Applied Antineutrino Physics Workshop

An Alternative Design based on Inverse Beta Detection

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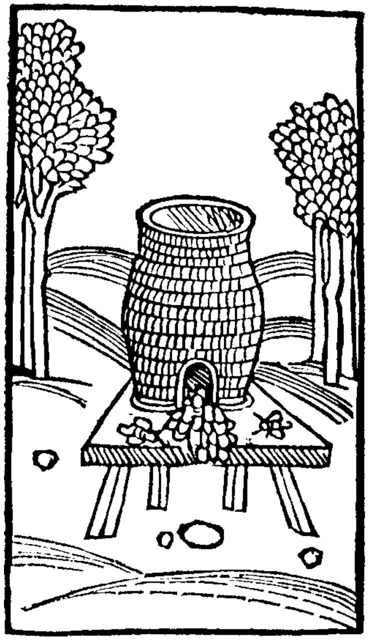

- History
- The immediate future
- The 2-3 yr. time frame
- The beehive
- Summary

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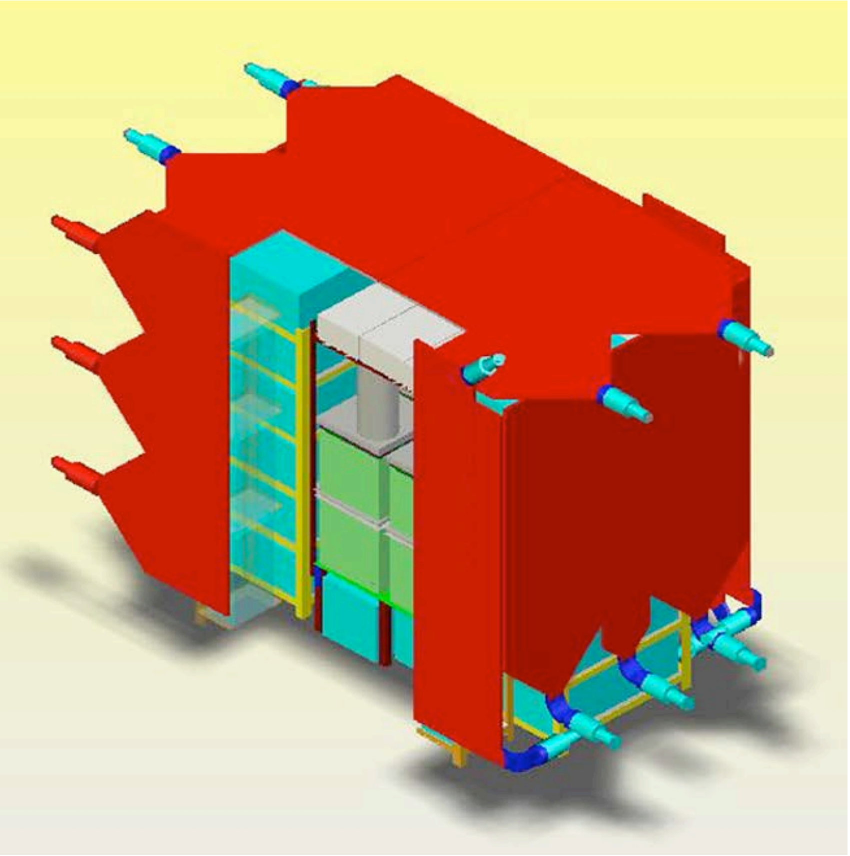
History

- Our first generation detector
  - Conservative design
  - It works!
  - Inefficient
  - Big



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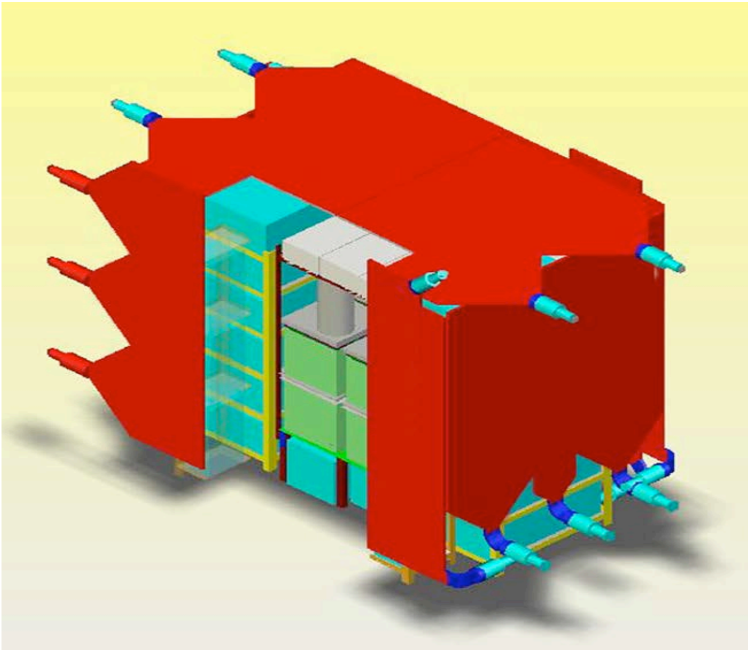
Immediate Future

