Highlights from Korea's HEP Activities

HEP Program in Korea

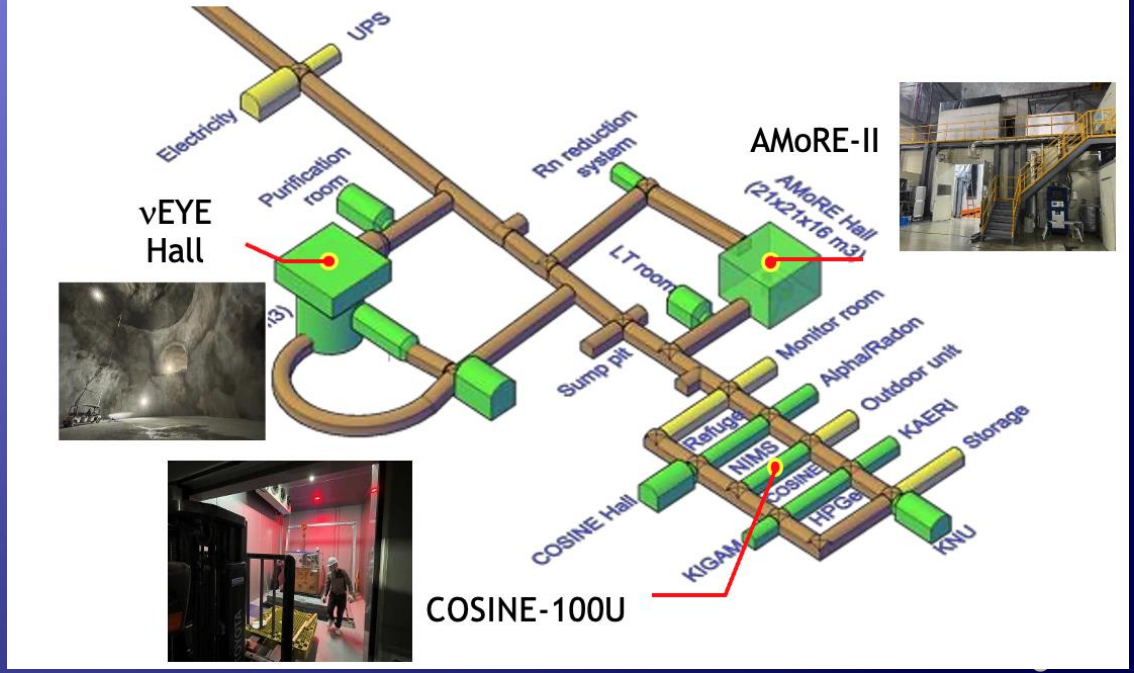
- **Domestic Programs**
  - IBS /CUP: dark matter, $0\nu\beta\beta$
  - IBS /DMAG: axion
  - Neutrinos
- **International Programs**
  - Colliders – CMS (~120), ALICE(~60), Belle-II(~45)
  - Detector R&D for Future Colliders: FCC, EIC
  - Neutrinos – JSNS2, SK/Hyper-K, DUNE, SHiP
  - JPARC programs
  - Fermilab program (DUNE, DAMSA etc)

Apologies for not covering all activities, talk will be focused on HEP-ex activities

IBS: Center for Underground Physics (CUP)

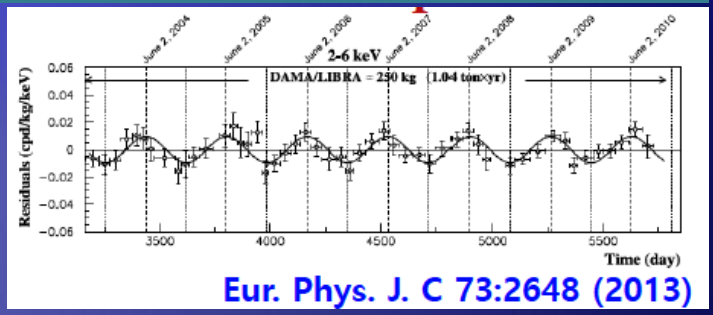
- **Yemilab: established new underground lab in 2022, moved from Y2L**

- **Y2L (700m): 2003-2023**
  - COSINE-100
  - AMoRE-I
- **Yemilab (1000m):2022~**
  - COSINE-100U, 200
  - AMoRE-II
  - νEYE
  - Cryogenic DM searches
  - …



CUP: COSINE-100 @ Y2L

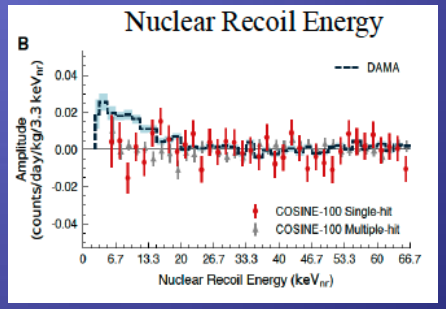
- Search for dark matters using DM-N elastic scattering
- Test DAMA/LIBRA's annual modulation signal with NaI crystals, 106kg

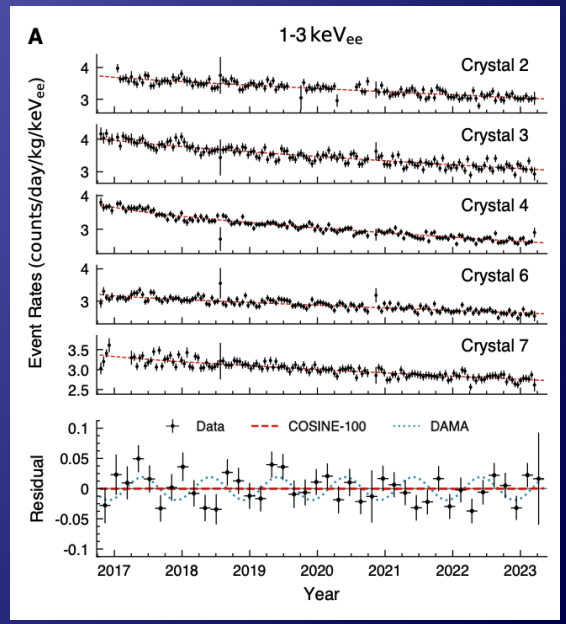


Eur. Phys. J. C 73:2648 (2013)

- No modulation signal observed !!
  - 6.4 years of data were fit with decaying bkgd model and modulation signal

E (keV_{nr})	A (counts/day/kg/3.3 keV_{nr})	
	COSINE-100	DAMA/LIBRA
6.7~20	0.001 ± 0.003	0.010 ± 0.001

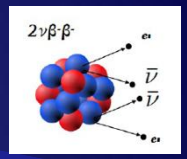




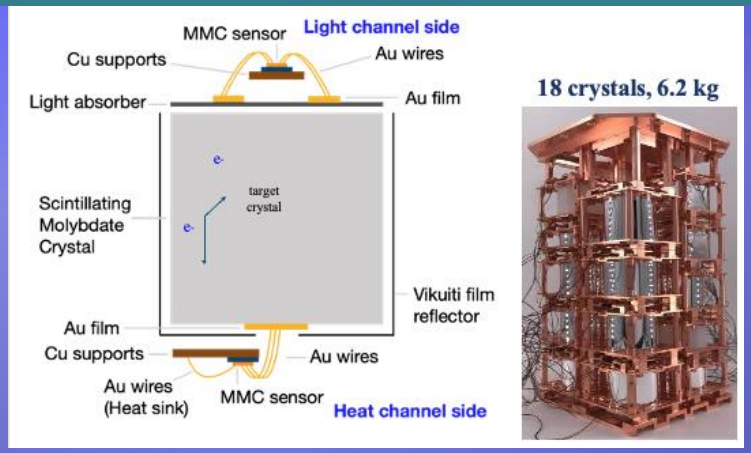
- Upgrade to COSINE-100U, -200 @ Yemilab with improved light yields

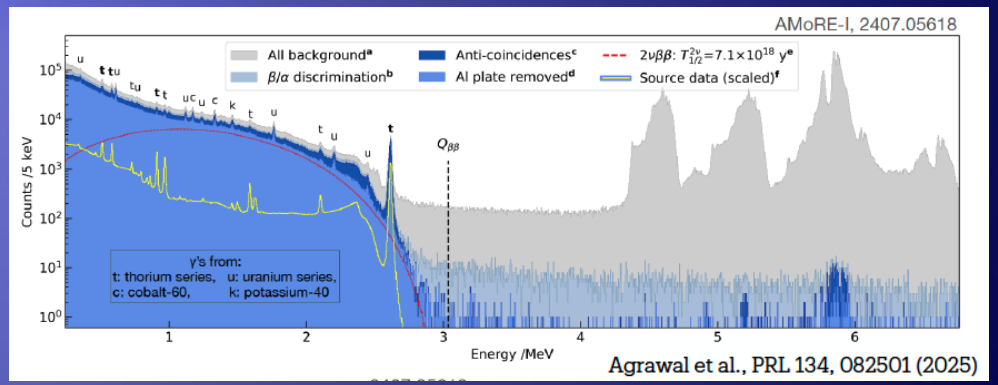
arXiv:2409.13226

CUP: AMoRE-I for $0\nu\beta\beta$ @ Y2L



- Search for neutrino-less double beta decay signal (Majorana ν)
- Mo-100 based scintillation crystal (XMO) as source and target at 10-20 mK: scintillating signa and phonon signal

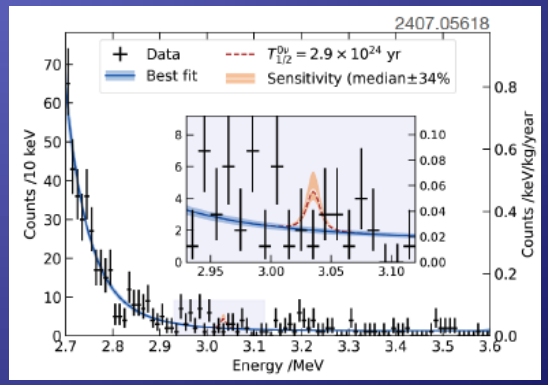


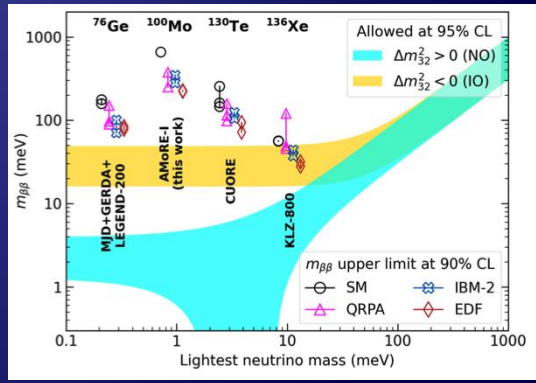


- Run 4kg Mo-100 for 4 yrs at 12mk
- Background : 0.025 counts/keV/kg/yr

$T^{0\nu}_{1/2} > 2.9\times10^{24}$ yr at 90% CL

The best half life limit for ^{100}Mo

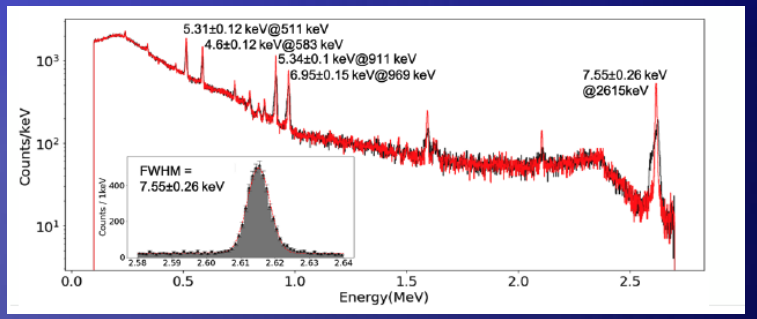


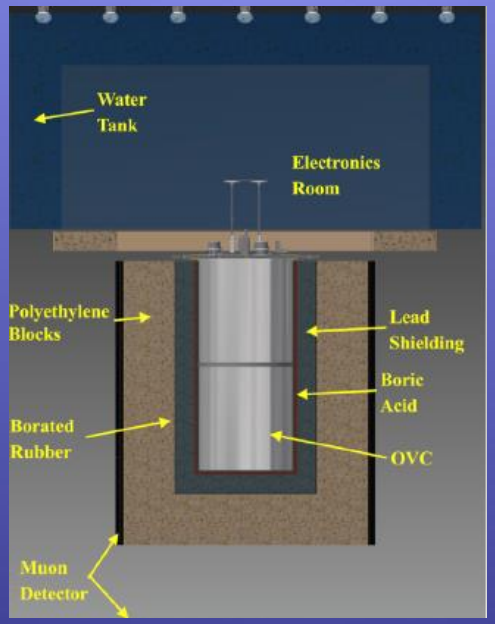


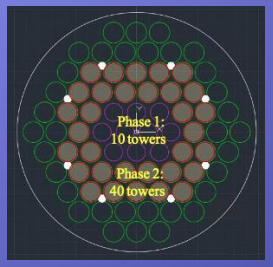
AMoRE-II @Yemilab

- AMoRE-II: 10 Countries, 25 Institutions
- 360 crystals (LMO+13CMO, ~85 kg ^{100}Mo)
- Bkgds goal < 10^{-4} count/keV/kg/year
- 5yrs op. can cover inverted mass ordering
- Schedule:
  - Phase 1: 90 crystals (2025-2026)
  - Phase 2: 360 crystals (2026-2030)

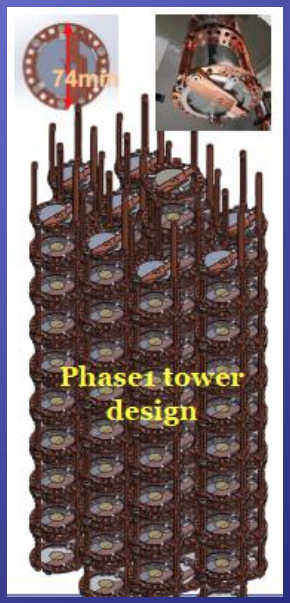
Satisfactory energy resolution:
EPJC 85, 172 (2025)



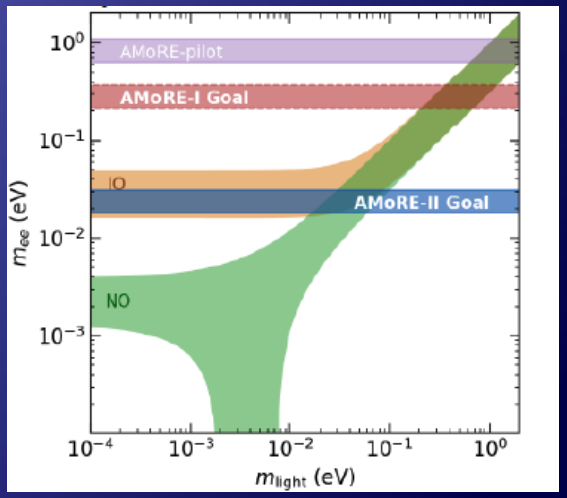





Detector/shielding scheme

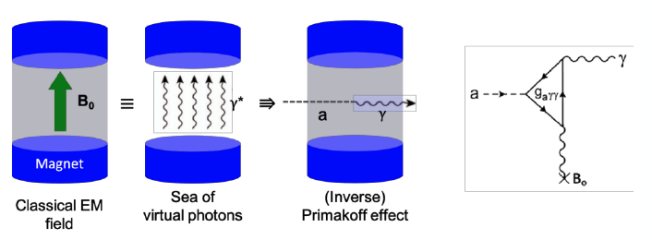


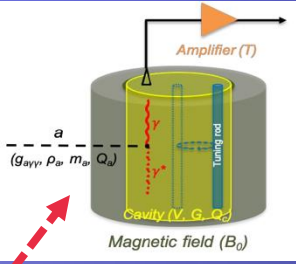
Sensitivity for ν mass



IBS: Dark Matter Axion Group (DMAG)

- Search for axion particle: solution to strong CP problem and dark matter candidate
- CAPP center is changed to DMAG group
- Detection by Primakoff effect

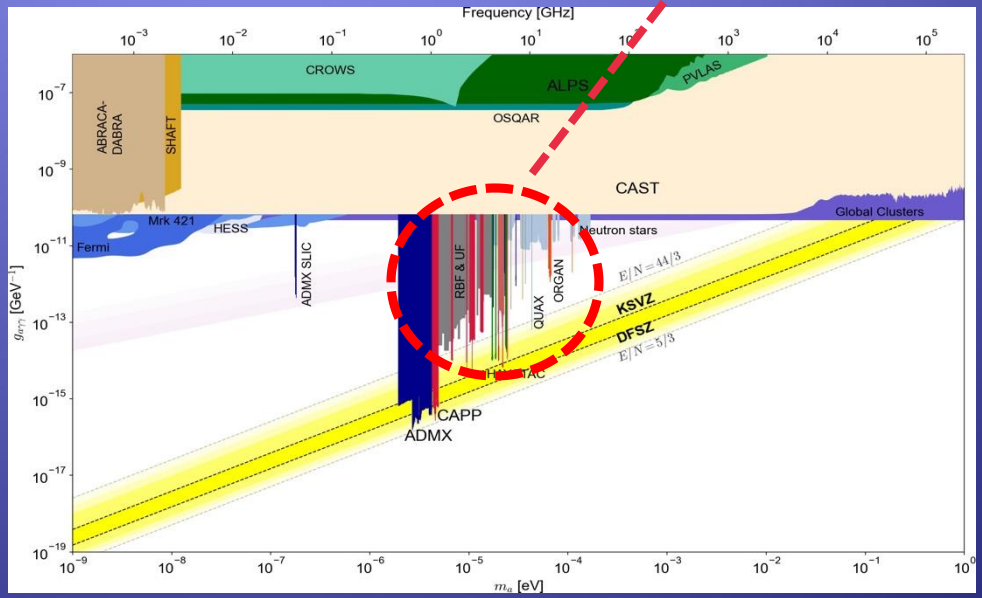




Dark matter halo in our galaxy

$$P_{a\gamma\gamma} \approx 9\times10^{-23}\ W \left(\frac{g_{a\gamma\gamma}}{0.36}\right)^2 \left(\frac{\rho_a}{0.45\frac{GeV}{cc}}\right) \left(\frac{f_a}{1.1\ GHz}\right) \times \left(\frac{B_0}{10.5\ T}\right)^2 \left(\frac{V}{37\ L}\right) \left(\frac{C}{0.6}\right) \left(\frac{Q_c}{10^5}\right)$$

(~100 photons/sec)



Unknown mass => scanning rate

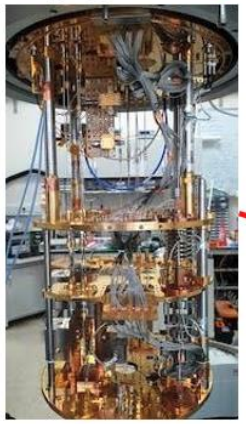
$$\frac{df}{dt} \approx 2\frac{GHz}{year}\left(\frac{5}{SNR}\right)^2 \left(\frac{0.2\ K}{T_{sys}}\right)^2 \left(\frac{P_{a\gamma\gamma}}{1x10^{-22}\ W}\right)^2 \left(\frac{10^5}{Q_c}\right)$$

$$\sim B_0^4 V^2 C^2 Q_c T_{sys}^{-2}$$

DMAG: How to achieve?

- *Enhancing the scan rate by improving experimental parameters*

Cryogenics T



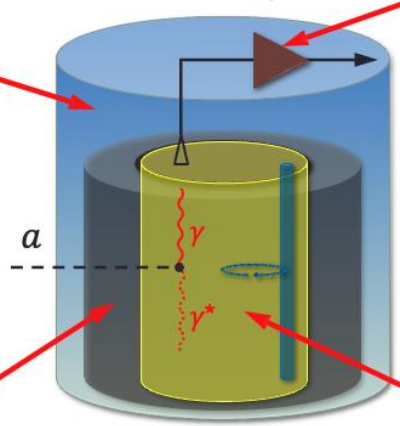
Lowering thermal noise

High field Magnet B

Boosting a→γγ conversion

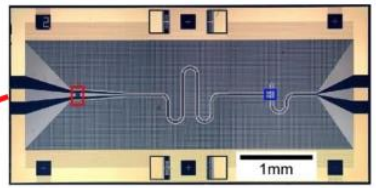
$$\frac{df}{dt} \sim B^4 V^2 C^2 Q_L T_{syst}^{-2}$$

P ~ 10^{-23} W



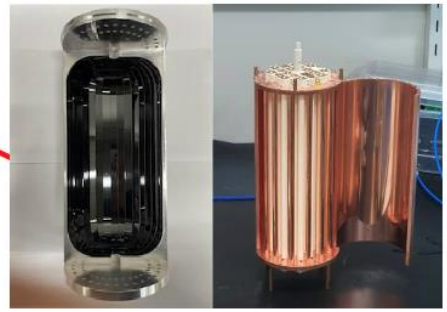
All are advanced and well mature!

Quantum noise limited amplifier T



Signal amplification w/ minimal noise added

Tunable High-Q resonator
V, Q, C, Δf



Resonant frequency tuning

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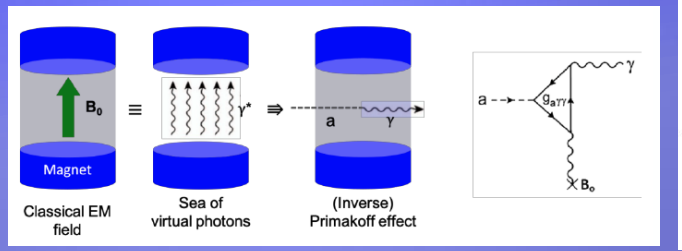
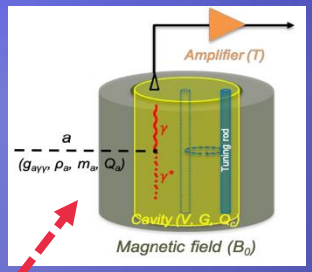
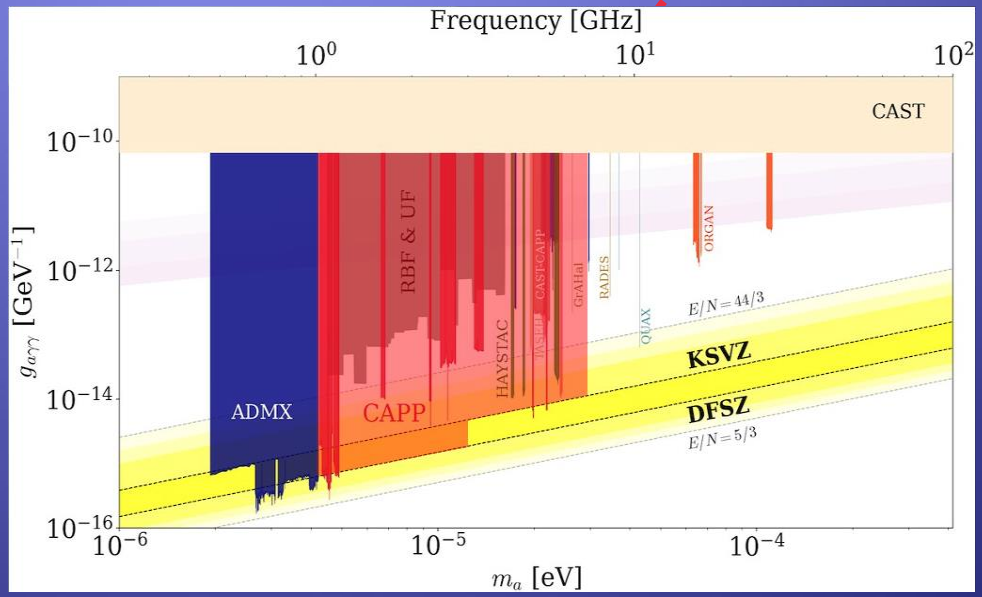




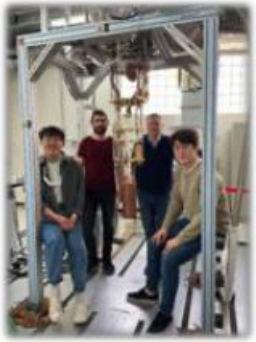


Prospects for 5 yrs

Axion search highlights

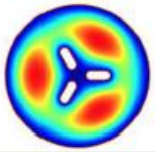
CAPP-8T
(8T/125mm)
HTS cavity + JPA
(2.3 GHz, Q ~ 3.5 M)
AQN search
Paper in preparation



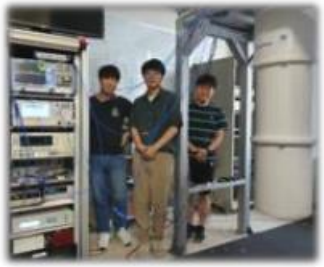



CAPP-8TB
(8T/165mm)
8-cell + JPA
(5.9 GHz, 400 mK)
Near KSVZ sensitivity
Paper in preparation



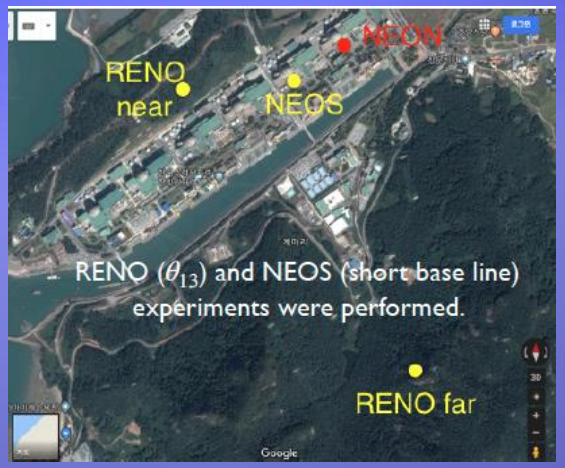

CAPP-12T
(12T/96m)
3-cell + JPA
(5.3 GHz, 400 mK)
KSVZ sensitivity
NM algorithm
PRL **133** 211803 (2024)

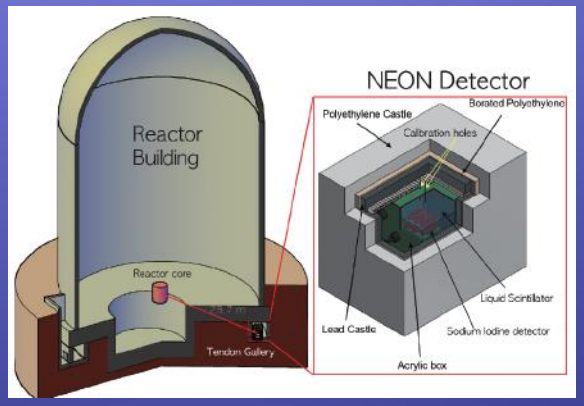


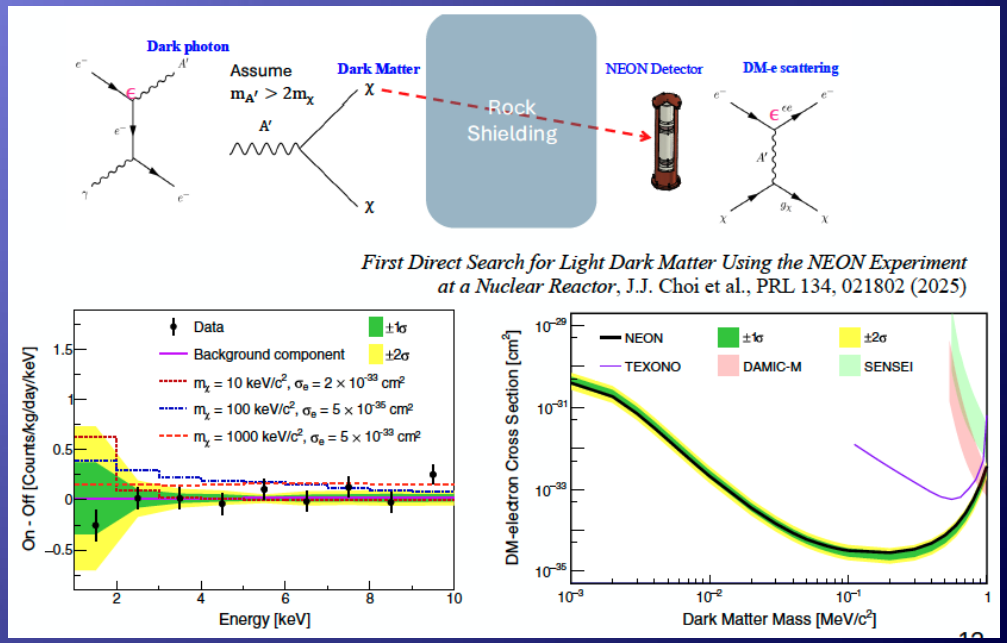
CAPP-12TB
(12T/320mm)
$f > 1$ GHz, $V = 37$ L, $T_{sys} < 250$ mK
df/dt ~ 2 MHz/day @ DFSZ
PRL **130** 071002 (2023)
Extended scan (Δf ~120 MHz)
PRX **14** 031023 (2024)
Ready for 300-MHz run w/ SC cavity

Physics with NEON

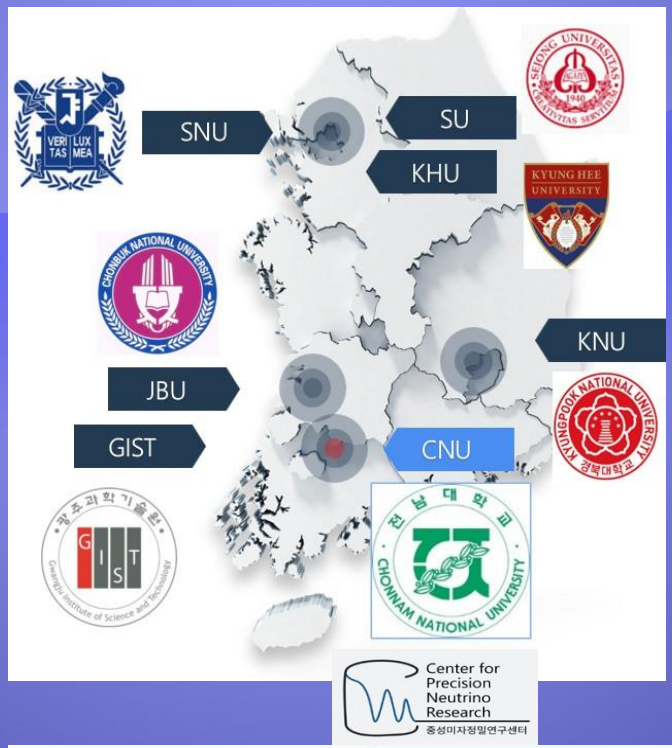
- Neon detector is installed at Hanbit nuclear power reactor (~23.7m)
  - ν coherent scattering, and dark matter search







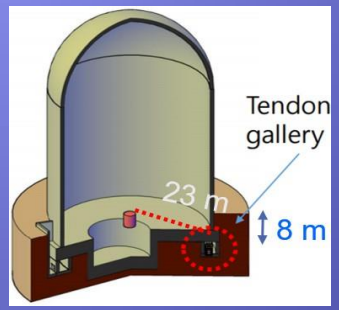
Center for Precision Neutrino Research

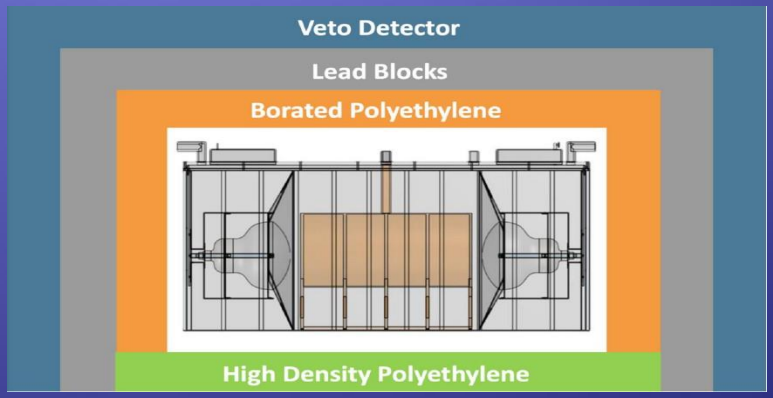


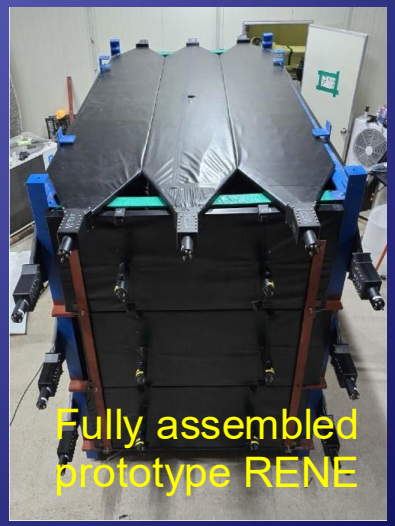
- **Science Research Center** program of Korea, 2022 (~ 50 members)
- International and domestic research hub of neutrino physics in Korea

Domestic: RENE

- **R**eactor **E**xperiment for **N**eutrino and **E**xotics (started in 2022):
  - Search for sterile neutrinos
  - Gd loaded (0.5%) liquid scintillator-based detector (350 L)
  - Two 20-inch PMTs mounted at both sides.
  - VETO is made of plastic scintillator.
  - Expect to install by summer 2025

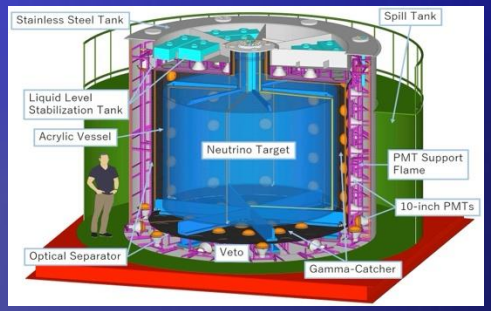


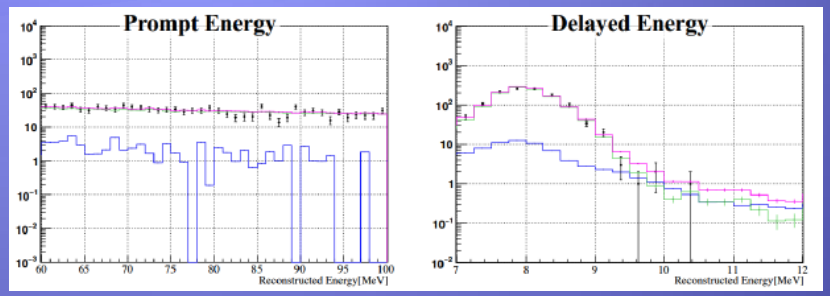


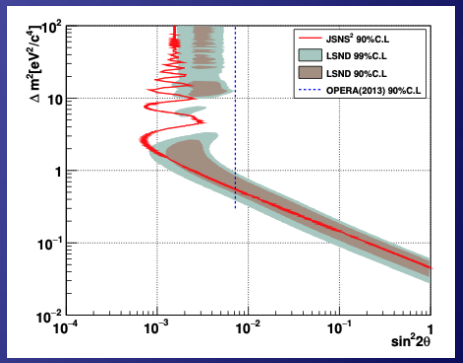


Programs @ J-PARC

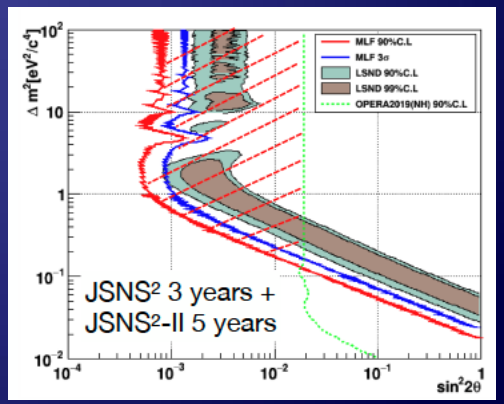
- JSNS^2 – **J**-PARC **S**terile **N**eutrino **S**earch at **J**-PARC **S**pallation **N**eutron **S**ource
  - Search for sterile neutrinos: direct confirmation of LSND sterile ν ($\Delta m^2 \sim 1$ eV^2)
  - Liquid scintillator-based detector, 24m from target
  - Physics Run (2021 ~ present)
- Pulse shape discrimination and bkgds studies are almost finalized





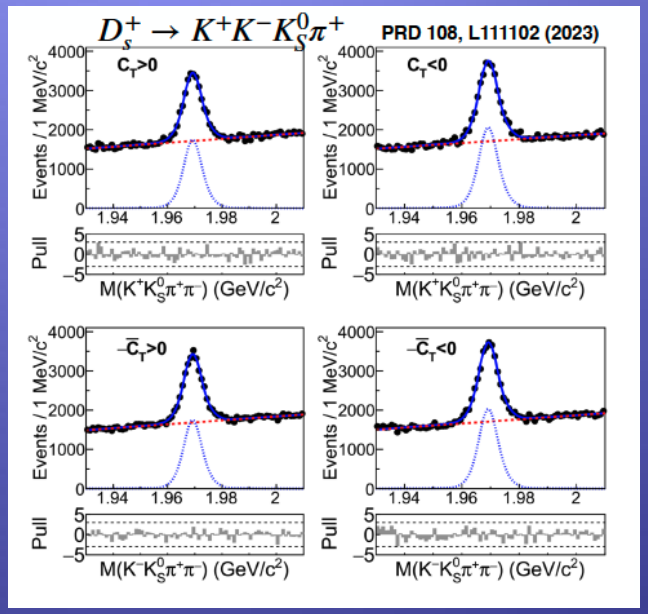


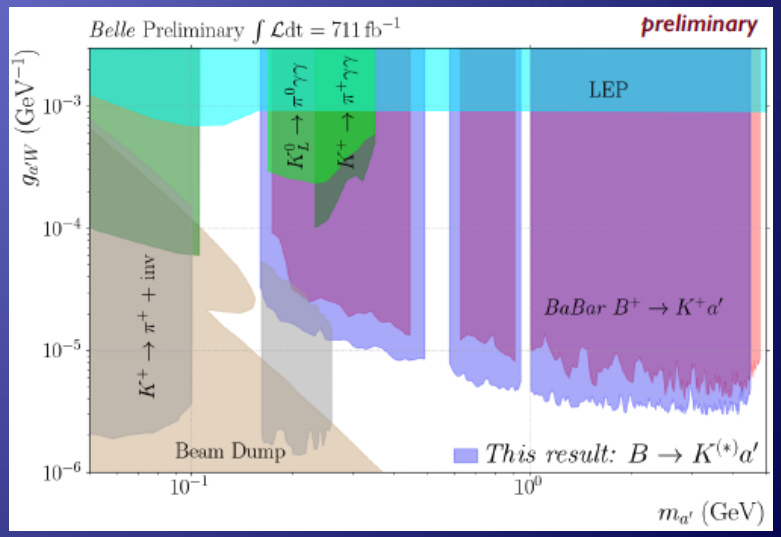
- About to open the signal region soon
- JSNS^2-II new far detector is under construction to reduce the systematic uncertainty



Belle-II @ KEK

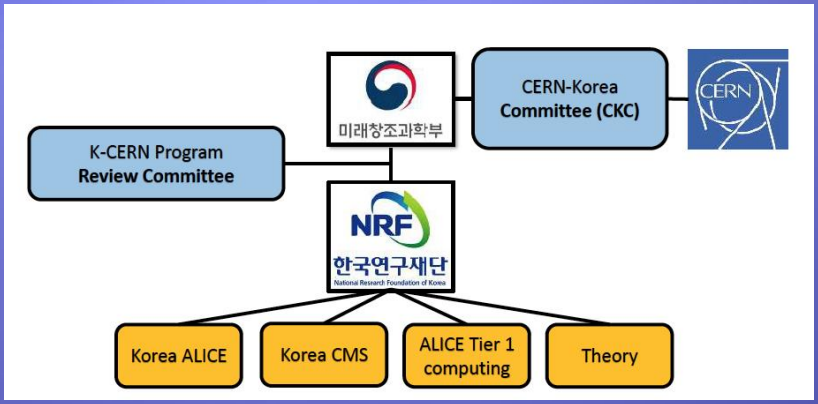
- Flavor Factory: Belle-II
- long history of participation in KEK experiments, AMY/Tristan, Belle/KEKB (since mid-1980s)
- active participation w/ leading roles in the collaboration (WG conveners, Phys. Coordi., co- Spokes @ Belle; IB Chair @ Belle II, etc.)
- recent physics highlights include Acp in 4-body decays, exotic hadron studies, dark sector & ALP in B decays, etc.





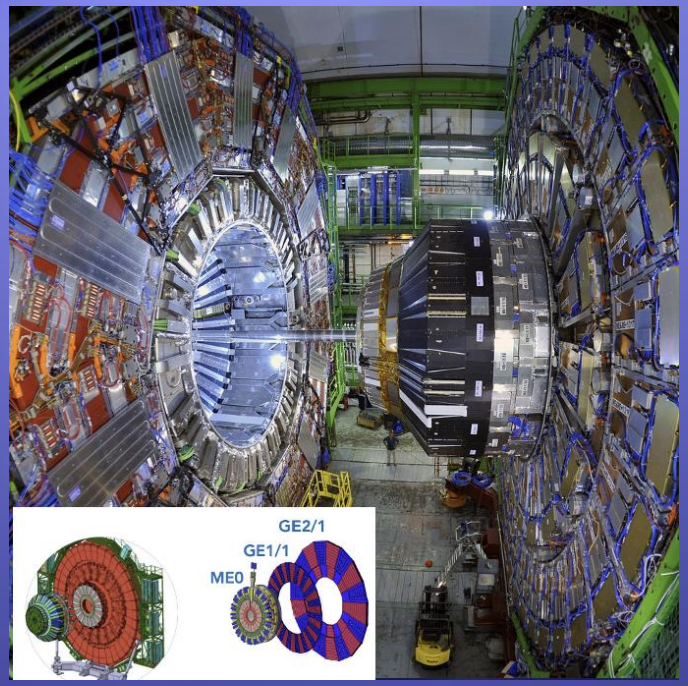
CMS @ LHC

- Korea-CERN Project was established between Korean government and CERN in 2006: ~8M$/year
- CERN-Korea Committee (CKC) reviews the Korea-CERN projects every six months
- Very Successful International Project



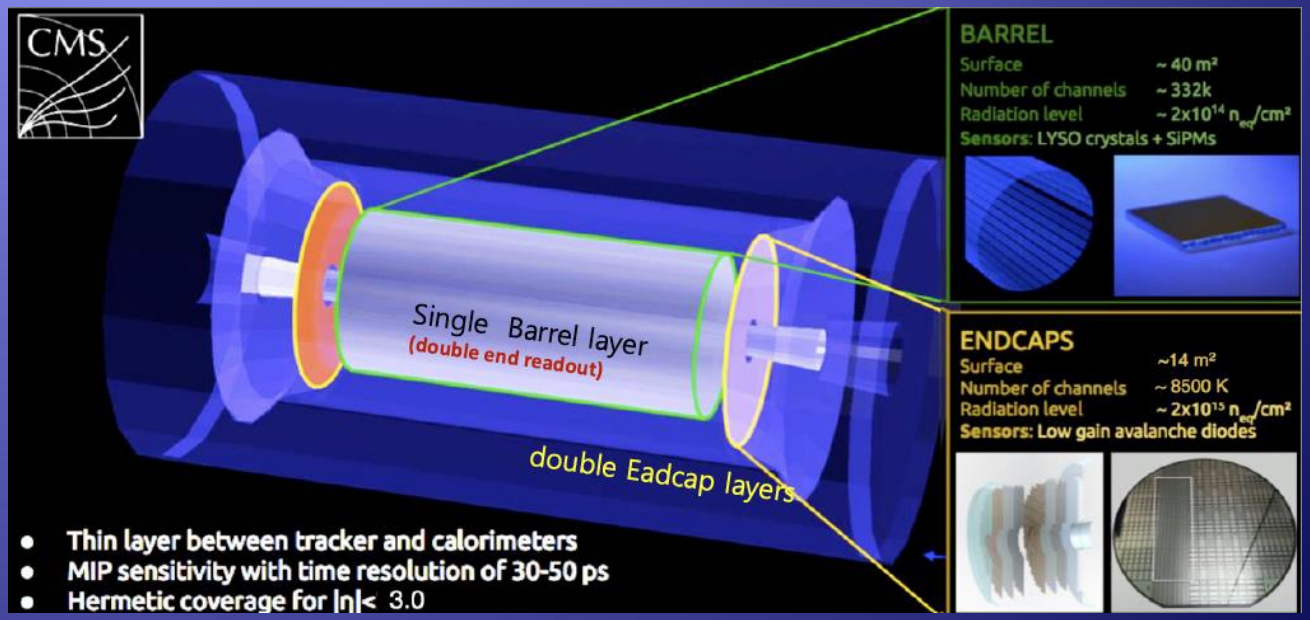
CMS Detectors by KCMS

- GEM foil & RPC gap productions for muon detectors
  - GE11, GE21, and ME0 GEM foils: to be done by 2026
  - RPC gaps for muon chambers: done
  - Detectors will be installed in 2026



MTD Detector by KCMS

- MTD (MIP Timing Detector): 30~50ps timing resolution to remove extra pp interactions
  - BTL: crystal scintillator + SiPM readout
  - ETL: silicon based sensor (LGAD)+ASIC readout (25% by KCMS)
- Beam test at CERN: 35ps timing resolution achieved
  - Built up the timing test setup, wafer postprocessing in Korea



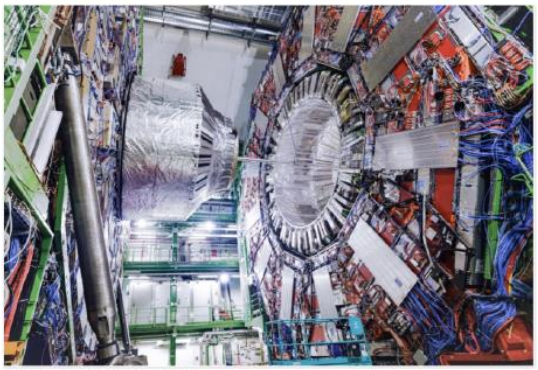
Few highlights by KCMS

CERN Press Release
EWK Mixing Angle Measurements

The CMS experiment at CERN measures a key parameter of the Standard Model

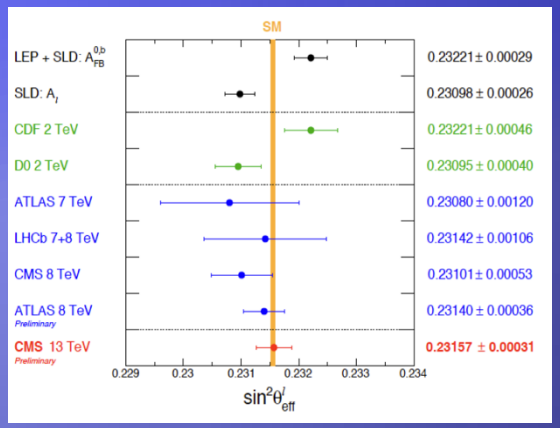
With this measurement the LHC is again demonstrating its ability to provide very high-precision measurements and bringing new insights into an old mystery

3 APRIL, 2024



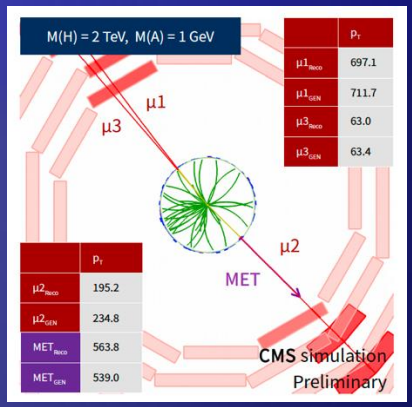
The CMS experiment (image: CERN)

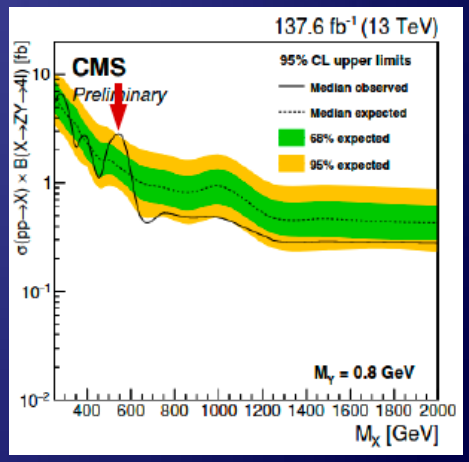
Last week, at the annual *Rencontres de Moriond* conference, the CMS collaboration presented a measurement of the effective leptonic electroweak mixing angle. The result is the most precise measurement performed at a hadron collider to date and is in good agreement with the prediction from the Standard Model.



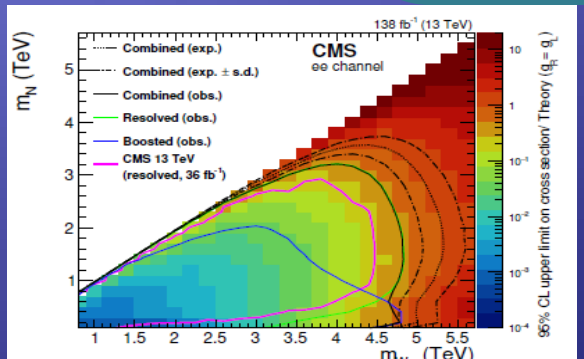
$\sin^2 \theta^{\ell} = 0.23157 \pm 0.00031$

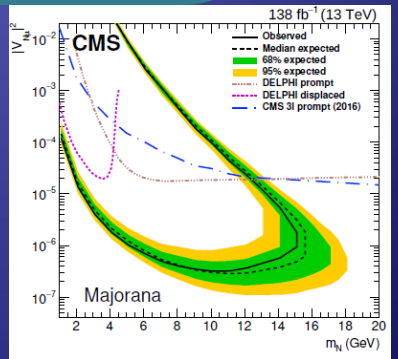
Z' searches





Heavy Neutrino Searches





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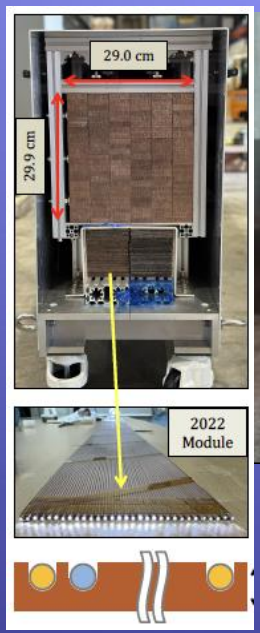
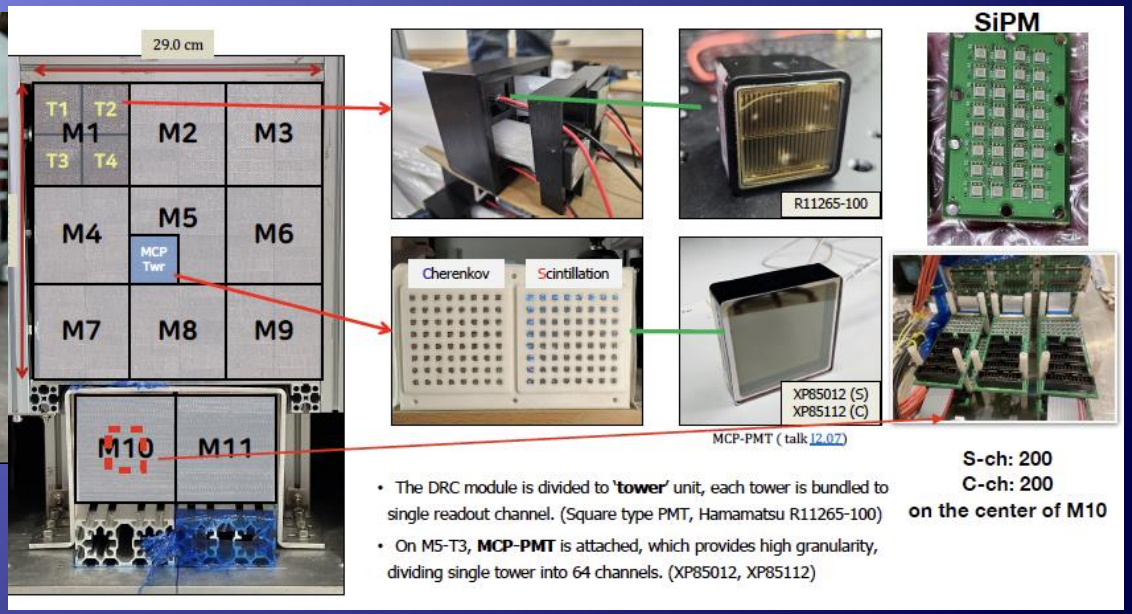
CMS-PAS-EXO-24-006

Korean activities for future colliders

- FCC: R&D of dual read-out calorimeter (DRC):
  - High-quality energy measurement of both e/g & hadrons:
    EM fraction in hadronic shower can be measured
  - Korean group (8 institutes) does all aspects of the DRC R&D
  - Module building, electronic & DAQ system, GEANT studies
  - Test-beam experiments and performance studies





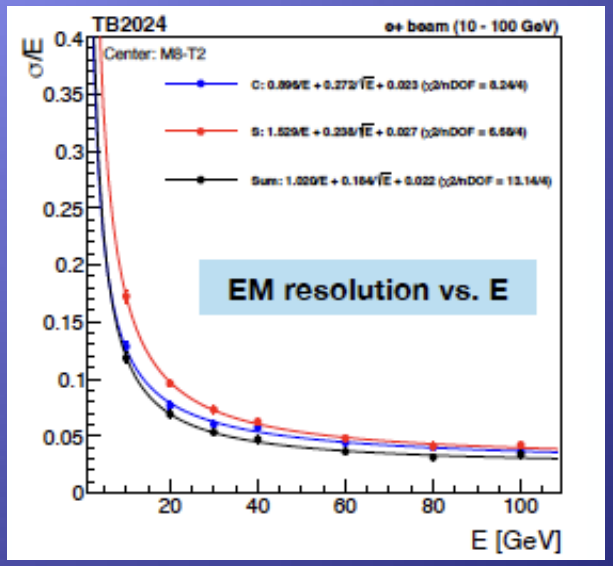
Module Building ('24)

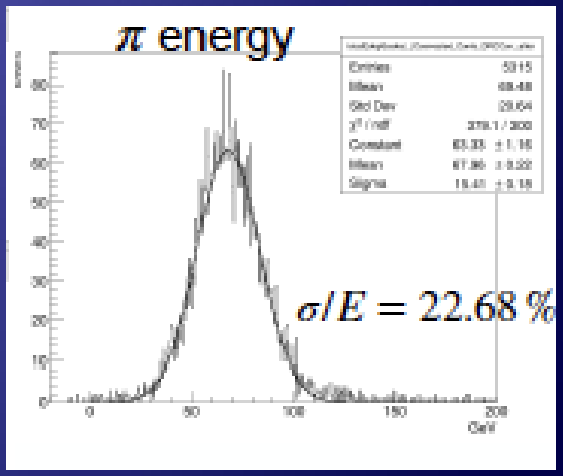
Electronics

DRC Activities at CERN

- Good results are obtained
  - EM energy resolution: σ/E ~1.020/E +0.184/sqrt(E)+0.022
  - Pion energy: σ /E ~ 22.68%

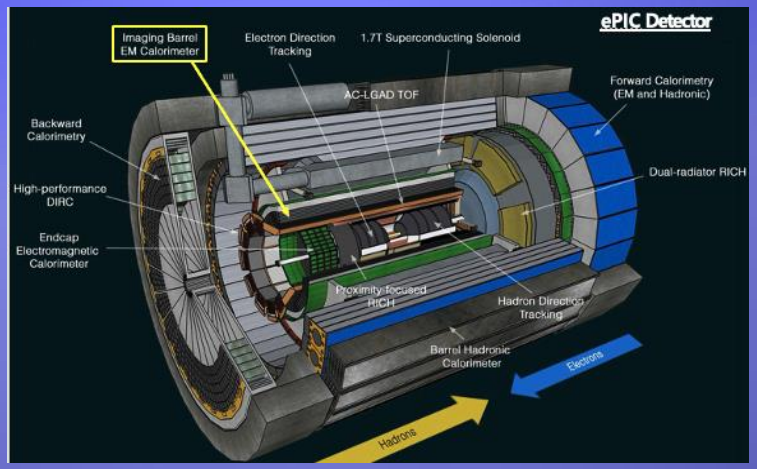
Research activities for FCC were expanded for EIC

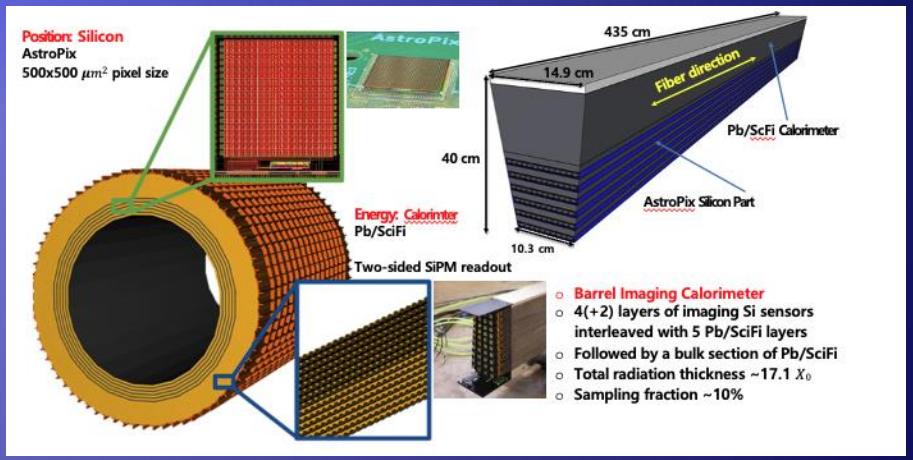




EIC activities for future colliders

- EIC: R&D of barrel imaging calorimeter (BIC)
  - Plan to contribute 50% by Korean group

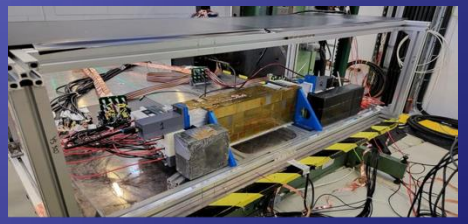


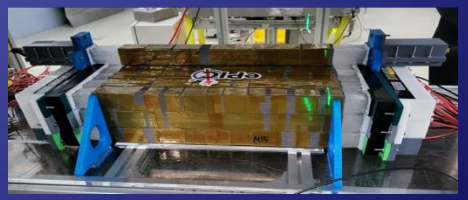


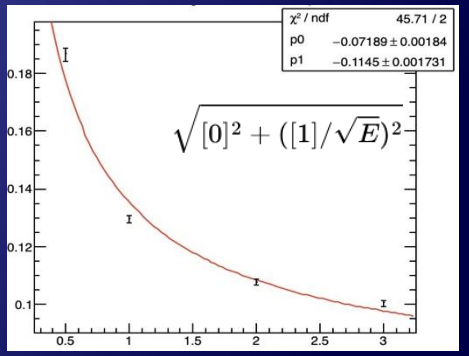
- BIC Beam Test
  - Perform beam-test for 1st prototype of BIC at CERN PS T10
  - Results:

    - Stochastic term: 11.5%

    - Constant term: 7.2%







Summary

- Korean HEP community has been working very productively for last 20 years in both domestic and international projects

- Domestic programs: focused on dark matter and neutrino physics
- International projects: focused on precision physics on the Standard Model and search for new physics at the Energy Frontier and Intensity Frontier

- Korean HEP community actively pushes for various R&D (detector, machine learning etc) in order to develop future HEP programs
  - Plan to establish a Research Cooperative Center to support international joint research activities and infrastructure facilities

HEP Collider Physics in Korea