DMTPC R&D since the Surface Run

James Battat

DMTPC Collaboration

MIT Pappalardo Fellow ('08-'11)

Bryn Mawr College (2011+)

DMTPC Collaboration

Boston University

S. Ahlen*, M. Chernicoff, A. Inglis, H. Tomita

Brandeis University

A. Dushkin, L. Kirsch, H. Ouyang, G. Sciolla, H. Wellenstein*

Bryn Mawr College

J. Battat*

Massachusetts Institute of Technology

C. Deaconu, D. Dujmic, P. Fisher*, S. Henderson, A. Kaboth, G. Kohse, R. Lanza, J. Lopez, E. Nardoni, R. Vanderspek

Royal Holloway University of London

J. Monroe**

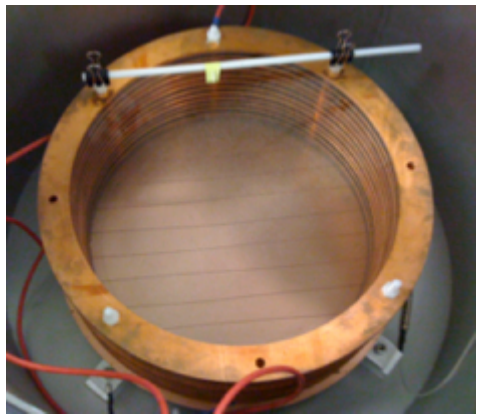
*) PI, **) Spokesperson

DMTPC detectors

Cylon Prototype

10L

R&D



Cylon

4Shooter

Construction & operations

Directionality

Recovering the 3rd dimension

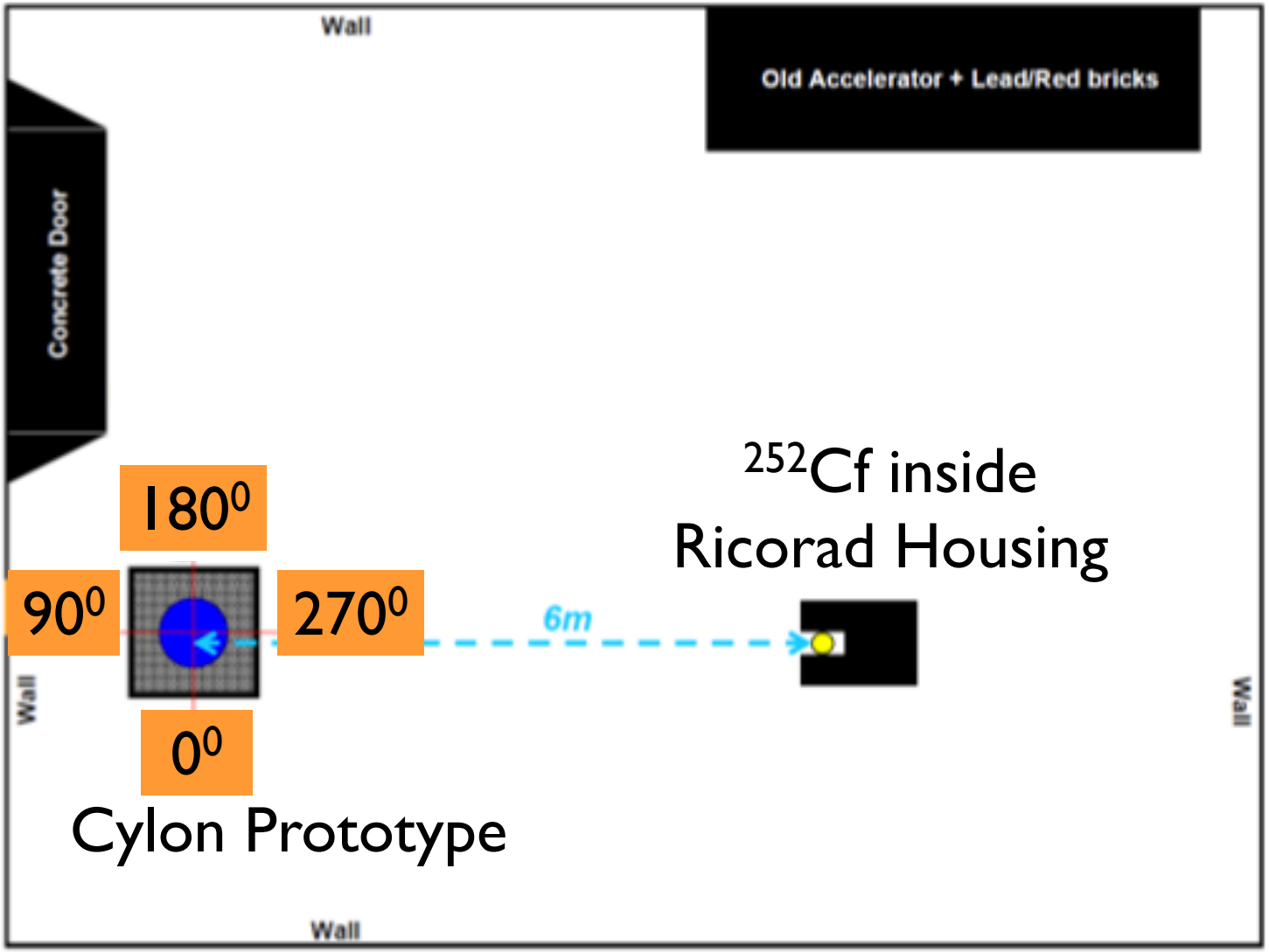
Triggering & vetoing

Cylon Prototype

EMCCD (Andor iXon +888)
30 cm diameter
20 cm drift

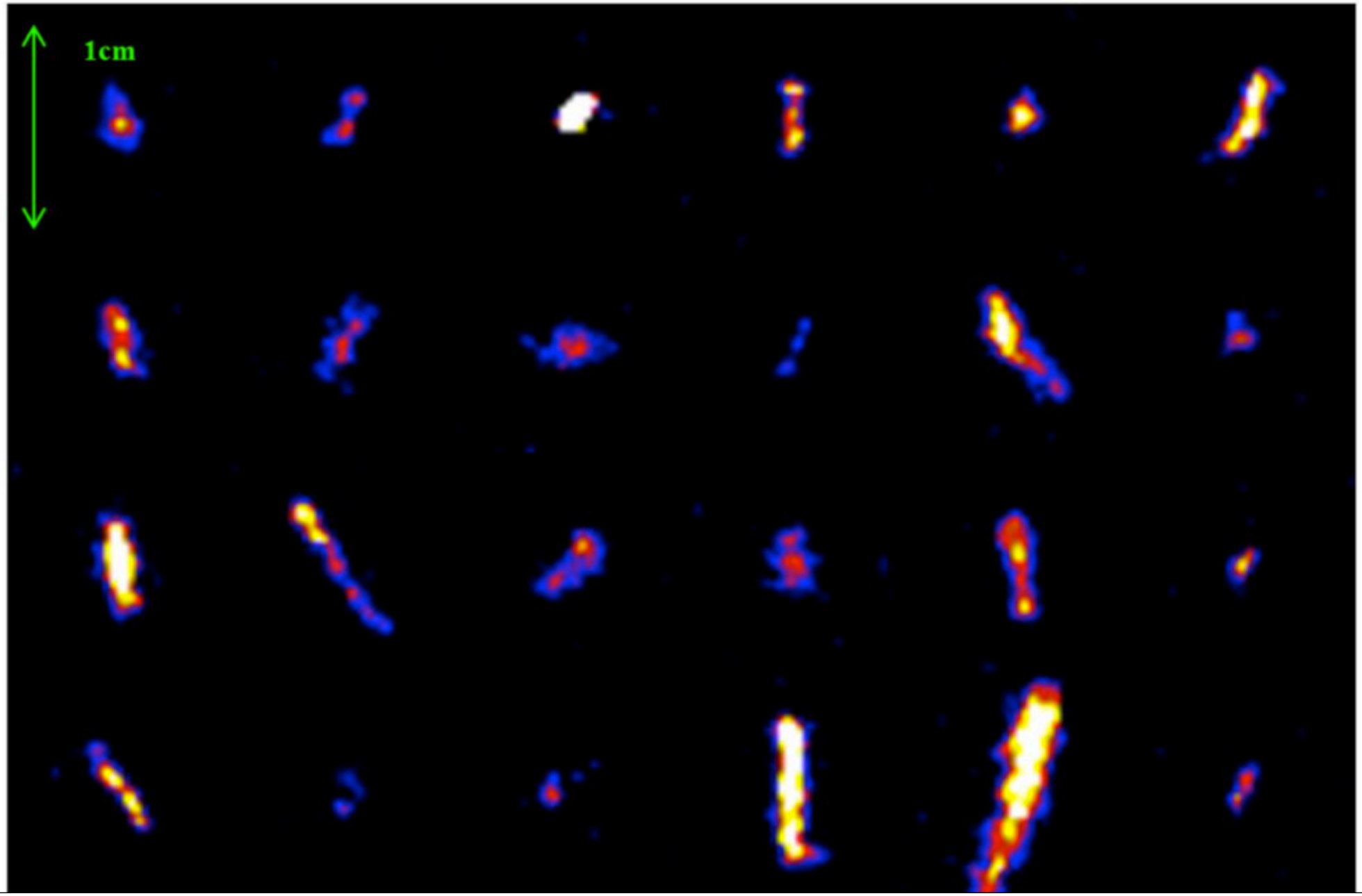
Directionality in Cylon prototype

Hartwig, Inglis, Tomita



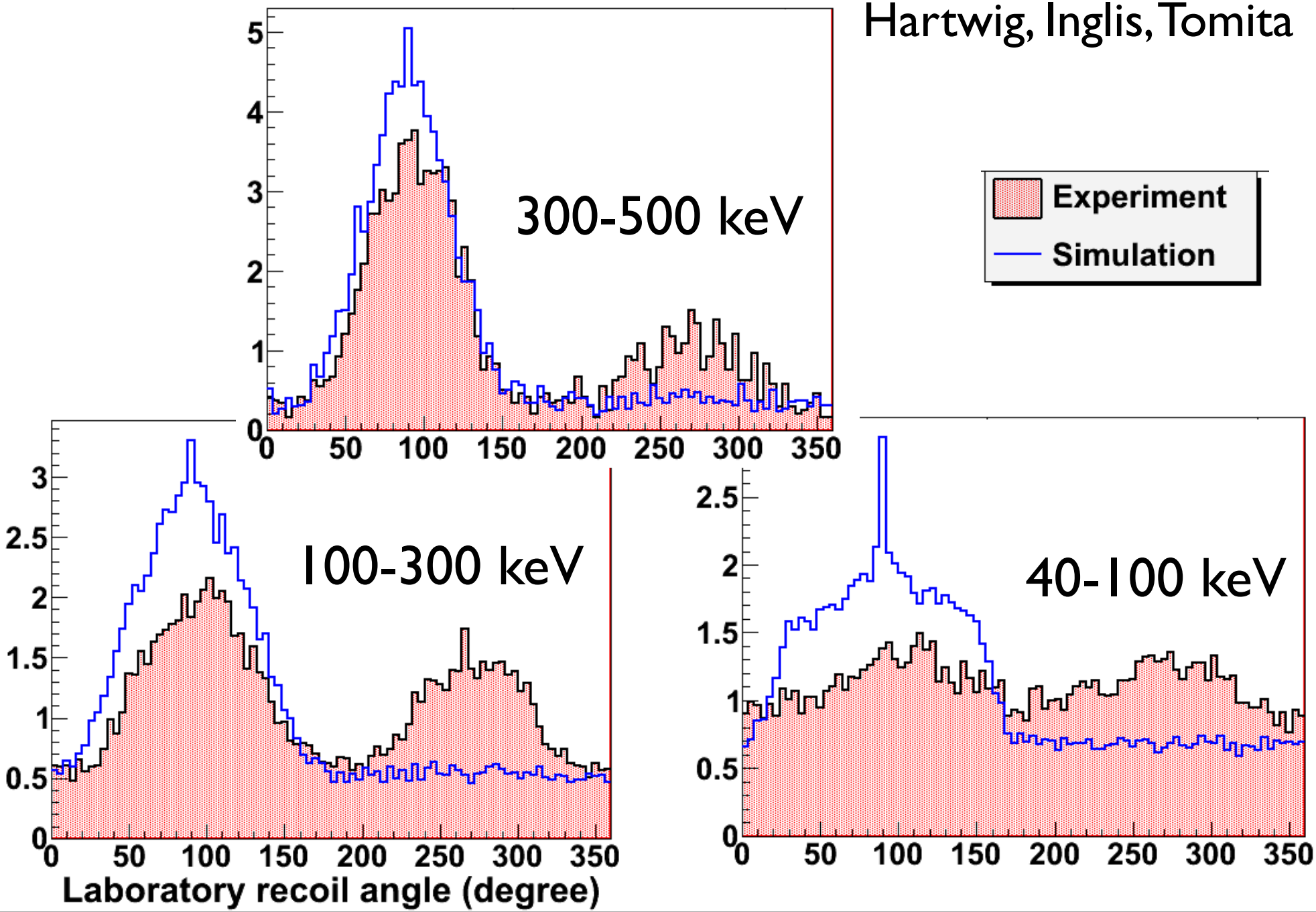
C, F Recoils in Cylon Prototype

^{252}Cf source 6 m away, 40 Torr CF_4 E_R ~ 50 keV to 300 keV



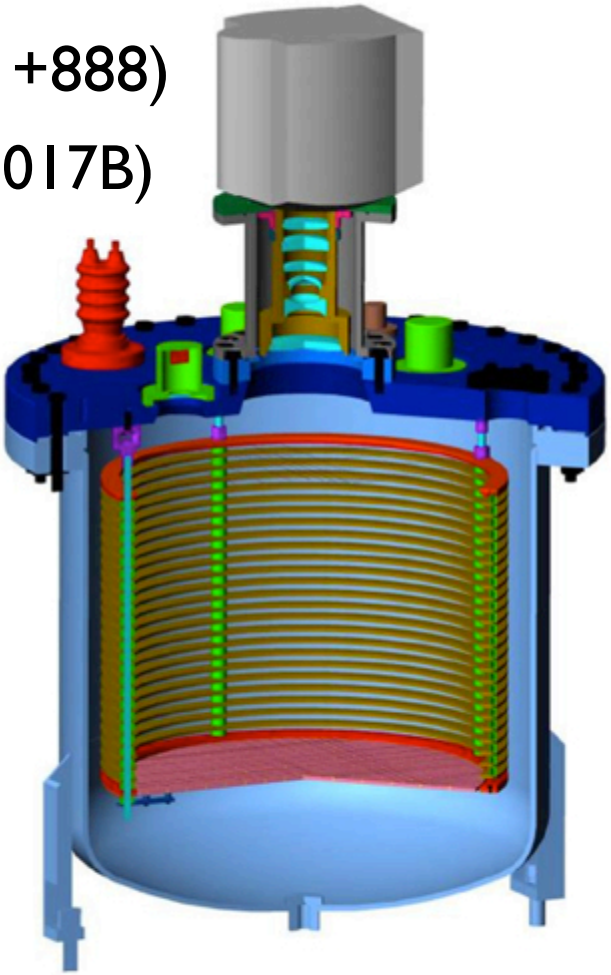
Directionality in Cylon prototype

Hartwig, Inglis, Tomita



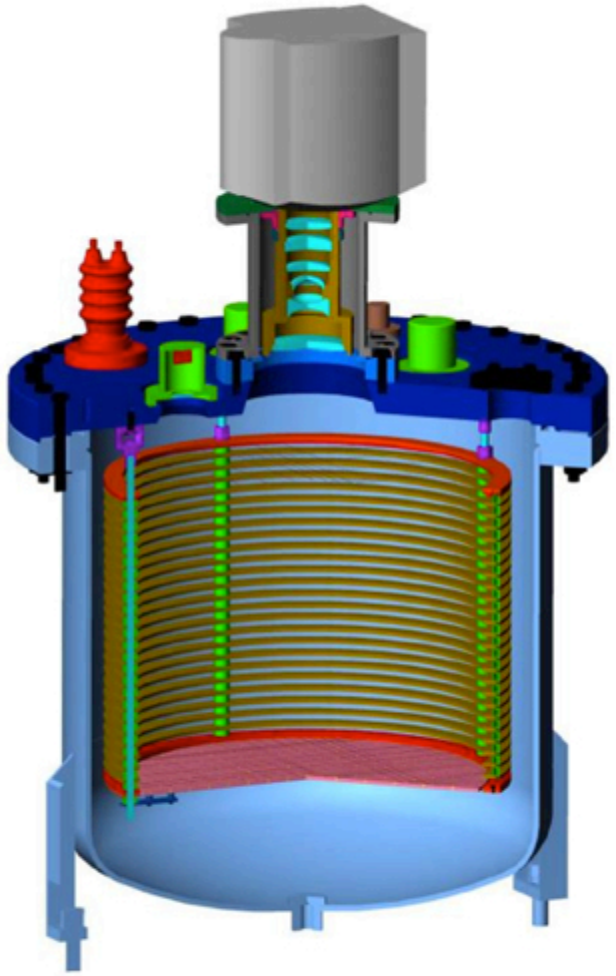
Cylon

EMCCD (Andor iXon +888)
4x PMT (Photonis XP2017B)
25 cm drift
30 cm diameter



(Design and CAD from Hermann Wellenstein)

