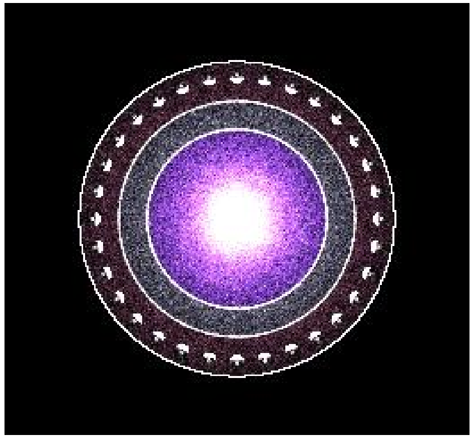
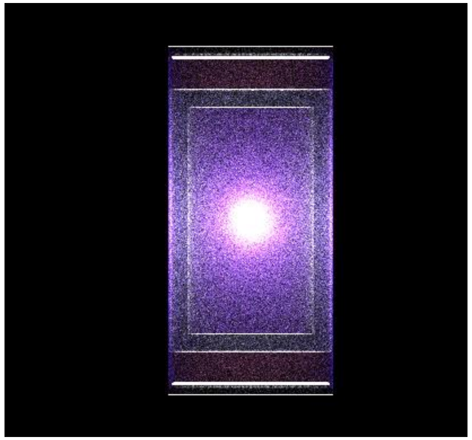
GLG4sim: Example with a θ_{13} Experiment at Daya Bay



MAND Workshop
June 2005



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Detector Concepts for Reactor θ_{13} Experiments

Some of the Common Features of these Experiments:

- 2 or 3 zones (target, gamma-catcher, buffer)
- Detecting reactor anti-neutrinos via inverse-beta decay (use delayed coincidence to suppress accidental backgrounds)
- High light yield liquid scintillator that also provides the target protons
- Gadolinium doping to define target volume

Many are also shared with KamLAND

Using GLG4sim for Daya Bay Detector Design Studies

2 Design Concepts Investigated:

- "Barrel-Mounted"
- "Endcap-Mounted"

Some Questions We Hope to Answer:

- What is the detected light yield and anticipated energy resolution (< 10% at 1 MeV) ?
- How uniform is the response?
- How does the design affect efficiency for signal detection?
- What is the potential for event vertex reconstruction?

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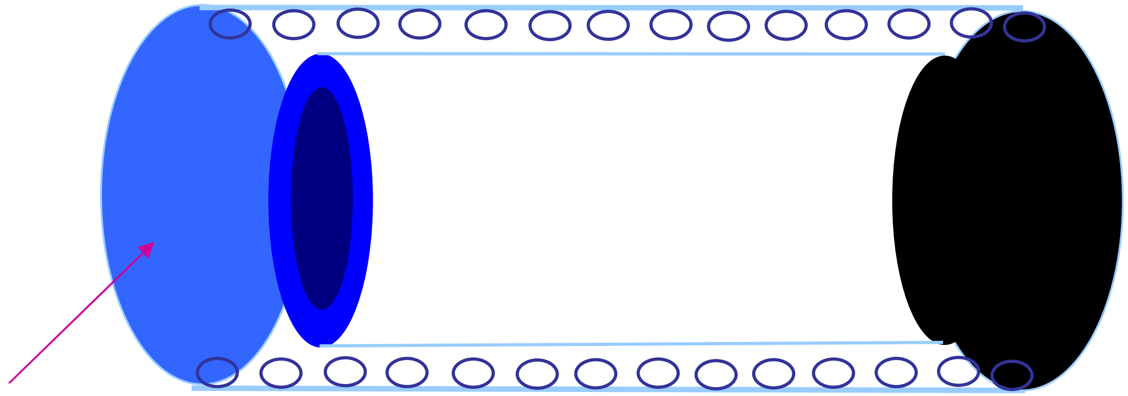
Barrel Mounted Design

PMT Coverage: Barrel Only
Target Volume: 40T



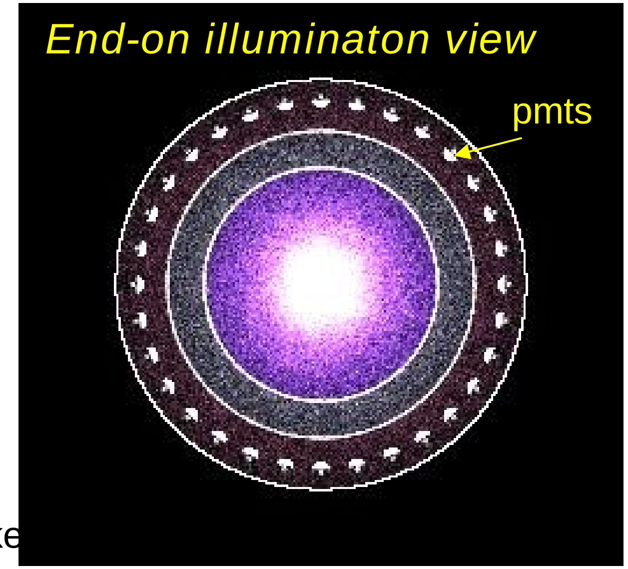
Diffuse Reflective Paint on endcaps Reflectivity = 0.9

