NEOS Result
and
Reactor SBL-ν Project

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WIN 2017 @ UC Irvine

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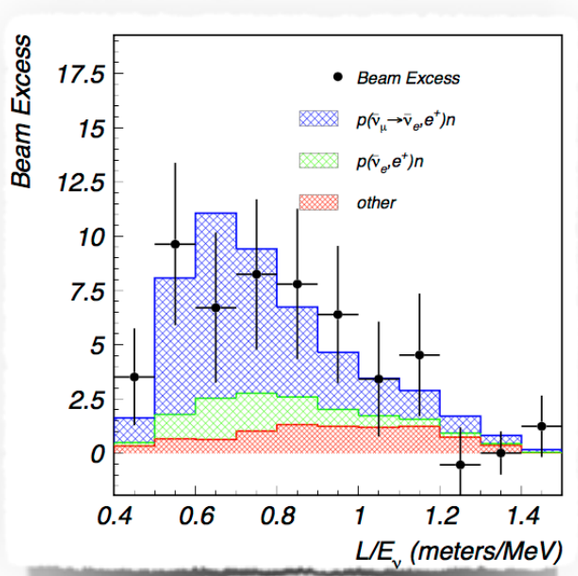
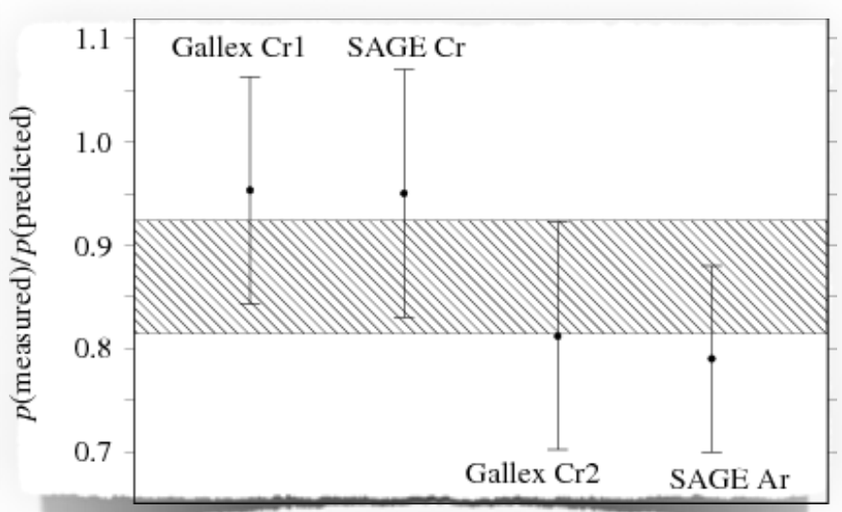
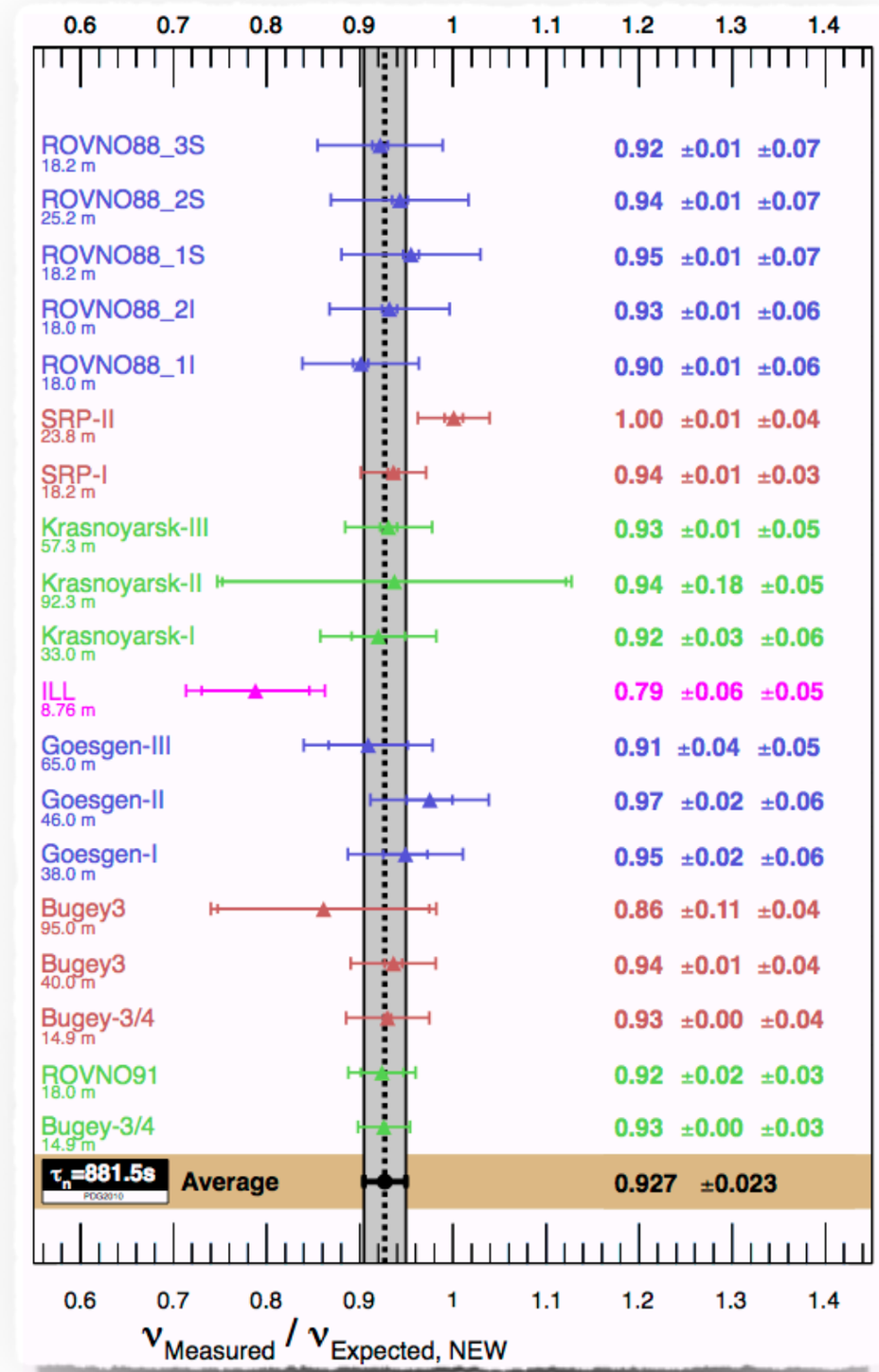
ibs

Introduction

- To verify the possible existence of a ~1 eV sterile neutrino
- Analyzing the spectral shape (not the absolute rate) of reactor antineutrino
- Single detector / no baseline resolution:
  - important to have an accurate reference reactor antineutrino flux/spectrum,
  - understanding the detector response, especially energy-charge relation, is crucial— calibration vs. simulation



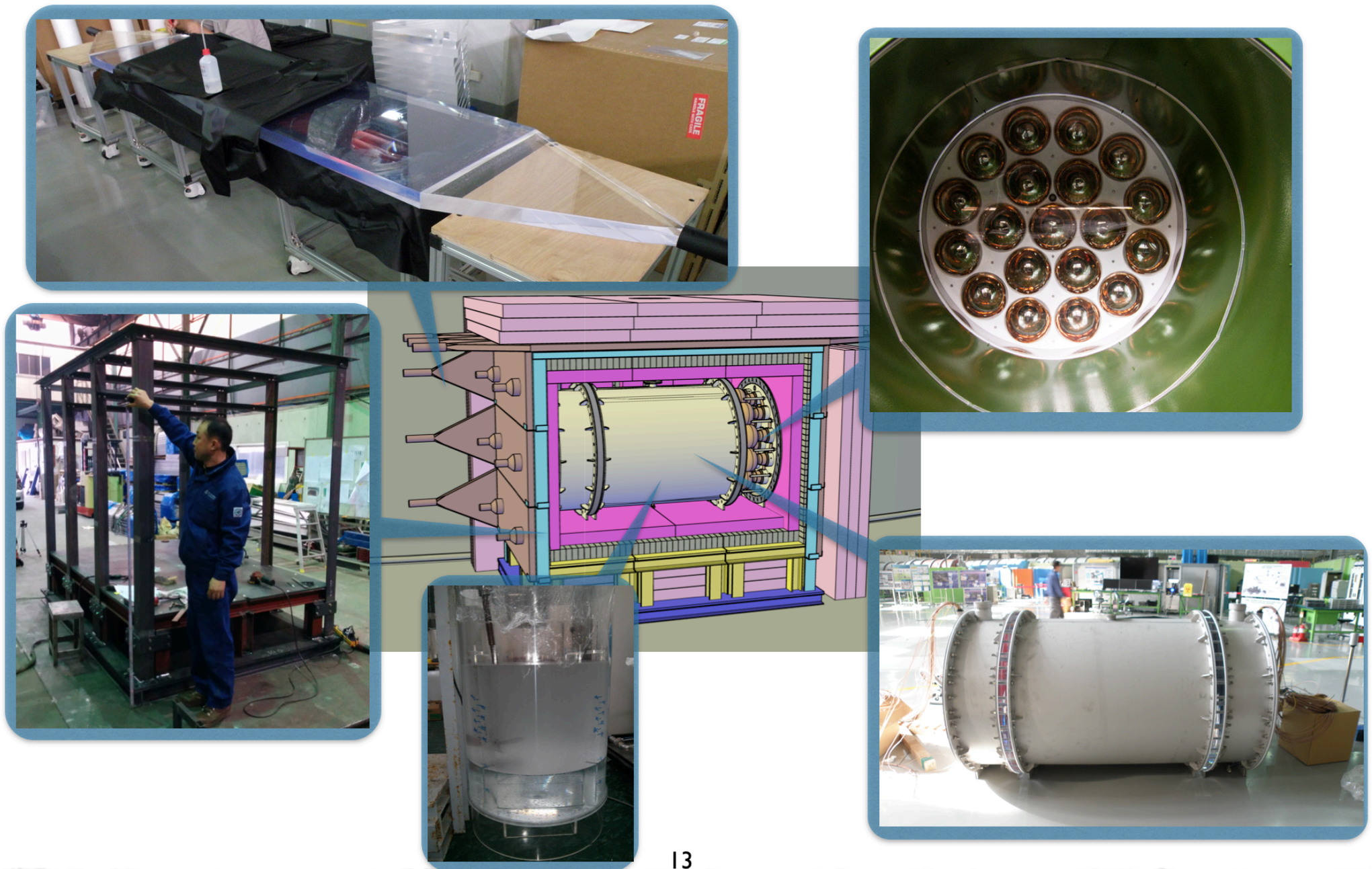




NEOS presented in Heidelberg 2015

Main Detector Under Construction

@ Korea Atomic Energy Research Institute



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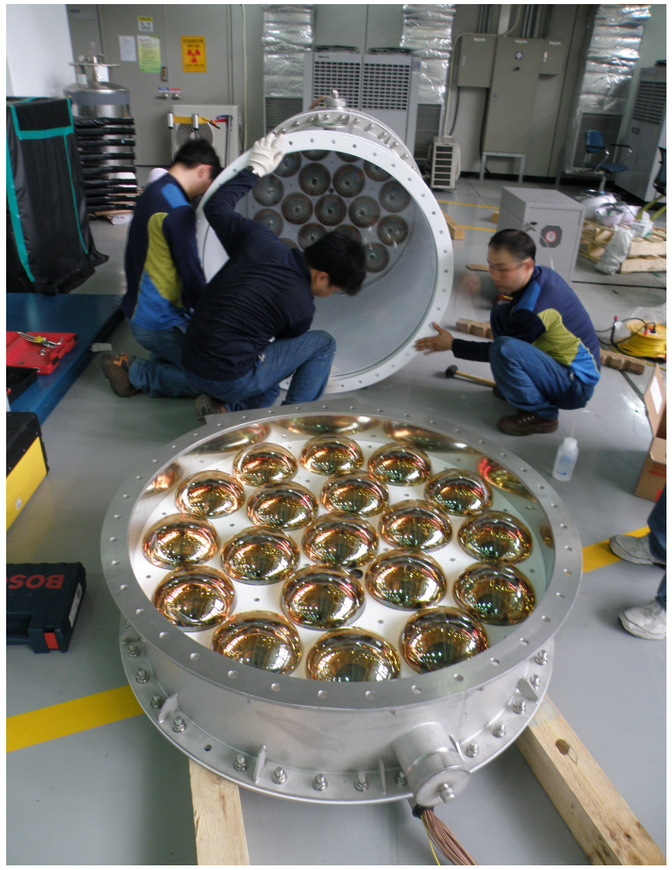
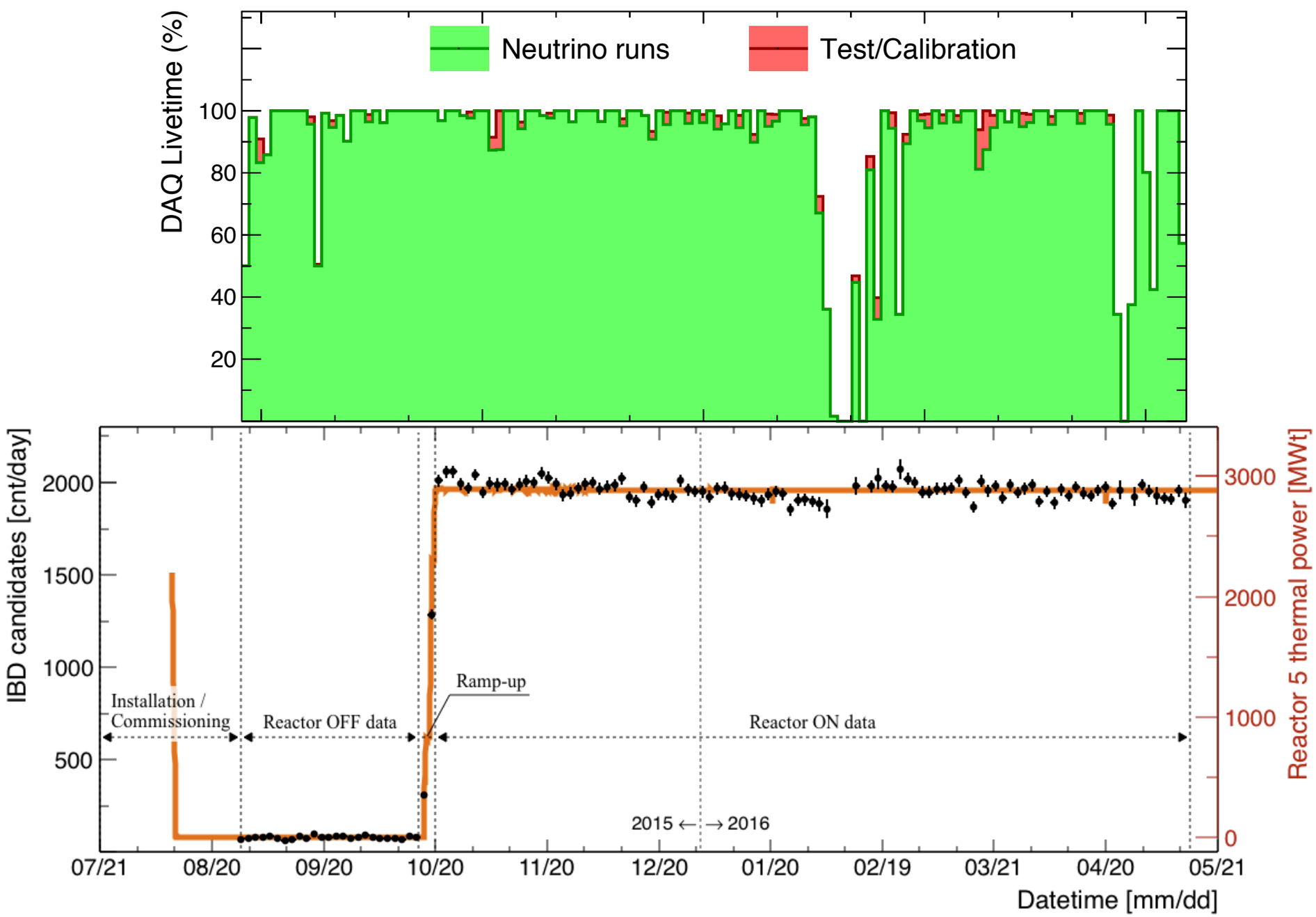
In July 2015,



