CEνNS Experiment Proposal at CSNS

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On behalf of CEνNS @CSNS Collaboration

SPCS 2022 Report

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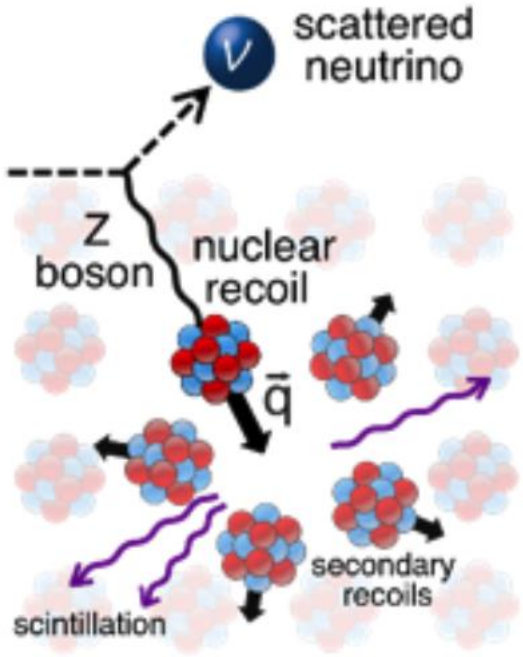
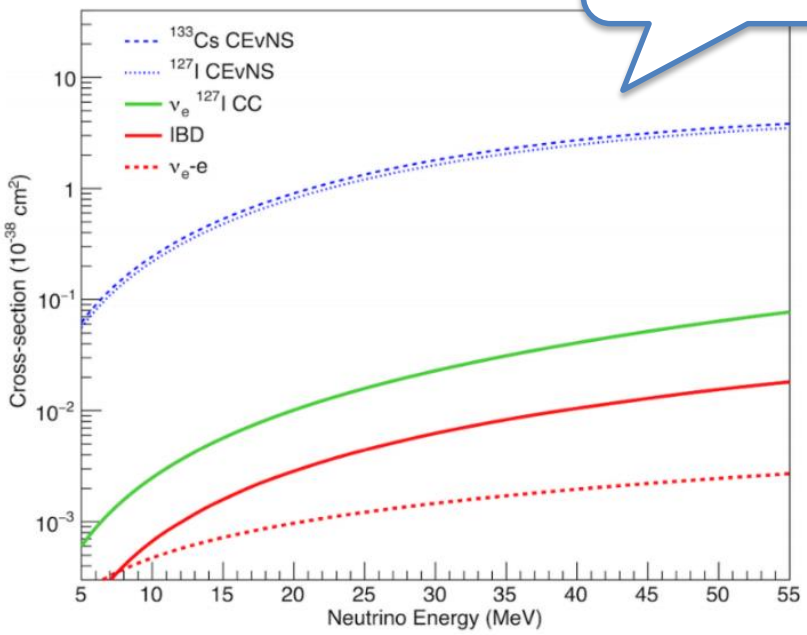
Outline

- CEνNS Introduction
- Neutrino From CSNS
- Experiment Design
- Event Selection
- Background Study
- Expected Performance
- Summary

CEνNS coherent elastic neutrino-nucleus scattering





CEνNS cross section is large!

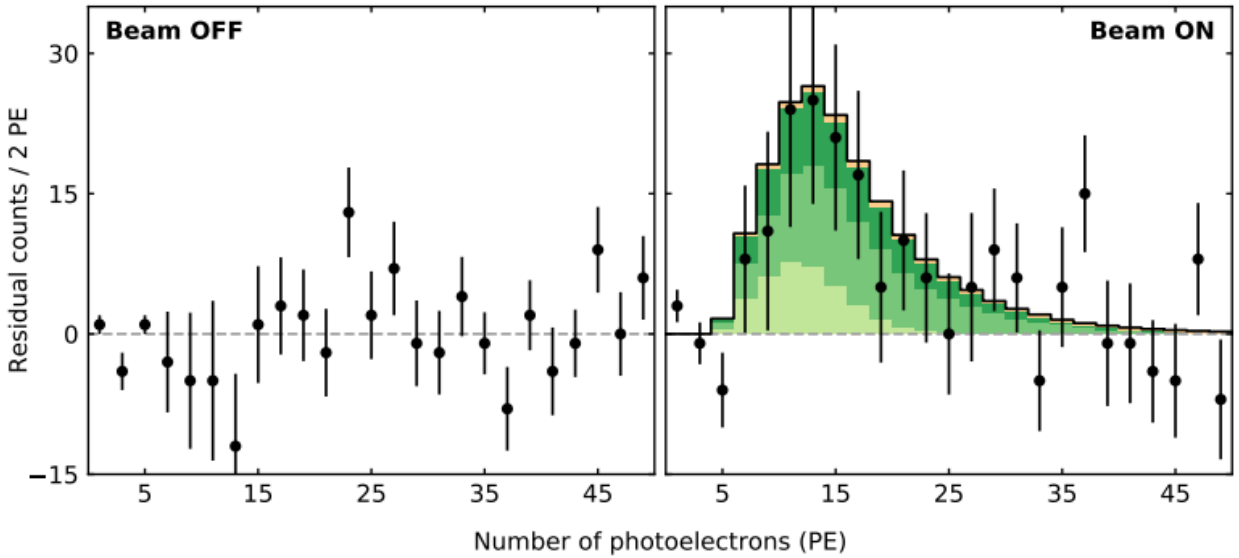
- CEνNS cross section is well calculable in the SM

$$\frac{\mathrm{d}\sigma_0}{\mathrm{d}E_r} = \frac{G_f^2}{4\pi} m_a [Z(4\sin^2\Theta_W - 1) + N]^2 \left(1 - \frac{m_a E_r}{2E_\nu^2}\right) \propto N^2$$

- Inspect SM at low momentum transfer
- Background of WIMP detection
- Neutrino from stars (Sun, supernova)
- Nuclear physics

Motivation

- COHERENT Collaboration Result
  - First Detection at 2017------CsI(Na)： 6.7σ significance， 1σ agreement with SM



  - 2020-------LAr：

    3σ significance, 1σ agreement with SM
  - Verification at 2021------CsI(Na): 11.7σ significance, 1σ agreement with SM

- Independent Experiment Verification is Important!

