Direction Sensitive Neutron Detector
+
Gaseous Xenon DMTPC

PRELIMINARY

Hidefumi Tomita

Cygnus 2009, MIT

BOSTON UNIVERSITY

DMTPC collaboration

- **Boston University**

  S. Ahlen, H. Tomita, A. Inglis

- **Brandeis University**

  H. Wellenstein, A. Dushkin, S. Goyal, F. Golub, N. Skvorodnev

- **Massachusetts Institute of Technology**

  P. Fisher, J. Battat, T. Caldwell, D. Dujmic, S. Henderson, A. Kaboth, A. Lee, J. Lopez, J. Monroe, T. Sahin, G. Sciolla, R. Vanderspek, R. Yamamoto, H. Yegorian

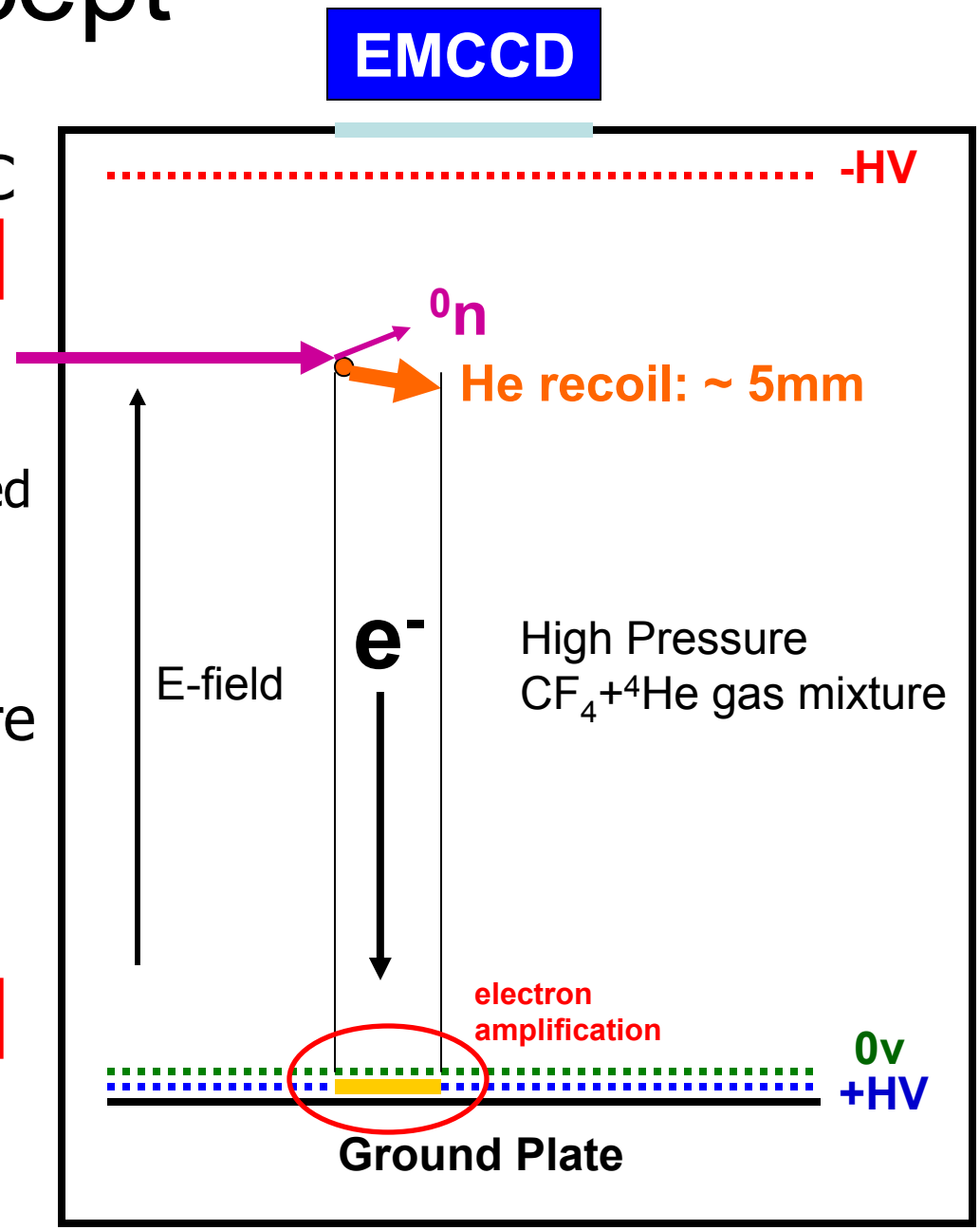
Outline

- Cylon – high pressure gas TPC, direction sensitive fissile neutron detector

- Xe-DMTPC – our latest/first study for optical readout of nuclear recoils in gas mixture with Xe

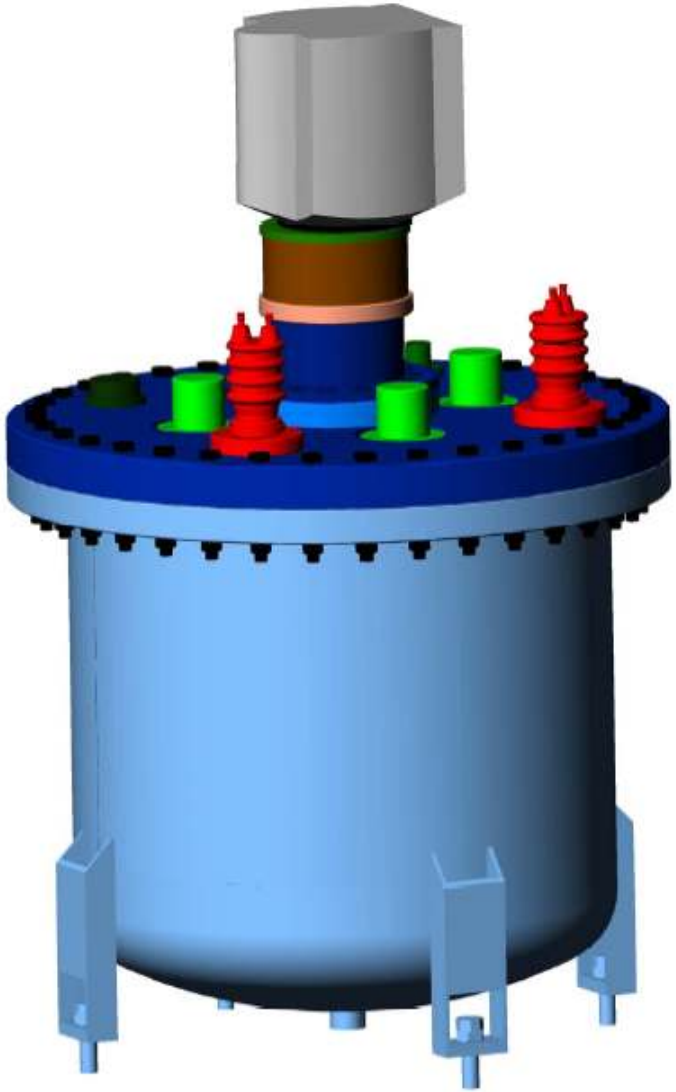
Detector concept

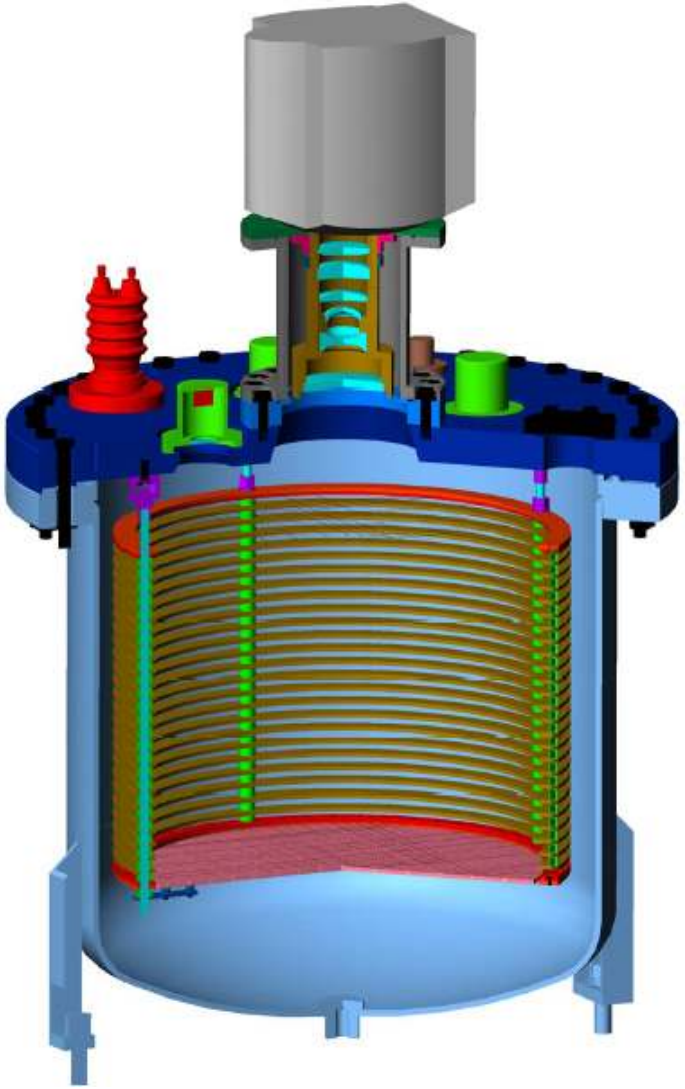
- High-pressure CF_4+^{4}He TPC
  - 3 bar → ^{4}He recoil ~ 5 mm
- EMCCD readout
  - High S/N ratio
  - Scintillation photons produced in avalanche
  - $\#\gamma_{\text{scintillation}} \propto \#e_{\text{ionization}}$
- CF_4+^{4}He is ideal gas mixture
  - Low transverse diffusion
  - Non flammable, non toxic
  - Good scintillation efficiency
  - Large cross section with ^{0}n



