PLANCK2024

26th Conference "From the Planck Scale to the Electroweak Scale"

CFTP Centro de Física Teórica de Partículas

Highlights from CMS

N. Leonardo, LIP & IST

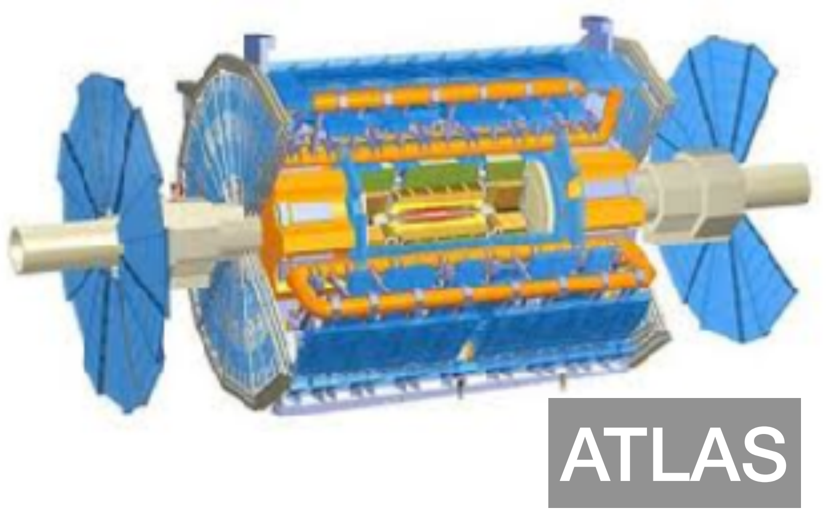
on behalf of the CMS Collaboration

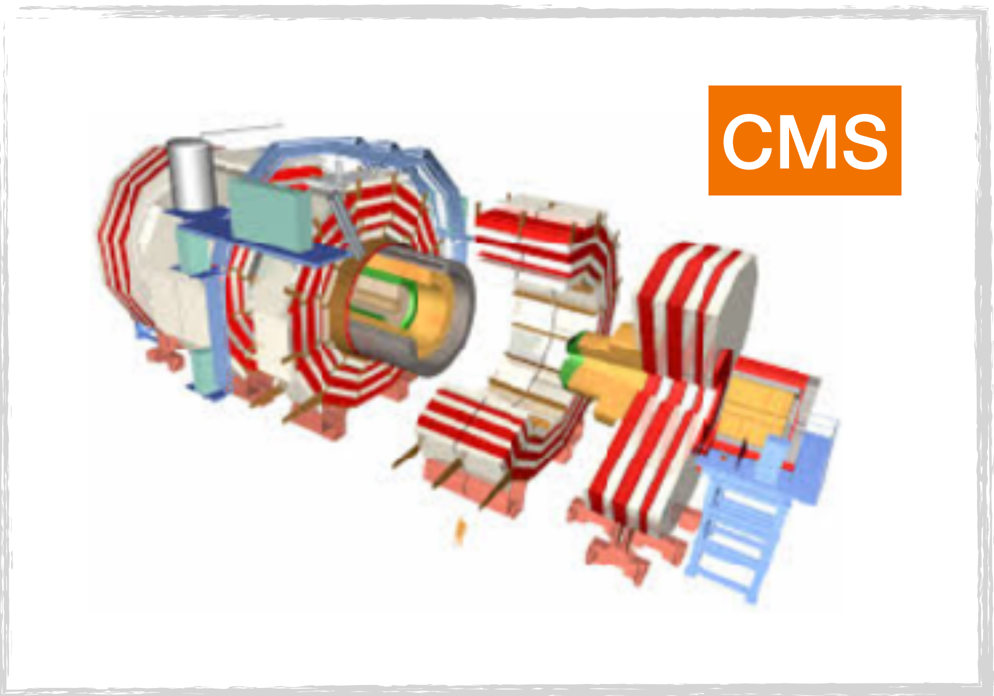
Lisboa, June 7th, 2024 (nuno@cern.ch)

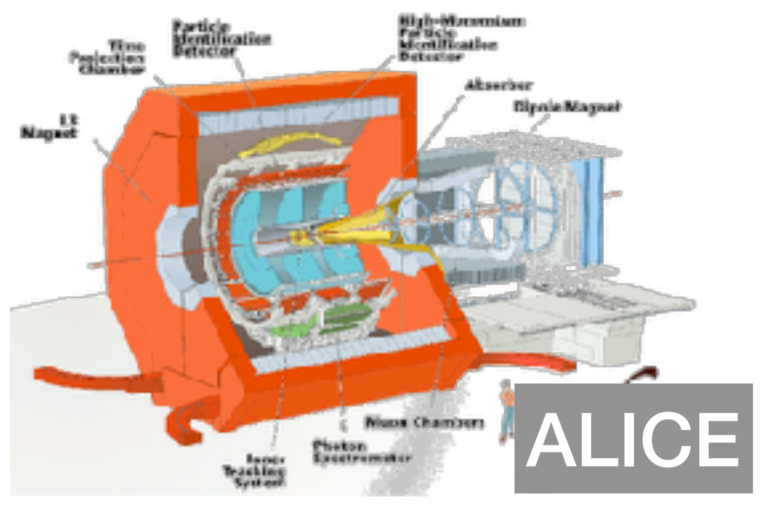
CMS LIP

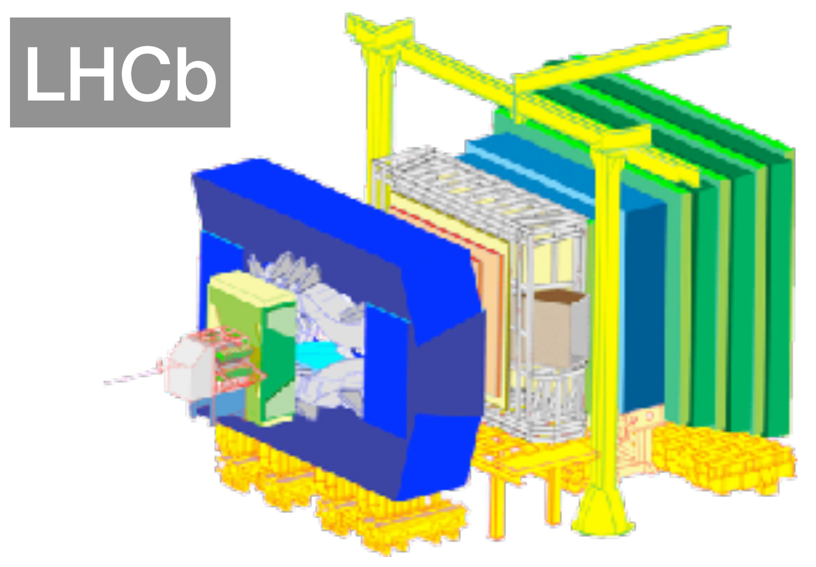
fct Fundação para a Ciência e a Tecnologia

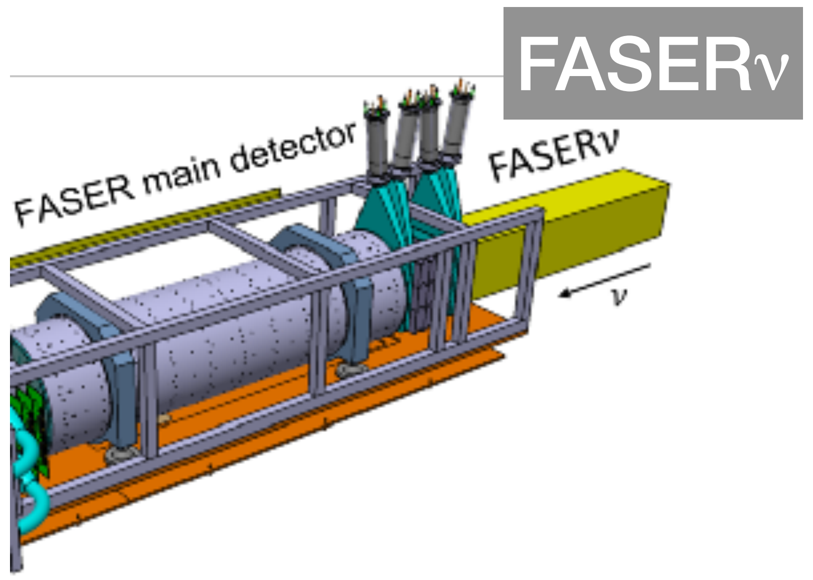
LHC: Detectors & Physics

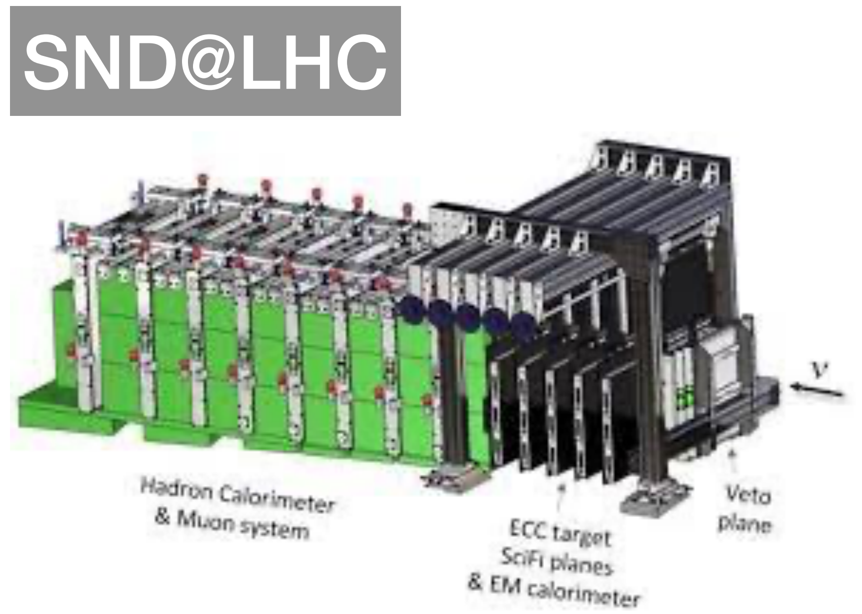




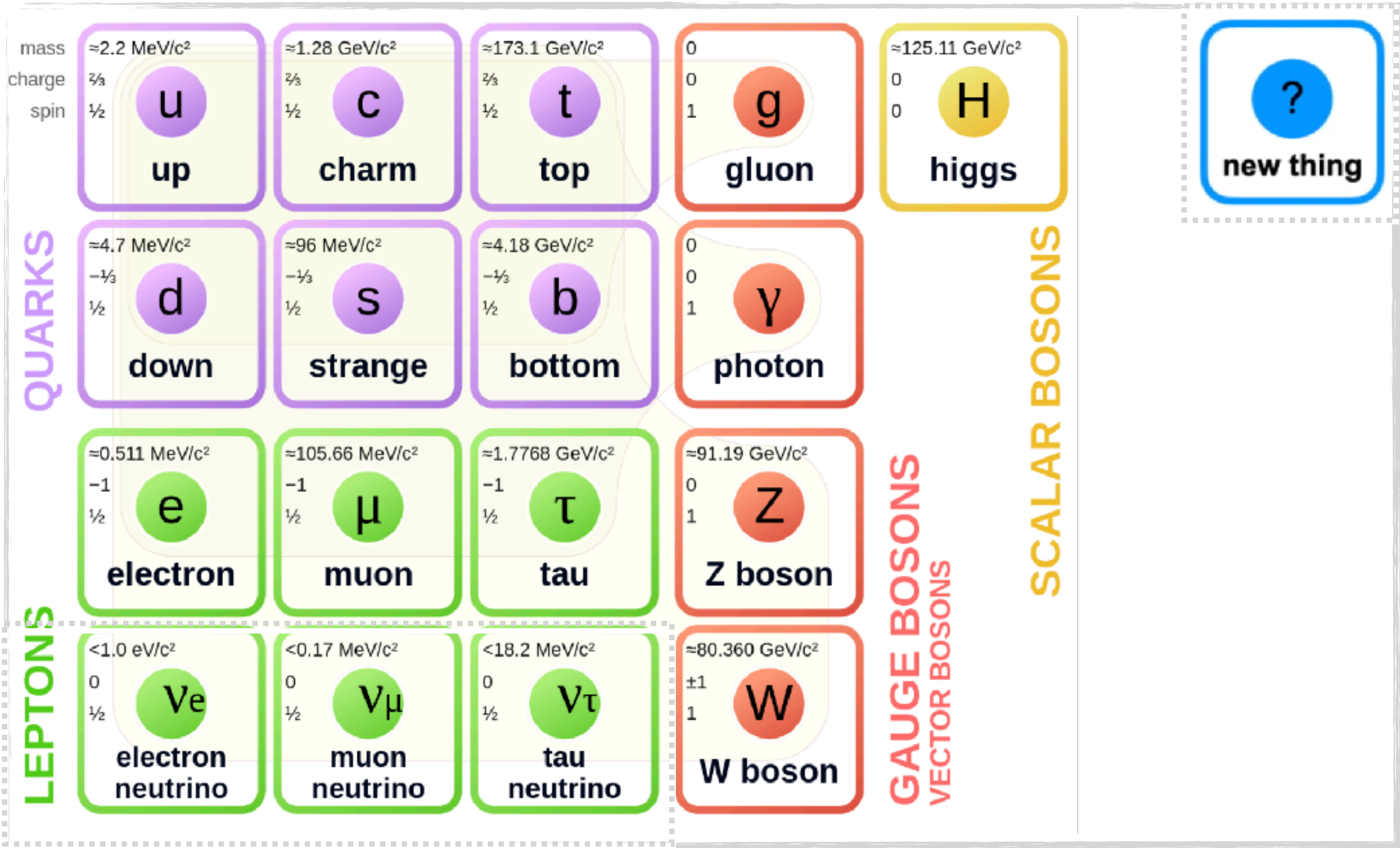




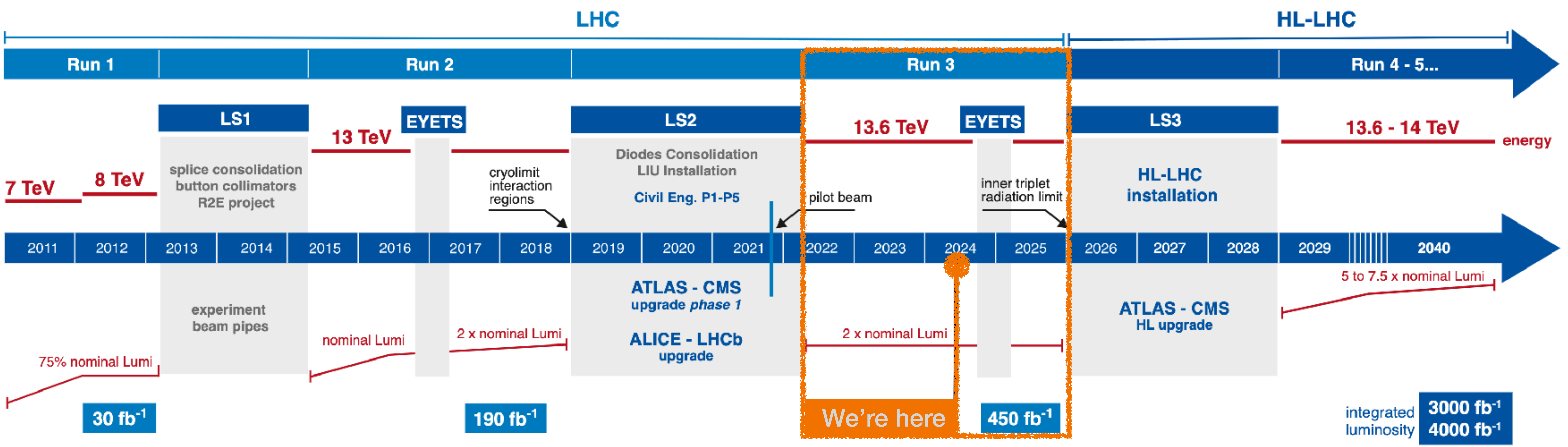




- LHC experiments capable to explore *all* SM particles & interactions
  - ➡ *Precision SM measurements*
- and probe for new particles & interactions
  - ➡ *Searches (direct & indirect) for new phenomena*



The LHC schedule



We're in the 10th data-taking year.

⇨

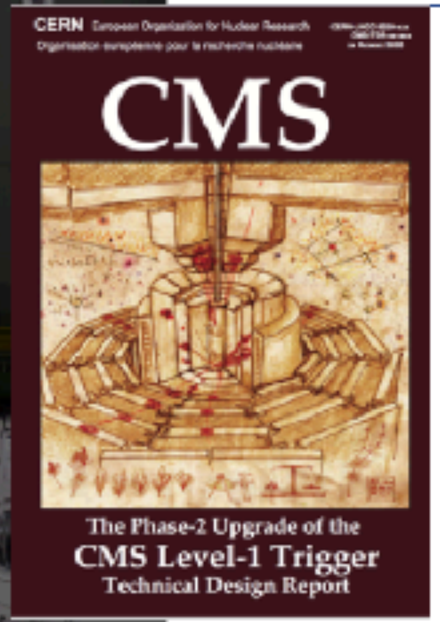
Accumulate large datasets

precision measurements
probe for rarer processes

Enhance apparatuses

(accelerator) increase luminosity
(detectors) increase performance

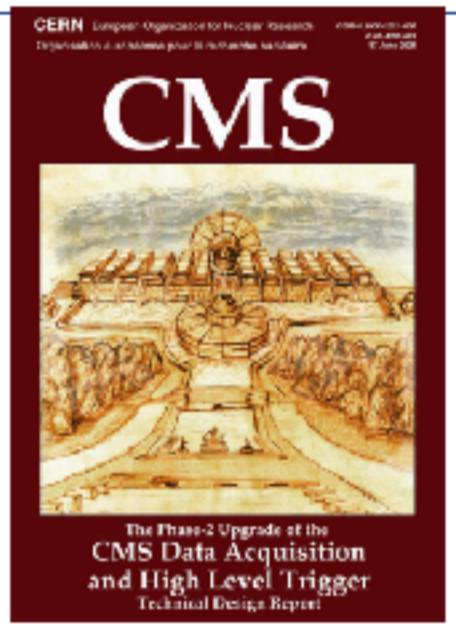
The upgraded CMS detector for HL-LHC



L1-Trigger

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

- Tracks in L1-Trigger at 40 MHz
- Particle Flow selection
- 750 kHz L1 output
- 40 MHz data scouting



DAQ & High-Level Trigger

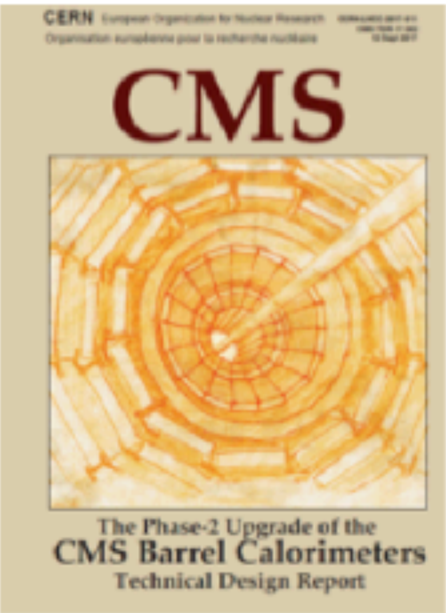
https://cds.cern.ch/record/2759072

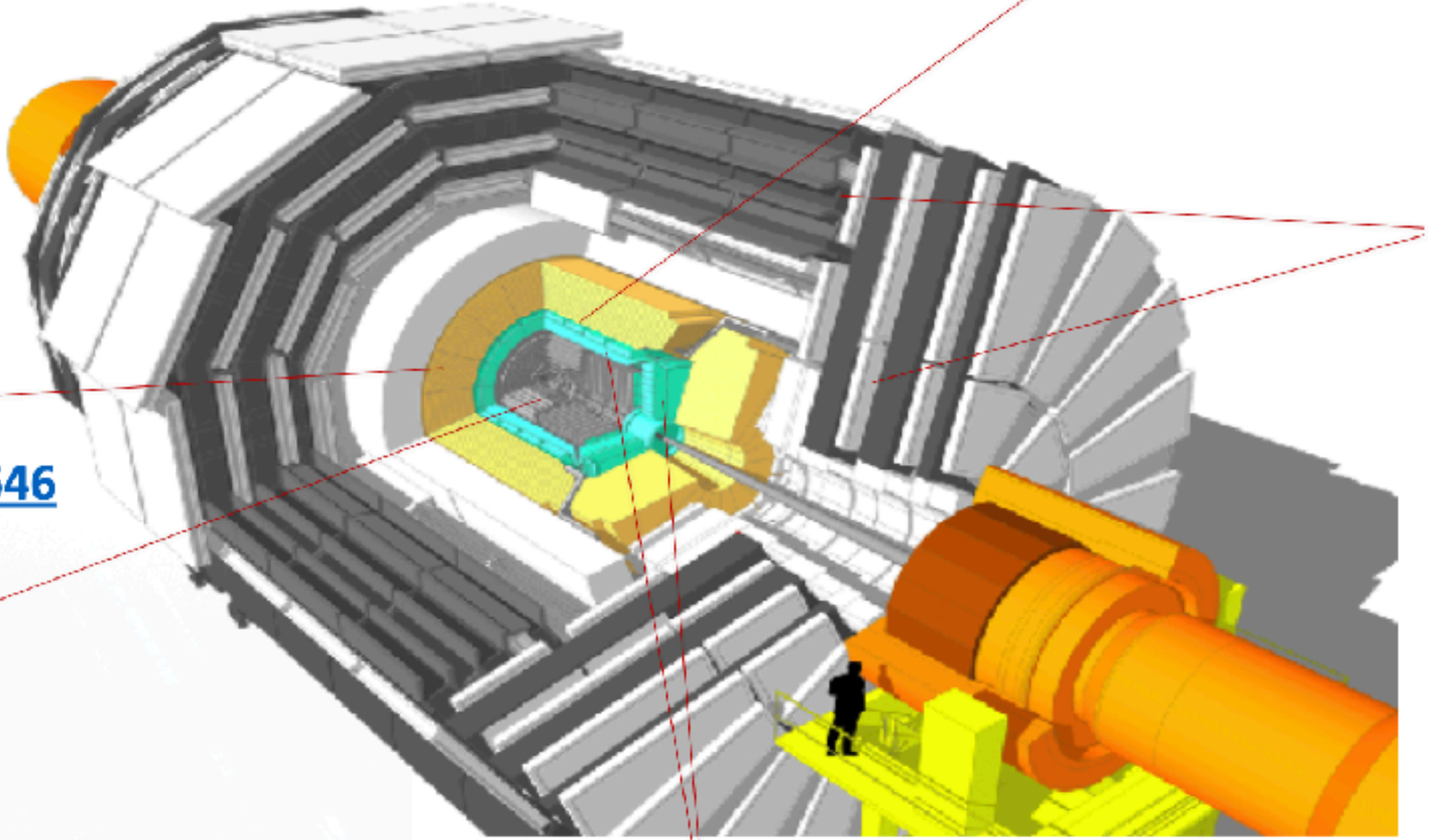
- Full optical readout
- Heterogenous architecture
- 60 TB/s event network
- 7.5 kHz HLT output

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

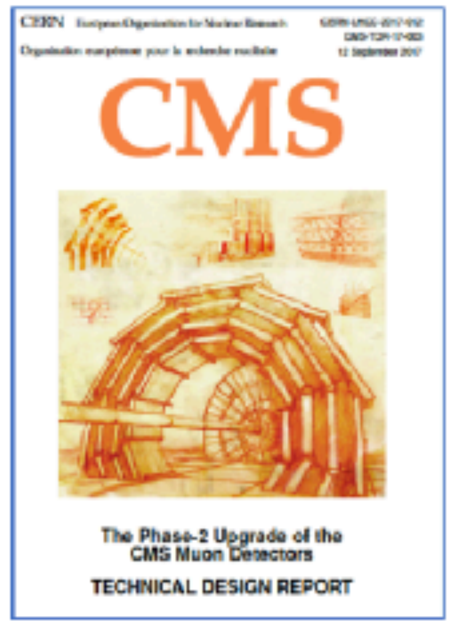


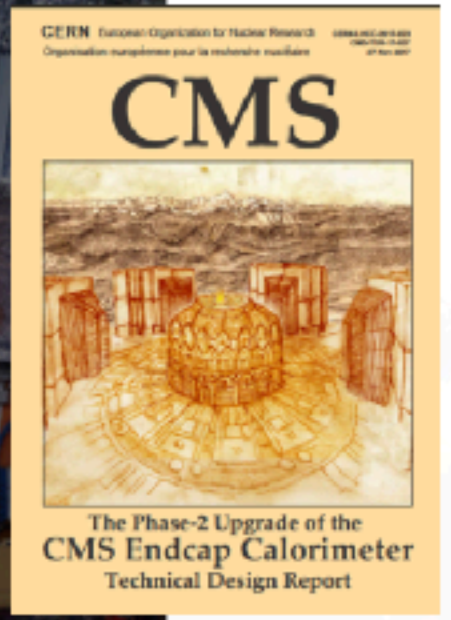


Muon systems

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

- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$

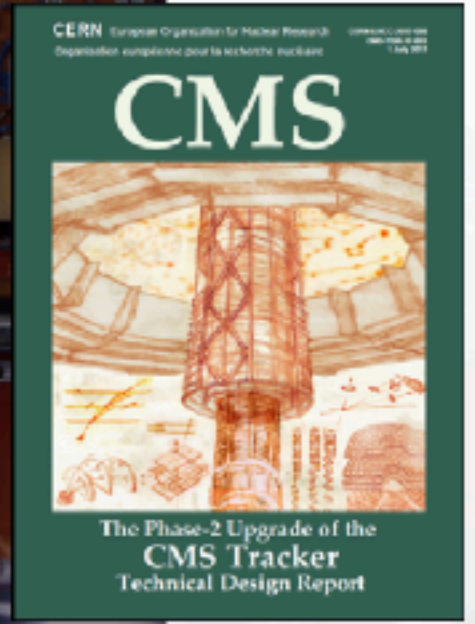




Calorimeter Endcap

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

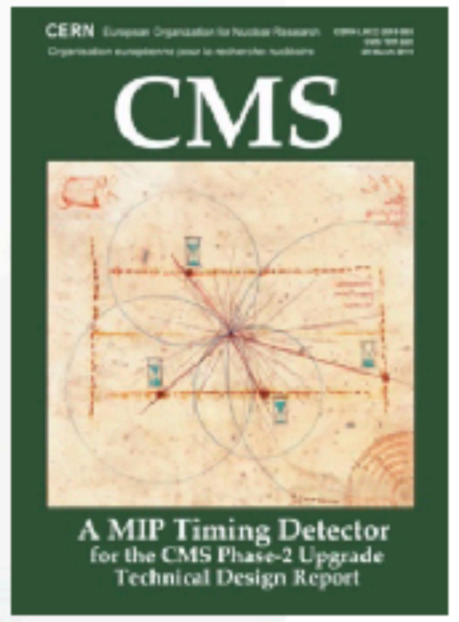
- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS



Tracker

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

- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$



MIP Timing Detector

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

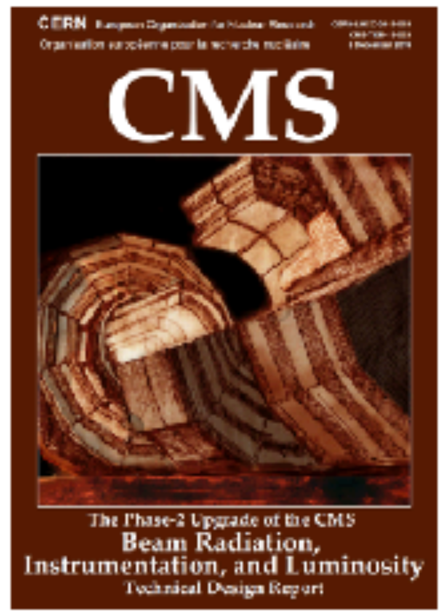
Precision timing with:

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

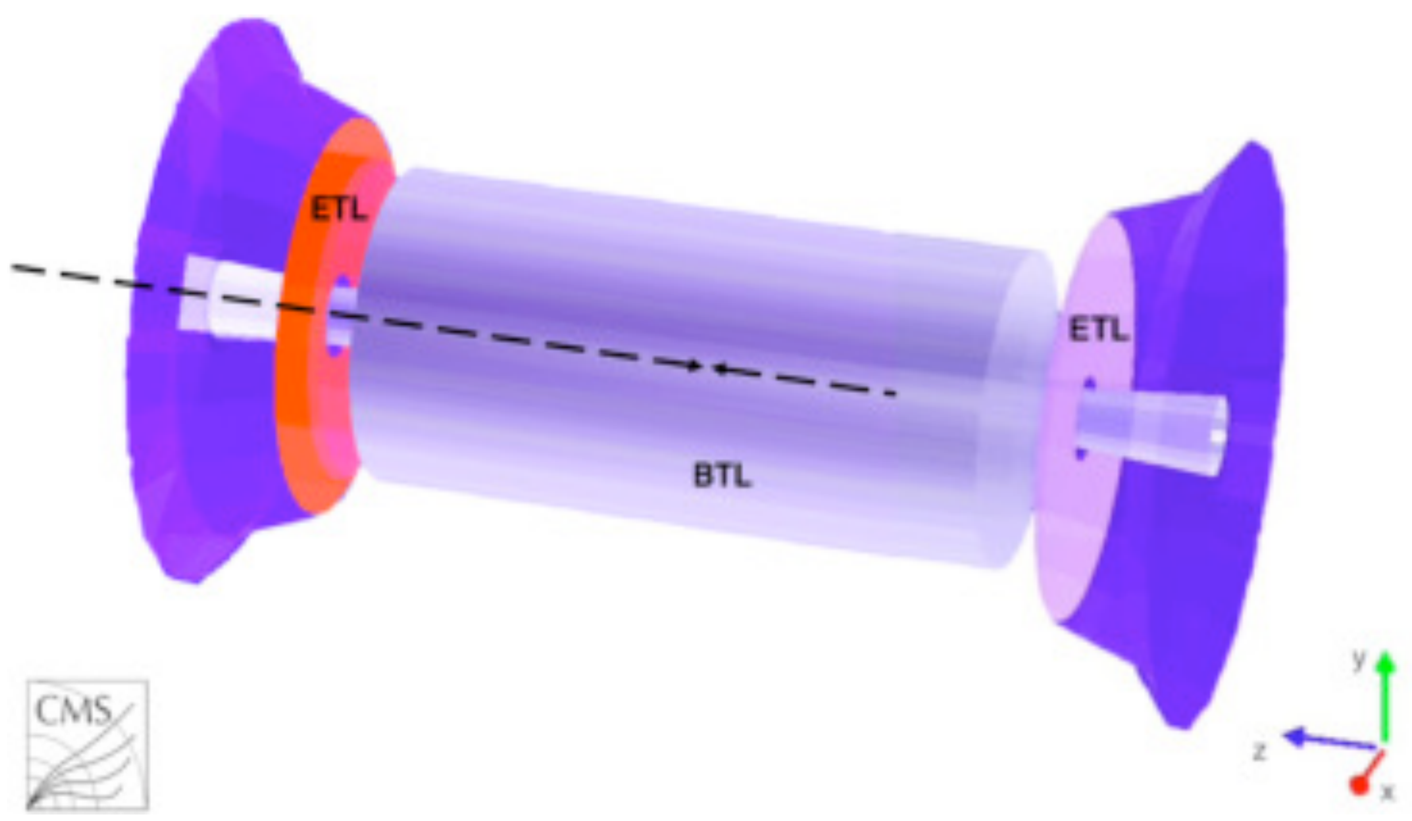
Beam Radiation Instr. and Luminosity

http://cds.cern.ch/record/2759074

- Beam abort & timing
- Beam-induced background
- Bunch-by-bunch luminosity:
  1% offline, 2% online
- Neutron and mixed-field radiation monitors



(HL-LHC upgrade example: Timing Detector)

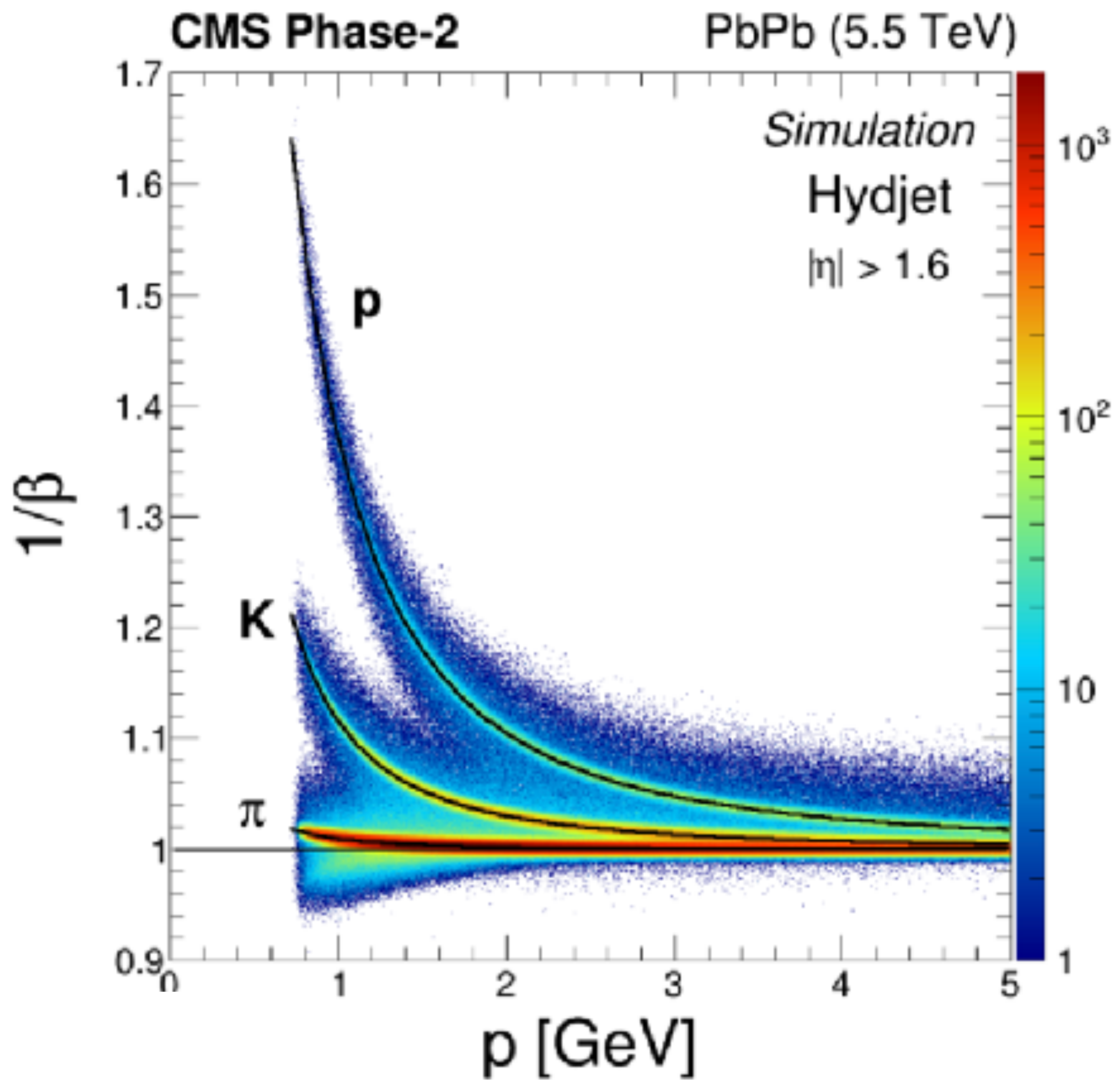


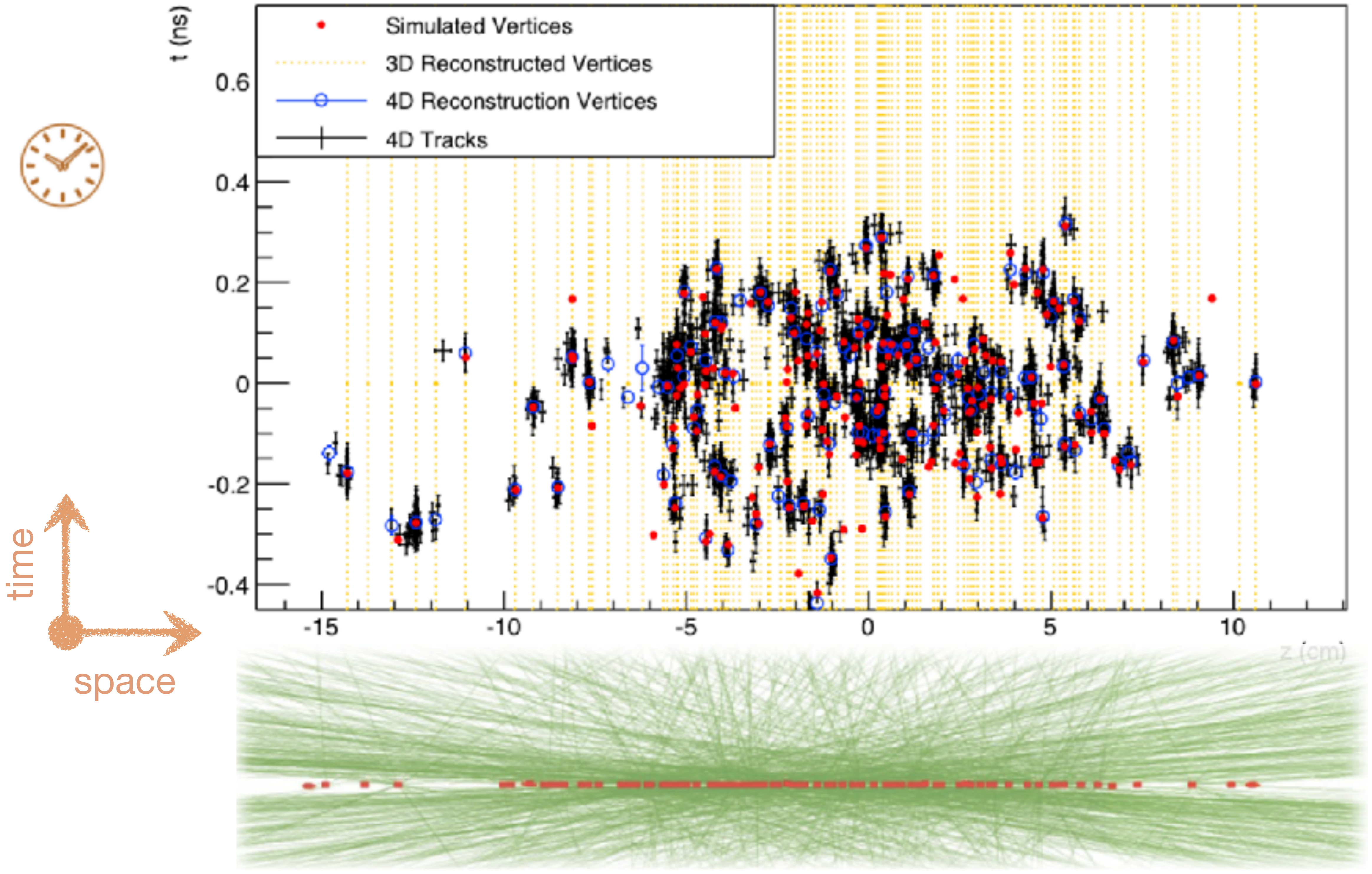
Measure the production time of minimum ionizing particles

- ❑ Longitudinal spread of bunches
- ❑ Interactions in a bunch crossing spread with rms ~ 200 ps

Motivations

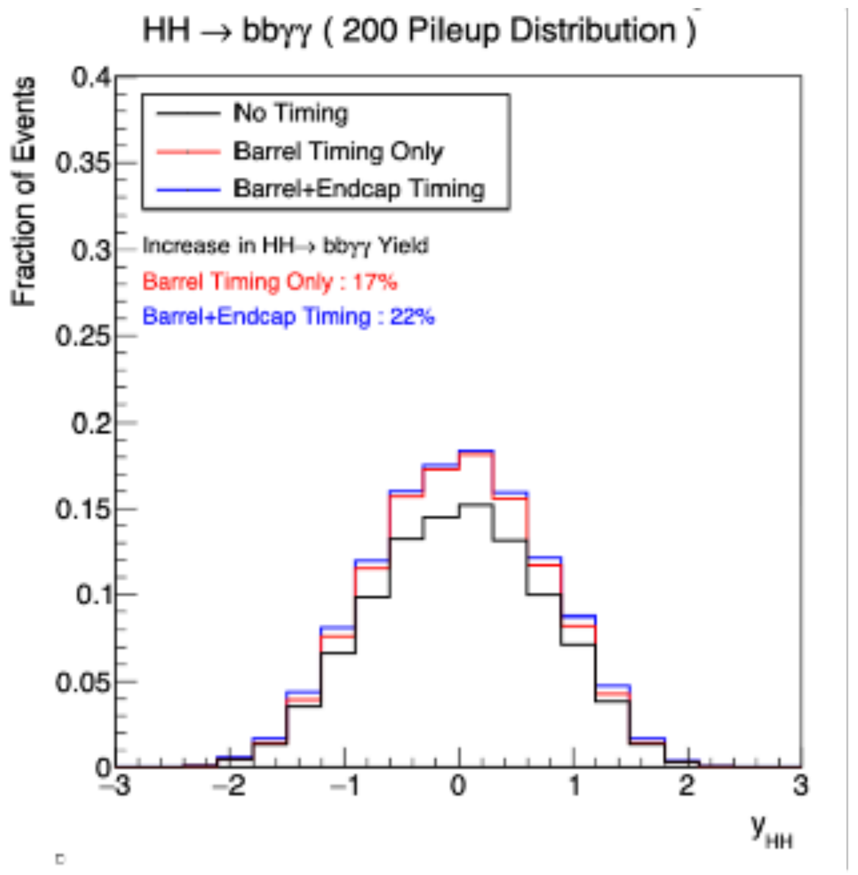
- ❑ Pileup mitigation
- ❑ Searches for beyond the standard model
  - ▪ Delayed particles
  - ▪ Time-of-flight of heavy stable charged particles (HSCPs)
- ❑ Particle identification





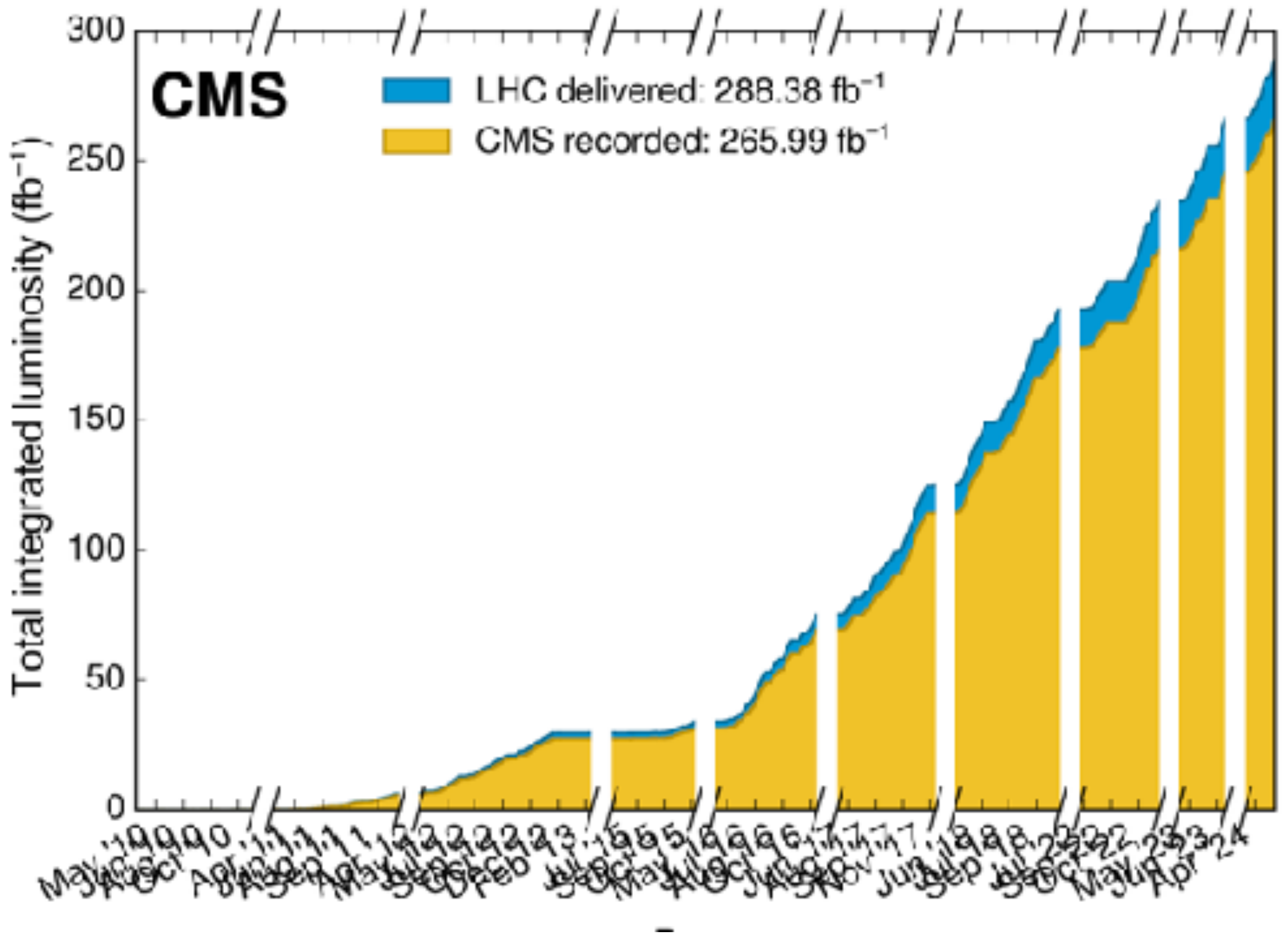
Impact on physics

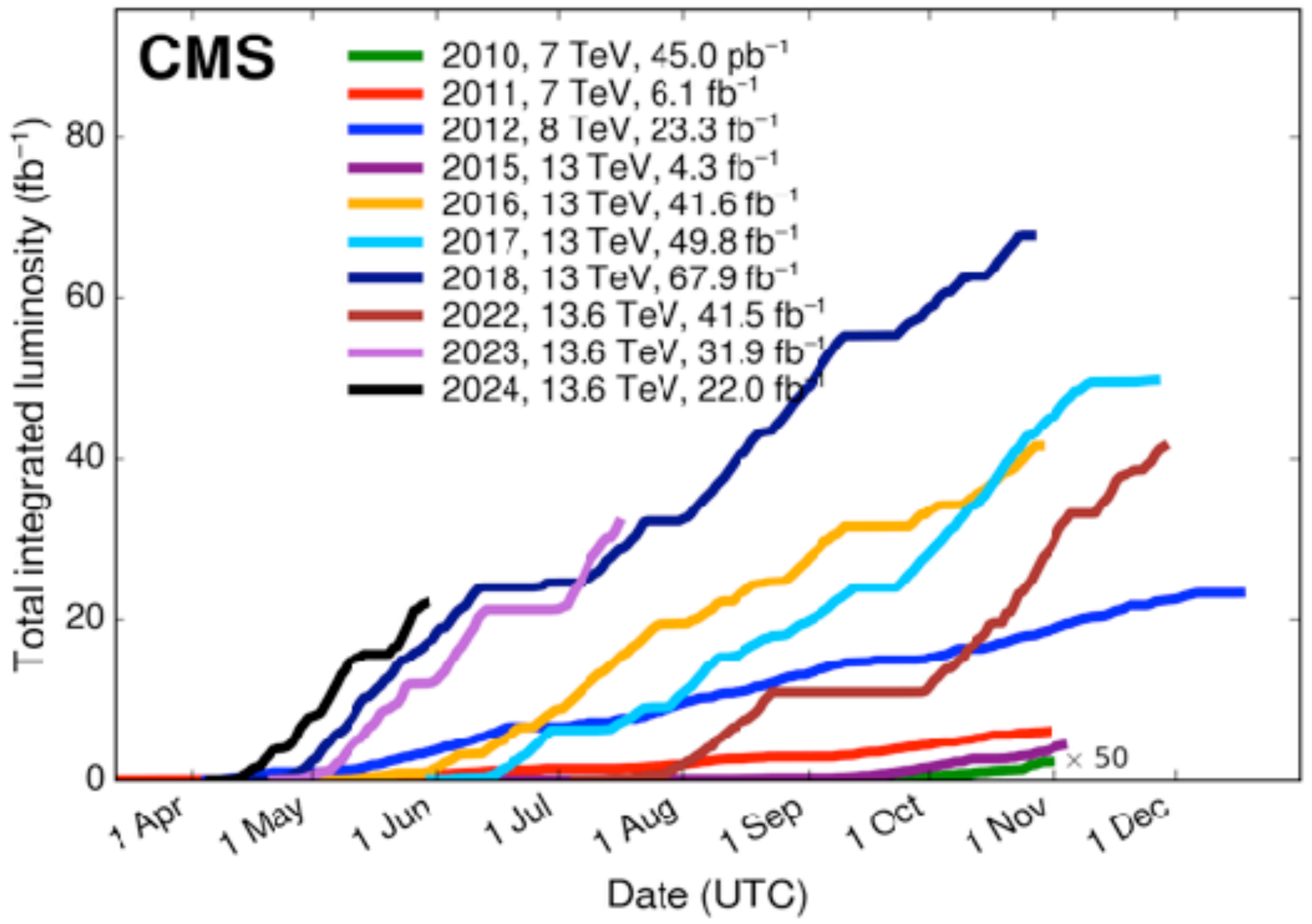
- ❑ 10 – 12% improvement in p_T^{miss} resolution
  - ▪ H ⟶ ττ, BSM searches
- ❑ HH production: +20% signal yield
- ❑ PID for heavy ion physics

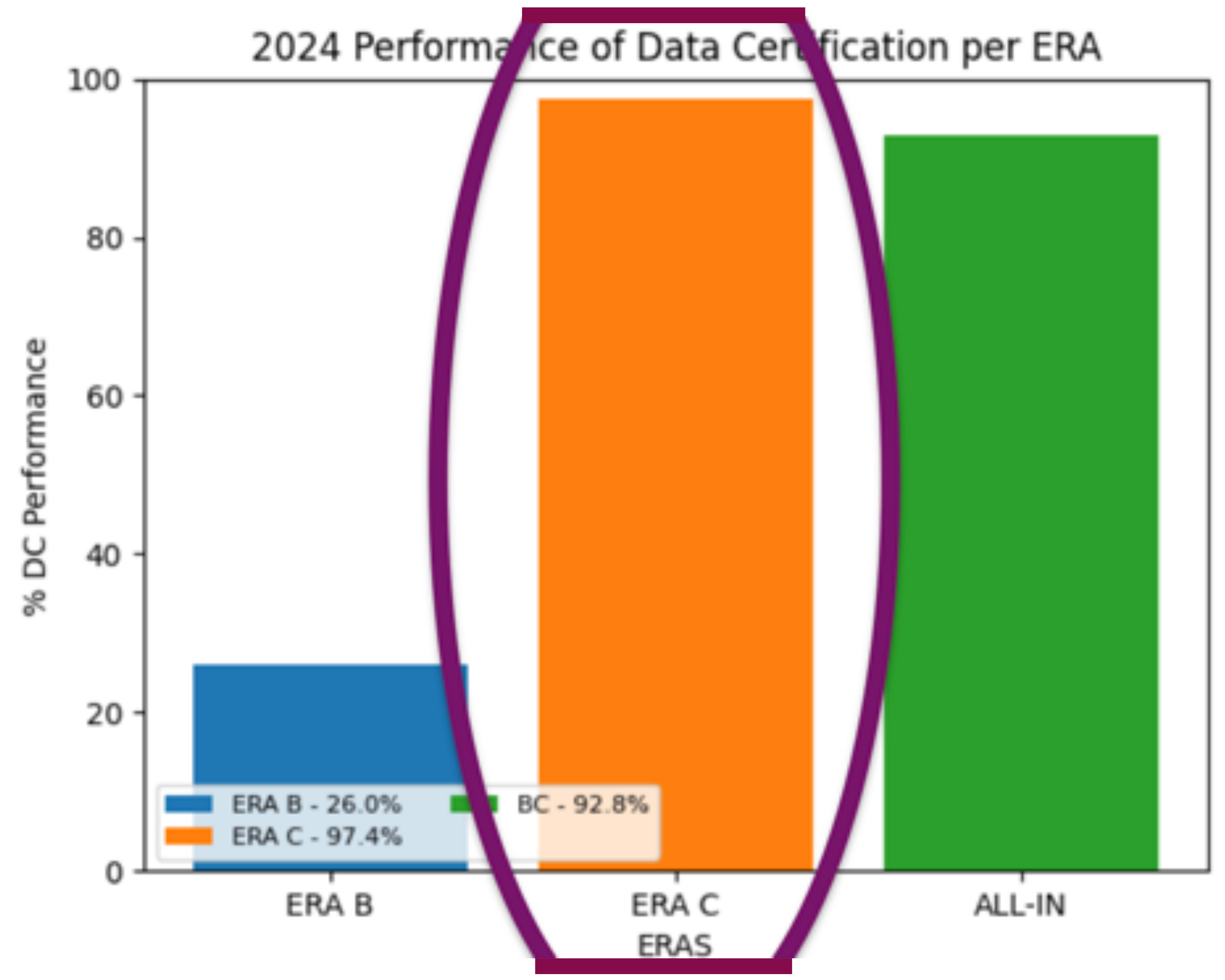


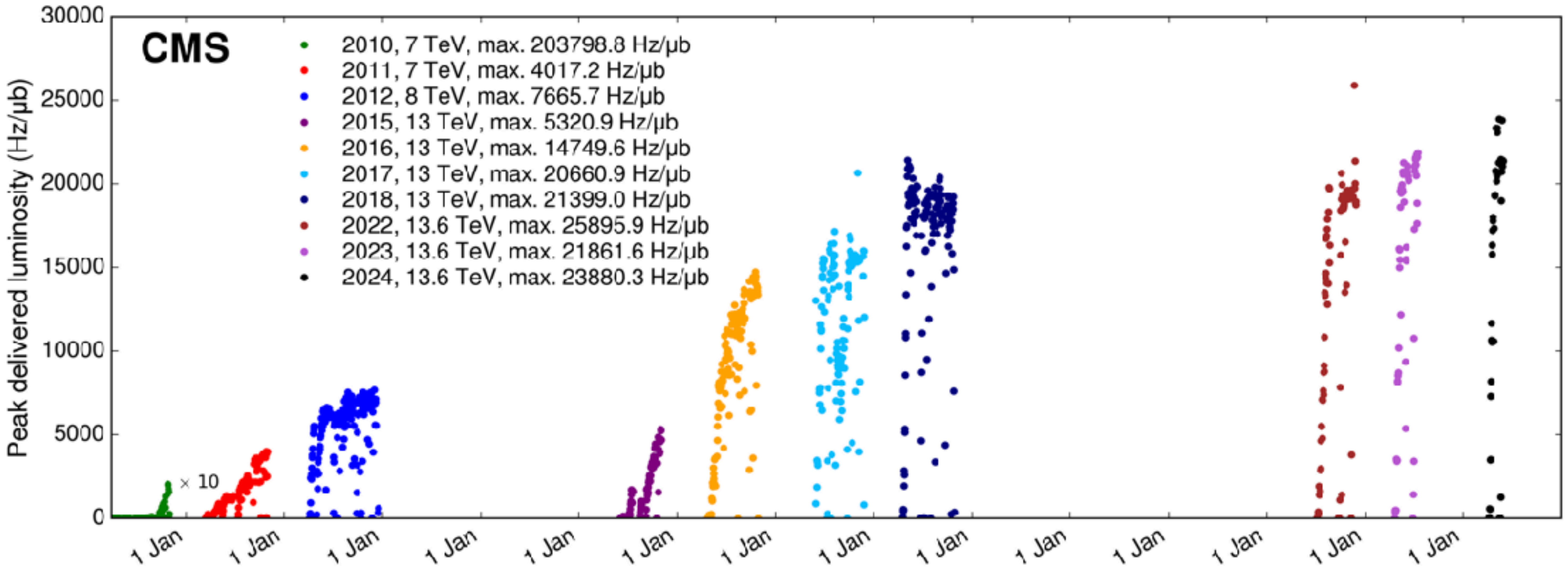
➥ Status (BTL): about to start module production

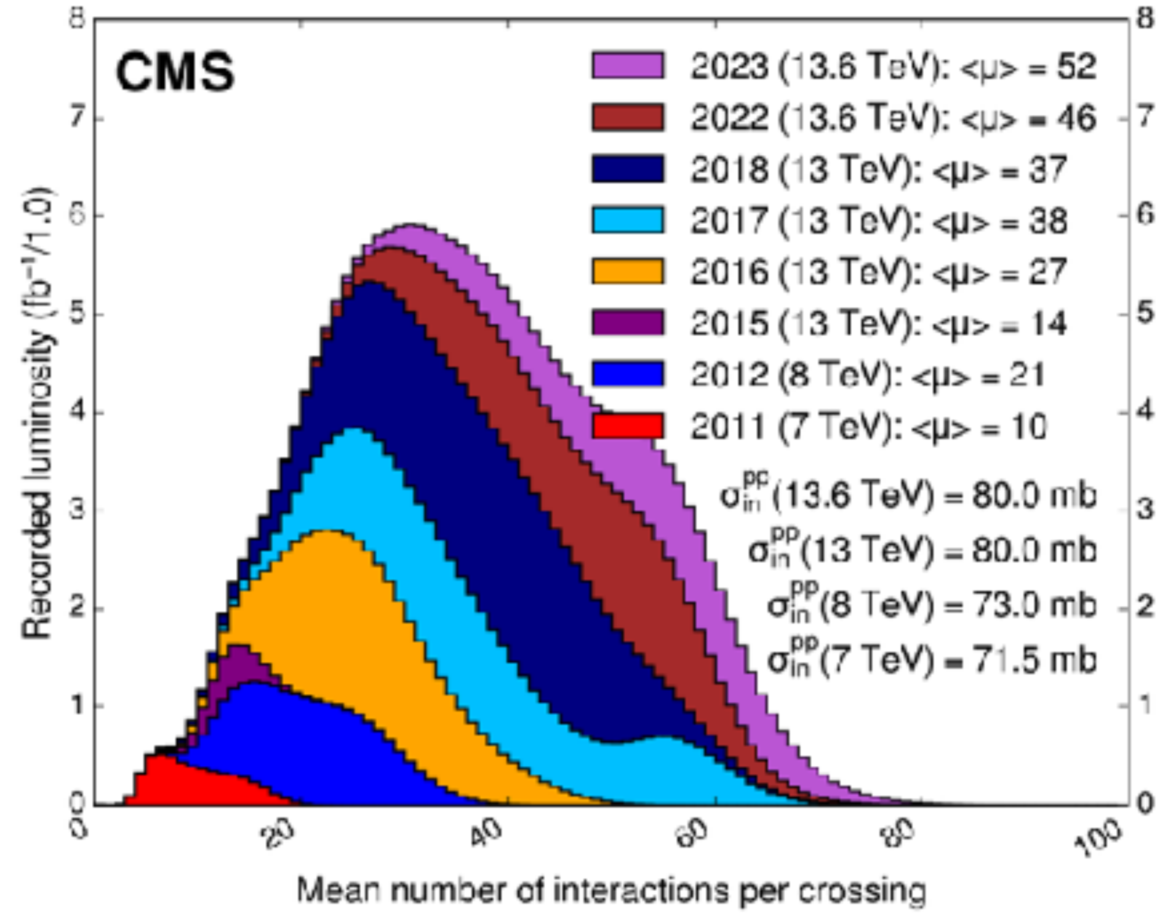
Efficiently collecting large, rich data sets



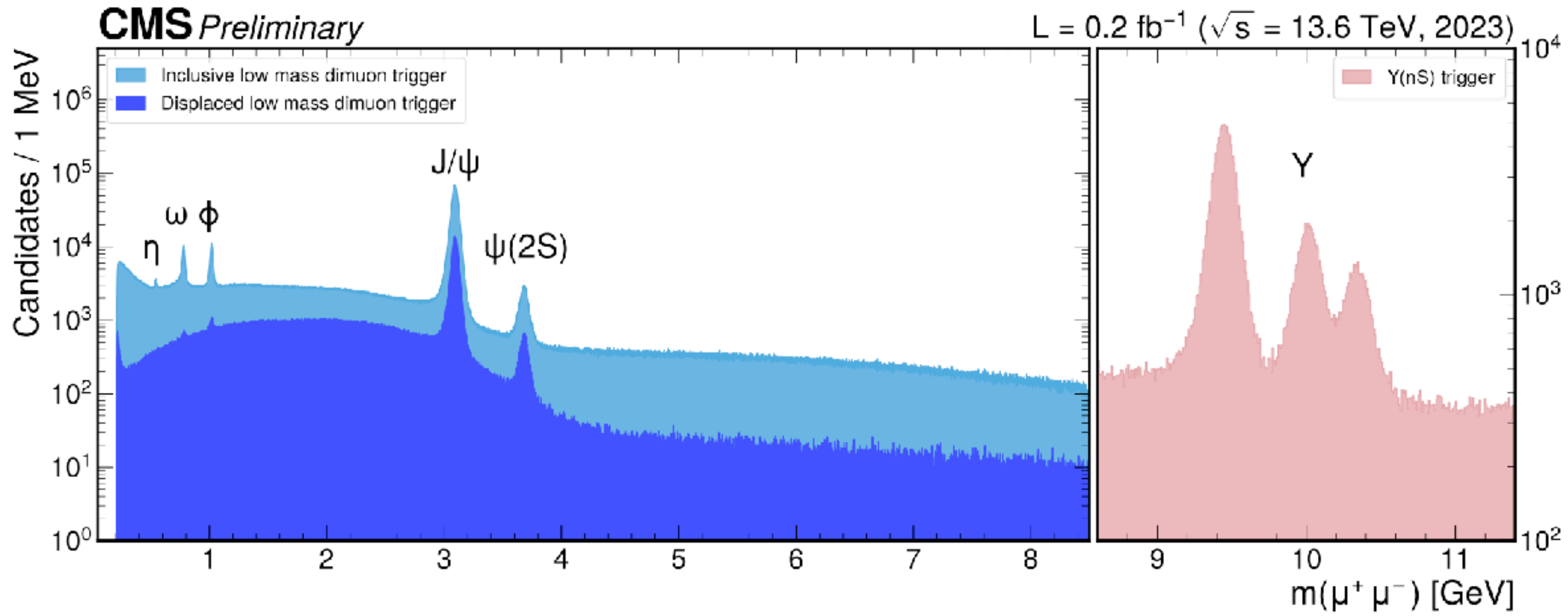


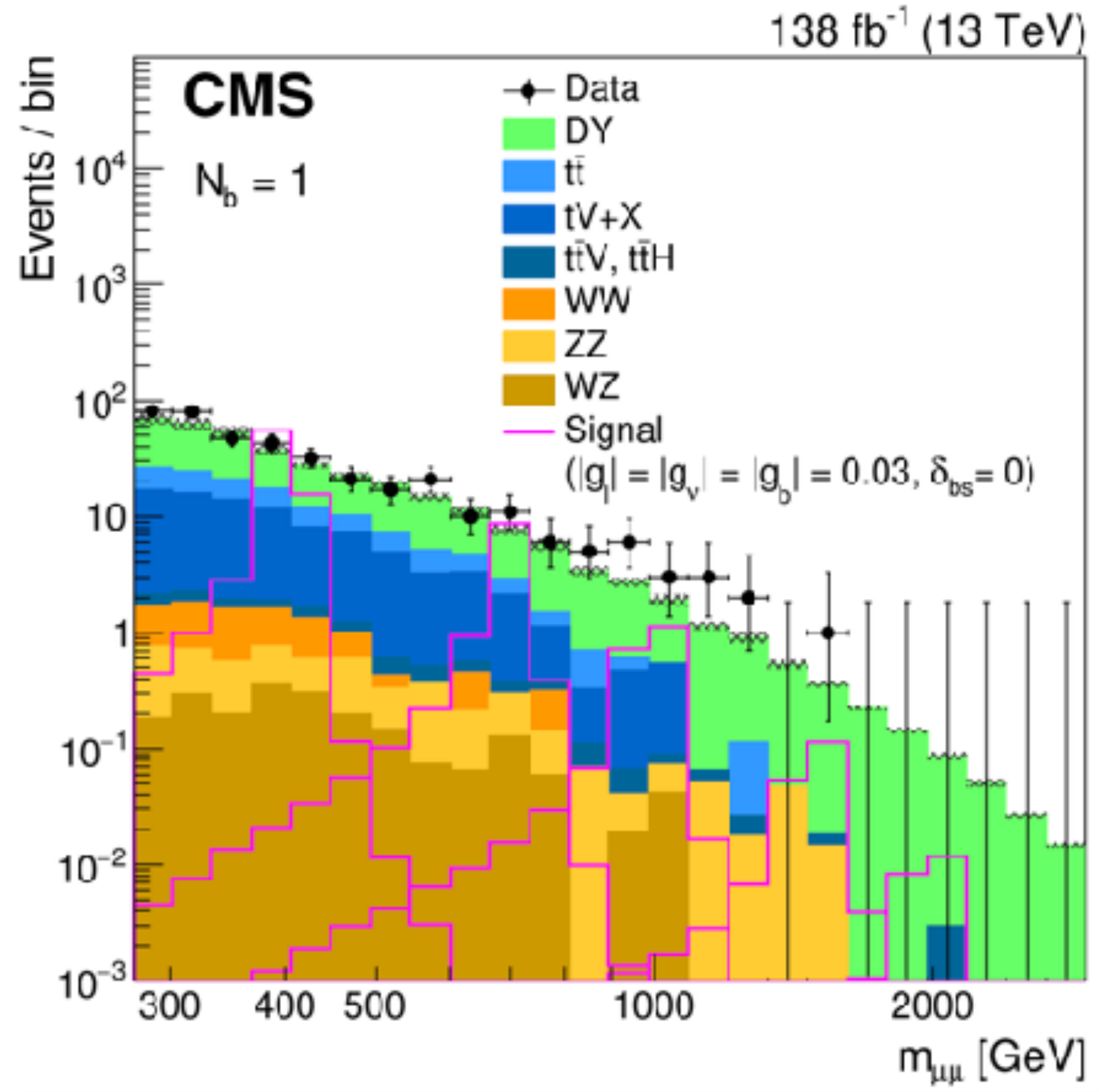


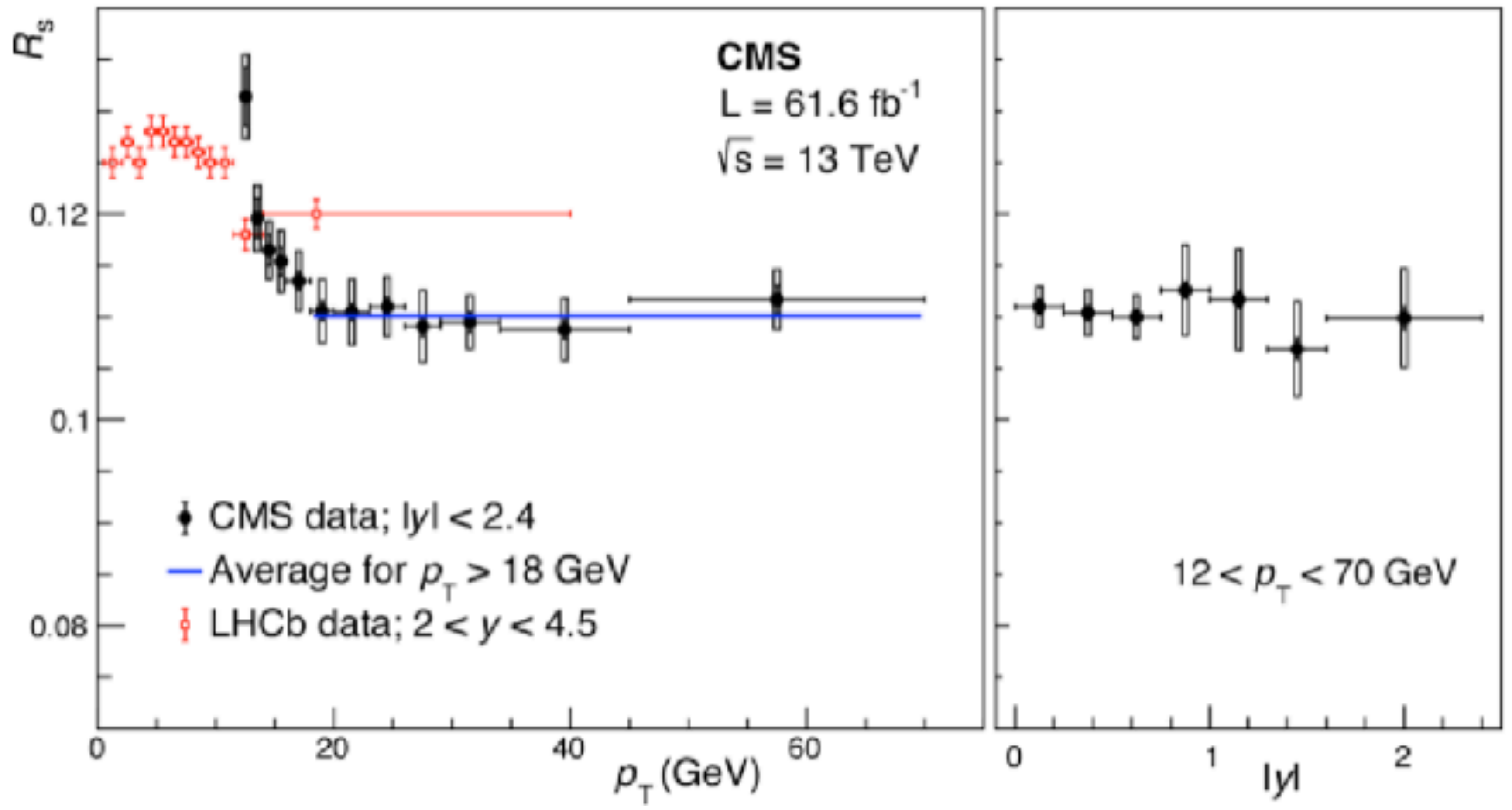


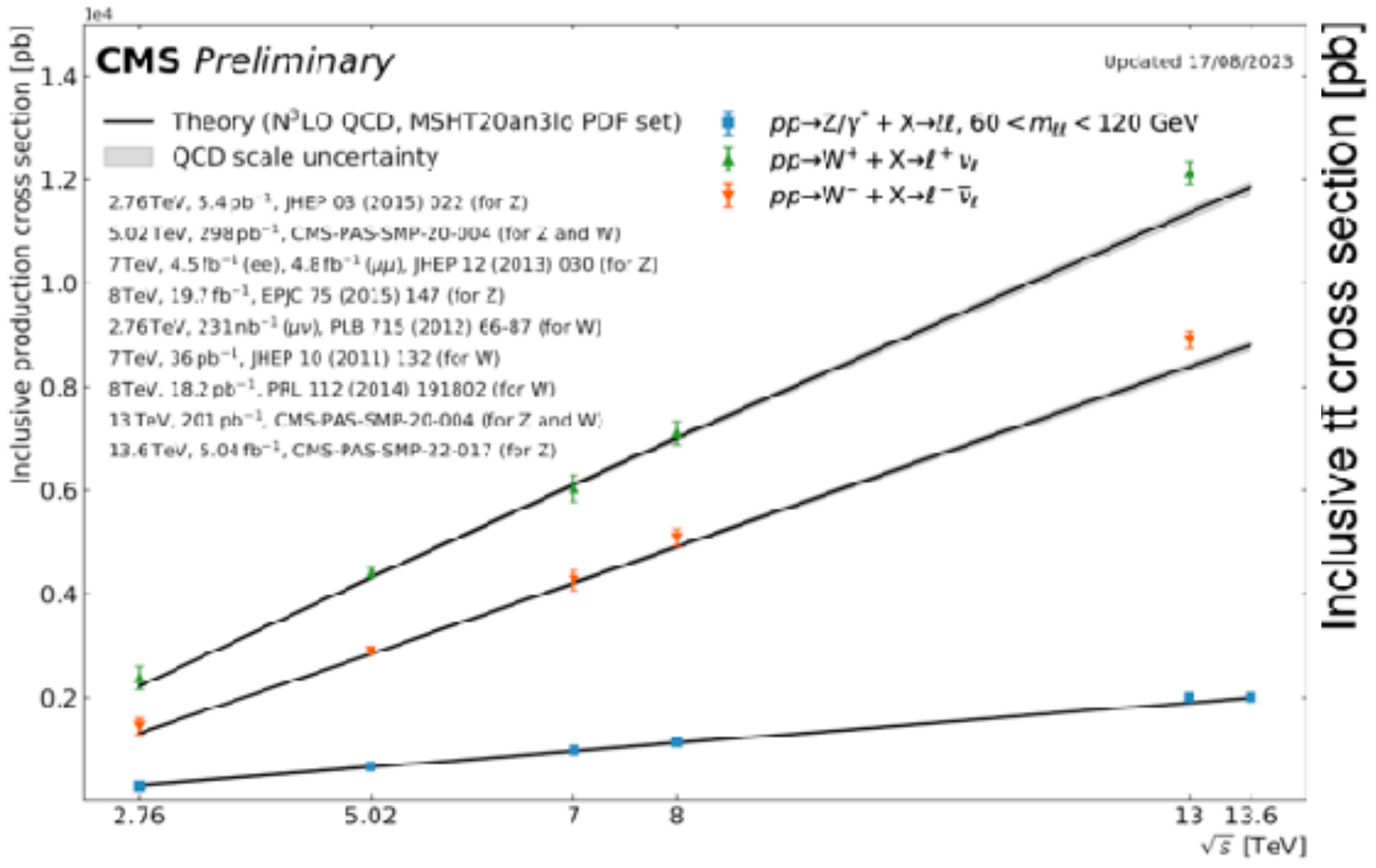


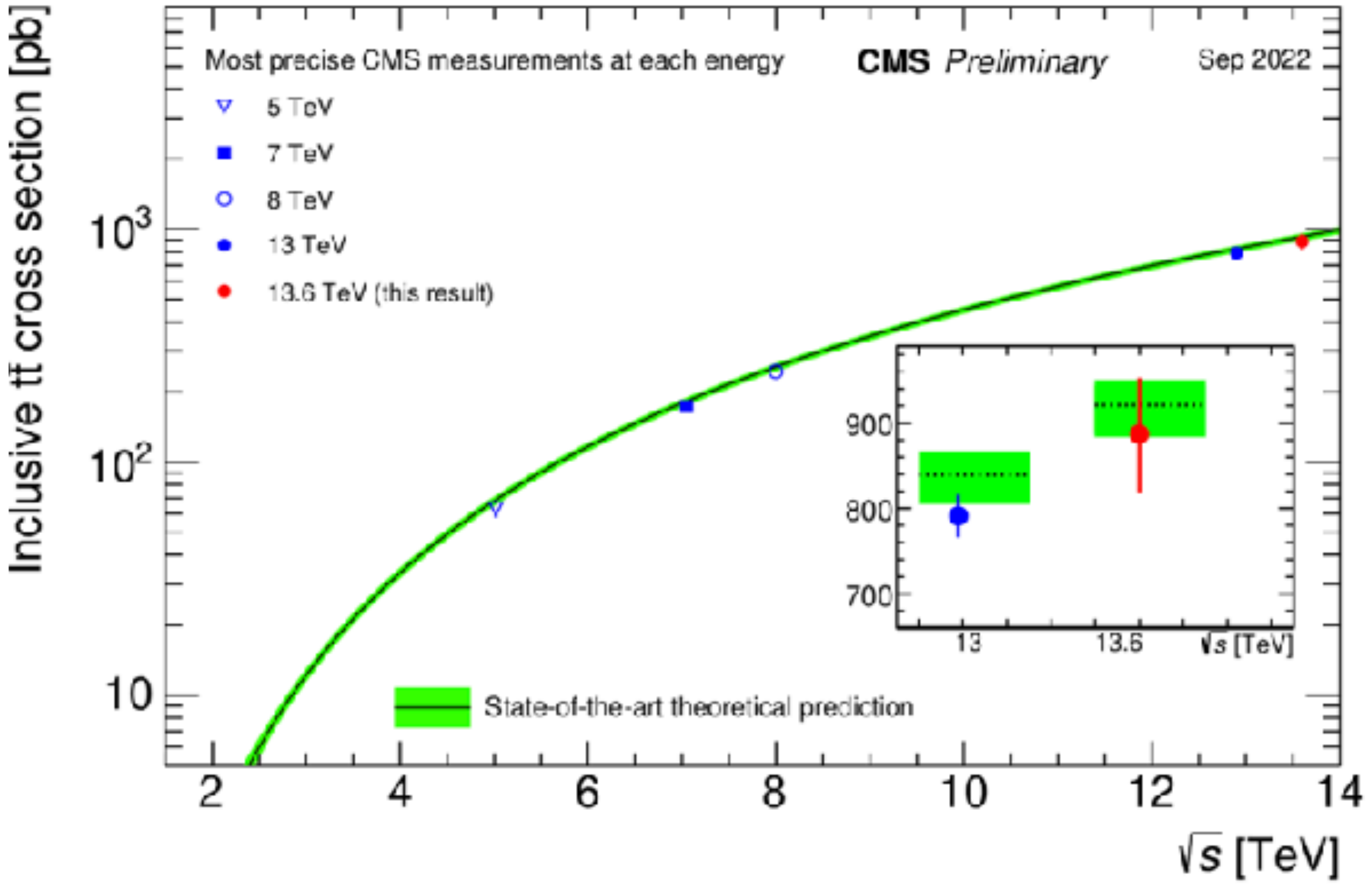
Probing different kinematics, m & √s



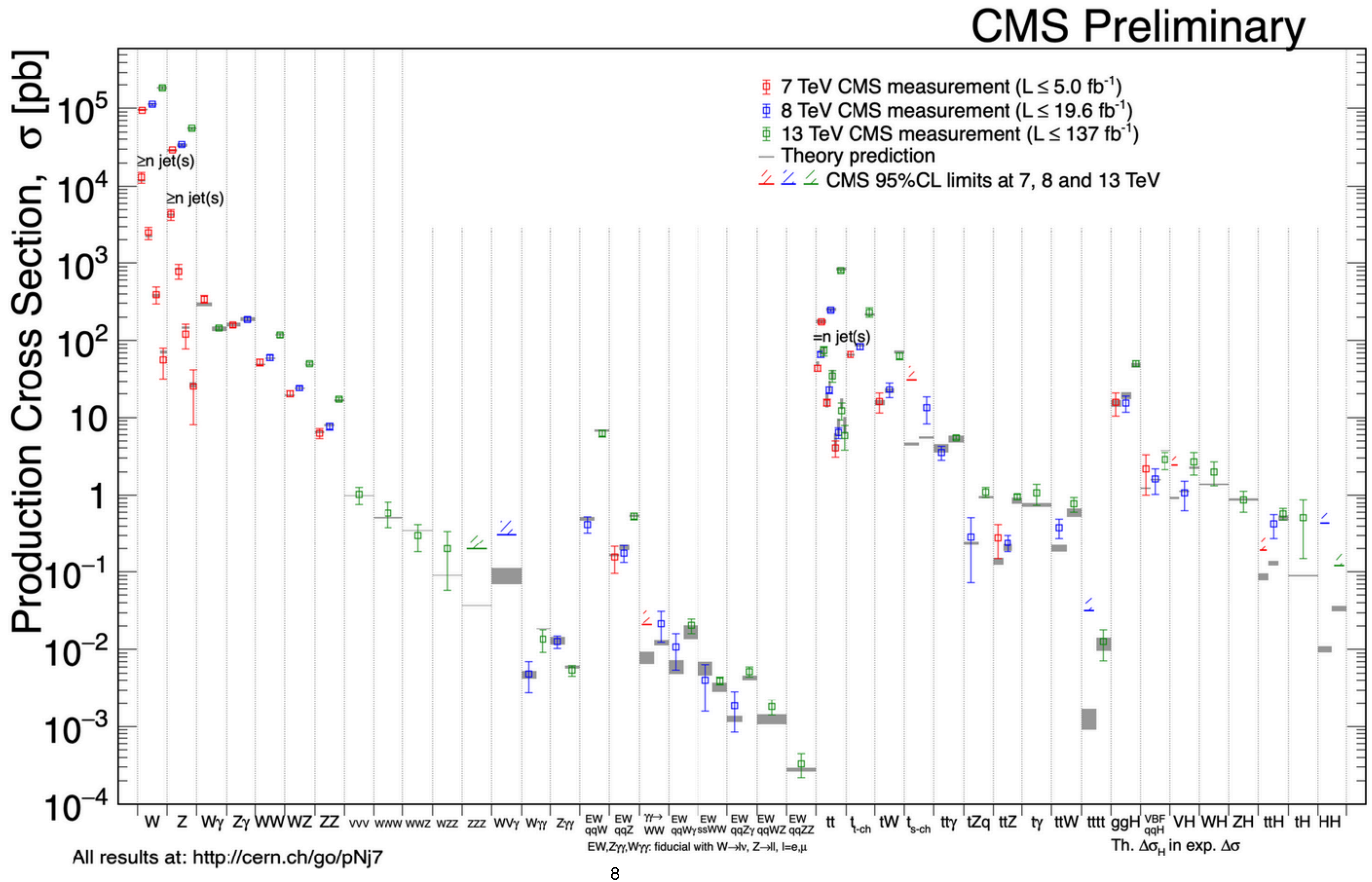






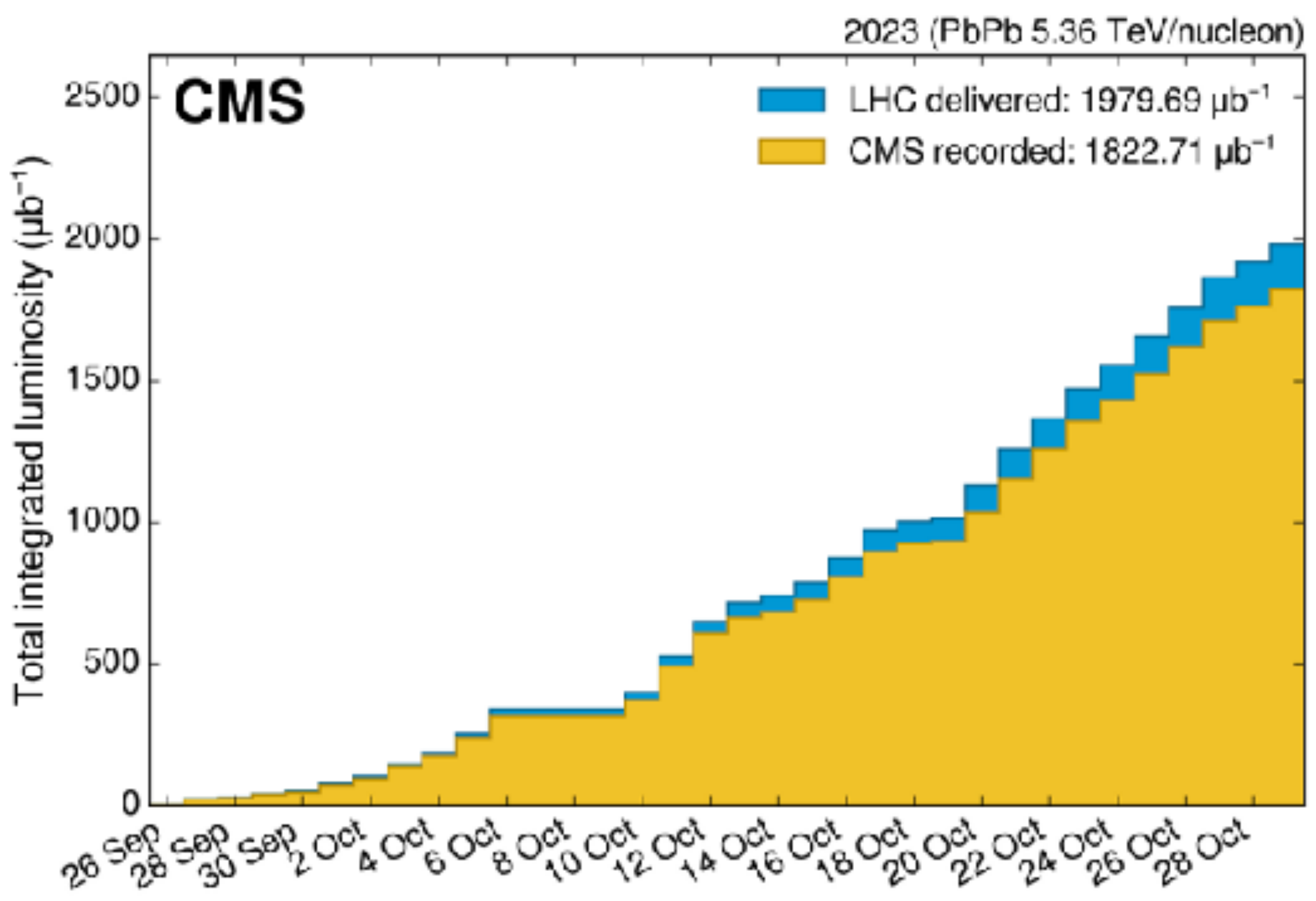


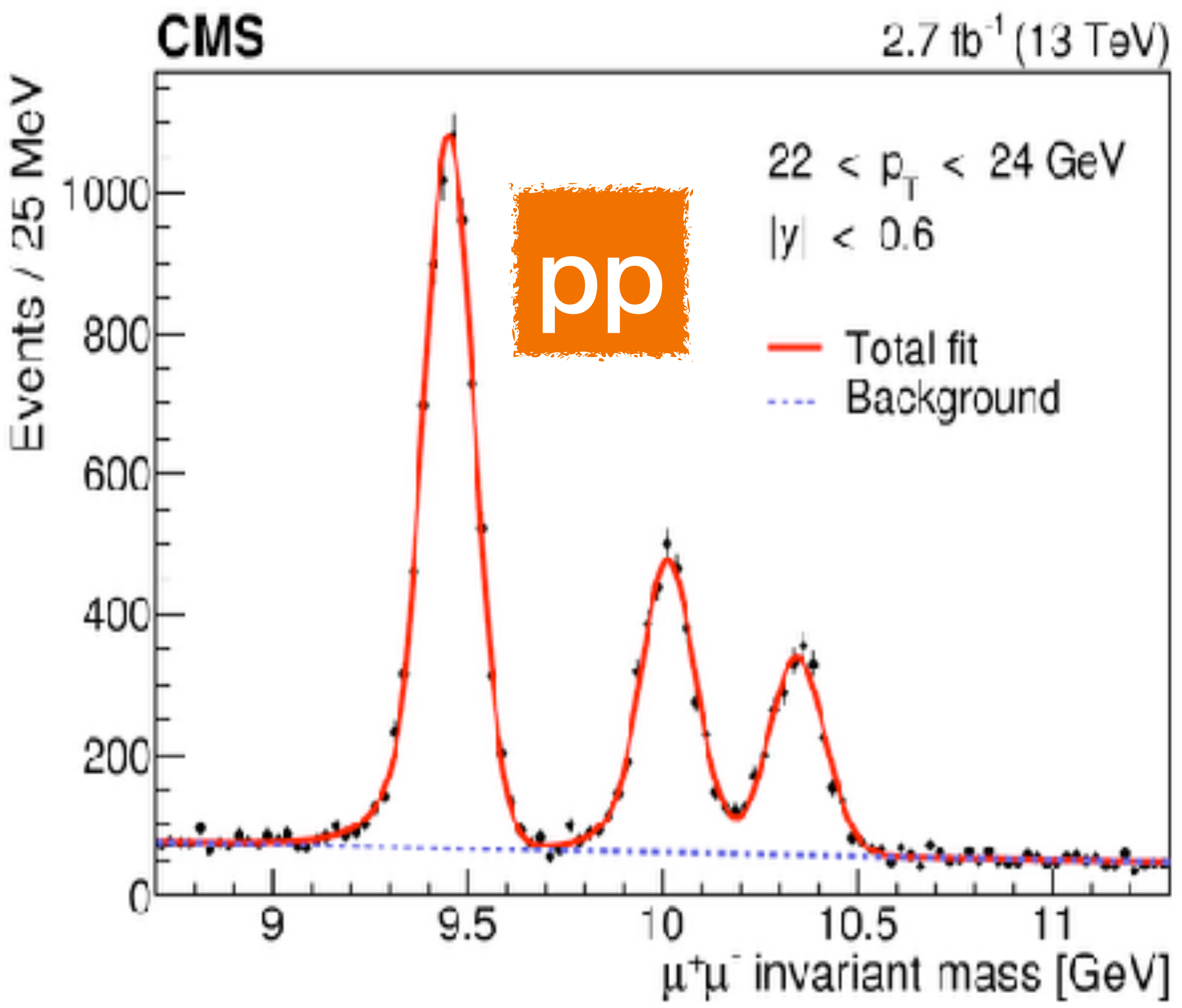
Probing multiple final states

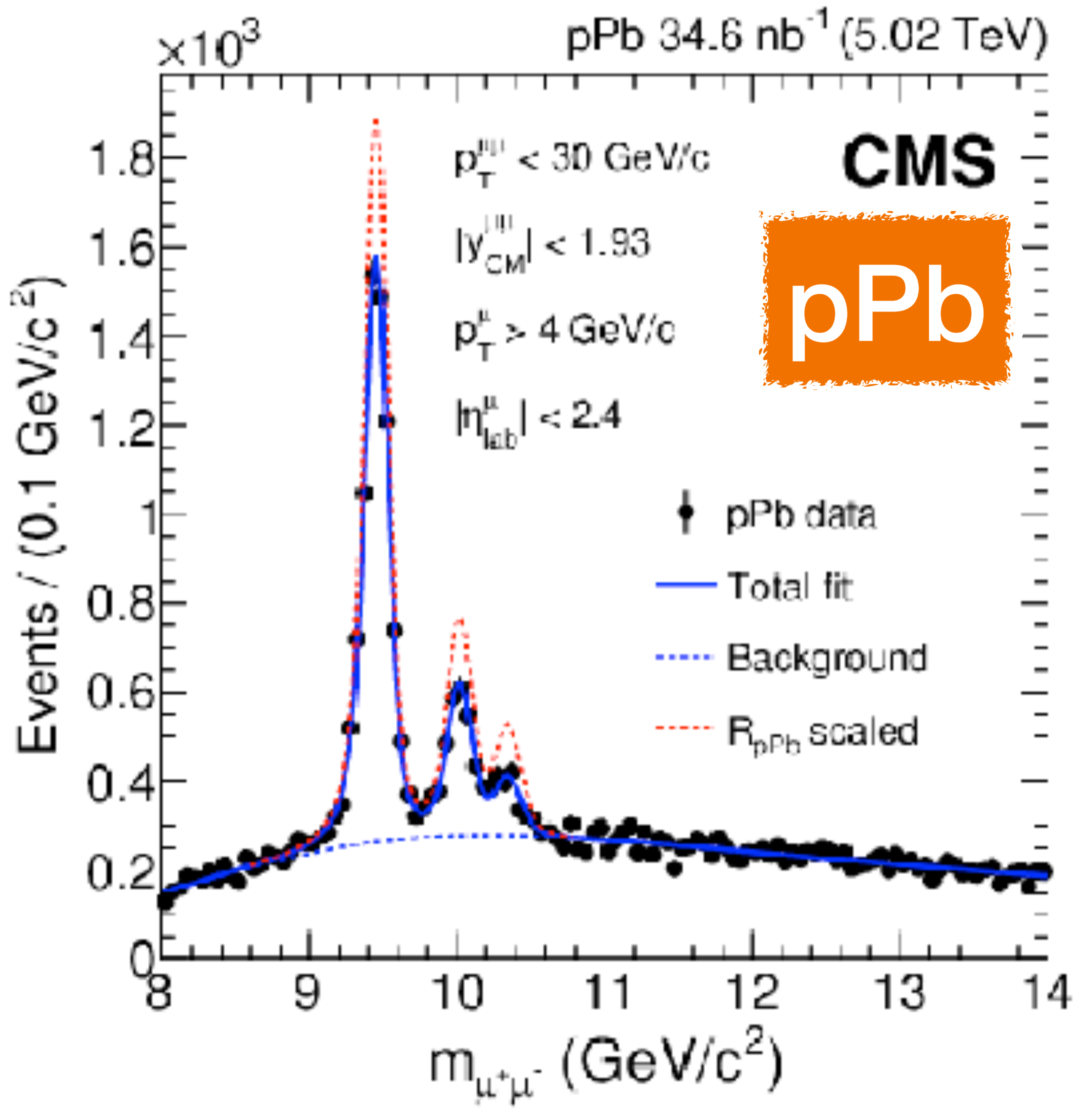


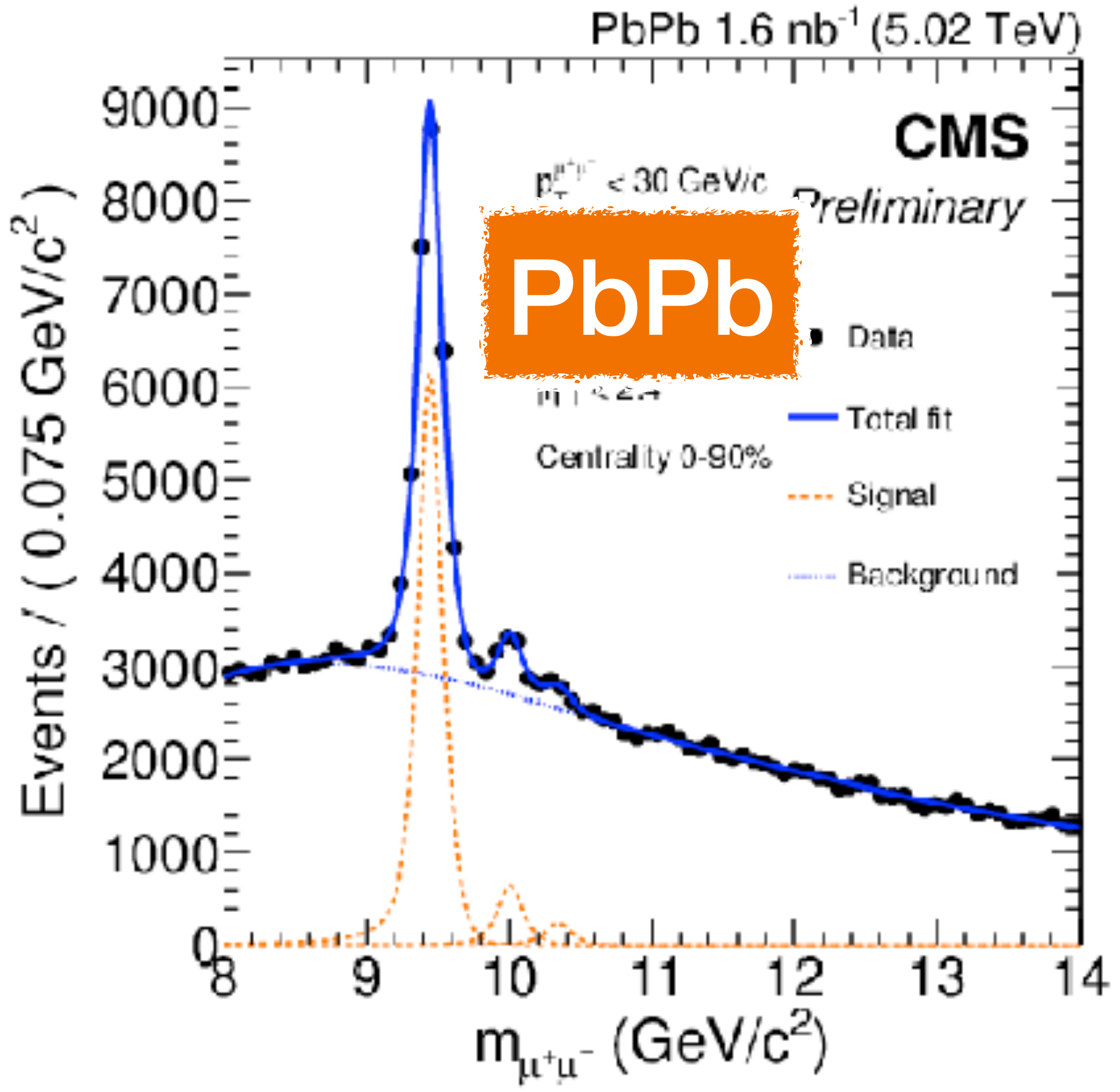
Rarer

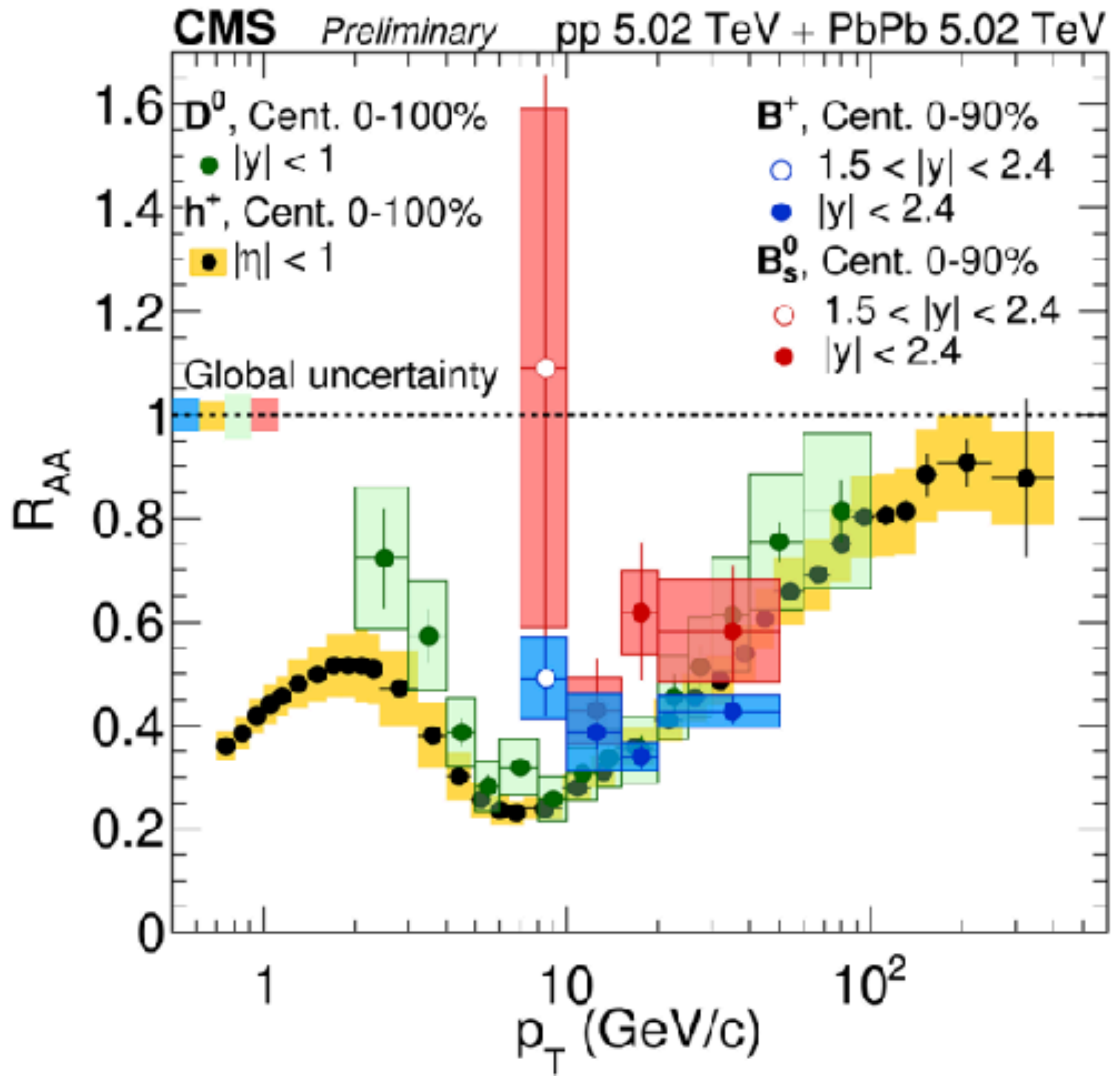
Exploring different collision systems

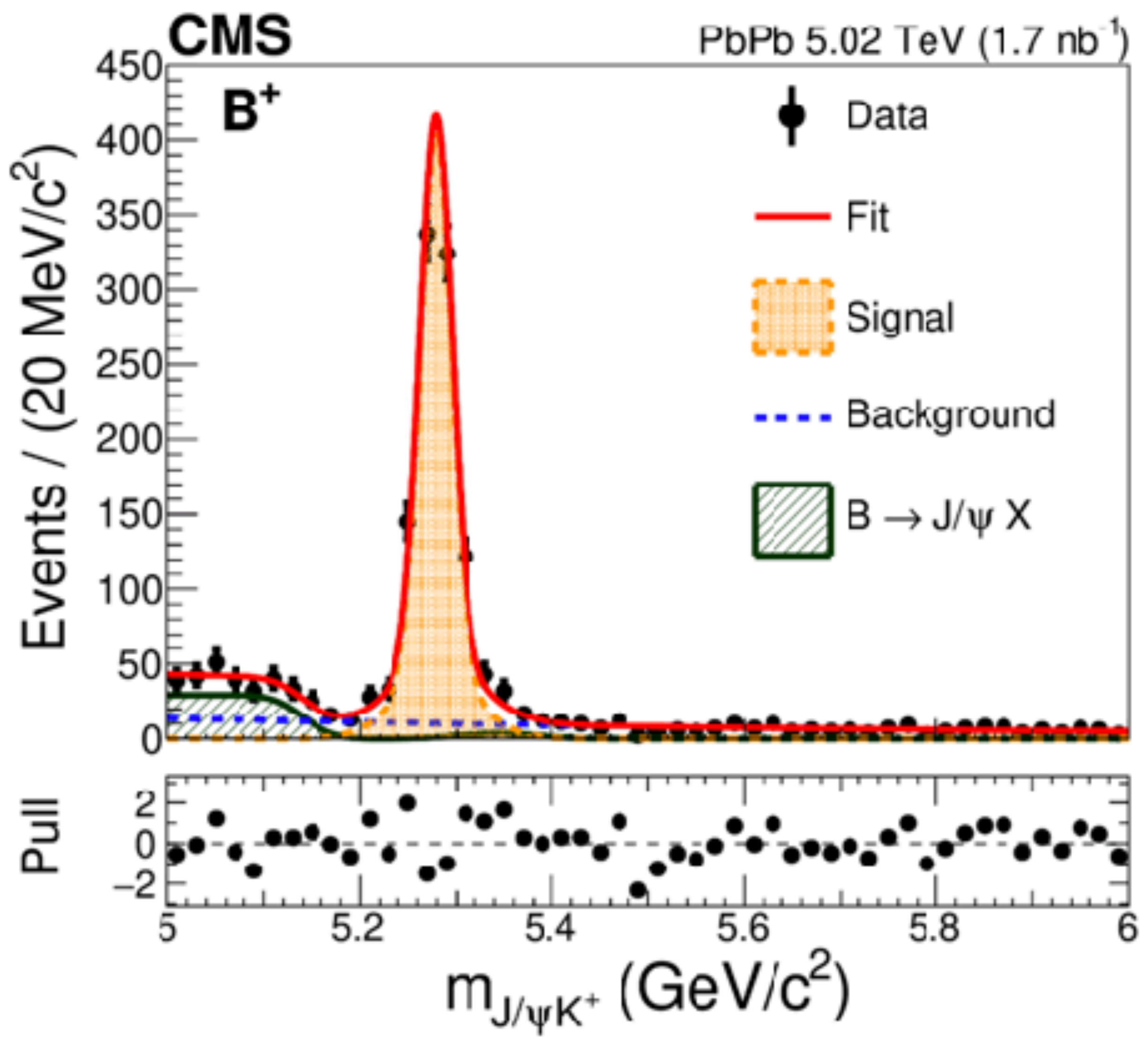


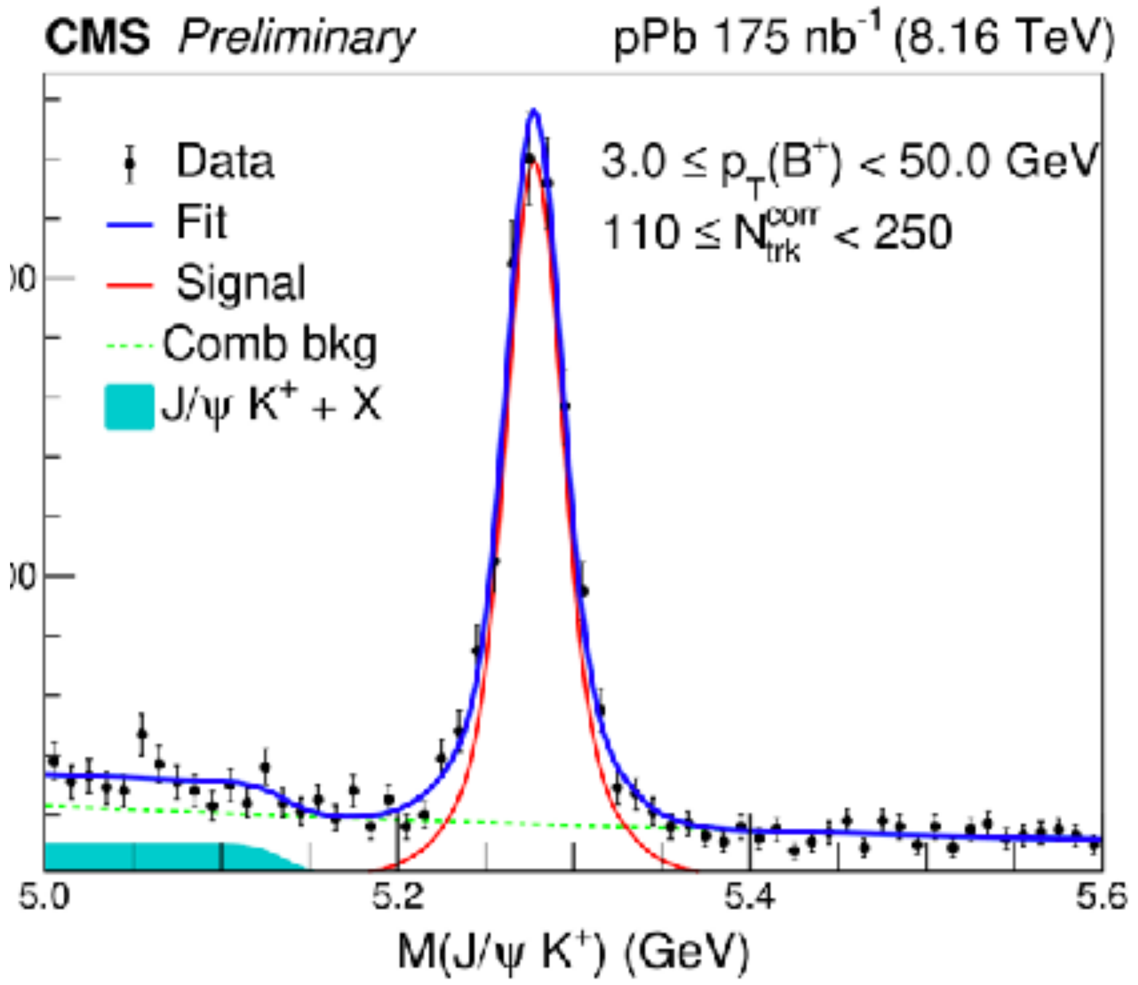


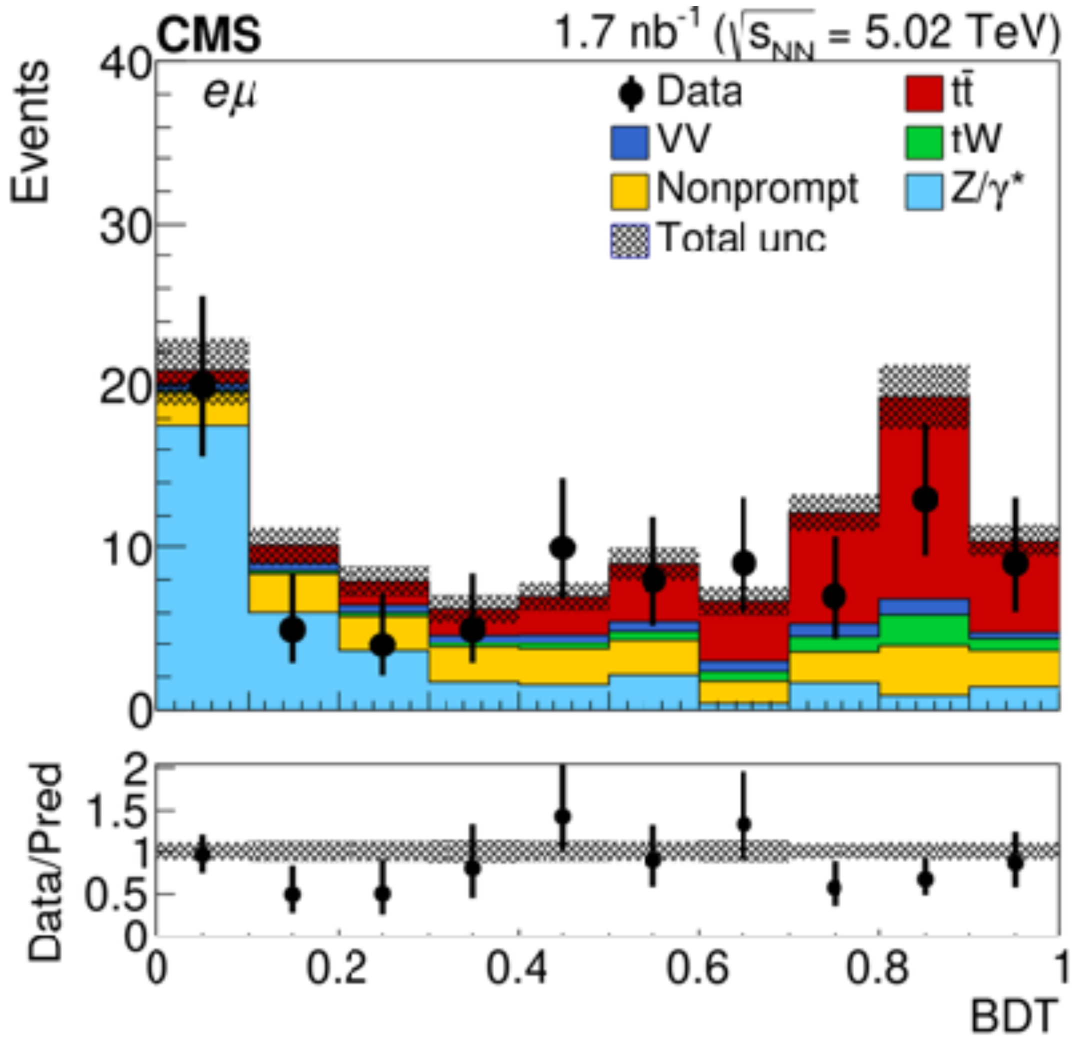




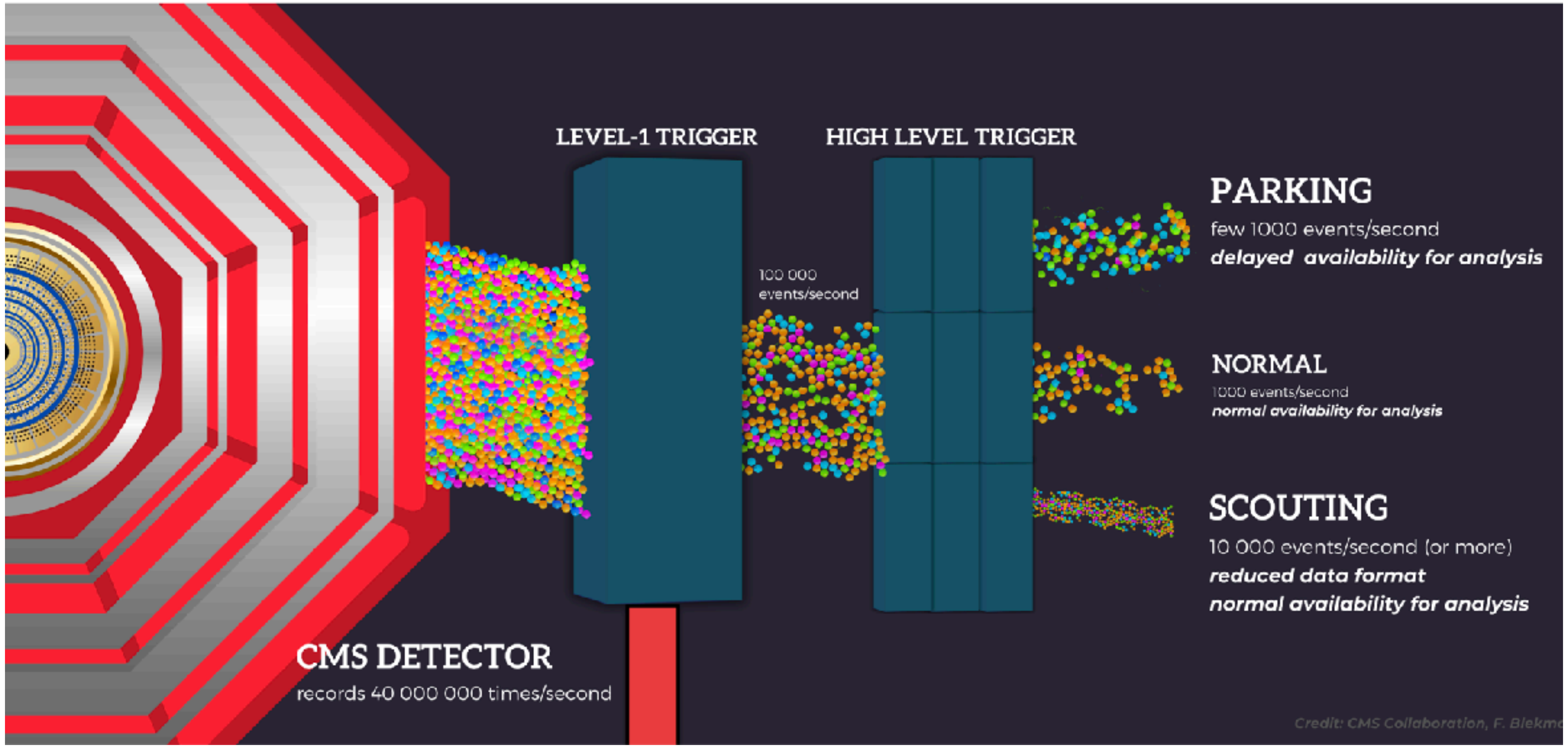


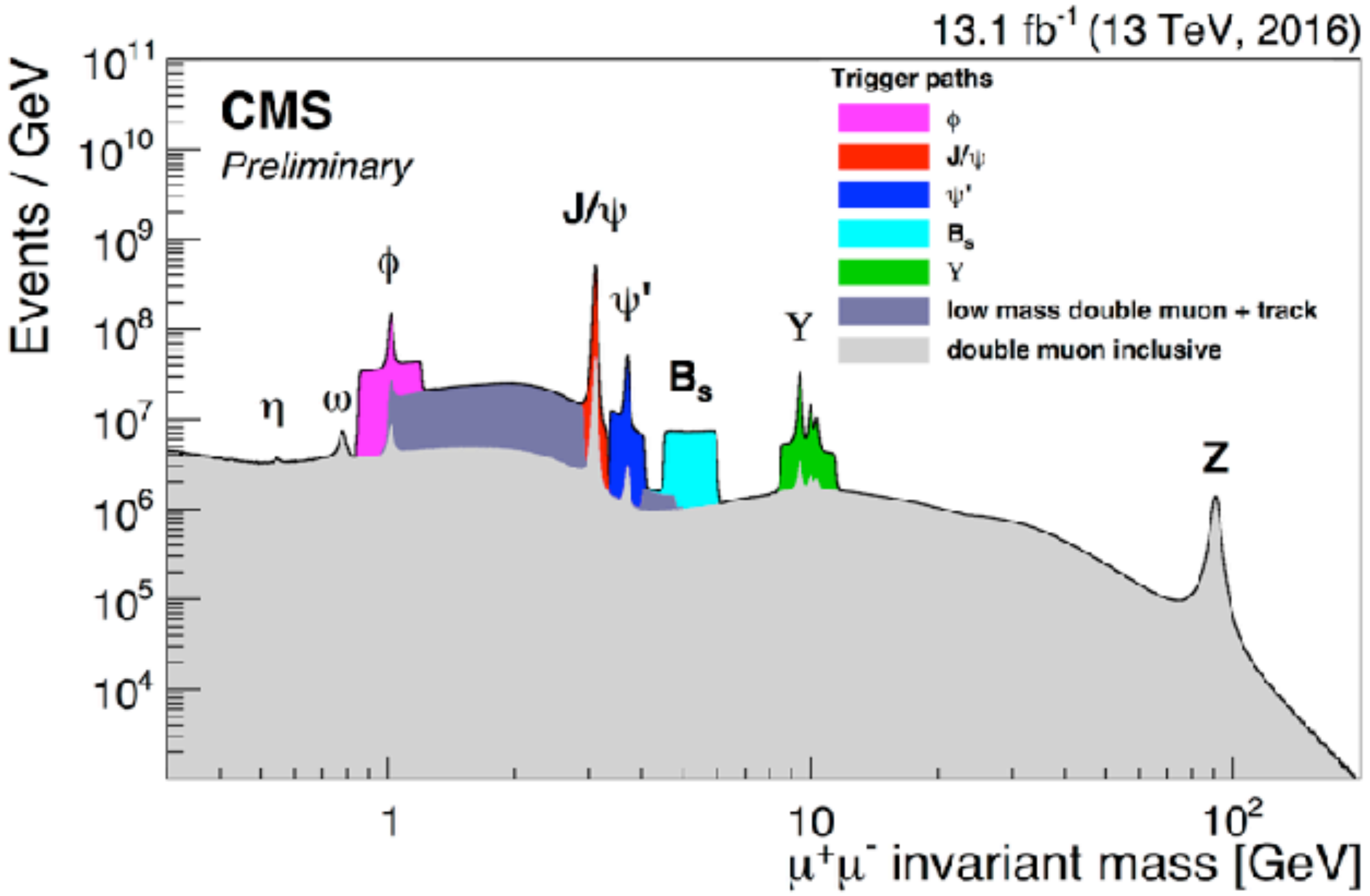


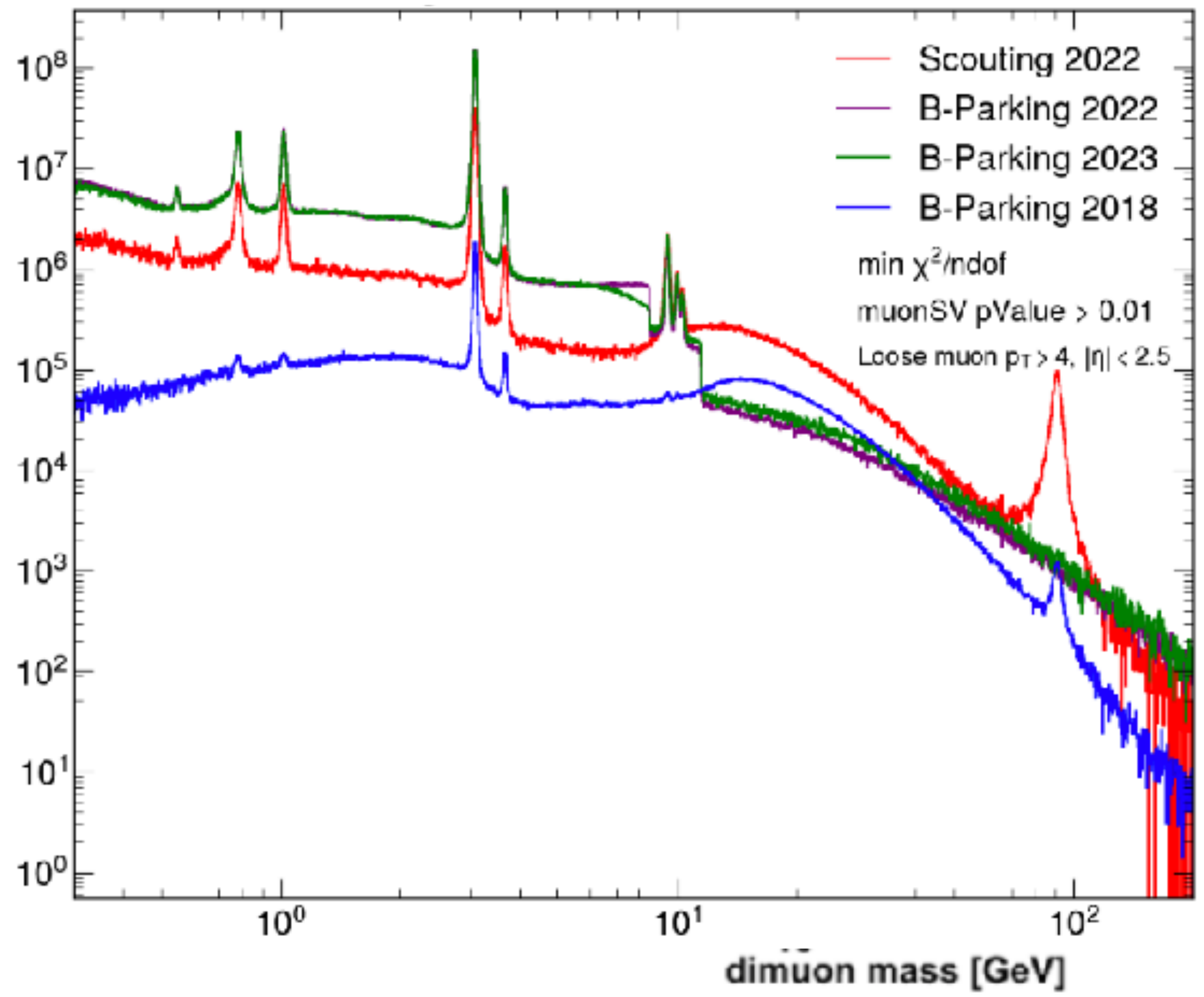




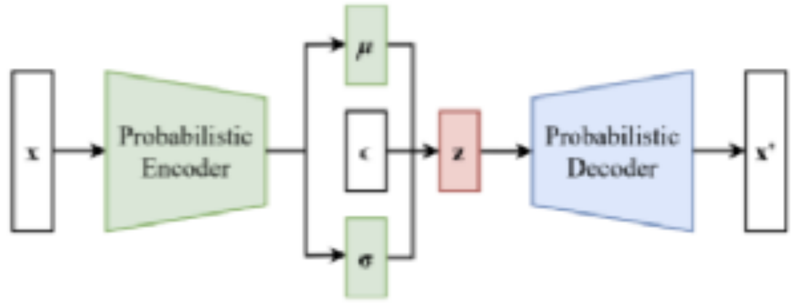
Beyond luminosity: Trigger strategies in Run3







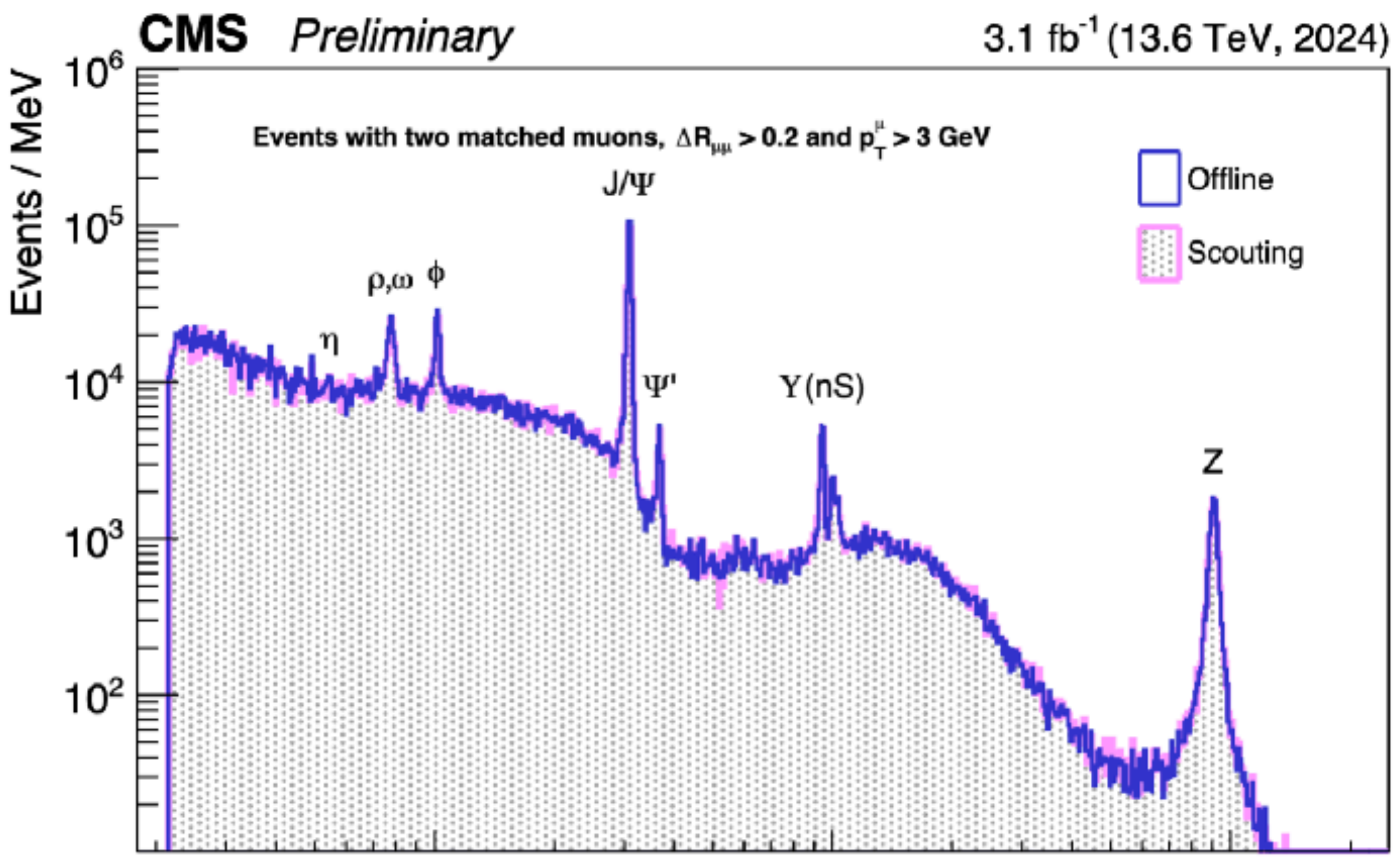
AXOL1TL



- New L1 systems, improved HLT (with GPU)
- Anomaly detection at L1 (variational/convolutional NN auto encoder)
- Additional data taking streams: **Parking & Scouting**

Novel data-taking paradigms

arXiv:2403.16134

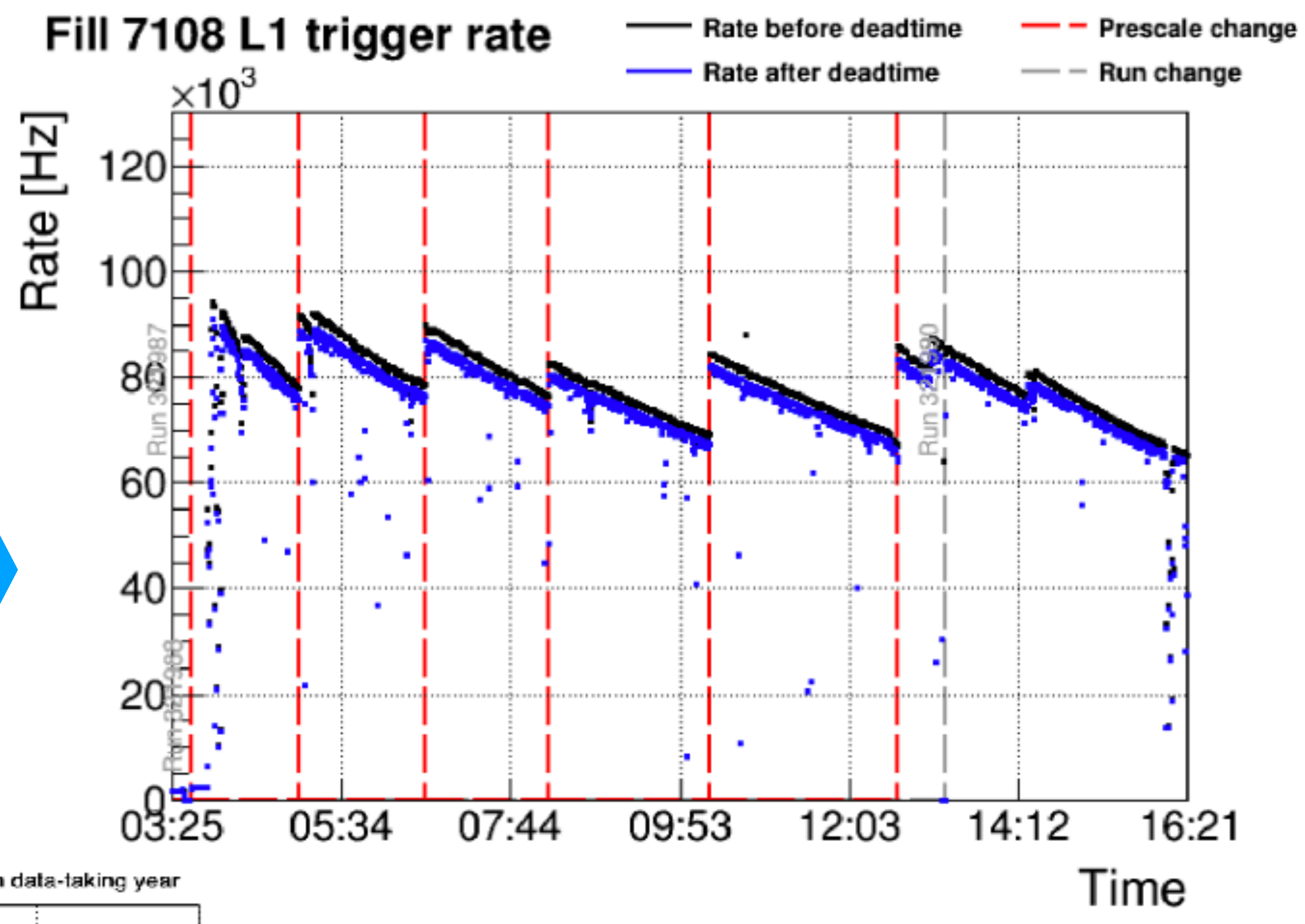


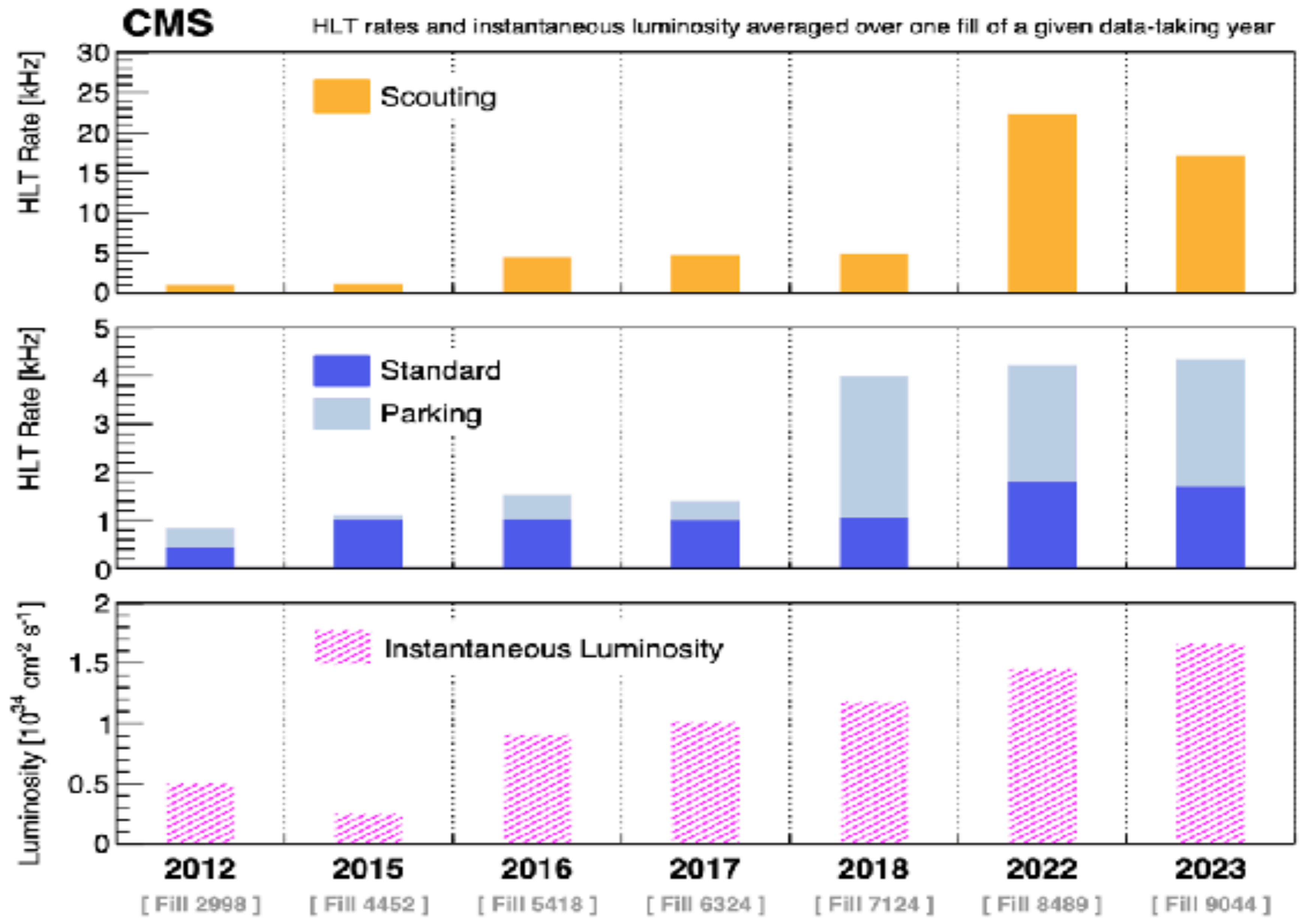
Data Scouting

Reduced event content e.g. trigger info only

Data Parking

Park RAW data, delayed RECO





CMS DP/2018_055

Trigger bandwidth

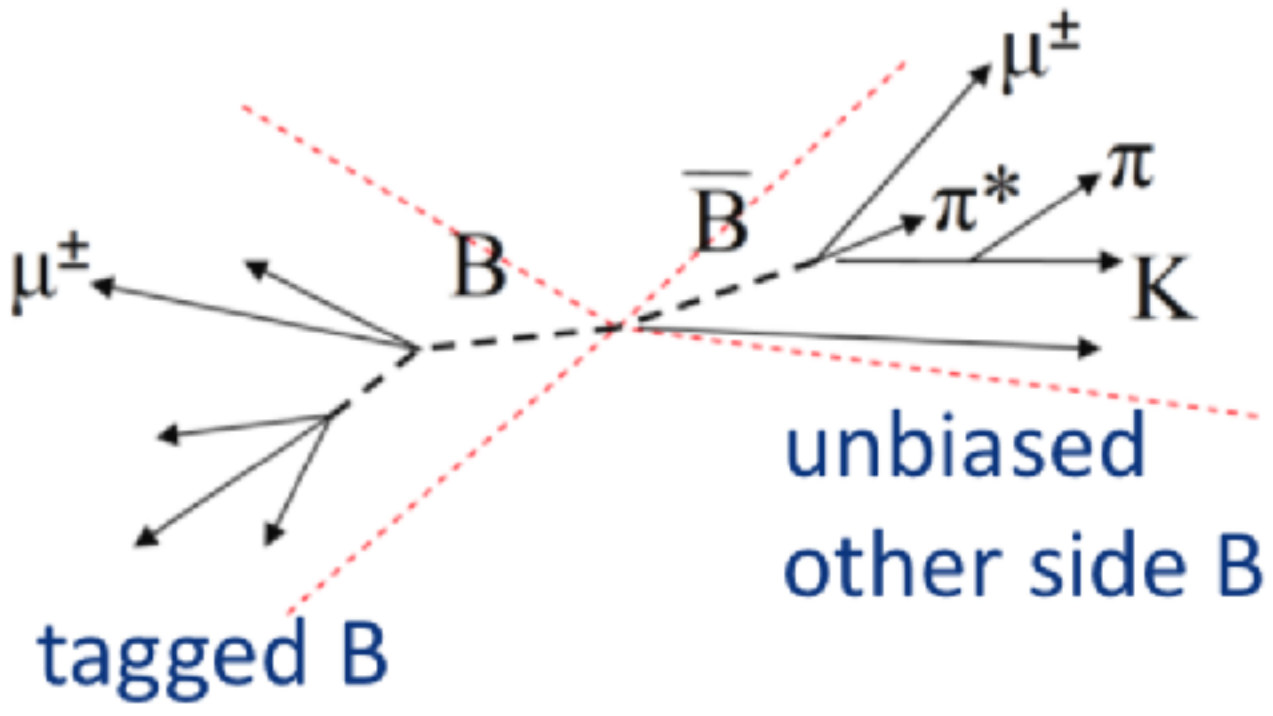
Event rate ~ 1 kHz x Event size ~ 1 MB = ~ 1 GB/s

increase rate ↩ decrease event size

5 kHz x 1.5 kB = 7.5 MB/s

CMS DP/2019_043

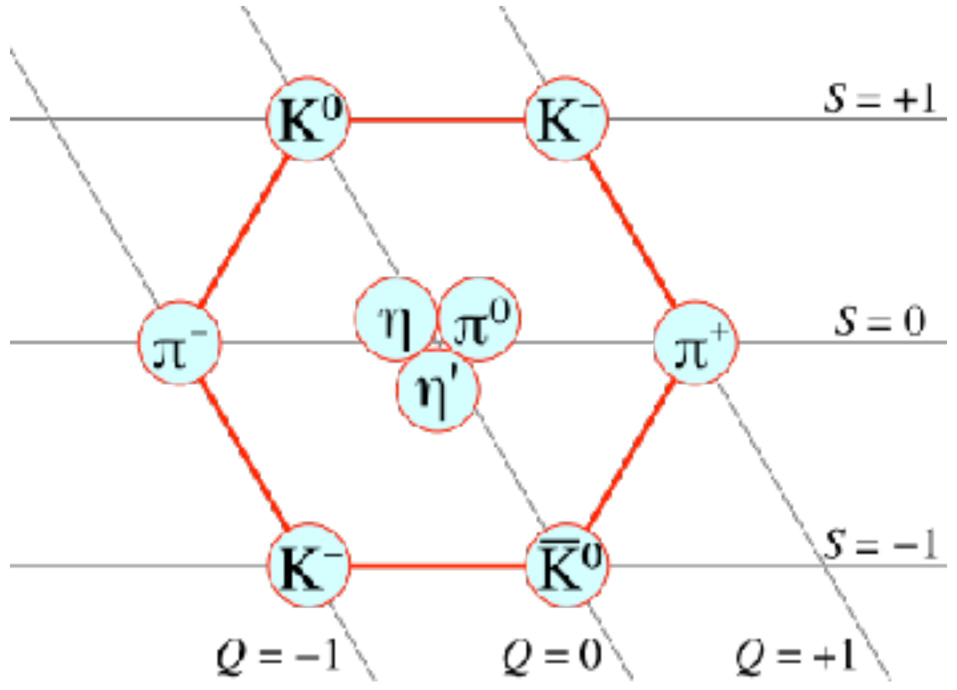
Example: "B parking"

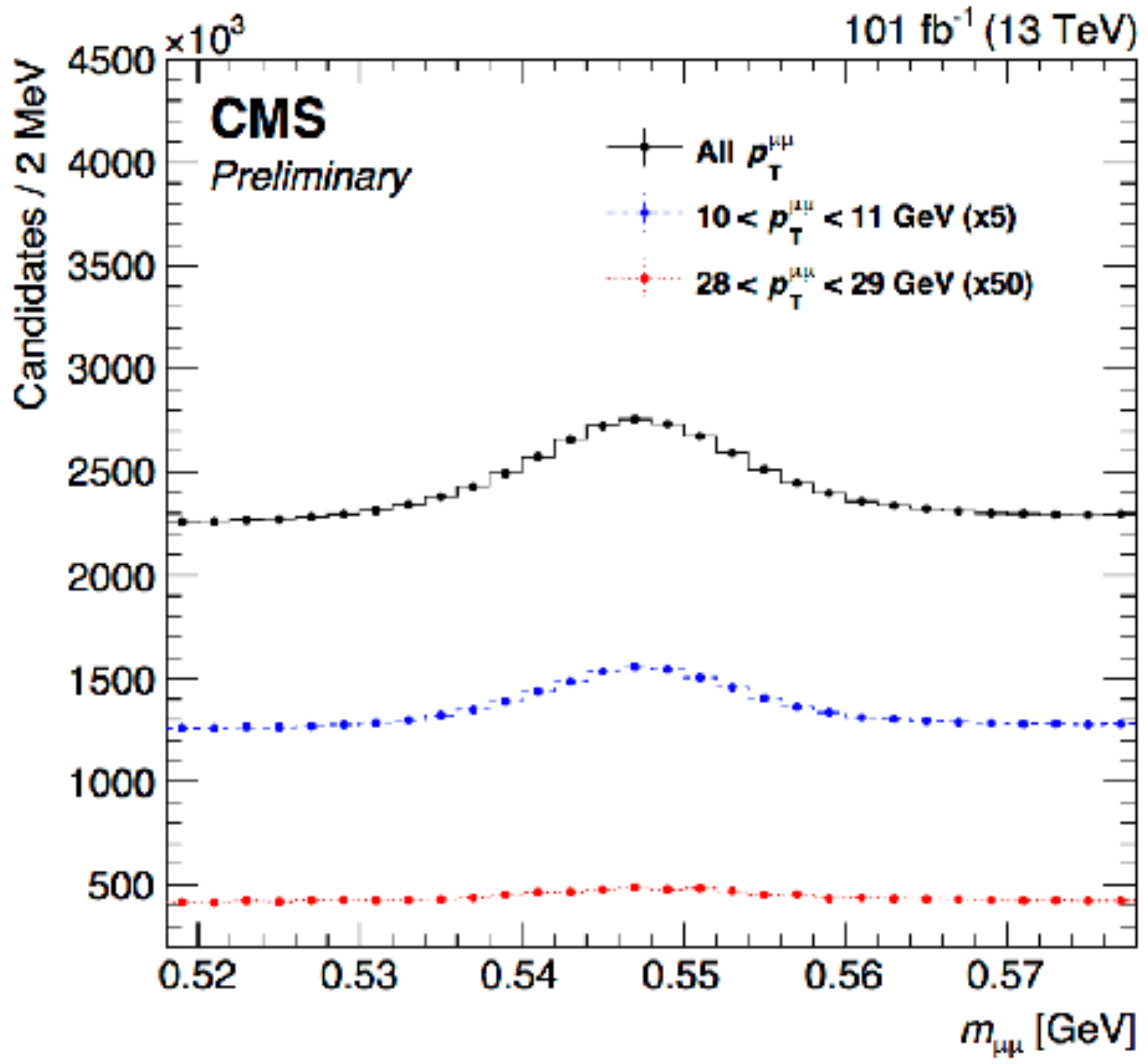


➥ Access to **hadronic** channels

Observation of rare η decay

- observation of the double-Dalitz **$\eta \to 4\mu$** decay
  - first **positive observation** employing **scouting** data in CMS
- studies allow precision tests of SM and sensitive to BSM
  - test low-energy QCD, hadronic contribution to $(g-2)_\mu$, search new light particles



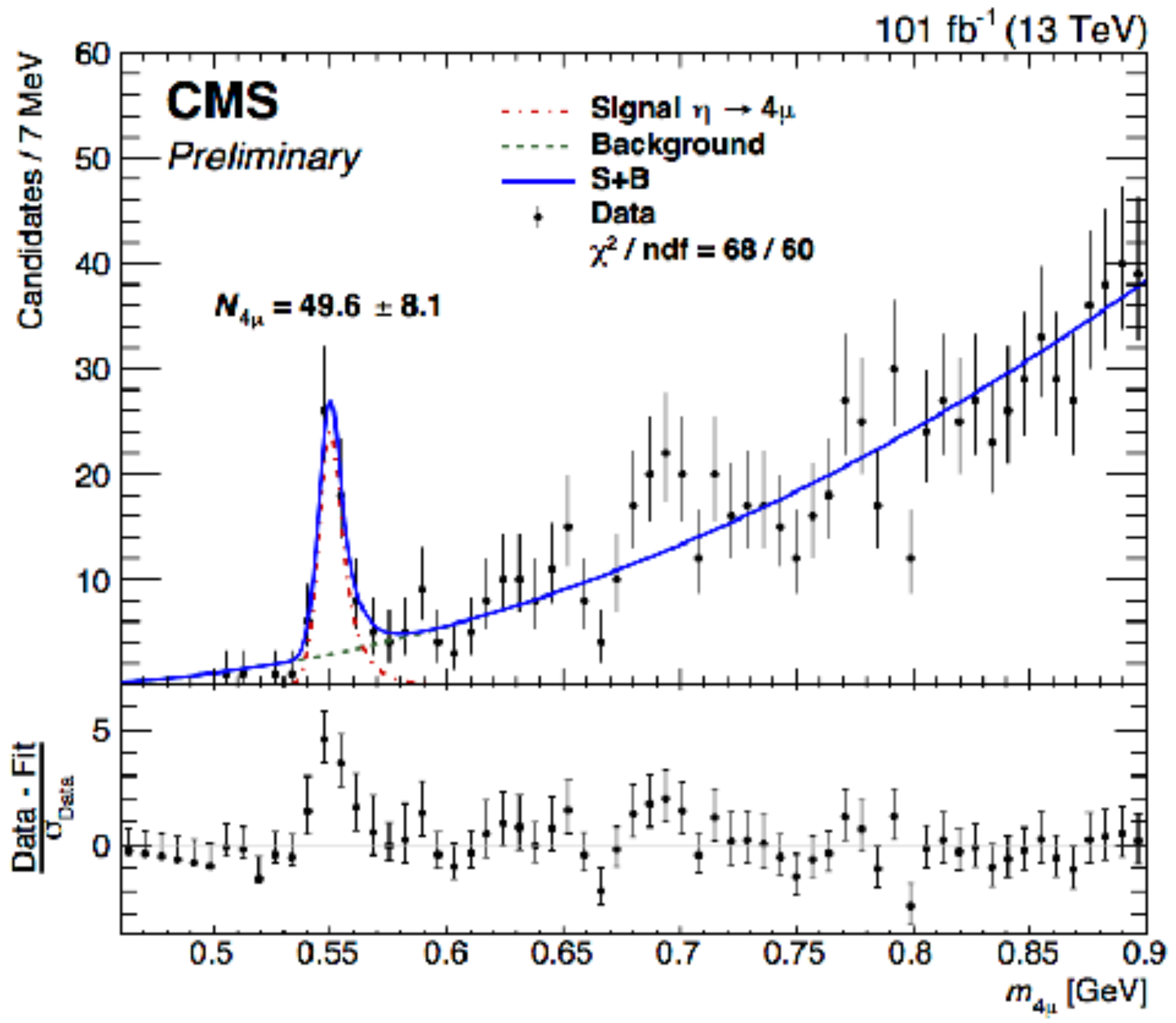


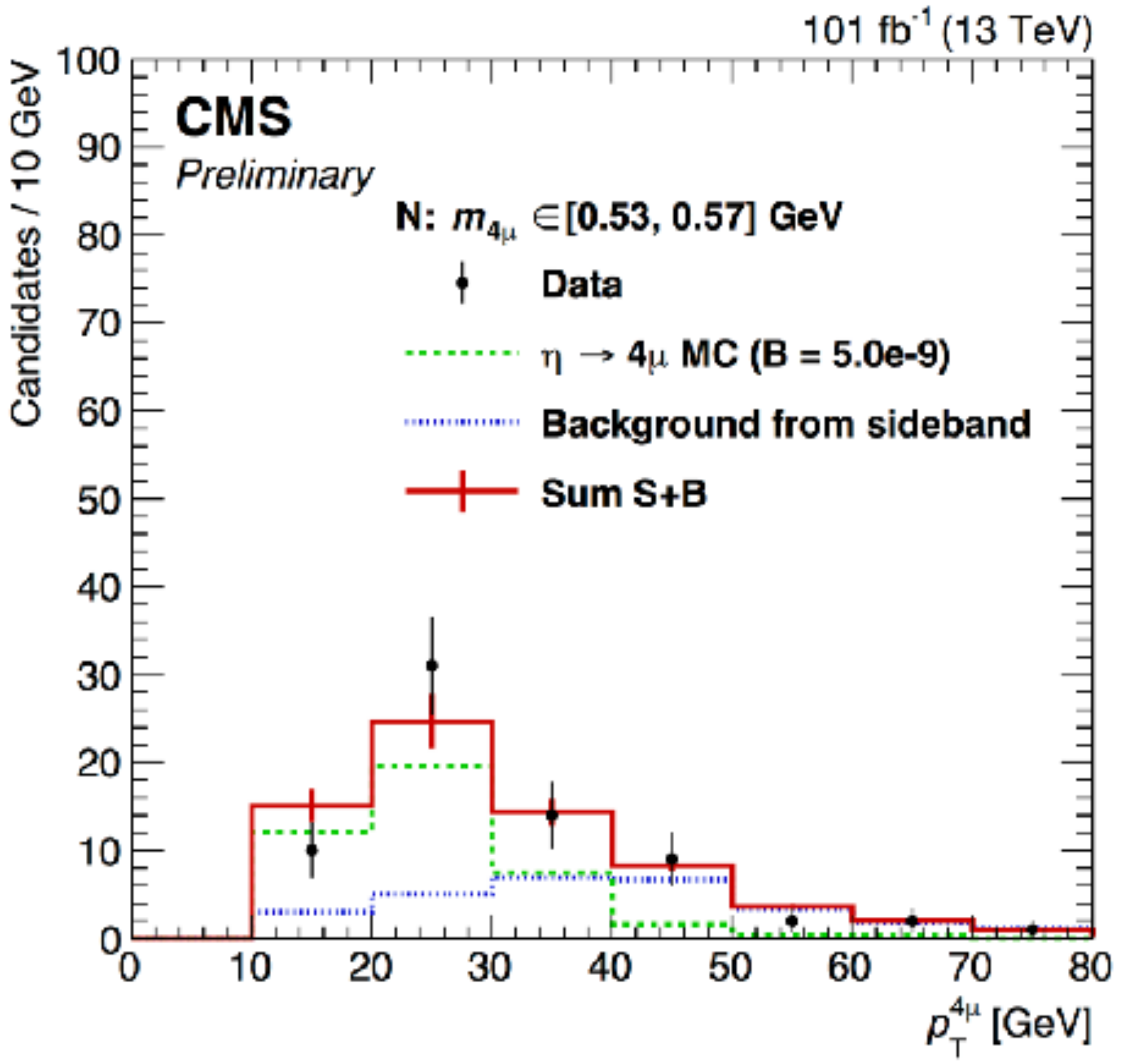
$B(\eta \to \mu\mu)$ =

5.8(0.8)×10^{-6}

$$N_{\mu\mu} \approx 4.5 \cdot 10^6$$

$$N_\eta \approx 10^{12}$$





$$\frac{B_{4\mu}}{B_{2\mu}} = \frac{N_{4\mu}}{\sum_{i,j} N_{2\mu}^{i,j} \frac{A_{4\mu}^{i,j}}{A_{2\mu}^{i,j}}} = (0.9 \pm 0.1\,(\text{stat}) \pm 0.1\,(\text{syst})) \times 10^{-3}$$

$$\mathcal{B}(\eta \to 2\mu) = (5.8 \pm 0.8) \times 10^{-6}$$

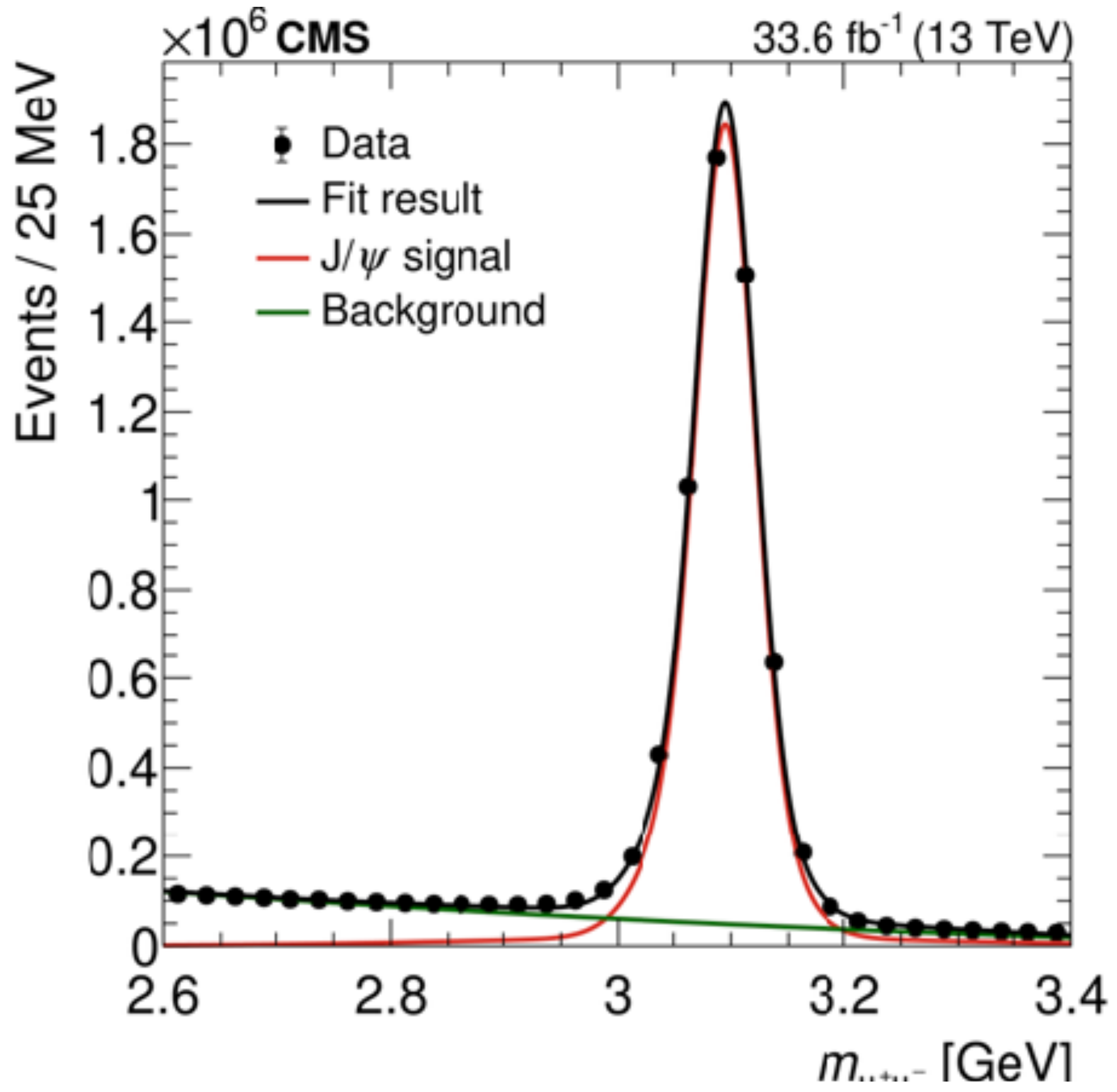
$$\boxed{\mathcal{B}(\eta \to 4\mu) = (5.0 \pm 0.8\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.7\,(\mathcal{B})) \times 10^{-9}}$$

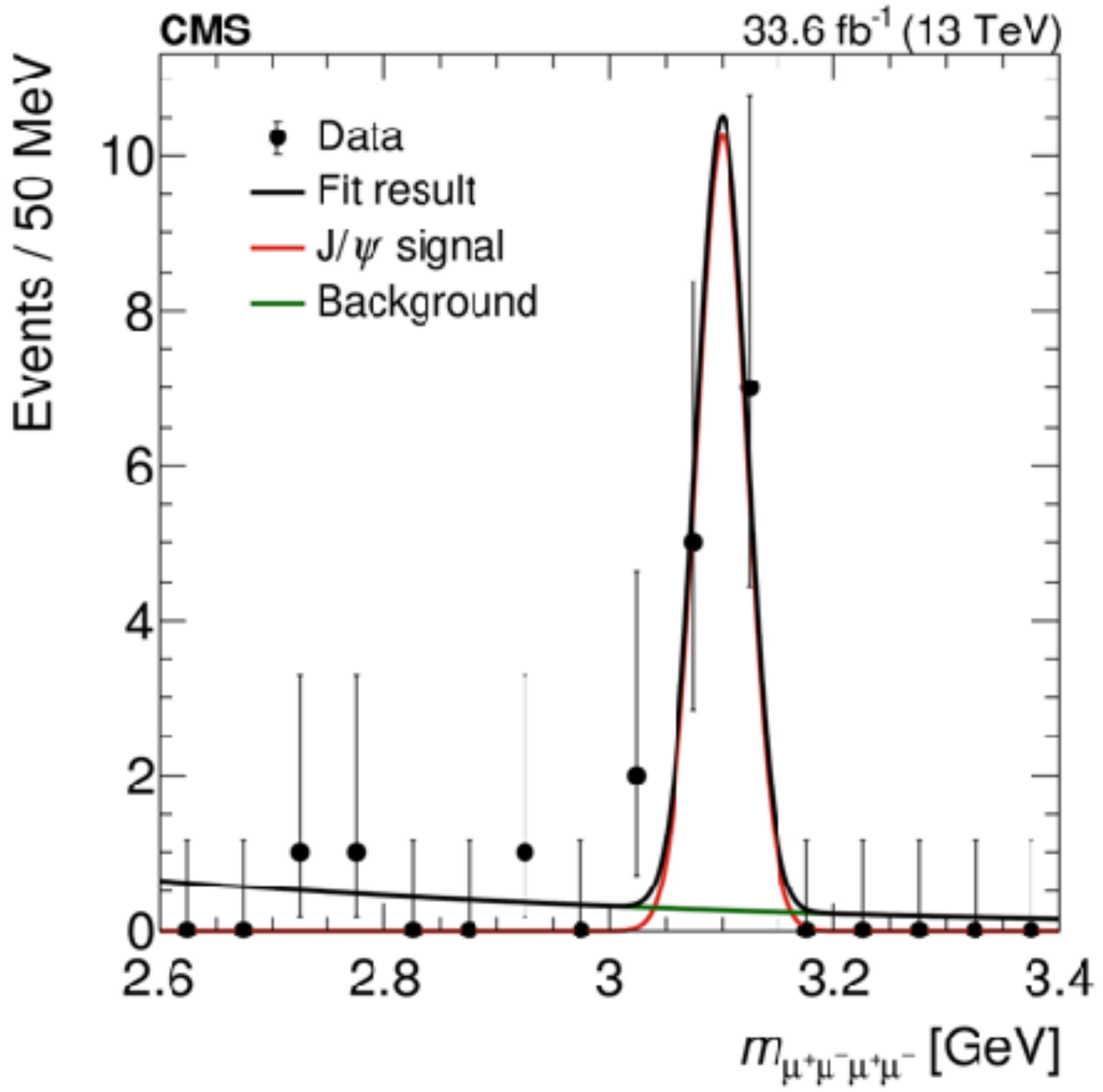
*(in agreement with SM prediction: **3.98±0.15x10^{-9}**)*

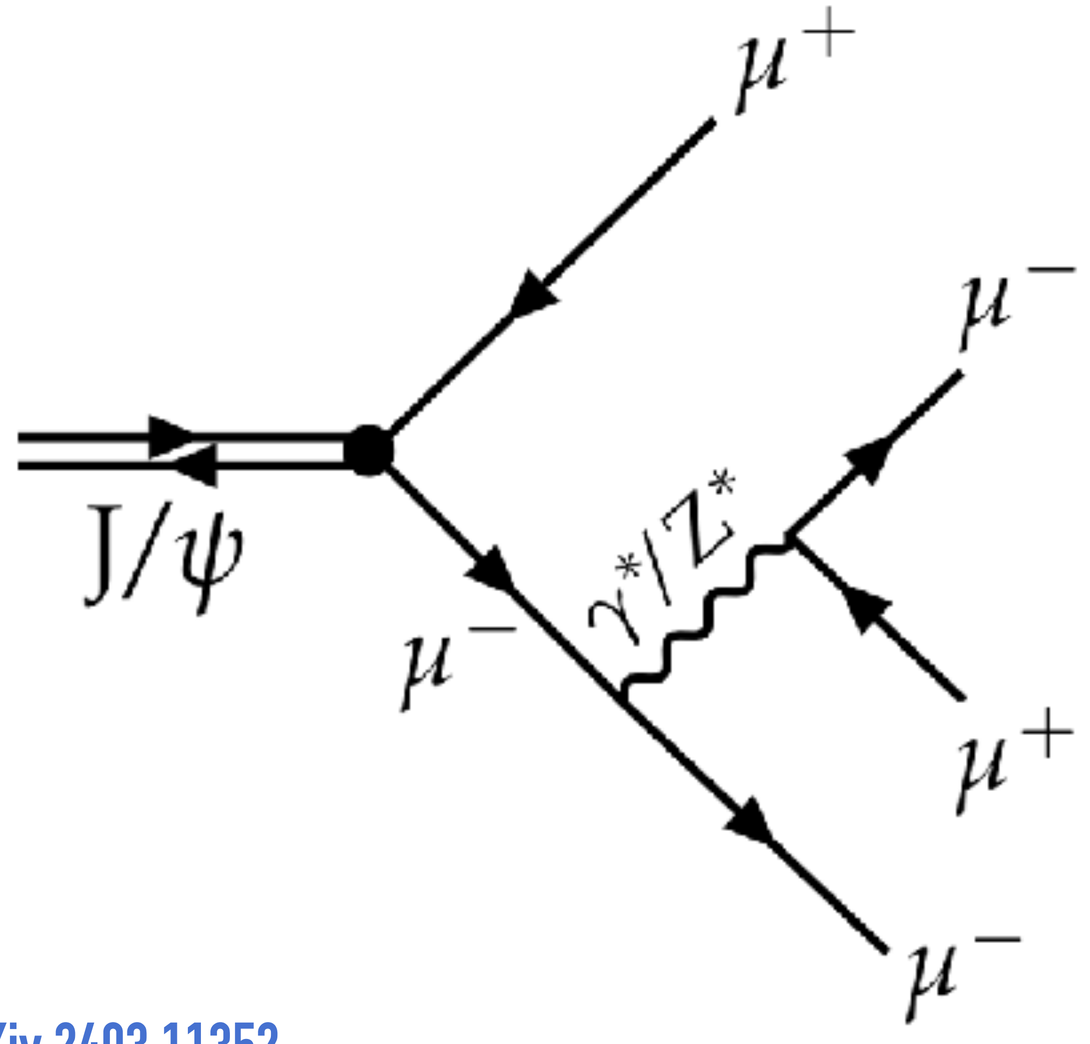
PRL 131 (2023) 091903

Observation of rare J/ψ decay

- large production rate at LHC ➥ allows to probe very rare leptonic decays
- J/ψ robustly reconstructed to dileptons (J/ψ→ll, Z→ll: "standard candles")
- recently J/ψ→4e and 2μ2e found at BESIII
- CMS delivers **first observation** of J/ψ→4μ decay, exploring **parking** data stream
- new testing ground for QED predictions (+BSM)







arXiv:2403.11352

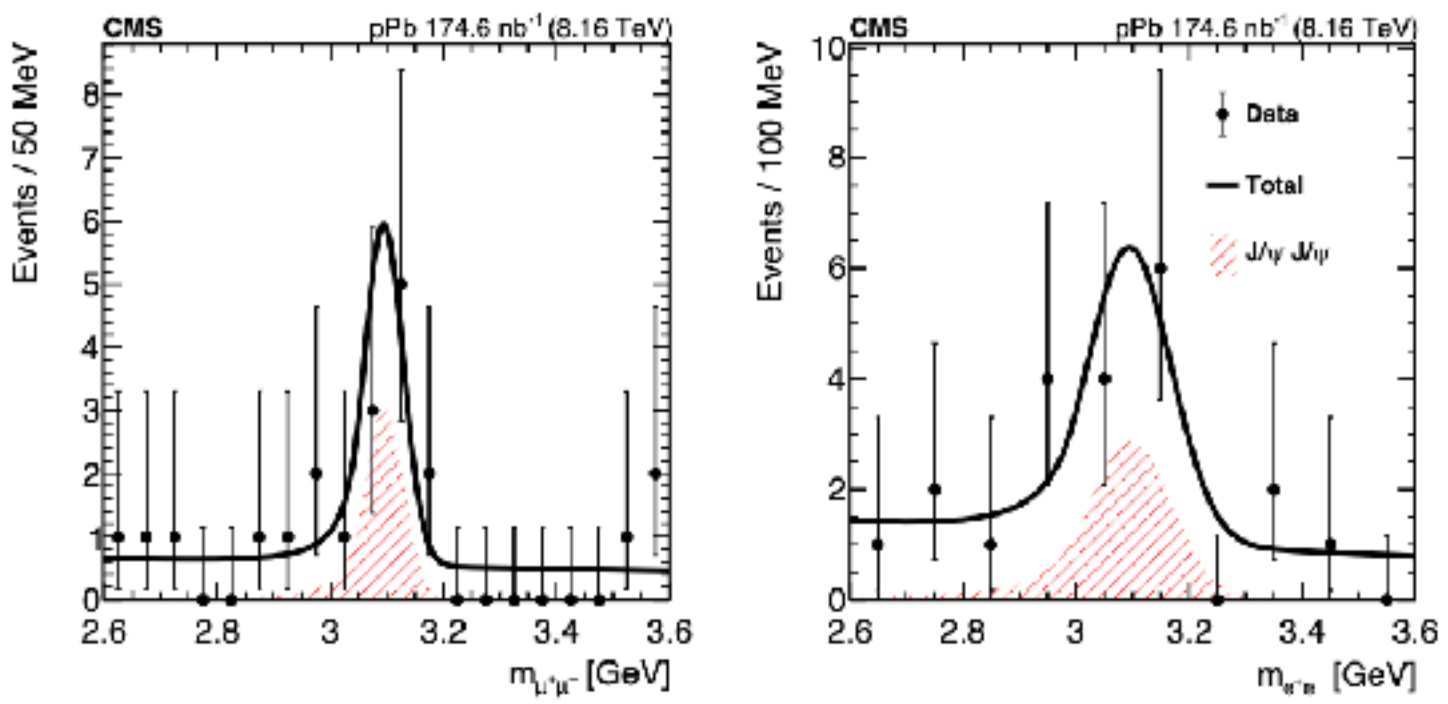
$$\mathcal{B} = 10.1^{+3.3}_{-2.7} \pm 0.4 \times 10^{-7}$$

(in agreement with SM prediction: $9.74 \pm 0.05 \times 10^{-7}$)

Observation of n-J/ψ production and MPI

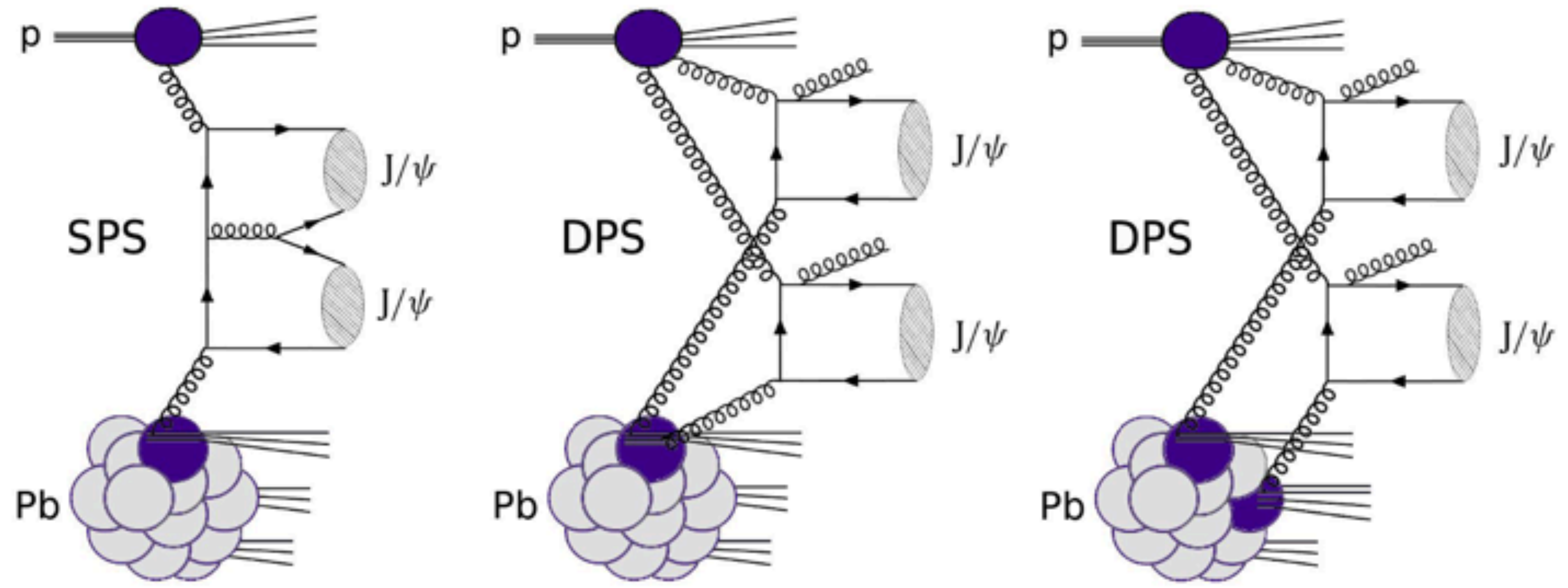
- facilitates study multi-parton interactions (MPI)
  - probe proton partonic structure, tune MC generators
- first observation of p+Pb→J/ψJ/ψ→4μ CMS-PAS-HIN-23-013 (2024)

ψψ

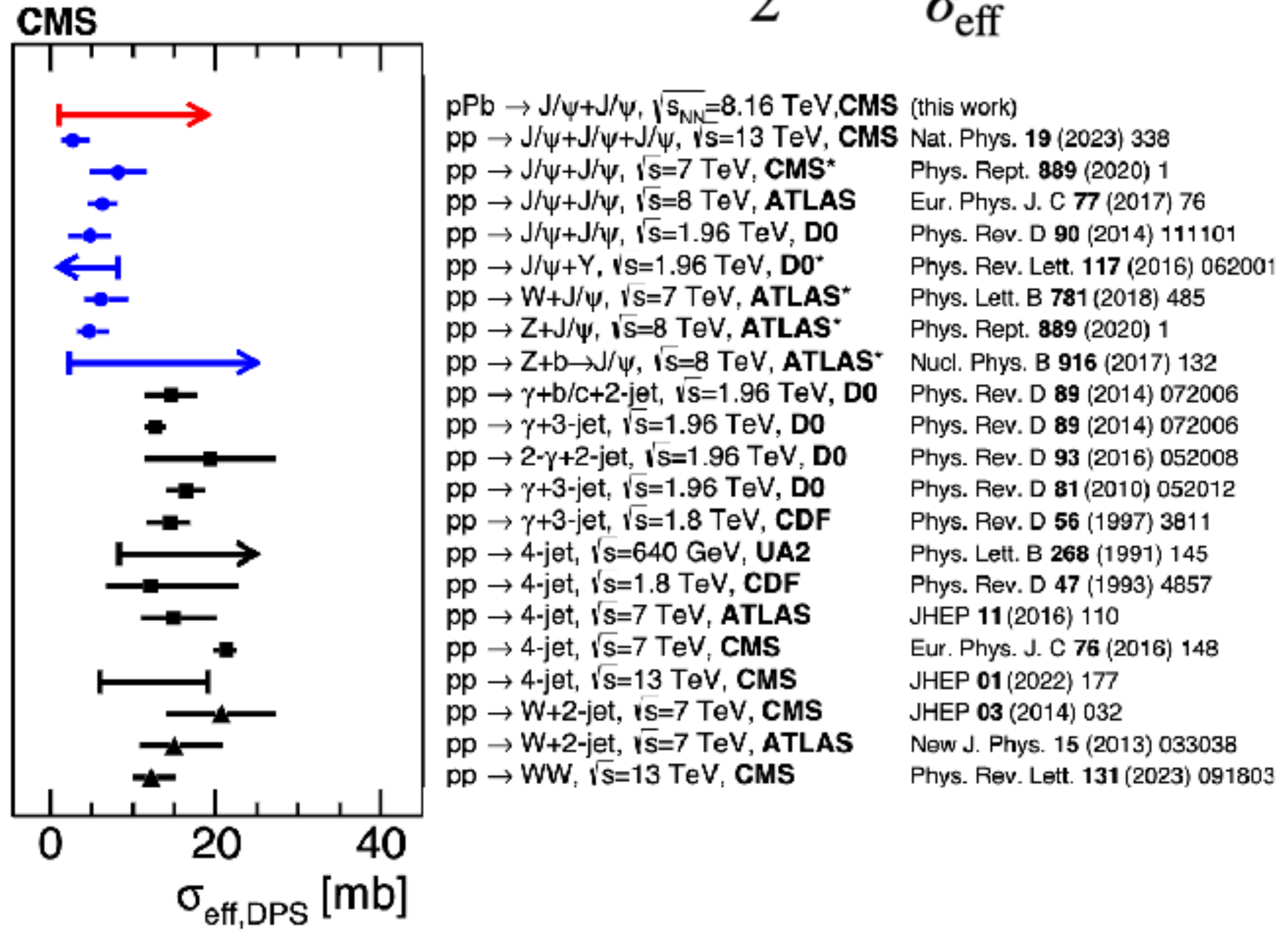


$$\sigma(\mathrm{pPb} \to \mathrm{J}/\psi \mathrm{J}/\psi + \mathrm{X}) = \frac{N_{\mathrm{sig}}}{\epsilon\, \mathcal{L}_{\mathrm{int}}\, \mathcal{B}^2_{\mathrm{J}/\psi\to\mu^+\mu^-}}$$

➠ 22.0 ± 8.9 (stat) ± 1.5 (syst) nb

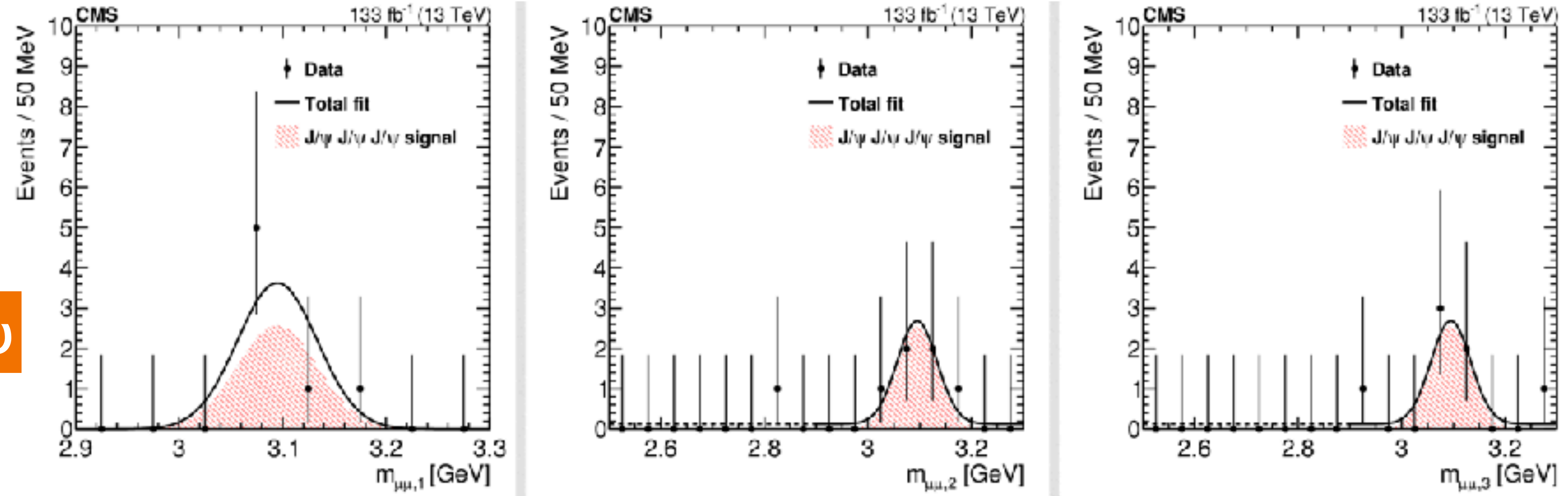


$$\sigma^{hh'\to ab}_{\mathrm{DPS}} = \frac{m}{2}\frac{\sigma^{hh'\to a}_{\mathrm{SPS}}\,\sigma^{hh'\to b}_{\mathrm{SPS}}}{\sigma_{\mathrm{eff}}}$$



- first observation of pp→3J/ψ→6μ NP 19 (2023) 338

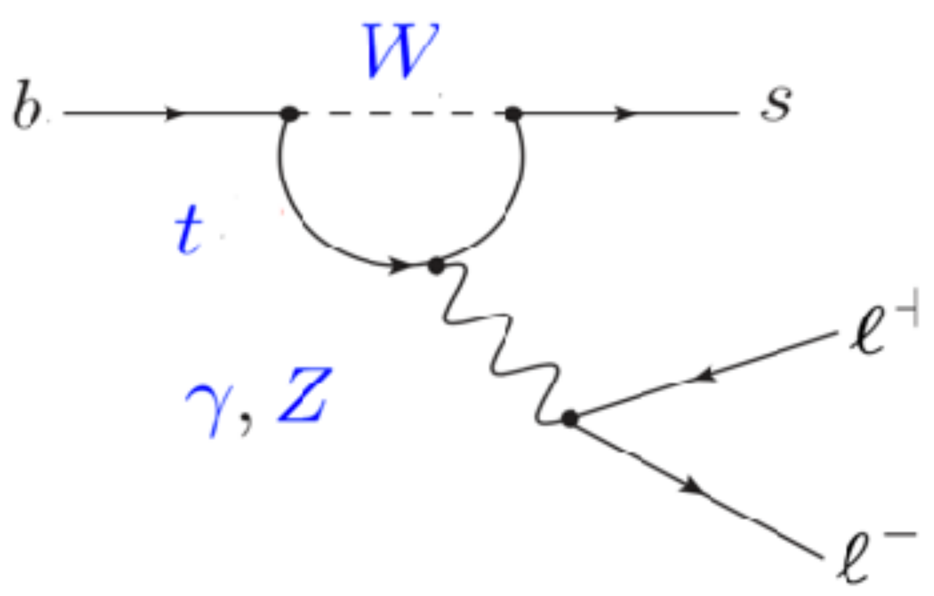
ψψψ

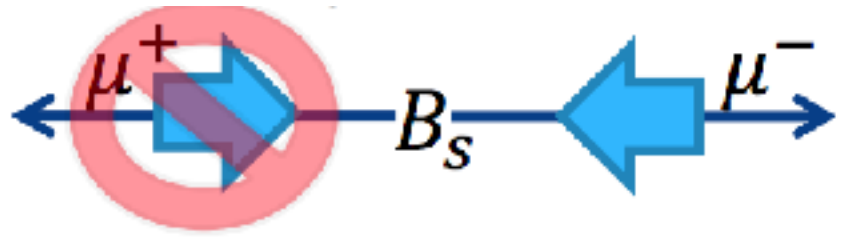


$$\sigma(\mathrm{pp} \to \mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{J}/\psi\,\mathrm{X}) = N^{3\mathrm{J}/\psi}_{\mathrm{sig}} / (\epsilon\, \mathcal{L}_{\mathrm{int}}\, \mathcal{B}^3_{\mathrm{J}/\psi\to\mu^+\mu^-})$$ ➠ $272^{+141}_{-104}\,(\mathrm{stat}) \pm 17\,(\mathrm{syst})\,\mathrm{fb}$

Measurement of rare B decay

- FCNC and helicity-suppressed B decays, highly sensitive to NP
  - $B_s \to \mu\mu$, observed, entering precision regime
  - $B^0 \to \mu\mu$, simultaneous search is pursued, first evidence might emerge
- effective lifetime: only heavy eigenstate decays to dimuons *in SM*

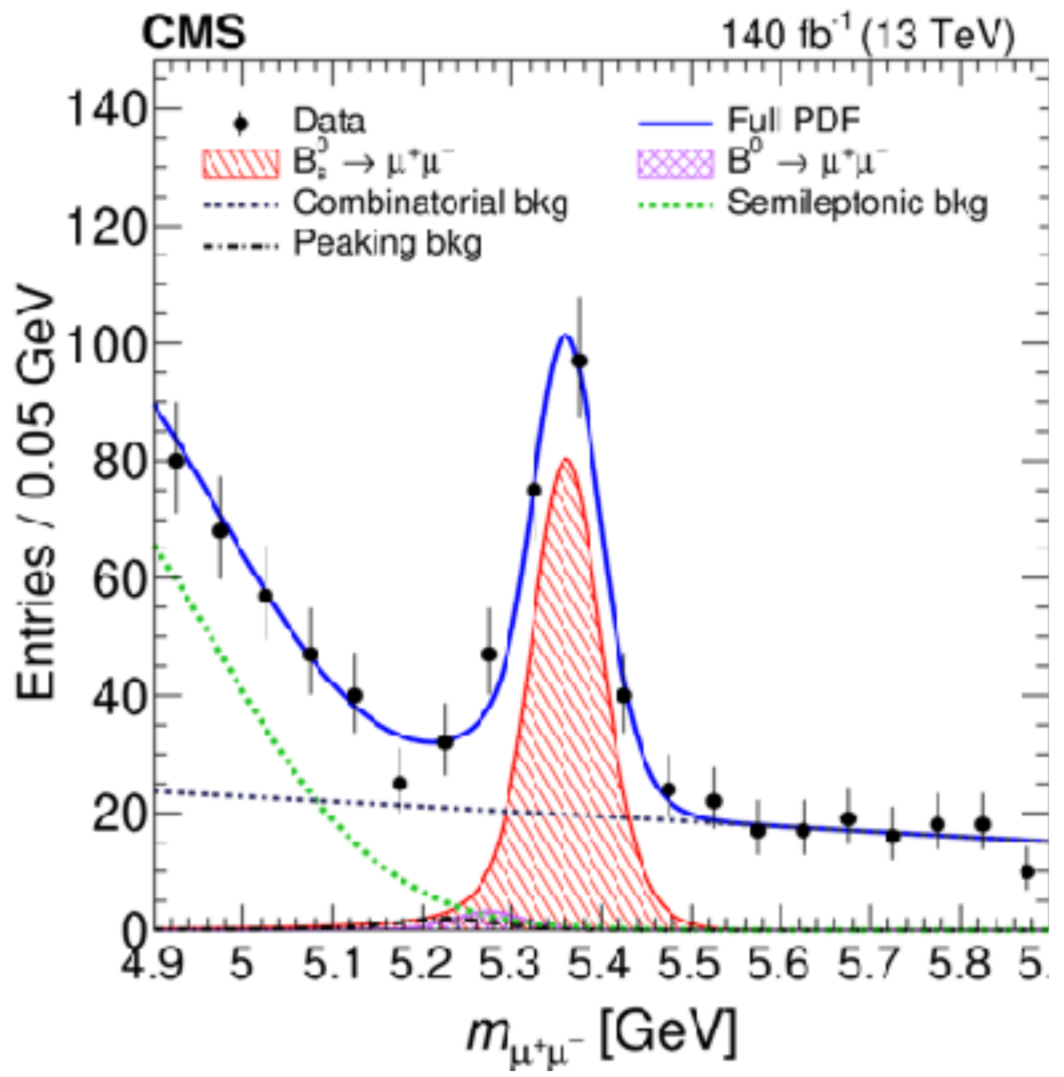


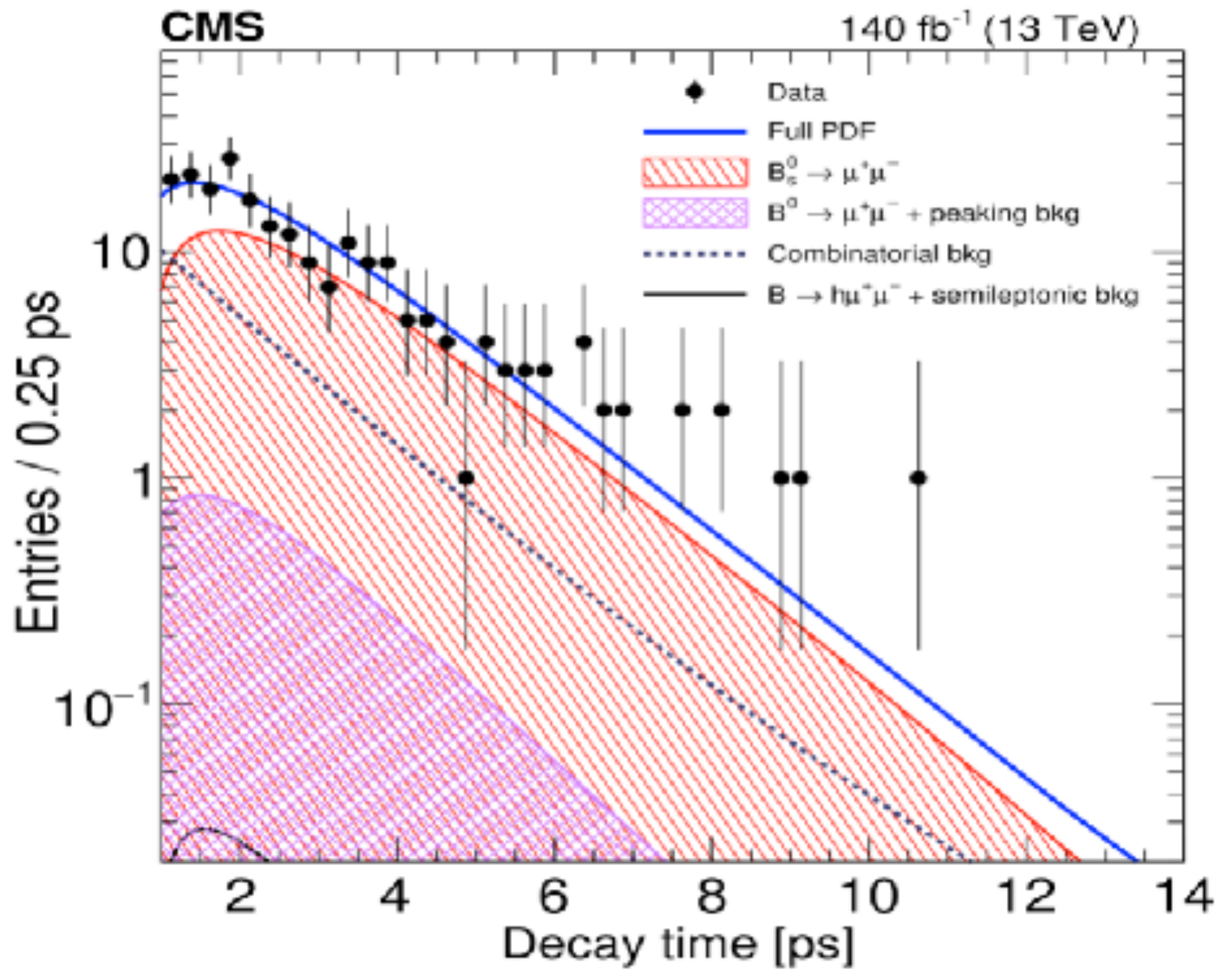


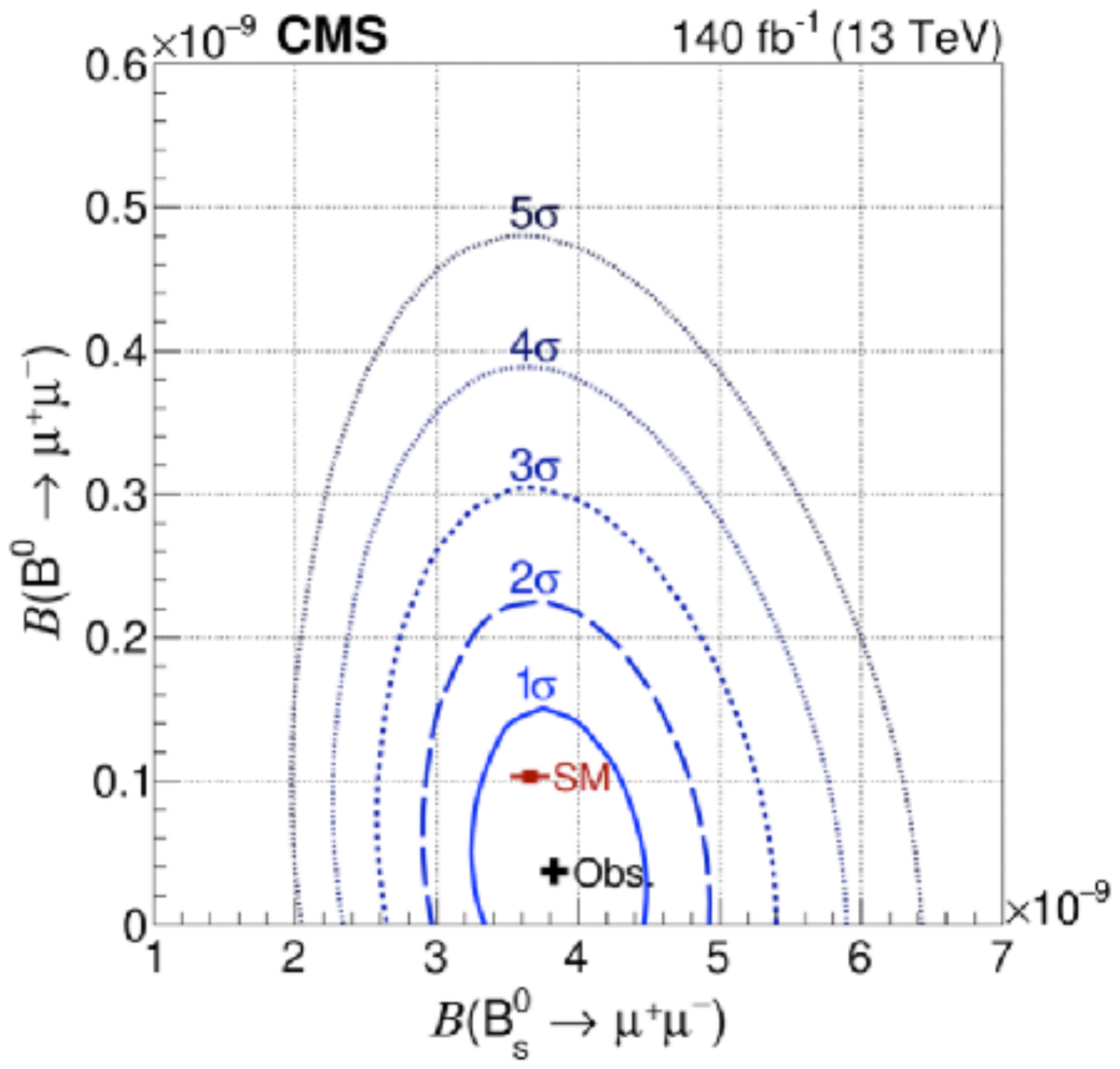
$$\tau_{\mu^+\mu^-} \equiv \frac{\int_0^\infty t\,\Gamma(B_s(t)\to\mu^+\mu^-)\,dt}{\int_0^\infty \Gamma(B_s(t)\to\mu^+\mu^-)\,dt} = \frac{\tau_{B_s^0}}{1-y_s^2}\left(\frac{1+2\mathcal{A}_{\Delta\Gamma}^{\mu^+\mu^-}y_s+y_s^2}{1+\mathcal{A}_{\Delta\Gamma}^{\mu^+\mu^-}y_s}\right)$$

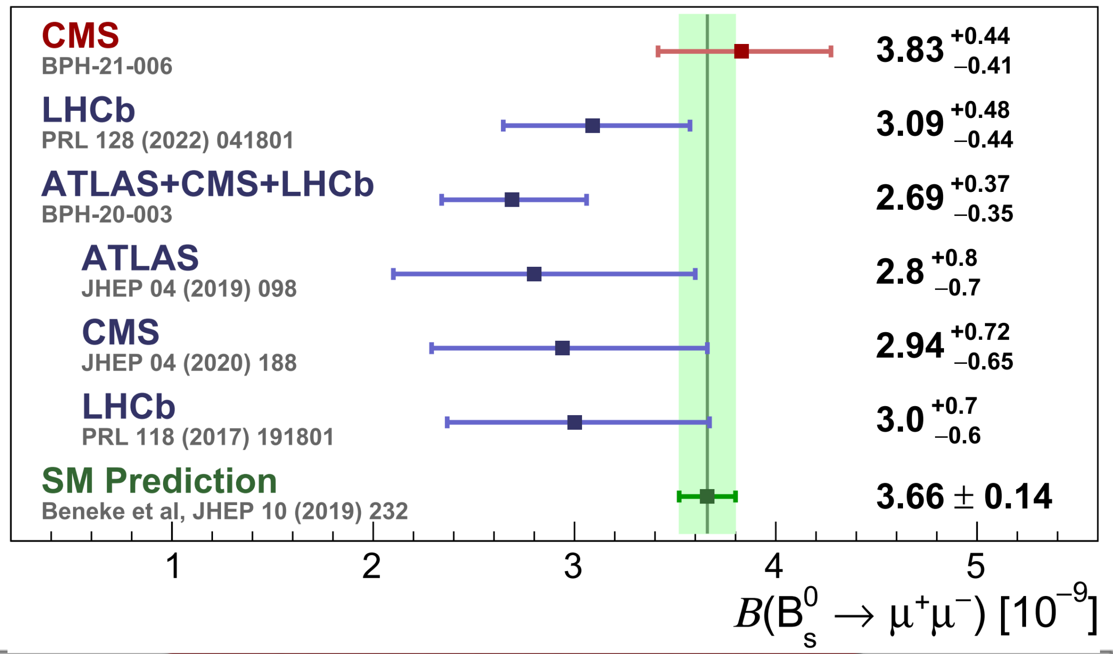
$$\mathcal{A}_{\Delta\Gamma}^{\mu^+\mu^-} \equiv -\mathcal{R}(\lambda)/(1+|\lambda|^2)$$
$$y_s \equiv \tau_{B_s^0}\Delta\Gamma_s/2$$

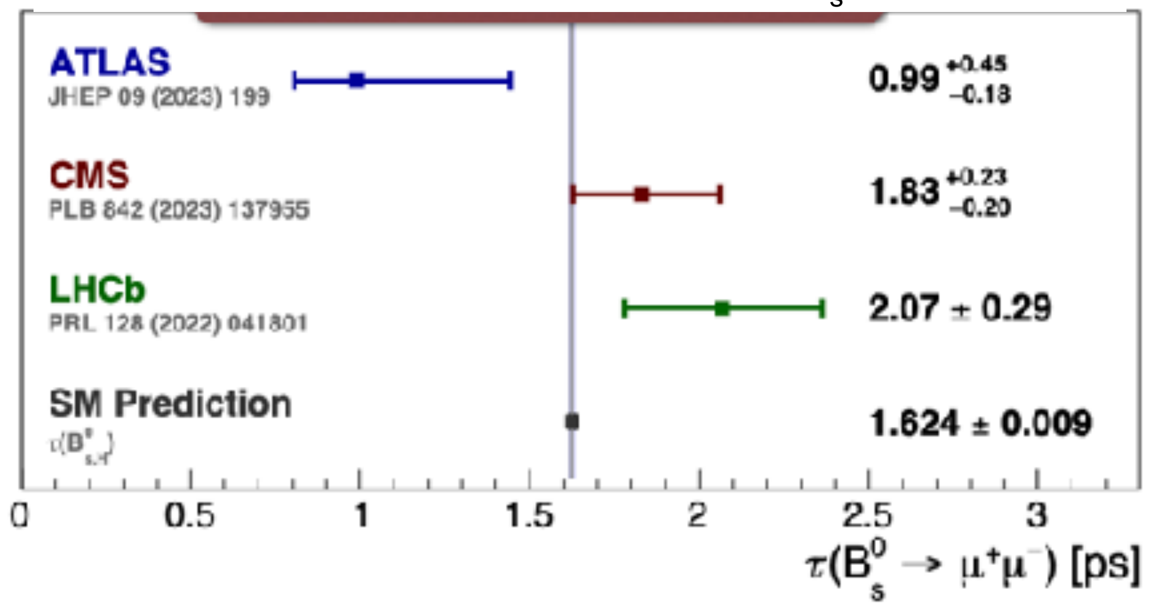
PLB 842 (2023) 137955





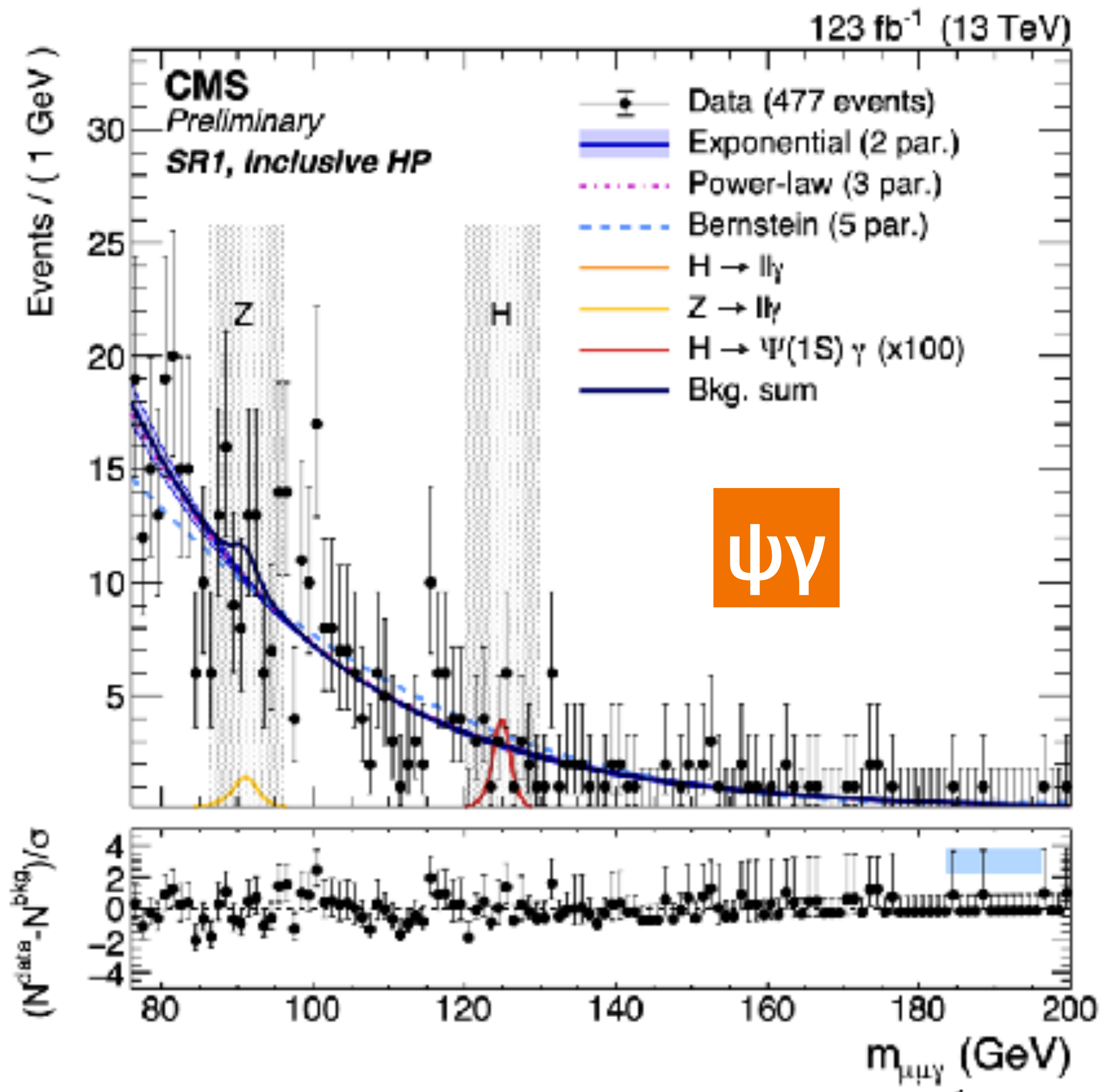


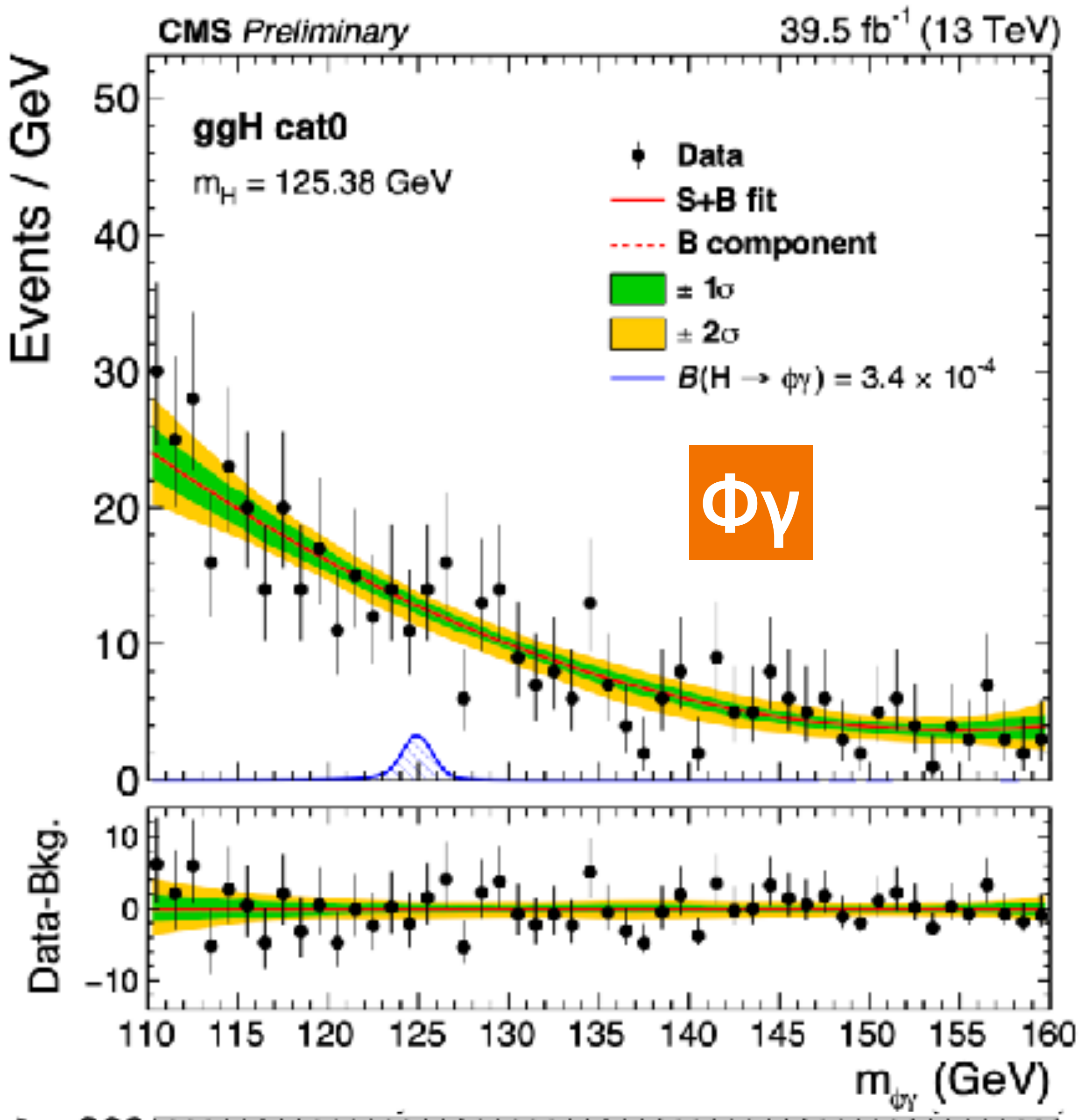




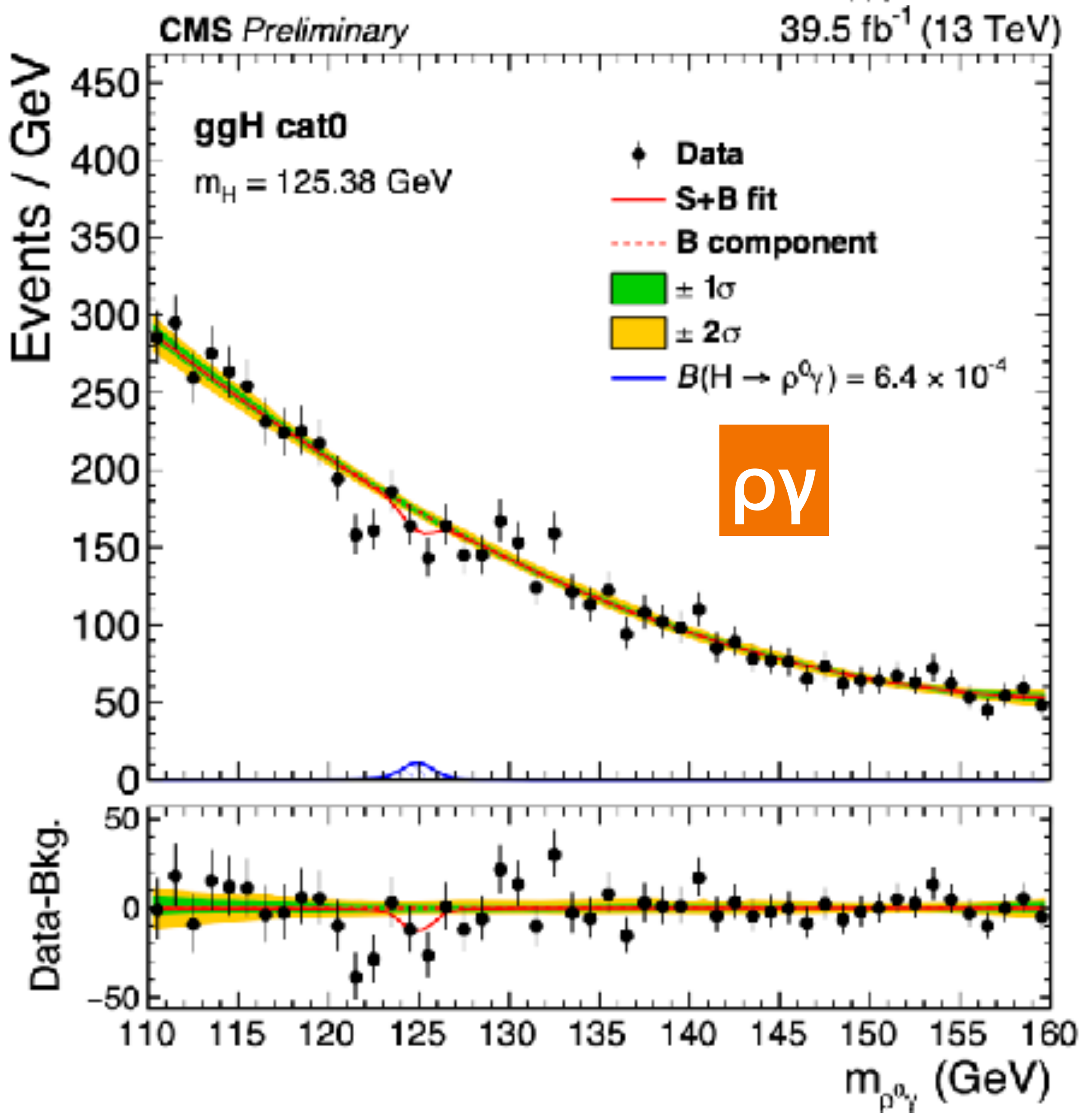
Search for rare Higgs (and Z) decays

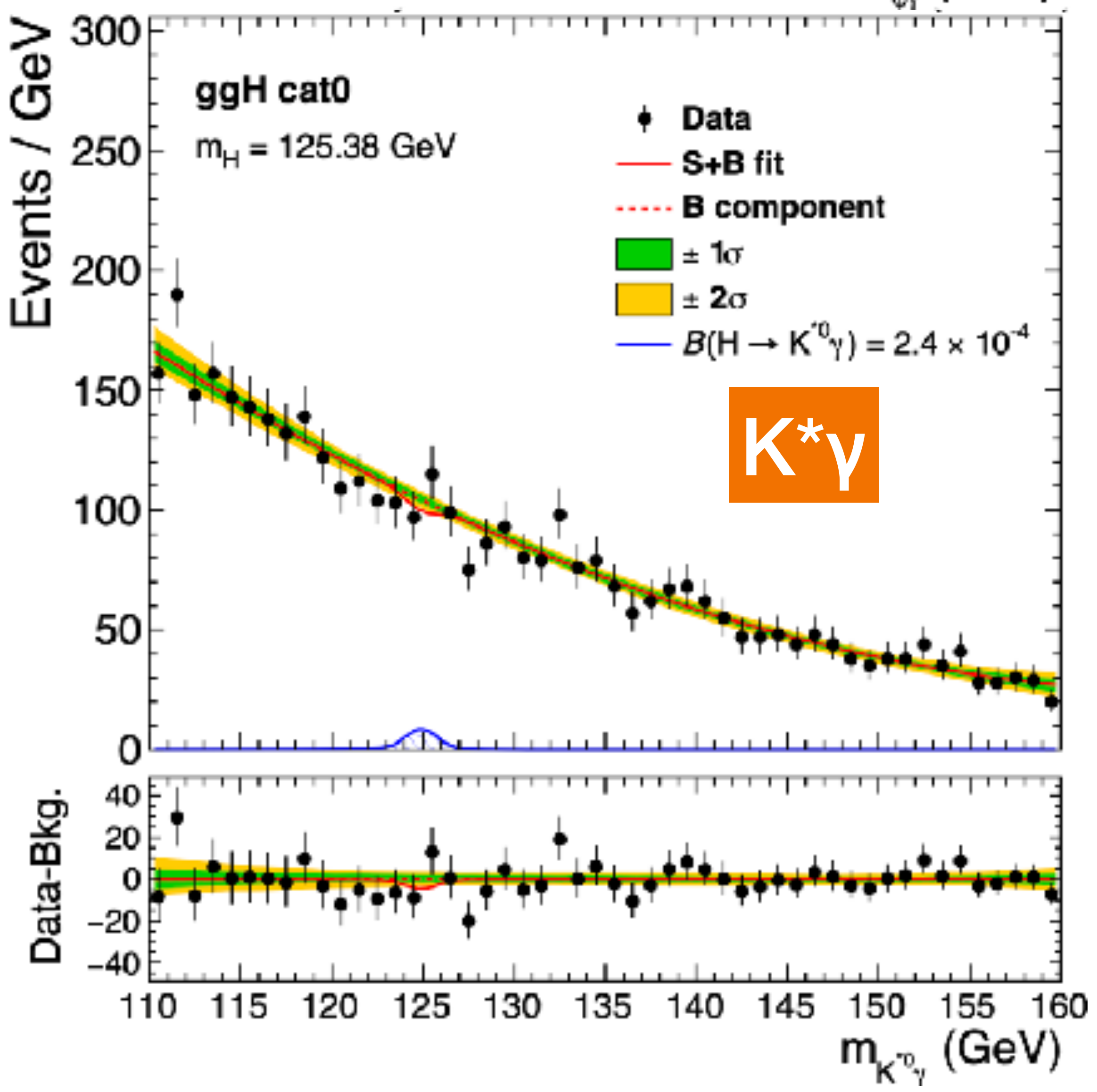
CMS-PAS-SMP-22-012 (2023)



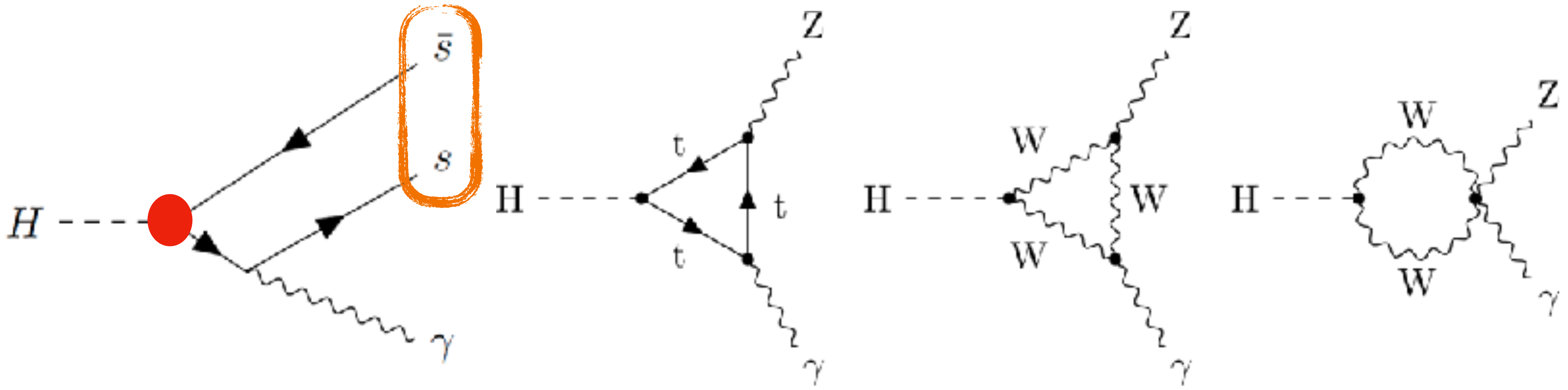


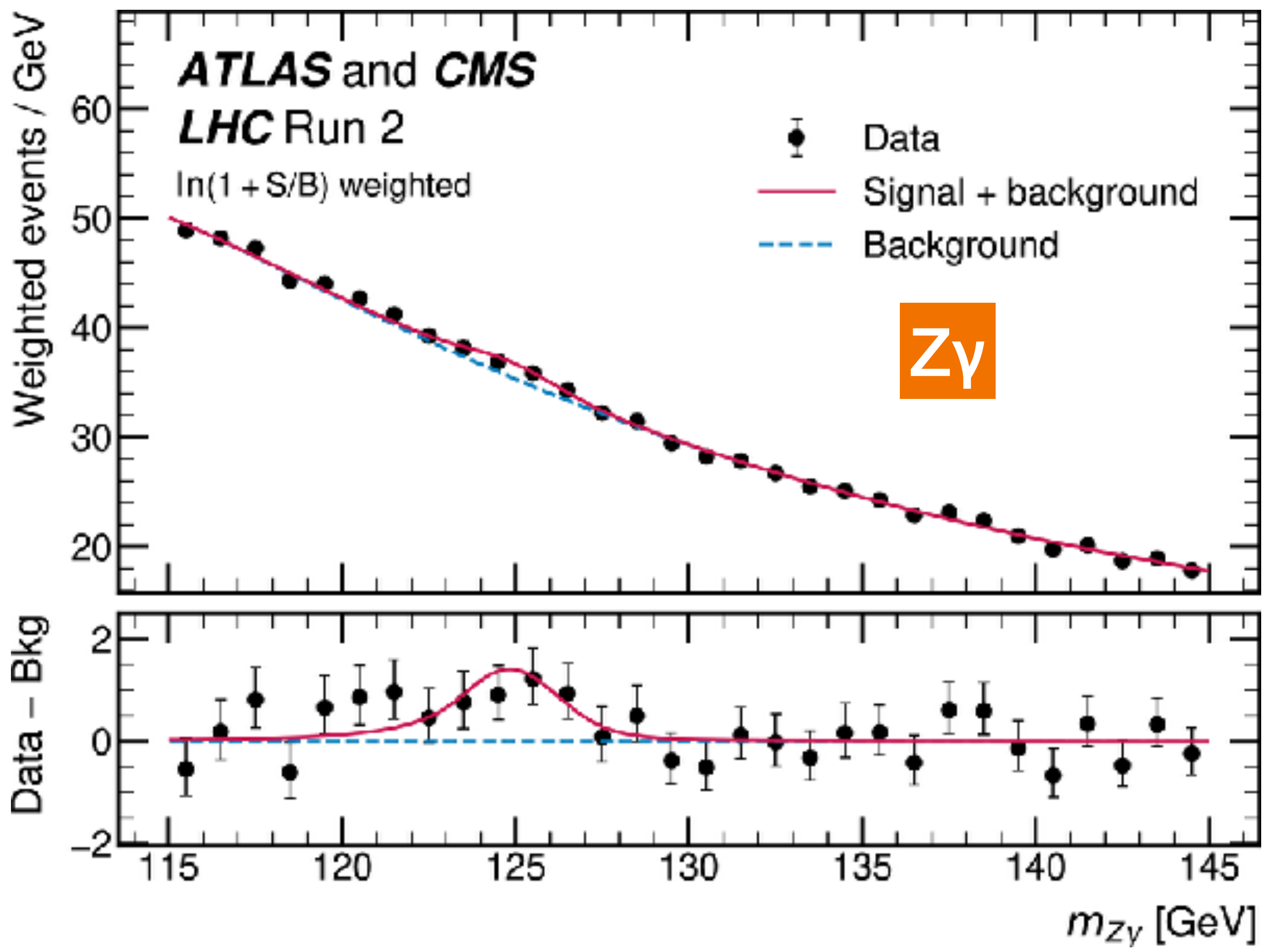
CMS-PAS-HIG-23-005 (2024)





⇦ probe Yukawa couplings to light quarks





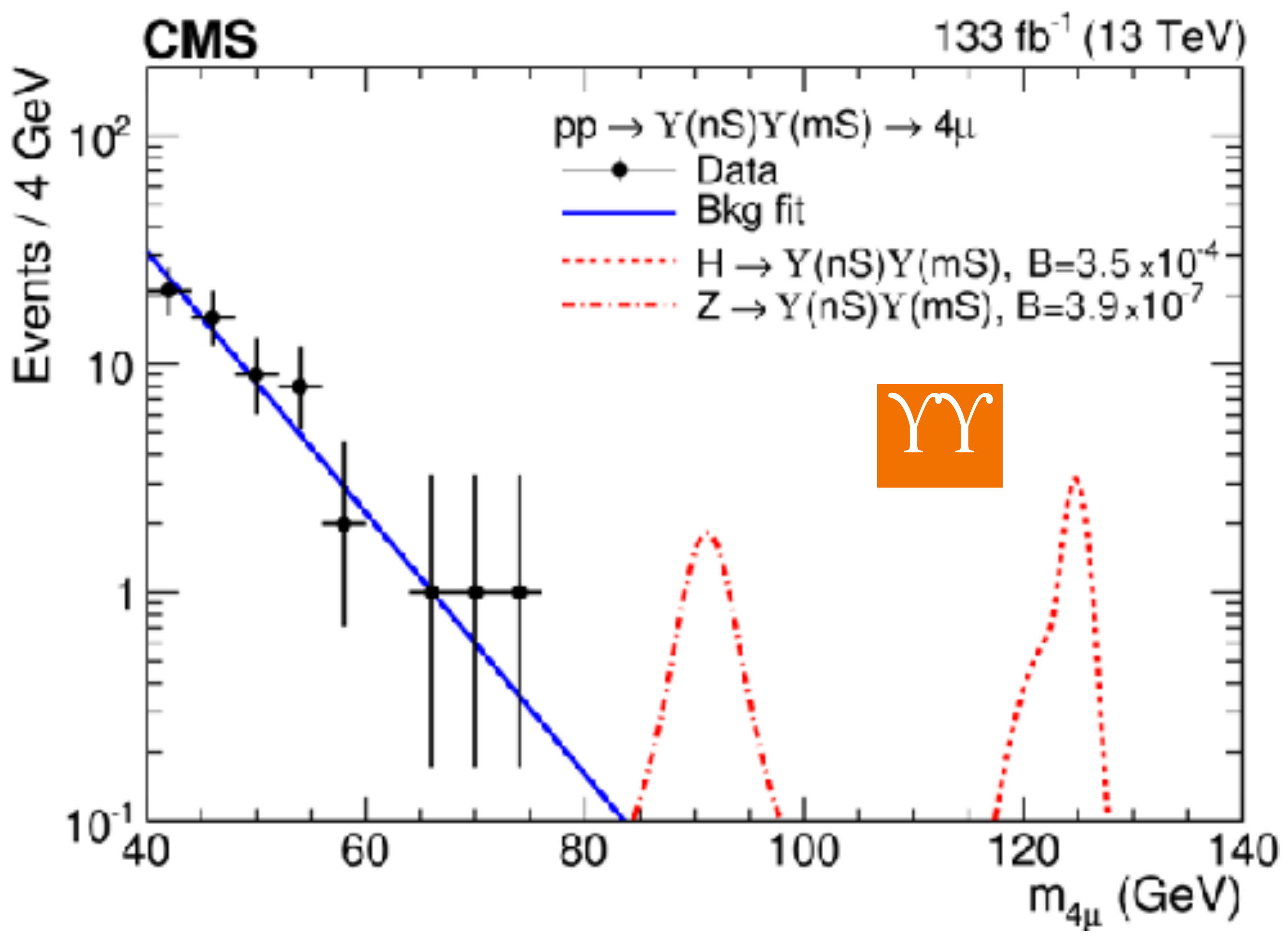
ATLAS and CMS, PRL 132 (2024) 021803

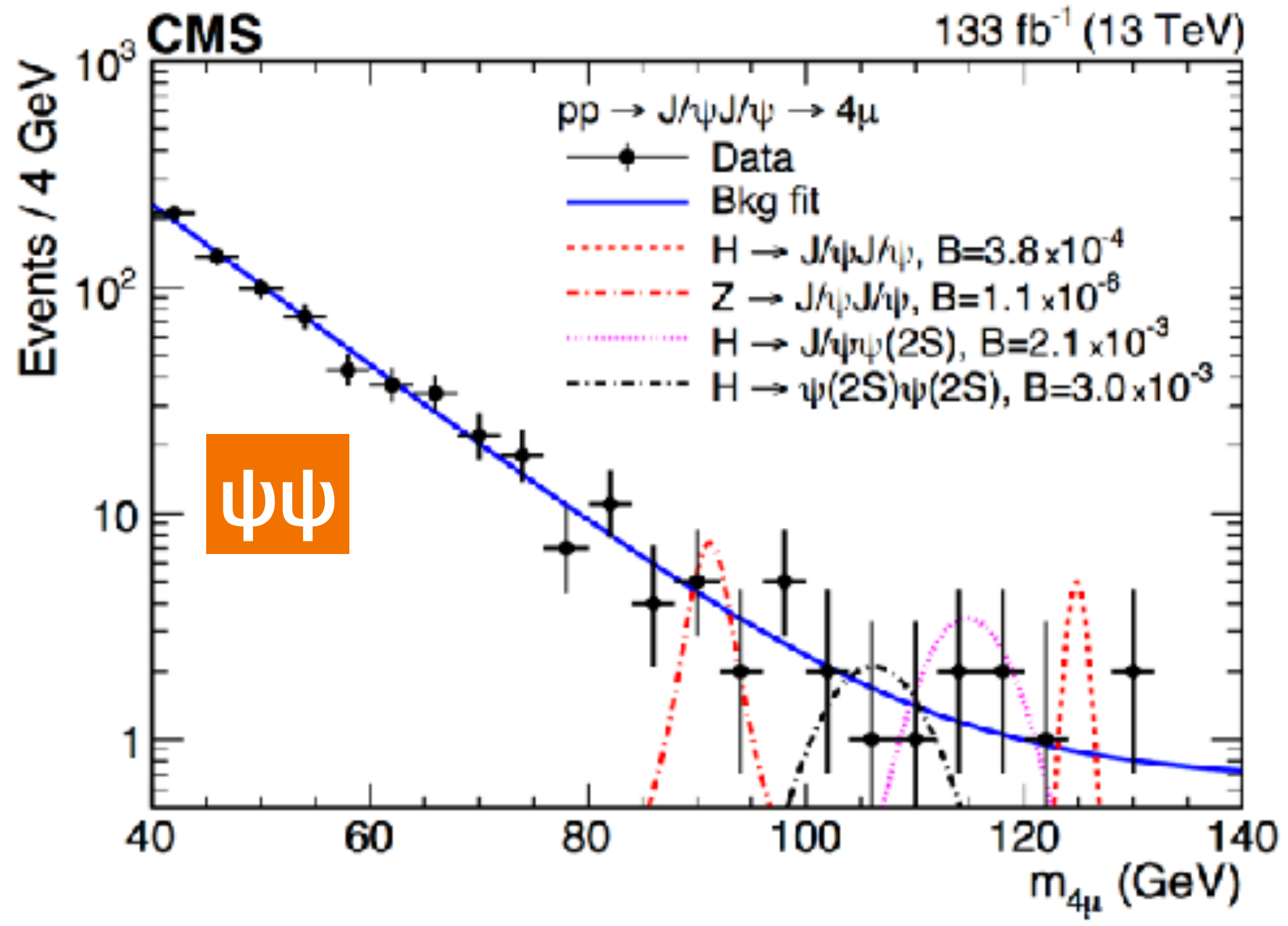
➡ first **evidence** of H→Zγ (3.4σ;μ~2.2)

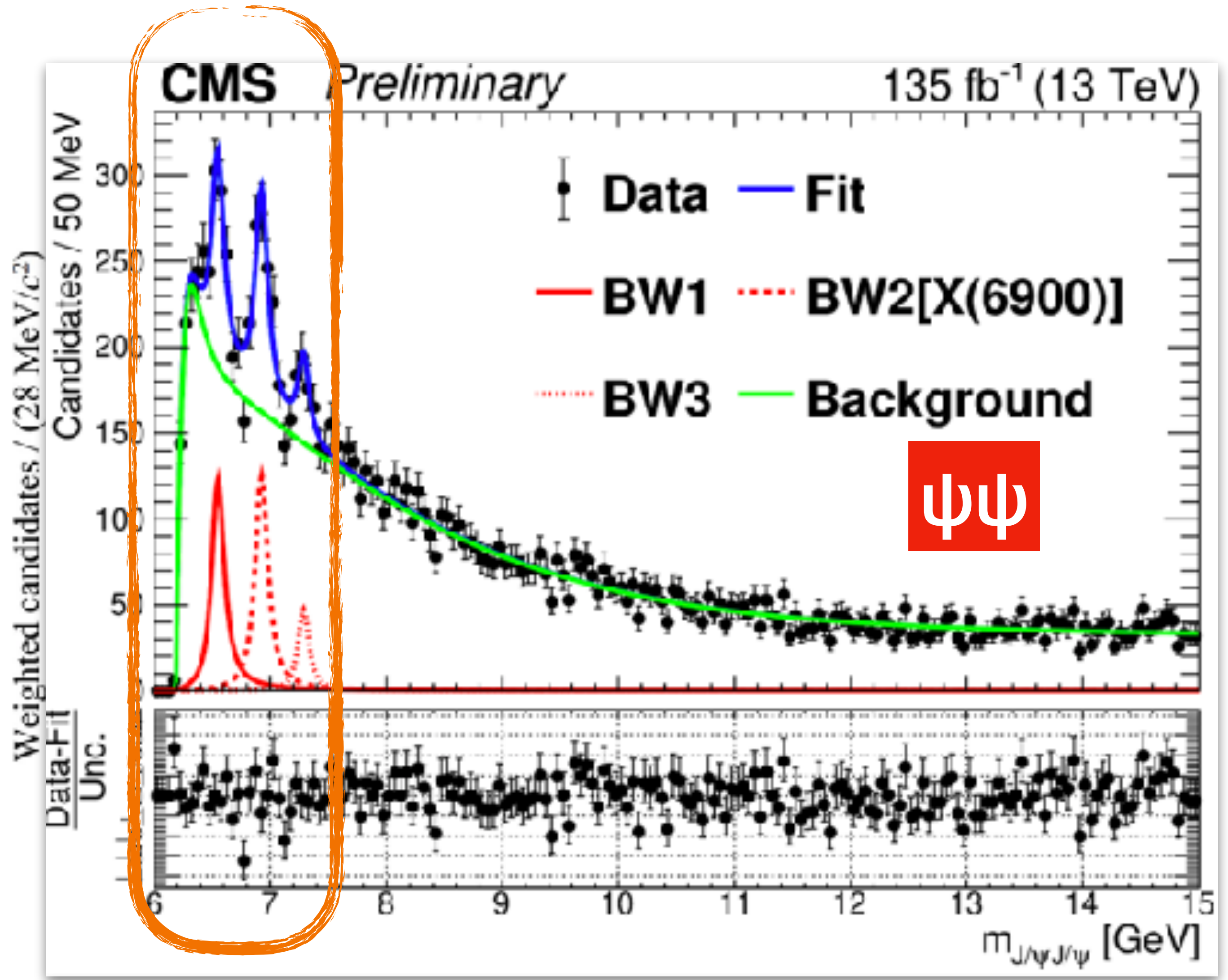
$$\mathrm{BR}(H \rightarrow Z\gamma) = (3.4 \pm 1.1) \times 10^{-3}$$

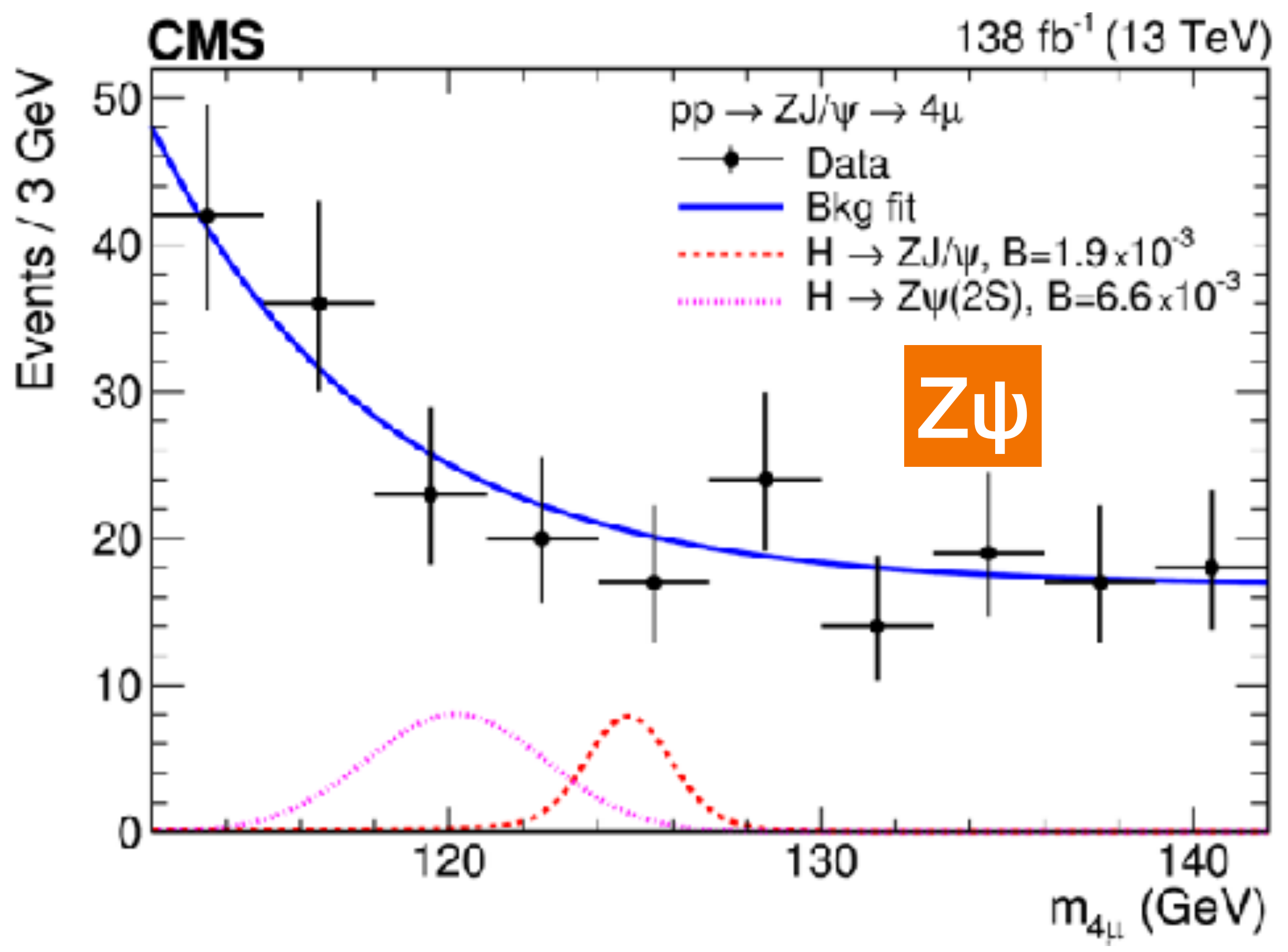
Probing further mass spectra

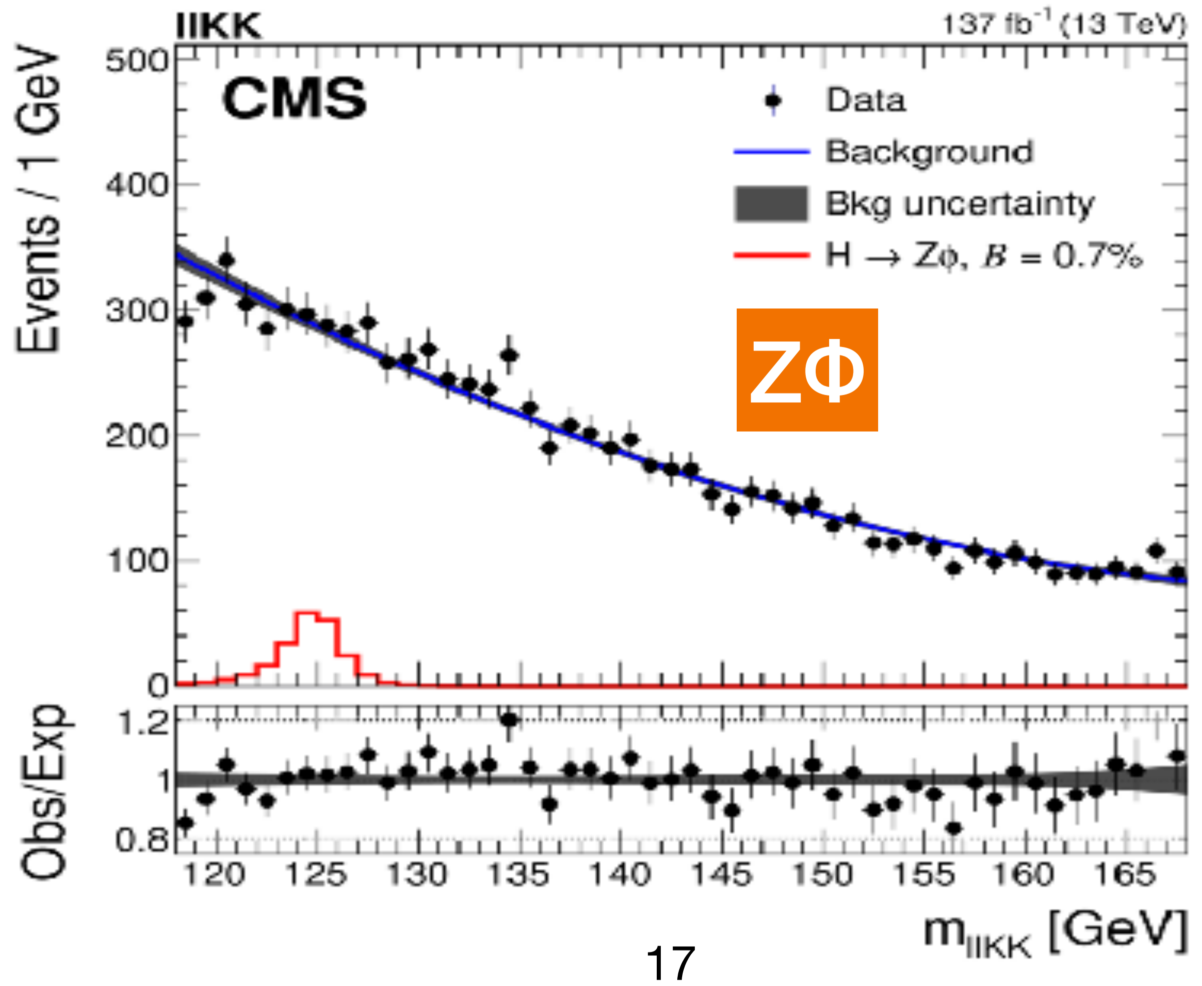
- final states with standard candles (Z, onia) provide clean and robust canvases for searches
  - at both low-p_T and high-p_T

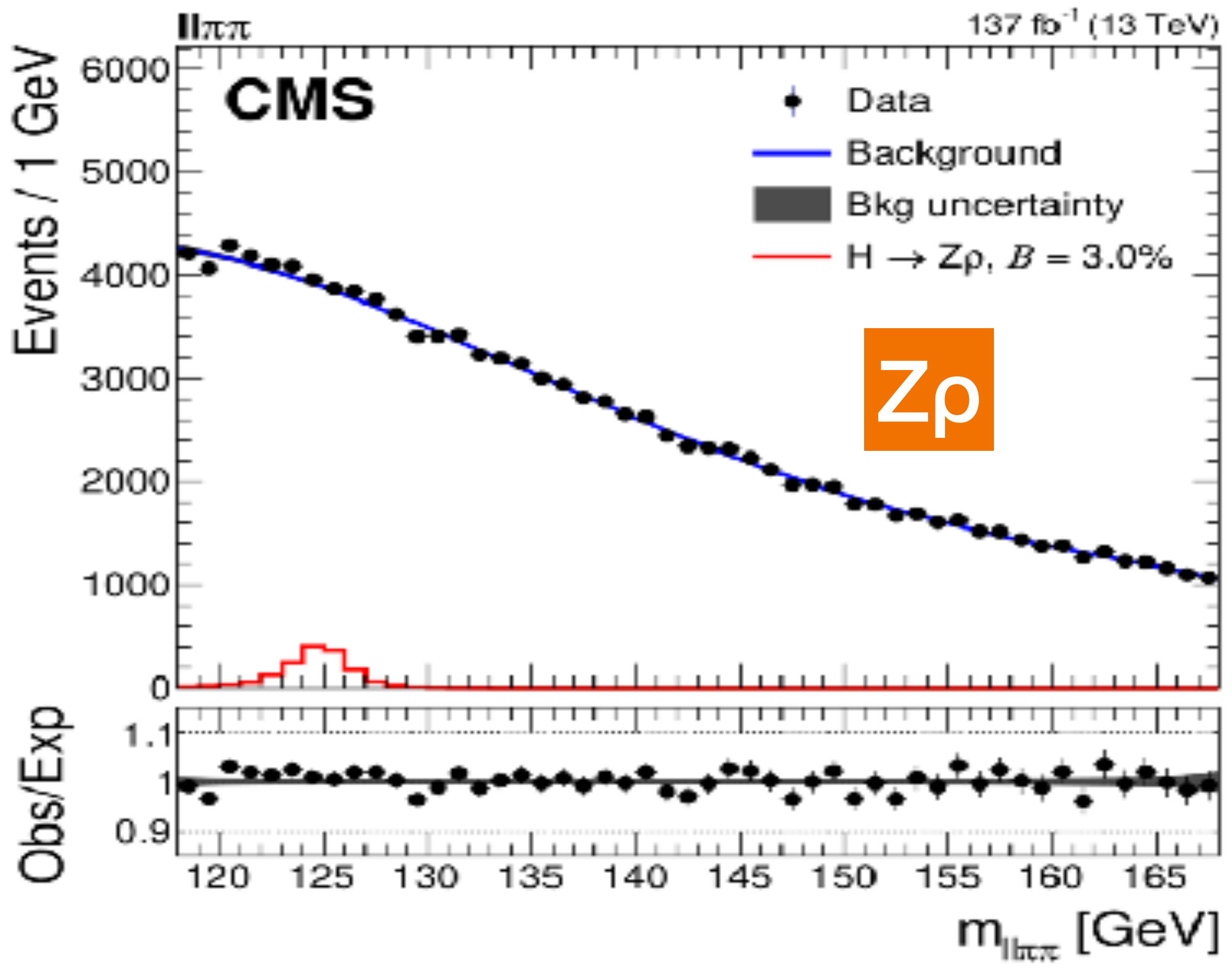










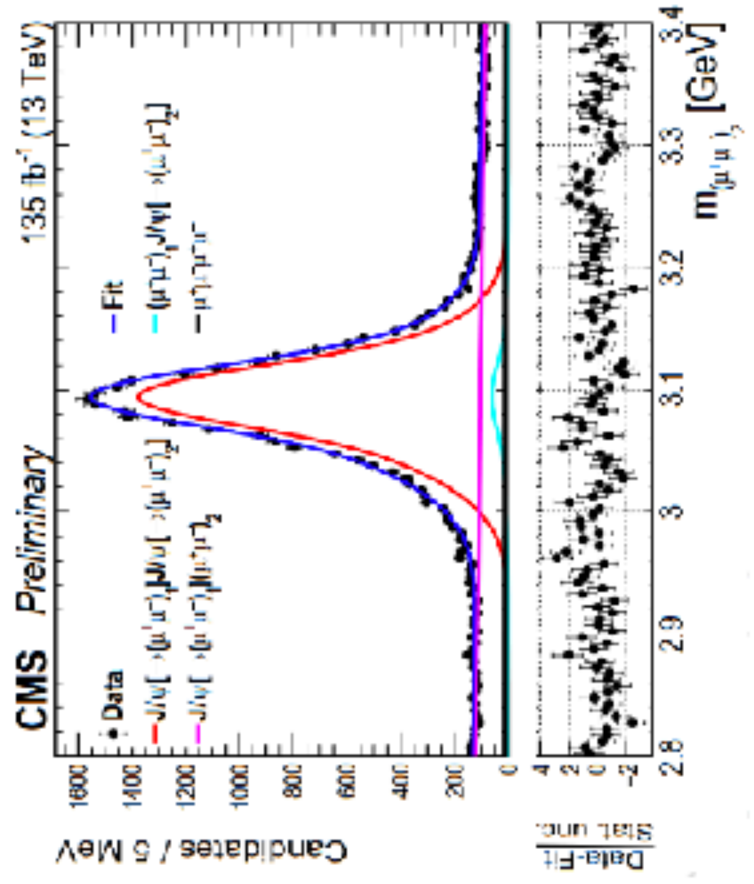


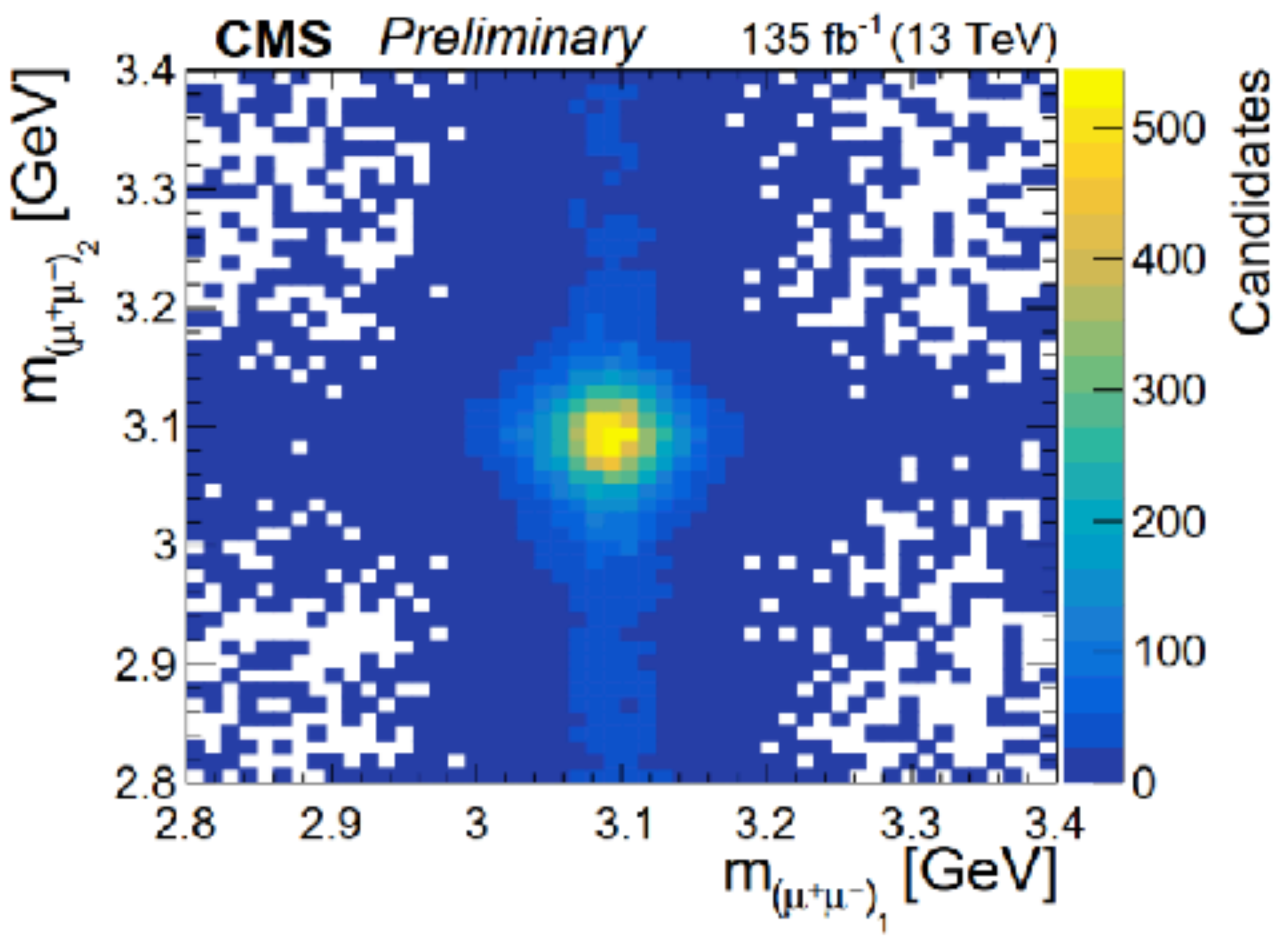
Phys. Lett. B 842 (2023) 137534

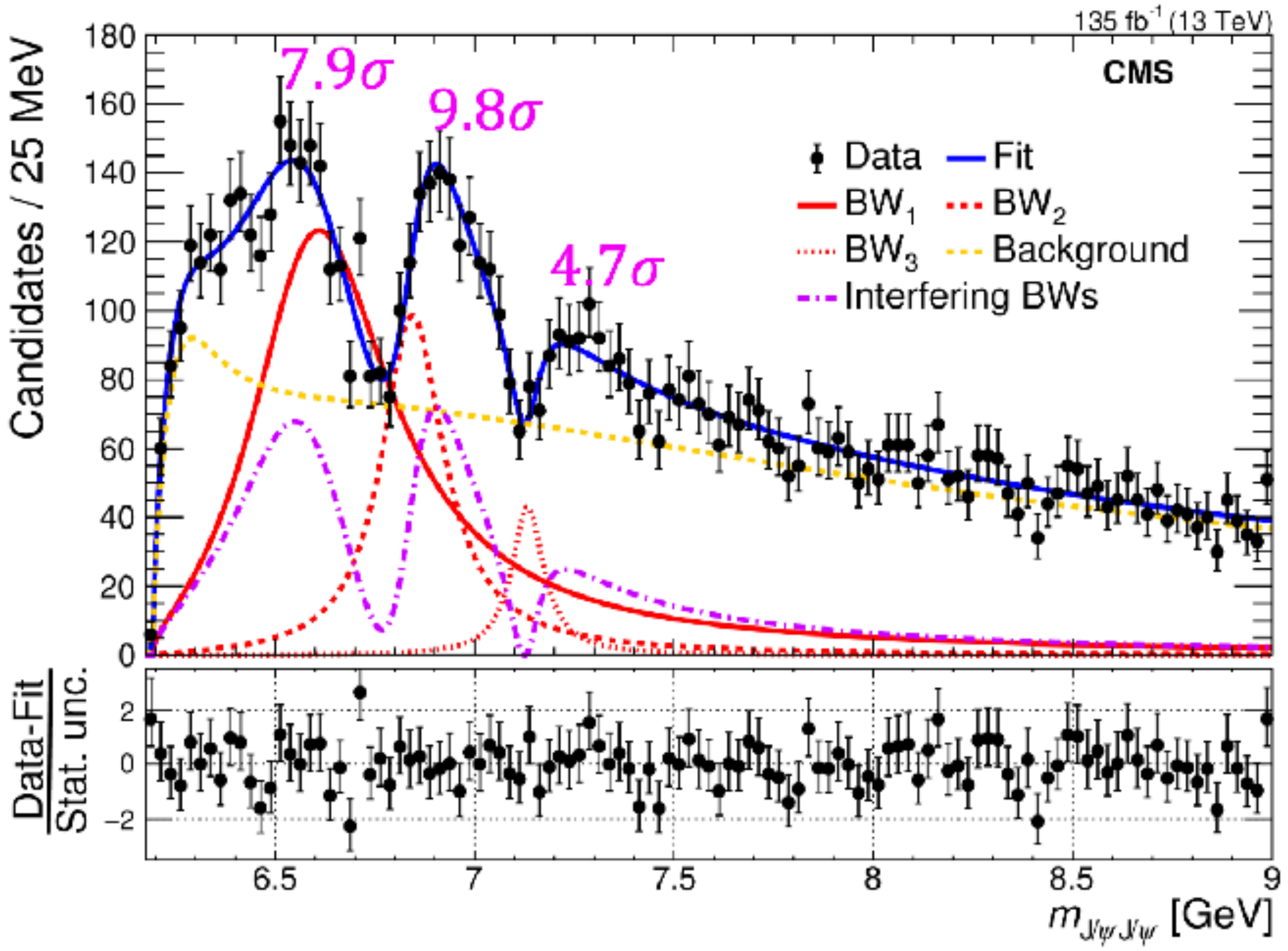
JHEP 11 (2020) 039

Observation of structures in J/ψJ/ψ mass spectrum

- CMS explored extended di-J/ψ mass spectrum
- several structures revealed near threshold
  - X(6900) confirmed, compatible with LHCb
  - plus two new structures detected: X(6600), X(7100)
  - observation of all-heavy **tetraquark** candidates
- signals described by three *interfering* BW functions

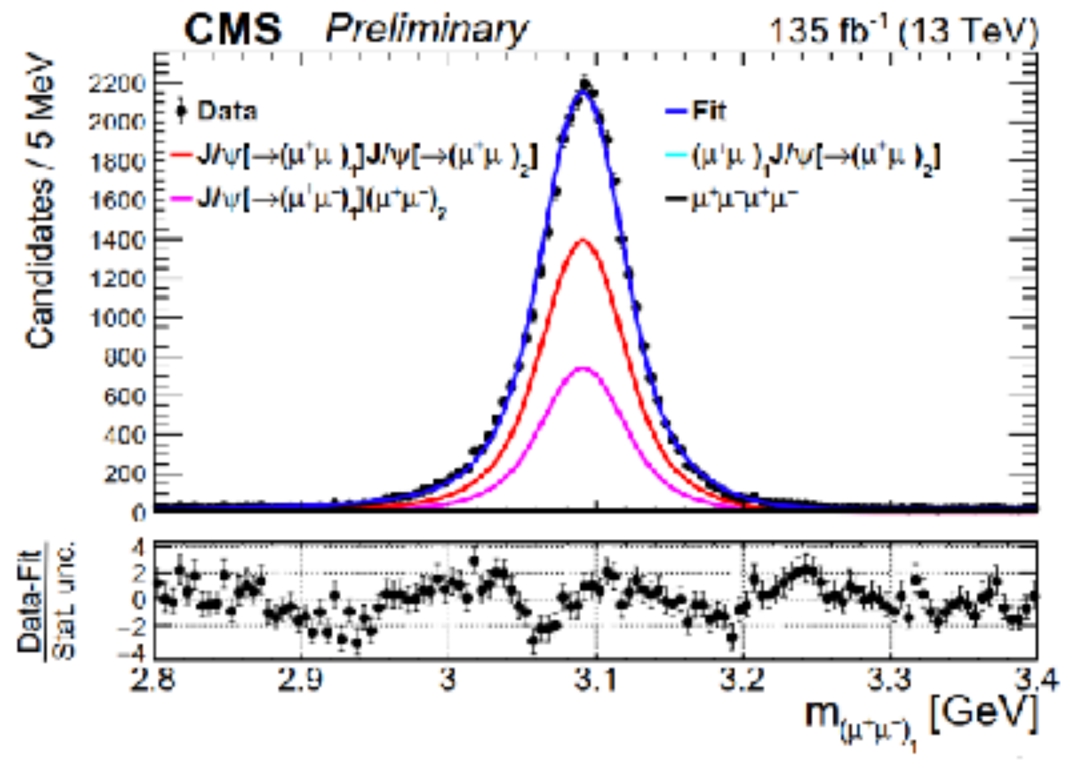






X(6600) X(6900) X(7100)

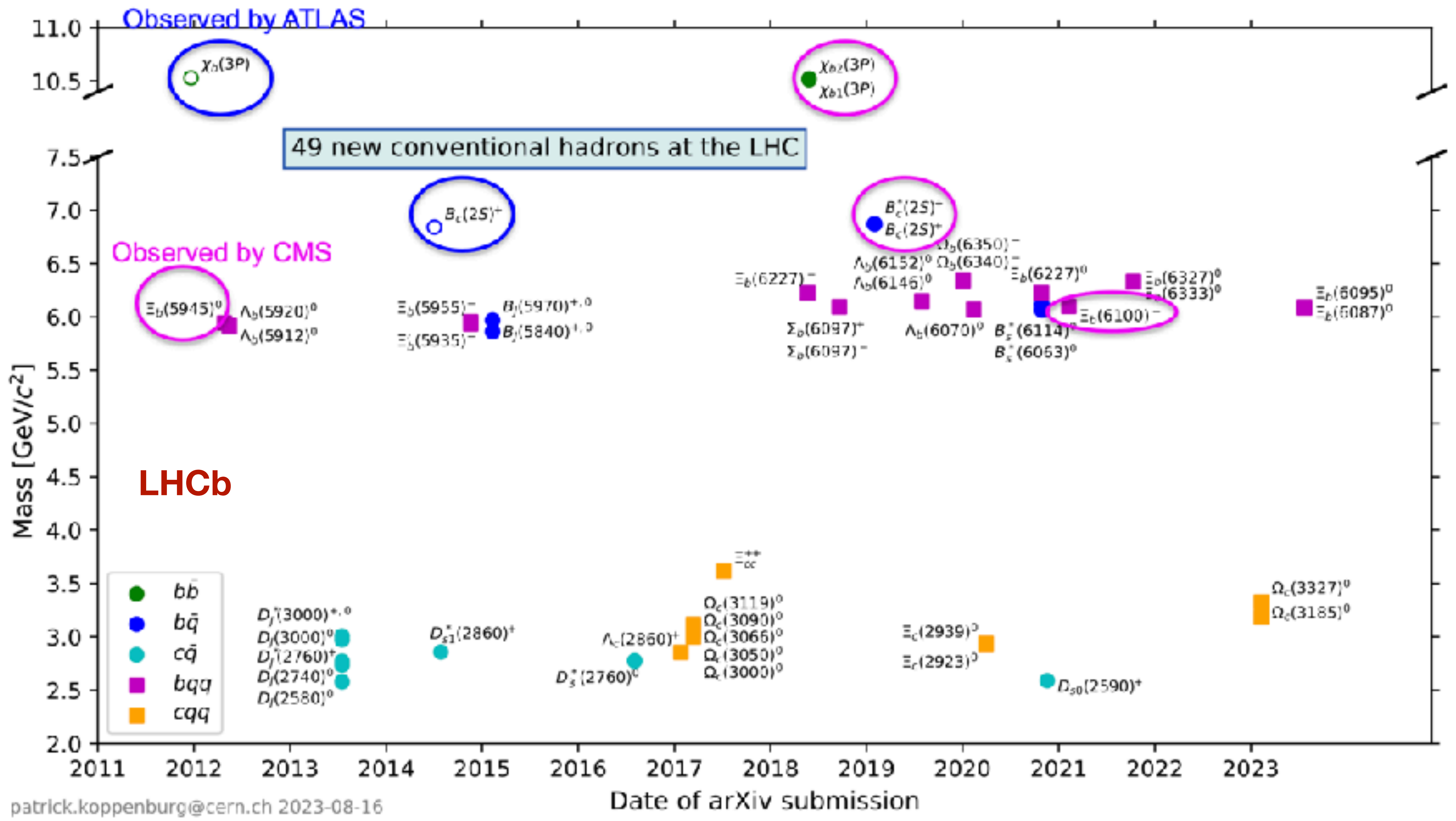
$J/\psi J/\psi \to (\mu\mu)_1(\mu\mu)_2$

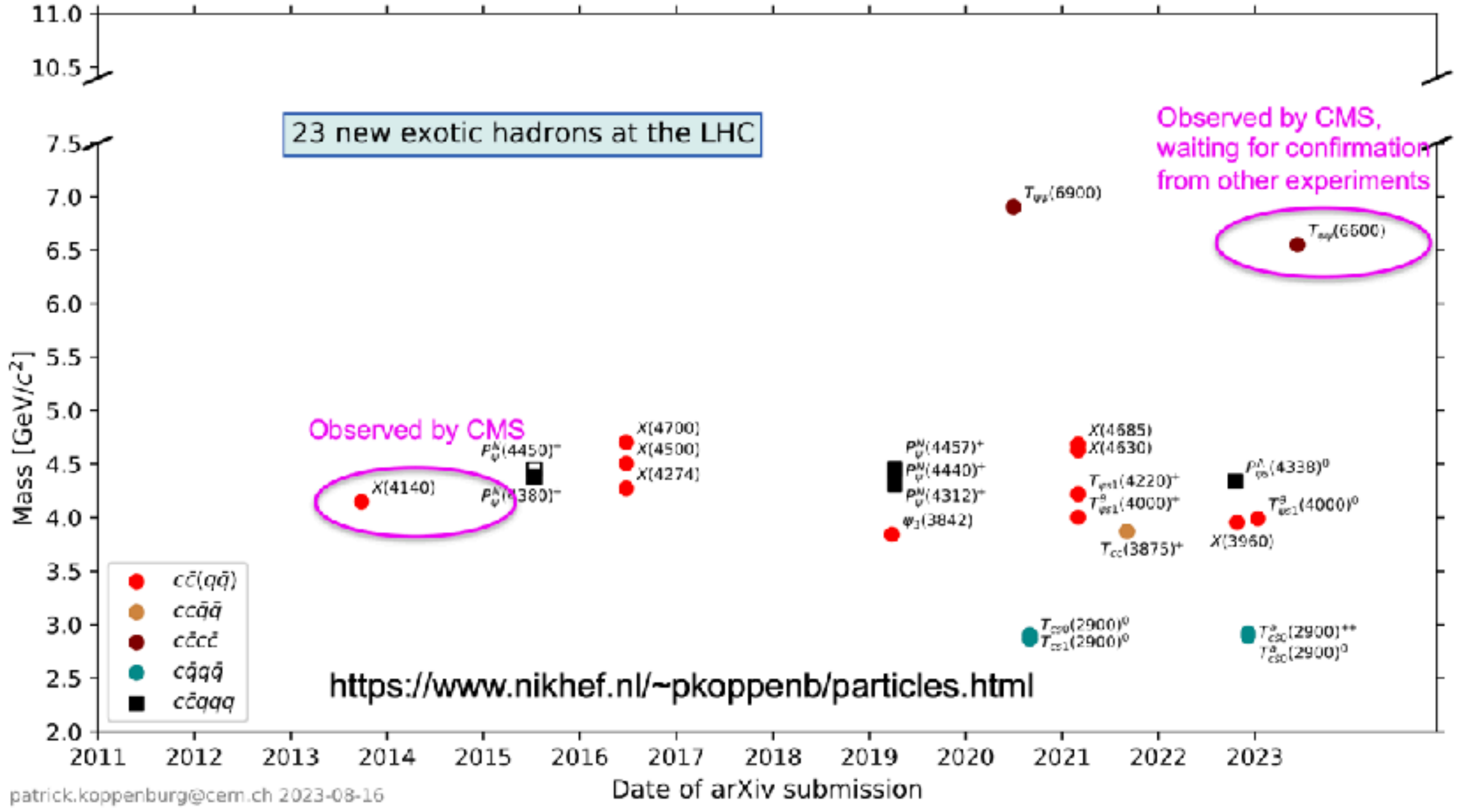


PRL 132 (2024), 111901

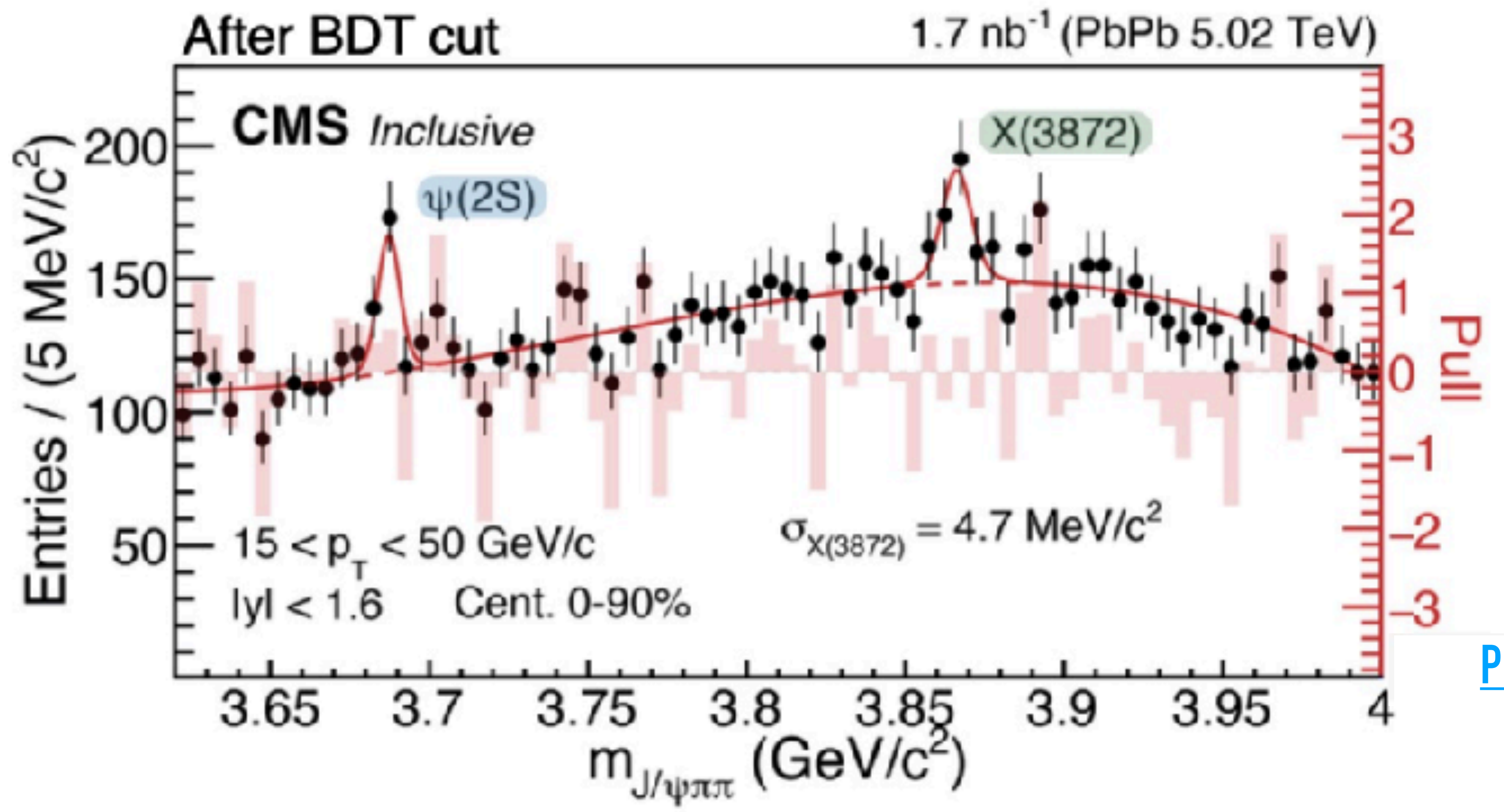
	BW_1	BW_2	BW_3
m [MeV]	6638^{+43+16}_{-38-31}	6847^{+44+48}_{-28-20}	7134^{+48+41}_{-25-15}
Γ [MeV]	$440^{+230+110}_{-200-240}$	191^{+66+25}_{-49-17}	97^{+40+29}_{-29-26}

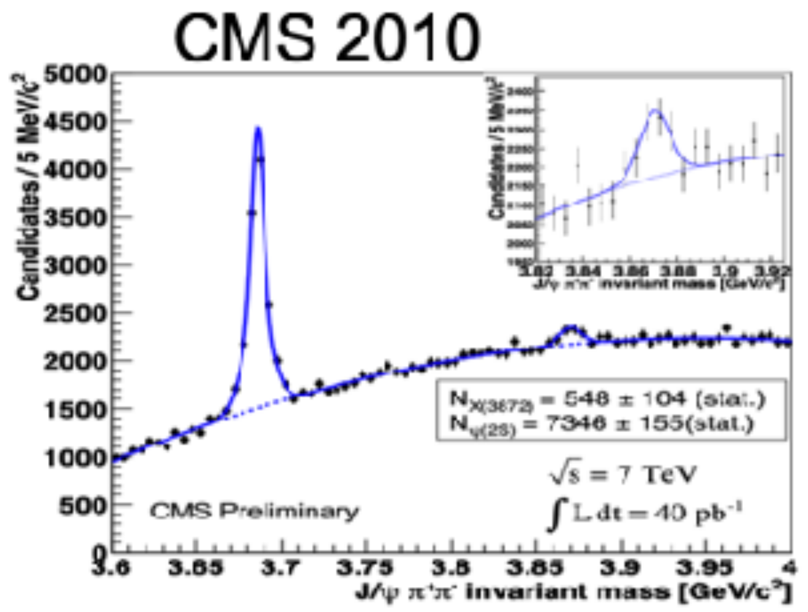
New states, conventional and exotic





- also extending spectroscopy studies to nuclear collisions
- fist evidence of X(3872) in PbPb collisions

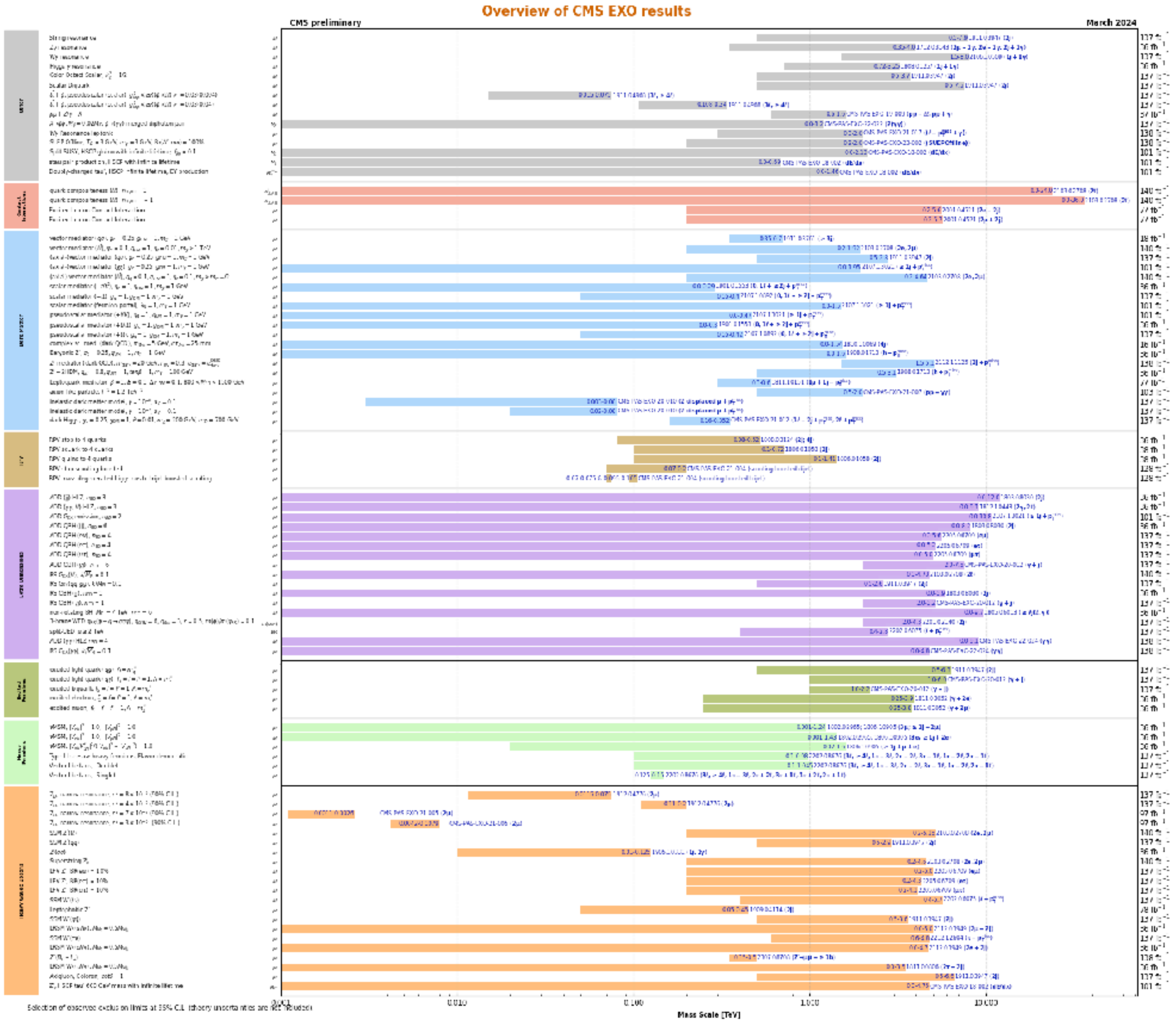


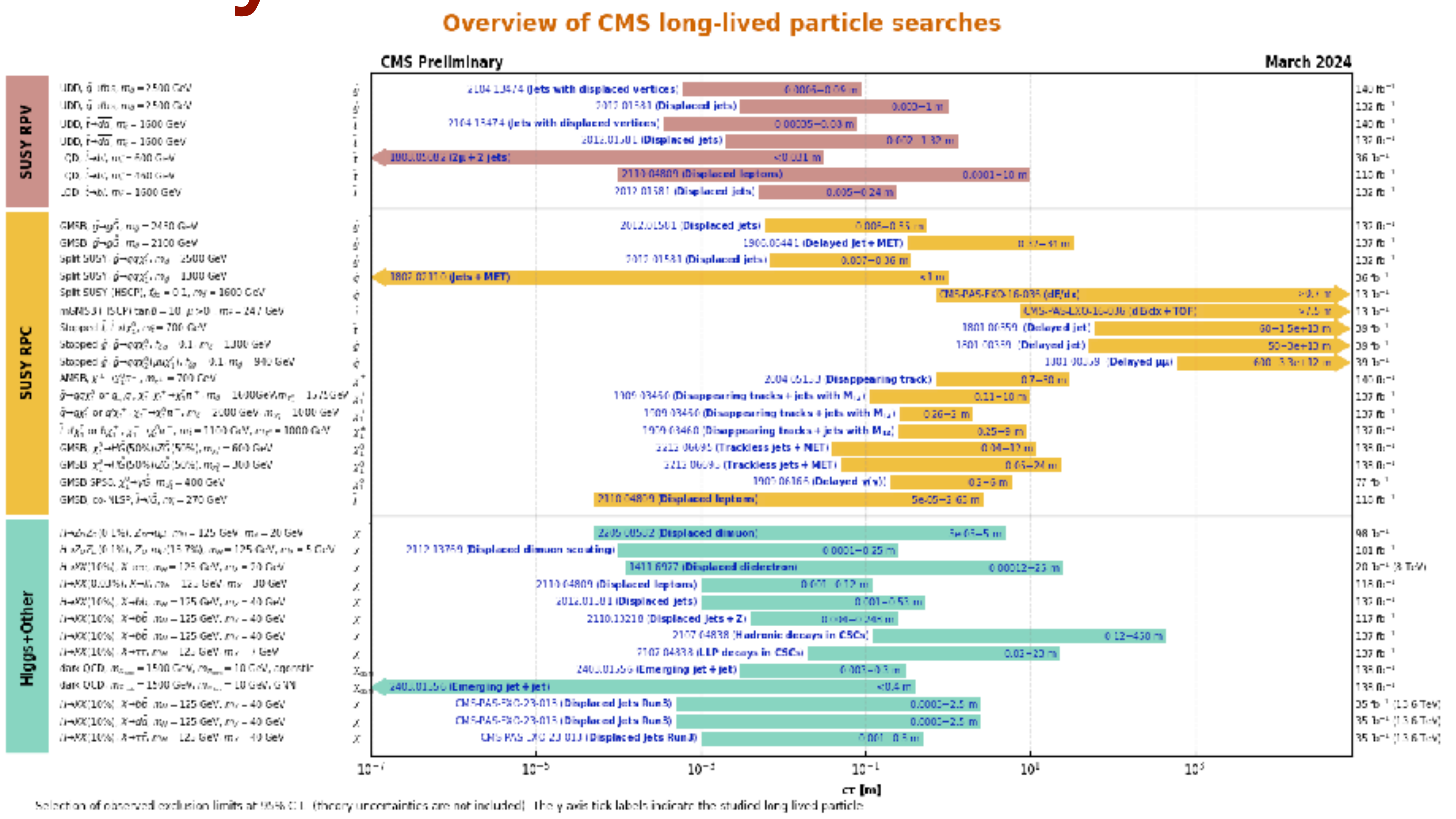


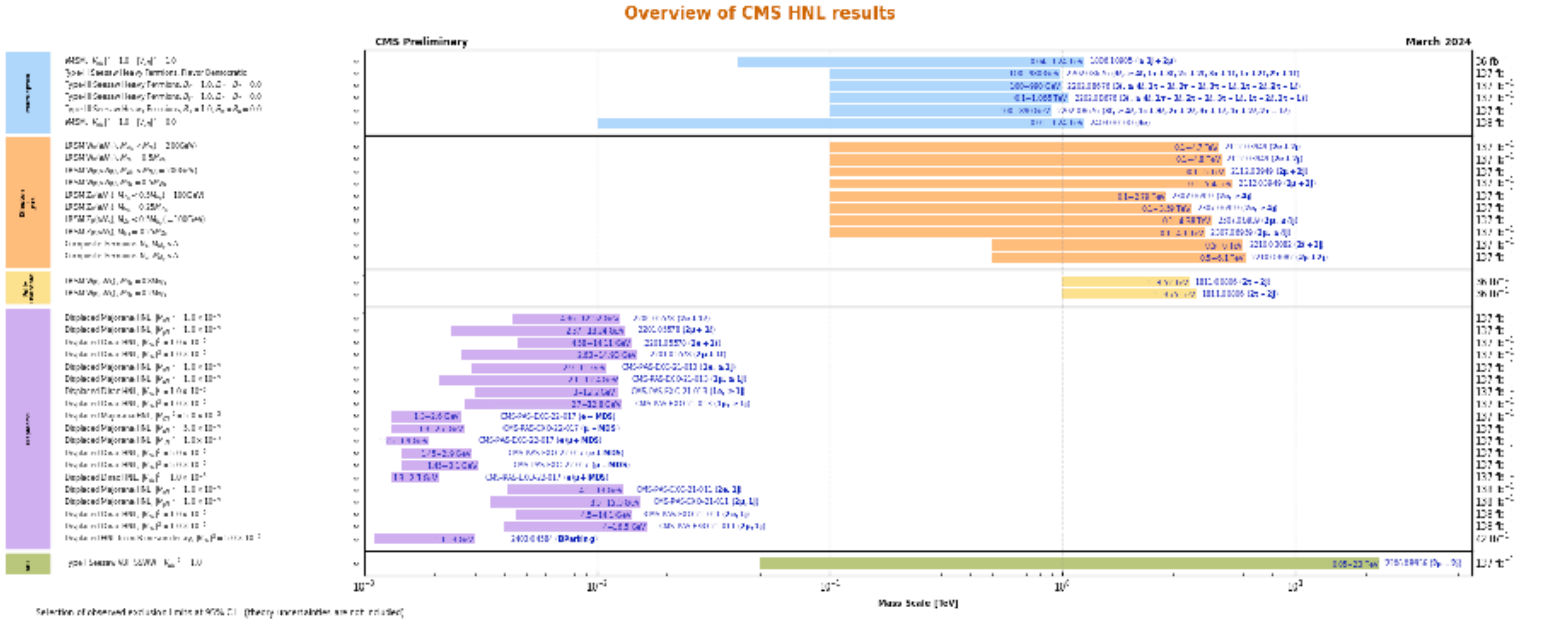
PRL 128 (2022) 032001

Any new (-physics) particles yet?

Any new (-physics) particles yet?

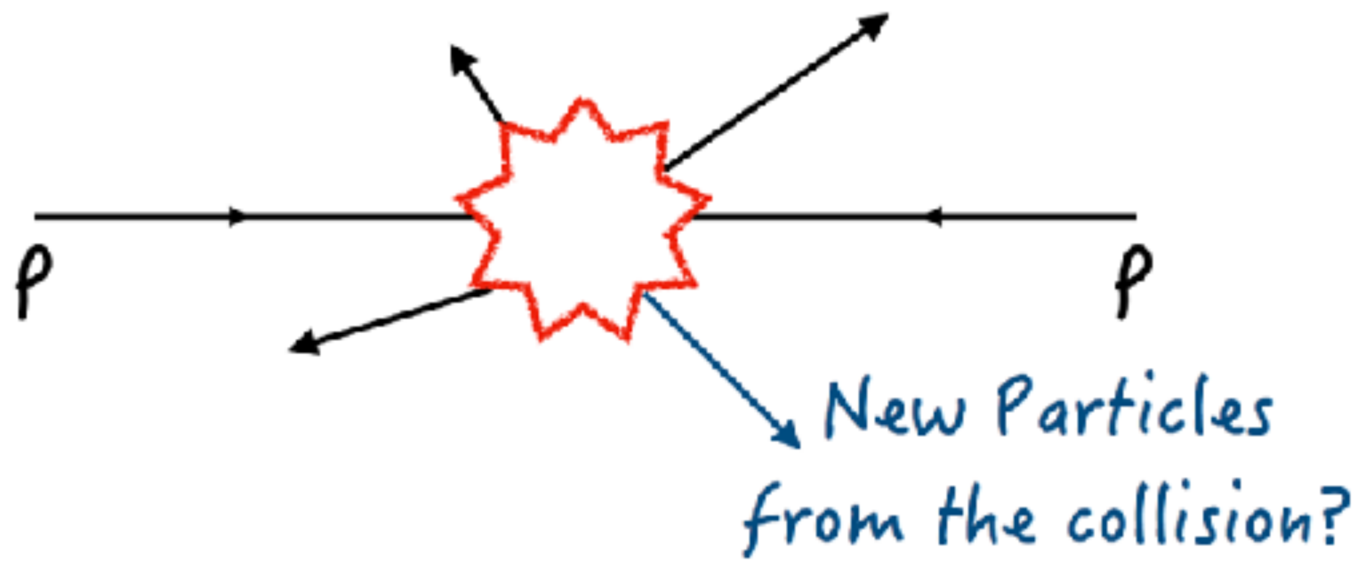




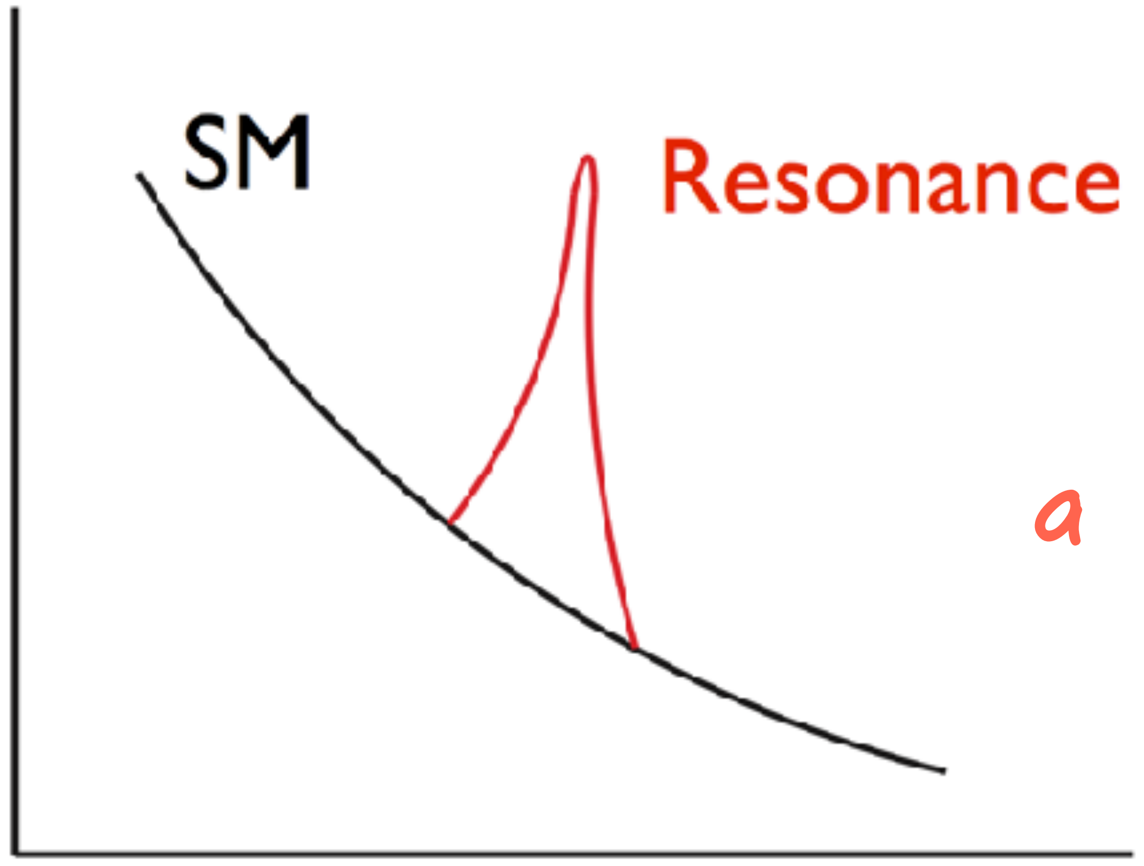


https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/ https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/ https://twiki.cern.ch/twiki/bin/view/CMSPublic/SummaryPlotsEXO13TeV

Direct Evidence for NP

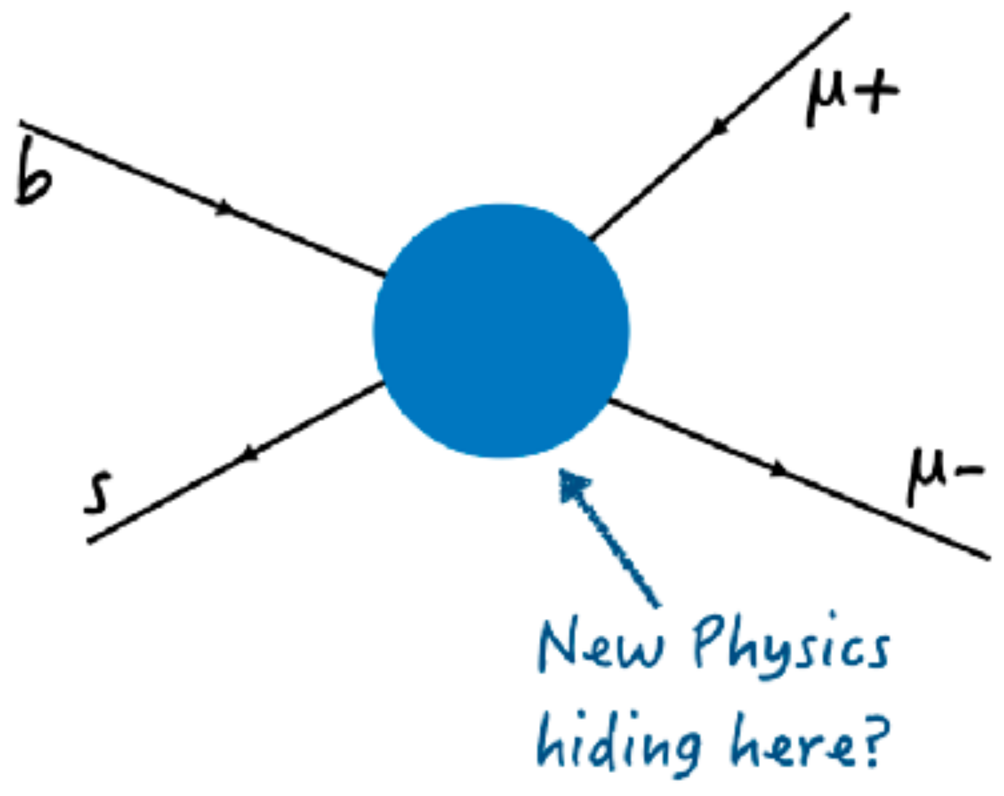


- searching for the decay products of NP particles produced in collision

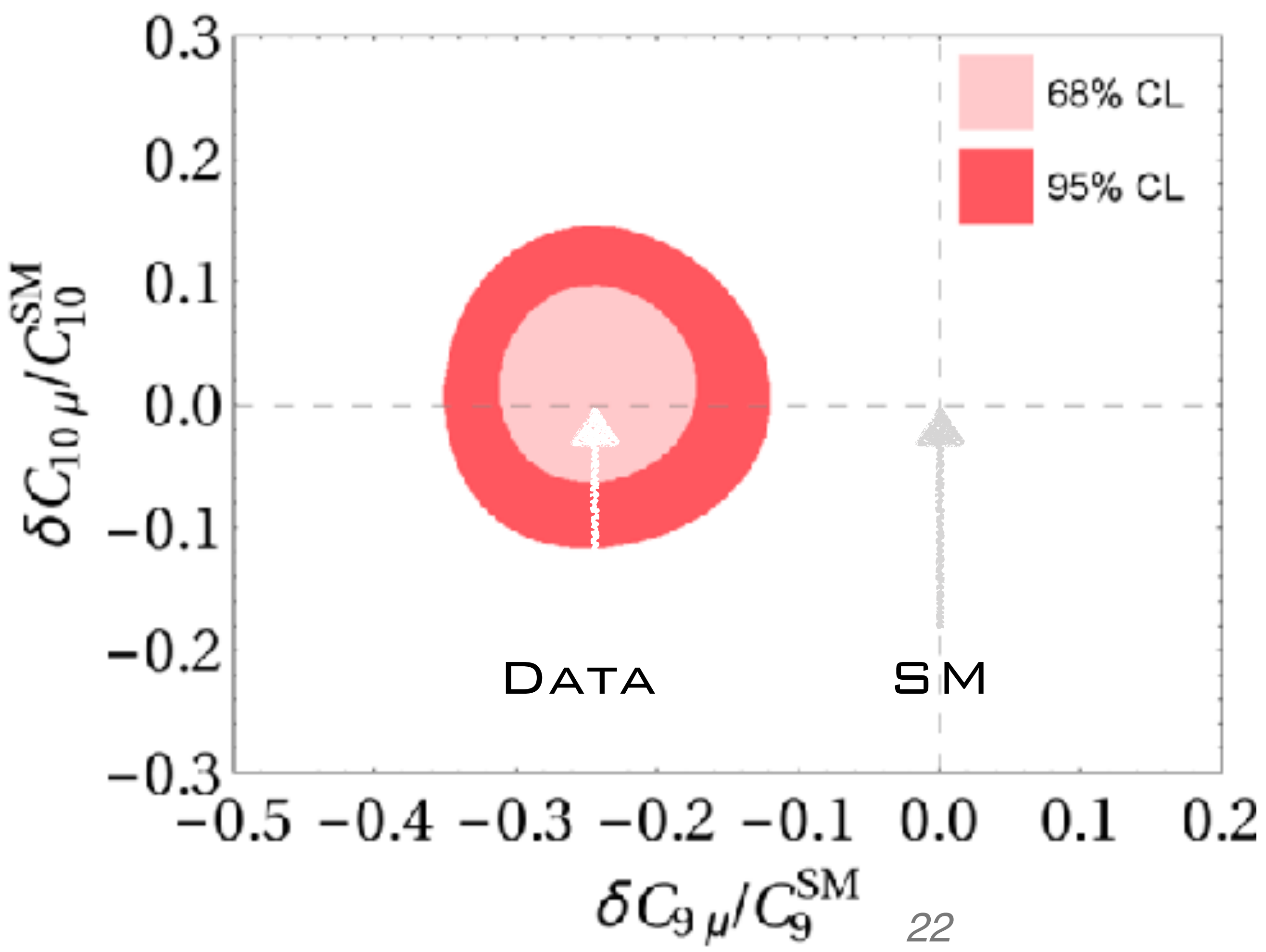


a la Higgs

Indirect: Quantum **Imprints** of *NP*



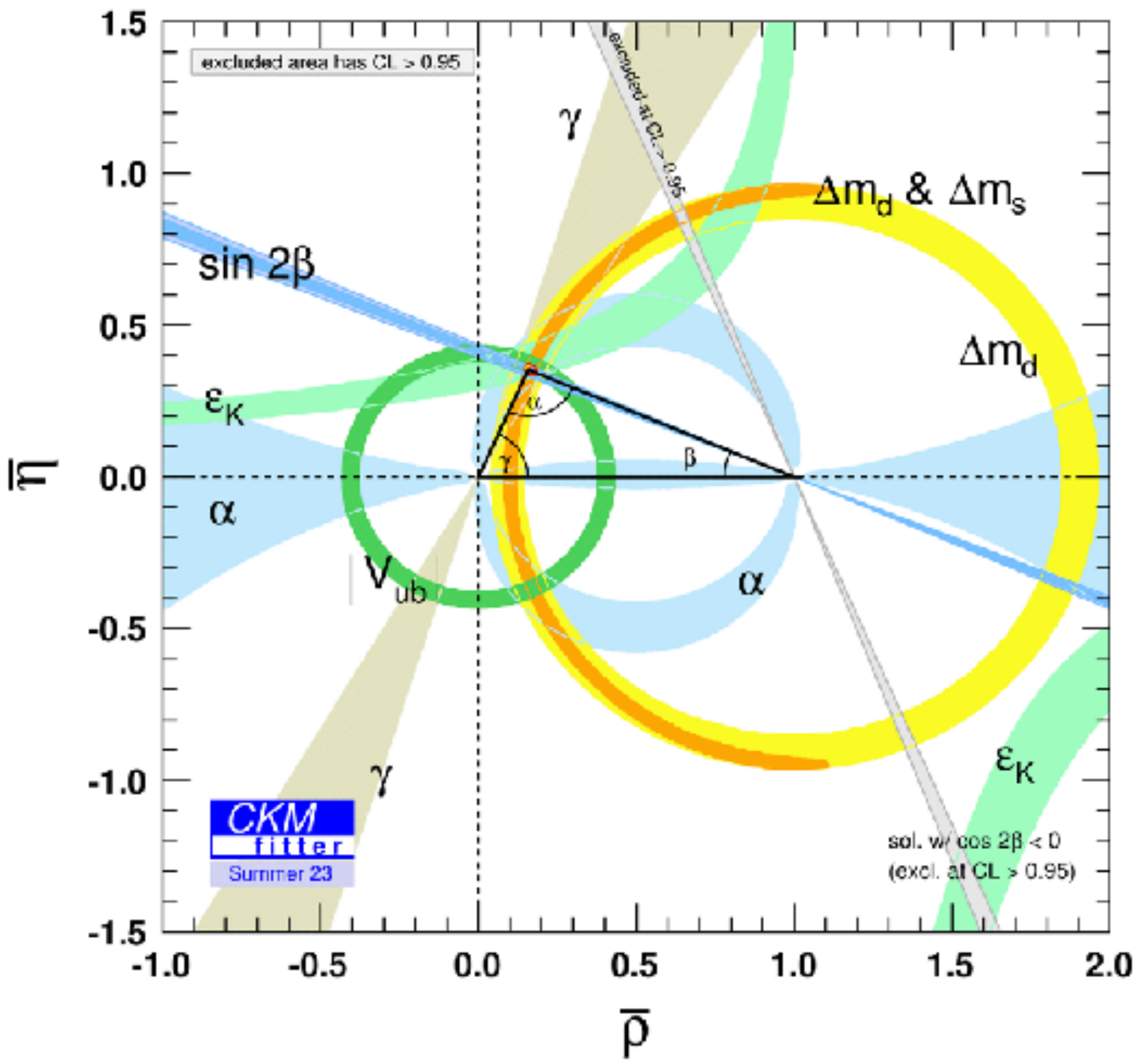
- searching for effects of NP particles running in quantum loops (virtual)

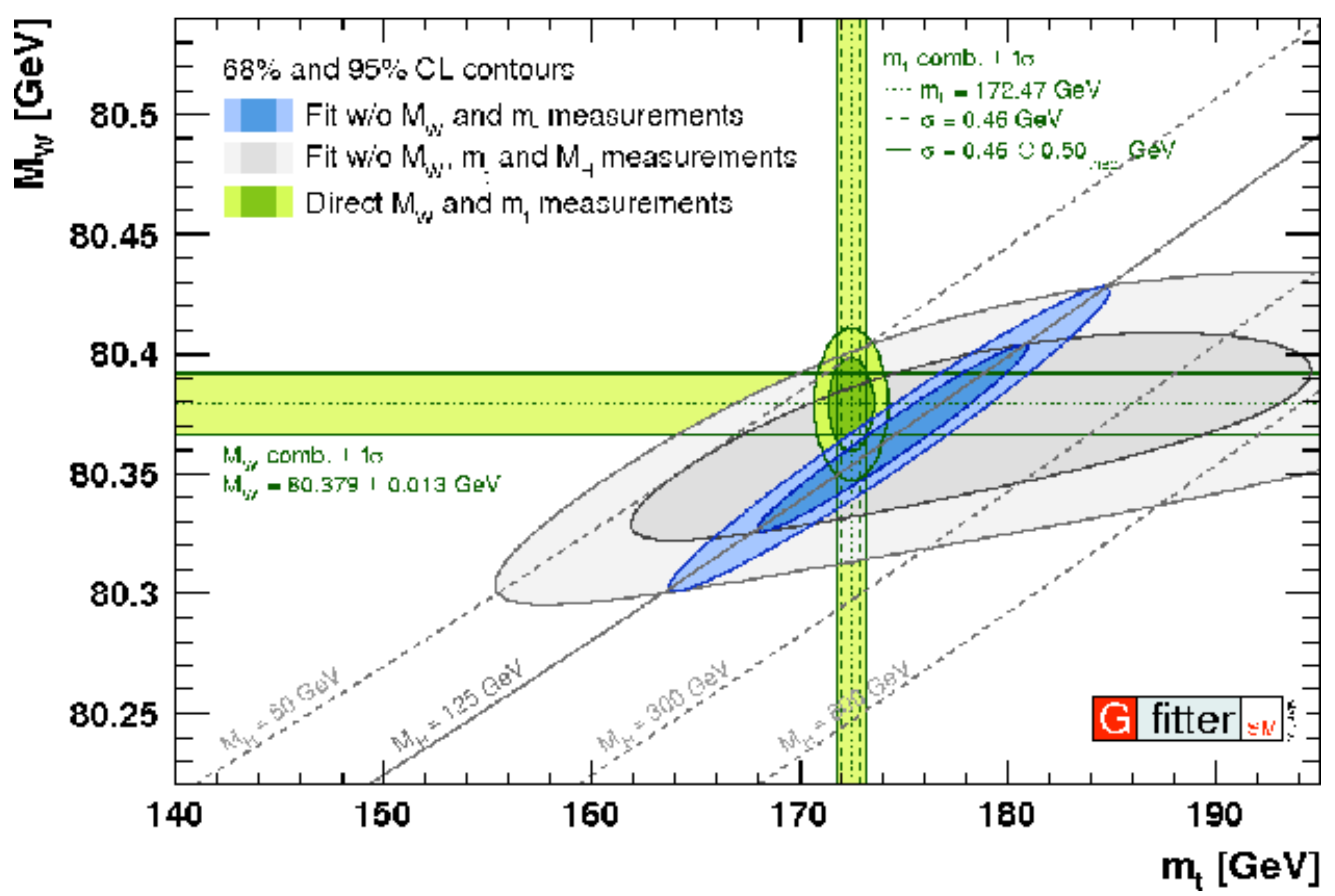


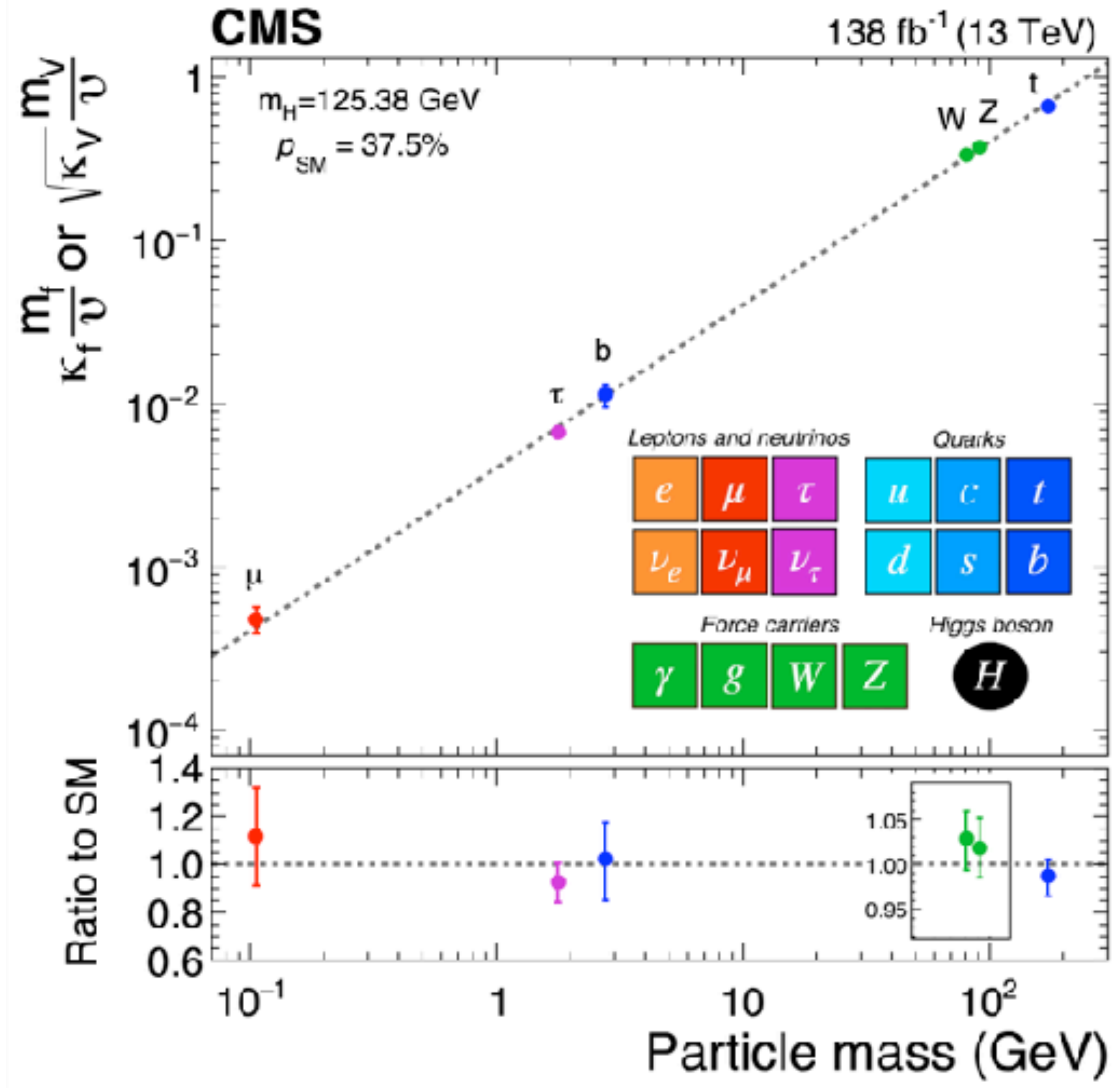
precision

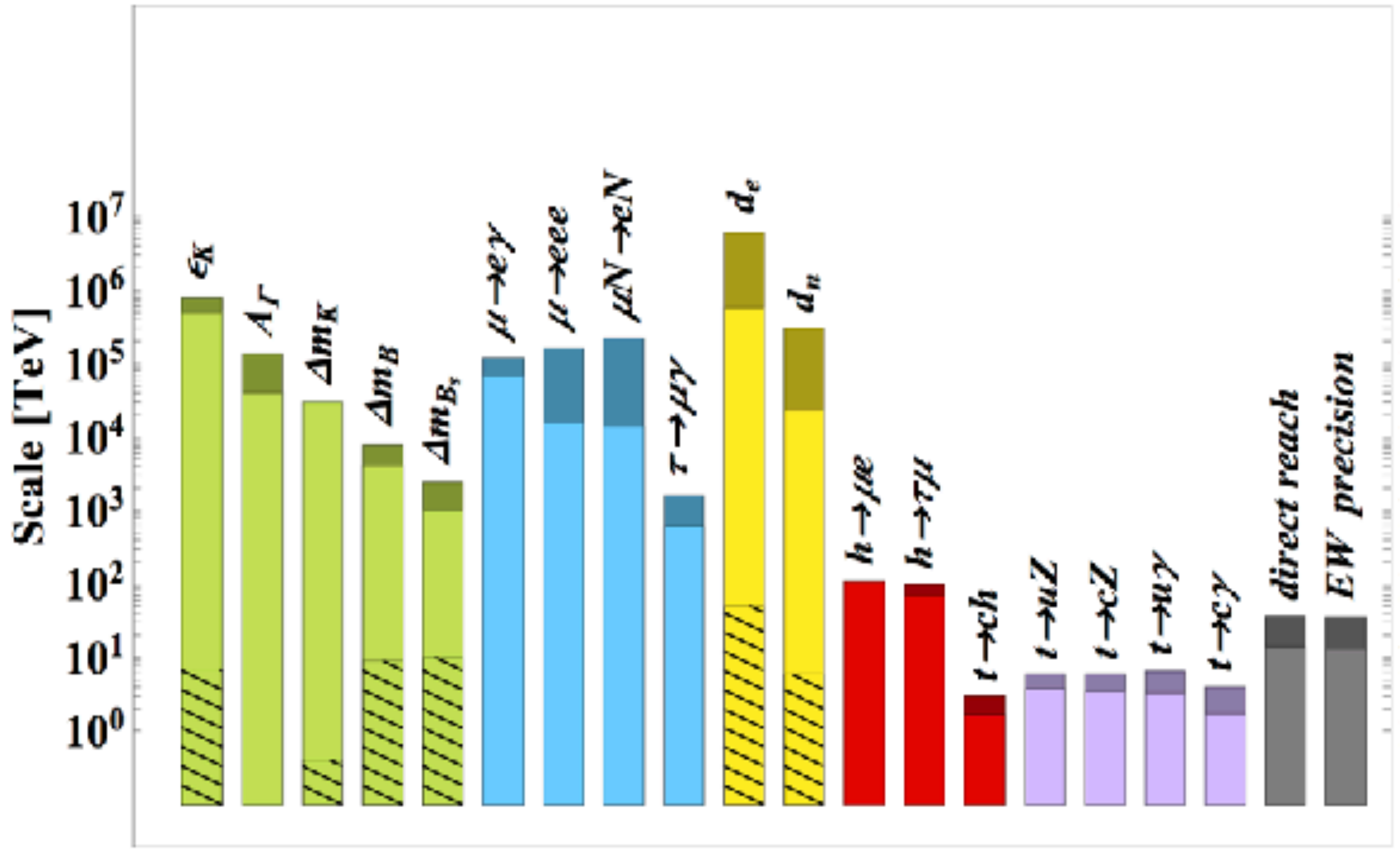
↪ (SM)EFT!

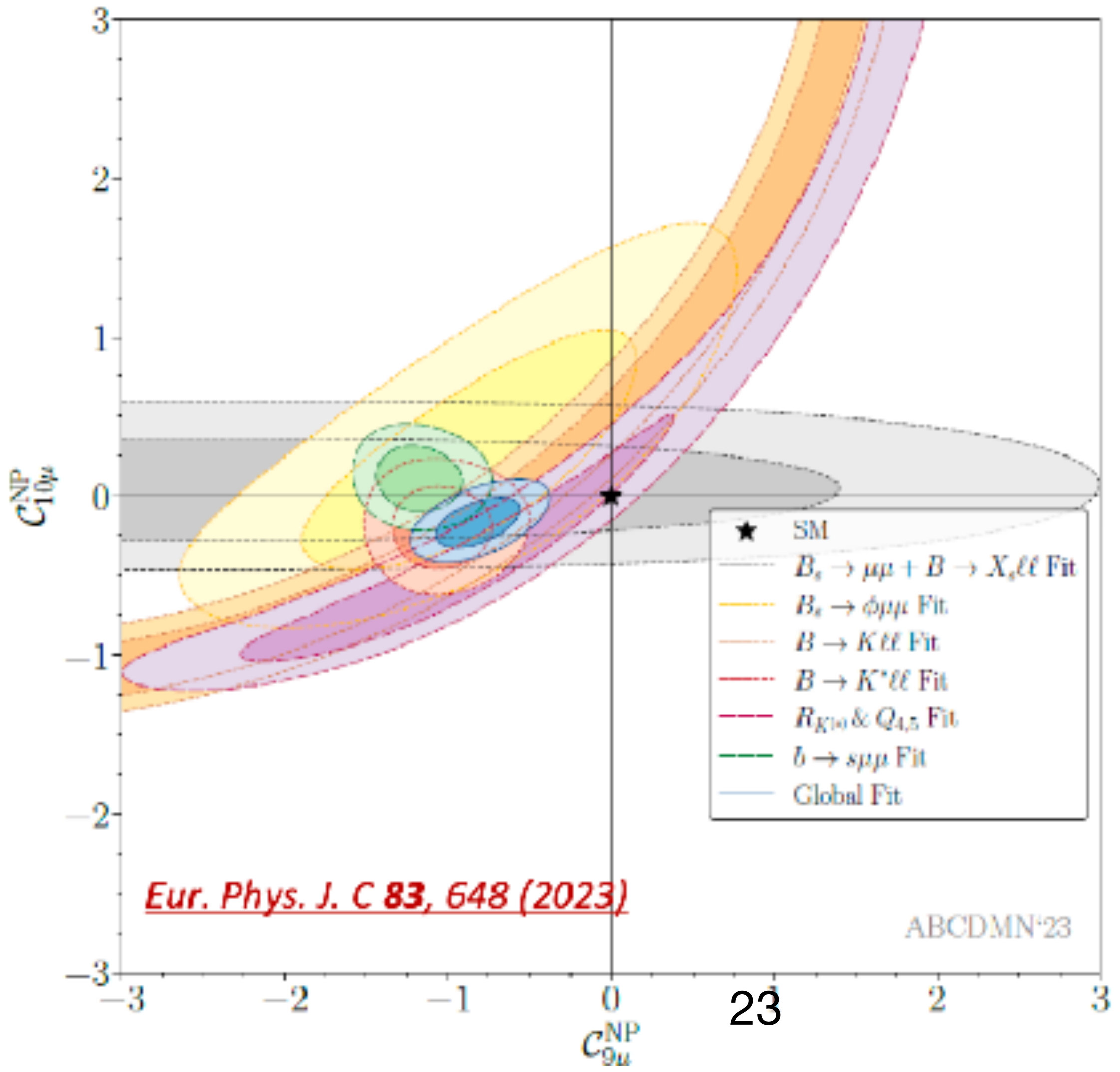
Indirect NP searches: precision measurements

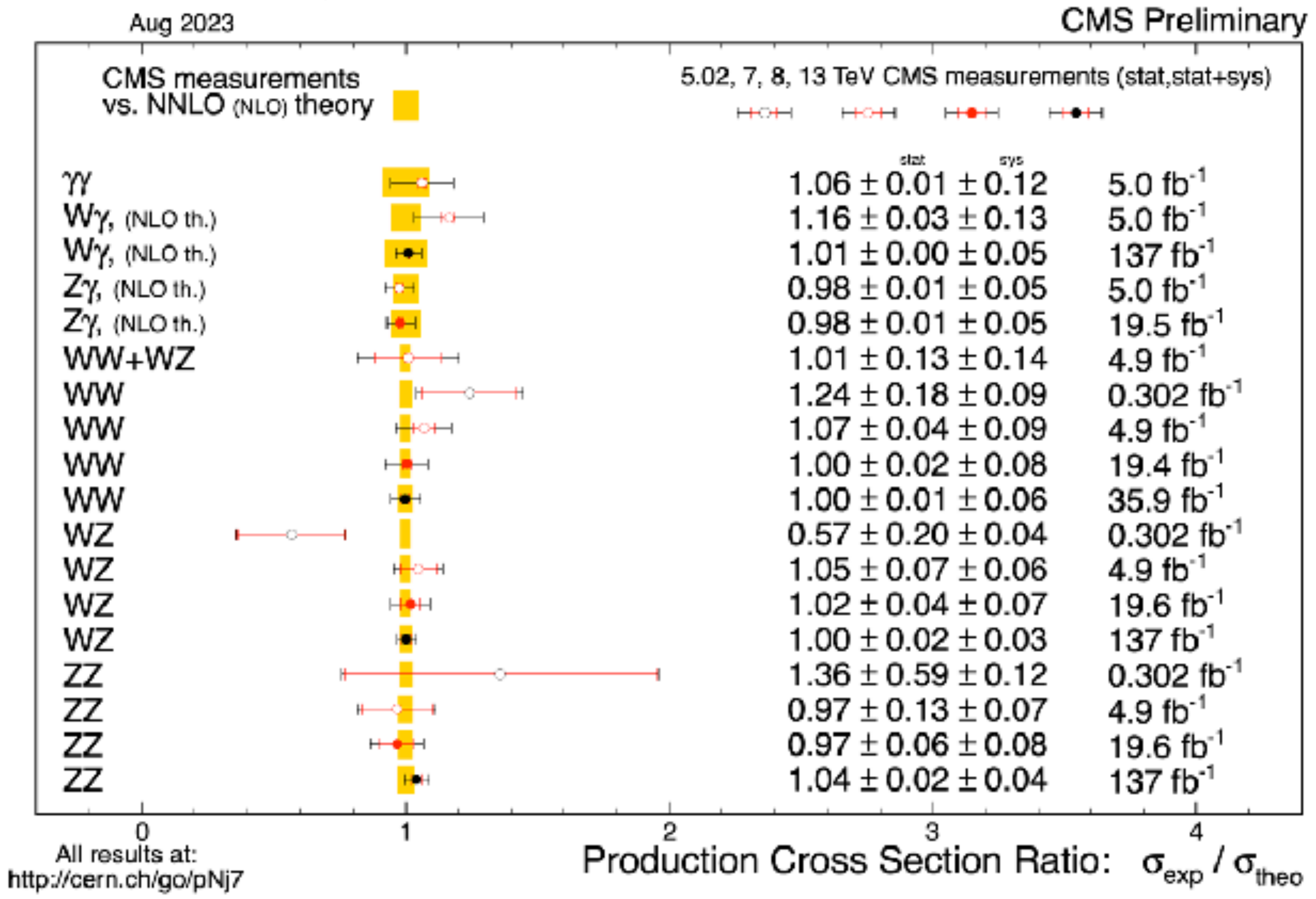






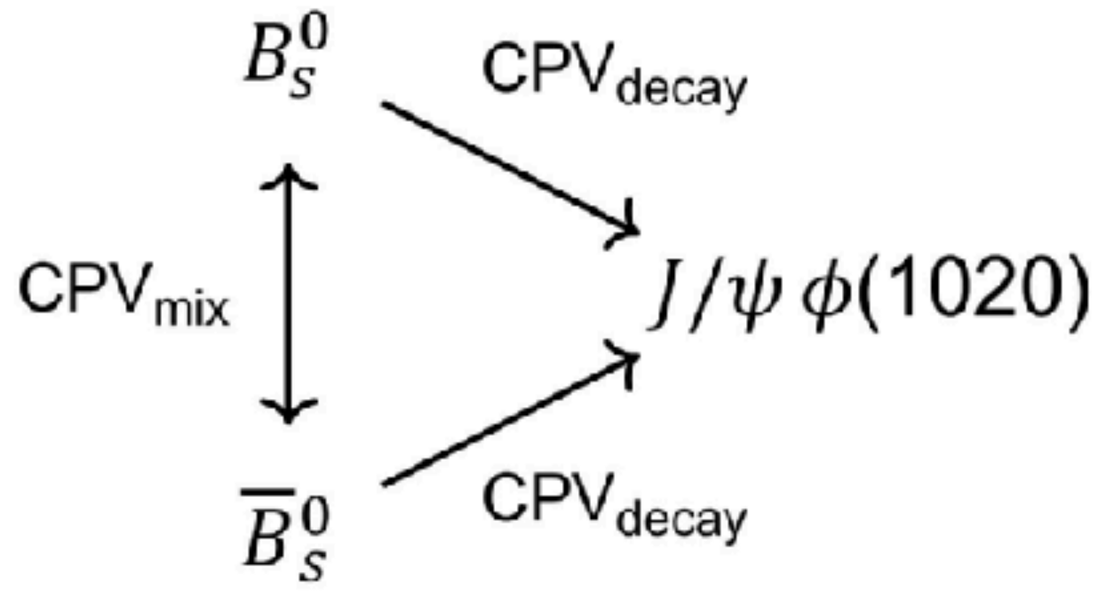


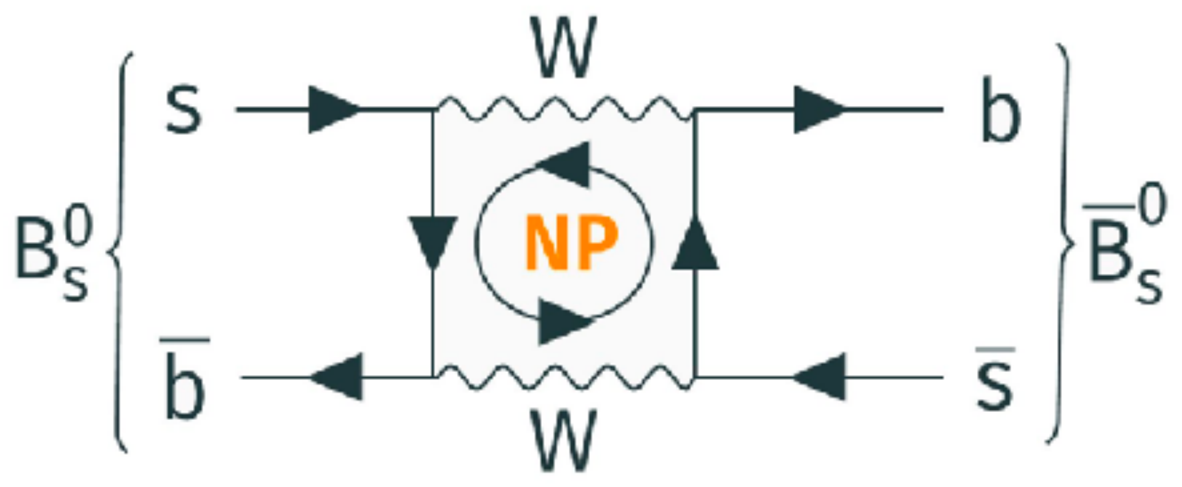




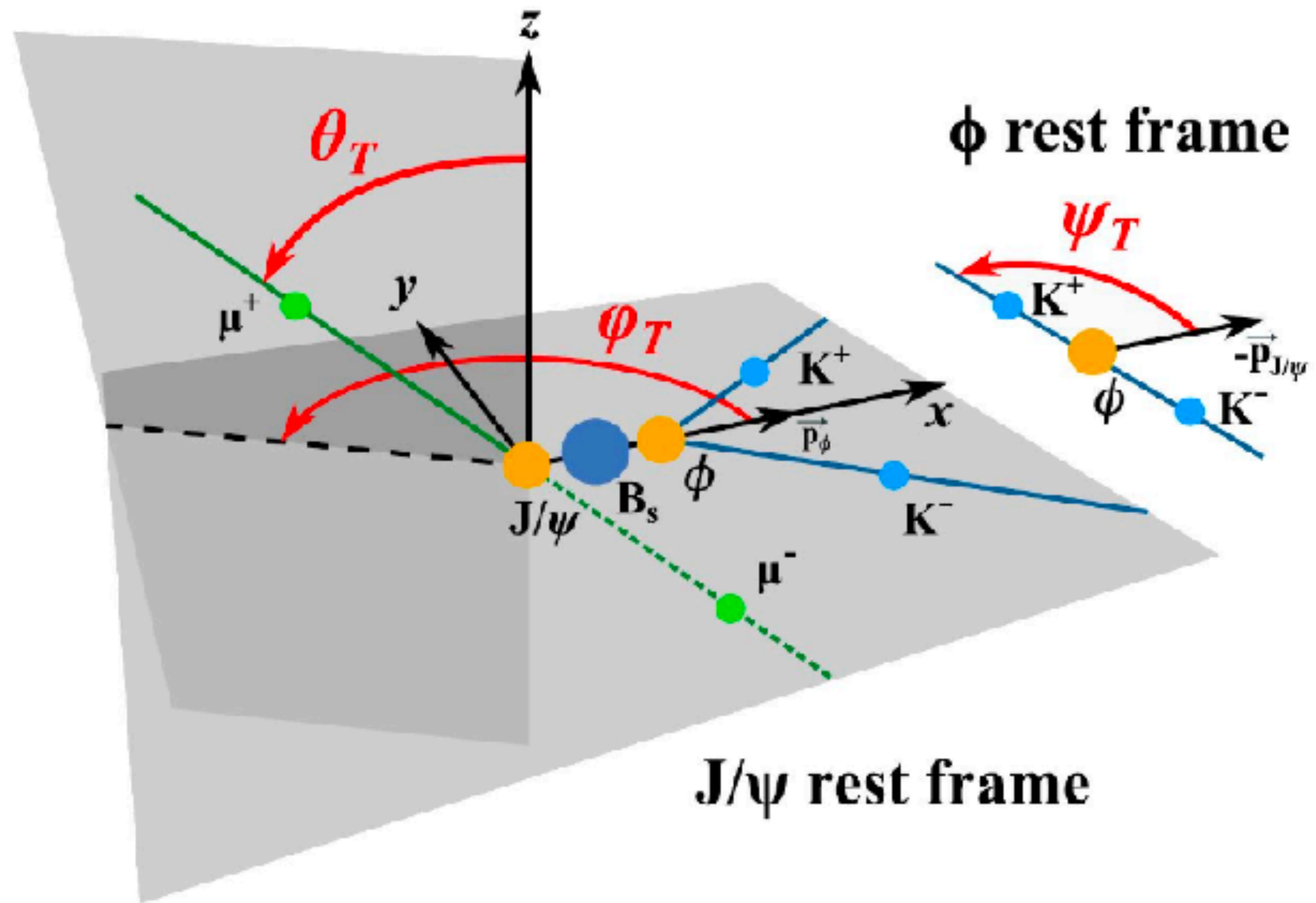
CP violation: beauty

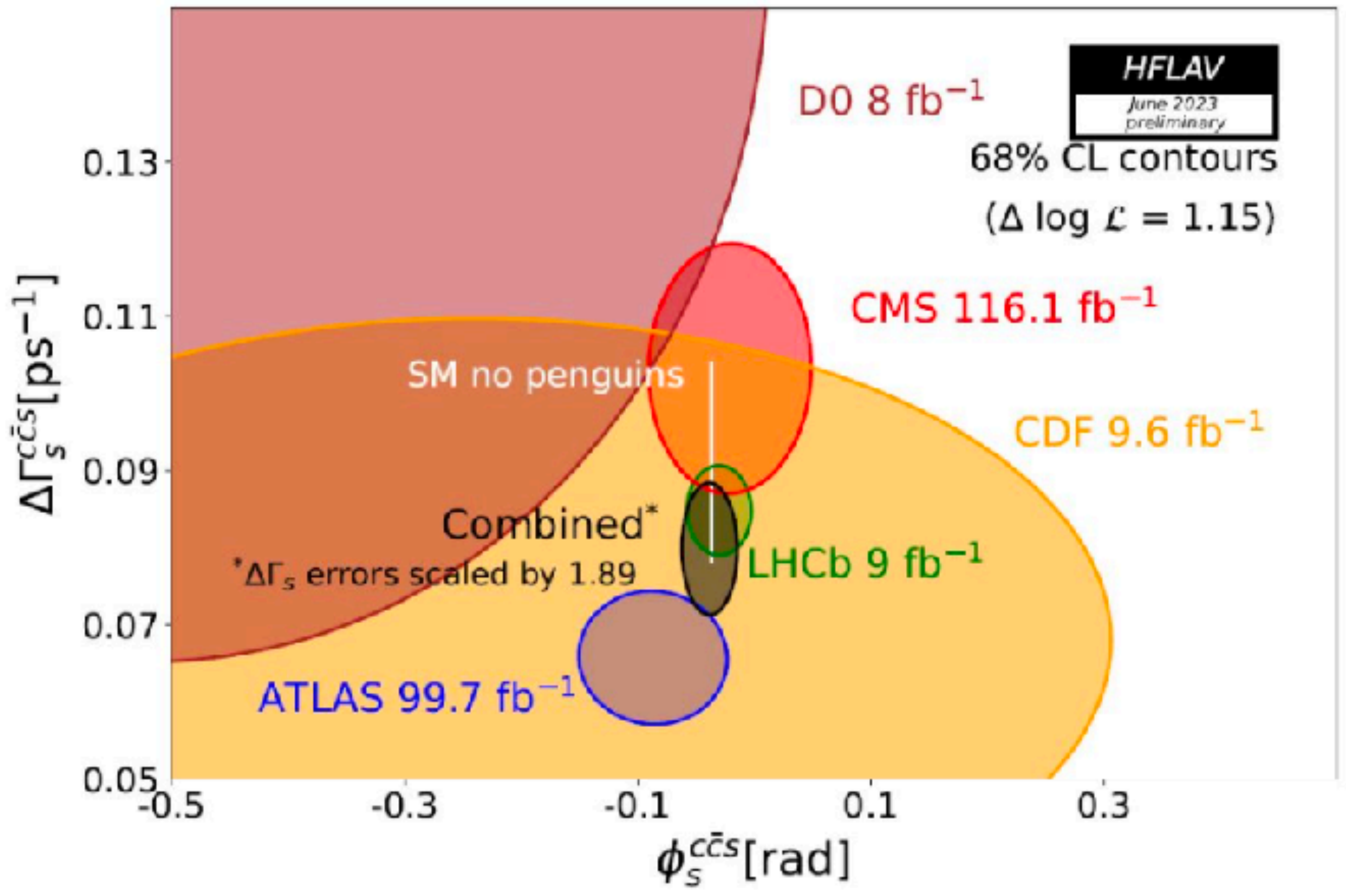
- CPV in interference between mixing and decay of $B_s \to J/\psi\Phi$
- Measure the weak phase $\Phi_s \approx -2\beta_s + \Phi_s^{NP}$
- New physics can change Φ_s sizeably [B_s mixing]
- Core ingredients
  - time-dependent **angular** analysis
  - time-dependent **flavour** analysis
  - flavour **tagging**





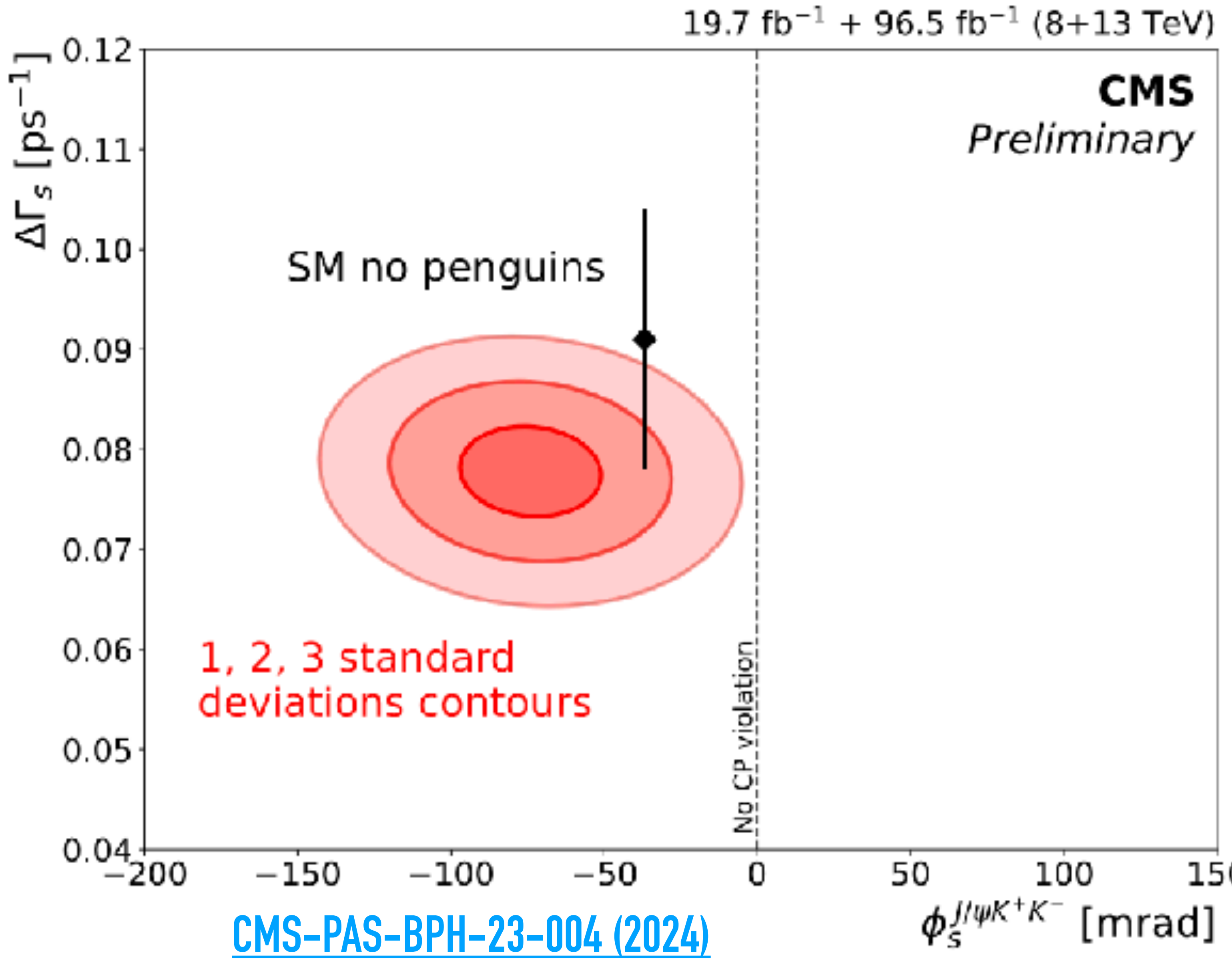
$$\Gamma\left(B_s^0{}_{(\rightsquigarrow \overline{B}_s^0)} \to f\right)(t) \overset{?}{\neq} \Gamma\left(\overline{B}_s^0{}_{(\rightsquigarrow B_s^0)} \to f\right)(t)$$





CP violation: beauty

- First **evidence** of CP violation in this decay ($\Phi_s \neq 0$)
- *Decisive* analysis improvement: **flavour tagging**
  - opposite-side algorithms: muon, electron, jet charge
  - **same-side** algorithm developed and deployed first time
  - use state-of-the-art ML techniques
  - reached best performance at hadron colliders (~Tevatron)

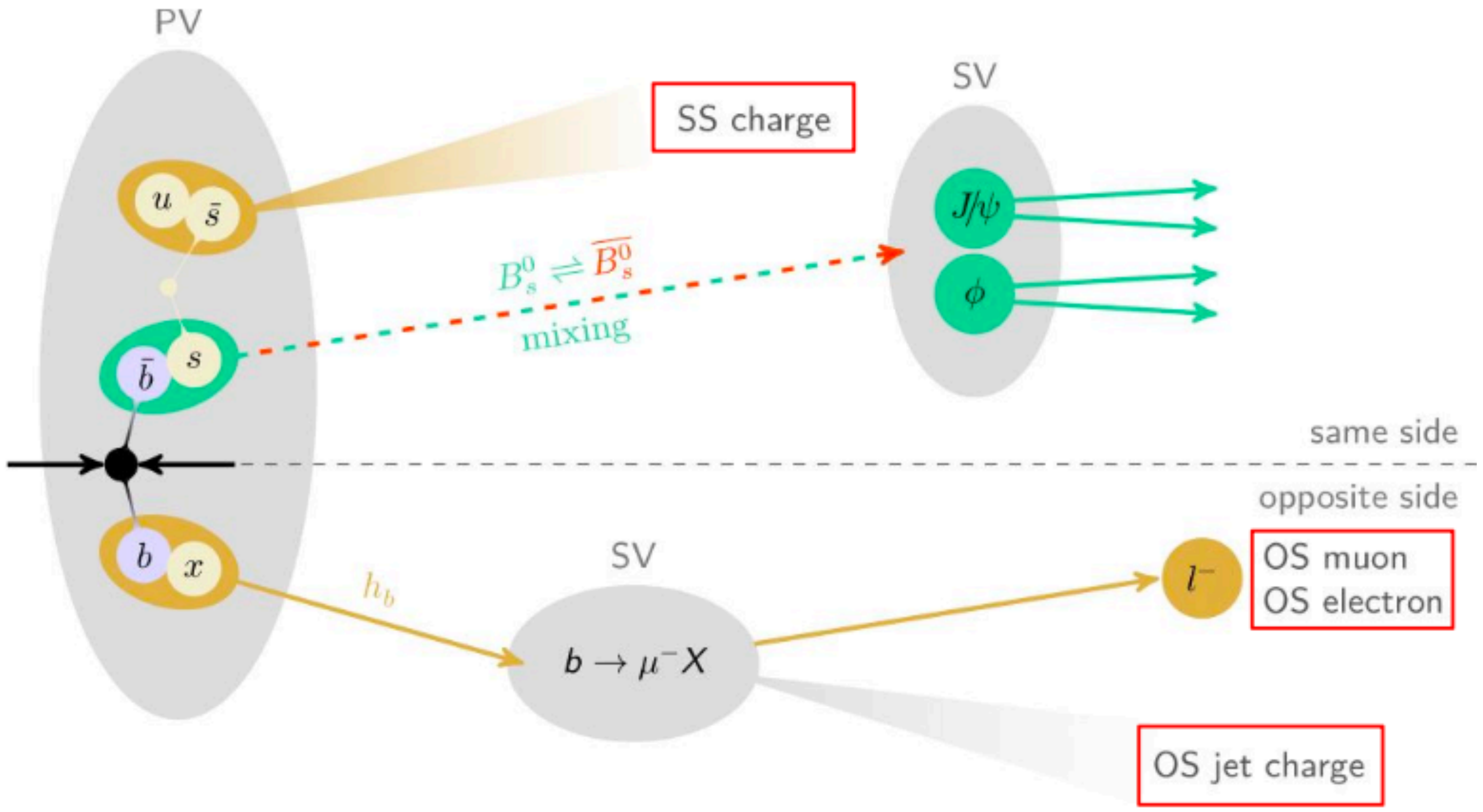


CMS-PAS-BPH-23-004 (2024)

$$\text{sensitivity} \propto \sqrt{\frac{\boxed{\epsilon_{tag}\mathcal{D}^2_{tag}} N_{sig}}{2}} \sqrt{\frac{N_{sig}}{N_{sig}+N_{bkg}}}\, e^{-\frac{\sigma_t^2 \Delta m_s^2}{2}}$$

- statistics + σ_t + flavour tagging

Category	ε_{tag} [%]	$\mathcal{D}^2_{eff}$	P_{tag} [%]
Only OS muon	6.07 ± 0.05	0.212	1.29 ± 0.07
Only OS electron	2.72 ± 0.02	0.079	0.214 ± 0.004
Only OS jet	5.16 ± 0.03	0.045	0.235 ± 0.003
Only SS	33.12 ± 0.07	0.080	2.64 ± 0.01
SS + OS muon	0.62 ± 0.01	0.202	0.125 ± 0.003
SS + OS electron	2.77 ± 0.02	0.150	0.416 ± 0.005
SS + OS jet	5.40 ± 0.03	0.124	0.671 ± 0.006
Total	55.9 ± 0.1	0.100	5.59 ± 0.02



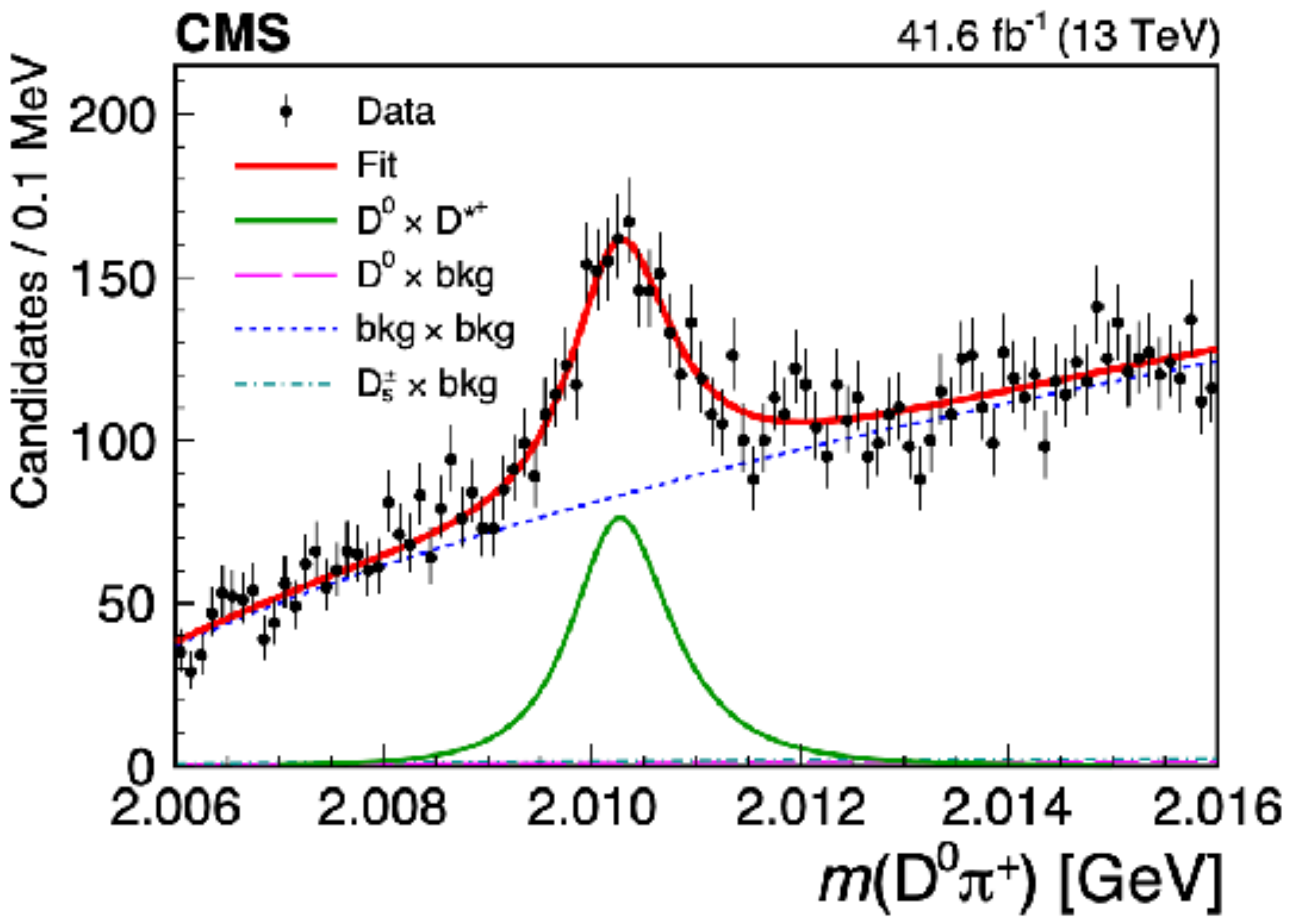
CP violation: charm

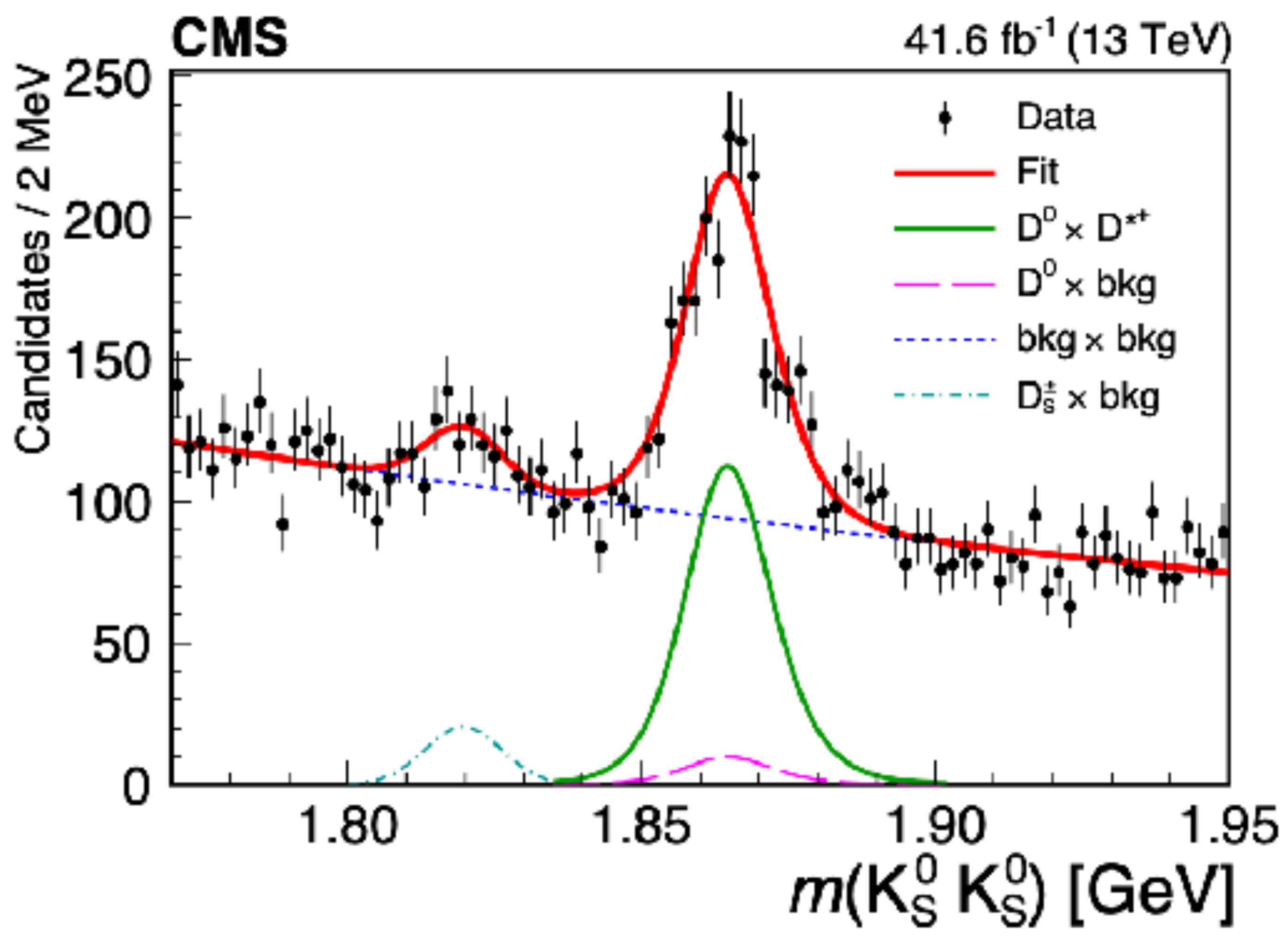
CMS-BPH-23-005, arXiv:2405.11606

- CPV in up-quark sector not as studied as in down sector
  - observed by LHCb in 2019 in $D^0 \to K^+K^- / \pi^+\pi^-$
- amount of CPV in D sector suppressed by GIM, CKM
- explore fully hadronic channels collected in parked stream
  - D^0 mesons from $D^{\pm *} \to D^0\pi^\pm$, where π charge tags D^0 flavour
- measure the CP asymmetry in $D^0 \to K_s K_s$ decay

$$A_{CP}(K_S^0K_S^0) = \frac{\Gamma(D^0 \to K_S^0K_S^0) - \Gamma(\overline{D}^0 \to K_S^0K_S^0)}{\Gamma(D^0 \to K_S^0K_S^0) + \Gamma(\overline{D}^0 \to K_S^0K_S^0)}$$

  - $D^0 \to K_s \pi^+\pi^-$ used to cancel production/detection efficiencies
  - $A_{CP}(K_sK_s) = 6.2 \pm 3.0 \pm 0.2 \pm 0.8\ (A_{CP}(\pi^+\pi^-))\ \%$
  - consistent with no CPV (2σ), and LHCb (2.7σ), Belle (1.8σ)
  - **first** direct CPV measurement by CMS in the charm sector





Weak mixing angle

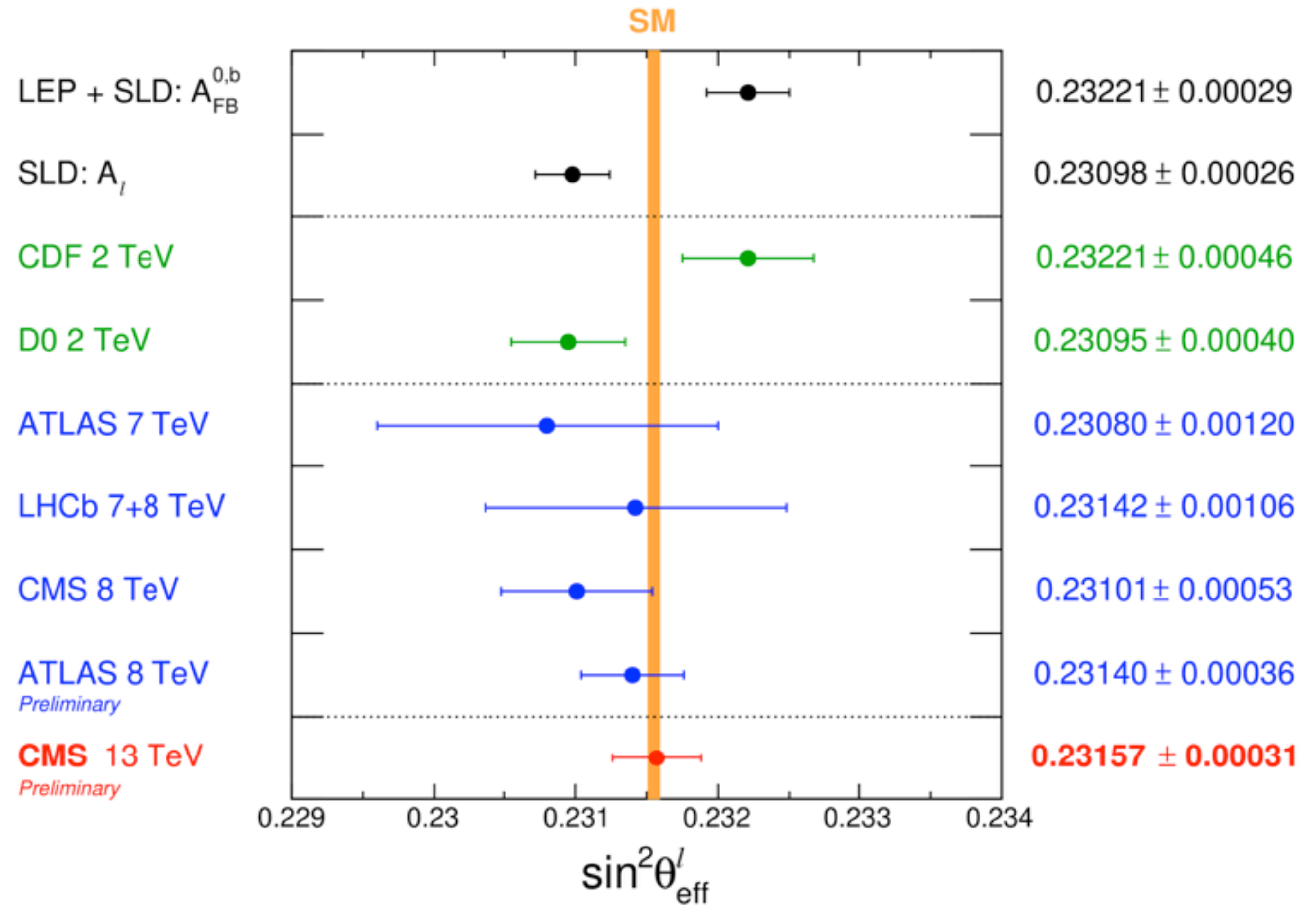
CMS-PAS-SMP-22-010

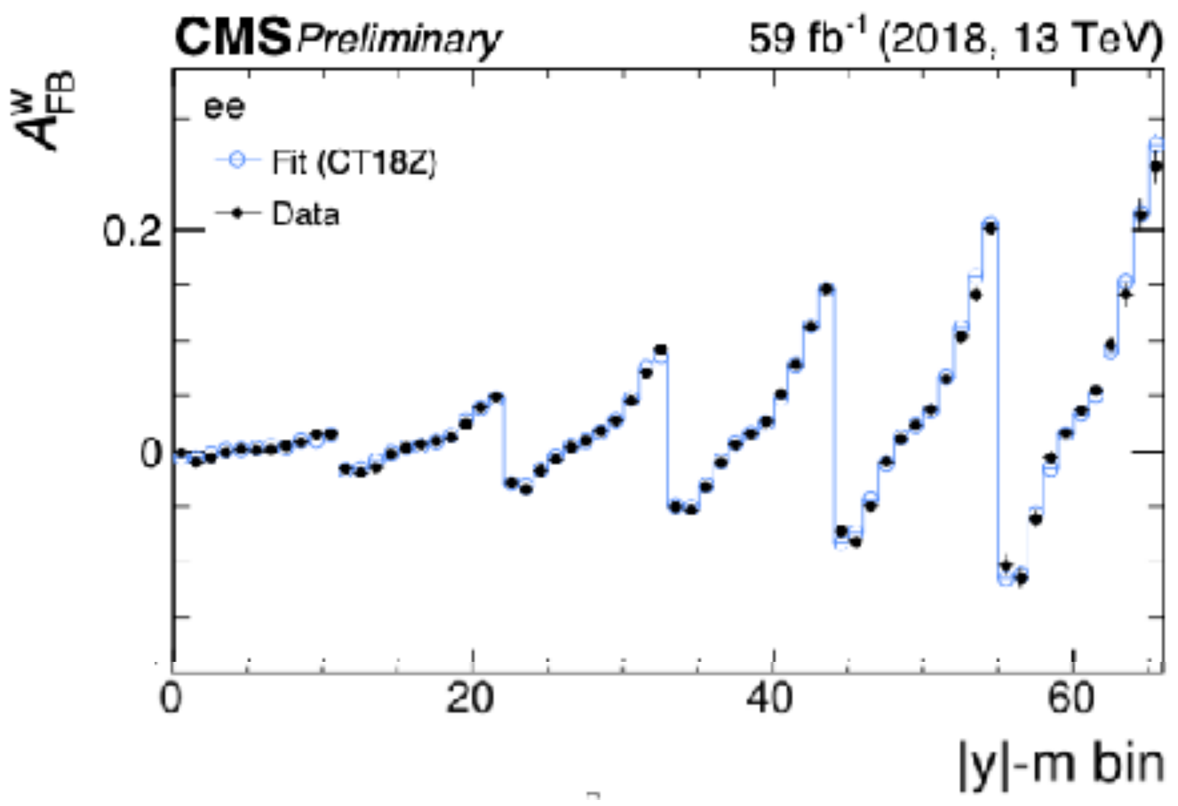
- precision measurement of EWK key parameter

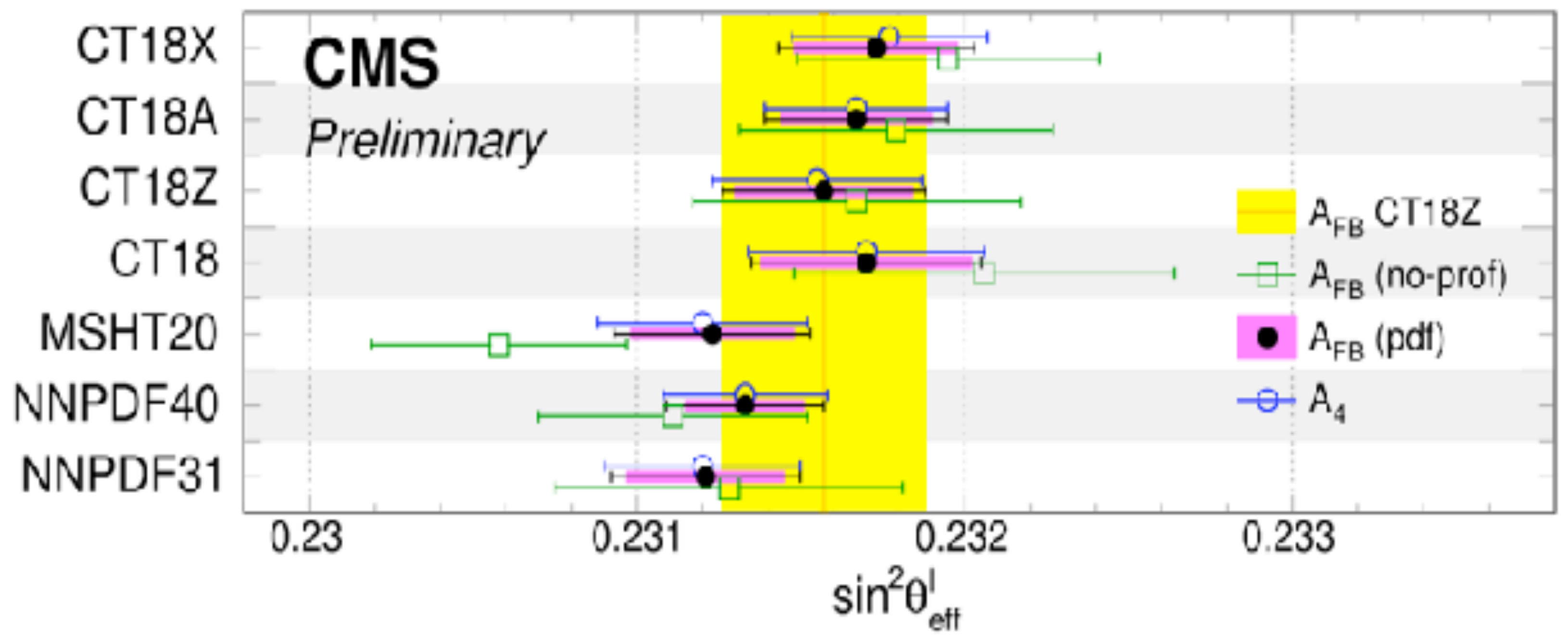
$$\sin^2\theta^\ell_{\text{eff}} = \kappa(1 - m^2_{\text{W}}/m^2_{\text{Z}})$$

- effective mixing angle extracted from A_{FB}(ee,μμ)
  - of Z/γ→ll, measured in bins of y(ll) and m(ll)
- different PDF sets are profiled (nominal: CT18Z)

$$\boxed{\sin^2\theta^\ell_{eff} = 0.23157 \pm 0.00010(stat) \pm 0.00015(syst) \pm 0.00009(theo) \pm 0.00027(PDF)}$$



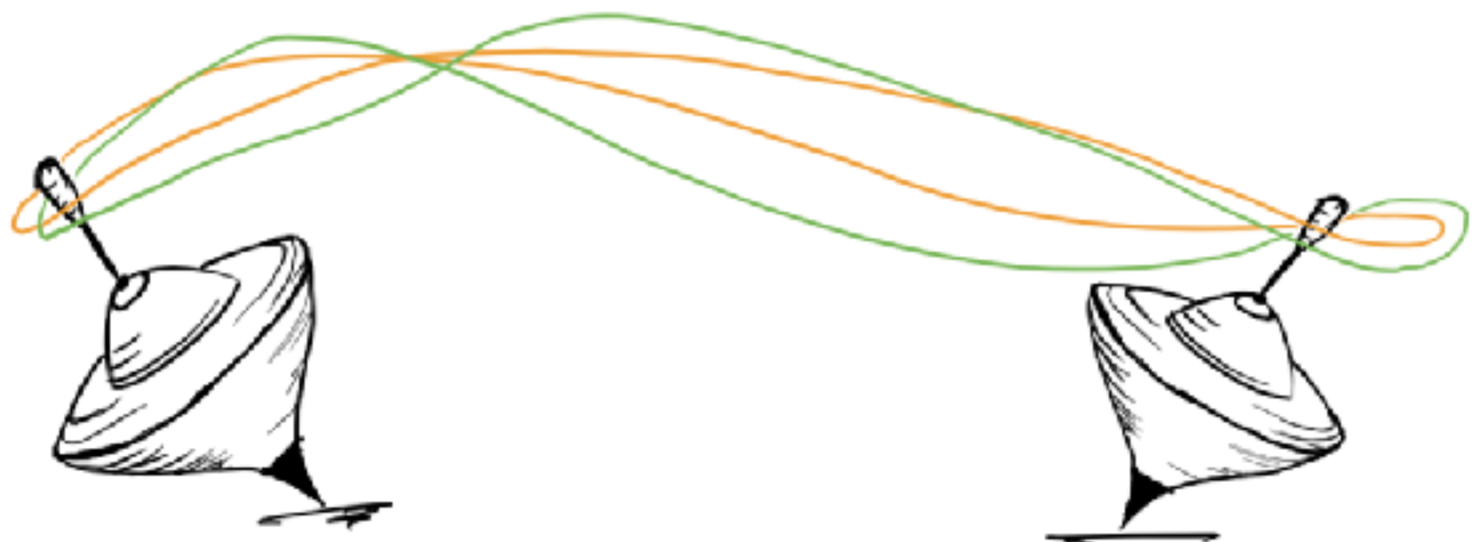


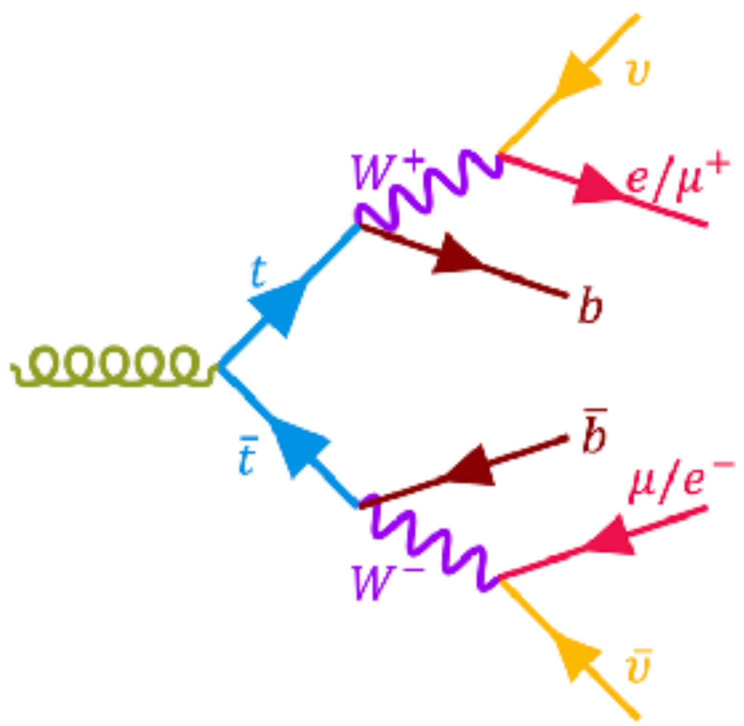


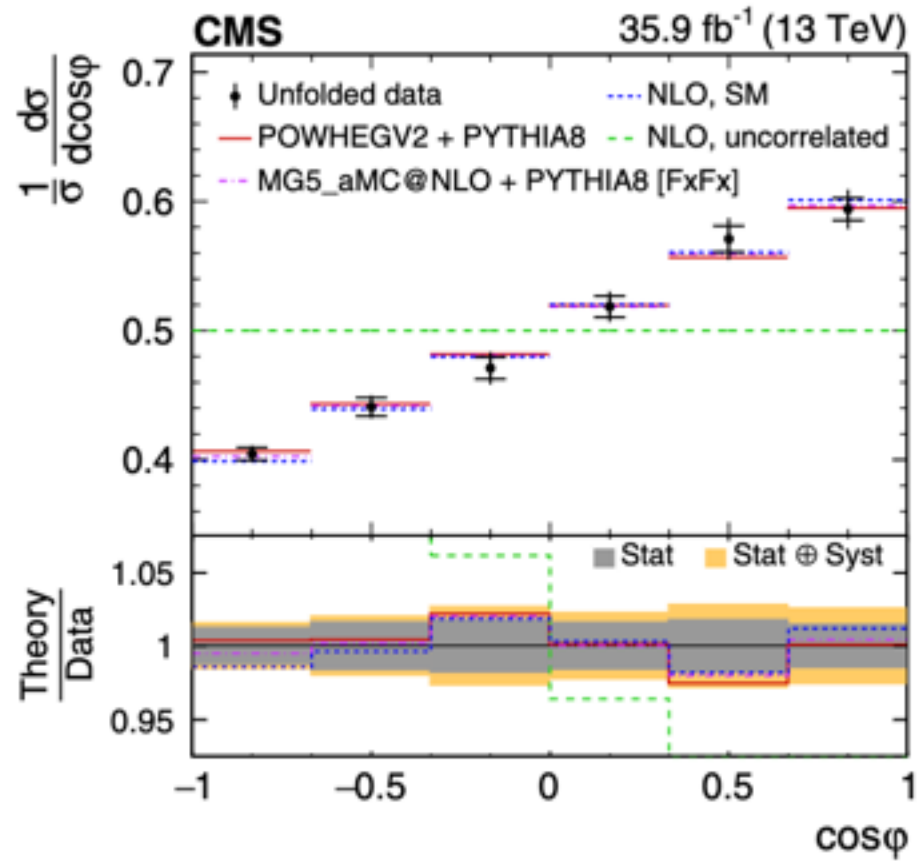
- best hadron collider measurement
- matches LEP/SLD **precision**
- compatible with SM prediction
- helps resolve longstanding tension between previous measurements

Top entanglement

- entanglement present in top quark pairs can be measured using spin correlation variables







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$$\frac{1}{\sigma}\frac{d\sigma}{d\cos\varphi} = \frac{1}{2}(1 - D\cos\varphi)$$

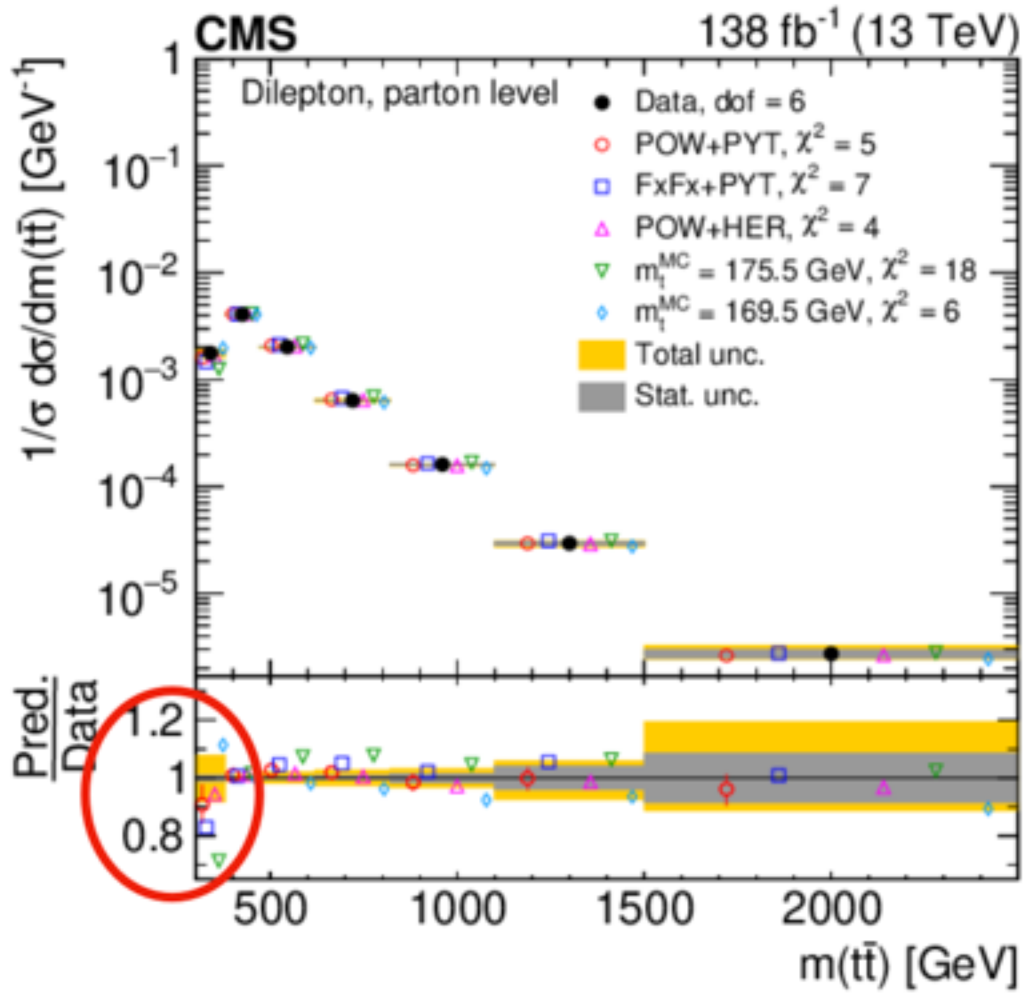
$$D = -\frac{\mathrm{tr}[C]}{3}$$

$$\cos\varphi = \hat{\ell}_1 \cdot \hat{\ell}_2$$

$$\mathrm{tr}[C] > 1$$

- sufficient condition for entanglement given by condition on entanglement proxy D: D<-1/3
- select low-mass region (345 <m_{tt}< 400 GeV): dominated by gg production, higher statistics

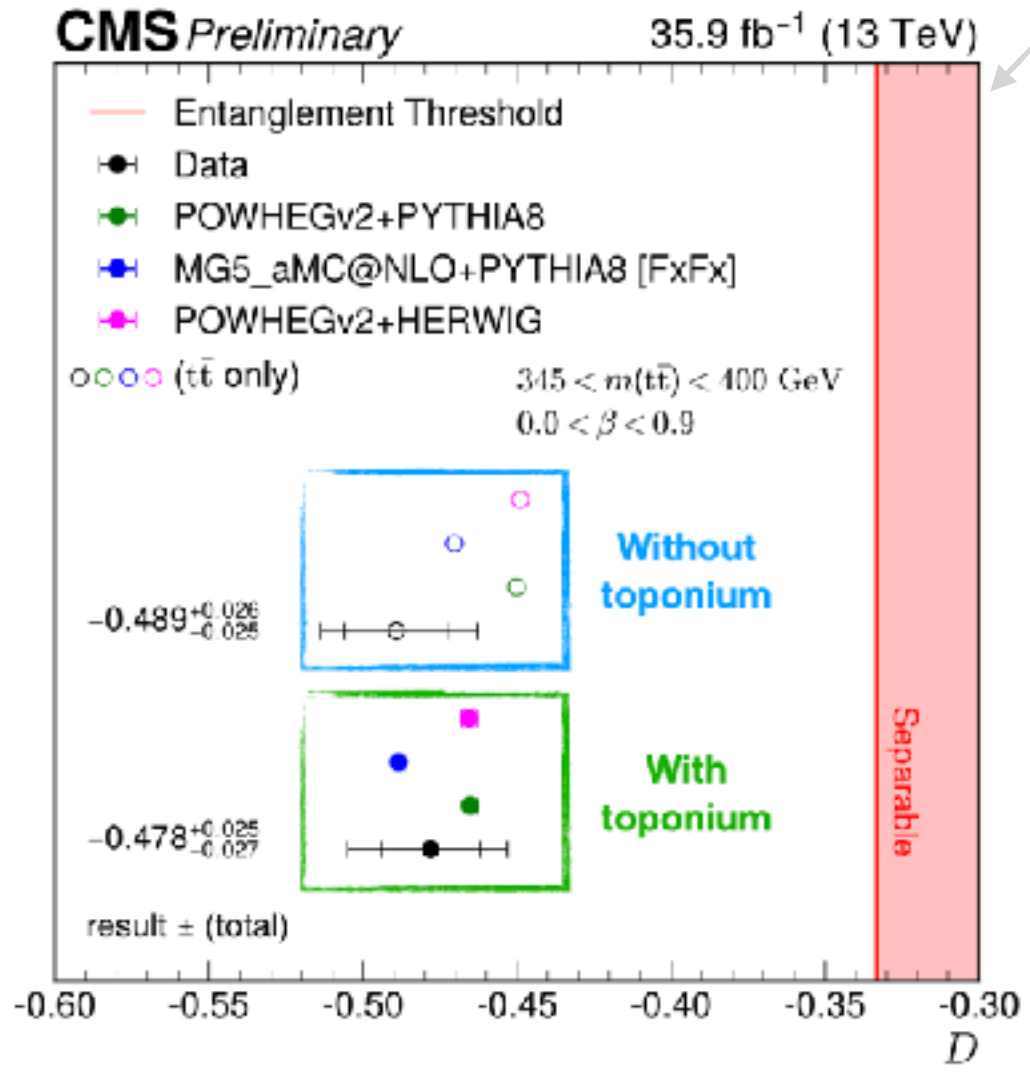
arXiv:2402.08486



↤ modelling improved including toponium
(effects from tt bound state near threshold)

$$\boxed{D_{obs} = -\,0.478 \pm 0.017(\mathrm{stat})^{+0.018}_{-0.021}(\mathrm{syst})}$$

➥ >5σ observation of **tt entanglement** ↦



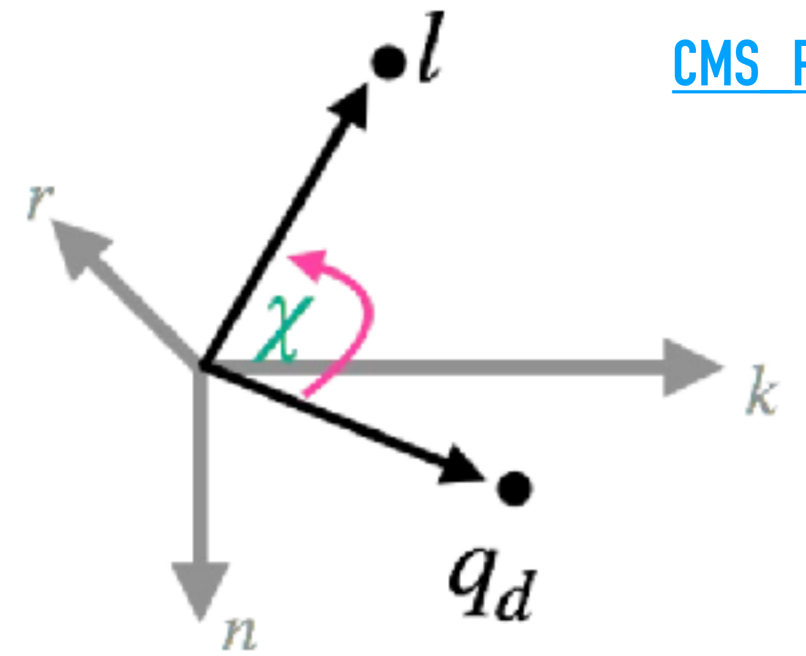
CMS-PAS-TOP-23-001, CMS-PAS-TOP-23-007

A step further

- measure polarisation (P) and spin correlation matrix (C)
  - from fit to angles of the two decay products (l, jet$_d$)
- maximally entangled states
  - at threshold: singlet ↦ higher sensitivity via dilepton channel
  - at high m(tt): triplet ↦ higher sensitivity via l + jets channel
- entanglement observed at 6.7σ, from full matrix and at high mass

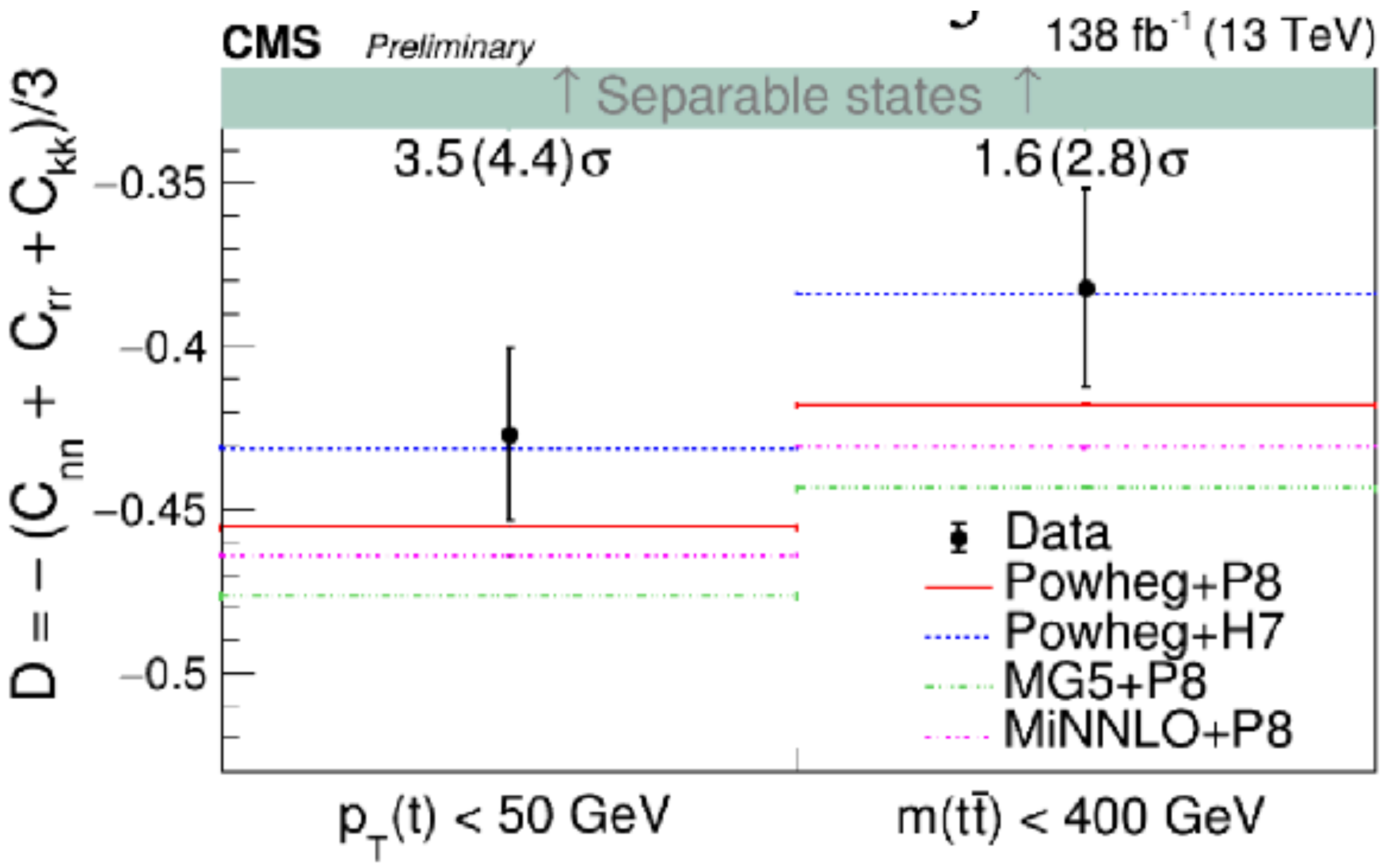
➡ explore single-lepton tt events

CMS_PAS-TOP-23-007



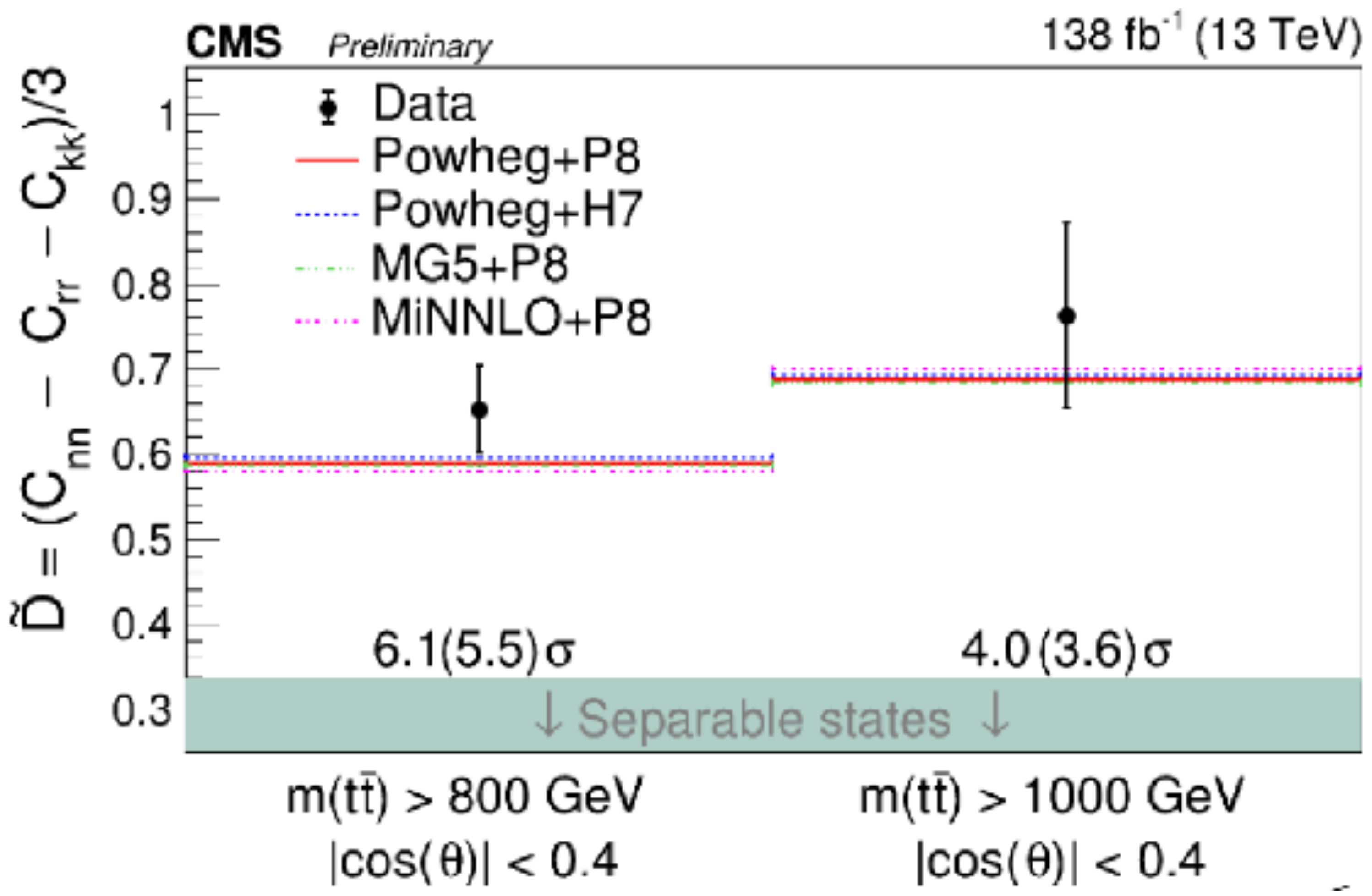
$$\frac{d\sigma}{d\cos\chi} = A(1 + D\kappa\bar{\kappa}\cos\chi)$$

$$C_{nn} + C_{rr} + C_{kk} = Tr(C) = -3D \rightarrow \boxed{D < -\frac{1}{3}}$$



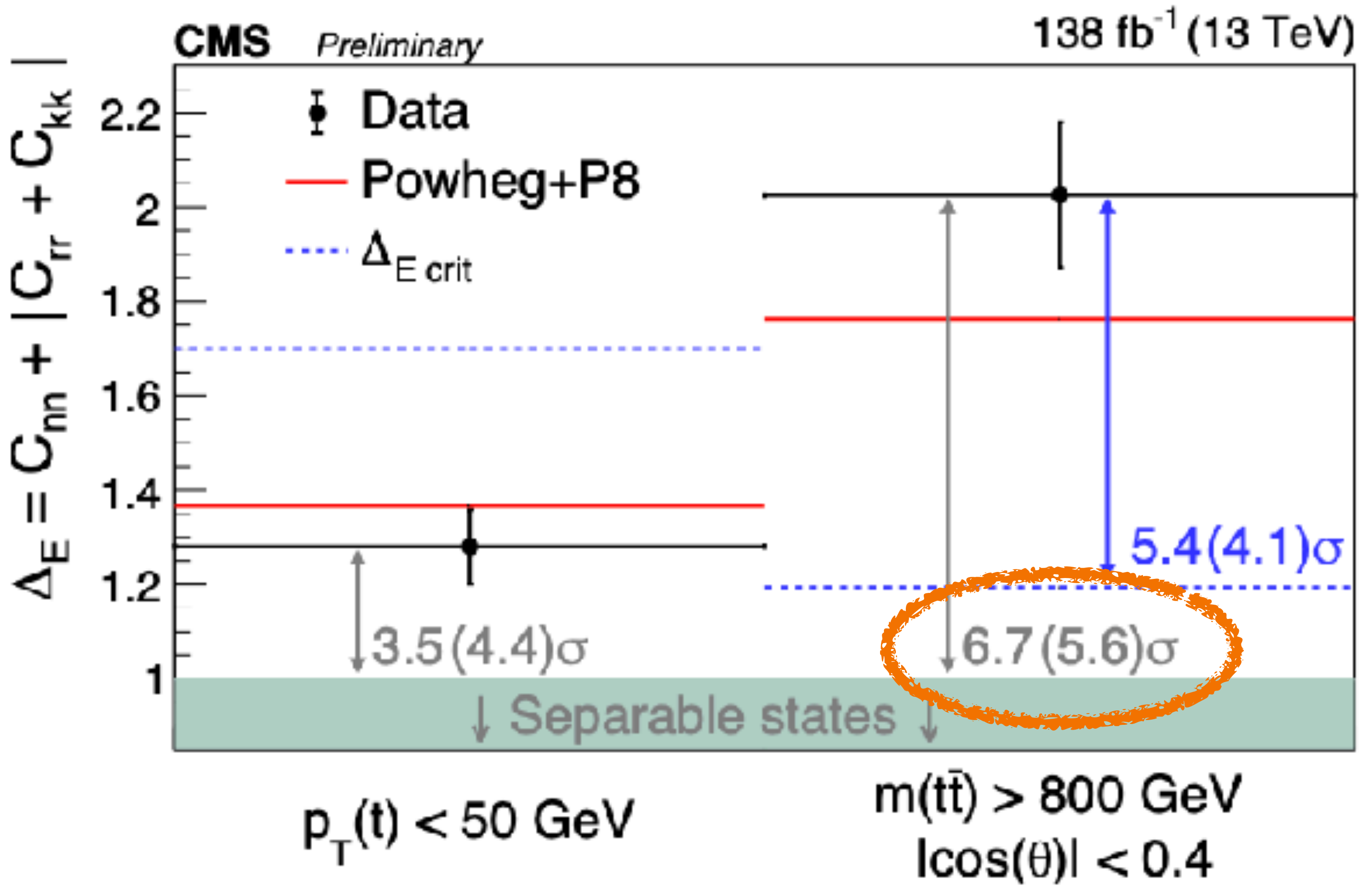
$$\frac{d\sigma}{d\cos\tilde{\chi}} = A(1 + \tilde{D}\kappa\bar{\kappa}\cos\tilde{\chi})$$

$$C_{nn} - C_{rr} - C_{kk} = 3\tilde{D} \rightarrow \boxed{\tilde{D} > \frac{1}{3}}$$



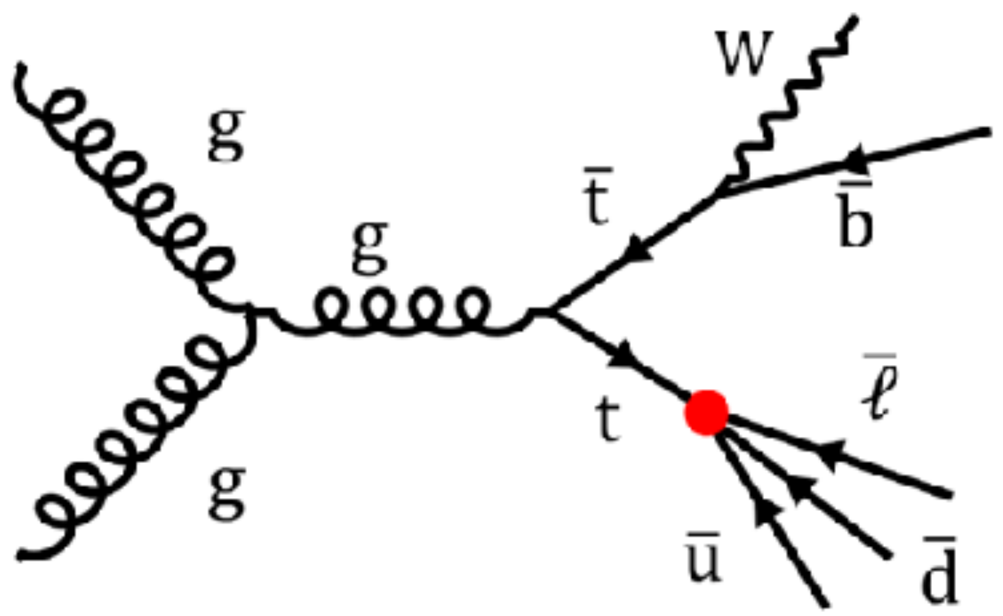
$$\frac{d\sigma}{d\Omega d\bar{\Omega}} = \sigma_{norm}(1 + \kappa\vec{P}\cdot\Omega + \bar{\kappa}\vec{\bar{P}}\cdot\bar{\Omega} - \kappa\bar{\kappa}\Omega\cdot C\cdot\bar{\Omega})$$

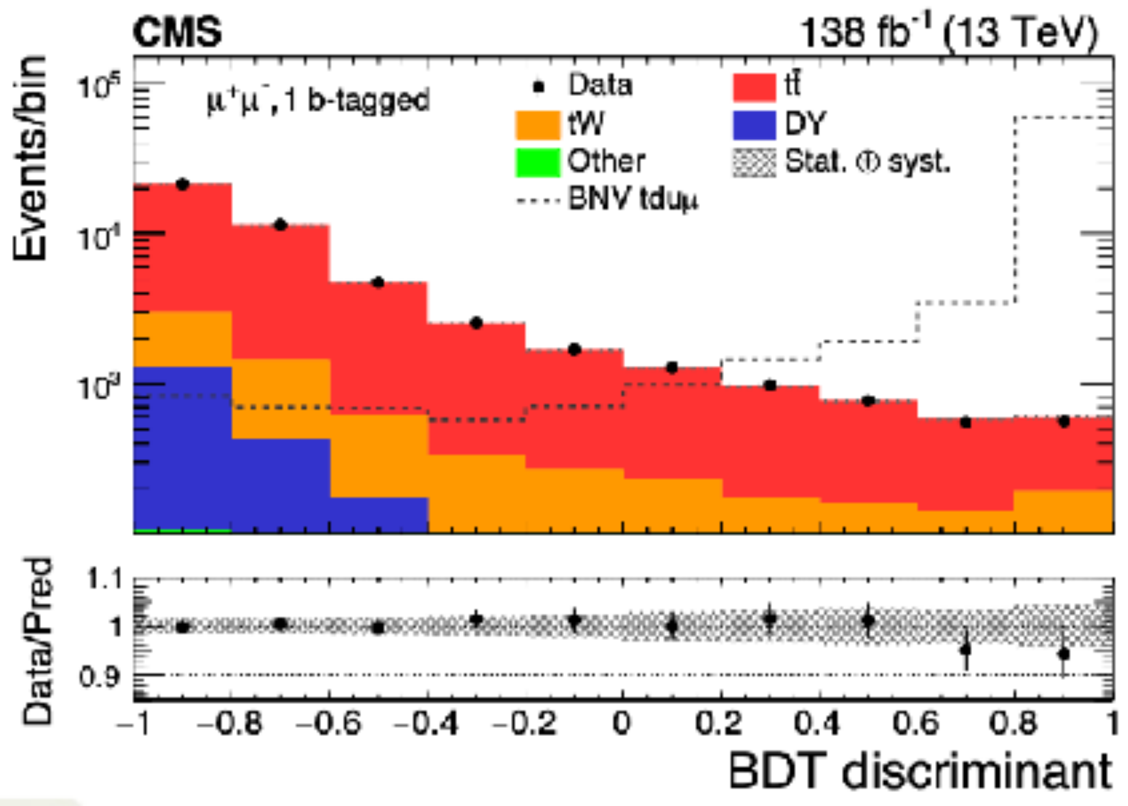
$$\Delta_E = C_{nn} + |C_{rr} + C_{kk}| > 1 \qquad \boxed{\Delta_E > 1}$$

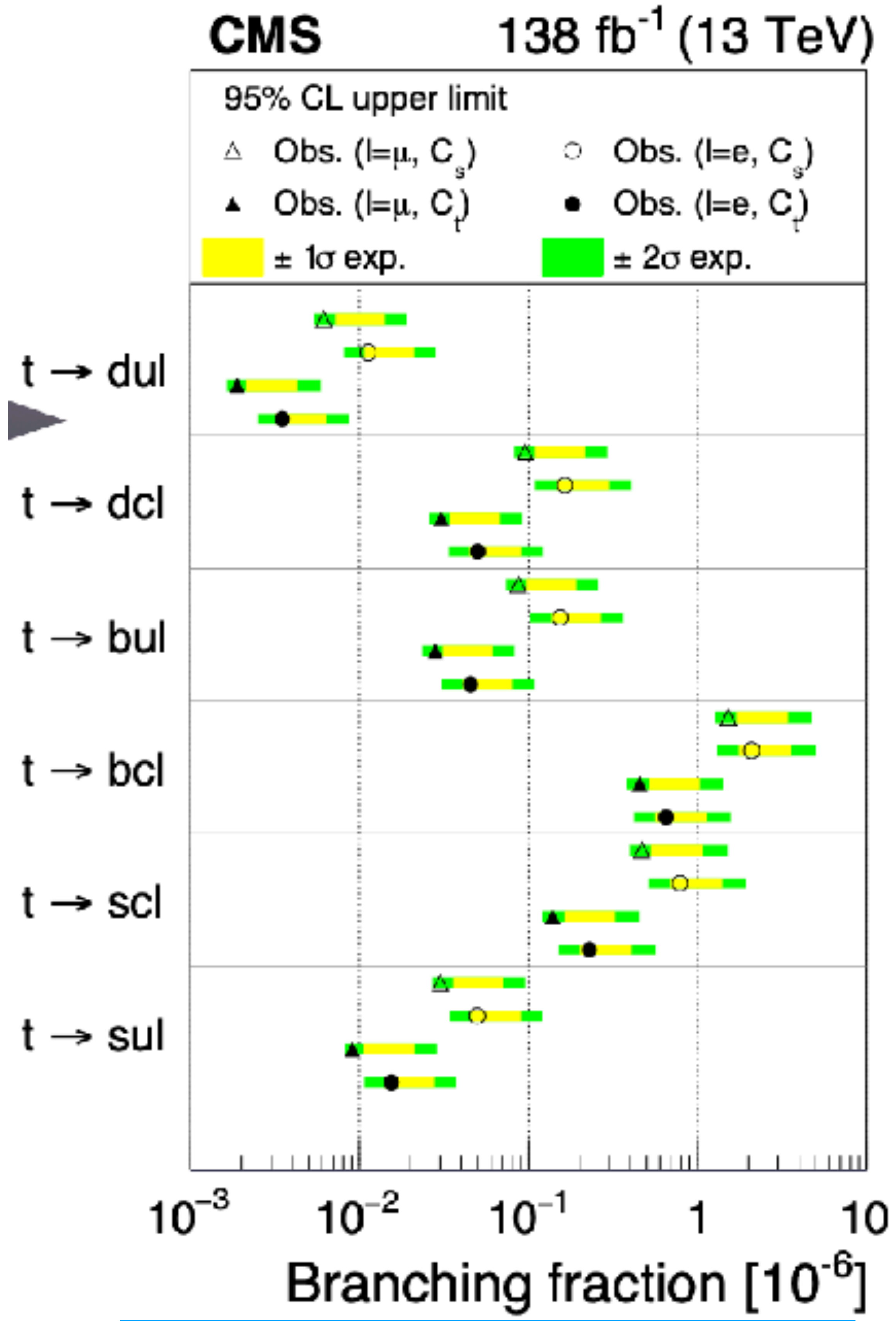


Search for symmetry violations: top (BNV, LFV)

- Baryon number violation (BNV)
  -

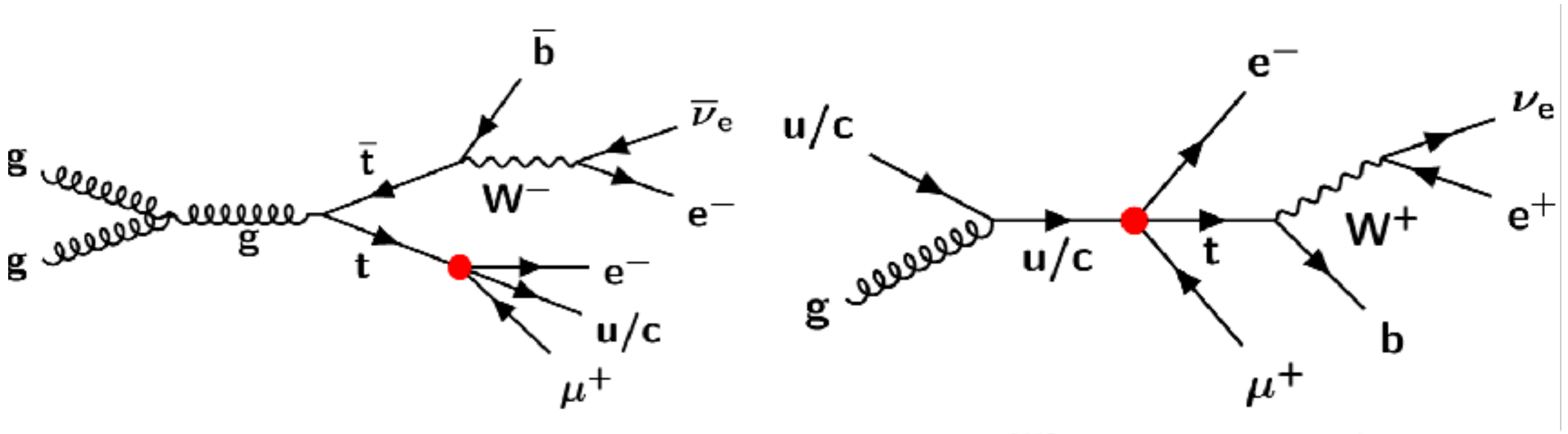




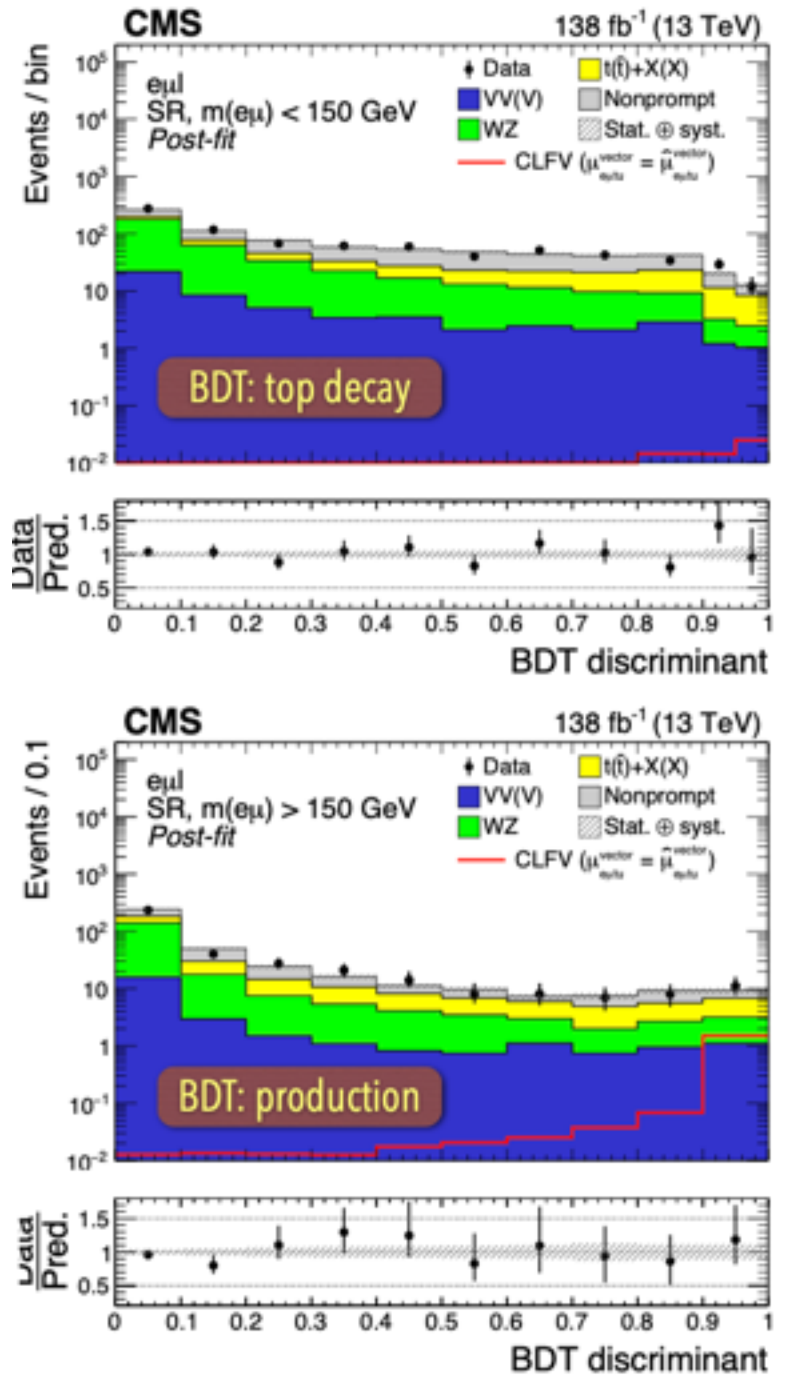


ULs: 2×10^{-9} to 2×10^{-6}

- Charged lepton flavour violation (CLFV)
  -



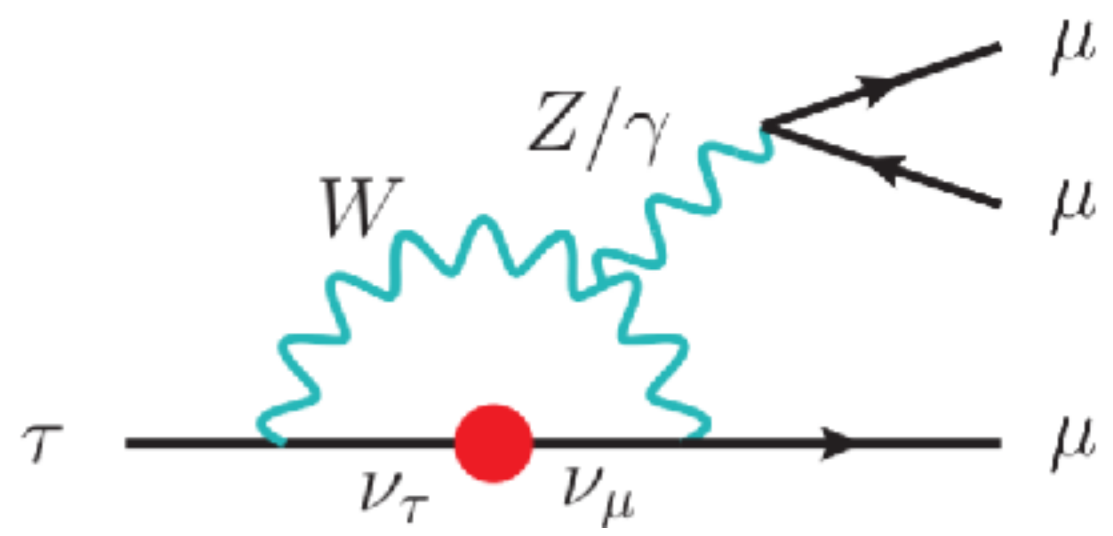
Coupling	Lorentz structure	Obs. limit
eμtu	tensor	3.2×10^{-8}
	vector	2.2×10^{-8}
	scalar	1.2×10^{-8}
eμtc	tensor	4.98×10^{-7}
	vector	3.69×10^{-7}
	scalar	2.16×10^{-7}

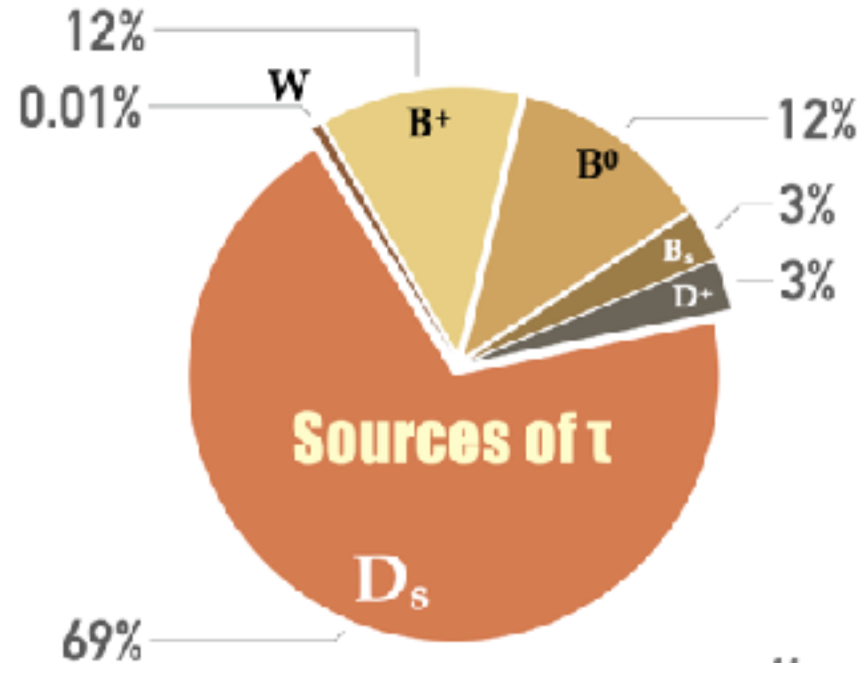


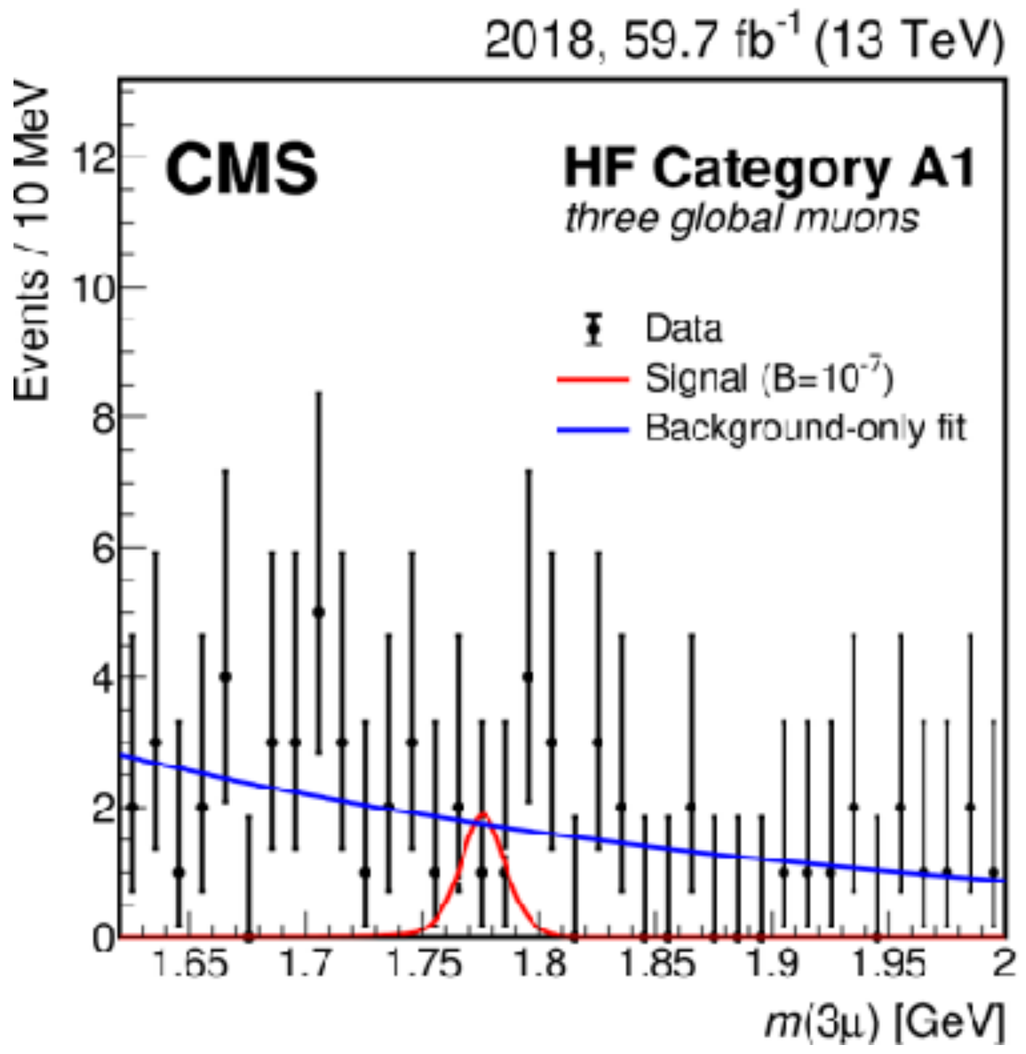
ULs: 3×10^{-8} to 5×10^{-7}

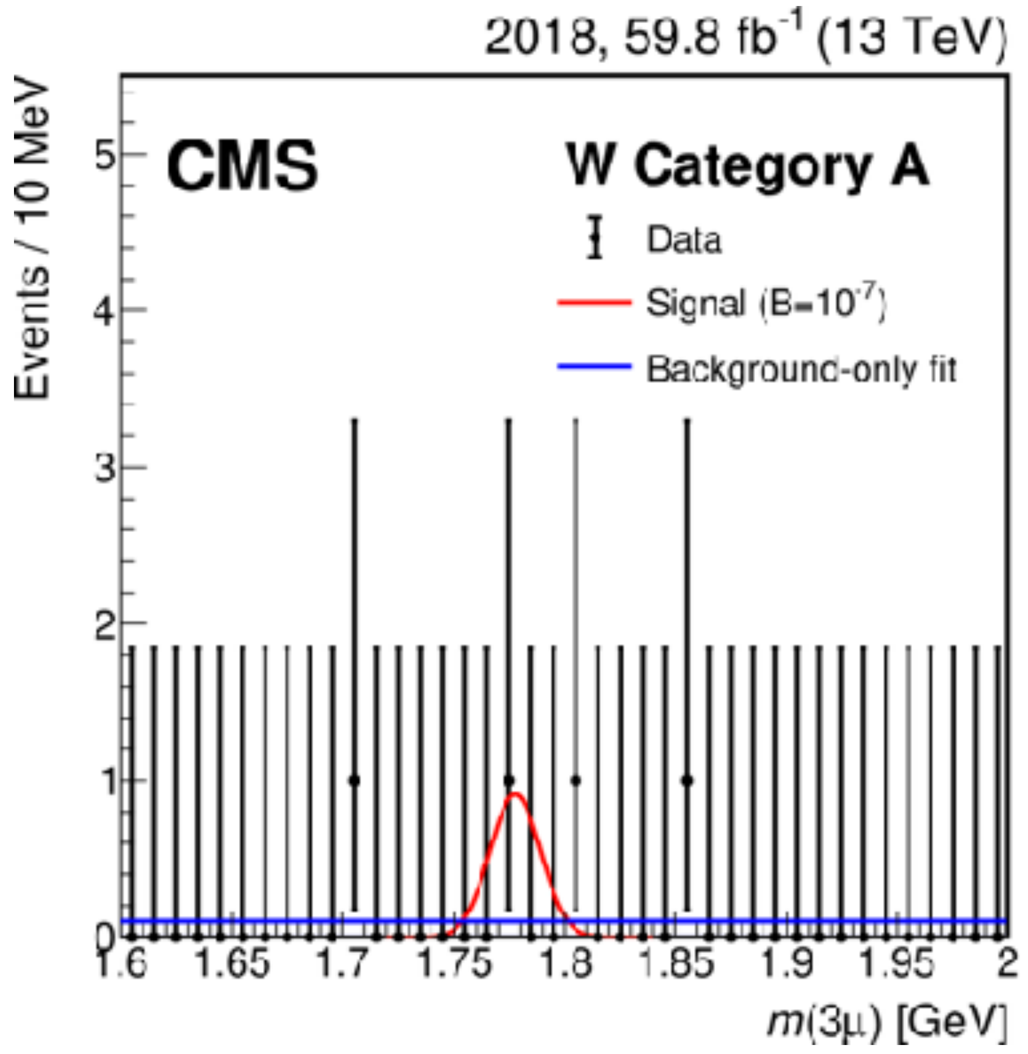
Search for symmetry violations: τau (CLFV)

- charged lepton flavour violating (CLFV) decay, $\tau \rightarrow 3\mu$
- inaccessible BF in SM, may be sizeably enhanced by NP
- explore complementary τ sources
  - Heavy flavour decay: dominant ($\sim 10^{11} \tau/\mathrm{fb}^{-1}$), low p_T, forward
  - W-boson decay: much less ($\sim 10^{7} \tau/\mathrm{fb}^{-1}$), but higher p_T, central
- event categories based on mass resolution, year, channel
- no signal hint observed, obtain combined Run2 UL results







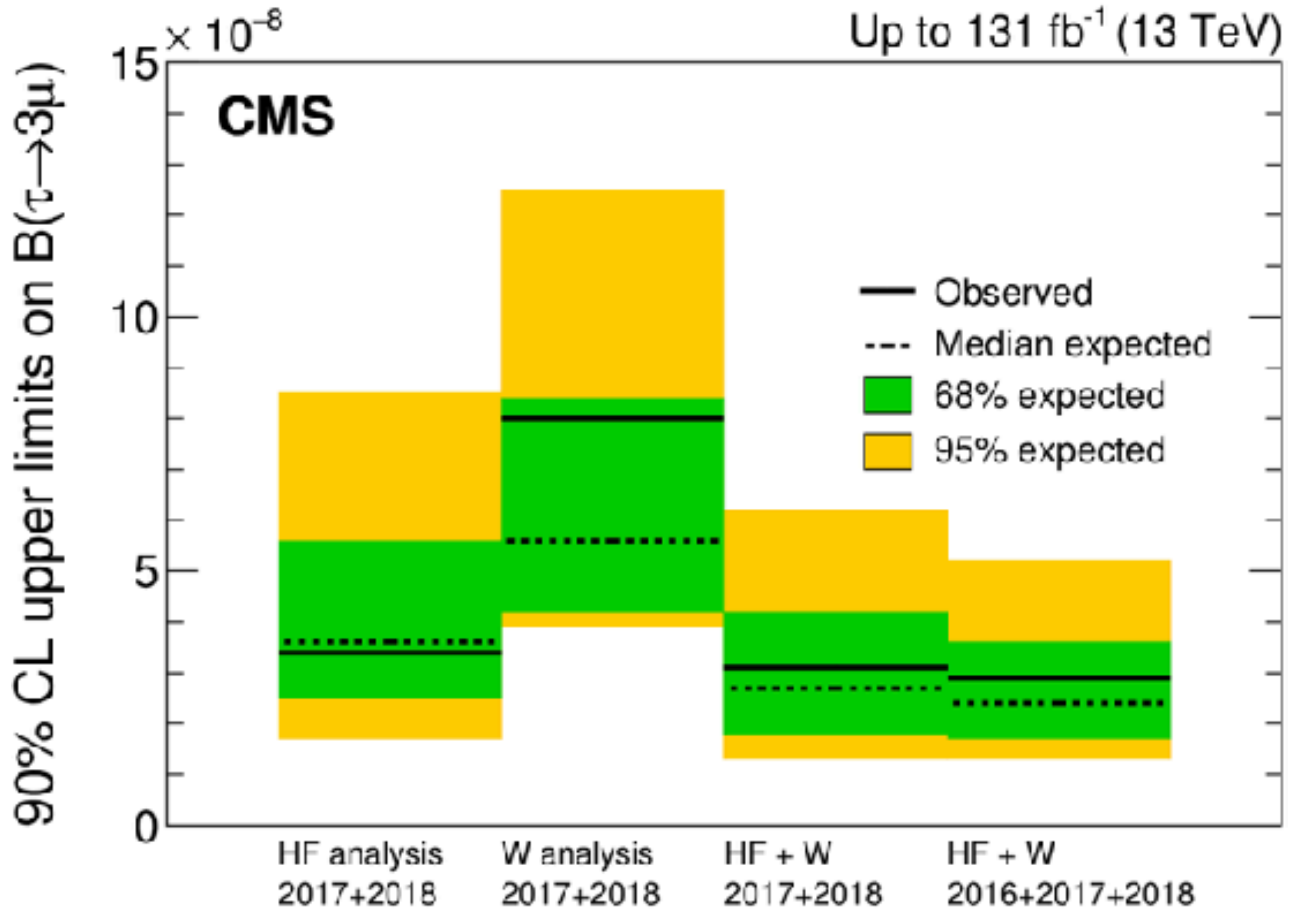


PLB 853 (2024) 138633

UL @90% CL:

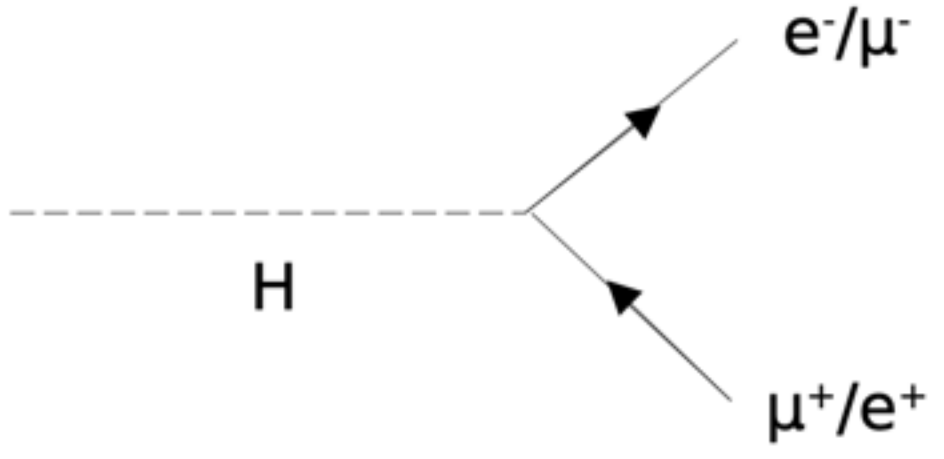
CMS
$<2.8 \times 10^{-8}$

Belle
$<1.9 \times 10^{-8}$

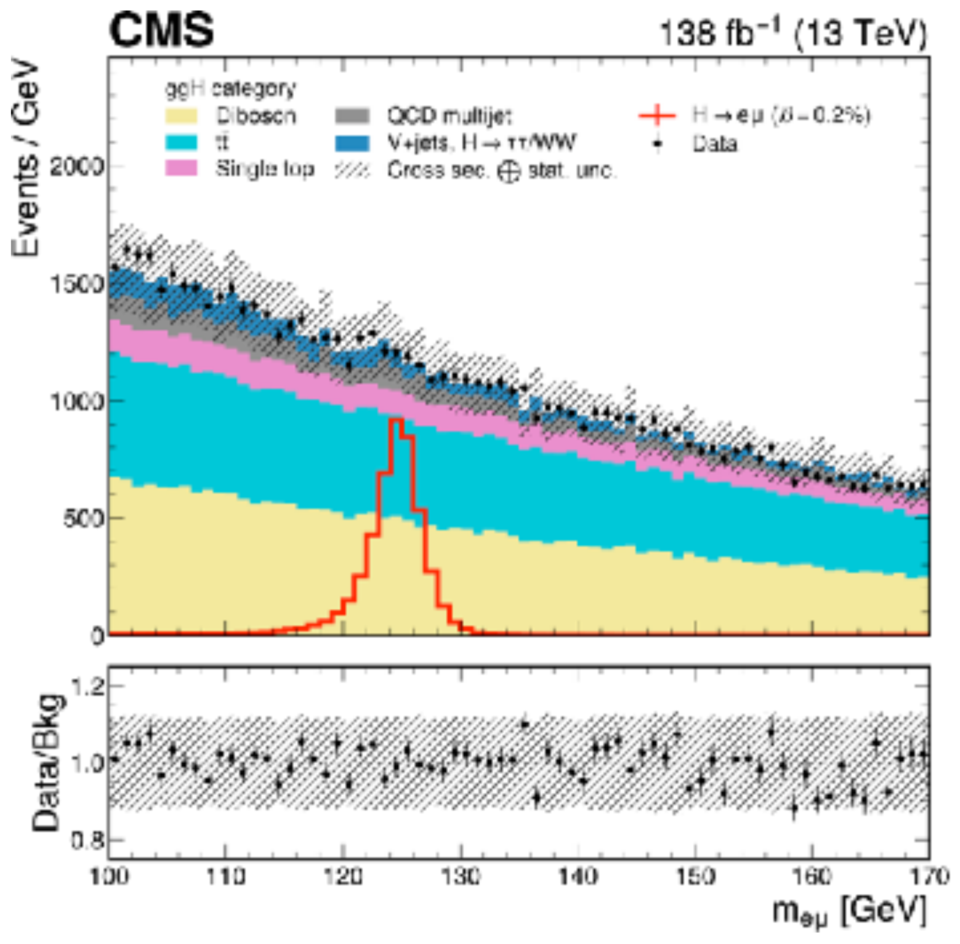


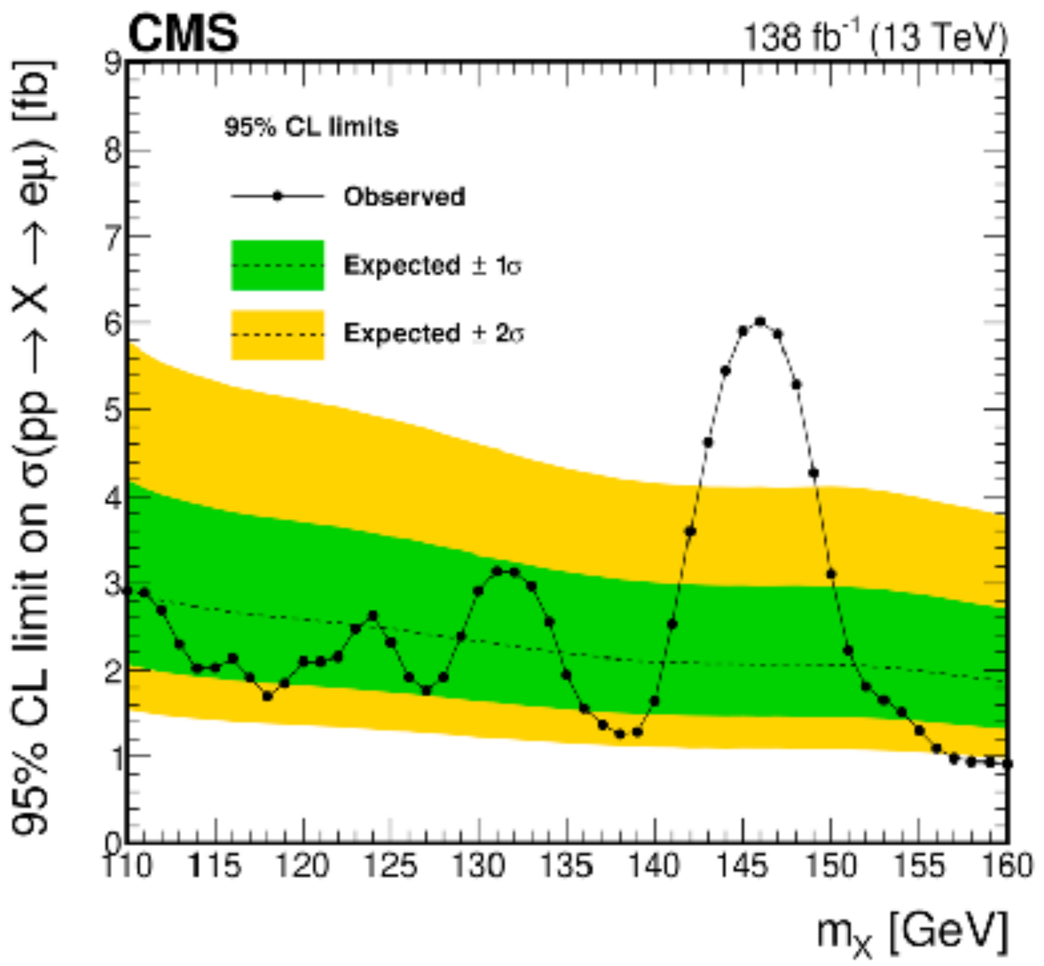
Search for symmetry violations: Higgs (LFV)

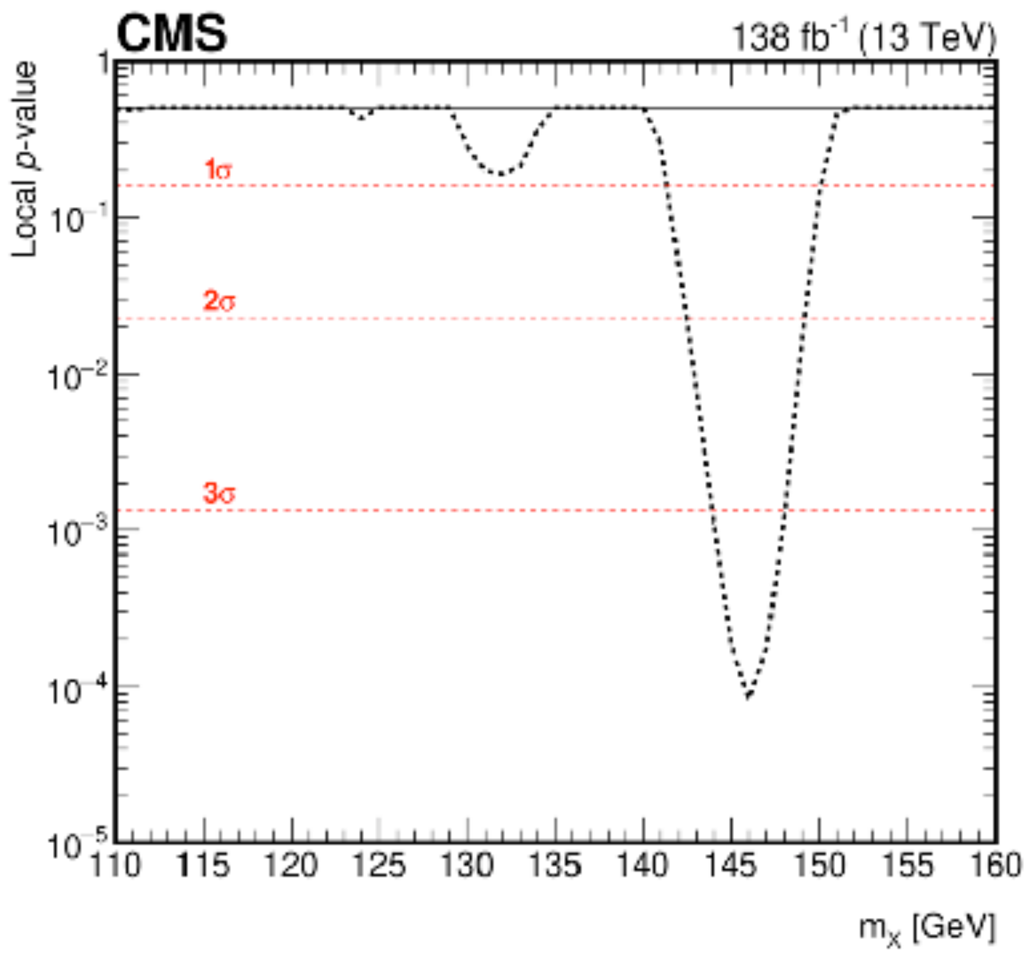
- Searched for the LFV decay H→μe
  - no excess, obtained exclusion BF < 4.4 10^{-5} @95% CL
- scanned m(eμ) mass range (110 - 160GeV) for BSM Higgs
  - excess detected at about 146 GeV
  - significance: 3.8σ (local), 2.8 (global)

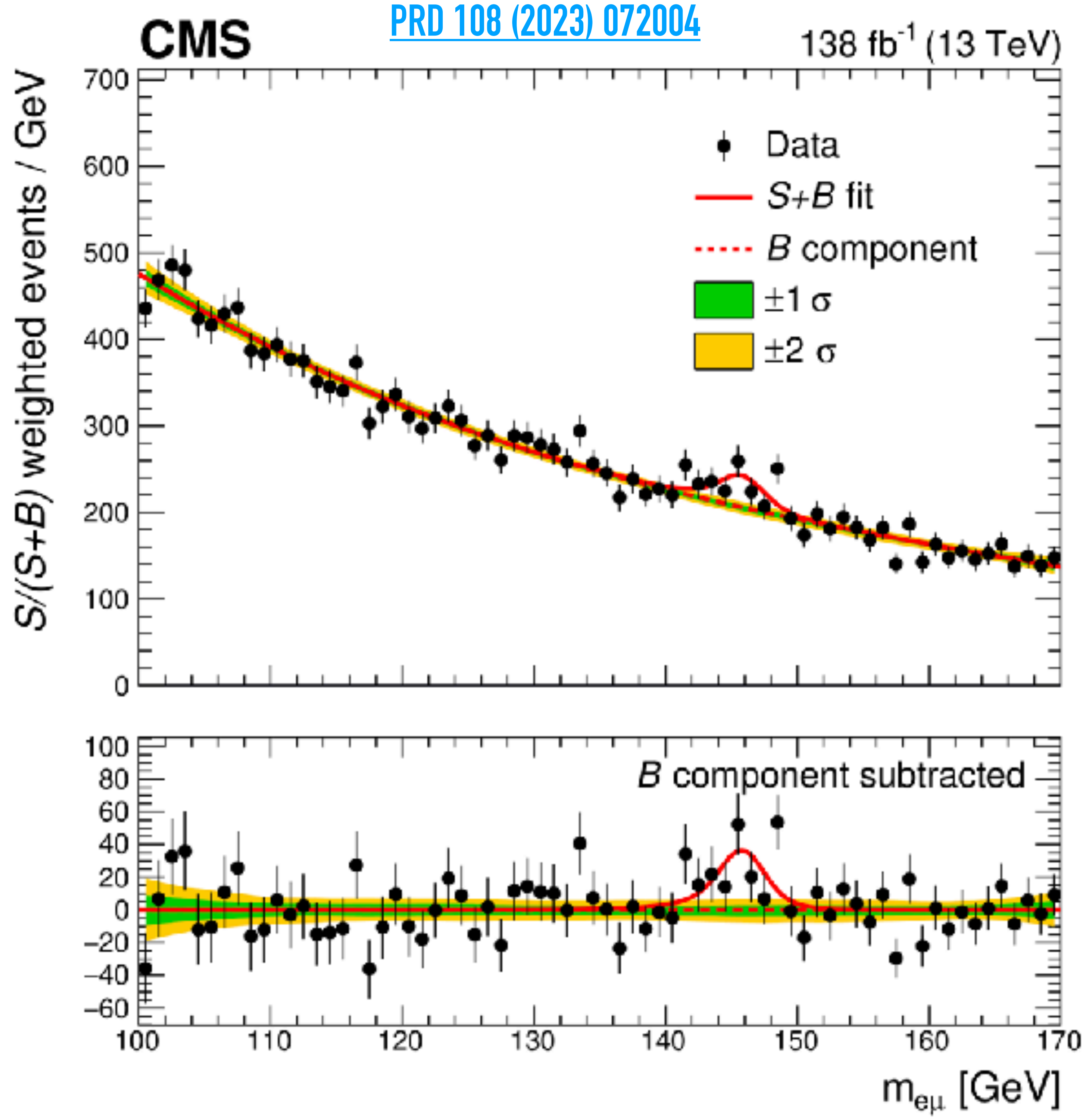


PRD 108 (2023) 072004





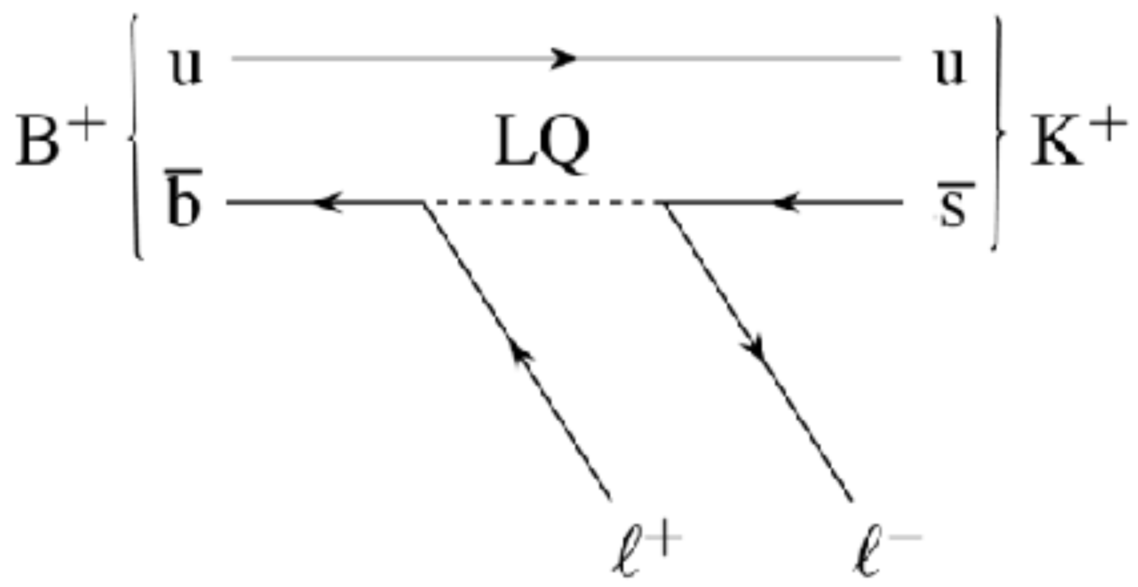




Remark: 2σ - 3σ excesses aren't statistically exceptional; e.g. diphoton excesses at 750 GeV (wikipedia) and at 95 GeV (https://indico.cern.ch/event/1297350/)

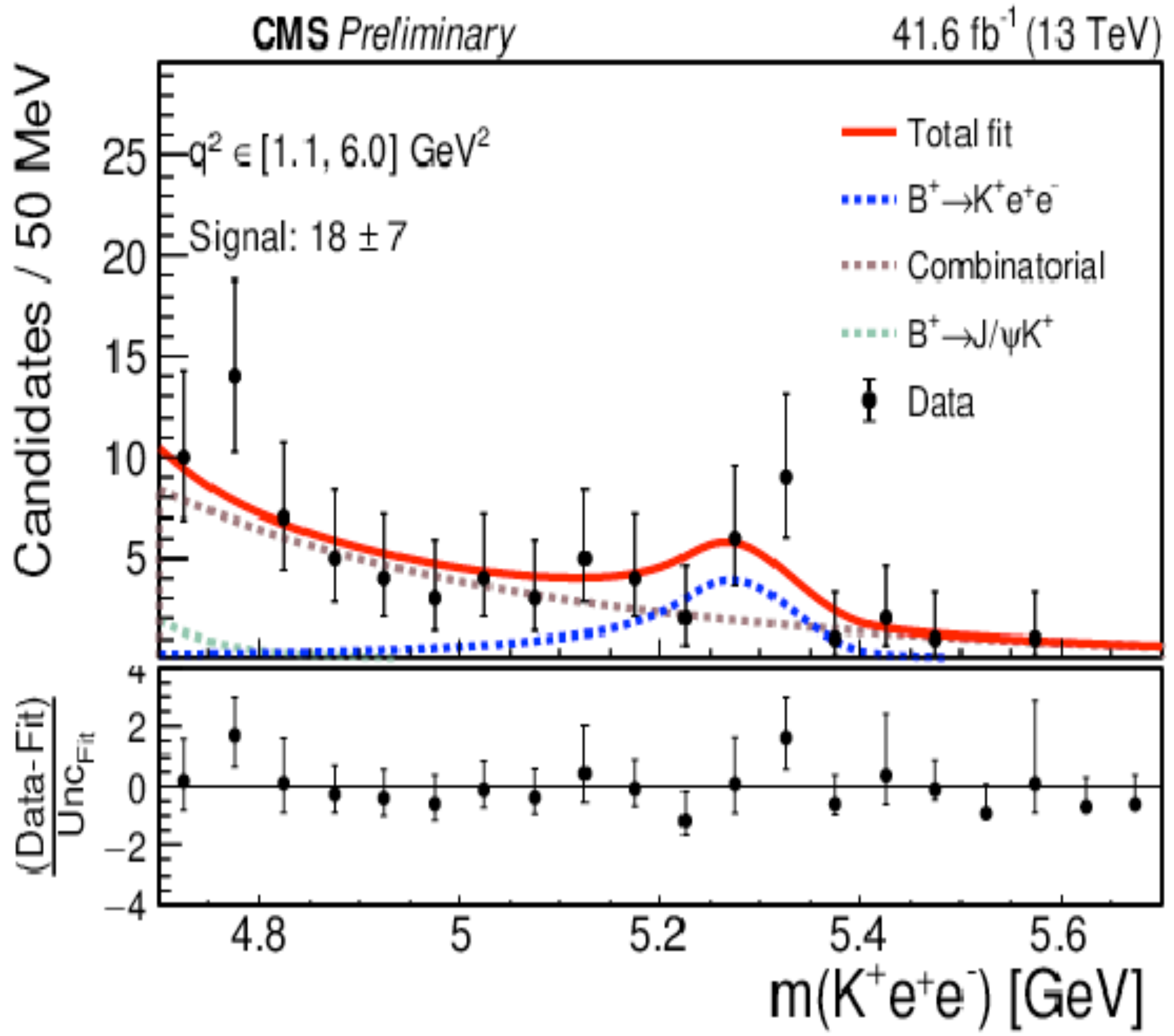
Search for symmetry violations: B (LFUV)

- Violation of lepton flavour **universality** (LFU) probed in B decays
  - history of hints from both FCNC b→sll and tree-level b→clν decays
- B→Kll decays use B **parking** data



B+→K+ ll

μ vs e



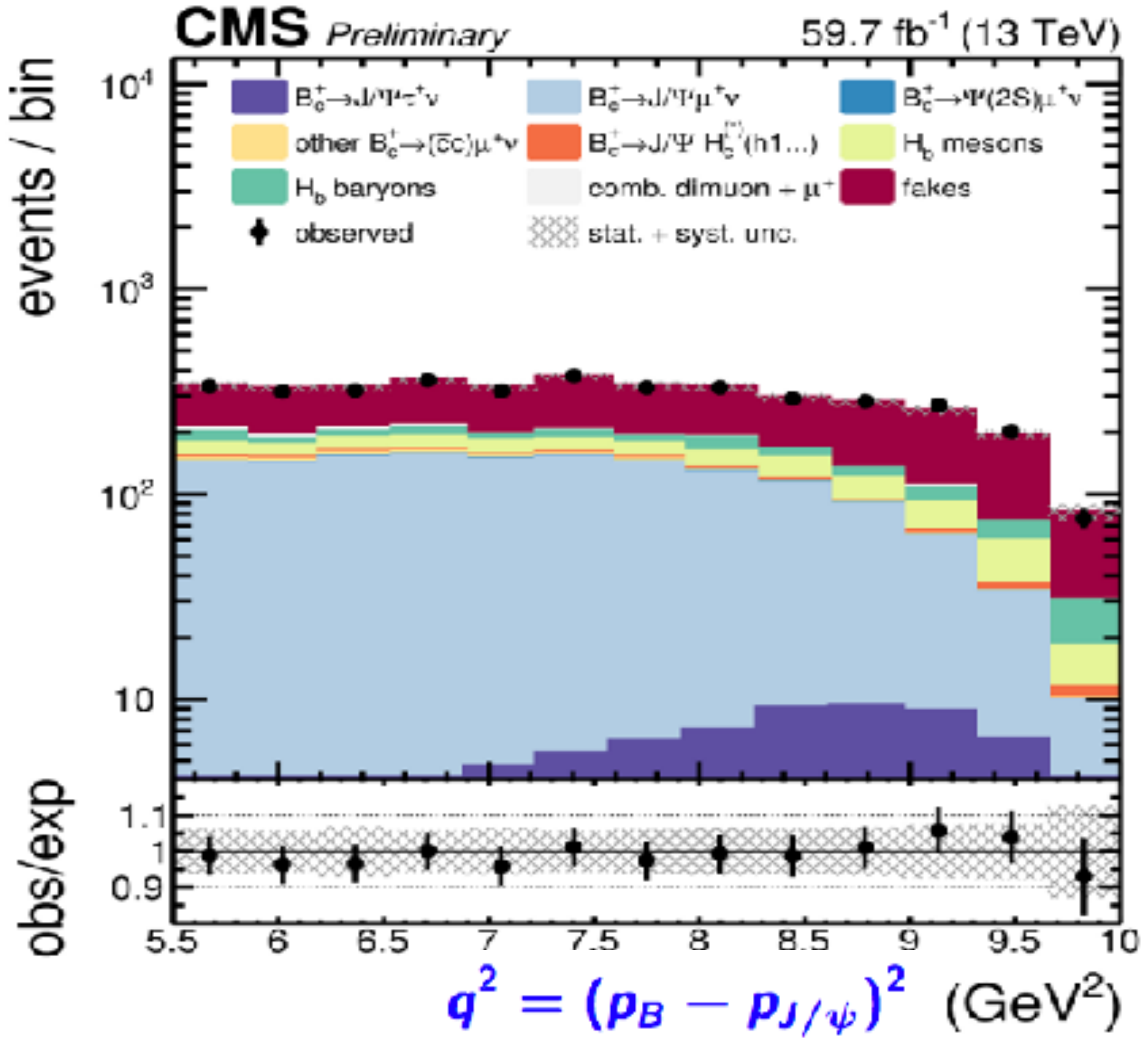
$$R_K = \frac{BF(B\rightarrow \mu\mu K)}{BF(B\rightarrow eeK)}$$

$R_K = 0.78^{+0.46}_{-0.23}$ (stat) $^{+0.09}_{-0.05}$ (syst)

CMS-BPH-22-012

Bc→J/ψlν

τ vs μ



$$R(J/\psi) = \frac{\mathcal{B}(B_c^+ \rightarrow J/\psi\tau^+\nu_\tau)}{\mathcal{B}(B_c^+ \rightarrow J/\psi\mu^+\nu_\mu)}$$

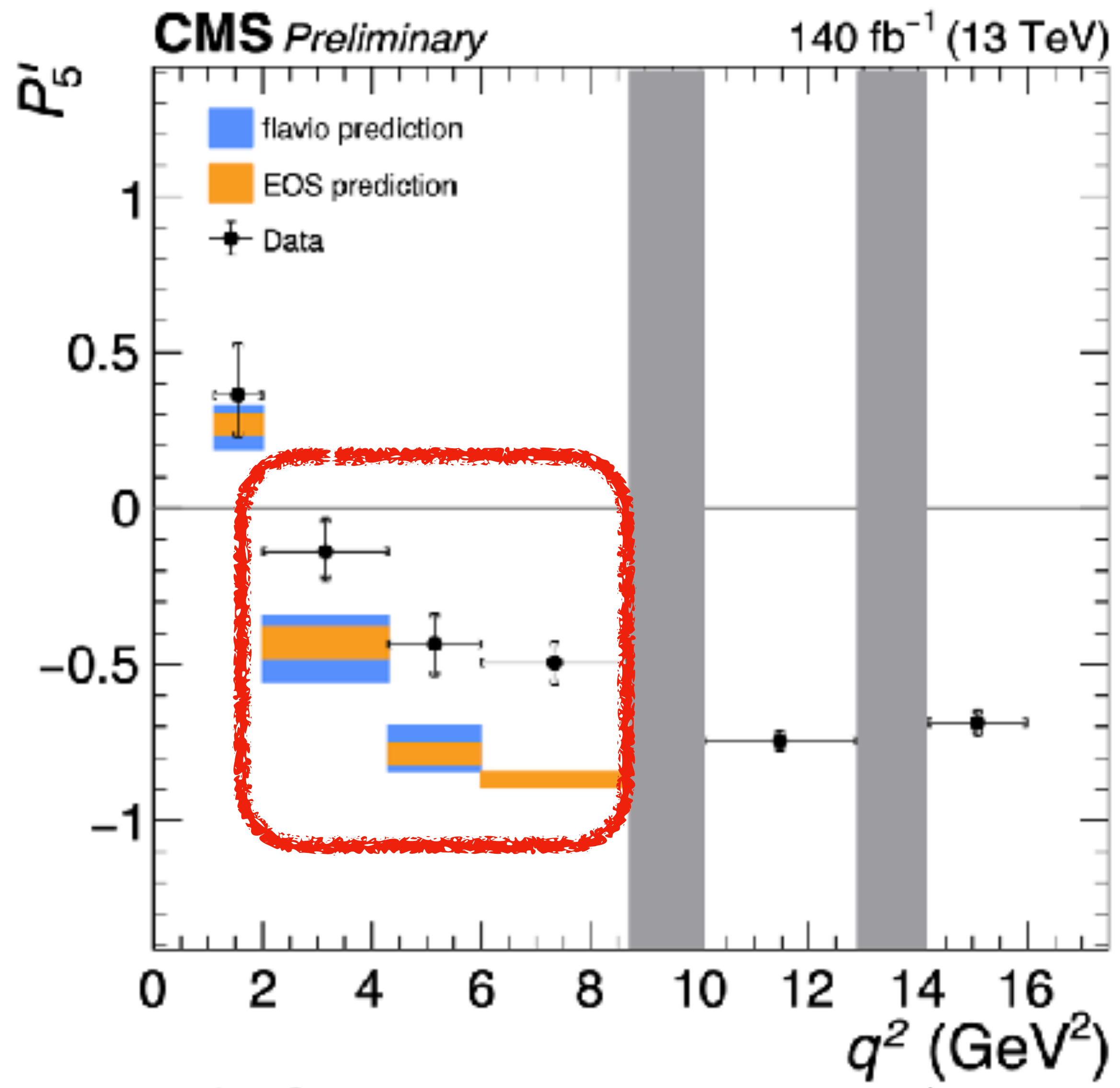
$$= 0.17 \pm 0.33$$

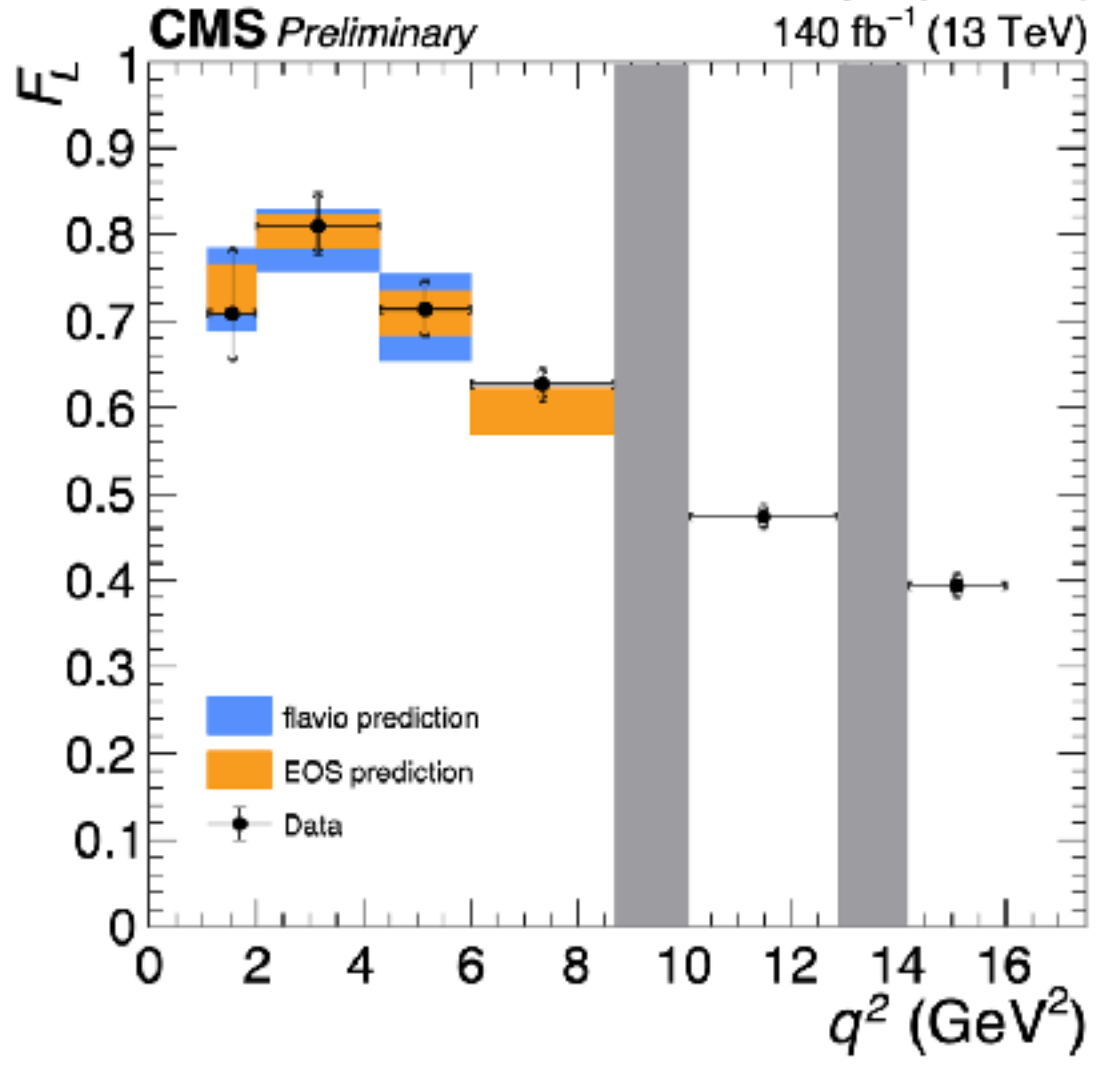
SM 0.2582(38)

CMS-BPH-22-005, arXiv:2401.07090

Flavour anomalies? b→sμμ angular analysis

- the FCNC b→sll transitions offer high sensitivity to NP
  - long history of searches for hints of NP (flavour anomalies)
- longstanding discrepancy, reported by LHCb, in angular observables in the $B^0 \to K^*\mu\mu$ decay
- measurement of complete set of CP averaged variables
  - angular parameters extracted from fit to m_B and 3 angles
- performed in bins of dilepton invariant mass squared, q^2
  - different ranges are sensitive to different NP (EFT operators)
  - exclude resonant regions (charmonia)
- results among most precise measurements of this decay
  - compatible with previous measurements (incl. LHCb)
  - tension (2.7-3.2σ) with available prediction for $2>q^2>6$ GeV^2





CMS-PAS-BPH-21-002 (2024)

Summary

- CMS is accumulating increasingly sensitive datasets, with novel data-taking paradigms
- Upgrade for Hi-Lumi phase, with detector projects transitioning into production

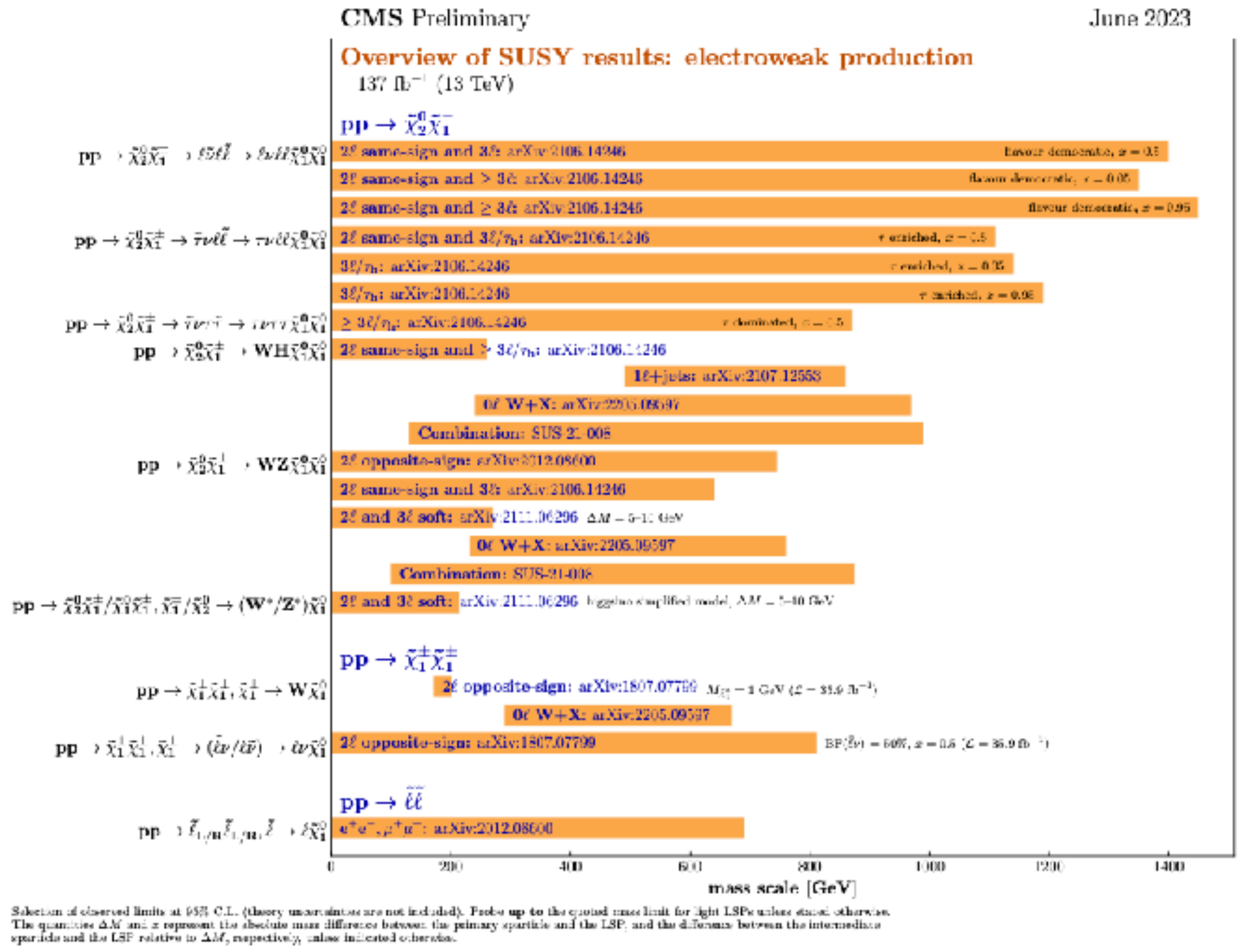
- Carrying out a comprehensive physics program
- Exploring rare (and forbidden) processes as sensitive NP probes
- Entering era of precision measurements (and EFT towards NP)

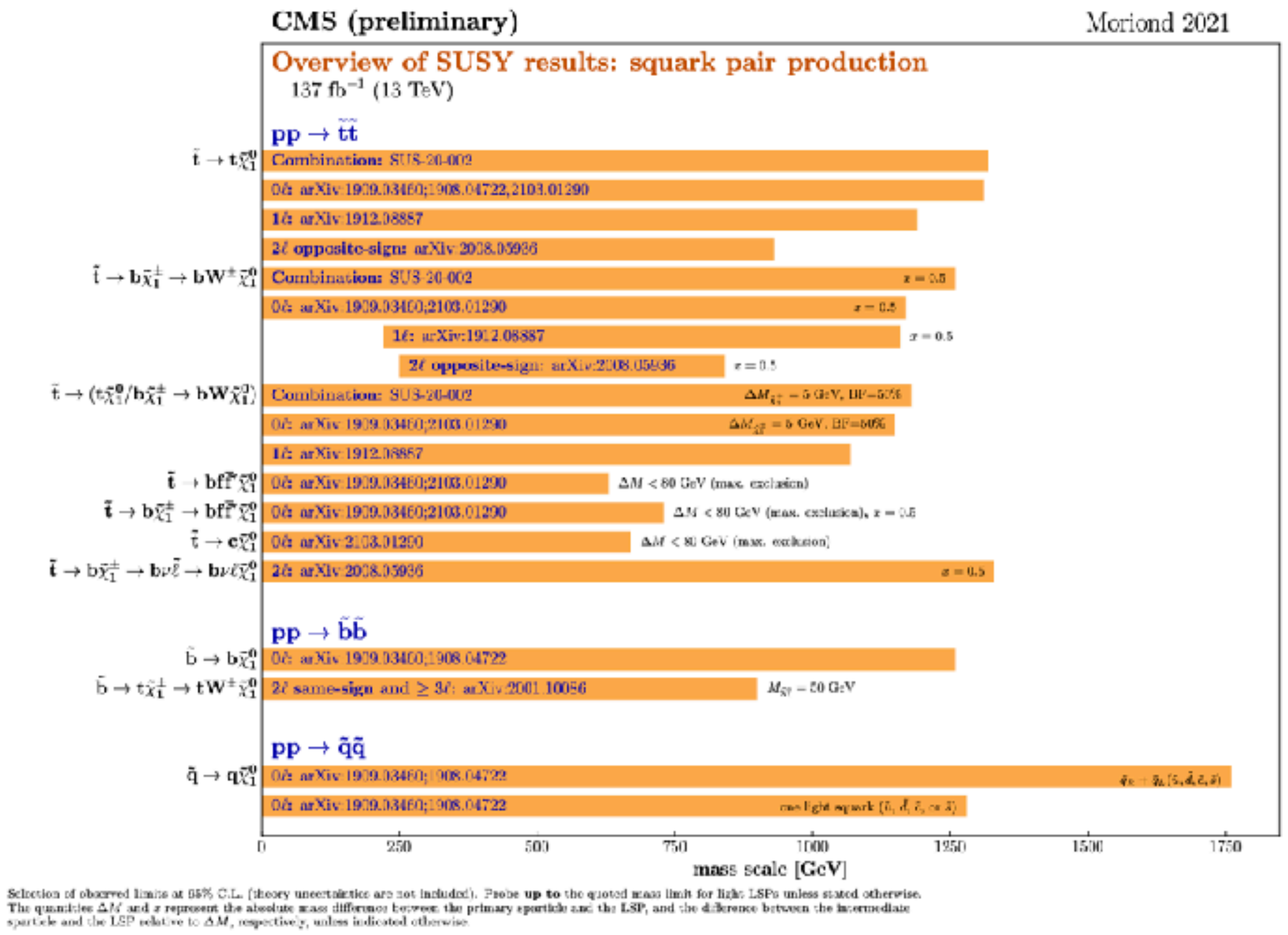
- Ongoing Run3 shall facilitate more **precise** measurements and new **observations**

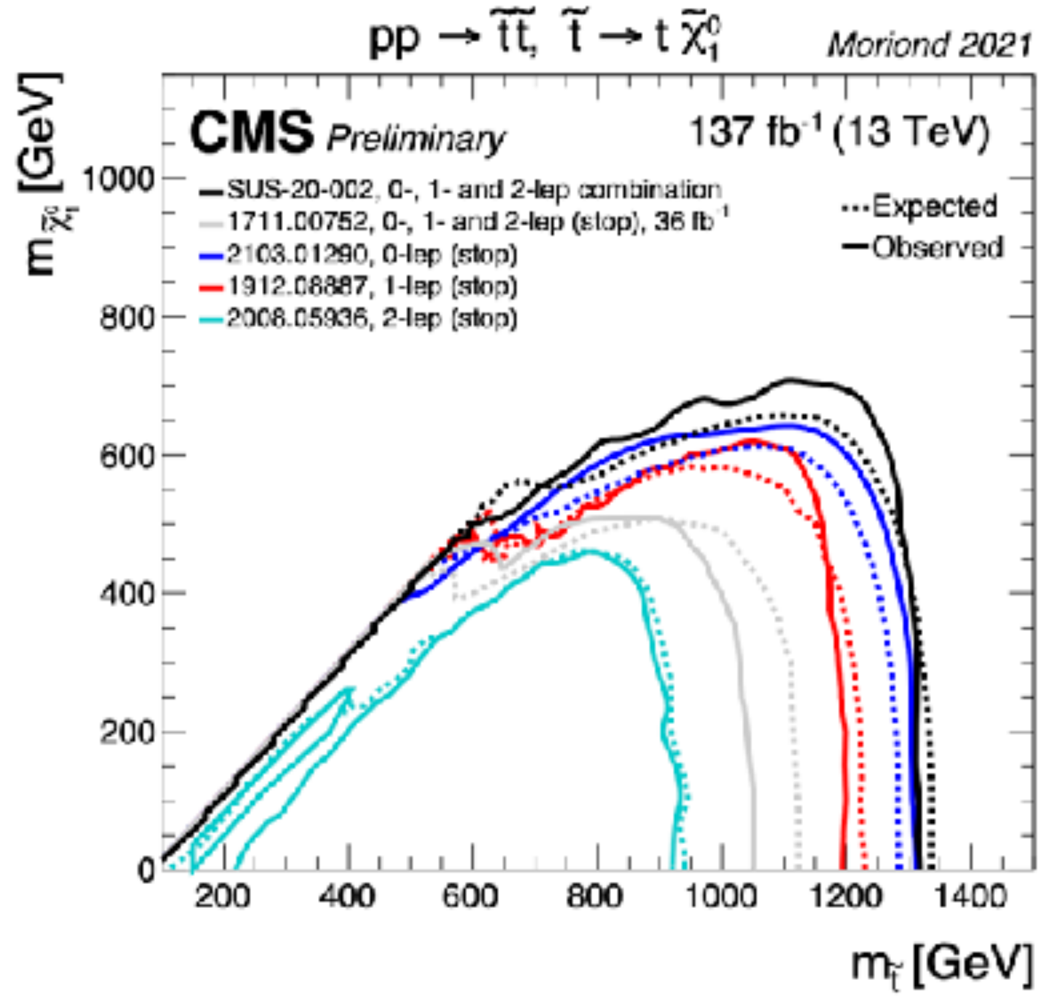
Stay tuned. *Thank you for listening!*

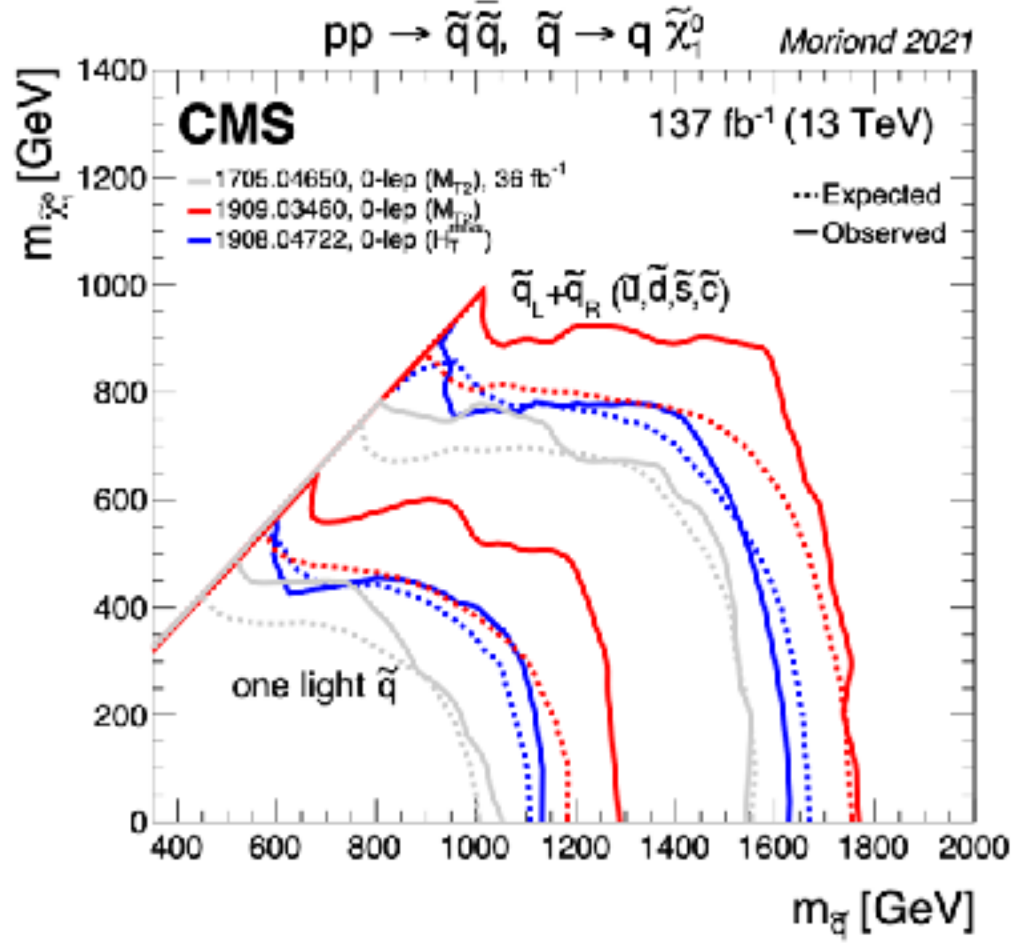
Backup

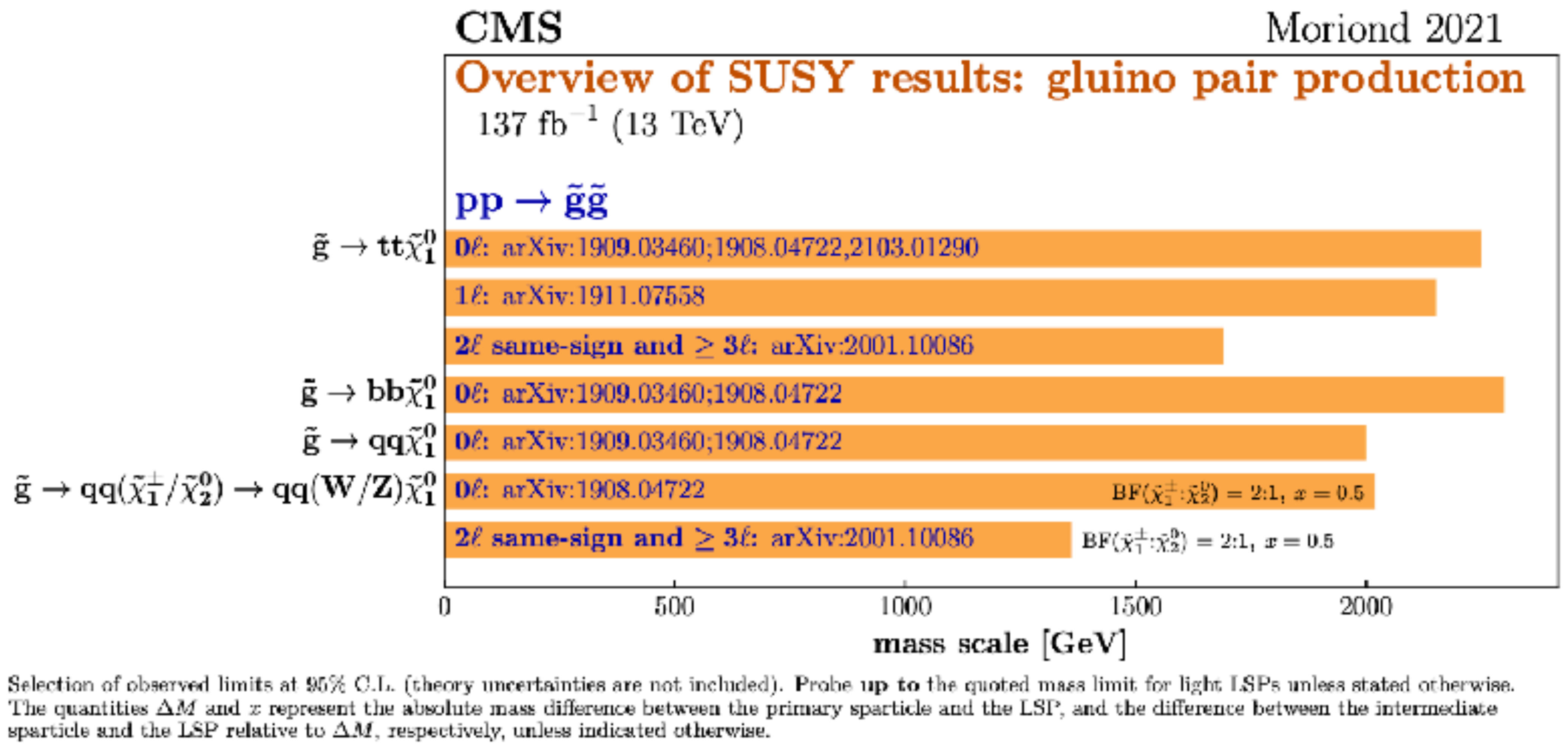
Searches for new particles (SUSY)

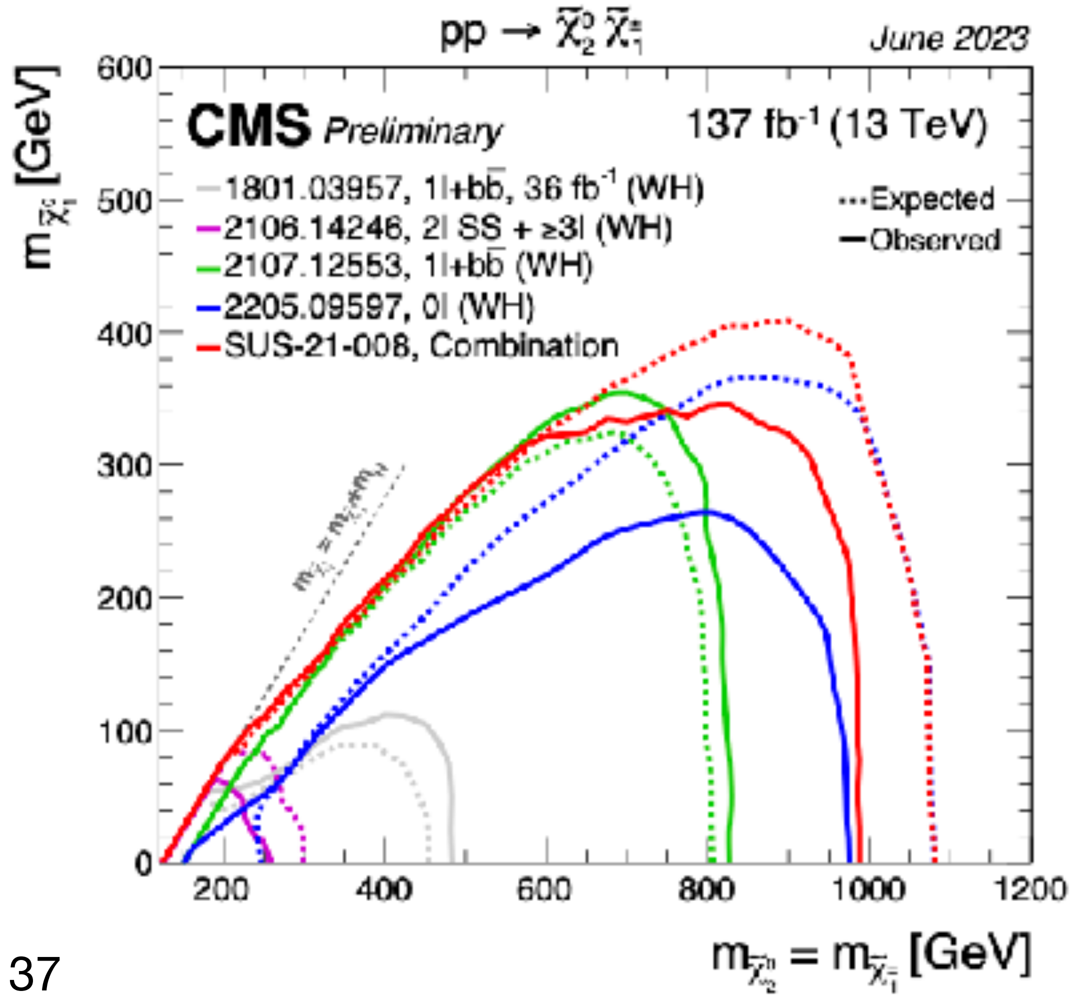








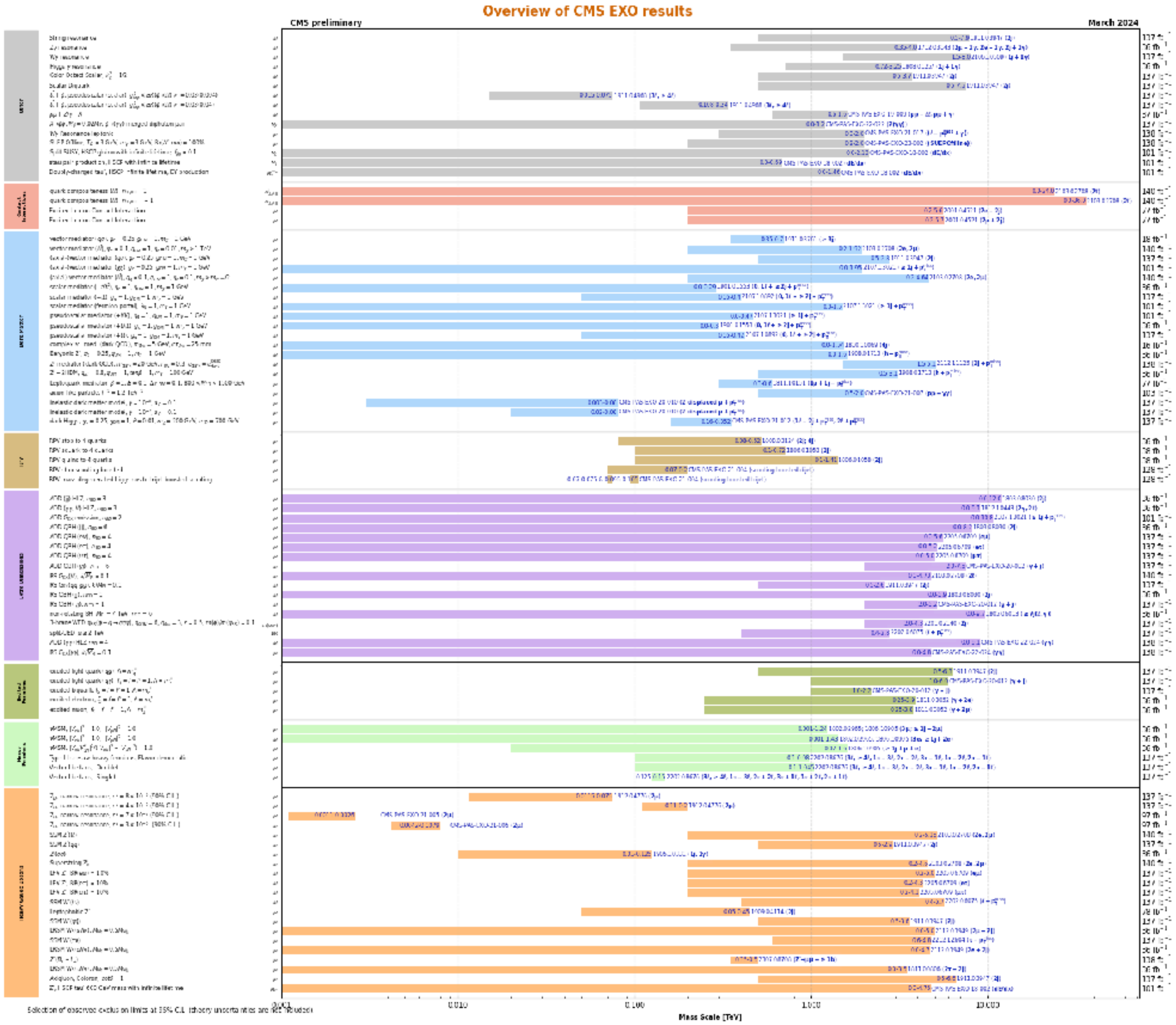


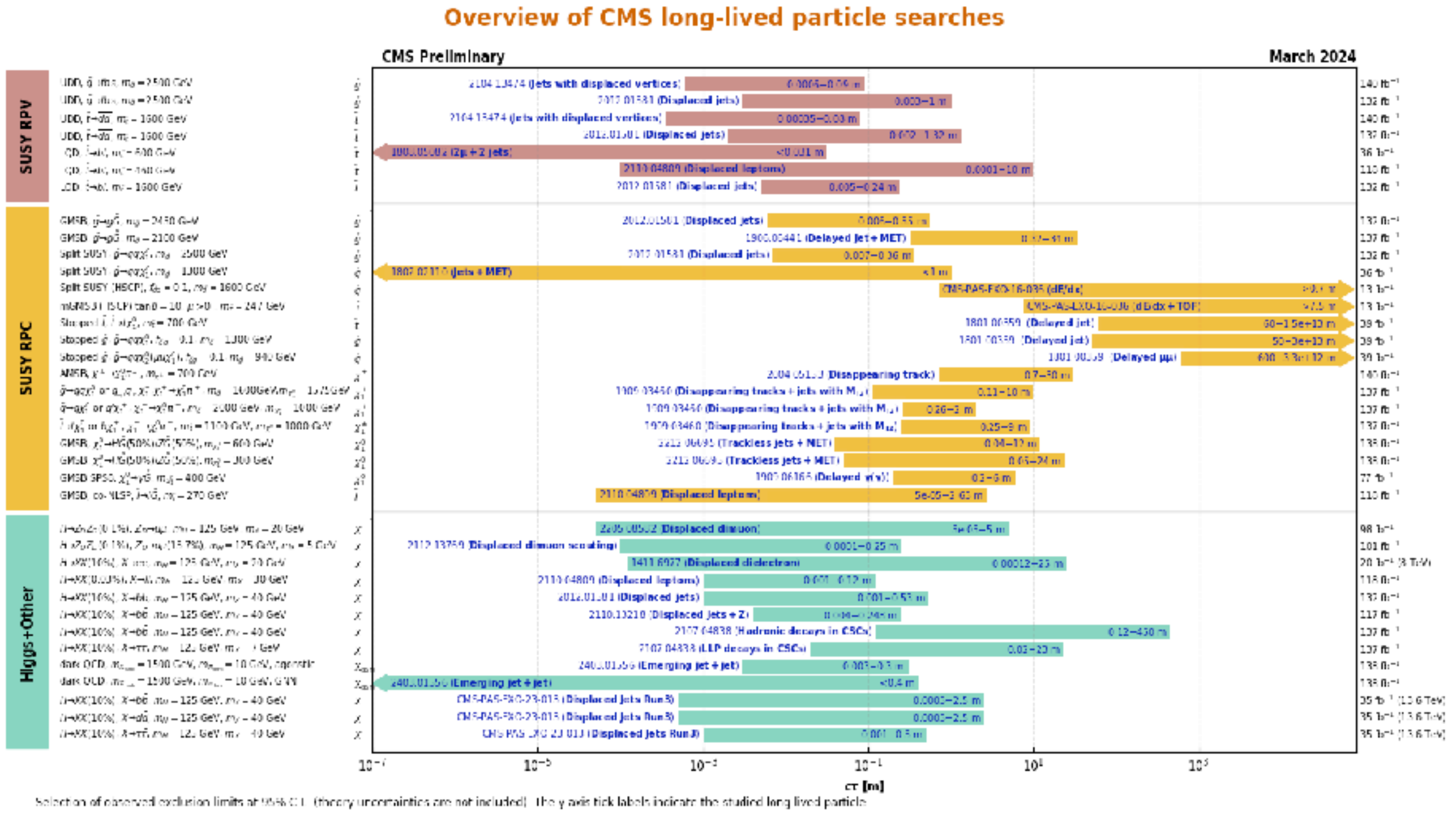


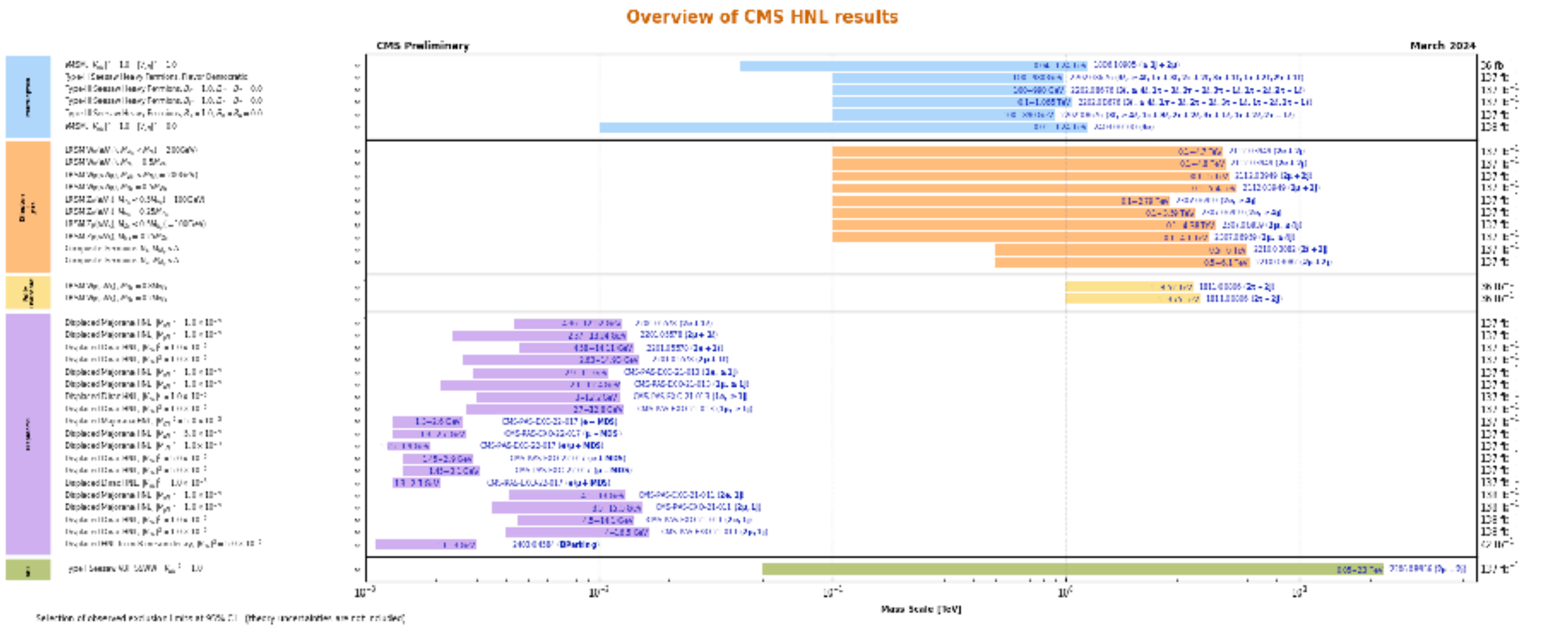
https://twiki.cern.ch/twiki/pub/CMSPublic/PhysicsResultsSUS/

https://cms-results.web.cern.ch/cms-results/public-results/publications/SUS/

Searches for new particles (Exotica)



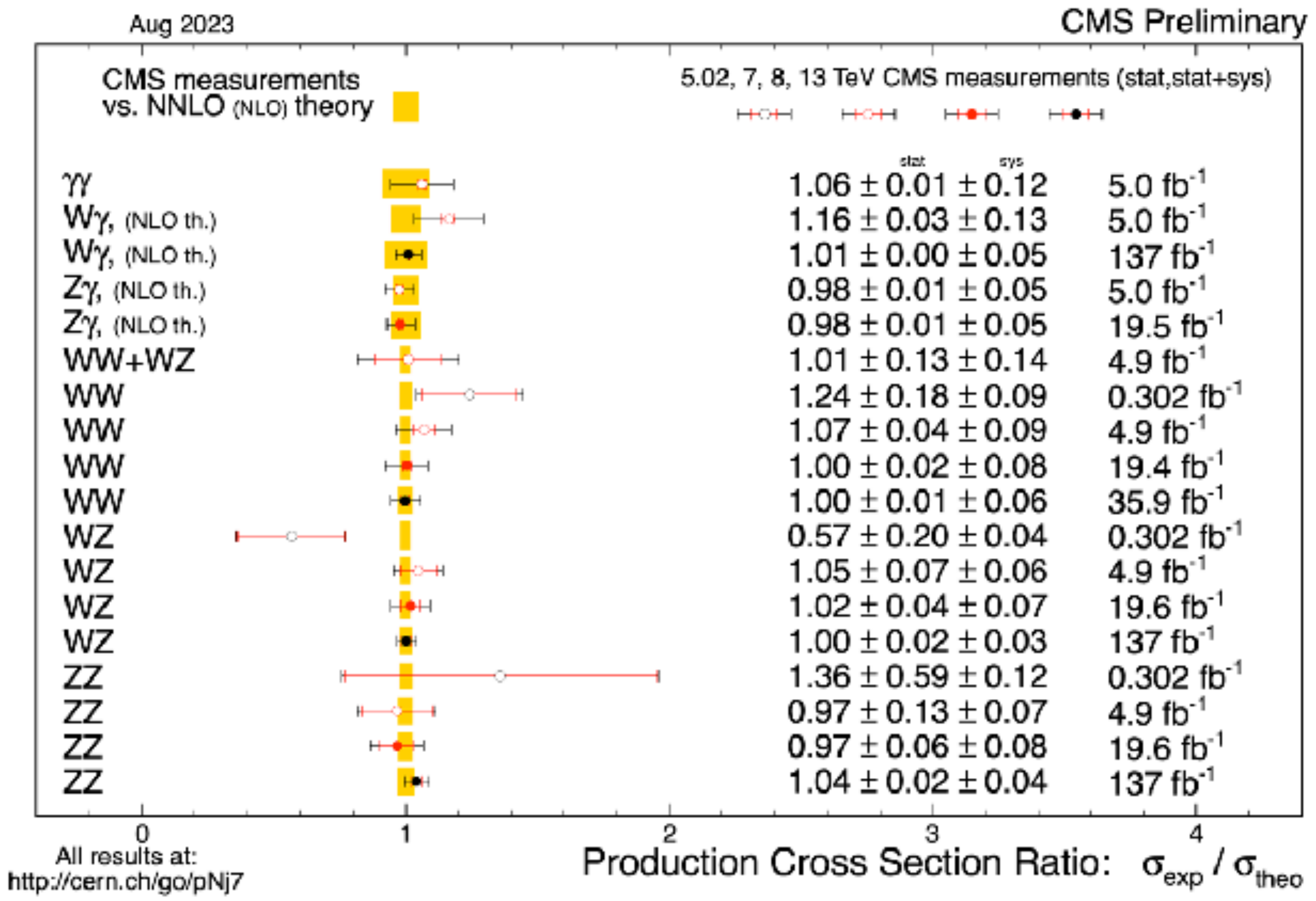


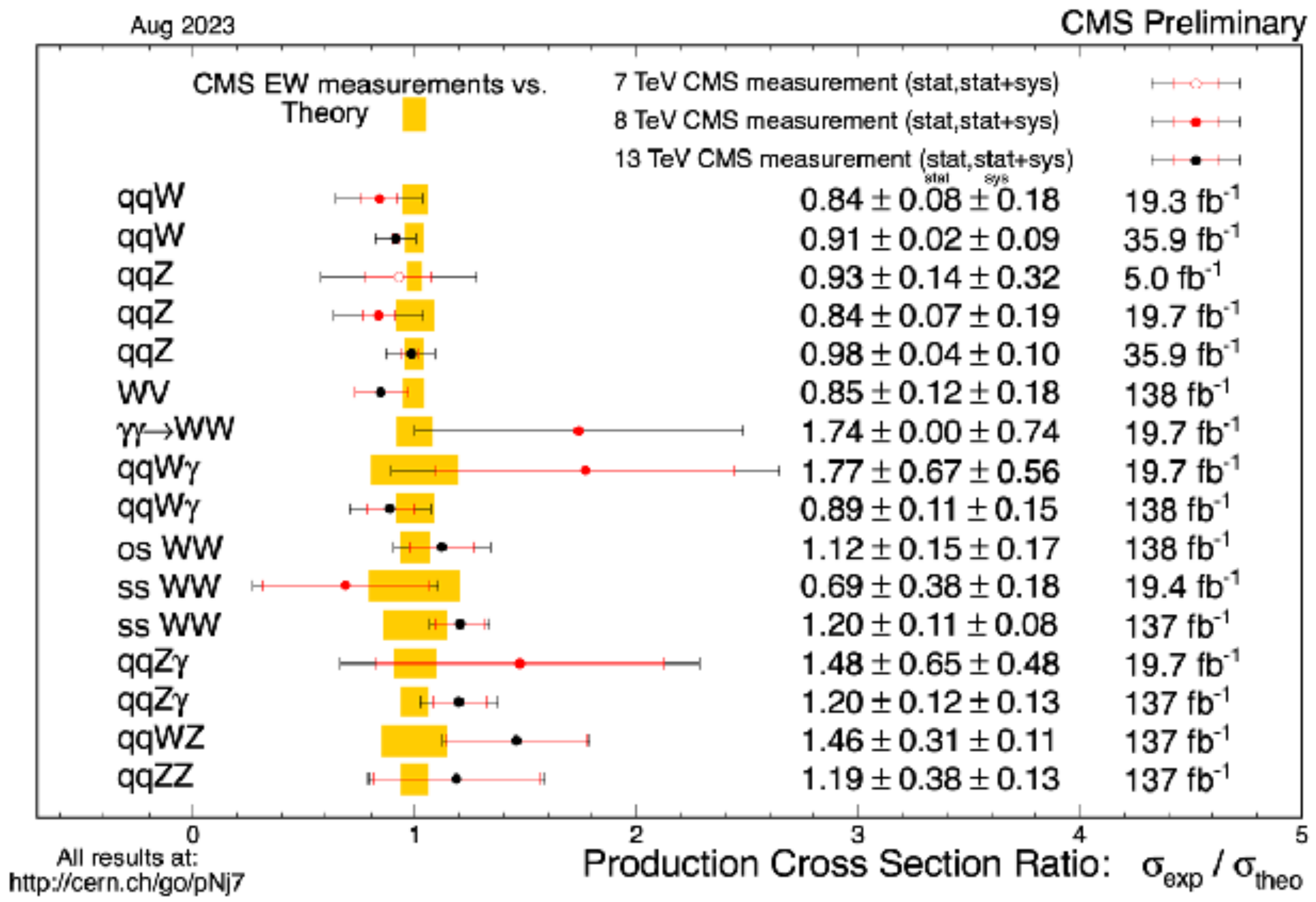


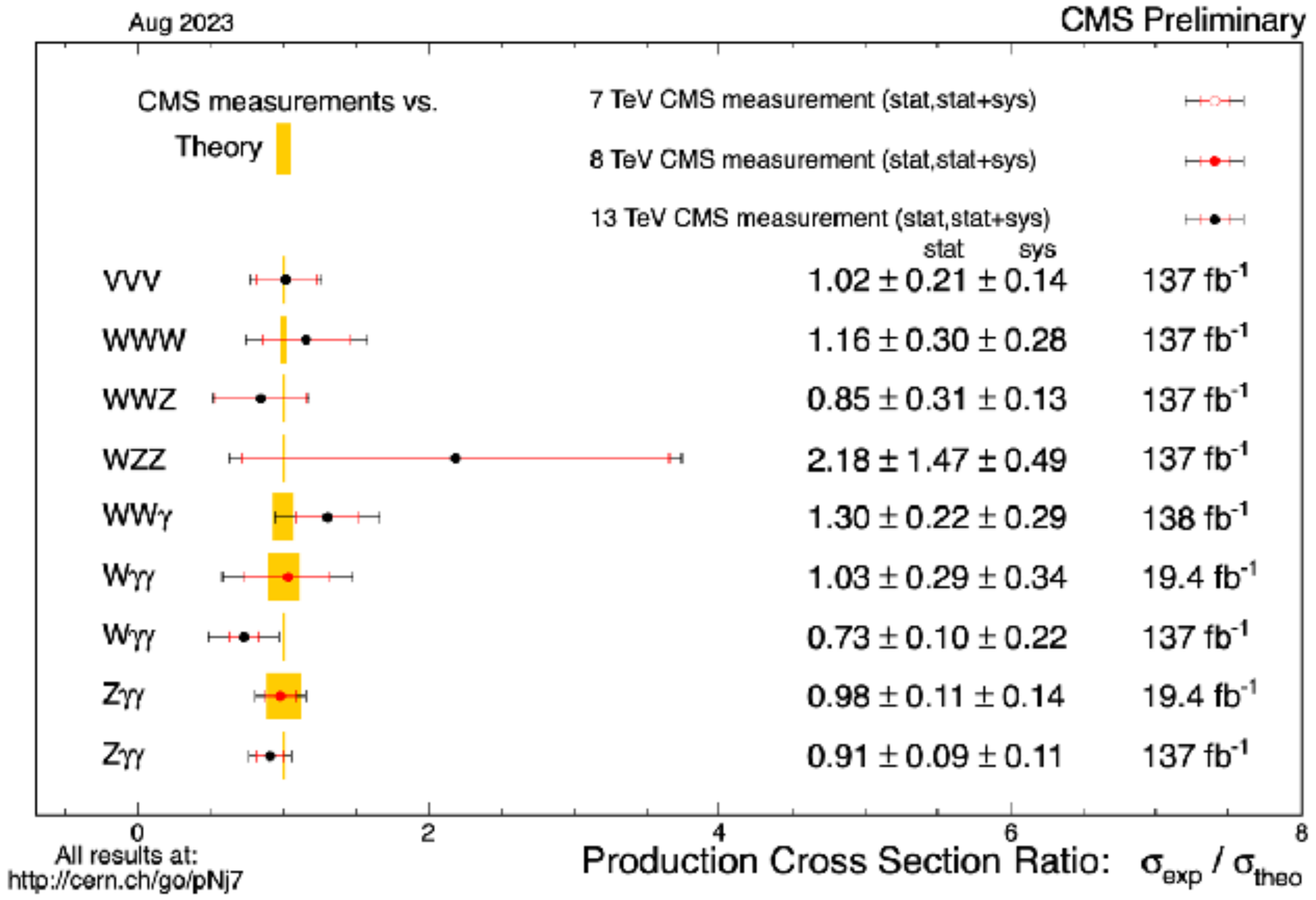
https://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/

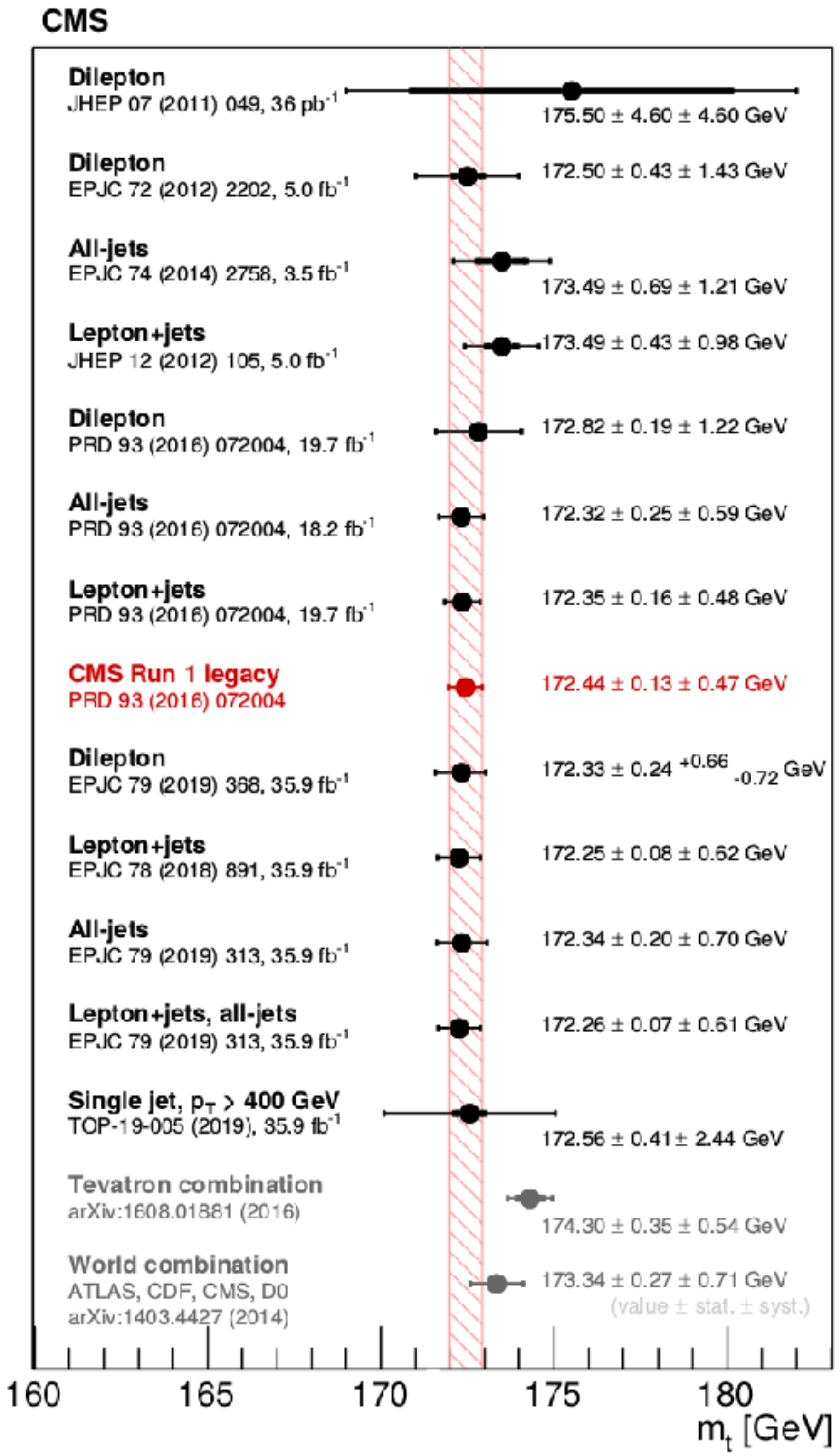
https://twiki.cern.ch/twiki/bin/view/CMSPublic/SummaryPlotsEXO13TeV

Precision measurements: electroweak & top









https://cms-results.web.cern.ch/cms-results/public-results/publications/TOP/

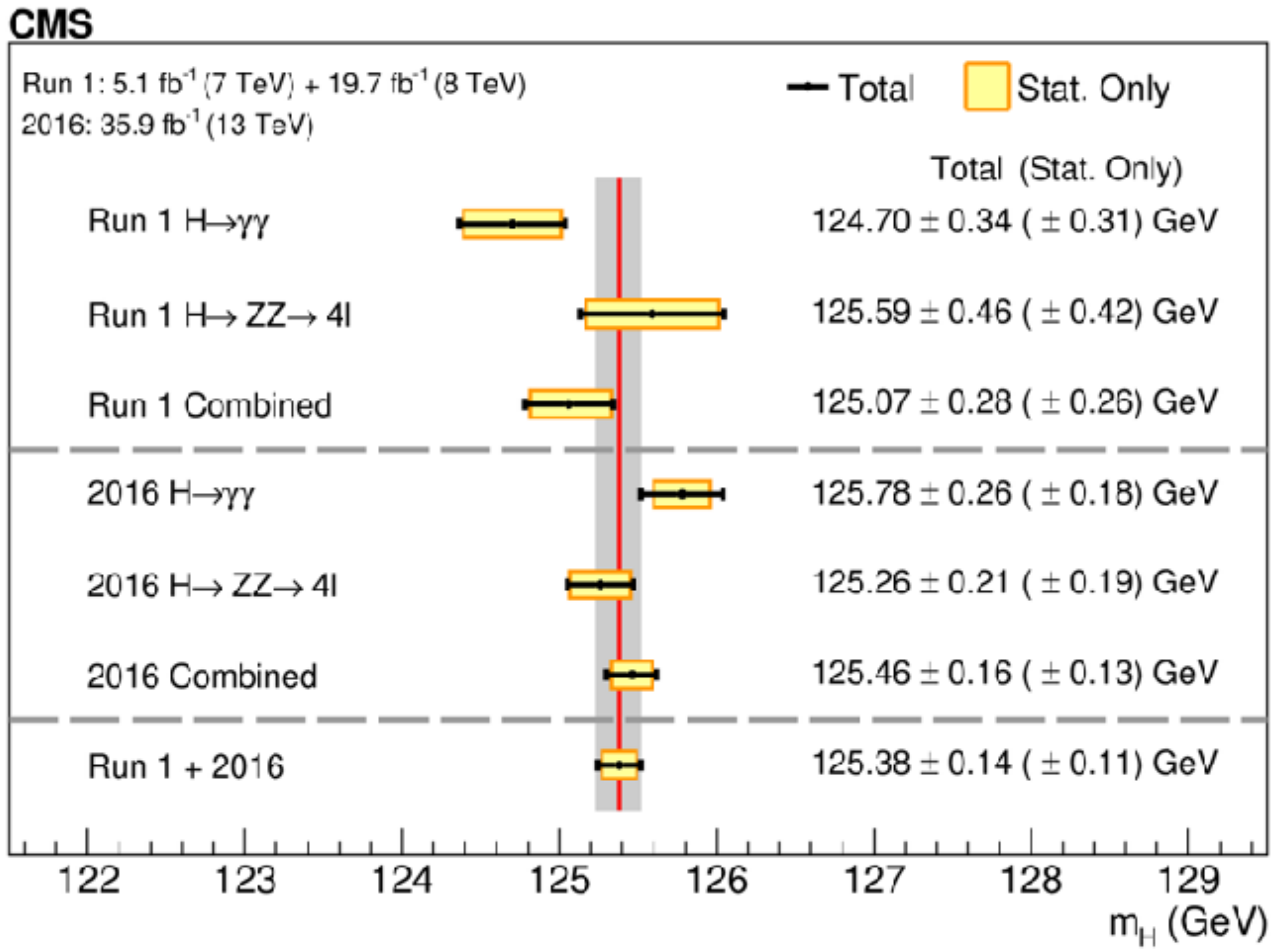
https://cms-results.web.cern.ch/cms-results/public-results/publications/SMP/

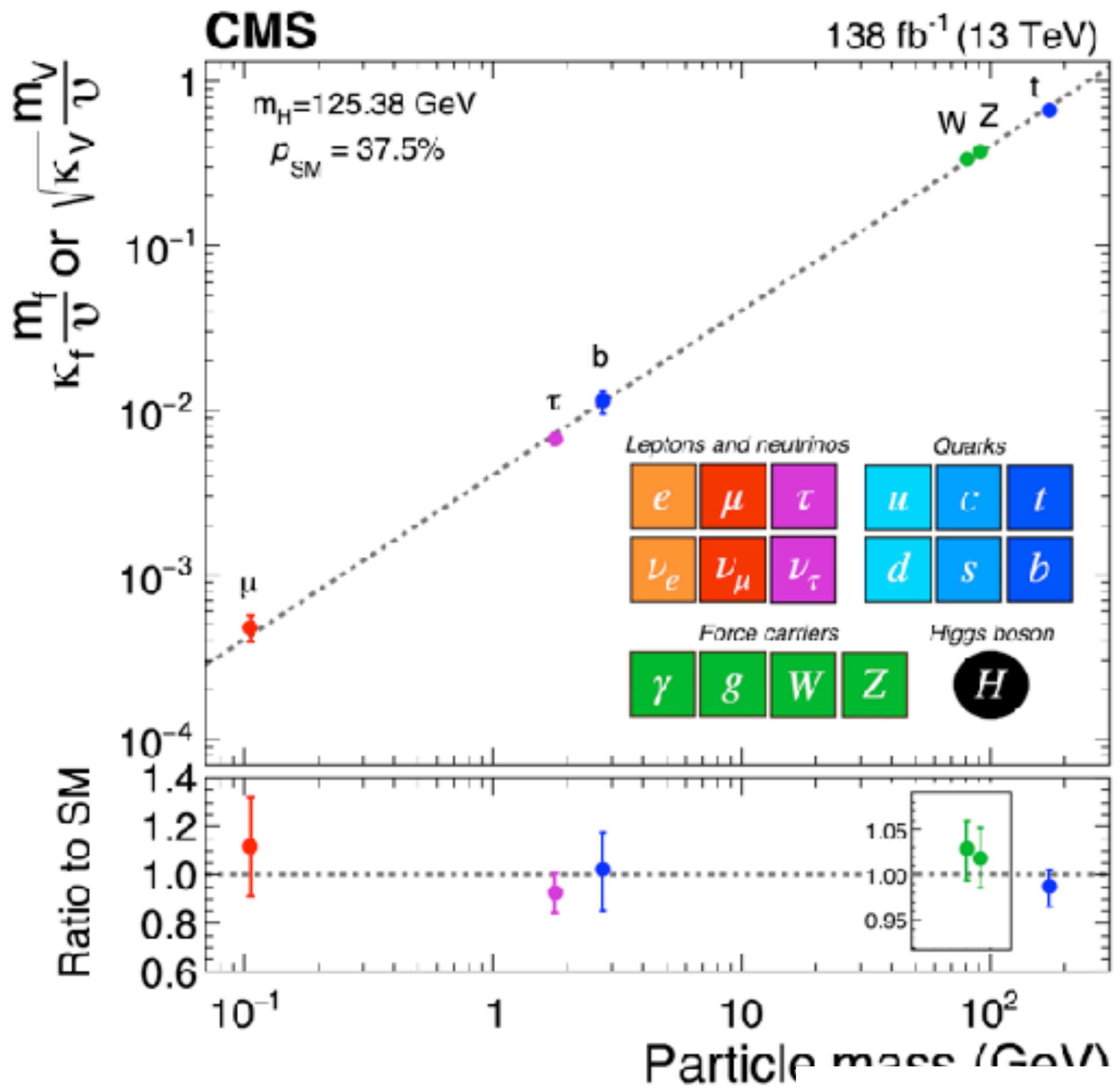
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP

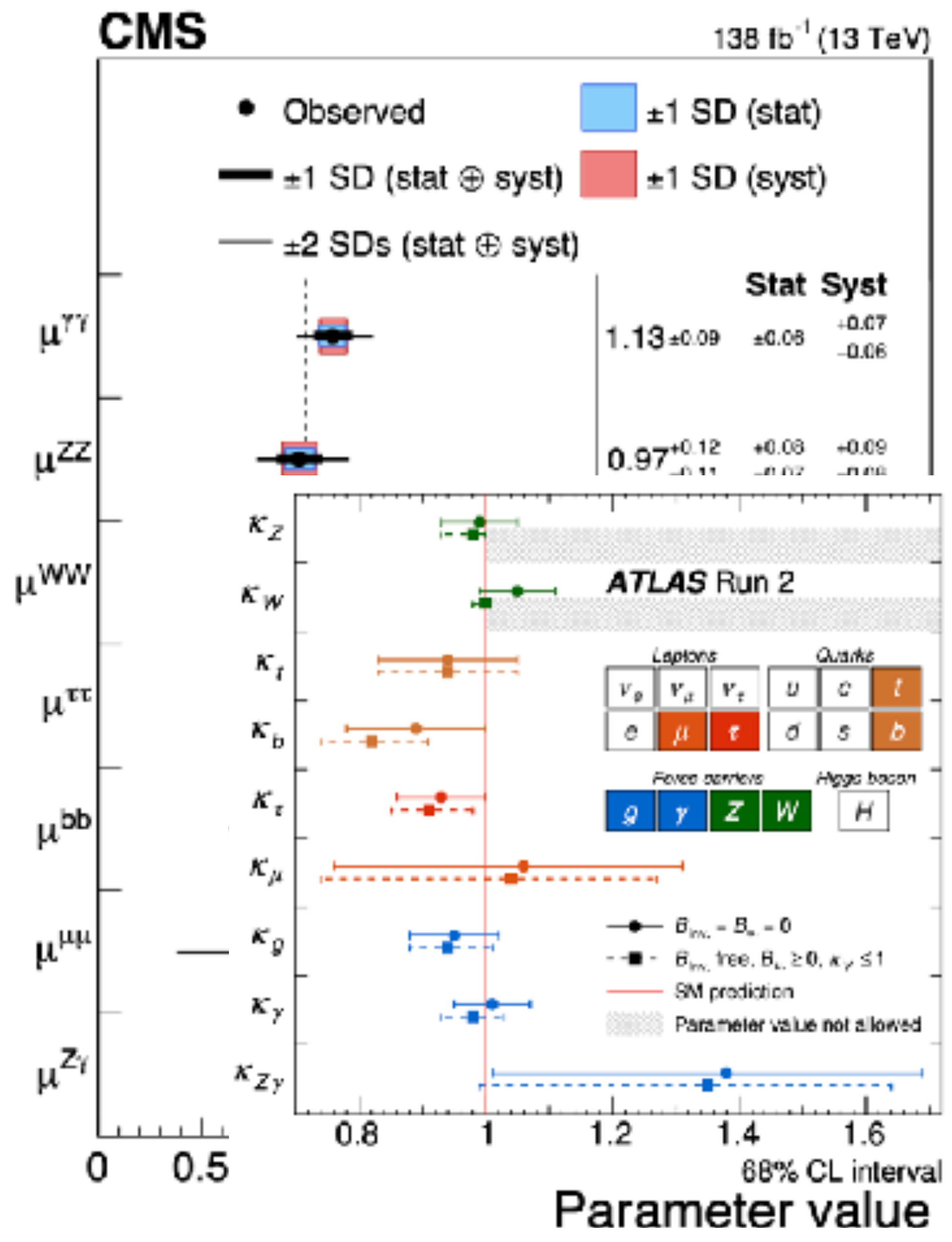
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsSMP

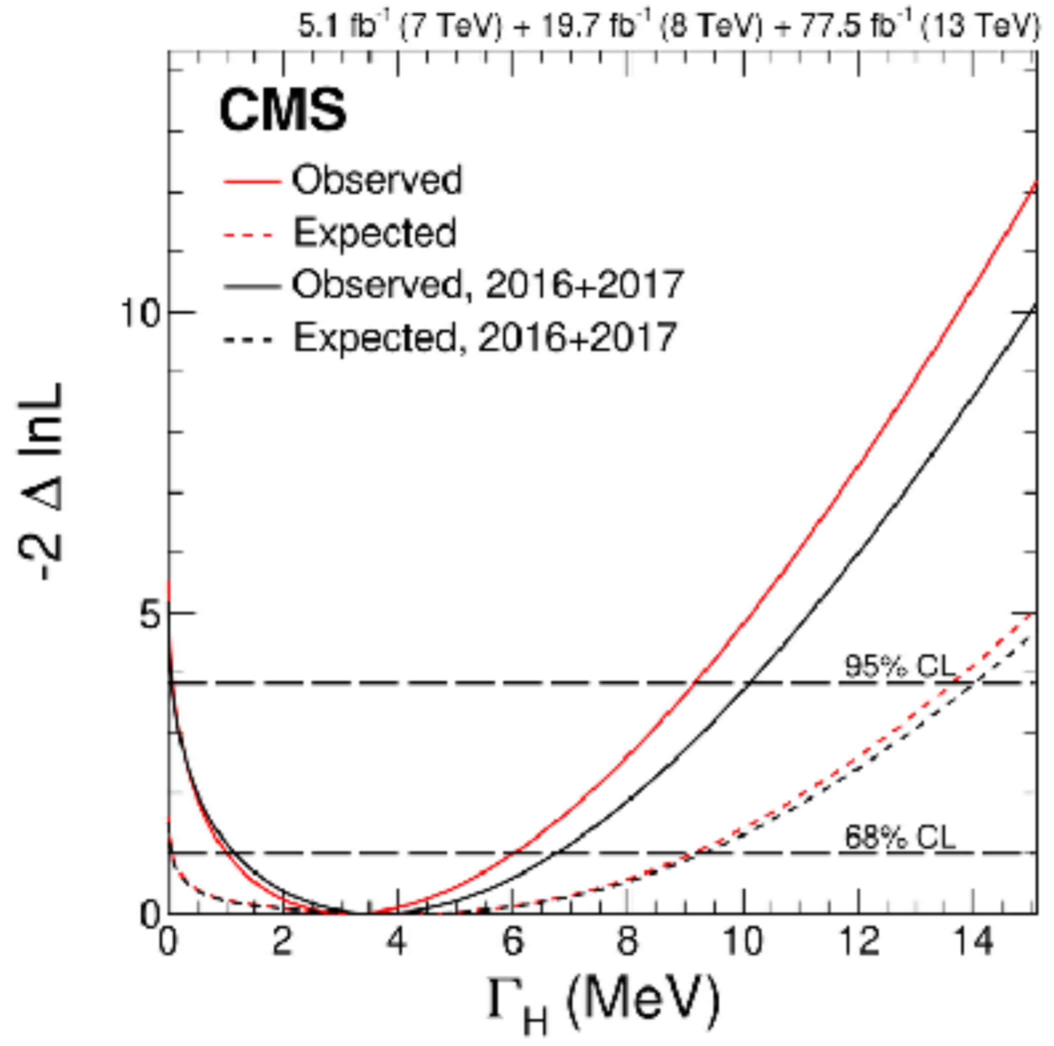
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsCombined

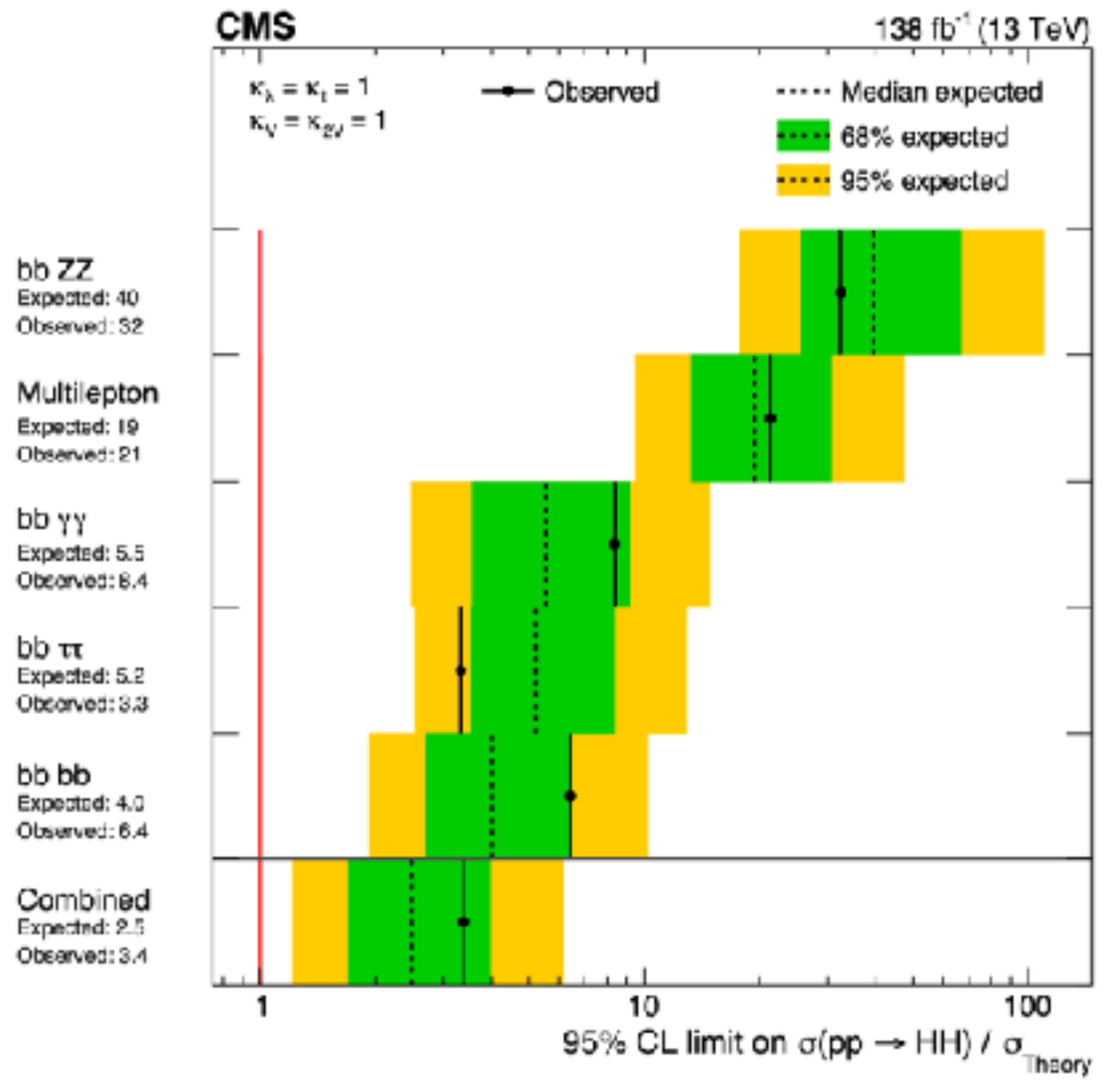
Precision measurements: Higgs

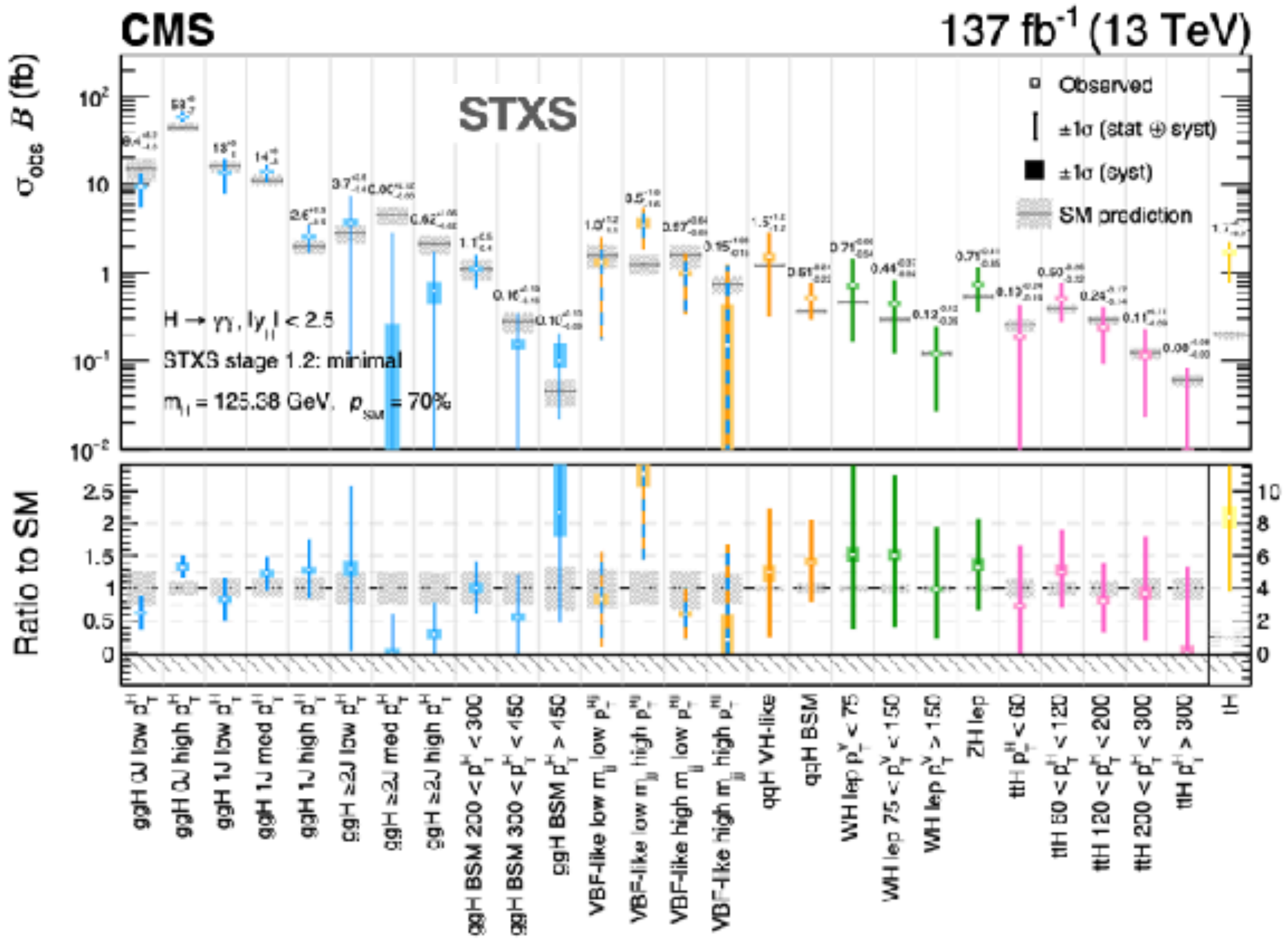






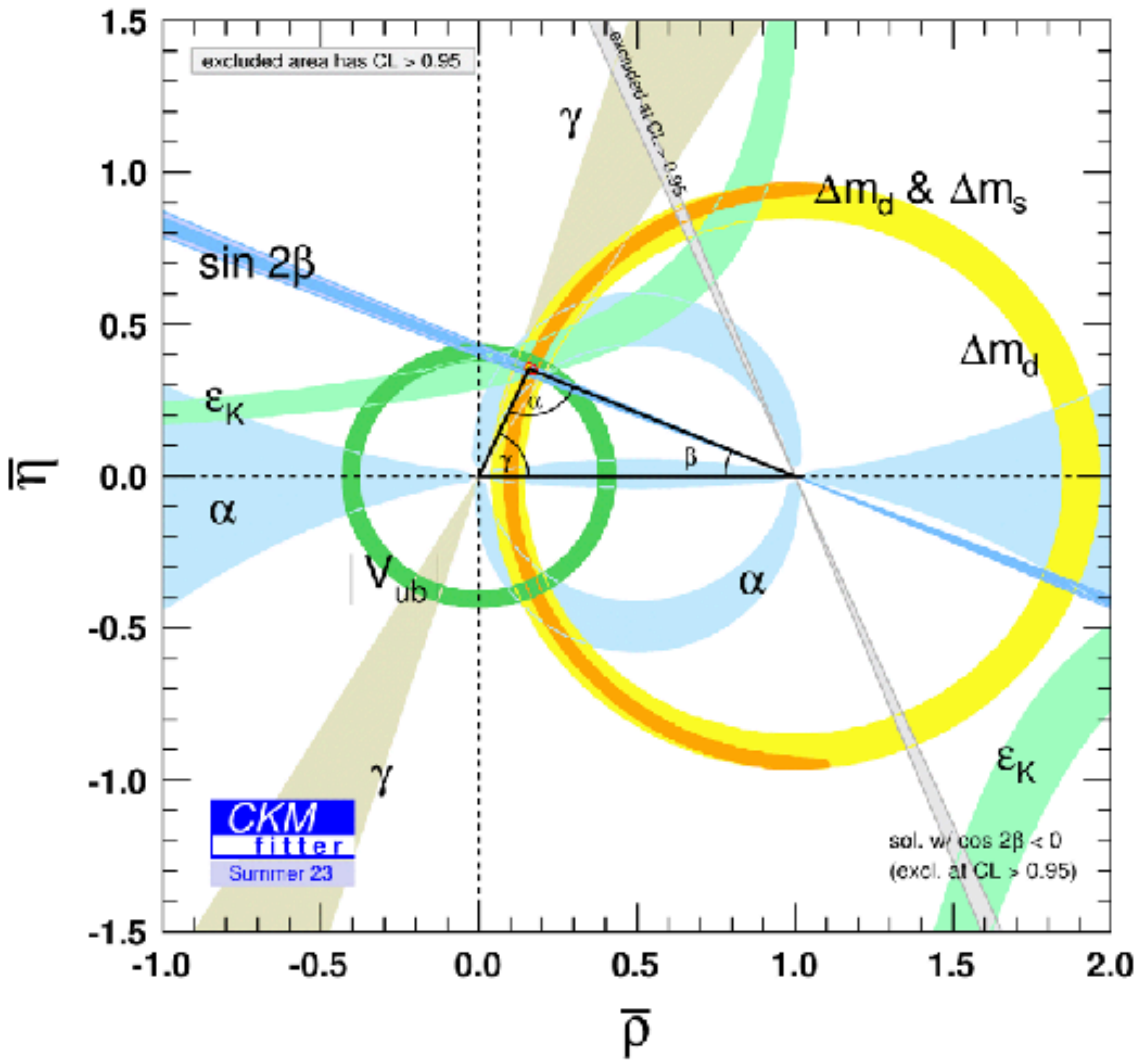


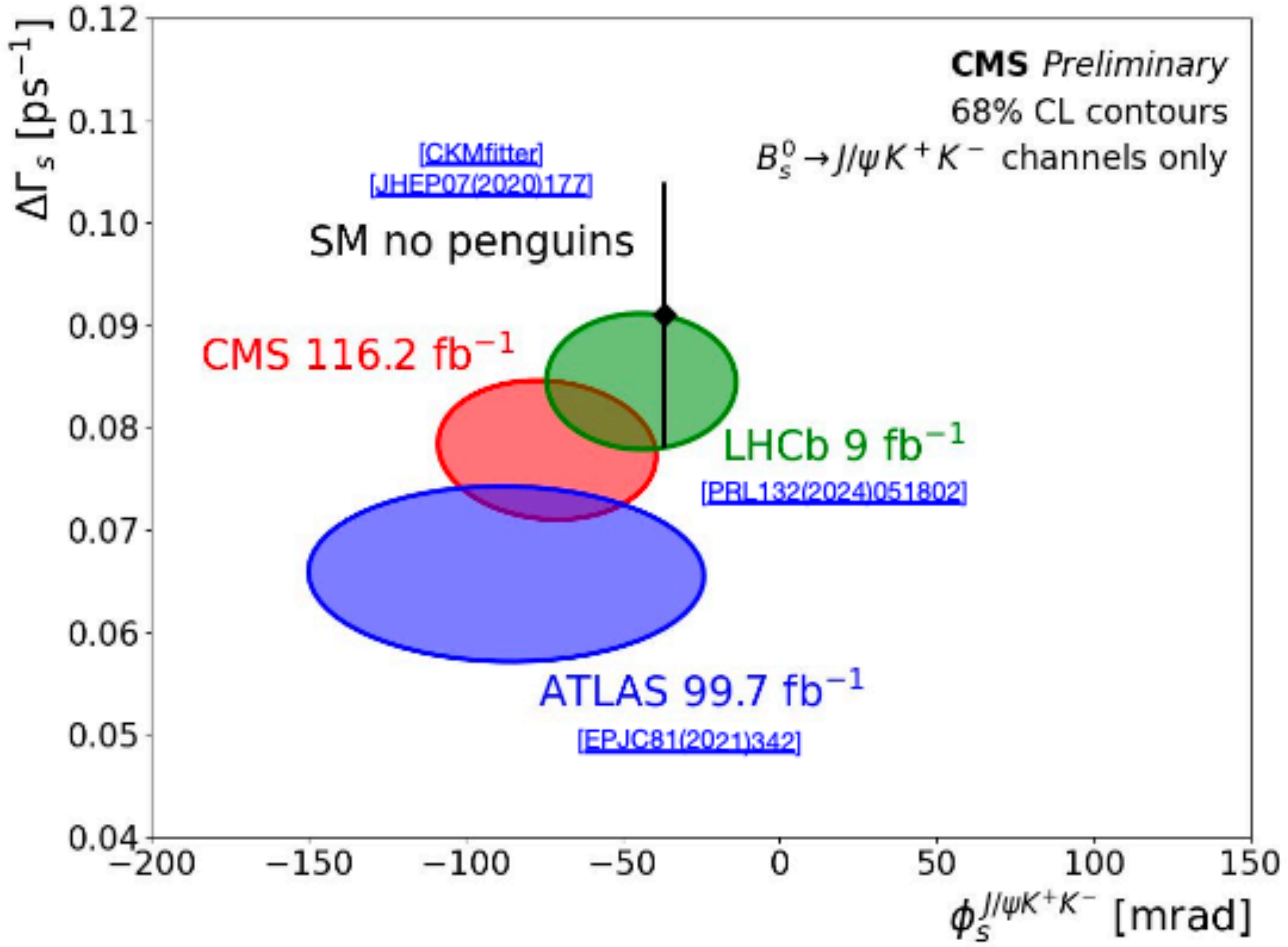


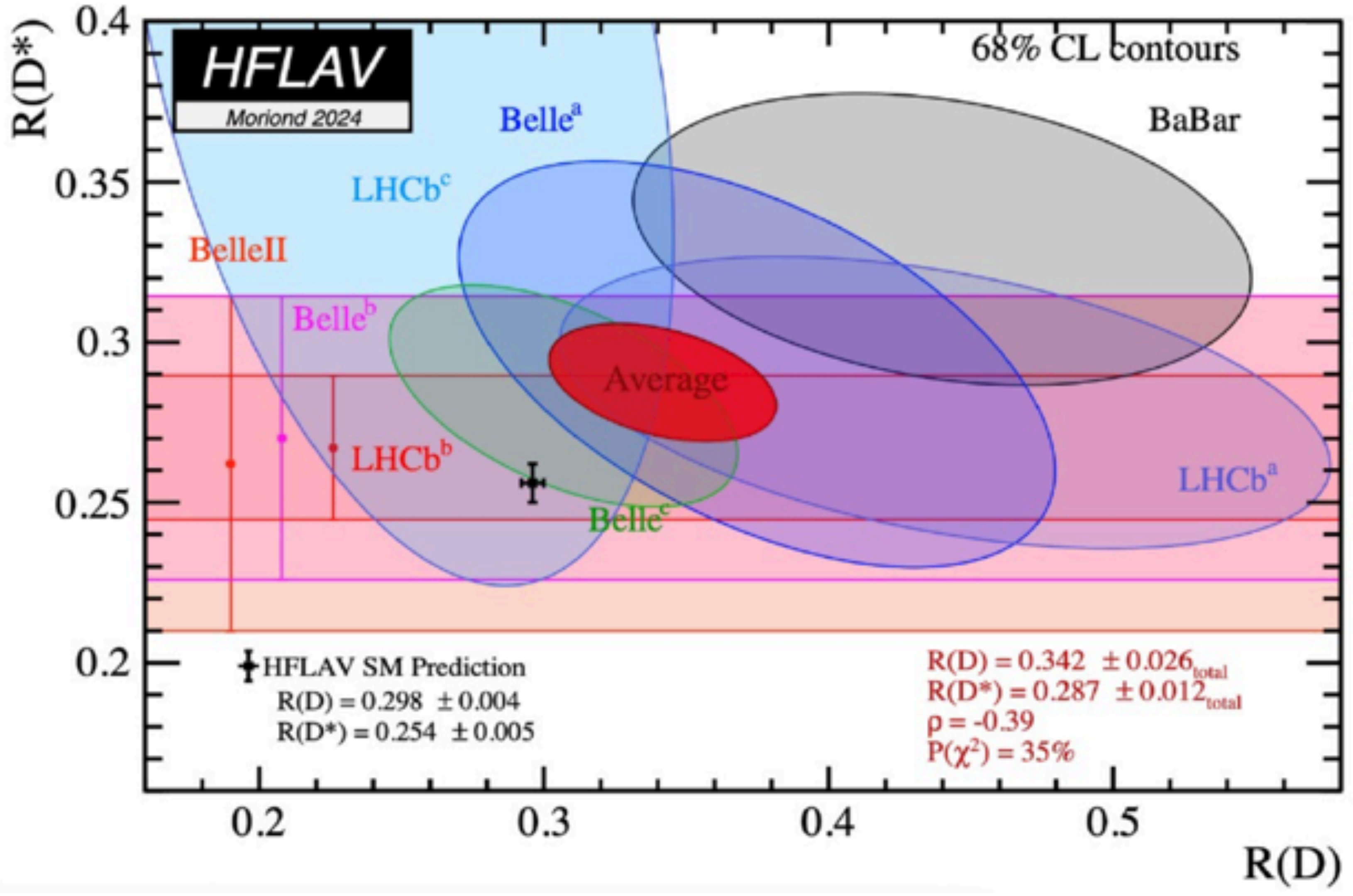


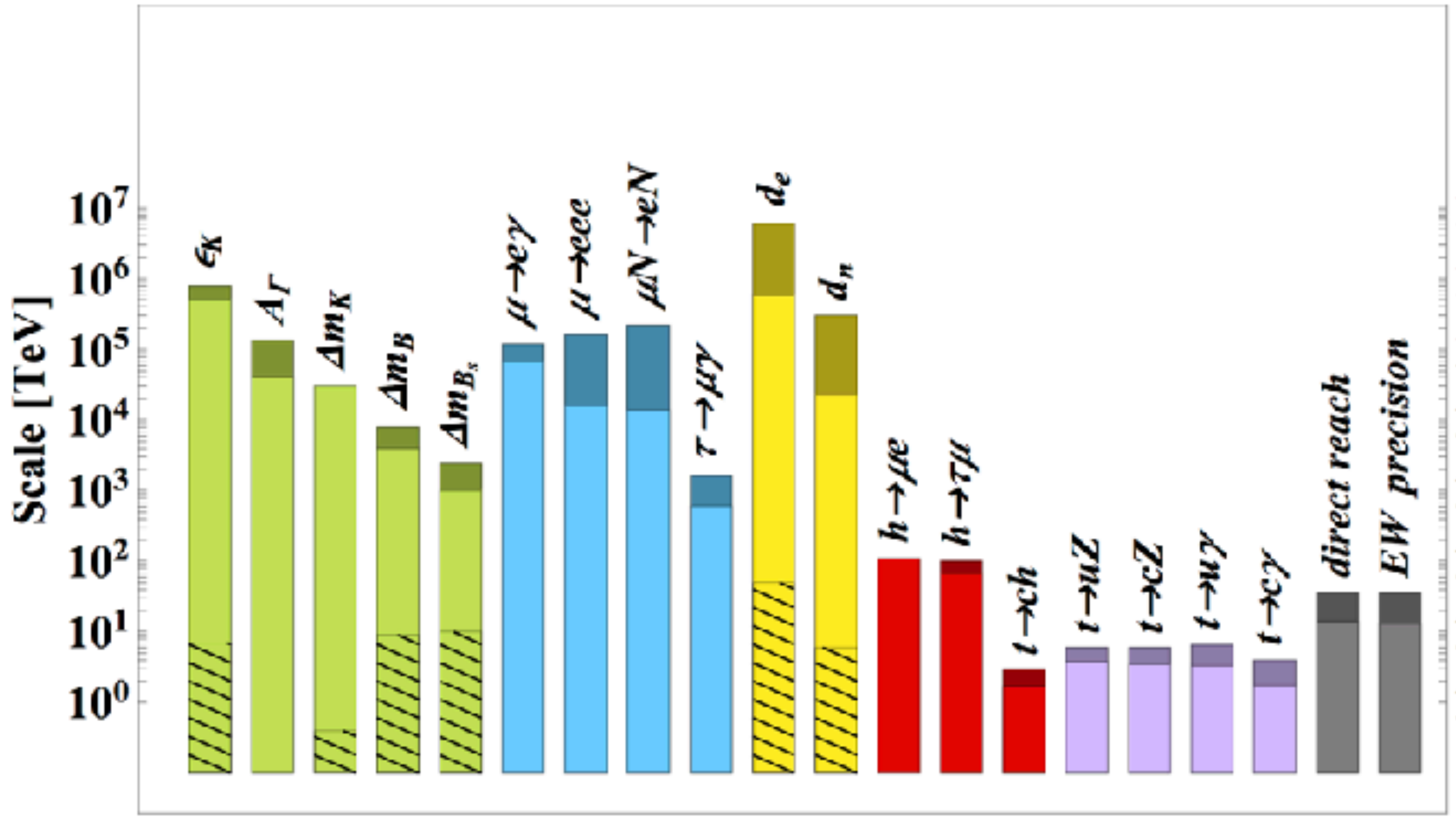
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsHIG

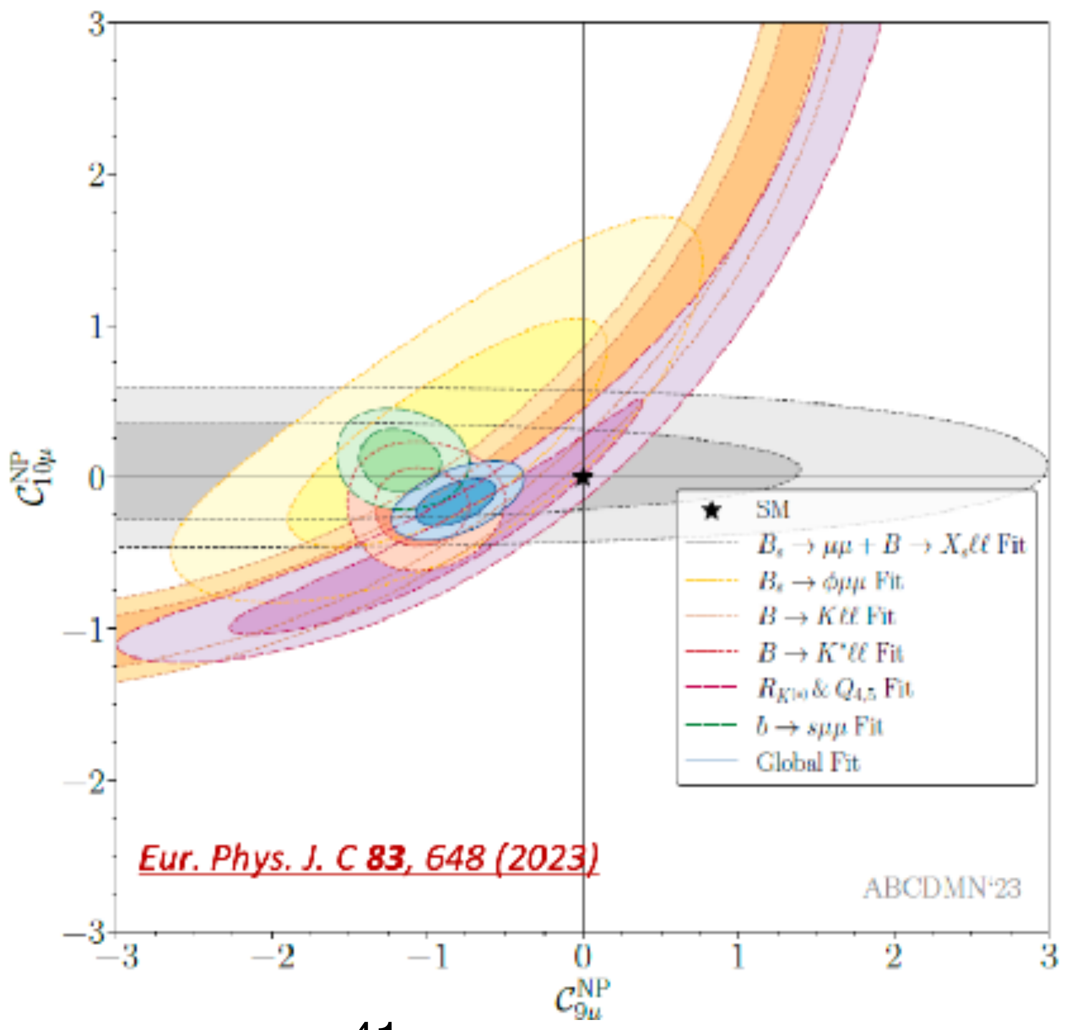
Precision measurements: flavour

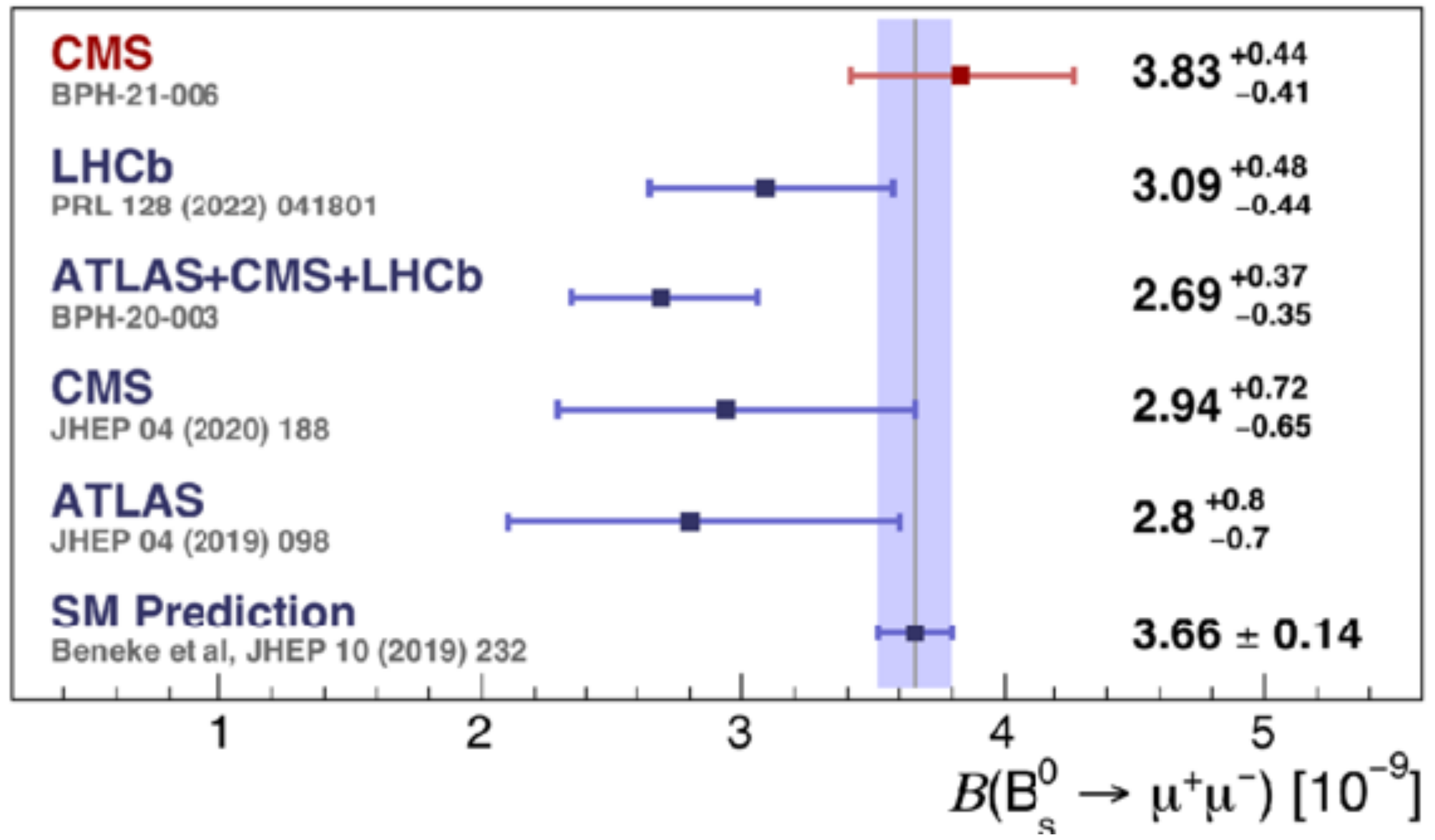












http://ckmfitter.in2p3.fr/ http://www.utfit.org/ https://hflav.web.cern.ch/

https://cms-results.web.cern.ch/cms-results/public-results/publications/BPH/

CPV: H

https://cms-results.web.cern.ch/cms-results/public-results/publications/HIG-21-006/index.html

LQ and Z’

gamma gamma -> tau tau