China Spallation Neutron Source CSNS

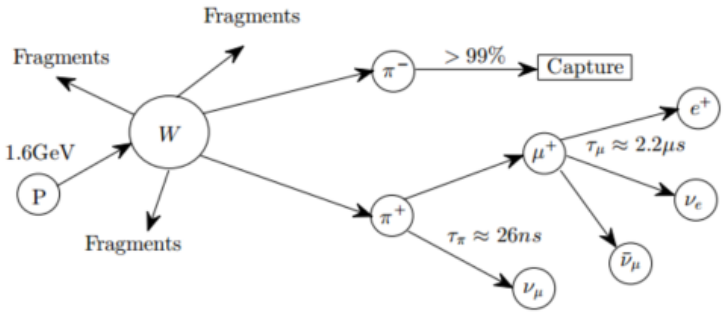
Guangdong Province

China Spallation Neutron Source CSNS

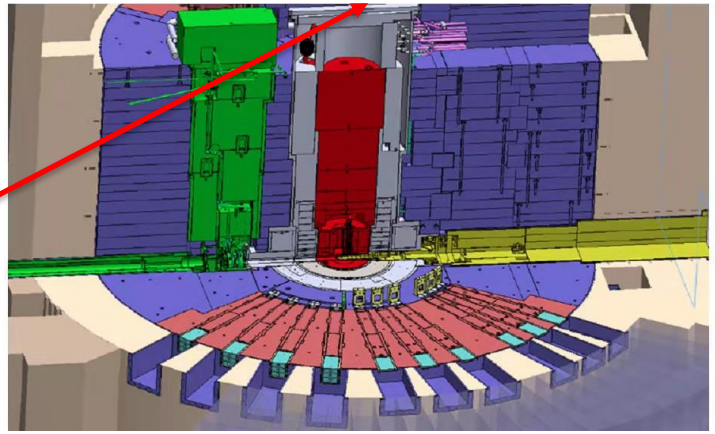
Huang, Ming-Yang *Chinese Physics C* 40.6 (2016): 063002

- CSNS Parameters
  - Proton Energy: 1.6GeV
  - Beam Power: 140kW
  - Target: Tungsten (W)
  - Target Size: $7 \times 17 \times 60 cm^3$
  - Frequency: 25Hz
- Detector Location
  - Neutrino Flux: ~$2.42 \times 10^{10} /cm^2 h$ per flavor @ 10.5m (8.2m+2.3m shield)

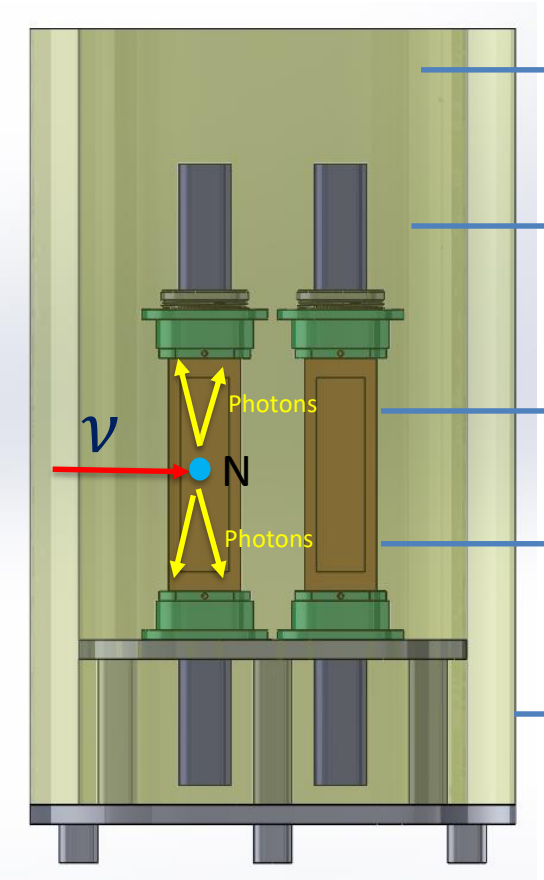
- Neutrino production
  - Neutrinos via Pion Decay-at-Rest(DAR)
  - 0.17/proton/flavor or higher!

