



한국-CMS (KCMS) 실험 사업팀

김태정 (한양대)

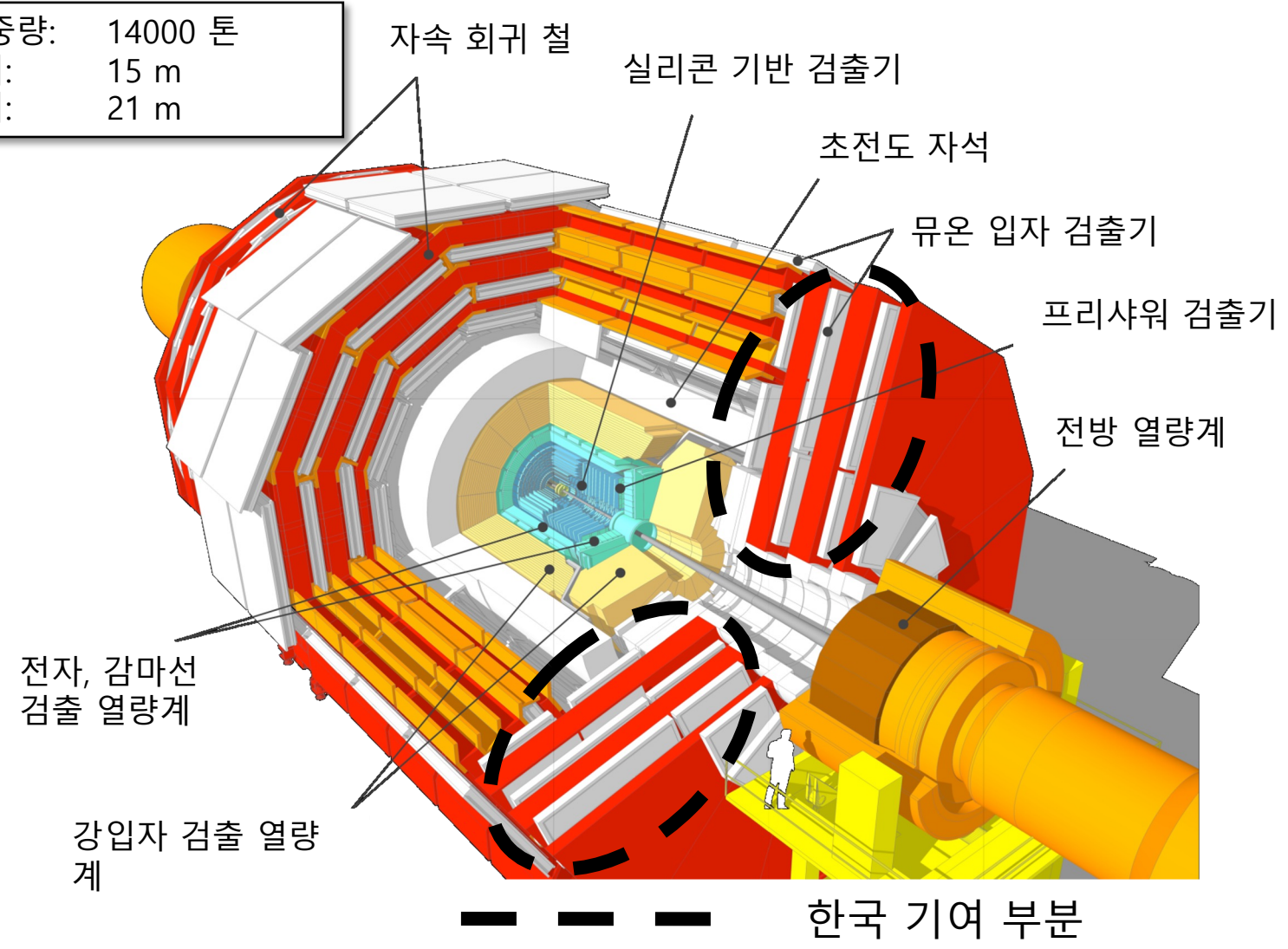
2022 Meeting of the Division of Particles and Fields of the KPS

2022. 12. 16.

CMS 실험 개요

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%)



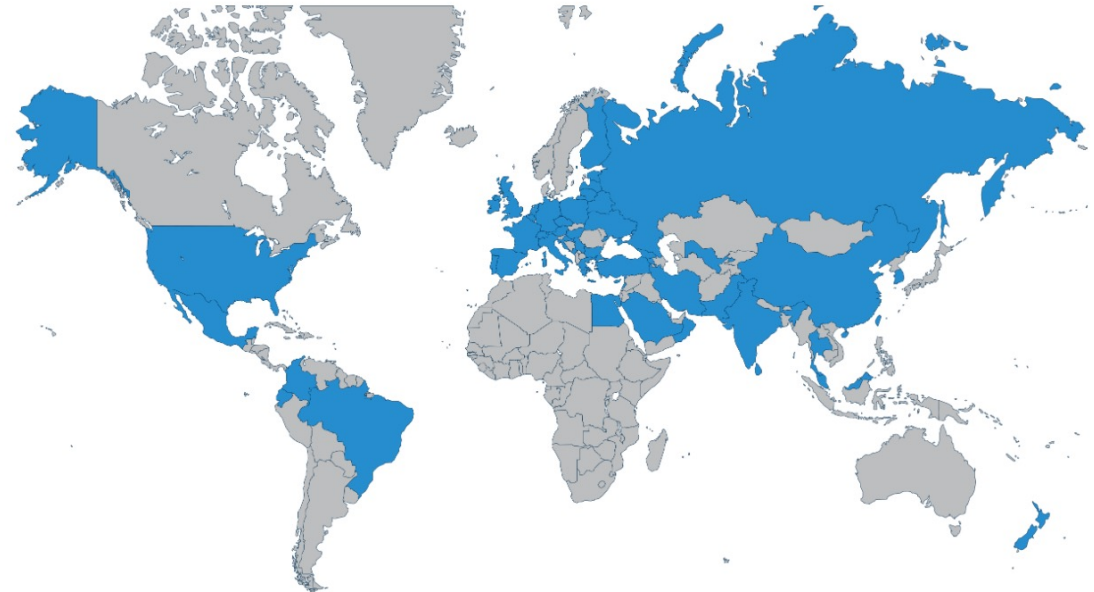
2942
PHYSICISTS
(1036 STUDENTS)

