Mainz [July/25] PSCAL Prototype Testing Data Analysis

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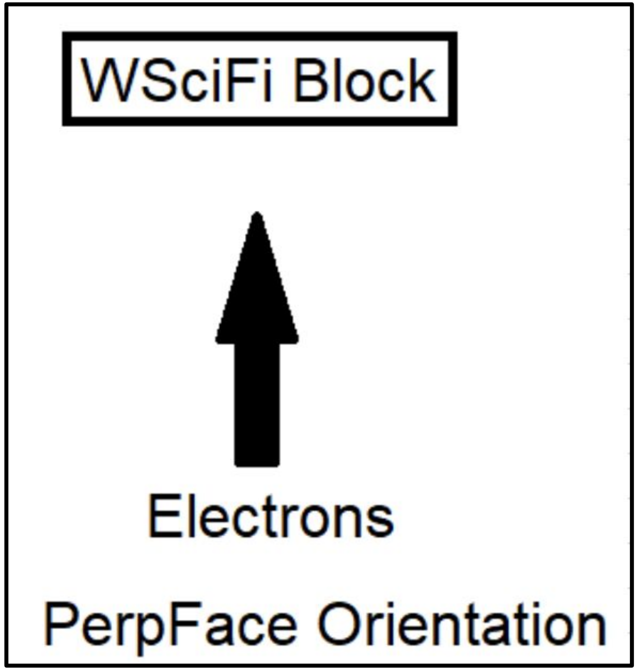
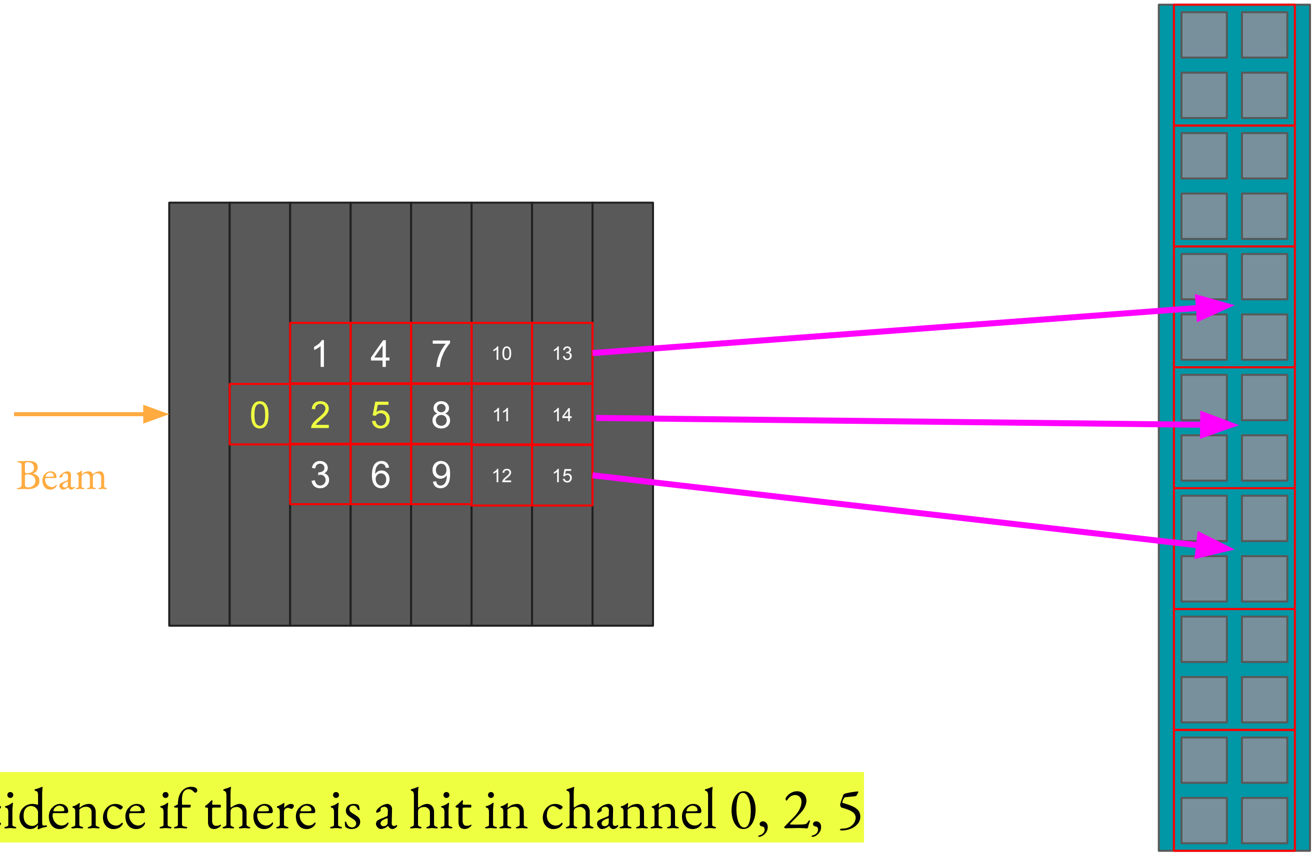
Data Details

