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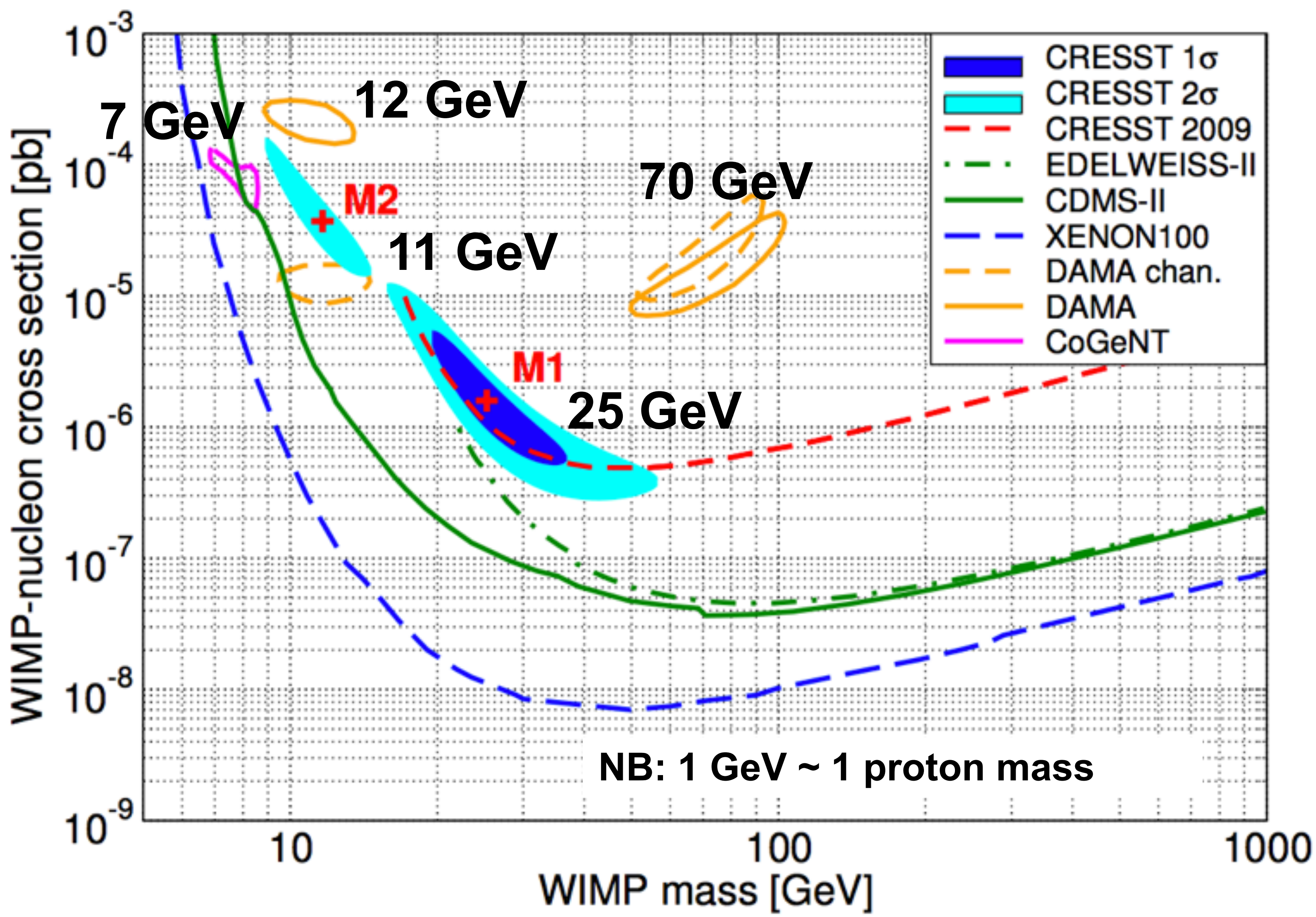
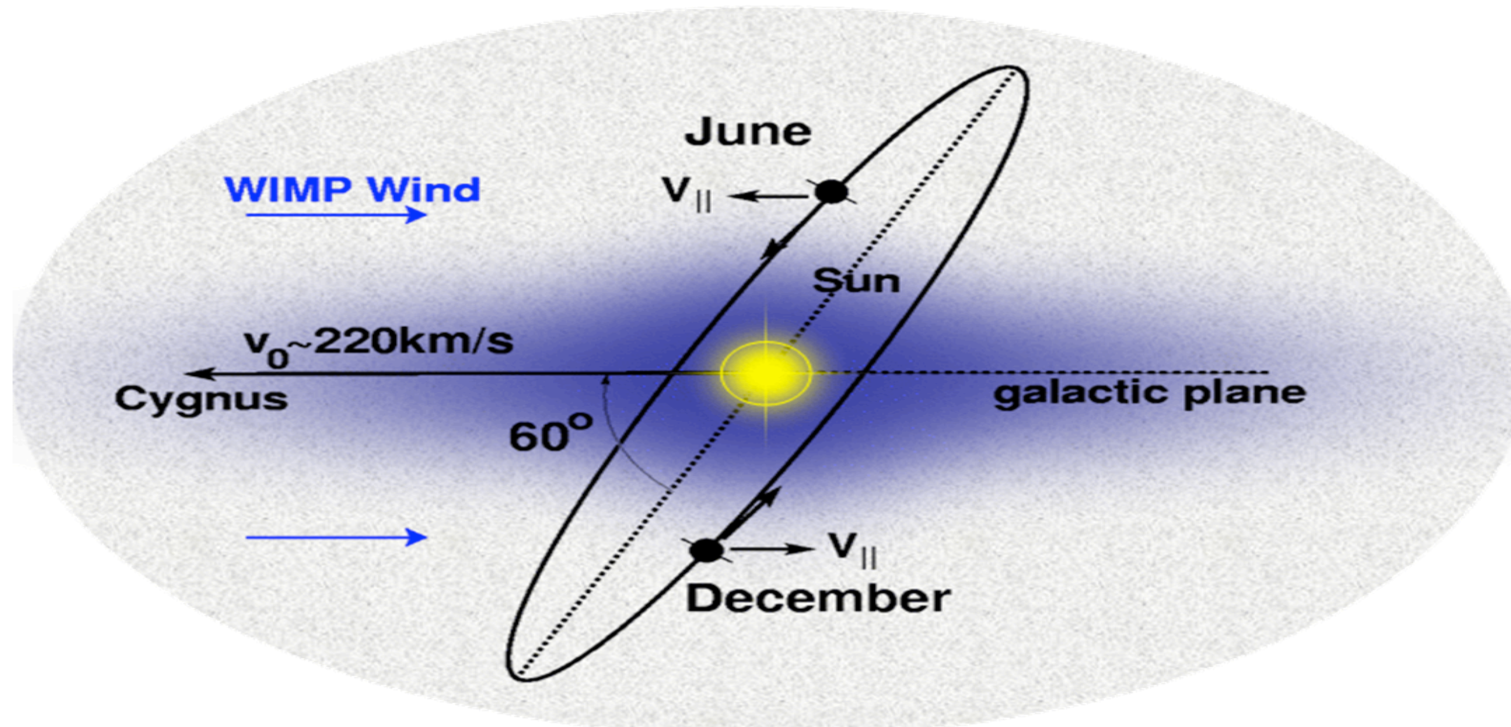
Dark Matter Galactic Signatures

Edward Daw
The University of Sheffield
New Paths to Particle Dark Matter
Oxford University
29th March 2012

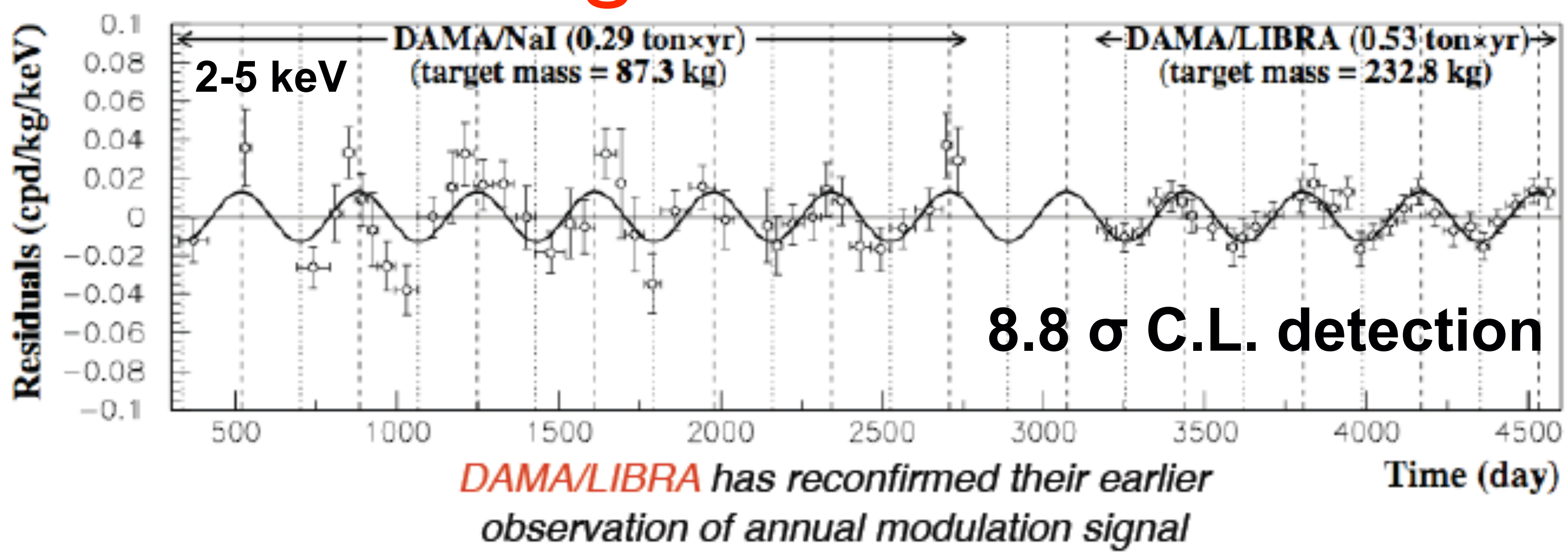
An Intriguing Time for Dark Matter Searches



Annual Modulation



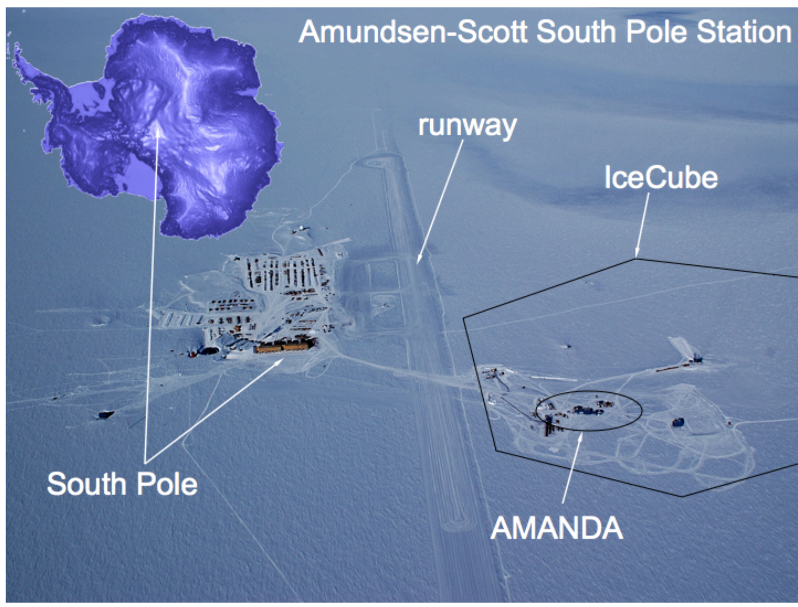
DAMA signal in Sodium Iodide



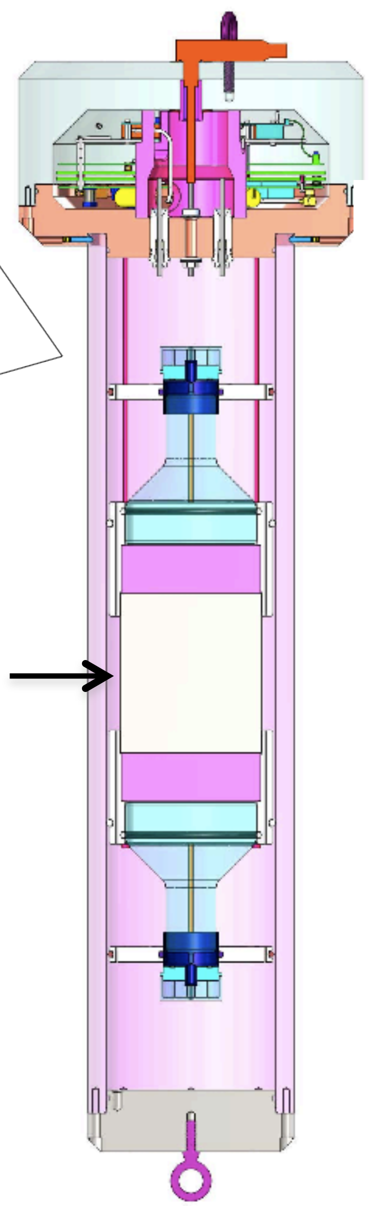
~11.5 years, 192,000 kg-days of data

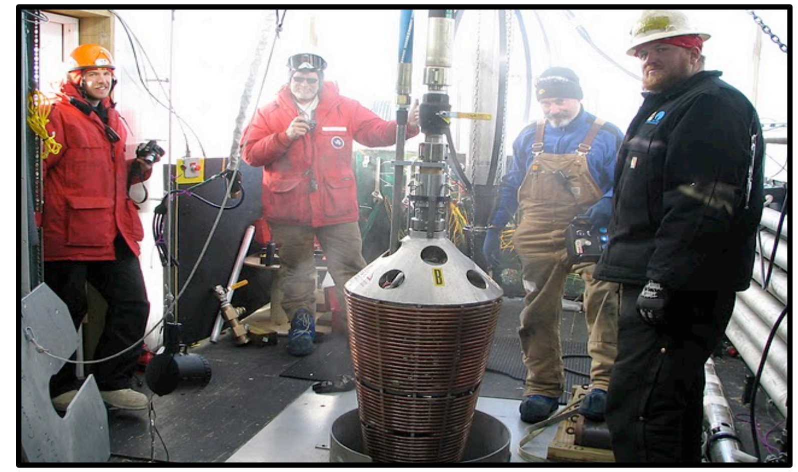
Probing the DAMA Signal in Antarctic Ice

DM-ICE

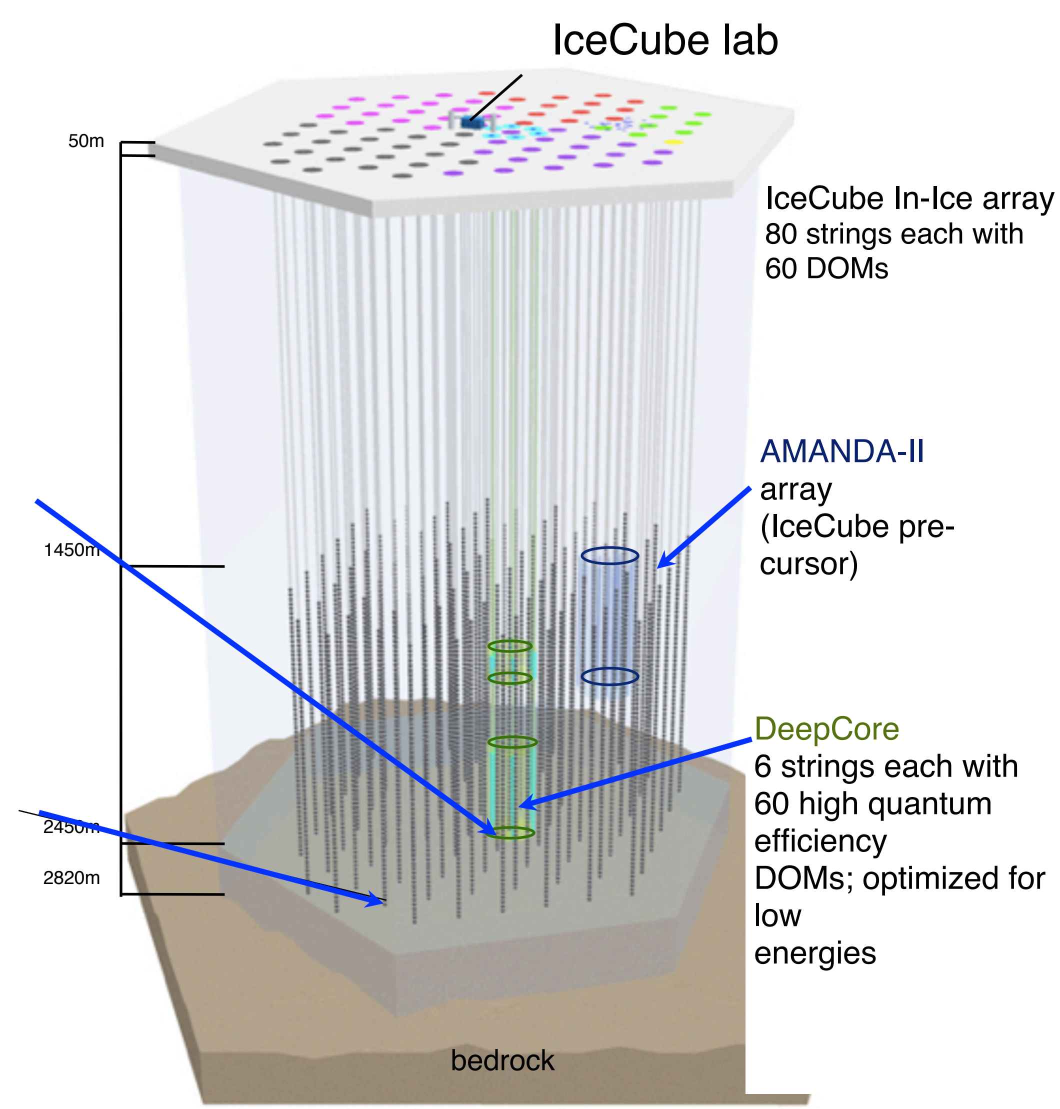


2 prototype modules installed



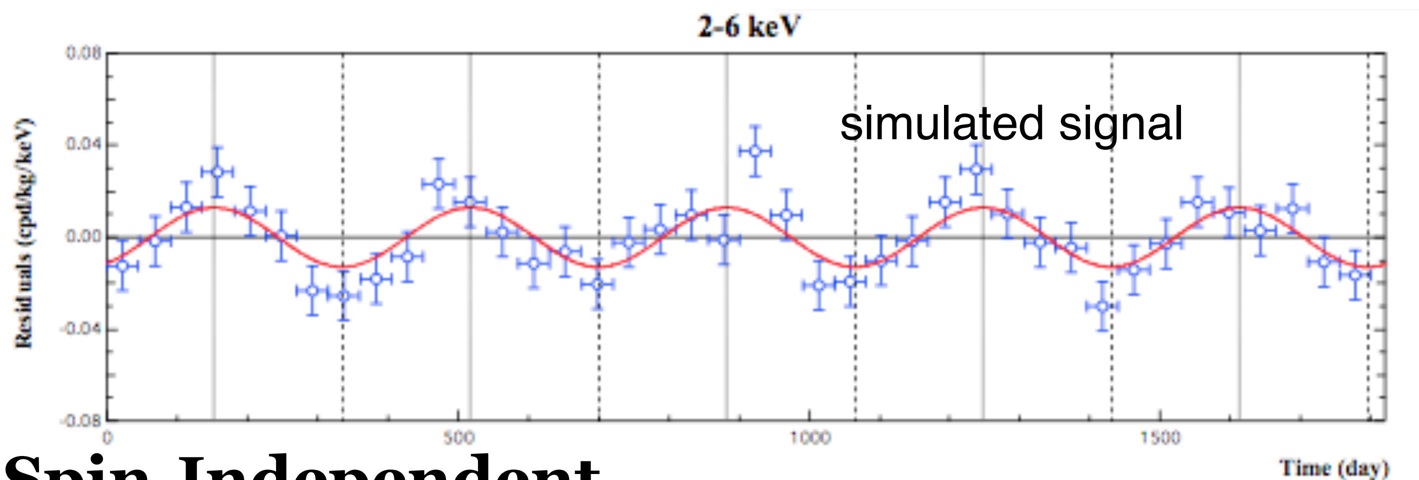


NAIAD NaI Crystal (8.5 kg)