1065
ENGINEERS

281
TECHNICIANS

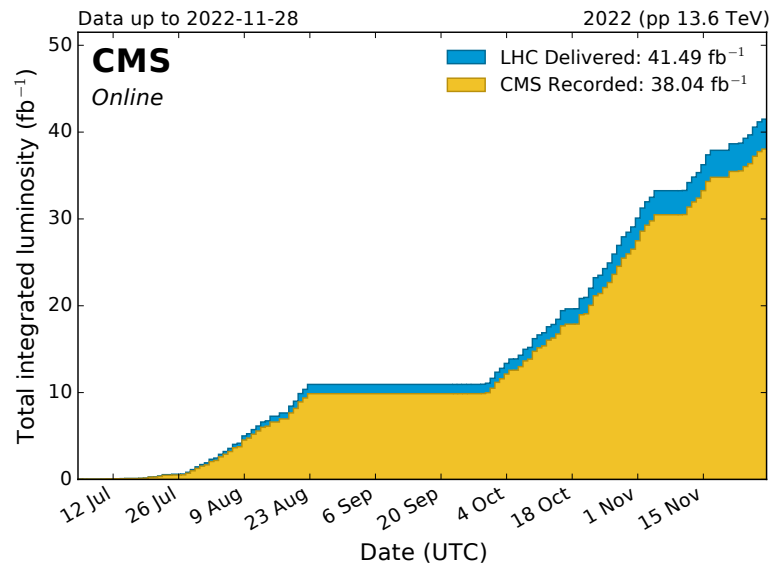
229
INSTITUTES

51
COUNTRIES &
REGIONS



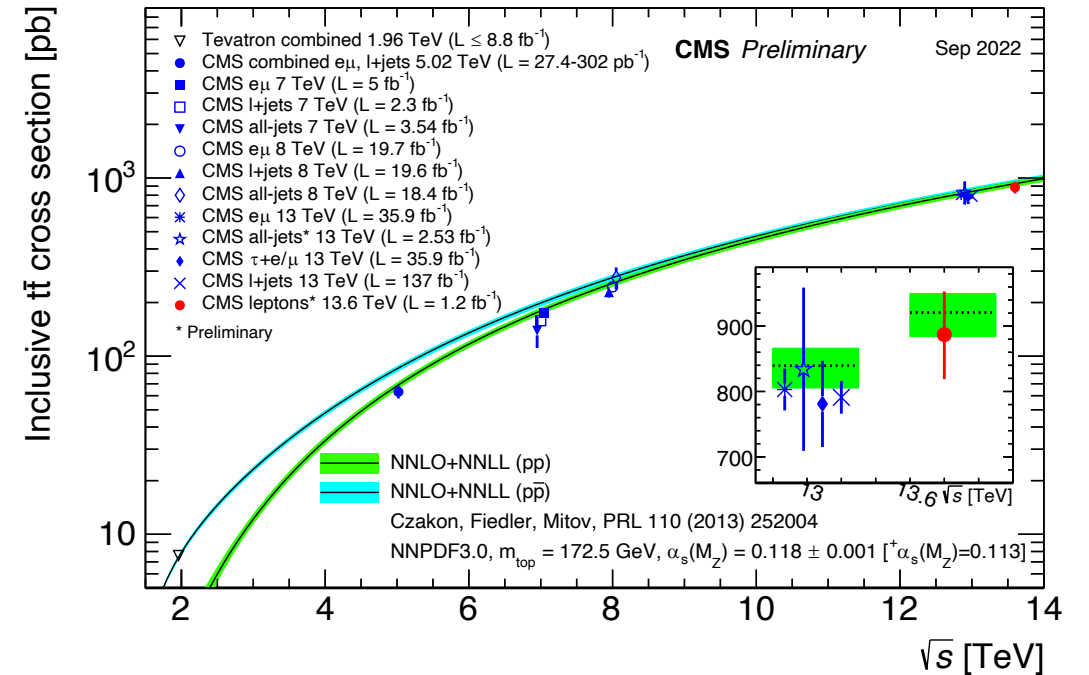
Run 3 status

- 양성자 충돌 에너지는 13 TeV 에서 13.6 TeV 로 증가
- 2022년 7월 Run 3 시작하여 2025년까지 가동 예정
- Run 3에서 총 300 fb⁻¹ 해당하는 데이터 생산 예정
- 현재 40 fb⁻¹ 정도의 데이터 획득
- 초기 데이터를 이용하여 데이터 분석이 진행
- 새로운 충돌 에너지에서 cross section 측정 위주



CMS-PAS-TOP-22-012

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



한국 CMS 실험팀

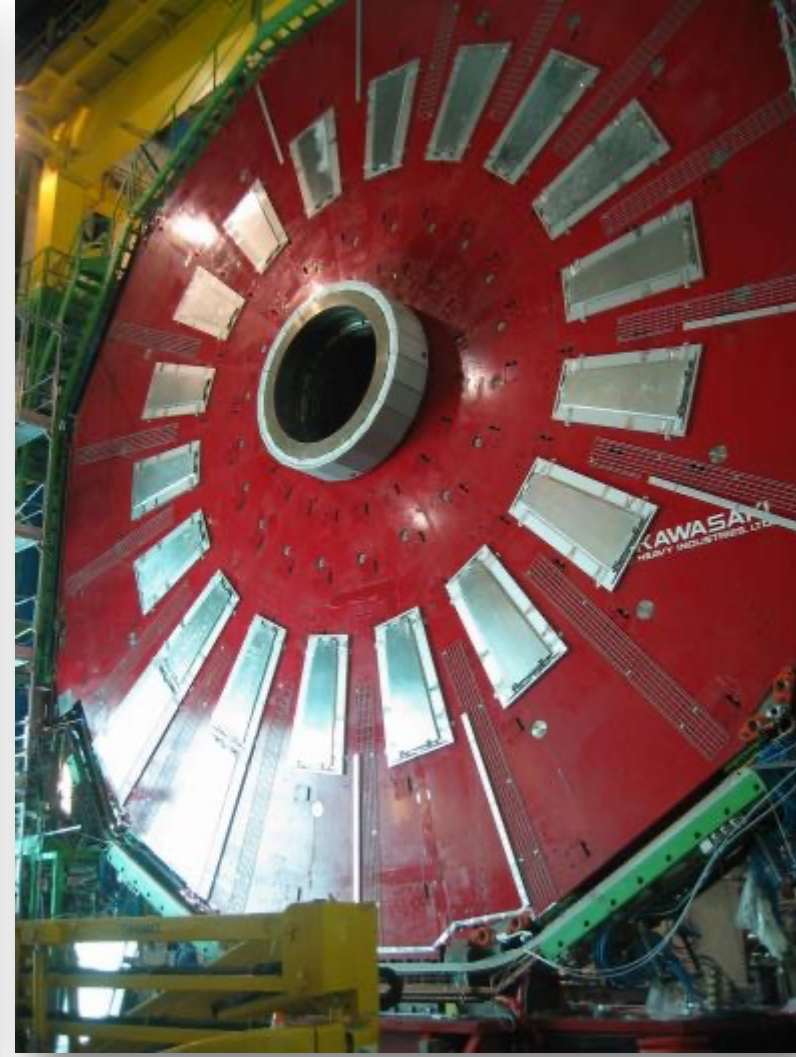
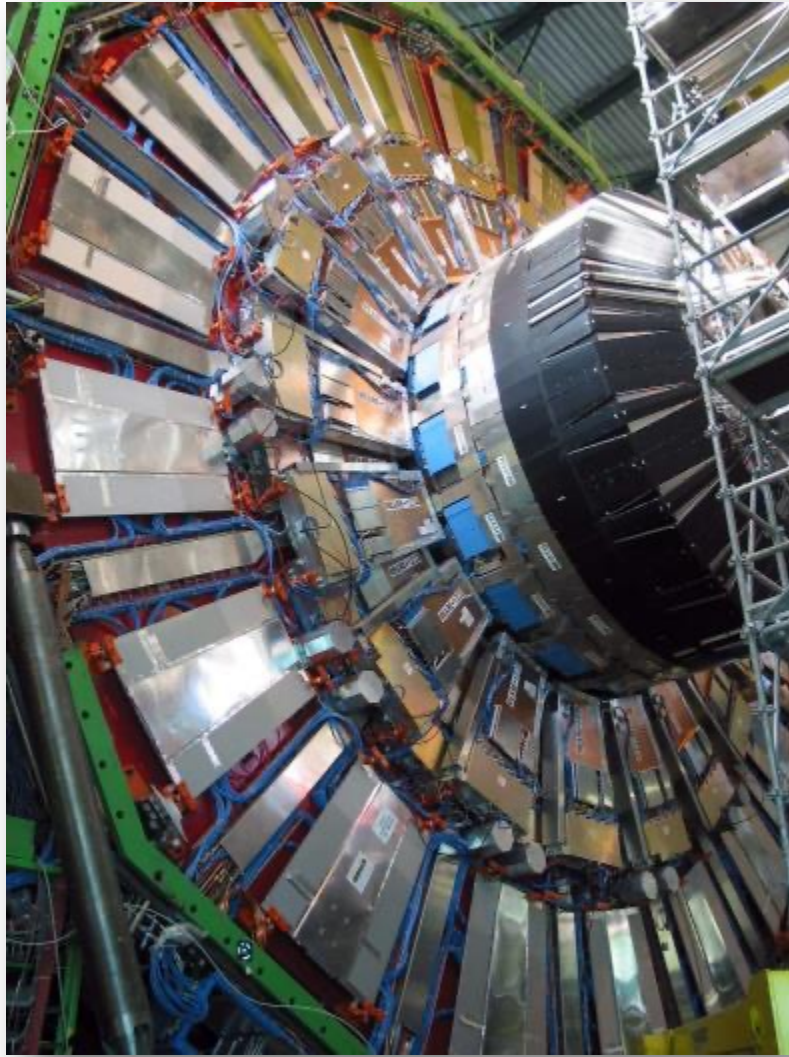
한국의 CMS 참여

- 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



2006: Korea-CERN Program launch

- 2006: CERN-Korea Collaboration Agreement
 - Won-Hwa Park, Ambassador of the Republic of Korea to Switzerland
 - Rober Aymay, Director General of the CERN



