ECAL RESOLUTION STUDIES AND UPDATE

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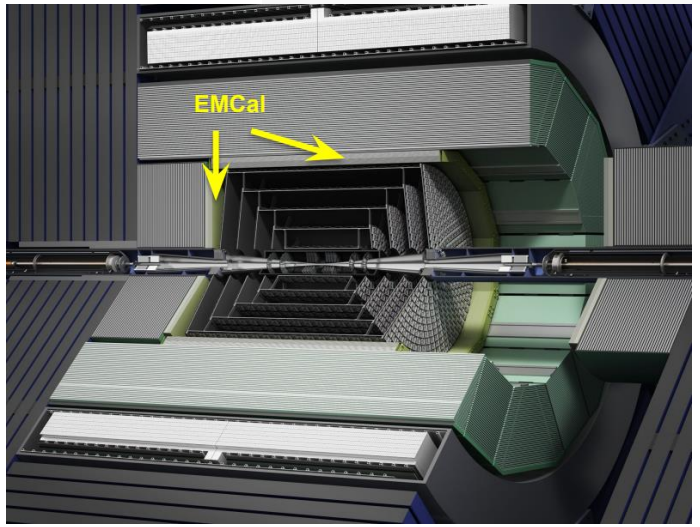
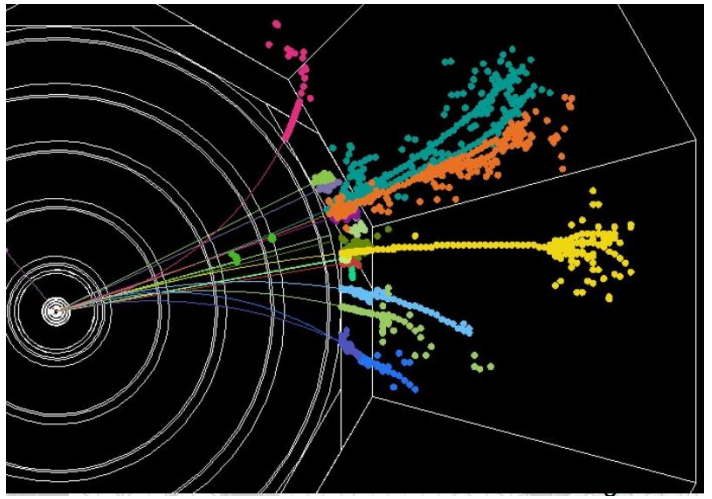
OUTLINE

- KPiX
- Reminder of What Has Been Done
  - Test Beam Simulation and Comparison to KPiX data
  - How we start applying these to the full detector model
- Current Geometry Studies
  - Effects on Resolution
    - Changing order and makeup of ECAL Layers
- Quick Update on FCNC
  - Touching on Duplicate Event Removal
  - First Look at Data in Region Orthogonal to SR

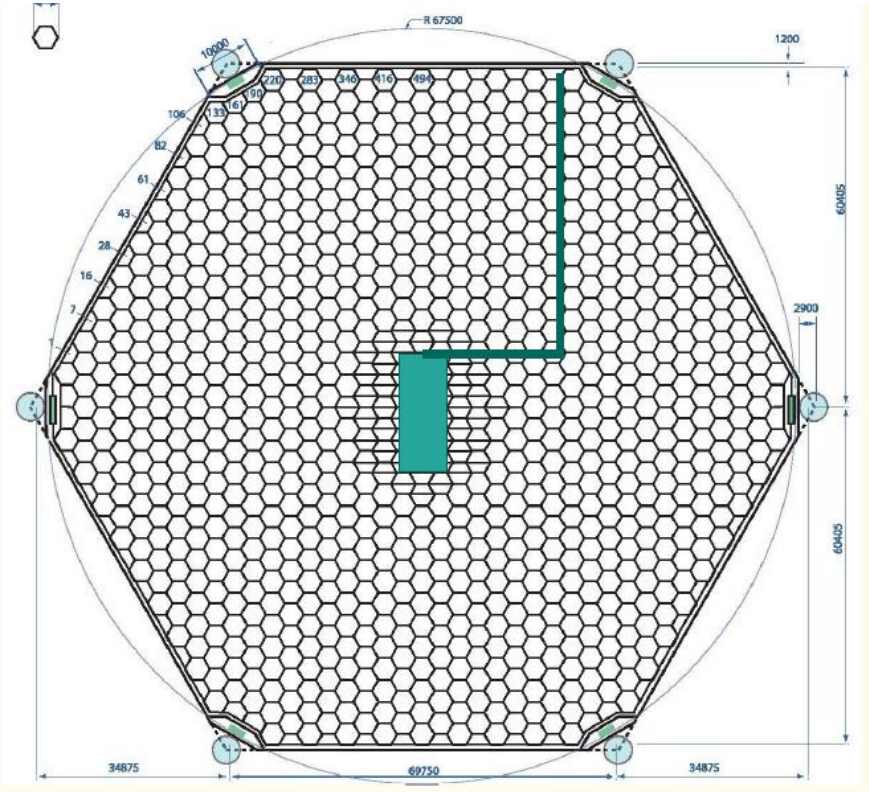
PARTICLE FLOW CALORIMETRY

- SiD has been designed to use Particle Flow Calorimetry to measure all final states with precision
- We expect excellent jet energy resolution
  - Measure charged momenta with tracker, neutral energies with calorimeters
  - Requires very fine segmentation
- An "Imaging ECAL" is a crucial part of the design
  - Silicon-Tungsten based calorimeter is being developed for a high granularity ECAL
  - KPiX ASIC for readout of silicon pixels





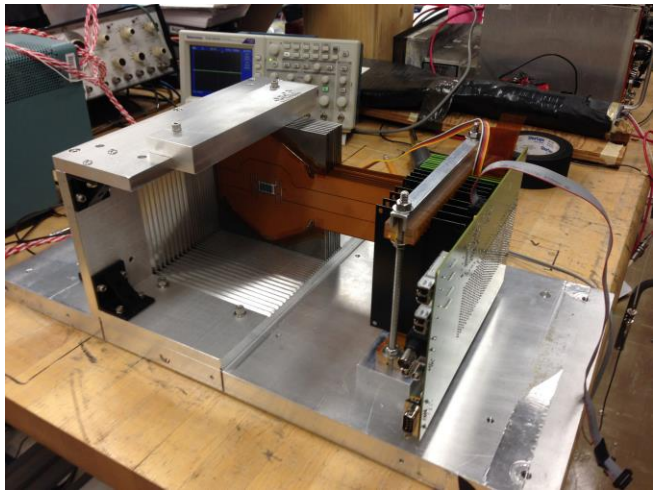
KPIX

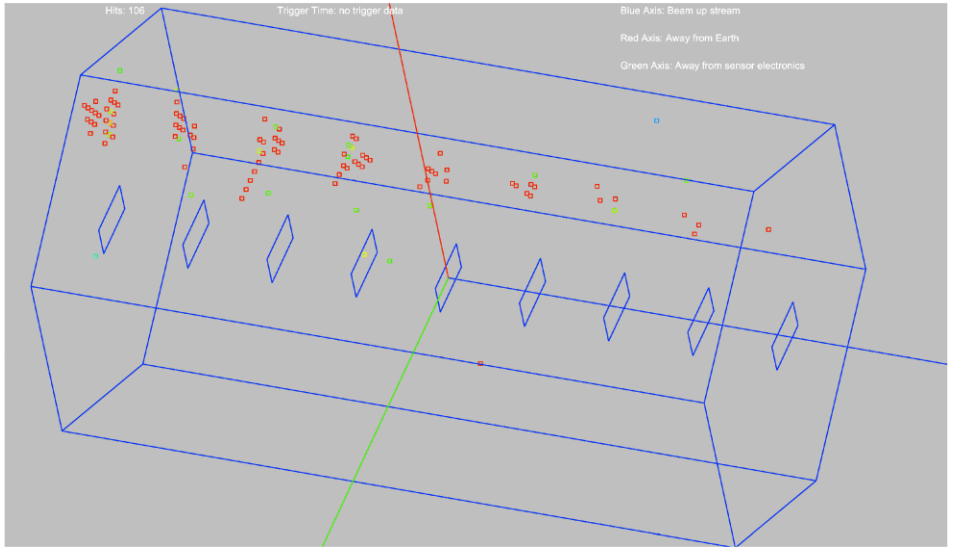


- 6 inch wafers
- 1024 13mm^2 pixels
- Readout and cable are bump-bonded directly to the sensor
- Test beam studies have happened with an initial version of this KPiX sensor design
- Will come back to the geometry and its effect on resolution measurements

TEST BEAM STUDIES

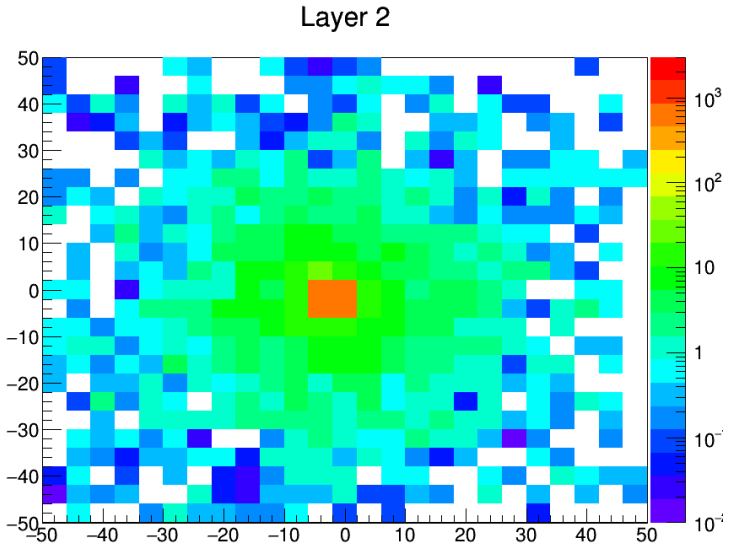
- Small 9 layer stack was placed into SLAC test beam
- Sensor issues have been found and change the design going forward
  - Cross Talk, Dead Pixels, …
- Many electron events were seen that we can analyze and compare with simulation to improve understanding of the system
  - Resolution, Identification (how well we can tell how many electrons are in an event)





SIMULATION STUDIES

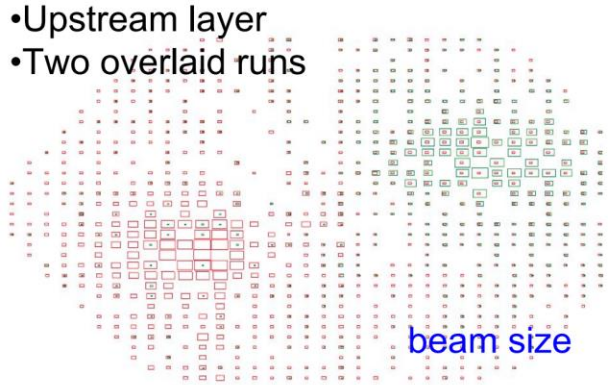
- Geant4 Simulation created of 40x40cm plane of alternating Si (320 μm) and W (2.5mm,5/7 χ_0)
  - 40 (thin W) layer detector simulated simulated, only include 9 to match test beam stack for comparisons sake
  - Electrons fired at origin of various energies (in particular 12.1 GeV, test beam energy)
  - Want to try to match test beam running conditions

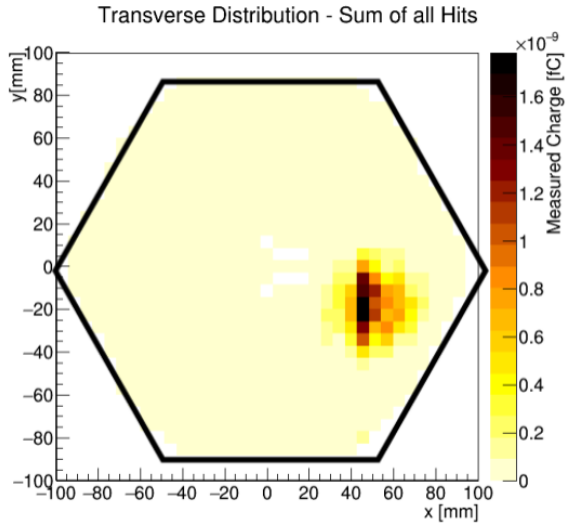


1000events, 10GeV. Energy in MeV deposited (all events summed) on the z-axis.

COMPARISONS (CONT.)

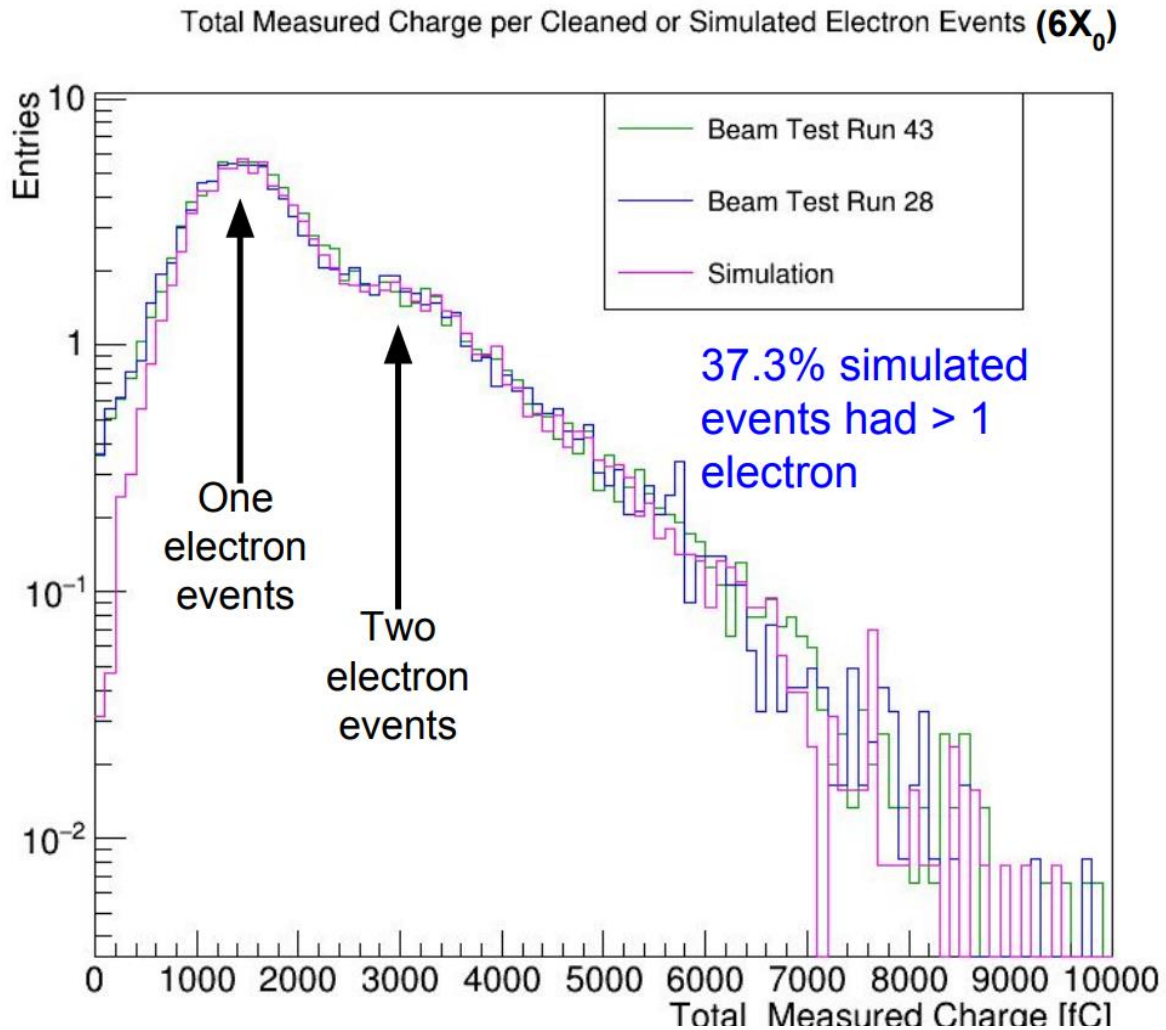
- Attempted to model distribution of electron multiplicity and errors in test beam
  - 10% pixels randomly removed from each layer
  - Poisson distribution of simultaneous electrons per event used <n>=0.8725
  - Shifted from central area (more densely pixelated, also test beam was shifted away)
  - Match hit to KPiX pixel location



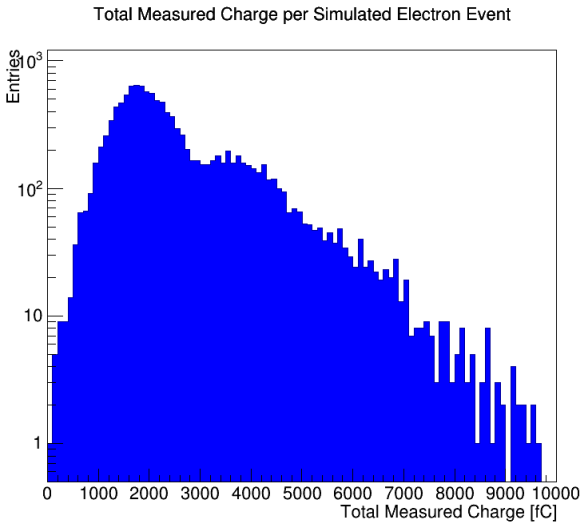


COMPARISONS (CONT.)

