



# KCMS Activities and Plans for CMS

**Tae Jeong Kim (Hanyang University)**  
**CERN-Korea-Committee meeting**

2024. 10. 28

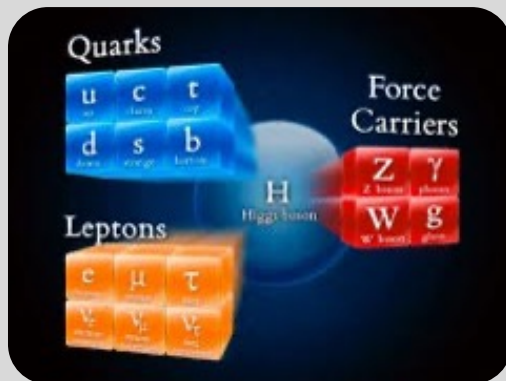
# Discovery of New Physics



## Discovery of the Higgs boson

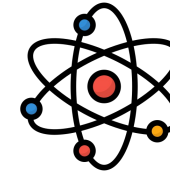
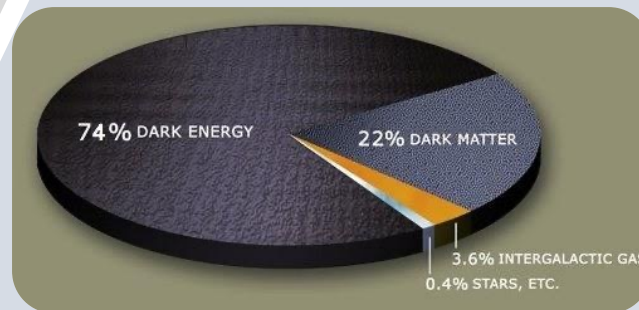
Standard model complete?

Suggest another way for new physics



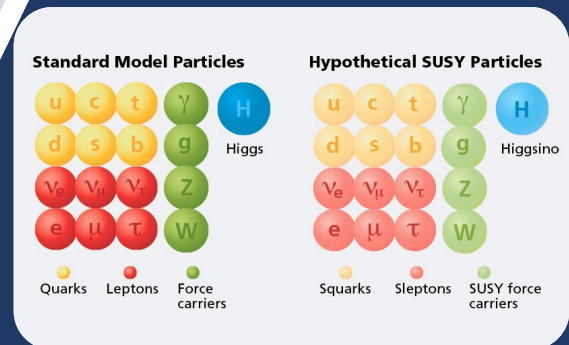
## Unsolved problems in the Standard Model (SM)

- Dark matter
- Higgs boson mass (naturalness problem)
- Matter-Antimatter asymmetry



## Searching for new physics beyond SM

- Search for Supersymmetry
- Precision measurement - Anomaly detection
- AI for big data



# Korea-CMS (KCMS) Collaboration

- 11 Institutes** : KNU (Kyungpook), KHU (Kyung Hee), KU (Korea), SNU (Seoul National), UOS (Univ. of Seoul), SKK (Sungkyunkwan), SJU (Sejong), YU (Yonsei), CNU (Chonnam), HYU (Hanyang), GWNWU (Gangneung-Wonju)