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



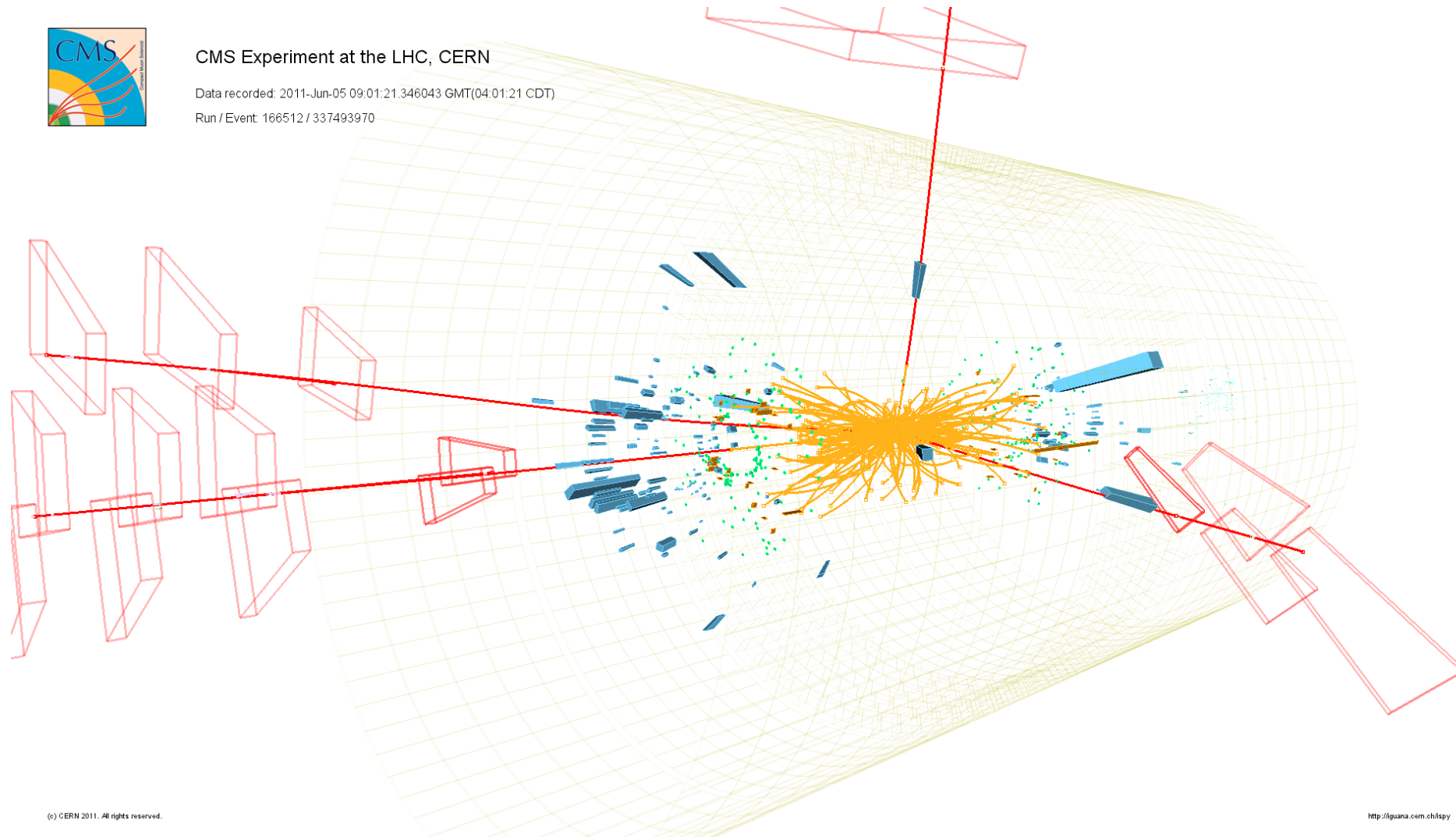
- 전체 CMS 인원에서 약 2.4% 정도의 규모 – 10번째로 큰 규모



CMS Experiment at the LHC, CERN

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

Run / Event: 166512 / 337493970



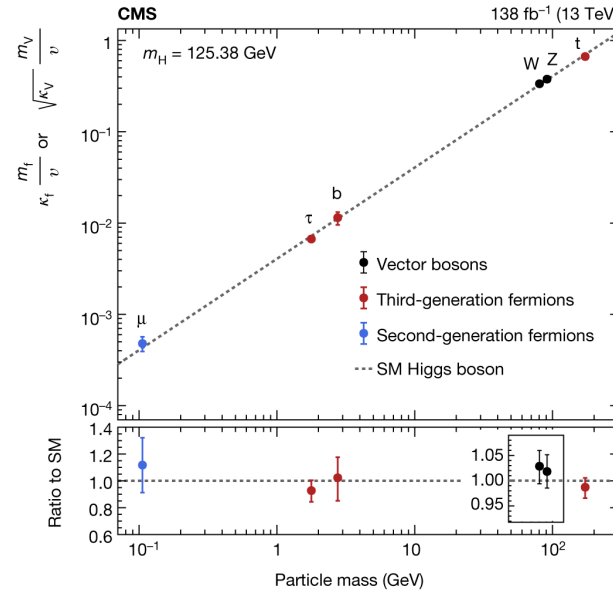
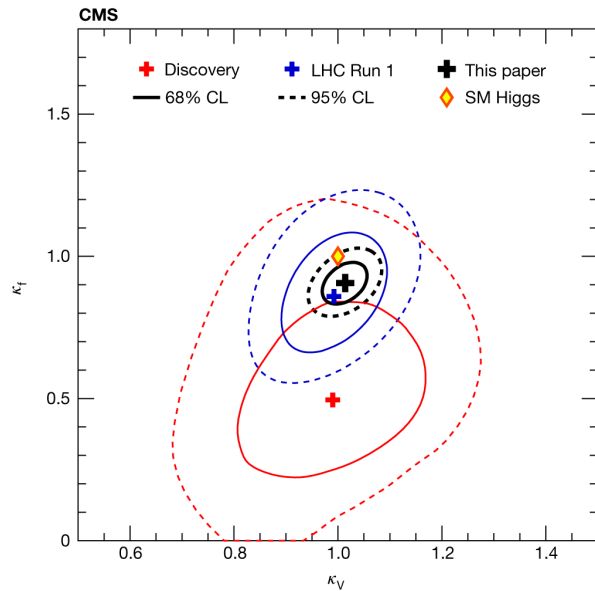
(c) CERN 2011. All rights reserved.

<http://guana.cern.ch/ispv>

우리나라가 만든 검출기에서 발견된 뮤온 입자

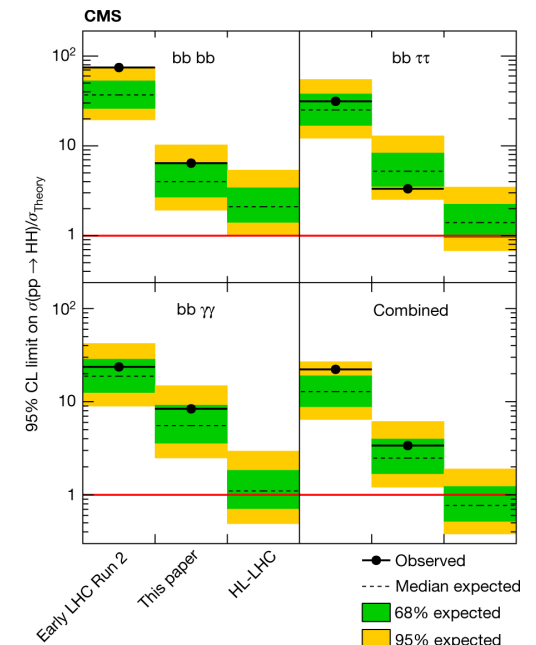
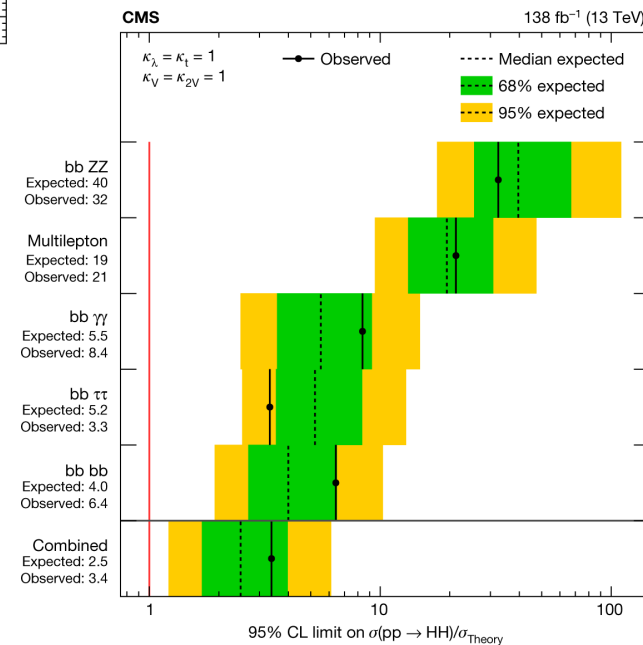
10 years after Higgs discovery

