SAND2015-0653PE

Jan 30, 2014

NEUTRON SCATTER CAMERA MEASUREMENTS AT SNS

Belkis Cabrera-Palmer
Mark Gerling
David Reyna

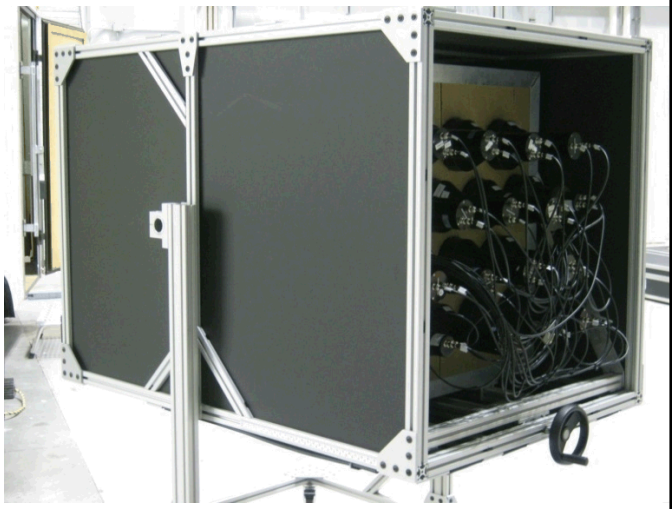
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Overview

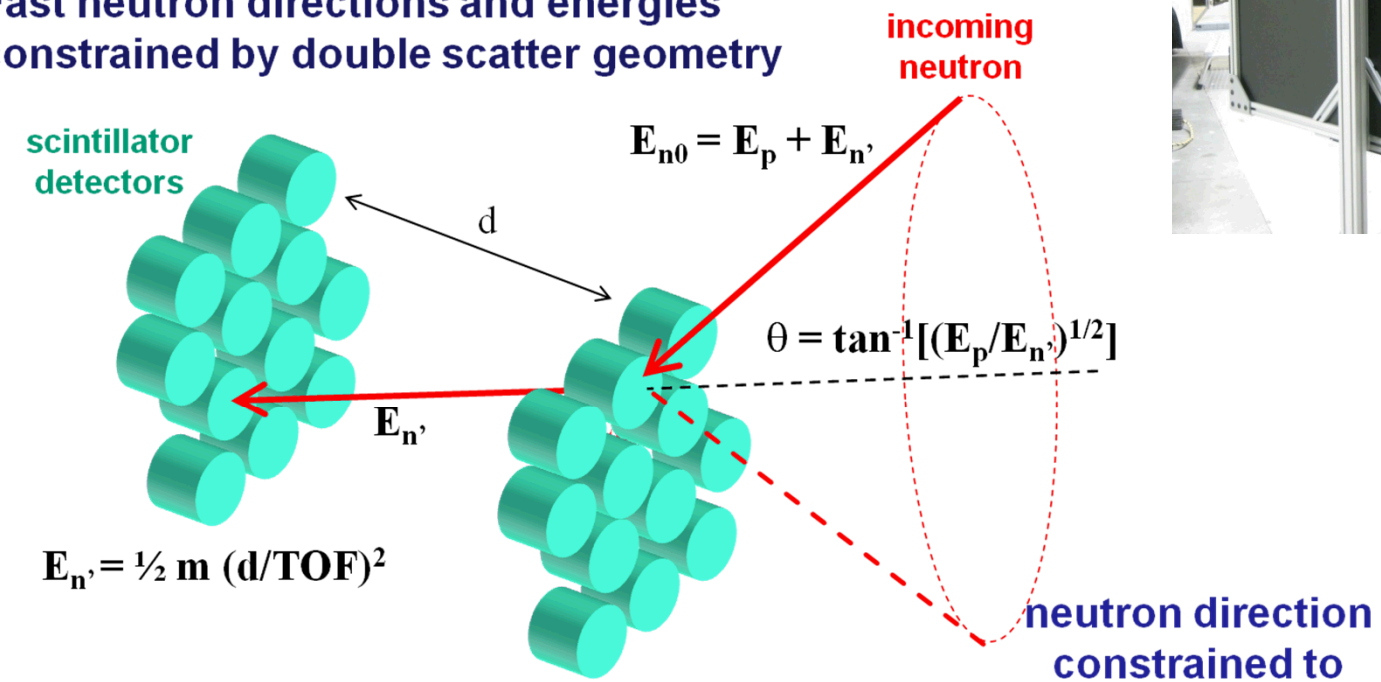
- First, we give a summary of Neutron Scatter Camera (NSC) measurements done so far at the SNS.
- The focus of this talk is to review all results for basement locations 11 and 2.5. We will show previous results for beamline 14a for comparison.
- We start with the newest data, basement-11.

Neutron Scatter Camera (NSC)

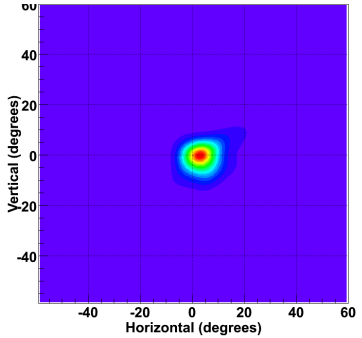
- Fast neutron imaging spectrometer
- Variable plane separation allows tradeoff of effective area, image resolution



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.***

Summary of NSC data at SNS

Location-1: Beamline 14a:
- About 42 days of Beam-On data (so far, only 8 days have been fully processd)
- 3 days of Beam-Off
- Neuron Generator

2013

On | Off | On

Aug 15 — Sept 30 — Oct 3 — Oct 29 — Dec 6

Location-2: Basement 2.5:
- Beam-On: 5days
- Beam-Off: none

Location-3: Basement 11:
- Beam-On: 7 days in October plus 27 days starting in November.
- Beam-Off: 33 days starting Sept plus 22 days starting end of October

