RMD
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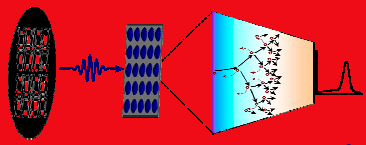
NASA SBIR

Scintillation Detectors for Space Radiation and Dosimetry

Goal: Neutron Dosimeter



Instrument Research & Development

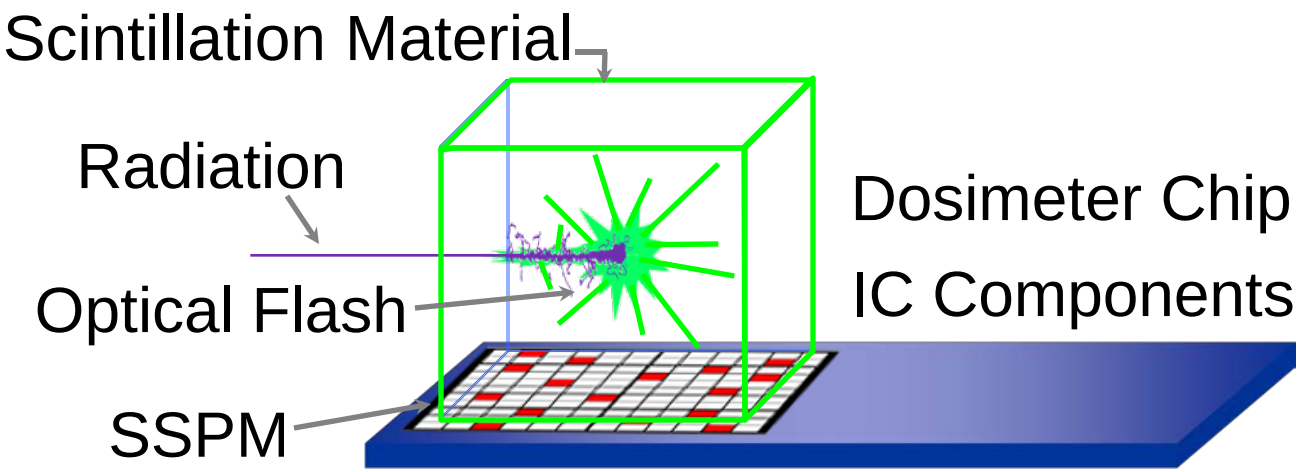
James Christian

August 2012

E.B. Johnson, C.M. Whitney, X.J. Chen, S.M. Vogel, E.V.D. van Loef, R. Hawrami, J.Glodo, L.S. Pandian, K.S. Shah, T.H. Prettyman, E. Benton

PSI OSU

Compact Dosimeter Concept

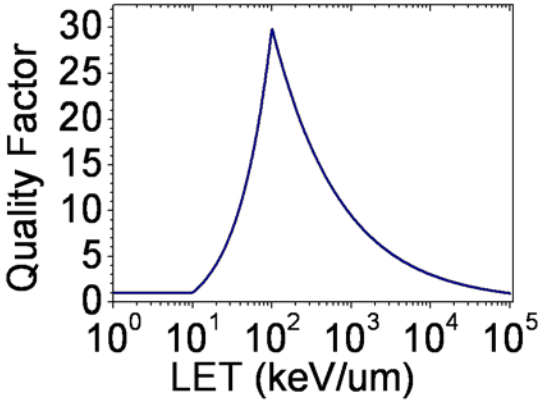


- Scintillation detector and SSPM
- Simplistic
  - Anti-coincidence (distinguished ions from n, γ)
- Scintillation material capabilities
- Neutron dose (2°) important, lots of “stuff”

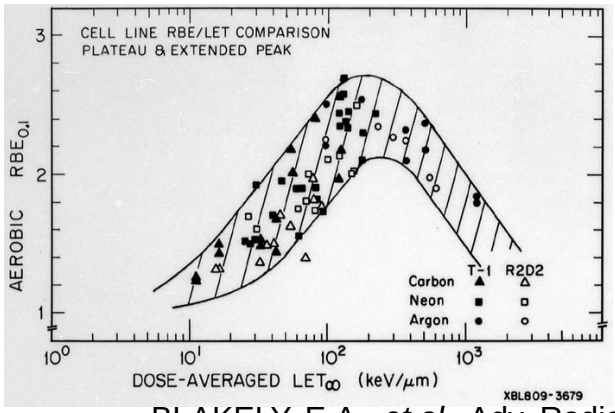
Dose

- Absorbed dose (TID)
- Human-equivalent dose: Tissue and Q (quality factor)
  - Q: “legislated” relative biological effectiveness (RBE) for cancer endpoint: depends on E and LET
- Displacement Damage Dose (NIEL – non-ion. E loss)

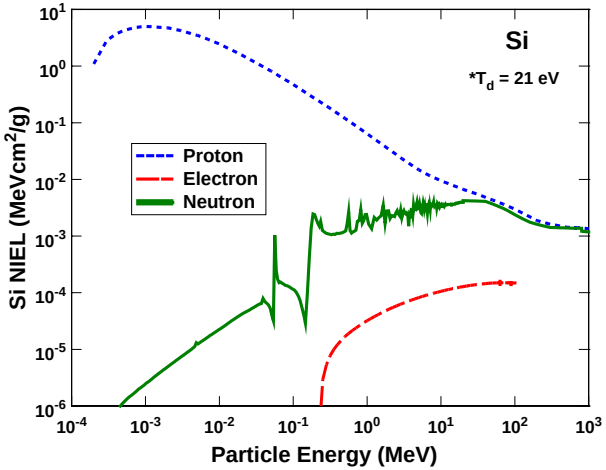
ICRP 60 (1991a)



