DMTPC: a direction-sensitive dark matter detector -- first limit

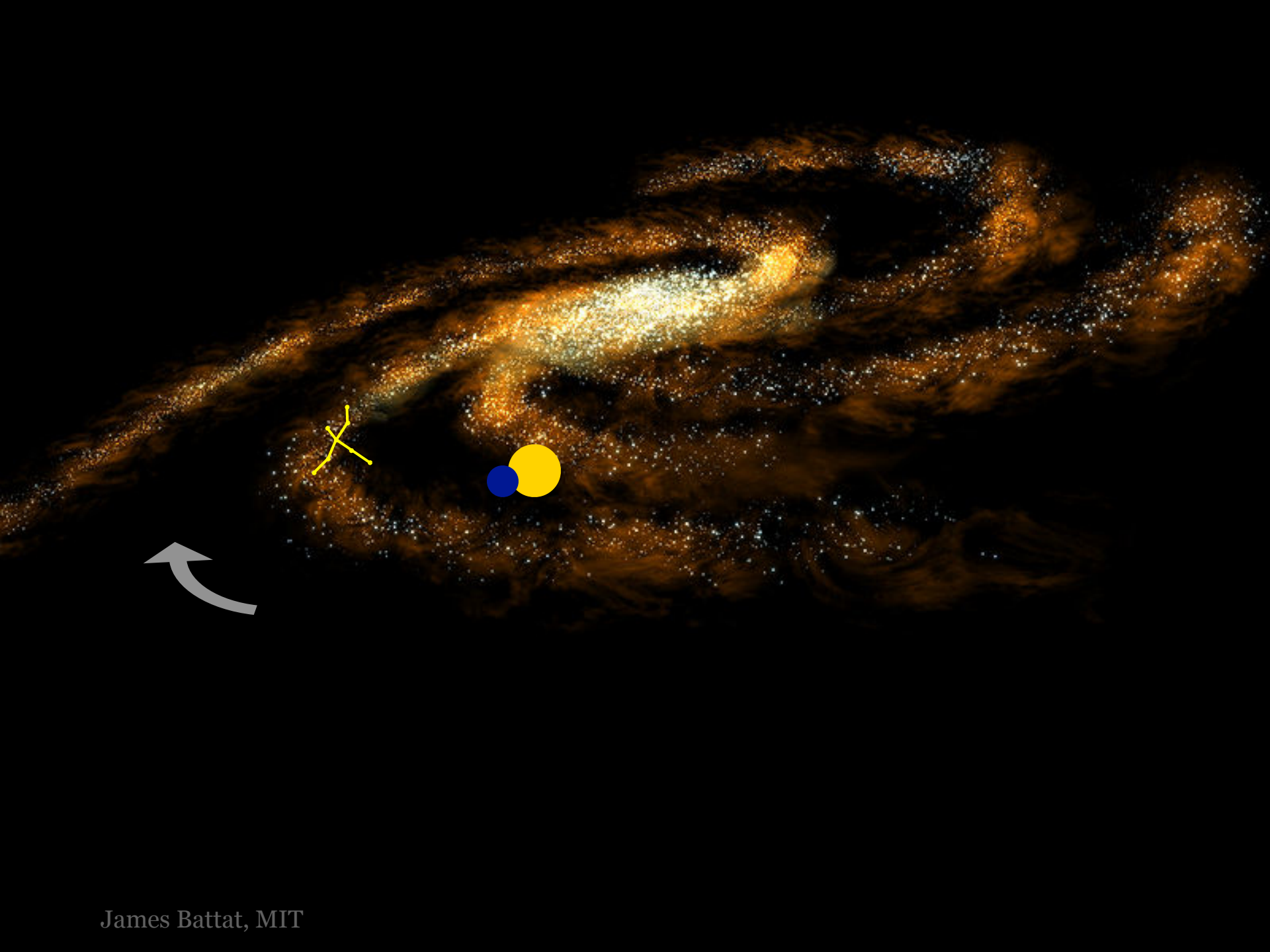
James Battat
(for the DMTPC collaboration)

IDM 2010

July 27, 2010

Outline

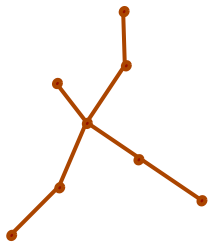
- The directional signature
- The DMTPC detector
- Results from DMTPC 10L surface run
- DMTPC underground
- Scaling up: 4shooter and m^3

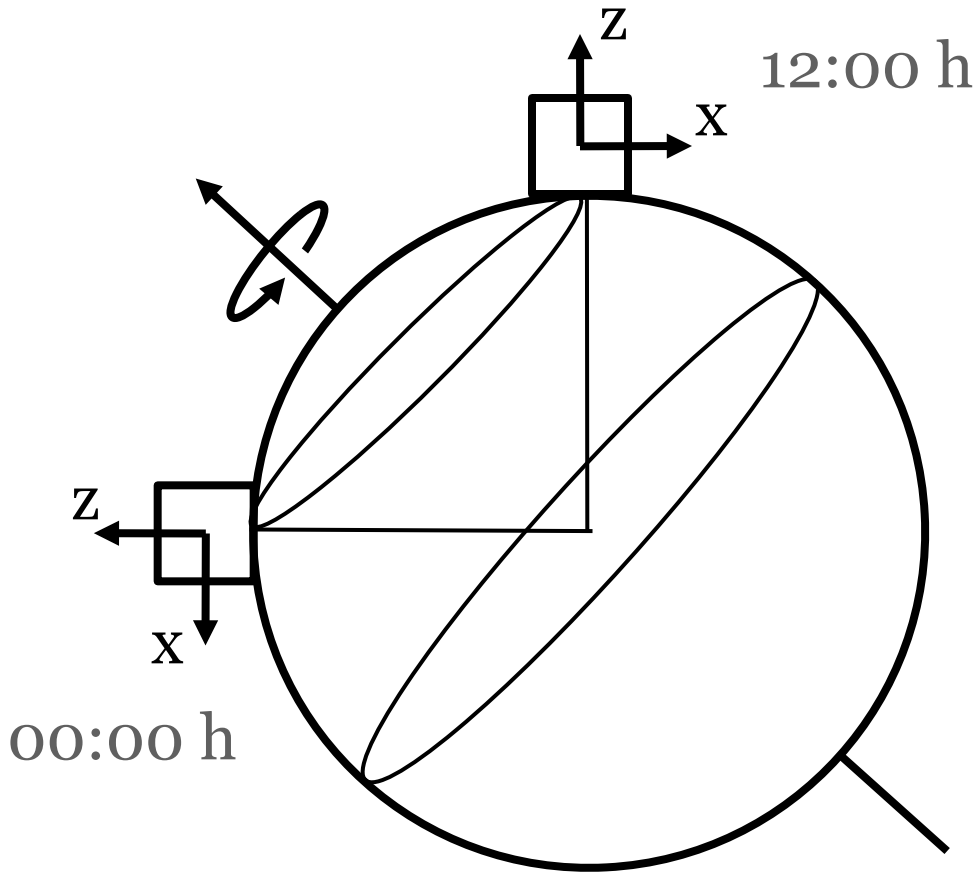


James Battat, MIT

The direction modulation

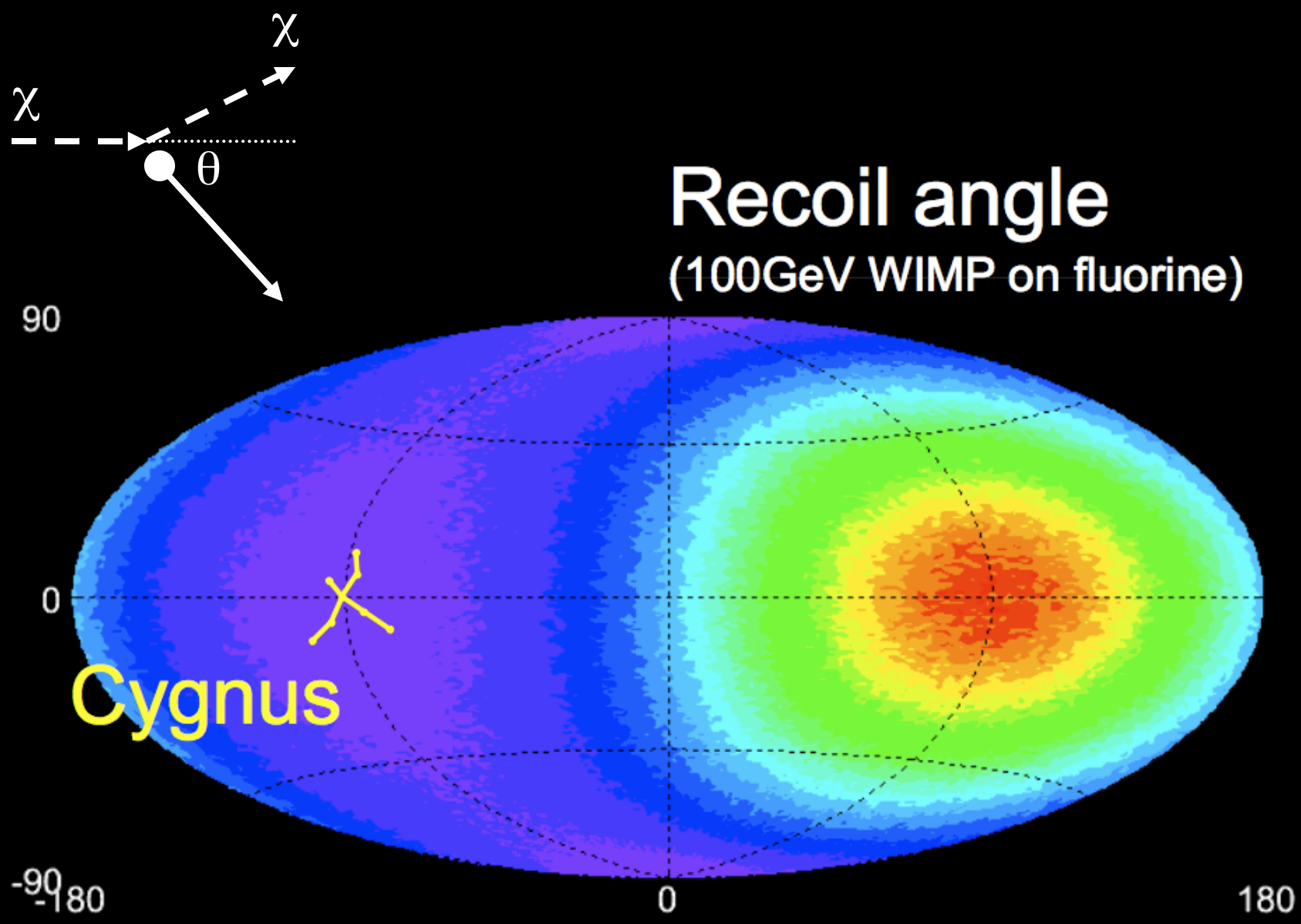
Cygnus

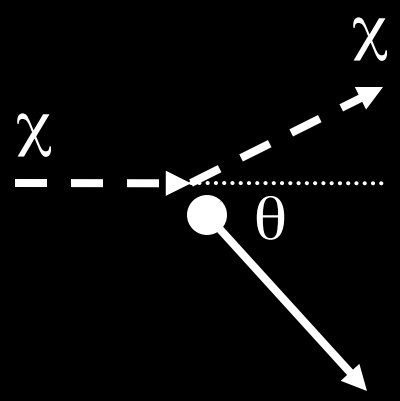


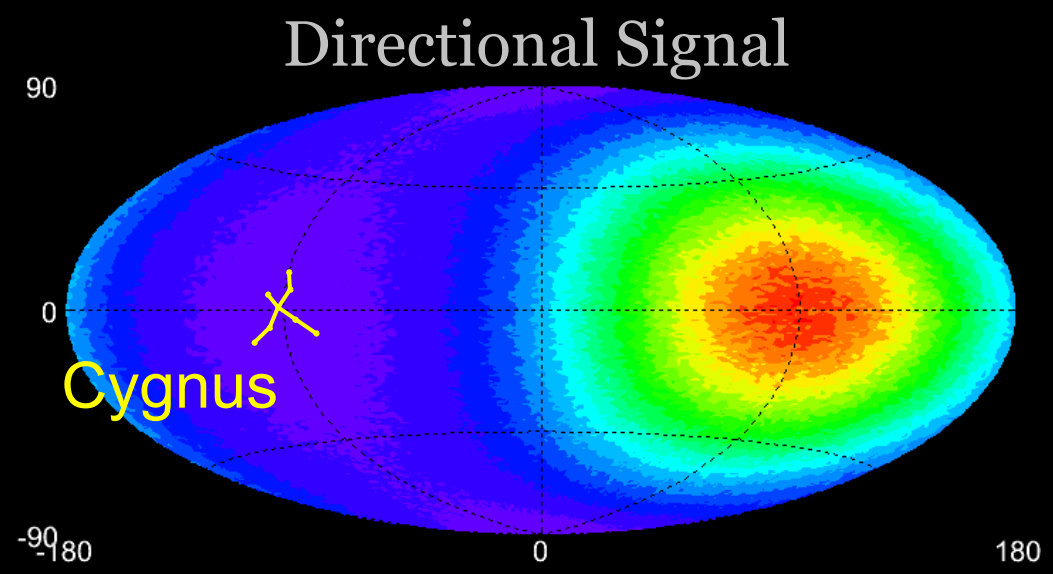


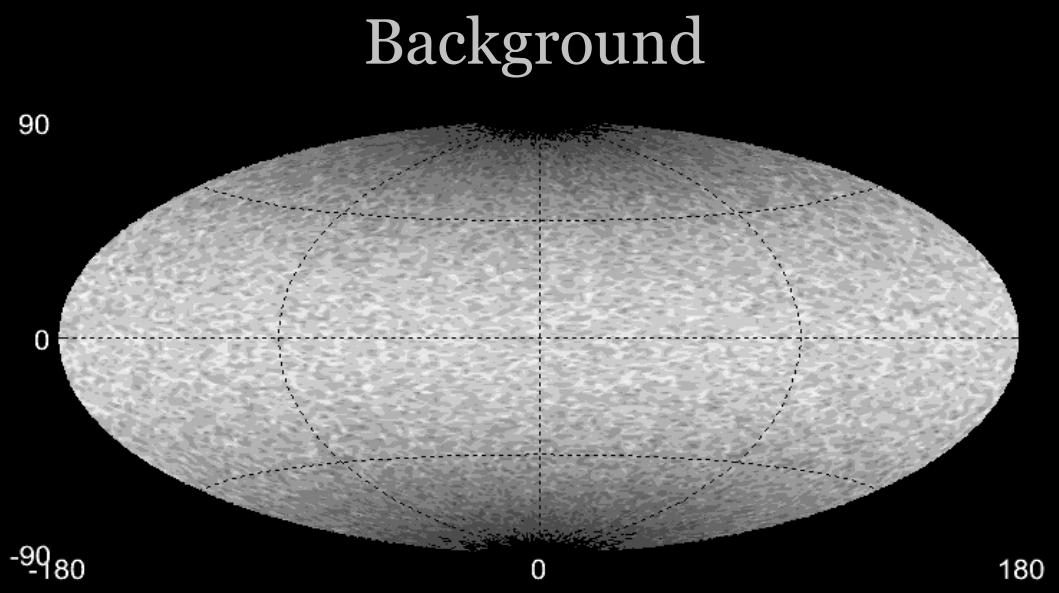
Declination of Cygnus ~42°

Spergel, PRD, 1988


χ
χ
θ
Recoil angle
(100GeV WIMP on fluorine)
90
0
-90
-180
0
180
Cygnus


χ
χ
θ


Directional Signal
90
0
-90
-180
0
180
Cygnus


Background
90
0
-90
-180
0
180

“The case for a directional dark matter detector and the status of current experiments”