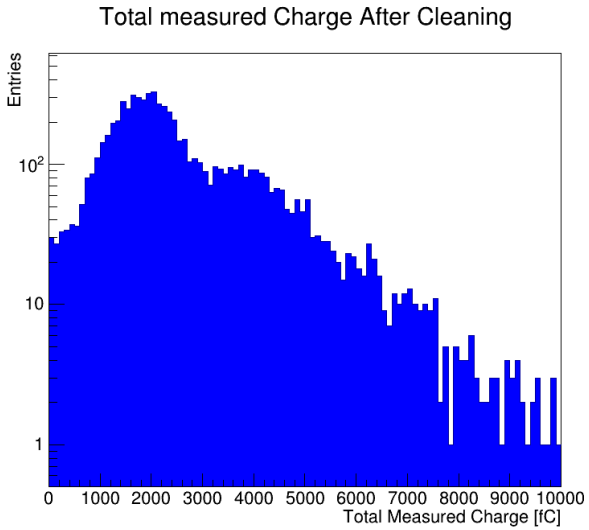
- Excellent agreement to test beam data.
- Couldn't remove all of the low E shoulder during test beam cleaning (lots of ~0fC hits)

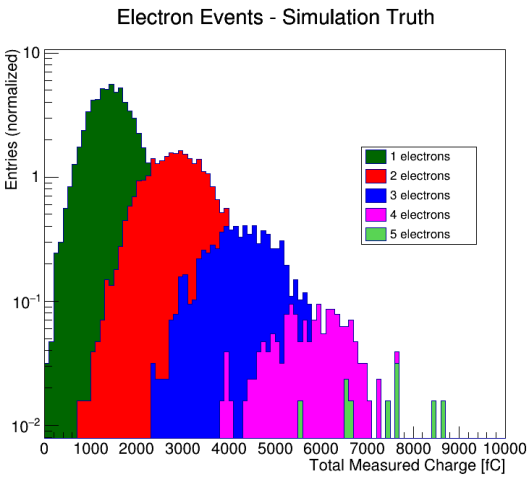


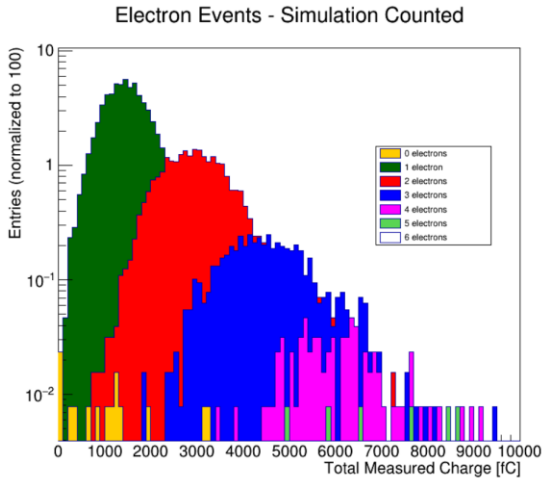
COUNTING ELECTRONS

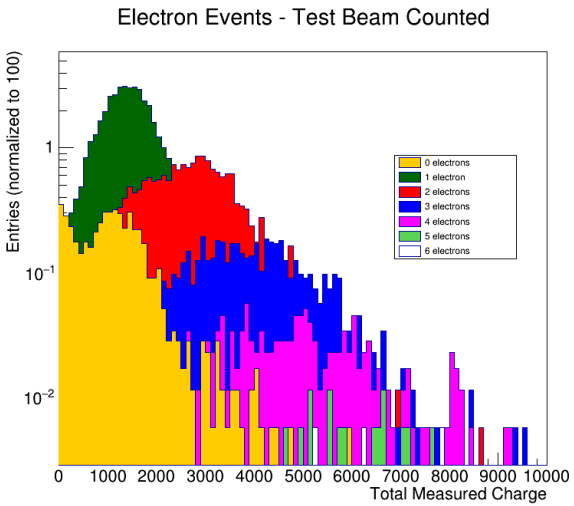


- Algorithm used to count the number of electrons in the even based on energy distributions throughout the detector.

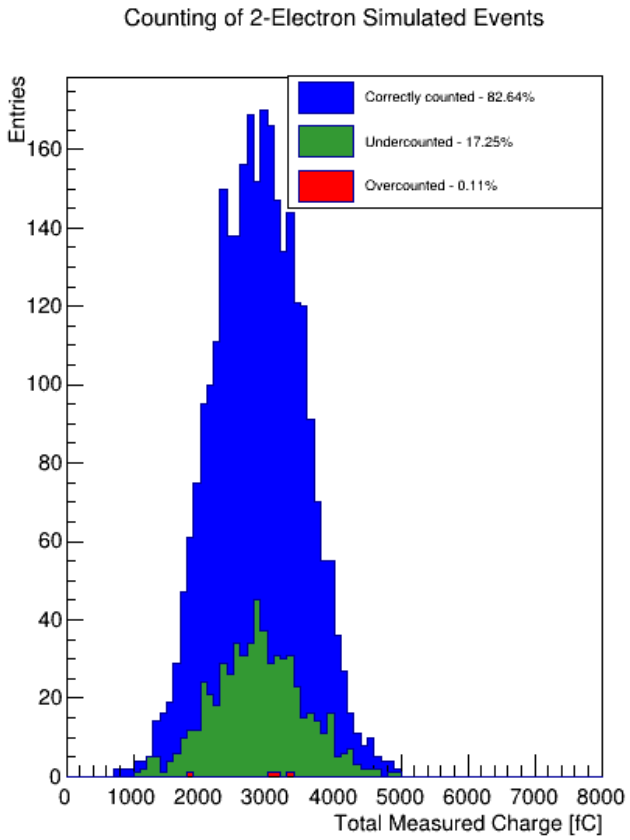


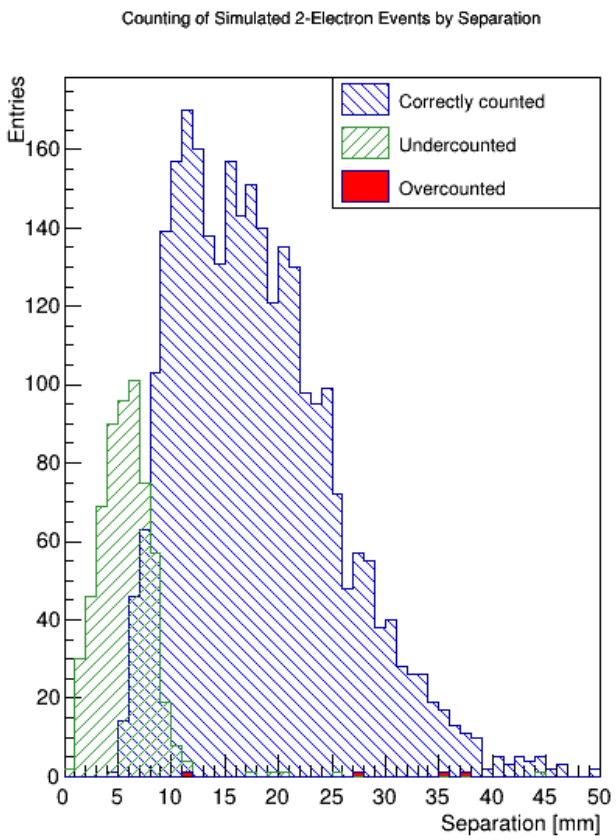


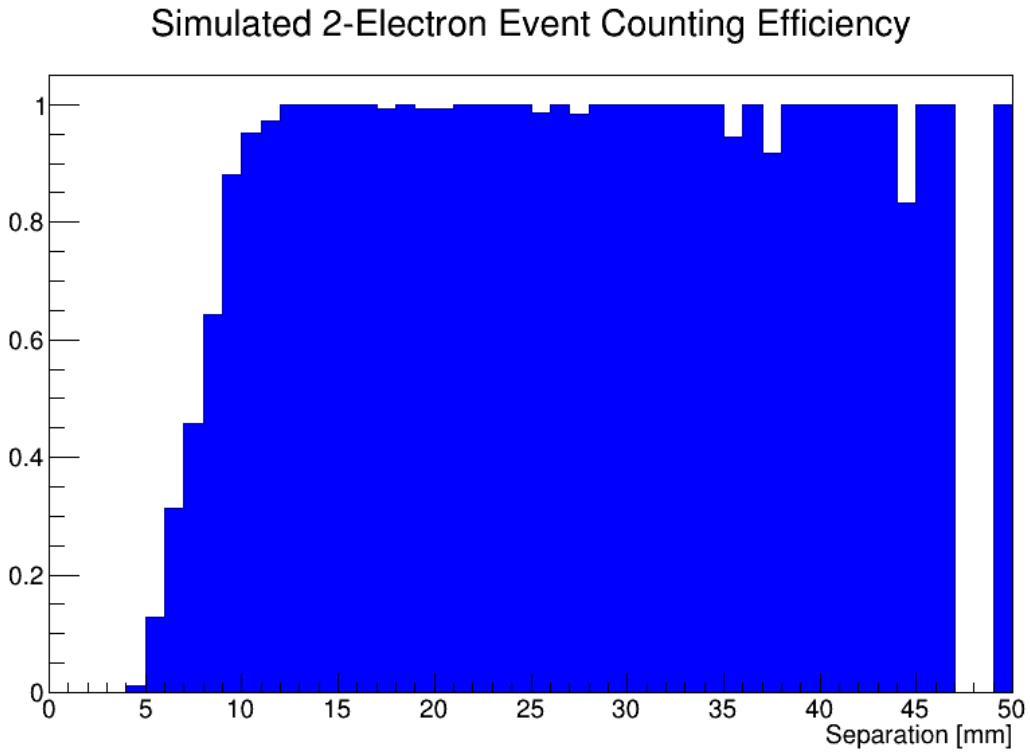




COUNTING ELECTRONS (CONT.)