Deq = RBE × D_R → Specific



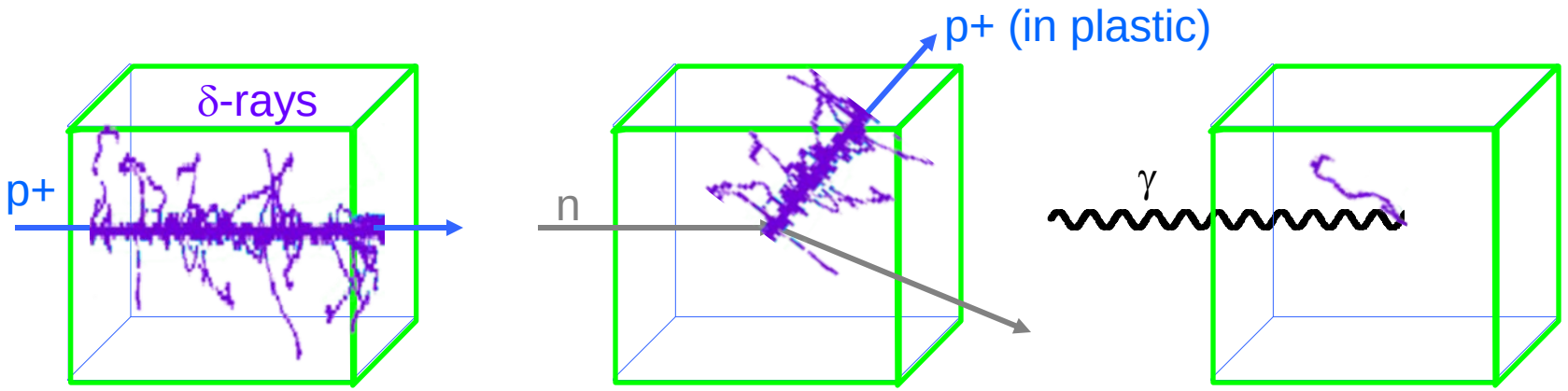
BLAKELY, E.A., *et al.*, Adv. Radiat. Biol. **11** (1984) 195–389.



S. Messenger, SPENVIS Workshop 2005

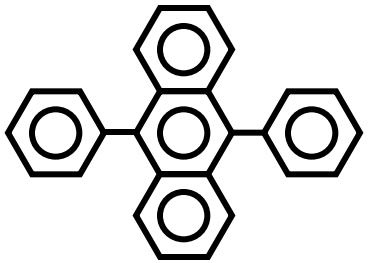
- Identify Particle Type
- Linear Energy Transfer (LET = $\left(\frac{dE}{dx}\right)$) or E
- (Dose rate)

Interactions with H_nC_m Scintillator

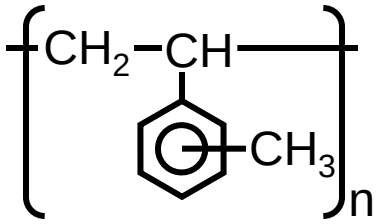


$$\frac{dL}{dx} = \frac{S \cdot \left(\frac{dE}{dx}\right)}{1 + kB \cdot \left(\frac{dE}{dx}\right) - C \cdot \left(\frac{dE}{dx}\right)^2}$$

DPA



PVT (EJ200)



- DPA is a “new” $H_{18}C_{26}$ material (~tissue density)
- Light ∝ Absorbed Dose TID: Birks legacy (*S* & *kB* quenching)
- Recoil proton (in plastic) related to neutron energy

