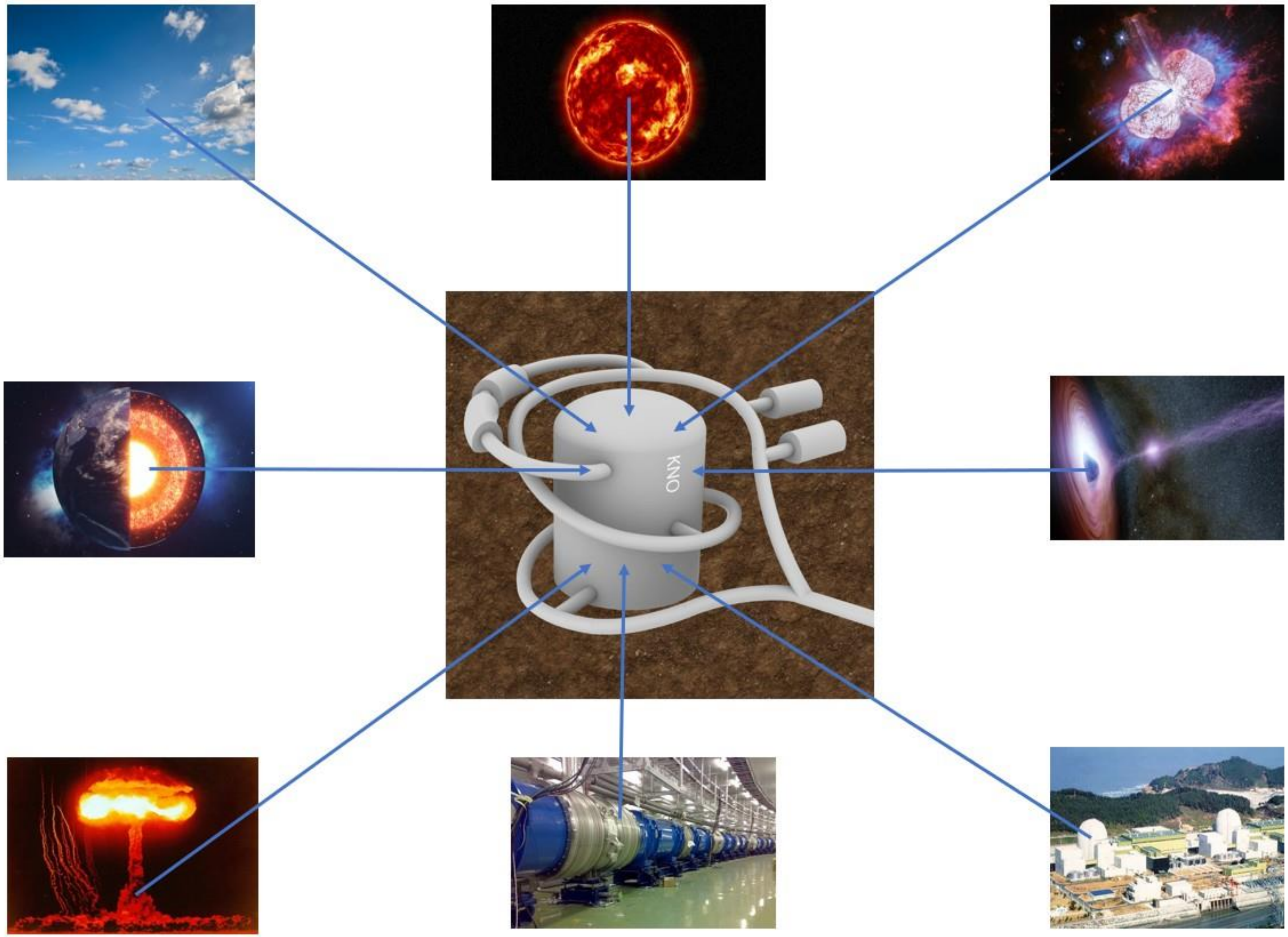
Korea Neutrino Observatory (KNO)

Intae Yu

Sunkyunkwan University

Dec. 4, 2020

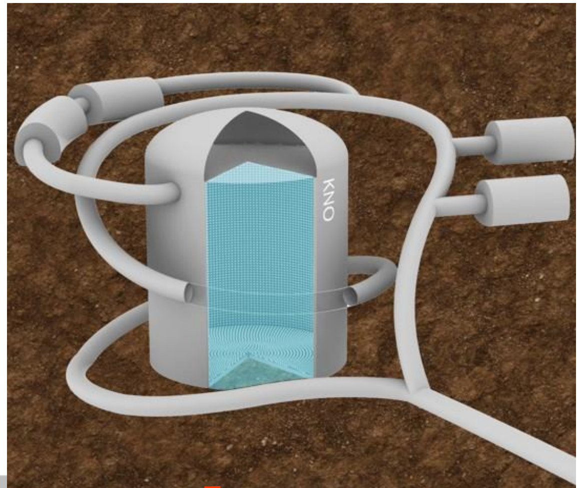
KNO Science



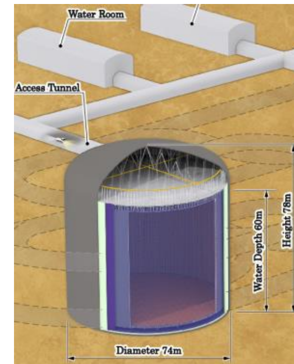
Far Detector to J-PARC beam

KNO

>0.26Mt ?



~1.5 deg. off axis

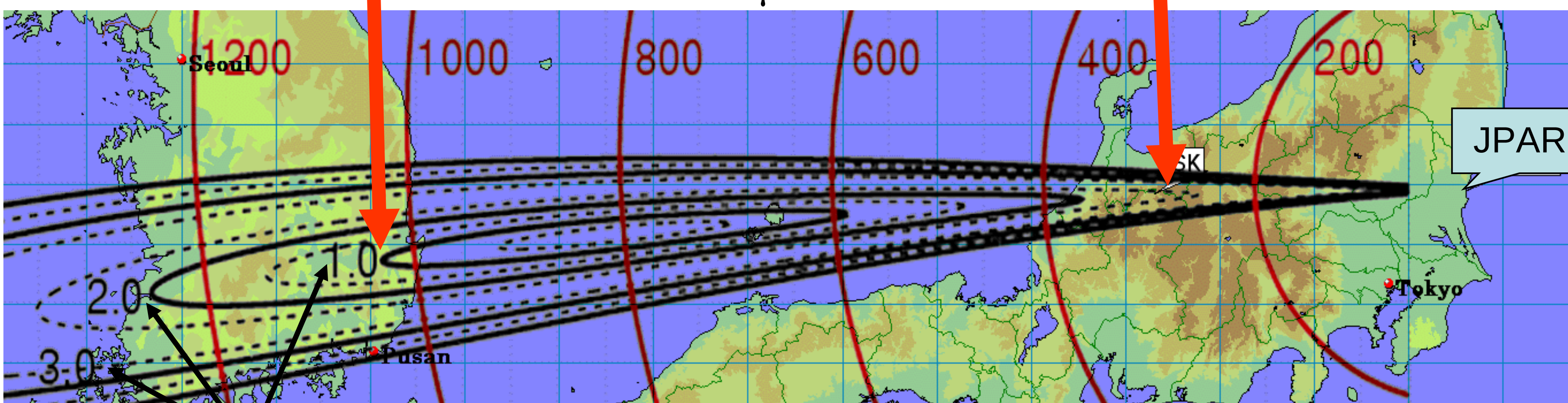


Hyper-K

0.26Mt

2.5 deg. off axis

The J-PARC ν_μ beam comes to Korea.



Off-axis angle

see hep-ph/0504061

By K. Hagiwara, N. Okamoura, K. Senda

Pros and Cons of KNO

☐ Pros

- 1st and 2nd oscillation maxima at KNO → more sensitive to leptonic CP violation

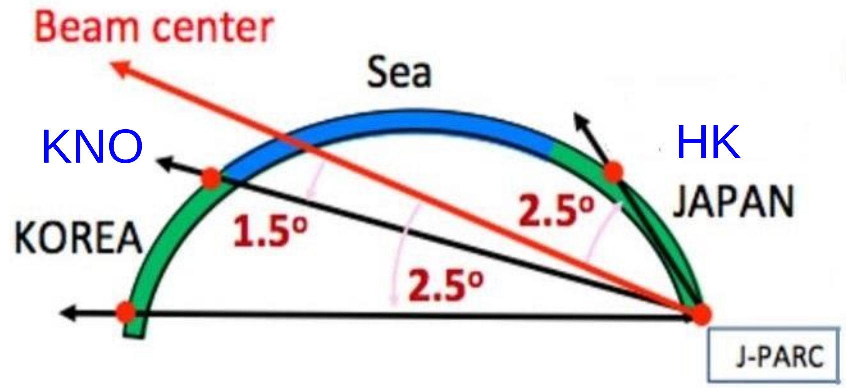
- Higher mass density and longer baseline (~1100 km)
  → better determination of neutrino mass hierarchy and better sensitivity to non-standard neutrino interactions

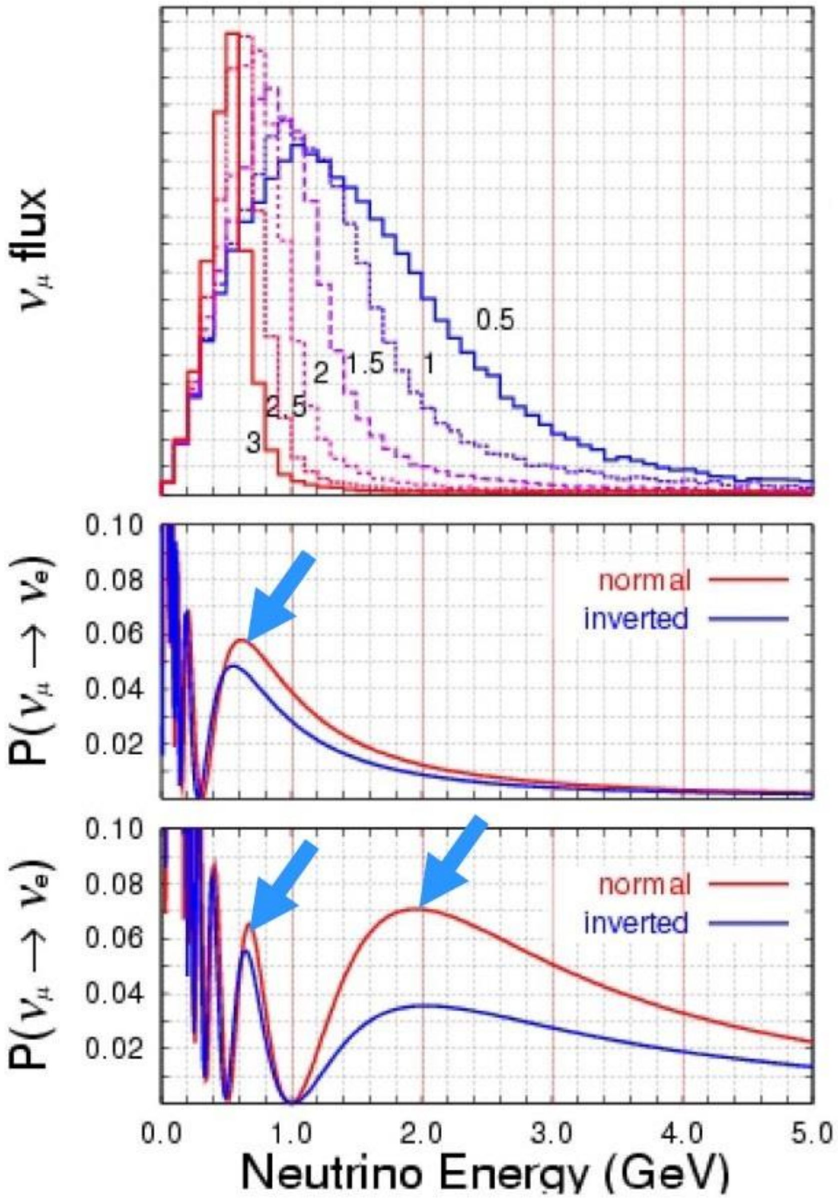
- Larger overburden (~1000 m) → better sensitivity to neutrinos of astronomical origin (solar/SN/galactic..)

☐ Cons

- Neutrino beam flux at KNO is ~ 10 times smaller than HK flux due to longer baseline
- Construction may start later than HK

Neutrino Oscillations in KNO & Kamioka





← Profile of off-axis beams

← $P(\nu_\mu \rightarrow \nu_e)$ at SK

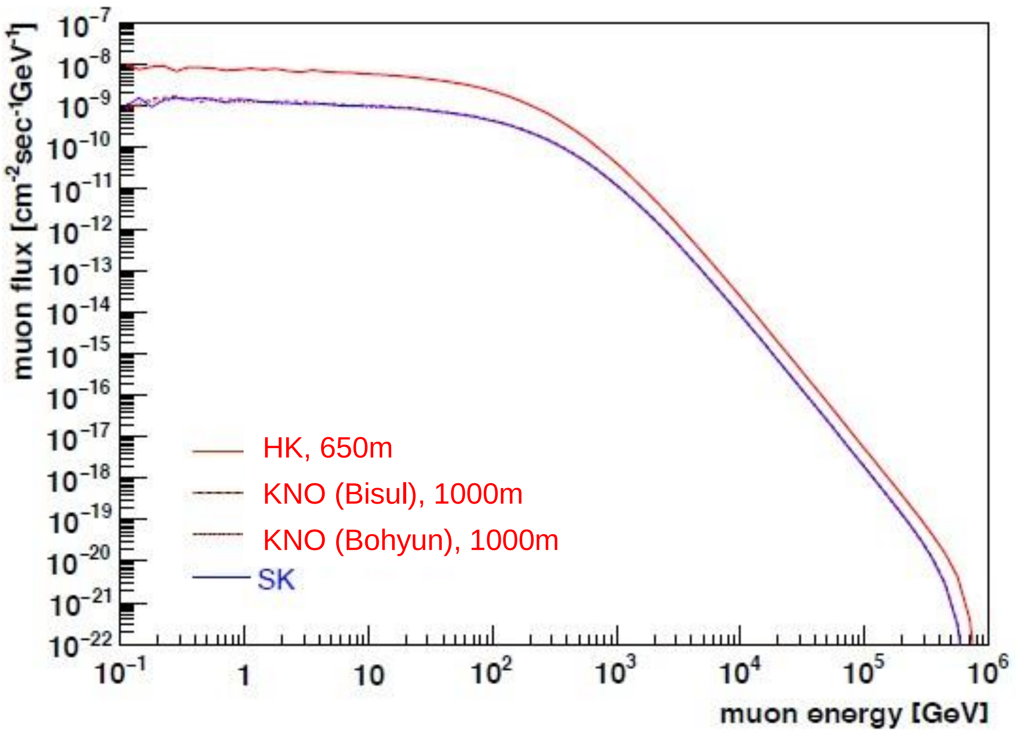
(L=300 km) → 1st osc. max. only

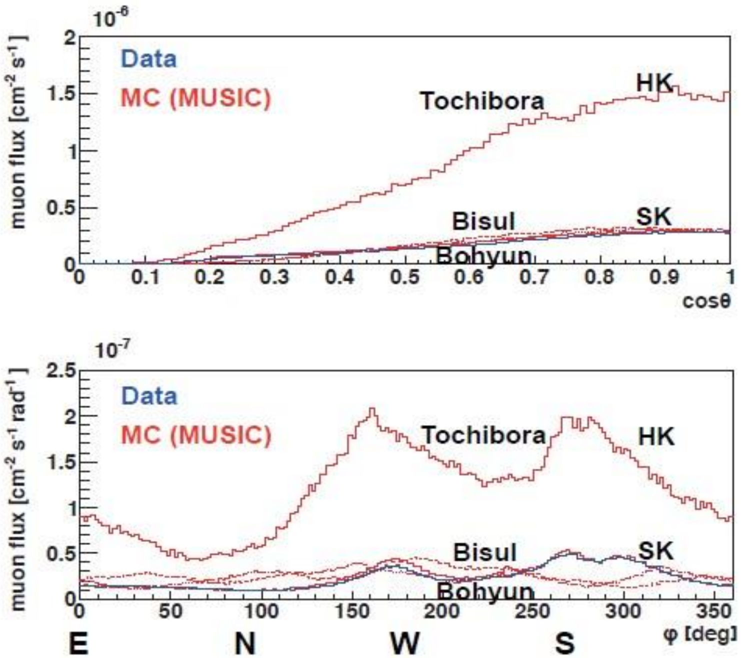
← $P(\nu_\mu \rightarrow \nu_e)$ at Korea

(L=1100 km) → 1st and 2nd osc. max.

Cosmogenic Muon Flux

- Overburden of KNO site ~ 1000 m (HK: 650 m)
- Muon flux at KNO is 5 times smaller than HK flux
  → less cosmogenic backgrounds
  → better sensitivity to astrophysical neutrinos



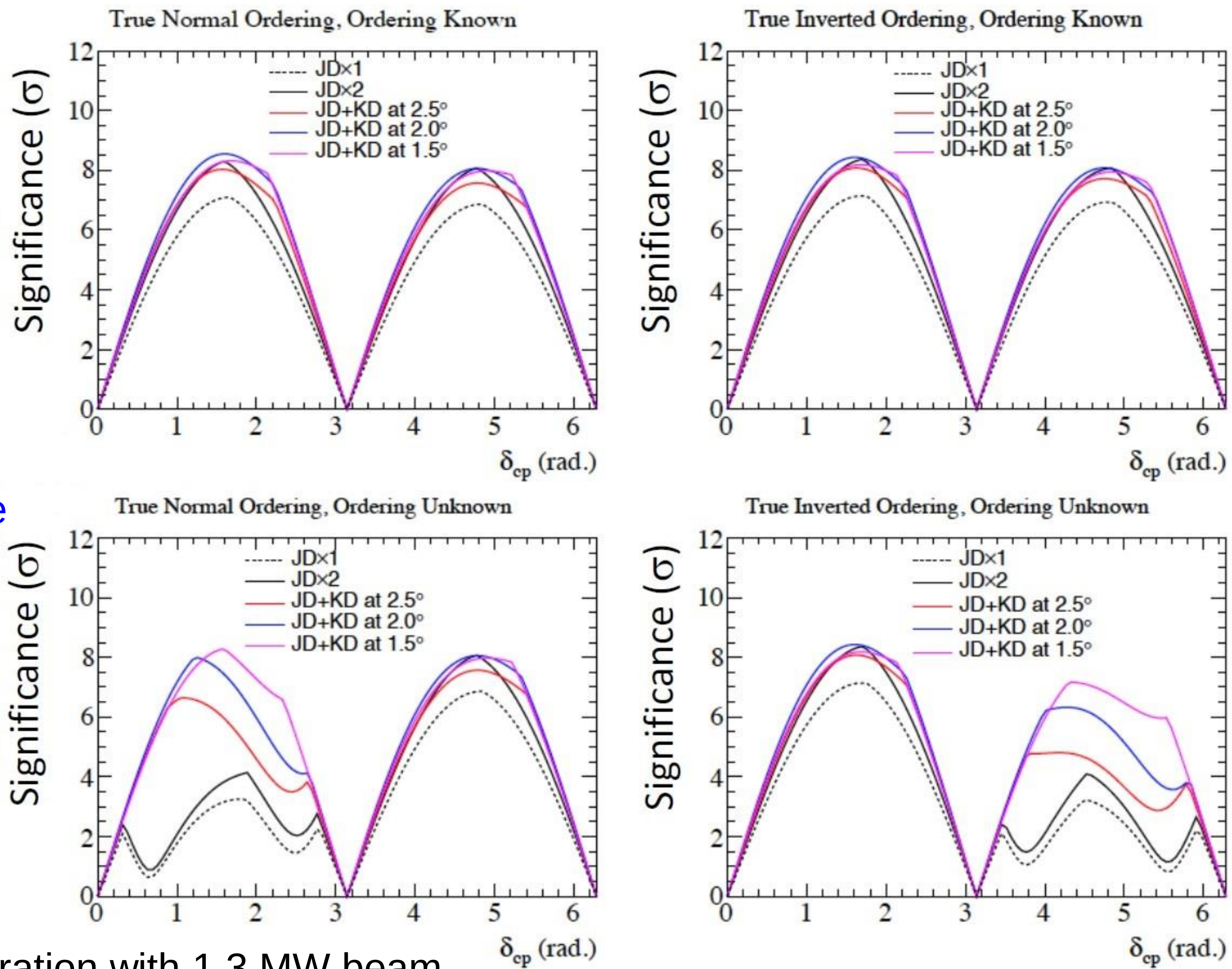


Physics Potential at KNO: δ_{cp}

Known MO

Unknown MO

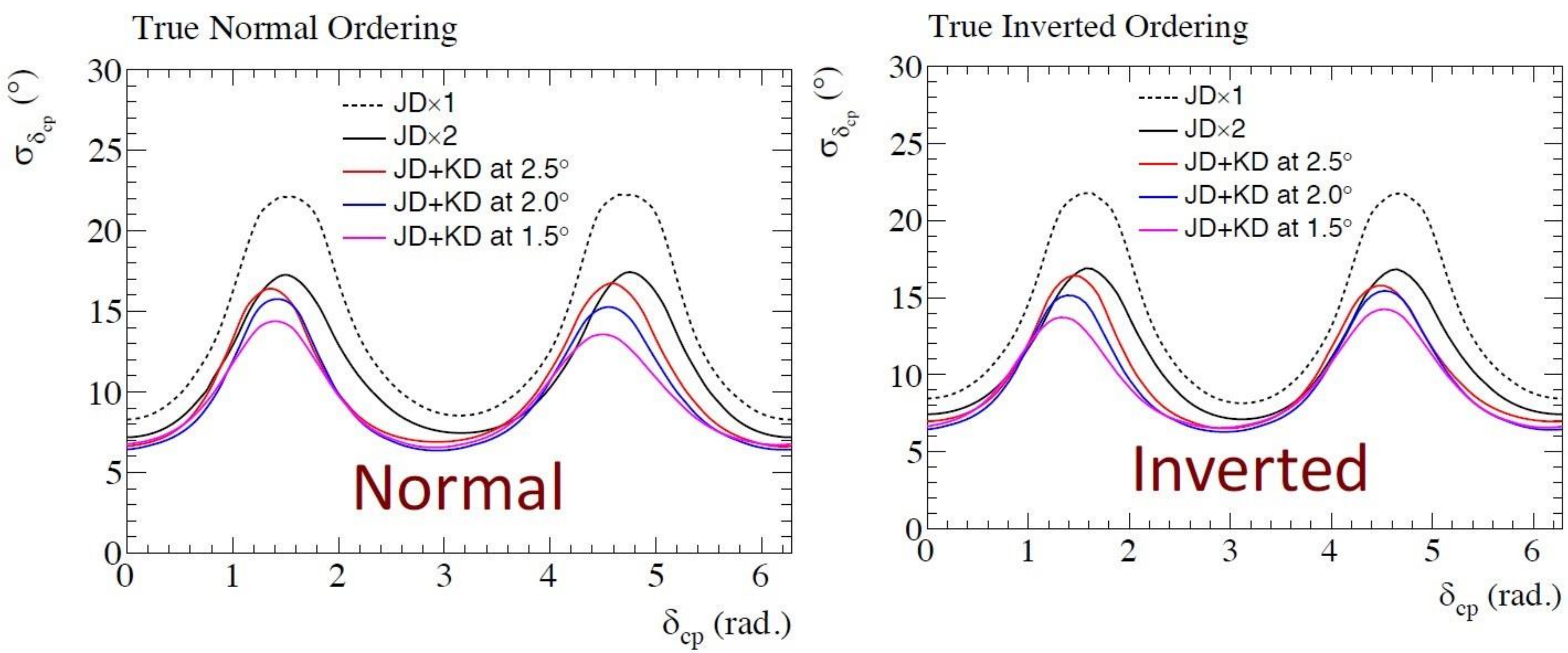
KNO, HK
0.26 Mton
40% coverage



10 years of operation with 1.3 MW beam

Physics Potential at KNO: δ_{cp} Precision

→ Very important for flavor symmetry model of neutrino mixing
S. Petcov in ICHEP 2018

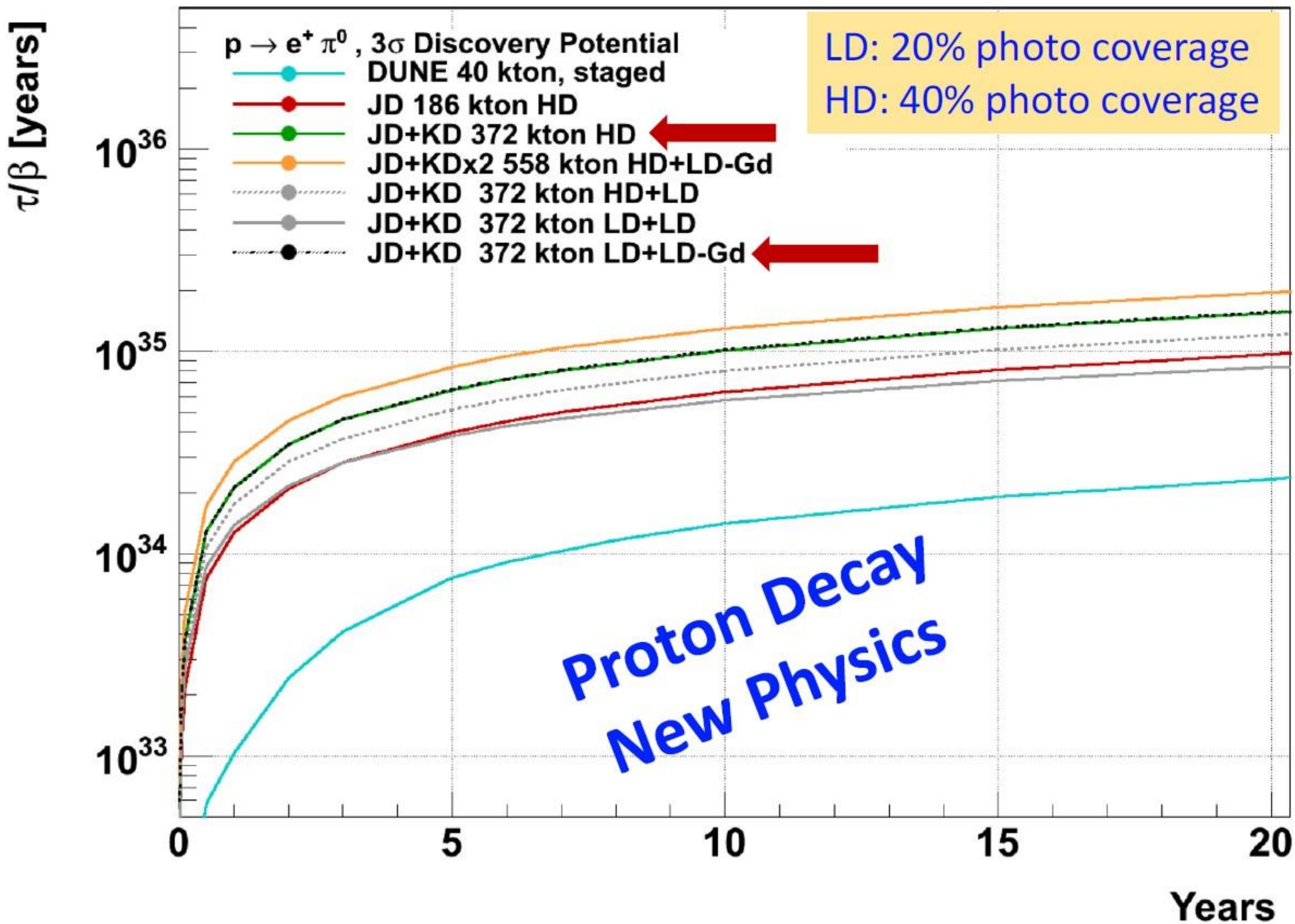


KNO, HK
0.26 Mton
40% coverage

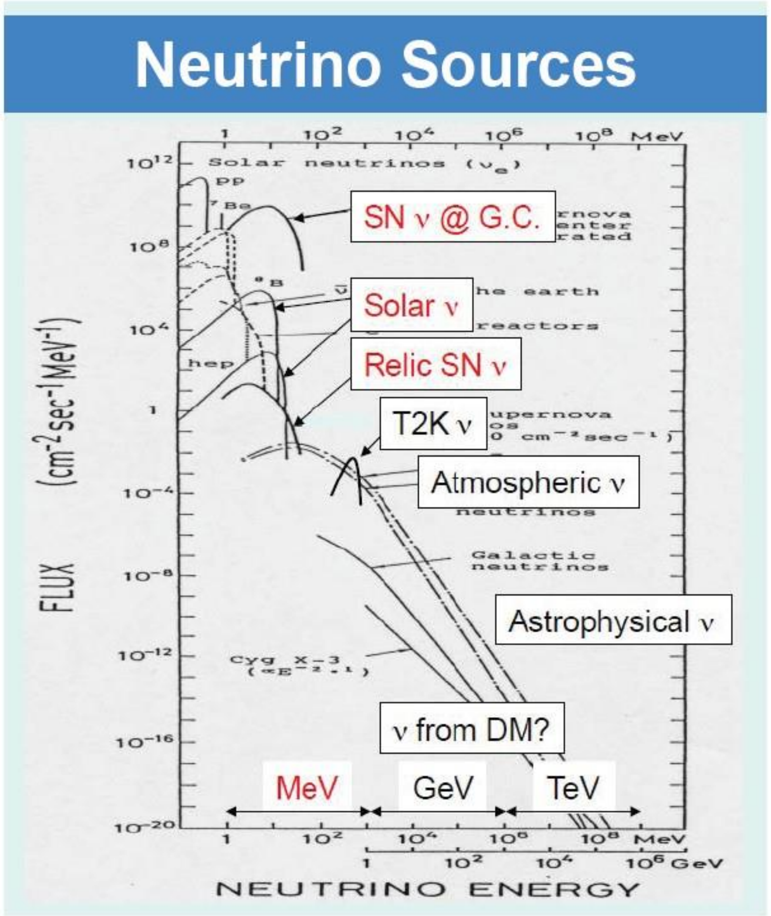
At maximum CP violation: JD+KD 1.5°: $\sigma(\delta_{CP})$ = 13~14 degree
JD x 2 : $\sigma(\delta_{CP})$ ~ 17 degree
JD x 1 : $\sigma(\delta_{CP})$ ~ 22 degree

10 years of operation with 1.3 MW beam

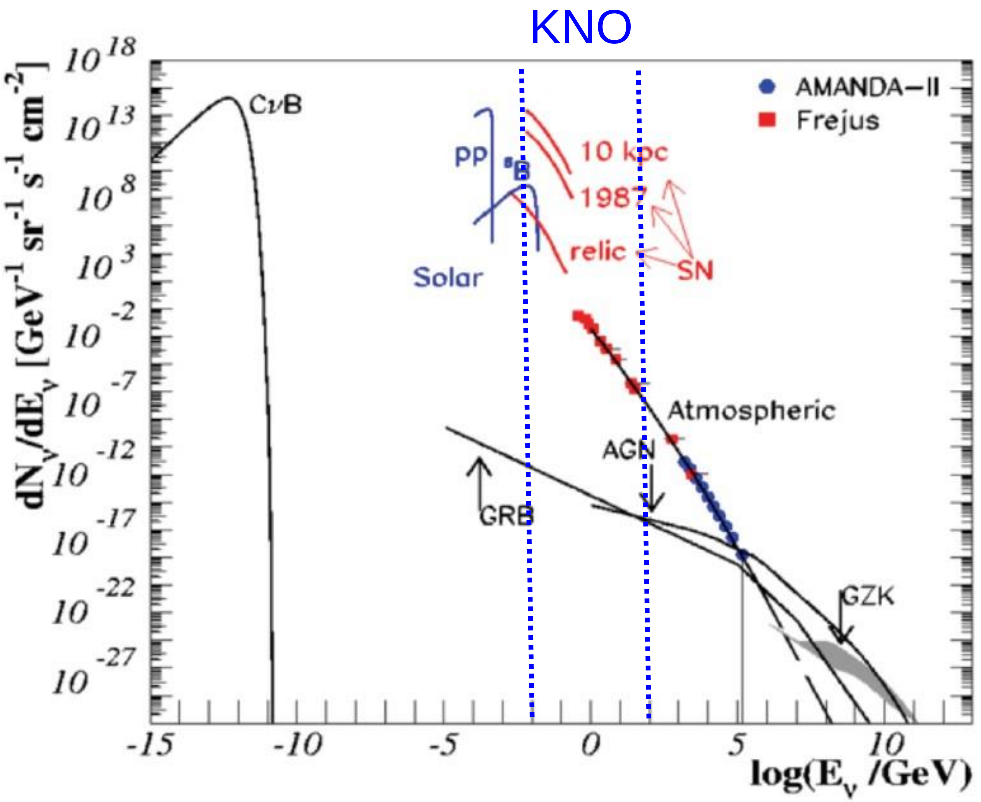
Discovery Potential for $p \rightarrow e^+\pi^0$ Decay



Neutrinos of Astronomical Origins



Astrophysical Neutrinos



GRB/AGN as neutrino sources in the energetic jet via

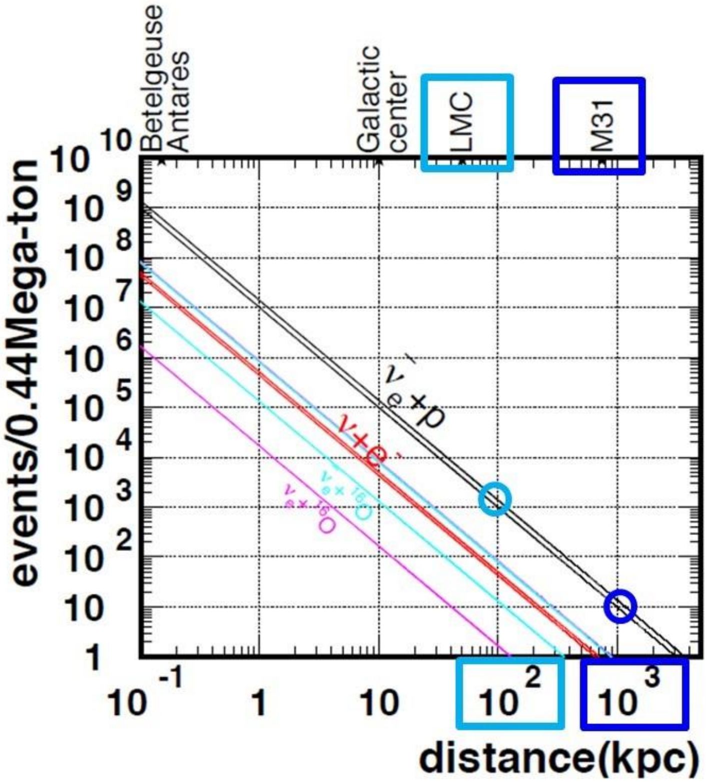
$$p + \gamma \rightarrow \Delta^{+} \rightarrow \pi^{+} + n \rightarrow e^{+} + \nu_e + \bar{\nu}_\mu + \nu_\mu + n.$$

Halzen, Francis Nuovo Cim. C037 (2014) no.03, 117-132, Astron.Nachr. 335 (2014) 507

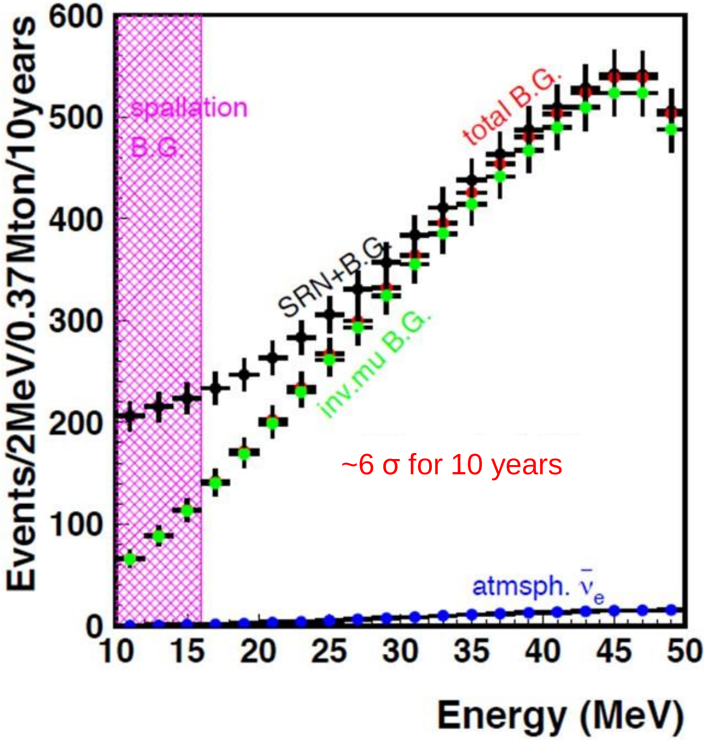
Neutrinos from Super Nova

- Super Nova Neutrinos (SN)
- Super Nova Relic Neutrinos (SRN)

SN neutrino rate



SRN spectrum



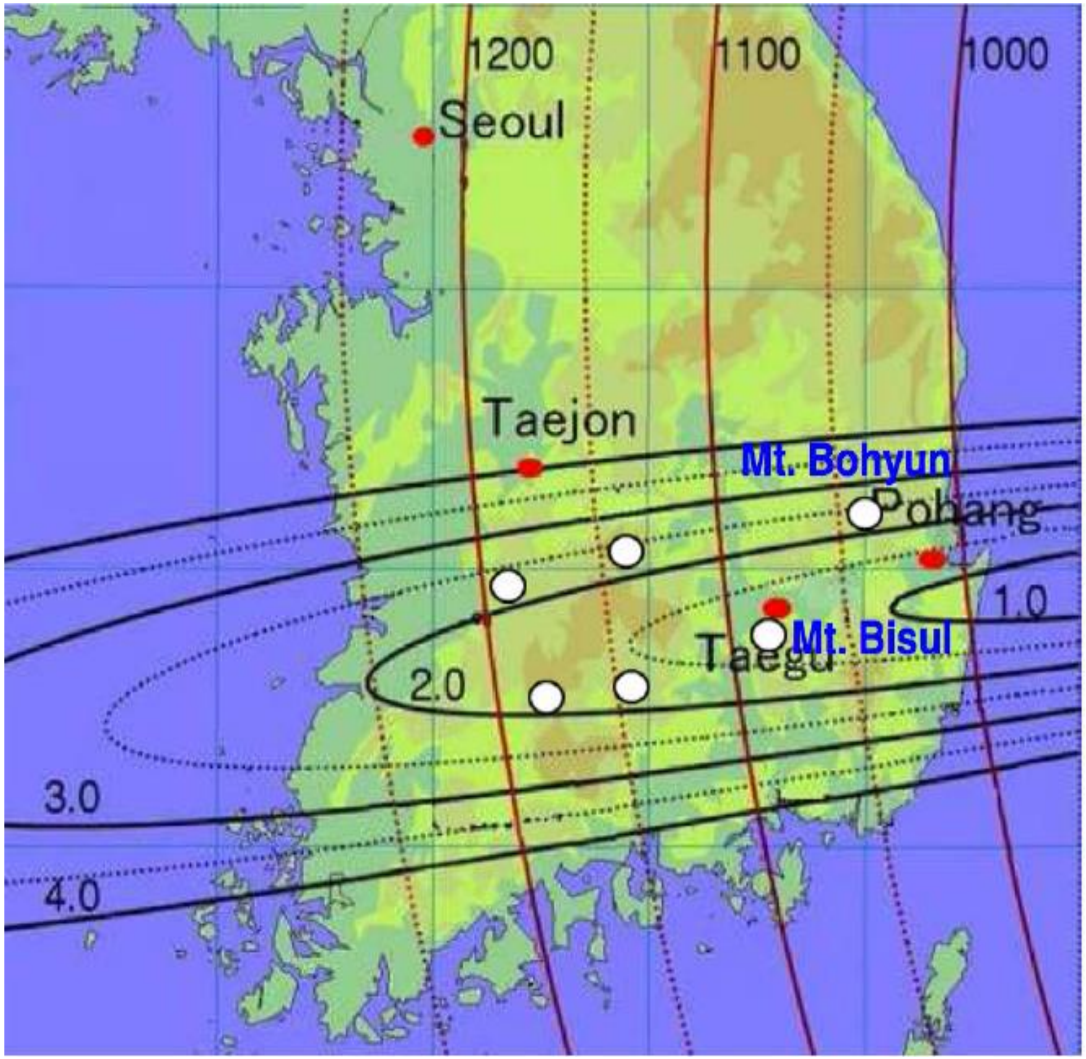
Neutrinos from Other Astronomical Sources

- Neutrinos from active galactic nuclei and microquasars
- Neutrinos from interactions of cosmic protons and nuclei in the Galaxy
- Neutrinos from gamma-ray bursts (GRB)
- Neutrinos from clusters of galaxies
- Neutrinos from dark matter decays

Multi-Messenger Astronomy

KNO: Powerful Neutrino Telescope

KNO Candidate Sites



Site	Height (m)	Baseline (km)	Off-axis angle (degree)	Elements of rock
Mt. Bisul	1084	1088	1.3°	Granite porphyry, Andesitic breccia
Mt. Hwangmae	1113	1140	1.8°	Flake granite, Porphyritic gneiss
Mt. Sambong	1186	1180	1.9°	Porphyritic granite, Biotite gneiss
Mt. Bohyun	1124	1040	2.2°	Granite, Volcanic rocks, Volcanic breccia
Mt. Minjuji	1242	1140	2.2°	Granite, Biotite gneiss
Mt. Unjang	1125	1190	2.2°	Rhyolite, Granite porphyry, Quartz porphyry

Activities on Detector R&D : PMT

- Two independent approaches of PMT R&D

- Development of Silicon PMT
  - Kyungpook National University in collaboration with Russian group
  - Hybrid PMT using photocathode, scintillator, and SiPM

- Development of conventional PMT
  - University of Seoul in collaboration with Korean company MECARO
  - Work on 3 inch PMT first and move to larger PMT

More Activities on Detector R&D

- Water purification system, radon vacuum degasifier, high sensitive radon detector
  - Seoul National University in collaboration with Korean company DICOTECH
  - prototype construction

radon degasifier prototype

radon detector

KNO Software Development

- Develop a KNO simulation/reconstruction package which can be used to study sensitivities and to optimize the detector design

NuWro (neutrino generator)

⇩

WCSIM (detector simulator)

⇩

KNO reconstruction

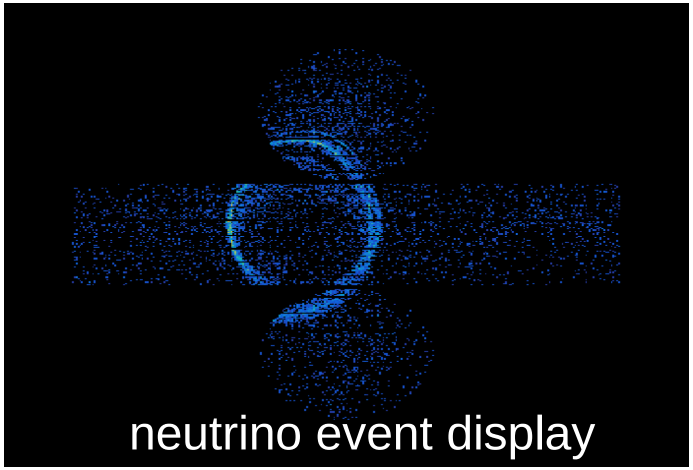
⇩

Neutrino Energy

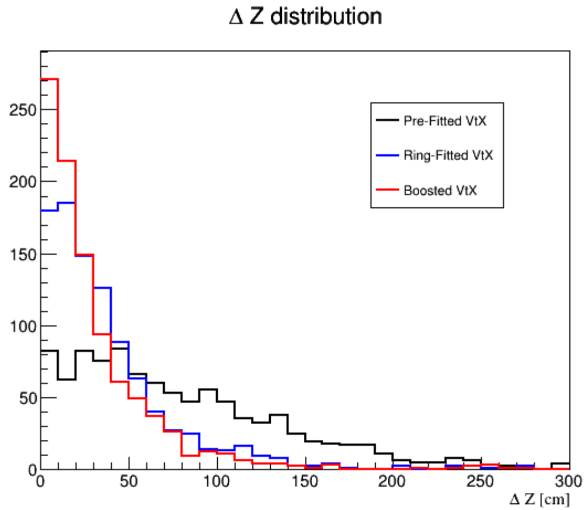
Neutrino Direction

Neutrino Type

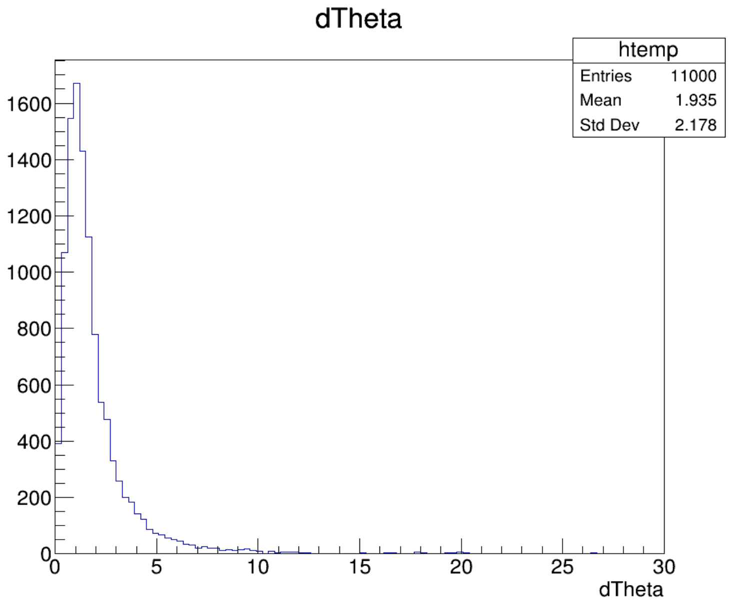
KNO simulation: Preliminary Results



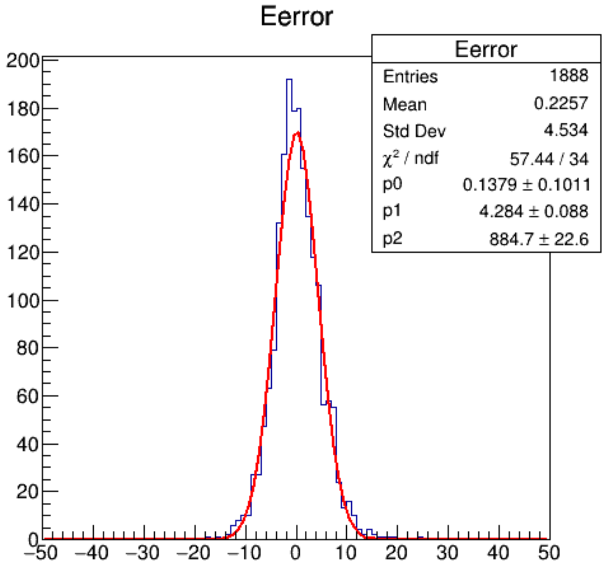
neutrino event display



vertex resolution



angular resolution

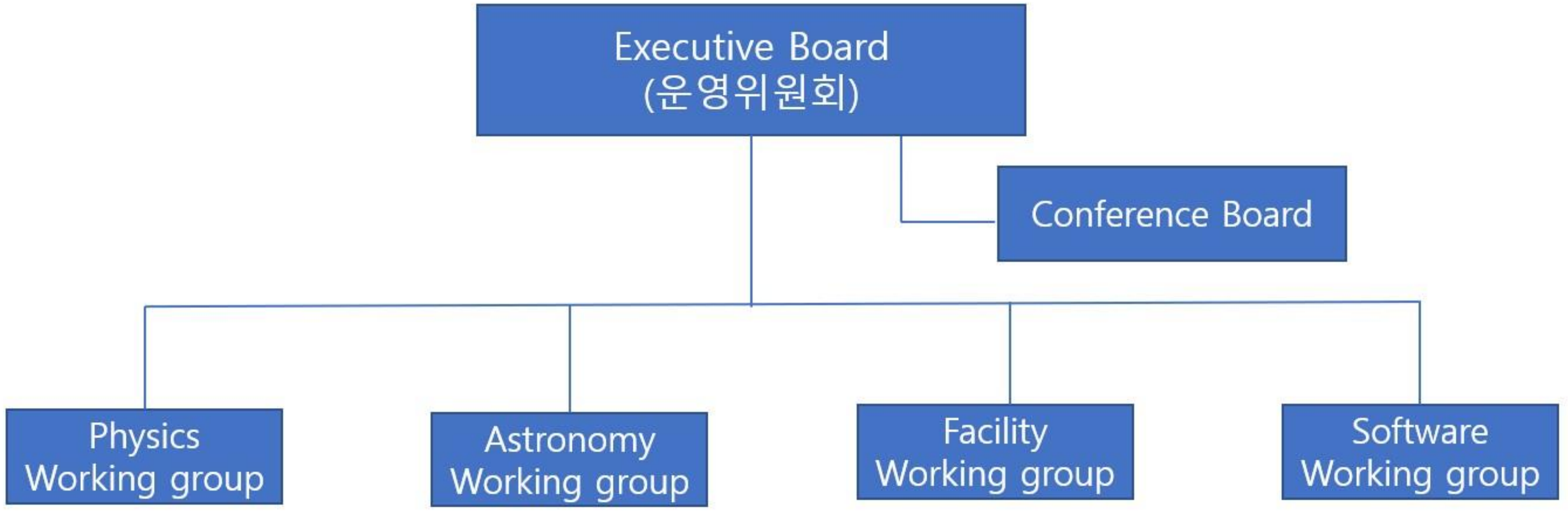


energy resolution

KNO Organization Expansion (2020.8~)

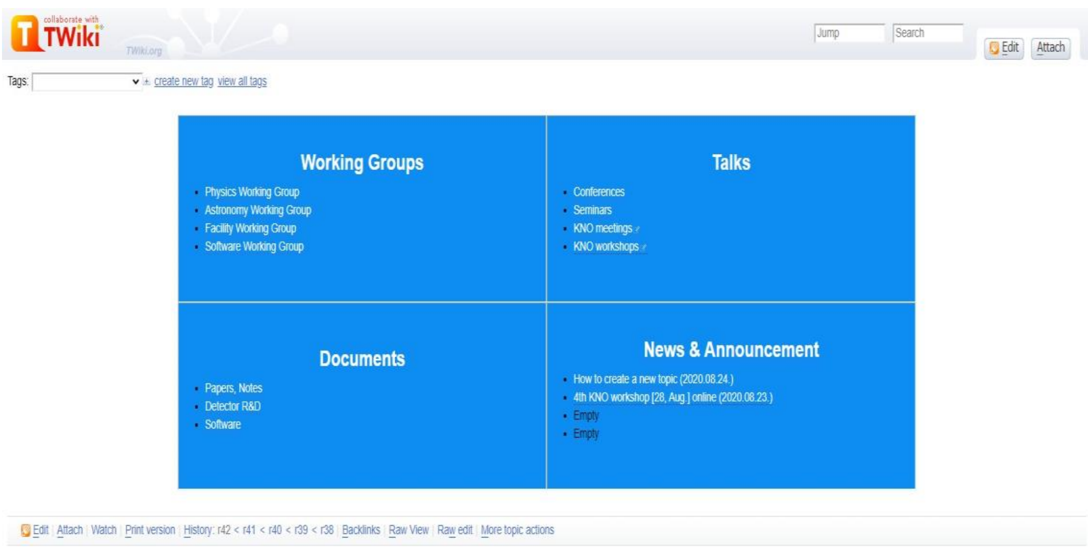
- KNO needs more manpower and resources
- KNO working groups have been reorganized
- KNO web site is open (www.kno.or.kr)

KNO Organization Chart

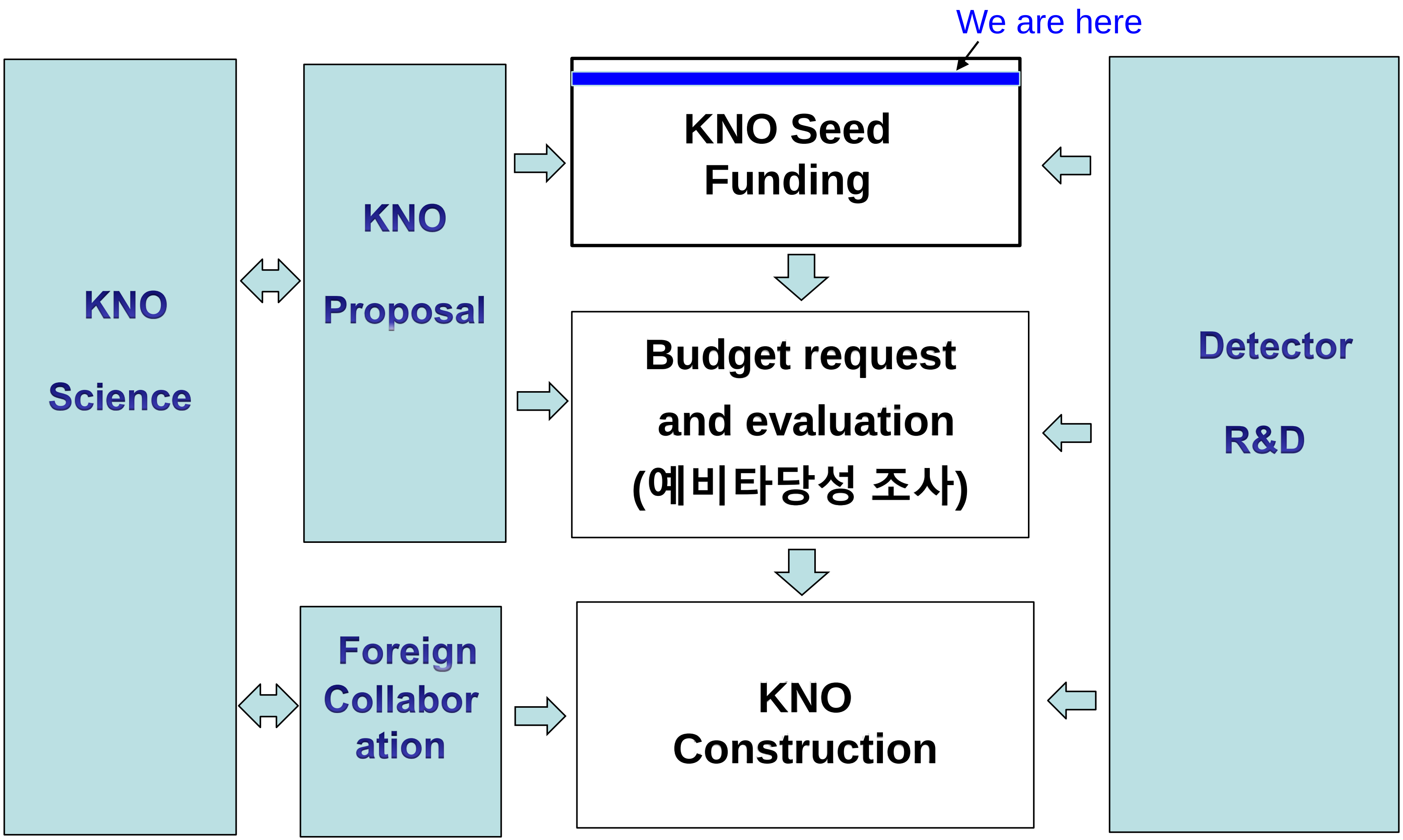


KNO Web Site

- KNO public page : www.kno.or.kr
- KNO internal page: twiki system
- KNO meeting page: indico system



KNO Strategy



Prospect for KNO

- A water Cherenkov detector such as KNO is a well established technology.
- Neutrino community in Korea have enough expertise for successful construction of KNO but lack manpower.
- KNO may be a latecomer compared to Hyper-K or DUNE but KNO has some advantages such as lower cost, shorter construction period, and larger detector volume.
- There is no dedicated process for a large science project like KNO (~$300M). KNO must go through the process for construction of a large public infrastructure.
- Our goal is to start construction of KNO in 2023.

Summary

- KNO greatly enhances physics sensitivities in the measurements of leptonic CP violation, mass ordering, proton decay, NSI, and many others
- KNO may serve as the largest underground neutrino telescope for multi-messenger astronomy
- KNO organization and working groups are formed and active (New members are welcomed)
- Efforts on detector R&D and science are in progress
- KNO can be a flagship project for Korean HEP for the next 10 years