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

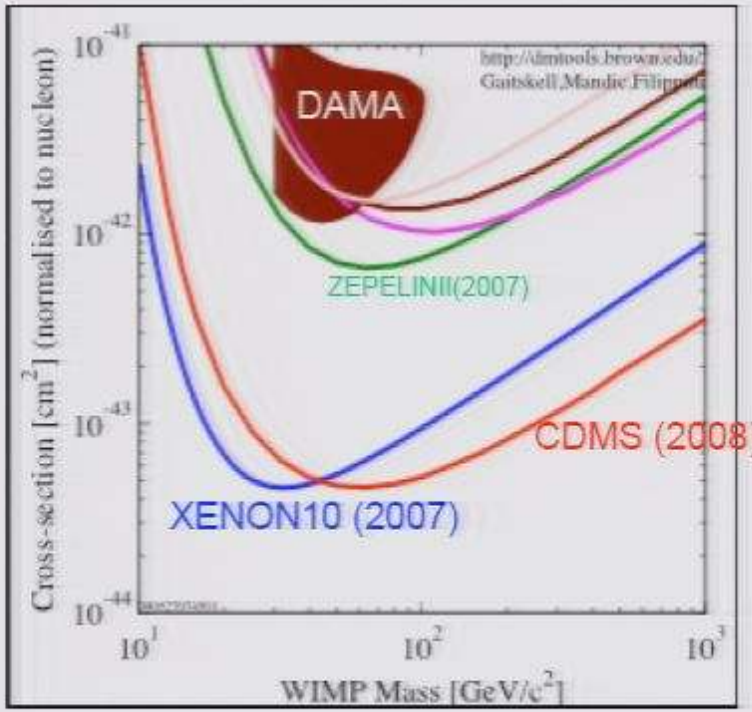
Abstract: Directional detection of dark matter can provide unambiguous observation of dark matter (DM) interactions even in the presence of insidious backgrounds. The DM-TPC collaboration is developing a detector with the goal of measuring the direction and sense (\'\'head-tail\'\') of nuclear recoils 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 (1m^3) 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?

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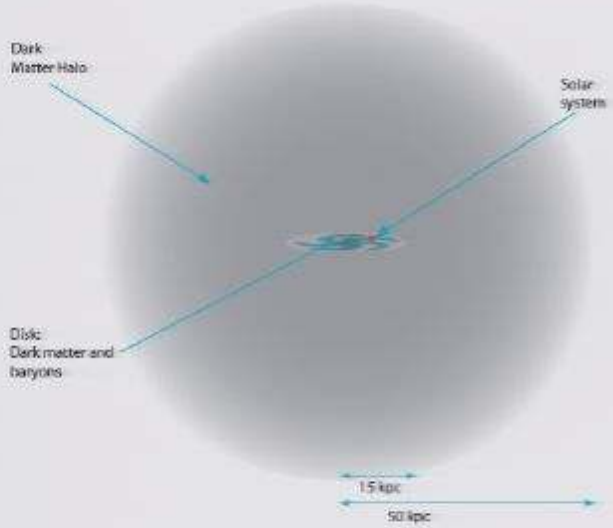
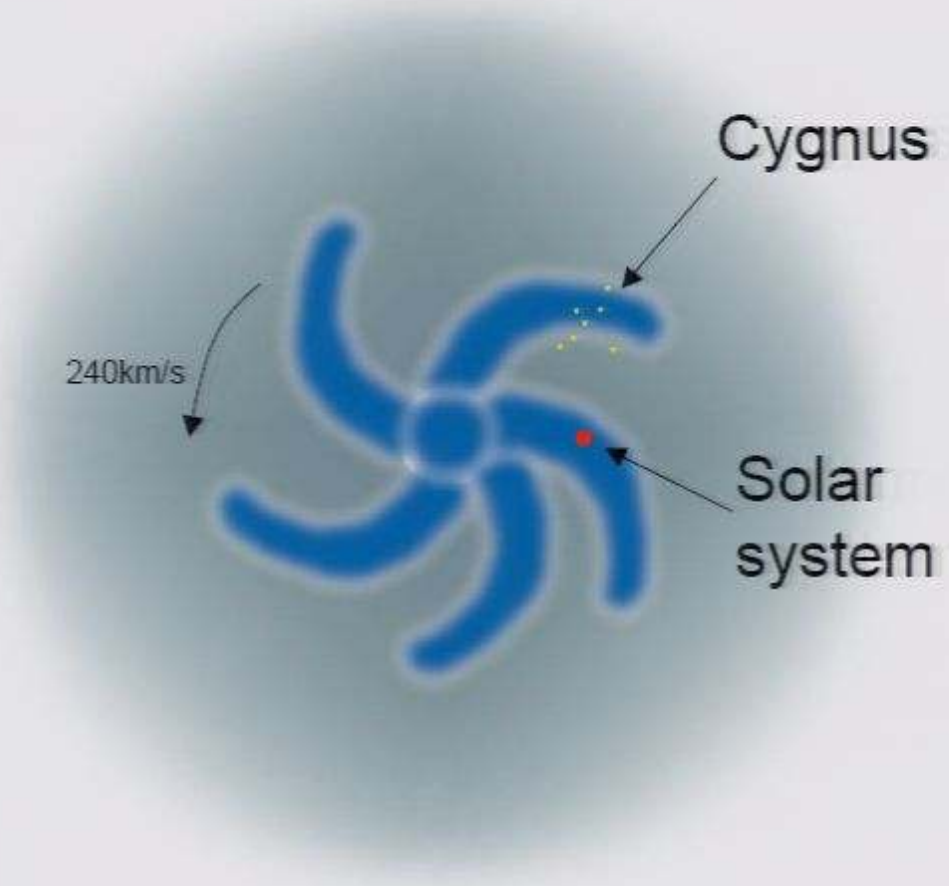
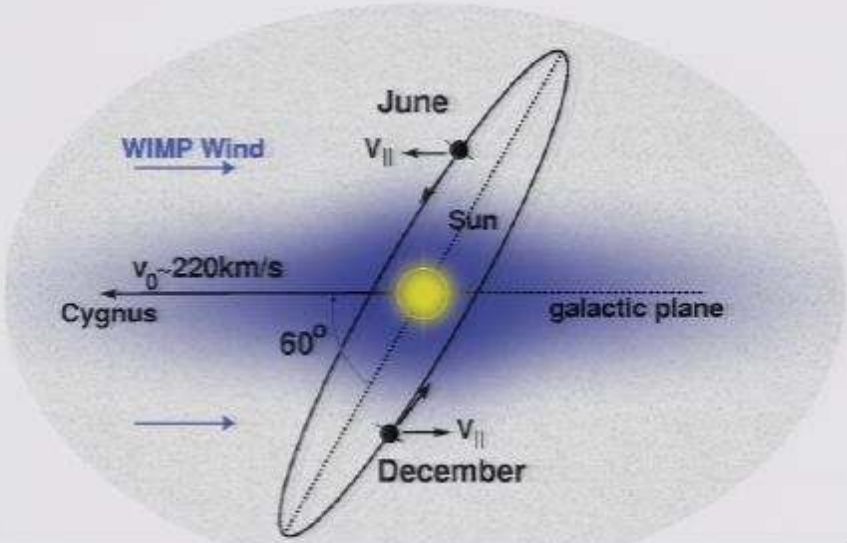
Dark Matter Wind

