ECAL Optimization (Progress)

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Outline

Motivation:

- Each ECAL layer costs > $2 million
- Want to minimize cost while maintaining current performance
- In this study, we measure performance based on photon resolution

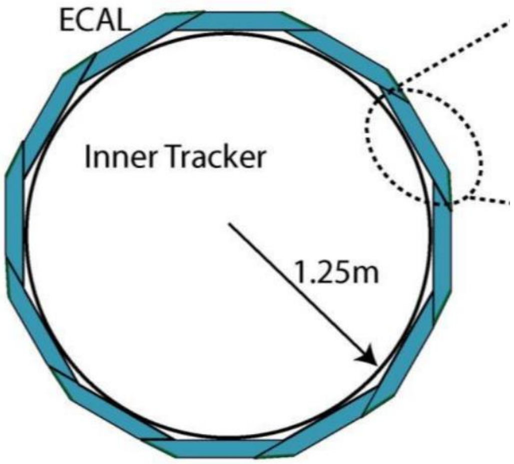
Current progress:

- Calibration – Some interesting findings/issues?
  - Angular dependencies in Phi and Theta
- Photon resolution analysis
  - Changing total number of layers
  - Changing ratio of thin and thick layers
  - Want to look for optimal design that gives good resolution

Interesting Calibration Findings

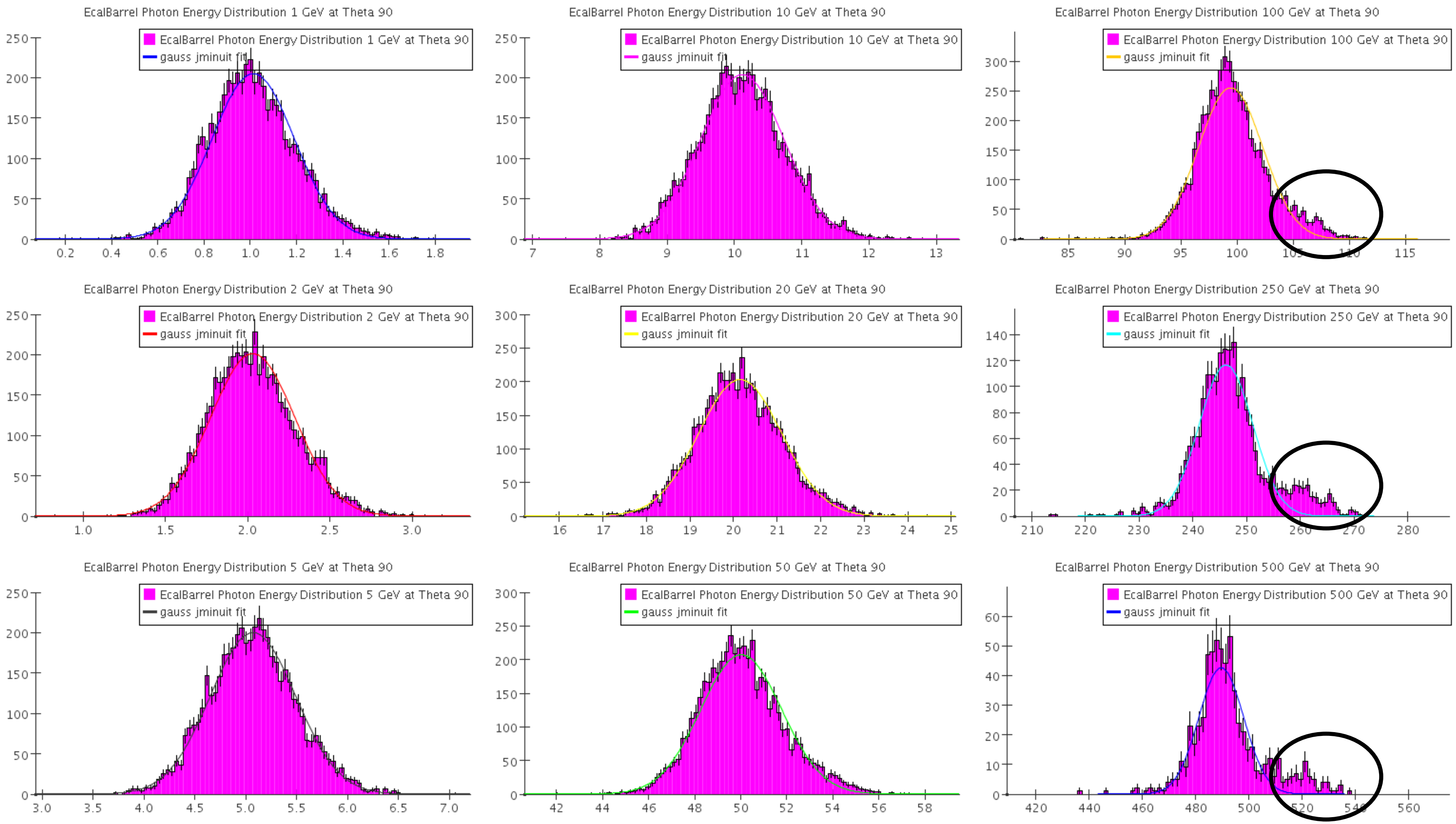
A few things about the current ECAL calibration

