



# 한국-CMS (KCMS) 실험 사업팀

김태정 (한양대)

제 1회 고에너지물리학회 학술대회@부산대학교

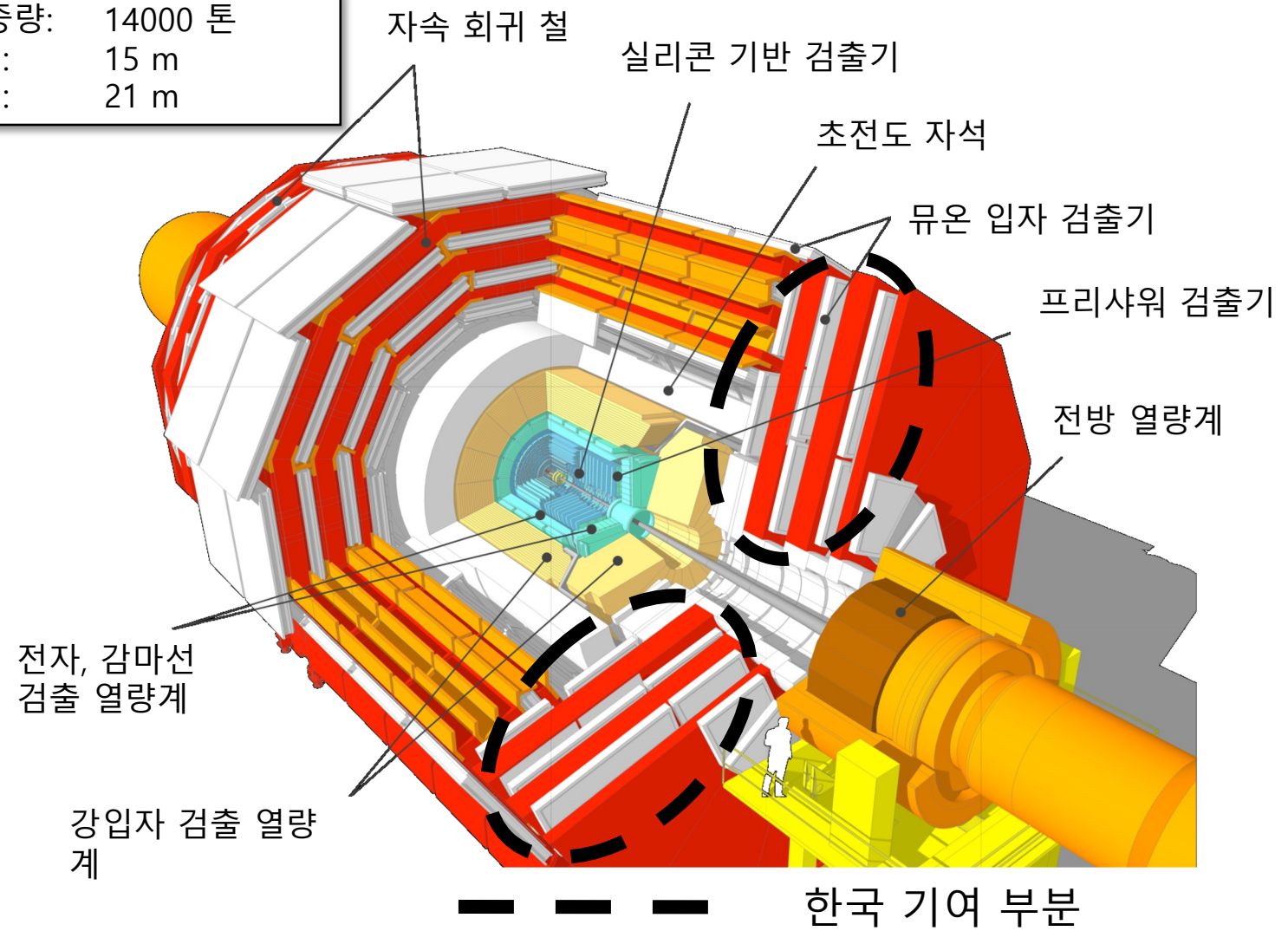
2022. 11. 18.

# CMS 실험 개요

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# CMS 검출기

총 중량: 14000 톤  
높이: 15 m  
길이: 21 m



# CMS 실험

- 55개국, 239개 연구기관 참여
- CMS 실험 건설 비용: 약 700 MCHF (8천5백억원)
- 주요 성과: 힉스 입자 발견, 논문 1000편 이상

총 5000명  
한국: 122명 (2.4%)



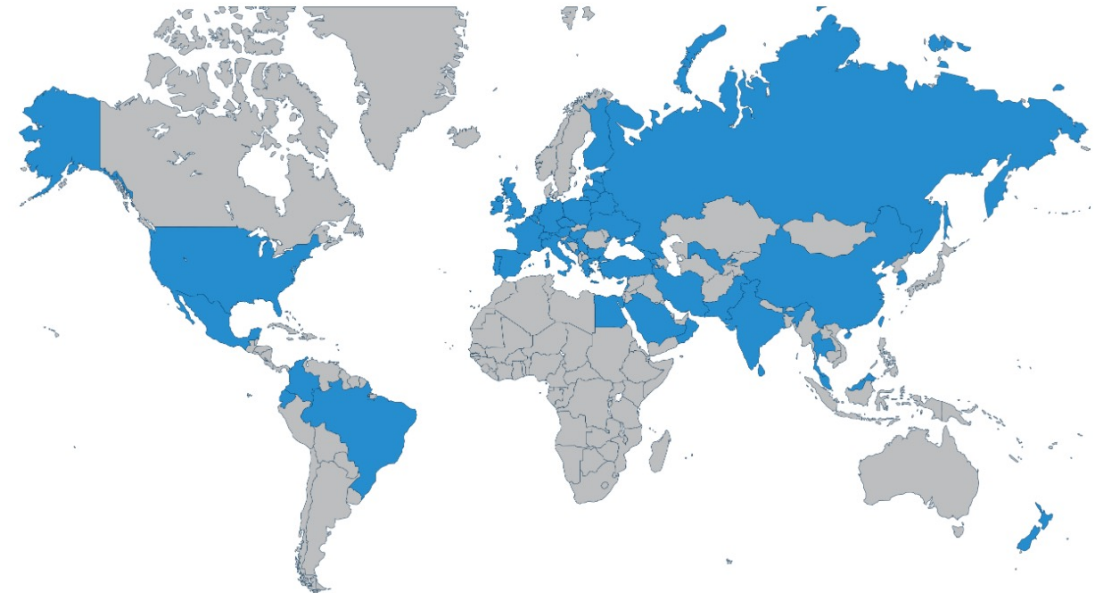
2942  
PHYSICISTS  
(1036 STUDENTS)

