CAST High Energy Calorimeter

CAST 22nd Collaboration Meeting

Thursday & Friday, 19 & 20 August 2004

Detector Installed and Operational

- Calorimeter Installation: 18 February, 2004
- First Solar Tracking Run upon 2004 restart: 10 June, 2004

(See presentation during 21st CAST Collaboration Meeting for more details on installation)

Reminders: Calorimeter Design and Properties

- Large inorganic scintillating crystal ($CdWO_4$) selected for low intrinsic BCKG, γ efficiency and PSD
  - Ø45mm x 50 mm , 0.6 kg
- Low-background photomultiplier tube (PMT)
- <0.02 Bq ^{210}Pb/kg inner Pb shield, Rn displacement
- Plastic scintillator as a 4π active muon veto
- Borated thermal neutron absorber
- Sub-200 keV threshold
- 200 MeV dynamic range
- (See Joaquin's past talk for more details)

Calorimeter Status

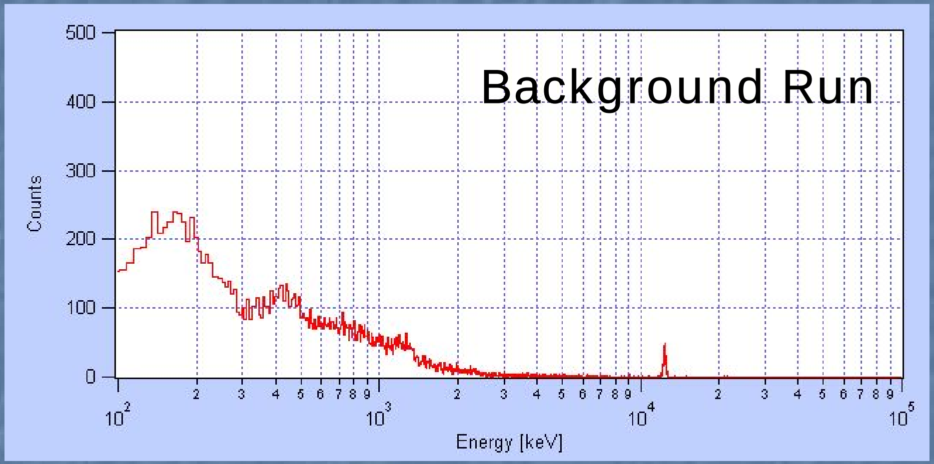
- Data Report
  - Tracking Runs = 58
  - Missed Runs = 12 (quenches, interventions, etc…)
  - Approximate Tracking Time: ~90 hours (9.28 hrs for this "analysis")
  - Approximate Background Time: ~800 hours (130.5 hours for this "analysis")
- Detector and DAQ Monitoring
  - Gain Stability
  - Data Transfer

DAQ

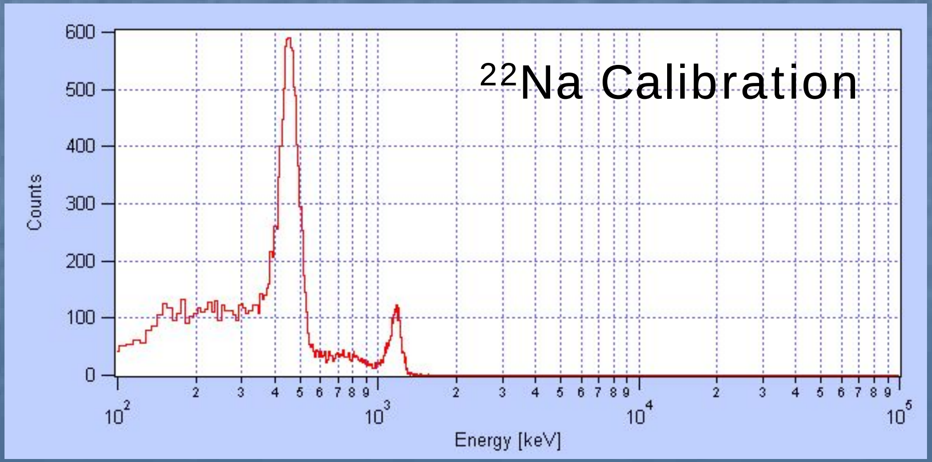
- XIA Digital Spectrometer
  - Pulse shape waveform acquisition
- Spectrometer Software (modified proprietary)
  - Little online detector information, but reliable
  - Significant shifter interaction (moving towards more remote control from Chicago)
- Calibration procedure
  - Manual placement of γ-ray source but…
  - Natural lines (511 keV, ^{40}K) allow gain-shifting
- Data File Transfer: currently manual (moving towards automated)

DAQ

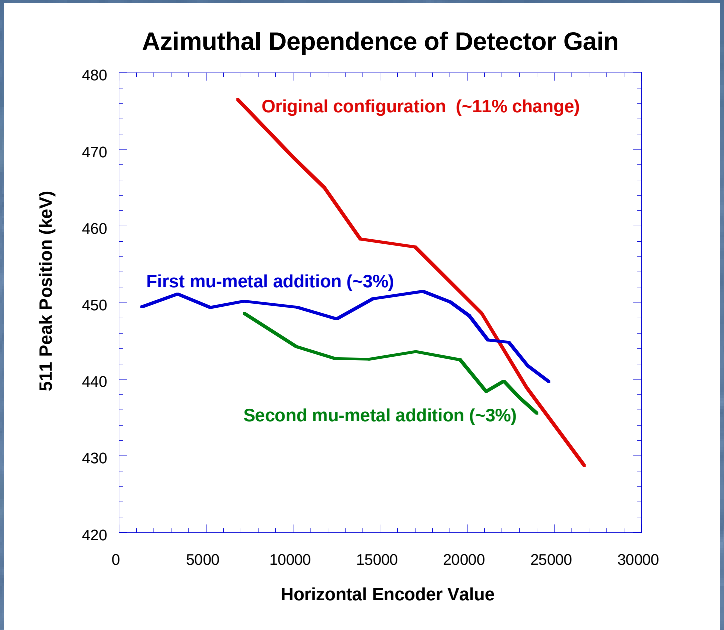
- Energy spectra automatically produced at the end of a run

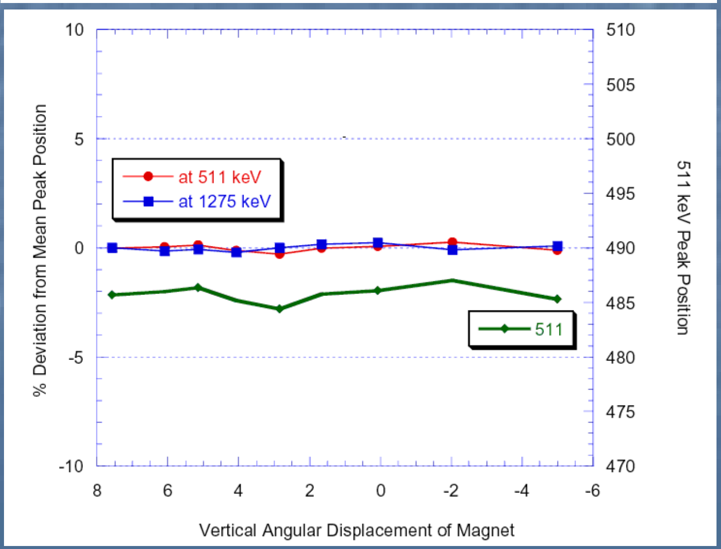


- MCA included as part of the digital spectrometer…good monitor of detector between runs