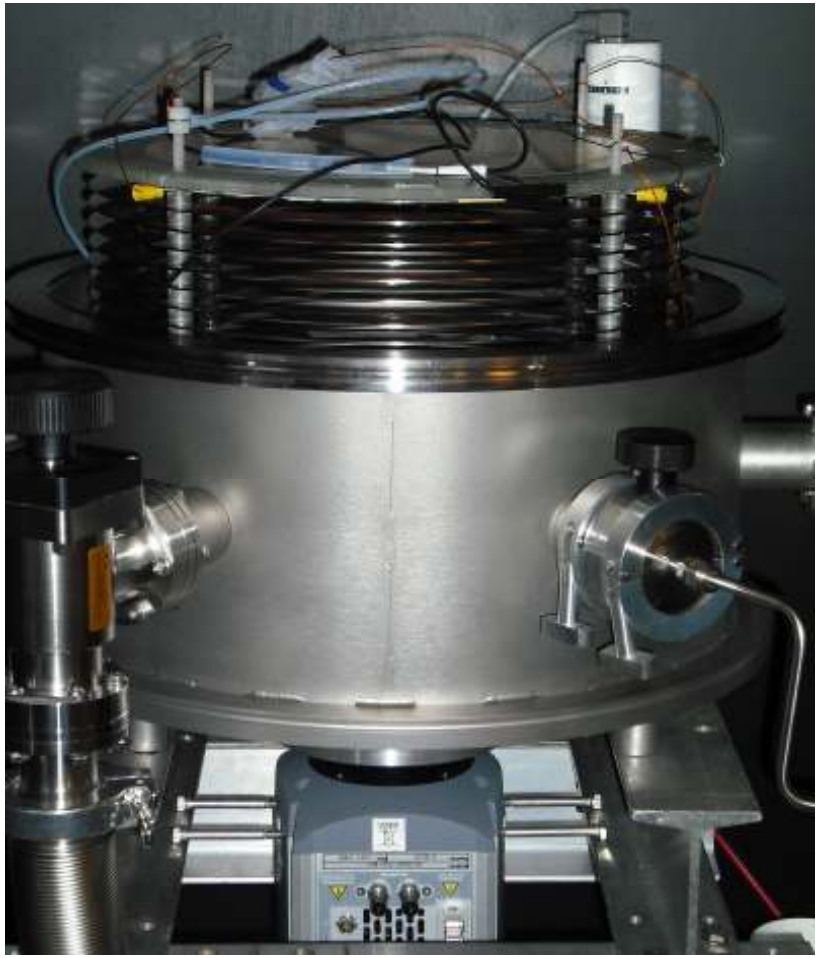
Cylon Neutron Detector

40cm diameter anode x 25cm drift region





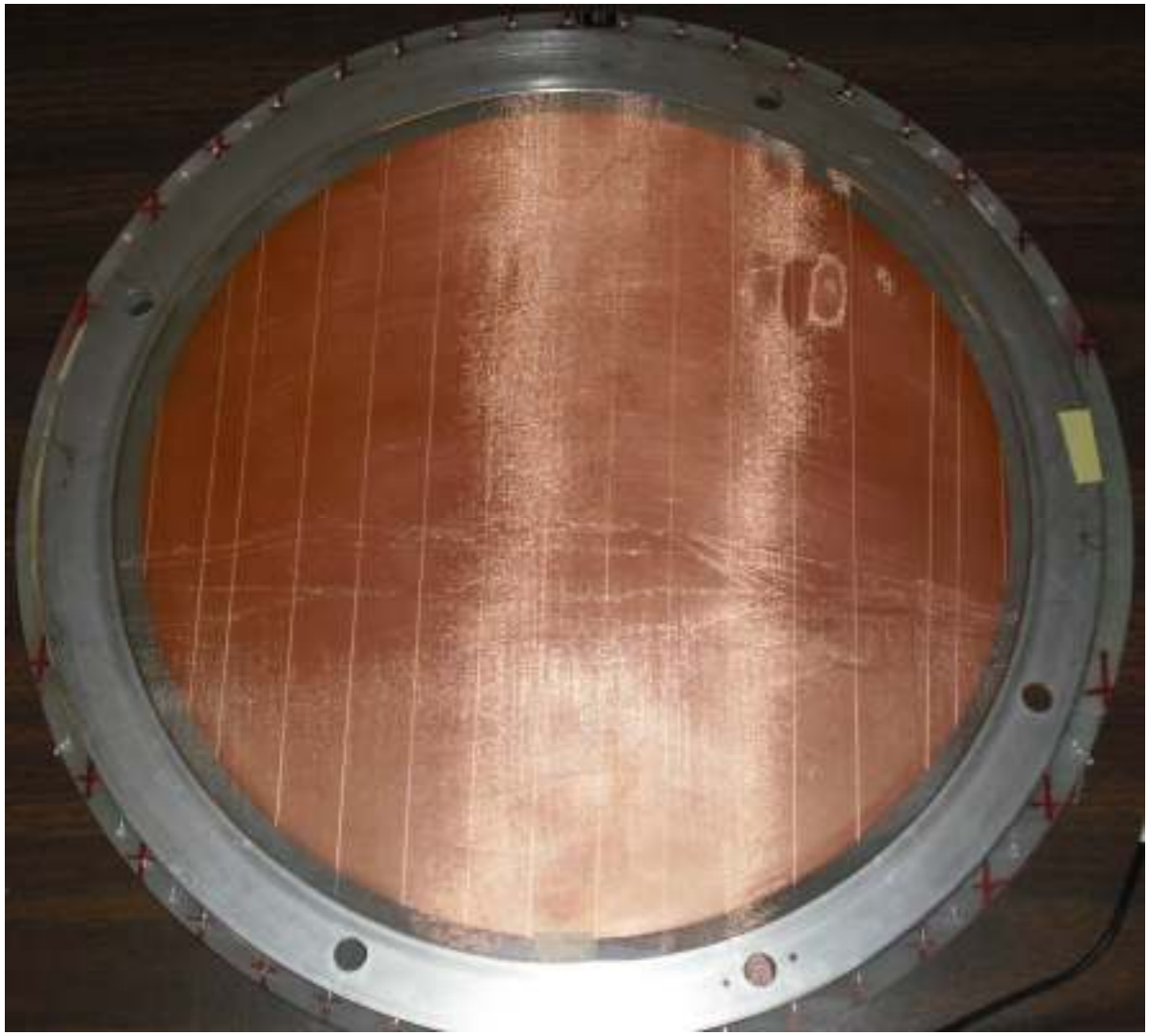
DMTPC Prototype Detector



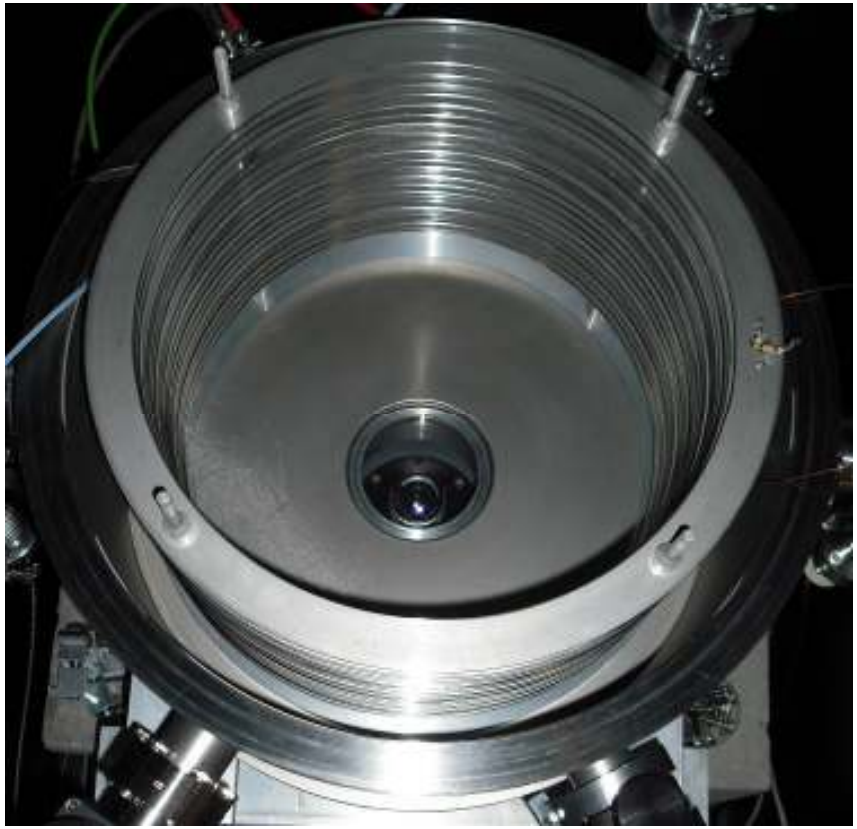
Lesker 16” diameter vacuum chamber

(~14 liters detector)

30cm Diameter Anode Mesh (prototype)



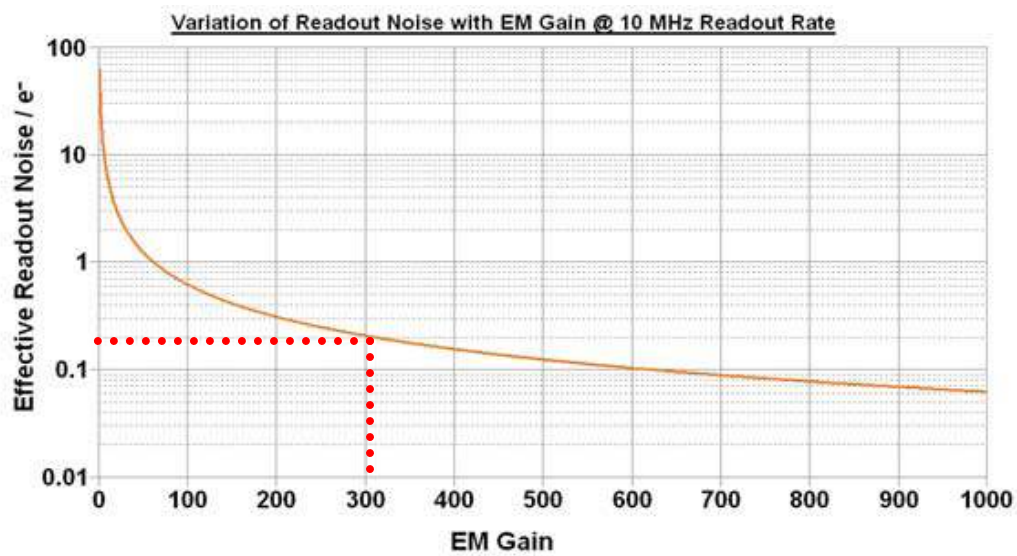
20cm Drift Length Field Cage (prototype)



Lens to Anode distance = 35cm

Electron Multiplier CCD (EMCCD)

Active Pixels	1024 x 1024	
Pixel Size (W x H; µm)	13 x 13	
Image Area (mm)	13.3 x 13.3	
Active Area Pixel Well Depth (e^-, typical)	80000	
Gain Register pixel well depth (e^-, typical)	730000*2	
Max Readout Rate (MHz)	10	
Frame Rates (frames per sec)	8.9 (full frame)	
Read Noise (e^-)	< 1 to 47 @ 10 MHz	
10 MHz through EMCCD amplifier	47	<1



Andor iXon +888 (Back Illuminated)

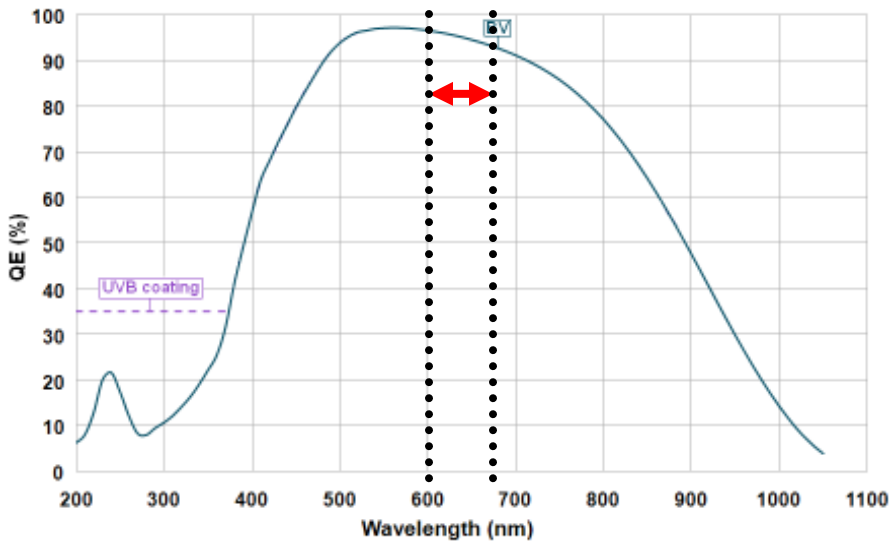
+

Custom-made 60mm Schneider Lens

(17mm Schneider Lens for prototype)