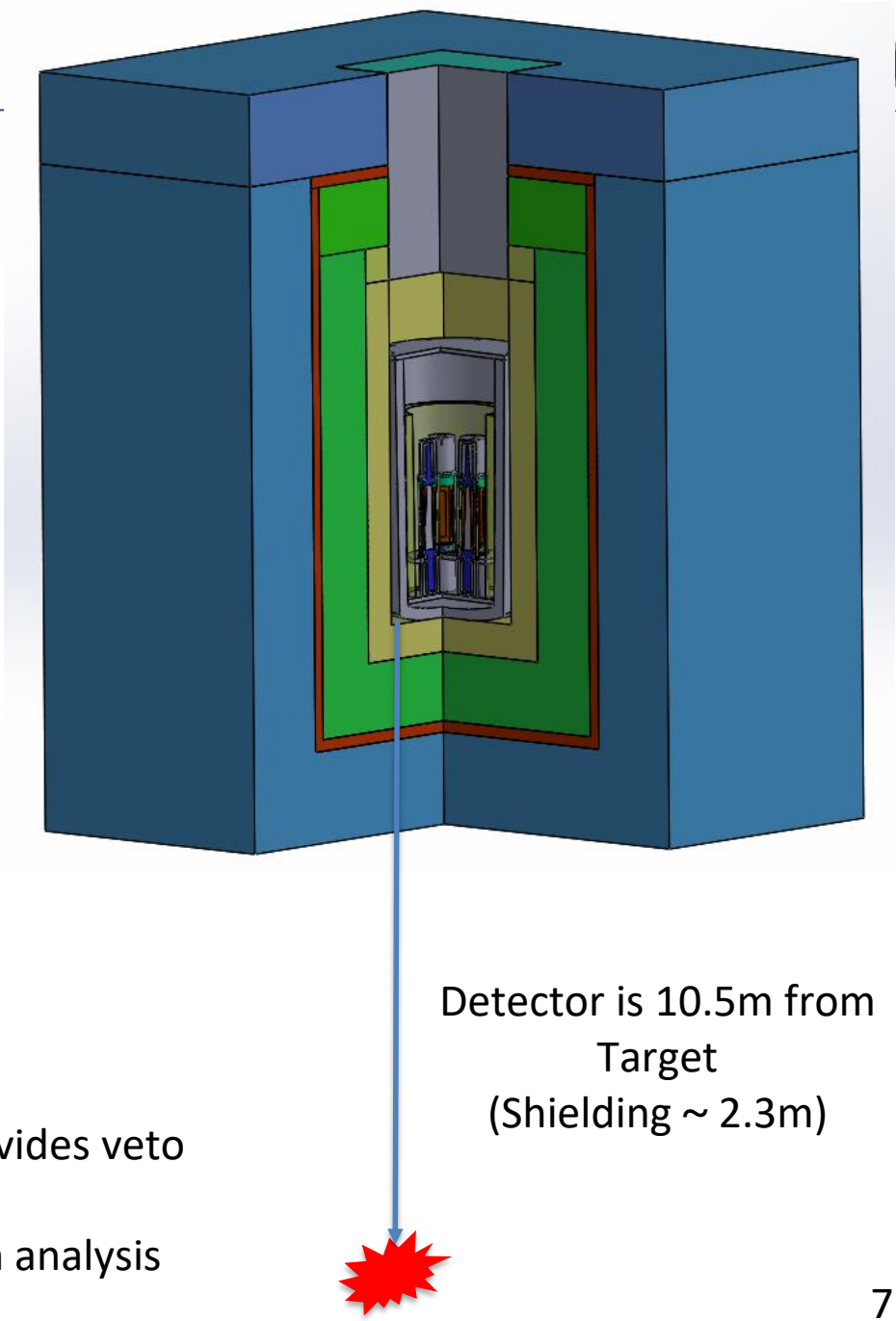


8.2m above target



Experiment Design





1. CSNS beam provides trigger signal
2. Cosmic ray anti-coincidence system provides veto
3. Flash ADC data taking at 8 channel
4. 50μs data taking window and waveform analysis

High Lights of this Design

- 10.5m from target, neutrino flux strengthened by R^2 factor
  - Compared with COHERENT 20m， around 4 times stronger

EPJC(2020)80:1146

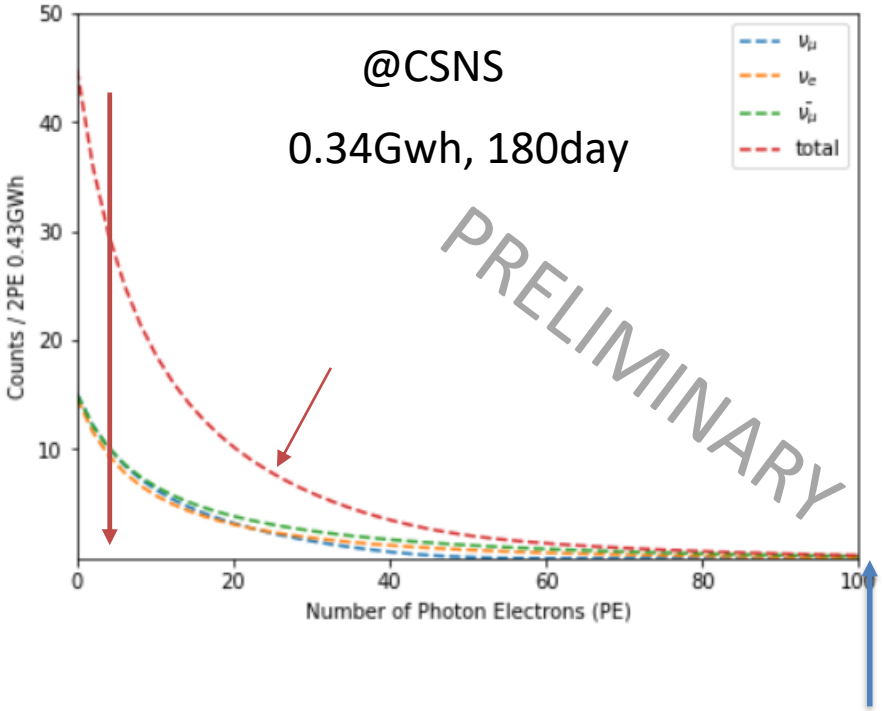
- Light Yield of CsI is 33.5pe/keVee @ 77K
  - Light Yield of CsI(Na) is 13.5pe/keVee @ 293K, ~2 times higher (COHERENT)