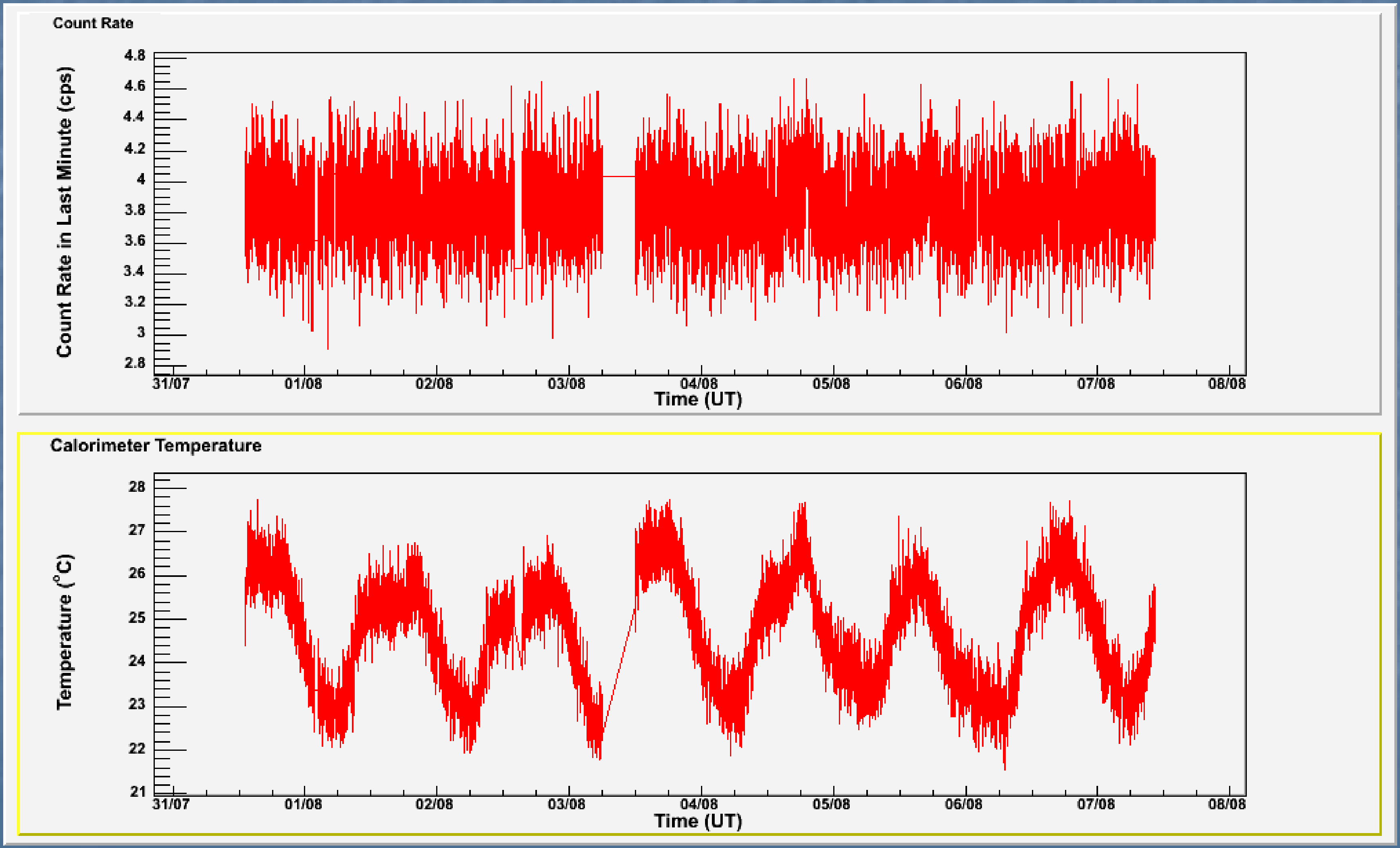
Detector Stability: Gain



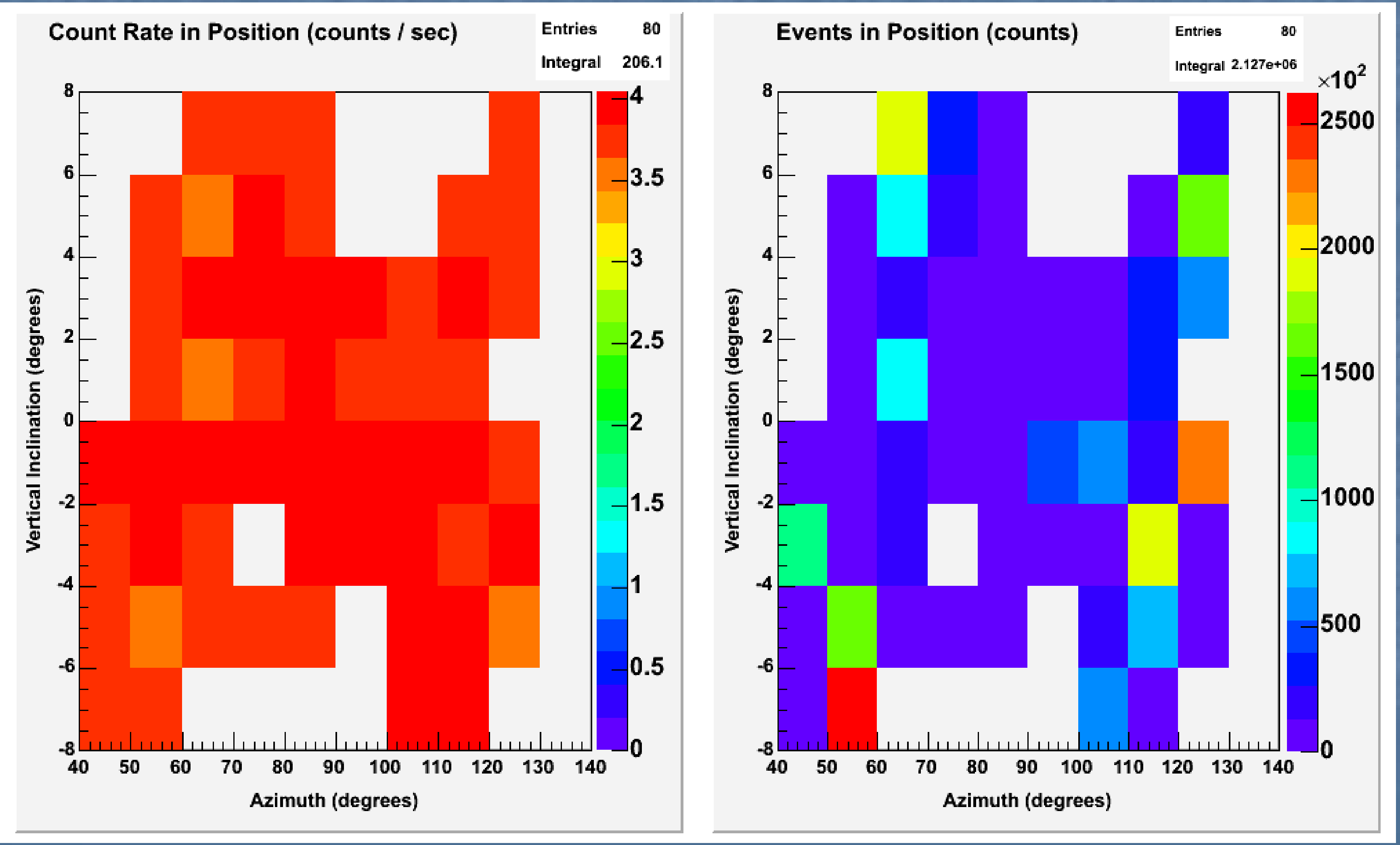


- Initial measurements revealed as much as 11% changes in gain, ambient B-field responsible
- Only along horizontal (does not affect tracking)
- Mu-metal reduces overall change to ~3% and mostly over a small horizontal region
- Gain shift of data offline using natural 511 keV and ^{40}K lines corrects the residual effect (1 hr periods contain enough statistics)