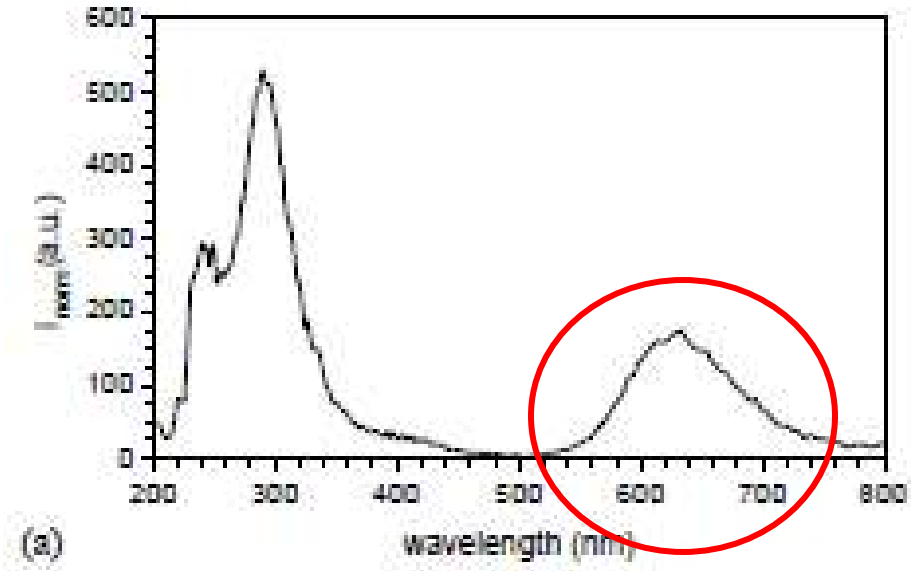
EMCCD Quantum Efficiency

Red – IR region:
QE > 90%



Specification from Andor

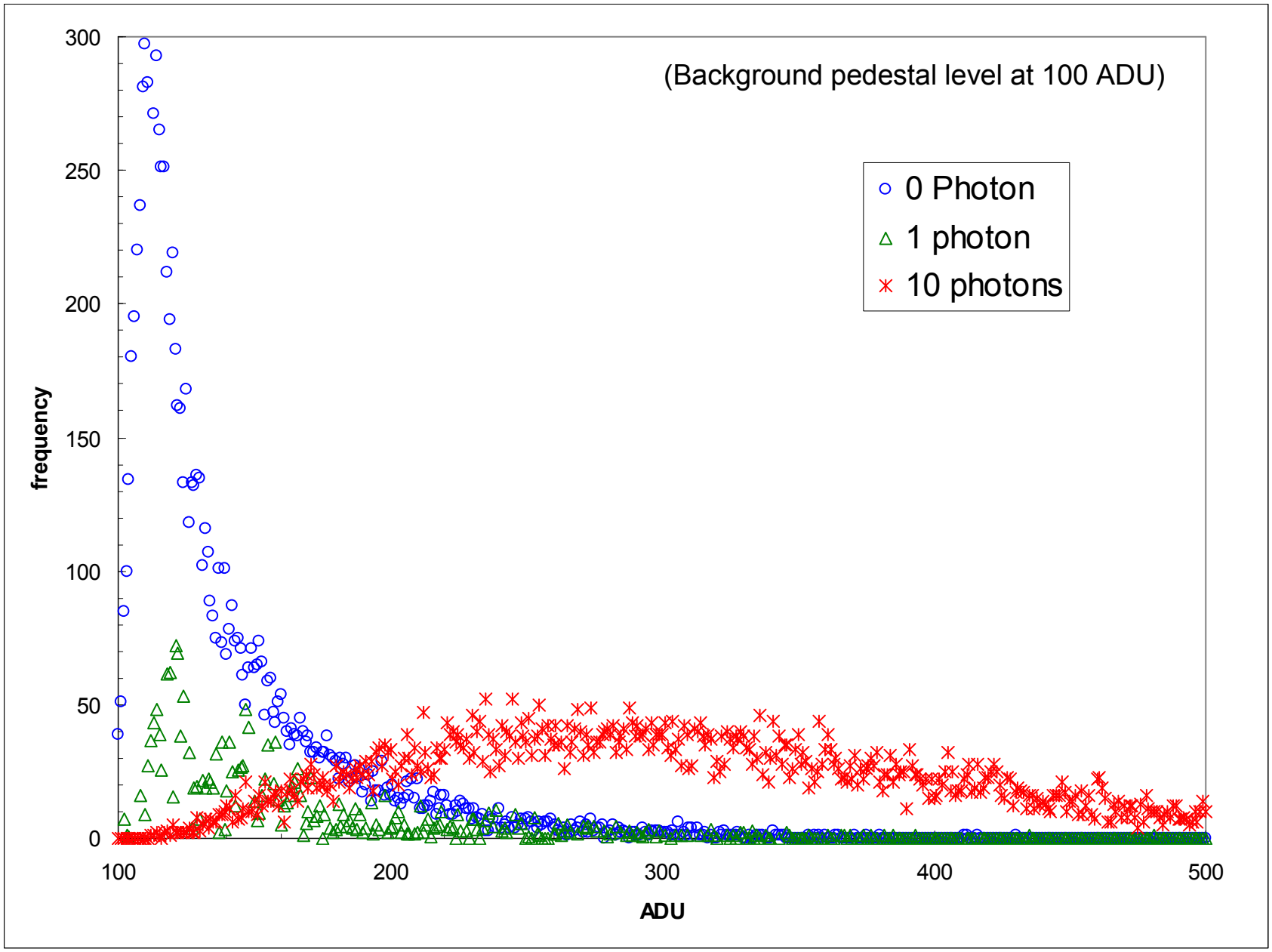
CF_4 + ^{4}He spectrum



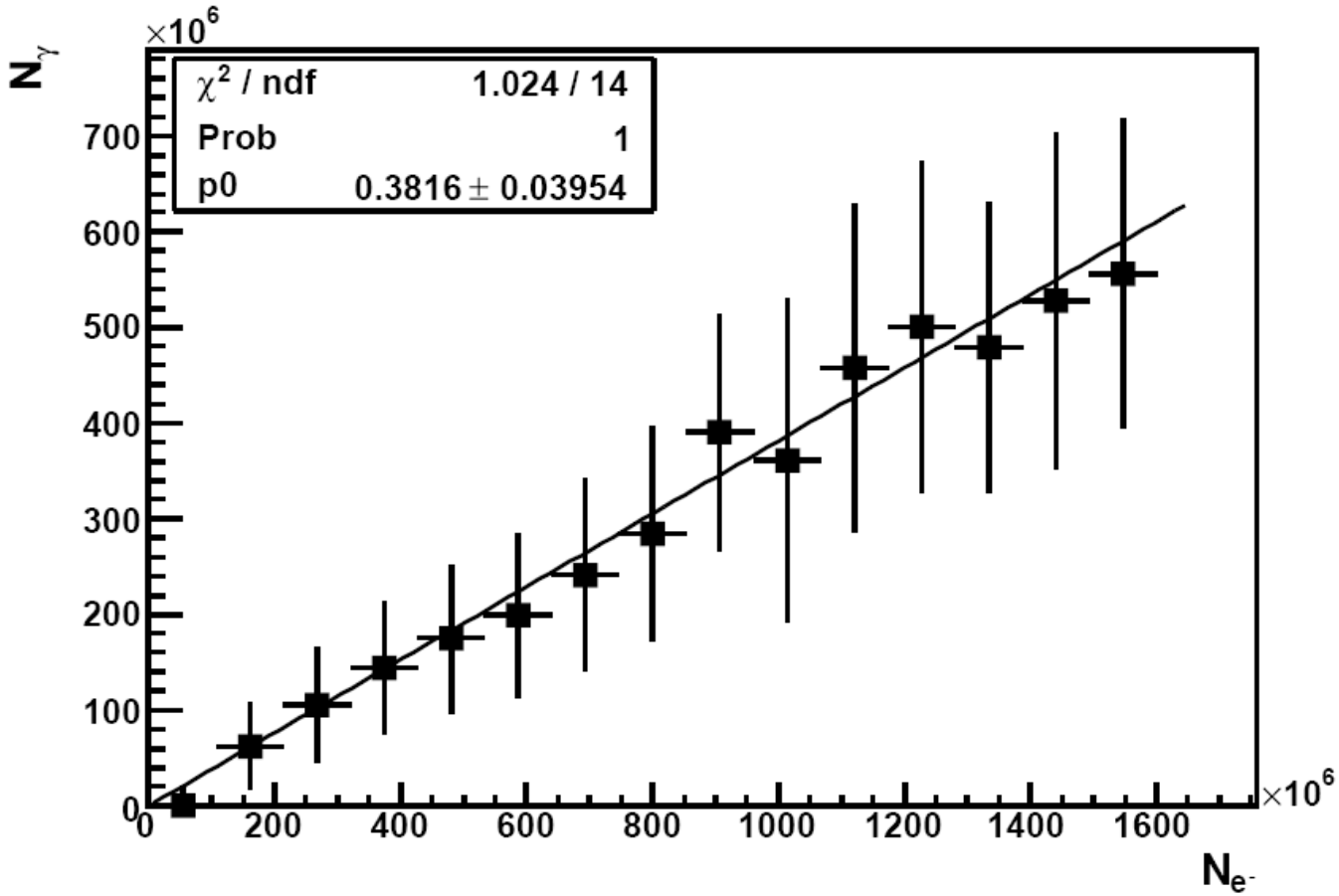
Fraga et al, Nuclear Instruments & Methods in Physics Research A 504 (2003)88-92