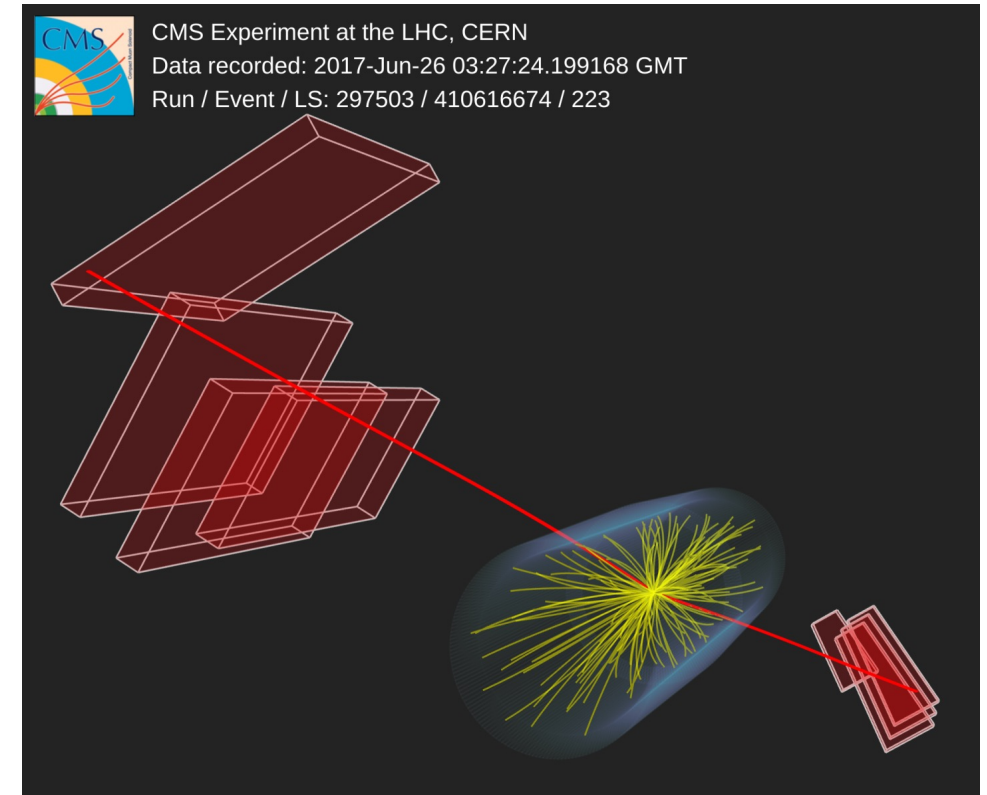
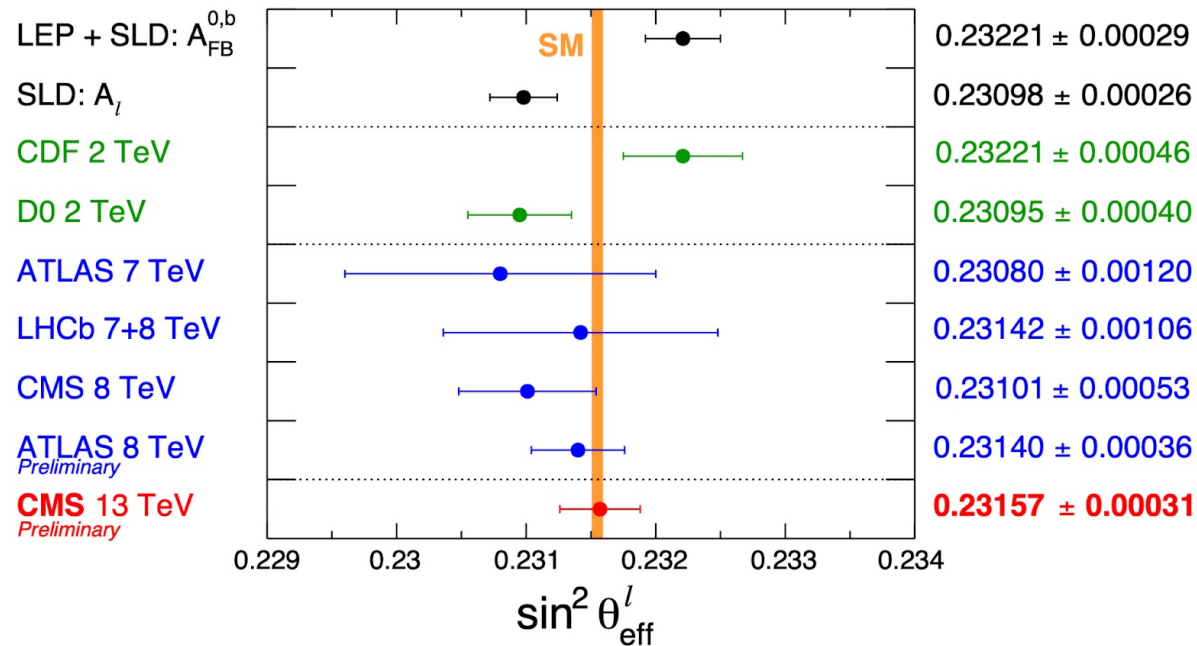
Stage	year	M&O-A	Prof.	Postdoc	Grad. students	Tech. staff	Total
4	2016	32	15	20	46	5	86
5	2021	36	17	23	73	9	122
6	2022	36	17	27	68	8	120
6	2023	35	15	23	72	8	118
6	2024	34	16	22	72	11	121



- Around 2.4% of total CMS collaboration – **10<sup>th</sup> largest**

# KCMS 2024 physics highlights

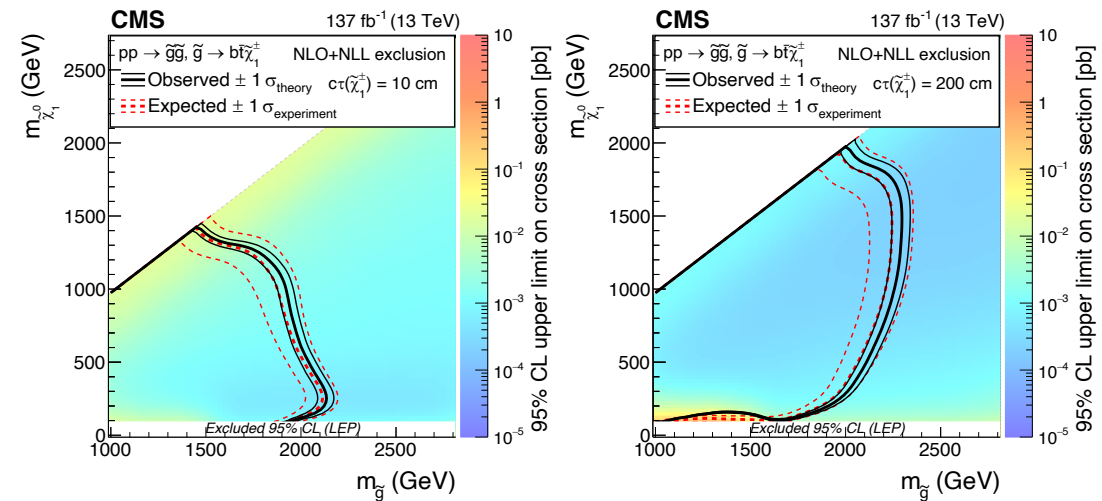
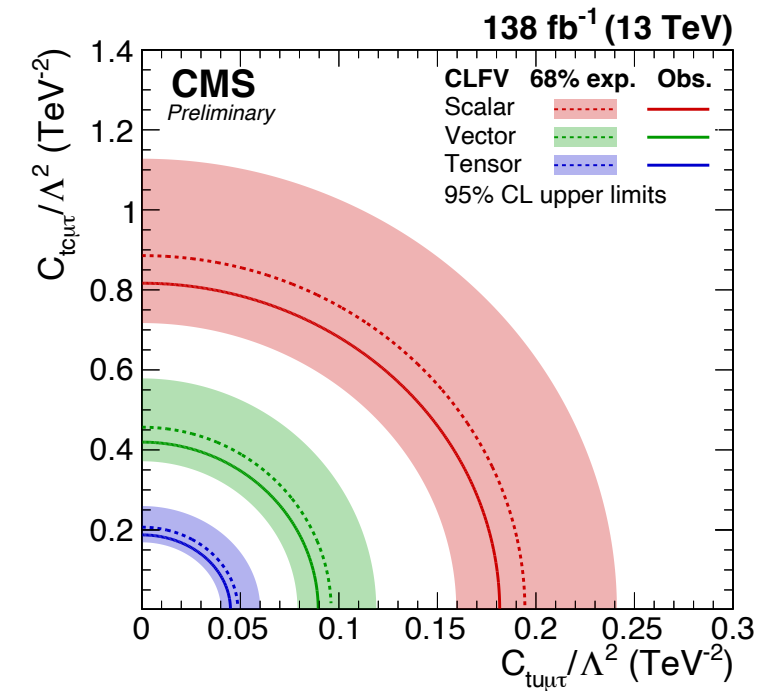
- The most precise measurement on the weak mixing angle from the CMS experiment (SMP-22-010)
- Using the events where a Z boson decays to a pair of leptons using the forward-backward asymmetry of these two leptons