1065  
ENGINEERS

281  
TECHNICIANS

229  
INSTITUTES

51  
COUNTRIES &  
REGIONS



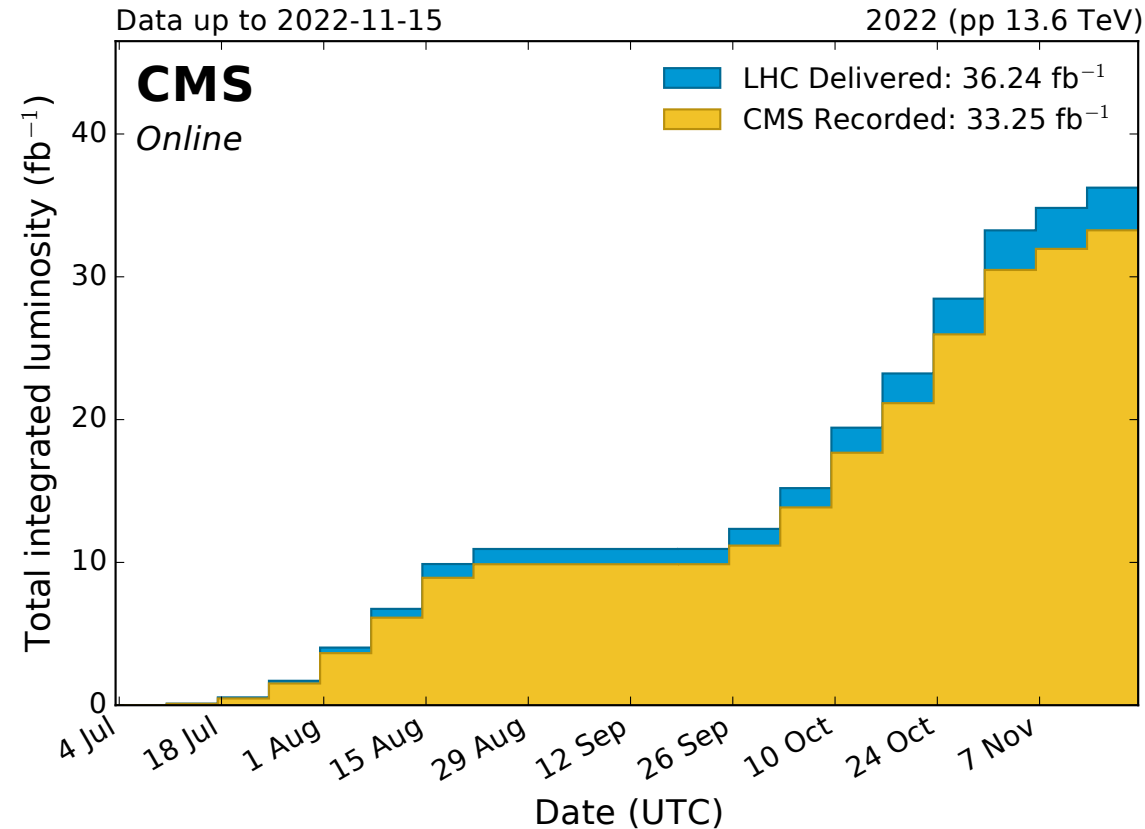
# CMS status

- 2022년 7월 18일 Run 3 Physics Run 시작
  - 2025년까지 운영 예정
- 양성자 충돌 에너지는 13 TeV 에서 13.6 TeV 로 증가
- Run 3에서 총 300 fb<sup>-1</sup> 해당하는 데이터 생산 예정



# Run 3 status

- 현재 예상보다는 작은  $34 \text{ fb}^{-1}$  정도의 데이터 획득
- 초기 데이터를 이용하여 데이터 분석이 진행되고 있고
- 대부분의 경우 새로운 충돌 에너지에서 cross section 측정 위주



# 한국 CMS 실험팀

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# 한국의 CMS 참여

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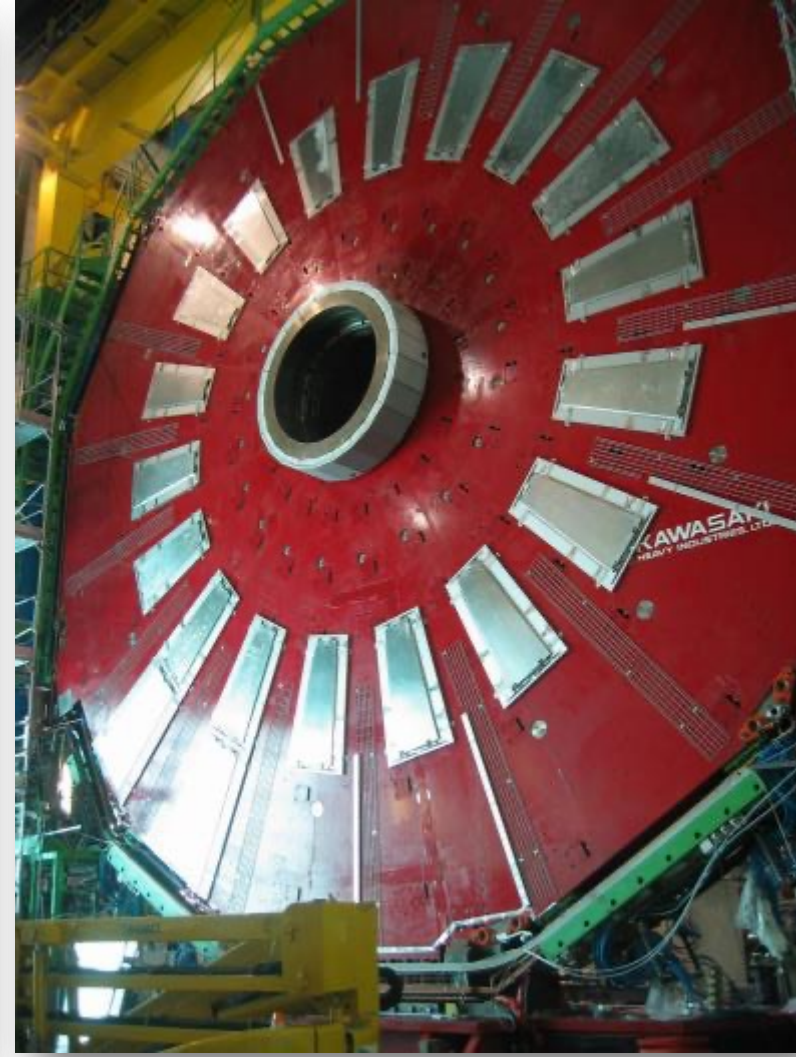
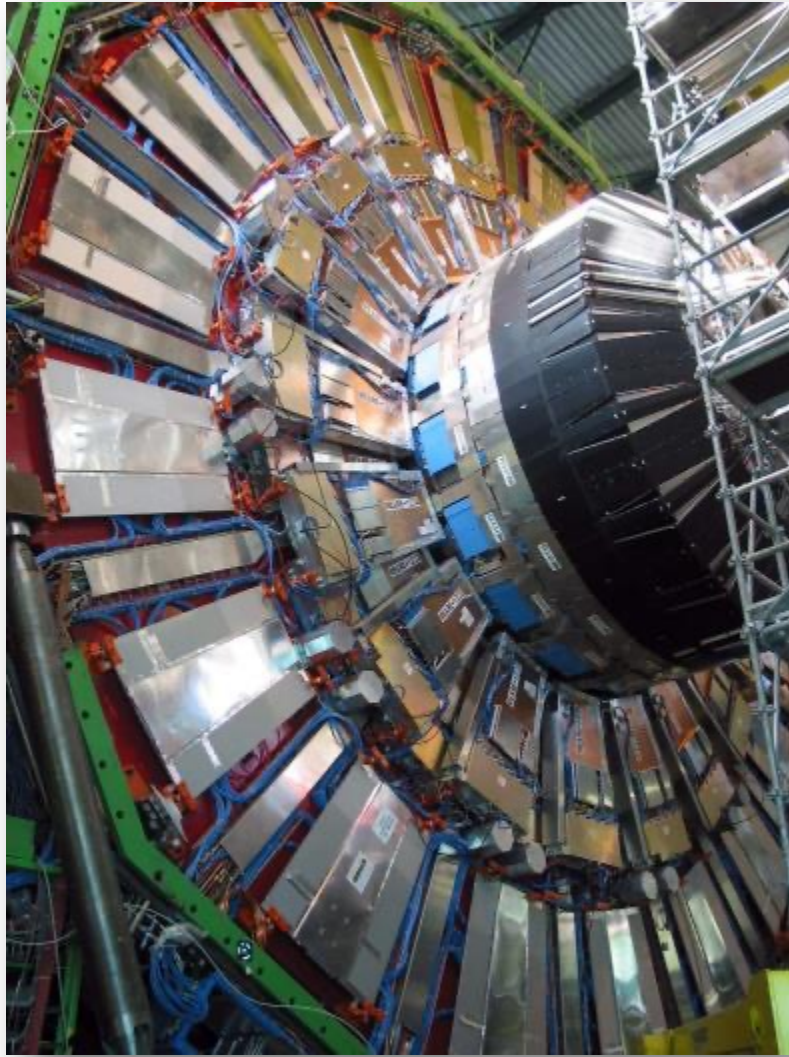
- 1998-2011년까지 한국은 CMS검출기 제작에 총 20억원을 현금/현물로 지원 (총 건설비 대비 약 0.23%)
  - 초전도자석의 테이블
  - 전방 뮤온 검출기 중 RPC 제작
  - DAQ시스템 건설에 공헌