Triggering with Cylon's PMTs

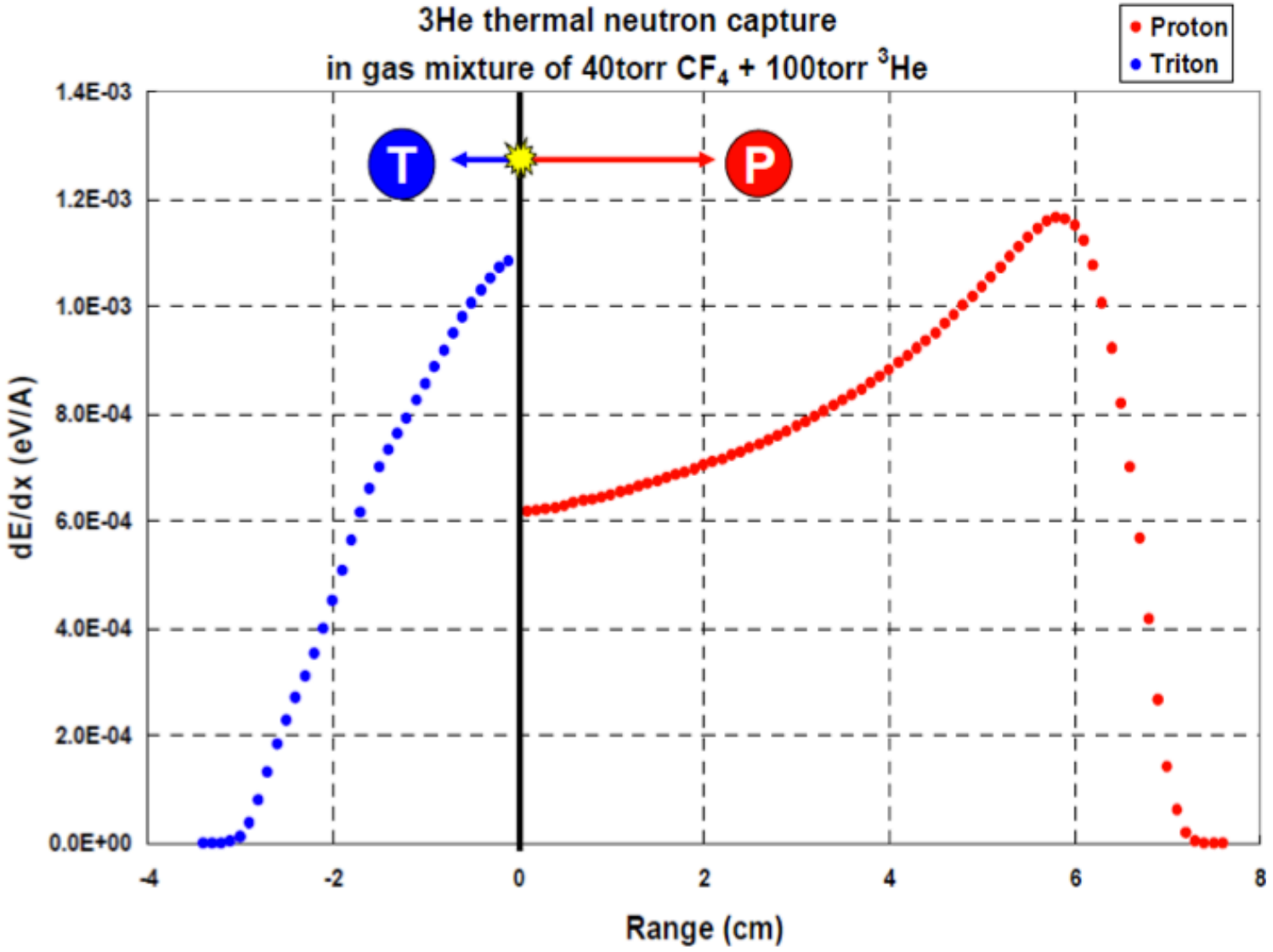


(Design and CAD from Hermann Wellenstein)

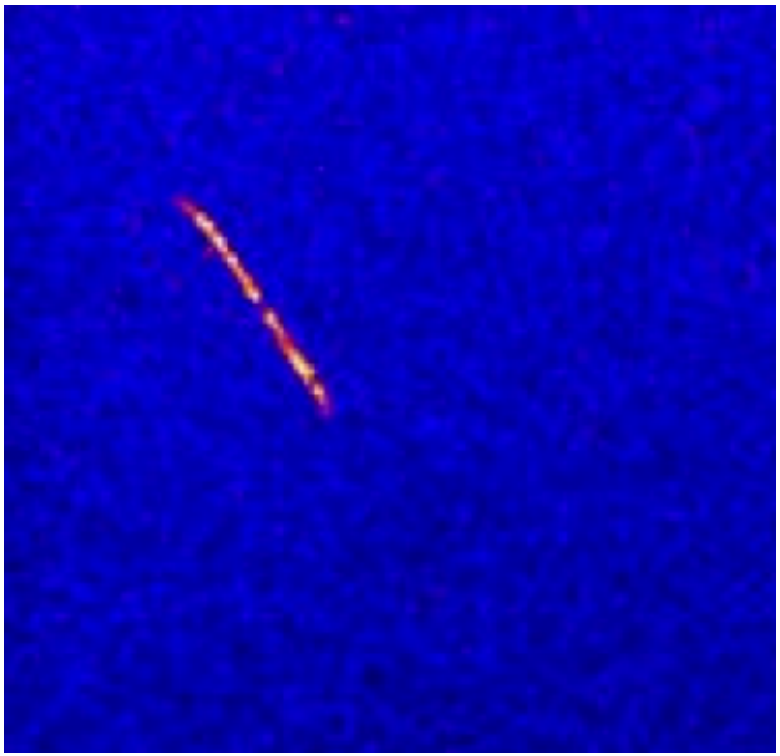
- 4 PMTs in 4-fold coincidence
- Signal = analog sum
- Trigger down to 20 keV
- Reduces backgrounds & data rate
  (60 mHz ~ 1evt /16 sec)

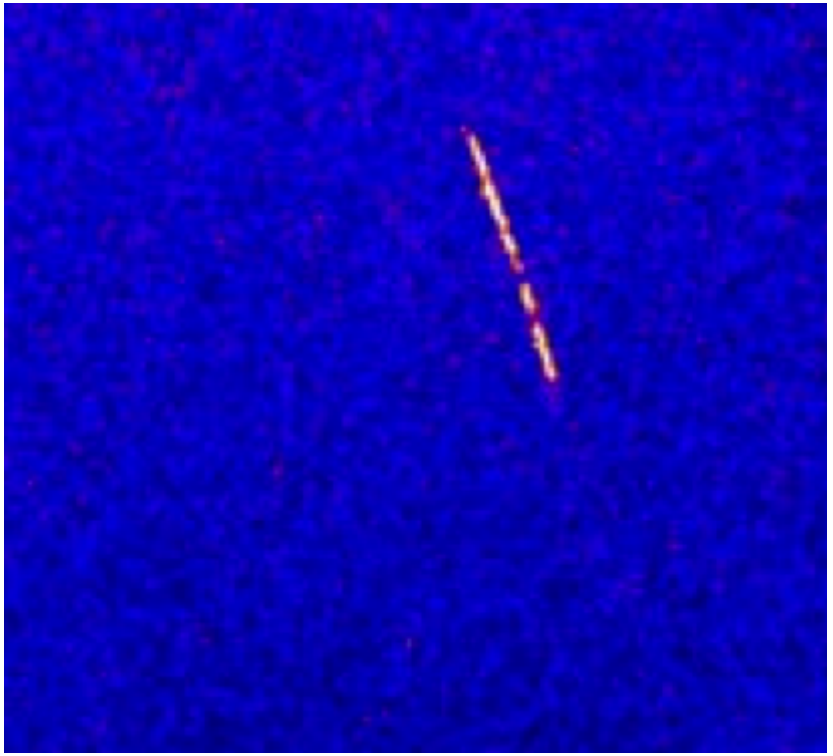
Calibrating with ^{3}He

$$n + {}^3\mathrm{He} \rightarrow \mathrm{T}(190\ \mathrm{keV}) + \mathrm{P}(570\ \mathrm{keV})$$