2014

On | Off | On | Off | On | On

June 20 — June 25 — Sept 18 — Oct 21 — Oct 28 — Nov 19 — Dec 21

Location-3: Basement 11

2015

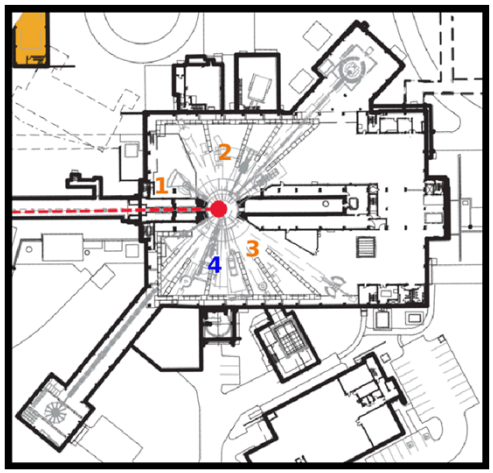
Off | On

Jan 8 — Jan 17 — Present…

Summary of NSC data at SNS, cont…

Analysis improvements done for basement-11 and basement-2.5 (4 in figure) data:

- Better energy calibration: using simulation of K, Th and muon peaks.
- Restrict neutron flux to 1.3us beam extraction window. Also reported flux for a 2.2us post-beam window
- Normalize by beam power.



Still to do for beamline-14a (2 in figure) :

- Improve energy calibration
- Restrict neutron flux to 1.3us beam window (2.7us previously used)
- Normalize by beam power
- Process remaining beamline-14a data: use to validate NSC efficiency modeling

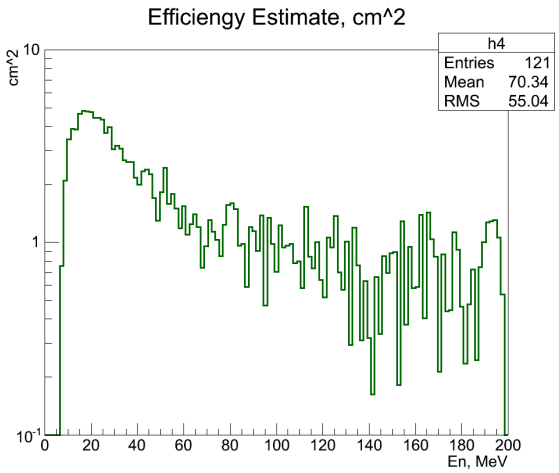
All:

- Model NSC efficiency and apply to all measured spectra to improve flux results and image

Rough Estimate of the NSC efficiency

- We are still just roughly estimating the NSC efficiency, dividing the background spectra measured in beamline 14a by the Ziegler spectrum of surface cosmic neutrons.
- So, the reported fluxes are just a first order estimate at best.
- We currently are modeling the NSC response to unfold the incoming spectral flux from the measured spectra.

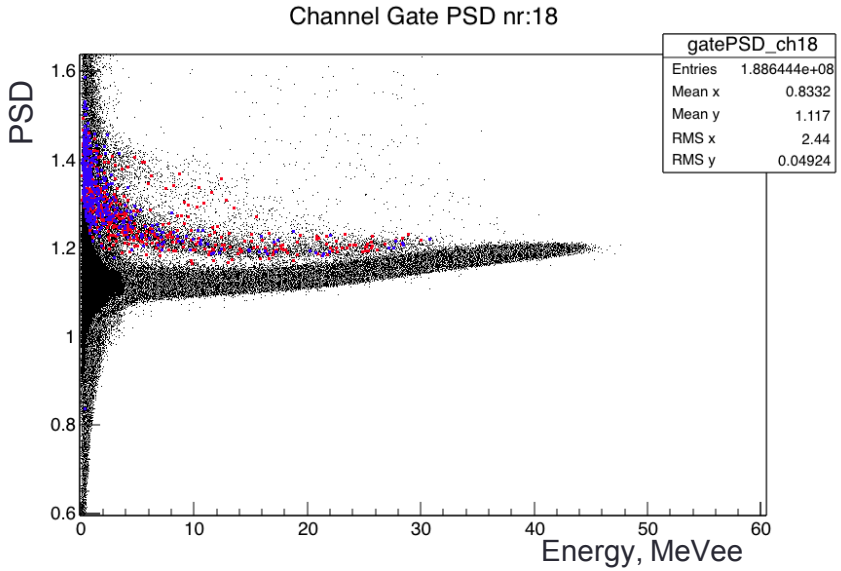
$$\text{Efficiency}(cm^2) \sim \frac{\text{Beamline14a Measured Background (n/MeV/s)}}{\text{Ziegler Flux (n/MeV/s/cm}^2\text{)}}$$



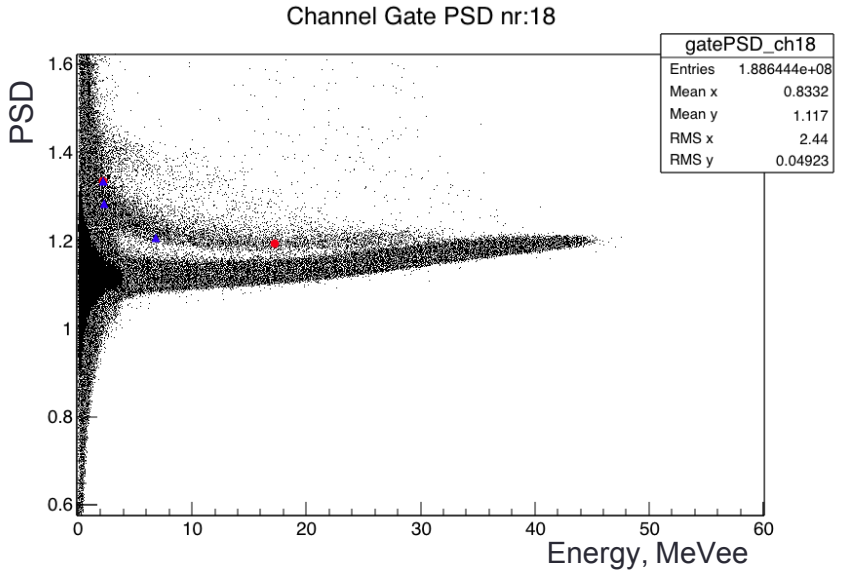
NSC methodology

- As usual, neutrons are selected via PSD. Then, consecutive neutron hits (**n0**,**n1**) in separate detectors are selected by time-of-flight, and the energy and direction of the incoming neutron are reconstructed.

