SAND2014-16276PE

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NEUTRON SCATTER CAMERA MEASUREMENTS AT SNS

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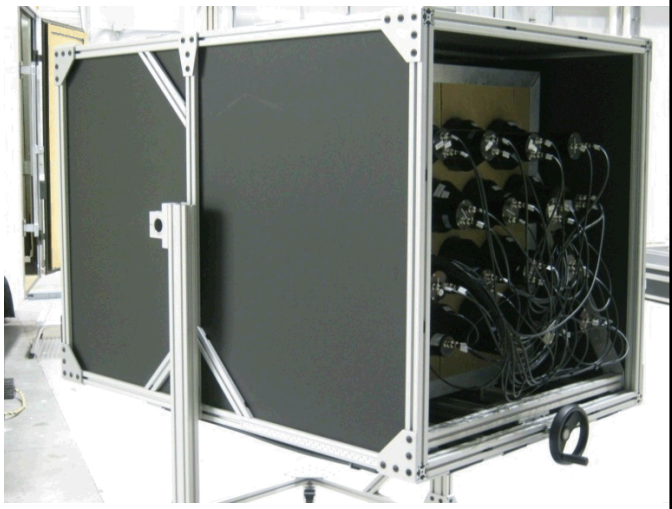
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Outline

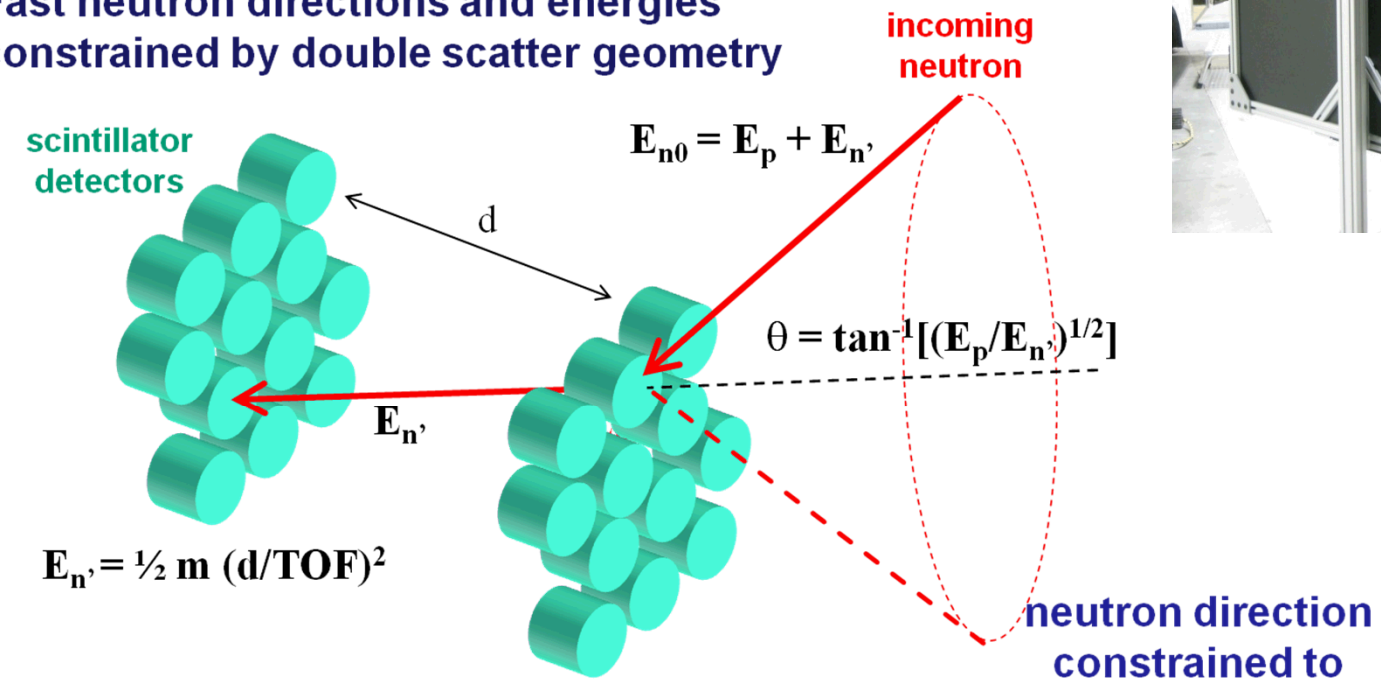
- Review of NSC results measurement at beamline 13a
- Estimate of absolute flux
- Results of basement measurements (preliminary)

What is a Neutron Scatter camera?

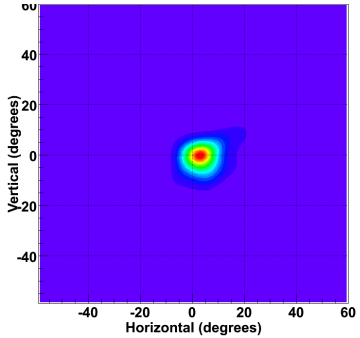
- Fast neutron imaging spectrometer
- Variable plane separation allows tradeoff of effective area, image resolution



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

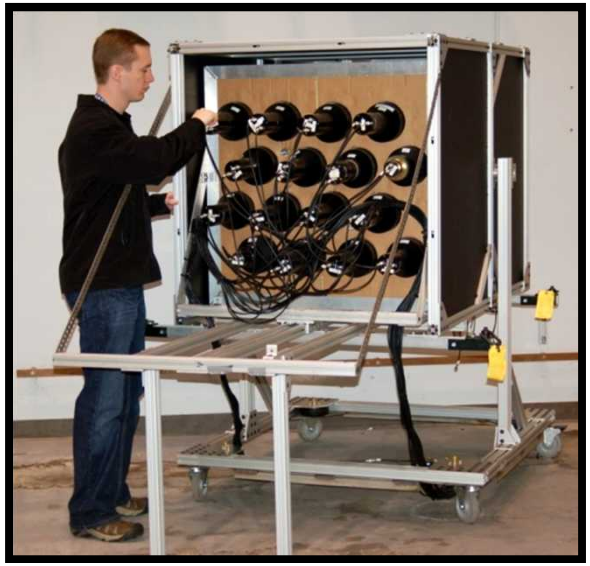
- ***Neutron energy spectrum.***
- ***Compton imaging.***