Sample P+T tracks

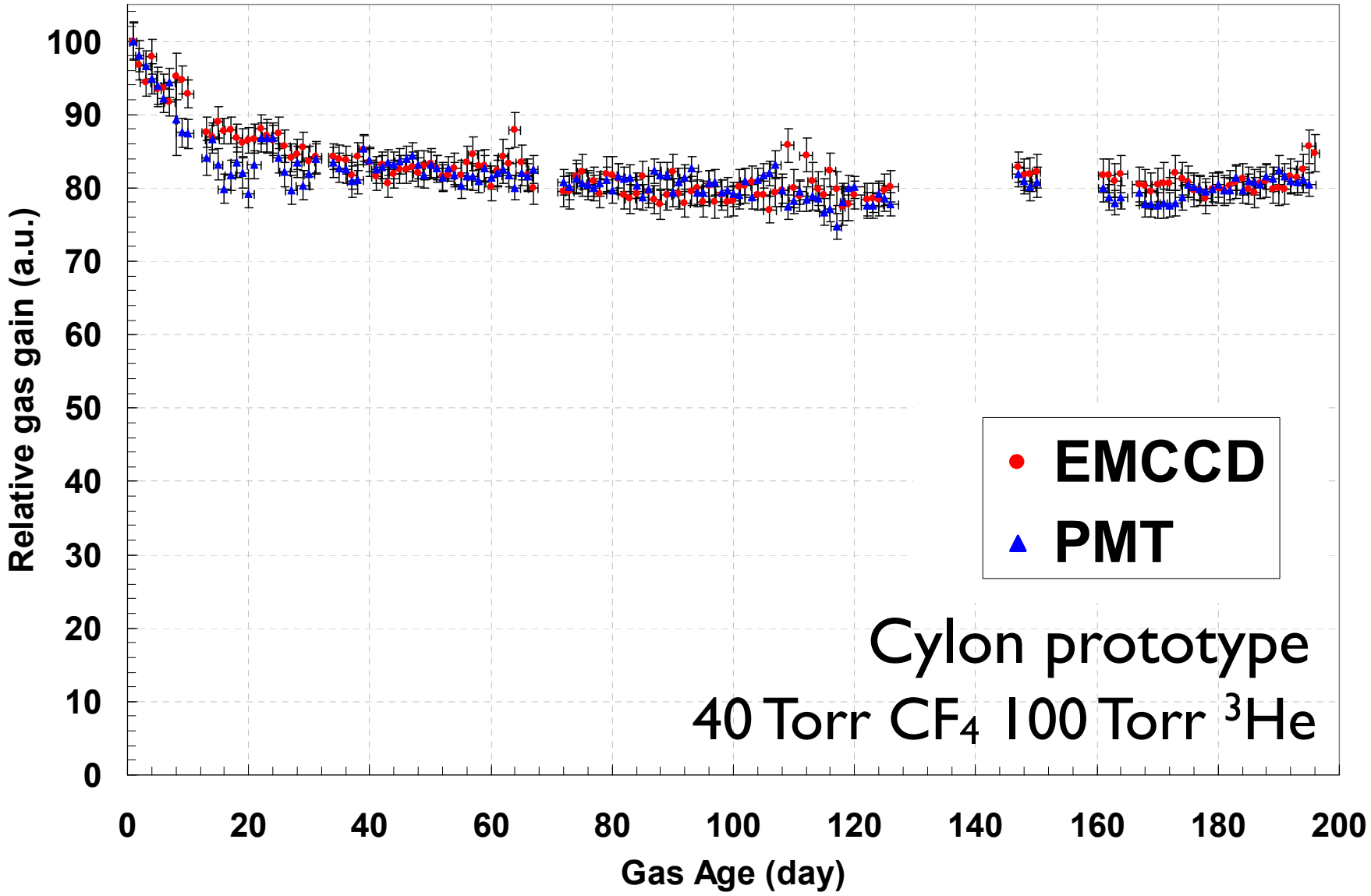




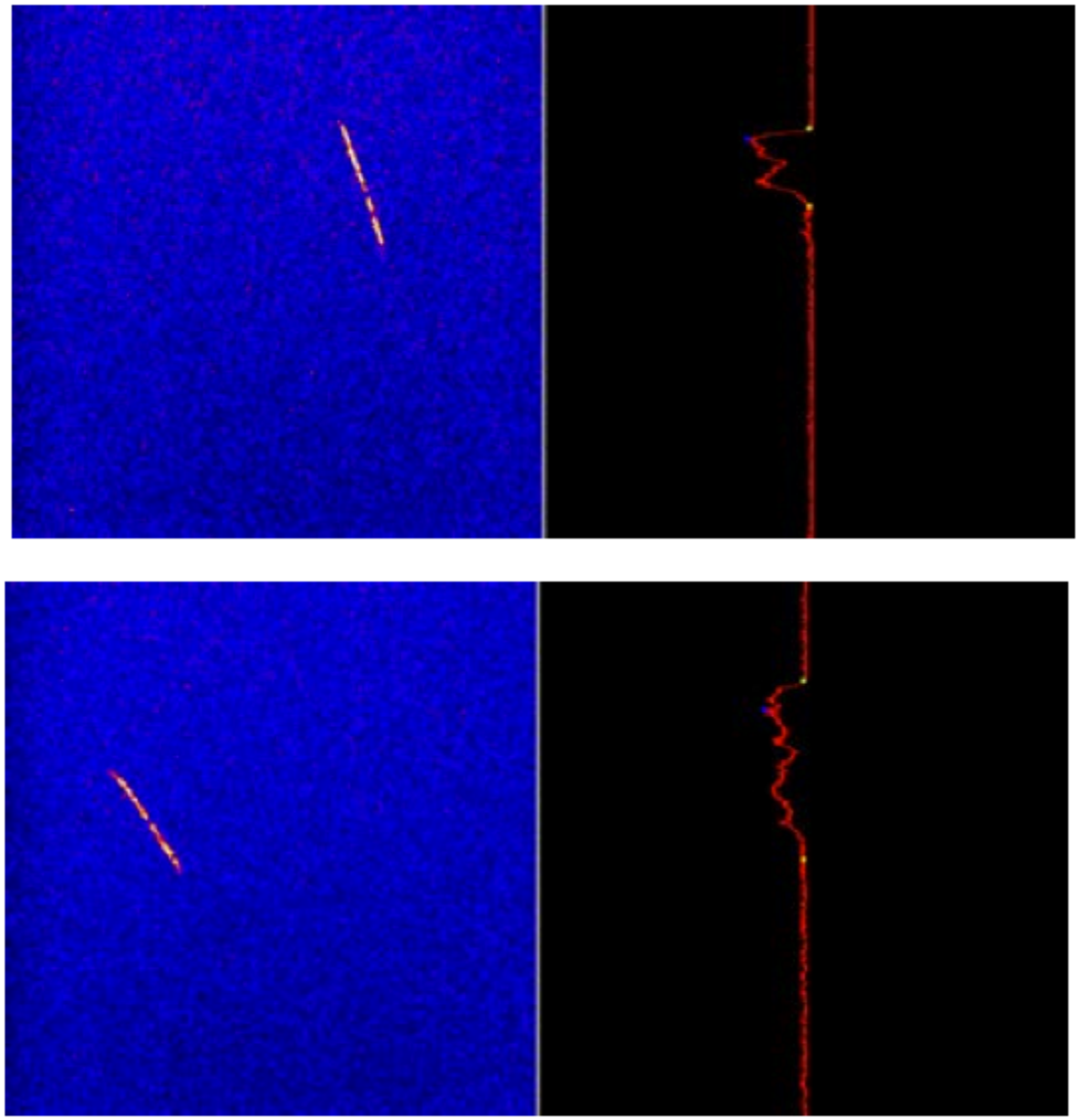
Gain stability over months

No gas exchange or recirculation

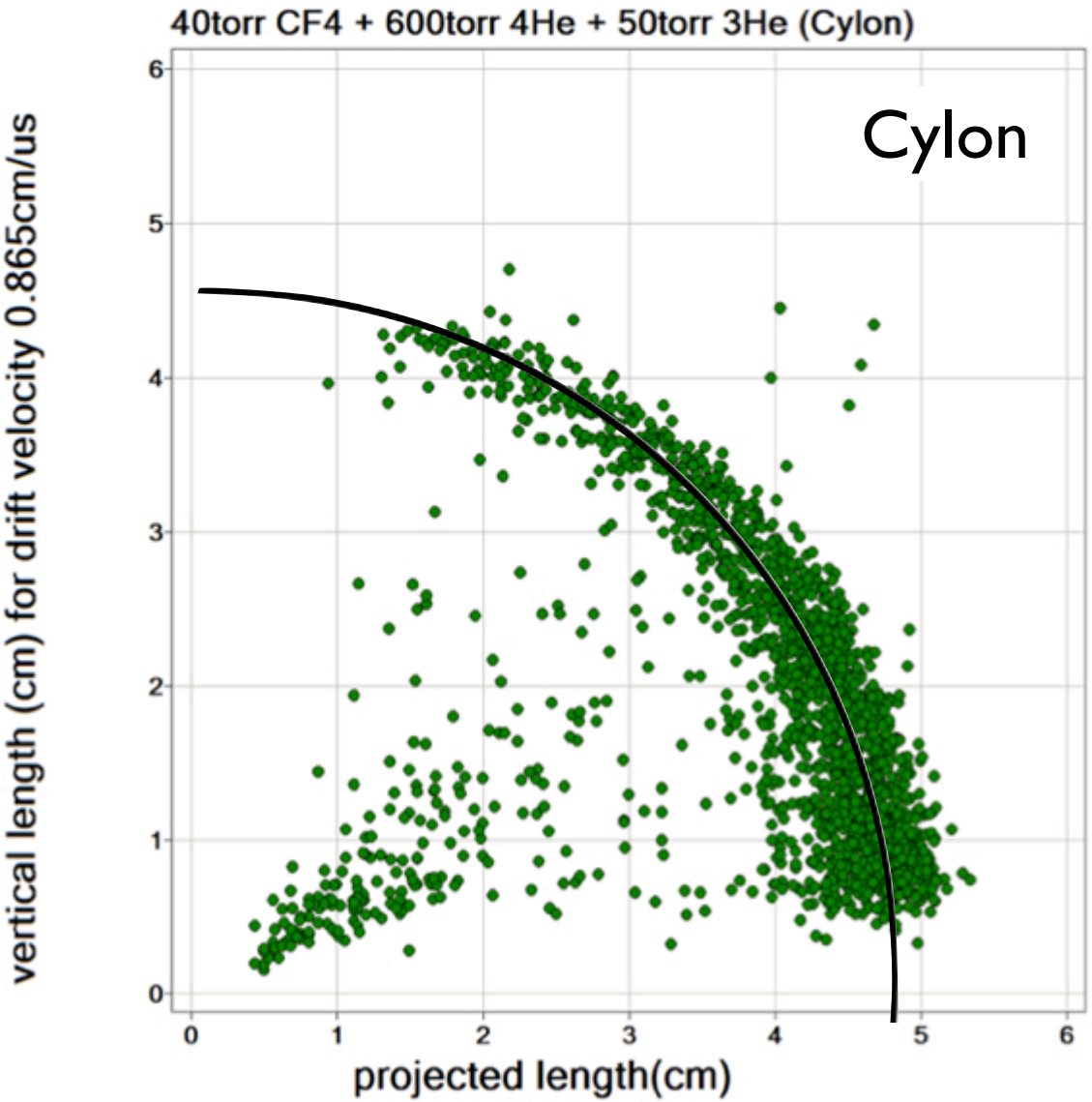
Tomita

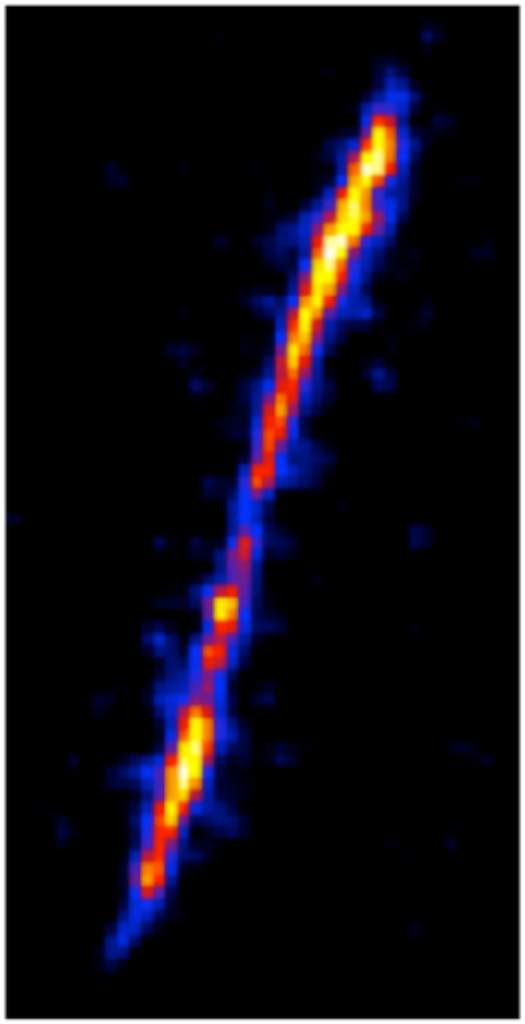


3rd dimension from PMTs



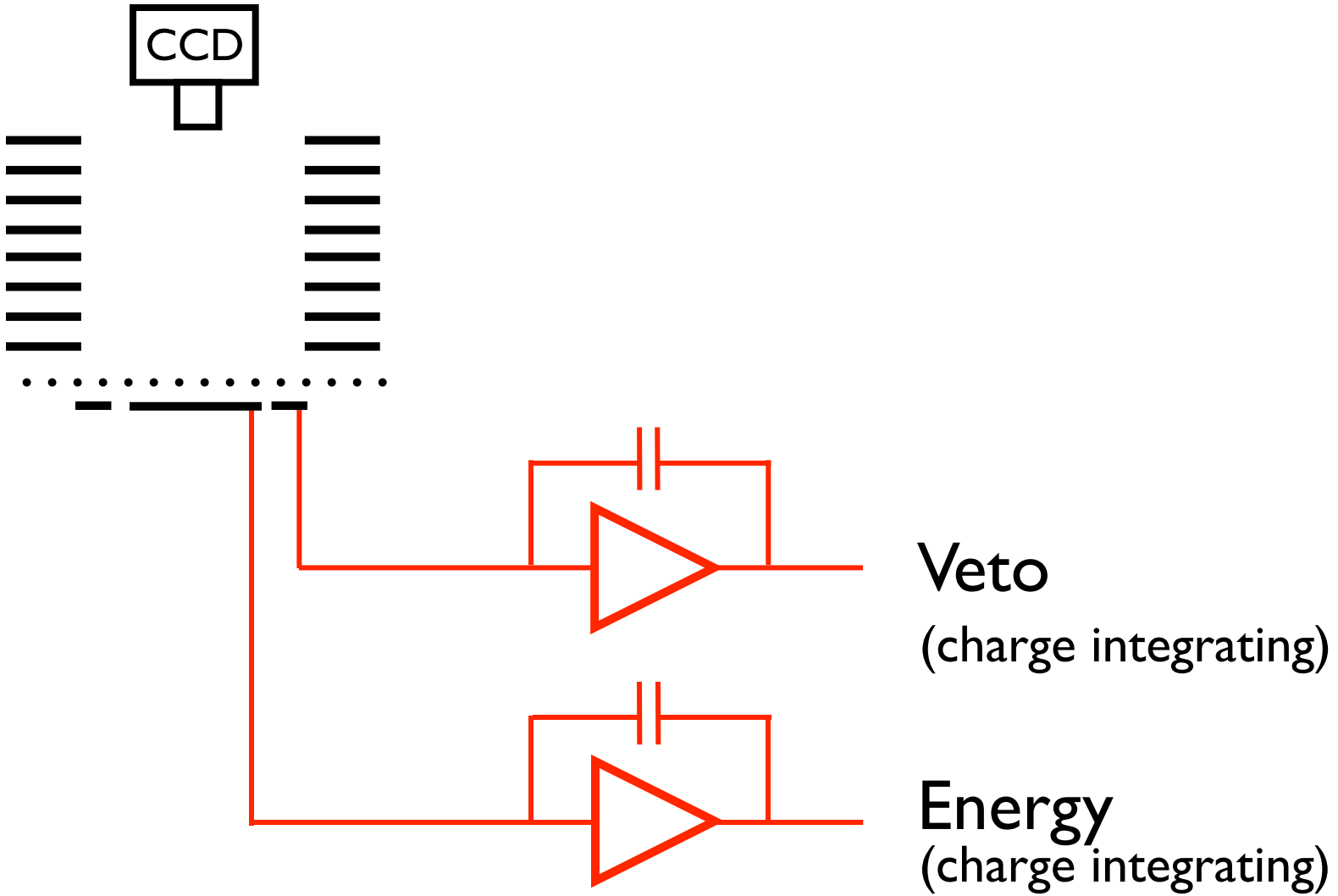
3rd dimension from PMTs





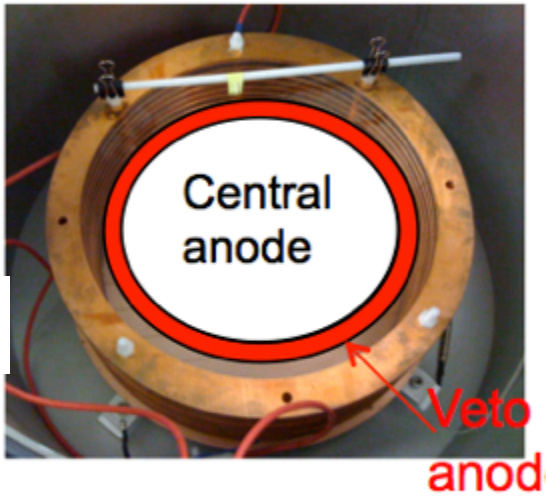
$$n + {}^3\mathrm{He} \rightarrow \mathrm{T}(190\ \mathrm{keV}) + \mathrm{P}(570\ \mathrm{keV})$$