Detector Stability:
Event rate over Time & Temp

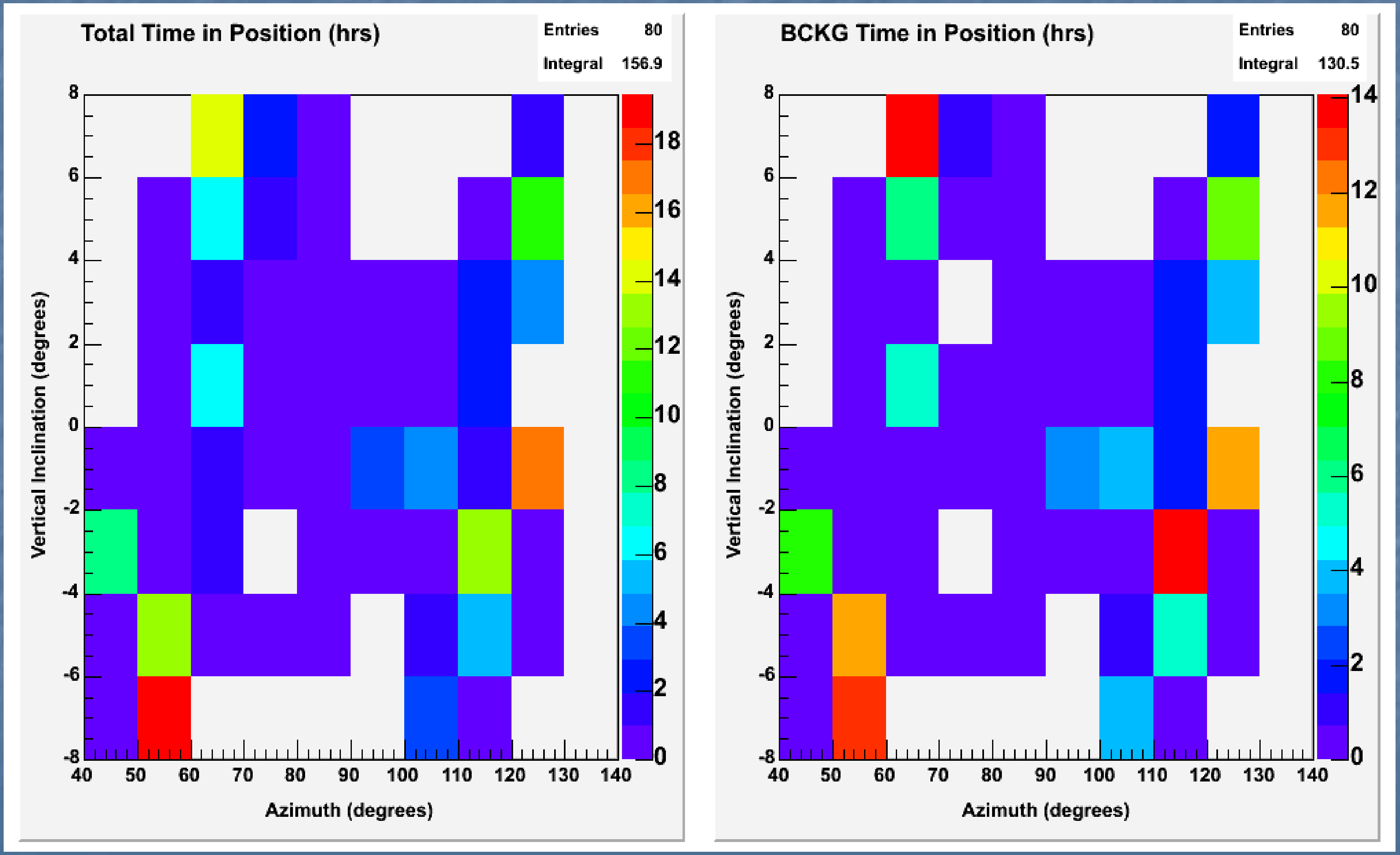


Detector Stability: Event rate over Position



D. Miller

Monitoring of Systematics:
To be continued…



Calorimeter Data Processing

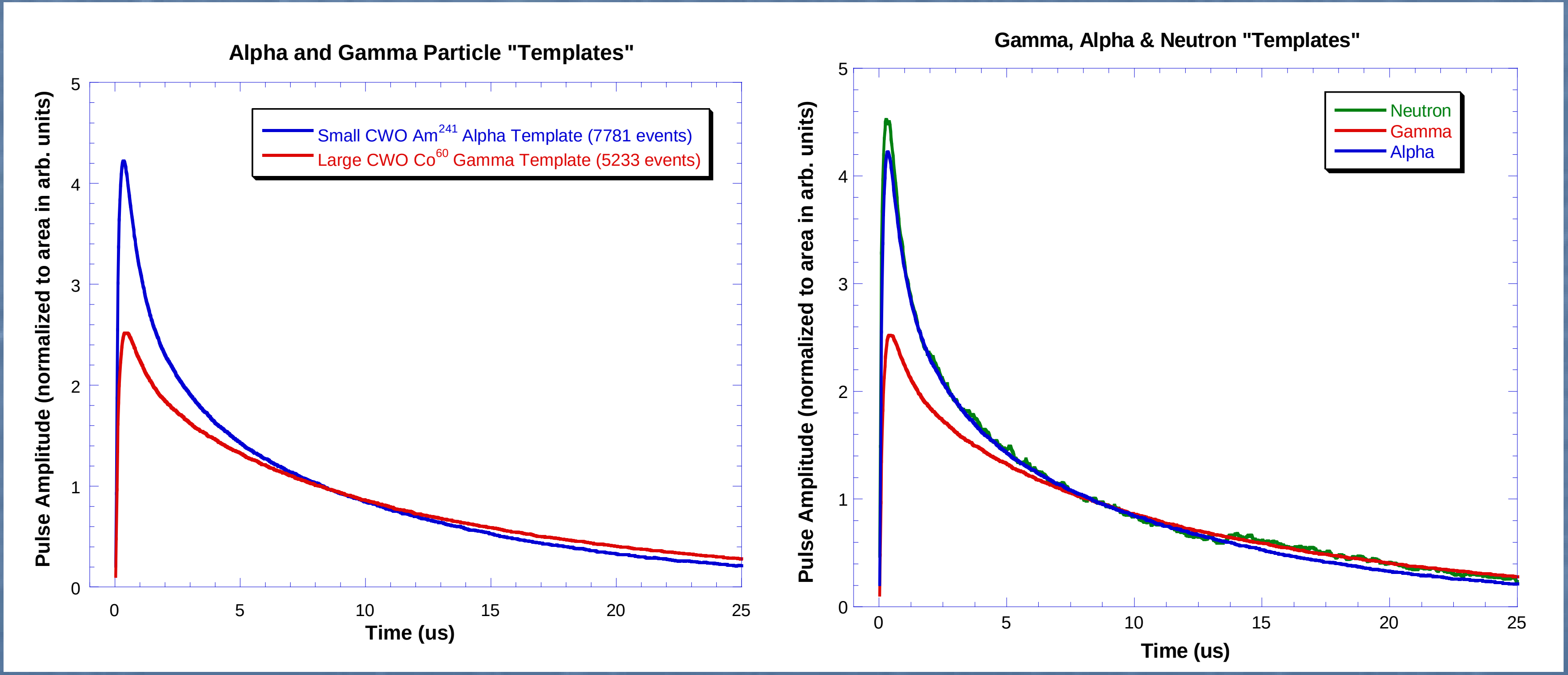
- Pulse waveform acquisition with digital spectrometer
- Rejection of ~95% muon induced events in coincidence with active muon veto
  - but waveforms preserved for crosschecks: correct PID for muon events, muon event rate, etc.
- Livetime calculation using LED pulser (~93%)
- Pulse Shape rejection of spurious PMT events, pulser events, α's, neutron recoils (in progress)

Pulse Shape Discrimination

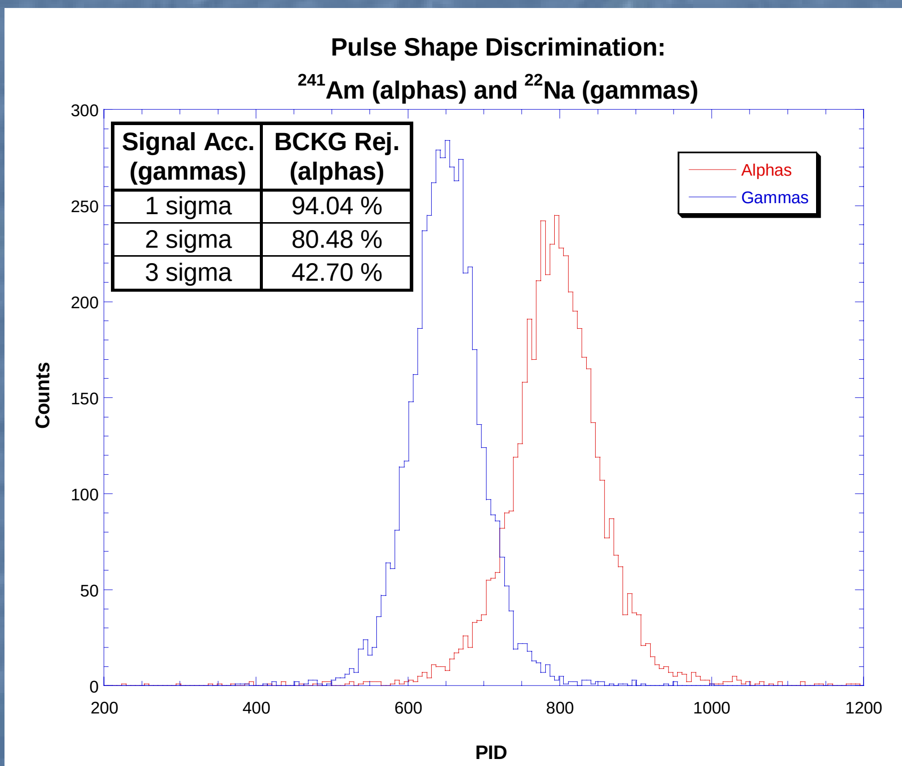
- Offline pulse shape pattern recognition similar to that used in double-beta decay
  - see *Fazzini et al. "Pulse Shape Discrimination with $CdWO_4$ crystal scintillators" NIMA 410(98)213* for many details