Nature volume 607, pages60–68 (2022)



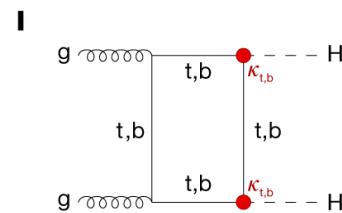
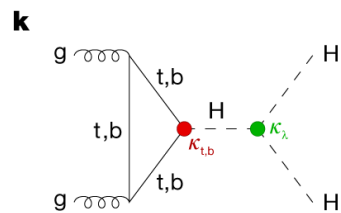
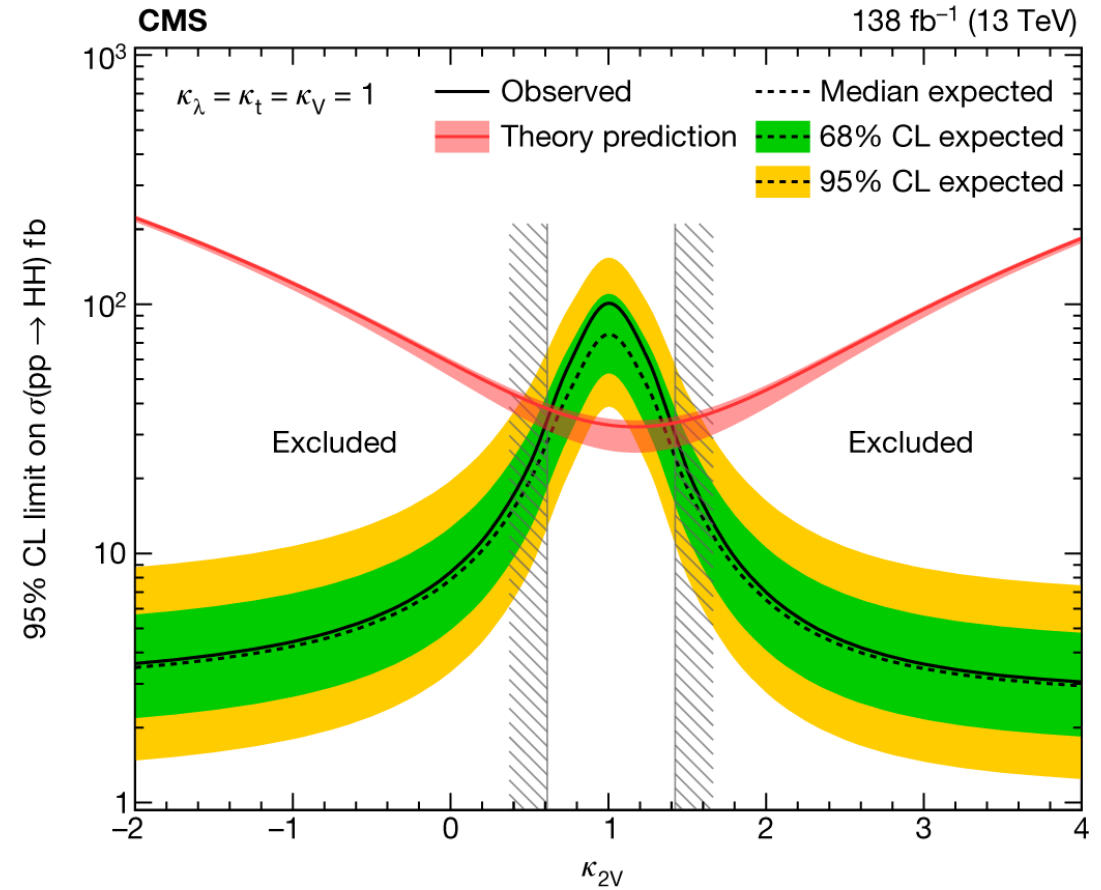
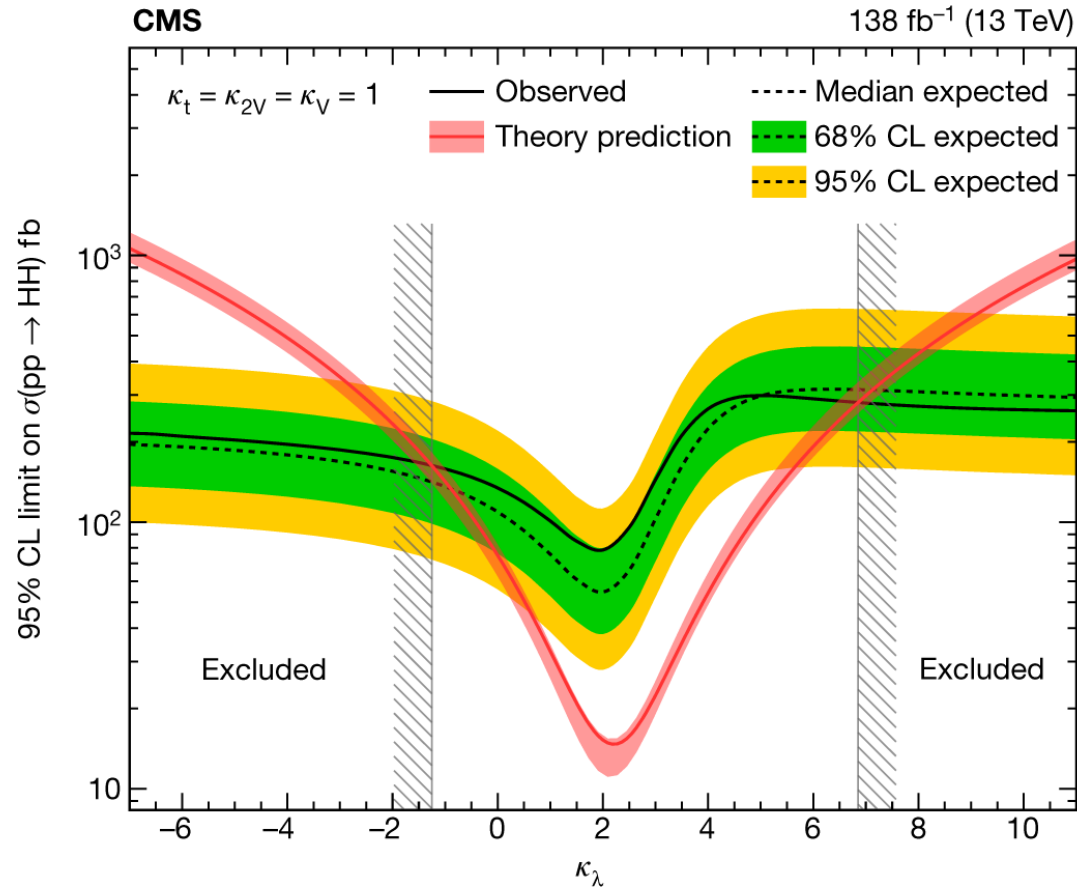
- Combination of HH results for the three most sensitive channels (4b, 2b2τ, 2b2γ)
 - Reaching $\sim 3\times$ sensitivity, expect SM sensitivity with HL-LHC

- Combination of multiple results fitting for coupling modifier

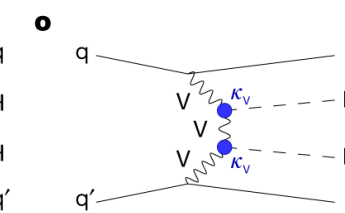
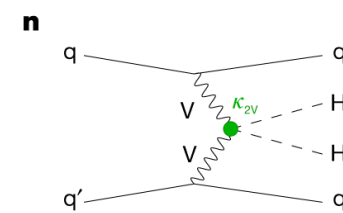
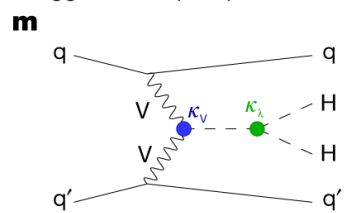