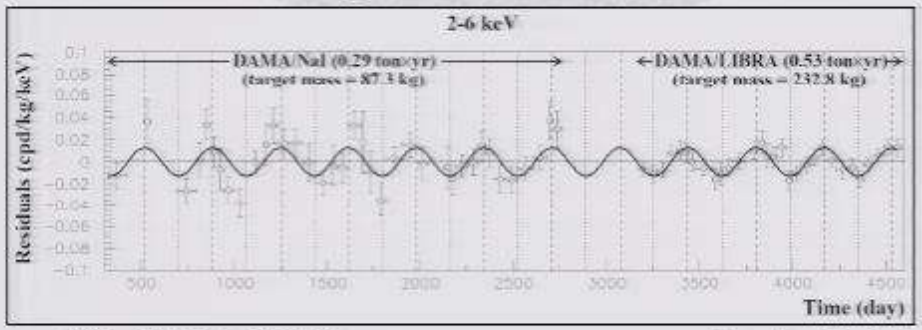




Direction-sensitive DM search

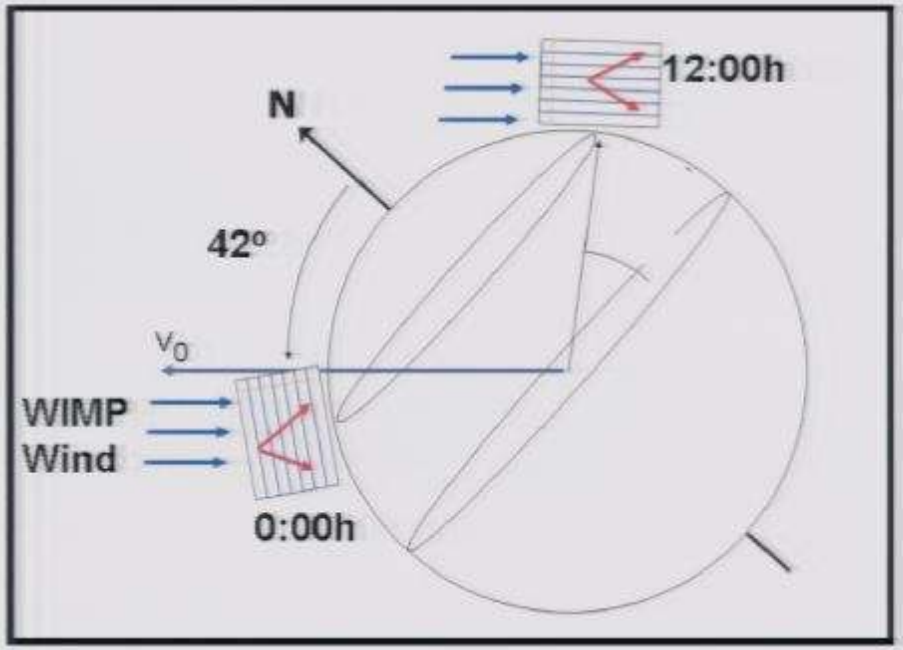
If DAMA annual oscillations (1-2%) due to DM wind…





arXiv:0804.2741

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



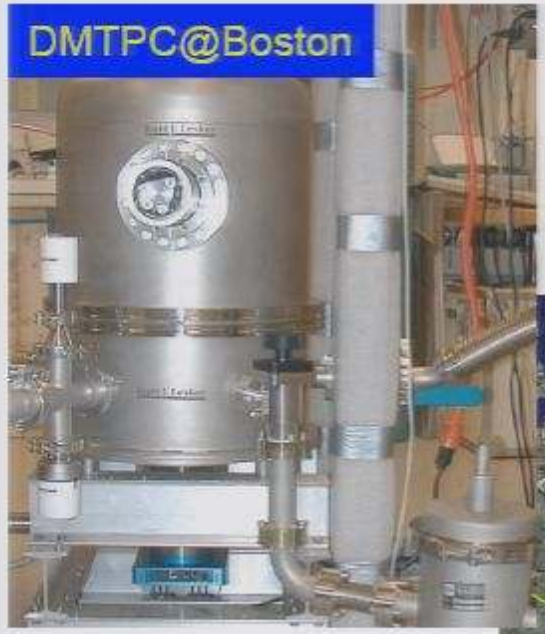
Spergel, PRD37

Denis Dujmic, PA

Directional detector needed!

Directional DM Detectors

DMTPC@Boston

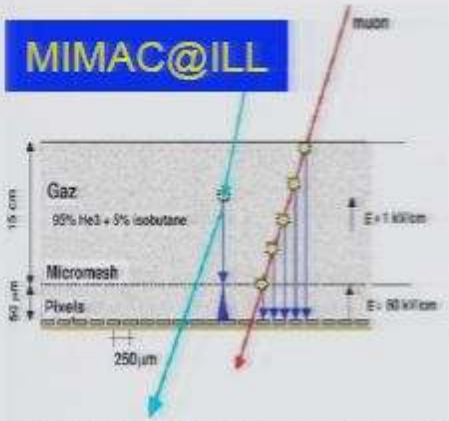


CF4 gas, micromesh+CCD readout, direction tag; D. Dujmic, et al., NIM A 584:337 (2008)

DRIFT@Boulby

wire readout, CS_2 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, CF_4 gas; 3mo surface run; K. Miuchi, et al., Phys.Lett.B654:58-64 (2007)

Denis Dujmic, PASCOS08

Pirsa: 08060182

DMTPC Collaboration

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A. Roccaro
Boston University

