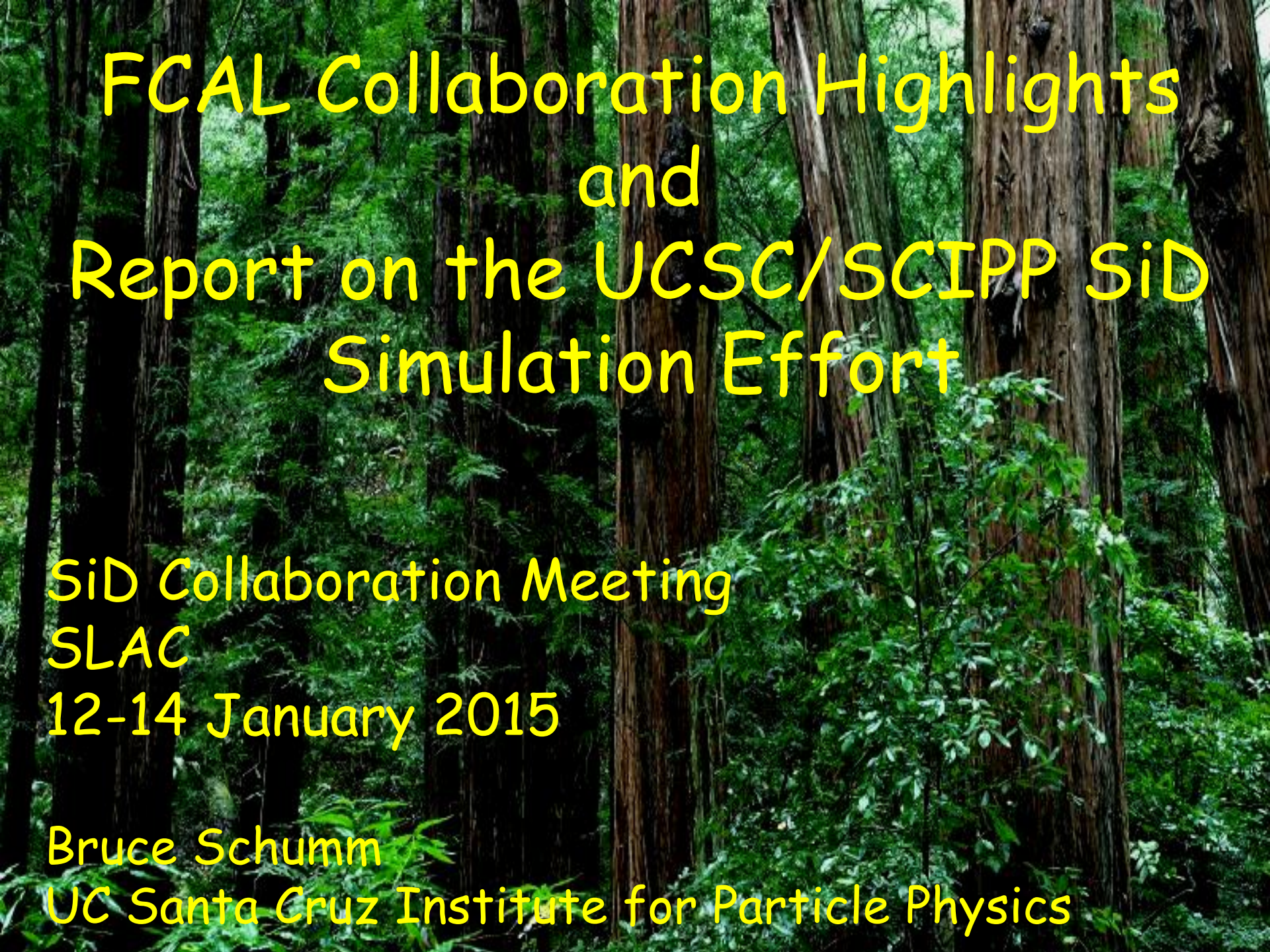


FCAL Collaboration Highlights and Report on the UCSC/SCIPP SiD Simulation Effort

SiD Collaboration Meeting
SLAC
12-14 January 2015

Bruce Schumm
UC Santa Cruz Institute for Particle Physics

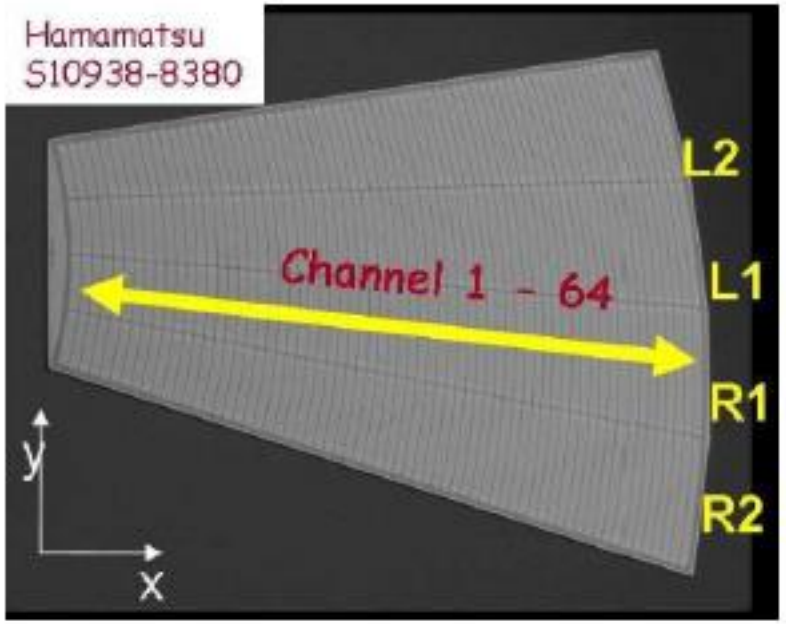
Coup d'etat…

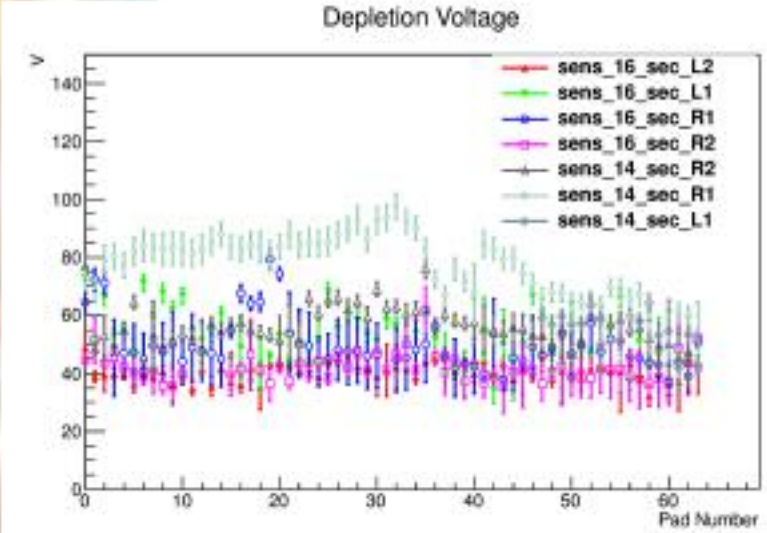
- I have largely commandeered this talk to present our simulation work at SCIPP for purposes of discussion and guidance, and to point out where we need support
- I will start with some quick highlights of the broader FCAL effort
- Formally, I should have had this first portion of the presentation sanctioned by FCAL, but I came too it to late
- So this is NOT an official FCAL collaboration presentation, and should not be taken as such. All errors and omissions are mine. All slides are dated (LCWS14 in October); I'll give a couple of verbal updates.

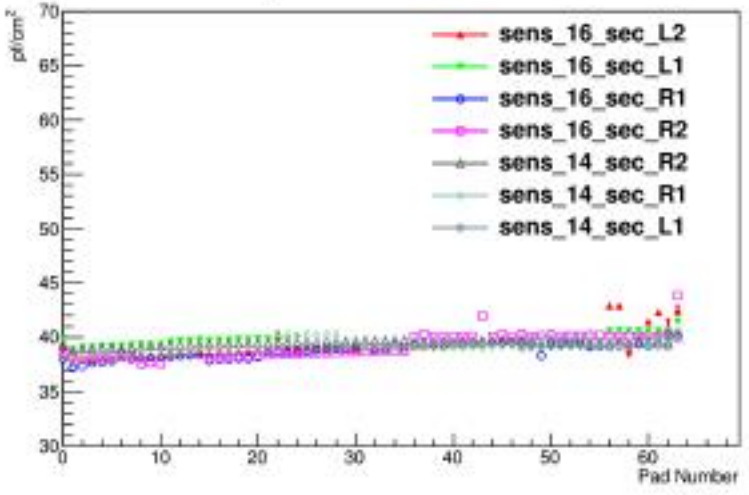
LumiCal sensor

Sasha Boryson
LCWS14

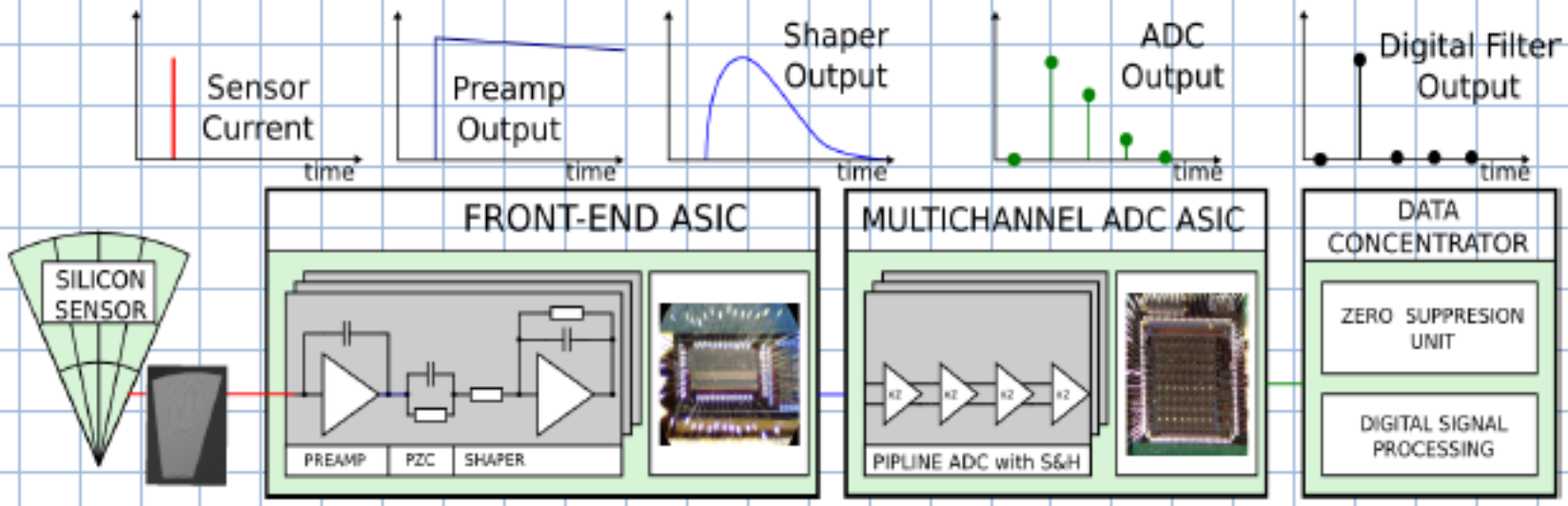
- Silicon sensor
- thickness 320 µm
- DC coupling with read-out electronics
- p^+ implants in n material
- radial pad pitch 1.8 mm
- Azimuthal pitch 7.5°







LumiCal Readout Chain



- **Existing LumiCal detector readout comprises:**
- 8 channel front-end ASIC with preamp & CR-RC shaper Tpeak~60ns, ~9mW (AMS 0.35um)
- 8 channel pipeline ADC ASIC, Tsmp<=25MS/s, ~1.2mW/MHz (AMS 0.35um)
- FPGA based data concentrator and further readout

Angel Abusleme LCWS14

New developments for LumiCal detector readout:

- Prototype front-end ASIC in CMOS 130 nm under development... (presented at TWEPP2014)
- Prototype SAR ADC ASIC in CMOS 130 nm - fabricated and working well, already presented at TWEPP2013

Electronics for FCAL: Summary

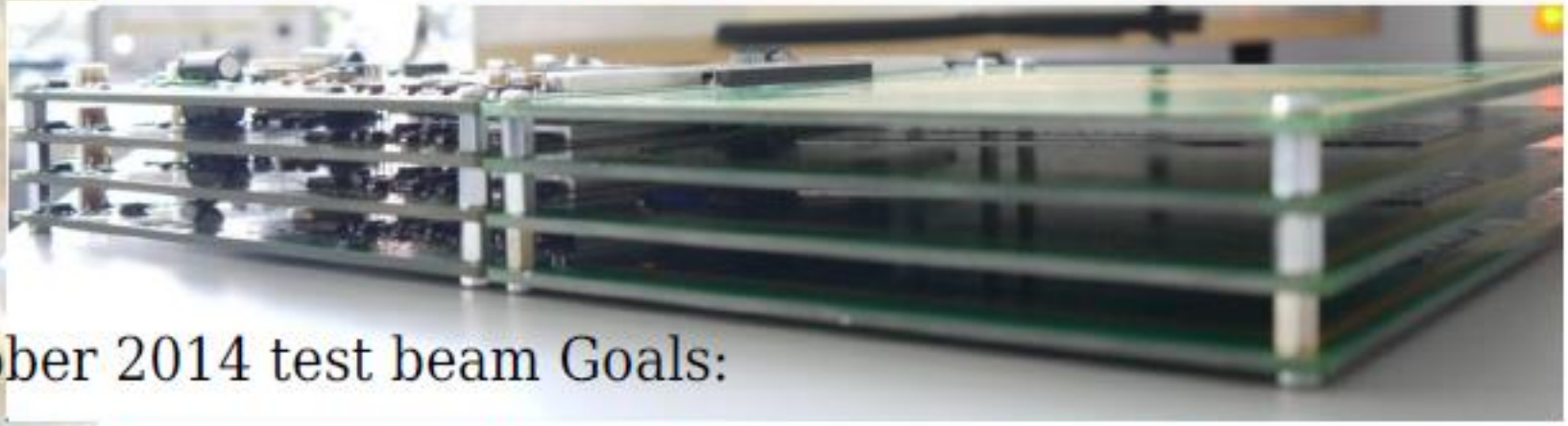
- **AGH and PUC are designing electronics for FCAL**
  - AGH: LumiCal, current design also works for BeamCal
  - PUC: BeamCal, now converging through non-standard design ideas
- **LumiCal**
  - Readout IC in AMS0.35 which we still want to use for multiplane tests
  - 8-channel front-end in CMOS 130 nm, good for test-beam purpose and FCAL studies
  - Successfully designed and tested a 10-bit SAR ADC in CMOS 130nm
  - New 8 channel 10-bit SAR ADC in CMOS 130nm waiting for tests (next 2 months)
- **BeamCal**
  - 3-channel Readout chain in 180nm (2010), tested
  - ADC linearity compensation (2012 – 2013)
  - Arbitrary weighting function synthesis (2013 – 2014)
  - Intentionally nonlinear ADC (ongoing work)

Angel Abusleme
LCWS14

Beam Test of LumiCal Prototype

Sasha Boryson
LCWS14

- Four LumiCal modules have been assembled.
- They were tested in AGH-UST (Krakow) to work together;
- Read out boards were modified to reduce the noise.



October 2014 test beam Goals:

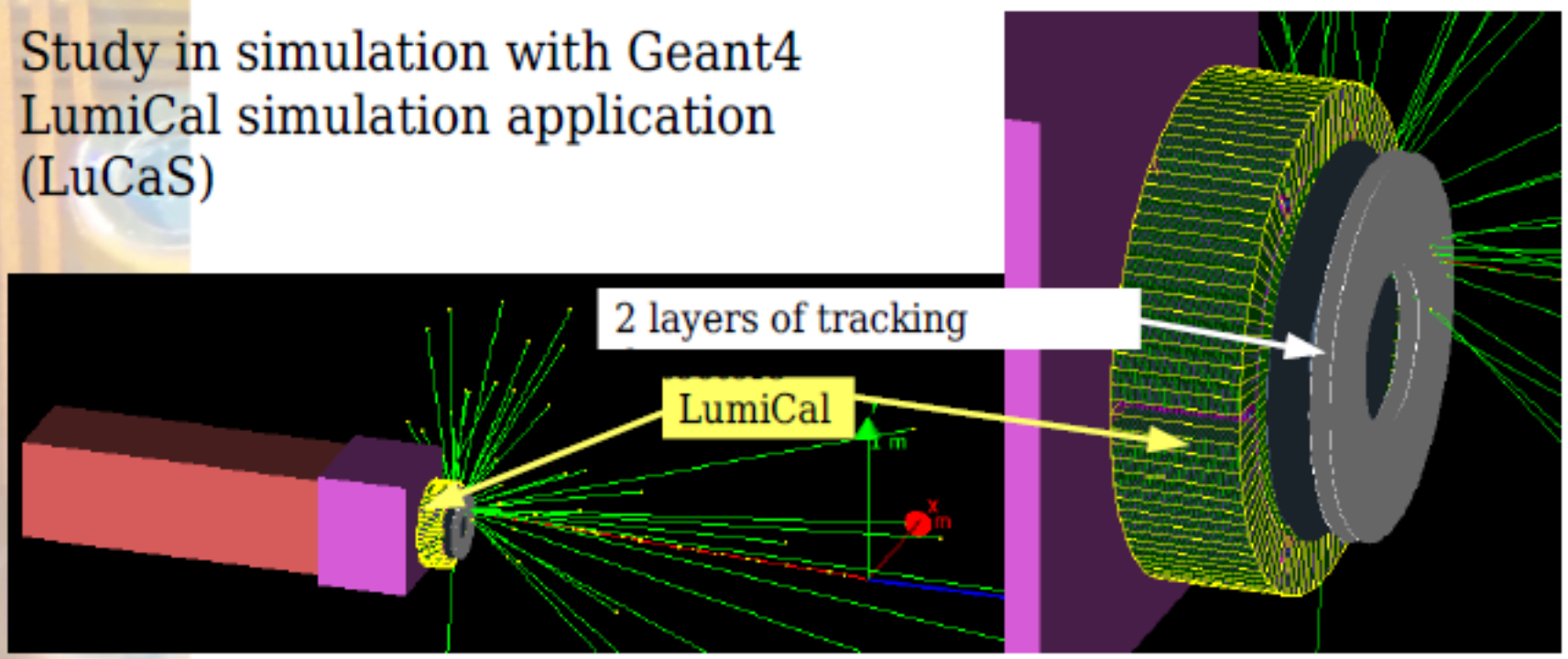
- Tests of the prototype with four detector modules working together;
- Study electromagnetic shower development in a precise and well known structure and compare it with MC;
- Test and improve reconstruction algorithm and particle tagging;
- Measure energy resolution and polar angle reconstruction precision.

Tracking Detector in Front of LumiCal

Sasha Boryson
LCWS14

- Improve polar angle measurement accuracy – important for precise luminosity evaluation;
- Provide information for better LumiCal sensors alignment;
- Provide more information to enable e/γ identification, important for various physics study.

Study in simulation with Geant4 LumiCal simulation application (LuCaS)



Summary

Sasha Boryson
LCWS14

- In the present conceptual design LumiCal and BeamCal detectors can provide luminosity measurements with precision required for physics analysis in linear collider experiments. But if the beam conditions change (e.g. L*) redesign will be required.
- Improvements can still be made in the integration of LumiCal in ECAL.
- Investigation of the performance of LumiCal in combination with tracking detector is in progress.
- There are 4 assembled LumiCal modules, plenty of tungstan absorber plates and mechanical frame ready for calorimeter prototype beam test.
- The paper summarizing the results from 2010 to 2012 beam tests of fully assembled modules is in final preparation. The performance of the modules matches the requirements.
- Development of the next generation of readout chips and detector modules for LumiCal and BeamCal are in progress.

Thanks for your attention!

Simulation Work at UCSC/SCIPP

The SCIPP SiD Simulation Group

The group consists of UCSC undergraduate physics majors

- Christopher Milke (Lead)* — 4th year (will stay for 5th)
- Bryce Burgess, George Courcoubetis — 4th year
- Alix Feinsod, Jane Shtalenkova — 3rd year
- Olivia Johnson — 2nd year

Lead by myself, with technical help from Norman Graf

*Supported part time by our Department of Energy R&D grant

Main effort: BeamCal design and performance studies

Additional study: Forward calorimeter occupancy

Forward Calorimeter Occupancy

Idea: Need to determine how many KPiX buffers needed to read out an entire train of ILC backgrounds (pair backgrounds, high-cross section processes)

Status: Is senior thesis project for George Courcoubetis

*) Have identified list of processes (about 50 in all) that will produce at least 0.1 events per train

*) Will need to form or obtain combined input file of simulated samples with this assortment of events, as well as pair backgrounds (Norman/Tim will help)

*) Are learning how to take simulated events and find hit channels in FCAL

NEEDED: Continued support as questions arise.

BemCal Performance and Design Studies

*) Benchmarking BeamCal reconstruction algorithms

*) Radial vs. rectilinear segmentation

*) Anti-DID field (modeling, effect on performance)

*) Performance vs. segmentation scale

*) Geometrical acceptance issues (how big a spent-beam hole can we get away with?)

*) BeamCal position (effect on performance and detector occupancy)

The SCIPP Reconstruction Algorithm and Background Sensitivity

Nomenclature:

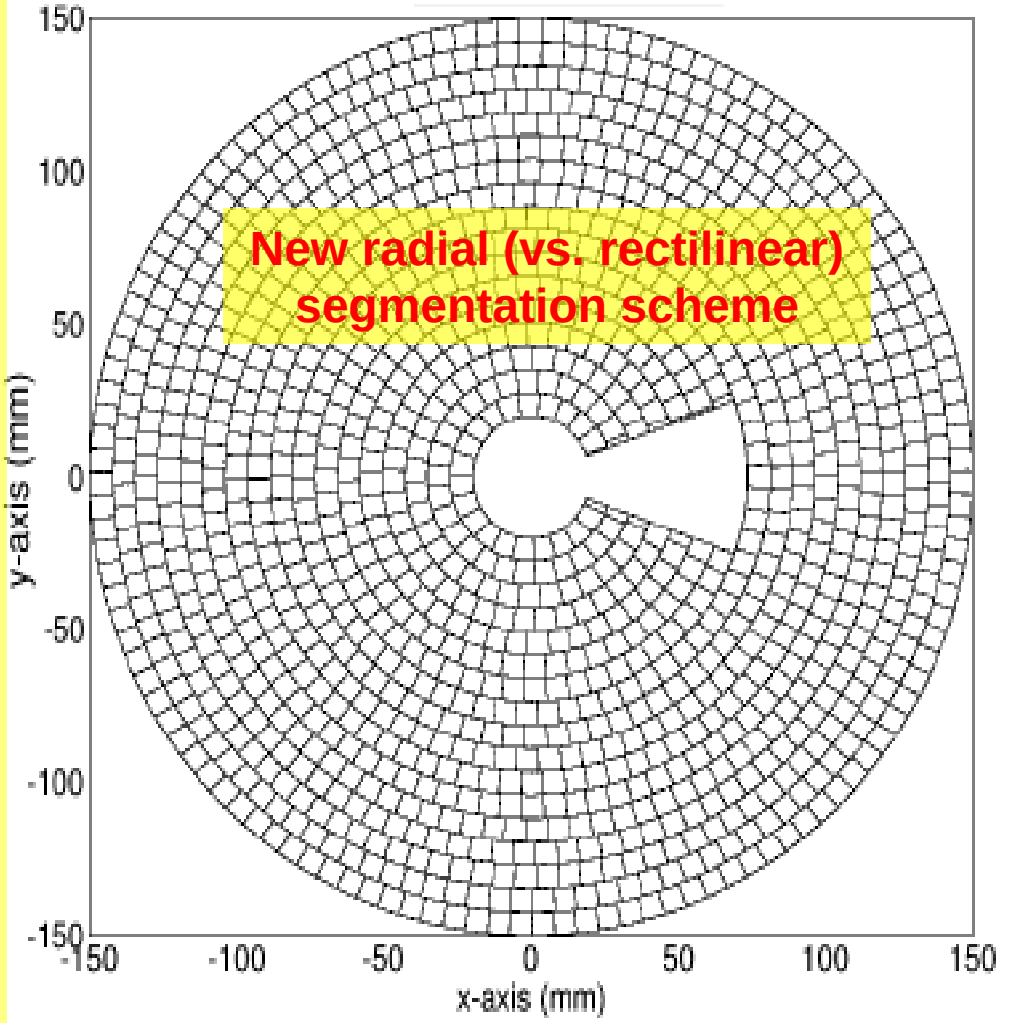
Tile: An individual BeamCal segment

Palette: A collection of tiles within a layer, centered on a given tile and including some number of neighbors

"P0" = tile alone

"P1" = tile + nearest neighbors

"P2" = P1+next-to-nearest neighbors



Cylinder: A palette extended through the depth of the BeamCal

Details of the SCIPP Reconstruction Algorithm

For any given segmentation strategy and scale, we don't know which palette choice will be optimal (P0, P1, P2,…)

➔ Explore efficiency/purity with several choices and take best for that segmentation scheme

For each palette choice, perform the following event-by-event

- Subtract mean background from each palette
- Seed reconstruction with 50 most energetic palettes
- Extend these 50 palettes into cylinders, summing energy along the way
- Accept as signal candidate any event for which the most energetic cylinder is greater than a cut ("sigma cut") expressed in terms of the rms width of the mean-subtracted background in that cylinder

More Details of the SCIPP Reconstruction Algorithm

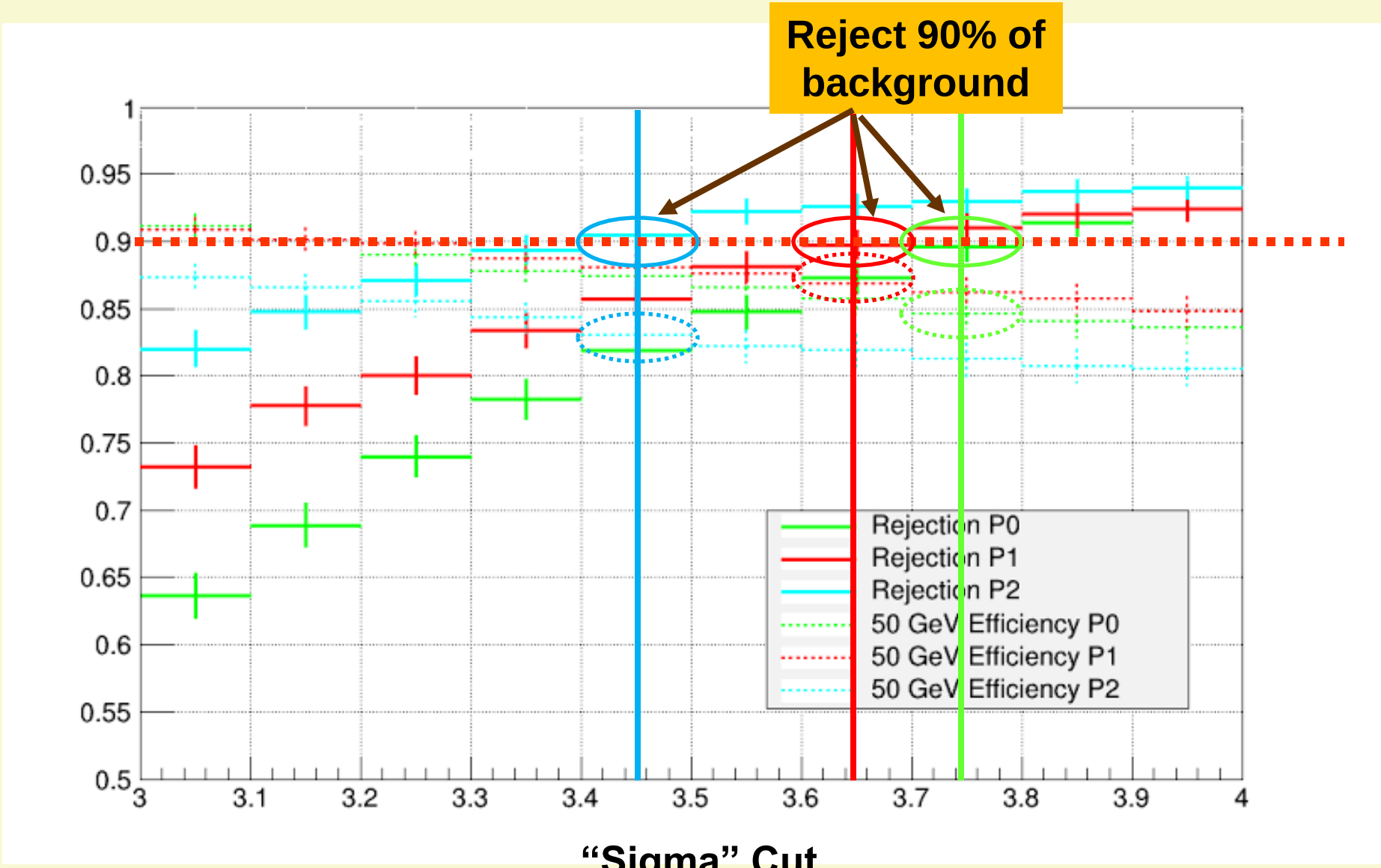
Choice of the value of the sigma cut

- BeamCal used to detect electrons/positrons from low-Q^2 two-photon event that can mimic degenerate SUSY scenarios
- SUSY signal events will have no forward e^+ or e^- so it will look like a “background” event in the BeamCal
- The fraction of BeamCal background events mistakenly identified as BeamCal signal events (and thus rejected) is a SUSY-signal inefficiency
- The sigma cut is selected to mis-identify 10% of BeamCal background events as BeamCal signal events

With this cut established, the efficiency of the BeamCal reconstruction algorithm can be explored as a function of radius

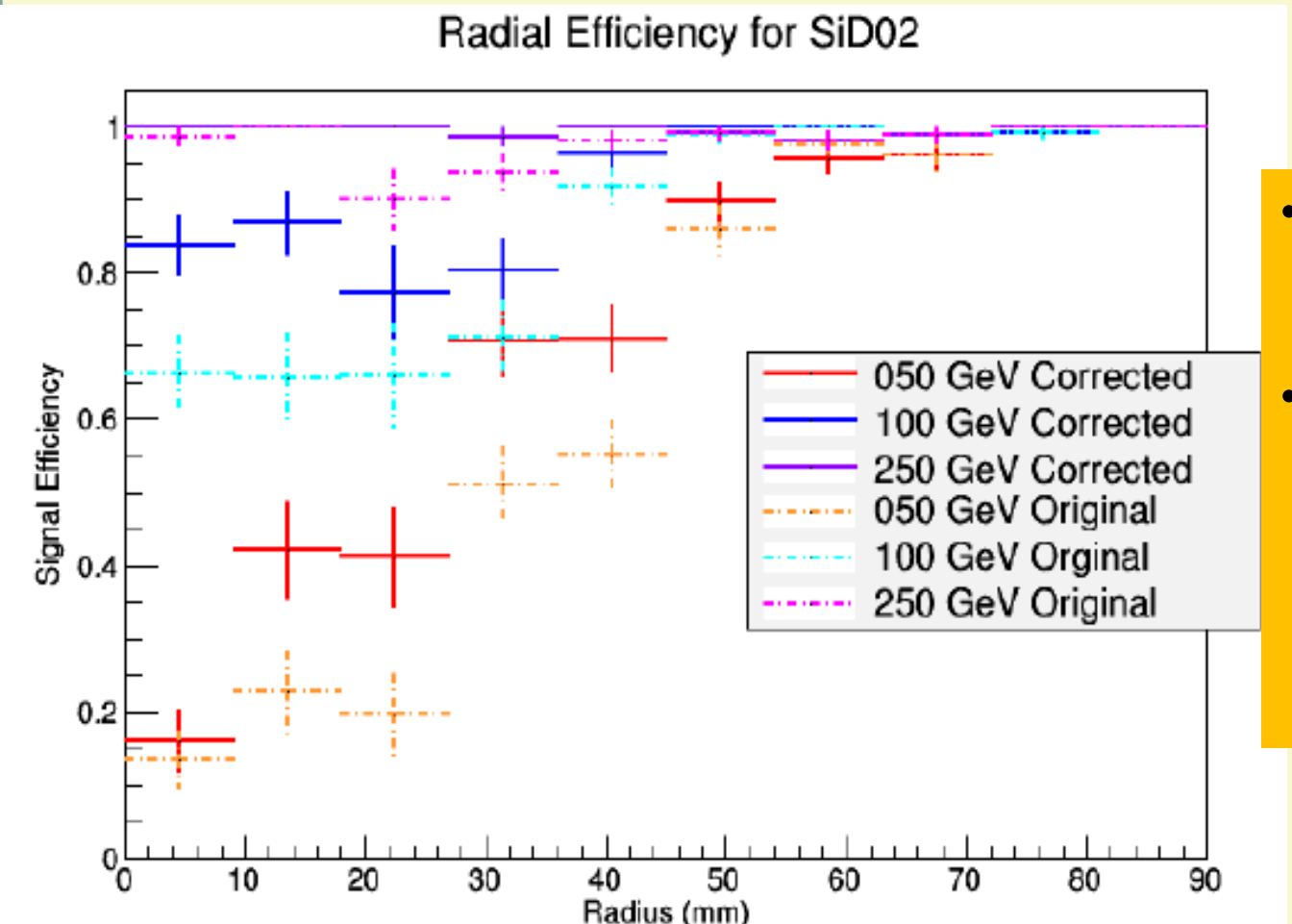
“Palette” Size Selection

Optimize 50GeV reconstruction efficiency@10% fake rate



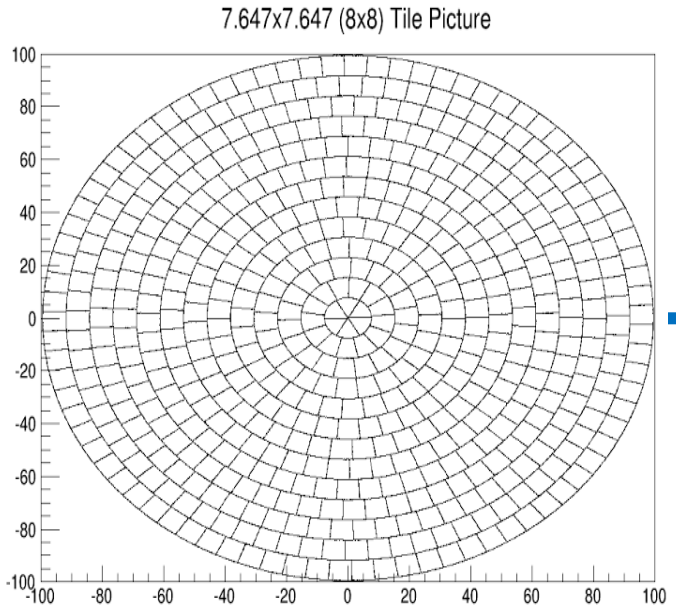
Effect of S/N on BeamCal Reconstruction Performance I

x2 background achieved (accidentally) by overlaying the two (±z) halves of the BeamCal ("Original" in plot)



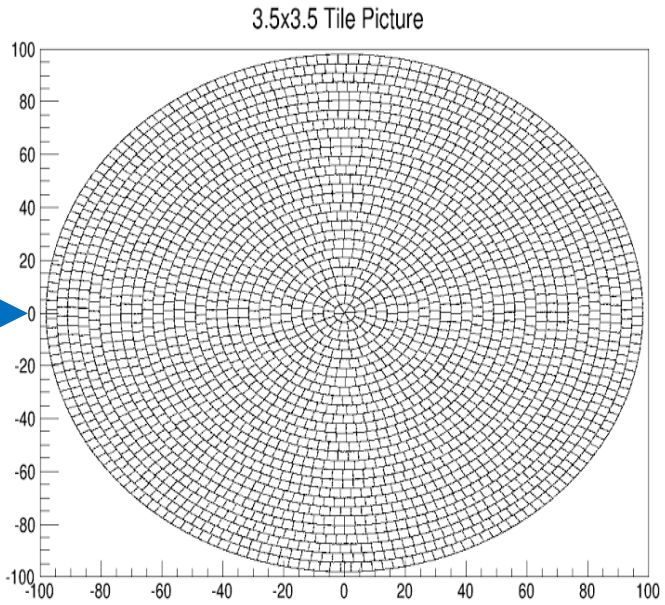
- **Model is SiD02, no anti-DID**
- **"Original" is with the x2 background, and is close to SiDLoi3 no anti-DID (most conservative of all models)**

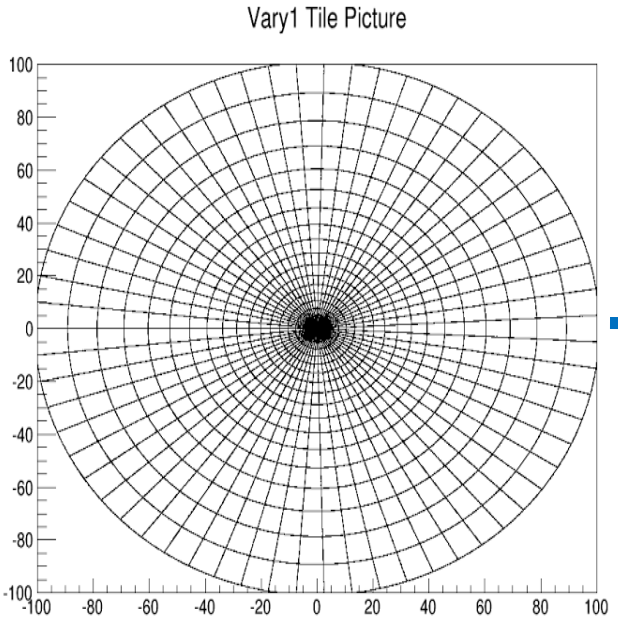
Tiling strategy and granularity study



Constant

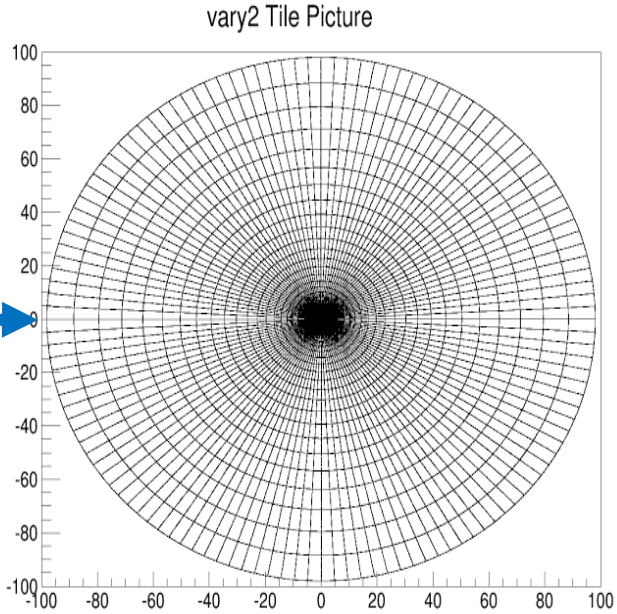
7.6x7.6
5.5x5.5
3.5x3.5



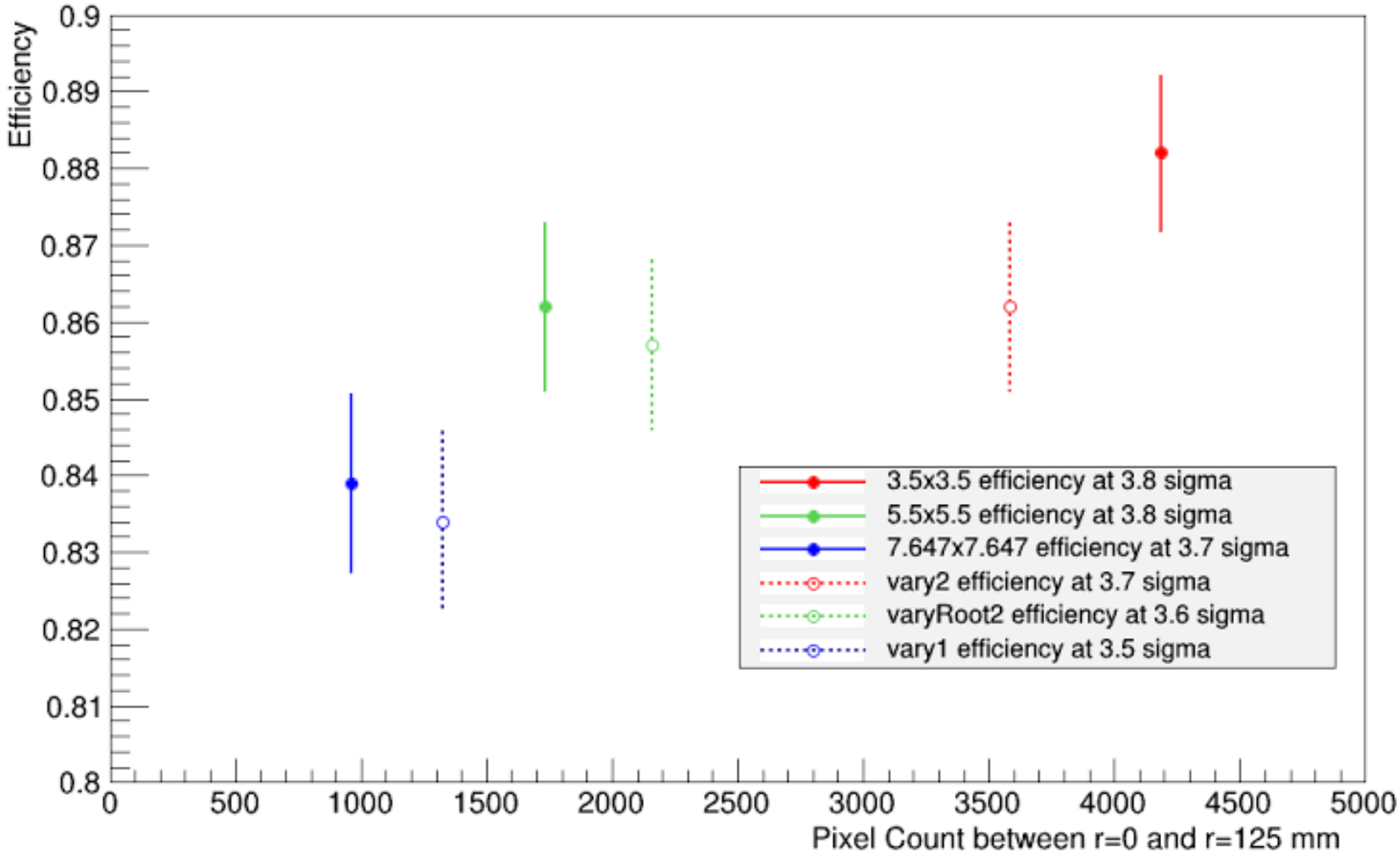


Variable

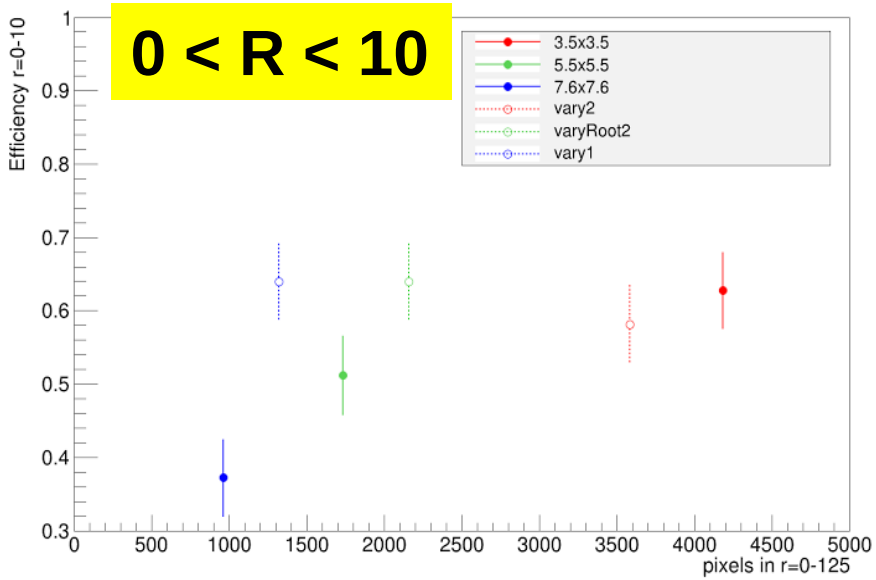
Nominal
Nominal/√2
Nominal/2

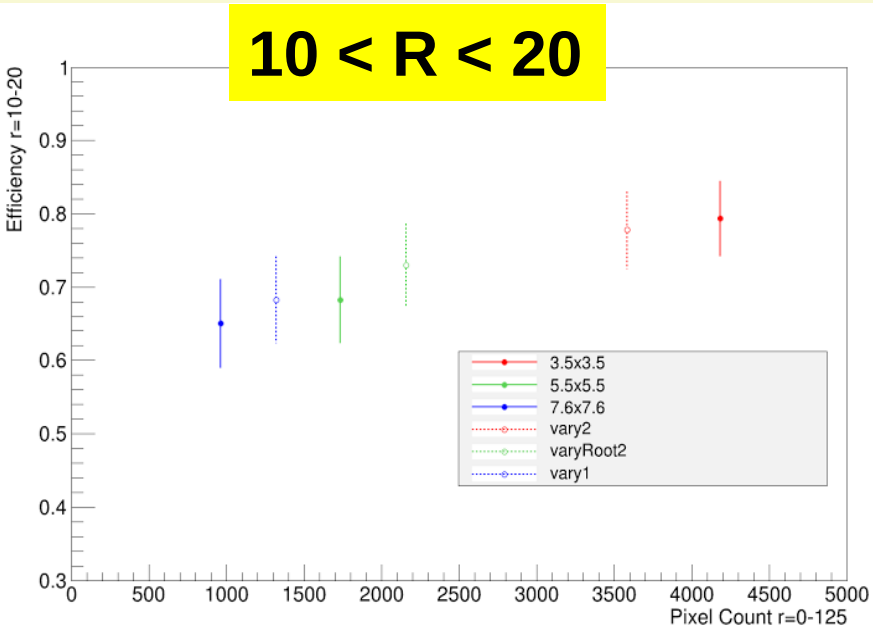


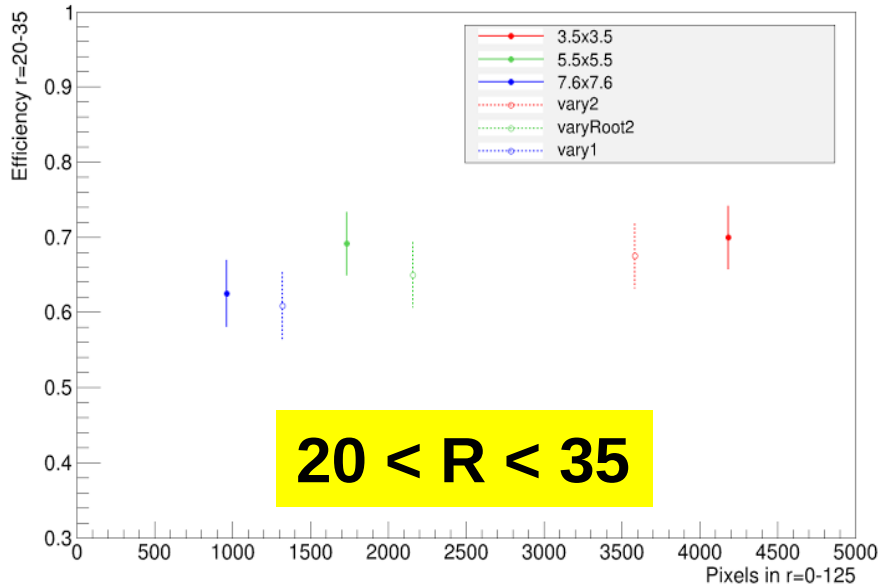
Comparison of Segmentation Schemes Overall Efficiency vs. # of pixels

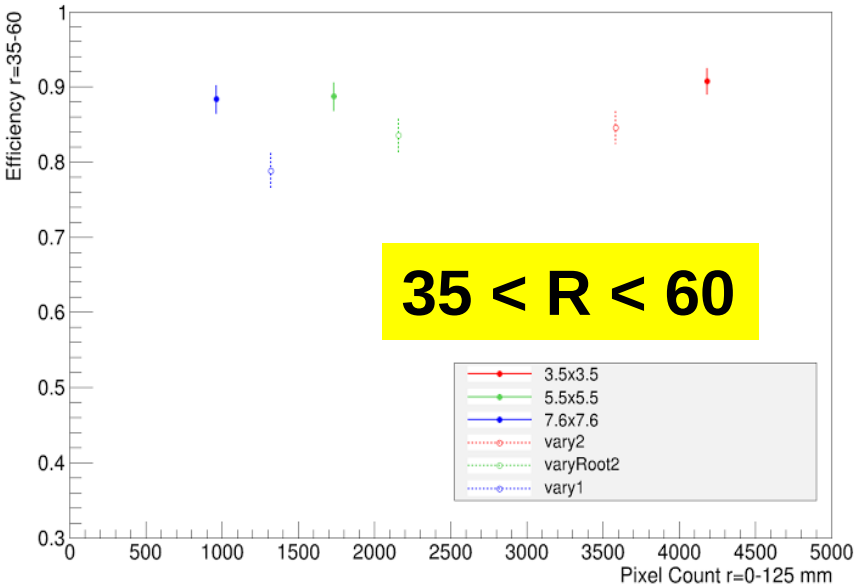


Efficiency v. #pixels in radial slices (50 GeV)









Ongoing Projects and Plans

Reconstruction Code Benchmarking

Milke is implementing one of the two BeamCal reconstruction algorithms from the ILD-oriented FCAL members (Andre Sailer's code)

- Will run on the SiD-oriented input files
- Will compare results to those of our reconstruction in apples-to-apples comparison
- Study will either be used to improve our algorithm or confirm its efficacy

Anti-DID Studies

Want to compare current parametrization of the non-solenoidal field components to the exact model.

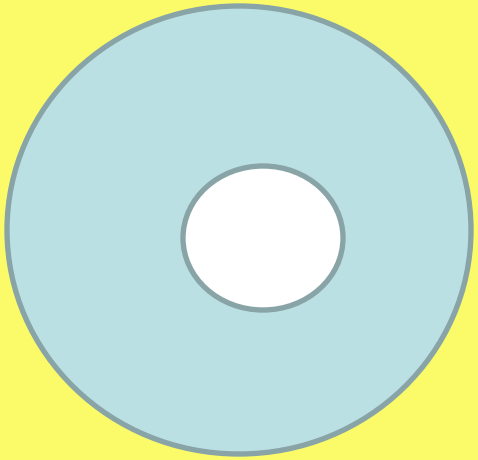
- Have the specifications for the parameterization from Takashi
- Have established with Tom M. and confirmed with Norman the grid over which the exact calculation should be done

NEEDED: For Wes Craddock to carry out that calculation and get the results to us (soon please?)

Also: Burgess is exploring the performance difference between the SiD02 (DBD) BeamCal geometry and that of SIdLoi3, with and without the anti-DID field

Exit Hole Geometry

Want to see what we can get away with in terms of simplifying the exit-hole geometry. For example, we discussed comparing the following two options



Feinsod and Shtalenkova are almost done learning how to use the reconstruction, and will explore this soon. Will produce efficiency vs. radius plots with and without the geometrical acceptance effects.

MAJOR PROJECT

BealCal Position (L*)

Need to understand the effect of moving the BeamCal position

- BeamCal reconstruction performance
- Backsplash into (vertex) detector

NEEDED: Help from Norman in learning how to do the simulation of single electron “signal” (even radial and azimuthal illumination at fixed electron energy) and pair backgrounds, including backsplash into detector elements

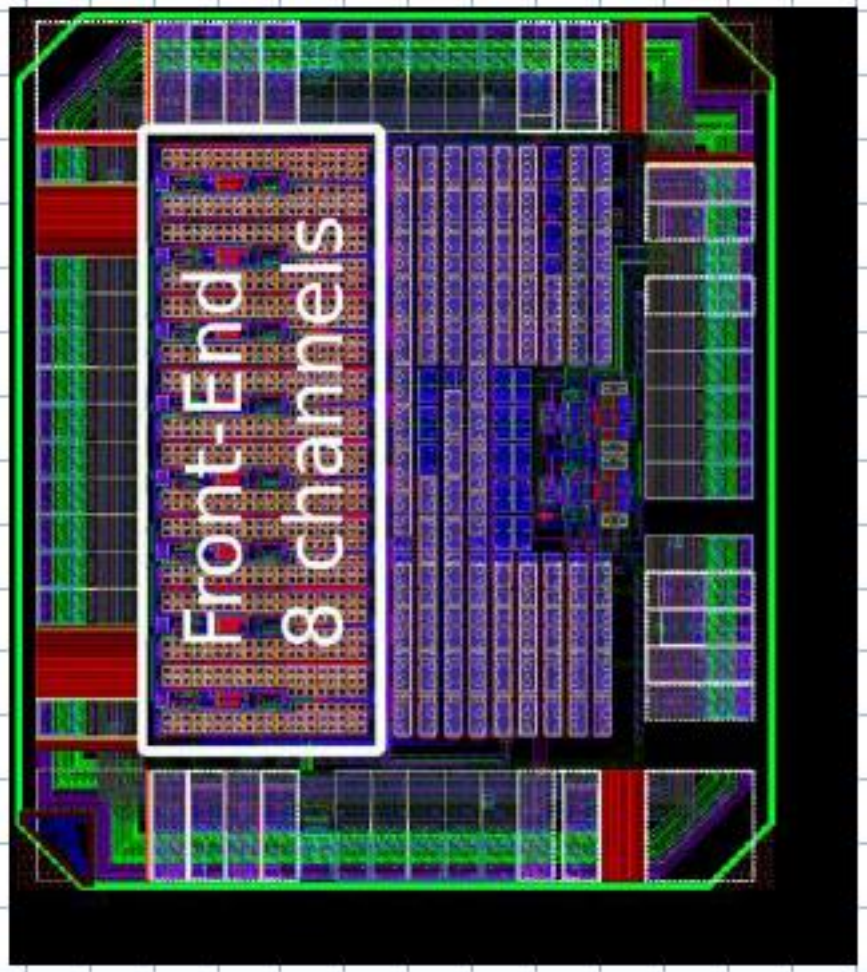
Parting Thoughts

- The SCIPP simulation group is active on a number of fronts.
- In addition to expanding our BeamCal efforts, we are also looking into the forward EMCal occupancy.
- We have a number of studies in mind, largely related to answering design questions about the BeamCal. We continue to be open to suggestion or refinements.
- Support from Norman and others will remain essential.

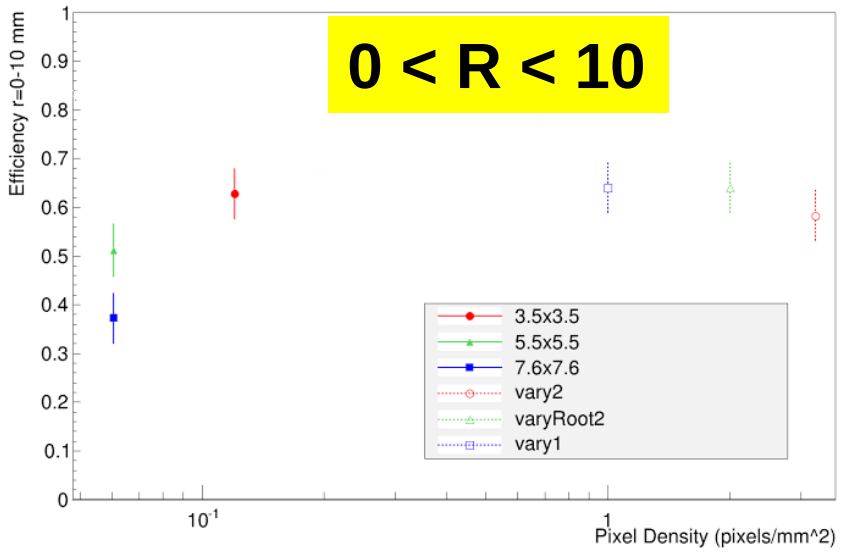
New 8-channel front-end in CMOS 130 nm

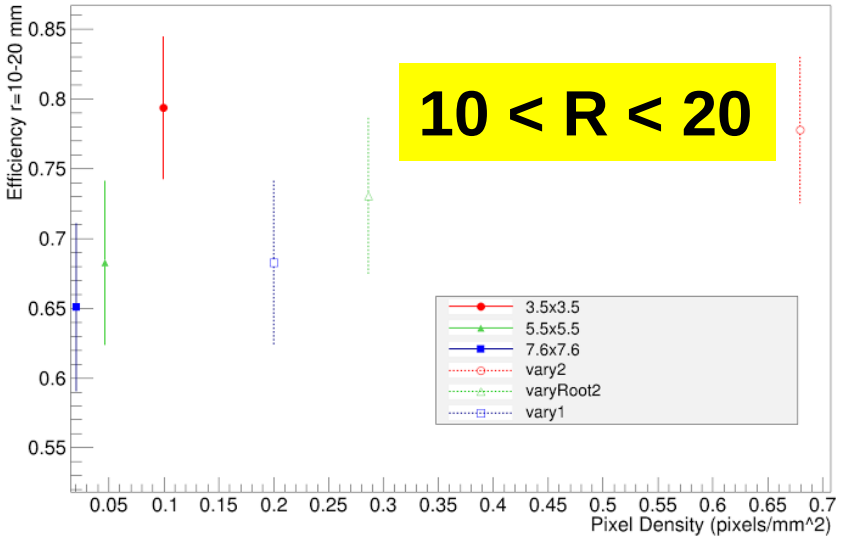
CMOS 130 nm technology

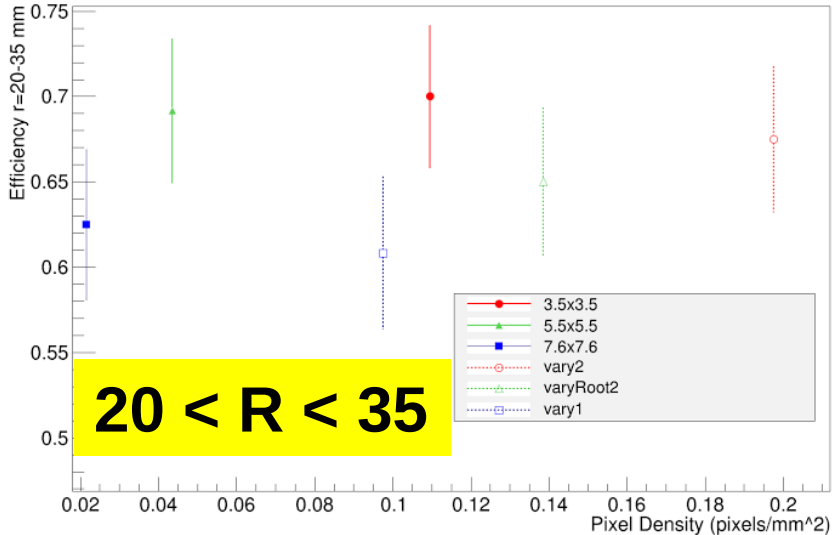
- 8 channels
- Detector capacitance Cdet ≈ 5 ÷ 50pF
- CR-RC shaping with peaking time Tpeak ≈ 50 ns
- Variable gain:
- calibration mode - MIP sensitivity
- physics mode - input charge up to ~6 pC
- Power pulsing
- Peak power consumption ~1.5 mW/channel
- Pitch ~140 um
- Noise: ENC ~ 1000e– @10pF
- Crosstalk < 1%

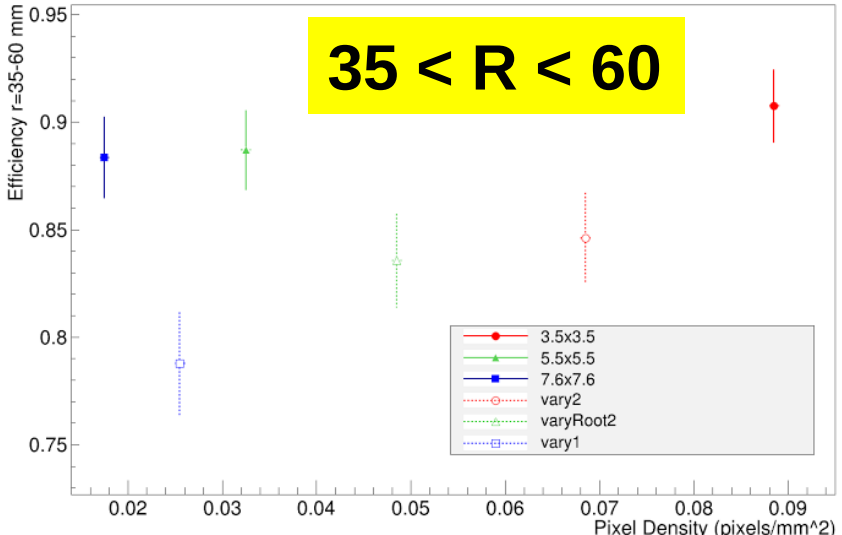


Efficiency v. pixel density in radial slices



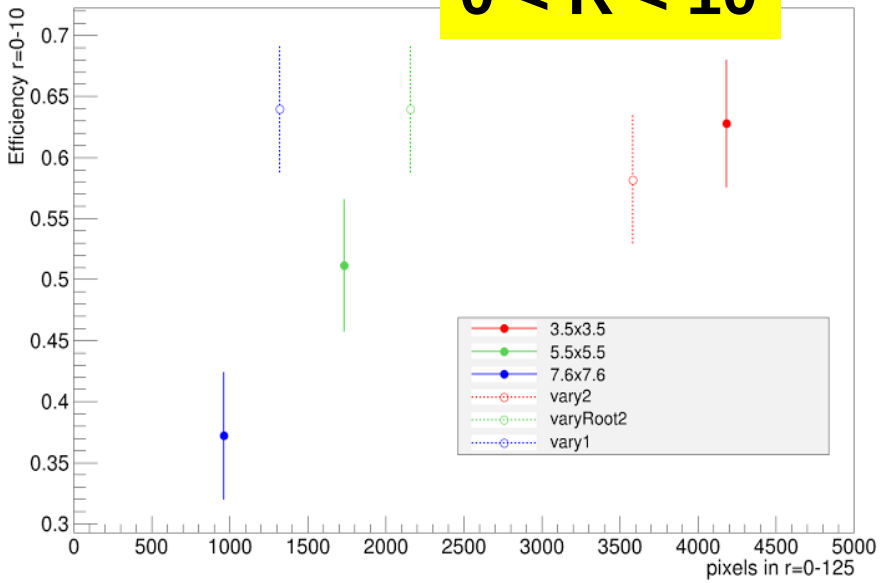




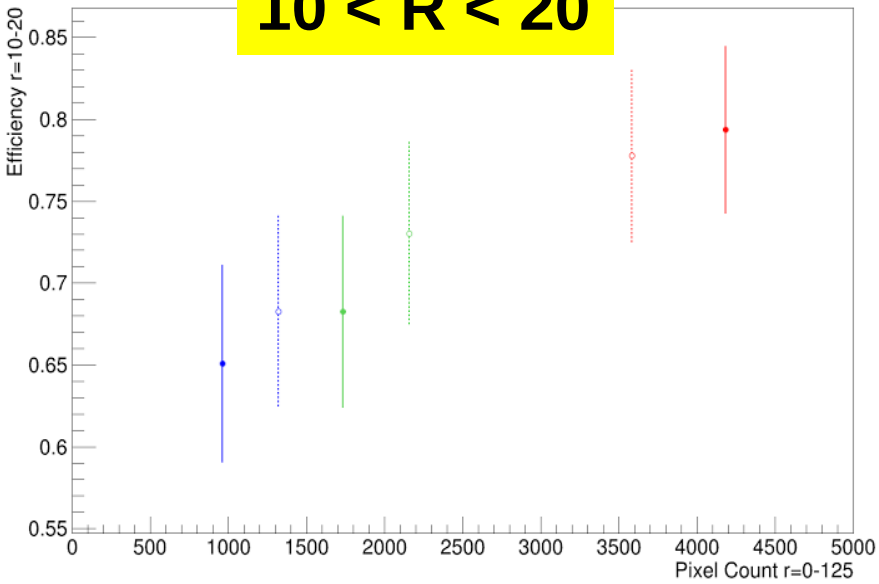


Efficiency v. #pixels in radial slices (50 GeV)

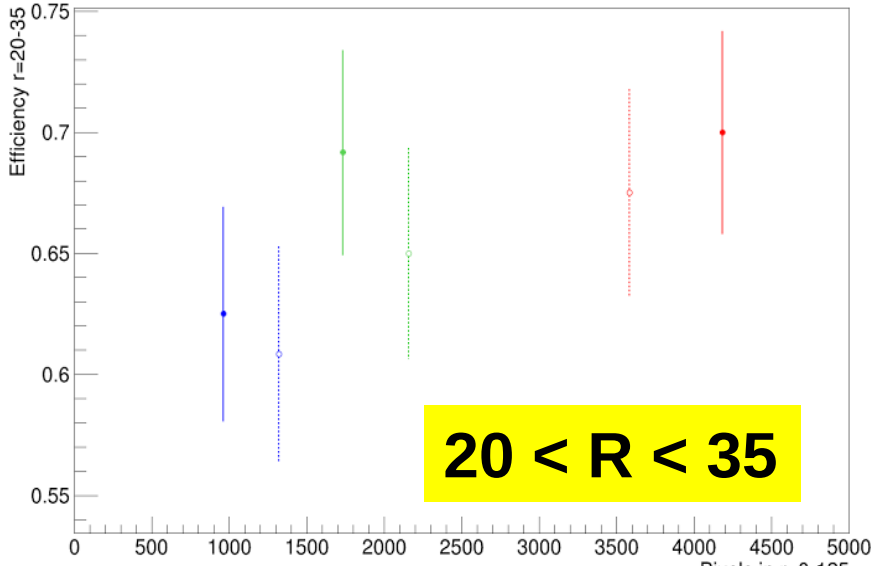
0 < R < 10



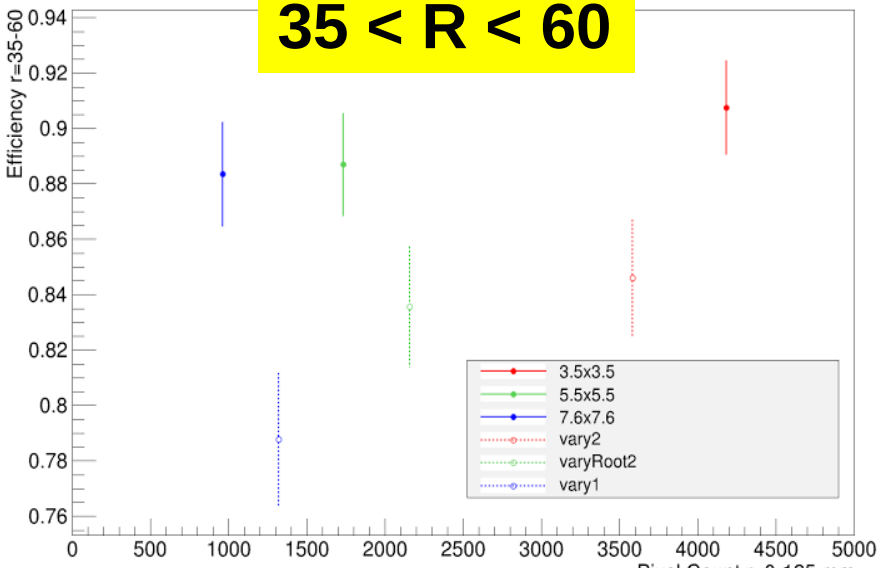
10 < R < 20



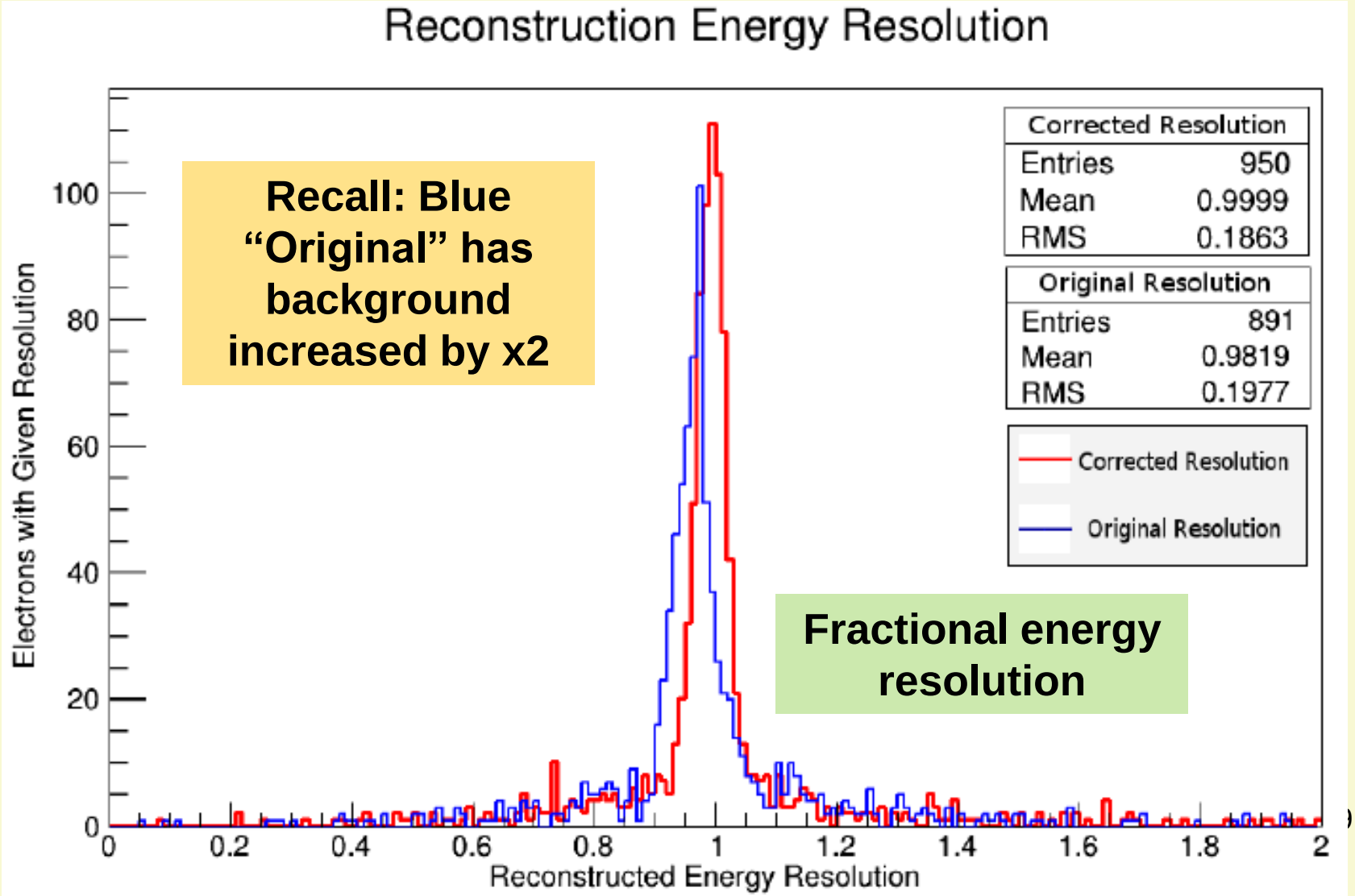
20 < R < 35



35 < R < 60



Effect of S/N on BeamCal Reconstruction Performance II



Effect of S/N on BeamCal Reconstruction Performance III