Charge readout for triggering, particle i.d., 3D tracking and fiducialization



x,y fiducialization and CCD artifact reduction with charge

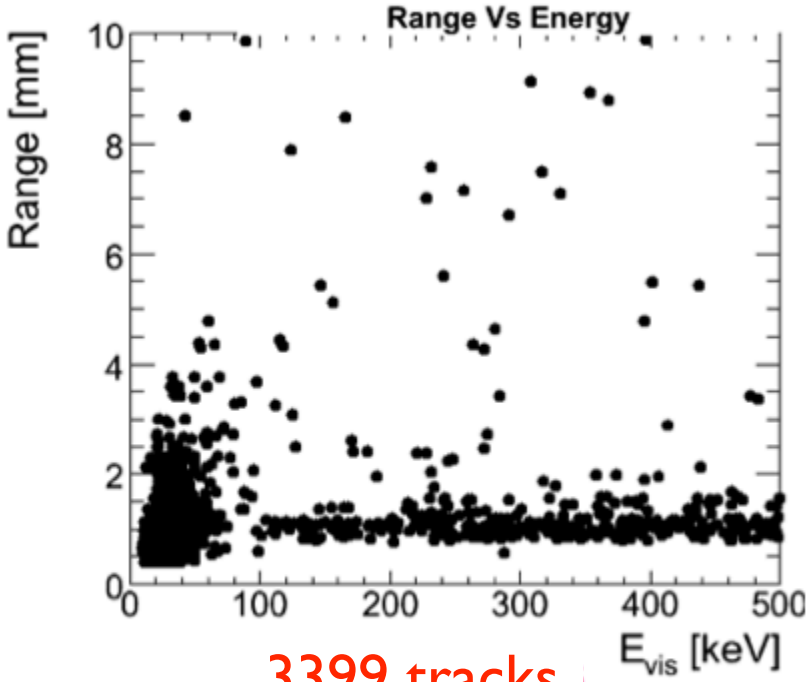
Dujmic, Lopez



Charge integrating amplifiers

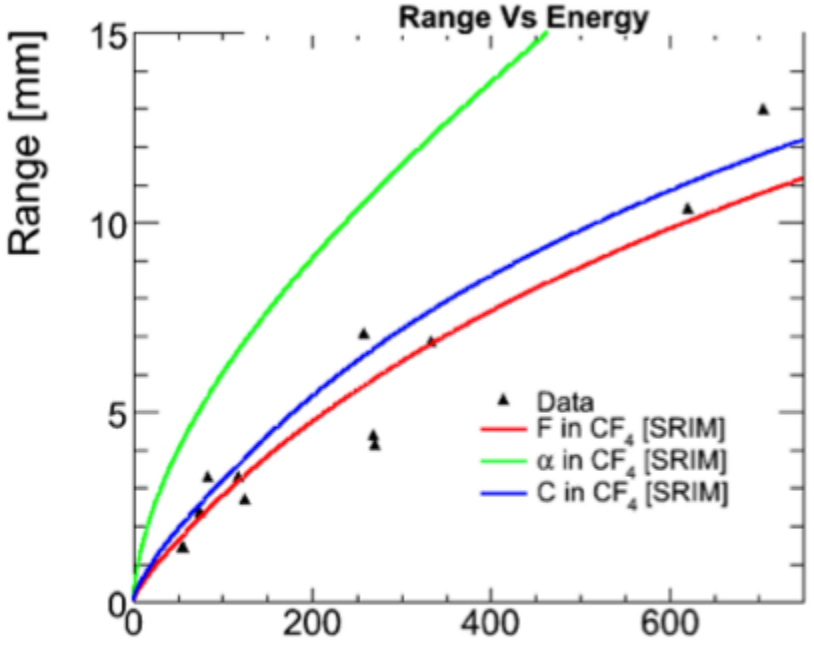
14h run: CCD only vs. CCD+charge

Recoil candidates in CCD only



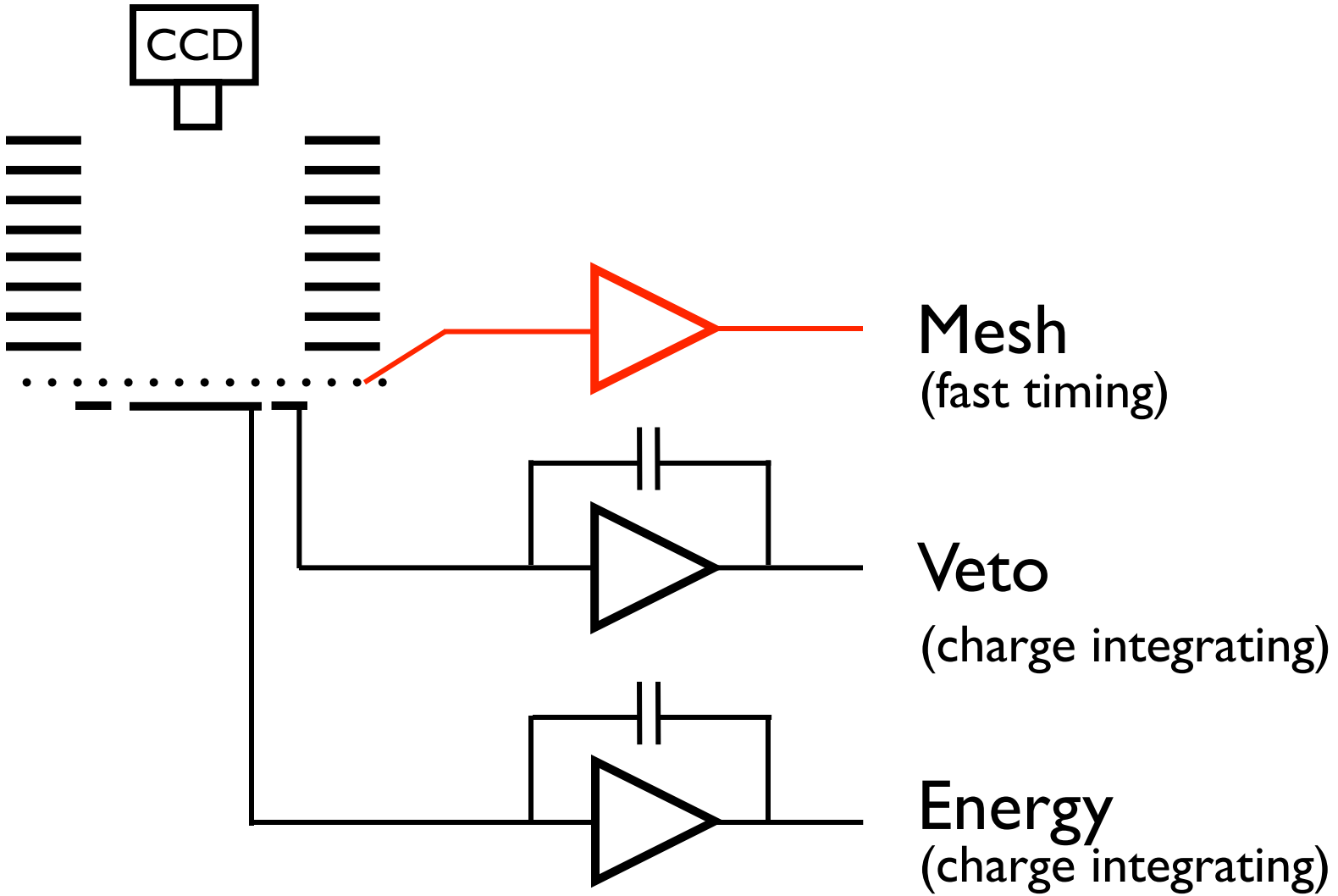
3399 tracks

+ charge in central anode, not veto



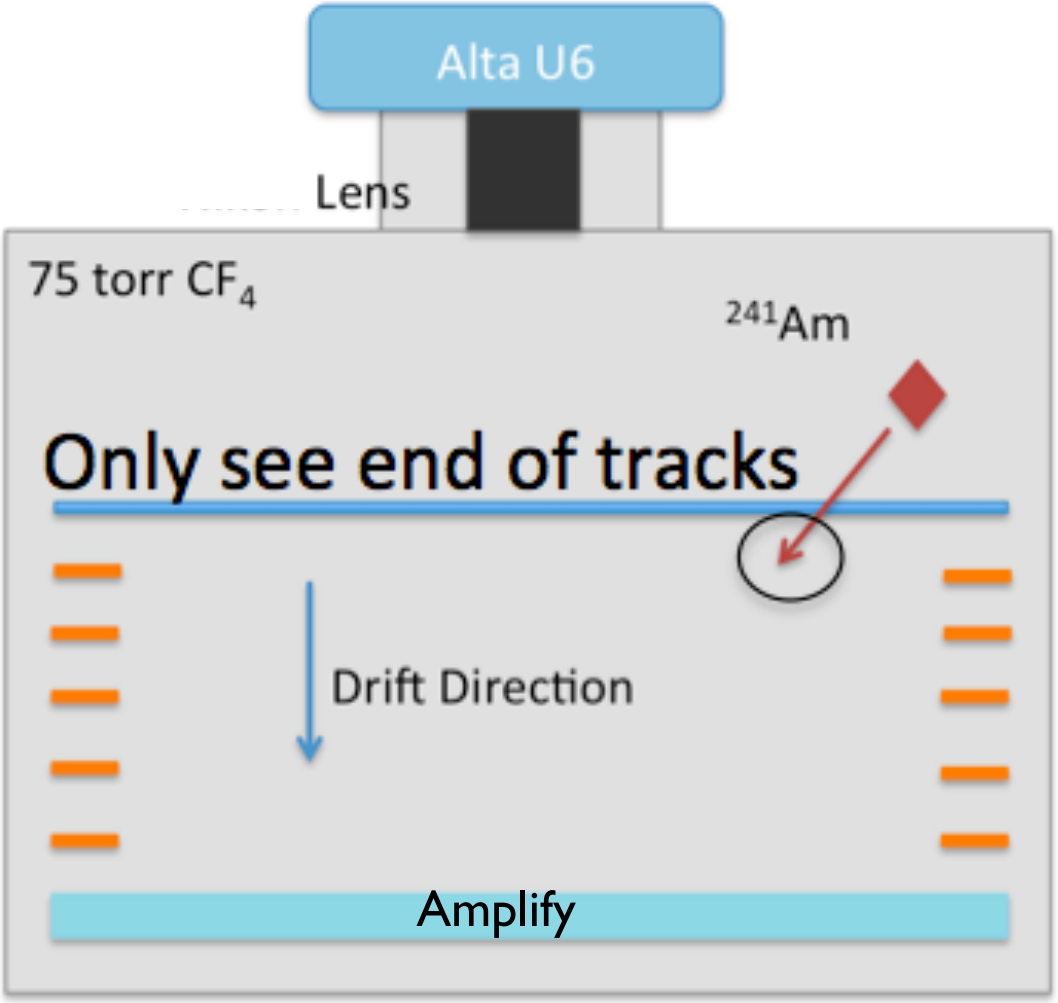
12 tracks, NR-like

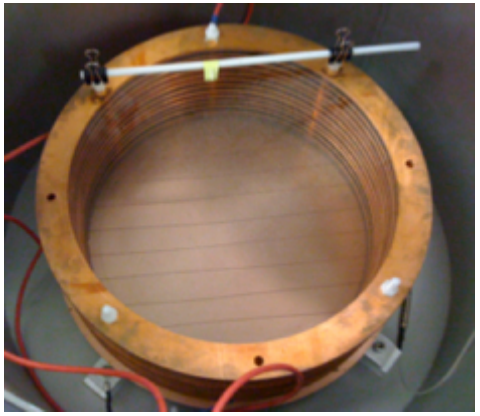
Charge readout for triggering, particle i.d., 3D tracking and fiducialization

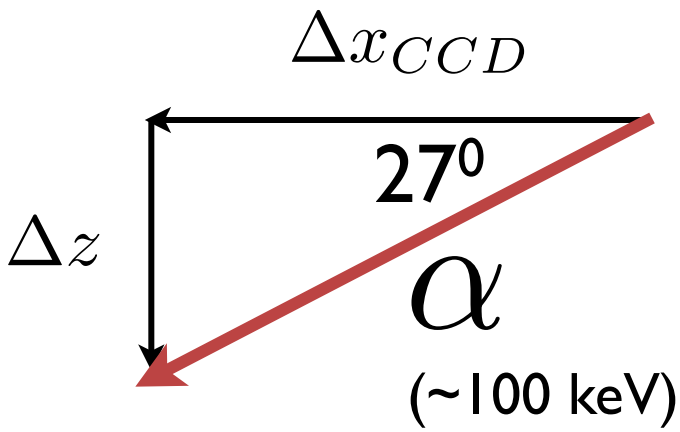


Low energy tracks of known angle

Dujmic, Lopez



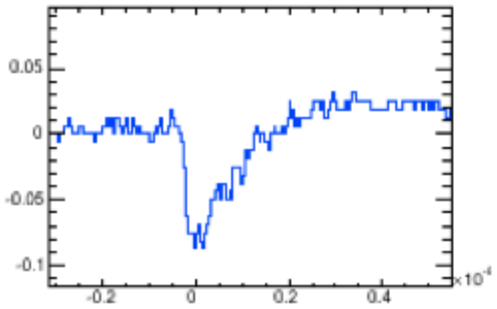


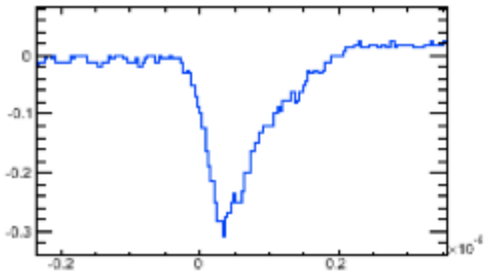


10 cm drift

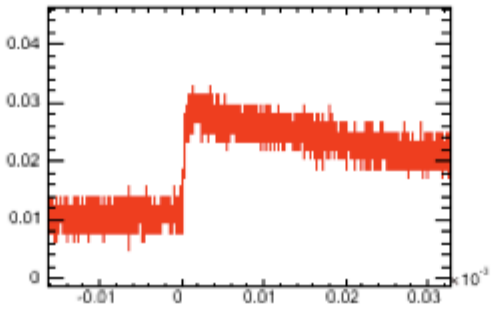
$$\Delta z_{CCD} = \tan(27^0)\Delta x_{CCD}$$

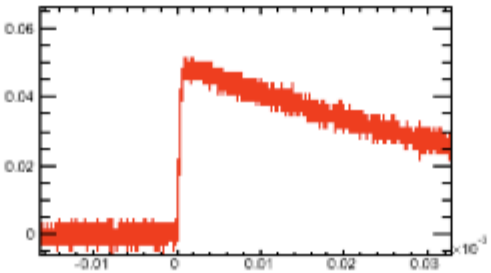
Mesh
(timing)



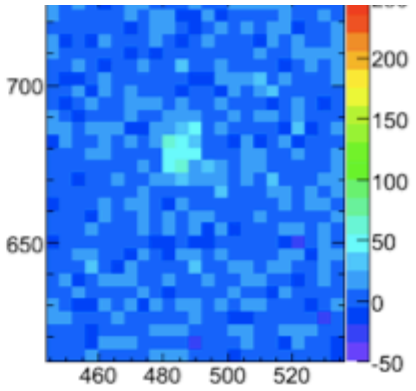


Anode
(E)

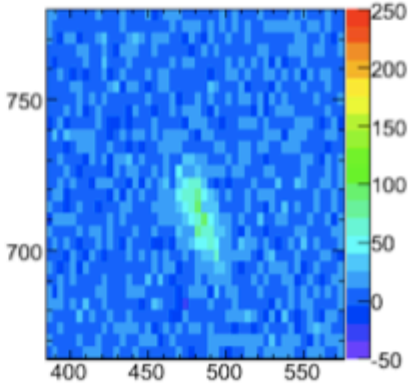




CCD
(E, tracking)