Number of PMT’s: 608
Coverage:
12% *on barrel*

R_{target} = 1.5m
L_{target} = 7.1m

$R_{catcher}$= 2.0m
$L_{catcher}$= 8.0m

R_{tank}= 2.6m
L_{tank}= 9.0m

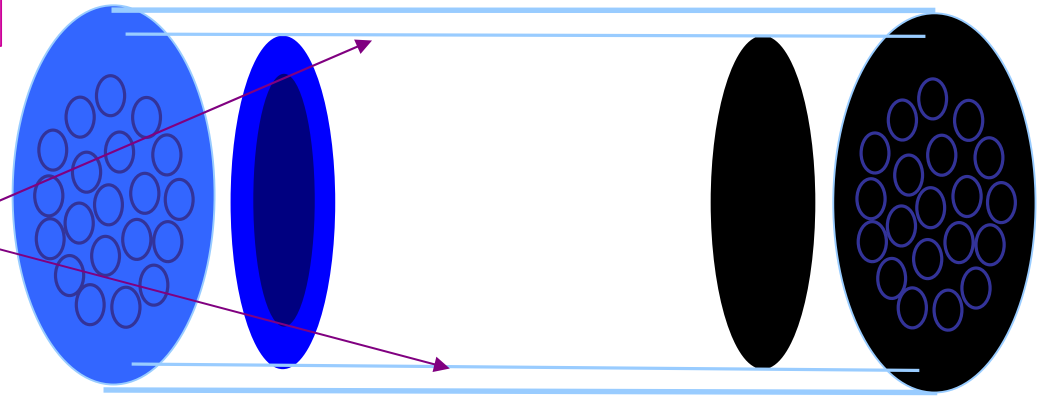


Endcap Mounted Design

PMT Coverage: Endcap Only
Target Volume: 40T

$E \alpha \sqrt{P_1P_2}$

Diffuse Reflective Paint On barrel Reflectivity = 0.9



Number of PMT's: 606
Coverage: 65% *on endcaps*

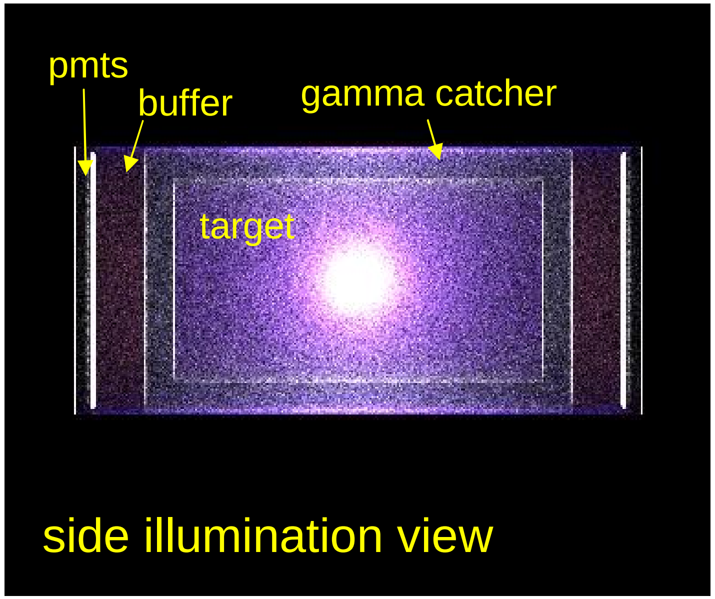
R_{target} = 1.7m
L_{target} = 6.0m

$R_{catcher}$= 2.1m
$L_{catcher}$= 7.0m

R_{tank}= 2.7m
L_{tank}= 9.3m

Motivation:

- Larger target radius,
- Easier to replace PMT's
- Higher light yields and potentially more uniform



