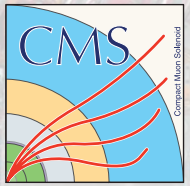
LFV and related rare decays at ATLAS and CMS

LHCP 2024, Boston, 4 June 2024



Marc Huwiler[1]

On behalf of the ATLAS and CMS collaborations

[1]CMS, University of Zurich

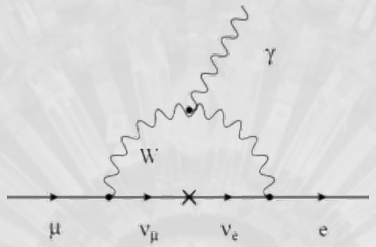
University of Zurich[UZH]

LFV, LFUV, and possible NP

Lepton Flavour Violation (LFV)

no symmetry enforcing lepton flavour conservation in SM

- ν oscillations → LFV in neutral leptons
- charged lepton flavour violation (cLFV) through ν mixing at 10^{-55}
- cLFV at higher rate → NP?



Lepton Flavour Universality Violation (LFUV)

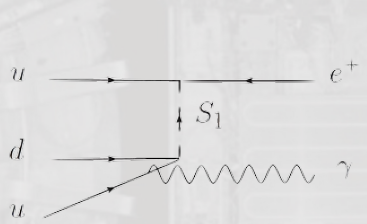
In the SM, the couplings of the leptons to the gauge bosons (W, Z) are of equal strength

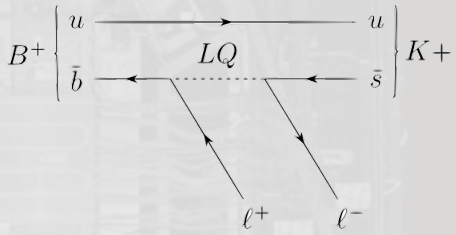
- the Yukawa coupling exhibits a *flavour structure*, giving each charged lepton family different mass
- additional forces could exhibit similar favour structures, and have enhanced couplings to 3rd generation leptons

Possible *New Physics* (*NP*) explanations

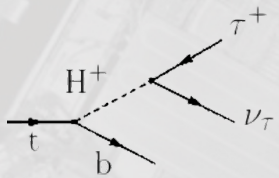
Many BSM models predict rates up to 10^{-8}
→ *within reach of current experiments!*

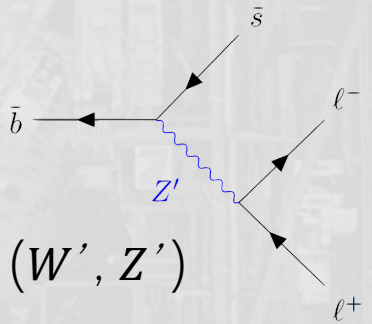
- Leptoquarks





- Extended Higgs sector / Technicolor





- Heavy Gauge bosons (W', Z')

Content

LFV | **LFUV**

TOP

-  $\mu\tau qt$ coupling in t *production and decay* (arXiv:2403.06742)
-  $e\mu qt$ coupling in t *production and decay* (arXiv:2312.03199)

-  $R(W)$ in $t\bar{t}$ (arXiv:2403.02133)
-  $R(W)$ τ/μ (Nature Phys. 17 (2021) 813)
-  W branching ratios (Phys. Rev. D 105)

B

-  $\tau \to 3\mu$ decay (Physics Letters B 853 (2024))

-  $R(J/\psi)$ leptonic (CMS-PAS-BPH-22-012)
-  $R(K)$ and $\mathcal{B}(B^{\pm} \to \mu^{\pm}\mu^{\mp}K^{\pm})$ (arXiv:2401.07090)

older results in backup...

