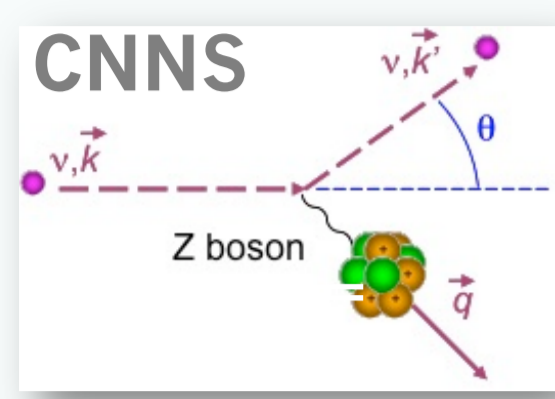


Background Studies for Germanium Neutrino Detection System

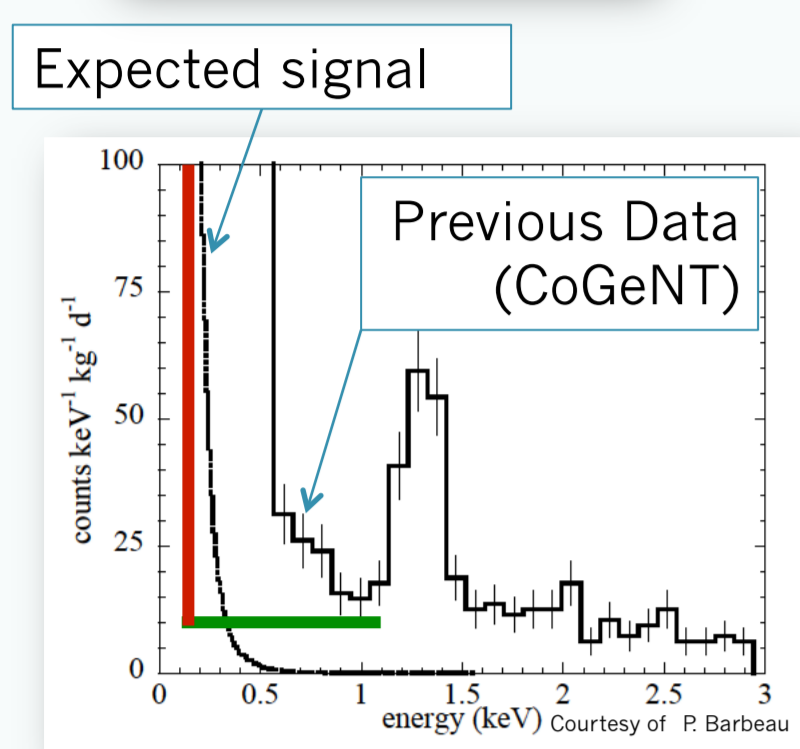


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Overview



- Reactor Monitoring with HPGe detectors is based on the as-yet undetected Coherent Neutrino-Nucleus Scattering (CNNS)
- Expected CNNS count rate at 25m from reactor core: **5 counts / kg-day in region-of-interest (ROI) <1 keV**