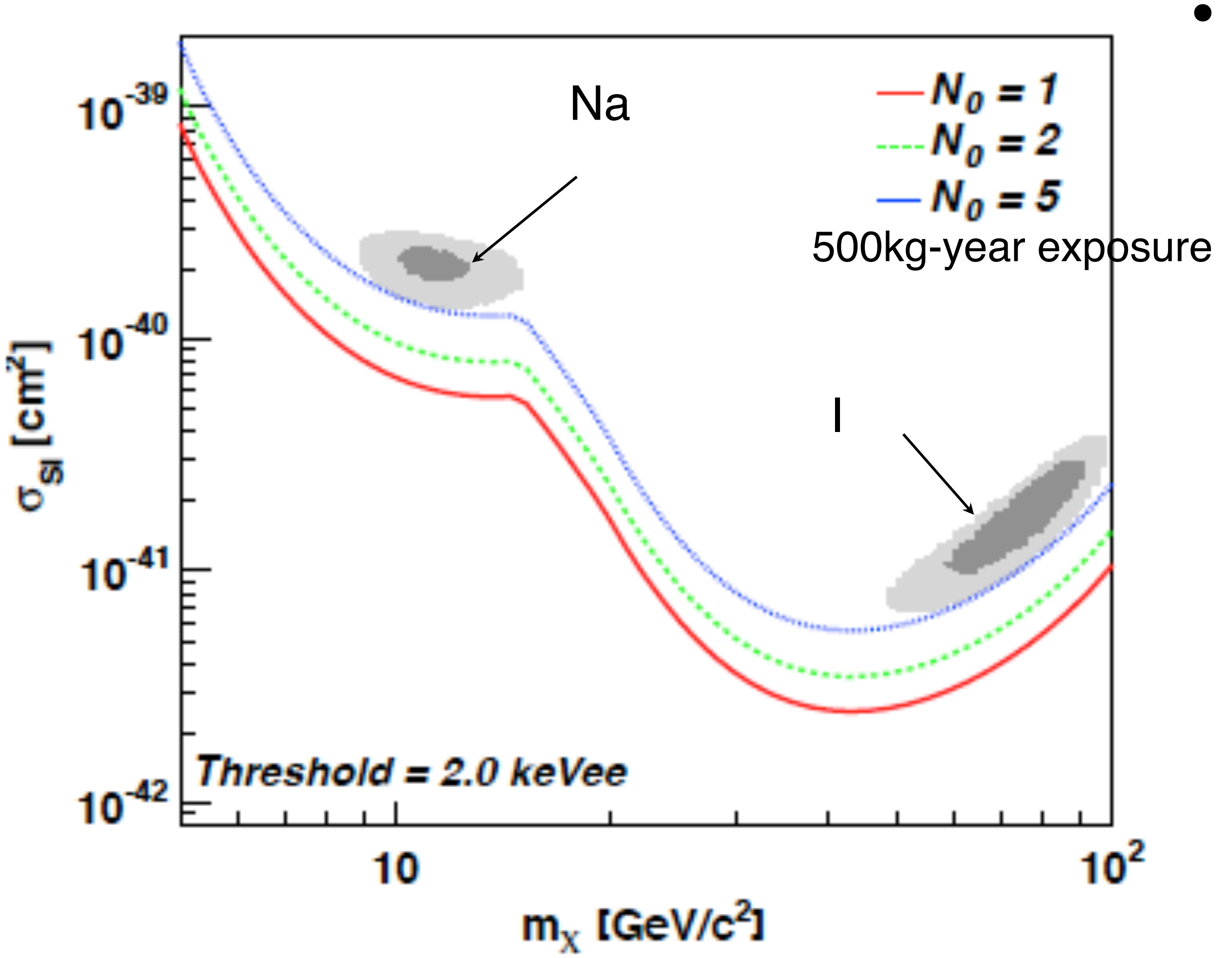


DM-ICE sensitivity

Model-Independent: Assume DAMA-like signal, statistics



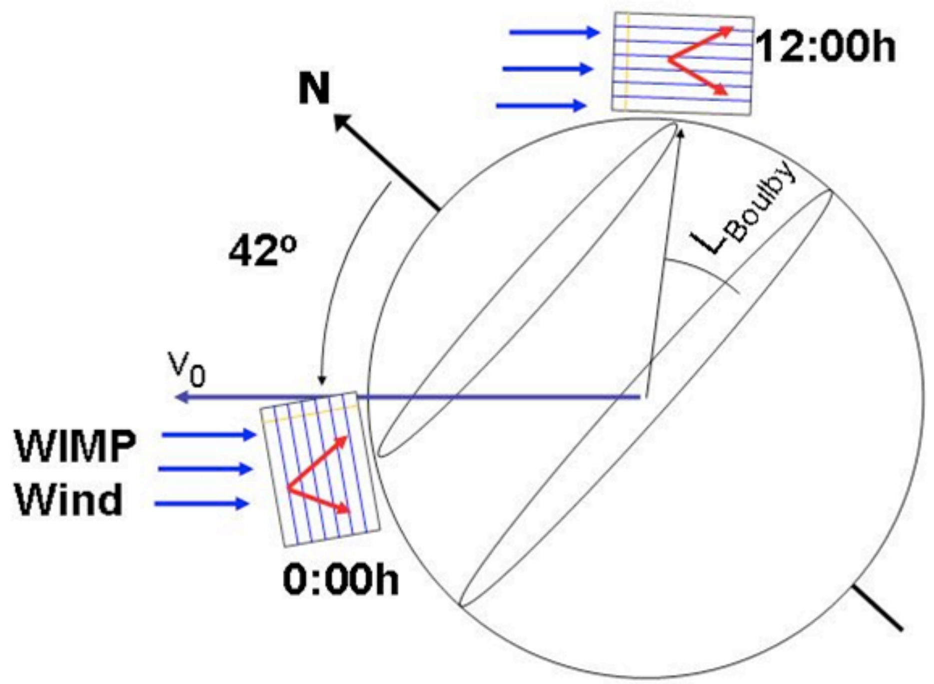
Spin-Independent



- 5-σ detection of DAMA-like signal with a 250-kg / 2-year running time (2 - 4 keV) and comparable backgrounds to DAMA

http://arxiv.org/abs/1106.1156

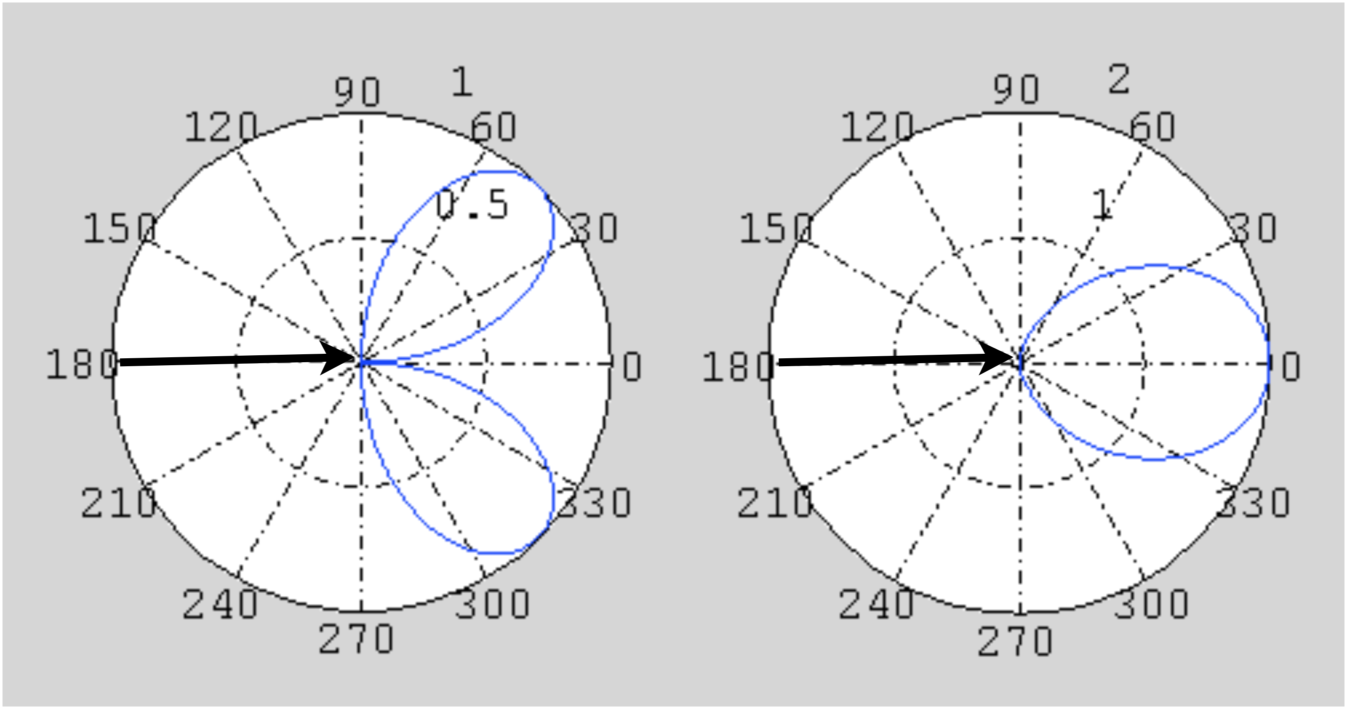
Diurnal Modulation



The direction of the WIMP wind relative to the detector varies as the Earth rotates on its axis.

PROBABILITY DENSITY FOR TARGET RECOIL ANGLE

RECOIL ENERGY VS TARGET RECOIL ANGLE



Recoil track direction correlated with WIMP direction of incidence. Seek oscillation in track orientation having diurnal frequency.

Gas detectors

High density liquid or solid targets in which WIMPs cause 1keV-100keV nuclear recoils yield tracks a few nm long. Unresolvable with current tech.

However, a low pressure gas may yield tracks a few mm long for a few keV energy deposit.

Gas detectors have to be much larger in volume than liquid or solid targets to achieve the same target mass, but they are good at rejecting gamma backgrounds, and they have the potential to detect diurnal modulation.

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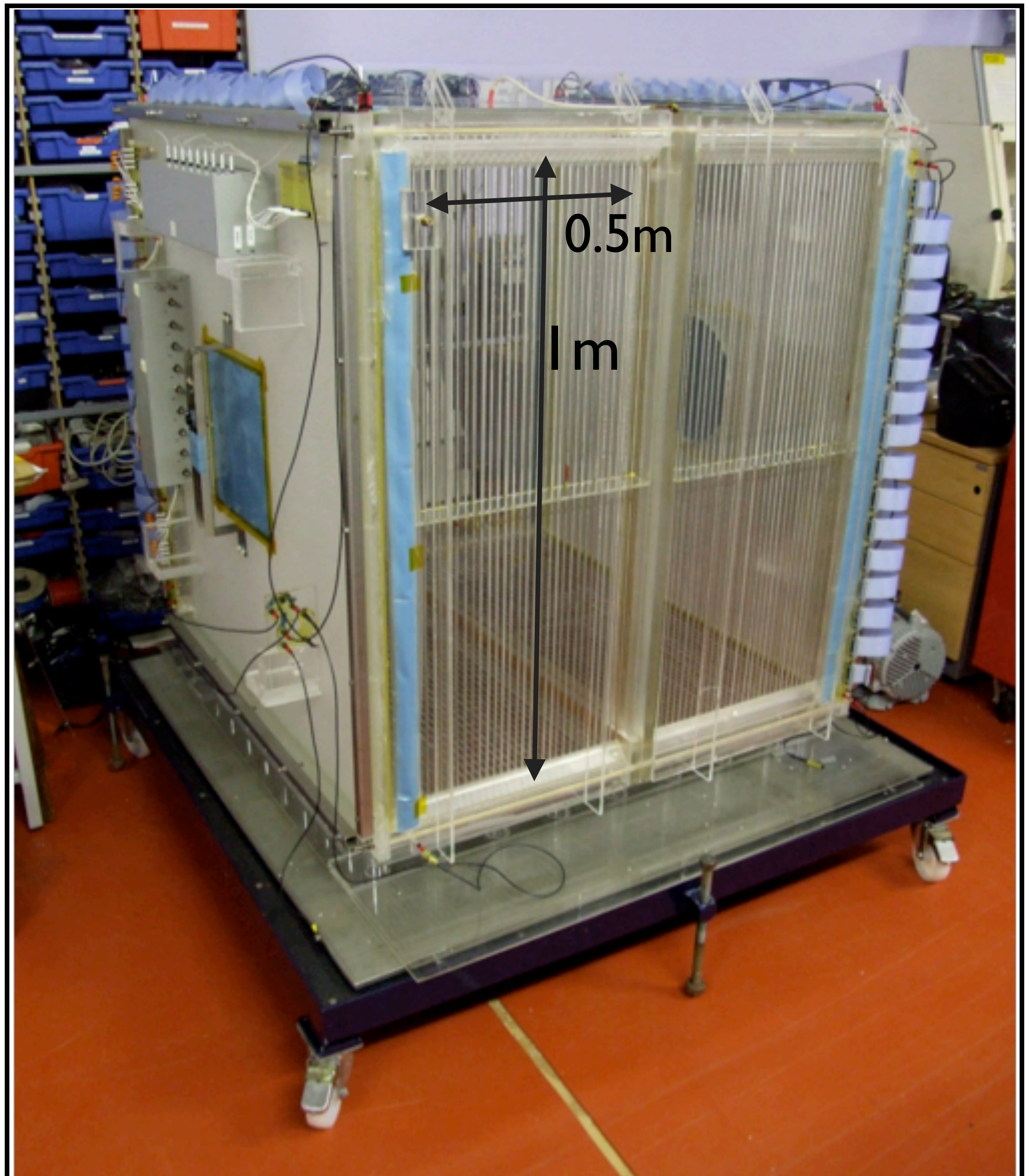
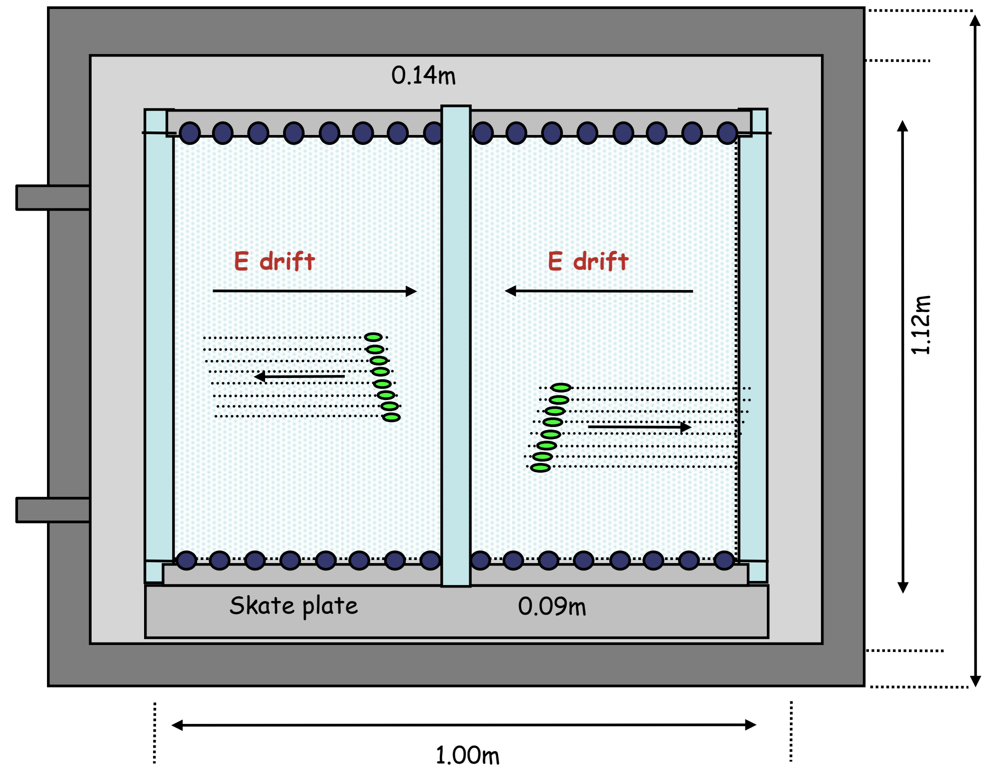
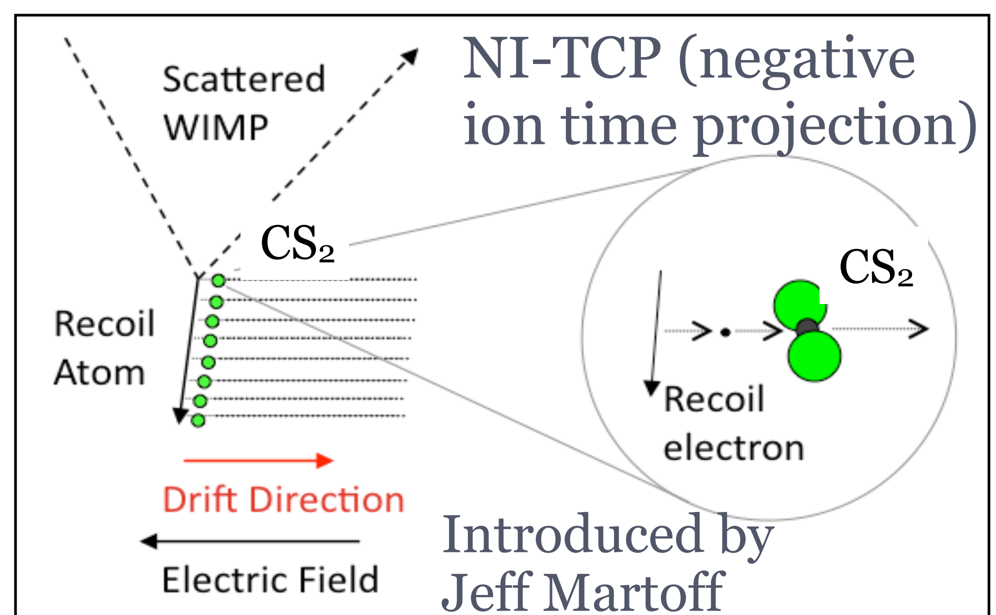
DRIFT-II