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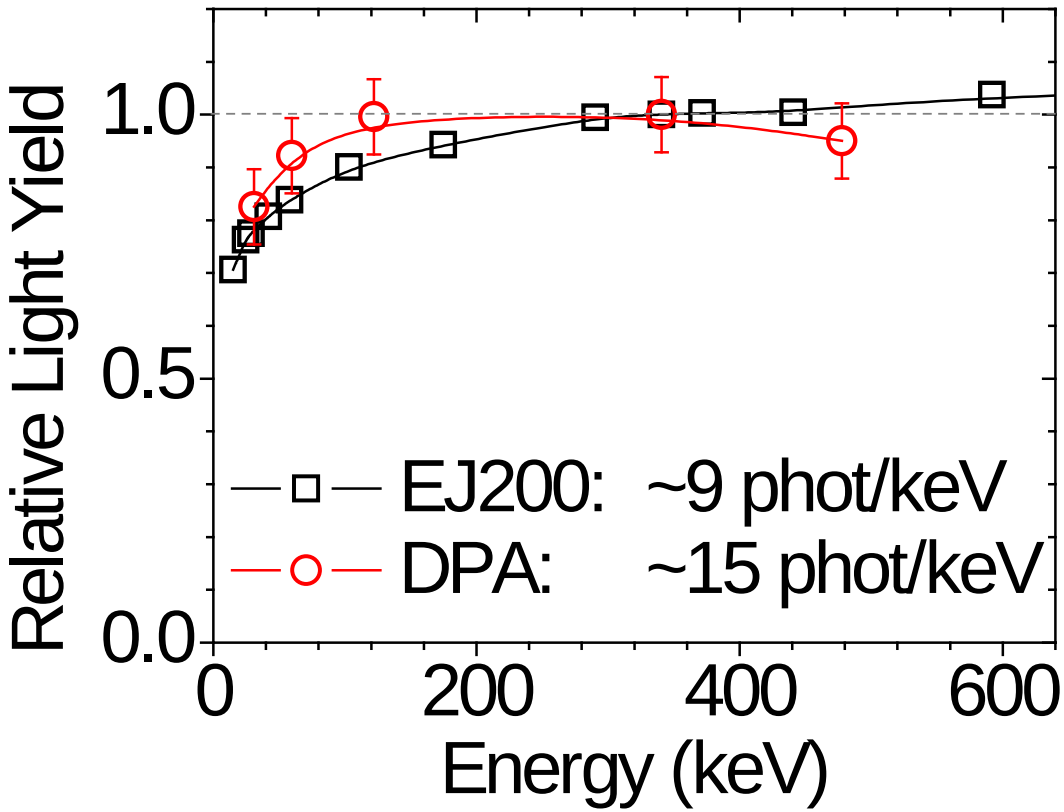
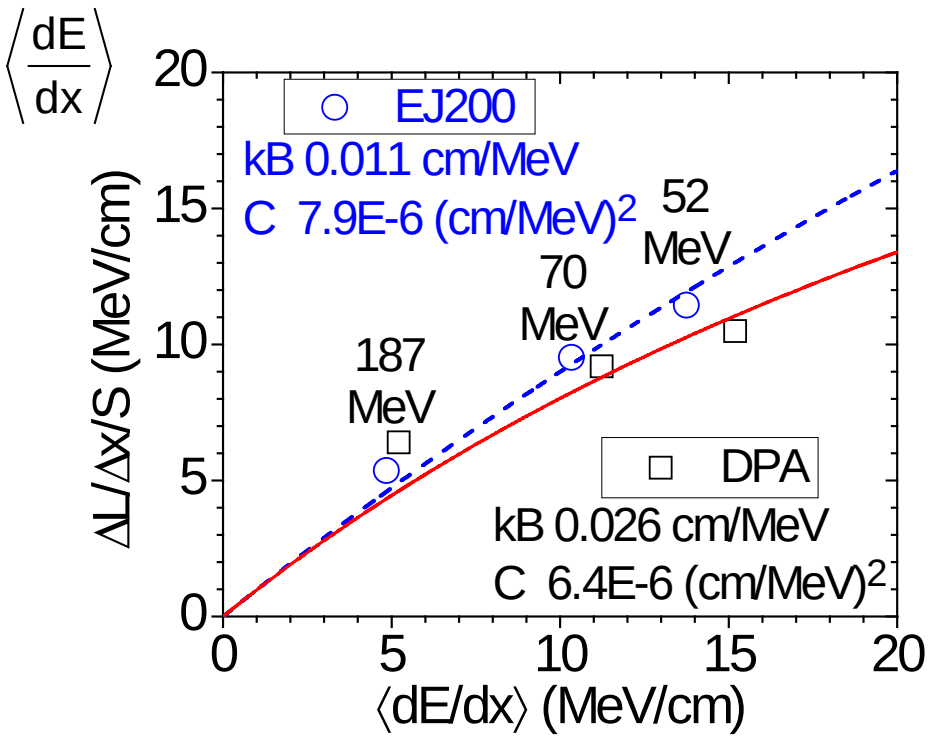
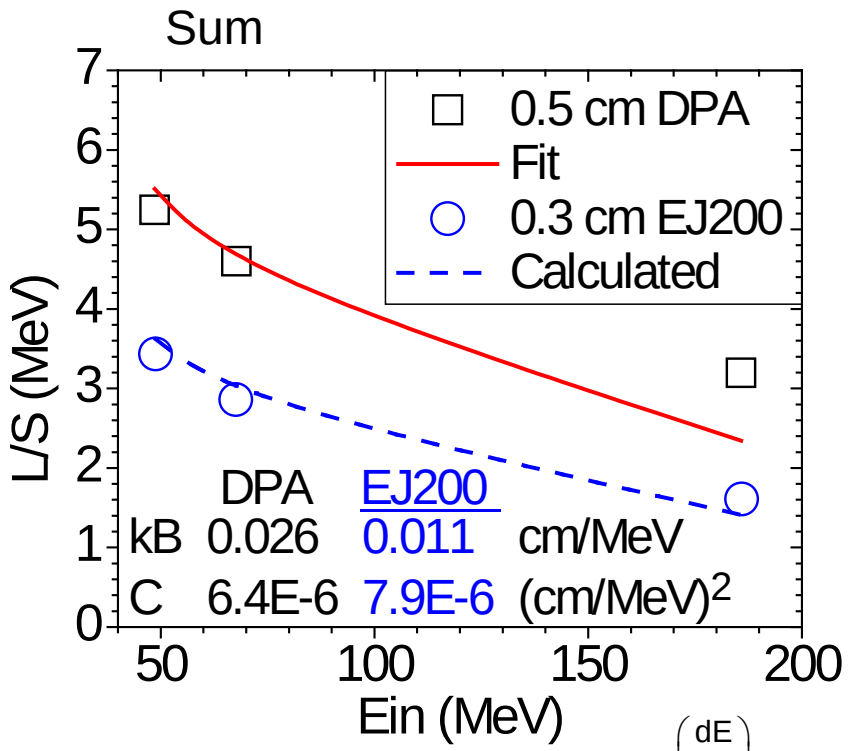
Proportionality with gammas: S-term



- S-term related to gamma ray energy resolution
- ~15 k photons per MeV (bright – as high as 20)

Characterize *kB*-term (protons)