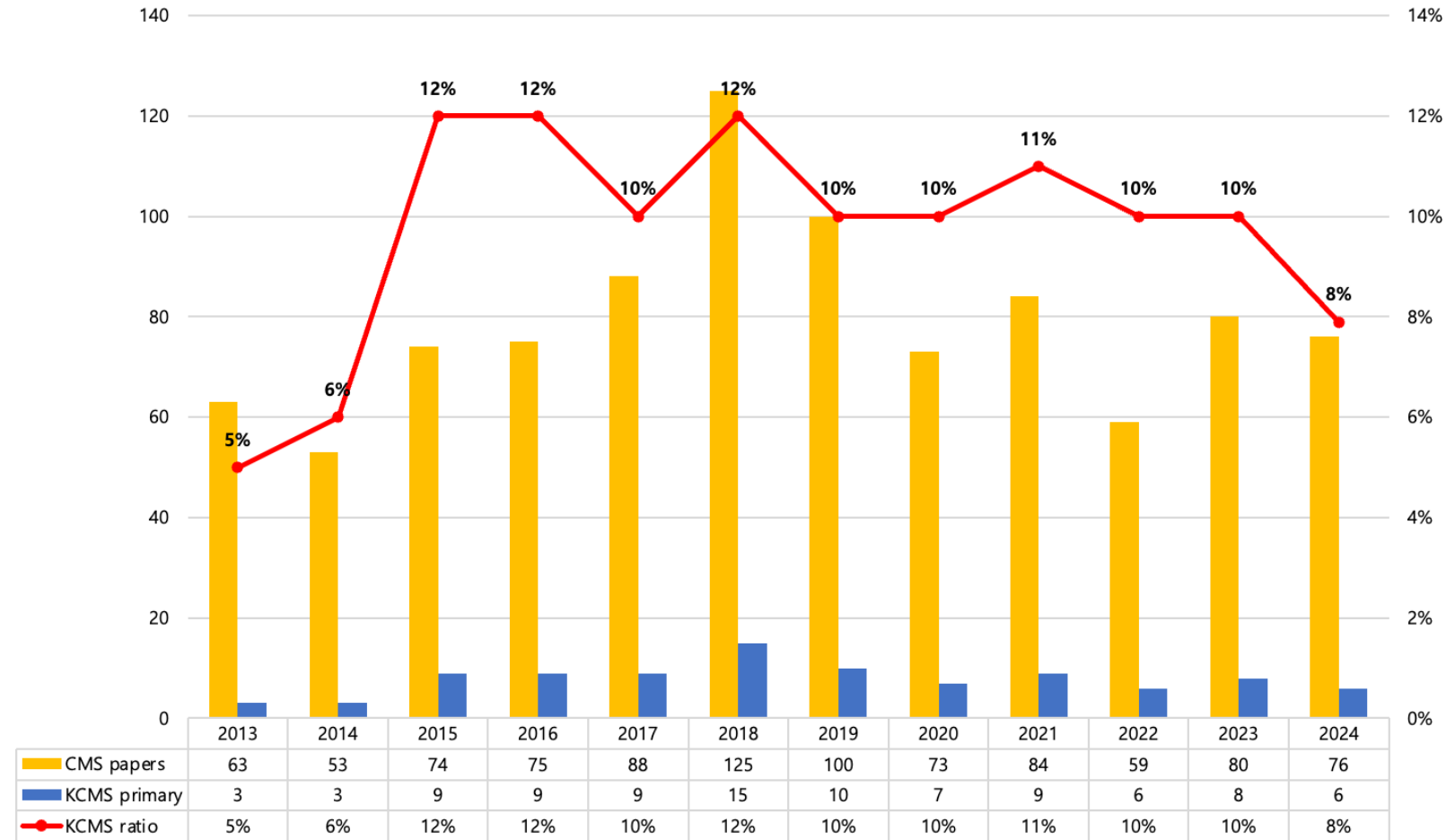
- This analysis was performed by the KCMS members (Prof. Unki Yang, PhD students Won Jun, Hyon-San Seo)