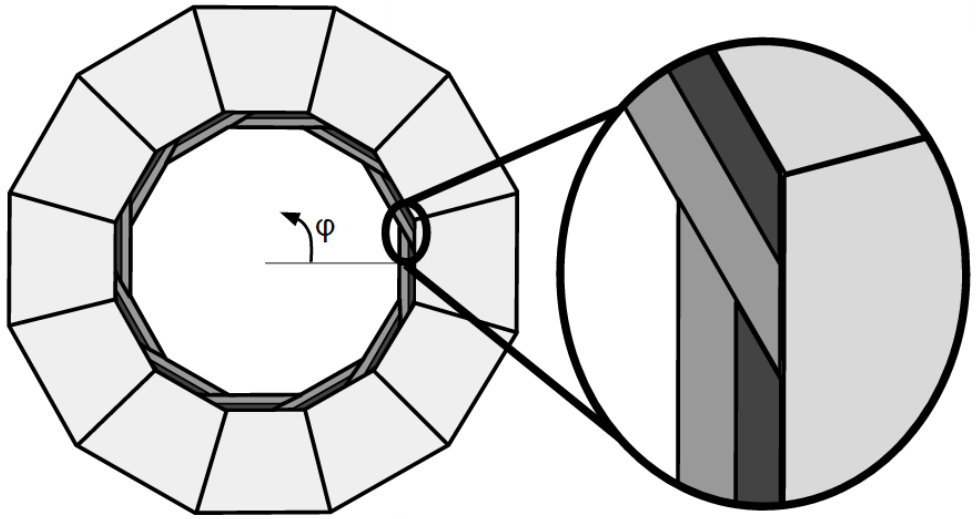






No field, just simple detector simulation

ECAL GEOMETRY AND ITS EFFECTS

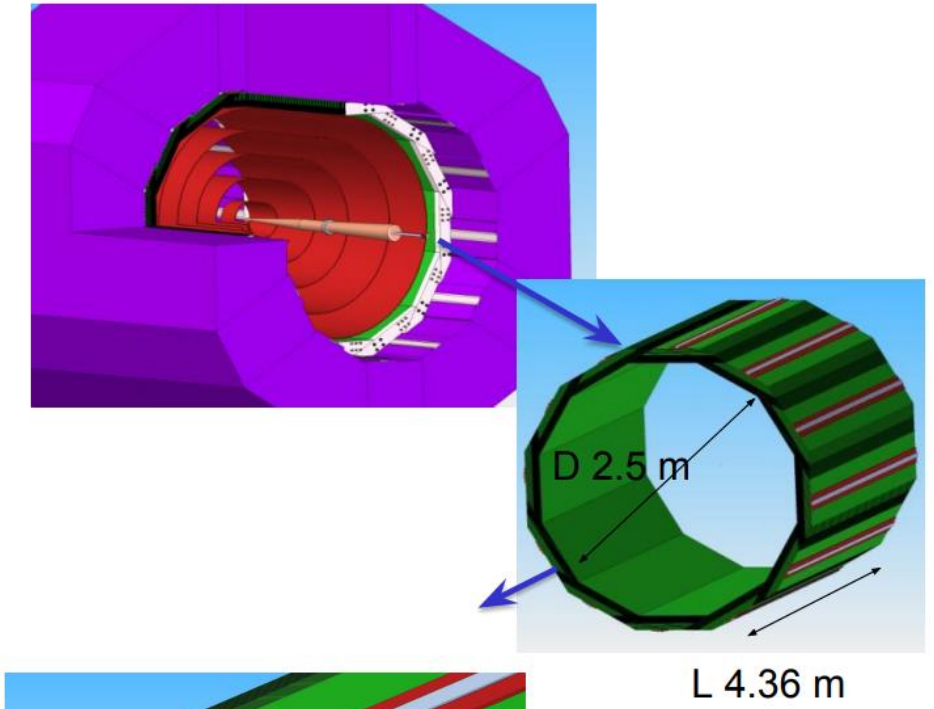


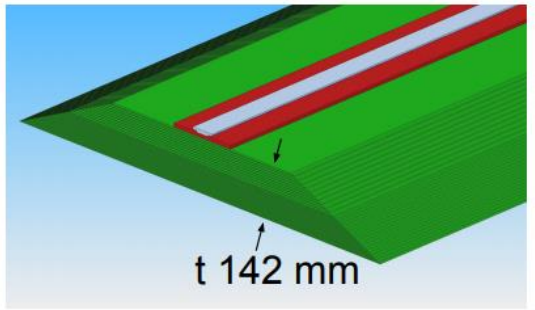
20 layers 2.5mm W

10 layers 5mm W

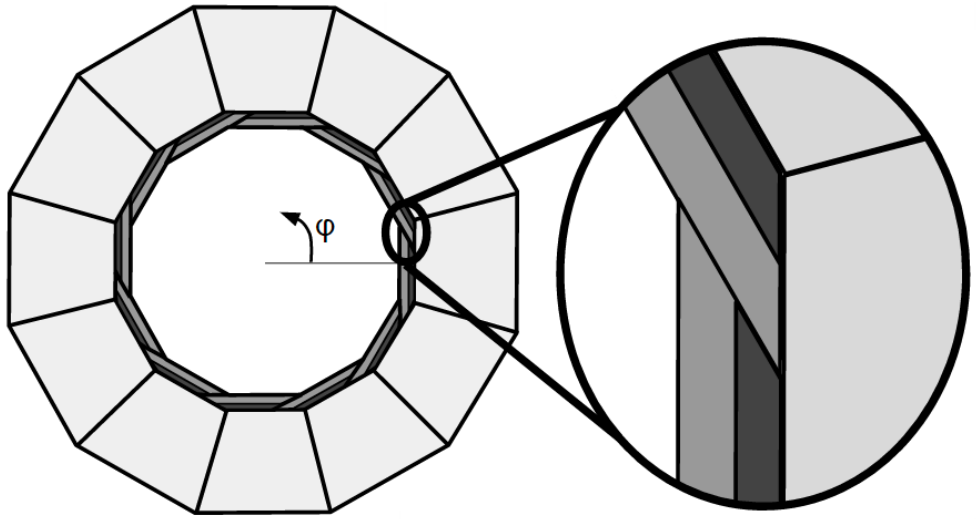
30 gaps 1.25mm w/pixel sensors

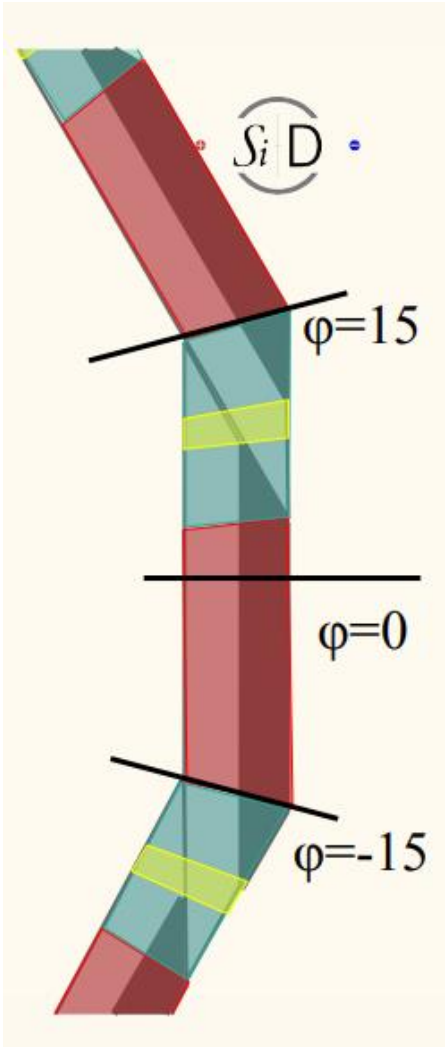
29 χ_0

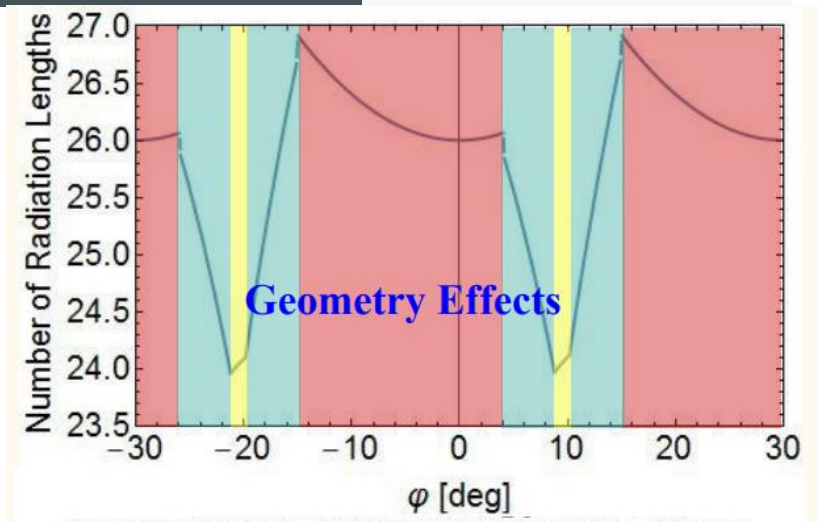


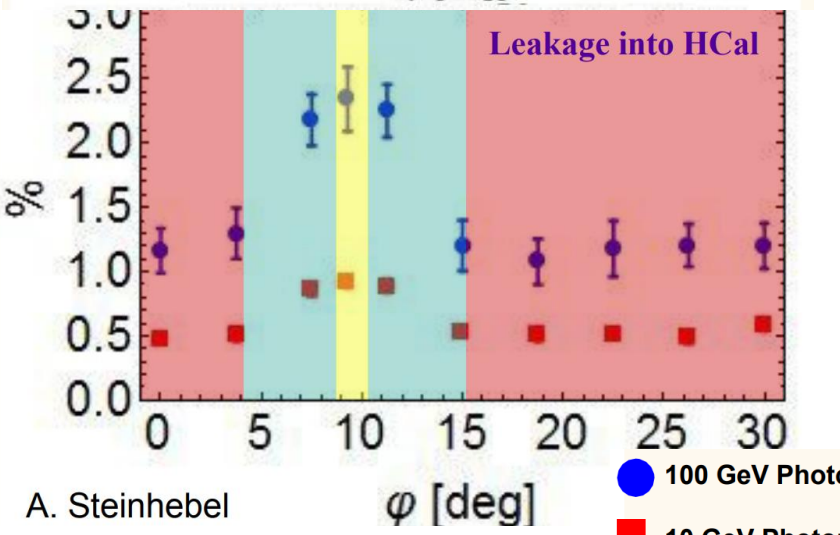


GEOMETRY EFFECTS



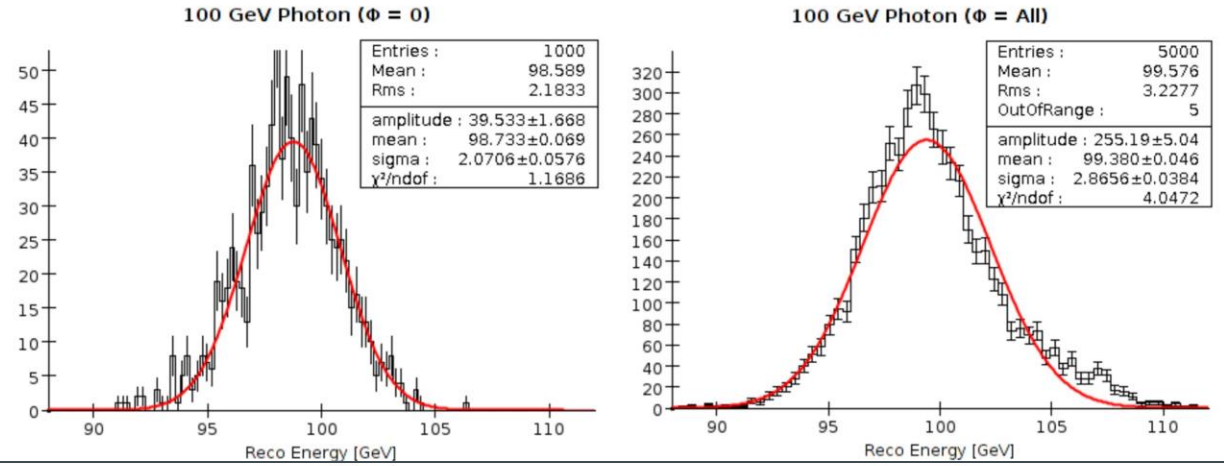






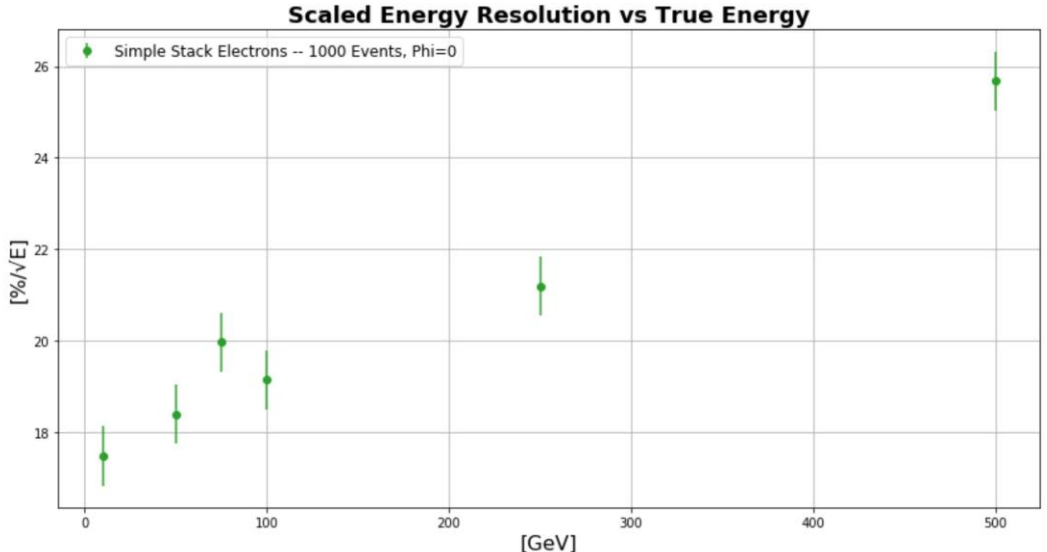
Leakage into HCAL in overlap region increases due to less material, phi dependent

RESOLUTION EFFECTS FROM GEOMETRY



Previous resolution study (Da An, et al. 2014) using 100 GeV photons in sidloi3.

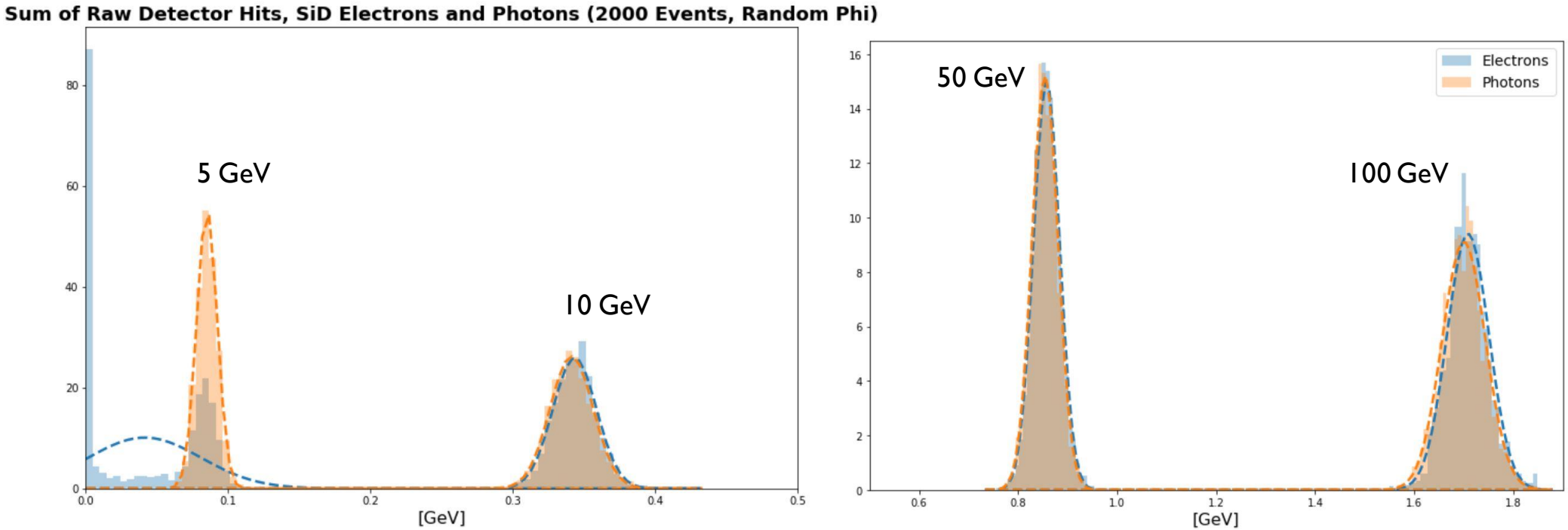
- $\phi = 0$ → Resolution ~ $21\%/\sqrt{E}$
- $\phi = All$ → Resolution ~ $29\%/\sqrt{E}$



Resolution study using 10, 50, 75, 100, 250, and 500 GeV electrons using Simple Geant4 Stack Simulation

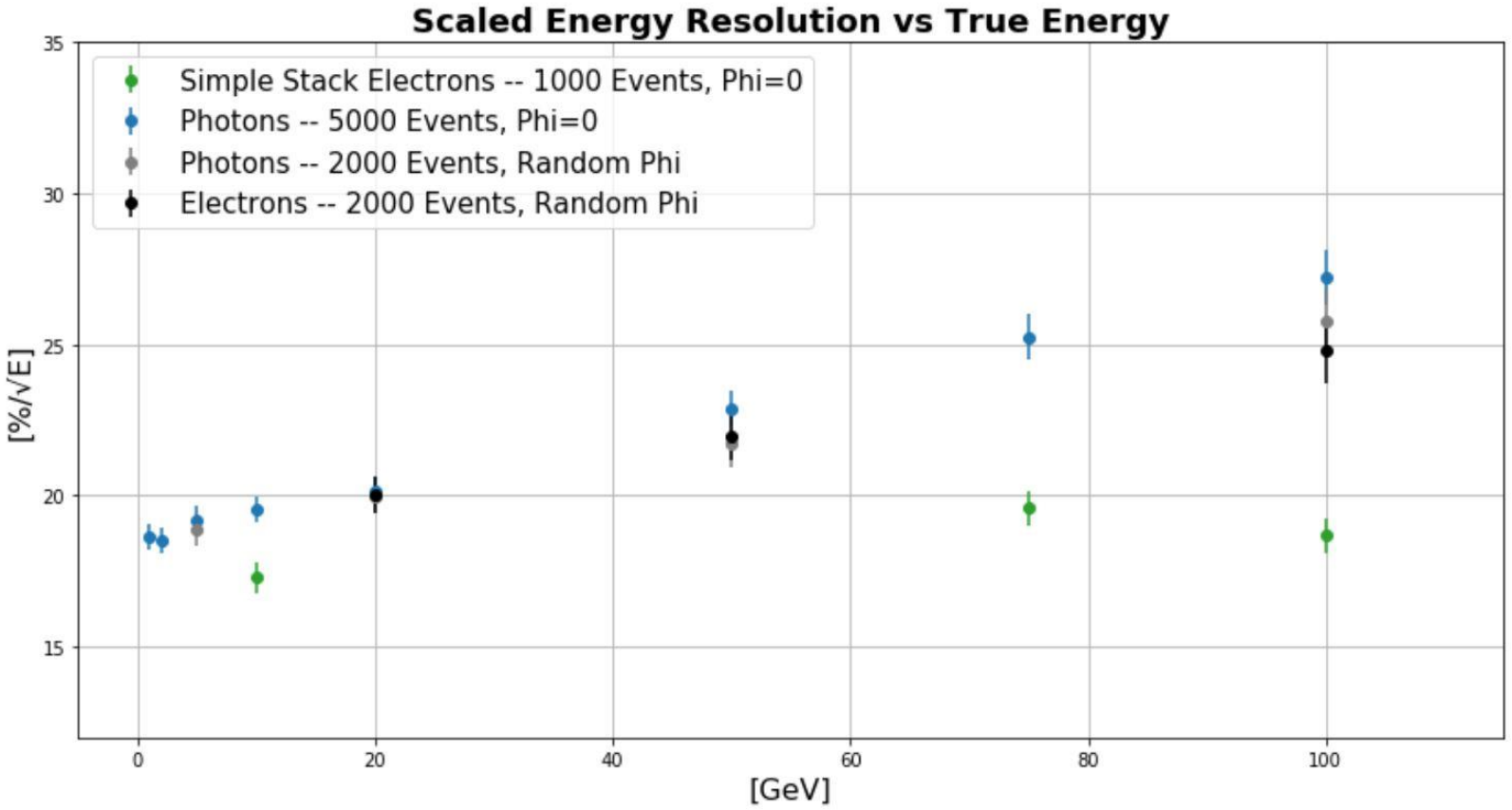
- For lower energy e- (<100 GeV), Resolution much closer to design expectation ($17\%/\sqrt{E}$)

DISTRUBUTIONS



- Use cone width $\phi \pm 0.2$ rad constraint on hit locations (avoid backscatter)
  - ϕ determined from incident MC particle, not actual hits in detector
  - Ignore 5 GeV electrons in resolution plots, B-field effects → shower gets missed with ϕ constraint

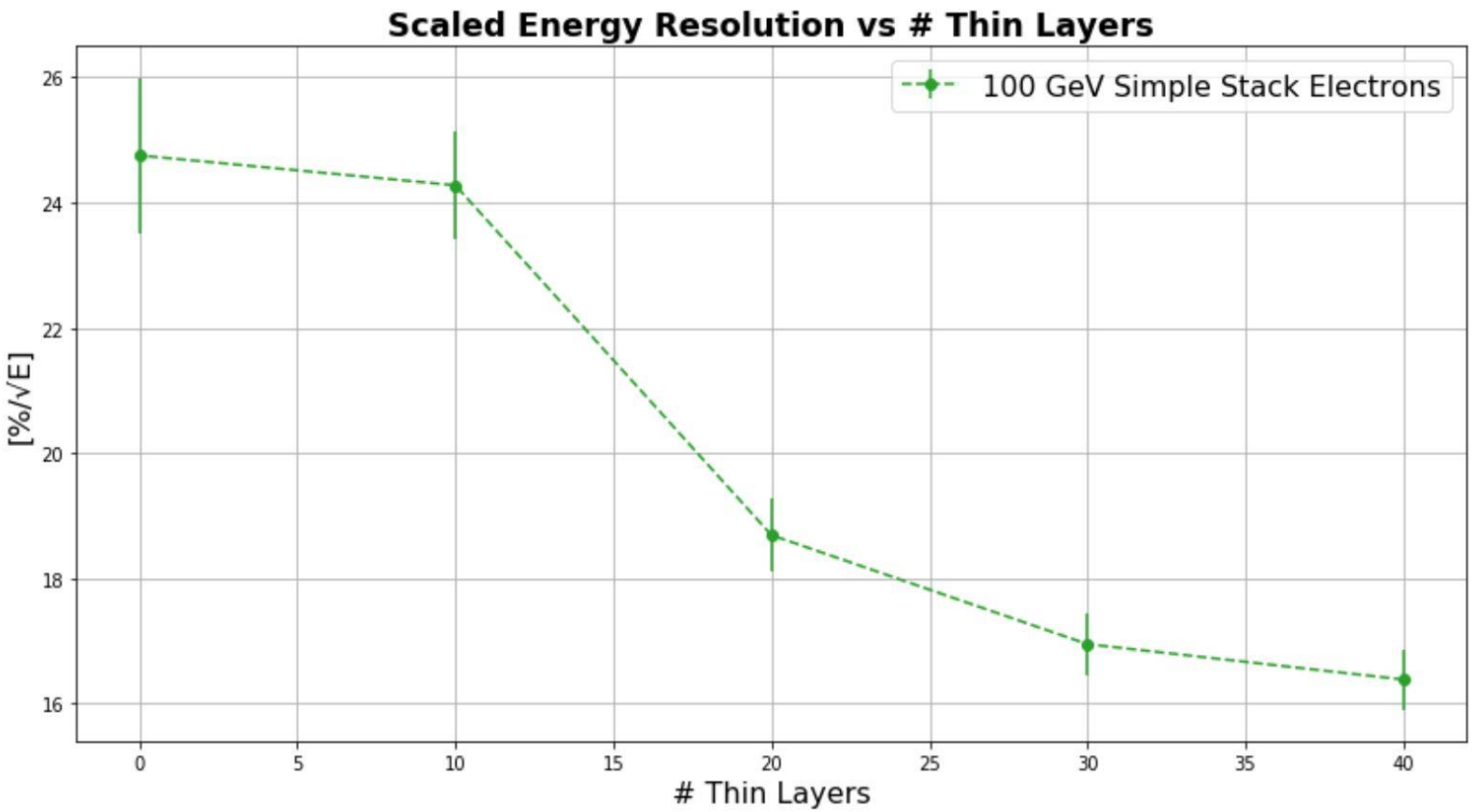
COMPARISONS



Discrepancies

- SiD resolution degrades much faster than the simple stack resolution
- 100 GeV SiD photons for $\phi = 0$ have Res ~ $28\%/\sqrt{E}$ compared to ~ $21\%/\sqrt{E}$ from previous sidloi3 study
- $\phi = All$ 100 GeV SiD photons have slightly better resolution than previous sidloi3 study; $\sim 26\%/\sqrt{E}$ compared to ~ $29\%/\sqrt{E}$