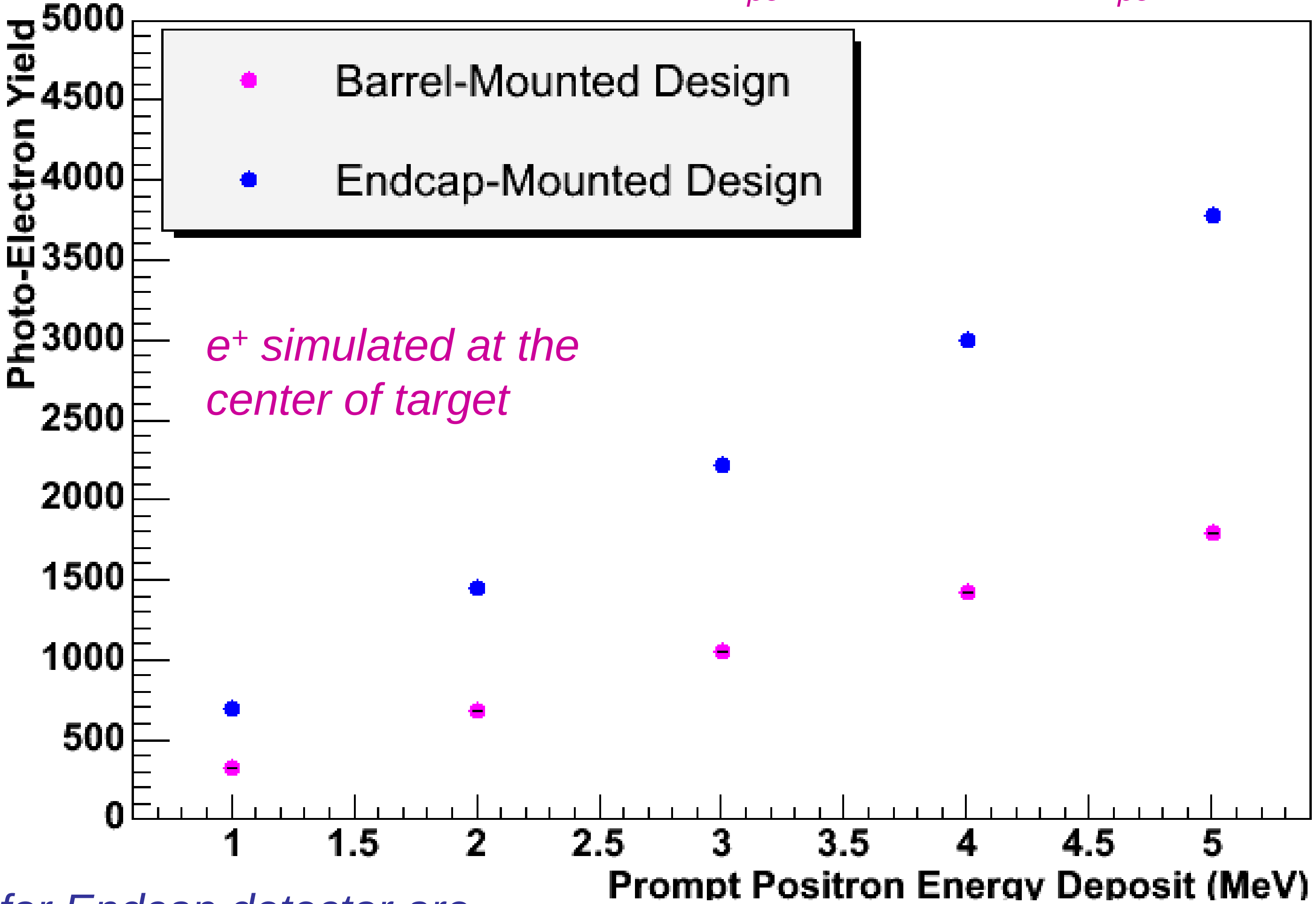
Features of GLG4sim Exploited by These Studies

- KamLAND-like materials descriptions (including liquid scintillator optical properties).
- Custom-written processes for optical photon propagation, scintillation and interaction w/ PMT photocathode
- Existing code infrastructure (flexible file ouput, user interface, nice visualization tools).
- Familiarity (for me)

