Nuclear Recoil Calibration in Pressurized Noble Gasses

Results from the SIGN R&D Program

J.T. White

Texas A&M University

Hunt for Dark Matter -FNAL 5/11/07

TAMU – JT White
UCLA – H. Wang

Why Gaseous Nobles?

- Neon:
  - Electron mobility➔ possible S2/S1 discrim.?
    ➔ fiducial well defined

- Xenon & Argon & Neon
  - Room temperature operation
  - Simpler purification
  - No leveling
  - No Cryo, etc

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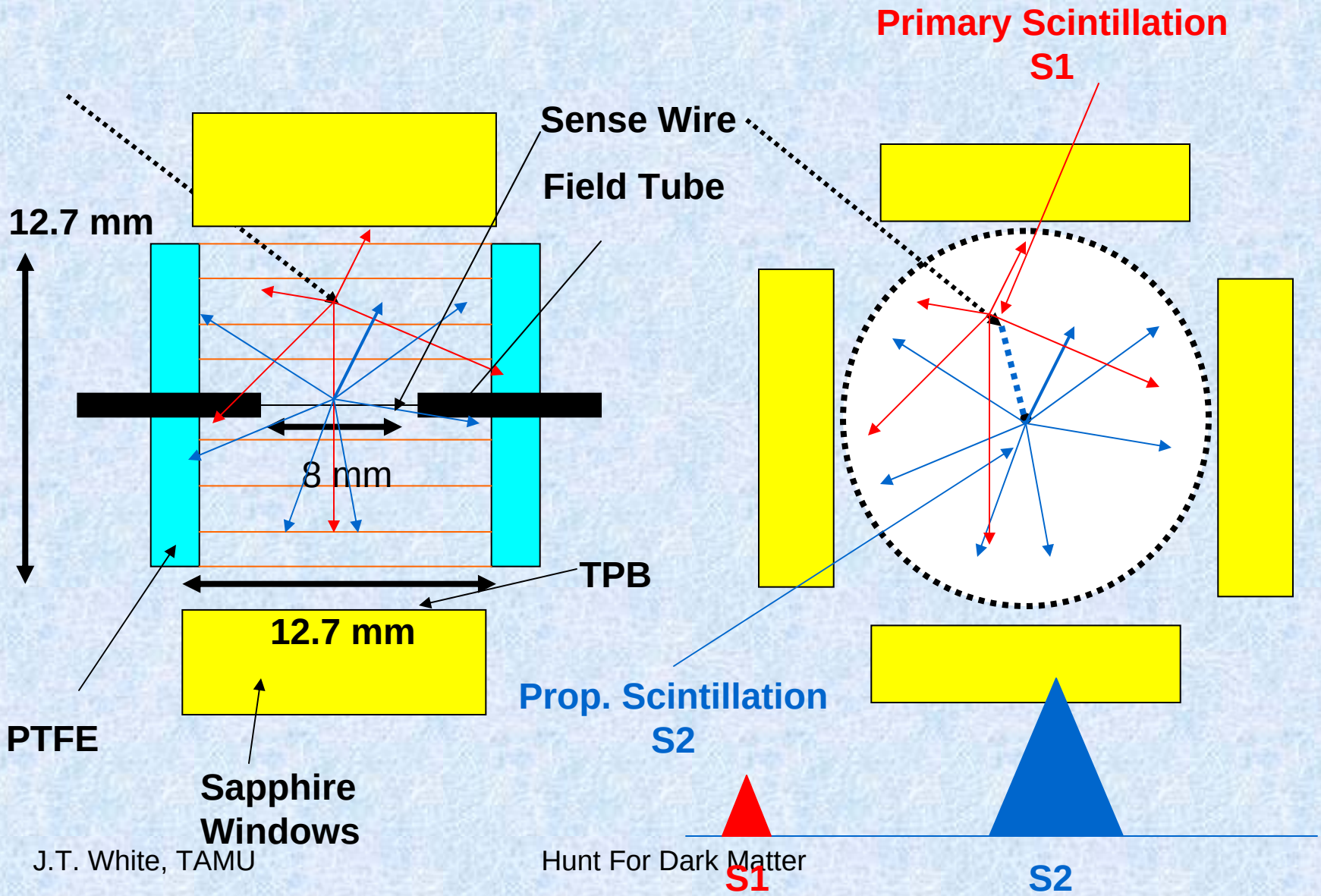
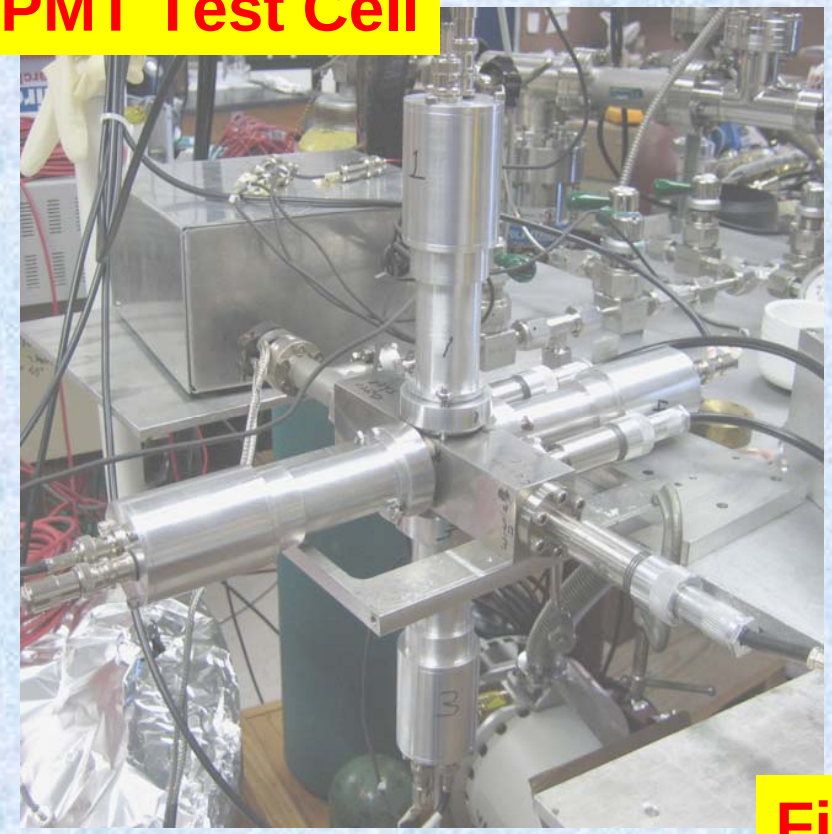
So-
Is there S2/S1 discrimination???

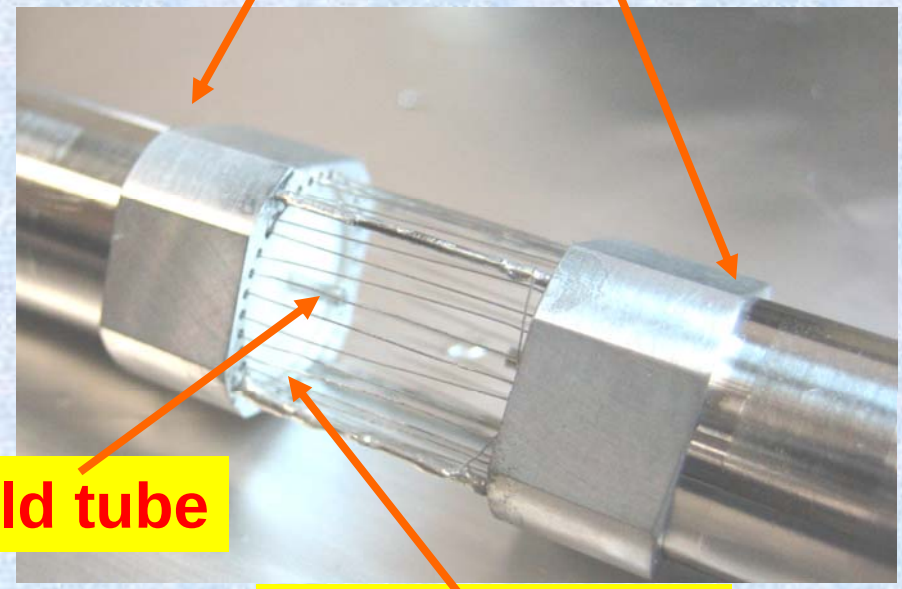
100 atm Test Cell



Nuclear Recoil Discrimination?

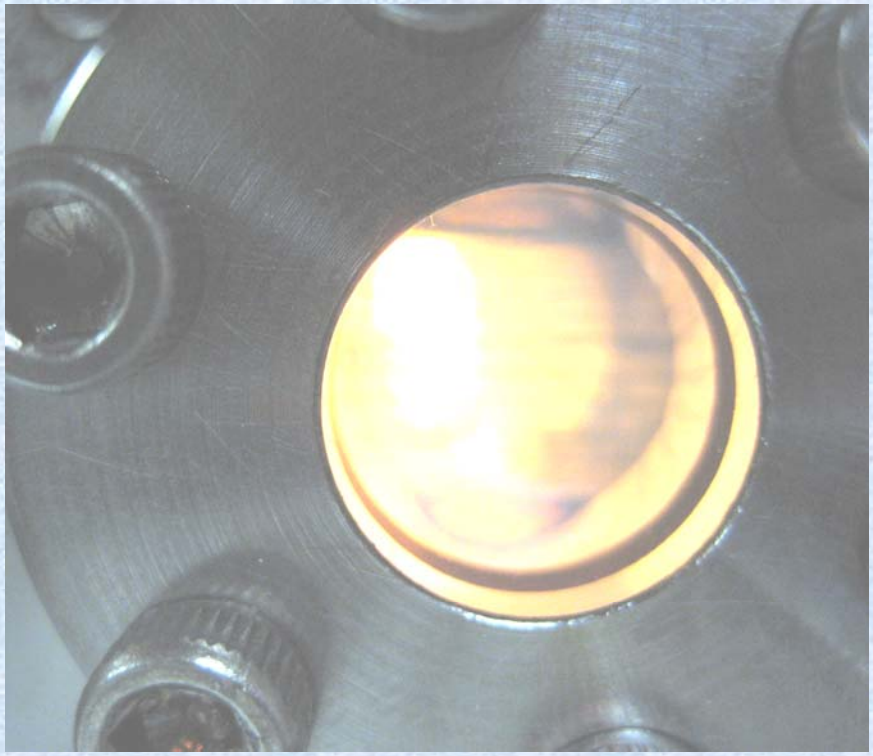
4-PMT 100 atm Test Cell



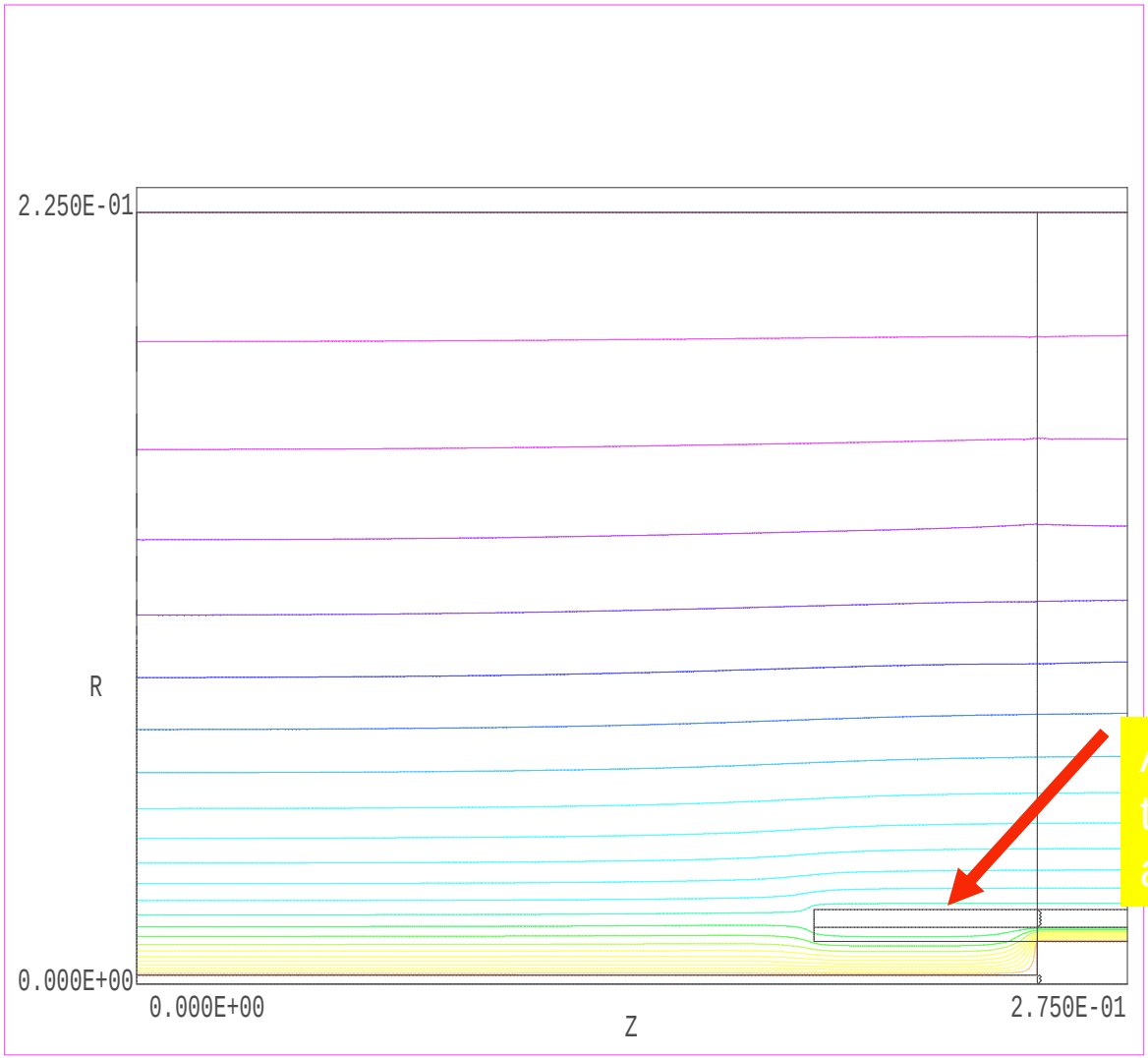


Sapphire Windows

TPB coating



Field Tuning



File prefix: tetrav2.EOU
Plot type: Contour
Quantity: Potential (V)

Minimum value: 0.000E+00
Maximum value: 4.198E+03

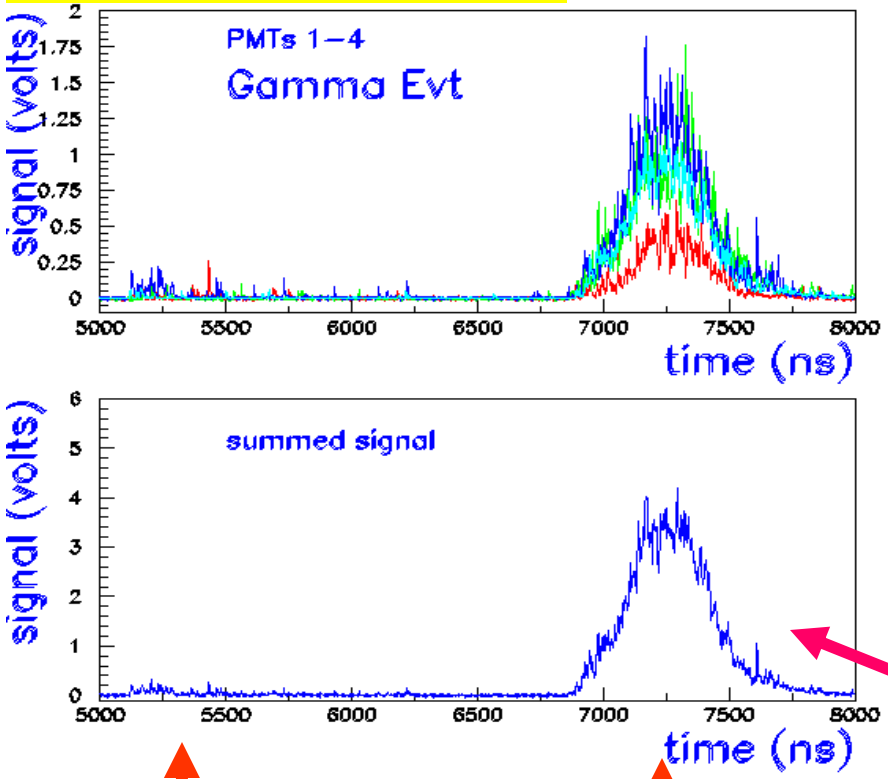
3.498E+02
6.997E+02
1.049E+03
1.399E+03
1.749E+03
2.099E+03
2.449E+03
2.799E+03
3.148E+03
3.498E+03
3.848E+03
4.198E+03