72keV



135keV

Ortec VT120B
Gain: 200
BW: 10 - 350 MHz

Cremat CR-113
Gain: 1.5 mV/pC
Rise: 20 ns + 0.25 C_{in}

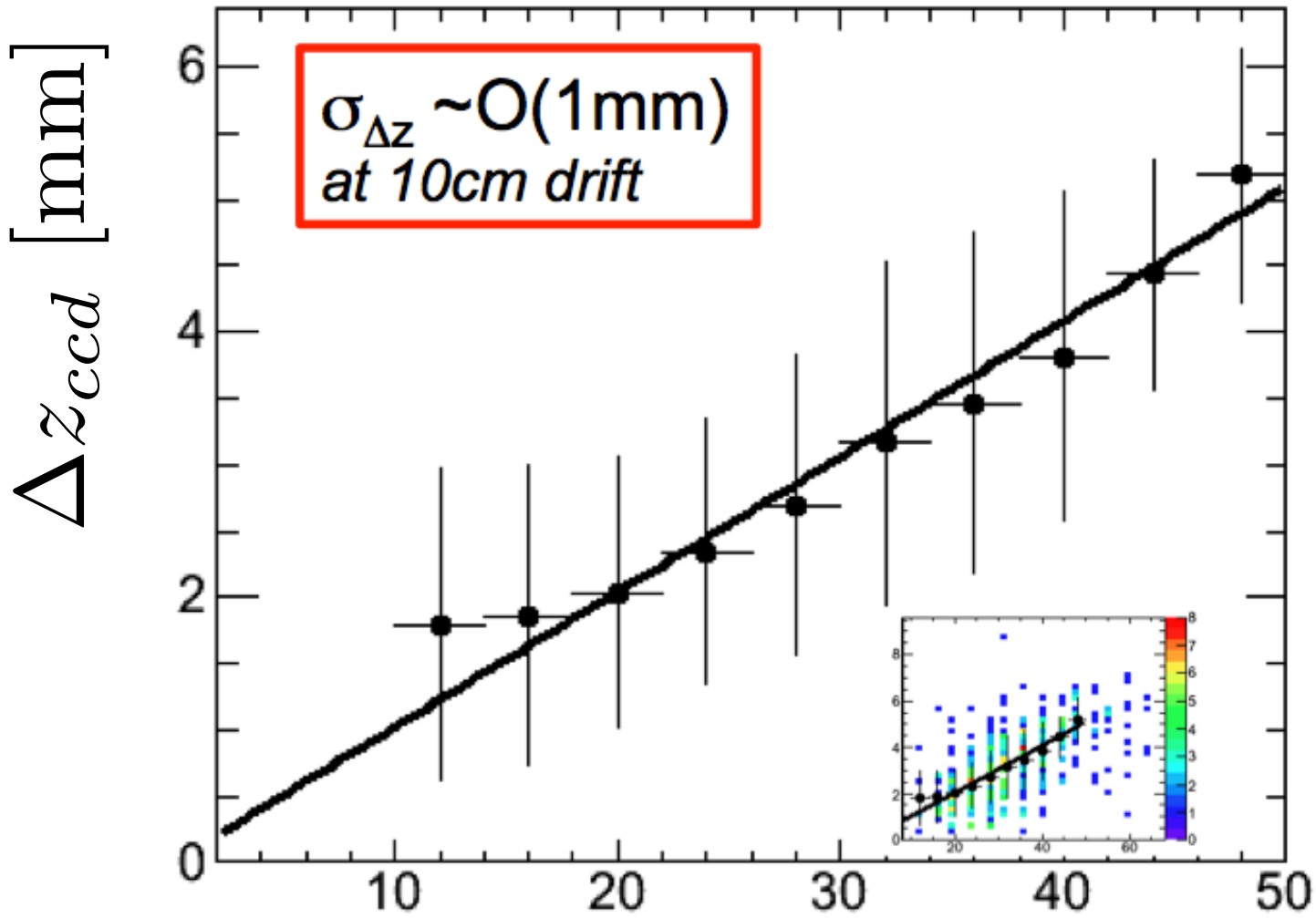
154 um/pix

Waveform digitizer: Alazar ATS860 250 MHz sampling

Dujmic

3rd dimension from charge

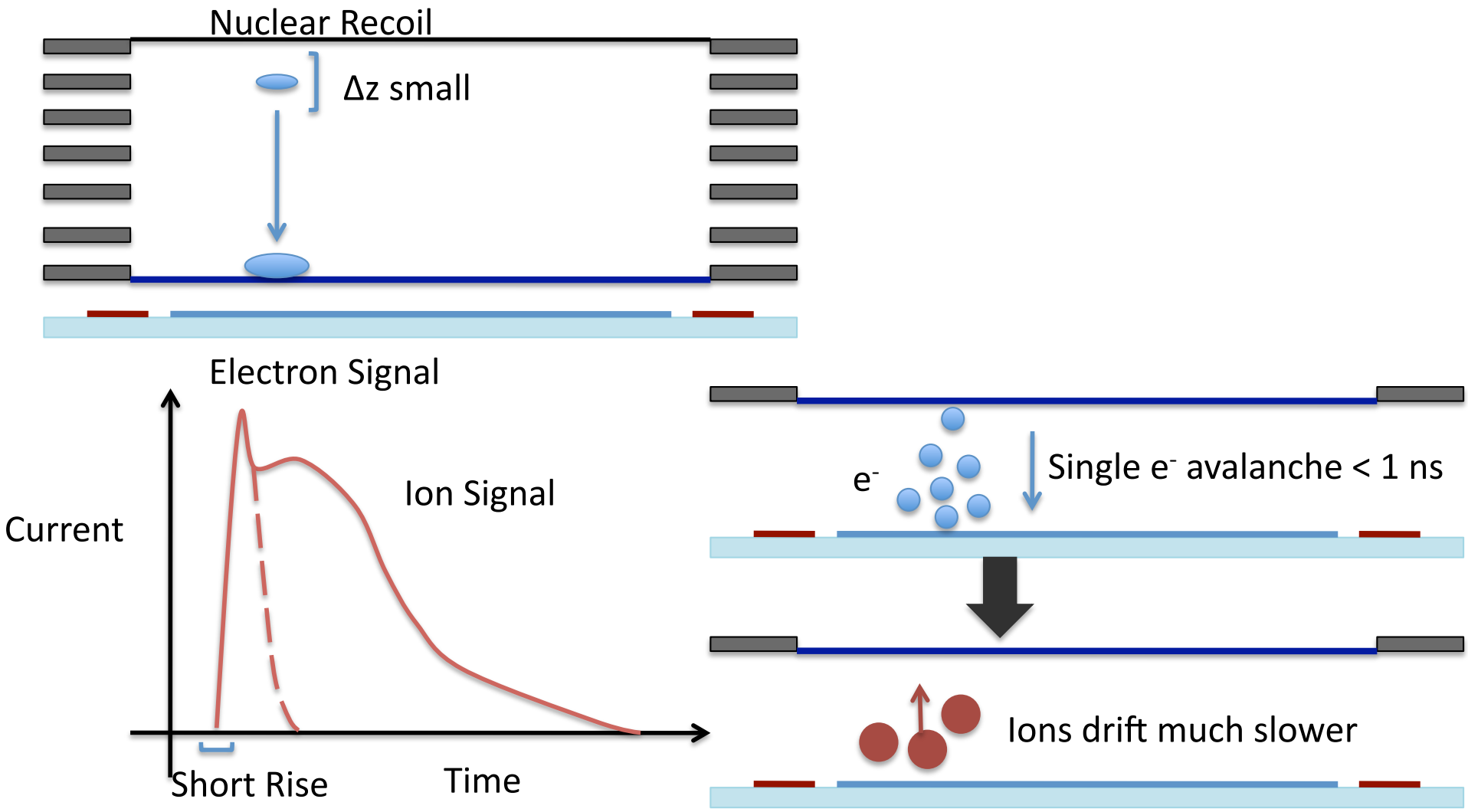
Dujmic



Vert. error bars = RMS (Track angles and detector resolution)