See talk on KLG4sim and other GLG4sim talks for more specifics

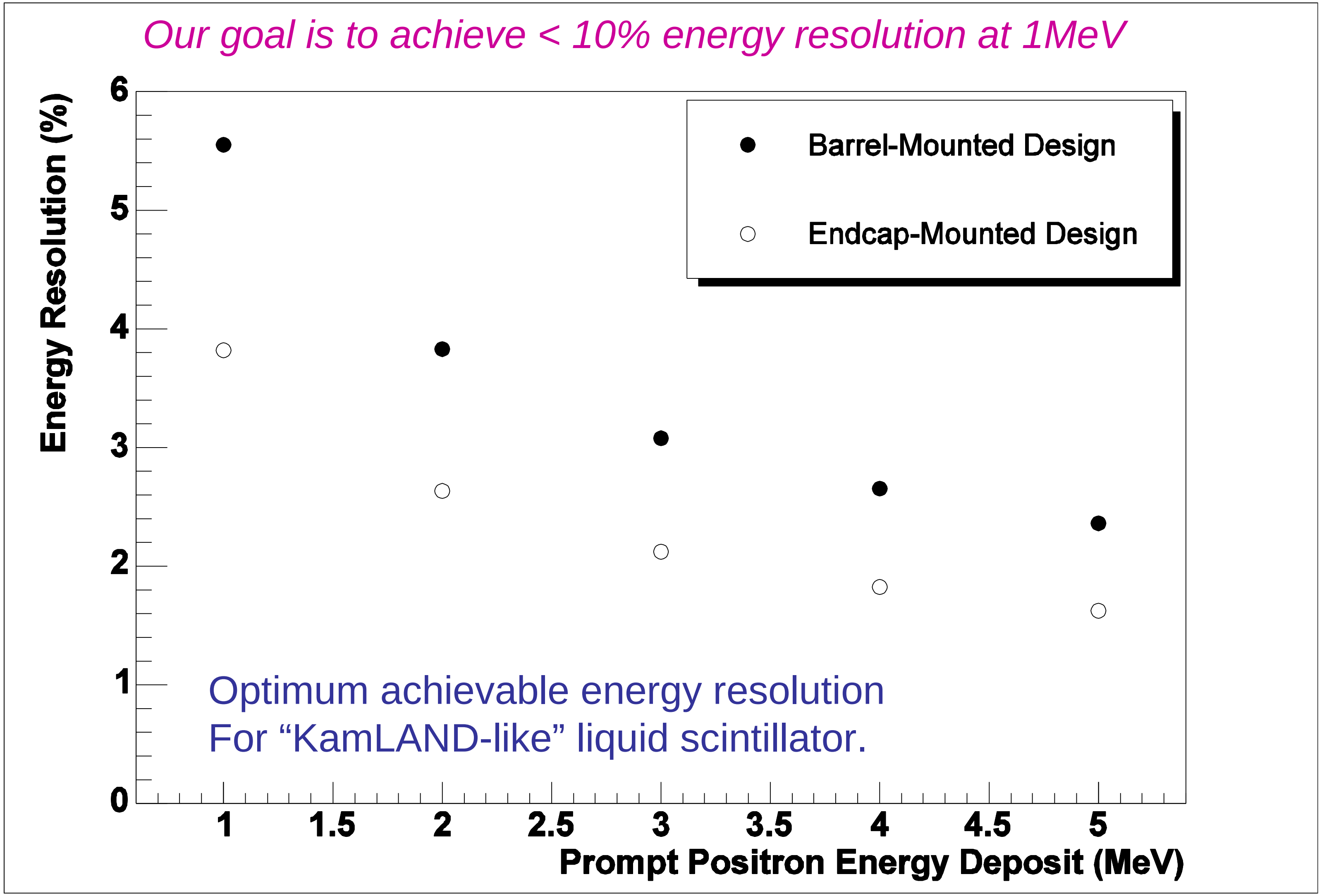
Looking for High Light Output

To Leading Order: E α N_{pe}, so ΔE/E α 1/√N_{pe}

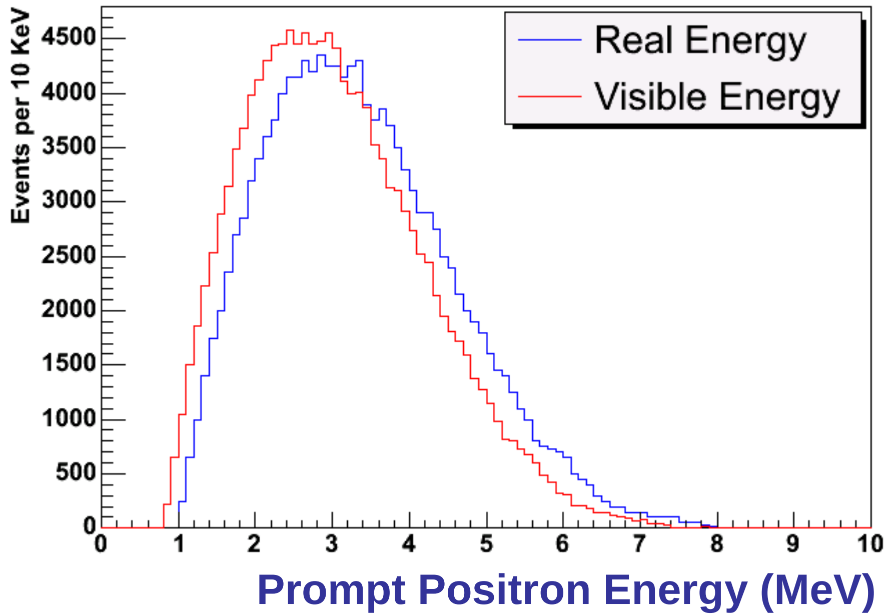


Results for Endcap detector are sensitive to attenuation length and reflectivity

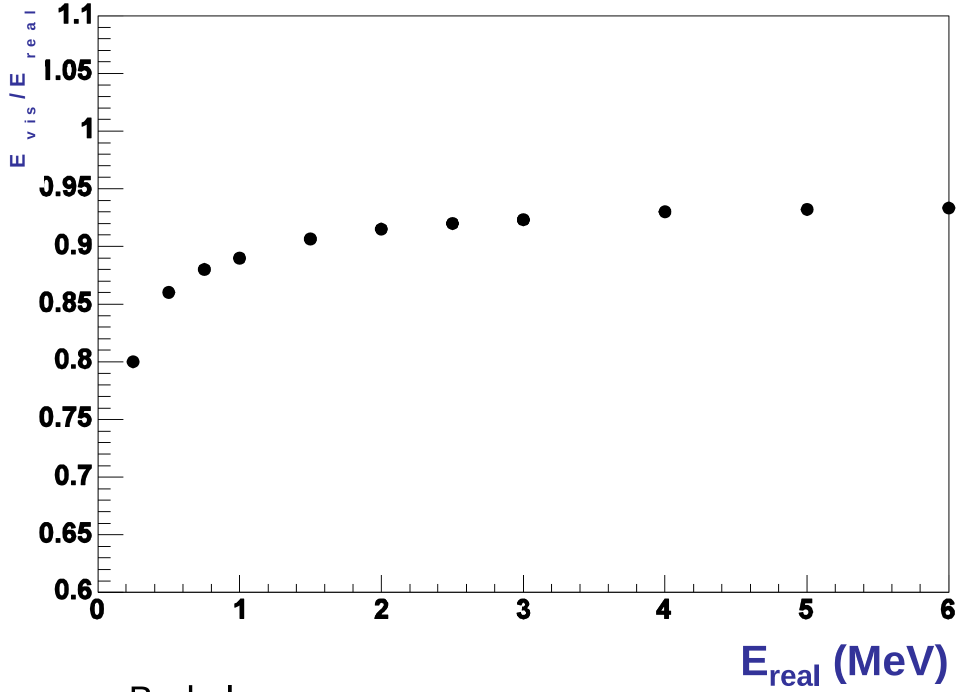