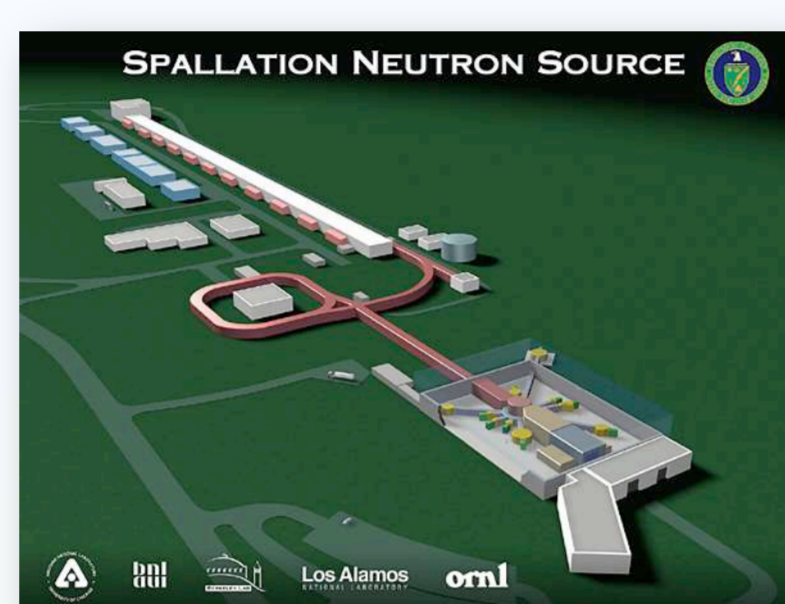
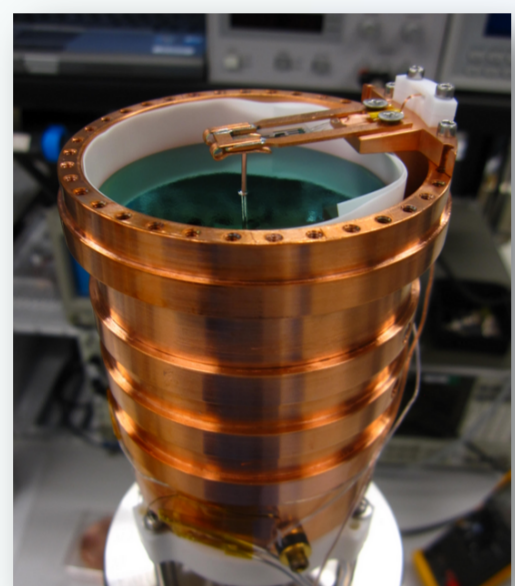


- Requirement of kg-scale HPGe detector with electronic noise levels so far only achieved with few-gram detectors: **~100 eV electronic threshold**
- Requirement of stringent background reduction and rejection: **<10 bkgnd counts/kg-day in ROI <1 keV**

Goal

Development of advanced low-threshold Ge detection technology and proof of its applicability to reactor monitoring via CNNS detection:

Develop Ge detector of 1pF, 1pA, <100 eV (talk by P. Barton)



1st time observation of CNNS:
 • Possible at SNS with conventional Ge technology.

Why is this work important?

- Antineutrino detectors are a non-intrusive tool for reactor safeguards, providing a verification method independent of the declaration of the reactor operator.
- Ge-based technology: smaller footprint and more compact and mobile alternative to scintillator-based detectors.
- Potential technological leap in HPGe detector fabrication.
- First time observation of CNNS.

Technical Approach

- For future reactor deployment, specification of shielding design from background modeling.
- For future SNS deployment, characterization of neutron background to assess CNNS experiment feasibility at available SNS locations.
- However, neither a reactor deployment nor an SNS deployment will take place within this project timeframe.

Background Work for Reactor Deployment

- Geant4 Model of full detector, shielding and underground tendon gallery:

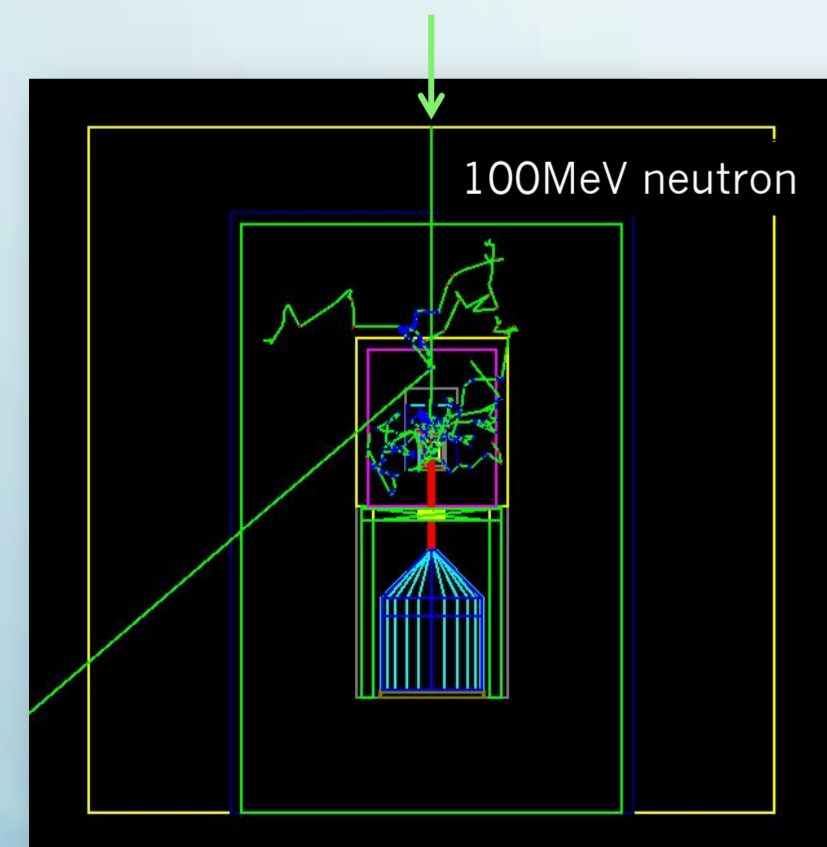
- Full info of events in HPGe detector
- Full info of events in Plastic Scintillator inner veto
- Info of ionizations in Muon veto
- Info of particles traversing the Poly Shield
- Info of particles traversing the Lead Shield