N. Skvorodnev, H. Wellenstein
Brandeis University

O.Bishop*, B. Cornell*[1], D. Dujmic, W. Fedus*, P. Fisher,
S. Henderson, A. Kaboth, J. Monroe, T. Sahin*,
G. Sciolla, R. Vanderspek , R. Yamamoto, H. Yegoryan*
Massachusetts Institute of Technology

Note:
* indicates undergraduate students
[1] also Harvard University

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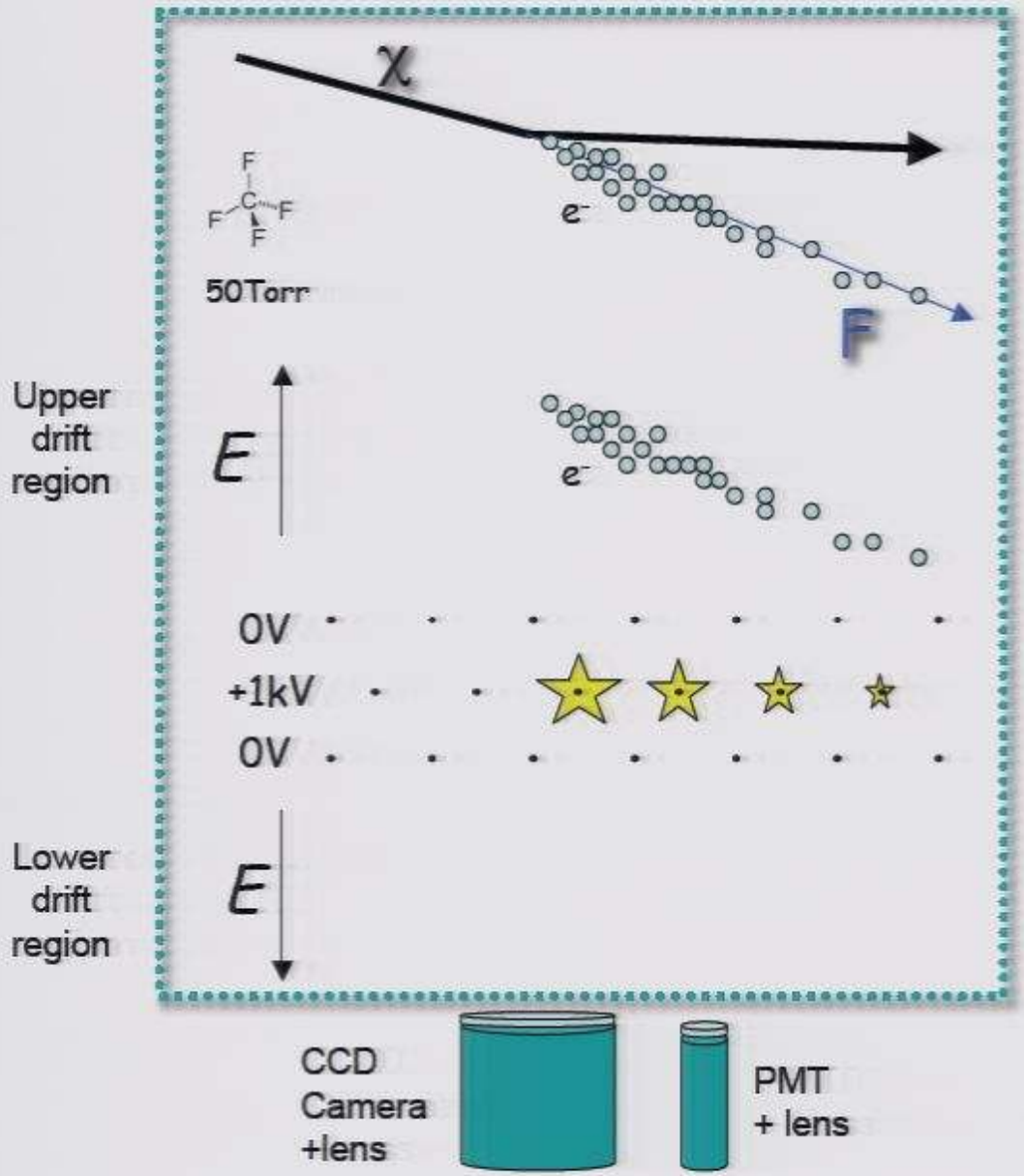
DMTPC



- WIMP-induced elastic recoil
  - F recoil ~1-2mm
  - 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

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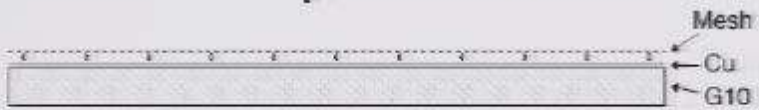
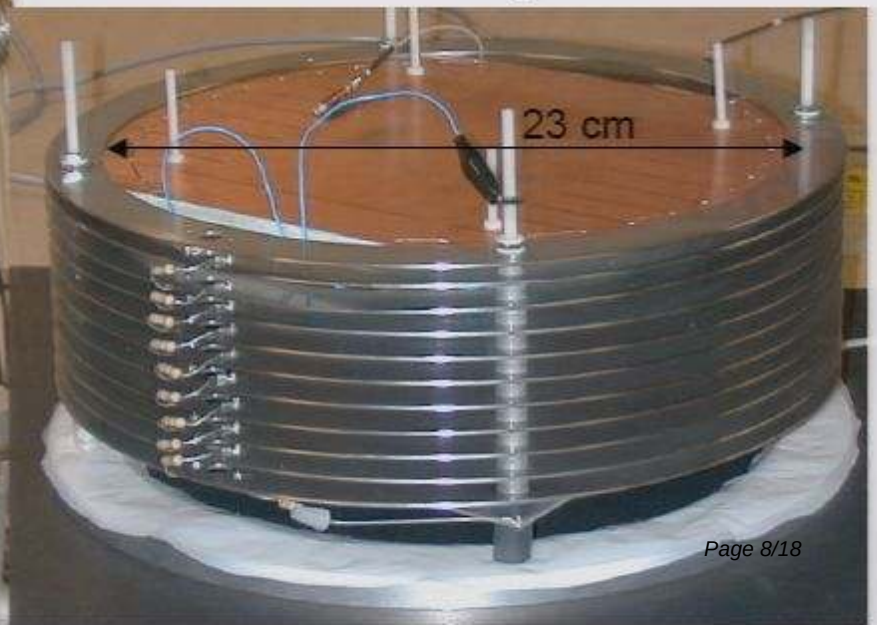
DM-TPC Prototype (~5 ℓ)

