Daya Bay Calibration System

- Energy Calibration Basics
- Calibration Subsystems
- Automated Source Calibration System
- Calibration Plans and Simulations

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Precise Determination of Energy

Between the near/far detector pair, require a relative

$$\frac{\delta E}{E} \leq 1\%$$

charge → $$Q(E,\vec{x}) \propto E_{vis} \times \Re(\vec{x})$$ ← "response function"

Visible energy at detector center

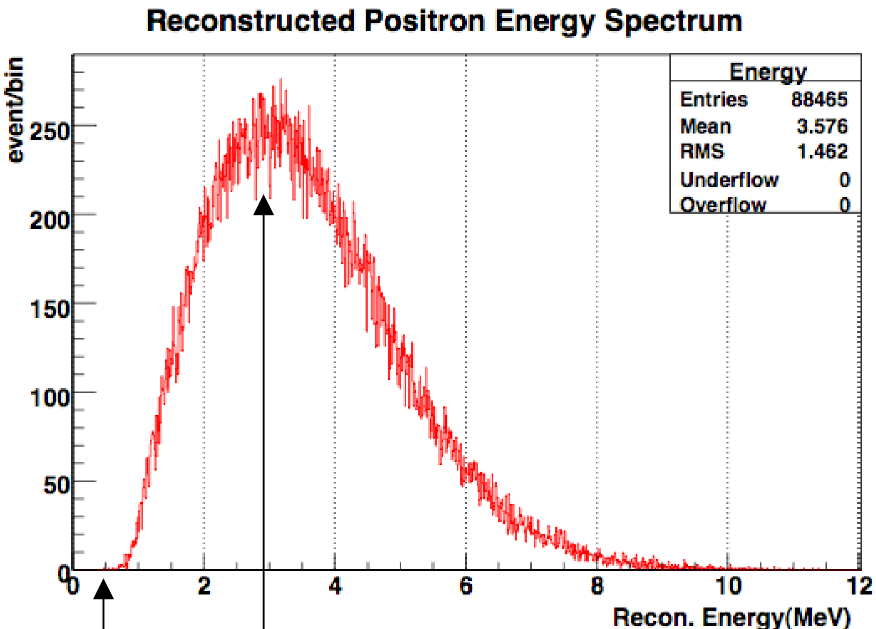
- Basic requirement: radioactive sources=fixed energy
- Response function is position-dependent: source at different places to sample the response function in entire fiducial volume

Subsystems

- LED source for gain, threshold, and timing calibration
- Manual source deployment system for full-volume characterization
- Automated source deployment system for routine calibration.
- Use tagged cosmogenics for continuous monitoring of detector performance

