SAND2014-2842P

Status of Scatter Camera Measurements at the SNS

David Reyna
Belkis Cabrera-Palmer
Mark Gerling
Sandia National Laboratories, CA

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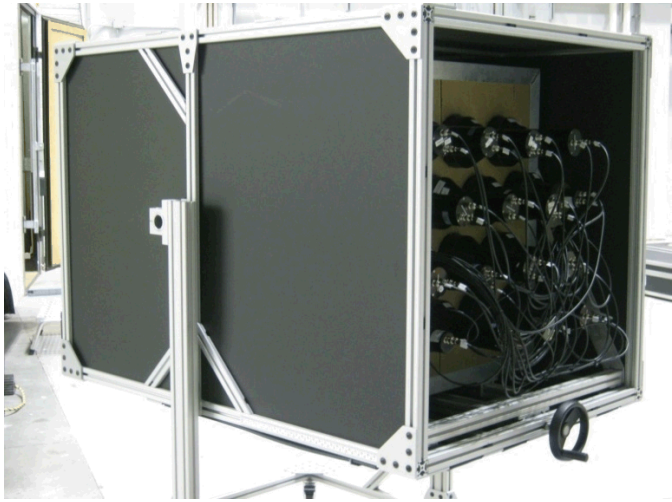
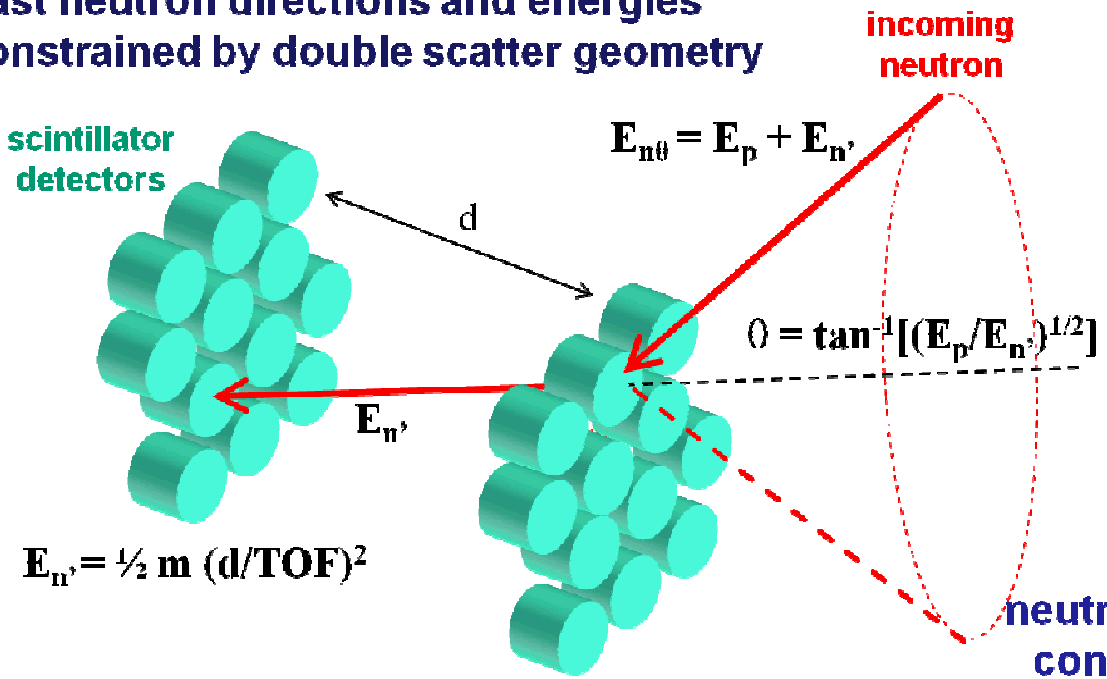
What is a Neutron Scatter Camera?

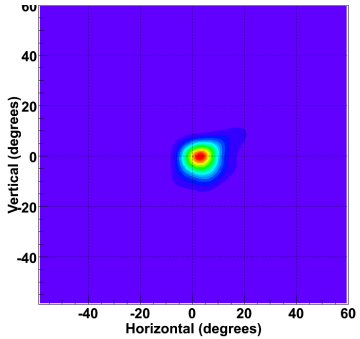
- Fast neutron imaging spectrometer
- Variable plane separation allows tradeoff of effective area, image resolution



Fast neutron directions and energies constrained by double scatter geometry



neutron direction constrained to cone surface



An MLEM-reconstructed neutron point source image.