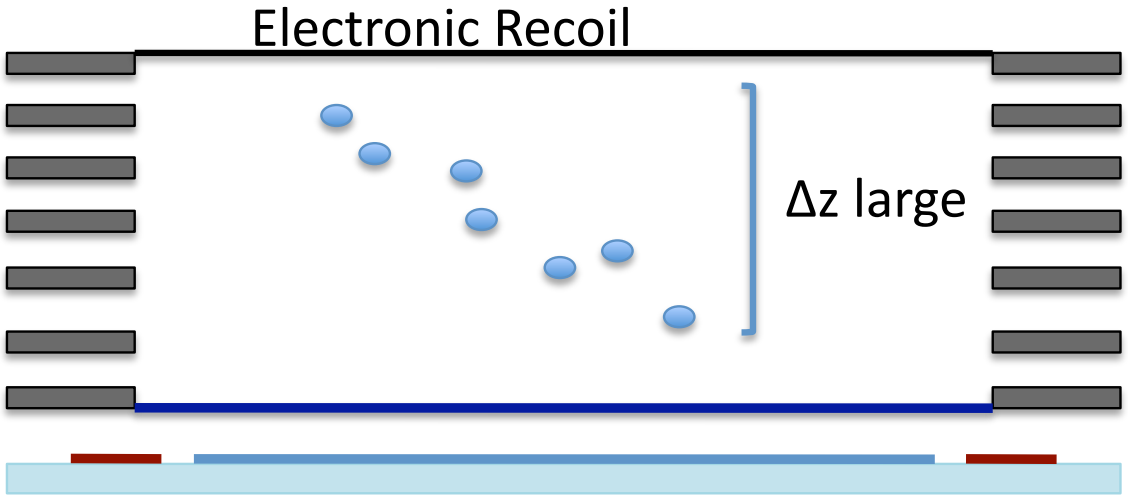
Gamma rejection with charge

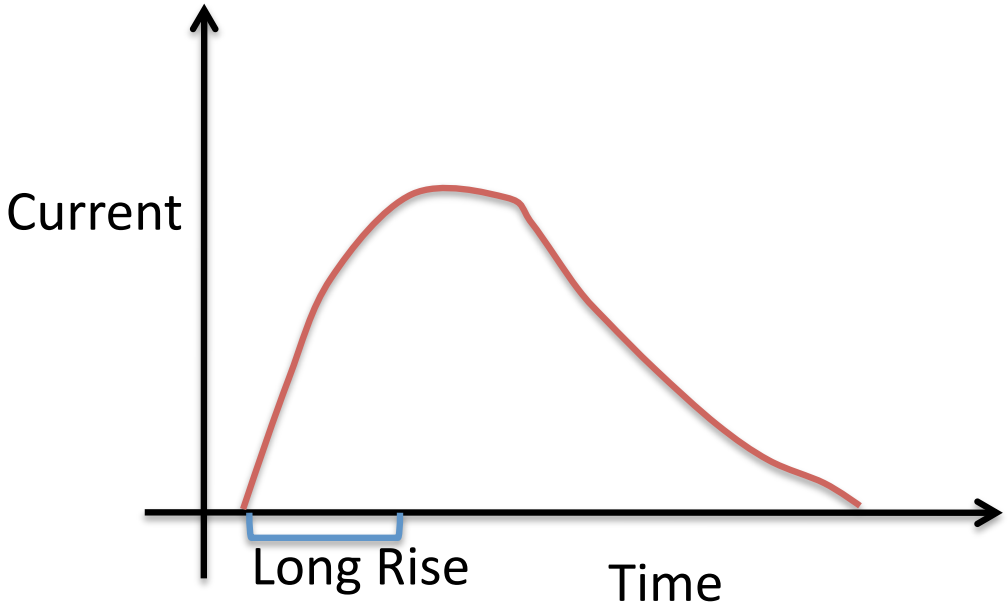
Lopez



Gamma rejection with charge

Lopez

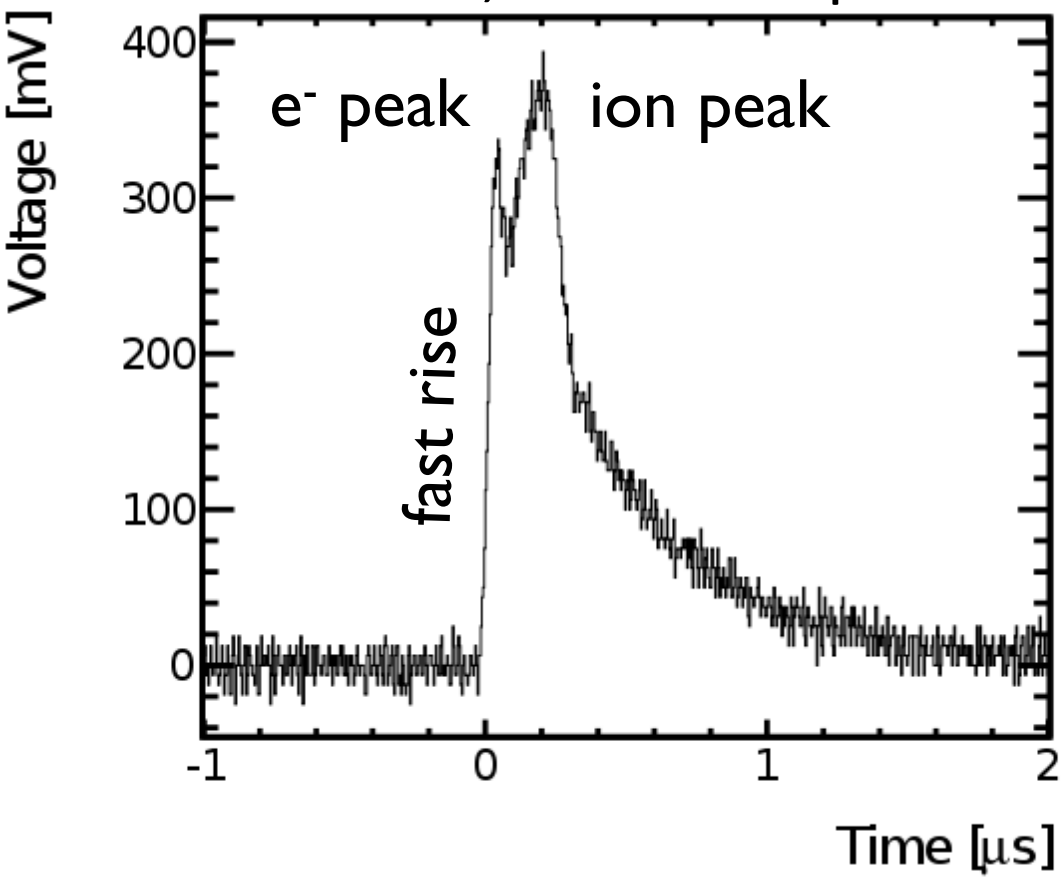




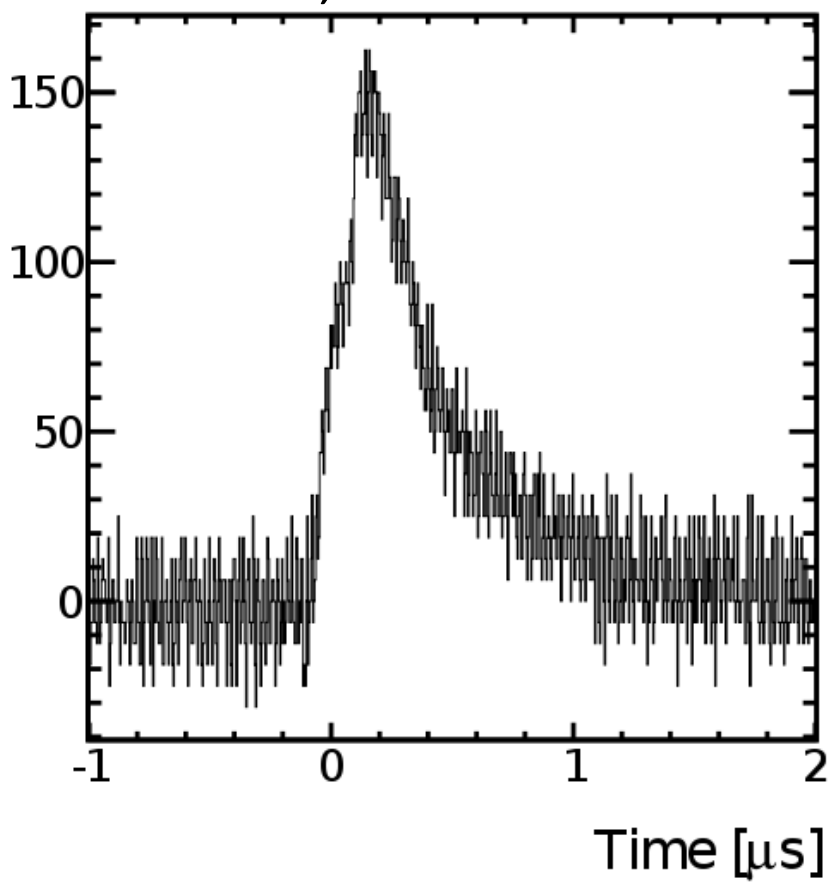
Pulse shape parameters

Lopez

Mesh, 140 keV Alpha



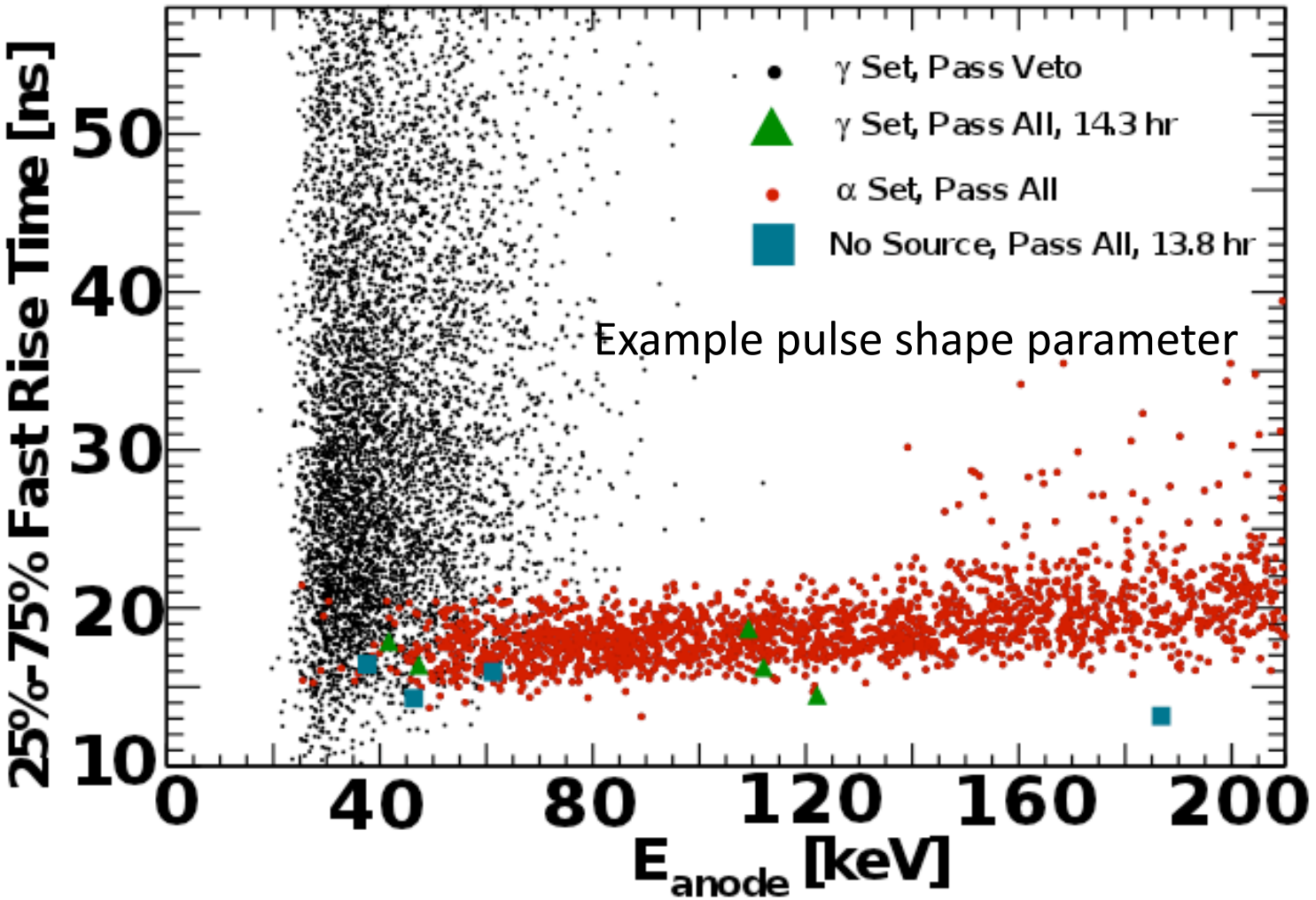
Mesh, 60 keV Electron



Amplifier
Gain: 80
BW: DC - 350 MHz

Pulse Shape Analysis

Lopez



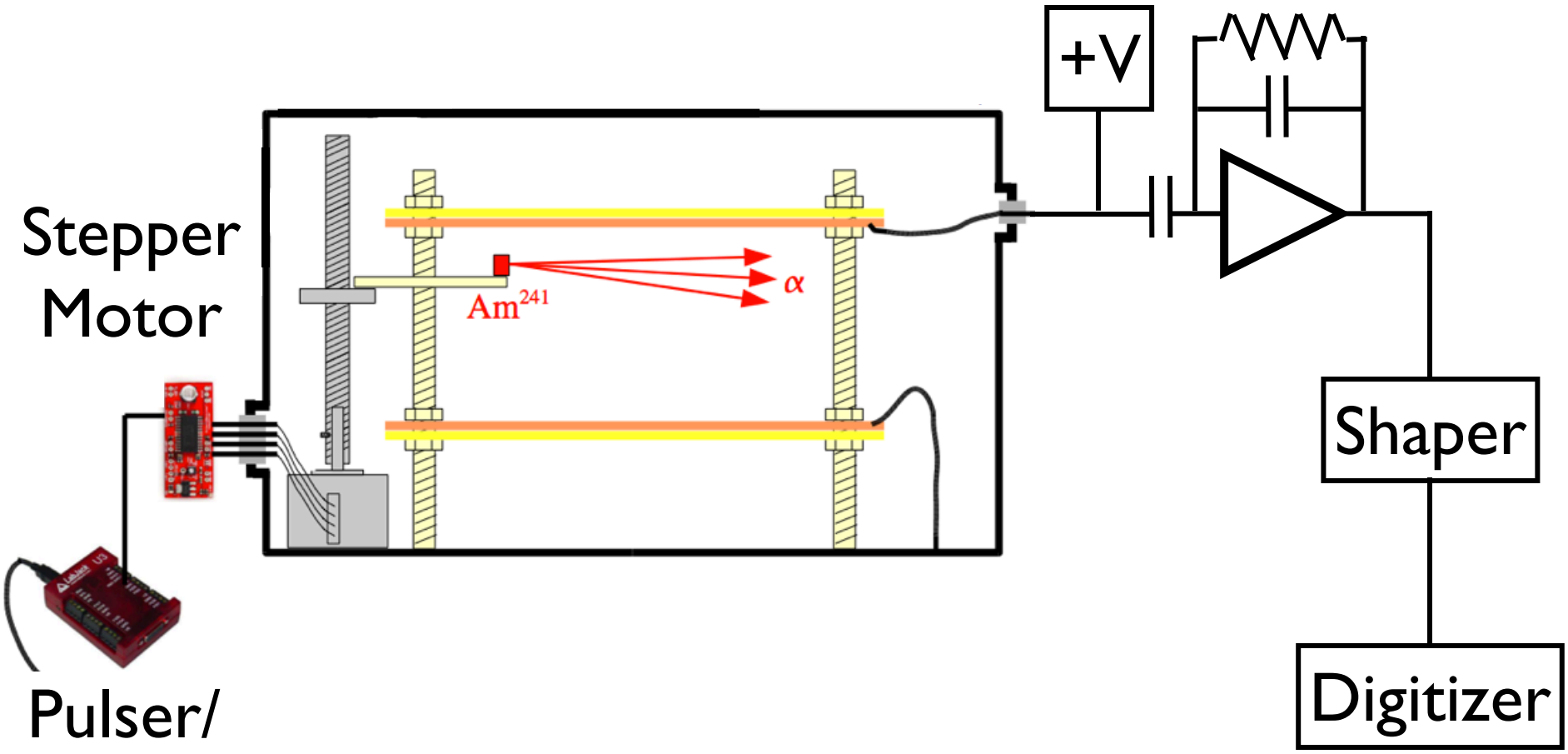
PSA alone gives 10^{-3} e^- rejection

By requiring a match in CCD, zero of ~5.8×10^5 e^- recoils pass cuts