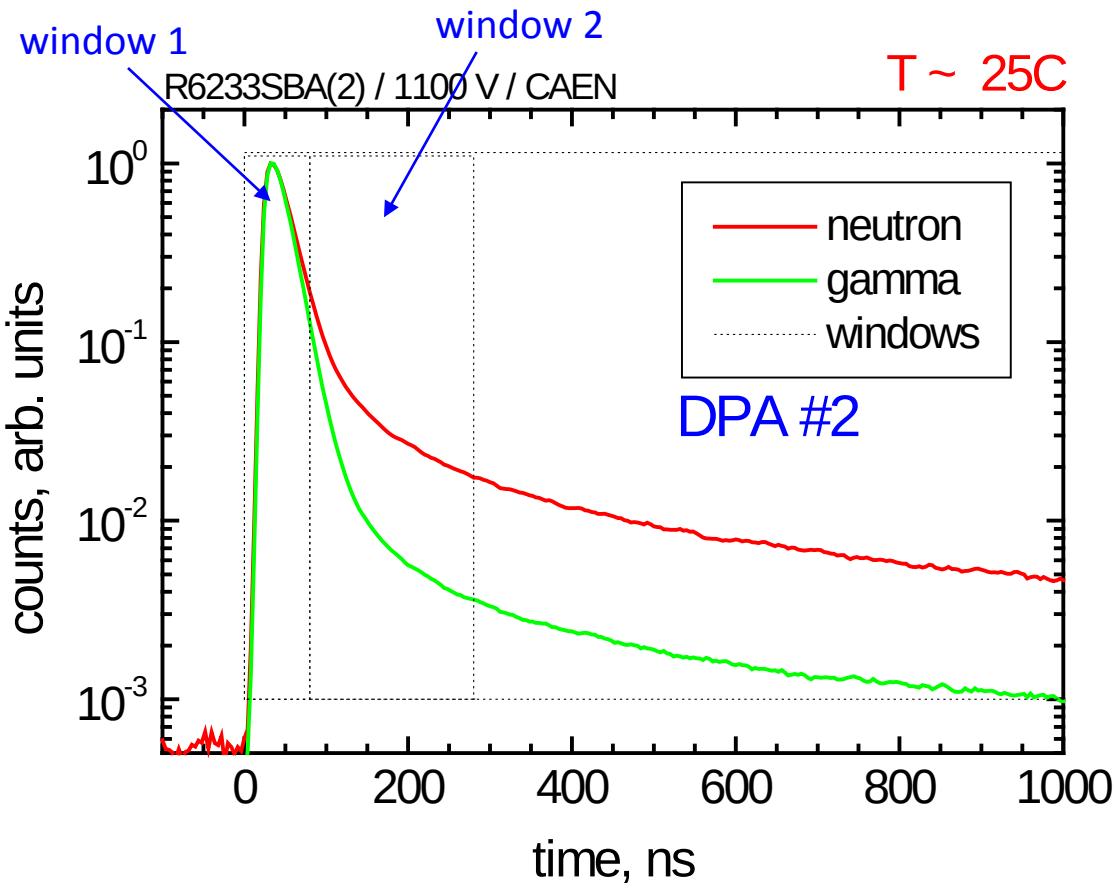




- *kB* larger in DPA than EJ200 (*C*-term fixed)
  - More δ-ray/ionization quenching
  - Deviation not analysis (Experimental factors)

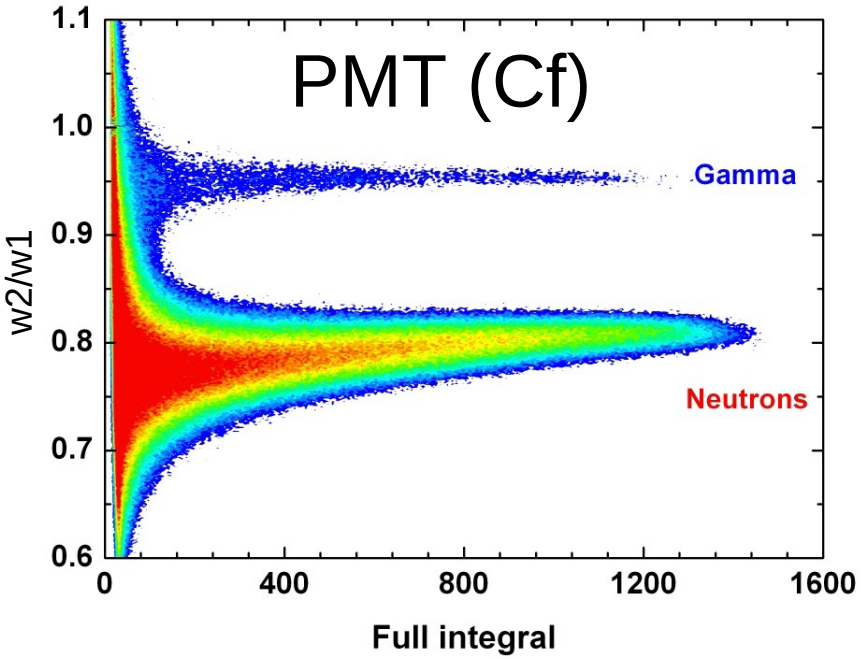
$$S \cdot \sum_i \frac{\left(\frac{dE}{dx}\right)_i}{1 + kB \cdot \left(\frac{dE}{dx}\right)_i + C \cdot \left(\frac{dE}{dx}\right)_i^2}$$