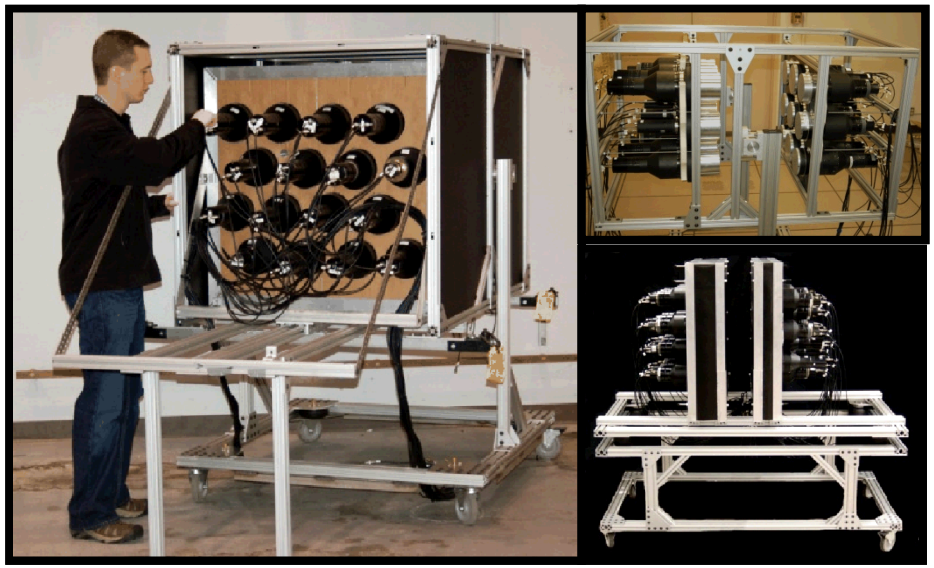
Multimode capability includes

- ***Neutron energy spectrum.***
- ***Compton imaging.***

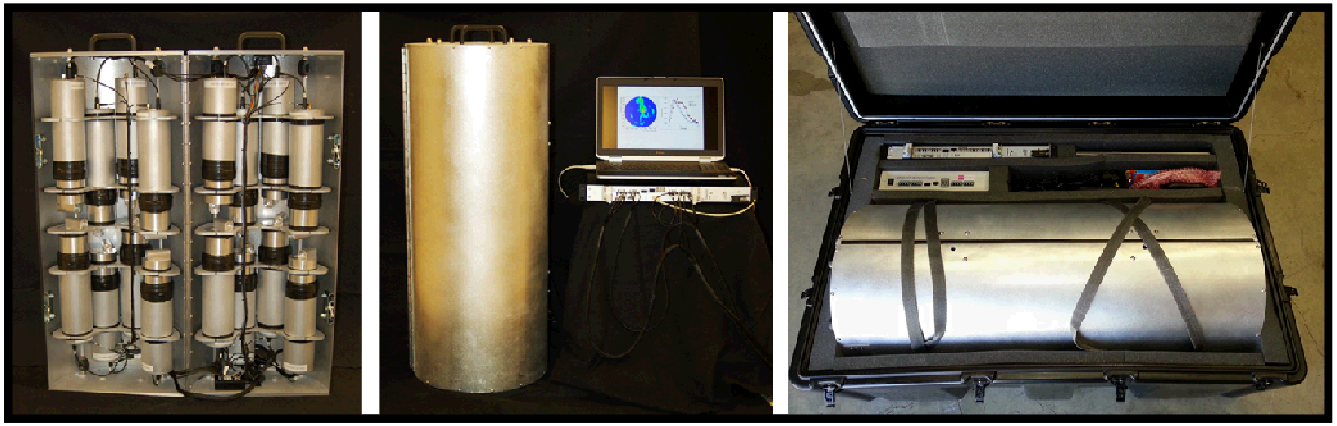
Sandia's Neutron Scatter Cameras

Neutron Scatter Camera, 32 elements

Previous Generations

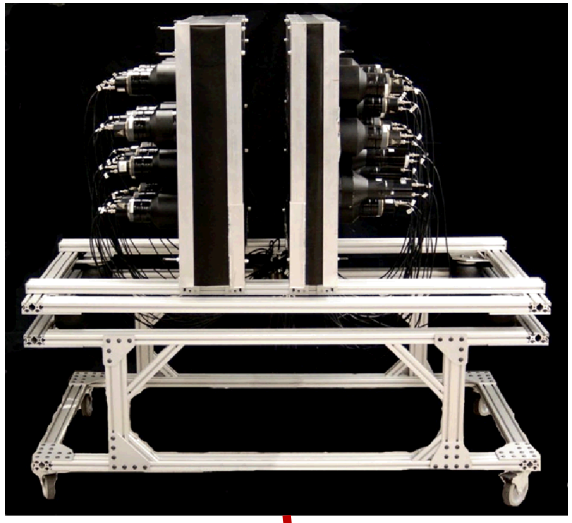


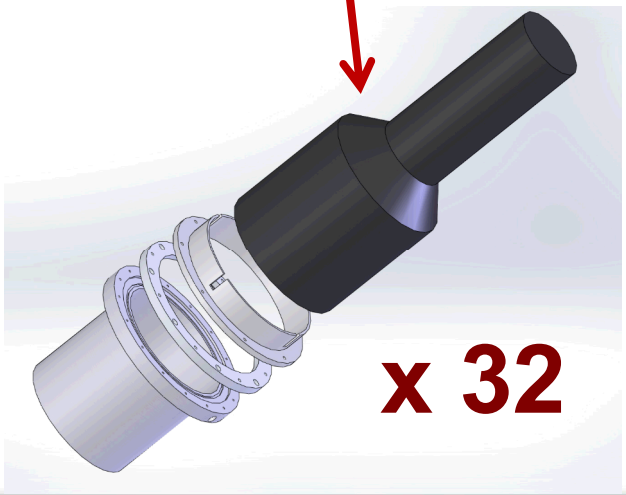
MINER: Compact 16 element NSC



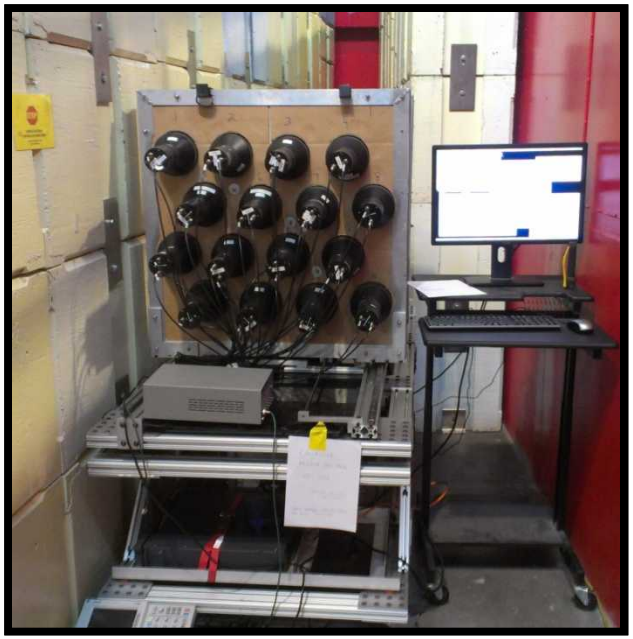
Liquid Scintillator Detectors

- Detector design refined over several generations of Neutron Scatter Camera
  - 16 - 5”D x 5”H and 16 – 5”D x 2”H liquid scintillator cells (EJ-309)
  - 5” Hamamatsu PMTs
  - 16 x 1.6L and 16 x 0.65L detectors: total active volume ~36 L
- Improvements Required to handle neutron energies > 10 MeV
  - New ADCs with larger range (Struck 3316)
  - Modified DAQ to work with new electronics and beam spill triggers