# 1998-2006 : 자석 회전 장치

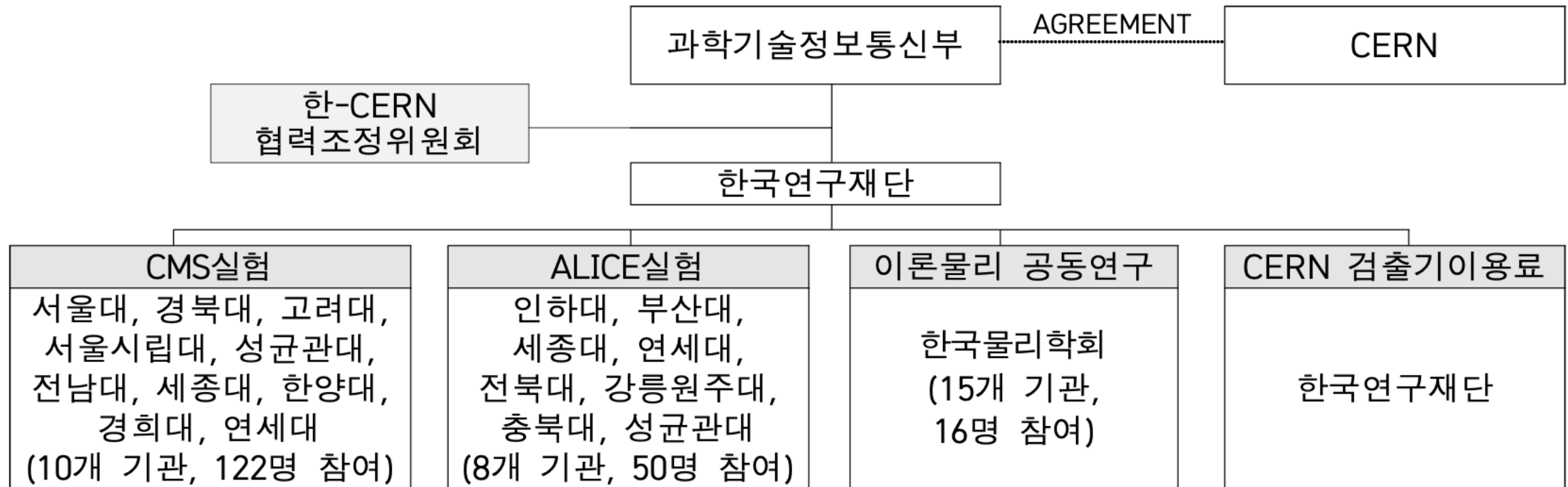


# 1998-2006 : 전방 뮤온 RPC 검출기



# Korea-CERN Program

- 2006 : CERN-Korea Collaboration Agreement



# 한국-CMS (KCMS) 실험팀

- 10개 대학

경북대, 경희대, 고려대, 서울대, 서울시립대, 성균관대, 세종대, 연세대, 전남대, 한양대

단계	연도	총 예산 (억원)	교수	연구원	대학원생	기술, 행정	총 인원
3	2013	22.0	13	18	36	10	77
4	2016	22.5	15	20	46	5	86
5	2021	30.6	17	23	73	9	122
6	2022	33.4	17	27	68	8	120



- 전체 CMS 인원에서 약 2.4% 정도의 규모 – 10번째로 큰 규모

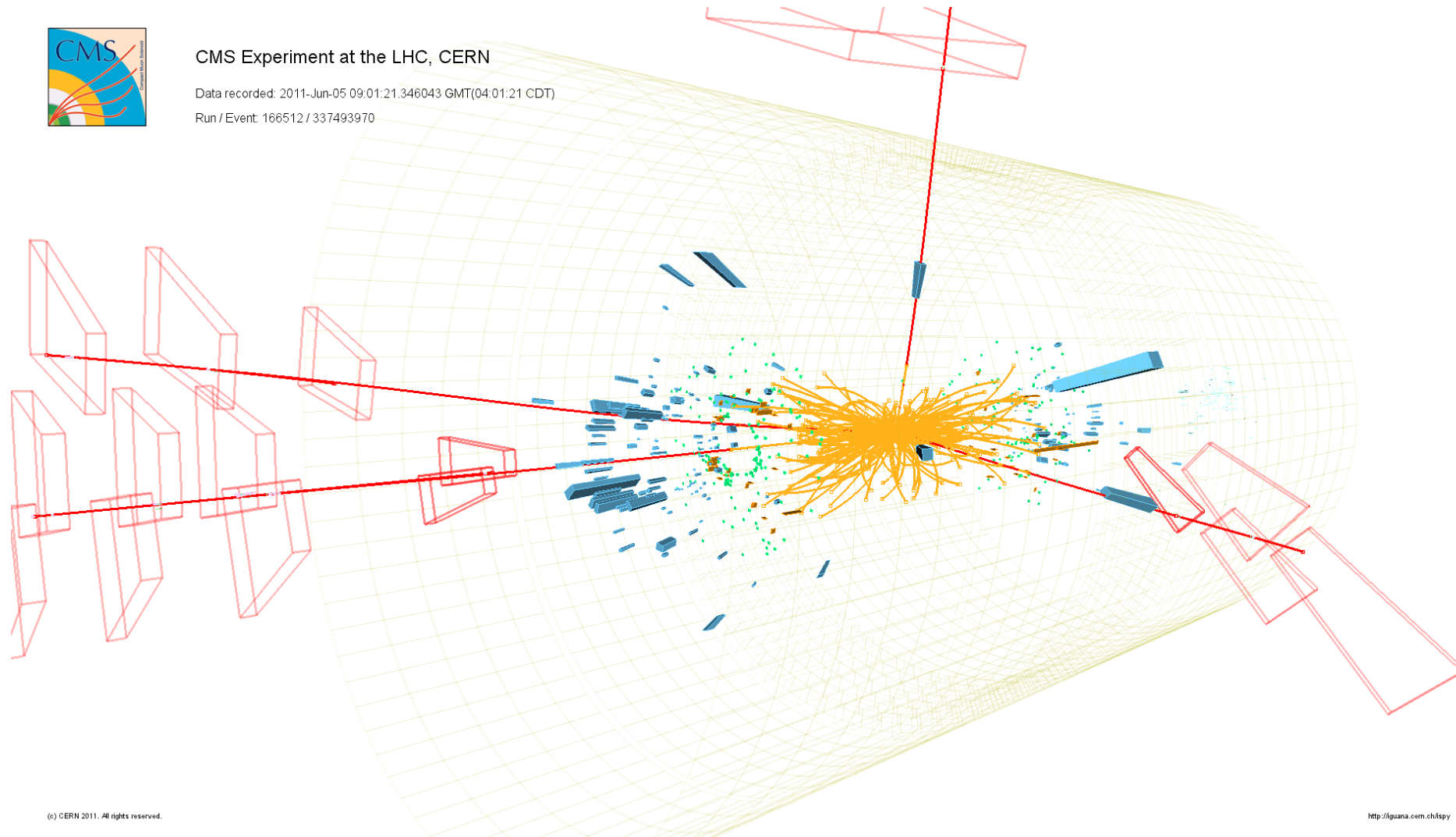
# 힉스 생성 (2012)



CMS Experiment at the LHC, CERN

Data recorded: 2011-Jun-05 09:01:21.346043 GMT(04:01:21 CDT)

Run / Event: 166512 / 337493970



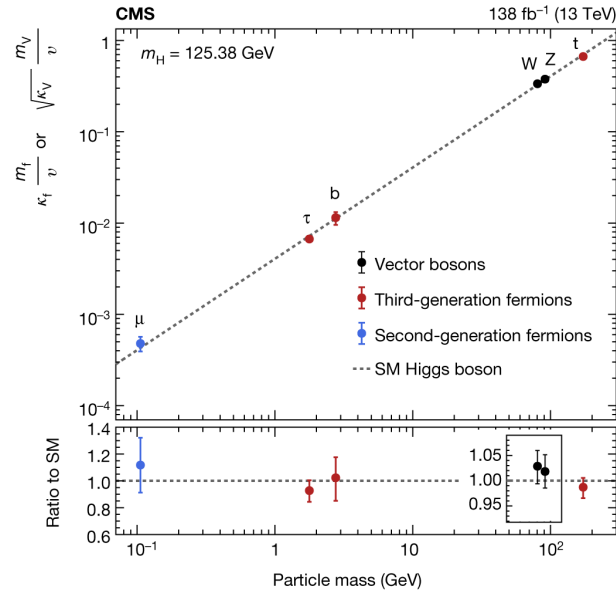
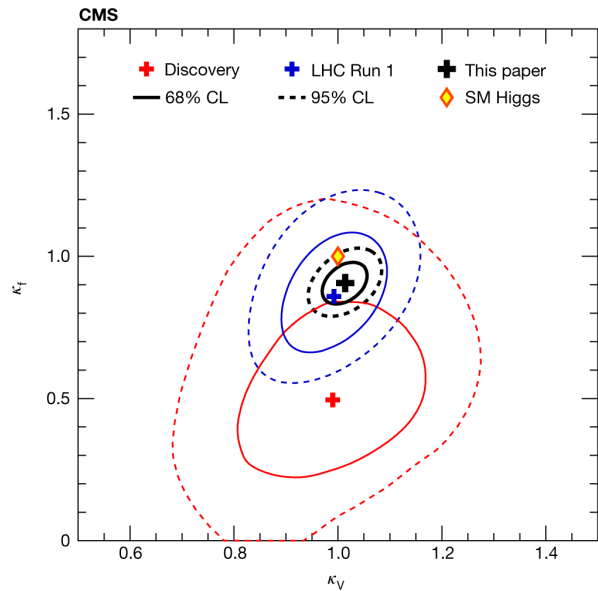
(c) CERN 2011. All rights reserved.