- Tendon gallery is 3 meter wide and tall, at 25 m.w.e. depth from surface.

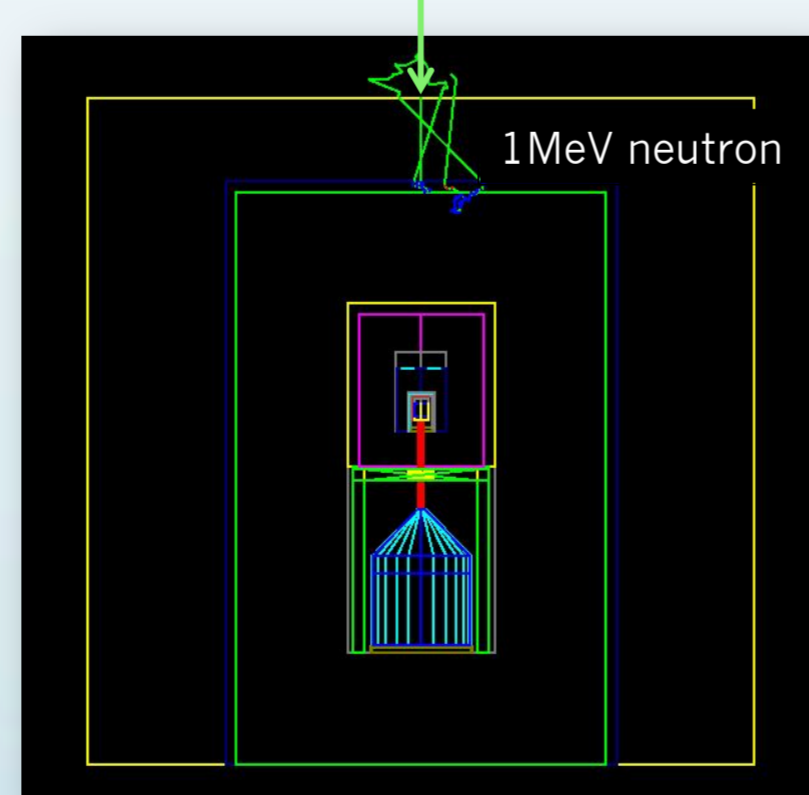
- Quench energy deposited by recoiling nuclei and by neutron elastic scatters.

- Complex timing analysis:

- Form pulses according to DAQ time resolution of 3 μ s.
- Reject Ge pulses in coincidence with the two active vetoes
- Reject Ge pile-up and Multi-Site pulses since neutrino interactions are Single-Site:



- Toy simulation:** high energy mono-energetic neutrons incident vertically from the Tendon Gallery ceiling into the top of the shield.