A. Kaboth, et al. (DMTPC), Nuclear Instruments and Methods, A592:63-72, 2008

1 photon = 20 ADU



0.4 photons per electron in CF_4 gas at amplification region



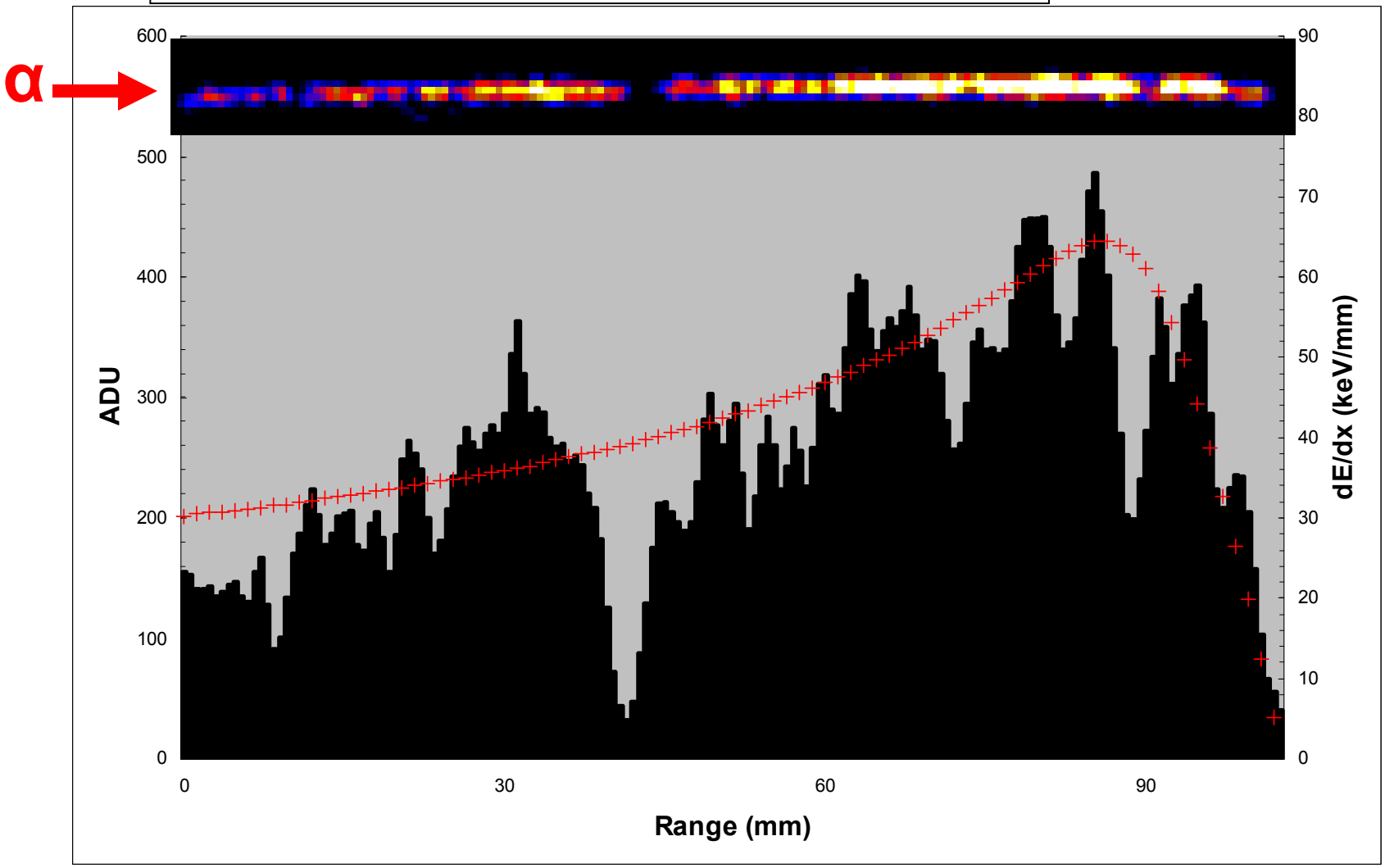
(A. Kaboth, et al. (DMTPC), Nuclear Instruments and Methods, A592:63-72, 2008)

(A. Pansky, et al., Nuclear Instruments and Methods, A504:1-3, 2003, 88-92)

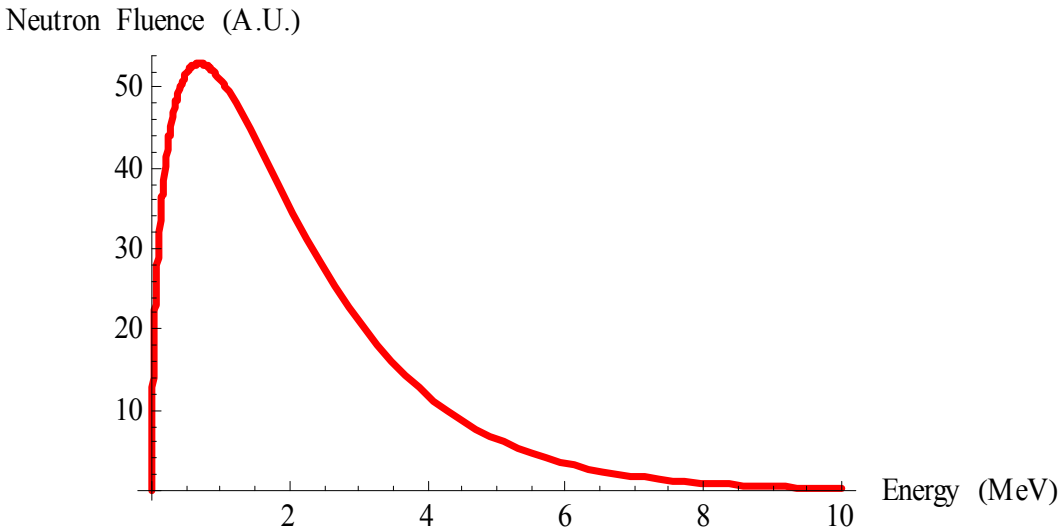
Directionality – “Head-Tail”

Red Markers: MC (SRIM) simulation

Histogram: Data from ^{241}Am α at “40torr CF_4 + 600torr He_4”