Energy Resolution



Looking at Visible Energy

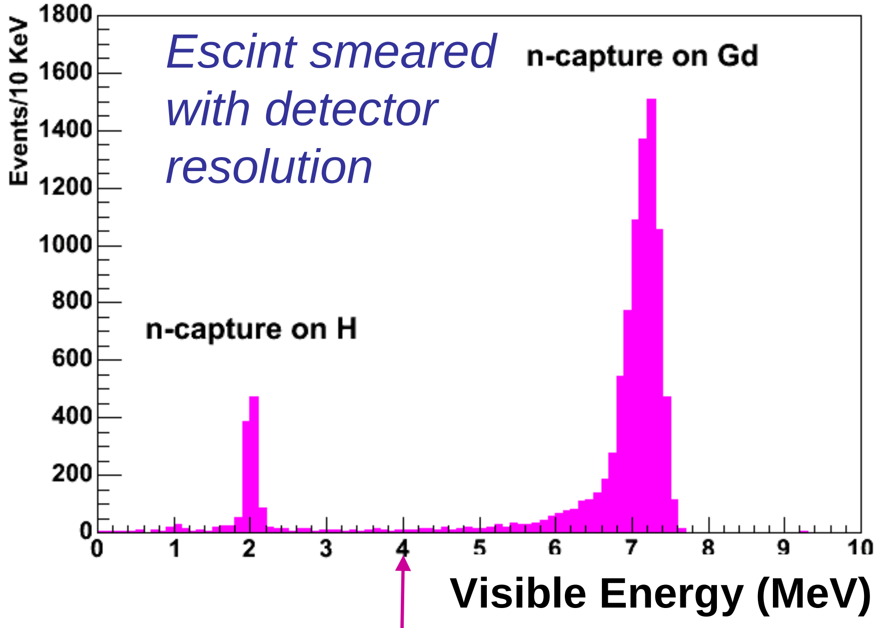


Run with optical sim. off and look at "Escint": A nice shortcut if results don't depend on detailed optical simulation



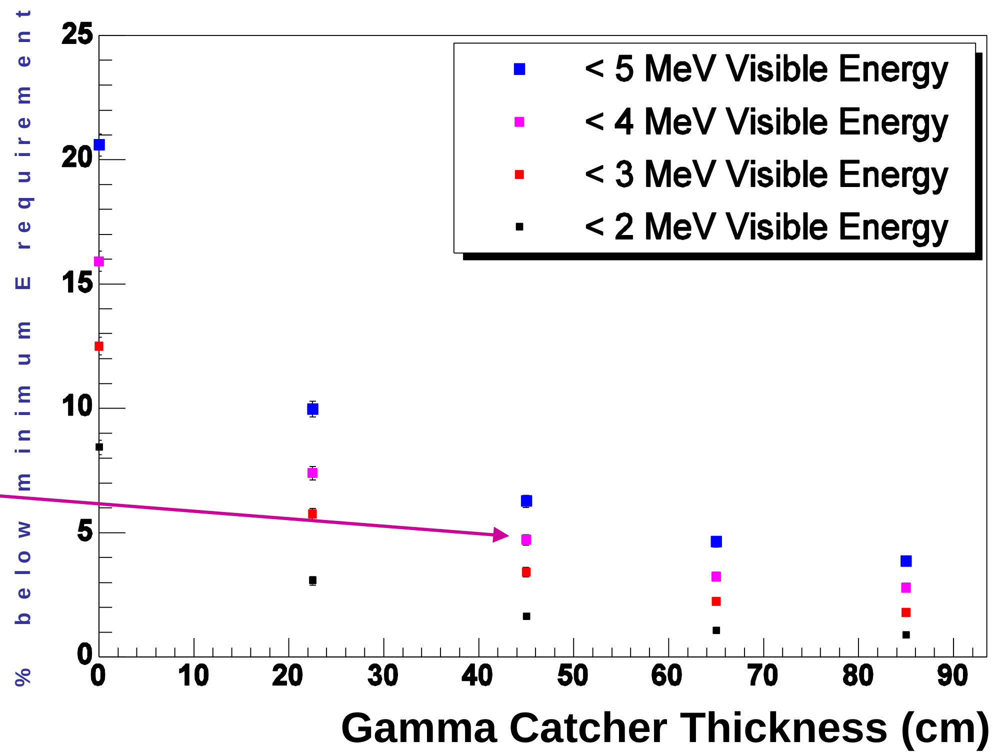
Convolute with expected detector resolution to simulate positron energy spectrum