90% upper limit in e^- misid:
1 in 170,000
statistics limited

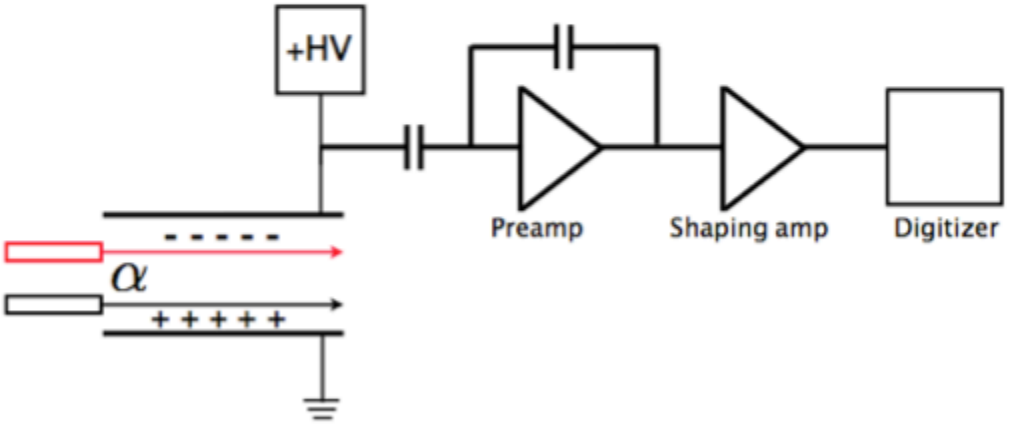
Fiducialization in z with charge

Henderson



Fiducialization in z with charge

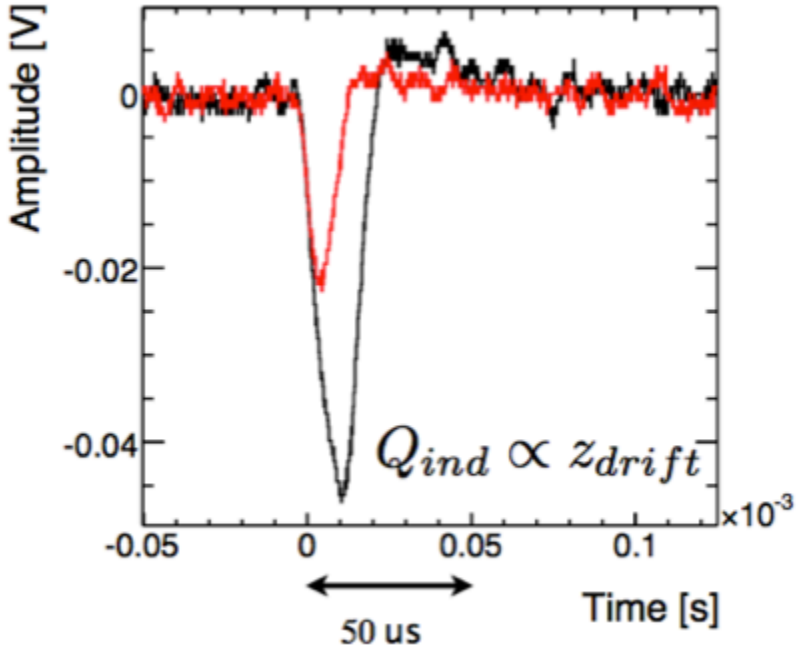
Henderson

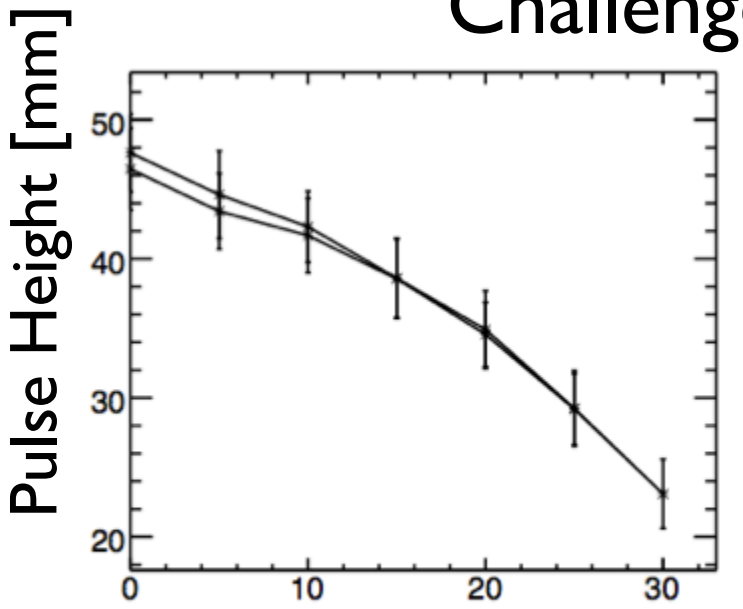


$$Q_{ind} = Q_S \frac{z_{drift}}{d}$$

^{241}Am makes 10^5 e$^-$

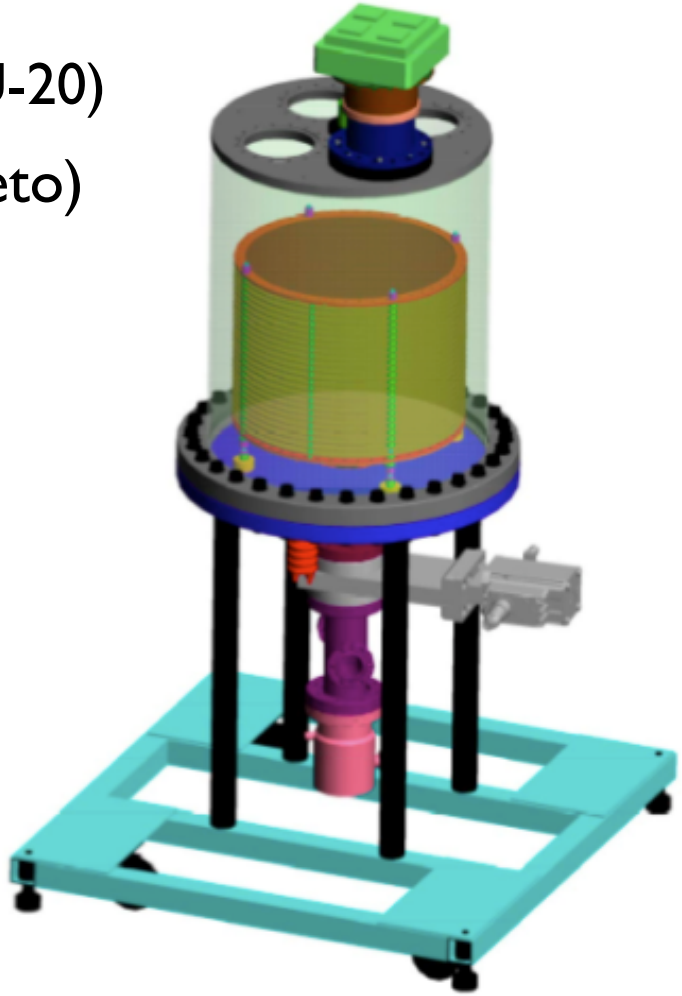
Challenge: 10^3 e$^-$



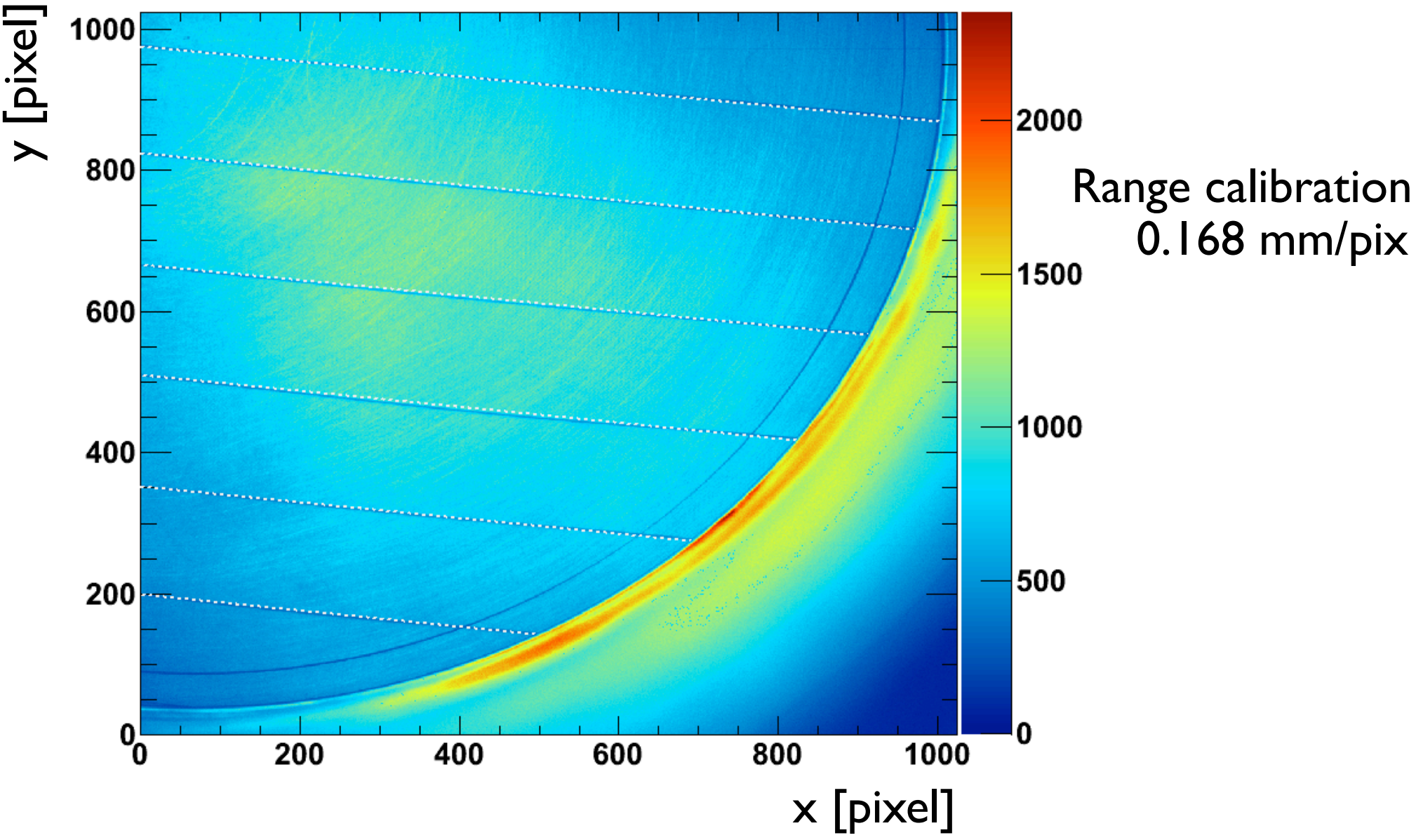


4shooter

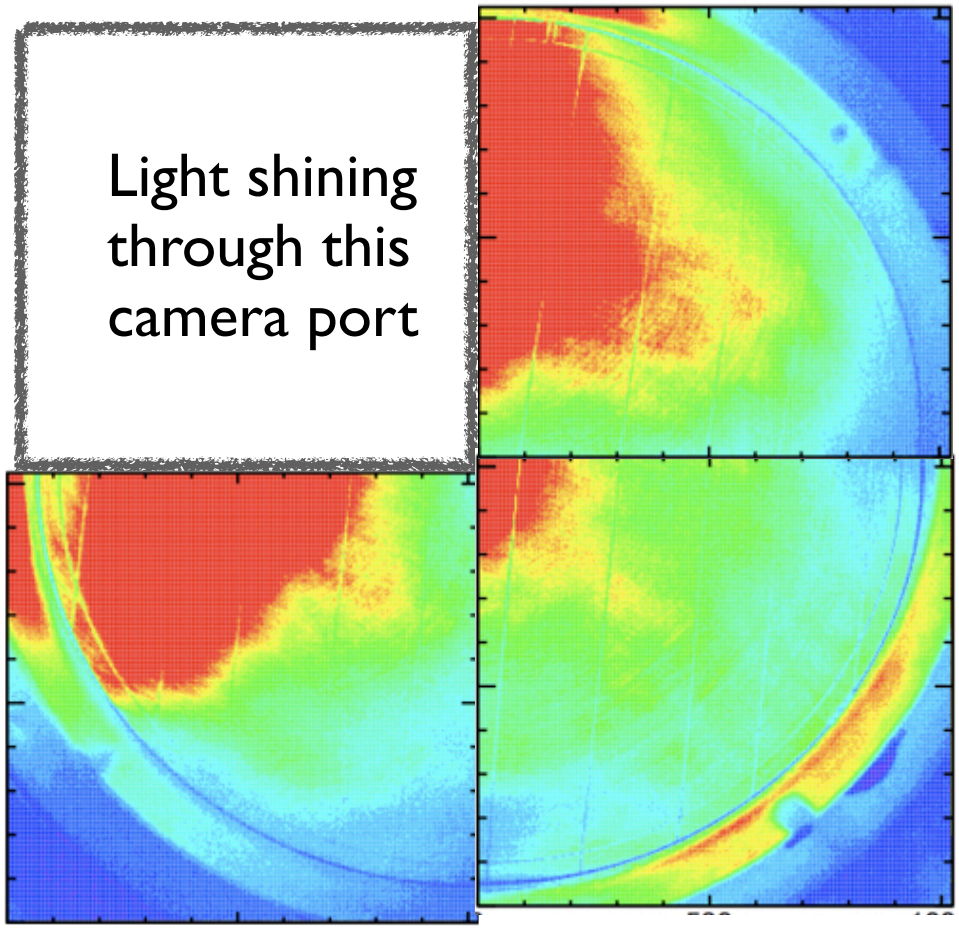
4x CCD (Alta U6)
3x PMTs (Ham. R7400U-20)
Charge (mesh, anode, veto)
25 cm drift
30 cm diameter