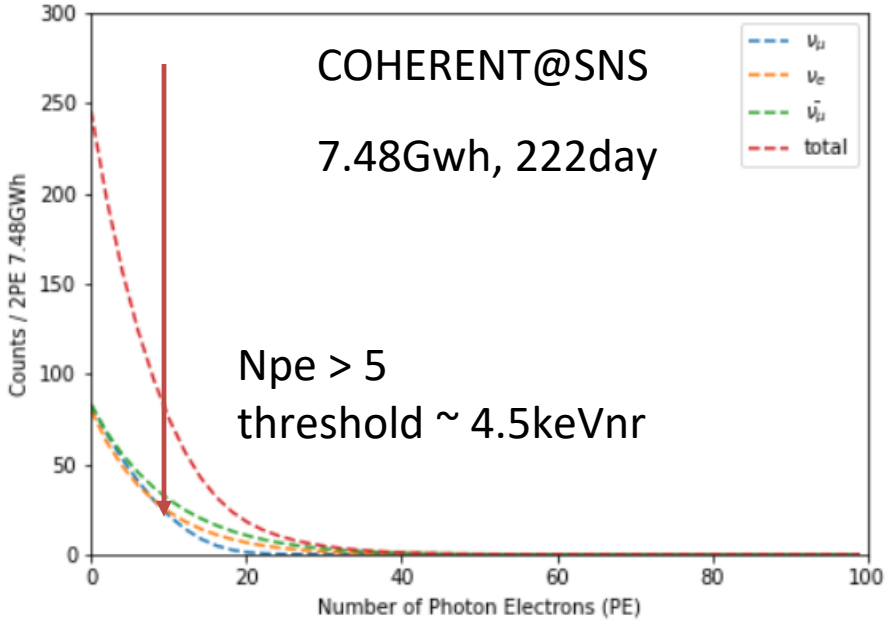
- PMT has lower dark noise level, and the PMT is a low radioactivity PMT
  - 111Hz @ 77K (Our measurement)

- Double side PMT readout to suppress Cherenkov and dark count background
  - Cherenkov background dominate @ COHERENT. This design can suppress the Cherenkov background.
- Trigger by CSNS to suppress background； Waveform analysis to select event.

CEνNS Signal Spectrum

Redraw from COHERENT THESIS





3 keVee

- Beam Power of CSNS is 10 times weaker than SNS， total number of neutrino generated would be 10 times smaller
- But higher light yield of CsI @ 77K would lower the threshold, and causing actually more detectable events.

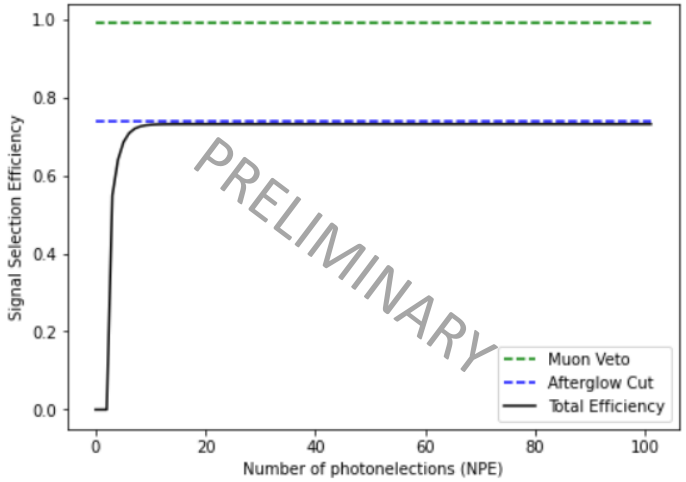
Event Selection

1. No veto signal from Cosmic ray anti-coincidence system
2. Waveform Analysis： PE number at pretrace smaller than $N_{pt} \leq 3$ to suppress after glow background
3. For Each CsI Detector， requiring PMT PE number to suppress dark count and Cherenkov background

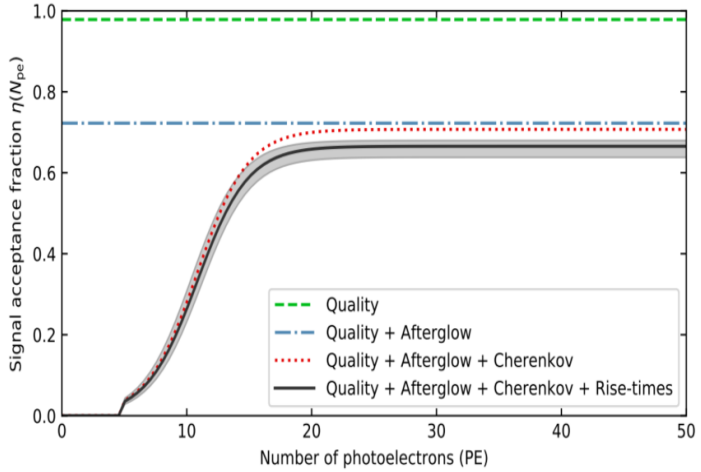
$$NPE_1 \geq 1 \;\&\&\; NPE_2 \geq 1$$

4. For each trigger, only one CsI detector satisfying 3， to suppress Compton or Multi-scattering events
5. Requiring total PE number： $4 \leq N_{PE} \leq 72$

@CSNS



COHERENT@SNS (Constrained by Cherenkov Cut)