No time window: all n0 and n1 selected in for this cell are shown.

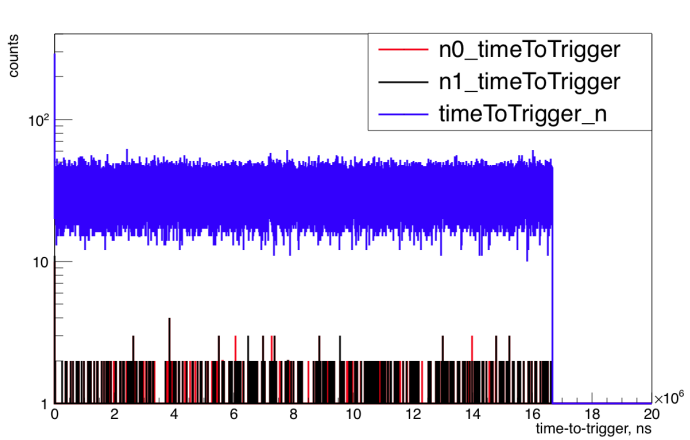


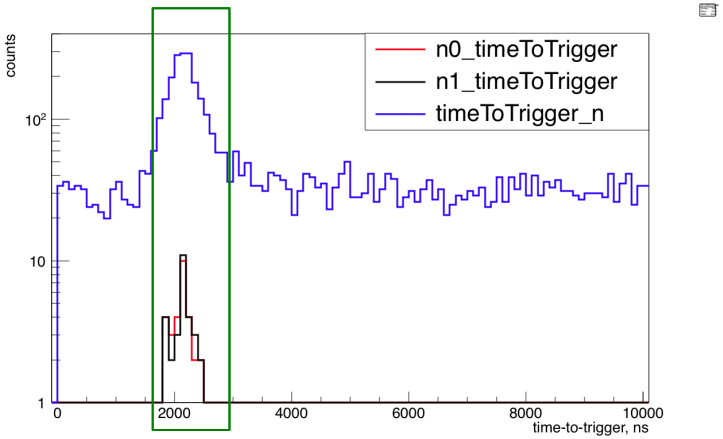
1.3us beam window: only the n0 and n1 within the window are shown.



Beam On data Oct 19 to Oct 27, 2014 basement 11

- Plot of time to the last trigger , selecting only for neutrons (blue) shows a spike at beam time
- Select neutron pairs (n0,n1) (**black**, red) to calculate spectrum.
- Most neutron pairs are in beam window starting at 1.6us with a total duration of 1.3us.





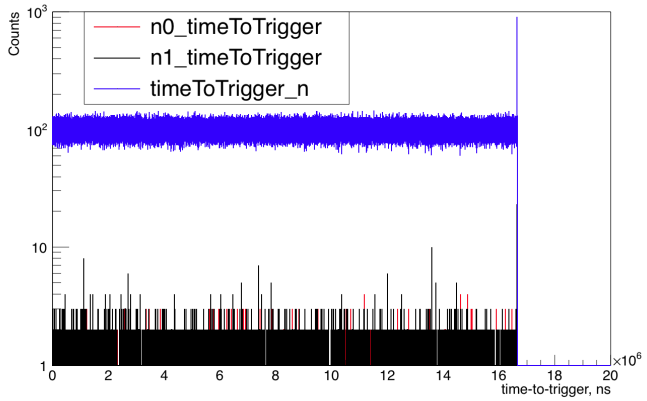
Window = 1.3us,
bin width 100 ns

Zooming…

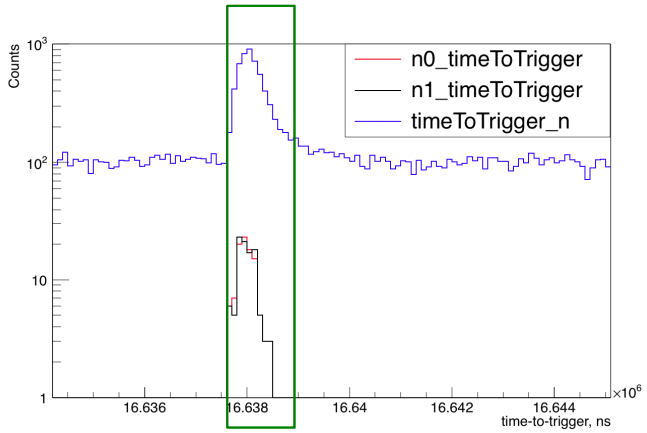
Full 7 days

Beam On data Nov 19 to Dec 21, 2014, basement 11

- On October 28, the trigger channel was changed and the signal polarity inverted. The latter caused the trigger to be shifted by about 30us in the “time to the last trigger” histogram.
- Again, there is a spike when selecting for neutrons (blue), (which is visible even without n-selection)
- The spike is present when selecting for neutron pairs (n0,n1) (**black**, red).
- We choose again a beam window of 1.3us duration, but starting at 16,663.7us (due to the trigger shift)