# KCMS 2024 physics highlights

- Search for Lepton Flavor Violation in top quark sector with the final state of tau
- Preliminary results (TOP-22-011)
- Ece Asilar, Yeonsu Ryu, Prof. Taejeong Kim
- Search for supersymmetry with disappearing tracks at 13 TeV
- PRD 109, 072007 (2024) (SUS-21-006)
- Sezen Sekmen, Sang-il Park, Prof. Sehwook Lee



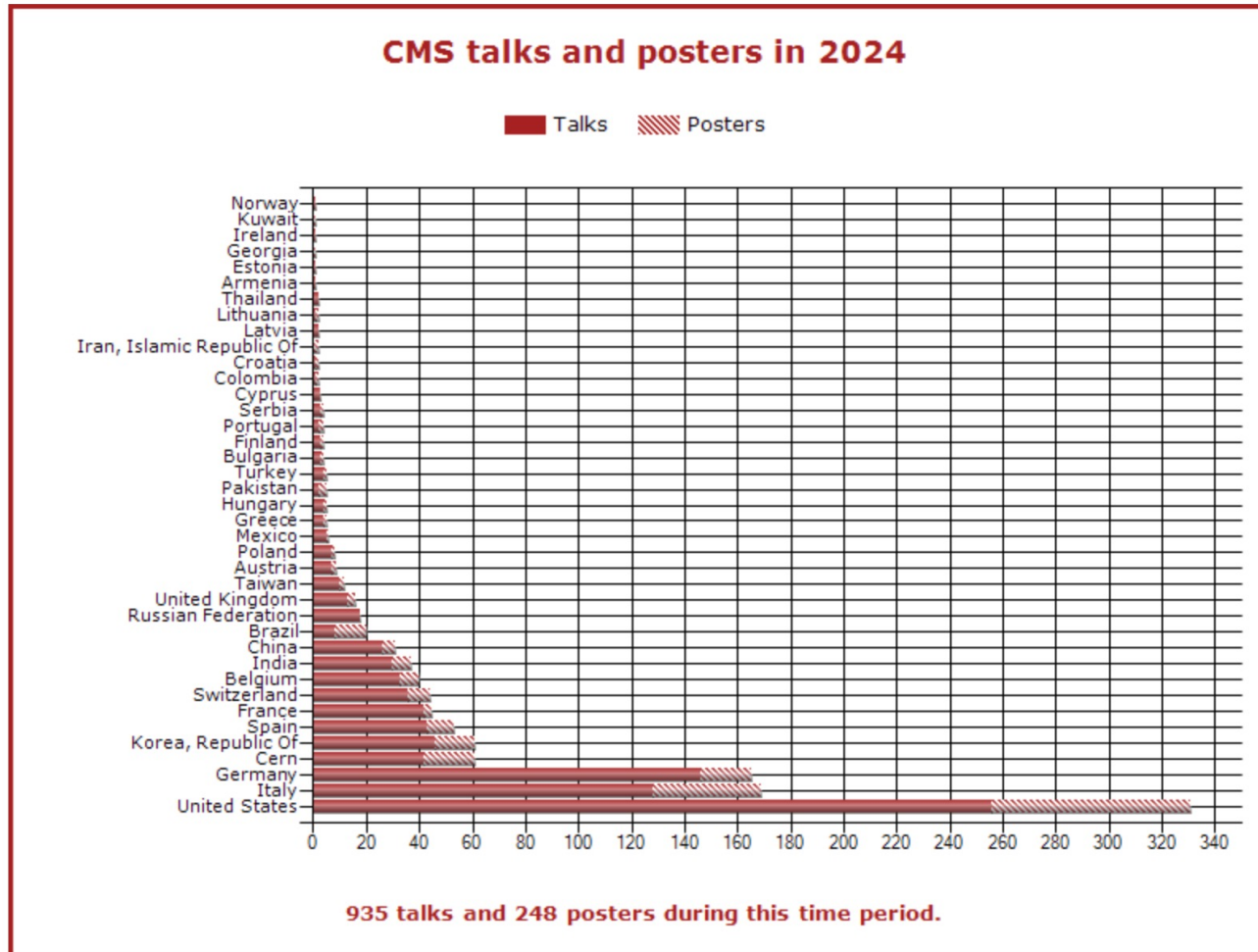
# KCMS Papers



- CMS papers with primary authorship by KCMS
- We expect the similar rate in 2024