Adjust field tube potential to optimize E-field uniformity along sense wire

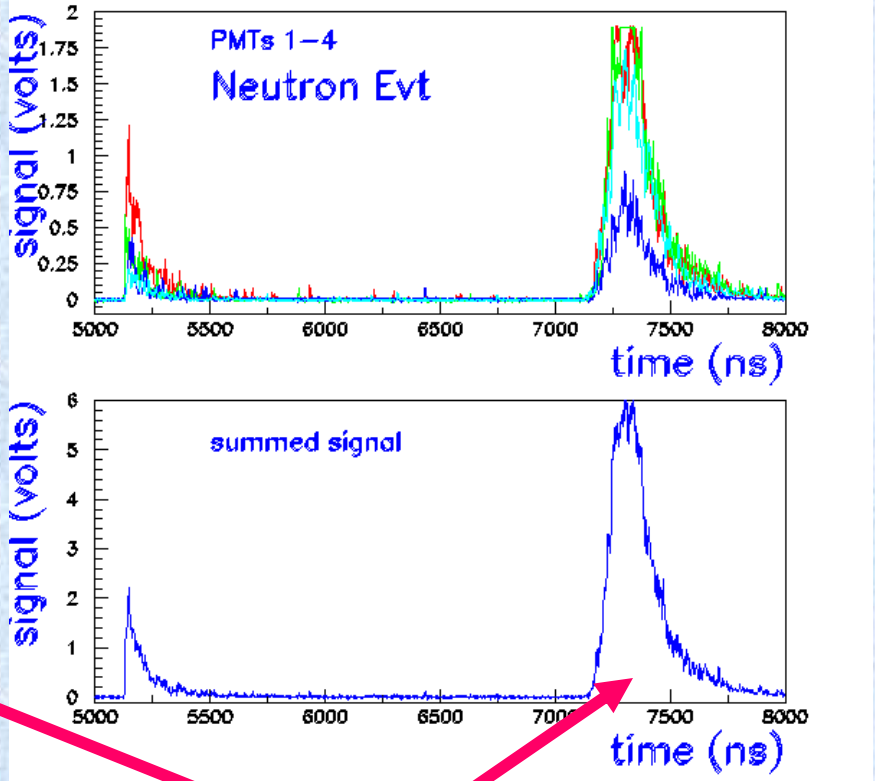
Current view window

Event Waveforms (Ne-Xe example)

Gamma Event



Neutron Event

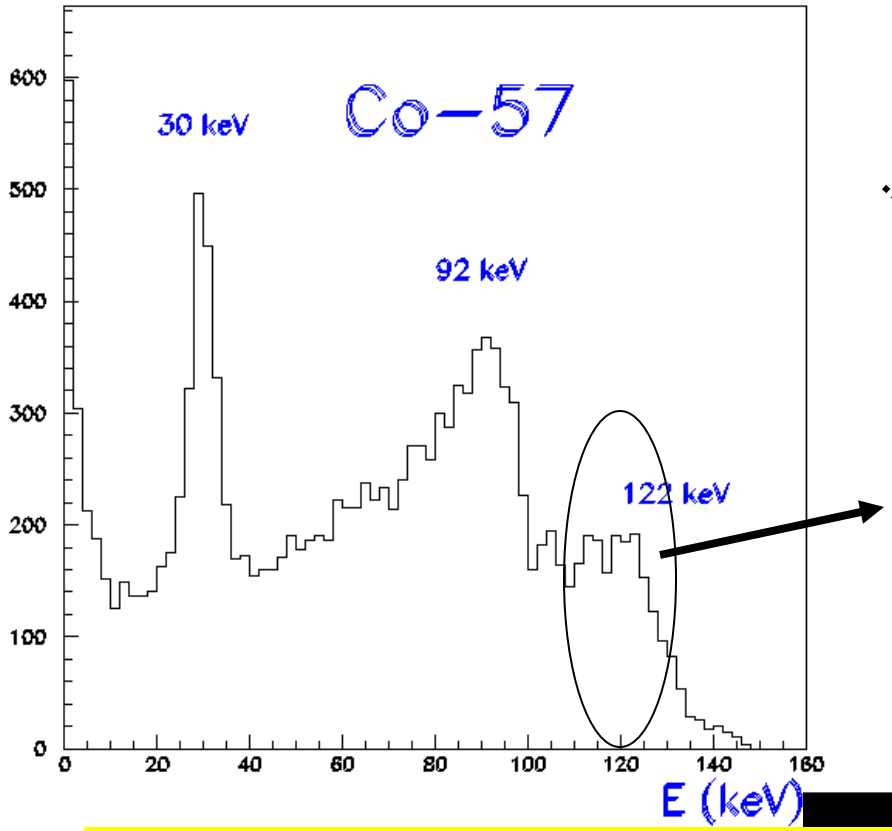


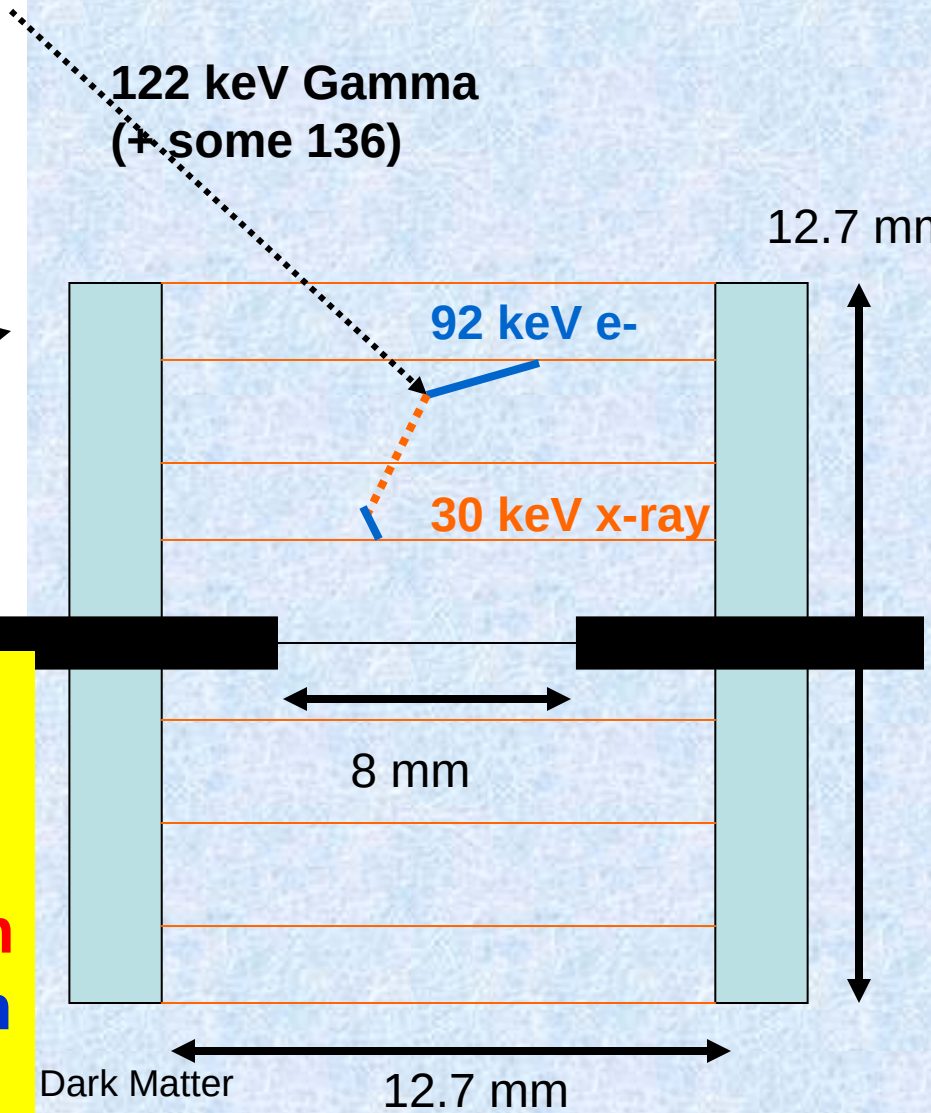
Primary (S1)

Secondary (S2)

Areas Same
i.e. ionization same

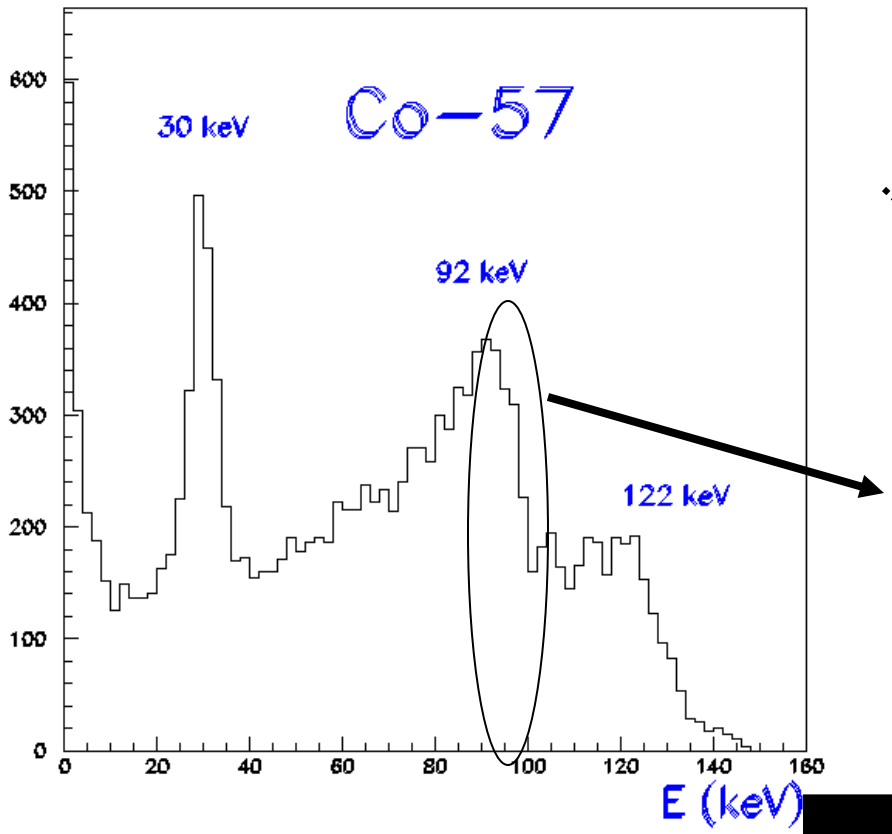
Calibration

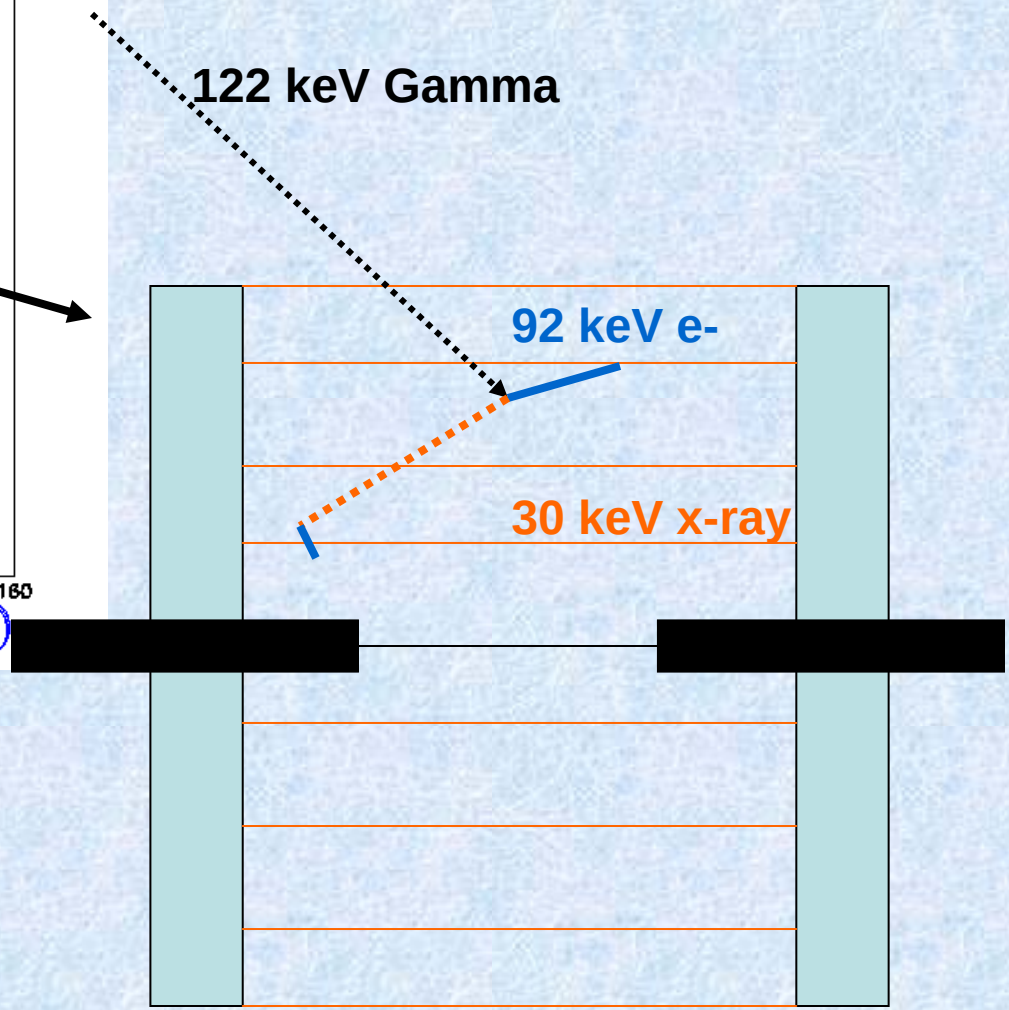




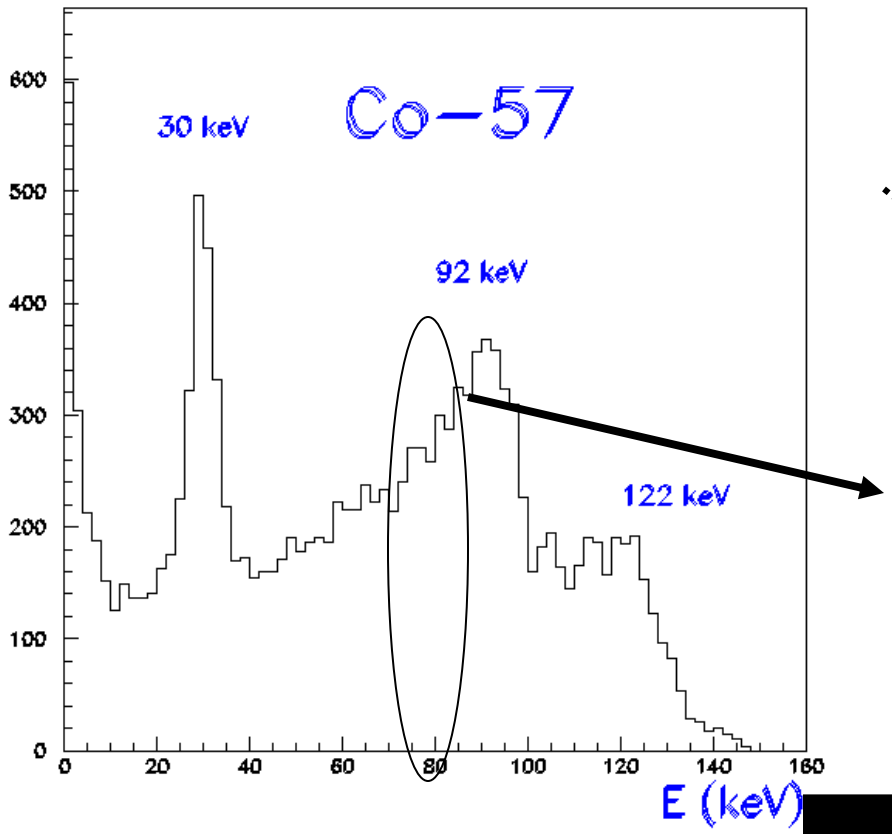
Xe gas: 20 atm
mfp 30 keV x-ray ~ 1 cm
Range 92 keV e- ~ 2 mm
Range 30 keV e- ~ 0.2 mm
Leff ~ 4.5% if Ws=76ev/ph
Qgain ~ 1.2 p.e./e- (here)