Since then,

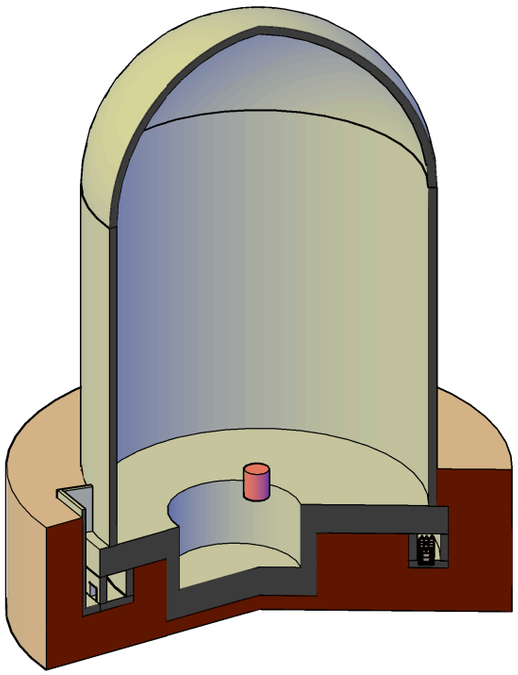
- 46 days' reactor off data + 180 day's reactor on data + calibration
  - stable reactor operation, ~90% DAQ efficiency

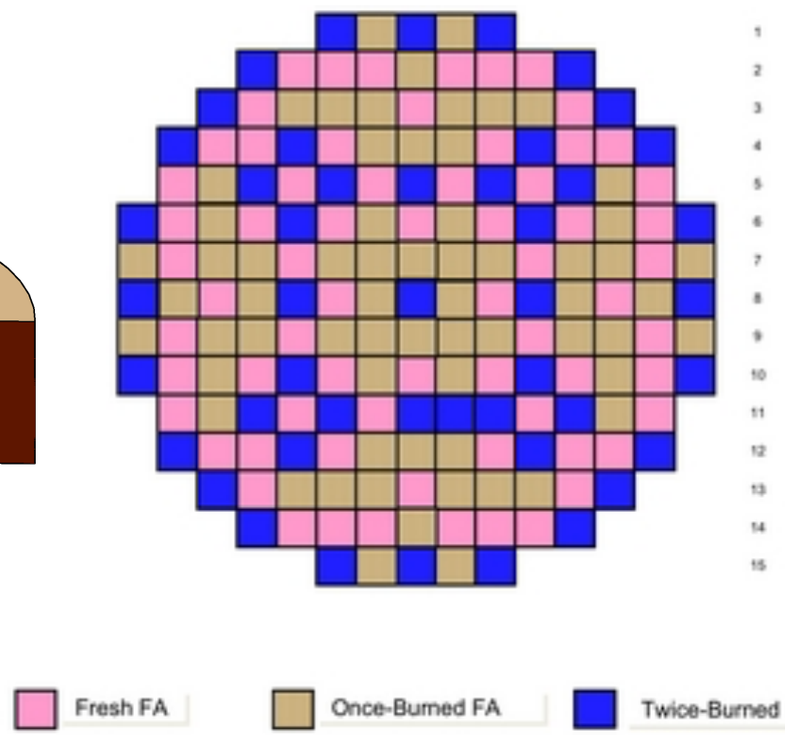


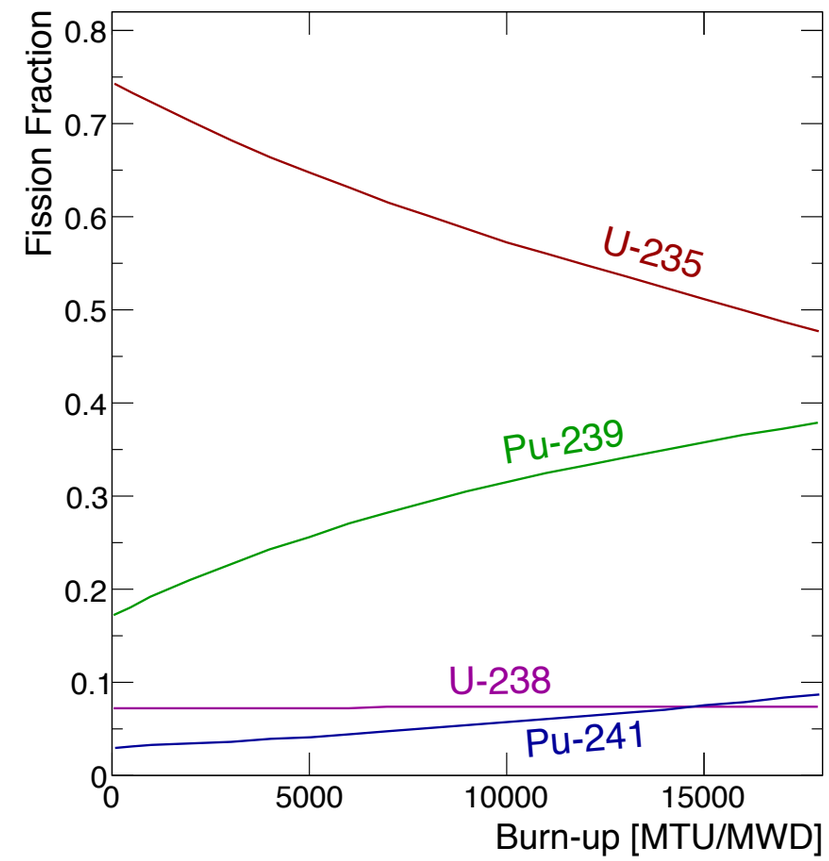
Experimental Site

- Reactor Unit 5 in Hanbit Nuclear Power Plant, Yeonggwang, South Korea
- Same reactor complex used for RENO experiment

Active Reactor Core

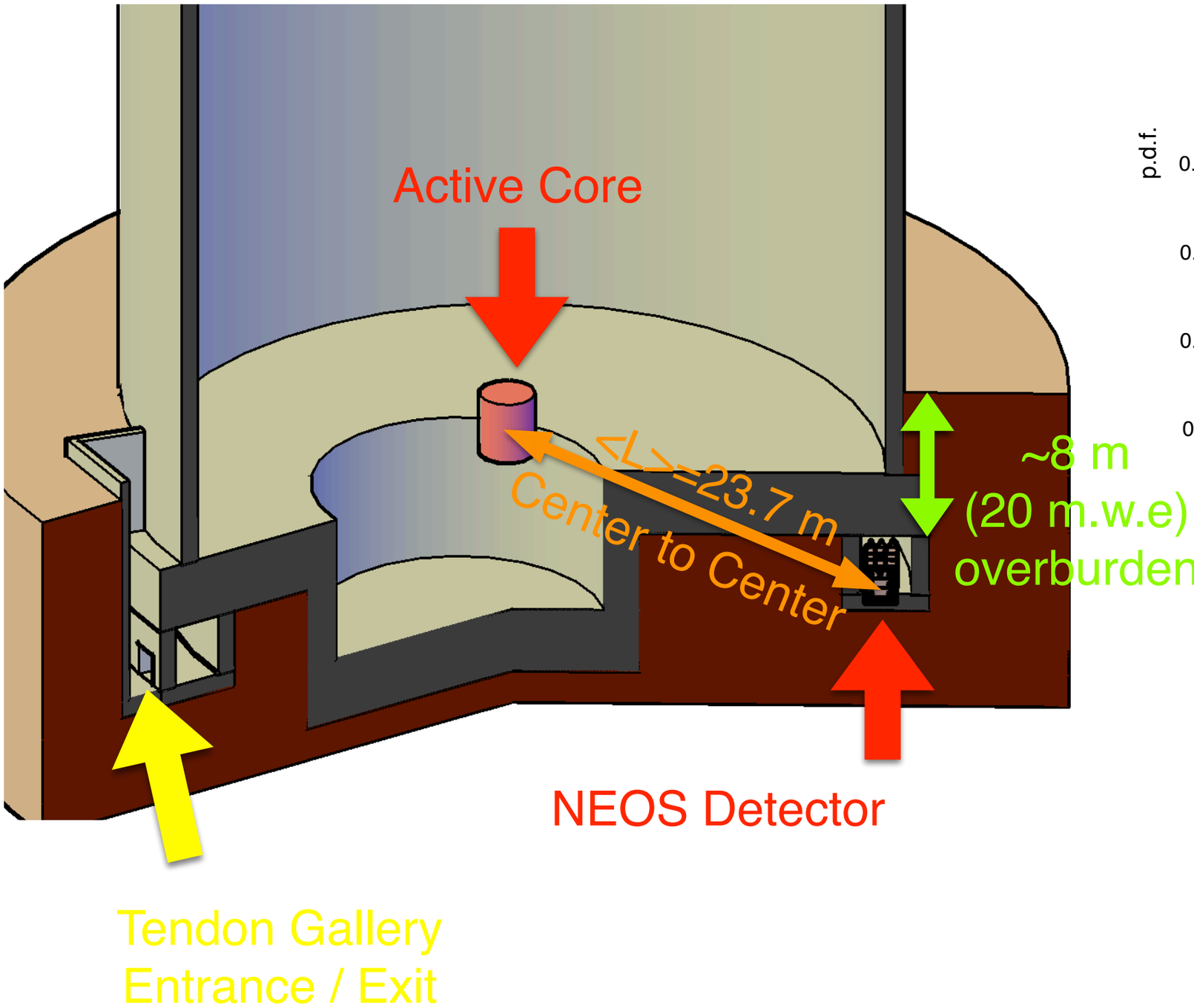


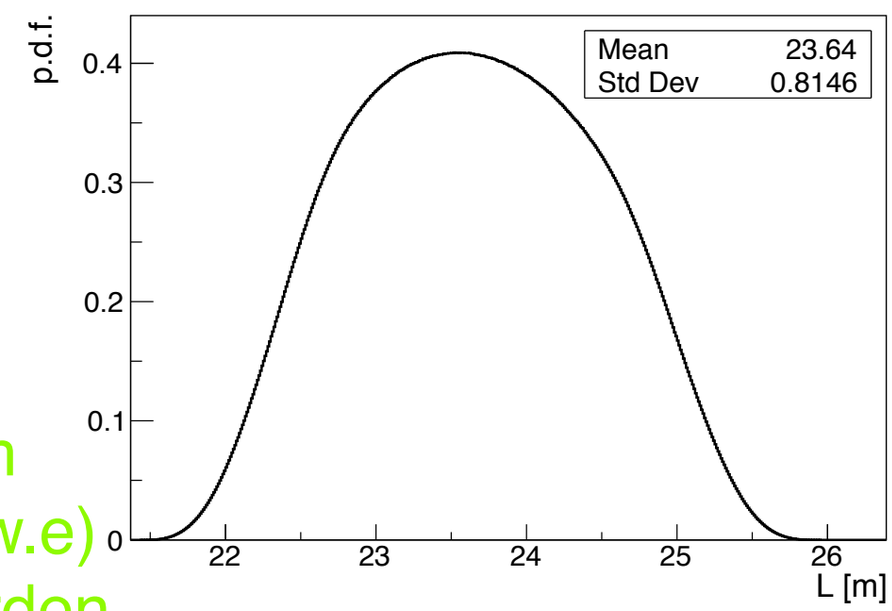




- 177 fuel rods, low enriched (4.65%) uranium-235 (LEU) fuel
- Refueling by changing 1/3 of fuel rods for each burn-up cycle (~1.5 year)
- Active core size: 3.1 m (ϕ), 3.8 m (h)

Detector Location / Baseline

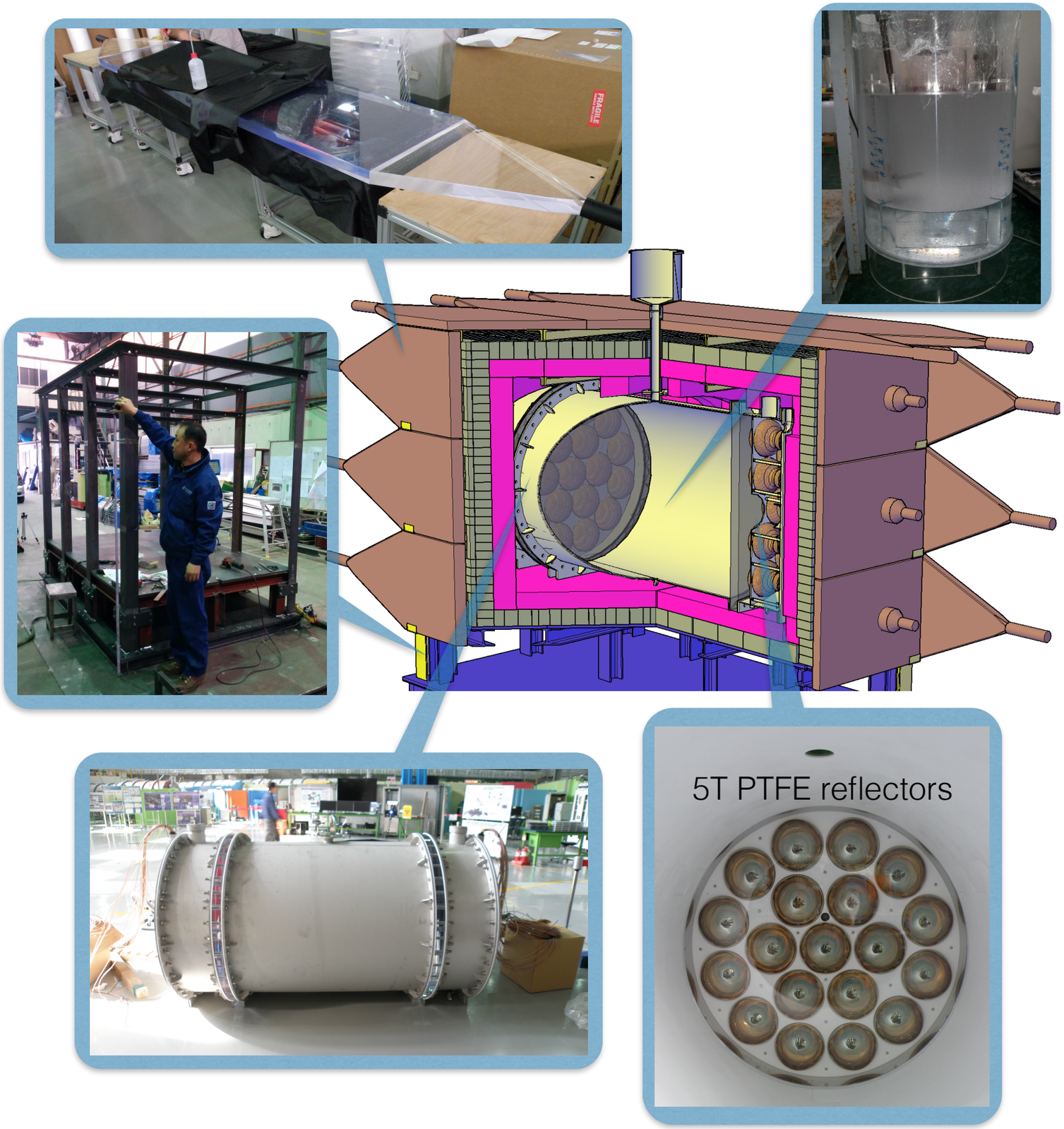


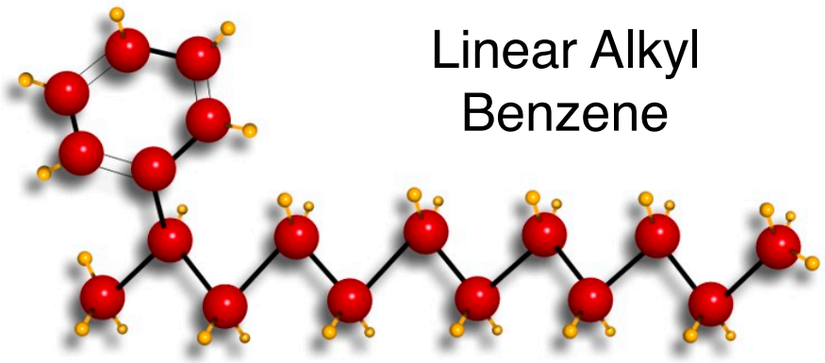


ν travel distance assuming:

- uniformly generated in cylindrical core
- IBD interaction uniformly distributed in target
- $1/L^2$ effect

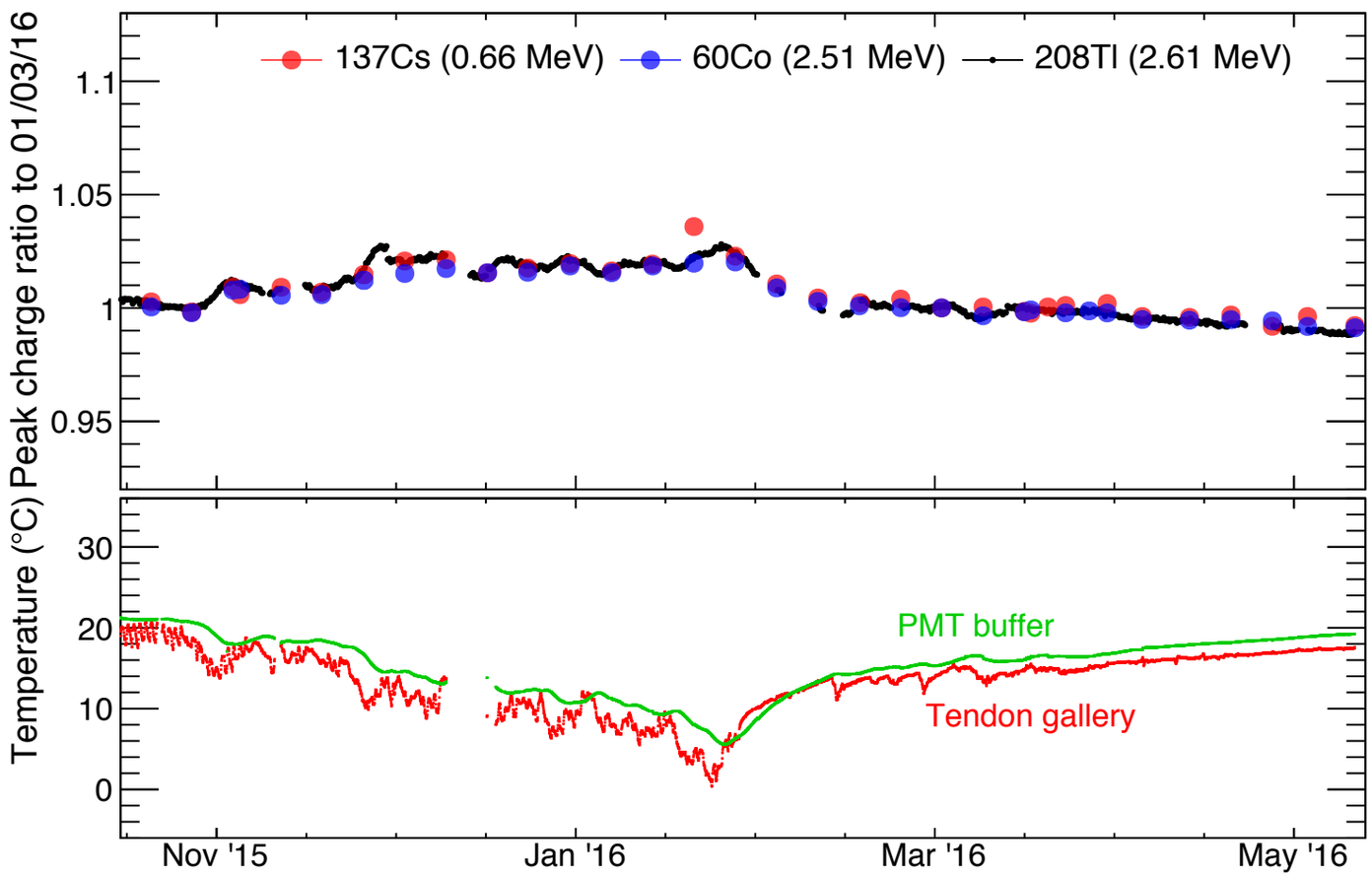
Detector Specification

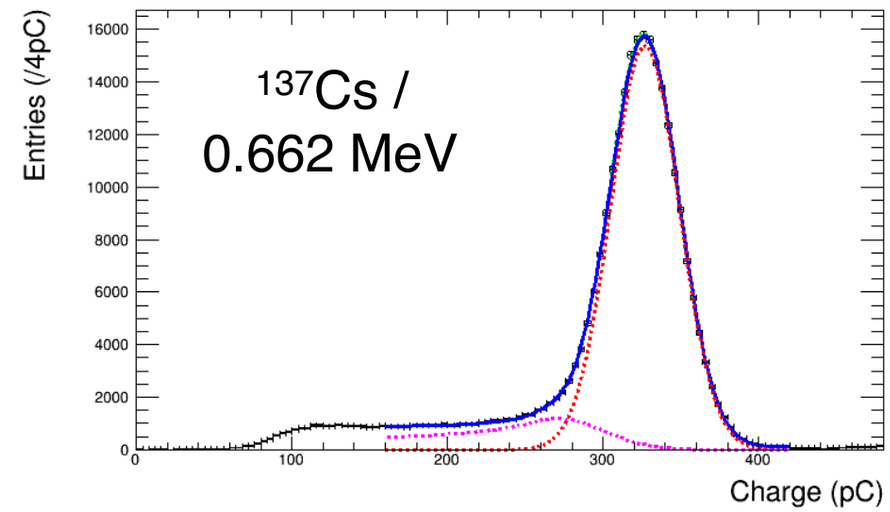


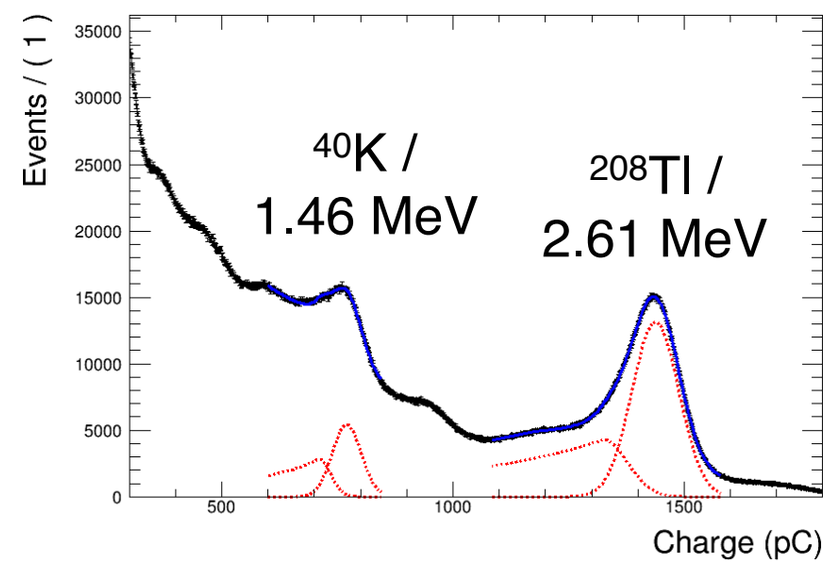


- Homogeneous LS target
  - 1008 L volume (R 51.5, H 121) cm
  - LAB+UG-F (9:1)
  - 0.5% Gd loaded for high neutron capture efficiency
  - 38 8″ PMT in mineral oil buffer
- Shieldings
  - 10 cm B-PE (n), 10 cm Pb (γ)
  - active muon counter
- Data AcQuisition
  - 500 MS/s FADC (waveform)
  - 62.5 MS/s SADC (μ veto)
- Source calibration through chimney

Calibration campaign

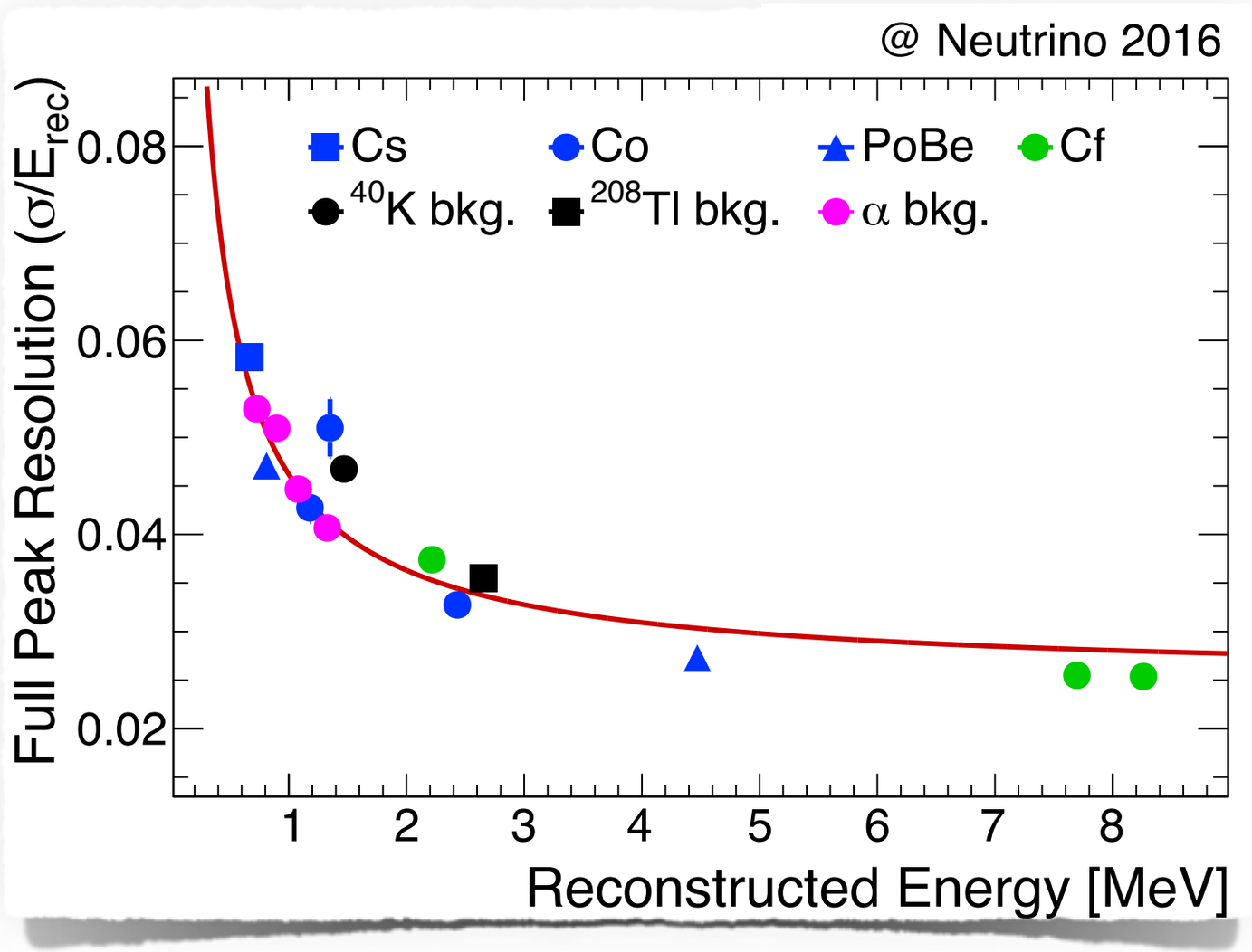


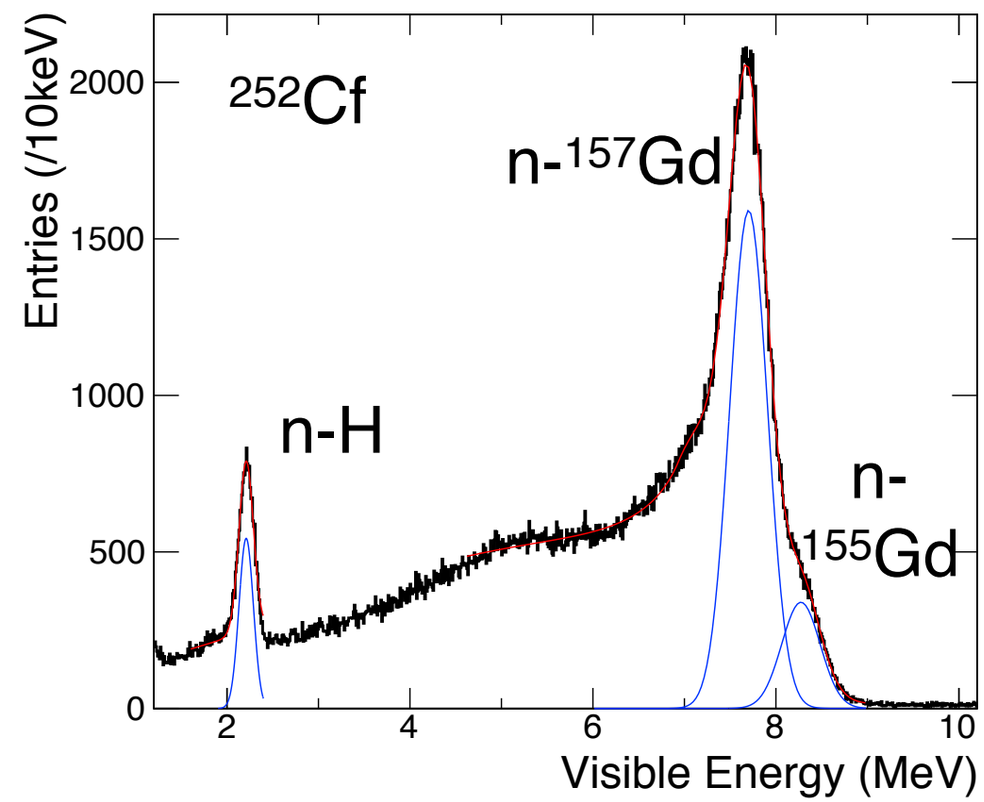




- Once a week with point sources:
  - ^{137}Cs (γ, 0.66 MeV), ^{60}Co (γ, 1.17/1.33 MeV), ^{252}Cf (n, 8 MeV γ from Gd capture), PoBe (n, 4.4 MeV γ)
- Internal/External background (volume sources, continuous):
  - ^{40}K (γ, 1.46 MeV), ^{208}Tl (γ, 2.6 MeV), ^{230}Th > ^{226}Ra > ^{222}Rn > … chain (α, β, γ)
  - used for time / position dependence corrections

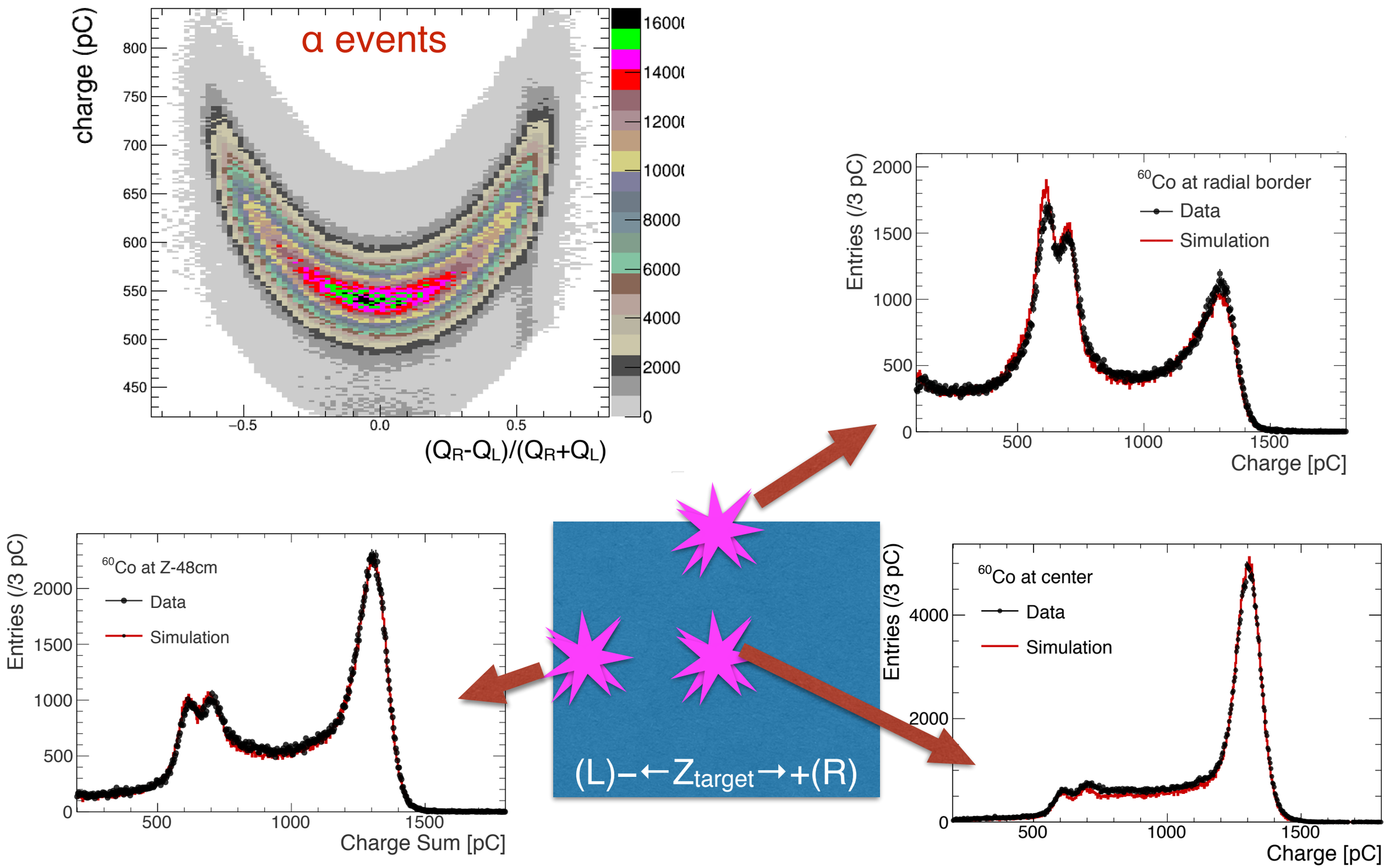
Energy resolution



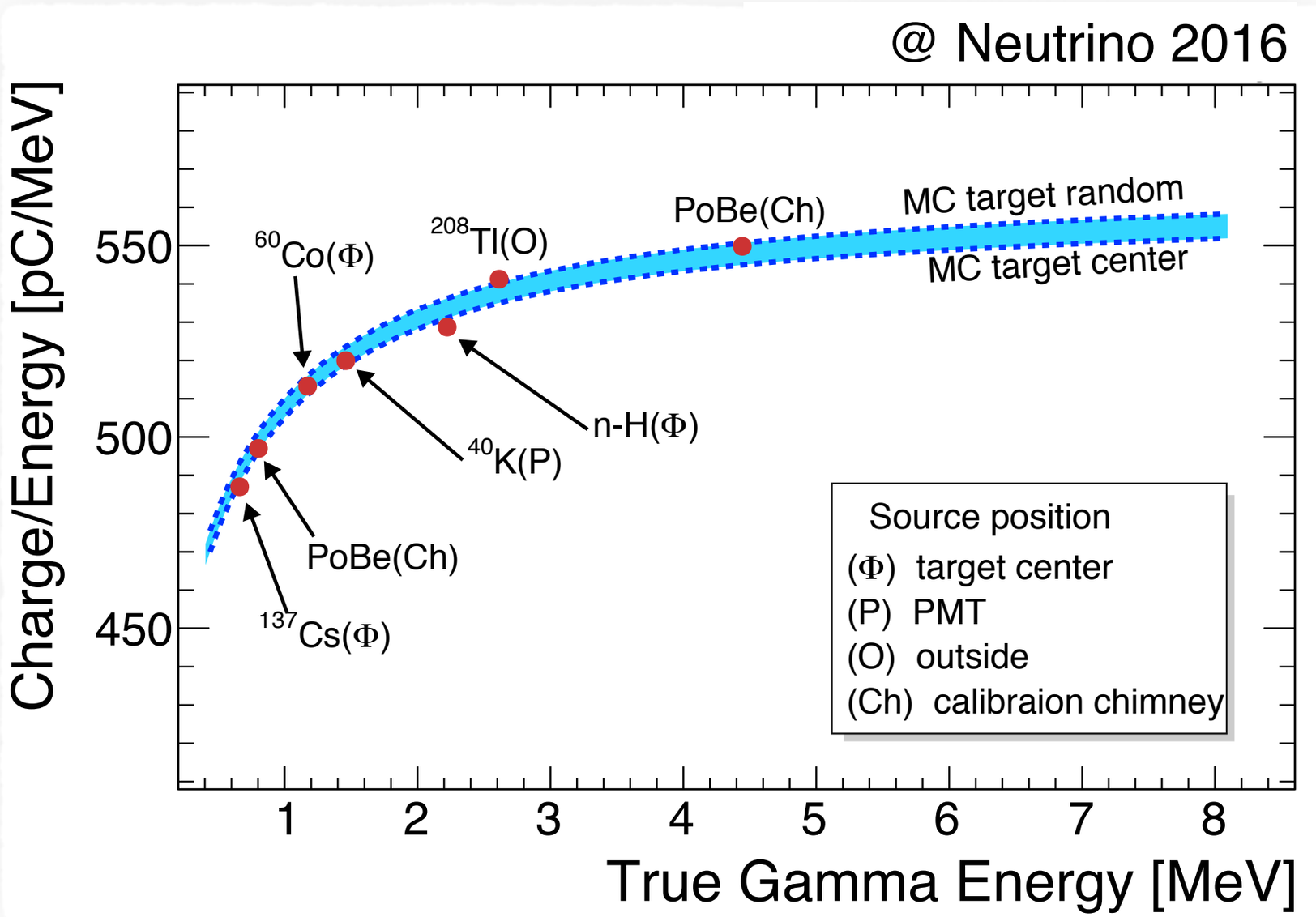


- $\sigma(E) = 5\%\sqrt{E}$ /MeV at 1 MeV for a full peak

Non-Uniform Response / Escaping γ

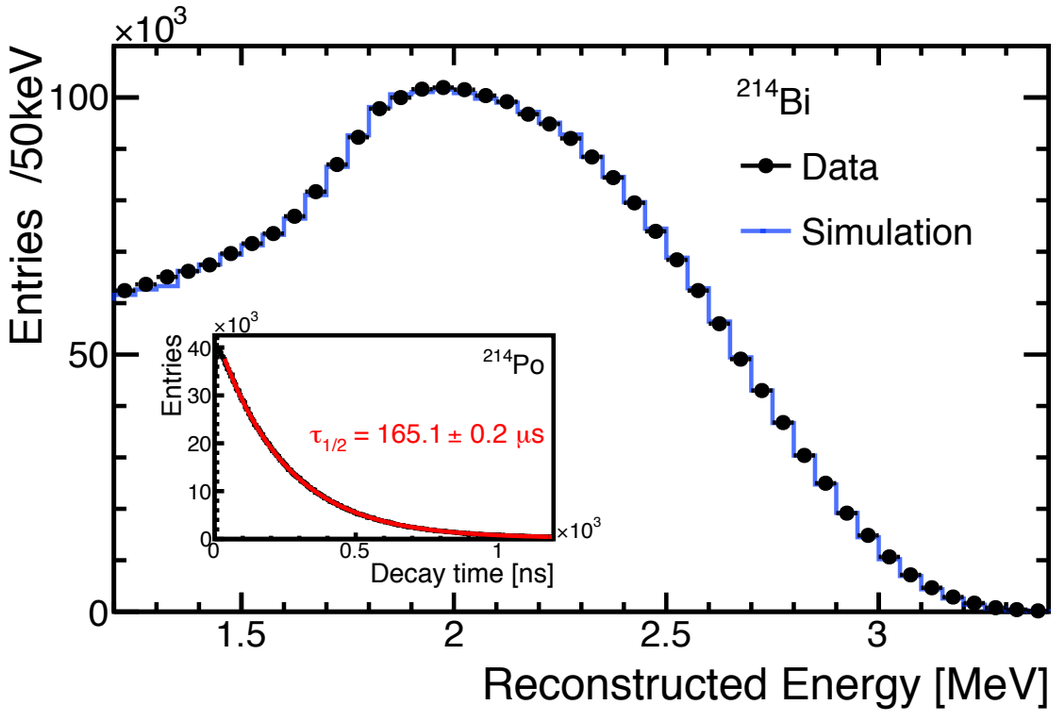


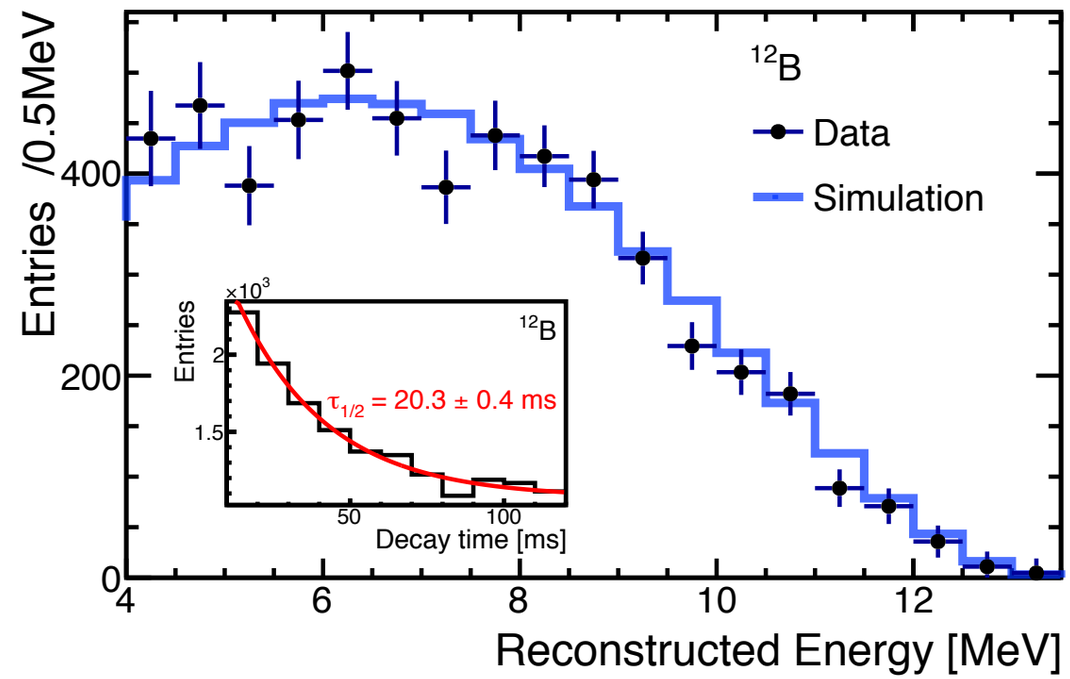
Non-Linear Charge Response to Energy

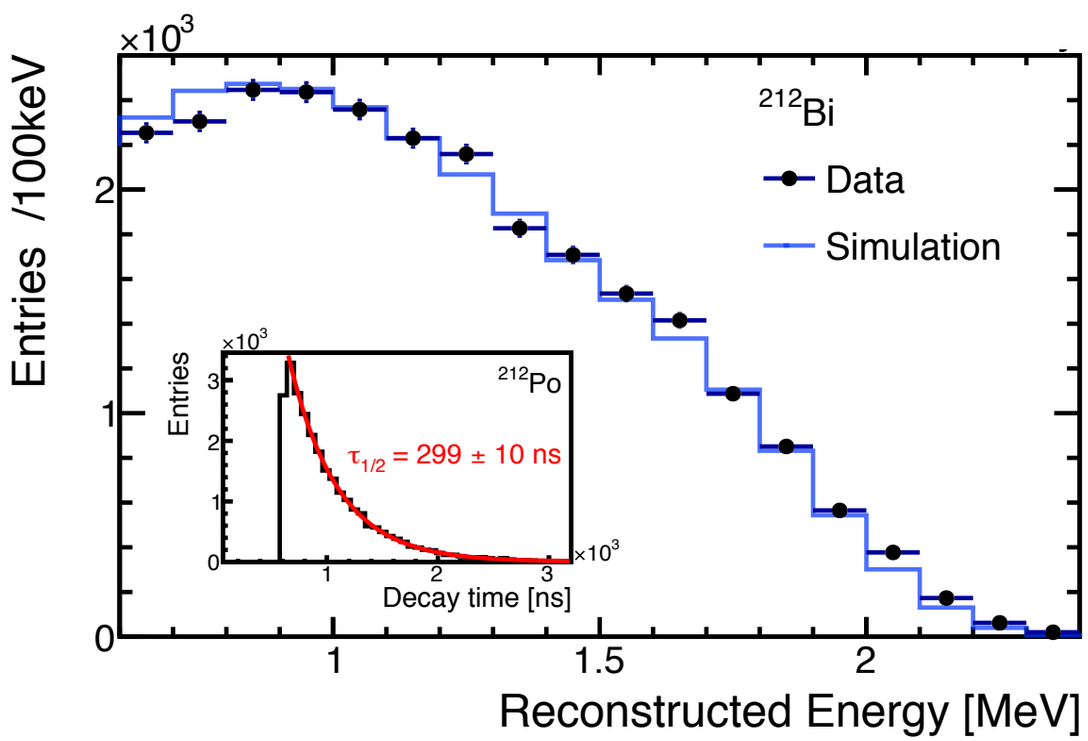


- Signal quenched at low energy
- Cerenkov light important at higher energy

β-Decay Events and Simulation

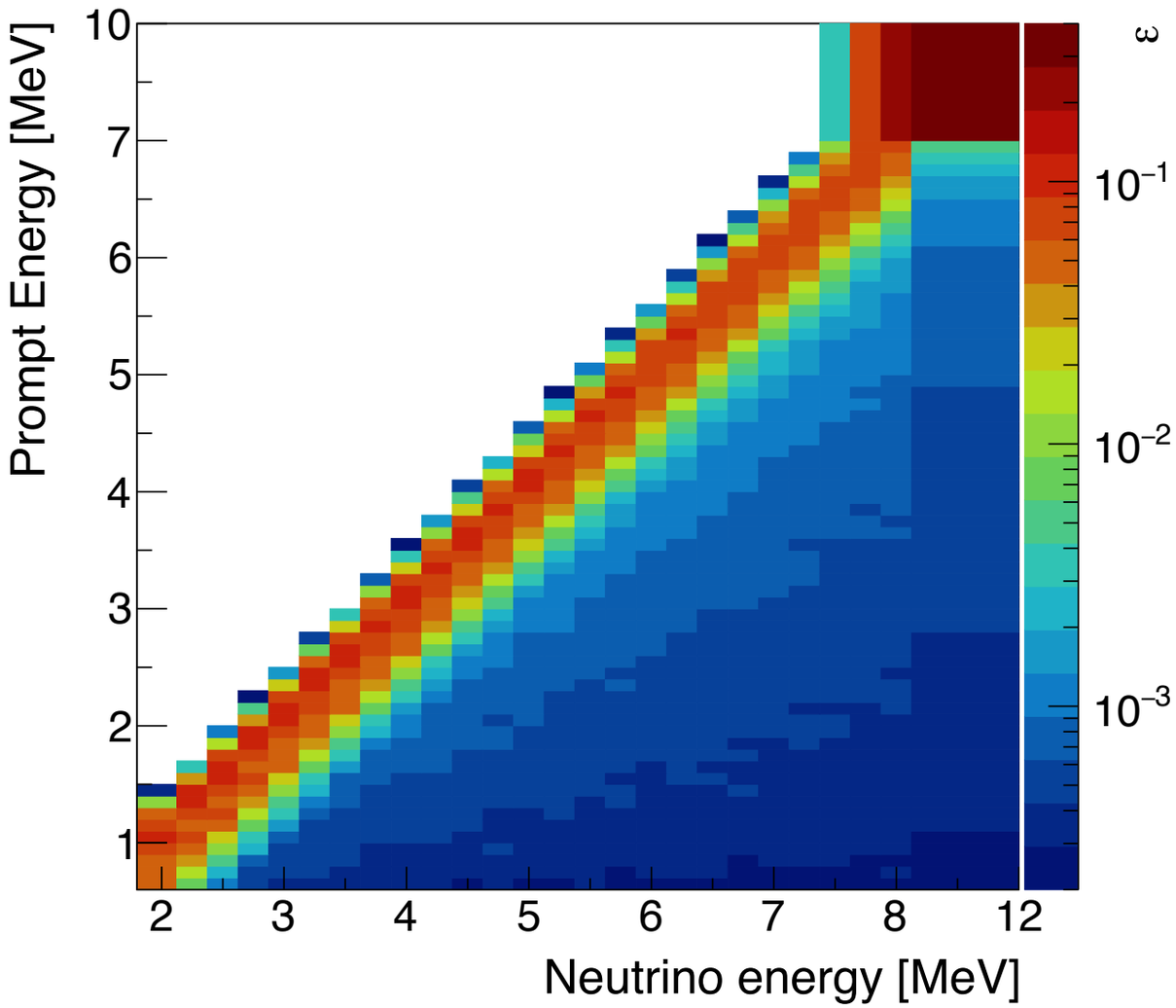


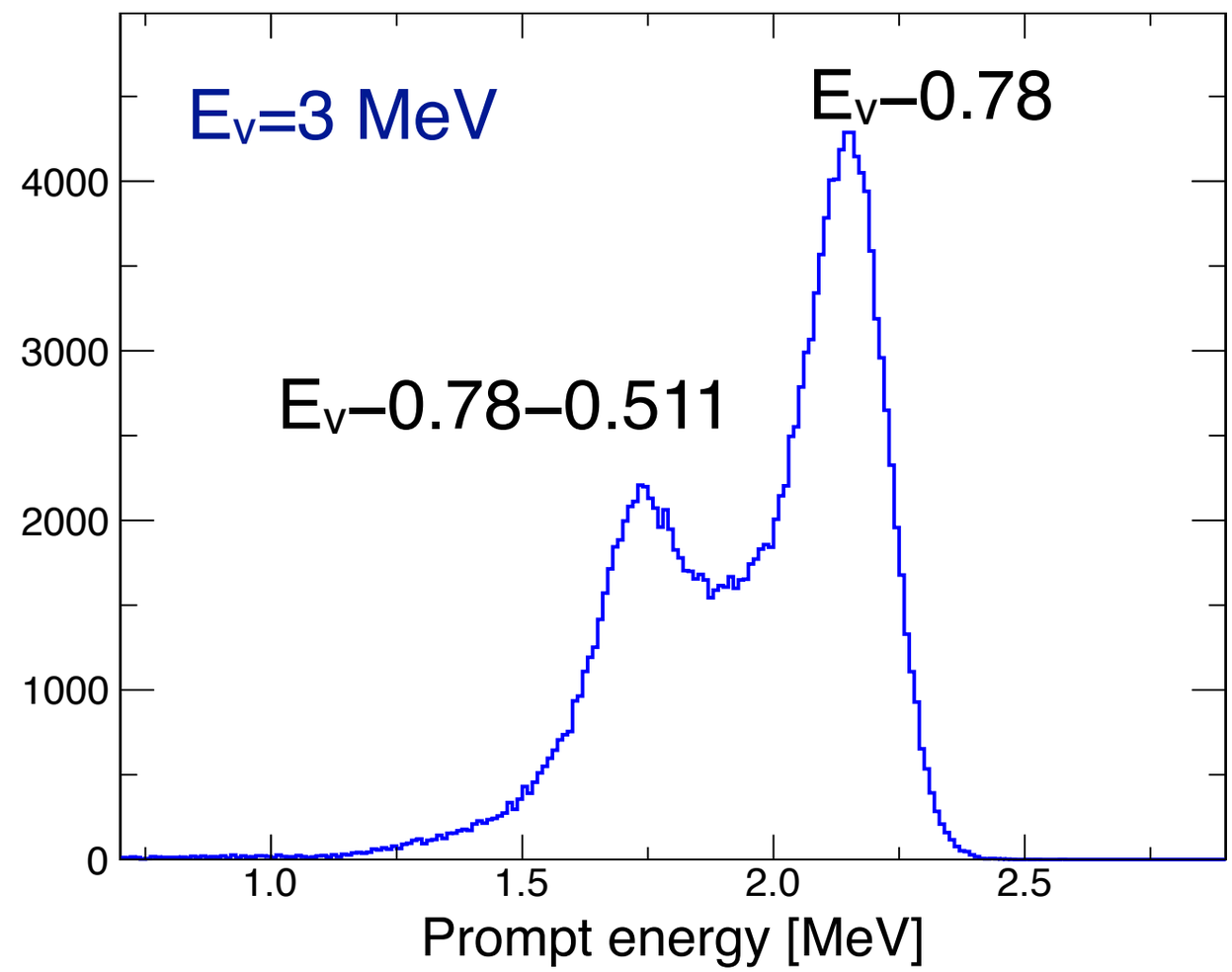




- Geant4 based MC simulation
  - LS, PMT optical properties,
  - full simulation of physics processes including trigger simulation
- Excellent agreement with data in the energy r.o.i:
  - Energy resolution
  - Non-linearity
  - Escaping γ

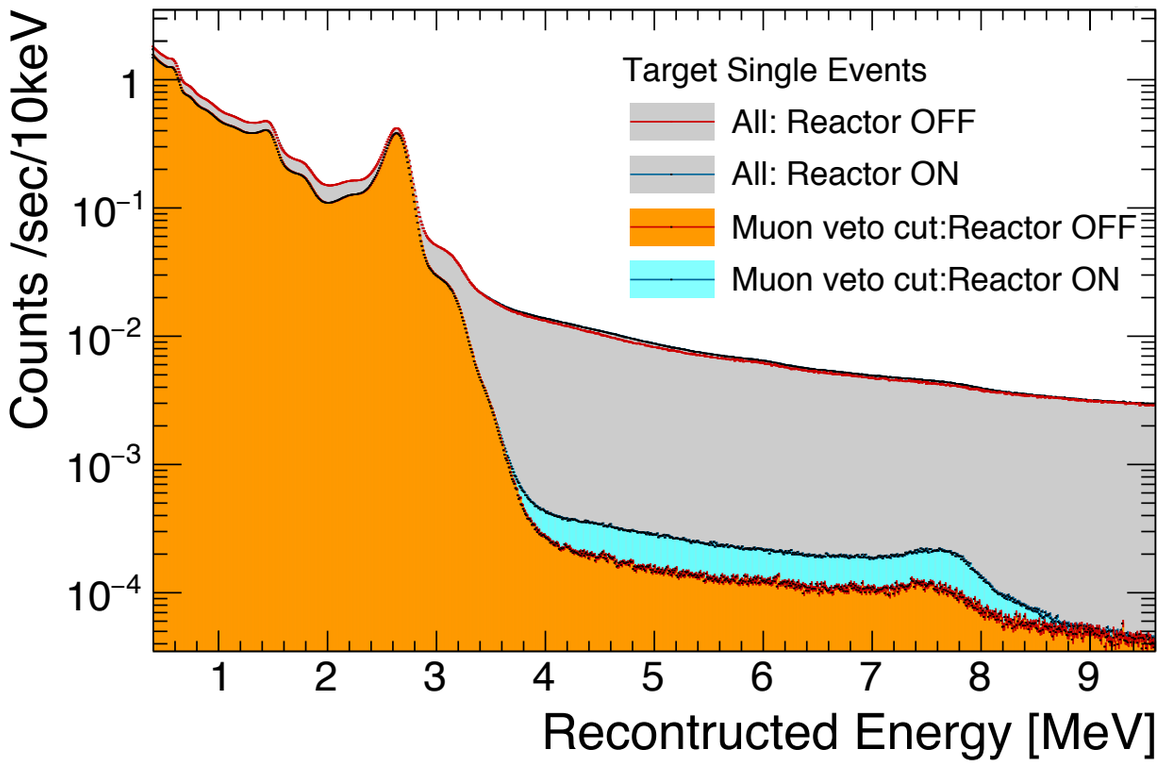
Response to neutrinos (MC)





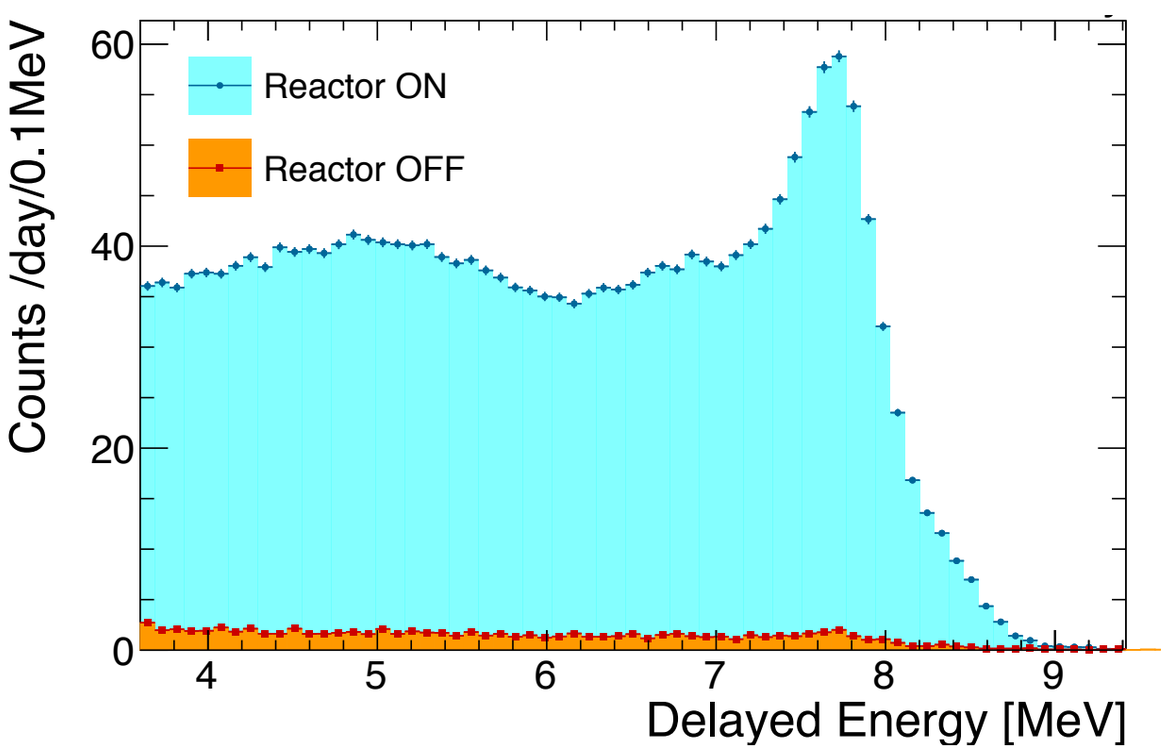
- Severe distortion due to escaping gamma.

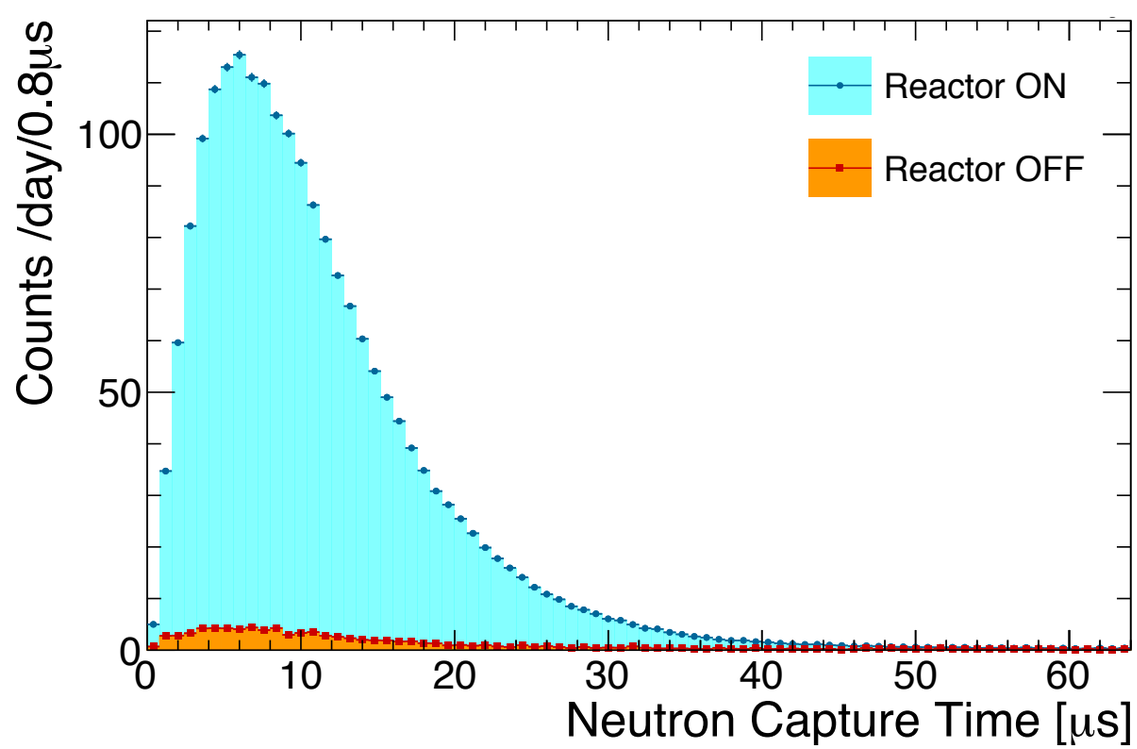
IBD Reconstruction



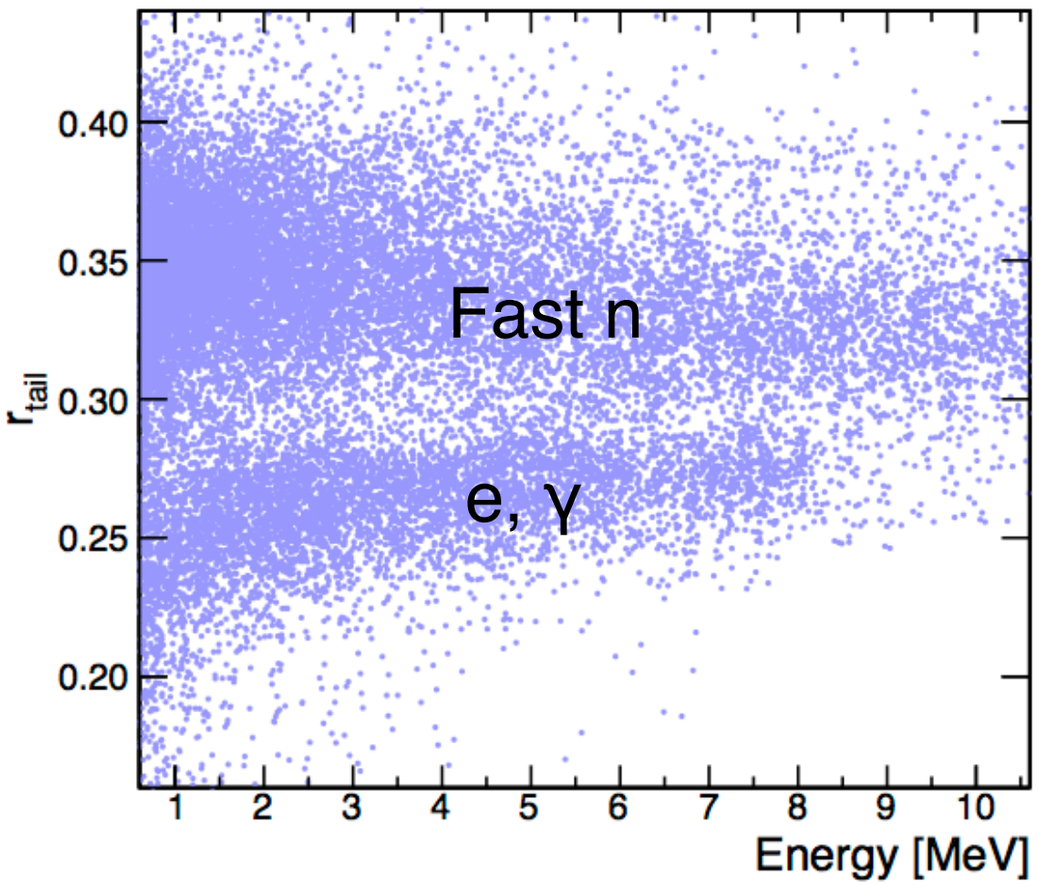
Selection rules developed for best S/N ratio:

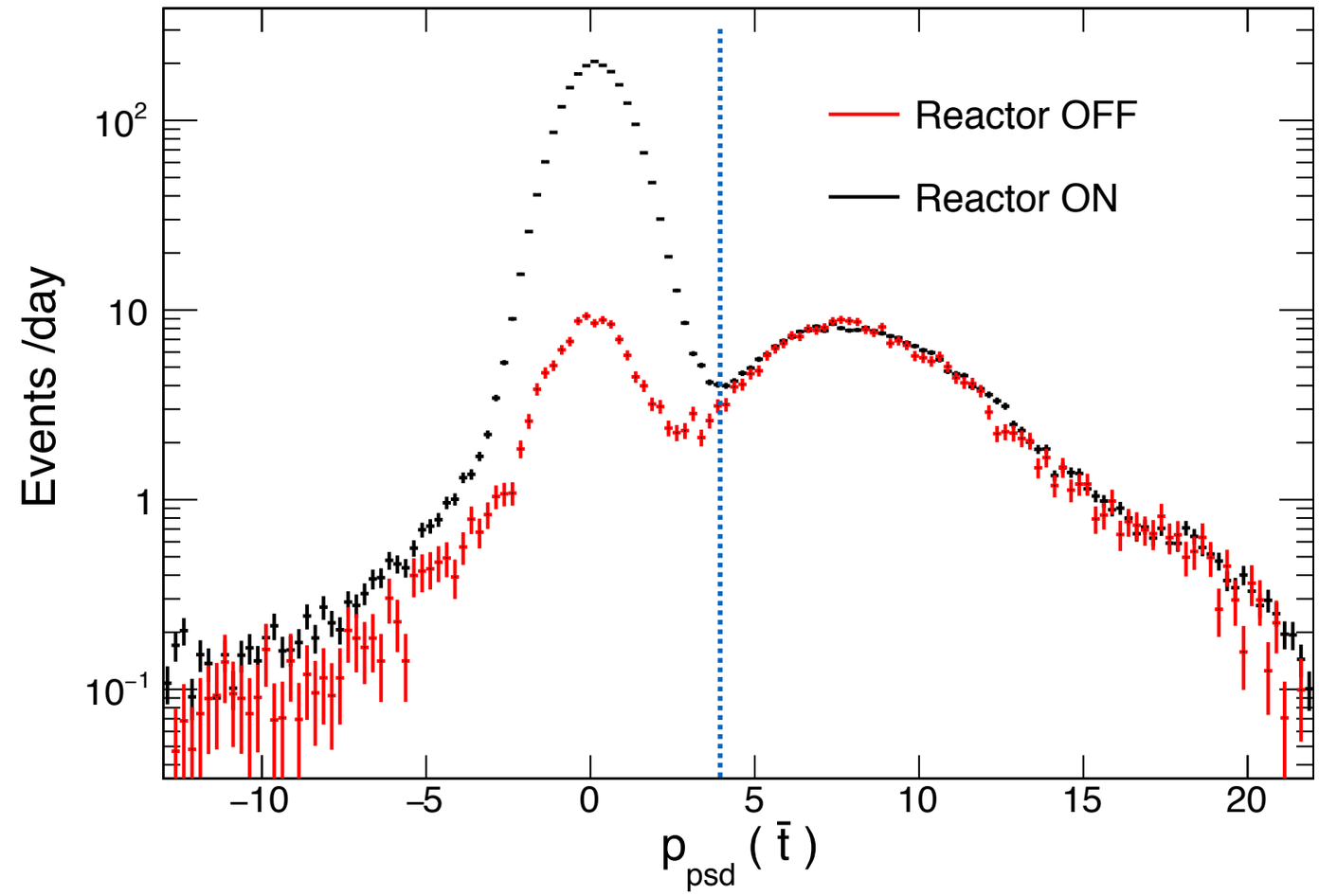
- Prompt energy: 1-10 MeV
- Delayed energy: 4-10 MeV
- Time coincidence: 1-30 μs
- Multiplicity: no event before (after) 30 (150) μs from the prompt/delayed pair
- Muon veto: 150 μs
- Pulse shape discrimination





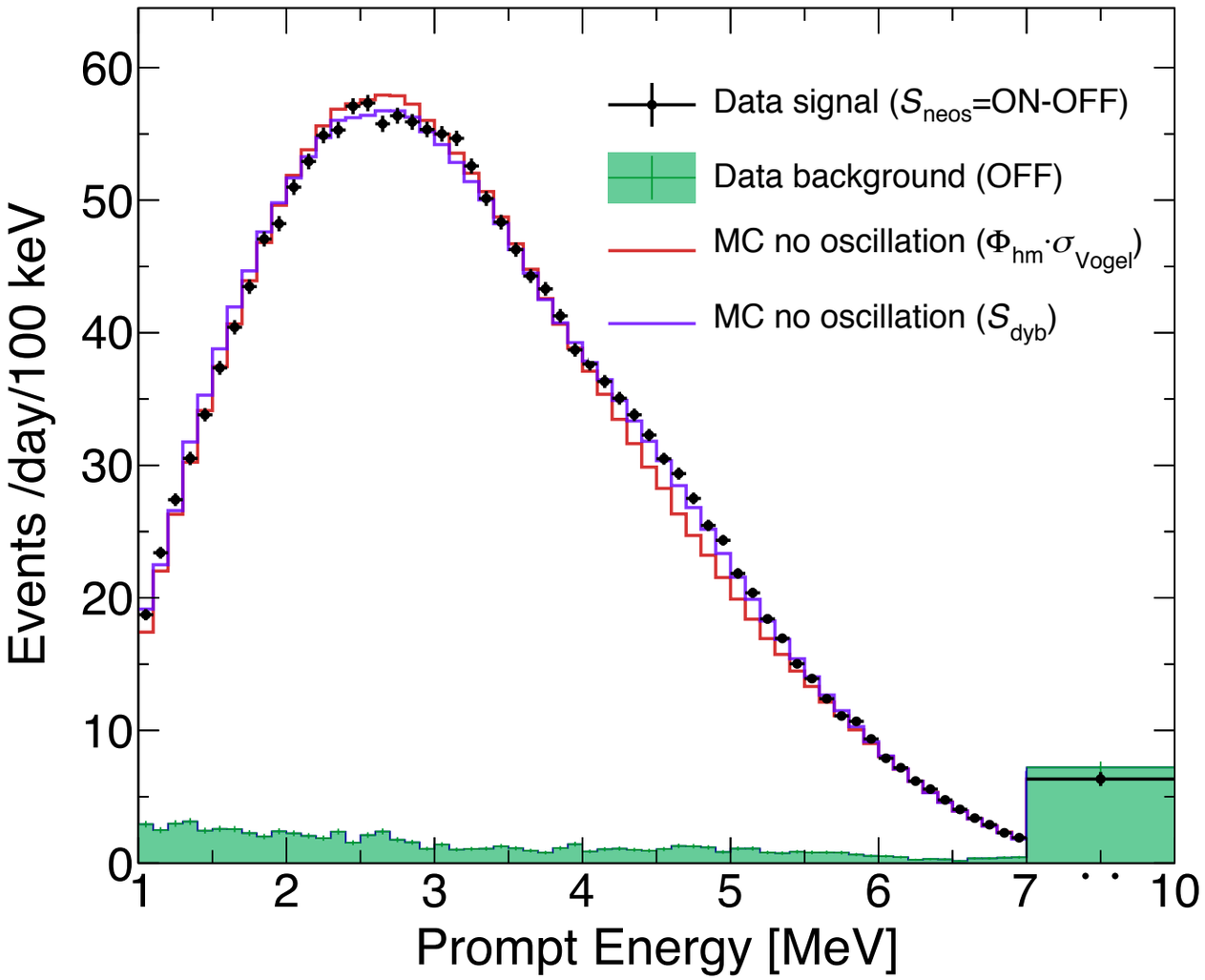
Pulse Shape Discrimination

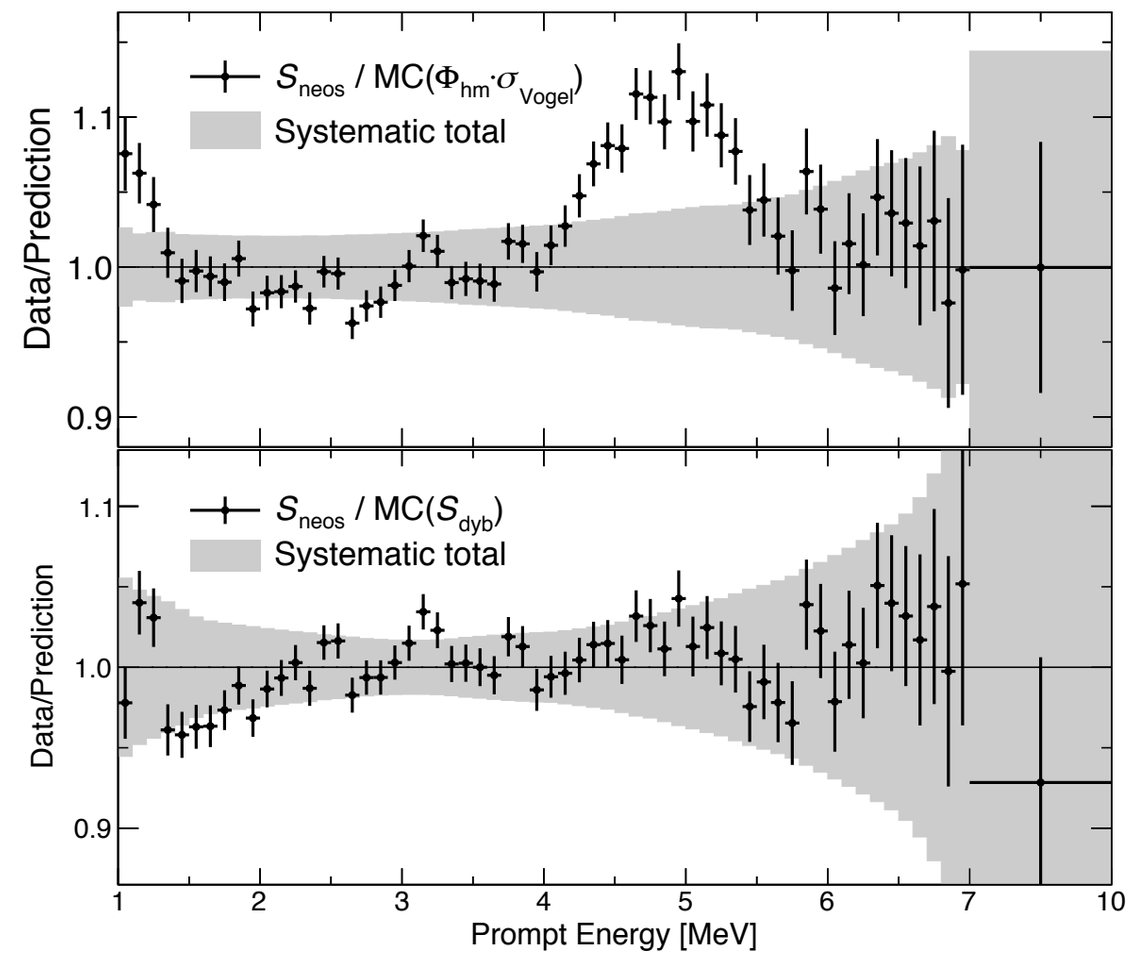




- Using relatively slower detector response of fast neutron's scattering event
- Qtail/Qtot or meantime of waveform.
- LAB + DIN (UG-F) mixed LS.
- More than 70 % of IBD background could be reduced.

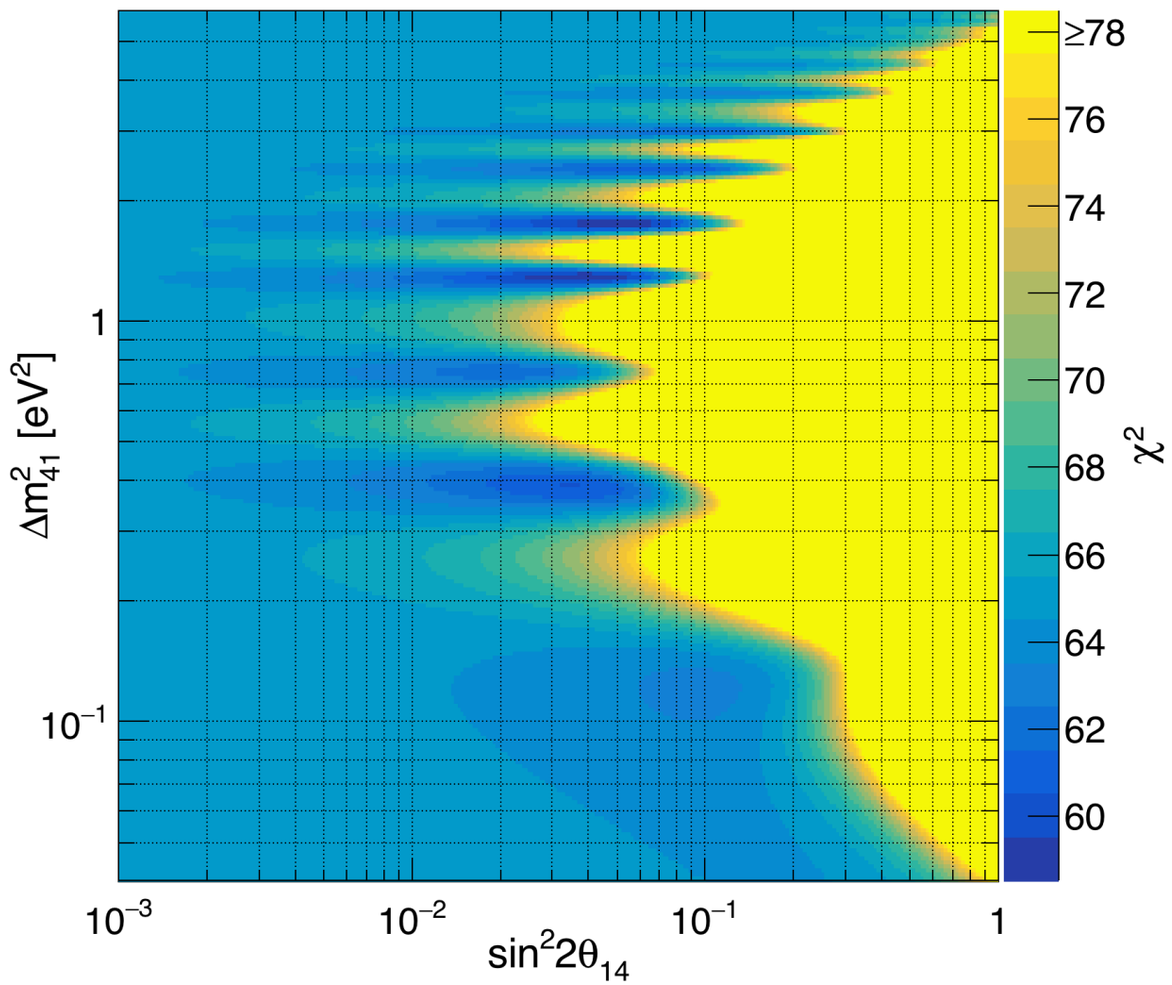
Prompt Energy Spectrum



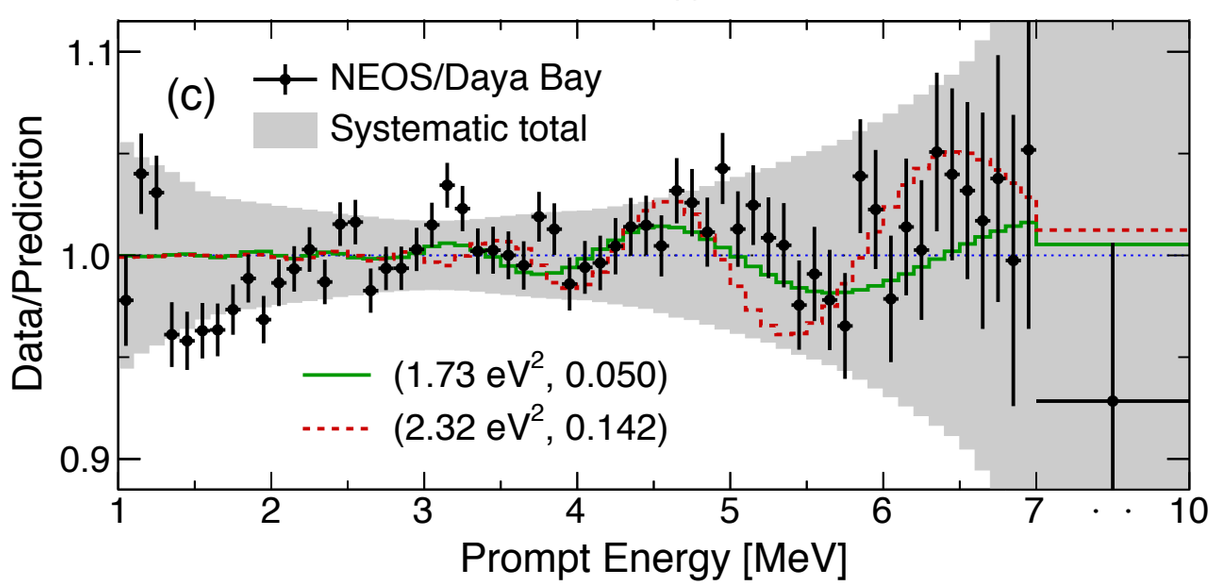


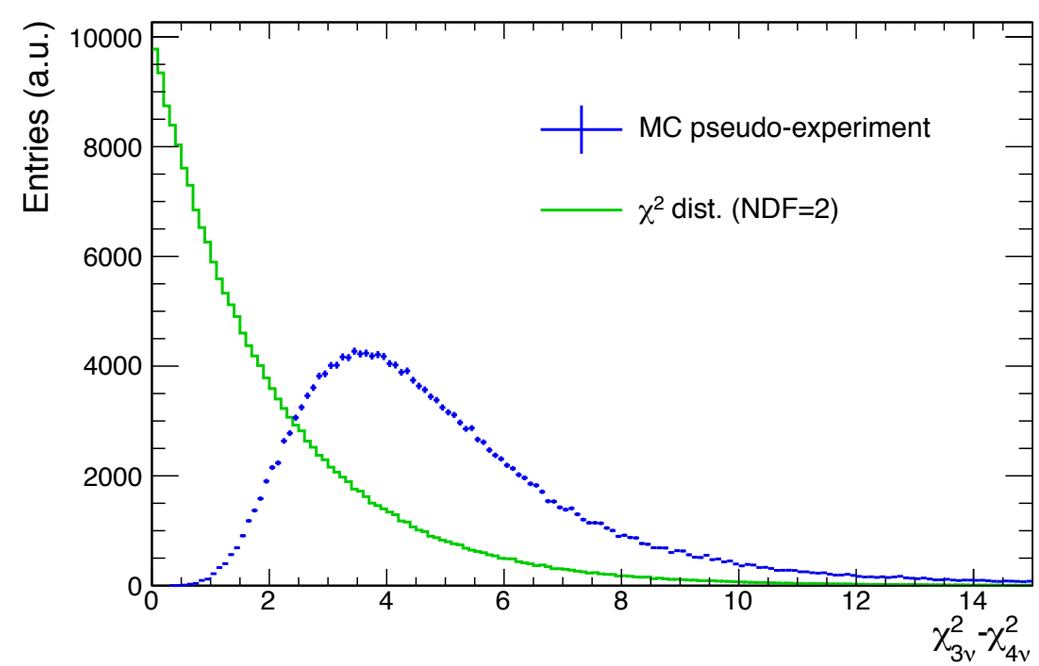
- S / N ~ 23
- vs H-M: 5 MeV bump, not so practical to do the oscillation analysis
- vs Daya Bay: bump not totally disappeared, fission fraction difference
- Systematic uncertainties for the shape analysis:
  reference spectrum > energy recon. >> background fluc., S2 cut efficiency …

SBL Oscillation

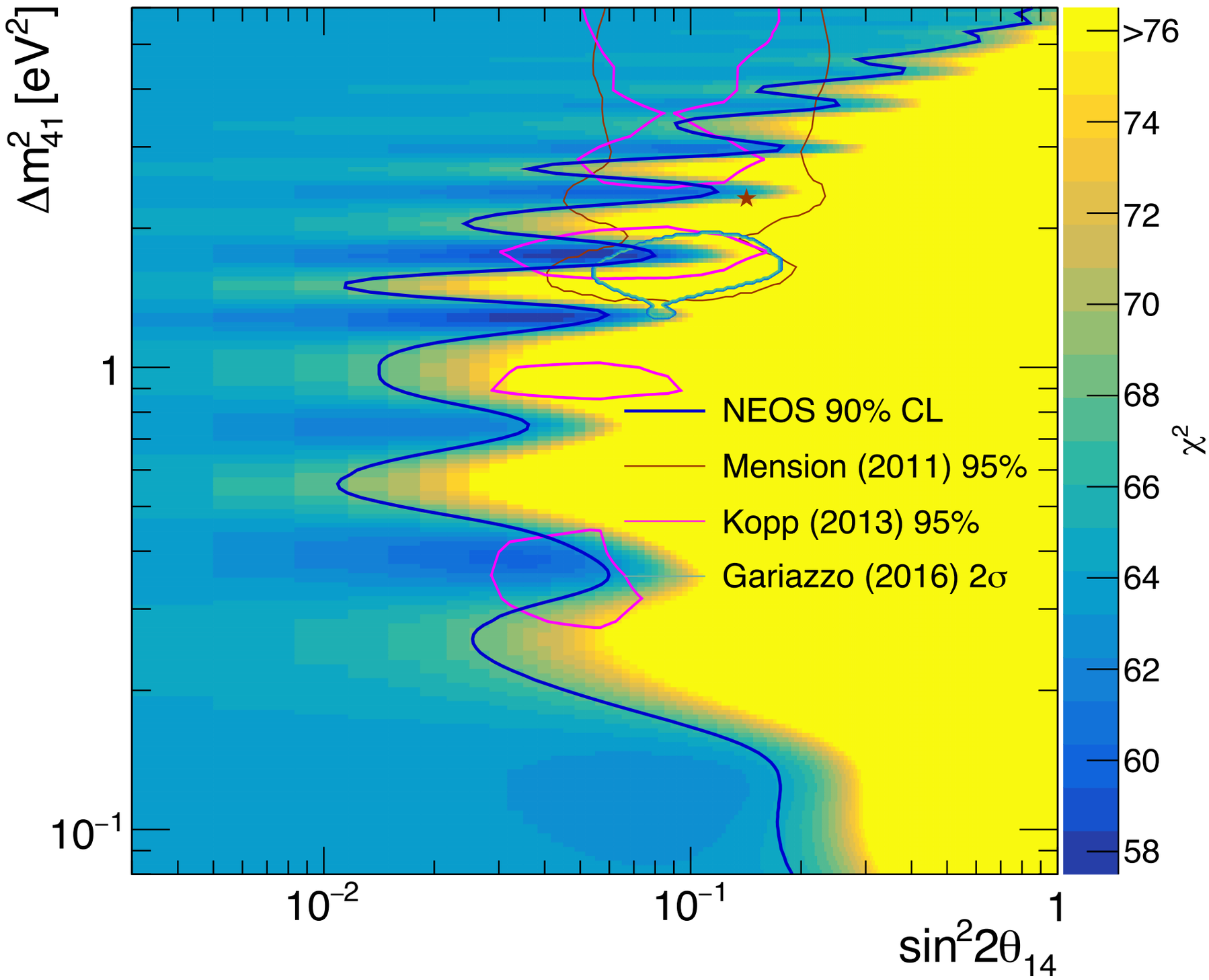


- χ^2 minima are found at ($\sin^2 2\theta$, Δm^2)=(0.04, 1.3 eV^2), (0.05, 1.73 eV^2) with $\Delta\chi^2 = \chi^2_{3\nu} - \chi^2_{4\nu} = 6.5$.
- p-value ~ 22%.
- No strong sign of 3+1 active-to-sterile ν oscillation.
- Small mixing, similar mass squared difference.





