CMS Status

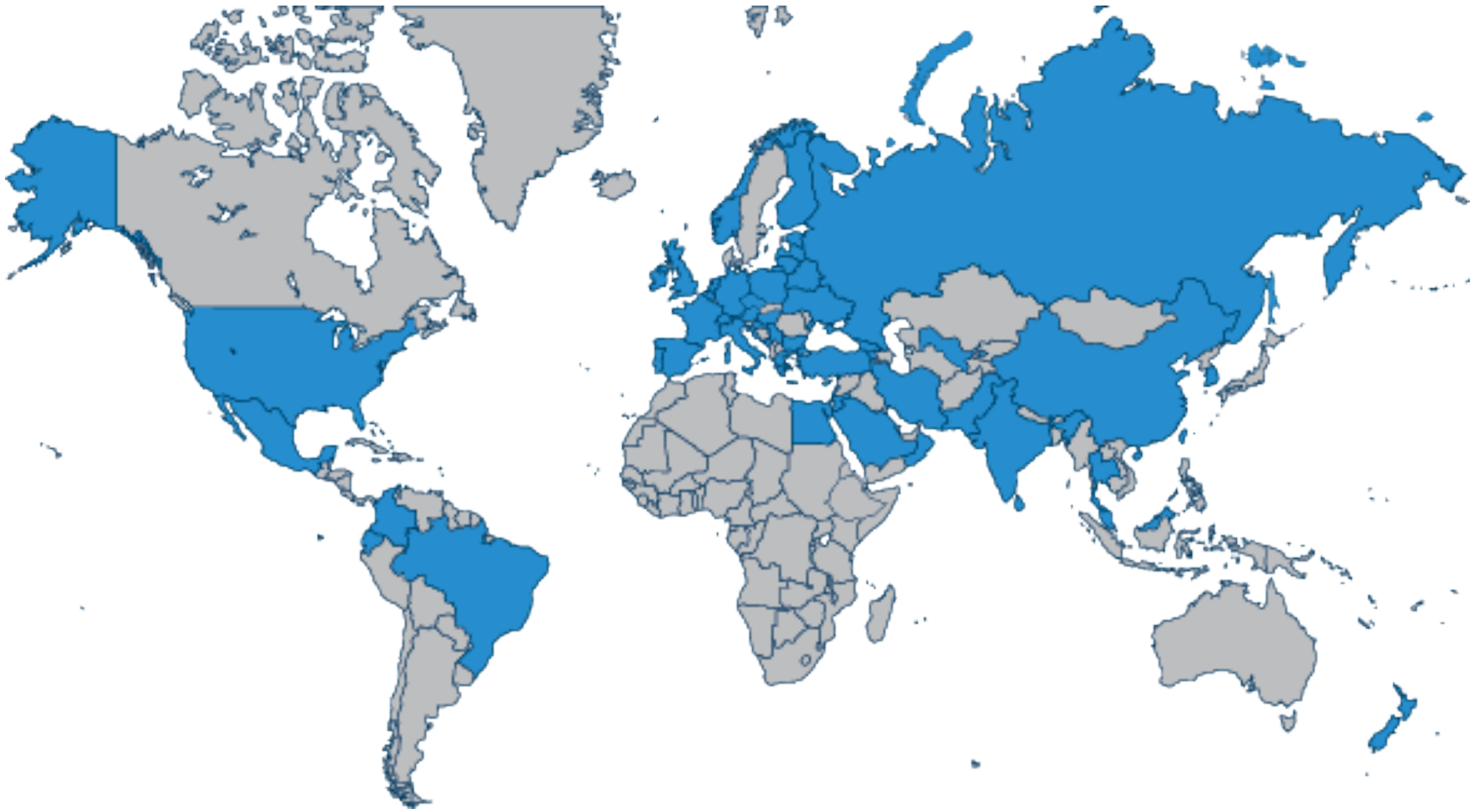
LISHEP - Session C - July 8th 2021

L. Malgeri for the CMS Collaboration

Outline

- The CMS Collaboration
- Long Shutdown 2 (LS2) activities
- Run 3 preparations
- Highlights from recent physics analysis results
- Upgrades for HL-LHC: CMS status

The CMS Collaboration

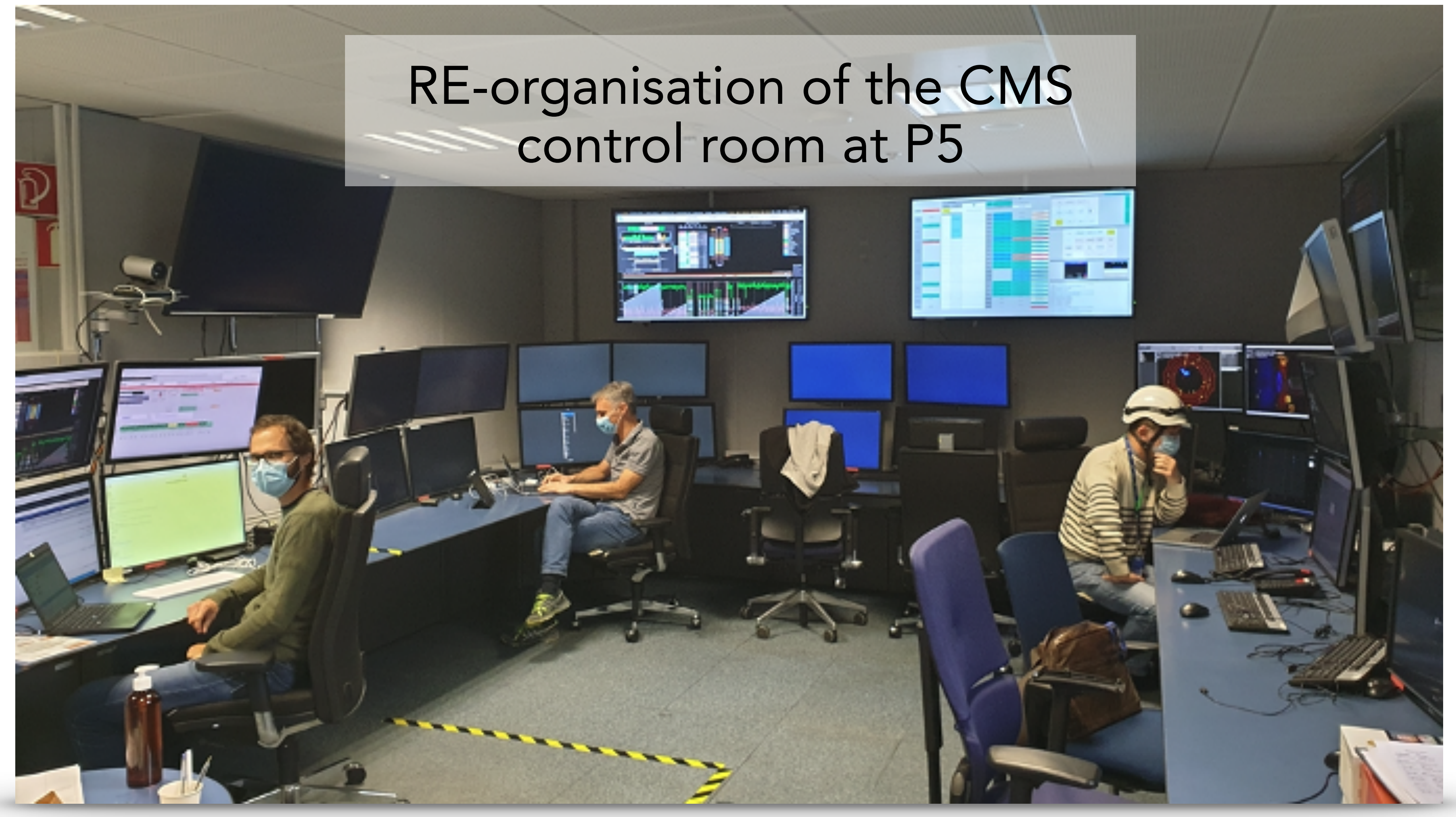


- **241 Institutes** (including 23 Associated and 8 Cooperating) from **54 Countries**
- **2105 authors**
- 1881 PhD physicists
- 1031 PhD students
- 971 undergraduate students
- 1024 engineers
- **5302 members** in total (incl. technicians, theorists, admin.)

COVID effect

- We have now been working for more than a year under Covid-19 restrictions.
- The situation is easing in Europe and US but stays dramatic in other regions of the World where many members of the big CMS family live. Brazil is one of them. The personal and social tolls are immense.
- We look forward hoping that that the vaccination campaigns will be effective and will lead all of us out of this emergency.

- In CMS we are continuously monitoring the effect on our activities.
- The dedication and expertise of our community allowed to keep the delays to a minimum:
  - between 3 to 8 months delays in LS2 and Upgrades activities, respectively
  - the current paper production rate and the physics publications planning is sustained
  - many colleagues "keep up" with overtime work and increasing stress level
  - others with less favourable social conditions are severely affected
    - This is a risk we cannot accept and with long term consequences



LHC Timeline

LHC Timeline

Next slides on:

- Long Shutdown 2 activities
- Run3 preparation
- Recent physics results on Run2

LS2 activities

LS2 = Long Shutdown 2 since 2019
Collisions to return mid 2022

Strip tracker
- kept cold to avoid reverse annealing (but warmed during beam pipe bake-out)

HCAL
- completion of Phase-I upgrades

Pixel detector
- replace first barrel layer
- replace all DCDC converters

Magnet
- at room temperature since mid 2020
- maintenance work: free wheel thyristor, cryo-cooling, power, pumps, etc.

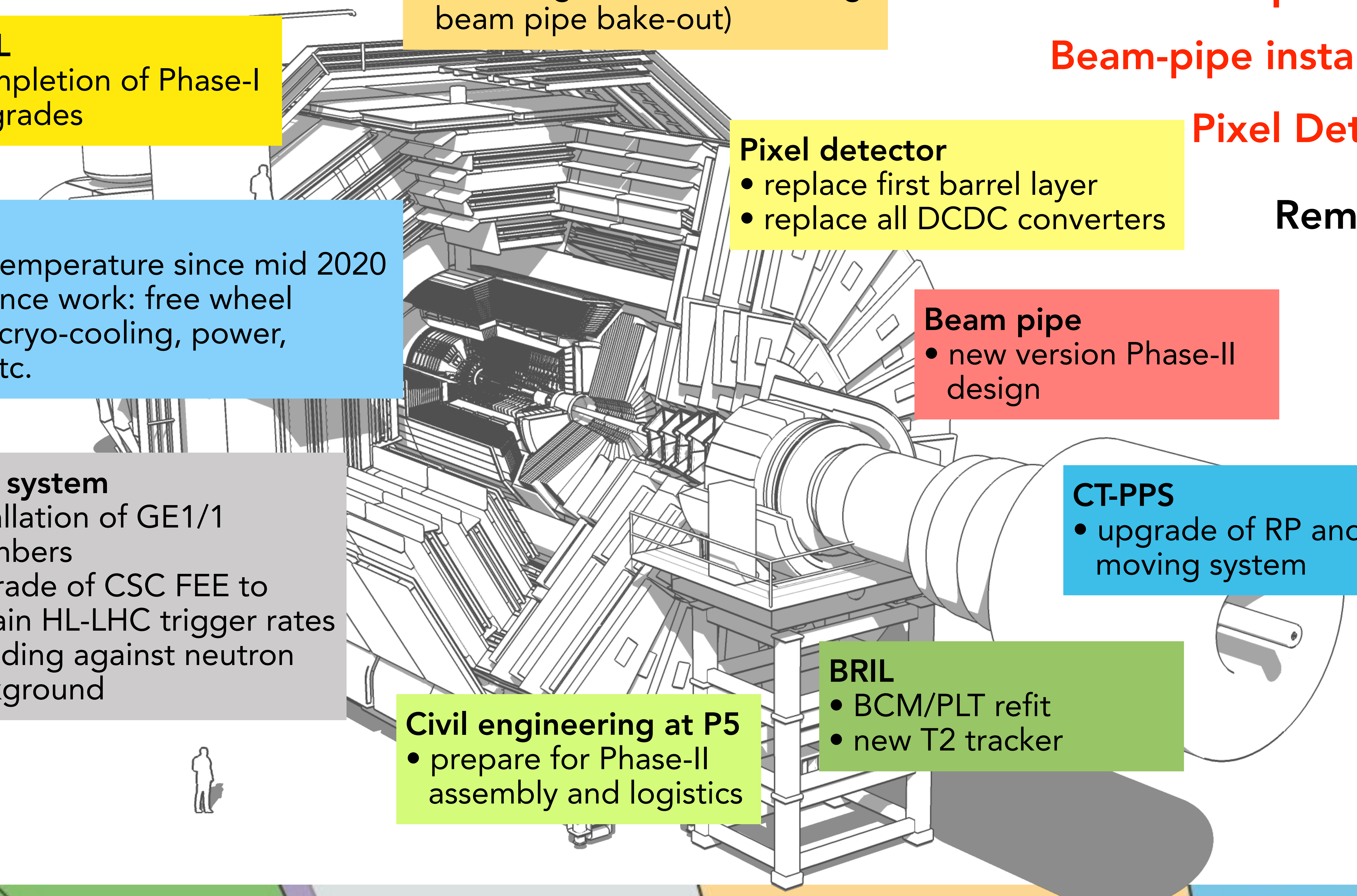
Beam pipe
- new version Phase-II design

Muon system
- installation of GE1/1 chambers
- upgrade of CSC FEE to sustain HL-LHC trigger rates
- shielding against neutron background

CT-PPS
- upgrade of RP and moving system

BRIL
- BCM/PLT refit
- new T2 tracker

Civil engineering at P5
- prepare for Phase-II assembly and logistics



Work on HCAL Barrel (SiPM readout) completed in Oct. 2019

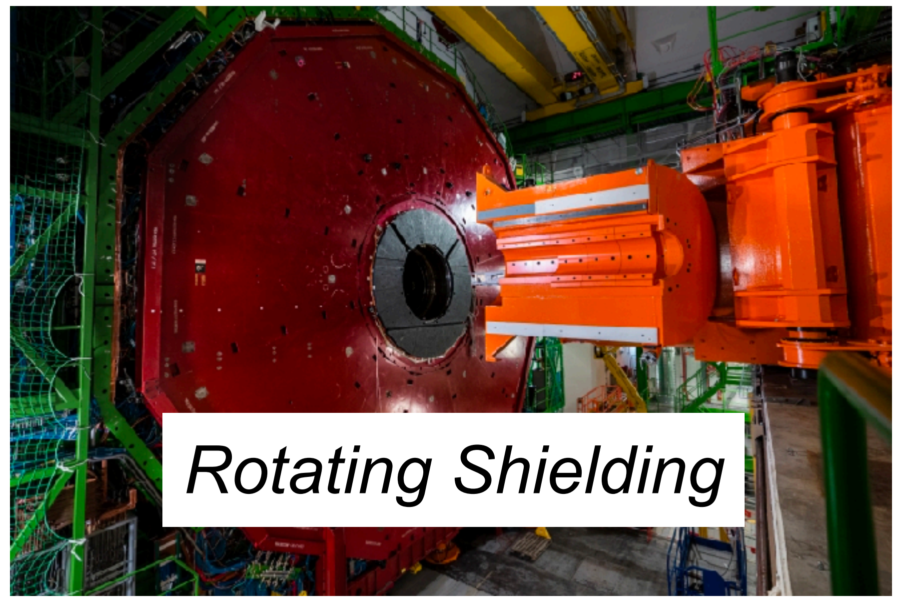
Muon critical path completed in Dec. 2020

Beam-pipe installation and bake-out completed in May 2021

Pixel Detector installation completed in June 2021

Remaining activities:
- yoke closing (starting mid July)
- magnet restart (3.8T) and tests
- comics runs at ~4T (CRAFT, 24/7)

After Pilot Beam Test in Oct 2021
- Phase-II muon demonstrators
- new forward shielding

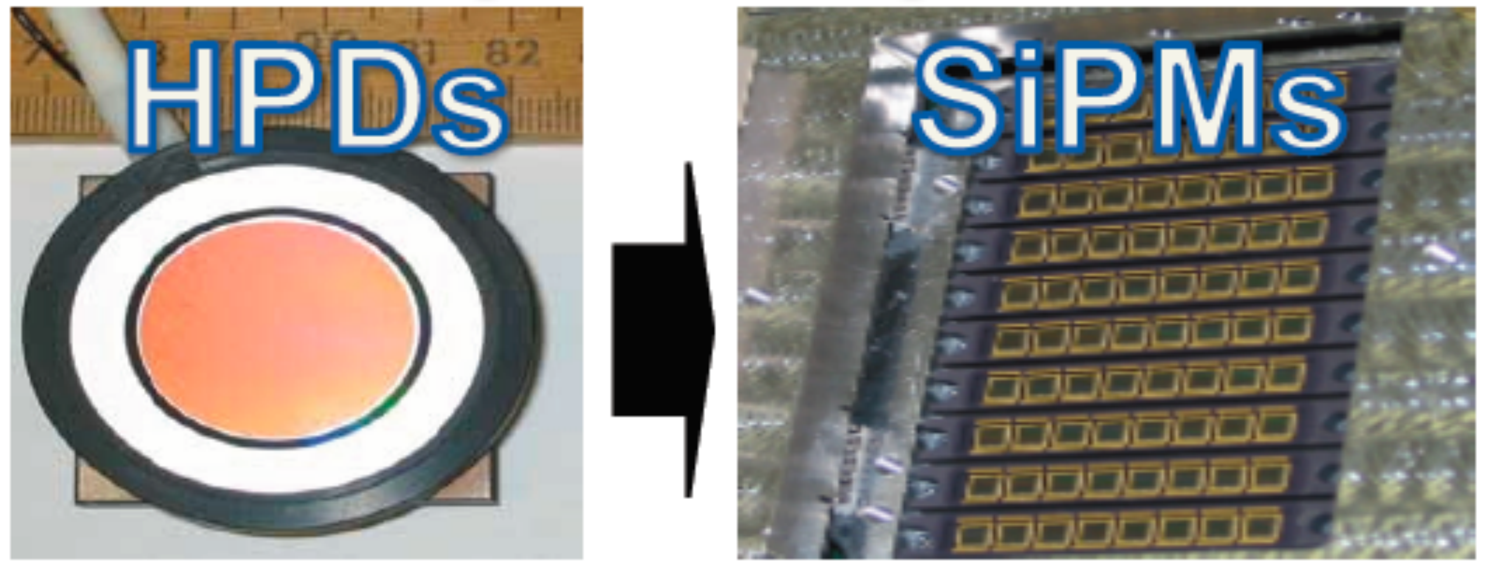

Rotating Shielding

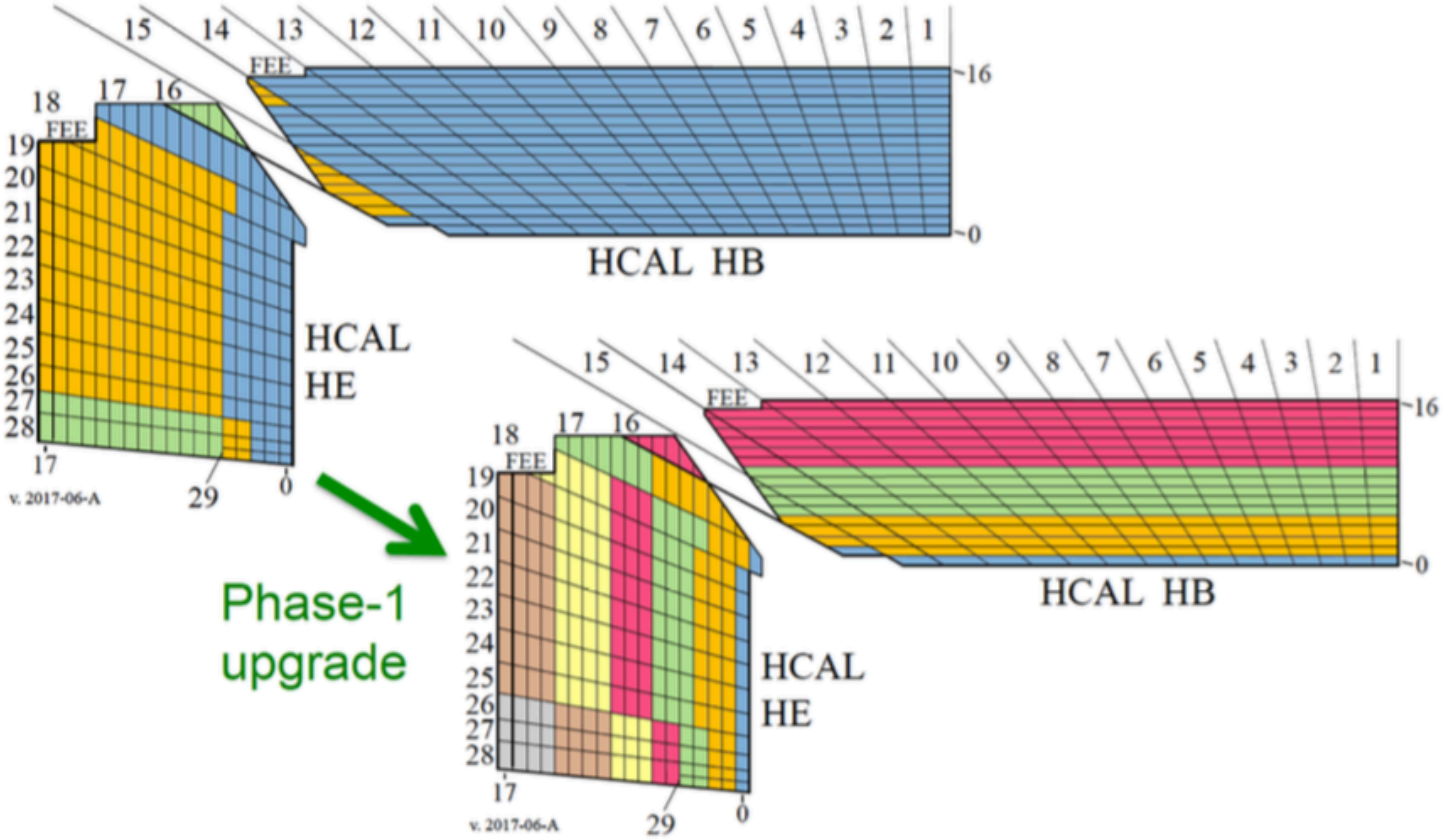
Few LS2 highlights: Hadronic Calorimeter

New HCAL SiPM readout

- improved longitudinal segmentation
- improved photon detection efficiency

HE/HB: improved photosensors

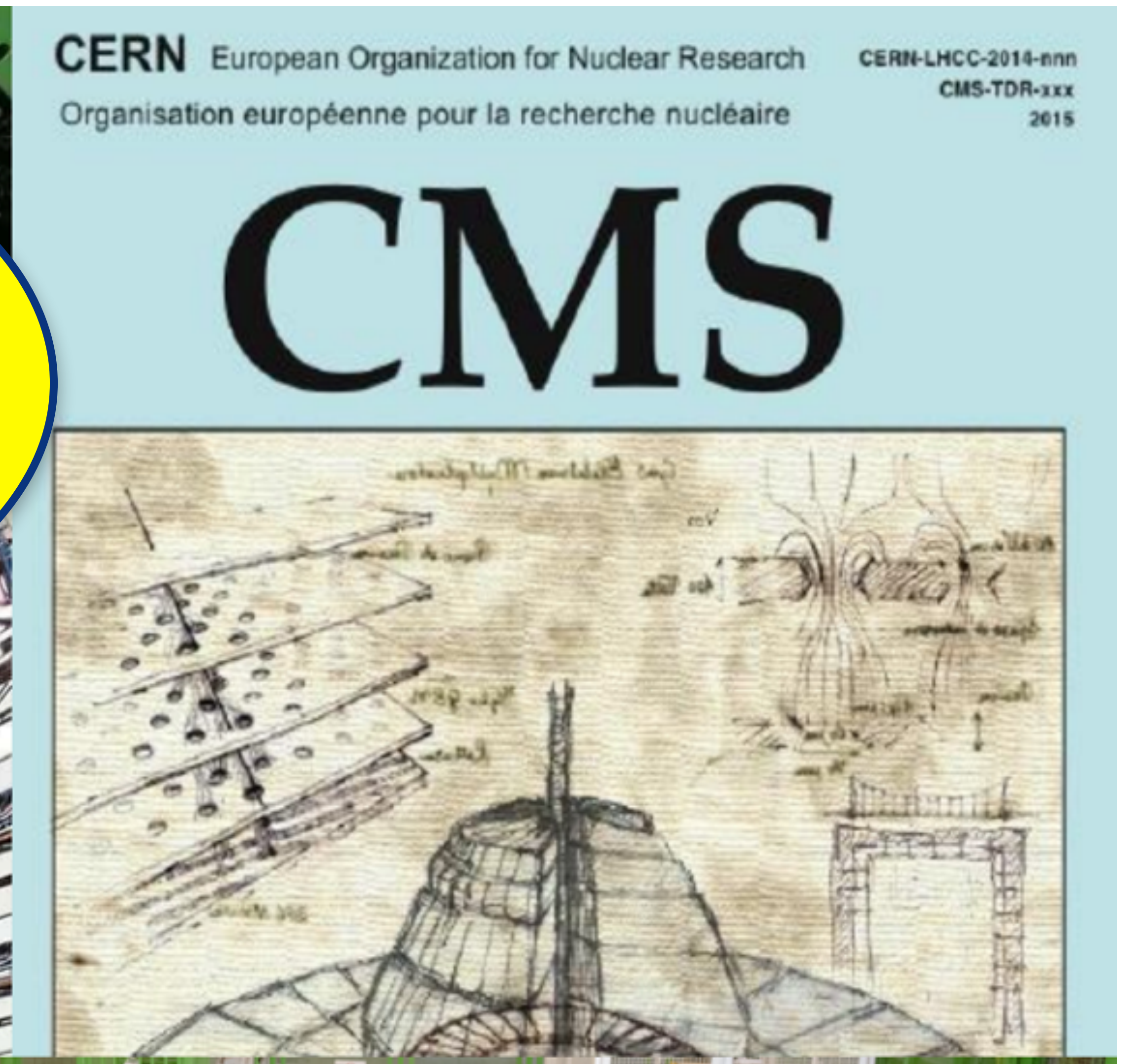




Few LS2 highlights: new Muon detector

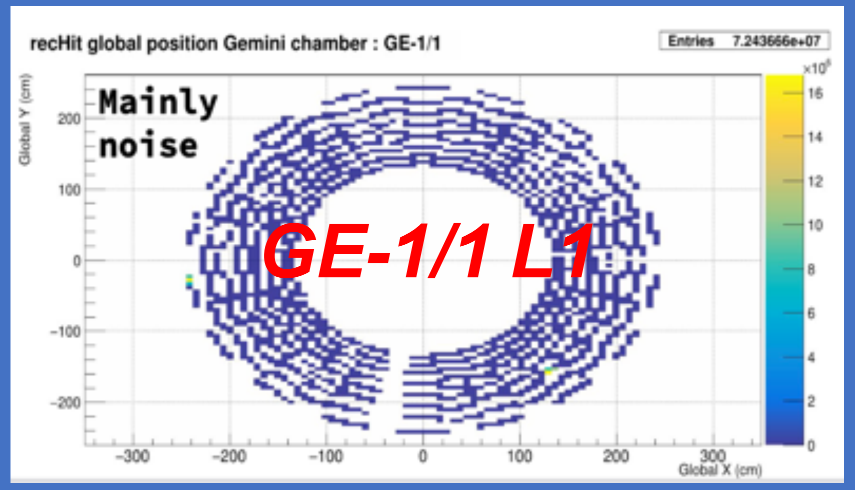
GEM (GE1/1) installation completed in 2020.
First phase2 detector installed!

Important milestone for CMS collaboration as the first complete Phase II Upgrade detector, with a brand new detector technology, the GEMs, complementing the Muon system



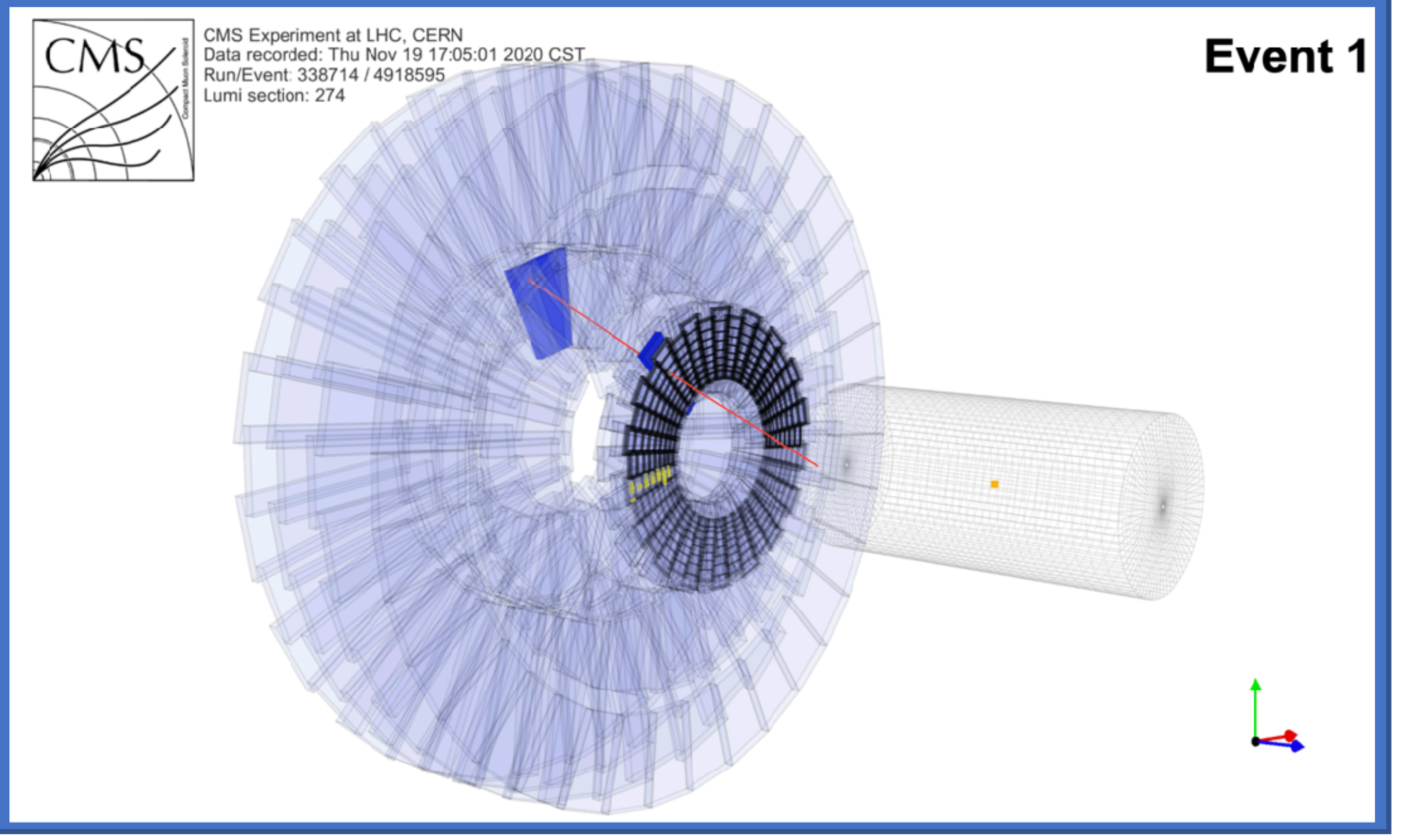
GEM

Commissioning and analysis of cosmic data



masked

➢ **MWGR#5:** First muon



Few LS2 highlights: new Beam Pipe

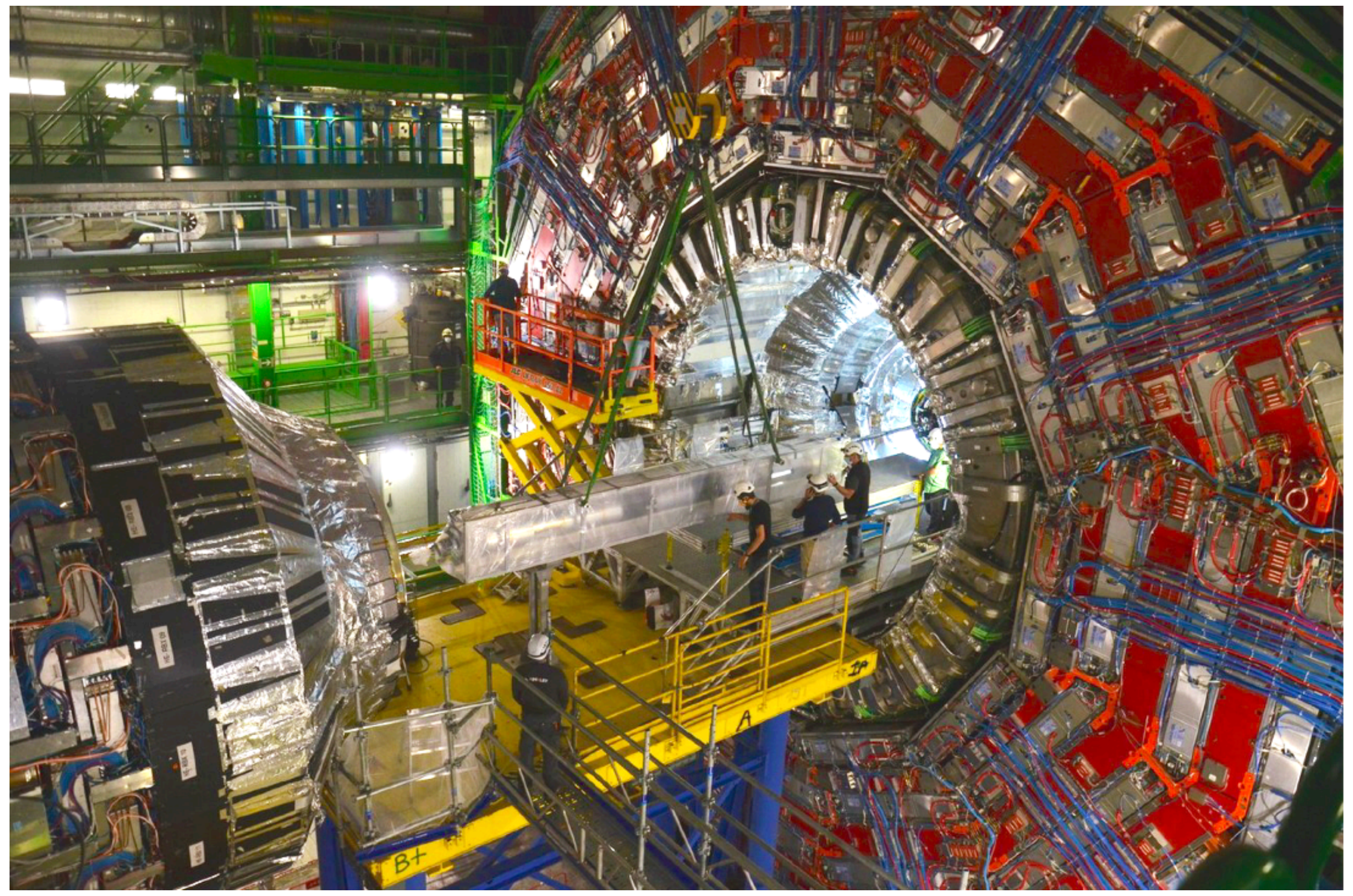
New CMS beam pipe for Phase-II

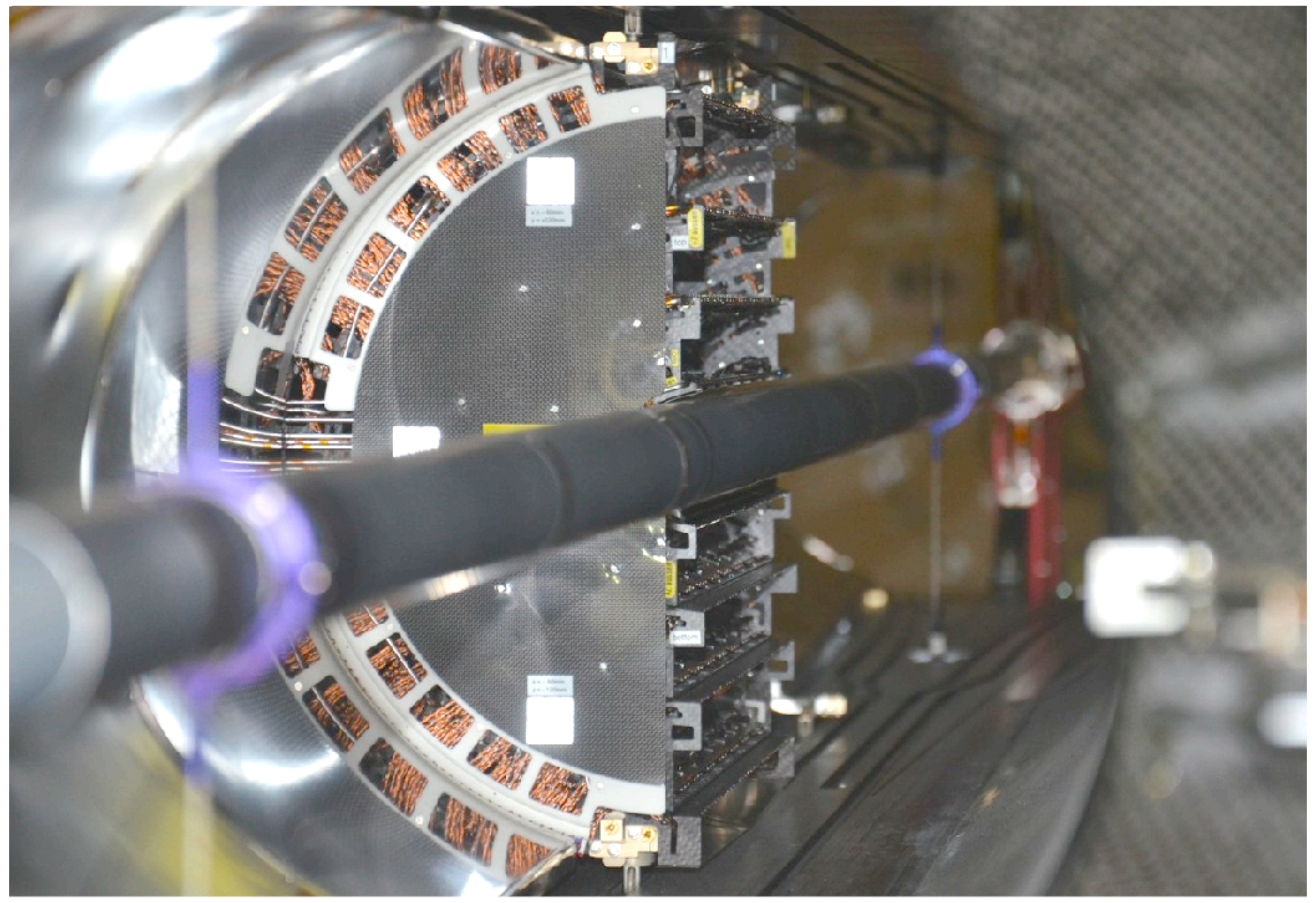
- installation complete, fully aligned and leak tested
- bake-out completed

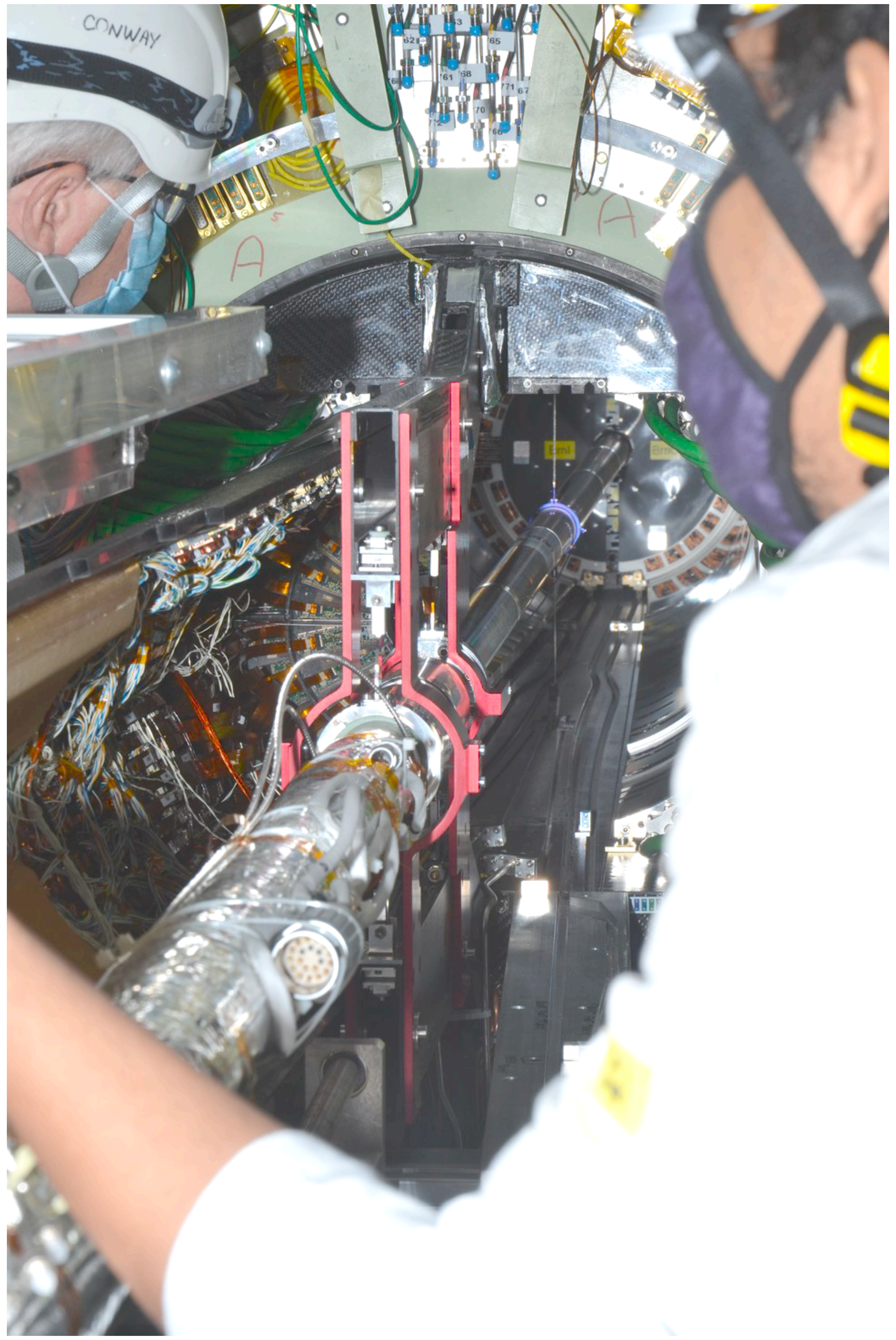
Few LS2 highlights: PIXEL detector

Fully-refurbished pixel detector

- new BPIX layer 1: new chip with lower thresholds and better radiation tolerance
- replacement of DCDC converters
- Breaking news: installation just finished last week: checkouts are going on.







CERN Live Event on June 29, just after FPIX installation (with pre-recorded footage of BPIX installation)

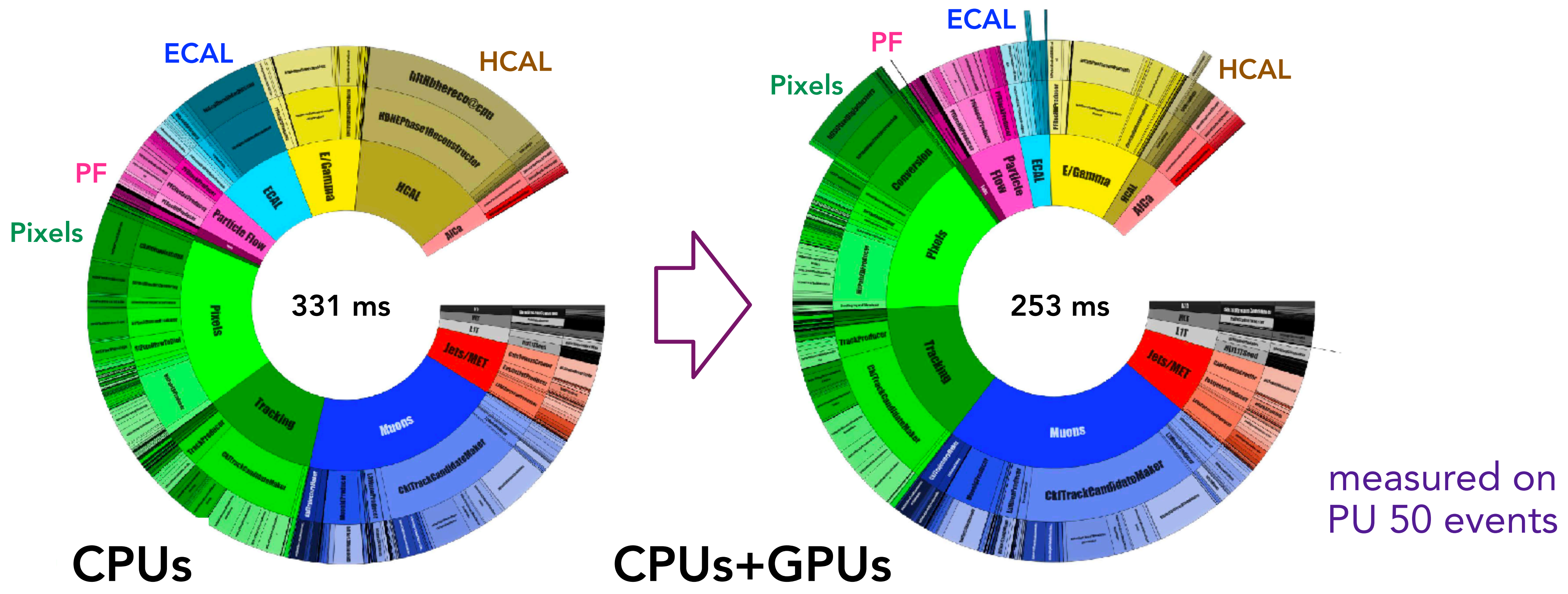
Run3 preparation

Run 3 will not be just a luminosity increase for CMS.
Several improvements planned and exploration of new phase space.

Moving to heterogeneous architecture in High Level Trigger, with mixed CPU/GPU:

- already achieved 25% reduction of CPU time
- opens new possibilities for trigger algorithms leveraging on GPUs
- a testbed for HL-LHC Computing and triggering

Heterogeneous online reconstruction

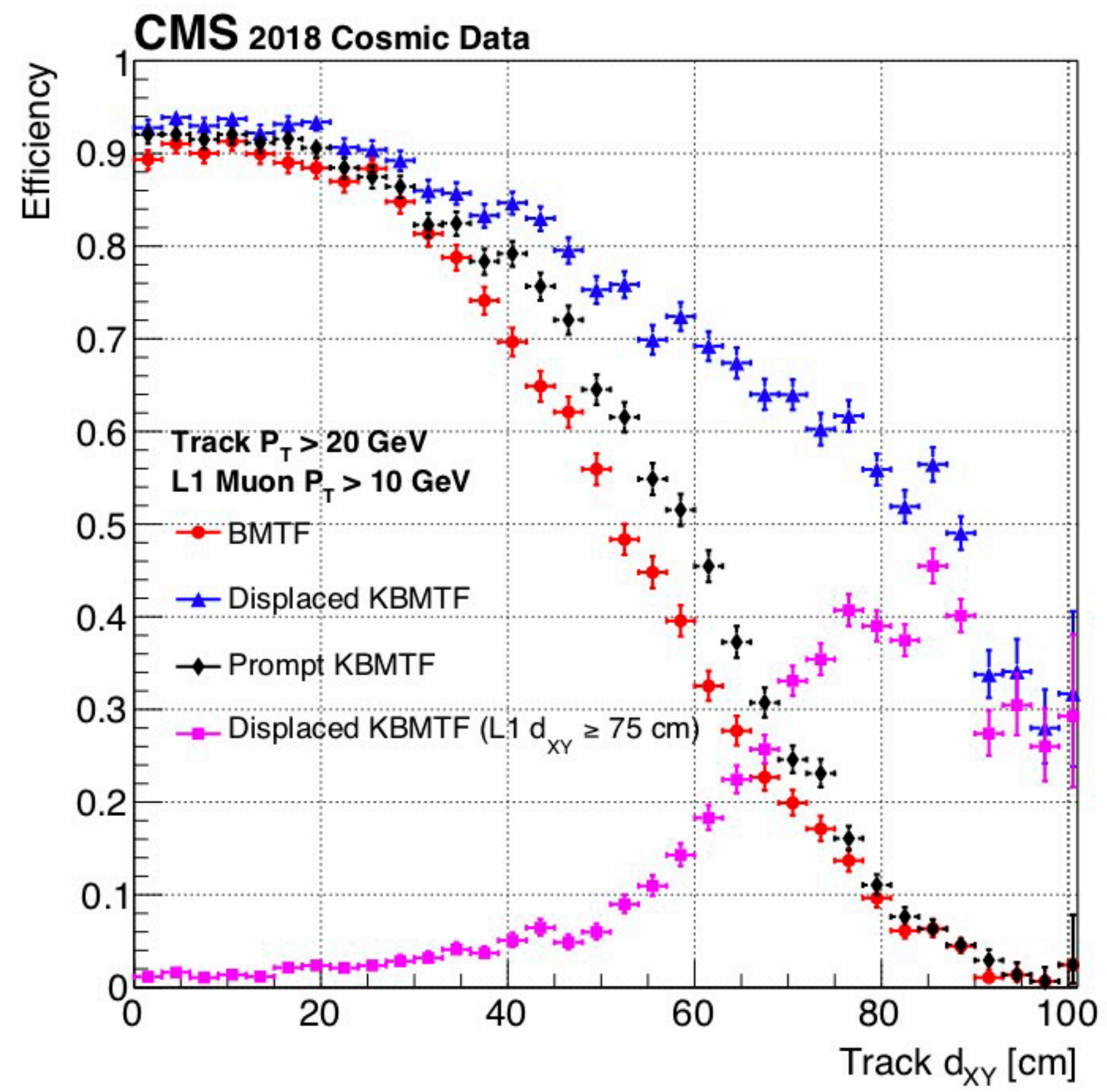


New phase-spaces:

- increase data scouting and data parking
- dedicated and improved long-lived particle triggers
- extensive use of ML techniques

L1-Muon trigger

- Kalman track finding for displaced muons



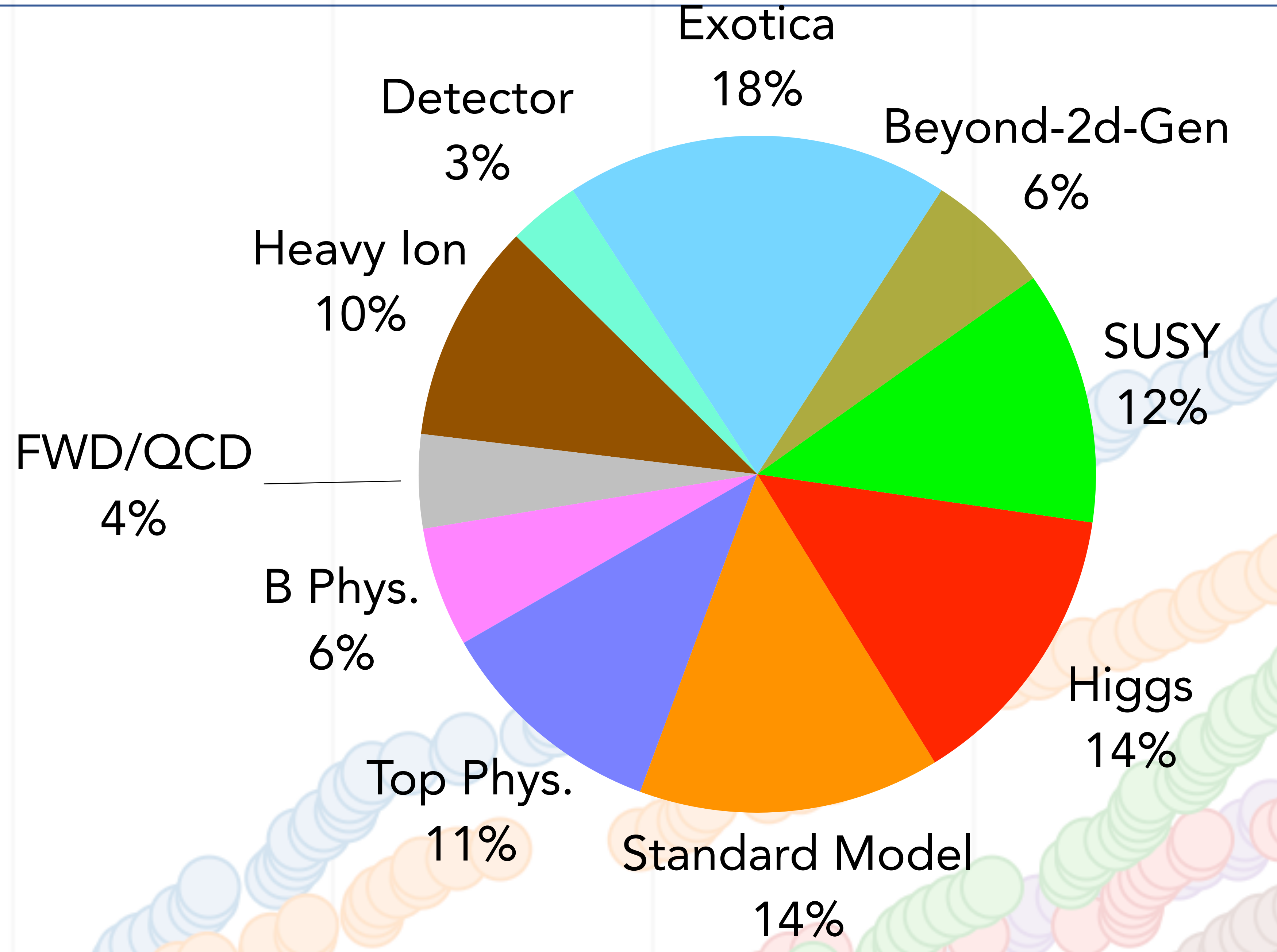
Computing and Offline software

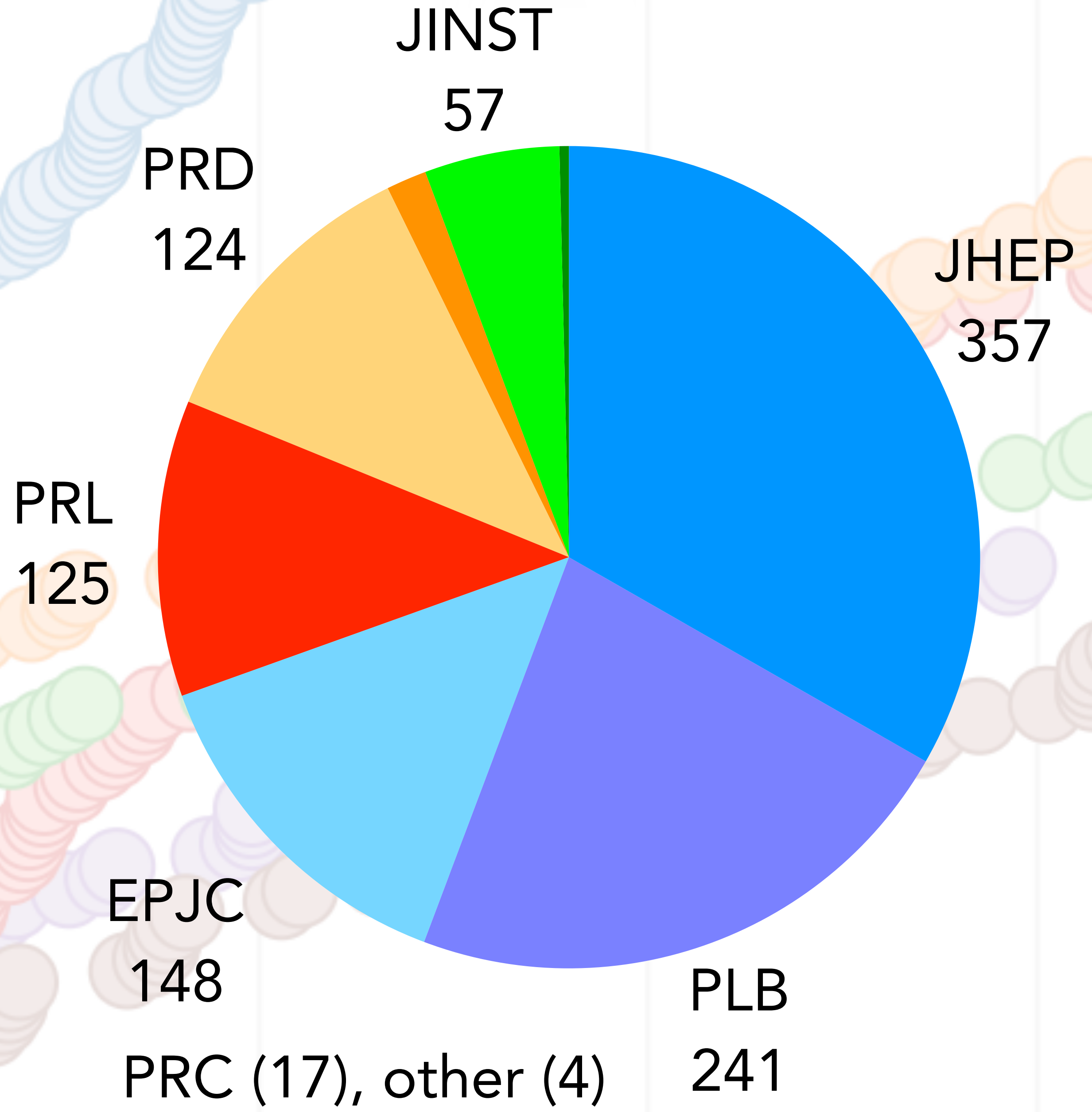
- increased use of opportunistic computing
- 10% faster full simulation
- improved fast simulation

Highlights from Physics results

Publications status

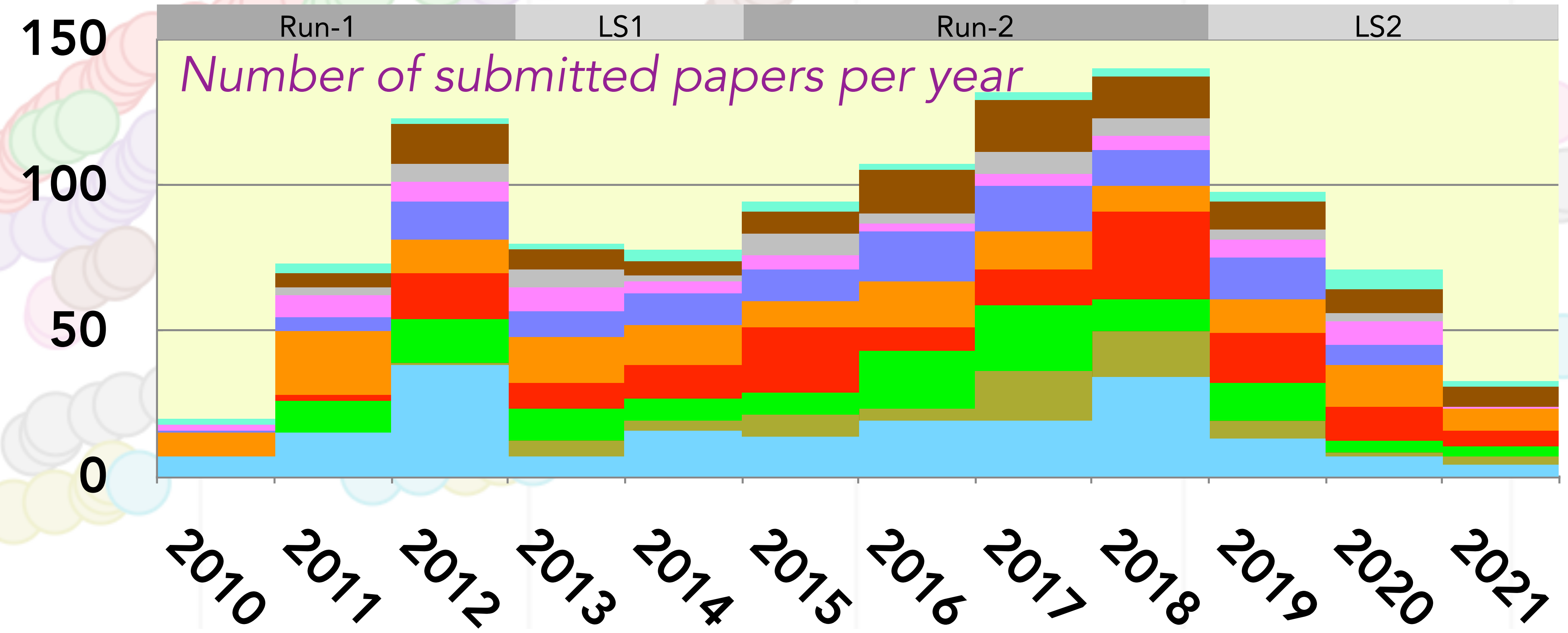
1048 papers based on **collision data**
(+25 on cosmic data)
- **1018** published
- 574 based on Run-1 data
- 474 based on Run-2 data





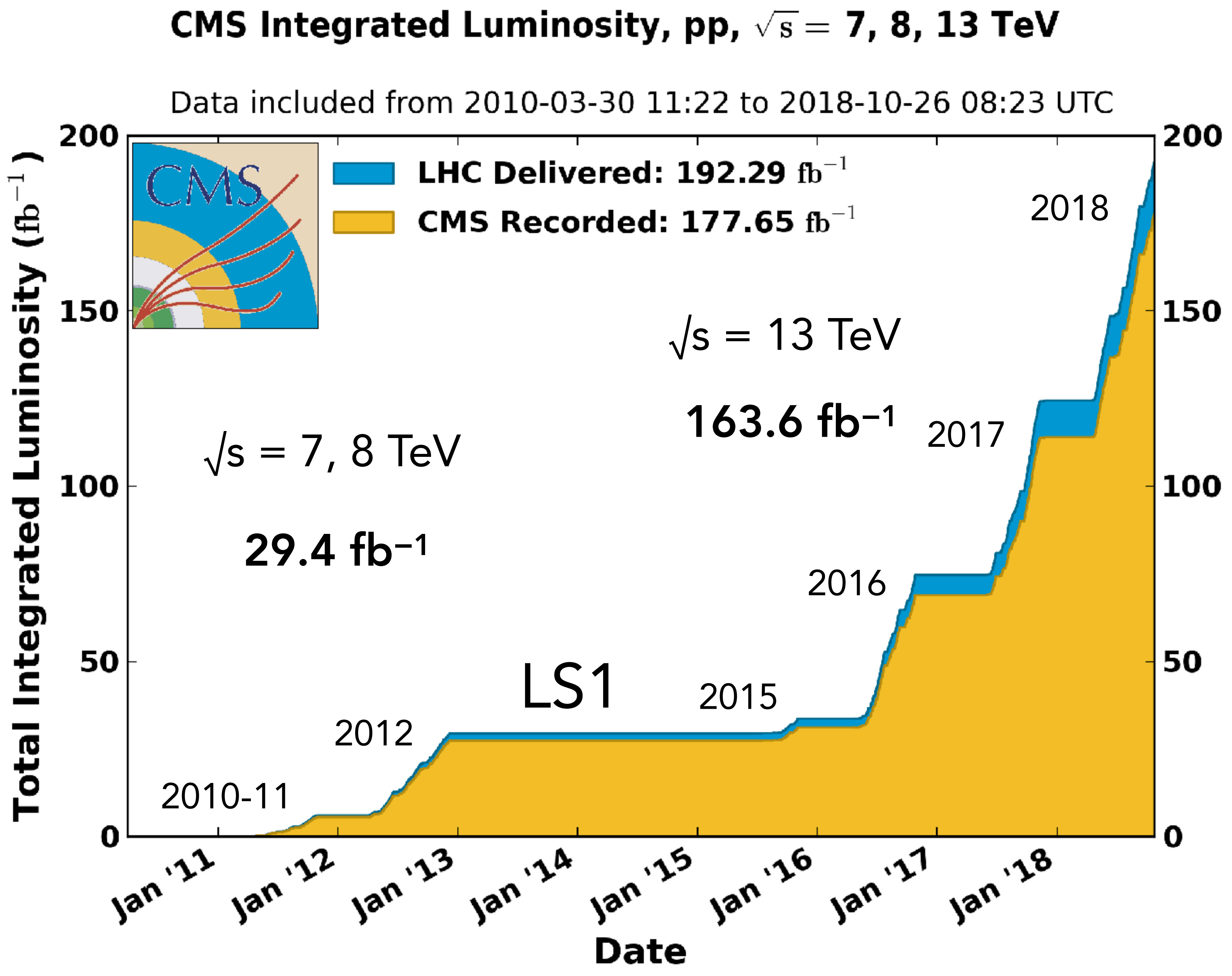
CMS titles
- 530 "Search for"
- 39 "Observation"
- 18 "Evidence"
- 309 "Measurement"

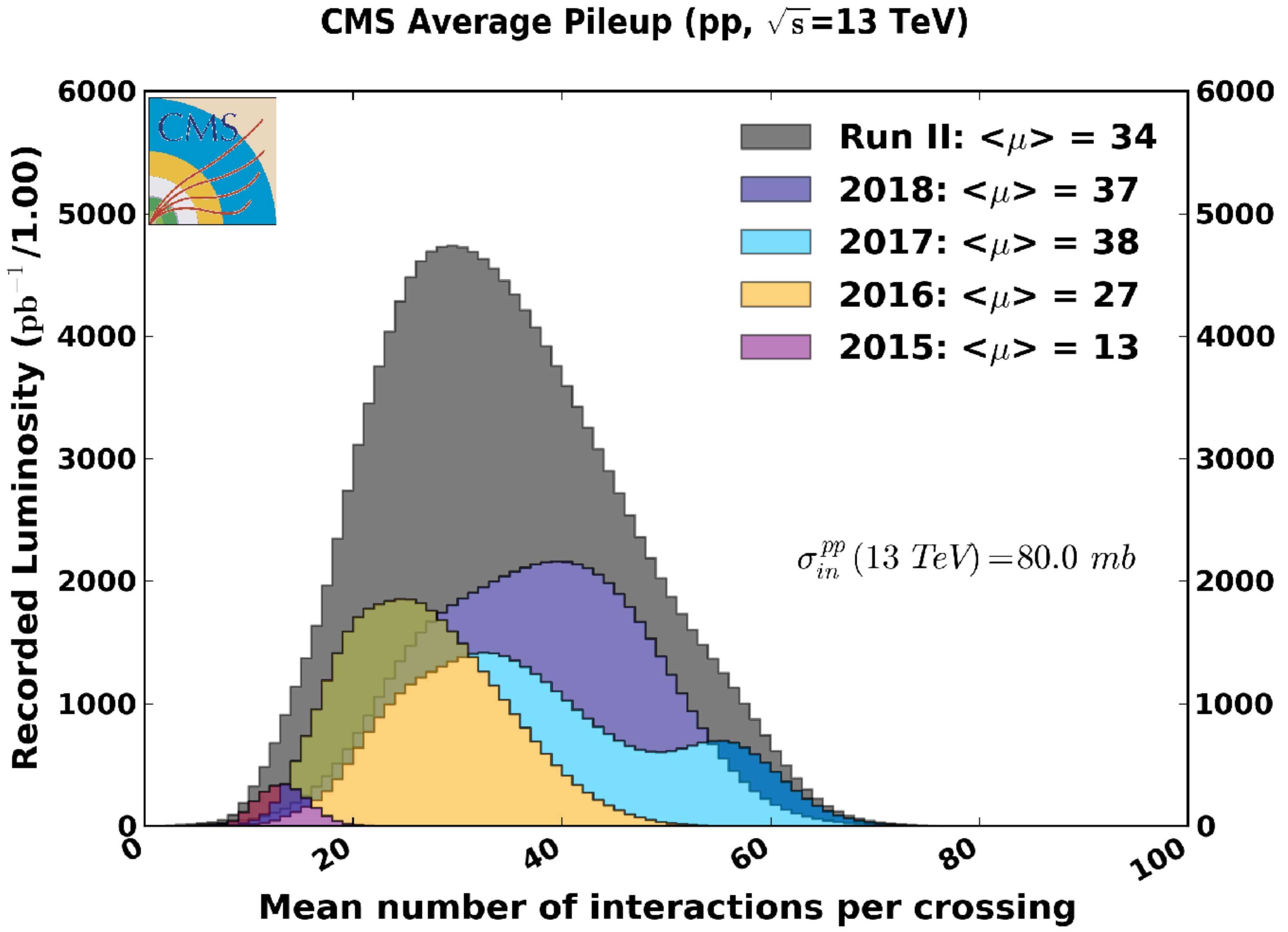
CMS with friends
- **ATLAS**: 5 (4 JHEP, 1 PRL)
- **LHCb**: 1 (Nature)
- **Totem**: 3 (1 JHEP, 2 EPJC)



As of July 1, 2021

Data Taking





CMS Dataset Run-2

- 2016-2018: **137 fb^{-1}** of pp data “good for physics”
- data-taking efficiency > 92% (2018: 94%)
- number of pp interactions per beam crossing (PU): <μ> = 34

CMS Triggers for Run-2 (1.6 kHz)

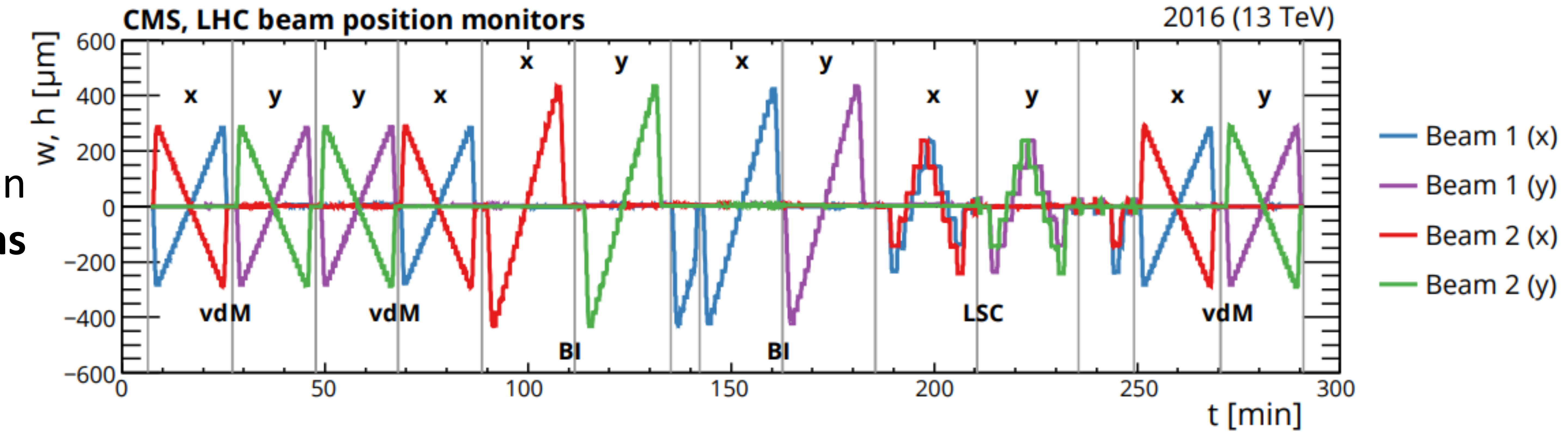
- Standard triggers (leptons, jets, MET)
- **B-parking triggers** (up to 5 kHz)
  10B events enriched in un-biased B decays
- Scouting triggers: reduced events with physics objects

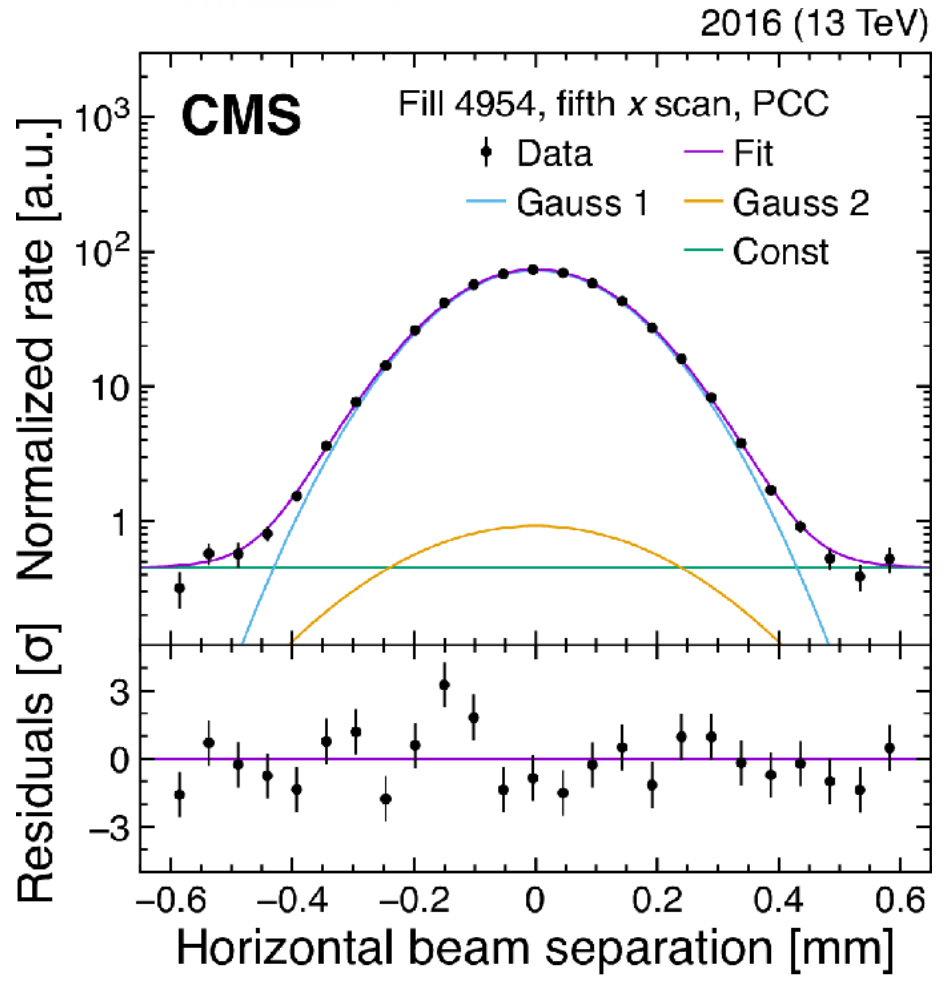
First paper on Precision Luminosity Measurement

CMS-LUM-17-003
Submitted to EPJC

Absolute luminosity scale measured for individual bunch crossings

beam-separation
van der Meer scans



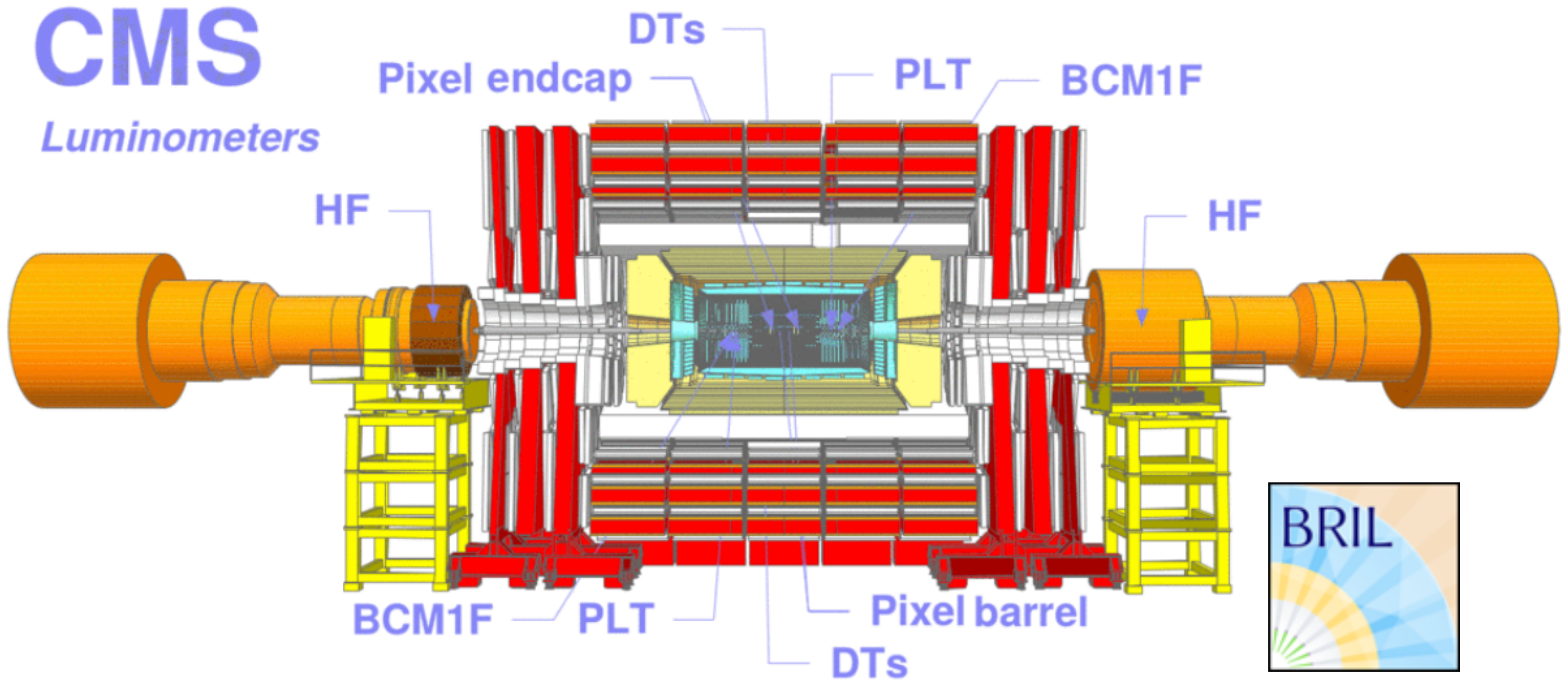


Obtained **relative precision**

- **1.6% in 2015** (2.2 fb^{-1})
- **1.2% in 2016** (36.3 fb^{-1})

Main sources of uncertainties

- differences between measured beam positions and the ones provided by the LHC
- factorizability of the transverse spatial distributions of proton bunches
- modelling of interactions among protons in the colliding bunches



PLT *= Pixel Luminosity Telescope*
BCM *= Beam Conditions Monitor*
HF *= Forward Hadron Calorimeter*
PCC *= Pixel Cluster Counting*

And also:
- 1.9% in 2017 at √s = 5.02 TeV (302 pb^{-1}) CMS-PAS-LUM-19-001

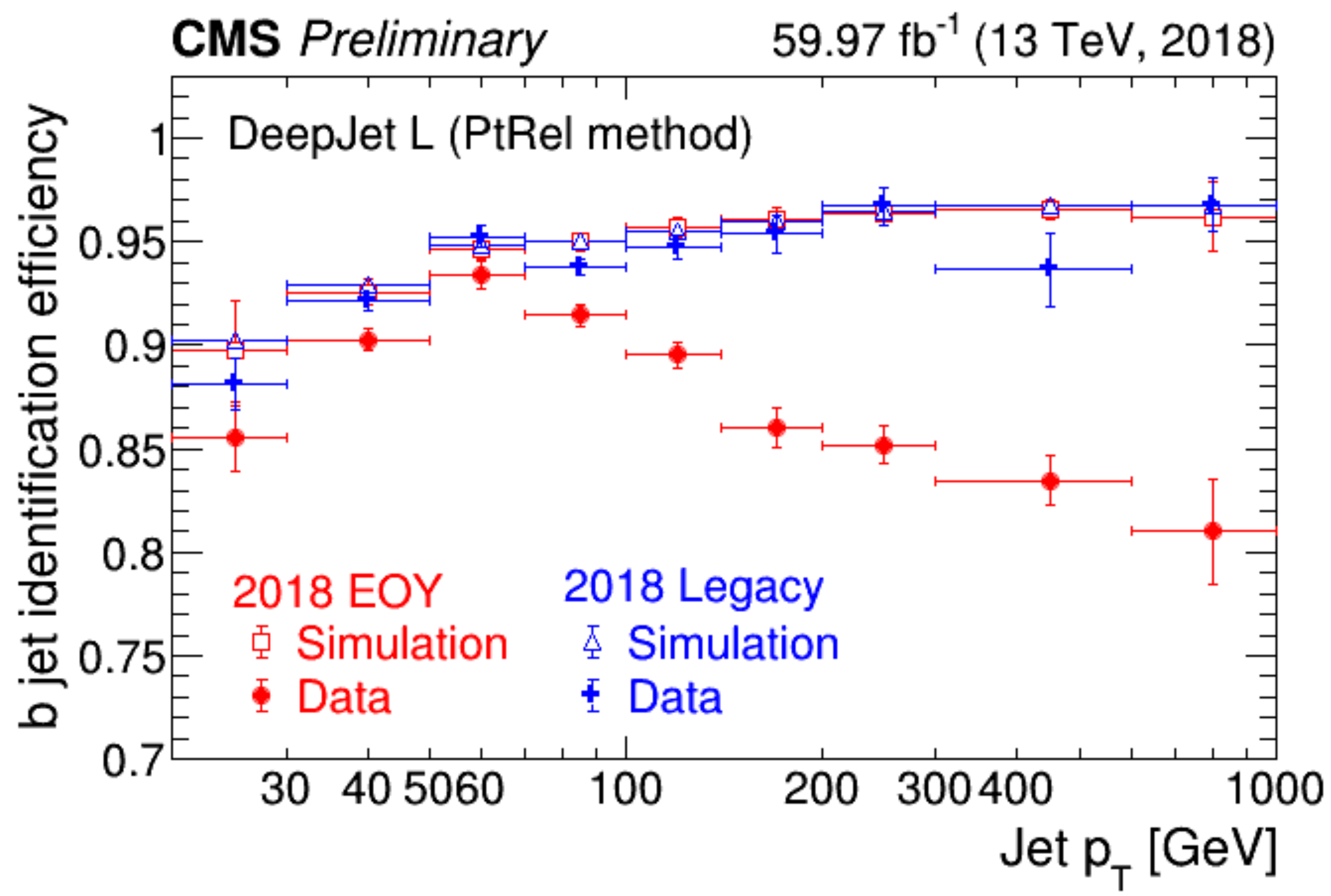
Physics enablers:

- we just completed a “legacy” reprocessing of all Run2 data aiming at best calibration and alignment for future analyses
- we are moving to machine learning (ML) methods for many of our object reconstruction/ID and analysis techniques

Physics enablers: recent examples

B-jet performance in Legacy reconstruction using Deep Neural Networks

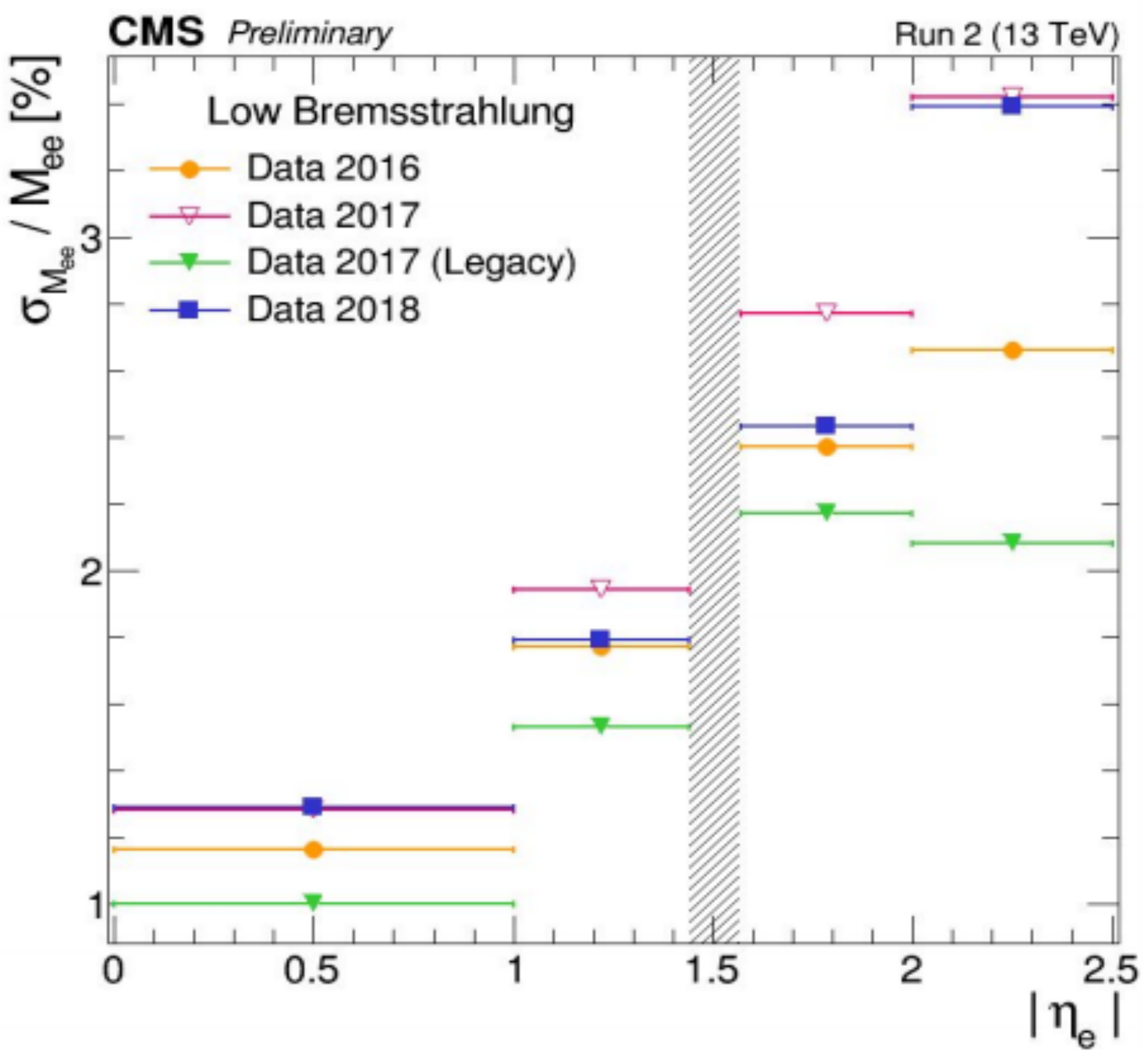
CMS-DP-2021-004

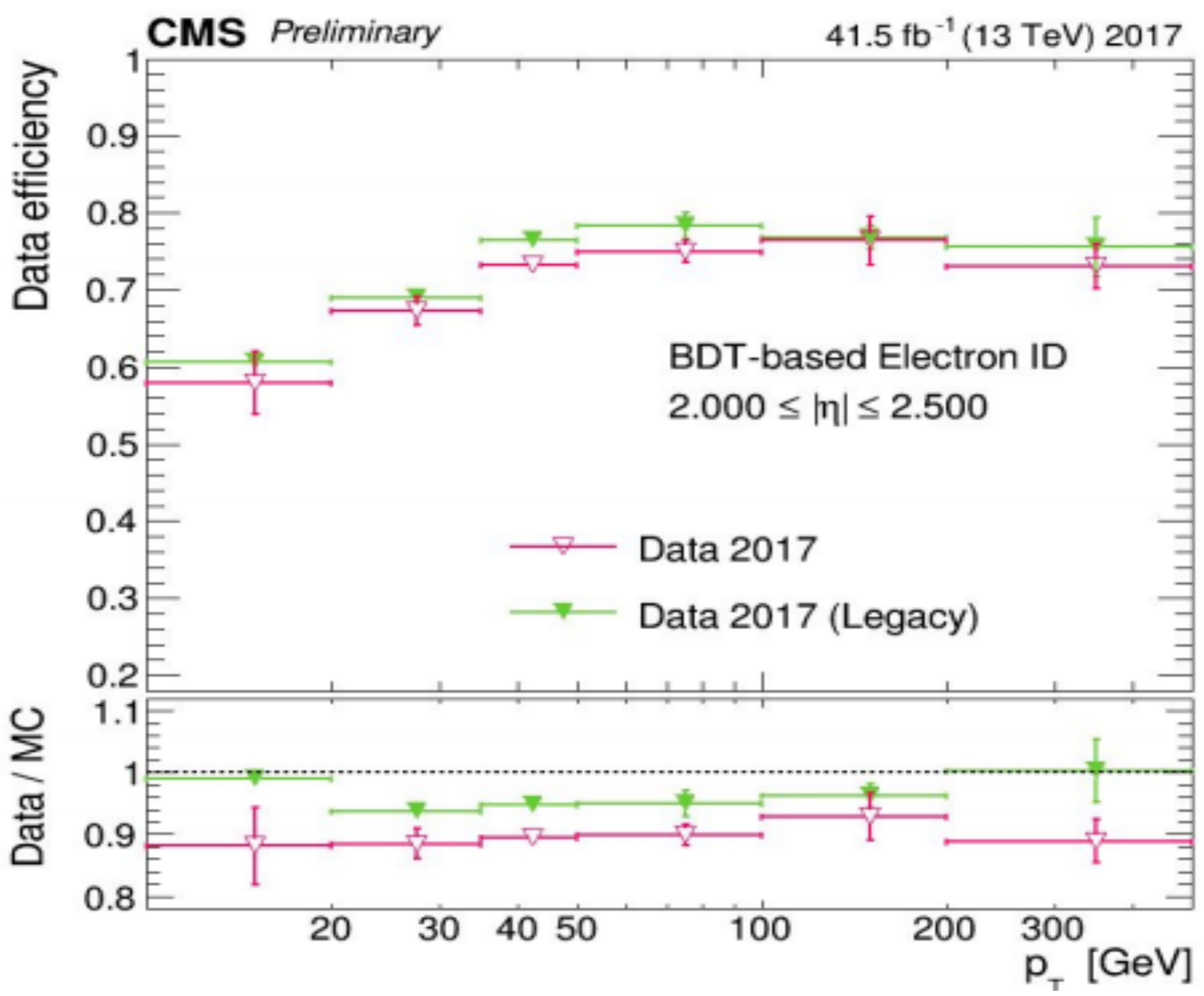


Improved efficiency observed for data in Legacy w.r.t End-Of_Year reconstruction over a wide range of jet p_T.

Measured performance for electrons and photons with Legacy reconstruction for 2017

CMS-DP-2020-037





Different ways to search for New Physics

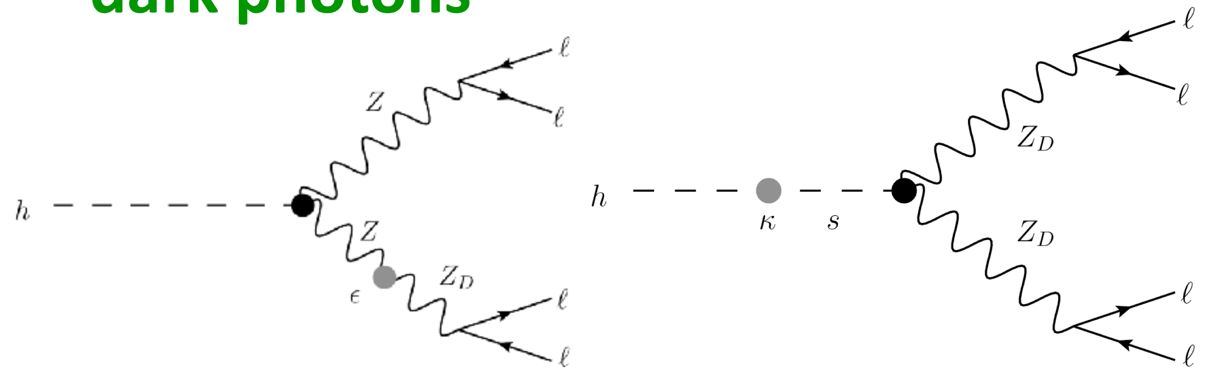
Exploring new data taking paradigms

Displaced dimuon resonances in scouting data

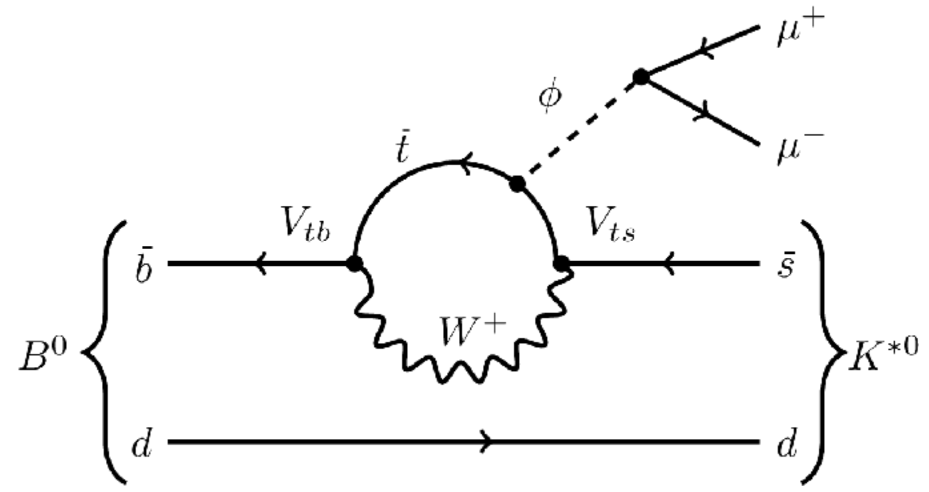
CMS-PAS-EXO-20-014

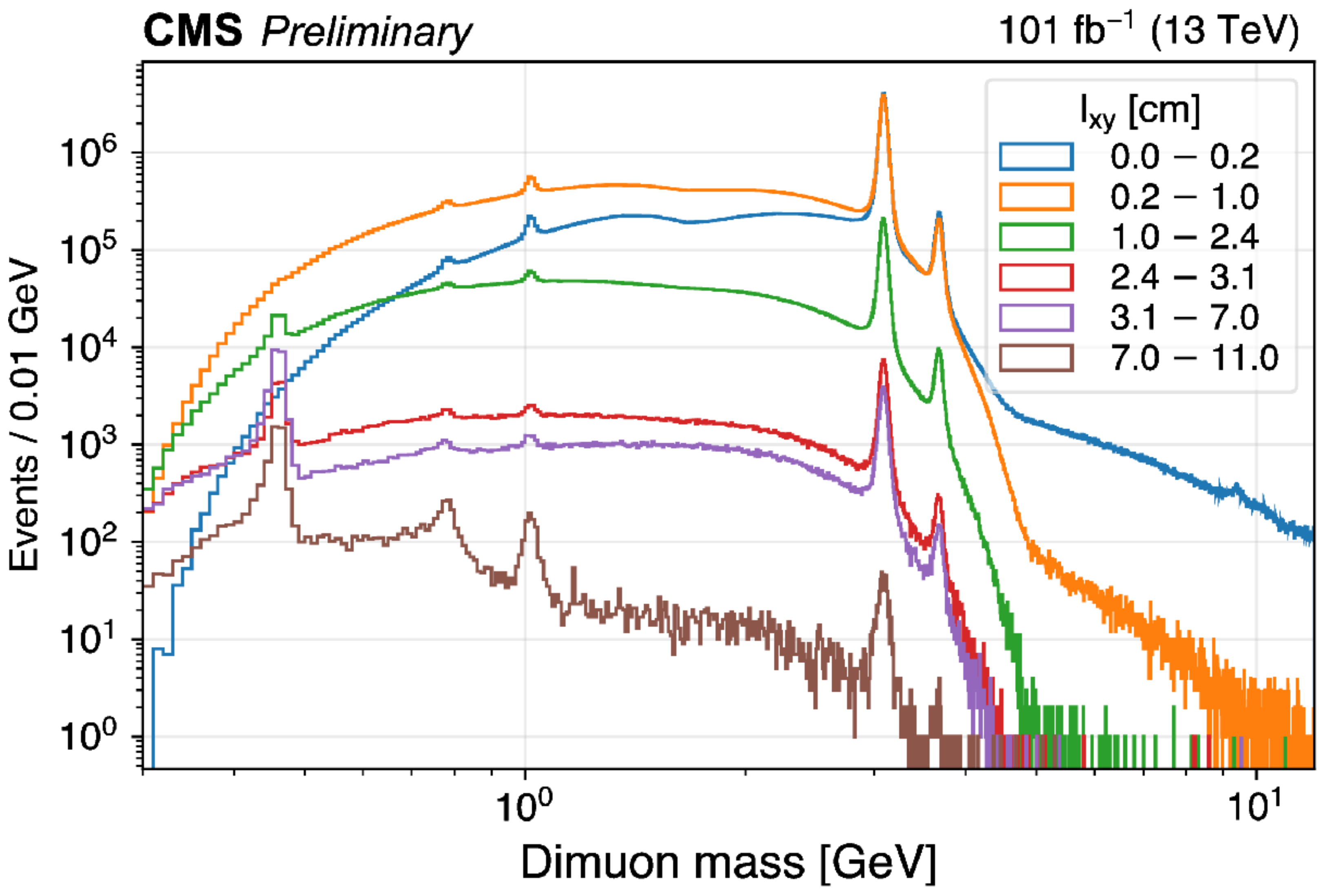
- Use low threshold dimuon triggers reconstructed at HLT level in real time (scouting data) to search for a displaced dimuon mass peak
- No excess found in data and exclusion limits derived in different models and for different lifetimes from 10^{-1} to 10^{4} mm and masses from 0.3 to 50 GeV
- Most stringent constraints to date in a wide range of signal mass and lifetime hypotheses

Production through one or two long lived dark photons

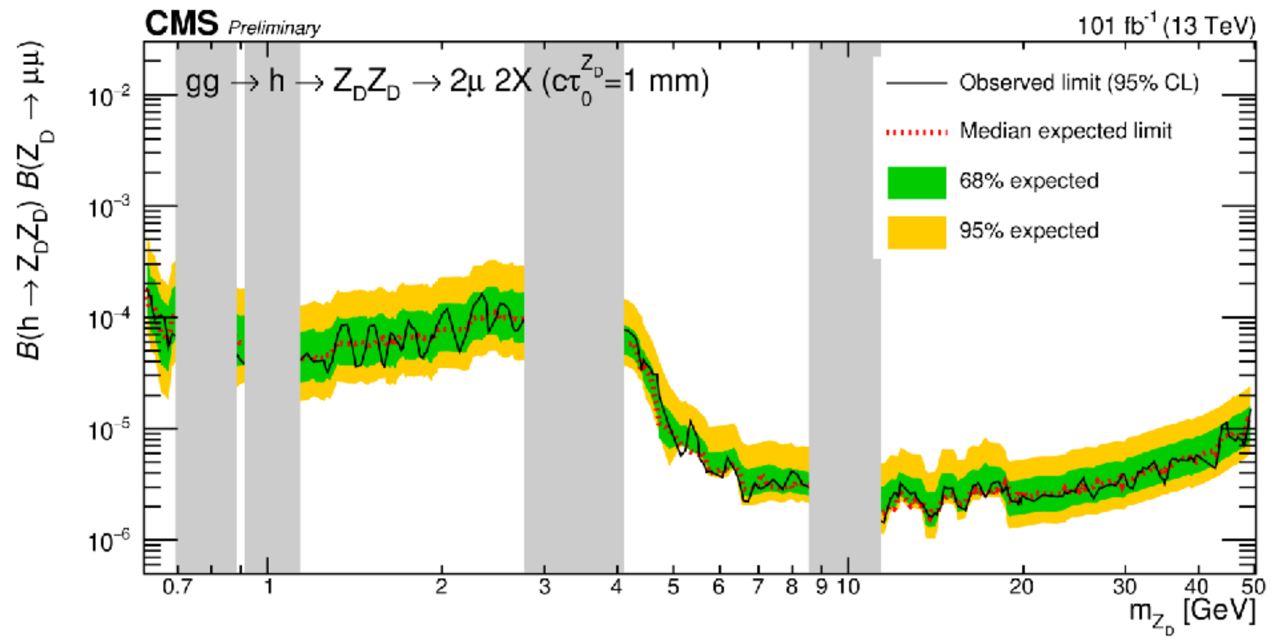


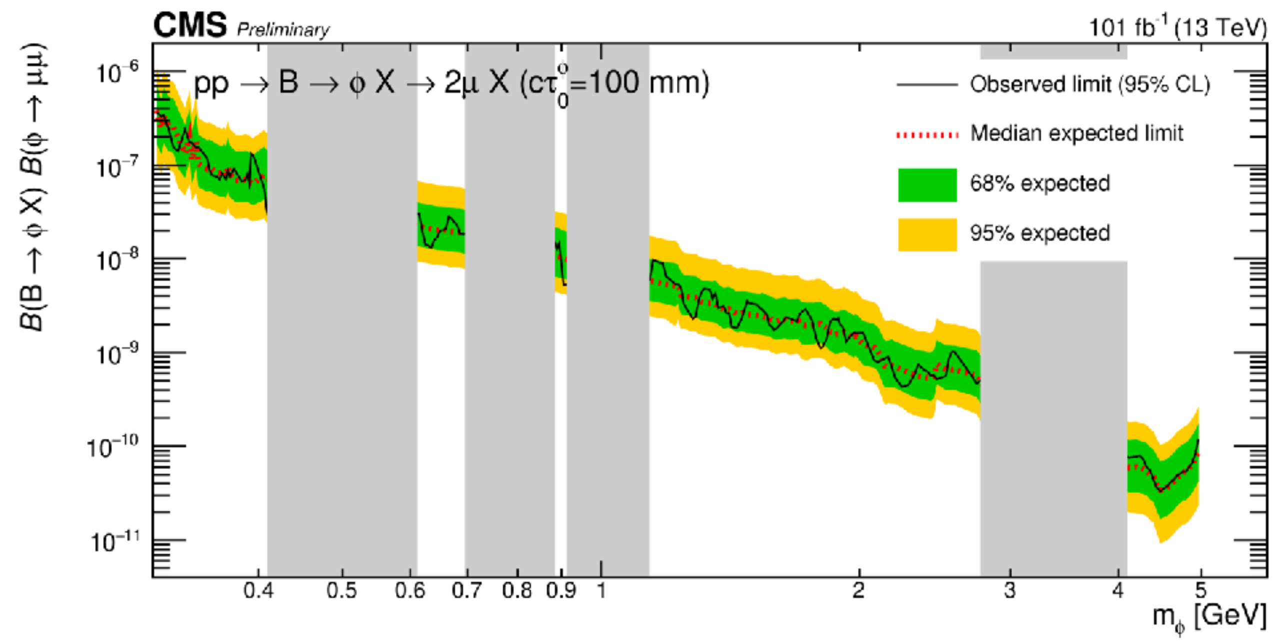
B decay to a long lived scalar





l_{xy} transverse displacement of the dimuon vertex





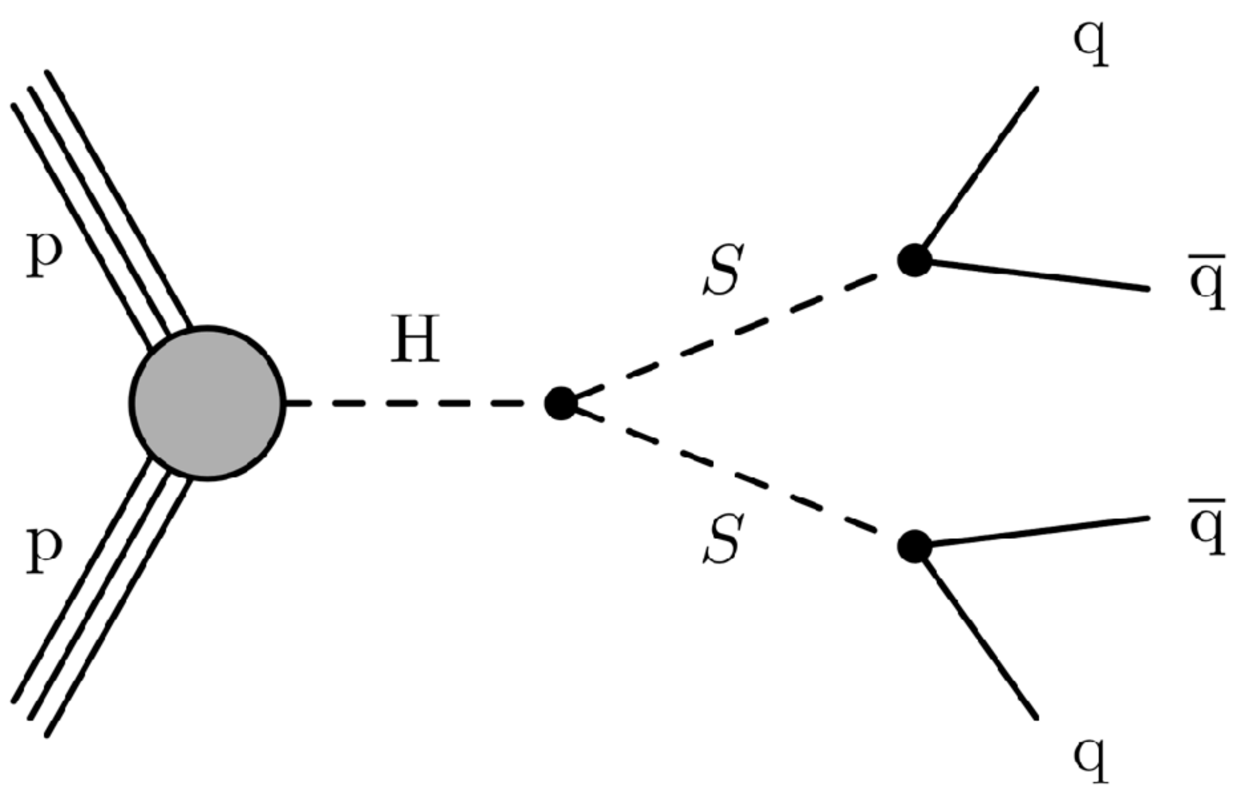
In grey: masked regions around known di-muon and di-hadron resonances

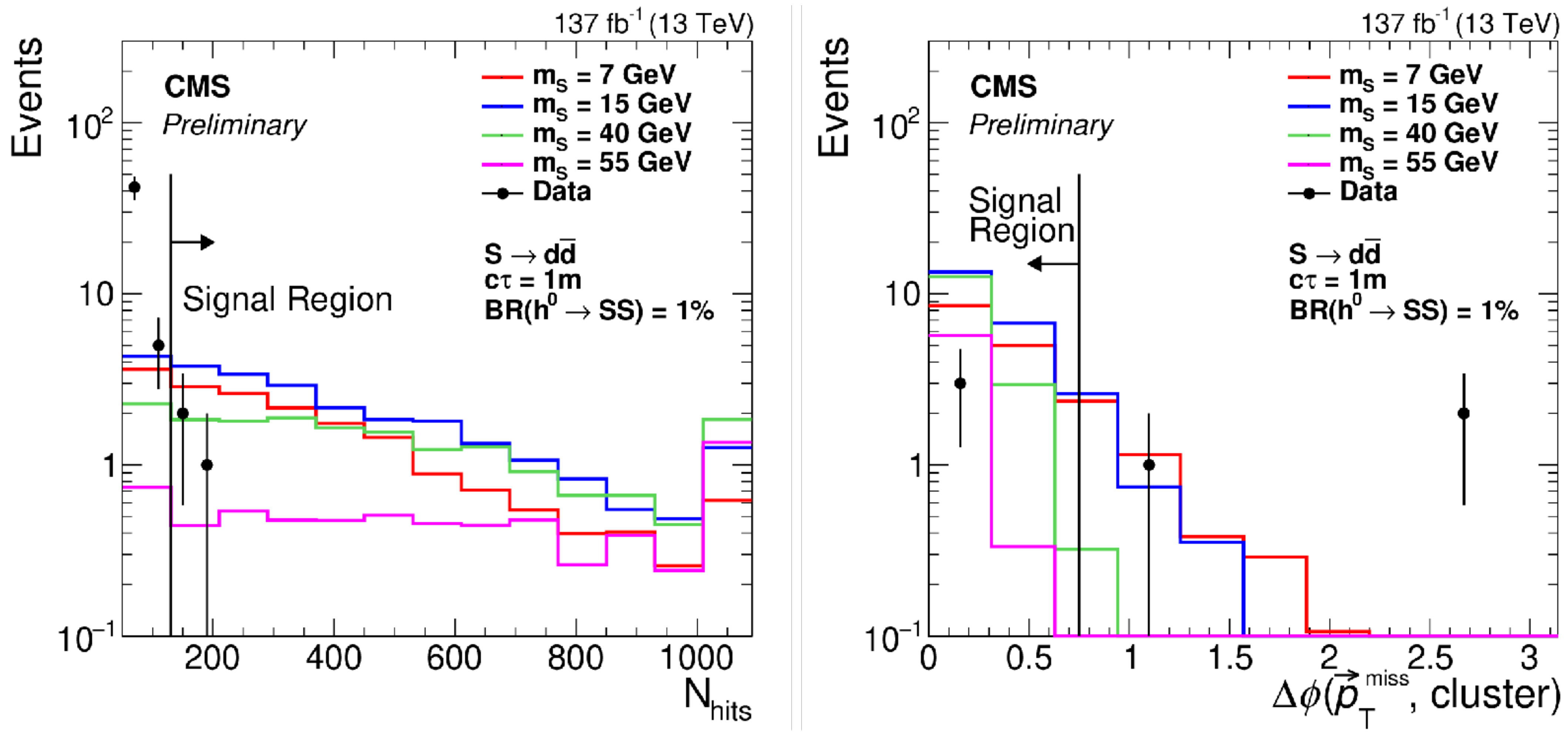
Exploring new phase spaces

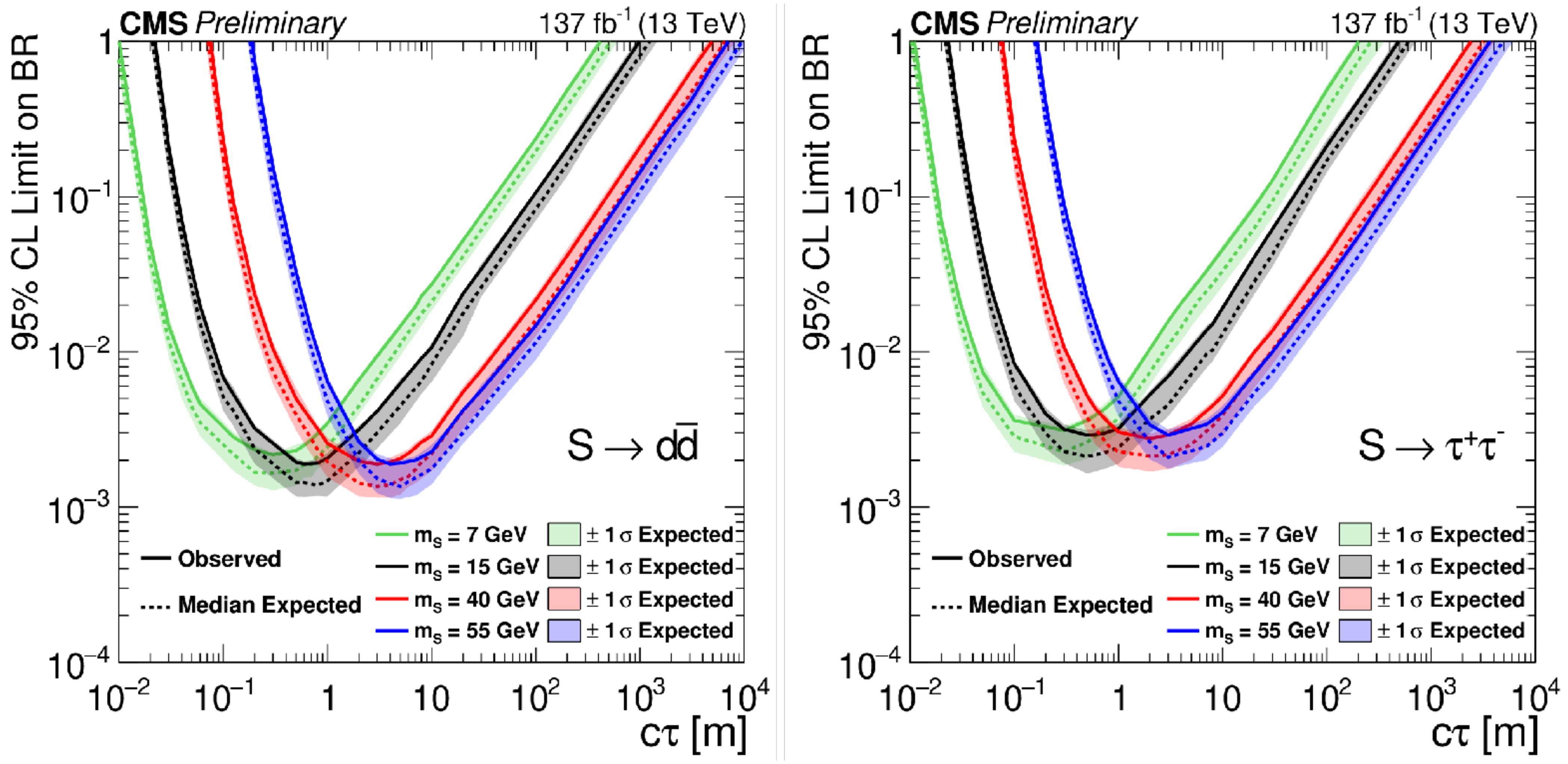
Searching for Long Lived Particles in the muon detectors

CMS-PAS-EXO-20-015

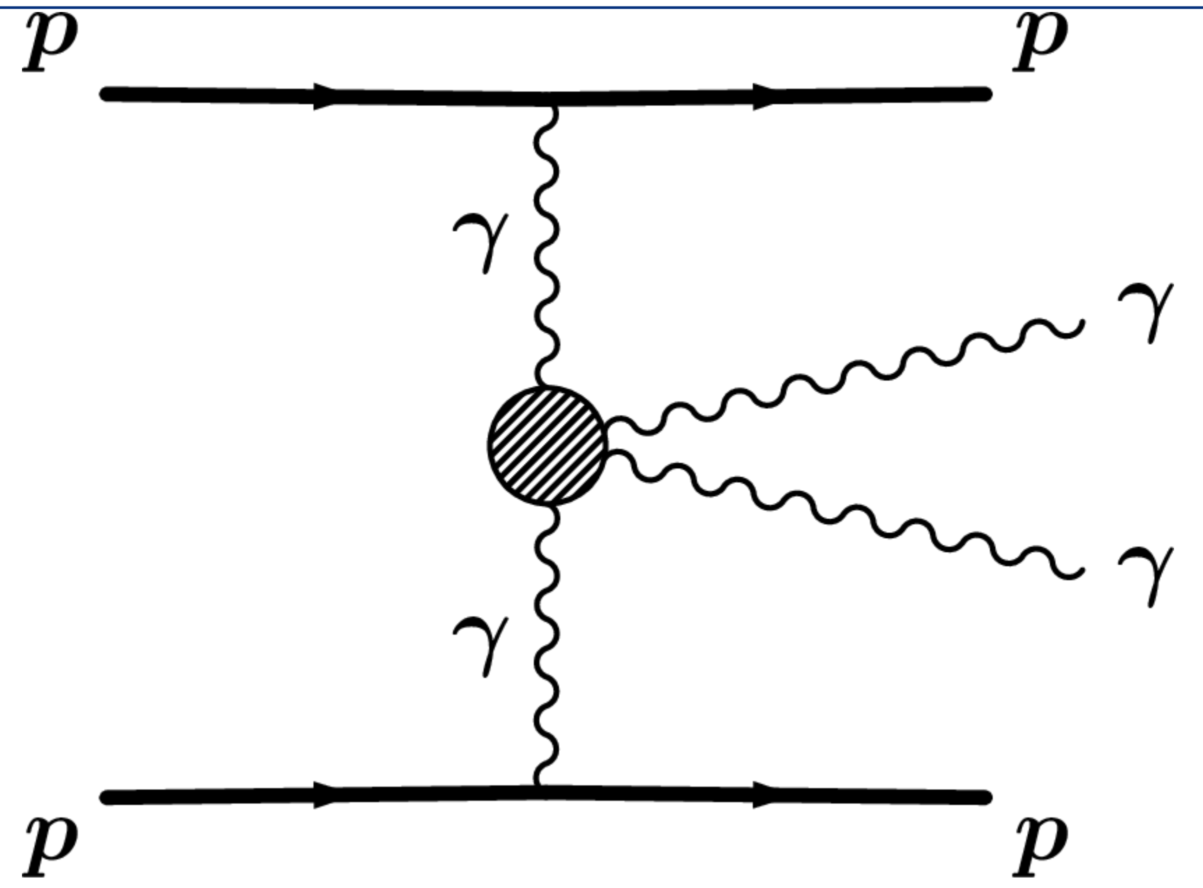
- A first search for LLPs has been performed, using the CSC detector as a calorimeter
- Looking for a SM Higgs boson decaying into a pair of long-lived scalars
- The number of hits in the CSC is used, together with the requirement of transverse missing momentum pointing towards the CSC hit cluster





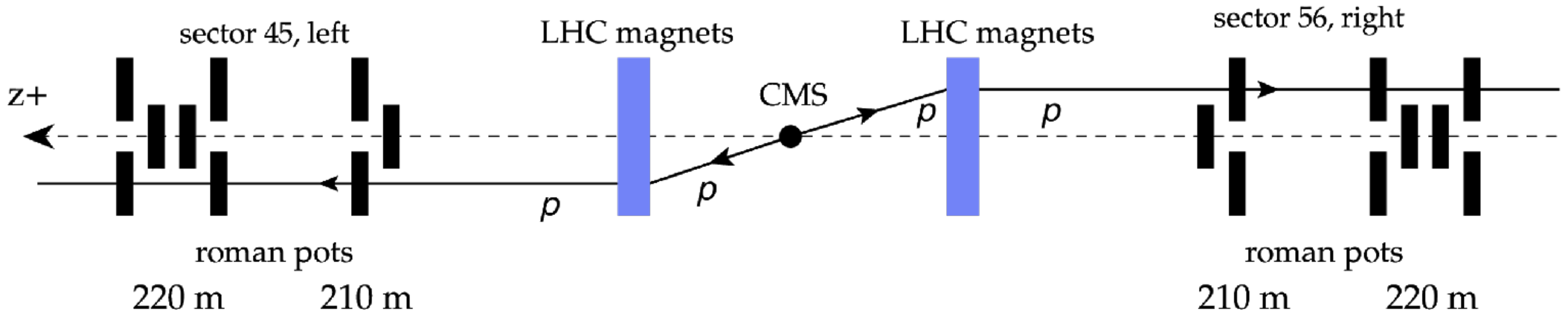


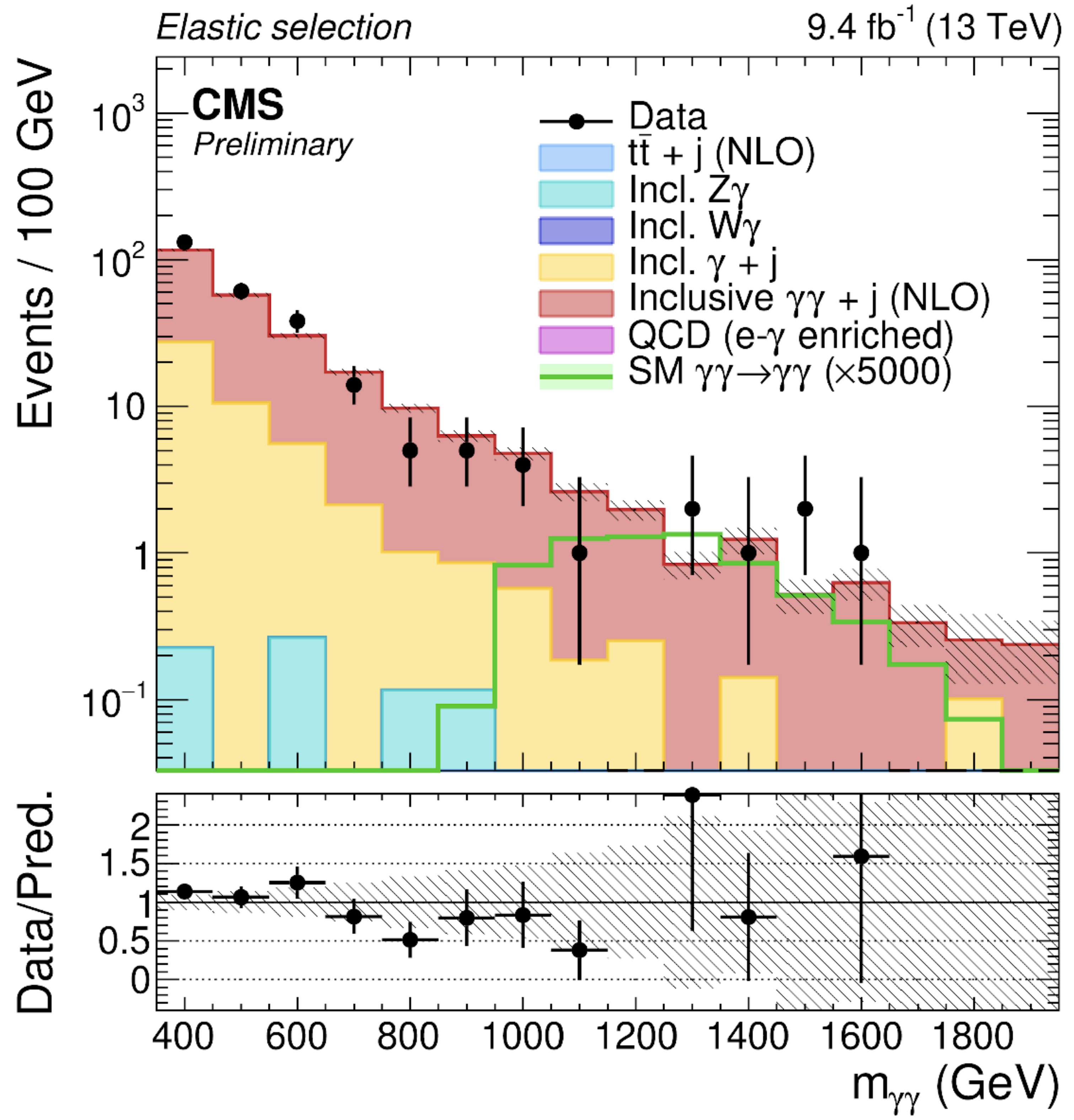
γγ production: joint TOTEM-CMS result



$$L_8^{\gamma\gamma\gamma\gamma} = \zeta_1 F_{\mu\nu}F^{\mu\nu}F_{\rho\sigma}F^{\rho\sigma} + \zeta_2 F_{\mu\nu}F^{\mu\rho}F_{\rho\sigma}F^{\sigma\nu}$$

$$|\zeta_1| < 3.7 \times 10^{-13}\ \text{GeV}^{-4} \quad (\zeta_2 = 0),$$
$$|\zeta_2| < 7.7 \times 10^{-13}\ \text{GeV}^{-4} \quad (\zeta_1 = 0).$$





- Search for photon-photon scattering with high invariant mass ($M_{\gamma\gamma}$ > 350 GeV)
  - Very low xsec in SM
  - Probe for NP in anomalous quartic couplings
- Exploit CT-PPS capabilities (joint TOTEM-CMS result)
  - Independently reconstruct the di-photon system from proton kinematics
  - No events survive when requiring PPS matching
- Set limits on quartic couplings coefficients

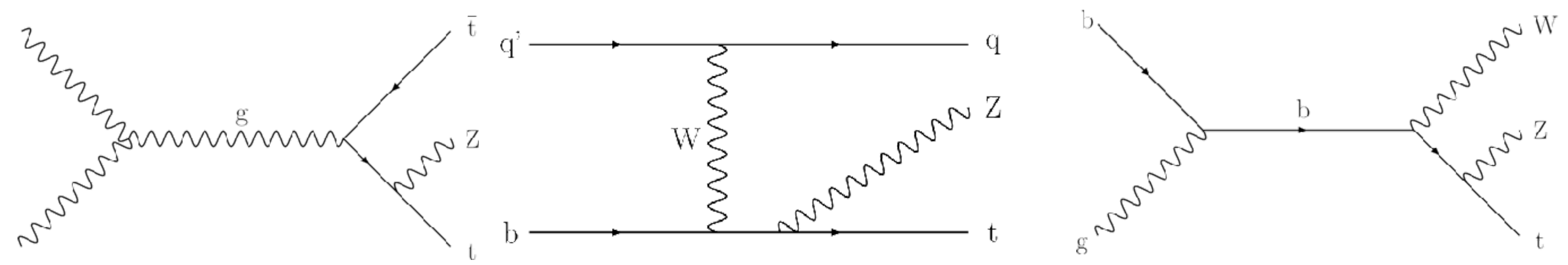
EXO-18-014

Probing New Physics Through Effective Fields

Recent example: t(t)Z in multiplepton events

- Search for new top interactions in the EFT framework
- Use Z produced with a single top or a pair of top quark pairs in multi-lepton final states
- Sensitivity to the EFT parameters optimized using machine learning techniques
- Several signal (3l and 4l) and control (WZ and ZZ BG enriched regions) used
- All results are found in very good agreement with the SM and limits on the EFT parameters are derived

Tree level diagrams for ttZ and tZ production

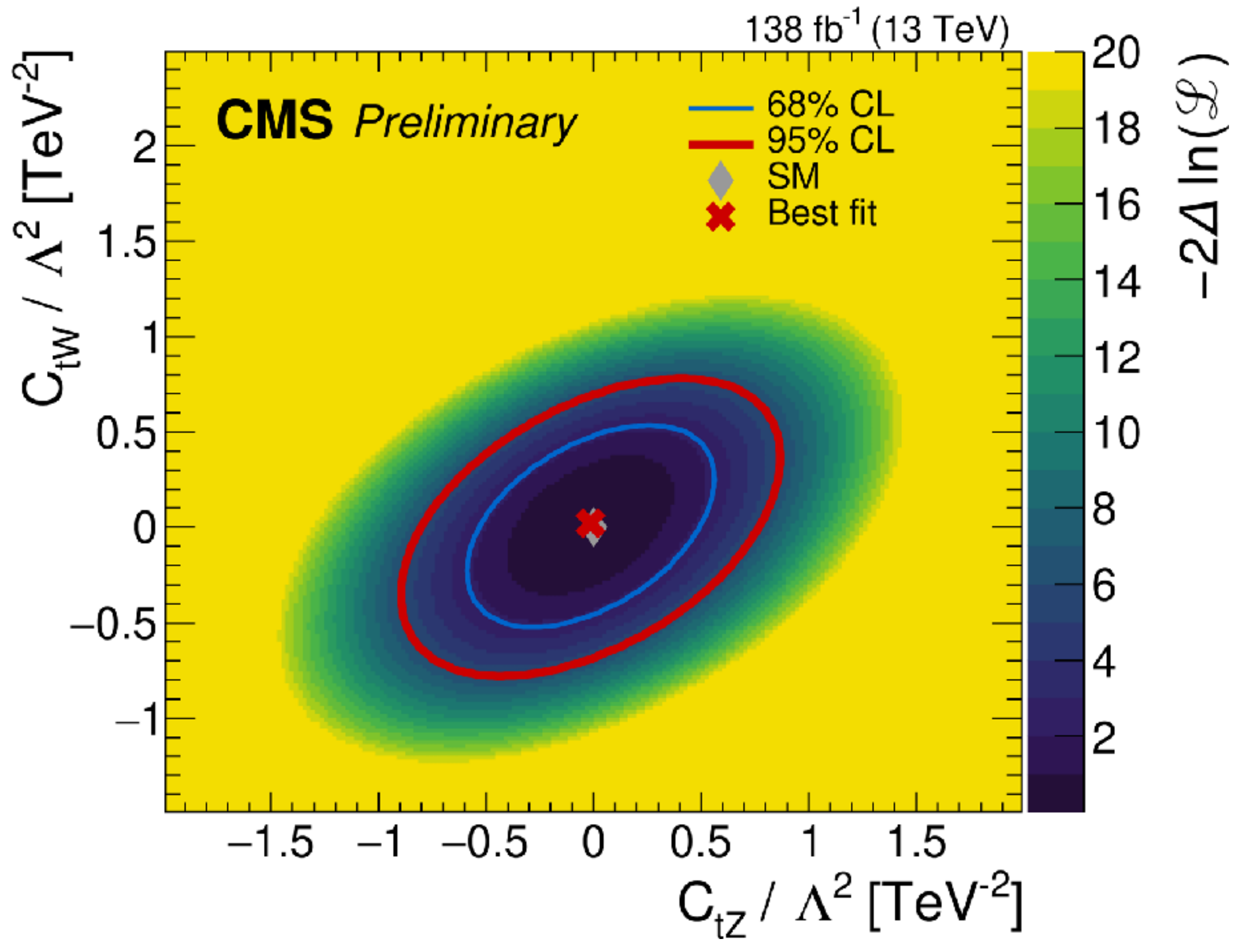


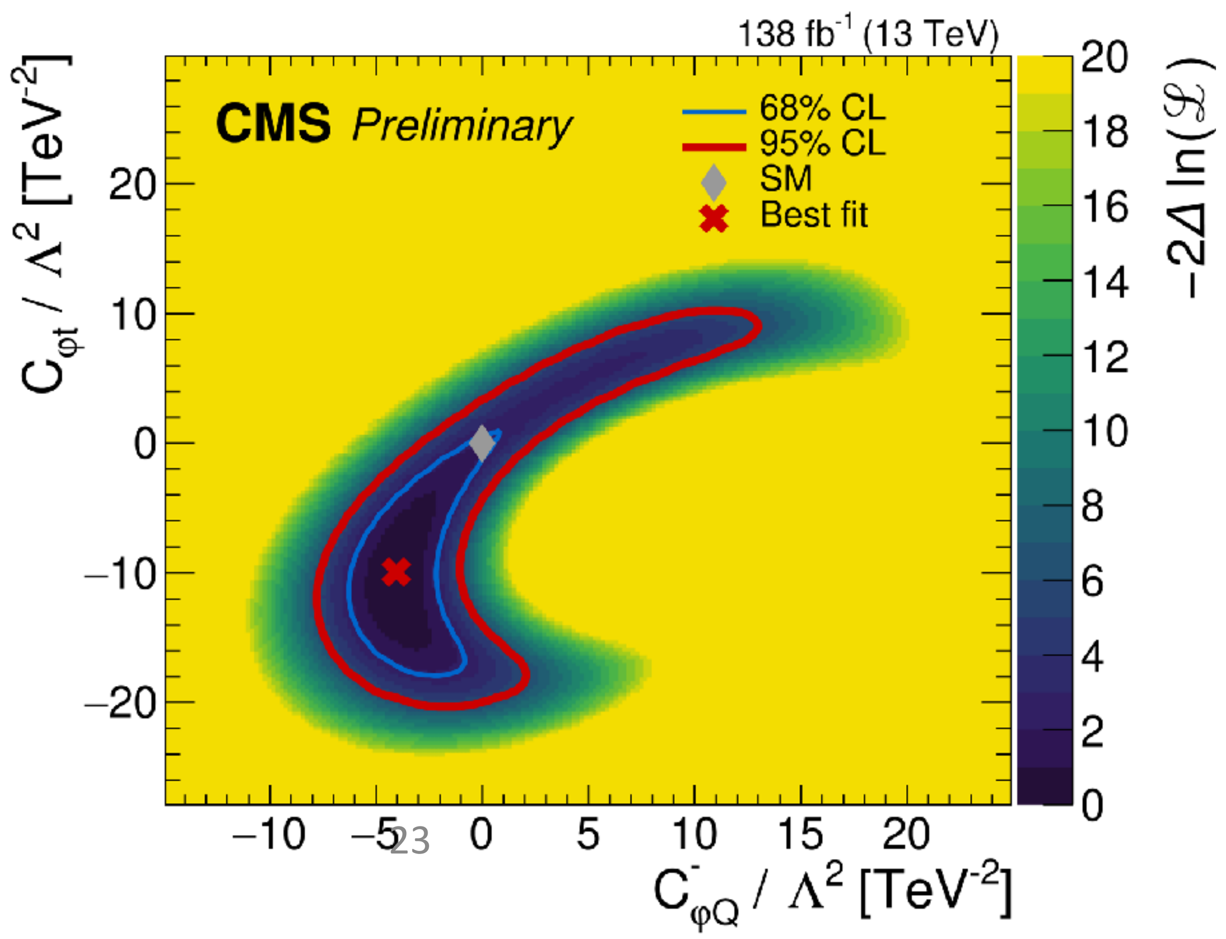
Selection requirement	SR-3ℓ	SR-t$\bar{t}$Z-4ℓ	WZ CR	ZZ CR
Lepton multiplicity	=3	=4	=3	=4
$m_{3\ell} - m_Z$	—	—	>15 GeV	—
Z boson candidates multiplicity	=1	=1	=1	=2
Jet multiplicity	≥2	≥2	—	—
b jet multiplicity	≥1	≥1	=0	—
p_T^{miss}	—	—	>50 GeV	—

Dimension-six EFT operators considered and relative Wilson coefficients

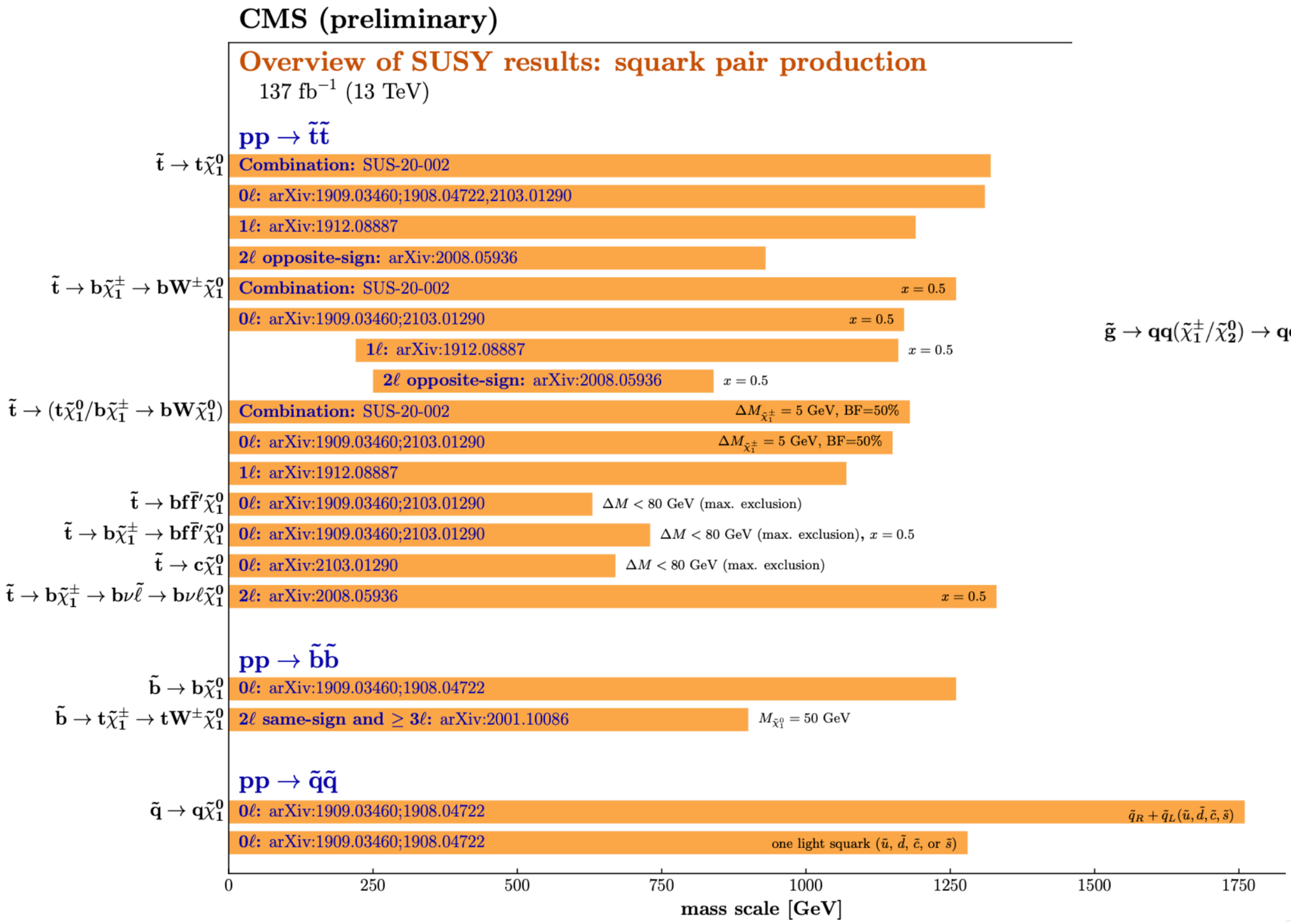
Operator	WC	Mapping to Warsaw-basis coefficients
$\mathcal{O}_{tZ}$	c_{tZ}	$\mathrm{Re}\{-s_W c_{uB}^{(33)} + c_W c_{uW}^{(33)}\}$
$\mathcal{O}_{tW}$	c_{tW}	$\mathrm{Re}\{c_{uW}^{(33)}\}$
$\mathcal{O}_{\varphi Q}^{3}$	$c_{\varphi Q}^{3}$	$c_{\varphi q}^{3(33)}$
$\mathcal{O}_{\varphi Q}^{-}$	$c_{\varphi Q}^{-}$	$c_{\varphi q}^{1(33)} - c_{\varphi q}^{3(33)}$
$\mathcal{O}_{\varphi t}$	$c_{\varphi t}$	$c_{\varphi u}^{(33)}$

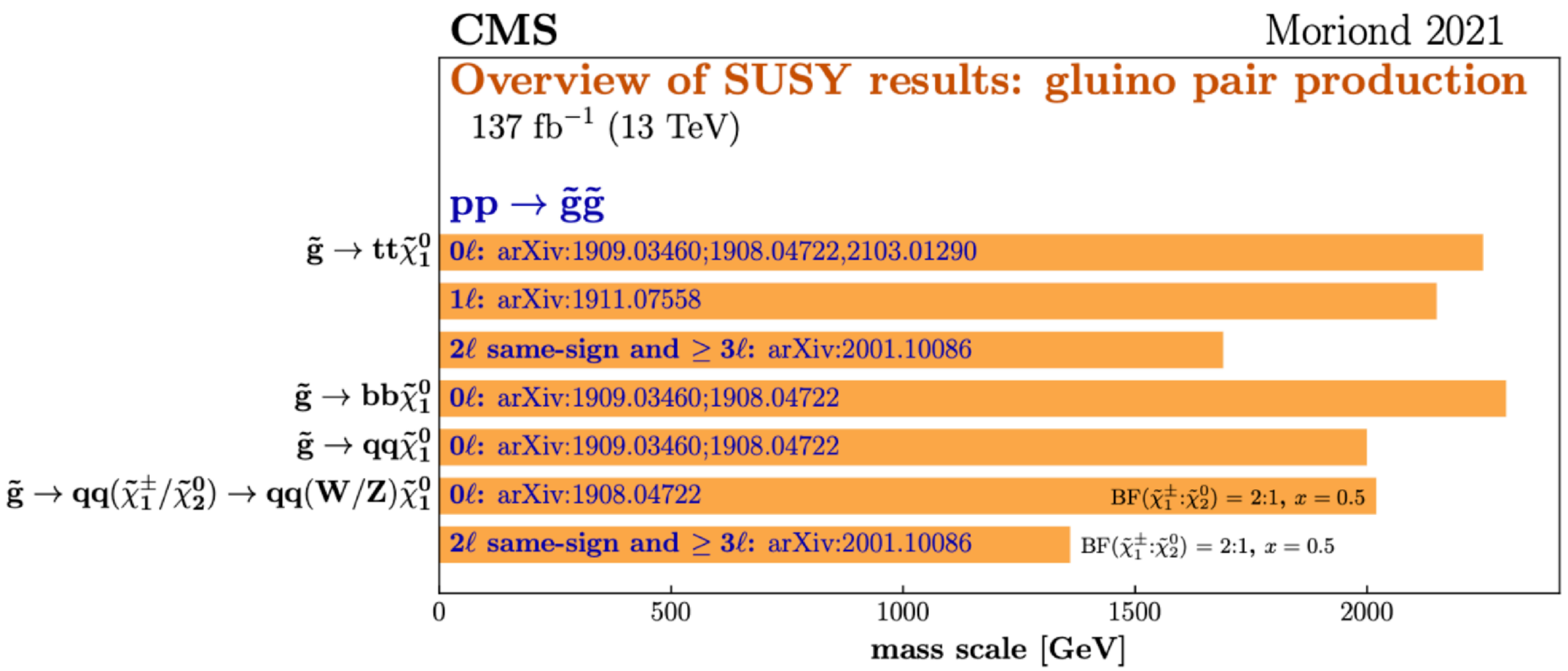
CMS-PAS-TOP-21-001

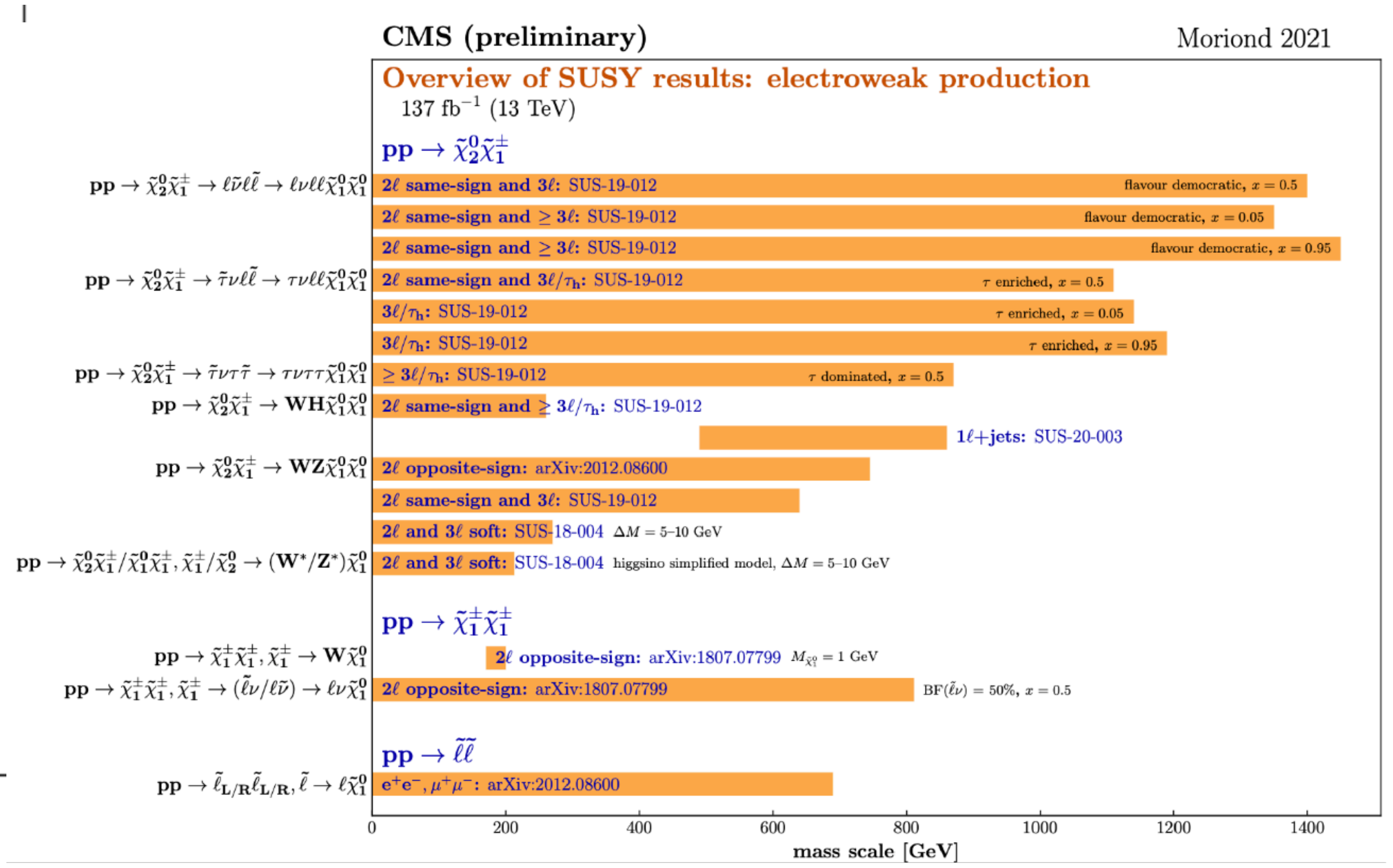




SuperSymmetry searches: current reach







Exotica searches: current reach

Contact Inter.

Dark Matter

R-Parity Viol.

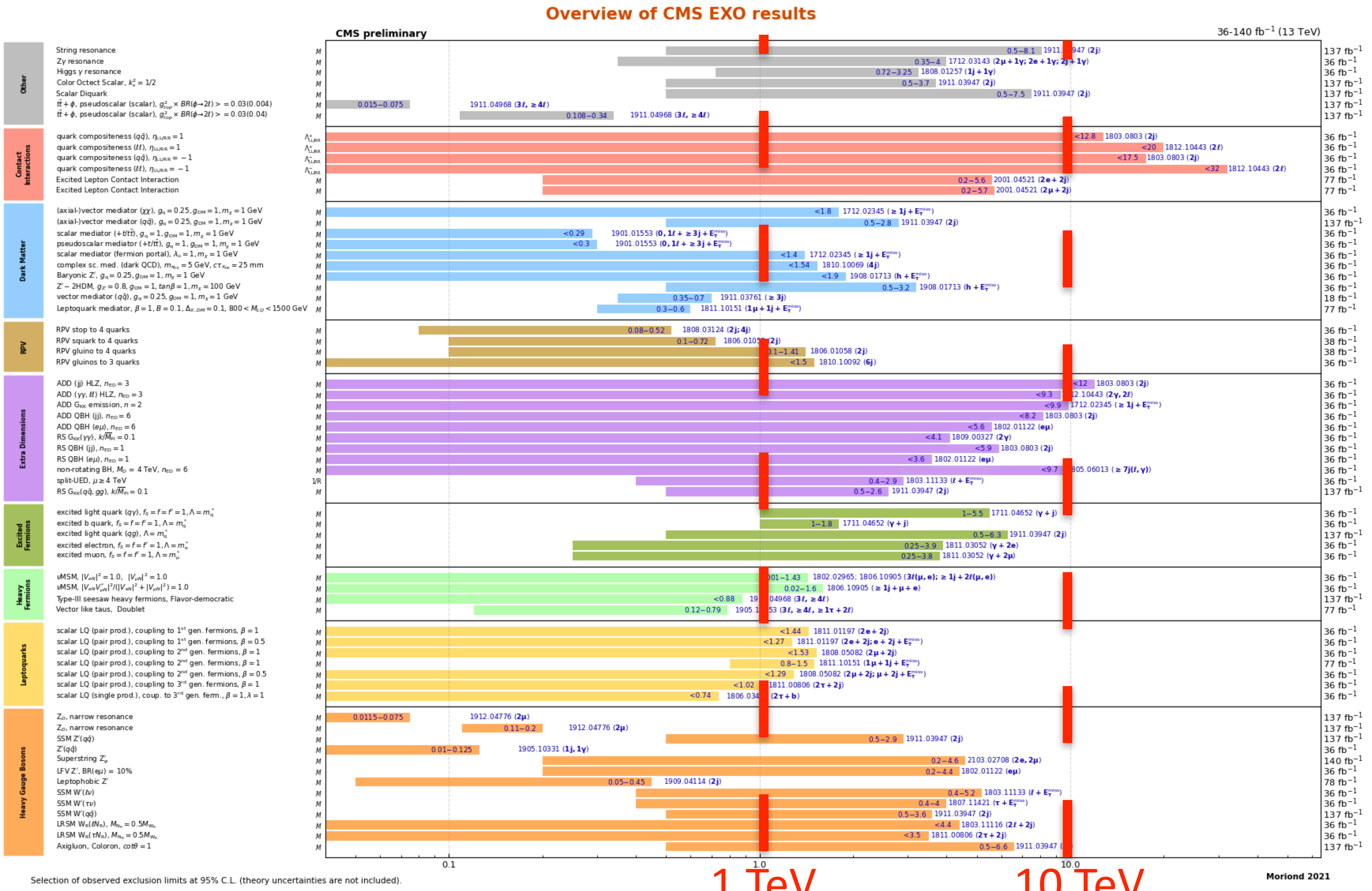
Extra Dimensions

Excited Ferm.

Heavy Ferm.

Leptoquarks

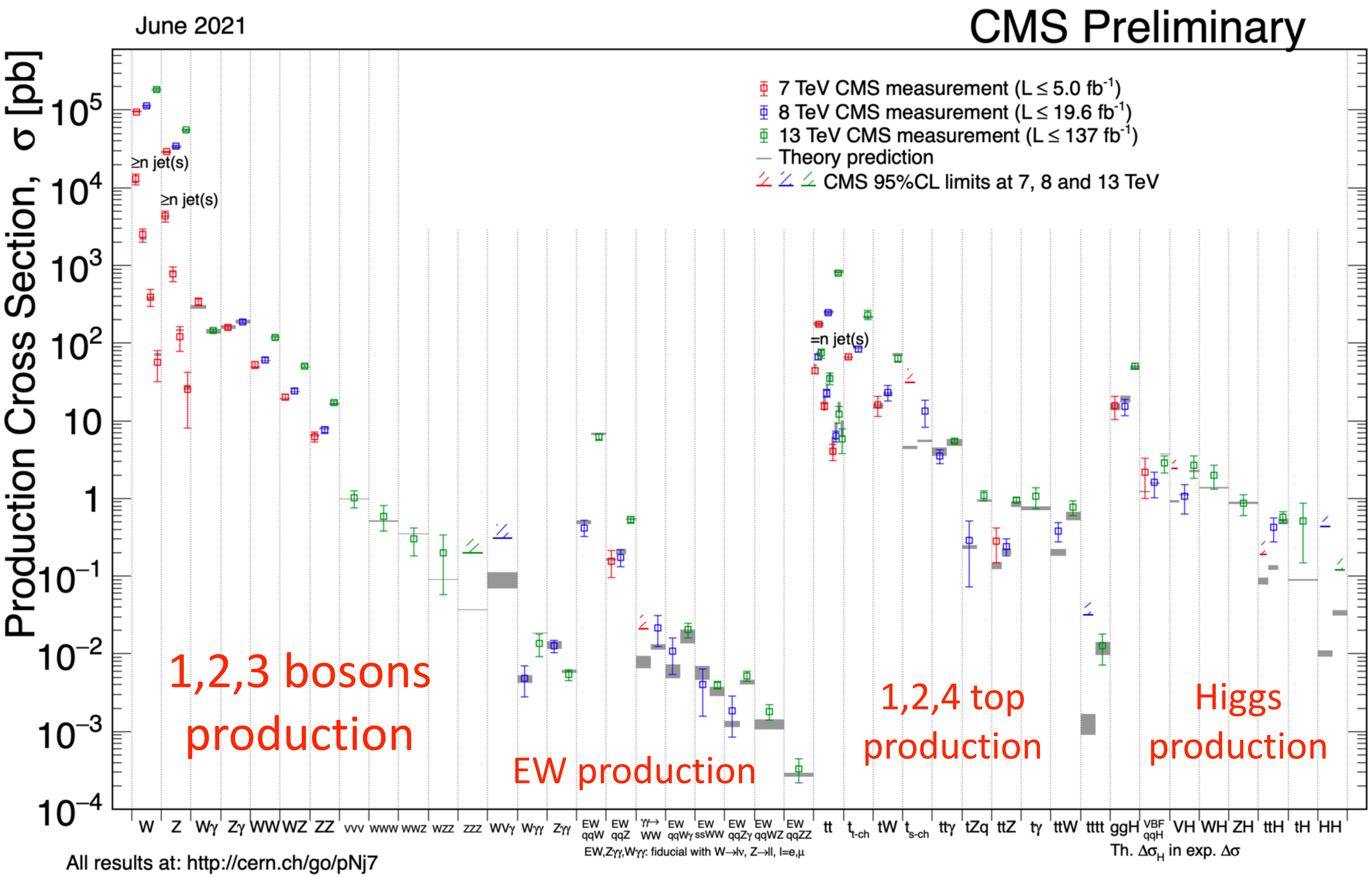
Heavy Bosons



1 TeV

10 TeV

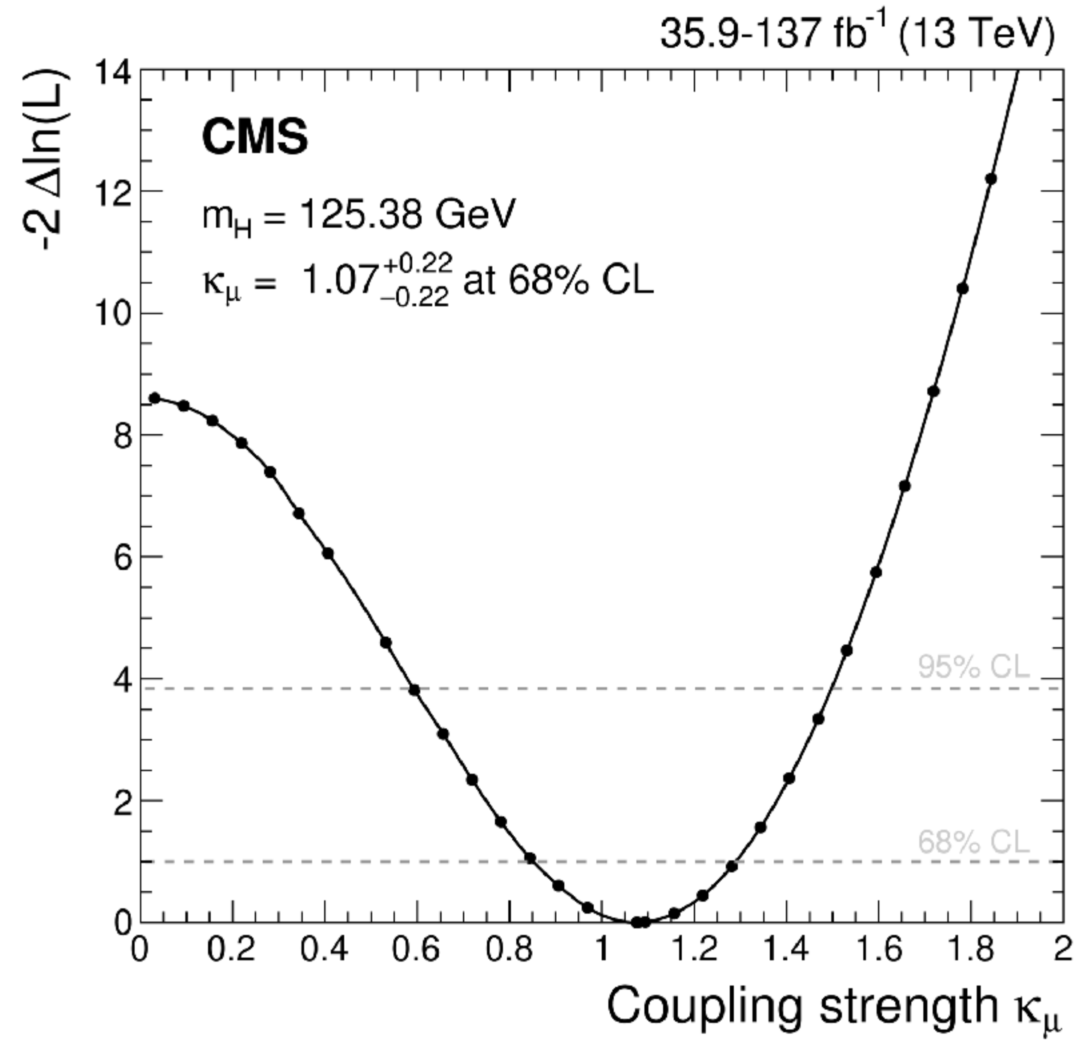
The feast of SM measurement



Higgs Couplings Summary

In the **kappa framework** , fit for 6 coupling strength modifiers (κ) for $m_H = 125.38\,\mathrm{GeV}$

$$\kappa_\mu = 1.07 \pm 0.22\,(\mathrm{at}\ 68\%\mathrm{CL})$$



CMS-HIG-19-006
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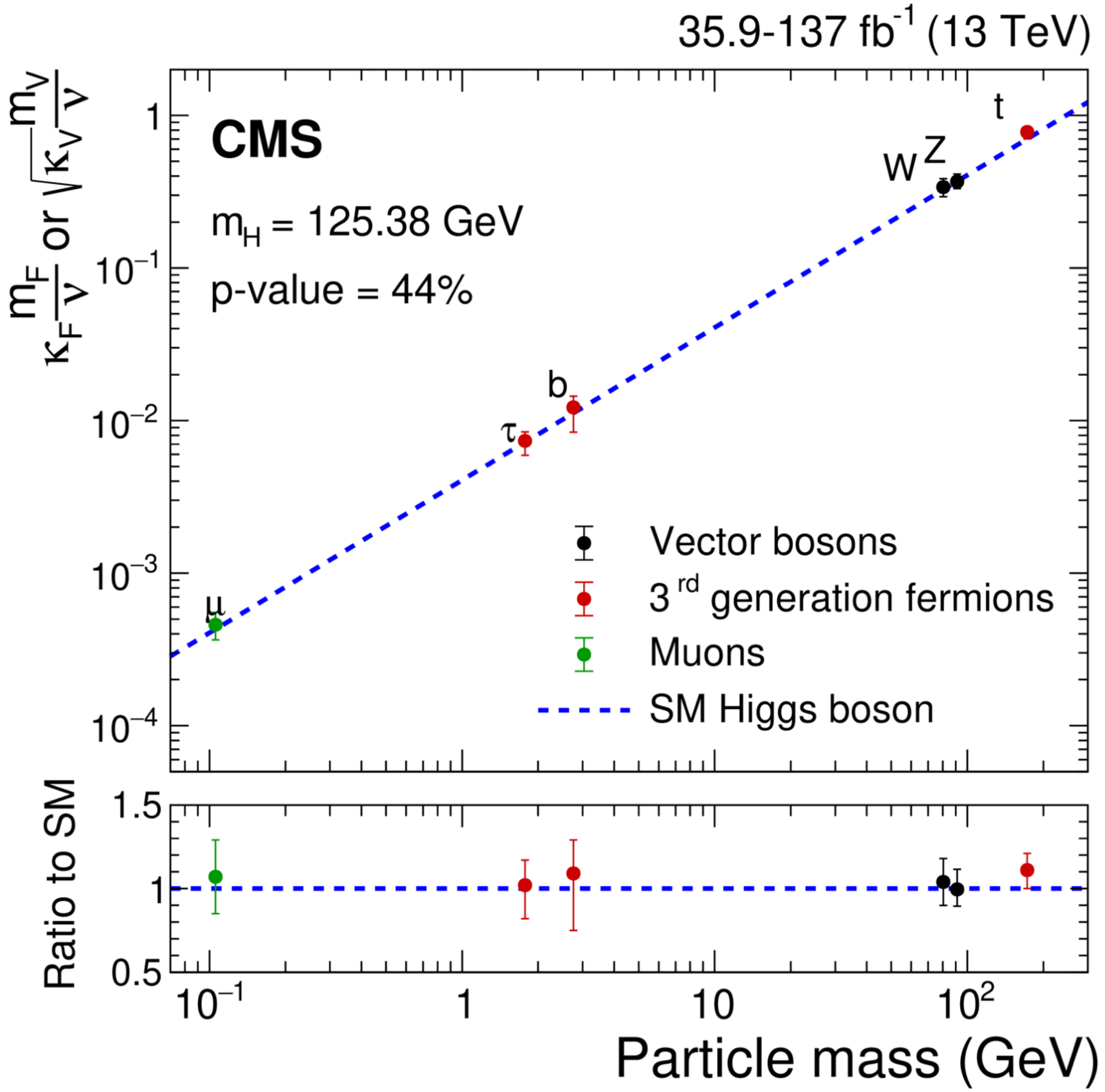
confidence intervals for a Higgs boson coupling to a second generation fermion !!



CMS *p*-value for SM hypothesis (all κ=1): **44%**

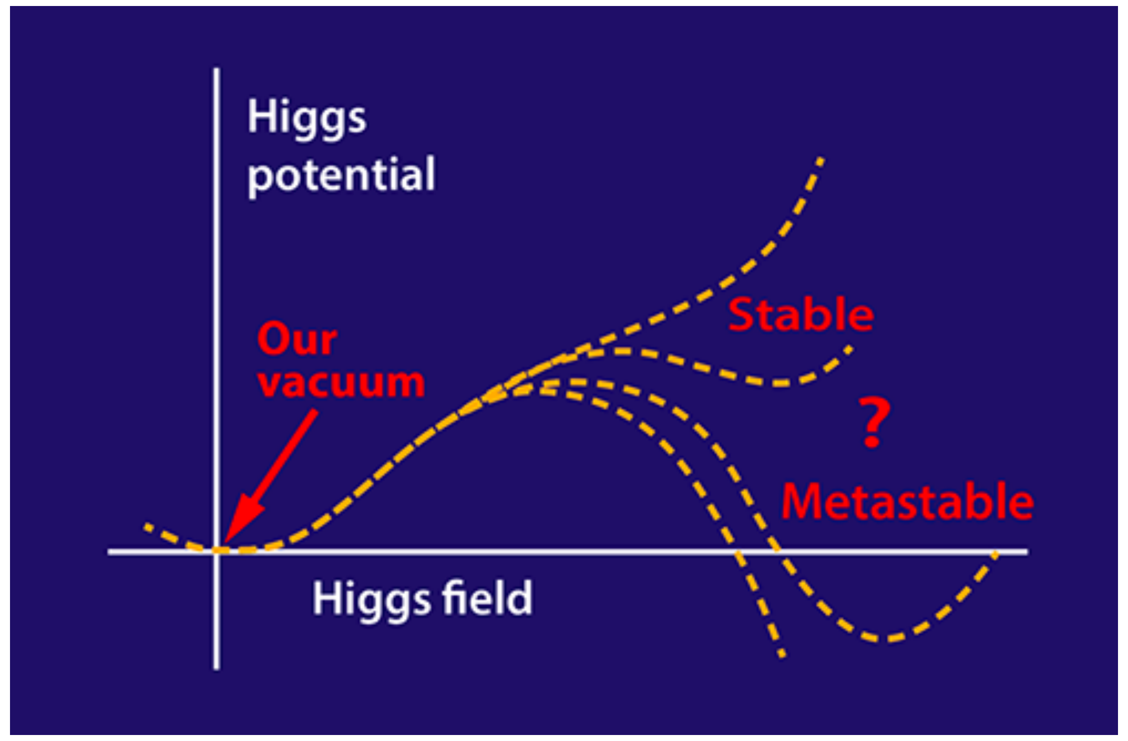
Double Higgs non-resonant production

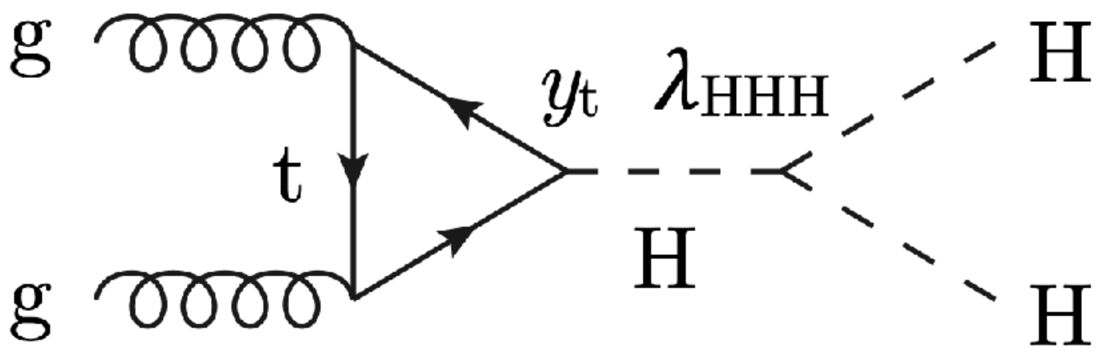
CMS-PAS-HIG-20-005

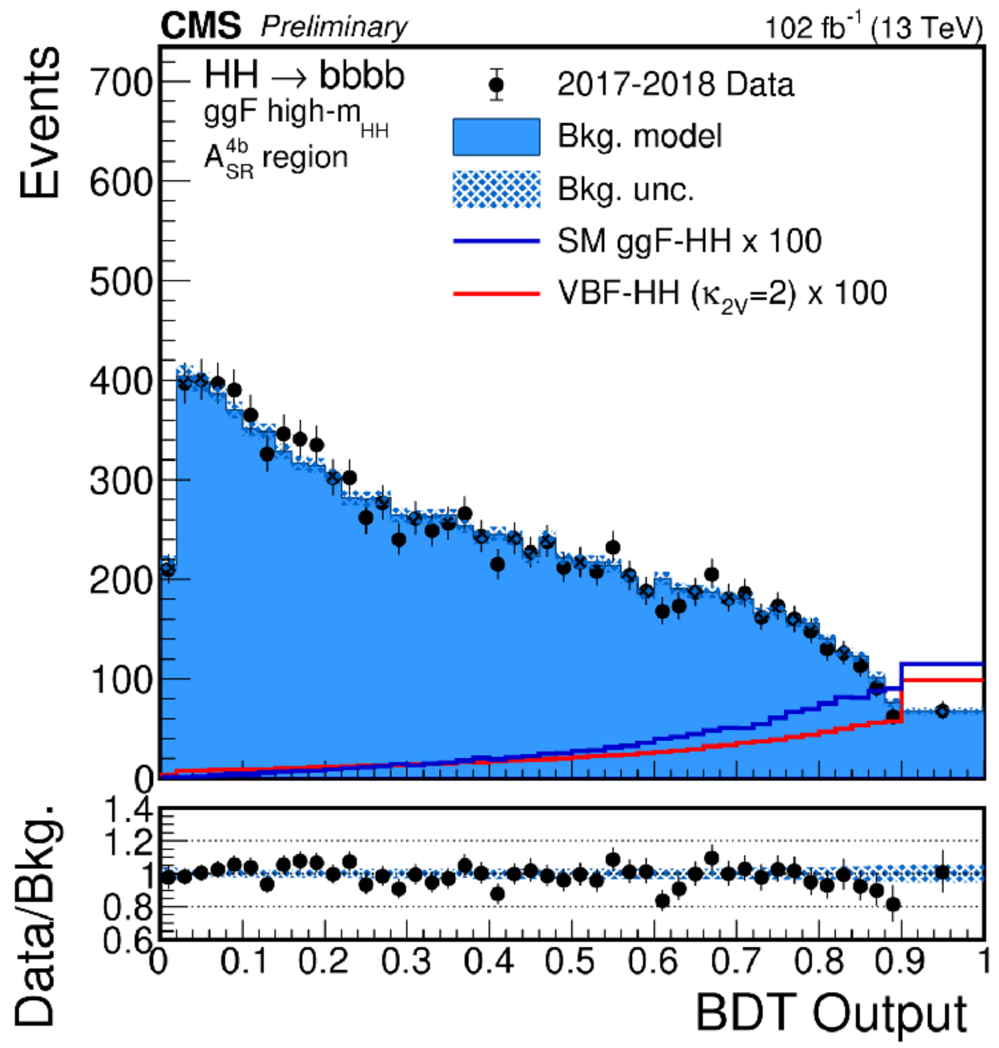
- Di-Higgs production to explore multiple couplings
  - HHH, HVV, HHVV
- New analysis for the 4b final state
  - $bb\gamma\gamma$ result published early this year
- Completely redesigned analysis:
  - New pixel detector for 2017/2018 data taking => better b-tag
  - New NN b-tagging (DeepFlavour)
  - New multivariate analysis strategy
  - New background estimation from multiple control regions
- Results
  - Observed limit 3.6 x SM at 95% CL (most stringent limit to date)
  - Expected limit 7.3 x SM at 95% CL (5x improvement to our previous Run 2 2016 result)

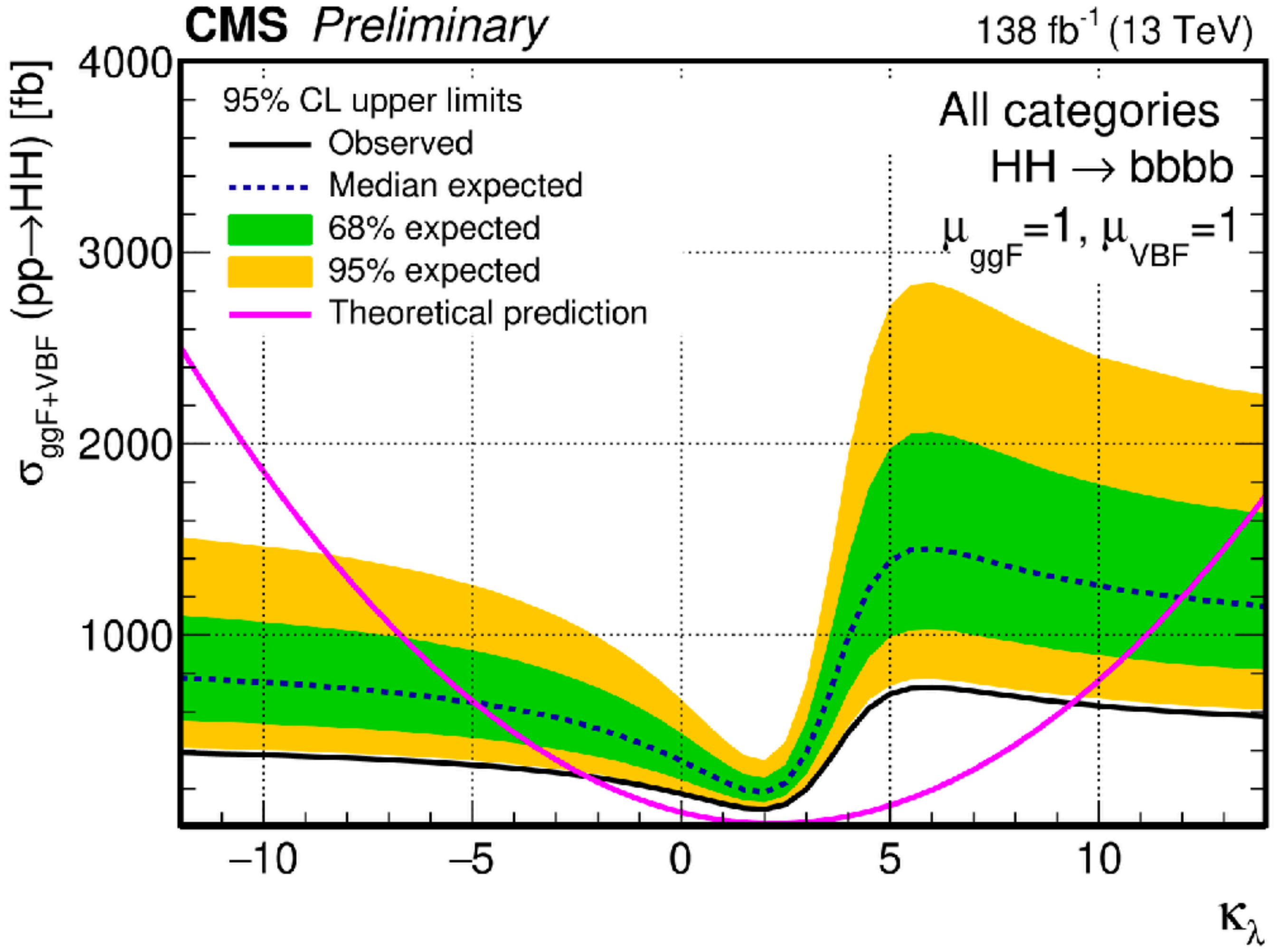
The double H coupling probes the structure of the Higgs potential:

$$V(\Phi) = -\mu^2\Phi^\dagger\Phi + \lambda(\Phi^\dagger\Phi)^2$$







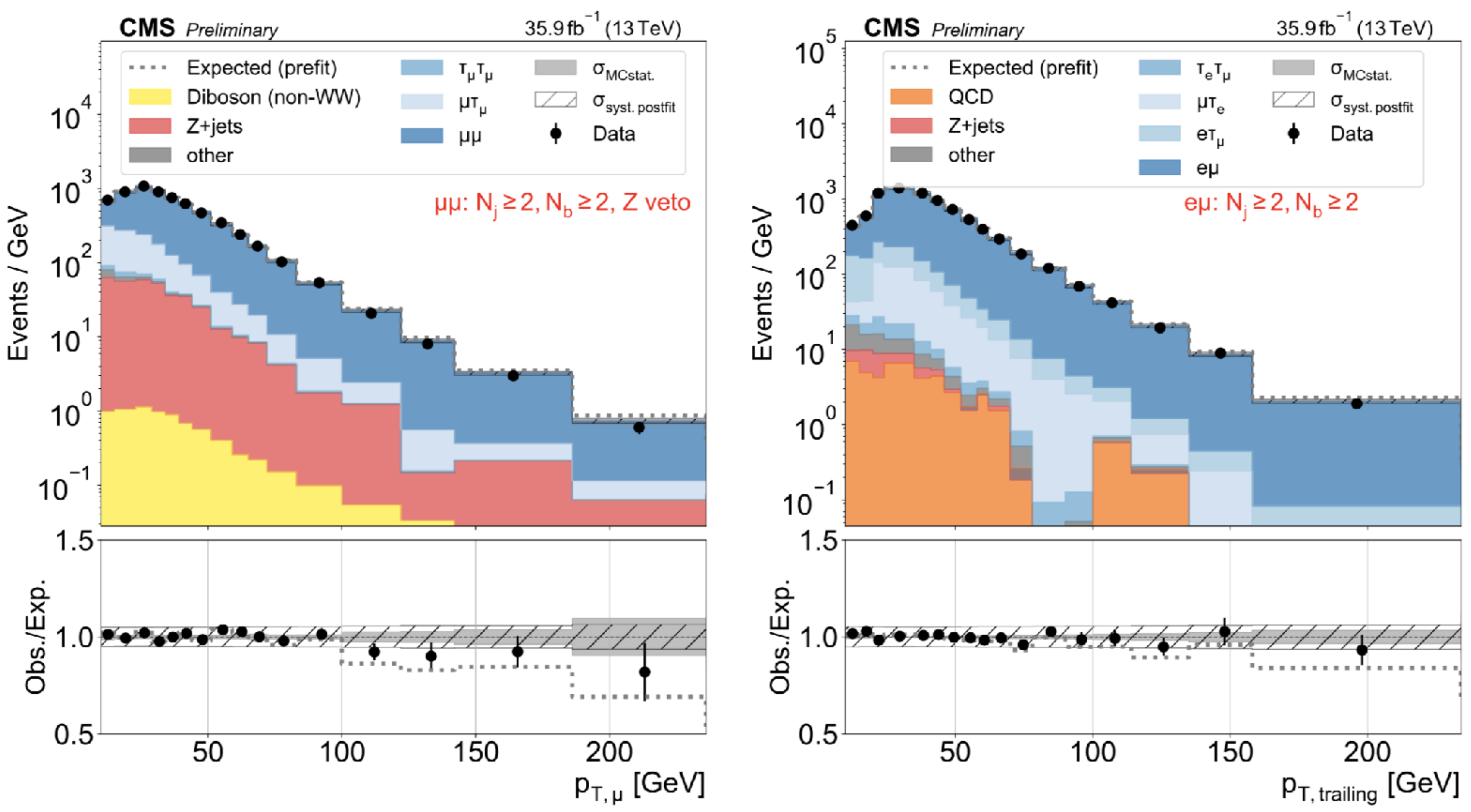


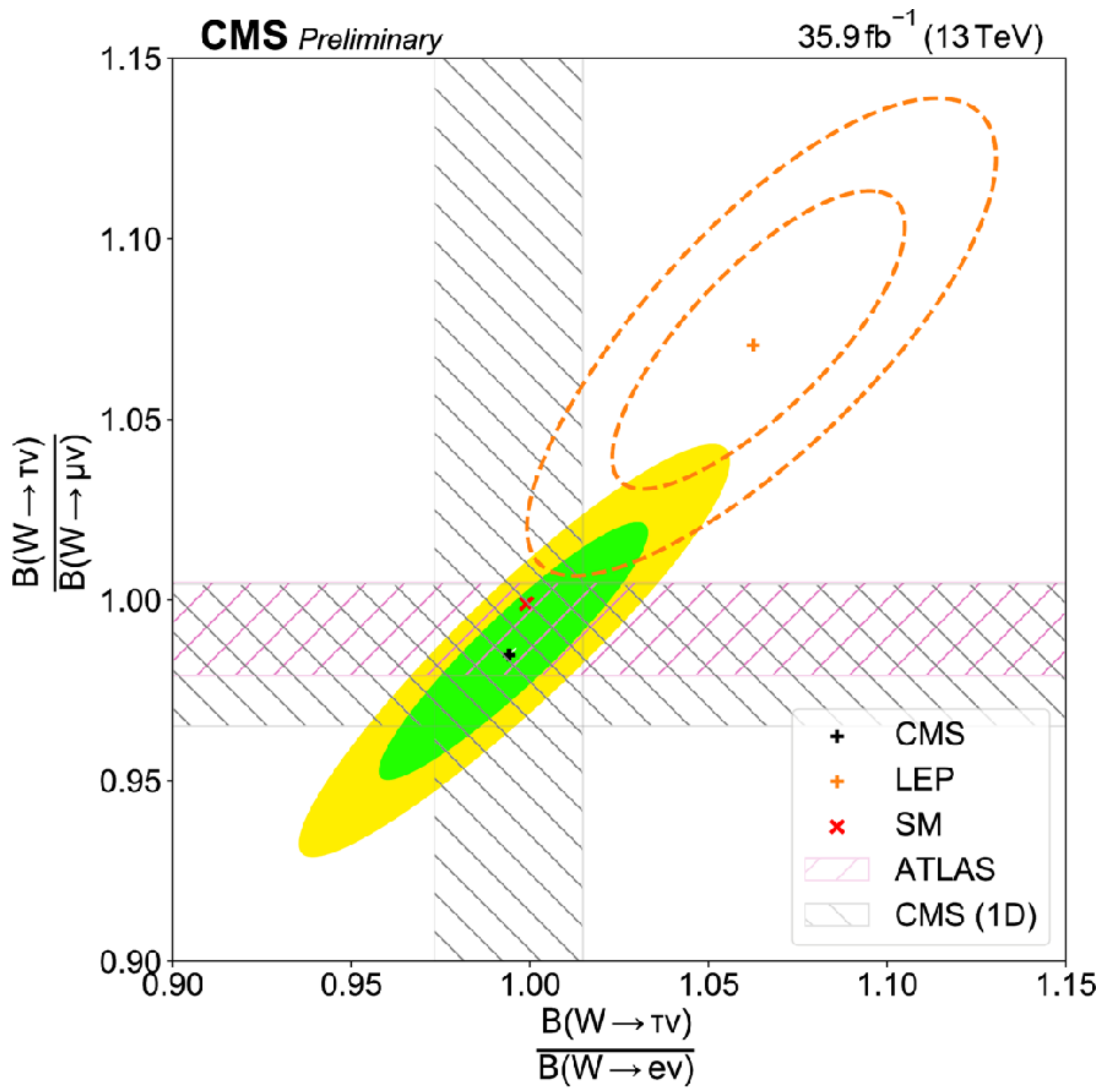
Measurement of W BRs

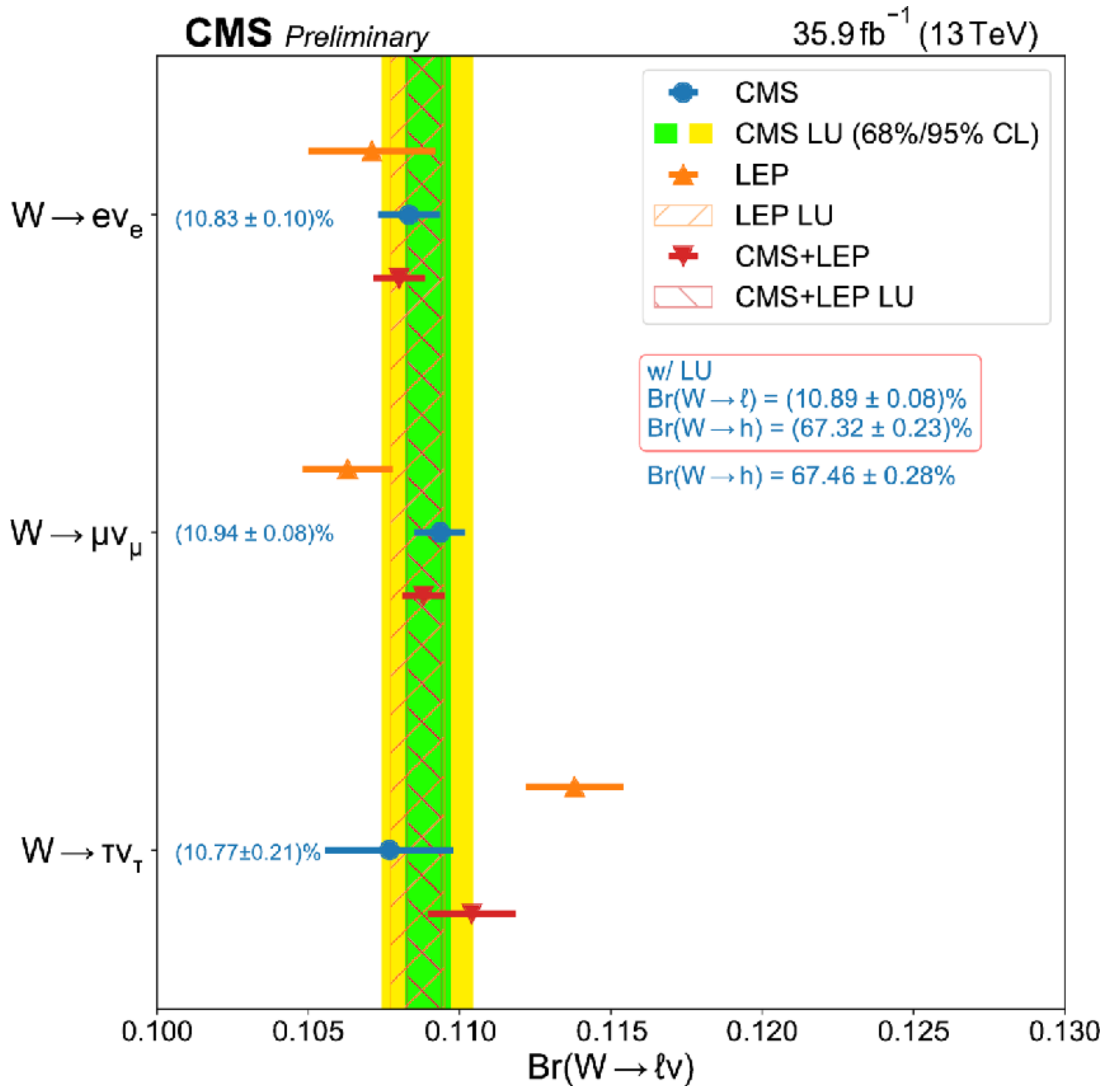
- Events with two W or a W + jets are used to measure BR of W
- Precision slightly better than LEP
- Currently exploiting pT as a way to distinguish prompt muons from muonic decays of taus
  - ATLAS also used IP and full Run2 in their analysis targeting tau/mu ratio

CMS-PAS-SMP-18-011

	CMS	LEP
$\mathcal{B}(W \to e\bar{\nu}_e)$	$(10.83 \pm 0.01 \pm 0.10)\%$	$(10.71 \pm 0.14 \pm 0.07)$ %
$\mathcal{B}(W \to \mu\bar{\nu}_\mu)$	$(10.94 \pm 0.01 \pm 0.08)\%$	$(10.63 \pm 0.13 \pm 0.07)$ %
$\mathcal{B}(W \to \tau\bar{\nu}_\tau)$	$(10.77 \pm 0.05 \pm 0.21)\%$	$(11.38 \pm 0.17 \pm 0.11)$ %
$\mathcal{B}(W \to h)$	$(67.46 \pm 0.04 \pm 0.28)\%$	–
with LU		
$\mathcal{B}(W \to \ell\bar{\nu})$	$(10.89 \pm 0.01 \pm 0.08)\%$	$(10.86 \pm 0.06 \pm 0.09)\%$
$\mathcal{B}(W \to h)$	$(67.32 \pm 0.02 \pm 0.23)\%$	$(67.41 \pm 0.18 \pm 0.20)\%$



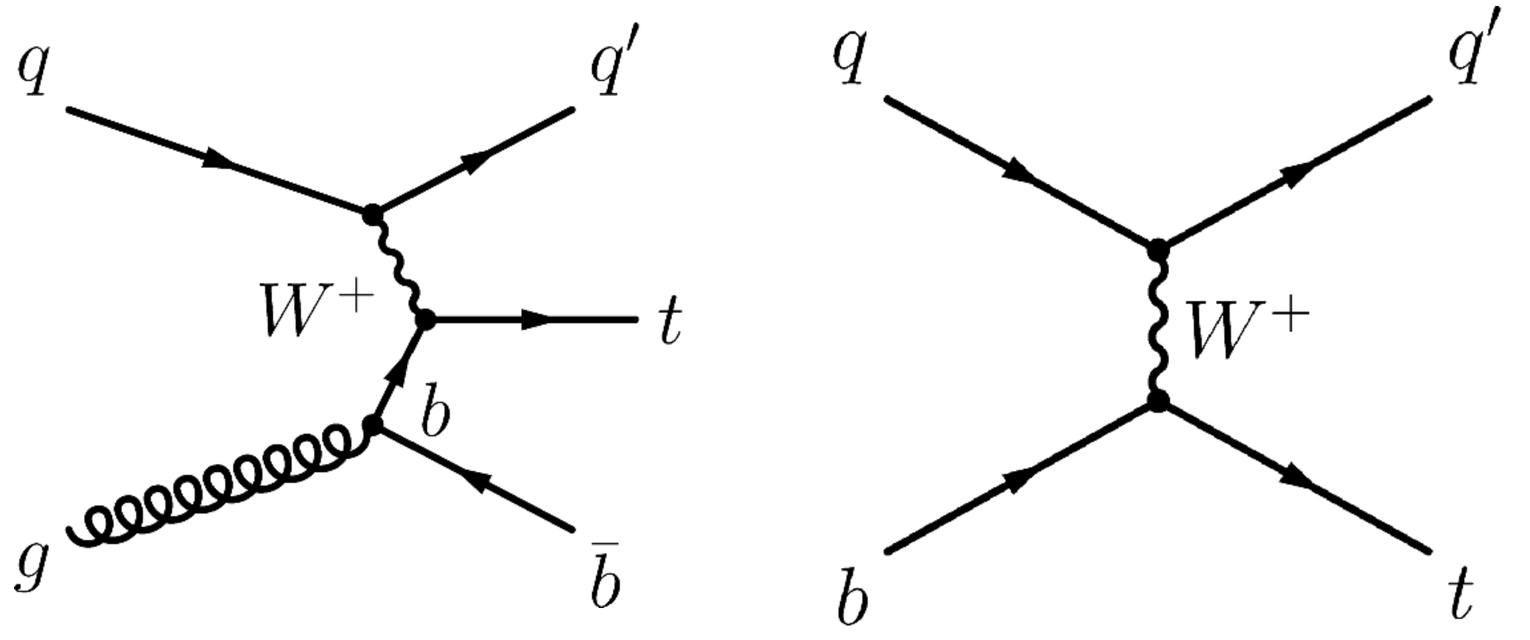


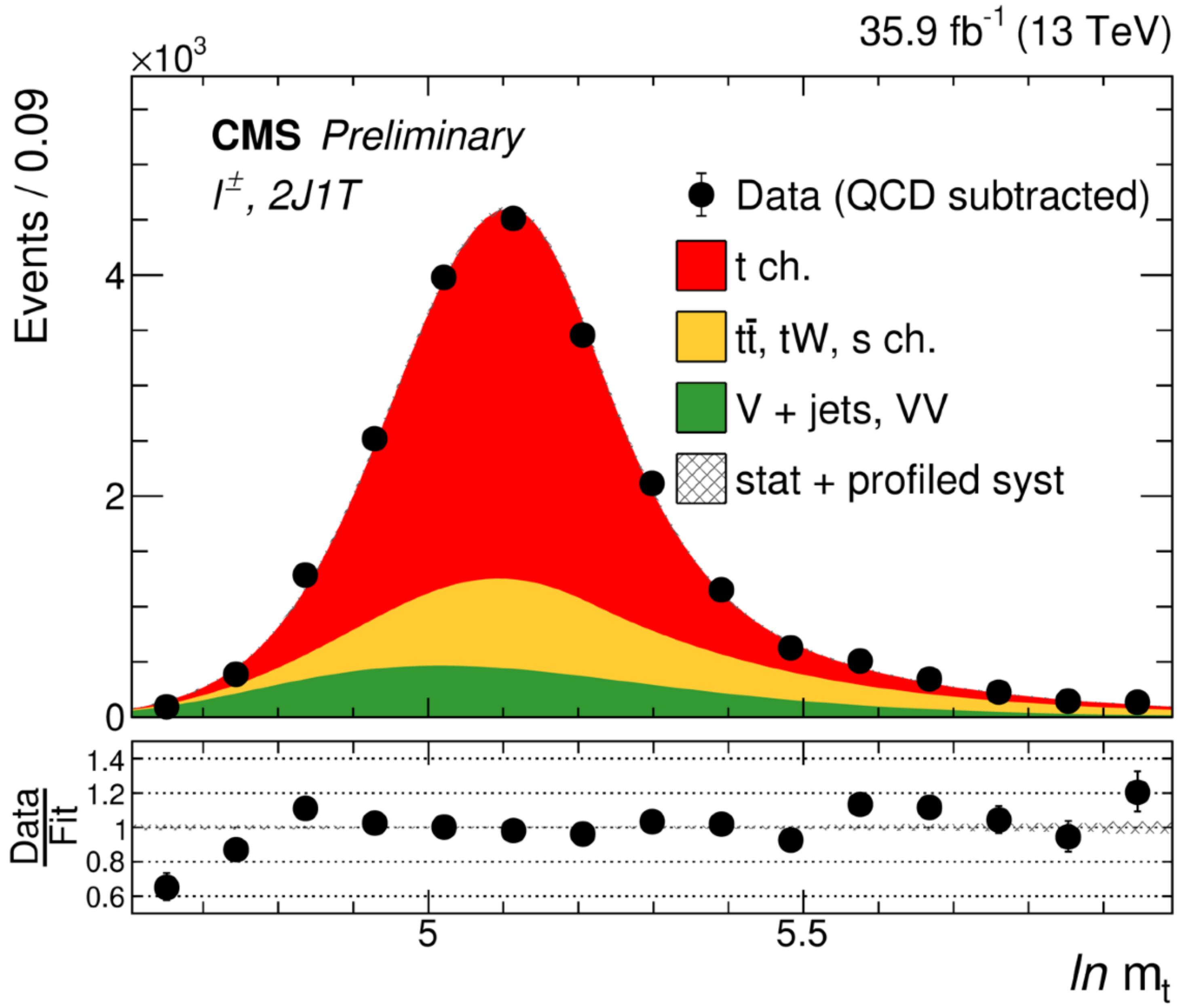


M_{top} from single-top events

- Measurement based on 2016 data
- Selection requiring an isolated energetic lepton (muon or electron) and two jets
- One b-tagged jet is required
- The mass of the top quark is found to be be $172.13^{+0.76}_{-0.77}$ GeV, The difference of masses of top quark and antiquark is measured to be $0.83^{+0.77}_{-1.01}$ GeV

t-channel single top production at LO in four- and five-flavor schemes

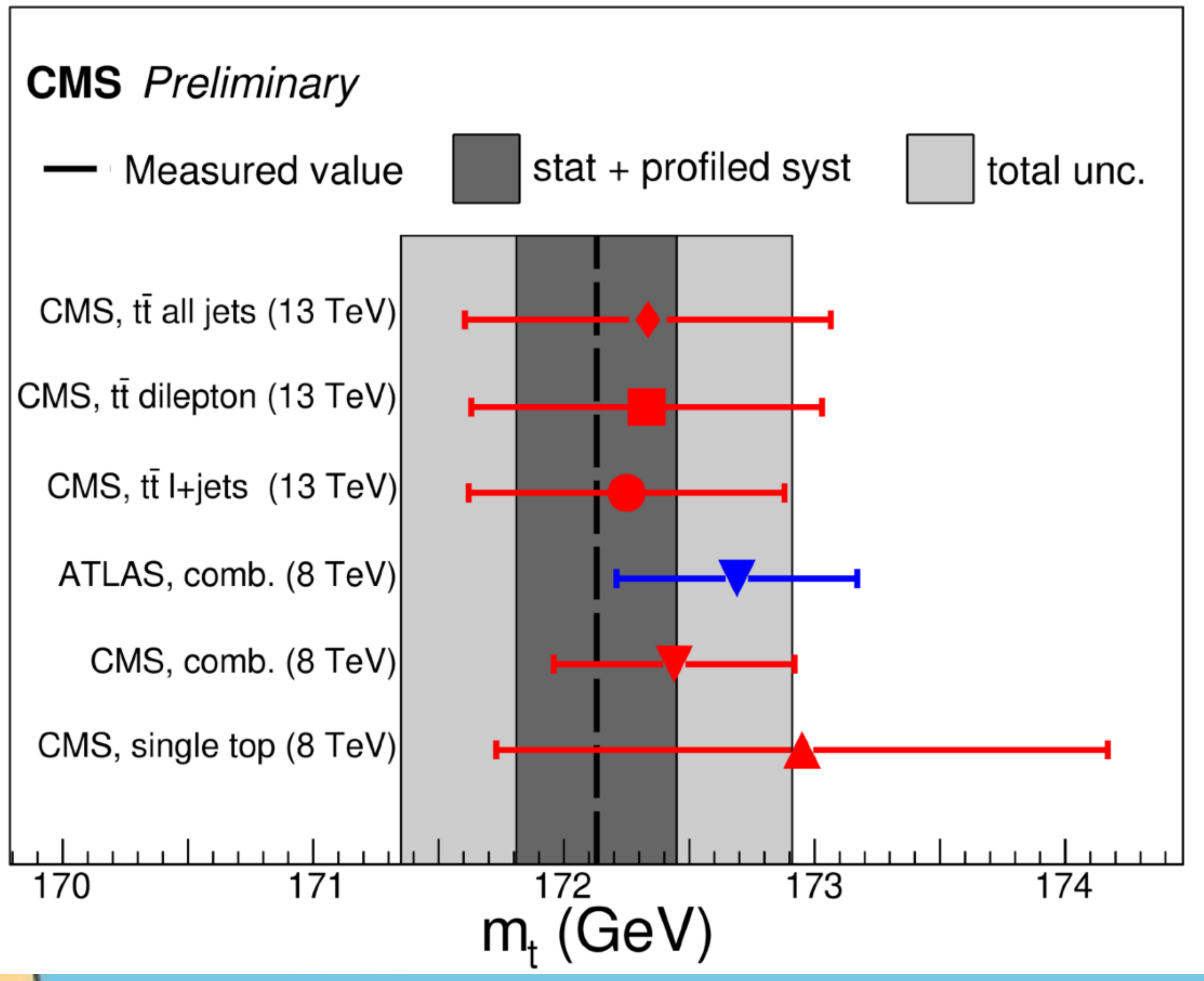




Fitted
In top mass

CMS-PAS-TOP-19-009

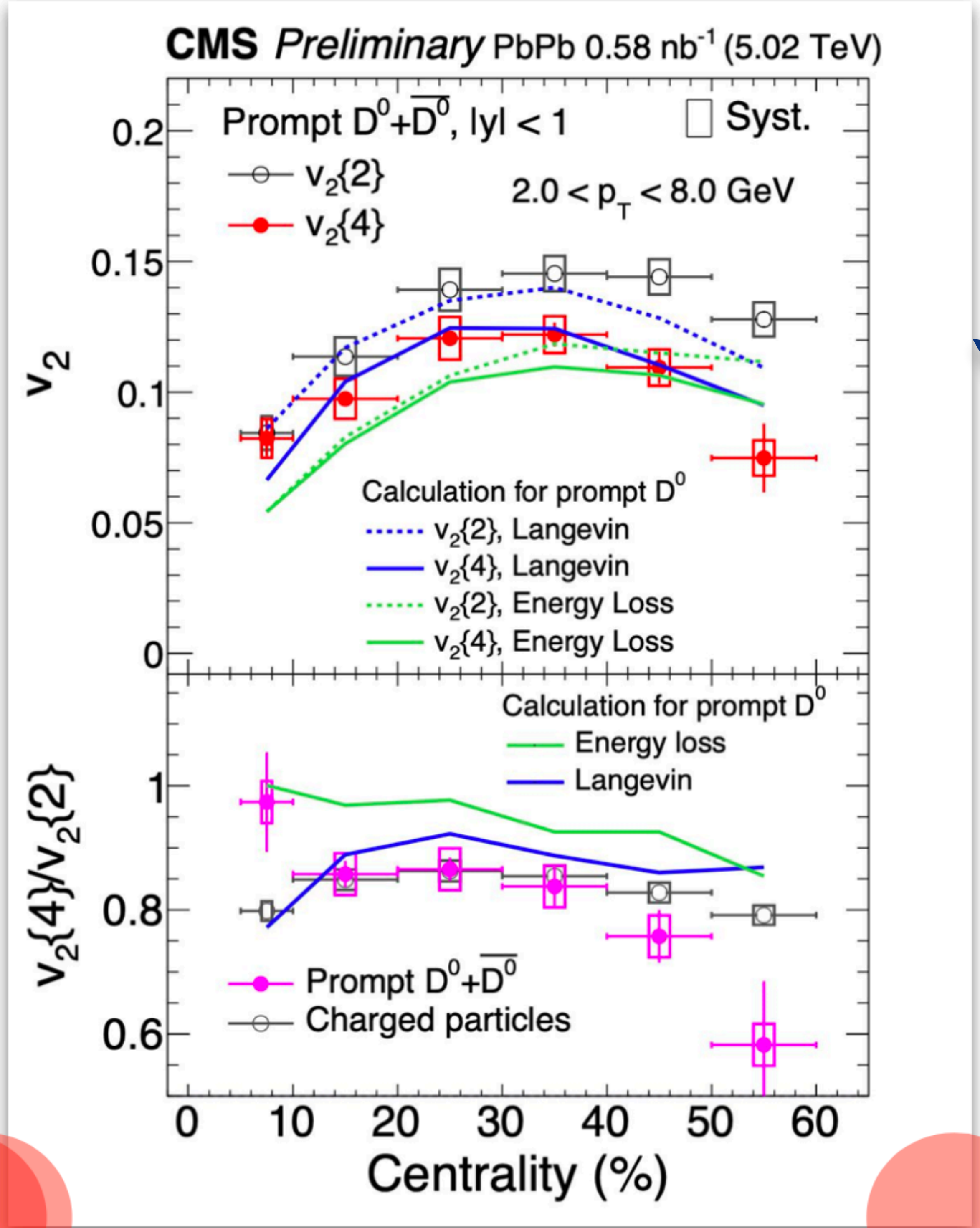
Measured m_t compared to previous measurement

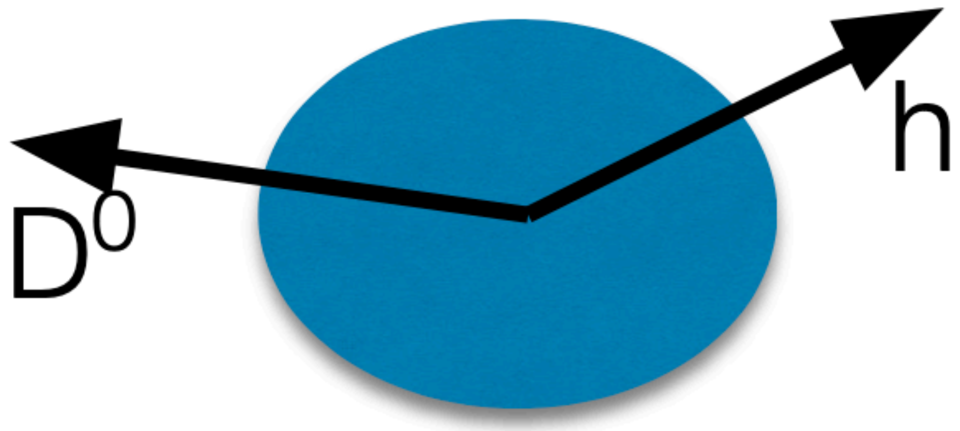


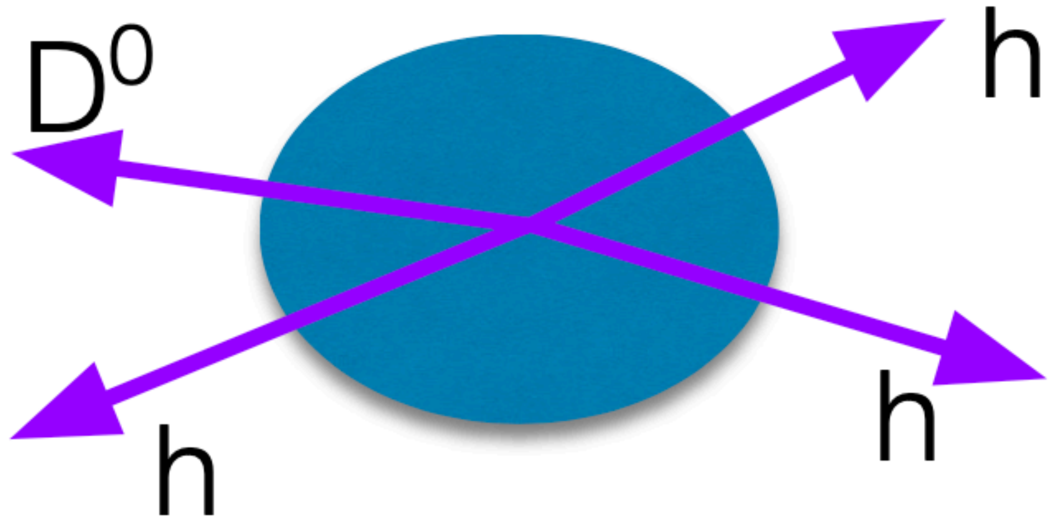
Note: the grey band is the new measurement.

Heavy Ions: collectivity of D meson

HIN-20-001







v_2 from 2-particles correlation

v_2 from 4-particles correlation

Difference between $v_2\{2\}$ and $v_2\{4\}$ sensitive to flow fluctuations

Flow fluctuation different between **D^0** and **light hadrons**

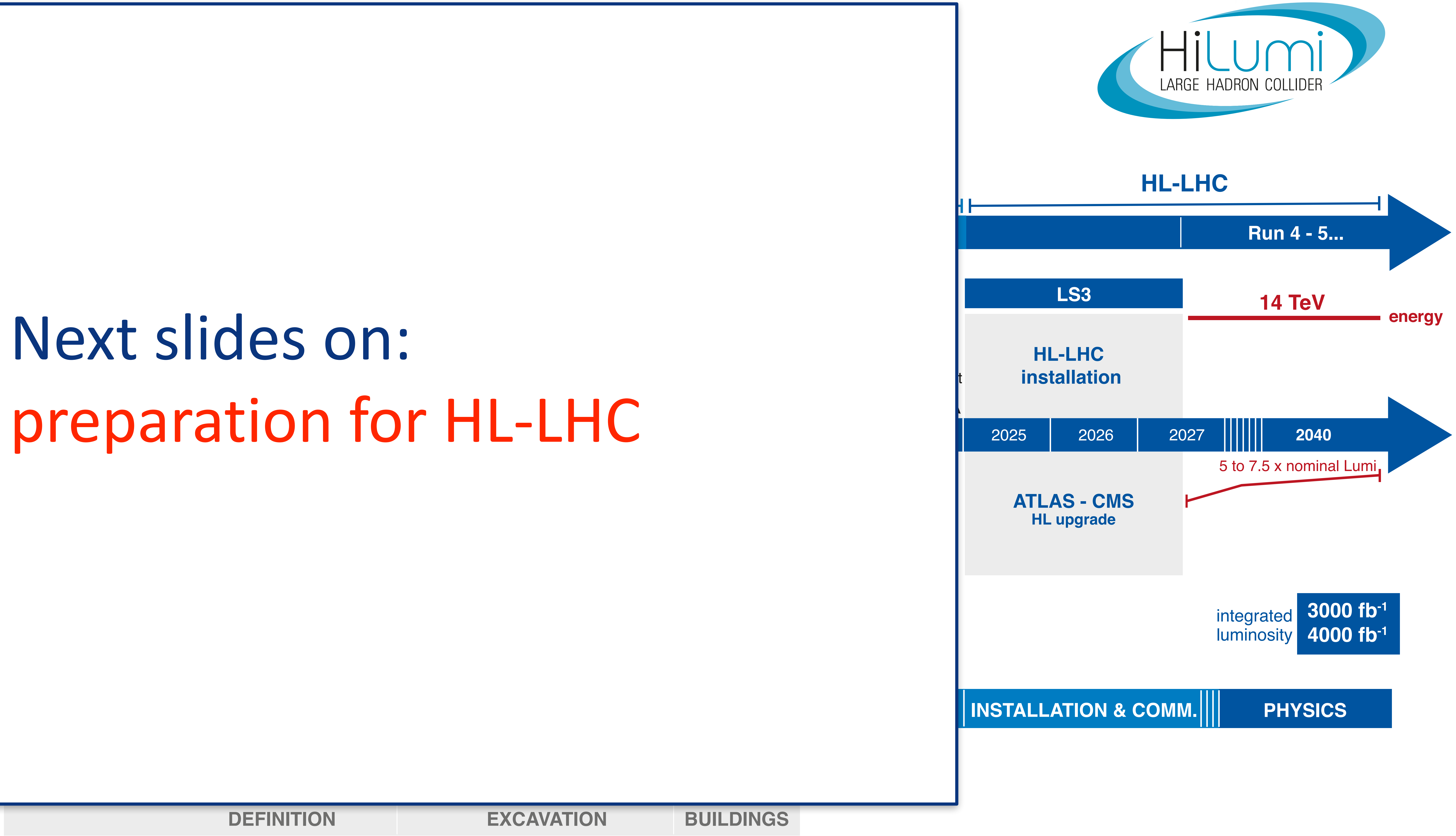
Disentangle different types of fluctuations

First measurement of D^0 $v_2\{4\}$

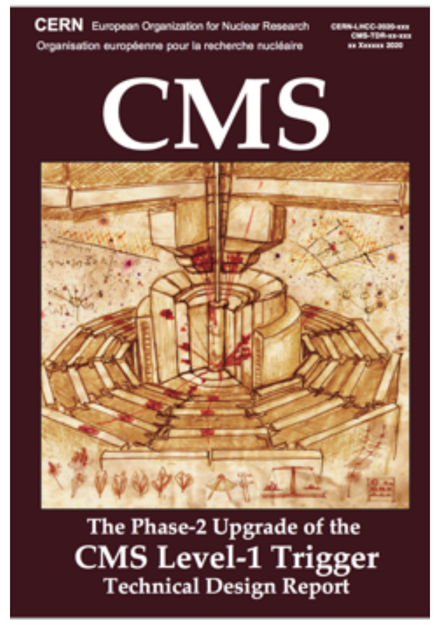
LHC Timeline

Next slides on:

preparation for HL-LHC



CMS Upgrades Status



L1-Trigger HLT/DAQ

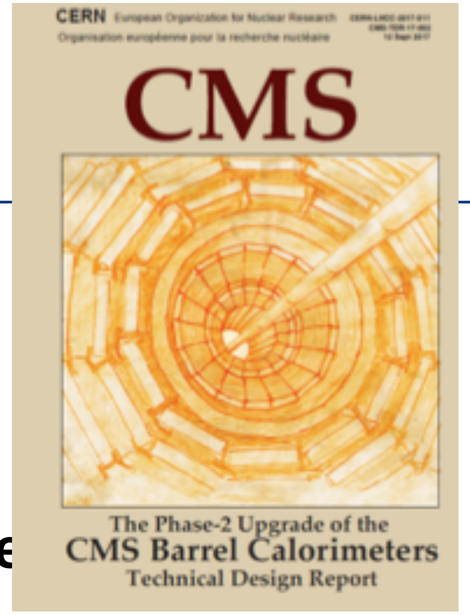
https://cds.cern.ch/record/2714892
https://cds.cern.ch/record/2283193

- Tracks in L1-Trigger at 40 MHz
- PFlow selection 750 kHz L1 output
- HLT output 7.5 kHz
- 40 MHz data scouting

Barrel Calorimeters

https://cds.cern.ch/record/2283187

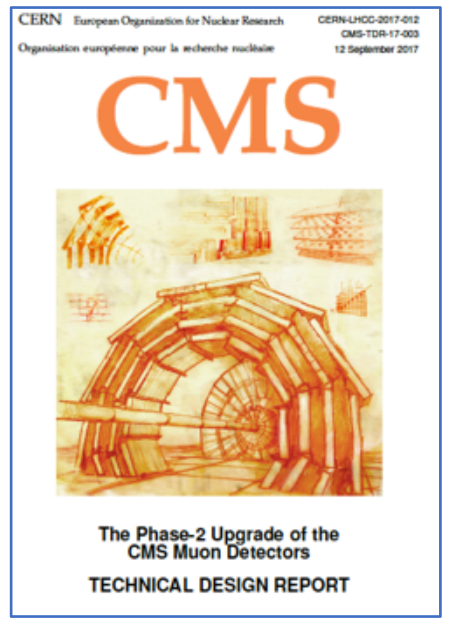
- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards

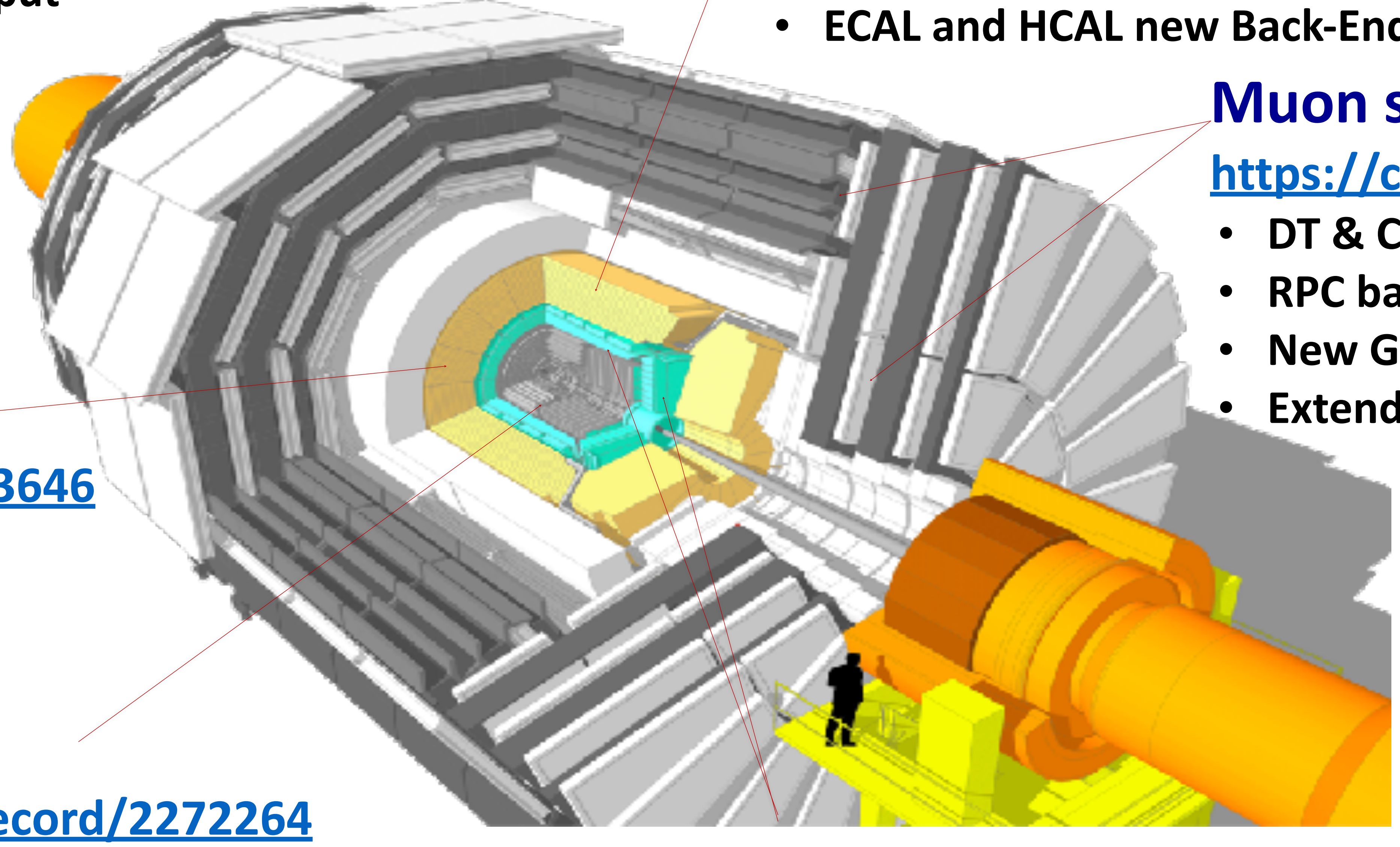


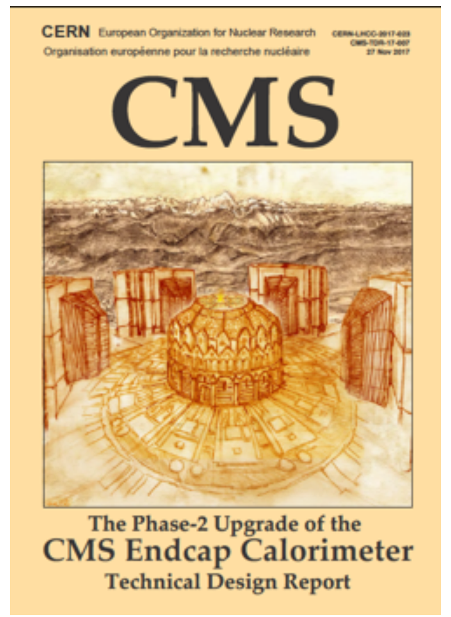
Muon systems

https://cds.cern.ch/record/2283189

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC 1.6 < η < 2.4
- Extended coverage to η ≃ 3







Calorimeter Endcap

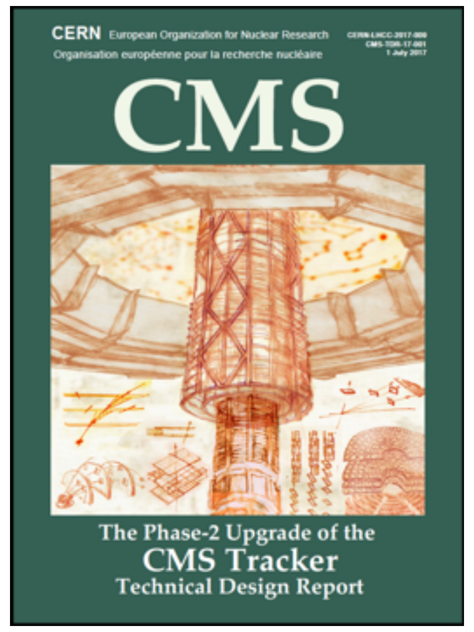
https://cds.cern.ch/record/2293646

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Beam Radiation Instr. and Luminosity

http://cds.cern.ch/record/002706512

- Bunch-by-bunch luminosity measurement: 1% offline, 2% online



Tracker https://cds.cern.ch/record/2272264

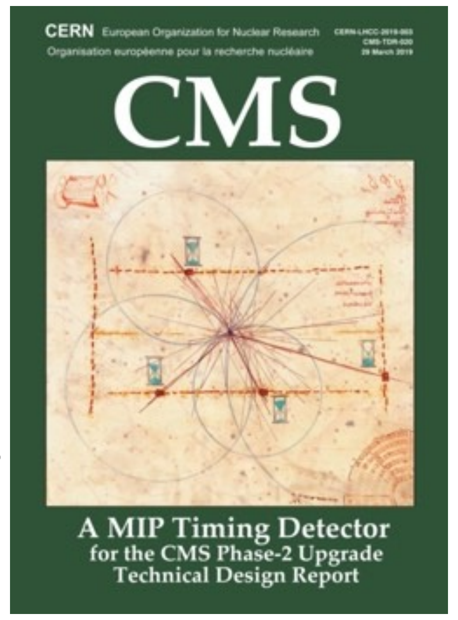
- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to η ≃ 3.8

MIP Timing Detector

https://cds.cern.ch/record/2667167

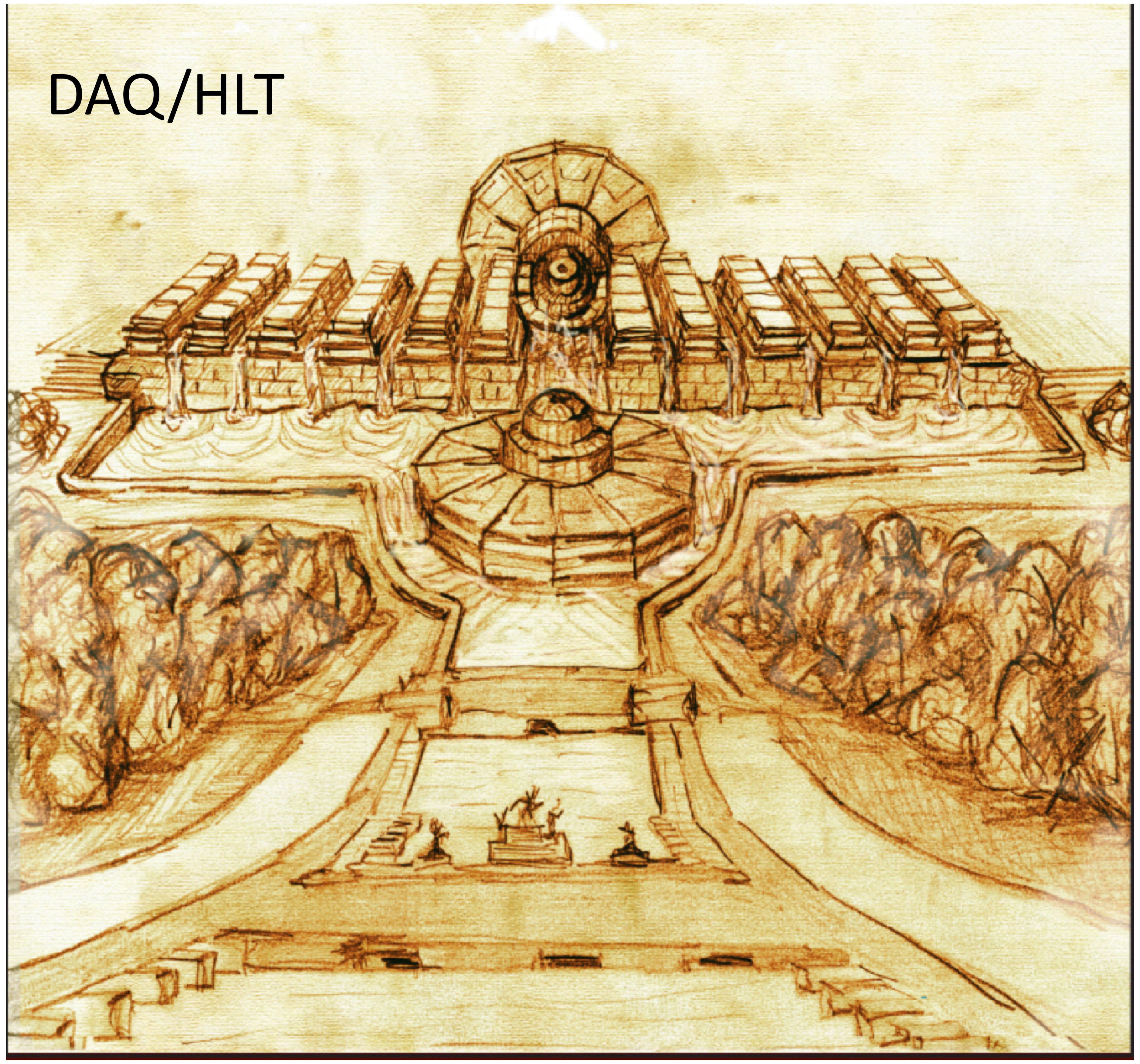
Precision timing with:

- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

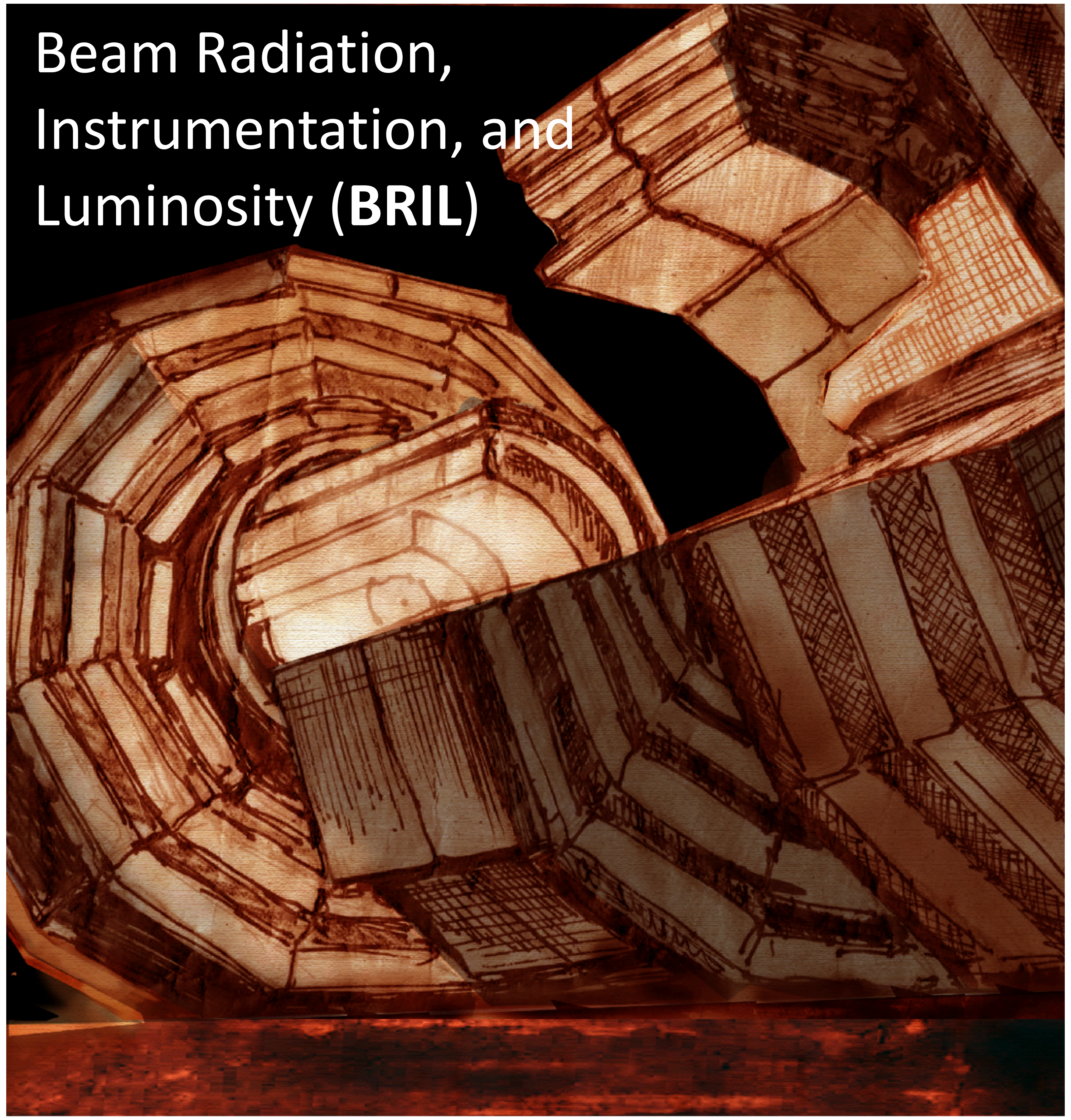


All shown Technical Design Reports approved by the LHC Committee.
Two under scrutiny.

Last two TDR



Thresholds and rates meeting specification at PU=200 with algorithms of today!

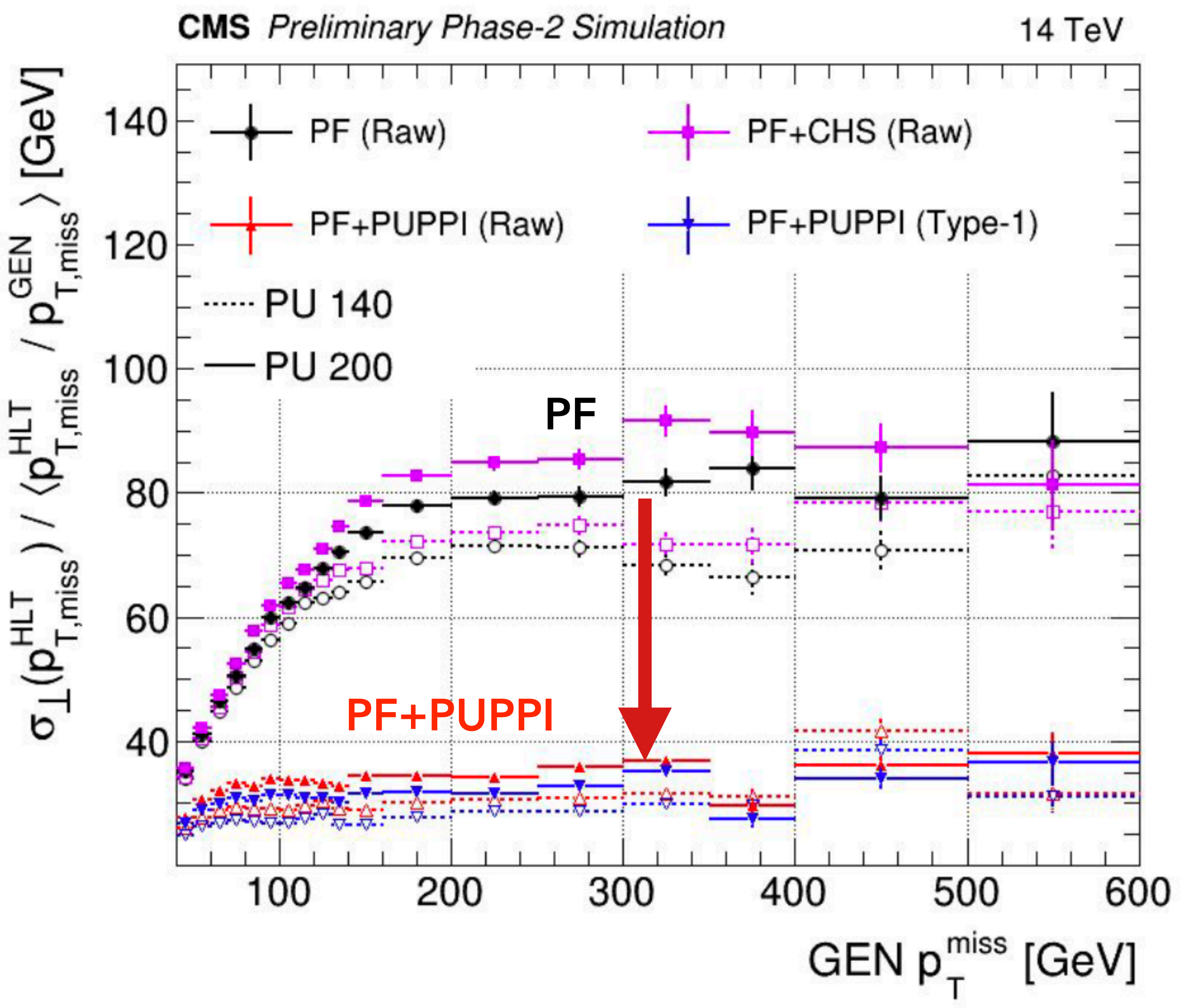


Exploit almost all CMS systems for luminosity with the goal of 1% precision

HLT TDR: few excerpts

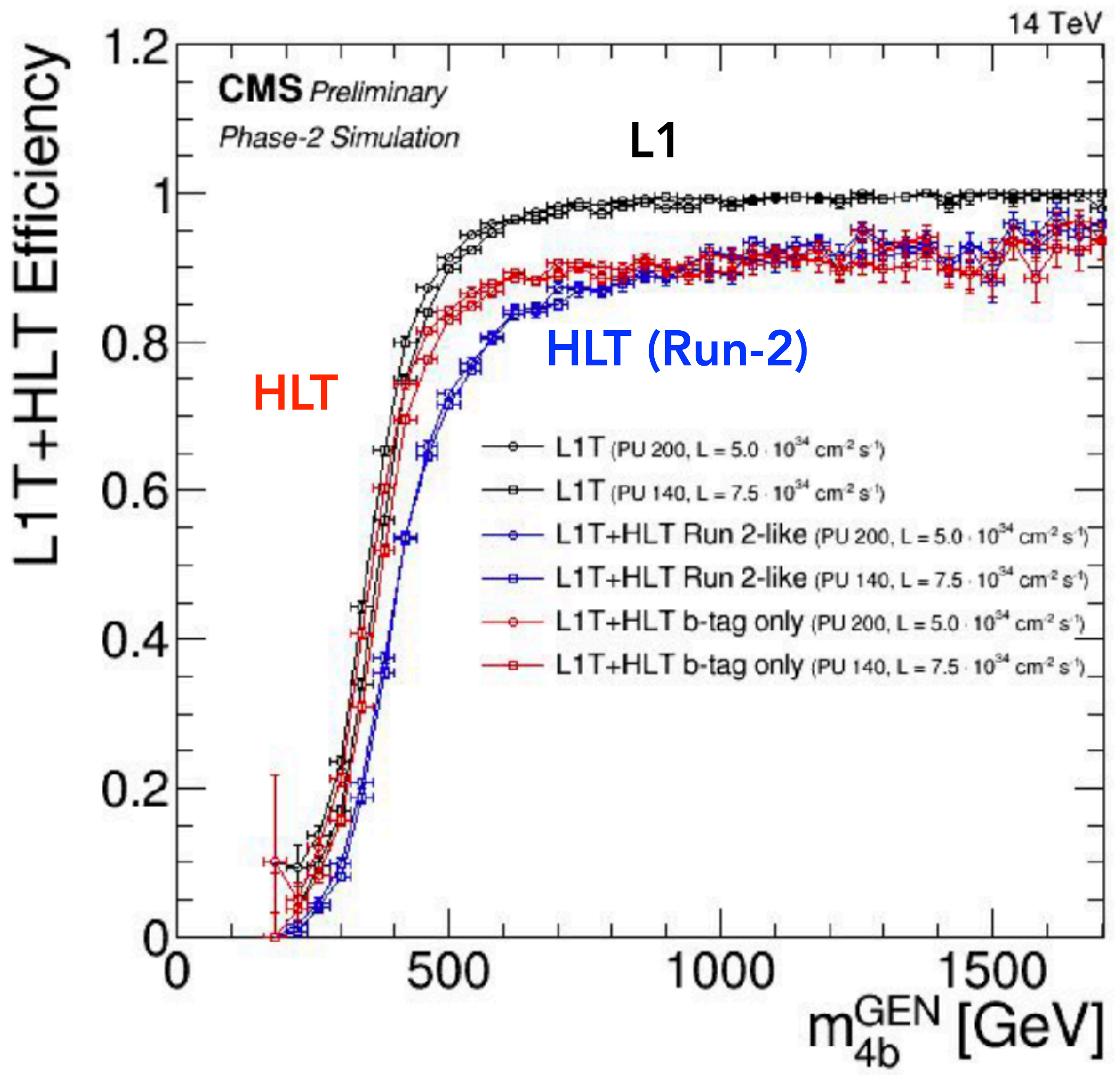
Phase-II HLT

- Physics performance already matching expectations with thresholds similar to that of Run-2
- Timing-wise, **only** a factor ~2 still to be gained for Run-4



Response-corrected MET resolution

The PUPPI algorithm (red) mitigates PU effectively.



$HH \rightarrow b\bar{b}b\bar{b}$ **trigger efficiency**

L1T (black), L1T+HLT with Run-2 algorithm (blue), L1T+HLT with lower p_T and H_T thresholds and DeepCSV b-jet tagging (red) for same rate (50Hz)

Trigger type	Phase-1		Phase-2			
	Threshold [GeV]	% rate	L1T seed	Threshold [GeV]	Rate at ⟨PU⟩ = 140 [Hz]	Rate at ⟨PU⟩ = 200 [Hz]
Single μ	50	3%	TkMu_22			
Single μ (isol.)	24	14%	TkMu_22			
Double μ	37, 27	1%	TkMu_15_7			
Double e	25, 25	1%	TkEle_25_12 OR StaEG_37_24			
Double e (isol.)	23, 12	1%	TkEle_25_12 OR StaEG_37_24			
Single γ	200	1%	StaEG_51			
Single γ (isol.)	110, EB only	1%	StaEG_51 OR [illegible]			
Double γ	30, 18	2%	StaEG_37_24 OR TkIsoPho_22_12			
Double τ	35, 35	3%	HPSPFTau_21_21			
Single jet	500	1%	PuppiJet_230			
H_T	1050	1%	PuppiHT_450			
Missing p_T	120	3%	PuppiMET_220			
Multijets with b-tagging	$H_T = 330$ jets = 75, 60, 45, 40	1%	PuppiJet_70_55_40_40_PuppiHT_328			
Individual Rates Sum		49%				
Whole Menu Rate						

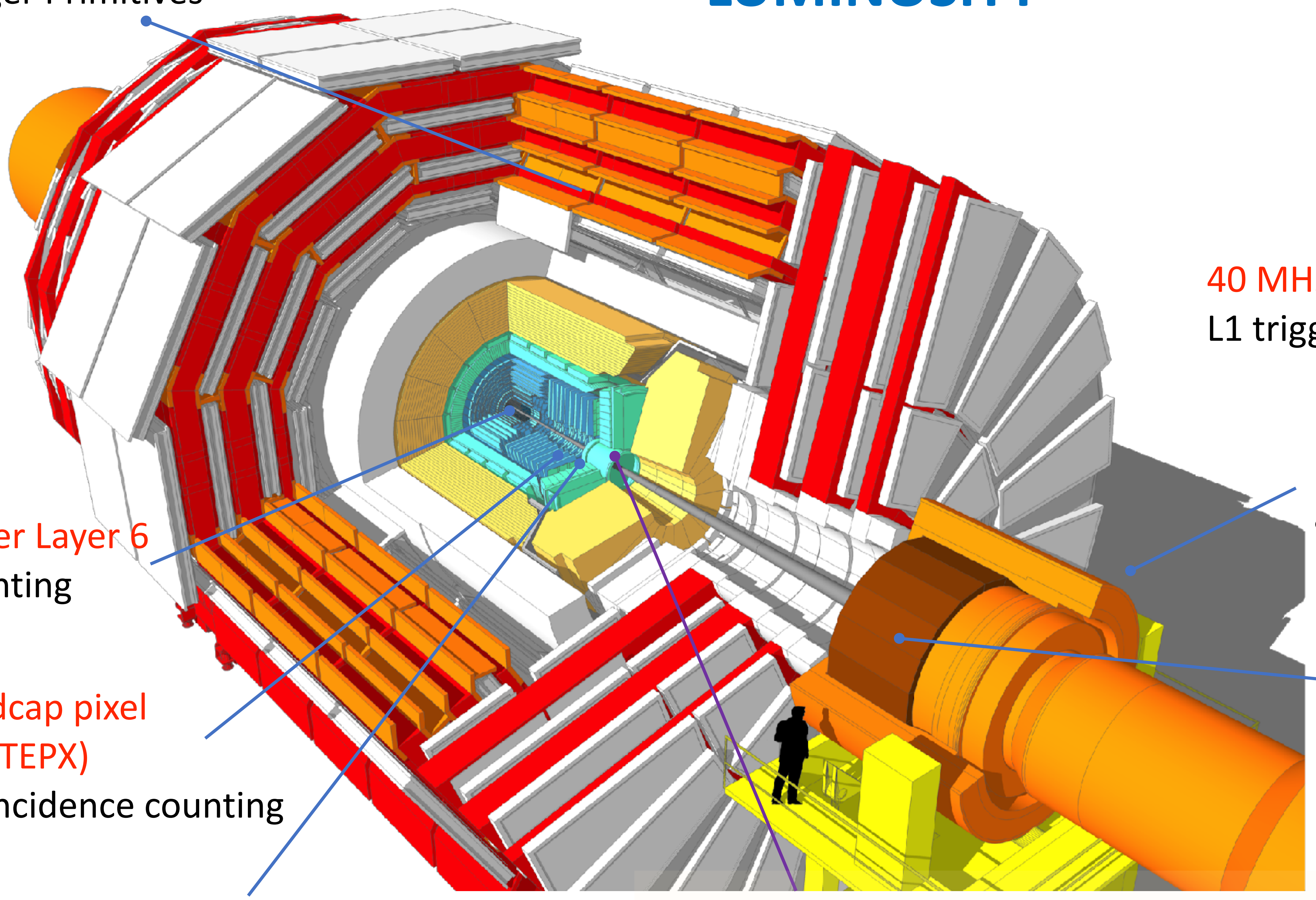
Established a menu (50% of todays)
- Rates and thresholds at PU=200 are compatible to today's

compare thresholds

Expect to offload to GPU:
50% for Run4 at 140 PU
80% for Run5 at 200 PU

BRIL System for HL-LHC

CMS SUB-SYSTEMS for bunch by bunch PHASE2 LUMINOSITY



Fast Beam Condition Monitor (FBCM)
standalone luminometer: hit zero-counting lumi and BIB

- orthogonal systematics to other CMS subsystems & fully independent operation

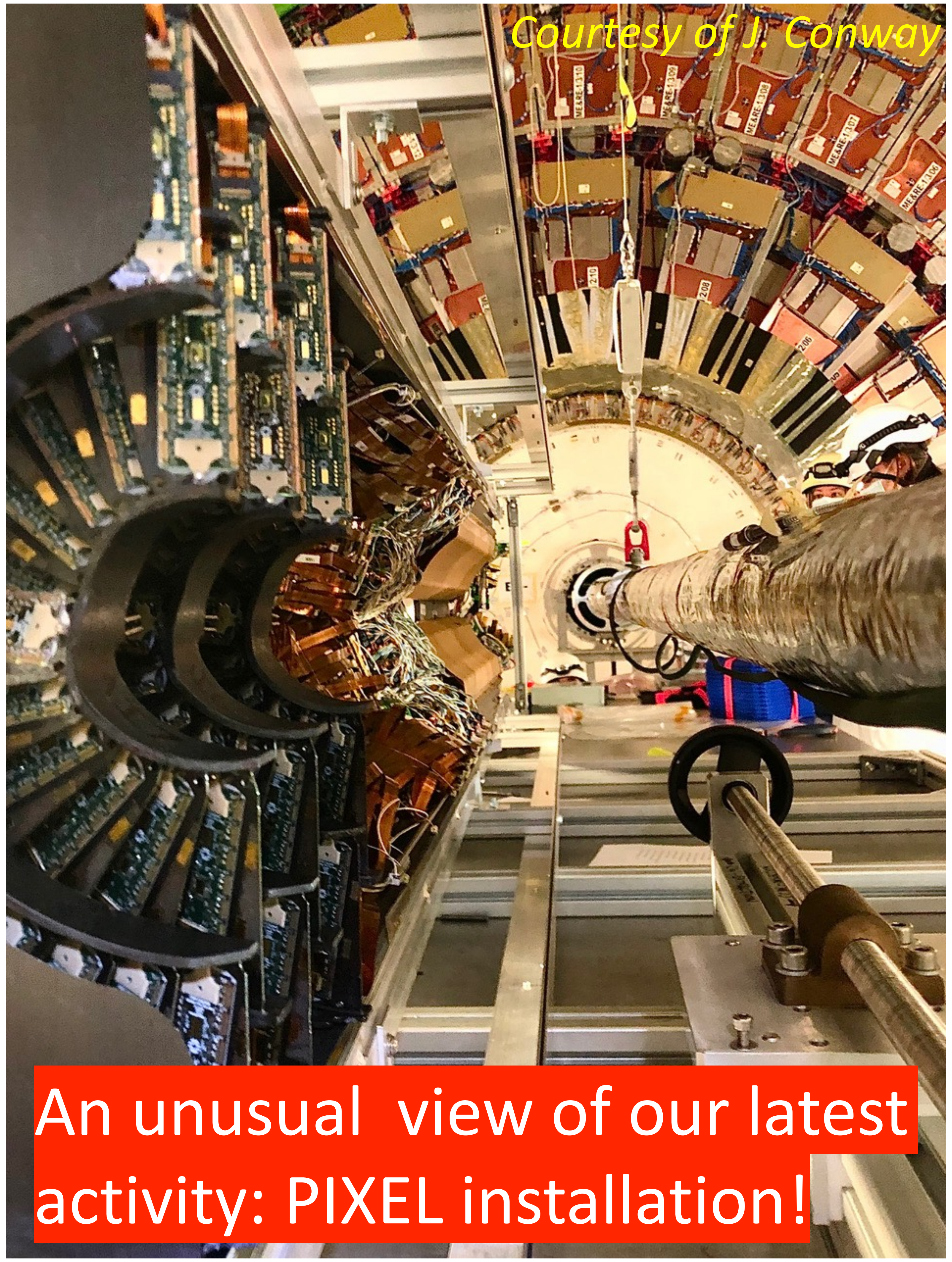
Goals:

- **Offline** bunch-by-bunch (BbB) luminosity with **1%** precision for physics
- **Online** (BbB) & orbit integrated luminosity with **< 2%** precision
  - even outside CMS data taking

1. **in the proposed scheme, luminosity will become a consumer of CMS subsystem data, much like the trigger and DAQ**
2. **also pursuing a simple, reliable and independent high precision luminometer to provide:**
   - **orthogonal systematics to other CMS subsystems**
   - **sub-BX time resolution, bunch-by-bunch measurement**
   - **fully independent operation**

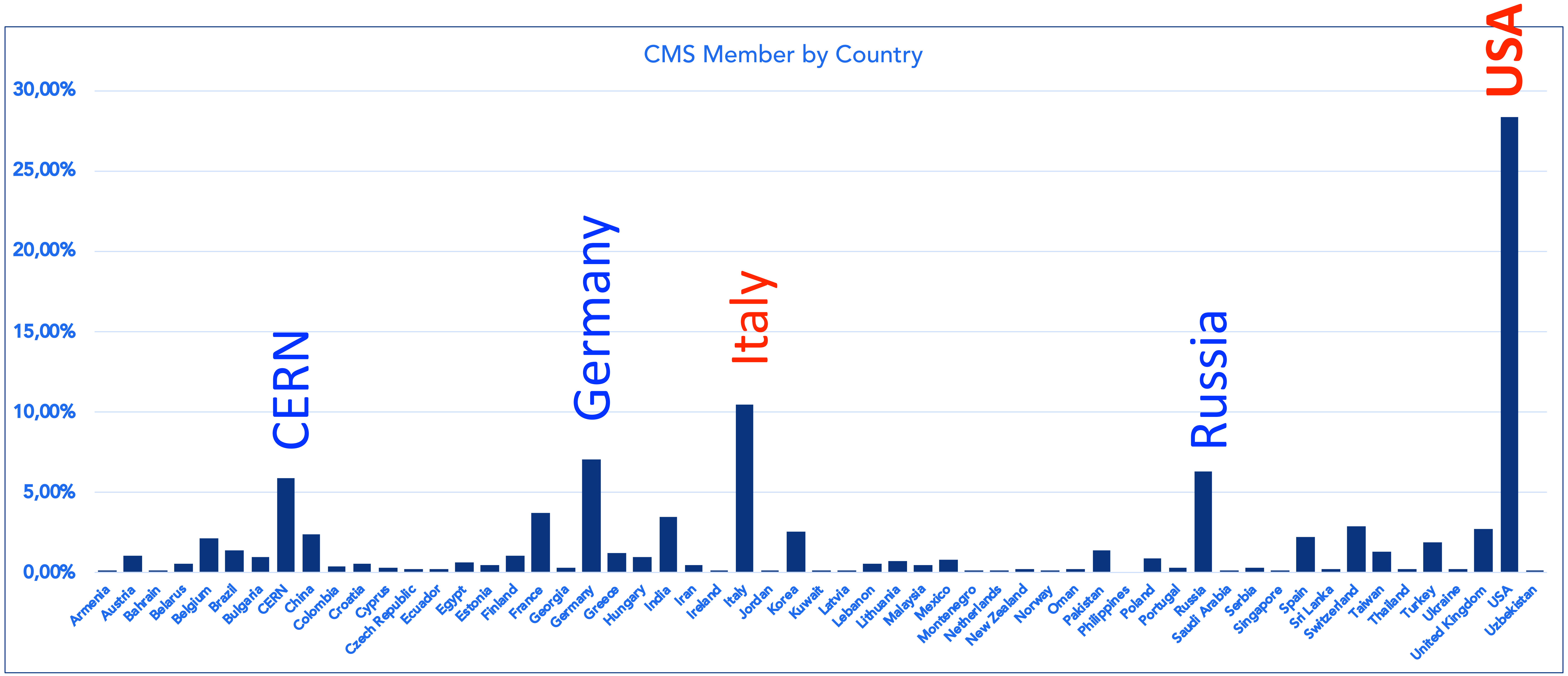
Summary

- The last year was not an easy year for the entire world.
- Despite the difficulties, technical and sociological, CMS was able to adapt and continue its program:
  - LS2 activities are on track for a first pilot beam in October 2021
  - CMS will be ready for Run3 in 2022 with new ideas to explore new phase spaces!
  - The detector upgrade program is continuing full swing setting new paradigms in detector and data taking operations for HEP.



BACKUP

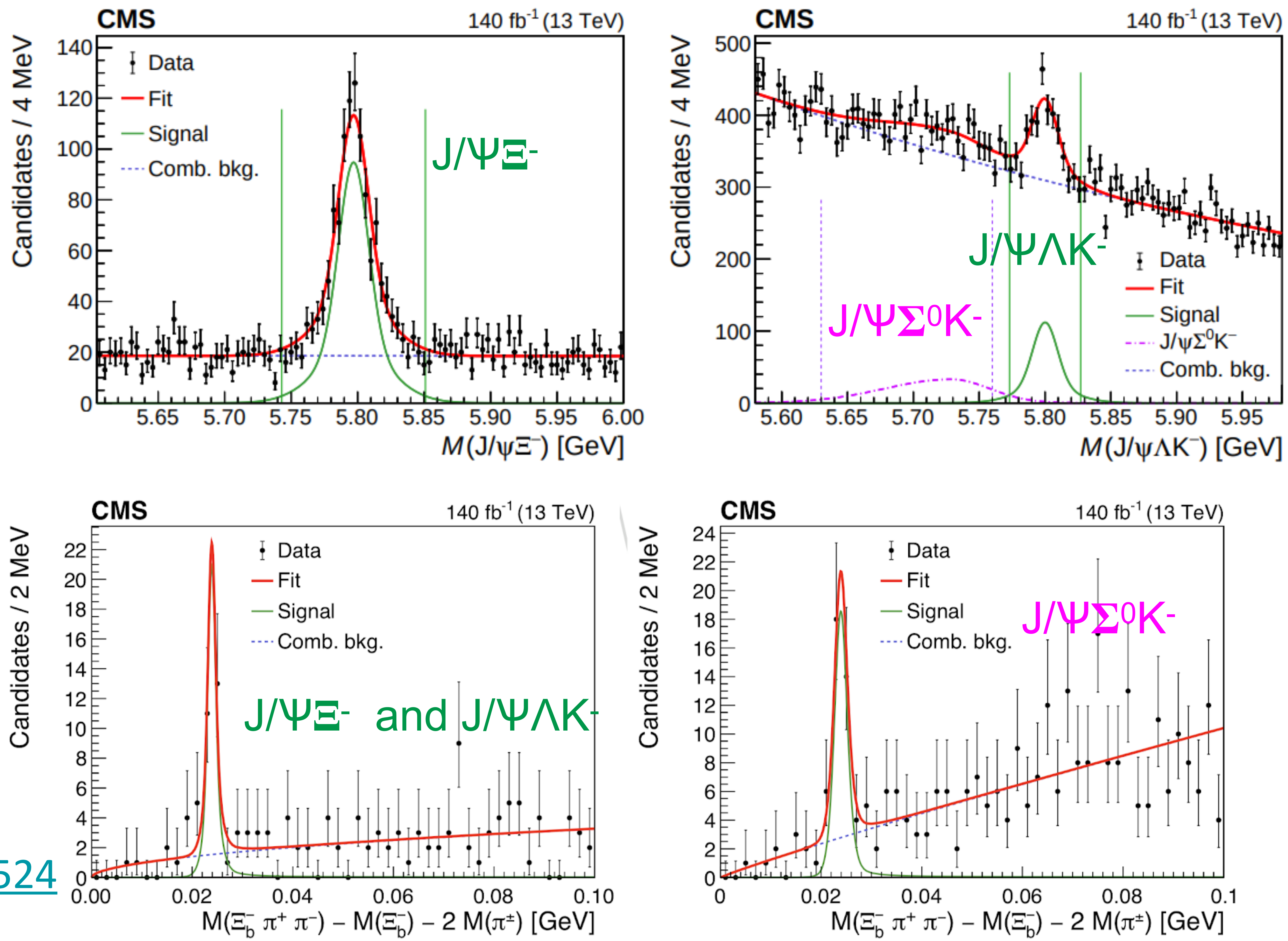
CMS Members per Country



Then: France, India, Switzerland, UK, Korea, China, Spain, Belgium, Turkey, Brazil, Taiwan, …

Observation of a new baryon

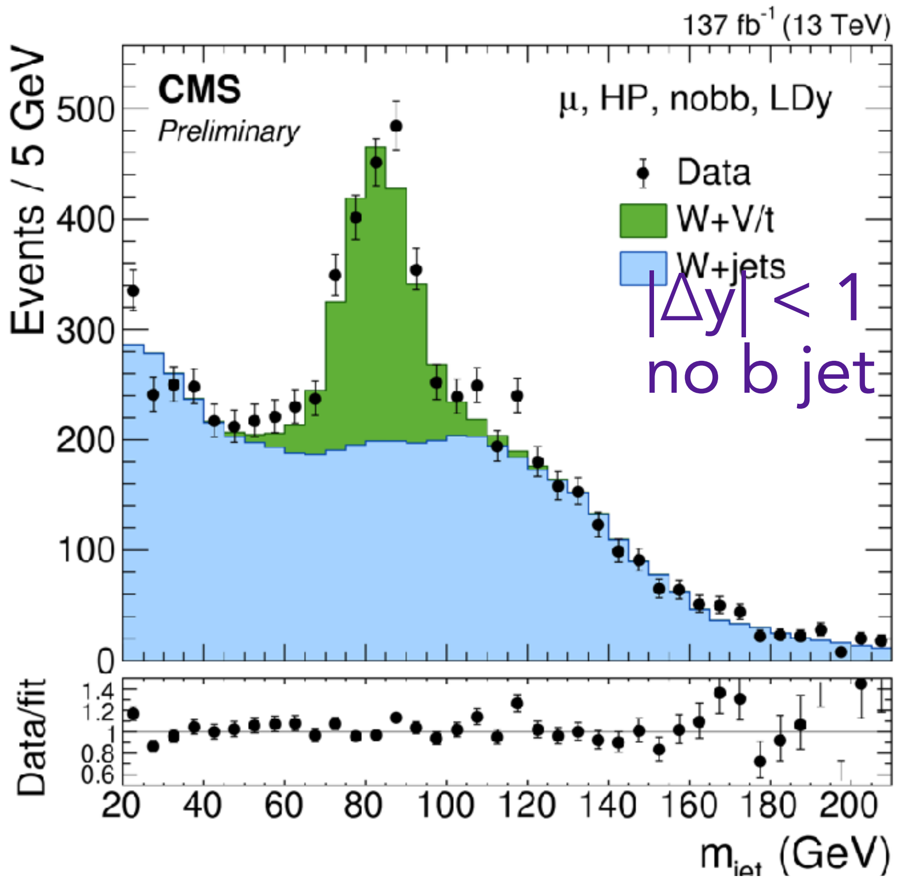
- Observation of a new $\Xi_b(6100)^-$ state decaying into $\Xi_b^- \pi^+ \pi^-$
- M($\Xi_b(6100)^-$)=6100.3 ± 0.2(stat) ± 0.2(syst) $\pm 0.2(\Xi_b^-)$ MeV
- Significance = 6.2 – 6.7 σ
- Peak visible both when the ground state Ξ_b^- is **fully reconstructed** and in **partially reconstructed** channels

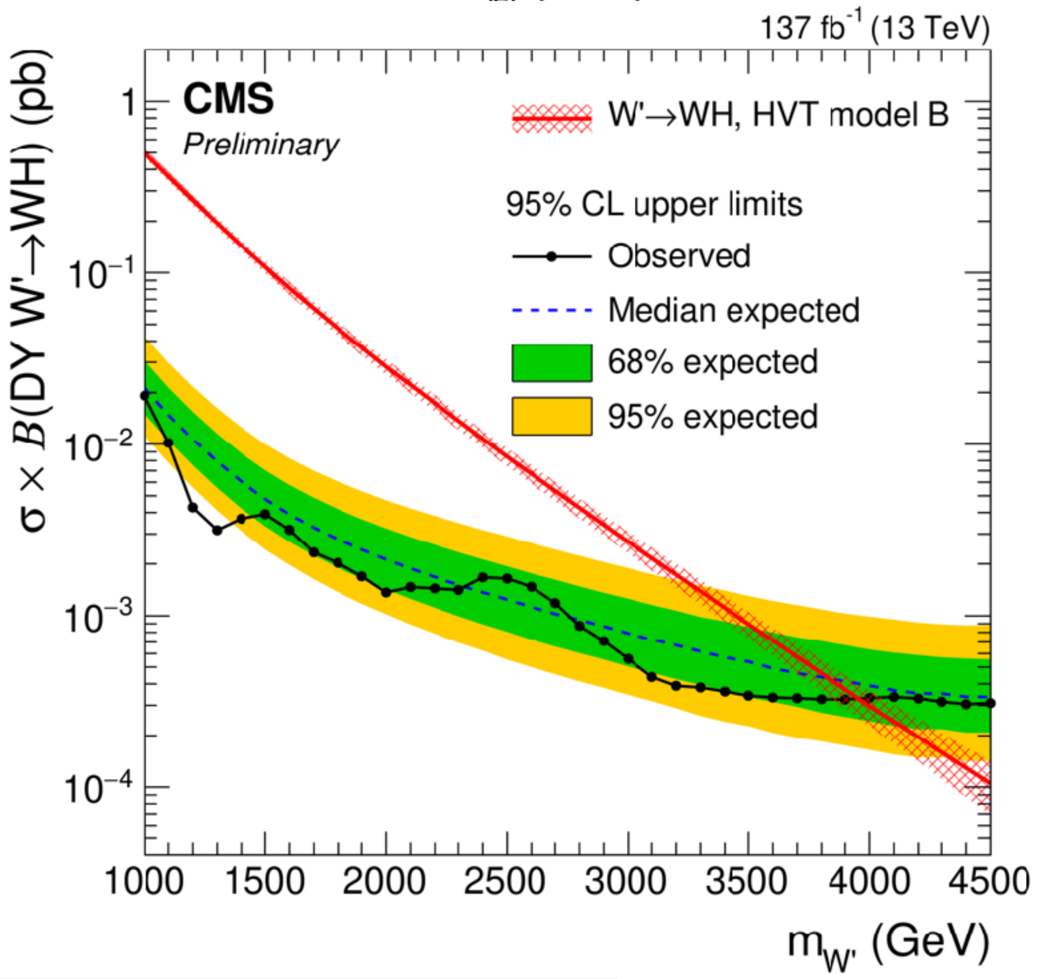


http://arxiv.org/abs/2102.04524
[accepted by PRL]()

Boosted topology searches

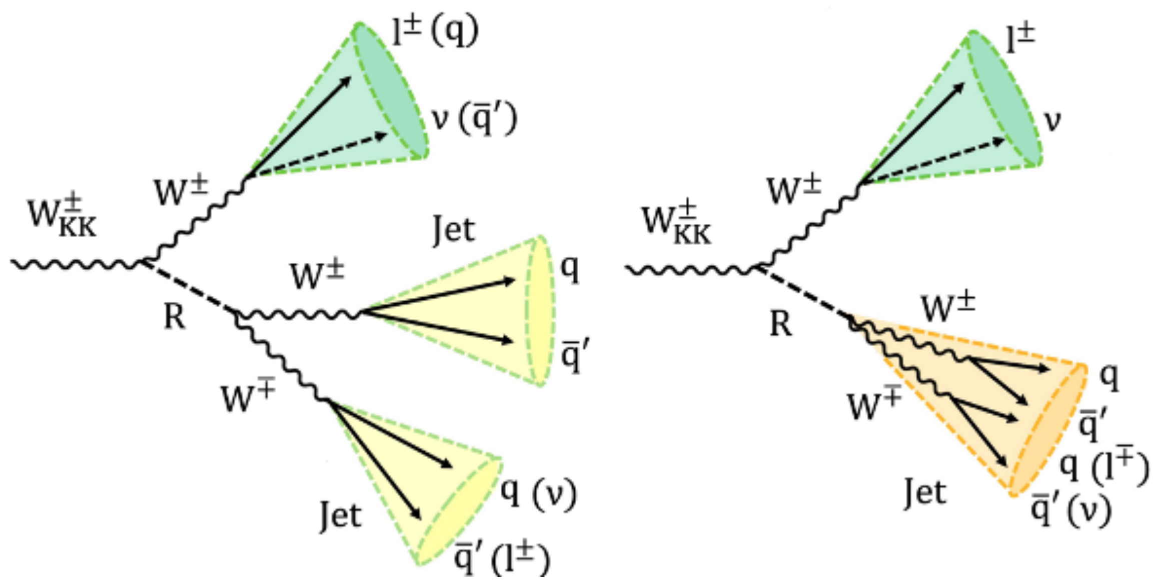
Search for WV resonances (V = W, Z, H)

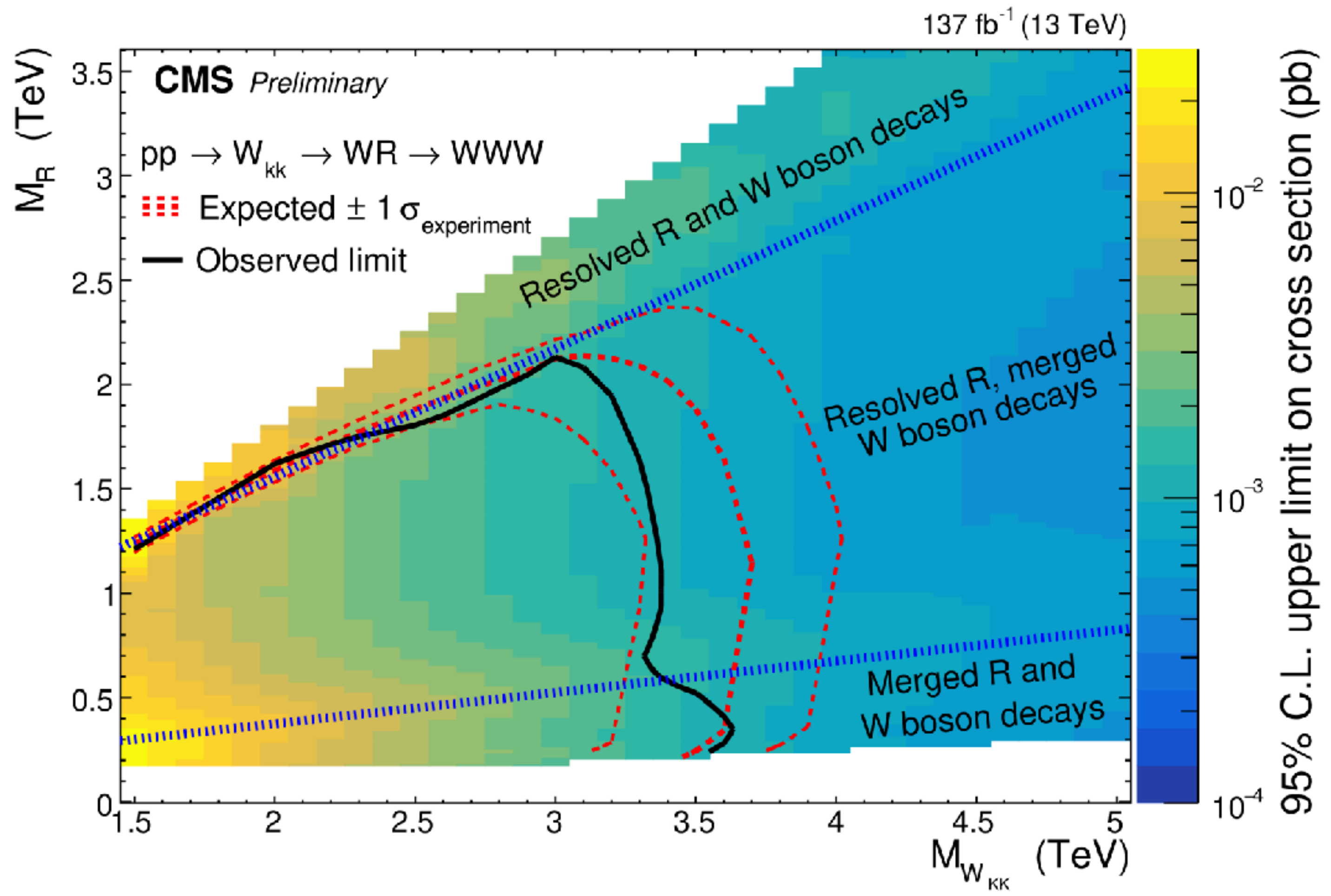




CMS-PAS-B2G-19-002

Search for resonances decaying in cascade through to three W bosons

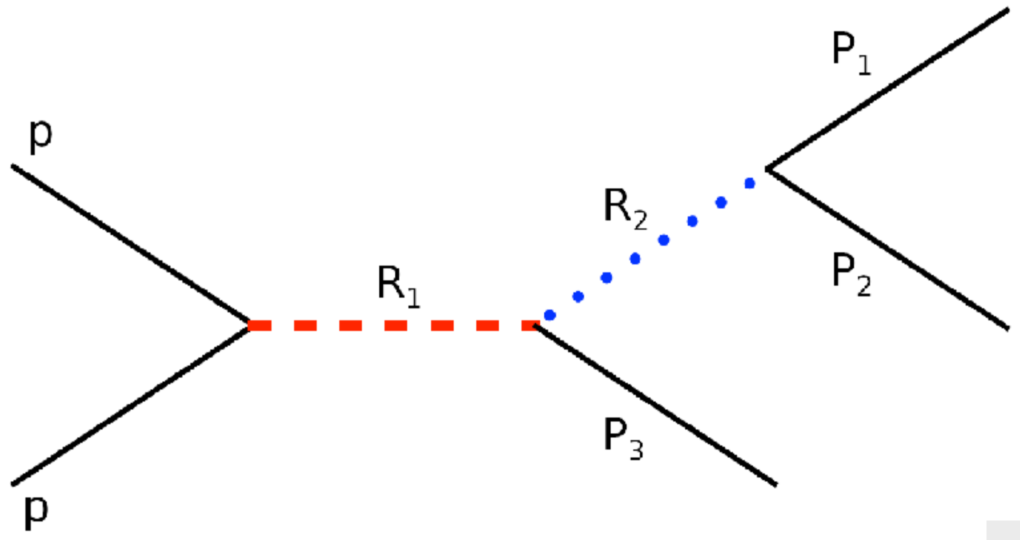




CMS-PAS-B2G-20-001

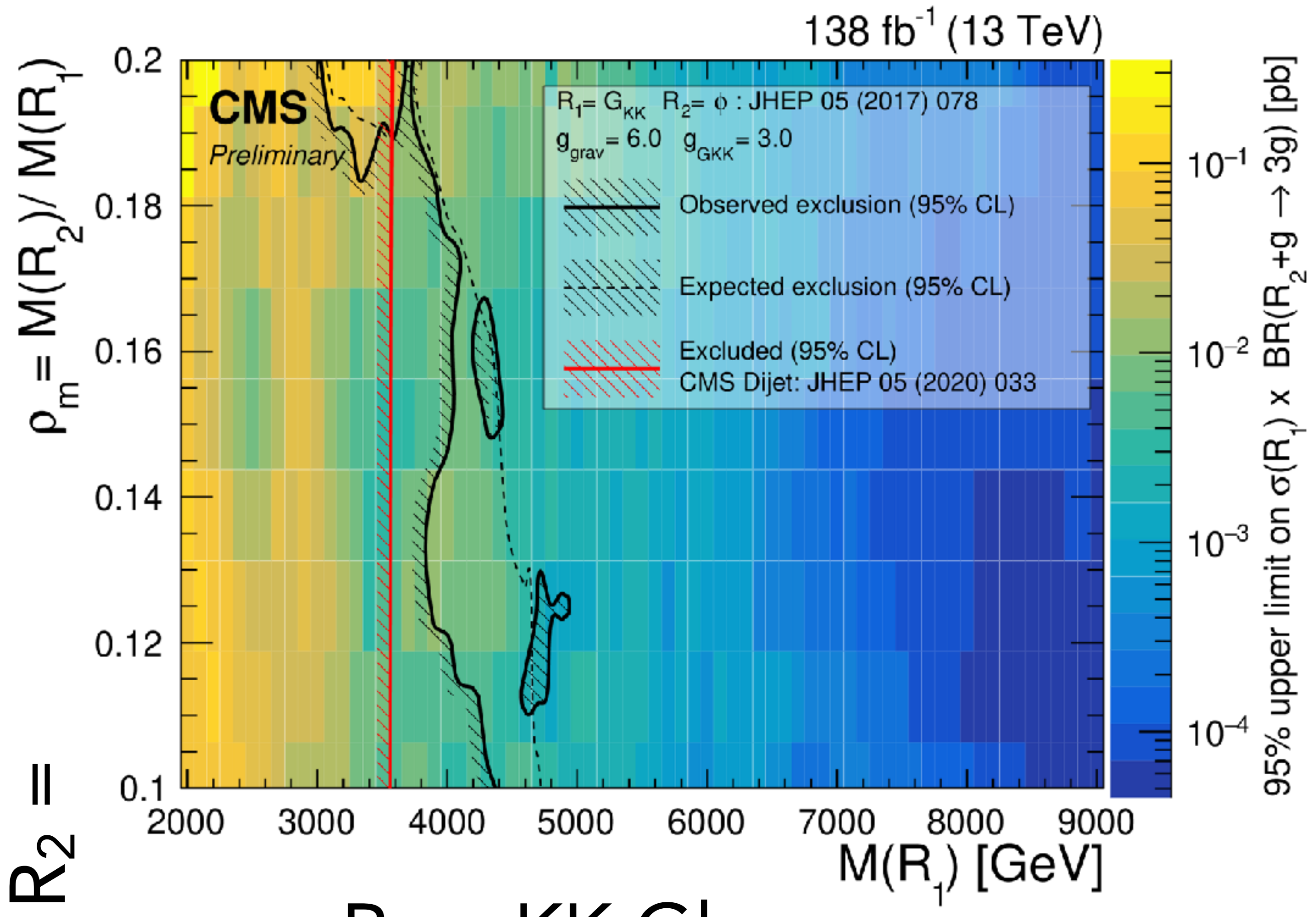
Phys. Briefing

Search for resonances in 3 jets final states where 2 jets are merged



boosted dijet resonance reconstructed as single jet containing jet substructure consistent with a two-body decay

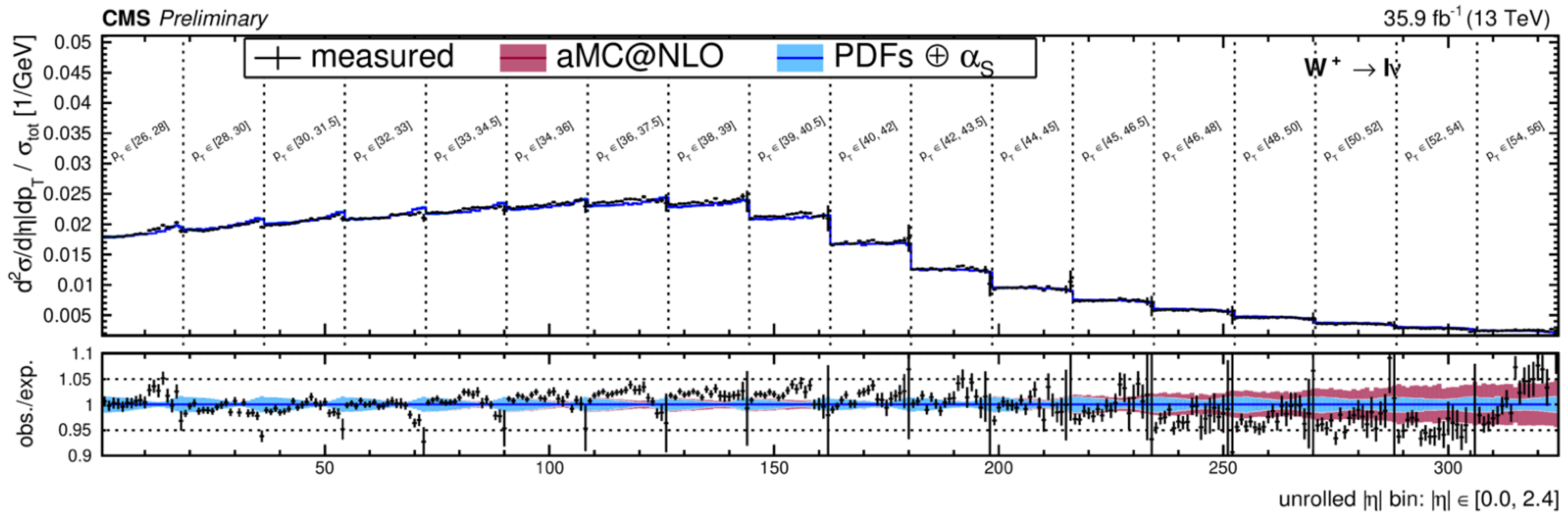
CMS-PAS-EXO-20-007

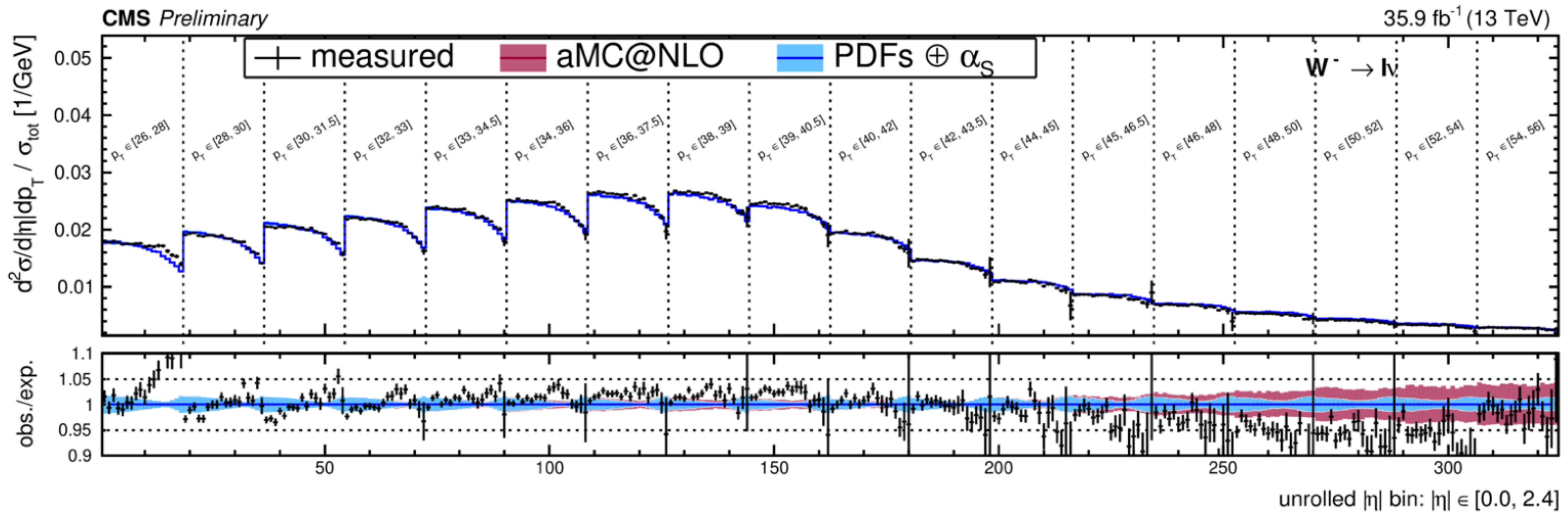


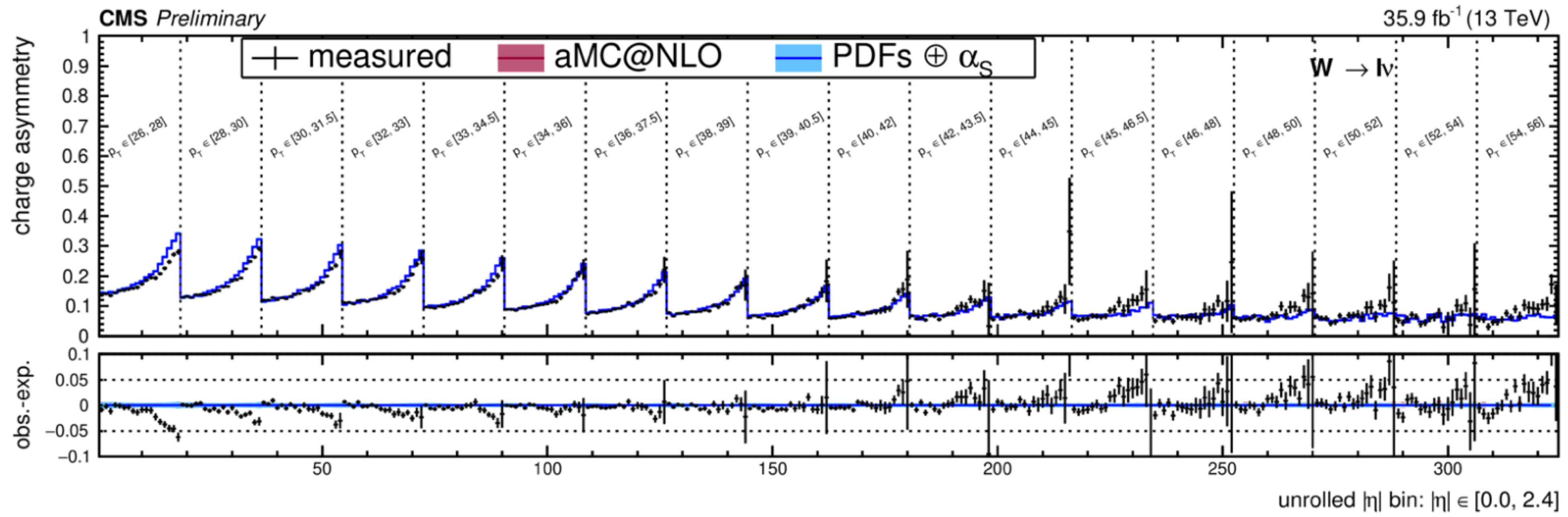
W helicity measurement

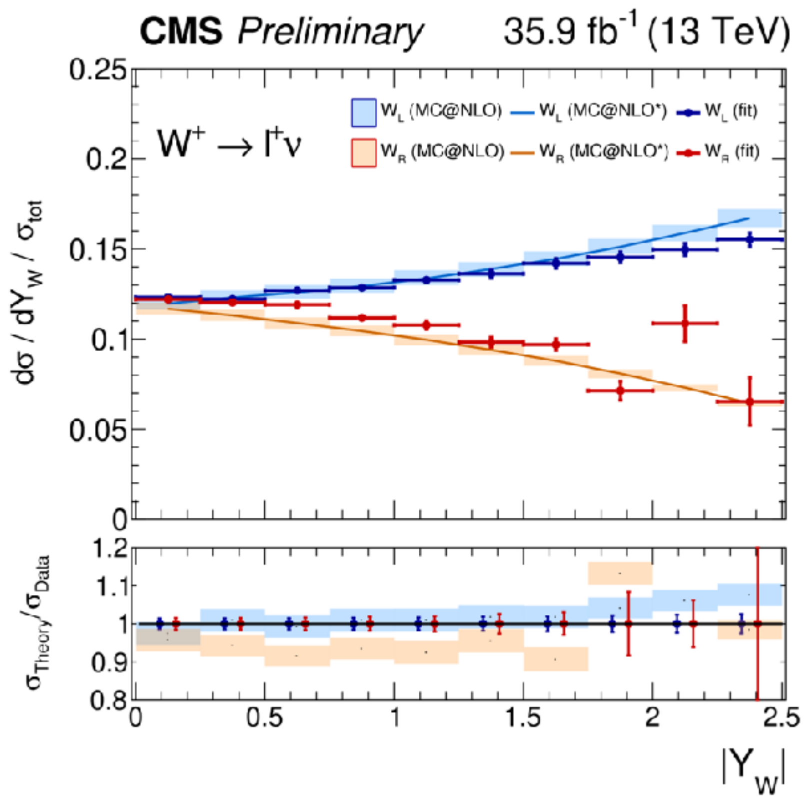
- Crucial milestone analysis, first step towards W mass measurement
- Uses electrons and muons and measures double differential cross section in η, p_T and for W^+ and W^-
- Differential cross section and charge asymmetry are extracted for the two helicity states with a template fit
- Strong constraints on the PDF

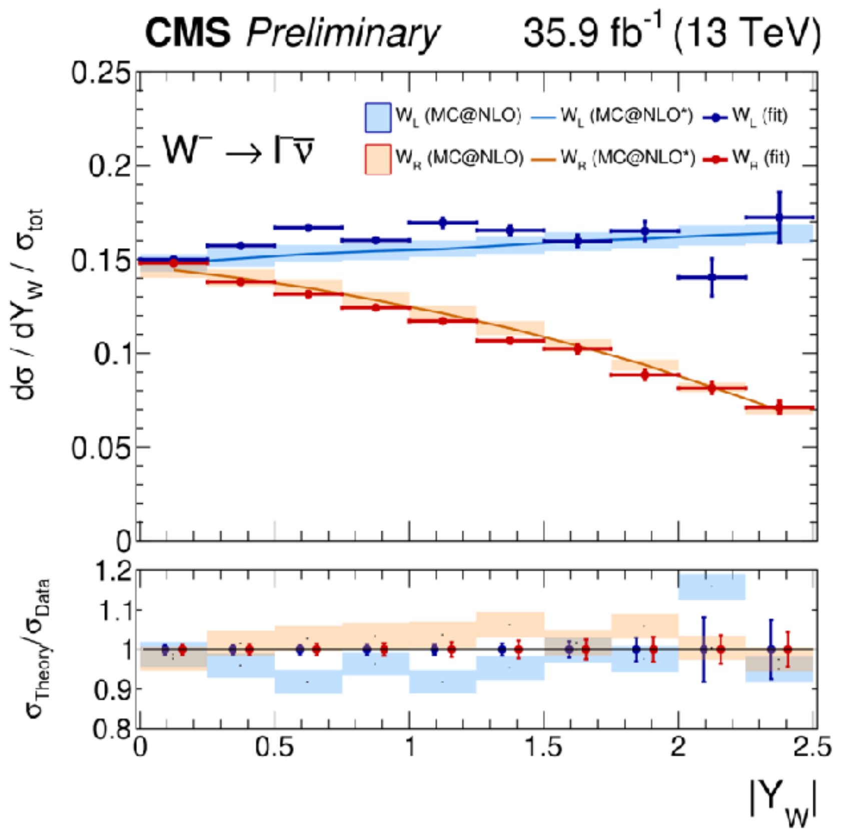
CMS PAS SMP-18-012

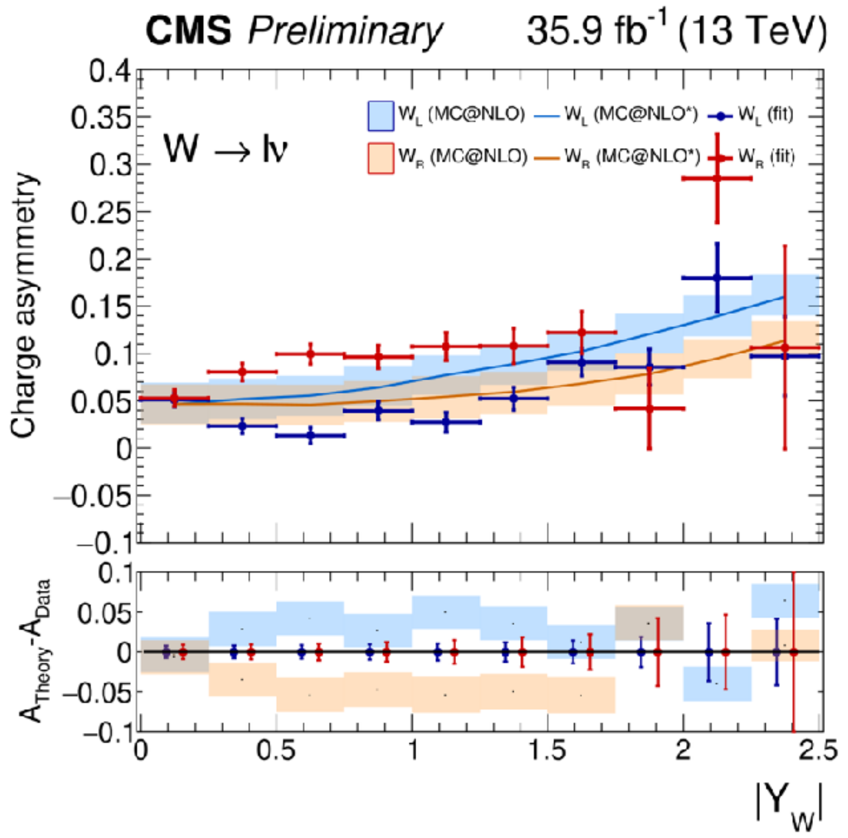








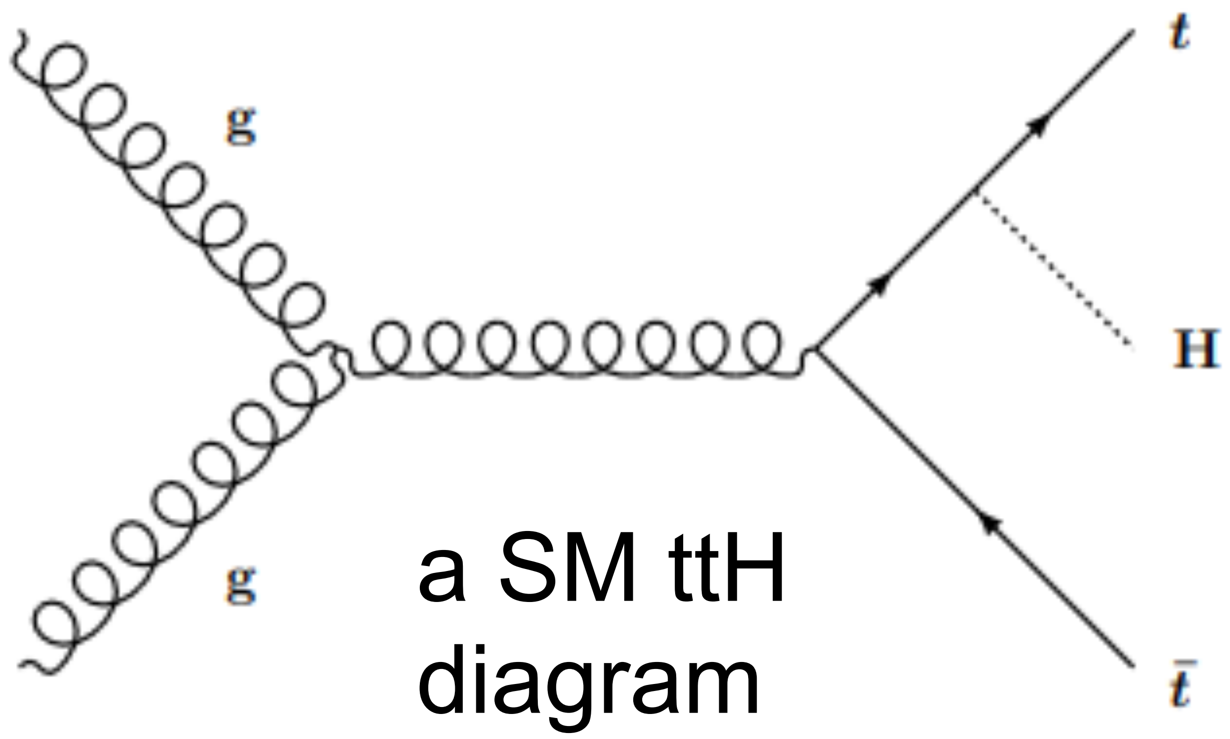




Top+leptons final state: EFT interpretation

TOP-19-001

- Search for new physics in top+leptons final states
- Multiple processes possibly affected by NP studied defining 35 final state categories
- Generic interpretation via EFT fitting 16 dimension-6 operator coefficients



a SM ttH diagram

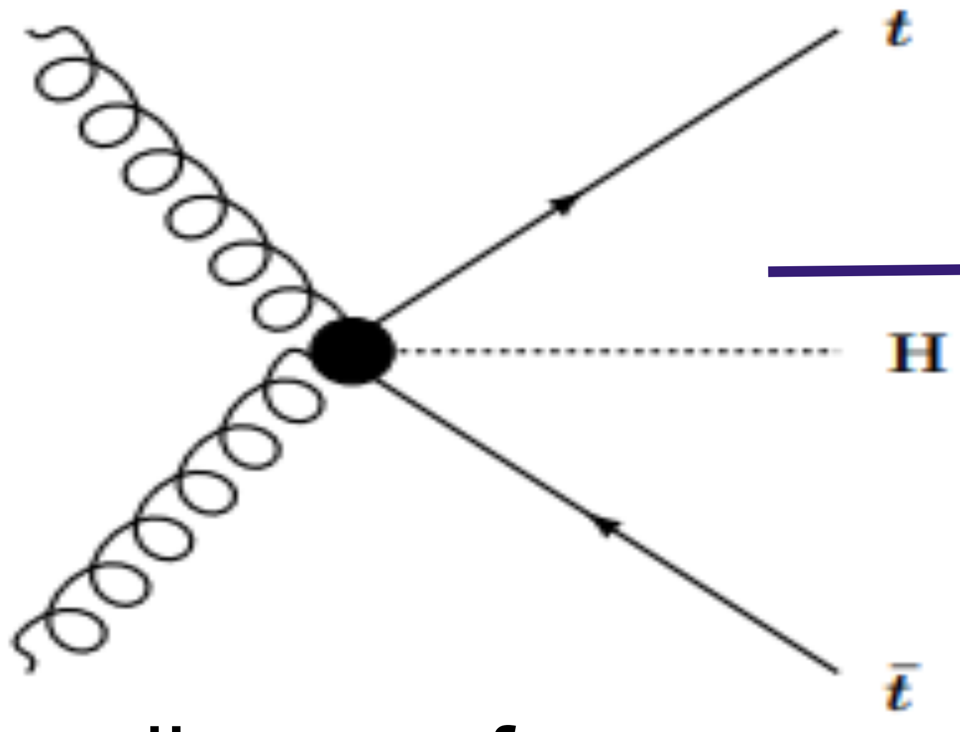
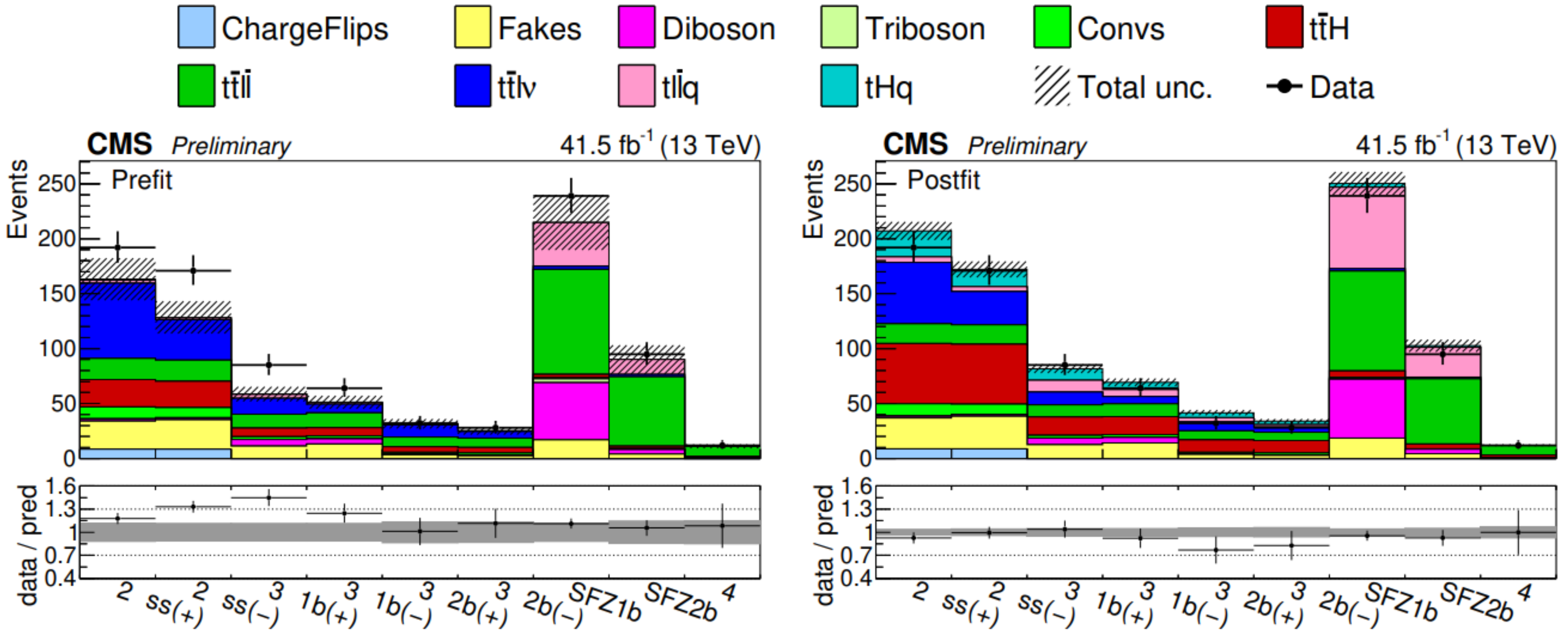
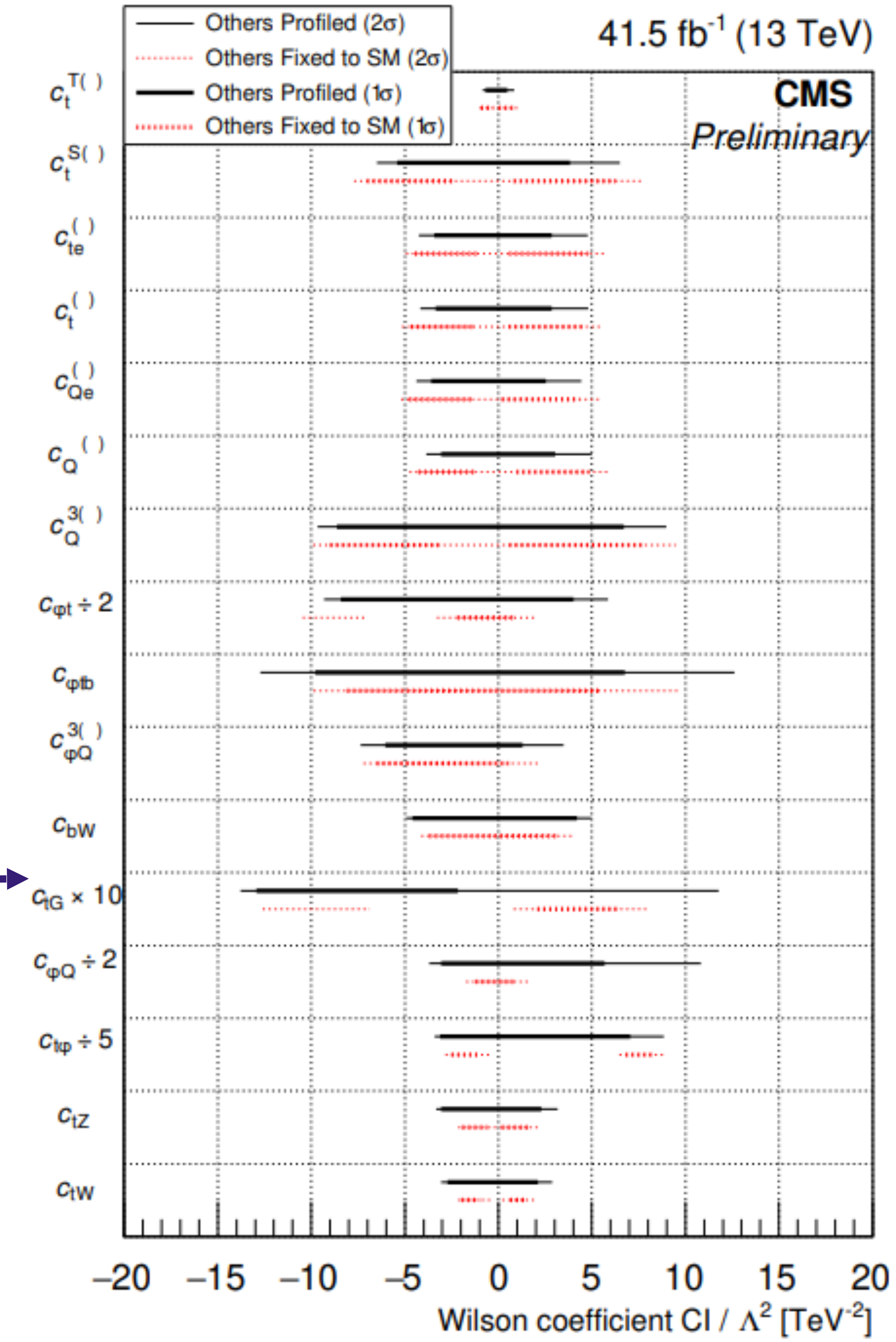


diagram from a dim-6 operator

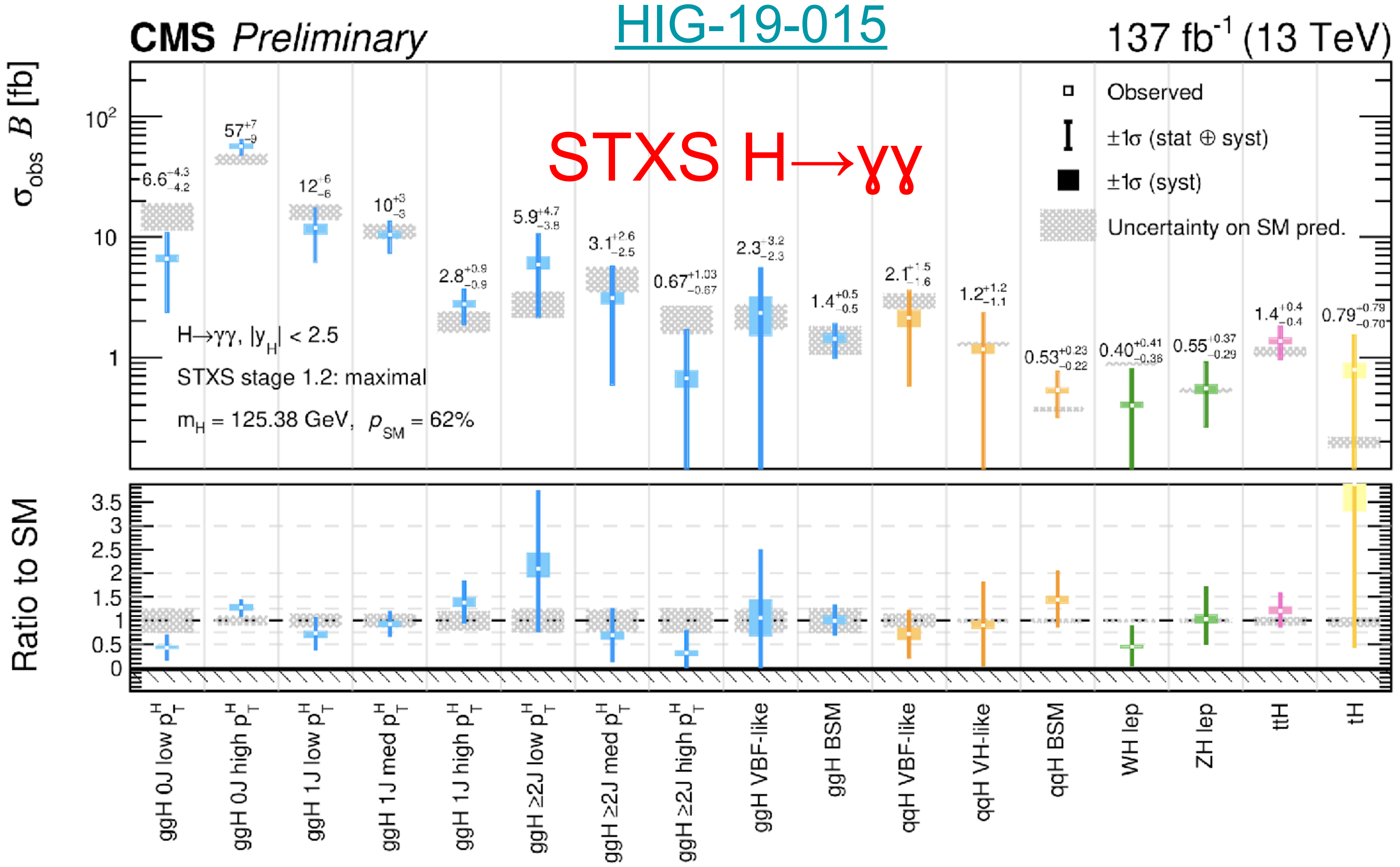


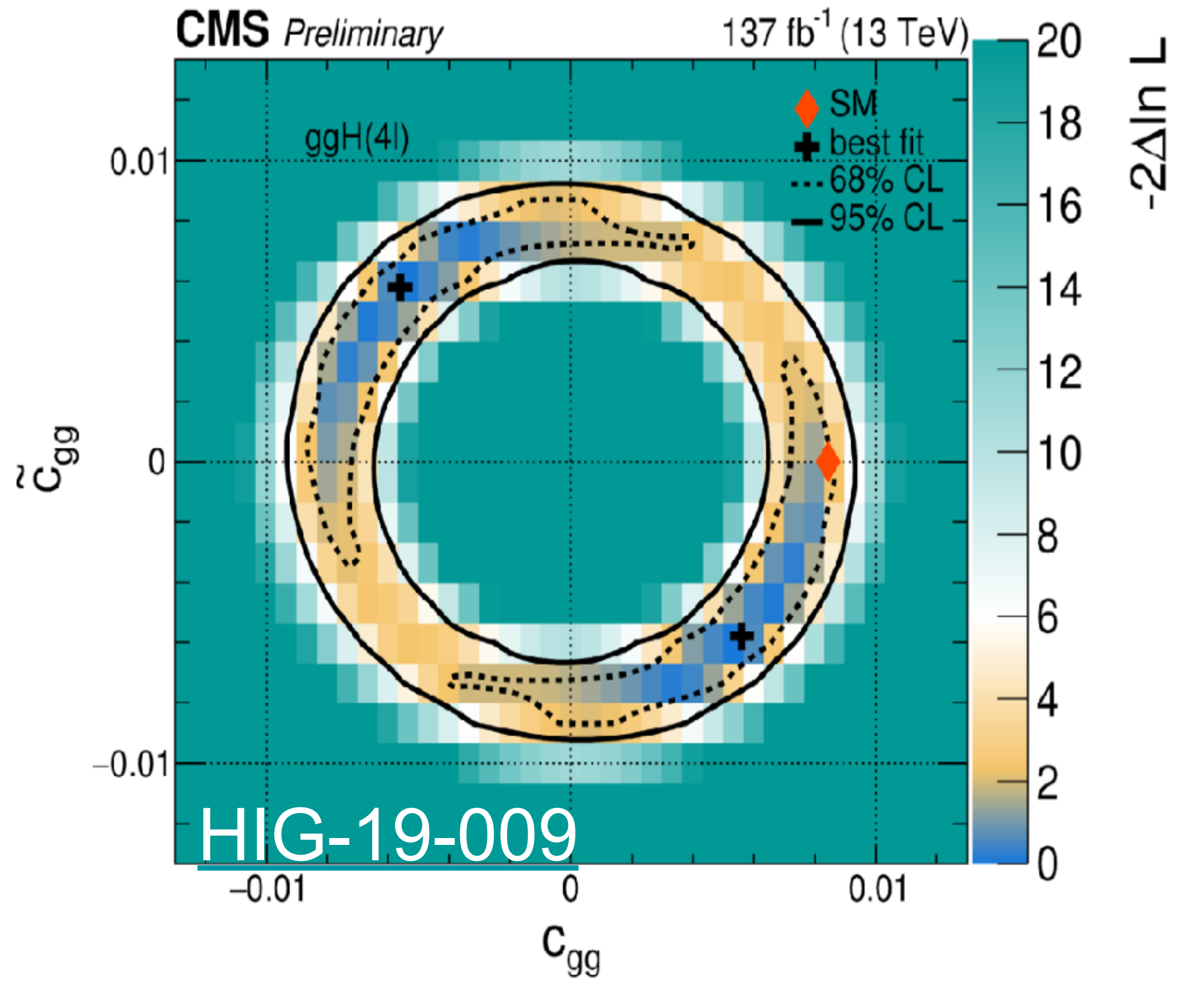


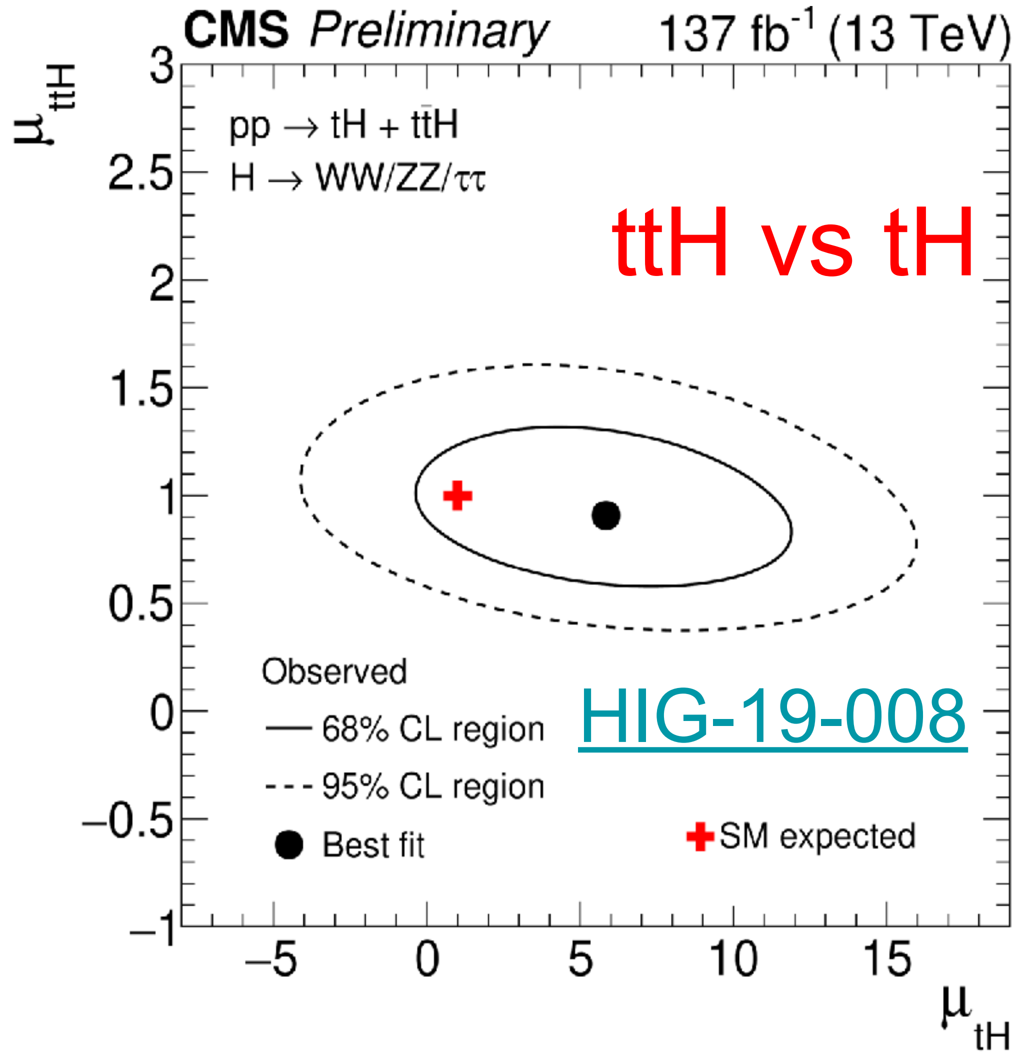
Higgs properties

Multiple results for H characterization:

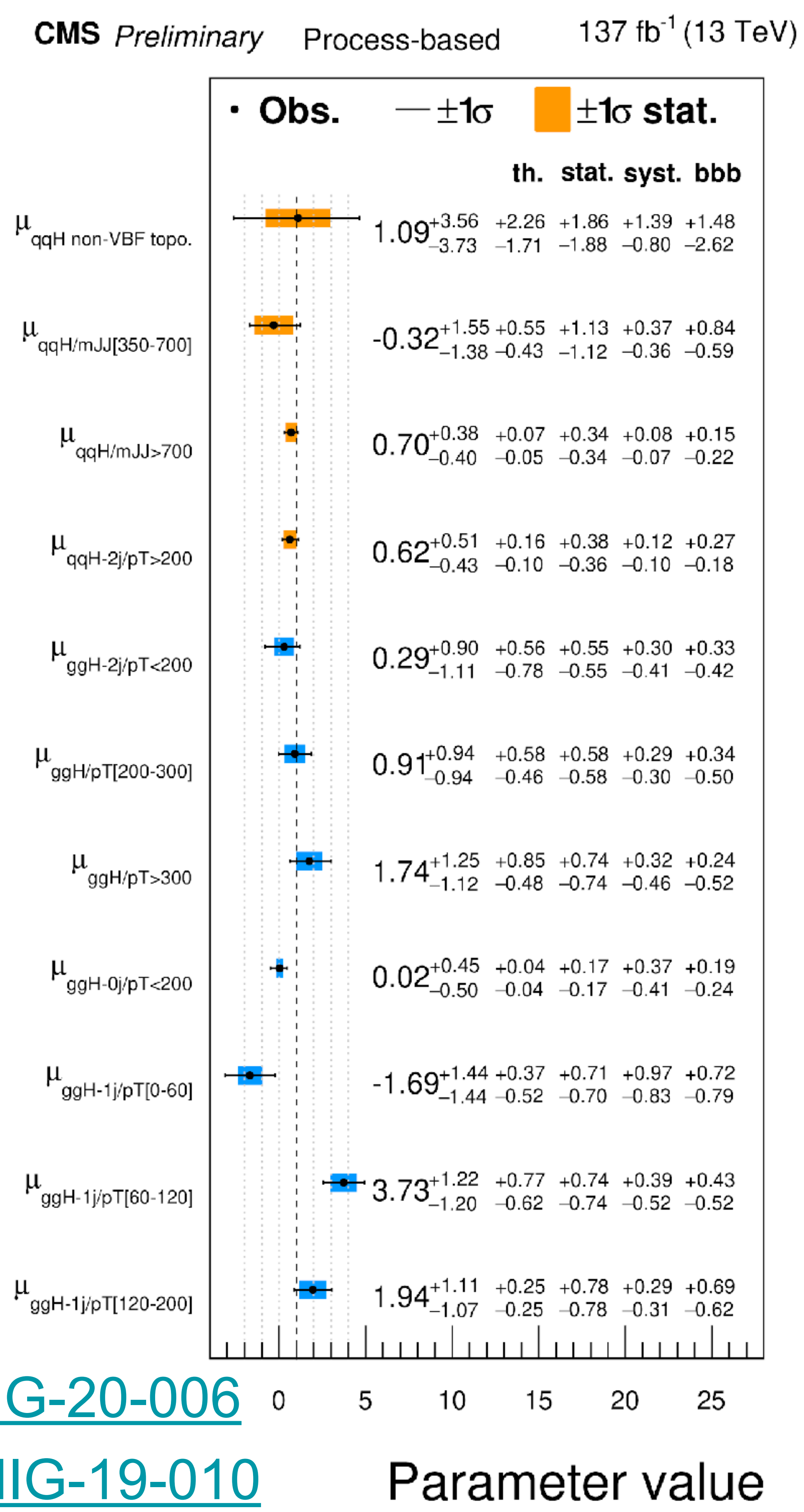
- STXS differential measurement in H→γγ and H→$\tau\tau$
- CP violation in H→$\tau\tau$
  - mixing angle even/odd $\phi_{\tau\tau}$=4+-17°
  - 3.2σ exclusion of pure CP-odd
- Anomalous coupling with EFT interpretation in 4L
- tH and ttH measurements in multi-lepton channel







STXS H→$\tau\tau$



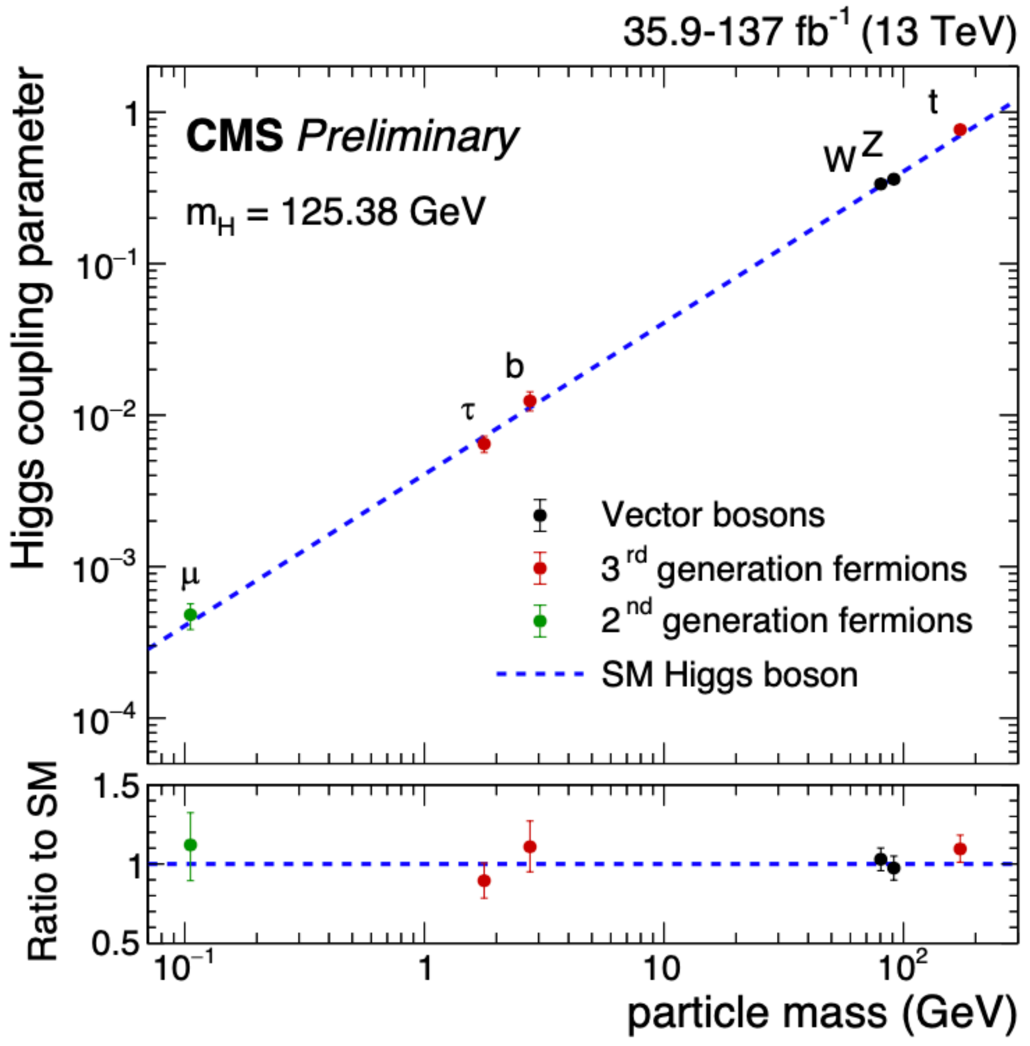
HIG-20-006

HIG-19-010

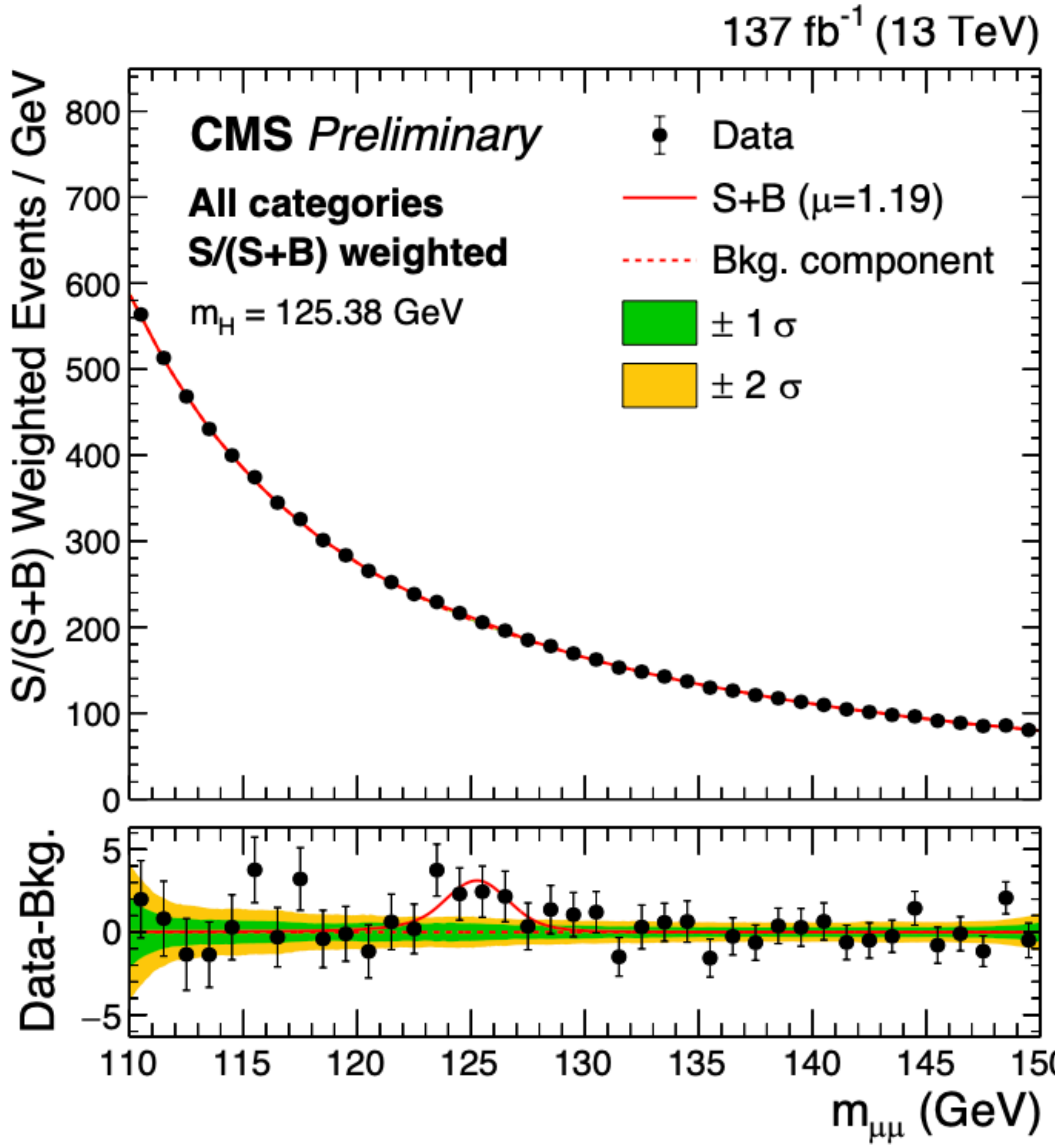
$H \rightarrow \mu\mu$

Measurement of $H \rightarrow \mu\mu$

(full run 2 data)



- four components targeting ggH, VBF, VH, and ttH
- similar sensitivity for ggH and VBF:
  - ➡ggH => highest X-sec
  - ➡VBF signature provide extra sensitivity
- results combined with Run1 data at 7and 8 TeV (for MH=125.38 GeV)
- analysis largely based on advanced machine learning techniques



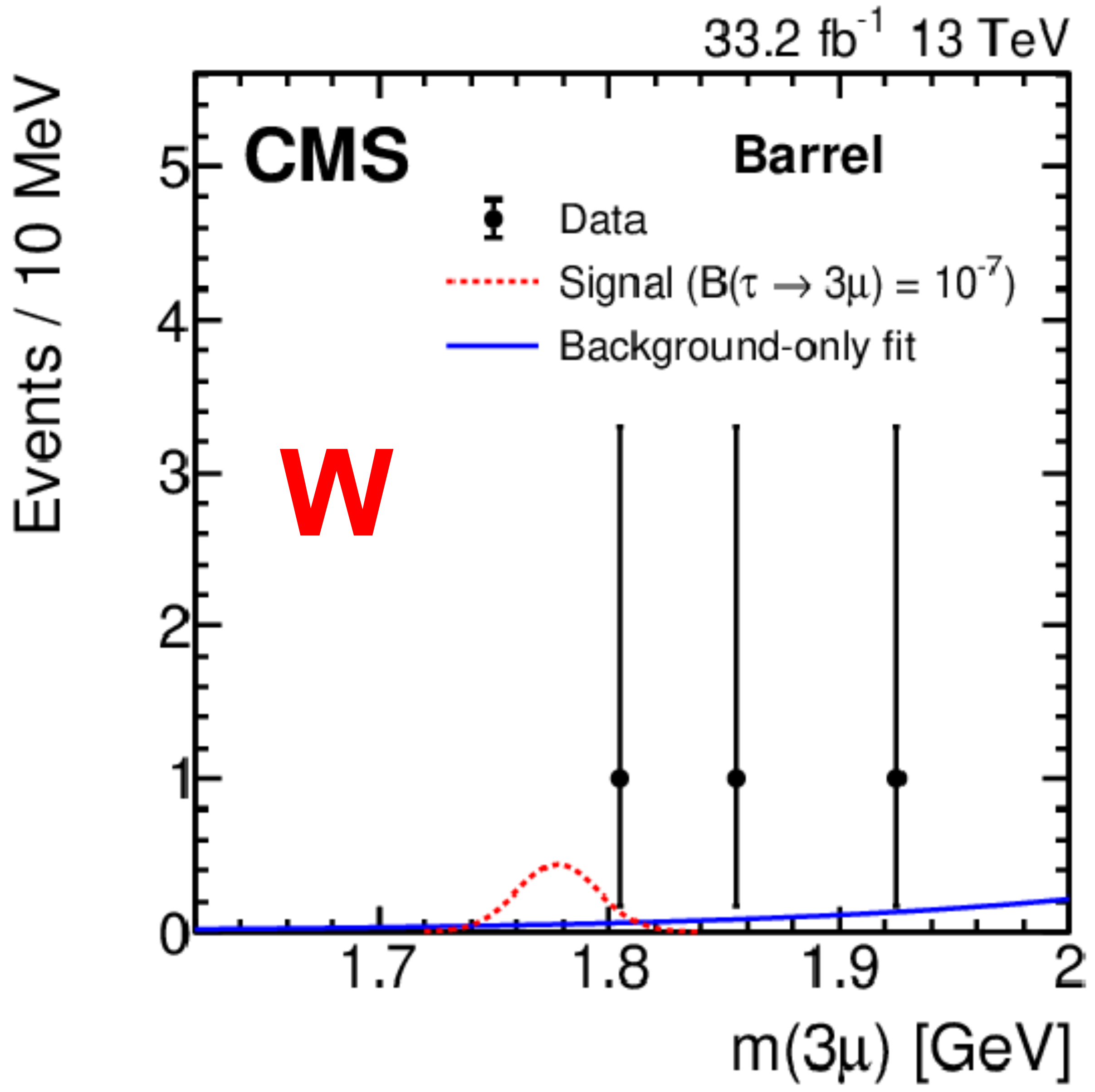
First ever evidence:

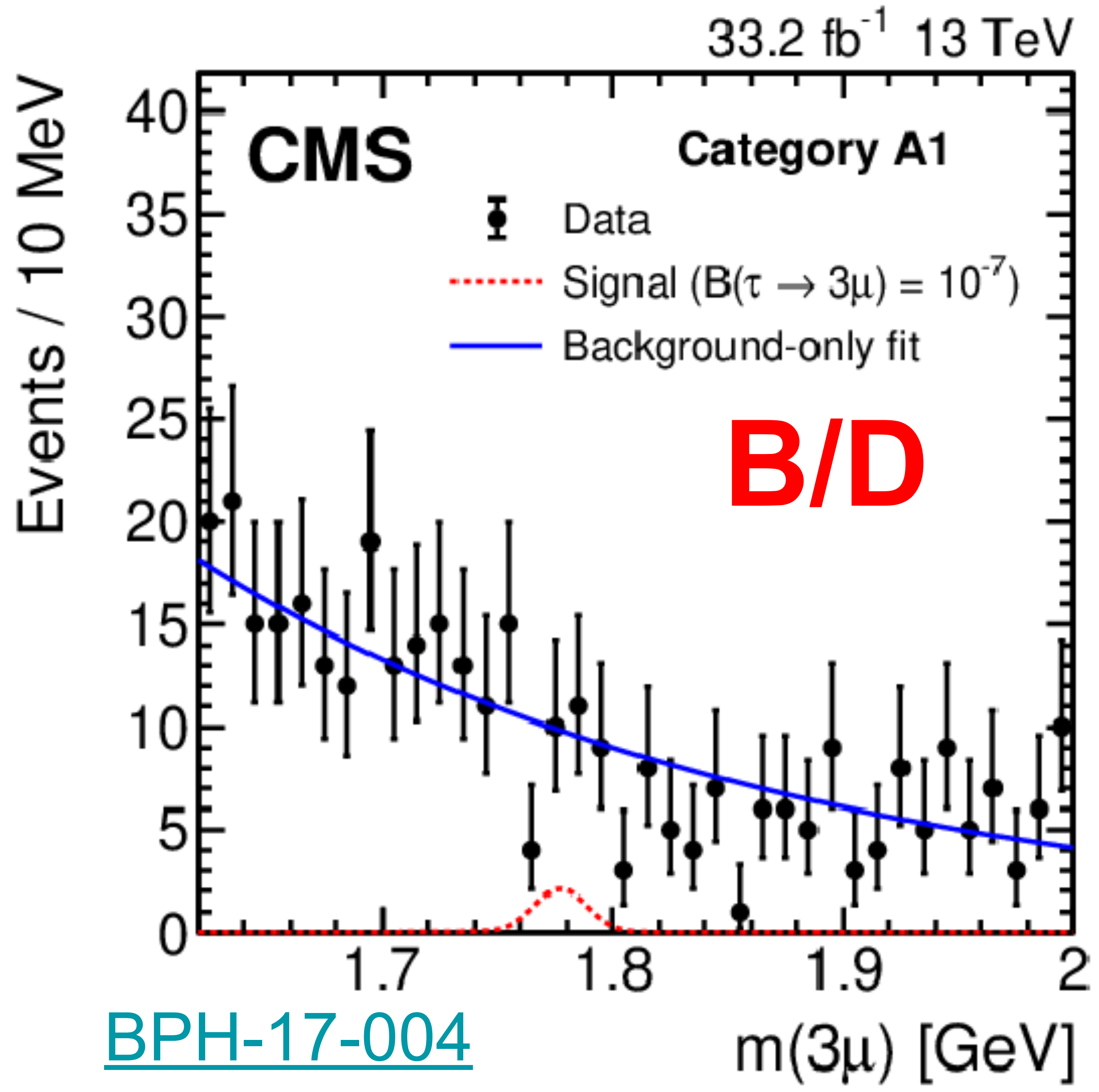
significance: 3.0σ obs (2.5σ exp)

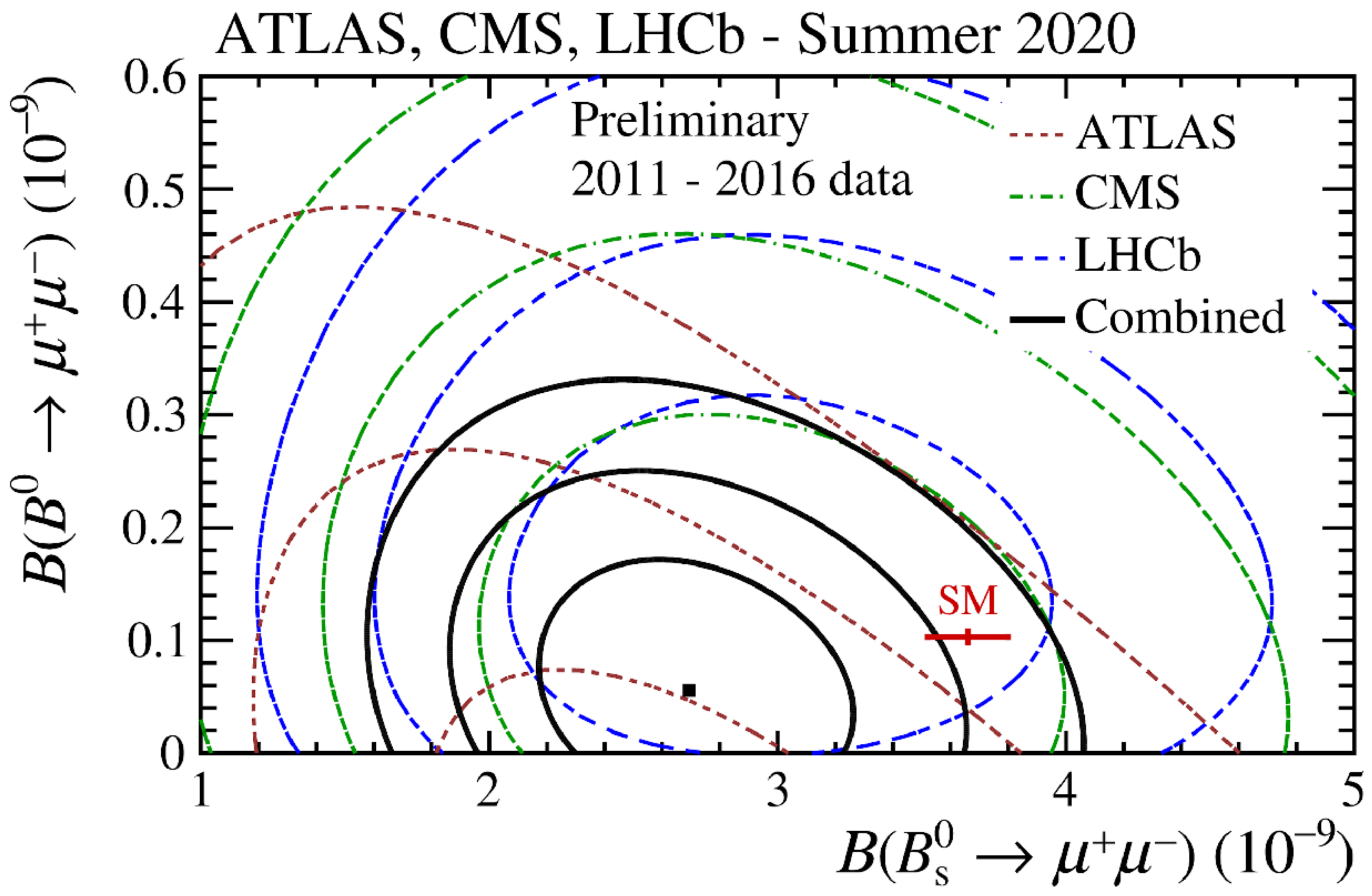
signal strength: $\mu = 1.19^{+0.41}_{-0.39}$ (stat)$^{+0.17}_{-0.16}$ (syst)

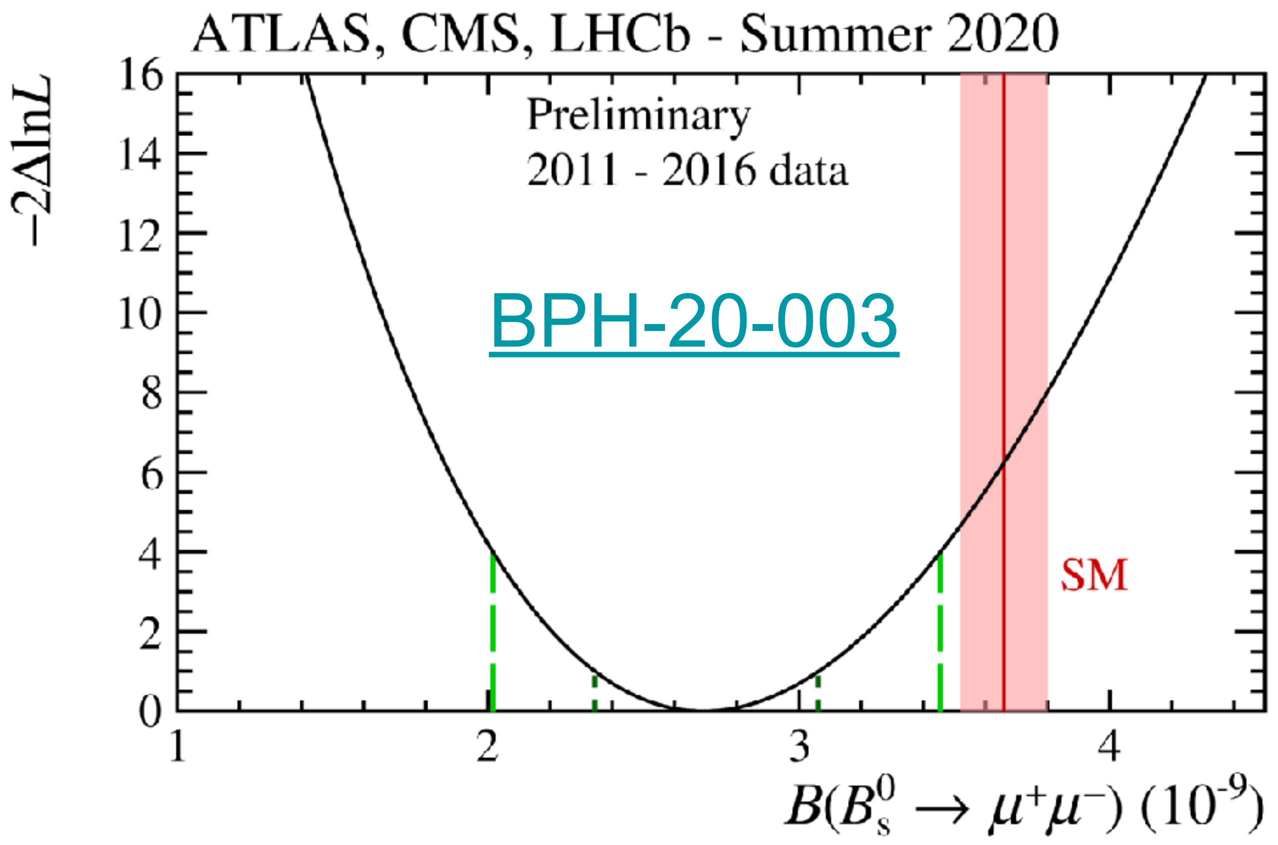
B physics: CMS latest results

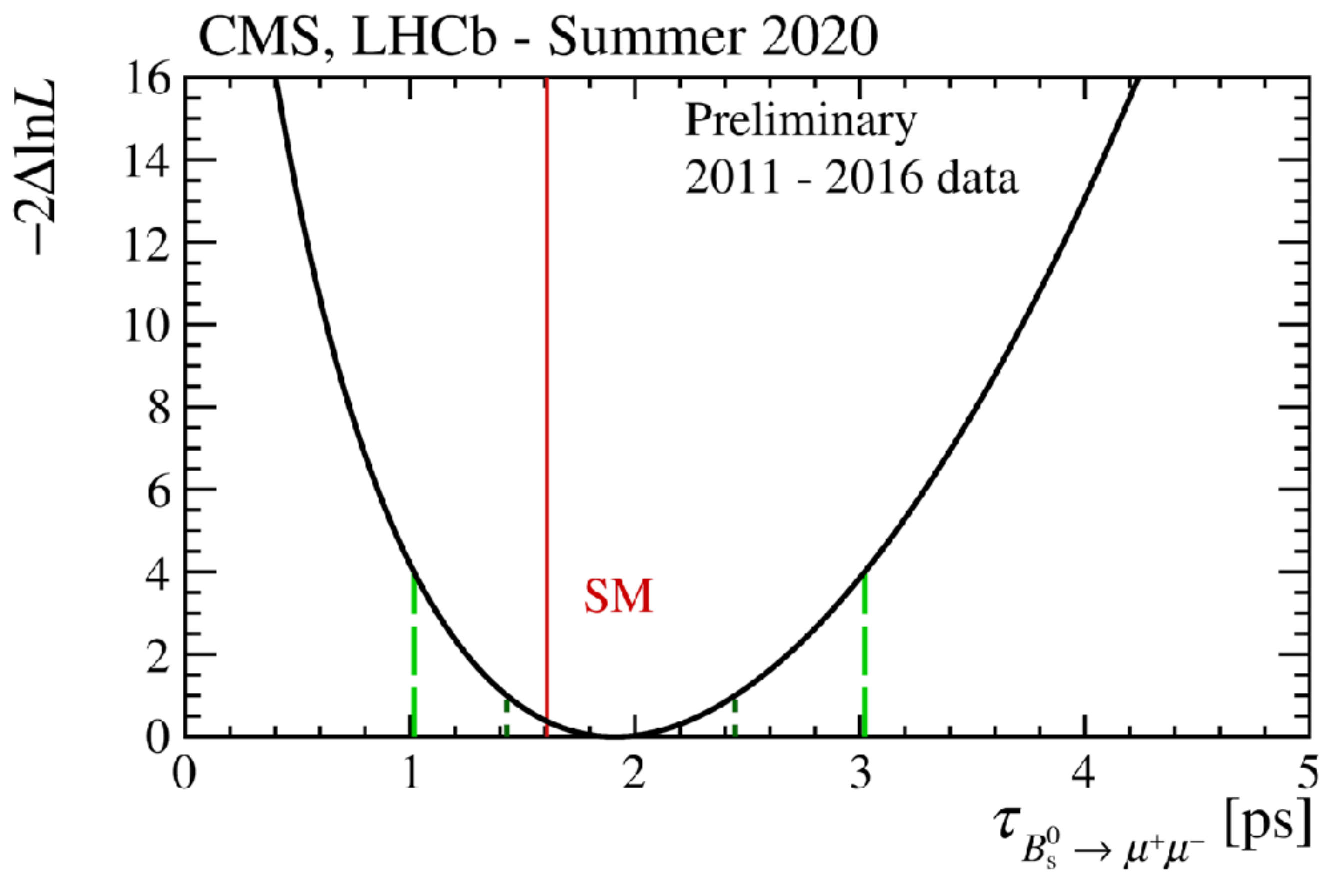
- Submitted paper on $\tau \rightarrow 3\mu$
  - combining W production with heavy flavour production
  - obs(exp): 8.0 (6.9) x 10^{-8} @90% CL
- Combination of Bs$\rightarrow \mu\mu$ with ATLAS and LHCb
  - $B(B^0_s \rightarrow \mu\mu)$ = 2.69 +0.37 - 0.35 × 10^{-9}
  - $B^0_s \rightarrow \mu\mu$ lifetime τ = 1.91 +0.37 -0.35 ps
  - $B(B^0 \rightarrow \mu\mu)$ < 1.6 × 10^{-10} (90% CL)





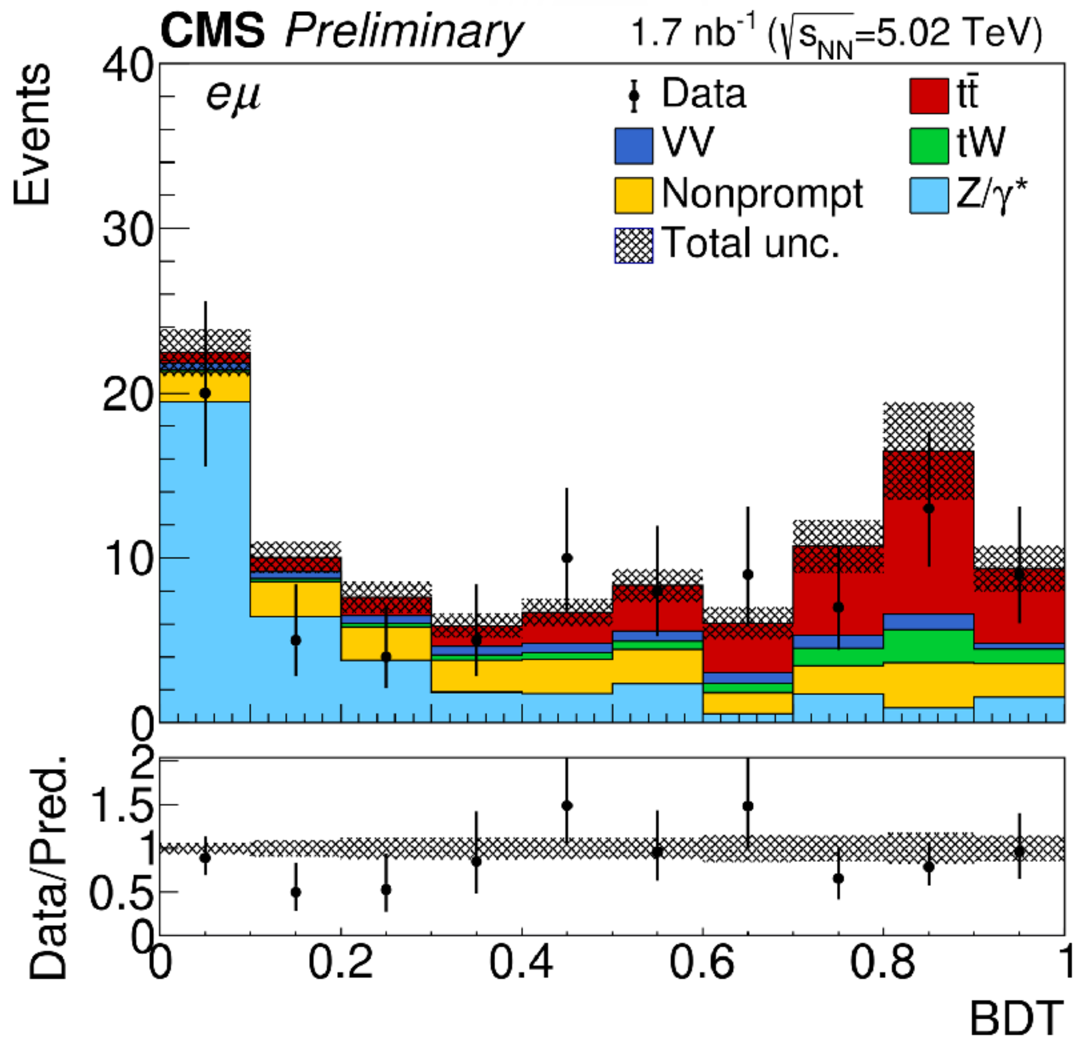


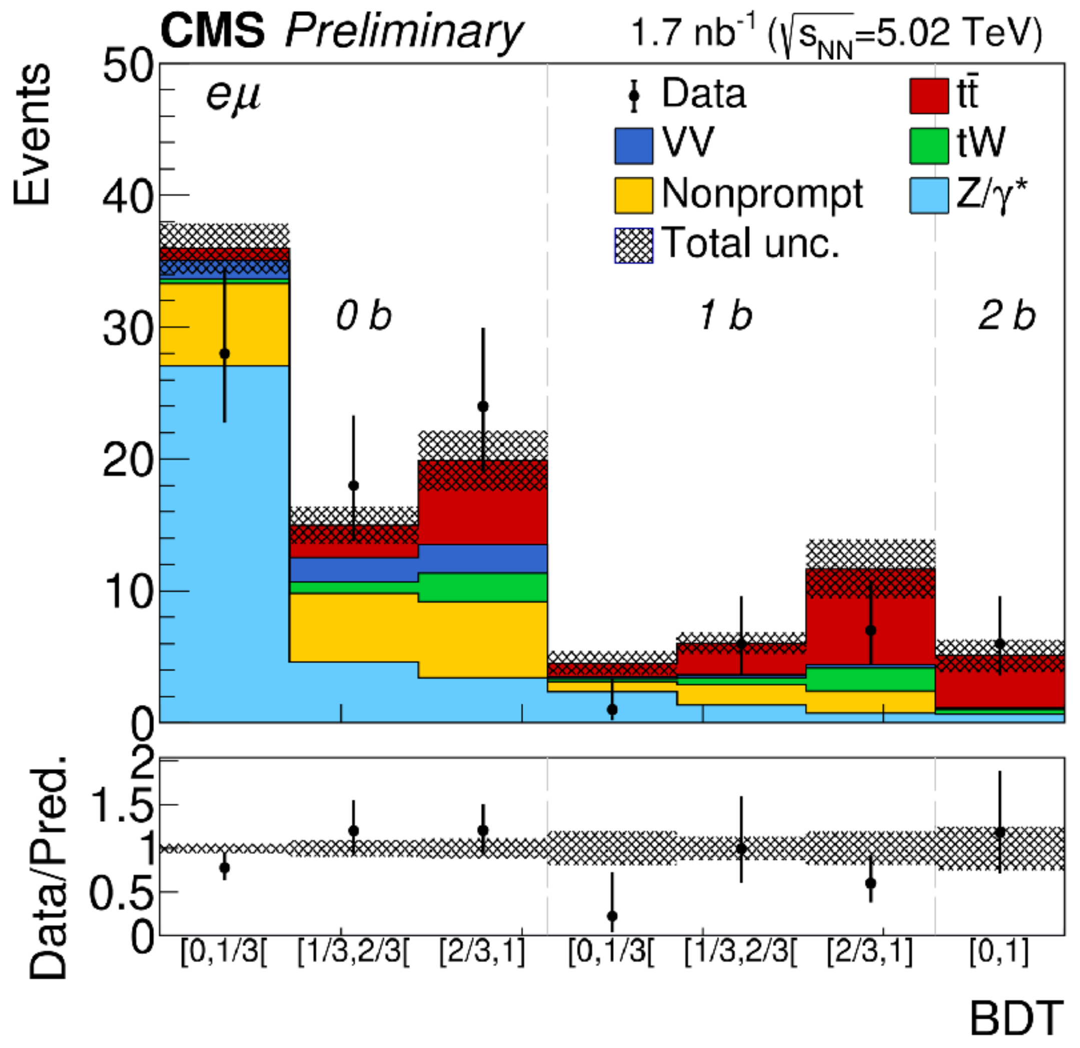




Evidence for top pair production in PbPb collisions

- Top quarks can be used as probes for nPDF at high x and as tools for parton energy loss
  - Decay well before QGP formation
- Selection uses dilepton events (ee, μμ, eμ channels)
  - BDT using only information related to leptons
- Results from fit to the BDT distributions
  - 2 fits, either b-jet agnostic, or including N_b
  - The result with the higher sensitivity (including N_b) yields an obs (exp) significance of 4.0 (6.0) s.d.
  - The cross section estimates without / with N_b are compatible with each other, 2.02±0.69μb and 2.56±0.82μb, and lower (but compatible with) the expectation
- First (strong) evidence for top quark pair production in PbPb!
  - Following the first observation in pPb (CMS, Phys. Rev. Lett. 119 (2017) 242001)

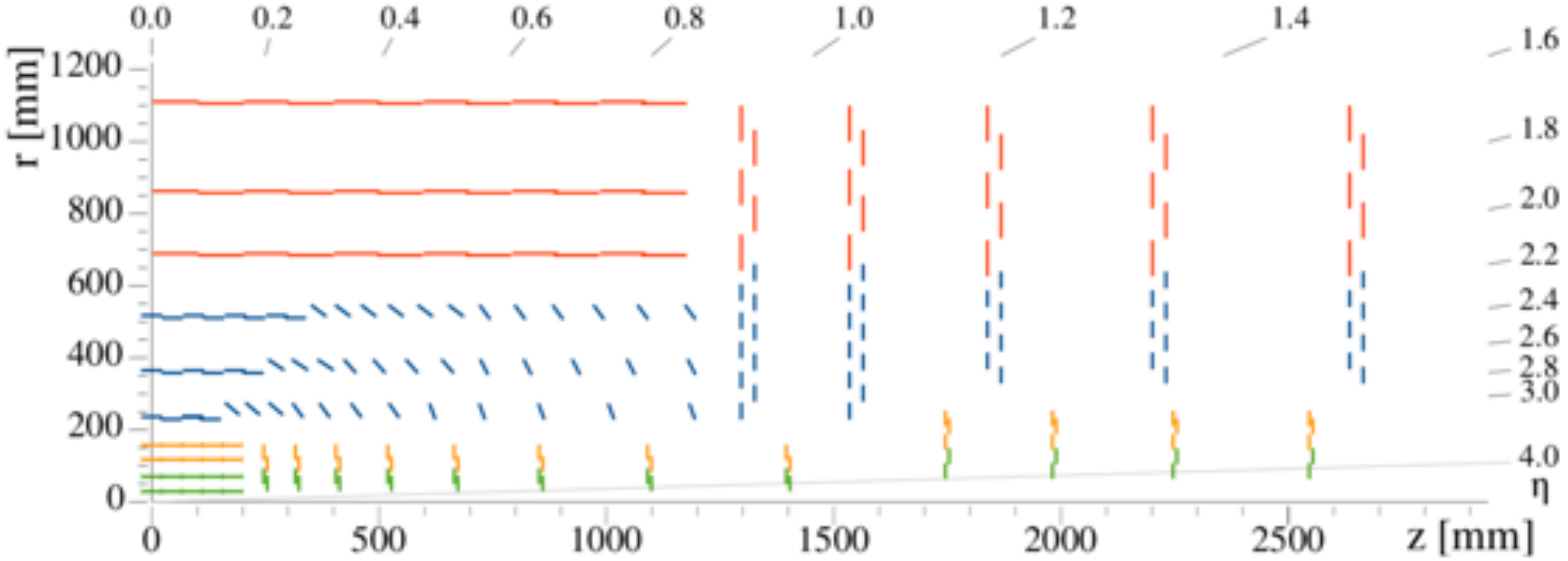


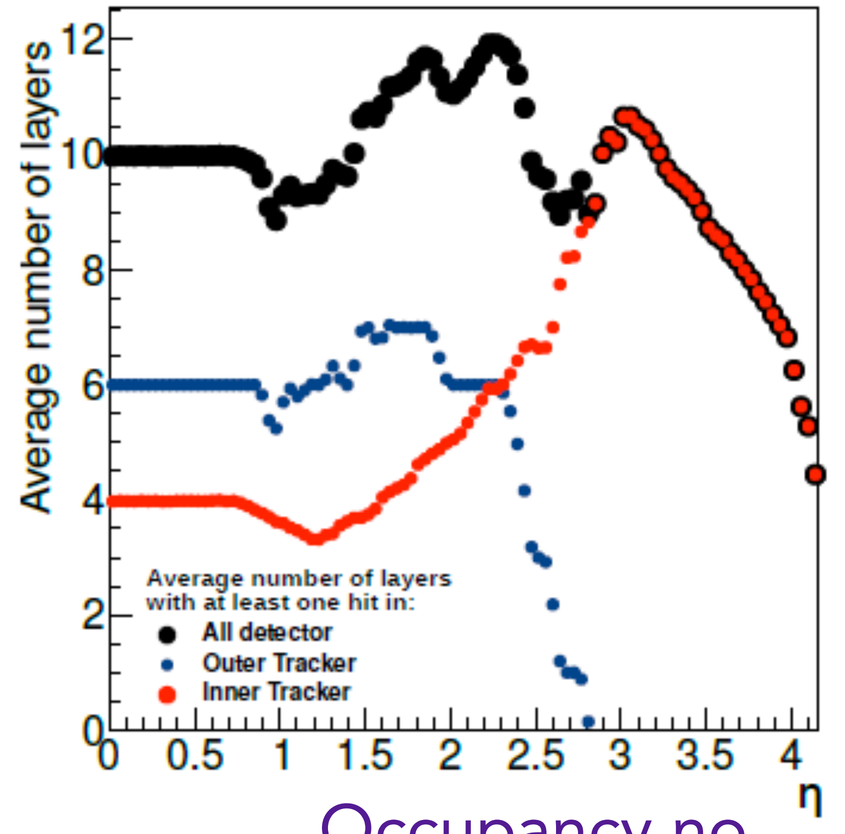


HIN-19-001

CMS Phase2 Tracker

Key features
- more granularity
- lower material budget
- extended coverage
- tracking included at L1-trigger level

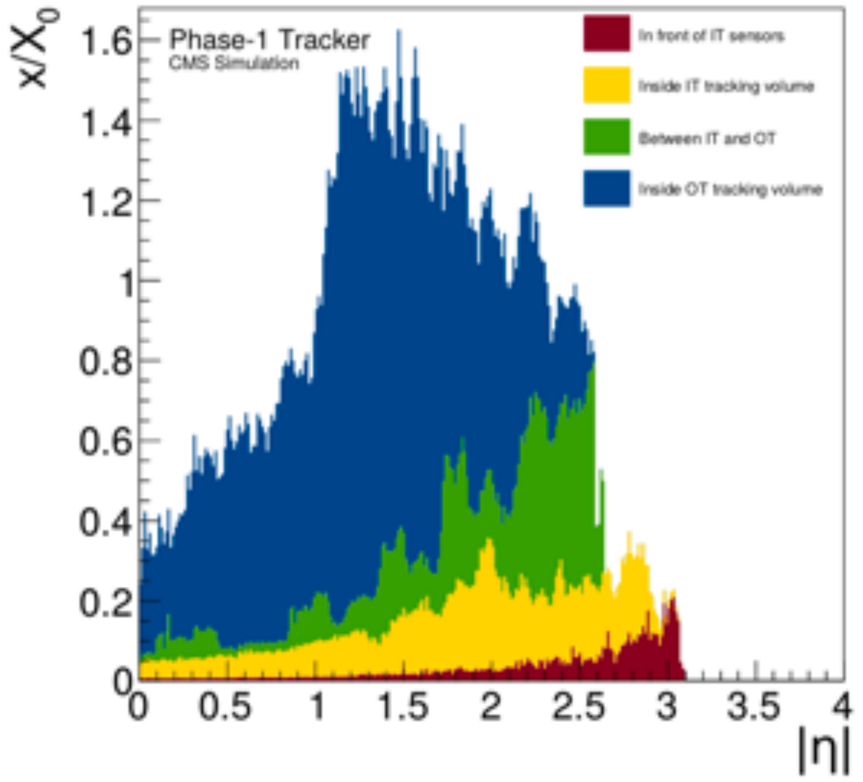




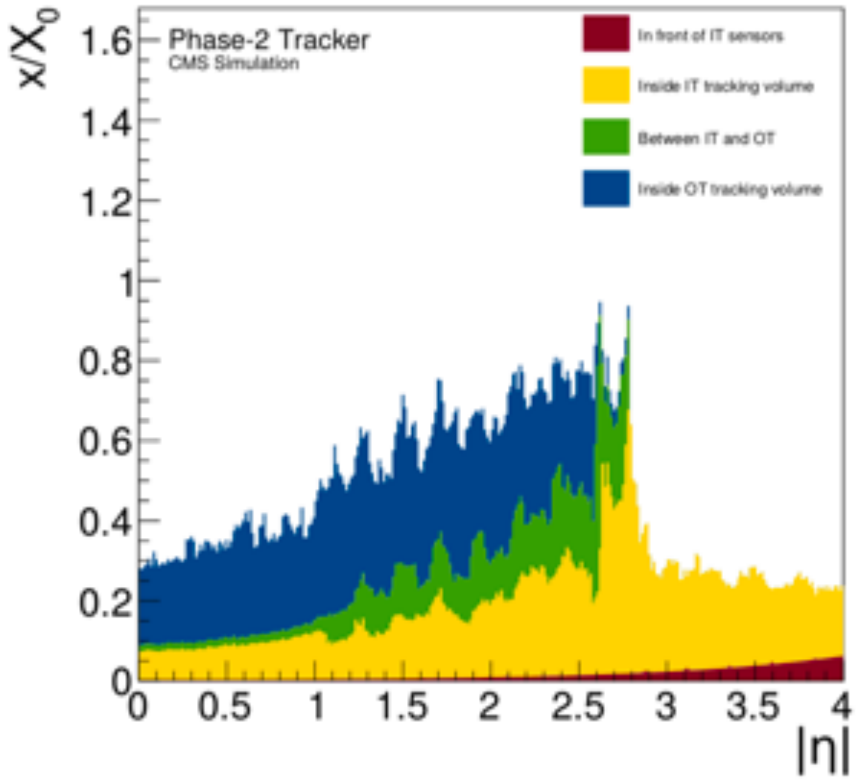
Occupancy no larger than 3%

Material budget

present tracker

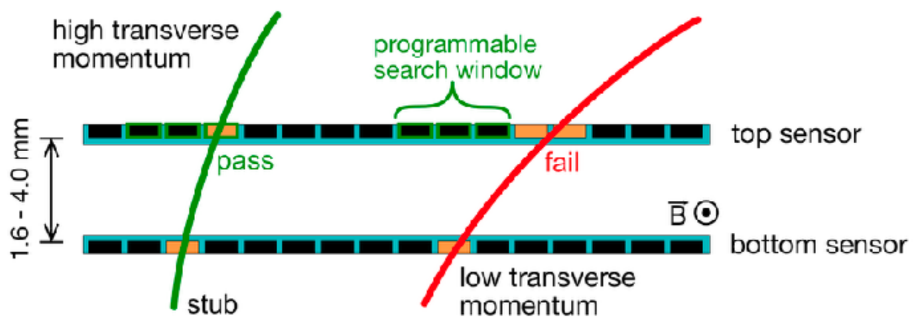


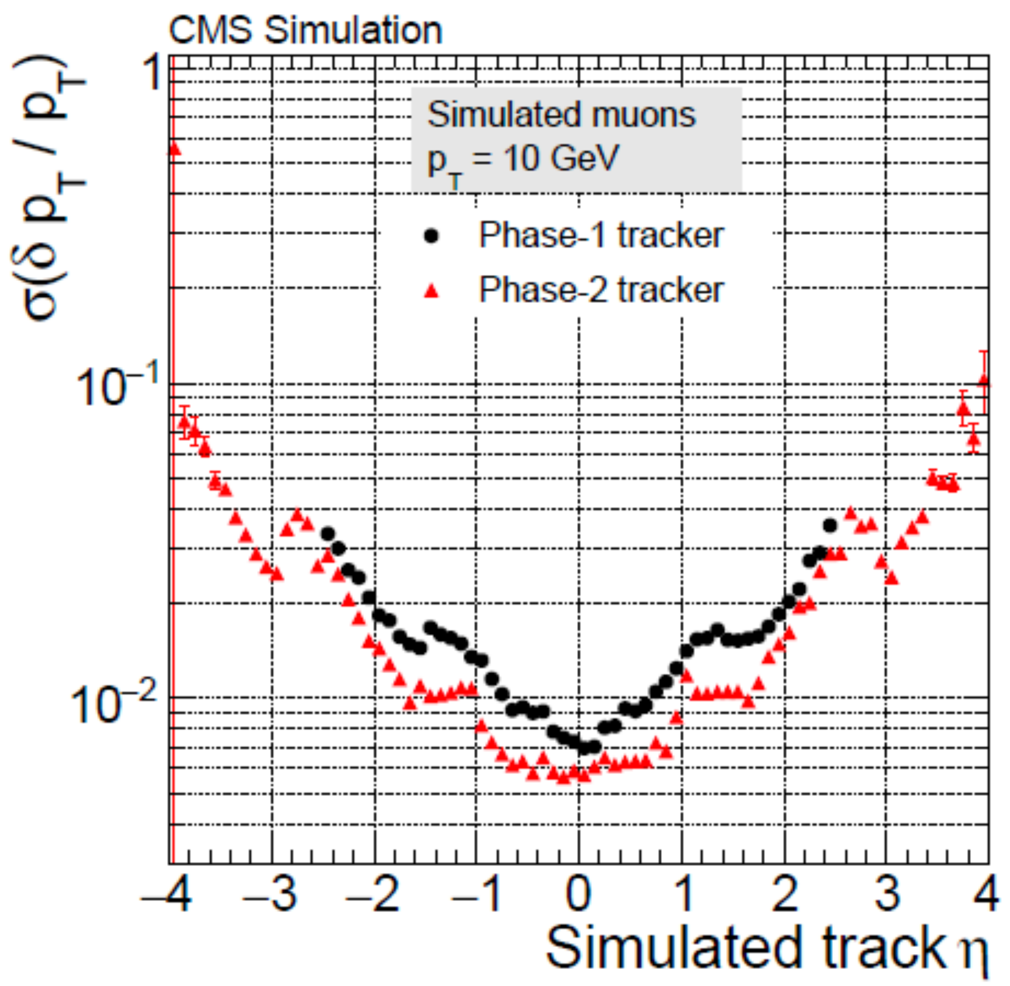
upgraded tracker



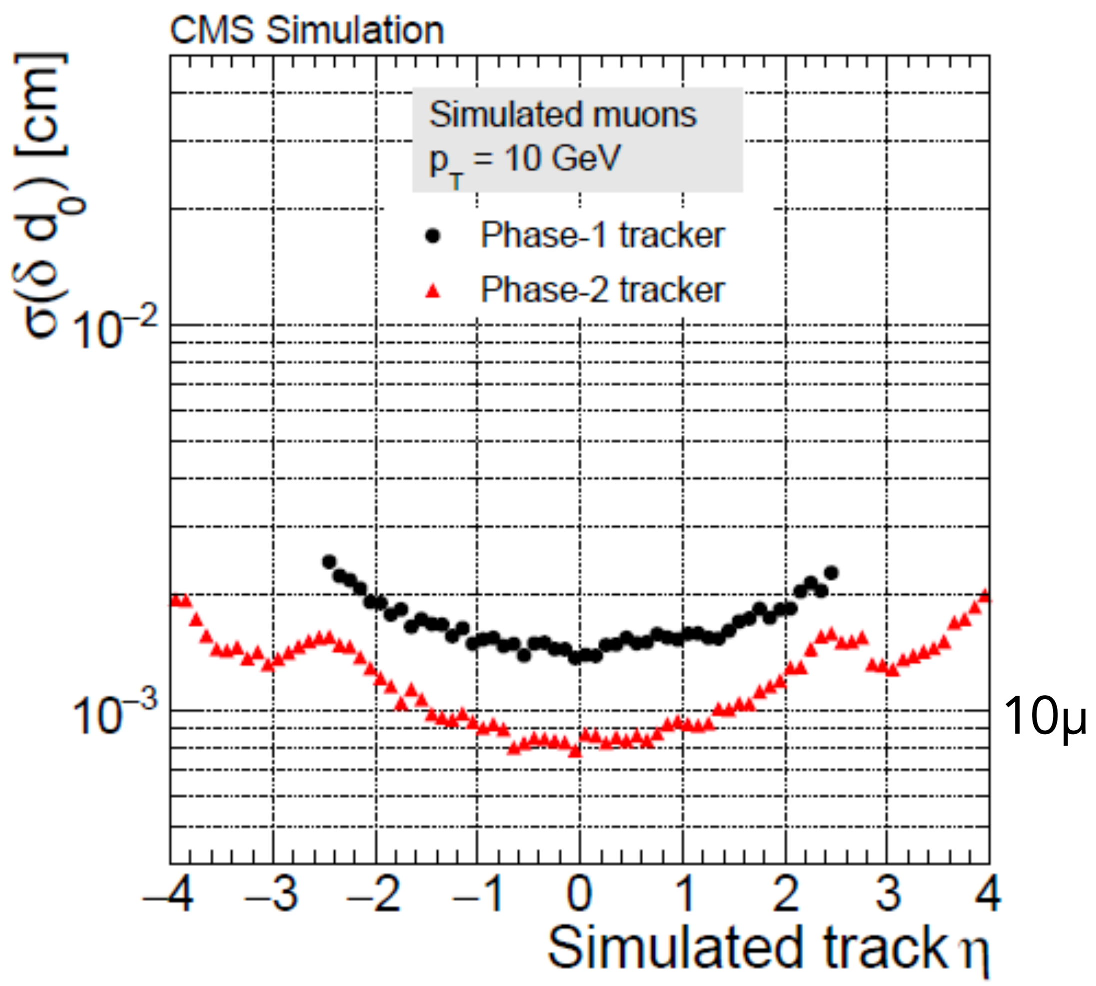
Expected performance
compared to present tracker

Local rejection of low p_T tracks



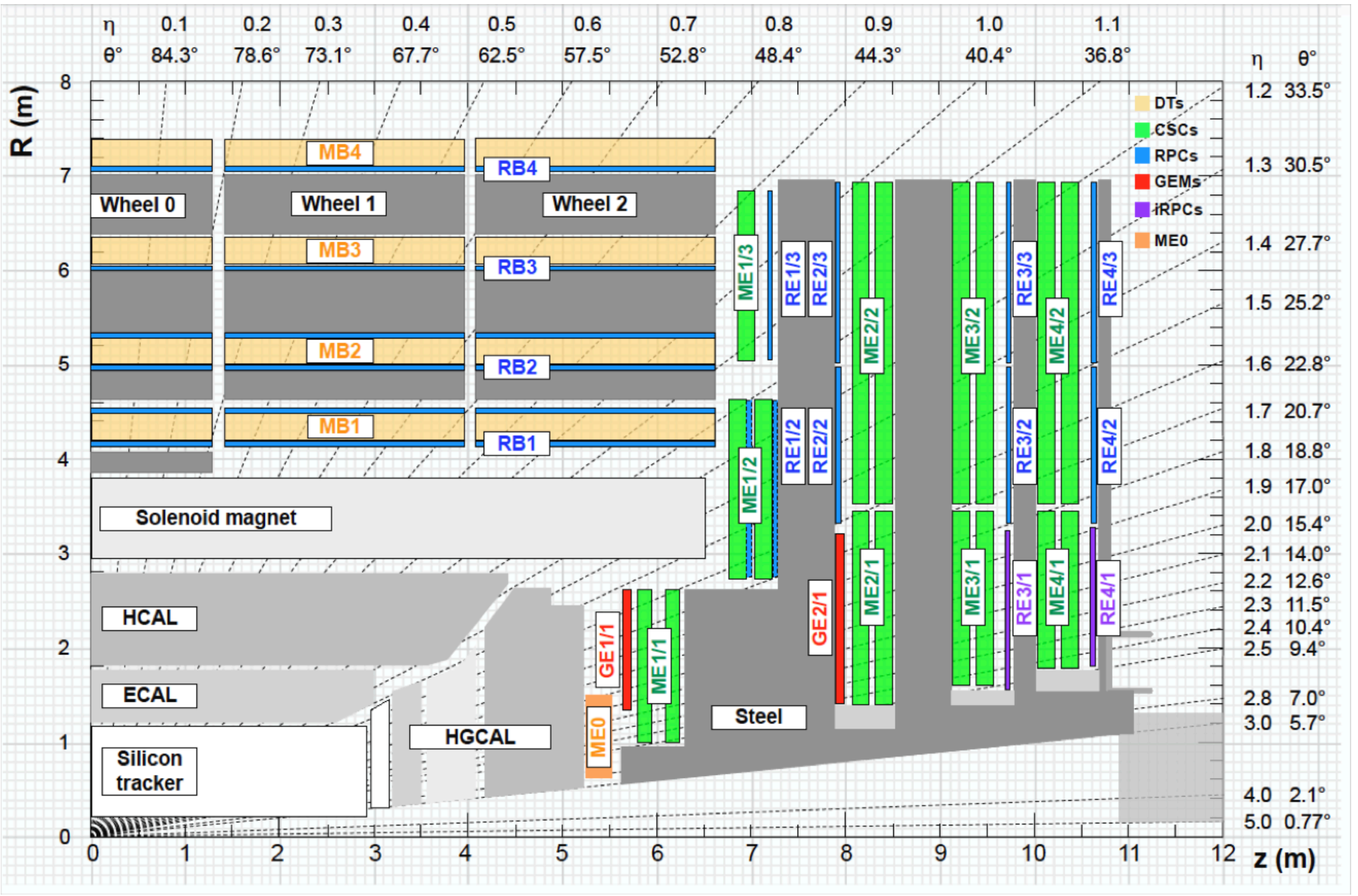


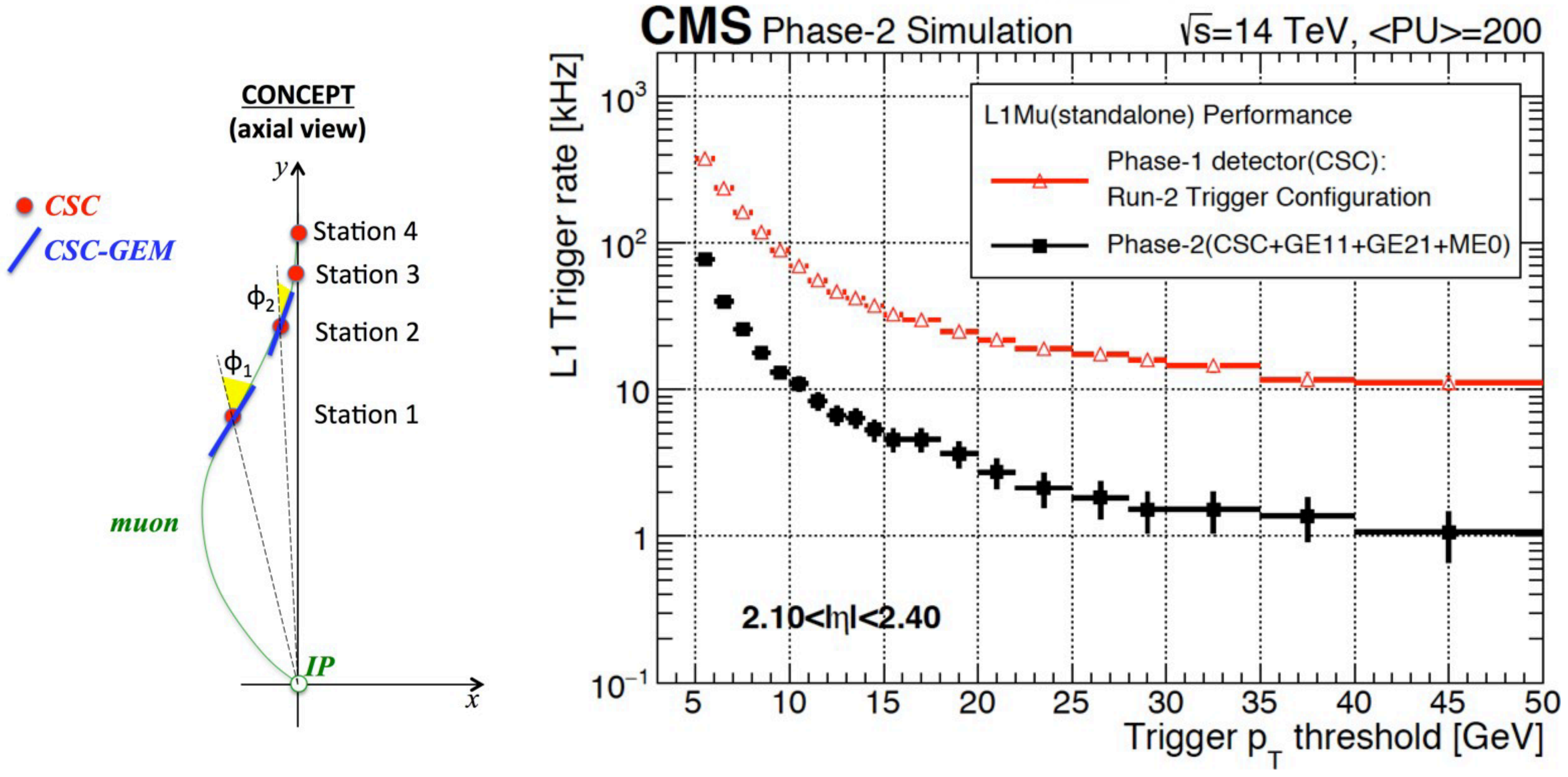
transverse momentum



transverse impact parameter

CMS Phase2 Muon System





Barrel and Endcaps

- Replacement of readout electronics for the new L1 trigger conditions

Endcaps

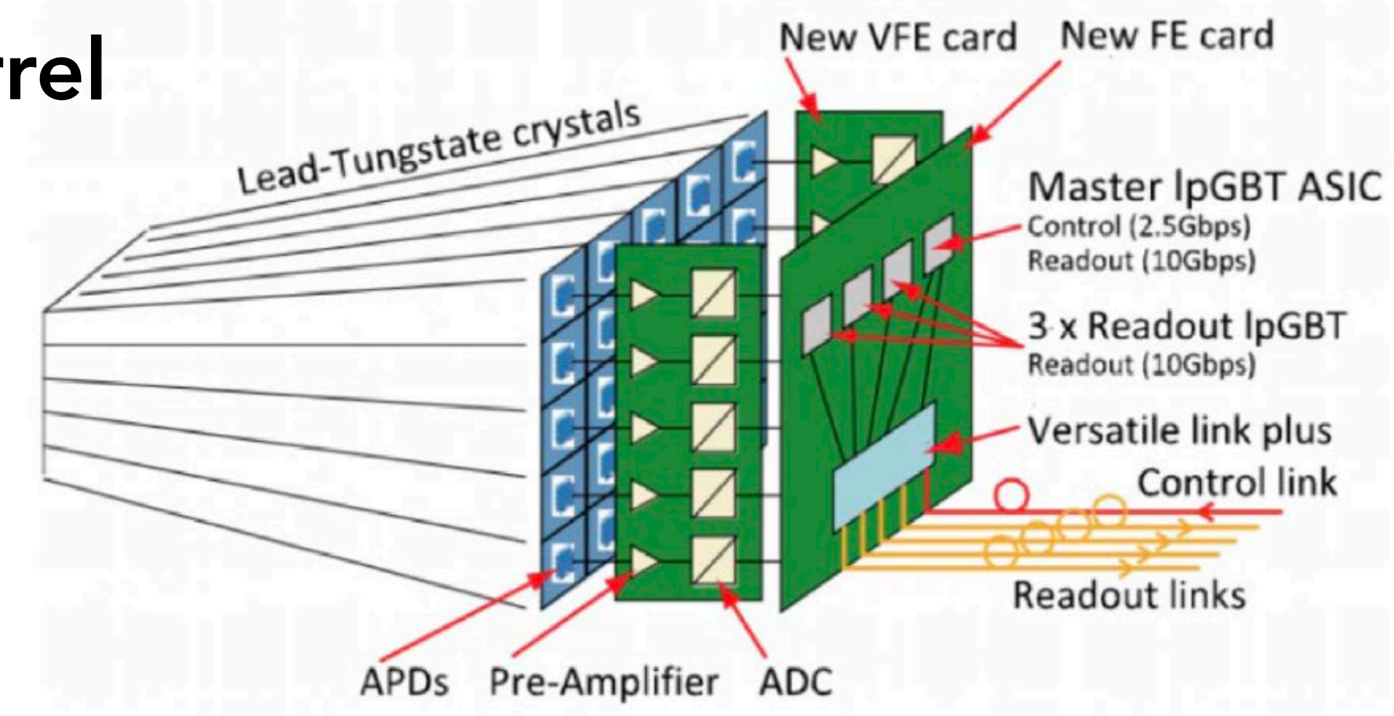
- Robust trigger up to |η| = 2.4 thanks to **RPC stations** RE3/1 and RE4/1 and 2-layer **GEM stations** GE1/1 and GE2/1
- Trigger extension up to |η| = 2.8 6-layer **GEM station** ME0

2 GEM/CSC "tandems"

- measurement of "local" μ direction (sensitive to p_T)
- standalone L1-trigger rate drops by factor up to 10
- important for off-pointing muon triggers (search for LLPs)

CMS Phase2 Calorimetry

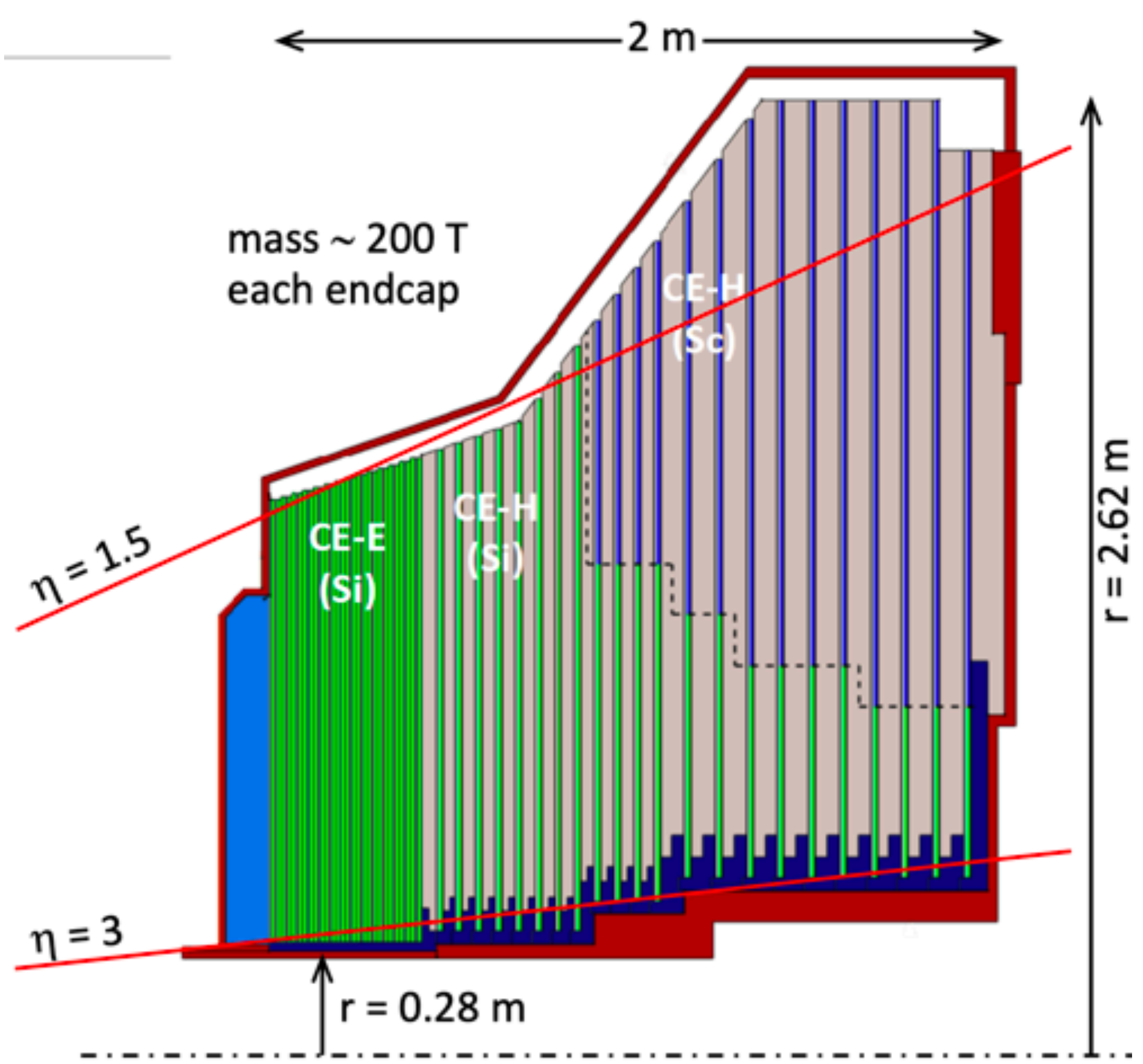
Barrel

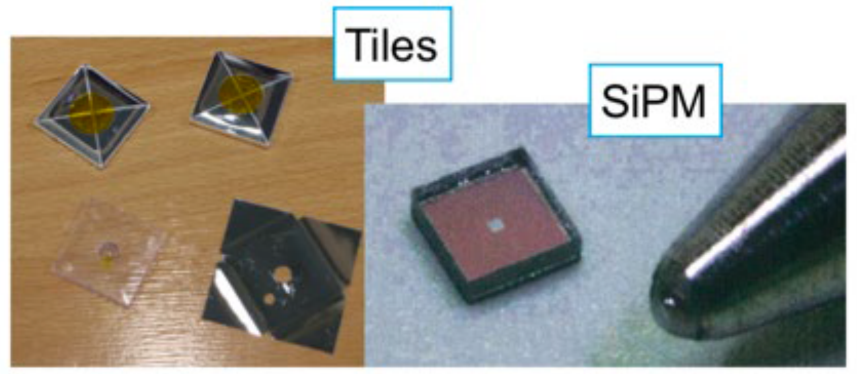


New ECAL on-detector electronics

- digitisation at 160 MHz
- online pulse shape discrimination against spikes
- trigger granularity = single crystal
- 30 ps time resolution ($E_\gamma > 50$ GeV)
- cooled at 9°C to mitigate APD ageing

Endcaps: High-Granularity Calorimeter (HGCAL)





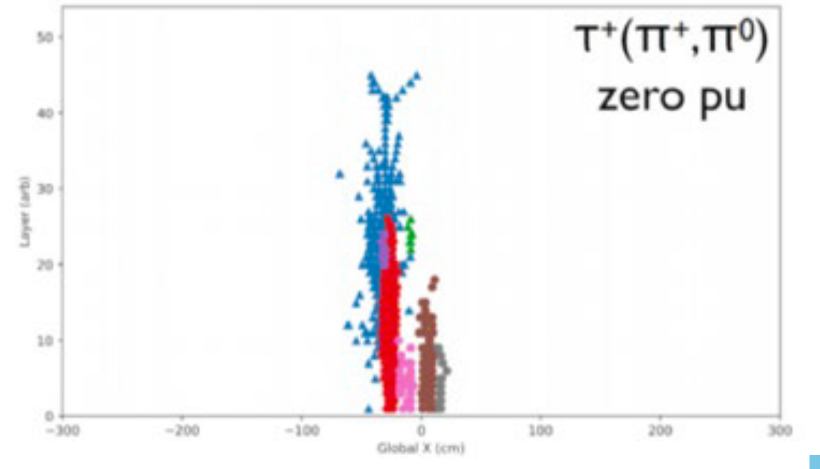
Electromagnetic (CE-E)

- Cu/CuW/Pb absorbers
- Si sensors, hexagonal modules
- 28 layers
- 25.5Xo and 1.7λ

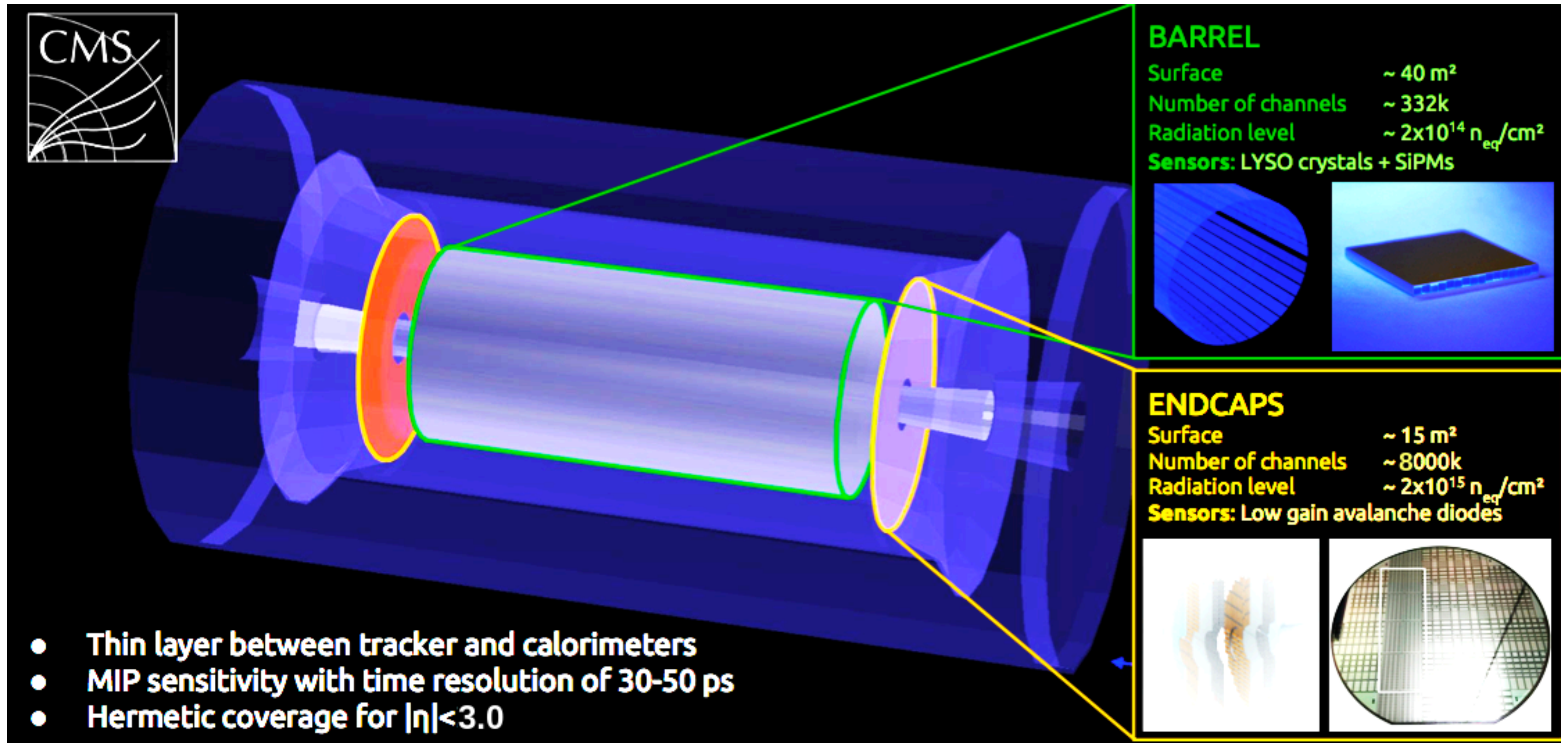
Hadronic (CE-H)

- steel absorbers
- High-radiation regions: Si sensors
- Low-radiation regions: scintillation tiles with SiPM readout
- 22 layers
- 9.5λ (including CE-E)

6M Si channels
240k scint. channels

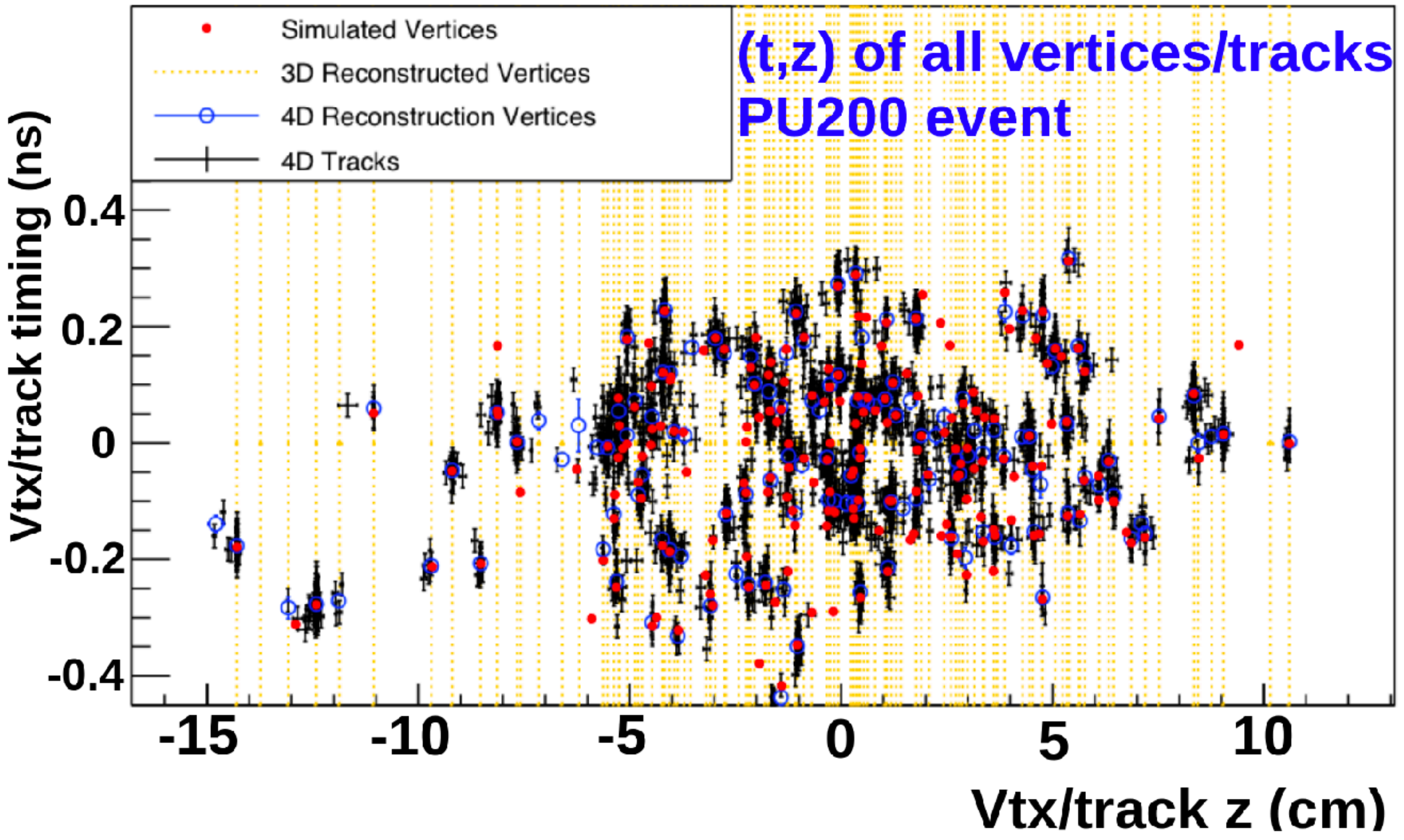


CMS Phase2 Timing Detector



The MTD features

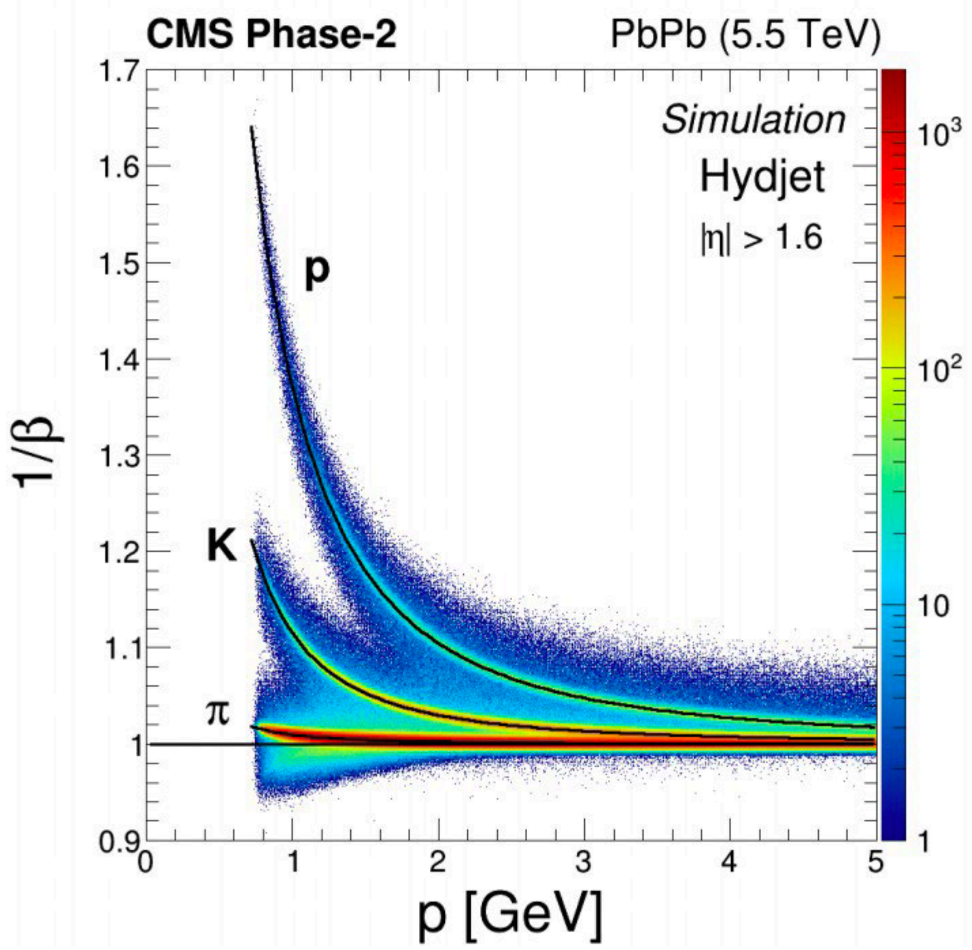
- a time resolution of 30-50 ps for MIPs
- a 4th dimension for PU rejection



Precise timing allows for the removal of spurious tracks from PU, this improving on

- lepton isolation and identification
- jet reconstruction and flavour tagging
- missing p_T reconstruction

Precise timing also offers time-and-flight identification at low momenta (relevant in HI)



The MTD uses well-established technologies

- Barrel:
  LYSO crystals with dual end SiPM readout
- Endcaps:
  Low Gain Avalanche Detectors (LGAD)