CONFIRM SIMPLE STACK BEHAVES AS EXPECTED

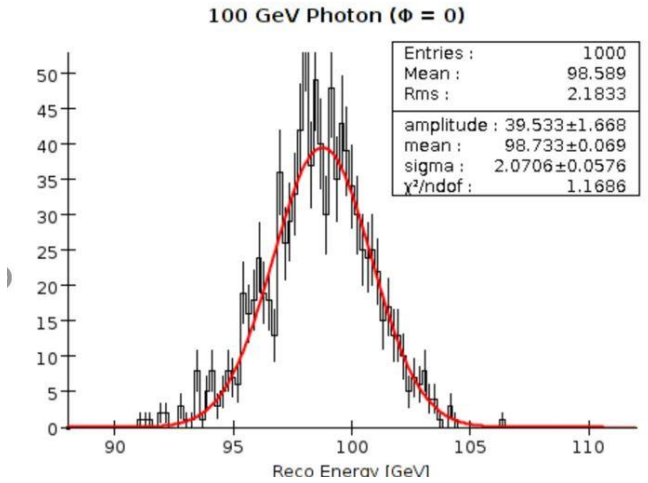


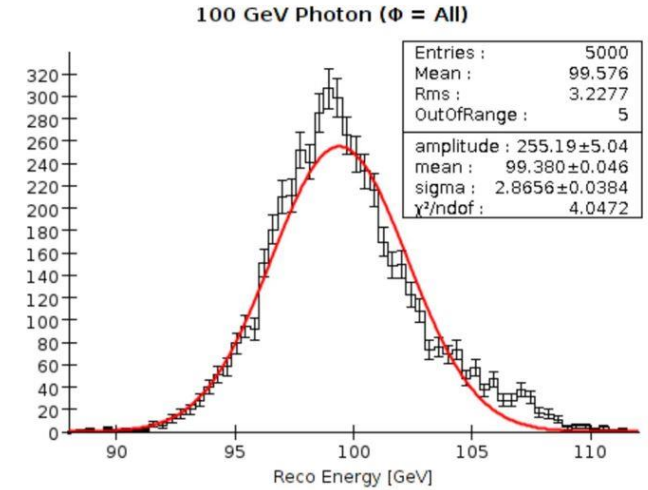
Vary the number of thin and thick layers for simple stack electrons

- #Thick Layers = (40 - #Thin) / 2
- Expected resolution of 40 thin ~$17\%/\sqrt{E}$
  - measured $16.6\%/\sqrt{E}$
- Expected resolution of 0 thin layers to degrade by $\sqrt{2}$ (~$24\%/\sqrt{E}$)
  - measured $25\%/\sqrt{E}$
- **Conclusion**: simple stack behaves as expected

*Note: Simple stack absorbers are pure W

SIDLOI3 RESULTS





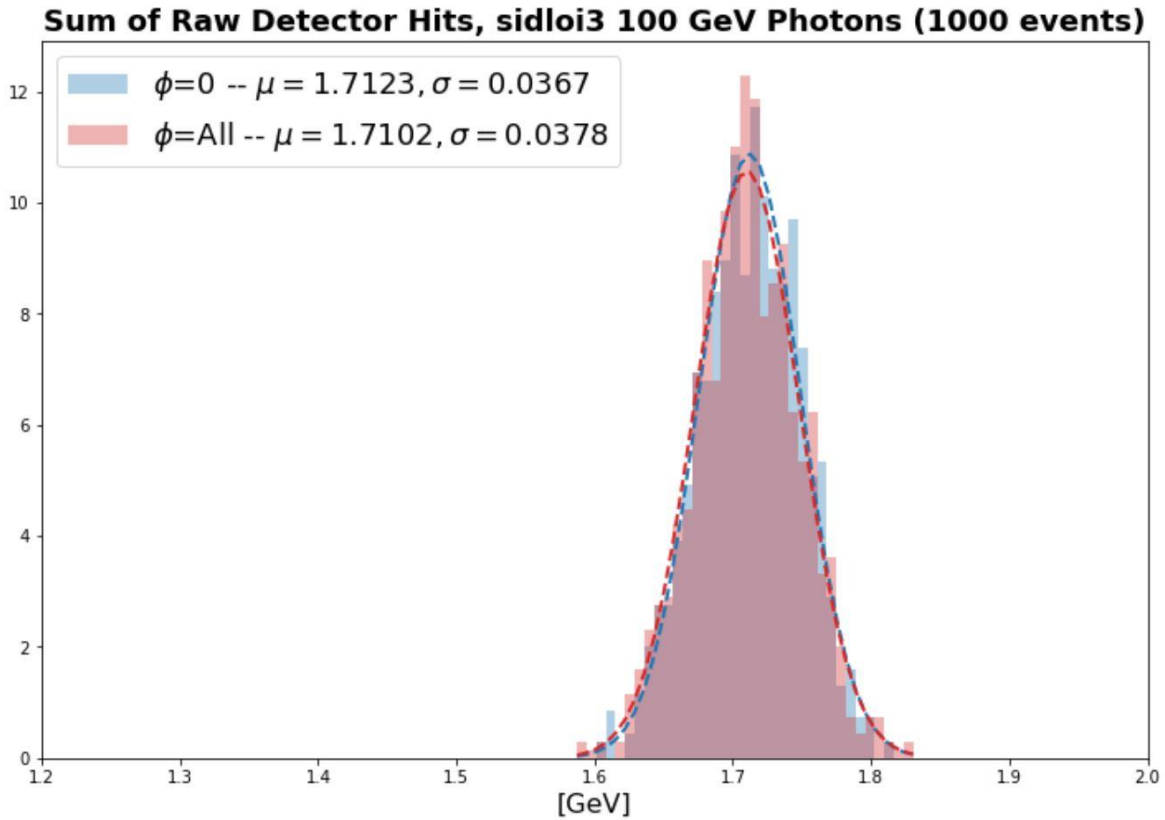
Large difference between $\phi = 0$ and $\phi = All$

← Previous study

(Da An, et al.)

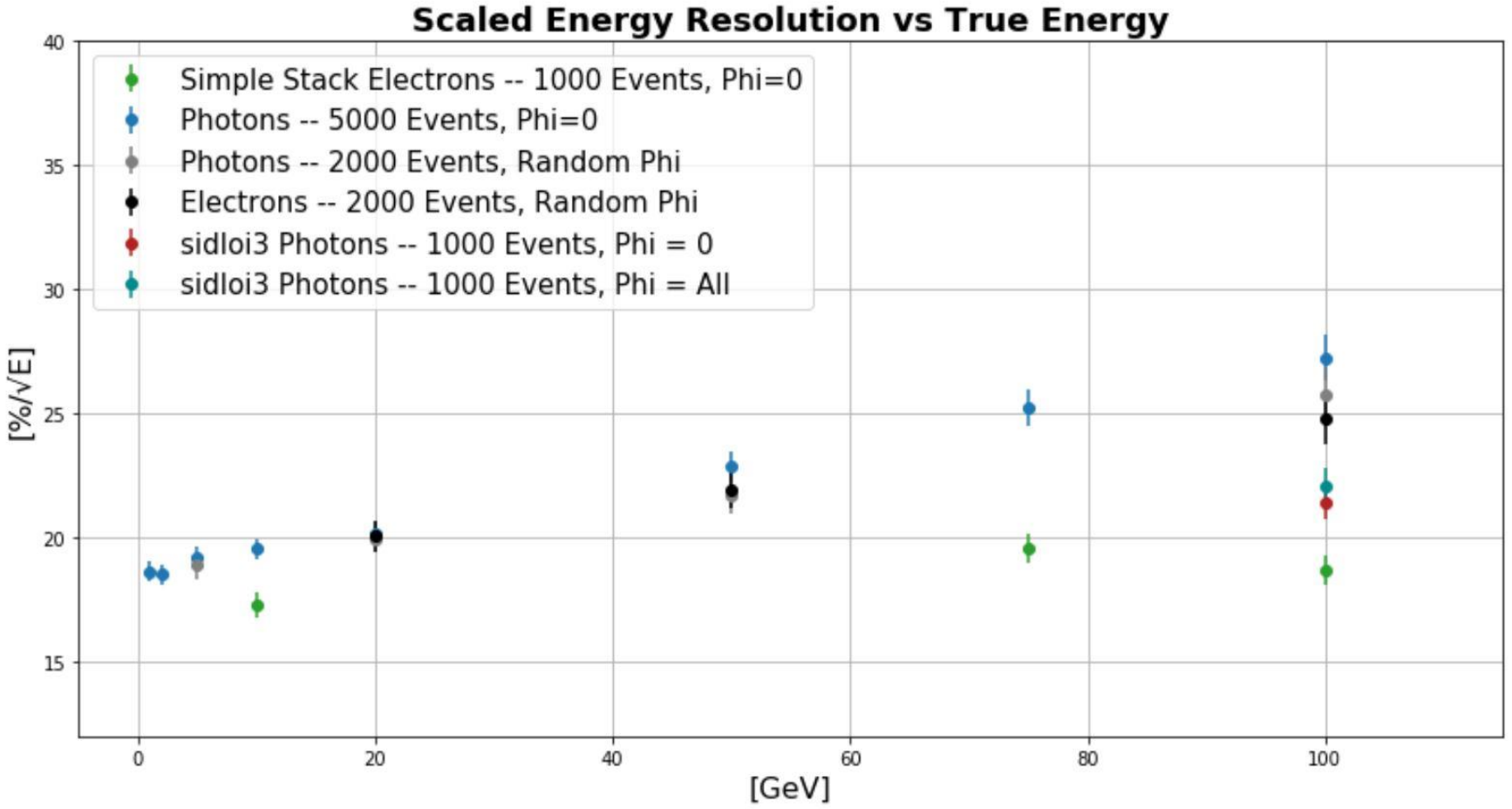
Current study →

(what is used on following resolution plot)



Small/negligible difference between $\phi = 0$ and $\phi = All$

SIDLOI3 RESULTS (CONT.)



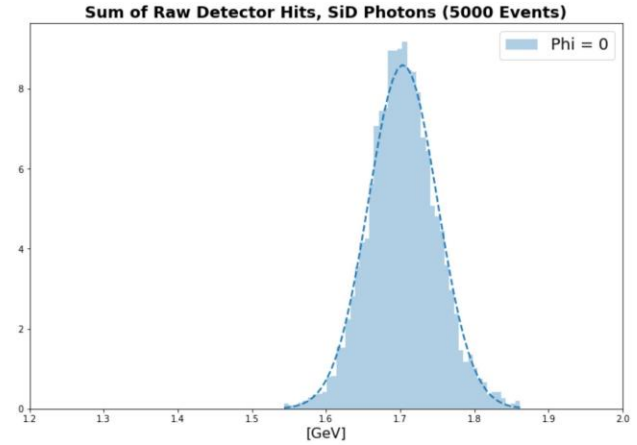
<u>Consistency</u>

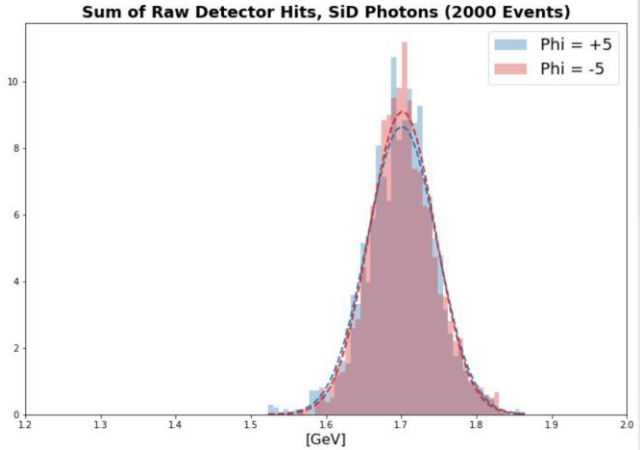
- Resolution at $\phi = 0$ for old and current sidloi3 studies match

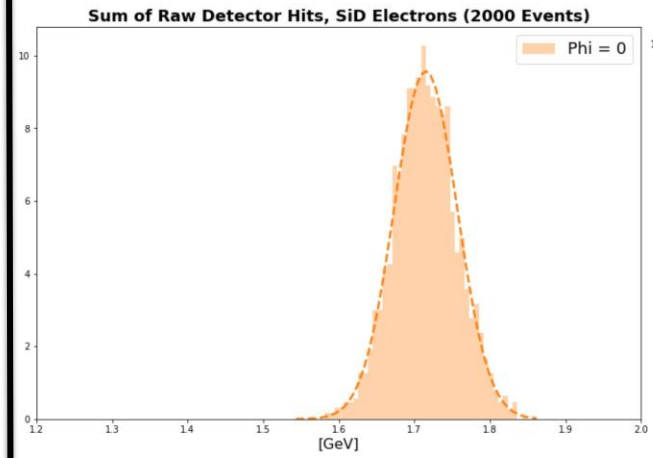
<u>Discrepancy</u>

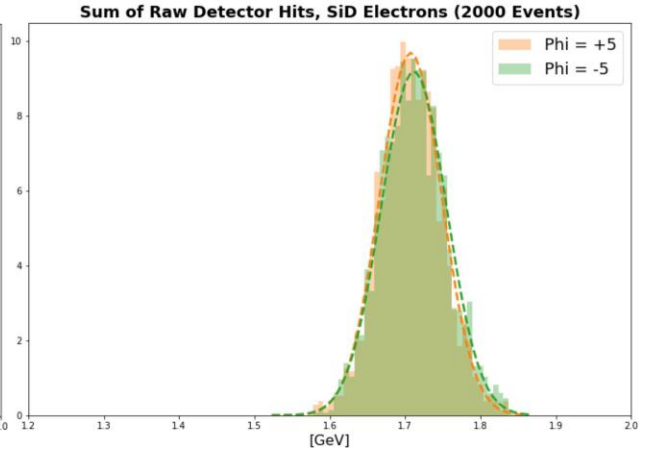
- For $\phi = All$, old and current studies do not match ($\sim 29\%/\sqrt{E}$ compared to $\sim 22\%/\sqrt{E}$)

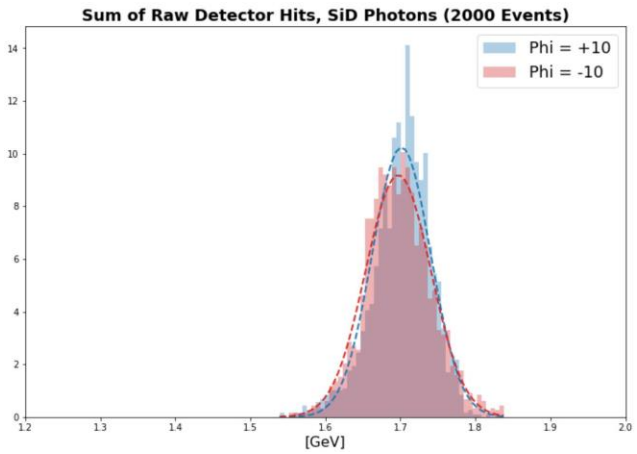
HOW DOES INCIDENT HIT LOCATION IN MODULE AFFECT RESOLUTION?