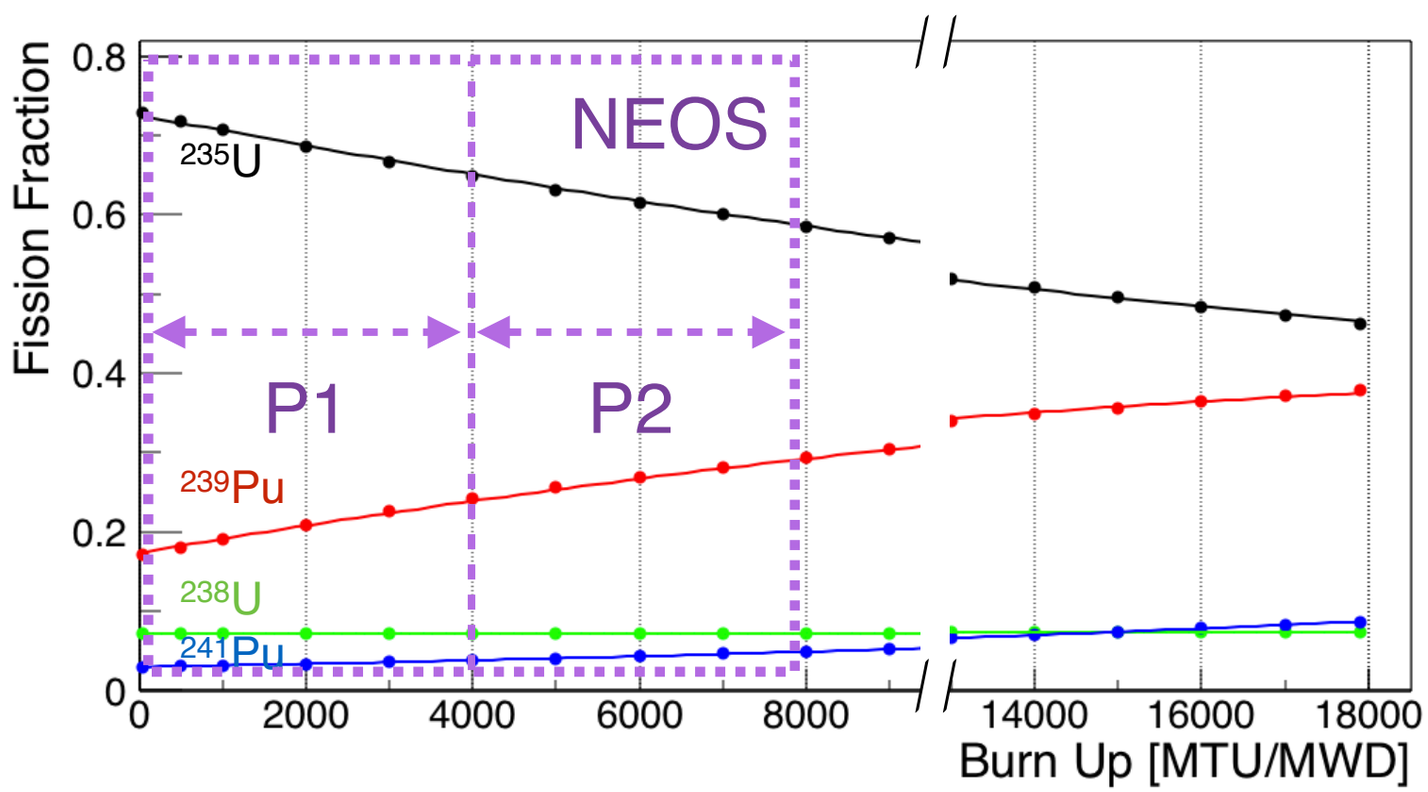
Limits

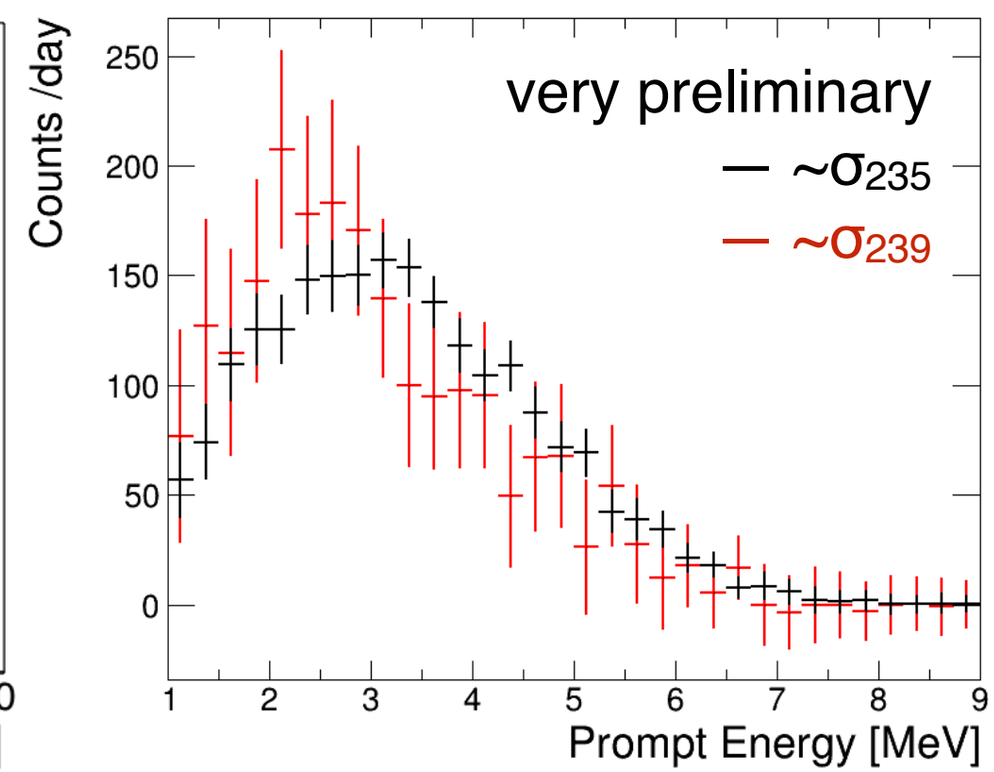


arXiv:1610.05134 / Phys. Rev. Lett. **118**, 121802 (2017)

NEOS status / summary

- NEOS is over due to regular maintenance of the tendon gallery (once every 5 years)
- No strong evidence of oscillation from active-to-(~1 eV) sterile mixing.
- Tendon gallery is a nice place for reactor neutrino experiment, but
- Severe escaping γ effect with a small volume detecter without γ catcher.
- Measurement of 1 whole burn-up cycle should help to understand the spectrum in detail.





What’s next?

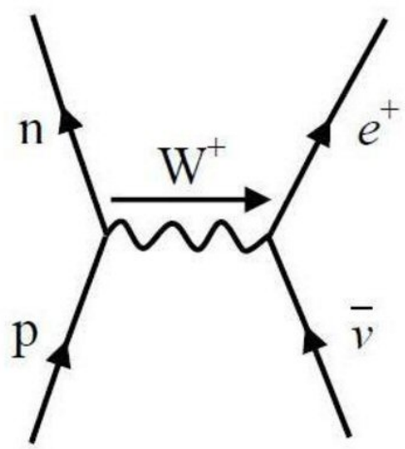
New Reactor(s) Planned in Korea?

- Advanced Power Reactor (APR) 1400.
- A couple under construction, severals under implementation design.
- The design thermal power is close to 4 GW, 1.5 times higher than the current ones (Hanbit NPP).
- We are writing a **letter of intent**, proposing a dedicated room for various neutrino experiments in the newly built commercial nuclear power station.
- Your contribution is welcome.

Neutrino physics programs

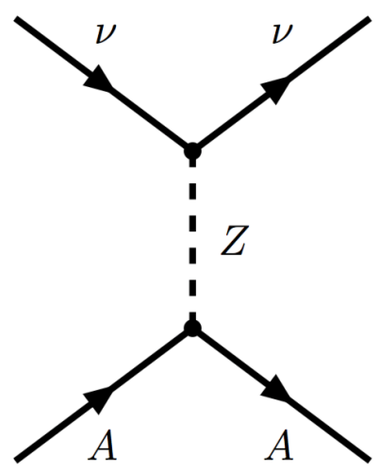
sterile?

IBD

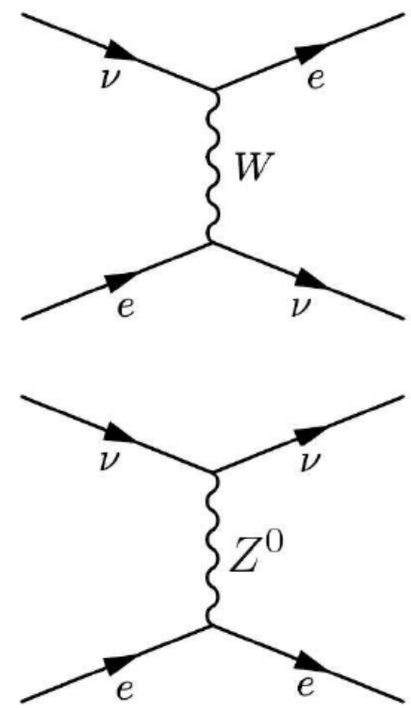


Precision / Resolution

vN coherent



ve elastic



Threshold / background

etc

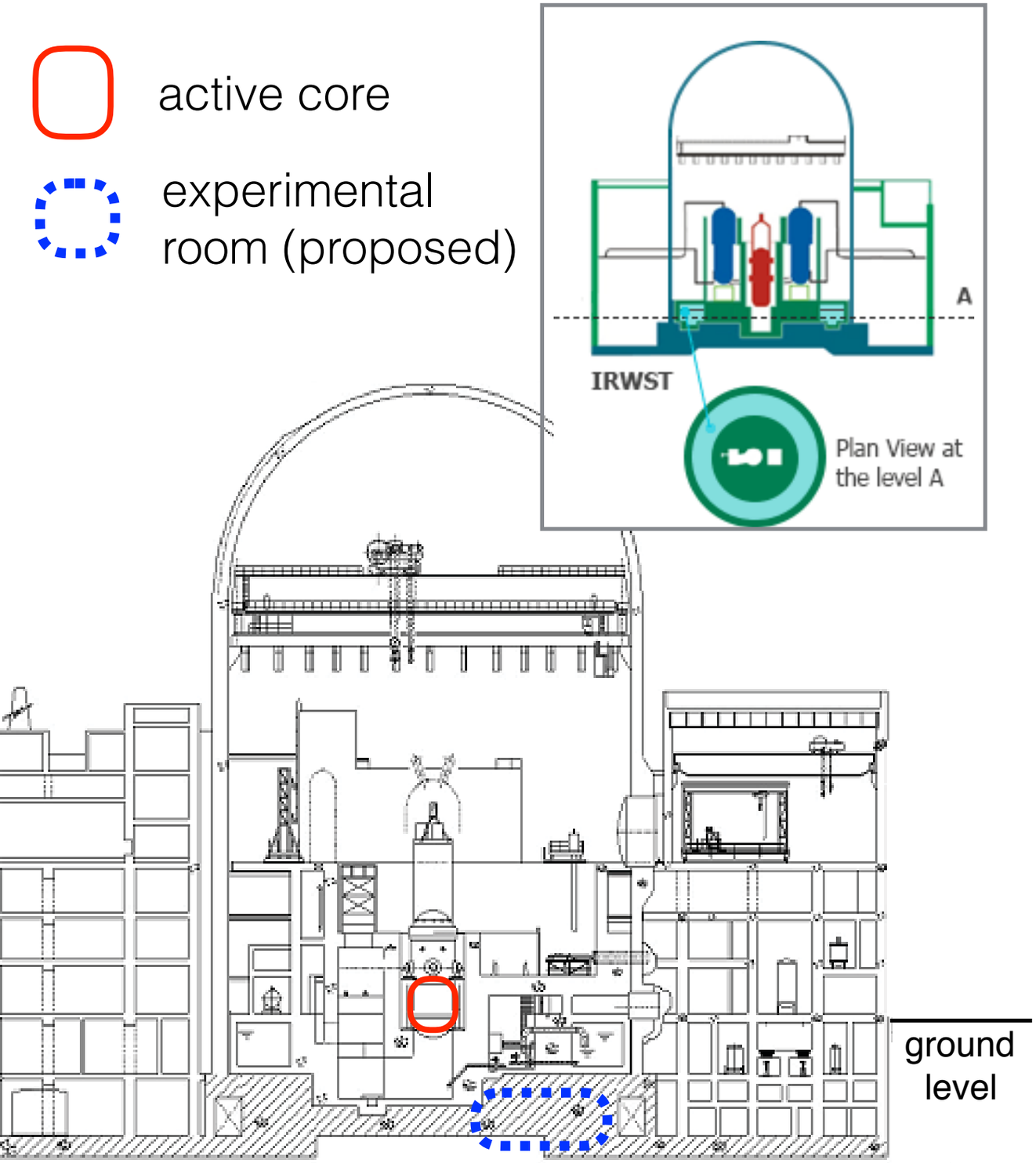
?

- High ν flux / low muon related background.
- Relatively larger space for installing additional shielding or detector scale-up.
- Reactor on/off for background subtraction.

Dedicated room for neutrino experiments

active core

experimental room (proposed)



	NEOS @ tendon gallery	Proposed new room
core diameter	312.4 cm	365 cm
core height	381 cm	
thermal power	2815 MW	3983 MW
distance to core	24 m	~18 m *
overburden	>20	
muon rate	~0.2 cm^{-2} min^{-1} *	
rectangular space (WxDxH m^3)	4 x 2.5 x 3.3	8 x 5 x 4 *
# of IBD events to be detected (NEOS detector)	~2000 per day	~5000 per day *