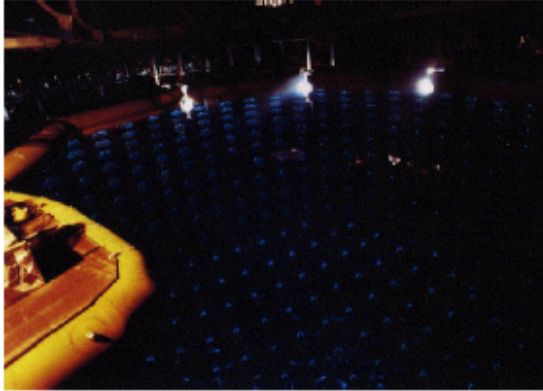


# **Korea Neutrino Observatory (KNO) Organization and Proposal**

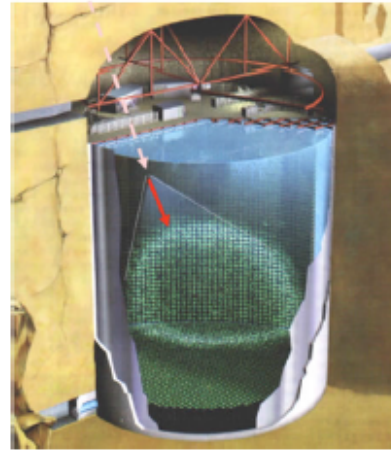
**I                      Intae Yu**  
**Sunkyunkwan University**  
**Nov. 2, 2018**

Kamiokande (1983-1996)  
3000 ton



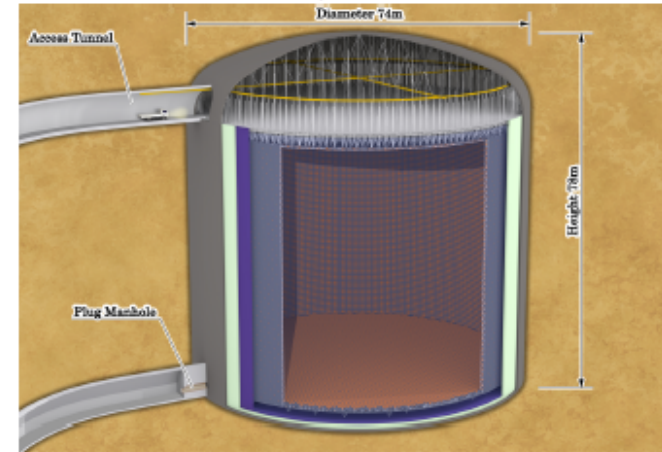
- Neutrinos from SN1987a.
- Atmospheric neutrino deficit.
- Solar neutrinos.

Super-Kamiokande (1996- )  
50,000 ton



- Atmospheric neutrino oscillation.
- Solar neutrino oscillation with SNO.
- Far detector for KEK-PS (K2K) and J-PARC beam (T2K): electron neutrino appearance.
- World leading limit on proton lifetime  $> 10^{34}$  years.

Hyper-Kamiokande ( $\sim 2026-$ )  
 $2 \times 260,000$  ton

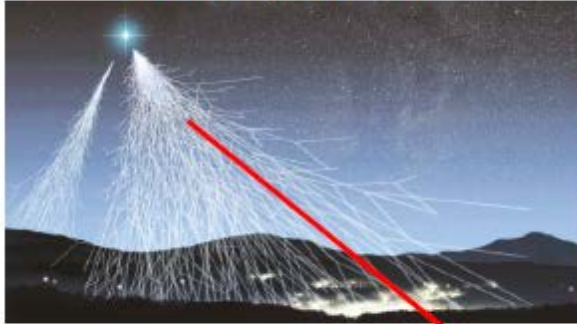


Physics programme:

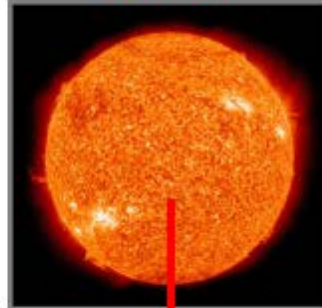
- Neutrino oscillations: Mass Hierarchy, Leptonic CP violation,  $\theta_{23}$  Octant, ...
- Nucleon decay:  $p \rightarrow e^+ \pi^0$ ,  $p \rightarrow K^+ \bar{\nu}$ , ...
- Neutrino astrophysics: Solar neutrinos, Supernova neutrinos, WIMP searches

# Overview of Hyper-K Physics

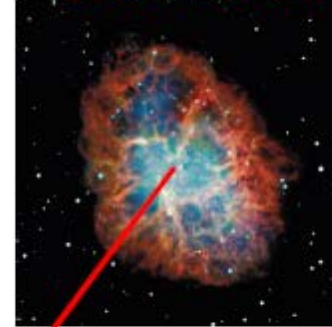
Atmospheric  $\nu$



Solar  $\nu$



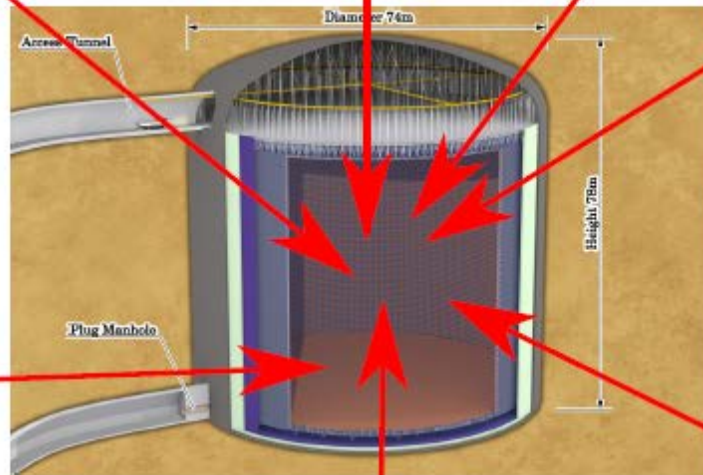
Supernova  $\nu$



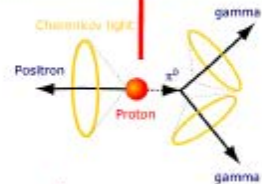
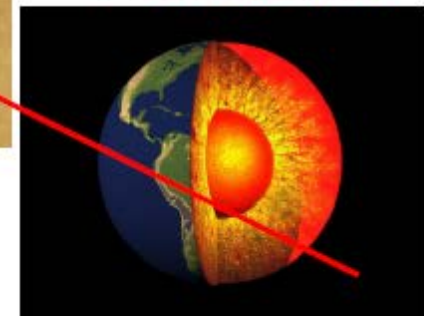
WIMP  $\chi\chi \rightarrow \nu\nu$



Beam  $\nu$



$\nu$  Tomography



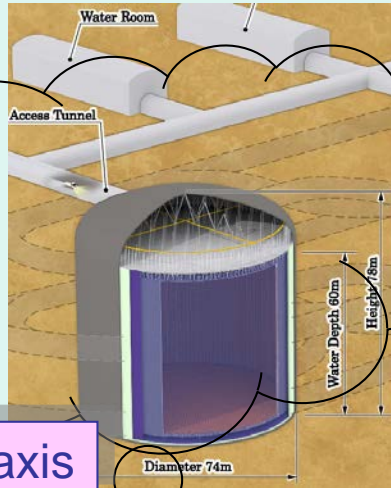
Nucleon Decay

# Status of Hyper-Kamiokande

- Hyper-Kamiokande proto-collaboration was formed
- Two host institutions: U of Tokyo (ICRR), KEK (IPNS)
- Japanese funding agency (MEXT) will provide a seed funding for Hyper-K in 2019. → standard process in Japan for large projects to begin with a year of seed funding
- U of Tokyo commitment ensures that the Hyper-K construction will begin in April, 2020.

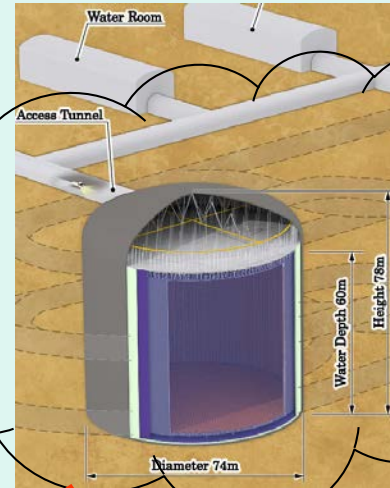
# Neutrino Detector in Korea

KNO



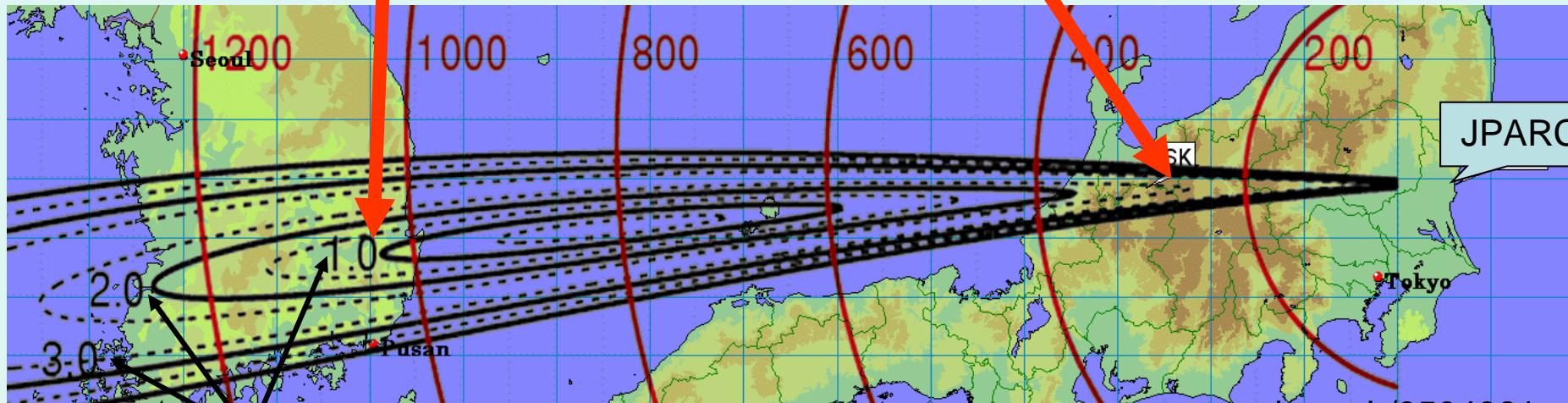
1.5 deg. off axis

Hyper-K



2.5 deg. off axis

The J-PARC  $\nu$  beam comes to Korea.

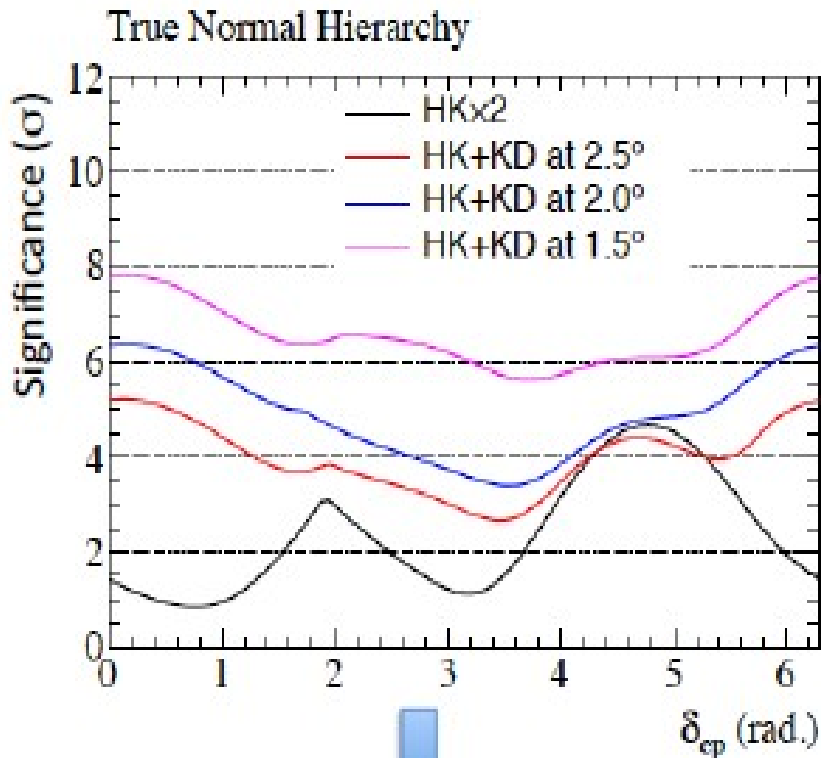


Off-axis angle

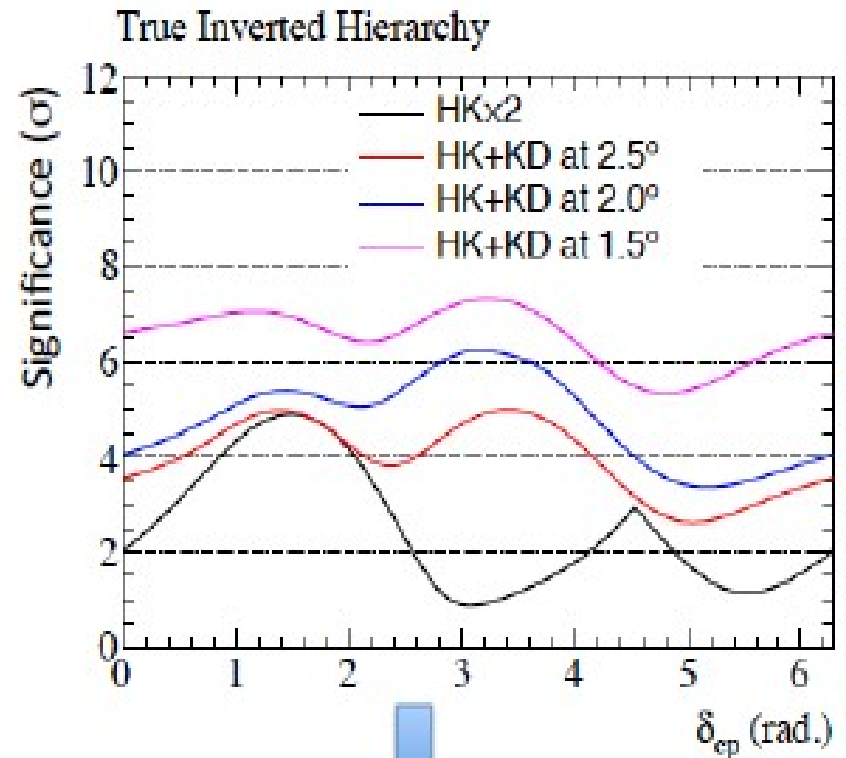
see hep-ph/0504061

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

# Physics Potential at KNO: Mass Ordering



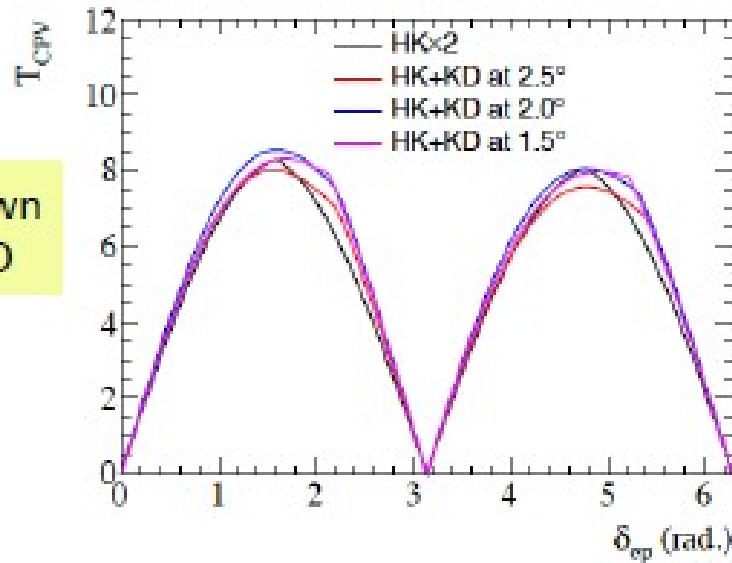
HK+KD  $1.5^\circ$ :  $6 \sim 8 \sigma$  for all  $\delta_{CP}$   
 HK x2 :  $1 \sim 4.5 \sigma$  for all  $\delta_{CP}$   
 ( $< 3 \sigma$  for most cases)



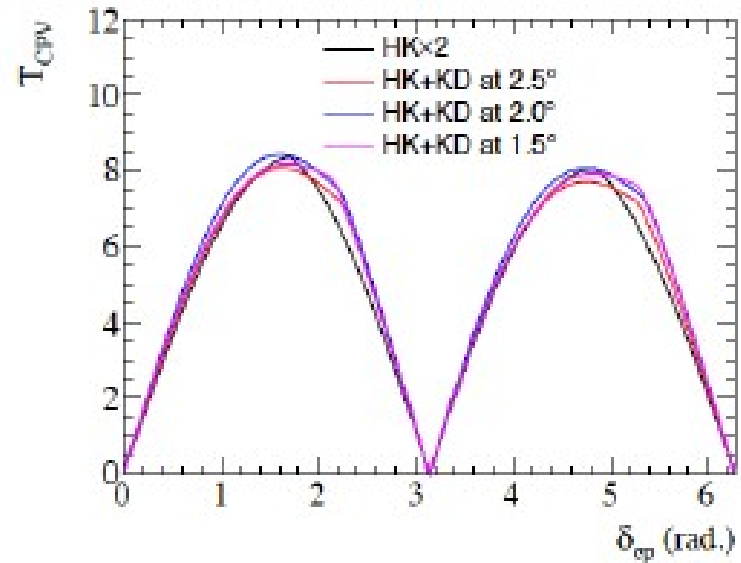
HK+KD  $1.5^\circ$ :  $5.5 \sim 7 \sigma$  for all  $\delta_{CP}$   
 HK x2 :  $1 \sim 5 \sigma$  for all  $\delta_{CP}$   
 ( $< 3 \sigma$  for most cases)

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

True Normal Hierarchy, Hierarchy Known

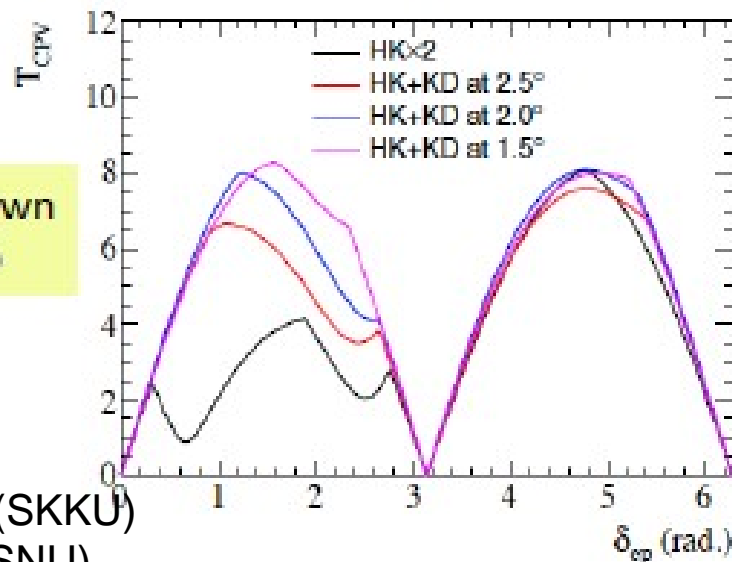


True Inverted Hierarchy, Hierarchy Known

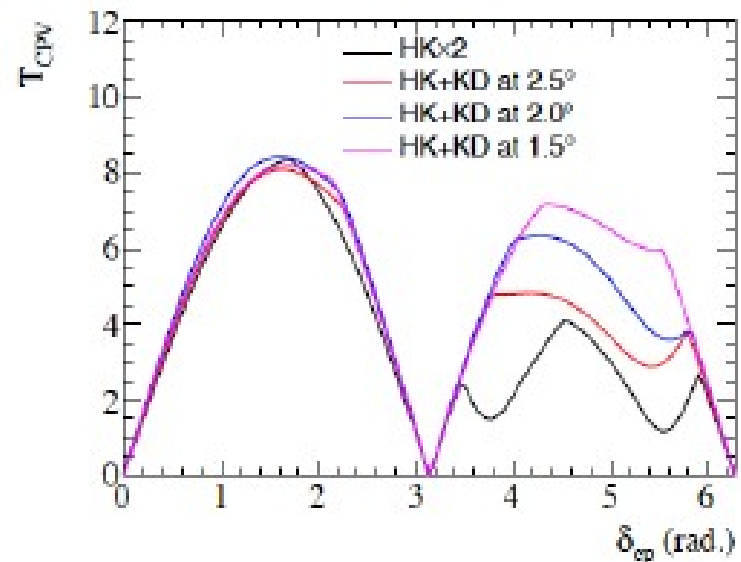


Known  
MO

True Normal Hierarchy, Hierarchy Unknown



True Inverted Hierarchy, Hierarchy Unknown



Unknown  
MO

# Physics Potential at KNO

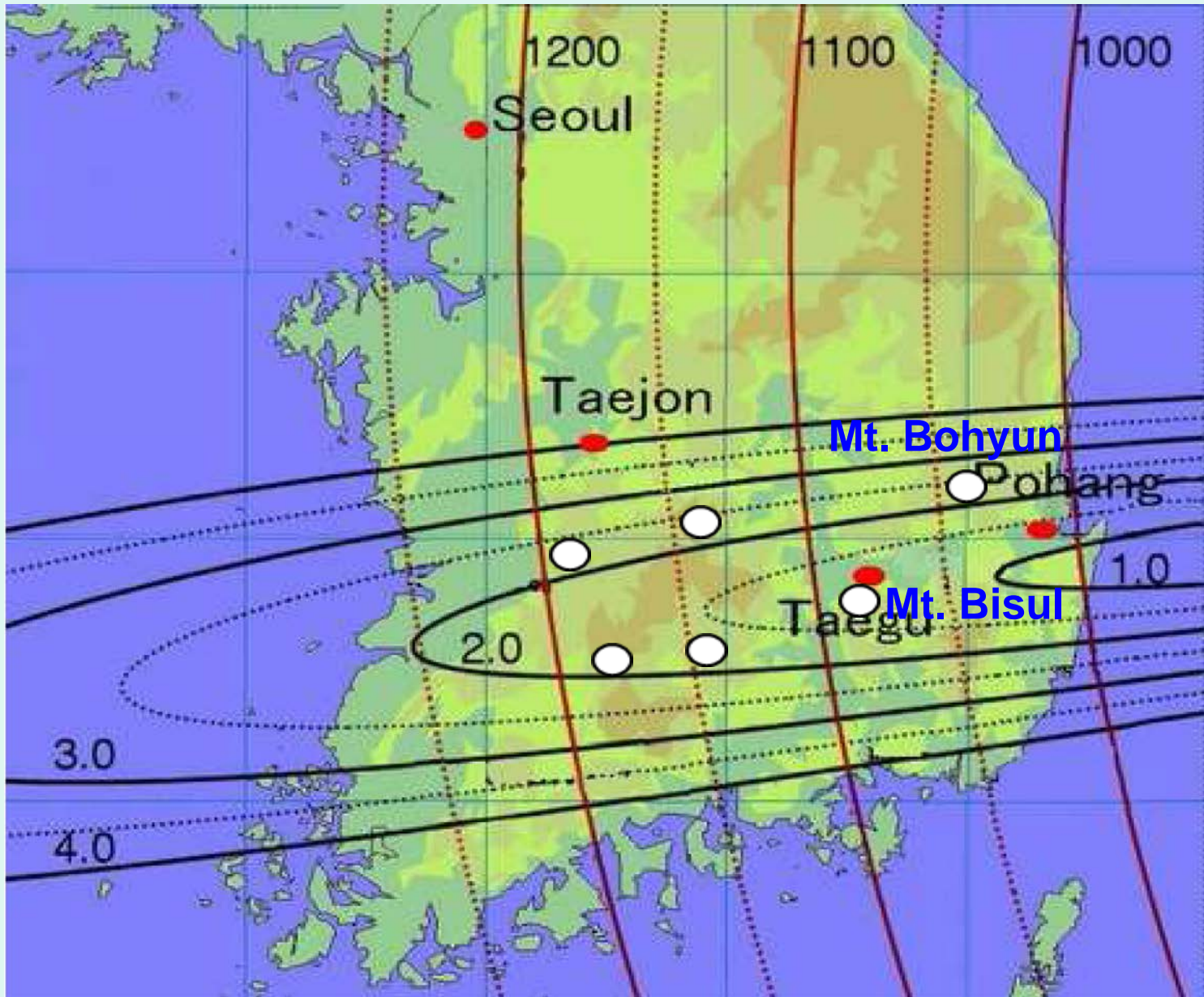
- KNO candidate sites have greater overburden than Japanese counterpart.

Detector site (overburden)	$\Phi$ ( $10^{-7} \text{ cm}^{-2}\text{s}^{-1}$ )	$\bar{E}_\mu$ (GeV)
Mt. Bisul (820 m)	3.81	233
Mt. Bohyun (820 m)	3.57	234
Mt. Bisul (1,000 m)	1.59	256
Mt. Bohyun (1,000 m)	1.50	257
Hyper-K (Tochibora, 650 m)	7.55	203
Super-K	1.54	258

- . Muon flux at KNO (1,000 m overburden) is ~5 times smaller than Hyper-K flux → smaller cosmic ray induced backgrounds
- The physics reach of KNO is better than that of Hyper-K in the field of SN, SRN, proton decay, dark matter and others.

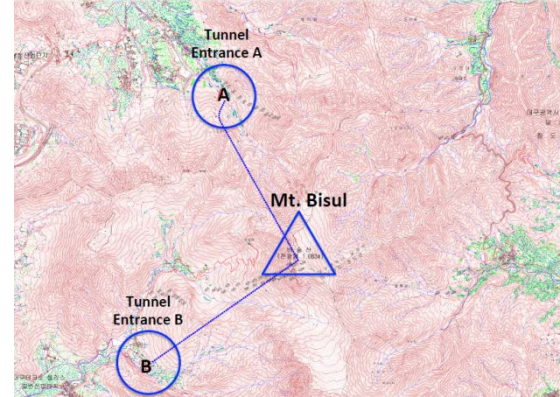


# KNO Candidate Sites

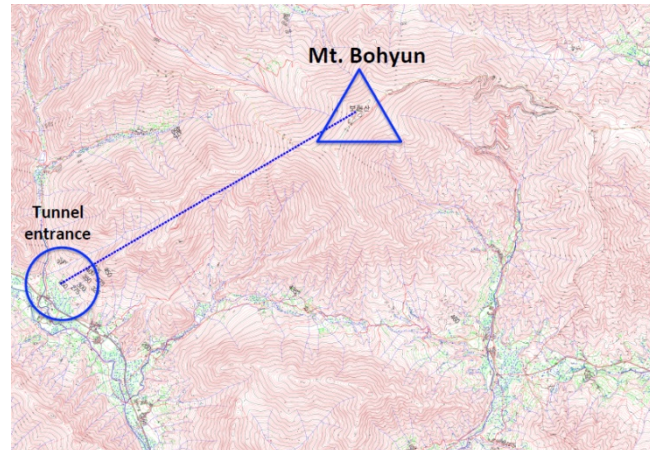


# KNO Candidate Sites – Bisul and Bohyun Mt

## 비슬산 (달성군)

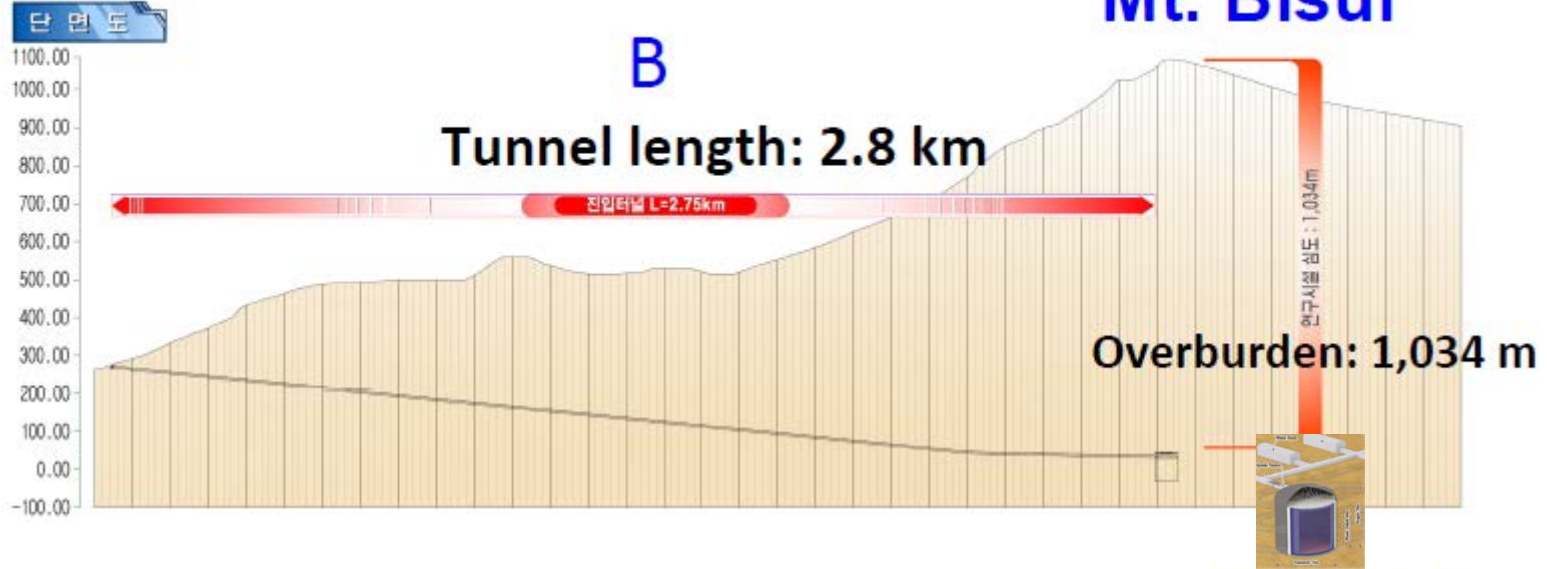


## 보현산 (영천시)



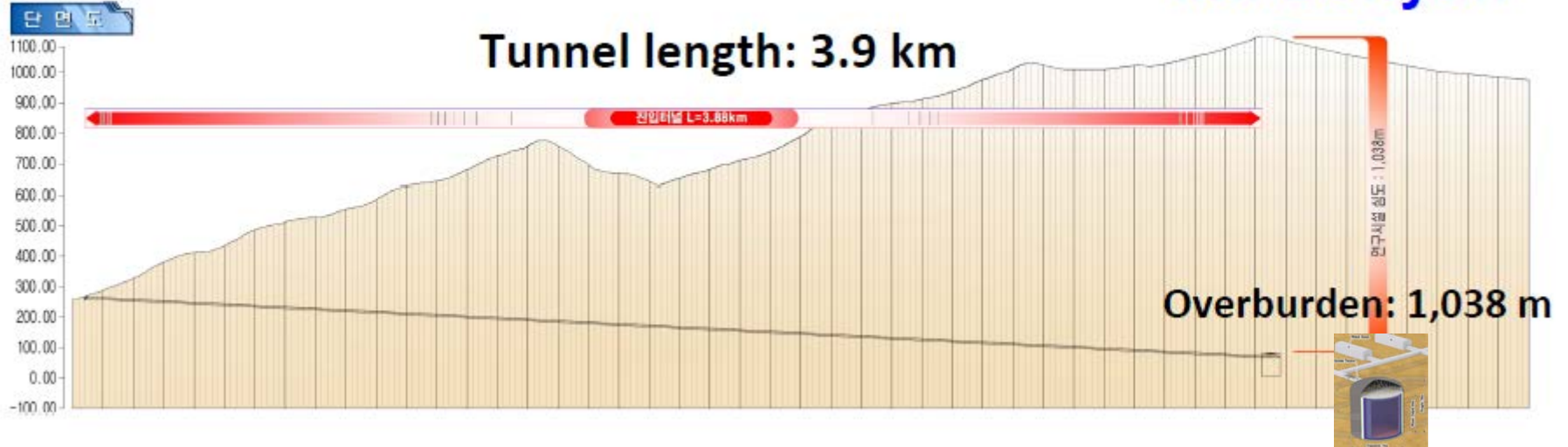
# Conceptual Design of KNO Tunnel

B구간 진입시 종단면도



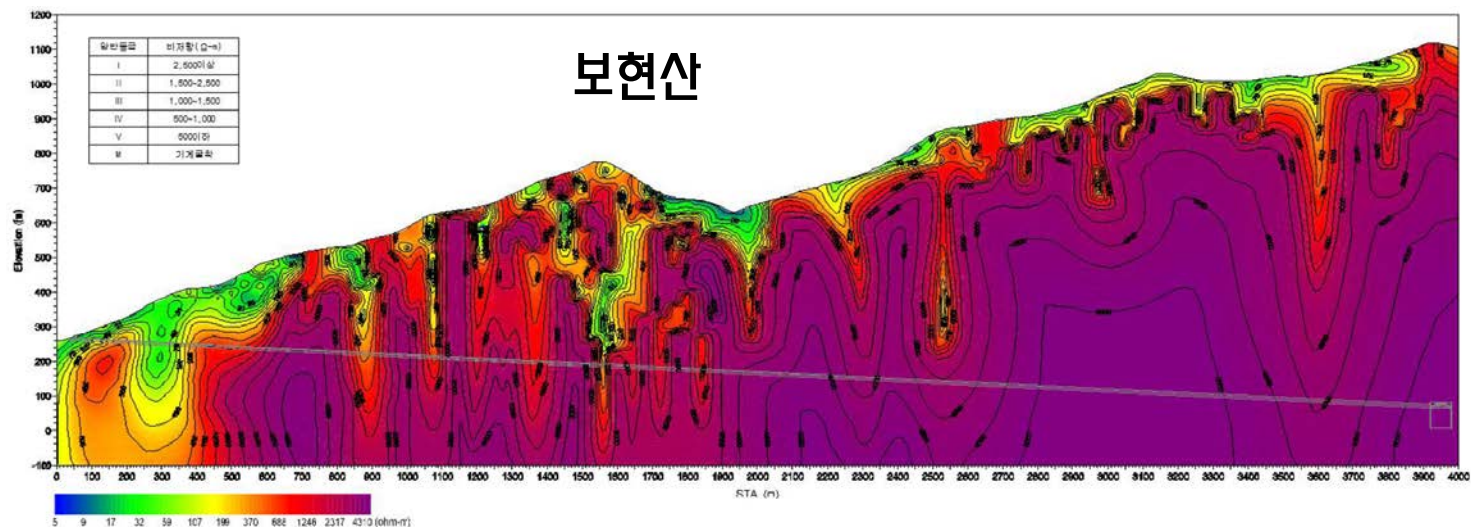
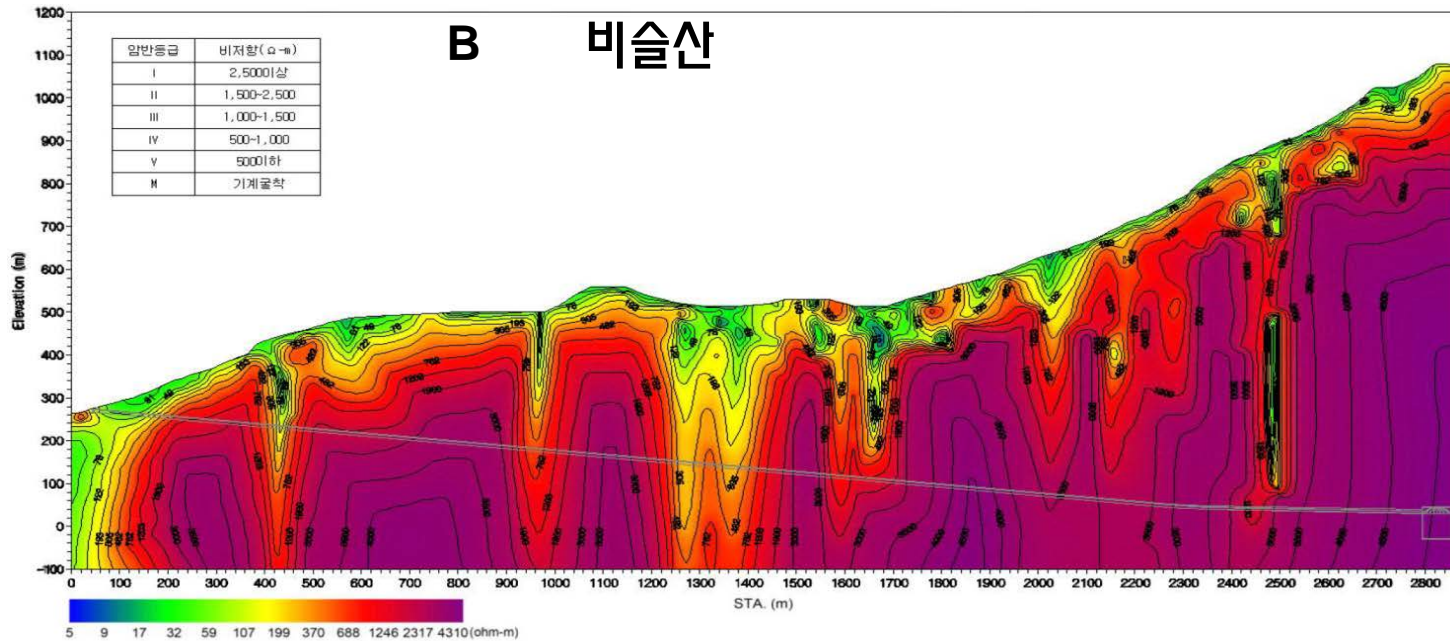
**Mt. Bisul**

A구간 진입시 종단면도

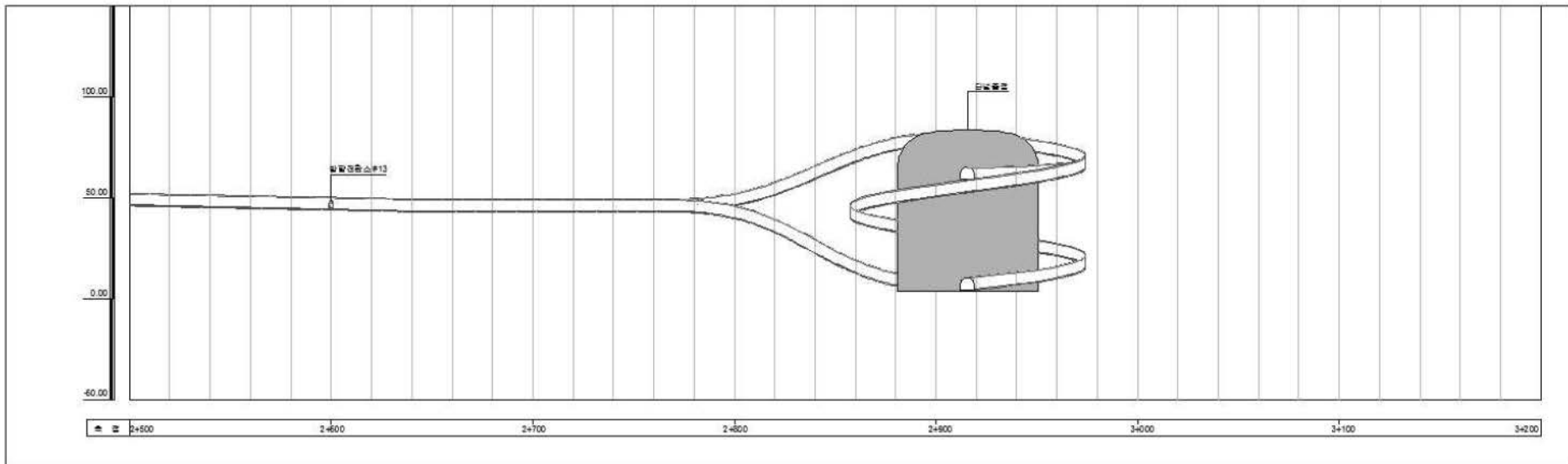
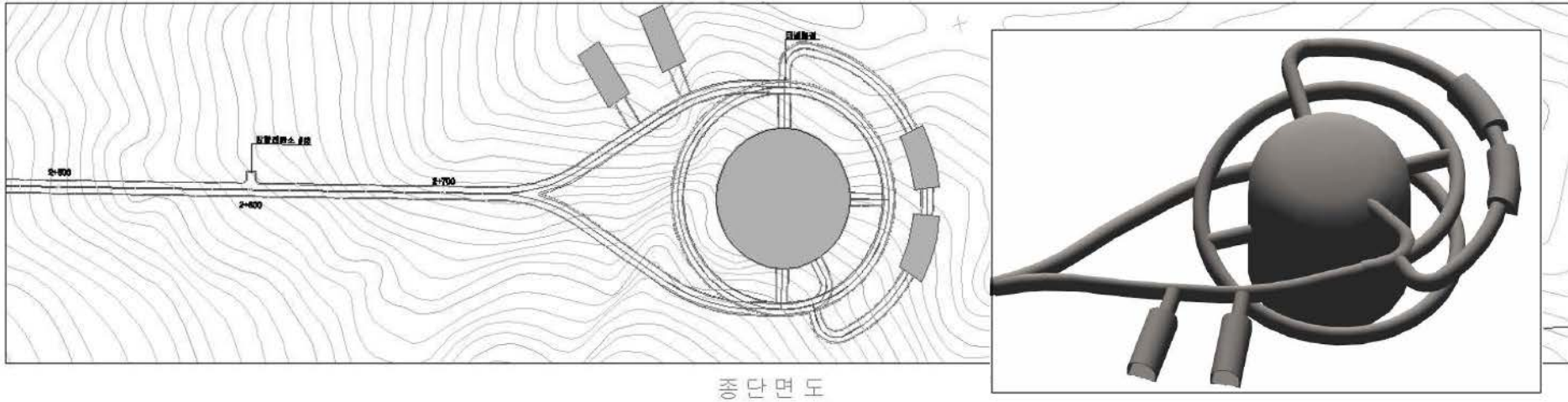


**Mt. Bohyun**

# Bedrock Investigation of KNO Sites



# Experimental Hall (Cavern)



# History of KNO

- Oct. 17, 2000: Another far detector using a JHF neutrino beam by S.B. Kim (KOSEF-JSPS Joint Seminar at KIAS)
- 2005/2006/2007: A large Cherenkov detector in Korea using a J-PARC neutrino beam (T2KK) by T. Kajita.  
→ 3 joint workshops supported by KOSEF and JSPS
- 2011: Proposal of 0.5 M ton water Cherenkov Hyper-Kamiokande detector at Kamioka (LOI as arXiv:1109.3262 and arXiv:1412.4673v2)
- 2015: Staged construction of two HK detectors of each 0.25 Mton at Kamioka
- June 1, 2016: Meeting to begin discussions (Canada/Japan/US/Korea)
- June, 2016: A working group effort for sensitivity study

# History of KNO

- July 10, 2016: The first T2HKK meeting in London  
→ present a proposal to the HK collaboration  
→ organize a HK working group (T2HKK: S. Seo )
- Sep. 2, 2016: Workshop on 2nd HK detector in Korea (SNU)
- Oct. 20, 2016: Pioneering Symposium at KPS (Gwangju)
- Nov. 2016: A white report on T2HKK released (PTEP 2018)
- Nov. 21-22, 2016: International workshop on T2HKK (SNU)
- Nov. 24, 2017: 1<sup>st</sup> KNO Workshop (KNU)
- Aug. 21, 2018: 2<sup>nd</sup> KNO Workshop (KASI)
- Oct. 20, 2018: KNO Kick-off Meeting (Seoul Station)
- Nov. 2, 2018: 3<sup>rd</sup> KNO Workshop (KNU)

# KNO 추진단 1차 회의

## Agenda

**15:00~15:05 Introduction**

**15:05~15:20 Status of Hyper-K (C. Rott)**

**15:20~15:40 Status of KNO (I. Yu)**

**15:40~16:40 Discussion I (All)**

**16:40~16:50 Break**

**16:50~17:50 Discussion II (All)**



# KNO 추진단 구성

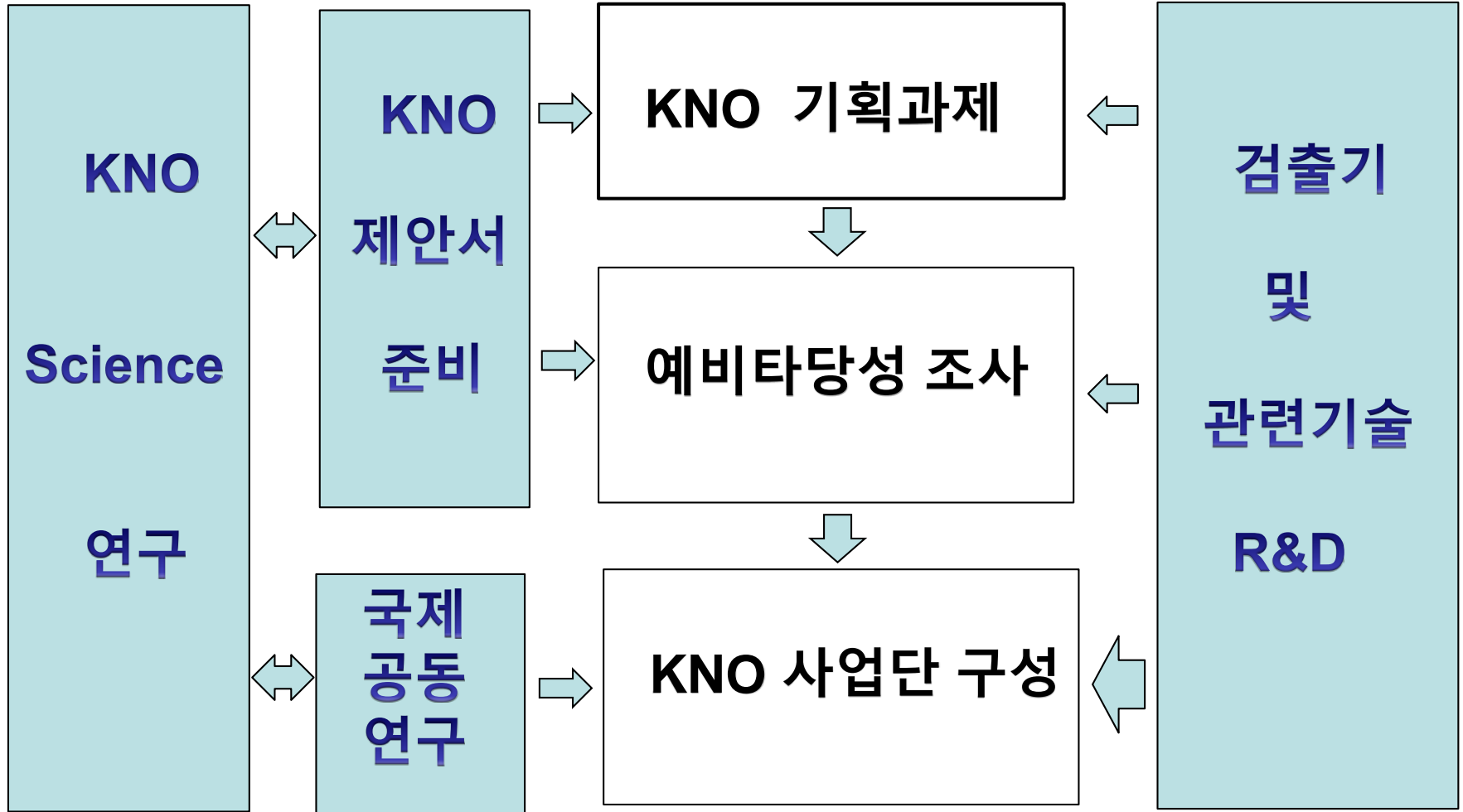
- 대정부/대지자체/대국민 팀 (박명구, 유인태)
- KNO 제안서 팀 (김상철, 서선희, 오용석)
- 국제협력 팀 (Carsten Rott)
- KNO Science 팀 (곽규진, 강신규)
- Detector R&D 팀 (김홍주, 주경광)

**KNO에 관심있는 분들의 참여를 적극적으로 환영합니다 !!**

# KNO 추진 전략 1

- 과학연구를 위한 세계적인 수준의 종합 지하실험시설  
- 물리/천문/지질/환경/...
- 검출기 관련기술 확보  
- photon sensor, water purification  
- 국내 관련 산업 및 지역 경제에 기여
- 국제공동연구를 통한 세계적인 선도 연구그룹 형성
- 국민참여형 과학시설을 구축해 국내과학진흥에 기여

# KNO 추진 전략 2



# KNO 이슈

- KNO 일정
  - Hyper-K construction (2020 ~ 2027)
  - KNO construction (2022? ~ 2027?)
- 검출기 관련 산업과의 협력관계 구축
  - 검출기 R&D (PMT,...)
- KNO 검출기 옵션
  - KNO Science Goal에 부합하는 검출기
  - KNO 일정에 연계
- KNO 사업비 확보 방안
  - 기획연구, 예비타당성조사
- Many others

# Summary

- KNO : World-Class Underground Research Facility

- Measurement of Neutrino Properties : CP phase, Mass ordering, Neutrino Oscillations, and others

- Multi-Messenger Astronomy: Supernova, Neutron Star/Black Hole, Solar Neutrino, and many others

- Searches for Proton Decays, Dark Matter, and others

- General Purpose Underground Facility :  
Environmental Radioactivity, Material Science,  
Biological/Medical Science, Geology, and others

Thank you