UNIVERSITY OF CALIFORNIA SANTA CRUZ
International Linear Collider

SiD FCal DBD Report

SiD Workshop
August 21-23 2012

Bruce Schumm
UCSC/SCIPP

Three Main Developments Reported in DBD

- **Bean Chip Development**
- **BeamCal Shower Reconstruction and Stau Co-Annihilation Region Study**
- **Radiation Damage Studies / Facility Planning**

The BEAN (Beamcal) Chip

Main Proponent:

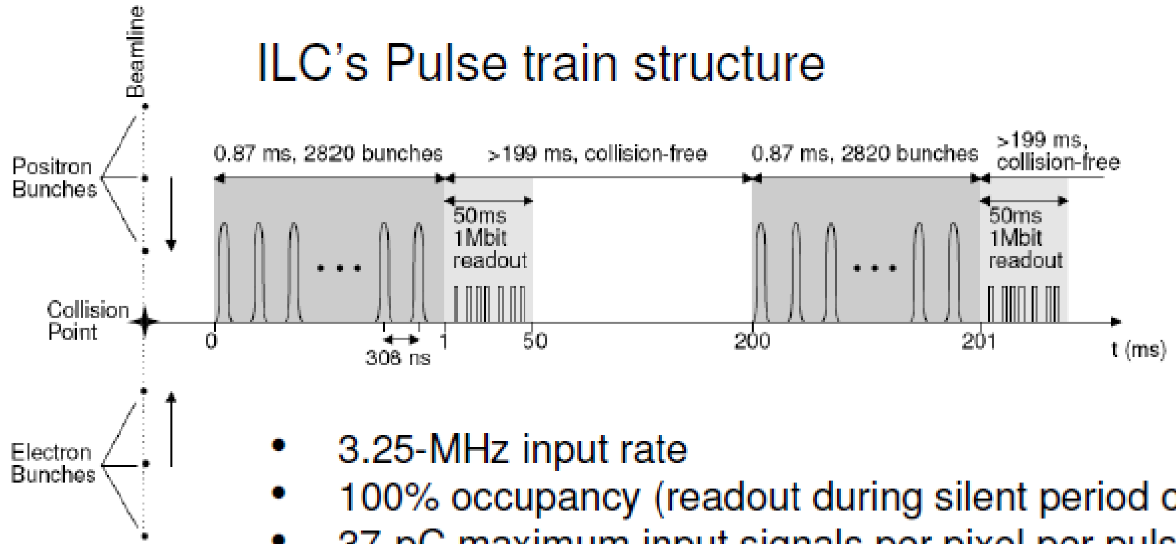
Angel Abusleme, Prof. of Electrical Eng.

Pontificia Universidad Católica de Chile

Initial development done at SLAC/Stanford (Abusleme was Stanford grad student)

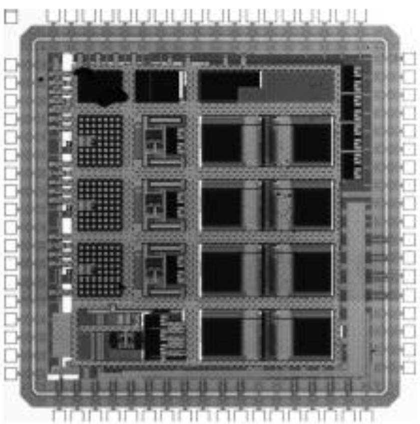
BeamCal Instrumentation ASIC Specs

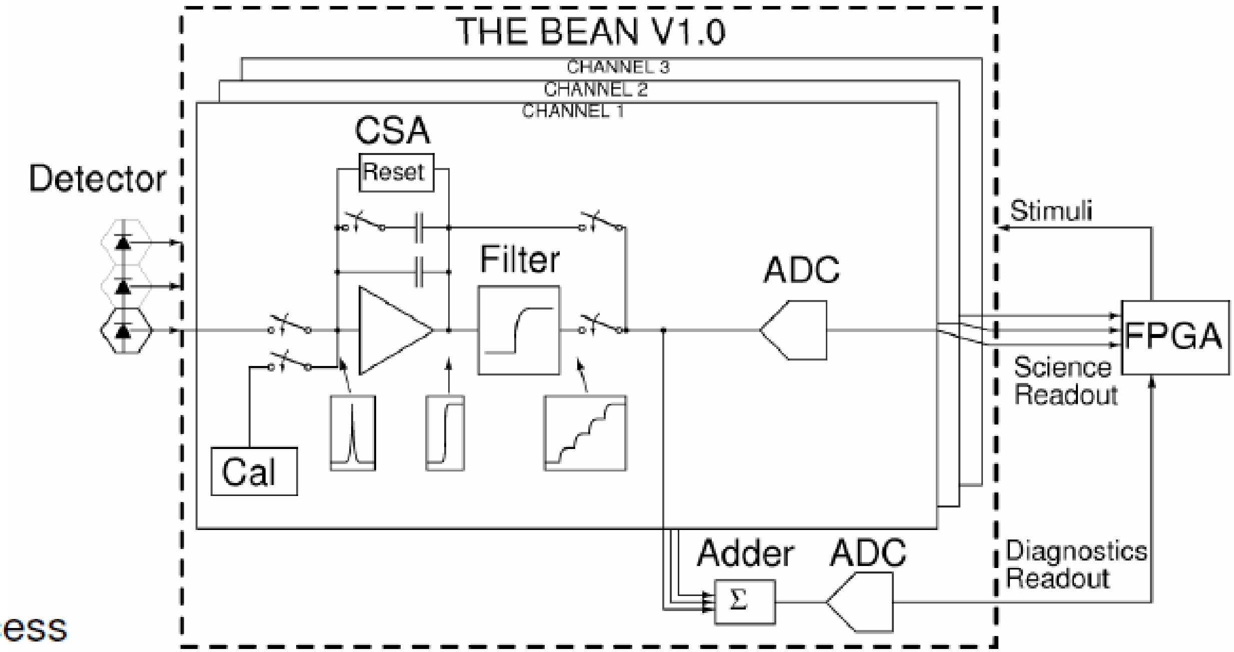
ILC's Pulse train structure



- 3.25-MHz input rate
- 100% occupancy (readout during silent period of pulse trains)
- 37-pC maximum input signals per pixel per pulse[1]
- 40-pF input capacitance[1]
- 10-bit resolution
- Dual gain (50x) for different modes of operation: standard data taking (SDT) and detector calibration (DCal)
  - SDT: large input signal; slew rate, bandwidth and adder challenges
  - DCal: smaller input signal; noise, baseline restoration and linearity challenges (tighter design space)
- 32 channels per chip
- Full-chip output (8-bit, 1-μs latency) for beam diagnostics
- Radiation tolerance to 1 Mrad total dose

The Bean Prototype: System-Level Design





- 180-nm TSMC process
- Fully independent channels
- Digital memory to store 32 channels x 2820 x 10-bit results per ASIC
- Precharge circuit for the charge-sensitive amplifier (CSA) to maximize output swing
  - CSA precharger doubles as on-chip pulser for electronics calibration
- SC adder followed by a dedicated ADC
- Gated reset for quick baseline restoration
  - This has noise consequences in DCal mode

“Proof-of-Principle” ASIC working largely as designed

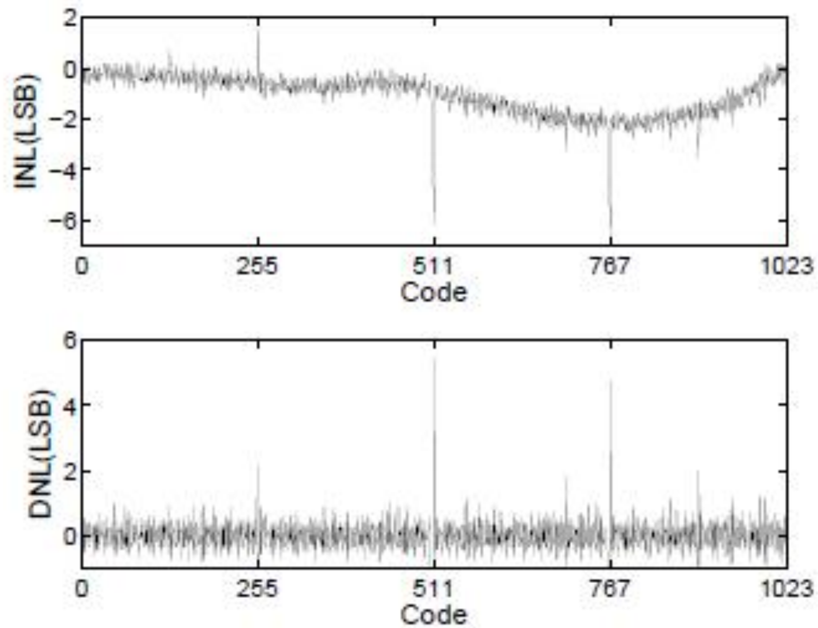


Figure 8.1.4: The Bean integrated (INL) and differential (DNL) non-linearity in the standard data-taking (SDT) mode.