- Incorrectly handles events where ECAL staves overlap
  - The particles essentially goes through only thin absorbers, which results in some larger detected raw energy
  - Because of this, resolution is worse by ~0.5-3%/$\sqrt{E}$ as we go from 1-20 GeV photon (compared to the case where we only fire straight into the ECAL at Phi=0); difference is worse as we go to higher energies (Slides 4-5)

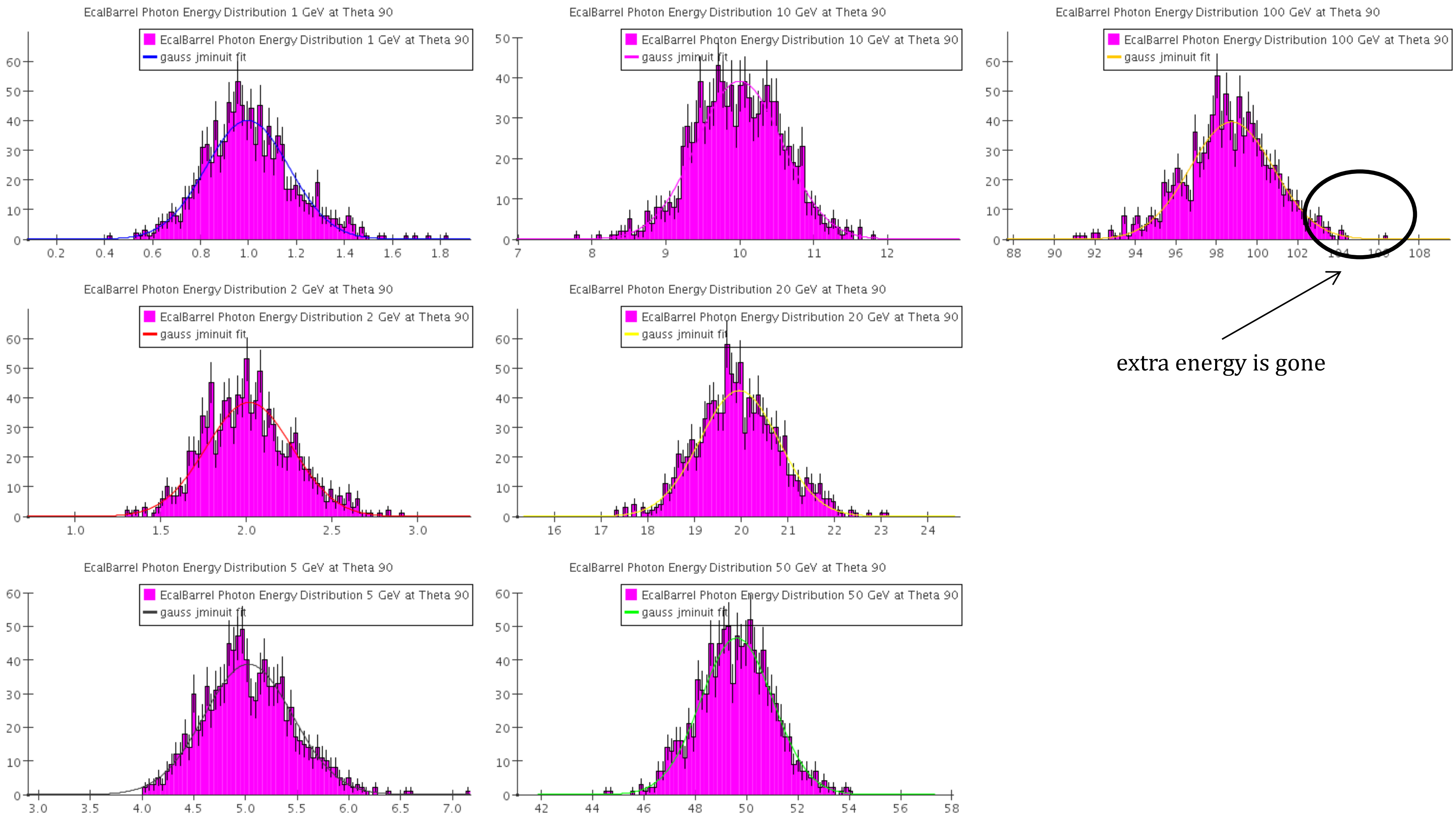


- Does not account for changes in Theta angle (Slide 6)
  - ~1% energy difference for photon at 10 GeV from Theta=90 to Theta=140
  - ~0.1% resolution difference for same thing