<http://iguanacms.ch/ispv>

우리나라가 만든 검출기에서 발견된 뮤온 입자

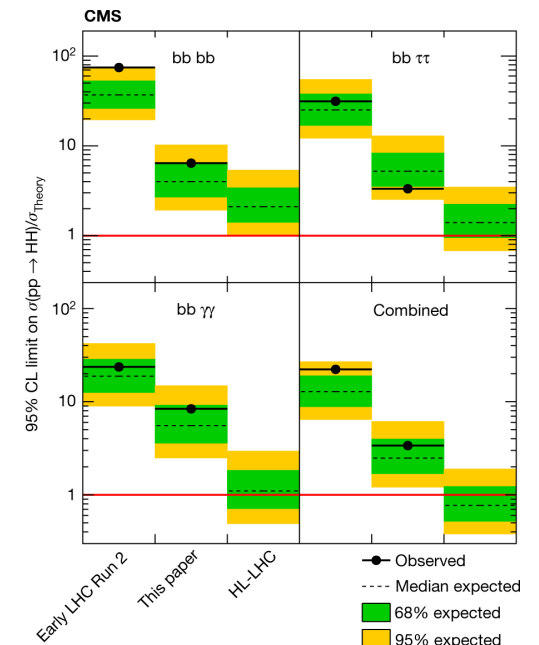
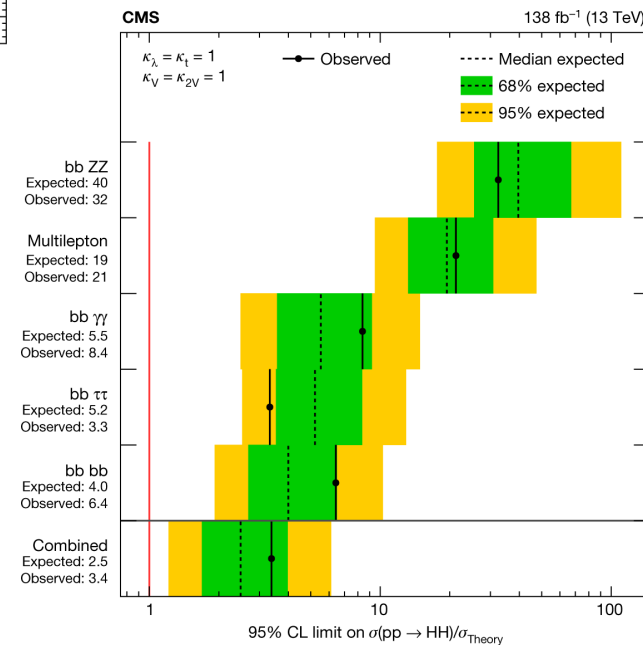
# 10 years after Higgs discovery

Nature volume 607, pages60–68 (2022)



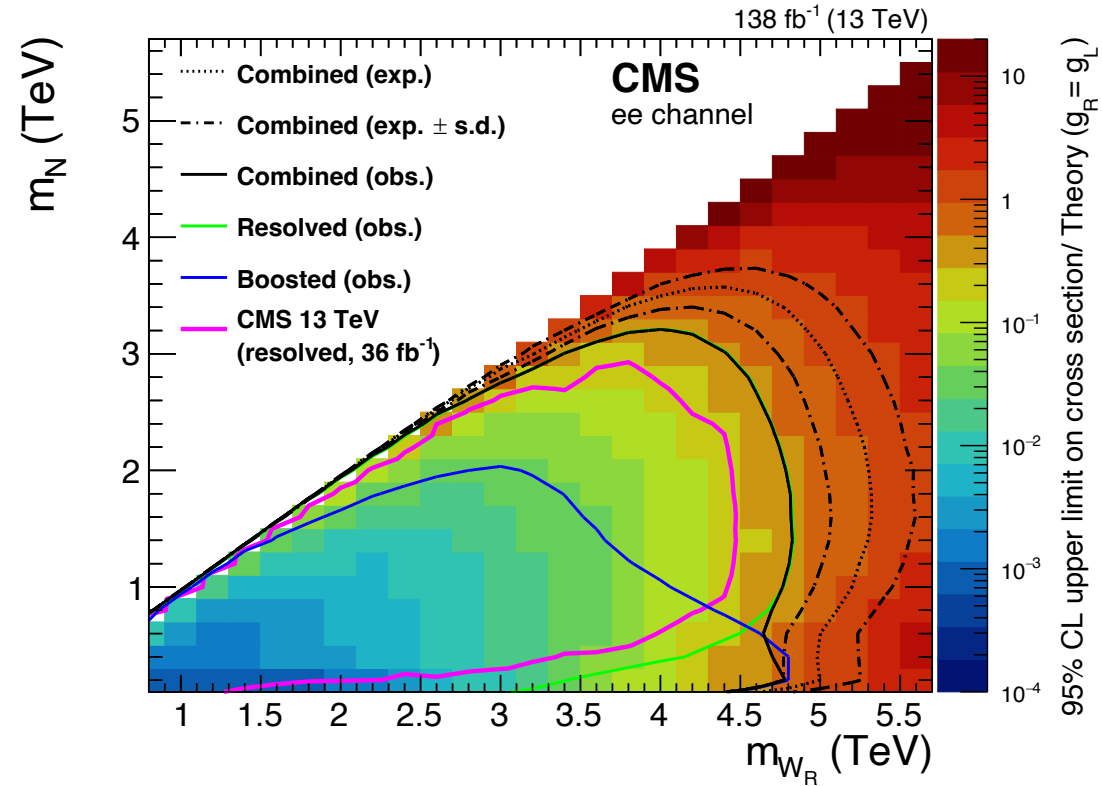
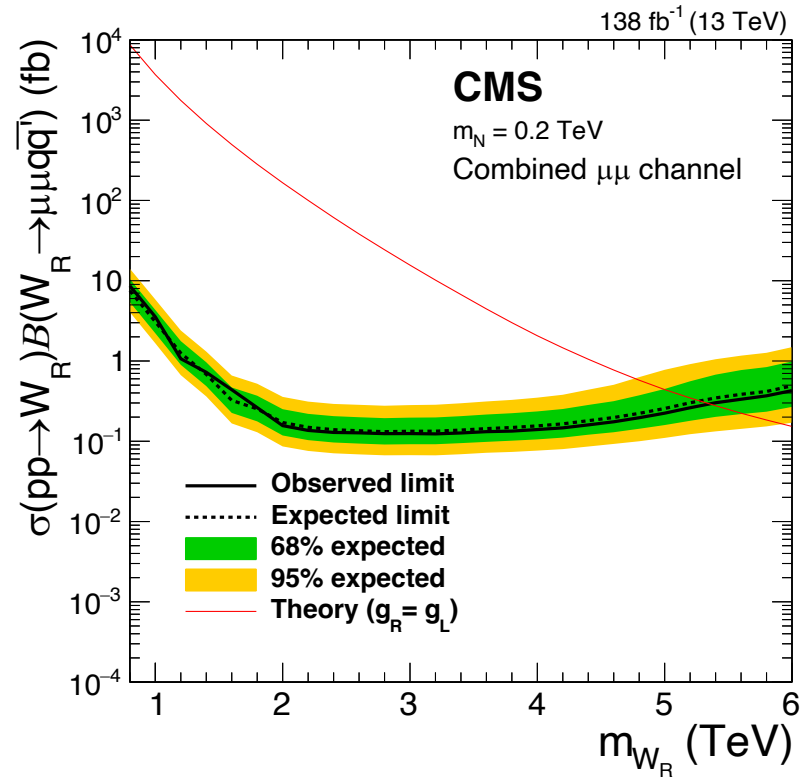
- Combination of multiple results fitting for coupling modifier

- Combination of HH results for the three most sensitive channels (4b, 2b2τ, 2b2γ)
  - Reaching ~3×sensitivity, expect SM sensitivity with HL-LHC