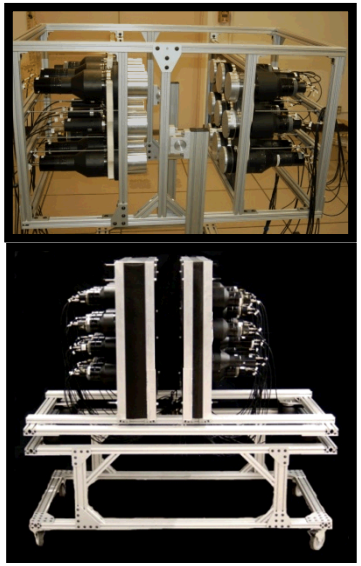
Neutron Scatter Camera

In case you not see these at the last meeting …

Neutron Scatter Camera, 32 elements

Previous Generations





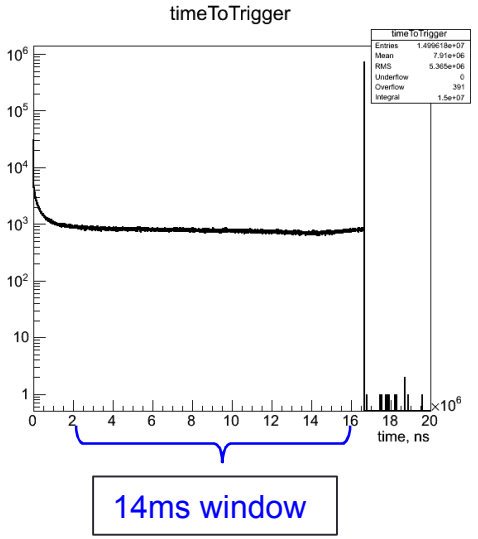
MINER: Compact 16 element NSC

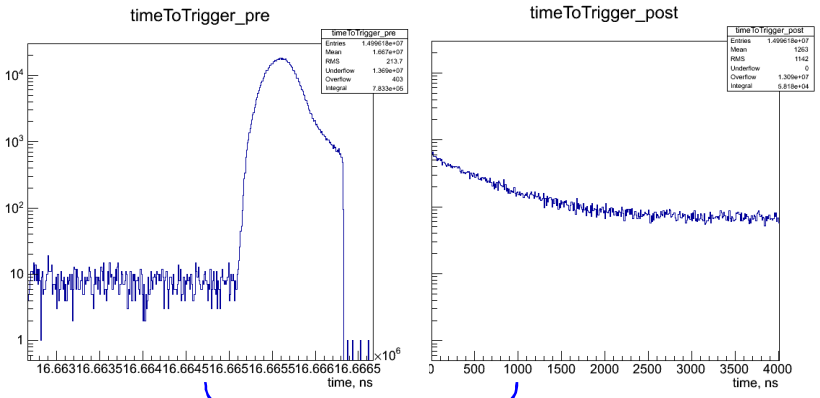
First Data at SNS: beamline 14a

- NSC deployed at beamline 14a, August 2013.
- During data analysis, several DAQ issues were found and resolved:
  - Corrected for channel-to-channel timing offset
  - Used waveform analysis to find trigger time (instead of ADC FIR trigger time)
- Calibration with DT neutron Generator:
  - Verified NSC spectroscopy in the 14MeV range (backup slides)
  - Verified NSC imaging methodology
- Data when SNS beam was off for several days were also recorded. We call these ‘background’ data, versus beamOn data.
- SNS 60 Hz trigger signal was recorded, but not the SNS beam signal.

Time windows

- SNS trigger signal is delayed with respect to actual beam.
- Plots show time to the last trigger before each event. Right plot shows the 60Hz trigger frequency (16.6ms period). Bottom plots zoom around trigger (at 0 and 16.6ms)
- In future data, we advanced the trigger to the origin of these plots to facilitate visualization.
- We considered several time windows in the analysis:
  - 2.766 us window around beam
  - 1002.766 us window around beam
  - 14ms window starting 2ms after the beam





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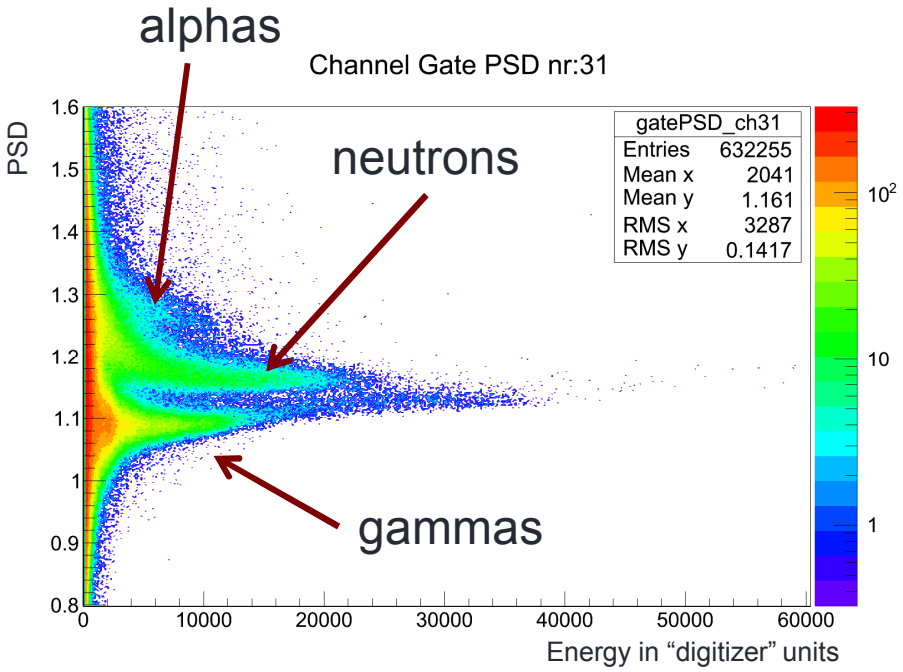
1007.7us window

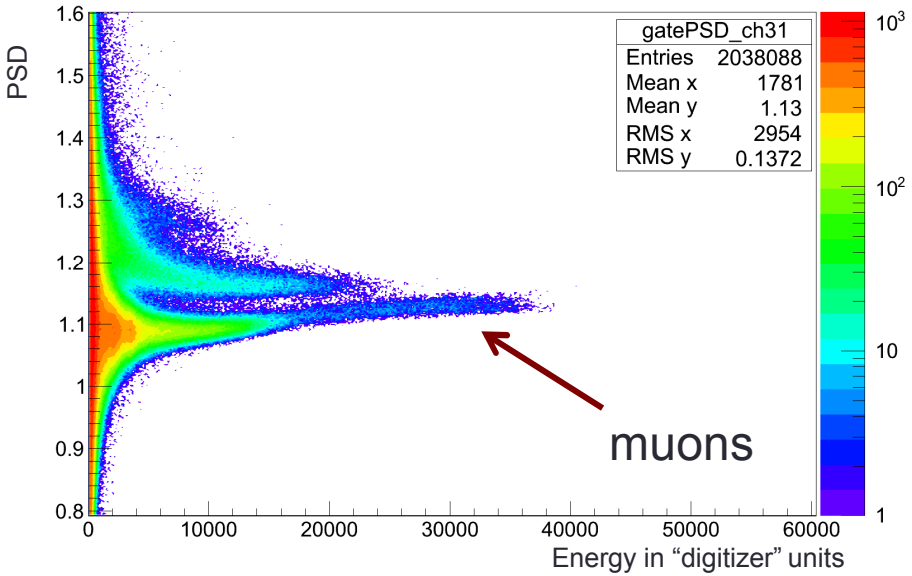
Neutrons selection: PSD and beam window

- Clear separation of neutrons and gammas using Pulse-Shape-Discrimination (PSD)
- Most neutrons are present within an order-of-1us window after SNS beam