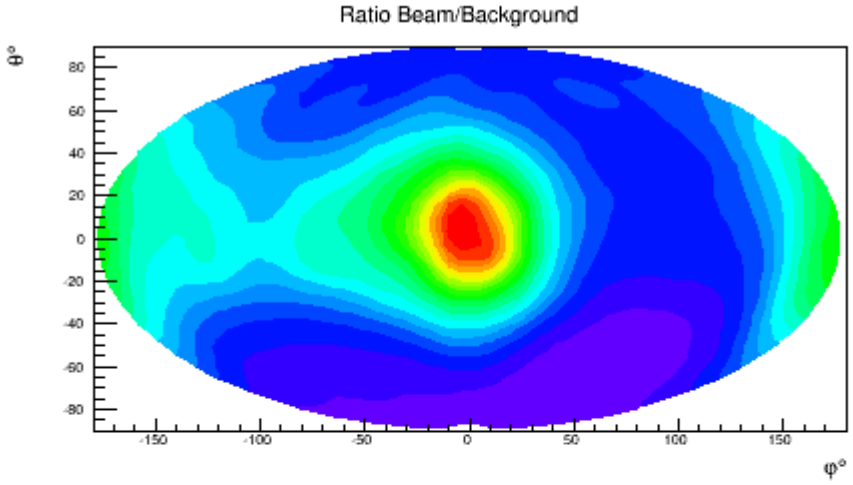


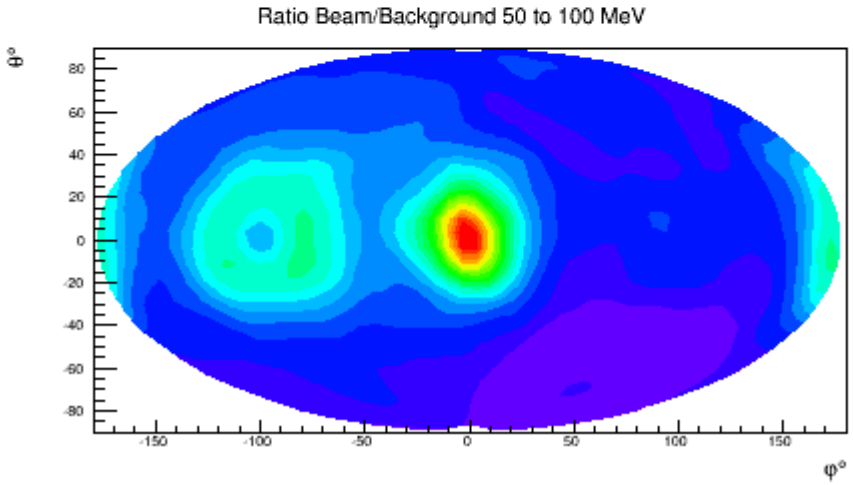
Neutron Scatter Camera @ the SNS



Note: NSC is actually facing “backwards”

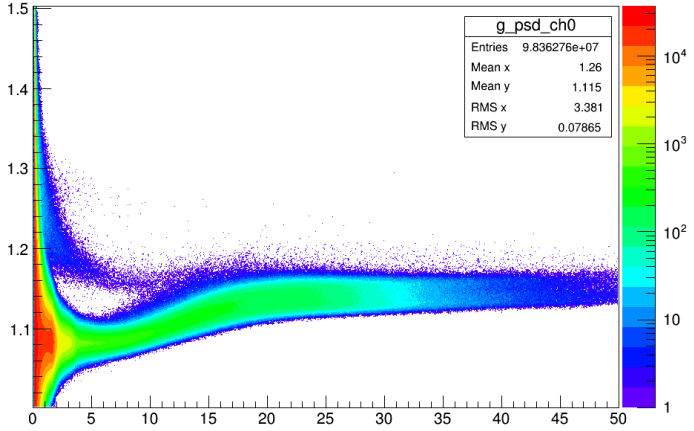
Initial Imaging Analysis





First Pass Looked Good… But with Questions

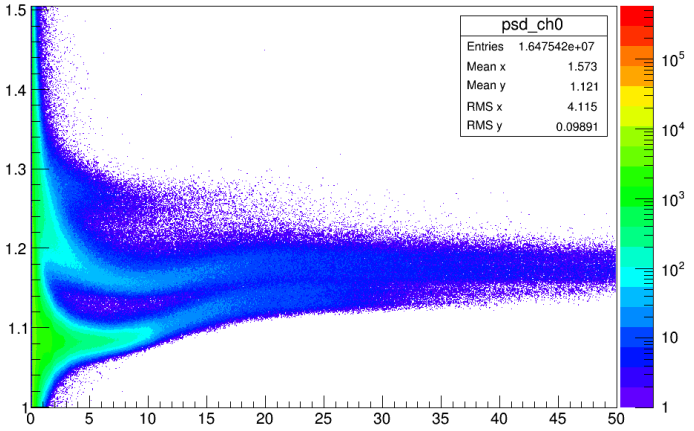
"Out of Beam" 15us window

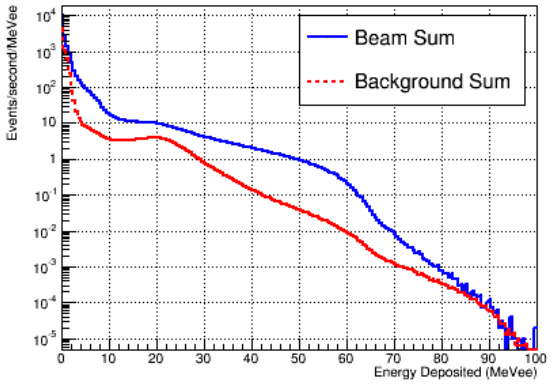


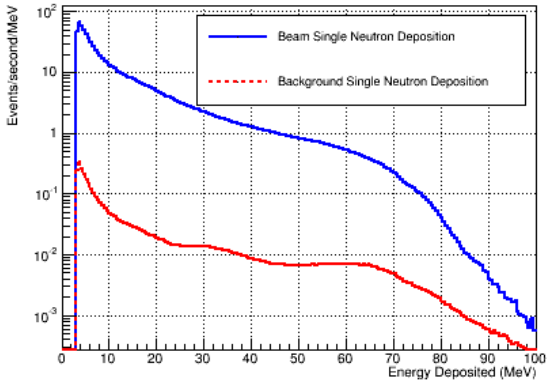
PSD showed significant neutron signal associated with beam spill

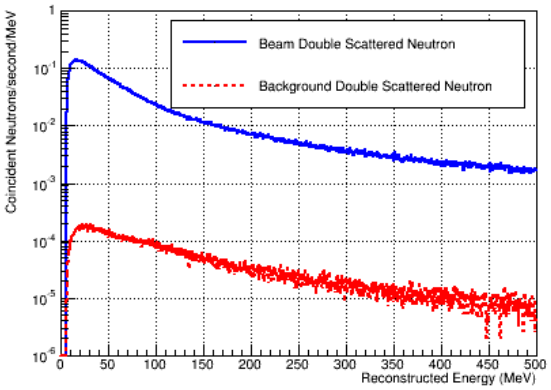
But why is the PSD so non-linear with energy?