Zooming…

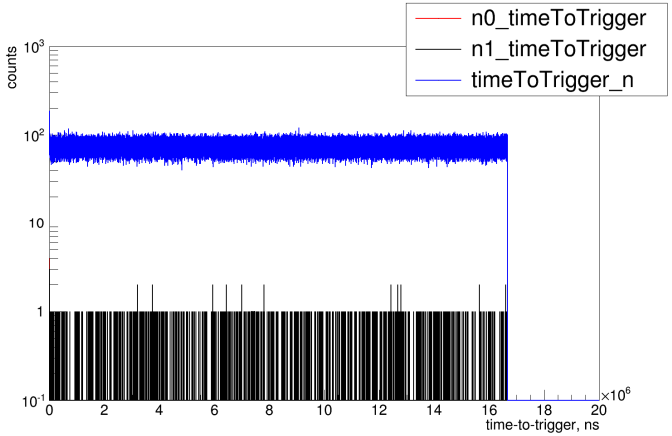


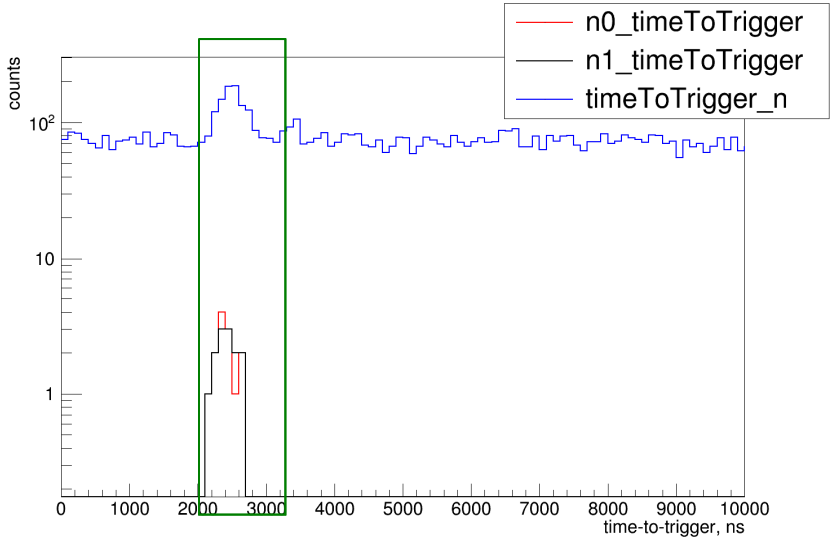
Window = 1.3us,
bin width 100 ns

Full 27 days

Beam On data June 20 to June 25, 2014, basement 2.5

- We already saw the beam in the basement 2.5 data
- Data was reprocessed restricting to a 1.3us duration, starting at 2.0us