See Steve Sadler's talk tomorrow !





S. Burgos et al., Nucl. Instr. Meth. A 584, 114 (2008)



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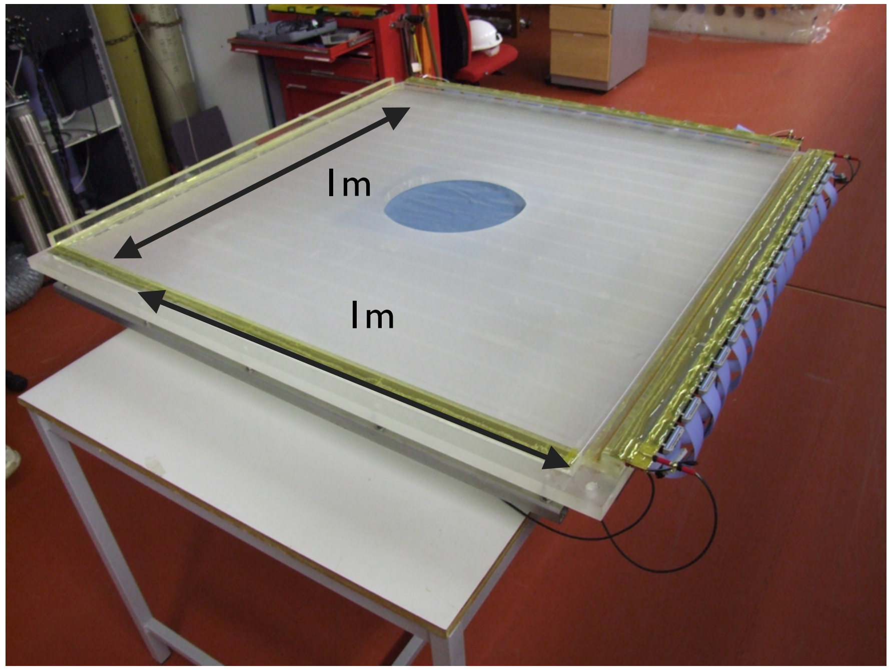
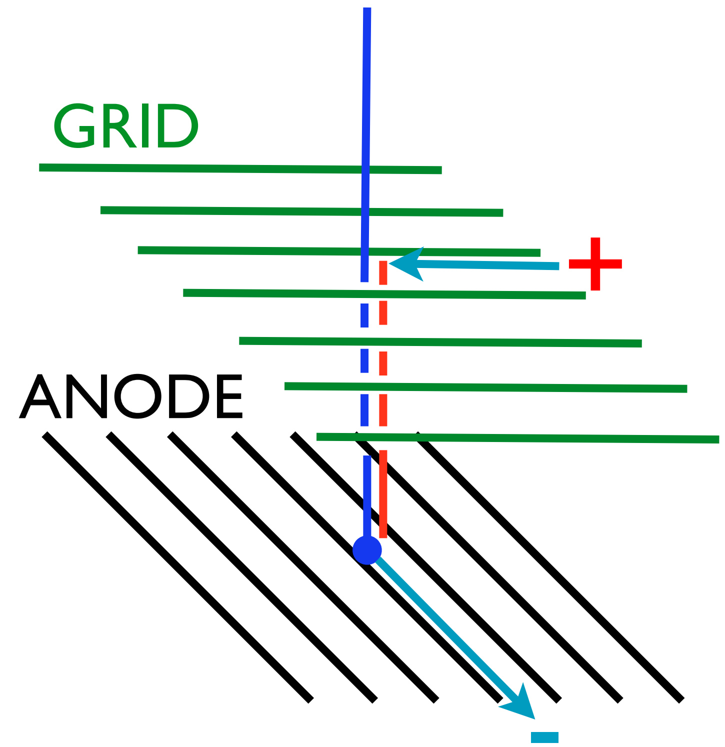
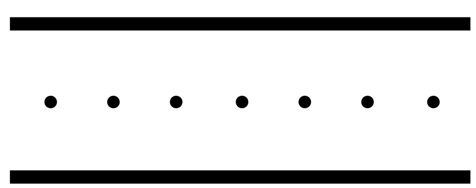
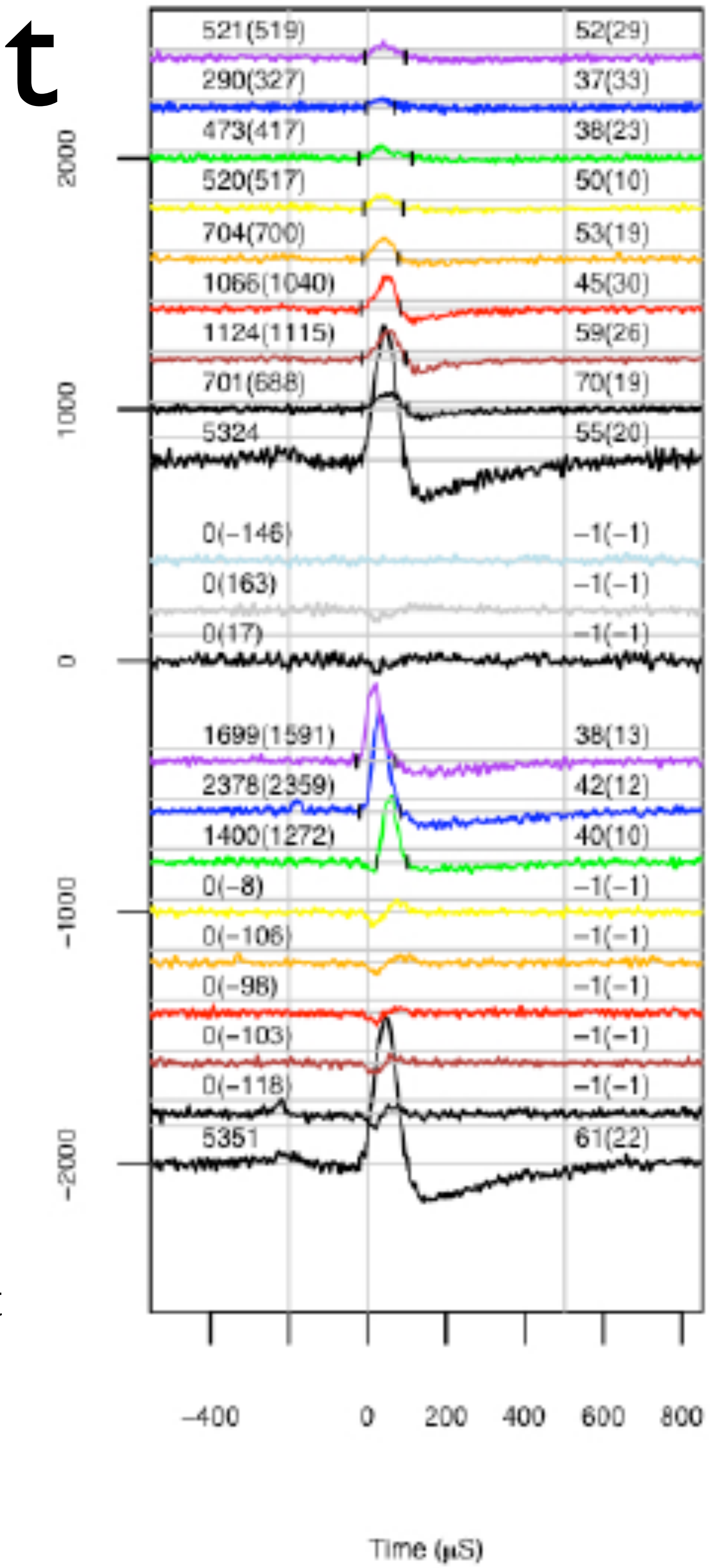
MWPC readout









- Anode plane of 512 20μm wires with 2mm pitch
- 2 grid planes of 512 100μm wires perpendicular to anode plane, 2mm pitch - one of which is read out

ΔX: Number of anode wires hit
ΔY: Number of grid wires hit
ΔZ: Drift time between start and end of track

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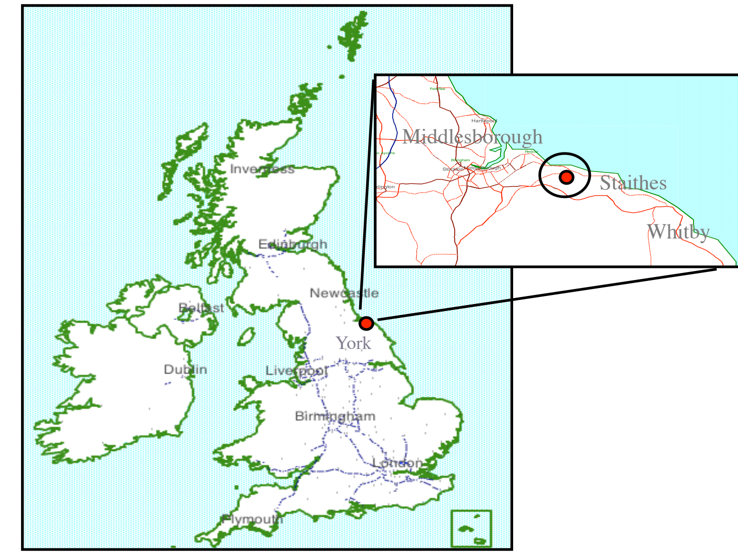
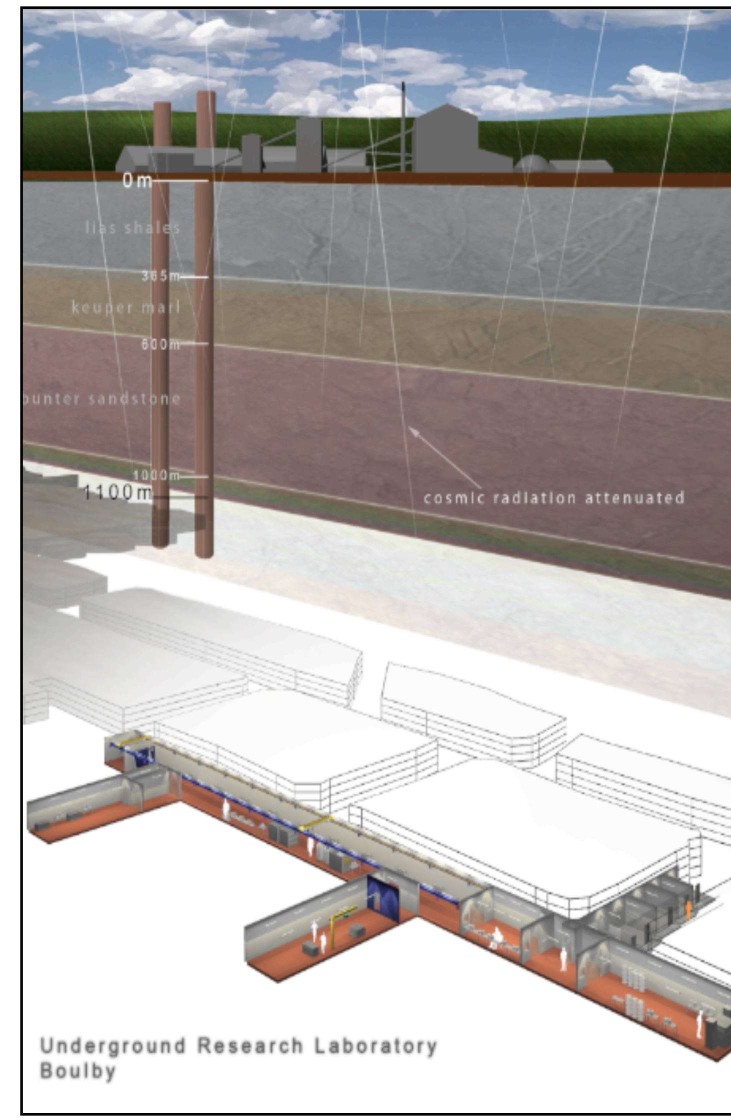
DRIFT-II at Boulby

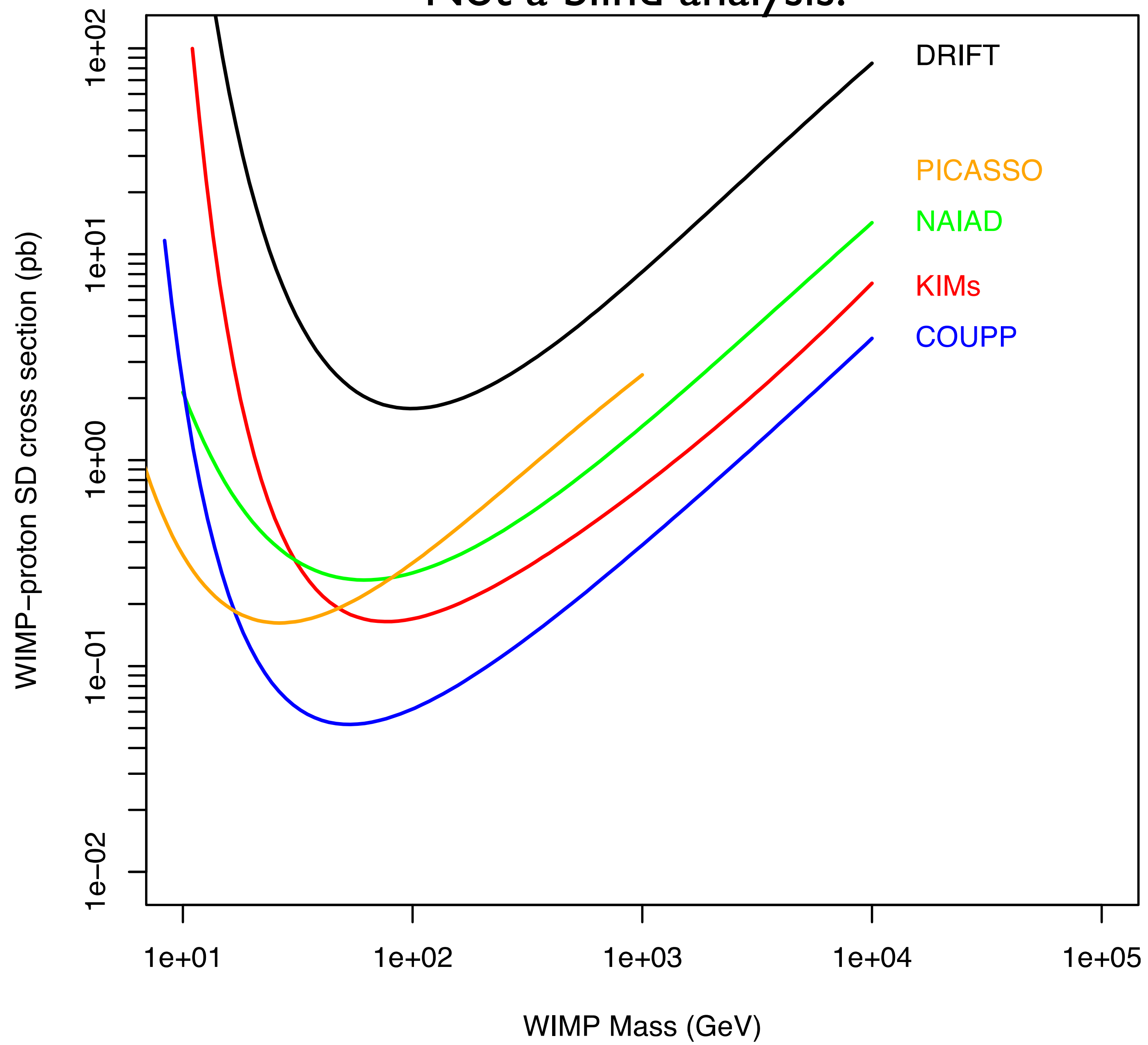


- Lab at depth of 1100m (2800 m.w.e)
- Cosmic ray flux = 4.1×10^{-8} $cm^{-2}\ s^{-1}$ [M. Robinson et. al, NIM A 511 (2003)]
- Polypropylene pellets of >67cm depth on all sides
- Equivalent to $40g/cm^2$ solid hydrocarbon passive shielding
- Lead shielding not required due to detector's inherent insensitivity to electron recoil events
- Experiment operations and use charge for underground site at Boulby provided by the U.S. National Science Foundation.