"In Beam" 1us window





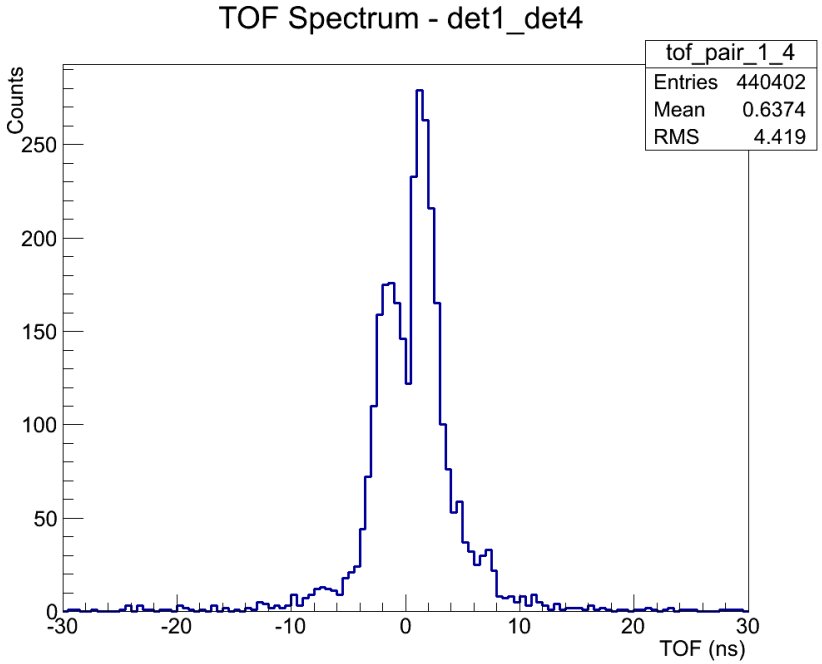




Single scatter spectra look OK, but double scatter data looks too "flat".

Even out of beam spill doesn't look at all like the Hess spectrum.

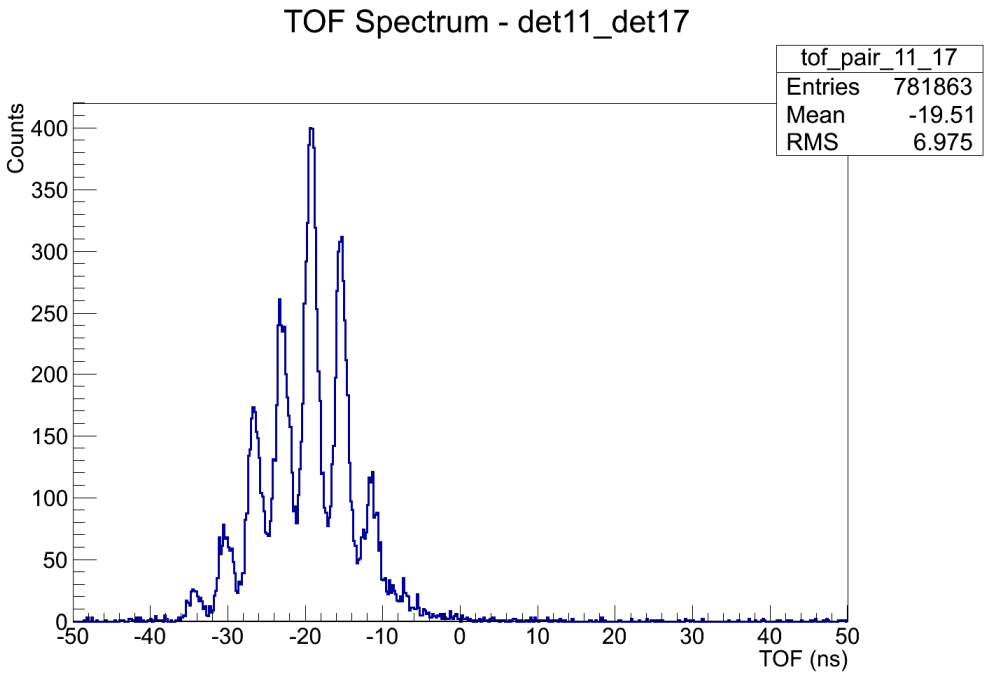
Checking Channel-to-Channel Timing



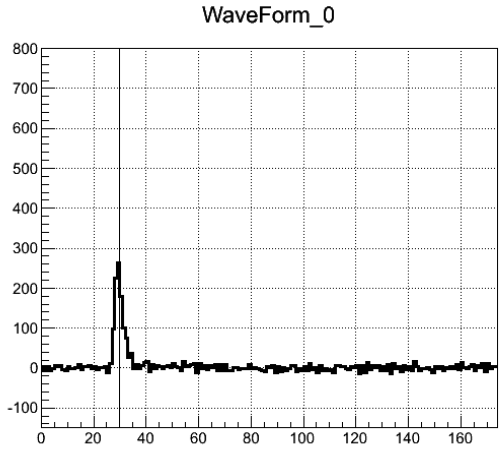
What we expected:

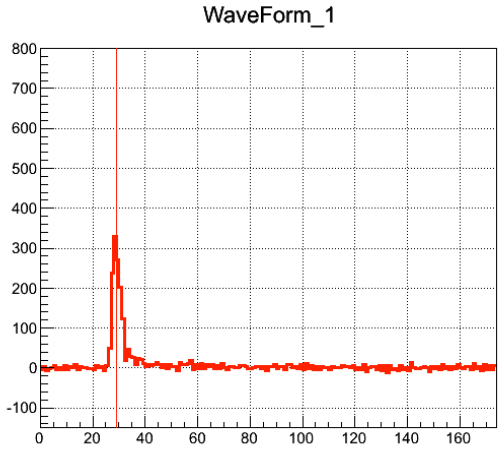
- 2 peaks separated by twice the known TOF between channels
- If timed correctly, should be centered around zero

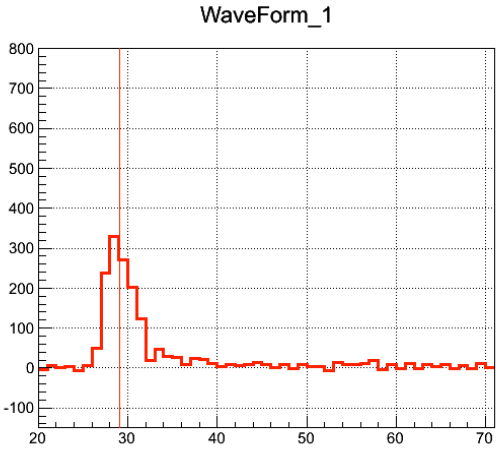
What we found: A horrible mess

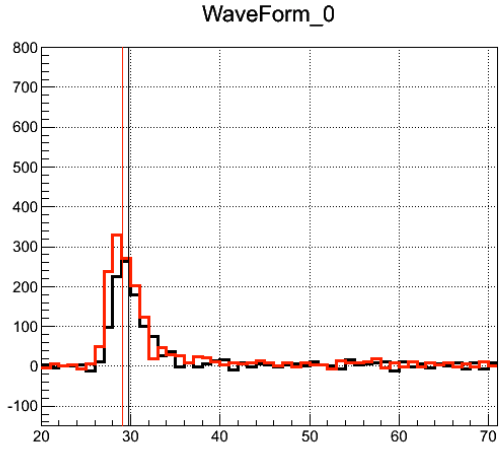


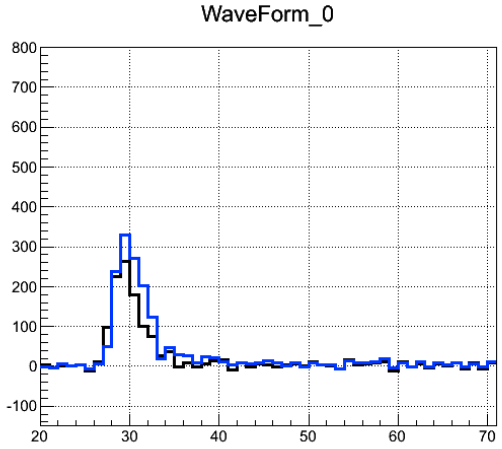
Trigger Timing









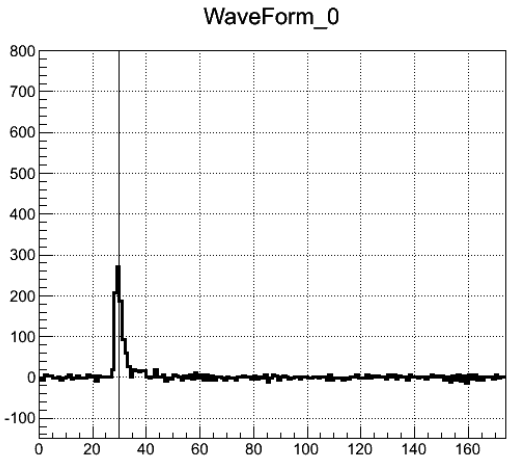


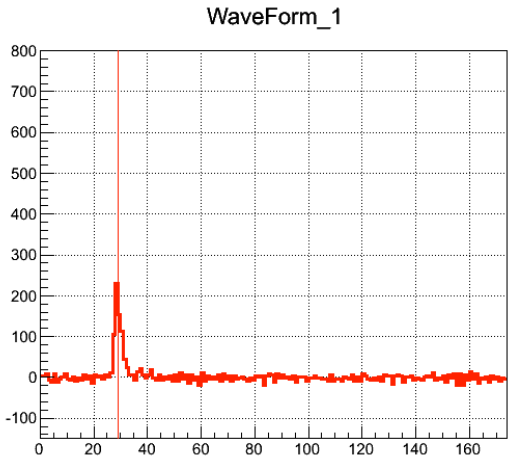
entry: 124

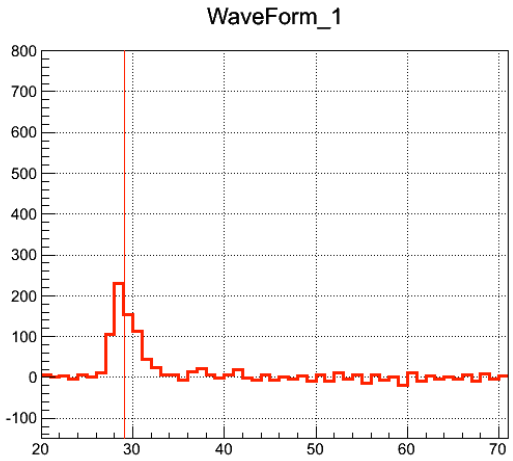
TOF(ns): 1.201
TOF_TS(ns): 4.000
Detector_0: 020
Detector_1: 024
Energy_0: 73.963
Energy_1: 97.879
PSD_0: -0.143
PSD_1: -0.045
Time_0(ns): 42648643.246
Time_1(ns): 42648644.447
TCorrection_0(ns): 119.246
TCorrection_1(ns): 116.447

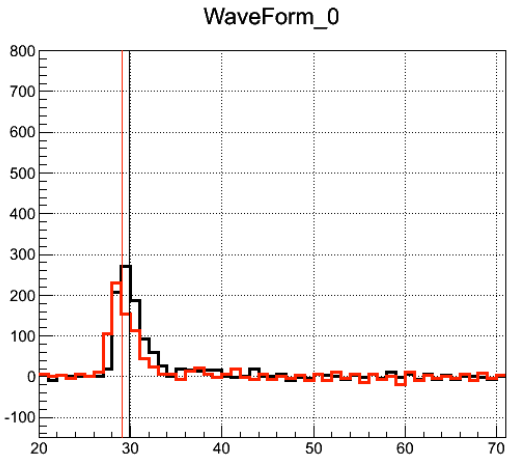
Trigger variability was causing events to be out of true time order (fixed for further data, but required waveform reconstruction to get useful information out of this dataset)