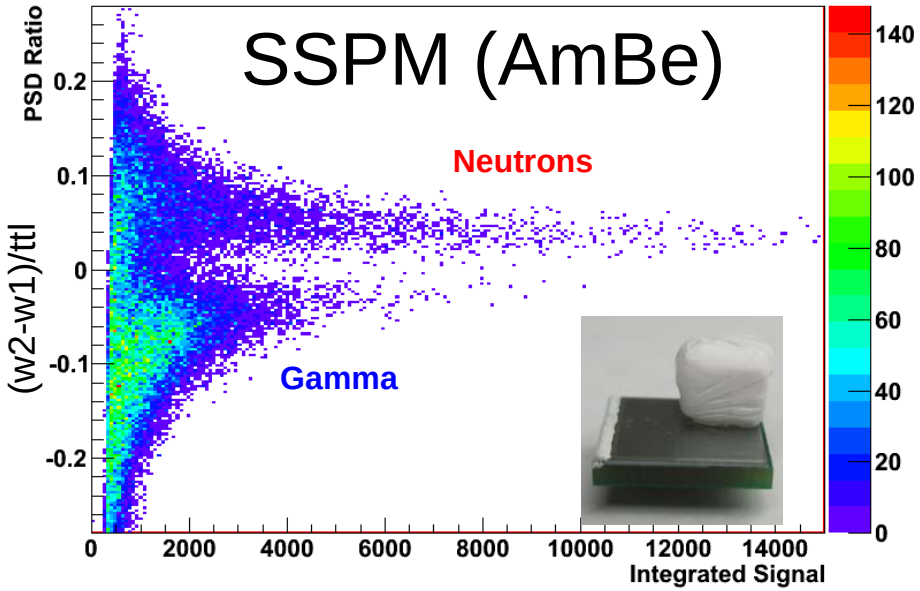
DPA emission time characteristics



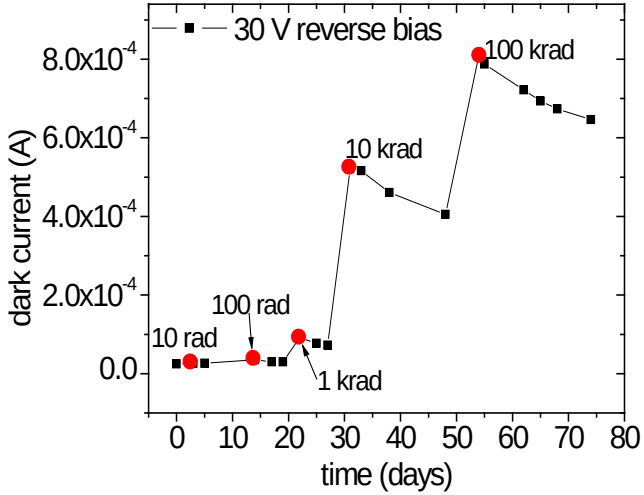
- Distinguishes gammas from neutrons

DPA neutron distinction





- Different sources
- Dark noise
- Effect of DDD



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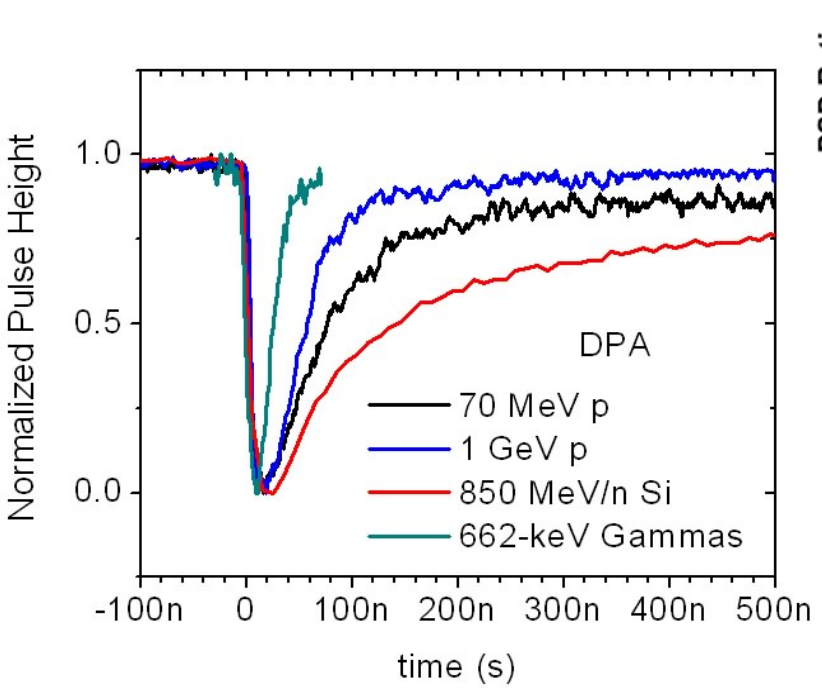
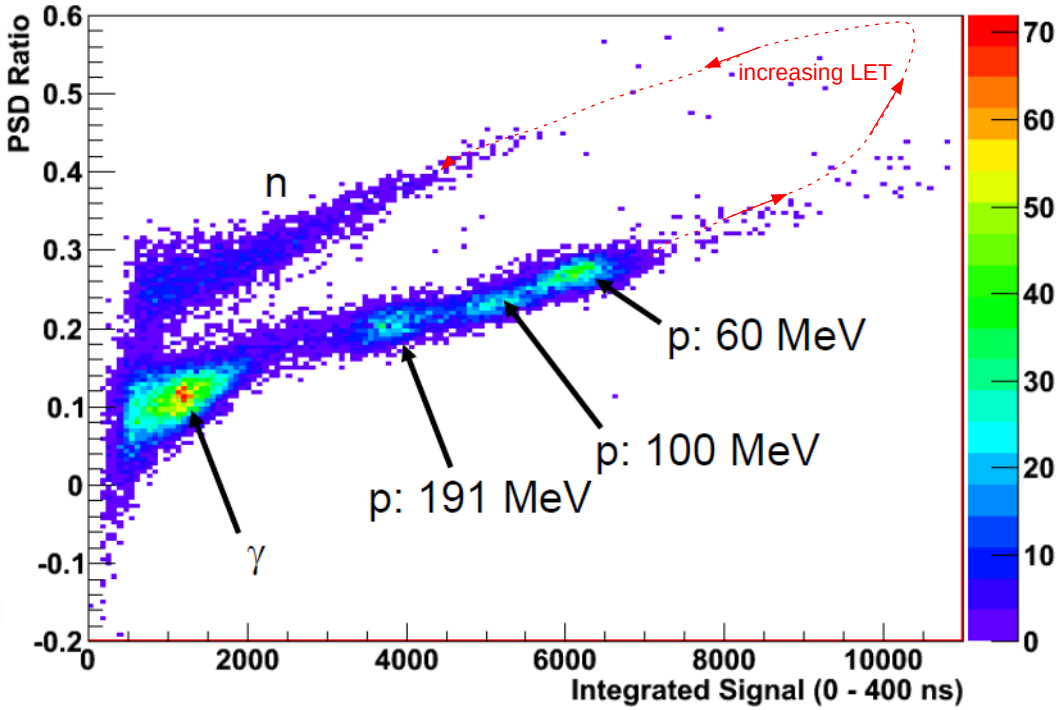
DPA population plot





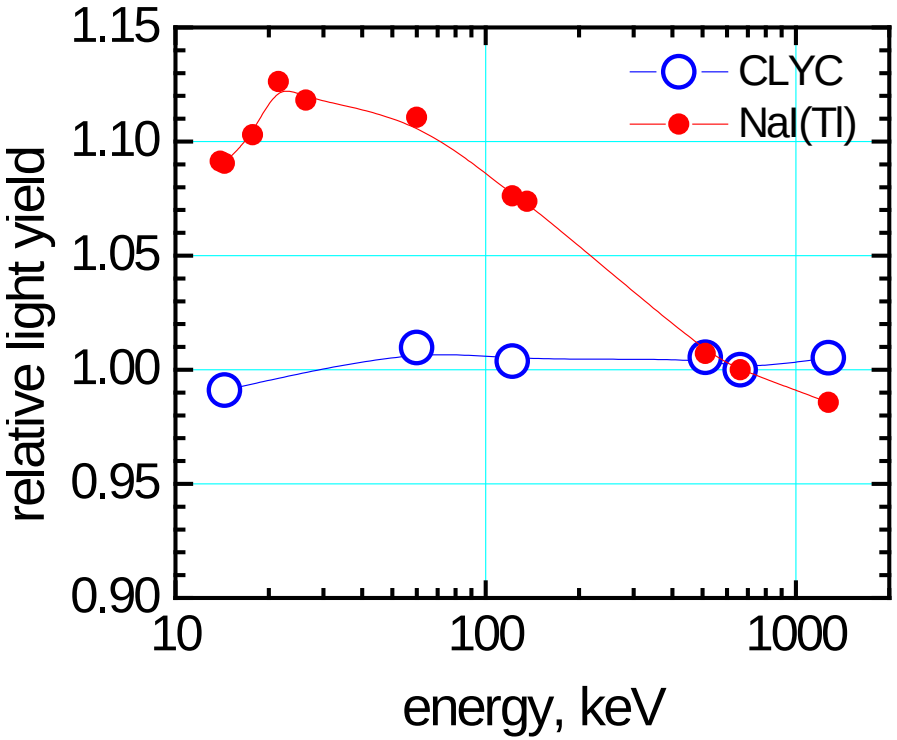
- Ideal beam measurement - *Optimistic* (avg. paths)
- DPA needs anti-coincidence