Results spectra in ROI = (0.1,1)keV for 100MeV neutron:

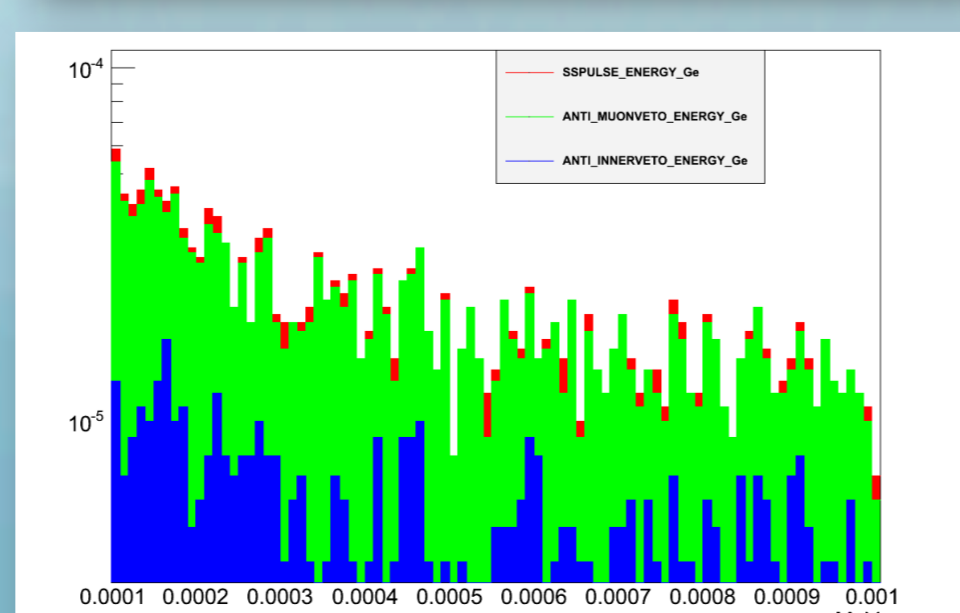
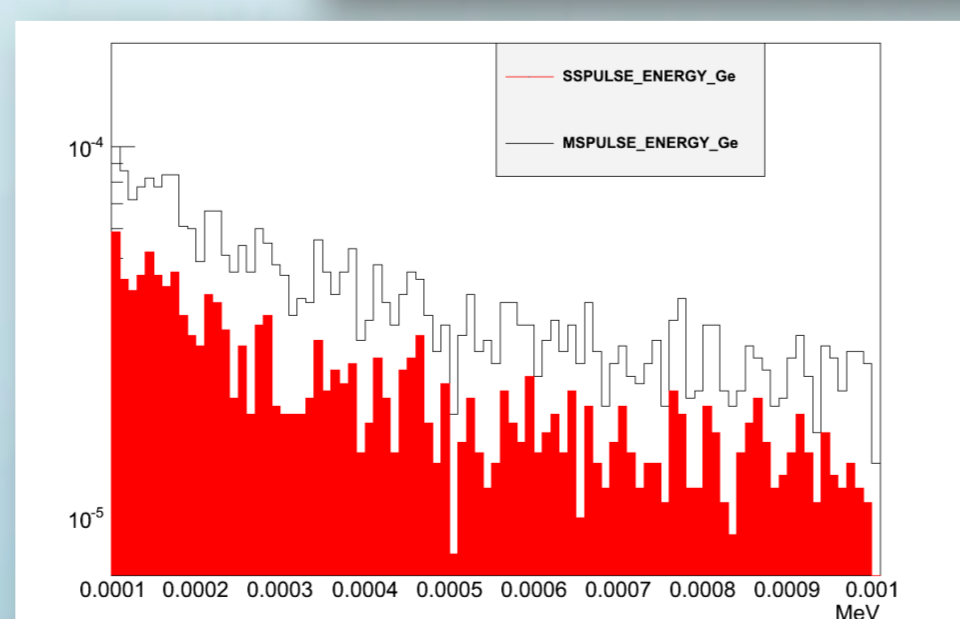
Black line: Prob. of depositions by Multi-Site pulses, 3.5E-3.
 Red filled: Prob. of depositions by Single-Site pulses: 1.9E-3.
So, filtering MS pulses rejects about ~46% of n background.

Using veto Anticoincidence Window of 10 μ s:

Green filled: after Muon Veto rejection.