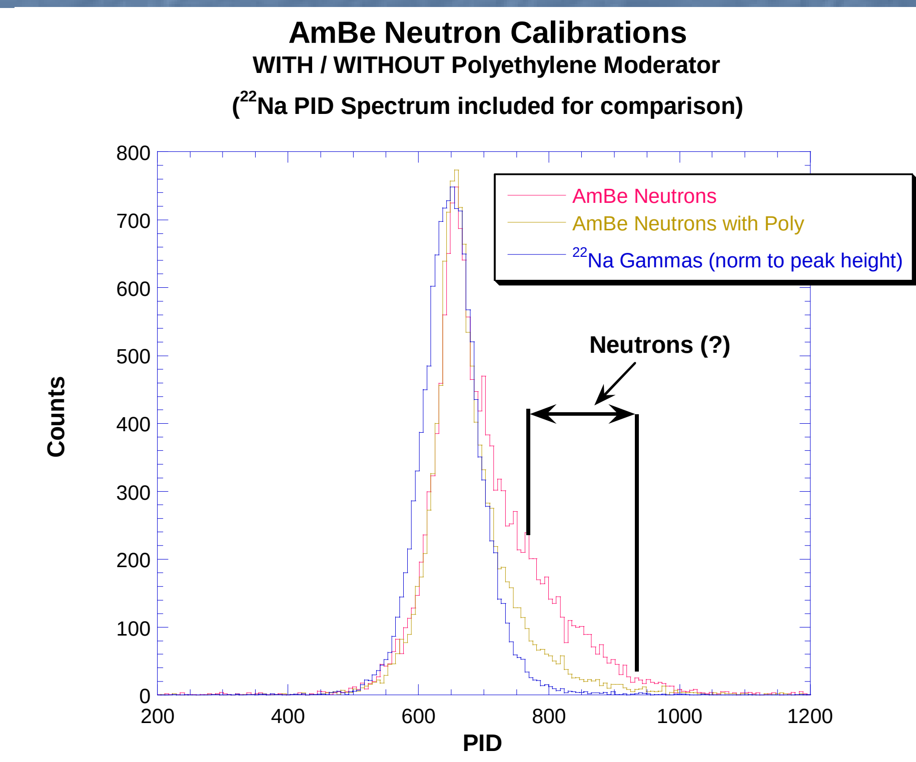
- Particle calibrations performed in Chicago
  - γ's : ^{22}Na, ^{54}Mn, ^{167}Cs, ^{60}Co, ^{88}Y, etc…..
  - α's : ^{241}Am
  - **n**'s : Am/Be, ^{252}Cf