2.7us beam window

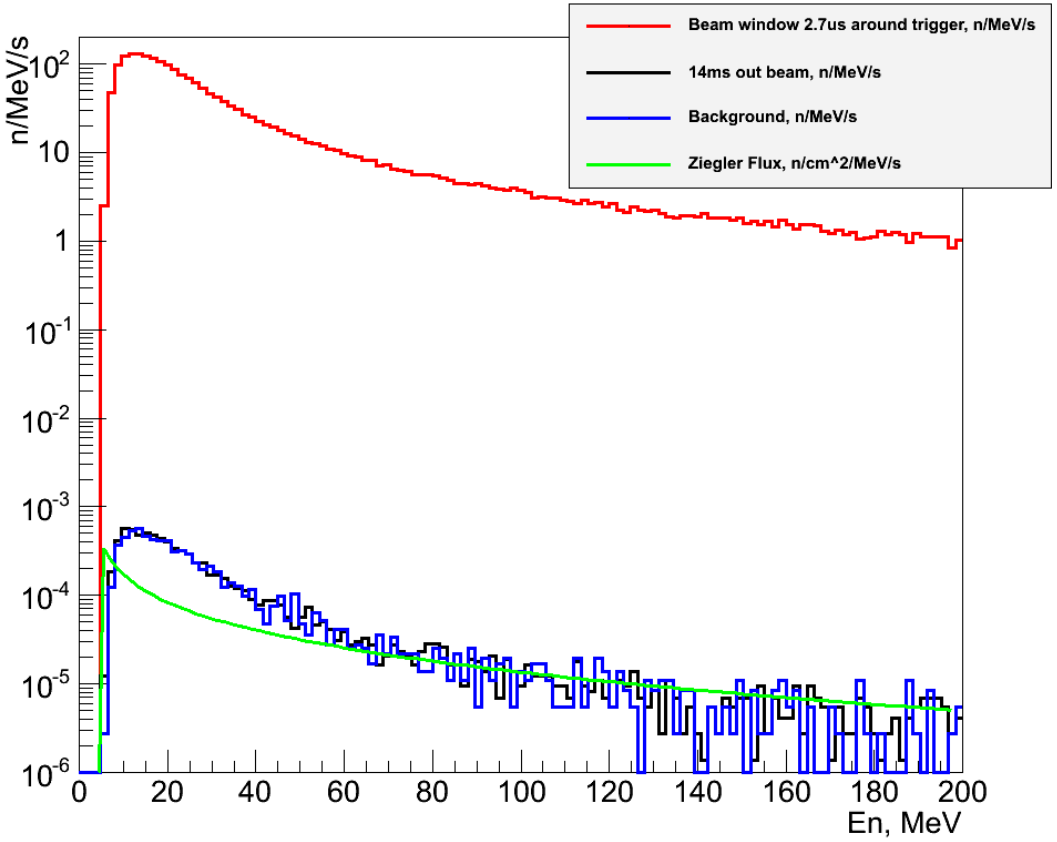


1001.7us beam window



Reconstructed Neutron Spectra at beamline 14a

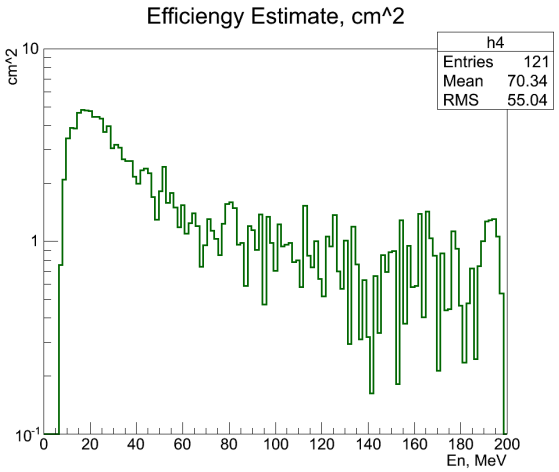
- Beam neutron rate (beam window 2.7us) about 5 orders above background
- Out of beam neutron rate (out of beam window 14 ms) same as background: no after beam halo
- Image in backup slides



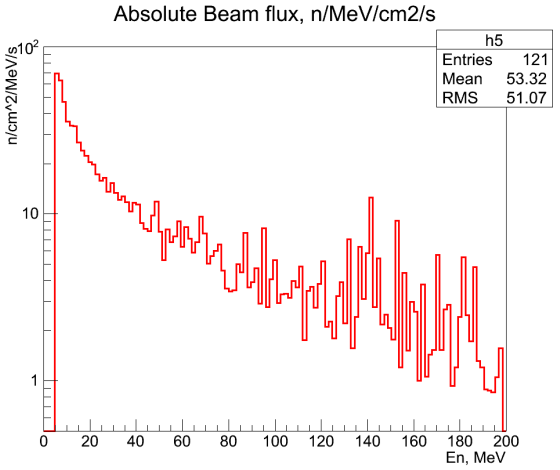
NSC Efficiency Estimate

Using Ziegler spectrum of cosmic neutrons to estimate NSC efficiency and absolute beam flux:

$$\text{Efficiency}(cm^2) = \frac{\text{Measured Background}(n/MeV/s)}{\text{Ziegler Flux}\ (n/MeV/s/cm^2)}$$

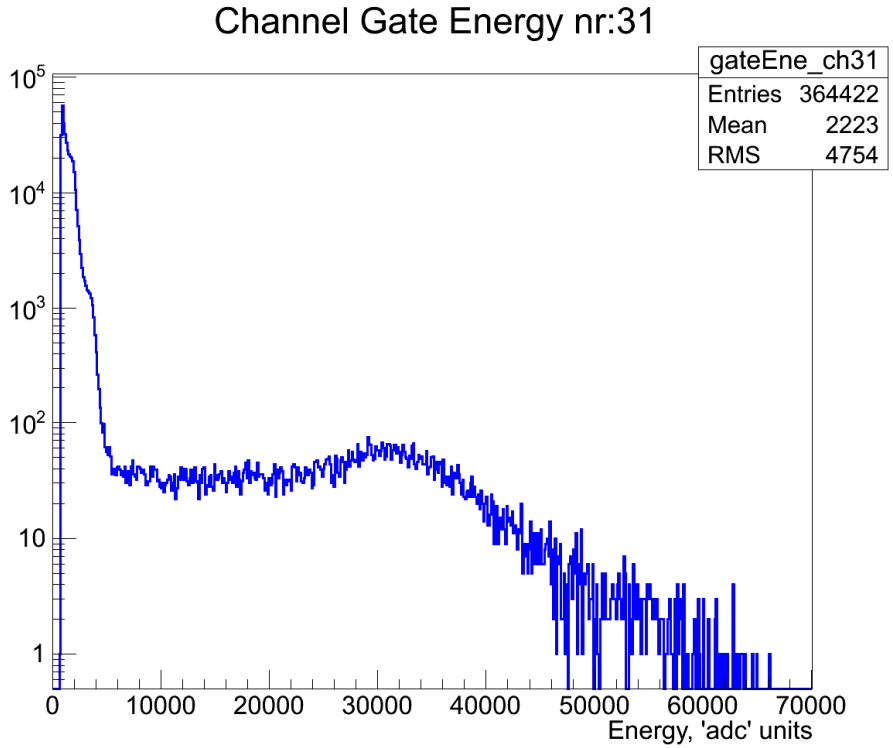


$$\text{Absolute Beam Flux}\ (n/MeV/s/cm^2) = \frac{\text{Measured beam window rate}\ (n/MeV/s)}{\text{Efficiency}\ (cm^2)}$$



Second data: SNS basement “2.5”