DRIFT-II spin-dependent limit

SPIN-Dependent WIMP-proton limit from 47.4 day exposure of 30:10 CS_2/CF_4.
Not a blind analysis.



E. Daw, J. R. Fox, J. -L. Gauvreau, C. Ghag, L. J. Harmon, M. Gold, E. Lee and D. Loomba *et al.*, Astropart. Phys. **35**, 397 (2012)

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RPR background

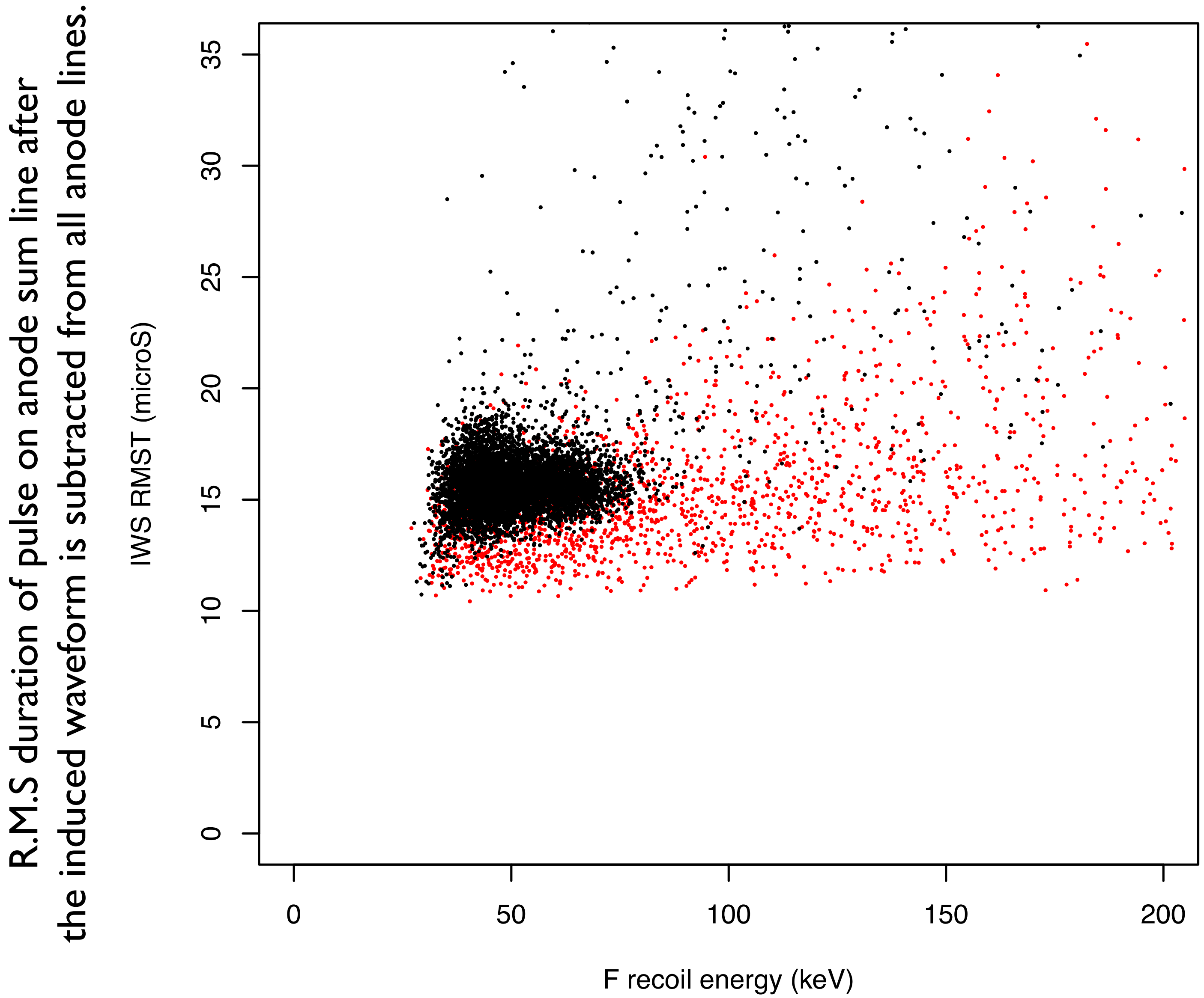
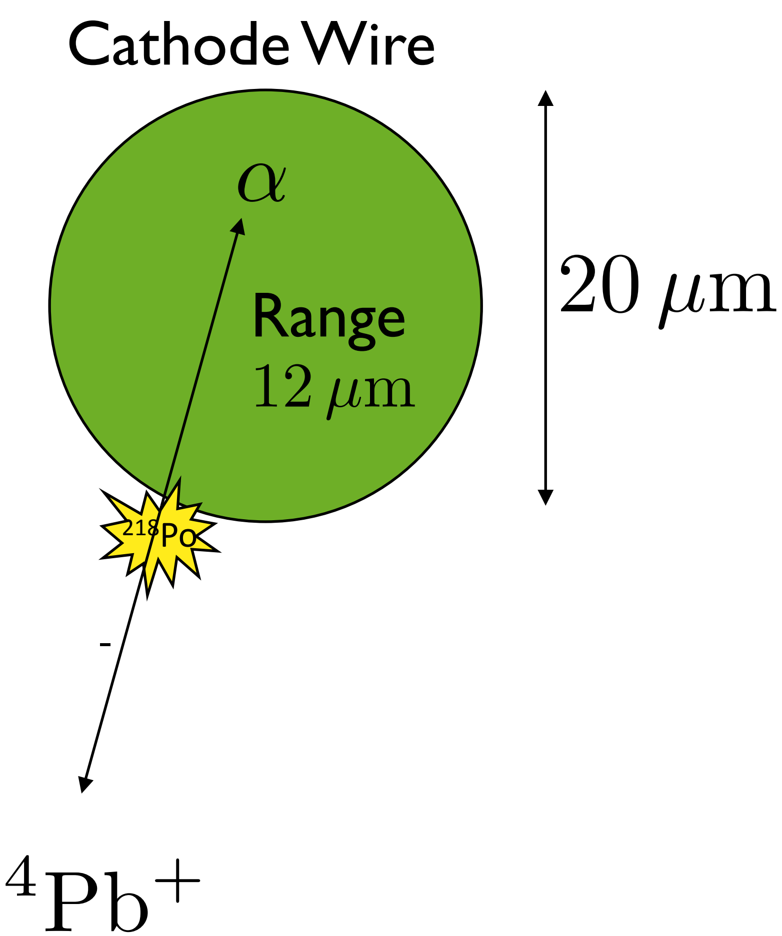


Fig. 2. A plot of the F recoil equivalent energy vs. the *IWS RMST*, which is a measure of the width of an observed event, for both science run events, shown in black, and neutron recoil events, shown in red. As expected, the neutron recoils events had, on average, smaller *IWS RMST*s than the RPR events providing a rough way of discriminating these two populations. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Black points are background data. Red points are data taken with a neutron source.



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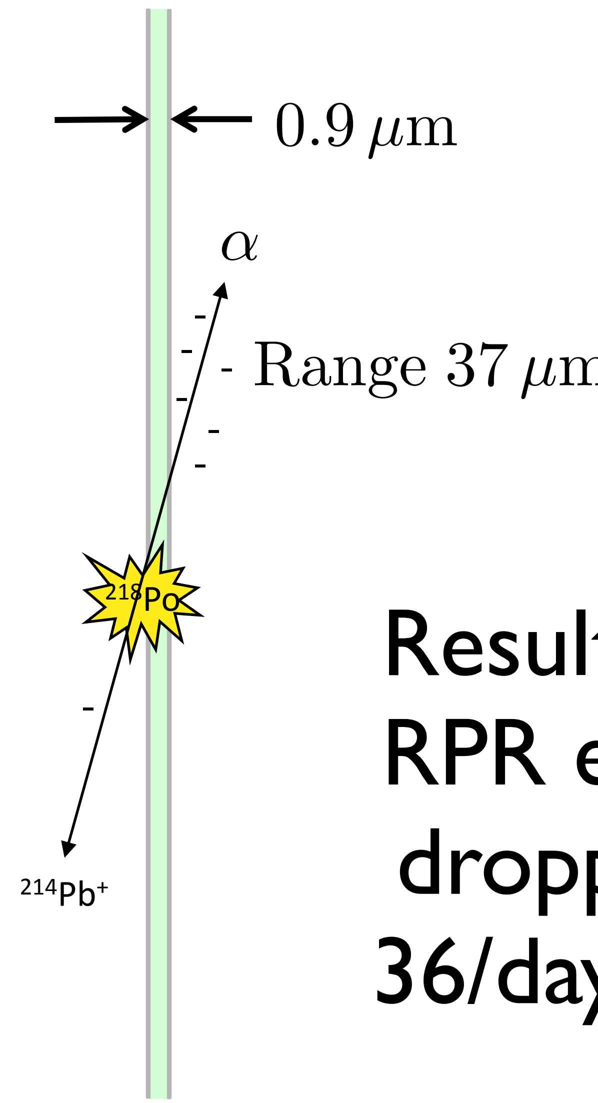
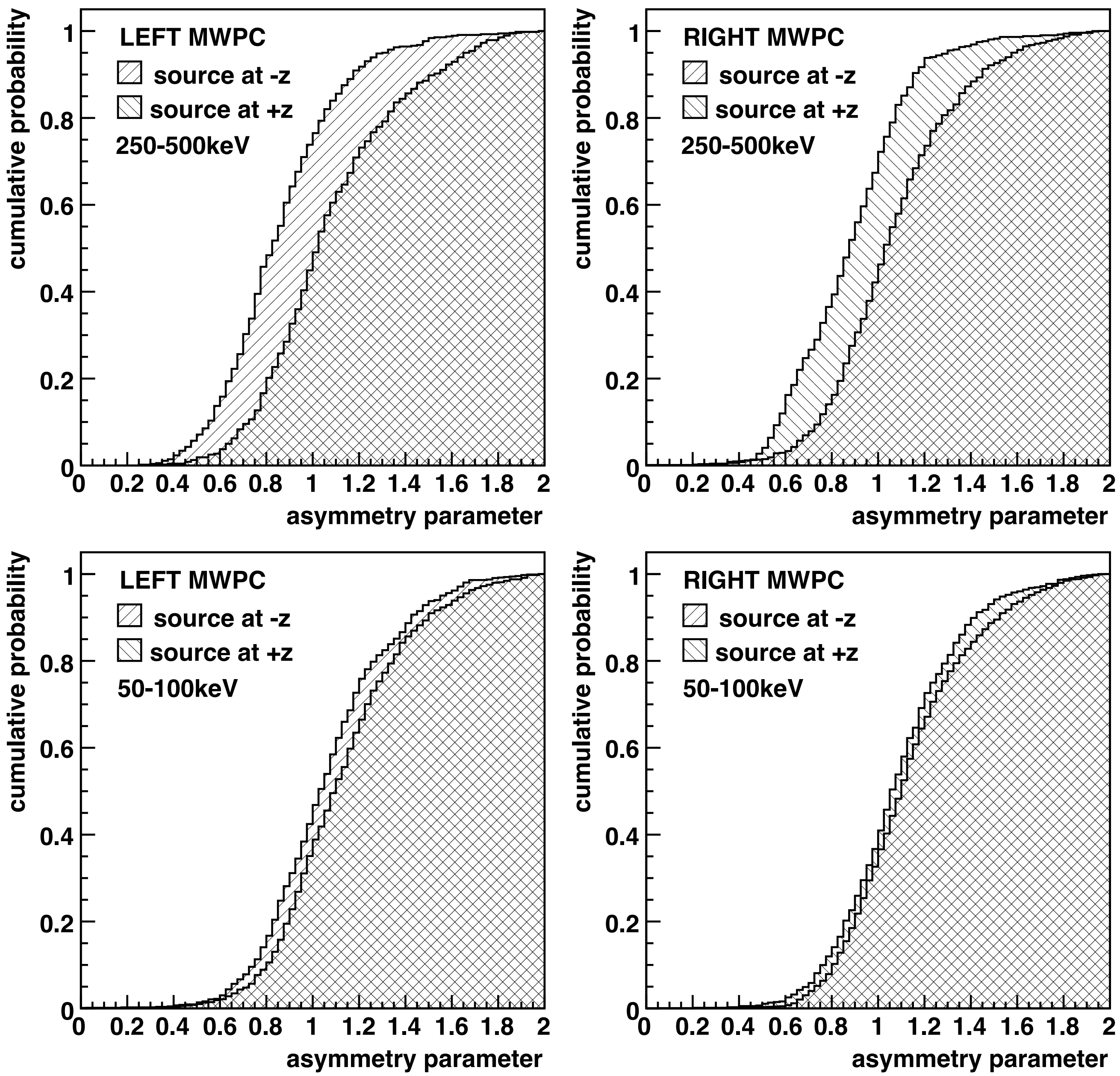
Aluminized Mylar Cathode



Resulted in the RPR event rate dropping from 36/day to 6/day.

Head-tail information in 50-100keV range from DRIFT

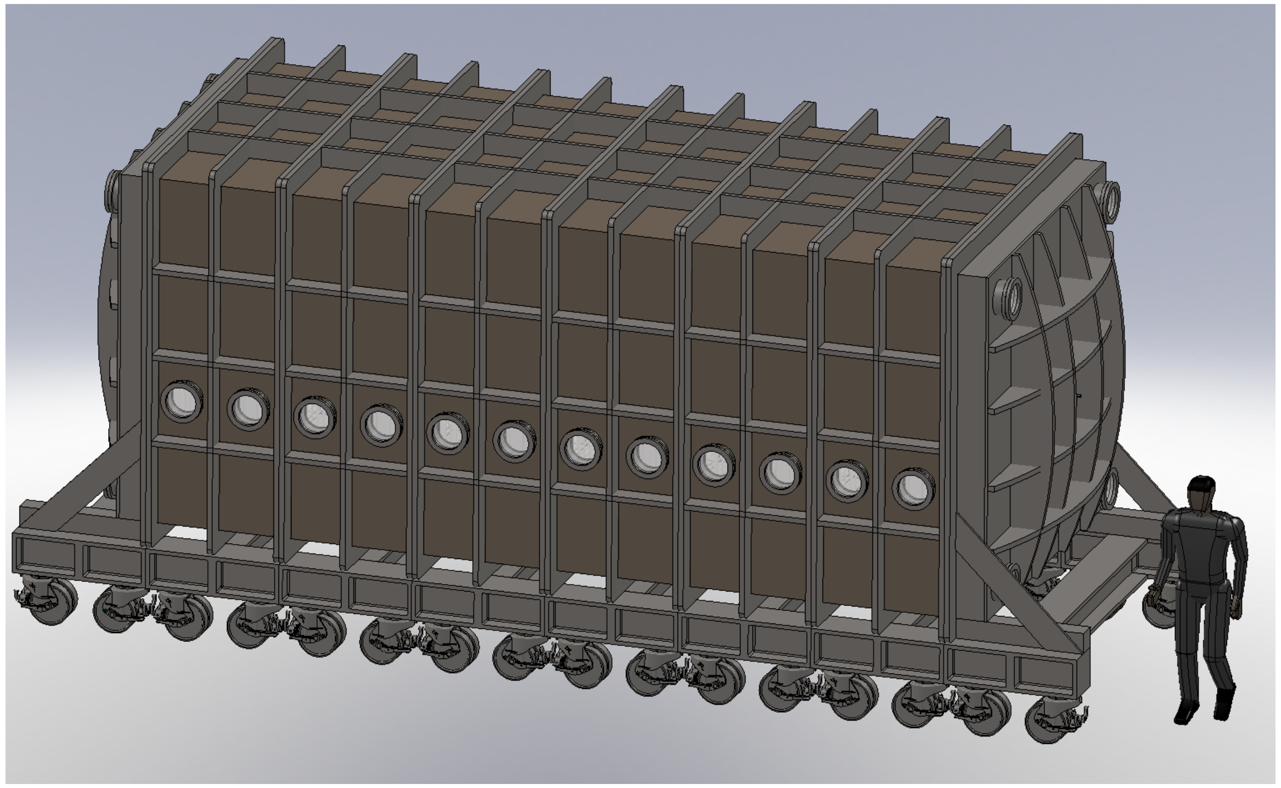


S. Burgos, E. Daw, J. Forbes, C. Ghag,
M. Gold, C. Hagemann, V. A. Kudryavtsev
and T. B. Lawson *et al.*, arXiv:0809.1831 [astro-ph] (2008).

DRIFT III

Results from further NSF funding for hardware, underground operations, and Boulby infrastructure.