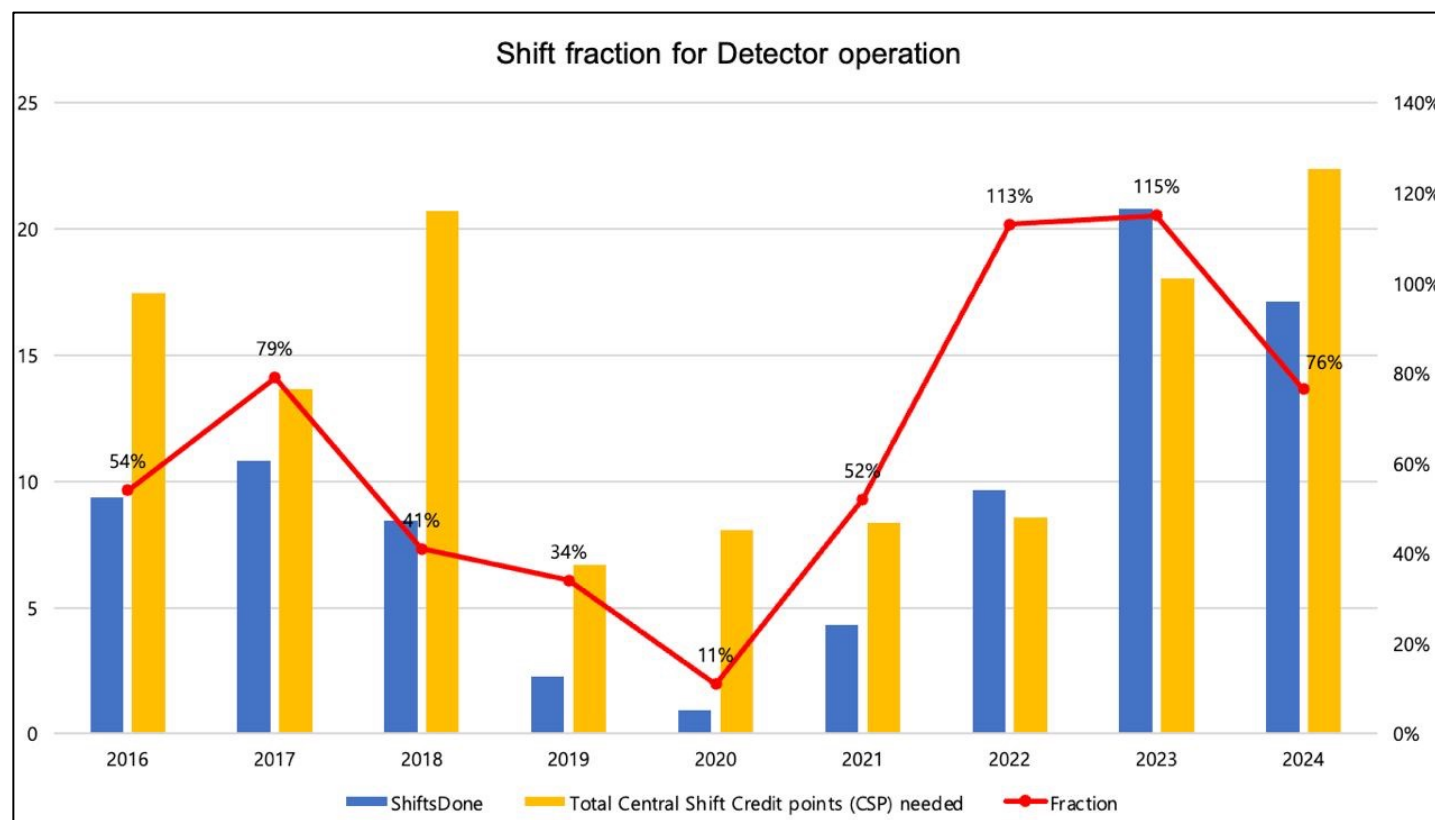
# Conference talks

- 5<sup>th</sup> rank in 2024
  - International conference – 18 talks
  - National conference – 43 talks



# Detector operations (%)

- **More students and postdocs are stationed at CERN**
  - Long term stay (> 1 year) : One faculty member, 3 postdocs, 3 students
  - Short term stay : 5 students as of now
- **Monitoring the rate for shift “done/needed” (still heavy-ion running)**





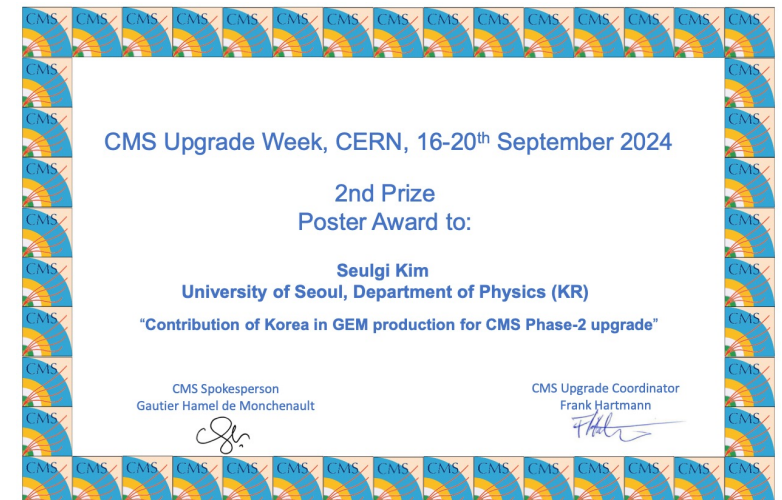
# KCMS 2024 leadership

- **Core leadership position**
  - **Tae Jeong Kim : Deputy of Muon system manger (L1)**
  - **Sezen Sekmen : SUSY group convener (L2)**
  - **Suhwan Lee : Field Operation Group convener (L2)**
- **Many postdocs and students playing a leading role in each physics or detector groups as coordinators and contact persons**

Name	Position	CMS leadership	Period
Tae Jeong Kim	Faculty	Muon SM deputy (L1)	2023.9~
Soohwan Lee	Student	FOG (Field Operations Group) (L2)	2024.9~
Sezen Sekmen	Postdoc	SUSY group convener (L2)	2024.9~
Kyuyeong Hwang	Student	Muon HLT convener (L3)	2024.9~
Won Jun	Student	Muon HLT convener (L3)	2022.9~
Junbin Lee	Student	GEN MC Validation convener (L3)	2022.9~
Jin Choi	Student	GEN MC & Interpretation convener(L3)	2022.9~
Junghwan Goh	Faculty	RPC DPG Coordinator (L2)	2017.5~
Ian Watson	Postdoc	GEM DPG Deputy Coordinator (L2)	2023.9~
Seulgi Kim	Student	GEM production convener (L2)	2023.3~
Jerime Merlin	Postdoc	GEM production coordinator (L2)	2021.6~
Ece Asilar	Postdoc	RPC technical coordinator (L2)	2022.9~
Seungkyu Ha	Postdoc	JME contact for Top PAG (L3)	2022.9~
Jieun Choi	Student	B2G HLT contact (L3)	2023.9~
Sanghyun Goh	Student	EXO high-Et electron contact (L3)	2022.9~
Changgi Huh	Student	SUSY JME contact (L3)	2023.3~