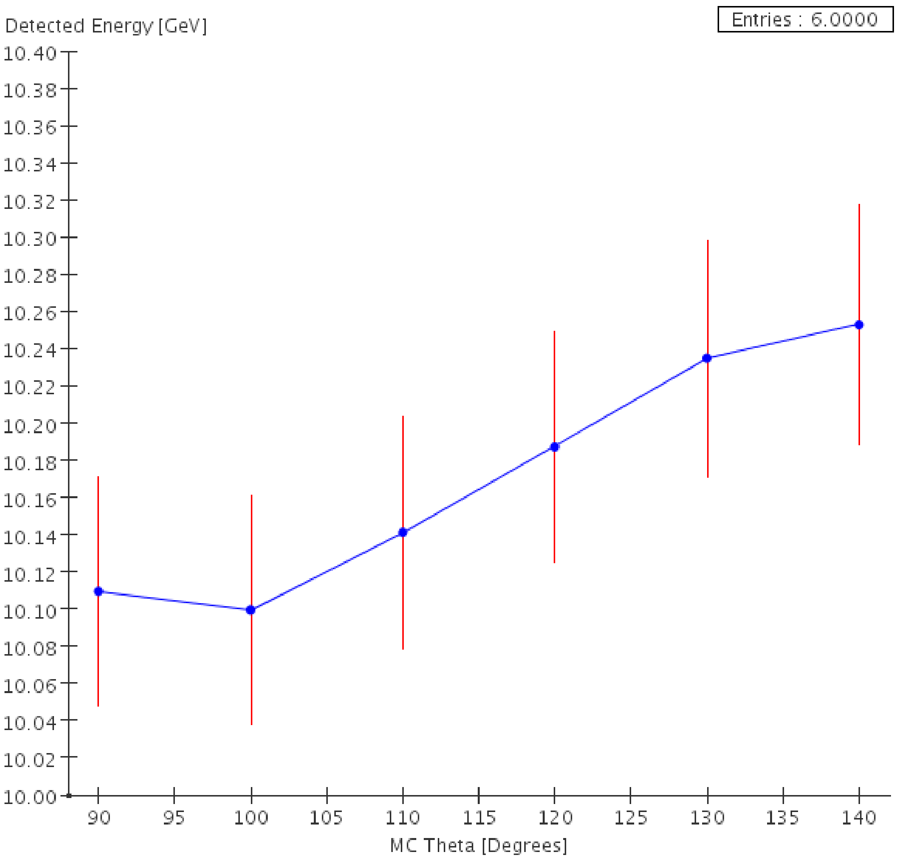
Photon Energy Distribution (Theta90, PhiAll)

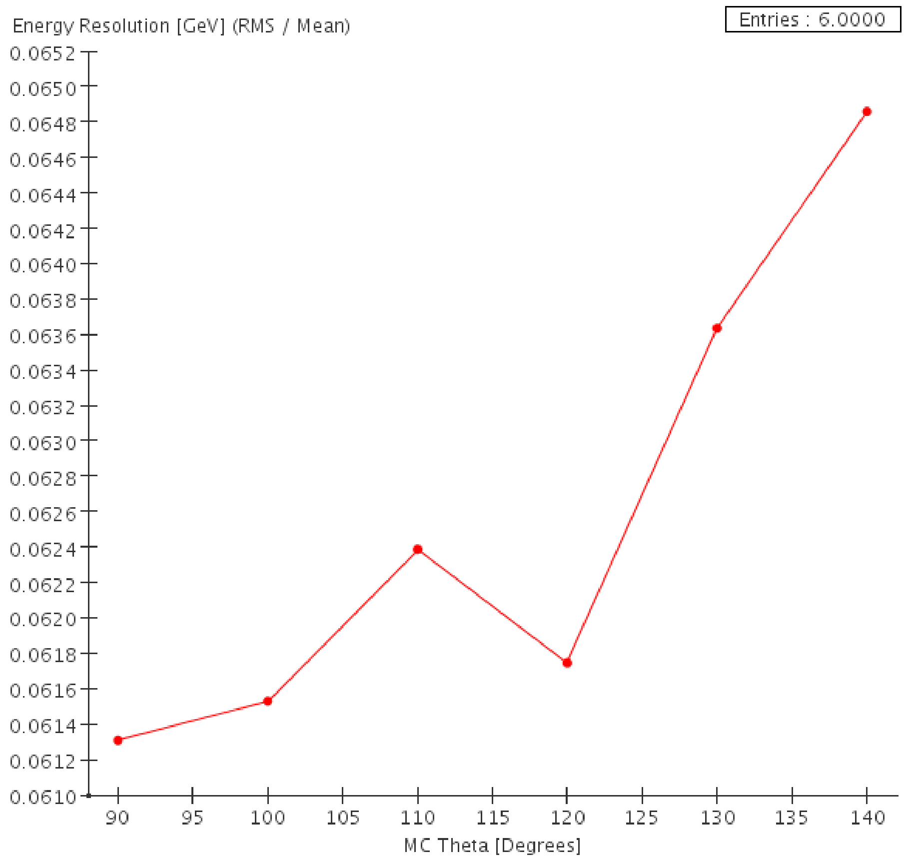


Photon Energy Distribution (Theta90, Phi0)



Theta Dependence





ECAL Photon Resolution

(Fixed thin layers at 2.5mm)