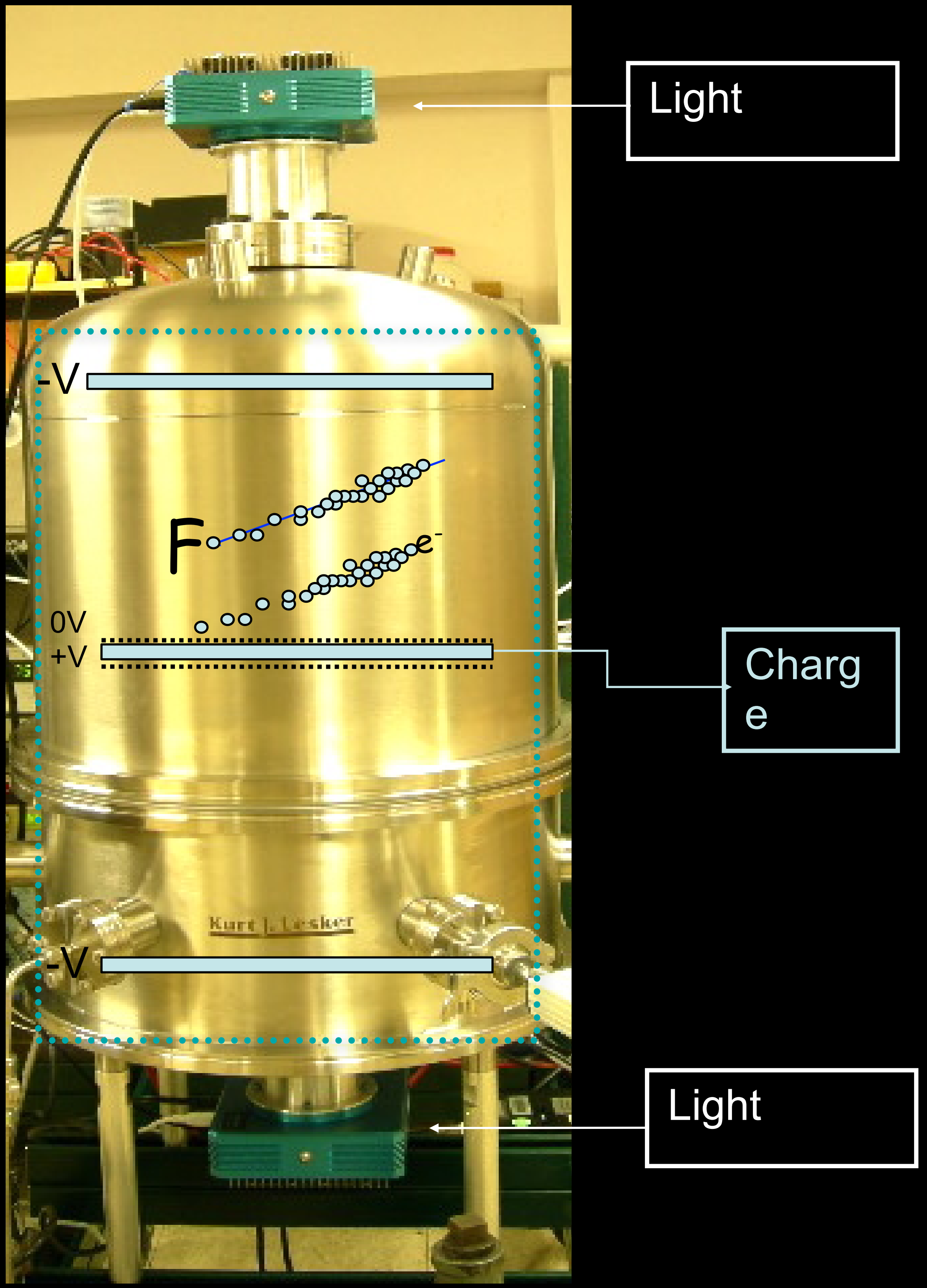
- Readout planes 4x bigger than DRIFT-II
- Same drift distance
- DRIFT-IIIa would have 10x the volume of a DRIFT-II class detector.
- Modular

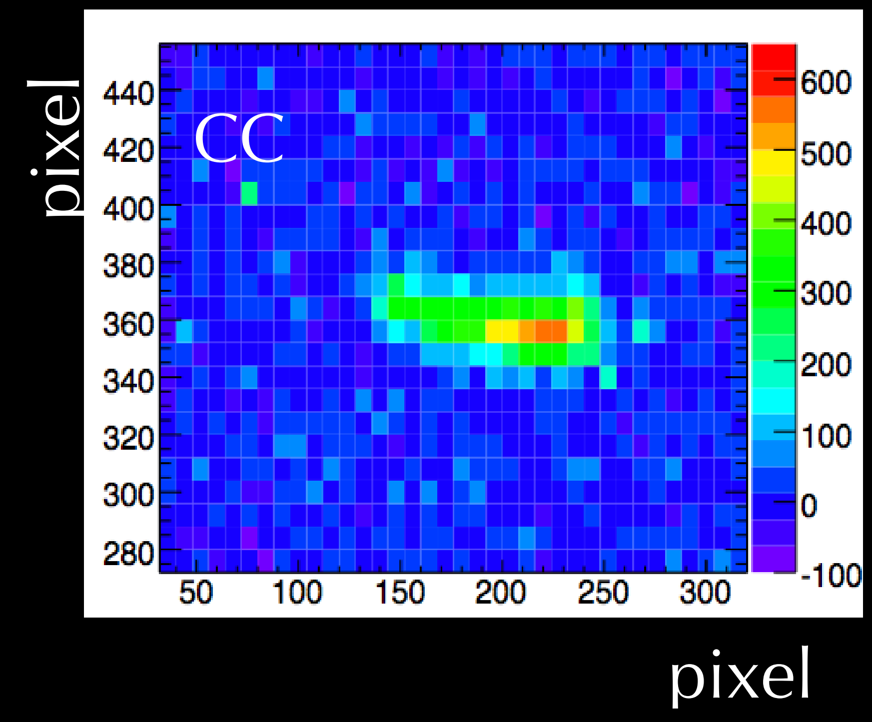


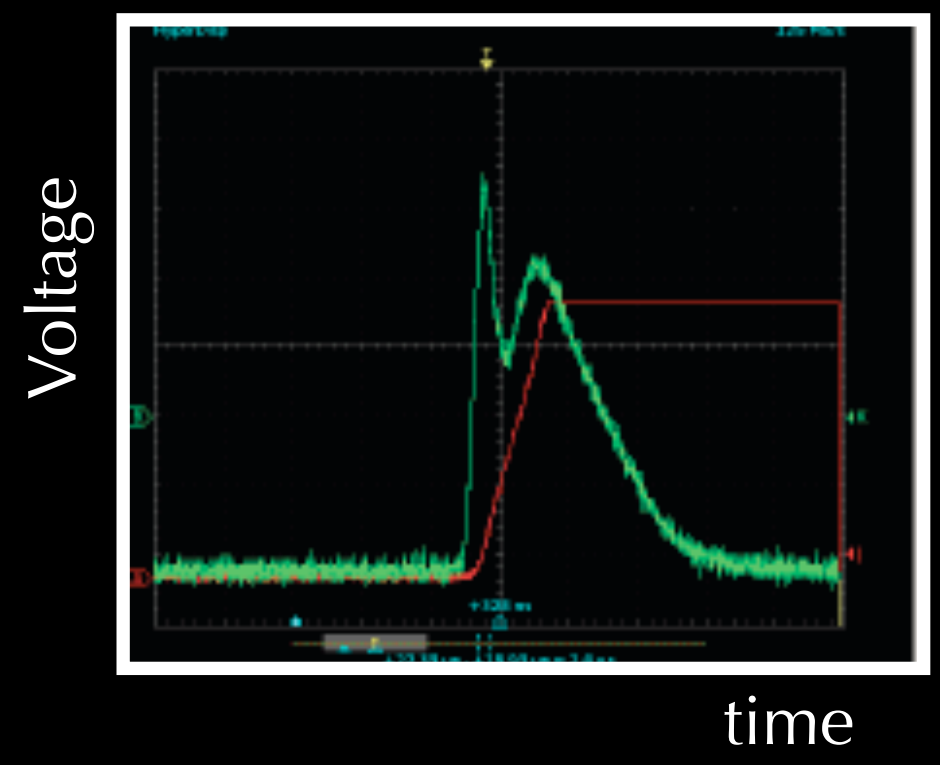
See Steve Sadler's talk tomorrow for more detail on DRIFT

DM-TPC Readout

(Thanks to Jocelyn Monroe for contributed material)



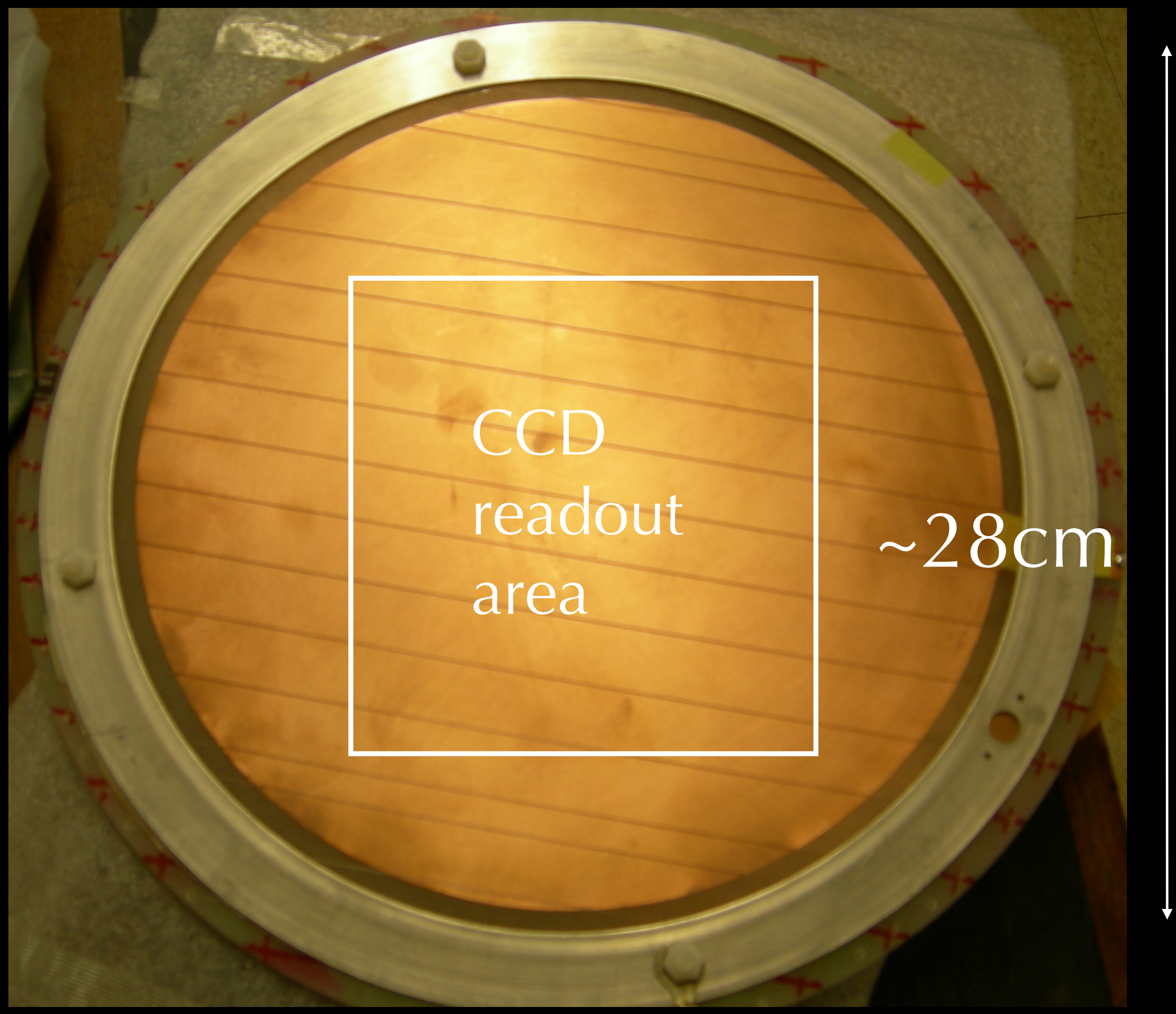




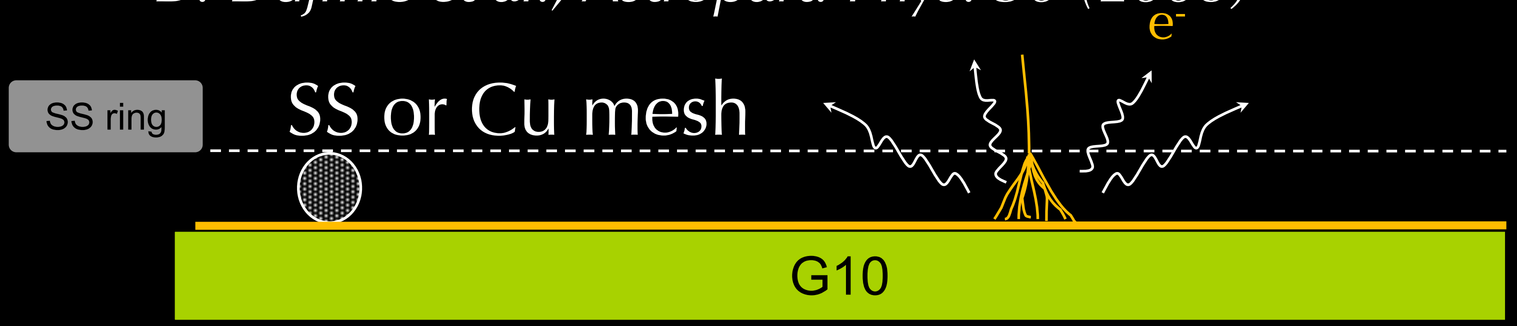
goal: charge and light= 2->3D

Amplification Plane

Copper Mesh, 256 um pitch



D. Dujmic et al., Astropart. Phys. 30 (2008)

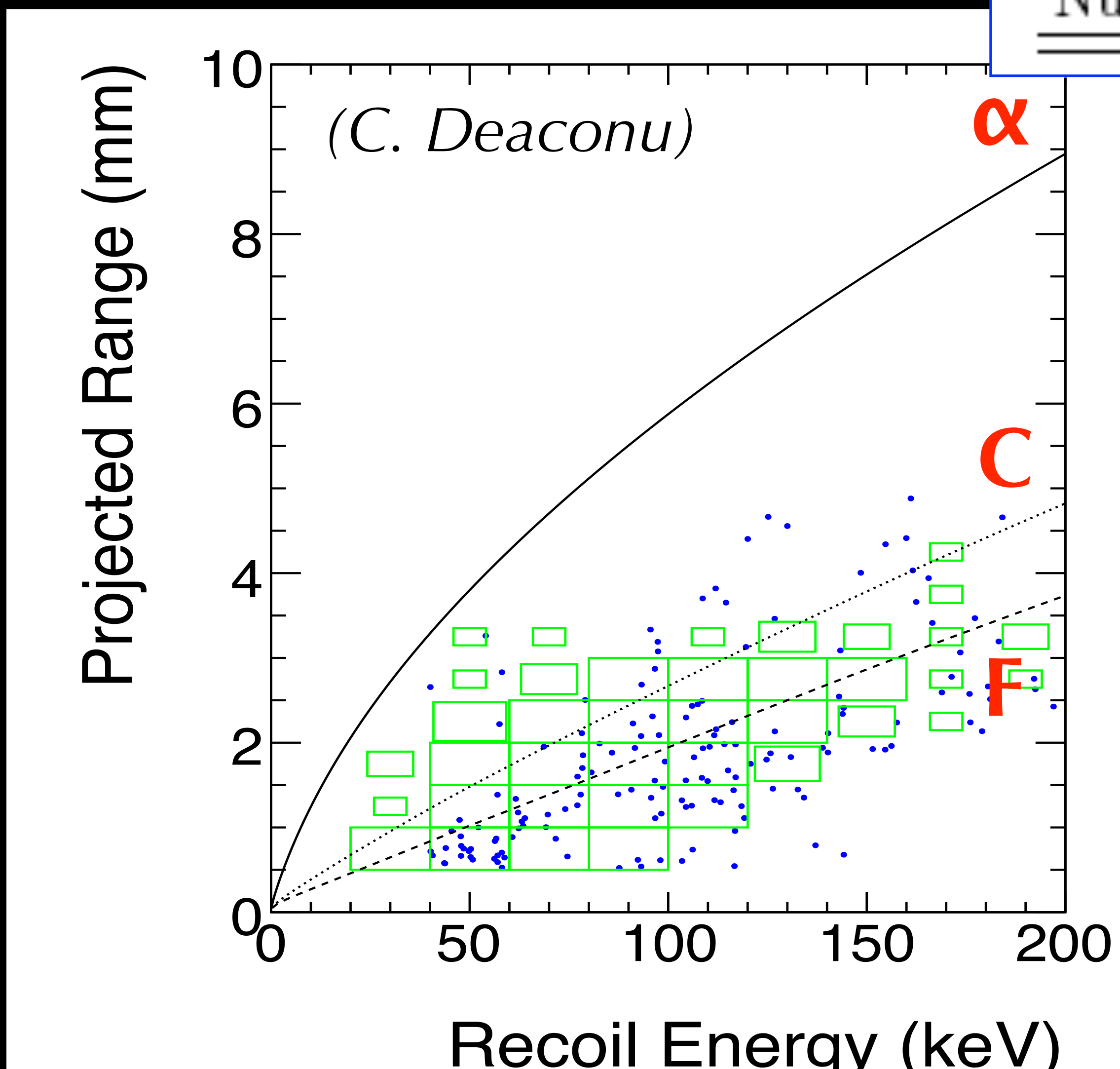


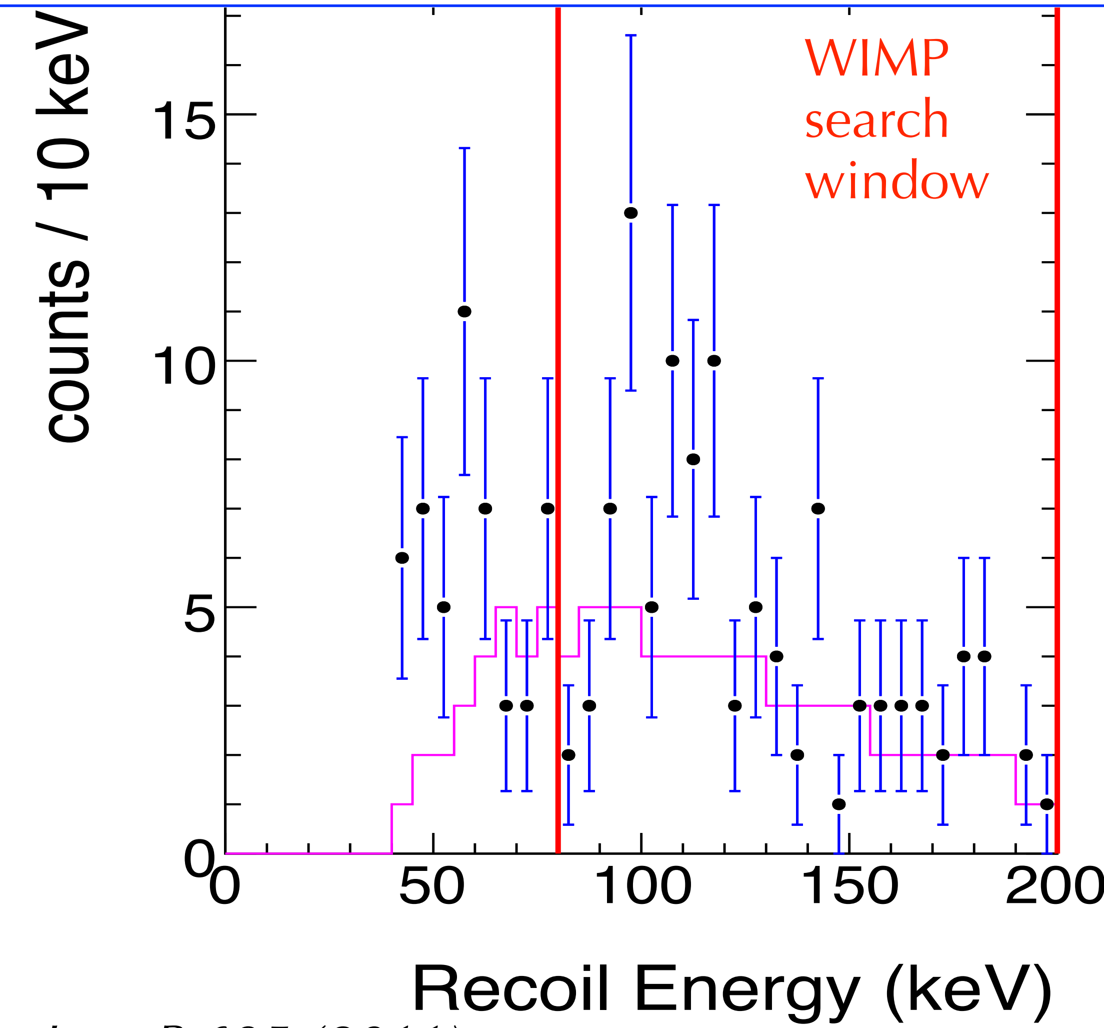
Resistive separators, dia=0.5mm, every 2.5cm

Surface Run Results

nuclear recoil selection cuts, set using calibration data (note: no charge readout)

Event Selection Cut	Rate (Hz)
All Tracks	0.43
Residual Bulk Images	0.15
CCD Interactions	4.4×10^{-3}
Alpha Candidates	8.2×10^{-5}
Nuclear Recoil Candidates in $80 < E_R < 200$ keV	5.0×10^{-5}



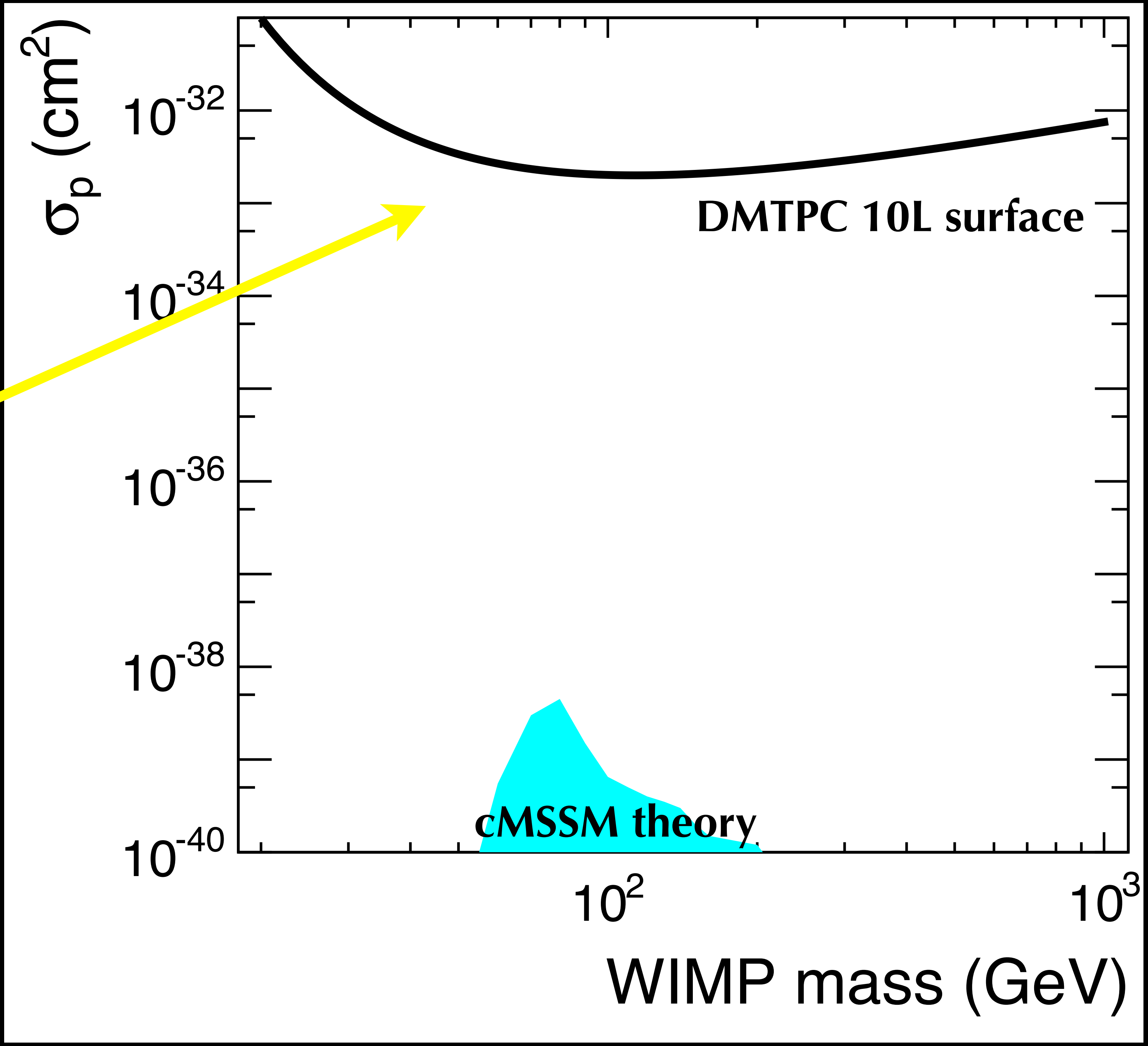


S. Ahlen et al., Phys. Lett. B 695 (2011)

surface neutron flux measurement: T. Nakamura, T. Nunomiya, S. Abe, K. Terunuma, and H. Suzuki, J. of Nucl. Sci. and Tech. 42 No. 10, 843 (2005).

observed 105 events above 80 keV threshold chosen for dark matter search (threshold chosen for max. recoil efficiency), consistent with neutron prediction (74 events)

DM-TPC Surface Run Result



DMTPC limit
(surface, 38 gm-day)

S. Ahlen et al.,
Phys. Lett. B 695 (2011)

Theory region:
Rozkowski et al JHEP 07 (2007) 075
Ellis et al PRD63 (2001) 065016

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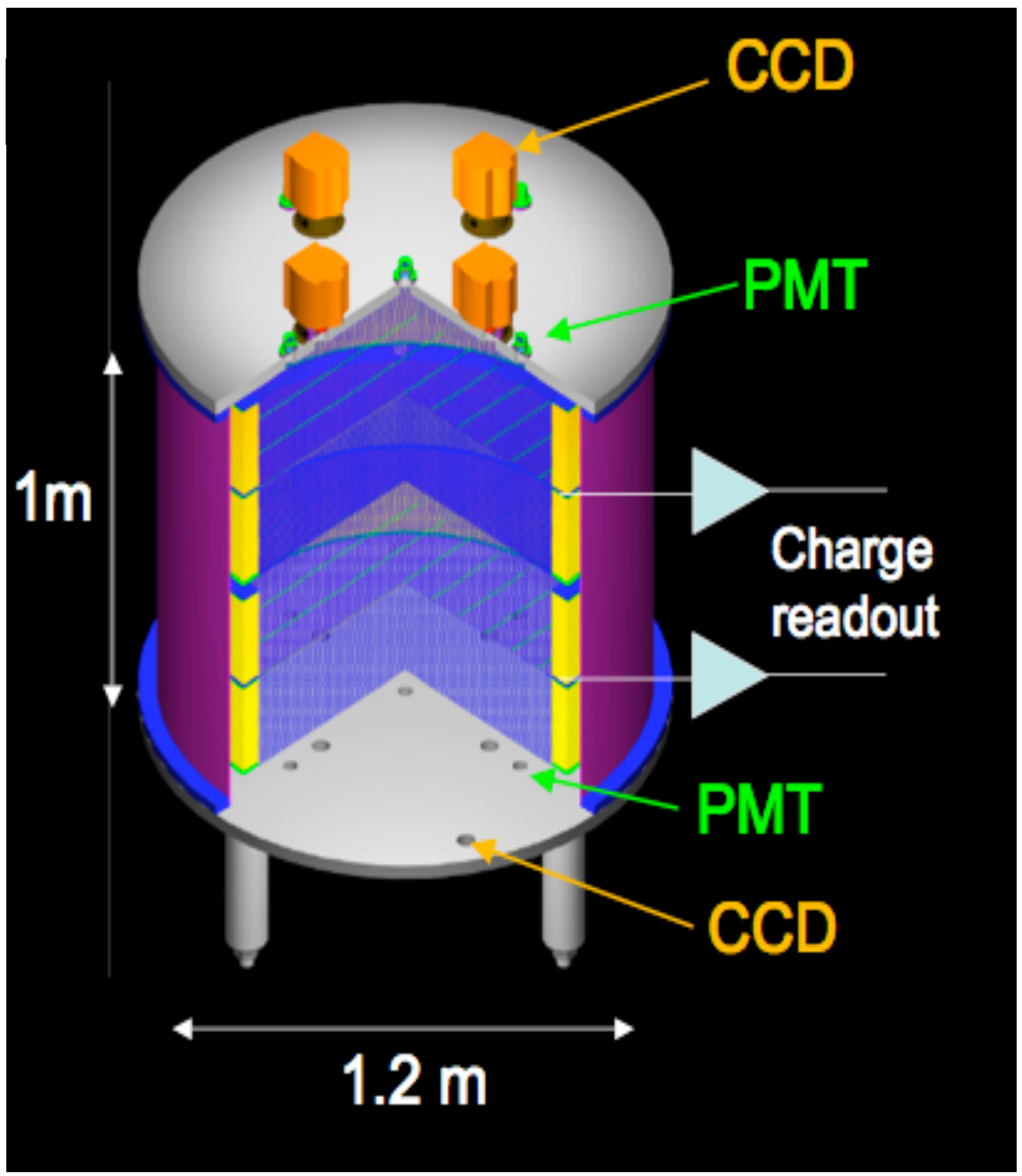
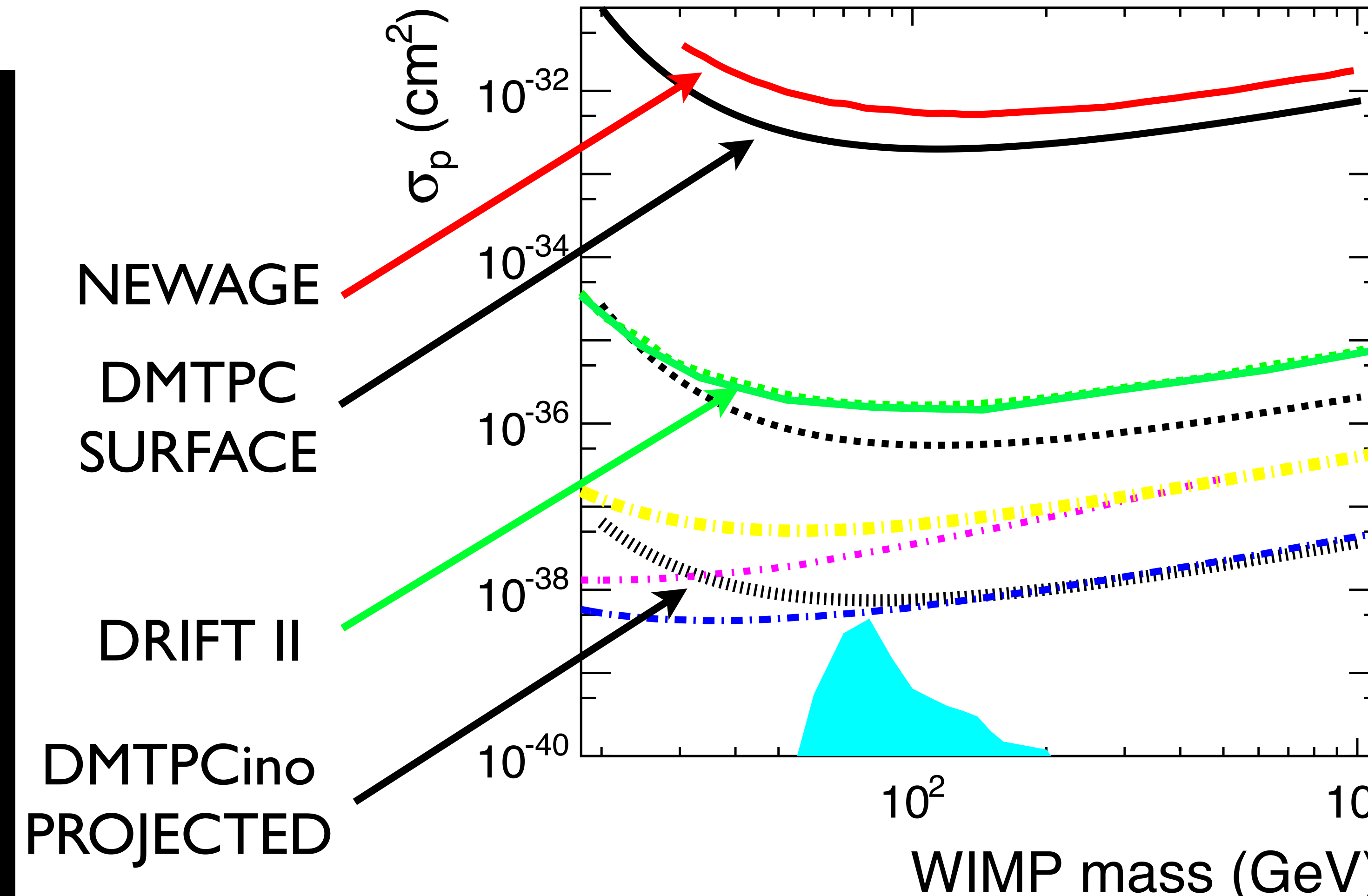
Plans for DMTPCino at WIPP