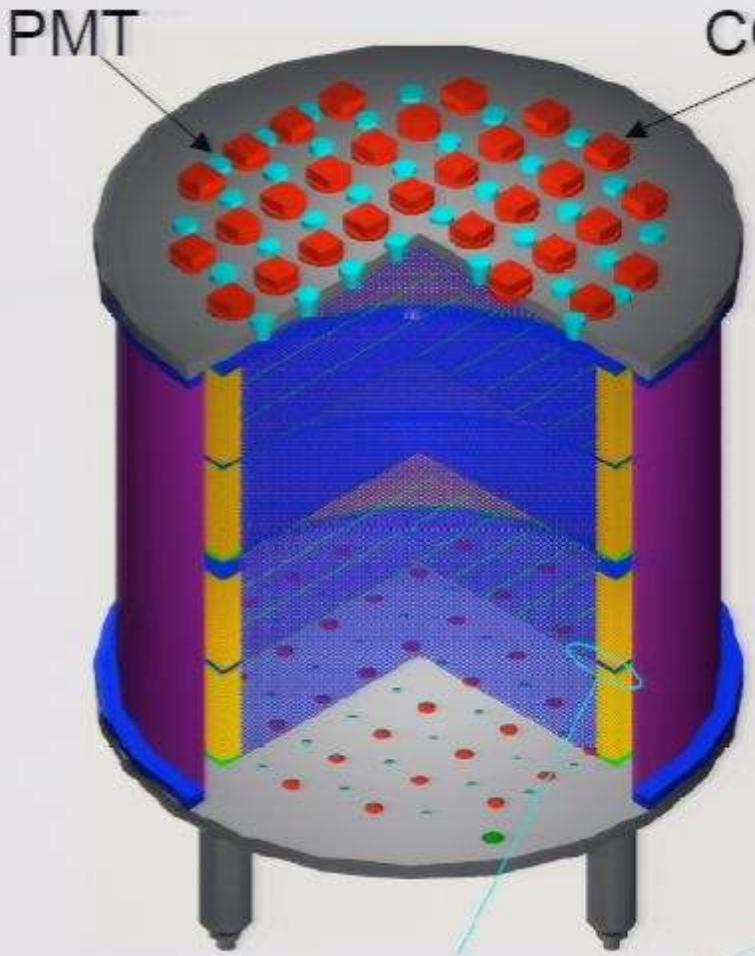
Surface operation at BU:



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



Next Stage: 1m^3 Module

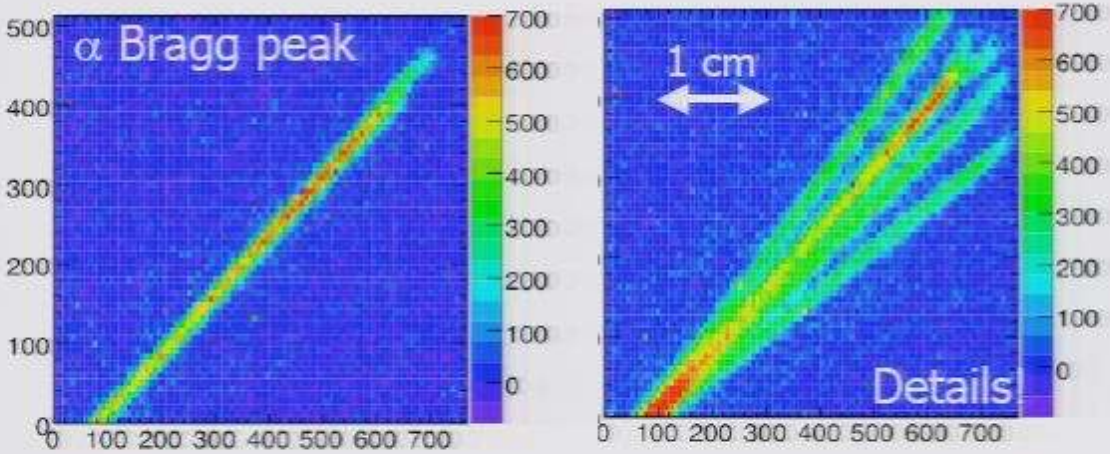


~1m mesh frames

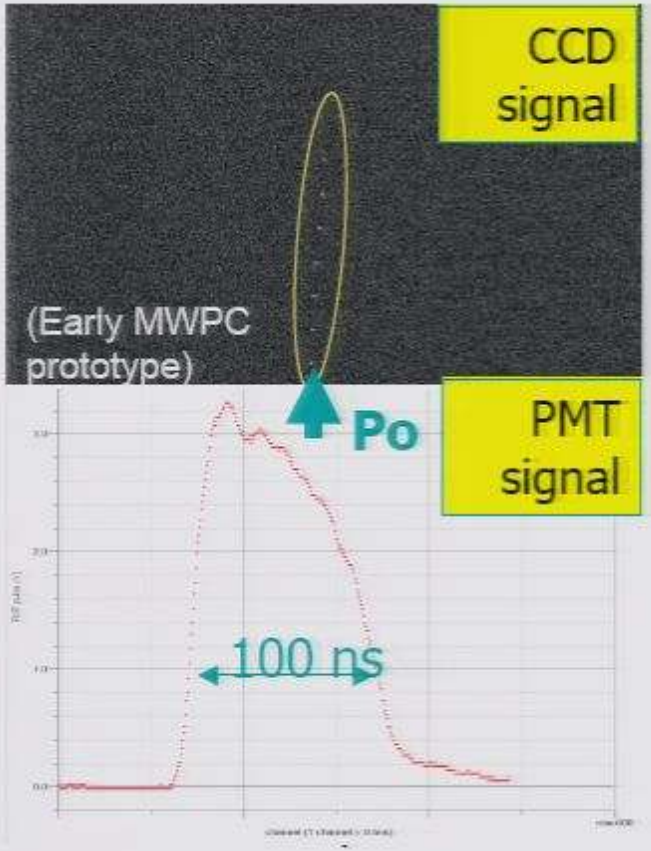
Amplification stage

2D (CCD) + 1D (PMT)