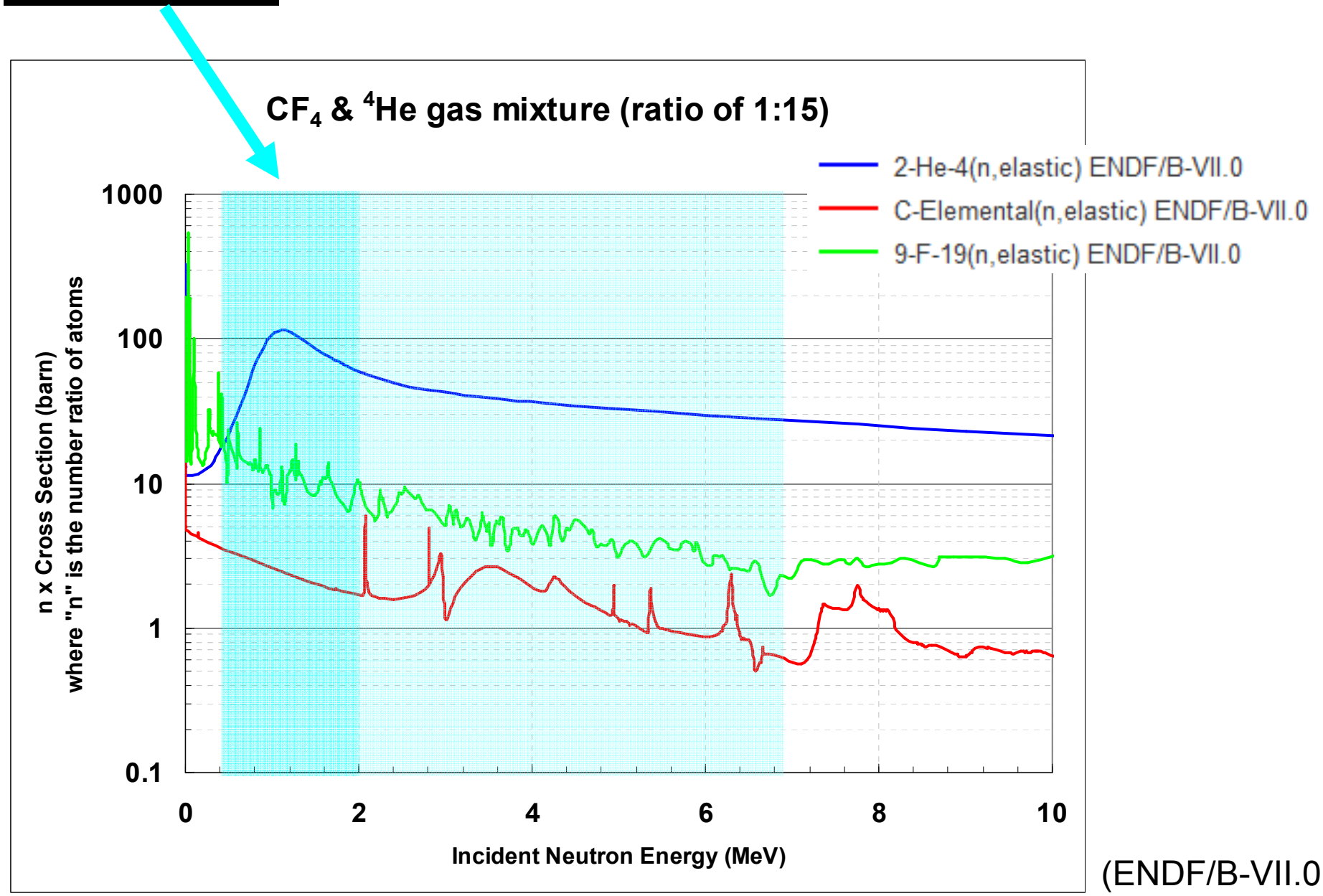


^{252}Californium Neutron Source at MIT

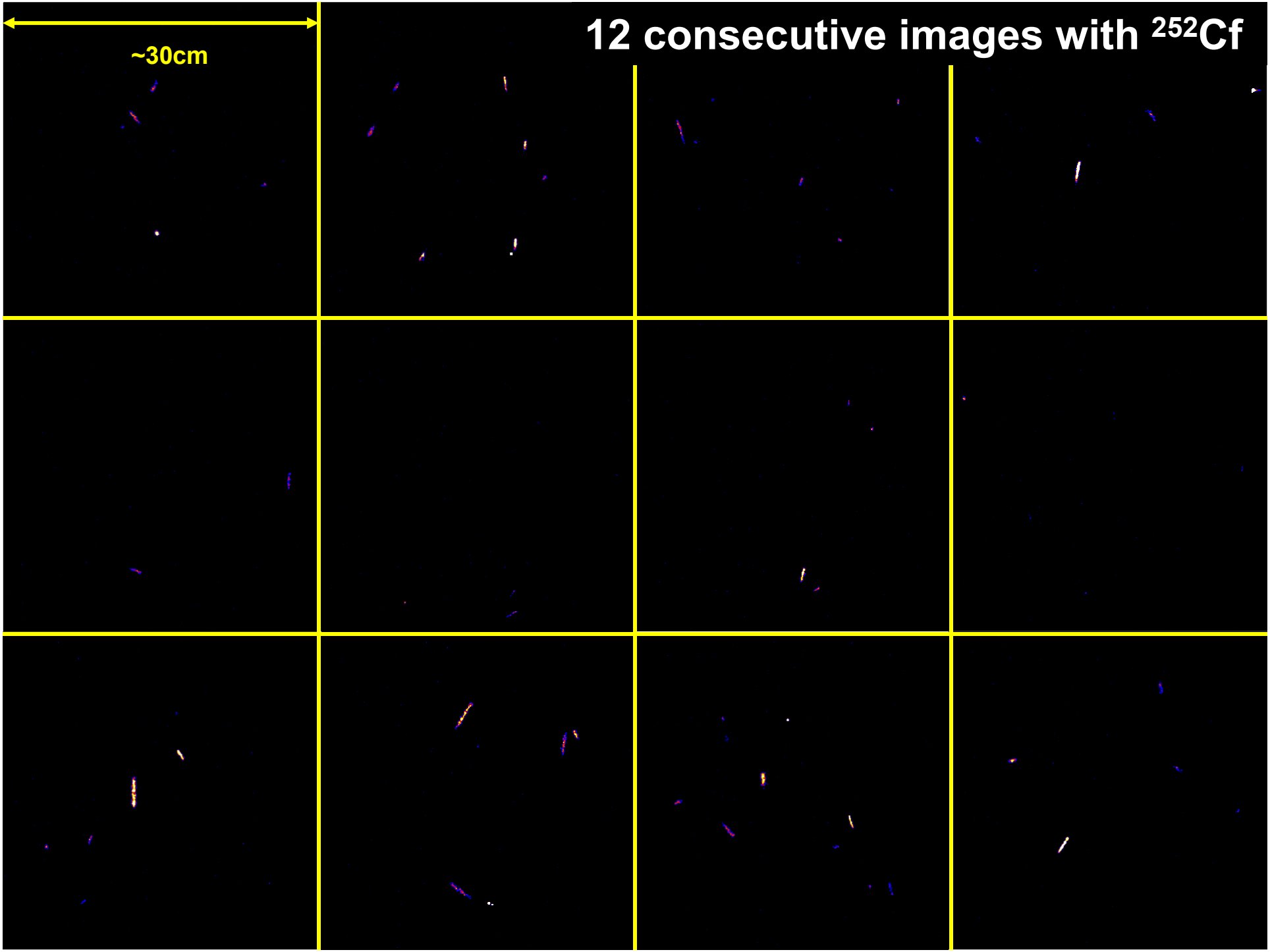


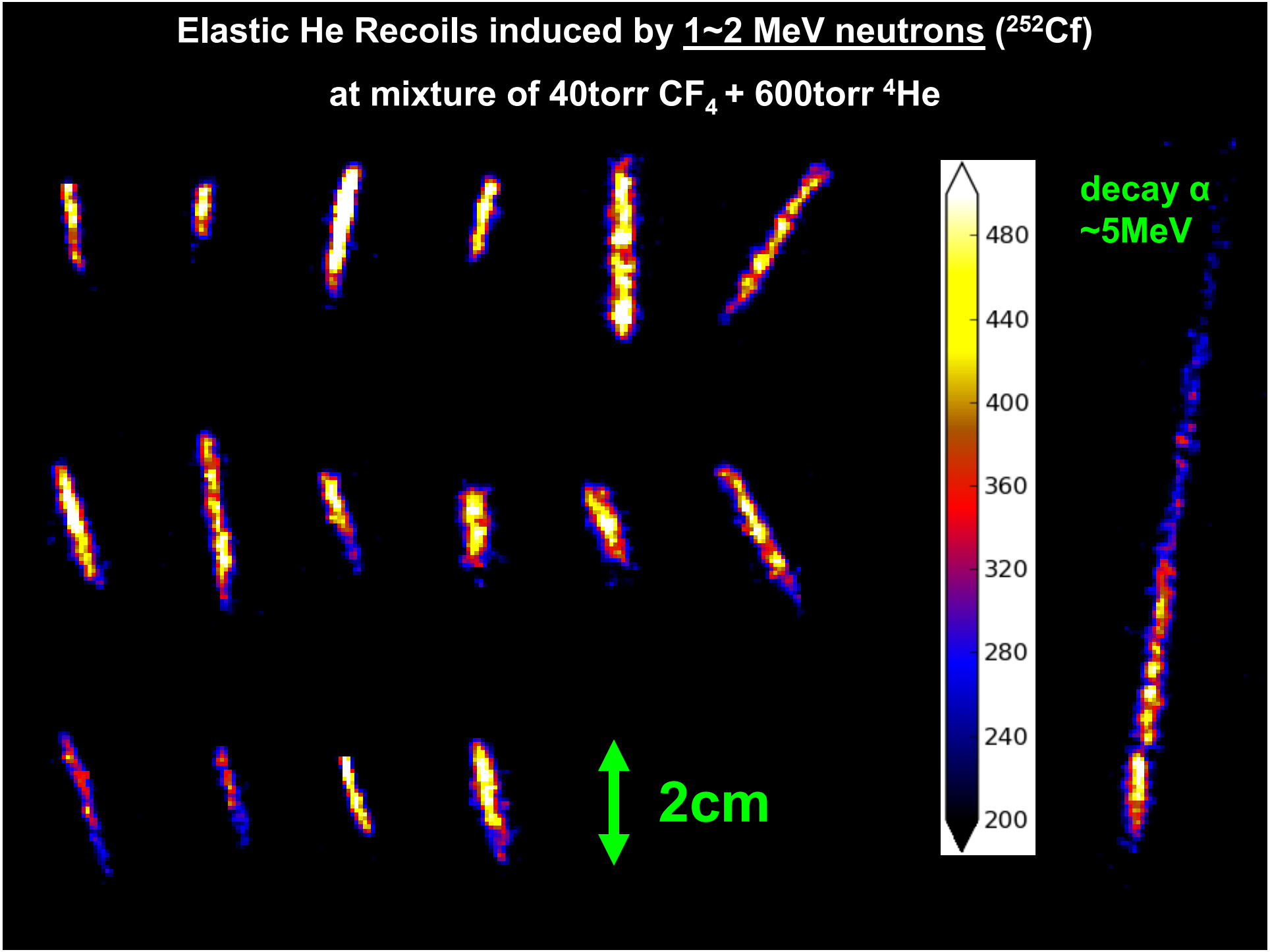
<u>Peaks at 1 ~ 2 MeV</u>

Neutron Cross Section

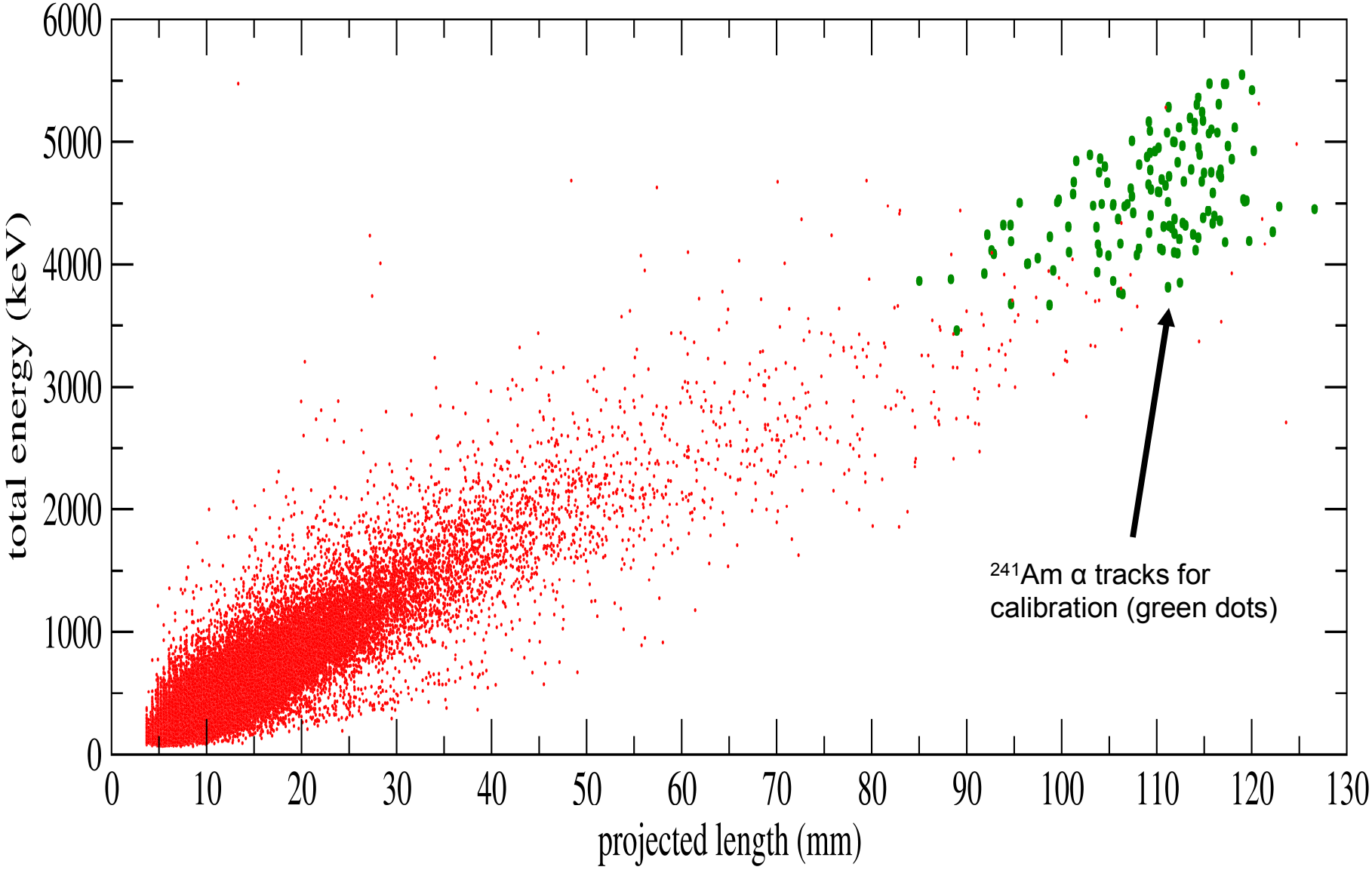


(ENDF/B-VII.0)


~30cm
12 consecutive images with ^{252}Cf

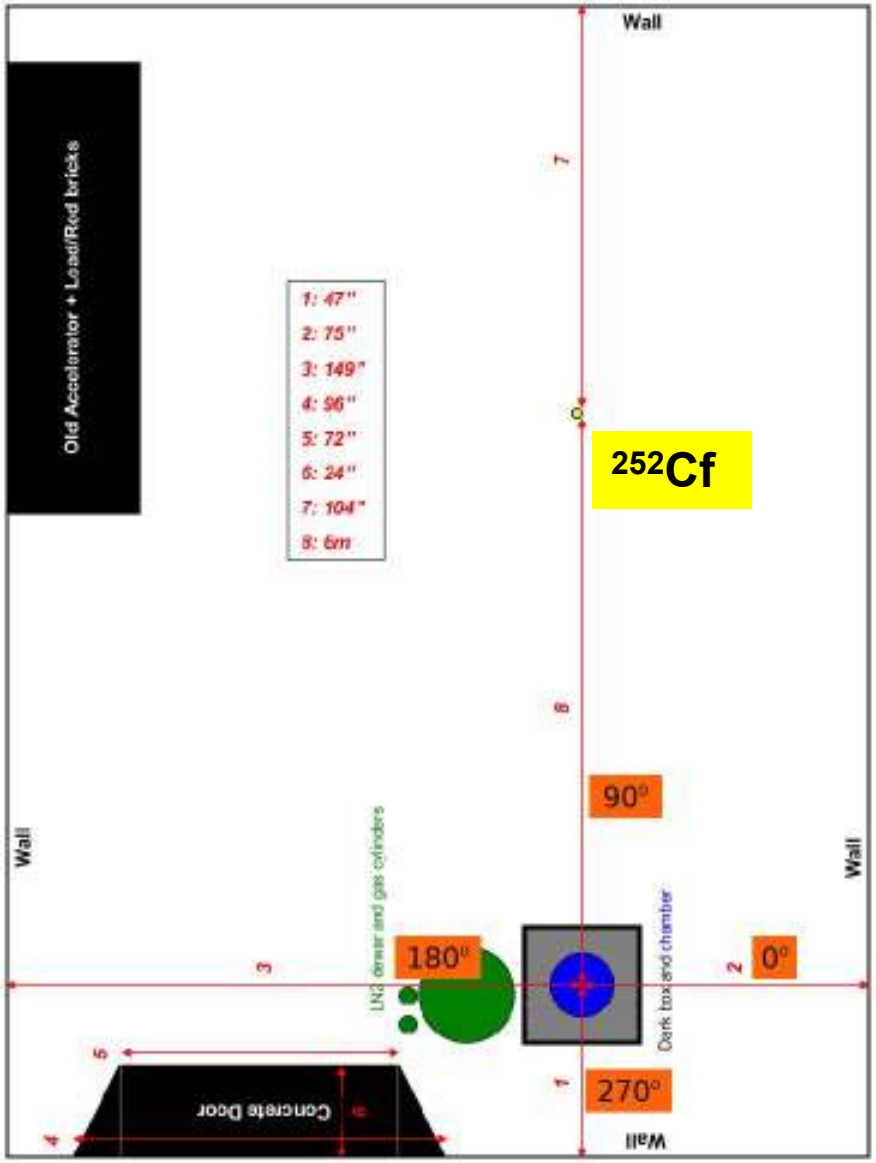

Elastic He Recoils induced by 1~2 MeV neutrons (^{252}Cf)
at mixture of 40torr CF_4 + 600torr ^{4}He
480
440
400
360
320
280
240
200
decay α
~5MeV
2cm