$R(W)$ at ATLAS

arXiv:2403.02133

$$R_W^{\mu/e} = \frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)} = \frac{\frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)}}{\sqrt{\frac{\mathcal{B}(Z\to\mu\mu)}{\mathcal{B}(Z\to ee)}}} \cdot \sqrt{\frac{\mathcal{B}(Z\to\mu\mu)}{\mathcal{B}(Z\to ee)}}$$

$= R_{WZ}^{\mu/e}$ measured

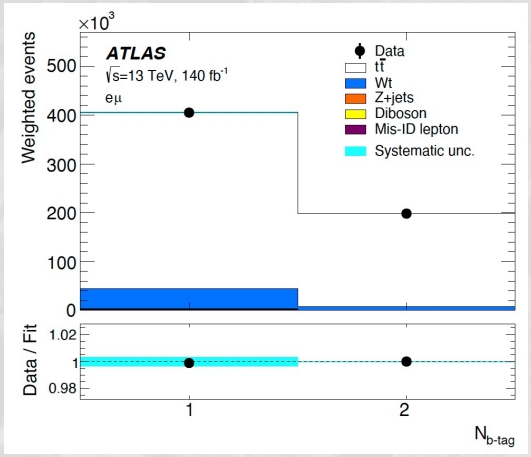
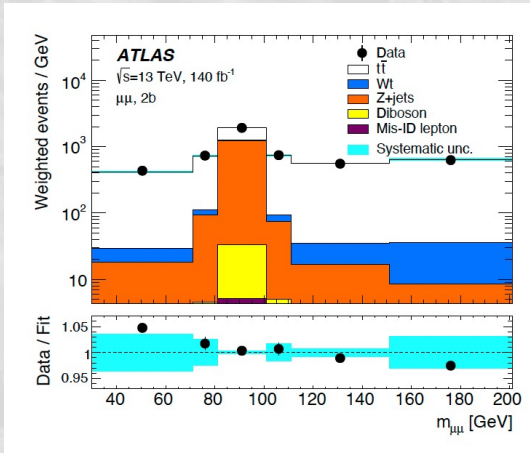
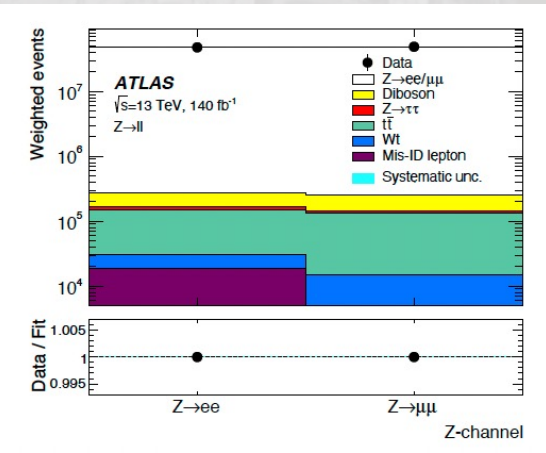
$= R_Z^{\mu\mu/ee} = 1.0009 \pm 0.0028$ taken from LEP2 and SLD

Full run 2 (140 fb^{-1}) 2015-2018

Comparing $\sigma_{t\bar{t}}$ in ee, $e\mu$, and $\mu\mu$ final states in 2 opposite charge leptonic $t\bar{t}$ events → cancel syst.

Simultaneous measurement of $R_Z^{\mu\mu/ee}$ (from $Z \to \ell\ell$ region) used as ***normalisation channel*** → **double ratio**: **reduce syst. due to lepton efficiencies**

- main bkg.: Z + *jets* (Z veto in $t\bar{t}$ ee and $\mu\mu$ regions + additional binning in $m_{\ell\ell}$)
- *Wt* and *WW* production also used as source of W for the determination of $R_{WZ}^{\mu/e}$