arXiv:0911.0323

DMTPC: a directional dark matter detector

Massachusetts Institute of Technology

J. Battat, C. Deaconu, D. Dujmic, P. Fisher (PI), S. Henderson, A. Kaboth, J. Lopez, J. Monroe, T. Sahin, G. Sciolla

Boston University

S. Ahlen (PI), A. Inglis, H. Tomita

Brandeis University

A. Dushkin, H. Wellenstein (PI)

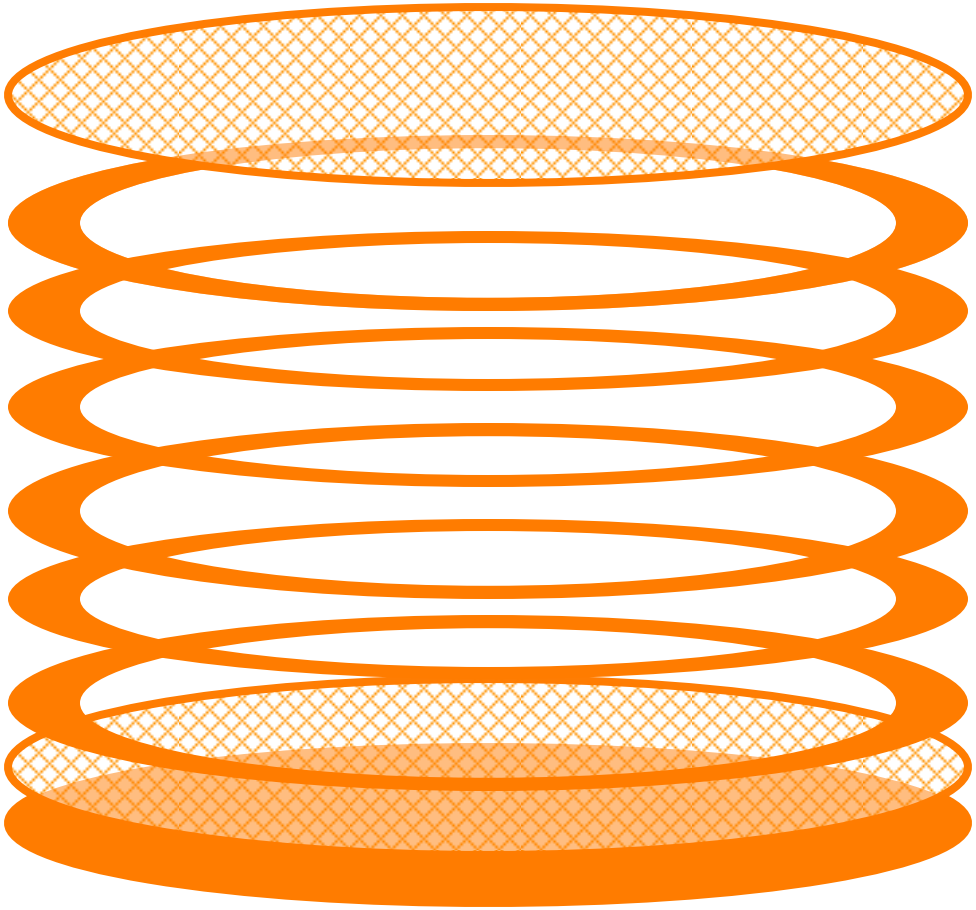
Detector Papers

D. Dujmic et al. [DMTPC] NIMA 584 (2007)
A. Kaboth et al. [DMTPC] NIMA 592 (2008)
D. Dujmic et al. [DMTPC] Astropart. Phys 30 (2008)