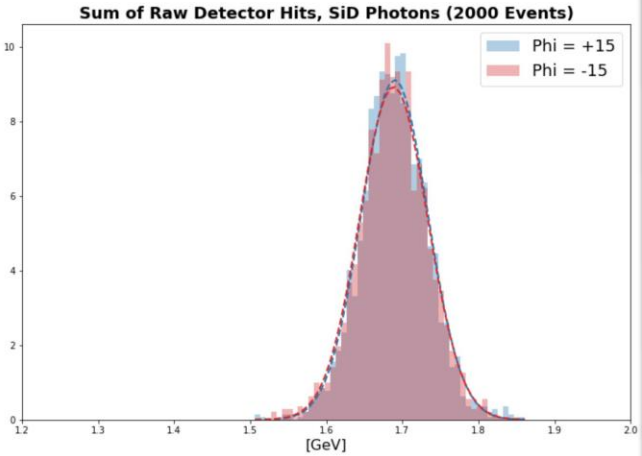


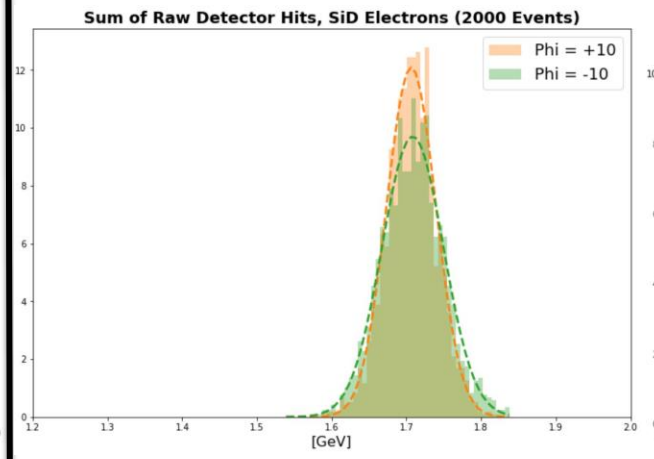


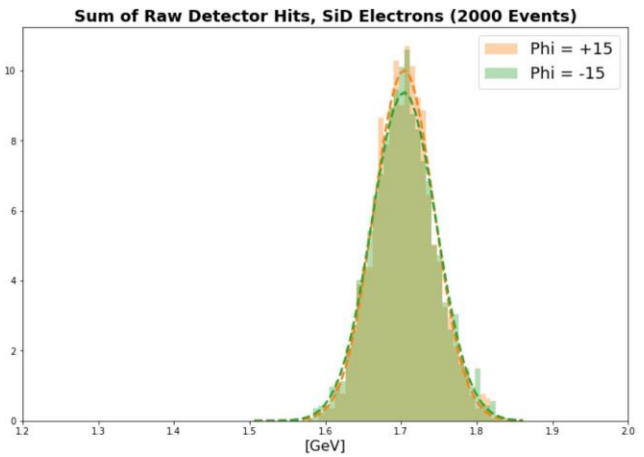




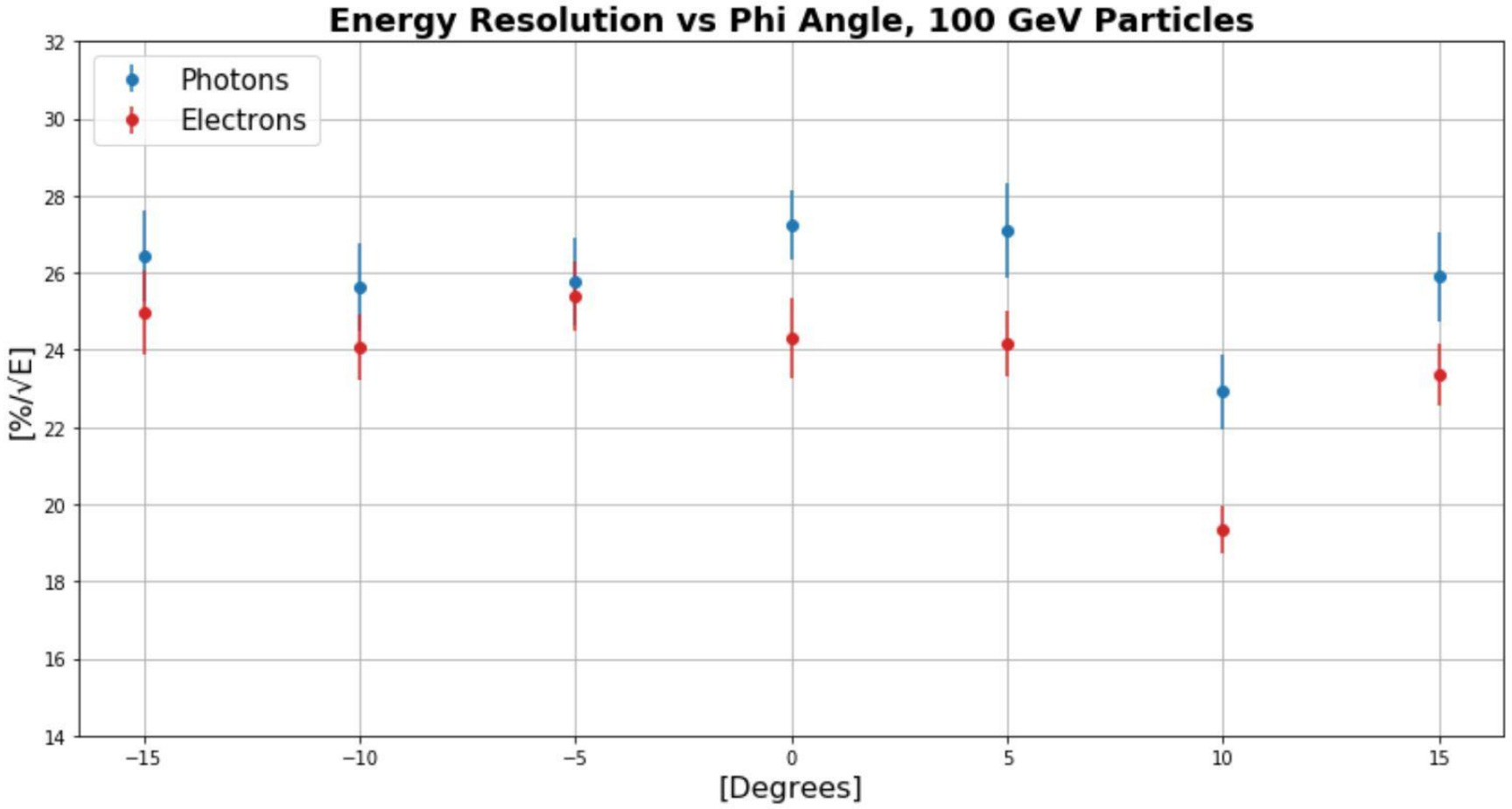








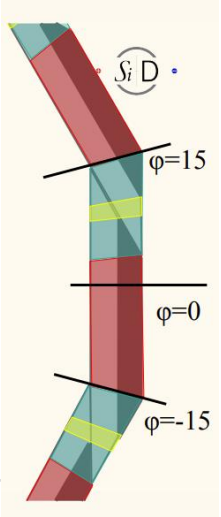
RESOLUTION DEPENDENCE ON PHI



Closest overlap region to normal incidence: $\sim -4^{\circ}$

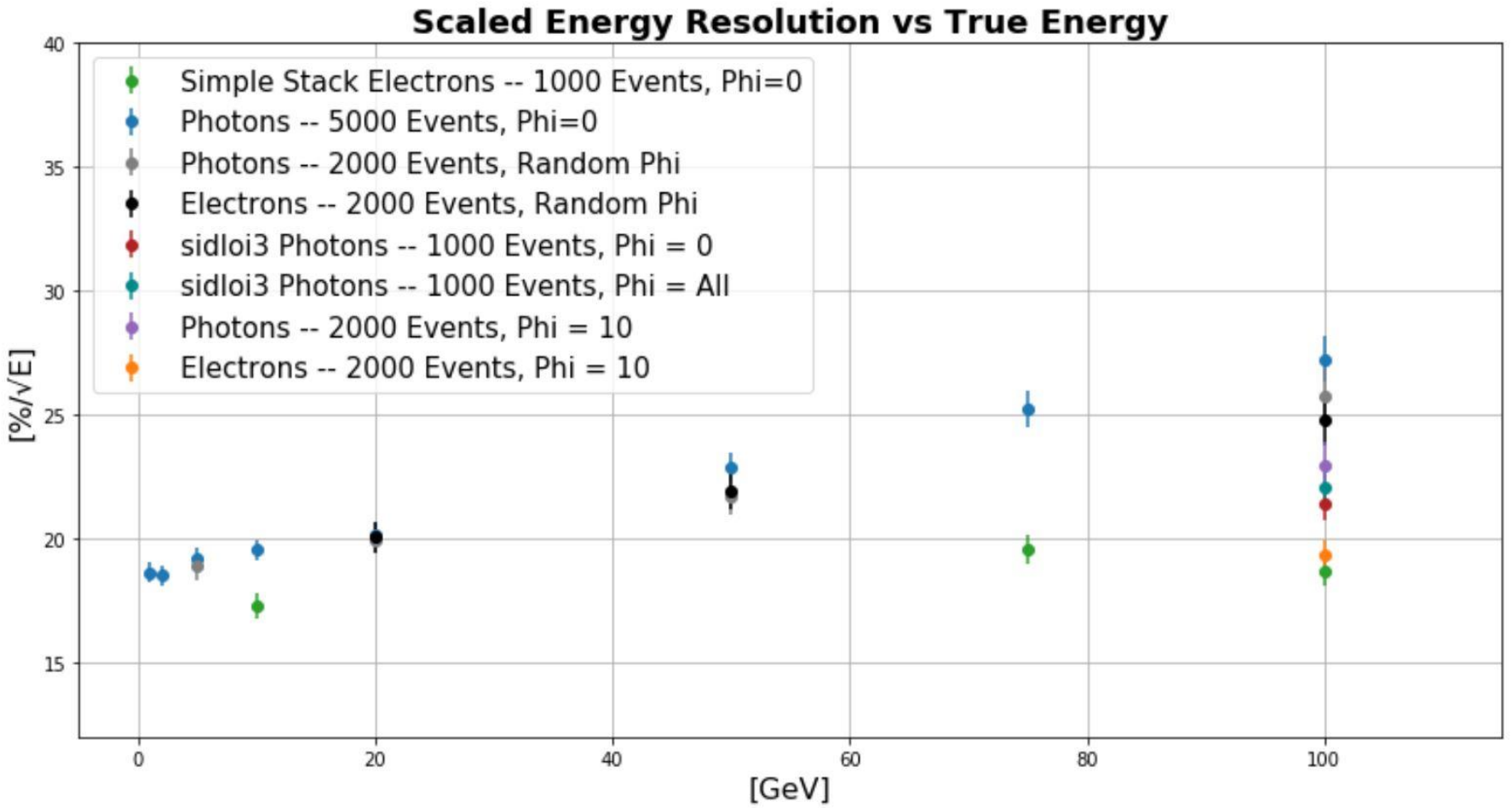
$\phi = 10^{\circ}$ ensures entire shower goes through center of module

100 GeV e- at $\phi = 10^{\circ}$ is comparable to simple stack



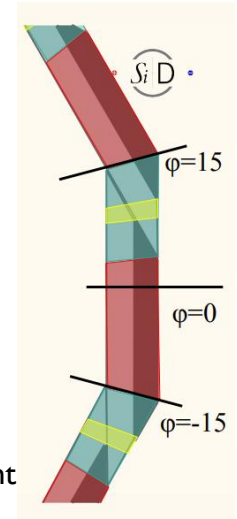
ϕ flipped from diagram on the right

SUMMARY OF CURRENT ANGULAR



Current SiD compares better to previous studies when incident particles are fired at $\phi = 10°$ instead of normal incidence

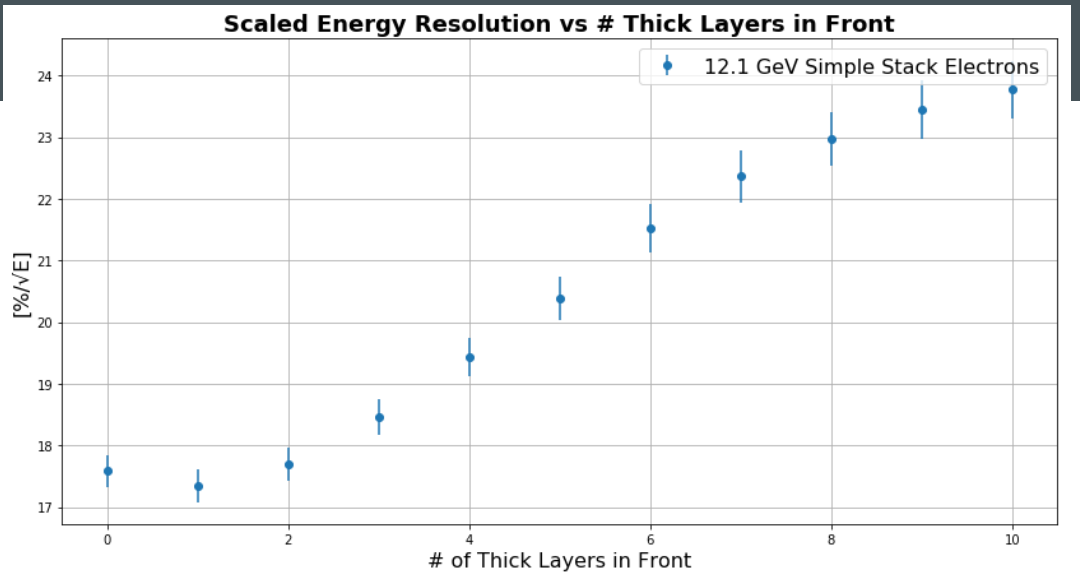
Shower mostly contained in nonoverlapping region

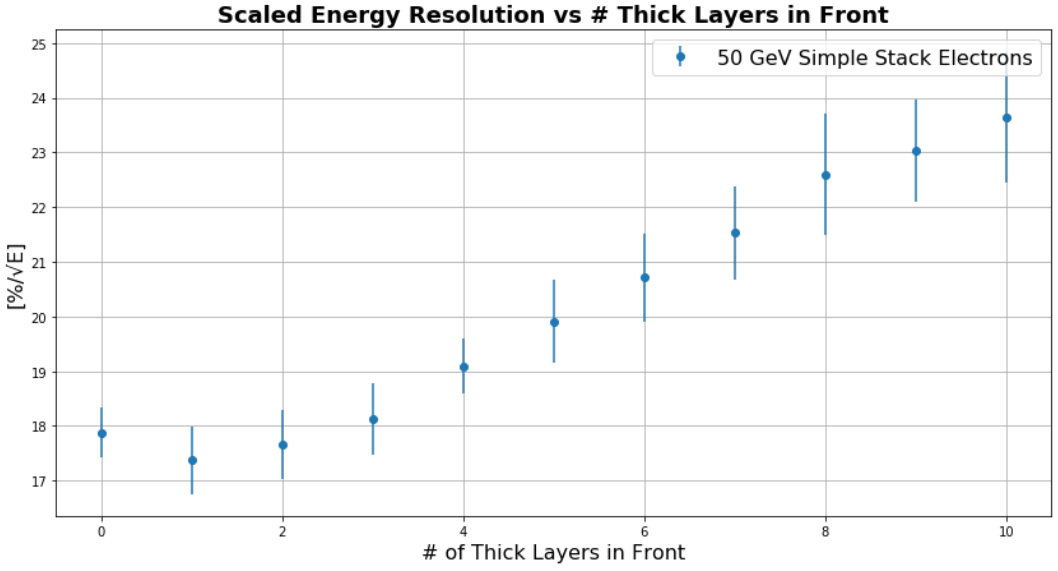


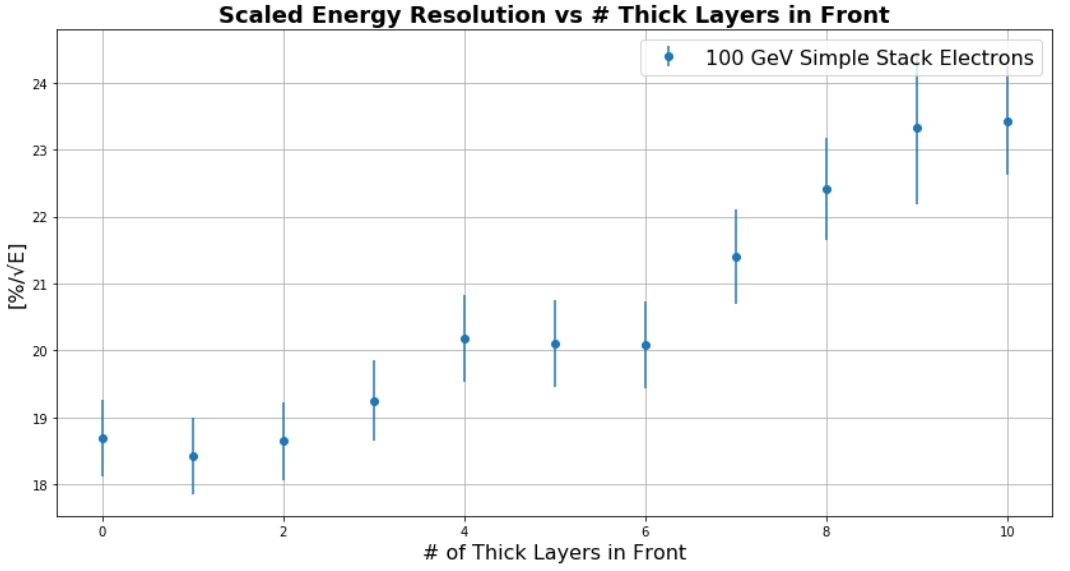
ϕ flipped from diagram on the right

LAYER SWAPPING

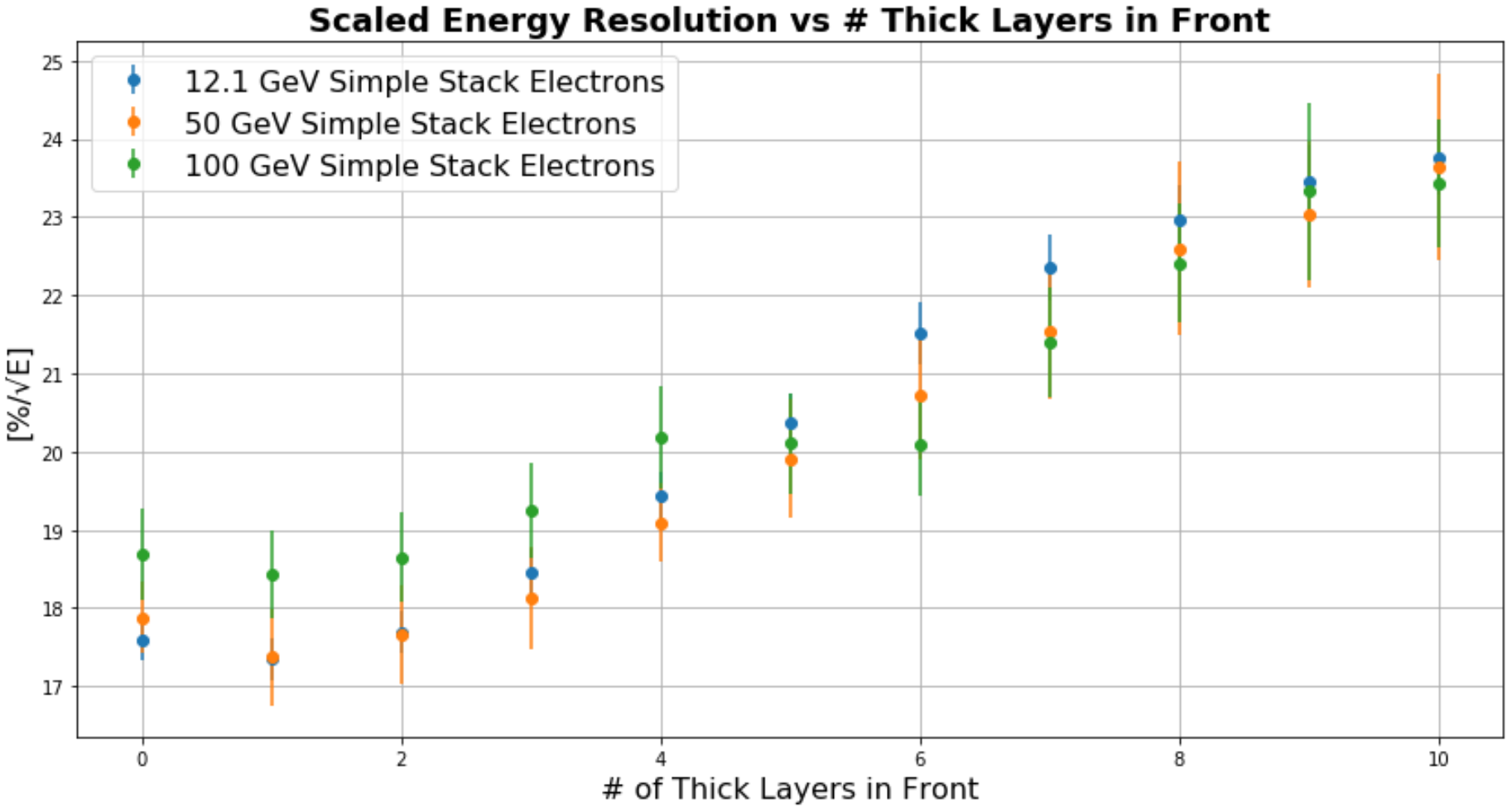
Changing to have thick layers at the front could decrease the cost as the importance of sampling goes down when the shower has yet to fully develop.
See similar resolution with 2 thick layers at the start







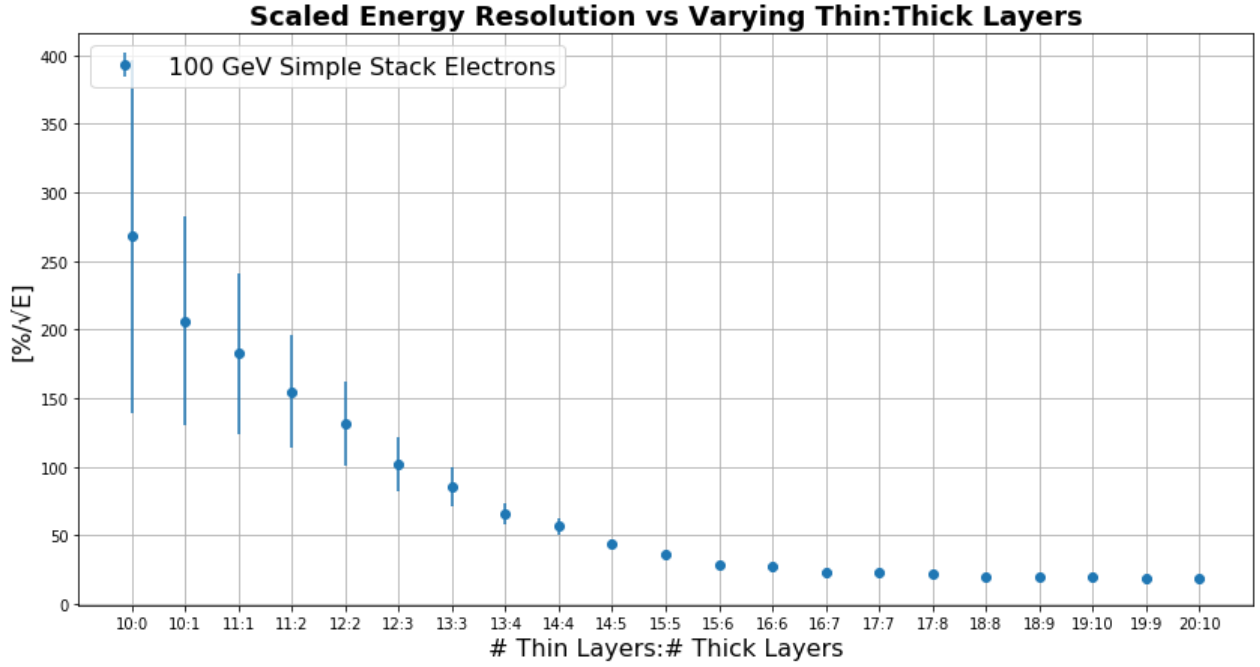
LAYER SWAPPING



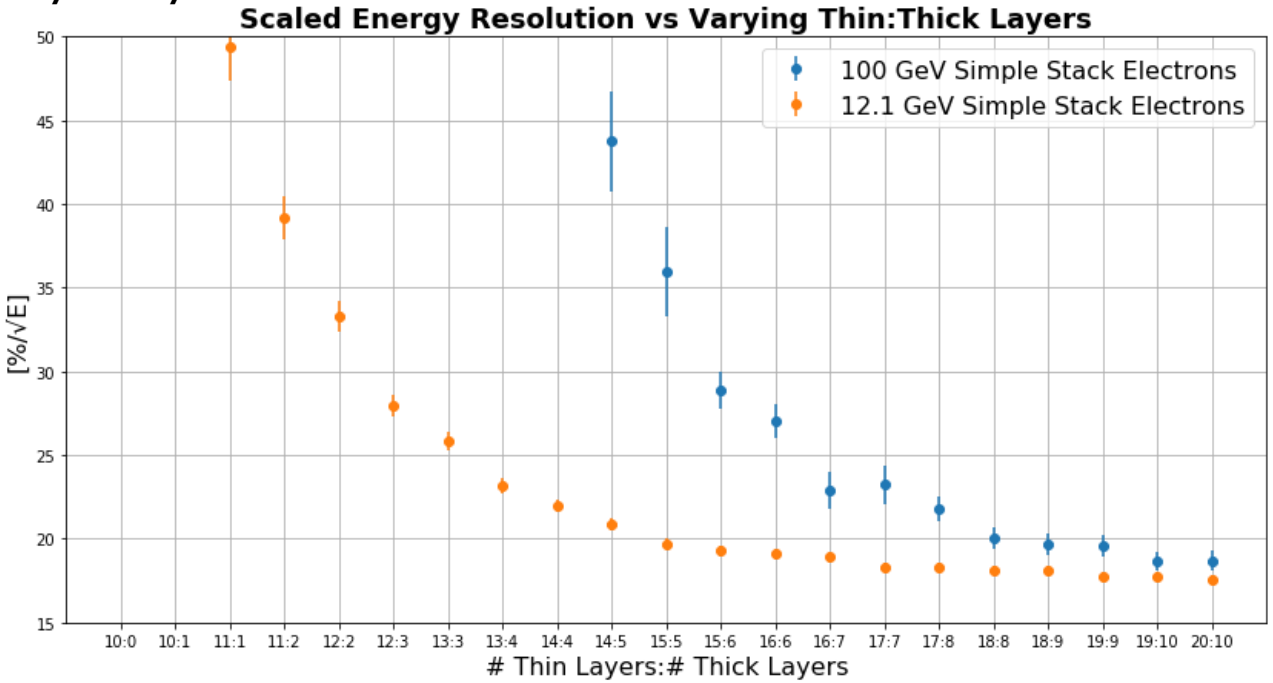
Consistently across energies see similar resolution with 2 thick layers in the front

D. Austin

COMPLETE REVISION OF LAYER STRATEGY



Initial studies of changing the number of thick and thin layers in the calorimeter. Not much in resolution loss in going to 18:8 but reduce necessary amount of Si layers by 4

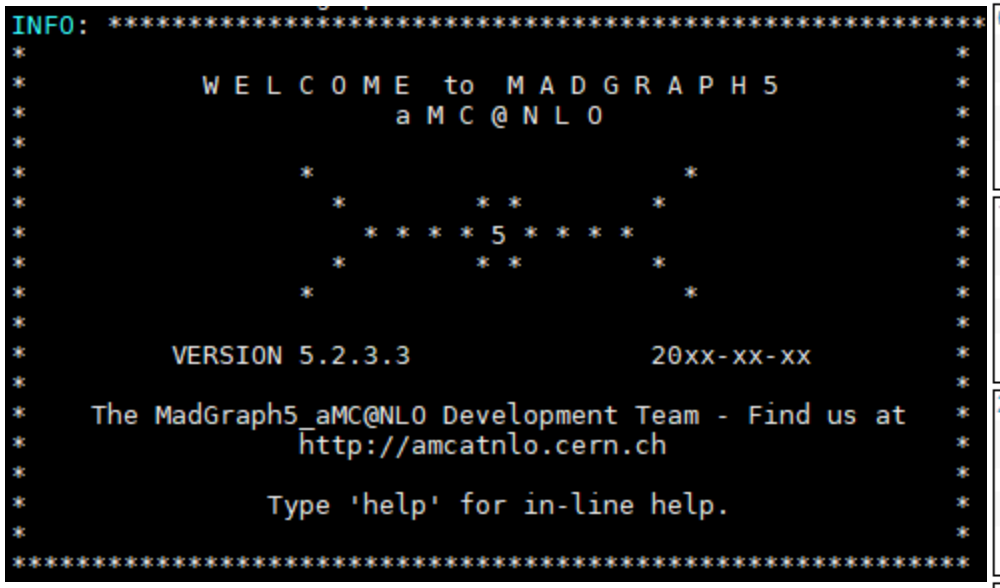


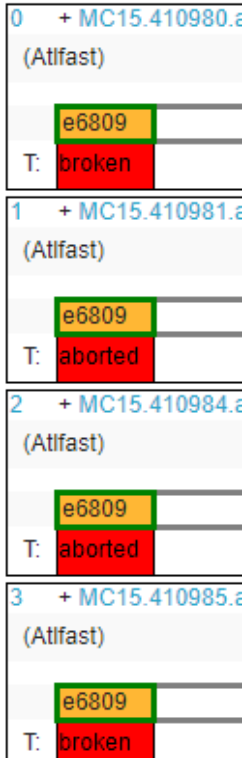
SUMMARY OF SID RESULTS

- Better understanding current results more every day
  - Resolution differences from initial design resolution to current design geometry
  - Comparison between versions of geometry can be tricky
- Complimentary studies can be done for potential layer reduction of SiD ECal
  - Rearrange Layers
  - Change number of layers

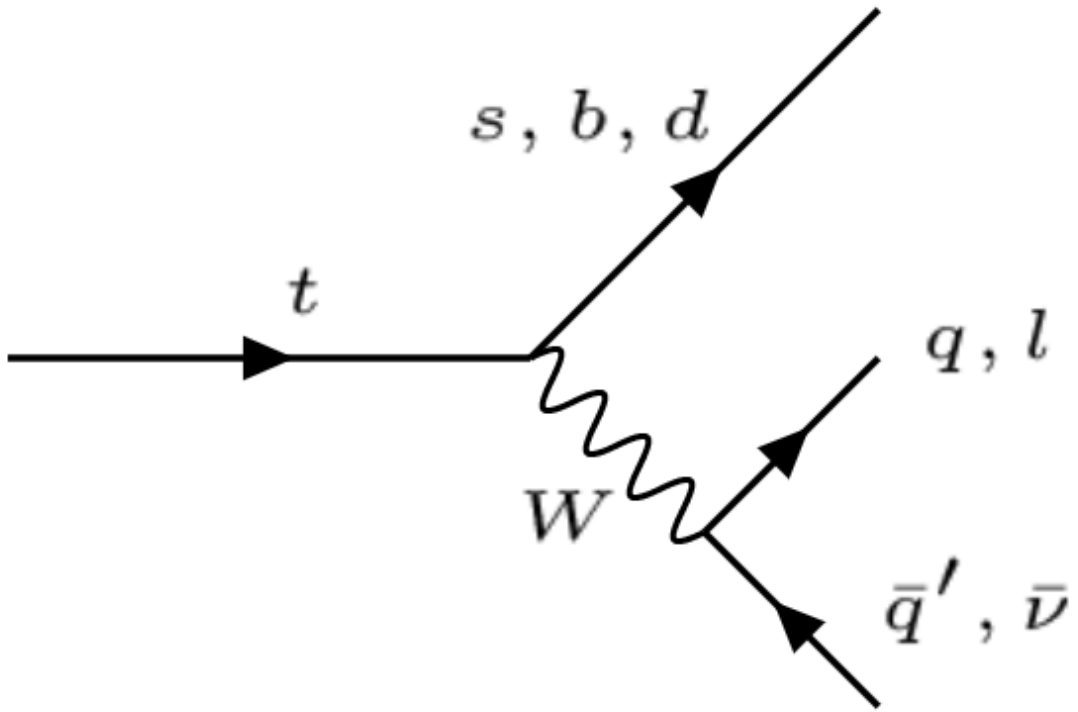
UPDATE ON FCNC

- Analysis is moving, slowly
- Awaiting new MC samples
  - Not working on grid, no one knows why
  - ATLMCPROD-6008
- Moving to R21
  - New signal and background MC

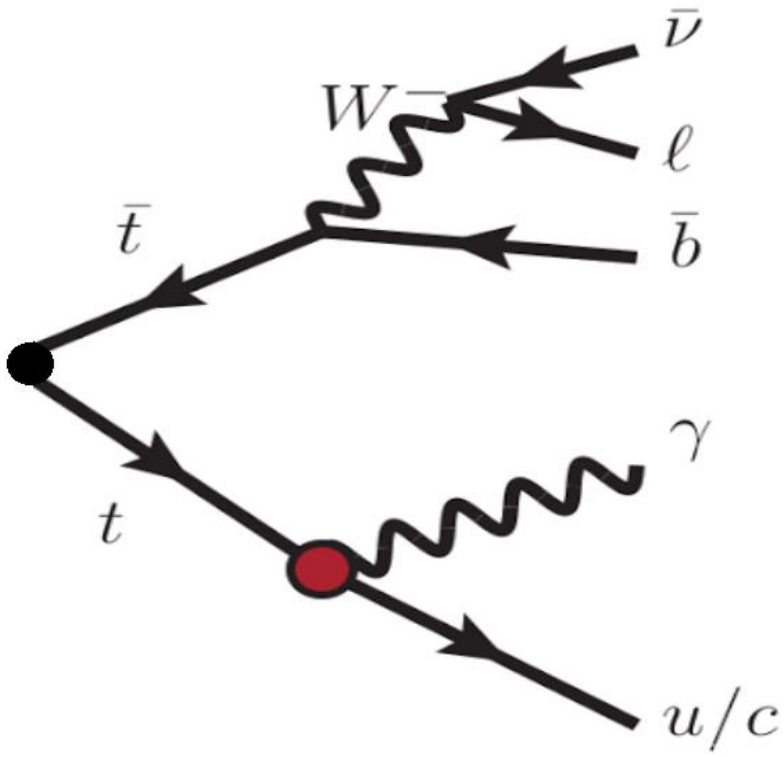




TOP DECAYS



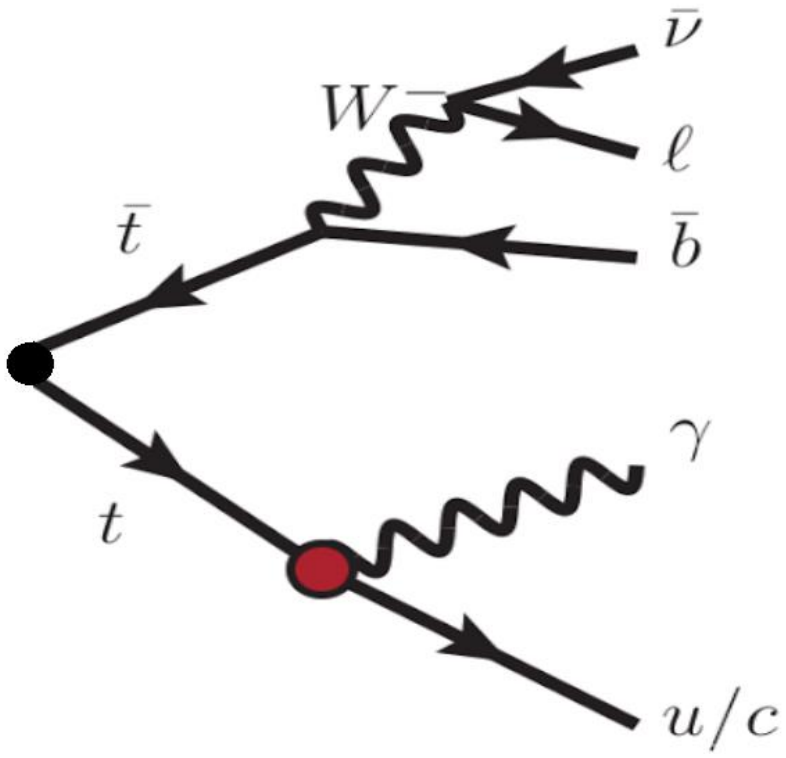
SM Top Decays



SignalEvent with FCNC Top Decay, very suppressed in SM

PRESELECTION CUTS

- We preselect events with objects that look like the signal
- Require:
  - == 1 lepton
  - == 1 Good Photon
  - MET
  - >=2 Jets (at least one being b-tagged)
- Event Duplication Removal
  - Expanded on slightly this time



REMINDER – DUPLICATE (OVERLAPPING) EVENT REMOVAL

- For $t\bar{t}$ and $V + jets$ samples, the prompt photon contribution is subject to large statistical uncertainty and its modelling is less trusted, it is why the $t\bar{t} + \gamma$ and $V + \gamma$ samples are used.
- For this to work phase spaces of events must be close to identical otherwise the overlap removal will take out too much

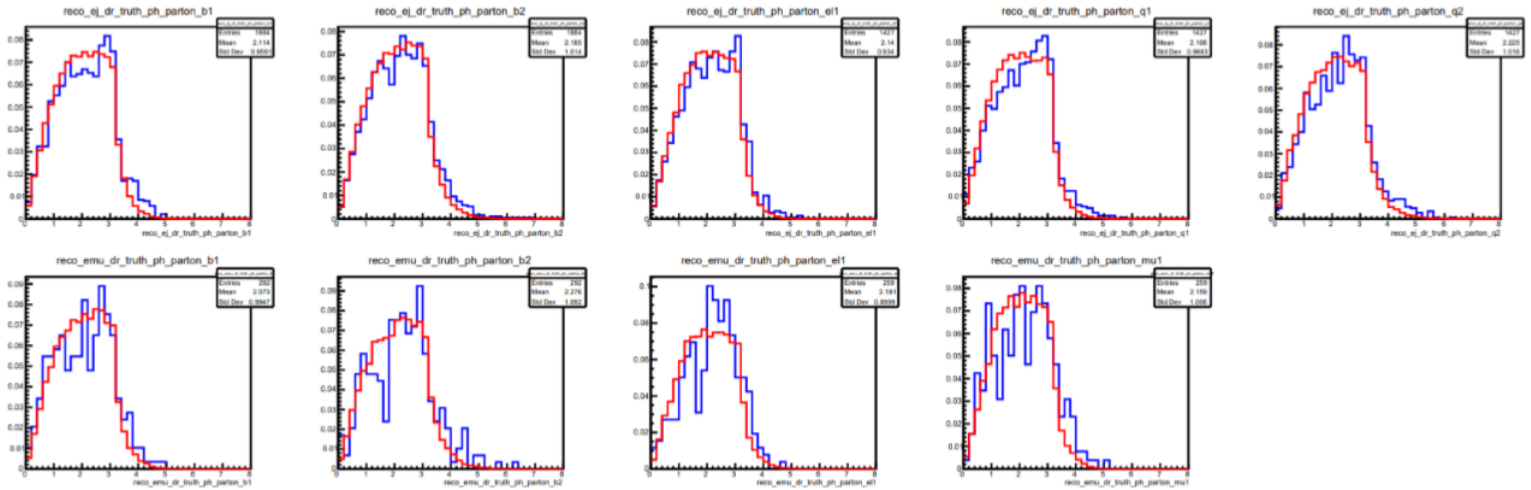


Figure: Overlaping Phase Space Regions of the photon and various objects [Y.Li] Red: $t\bar{t} + \gamma$ Blue: $t\bar{t}$

IMPLEMENTED DUPLICATE EVENT REMOVAL

- Due to large influence of photons on the analysis special samples are used for major backgrounds
  - Increases the MC statistics of the samples with photons
  - Must removal events that are the same
- 40-50% of previous ttbar, W+Jets samples are removed with this method and replaced
- Previous inclusion could hide smaller effects that could be helpful in the analysis

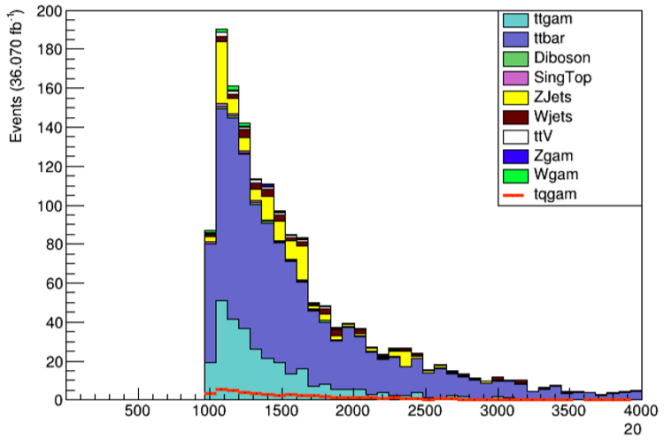


Figure: No OVR Photon ptcone20

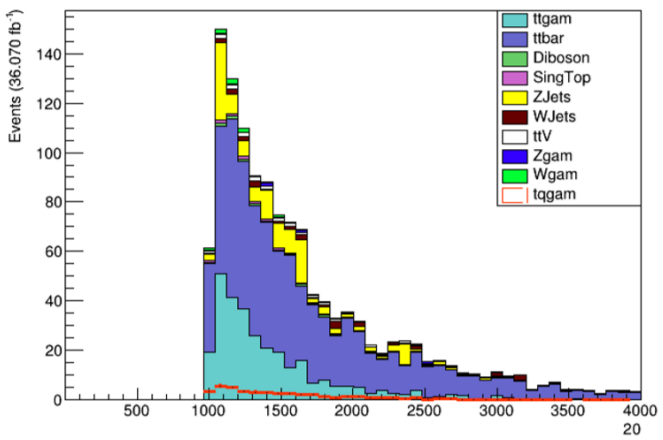
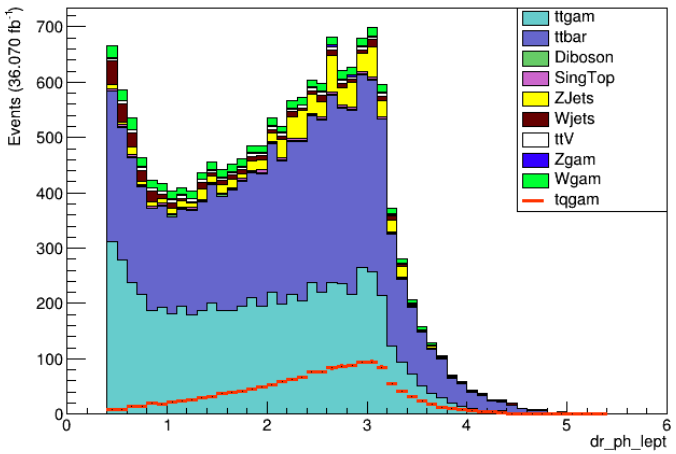
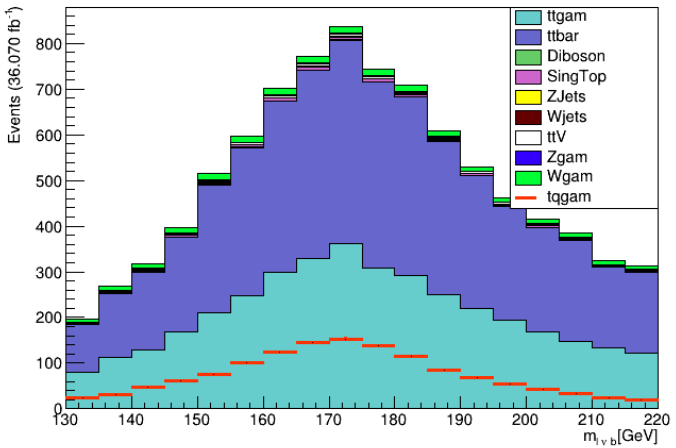


Figure: OVR Photon ptcone20

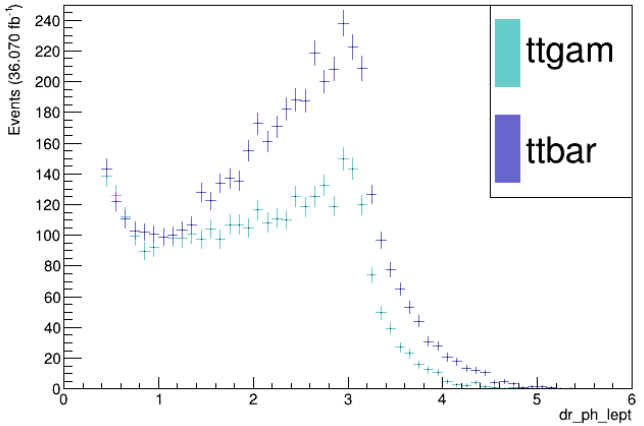
DUPLICATE EVENT REMOVAL

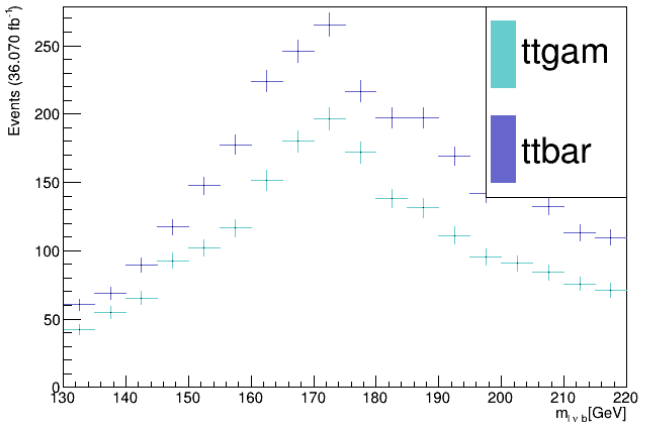
No Removal



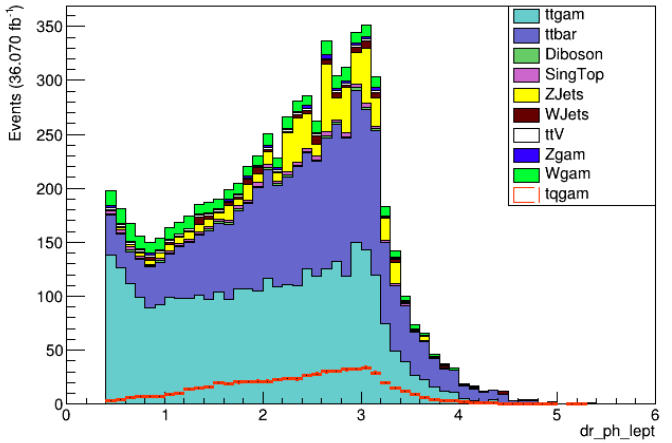


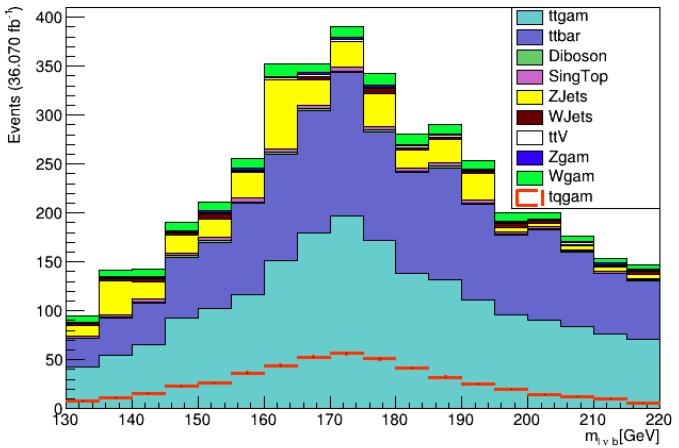
Just Major Samples





Post Removal



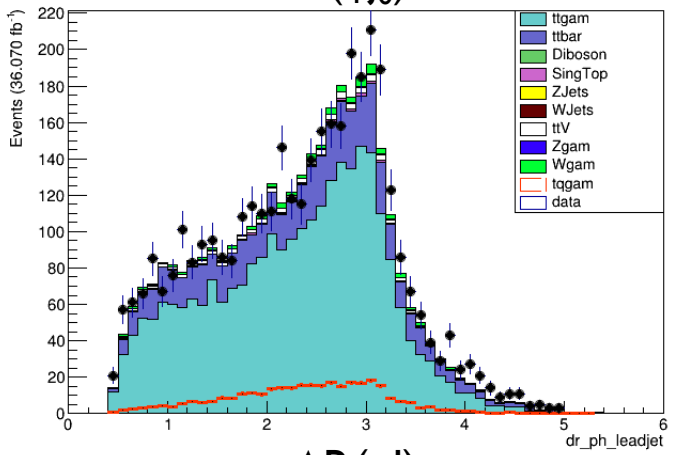


REGION IMPLEMENTATION

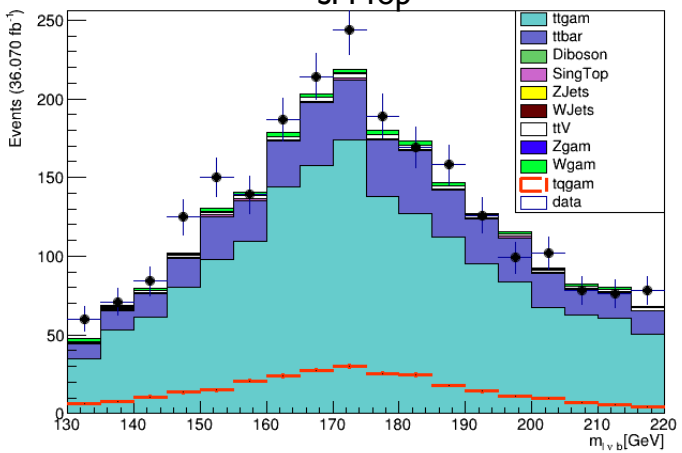
- Most important background to be well modeled is obvious ttbar/ttbar+gamma
  - Large increase in cross section at 13TeV
- We craft an orthogonal region to make sure we are modeling these well
- ttbar/ttbar+gamma region has been created
  - Preselection Cuts
  - >= 4 Jets (At least 1 b-tagged)
  - Orthogonal FCNC mass cut
  - Weak isolation cuts, currently

DATA IN TT+GAMMA VALIDATION REGION

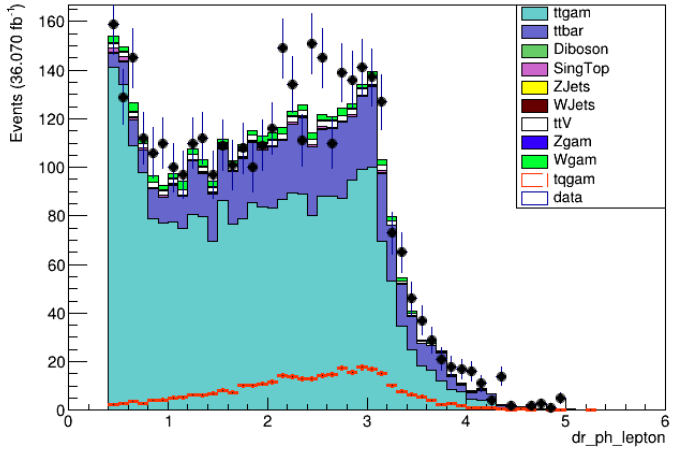
$\Delta R(\gamma j_0)$



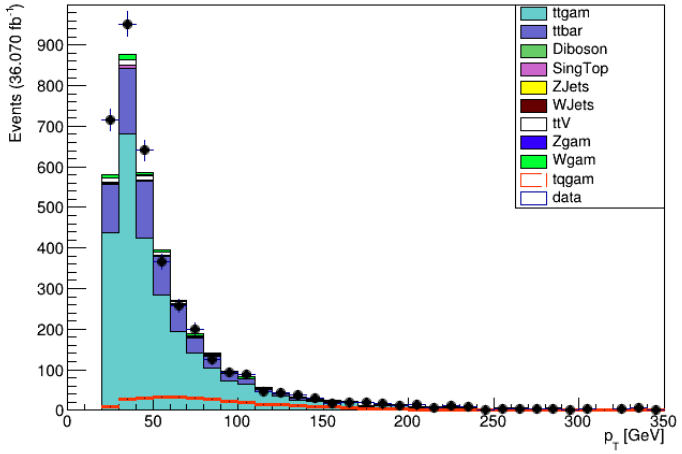
$m_{SM\ Top}$



$\Delta R(\gamma l)$



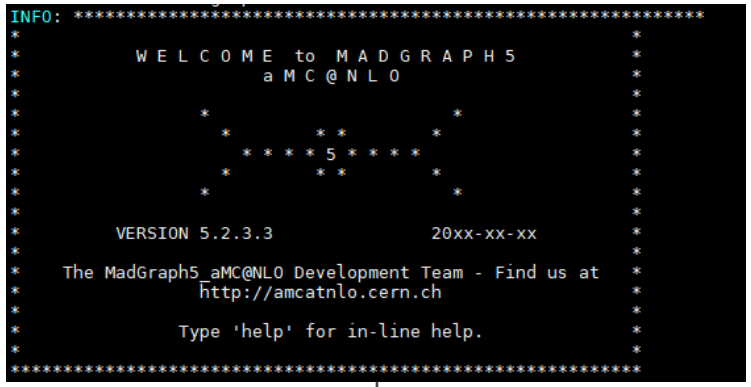
$\gamma : p_T$



Small average under modeling, explained most probably by previously shown errors in the older MC samples being used.