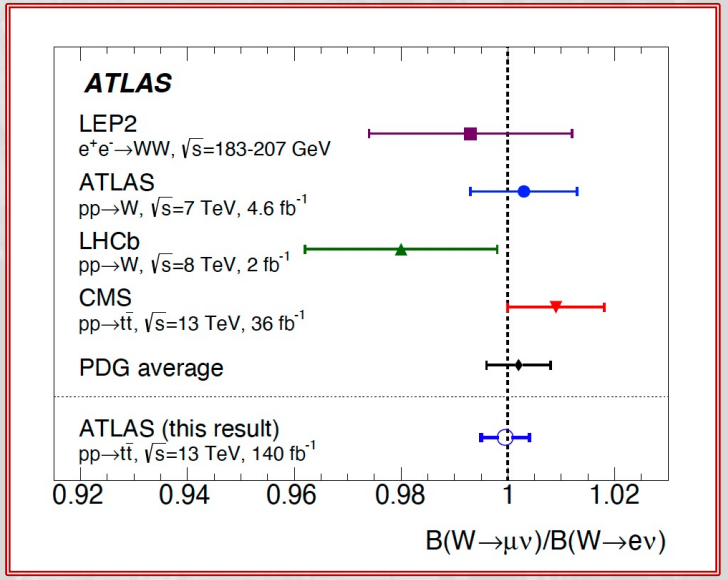
	$t\bar{t}$	$Z \to \ell\ell$
	• 1 and 2 b-jets selected	• no b-jet requirement
$e\mu$		
ee		
$\mu\mu$	• Further binned in $m_{\ell\ell}$ for each b-jet category	• Large Z mass window

$R(W)$ at ATLAS

Full run 2 (140 fb^{-1}, 2015-2018)

Simultaneous maximum likelihood fit of all regions

- extract all POI: $R_{WZ}^{\mu/e}$, $R_{Z}^{\mu\mu/ee}$, $\sigma_{t\bar{t}}$ and $\sigma_{Z\to\ell\ell}$



- $R_{Z}^{\mu\mu/ee} = 0.9913 \pm 0.0045$ *is 1.9 σ below 1 → attributed to lepton efficiencies*
- *double ratio protects* $R_{W}^{\mu/e}$ *against this effect (up to kin. differences of leptons between* $t\bar{t}$ *and* $Z \to \ell\ell$*)*
- systematically limited: PDF, lepton misID, Z+jet modelling, $t\bar{t}$ modelling

$$R_{W}^{\mu/e} = \frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)} = 0.9995(stat.) \pm 0.0022 \pm 0.0036\ (syst.) \pm 0.0014\ (ext.) = 0.9995 \pm 0.0045$$

- consistent with LFU and prev. measurements
- most precise to date (0.45% uncertainty)

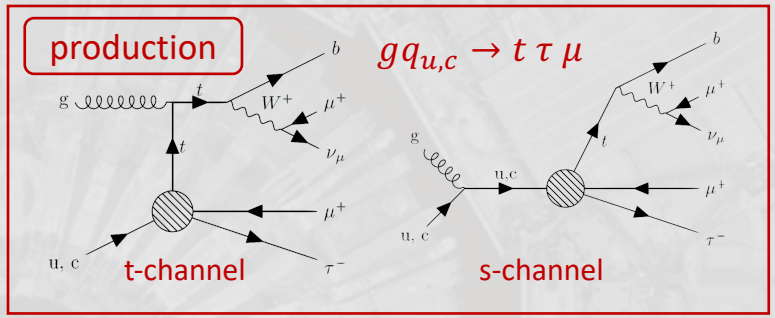
$\mu\tau qt$ coupling at ATLAS

arXiv:2403.06742

Full run 2 (140 fb^{-1}, 2015-2018)

Probe $\mu\tau qt$ coupling in EFT

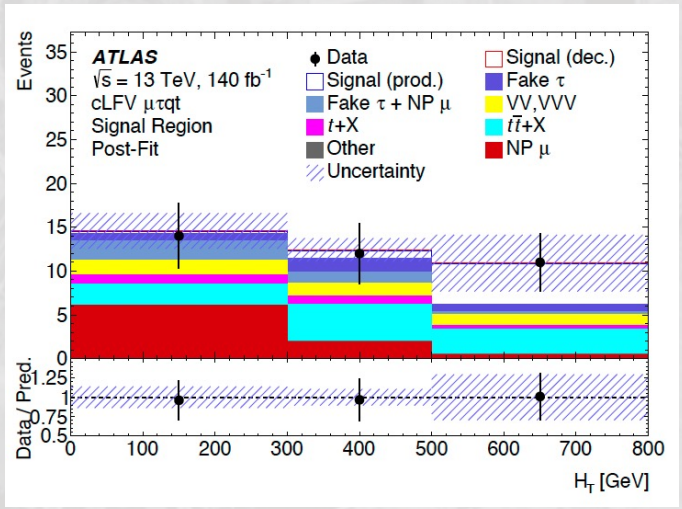
- 2L2Q operators in single-t production and t decay $(t\bar{t})$
- 2 same-sign μ, 1 hadronic τ_h , > 1 jet (among which 1 b-jet)