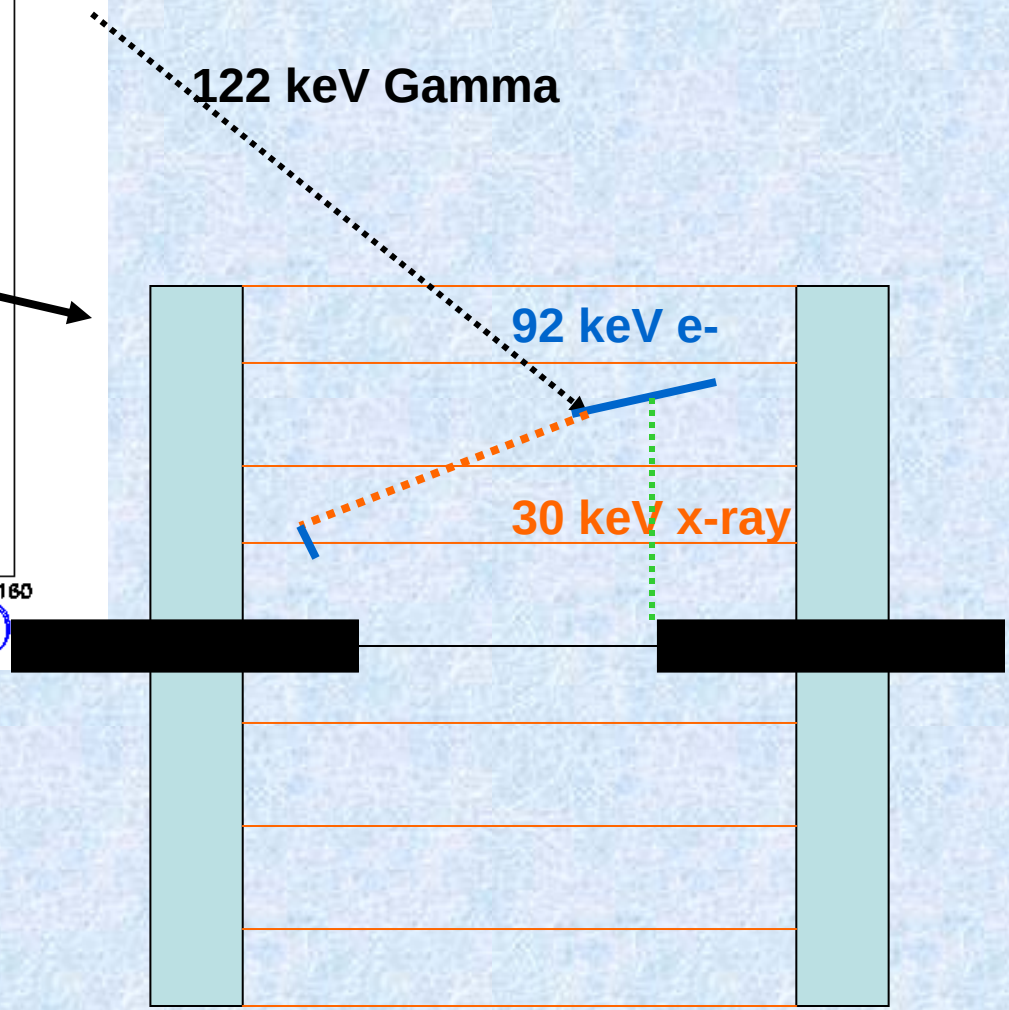
Calibration



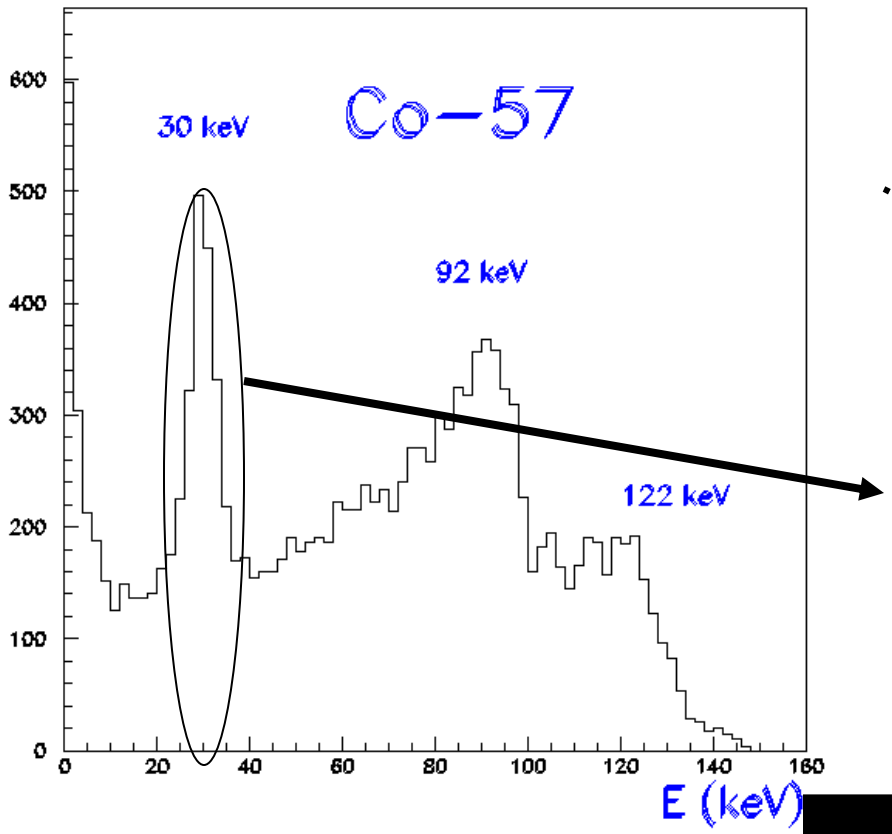


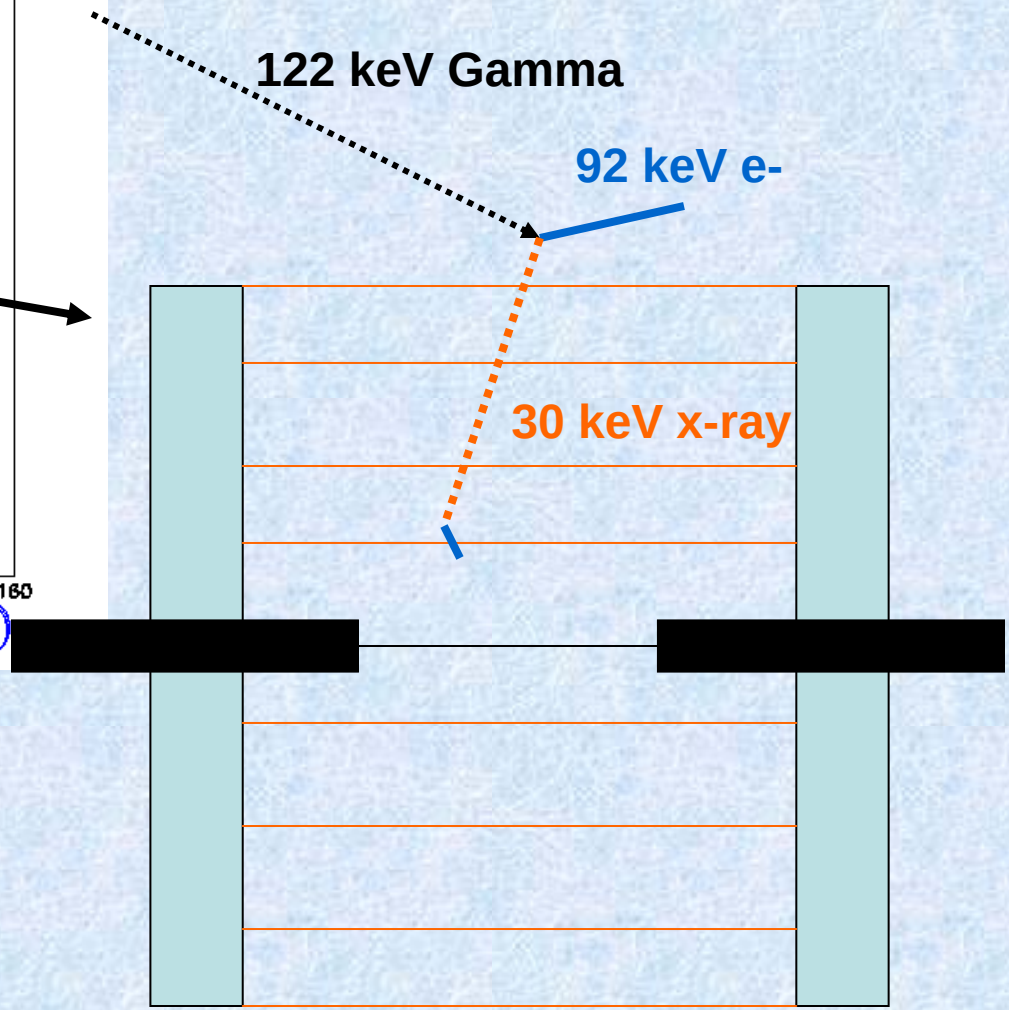
Calibration



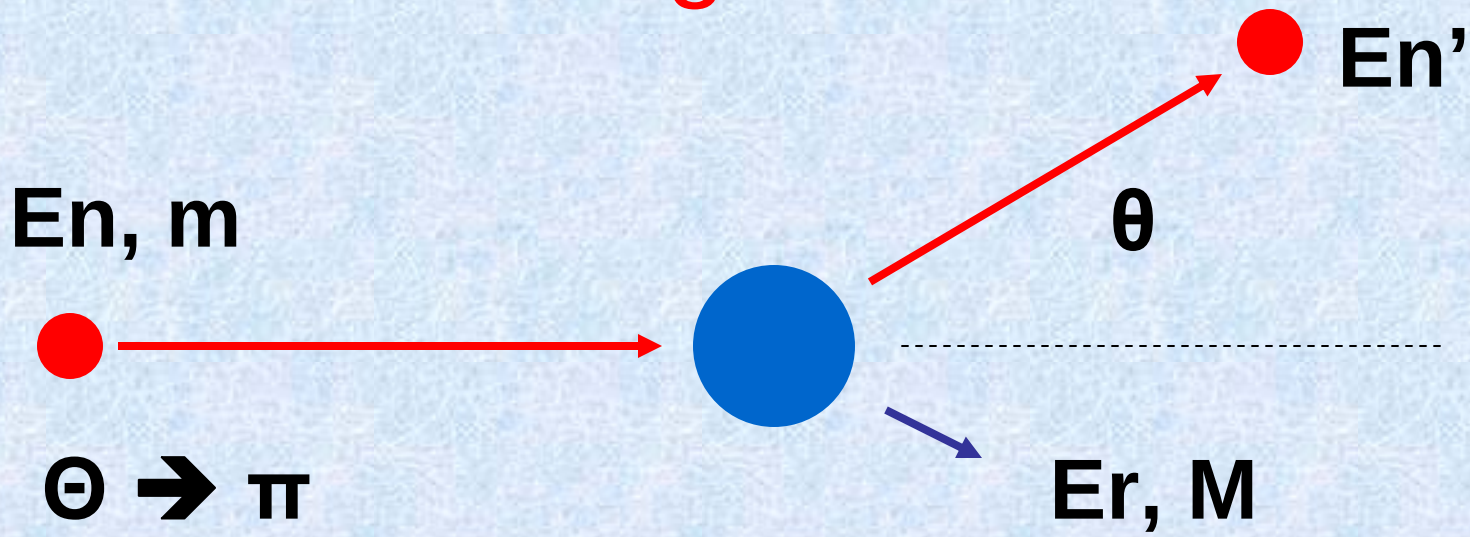


Calibration





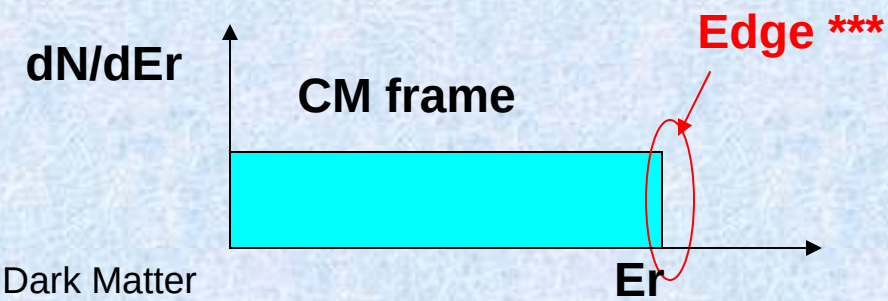
Neutron Scattering w/ Mono-Energetic Neutrons