4shooter: single image

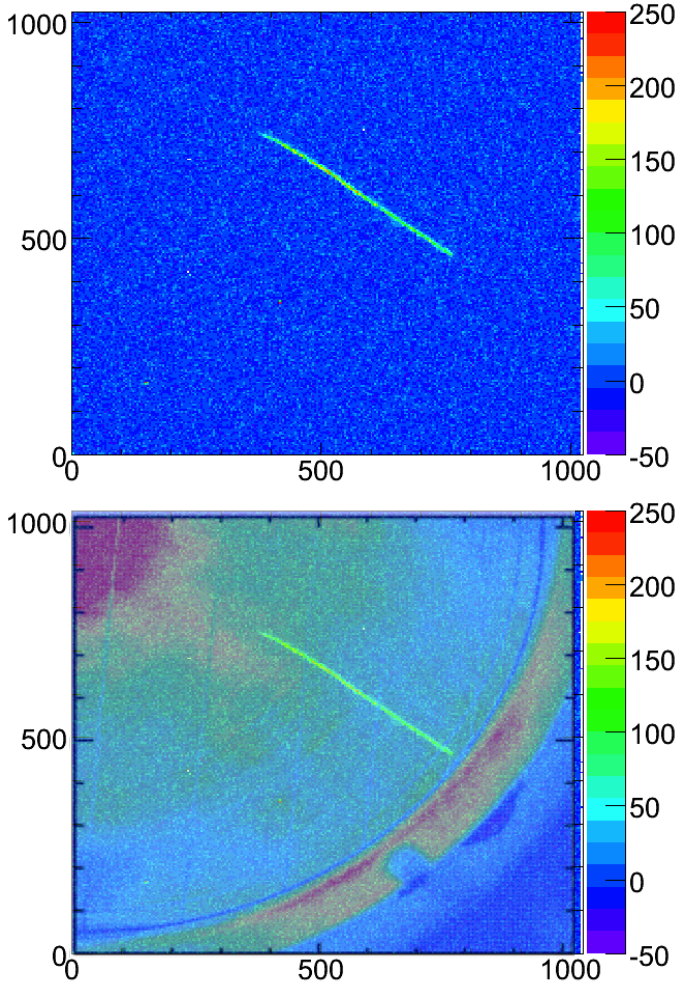


4shooter: composite image

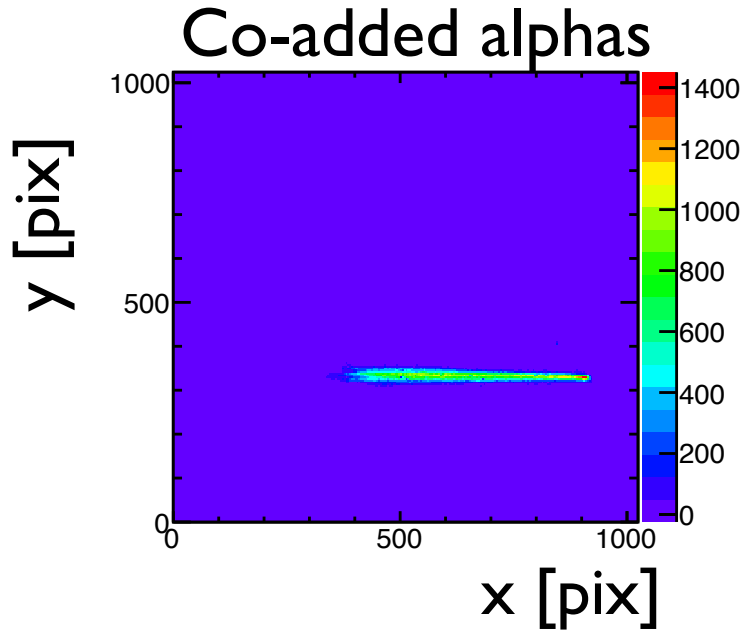


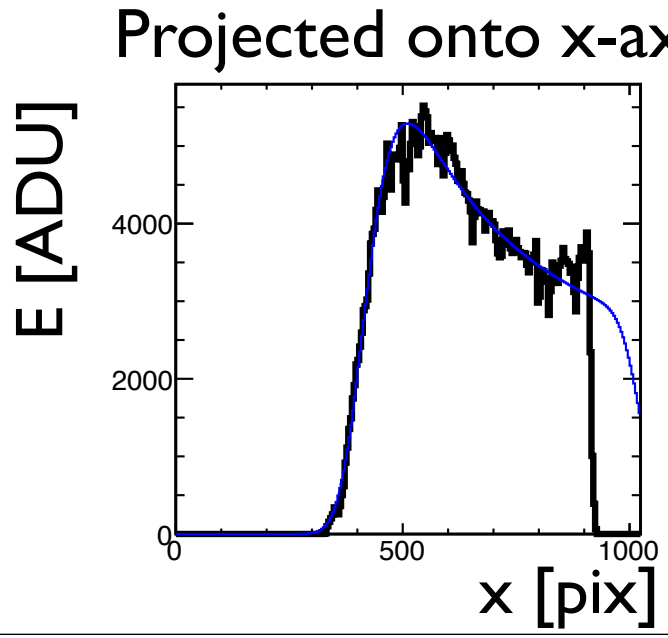
30.7 cm

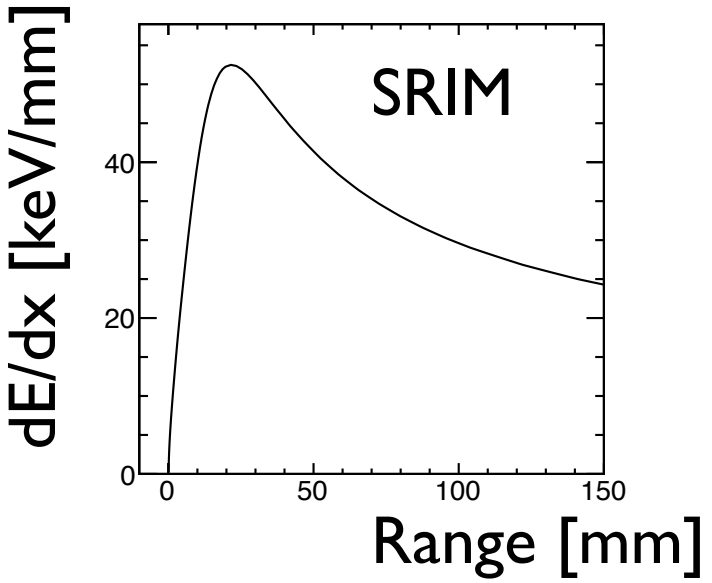
Calibration
alpha track



CCD energy and range calibration

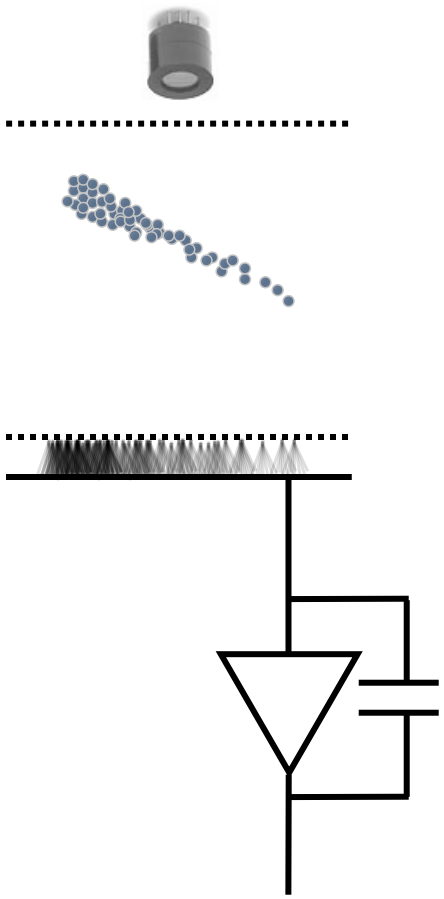


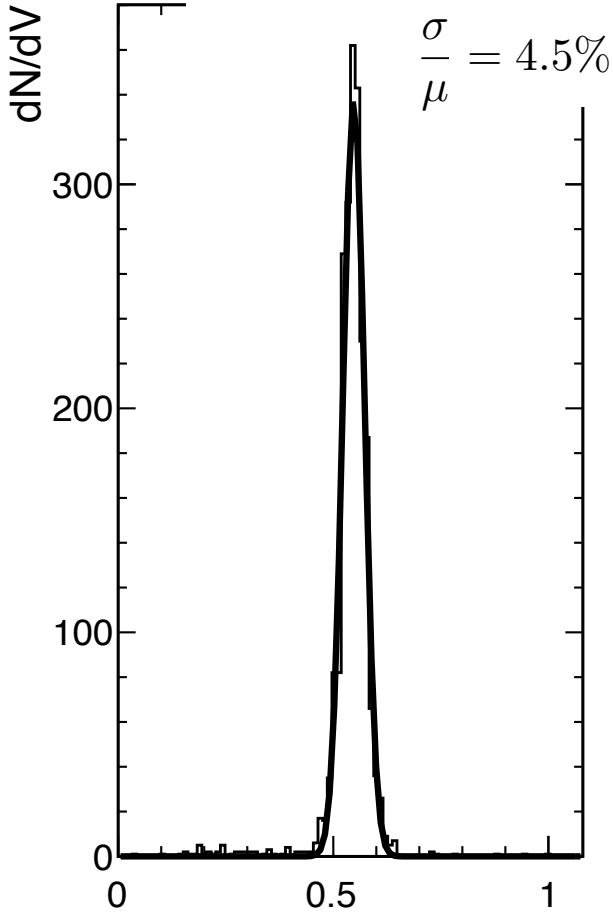




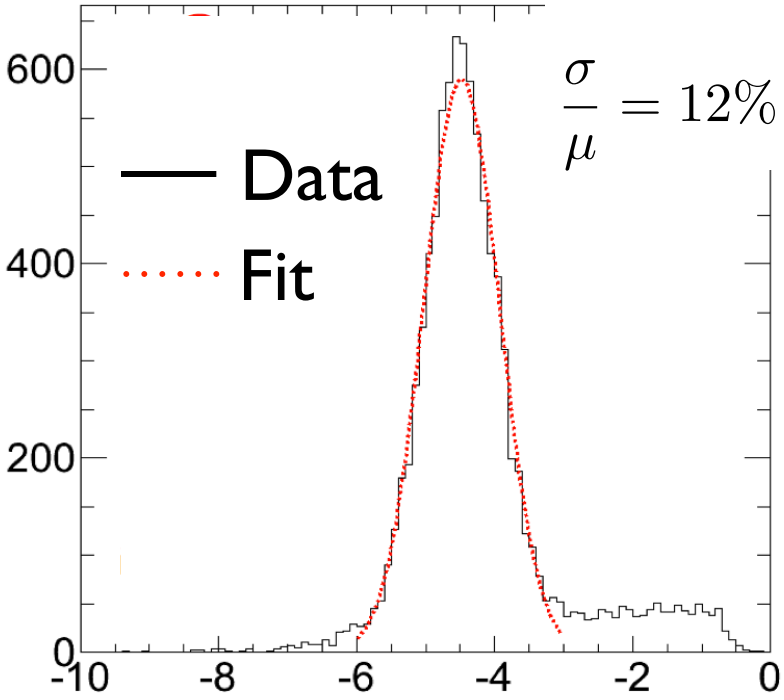
Alpha tracks from ^{241}Am source

4shooter PMT + Charge





Charge spectrum [V]

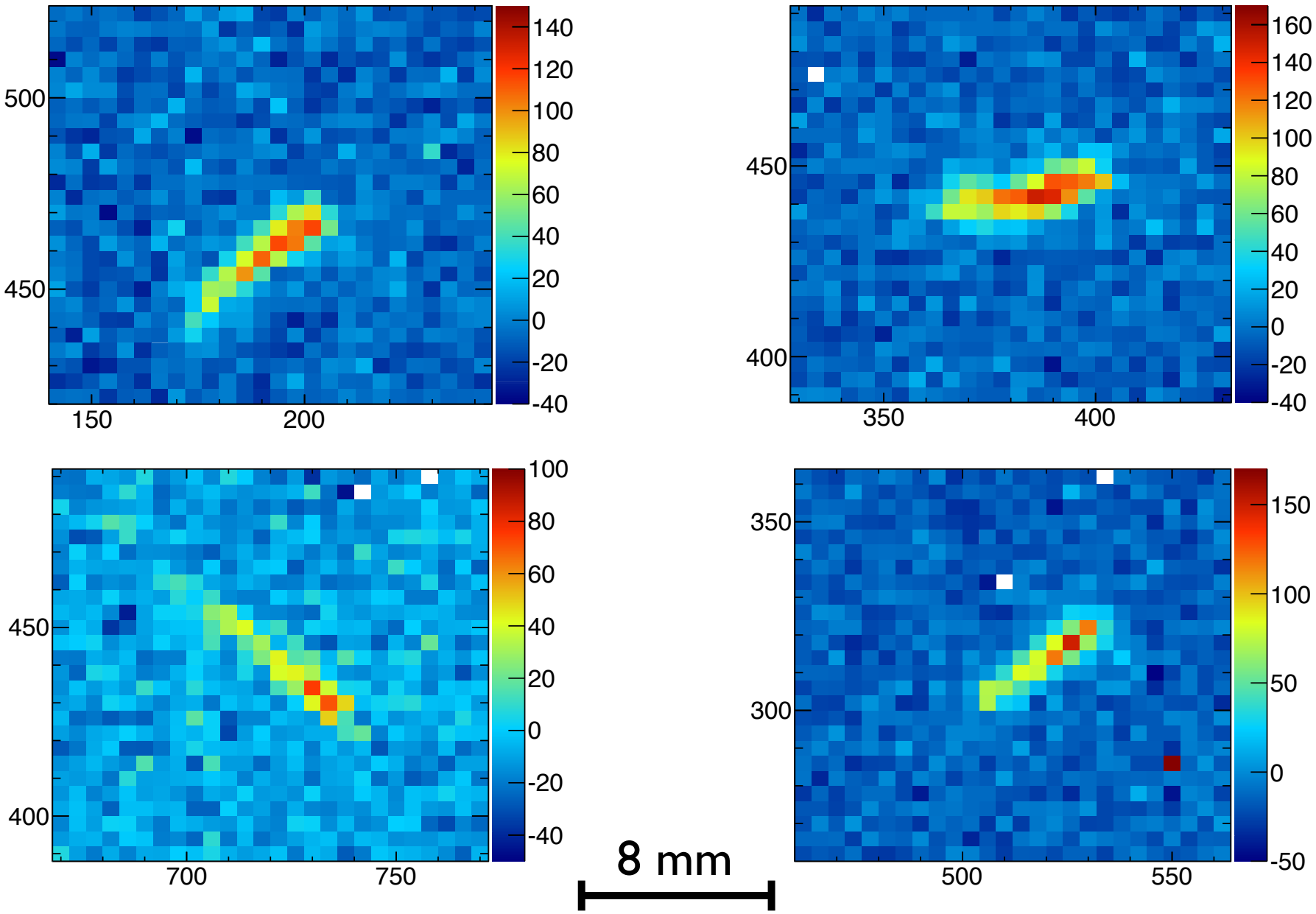


PMT spectrum [V*ns]

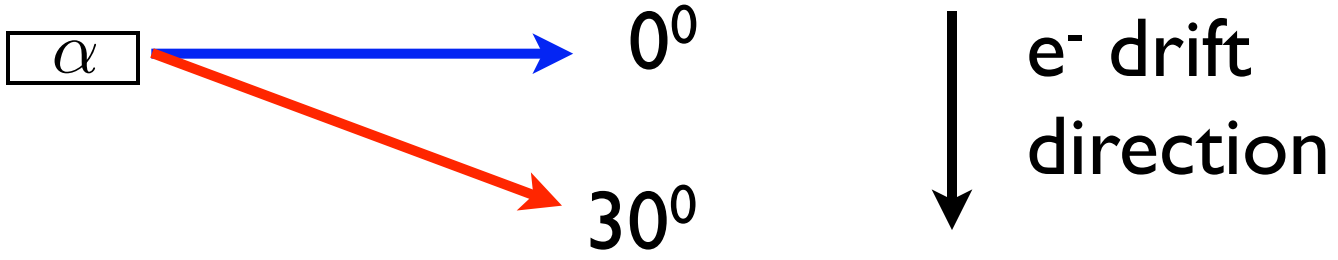
(4.5 MeV alpha source)

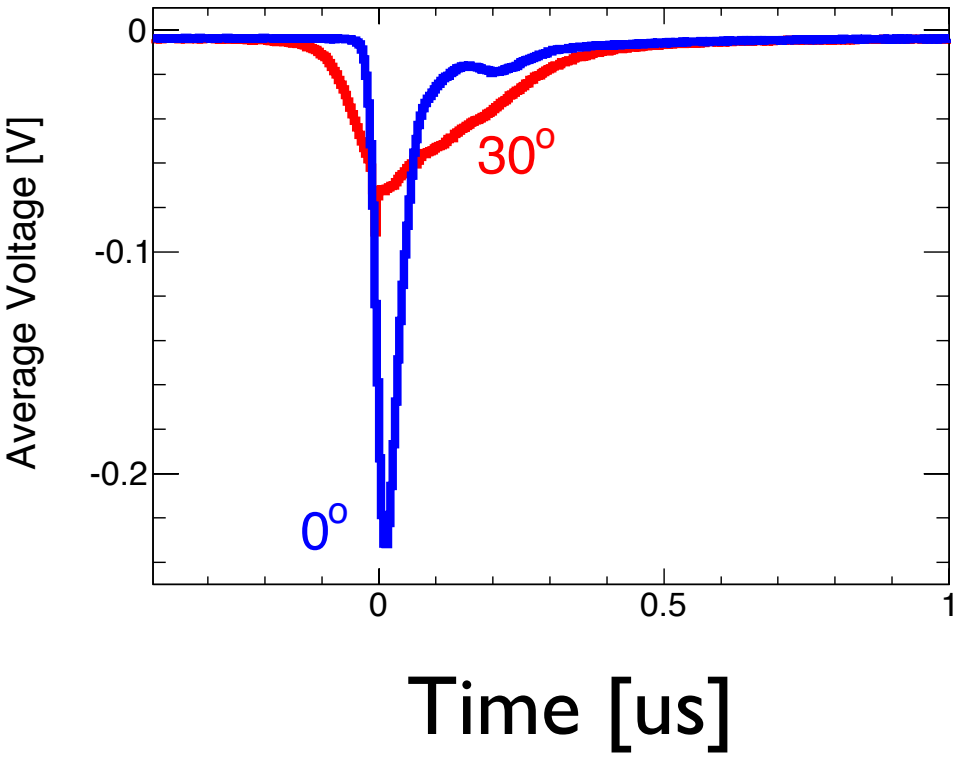
4shooter: Recoil Tracks

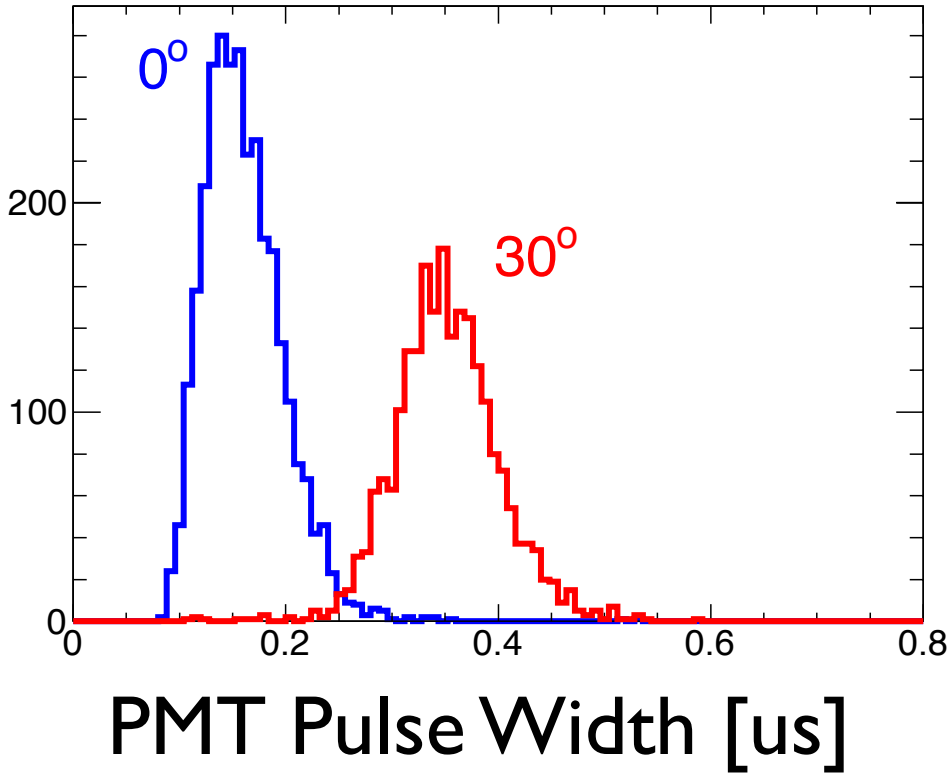
^{252}Cf source (at right)



3rd dimension from PMTs



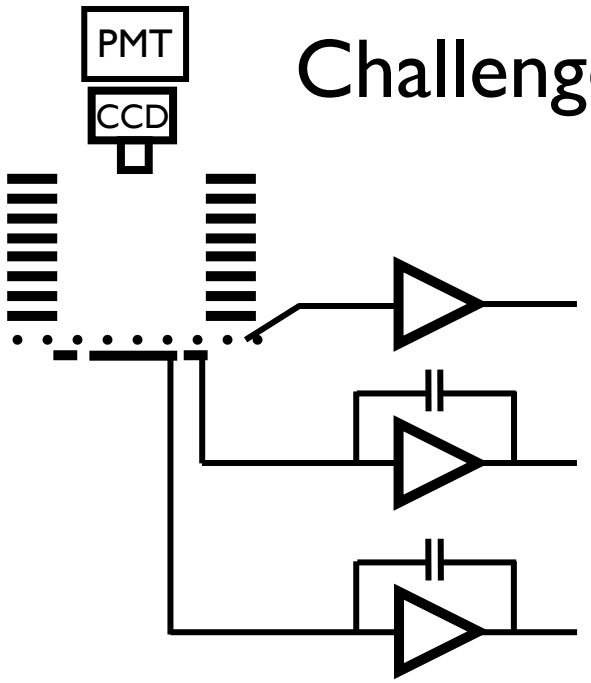




See also: Fraga et al. NIMA 581, 202-205 (2007)

Summary

PMTs [triggering
3D recon
bkg rejection
x/y fiducialization
z fiducialization] Charge



Challenges:

- Head-tail below 100 keV
- z fiducialization
- Disentangle z, dz, and dE/dx from pulses (charge & PMT)