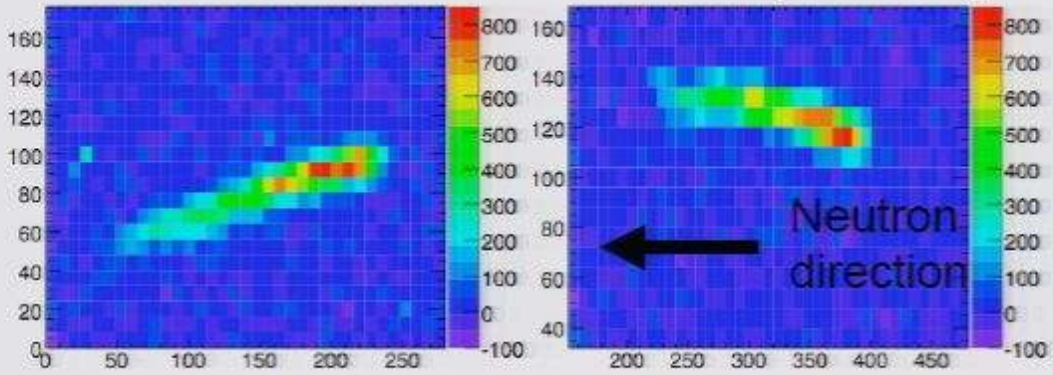
Alpha tracks (Am-241)



(Po background)



Nuclear recoils (Cf-252 exposure):



Denis Dujmic, PASCOS08

arXiv:0804.4827
arXiv:0803.2195
NIMA584,327 (arXiv:0708.2370)

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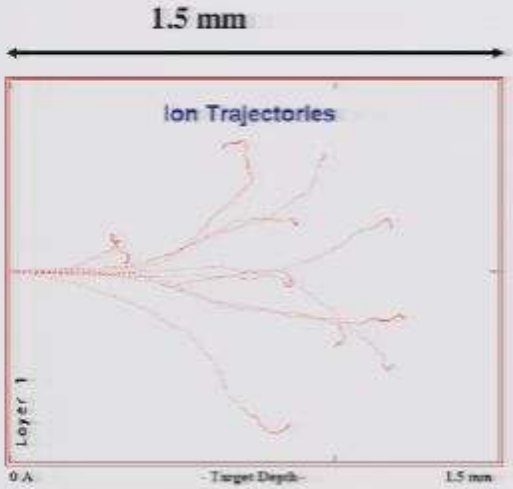
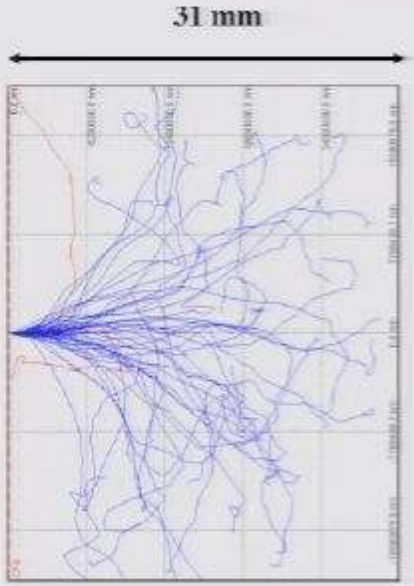
Background Rejection: Energy-Range

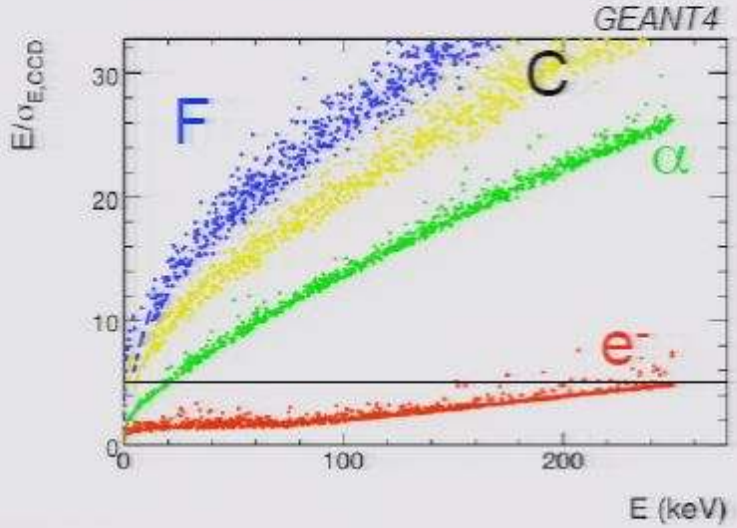


30keV F ions in 50mbar CF4. Typical ion range is about 1mm. These produce same ionization as 15 keV electrons.



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

Energy/readout noise



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

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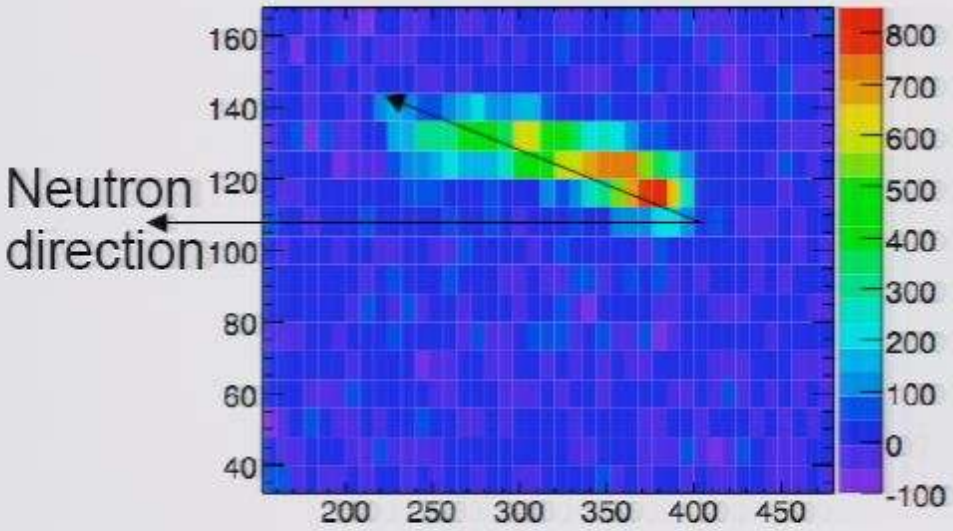
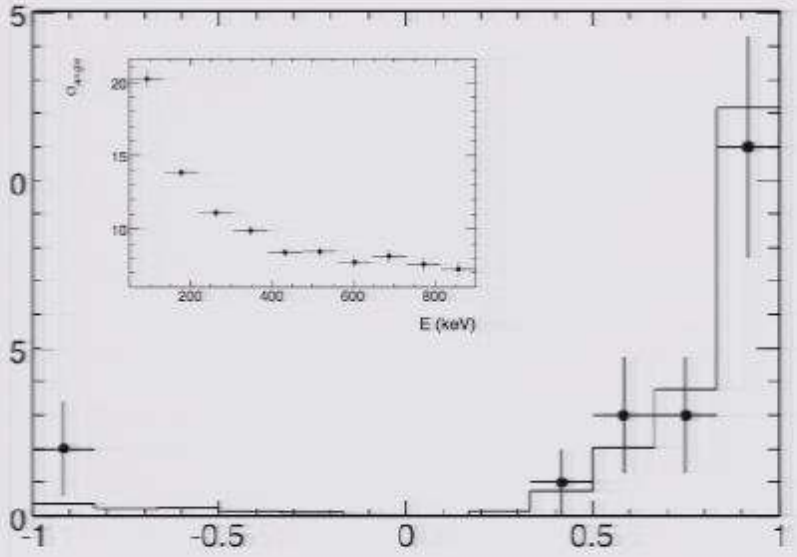
Direction + Sense (head-tail)