Surface Run Results

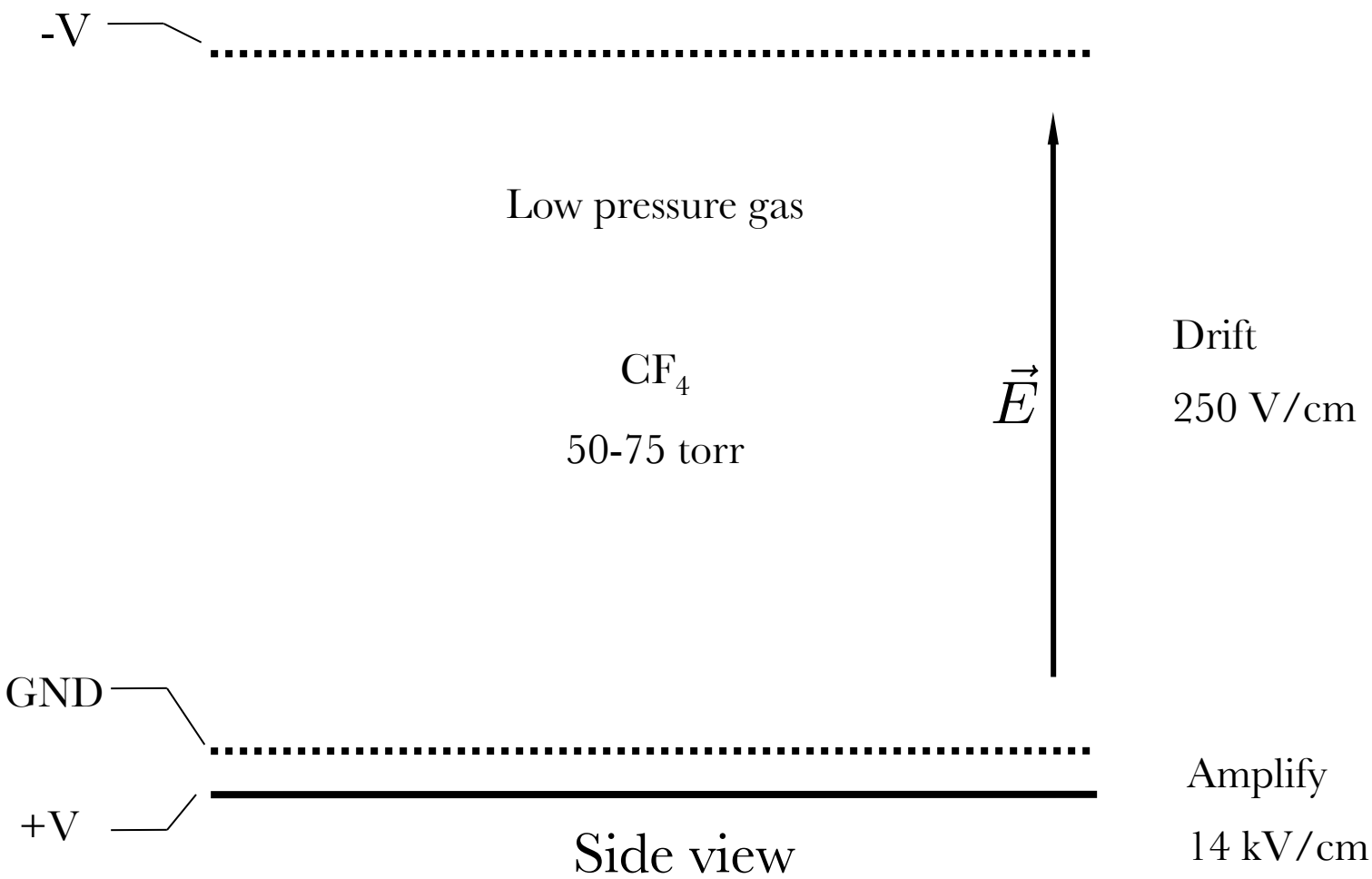
Ahlen et al. [DMTPC] arXiv:1006.2928

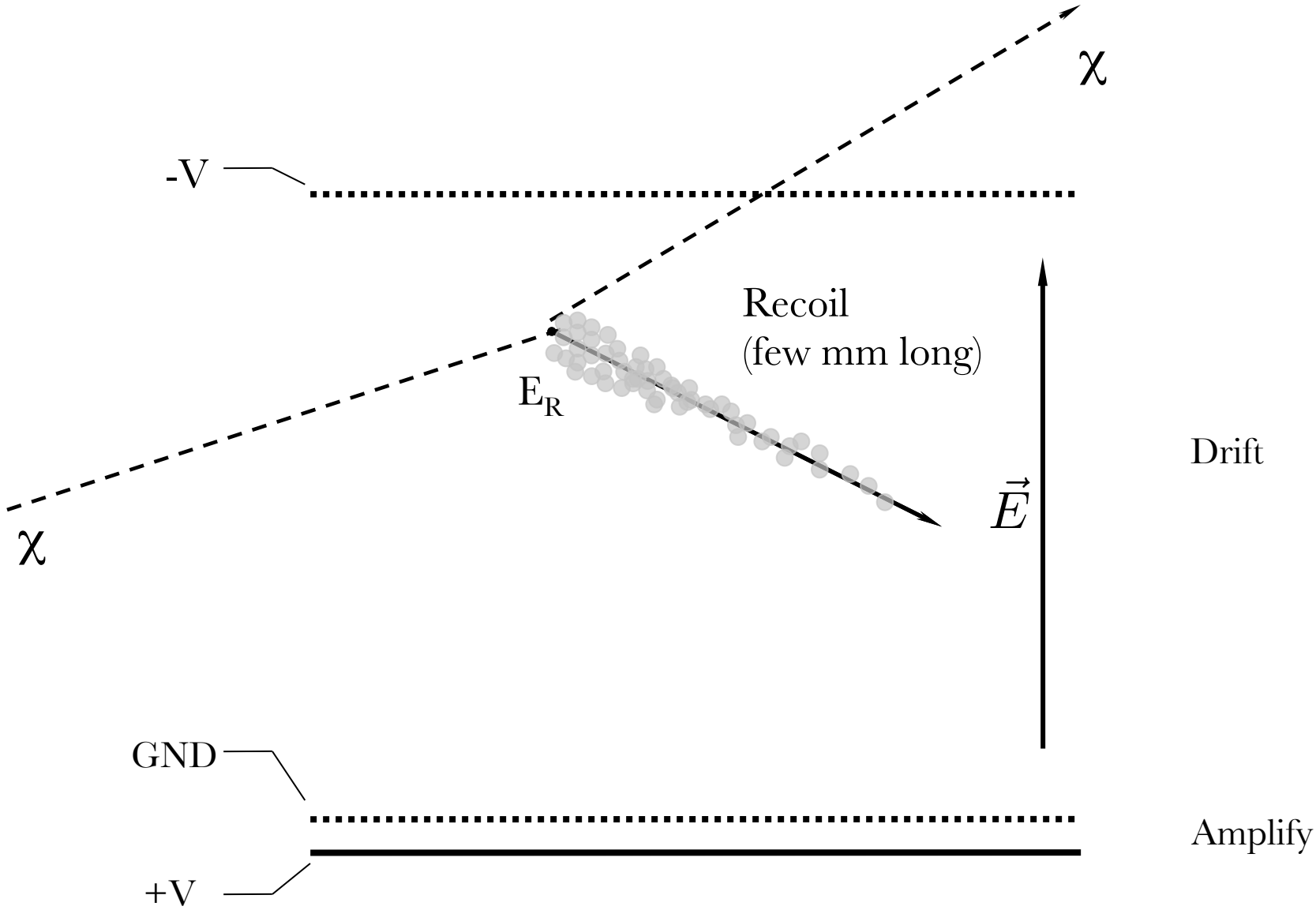
Time Projection Chamber

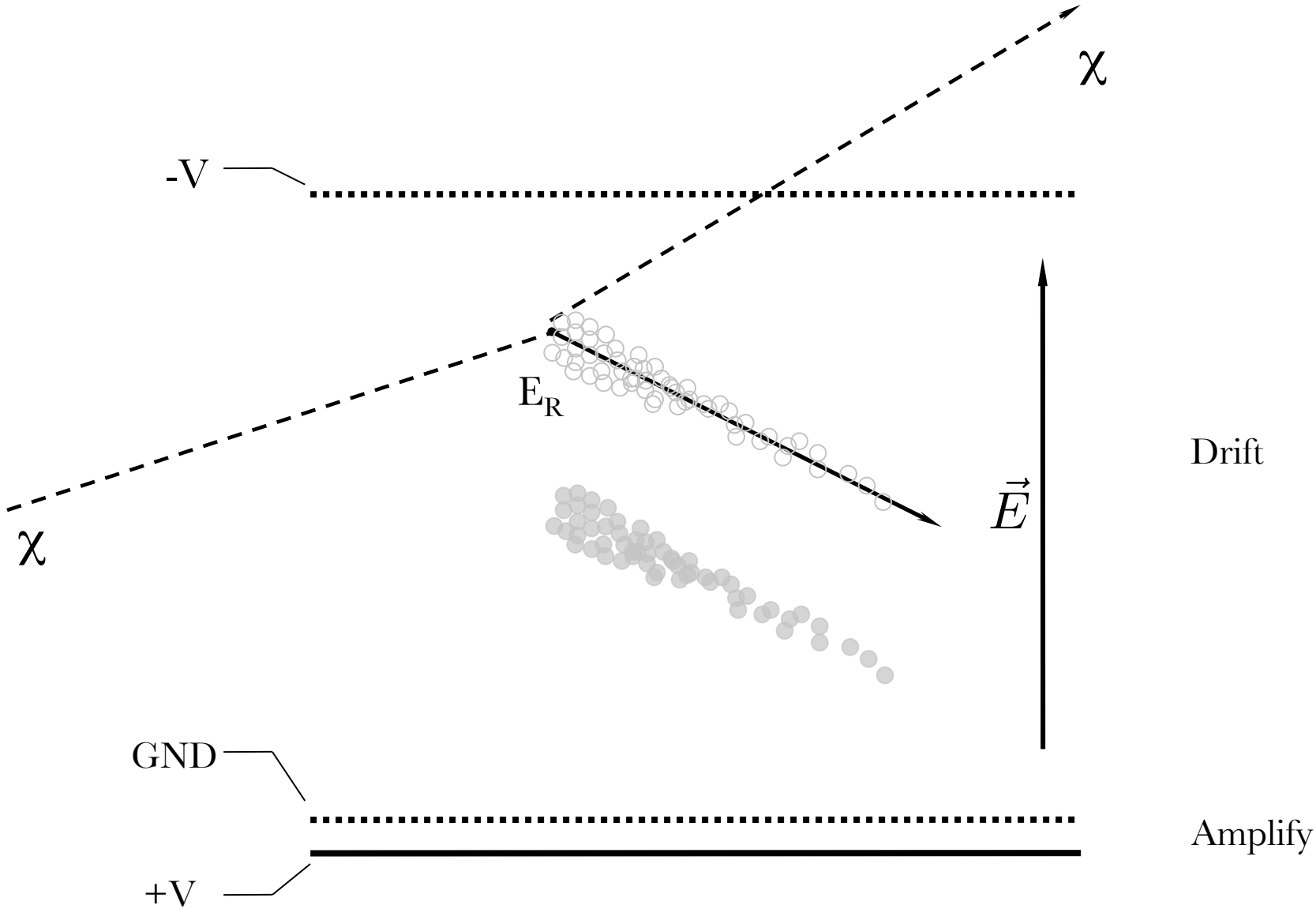


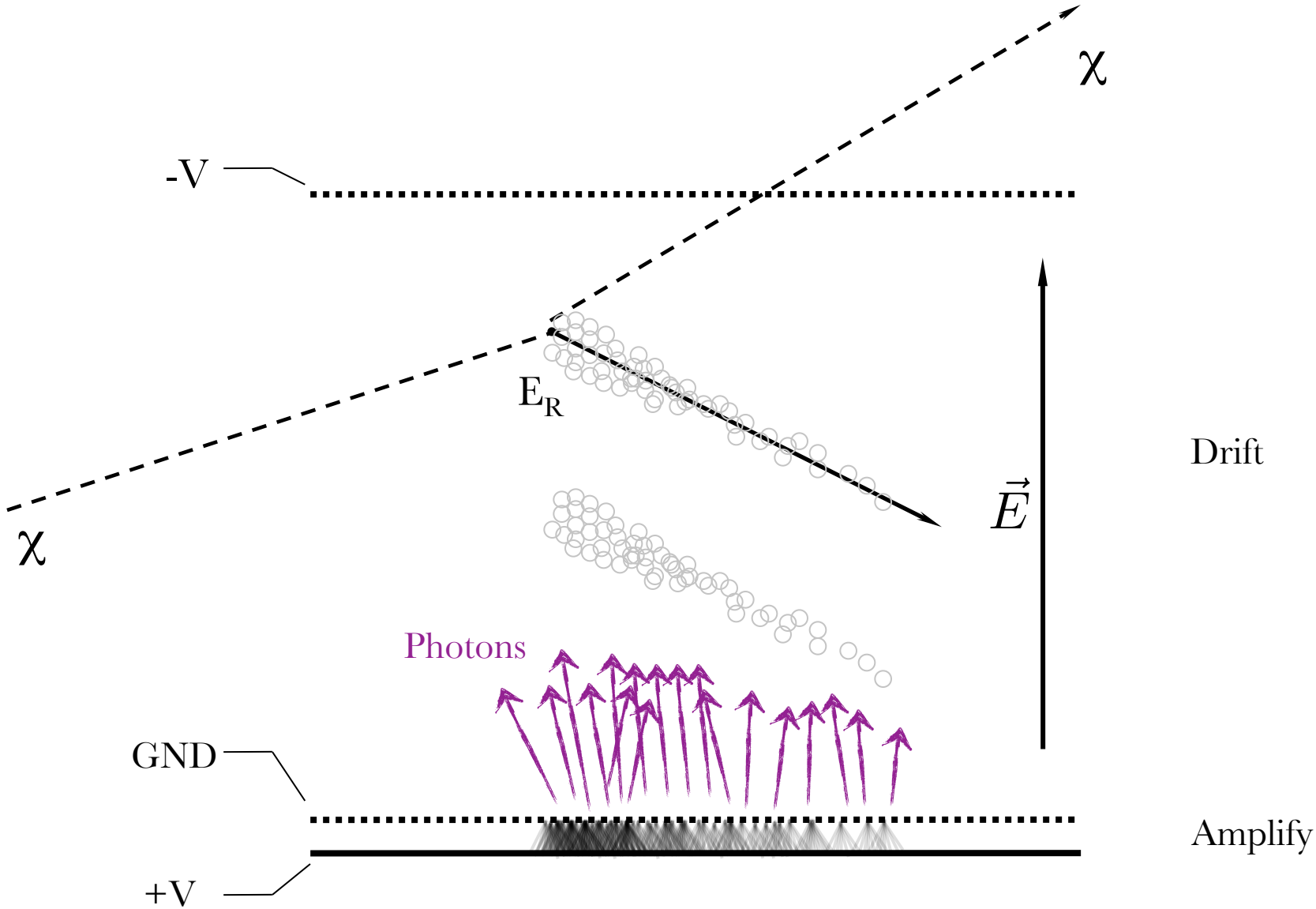
James Battat, MIT

Time Projection Chamber

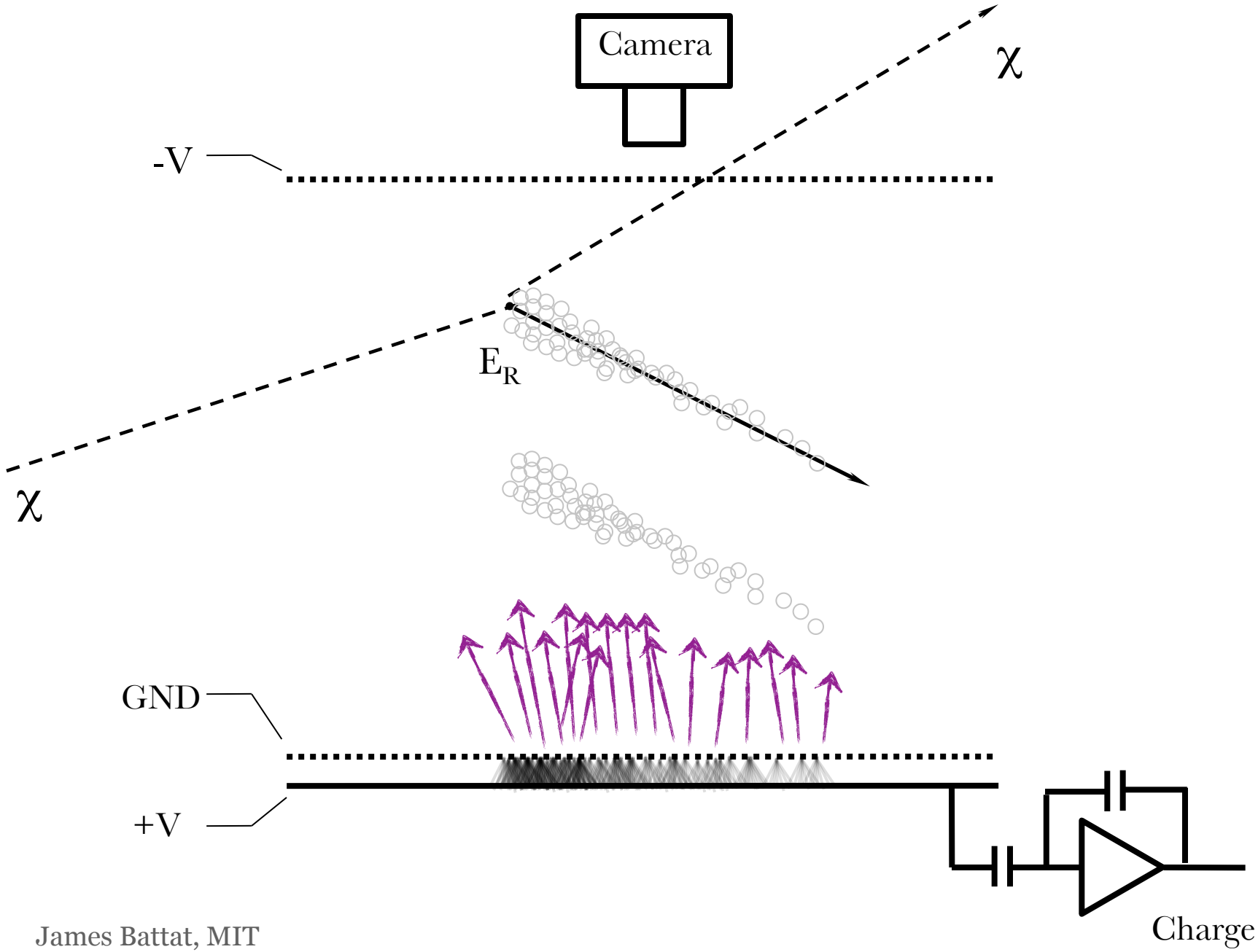



χ
-V
Recoil
(few mm long)
E_R
Drift
$\vec{E}$
χ
GND
Amplify
+V

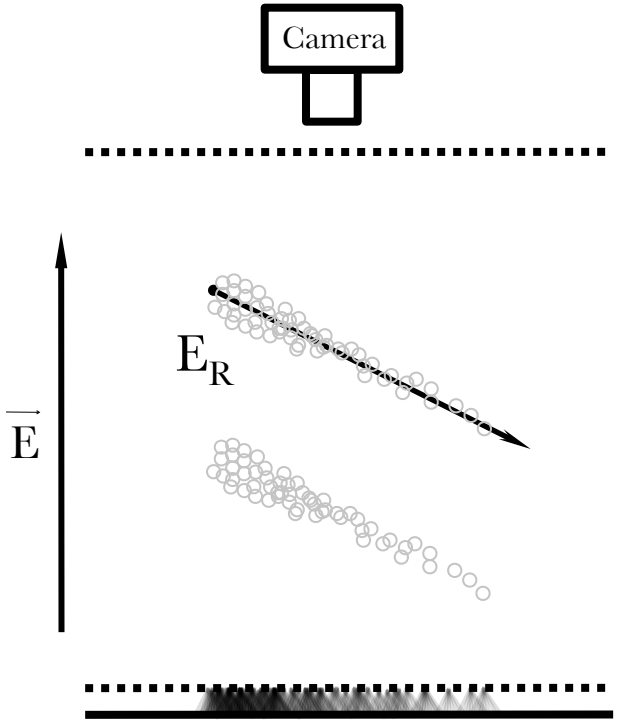

χ
-V
E_R
Drift
$\vec{E}$
