Overview of HEP Activities in Korea

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Chair of the Division of Particles & Fields in the Korean Physical Society

Sungkyunkwan University (SKKU), Suwon, Korea

FKPPL/TYL/FJPPL Workshop @ Jeju Island, May 8th, 2019

Outline

- Theory Activities
- Ongoing Domestic Experiments & Projects
- Ongoing International Experiments
- Future Projects
- Summary

Theory Activities

- Active Researches on Phenomenology, Quantum Field Theory, Cosmology, Gravity, and String Theory

- Institutes and Research Centers

  * Center for Theoretical Physics of the Universe (CTPU)

  * Center for Quantum SpaceTime (CQUeST)

  * Korean Institutes for Advanced Study (KIAS)

  * Asia Pacific Center for Theoretical Physics (APCTP)

- One of IBS (Institute of Basic Science) Centers

- Long-term Plan of CTPU

→ build three research groups with a co-director system (similar to MPI)

* Particle Physics and Early Universe Cosmology
* Formal Aspects of String Theory, QFT, and Gravity
* Astrophysics and Cosmology

- Members

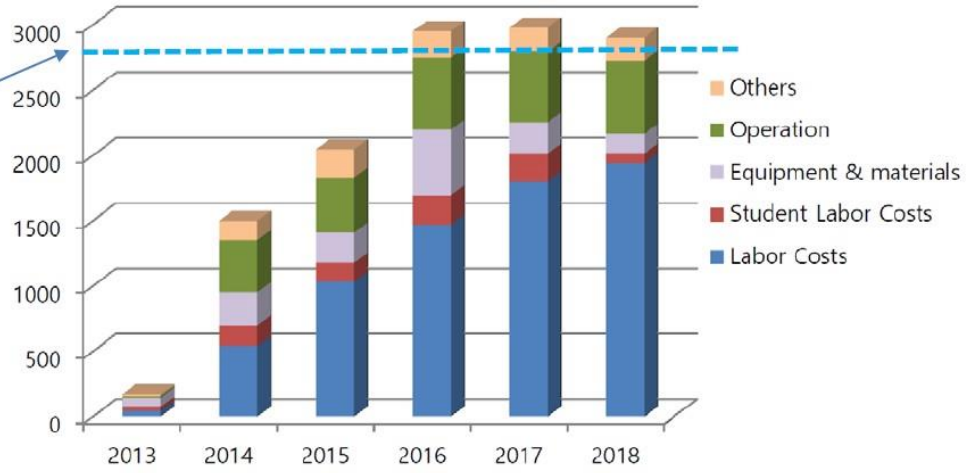
* Director: Prof. Kiwoon Choi
* 5 faculties, 17 postdocs, and 2 graduate students

of researchers and publications

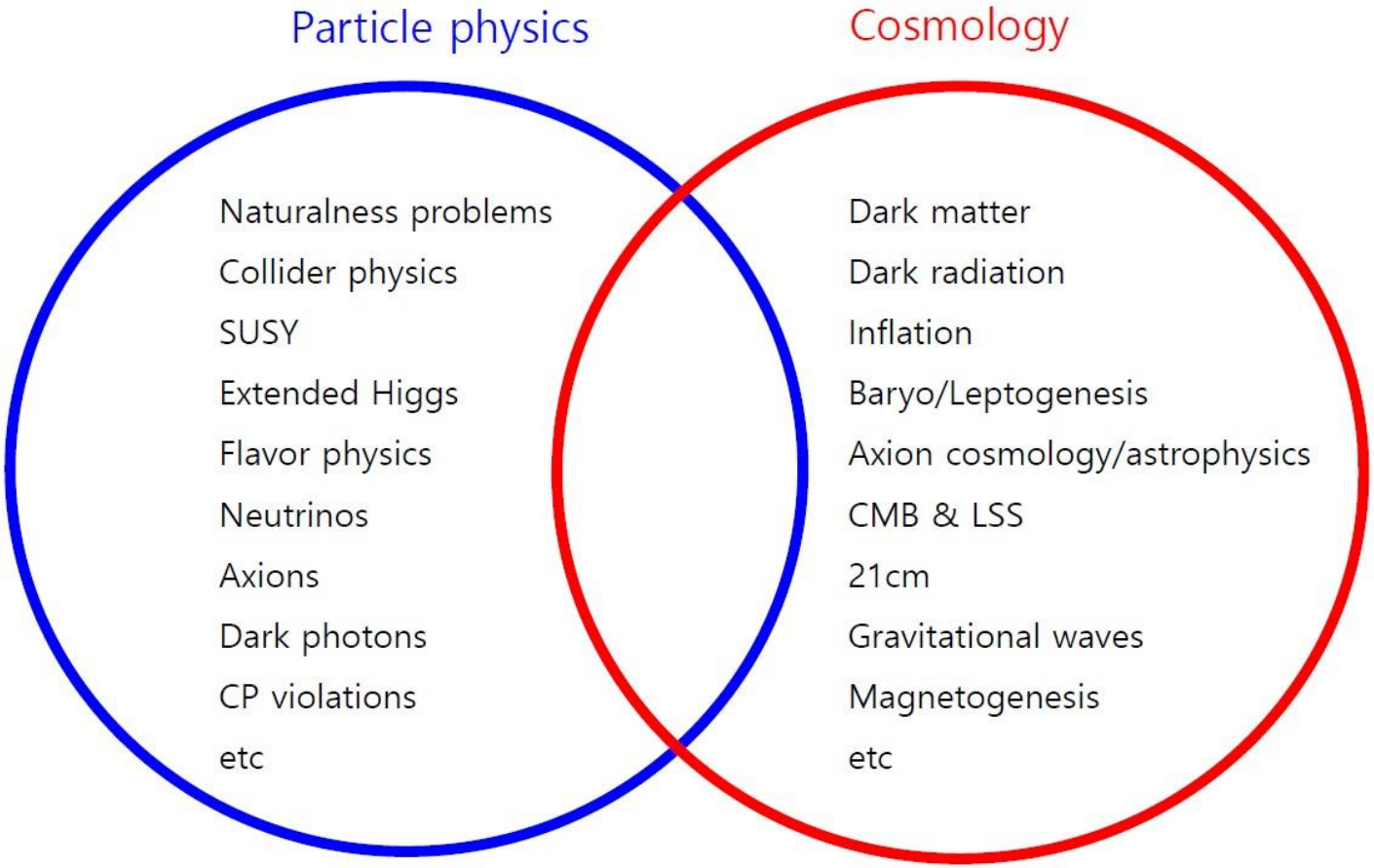
Year	Number of published articles (in the refereed journals)	Number of researchers
2013.11-2014.12	9 articles	6
2015.01-2015.12	20 articles	10
2016.01-2016.12	44 articles	17
2017.01-2017.12	51 articles	21
2018.01-2018.09	30 articles	23

Annual budget

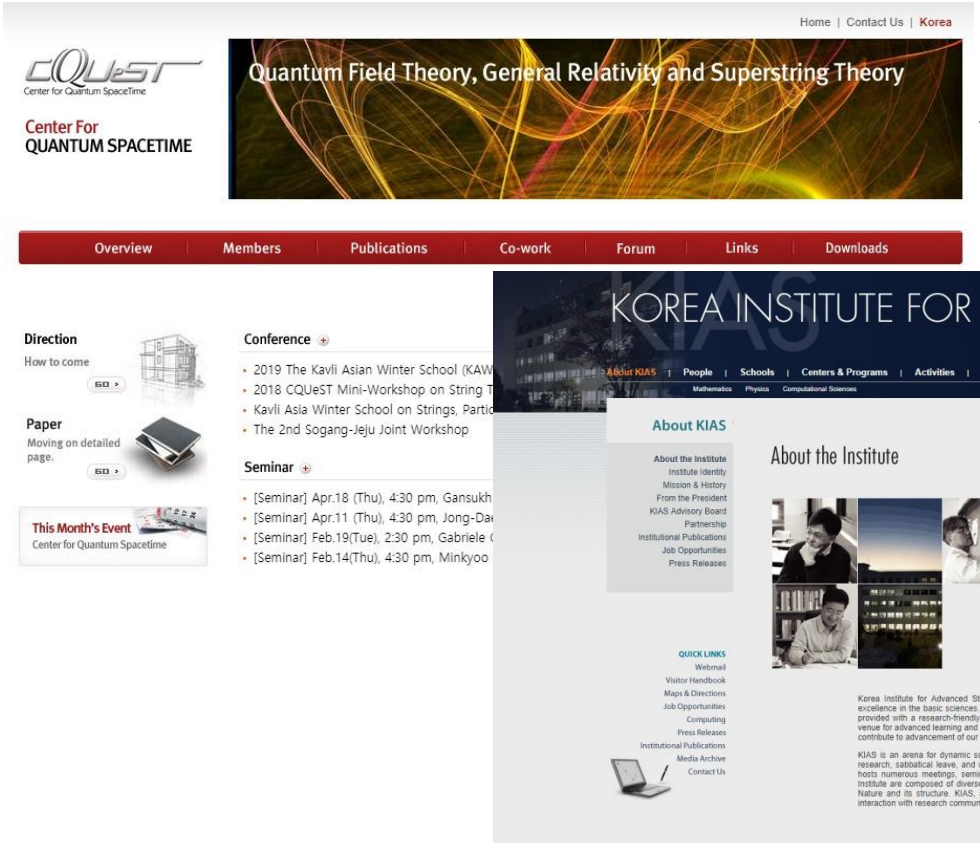
2.5M USD



Research topics covered during the last 5 years

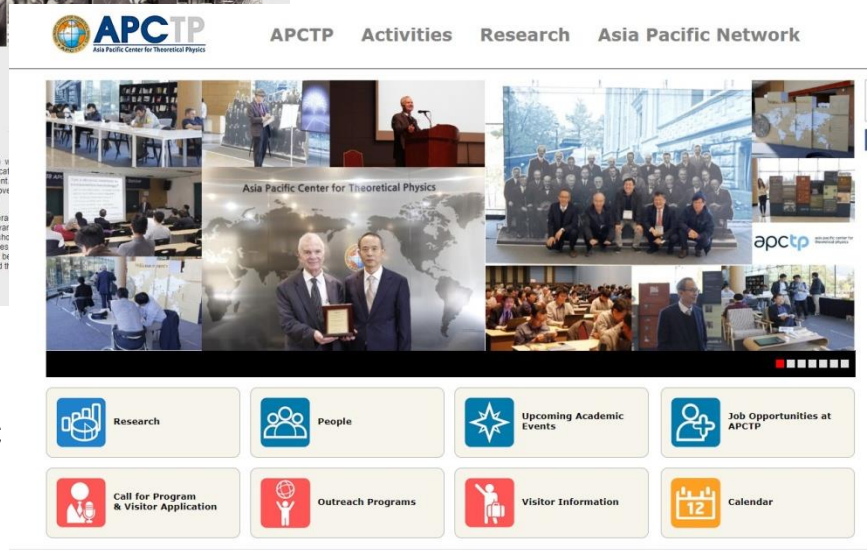


CQUeST / KIAS / APCTP



Supported by Center for Excellence program

Institute for Theoretical Physics, Mathematics, and Computational Sciences



Hub Institute of Theoretical Physics in Asia-Pacific Region with 16 Member Countries

Ongoing Domestic Experiments & Projects

- Non-Accelerator Experiments & Centers

  * RENO : Reactor Neutrino Experiment

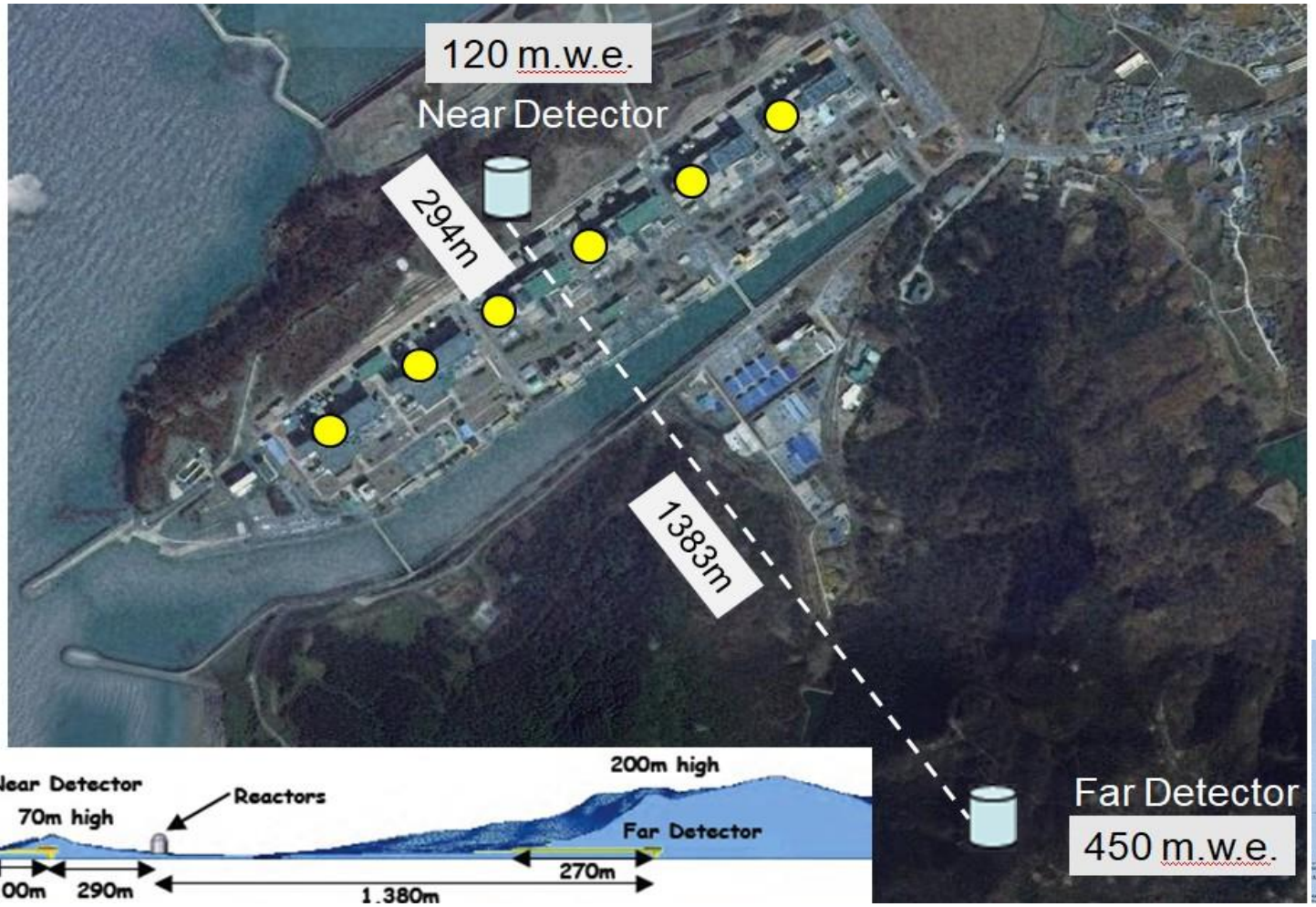
  * Center for Underground Physics (CUP) : IBS center

  * Center for Axion and Precision Physics Research (CAPP): IBS center

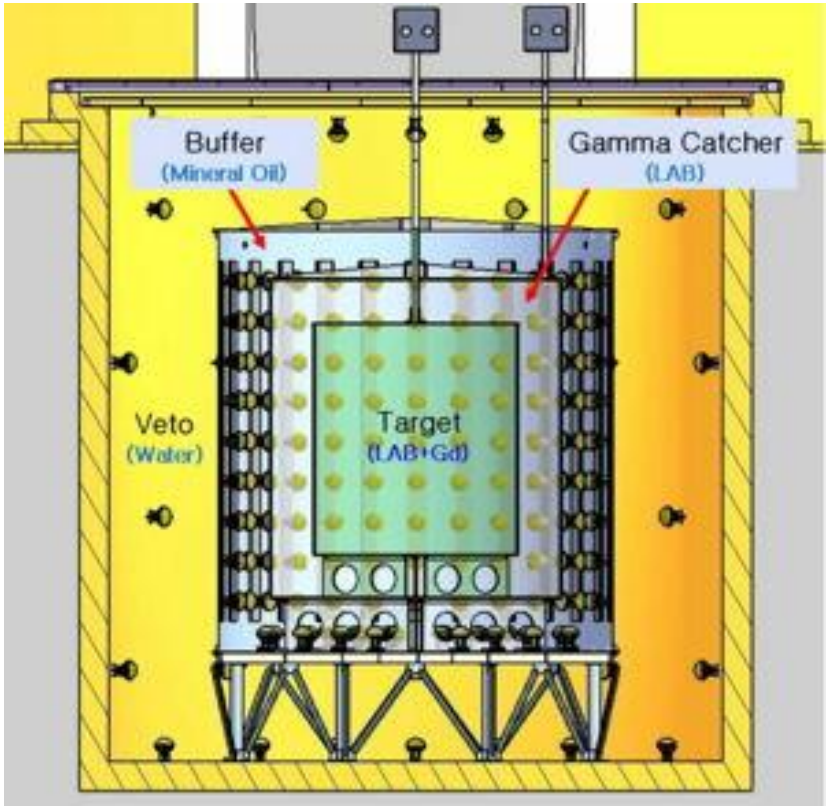
- Accelerator Project

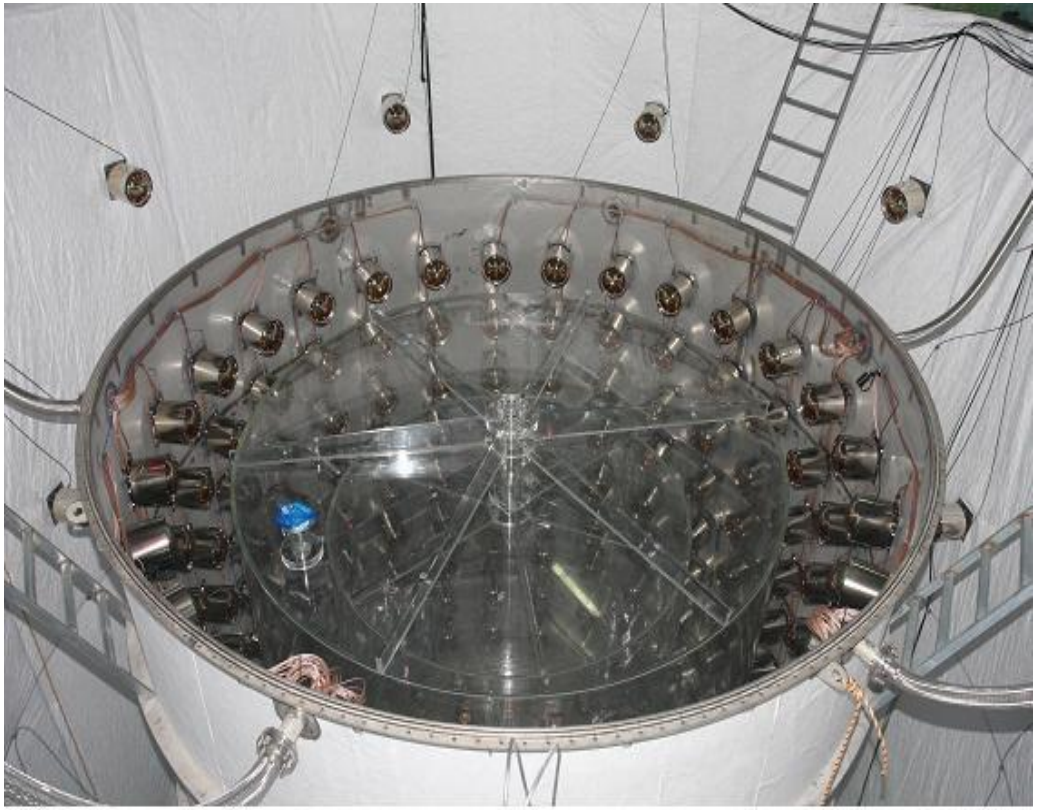
  * The Rare Isotope Science Project (RISP): IBS project

- Experimental Setup



- RENO Detector





Physics Results from RENO

- Measurement of $|\Delta m_{ee}^2|$ and θ_{13} with delayed n-Gd signals

  Daya Bay and RENO Experiments measured $|\Delta m_{ee}^2|$ and θ_{13} for the first time (2012 PRL)

- Fuel-composition dependent reactor antineutrino yield

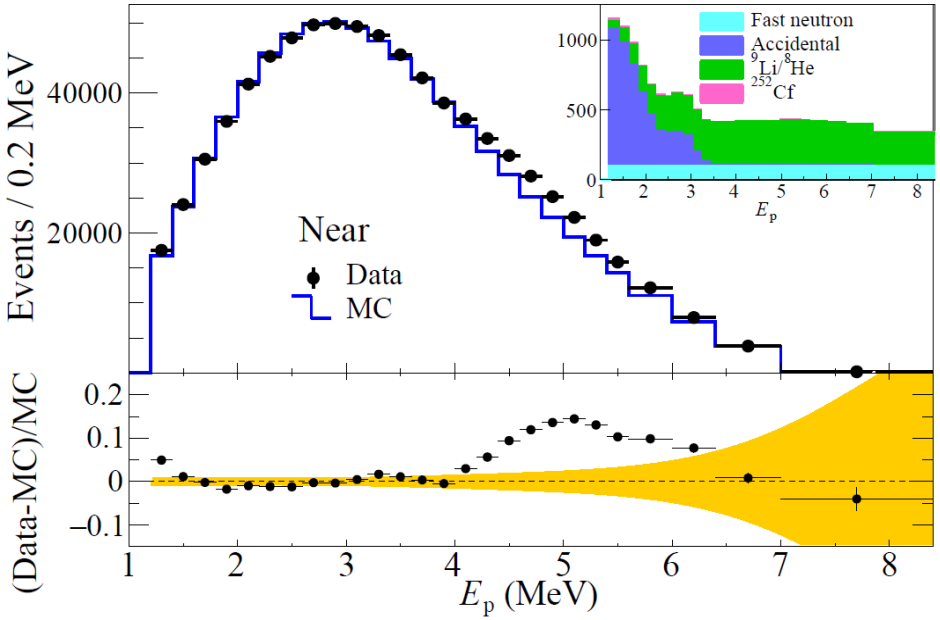
- Measurement of absolute reactor neutrino flux and spectrum

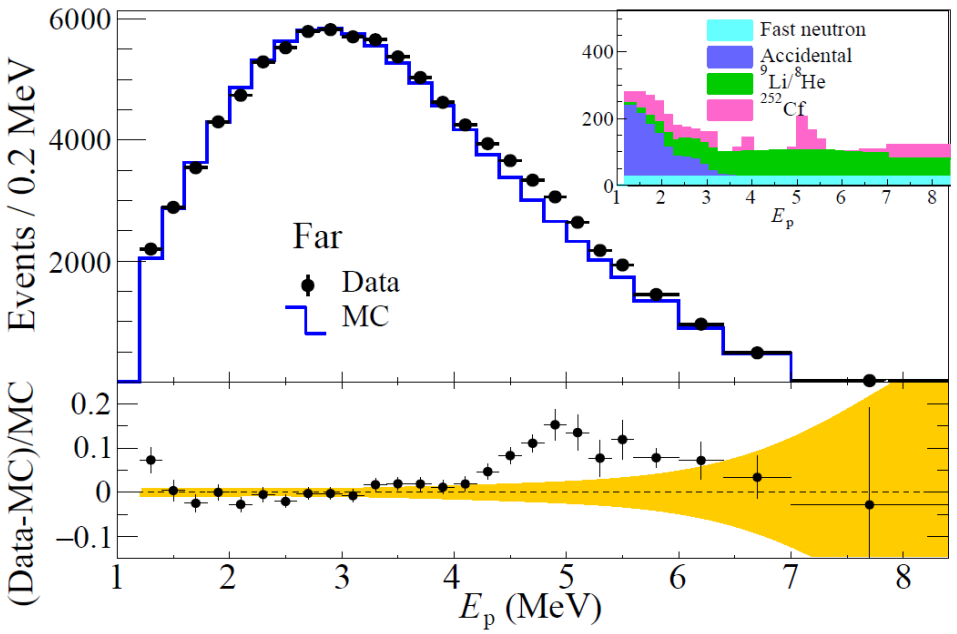
- Independent measurement of $|\Delta m_{ee}^2|$ and θ_{13} with delayed n-H signals

- Results from a sterile neutrino search

Physics Results from RENO

- First Observation of 5 MeV Excess in the Reactor Neutrino Energy Spectrum





Center for Underground Physics (CUP)

- One of IBS (Institute of Basic Science) Research Centers

  Director : Prof. Yeongduk Kim

- Projects

  * AMoRE Experiment: Neutrinoless Double Beta Decay Search

  * COSINE Experiment: WIMP Dark Matter Search

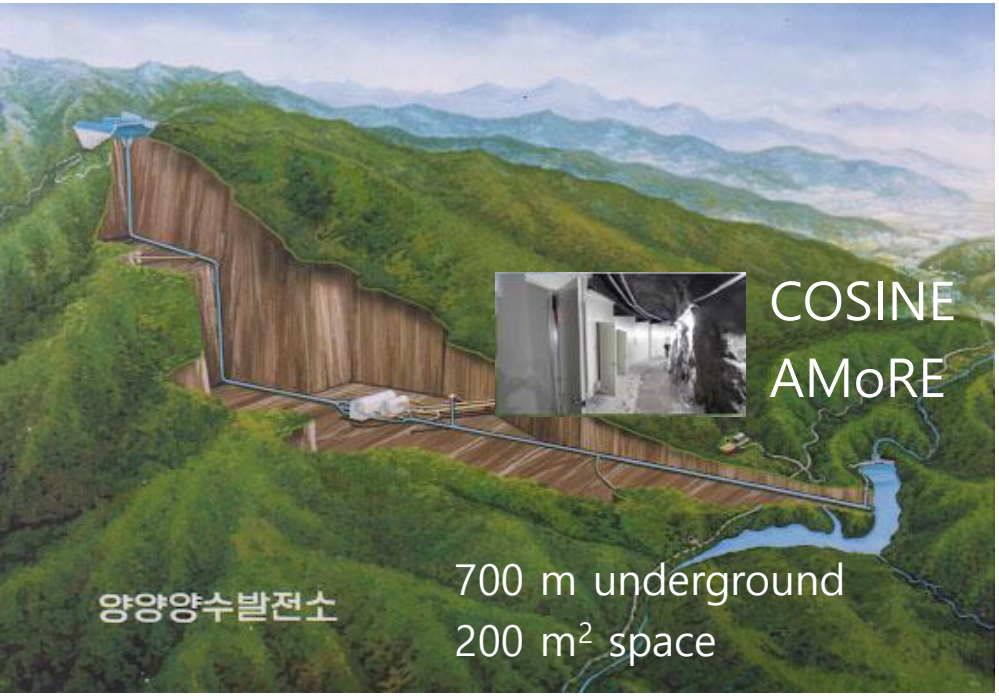
  * NEOS Experiment: Sterile Neutrino Search

- Annual Budget: ~9M USD/year (2013~)

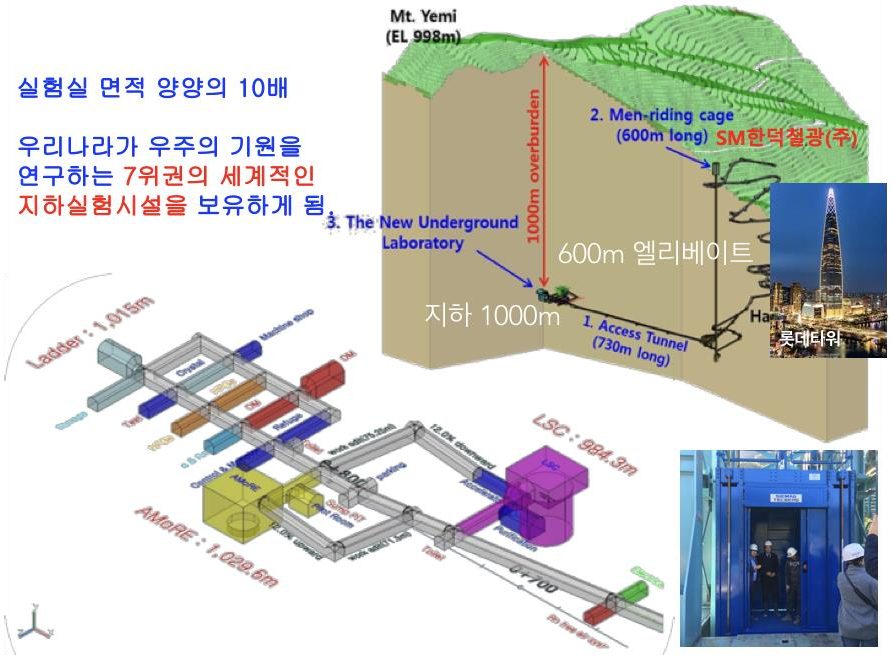
  For details, see Prof. Yeongduk Kim's talk tommorow

CUP : Underground Laboratories

Yangyang Underground Laboratory (2003~)



Yermi Lab (2018 ~)



- Yangyang underground laboratory

  * COSINE and AMoRE-pilot experiments are running

- Yermilab (2018~): under construction

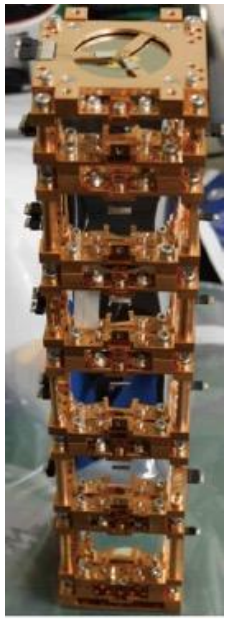
  * AMoRE-II and next generation dark matter experiments are planned

CUP : AMoRE Experiment

- Neutrinoless double beta decay with ^{100}Mo target nuclei
- Pilot is running. Preparing AMoRE-I. Extensive R&D for AMoRE-II

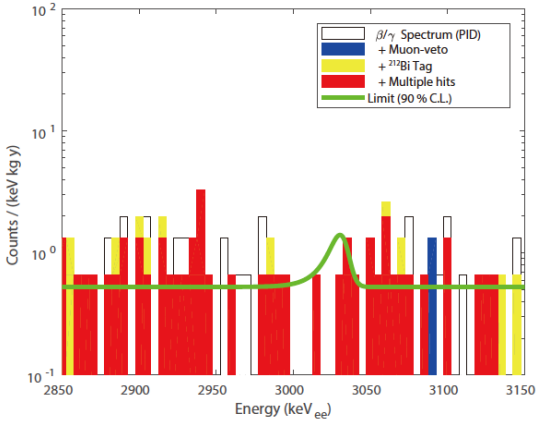
AMoRE-pilot (2018)

1.9 kg $CaMoO_4$



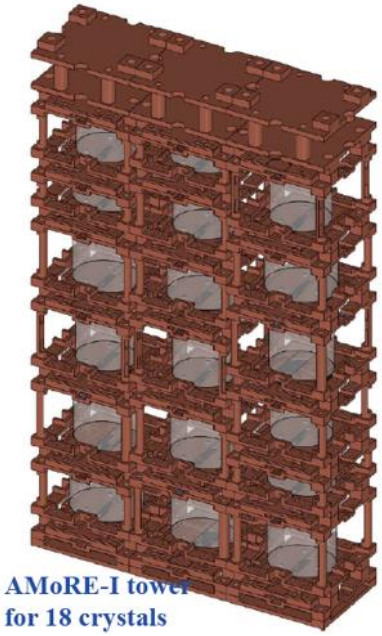
First result from pilot experiment

$T_{1/2}^{0\nu} > 9.5 \times 10^{22}$ y



AMoRE-I (2019~20)

~5 kg $CaMoO_4$



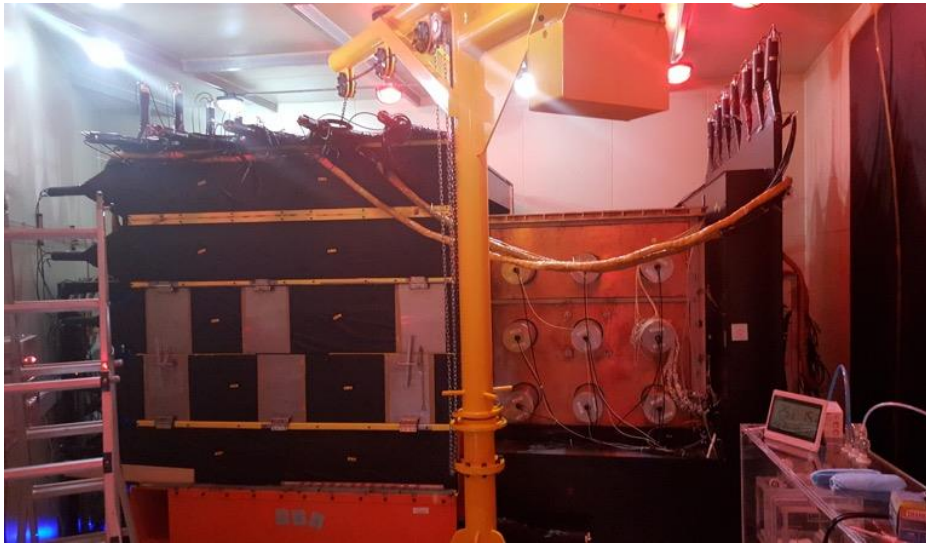
AMoRE-II (2020~25)

~200 kg $XMoO_4$

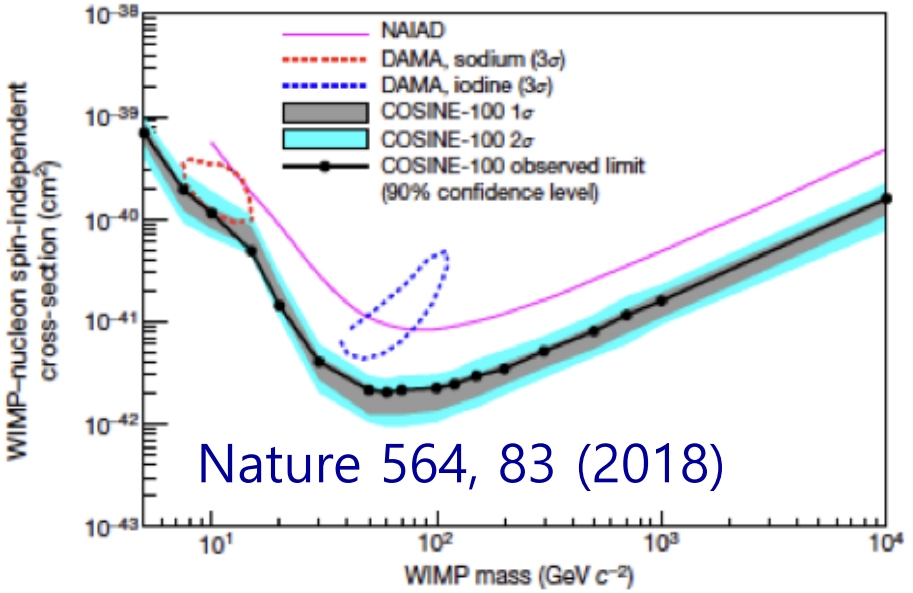
CUP : COSINE Experiment

- A Joint experiment between KIMS and DM-Ice with NaI(Tl) crystals to prove DAMA modulation signals
- Physics run with ~100 kg crystals (COSINE-100) was started from Sep, 2016.
- Further R&D to reduce internal background are actively ongoing for future COSINE-200 experiment.

COSINE-100 Detector



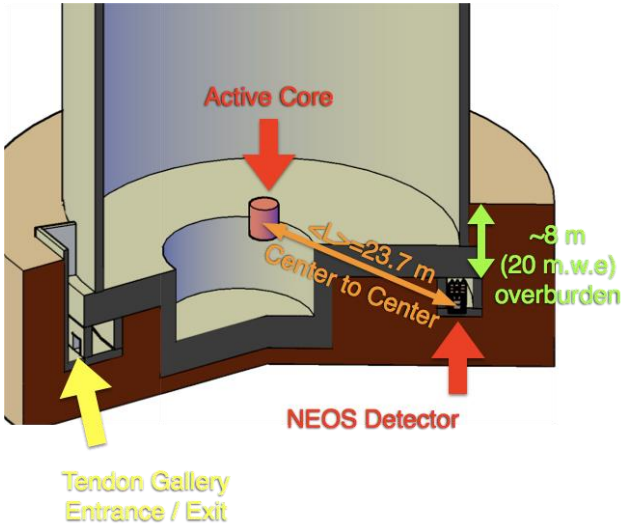
Model dependent coverage of DAMA/LIBRA with same NaI(Tl)



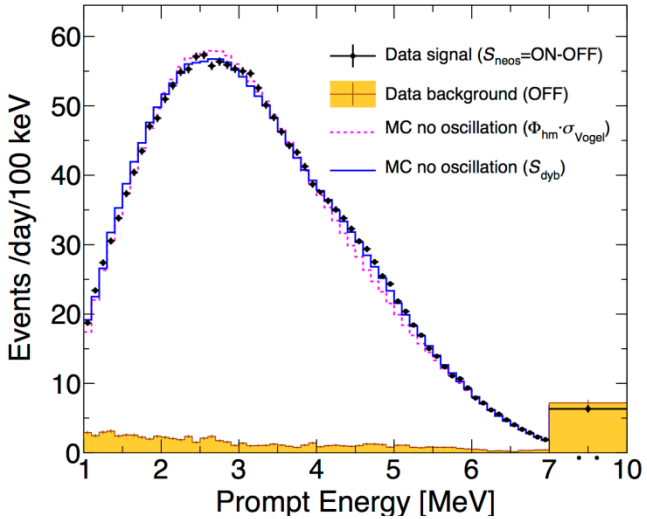
CUP : NEOS Experiment

- Searching for sterile neutrino at 24 m baseline at Hanbit Nuclear Power Plant
- Precise spectrum measurement at this short baseline, with low background
- No strong evidence for 3+1 SBL oscillation, set up a new stringent limit
- Start phase2 operation since Sep 2018

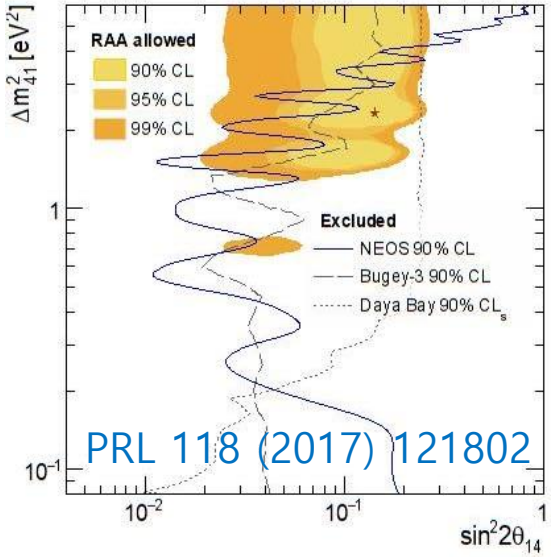
NEOS Detector



Neutrino Energy Spectrum



Physics Result



Center for Axion and Precision Physics Research (CAPP)

- One of IBS (Institute of Basic Science) Research Centers

  Director : Prof. Yannis Semertzidis

- Projects

  * Axion Search
  * Proton EDM
  * Muon g-2 Experiment
  * mu2e experiment
  * Precision Physics

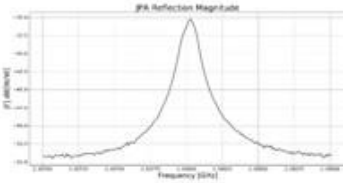
- Annual Budget: ~9M USD/year (2013~)

- Axion Search
  - *Enhancing the scanning rate*

$$\frac{df}{dt} \sim B^4 V^2 C^2 Q_L T_{syst}^{-2}$$

Cryogenics (T)
Lowering thermal noise

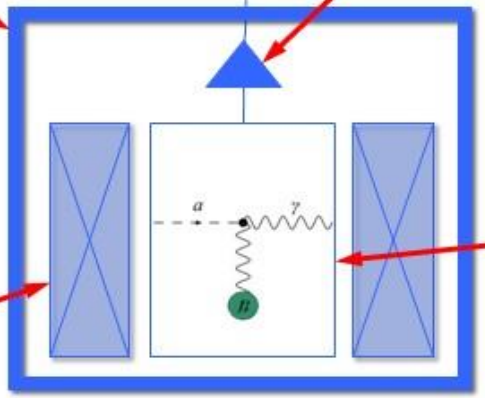
Quantum noise limited amplifier (T)
Amplification w/ minimal noise
(U. of Tokyo & RIKEN)



JPA gain measurement:
20 dB @ 2.3 GHz

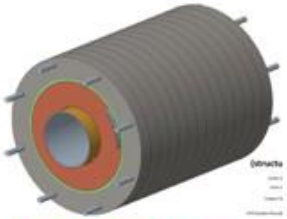
Functional JPA w/ in-house expertise

RF readout chain



Axion-photon conversion
(Primakoff effect)

High field HTS Magnet (B)
Boosting a→γγ conversion rate

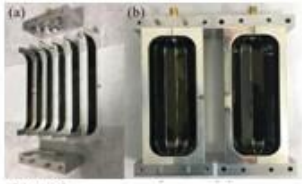


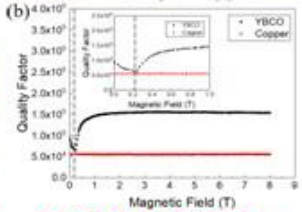
HTS 25T/100mm w/ BNL
(funding limited)
*IEEE T. Appl. Supercon. **29**, 5 (2019)*

LTS 12T/320mm (Oxford, 2020)

Microwave resonator (V,C,Q)
High frequency / high Q factor

Pizza cavity for high frequency
*Phys. Lett. B **777** 412 2018*



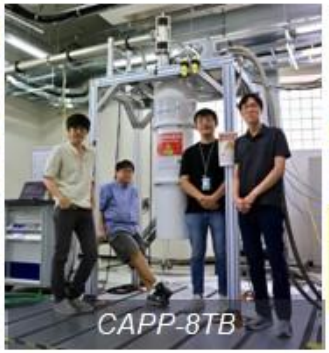


SC (YBCO) cavity under high B field
Arxiv: 1904.05111

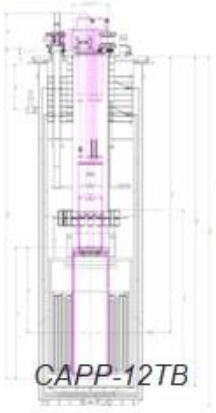
➢ Axion Search

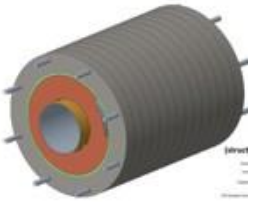
- *All the ingredients together, we will reach the DFSZ sensitivity even for 10% axion content in the local dark matter halo.*

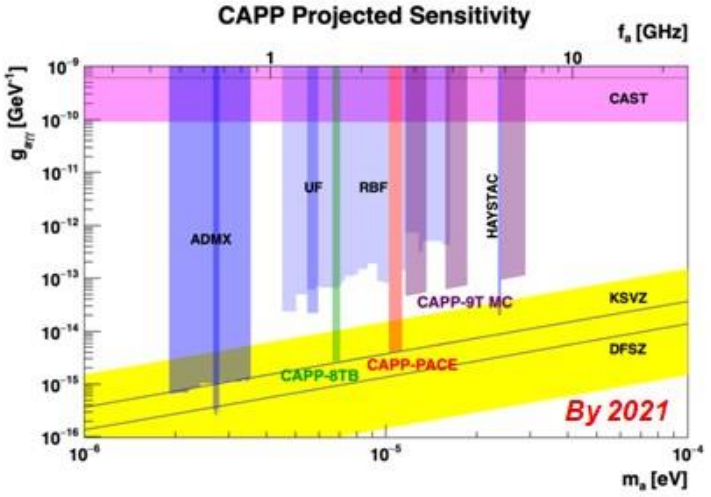

CAPP-PACE

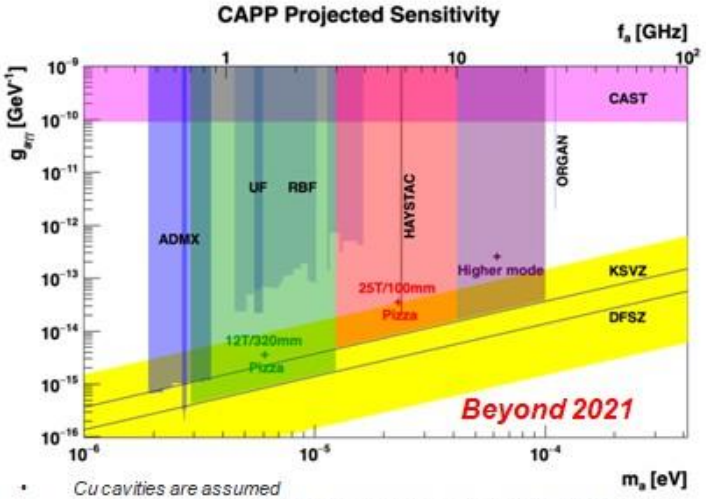

CAPP-8TB

CAPP-9T MC


CAPP-12TB


CAPP-25T

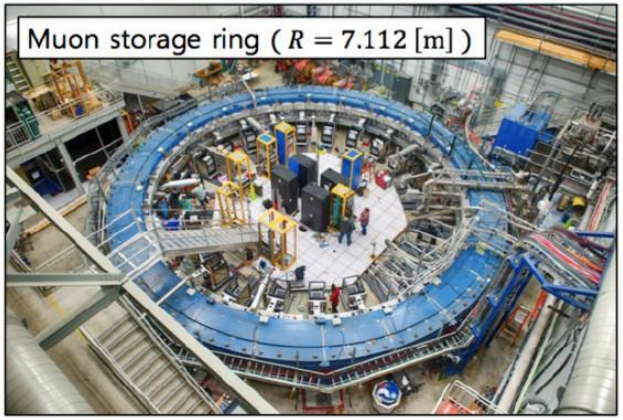




- *Cu cavities are assumed*
- *W/ SC cavities, down to 10% of axion dark matter content will be probed*

Fermilab muon g-2 experiment

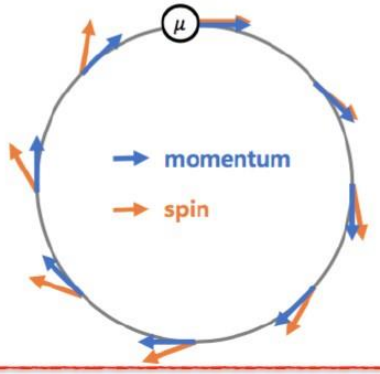
- Data taking in 2017
- CAPP's contribution in phase matching

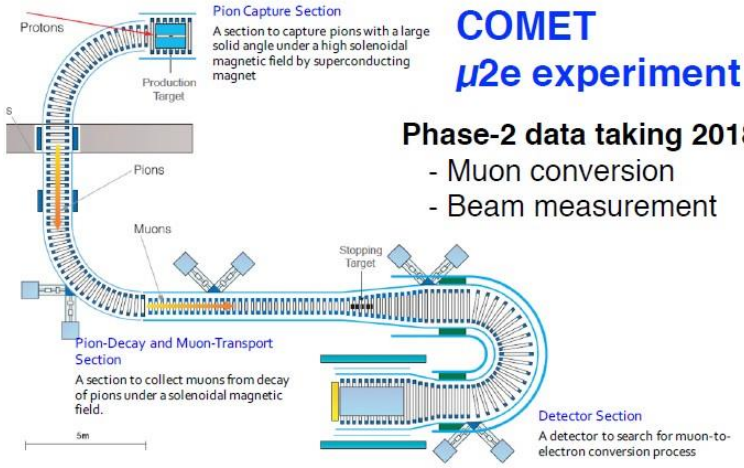


@MC-1 building, Fermilab

• Spin precession frequency

$$\boldsymbol{\omega}_a = -\frac{q}{m} a_\mu \mathbf{B}$$

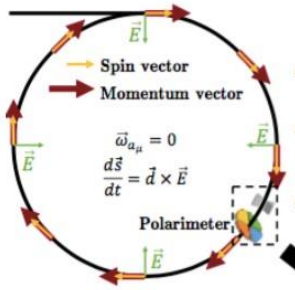




COMET μ2e experiment

Phase-2 data taking 2018
- Muon conversion
- Beam measurement

Proton EDM Experiment (proposal)



- A new method to search for and measure the **electric dipole moment of the proton (pEDM)** [1]
- Use polarized protons at the so-called **"magic" momentum** of 0.7 GeV/c
- Use **pure electric storage ring** with radius of ~ 40 m and an E-field of ~ 10 MV/m
- Goal: Measure pEDM down to 10^{-29} e cm over one year of measurement

The Rare Isotope Science Project (RISP)

- Goal: To build a heavy ion accelerator complex RAON, for rare isotope science research in Korea.

  * RAON - Rare isotope Accelerator complex for ON-line experiments

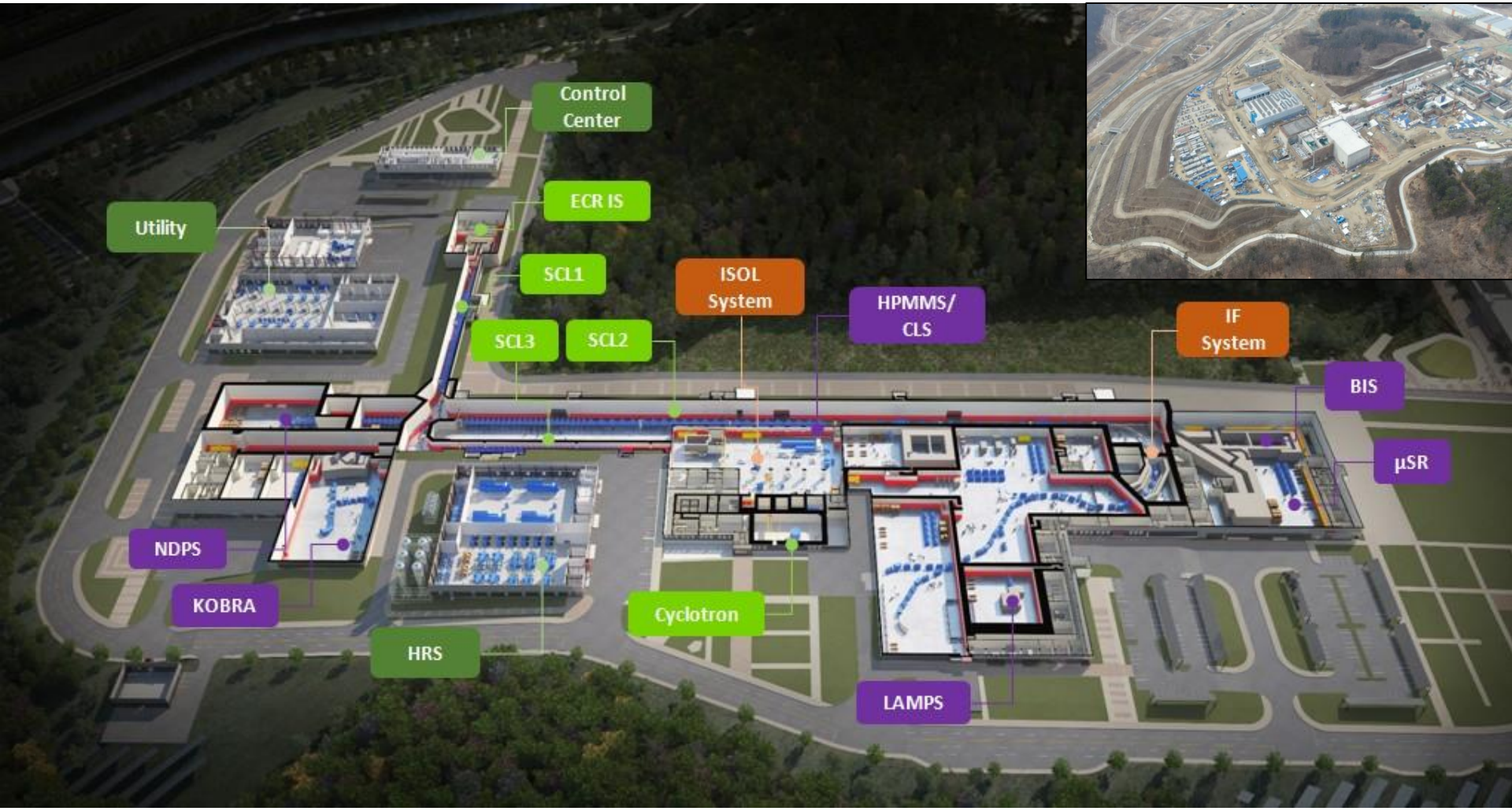
  - Providing high intensity RI beams
  - Providing high quality neutron-rich beams
  - Providing More exotic RI beam

- Budget: KRW 1,432 billion (US$ 1.26 billion, 1$=1,135krw)
  - accelerators and experimental apparatus : 460.2 billion won
  - civil engineering & conventional facilities : 972 billion won (incl. site 357 billion won)

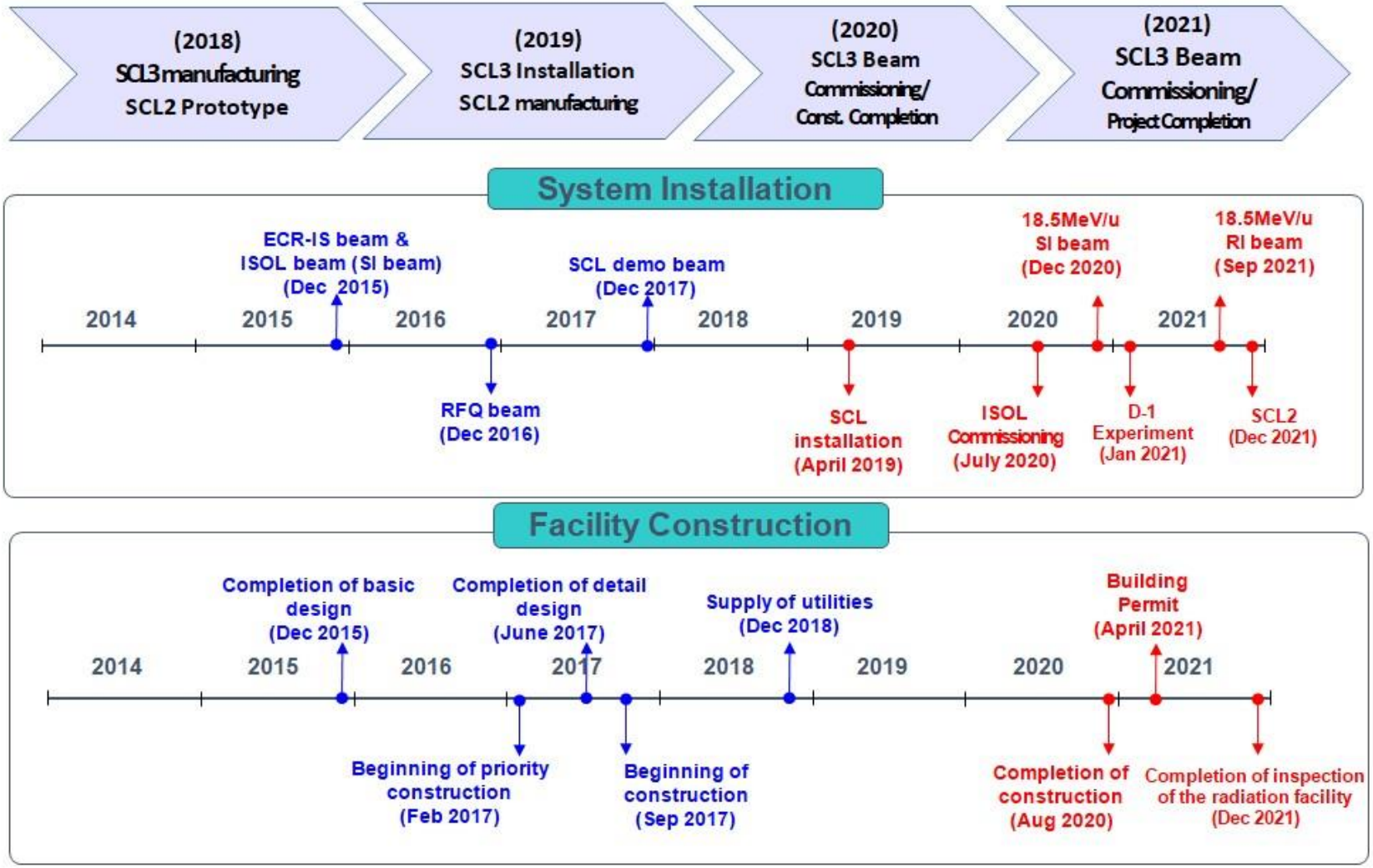
- Period: 2011.12 ~ 2021.12

For details, see director Kwon Myeon's talk tommorow

RAON Layout


Control Center
ECR IS
Utility
SCL1
ISOL System
HPMMS/ CLS
IF System
SCL3
SCL2
BIS
μSR
NDPS
KOBRA
Cyclotron
HRS
LAMPS

RISP Milestone



RAON Science Program

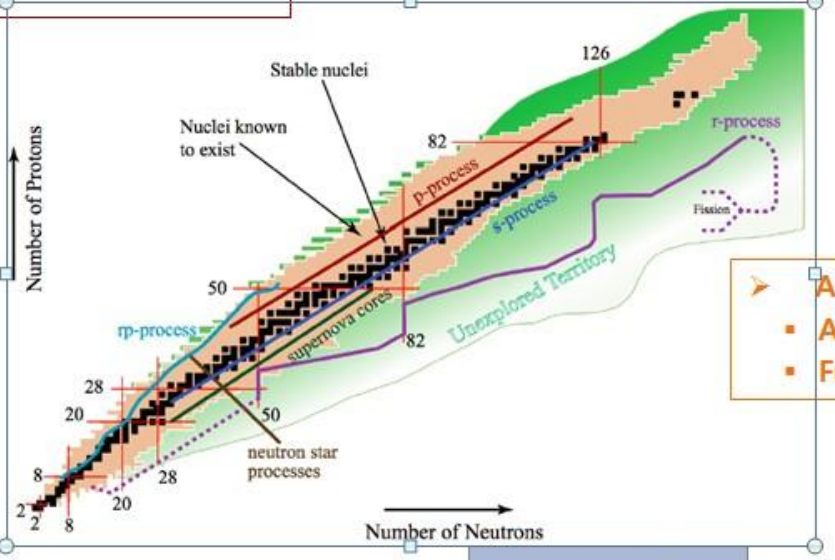
- **Nuclear Physics**
  - Exotic nuclei near the neutron drip line
  - Superheavy Elements (SHE)
  - Equation-of-state (EoS) of nuclear matter
  - Nuclear structure

Origin of Elements

Stellar Evolution

- **Nuclear Astrophysics**
  - Origin of nuclei
  - Paths of nucleosynthesis
  - Neutron stars and supernovae

~300 Stable isotopes
~3000Known isotopes
~10,000 isotopes expected



- **Atomic/Particle physics**
  - Atomic trap
  - Fundamental symmetries

Application

- **Material science**
  - Production & Characterization of new materials
  - β-NMR / μSR
- **Nuclear data with fast neutrons**
  - Basic nuclear reaction data for future nuclear energy
  - Nuclear waste transmutation
- **Medical and Bio sciences**
  - Advanced therapy technology
  - Mutation of DNA
  - New isotopes for medical imaging

Ongoing International Experiments

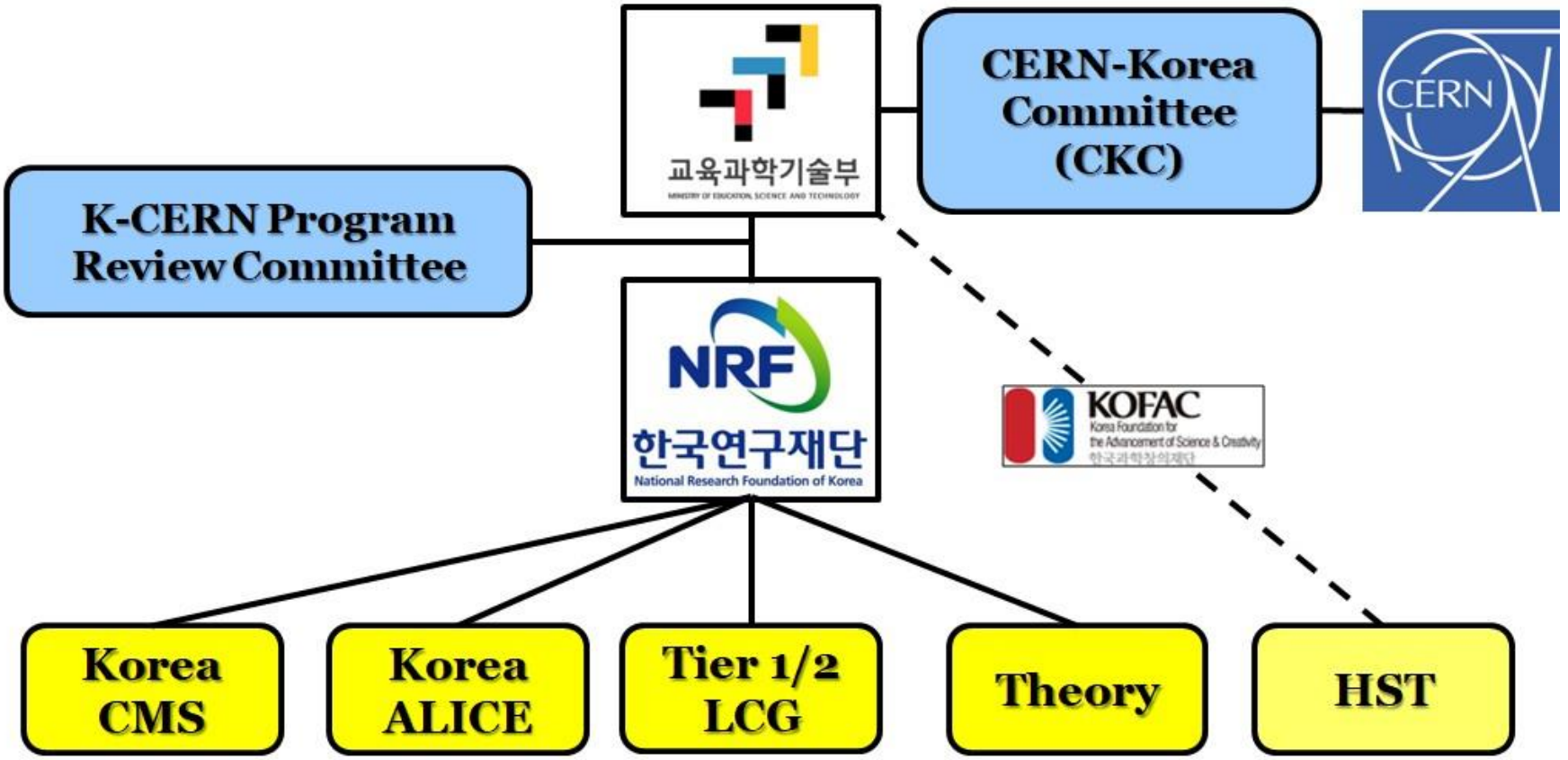
- CERN Experiments (Korea-CERN program)
  * CMS experiment
  * ALICE experiment
  * SHiP experiment

- KEK & J-PARC Experiments
  * BELLE II experiment
  * JSNS2 experiment

- Super-Kamiokande, ICECUBE and many others

Korea-CERN Program Organization

- Agreement signed by the Korean government and CERN (2007~)



CMS Experiment

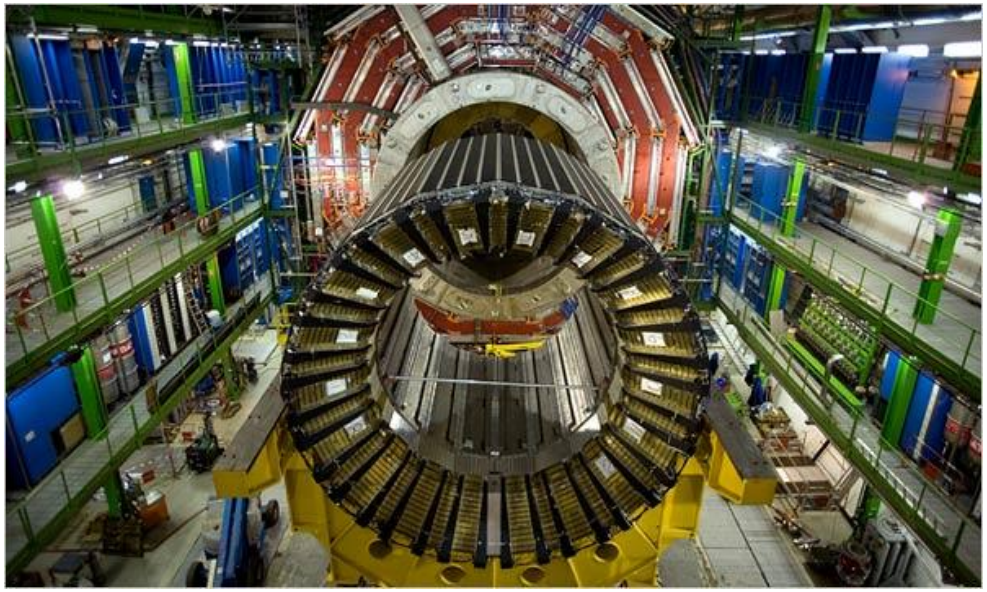
- Korea-CMS group

  * 9 Institutions:

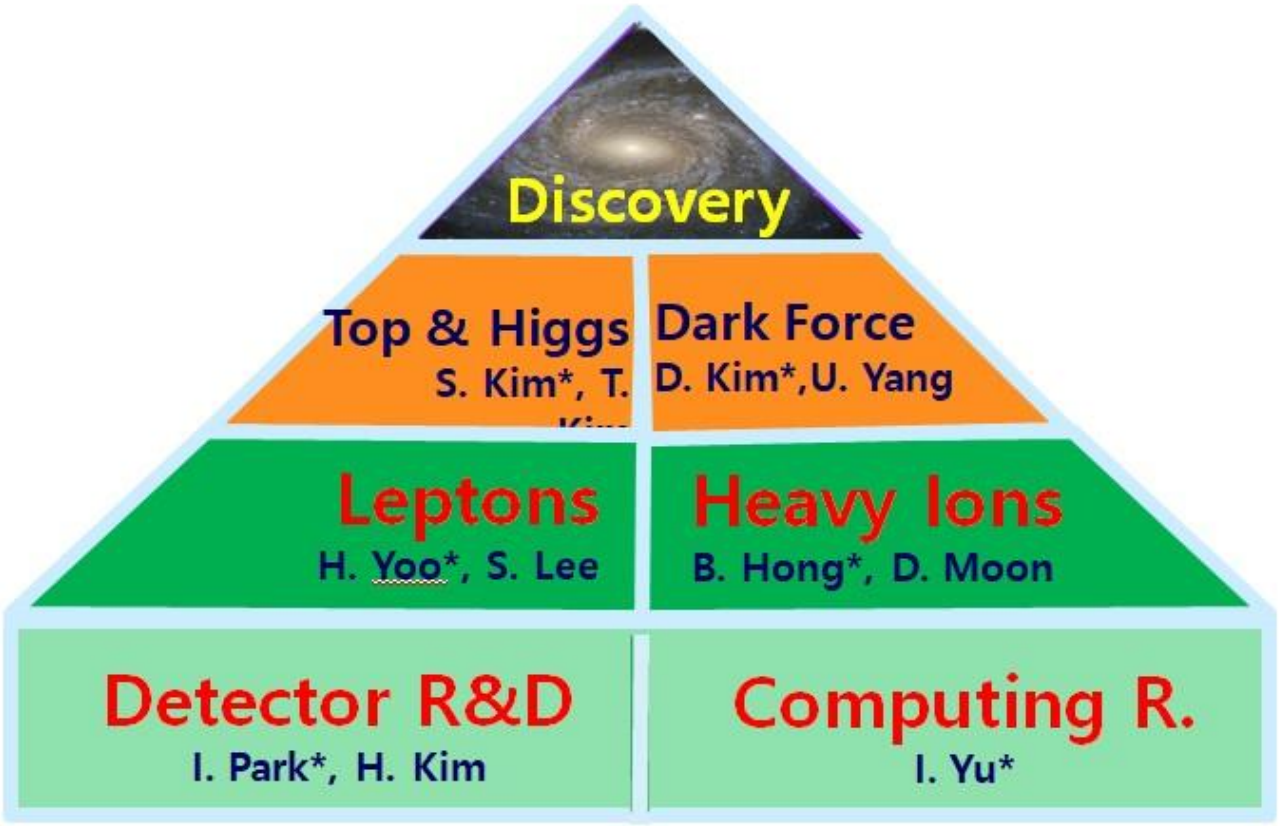
    CNU, Hanyang, Korea, KNU, Sejong, SNU, SKKU, UOS, Kyunghee

  * Budget (2019) : ~2.2 M USD

  * Manpower: 116 researchers (faculties, postdocs, students, technicians)



Korea-CMS Group : Research Activities



- 4 Task Force Teams, Detector R&D + Computing Resource works coherently

Korea-CMS Group : Research Activities

- SCI CMS papers: total 288 papers (2016~2019)

  * 33 papers by KCMS: 11% contribution

- Production of large GEM foils and GE11 chambers construction
- International & national conf. : 250 talks: (5.4% contribution)
- Core Leadership

  * Suyong Choi: CMS CB Deputy-chair, ONMS Represenative

  * Taejeong Kim: RPC Board Chair

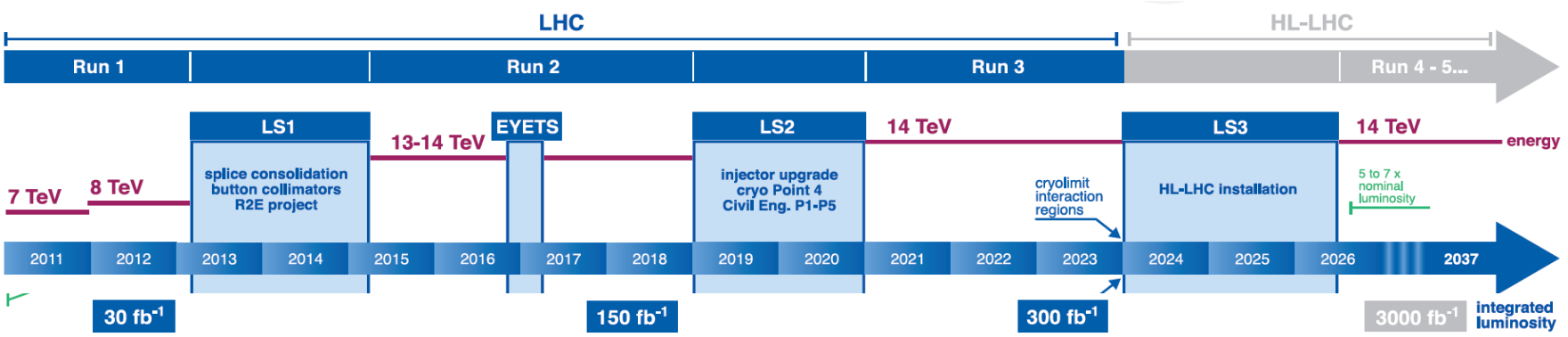
  * GEM DPG, RPC DPG, TSG group conveners

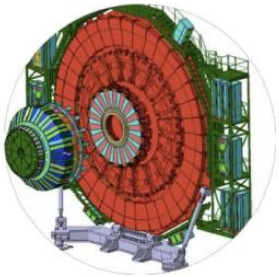
- CMS Achievement Award (2)
- Major International Conferences hosted

  * ICHEP2018, ISMD 2016

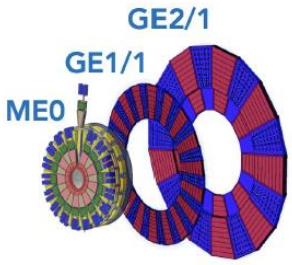
- 10^{th} Anniversary Ceremony of Korea-CERN Collab. (2017)

Korea-CMS Group : Detector Upgrade





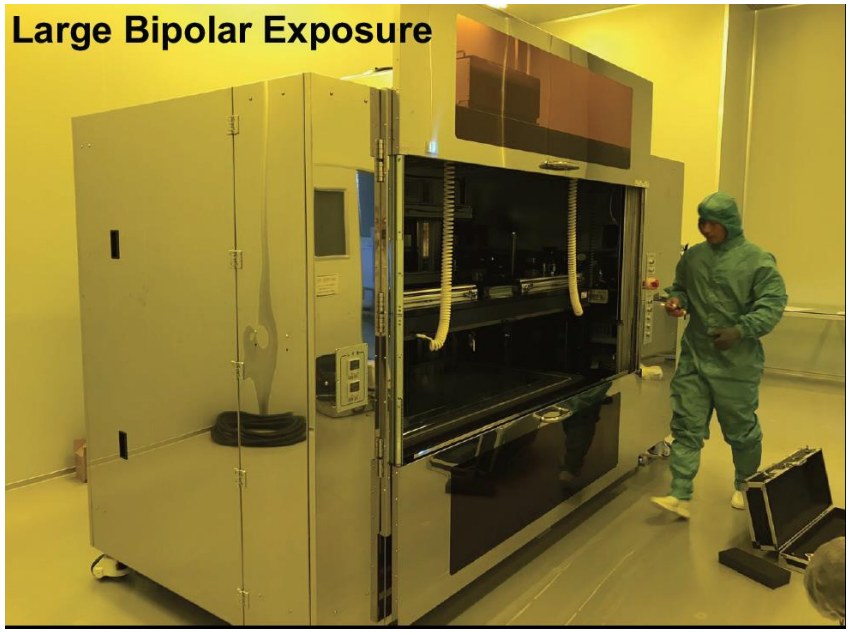
- LS2 2019
- GE1/1
- 144 chambers in 2 endcaps

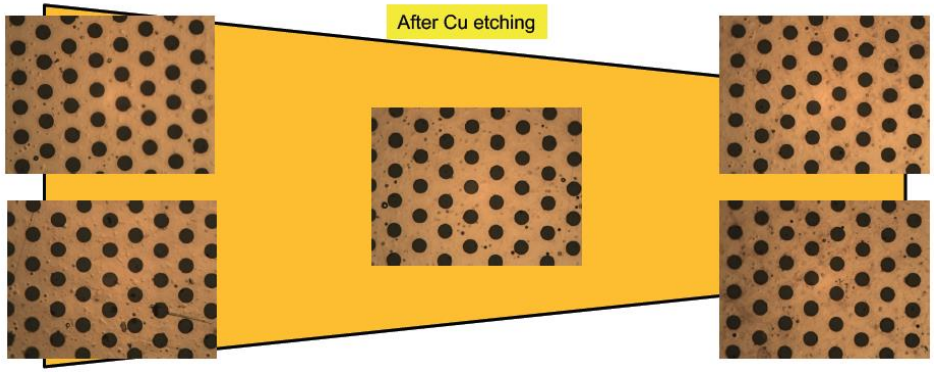


- LS3 2022
- Full Upgrade
- GE2/1
- ME0 increases η coverage from 2.4 to 2.8

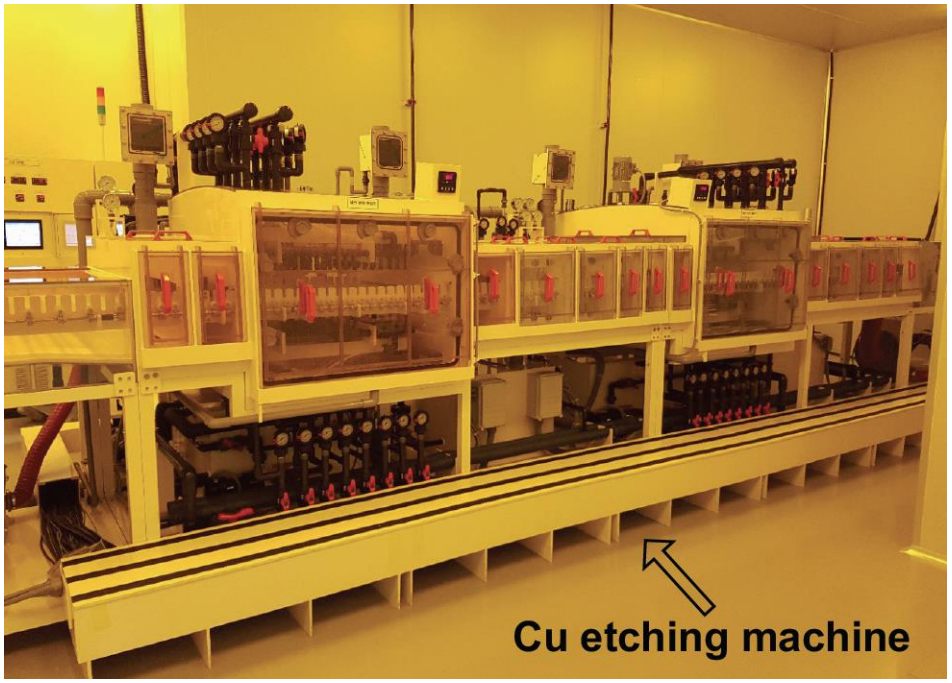
- LS2 : GE11 (2019~2020)
  - * Successful production of large GEM foils with Mecharo (Korean company)
  - * 30 GE11 Chamber Built
- LS3: GE21, ME0 (2024~2025)
  - * Prototype GEM production
  - * ~1100 GEM foils
- LS2 :iRPC (2019~2020)
  - * RPC gap test in progress

Korea-CMS Group: GEM Foil Production Facility





Mecharo Facility



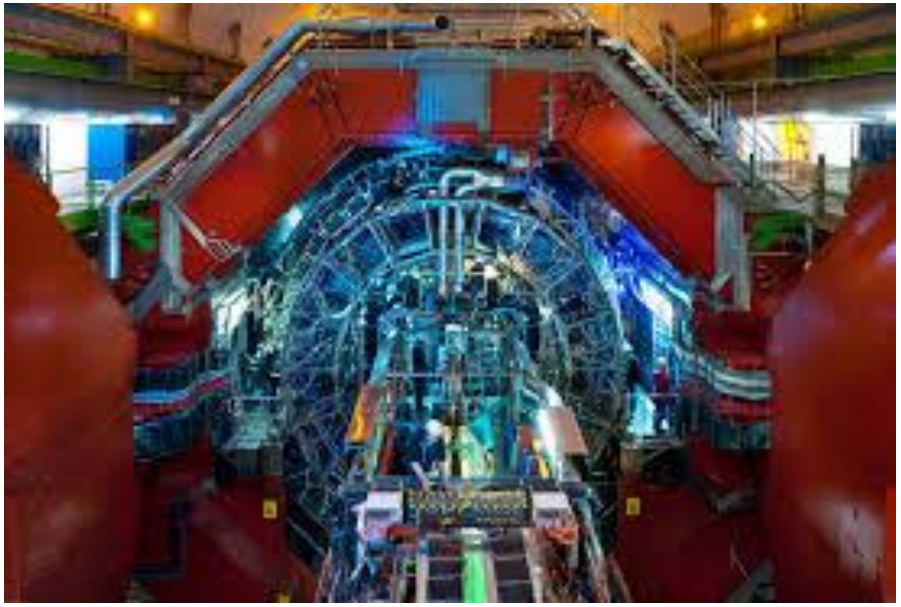
ALICE Experiment

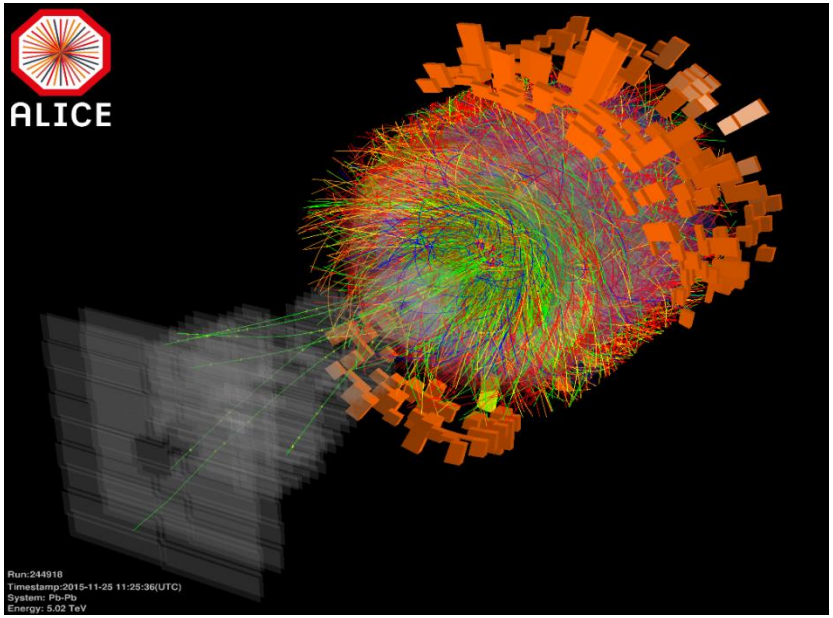
- Korea-ALICE group

  * 6 Institutions:

    CNU, GWNU, Inha, PNU, Sejong, Yonsei

  * Manpower: 32 researchers (faculties, postdocs, students)





Korea-ALICE Group : Research Activities

- SCI ALICE papers: total 93 papers (2016~2019)

  * 12 papers by K-ALICE: 13% contribution

"Measurement of electrons from heavy-flavour hadron decays in p-Pb collisions at root s(NN)=5.02 TeV" : PLB (2016)

"Pseudorapidity and transverse-momentum distributions of charged particles in proton-proton collisions at √s=13 TeV" PLB (2016)

"Production of Σ(1385)±and Ξ(1530)0 measured by ALICE in pp, p–Pb and Pb–Pb collisions at the LHC" : NPA (2017)

"Measurement of electrons from beauty-hadron decays in p-Pb collisions at √sNN= 5.02 TeV and Pb-Pb collisions at √sNN= 2.76 TeV" : JHEP (2017)

"Production of Σ(1385) ±and Ξ(1530)0 in p–Pb collisions at √sNN= 5.02 TeV" : EPJC (2017)

"Charged-particle multiplicities in proton-proton collisions at √s= 0.9 to 8 TeV" : EPJC (2017)

"Systematic studies of correlations between different order flow harmonics in Pb-Pb collisions at √sNN= 2.76 TeV" : PRC (2018)

Korea-ALICE Group : Detector Upgrade

- Inner Tracking System (ITS) Upgrade Project

  * Silicon chip test

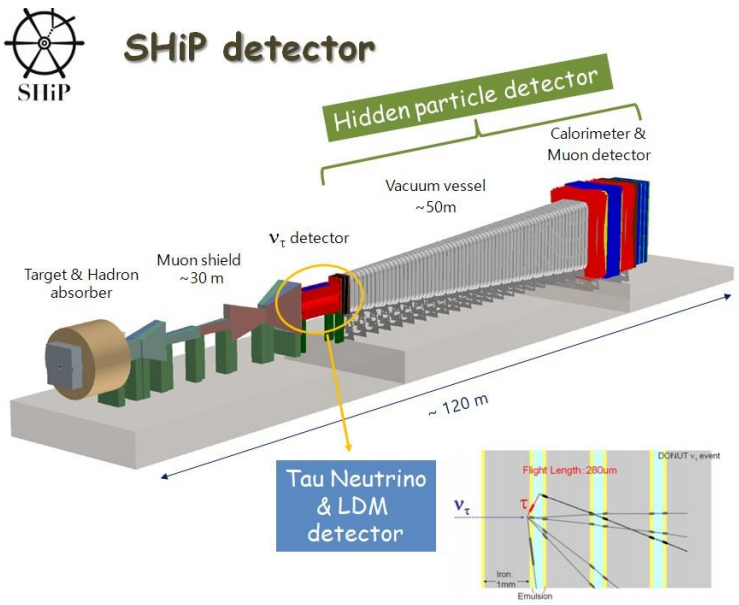
  * ITS HIC module construction

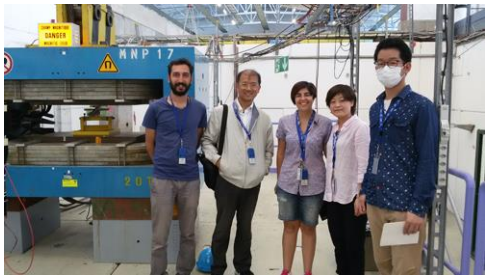
SHiP Experiment

- Search for hidden particles and light dark matter and study tau neutrinos
- Korea - SHiP group

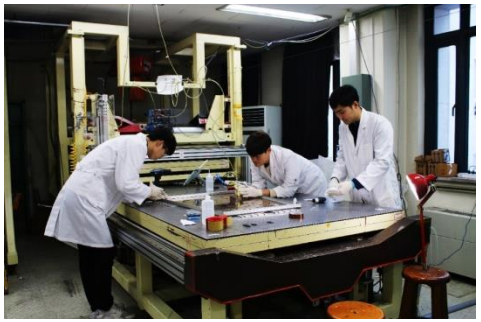
  * 5 Institutions & 11 members

    GNU, GNUE, JNU, Korea, SKKU
- The experiment will start data taking in 2026





Proton beam test of Compact Emulsion Spectrometer



Production of RPC gaps and strips

BELLE II Experiment

- Korea - Belle II group

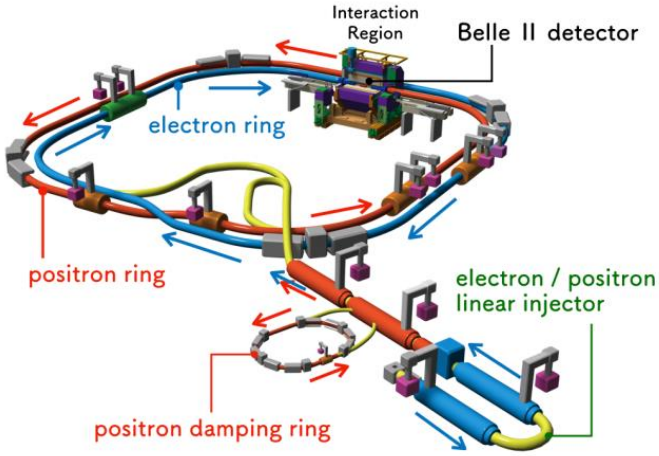
  * 7 Institutions:

    Gyeongsang, CNU, Hanyang, Korea, KNU, Soongsil, Yonsei

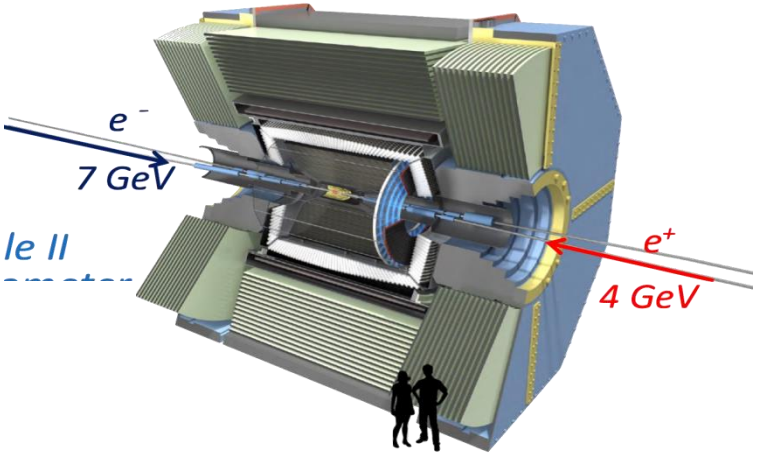
  * Successful Research Activities in Belle I experiment

    Discovery of X(3872) by Prof. S.K. Choi of Gyeongsang Univ.

    Prof. Y. Kwon of Yonsei Univ serves as the co-spokesperson of Belle I



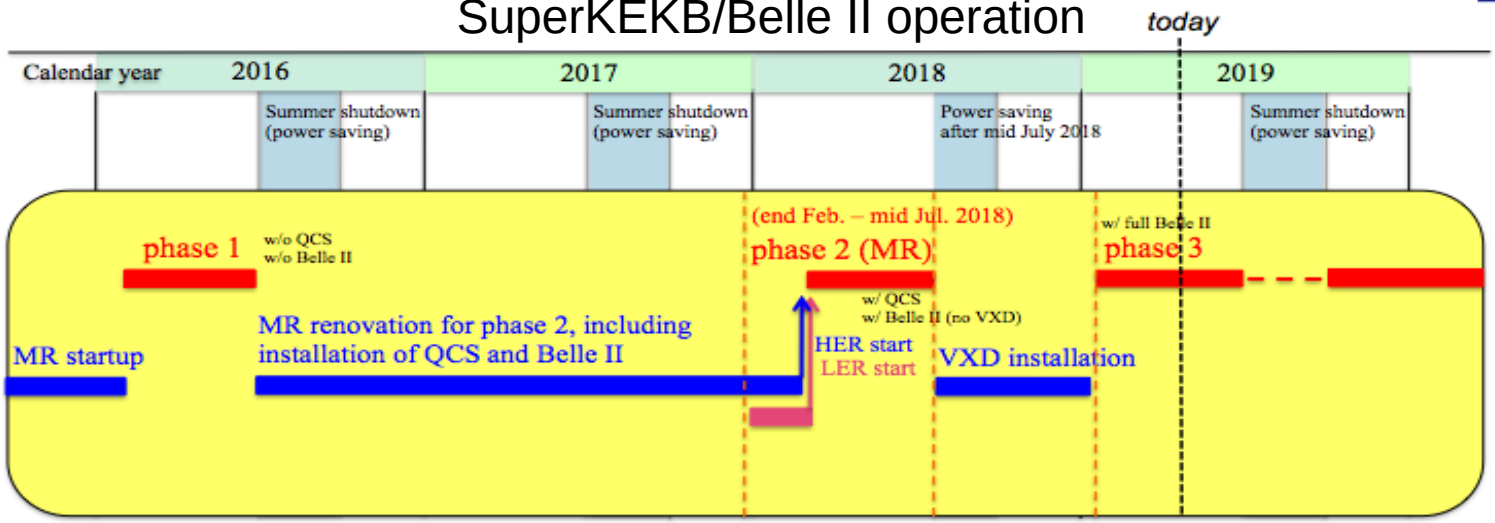
Super KEKB

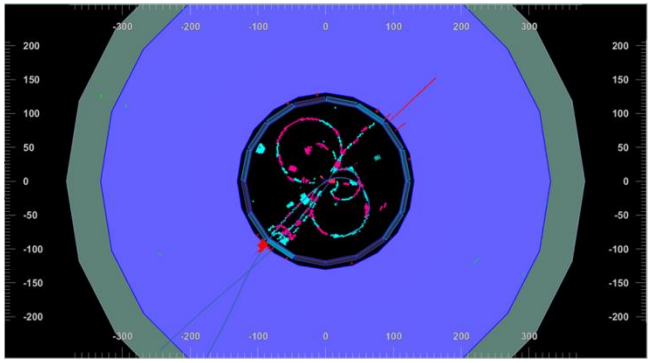


Belle II detector

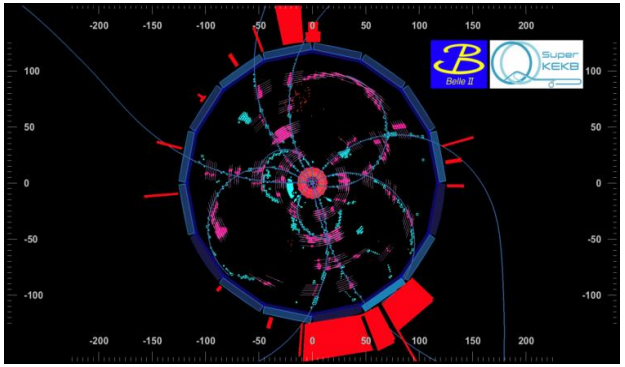
BELLE II Experiment

SuperKEKB/Belle II operation





First Collision in Belle II
Apr. 26, 2018



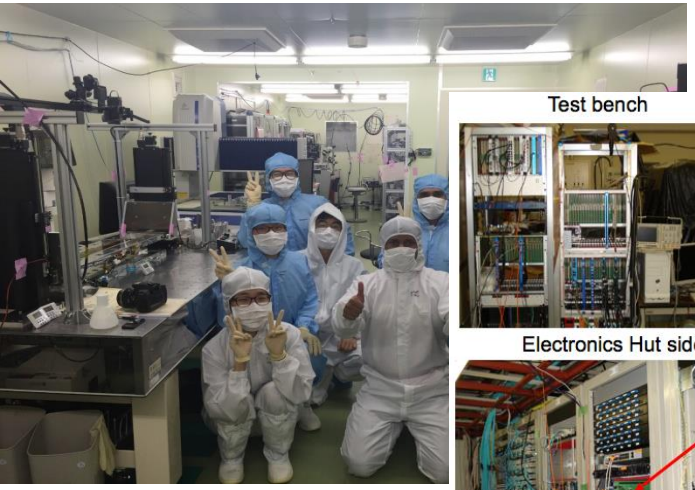
First BB-like Event in Belle II

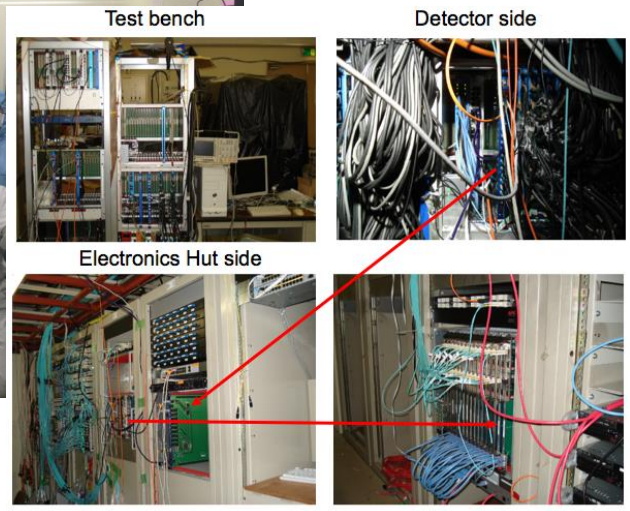
Korea-BELLE II Group : Research Activities

- Multi-quark & exotic hadrons — by Gyeongsang NU, Korea U
- Dark-sector search and exotic B decays — by Yonsei U, Chonnam NU
- B rare decays & CPV — by Hanyang U, Kyungpook NU
- Charm CPV — by Korea U
- Rare charm decays — by Soongsil U

Korea-BELLE II Group : Detector Upgrade

- Silicon Vertex Detector production and assembly (KNU)
- Calorimeter Trigger System (Hanyang U.)
- Online 3D Track Trigger (Korea U.)
- DAQ Monitoring (Yonsei U.)





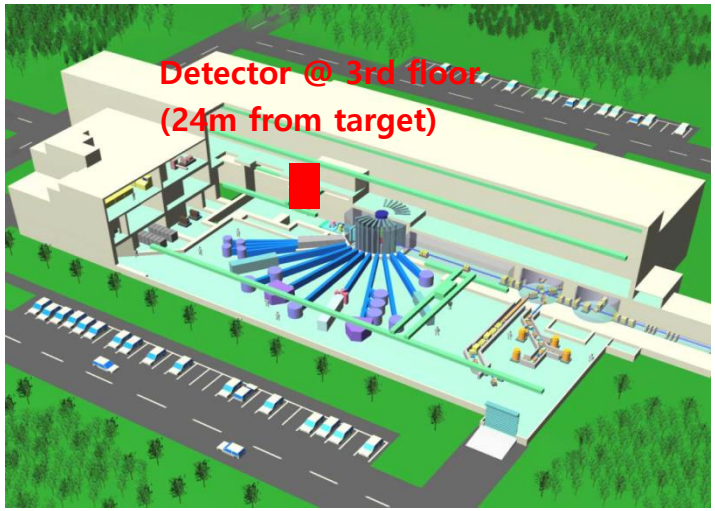
JSNS^2 Experiment

- Search for sterile neutrinos with a baseline of 24m and verify the LSND anomaly
- Korea - JSNS^2 group

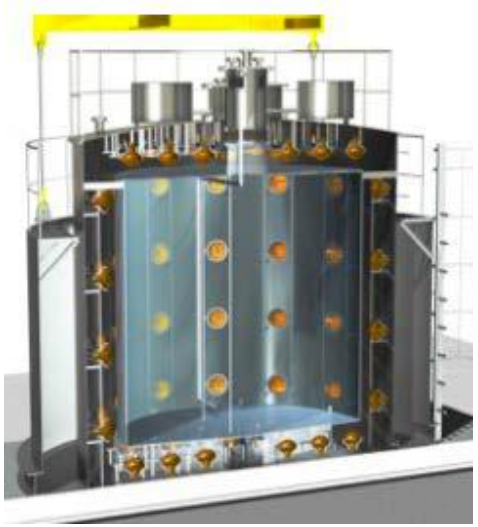
  * 7 Institutions:

    CNU, Donghsin, GIST, KNU, Seoyeong, SKKU, SNU

  * Prof. S.B. Kim of SNU serves as the co-spokesperson
- The experiment will start data taking in summer, 2019



J-PARC MLF



JSNS2 detector

Future Projects

- Domestic Projects

  * Center for Underground Physics : AMoRE-II, COSINE-200

  * Center for Axion and Precision Physics Research : ARIADNE

  * KNO (Korean Neutrino Observatory) Project

- International Projects

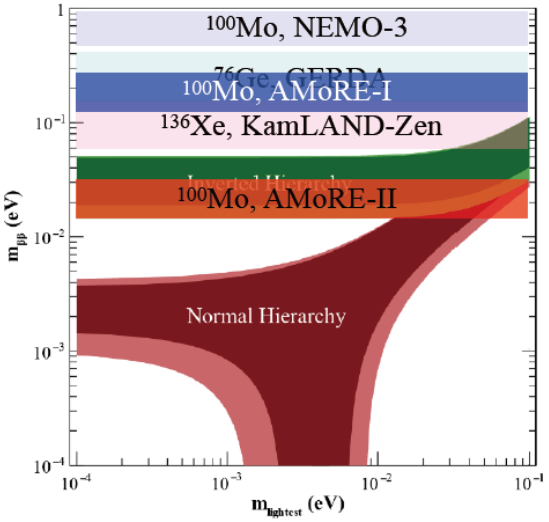
  * Next Generation Colliders : CEPC, HL-LHC, FCC

  * Next Generation Neutrino Experiments: DUNE, ICECUBE-Gen 2

- Many Others

Future Domestic Projects :CUP

AMoRE – II



Next-generation neutrinoless double beta decay experiment

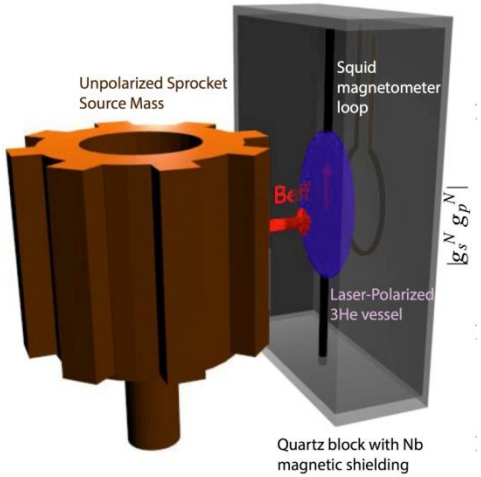
COSINE - 200

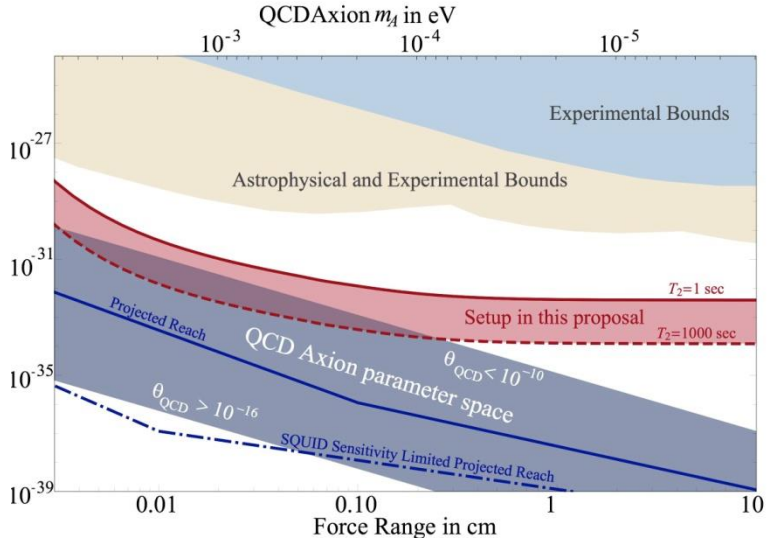
Next-generation WIMP dark matter experiment

Future Domestic Projects :CAPP

ARIADNE (Axion Resonant InterAction DetectioN Experiment)

* Axion as a force mediator between nucleons
* Probing wide range QCD axion
  Independent of cosmological assumptions
* Development at CAPP
  Large 3He polarization system
  SQUID w/ KRISS
  SC magnetic shielding w/ high Tc on Quartz substrate

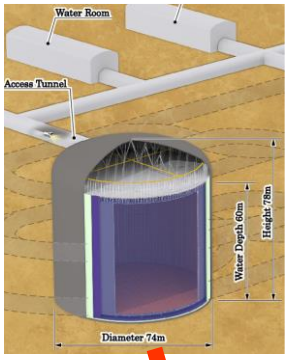




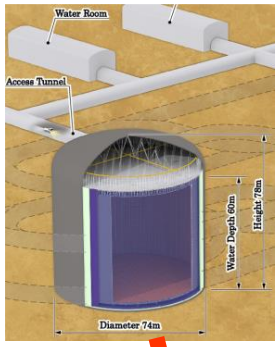
Future Domestic Projects : KNO

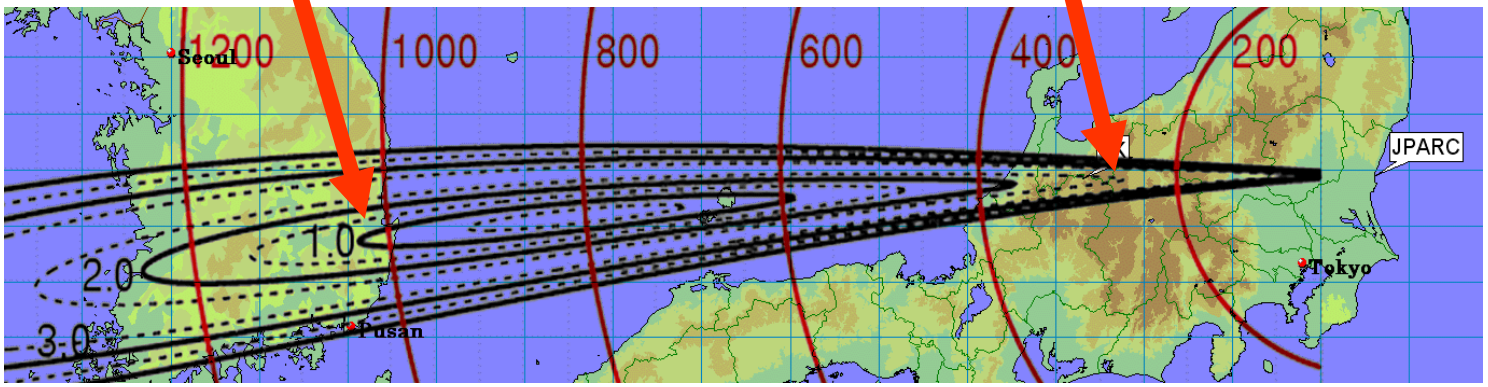
- Proposed as the 2nd detector of Hyper-Kamiokande (2016)

KNO



Hyper-K





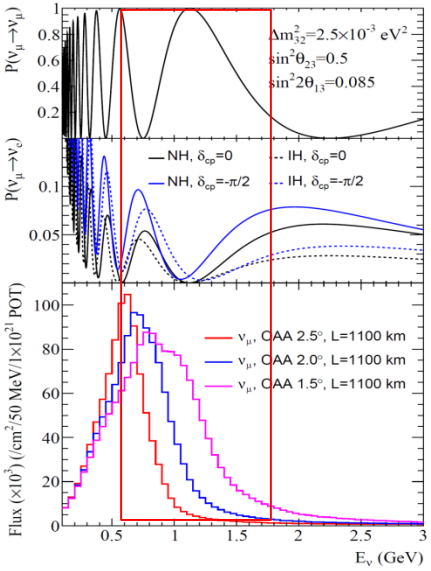
Future Domestic Projects : KNO

- KNO has some unique physics potentials
- KNO measure the second maxima of $\nu_\mu \rightarrow \nu_e$ oscillations
- Matter effect is larger at KNO → better sensitivity to mass hierarchy
- KNO has a larger overburden (~1000 m)

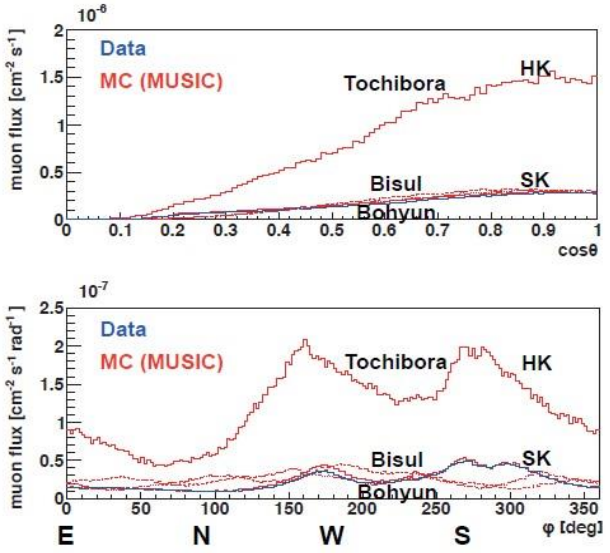
  * Lower cosmogenic background

  * Better sensitivity to astrophysical neutrinos (SN, SRN,..)

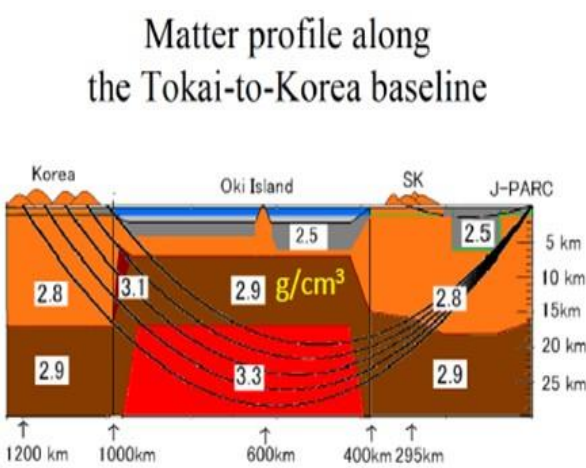
Neutrino Spectrum



Muon flux



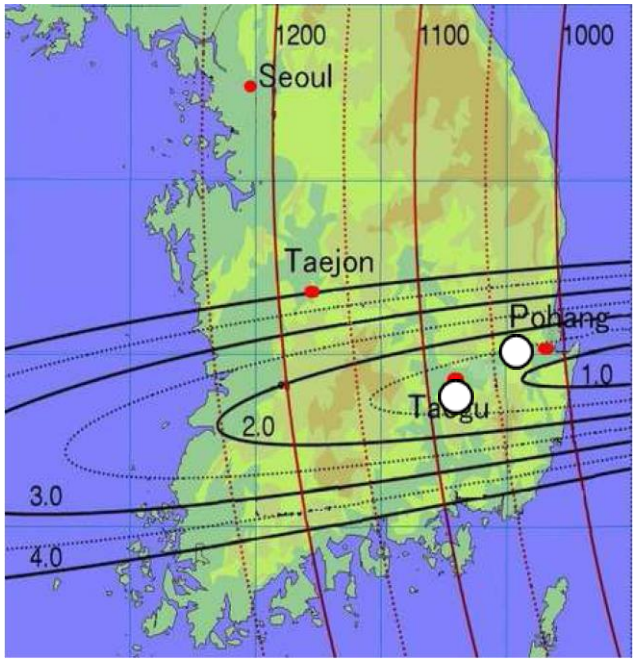
KNO matter profile



Future Domestic Projects : KNO

- KNO working group is formed
- Candidate sites are surveyed and preliminary studies are performed

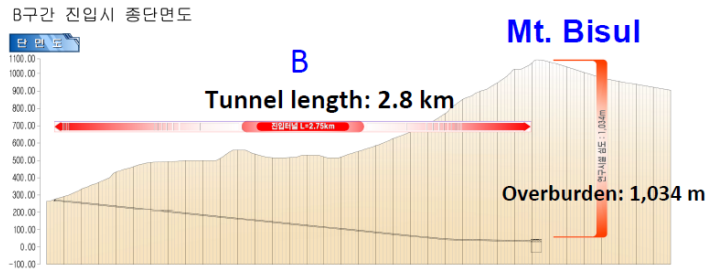
KNO Candidate Sites

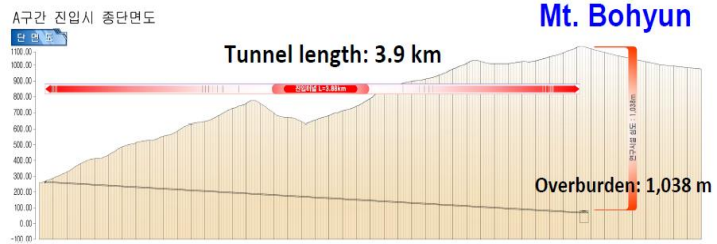


Mt. Bisul

Mt. Bohyun

Conceptual design of KNO tunnel

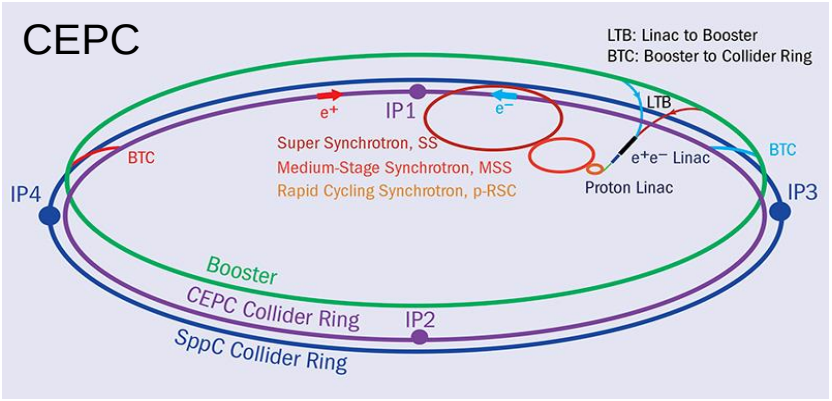




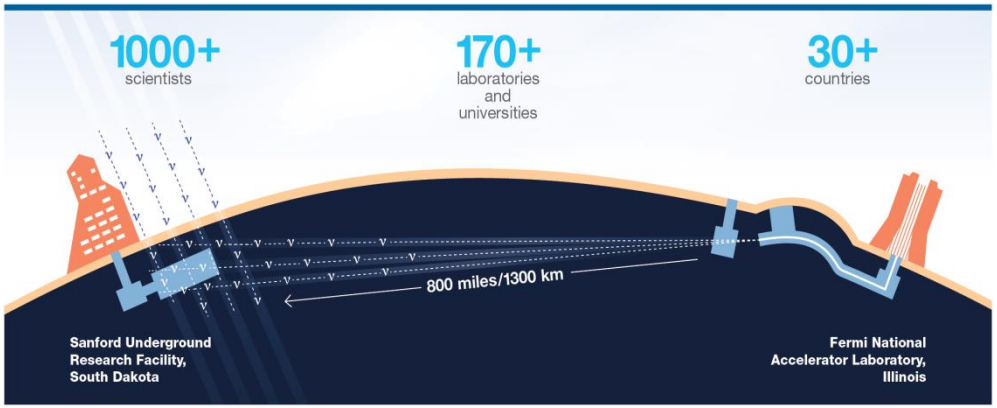
Future International Projects

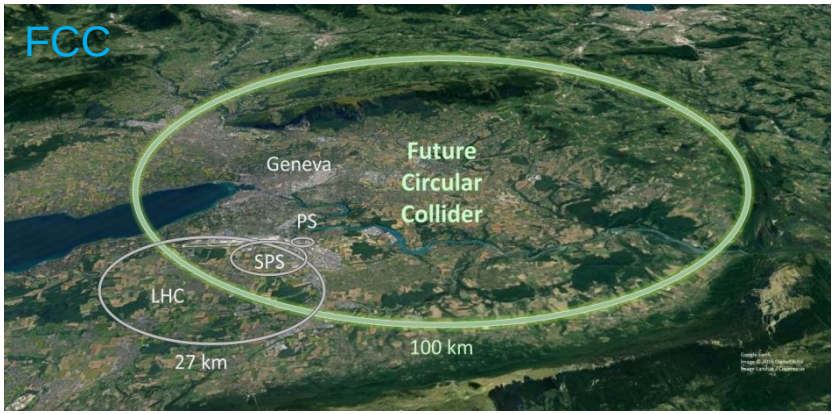
- Strong Interests in the future collider projects such as HL-LHC, CEPC, FCC
- Korean group are participating in the next generation neutrino experiments
  – DUNE and ICECUBE-Gen 2

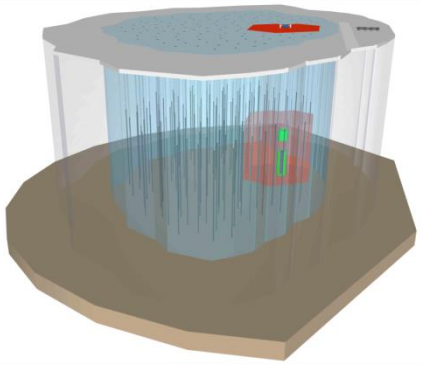
CEPC



DUNE







ICECUBE - GEN 2

SUMMARY

- Korea HEP community is growing fast for the past 10 years.
- Strong domestic HEP programs both in theory and experiment

  CTPU, RENO, CUP, CAPP,...
- Significant contributions to International HEP programs

  CMS, ALICE, BELLE II, ...
- Korea HEP physicists will play the leading role in the next-generation projects such as KNO, COSINE-200, AMoRE-II, and ARIADNE.
- Strong interests in participating the future projects such as HL-LHC, CEPC, FCC, DUNE, and many others