10 years after Higgs discovery

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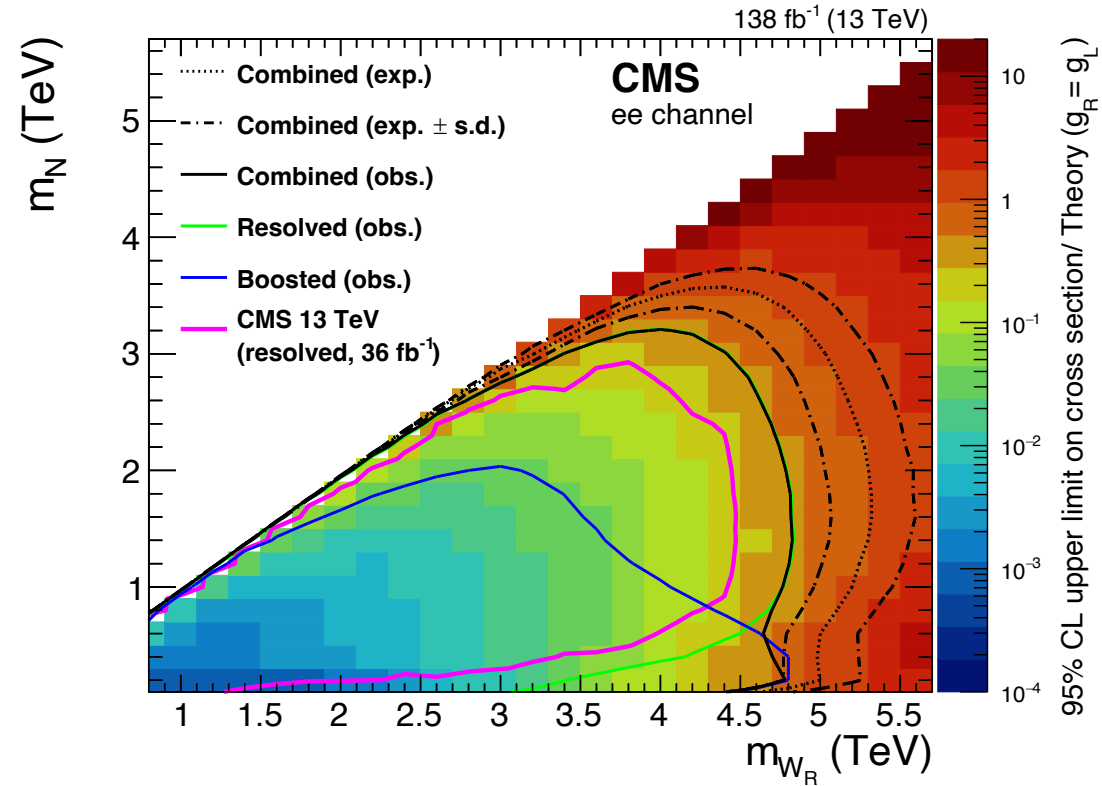
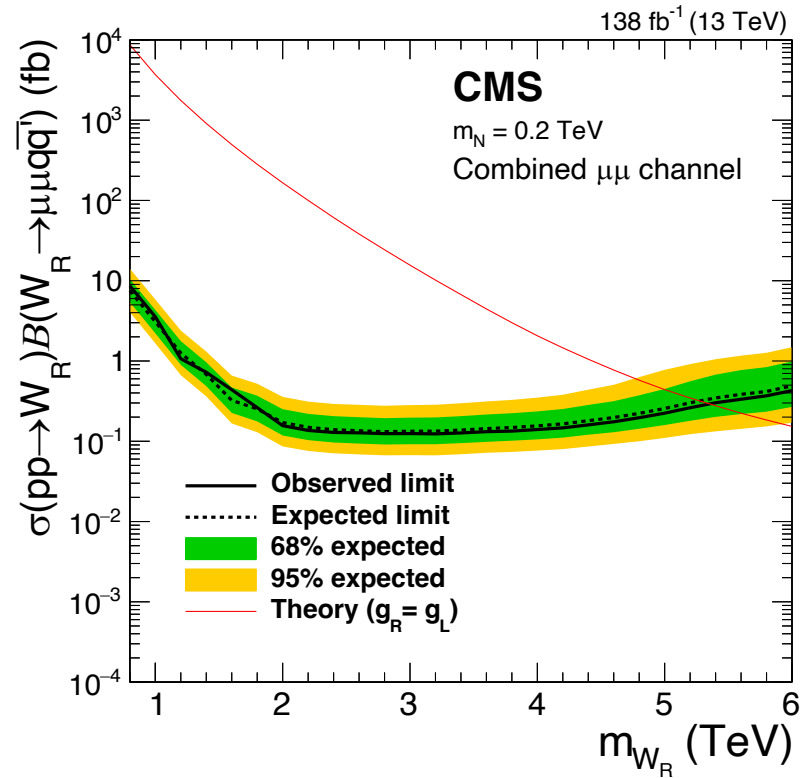
Higgs boson pair production



Excluded 0 multiple Higgs-gauge-boson interactions

Search for heavy neutrino

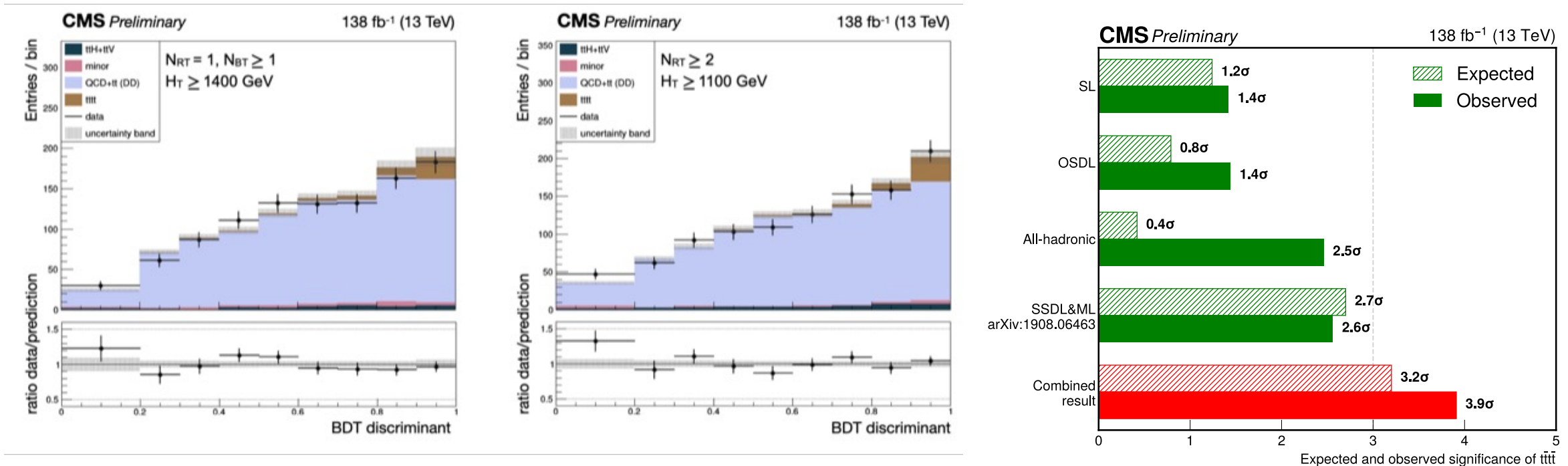
- Search for a right-handed W boson and a heavy neutrino in proton-proton collisions at 13 TeV
- $m_{W_R} < 4.7$ (4.8) and 5.0 (5.4) TeV for electron and muon channels are excluded