Integrated and differential non-linearity

BEAN ASIC: Next Steps

- Incremental improvements to filtering strategy
- Scale from 3 to 32 channels
- Some issues with higher noise in Calibration Mode need to be addressed
- Digital back-end (switched capacitor array) for storage of full beam-spill for quiescent readout
- Abusleme has obtained funding from Chilean government
- Working largely with FCAL group now

BeamCal Reconstruction and the Study of Stau Production in the Co-Annihilation Region

Edward Estrada
Alec Jenkins
Kevin Fiedler
Uriel Nauenberg

http://hep-www.colorado.edu/SUSY/stau1_signal_analysis.pdf

Cosmological arguments motivate a small mass difference between the stau and the LSP (which is the $\chi_1{}^0$, the lightest neutralino)

Model	B'	C'	D'	G'	I'
$\tilde{\tau}^-$	110.6	170.6	223.9	158.6	144.6
$\tilde{\chi}_1^0$	96.5	161.0	216.4	150.9	140.8

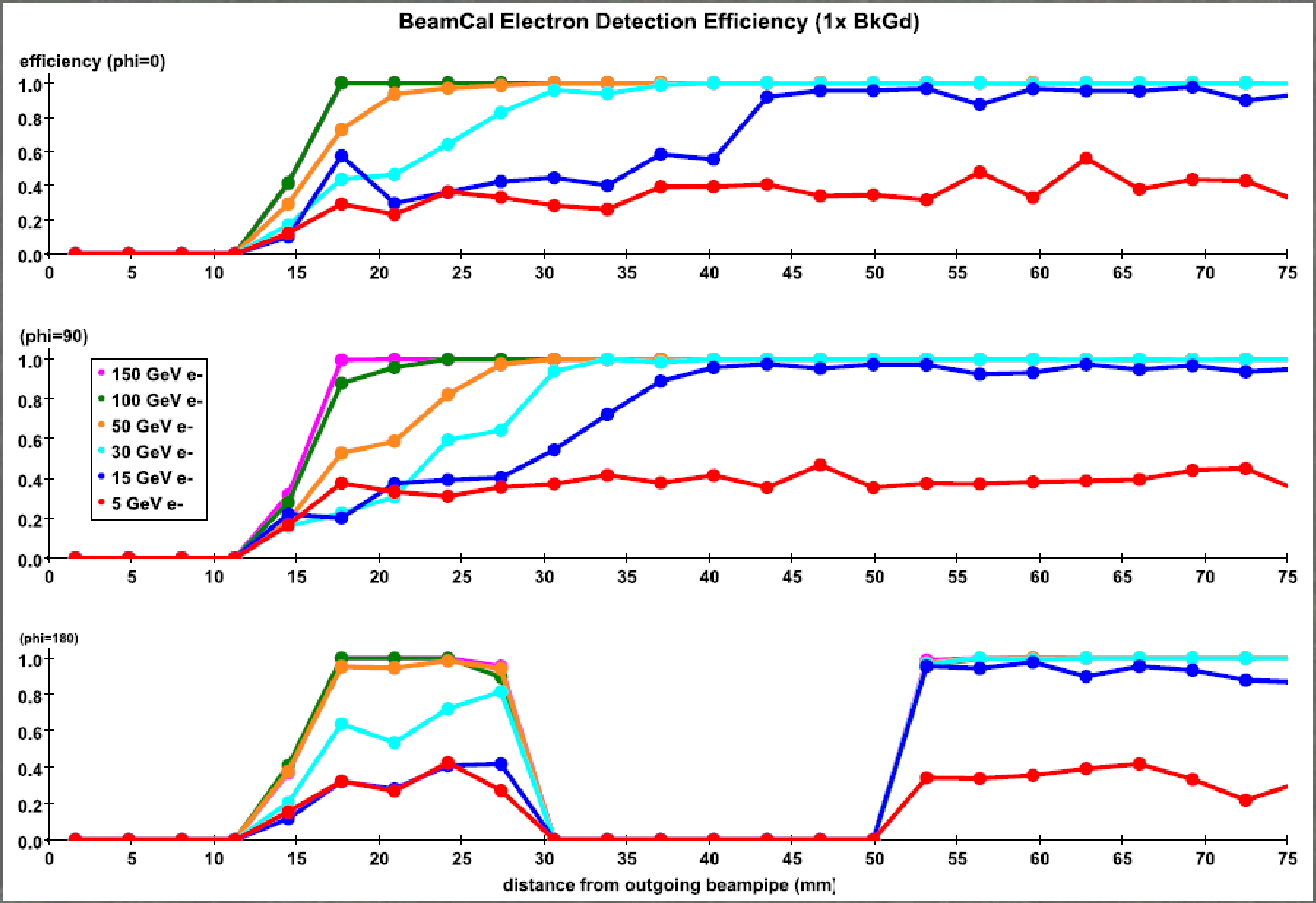
Masses in GeV

$$\tilde{\tau}^{\pm} \rightarrow \tau^{\pm}\tilde{\chi}_1^0$$

Sole decay mode leaves little energy in the detector

$$e^+e^- \rightarrow e^+\gamma^* e^-\gamma^*$$

Two-photon processes also leave little energy in the detector but substantial energy in the far-forward system from the deflected beam particles



BeamCal Electron Detection Efficiency (1x BkGd)
efficiency (phi=0)
(phi=90)
(phi=180)
150 GeV e-
100 GeV e-
50 GeV e-
30 GeV e-
15 GeV e-
5 GeV e-
distance from outgoing beampipe (mm)

Performance of C’ point with and without beamcal rejection

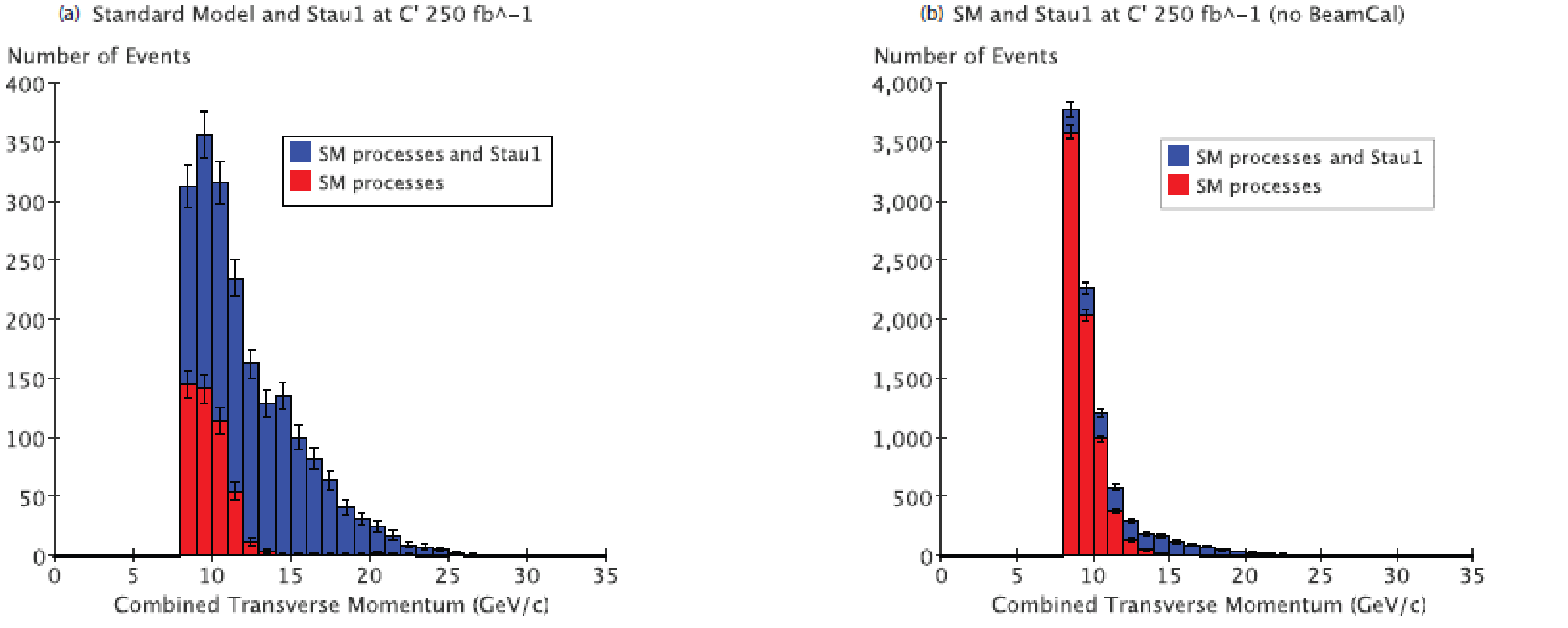
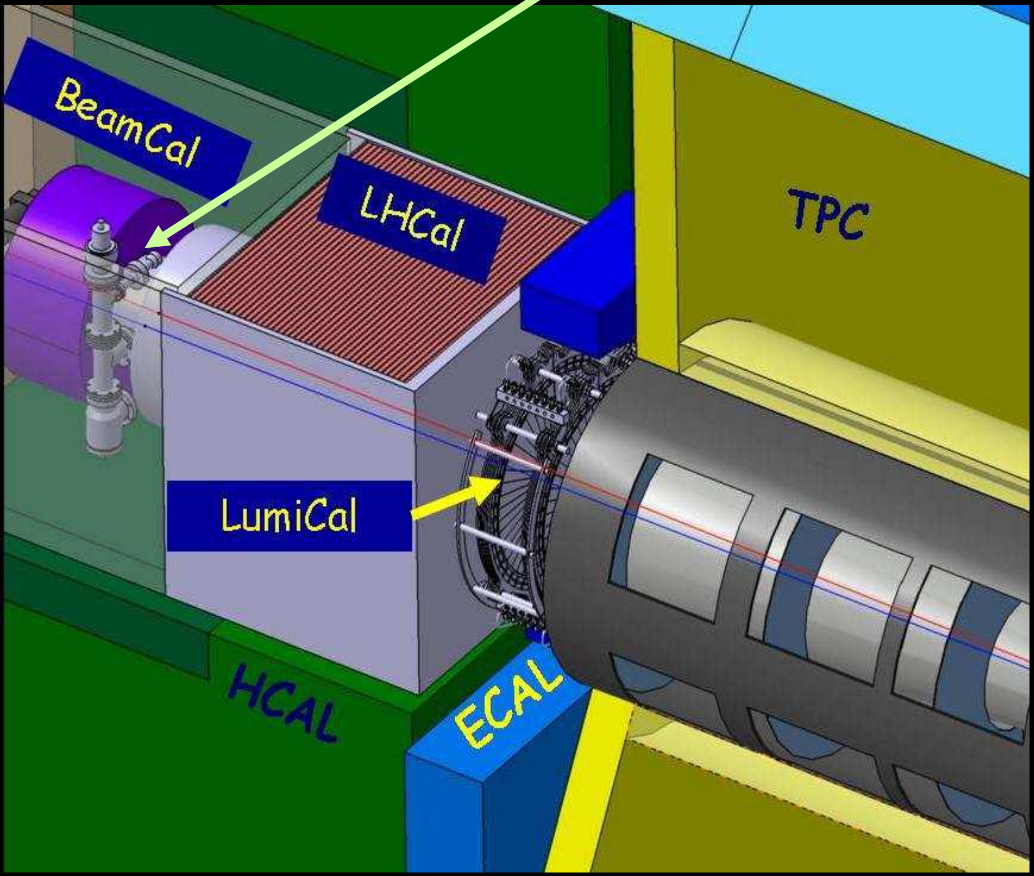