χ
GND
Amplify
+V

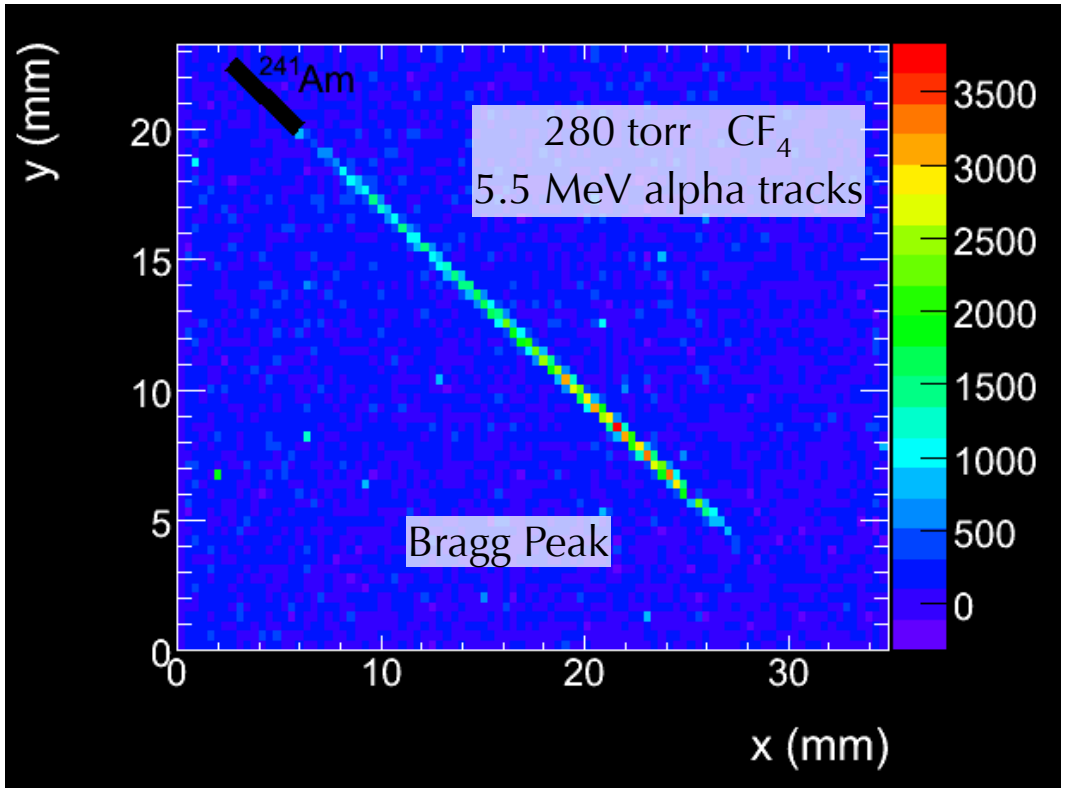


James Battat, MIT

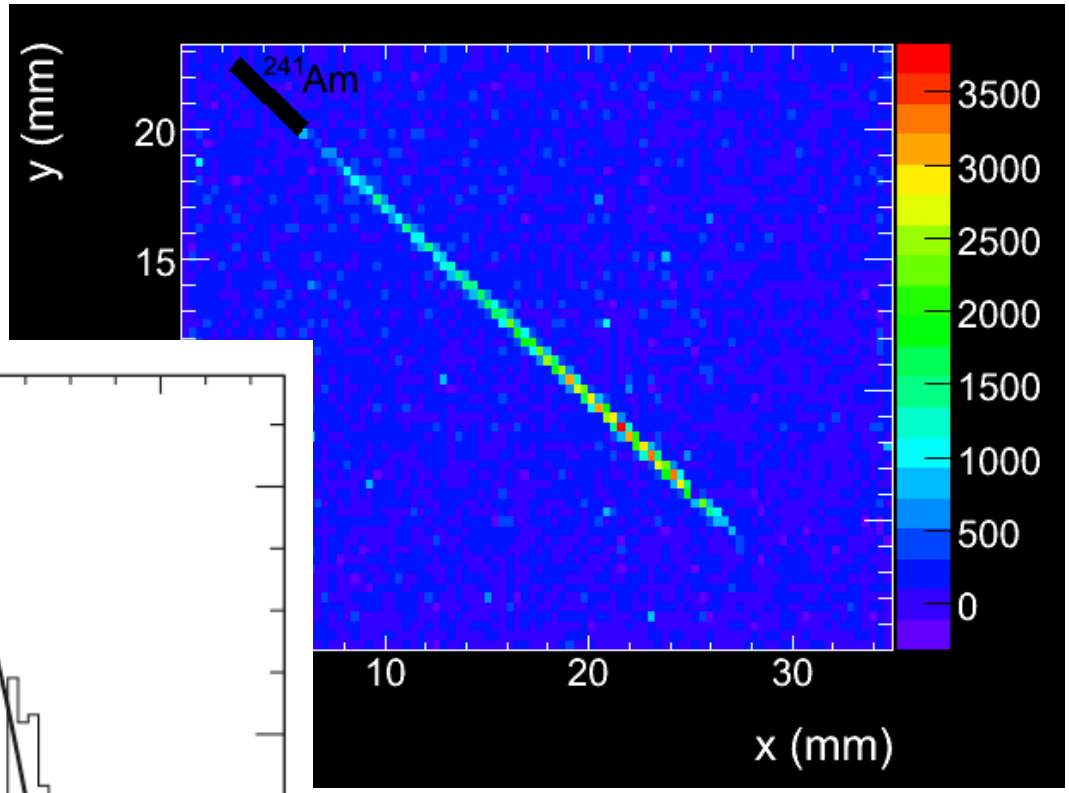


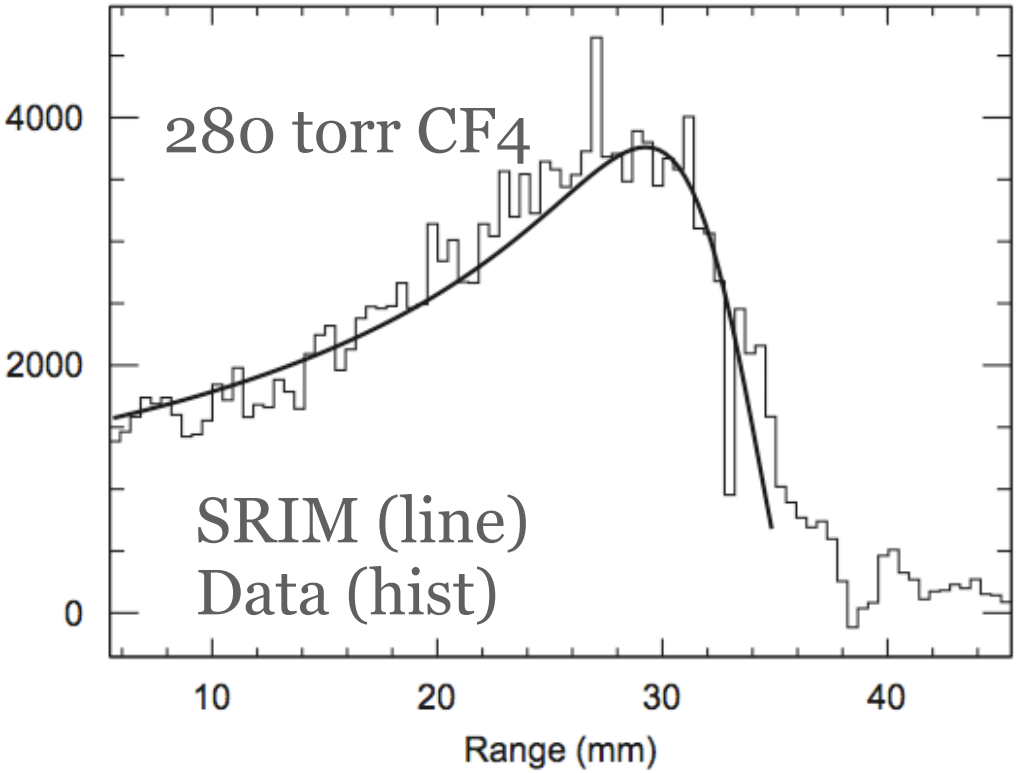
James Battat, MIT





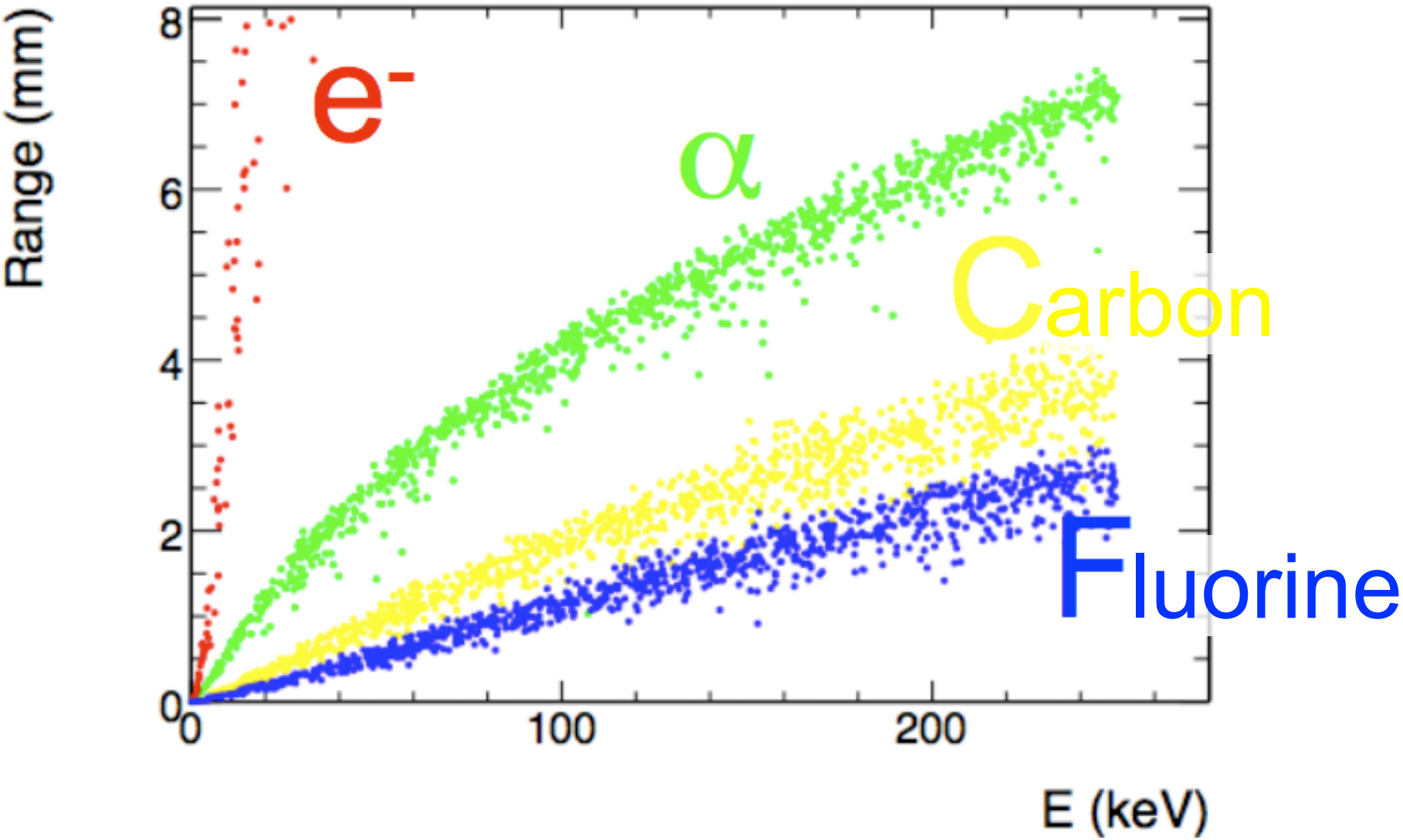
Track length (2d projection)
Track geometry
Energy (total light, charge)
dE/dx
Head-tail





James Battat, MIT

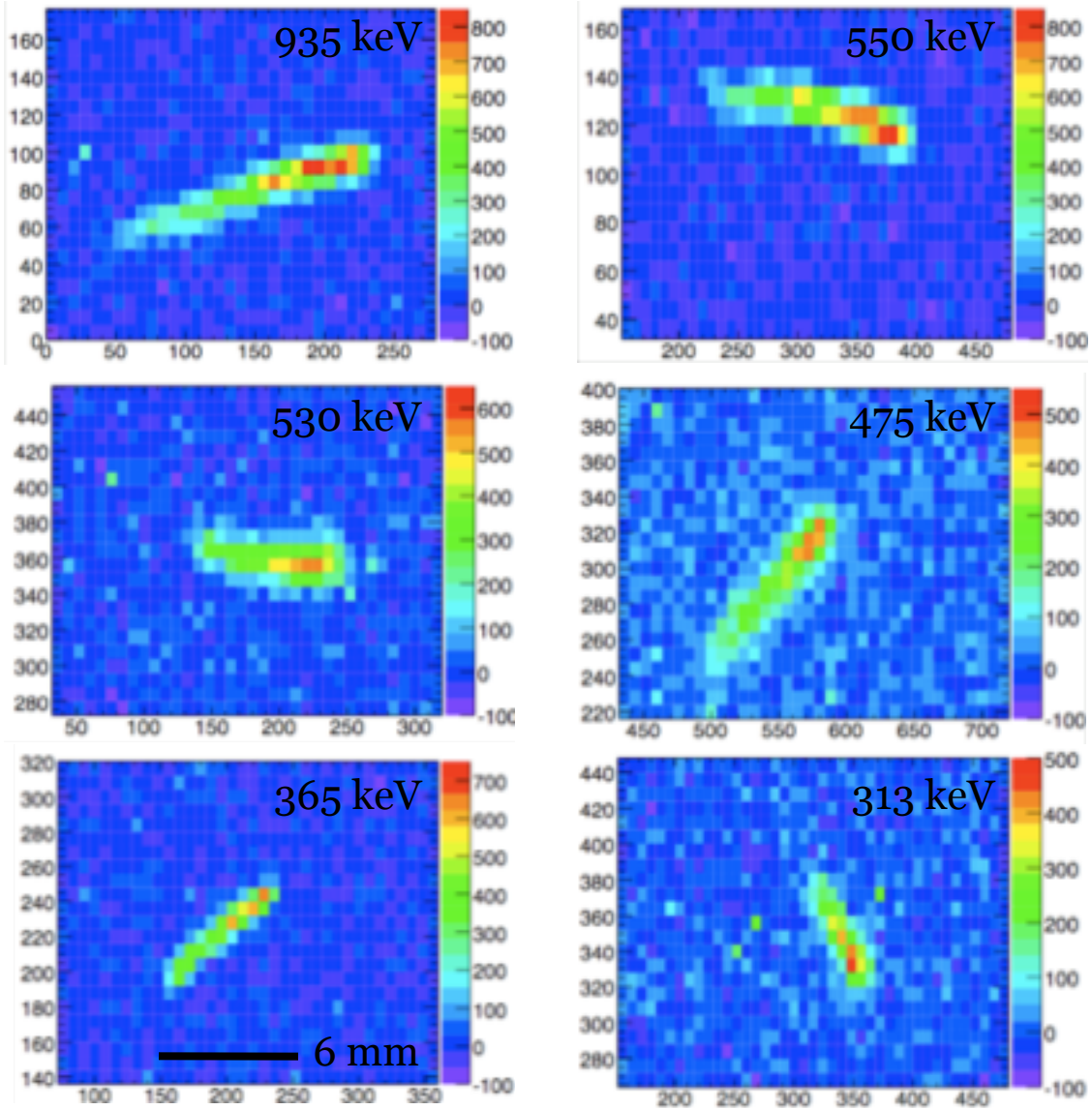
Particle Identification



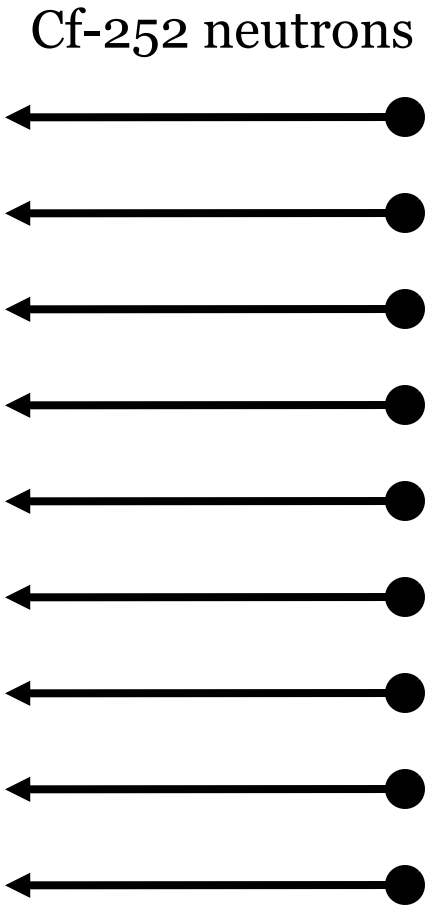
(simulation)