~100k tracks from ^{252}Cf data run

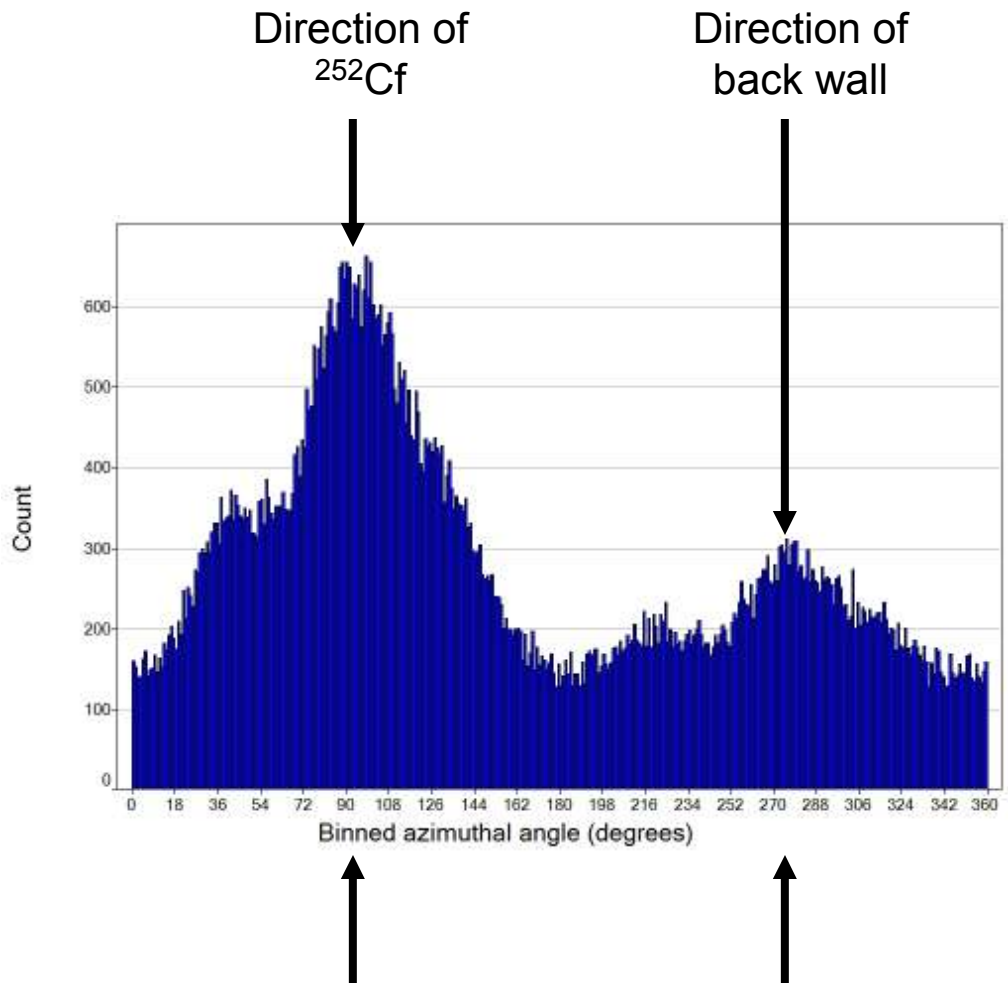


Directionality

angular distribution of ^{4}He recoil



(MIT NW13 basement lab)



90º **270º**

Cylon
currently under construction

Xe-DMTPC

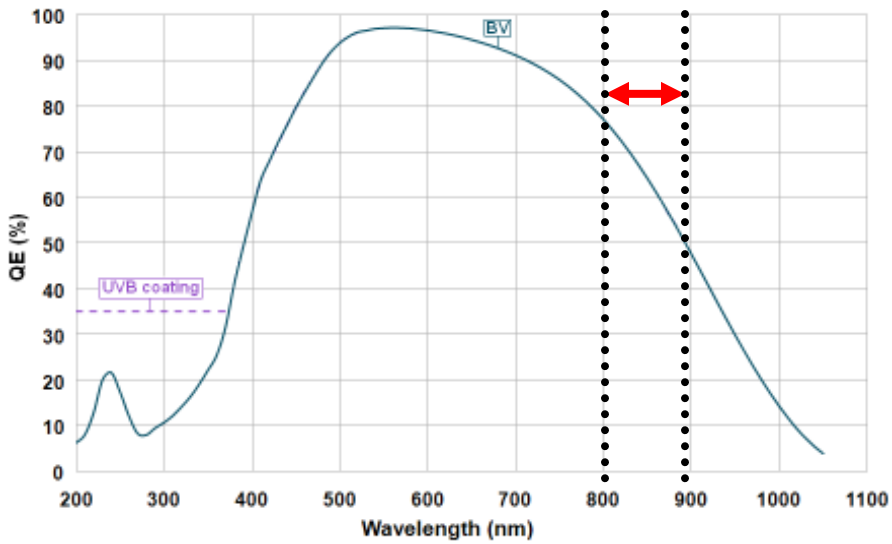
PRELIMINARY

- Same detection technique as F-DMTPC
- Low pressure Xenon gas
- Near Infrared (NIR) region scintillation
- Sensitive to ~50KeV Xe recoil
- Non Linearity of Xenon scintillation ???

(ADU NOT proportional to dE/dx ???)