Efficiency Studies

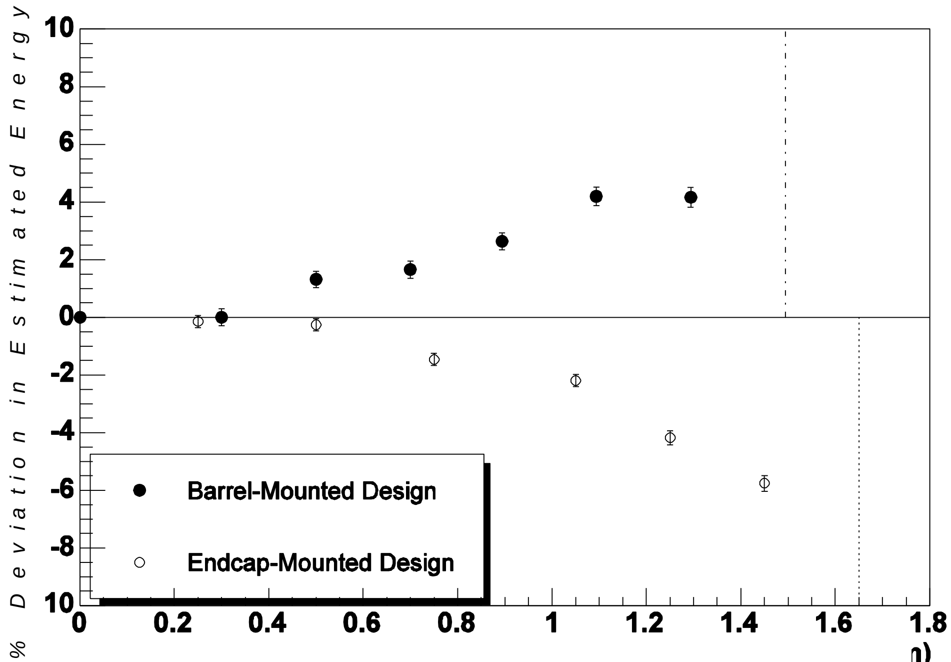


For 40 cm gamma catcher, we see a 5% efficiency loss in cascade detection, for a >4MeV visible energy requirement.

Cuts on delayed signal energy affect efficiency

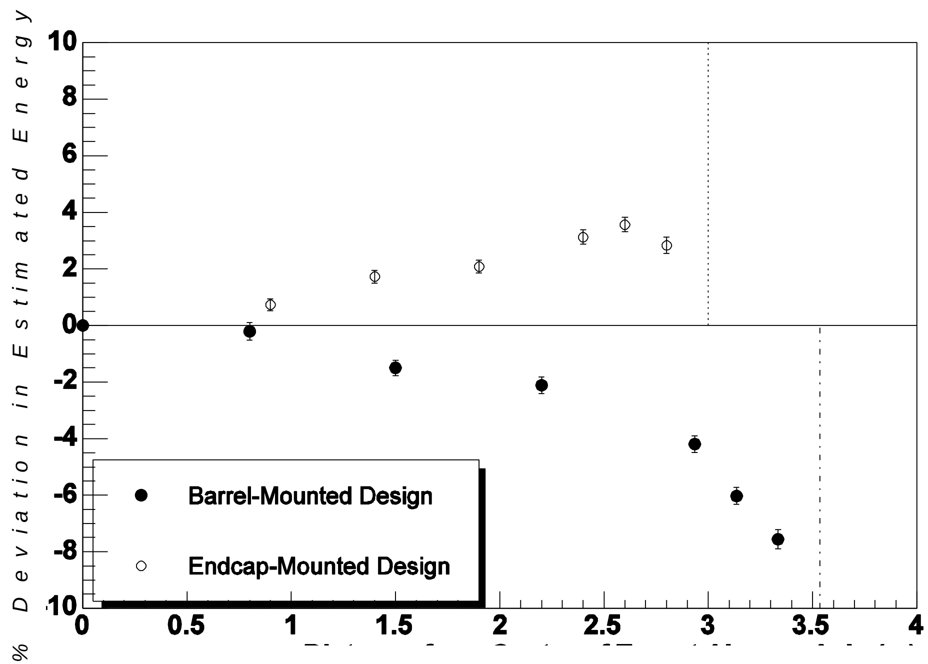


Uniformity



radial distance from center of target (m)

Checked with isolated 1 MeV e^+ simulated at discrete points along the z and r axis.

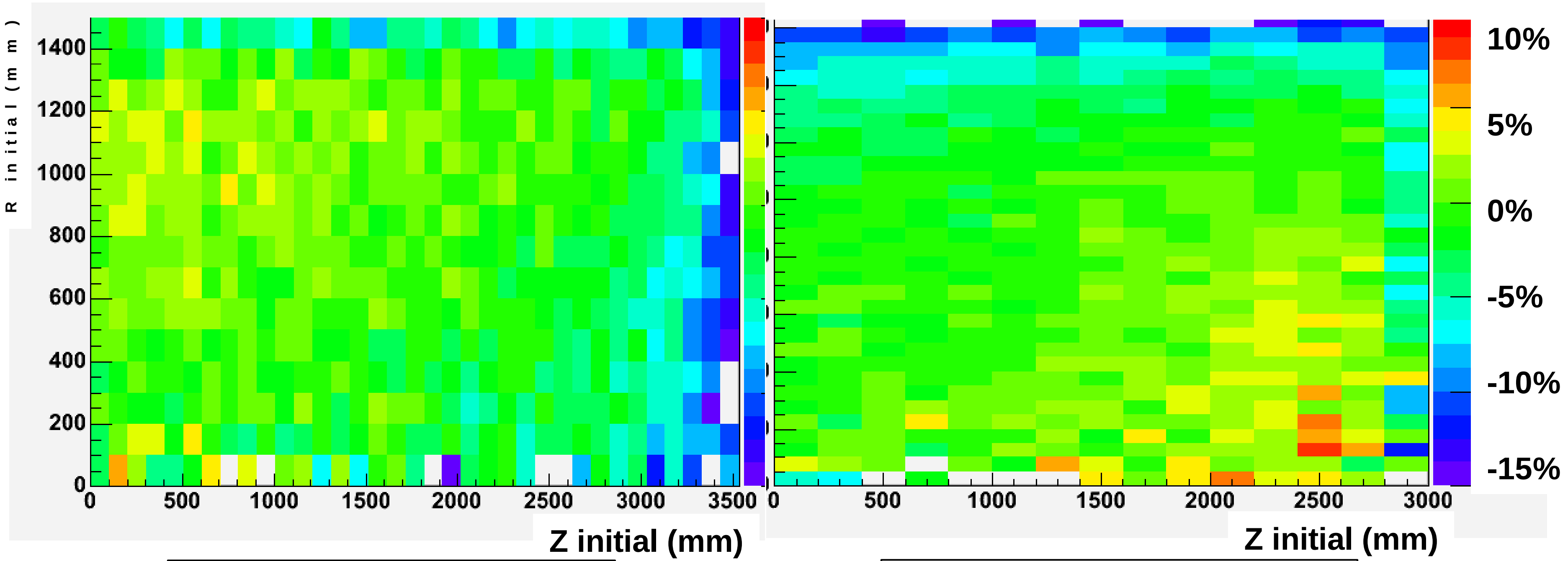


z distance from center of target (m)

Results for both detectors are quite sensitive to reflectivity!

Uniformity

Based on 20,000 1MeV e^+ uniformly filling target volume



Barrel-Mounted Design

Endcap-Mounted Design

Colors show potential bias in estimated E

We see a deficit of detected N_{pe} near reflecting surfaces and the opposite trend near photo-detecting surfaces.

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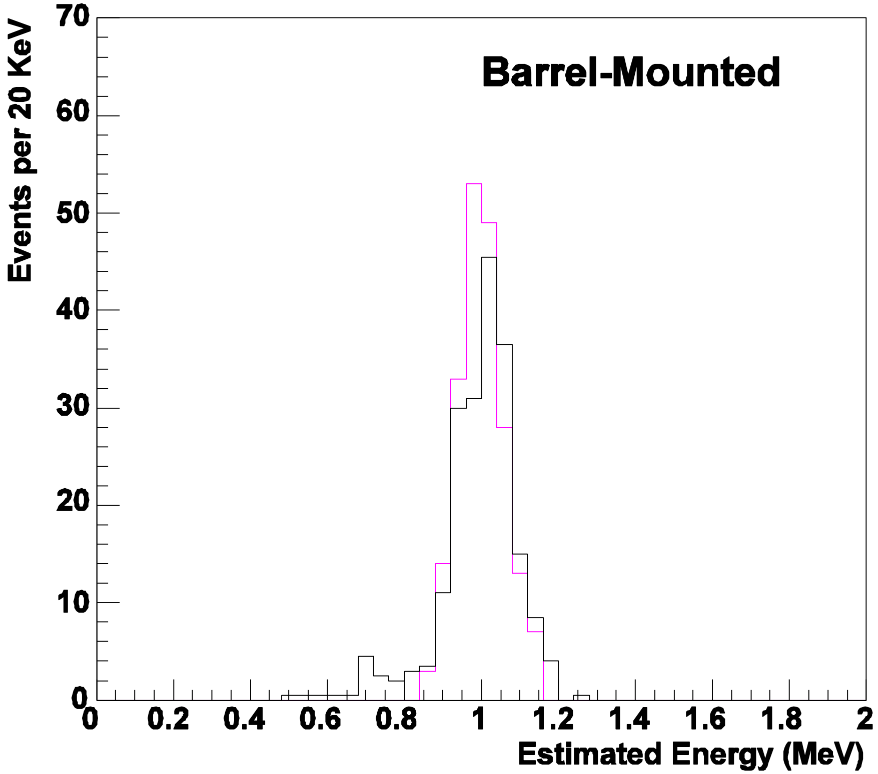
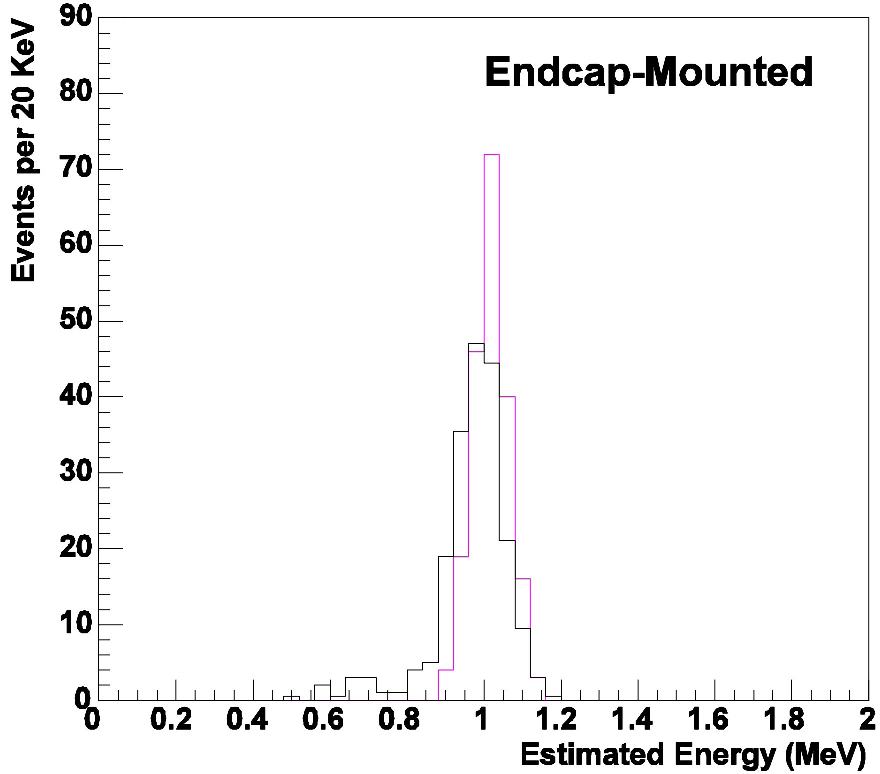
Energy Resolution Smearing from Non-Uniformity