Search for four-top production

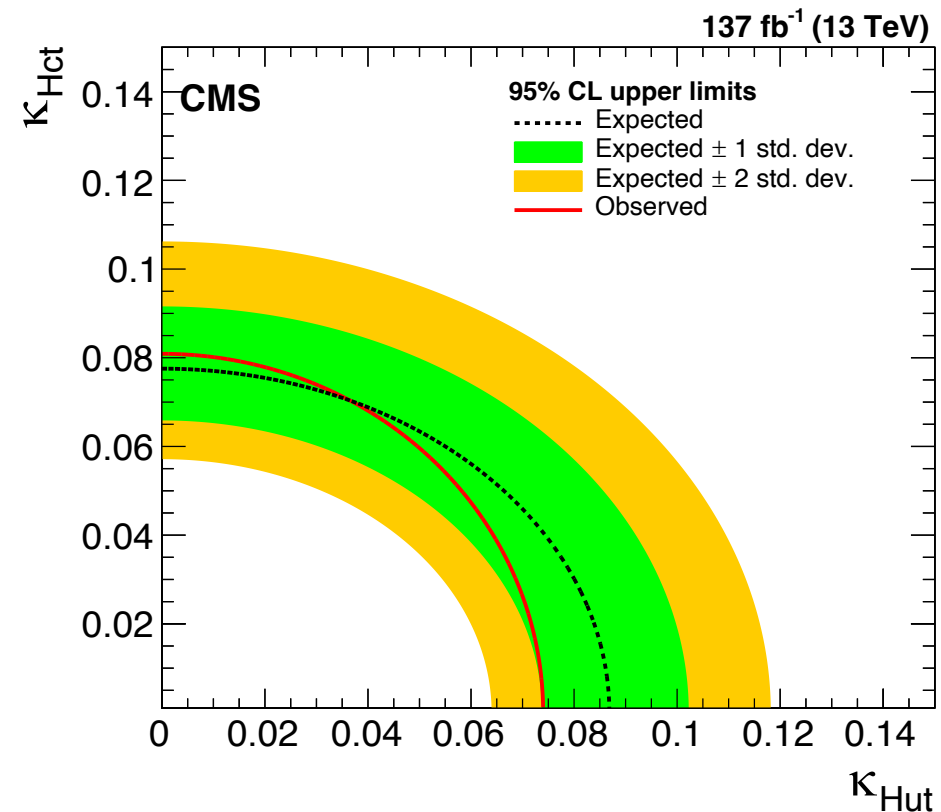
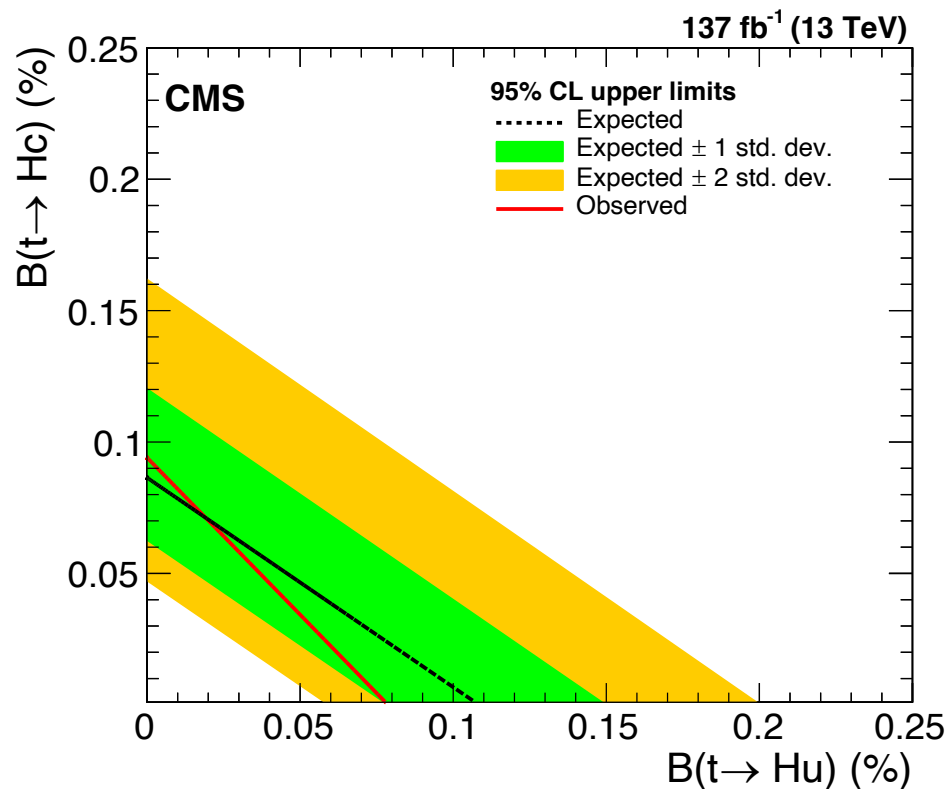
CMS-PAS-TOP-21-005

- 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 3.7σ (1.5σ expected)
- Combined with published CMS results in other final states, the significance is 3.9σ (3.2σ)

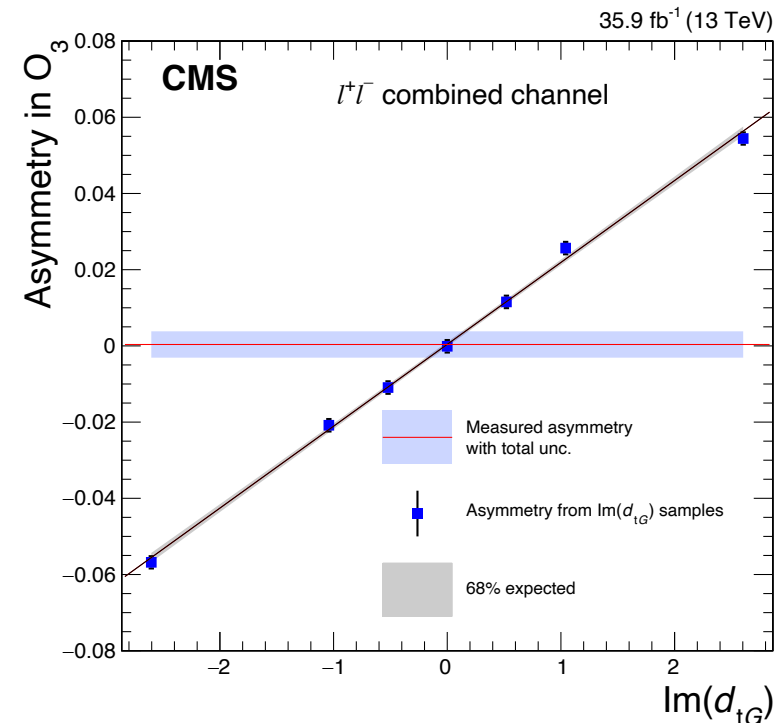
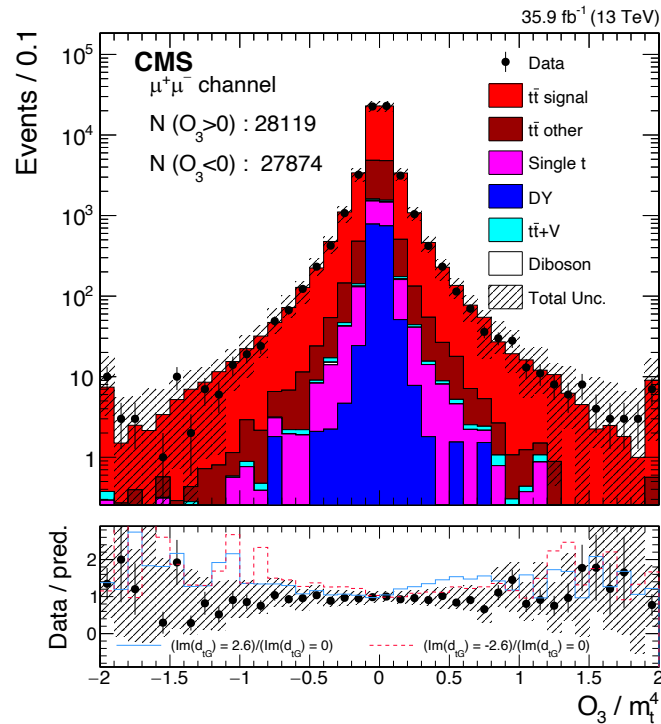