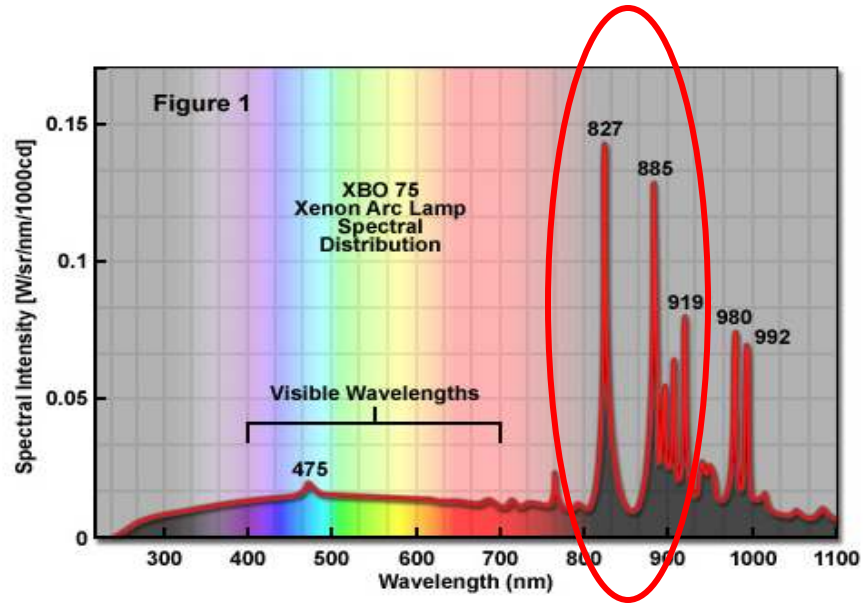
EMCCD Quantum Efficiency

NIR region:
QE of 50~70%



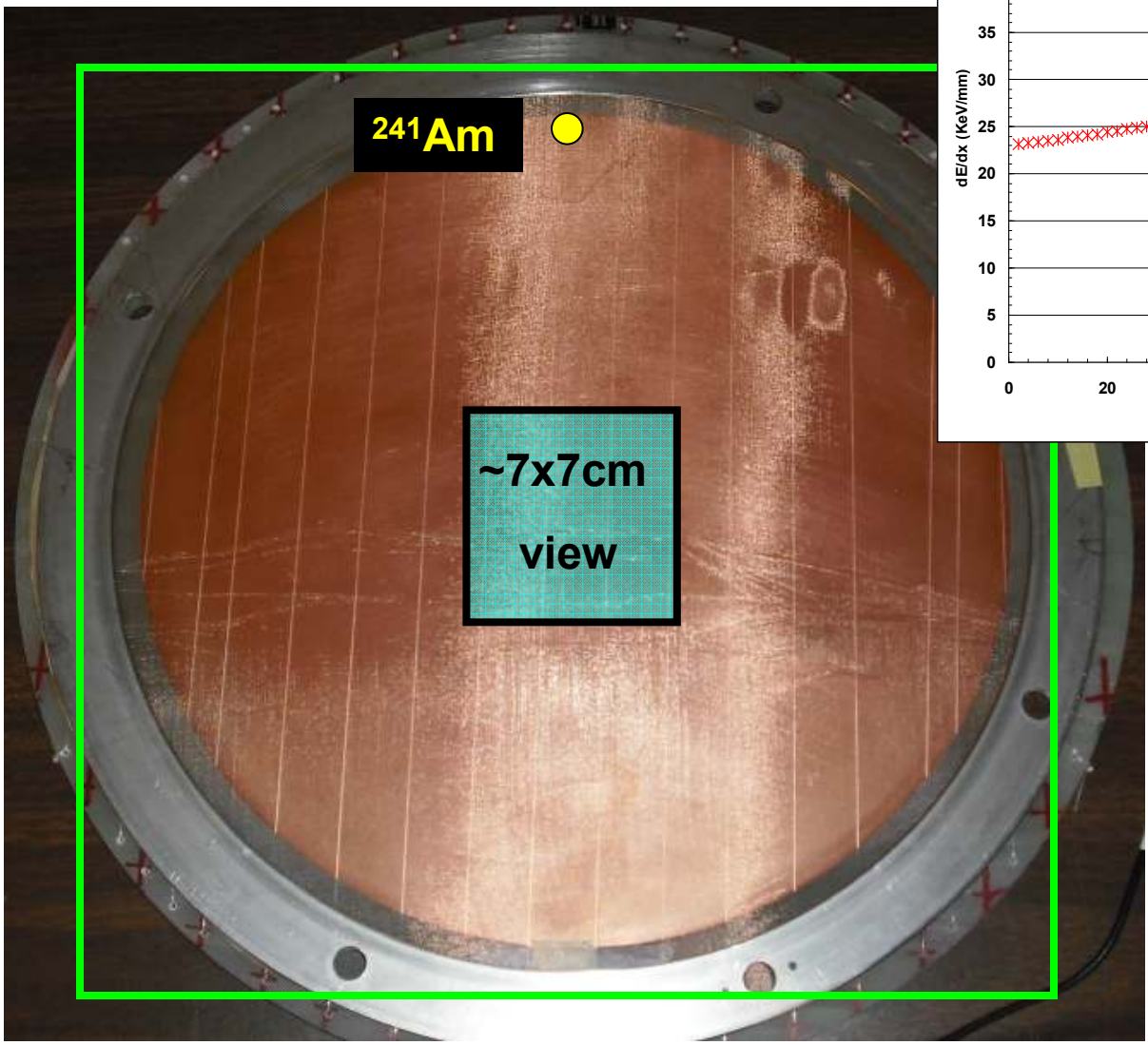
Specification from Andor

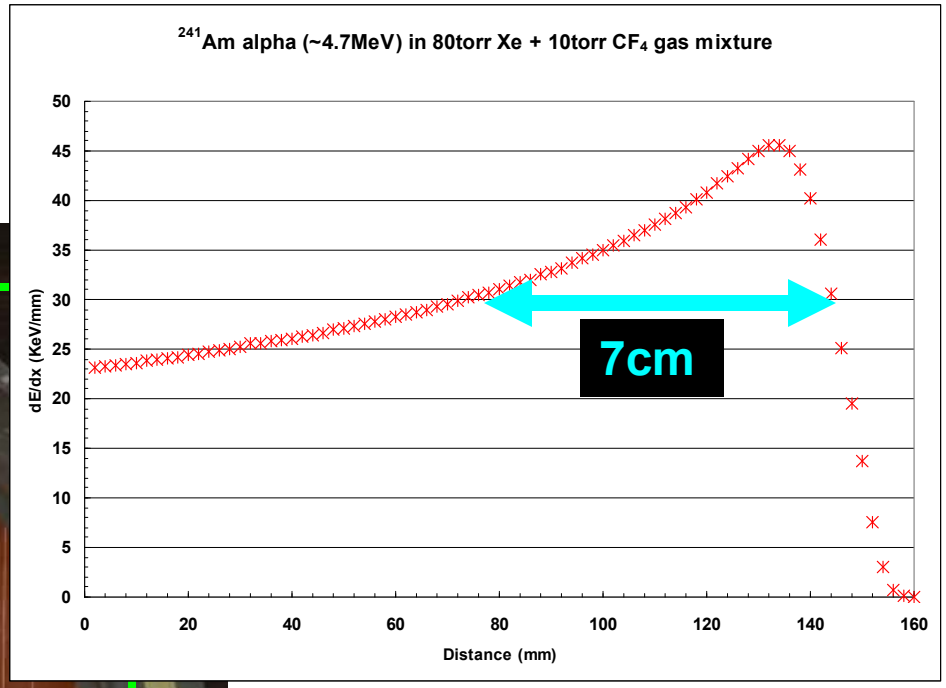
Xenon spectrum



Spectrum of Zeiss XBO-75 xenon arc lamp

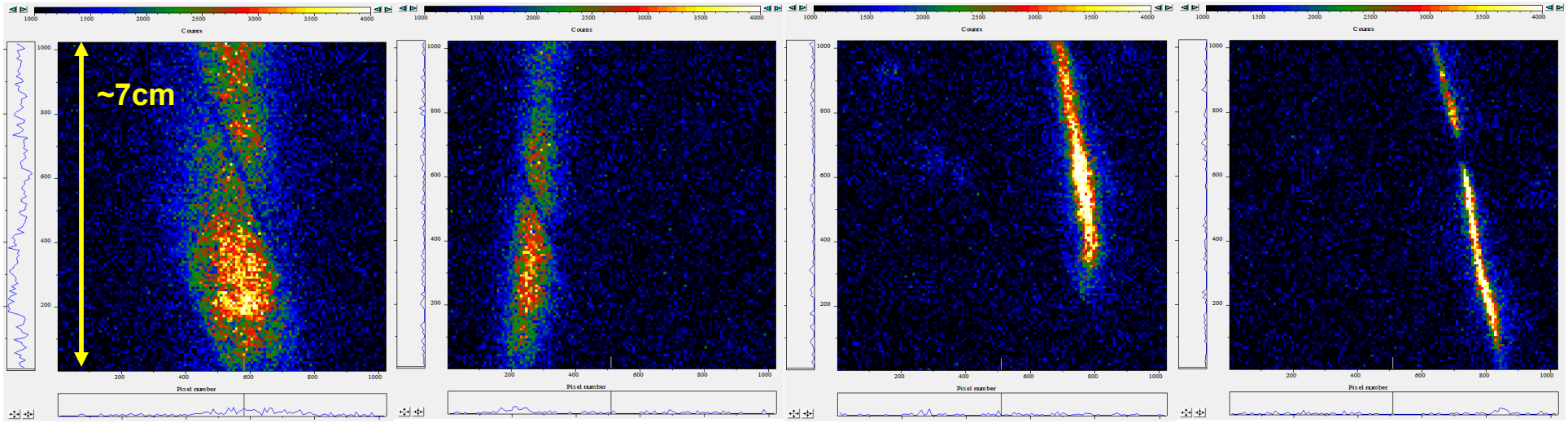
Set Up



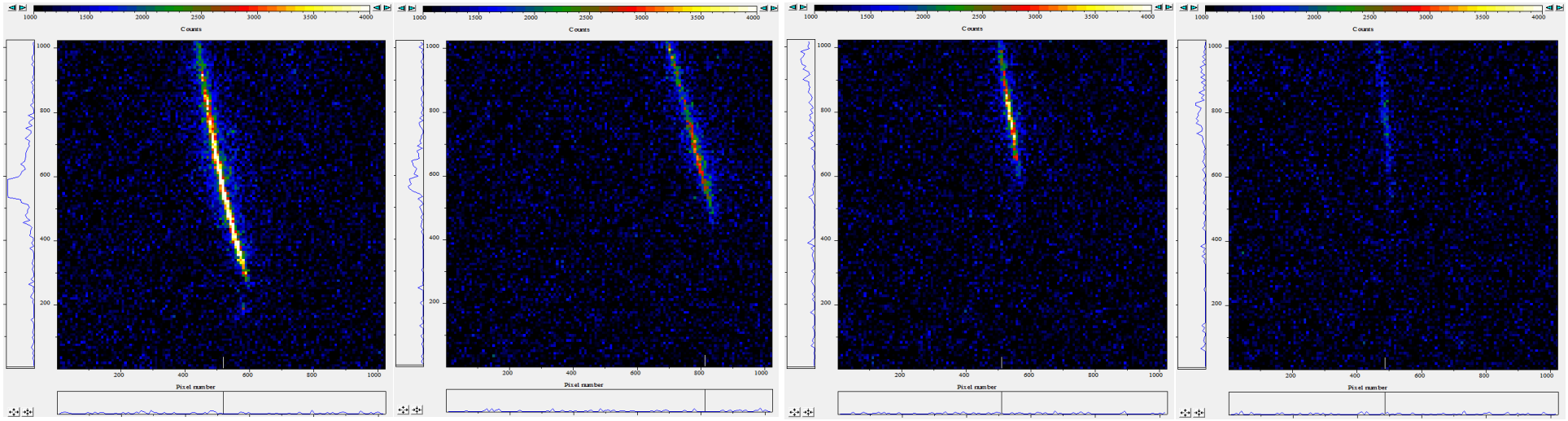


- EMCCD
- Schneider 50mm Lens
- ^{241}Am at 1cm from Anode plane

Optimization of gas pressure & mixing ratio



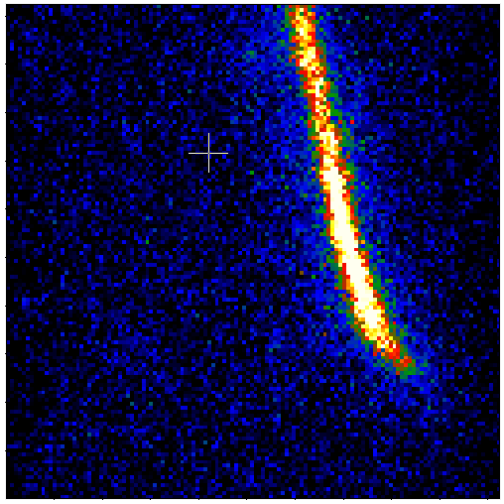
(80torr Xe) (80torr Xe + 1torr CF_4) (80torr Xe + 5torr CF_4) (80torr Xe + 10torr CF_4)



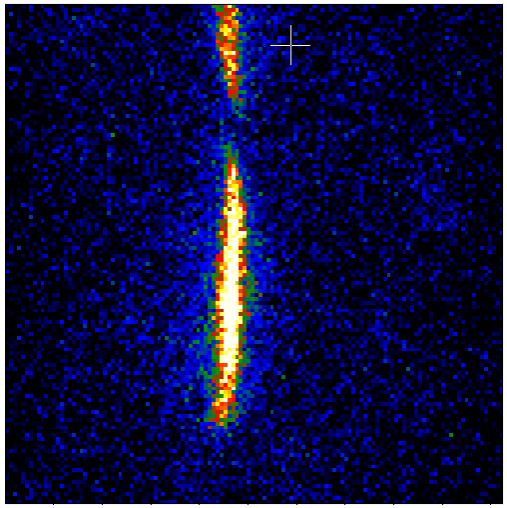
(80torr Xe + 15torr CF_4) (80torr Xe + 20torr CF_4) (80torr Xe + 25torr CF_4) (80torr Xe + 30torr CF_4)

Non Linearity of Gain ???

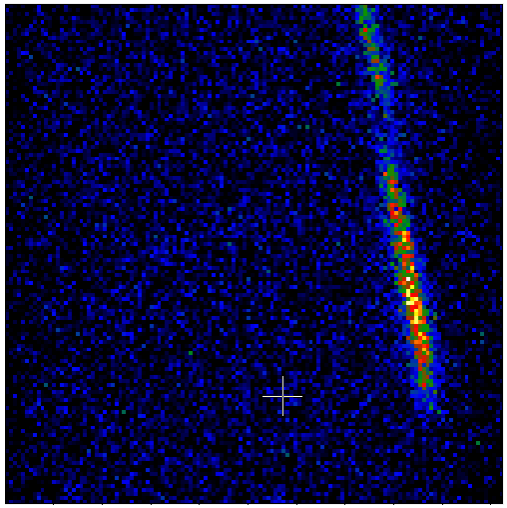
(80torr Xe + 10torr CF_4)



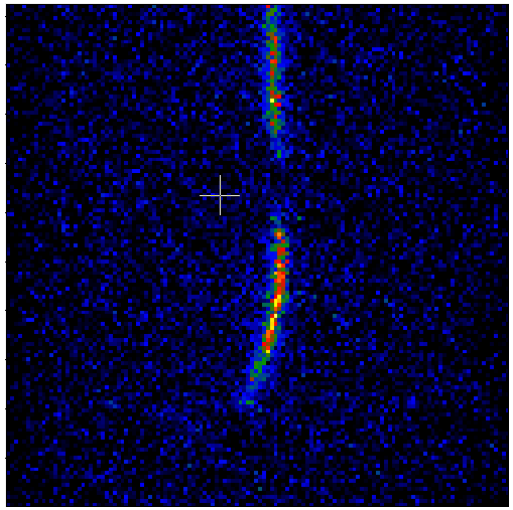
(Anode Voltage = +495v)