- NSC deployed at SNS basement, at what we are calling position 2.5
- High event rate due to low background gammas (< 500keV) coming form local water pipes, caused ADC dead time of ~25%
- So, hardware threshold was increased
- 5 days of beam-on good data starting on June 20, 2014

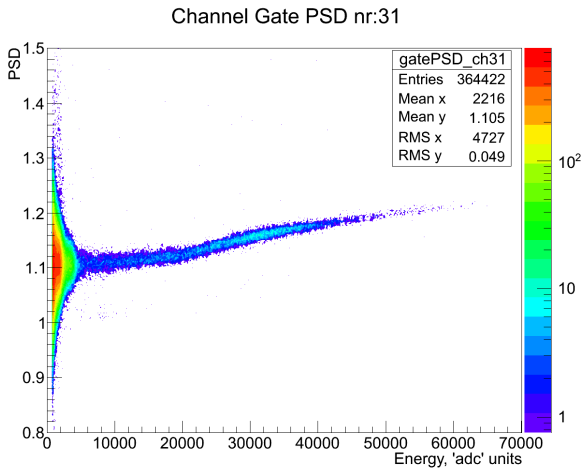


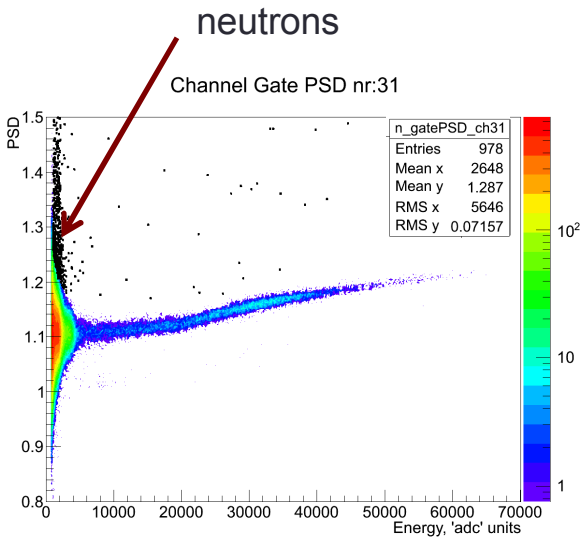
Histogram of Channel 31 Energy (in adc units), from a 2 hour file

Neutrons at the basement

- PSD plots show a large reduction in neutrons at the basement
- Right plot shows **neutron selection as black dots**

no time window; 2hour data file

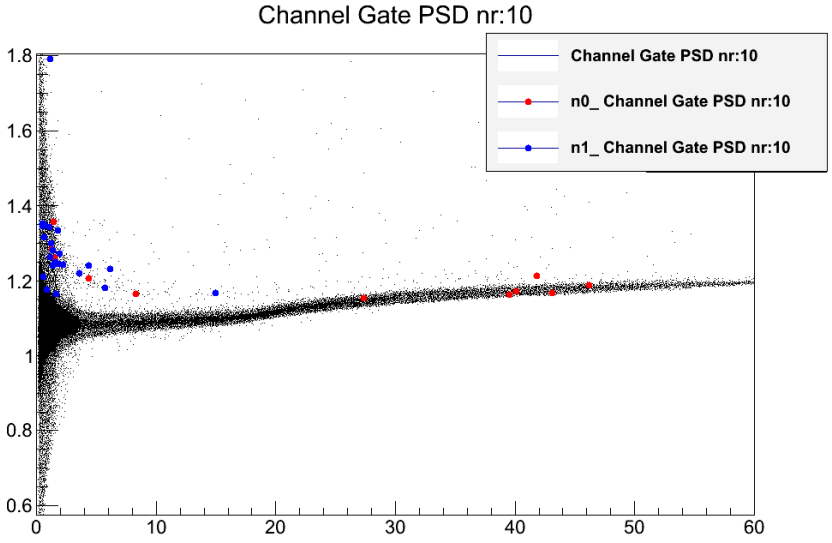




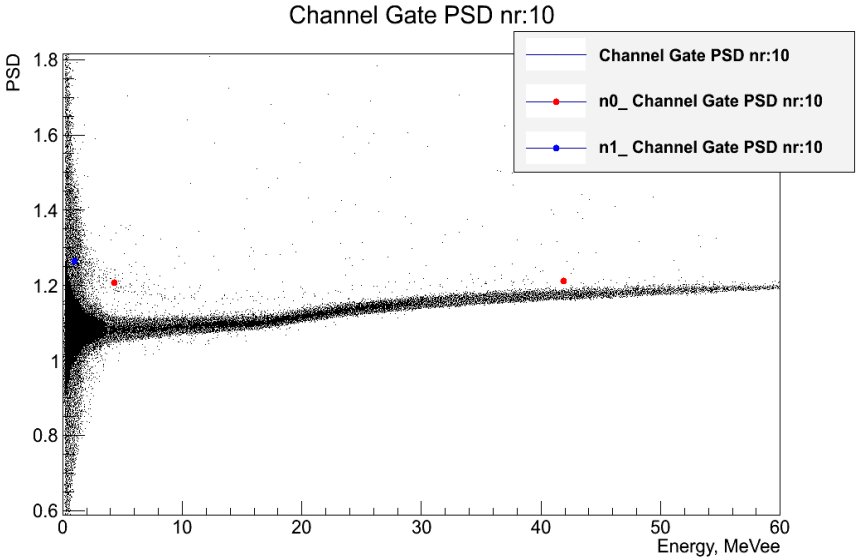
Neutron pair selection

- The neutron pair (n0,n1) selection (to derive the spectra in NSC fashion) further reduces the neutron population
- Restricting to the beam time window (next slides), cleans up most of gamma/muon contamination.

