Hyper-Kamiokande 구축 현황

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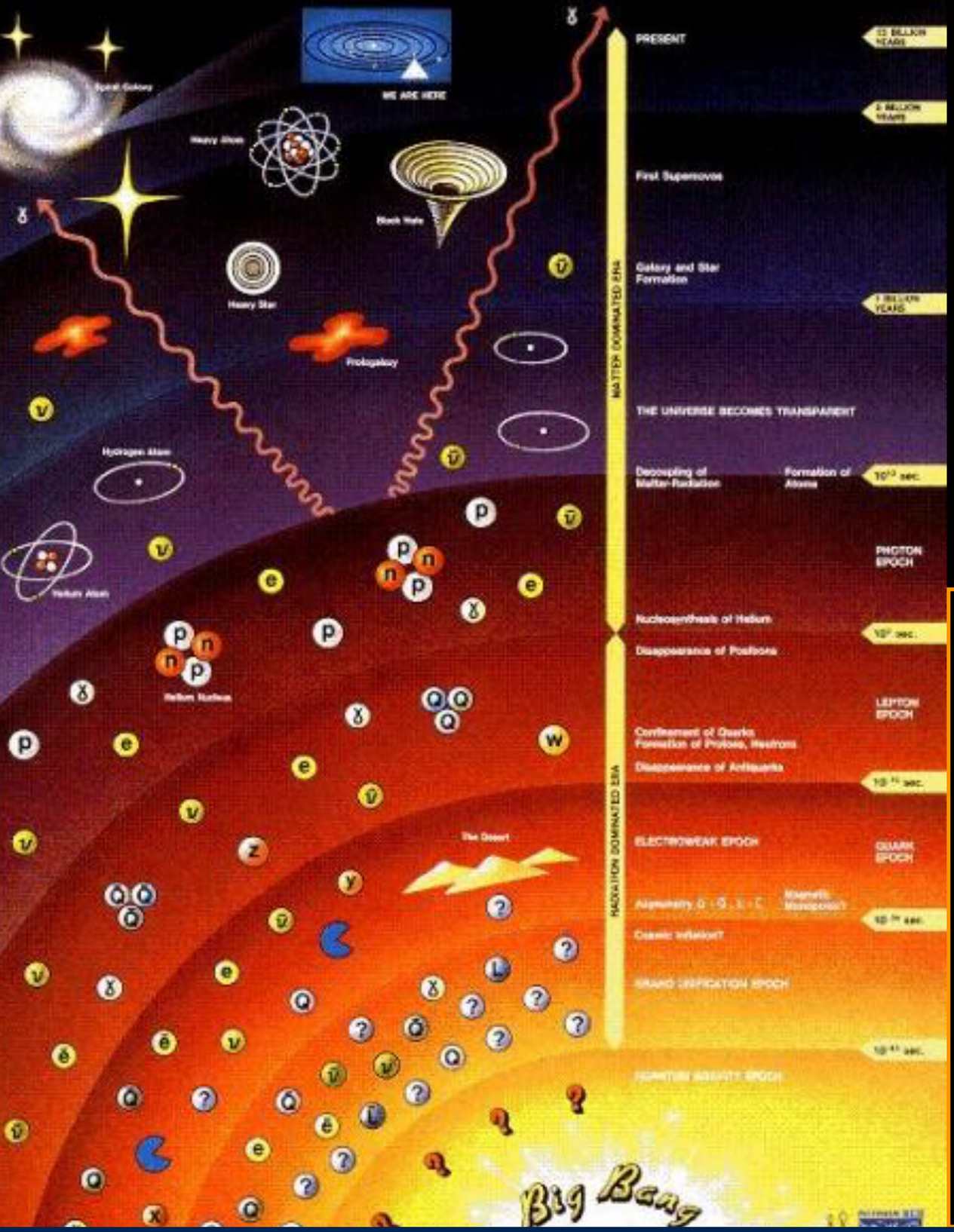
서울대학교

2026.06.12

한국고에너지물리학회 봄 학술대회

제주대학교

Why Do We Exist?



1,000,000,001

Matter

1,000,000,000

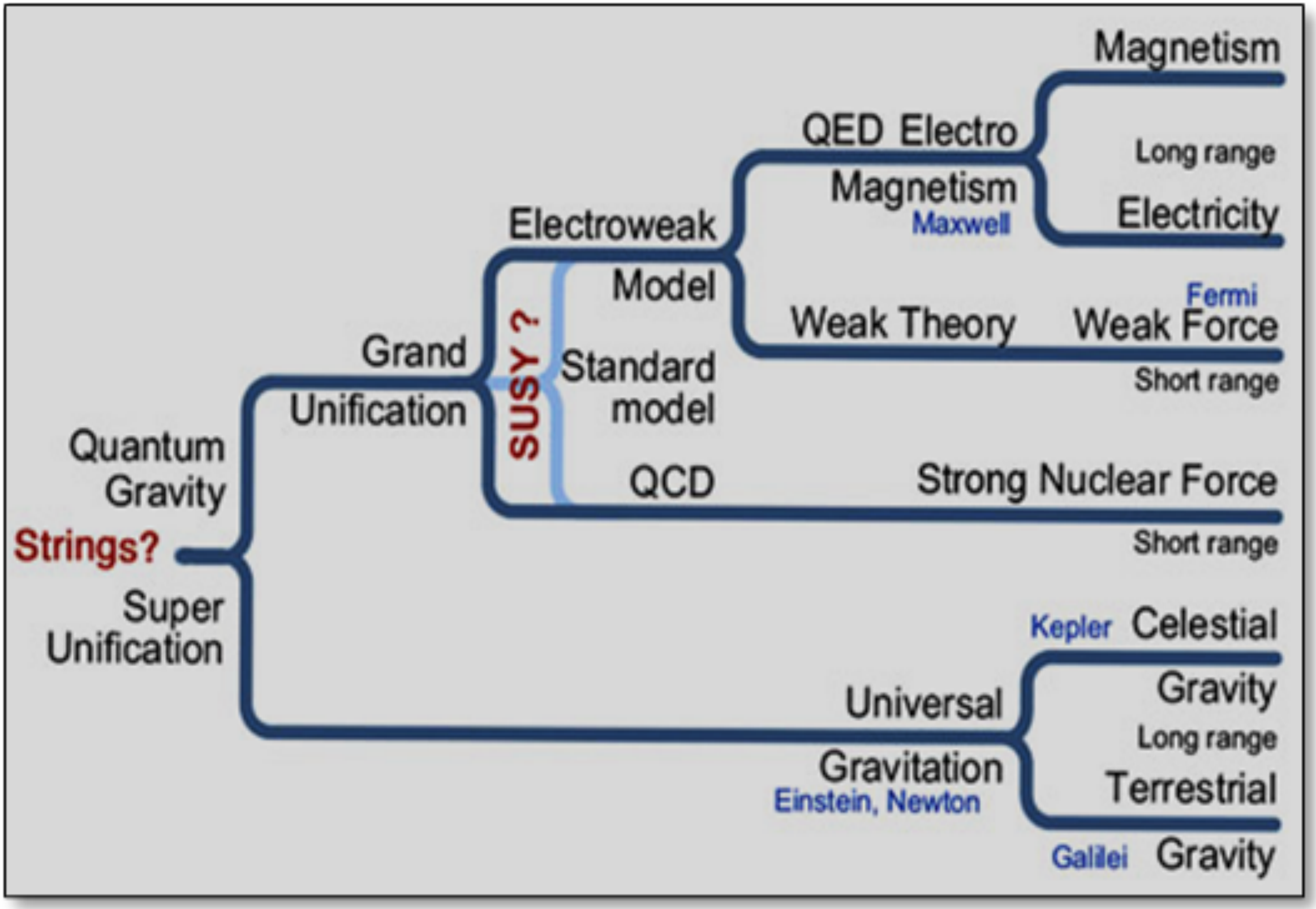
Anti-Matter

us (matter)

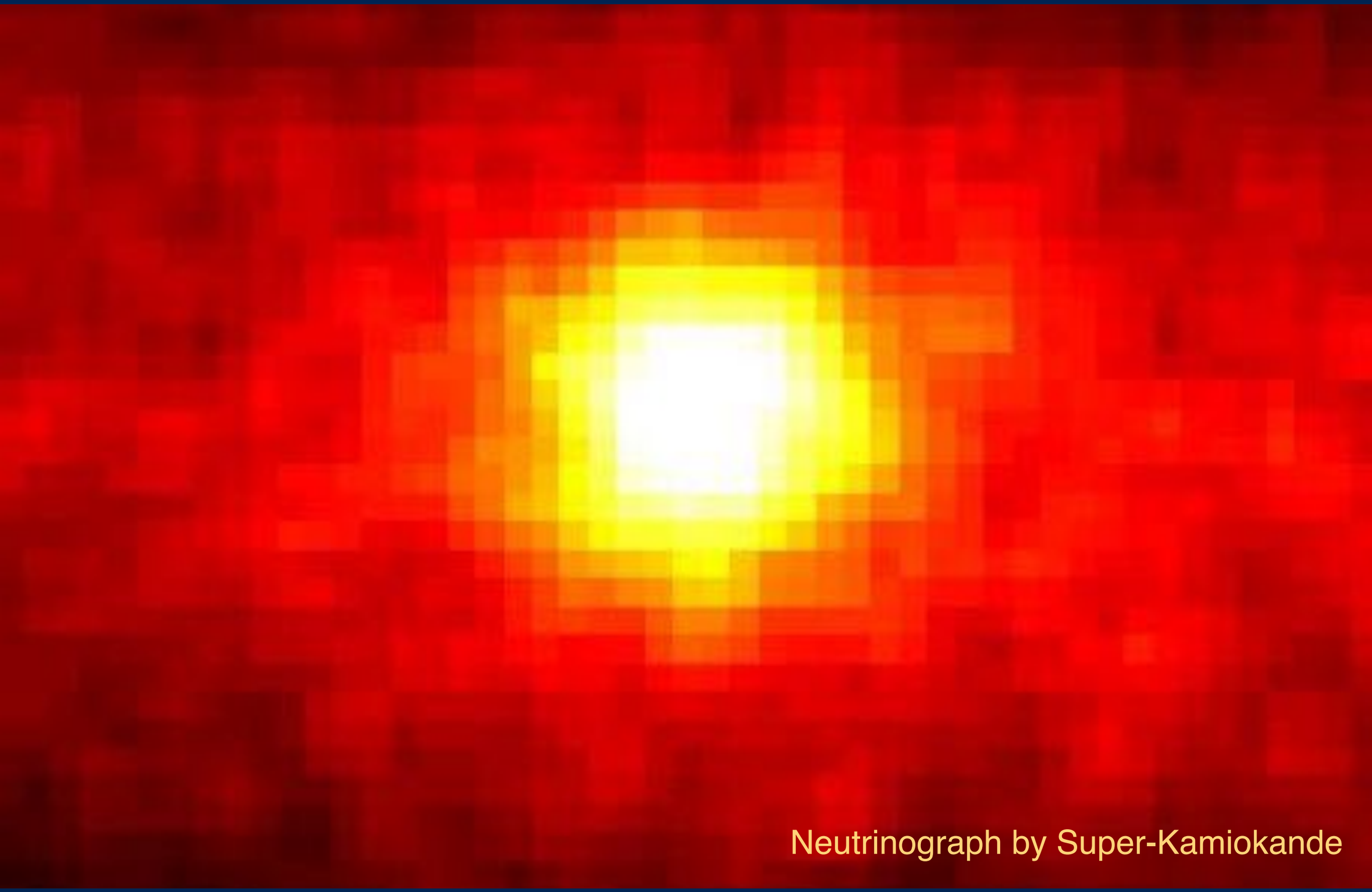
1

why? how?

Grand Unification?

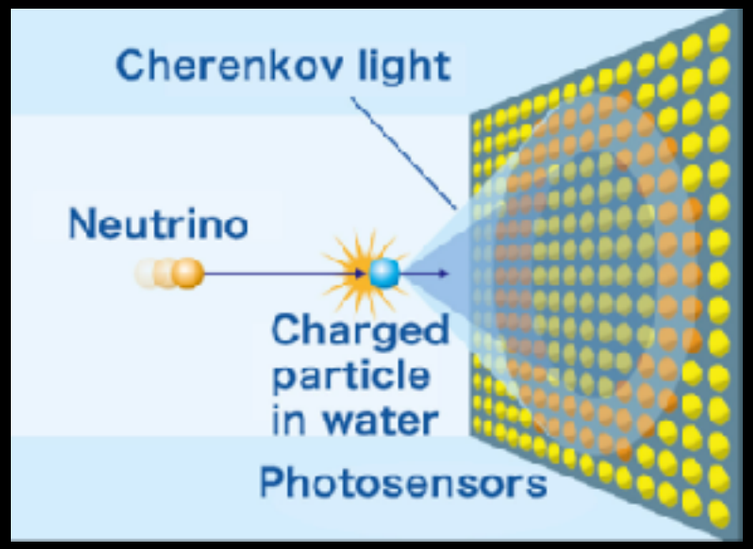


Transparent Universe



Neutrinograph by Super-Kamiokande

Kamiokande



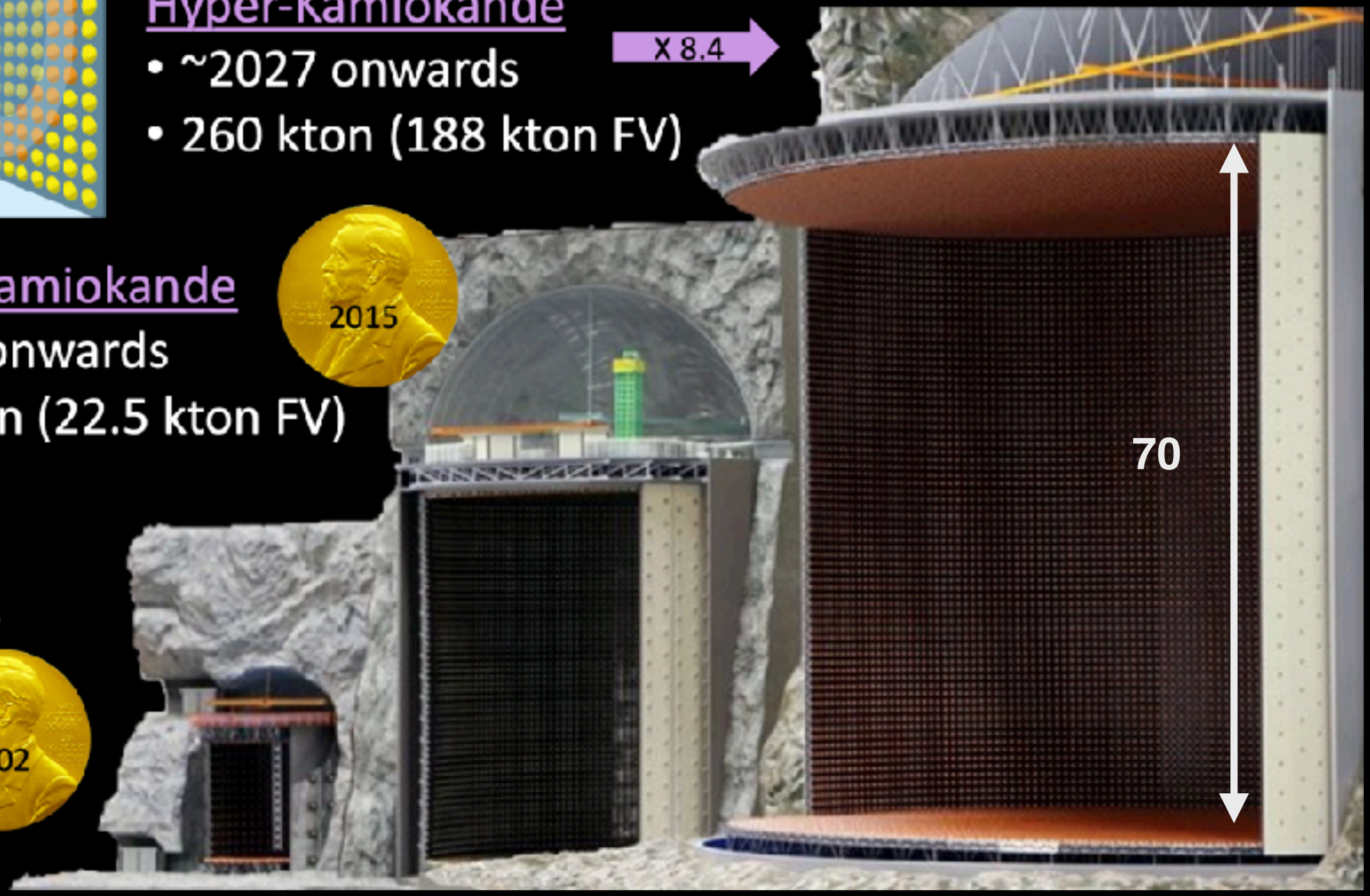
Hyper-Kamiokande
- ~2027 onwards
- 260 kton (188 kton FV)

X 8.4

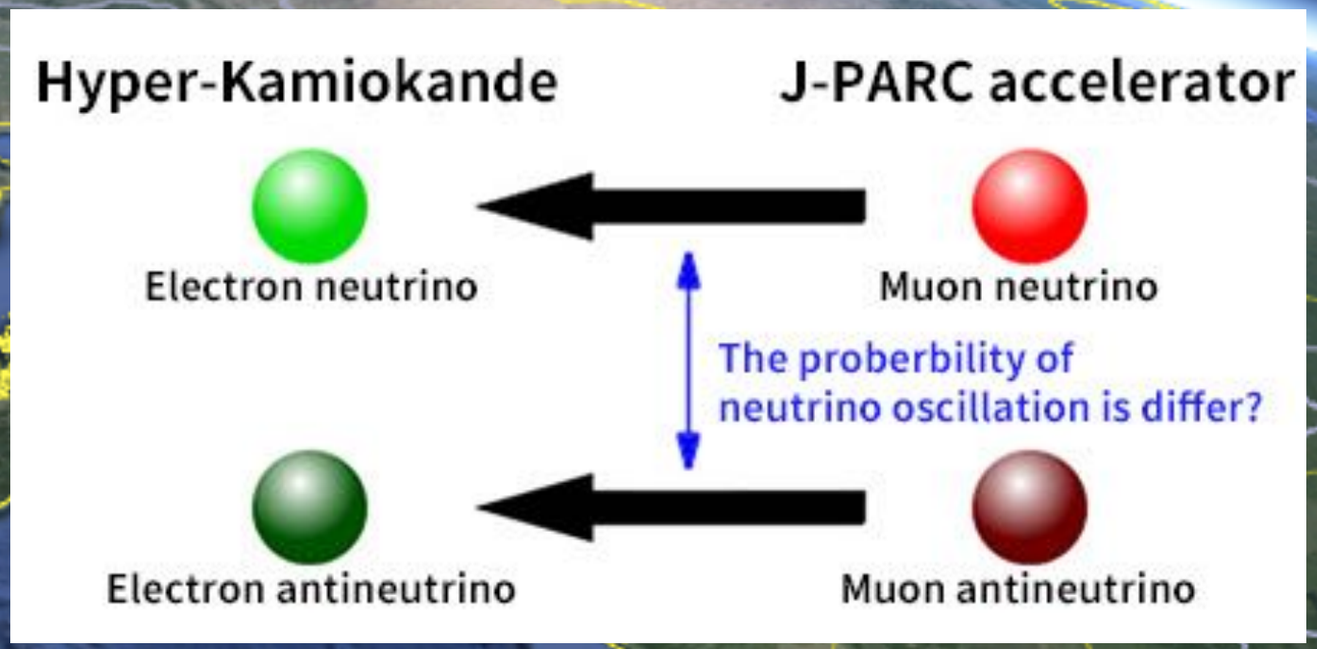
Super-Kamiokande
- 1996 onwards
- 50 kton (22.5 kton FV)

X 20

Kamiokande
- 1983 – 1996
- 3 kton



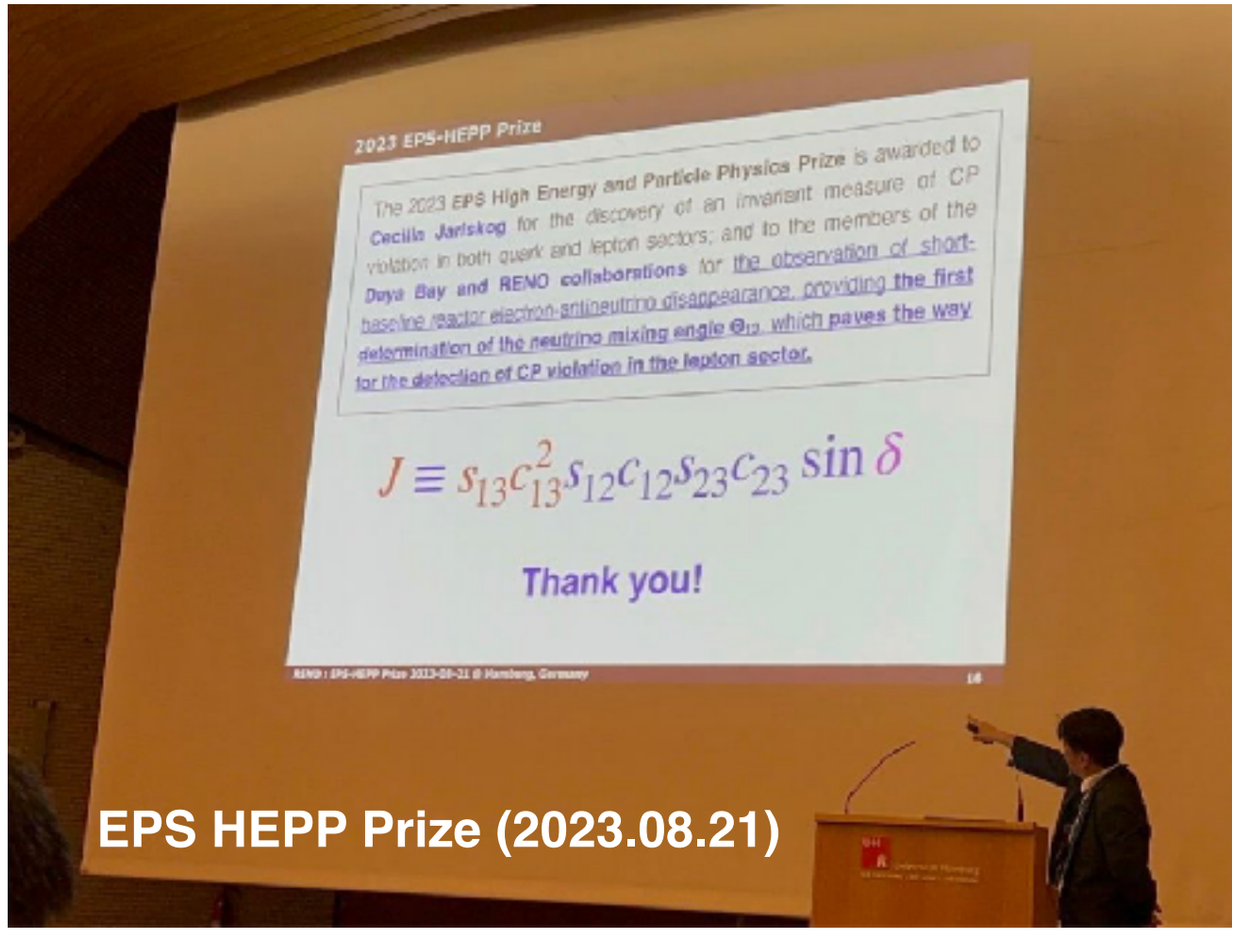
J-PARC to Hyper-K



CP-Phase

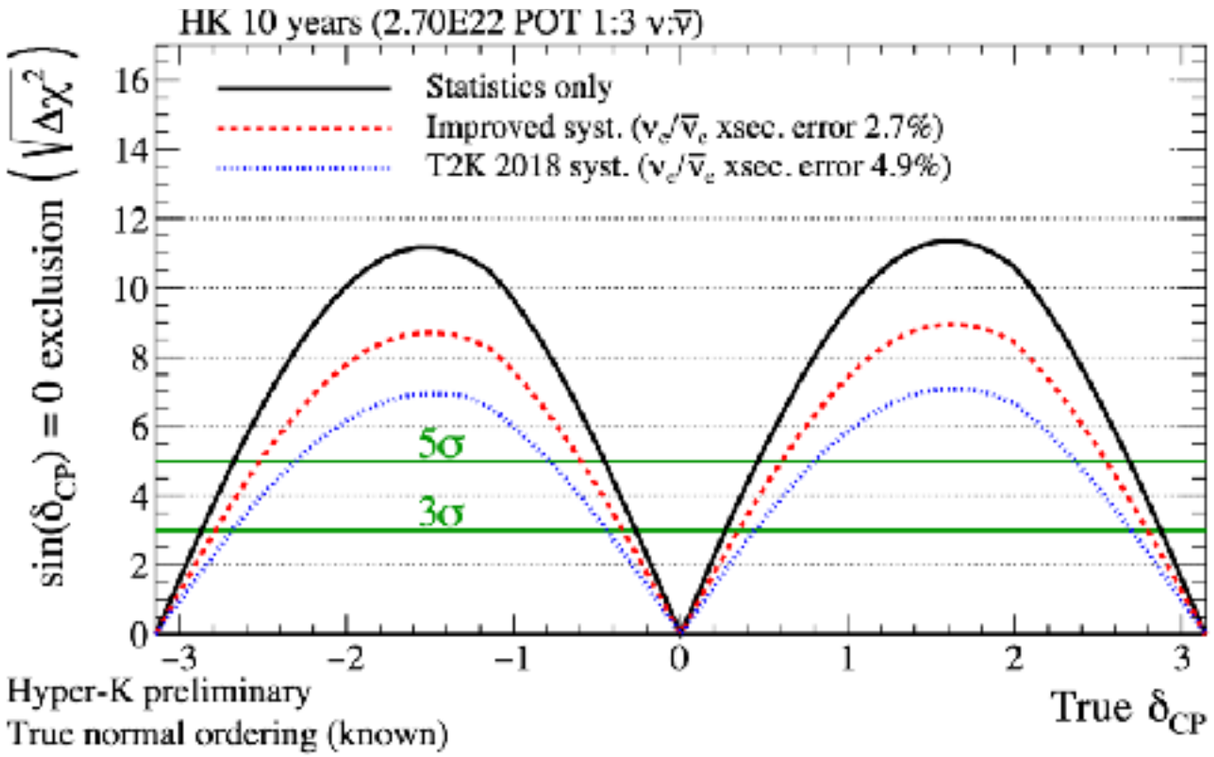
The 2023 **EPS High Energy and Particle Physics Prize** is awarded to **Cecilia Jarlskog** for the discovery of an invariant measure of CP violation in both quark and lepton sectors; and to the members of the **Daya Bay and RENO collaborations** for the observation of short-baseline reactor electron-antineutrino 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.**

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



EPS HEPP Prize (2023.08.21)

HK Physics

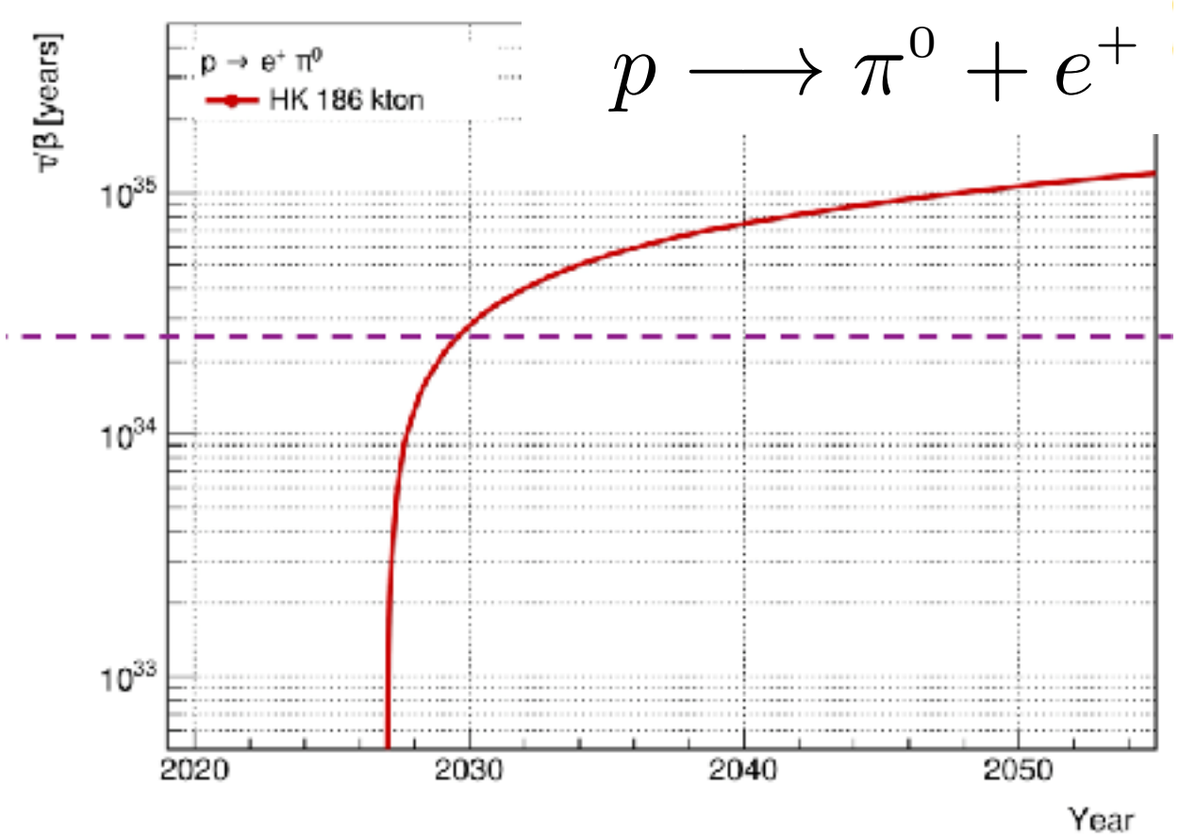


- **CP-phase measurement**

  10-years of J-PARC beam

  $\nu_\mu / \overline{\nu}_\mu$ = 1/3 run plan

➔ 61% of δ_{CP} can be probed at 5σ



$$p \longrightarrow \pi^0 + e^+$$

- **Proton decay**

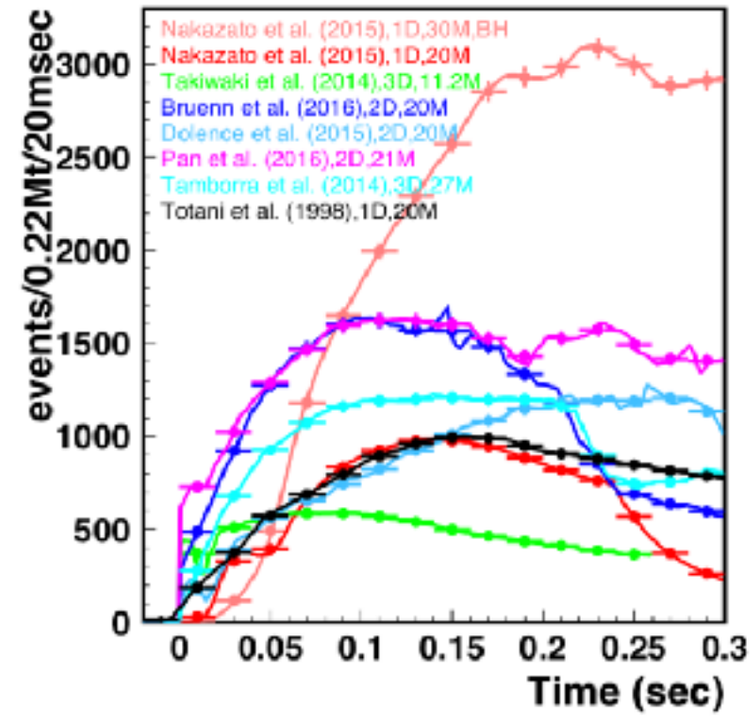
$\tau_p > 2.4 \times 10^{34}$ (SK measurement)

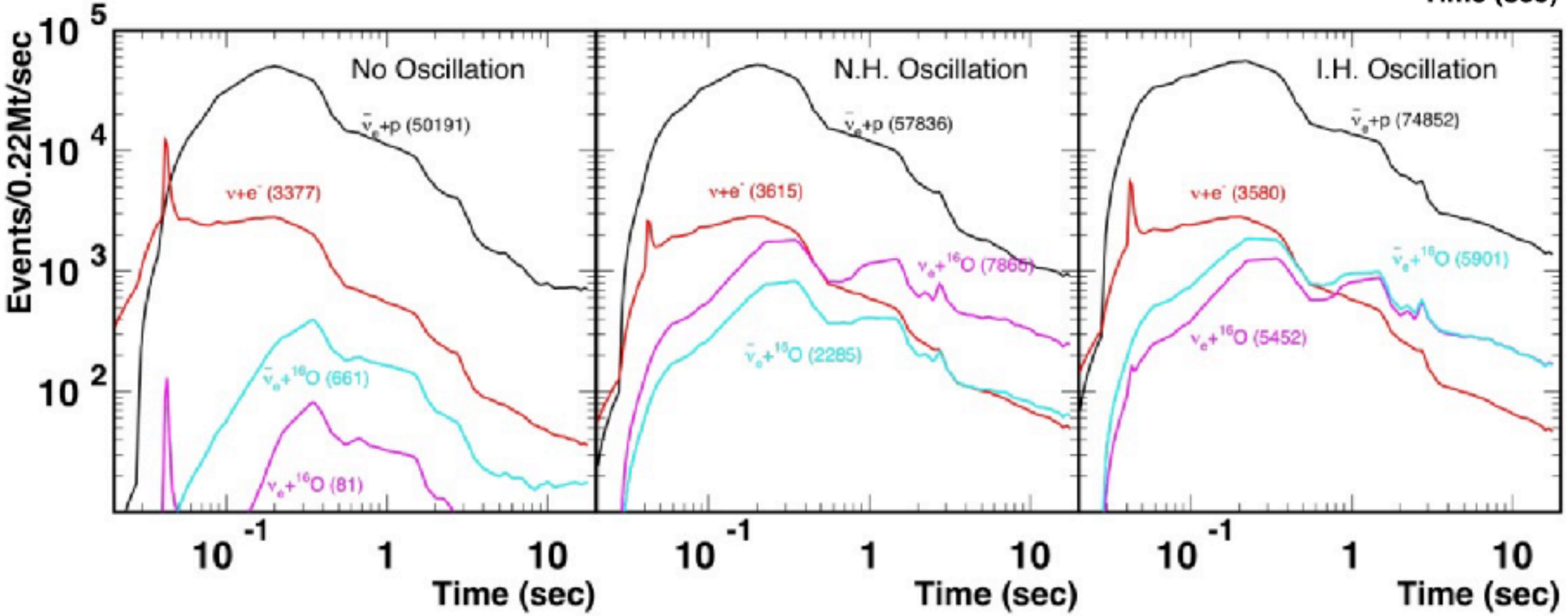
➔ Exceeding 25-years of SK limint in 2-years

HK AstroNeutrinos

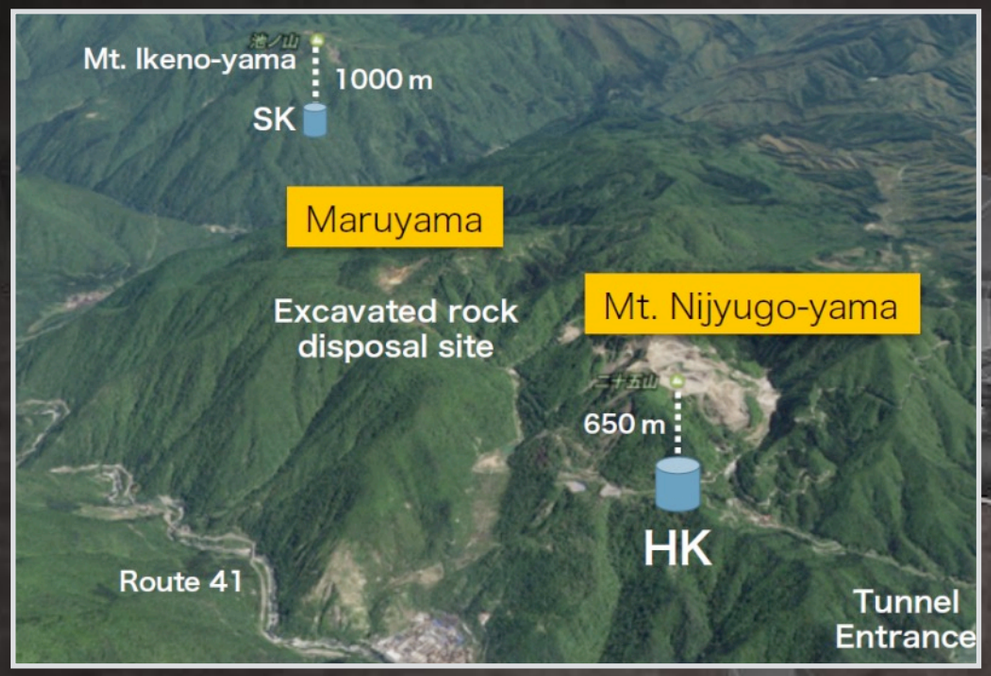
- **Neutrino Astrophysics**

  - Supernova neutrinos
  - Solar neutrinos
  - Atmospheric neutrinos
  - Dark matter search





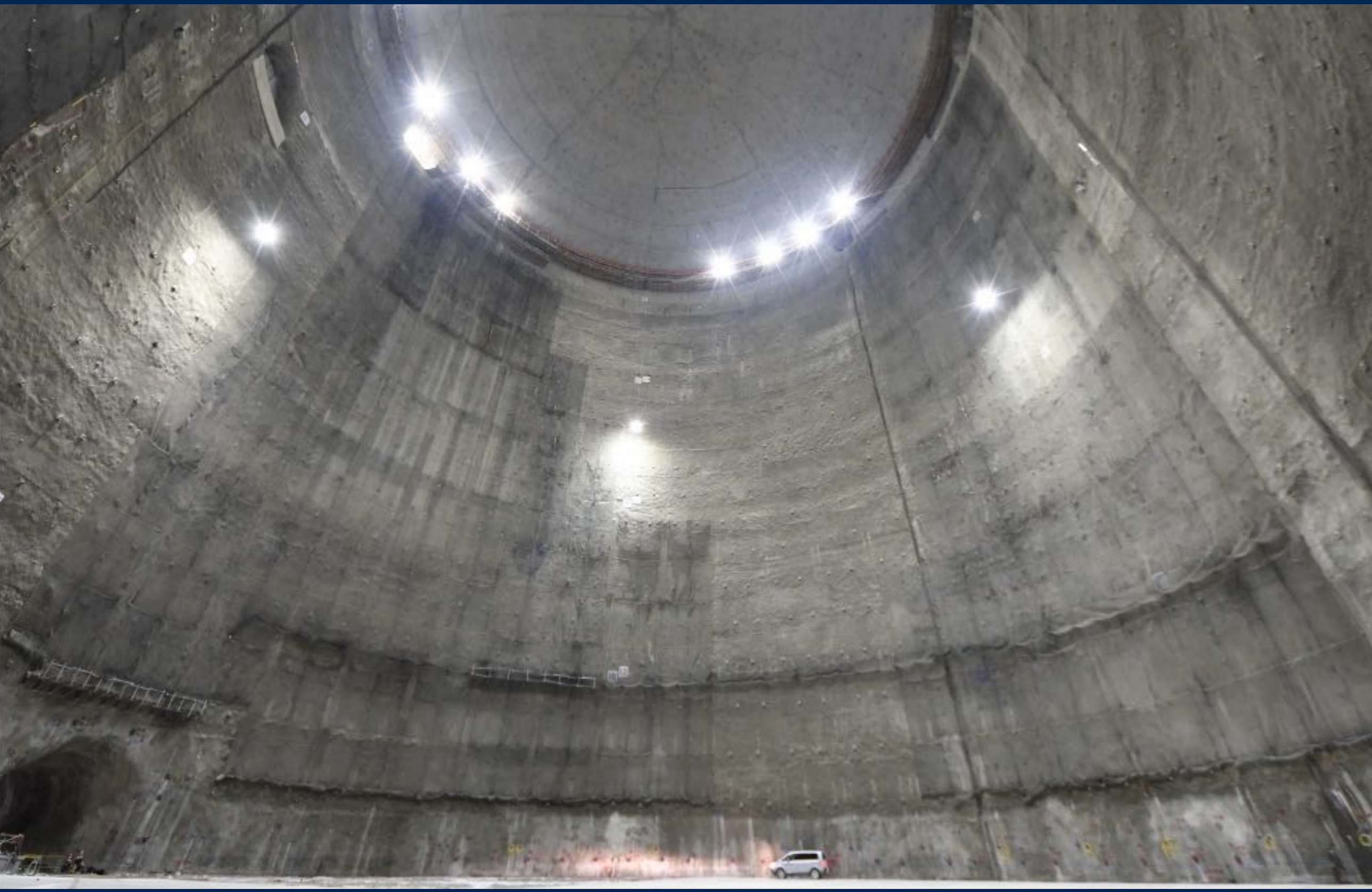
Hyper-Kamiokande



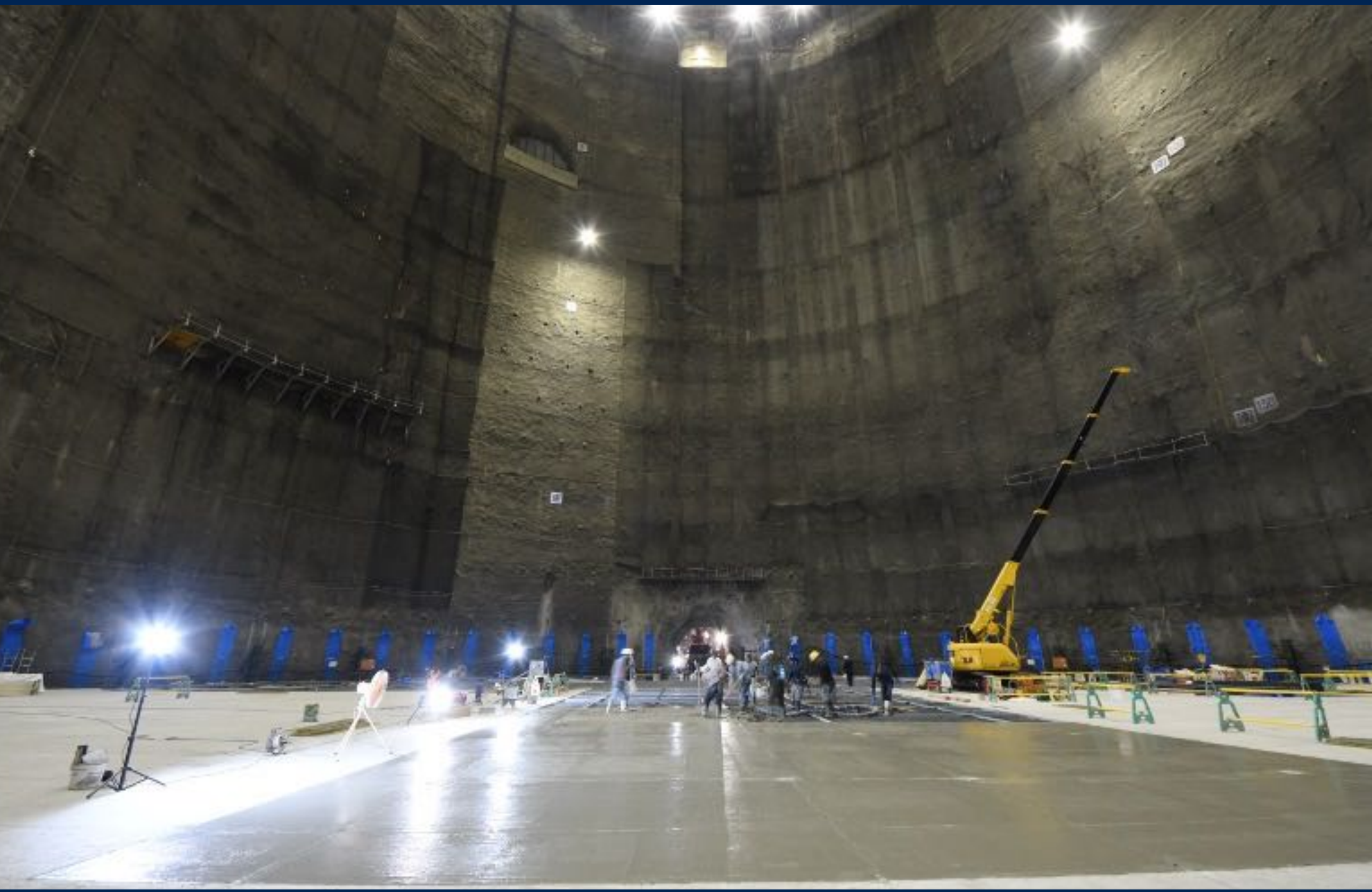
- 0.26 Megaton pure water
  190kt fiducial volume
- 20,000 50cm ID PMTs
- 3500 7.5cm OD PMTs
- 600m under the Nijyugo-yama

HK 구축 현황 (2024.6)

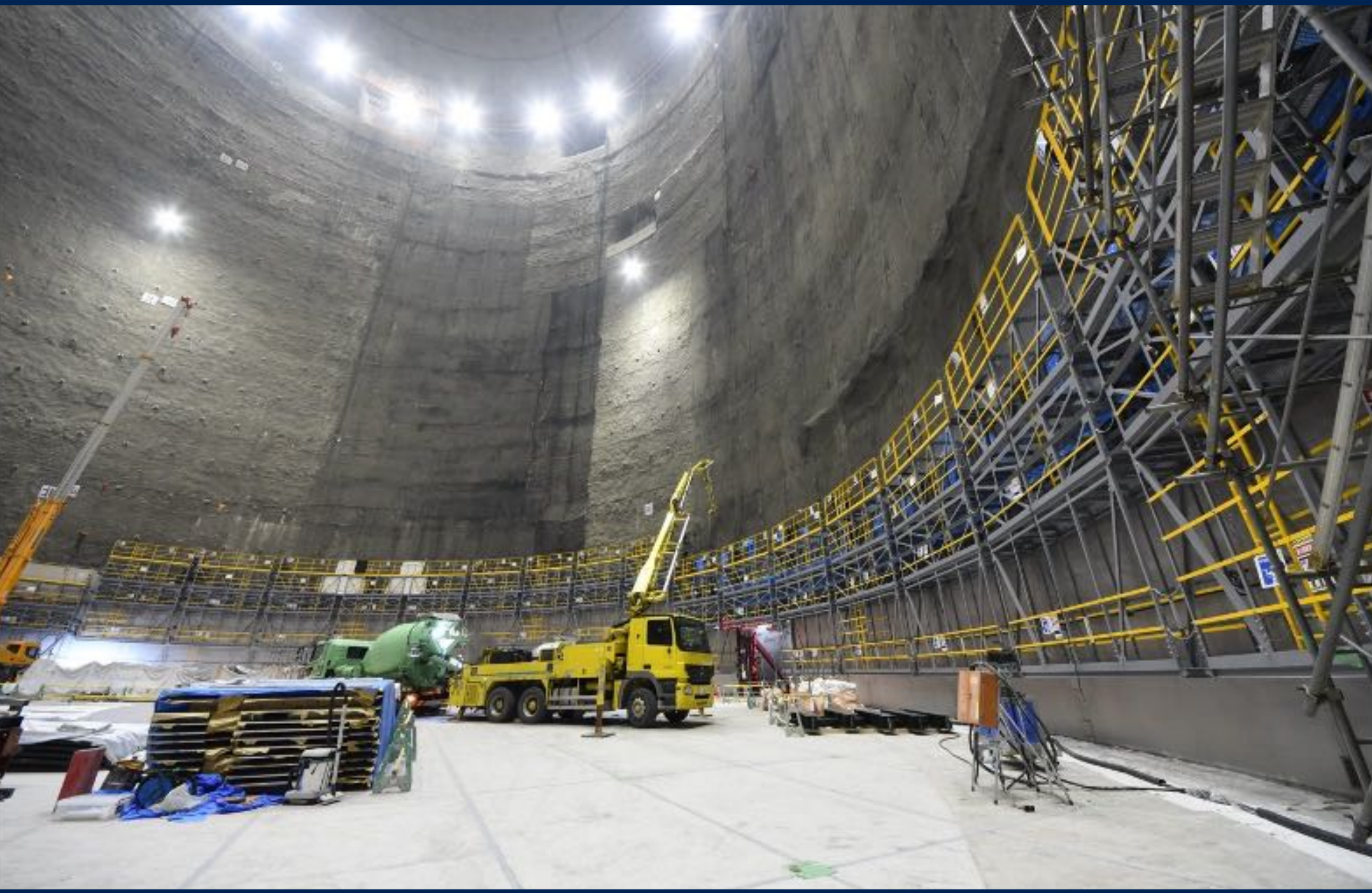
HK 구축 현황 (2025.8)



HK 구축 현황 (2025.11)

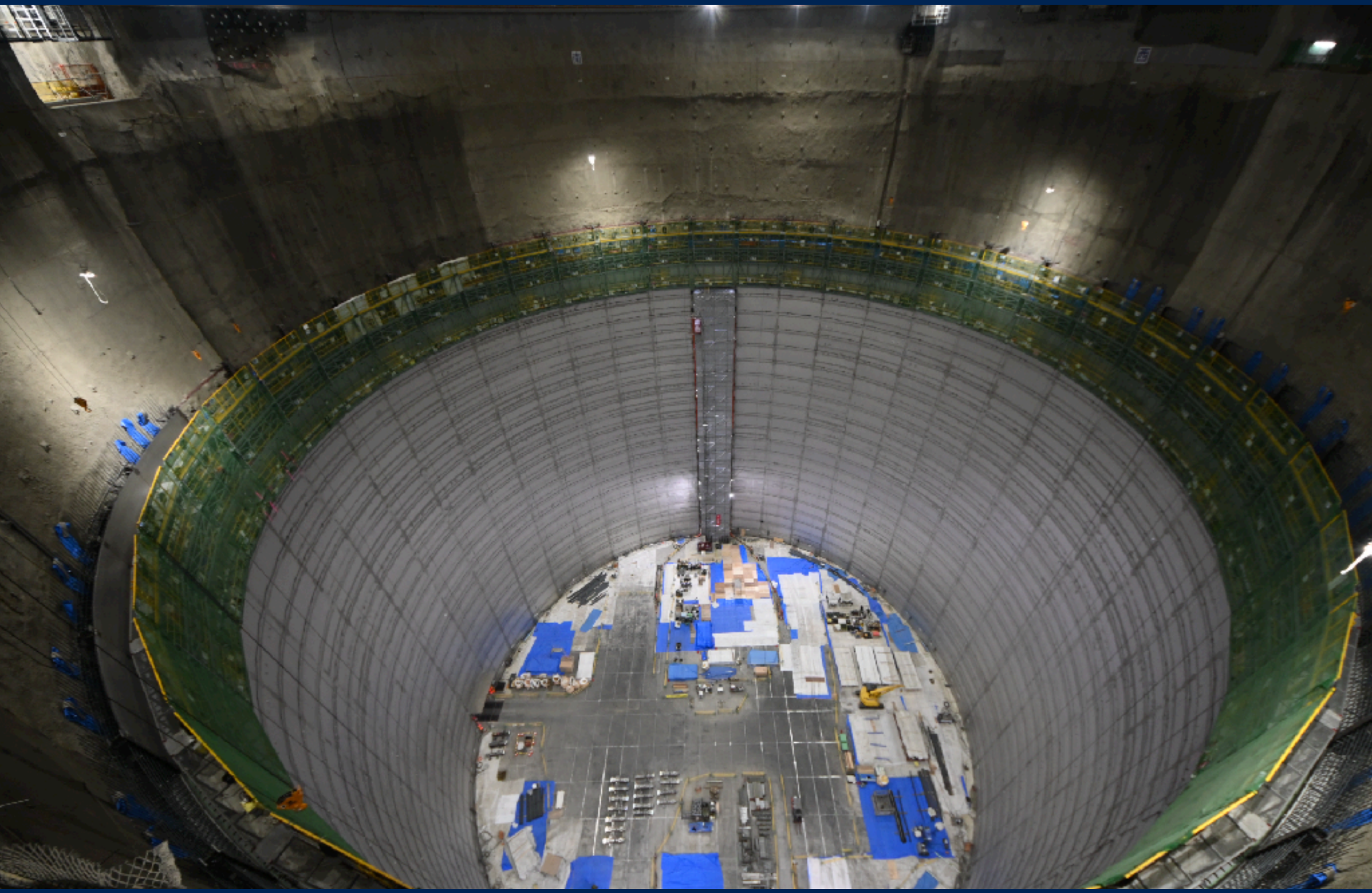


HK 구축 현황 (2026.3)



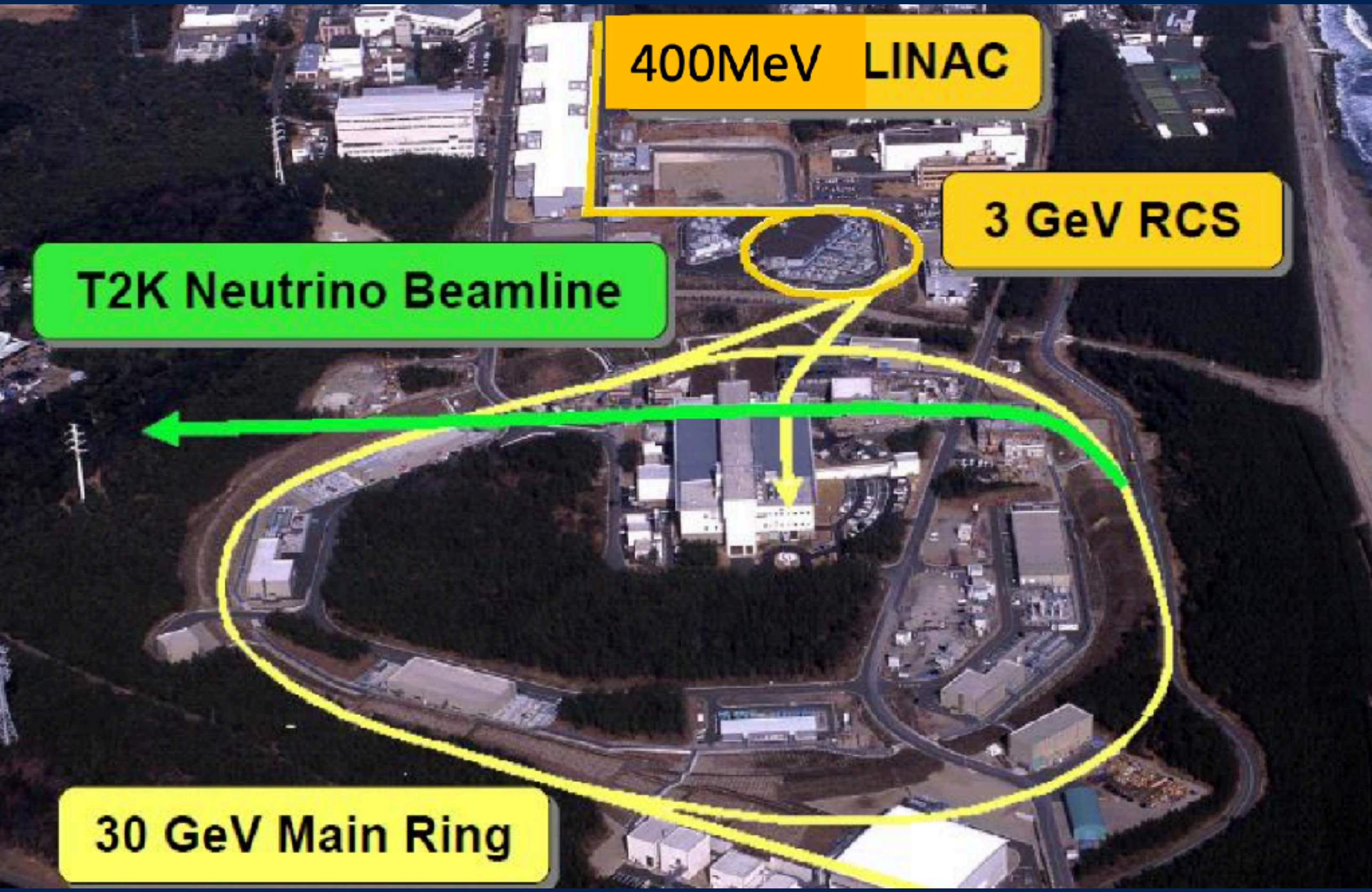
HK 구축 현황 (2026.5)

HK 구축 현황 (2026.5)

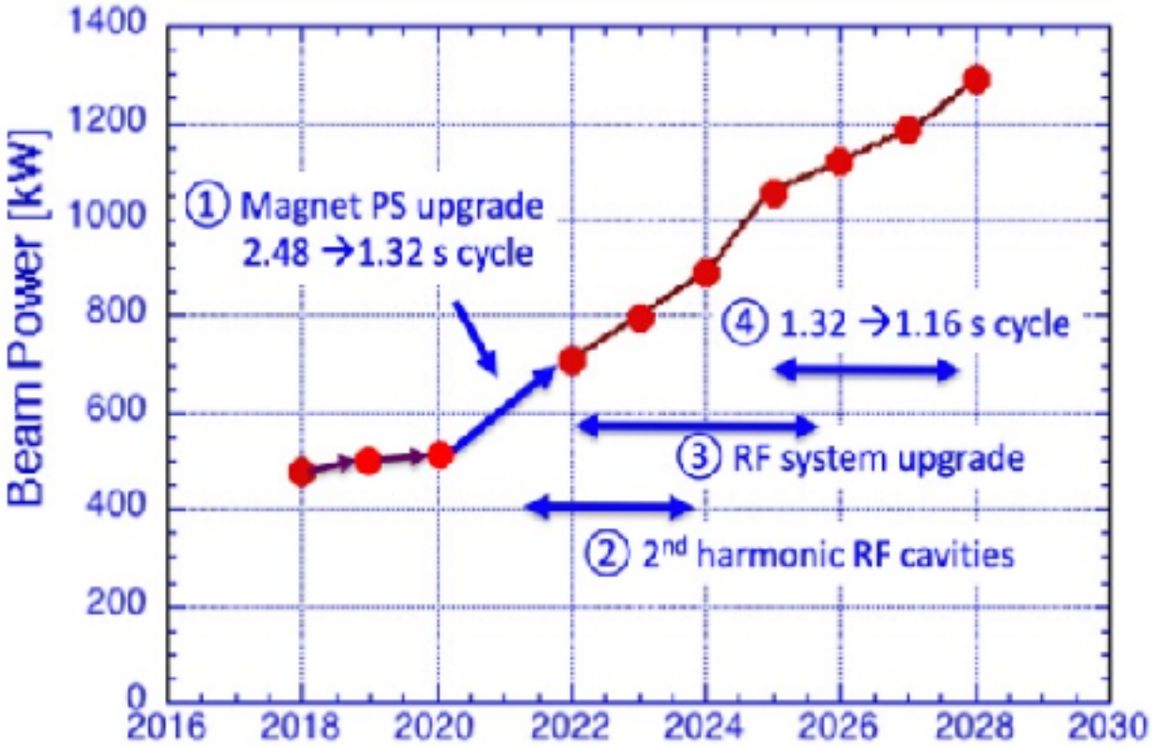


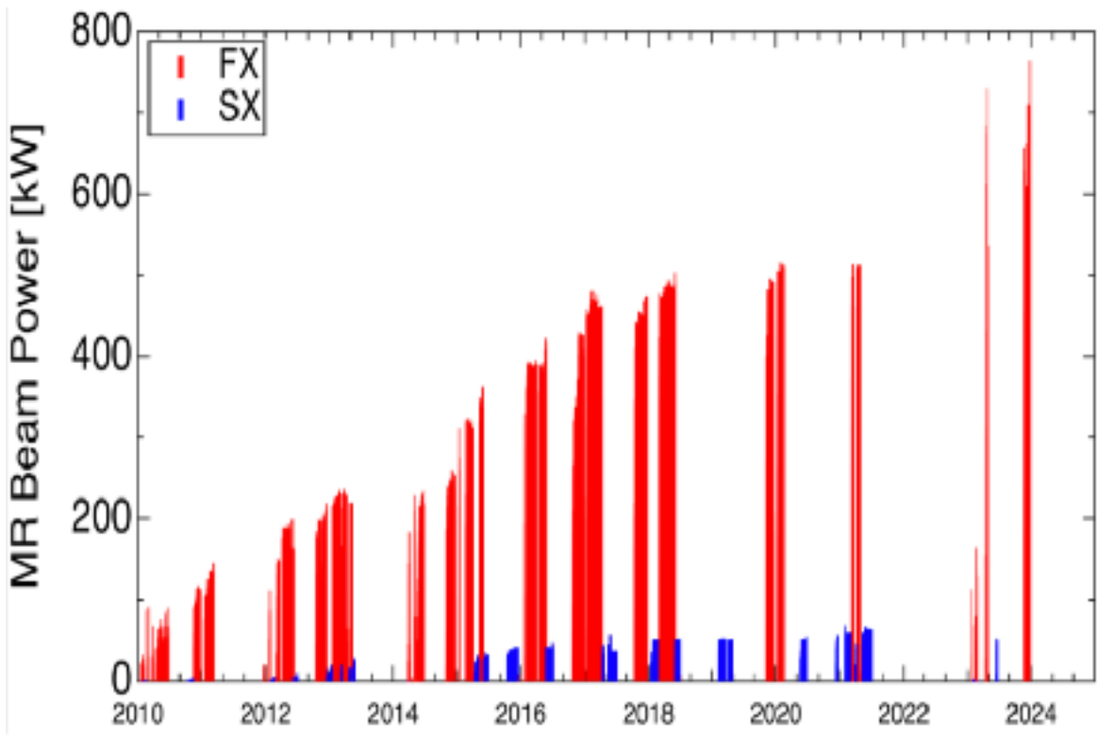
HK 구축 현황 (Water System)

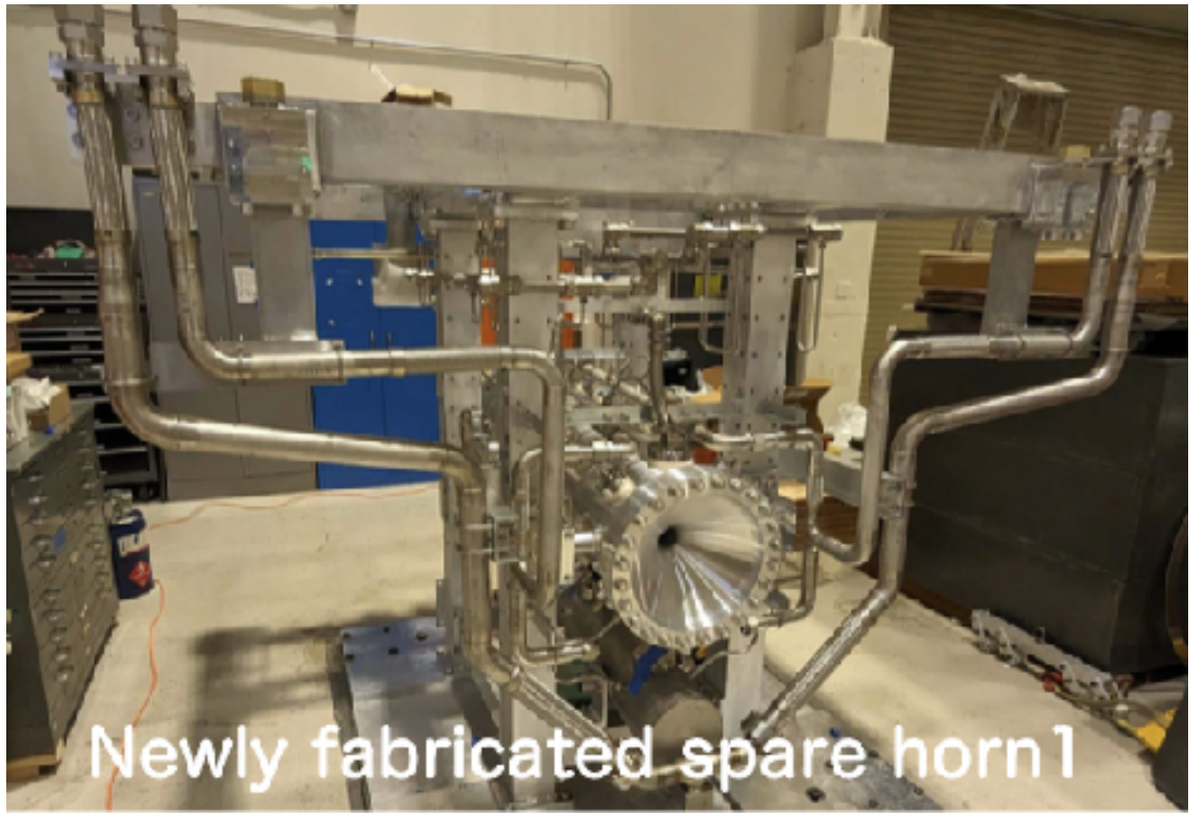
J-PARC Neutrino Beam Line



J-PARC Neutrino Beam Upgrade







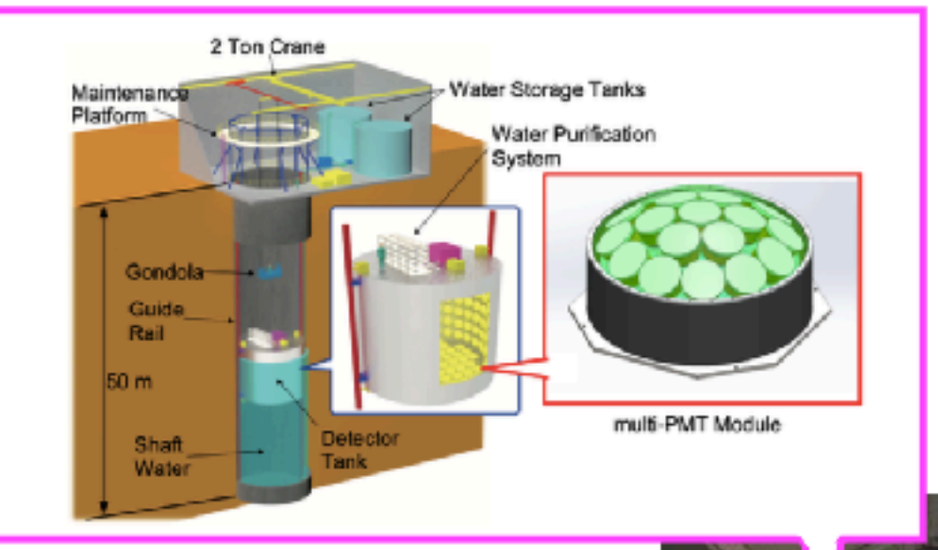
J-PARC Near Detectors

- T2K near detectors (280m downstream) measure beam profile

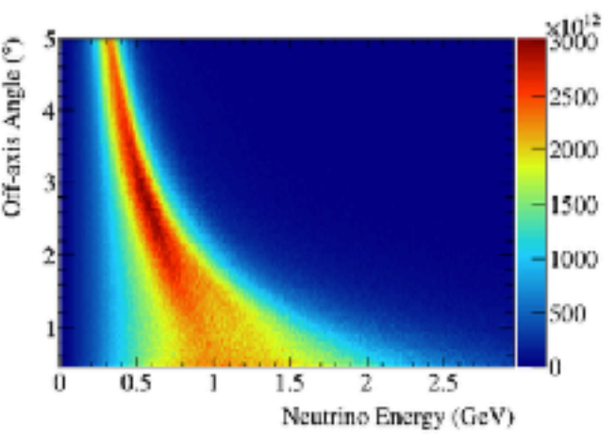
- Interactive Neutrino GRID
- On-axis neutrino detector
- Beam profile measurement

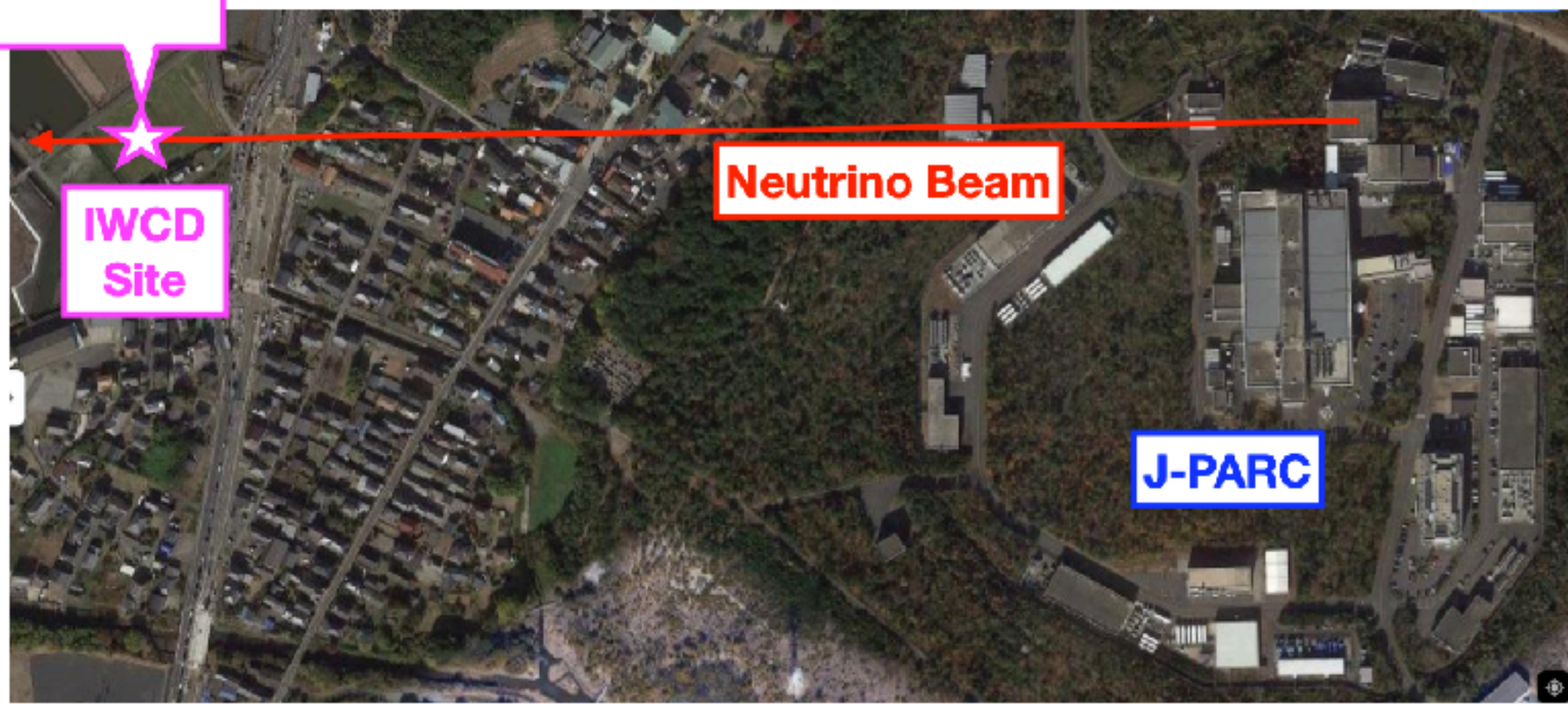
- Tracking detector serving as a near detector
- 280 [m] baseline w/ 2.5° off-axis
- **Flux and interaction of unoscillated neutrinos**
- target systematic below 4%, long term to <2%
- Detector upgrade completed in 2024
- Further upgraded to ND280++ in the future

Intermediate Water Cherenkov Detector



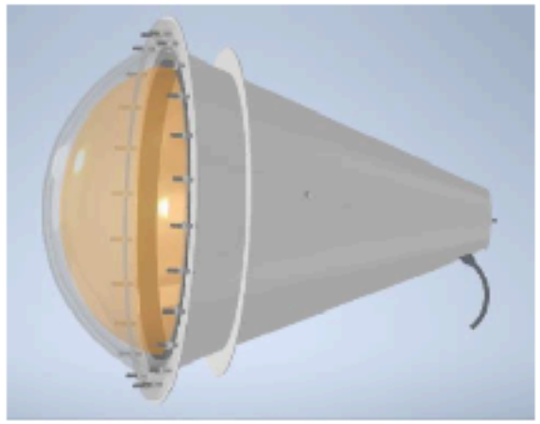
- 850m baseline with 1.5~4 degrees off-axis
- Vertically mobile detector
- Equipped with mPMTs
- Reduce energy-dependent systematics
- Under construction





HK Far Detector 구축

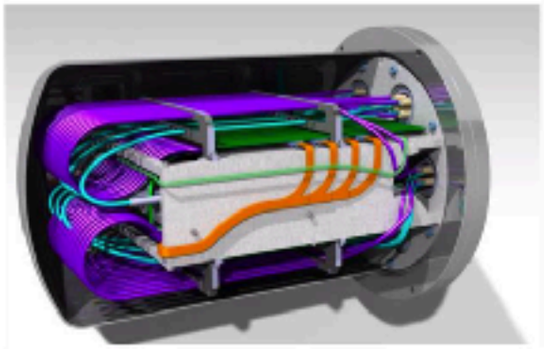
각 국가별로 세부 프로젝트 할당



FD1 (IDPMT)
Japan, Spain

FD2 (multi-PMT)
Czech, Canada, Italy, Mexico, Poland

FD3 (ODPMT, Tyvek)
Australia, Korea, UK



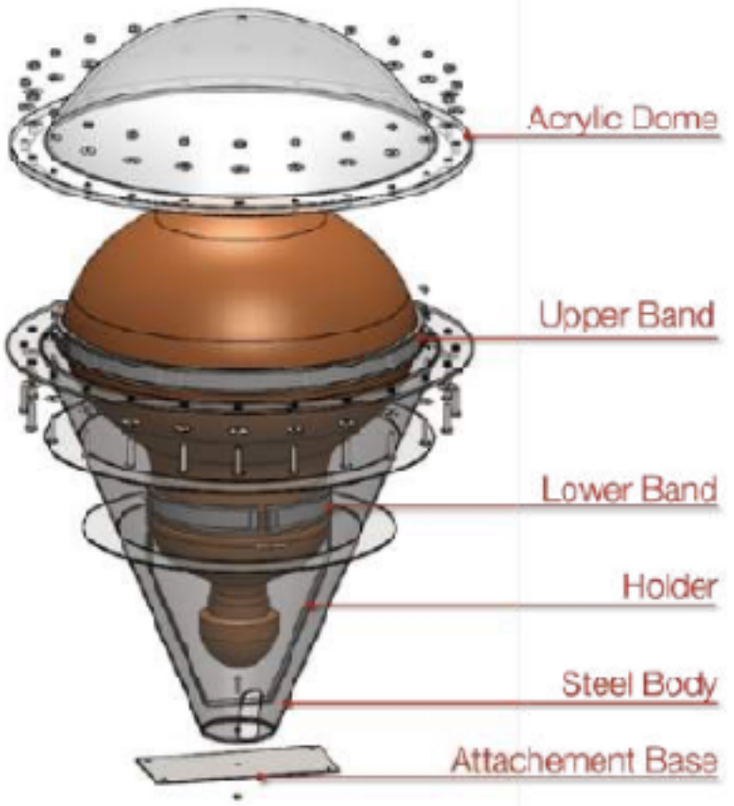
FD4 (Electronics)
France, Italy, Japan, Korea, Poland,
Spain, Switzerland, UK (for OD)

FD5 (DAQ)
UK

FD6 (Calibration)
Australia, Canada, Korea, Morocco,
Poland, Spain, UK, USA

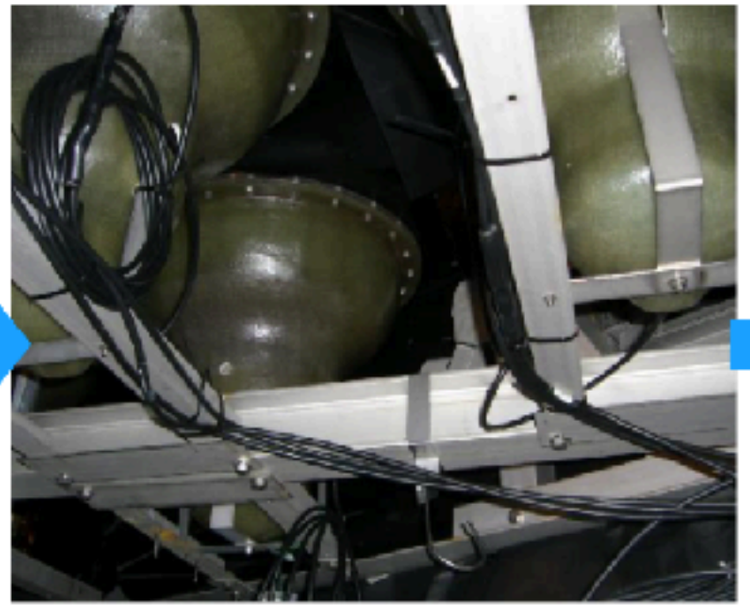
HK 50-cmD PMTs

9700/20000 50-cmD PMTs are delivered

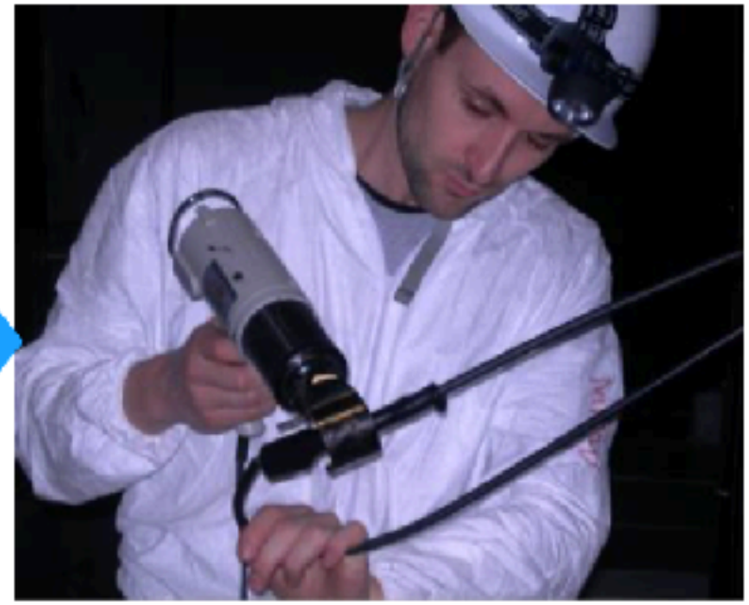


HK PMT Installation Test

PMT / electronics installation



Cable routing



Cable connection

Sheeting (black sheet / Tyvek sheet)

Installation check

HK 한국그룹

Korean Group Institutions

- Gwangju Institute for Science and Technology
- Kyungpook National University
- Dongshin University
- Seoul National University
- Sung Kyun Kwan University
- Ulsan Institute for Science and Technology
- Chunnam National University

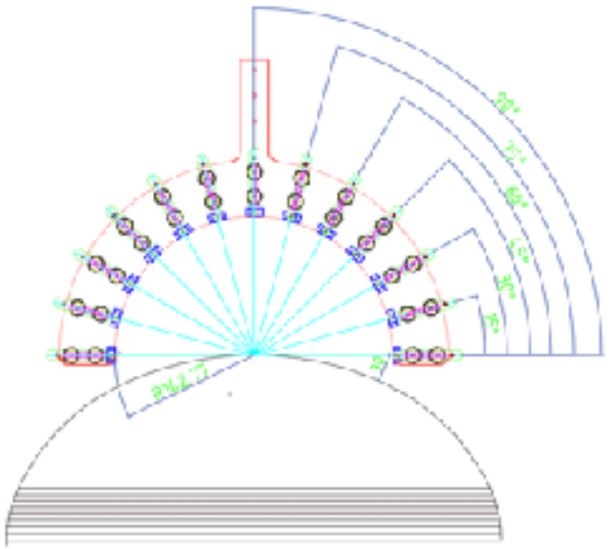
Korean Group's HK Commitment

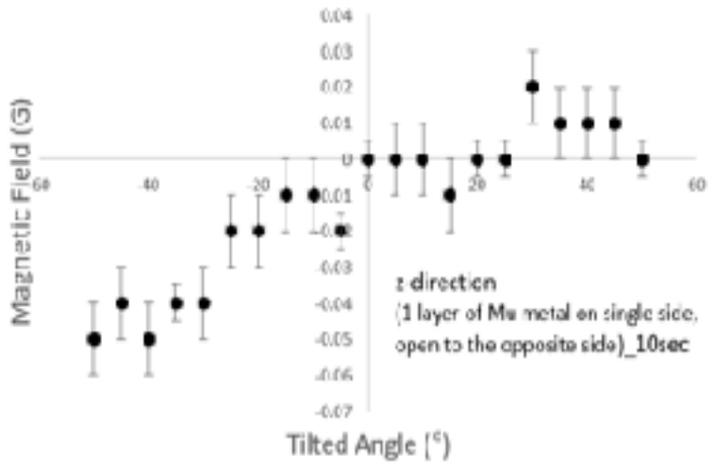
- Electronics system
- Inner Detector PMT (20-inch) pre-calibration
- Korean laser calibration system
- Computing support
- Outer Detector PMTs

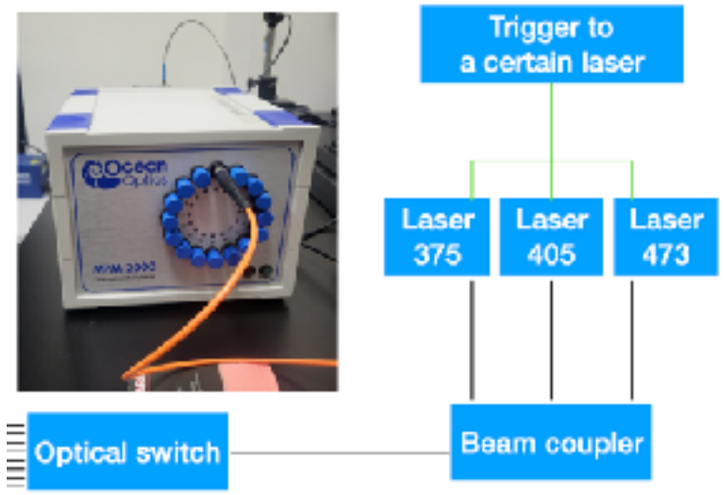
Center for Precision Neutrino Research
중성미자정밀연구센터

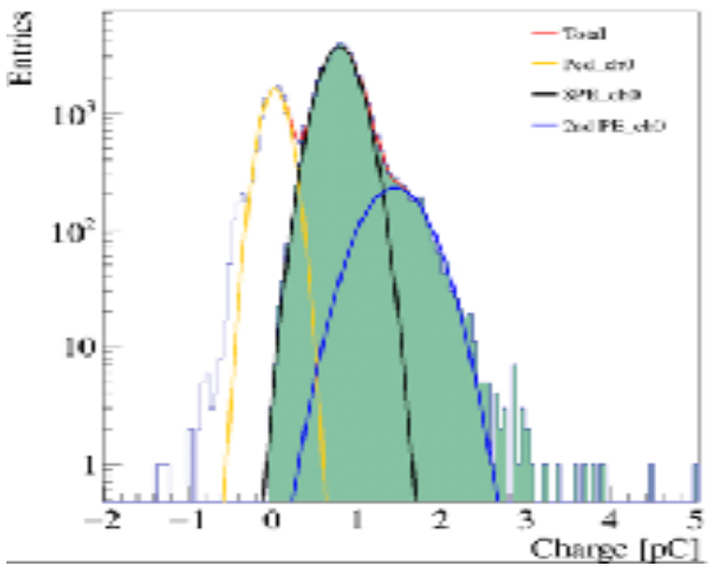
HK 한국그룹 (전남대, GIST)

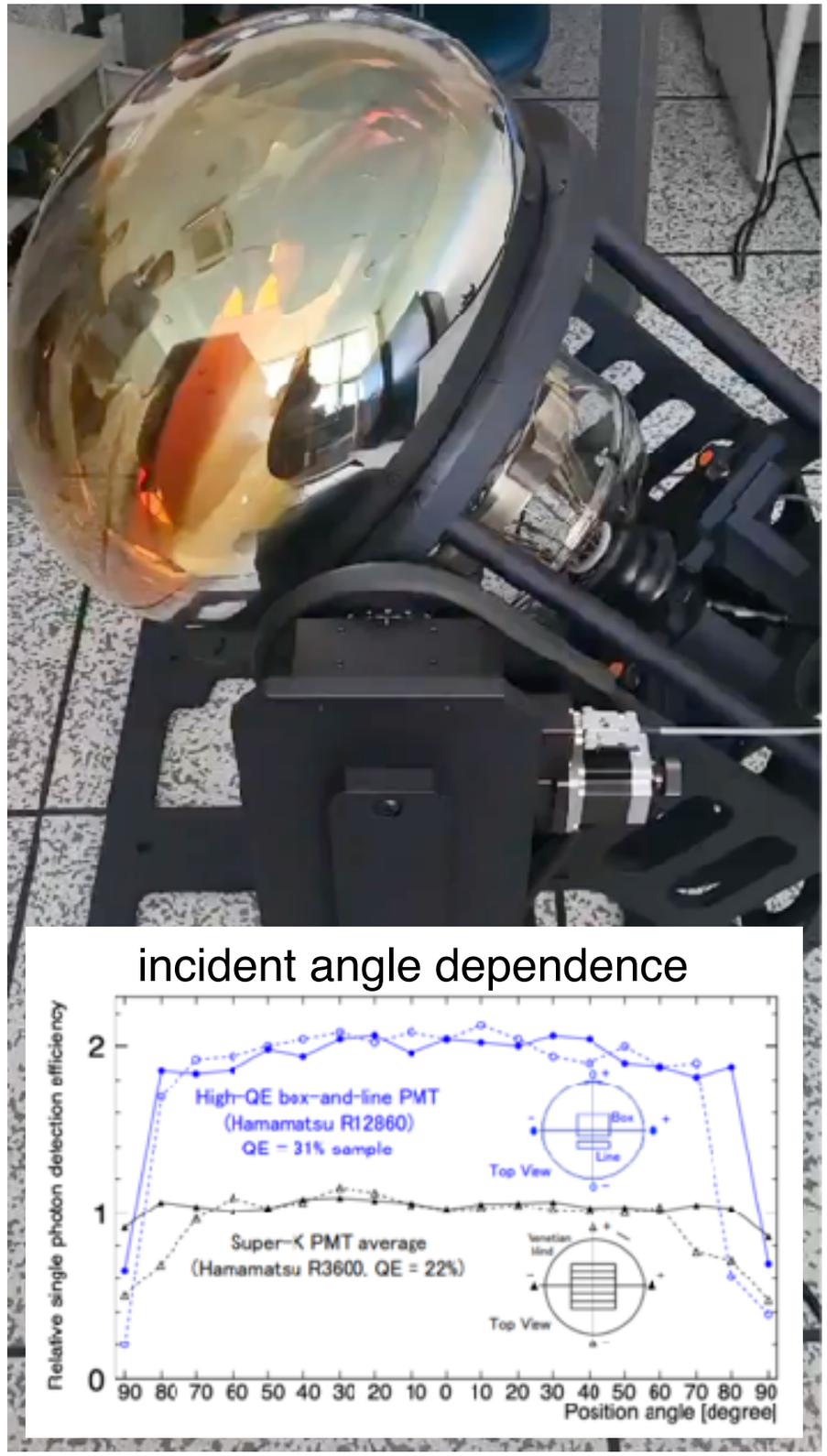
- **20-inch PMT pre-calibration**
  - Magnetic field dependence measurement
    w/ and w/o mu-metal shielding
  - Single p.e. and gain calibration
  - Incident angle dependence test







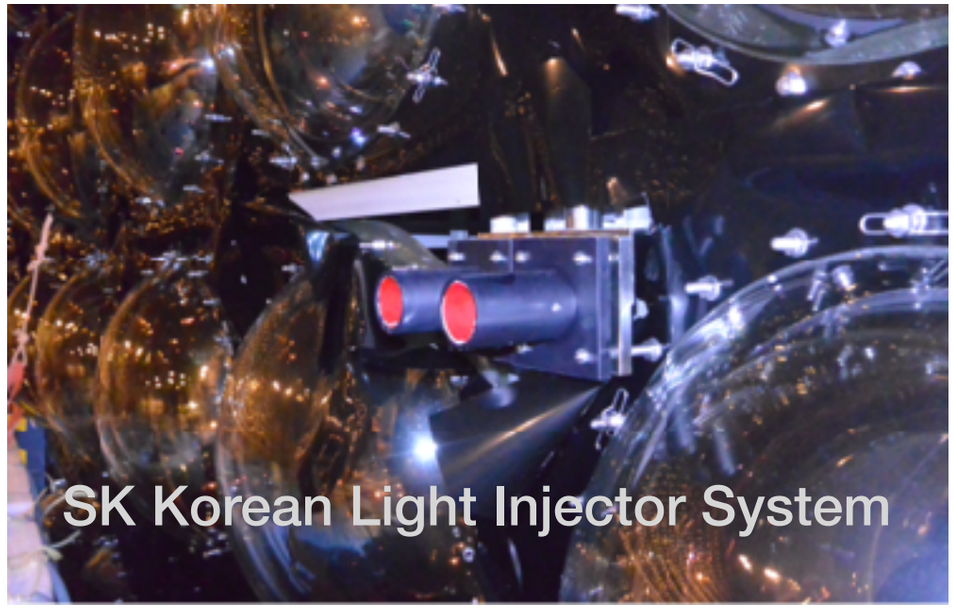


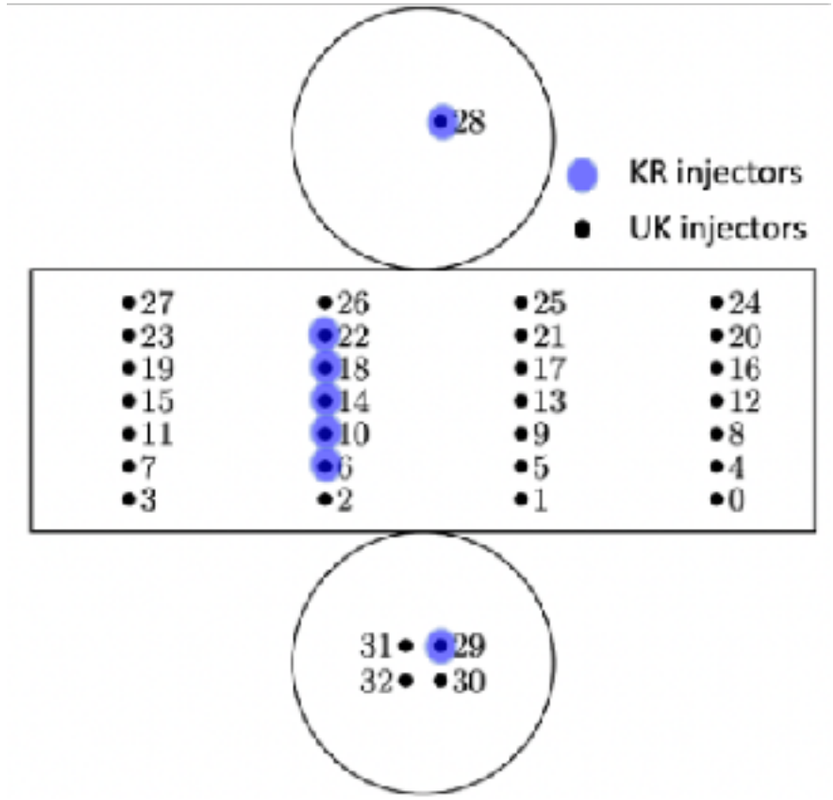


HK 한국그룹 (GIST, 서울대)

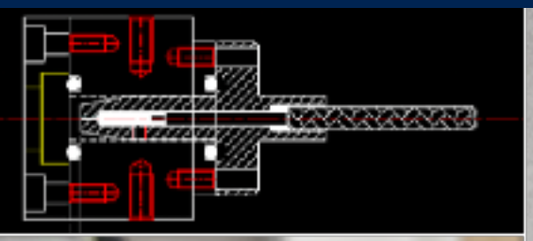
- **HK water transparency calibration system**
  - A successful operation of SK Korean light injector system
  - Korean group will install a similar calibration system for HK
    The opening angle from the injector: ~ 5°

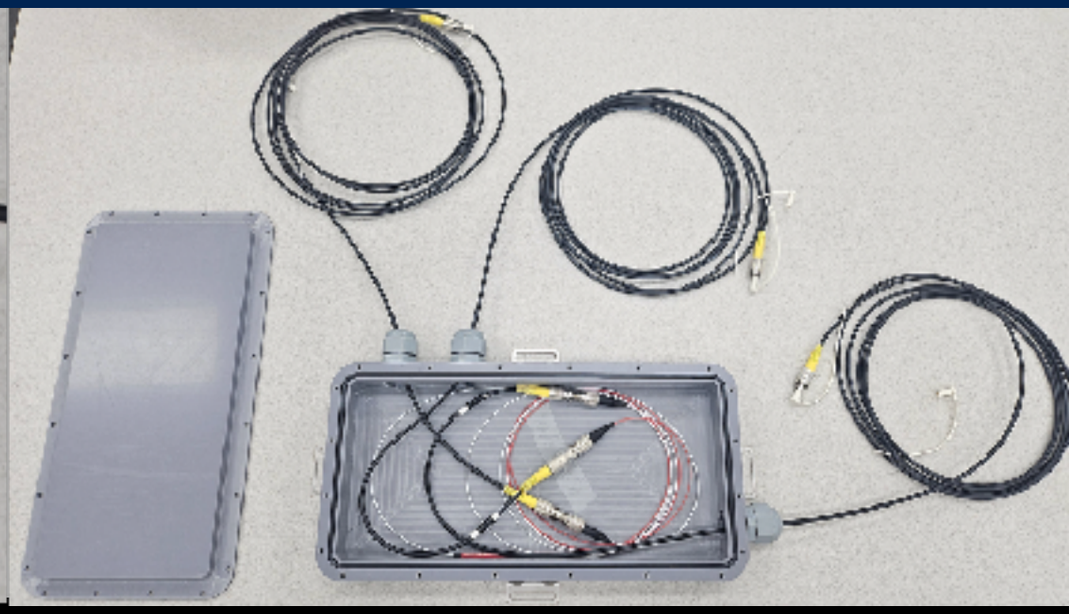
Light source
- Nano-pulse laser (~5 wavelengths for 300nm~500nm)
- A common light source for all injectors (w/ an optical switch)

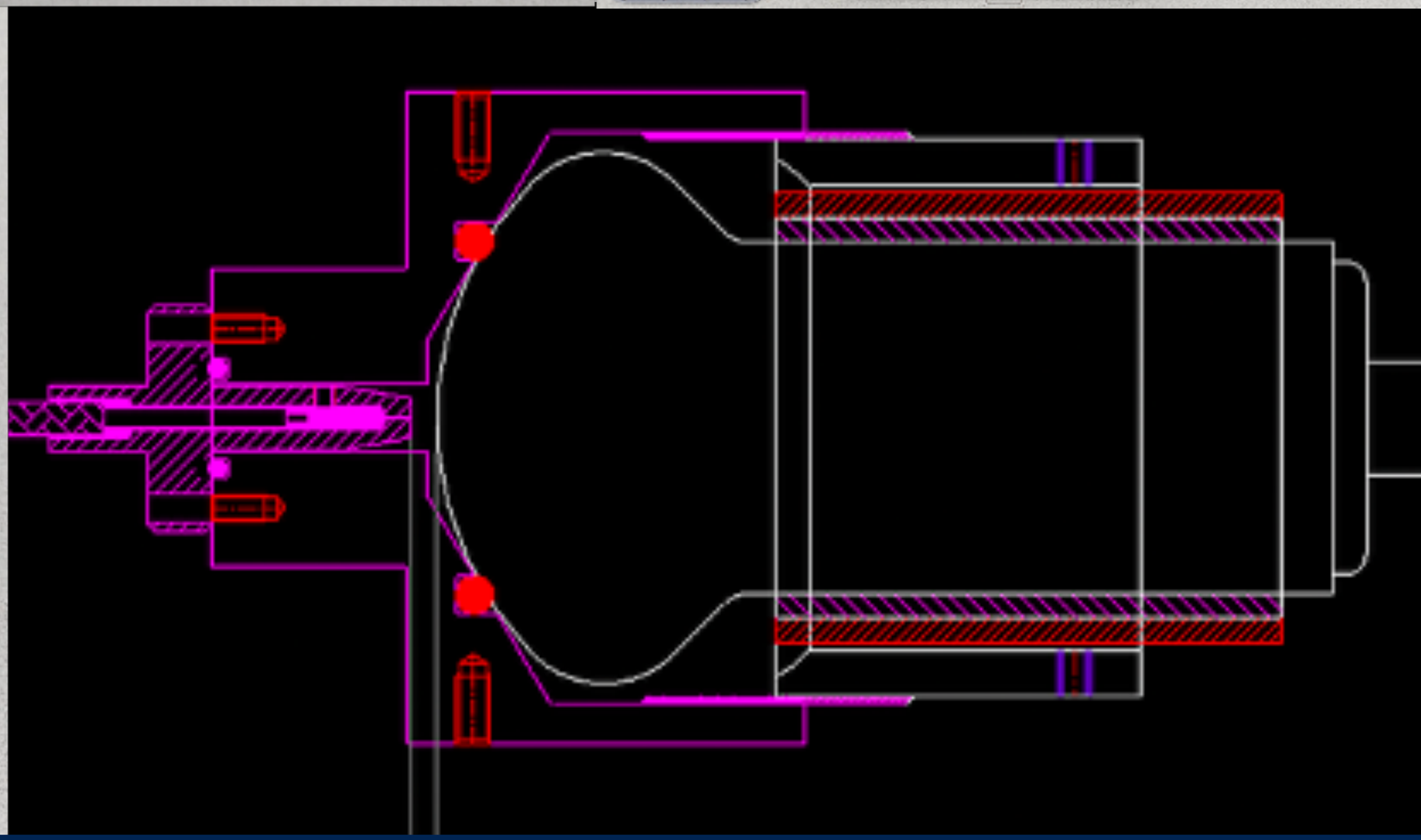

SK Korean Light Injector System



HK 한국그룹 (GIST, 서울대)







HK 한국그룹 (GIST)

Korean Group's HKOD PMT

- Joined FD3 group in September 2023
- 1M USD for OD PMT purchase (FY24~26, secured)
- PMT purchase schedule needs to be tuned
  The bidding process takes ~3 months (average)
  Close communication with the U.Tokyo is crucial

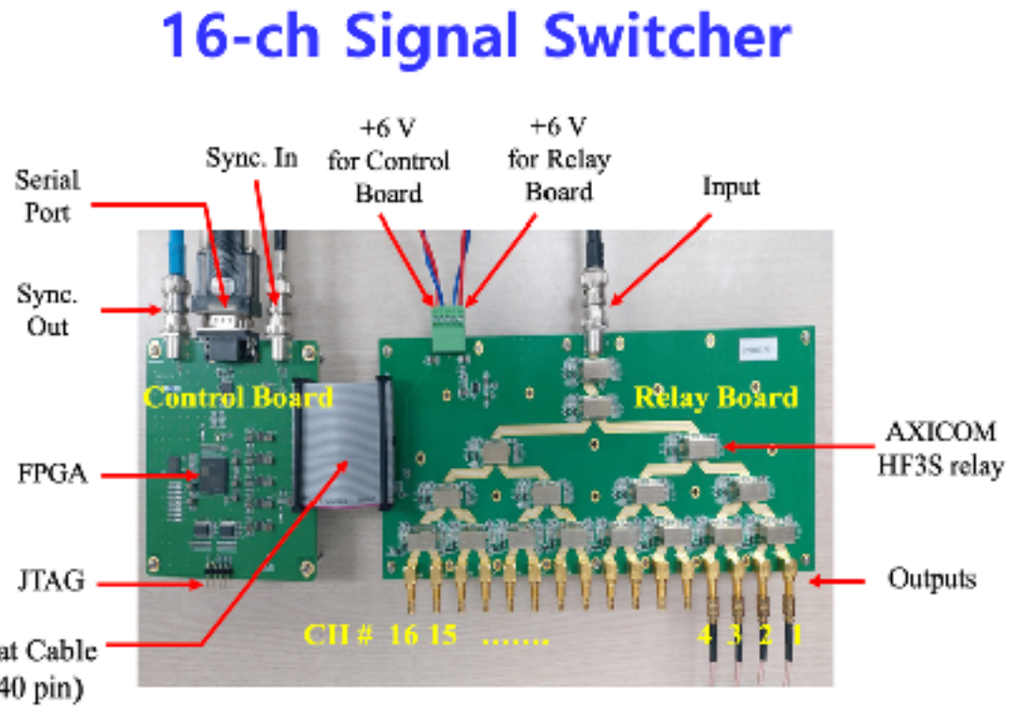
Korean Group's HKOD Activities

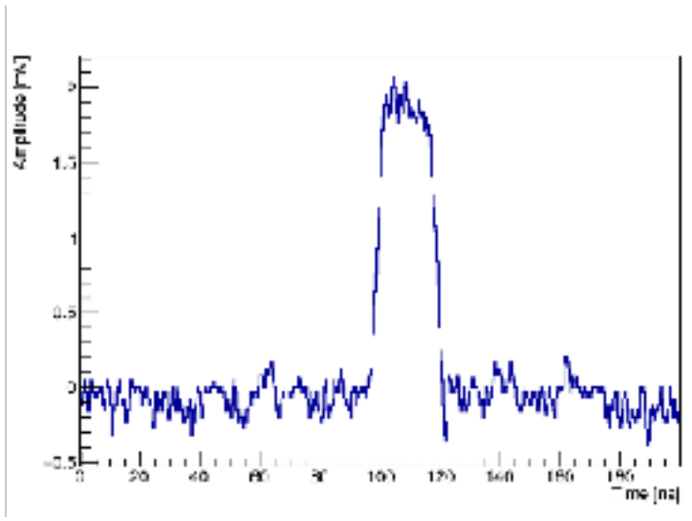
- NNVT 3-inch PMTs delivered at GIST
- OD PMT test will start soon
  - Dark rate
  - Single PE
  - Charge and timing response
  - Wavelength dependence
  - Stability
  - Temperature test (room temperature ±2°)

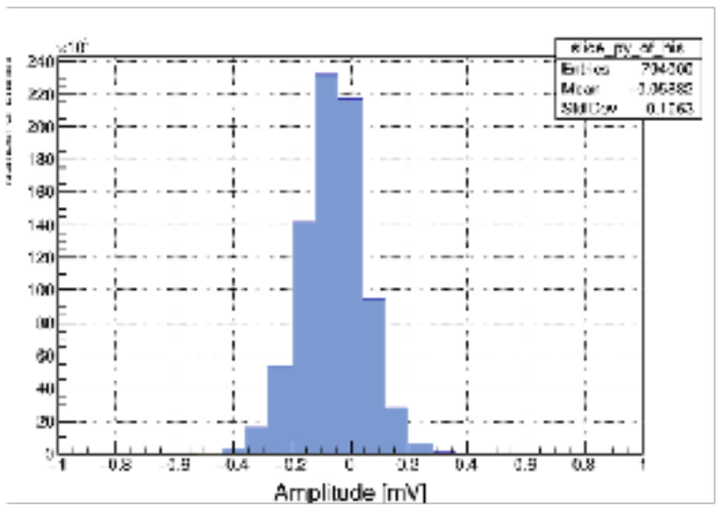
HK 한국그룹 (경북대, GIST, 서울대)

- **Signal Switcher for Electronics Test**

PMT signal simulator for electronics test







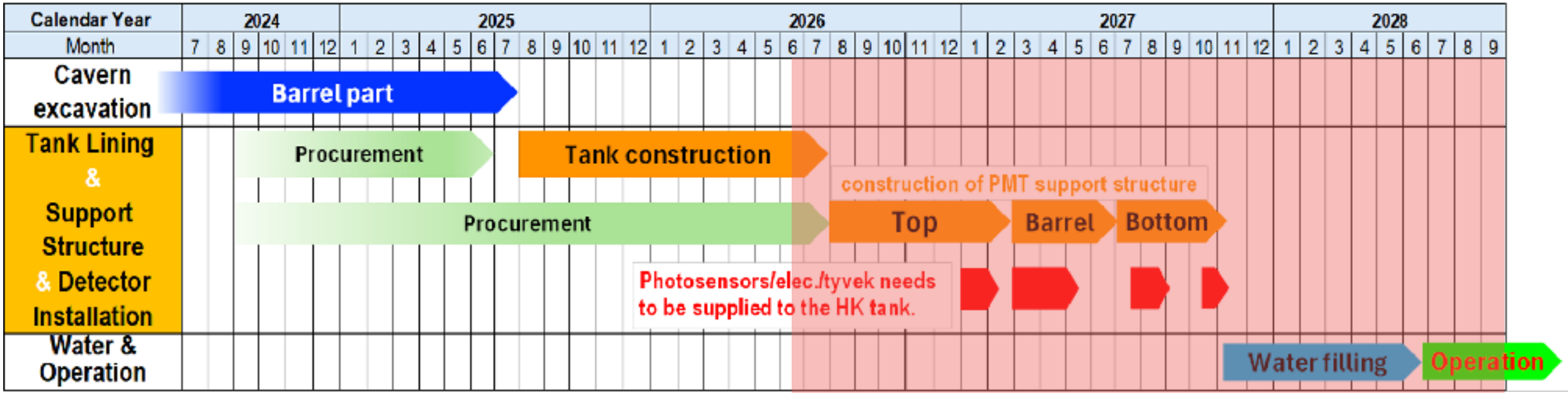
noise < 47μV

jitter < 97 ps

crosstalk < 0.64 mV

Units are sent to France, CERN, Korea

HK 구축 진행상황



- HK operation will begin in 2027
- 1.3 MW upgrade neutrino beam from J-PARC by 2027
- Upgraded and additional near detectors at J-PARC

- Korean HK Group is in charge of
  - Low noise OD Electronics
  - OD Feedthroughs (underwater)
  - Laser Calibration System (underwater light injectors)
  - PMT Tests
  - IWCD 구축 기여 (문부성 요청사항)

고에너지물리 한-일 국제협력 현황

중성미자실험

- Super-Kamiokande
- Hyper-Kamiokande
- **E56: JSNS²**

강입자실험

- E07 (J-PARC)
- E72 (J-PARC)
- E42 (J-PARC)
- E45 (J-PARC)
- **E17 KOTO experiment (J-PARC)**
- LEPS2 (SPring-8)
- E373 (KEK)
- RIBF (RIKEN)

- Korea-Japan PHENIX Collaboration

뮤온실험

- COMET (J-PARC)
- Muon g-2/EDM (J-PARC)

e+e-

- Belle I/II (KEK)

이론그룹

- 강입자이론
- 입자우주론
- 입자현상론
- 암흑물질
- Summer Institute Series

2023 고에너지물리학회
가을 학술회의 권영준 교수 (연세대학교)
발표자료 참조

고에너지물리 연구소 / 협력센터

- 한국 고에너지연구소: 미국의 Fermilab, 유럽의 CERN, 일본의 KEK 연구소와 같은 고에너지 국립연구소를 설립하는 것은 한국 고에너지연구자들의 오랜 염원
  - 한국 고에너지연구소: 해외 고에너지연구소와의 대외 협력 주체가 분명해짐
  - 국가의 미래 고에너지 연구 전략의 수립, 수행, 세계적 연구 환경에 능동적 대응 협력
  - 국가 연구소에 수반된 거대실험장치 프로젝트

- 한국 고에너지국제협력센터: 프랑스의 IN2P3, 이탈리아의 INFN 등과 같은 산학연계형 고에너지물리협력센터
  - 국제공동연구의 허브로 발전 (한-CERN 사업의 확장 또는 신규센터 설립)

- 통합 고에너지물리 검출기 연구센터
  - 대학과 기업으로 산재된 고에너지 검출기 개발 장비 집적화 지원
  - High-bay 크레인, 클린룸, 방사선 테스트 설비, 신개념 검출기 개발
  - 검출기 기술에 특화된 고급 엔지니어/기술인력 확보
  - 검출기학교 운영등을 통한 신진인력 확보

Summary

- Hyper-Kamiokande 실험 구축은 예정대로 2027년 검출기 운용시작을 목표로 큰 차질 없이 진행중
  - 오랜 공동연구를 통해 축적된 상호 신뢰와, 지리적으로 근접한 장점을 활용하여 HK 한국그룹의 역할이 크게 확대되고 있음

- 과학적 국제"협력"이 가능하게 해주는 KNO 실험 추진중
  - 각계의 긍정적인 지원과 호응으로, 여러가지 난관에도 불구하고 KNO 추진 동력 확보

- 국가 고에너지물리 연구소 설립 필요
  - 국가별 고에너지물리 협의 주체 설립 지양
  - 과도기적 국제 협력 주체로서 고에너지 **국제협력 센터 대안 제시**
  - 임시 기구로서 통합 고에너지 검출기 연구센터 설립 필요