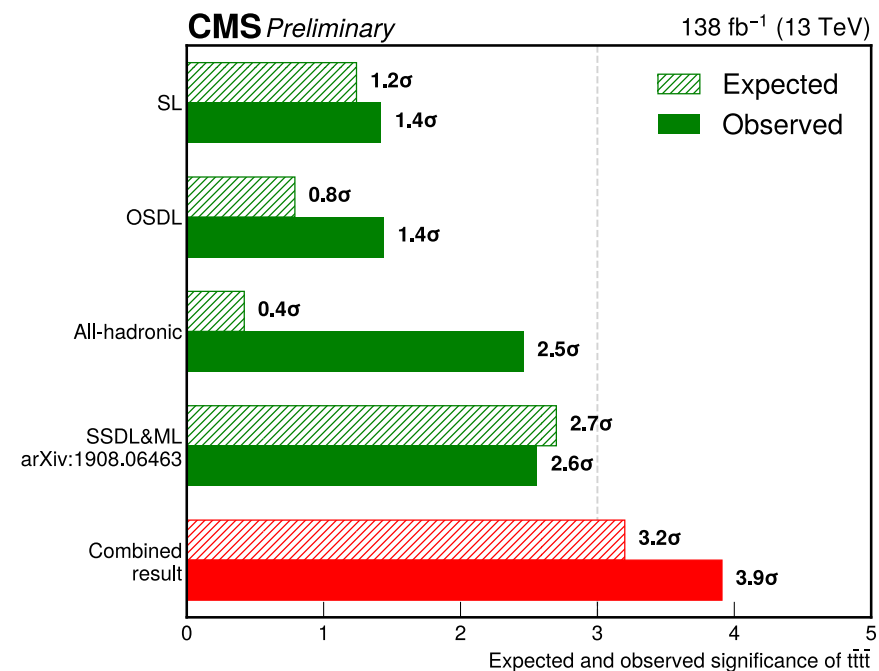
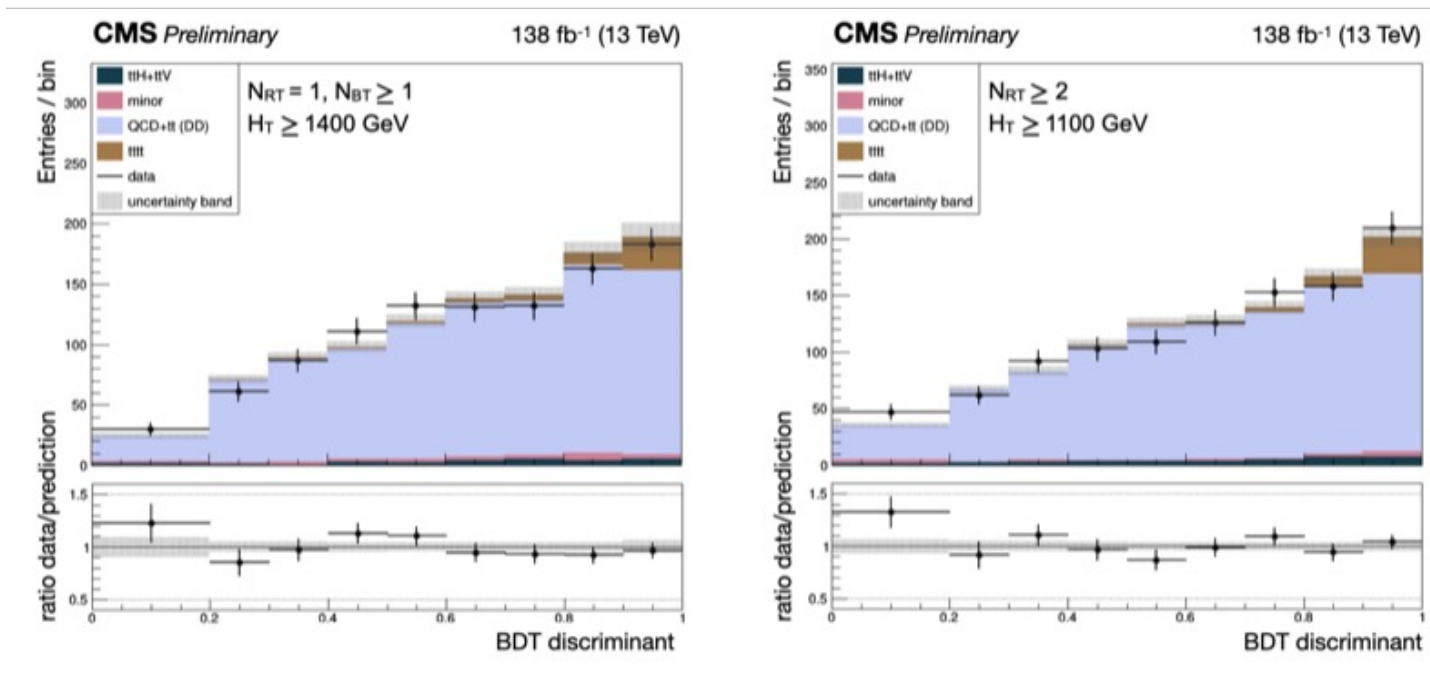
# Search for heavy neutrino

- Search for a right-handed  $W$  boson and a heavy neutrino in proton-proton collisions at 13 TeV
- $m_{W_R} < 4.7$  (4.8) and 5.0 (5.4) TeV for electron and muon channels are excluded



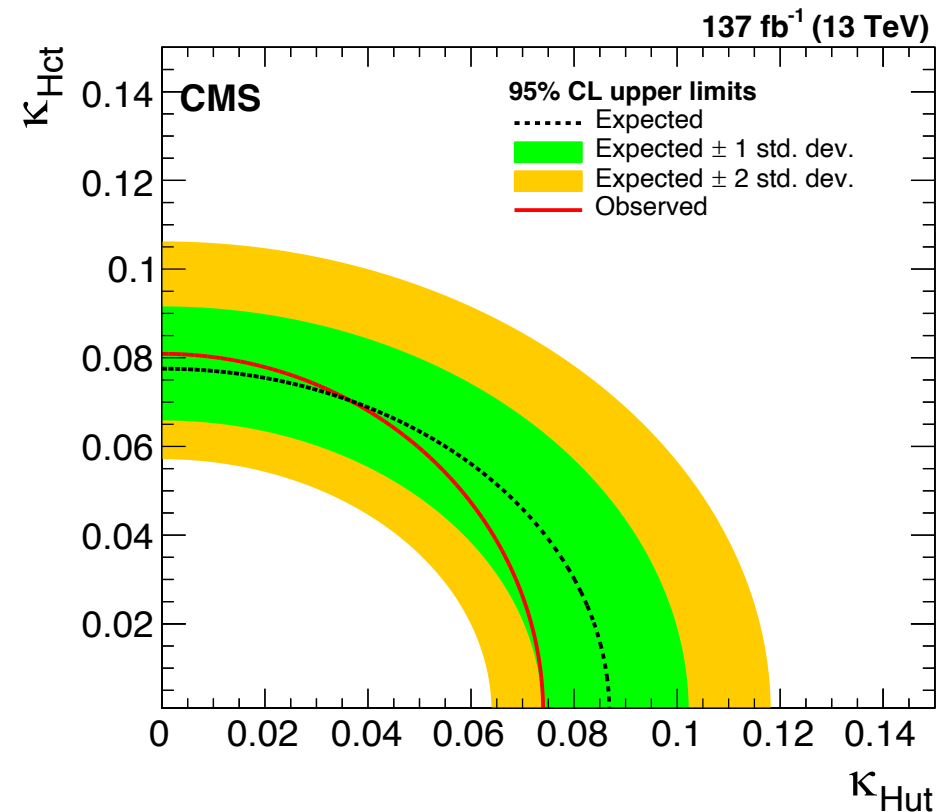
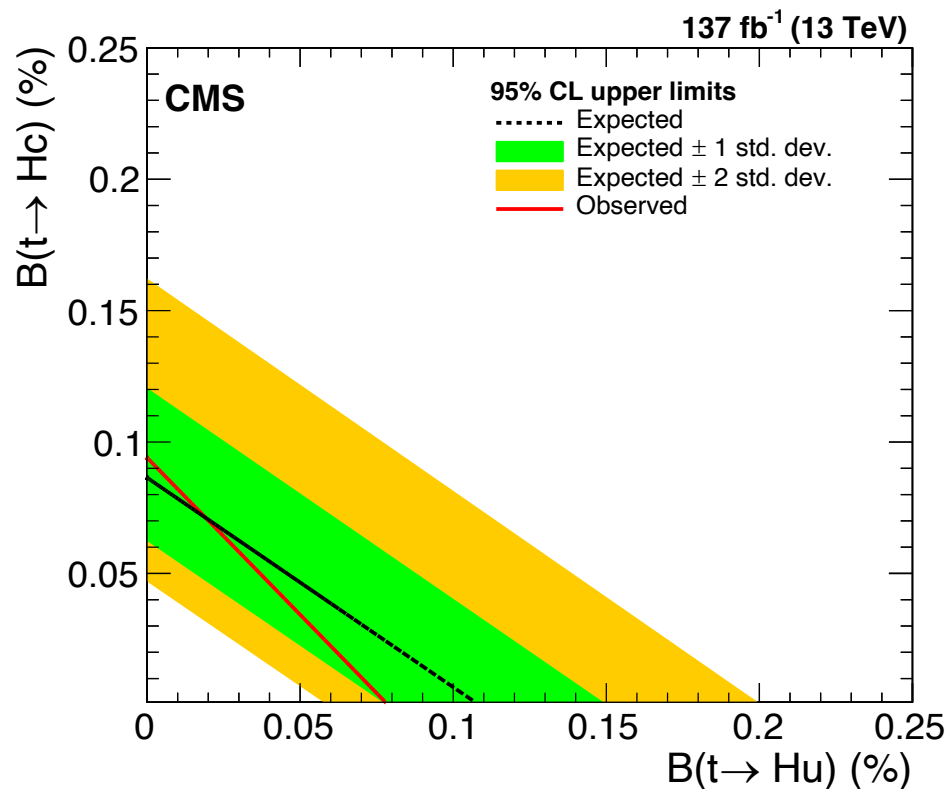
# Search for four-top production