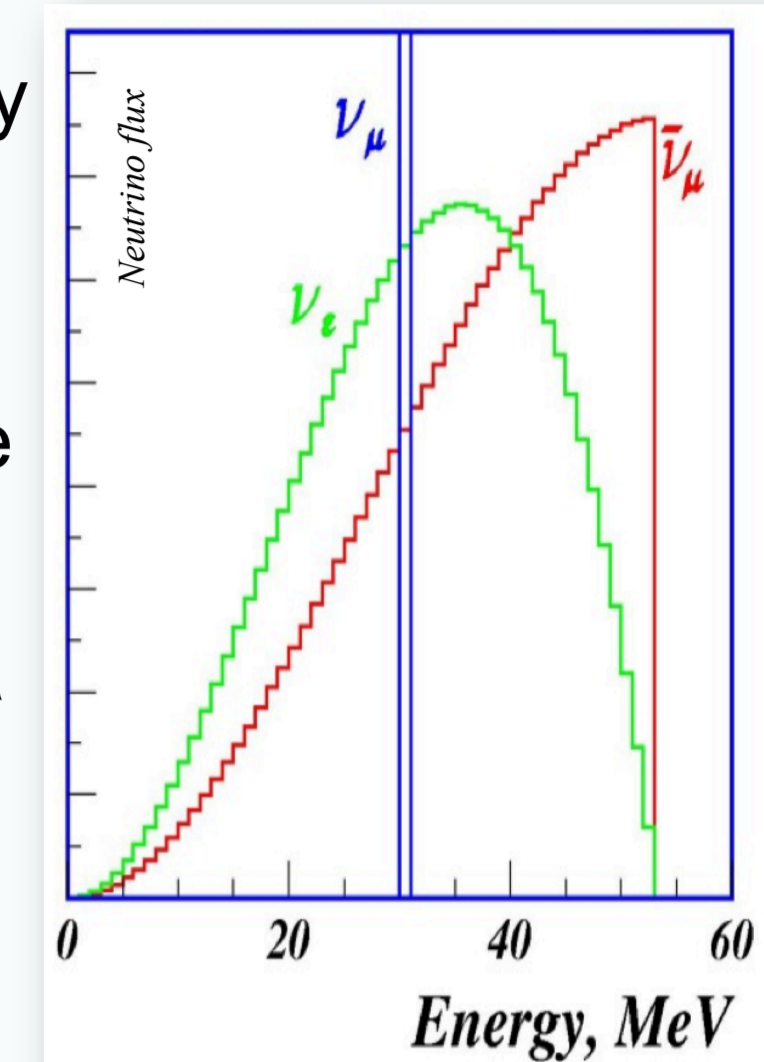
Blue filled: after Plastic Scintillator Inner veto.

So, the plastic inner veto by itself rejects another 75% of n background, which reduces COGeNT bckgrnd to values low enough to allow CNNS measurement.