Flavor changing neutral current

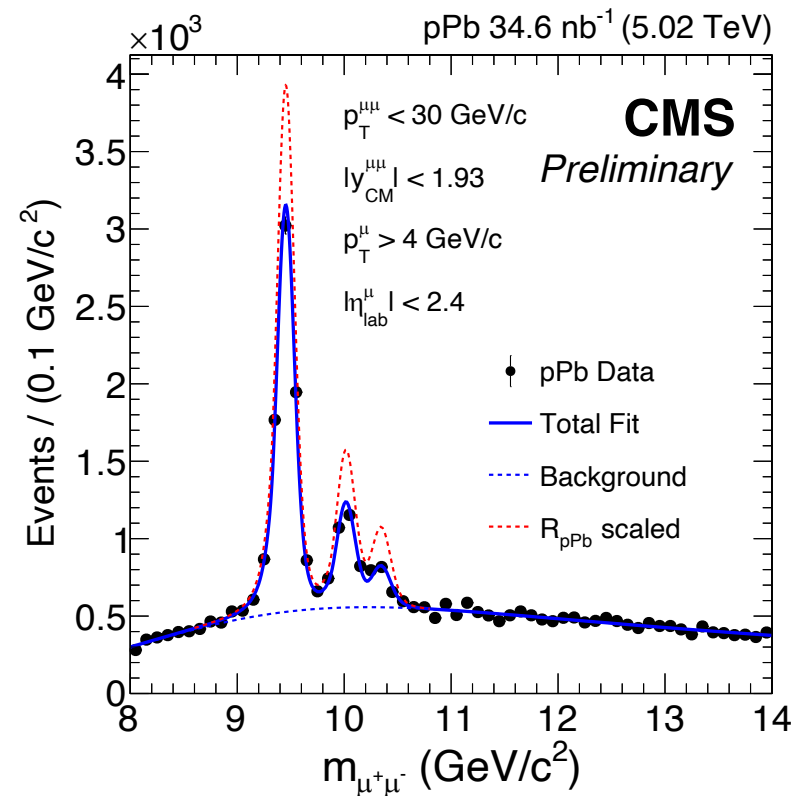
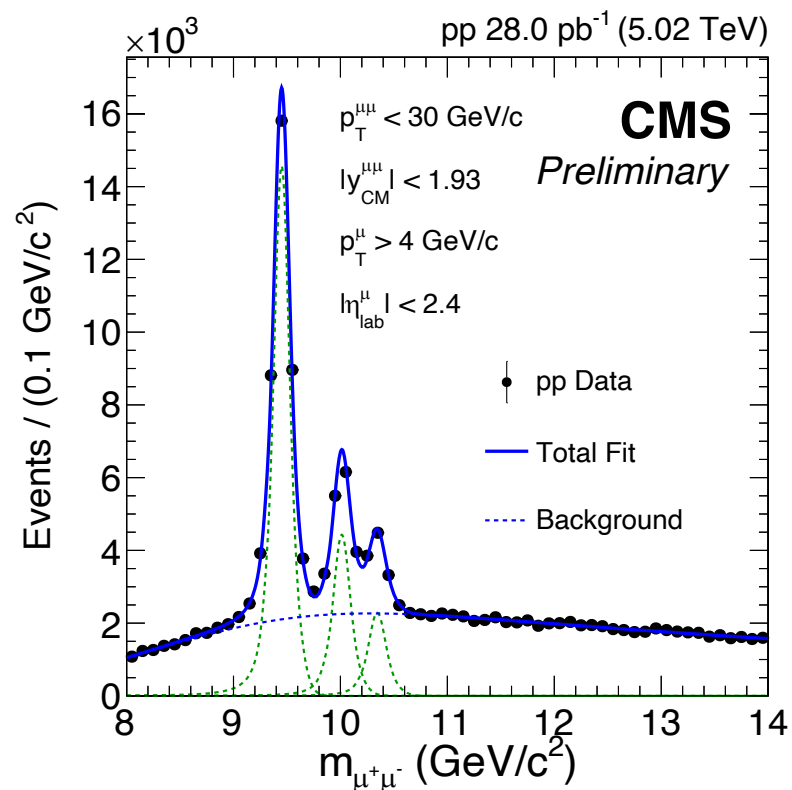
- Search for flavor-changing neutral current interactions of the top quark and the $H \rightarrow b\bar{b}$ at 13 TeV
- Observed (expected) Upper limit
 - $\text{Br}(t \rightarrow H_u) < 0.079$ (0.11)% and $\text{Br}(t \rightarrow H_c) < 0.094$ (0.086)%



- Search for CP violation in top quark pair production
- Using two variables :
 - O_1 - constructed from four-momenta of the charged leptons and the reconstructed top quarks
 - O_3 - four-momenta of the charged leptons and the b quarks originating from the top quarks
- Asymmetries in these observables are sensitive to CP violation



- Nuclear modification of Υ states in pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV
- Production cross sections of $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ and nuclear modification of R_{pPb} are obtained



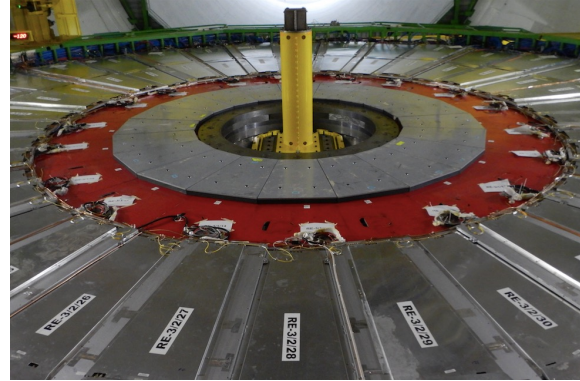
검출기 개발

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

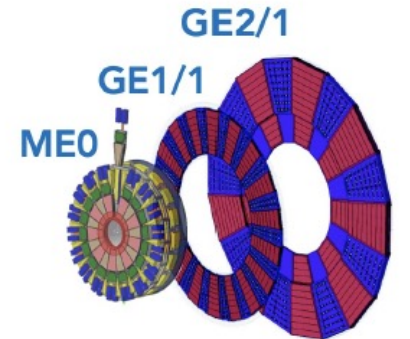
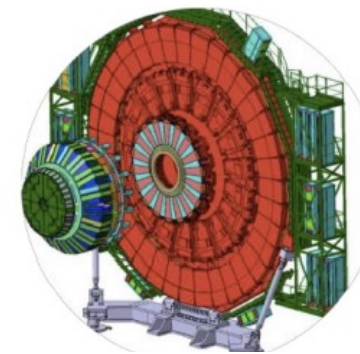
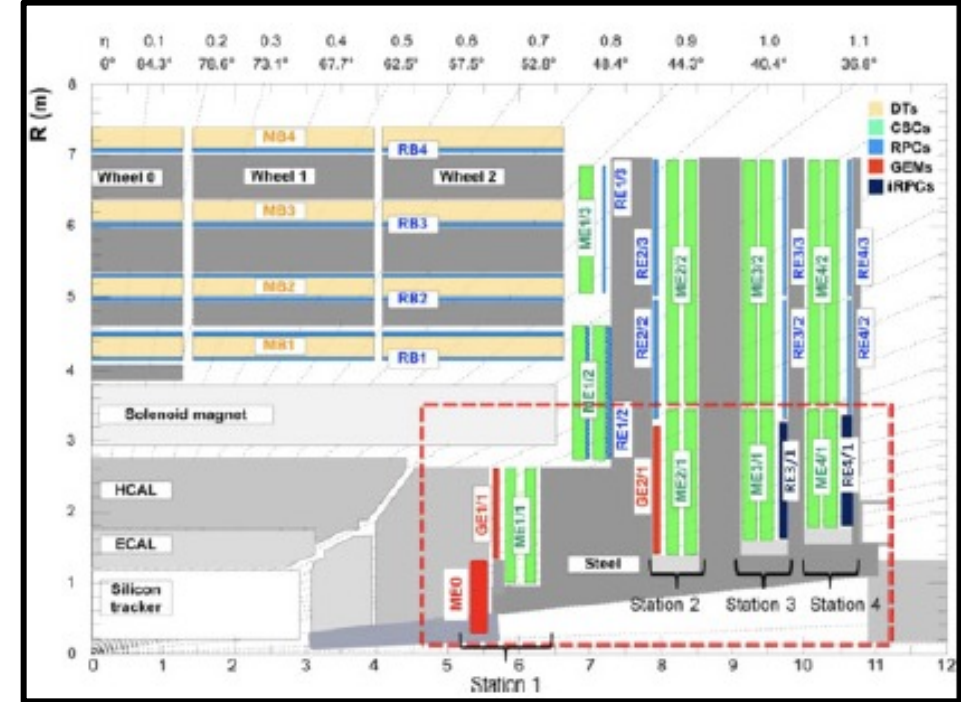
2026~
2028

