

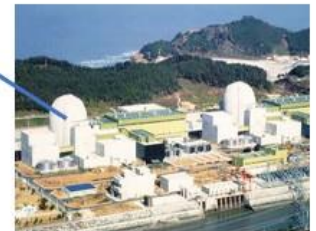
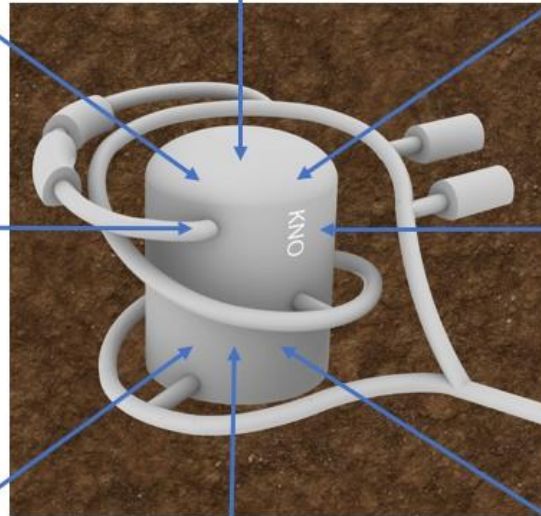
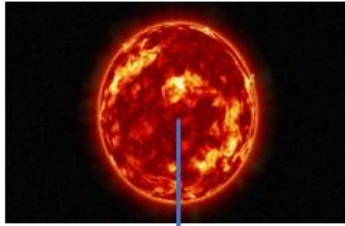
# **Korea Neutrino Observatory (KNO)**

**Intae Yu**

**Sungkyunkwan University**

**Dec. 4, 2020**

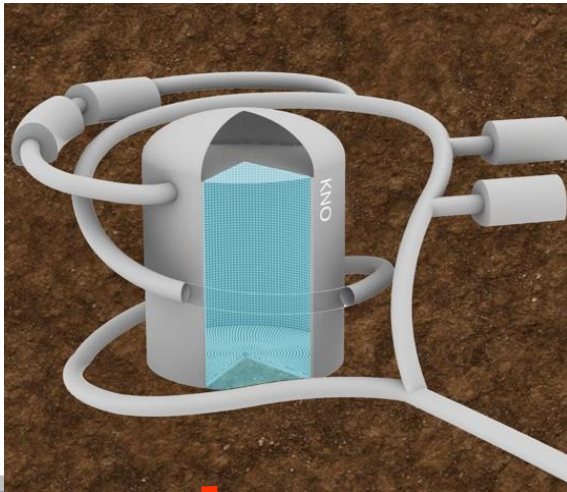
# KNO Science



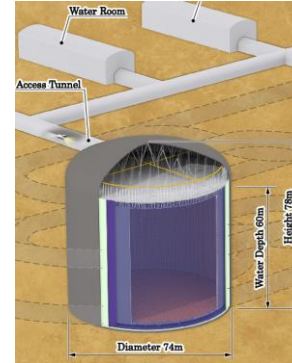
# Far Detector to J-PARC beam

**KNO**

>0.26Mt ?



~1.5 deg. off axis

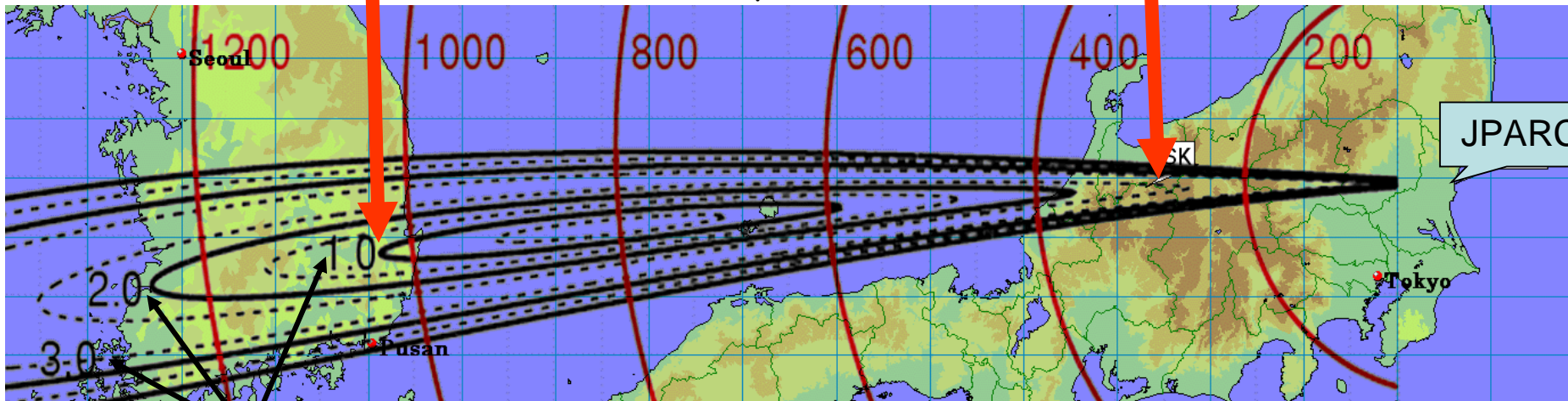


**Hyper-K**

0.26Mt

2.5 deg. off axis

**The J-PARC  $\nu_\mu$  beam comes to Korea.**



**Off-axis angle**

see hep-ph/0504061

By K. Hagiwara, N. Okamura, K. Senda

# Pros and Cons of KNO

## □ Pros

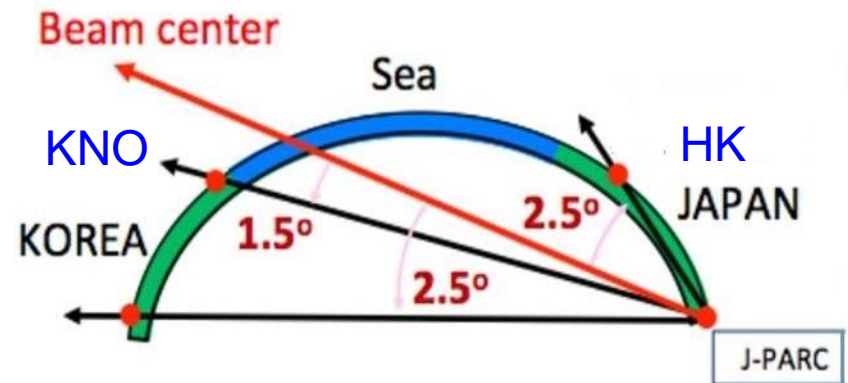
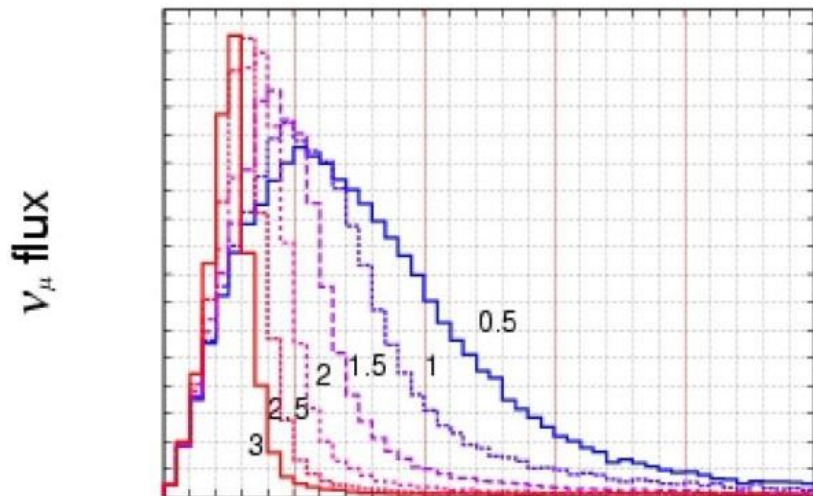
- 1<sup>st</sup> and 2<sup>nd</sup> oscillation maxima at KNO → more sensitive to leptonic CP violation
- Higher mass density and longer baseline (~1100 km) → better determination of neutrino mass hierarchy and better sensitivity to non-standard neutrino interactions
- Larger overburden (~1000 m) → better sensitivity to neutrinos of astronomical origin (solar/SN/galactic..)

## □ Cons

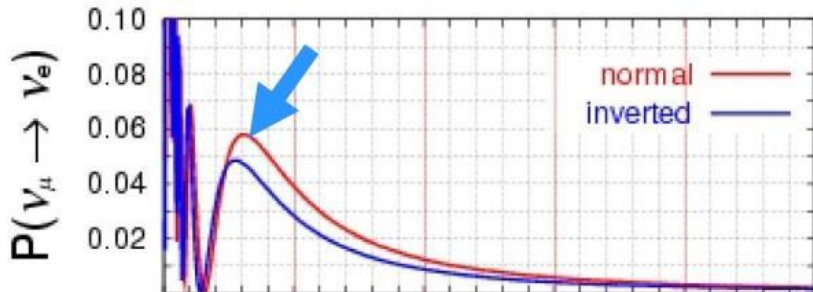
- Neutrino beam flux at KNO is ~ 10 times smaller than HK flux due to longer baseline
- Construction may start later than HK



# Neutrino Oscillations in KNO & Kamioka

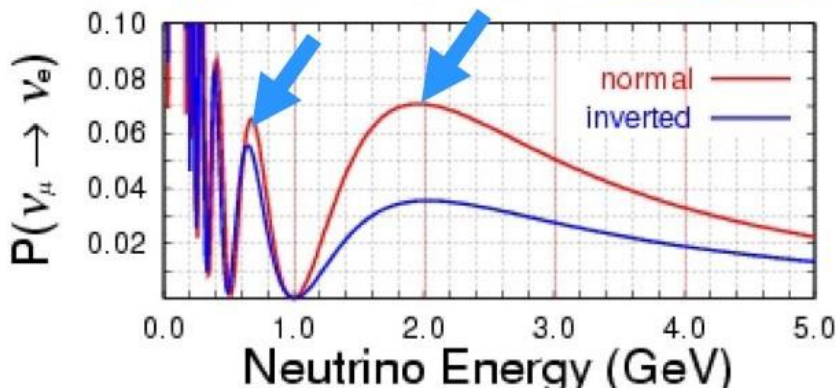


← Profile of off-axis beams



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

( $L=300$  km)  $\rightarrow$  1<sup>st</sup> osc. max. only

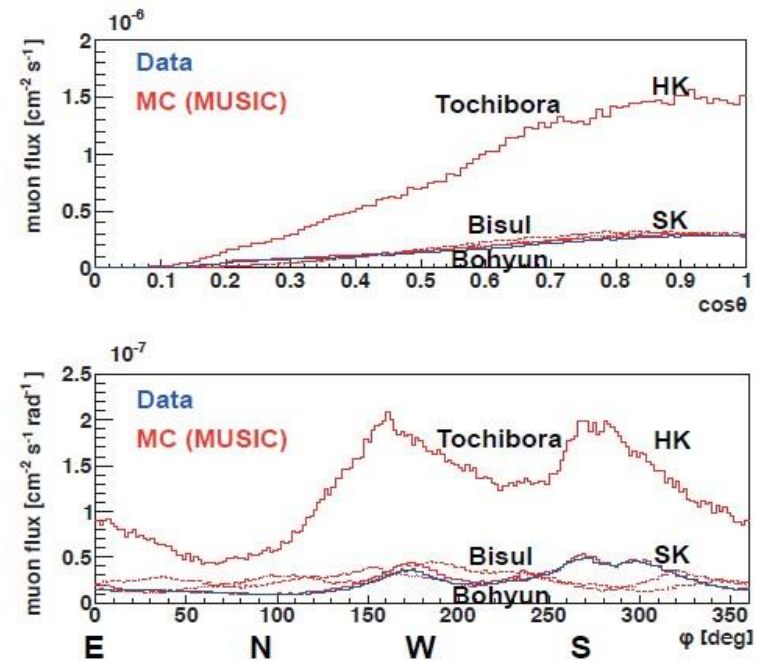
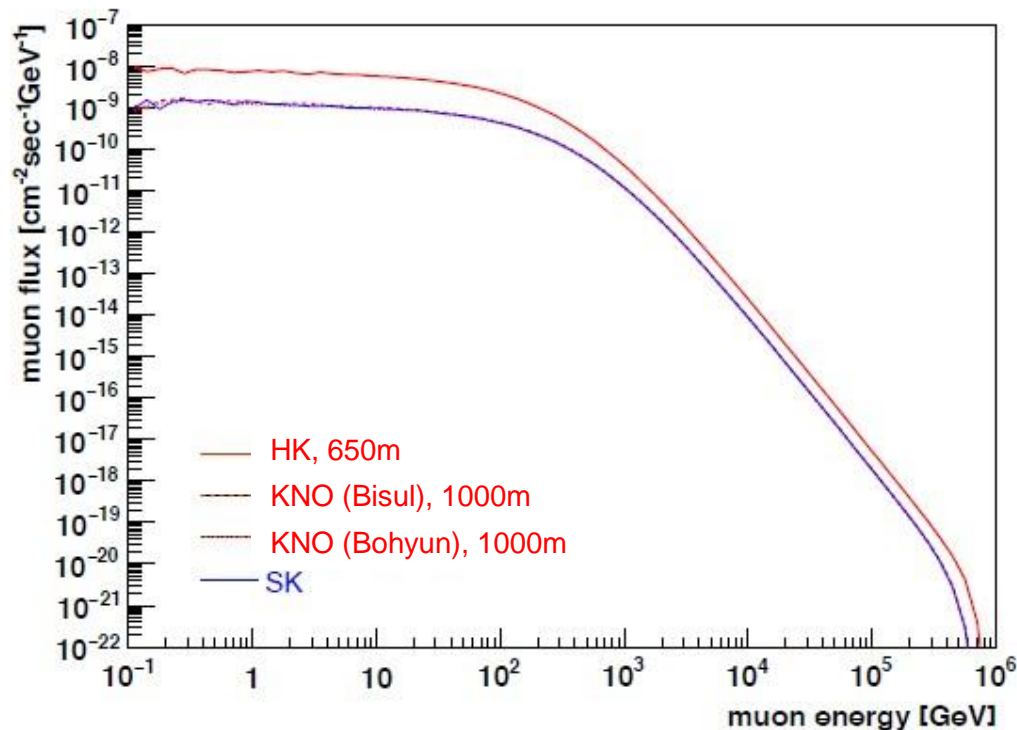


←  $P(\nu_\mu \rightarrow \nu_e)$  at Korea

( $L=1100$  km)  $\rightarrow$  1<sup>st</sup> and 2<sup>nd</sup> 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

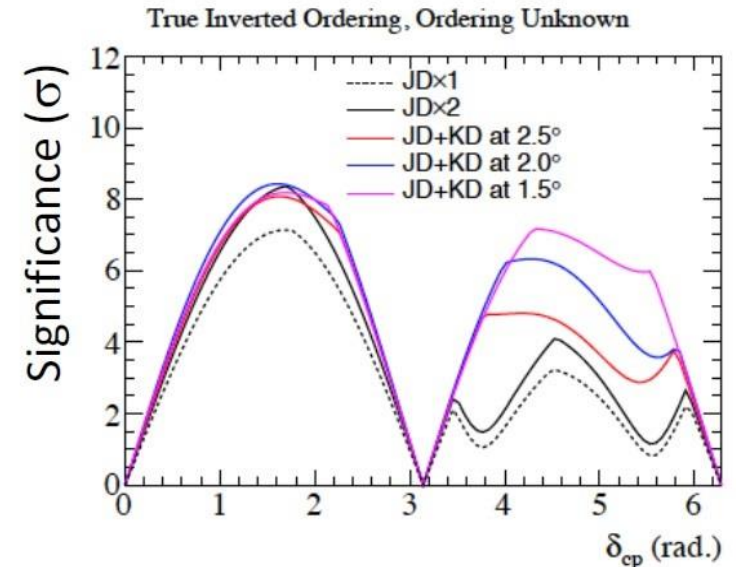
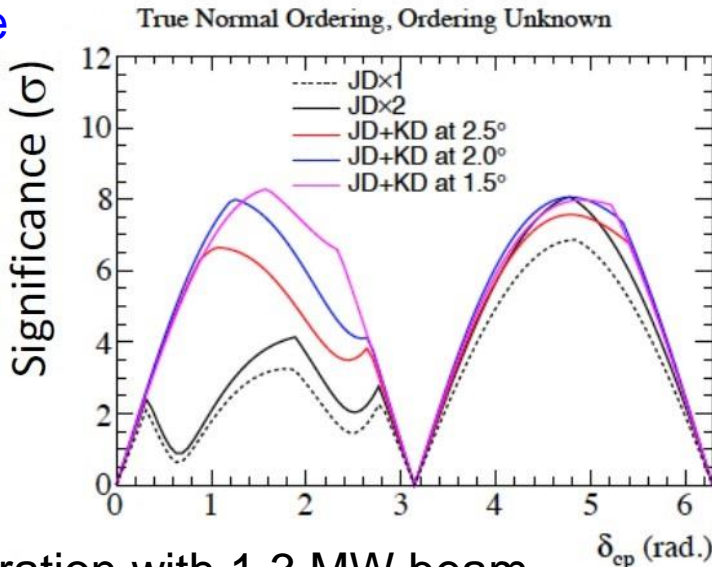
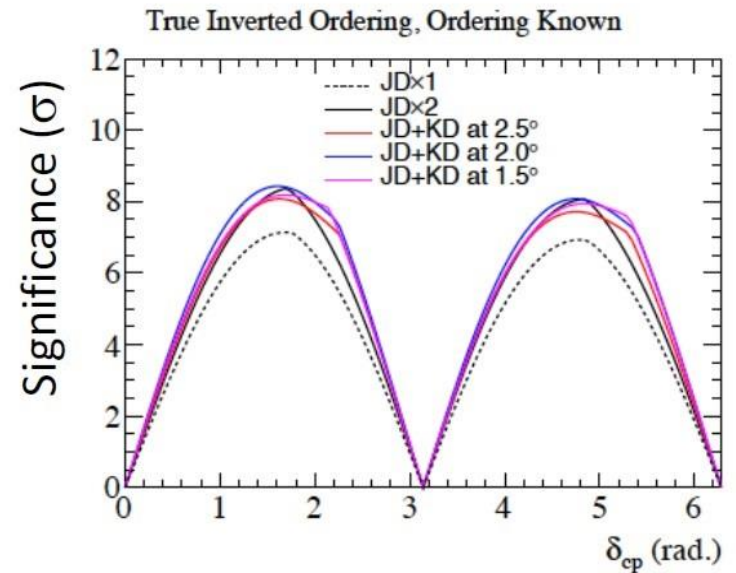
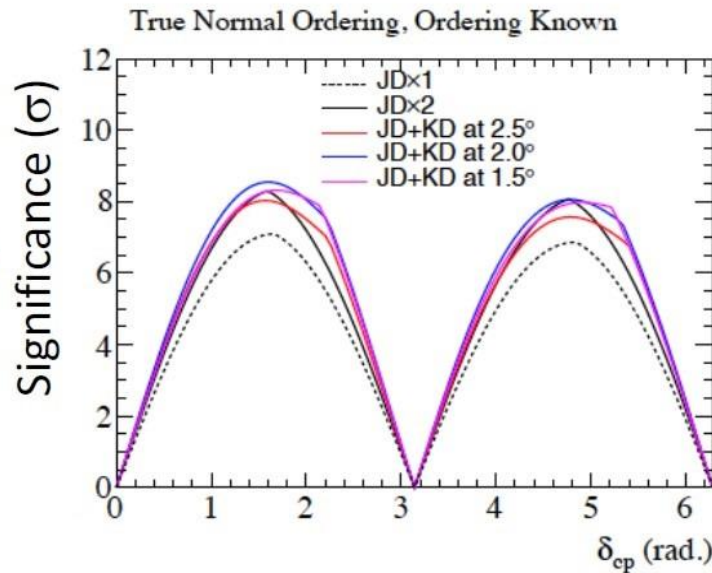


# Physics Potential at KNO: $\delta_{cp}$

Known  
MO



KNO, HK  
0.26 Mton  
40% coverage



Unknown  
MO

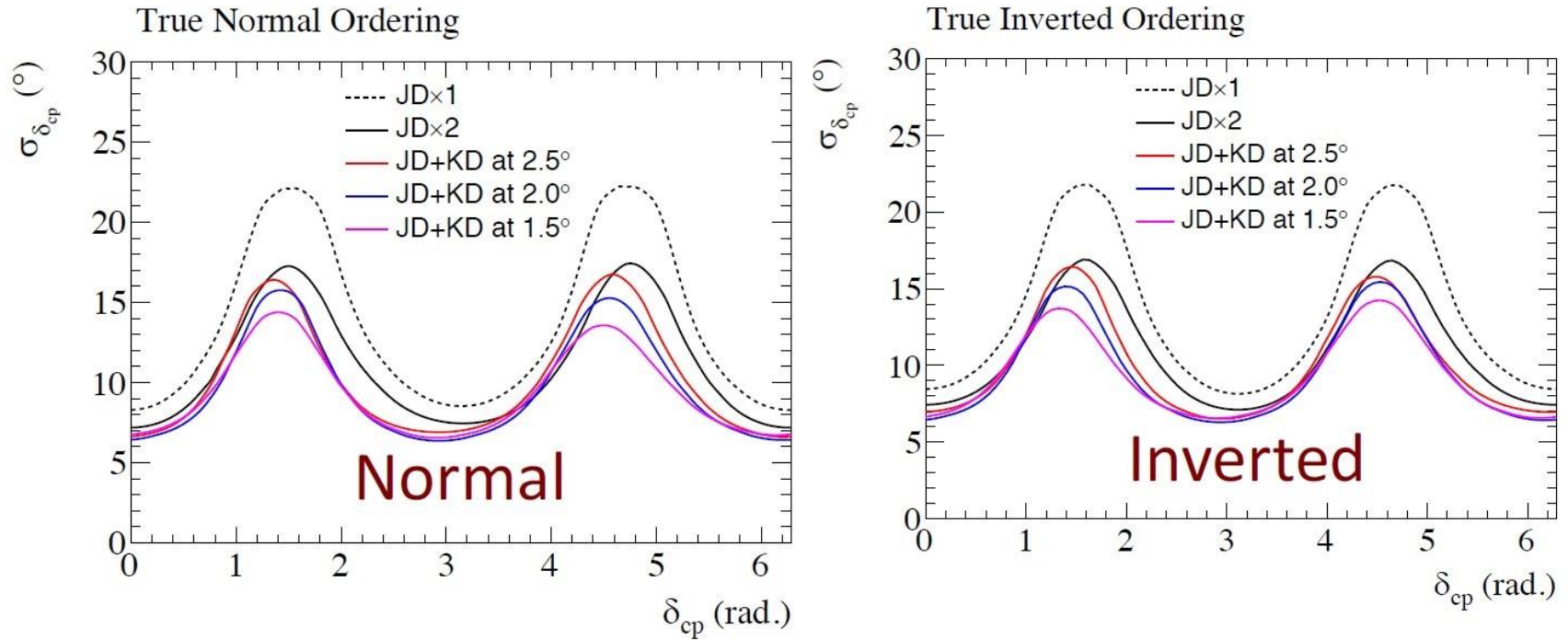


10 years of operation with 1.3 MW beam



# Physics Potential at KNO: $\delta_{cp}$ Precision

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



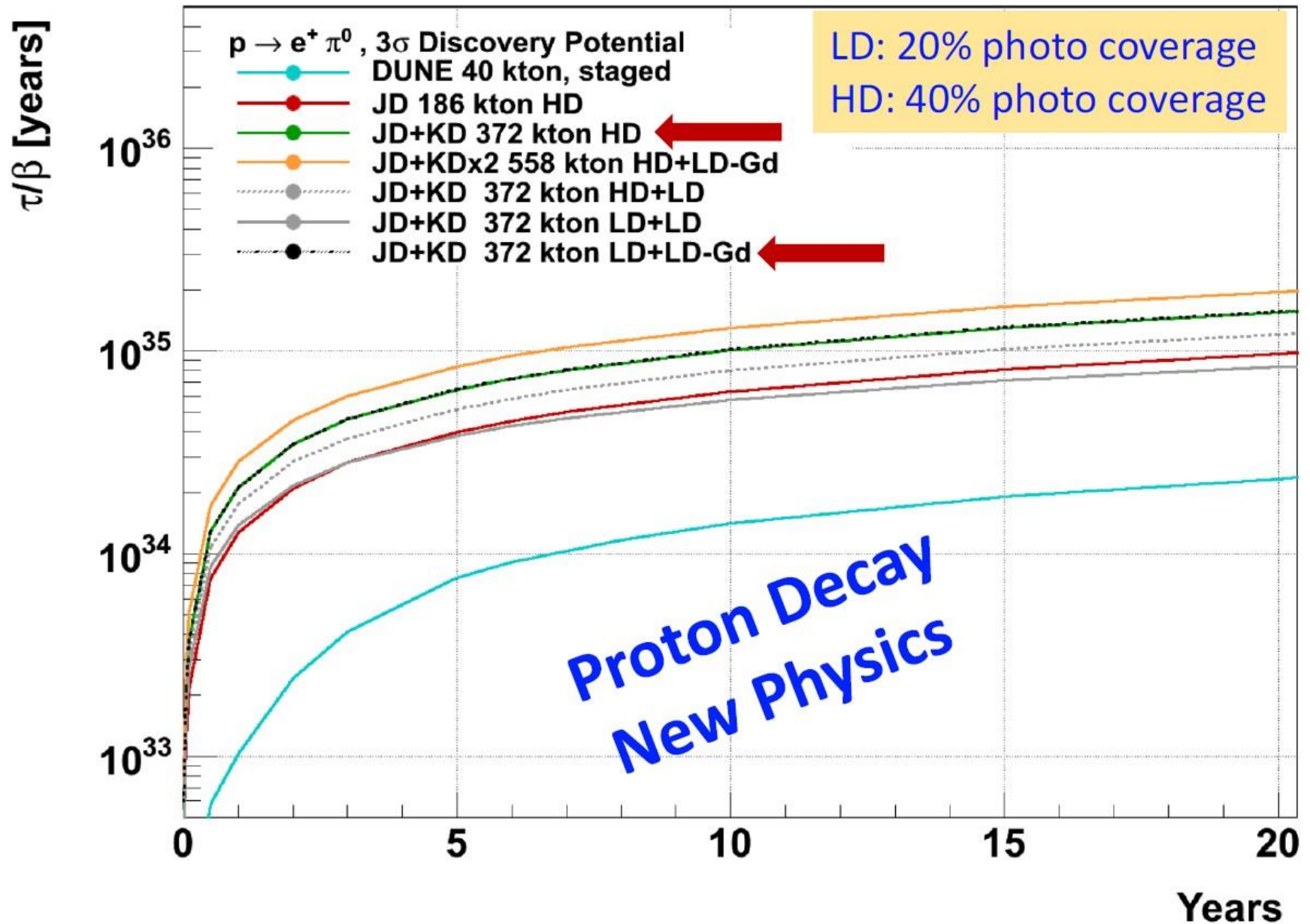
**KNO, HK**  
0.26 Mton  
40% coverage

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

10 years of operation with 1.3 MW beam

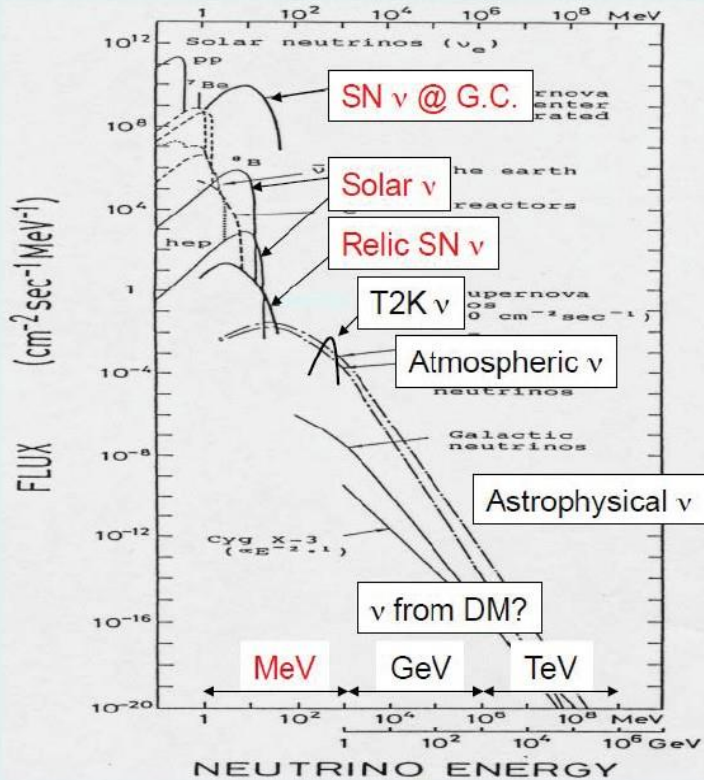


# Discovery Potential for $p \rightarrow e^+ \pi^0$ Decay

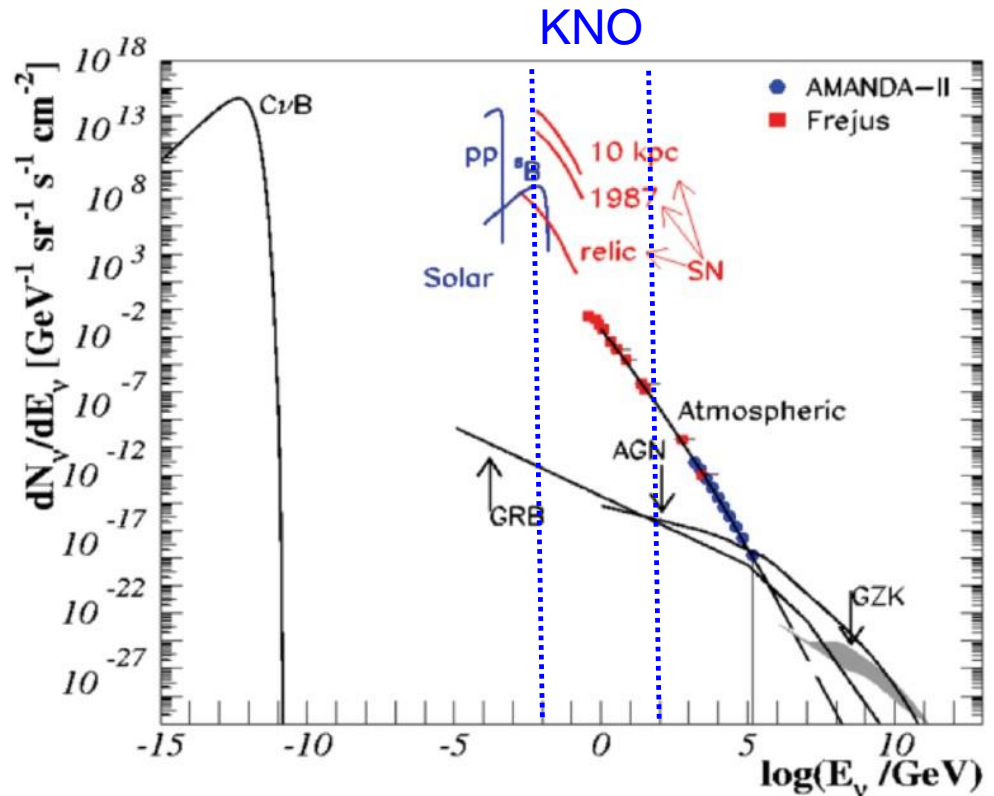


# Neutrinos of Astronomical Origins

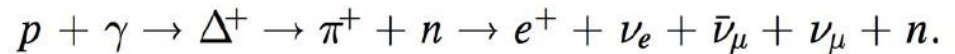
## Neutrino Sources



## Astrophysical Neutrinos

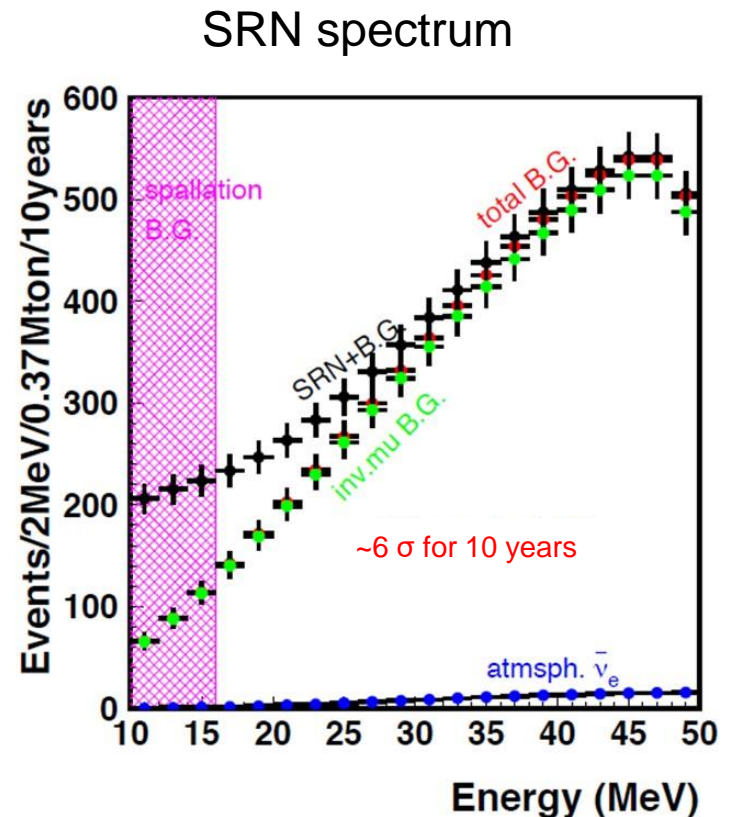
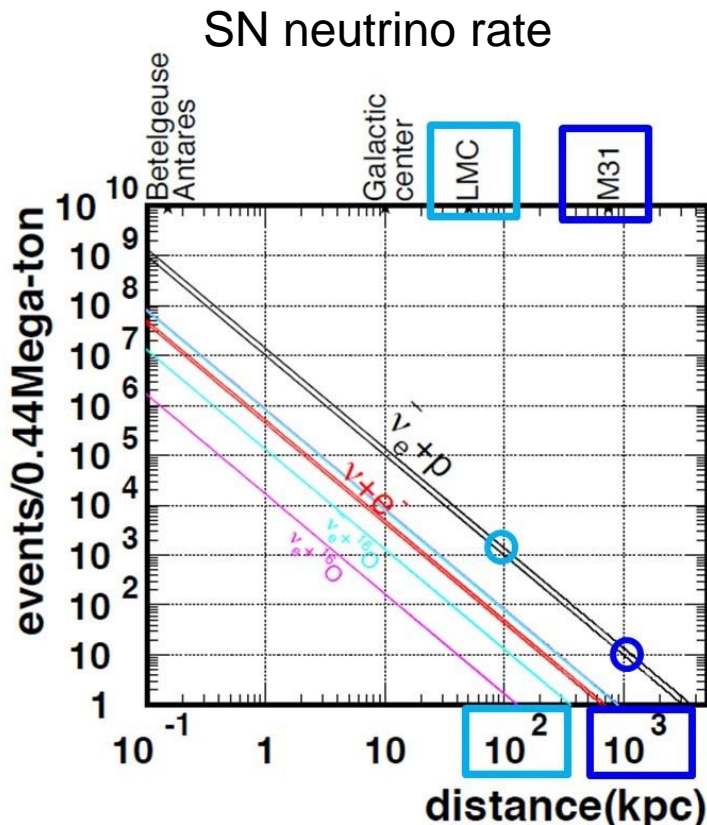


GRB/AGN as neutrino sources in the energetic jet via



# Neutrinos from Super Nova

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



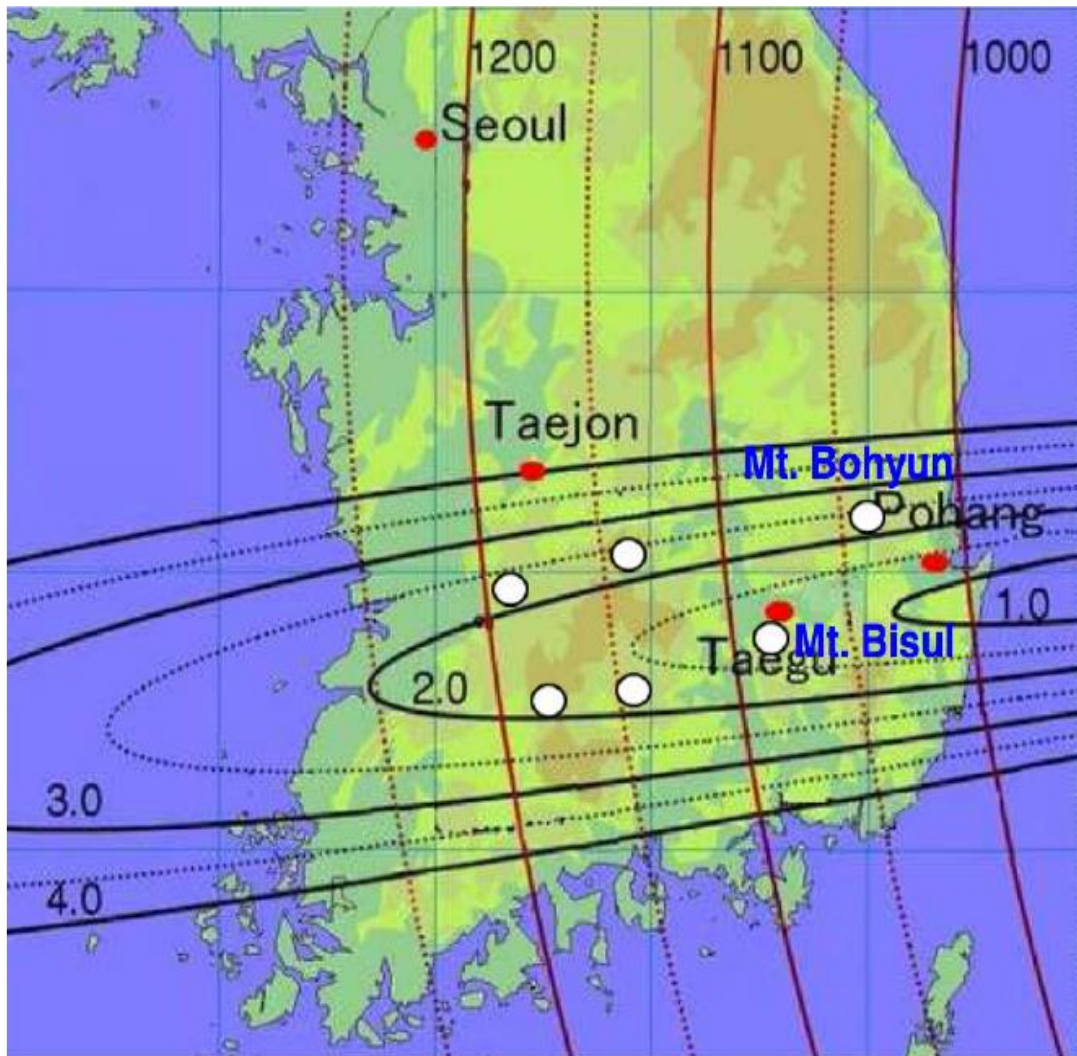
# Neutrinos from Other Astronomical Sources

- 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



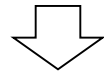
radon detector



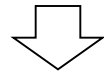
# KNO Software Development

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

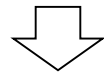
NuWro (neutrino generator)



WCSIM (detector simulator)



KNO reconstruction



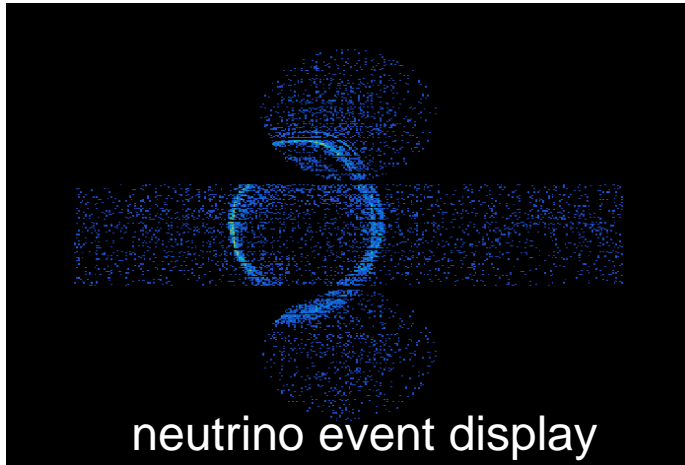
Neutrino Energy

Neutrino Direction

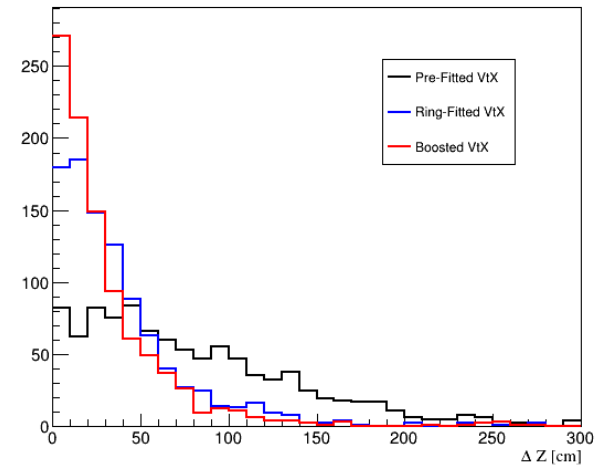
Neutrino Type



# KNO simulation: Preliminary Results

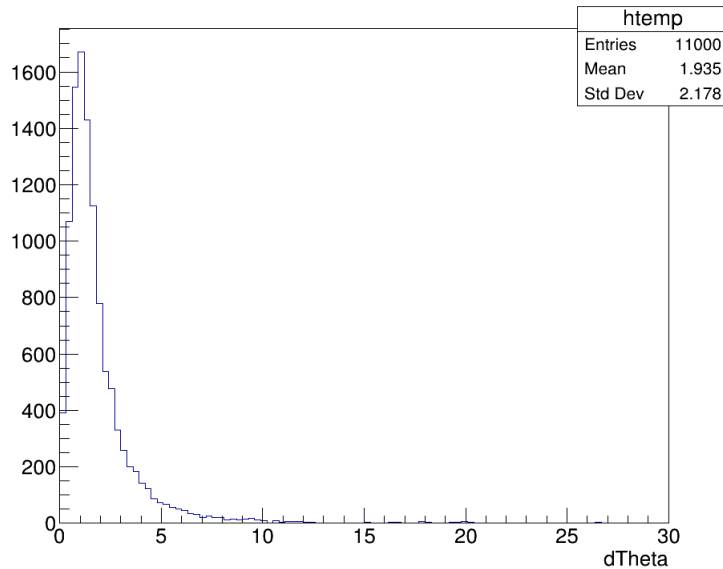


$\Delta Z$  distribution



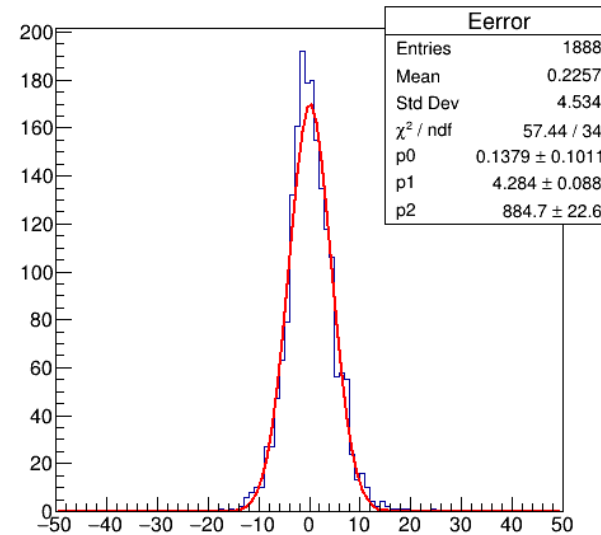
vertex resolution

dTheta



angular resolution

Error

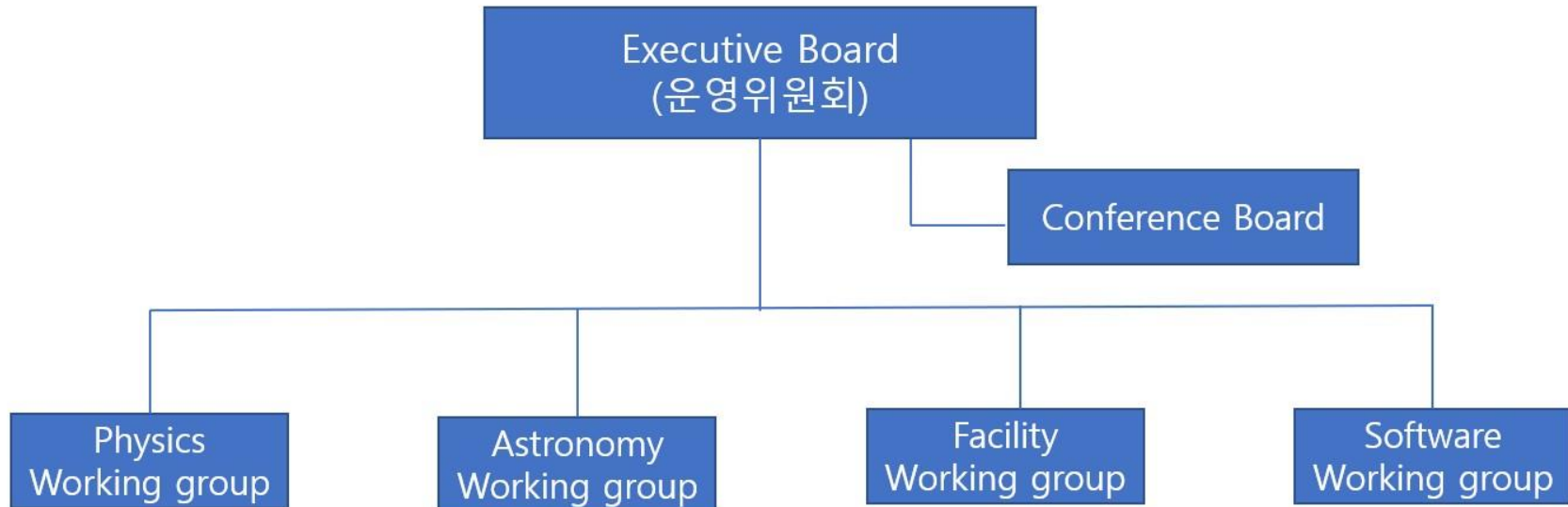


energy resolution

# 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](http://www.kno.or.kr))

## KNO Organization Chart



# KNO Web Site

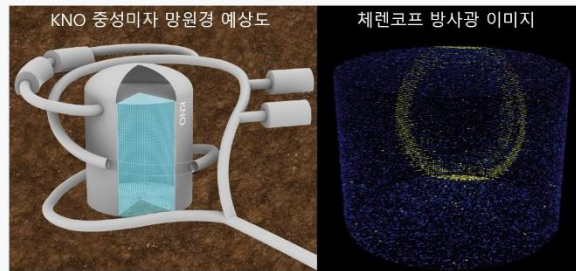
- KNO public page : [www.kno.or.kr](http://www.kno.or.kr)
- KNO internal page: twiki system
- KNO meeting page: indico system

KNO HOME SCIENCE KNO ORGANIZATION INTERNAL LINKS CONTACT Q

## Korean Neutrino Observatory (KNO)

한국 차세대 중성미자 관측시설 (Korean Neutrino Observatory: KNO)은 향후 중성미자 연구를 선도할 수 있는 세계적인 프로젝트로 기대되고 있다. 중성미자(neutrino) 연구는 최근 전 세계적으로 활발히 진행되고 있는데, 중성미자가 우주를 이해할 수 있는 새로운 창을 제공할 것으로 기대되기 때문이다.

KNO의 핵심적인 장치는 수십만 톤의 순수한 물로 채워진 체렌코프(cherenkov) 중성미자 검출기(neutrino detector)이다. 지하 1000m의 깊이에 설치될 검출기는 기대한 지하 공동 안에 위치하며, 중성미자는 지각을 뚫고 들어가서 검출기 내부의 물과 반응을 하게 된다. 중성미자 반응에서 발생하는 체렌코프 방사선(cherenkov radiation)은 검출기 내부에 설치되는 수 만개에 달하는 광센서(photosensor)에 의해 측정되고 그 측정값은 중성미자의 에너지나 방향 등의 정보로 변환된다.



KNO는 초신성(supernova)이나 블랙홀(black hole) 등 우주에서 오는 중성미자를 관측할 수 있는 세계 최대의 지하 중성미자 망원경이 될 것이며, LIGO와 같은 중력파 관측기와 함께 다중 신호 천문학(multi-messenger astronomy)의 새로운 장을 열 것으로 기대되고 있다. 또한 입자 가속기 (particle accelerator) 등에서 나오는 중성미자를 측정하여 중성미자 분야의 중요한 난제들에 대한 근본적인 해답을 줄 수 있을 것으로 예상된다.

collaborate with TWiki TWIKI.org

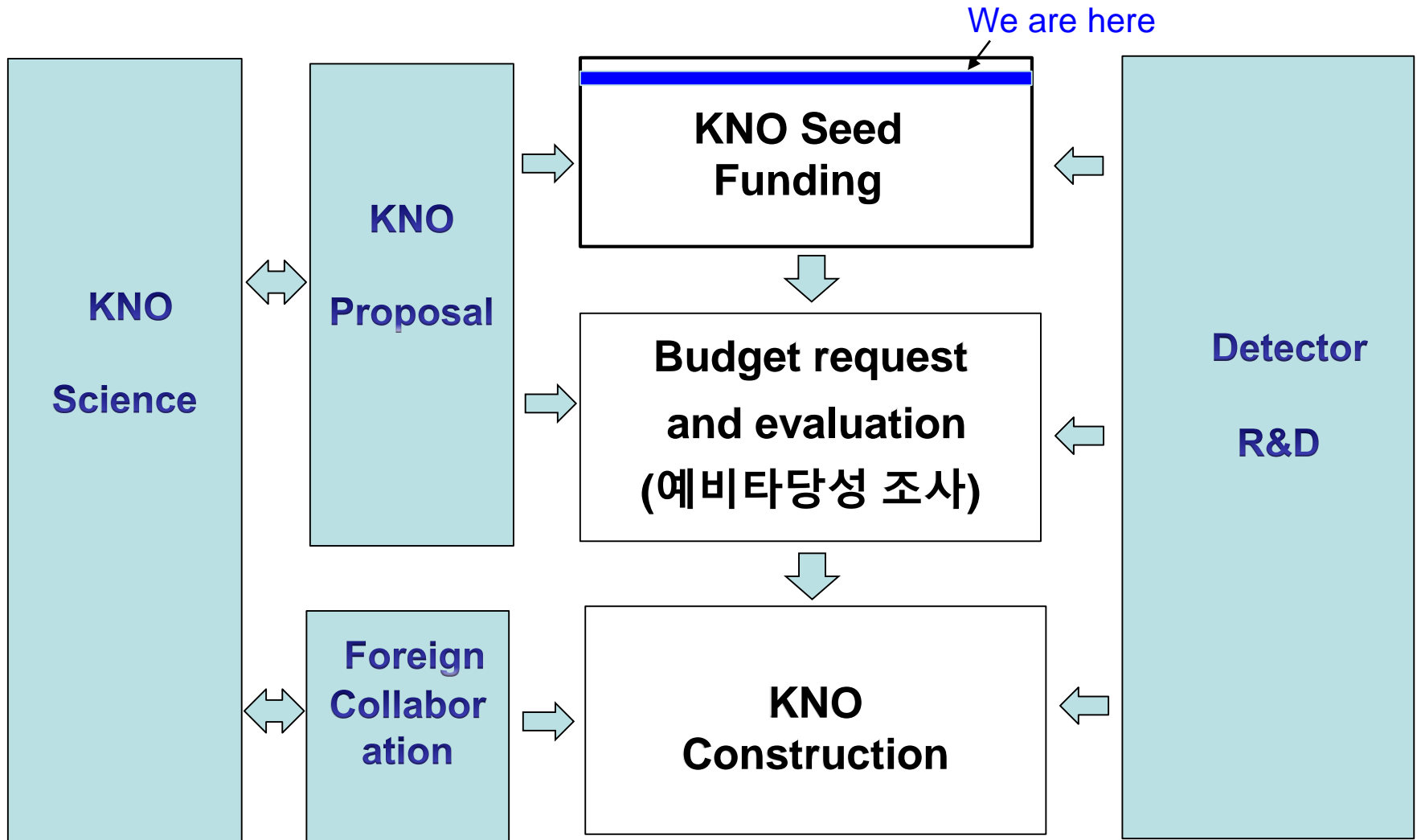
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Tags: create new tag view all tags

<h3>Working Groups</h3> <ul style="list-style-type: none"><li>• Physics Working Group</li><li>• Astronomy Working Group</li><li>• Facility Working Group</li><li>• Software Working Group</li></ul>	<h3>Talks</h3> <ul style="list-style-type: none"><li>• Conferences</li><li>• Seminars</li><li>• KNO meetings</li><li>• KNO workshops</li></ul>
<h3>Documents</h3> <ul style="list-style-type: none"><li>• Papers, Notes</li><li>• Detector R&amp;D</li><li>• Software</li></ul>	<h3>News &amp; Announcement</h3> <ul style="list-style-type: none"><li>• How to create a new topic (2020.08.24)</li><li>• 4th KNO workshop [28. Aug.] online (2020.08.23)</li><li>• Empty</li><li>• Empty</li></ul>

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# 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