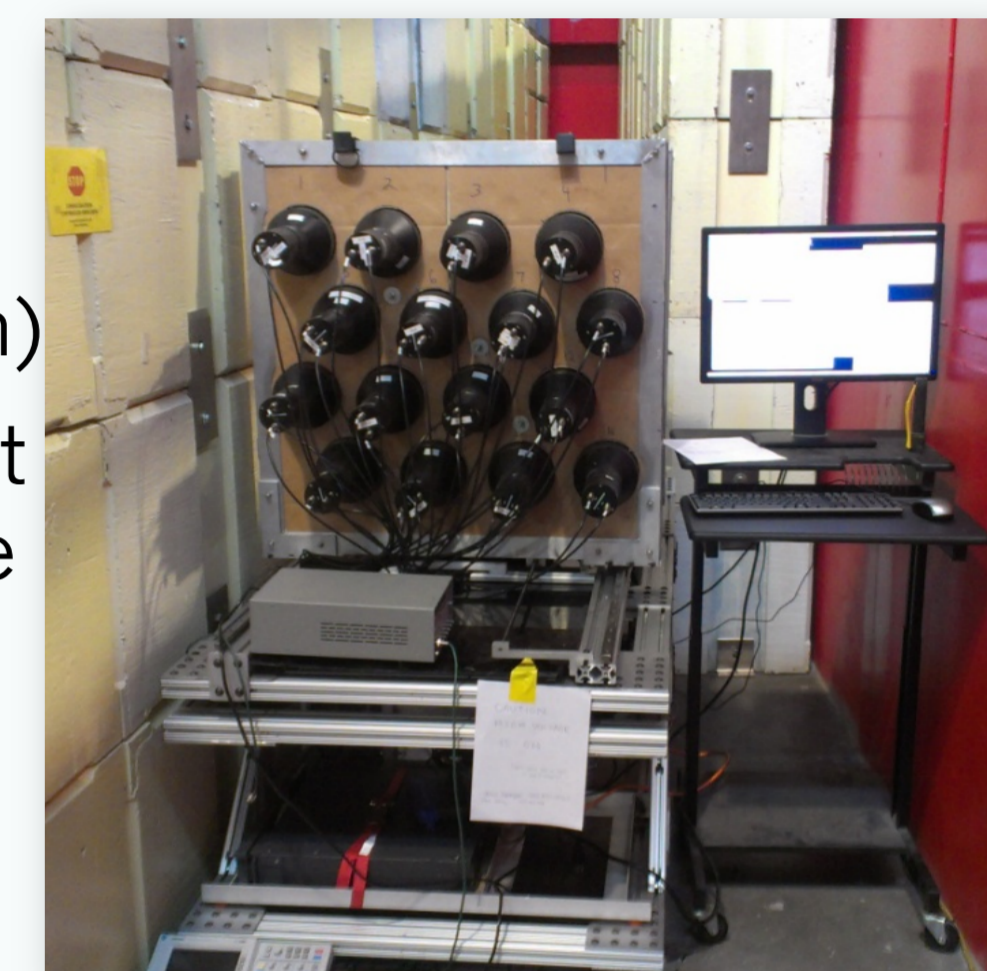
Background Work for SNS Deployment

- The Spallation Neutron Source (SNS) at ORNL as source of more energetic neutrinos: Ge ionization energy up to ~20keV.
- First-time observation of CNNS is possible with existing Ge technology: p-type point contact (PPC) HPGe detectors with threshold ~ 1keV.
- Lower neutrino flux of ~10⁷/cm²/s (~10¹²/cm²/s from a reactor) require about tens of kg of Ge.
- Beam timing allow backgrounds suppression by a factor of >1000.
- 'COHERENT' multi-institutional collaboration forming to measure CNNS at SNS.