1. Run 4, 18, 49, 50 (Different Tagger Location)
2. PerpFace - Module perpendicular to beam
3. Readout - SiPM of 50 μm microcells
4. SiPM offset voltage - 58.4 V
5. Algorithm: PSCAL_TestBeamAnalysis

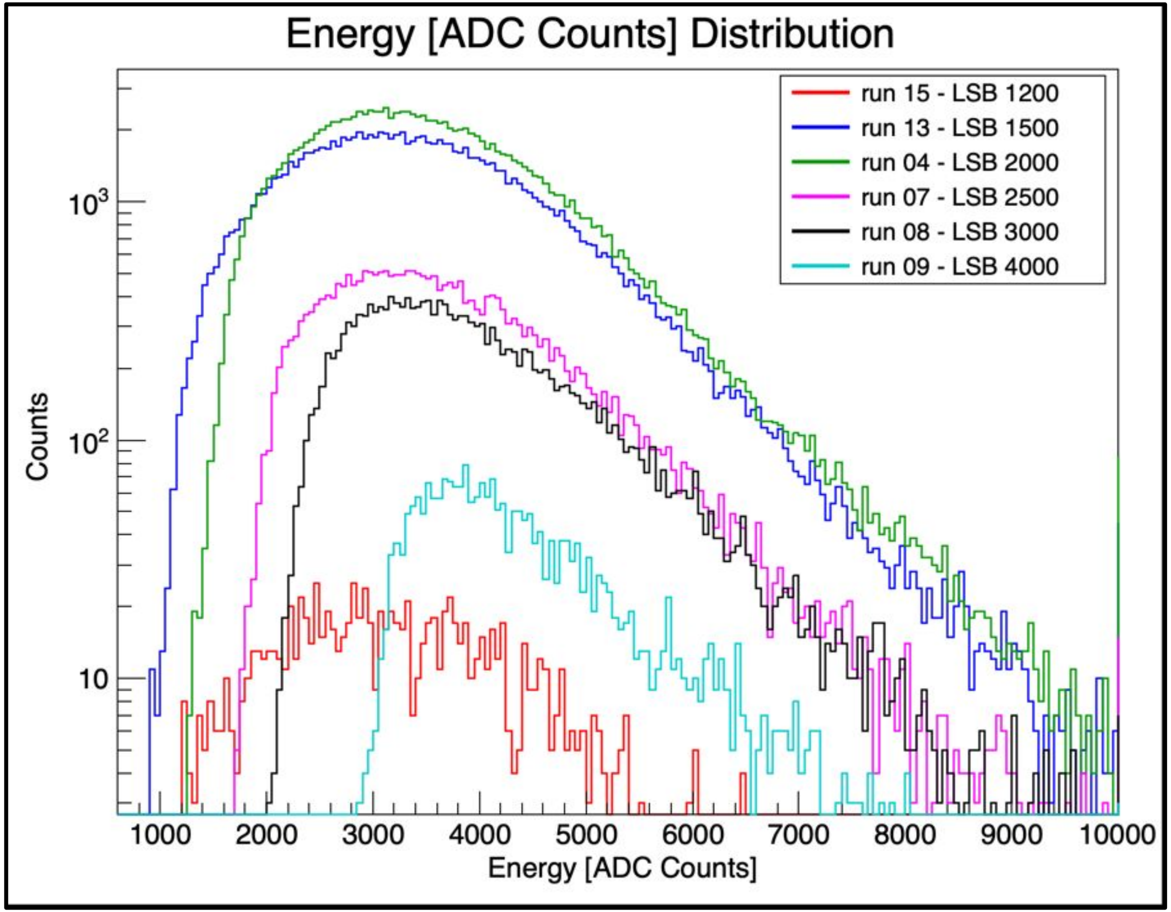


Orientation Details



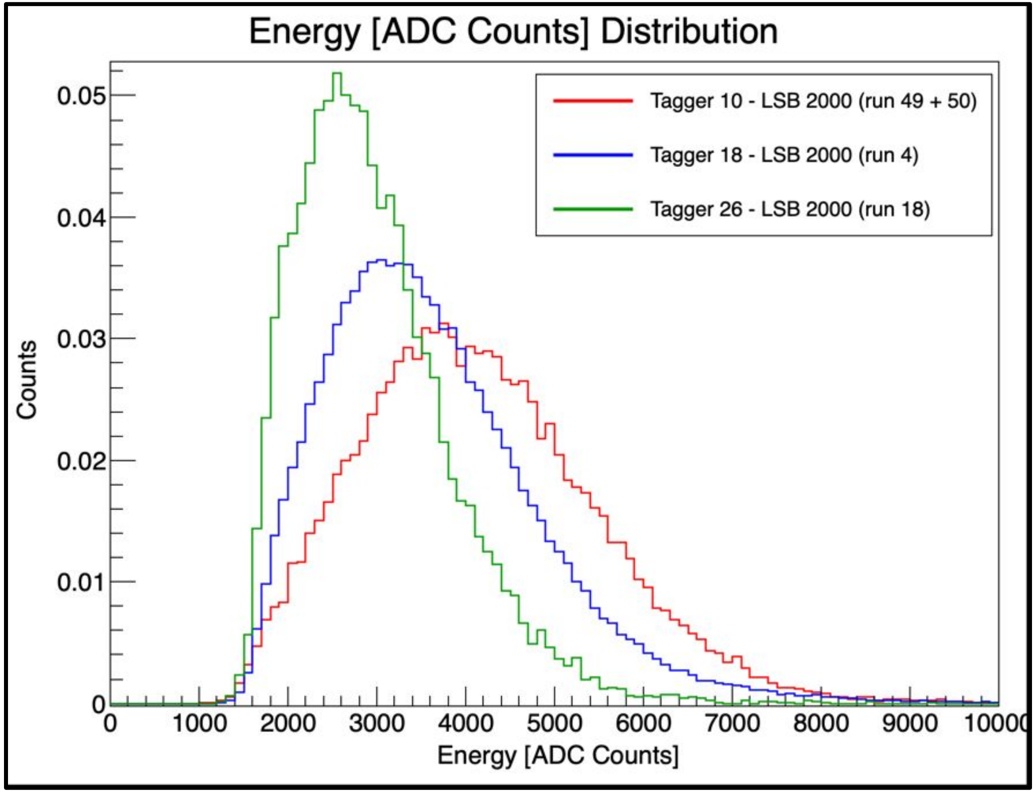
Coincidence if there is a hit in channel 0, 2, 5

[Previous Presentation] Energy Distribution for increasing LSB Threshold



- The peak appears at the same location

[Previous Presentation] Energy Distribution for different tagger location (keeping rest same)



Tag. Loc	Rec Eng. (ADC)	Gen Eng. (MeV)	ADC/MeV
Tag 10	4123	545 - 563.5 MeV	7.44
Tag 18	3615	410 - 425 MeV	8.65
Tag 26	2956	288.5 - 300.5 MeV	10.03

[new update] Contributors to ADC count fluctuations

ADC counts = Energy deposit × Photon yield × Collection efficiency × Gain fluctuations × Electronics response

1. The actual amount of energy deposited by the incoming particle in the active calorimeter medium.
   a. In DD4hep simulations, we observed it has normal distribution.
2. Number of scintillation photons produced per unit deposited energy.
3. Fraction of generated photons that actually make it to the photodetector (depends on geometry, fiber optics, reflections, absorption, etc.).
4. Variation in the amplification of the signal by the photosensor (PMT dynode chain, SiPM microcells, Avalanche multiplication).
5. Conversion of collected charge into an analog voltage pulse, then digitized into ADC counts. Includes shaping amplifiers, digitizer non-linearities, electronic noise scaling.