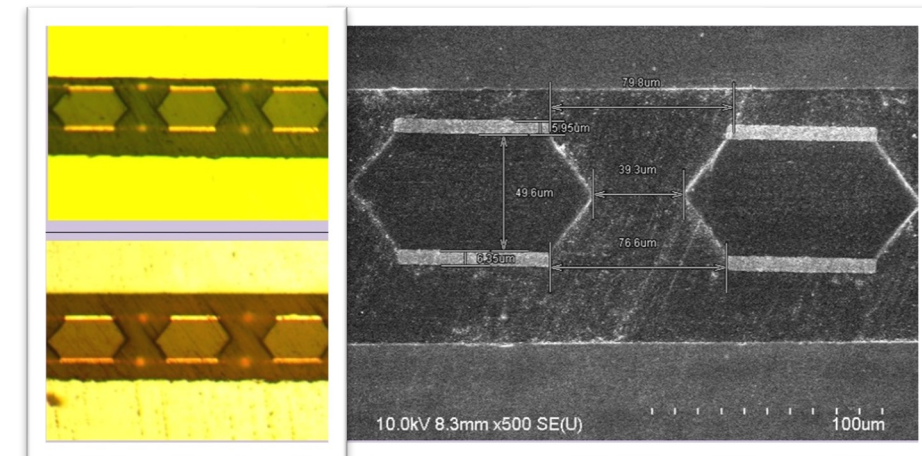
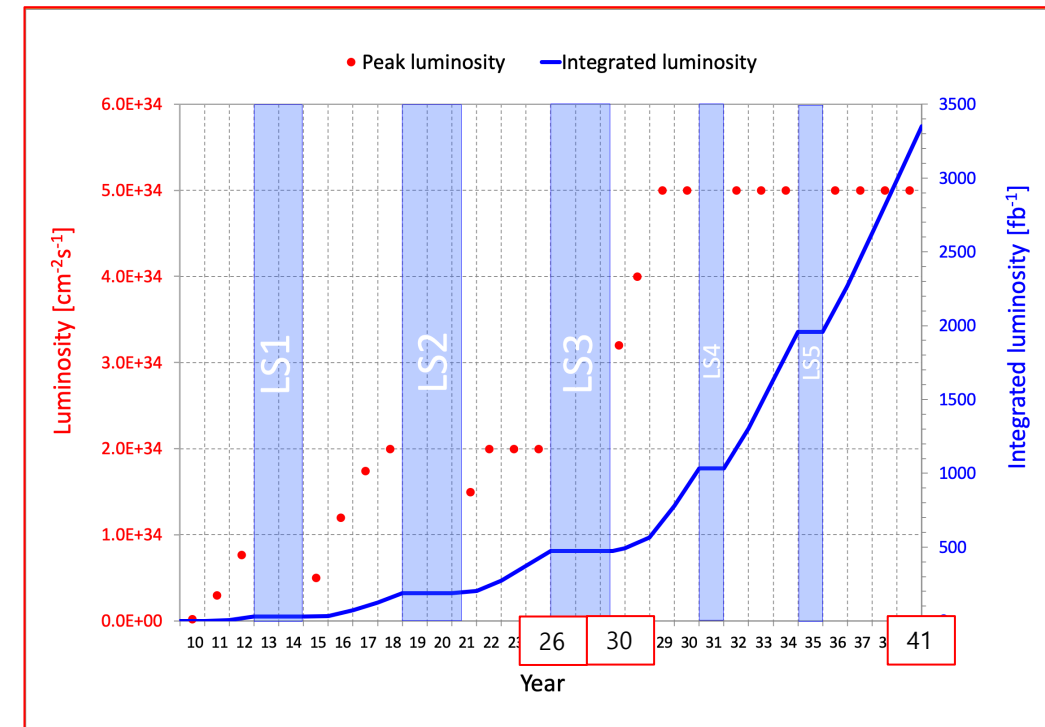
# KCMS 2024 Achievement

- **PhD certificates of 10**
  - moved to U. of Florida (Bobae Kim), Antwerp University (Hyejin Kwon), Argonne Natl. Lab (Changgi Huh) and KCMS as postdoc and also to industry
- **Won Jun: CMS award during CMS week in June**
  - *For his outstanding contributions to Muon HLT performance studies and online operations*
- **Seulgi Kim: 2<sup>nd</sup> Prize Poster award, CMS upgrade week, 16-20<sup>th</sup> Sep. 2024**
  - *Contribution of Korea in GEM production for CMS Phase-2 upgrade*