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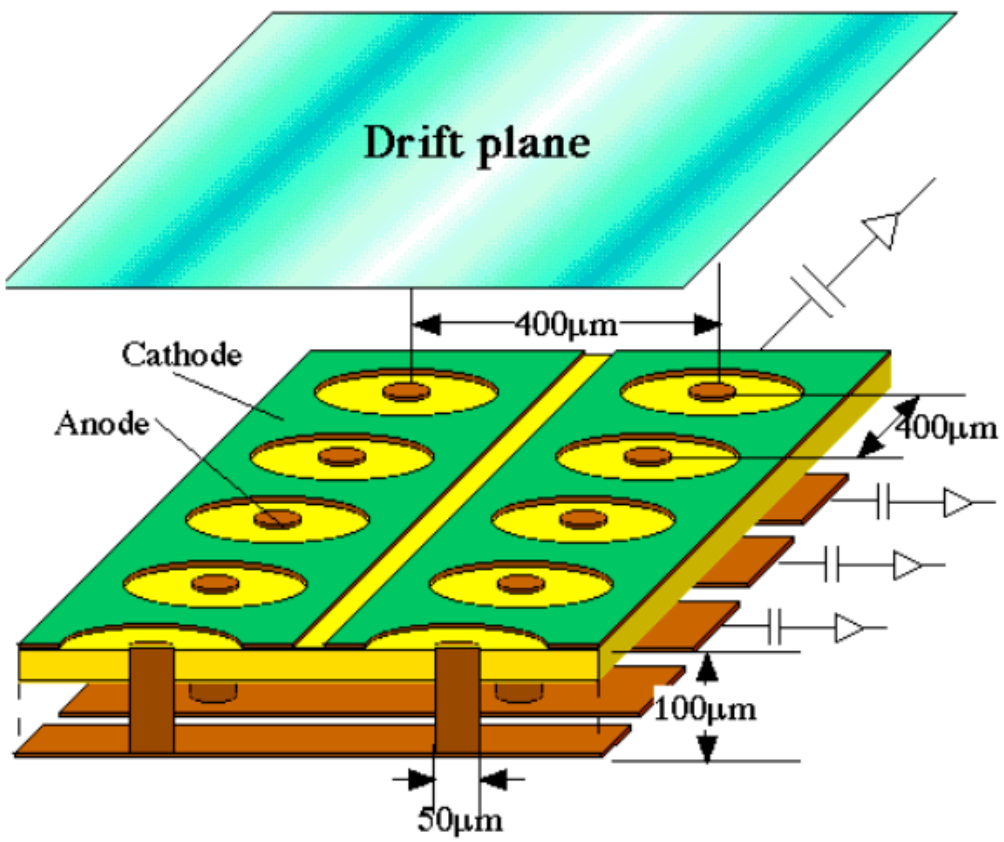
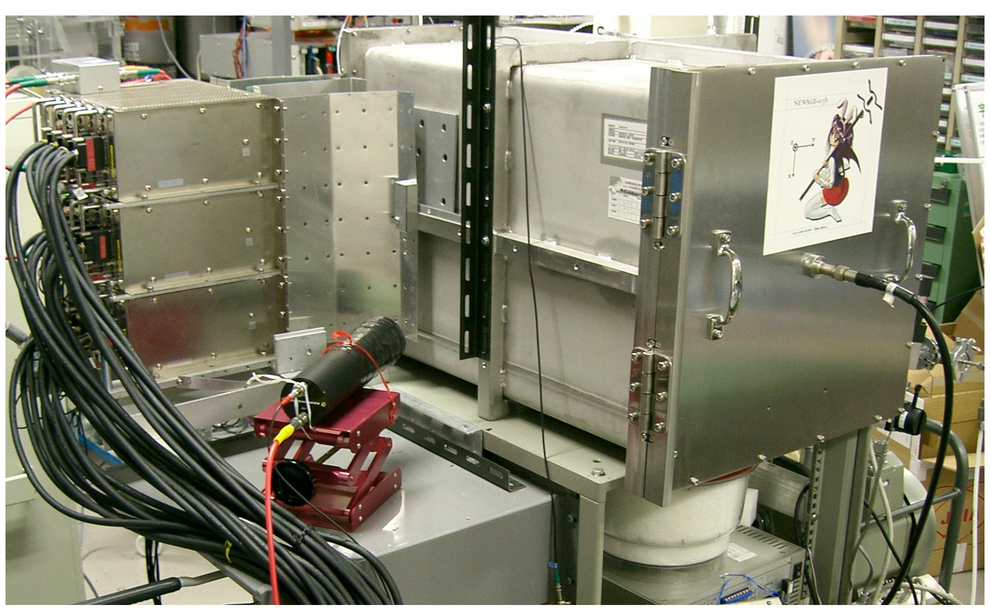
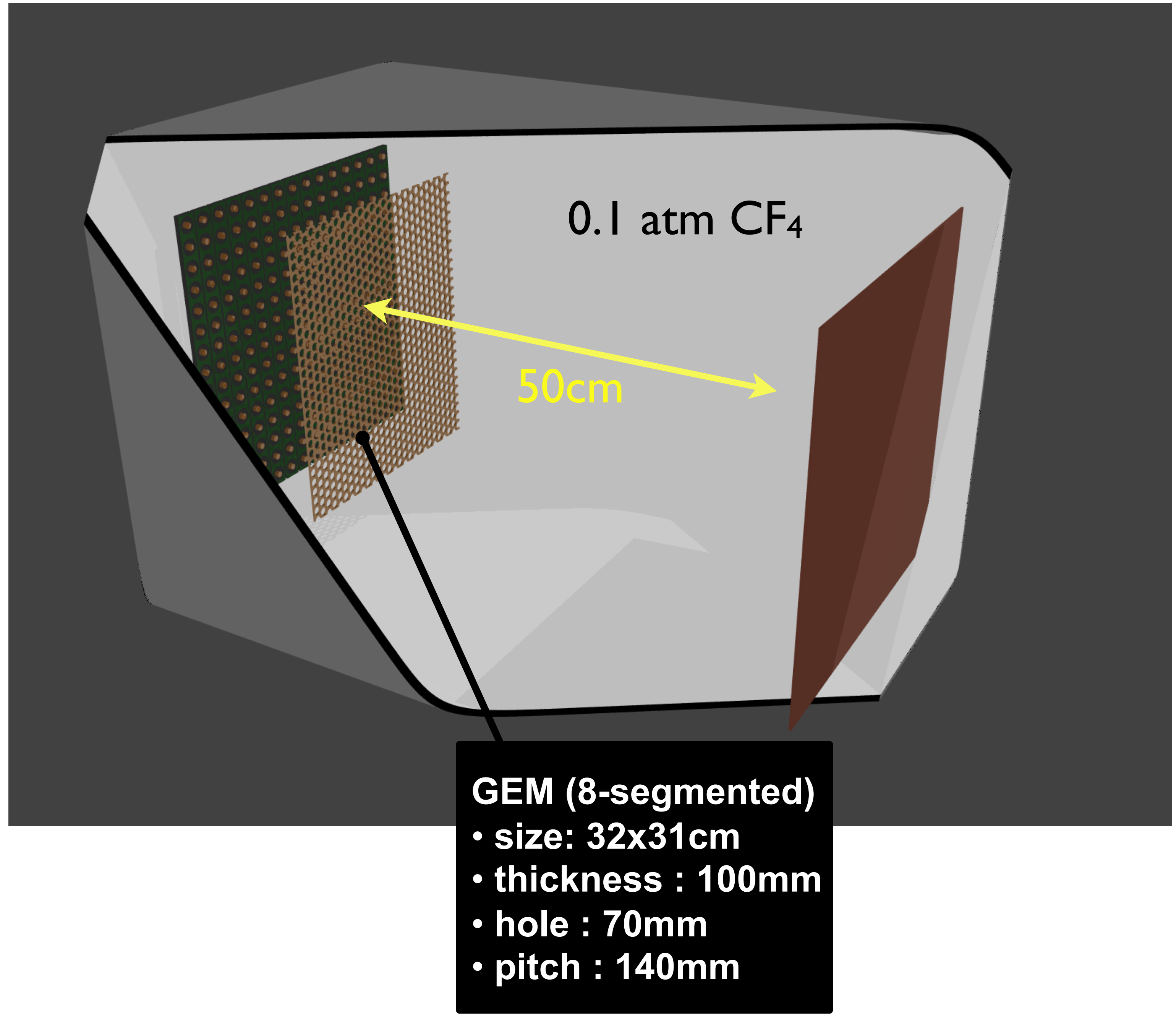
NEWAGE

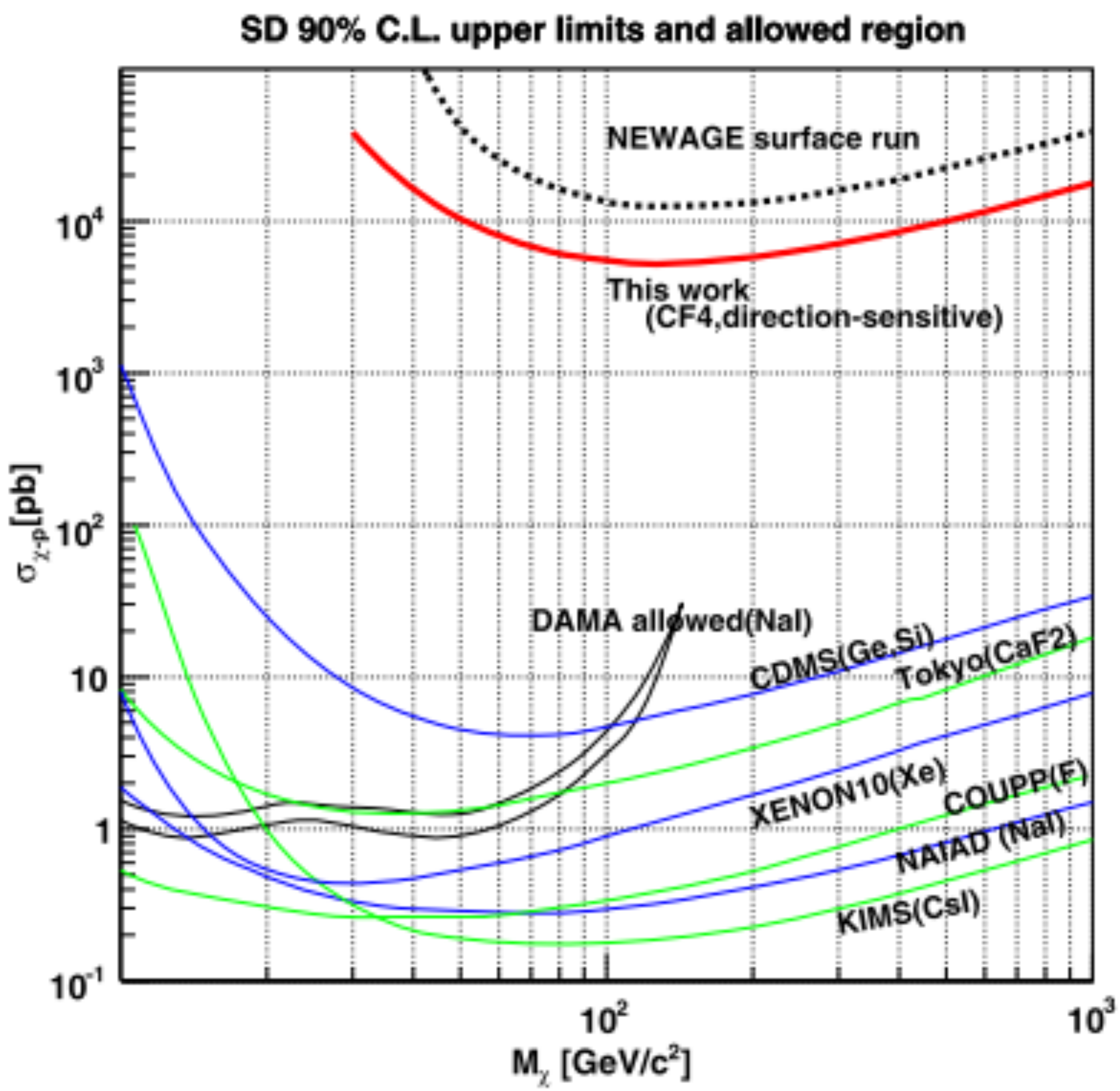






50cm drift distance, 32 by 31cm micro TPC readout.

NEWAGE surface results



Future 1m^3 detector proposed - 10^8 yen (£0.75M)

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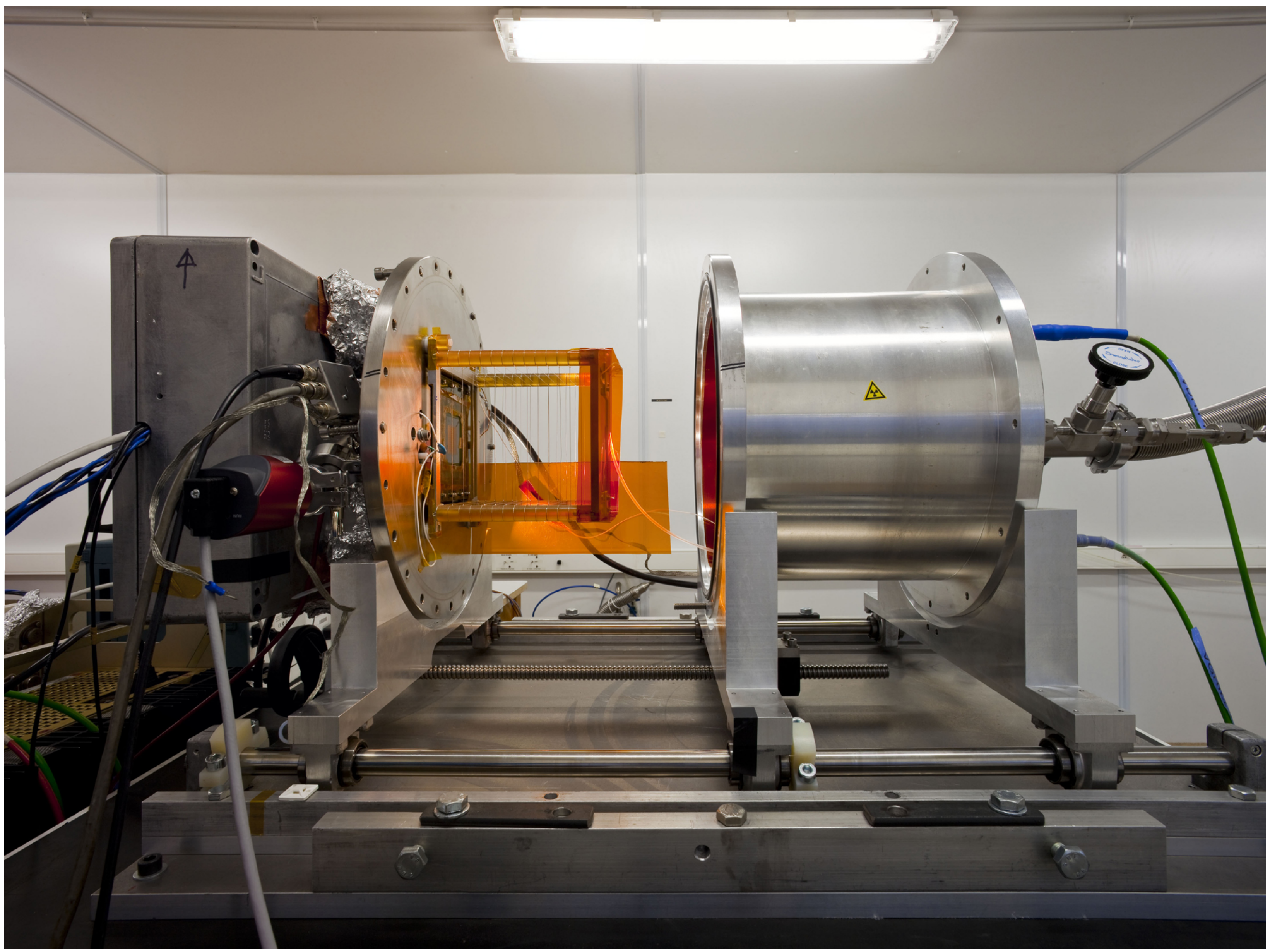
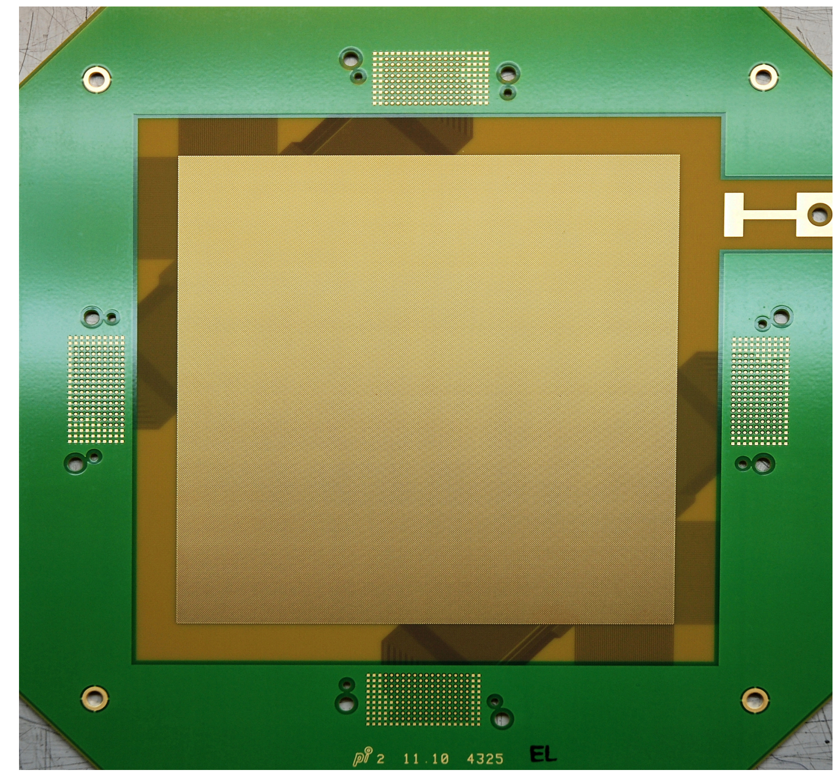
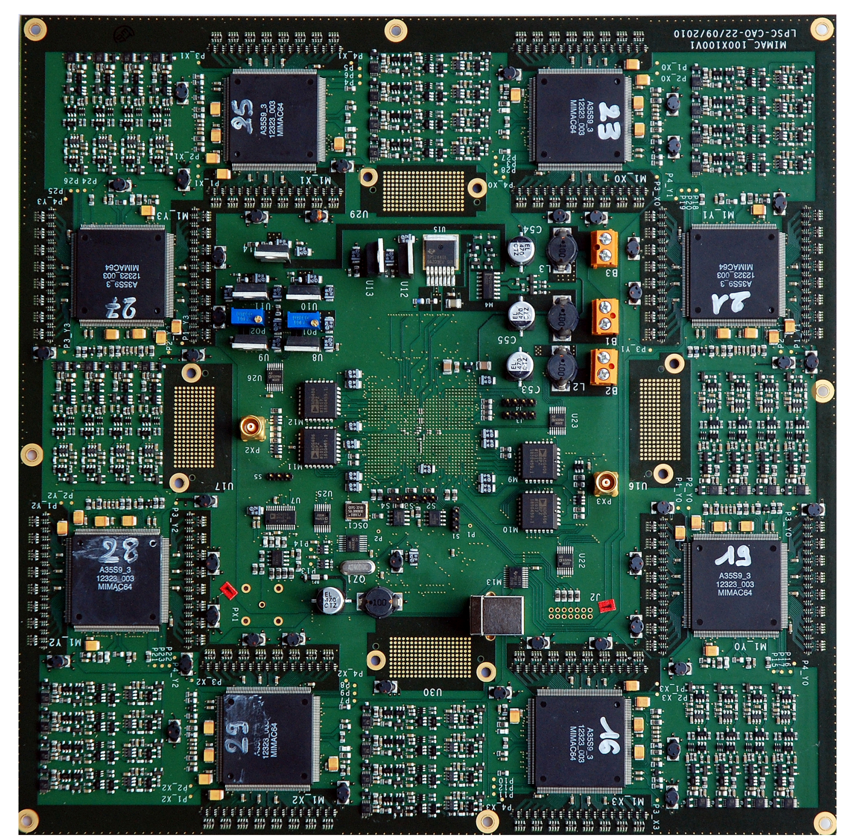
MIMAC