No time window; 5 days

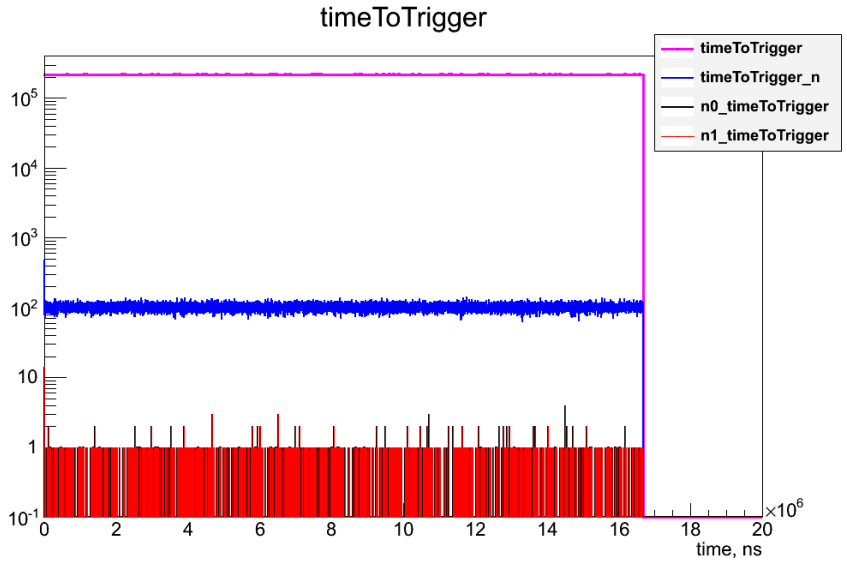


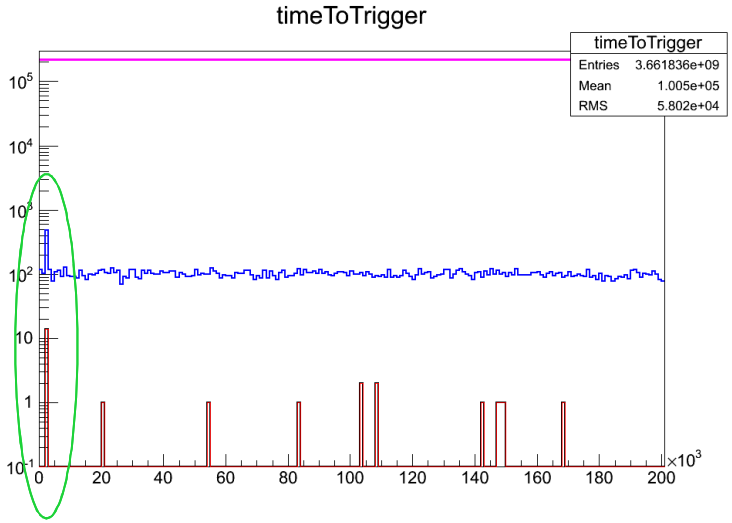
n0 and n1 are within a 2.7us beam window; 5 days



Beam events for basement data

- Plots of time to the last trigger shows not significant increase of event rate at beam time (pink)
- But selecting for neutrons (blue) does show a spike at beam time!
- When selecting neutron pairs (n0,n1), the spike remains (**black**, red)



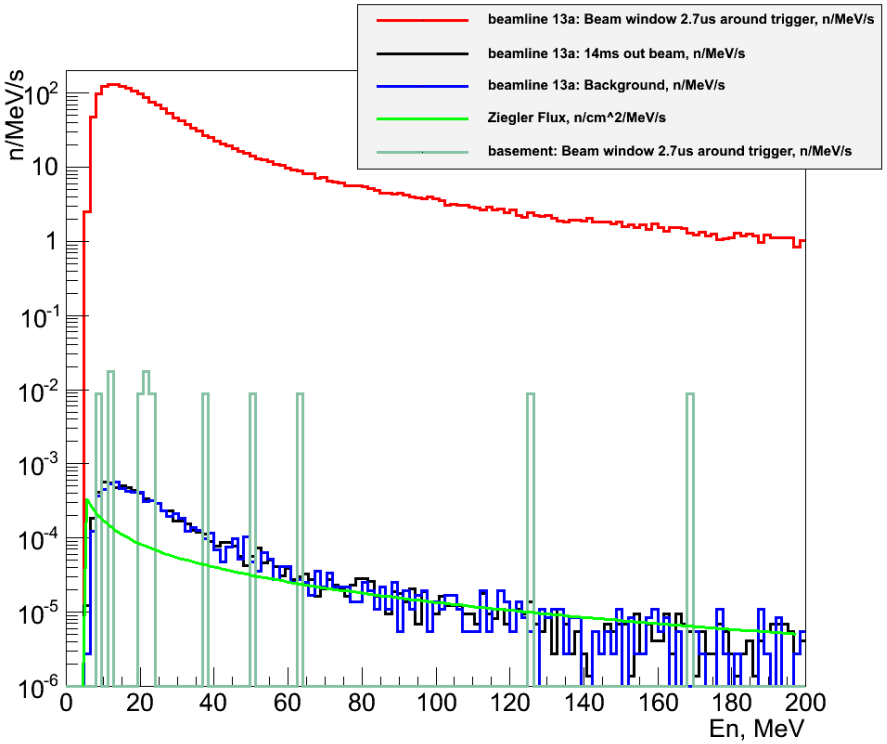


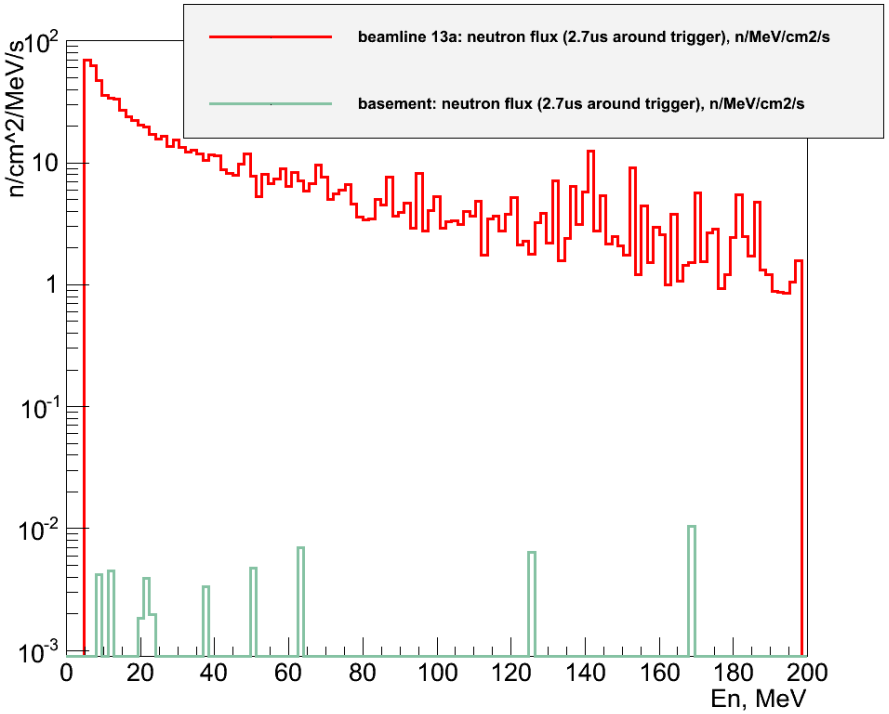
Zooming…

full 5 days

Neutron Flux at basement

- Take again a 2.766us window around the “beam” spike
- Left plot of the NSC measured spectra: now including basement data (green)
- Right plot of the estimated absolute neutron flux: now including basement data (green)