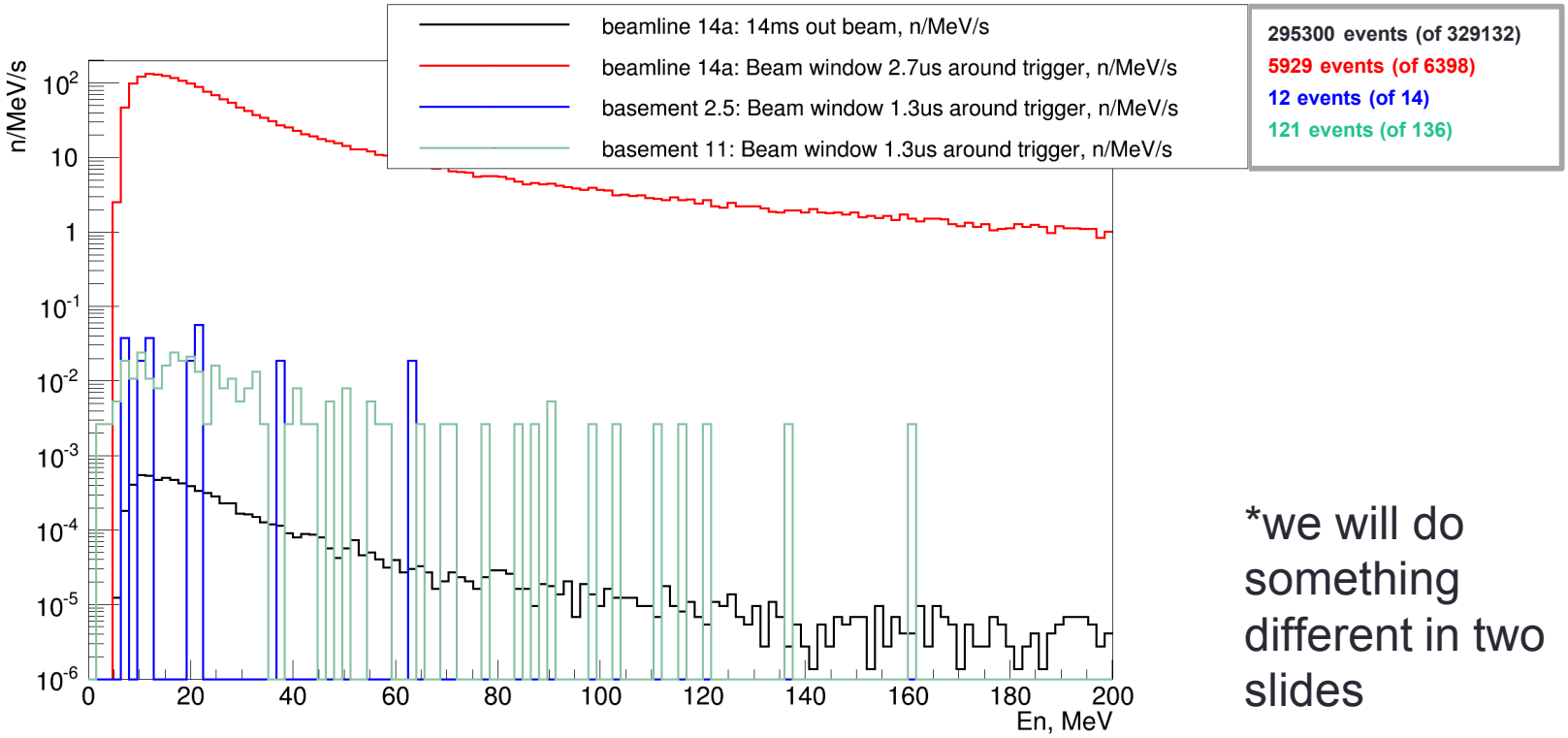
Window = 1.3us,
bin width 100 ns

Zooming…

Full 5 days

Reconstructed Neutron spectra: normalized by the Total Beam Live Time

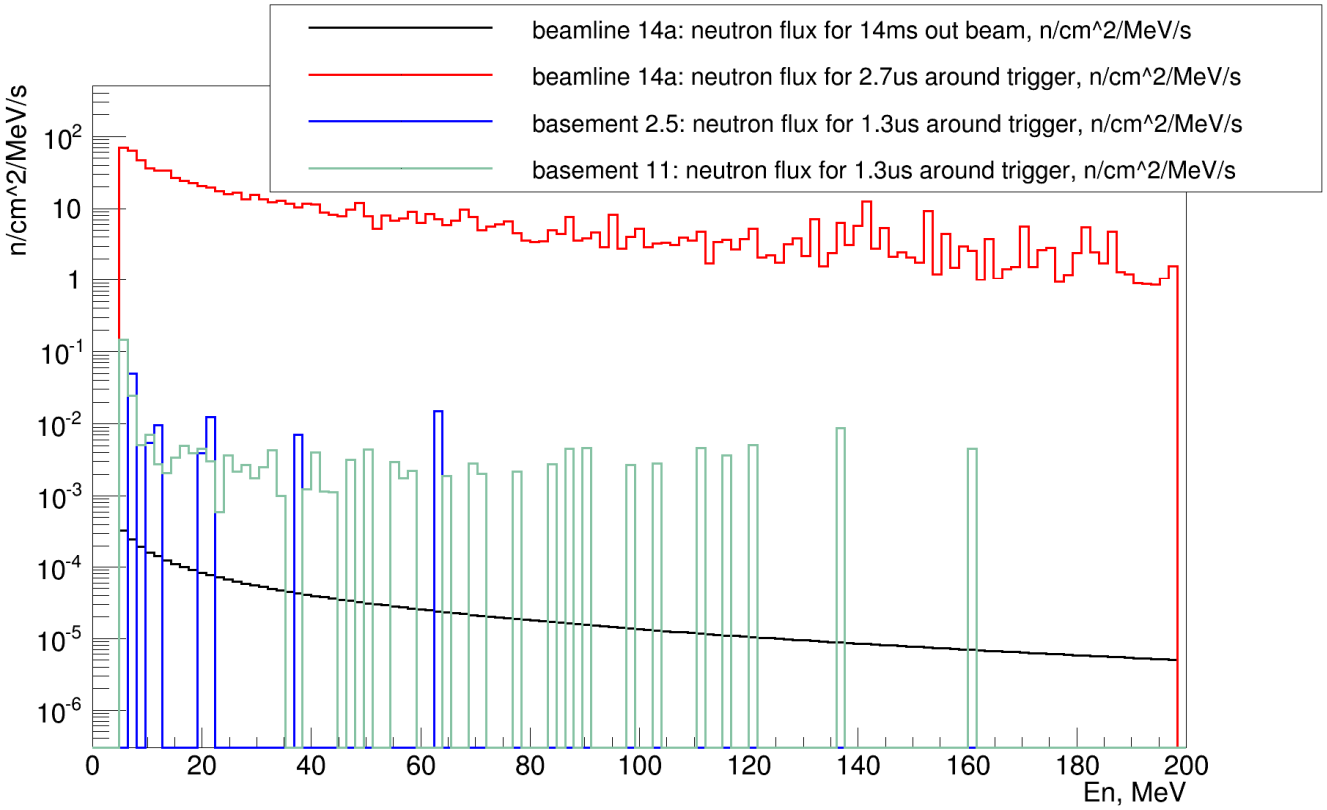
- As we have done so far*: the following histograms are obtained from the reconstructed neutron energy histograms, restricted to the the beam time window, over each full dataset, normalized by the **total beam live time of that dataset**, and then divided by the energy bin width (1.6MeV).