Pulse Shape Discrimination
Calibrations



Pulse Shape Discrimination *Calibrations*

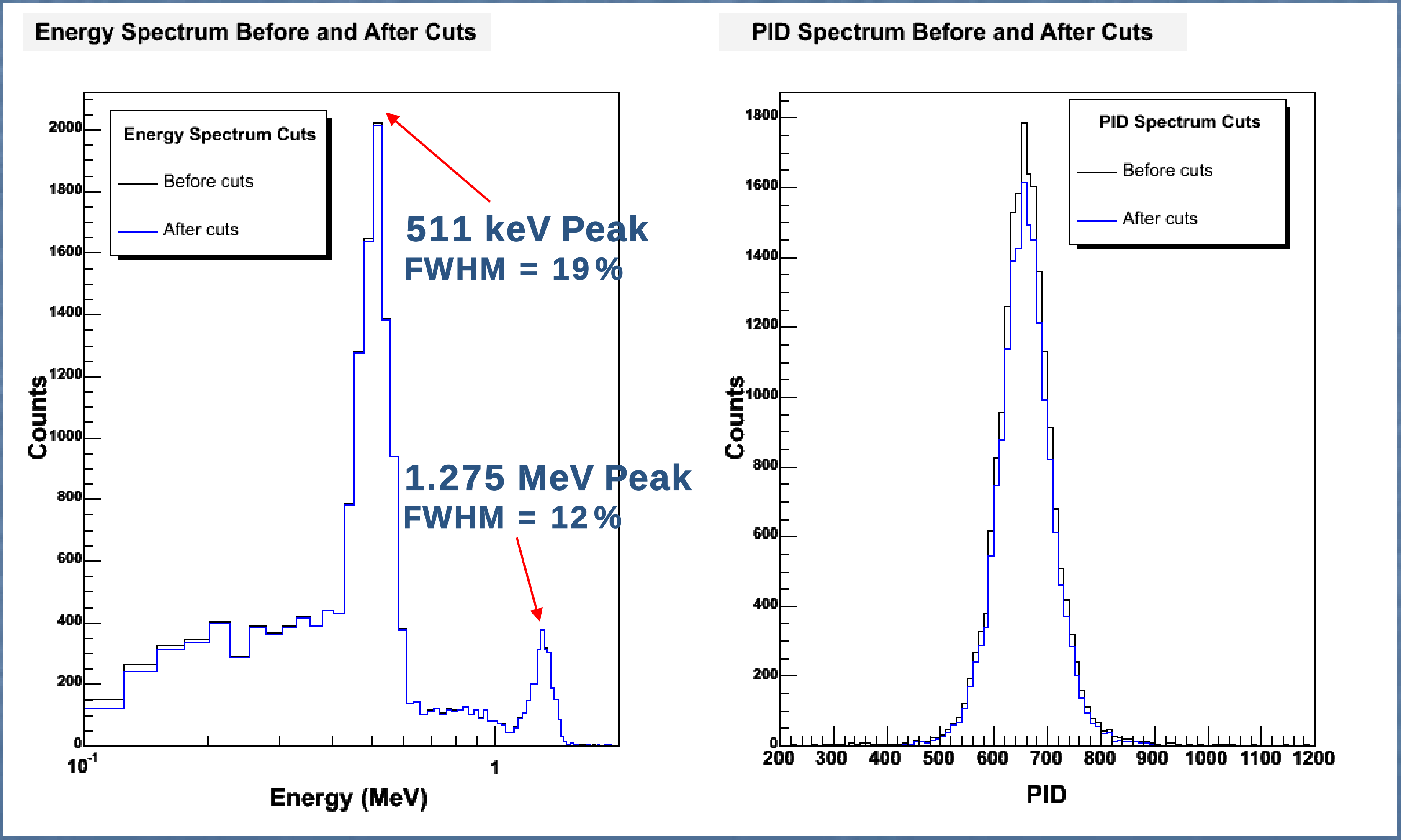




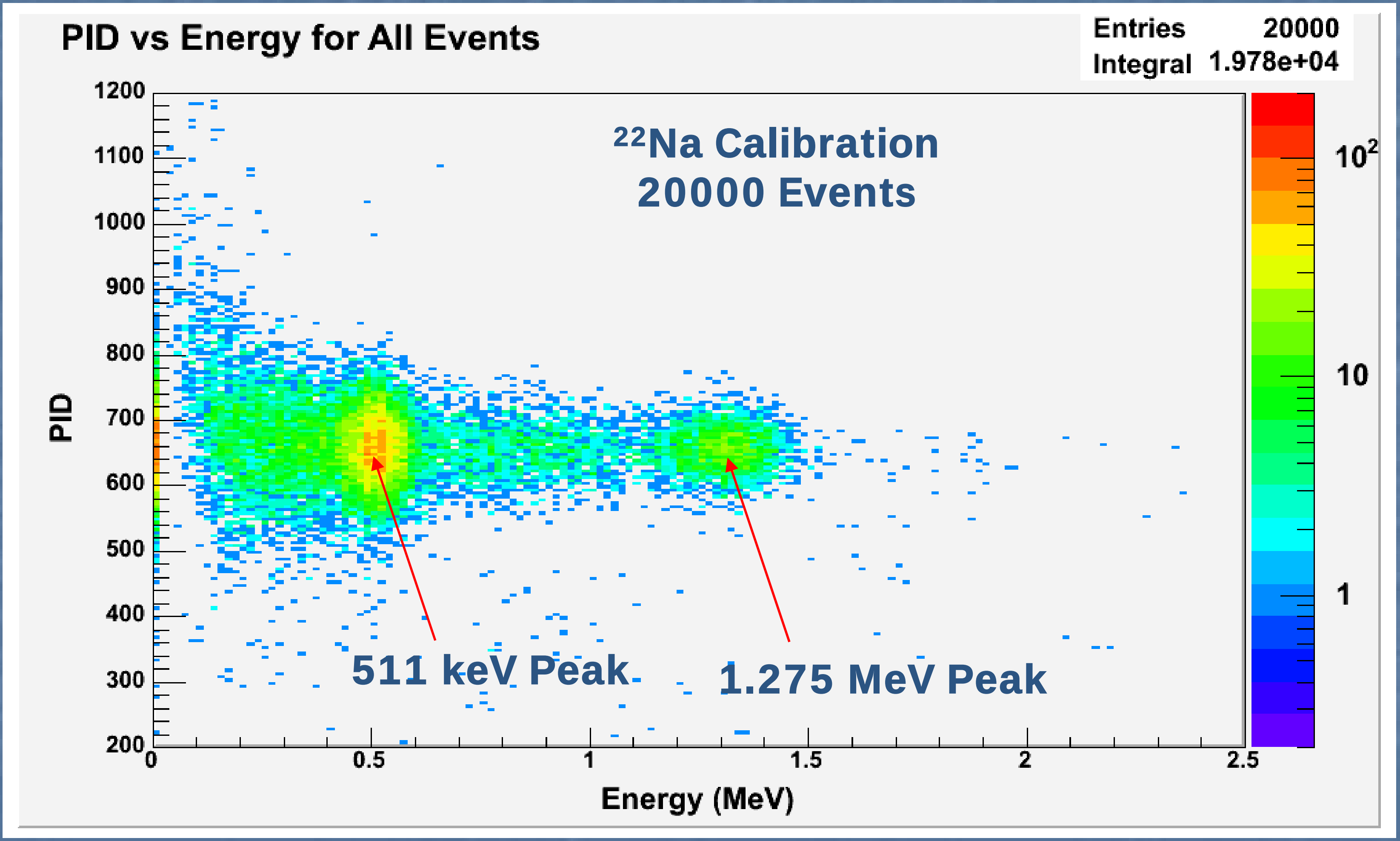
CERN Detector Operation

Detector Calibrations

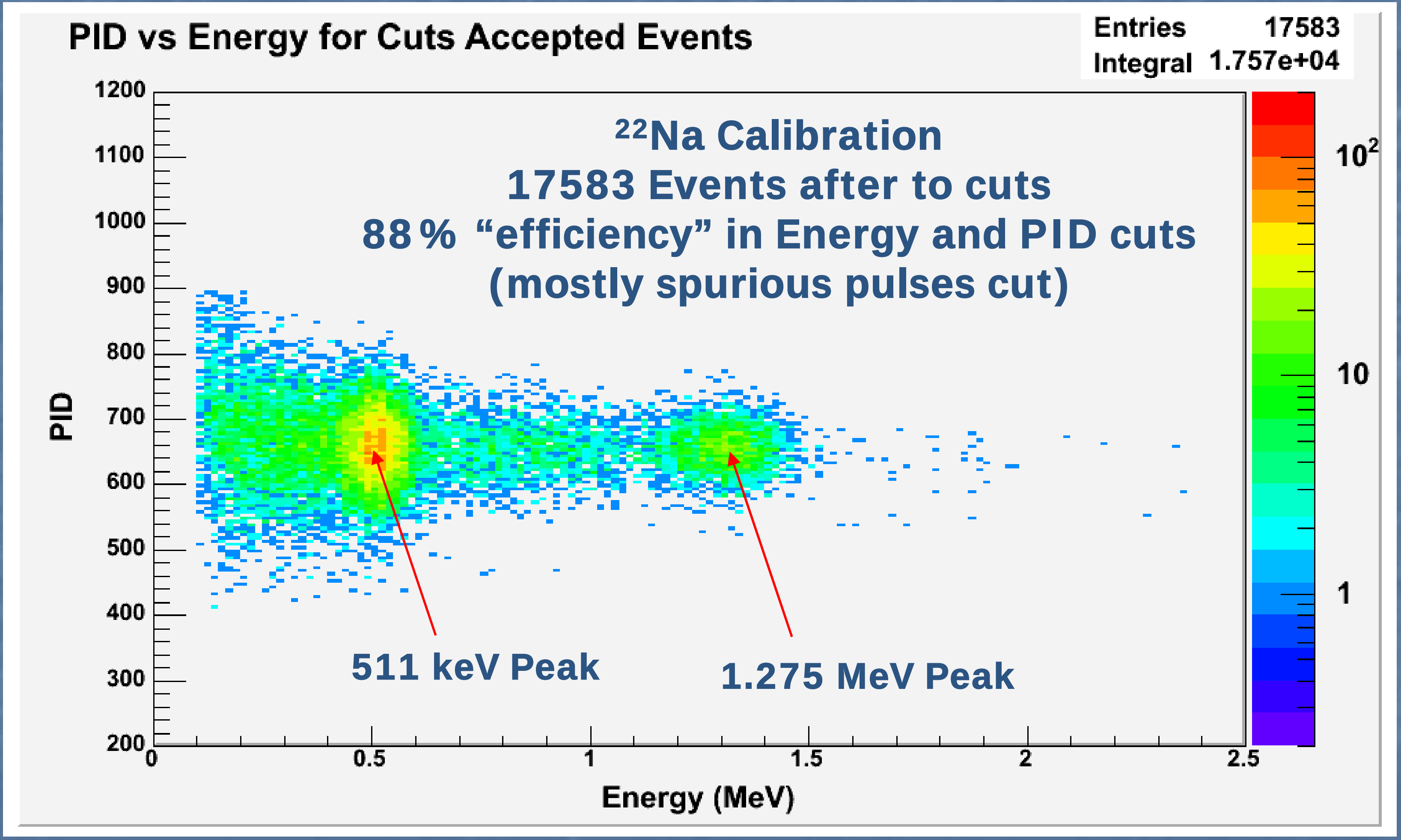
^{22}Na γ source



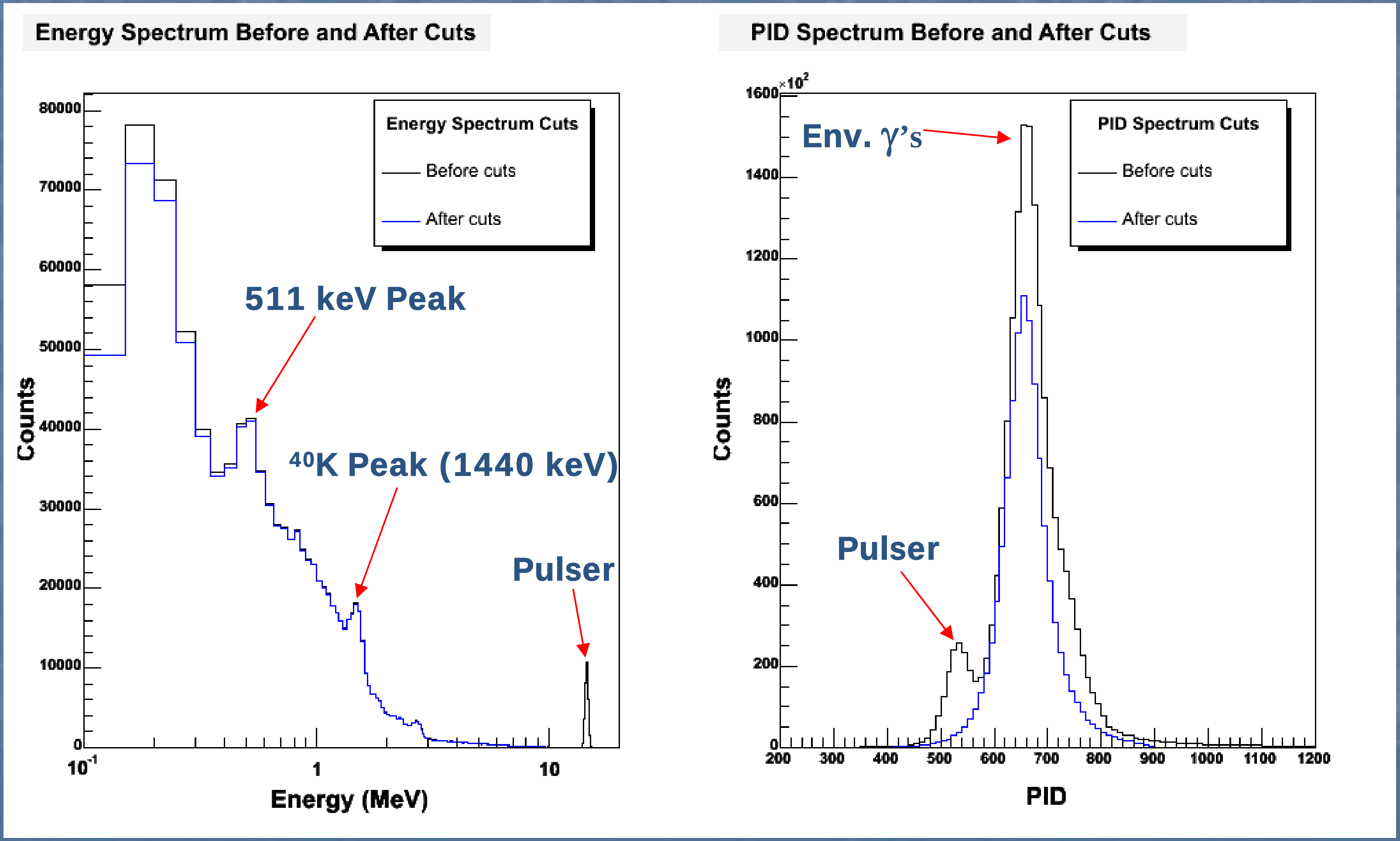
Detector Calibrations



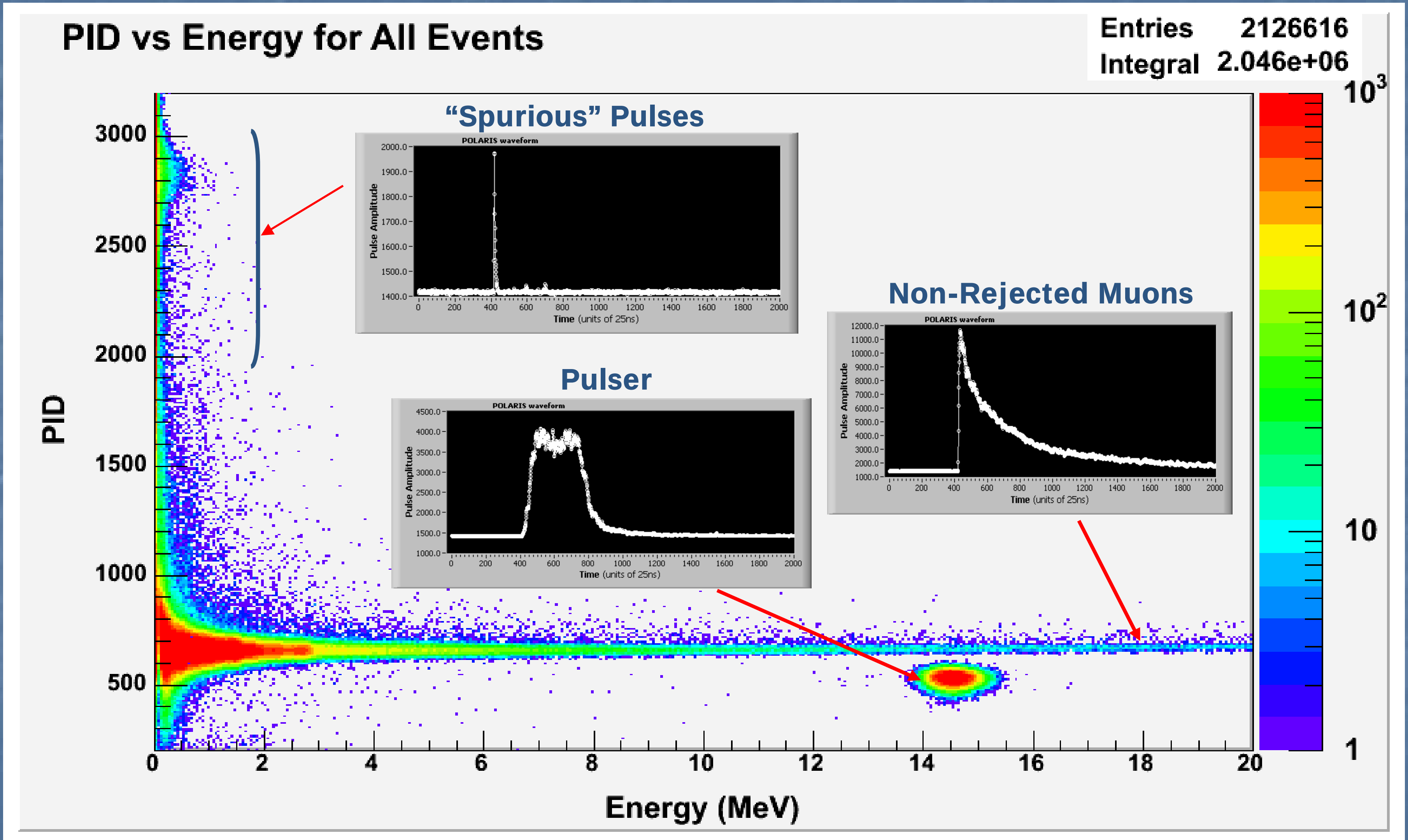
Detector Calibrations



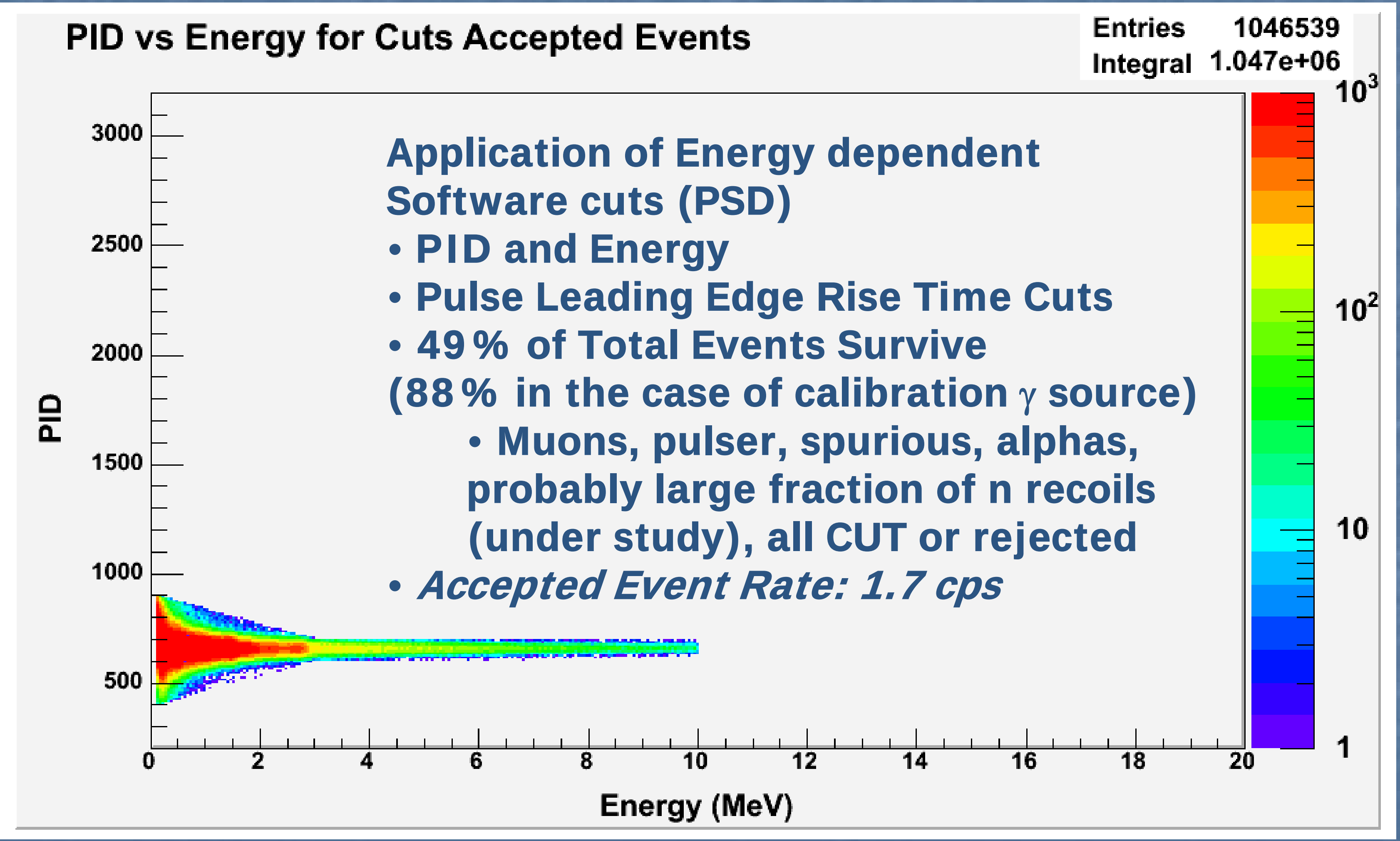
Calorimeter First Results



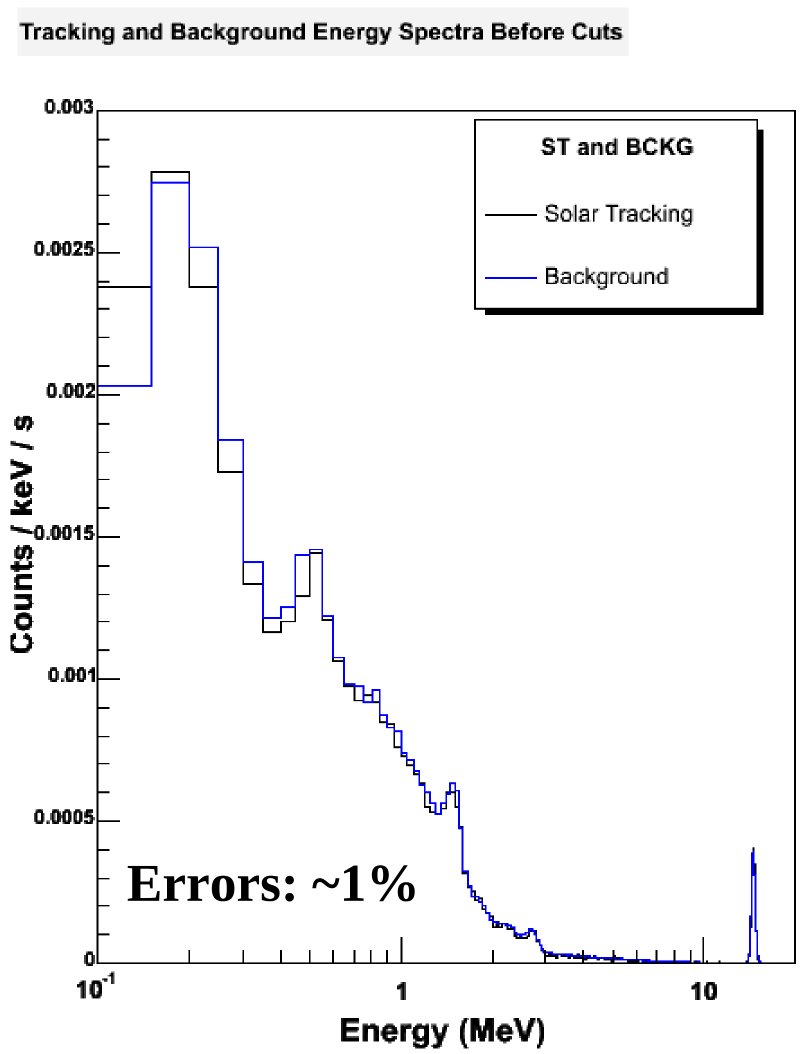
Calorimeter First Results

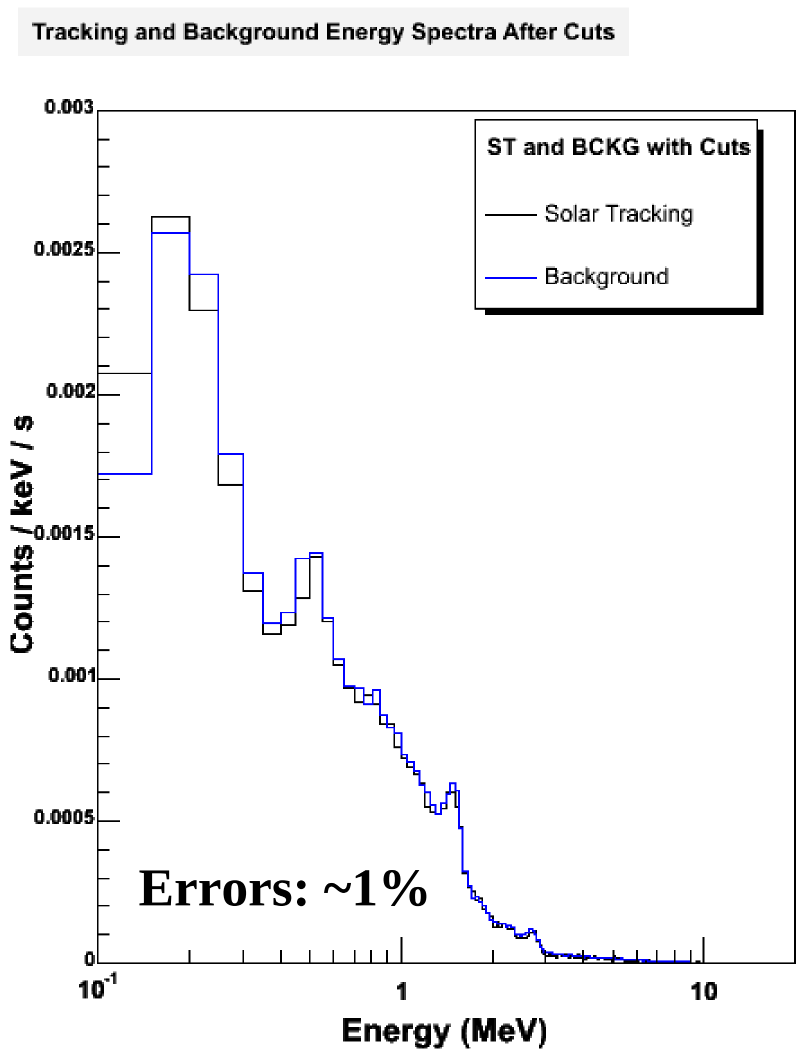


Calorimeter First Results



Tracking vs. Background Data





Prospects for the Calorimeter

- Improve DAQ procedure
  - Environmental radioactivity lines for calibration
- Automated File Transfer, remote access to PC
- Online Detector information
- Develop gamma peak search strategies and obtain limits on transitions of interest and relevant couplings

Other business

- The issue of Flex-Boron around the calorimeter
  - It is needed to avoid capture in CWO (10% reduction in present BCKG)
  - Neutron flux able to contribute to absorption in F-B is ~10^{-2} n/cm^2 s
  - F-B is ~5000 cm^2 (generous estimate), which means it is emitting 480 keV gammas at a rate of <~50/second. This is not a source…
  - large (Pb shielded) CWO catches about ~1 every fourth day
  - The "source" is at an average distance of ~30 cm from the μMs ⇒ few γ's going through its active region / minute. At 480 keV, the probability of interaction with Ar at 1 bar (over 1 cm) is ~ 10^{-4}…
  - The CCD is on top of everything shielded…
  - Is this really worth a Monte Carlo?

Recommendations for PRL/analysis

- The very real possibility that the present analysis is faulty must be addressed: the question of why the obtained 95% coupling is seen to be too small when tried on the raw data (Juan's last suggested test) needs to be answered. This should be the acid test for how conservative a method is (it is a method in itself, maybe the most straightforward)

- There is no need to delay publication if those concerned try to tackle the issues rapidly. Avoiding to face the issues is not a solution.

- Maximum Likelihood, rebinning, etc., need to be tried. We may be far from obtaining the best possible limits with the data at hand, esp. in the CCD. Why there has been such a paucity of approaches until recently is a sad thing to witness.

- The present draft conveys too little information in too much space. This is not the PRL format. Needs serious revisions, and probably several versions to be circulated, with less and less corrections looked for in every iteration. This does not have to be a slow process if we get organized.

A high-energy axion detector for CAST

(J.I. Collar, D. Miller, J. Vieira, EFI UoCh)

•**Goal:** extend sensitivity of CAST to axion-induced gammas from few tens of keV to ~150 MeV

•**Motivation**: If new boson couples to nucleons, it can substitute for a γ in plasma and nuclear processes [1]. Solar luminosity via axion emission can be as high as few % of total. Search with helioscope has not been performed before.