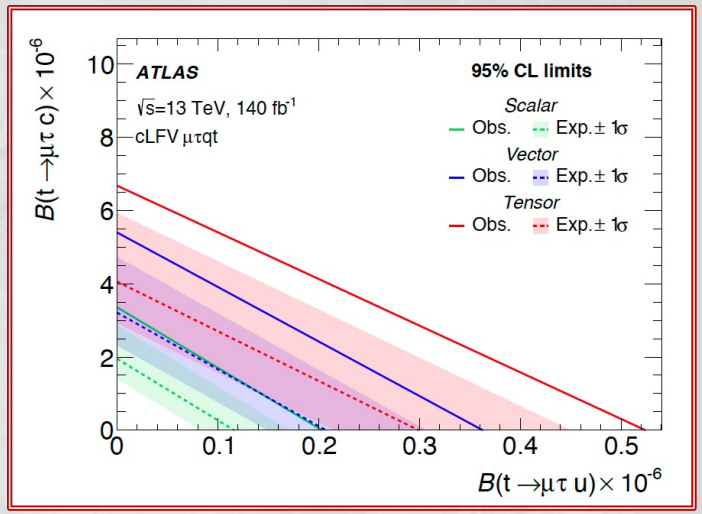


Most of the sensitivity

Limit on $\mathcal{B}(t \to \mu\,\tau\,q_{c,u})$ and on *Wilson coefficients* extracted with a binned profile-likelihood fit of H_T (scalar sum of transverse momenta)

- main bkg.: $t\bar{t} \to B \to \mu$, constrained from simultaneous fit of control region (data-driven)
- **statistically dominated**, main syst.: *tt+X*, *diboson*, *signal parton showers*





Inclusive limit (w. EFT flavour structure assumption) at 95% CL:

Observed: $\mathcal{B}(t \to \mu\,\tau\,q_{c,u}) < 8.7 \cdot 10^{-7}$ (expected $< 5 \cdot 10^{-7}$)

$e\mu qt$ coupling at CMS

arXiv:2312.03199

Probe $e\mu qt$ coupling in EFT

- 2L2Q operators in t *production* and *decay*
- $e^{\pm}\mu^{\mp}$ from LFV interaction (w. opposite q) + 1 additional lepton from the t decay, >1 jet (1 b-jet)

Full run 2 (2016-2018, 138 fb^{-1})

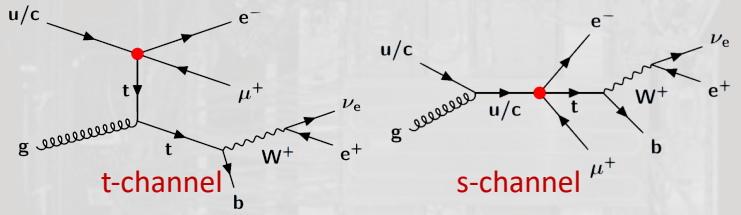
Limit on *Wilson coefficients* and $\mathcal{B}_r$ extracted with a *maximum likelihood fit* of the BDT discriminants

	(scalar)	(vector)	(tensor)
$\mathcal{B}(t \to e\,\mu\,u)$	$< 1.2 \cdot 10^{-8}$,	$< 2.2 \cdot 10^{-8}$,	$< 3.2 \cdot 10^{-8}$
$\mathcal{B}(t \to e\,\mu\,c)$	$< 2.16 \cdot 10^{-7}$,	$< 3.67 \cdot 10^{-7}$,	$< 4.98 \cdot 10^{-7}$