*we will do something different in two slides

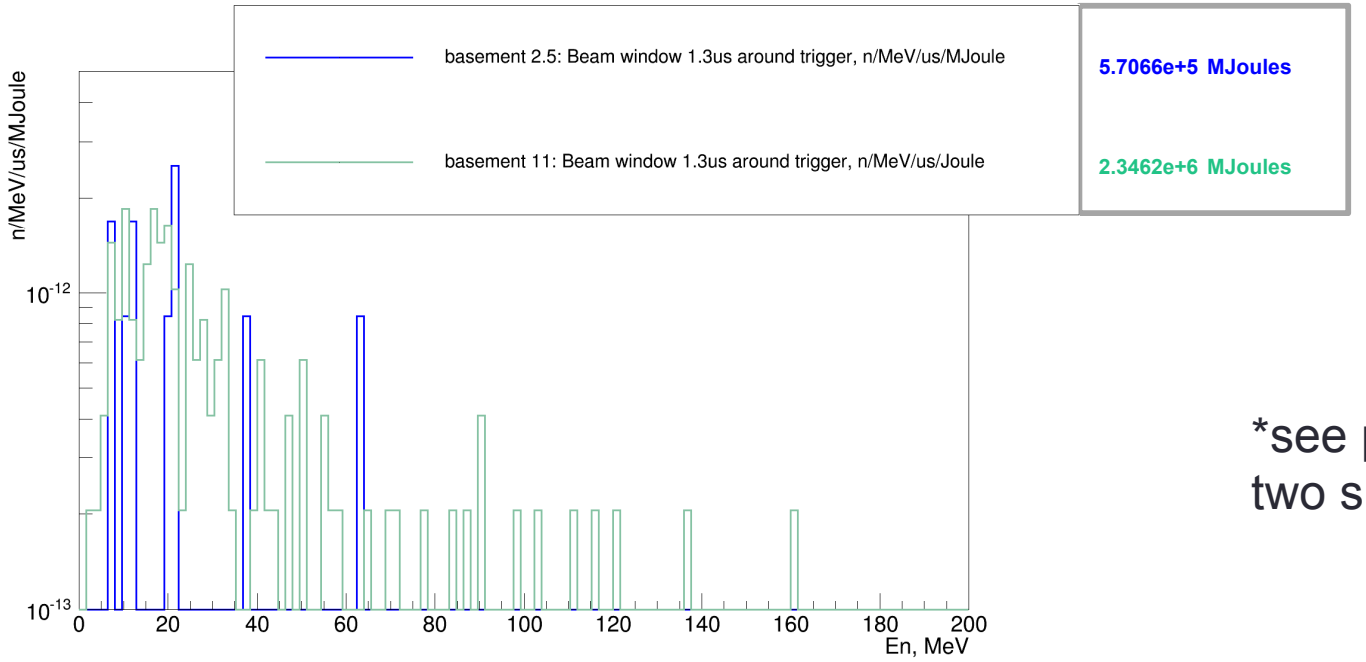
Estimated Neutron Fluxes, normalized by the Total Beam Live Time

- Then, we divide by the estimated efficiency to get the flux in n/cm^2/MeV/s:



Reconstructed Neutron spectra: normalized by the Total Beam Power

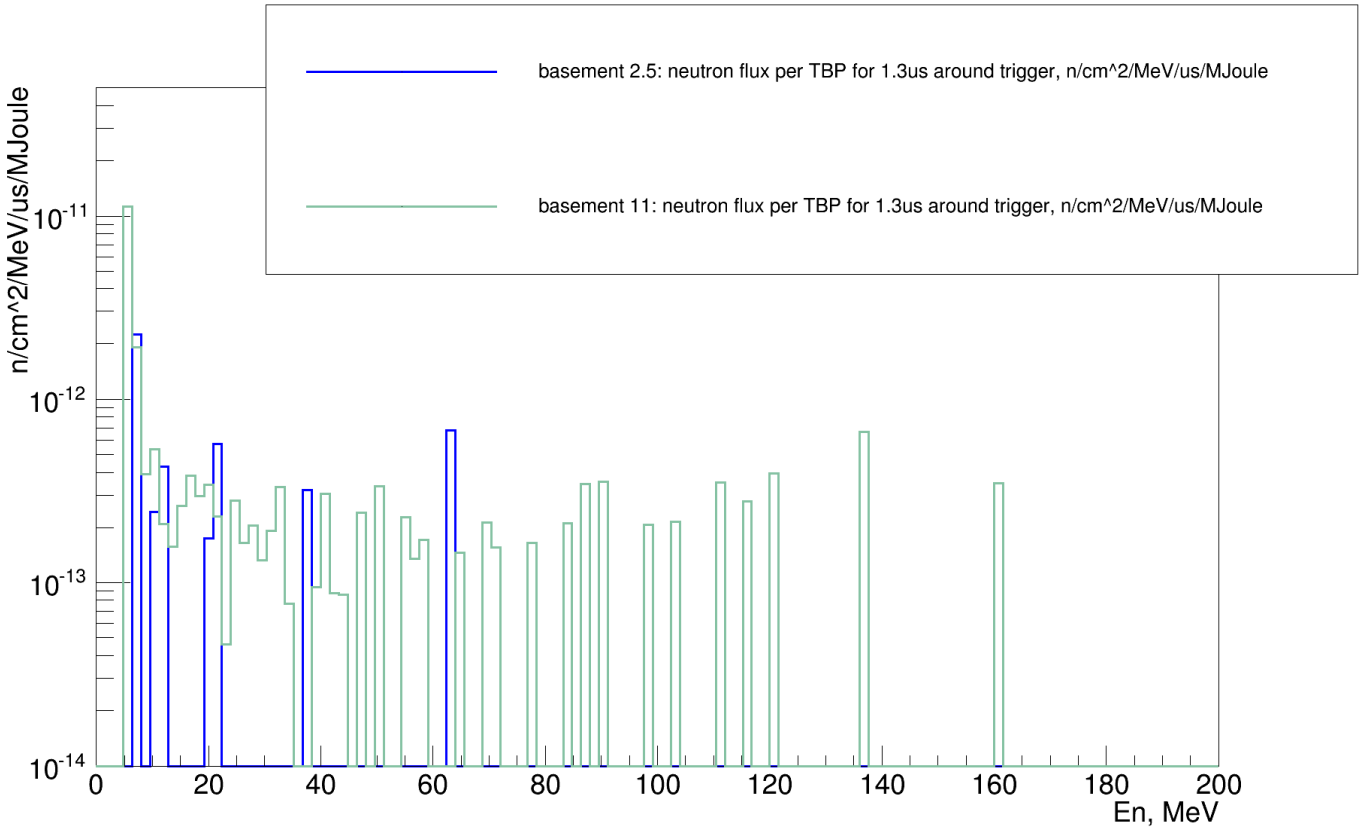
- Instead of what we've done so far*: the following histograms are obtained from the reconstructed neutron energy histograms, restricted to the the beam time window, over each full dataset, normalized by **the total beam power of that dataset** and by **the beam time window duration (1.3 us)**, and then divided by the energy bin width (1.6MeV).