Θ → π

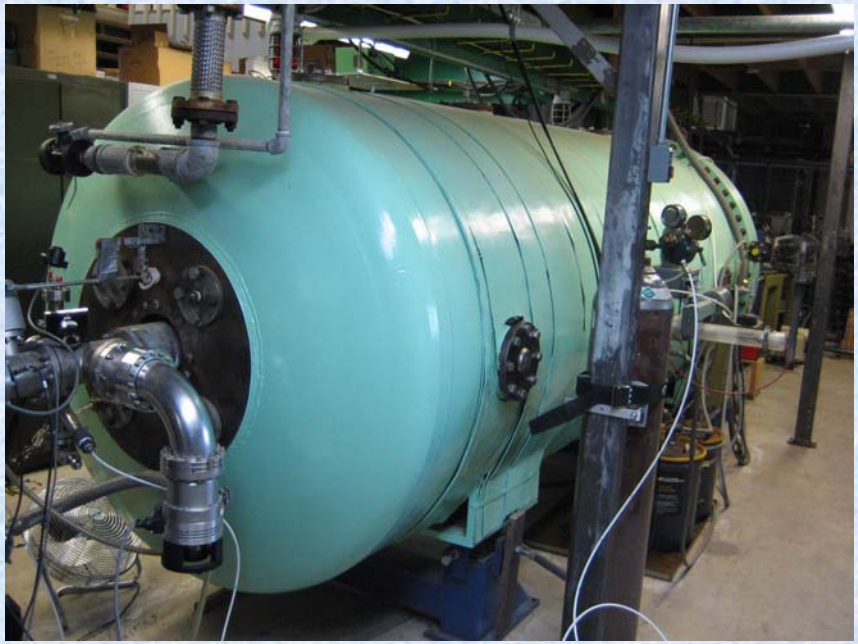
Er → Ermax = (4 m M/(m+M)^2) En

S – Wave →

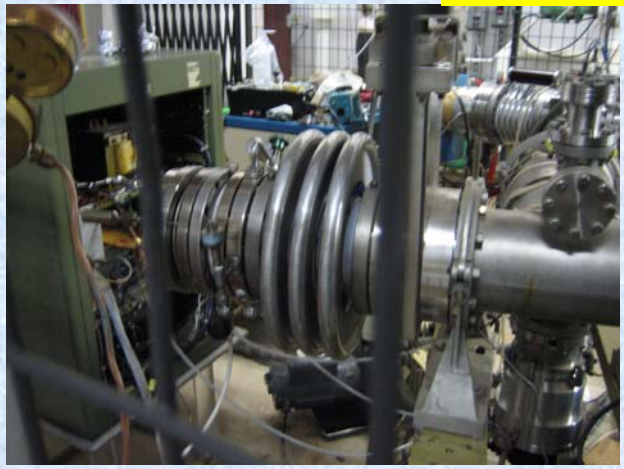


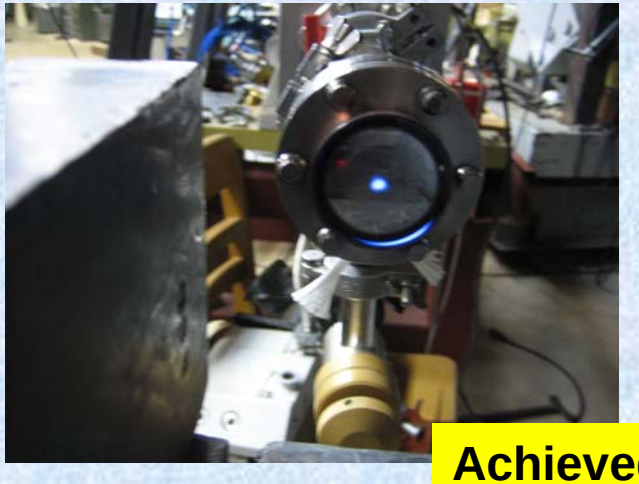
4-MeV Proton Accelerator at TAMU

Tandem van de Graaff



Duoplasmatron Ion source up to ~ 15 uA

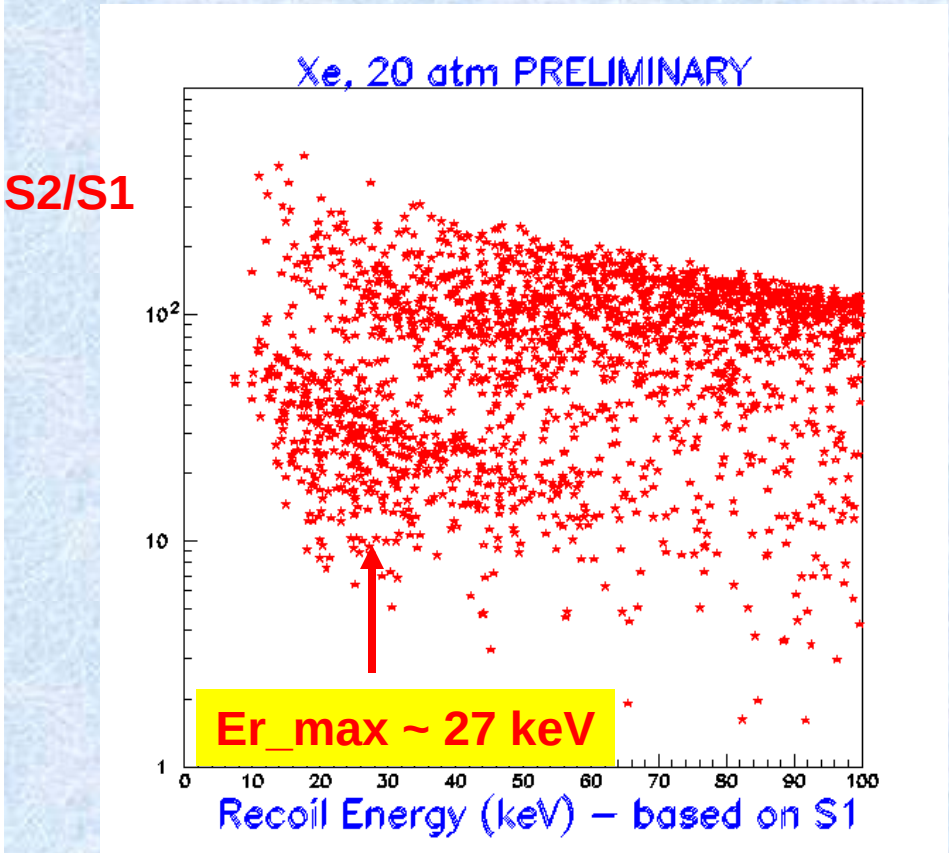


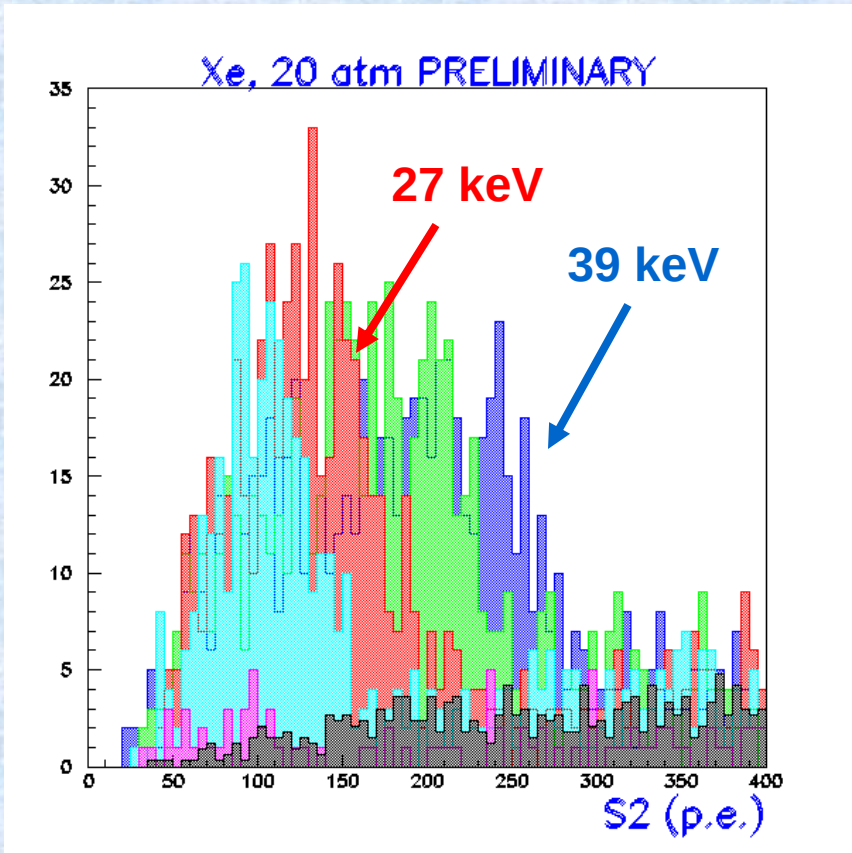


Monochromatic neutrons up to 2 MeV using ^{7}(Li(p,n)^{7}Be reactions.