# Phase 2 upgrade contributions

- **GEM11: 592 kCHF (complete)**
- **GE21, ME0 (2024~2026): 2.262 MCHF**
  - 456(GE21), 666(ME0) foils:2064kCHF
  - Glass mask (5 pairs):198kCHF
- **iRPC Upgrade: 400 kCHF (complete)**
  - RPC GAP: 286 kCHF (in-kind)
  - Shipping + chamber components (114kCHF)
- **Common Fund (MoU)**
  - 729 kCHF (2018-2026)
- **MTD upgrade: 2.2 MCHF (MoU:done)**
  - LGAD sensor and Bumpbonding, etc.
- **Total contribution with MTD on the Phase 2: ~6.2 MCHF**



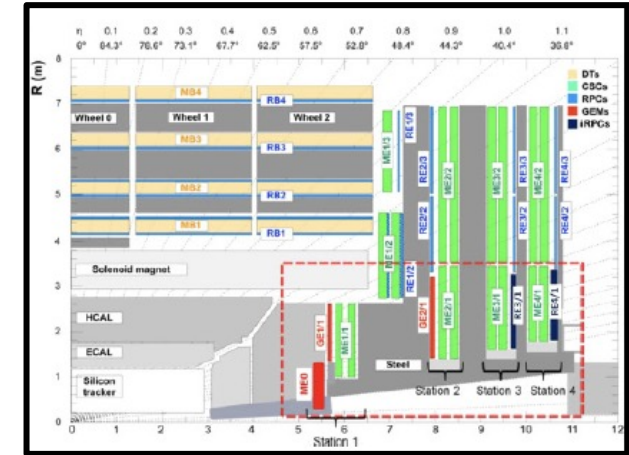
# RPC (Resistive Plate Chamber)

- **RPC MoU completed**

- As of 2024 July, total of 250 RPC gaps (RE3/1, RE4/1) have been shipped to CERN
- 220 RPC passed the final QC at CERN
- 10 gaps not passed QC during shipping and 20 due to high current during long term high voltage test → plan to repair

- **Future plan**

- KODEL (Korea Detector Lab) will be moved to another institute
- Will try to maintain the RPC facility
- Can also be used for muon detector R&D (e.g. DRD1 collaboration)



Gaps at 904 from Korea

# GEM (Gas Electron Multiplier)

- **GEM Foil Production**

- At CERN MPT workshop, 124 GEM foils were produced
- At IBS GEM facility, by Oct in 2024, 350 GEM foils were produced
- Among them, 204 foils have passed the QC and shipped to CERN
- Total of 328 GEM foils are ready for installation (total of 666 foils are needed by 2025)

- **GEM Foil production future plan**

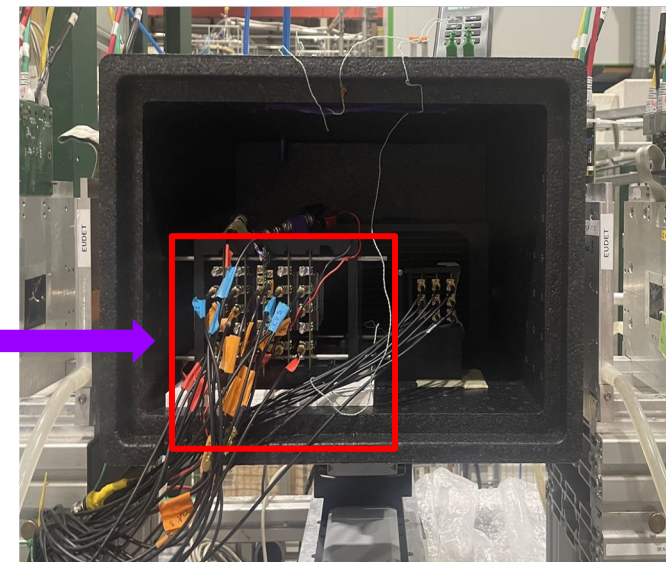
- By the end of 2025, we will complete ME0 GEM Foil
- GEM ME0 will start to be installed in 2026
- Will use the facility @ IBS for the future R&D



# MTD (MIP Timing Detector)

Dark box chilled to 15 °C

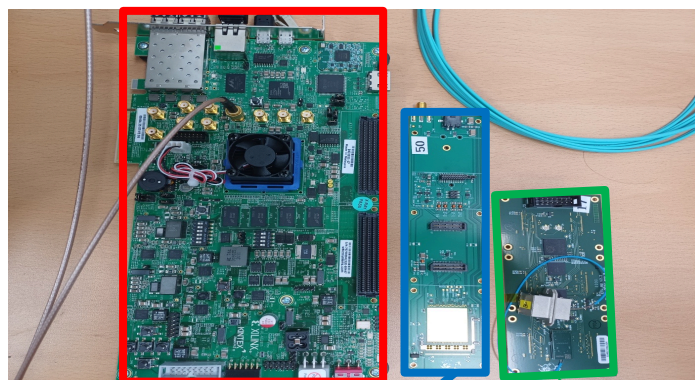
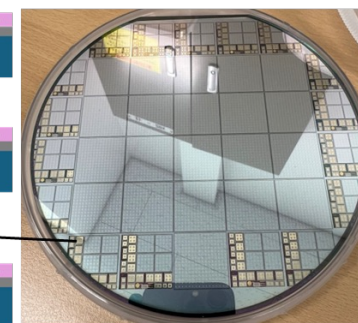
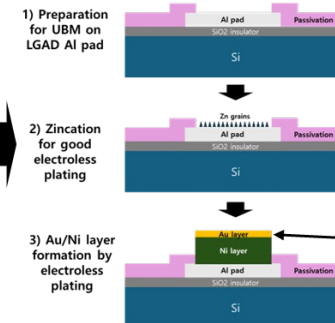
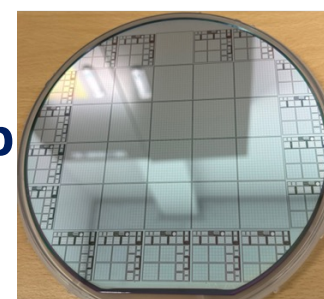
- **Beam test at SPS H6 was done**
  - Reached 35 ps timing resolution for LGAD sensor post-processed in Korea
- **Built up the timing test setup in Korea**
  - Measure the timing resolution
  - ETL module v1 and v2 will be test there
- **R&D for wafer postprocessing in Korea** →
- **Bump-bonding performance test with dummy chip**