*see previous two slides

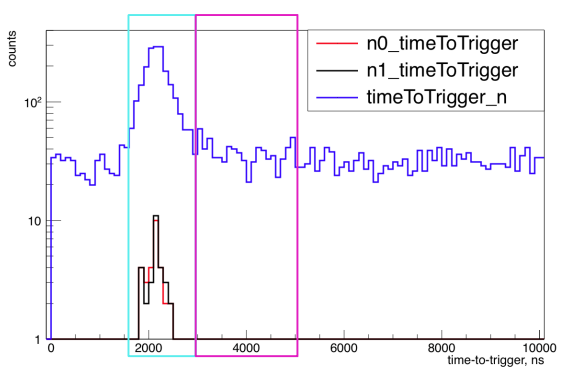
Estimated Neutron Fluxes, normalized by the Total Beam Power

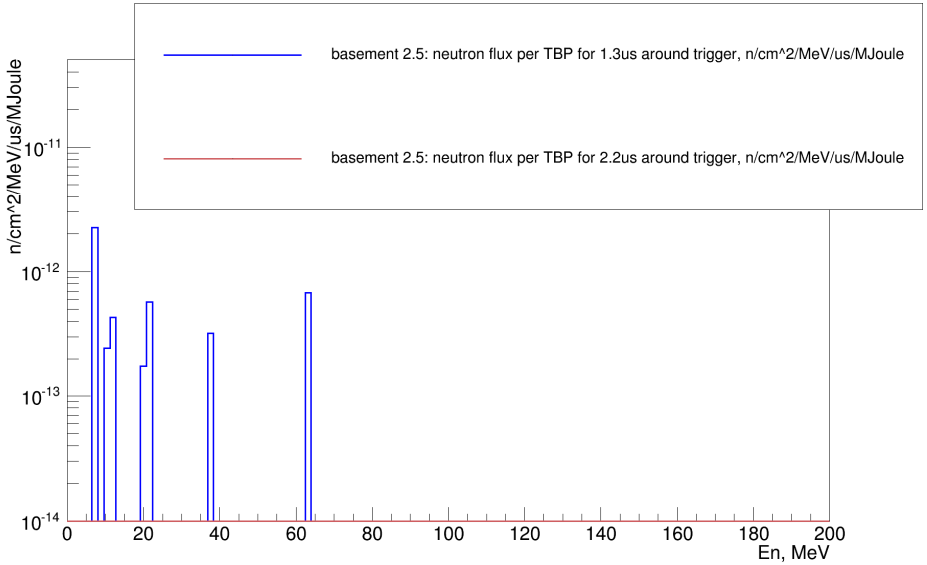
- Then, we divide by the estimated efficiency to get the corresponding flux in n/cm^2/MeV/us/MJoule:



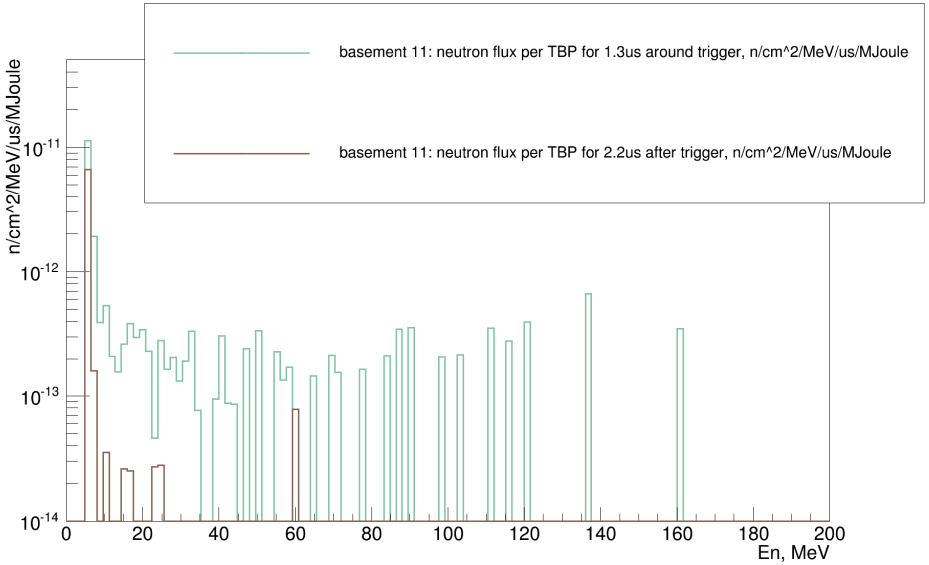
Estimated Neutron Fluxes in post-beam window of 2.2us

- We also report the flux a 2.2us window starting immediately after the extraction beam window (1.3us).