James Battat, MIT

Measurement of head-tail (E>100 keV)



100 pixels = 6 mm



P = 75 torr

James Battat, MIT

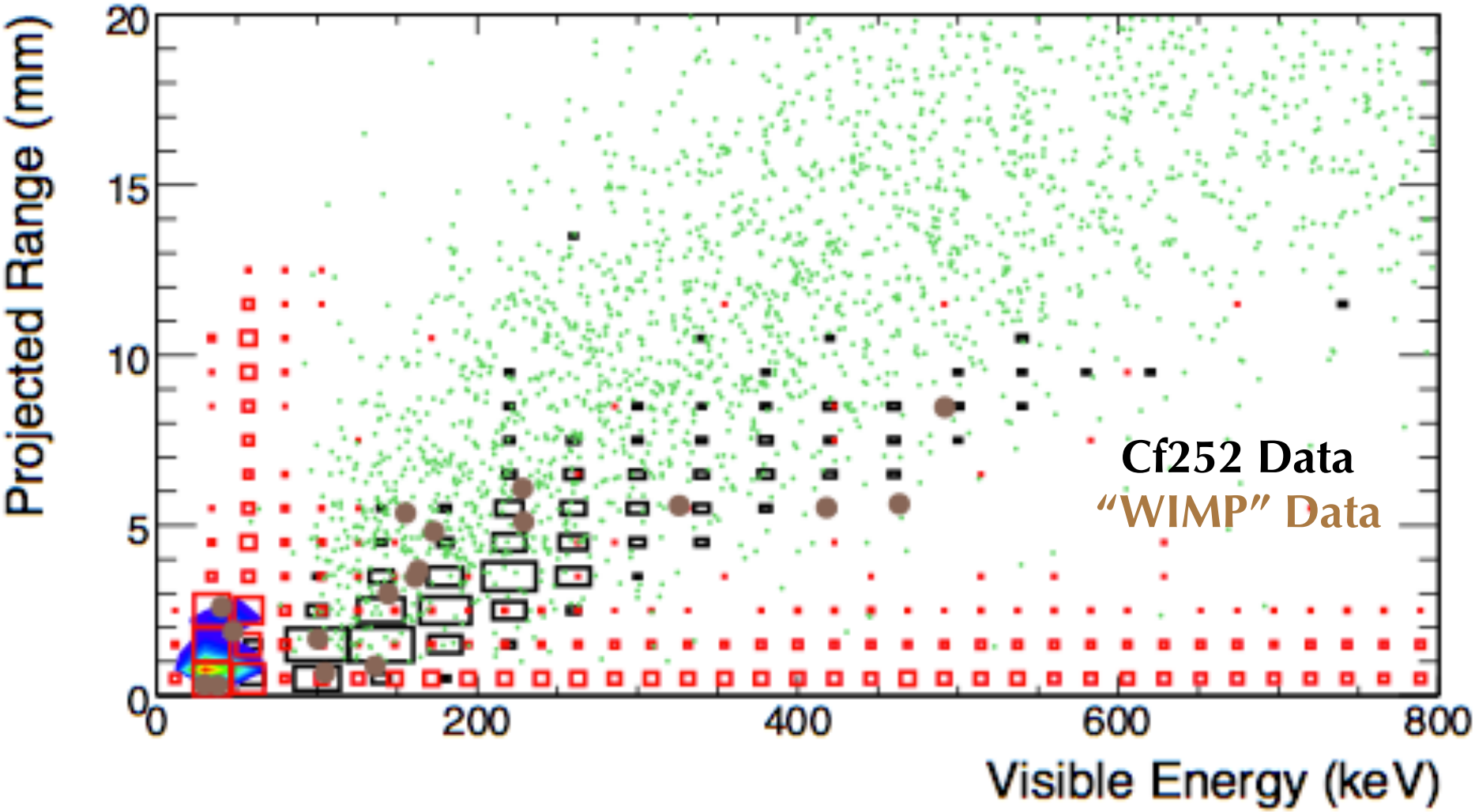
Dujmic et al. Astropart. Phys. 30 (2008) arXiv:0804.4827

Surface Run at MIT

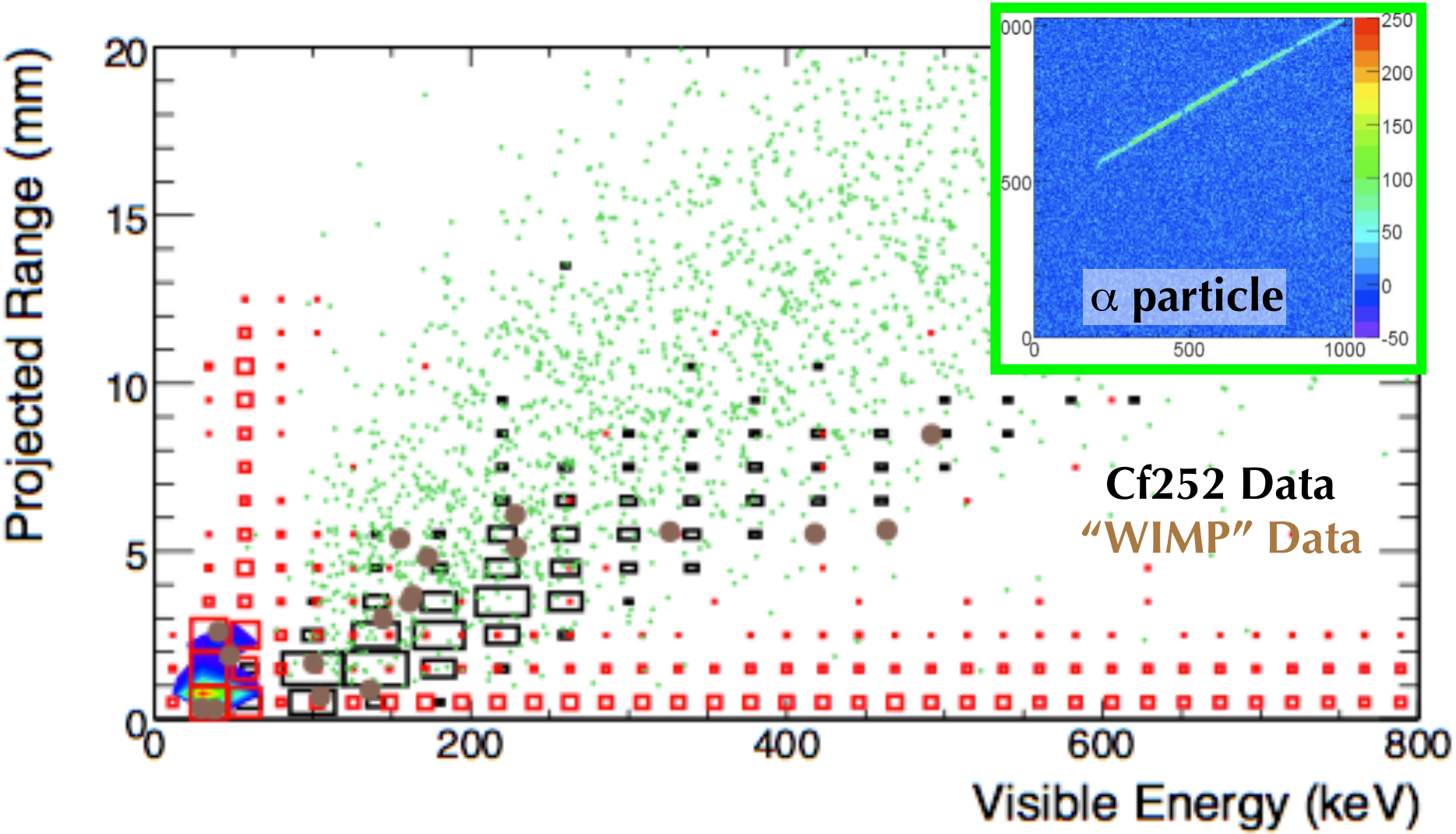
S. Ahlen et al. arXiv:1006.2928

- 10 Liter, dual TPC
- 75 Torr CF_4
- 3.3 g target mass
- CCD readout only (no charge)
- Daily gas refill
- Run in a basement lab at MIT
- Remote operation