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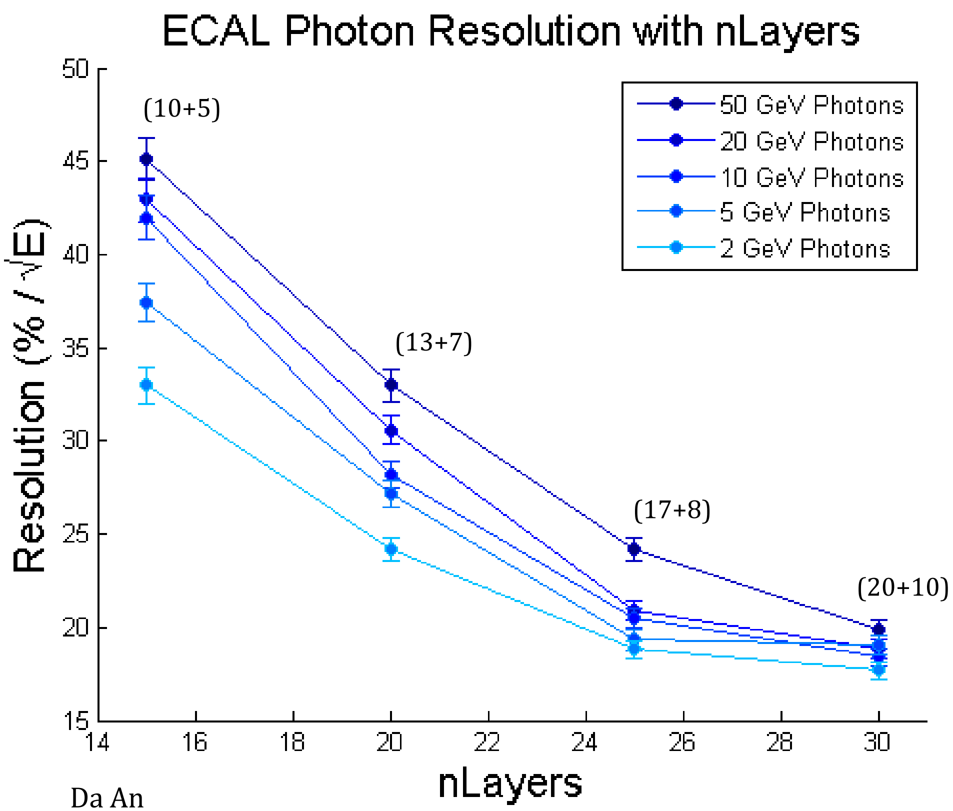
- Total W thickness held fixed at 100mm
- Ratio of (# of thin layers) to (# of thick layers) held fixed at ~2:1
- Thin layer thicknesses held fixed at 2.5mm
- Resolution is given by σ_E/E, where σ_E and its error is given from a Gaussian fit

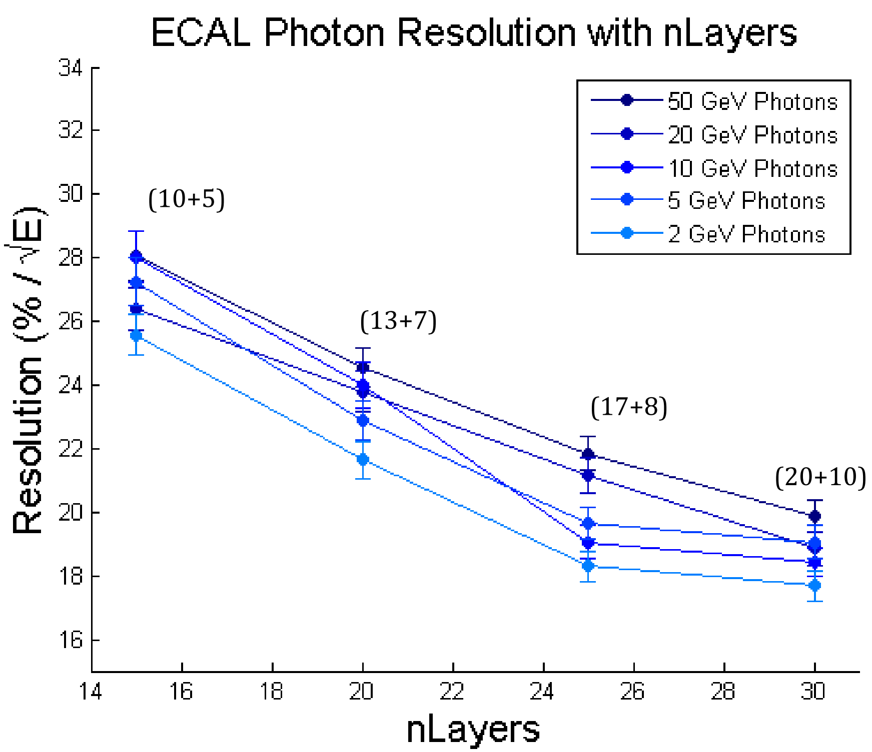


Photon Energy	15 (10+5) $[\%/\sqrt{E}]$	20 (13+7) $[\%/\sqrt{E}]$	25 (17+8) $[\%/\sqrt{E}]$	30 (20+10) $[\%/\sqrt{E}]$
50 GeV	45.1	33.0	24.2	20.0
20 GeV	42.9	30.5	20.9	18.9
10 GeV	42.0	28.2	20.5	18.4
5 GeV	37.4	27.2	19.3	19.1
2 GeV	33.0	24.2	18.8	17.7
Thicknesses (thin, thick) [mm]	(2.5, 15.0)	(2.5, 9.64)	(2.5, 7.18)	(2.5, 5.0)

Resolution degrades by only a couple % from 30 to 25 layers, but degrades significantly for 20 and 15 layers

ECAL Photon Resolution
(Fixed 50mm+50mm thin+thick layers)

- Total W thickness held fixed at 100mm
- Ratio of (# of thin layers) to (# of thick layers) held fixed at ~2:1
- Ratio of (total thin layer thickness) to (total thick layer thickness) held fixed at 1:1
- Resolution is given by σ_E/E, where σ_E and its error is given from a Gaussian fit



Photon Energy	15 (10+5) [$\%/\sqrt{E}$]	20 (13+7) [$\%/\sqrt{E}$]	25 (17+8) [$\%/\sqrt{E}$]	30 (20+10) [$\%/\sqrt{E}$]
50 GeV	28.1	24.5	21.8	19.9
20 GeV	26.4	23.8	21.2	18.8
10 GeV	28.0	24.0	19.1	18.4
5 GeV	27.2	22.9	19.7	19.1
2 GeV	25.6	21.6	18.3	17.7
Thicknesses (thin, thick) [mm]	(5.0, 10.0)	(3.84, 7.14)	(2.90, 6.25)	(2.5, 5.0)

Larger total thin layers thickness than previous slide.
Better resolution for all nLayers than previous slide

ECAL Photon Resolution

(Changing ratio of thin and thick – 30 layers)

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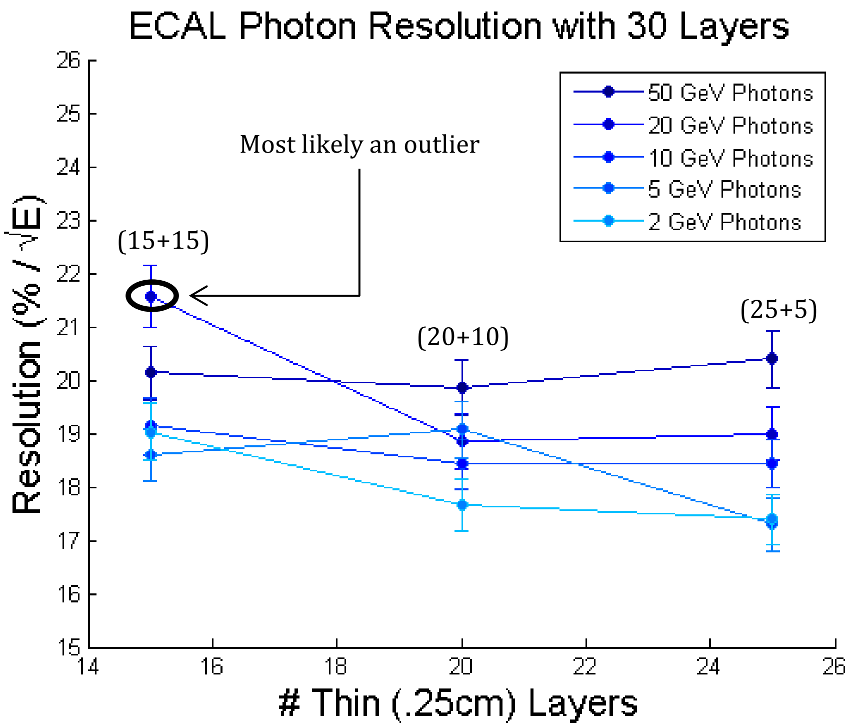
- Total W thickness held fixed at 100mm
- Ratio of (# of thin layers) to (# of thick layers) changes – 1:1 – 2:1 – 5:1
- Thin layer thicknesses held fixed at 2.5mm
- Resolution is given by σ_E/E, where σ_E and its error is given from a Gaussian fit

Photon Energy	30 (15+15) $[\%/\sqrt{E}]$	30 (20+10) $[\%/\sqrt{E}]$	30 (25+5) $[\%/\sqrt{E}]$
50 GeV	20.1	19.9	20.4
20 GeV	21.6	18.9	19.0
10 GeV	19.1	18.4	18.4
5 GeV	18.6	19.1	17.3
2 GeV	19.0	17.6	17.4
Thicknesses (thin, thick) [mm]	(2.5, 4.16)	(2.5, 5.0)	(2.5, 7.5)

Deviation in resolution is small among all three different ratios

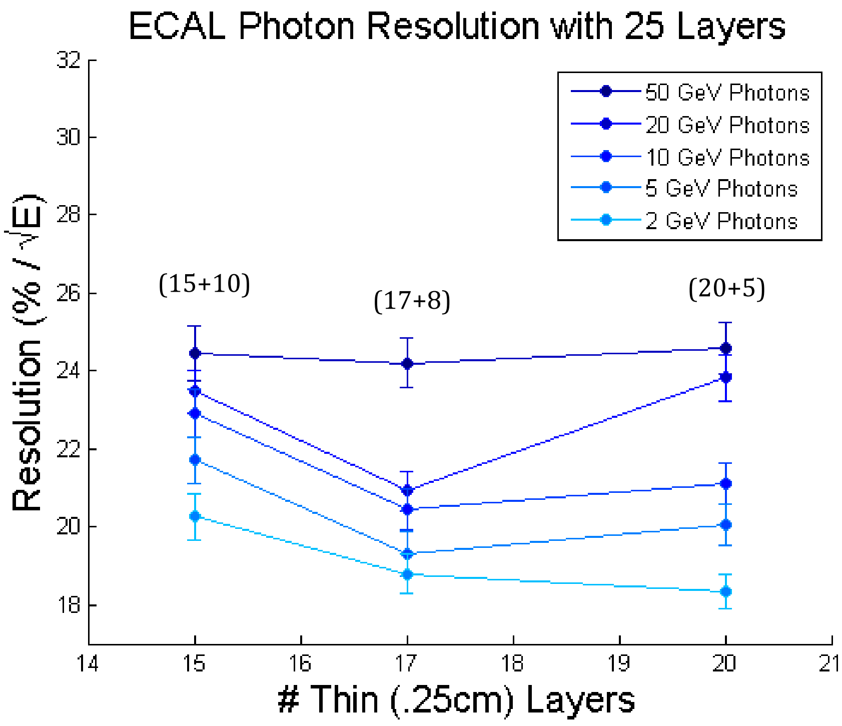


ECAL Photon Resolution

(Changing ratio of thin and thick – 25 layers)

- Total W thickness held fixed at 100mm
- Ratio of (# of thin layers) to (# of thick layers) changes – 3:2 – 2:1 – 4:1
- Thin layer thicknesses held fixed at 2.5mm
- Resolution is given by σ_E/E, where σ_E and its error is given from a Gaussian fit

Photon Energy	25 (15+10) [$\%/\sqrt{E}$]	25 (17+8) [$\%/\sqrt{E}$]	25 (20+5) [$\%/\sqrt{E}$]
50 GeV	24.5	24.2	24.6
20 GeV	23.5	20.9	23.8
10 GeV	22.9	20.4	21.1
5 GeV	21.7	19.3	20.0
2 GeV	20.2	18.8	18.3
Thicknesses (thin, thick) [mm]	(2.5, 6.25)	(2.5, 7.18)	(2.5, 10.0)



Deviation in resolution is more significant, the 2:1 ratio (17+8) gives the optimal resolution.

Summary

Calibration

- Relevance of angular effects in calibration are unclear
- Maybe look further into how this affects other simulation studies
- Maybe try to correct for these dependencies

Photon resolution analysis

- Thin gives good resolution, Thick gives bad resolution
  - As the average thickness of each layer decreases, the resolution gets worse (in this current study, we keep the total thickness of W at 100mm, so this statement is analogous to saying "as the number of layers decreases, the resolution gets worse")
- Ratio of total Thin thickness to total Thick thickness near 1:1 gives smallest resolution range
  - As the difference between Thin and Thick layer thicknesses increases, the resolution range increases; this is because of the previous point
  - Example: Thin at 50mm + Thick at 50mm gives $\sim 2\%/\sqrt{E}$ range; while Thin at 25mm + Thick at 75mm gives $\sim 10\%/\sqrt{E}$ range
- Ratio of # Thin layers to # Thick layers near 1:1 gives smallest resolution range
- So, ideally, we want the entire ECAL to have 2.5mm layers (thinnest mechanically sound)
  - But this would cost too much…