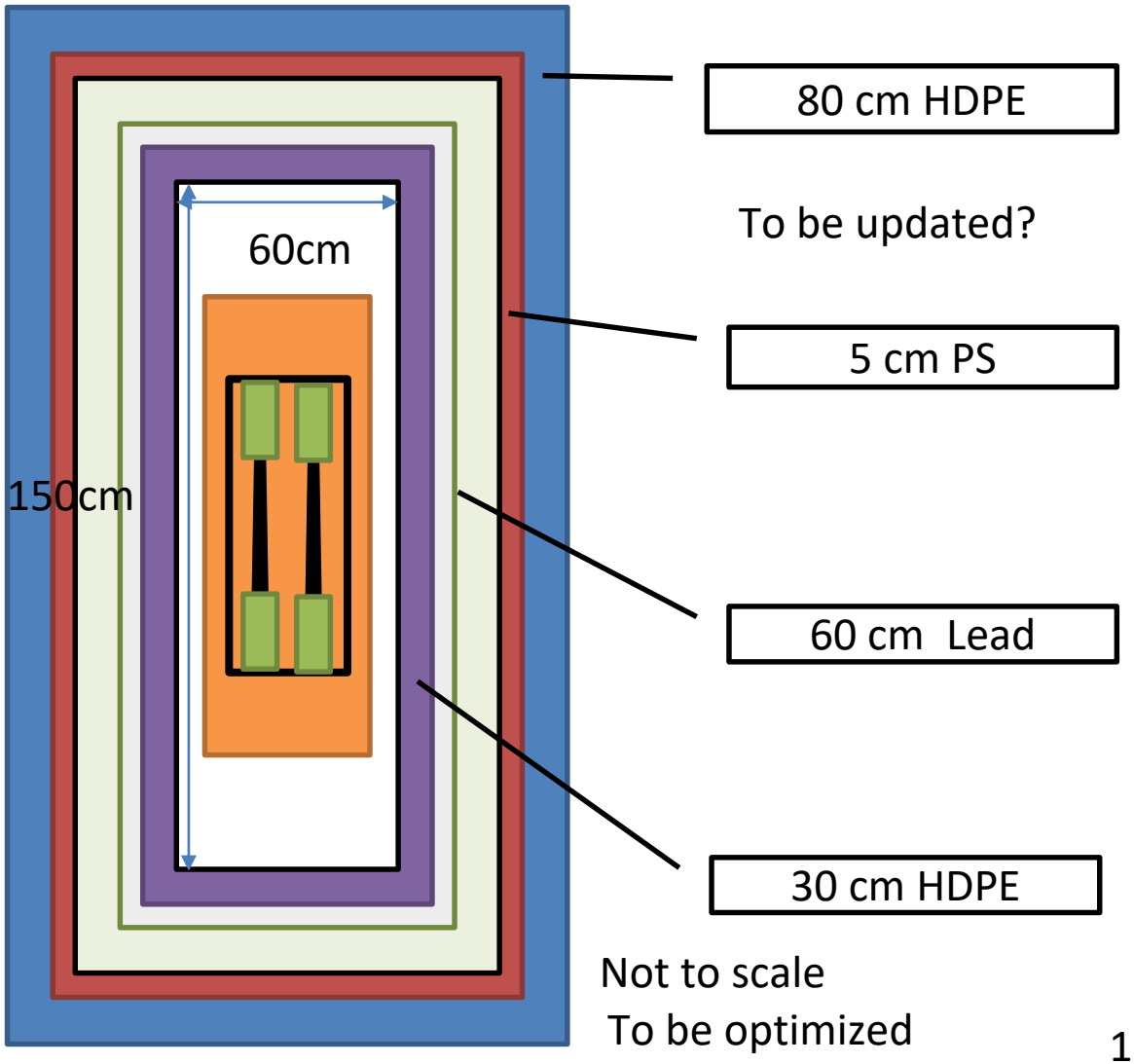


Selection Efficiency Curve

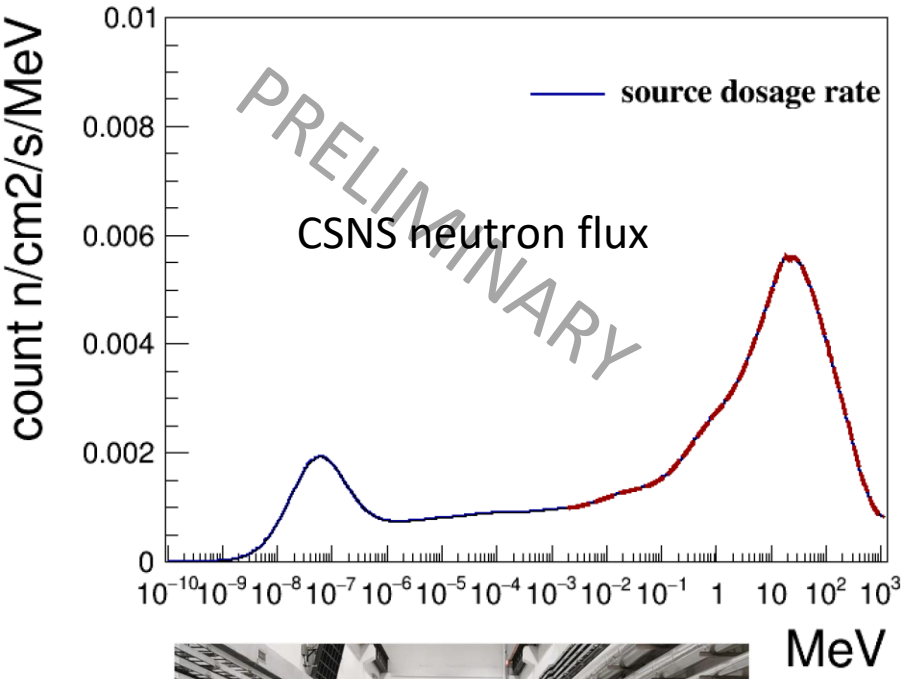
Background Study

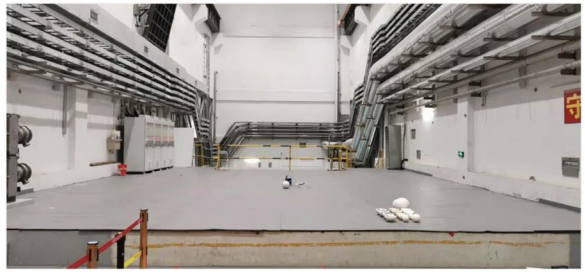
- Simulation Software is developed based on Geant4