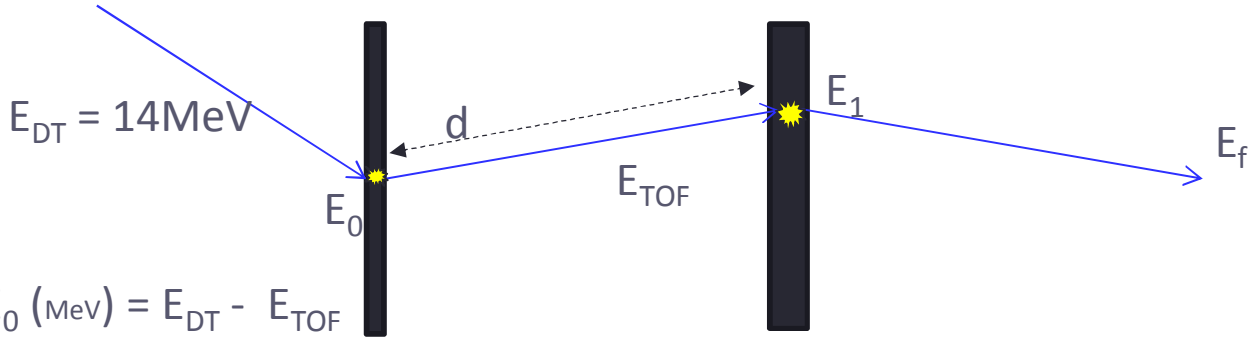




Backup Slides

Calibration of NSC with DT neutron generator, beamline 14a

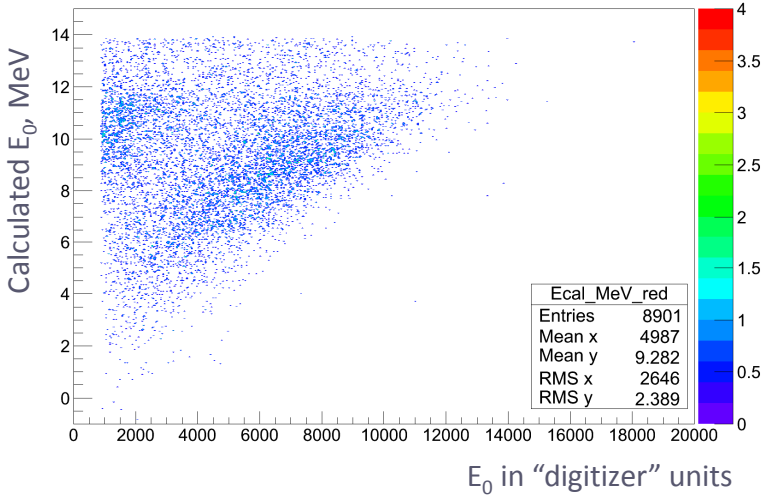
- We use a DT neutron Generator to produce an energy calibration to convert the energy deposited in the first detector E_0 from "digitizer" units to MeV.



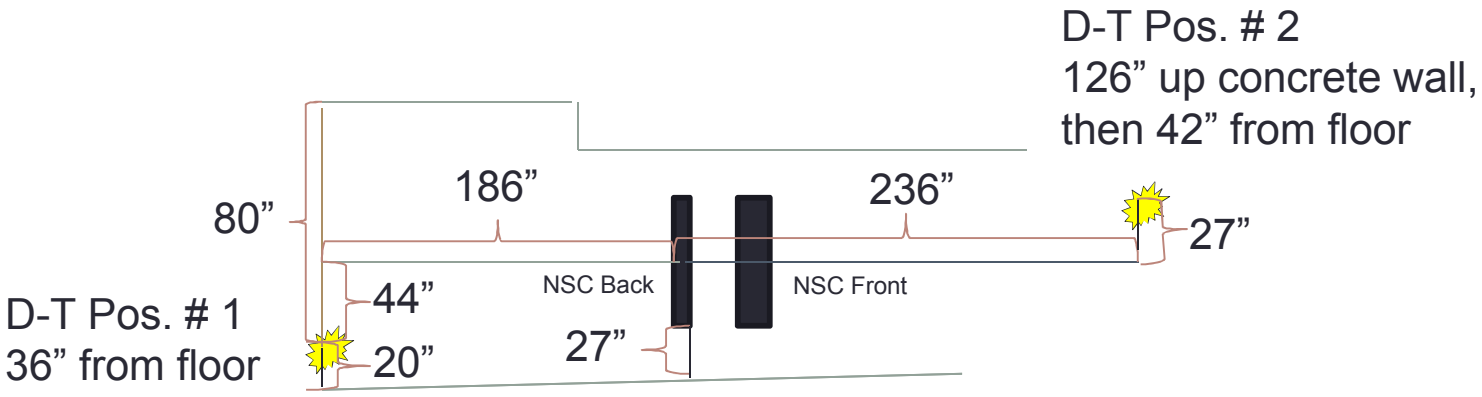
Calculate E_0 (MeV) = E_{DT} - E_{TOF}

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 that timing issues are fixed
- Calibration trend is clearly present; wide spread due to poor scintillator energy resolution



DT Generator position diagram, beamline 14a

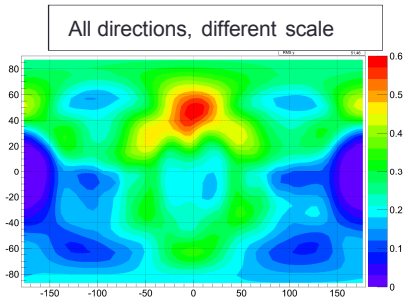


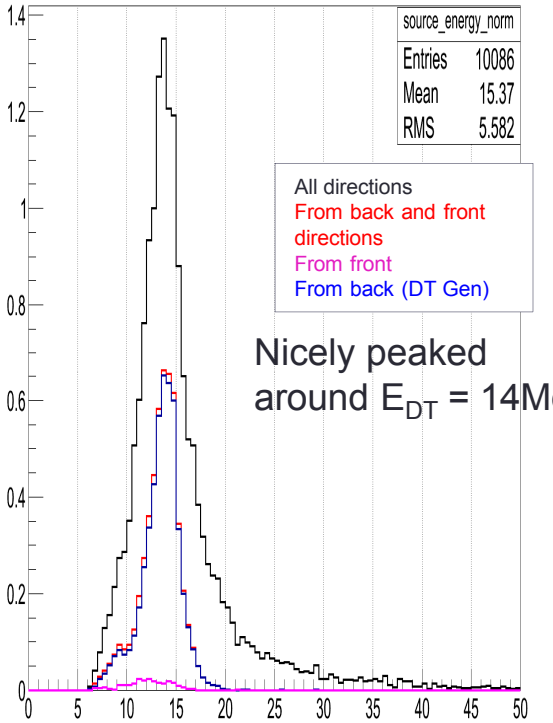
- NSC measurements to middle of 2” plane
- Wall dimensions *very* rough in this drawing.

Beam Target is in this direction…

DT generator: source spectrum and image

- NSC efficiency varies with direction, with maximum efficiency within a 60-degree cone in the forward and backward directions and dips in efficiency on the side directions