Figure 8.1.6: (a) PT distribution with BeamCal veto and (b) without at the benchmark point C’.


Radiation
Damage
Facility

The Issue: ILC BeamCal Radiation Exposure



ILC BeamCal:

Covers between 5 and 40 miliradians

Radiation doses up to 100 MRad per year

Radiation initiated by electromagnetic particles (most extant studies for hadron – induced)

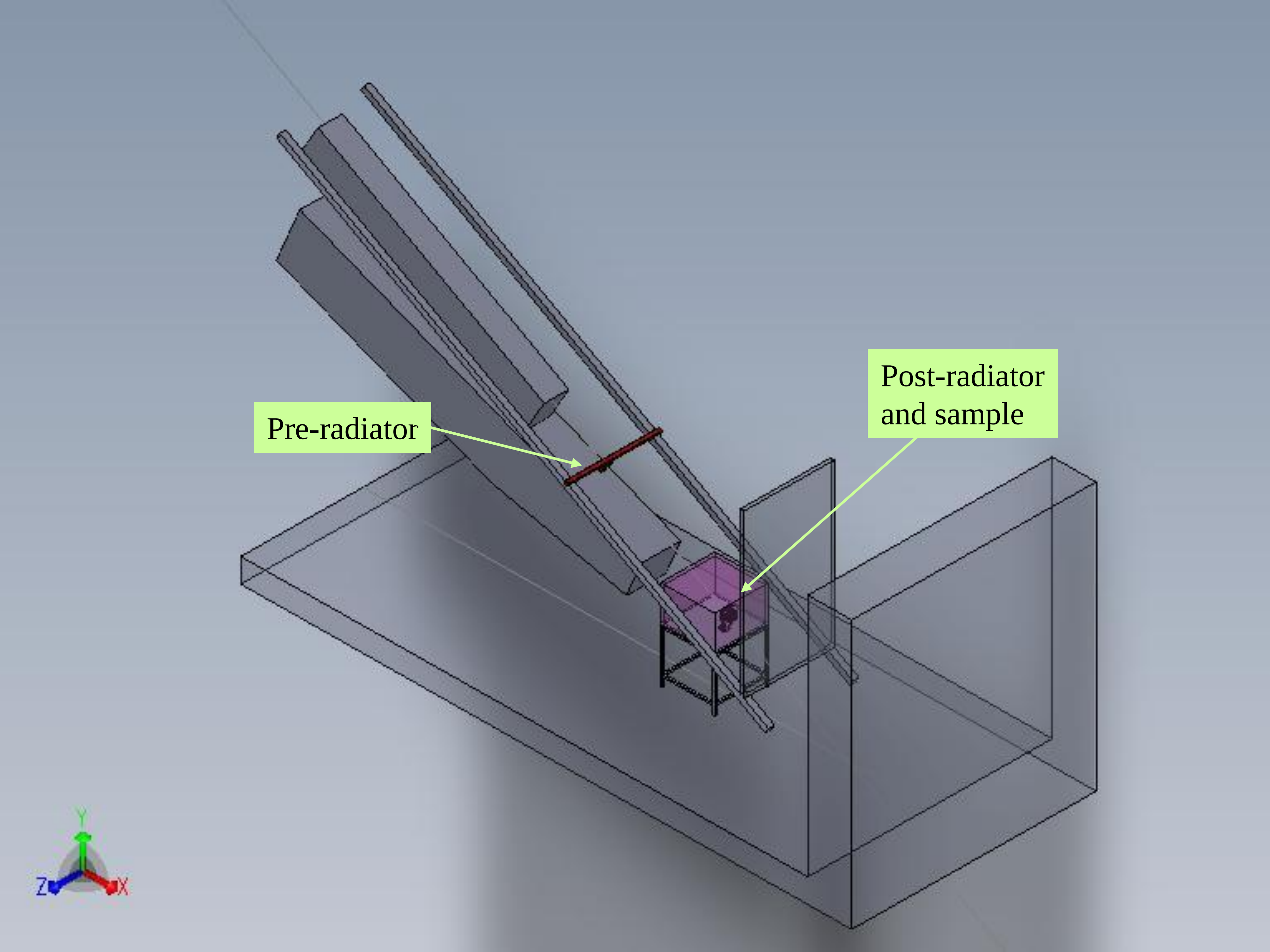
EM particles do little damage; might damage be come from small hadronic component of shower?

Hadronic Processes in EM Showers

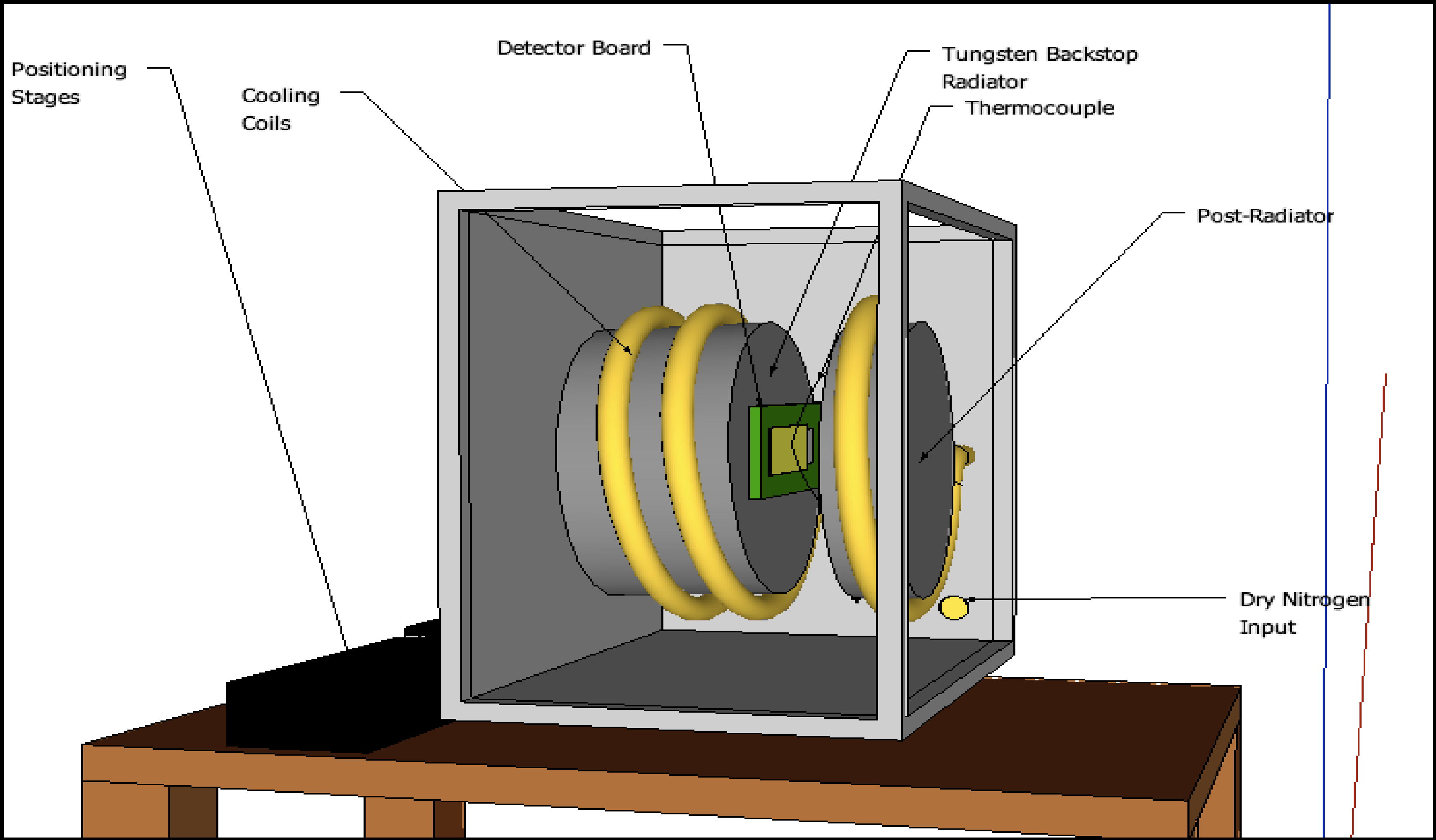
There seem to be three main processes for generating hadrons in EM showers (all induced by **photons**):

- Nuclear ("giant dipole") resonances
  - Resonance at 10-20 MeV ($\sim E_{critical}$)
- Photoproduction
  - Threshold seems to be about 200 MeV
- Nuclear Compton scattering
  - Threshold at about 10 MeV; Δ resonance at 340 MeV

➔ These are largely isotropic; must have most of hadronic component develop near sample

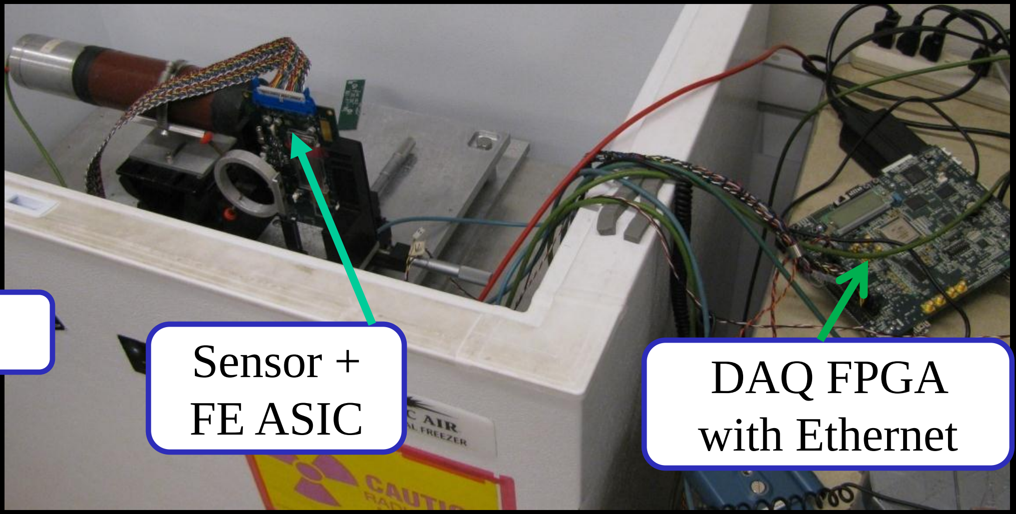

Pre-radiator
Post-radiator and sample
Y
Z
X

Hadronic Processes in EM Showers



Status: Thermal prototype under testing at SCIPP

Charge Collection Apparatus



Upgrading CC Apparatus for multiple samples

- New detector board to modularize system (connector rather than bonds)
- Two pitch adapters (lithogaphic) to accommodate different detector pitches
- Modications to ASIC board
- Nearing completion

Run Plan

To acheive uniform illumination over 0.25x0.75 cm region (active area of SCIPP's charge collection measurement apparatus), must raster in 0.05cm steps over 0.6x1.5 cm:

$$1\,GRad \approx \frac{650}{I_{beam}(nA) \bullet E_{beam}(GeV)}\,hours$$

e.g. 100 MRad at 1.25 nA 13.6 GeV e^- ➔ 4 hr

Will request beam time in early 2013 (ESTB workshop tomorrow!)

BeamCal Simulations

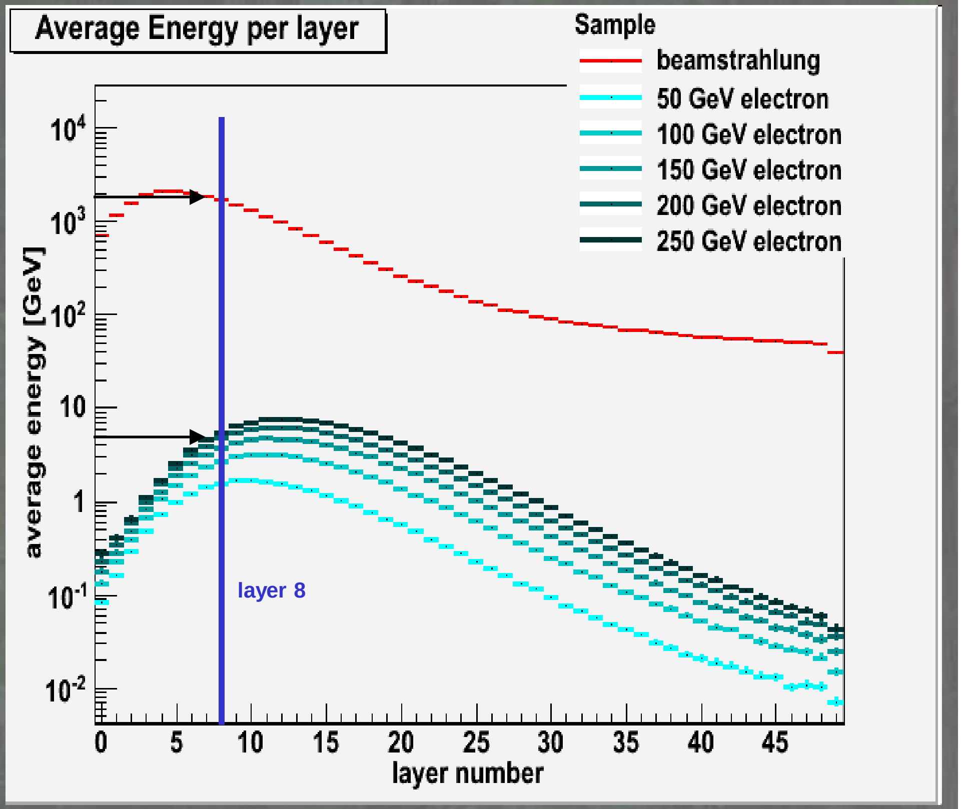
Goal:

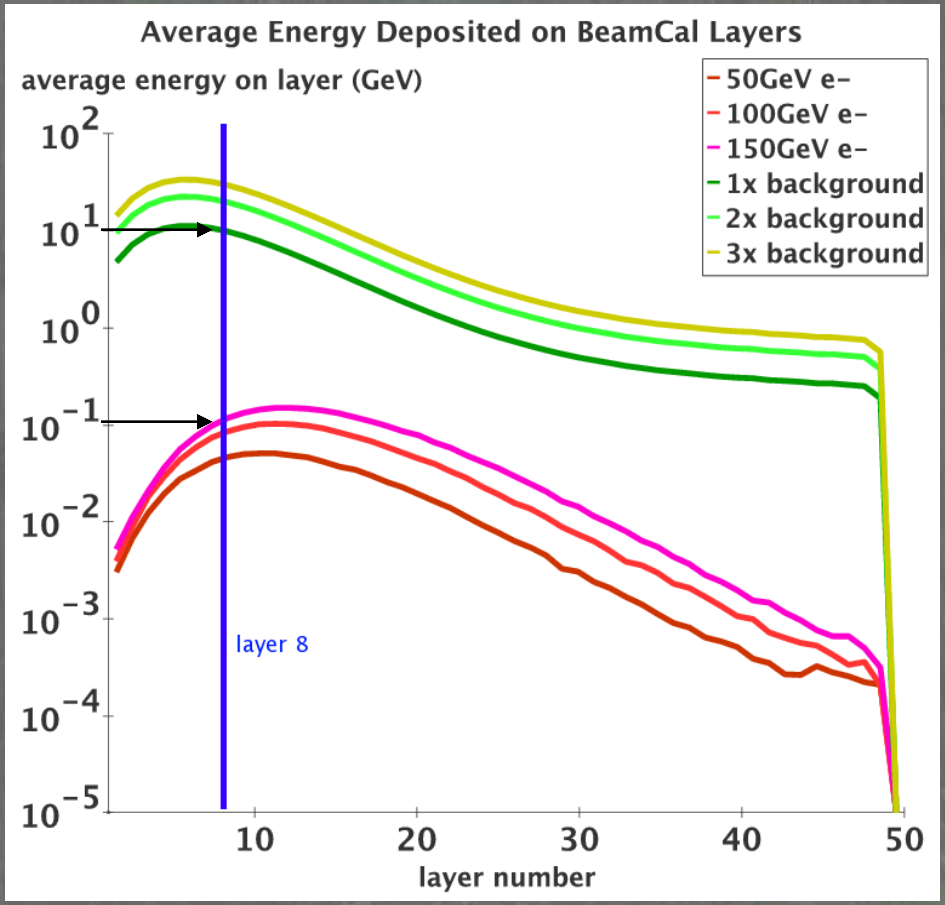
- **Reproduce Colorado studies of BeamCal electron ID efficiency/purity**
- **Determine sensitivity to increased/decreased background accumulation rates (different beam-delivery configurations)**

Reconstruction Algorithm

- Choose seed layer
- Subtract mean background from all pixels
- Sum energy in sliding window (“tile”) of NxN beamcal pixels (N is optimized)
- Chose highest 50 tile depositions in layer [determine efficiency that electron is one of them]
- Reject spurious tiles via longitudinal patterns

Signal to Noise Comparison



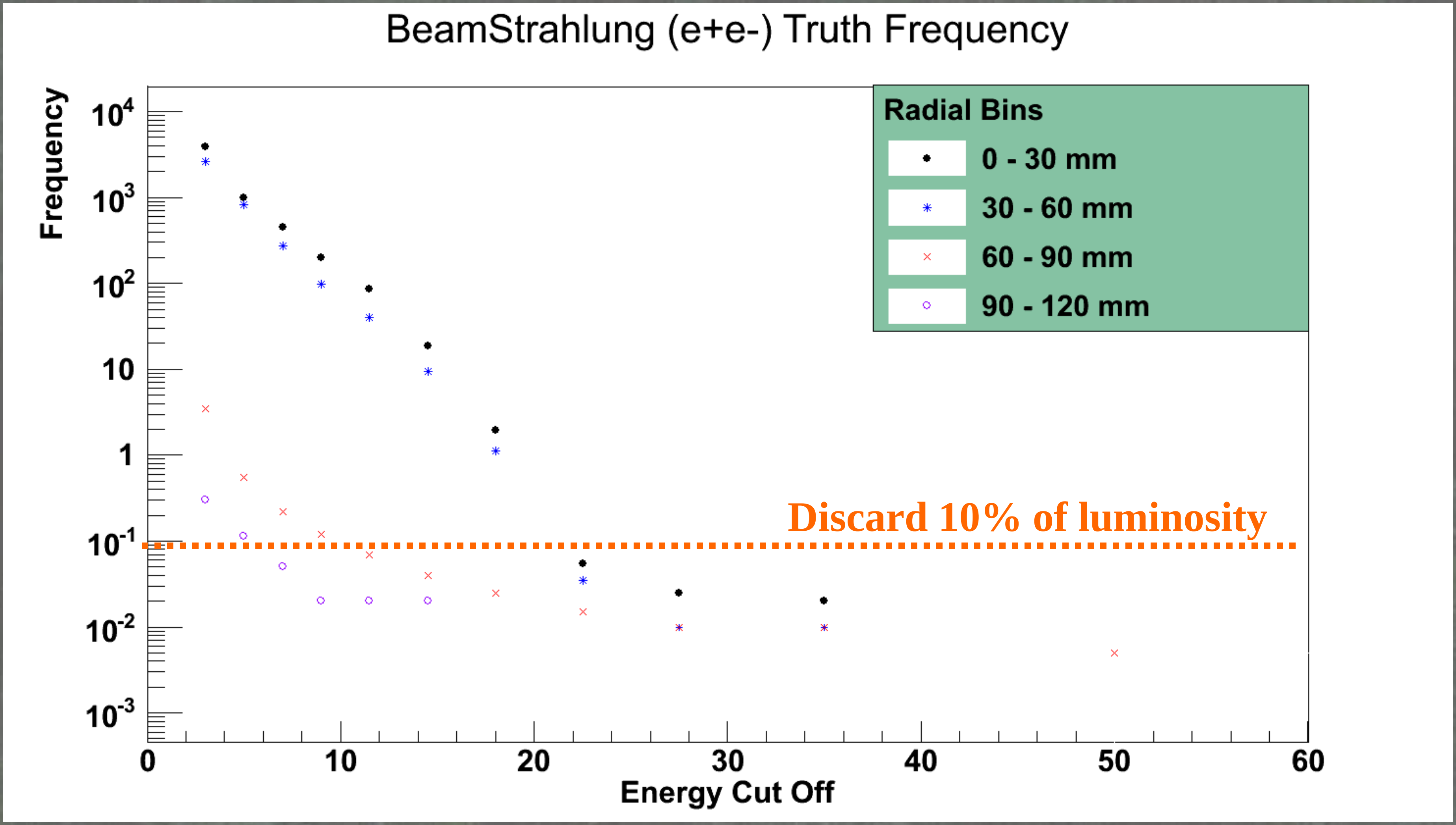


Colorado: Mean background is x100 mean signal

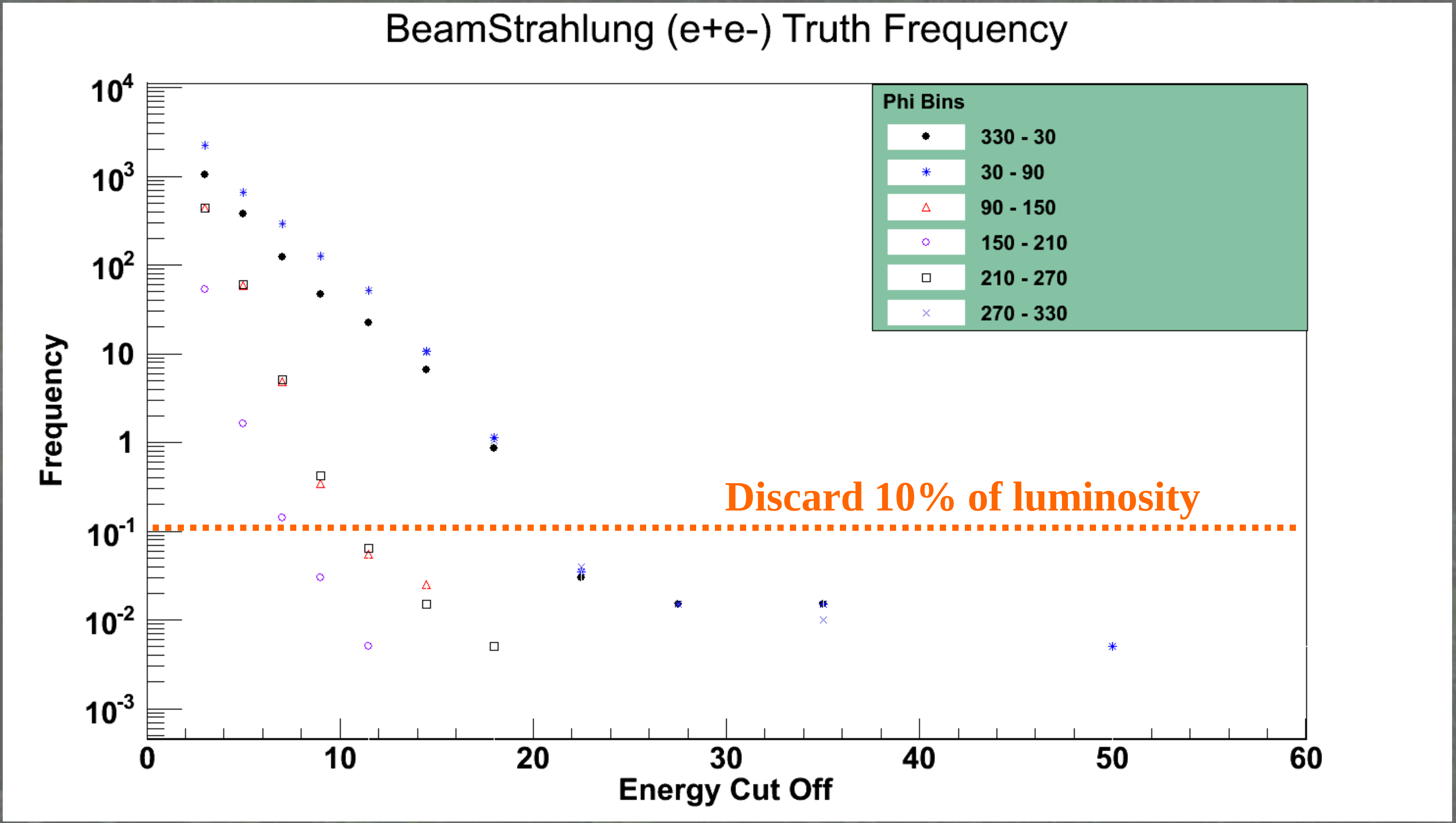
SCIPP: Mean background is x500 mean signal