LS3 : GE21, ME0

- GE21, ME0 foil production

RPC 저항판검출기
GEM 기체전자증폭기

LS Long Shut down
ME Muon Endcap

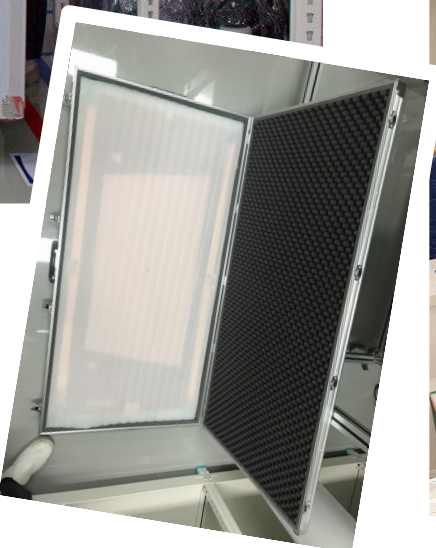
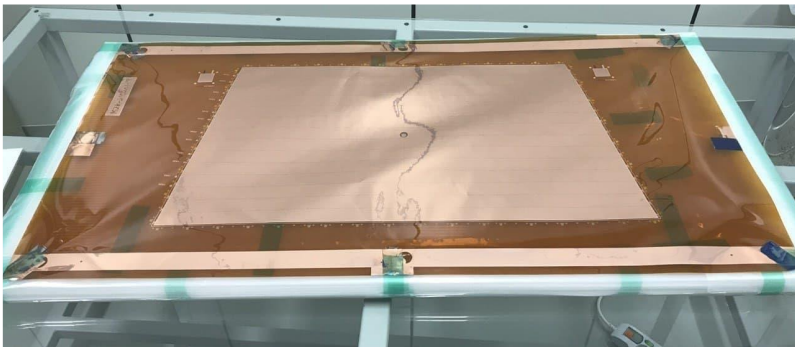
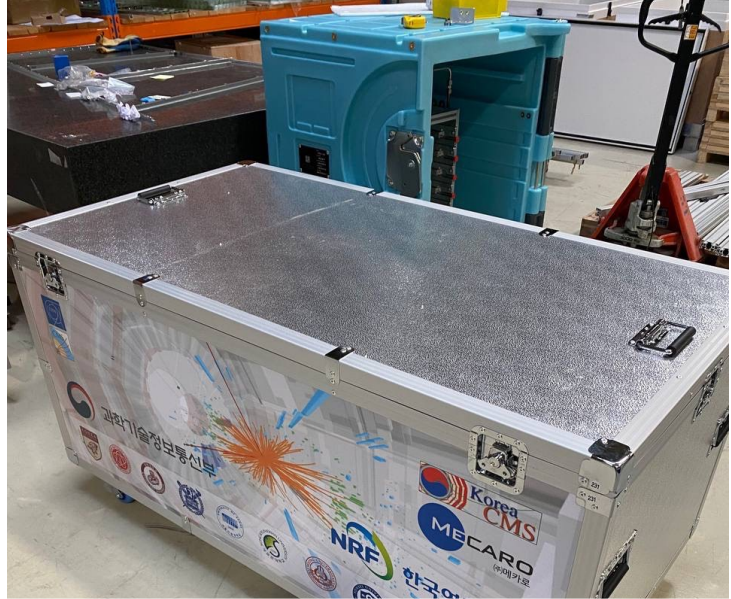


GE1/1 설치 및 운영



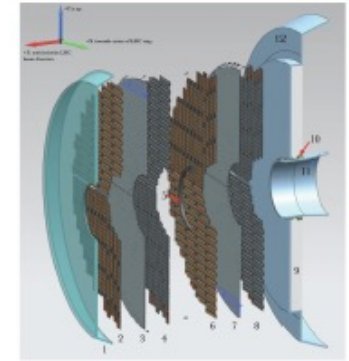
GE21 production

2nd delivery

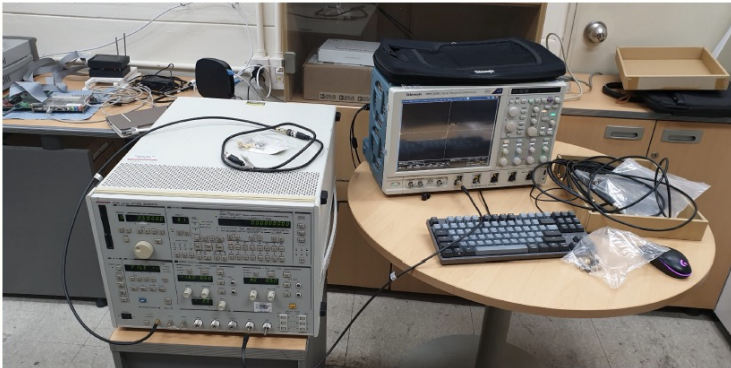


MTD R&D

- 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



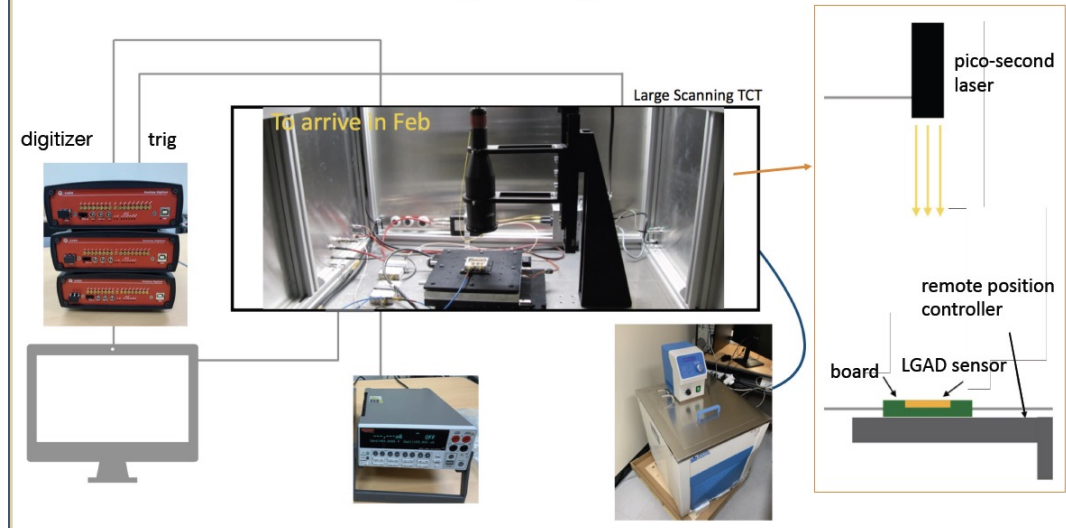
ETROC1 Test set up at KNU



- 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)

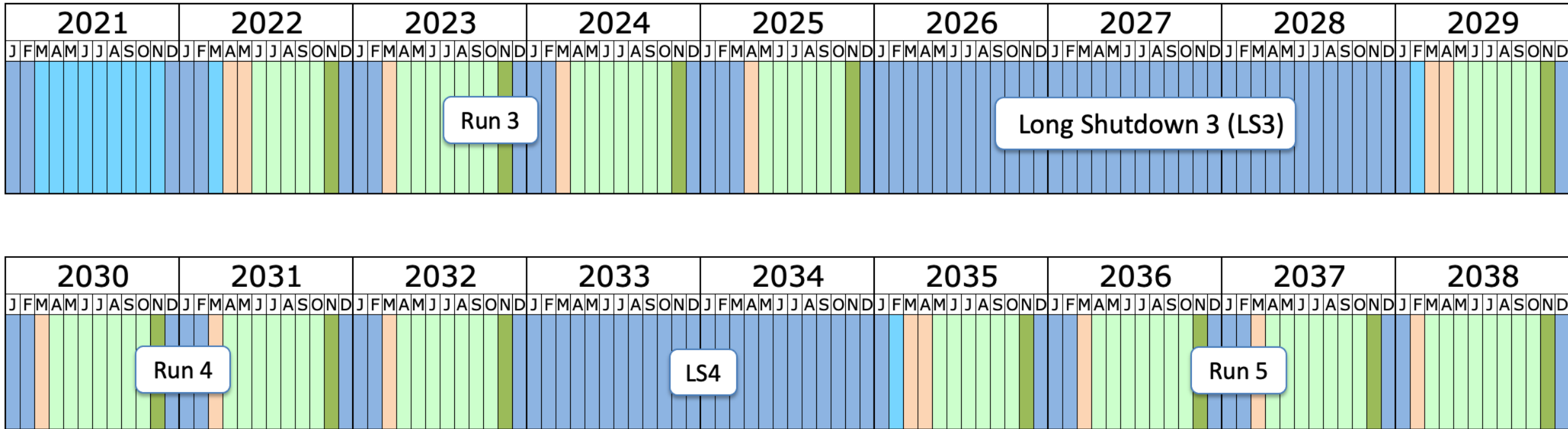
LGAD Sensor testing using laser at KU



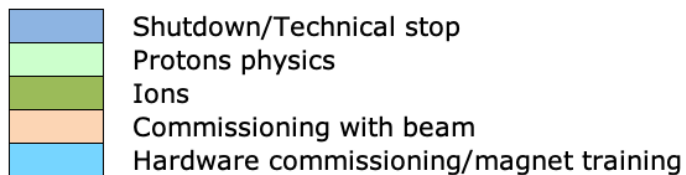
검출기 통합 운영

- HL-LHC를 위한 RPC 묶은 검출기 생산 시작하여 내년 납품 완료 목표
 - 한국 CMS에서 RPC gap 생산 후 Ghent 대학으로 보내고 있음
 - 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
 - 웨이퍼 후 공정 및 LGAD 센서 제작
 - Bump bonding
- 추후 GEM, RPC, MTD 검출기 사업을 하나의 통합된 장소에서 효율적으로 운영하고자 함
 - 엔지니어 및 생산 시설 인프라 공유

Schedule for the future



Last updated: January 2022



- 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