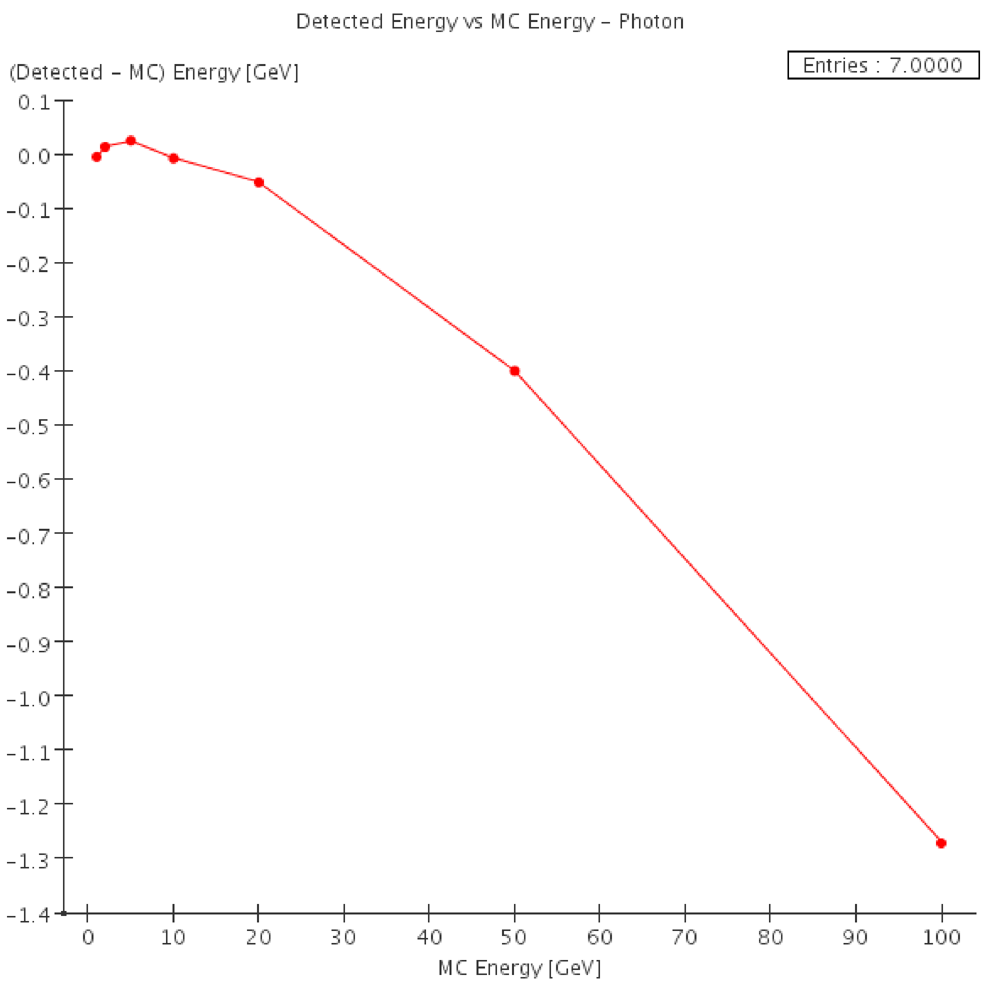
Future Work

What still needs to be done:

- Current summary of results is qualitative, is there a quantitative representation?
- Study of multiple photons (thinner layers will probably give better performance)
- Visualization of detector cross section (to check for overlaps and such)
- Implementing PandoraPFA, which will allow for:
  - More accurate calibration i.e. sampling fractions
  - Extension of analysis to jets