→ Weak experimental limits already exist from observed solar γ flux below 5.5 MeV ($a \rightarrow \gamma\gamma$ following $p + d \rightarrow He + a$) [2].

→ Other reactions of interest exist (e.g., 2.2 MeV from $p + n \rightarrow d + a$, 511 keV from $e^+ + e^- \rightarrow a + \gamma$, 477 keV from $^7Be + e^- \rightarrow {}^7Li^* + \nu_e$ [3], etc.)

→ A generic search should not be limited to M1 transitions [4]. Should surpass sensitivity of searches for anomalous production of single γ's in accelerators [5]. May surpass sensitivity to small branching ratios (~<10^{-5}-10^{-6}) in laboratory searches [6]. (calculation of expected sensitivity in progress)

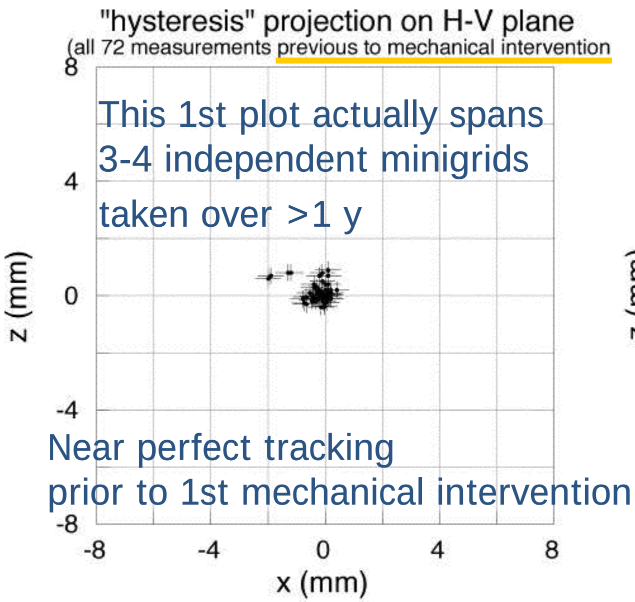
•**Must be compact and non-intrusive**, yet reach the lowest possible sea-level background and highest efficiency

→ Careful design and selection of detector and shielding materials

→ Use of Pulse-shape background discrimination in lieu of additional shielding

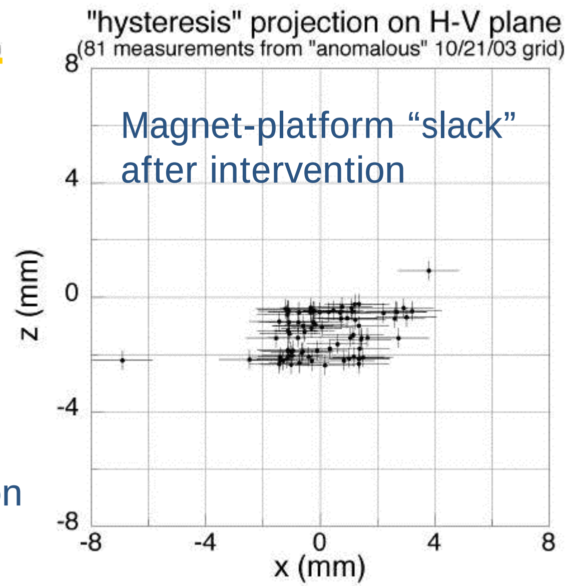
[1] G. Raffelt, "Stars as laboratories for fundamental physics", University of Chicago Press, Chicago and London (1996).
[2] G. Raffelt and L. Stodolsky, Phys. Lett. B119, 323 (1982).
[3] M. Krcmar et al., Phys. Rev. Lett. (hep-ex/0104035)
[4] G. Raffelt, Priv. Comm..
[5] C. Hearty et al., Phys. Rev. D 39(1989)3207.
[6] A. V. Derbin et al., Phys. At. Nucl. 65 (2002)1335; M. Minowa Phys. Rev. Lett. 71(1993)4120.

A history of hysteresis

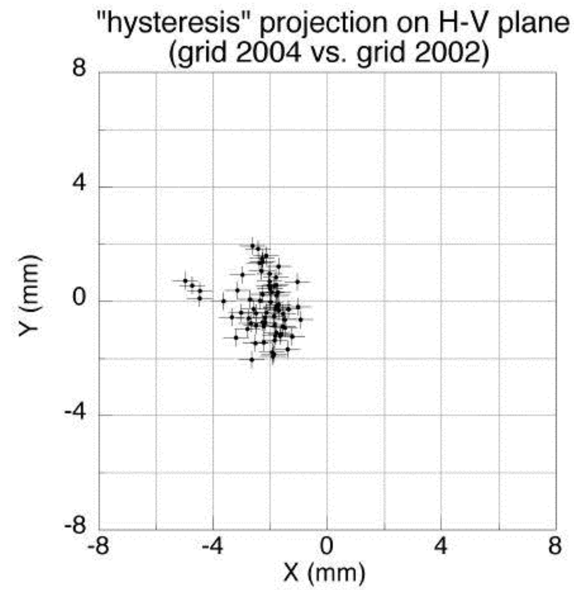


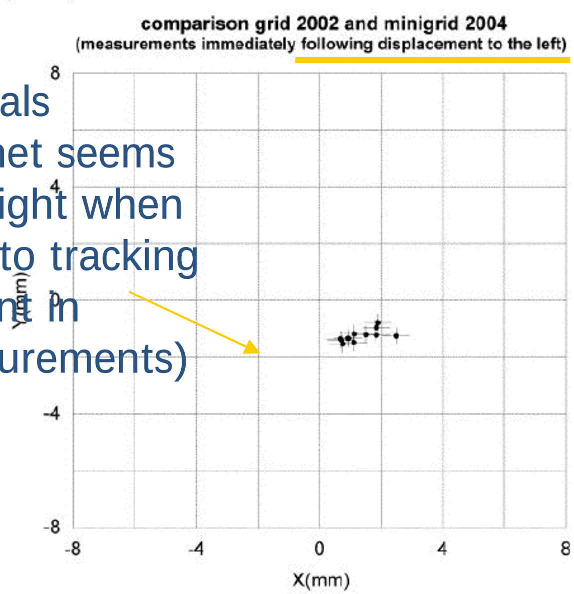
This 1st plot actually spans 3-4 independent minigrids taken over >1 y

Near perfect tracking prior to 1st mechanical intervention

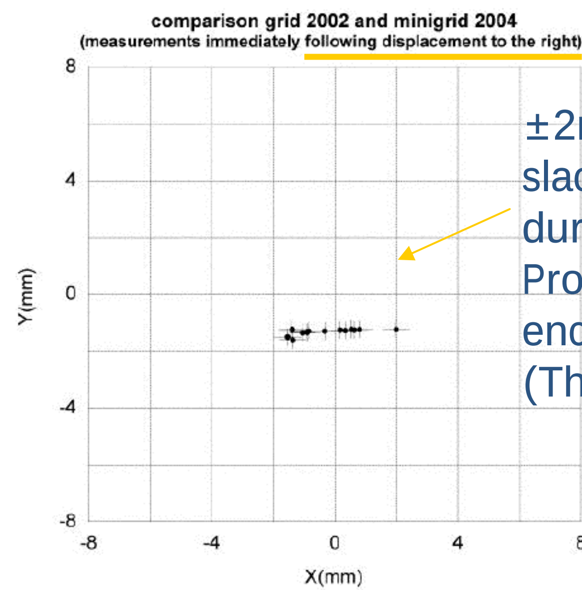


Magnet-platform “slack” after intervention





last minigrid reveals that indeed magnet seems to “stick” to the right when moving opposite to tracking direction (apparent in mechanical measurements)



±2mm horizontal slack always present during tracking. Problem with vertical encoder solved? (Thomas?)

Upcoming mechanical intervention(s)

- There is a before and after the previous in tracking precision: we should have learned a lesson
- The recent engineering study concludes that there is no risk to personnel or system from the existing condition of the structure.
- The point has been made recently that new interventions would keep the tracking system from further deterioration (?!): Grid measurements after previous intervention show no evidence of any evolution (see previous transparency)
- What this means is that whatever is planned for the next round should be extremely conservative and should keep tracking quality in mind: there is no guarantee that we could recover it
- The UoC team does not have the manpower to pick up the pieces: if unnecessary modifications are made that damage the tracking, somebody else should start planning to mend things.