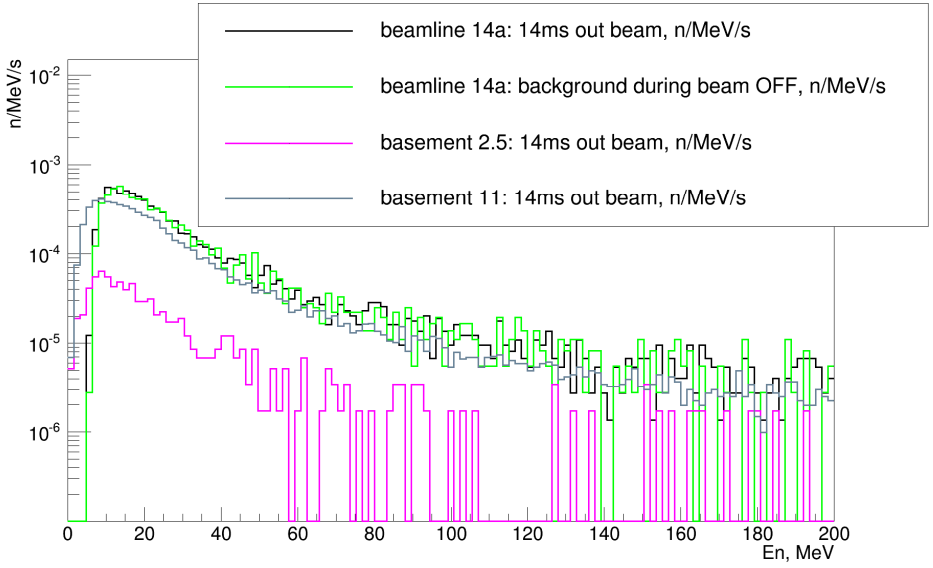
Basement 2.5

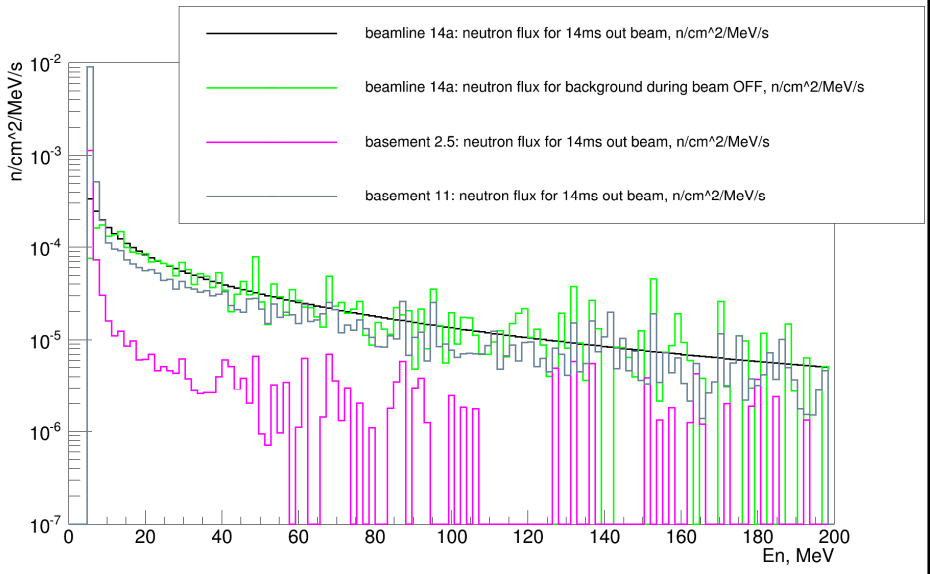


Basement 11

Neutron Background Spectra – outside the beam window

- The neutron background was measured for a time window of 14ms not including the beam (that we are calling out-beam window)
- Left histograms are normalized by the Total Live Time of out-beam window for each dataset
- Then, right histograms are the fluxes obtained dividing by the efficiency

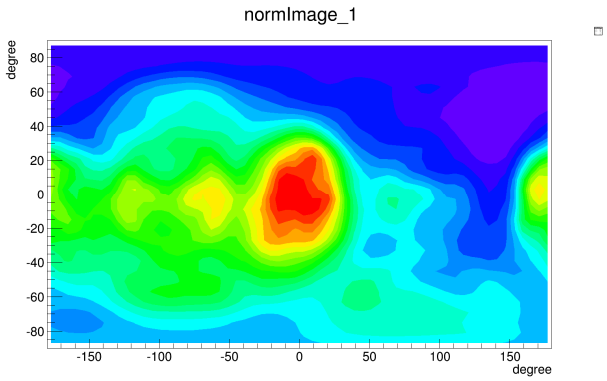




Images during 1.3us beam window

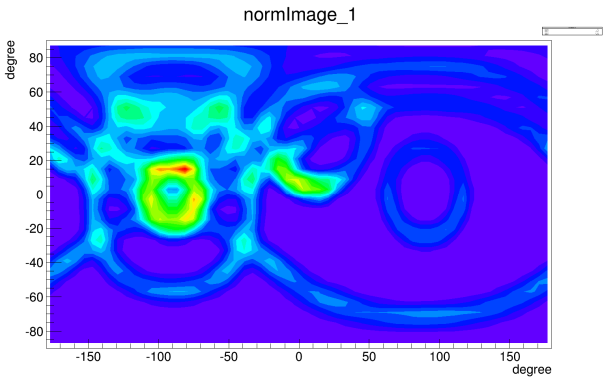
These images are created dividing by background image in order to normalize angular efficiency variations:

Beam Line 14a

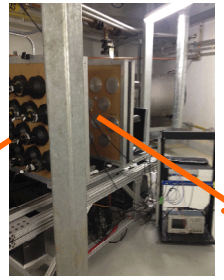


0^0 towards the SNS target

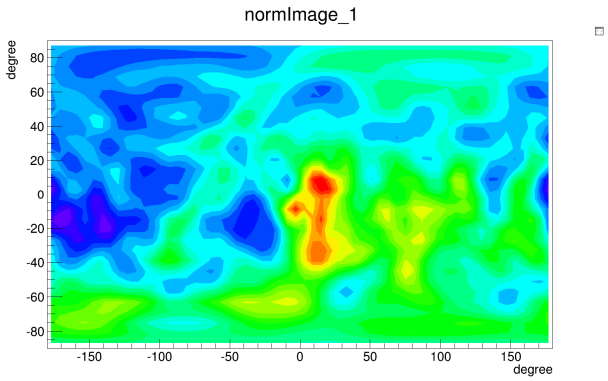
Basement 2.5



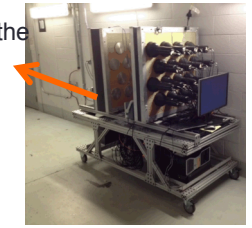
0^0



Basement 11



0^0 towards the SNS target



Conclusions

- Basement 2.5 and 11 have comparable neutron fluxes during beam extraction window (1.3us).
- Post beam window (2.2us) show large reduction in neutron flux for both basement locations.
- Images show most of neutrons coming from about the beam direction.
- Larger overburden at basement 2.5 reduces cosmic neutron background about 1 order of magnitude compared to basement 11.