- All contributors to fluctuations are positive and multiplicative. The log(ADC Counts) is additive and can be approximated with normal distribution.
  - This motivates the use of Log-Normal Distribution as Fit Equation.

[new update] The Fit Equation

Log-Normal Distribution Formula

If X is log-normally distributed, its probability density function (PDF) is:

$$f(x;\mu,\sigma) = \frac{1}{x\,\sigma\sqrt{2\pi}} \exp\left(-\frac{(\ln x - \mu)^2}{2\sigma^2}\right), \quad x > 0$$

Explanation of the Formula

- $x > 0$: The distribution is only defined for positive values.
- $\ln x$: The natural log of x. If you take $\ln(X)$, you get a normal distribution with mean μ and standard deviation σ.
- μ: The mean of the underlying normal distribution of $\ln(X)$, not of X itself.
- σ: The standard deviation of $\ln(X)$. Larger σ → more skewed distribution.
- **Normalization factor** $\frac{1}{x\sigma\sqrt{2\pi}}$: Ensures the total probability integrates to 1.
- **Exponential term** $\exp(-(\ln x - \mu)^2/(2\sigma^2))$: Gives the familiar bell-shape in log space.

Key Statistical Values

- **Mean (Expected value):**

$$E[X] = e^{\mu + \frac{\sigma^2}{2}}$$

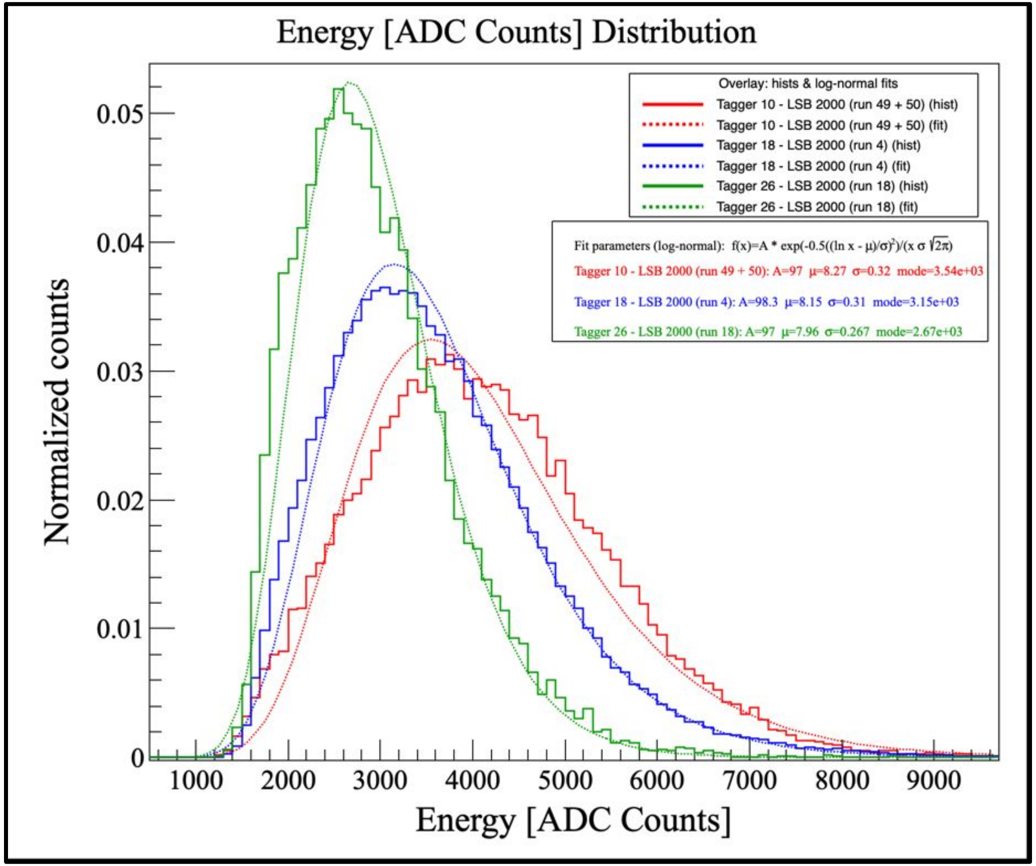
- **Median:**

$$\text{Median}[X] = e^{\mu}$$

- **Mode (most probable value):**

$$\text{Mode}[X] = e^{\mu - \sigma^2}$$