2D angle + head-tail from light asymmetry



Signed cosine of 2D recoil angle:



Cf-252, 75Torr $CF_4^{\cos(\theta_{Recoil})}$

arXiv:0804.4827

~100keV head-tail threshold

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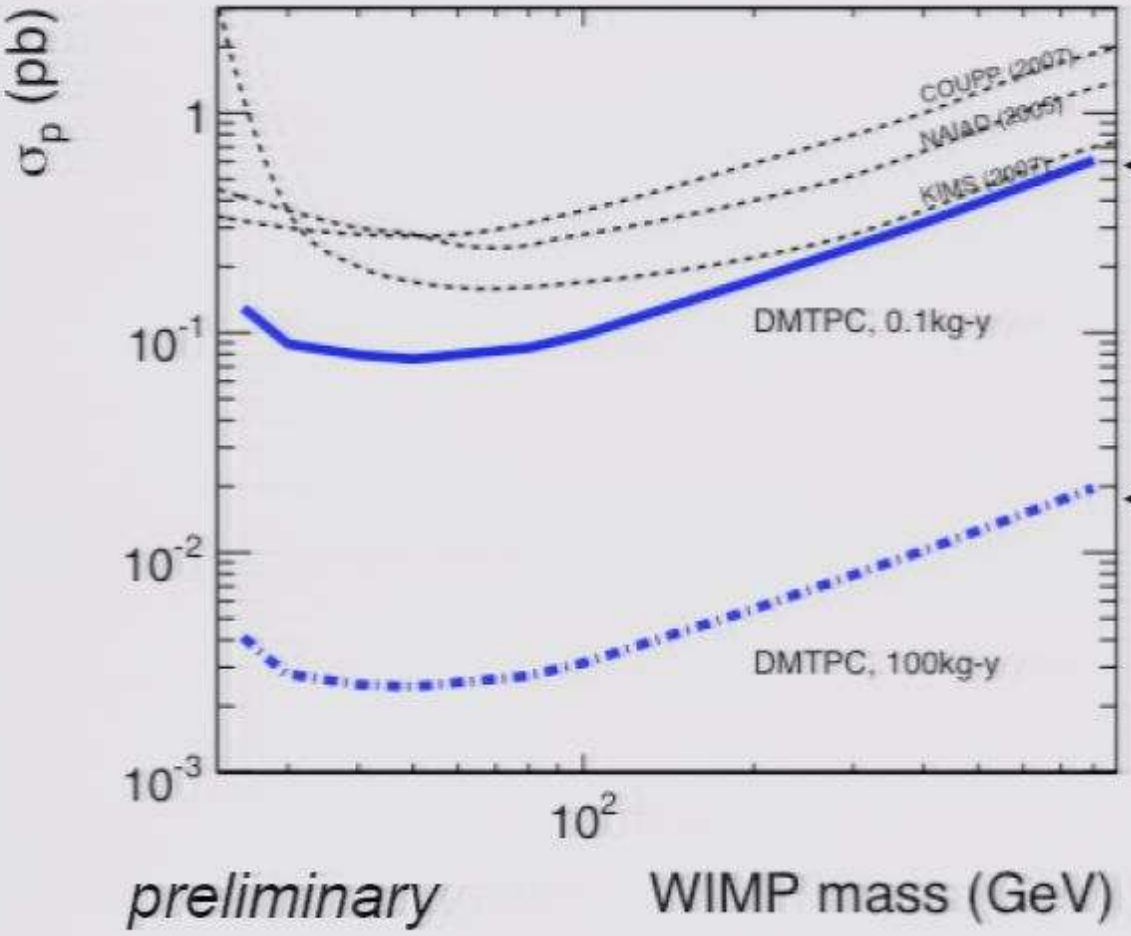
Physics Reach

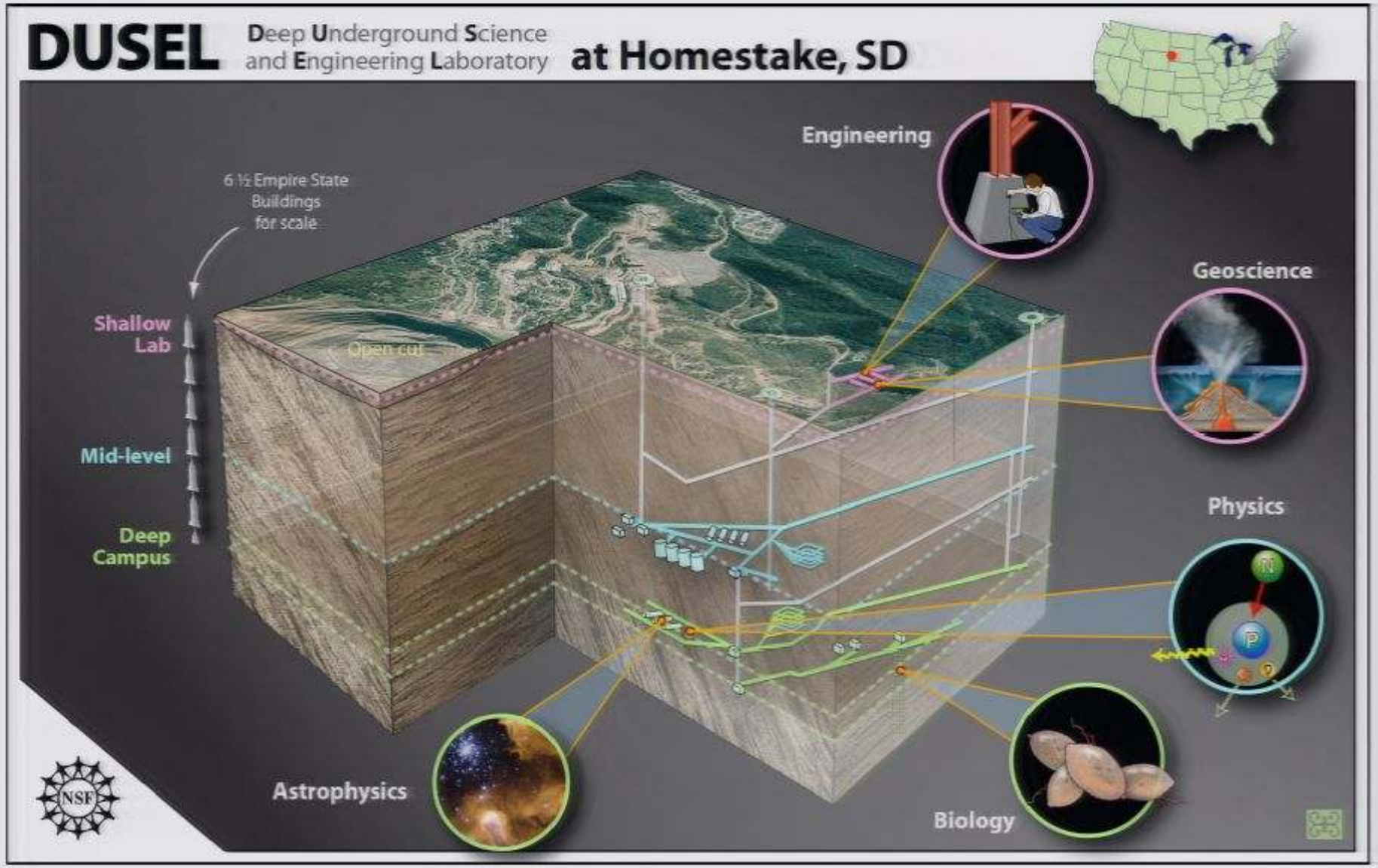
Spin-dependent:



← 1m^3 module (1/4kg; *improves current limits*)

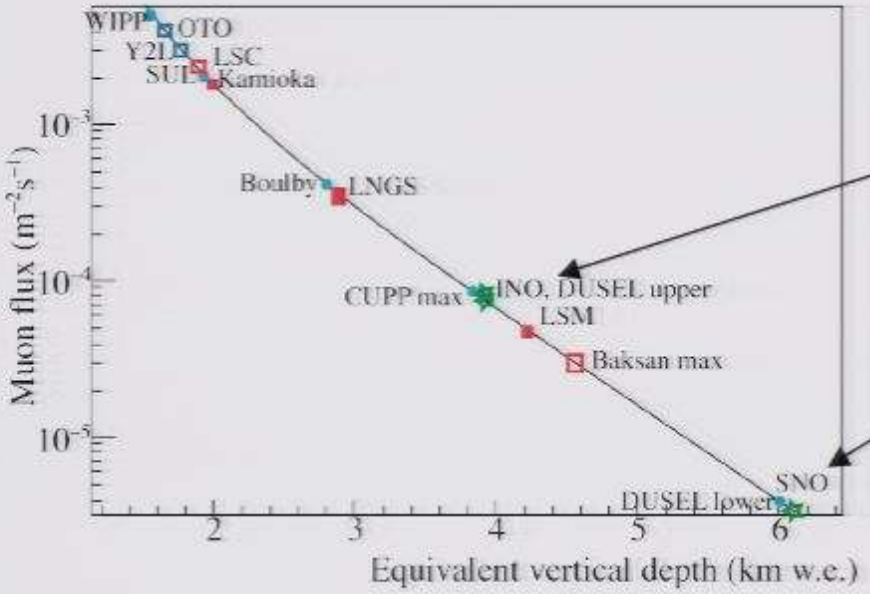
← 400× 1m^3 modules (100kg; *tests MSSM*)

Assumes bg of 0.01/(kg y keV)


DUSEL
Deep Underground Science and Engineering Laboratory
at Homestake, SD
Engineering
6 ½ Empire State Buildings for scale
Shallow Lab
Mid-level
Deep Campus
Open cut
Geoscience
Physics
Astrophysics
Biology
NSF

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)

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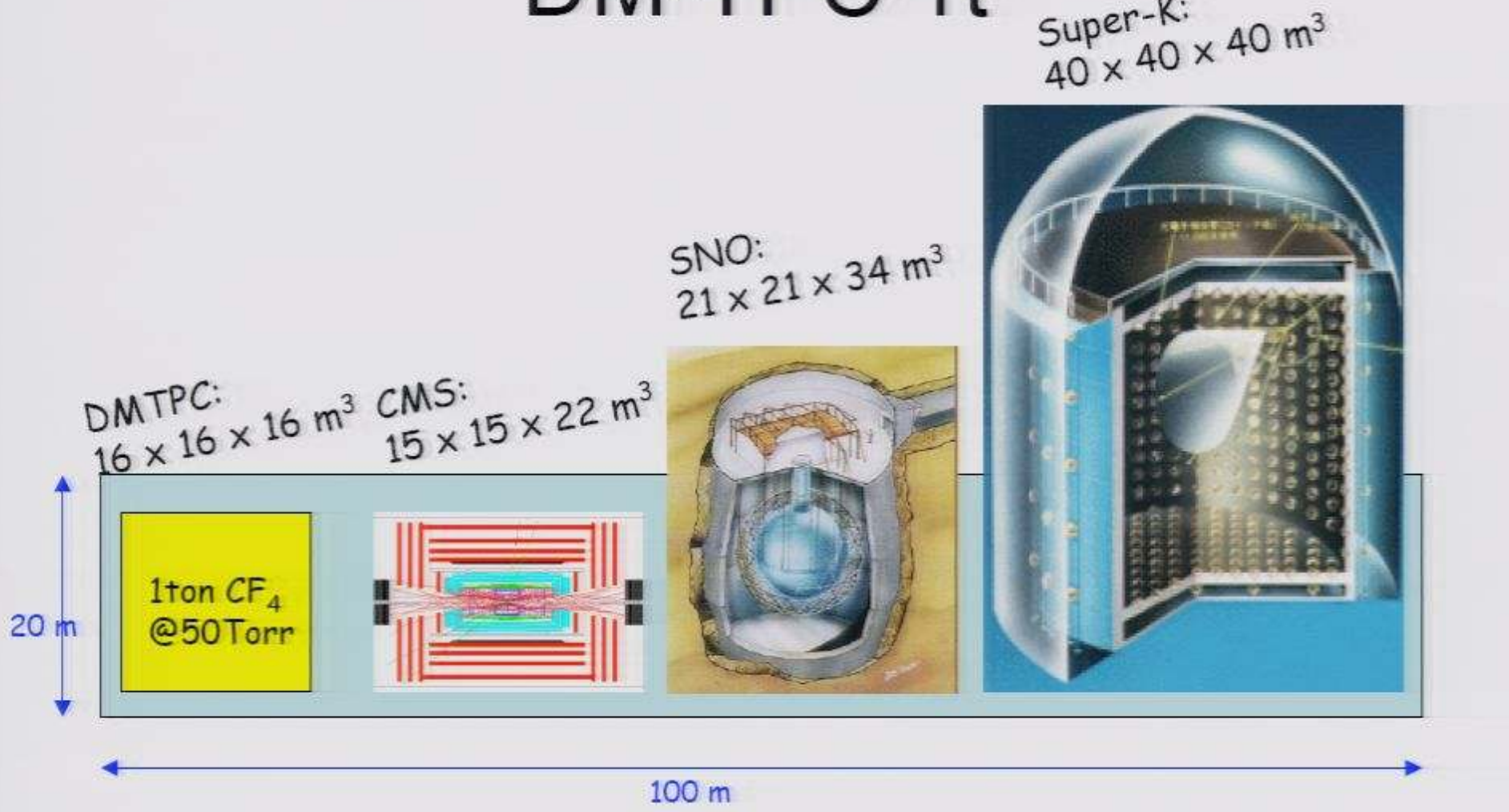
DM-TPC 1t