- Evidence for 4 top production
- Using events that have zero, one or two opposite-sign charged electrons or muons with full Run 2 data
- The observed significance  $3.7 \sigma$  ( $1.5 \sigma$  expected)
- Combined with published CMS results in other final states, the significance is  $3.9 \sigma$  ( $3.2 \sigma$ )



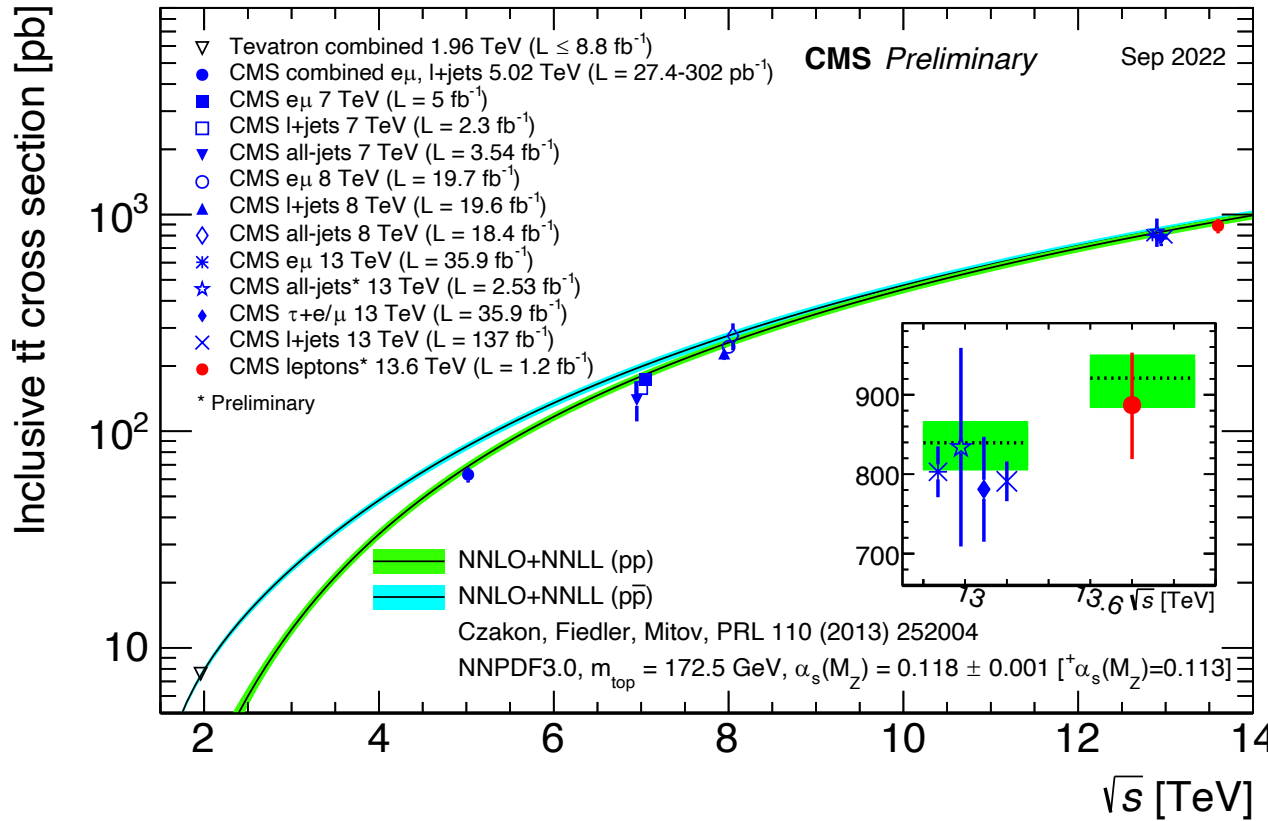


- Search for flavor-changing neutral current interactions of the top quark and the  $H \rightarrow b\bar{b}$  at 13 TeV
- Observed (expected) Upper limit
  - $\text{Br}(t \rightarrow H_u) < 0.079$  (0.11)% and  $\text{Br}(t \rightarrow H_c) < 0.094$  (0.086)%



# Run 3 result

- First measurement of the top quark pair production cross section in proton-proton collisions at 13.6 TeV



# 검출기 개발

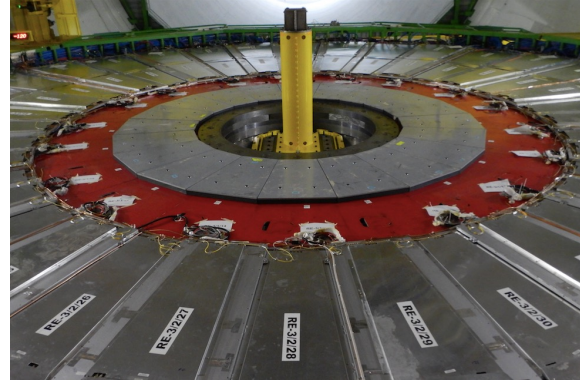
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# 검출기 개발 기여

2013~  
2014

## LS1 : RPC

- RPC Gap & Chamber
- Phase-1 RE4/2 installed



2019~  
2022

## LS2 : GE11, GE21, iRPC

- GE11 construction (complete)
- iRPC gap production
- GE21 foil production

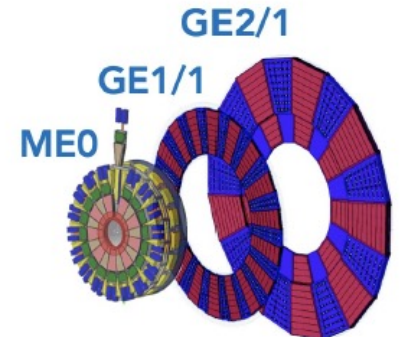
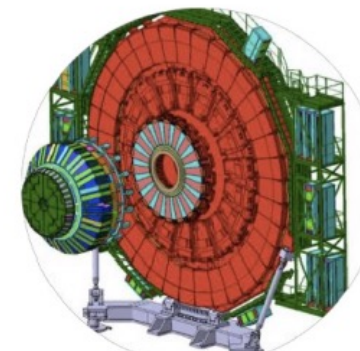
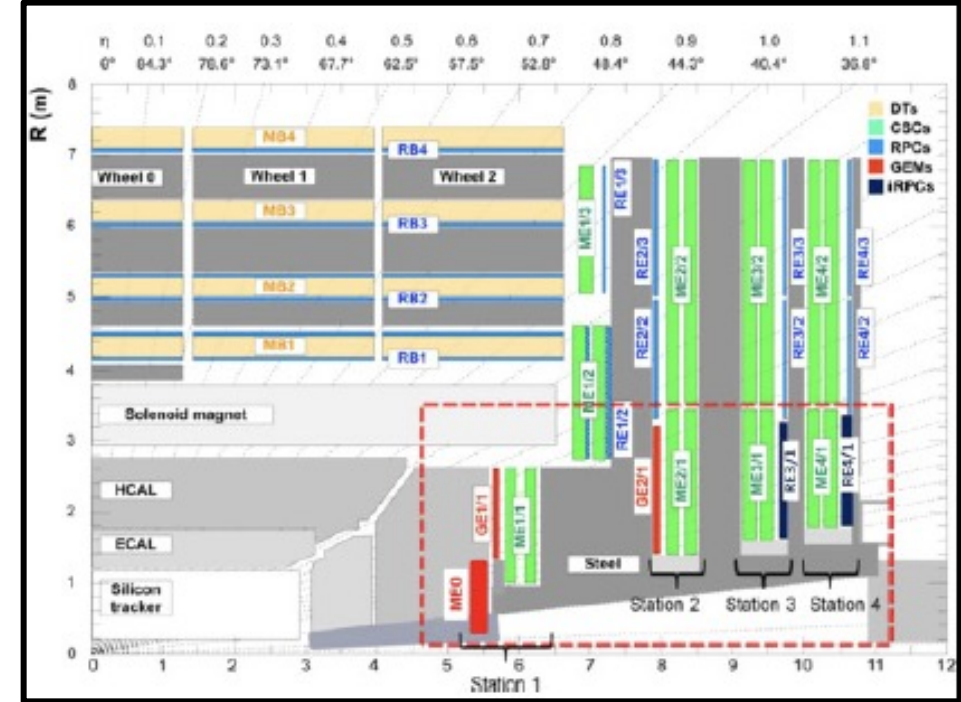
2026~  
2028