[new update] Energy Distribution for different tagger location.




```
Processing CompareDifferentTagger_LogNormal.cpp...
[Tagger 10 - LSB 2000 (run 49 + 50)]
  A      = 96.9818 ± 0.529743
  mu     = 8.2747 ± 0.00198786
  sigma  = 0.320229 ± 0.00139597
  mode (analytic)   = 3540.94
  max  (numerical) = 3540.94
[Tagger 18 - LSB 2000 (run 4)]
  A      = 98.2879 ± 0.244332
  mu     = 8.1512 ± 0.00087861
  sigma  = 0.30969 ± 0.000499406
  mode (analytic)   = 3150.43
  max  (numerical) = 3150.43
[Tagger 26 - LSB 2000 (run 18)]
  A      = 96.9967 ± 0.755451
  mu     = 7.96099 ± 0.00221618
  sigma  = 0.266774 ± 0.00126962
  mode (analytic)   = 2669.96
  max  (numerical) = 2669.96
```

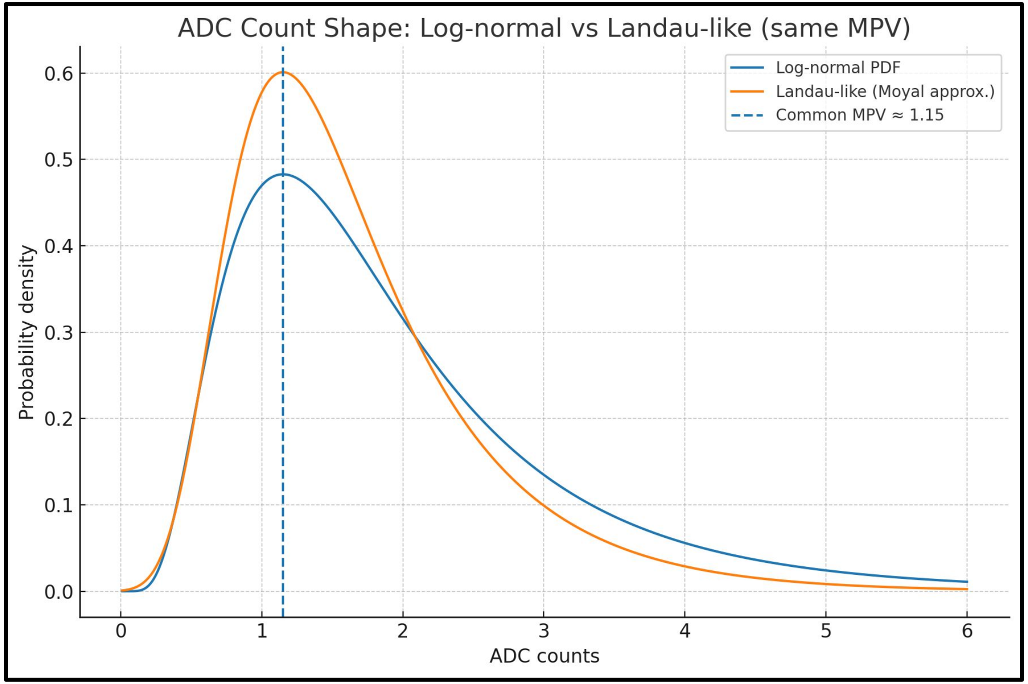
Tag. Loc - Rec Eng. (ADC) - Gen Eng. (MeV) - ADC/MeV

Tag 10 | 3540.94 | 545 - 563.5 (554) | 6.39

Tag 18 | 3150.43 | 410 - 425 (417.5) | 7.55

Tag 26 | 2669.96 | 288.5 - 300.5 (294.5) | 9.07

[new update] Log-Normal Vs Landau Distribution



- Landau preferred for thin absorbers [less contribution from high energy tails]
- Log-Normal for thick absorbers [contains high energy tails]

Summary

- Discuss the Log-Normal Distribution as a possible fit equation for the energy distribution seen at different tagger location.
- Any suggestions for further analysis.