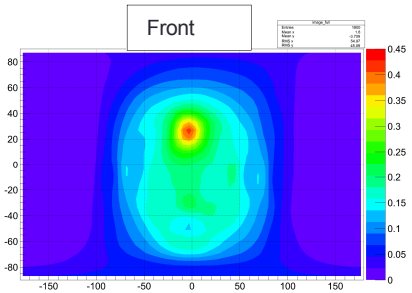


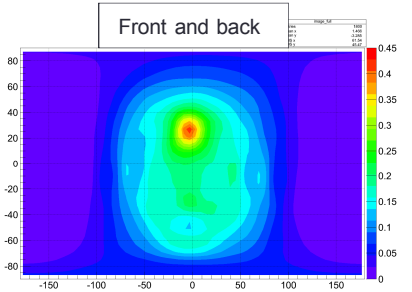


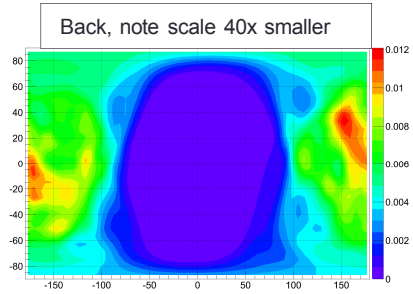
Front of NSC: DT generator

Back of NSC: nothing

Position 2: 15 minutes

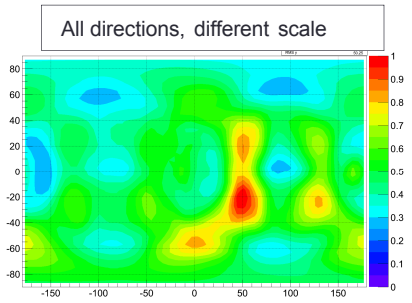




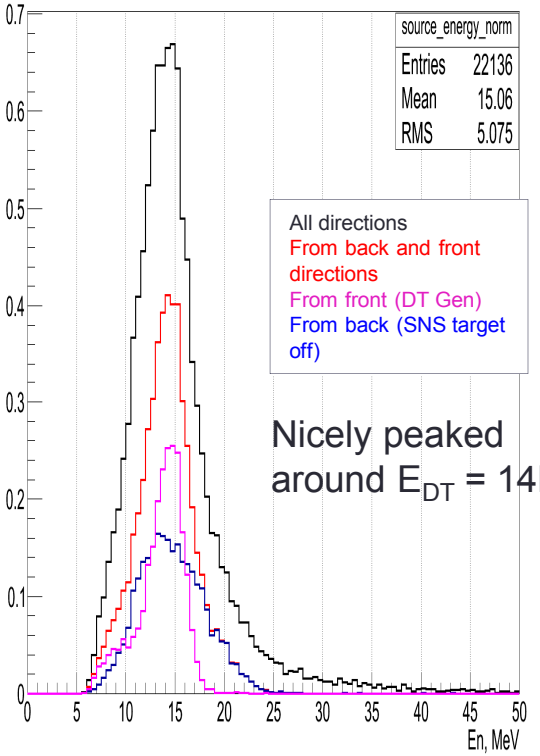


DT generator: source spectrum and image

- Observe that concrete walls create a “neutron” cave where DT neutrons backscatter

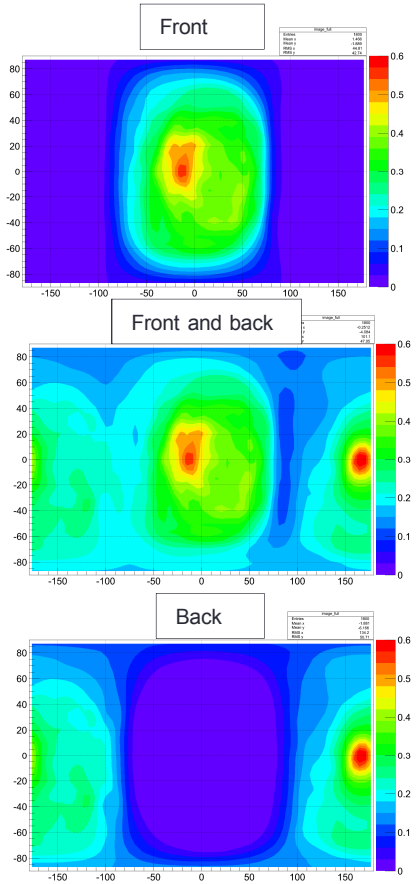


Position 1: 40 minutes



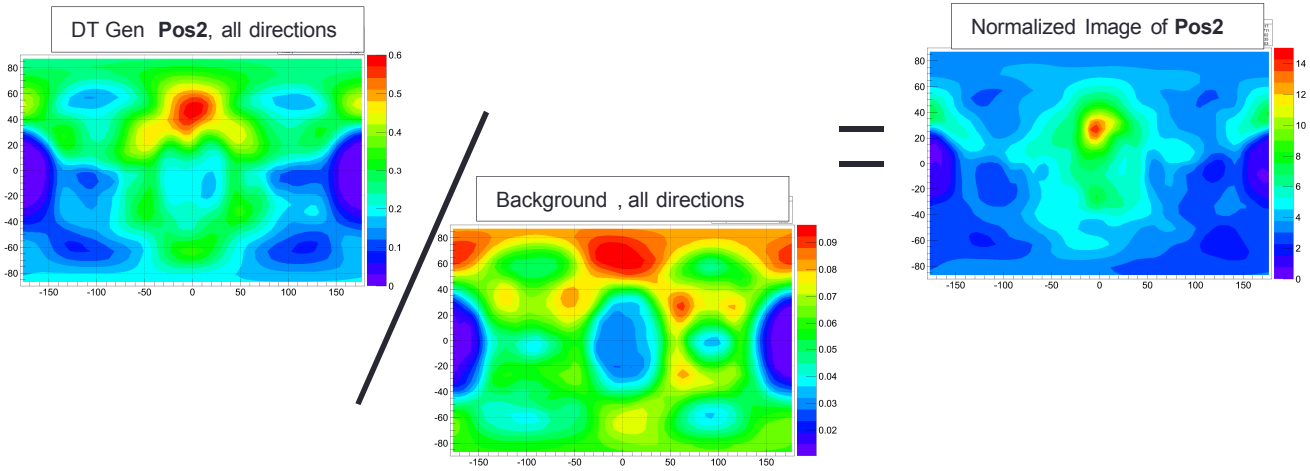
Front of NSC: BckScttrd DT n

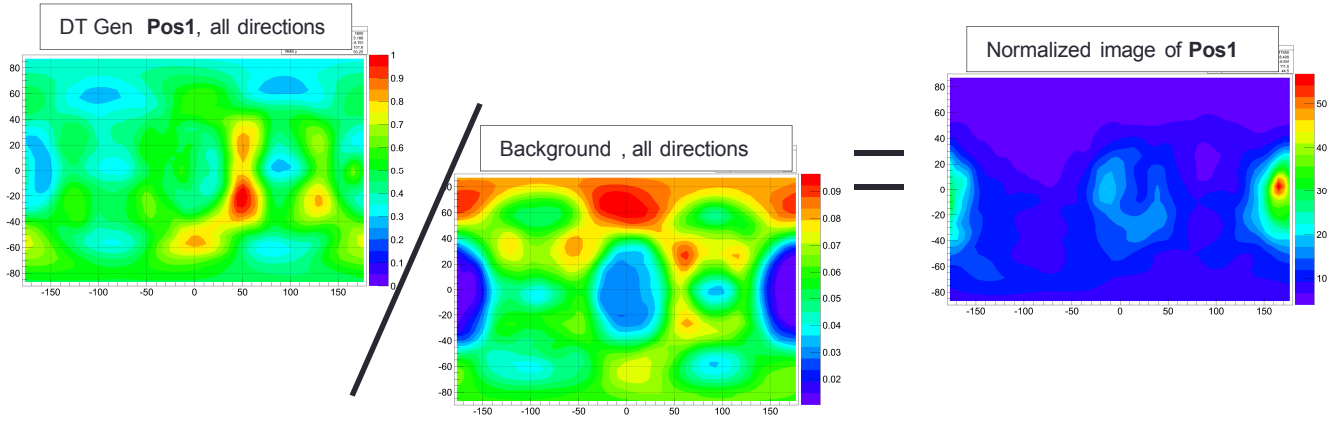
Back of NSC: DT generator



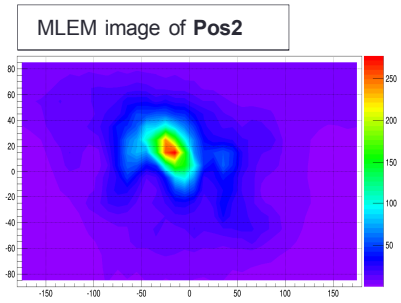
DT Generator images

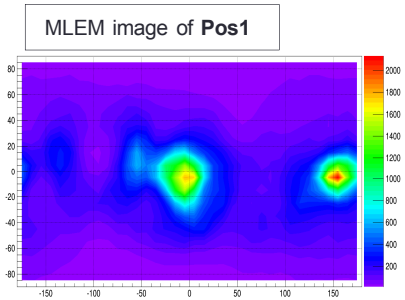
- Need to understand better NSC lateral efficiency. But, preliminarily, we can normalize the efficiency variation dividing by the background:





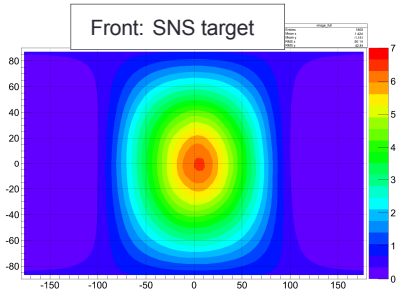
- …or applying MLEM

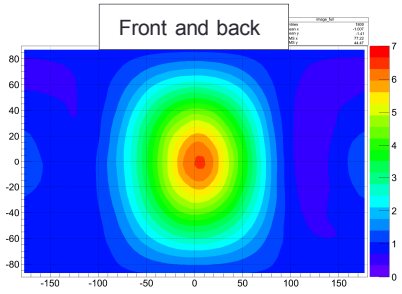


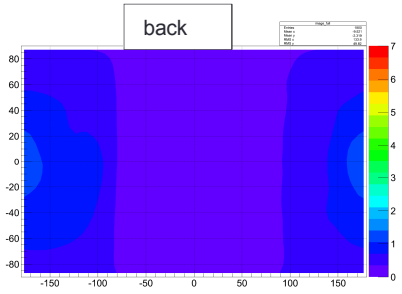


Beam On data, beamline 14a: 2.7us window around trigger

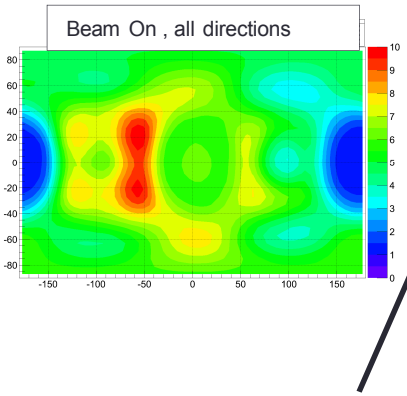
- Back and Front Images show SNS target on in the front direction

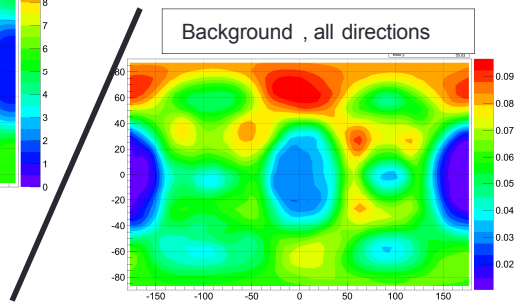


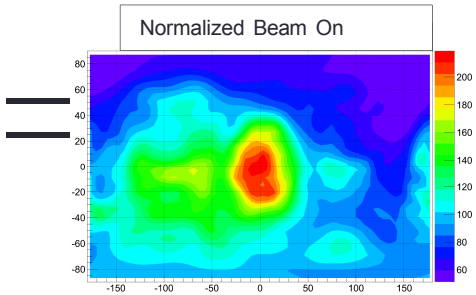


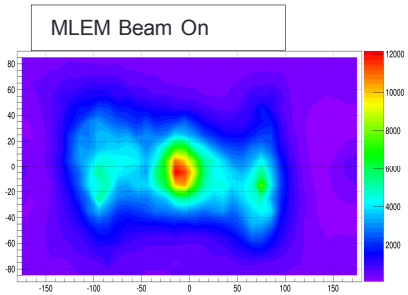


- Background Normalized image and MLEM image:



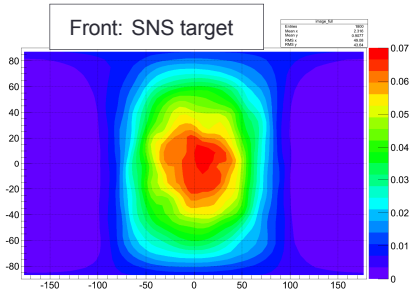


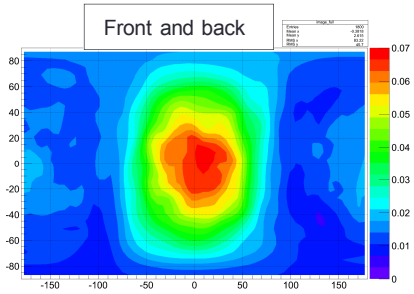


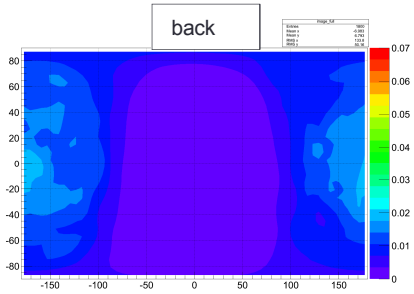


"Out" Beam data, beamline 14a: 14ms window outside trigger

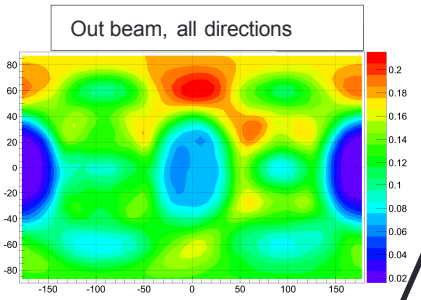
- Back and Front Images show SNS target on in the front direction

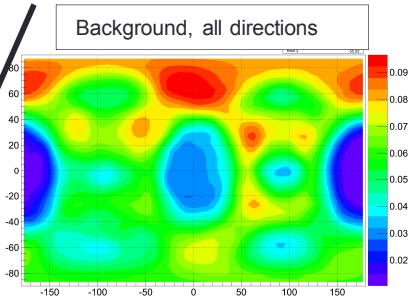


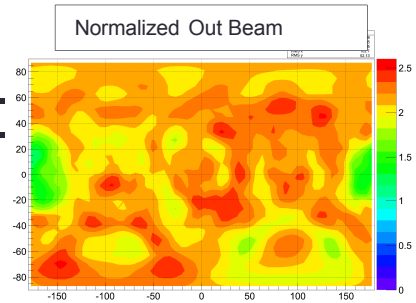


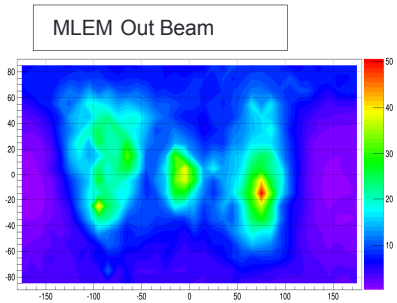


- Background Normalized image and MLEM image:









PSD basement data, position “2.5”

All 5 days: