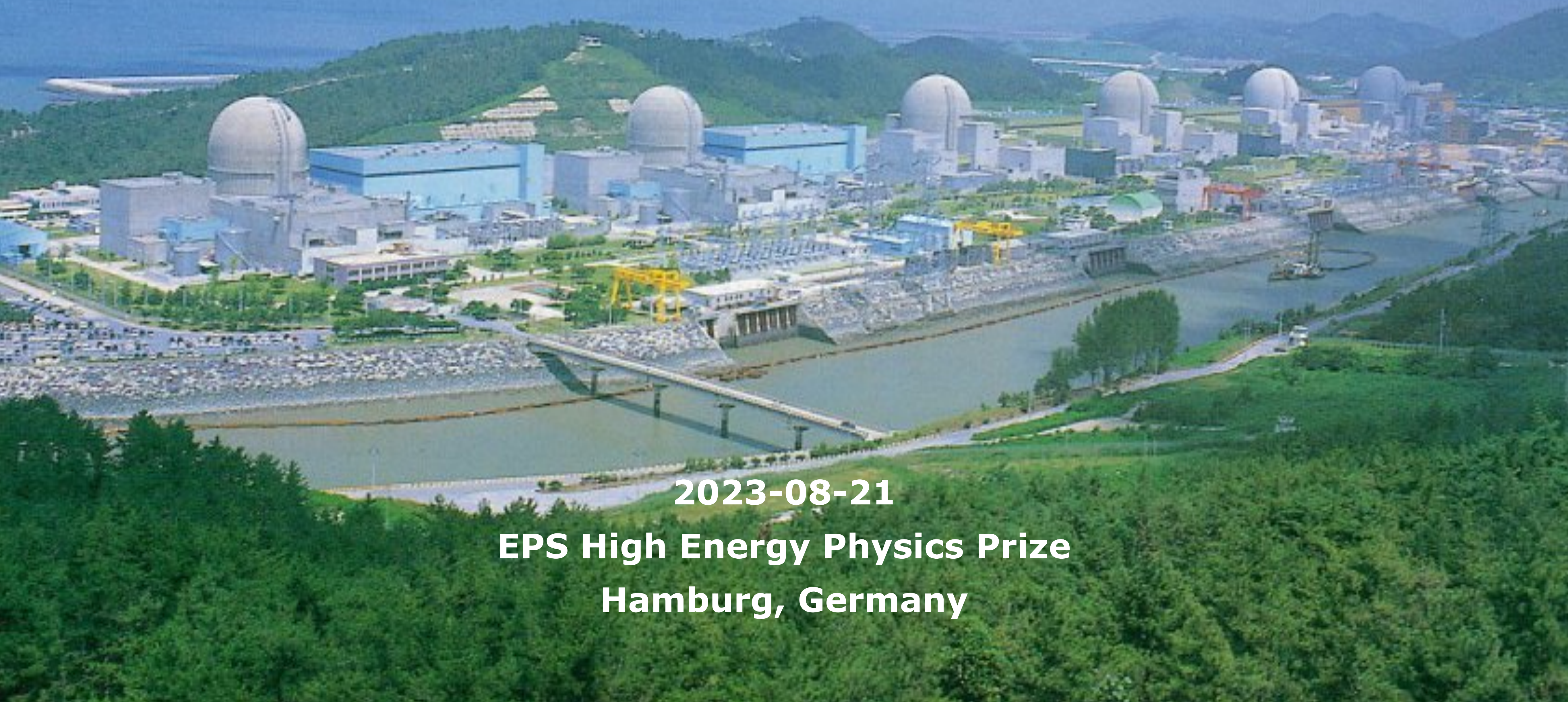
RENO ν θ_{13}

RENO

Measuring the Smallest Neutrino Mixing Angle



2023-08-21

EPS High Energy Physics Prize

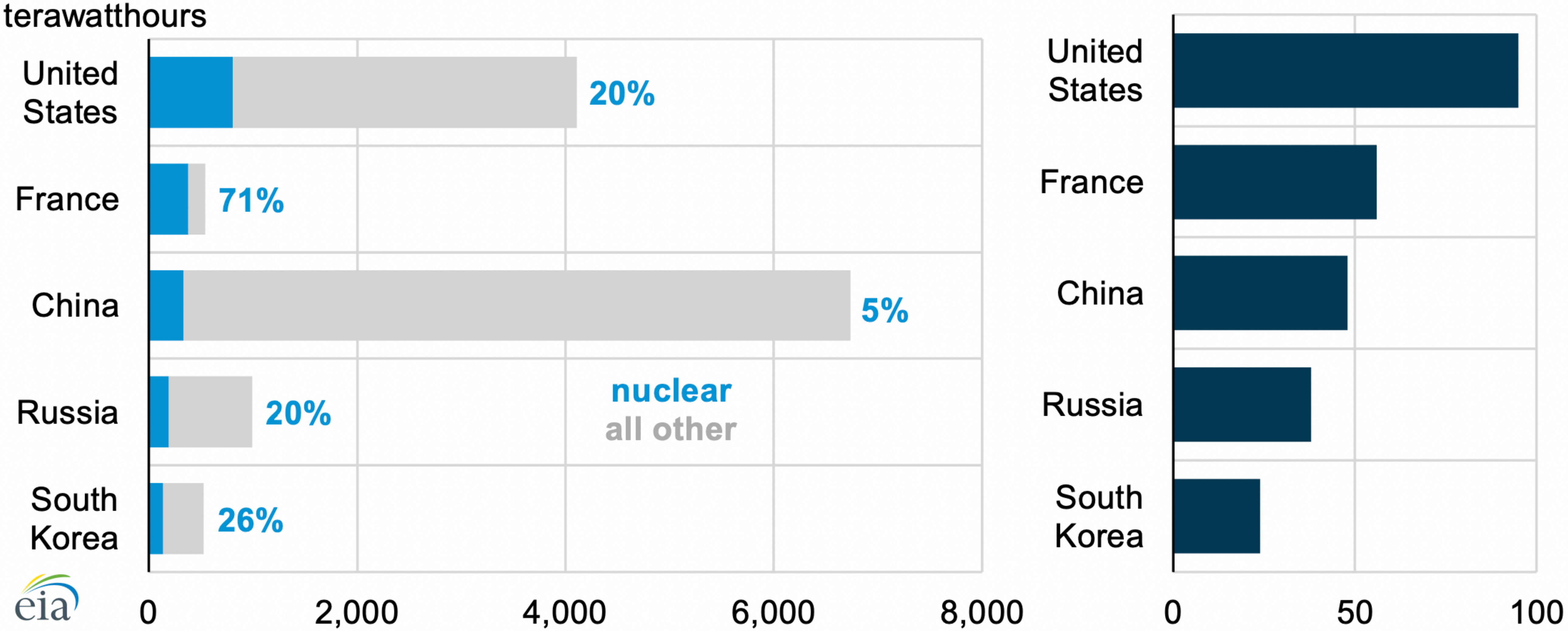
Hamburg, Germany

AUGUST 27, 2020 https://www.eia.gov

South Korea is one of the world's largest nuclear power producers

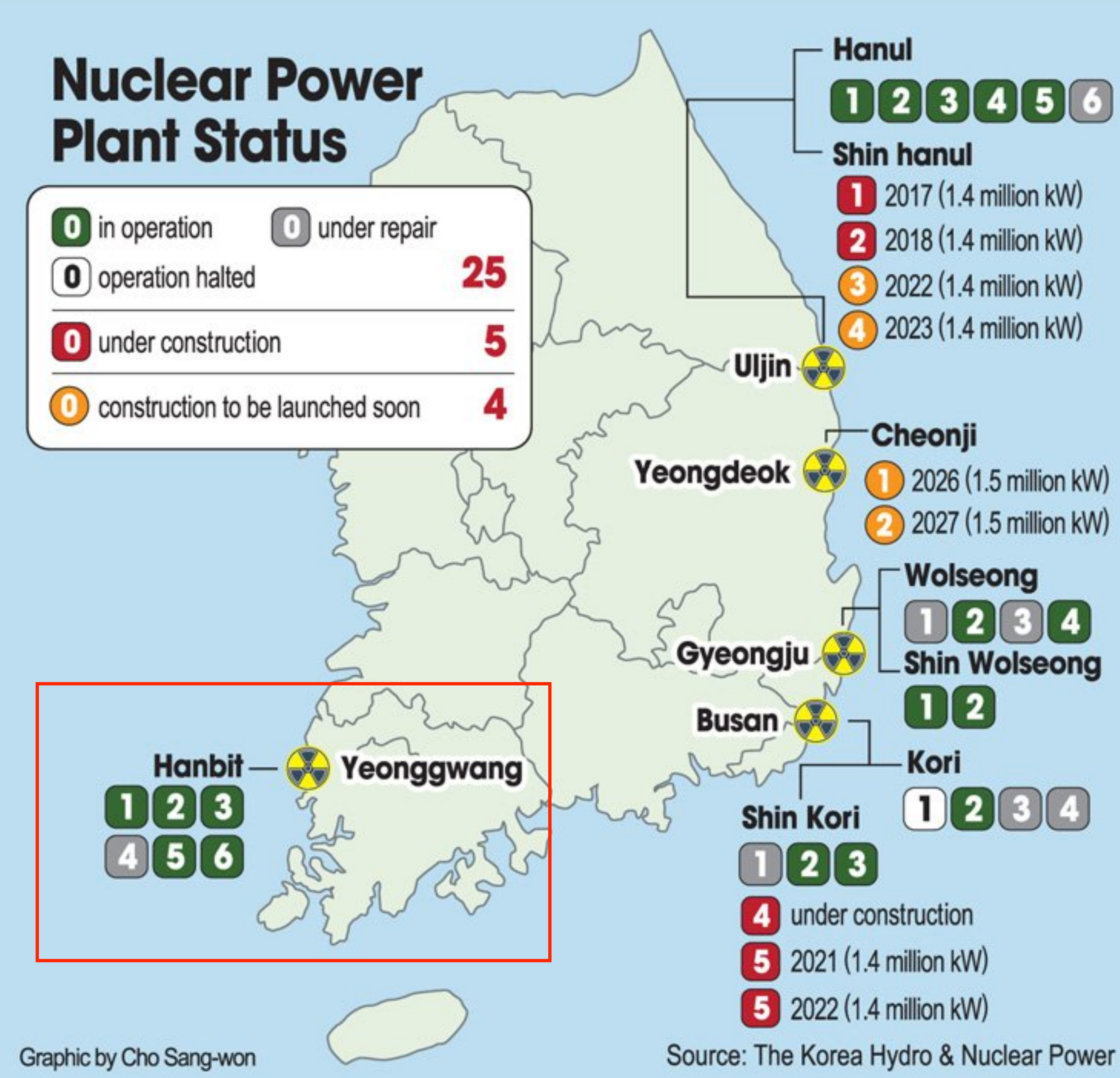
Share of total annual electricity generation from nuclear, top five nuclear power producers (2019)
terawatthours

Number of operational nuclear reactors (2020)



Source: International Atomic Energy Agency, Power Reactor Information System (IAEA-PRIS)

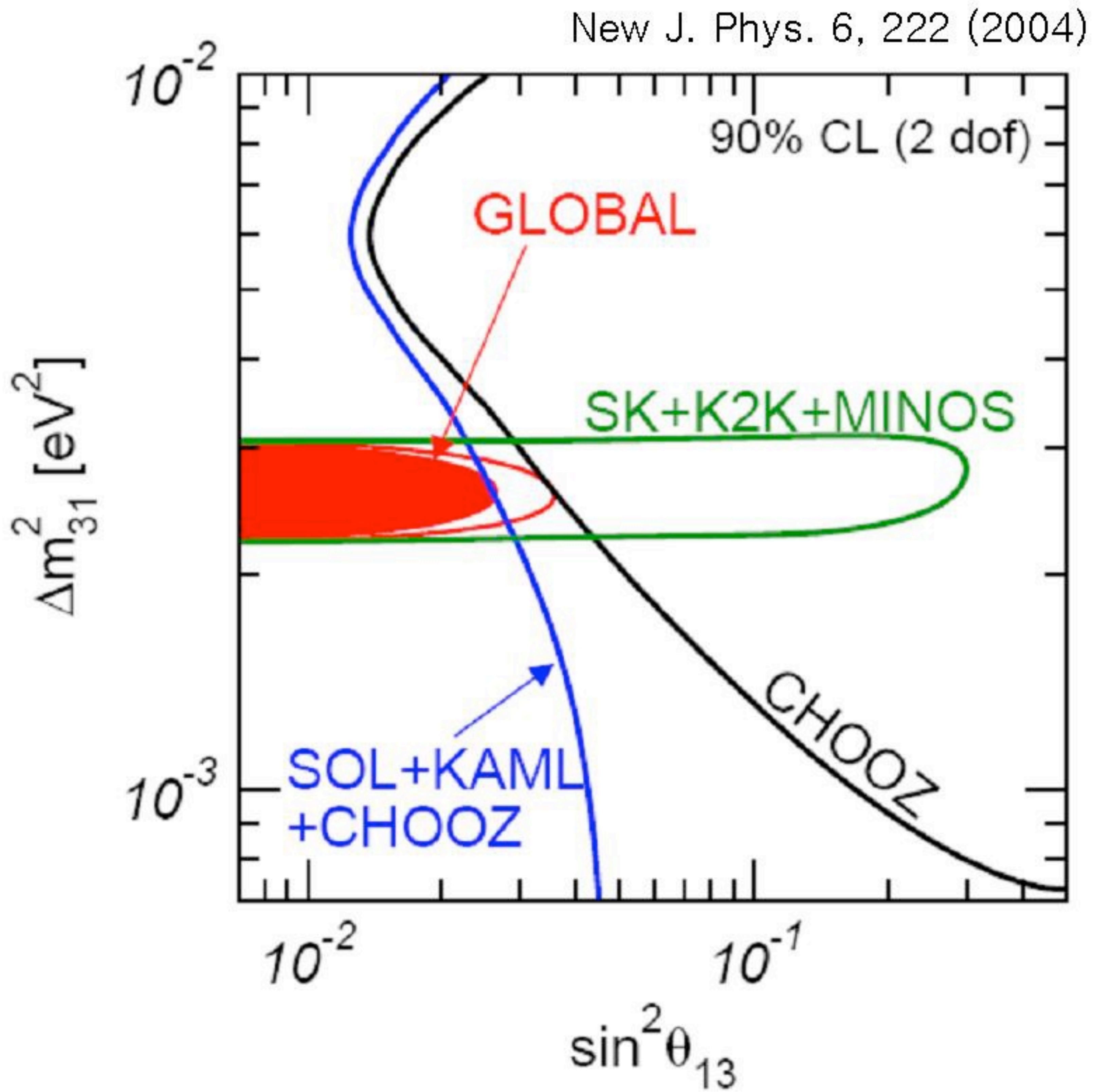
Nuclear Power Plants in South Korea



θ_{13} in 2004

θ_{13} might be extremely small (unknown)

"White paper report on using nuclear reactors to search for a value of θ_{13}*"* hep-ex/0402041 (2004)



Reactor Experiement for Neutrino Oscillation

RENO Institutions

- Chonbuk National University
- Chonnam National University
- Chung-Ang University
- GIST
- Dongshin University
- Gyeongsang National University
- KAIST
- Kyungpook National University
- Pusan National University
- Sejong University
- Seokyeong University
- Seoul National University
- Seoyeong University
- Sungkyunkwan University

Supporting Institution

- Hanbit Nuclear Power Plant
- Korea Hydro & Nuclear Power
- KISTI

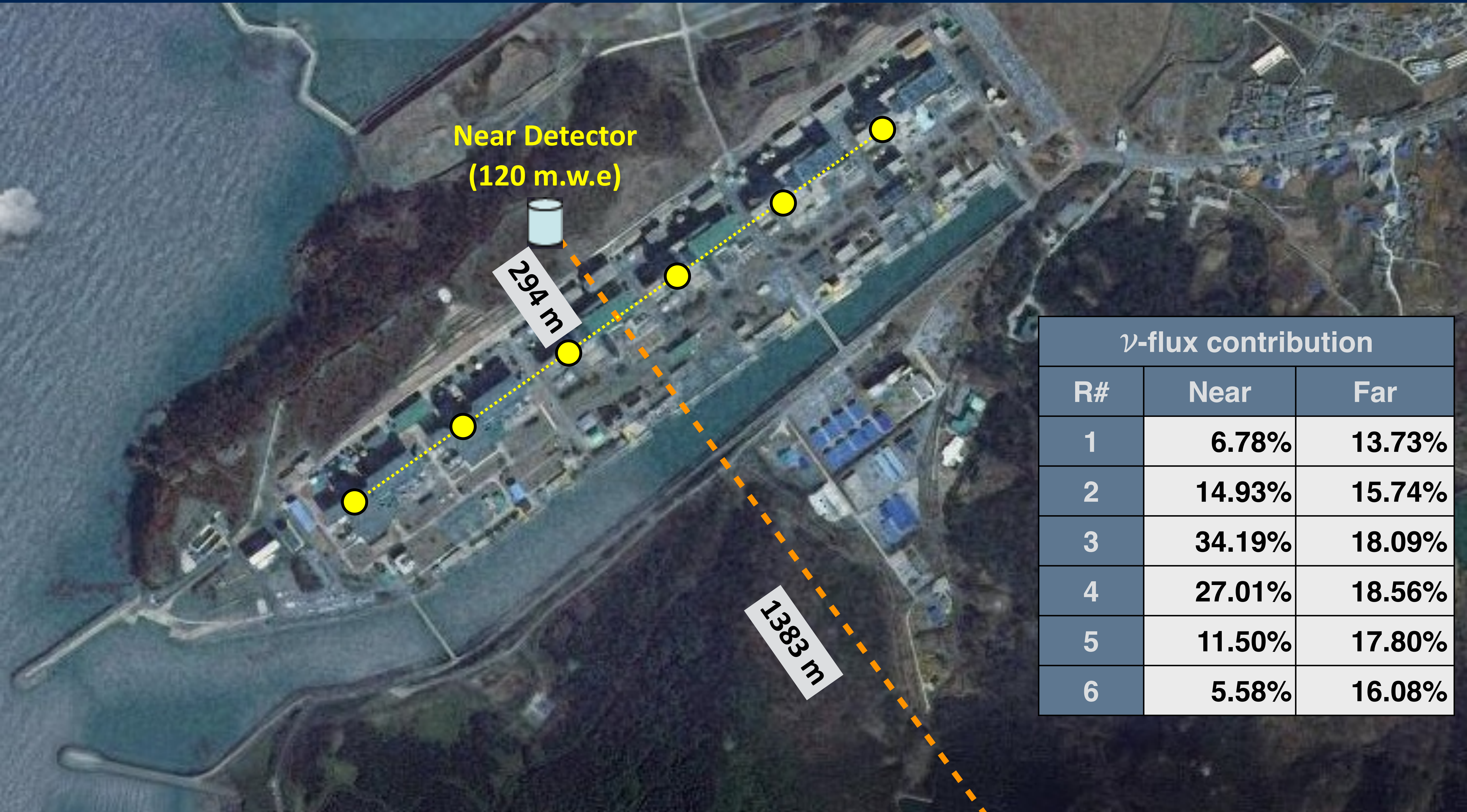
Funding Agency

- Korea Ministry of Science and ICT
- National Research Foundation of Korea

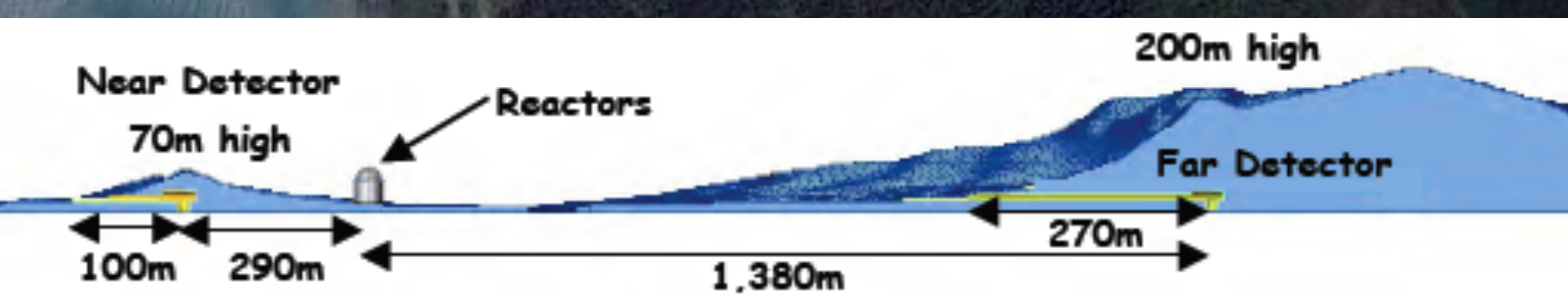

Proto-RENO (2004)


RENO Collaboration

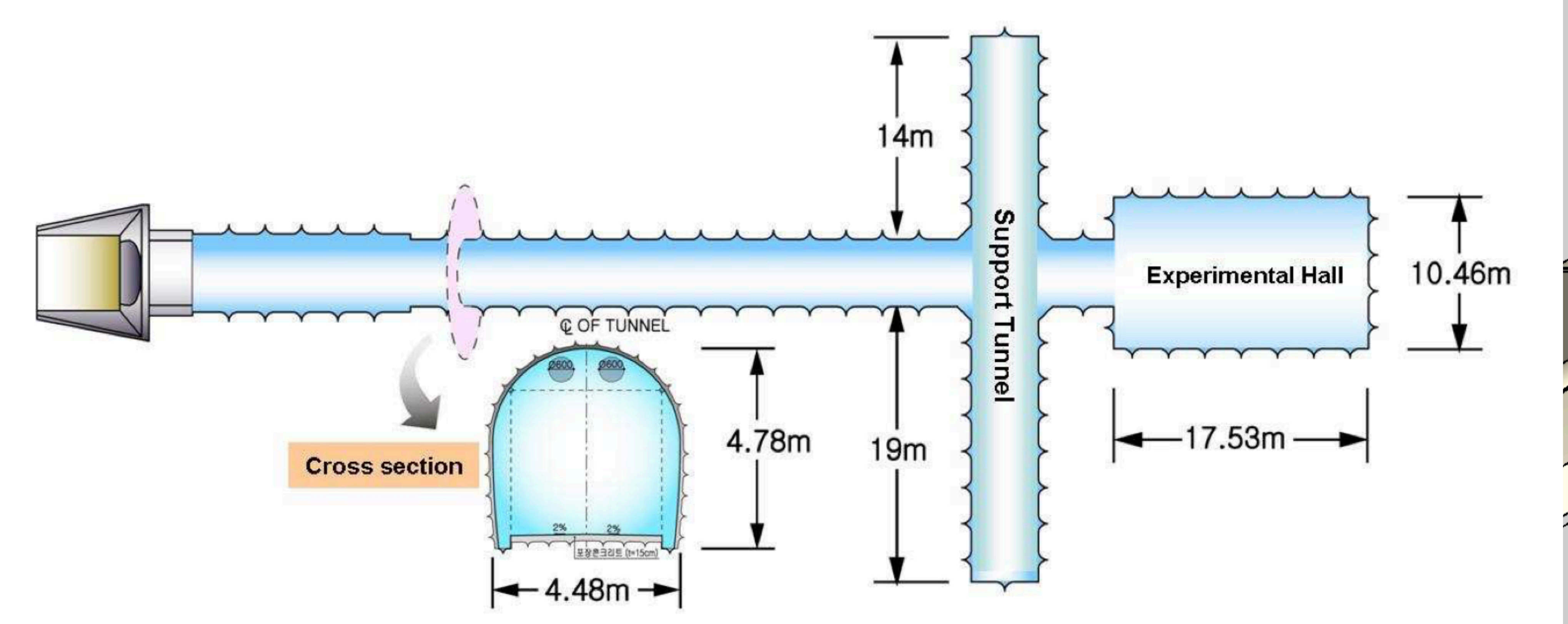
RENO Experimental Setup

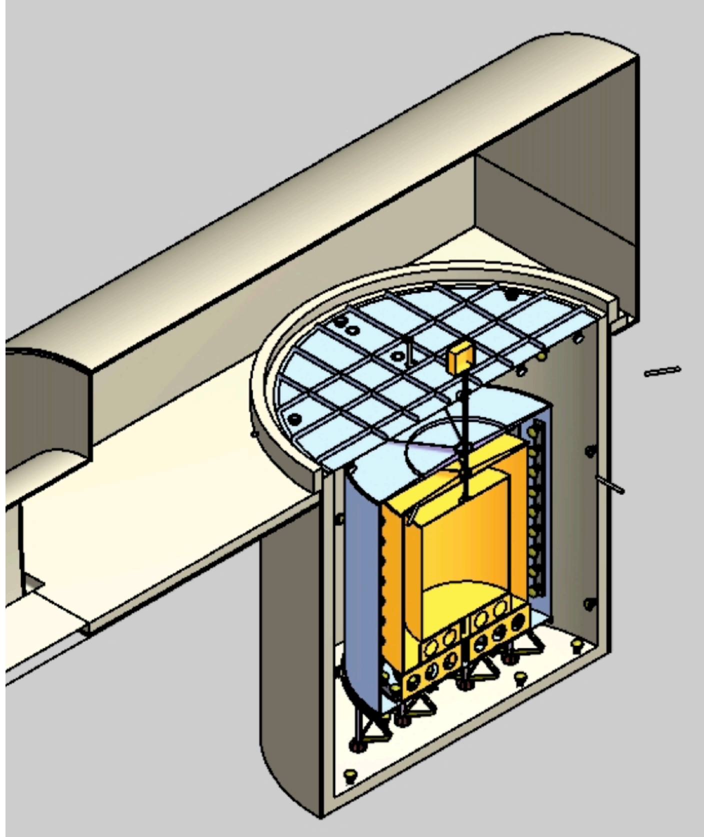


ν-flux contribution		
R#	Near	Far
1	6.78%	13.73%
2	14.93%	15.74%
3	34.19%	18.09%
4	27.01%	18.56%
5	11.50%	17.80%
6	5.58%	16.08%



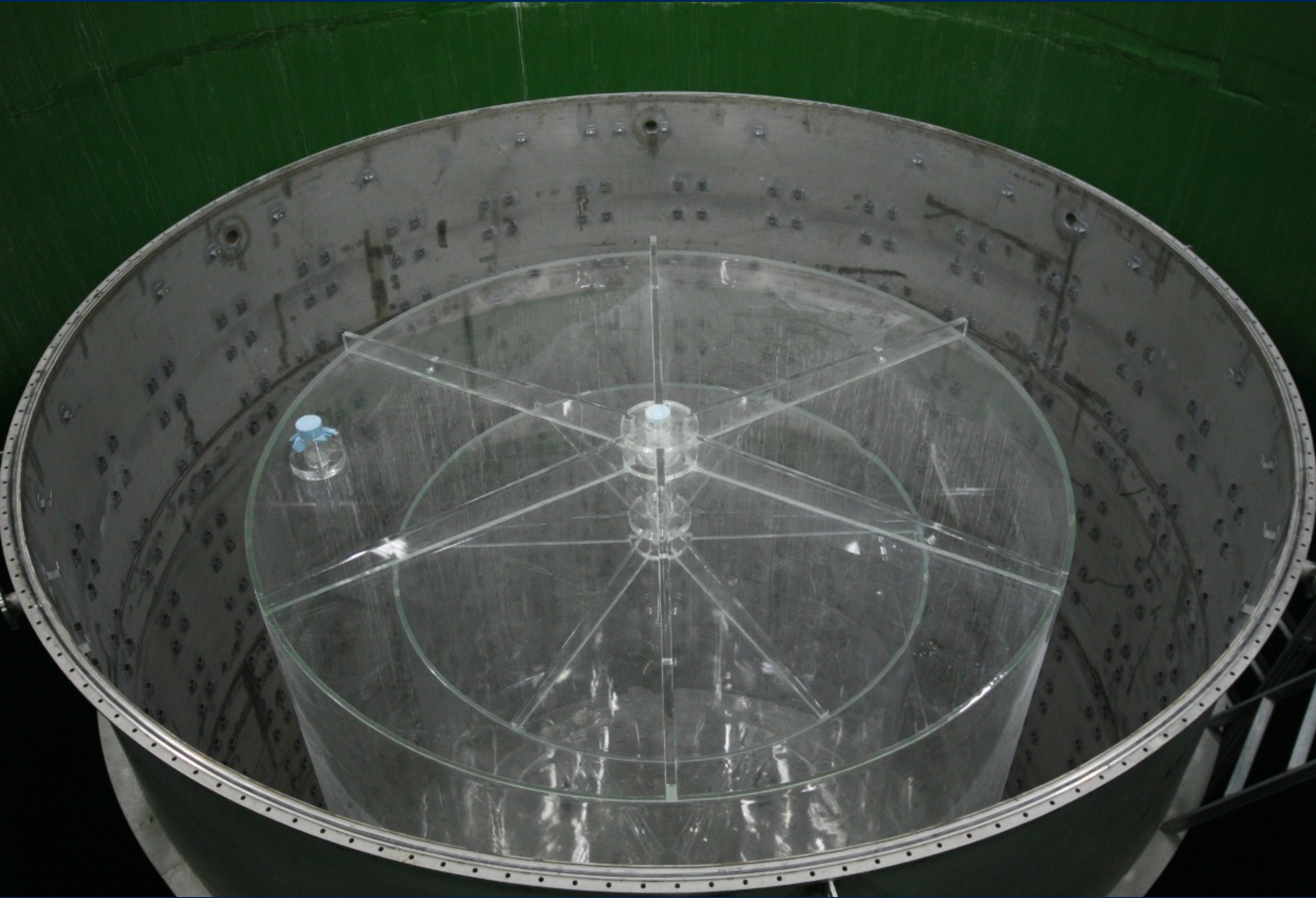
Near and Far Tunnels (Daewoo Eng. Co. 2008.6~2009.3)



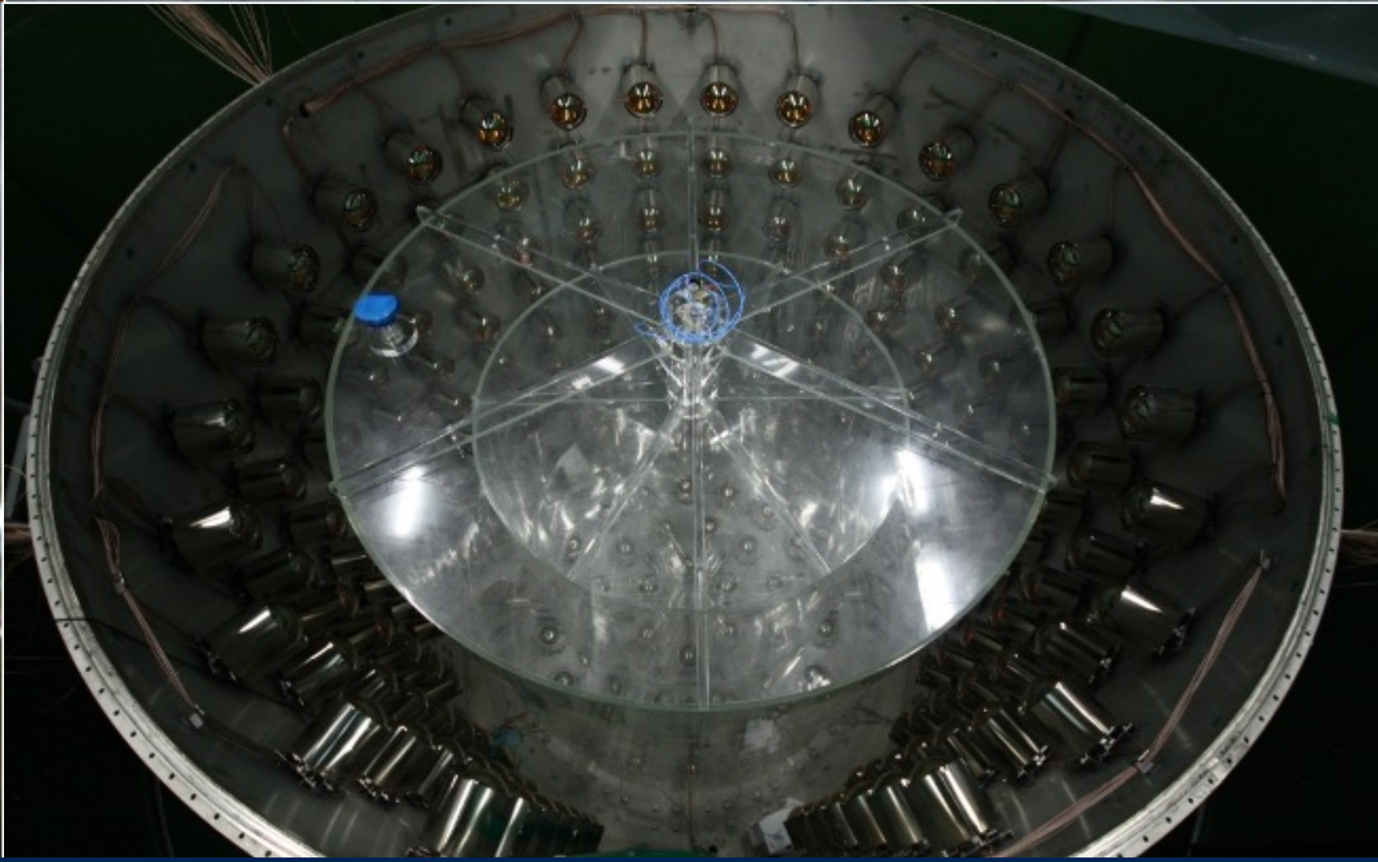


Acrylic Vessels (KOATECH Co. 2009.7~2010.6)

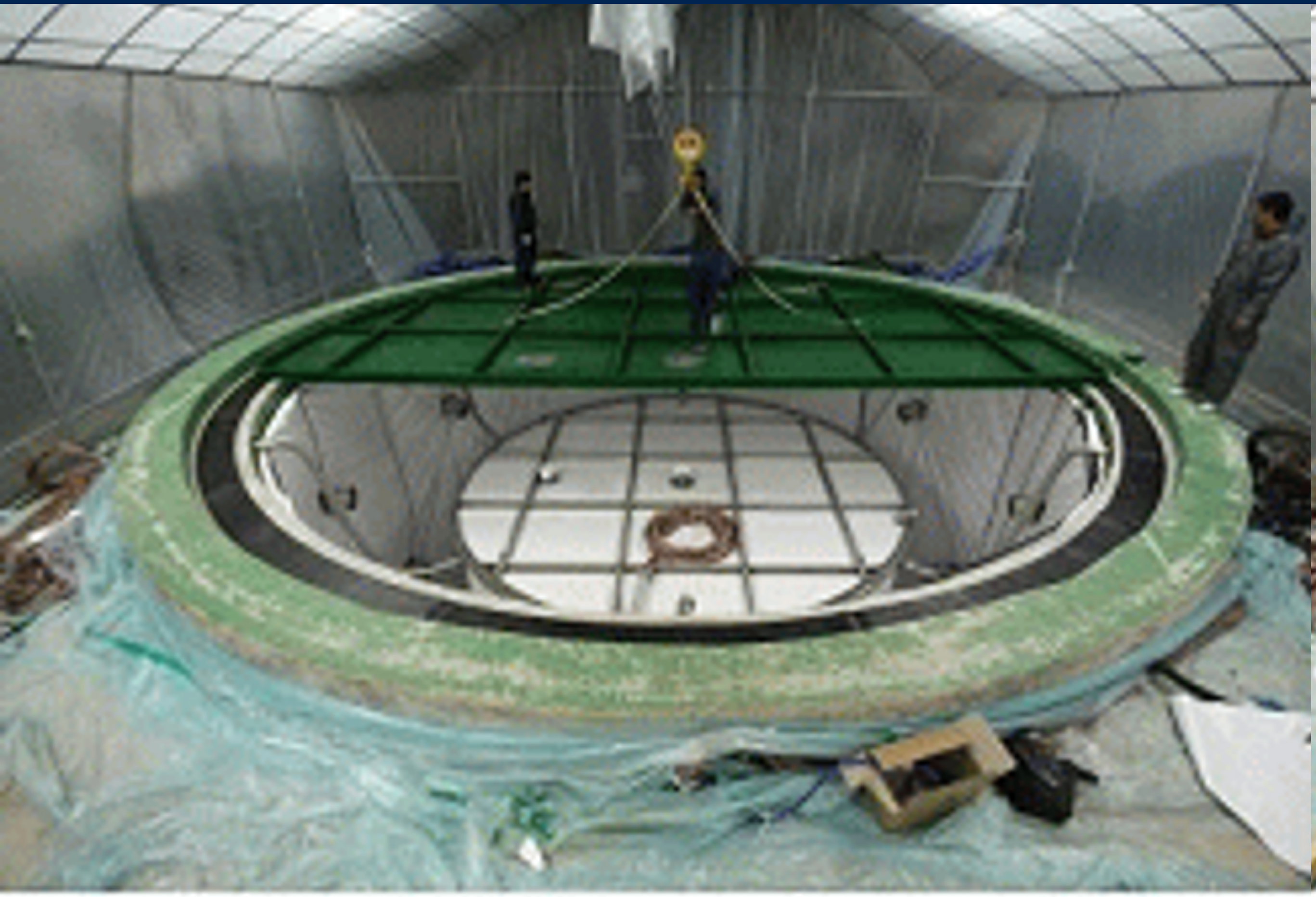
Stainless Steel Container (Geosan Co. 2010.6)

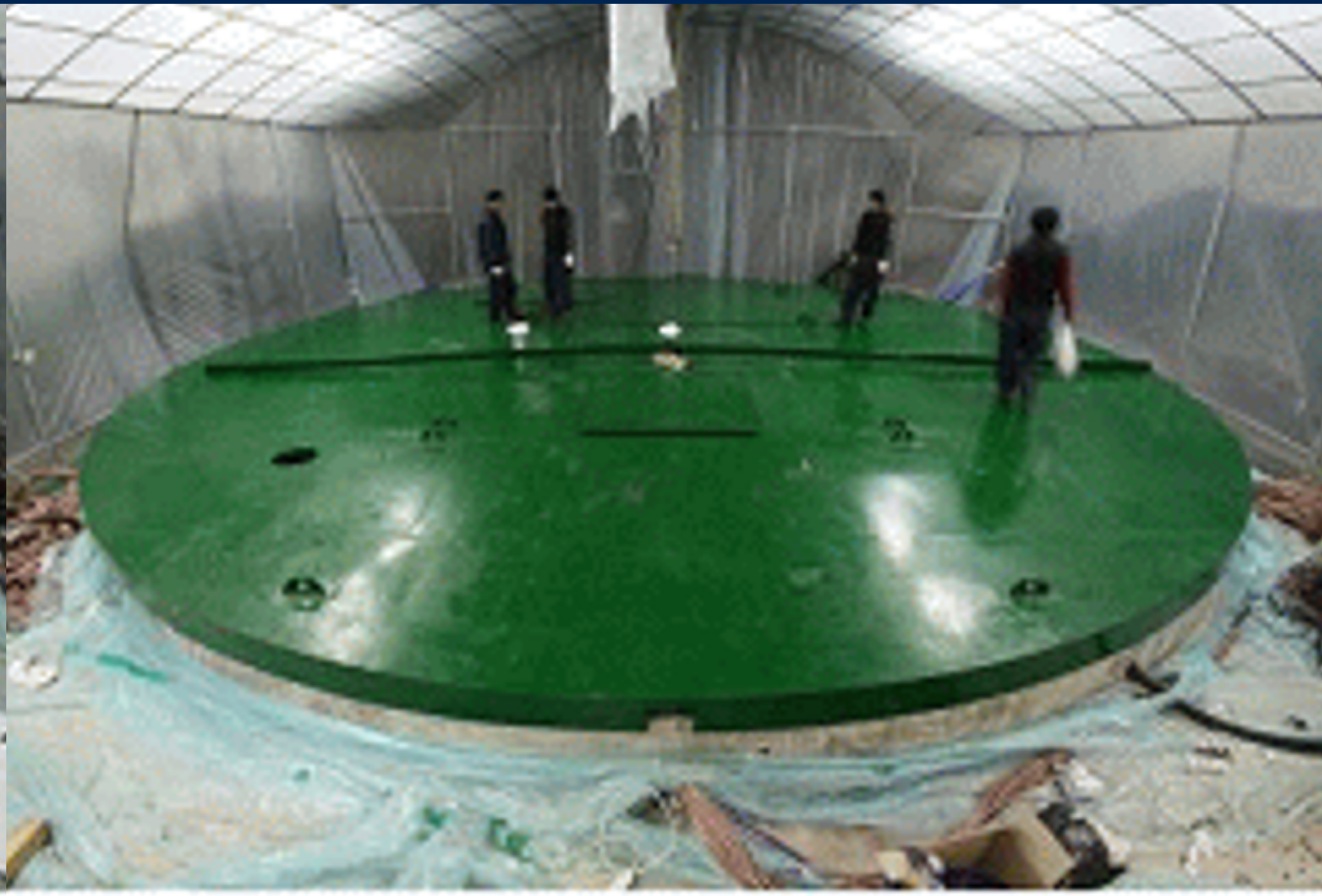


PMT Mounting (2010.8~2010)



Detector Closing (2011.1)





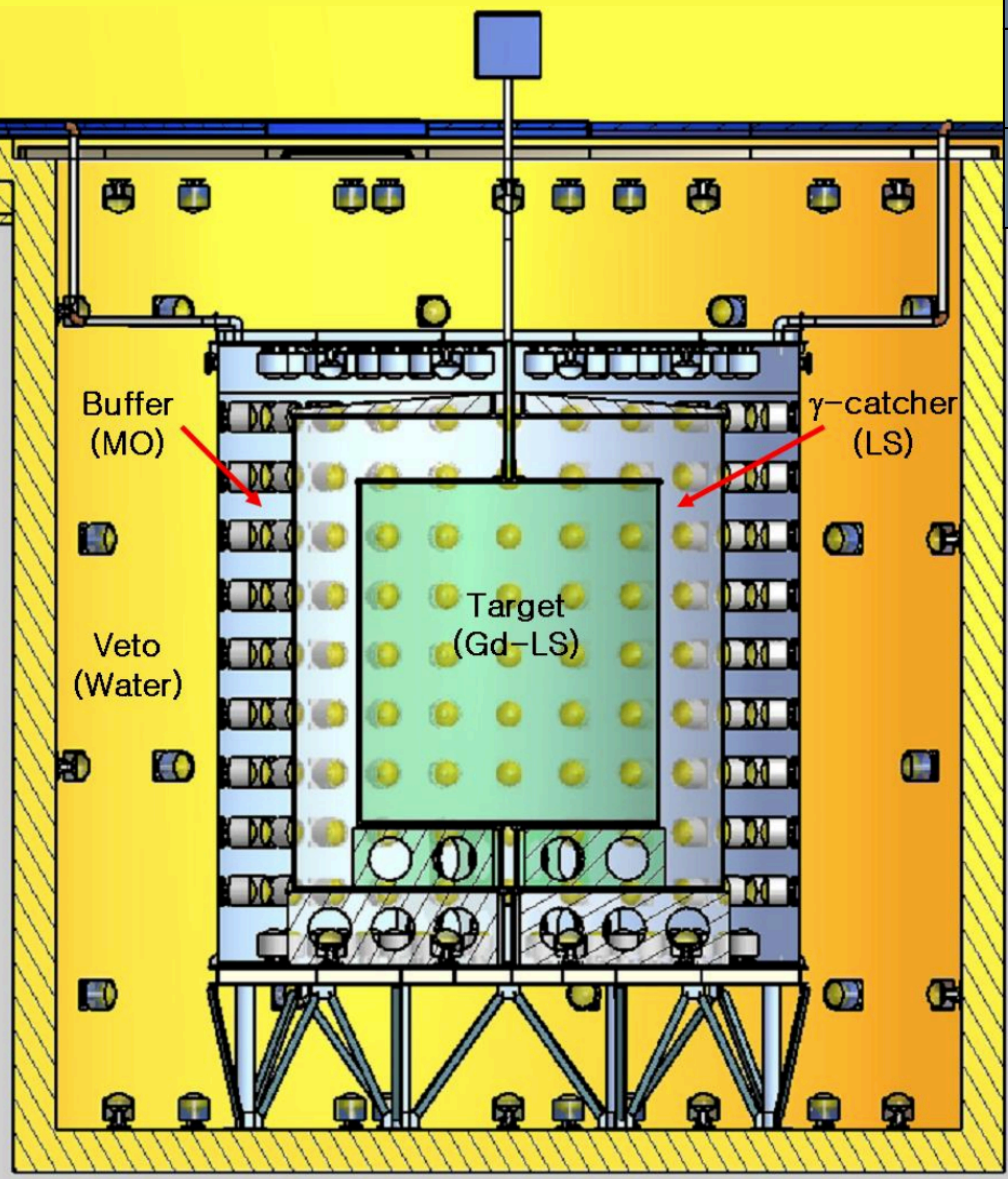
RENO Project Timeline

- **Site selection:** Nuclear complex at Yonggwang, Korea (2004)
- Formed **RENO collaboration** and proposal (2004)
- **Construction funding (~10M USD)** by Korea Ministry of Science and ICT (2006)
- Endorsement by local environmental activists (2006)
- Approval of using the land for detectors (2007)
- Permission of tunnel construction (2008)
- **Construction start** (2008)
- Complete detector construction (2011)
- **Commissioning (2011)**
- **Measurement of θ_{13} (2012)**

5-years from funding to θ_{13} measurement

RENO Detectors

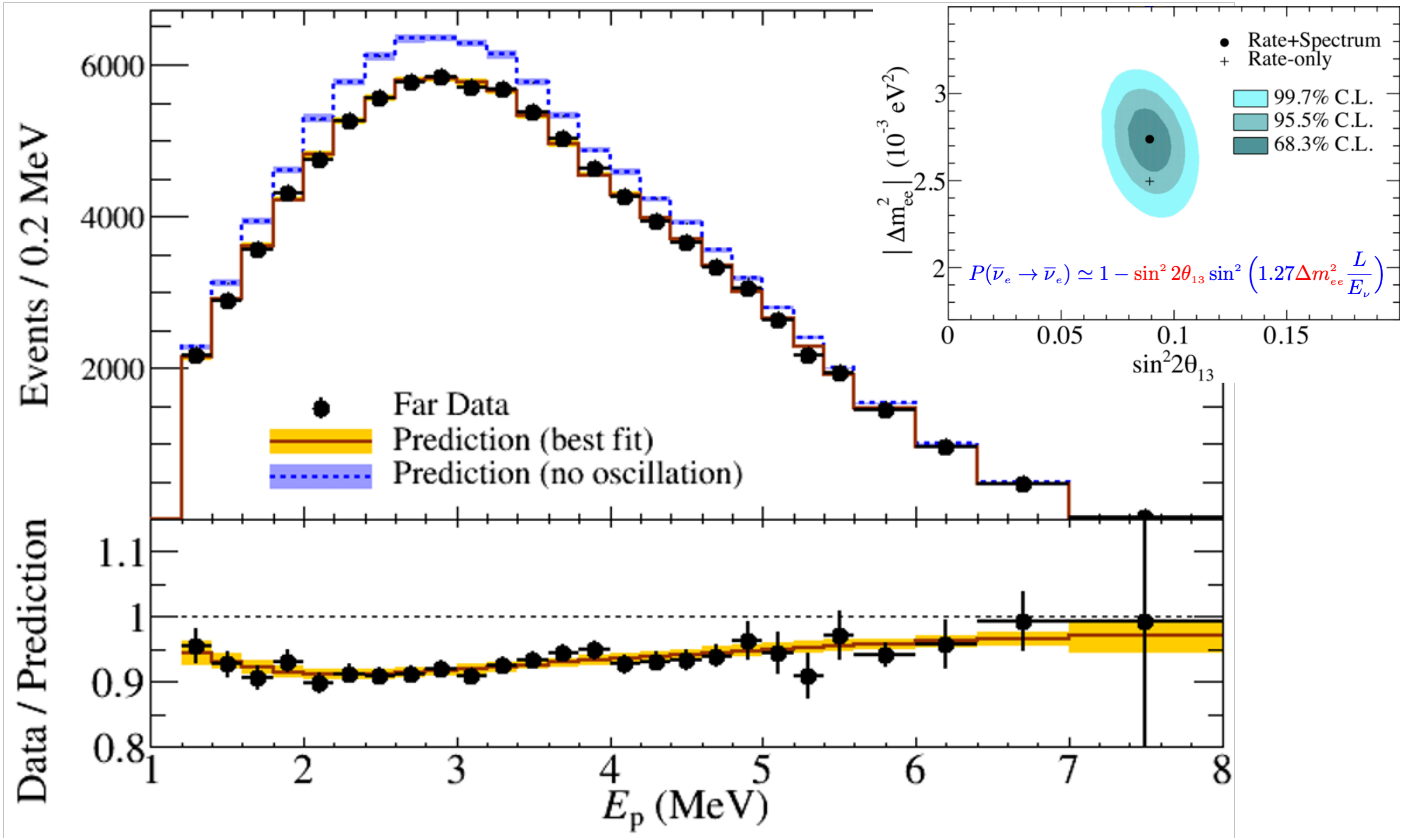
Identical detectors
at near and far sites



Detector	Material	Mass
IBD Target	Gd (0.1%)+LS	16.5 ton
Gamma Catcher	LS	30.0 ton
Buffer	Mineral oil	64.6 ton
Veto	Water	352.6 ton

354 ID PMTs and 67 OD PMTs
(10" HAMAMATSU R7081)

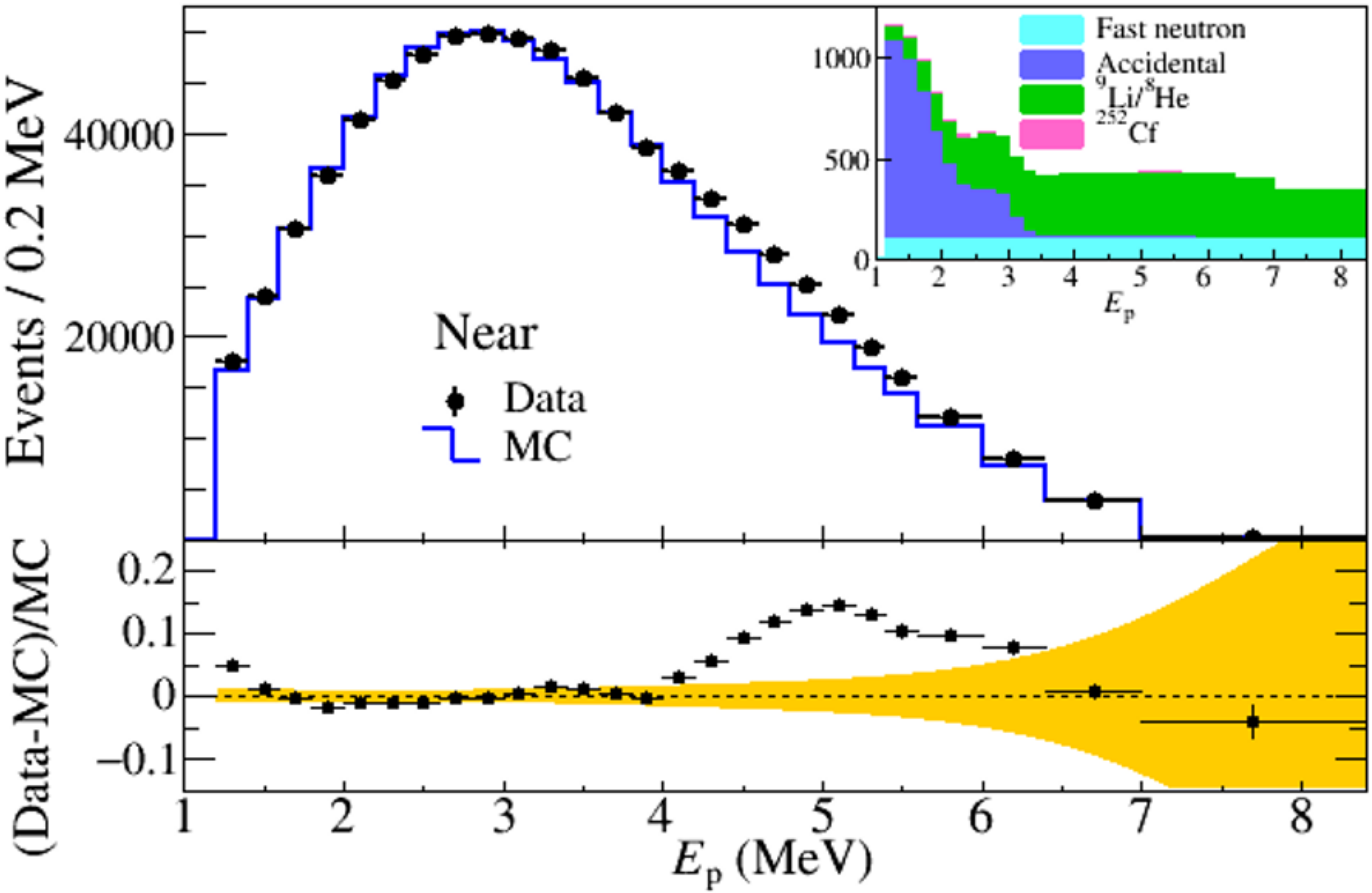
Measurement of $|m_{ee}|^2$ and θ_{13}



$$\sin^2\theta_{13} = 0.0896 \pm 0.0048\ (stat.)\ \pm\ 0.0048\ (syst.)\quad (\pm 7.6\%)$$

$$|\Delta m_{ee}|^2 = 2.68 \pm 0.12\ (stat.)\ \pm\ 0.07\ (syst.)\ [\times 10^{-3} eV^2]\quad (\pm 5.2\%)$$

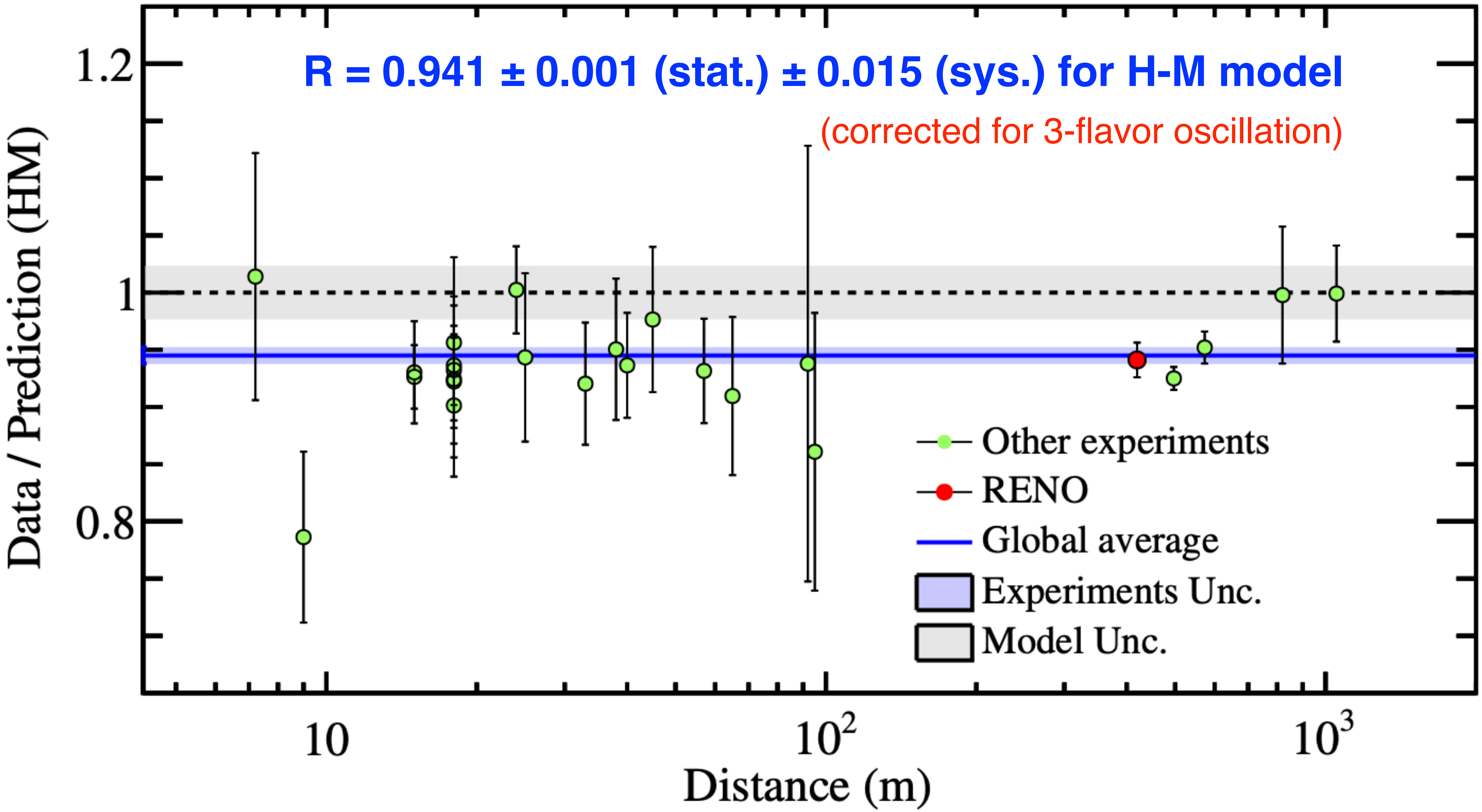
5 MeV Excess



Events / 0.2 MeV
40000
20000
Near
Data
MC
Fast neutron
Accidental
^{9}Li/^{8}He
^{252}Cf
1000
500
0
1 2 3 4 5 6 7 8
E_p
(Data-MC)/MC
0.2
0.1
0
−0.1
1 2 3 4 5 6 7 8
E_p (MeV)

Reactor Antineutrino Anomaly

PRD 104, L111301 (2021)

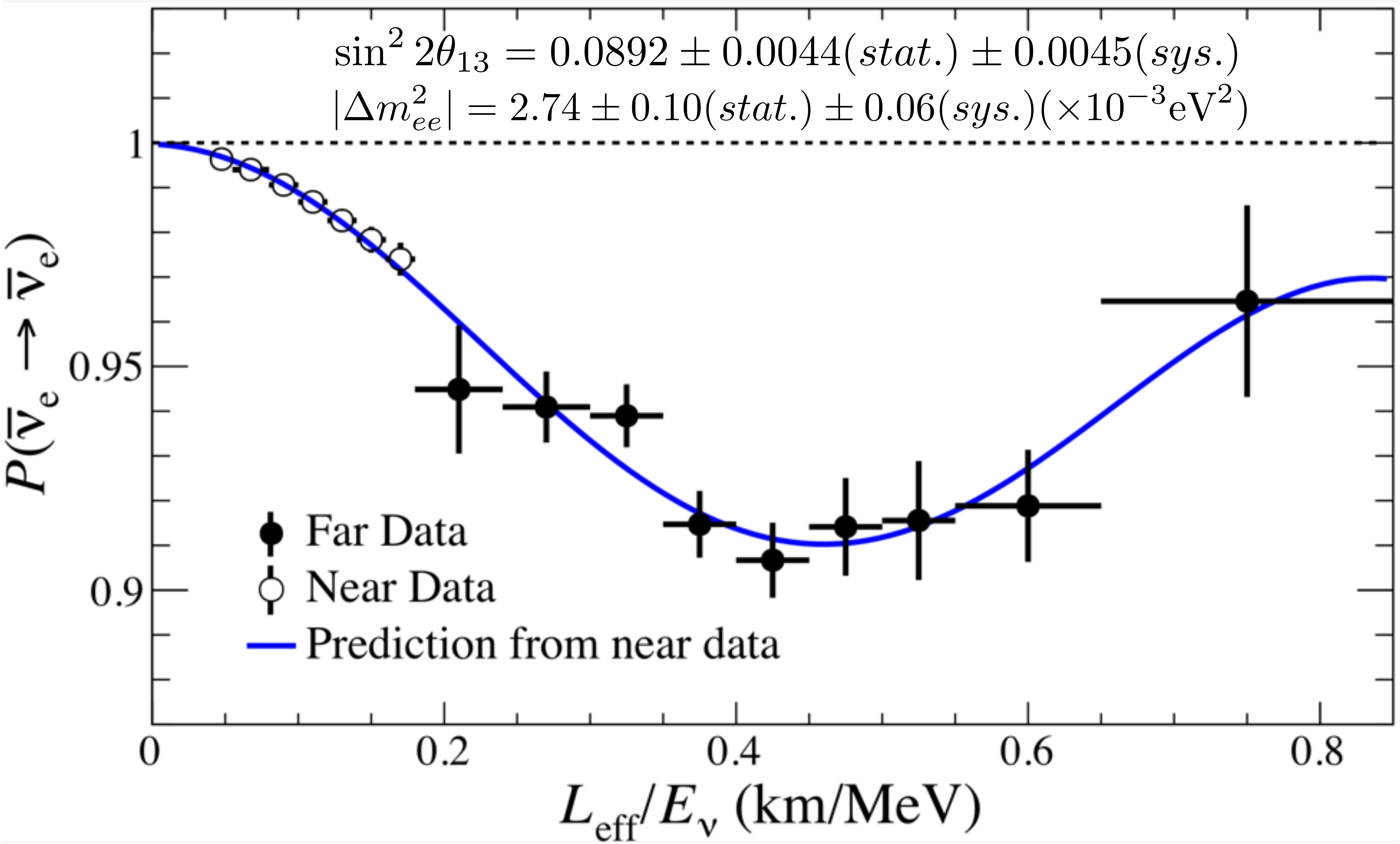


IBD yield: $\overline{y}_f = 5.852 \pm 0.124 (\times 10^{-43} \text{cm}^2/\text{fission})$

Average fission fraction: $\overline{F}_{235} : \overline{F}_{238} : \overline{F}_{239} : \overline{F}_{241} = 0.571 : 0.073 : 0.300 : 0.056$

Neutrino Oscillation: L/E Dependence

$$P(\overline{\nu}_e \to \overline{\nu}_e) \simeq 1 - \sin^2 2\theta_{13} \sin^2 \left(1.27\Delta m^2_{ee} \frac{L}{E_\nu}\right)$$



RENO Publications

- Observation of Reactor Electron Antineutrino Disappearance in the RENO Experiment
  Phys.Rev.Lett. 108 (2012) 191802
- Observation of Energy and Baseline Dependent Reactor Antineutrino Disappearance in the RENO Experiment
  Phys.Rev.Lett. 116 (2016) 21, 211801
- Measurement of neutrino mixing angle θ_{13} and mass difference from reactor antineutrino disappearance in the RENO experiment *Nucl. Phys. B 908 (2016) 94-115*
- Spectral Measurement of the Electron Antineutrino Oscillation Amplitude and Frequency using 500 Live Days of RENO Data *Phys.Rev.D 98 (2018) 1, 012002*
- Measurement of Reactor Antineutrino Oscillation Amplitude and Frequency at RENO
  Phys.Rev.Lett. 121 (2018) 20, 201801
- Fuel-composition dependent reactor antineutrino yield at RENO
  Phys.Rev.Lett. 122 (2019) 23, 232501
- Search for Sub-eV Sterile Neutrino at RENO
  Phys.Rev.Lett. 125 (2020) 19, 191801
- Observation of reactor antineutrino disappearance using delayed neutron capture on hydrogen at RENO
  JHEP 04 (2020) 029
- Measurement of Reactor Antineutrino Flux and Spectrum at RENO
  Phys.Rev.D 104, (2021) L111301
- Search for sterile neutrino oscillation using RENO and NEOS data
  Phys.Rev.D 105, (2022) L111101
- Measurement of cosmogenic 9Li and 8He production rates at RENO
  Phys.Rev.D 106, (2022) 012005
- Coming-up: nH interactions, Fuel decomposition, RENO 3800-days data analysis ...

The 2023 **EPS High Energy and Particle Physics Prize** is awarded to **Cecilia Jarlskog** for the discovery of an invariant measure of CP violation in both quark and lepton sectors; and to the members of the **Daya Bay and RENO collaborations** for the observation of short-baseline reactor electron-antineutrino disappearance, providing **the first determination of the neutrino mixing angle Θ_{13}**, which **paves the way for the detection of CP violation in the lepton sector.**

$$J \equiv s_{13} c_{13}^2 s_{12} c_{12} s_{23} c_{23} \sin \delta$$

Thank you!