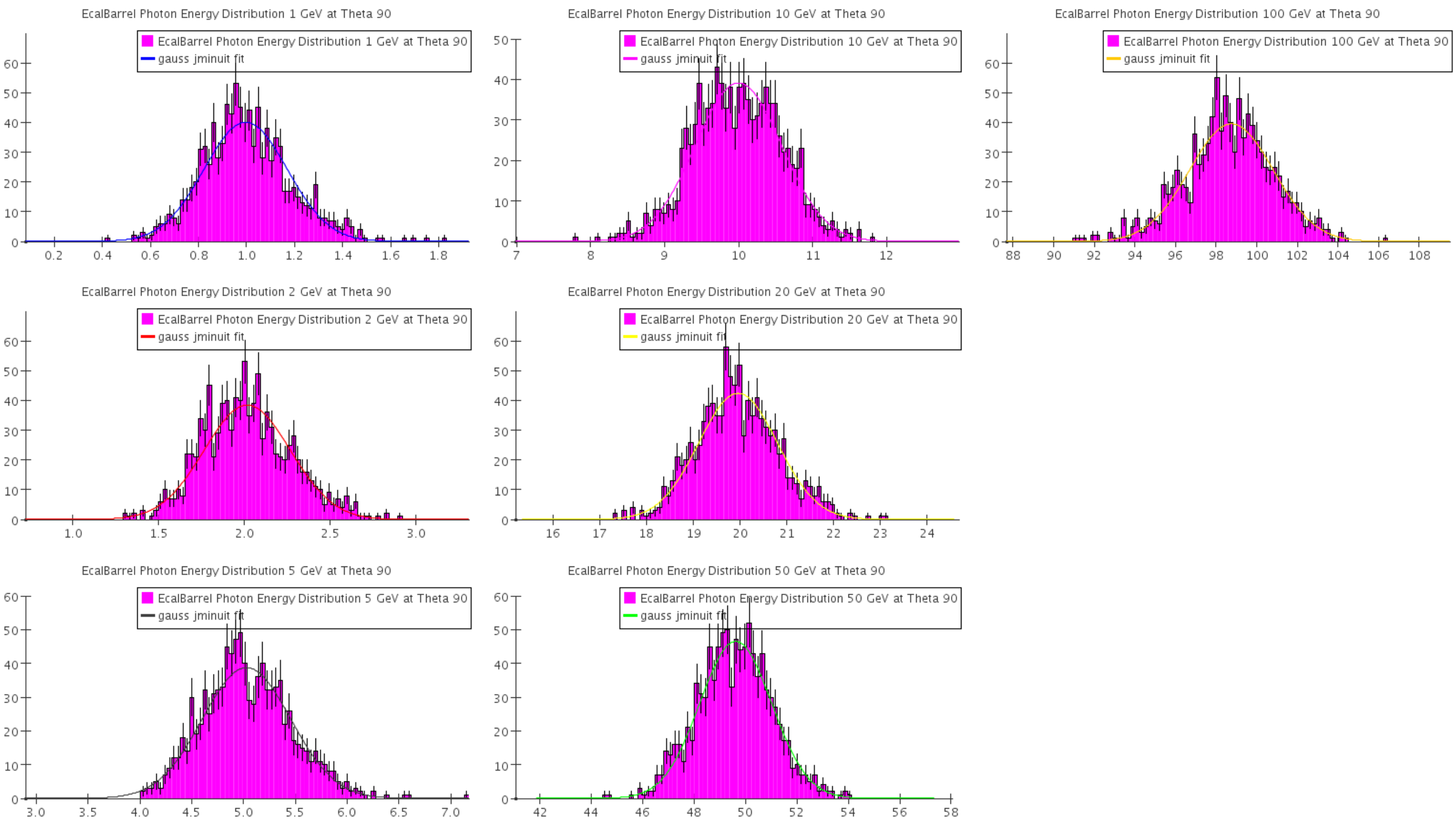
Backup Slides

Linearity of Detected Energy Vs MC Energy



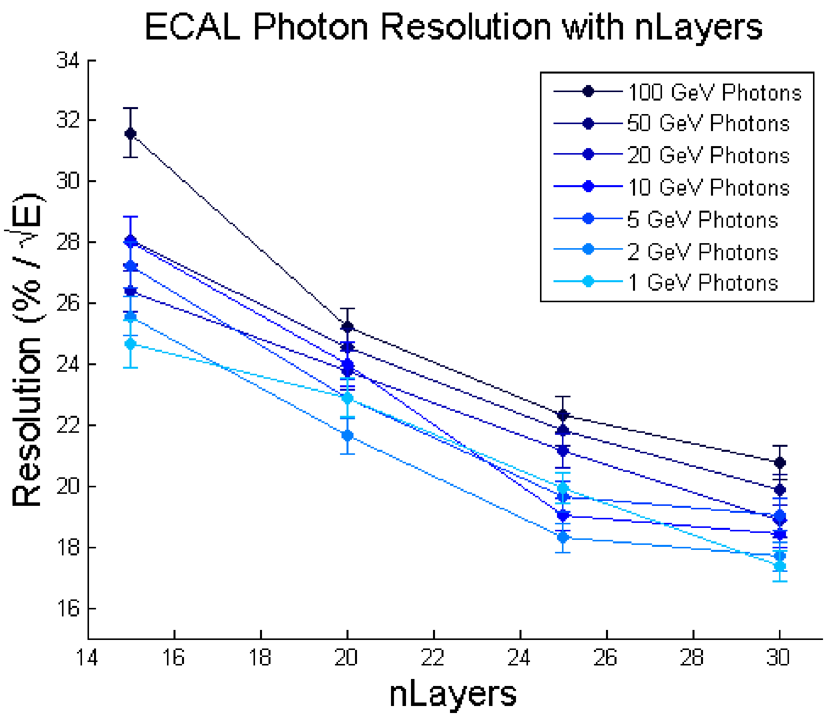
Shown is just the difference plot of detected energy and MC energy for the current sidloi3 20+10 layer ECAL. This only takes into account the hits from the EcalBarrel. If we add in the hits to the HcalBarrel, the linearity is improved from ~1% to ~0.1%

Example Photon Distributions after Calibration

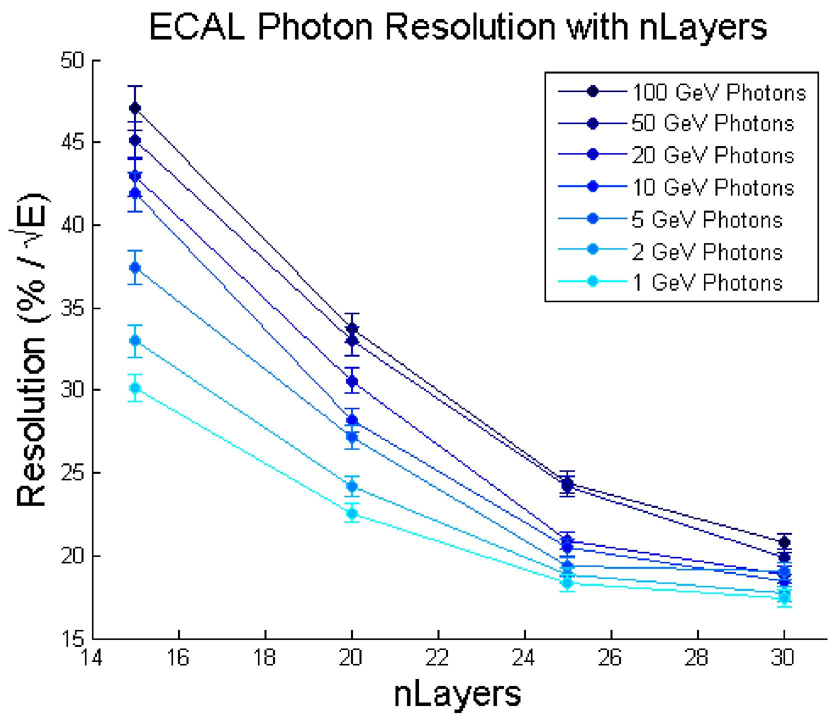


Additional Points for Resolution Evolution

Fixed thin at 2.5mm



50mm+50mm total thickness of thin+thick



Da An

Additional Points for Resolution Evolution