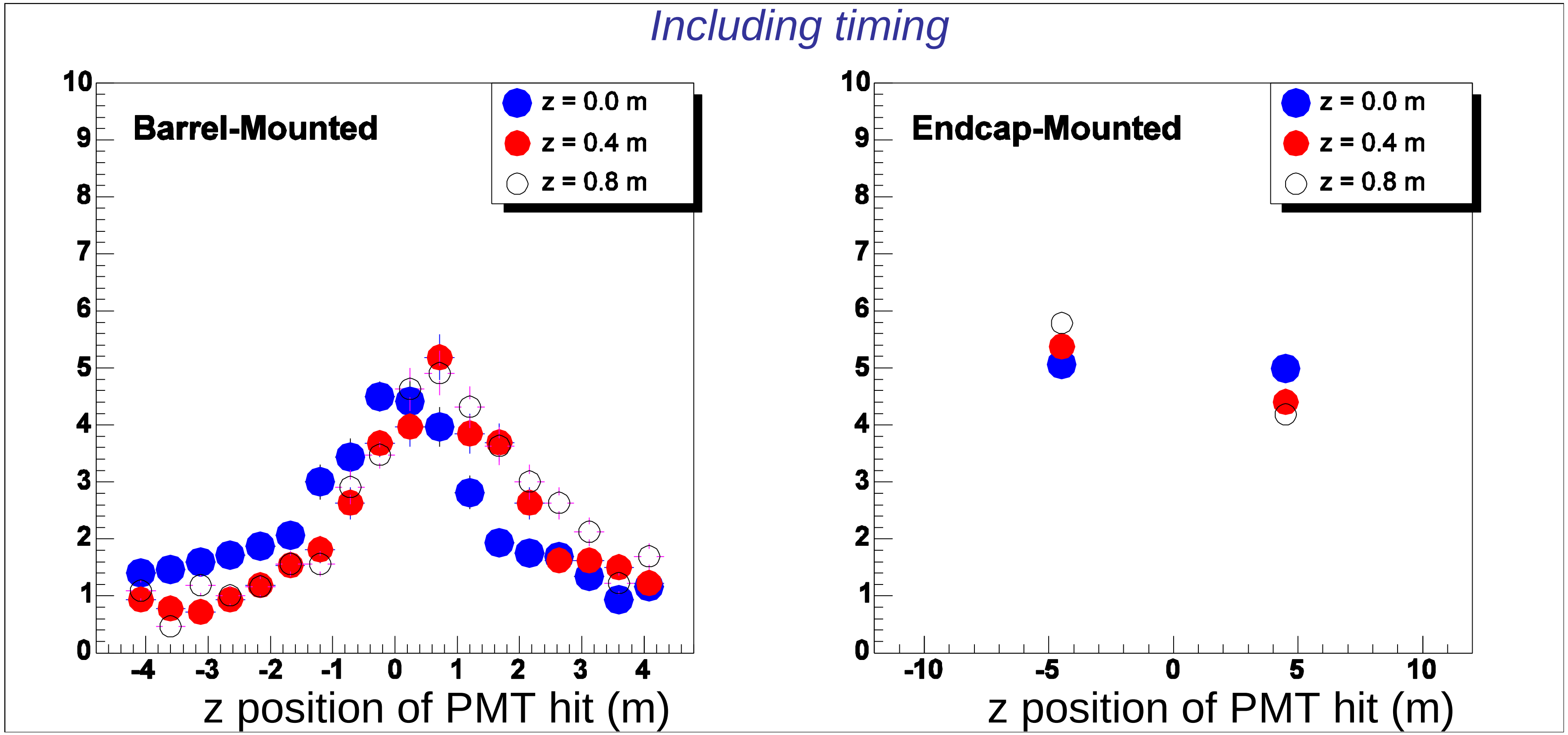




Neglecting to correct for position dependent deviations causes extra smearing in energy resolution. Even with the smearing we still achieve $\Delta E/E<10\%$ at 1MeV

Vertexing

Charge-based fits estimate z position to ~30cm. Can improve on this by Including timing



Radial distances harder to determine from charge distributions, needs more Investigation with toy time-based fits.

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Summary

We've been using GLG4sim to improve our understanding of how our two cylindrical detector designs work and to help optimize these designs.

- Light yield and anticipated energy resolution are good, optimal $\Delta E/E$ = 5-6%
- Uniformity: Deviations of 5-7% near boundaries in worst places, assuming no position corrections, energy resolution suffers a little, but both detectors still achieve <10% energy resolution.
- Efficiency loss in gamma cascade detection is small (~5%) for 40cm gamma catcher, still investigating other configurations.
- Event Vertex Reconstruction gives ~30cm resolution in z r position reconstruction likely to gain more from timing.

Notes

- Contact Glenn and get name of person who has gd capture extension for geant4
- Check that stainless is really reflecting in GLG4sim!!
- If you don’t do 1, then at least consider fixing hokey Gd generator with Dario’s suggestion
- Generate Gd peak plot without a gamma catcher.