## LS3 : GE21, ME0

- GE21, ME0 foil production

RPC 저항판검출기  
GEM 기체전자증폭기

LS Long Shut down  
ME Muon Endcap

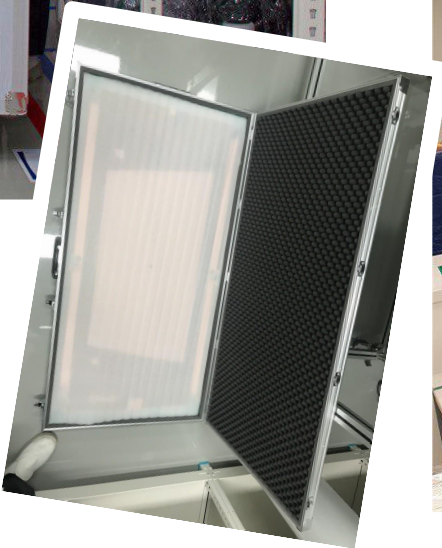
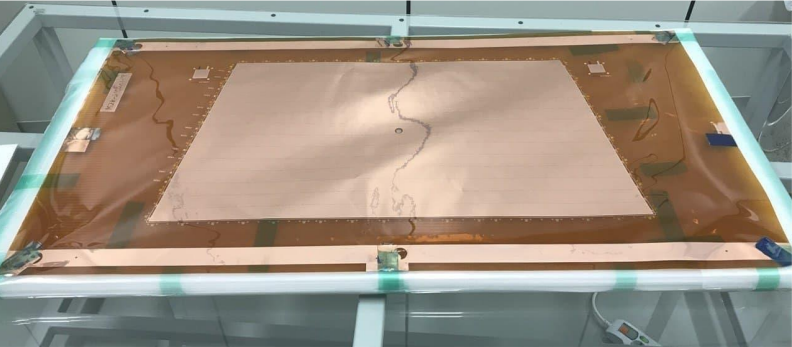
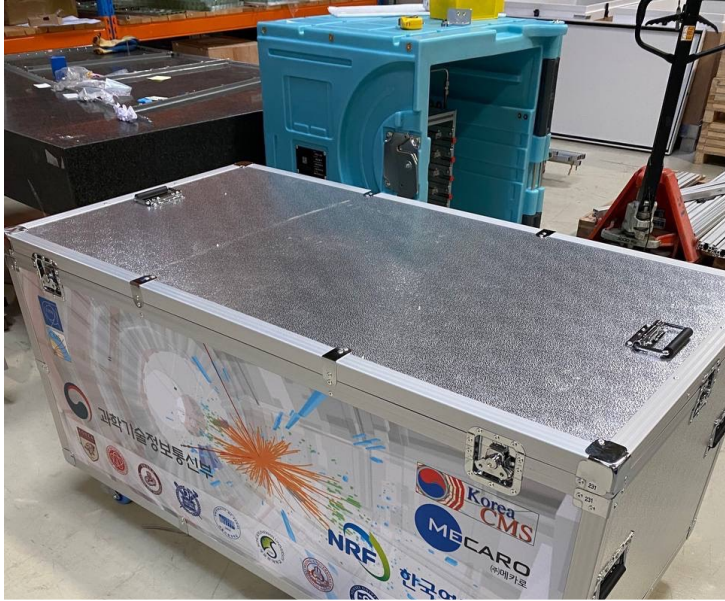


# GE1/1 설치 및 운영



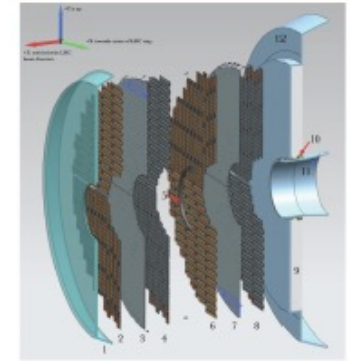
# GE21 production

2nd delivery

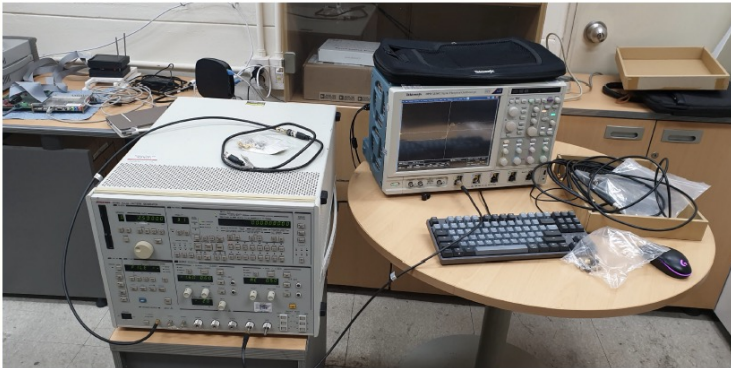


# MTD R&D

- 초고속 Timing 검출기 Phase II 업그레이드 사업에 참여할 계획
- Two major areas
  - Low Gain Avalanche Detector (LGAD) sensor development & test
  - ASIC readout chip (ETROC) development & test



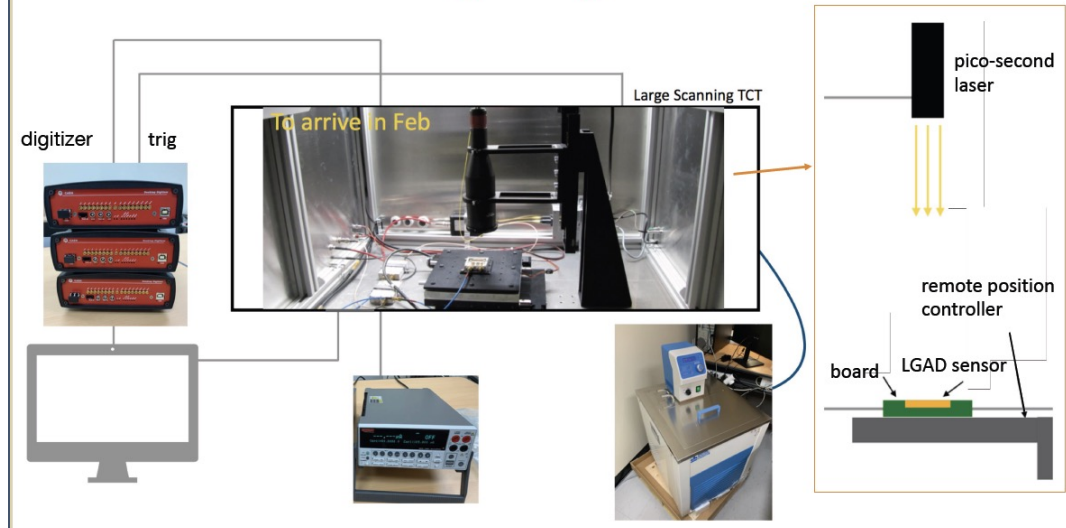
## ETROC1 Test set up at KNU



- ETROC1
  - 4x4 clock tree, preamp + discriminator + TDC
  - Goal: full chain front-end with TDC, 4x4 clock tree
  - This is the first full chain precision timing prototype

- Full array full chain ETROC1 charge injection testing at FNAL → results good
- ETROC1 and 5x5 LGAD sensor bump-bonded
  - Laser testing will be done
  - Test Beam (Dec – Apr 2021)