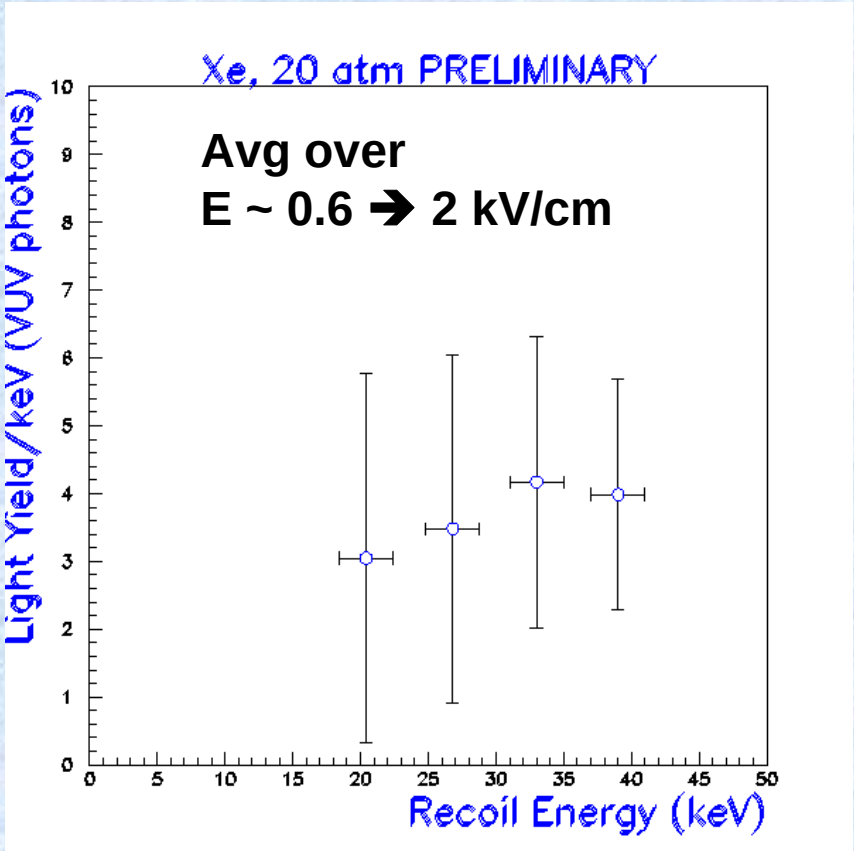
Achieved >1 uA on target ➔ >5E6 n/sr/s

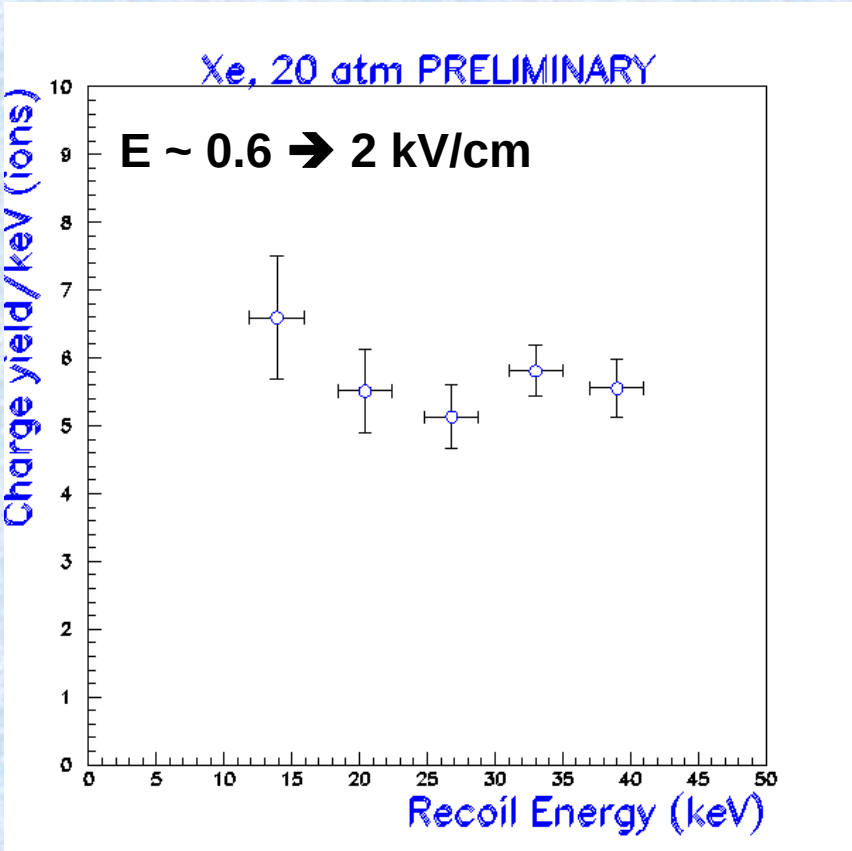
Xe – 20 atm
NR response





Xe – NR Light & Charge Yields

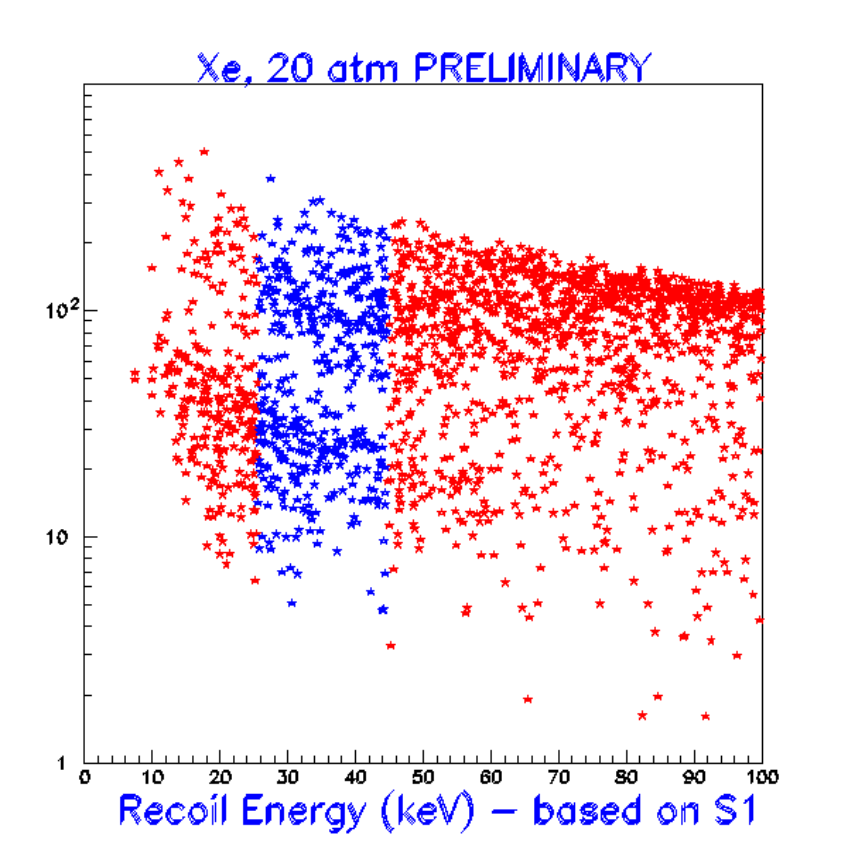


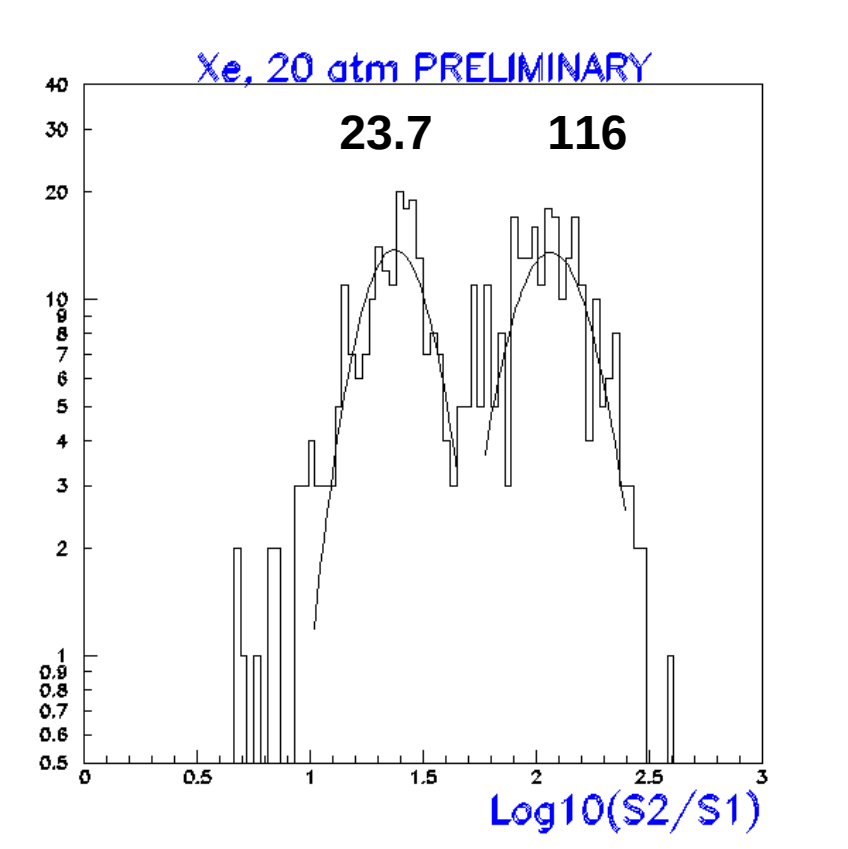


Assuming Leff=4.5%

Assuming Wi = 21.7 ev/e-

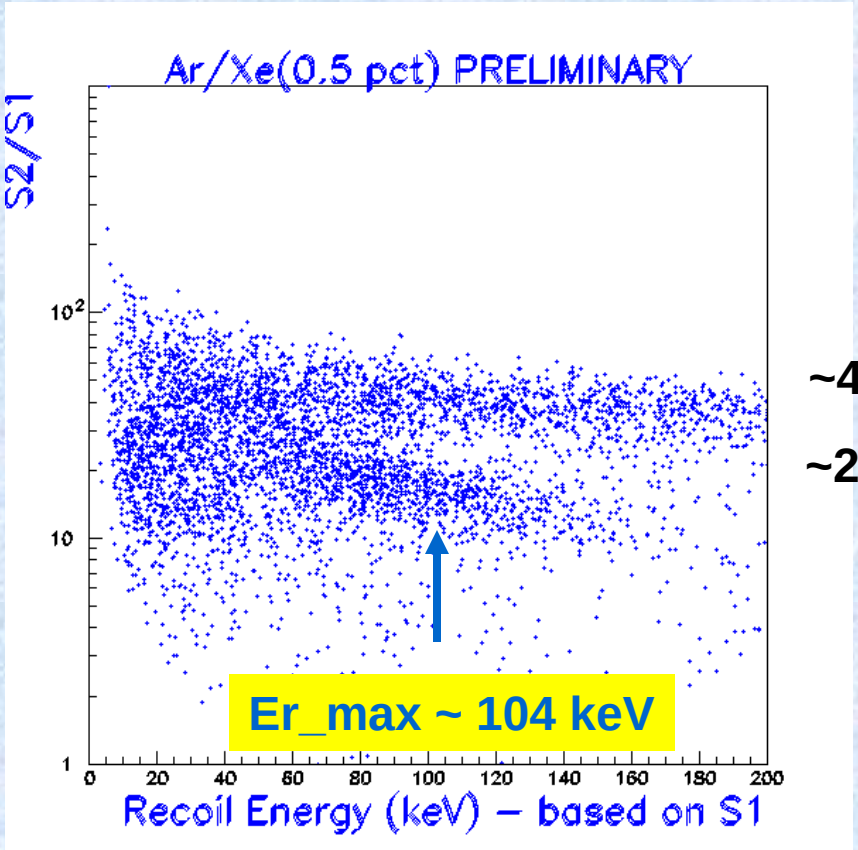
Xe – S2/S1 Discrimination





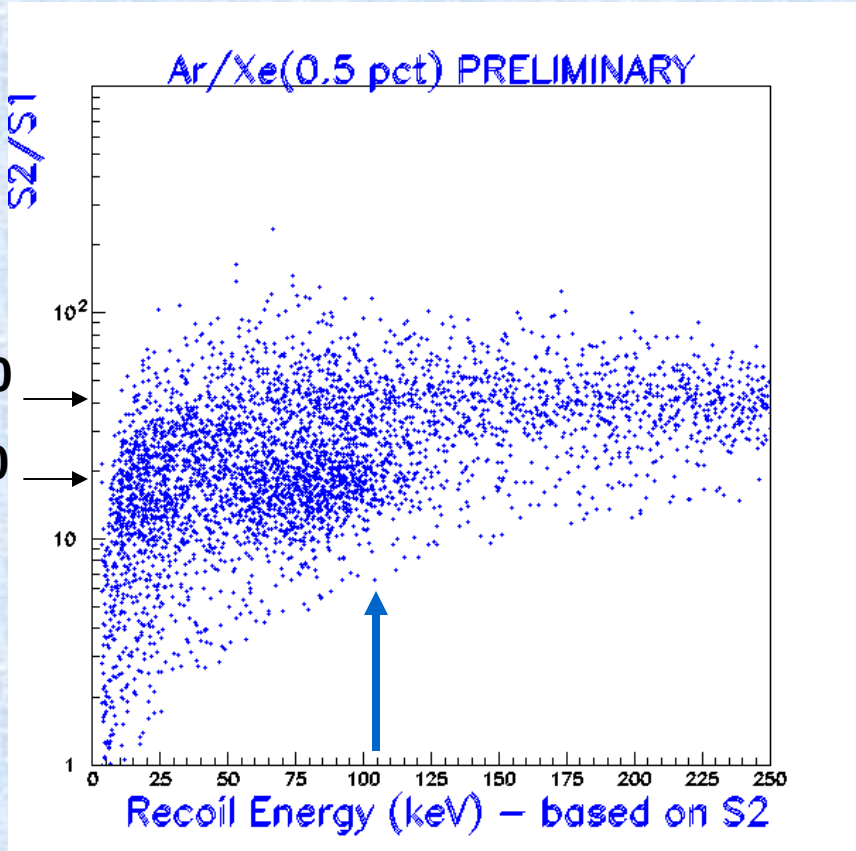
Centroid Separation > X4

ArXe(0.5%) – 50 atm
NR Response

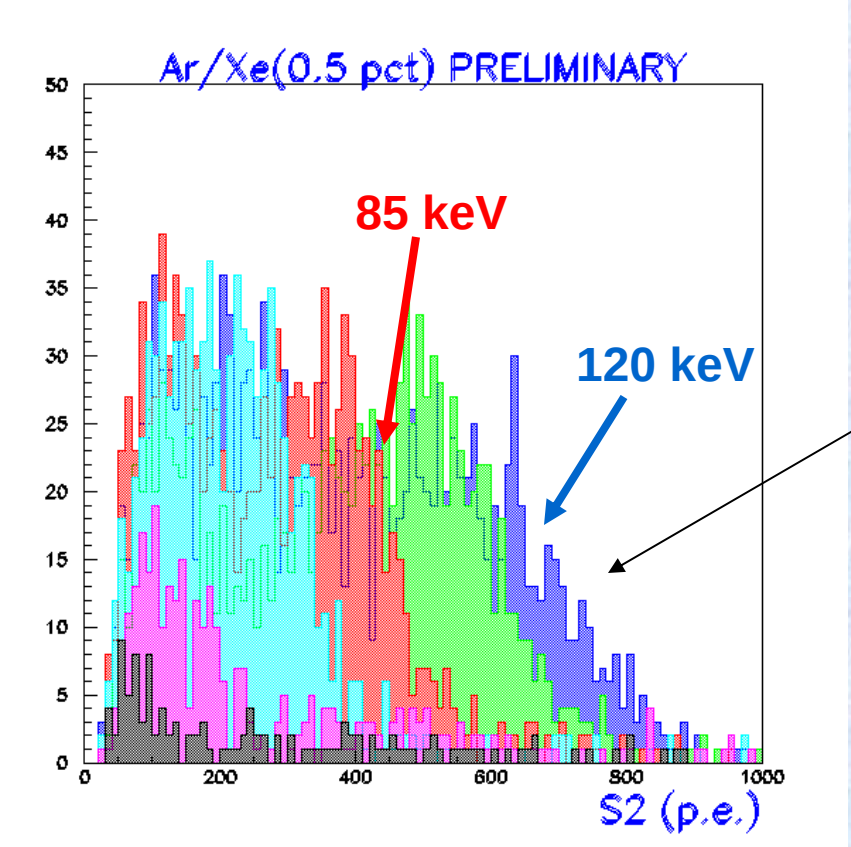


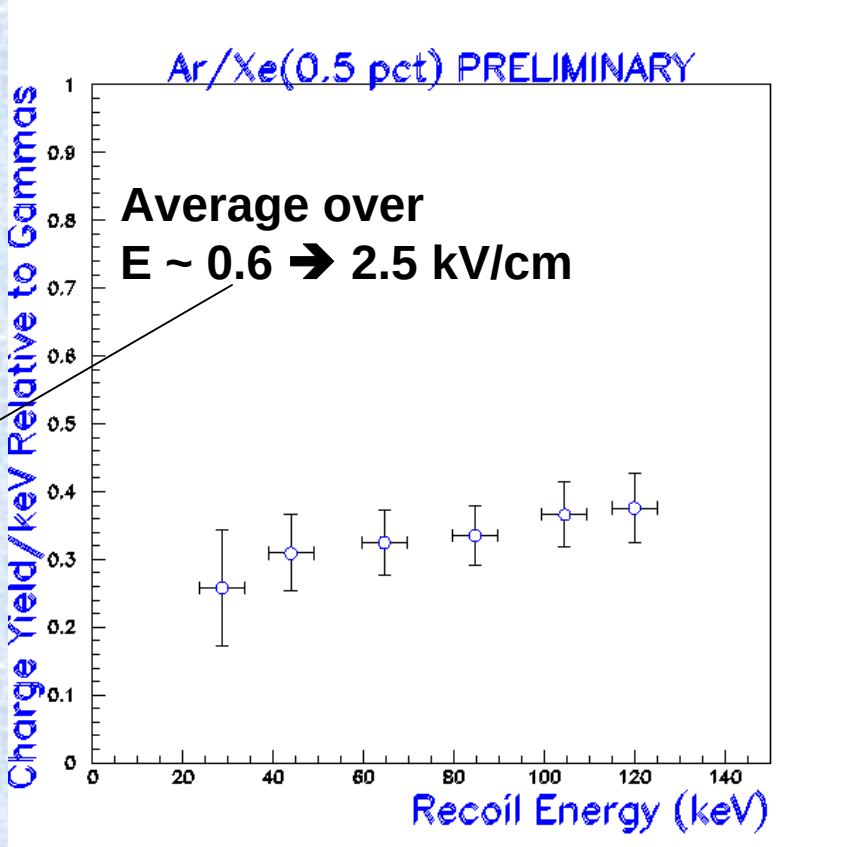
~40

~20

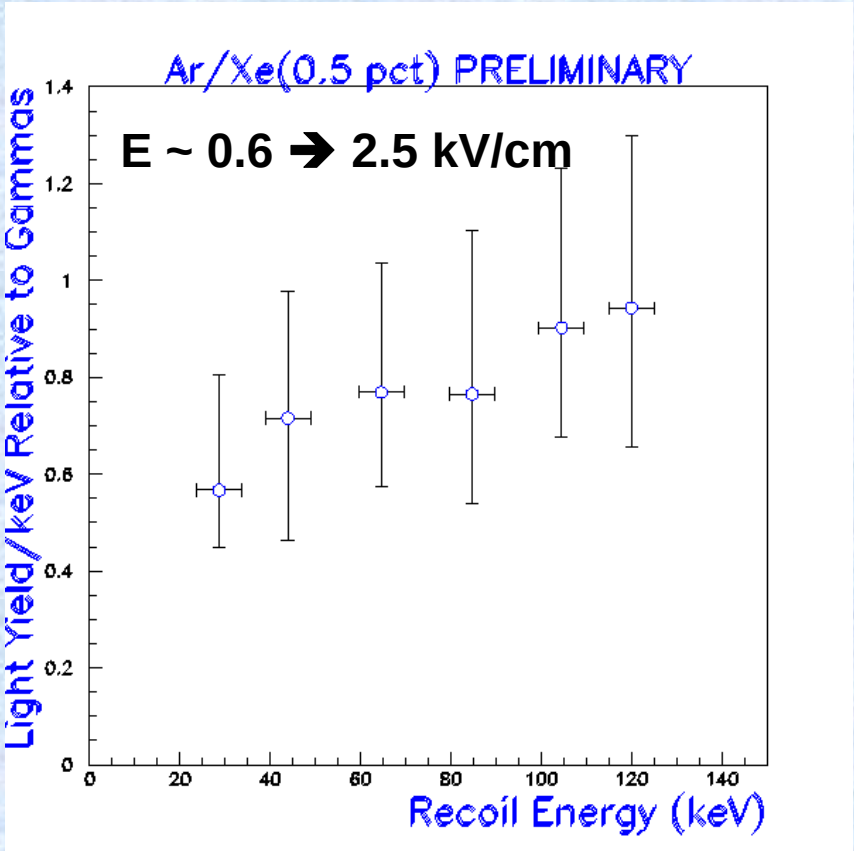


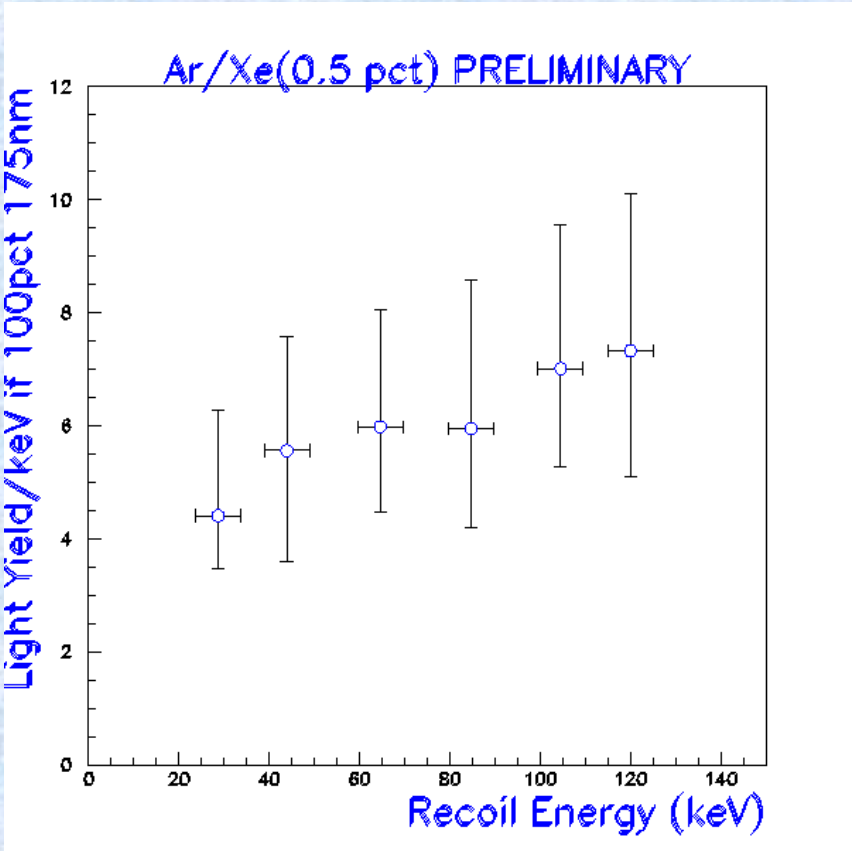
