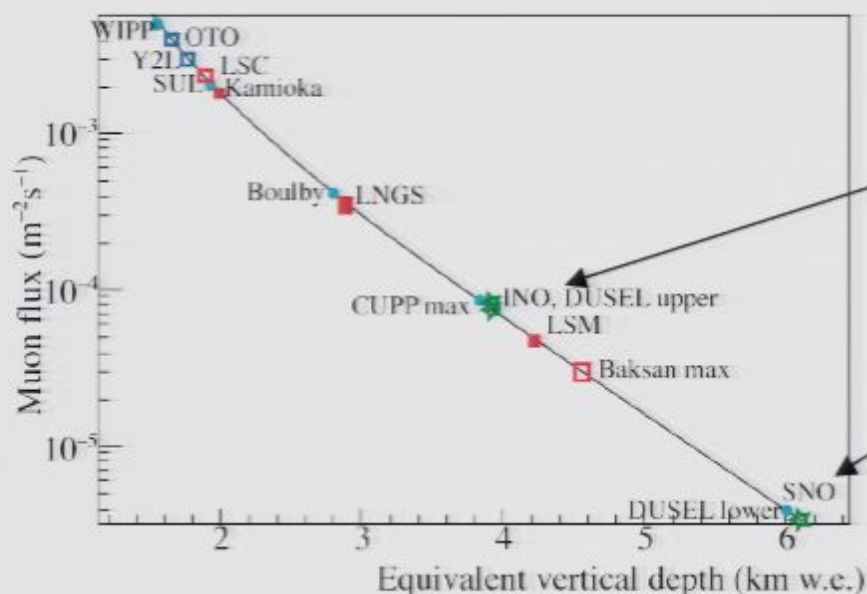


DUSEL Deep Underground Science and Engineering Laboratory at Homestake, SD



DUSEL

- Unique facility: large+deep caverns



Mid-level (4850ft): site of Ray Davis' experiment and birthplace "solar neutrino problem"; expanded with large caverns

Deep campus (7400ft): world-best shielding from cosmics + large caverns

- 2008- Lab development/physics experiments thanks to \$100M private grant by Sanford → Stanford Laboratory (SUSEL, 4850ft)
- 2012- US federal funding to complete deep lab (~\$600M/NSF)

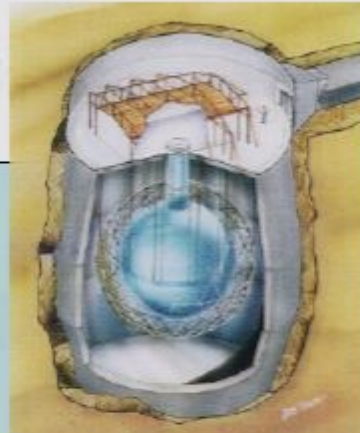
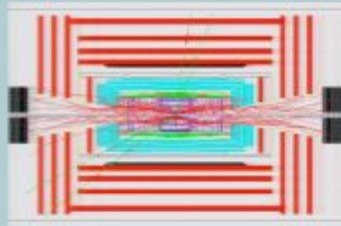
DM-TPC 1t

Super-K:
 $40 \times 40 \times 40 \text{ m}^3$

SNO:
 $21 \times 21 \times 34 \text{ m}^3$

DMTPC:
 $16 \times 16 \times 16 \text{ m}^3$ CMS:
 $15 \times 15 \times 22 \text{ m}^3$

20 m



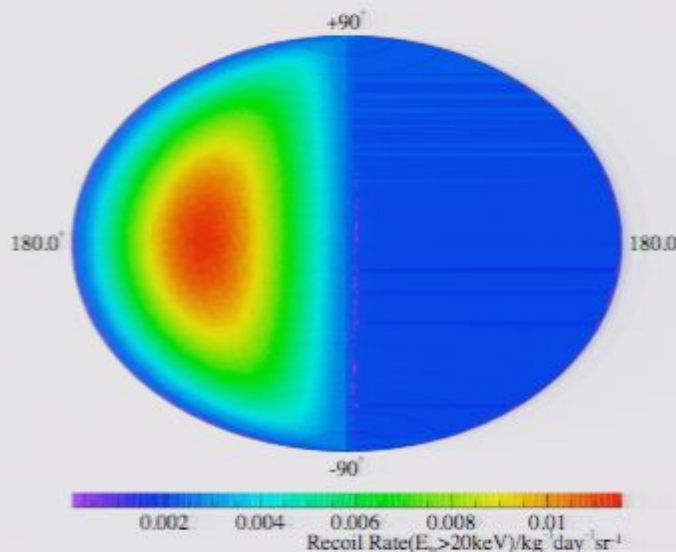
100 m

Proposed DUSEL cavern

UNO: $60 \times 60 \times 180 \text{ m}^3$

Summary

- Goal is to develop 100kg (1t) direction-sensitive detector for operation at DUSEL
- Unambiguous proof for dark matter by correlating signal with astrophysical phenomena
- Stepping stone into dark matter astronomy



~ O(10) events to detect WIMP wind
A. M. Green, B. Morgan, [astro-ph/0609115](#)

~O(10⁵) events to measure velocity anisotropy
O. Host, S. Hansen, [arXiv:0704.2909 \[astro-ph\]](#)

Physics Reach

Spin-dependent:

