GEANT4 Study for HCal Light Production and Collection Efficiency Correction

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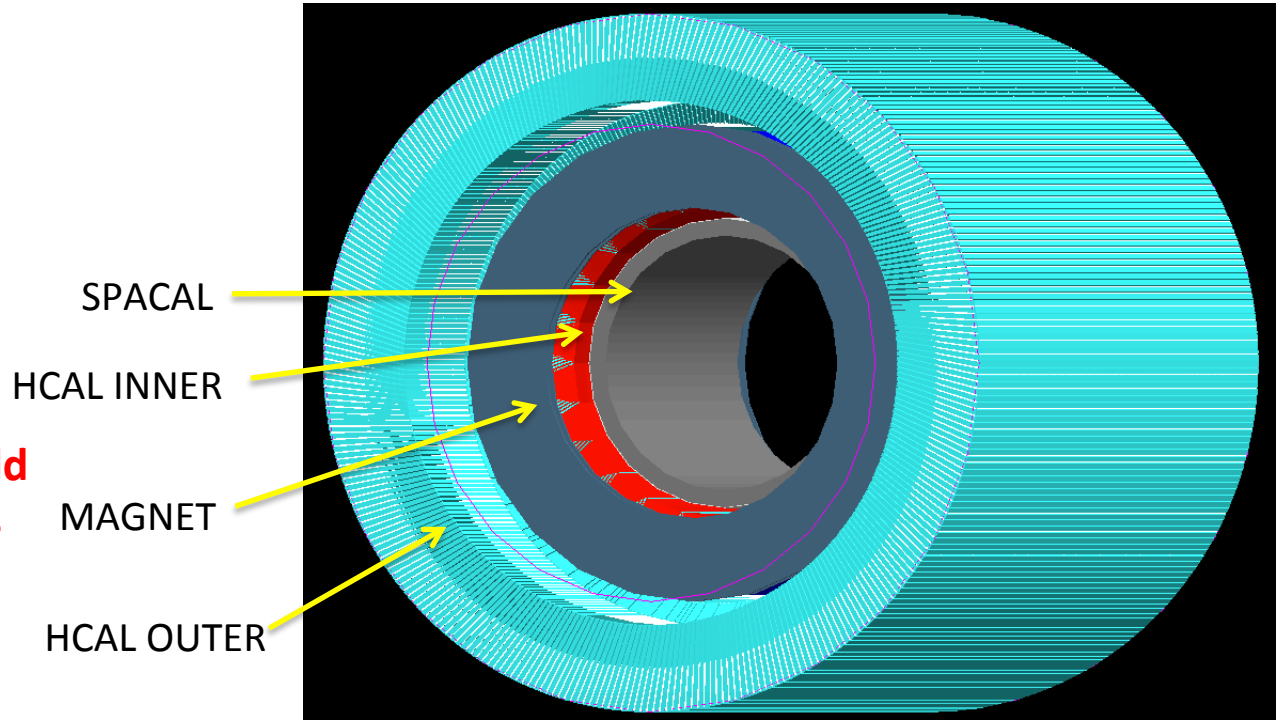
Thank to J. Huang and J. Lajoie

Detector Configuration

- SPACAL + Inner HCal + Magnet + Outer HCal
- Inner HCal:
  - Scint tile / Stainless steel
  - R(in)=116 cm, R(out)=135 cm
  - Scint thickness: 0.7 cm, # Scint tiles: 64x5
  - Tilted-angle: 29.4°
- 1D projective SPACAL
- sPHENIX field map
- 50 k, 30 GeV charge pion

- Outer Hcal:
  - Scint tile / Fe
  - R(in)=178 cm, R(out)=260.3 cm
  - Scint thickness: 0.7 cm, # Scint tiles: 64x5



- **HCAL Reference Design**
- **New sPHENIX software world**
- **G4 Step level light yield corr**
- **G4 Step Birks law light yield**
- **Ideal towering**

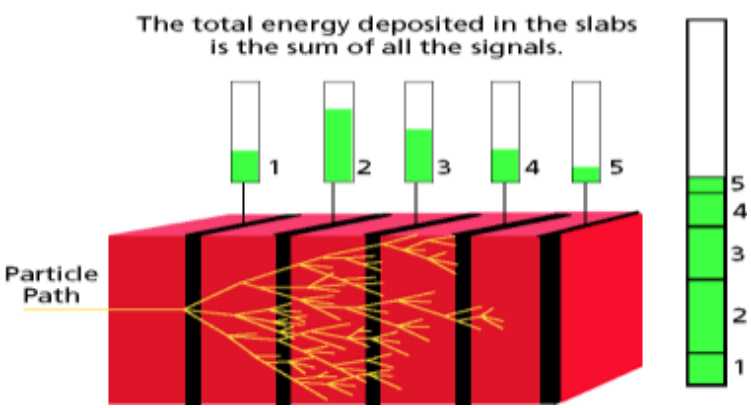
/direct/phenix+sim01/phnxreco/users/lxue/G4Sim_RefDesignLightYield

Light Production and Collection Efficiency

- The light production in GEANT4 is calculated based on the Birks law.
- The light collection efficiency at different position of the scintillator tile is different based on the test at Colorado and BNL.

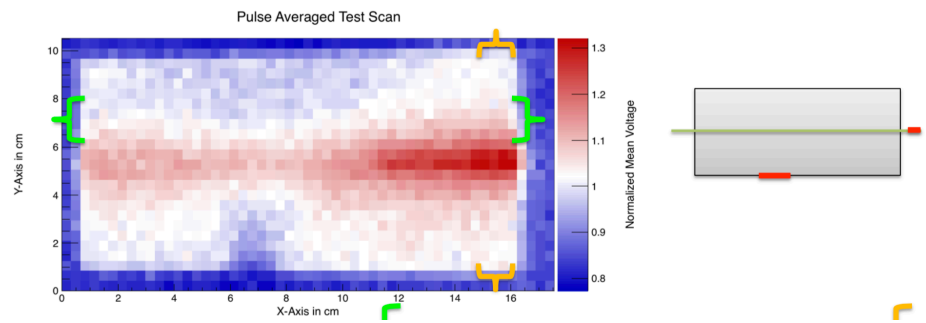
Light Production (Birks law):

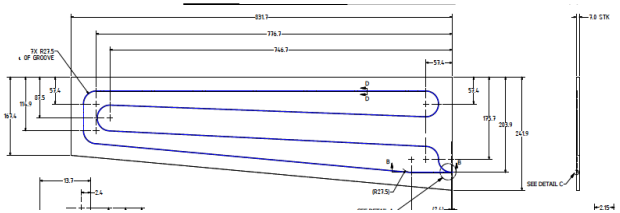
$$\frac{dL}{dx} = L_0 \frac{\frac{dE}{dx}}{1 + k_B \frac{dE}{dx}}.$$

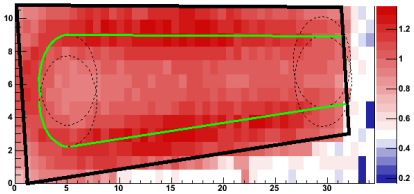


Implemented by J. Huang

Light Collection:







E. Kistenev

Previous Study vs. Current Study

Previous Study:

- G4 hit level light collection efficiency

- Inner Hcal:
  - Eff(R_{out})=1.0, Eff(R_{in})=0.80

$$eff = \frac{1.0 - 0.80}{R_{out} - R_{in}} \times (r - R_{in}) + 0.80$$

- HCAL OUTER:
  - Eff(R_{out})=1.0, Eff(R_{in})=0.15

$$eff = \frac{1.0 - 0.15}{R_{out} - R_{in}} \times (r - R_{in}) + 0.15$$

Current Study:

- G4 step level light production (birks law)
- G4 step level light collection efficiency
- Inner Hcal:
  - Eff(R_{out})=1.0, Eff(R_{in})=0.80

$$eff = \frac{1.0 - 0.85}{R_{out} - R_{in}} \times (r - R_{in}) + 0.85$$

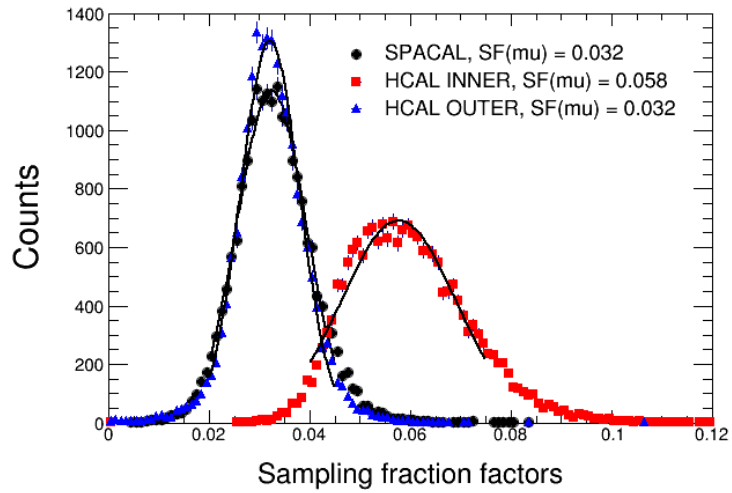
- HCAL OUTER:
  - Eff(R_{out})=1.0, Eff(R_{in})=0.15

$$eff = \frac{1.0 - 0.65}{R_{out} - R_{in}} \times (r - R_{in}) + 0.65$$

Sampling Fraction Factors

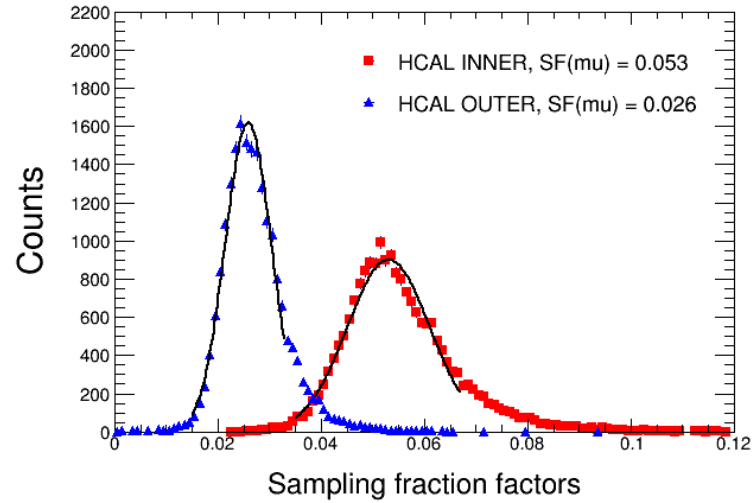
(1) No Light production & Correction:

$$SF(mu) = \frac{Escint(mu)}{Escint(mu) + Eabsorber(mu)}$$



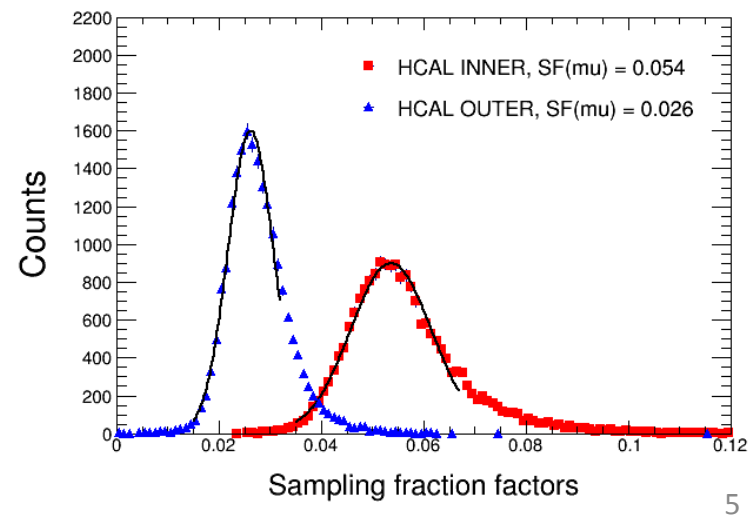
(2) Light correction:

$$SF(mu) = \frac{Escint(mu, light - corrected)}{Escint(mu) + Eabsorber(mu)}$$



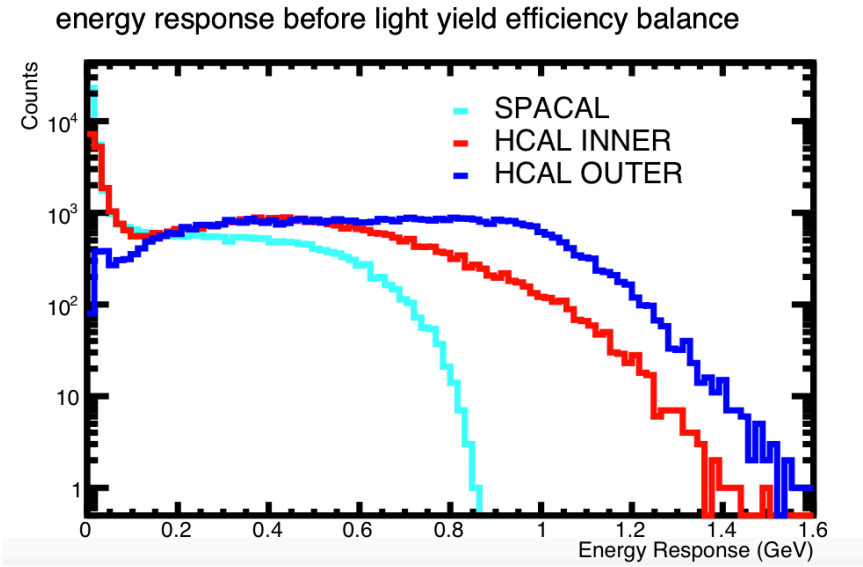
(3) Light correction + Birks law:

$$SF(mu) = \frac{Escint(mu, Birks\ law + light\ corrected)}{Escint(mu) + Eabsorber(mu)}$$

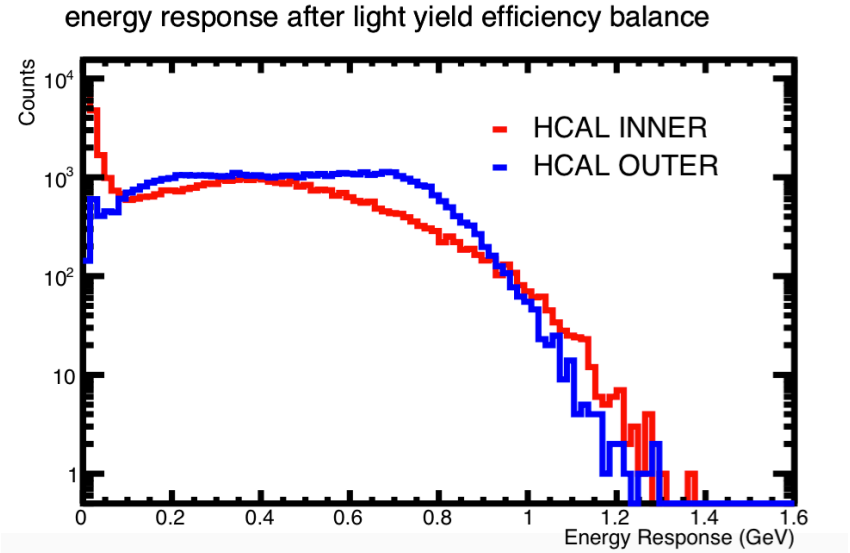


Energy Response

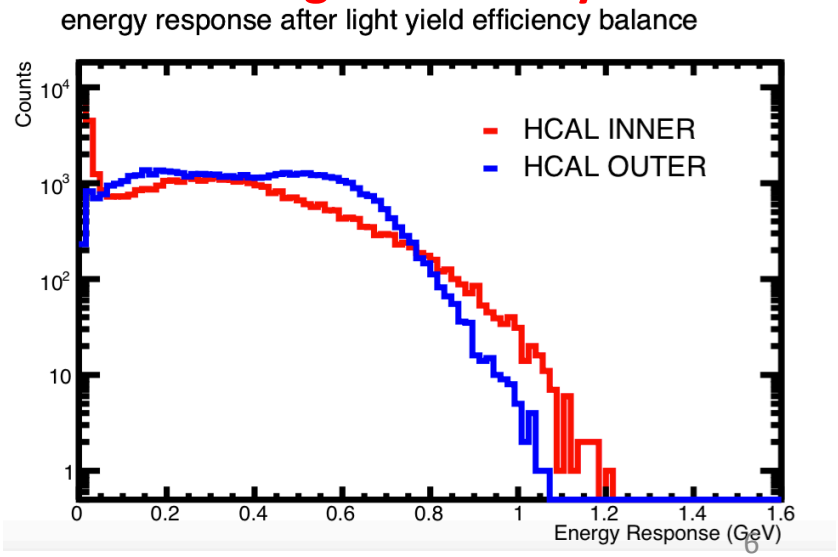
No Light Production & Correction



Light Efficiency Correction



Birks Law + Light Efficiency Correction

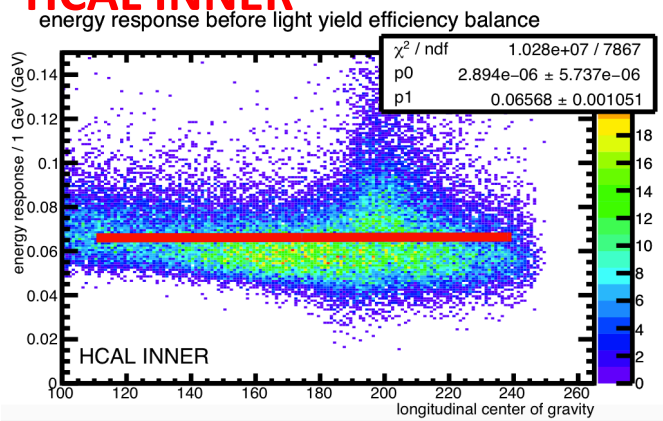


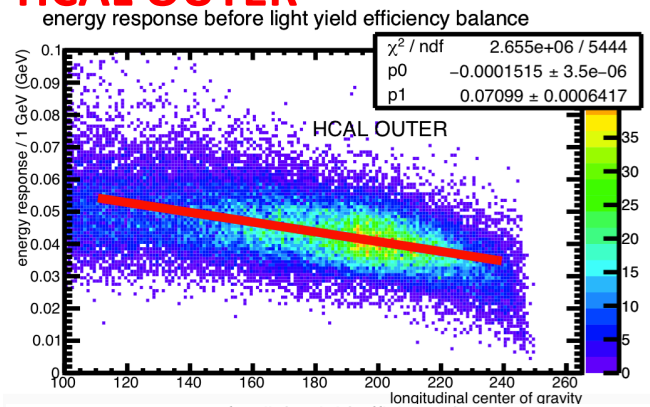
- We do see energy loss due to the light production (birks law) and the light collection efficiency correction.

Energy response vs. LCG

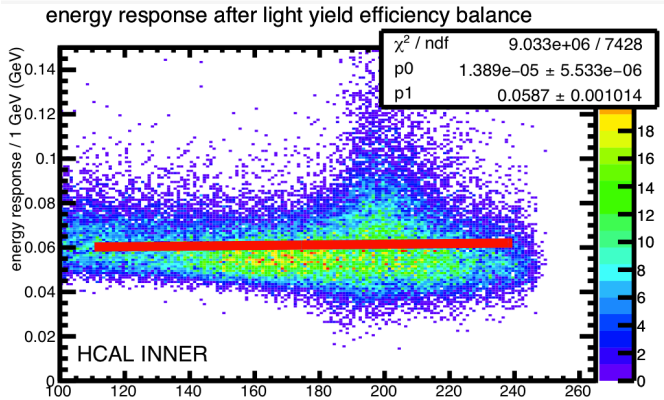
HCAL INNER | **HCAL OUTER**

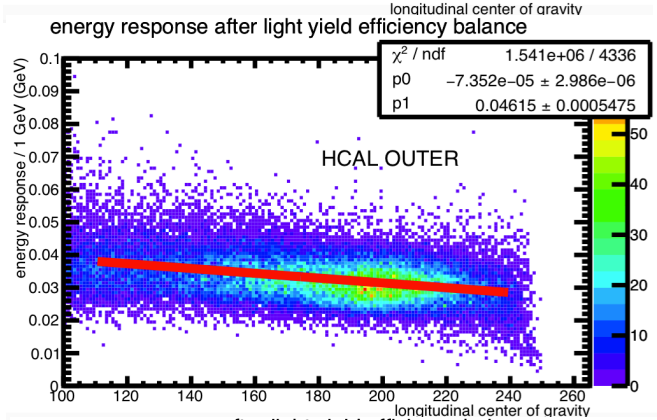
No Light Production & Correction



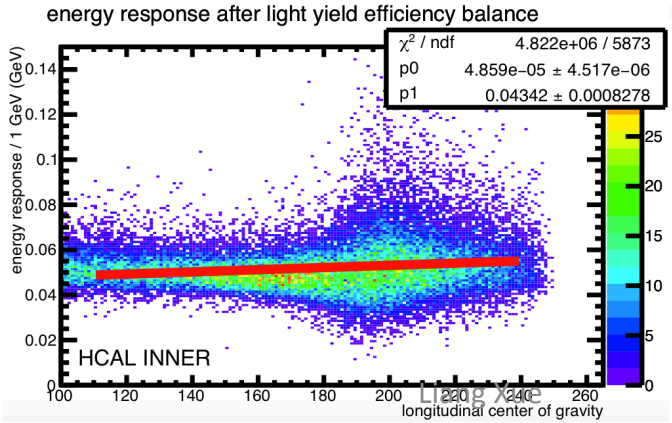


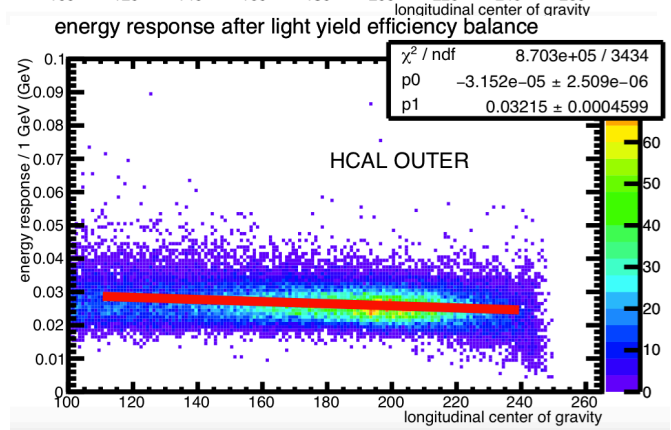
Light Correction



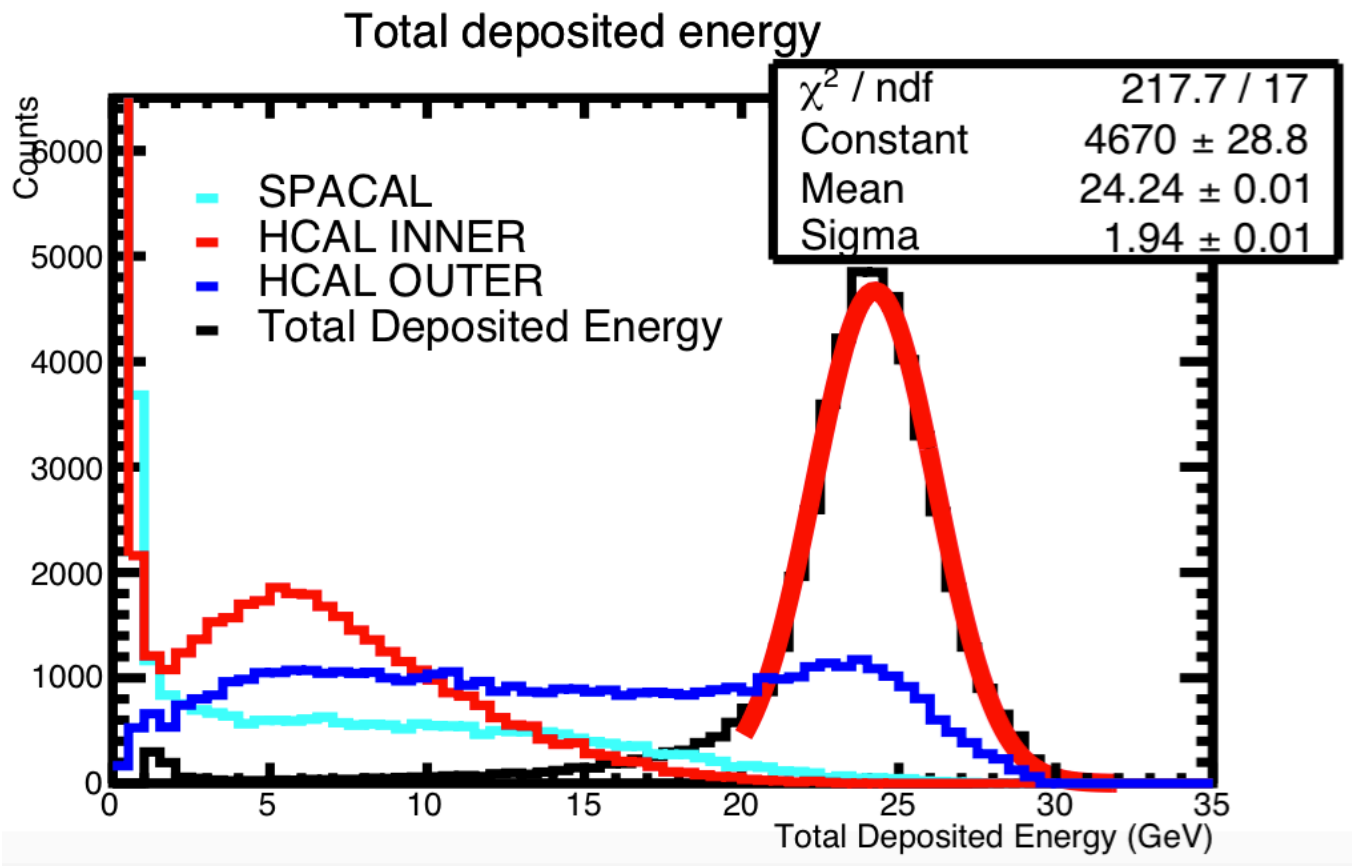


Light Correction & Birks Law





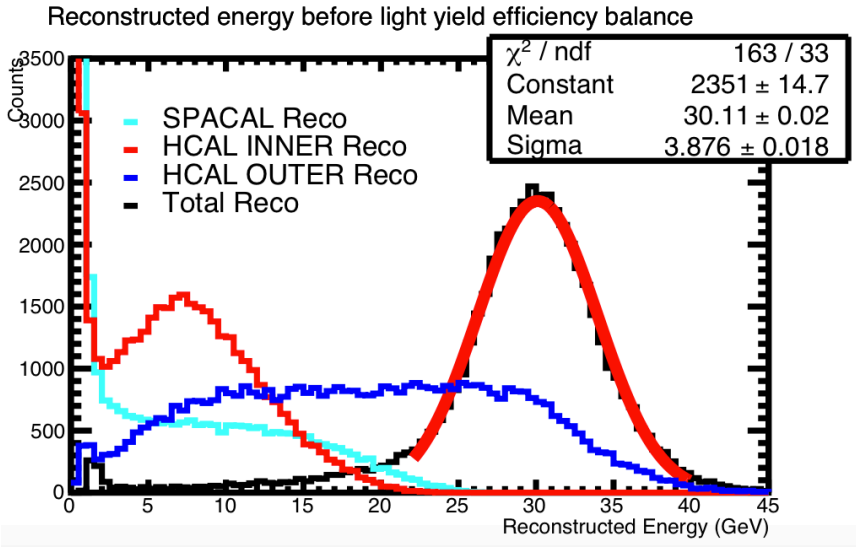
Total Deposited Energy in Calorimetry System



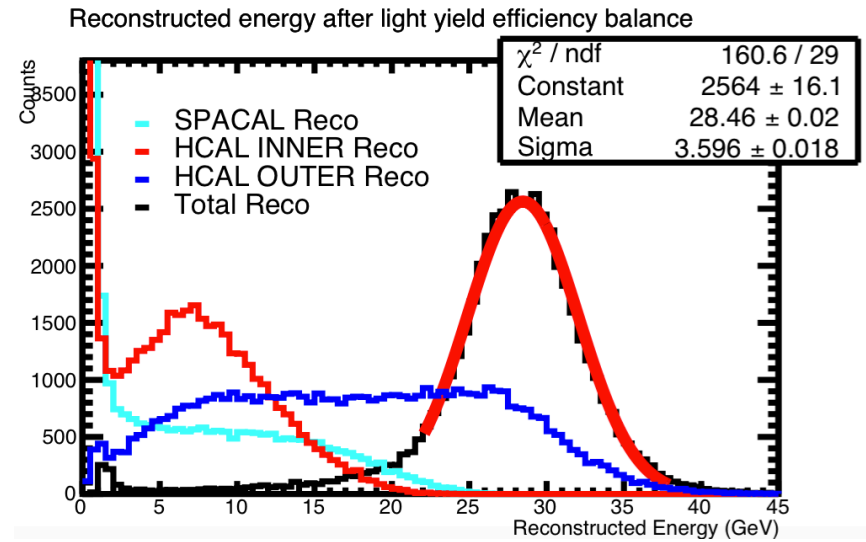
Due to energy leakage, energy loss in magnet/electronics/support structure, and energy loss with neutrons. The total deposited energy in calorimeter system is 24 GeV.

Reconstructed Energy

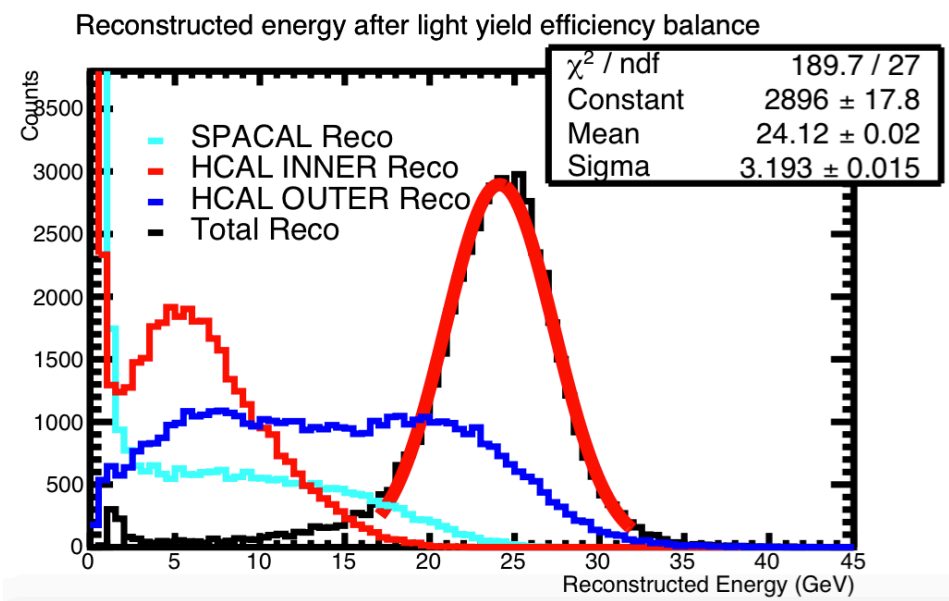
No Light Production & Correction



Light Efficiency Correction



Birks Law + Light Efficiency Correction

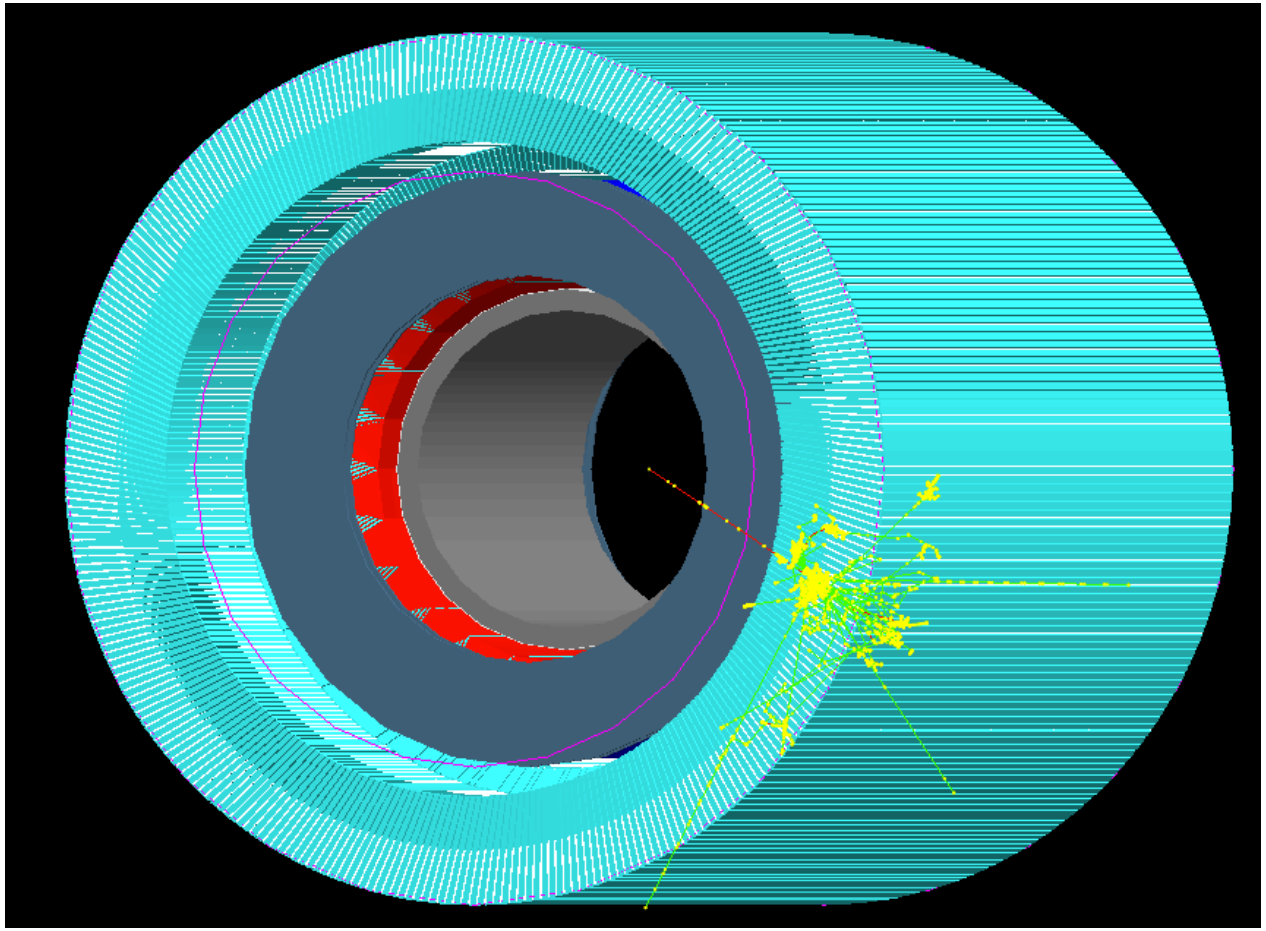


- Without light production & collection efficiency correction. The Rec energy is over estimated to be 30 GeV due to that SF(mu)<SF(hadron).
- With light collection correction, the Rec energy is ~28.5 GeV.
- With Birks law + Light Correction, the Rec energy is ~24 GeV

Summary

- The light production and collection efficiency correction is studied at G4 step level with 30 GeV pion for HCAL sPHENIX reference design.

Longitudinal Center of Gravity

$$LCG = \frac{CG(EMCal) \times E_{dep}(EMCal) + CG(H1) \times E_{dep}(H1) + CG(H2) \times E_{dep}(H2)}{E_{dep}(EMCal) + E_{dep}(H1) + E_{dep}(H2)}$$

Longitudinal center of gravity is calculated using real center of gravity (CG), and weighted with total deposited energy in each segment.