NEUTRINO AND DARK MATTER PROGRAMS IN KOREA

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Baksan

Center for Underground Physics (CUP)

- CUP is established at Institute for Basic Science (IBS) in Korea from 2013.
- Goals : Exploring
  1. **What is dark matter ?**
  2. **Fundamental properties of neutrinos ?**
  3. **What created the asymmetry in the Universe ?**
  4. **Extreme rare phenomena in energy region 10 eV – 1 TeV**

Brief History of CUP :

- **2003** Construction of Yangyang underground laboratory (Y2L).
- **2005-2012** KIMS-CsI dark matter experiment
- **2013. 7** CUP (IBS) Established.
- **2014. 9** Expansion of Y2L
- **2016. 1** AMoRE-Pilot Double Beta Decay Exp. Began.
- **2016. 9** COSINE-100 Experiment began.

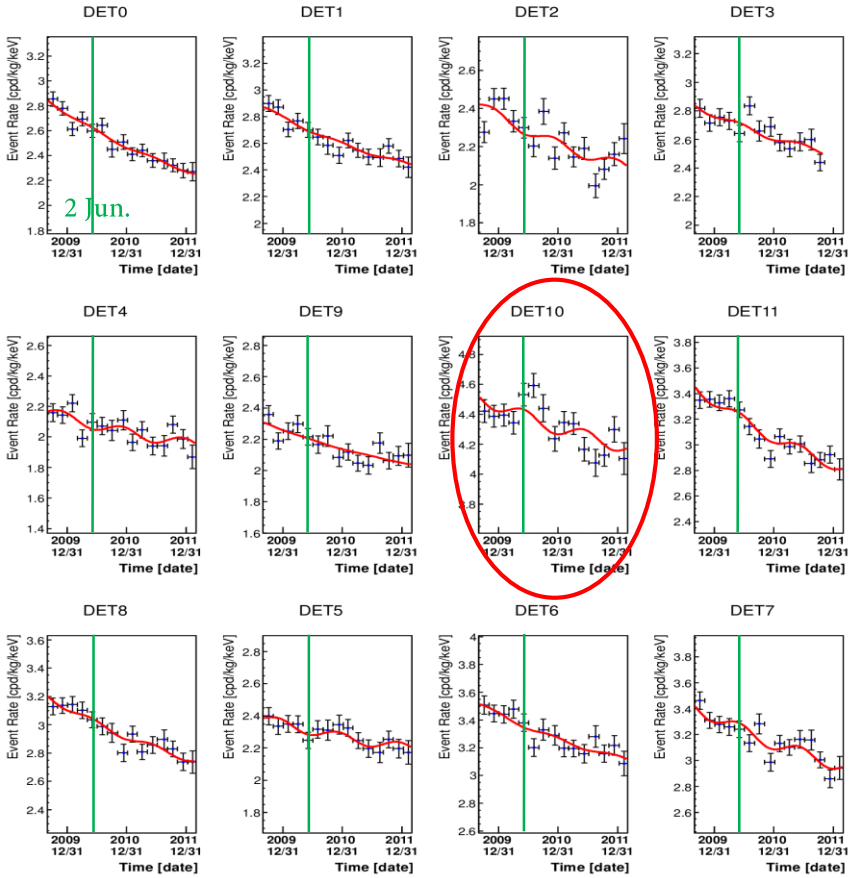
We have had a strong collaboration with Russian groups in many projects !!

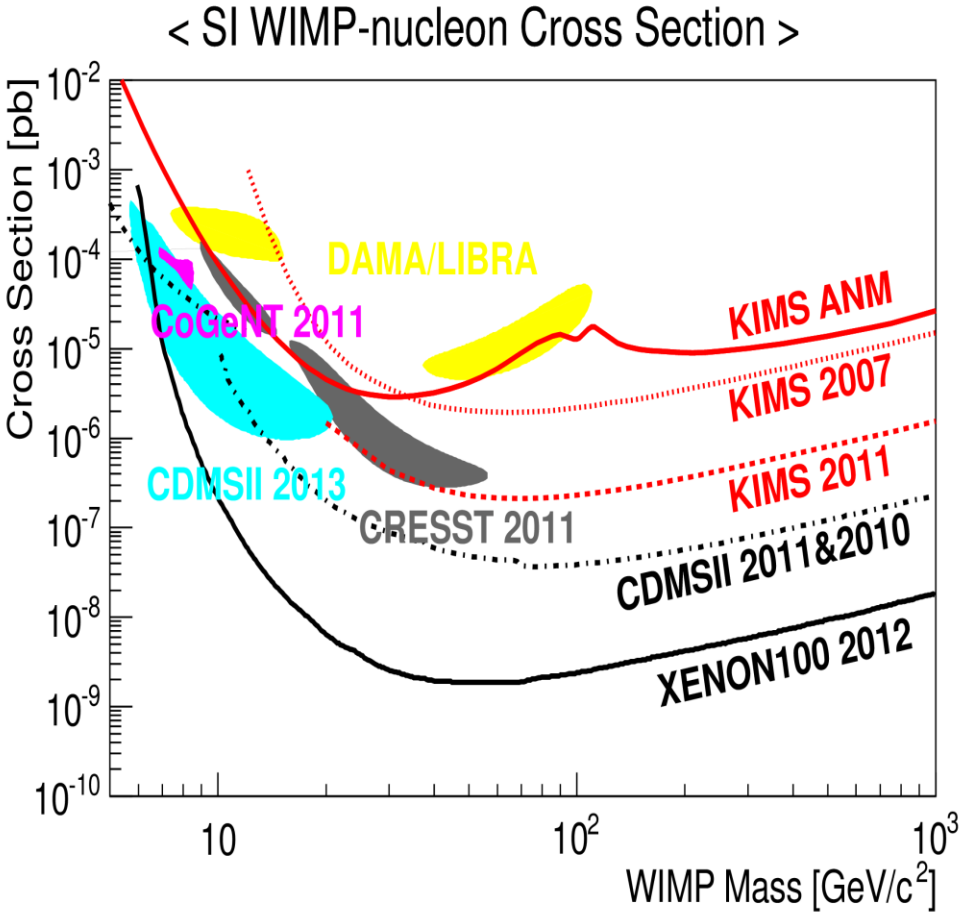
KIMS-CsI (2006-2012)

12 crystals (104.4kg) installed in the Cu shield.

2.5 year data (Sep. 2009 – Feb. 2012)

Background Level : 2~3 cpd/kg/keV





Overview of CUP

Members :

- 1 Director
- 2 Group Leaders
- ~25 Research Fellows
- 6 Technicians
- 3 Administrators
- ~25 Adjunct Students.

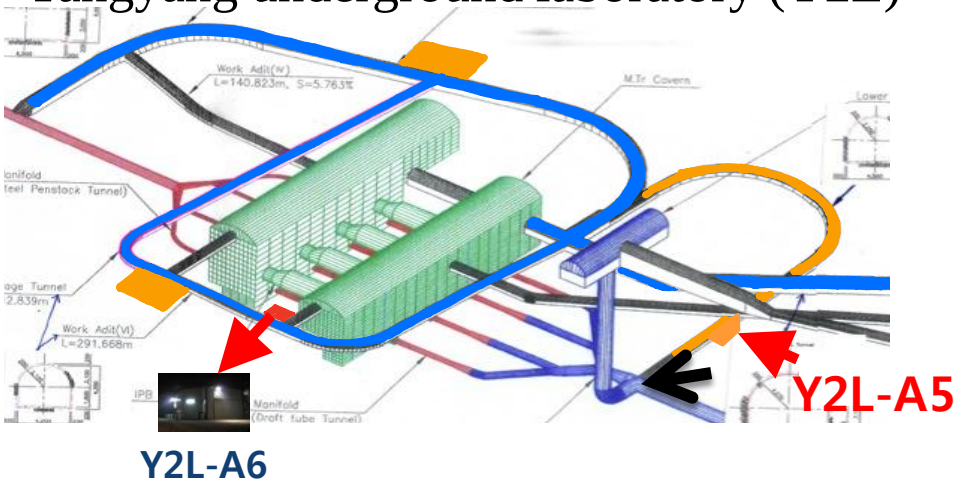
Budget :

Total ~ 9 M $ / year

- Human Resources : 35%
- Equipments, Materials : 50%
- Operational : 15%

Labs.

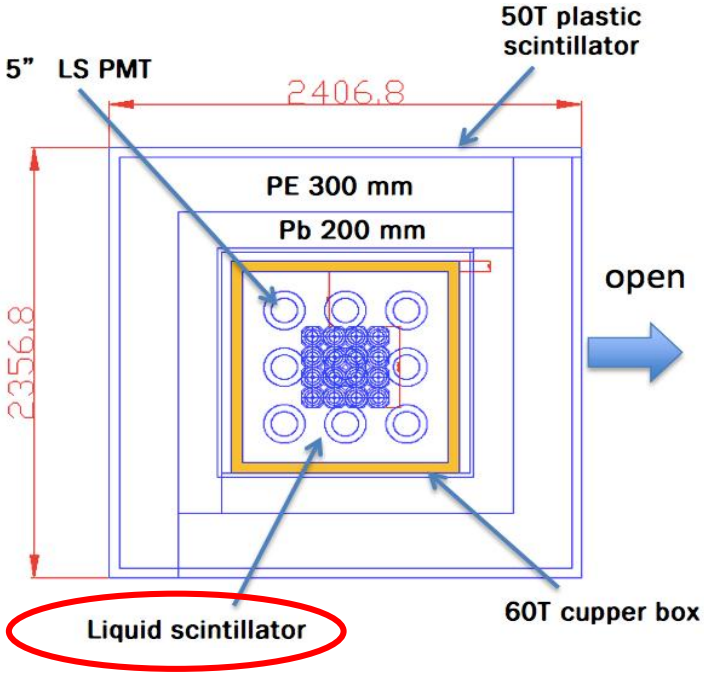
Yangyang underground laboratory (Y2L)



Daejeon Ground Lab.

COSINE-100 commissioned.

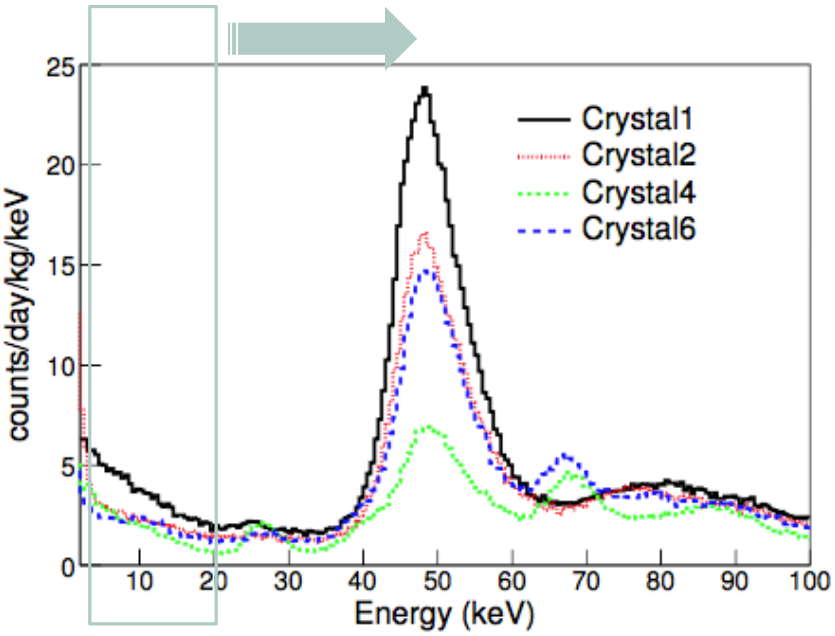
- DM-ICE group + KIMS-NaI group → COSINE at Y2L.
- 200 kg NaI(Tl) crystals inside liquid scintillator active veto.
- Phase I (100 kg) commissioned in Oct, 2016. → running stable.
- Develop purer crystals → Phase II exp. (2018-2019)

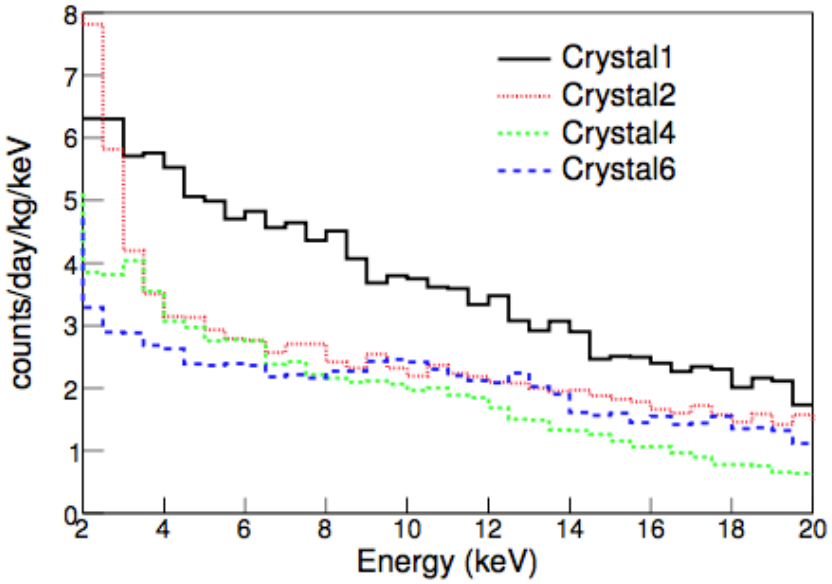


Energy spectrum

Energy spectrum

Preliminary

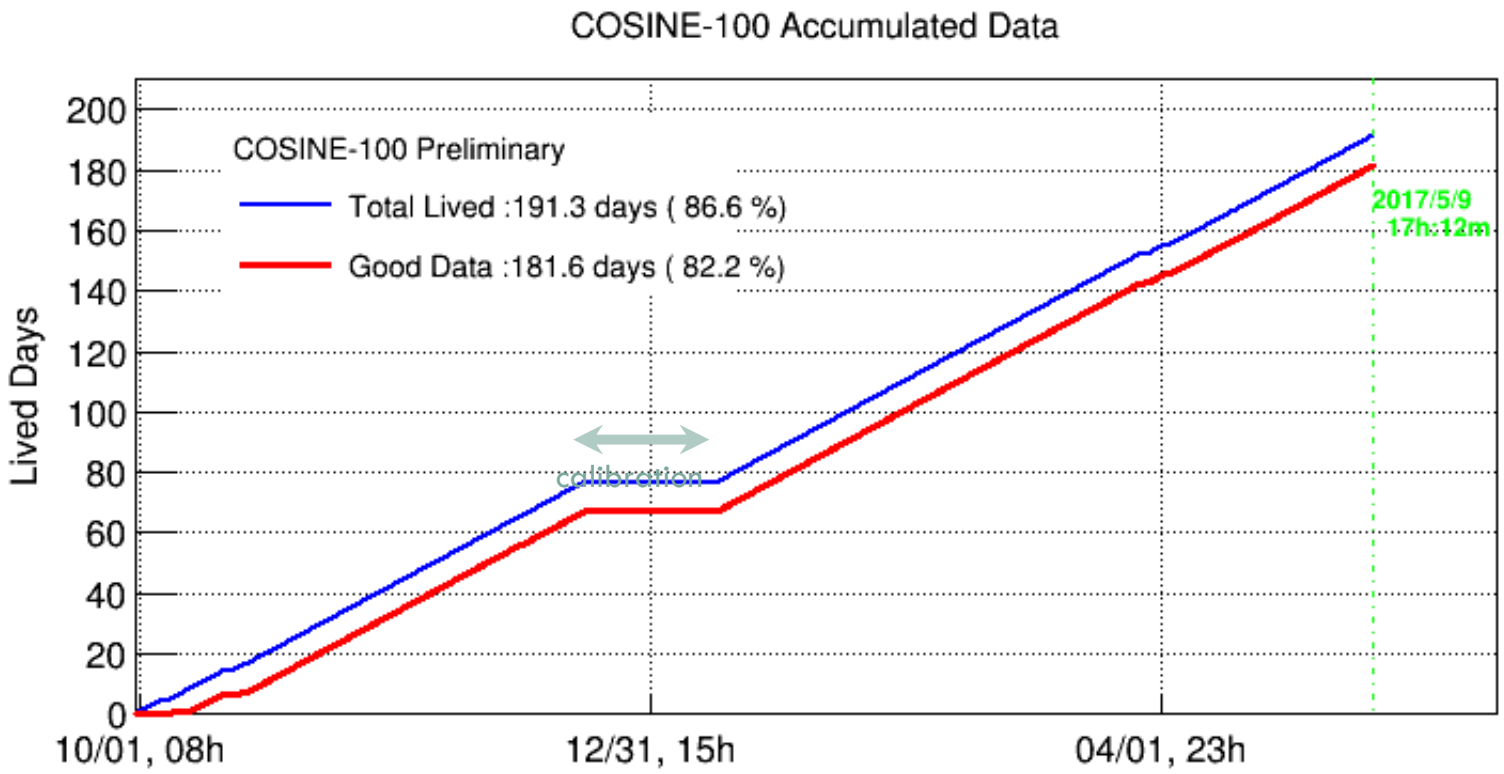




Event selections are applied

- Depending on crystal, background level ~3 dru at 2~20 keV.
- The current energy threshold is 2 keV, but it can be lowered by developing selection cuts.

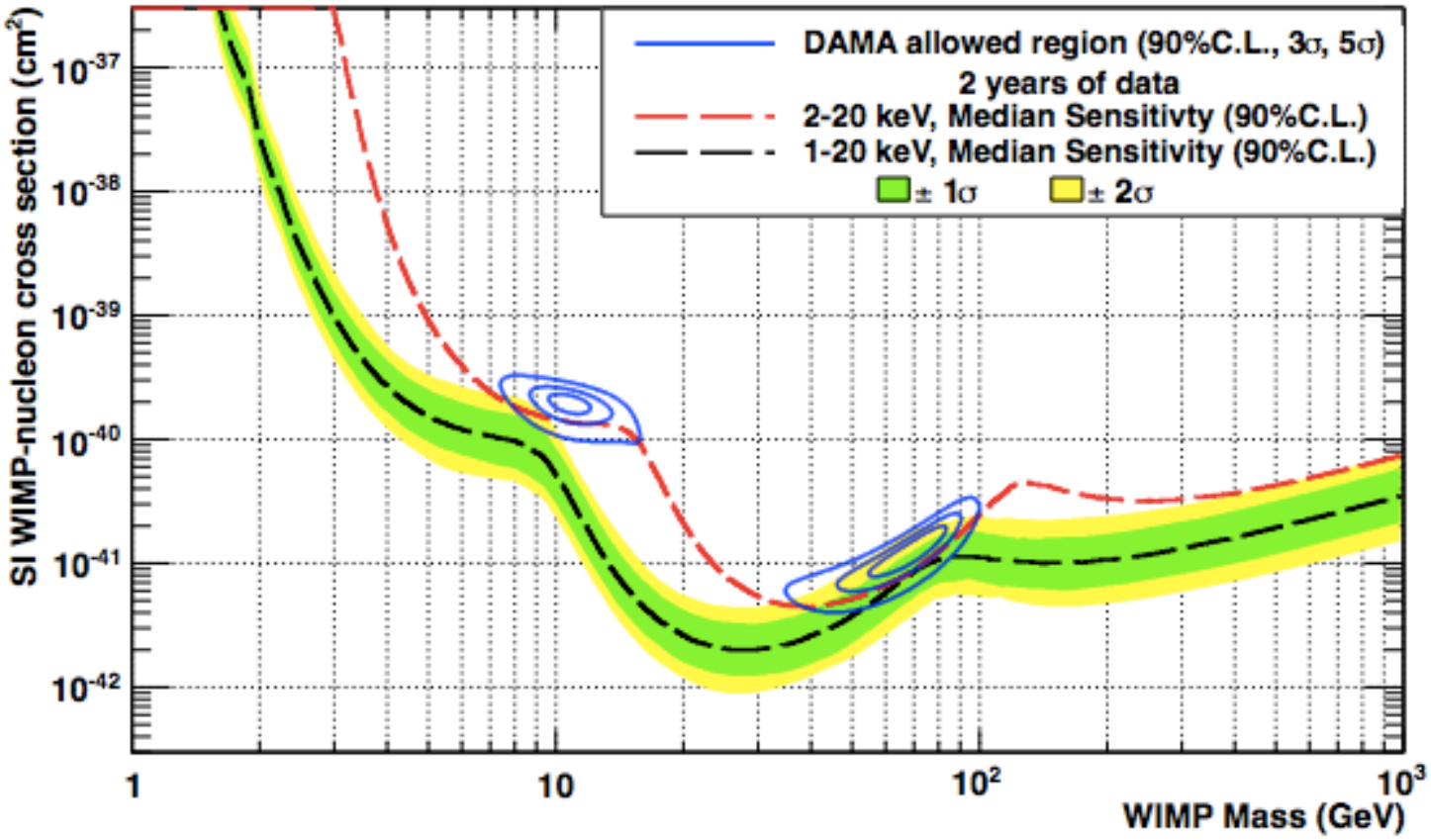
Accumulated data



We have around 181 days underground data by now.

Expected Sensitivity for COSINE-100

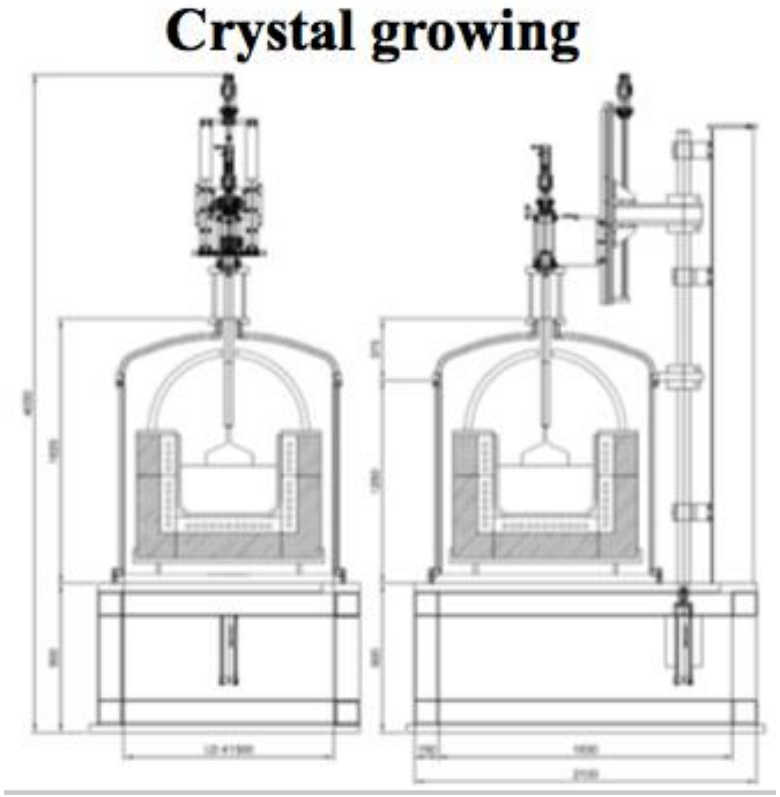
- Sensitivity is comparable with the DAMA.
- DAMA's new 6-year data and COSINE 1-year data will be released by the end of next year.
- COSINE-phase II with lower background and threshold will begin in 2018. Stay tuned !!



*Assumed 2 dru or 4 dru flat backgrounds depending on crystals.

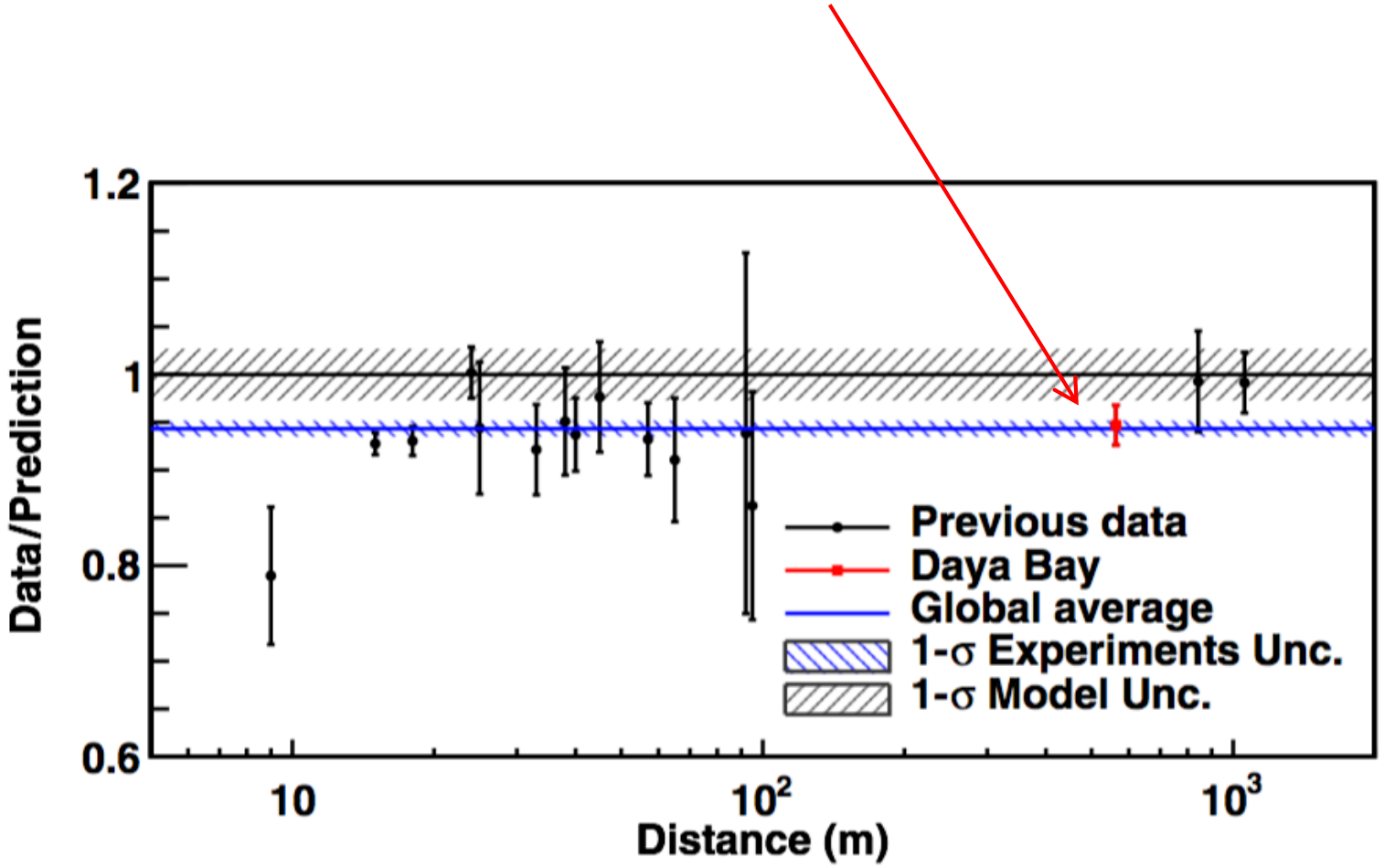
Phase II for COSINE

- Current background level is higher than DAMA background.
- Will grow large (100kg) single NaI(Tl) crystals at CUP with a help from French expert in Kyropoulous grower which is based on the same techniques of Saint-Gobain.
- Plan to run phase II from year 2018.
- If you are interested in COSINE, you can join COSINE collaboration by calling to Spokesp ersons, Hyunsu Lee or Reina Maruyama !!



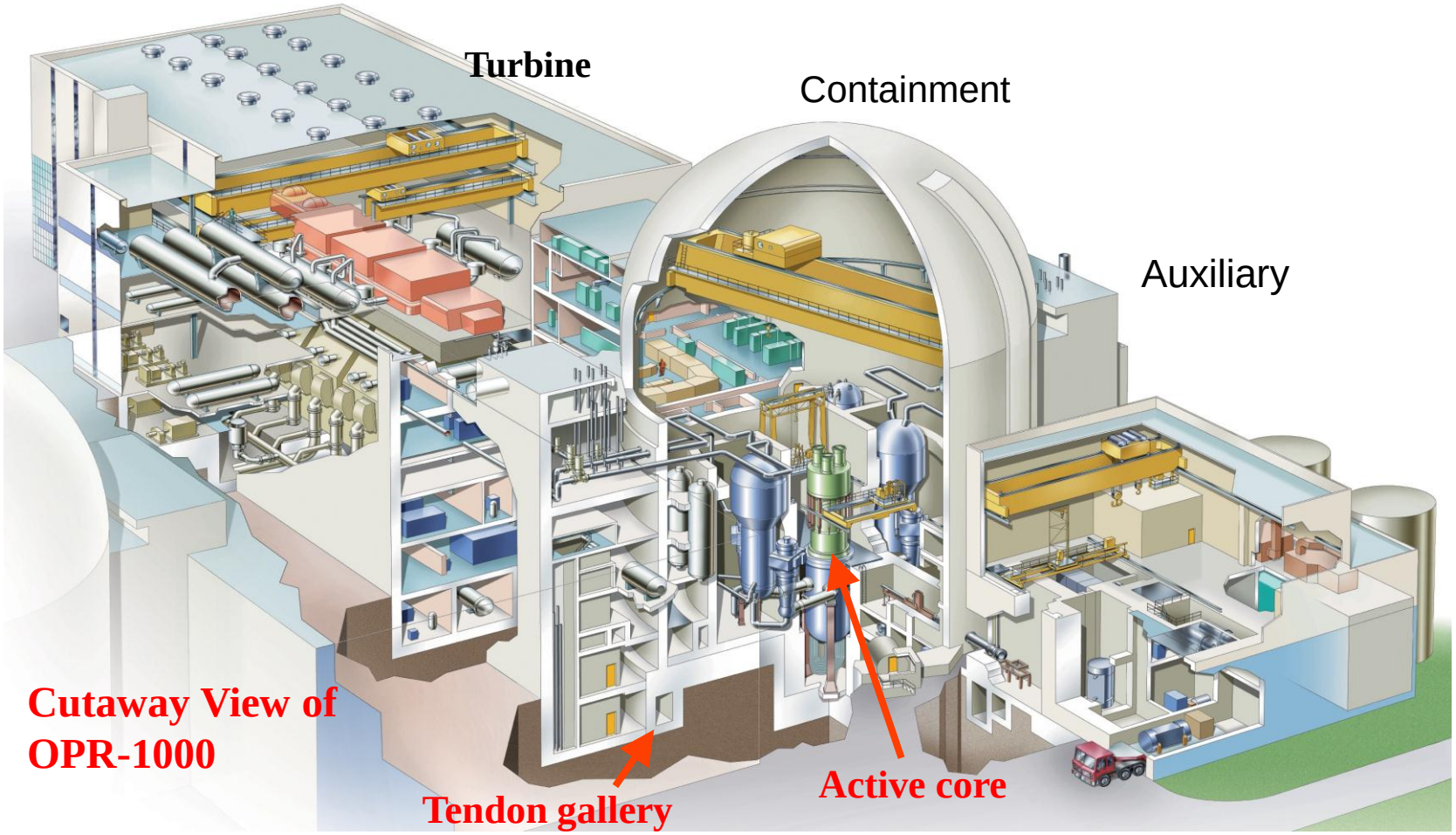
Reactor Anomaly & Sterile ν

- There are reports about the deficit of reactor neutrinos at baseline < 100m from the expected flux. ~ 6%
- This may be due to active to sterile neutrino oscillation, ~ 1eV.
- RENO, Double Chooz, DAYA BAY (PRL116, 061801) confirmed this effect.



NEOS (Neutrino Experiment for Oscillation at Short baseline)

- Possibility to do sterile neutrino experiment at the commercial power plant.
- Unique experiment with 3 baseline at the same time,
  -- NEOS (25m), RENO-near(~250m) , RENO-far(1300m)



NEOS Detector

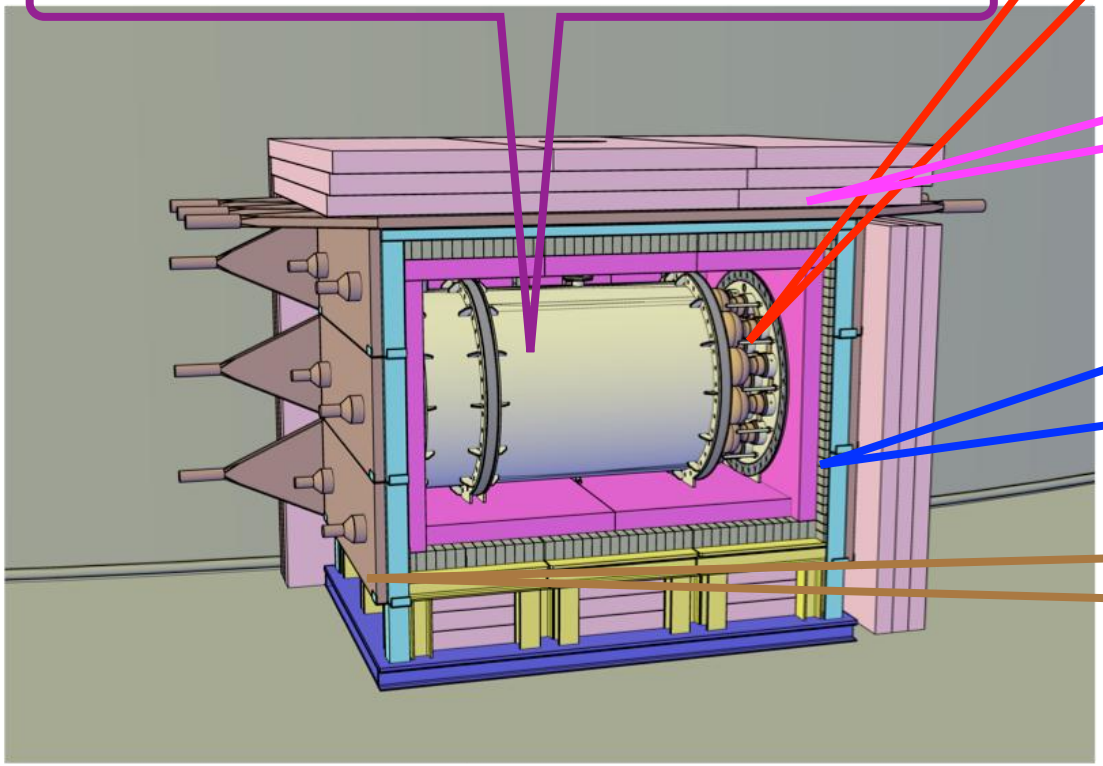
~ 1000 L Liquid Scintillator w/ 0.5 % gadolinium loaded.

8'' photomultiplier (PMT) in mineral oil

Borated polyethylene (10 cm)

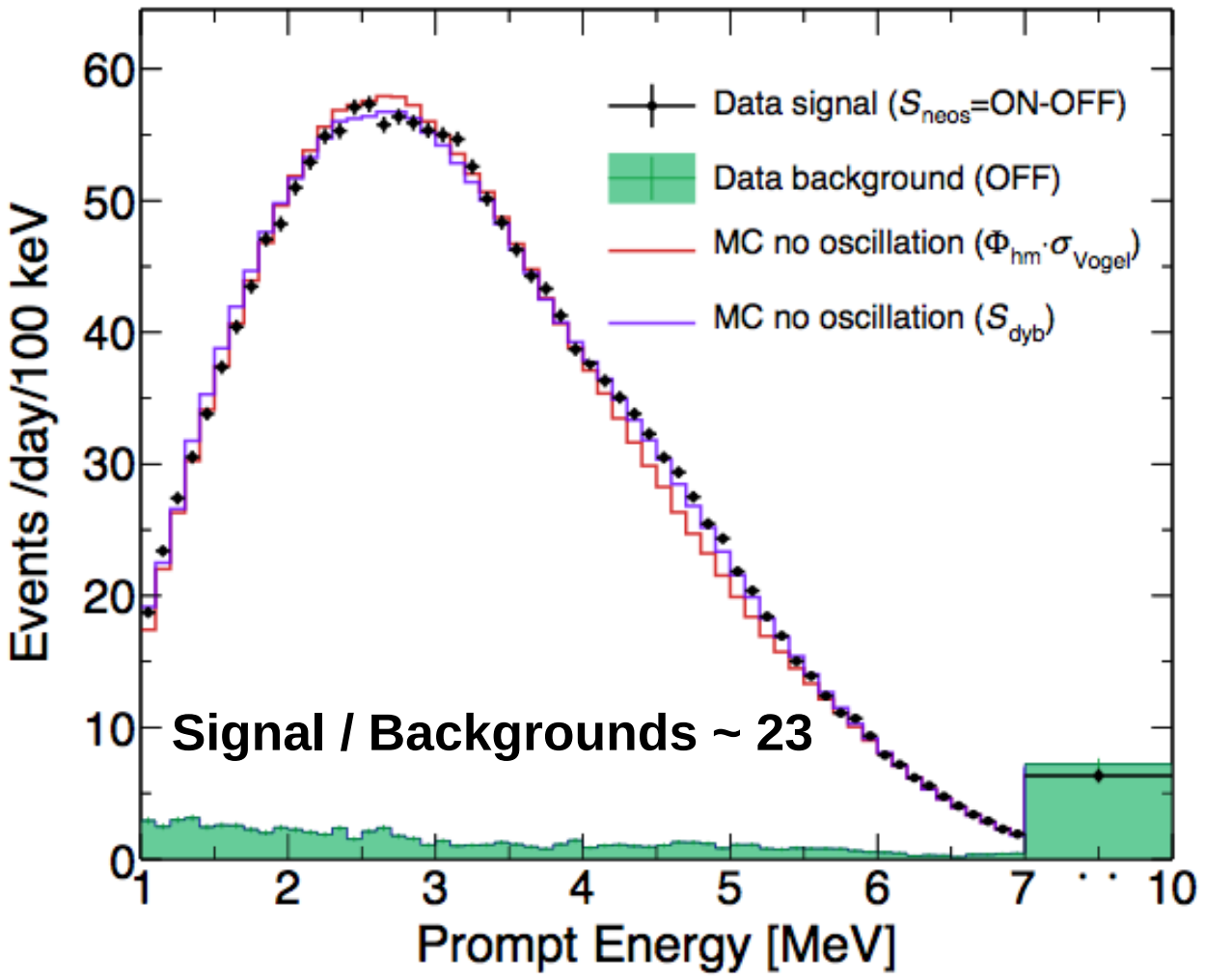
10 cm lead shield for gamma

4π muon detector veto made by plastic scintillator



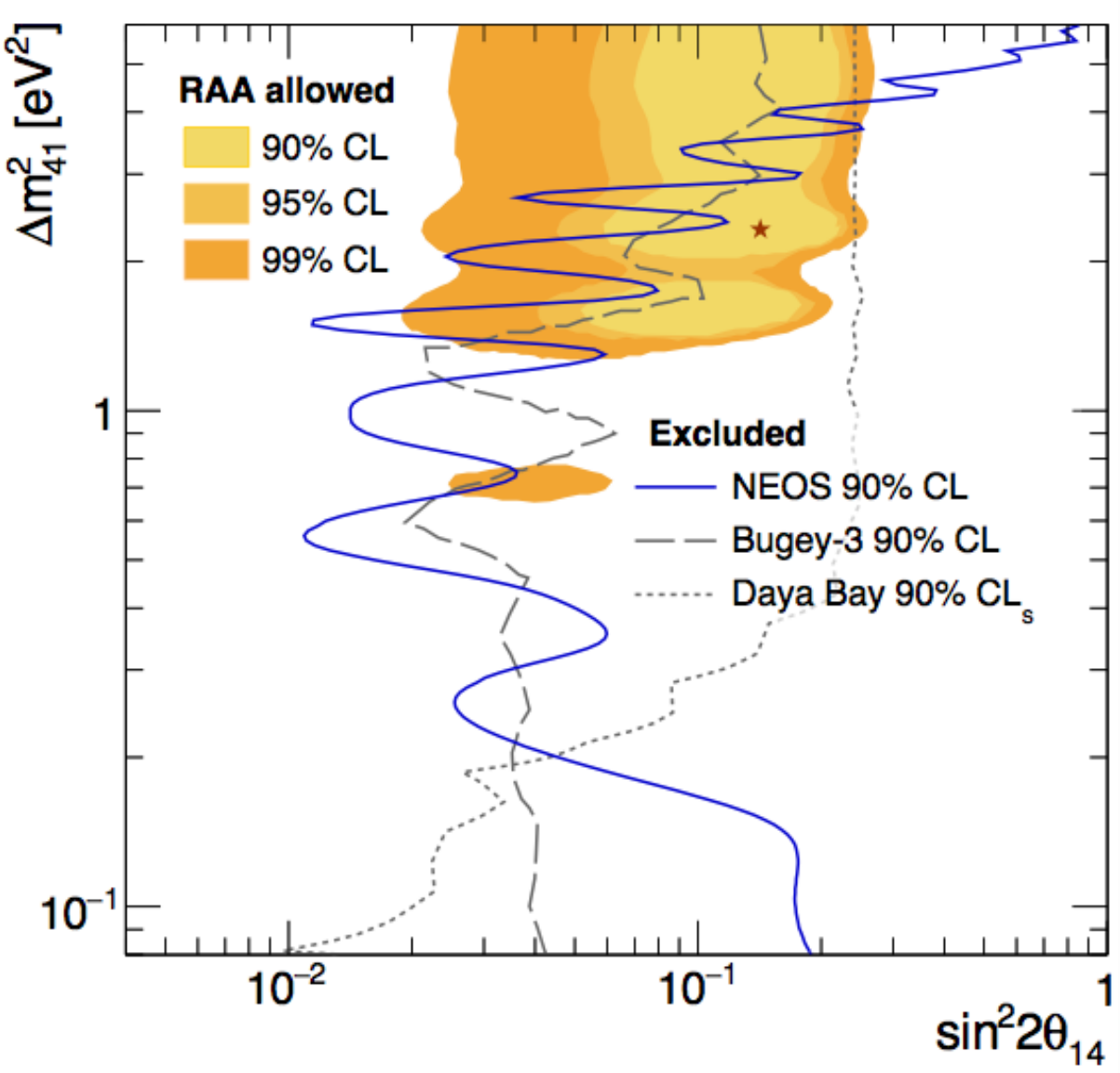
Prompt Energy Spectrum

- S/B ratio is high enough to investigate the energy spectrum in detail.
- We Do see the similar ~5MeV bump !



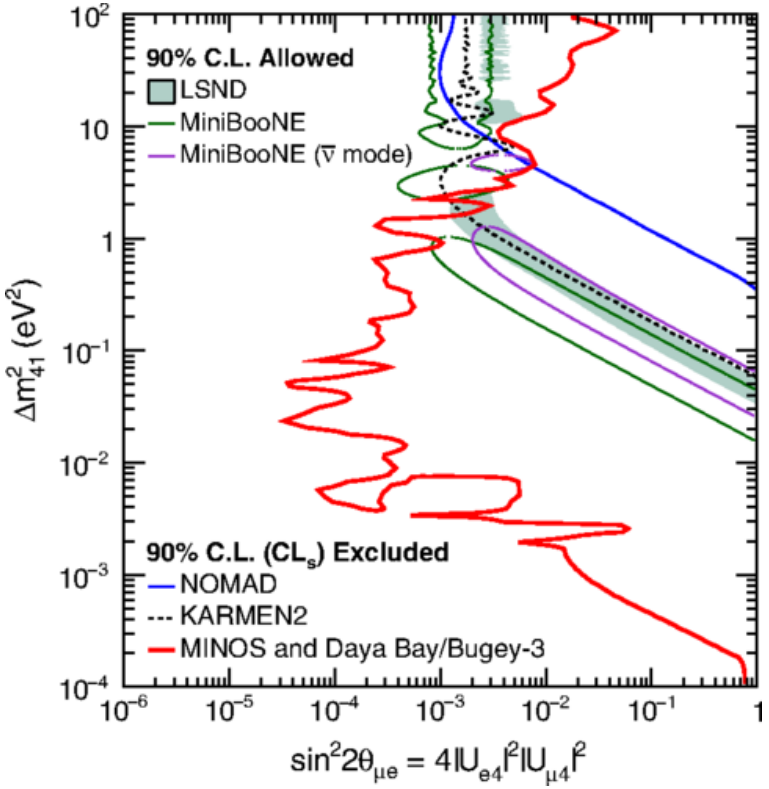
New Limits with Existing Data

Ko et al., PRL118 (2016) 121802

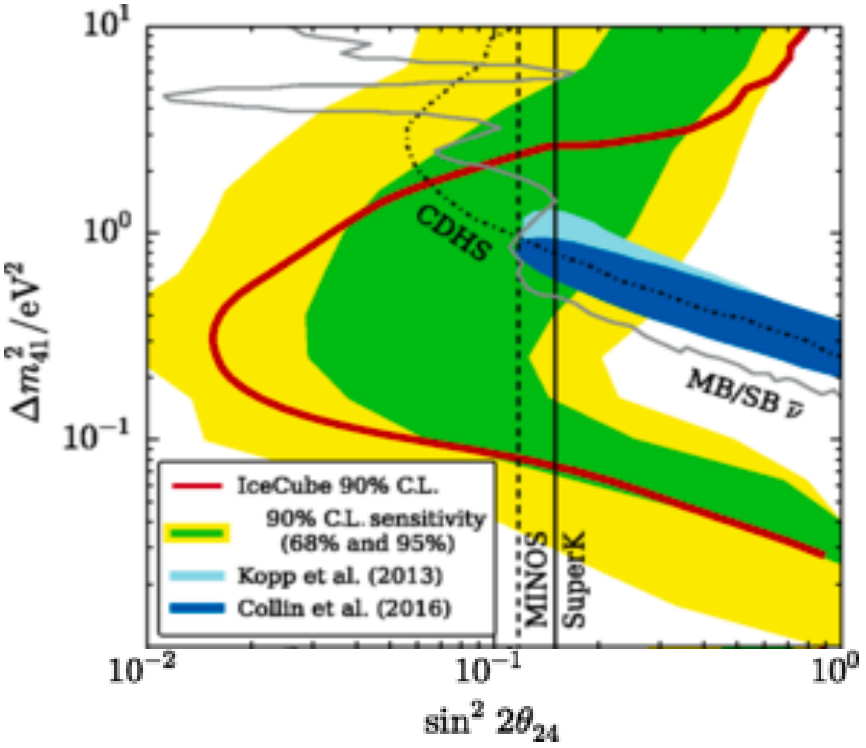


Combining World Data challenging LSND

MINOS/DayaBay/Bugey-3 : PRL117 (2016) 151801



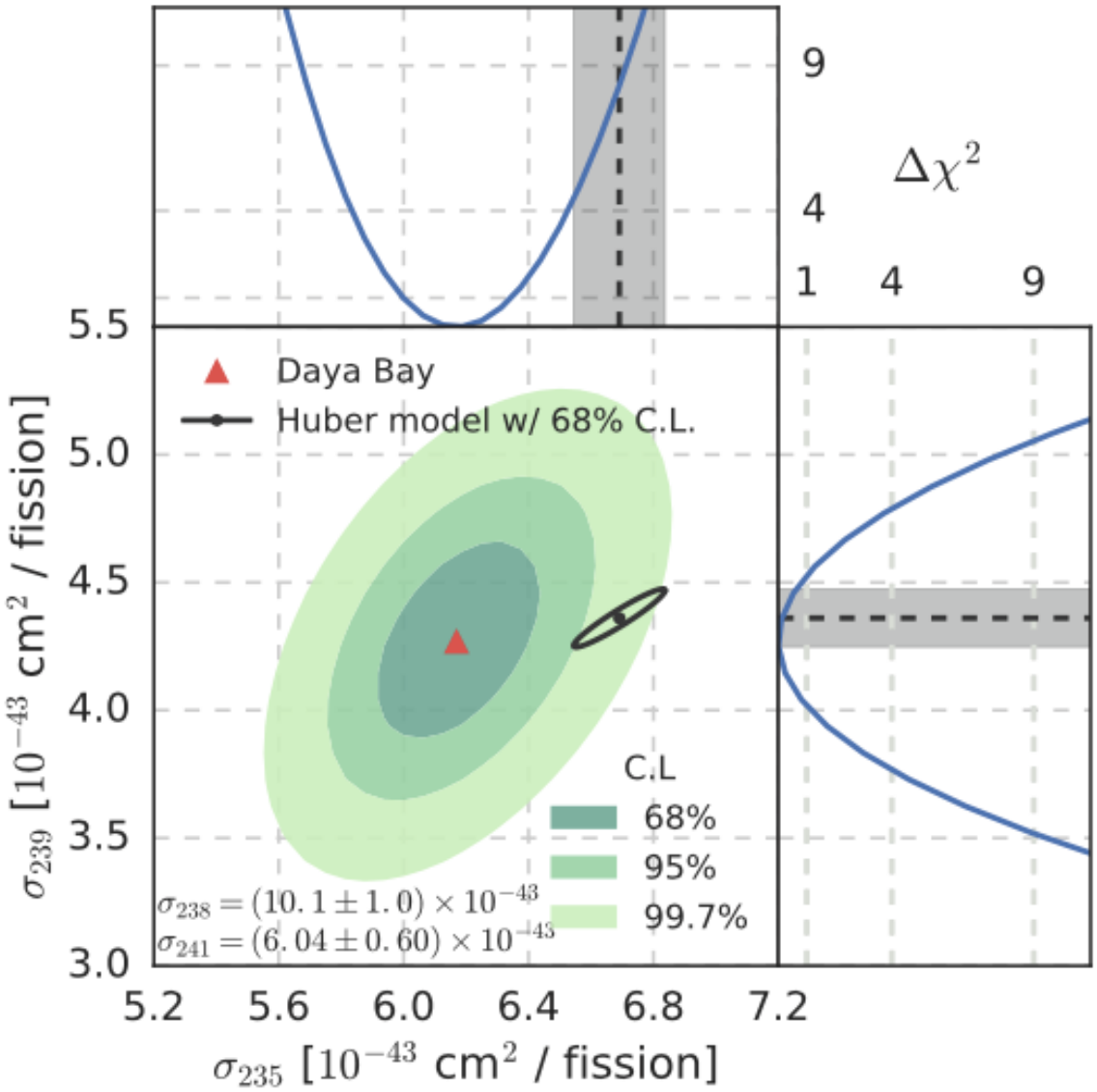
IceCube : PRL117 (2016) 071801



- **Combining $\bar{\nu}_e \rightarrow \bar{\nu}_e$ (θ_{14}), $\nu_\mu \rightarrow \nu_\mu$ (θ_{24}) to verify $\nu_\mu \rightarrow \nu_e$ ($\theta_{e\mu}$, LSND anomaly):**
  $\sin^2 2\theta_{\mu e} = 4\,|U_{e4}|^2\,|U_{\mu 4}|^2 = \sin^2 2\theta_{14} \sin^2 \theta_{24}$
- **Important to know the correlation between the experiments**

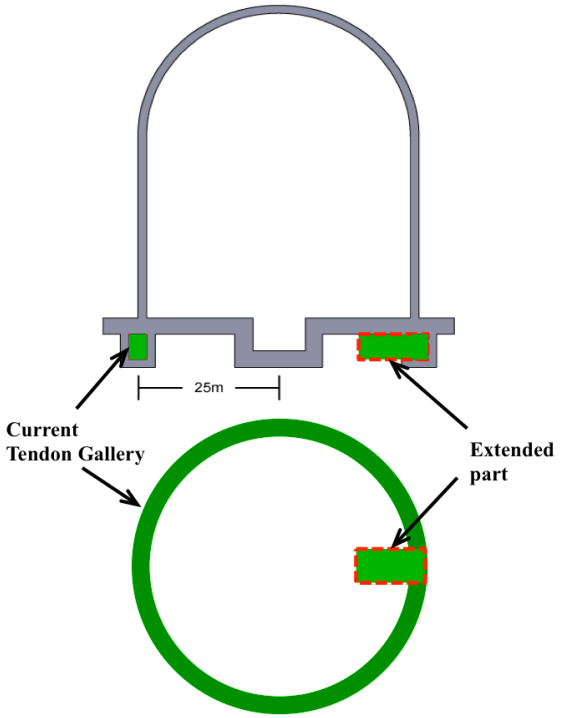
Daya Bay new result

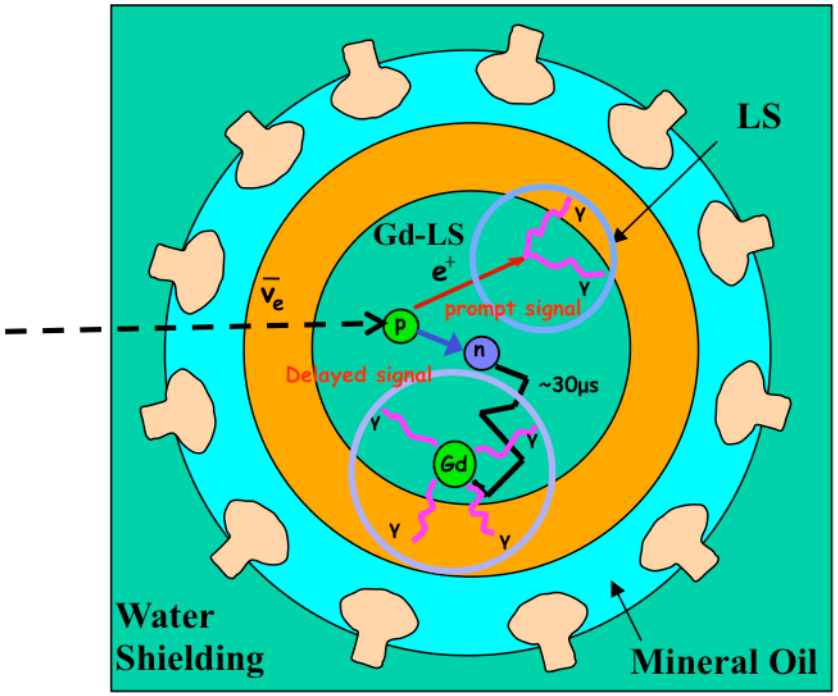
arXiv:1704.01082



- eV scale sterile neutrino interpretation for reactor neutrino anomaly is disfavored by 2.6 sigma.
- Reactor neutrino anomaly is mainly due to ^{235}U spectrum.

Future Project – NEOS-II

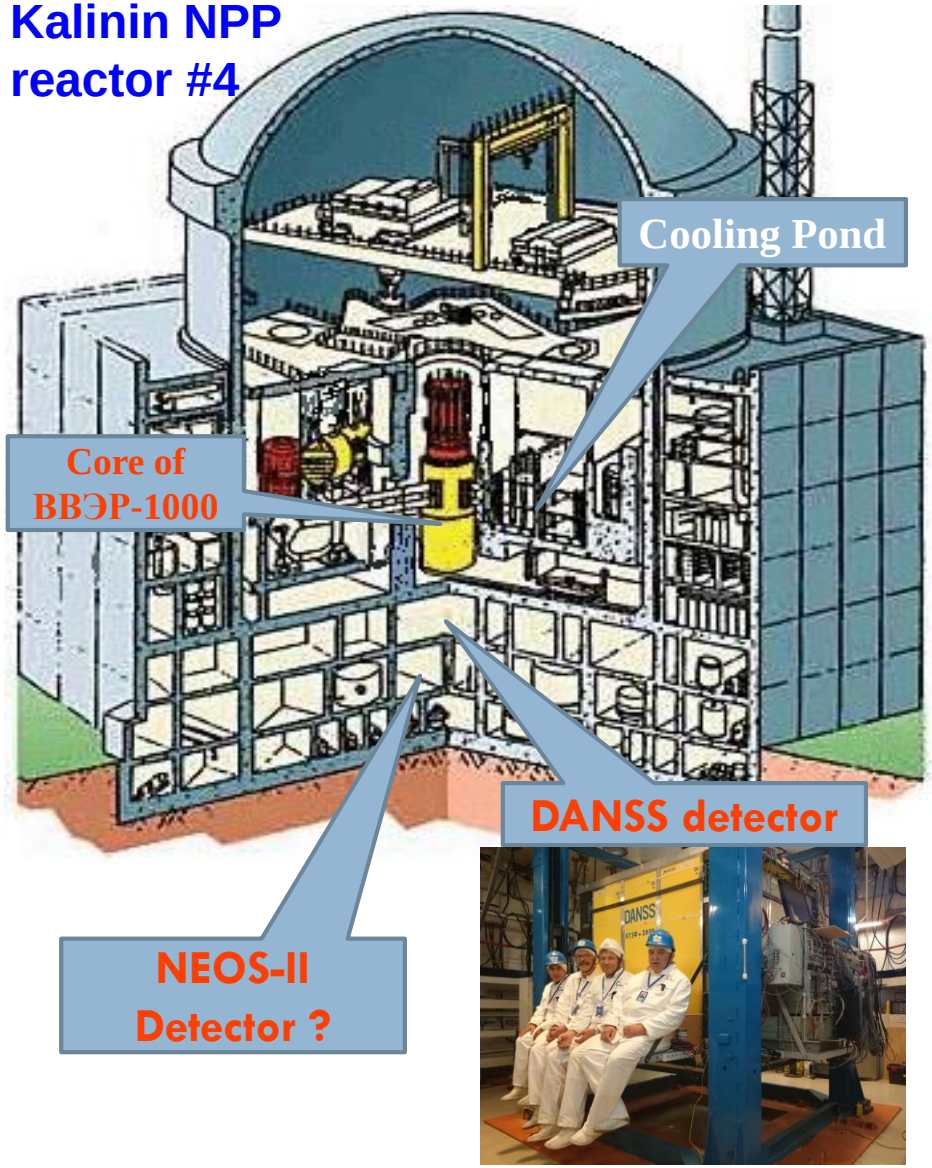


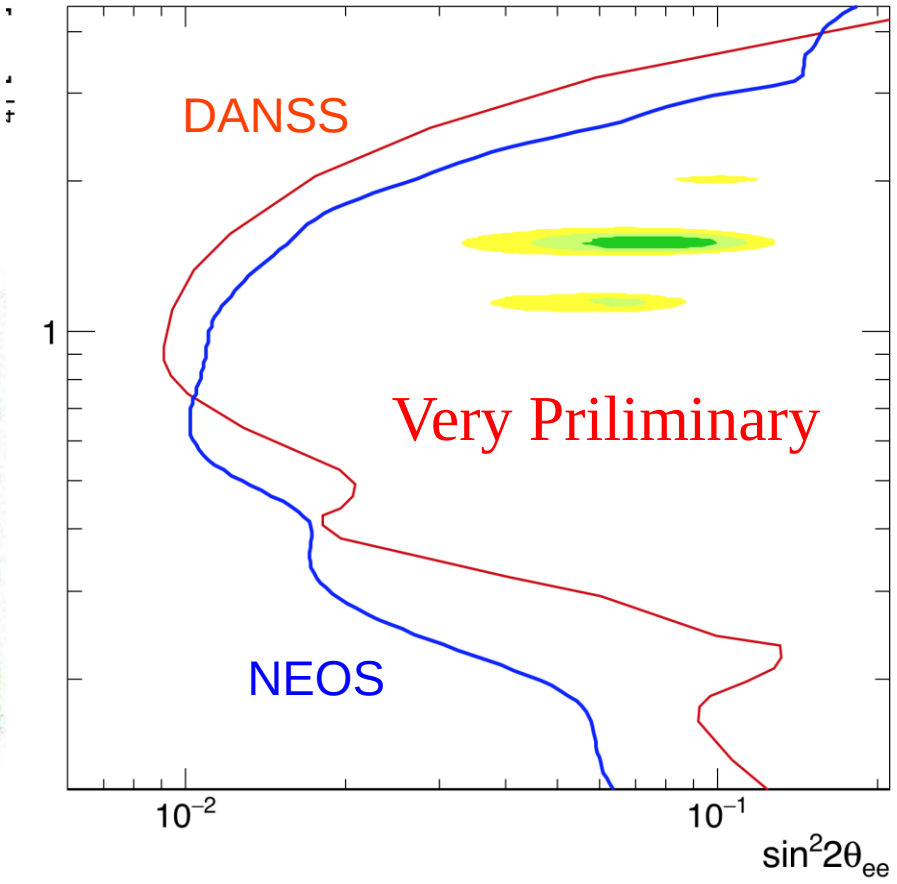


- New detector with photocathode coverage > 70% and Gamma Catcher, will have energy resolution better than 3%. → Ultimate reactor neutrino measurement.
- New Tendon Gallery can be made in a new reactor for dedicated neutrino experiments.

What if NEOS meets DANSS?

Kalinin NPP reactor #4

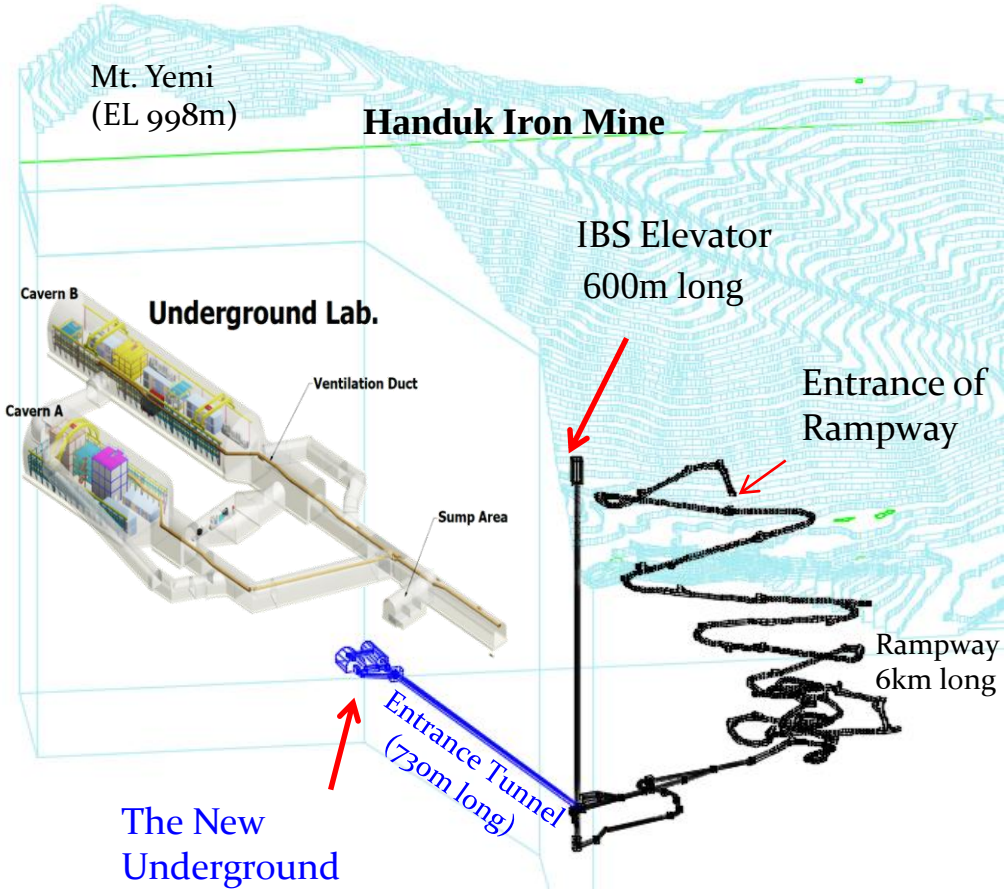




Complementary, especially for systematics
Discussion with Prof. Egorov (DUBNA)

Future Plans – Construction of new underground laboratory

- **We are constructing a new underground laboratory at an Active iron mine.**
- **1100 m depth & 2000 m^2 area for Dark matter and DBD experiments.**
- **Construction will be finished by year of 2019.**



- **AMoRE-II experiment with 10 m water tank.**
- **Future Dark Matter experiment with water tank shielding.**
- **Neutrino experiment with large liquid scintillator tank for solar neutrinos and potential dark photon search experiment.**

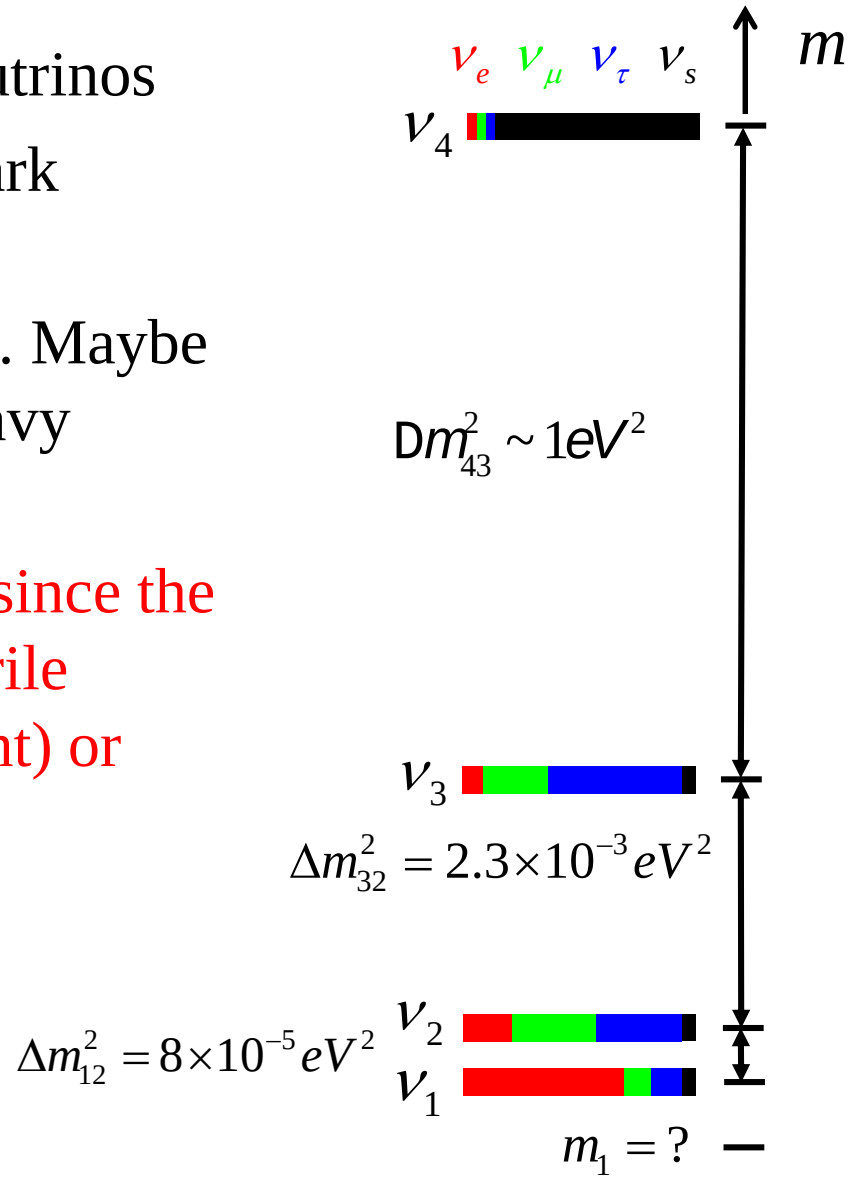
Summary

- **CUP is constructing a new world-class underground laboratory.**
- **COSINE will close in the DAMA issue and go further low mass WIMP search.**
- **Sterile neutrino search will continue, though reactor anomaly is questionable. New short baseline at accelerator will give new results.**

Поздравление с 50-летием искренне !

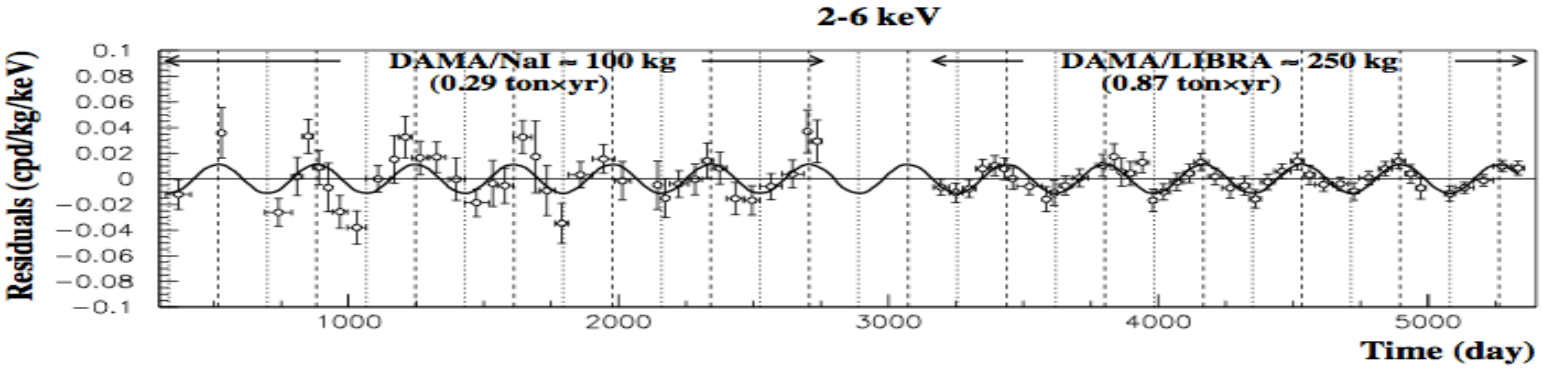
Sterile Neutrino Search – NEOS

- Sterile neutrinos – right-handed neutrinos
- Sterile neutrinos – maybe Warm Dark Matter
- Nothing is known about the masses. Maybe very light (m_n<<1MeV) or very heavy (m_n>>10^{10}GeV)
- Sterile neutrinos may be identified since the active neutrinos can oscillate to sterile neutrinos (disappearance experiment) or again oscillate to active neutrinos (appearance experiment).



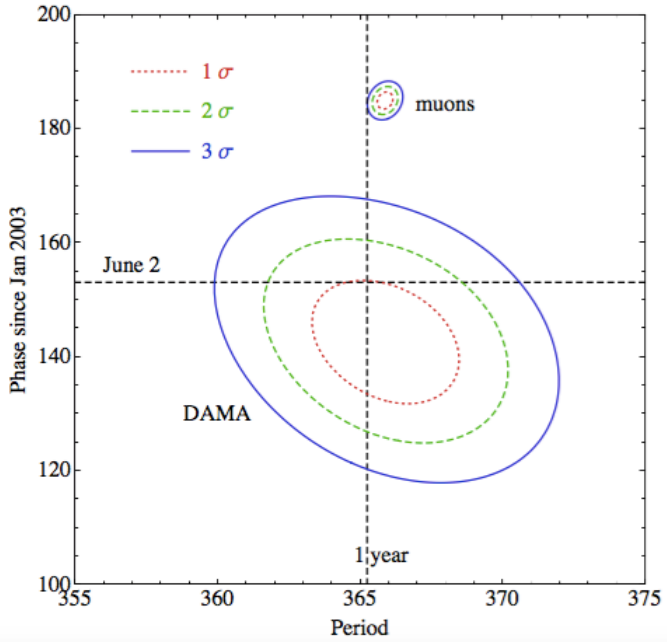
DAMA …….

- DAMA group reported modulation for 14 years consistently. → "DAMA anomaly"
- Direct check for DAMA is necessary even though other experiments rejected DAMA modulation signal based on standard WIMP-nucleon interaction.

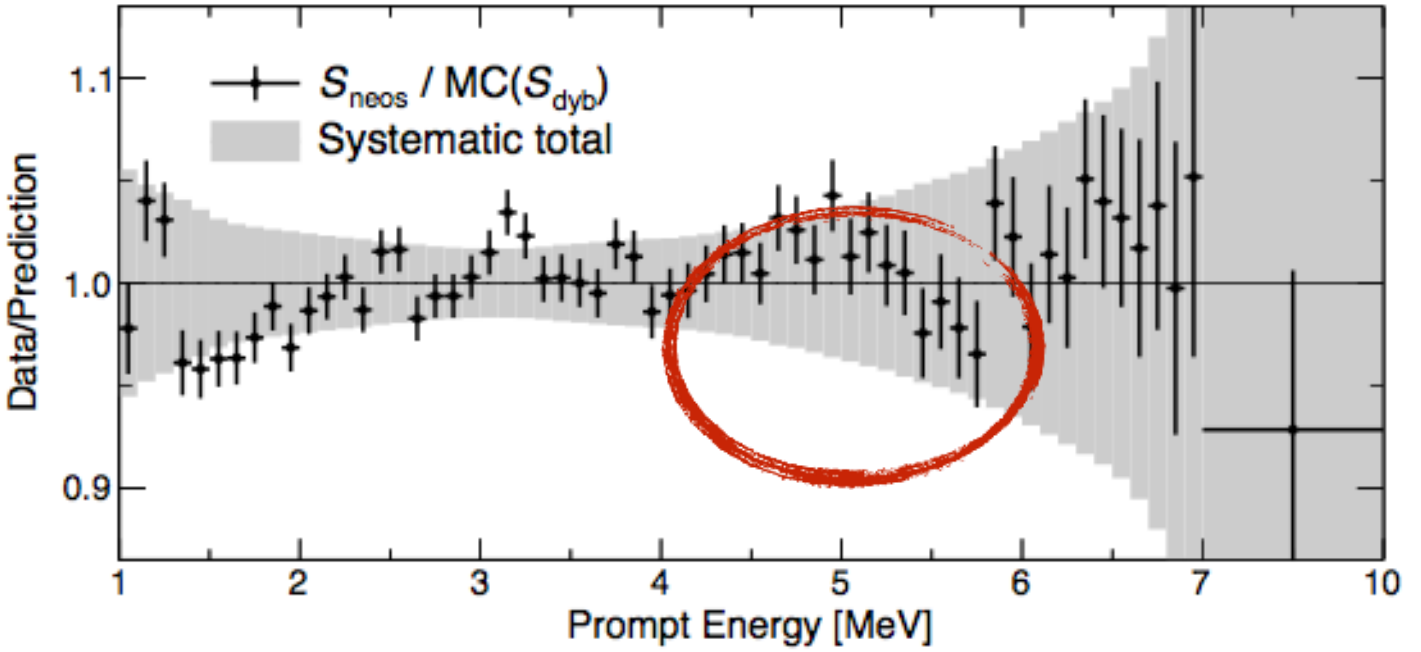


Difficulty

1. Muon (or solar neutrino) induced neutrons are not abundant to explain the modulation rate.
2. DAMA phase is 1 month earlier than muon phase.
3. DAMA group may present their another 6 years data in this year.



NEOS vs Daya Bay



- Bump got much smaller, but still seen:
  U-235 is responsible the bump?
- Note average fission fraction difference between two experiment

  (^{235}U, ^{238}U, ^{239}Pu, ^{241}Pu)

  NEOS: (0.655, 0.072, 0.235, 0.038)

  Daya Bay: (0.561, 0.076, 0.307, 0.056)