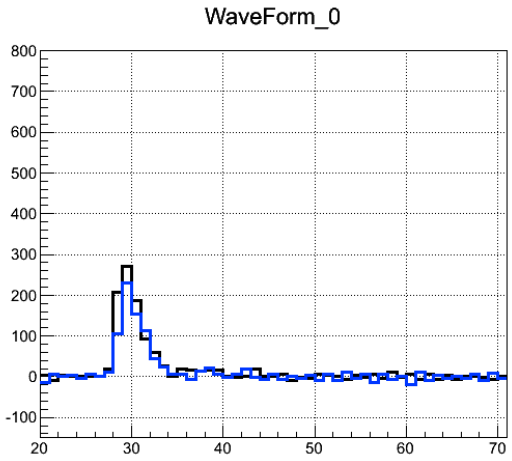
Trigger Timing









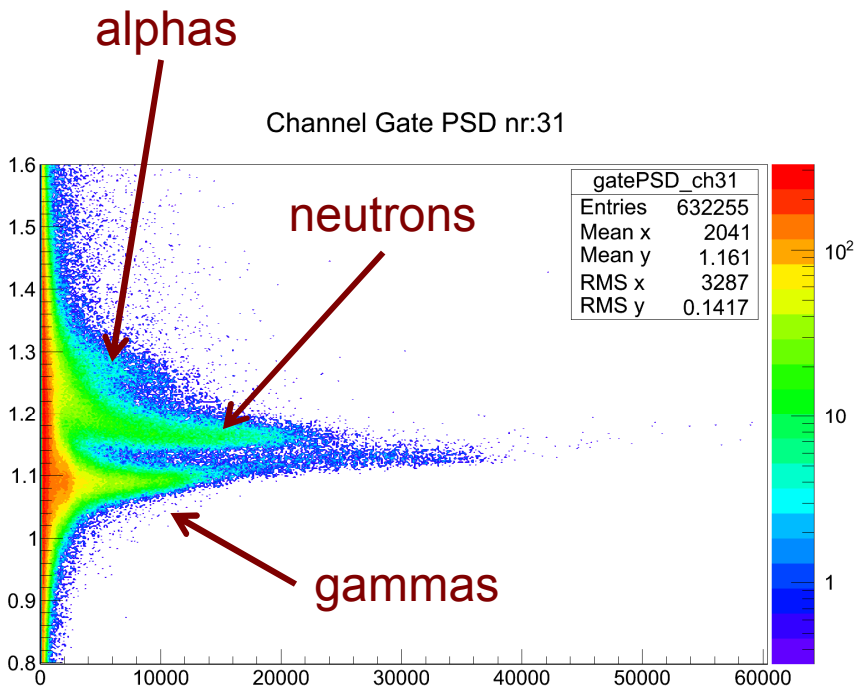


entry: 821

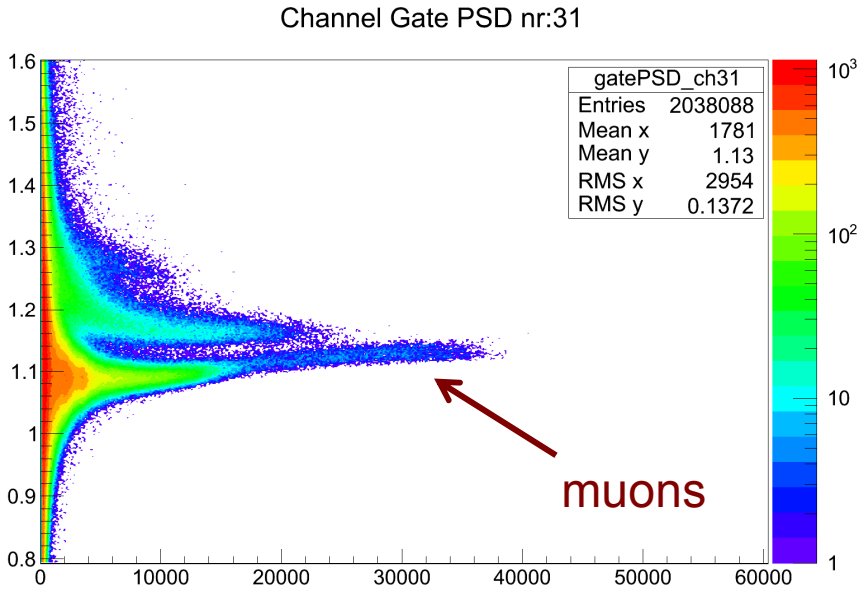
TOF(ns): 4.746
TOF_TS(ns): 8.000
Detector_0: 028
Detector_1: 029
Energy_0: 67.651
Energy_1: 53.935
PSD_0: -0.138
PSD_1: -0.081
Time_0(ns): 289701611.741
Time_1(ns): 289701616.488
TCorrection_0(ns): 119.741
TCorrection_1(ns): 116.488