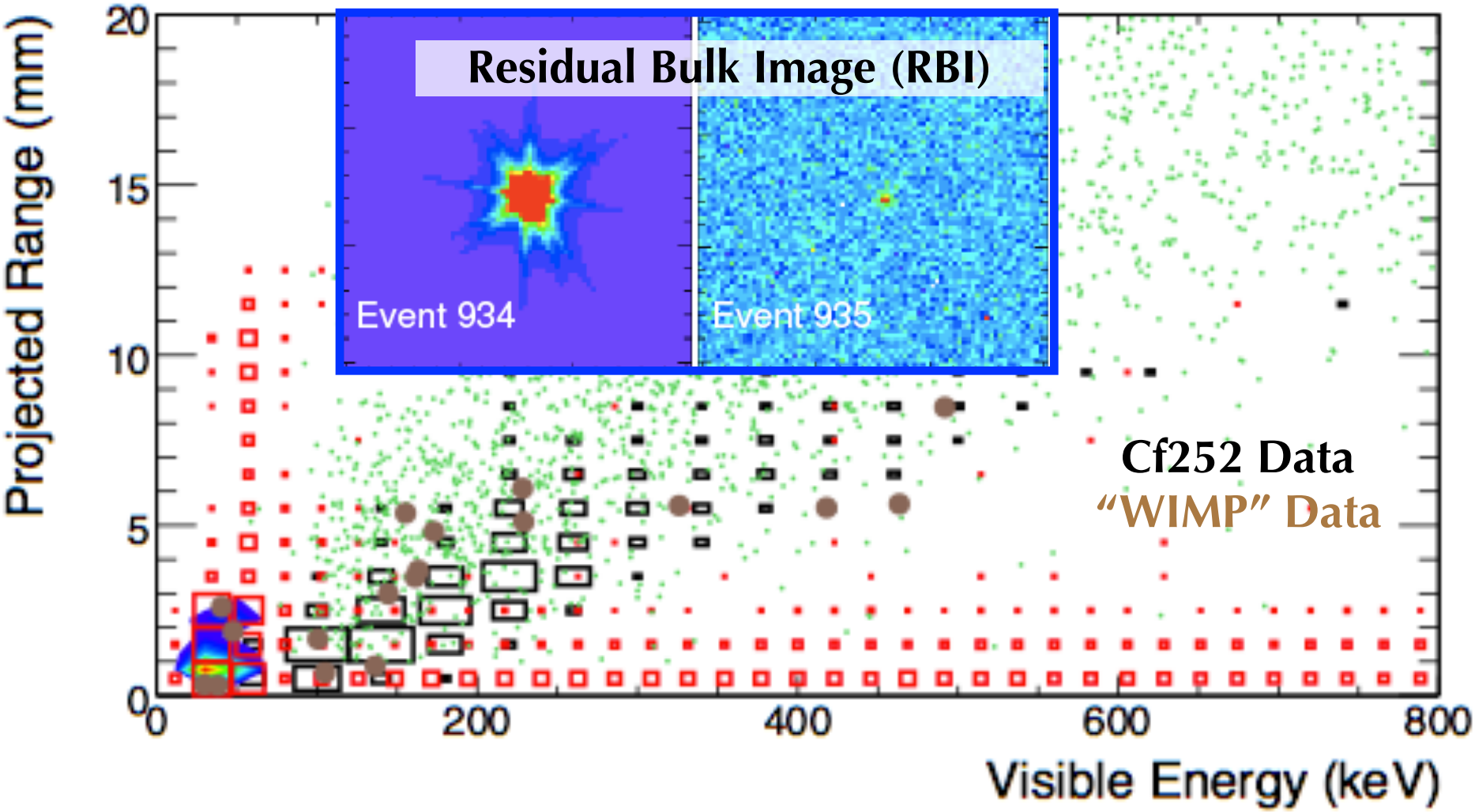
Surface Run Backgrounds



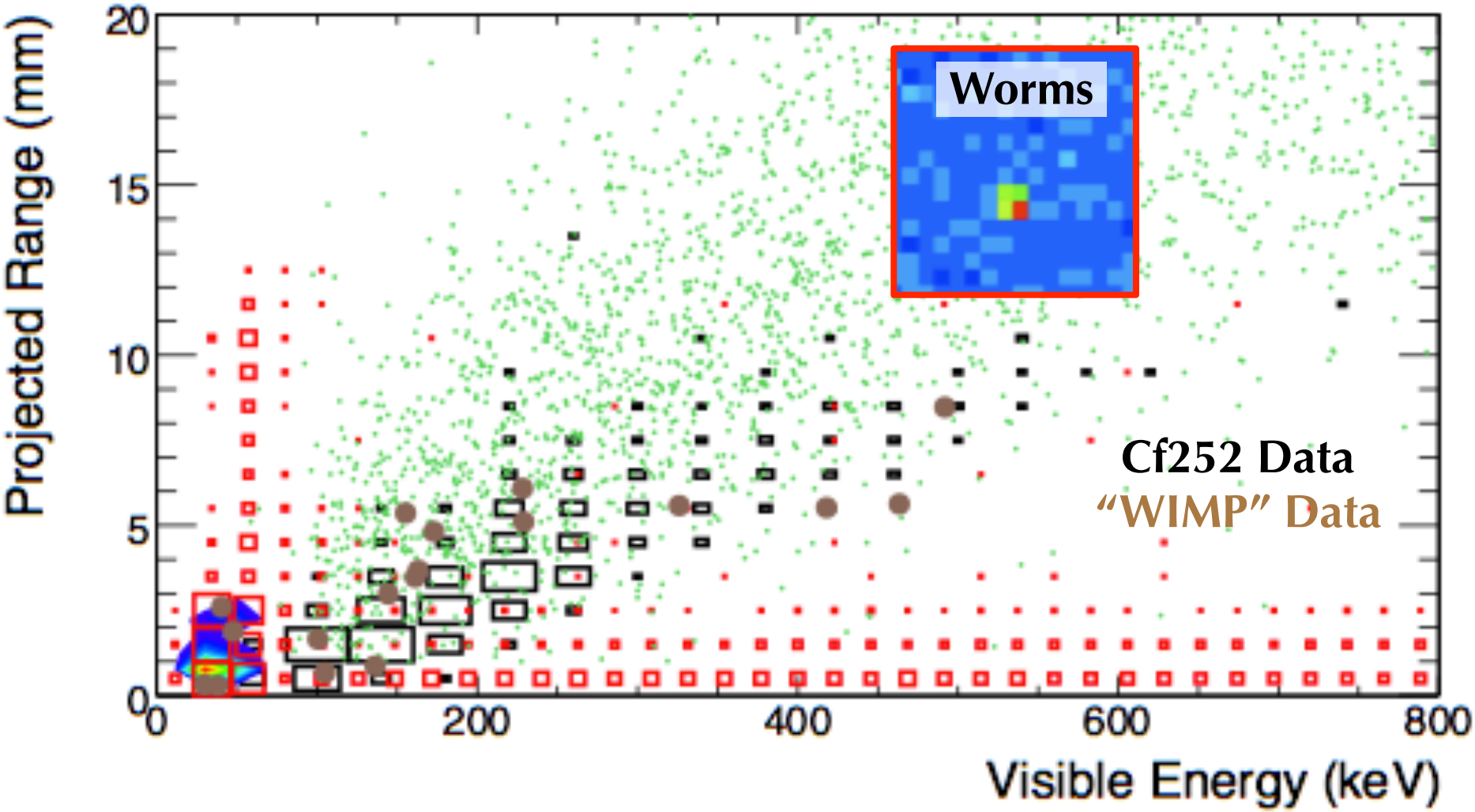
Surface Run Backgrounds



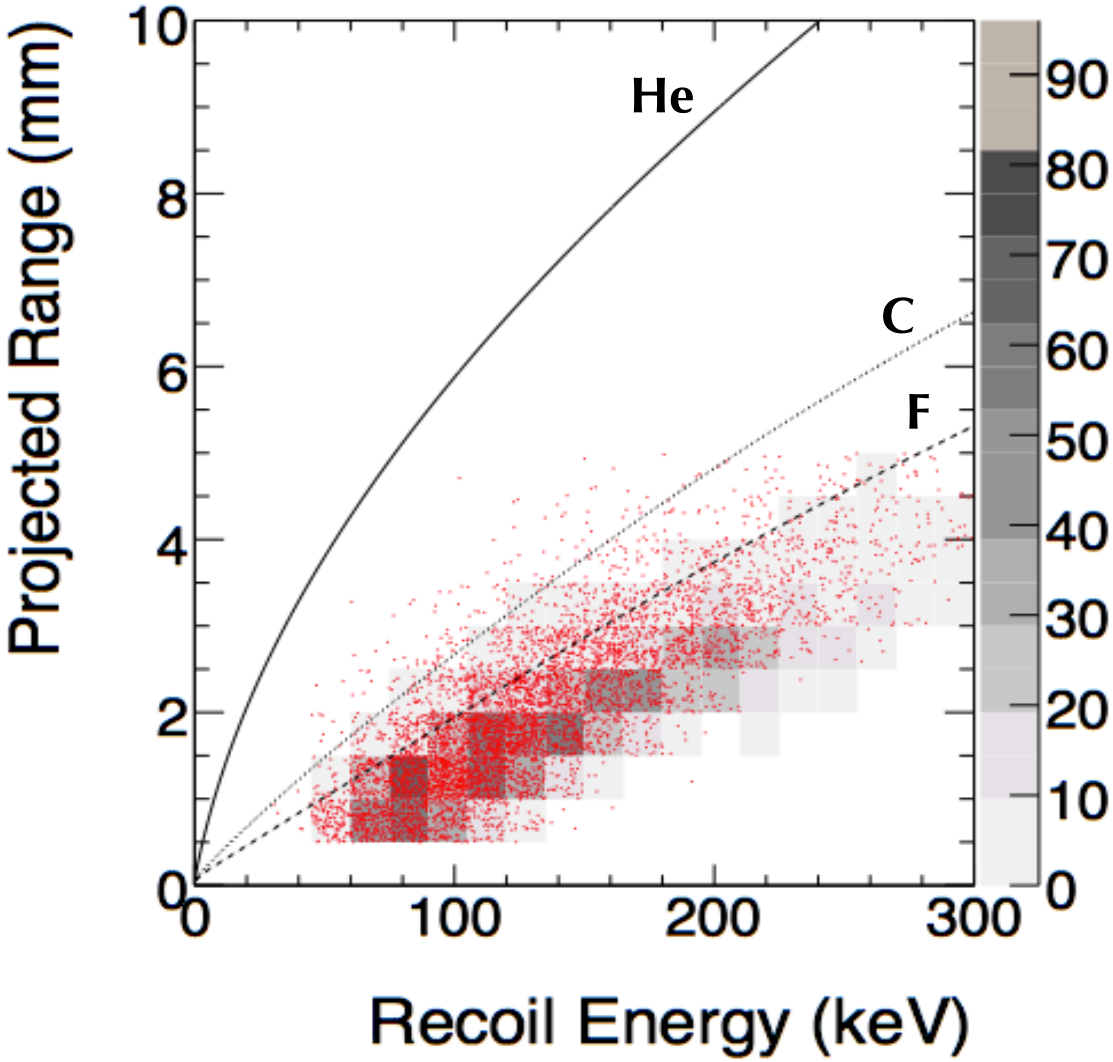
Surface Run Backgrounds



Surface Run Backgrounds



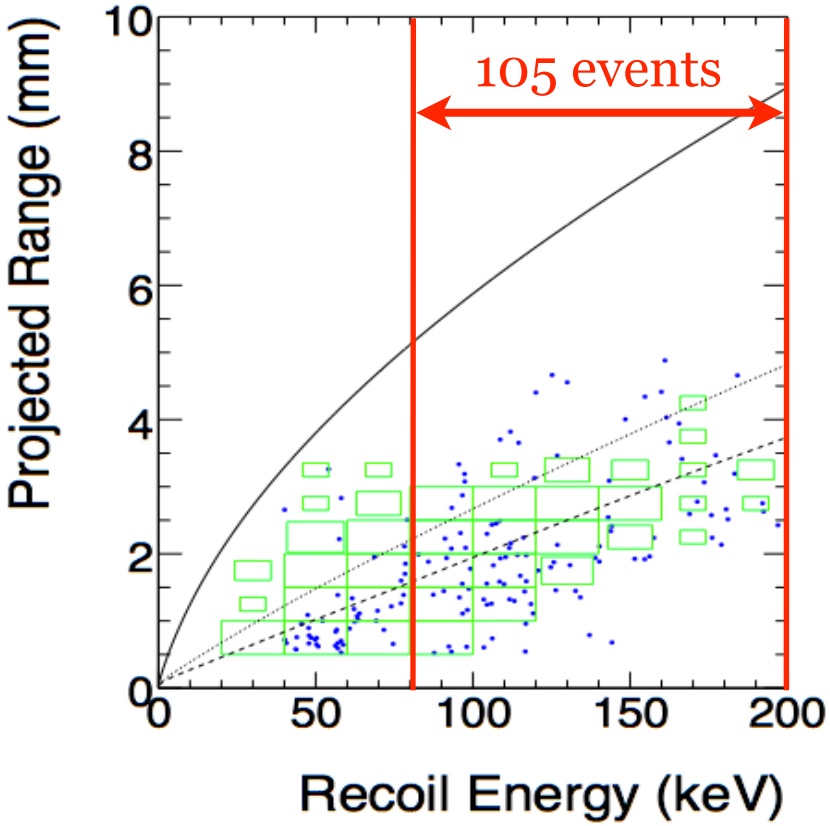
Calibration with ^{252}Cf neutrons

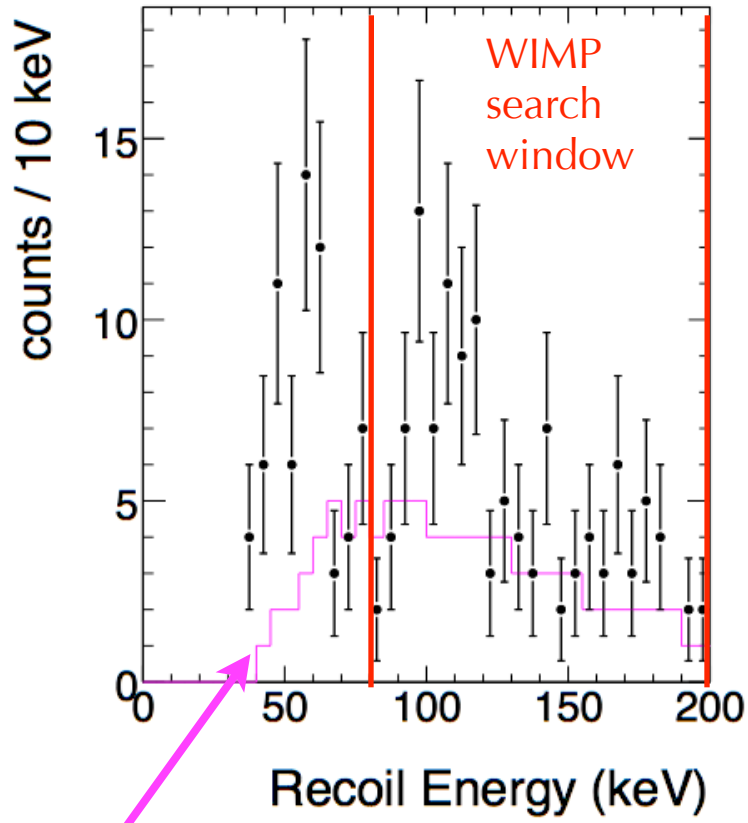


- 252-Cf neutrons
- WIMP cuts applied (alpha, RBI, worm)
- 50 keV events seen

Recoil Candidates

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}

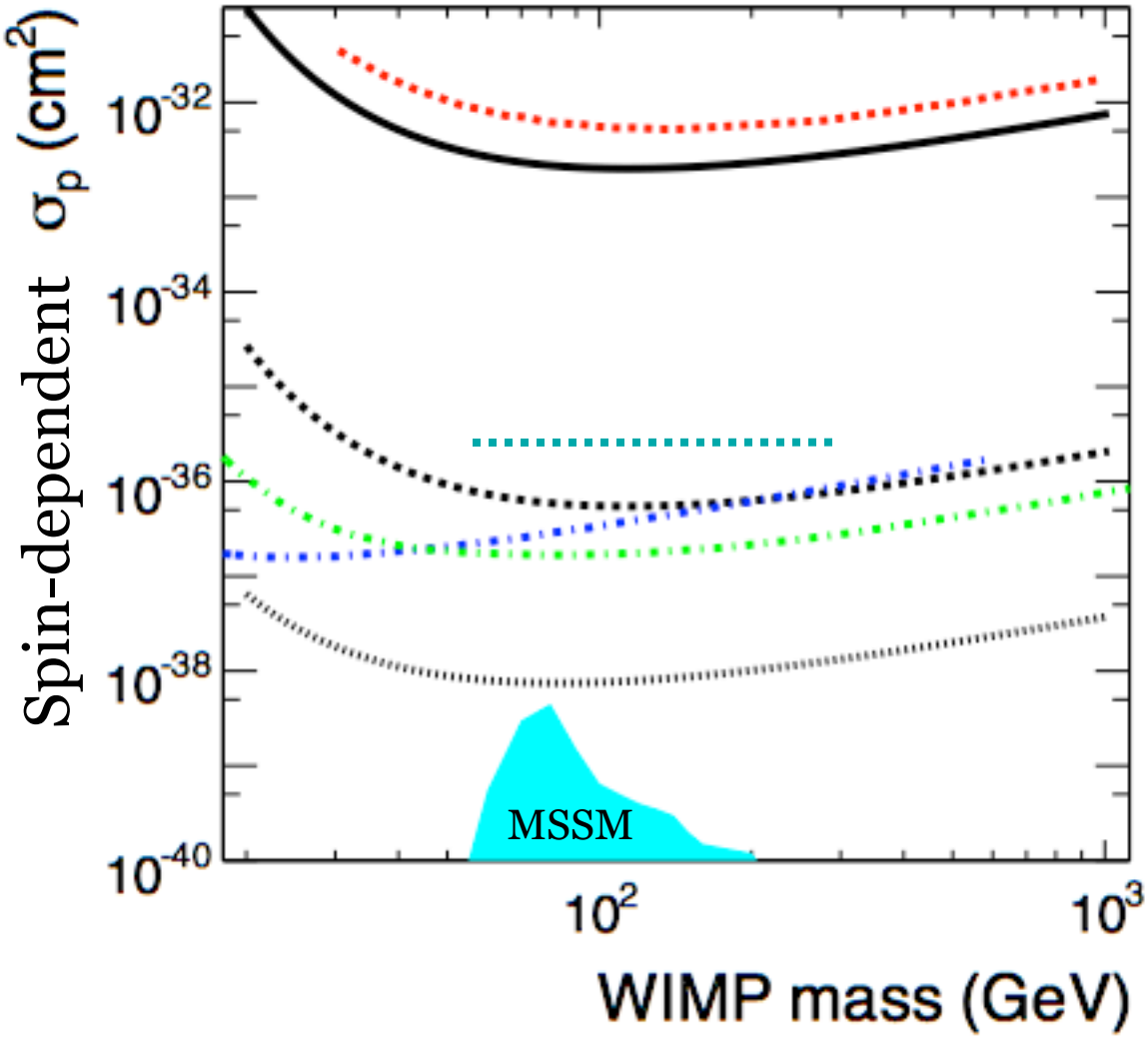




Neutron background expectation 74 events

T. Nakamura et al. J. of Nucl. Sci. and Tech. 42 No. 10, 843 (2005).

10L Surface Run Result



NEWAGE@Kamioka

DMTPC 10L Surface

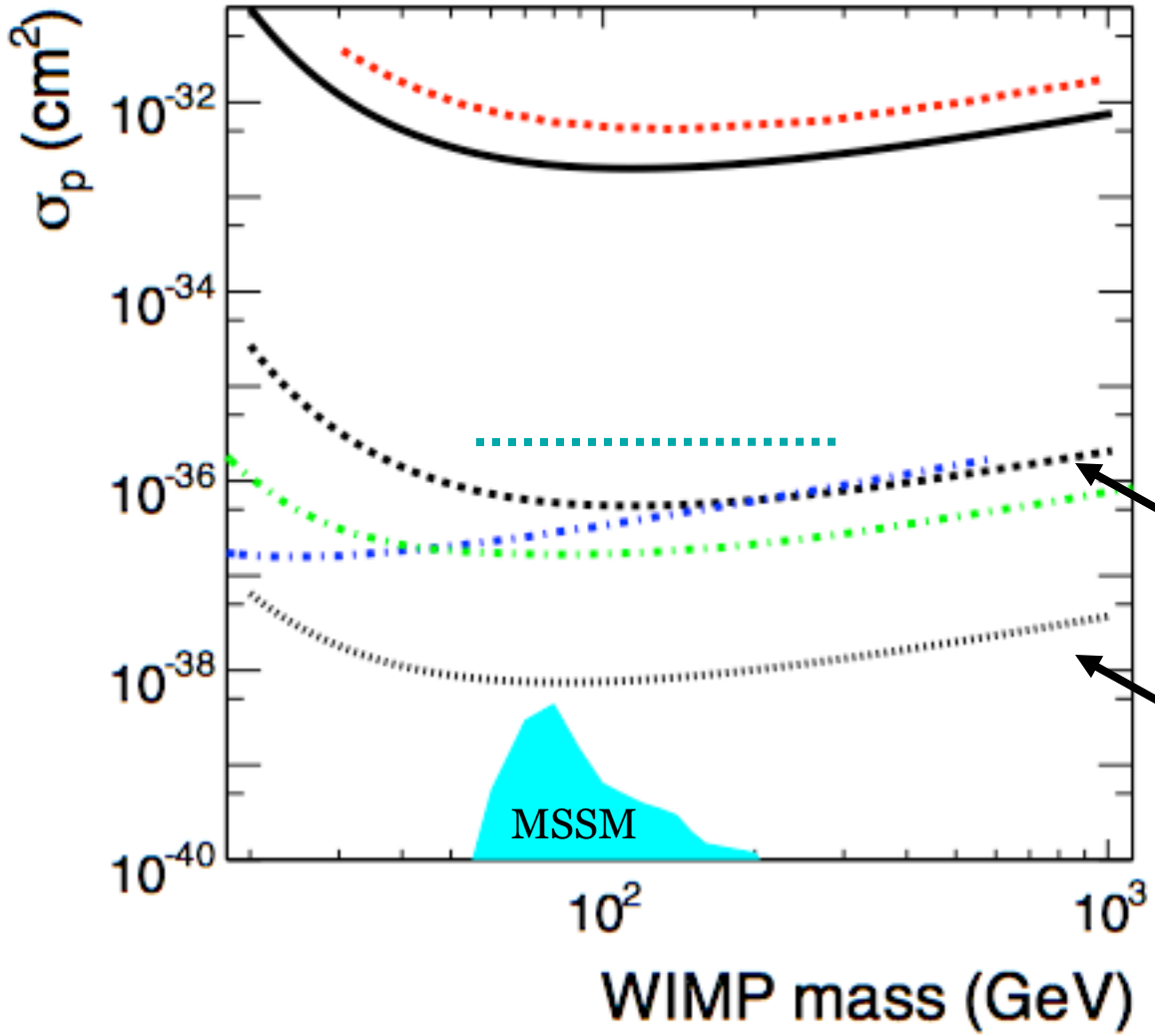