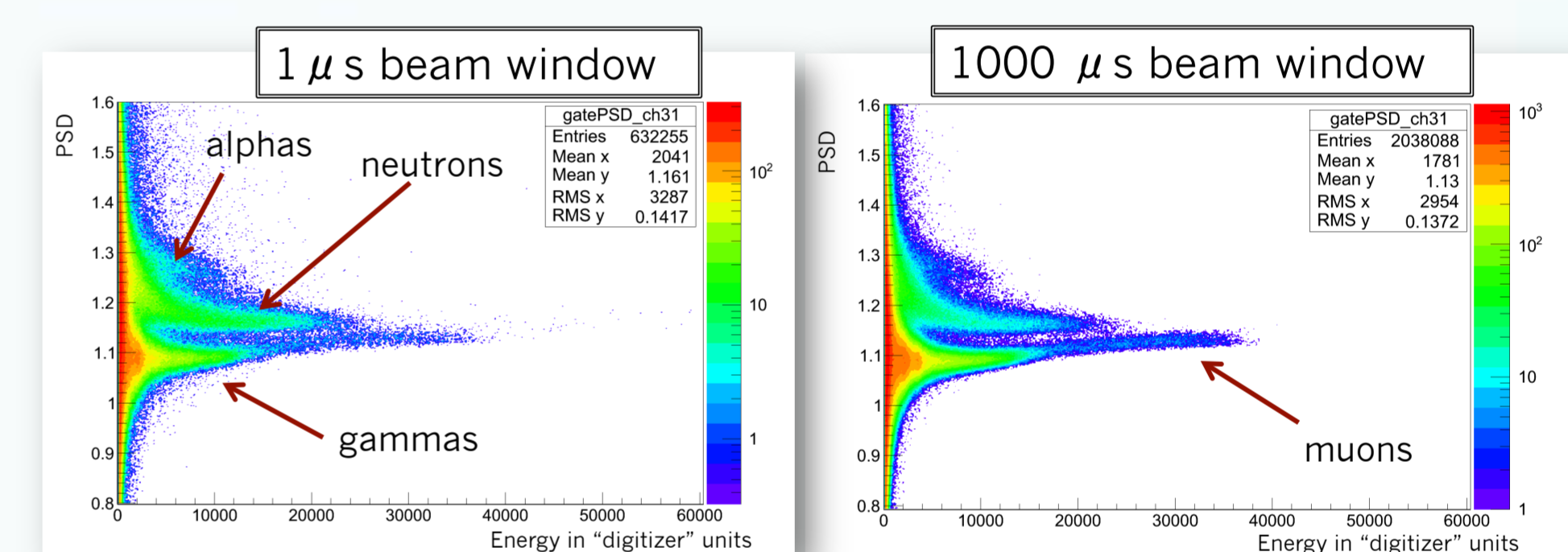
Study of neutron background at SNS

- Neutron Scatter Camera (NSC) deployed at SNS beamline 13a (first available location)
- Goal: Characterize neutron background at various SNS available locations to determine feasibility for CNNs measurement.
- Motivation: potentially intense neutron flux at beam-on time originated from the SNS target.



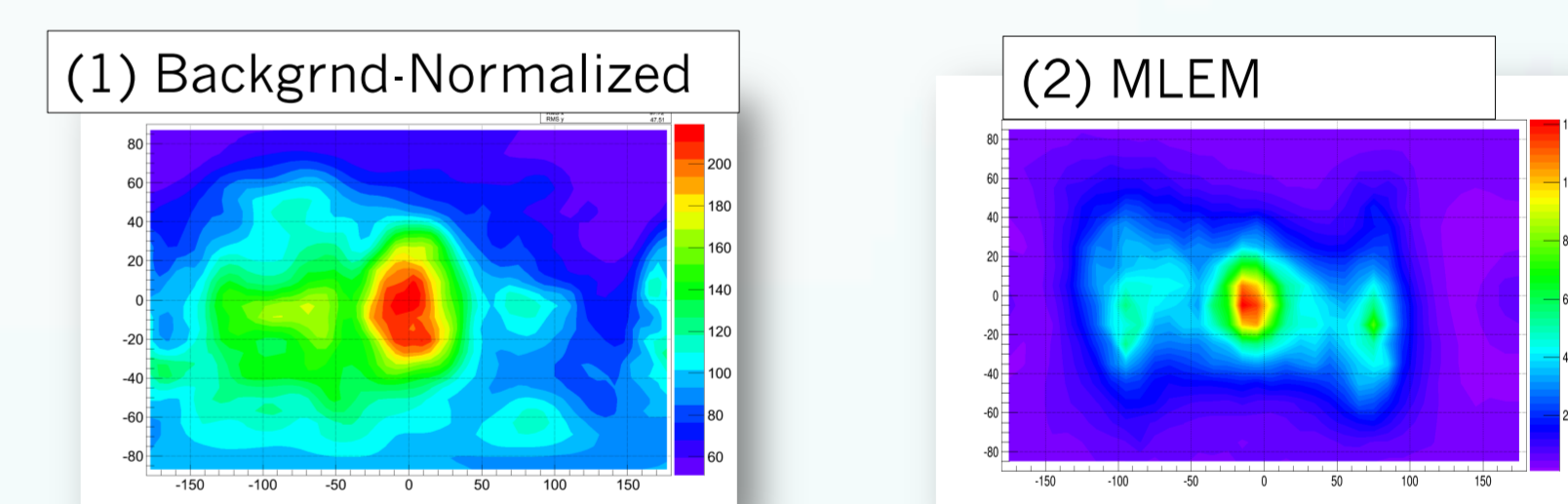
Results

PSD: Most neutrons are present within a 1 μ s window after SNS beam



Neutron Image: Need to understand better NSC lateral efficiency. Preliminarily, normalize efficiency variations (1) dividing by the background, or (2) applying MLEM (uses simulation and data):