Have been unable to understand what changed

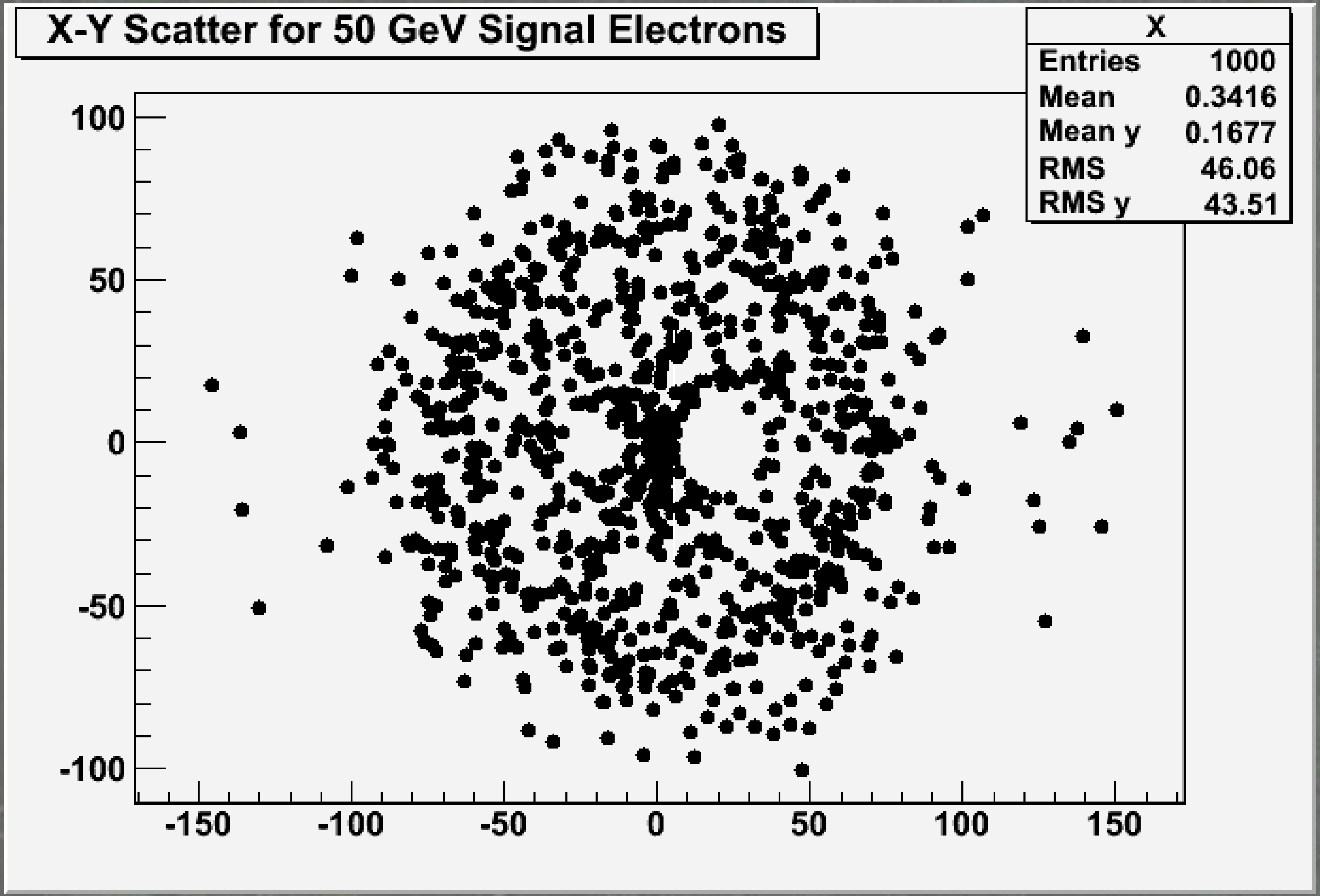
Background Distribution in Radial Bins



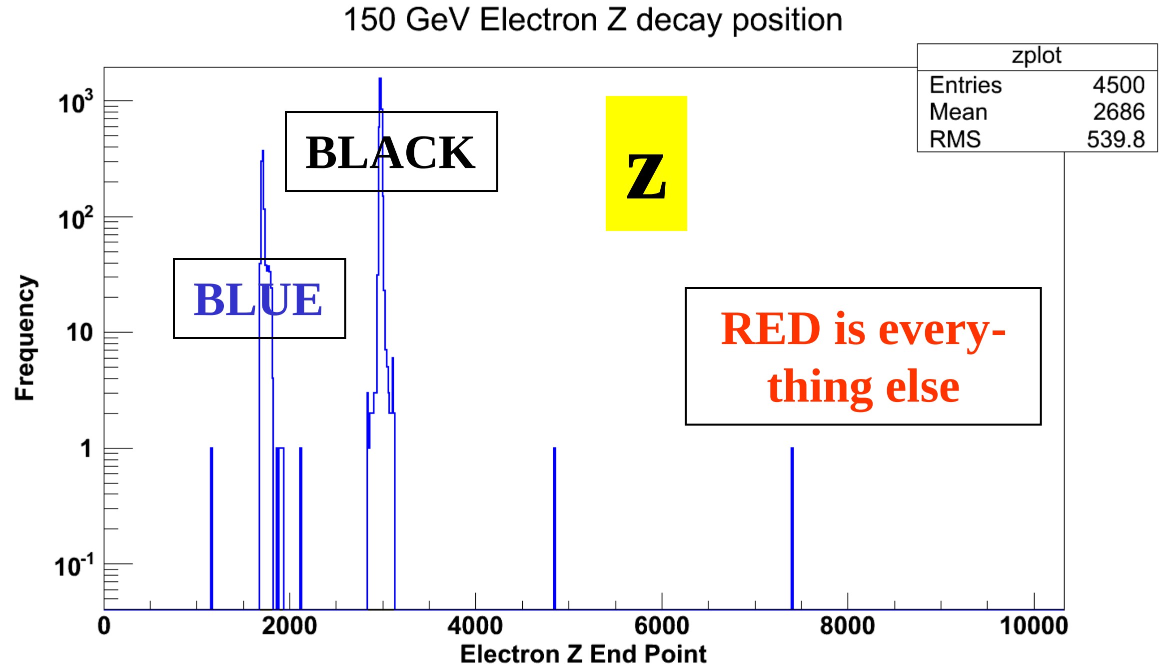
Background Distribution in Phi Bins

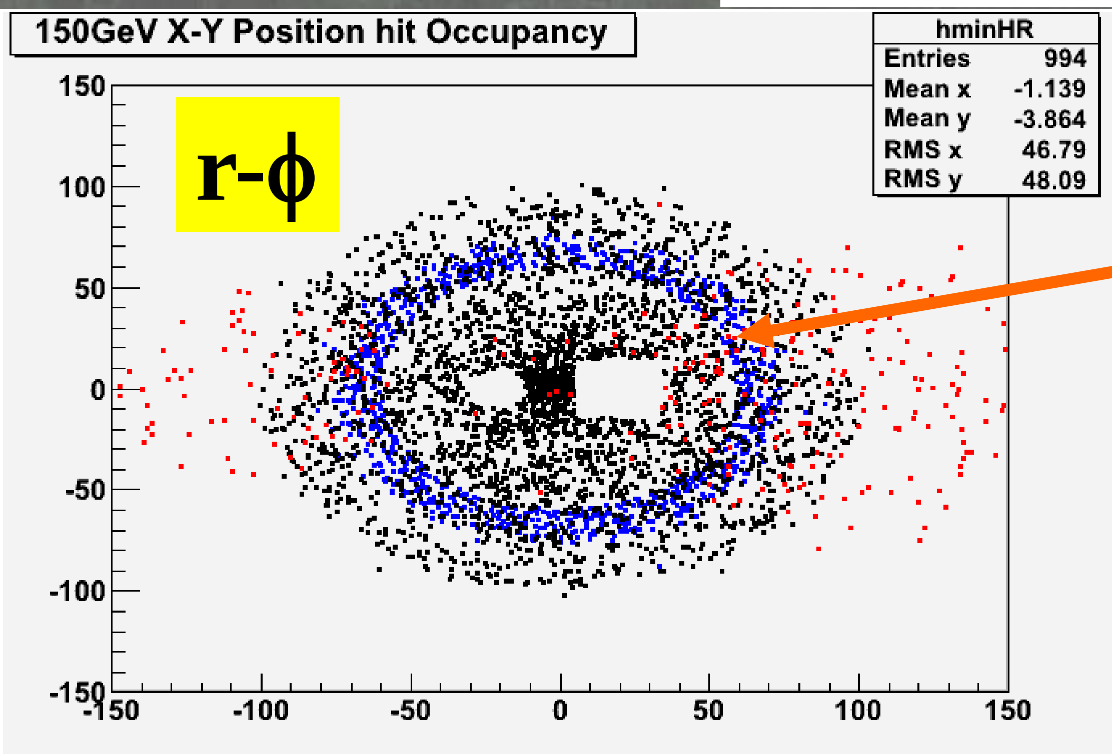


Signal Distributiuon (?) for 50 GeV Electrons



Interaction point of 150 GeV signal electrons





Not sure what this is supposed to be?

BeamCal Simulations: Next Steps

- Any thoughts on nature/origin of discrepancy between Colorado/SCIPP signal/background files?
  - Calibration
  - Configuration
  - Beam conditions…

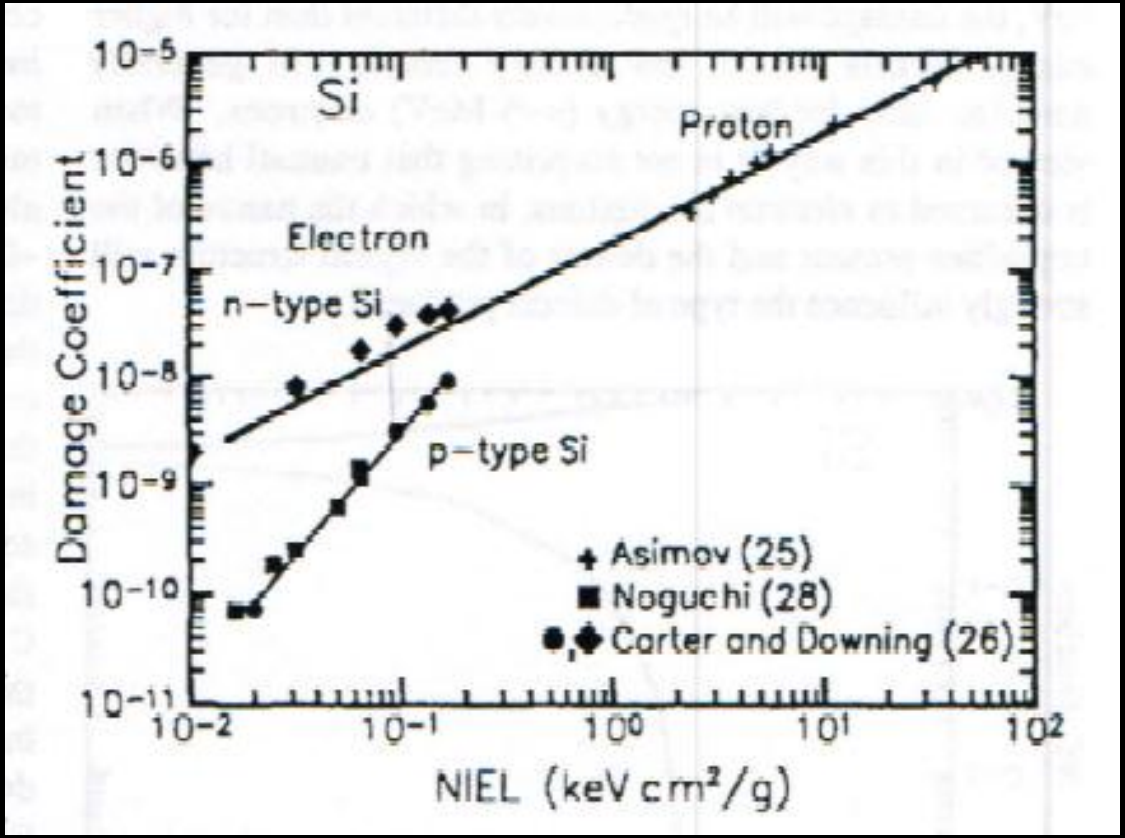
- For now, trying to develop Colorado-like analysis with degraded S/N

- Outcome not clear

➔ Plea for support

Backup

G.P. Summers et al., IEEE Trans Nucl Sci **40**, 1372 (1993)

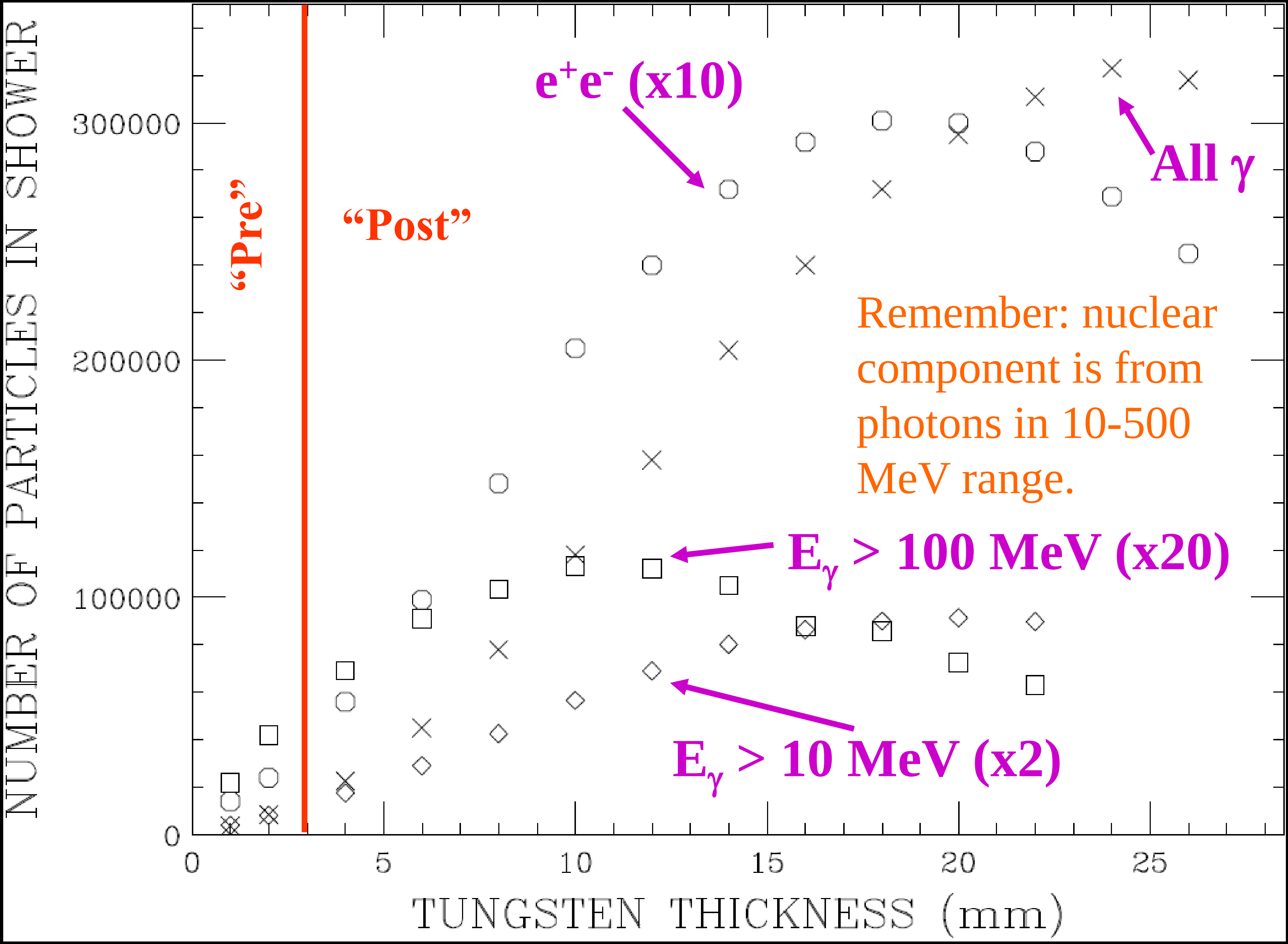


NIEL	e^- Energy
2×10^{-2}	0.5 MeV
5×10^{-2}	2 MeV
1×10^{-1}	10 MeV
2×10^{-1}	200 MeV

Damage coefficients less for p-type for E_{e-} < ~1GeV (two groups); note **critical energy** in W is **~10 MeV**

But: Are electrons the entire picture?

5.5 GeV Shower Profile



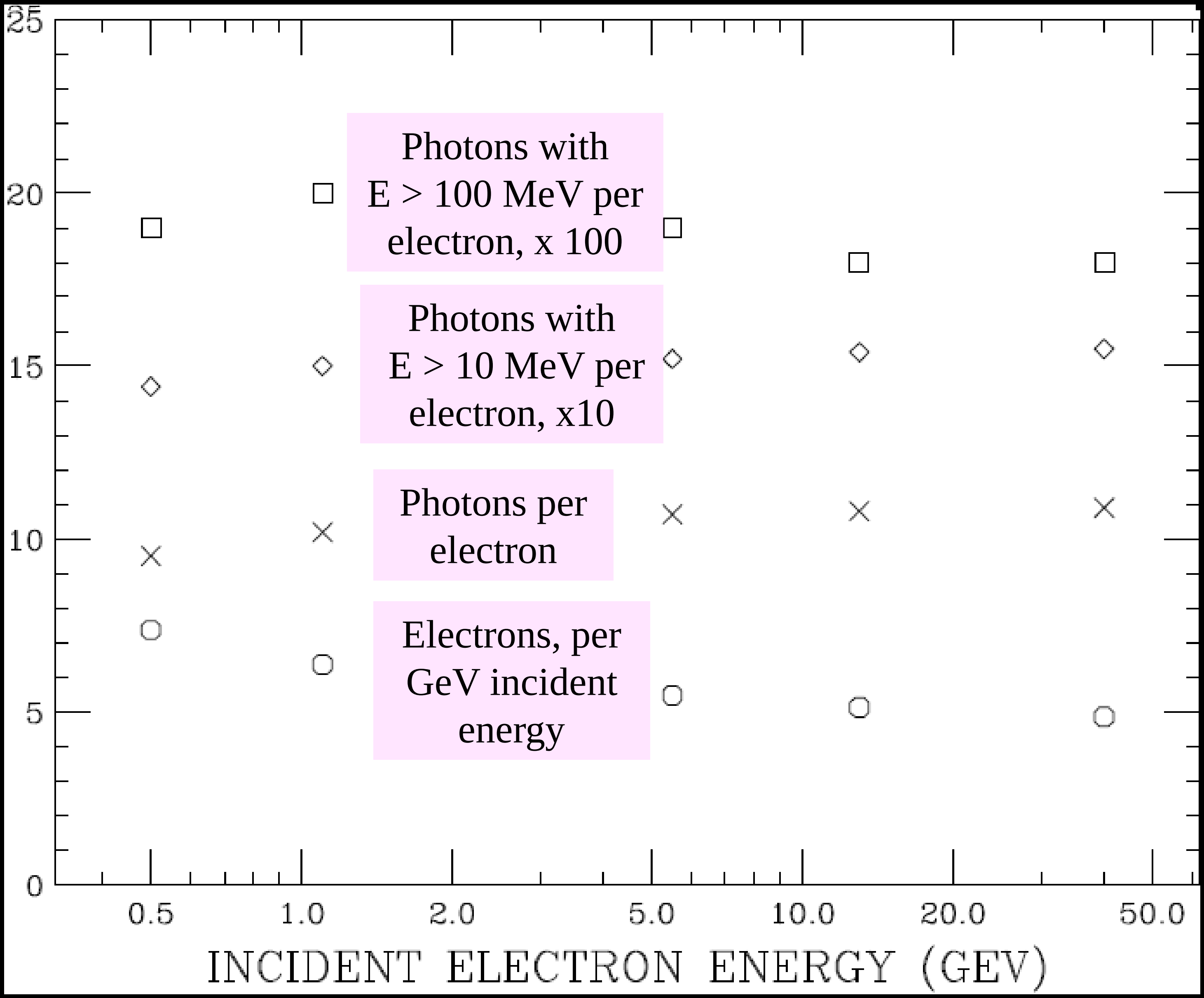
Parameters required for Beam Tests

To the presenter at the ESTB 2011 Workshop: please, fill in the table (at best) with the important parameters needed for your tests

Beam parameters	Value	Comments
Particle Type	electron	
Energy	Maximum	
Rep Rate	Maximum	
Charge per pulse	Maximum	
Energy Spread	Not a concern	
Bunch length rms	Not a concern	
Beam spot size, x-y	Large is helpful	Up to ~1 cm rms
Others (emittance, …)	Not a concern	

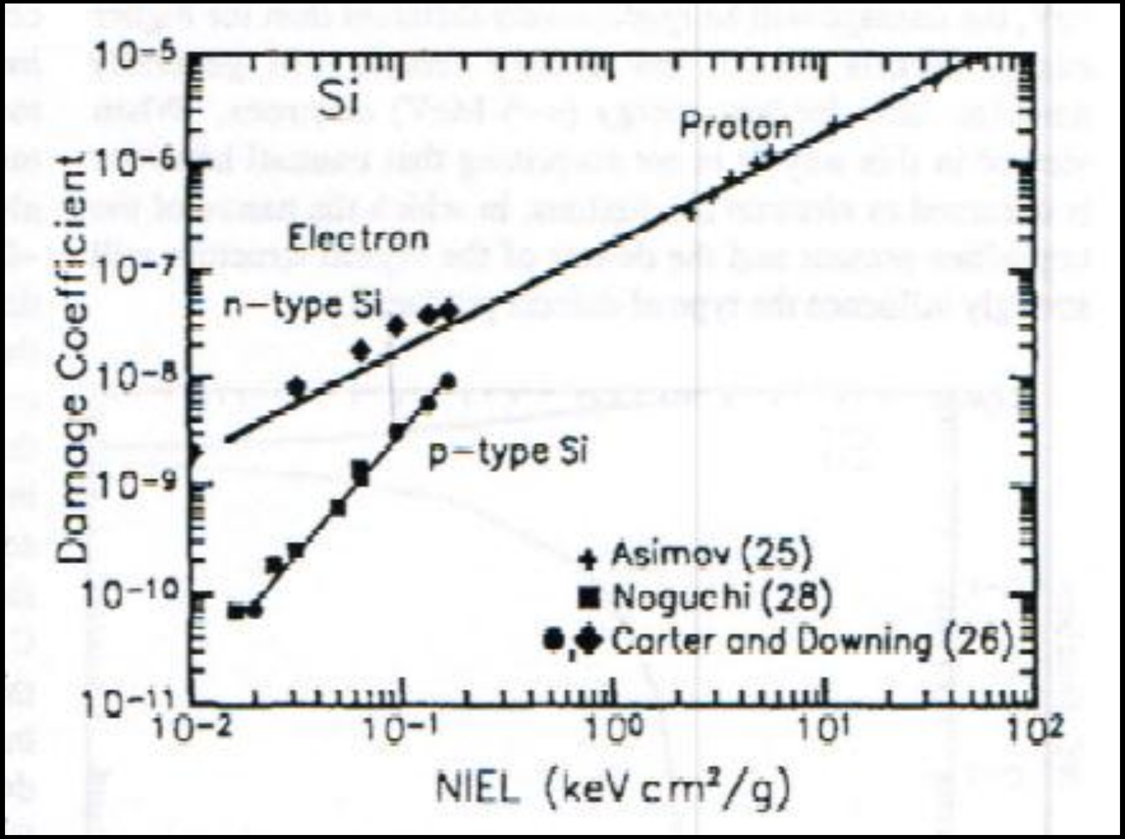
Logistics	Requirements
Space requirements (H x W x L)	1m x 1m x 1m (plus 20cm x 20cm x 20cm 1-2 meters upstream)
Duration of Test and Shift Utilization	Depends on available current
Desired Calendar Dates	CY 2012 (flexible)

Shower Max Results



➔ Photon production ~independent of incident energy!

G.P. Summers et al., IEEE Trans Nucl Sci **40**, 1372 (1993)



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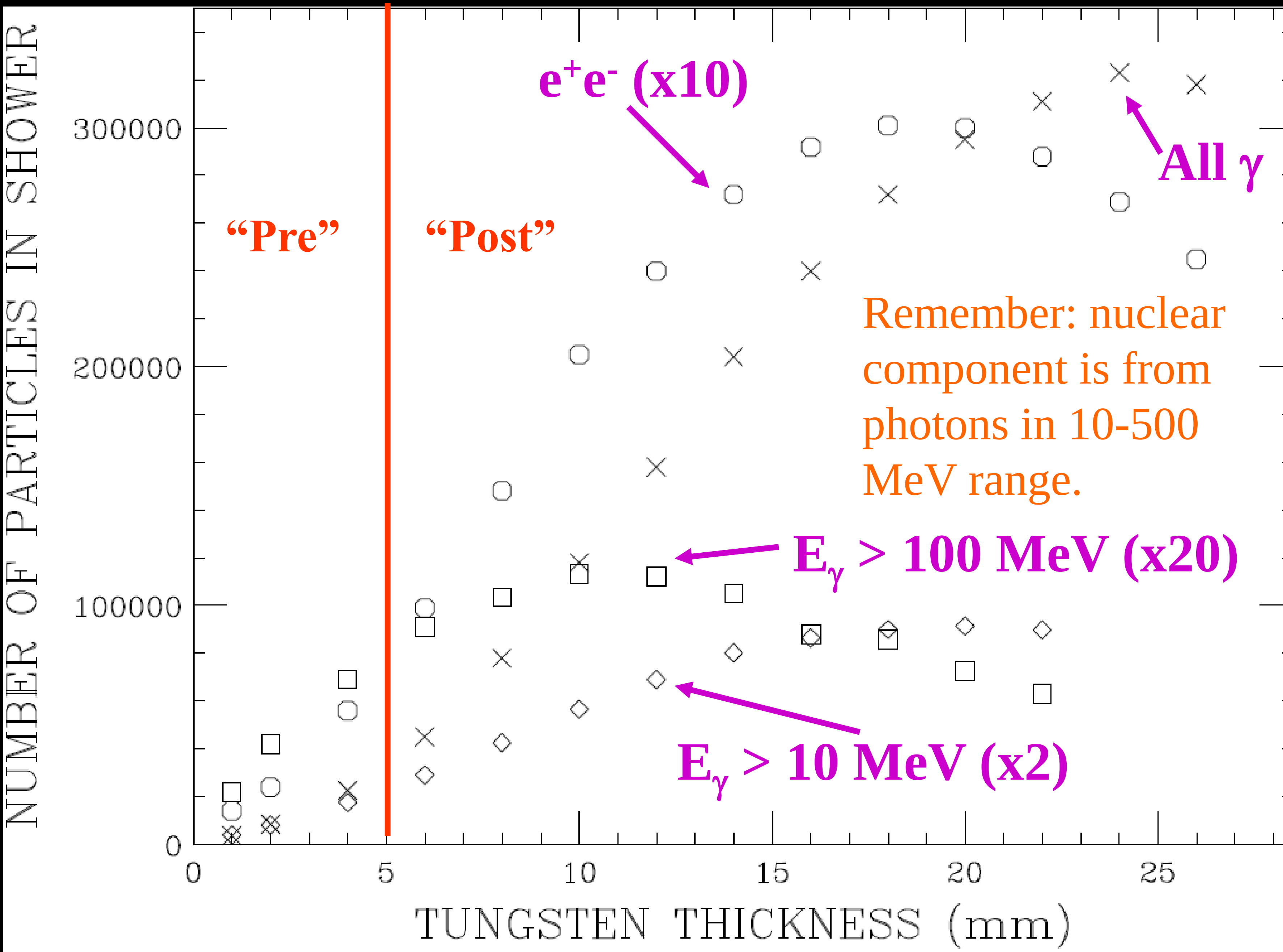

Conclusions

- Gearing up for radiation damage studies in realistic setting (Spring? Under consideration)

- Resources in place for further development of BEAN BeamCal readout ASIC; need to review specs

- Trouble reproducing canonical BeamCal reconstruction efficiency/purity traced to degraded signal/noise in the simulation (?)

➔ Support sought on latter two issues

NIEL (Non-Ionizing Energy Loss)

Conventional wisdom: Damage proportional to Non-Ionizing Energy Loss (**NIEL**) of traversing particle

NIEL can be calculated (e.g. G.P. Summers et al., IEEE Trans Nucl Sci **40**, 1372 [1993])

At $E_c^{Tungsten}$ ~ 10 MeV, **NIEL** is 80 times worse for protons than electrons and

- **NIEL** scaling may break down (even less damage from electrons/positrons)
- **NIEL** rises quickly with decreasing (proton) energy, and fragments would likely be low energy

➔ Might small hadronic fractions dominate damage?