DRIFT (UCLA2010)

PICASSO (2009)

KIMS (2009)

S. Ahlen et al.
arXiv:1006.2928

10L Surface Run Result



DMTPC 10L Surface

4shooter at WIPP

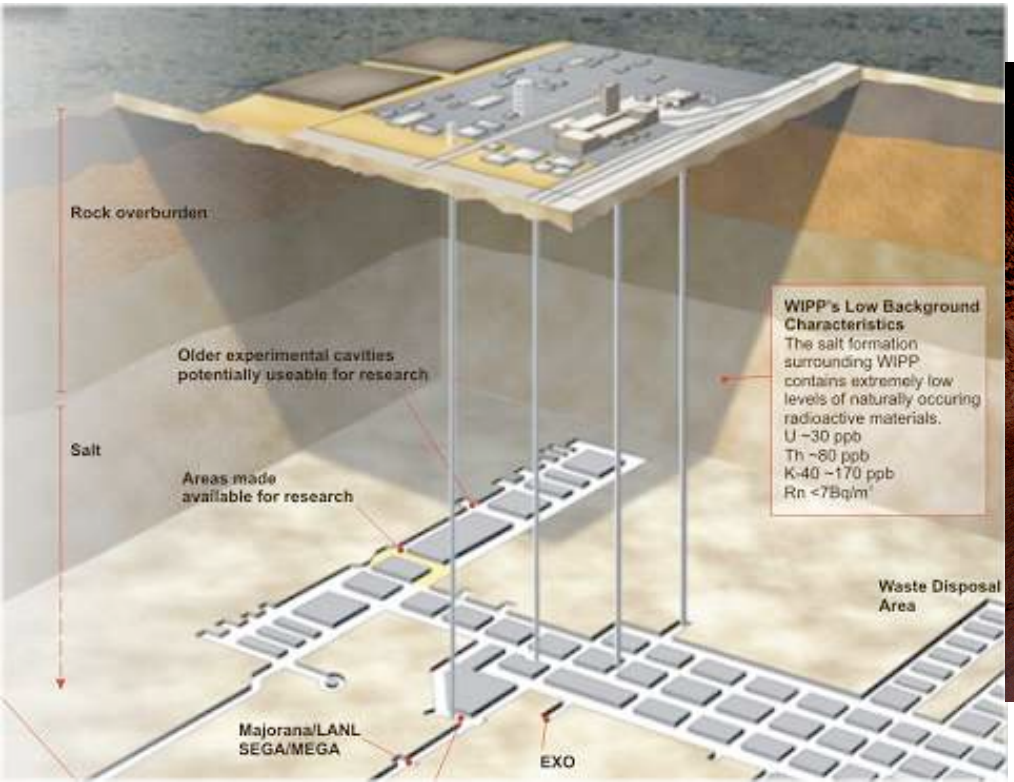
m³ at WIPP

S. Ahlen et al.
arXiv:1006.2928

Underground operations at WIPP

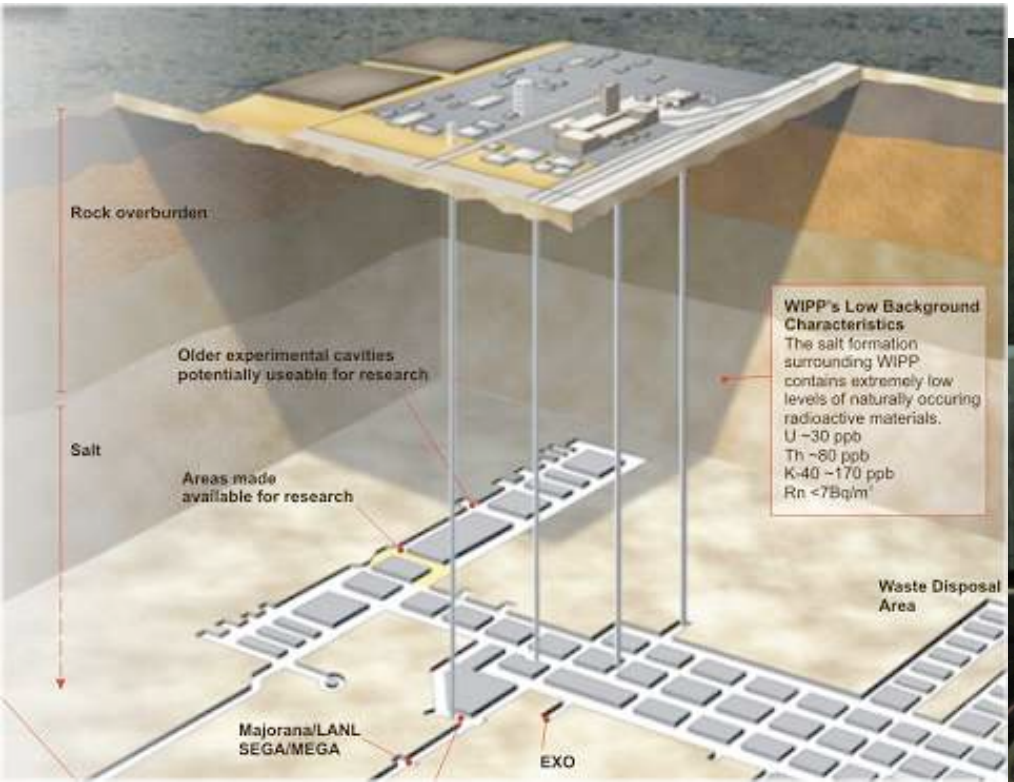
New Mexico, USA

- Low radon level < 7 Bq/m^3
- 1.6 km water equivalent
- << 1 event/yr neutron background



Underground operations at WIPP

- Underground lab delivered
- Electrical/internet by end of July
- Occupy in August



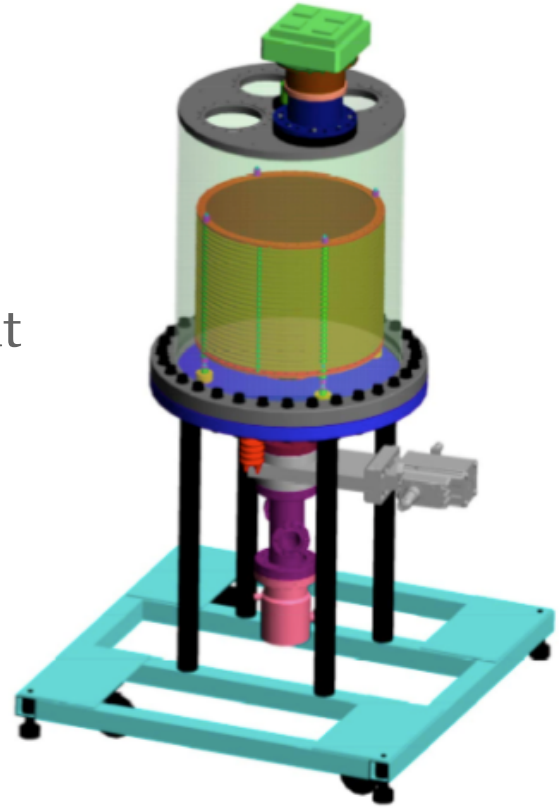
The 4shooter

Attention to materials
high-purity copper
non-thoriated welds

Higher vacuum
more stable gain

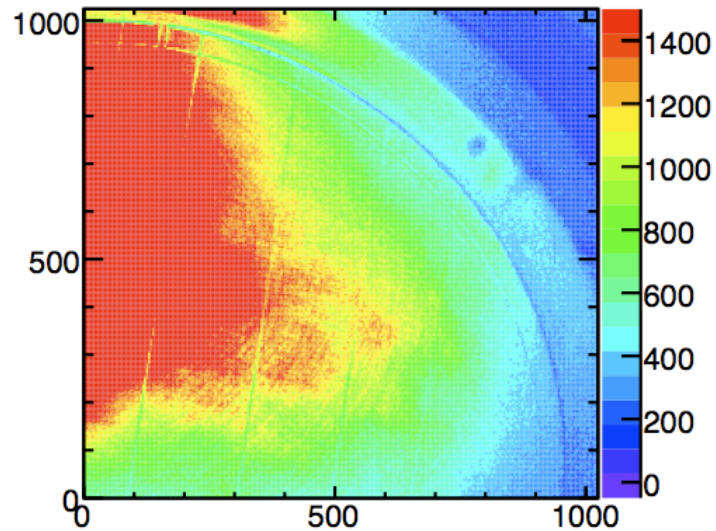
Advanced charge readout
3D track recon
worm veto