  - Beam related neutron (Dominant)
  - PMT dark count coincidence(Next Dominant)
  - Radioactive
  - Environmental gamma
  - Cosmic ray
  - Neutrino induced neutron

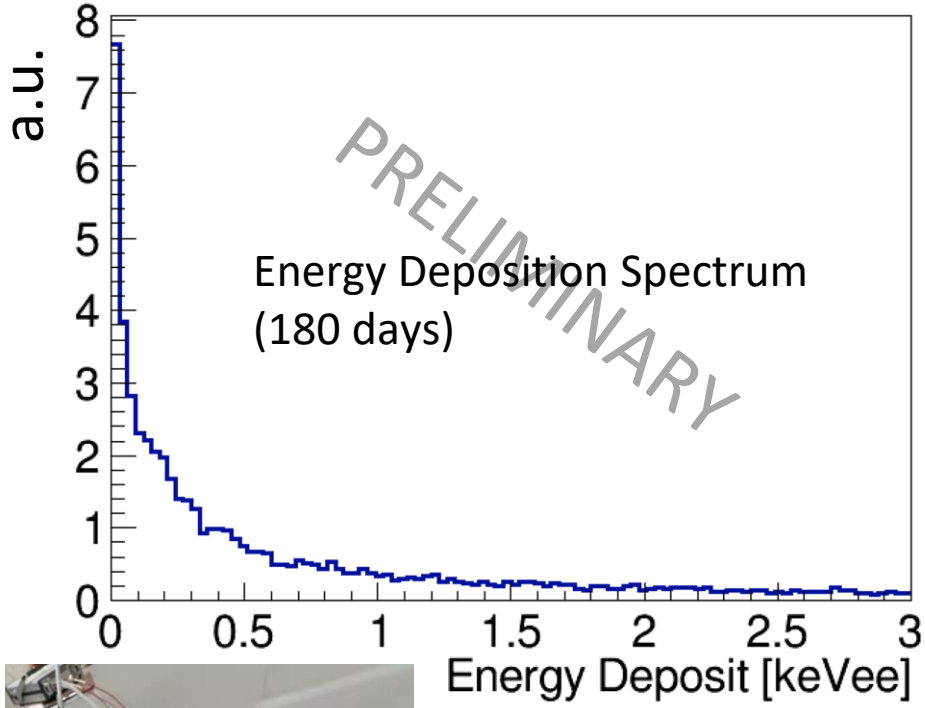


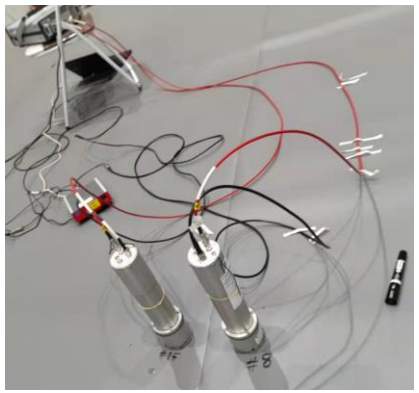
Beam related neutron





Bonner Multisphere Neutron Spectrometer

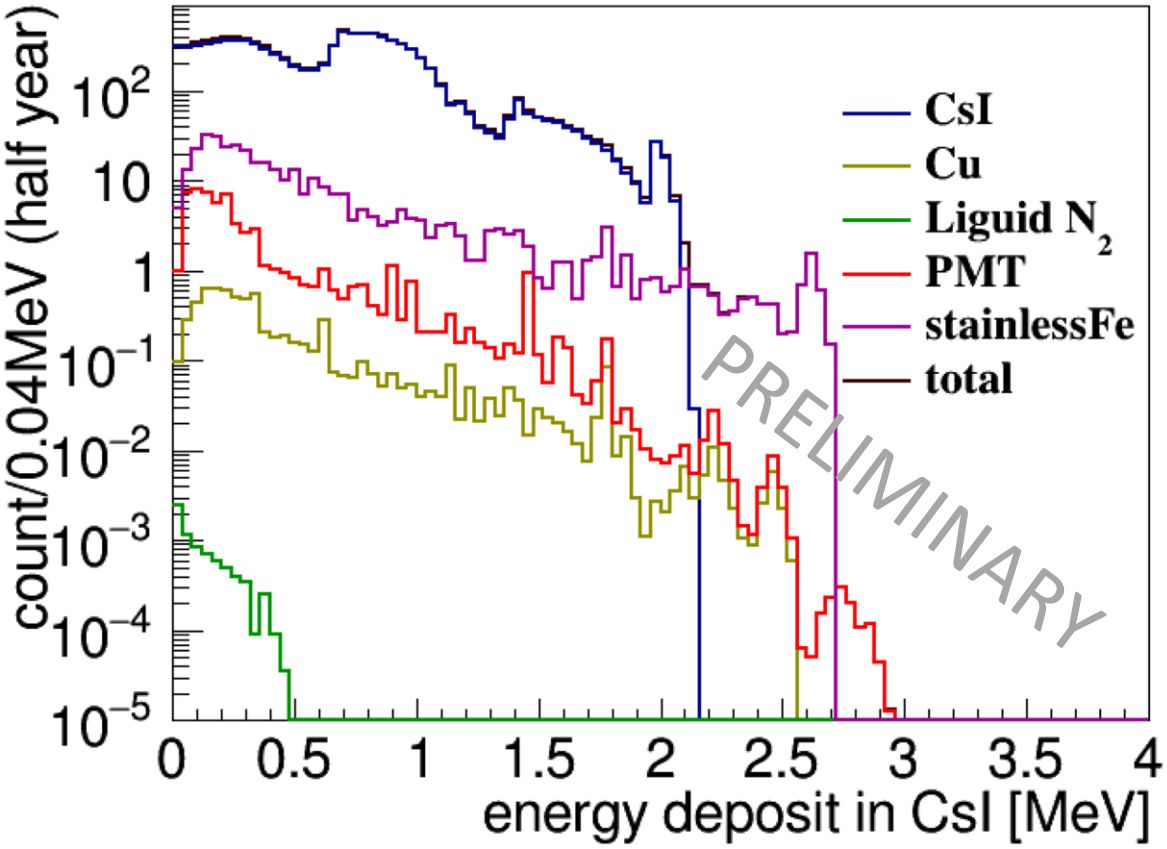




Liquid Scintillator
N/γ discrimination
Bkg time structure