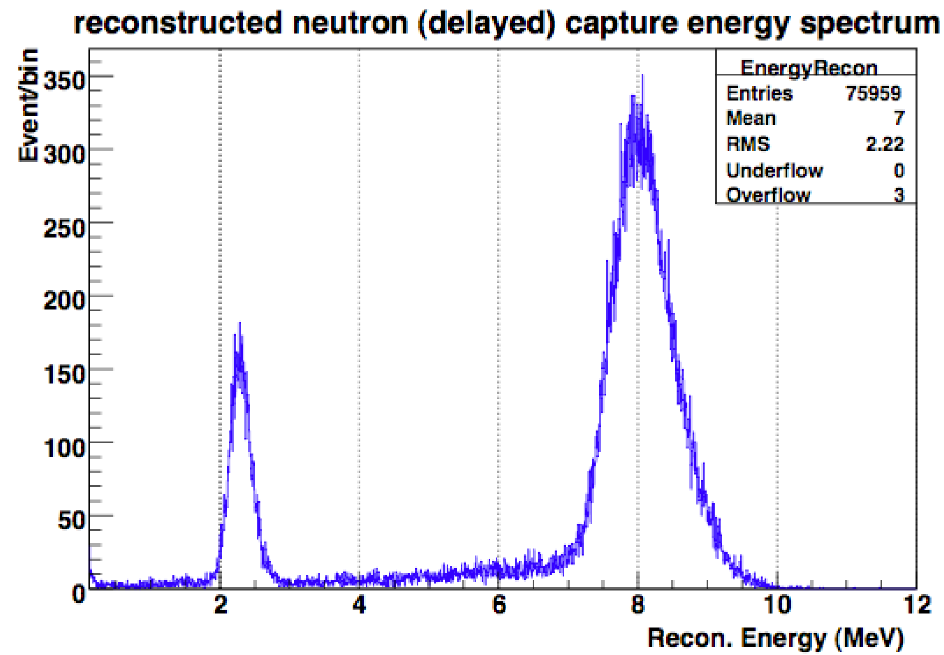
Inverse-beta Energy Spectra and Sources

Prompt Energy Signal



^{68}Ge ^{60}Co

Delayed Energy Signal



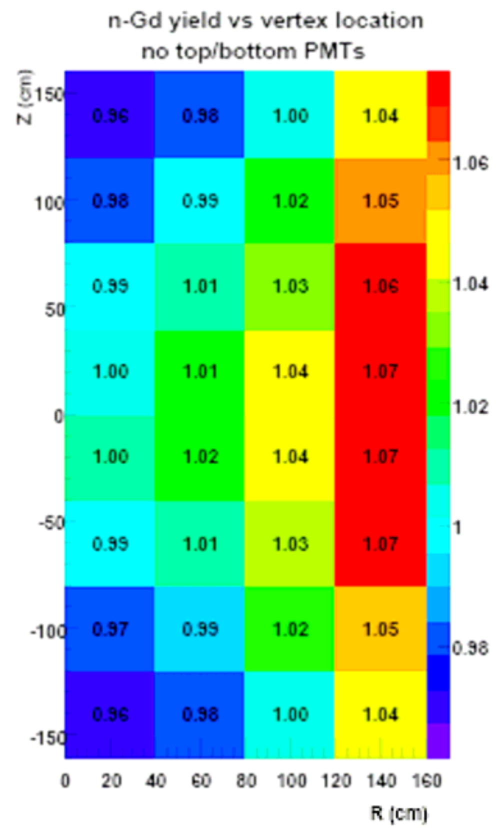
Neutron source

We plan three radioactive sources:

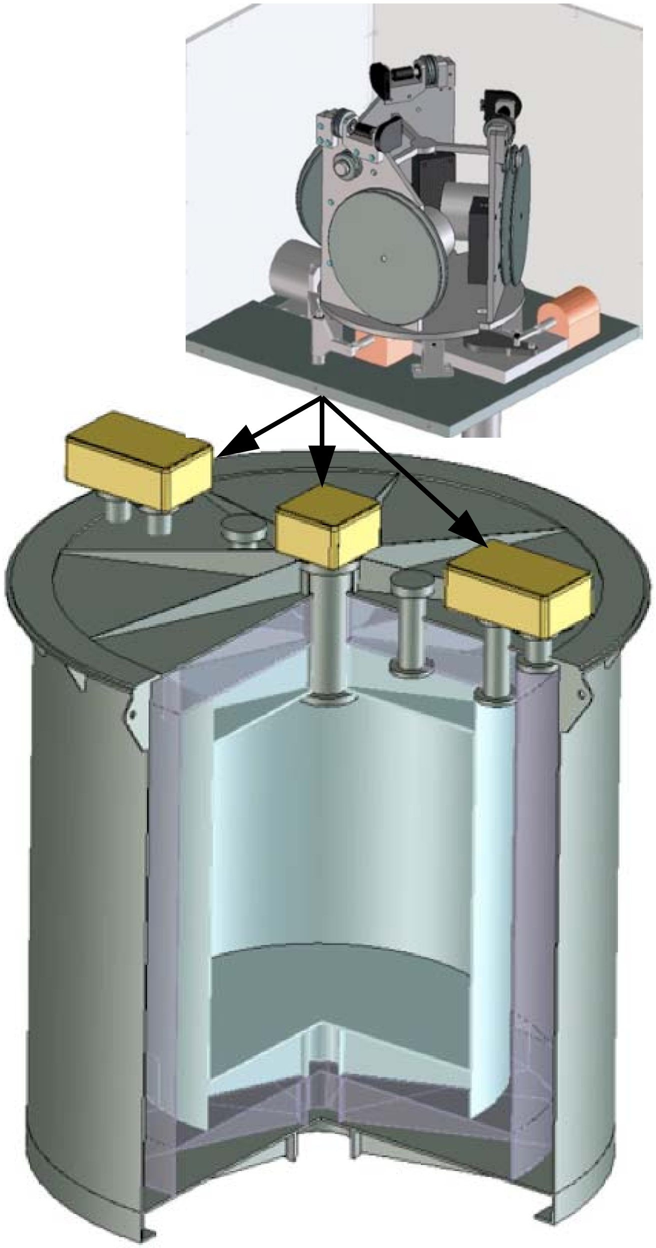
- ^{68}Ge, 0 KE $e^+ \rightarrow$ 1.022 MeV γ's $\rightarrow$ e^+ energy threshold
- ^{60}Co $\rightarrow$ 2.506 MeV γ's $\rightarrow$ e^+ energy scale
- Cf (or AmBe)$\rightarrow$ n $\rightarrow$ "delayed" capture on p (2.2 MeV γ) or Gd (8.0 MeV γ's) $\rightarrow$ neutron threshold and scale