MicroTPC Matrix of chambers
prototype chamber







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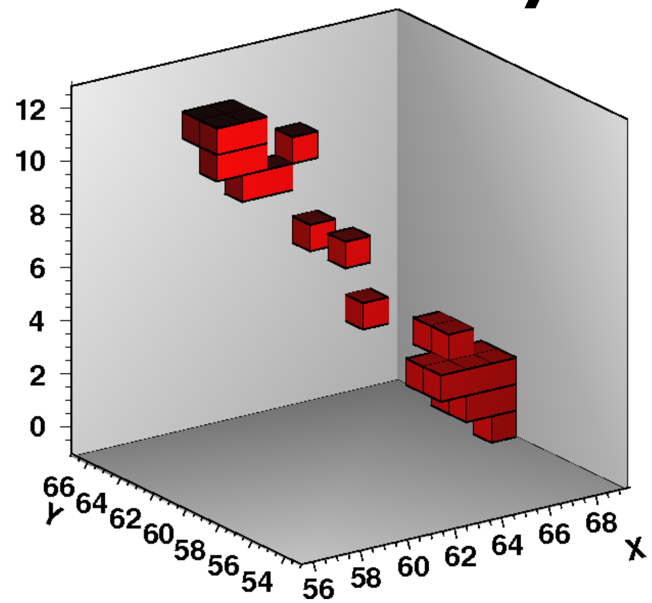
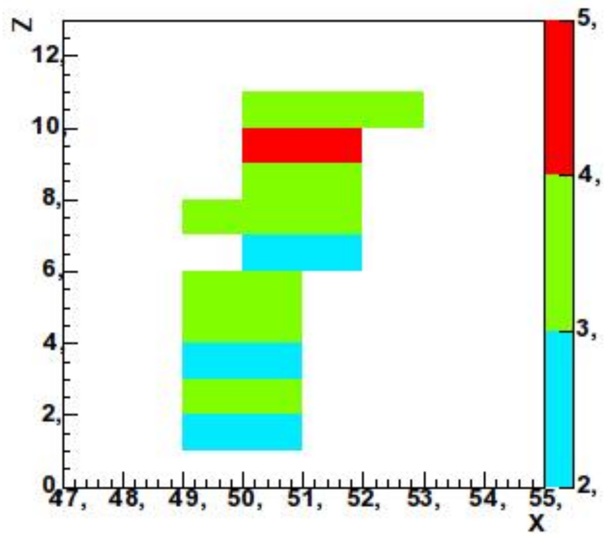
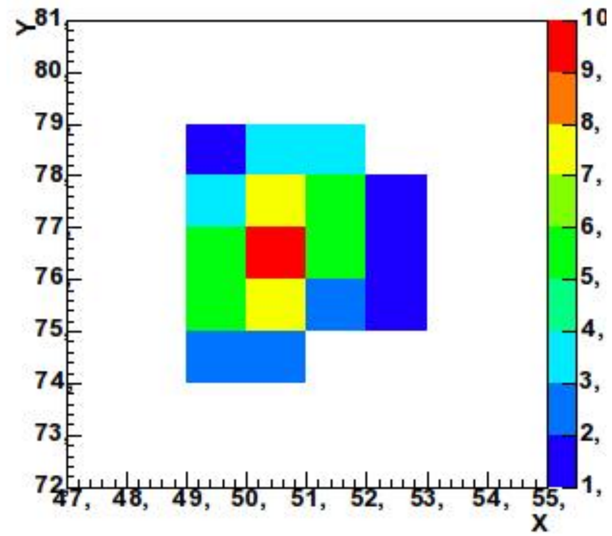
3D track reconstruction

^{55}Fe X-ray

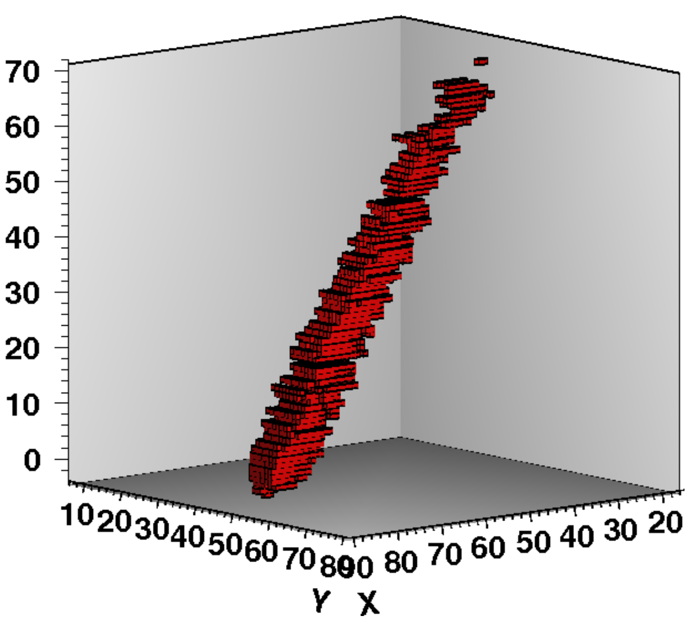


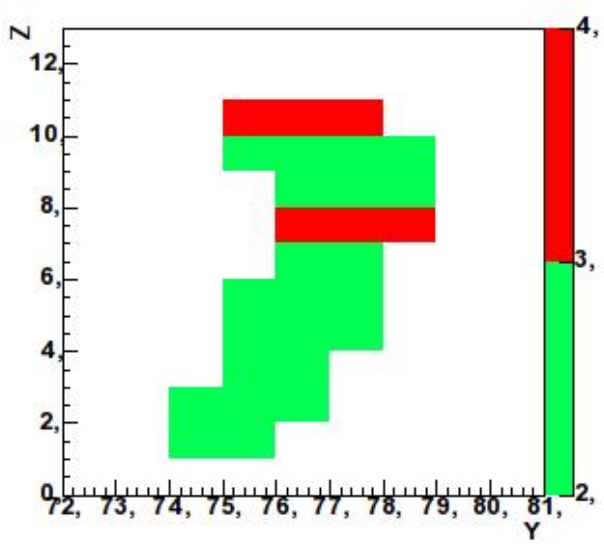


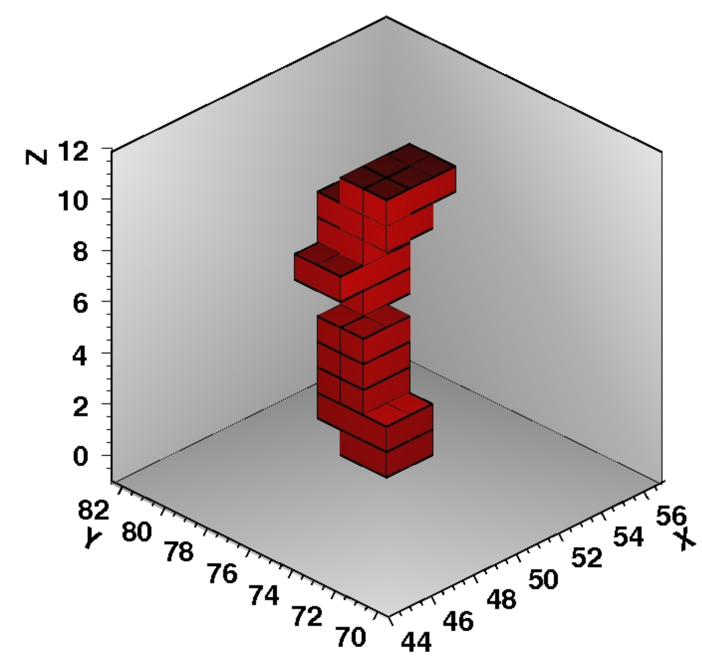


Recoil of 19F
(E_{ion}~40 keV)
in 50 mbar of
CF4 + CHF3 (30%)

$5.5\,\mathrm{MeV}\ \alpha,\ (^{222}\mathrm{Rn})$







http://arxiv.org/pdf/1006.1335.pdf

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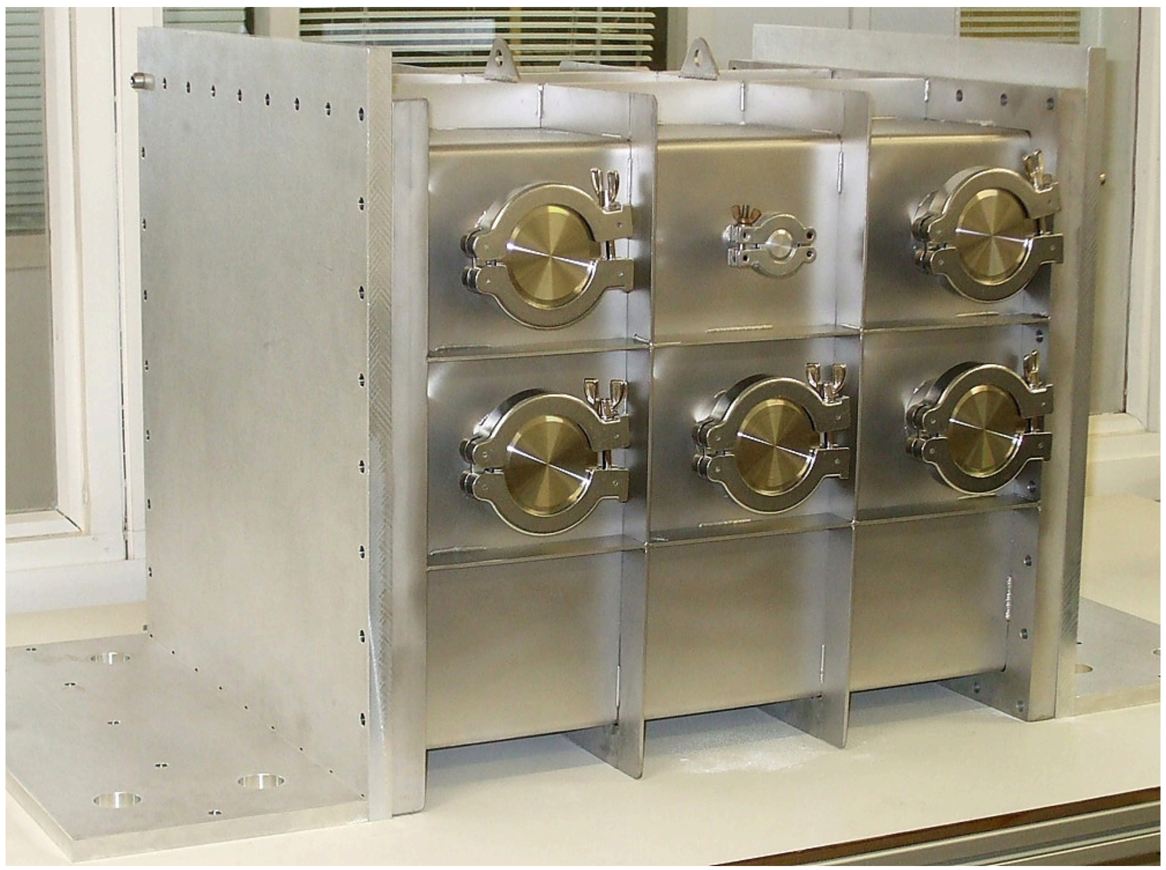
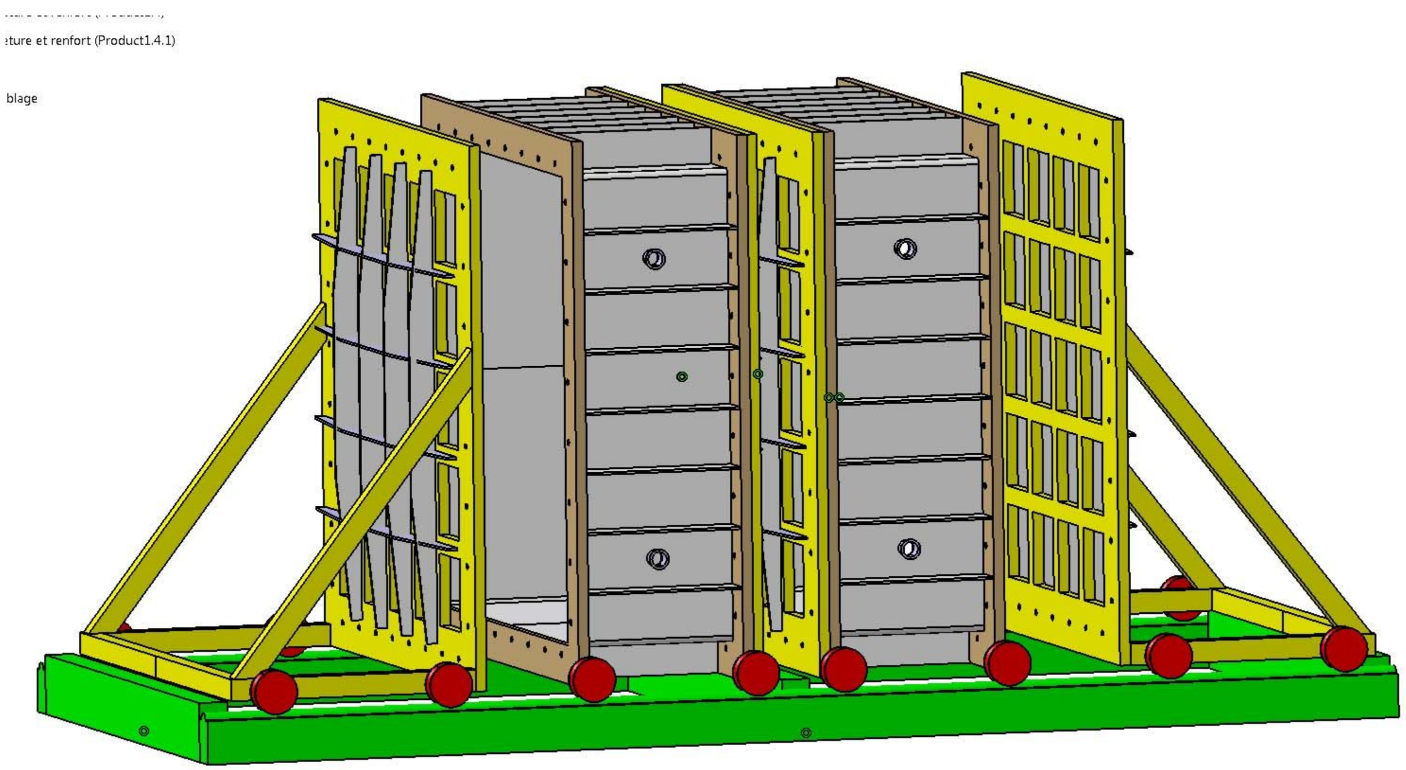
MIMAC Current Status, Future Plans



2 of 10 by 10 by 25 cm modules installed at Modane and



MIMAC 1 tonne

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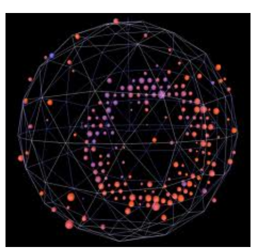
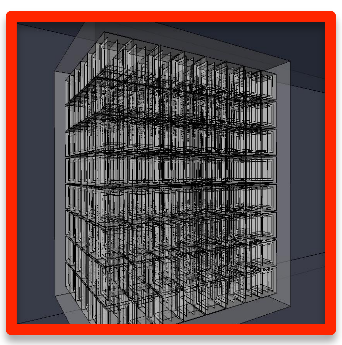
How big is a 1 tonne directional detector?

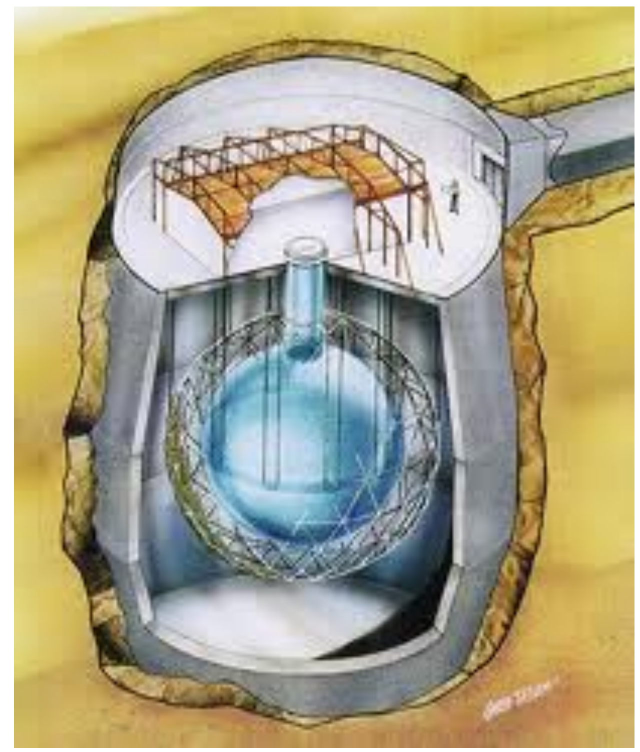
14x14x14m DRIFT



Mini-BooNE



MINOS



SNO

Super-Kamiokande

Large, certainly, but not out of the question. However, a project of this scale would require a large, coherent, international collaboration.

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Conclusions

Annual modulation is an important galactic signature. But, it's a terribly subtle.

Diurnal modulation is potentially more powerful.

Gas TPCs have demonstrated that they could detecting diurnal modulation. This may be the only way to be sure of a detection.

The U.K.D.M.C. / more recently the U.K. members of the DRIFT collaboration continue to improve sensitivity, scale up.

Several groups have made pioneering strides in new more finely segmented readout technology.

To build 1 tonne of Gas TPC will require an international collaboration. It is by no means an impossible task, using existing technology. Take the best of what everyone has, and pool it!