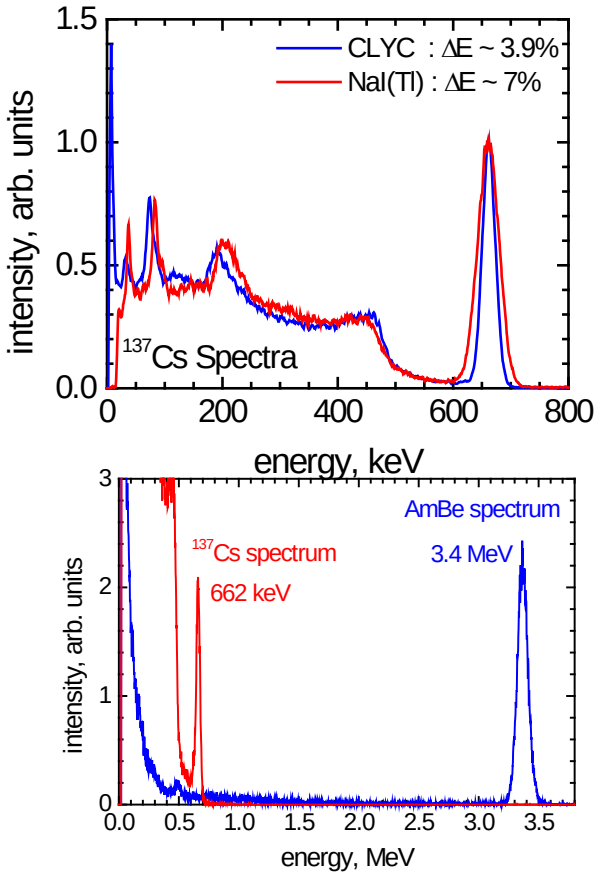
CLYC Scintillator

Cs_2LiYCl_6

^6Li: $^6Li + {}^1n \rightarrow {}^3H + {}^4\alpha$ 4.78 MeV 940 Barns

^{35}Cl: $^{35}Cl + {}^1n \rightarrow {}^{35}S$ 0.62 MeV <1 Barn





- Photon yield ~20 photons/keV
- CLYC proportional (good gamma E-resolution)

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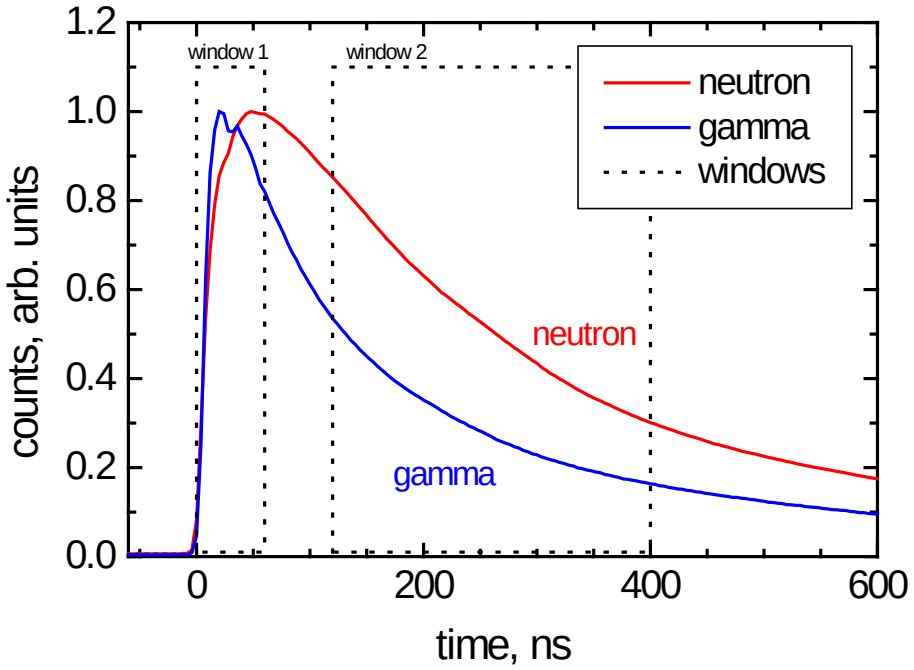
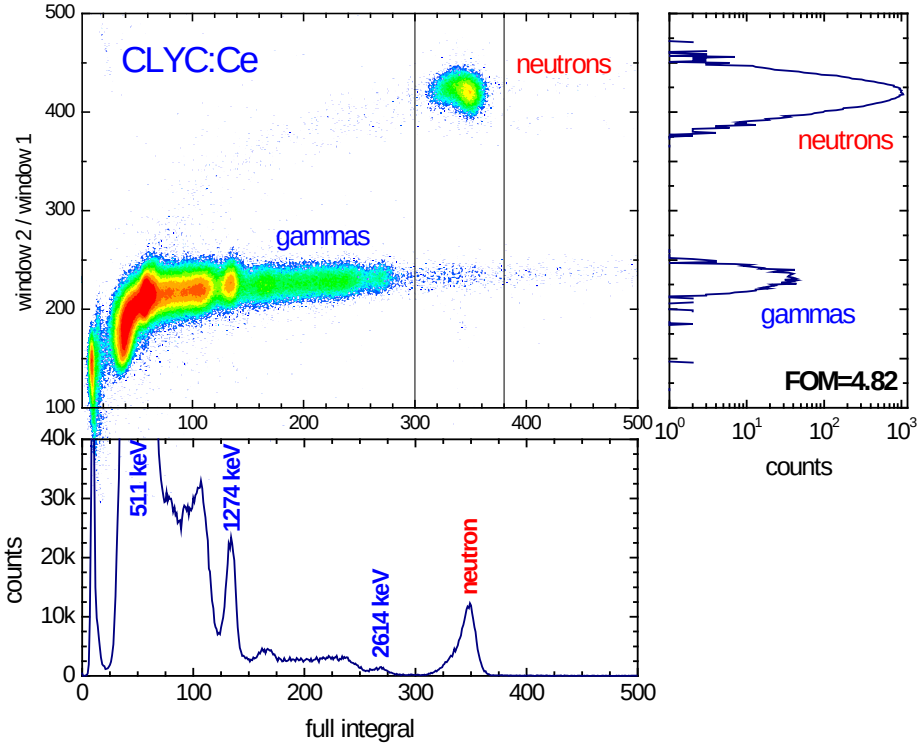
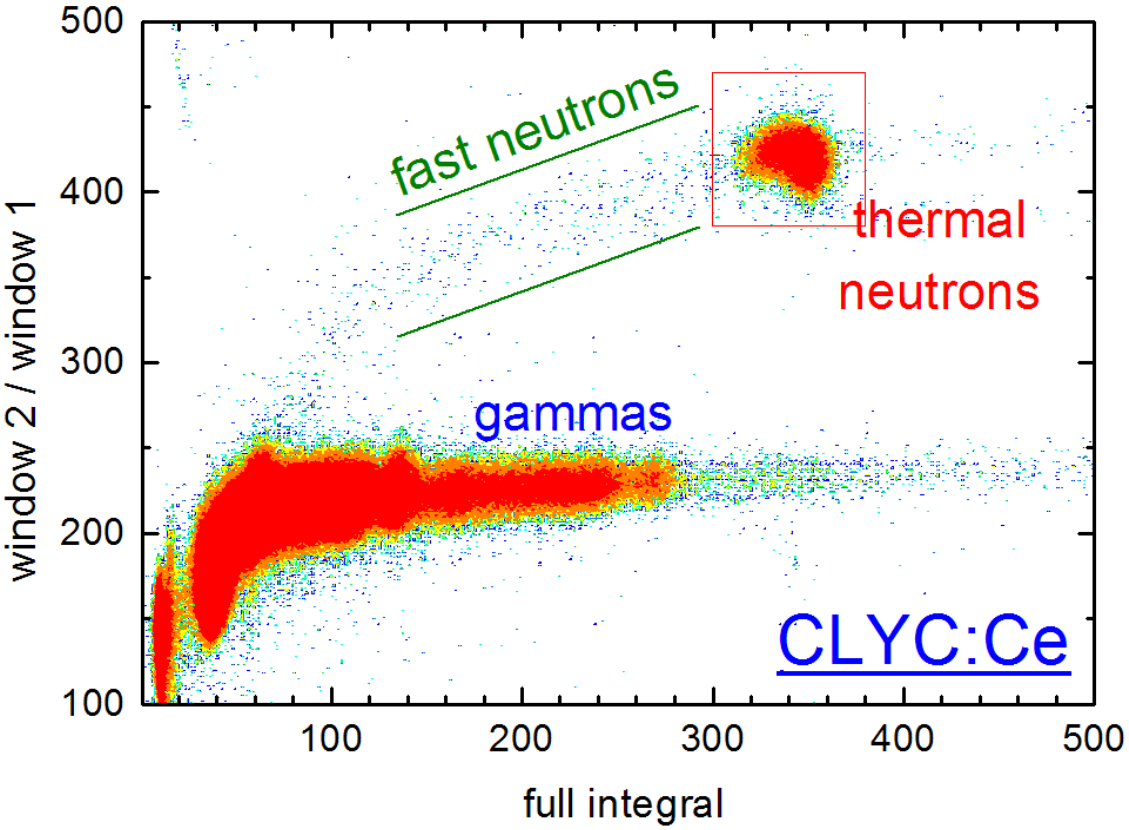
CLYC emission time characteristics

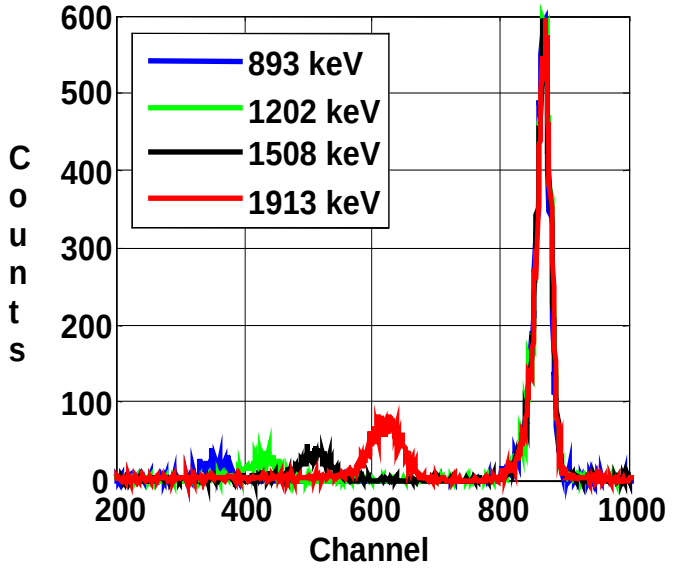


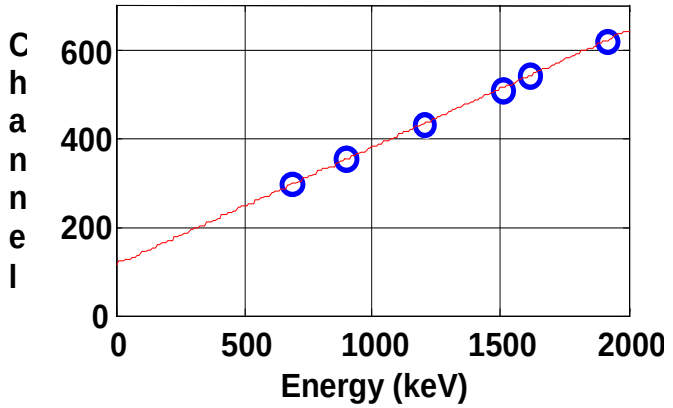


- Distinguish gammas from thermal neutrons (3-He)
- No p+ recoil, detect fast neutrons with 35-Cl

Measuring neutron energy with CLYC







- 35-Cl (n,p) reaction
- Fast Neutron Spectroscopy

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Summary

- Interesting Scintillation Materials
  - Thermal and fast neutron
  - Distinguish p+, n, & γ
  - Beam results optimistic

- Compact Neutron Dosimeters and Spectrometers
  - Anti-coincident shield
  - Pulse-shape discrimination (electronics)
  - SSPM detectors: compact, high gain

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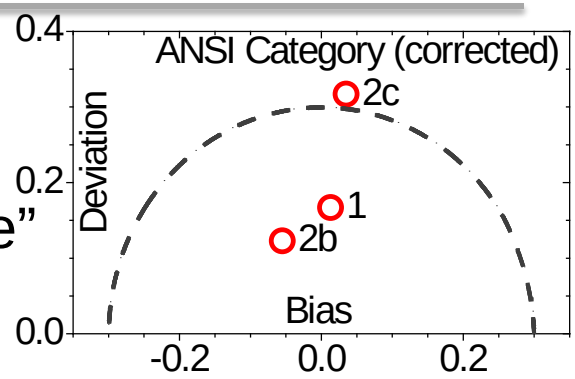
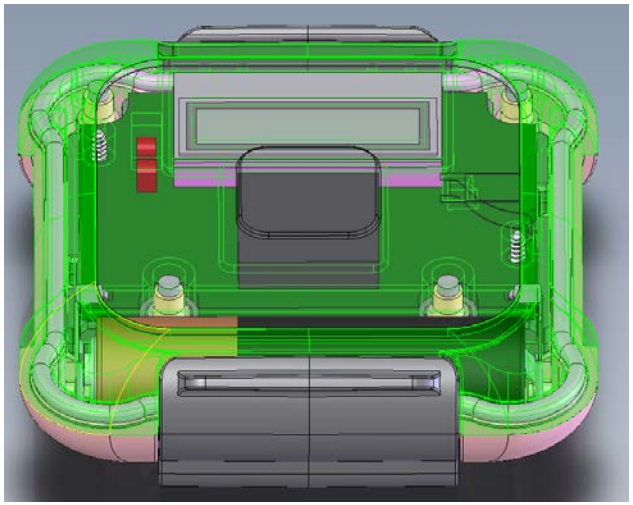
Achievements

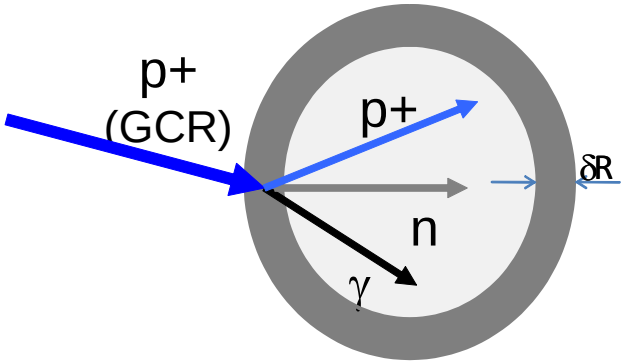
- Tested CLLBC Dosimeters at PNNL:
  - Category 1 – isotopes passed, x-ray failed
  - Category 2 – isotopes passed, x-ray “close”
- Designed Category-1 x-ray detector
- Received and tested new dosimeter chip
- Designed new compact version
- Developing HDD, SDD, assembly, testing, and QC protocols: ISO 9001 compliance
- Facilities: Constructed x-ray room, crystal preparation station, dry glove box, environmental chamber automation.
- Met with Stan Mavrogianis and Eric Daxon at HPS meeting

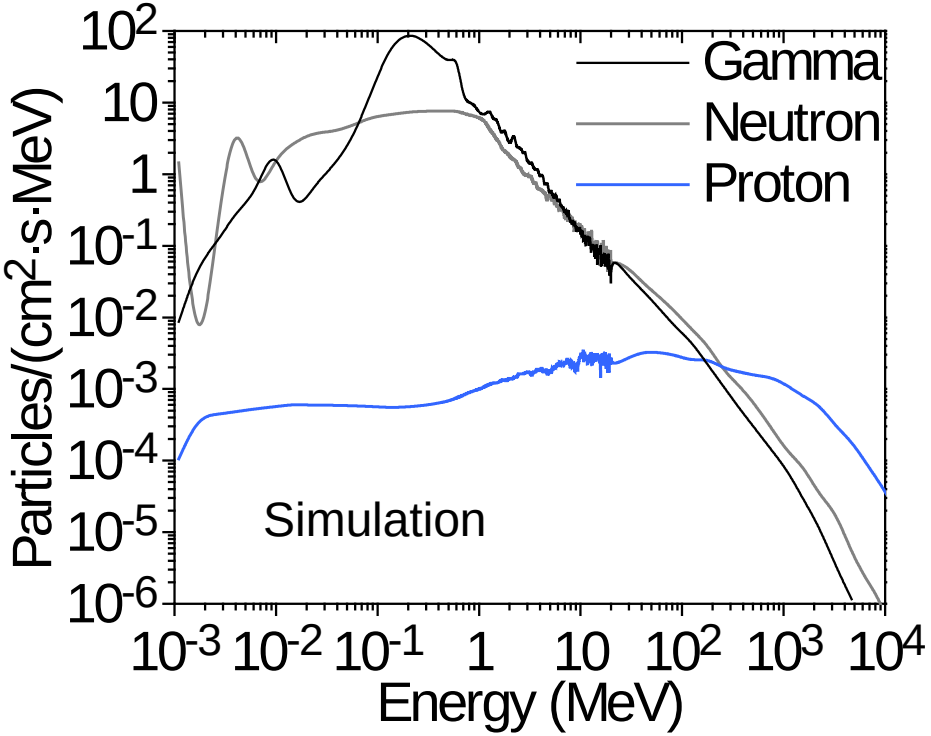




Space Environment

- Galactic Cosmic Rays (GCR), Solar Protons and Secondary Emission (gamma-rays, neutrons, and others)





- Neutron dose important, lots of background