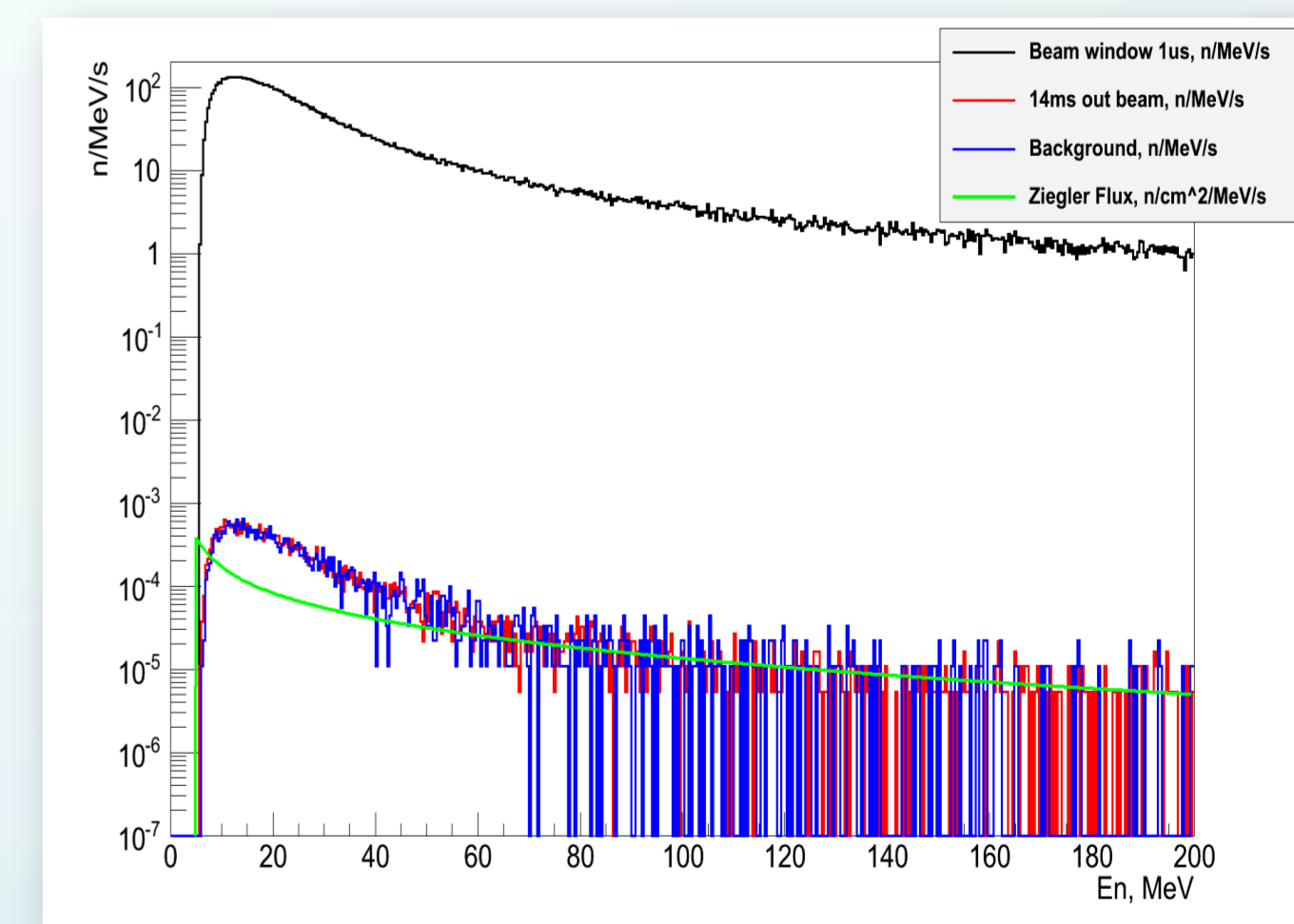
1- μ s window beam-on data:



Both images show neutrons from the SNS target plus neutrons spilling through the beamline walls.

Neutron Spectra:

- Neutron rate from 1- μ s window beam-on data about 5 orders of mag. larger than background
- Out-of-beam spectrum (14 ms window) is identical to background: no after-beam halo.



Expected Technical Challenges

- Given recent shutdown of available power reactor (SONGS), we need to identify other feasible reactors for a future deployment.
- For SNS deployment: (1) producing absolute neutron rates by determining neutron scatter camera efficiency at energies beyond its original design; (2) studying if possible to mitigate SNS neutron background with proper shielding design.

Future Work

- Continue NSC data analysis: determine absolute neutron rates.
- Measure neutrons at other SNS locations.
- Feasibility assessment of available SNS locations based on background characterization.
- If task approve, contact other reactor operators.