CONCLUSIONS

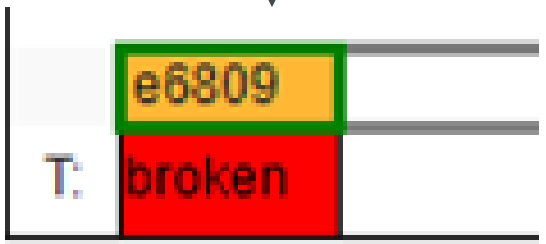
- Had been waiting for MC production to get going with R21
  - Held up with no end in site
  - Failing with site specific issues
    - Previously used sites have been decommissioned, replacements done work
- Going forward I will be preparing and running R21 MC releases on the grid and guiding that with what I know now



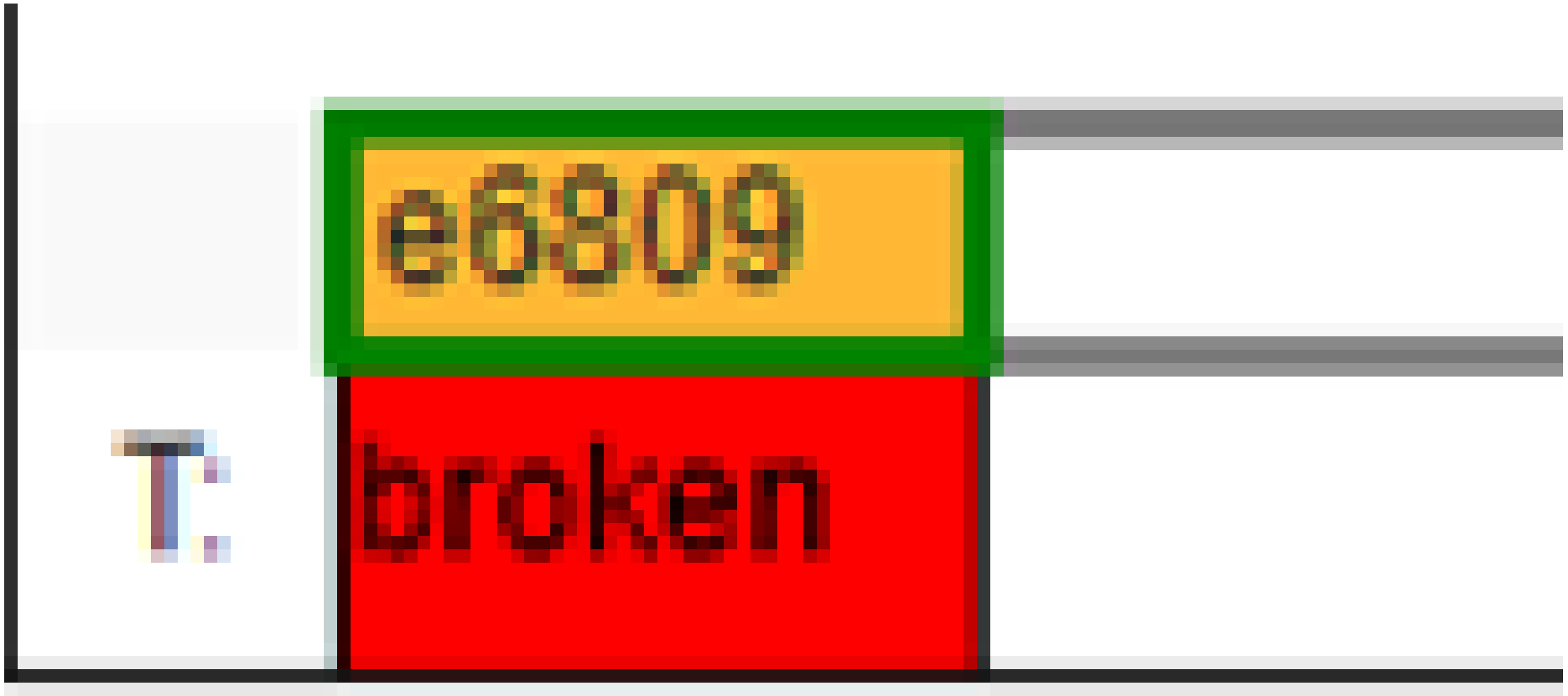
Local, LXPlus

```
INFO Application Manager Terminated successfully
INFO leaving with code 0: "successful run"
```

Grid



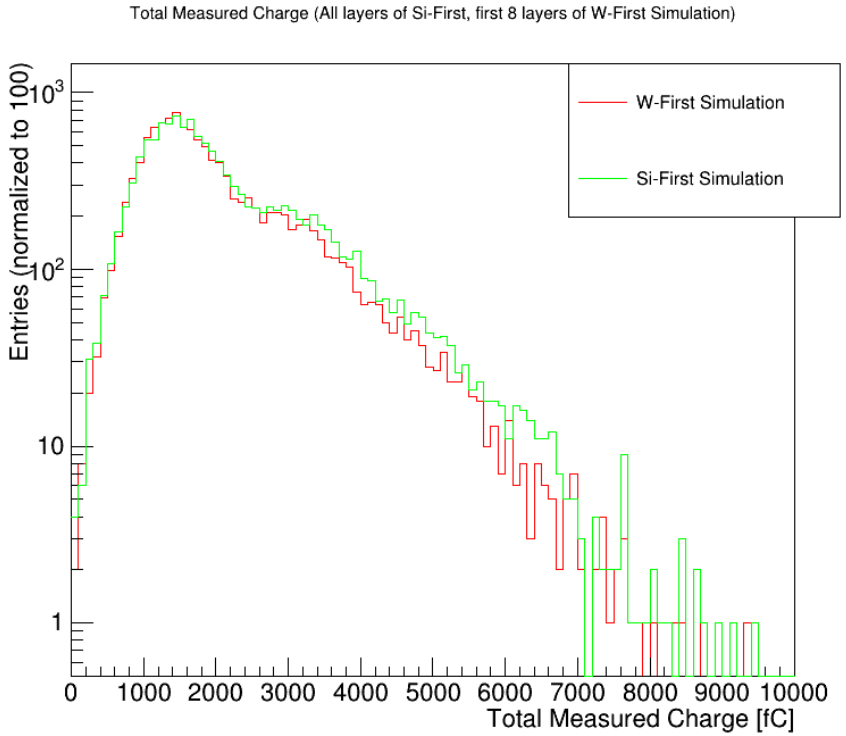
QUESTIONS



BACKUP

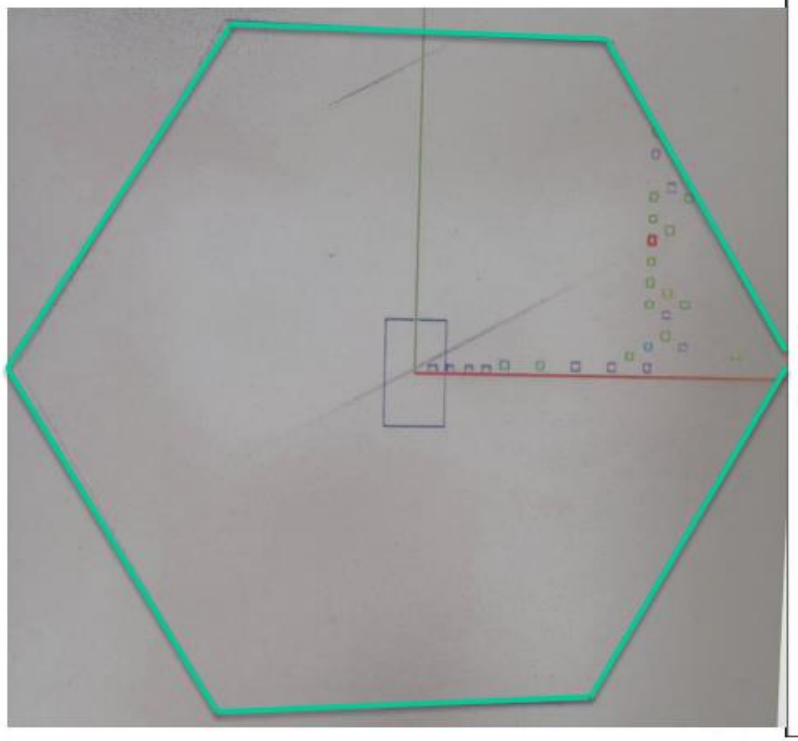
W-FIRST VS SI-FIRST SIMULATION

- Distribution of energies in simulation depending on which way the test beam was facing into the detector, small differences

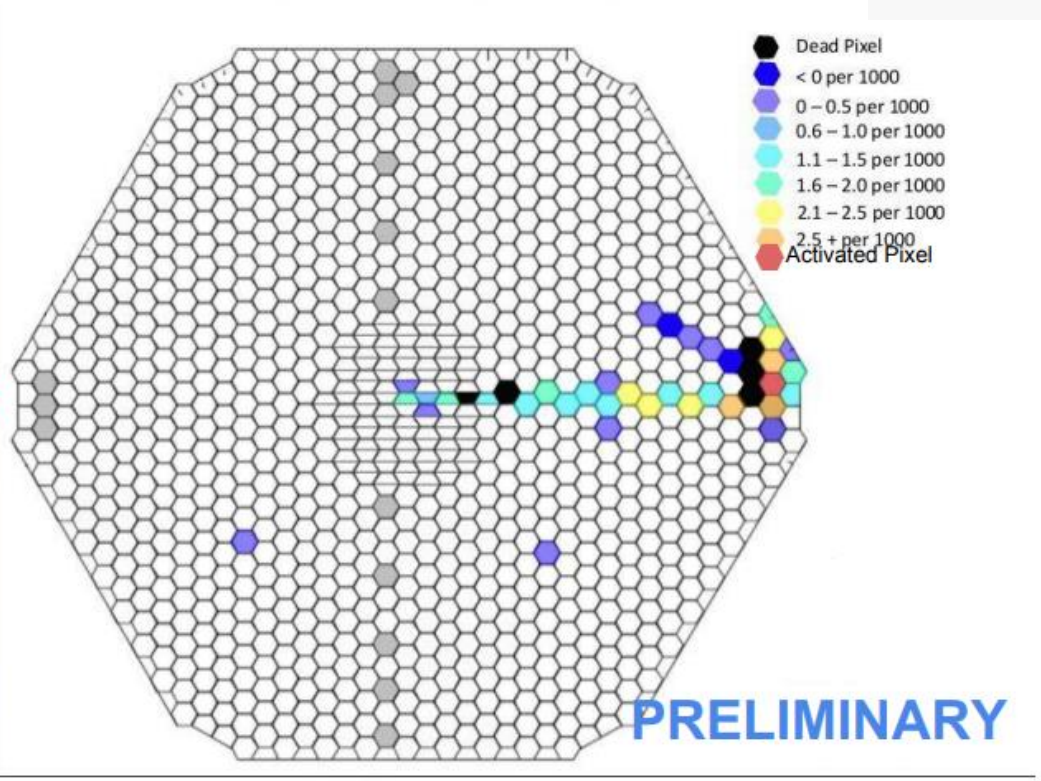


Cross-Talk on Test Beam Sensor

SLAC Test Beam



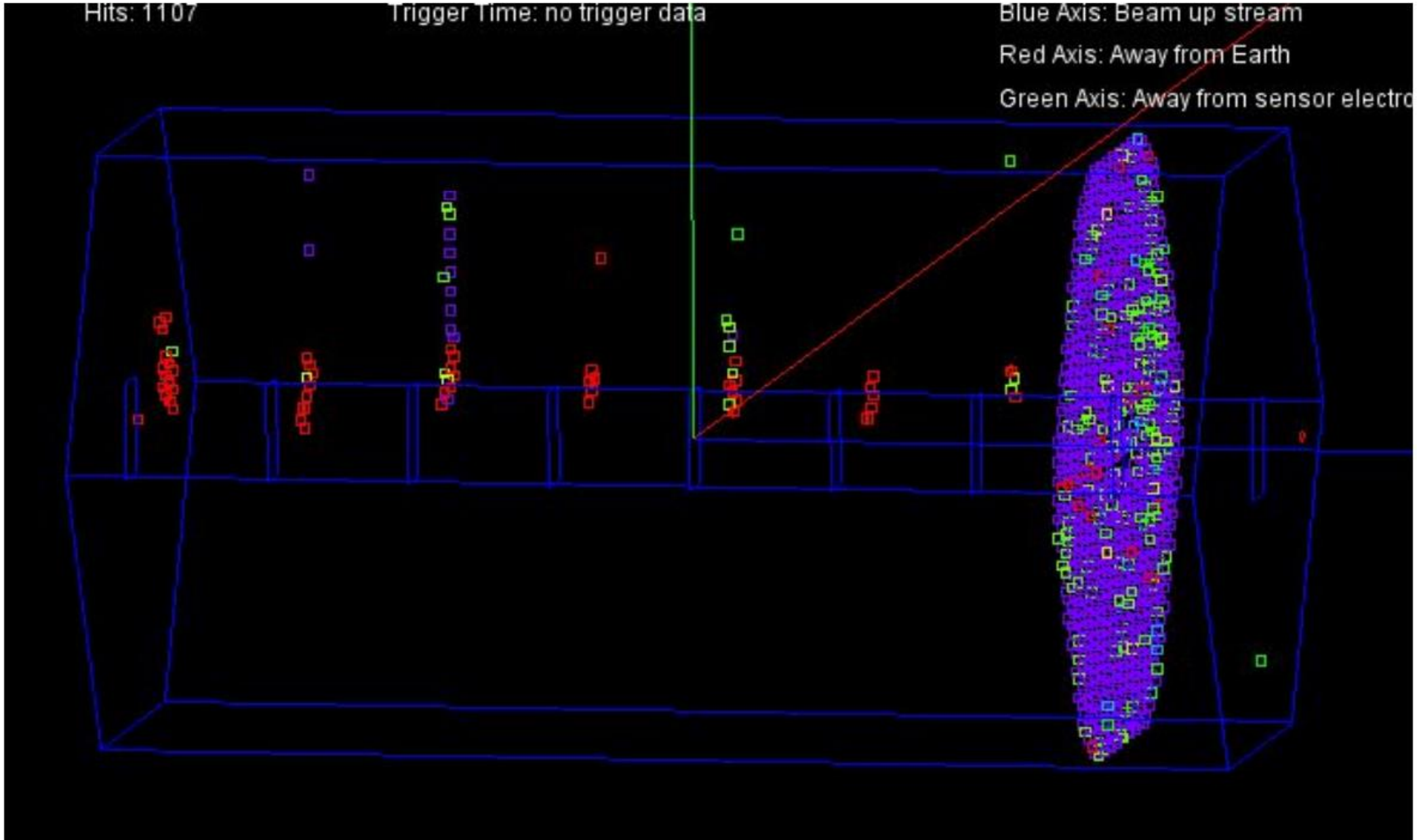
Probe-Tested Sensor



- Additional signal detected in pixels along trace of activated pixel (cross talk)
- Should be reduced with new shielded KPiX model

Work done at the University of Oregon:
C. Gallagher

"monster events" with many negative amplitude and out of time hits



BACKSCATTER