Ar – Charge Yield



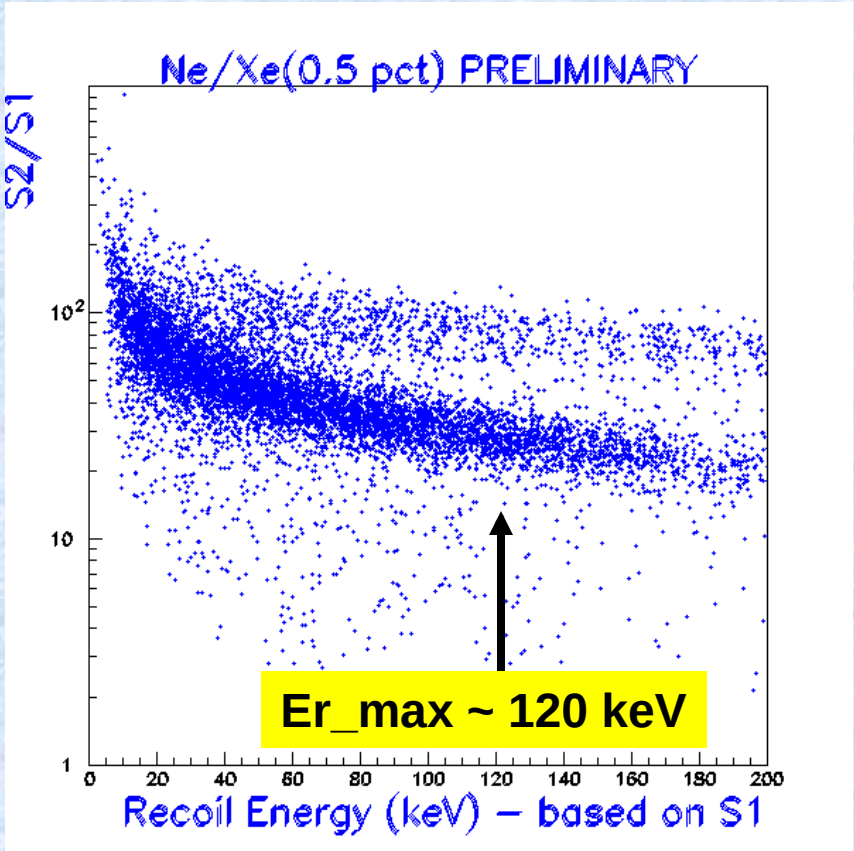


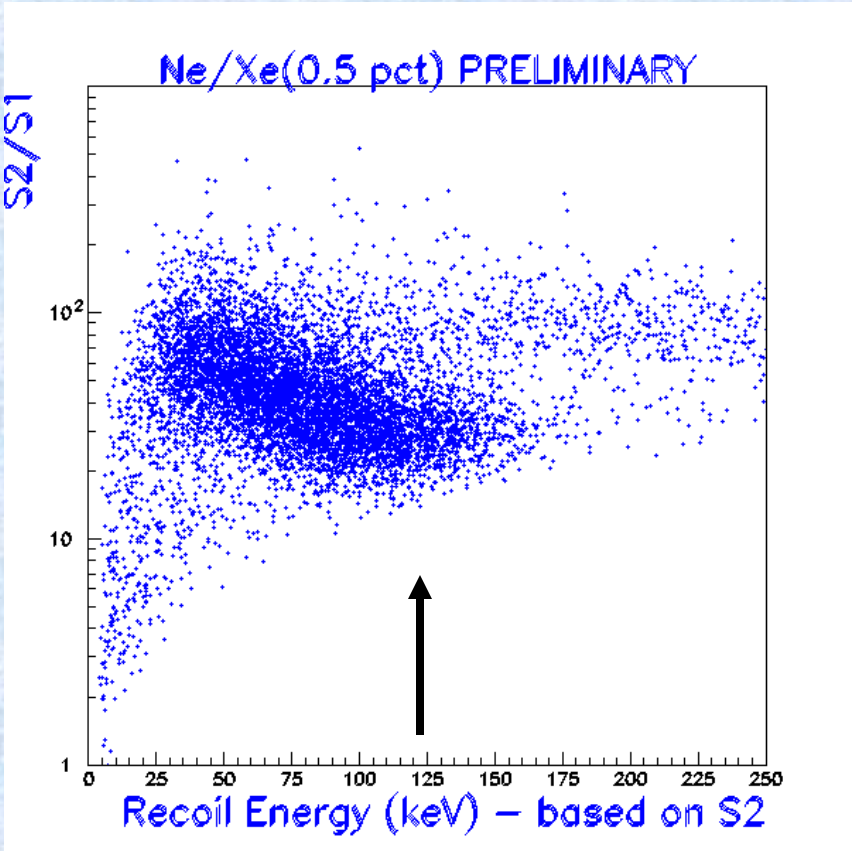
Ar – Light Yield



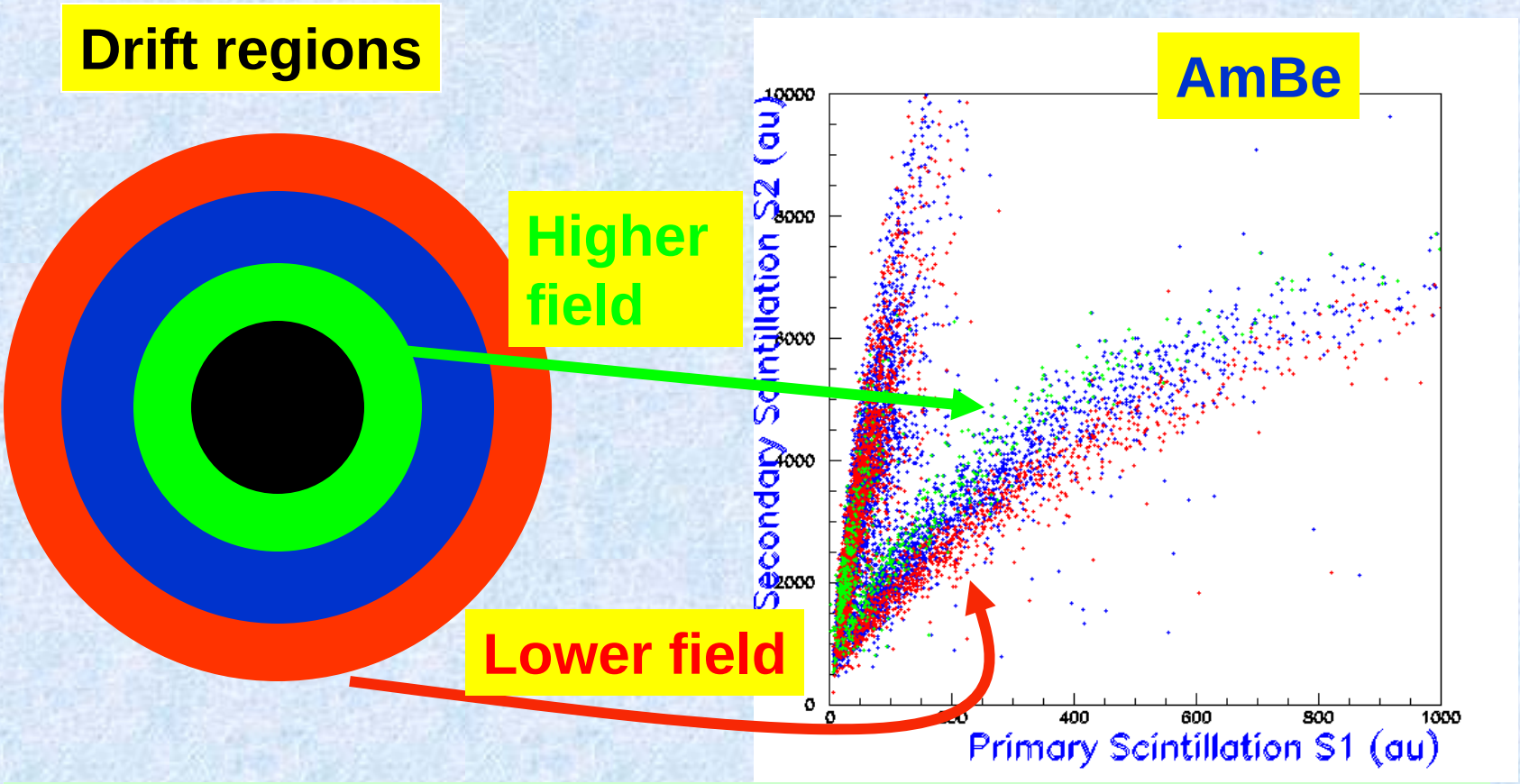


NeXe(0.5%) – 100 atm
NR Response





Nuclear Recoil Discrimination: S2 vs S1

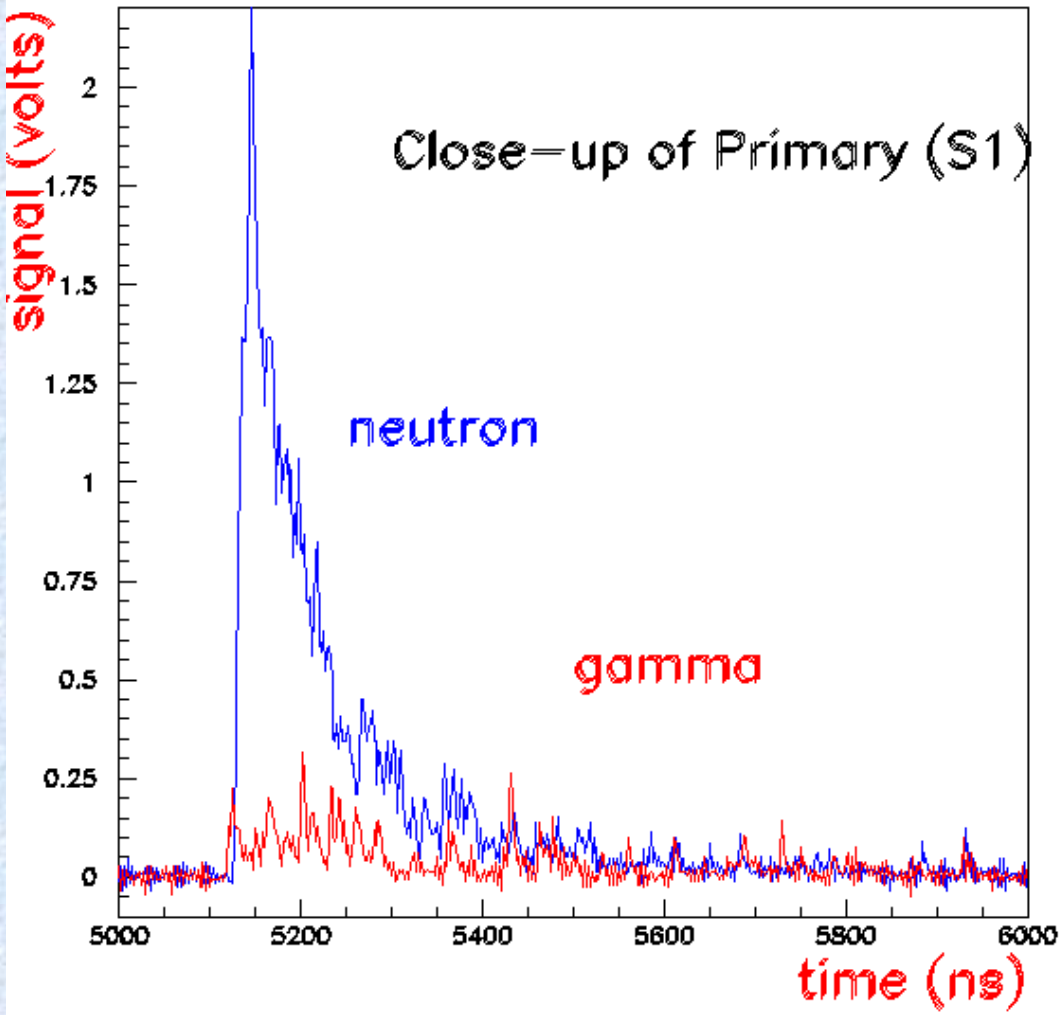


➔S2/S1 field (and density) dependent for nuclear recoils

➔Gammas unaffected (Emin ~ 600 v/cm here)

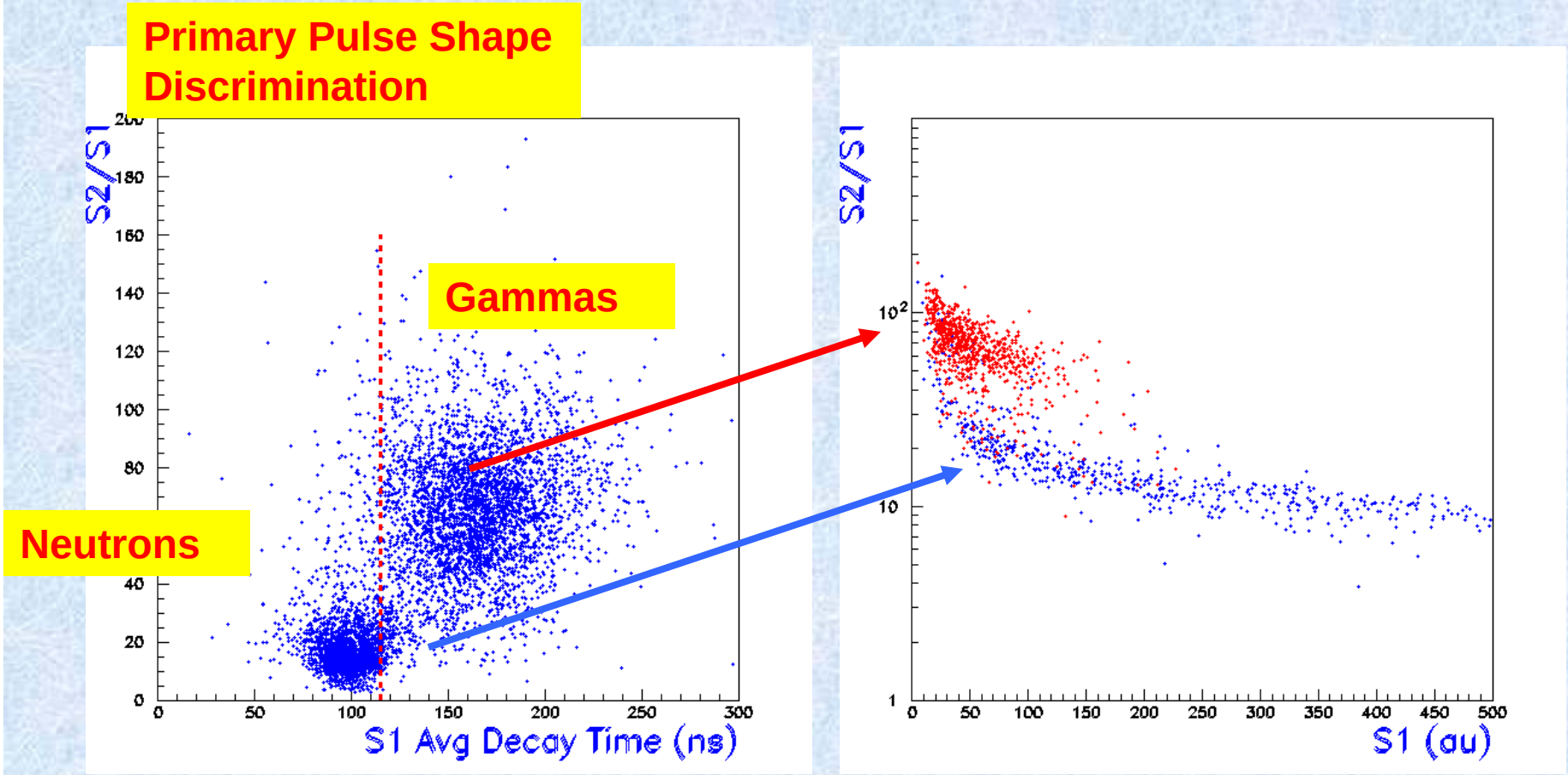
J.

Primary Pulse Shape Discrimination

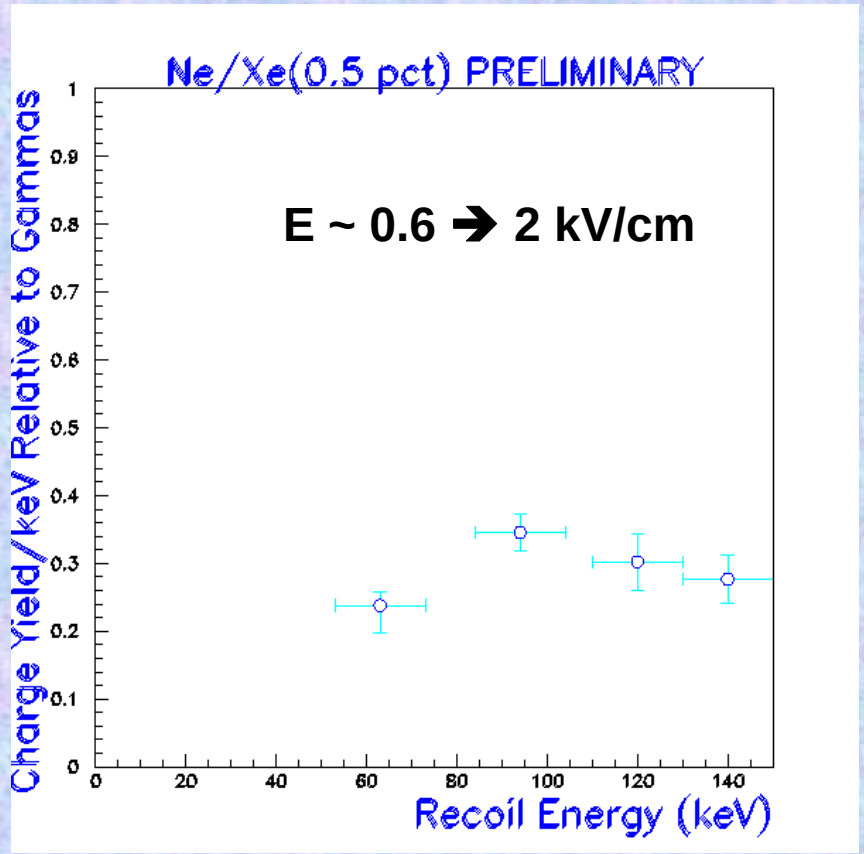


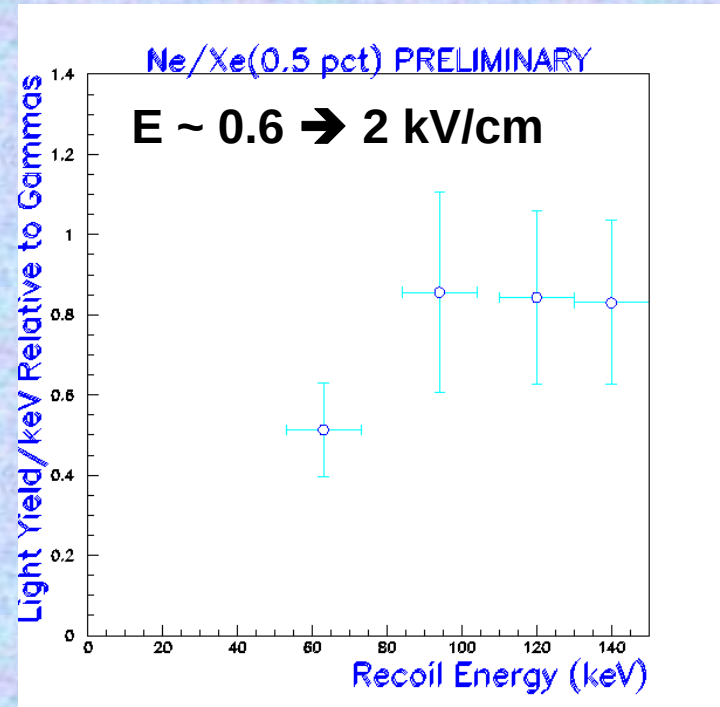
J.T. White,

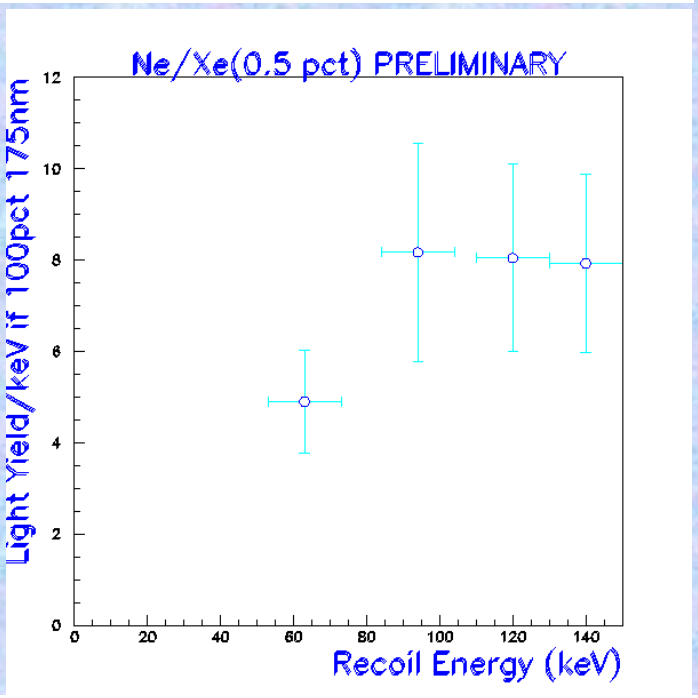
S2/S1 AND Primary Shape Discrimination!