120 GeV pion beam

LGAD wafer fabricated from foundry company

1) UBM process using electroless plating

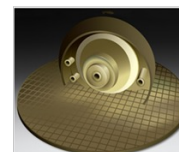


FPGA

Module v0b

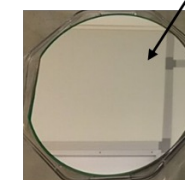
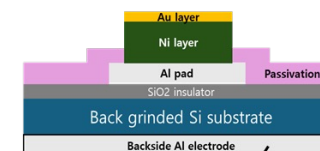
Readout Board v2.2

4) LGAD wafer dicing

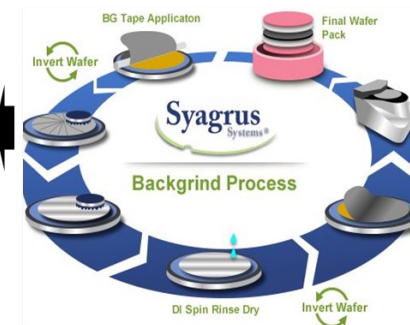


[Diced wafer]

3) Al metallization on LGAD backside



2) Wafer back-grinding for wafer thinning



# Outreach & workshop in 2024



Top-Higgs mini-workshop,  
May 29

## Interview with journalists



5th KCMS workshop@RAON, June 19~21



Journalist from Donga Science visiting P5

# Quantum Entanglement in High Energy Physics

@Hanyang Univ.

## KPS Pioneer session - Discovery of quantum entanglement in High Energy Physics

Thursday 24 Oct 2024, 14:24 → 18:10 Asia/Seoul

Oct 24 in Korea, last week!

Seminar Rm 1 (Yeosu Expo Convention Center)

Junghwan Goh (Kyung Hee University (KR)), Seodong Shin (Jeonbuk National University), Tae Jeong Kim (Hanyang University (KR))

**Description** Recently the quantum entanglement was discovered between pairs of top quarks for the first time by the ATLAS and CMS collaborations at the Large Hadron Collider (LHC). The top quark pairs are produced at the center of mass energy of 13 TeV which is more than 12 orders of magnitude higher than typical energy for laboratory entanglement experiments. This discovery shows the quantum entanglement can also occur at the high energy scale and the LHC can also be used to study quantum mechanics and quantum information. We will discuss this discovery of quantum entanglement in high energy physics in this pioneer session.

### 16:25 → 17:05 Entangled in Tops: How we turned ATLAS into the world's largest quantum information experiment

40m

A new sub-field has exploded onto the particle physics scene: testing fundamental features of quantum mechanics in collider experiments. A prominent initial result is the ATLAS Collaboration's observation of quantum entanglement between top-quark pairs, the first measurement of entanglement between free quarks, and the highest energy lab-based quantum information experiment to date. Entanglement between top-quark pairs is shown to be observable through measurement of a single angular observable. This talk shall discuss the motivation for using ATLAS as a quantum information experiment, and the experimental challenges and ultimate result of the ATLAS measurement. Shortcomings in current simulation tools and future ATLAS prospects will also be discussed, and attention given to the similarities and differences between recent CMS observations of the same phenomenon.

**Speaker:** Ethan Lewis Simpson (The University of Manchester (GB))

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### 17:15 → 17:55 Quantum Entanglement discovery in top quark events and perspectives into future colliders

40m

In quantum mechanics, a system is said to be entangled if its quantum state cannot be described as a simple superposition of the states of its constituents. If two particles are entangled, we cannot describe one of them independently of the other, even if the particles are separated by a very large distance. When we measure the quantum state of one of the two particles, we instantly know the state of the other. The information is not transmitted via any physical channel; it is encoded in the correlated two-particle system. The talk will discuss CMS results in the top quark production region with data provided by the Large Hadron Collider (LHC) at CERN. Results confirm the observation of entanglement in top quark events, even in presence of hypothetical top quark bound states, and providing a new quantum probe to the inner workings of the Standard Model. The talk concludes with an outlook on LHC perspectives into the 2040's and prospects at other proposed future colliders.

**Speaker:** Andreas Werner Jung (Purdue University (US))

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# International conference and workshops in Korea, 2025

- **18<sup>th</sup> International workshop on top quark physics**
  - **September 22-26, 2025**
  - **30 years after the top quark discovery (1995)**
  
- **Remote CMS week**
  - **December 1-5, 2025**
  - **For the first time, the whole CMS collaboration will come to Korea**

## 03 Conference Venue

**Venue** ▶ Hanyang University (Seoul)

- Conference room for 300 people (enough space with table)



Subway station line number 2

- There is a subway station (**Hanyang Univ. Station, green line number 2**) inside campus
- Lunch will be provided right next to the conference room

## CMS WEEK 2025 @ SEOUL ?



*After Run 3 operation,  
You can share excitement from  
Run 3 data in Korea!  
And make closer collaboration!*



# Thank you

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