Cleaned Up Waveform Analysis

1us beam window

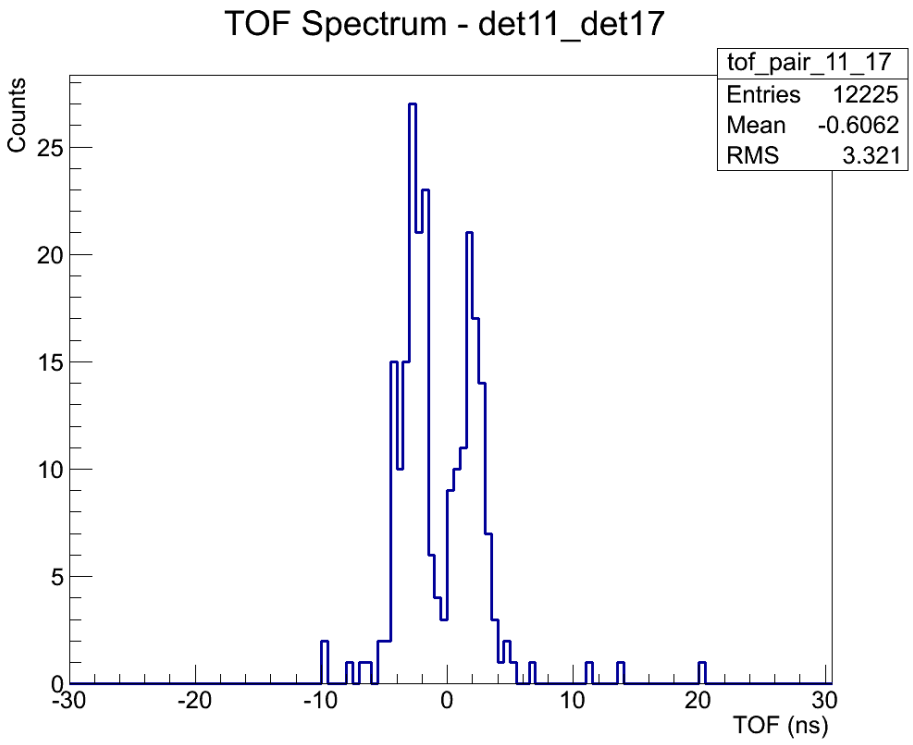


1000us beam window

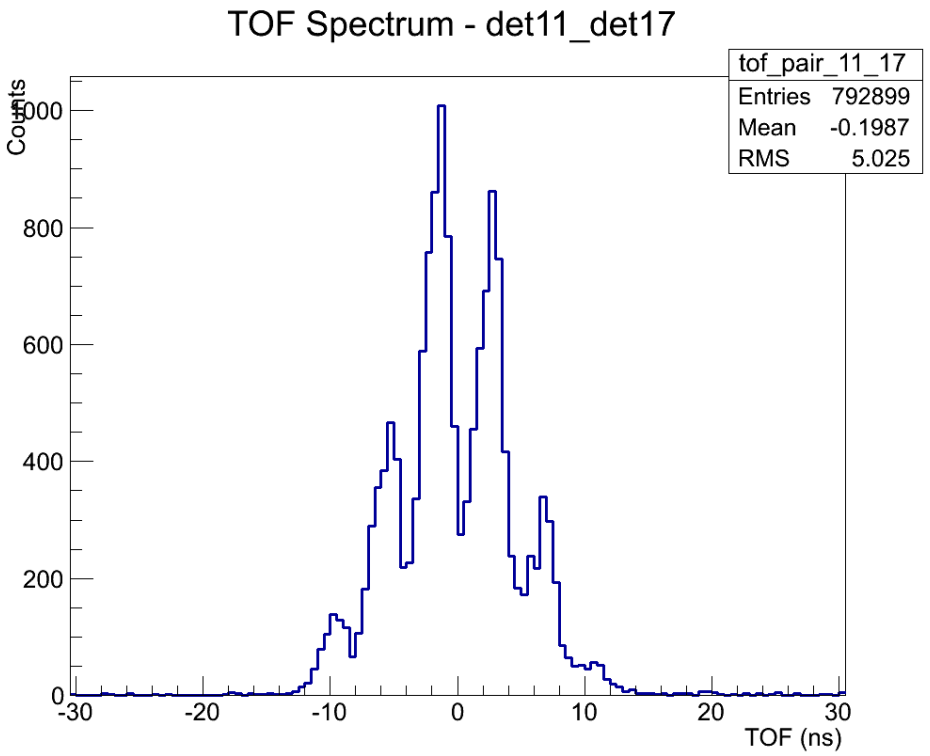


ADC-to-ADC phase lock

One Hour File



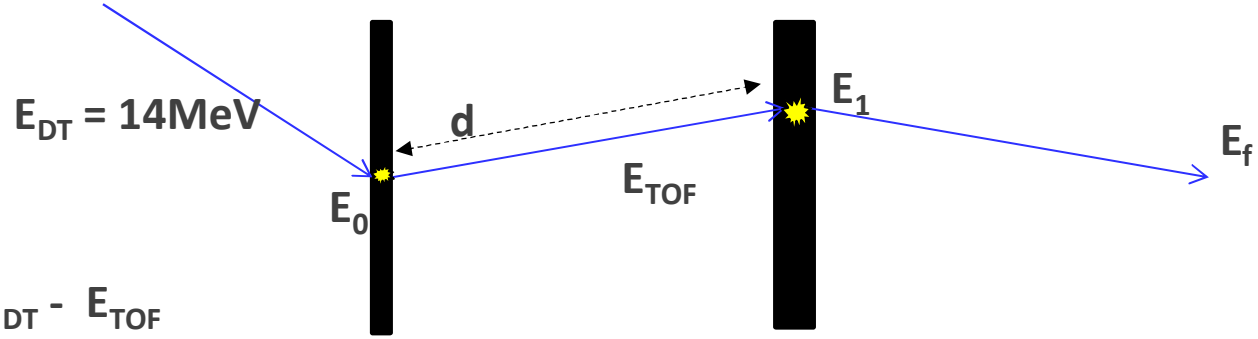
64 Hours



We now have ~490 Channel-to-Channel TOF corrections that are stable over time
+ an ADC-to-ADC correction that varies on a file-by-file (hourly) basis.

Calibration of NSC

- We use a DT neutron Generator to produce an energy calibration to convert the energy deposited in the first detector E_0 from "adc" units to MeV.