Ne – Q&L Yield

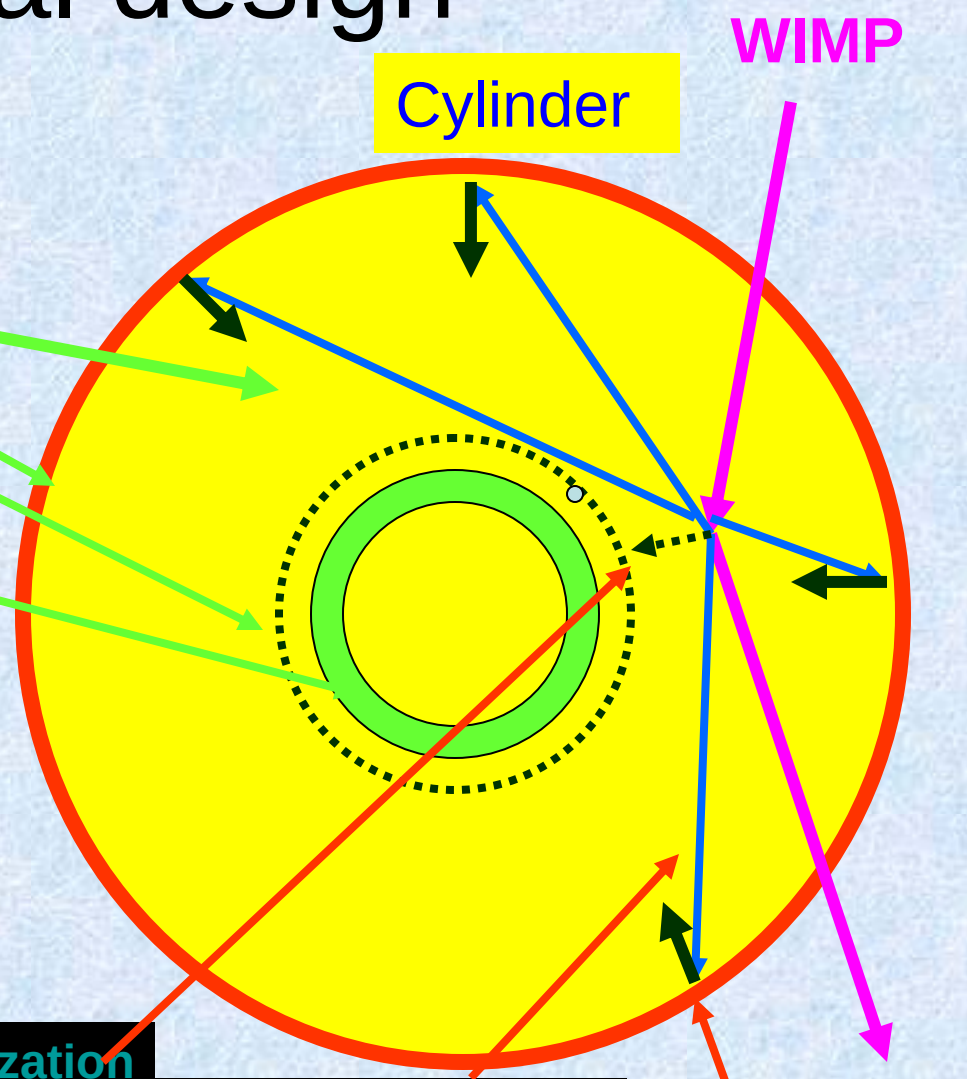

Ne/Xe(0.5 pct) PRELIMINARY
E ~ 0.6 ➔ 2 kV/cm
Charge Yield/keV Relative to Gammas
Recoil Energy (keV)


Ne/Xe(0.5 pct) PRELIMINARY
E ~ 0.6 ➔ 2 kV/cm
Light Yield/keV Relative to Gammas
Recoil Energy (keV)


Ne/Xe(0.5 pct) PRELIMINARY
Light Yield/keV if 100pct 175nm
Recoil Energy (keV)

SIGN conceptual design

- Gas
- CsI Photocathode
- Light gain structure
- WLS fibers



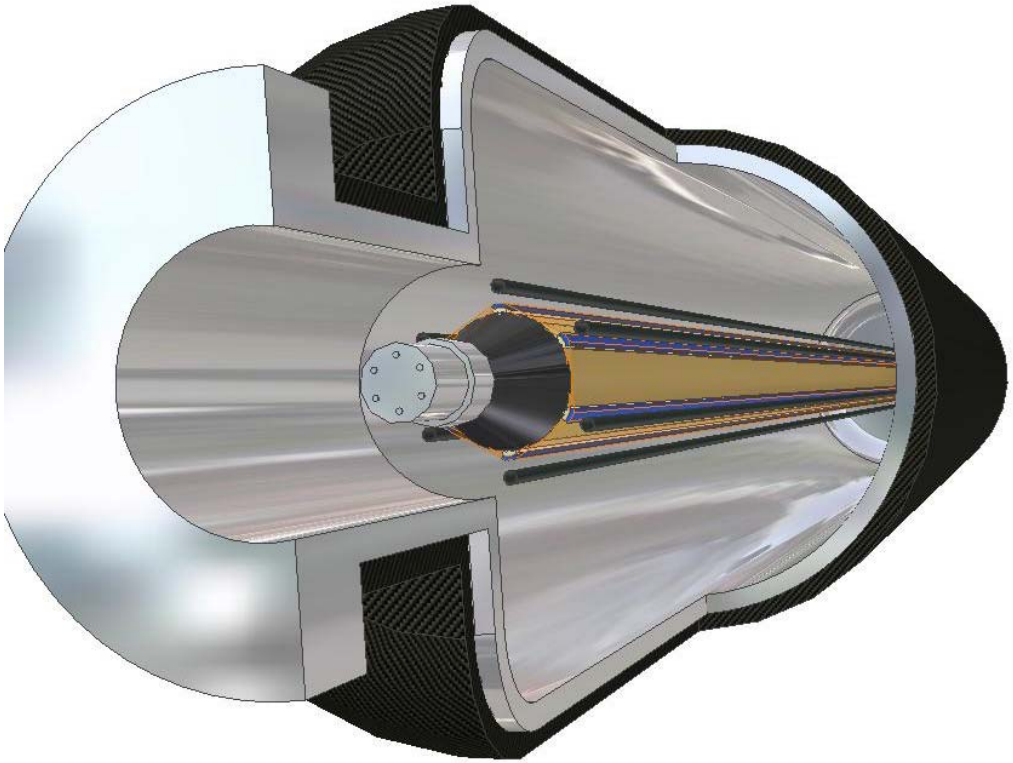
e.g.
Diameter ~ 60 cm
Length ~ 3 m
Mass >~ 100kg

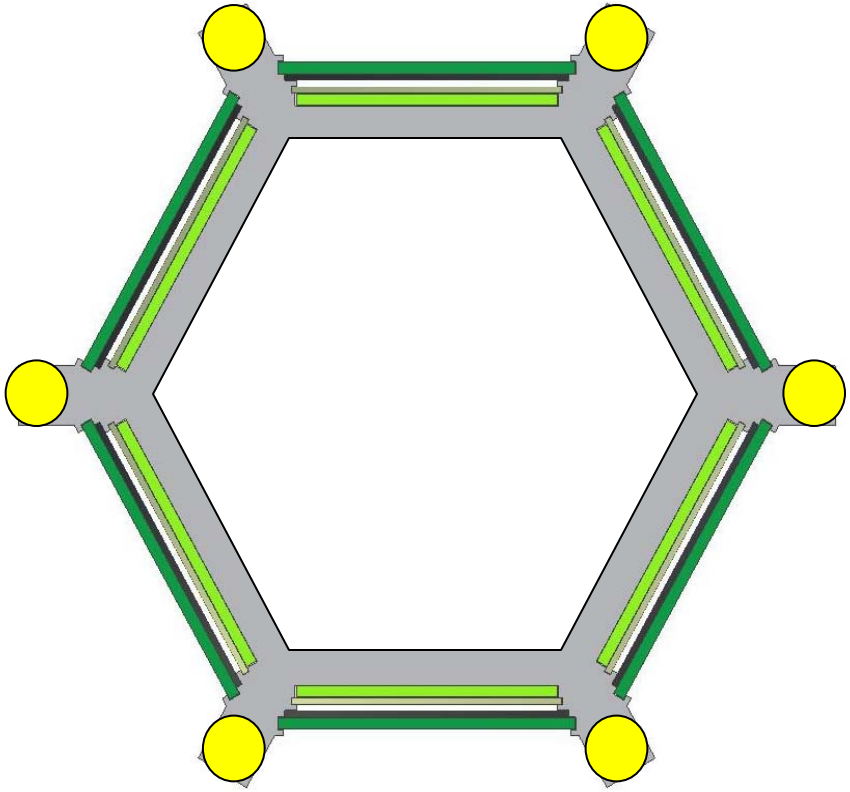
Primary Ionization

Prompt Scintillation

Photoelectrons

Detector Concept

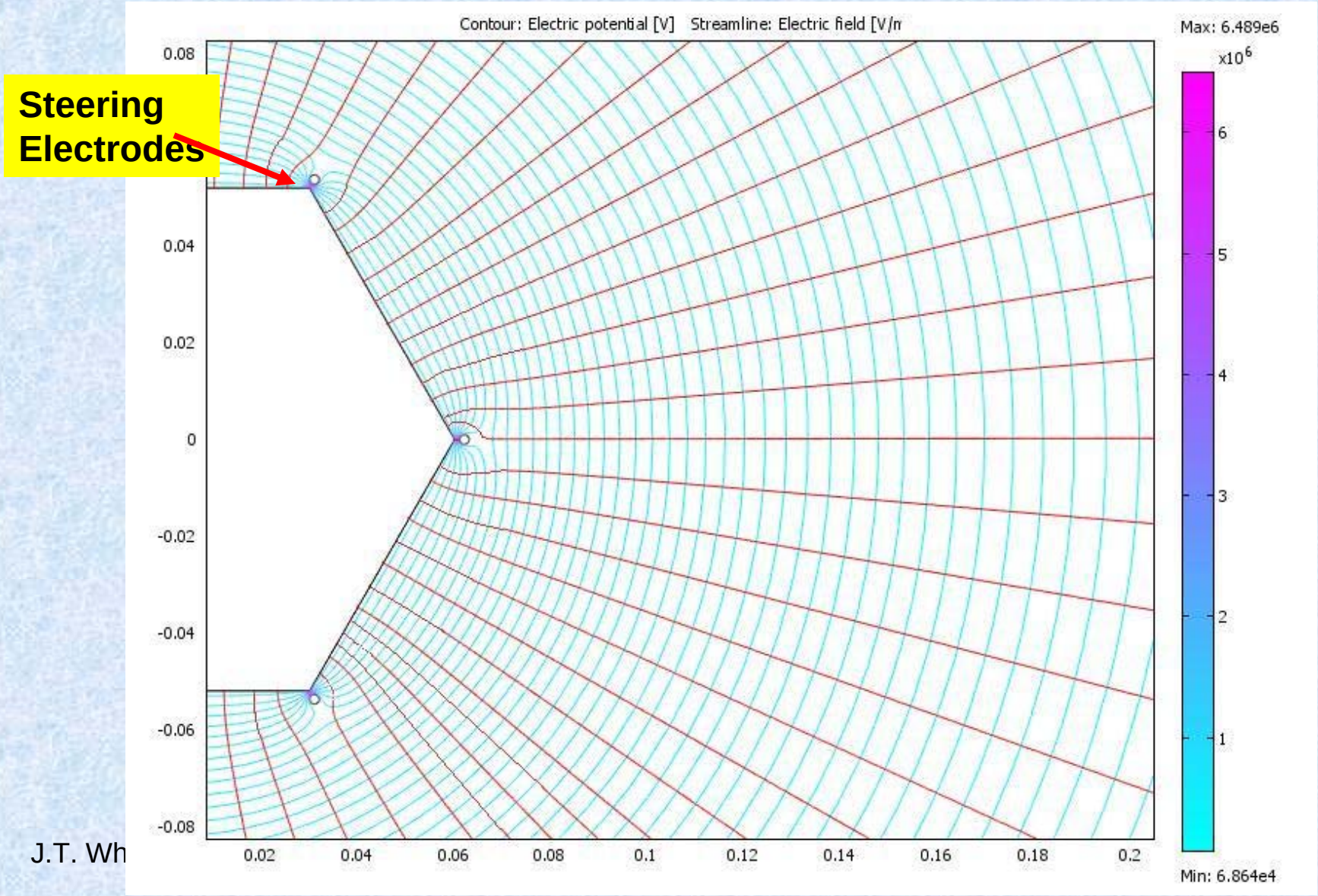




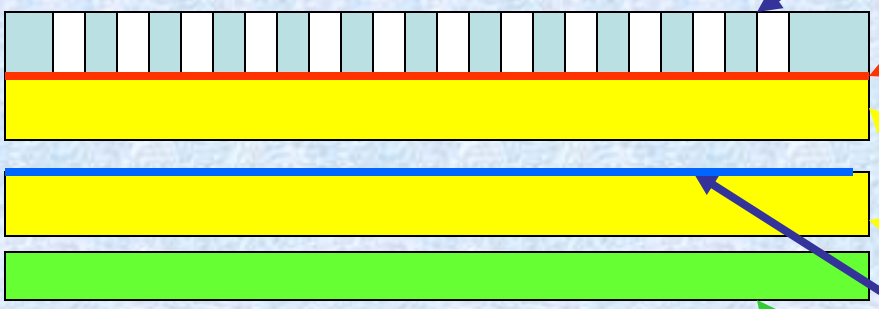
Composite Cylinder

Hub w/ WLS Fiber structure

Drift Flow


Steering Electrodes
Contour: Electric potential [V] Streamline: Electric field [V/m
Max: 6.489e6
x10^6
6
5
4
3
2
1
Min: 6.864e4
0.08
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2