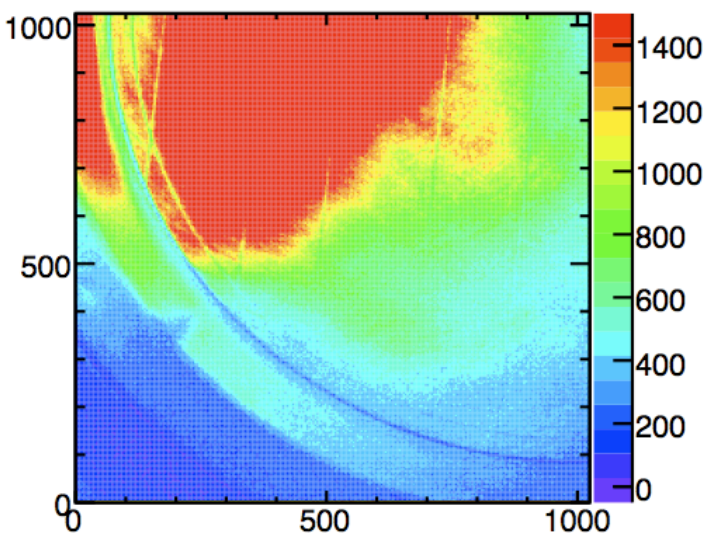
PMT signal
3D track recon
worm veto

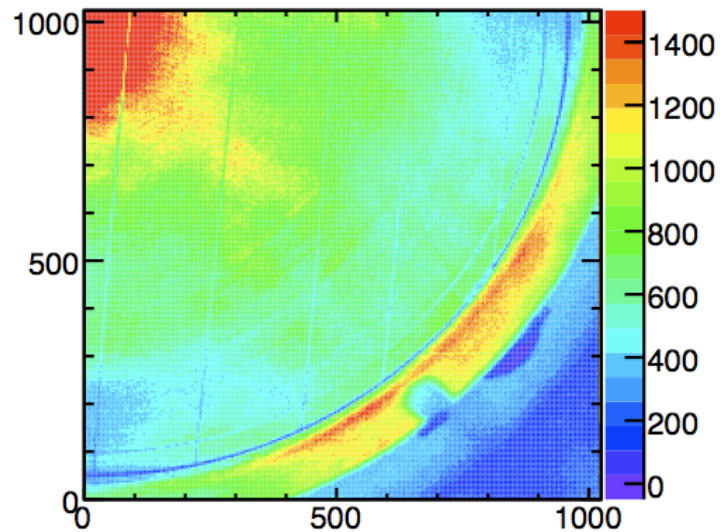


4Shooter -- illuminated anode

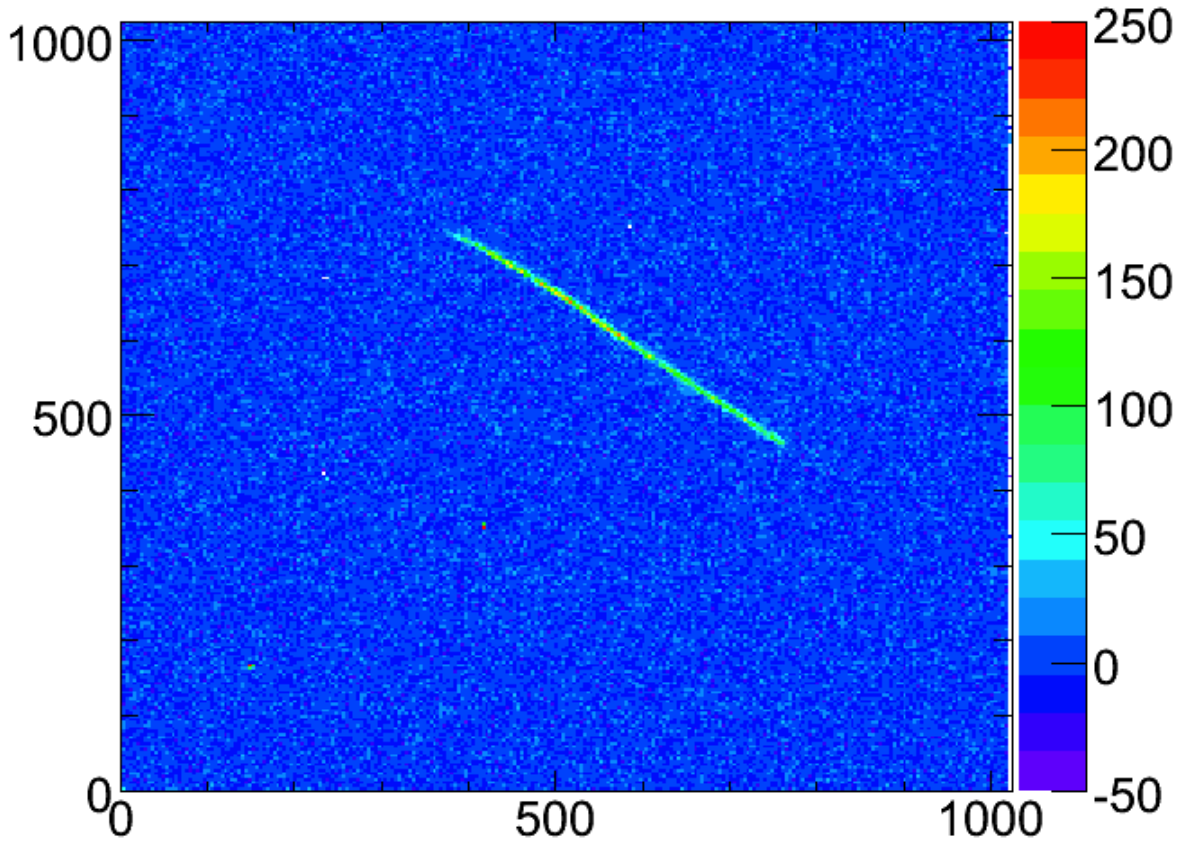
Light shining through this camera port



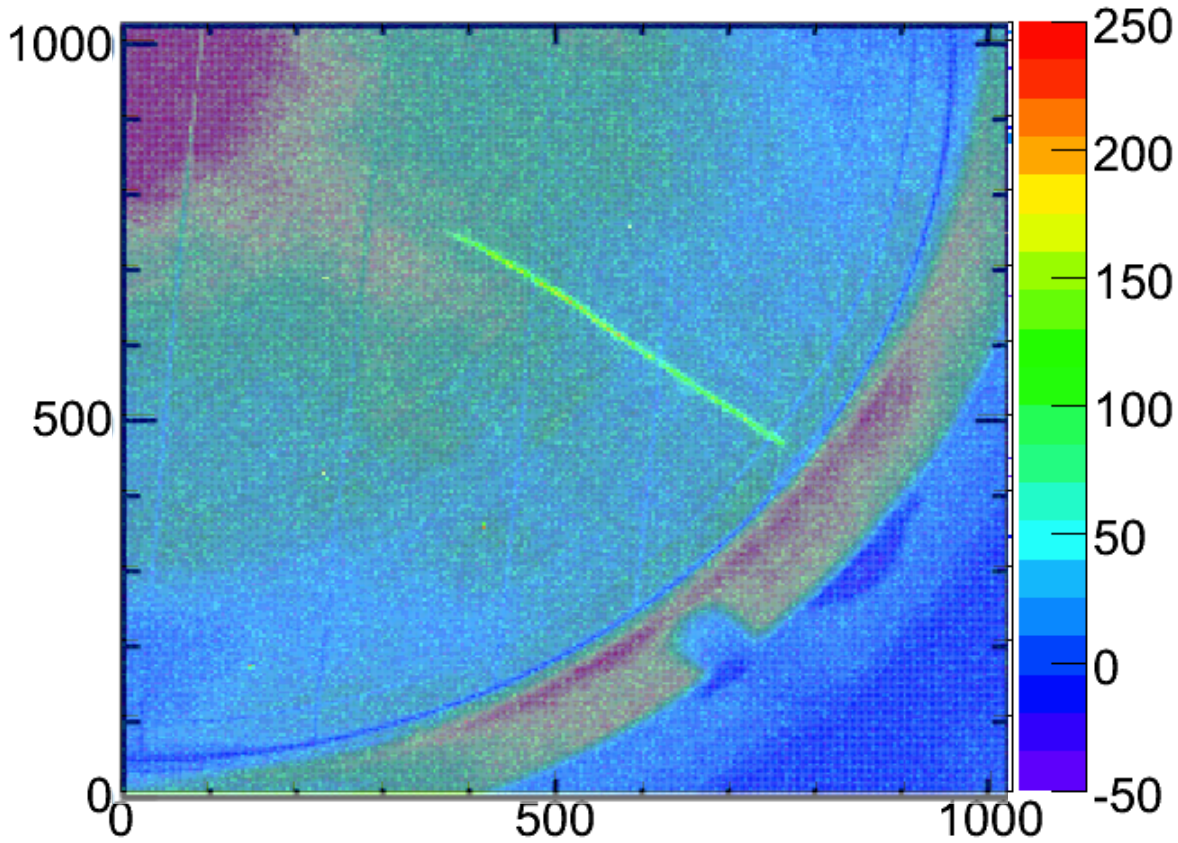




4shooter -- tracks

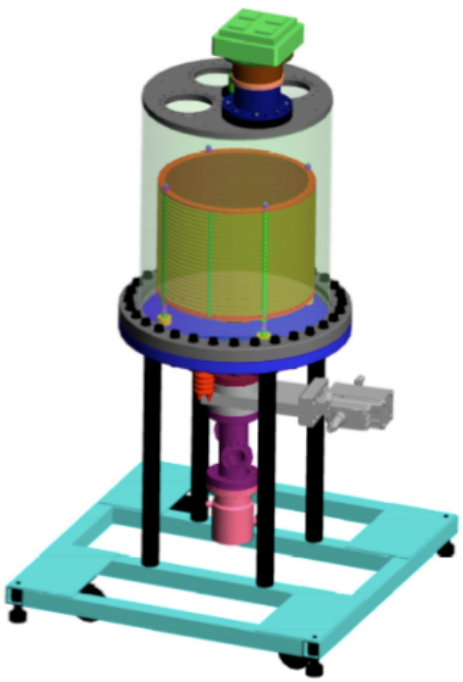


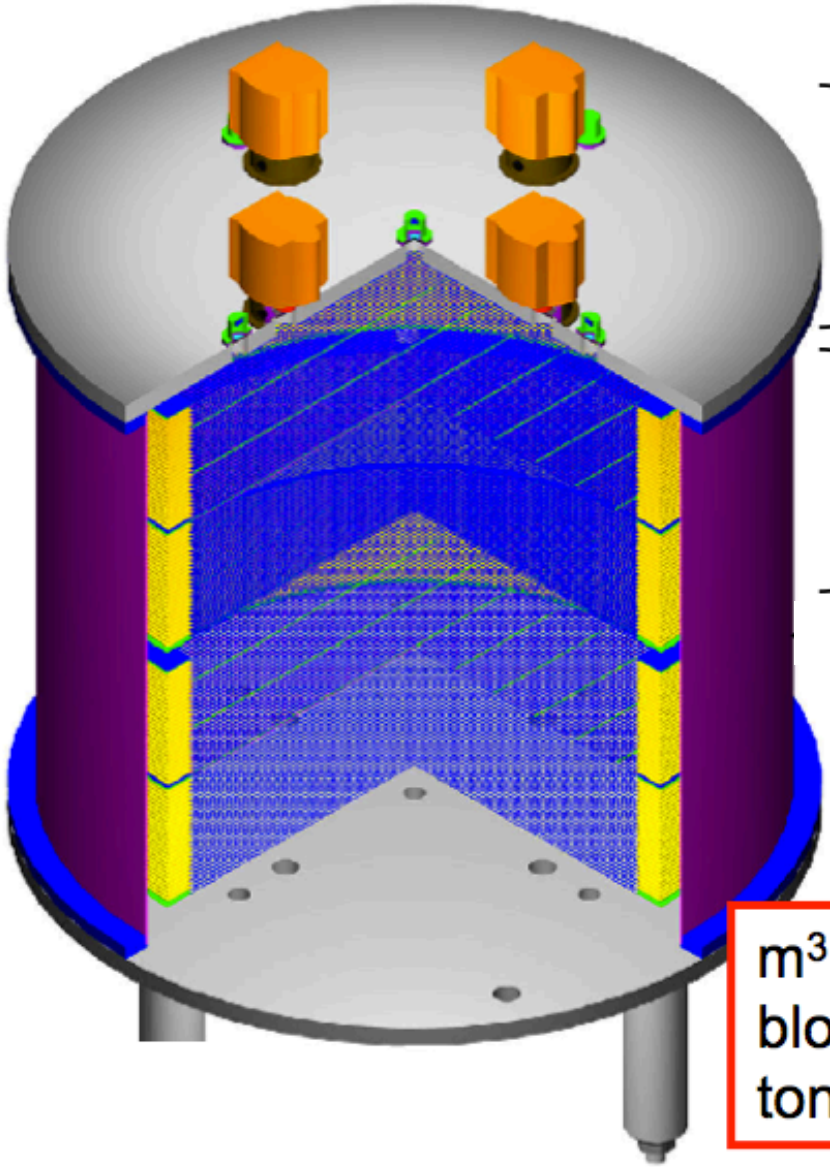
4shooter -- tracks



The cubic meter detector

- 4shooter = mini-m^3
- Funded to build 1 m^3





m^3 = a building block for multi-ton detector

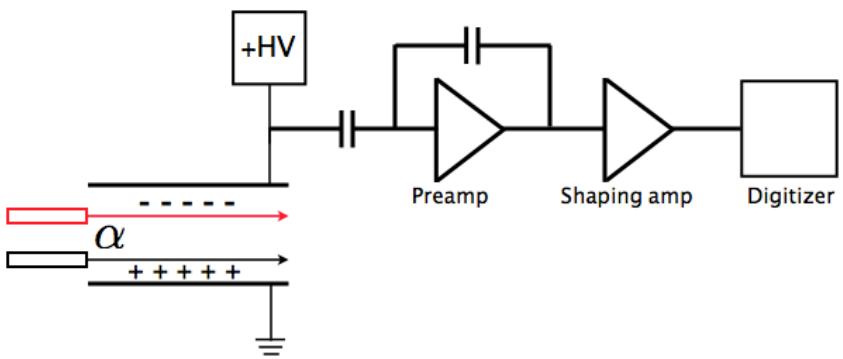
James Battat, MIT

DMTPC: Summary

- Demonstrated head-tail capability
- Surface run background study and SD limit
- Migrating underground to WIPP
- 4shooter detector commissioning
- Cubic meter funded, design underway

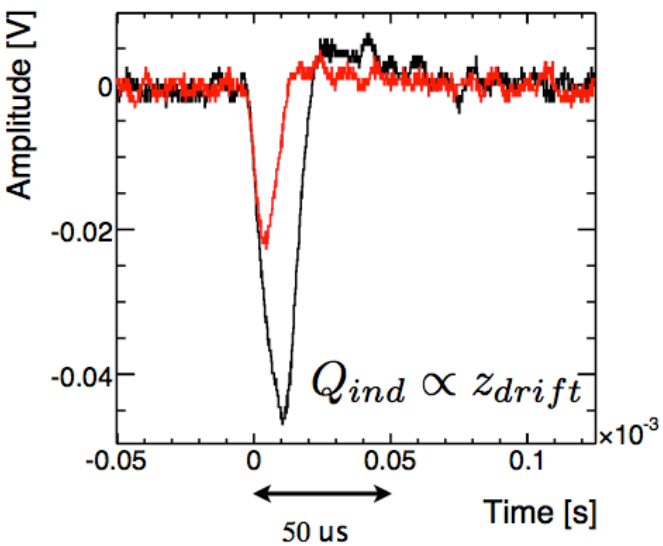
J.Battat,
S.Henderson

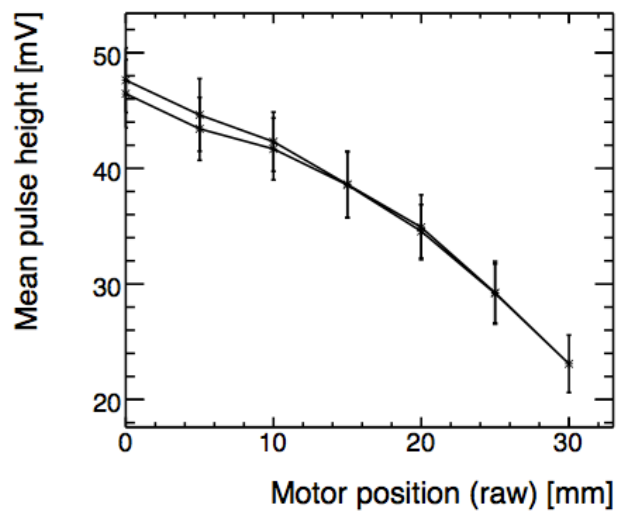
Fiducialization: z



z coordinate from pulse height

$$Q_{ind} = Q_s \frac{z_{drift}}{d}$$





END