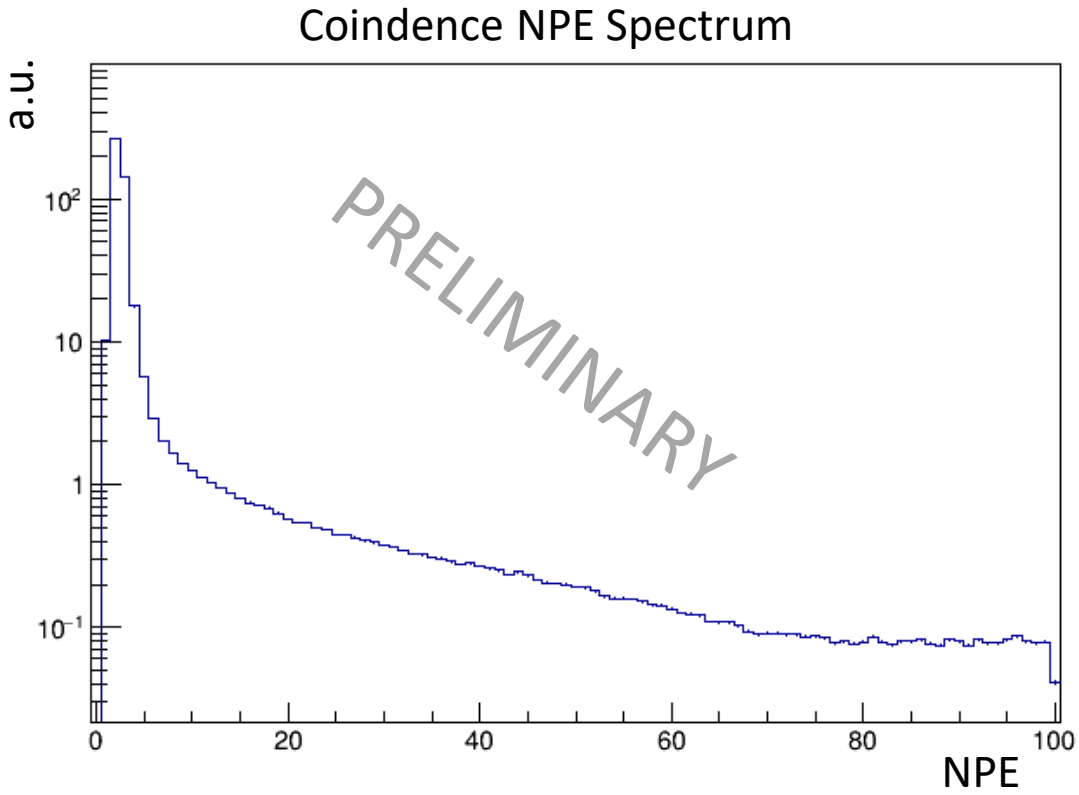
- After event selection，the number of BRN events surviving all cuts is ~650/180 days

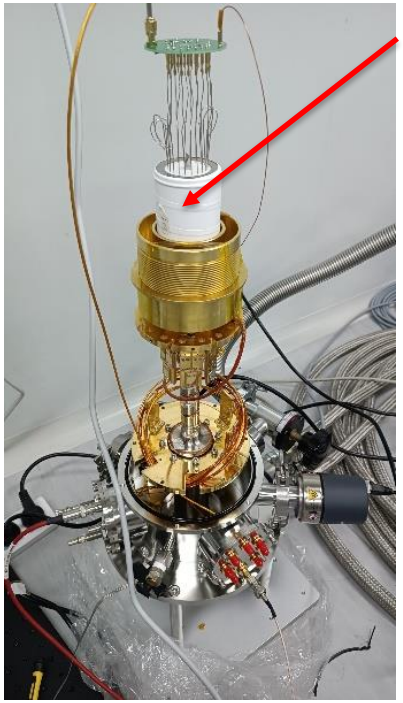
Radioactive background



- CsI dominate, stainless steel and PMT follows.
- After event selection， radioactive background events that surviving all cuts ，is ~7/180 day
- We can also try to measure the 661keV gamma peak of Cs137 to do a in-situ monitor of Cs137 background