Gas Light Multiplier Concept



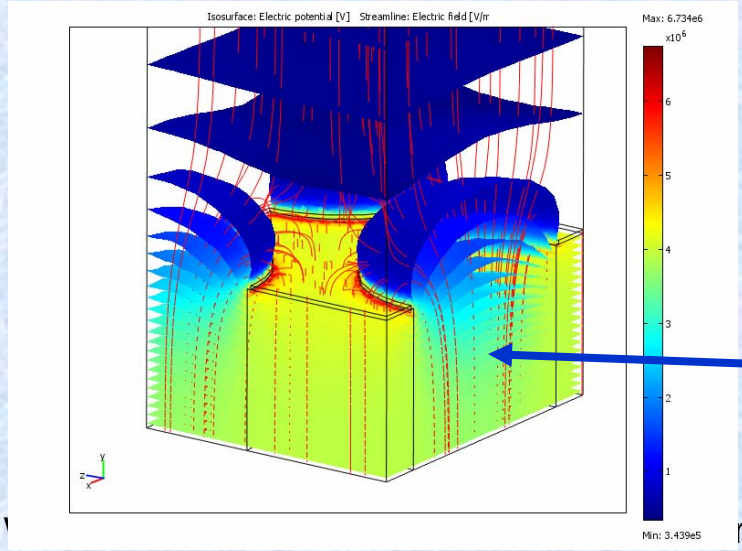
Cirlex metallized plate, ~ 1mm holes

Platinum coating – VUV transmitting

VUV synthetic silica plates

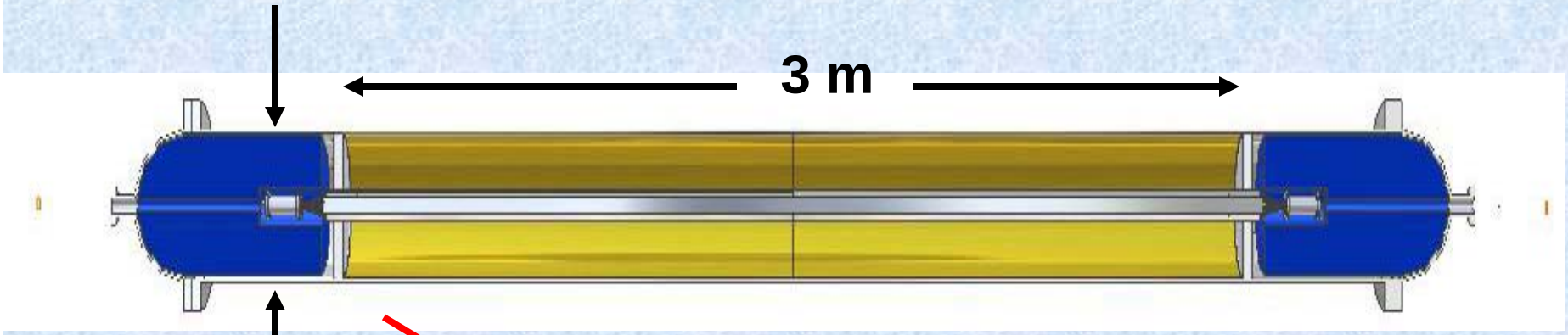
VUV -> blue phosphor coating

WLS Fibers



100% e- transmission
Fluorescence E/P>1
Lit – 0.006 p.e./vuv pho.

100 kg 20 atm Xe Prototype

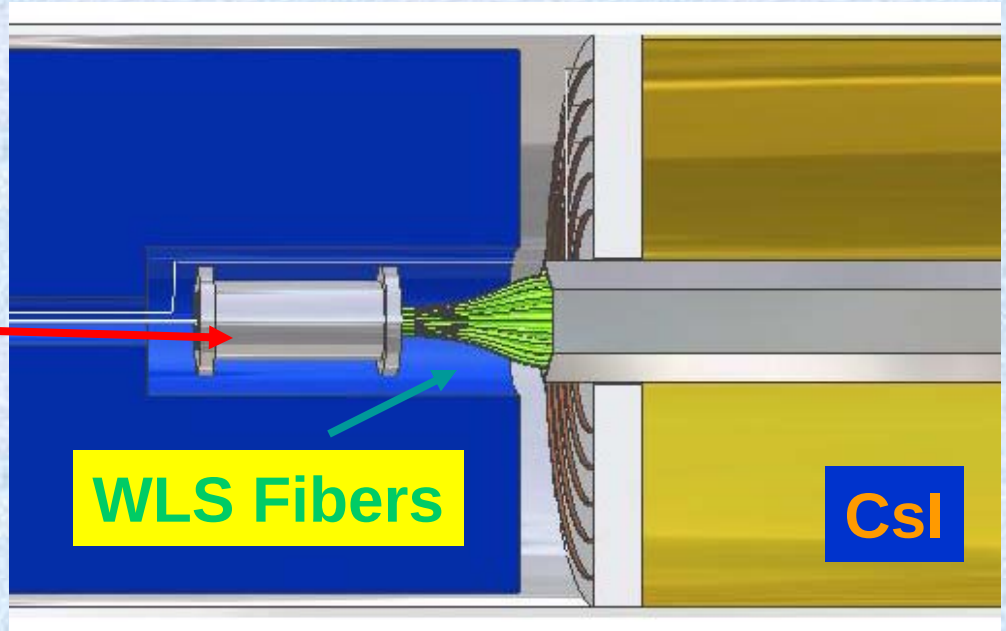


0.6 m

Shielding

PMT

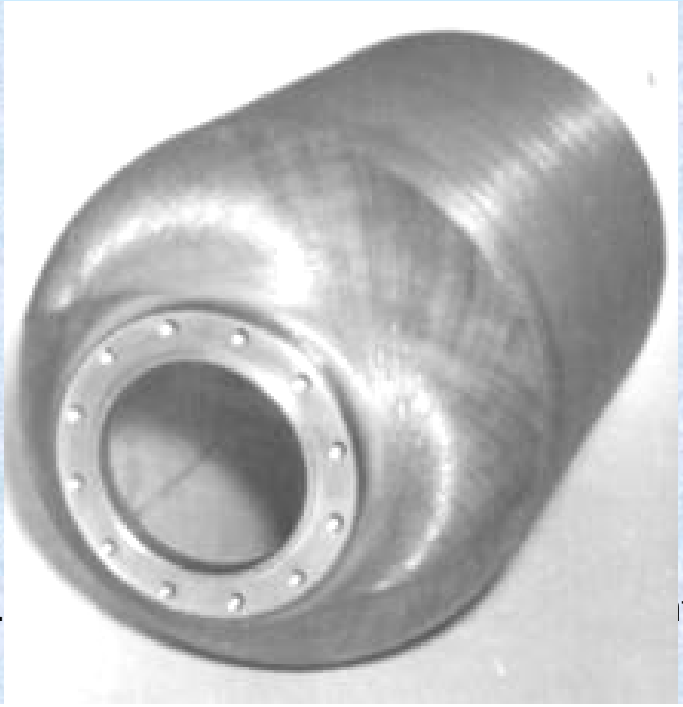
SS Tube
~0.25 inch wall



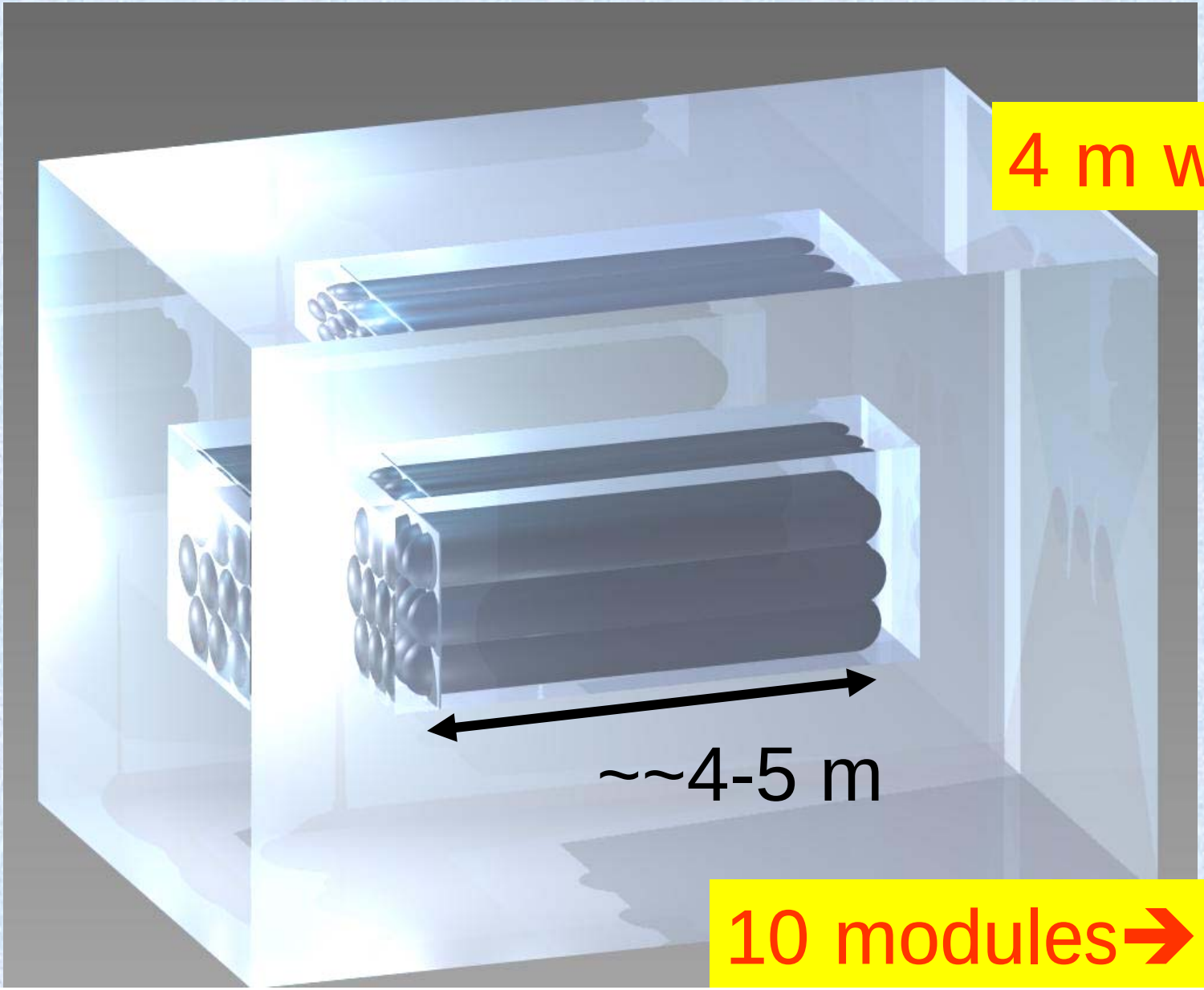
J.T. White, TAMU

Future→Composite Vessels

- **Carbon, Kevlar wound**
- **Some rated > 10000 psi !**
- **Used on mass transit (Methane)**)
- **Used for Hydrogen fuel cells**
- **On jets, spacecraft**
- **DOT certified !**



Shielding

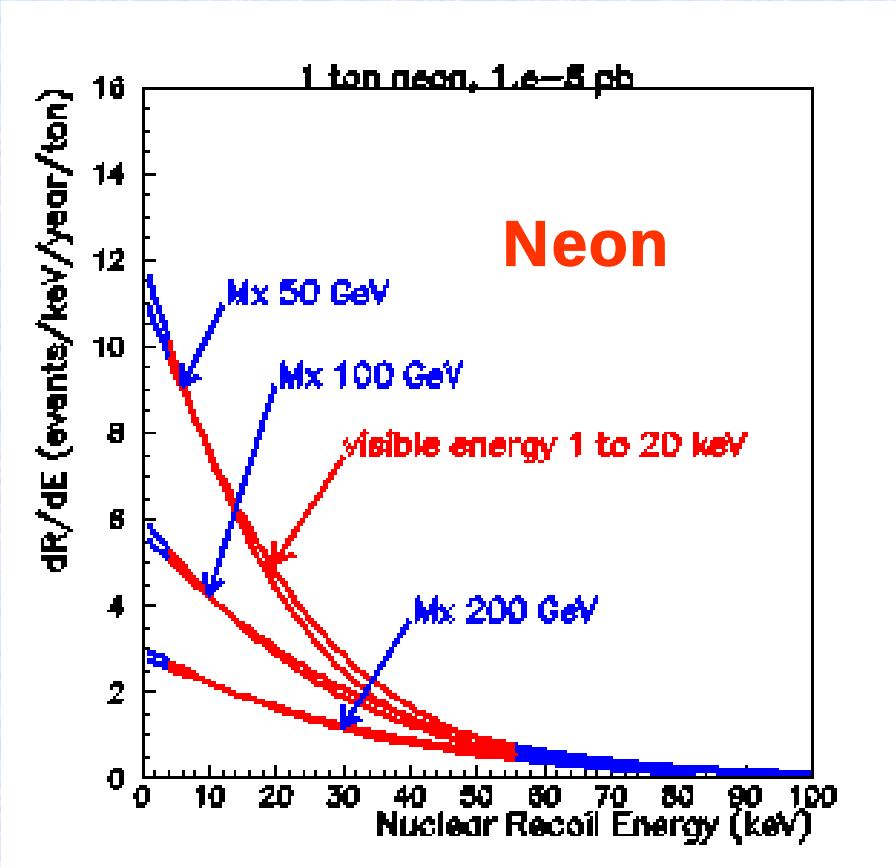


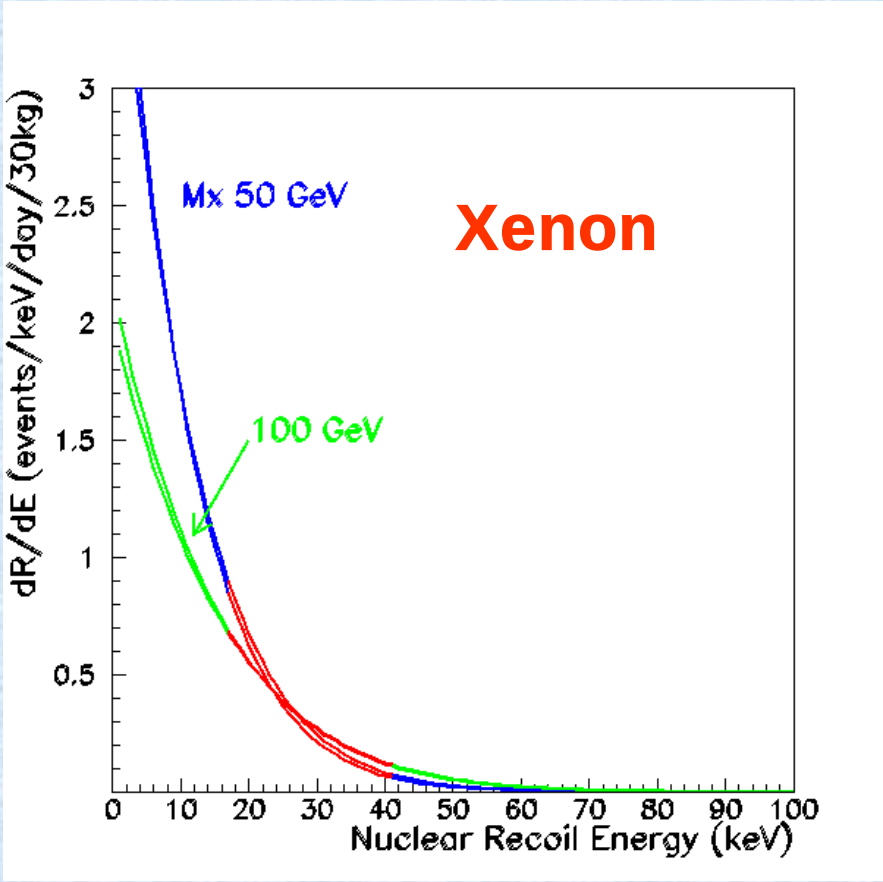
Summary

- Good S2/S1Discrimination observed in Pressurized Gaseous Xe, Ar, & Ne
- Room T, modular, minimal PMT count:

  . . . some advantages
- Plan to propose R&D program to test concept in 100 kg Xe proto-experiment to be ready in time for DUSEL
- If successful ➔ phased program:
  - Xe @ 20 atm - help in discovery?
  - → Ne @ 200 atm - help untangle WIMP Mass/halo V

WIMP – Recoil Spectrum





WIMP mass & velocity dispersion ➔ need different mass targers

Summary -cont

- Ne @ 3000 psi will require development of radioquiet composite vessel
  - »Doable but technically challenging

- But Xe @ 300 psi is sufficiently easy that …

Summary - Cont

- A caveman could do it…