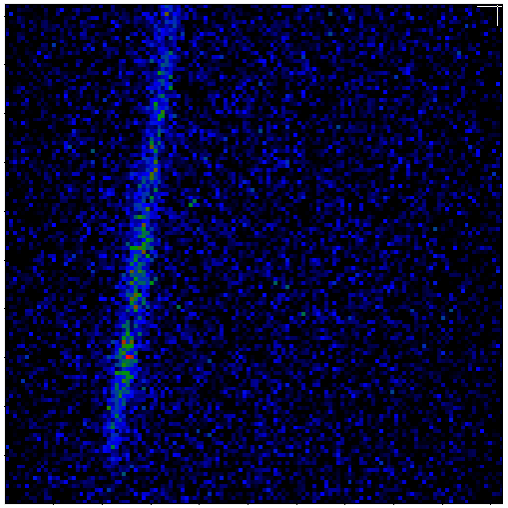
(490v)



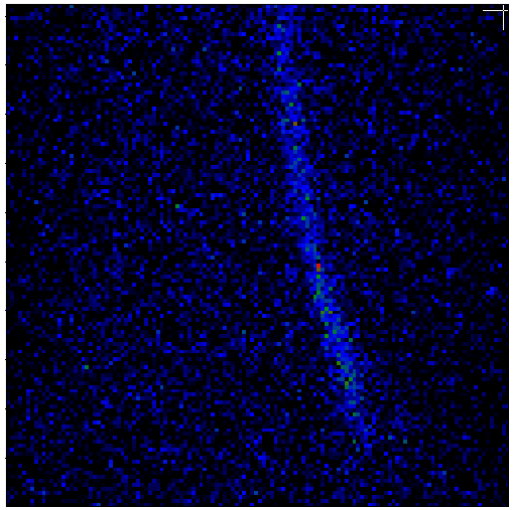
(480v)



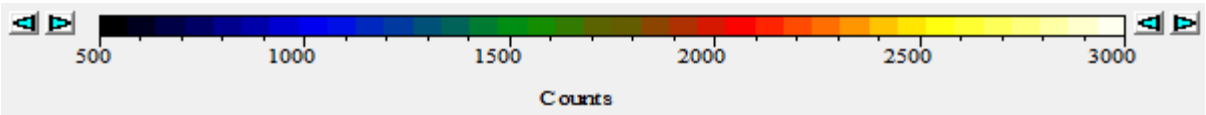
(470v)

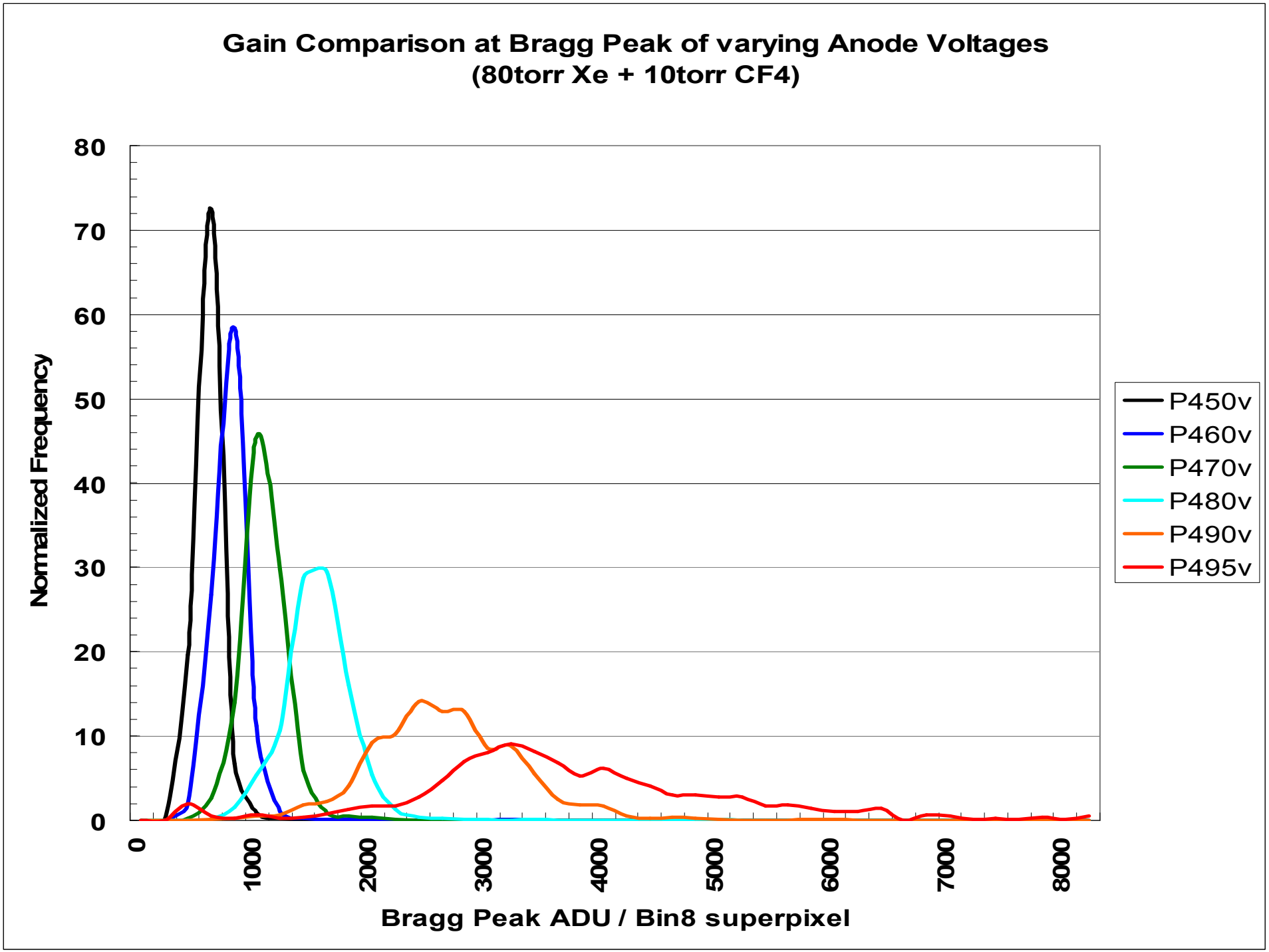


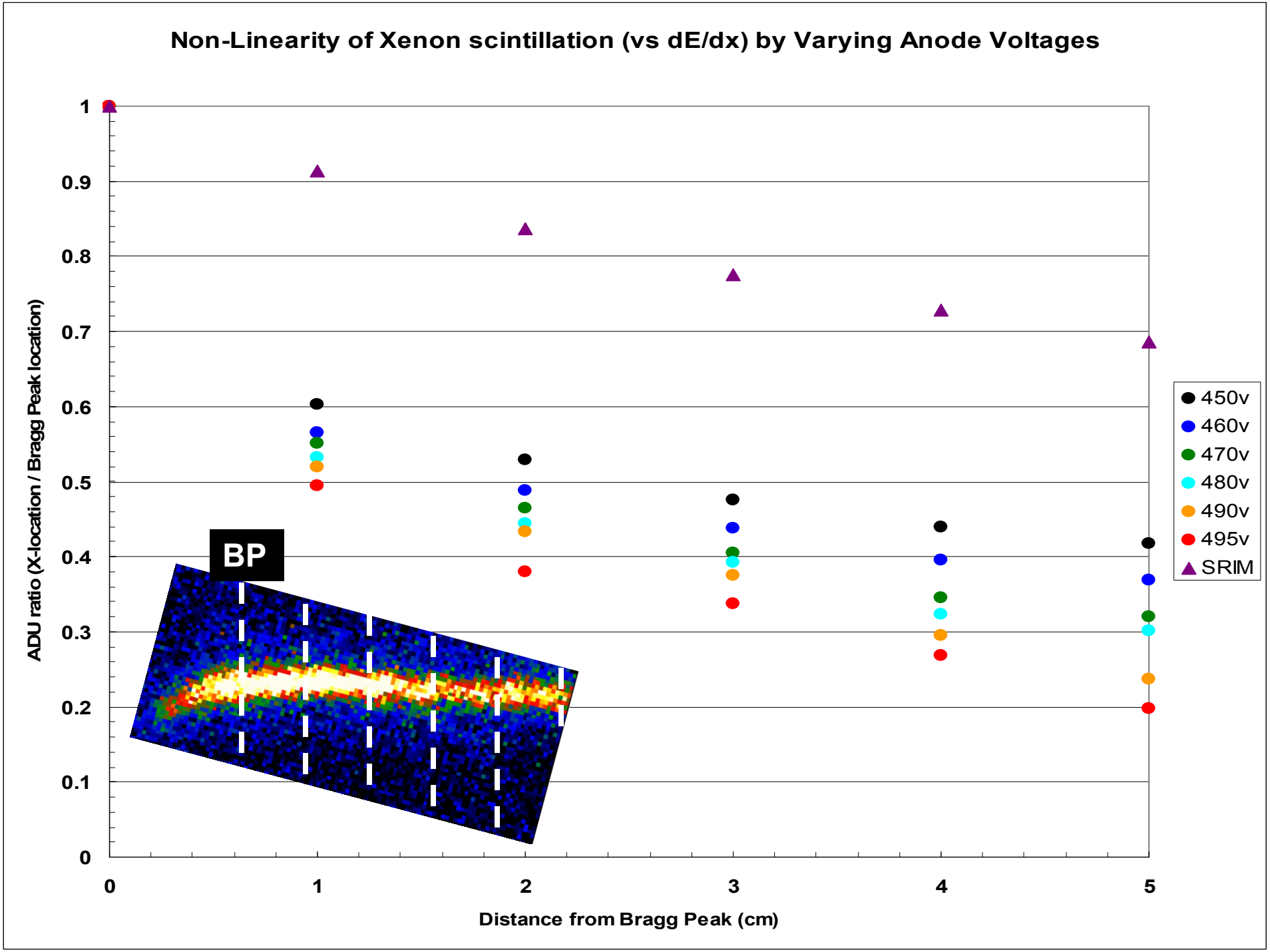
(460v)



(450v)




Gain Comparison at Bragg Peak of varying Anode Voltages
(80torr Xe + 10torr CF4)
Normalized Frequency
80
70
60
50
40
30
20
10
0
0
1000
2000
3000
4000
5000
6000
7000
8000
Bragg Peak ADU / Bin8 superpixel
P450v
P460v
P470v
P480v
P490v
P495v


Non-Linearity of Xenon scintillation (vs dE/dx) by Varying Anode Voltages
ADU ratio (X-location / Bragg Peak location)
Distance from Bragg Peak (cm)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
1
2
3
4
5
BP
450v
460v
470v
480v
490v
495v
SRIM

Summary

- We are starting R&D for low pressure gaseous-Xe TPC with optical readout
- With proven technique, the first model of Cylon will be up and running this summer

End

abstract

- Neutrons – known to mimic Dark Matter interaction – are one of the biggest background noises that we need to understand thoroughly in search for Dark Matter. Motivated as a study for background of Dark Matter research, the neutron detecting project has begun to stand on its own feet. Our new project – Cylon – is a neutron detector that can obtain the energy, length and angular distribution information of fast neutron induced recoil tracks. Heavy nuclei (such as plutonium) emit neutrons with known energy, and thus, Cylon can be used as a sensitive nuclear weapon detecting device with the strength of directionality. Cylon is a TPC (Time Projection Chamber) filled with mixture of CF4 and He4 gas to achieve the maximum scintillation and interaction efficiency.