PMT Dark Noise and Cherenkov



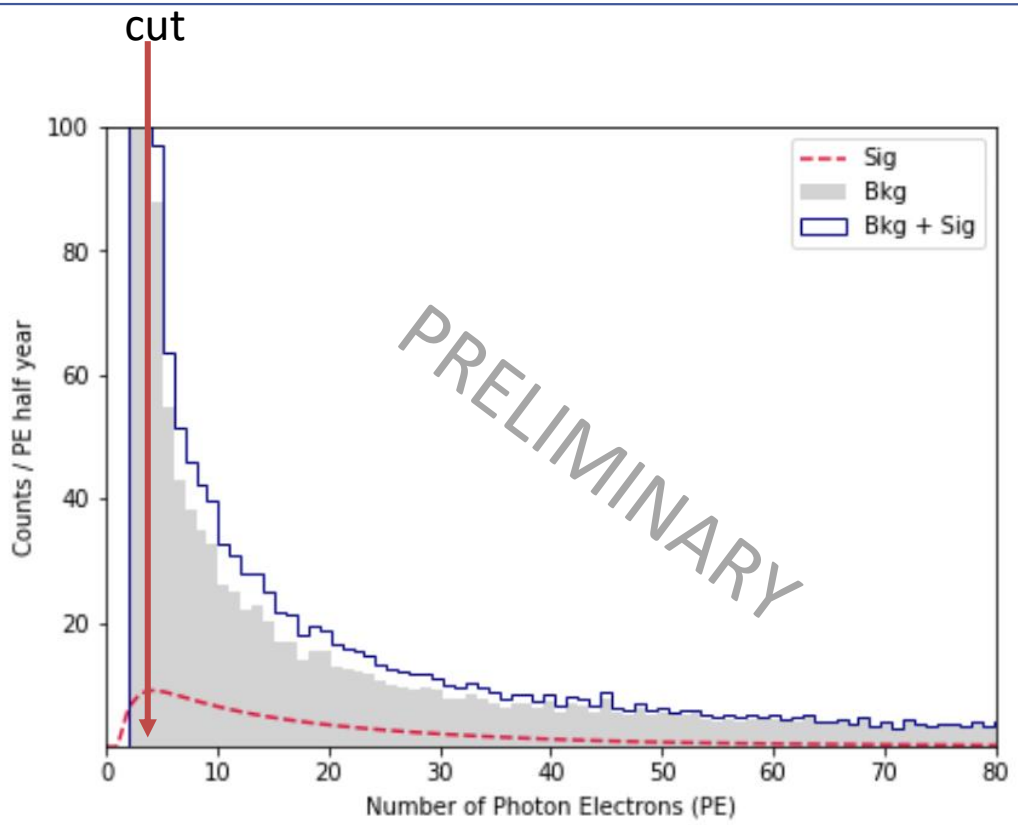


- At 77K, set Digitizer to low threshold and self-trigger mode
- Electron emission on Dynode and Cathode, and Cherenkov light are included
- Assuming PMTs are identical, background caused by coincidence of two PMTs that survives all cuts is ~160/180 days

Background Summary

Background Type	Total event number in 180 days	MC simulated events	Bkg number in signal region after cut
Radioactive	1.16×10^6	1.87×10^7	~7
Env gamma	4.72×10^8	10^{10}	~0.05
Beam related Neutron	2.69×10^6	10^7	~650(TBD)
PMT Dark Noise and Cherenkov	8.6×10^5		~160
Neutrino induced neutron	-	-	negligible
Cosmic ray induced radioactive isotypes	-	-	negligible

Threshold and Sensitivity

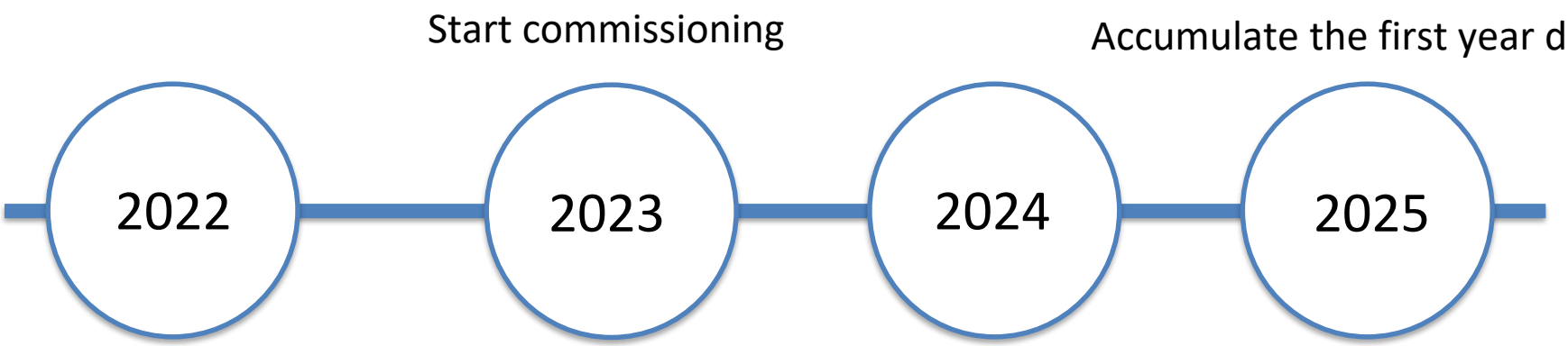


if 33.5pe/keVee LY is achievable

- Signal region : [4, 72]
- Total Signal Events: 160
- Total Background Events:820
- SN = $\frac{N_{sig}}{\sqrt{N_{sig}+N_{bkg}}} = 5.1$
  - In half year

- Npe Threshold taken as 4NPE, equivalently ~ 1.5keVnr recoil energy threshold

Time Table



On site background study
Detector assembly fabrication

Start data taking

Summary

- Independent verification of CEvNS signal is important
- CSNS allows the detector to be placed above the target at 10.2m, increasing the neutrino flux significantly, making it possible to detect CEvNS signal at CSNS.
- By neutrino produced in CSNS, using pure CsI @ 77K coupled with PMTs as detector which has high light yield and low dark noise, we hope to lower the energy threshold to ~1.5keVnr, and achieve 5 sigma detection in half a year.
- The data taking is to start in 2 years.

Thanks