Proposed DUSEL cavern

UNO: 60 ×60 ×180 m³

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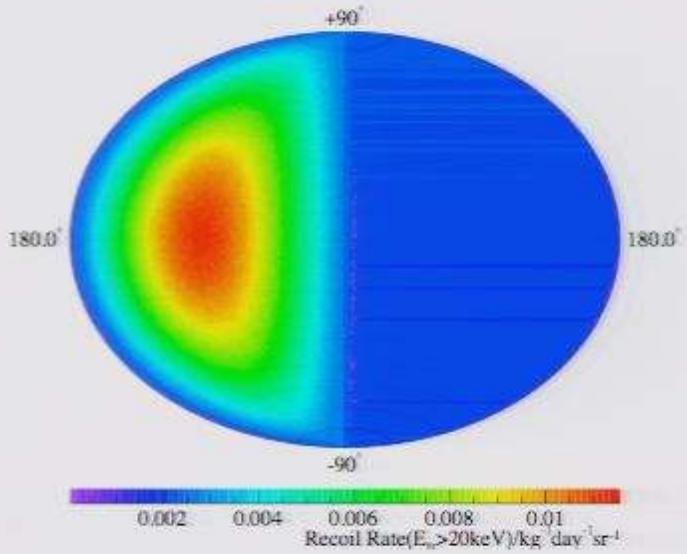
Summary

- 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(10^5) events to measure velocity anisotropy
O. Host, S. Hansen, arXiv:0704.2909 [astro-ph]

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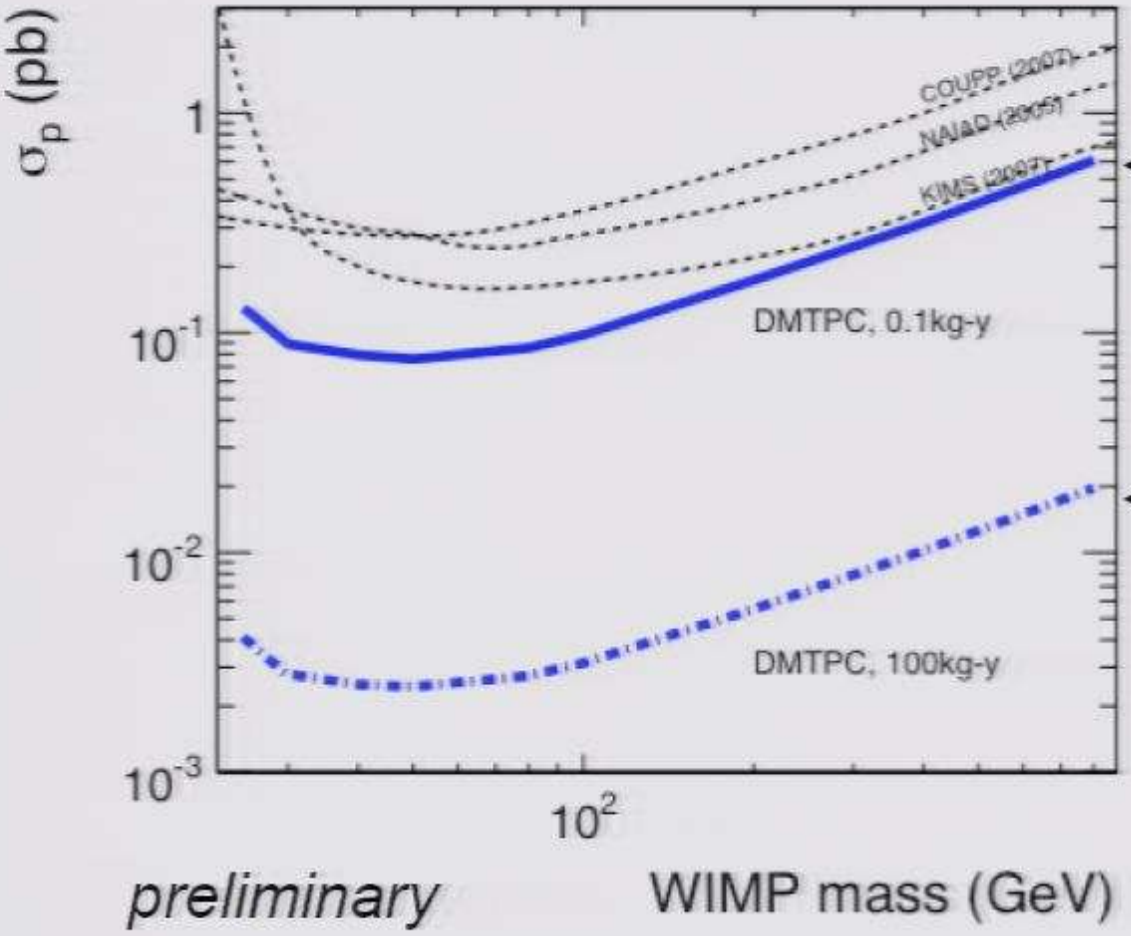
Physics Reach

Spin-dependent:



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