- The next generation detector
  - To be deployed quickly (mid 2007)
  - More efficient
  - A straightforward extension of existing work
  - Much better electronics
  - Probably a Gd loaded scintillator with better optics and more hermetic muon veto



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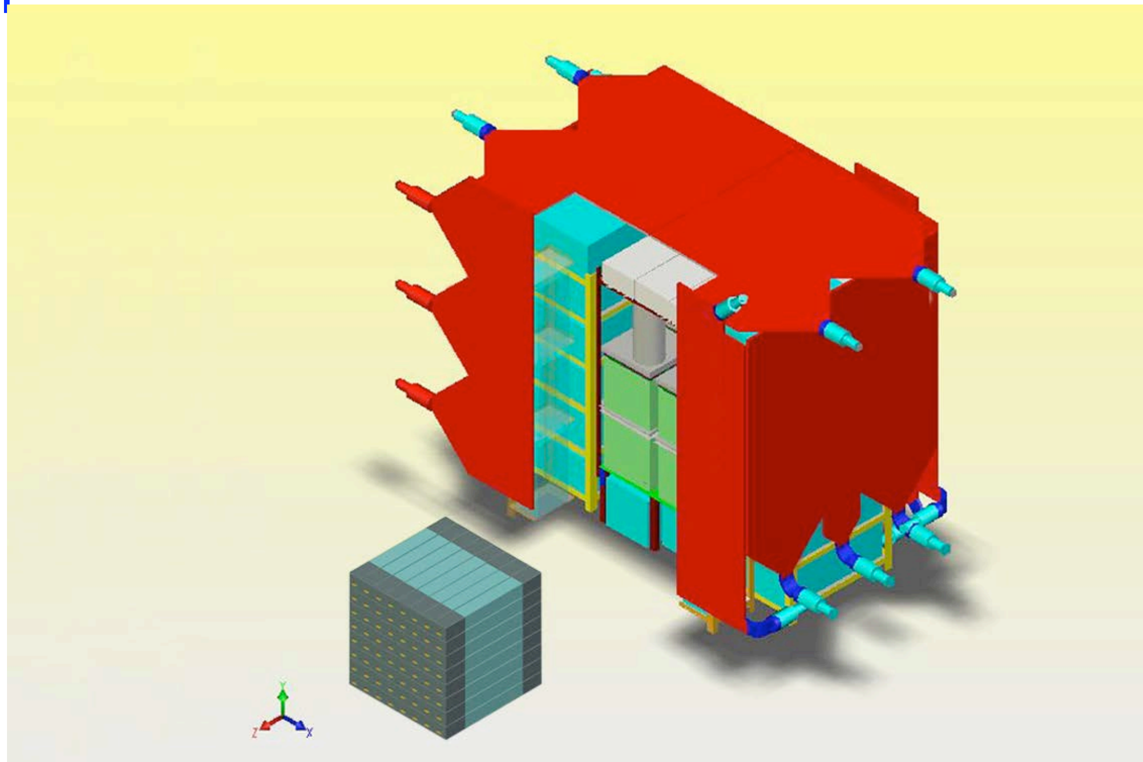
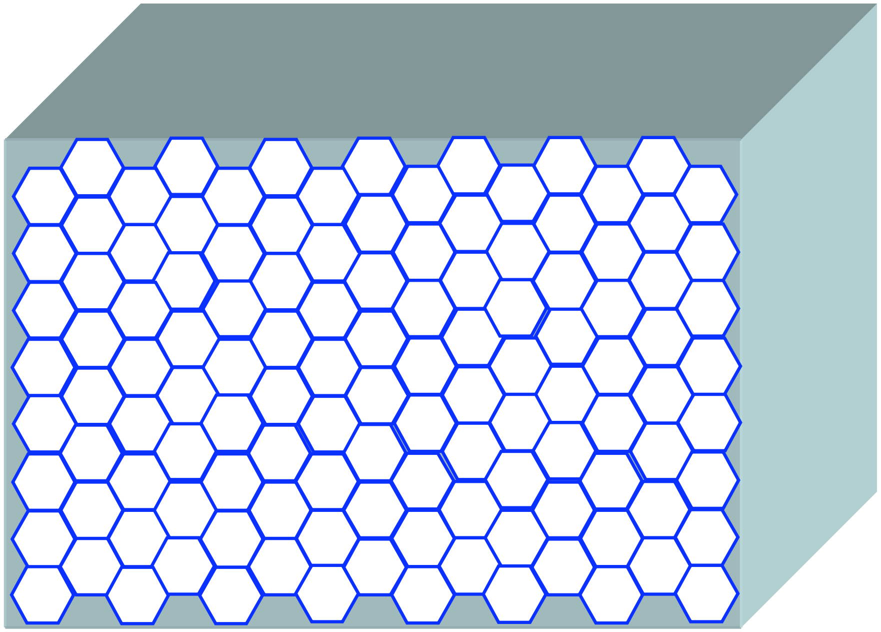
Intermediate future (2 to 3 yr.)

- My pitch!
- A relatively advanced inverse beta design
- Smaller!
- More efficient!



Proposed Design for 2 to 3 yr. Timeframe
"The Beehive"

- Liquid scintillator (~1 m^3)
- Honeycomb partition immersed in liquid scintillator
- Thin acrylic honeycomb coated with ^{6}LiF:ZnS(Ag) scintillator
- Read out with ~100 PMTs



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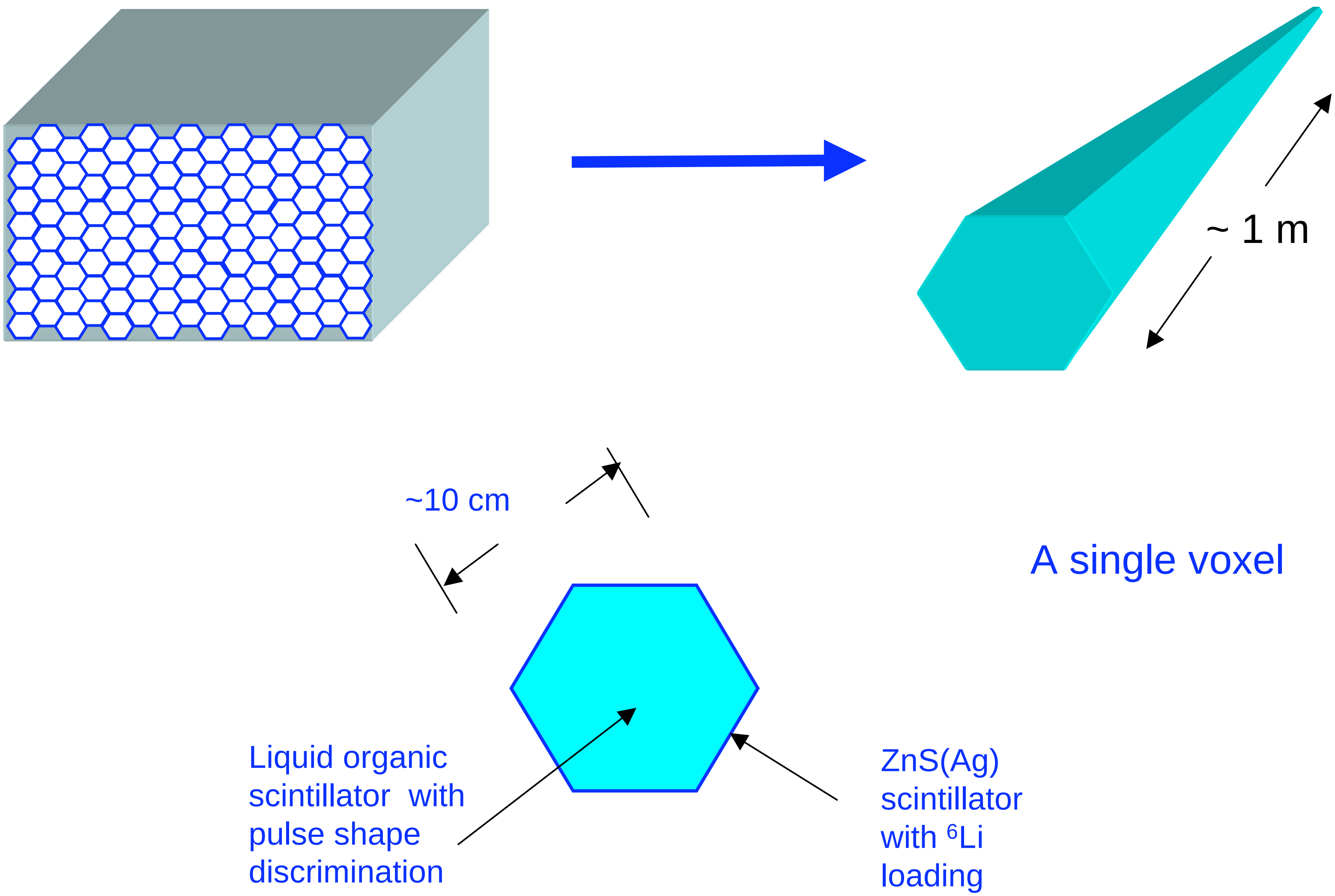
Proposed Design



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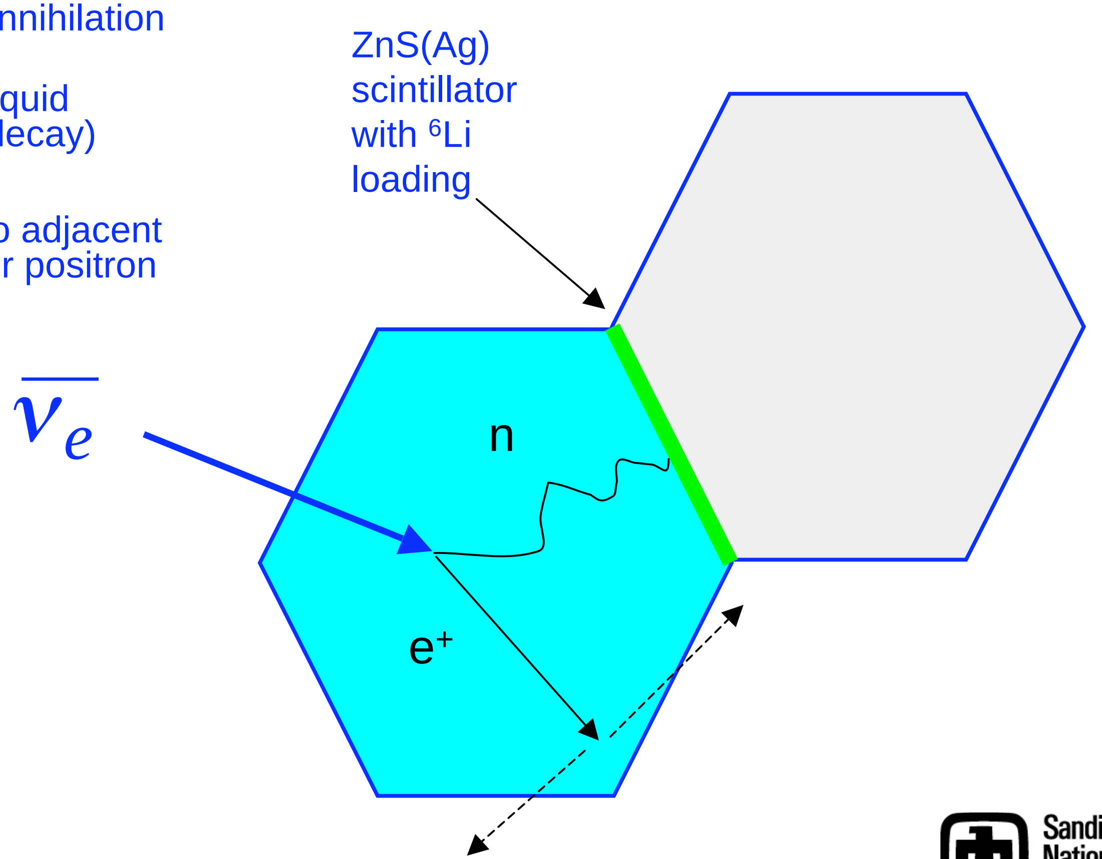
A neutrino hit in the proposed design

$$\overline{\nu_e} + p \rightarrow e^+ + n$$

- Neutrino interaction signature
  - Positron
    - one cell (discounting annihilation photons)
    - Electron-like event in liquid scintillator (fast pulse decay)
  - Neutron
    - Bright ZnS pulse in two adjacent cells about ~10 μs after positron



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Background events
Fast neutron enters detector

Existing Detector

- Mimics antineutrino capture
  - Pulse from n-p scatter
  - Followed by n-capture on Gd

Proposed Detector

- Cut because:
  - n-p scatter distinguishable from pulse shape

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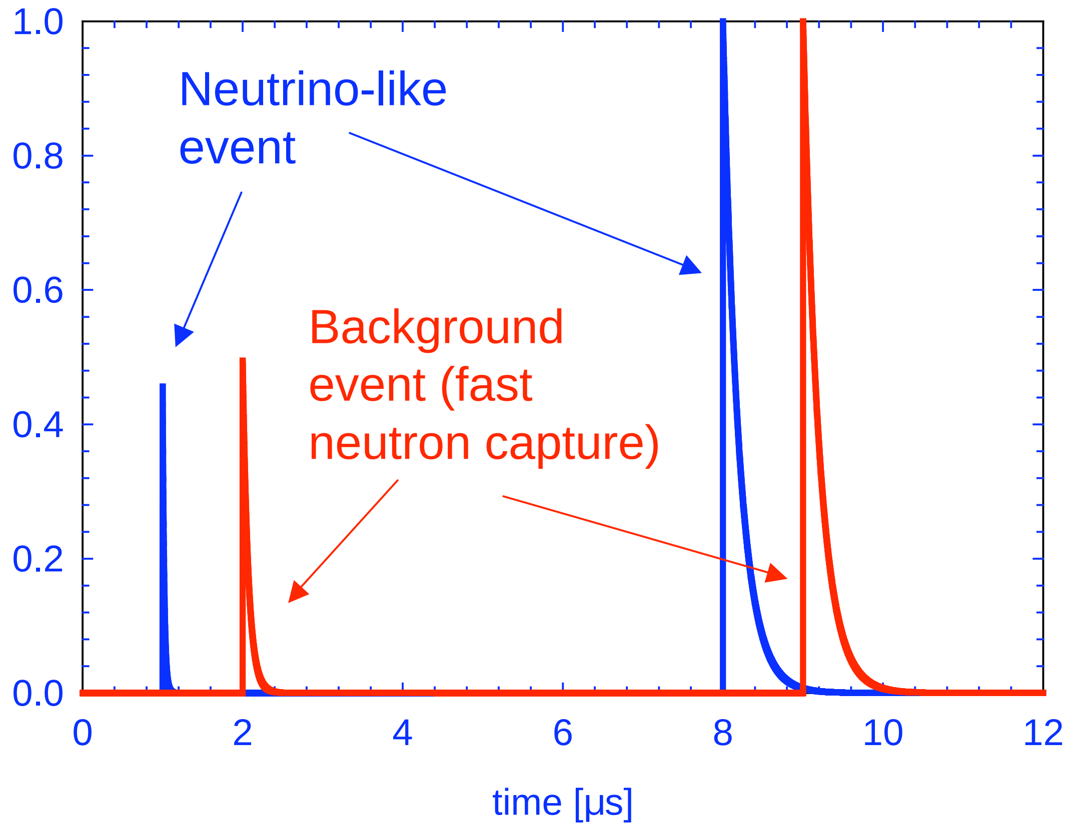
Background events
fast neutron into detector

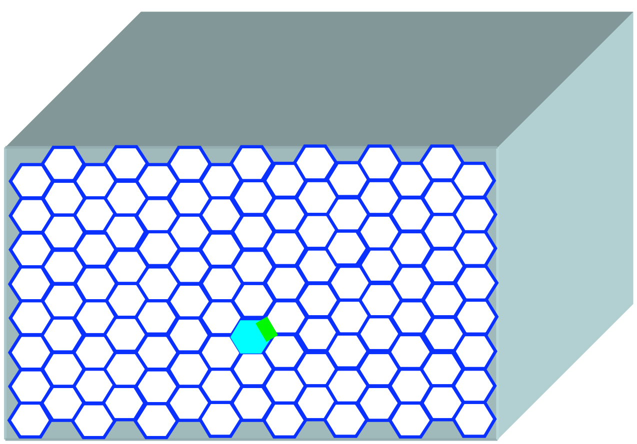


Background events slow neutron into detector coincident with gamma ray

Existing Detector

- Mimics antineutrino capture
  - Pulse from n-p scatter
  - Followed be n-cature on Gd

$$\overline{\nu_e} + p \rightarrow e^+ + n$$

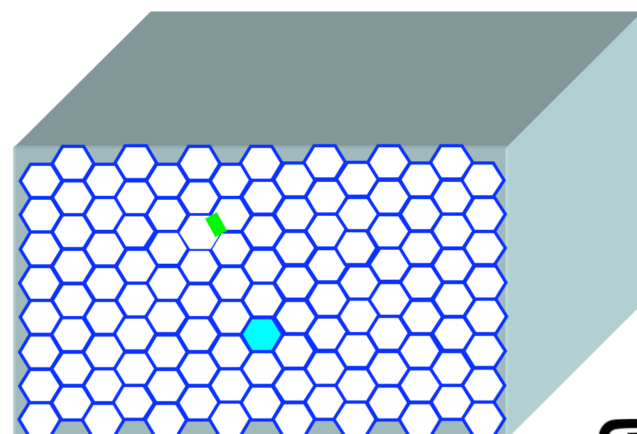


Proposed Detector

- Cut because:

  Gamma event very unlikely to be in same cell as neutron event

$$\upsilon + e^-;\ n + {}^6Li$$



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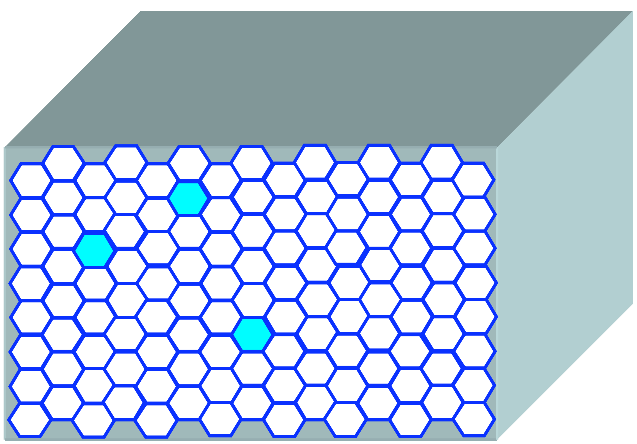
Background events
two chance gamma-rays within time window

Existing Detector

- Mimics antineutrino capture



Proposed Detector

- Cut because:

  No signal from ZnS scintillator

  gammas do not deposit enough energy in ZnS and light from neutron on Li is very large = Q= 4.8 MeV

  Light pulses from more than one cell

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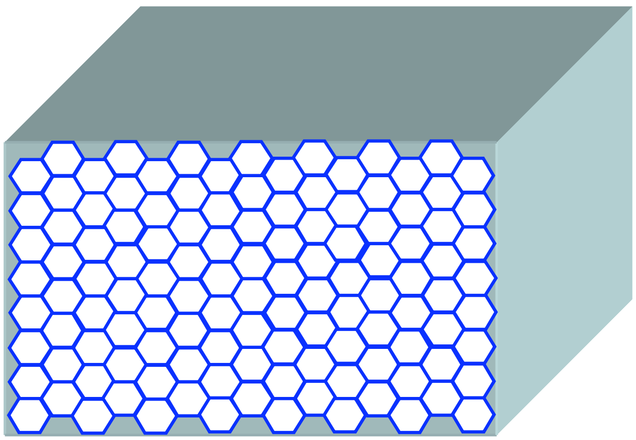
Beehive Detector

$$\overline{\nu_e} + p \rightarrow e^+ + n$$



- More efficient than existing detector
  - Due to ~100% effiency of neutron capture reaction in ^{6}LiF:ZnS(Ag) scintillator
- Greater background rejection
  - Phase space of signal cuts is much richer; easier to classify events
    - Spatial, pulse shape,and two types of scintillator

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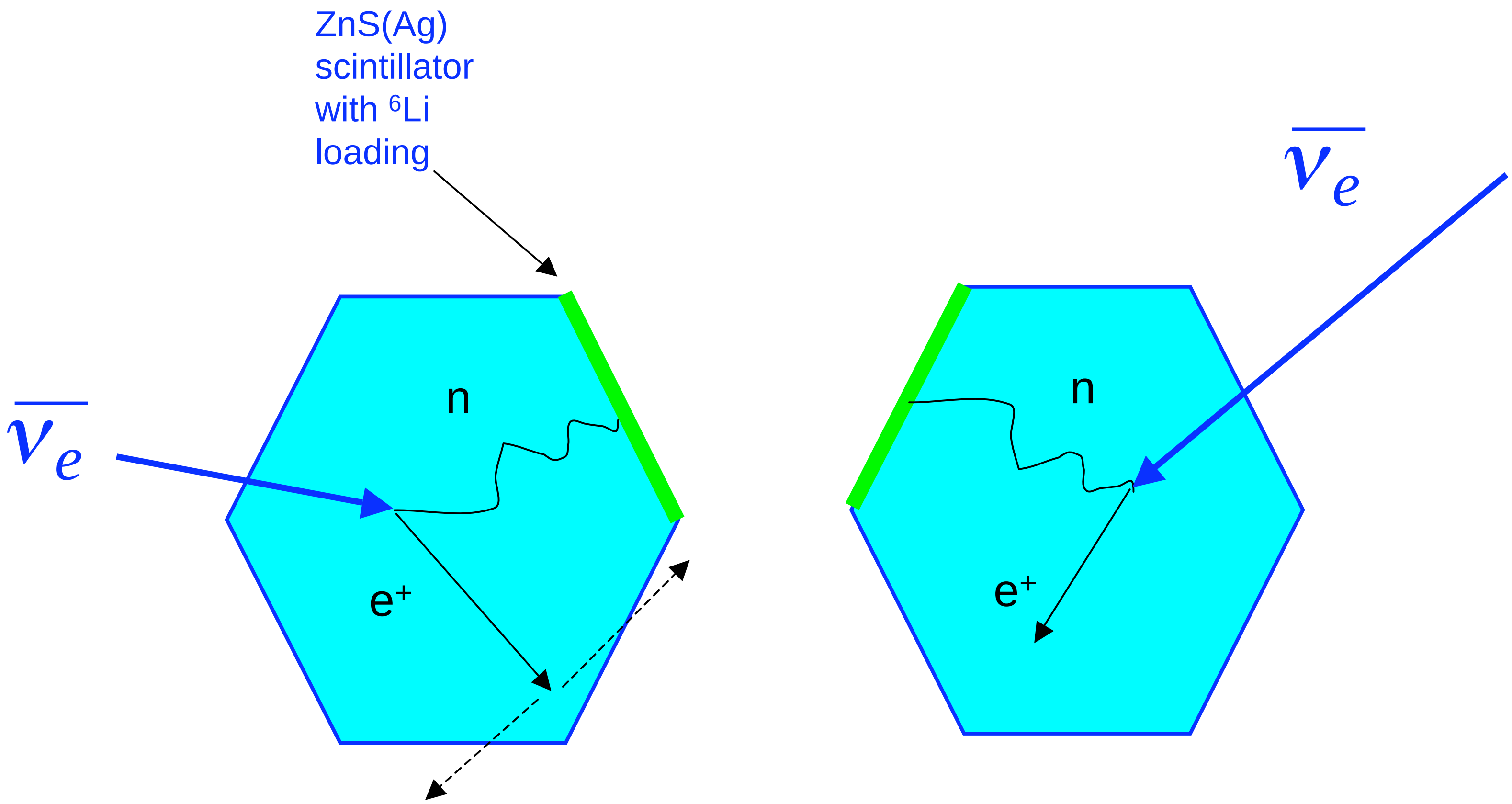
But Wait, There's More!
Some directionality!



But Wait, There's More!
Some directionality!

- Although neutron diffusion is a random walk, a slowing neutron preserves a memory (if sloppy) of its original momentum.
- This property has been observed and exploited in neutrino detection before.

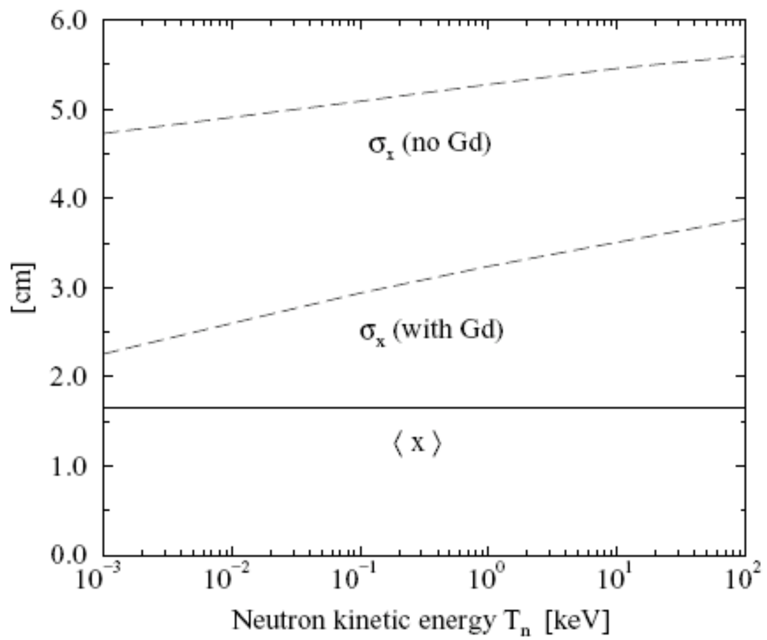


FIG. 5. The shift (solid line) $\langle x \rangle$ and width (long-dashed line) $\sigma_x = \sqrt{\langle x^2 \rangle - \langle x \rangle^2}$ for monoenergetic neutrons (initial kinetic energy T_n) emitted from the origin, moving initially along the x-axis. Note $\langle y \rangle = \langle z \rangle = 0$, and $\sigma_x = \sigma_y = \sigma_z$. We used a $(CH_2)_n$ liquid of density 0.80 g/cm^3, with or without 0.1% Gd doping by mass.

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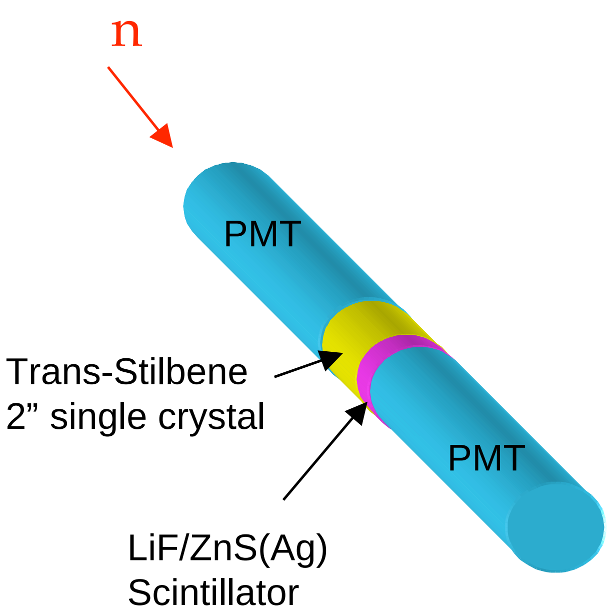
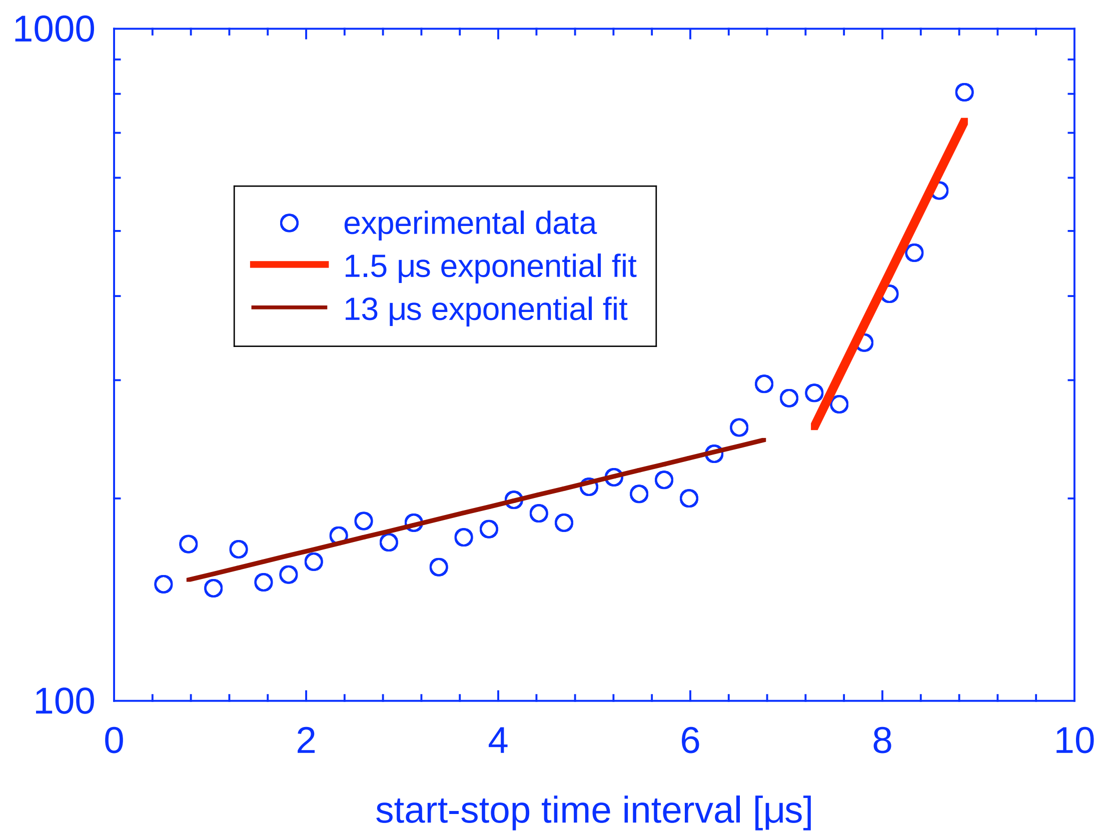
A recent experiment





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Summary and Acknowledgements

- A highly segmented detector with $^{6}LiF:ZnS(Ag)$ scintillator partitions looks very attractive for monitoring of reactor antineutrinos.
- We want to do some design experiments!

- We are very, very grateful to Sandia National Laboratories for giving us funding to study this concept under a Laboratory Directed Research and Development project:
  - Project Title: Neutrino Detection Technology Development
    Project Number: 102607

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