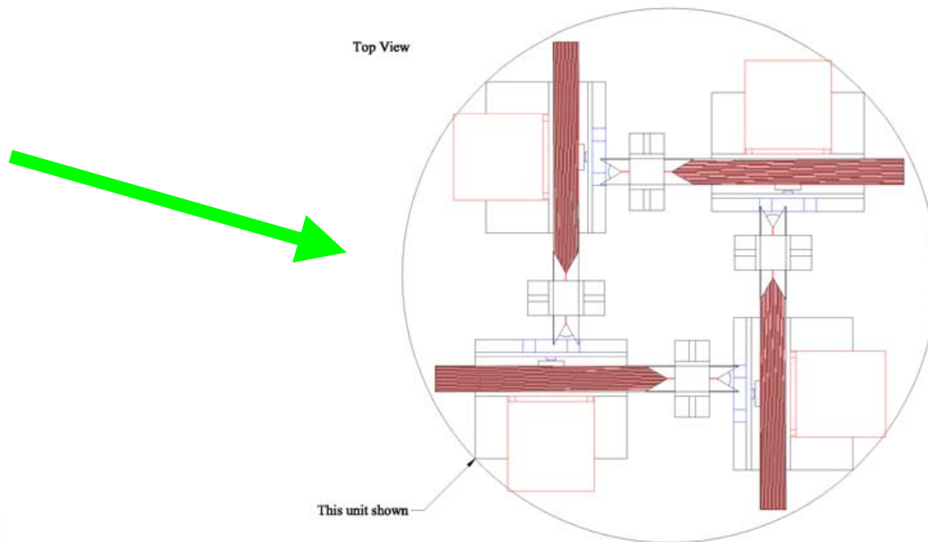
Spallation neutron for Daya Bay

- Muon induced neutrons thermalize and capture on Gd or H.
- Uniformly distributed in detector.
- Tagged by muon detector.
- Signals exactly like the inverse-beta neutron signal: Delayed energy 8 MeV (n-Gd) or 2.2 MeV (n-p). So calibrating E_{vis}.
- Combined with position reconstruction to give the detector position response function R(x).



Automated System Hardware

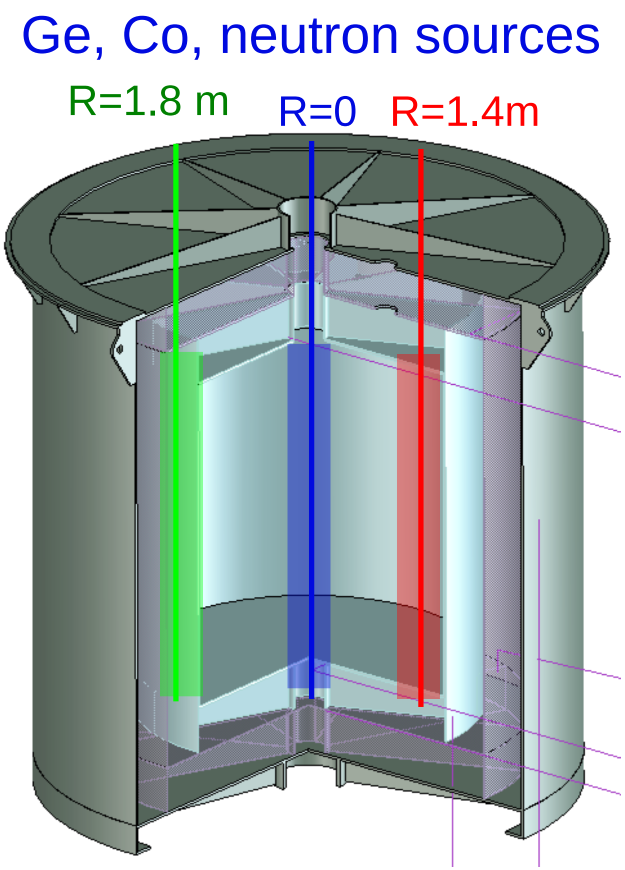


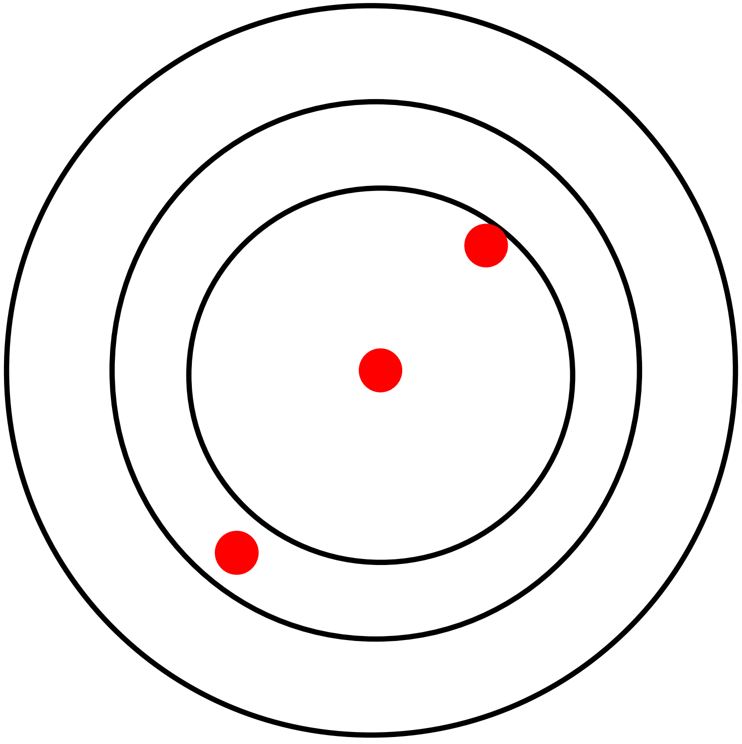


- 3 deploy system per module
- Each corresponds to one point in horizontal cross-section with full z axis.
- Each capable of deploying four different sources.

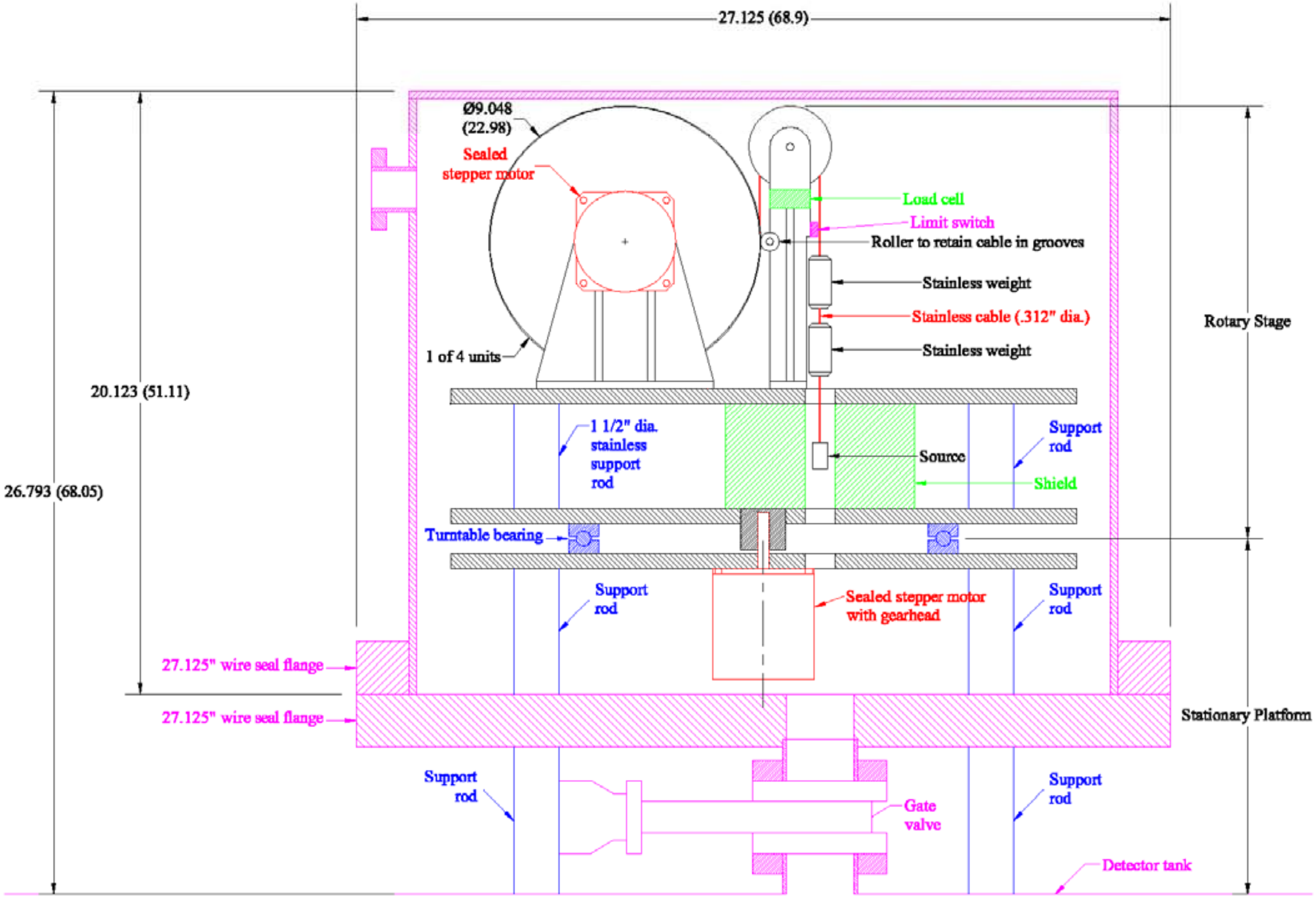
Three Ports/Units

- Central axis
- Outer radius of central region
- Gamma catcher region





One step motor unit



- One turn table, 4 step motors.
- Computer automated DAQ using position encoder, load cell readings.

Detector Parameters and Corresponding Calibration Strategy

Parameter	Calibration Method
Light yield in central region	Source @ center
Light yield in gamma catcher	Source in gamma catcher
Attenuation in central region	Neutron center/uniform ratio or Co center/corner ratio
Attenuation in gamma catcher	Source in gamma catcher
Tank reflectivity	Early/later light yield
Dead PMTs	Source @ center
Crud at the bottom of acrylic	Source along z axis

Carefully designing calibration to decouple different parameters.

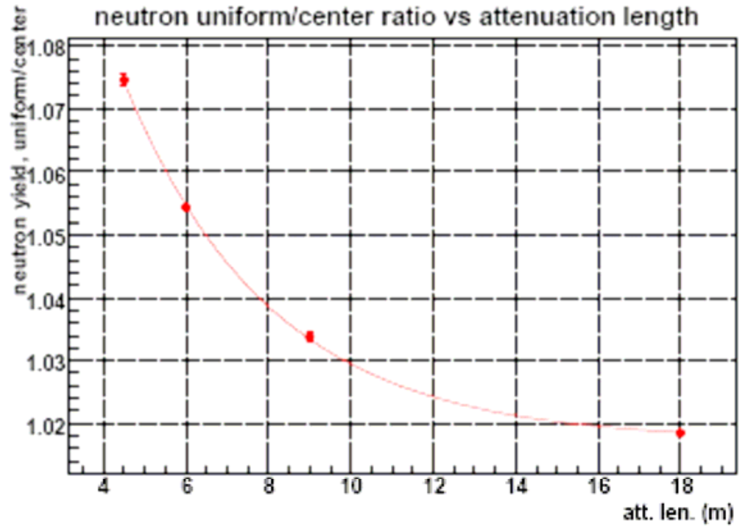
Change of Attenuation Length in Central Region

So the attenuation length affect the detector position uniformity, light yield does NOT.

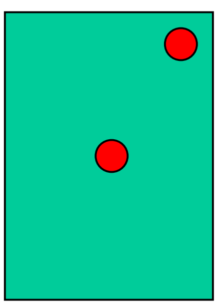
So “uniform”/”center” ratio ⇒ attenuation length.

- *“uniform”: spallation neutrons,*
- *“center”: calibration.*

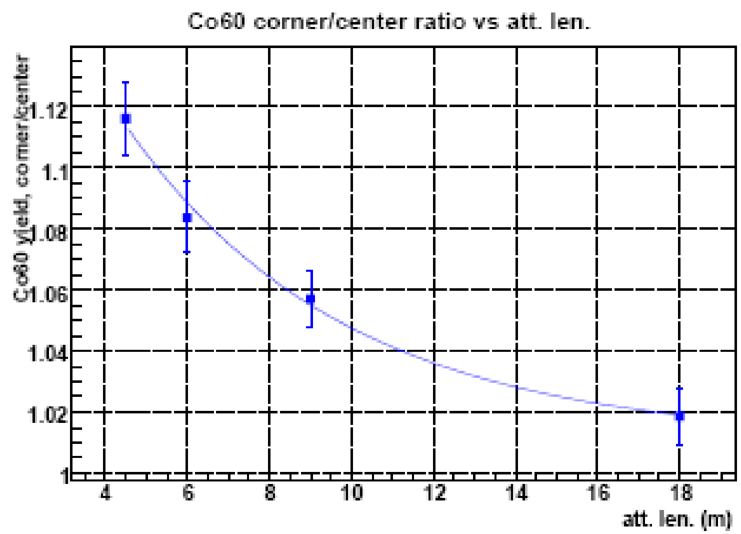
10,000 neutrons each.



Similarly, can use “corner”/”center” ratio.



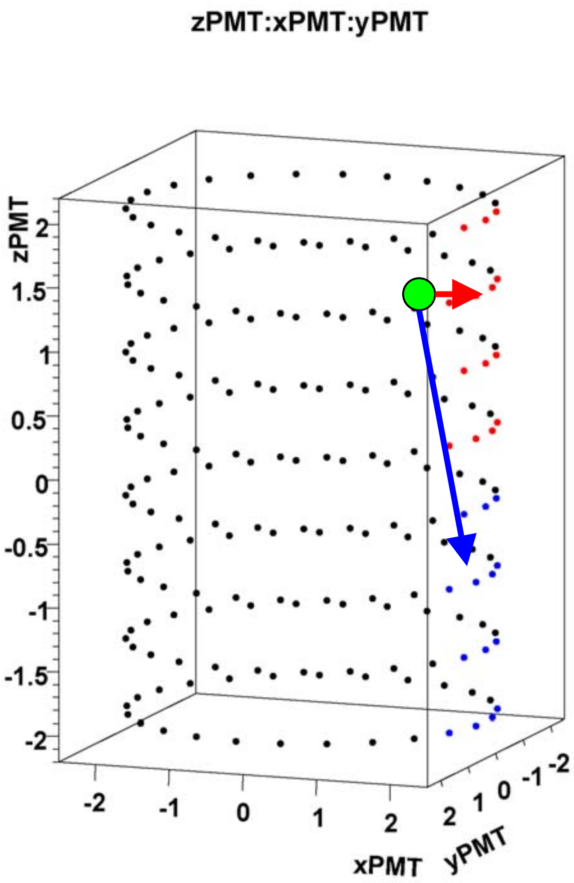
^{60}Co source, 1000 events each



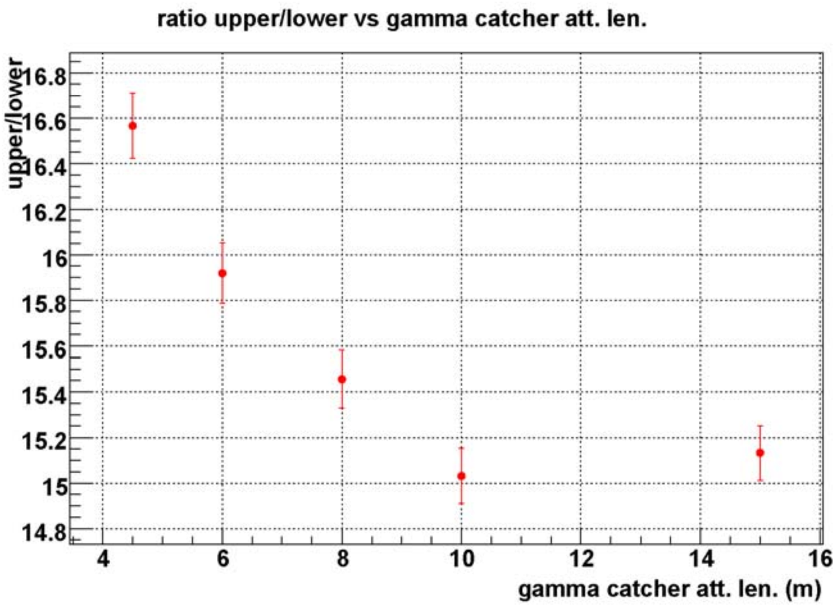
Change of Attenuation Length in Gamma Catcher

Q: How to calibrate the attenuation length in the gamma catcher only?

A: put a source in the gamma catcher.



Ratio of upper/lower “headon” tubes



Status Summary

We have a comprehensive plan for detector energy calibration.

Calibration system integrated in detector design.

Detail simulations of the calibration performance are ongoing.

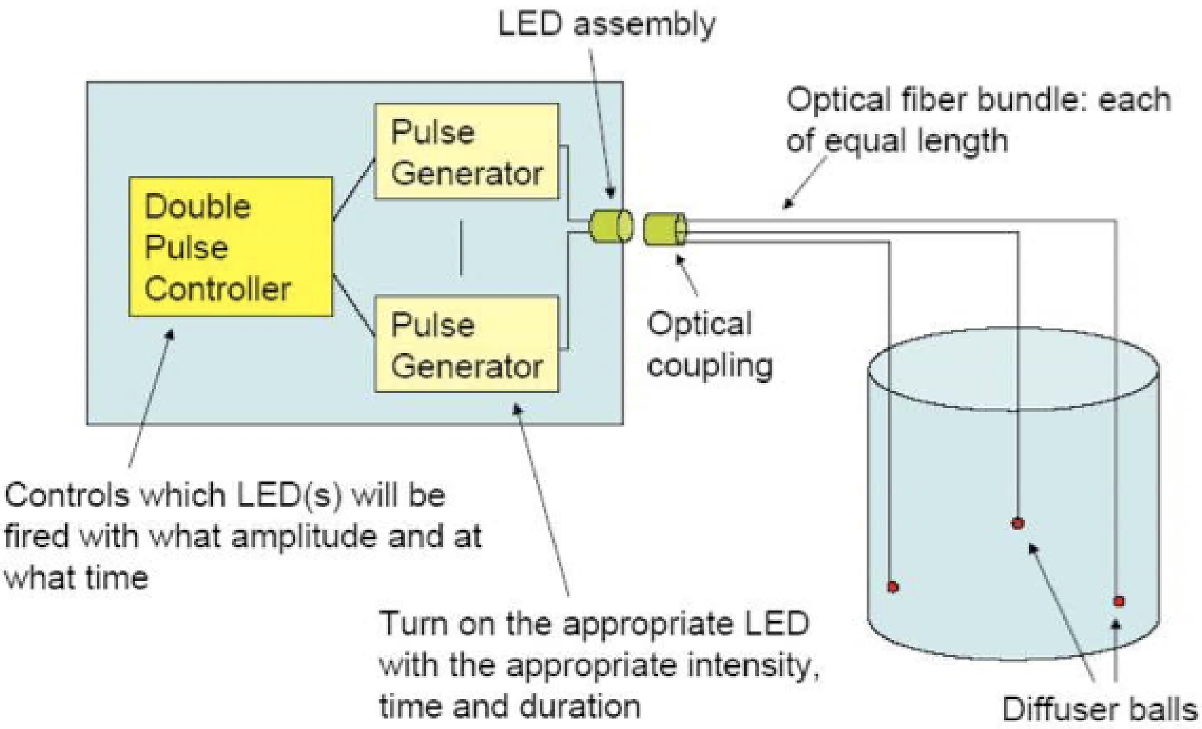
We are building prototype for the automated source deploy system.

Goal: to achieve a 1% near/far relative energy Uncertainty.

Backups

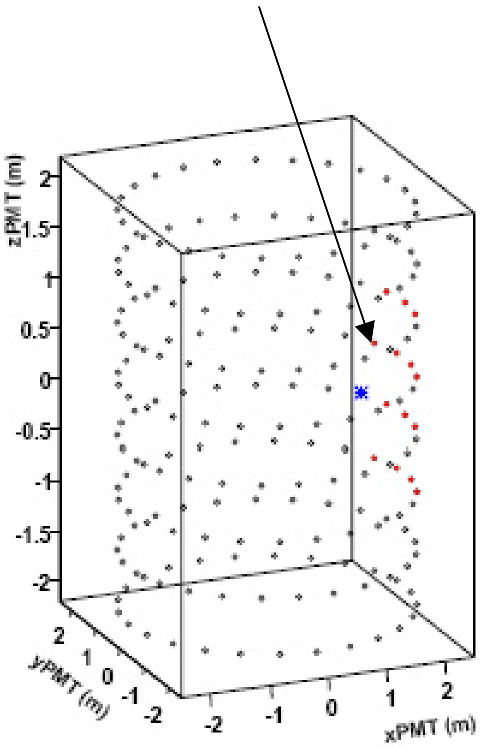
LED Calibration of the Antineutrino Detectors

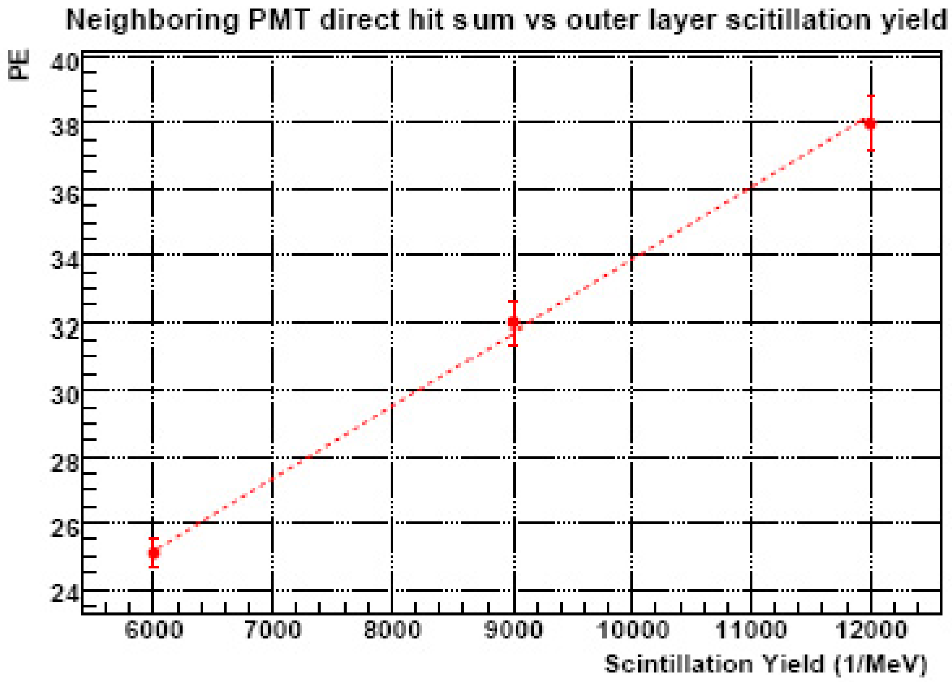
Calibration Goal: PMT gains and timing



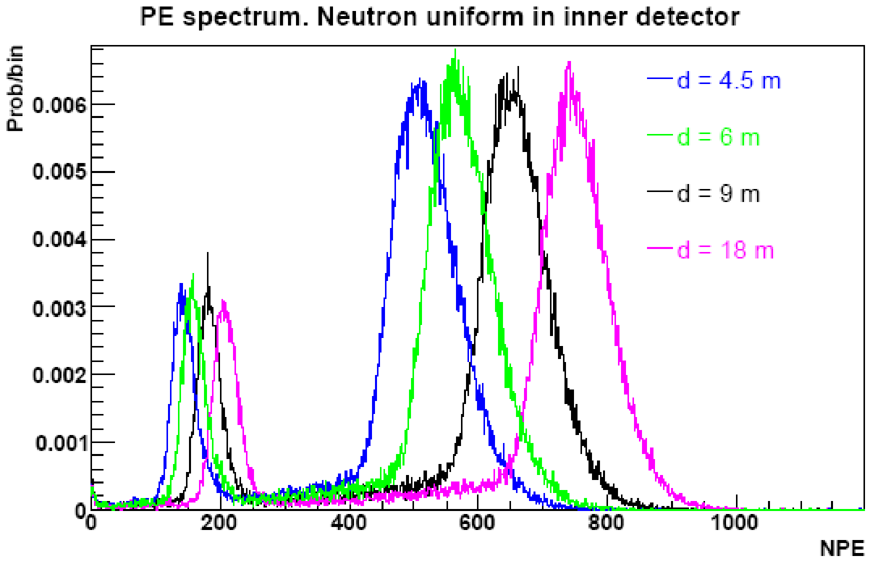
Change of Light Yield in Gamma Catcher

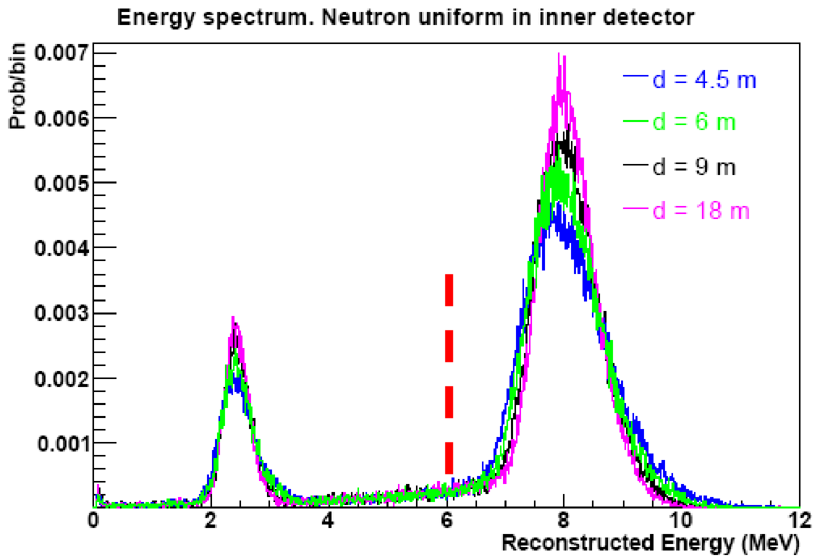
Put the source close to the outer layer and look at the tubes close-by. Short distance $\Rightarrow$ attenuation negligible.





Resulting Neutron Efficiency





$$\varepsilon = \frac{\text{detected events} > 6\ \text{MeV}}{\text{Total Gd capture events}}$$

0.1% variation for reasonable range of parameters.

Y (1/MeV)	L (m)	R	Neutron Efficiency(%)
9000	9	0.8	92.76
9000	4.5	0.8	93.05
9000	6	0.8	93.03
9000	18	0.8	92.69
9000	9	0.1	92.95
9000	9	0.45	92.81
6000	9	0.8	92.87
12000	9	0.8	92.80