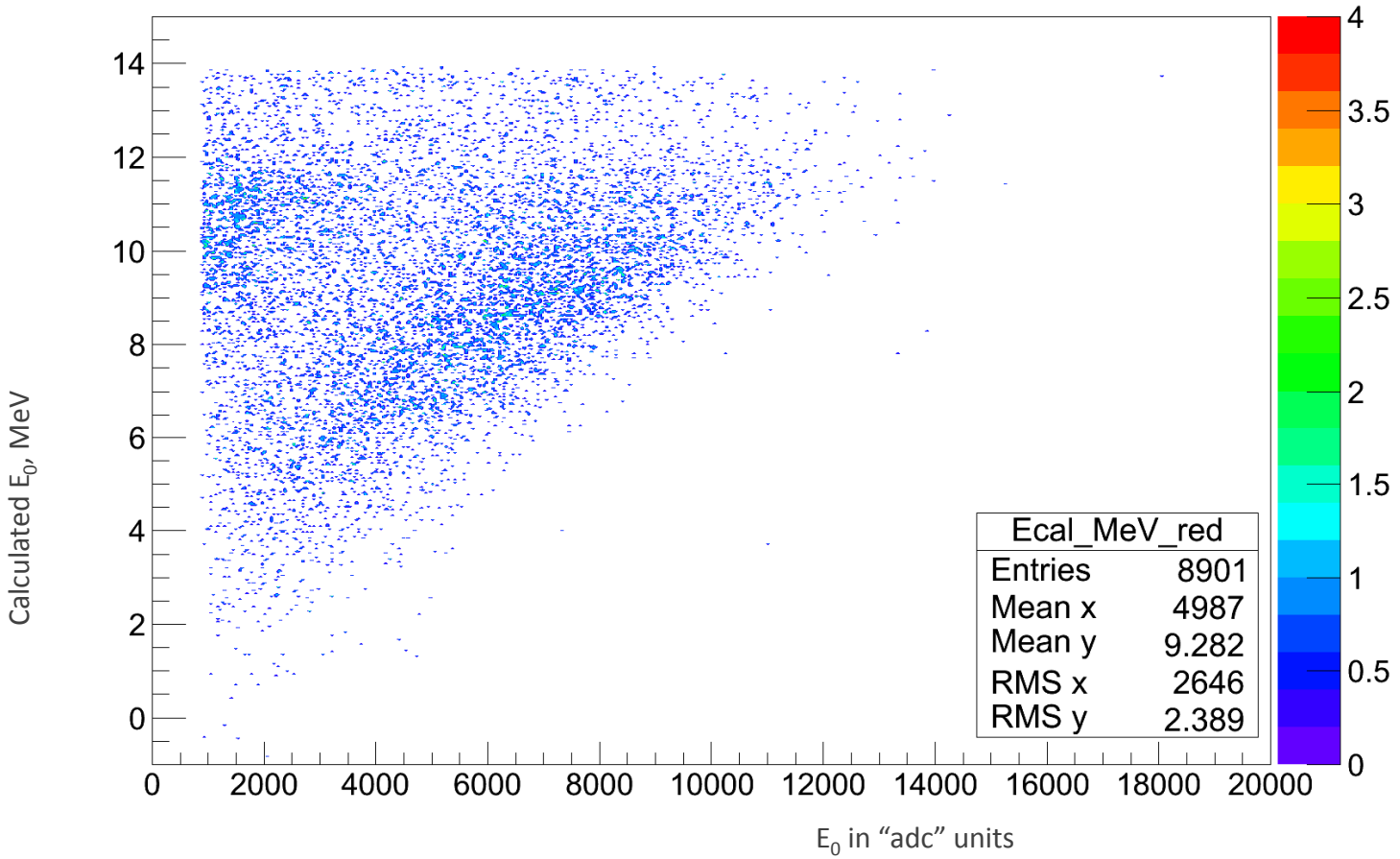


E_0 (MeV) = E_{DT} - E_{TOF}

where E_{TOF} (MeV)= 1/2 $M_p(d/TOF)^2$

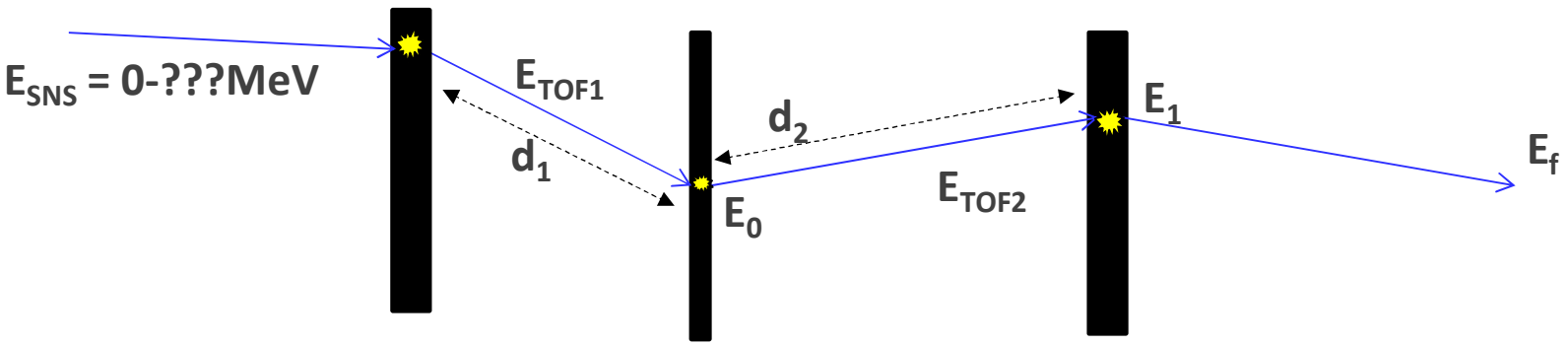
- This calibration in highly dependent on the correct measurement of the time-of-flight (TOF) between detectors.
  - Good cross-check if the Timing issues are fixed.

DT Calibration



Triple Plane Run

- Using Jason's additional plane of scintillators, we can use two time-of-flight measurements to calibrate energy deposition over a much larger energy range.



$$E_0\,(\text{MeV}) = E_{TOF1} - E_{TOF2}$$

where $E_{TOF}\,(\text{MeV}) = 1/2\, M_p (d/TOF)^2$

- This calibration in highly dependent on the correct measurement of the time-of-flight (TOF) between detectors and knowing the positions.

What's Next?

- Push forward with the old data to get a full beam neutron energy spectrum and image
  - We are sooooo close now that the timing is fixed.
- Confirm energy calibration
  - Need to look at quenching to confirm energy response
  - Improved cross-check with triple plane data out to higher energies
- Look at more recent data from triple plane run
  - Should be able to use the same machinery to get full spectra and image.
- Would like to make correction for ADC reflections
  - May not make a big difference in the final answer
  - Important if we want to do a true light-yield calibration
- I think we have enough data at this location, we just need to fully process it