## LGAD Sensor testing using laser at KU



# 검출기 통합 운영

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- HL-LHC를 위한 RPC 무온 검출기 생산 시작하여 내년 납품 완료 목표
  - 내년 생산을 끝으로 RPC 한국측 기여는 완료가 됨
- 메카로 기업에서 GEM foil 생산 중단
  - 중이온 가속기 부지와 안산 공단으로 장비 이동 후 내년 초에 재가동 목표
- MTD (초고속 타이밍 검출기) R&D 시작하였고 내년 MOU 체결 논의
- 추후 GEM, RPC, MTD 검출기 사업을 하나의 통합된 장소에서 효율적으로 운영하고자 함
  - 엔지니어 및 생산 시설 인프라 공유



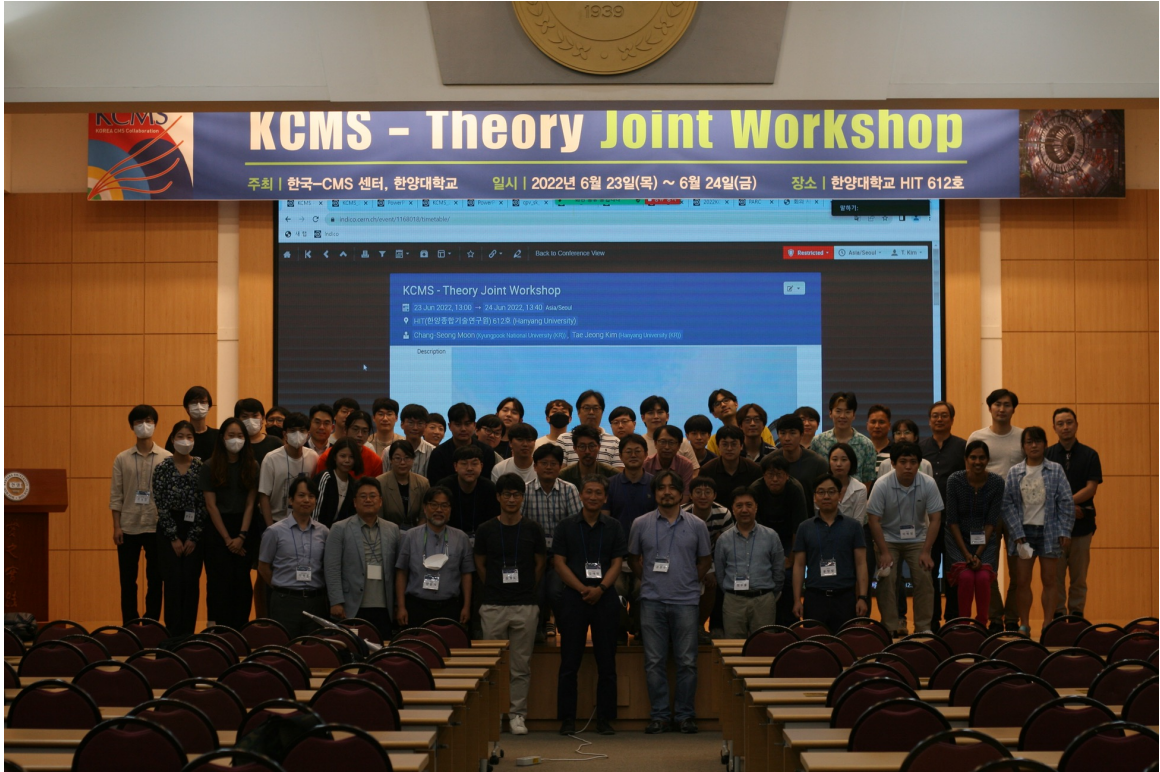
# Workshops and Conferences

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# KCMS-Theory Joint Workshop



- 6월 23-24일 한양대학교



# Strangeness Quark Matter

- 13-18 June 2022, Busan in Korea

**SQM 2022**  
The 20th International Conference on  
**STRANGENESS in QUARK MATTER**  
13-18 June 2022, Busan Republic of Korea

Scientific topics

- Strangeness and heavy-quark production in nuclear collisions and hadronic interactions
- Hadron resonances in the strongly-coupled partonic and hadronic medium
- Bulk matter phenomena associated with strange and heavy quarks
- QCD phase structure
- Collectivity in small systems
- Strangeness in astrophysics
- Open questions and new developments

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Byeong-Ho Park	INSU		
Bong-Hwi Lim	INSU		

**Information**

- <https://sqm2022.pusan.ac.kr>
- <https://indico.cern.ch/e/sqm2022>
- [sqm2022@hipex.phys.pusan.ac.kr](mailto:sqm2022@hipex.phys.pusan.ac.kr)



# AEPSHEP2022

- 10월 5일 – 10월 18일, 알펜시아 리조트
- 29개 나라에서 96명의 학생 참여
- 15 lectures and 6 discussion leaders



# AEPSHEP

2022

Asia-Europe-Pacific School of HEP

**05-18**  
OCTOBER 2022  
PYEONGCHANG  
SOUTH KOREA

<p><b>Scientific Programme</b></p> <p><b>Statistical Techniques</b> Nicolas Berger (LAPP)</p> <p><b>Prospects at LHC in Run-3 &amp; HL-LHC</b> Sarah Demers (Yale)</p> <p><b>O &amp; A Session</b> Fabrizio Gianotti (CERN)</p> <p><b>Field Theory &amp; the E-W Standard Model</b> Rohini Godbole (IISc, Bangalore)</p> <p><b>Instrumentation</b> Ingrid-Maria Gregor (DESY)</p> <p><b>Flavour Physics &amp; CP Violation</b> Xiao-Gang He (SJTU/NTU)</p> <p><b>Super Kamiokande</b> Takaaki Kajita (U. Tokyo)</p> <p><b>Neutrino Physics</b> Sin Kyu Kang (Seoul Tech.)</p> <p><b>HEP Outlook</b> Young-Kee Kim (U. Chicago)</p> <p><b>Physics &amp; BSM</b> Ryachiro Kitano (KEK)</p> <p><b>Heavy-Ion Physics</b> Yen-Jie Lee (MIT)</p> <p><b>Cosmology (incl. Dark Matter)</b> Hitoshi Murayama (IPMU)</p>	<p><b>QCD</b> Varunvelu Ravindran (IMSc, Chennai)</p> <p><b>Gravitational Waves</b> Jo van den Brand (Nikhef)</p> <p><b>Hadron Spectroscopy</b> Alexei Zhemchugov (JINR)</p> <p><b>Discussion Leaders</b></p> <p>Faisal Akram (Punjab U.)   Yu Seon Jeong (Chung-Ang U.)   Sachitha Kulkarni (U. Graz)   Jia Liu (PKU)   Huan-Sheng Shao (LPTHE)   Takahiro Torida (ISS)</p> <p><b>Committees</b></p> <p><b>International Advisory Committee</b> A. Bondar (BNP)   A. Datta (IFG)   K. Haragaki (KEK, Chair)   B. Heisenberg (DESY)   H. Hooran (NCP)   M. Sidor (MBO)   XY. Shen (IBEP)   D. Sosa (KIAS)   P. Jenster (ICNP2022)   H. Iwase (CERN)   H. T. Wong (Academia Sinica)</p> <p><b>International Organising Committee</b> A. Ahmad (NCP)   E. Barberio (Melbourne)   M. Bilenca (CEA)   J. L. Elisei (CERN)   Y. Hsiang (National Taiwan U.)   K. Kawagoe (Kyushu)   P. Ko (KIAS)   G. Majumda (IFG)   E. Mohanty (IISER)   M. Maitani (CERN, Chair)   S. Nanda (KPS)   S. Park (NIPAP/Pheno)   T. Schwaner-Salerno (DESY)   B. Shwartz (BNP)   O.Z. Wain (IBP)   S.L. Zhu (Beihang)</p> <p><b>Local Organising Committee</b> B. Chang (IBP, Chair)   B. Choi (Hanyang U.)   B. Cho (Korea U.)   B. Hong (Korea U.)   D. Kim (Kyungpook National U.)   H. Kim (Kyung U.)   T. Kim (Hanyang U., Co-chair)   P. Ko (KIAS, Co-chair)   M. Kwon (SNU)   Y. Jeon (Pohang U.)   J. Lee (S. Seoul)   C.S. Moon (Kyungpook National U.)   D. Moon (Chonnam National U.)   I. Park (S. Seoul)   D. Son (Kyungpook National U.)   M. Son (KAIST)   U. Yang (Seoul National U.)   J. Yoo (Korea U.)   Y. Yung (Kyungpook U.)</p>
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The Fifth Asia-Europe-Pacific School of High-Energy Physics  
For more information and to apply <https://indico.cern.ch/event/884244/>

# 한국 CMS 미래

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# 한국 CMS 미래

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- Should look ahead at least 20 years
- Need to train younger generation
- It is getting more important to communicate between theory and experiment
- Data will guide us to the future