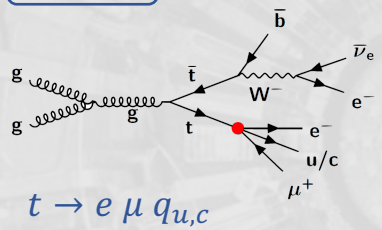
at 95% CL

production

$g q_{u,c} \to t\,e\,\mu$

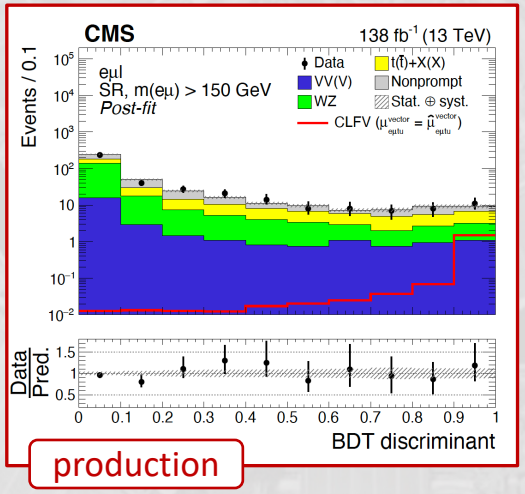


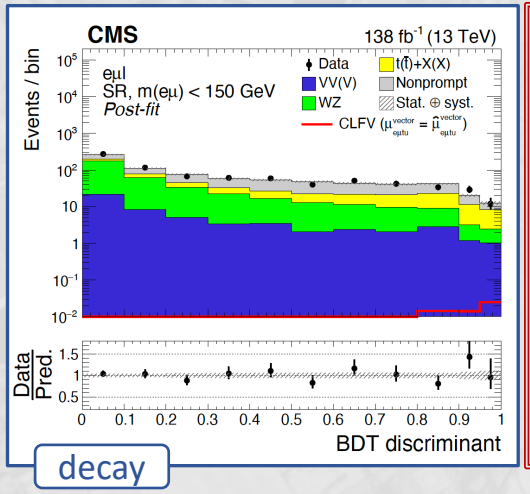
decay

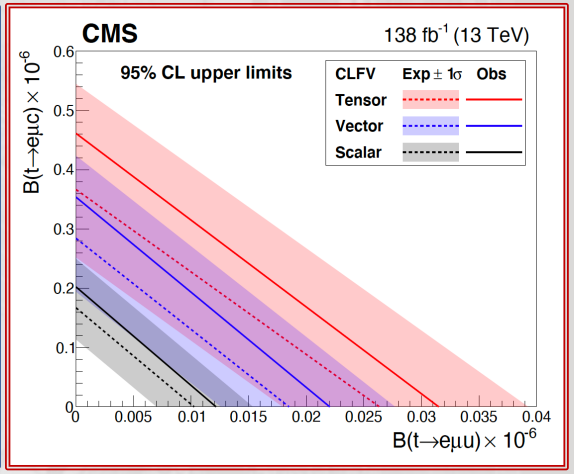


$t \to e\,\mu\,q_{u,c}$

- main bkg.: non-prompt leptons $t\bar{t} \to B \to e/\mu$
- statistically dominated, main systematics: lepton reco. and iso, jet modelling, non-prompt leptons







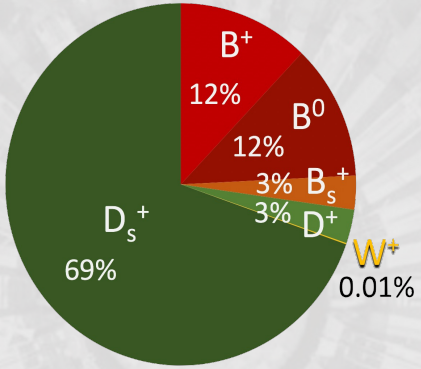
$\tau \to 3\mu$ at CMS

Physics Letters B 853 (2024)

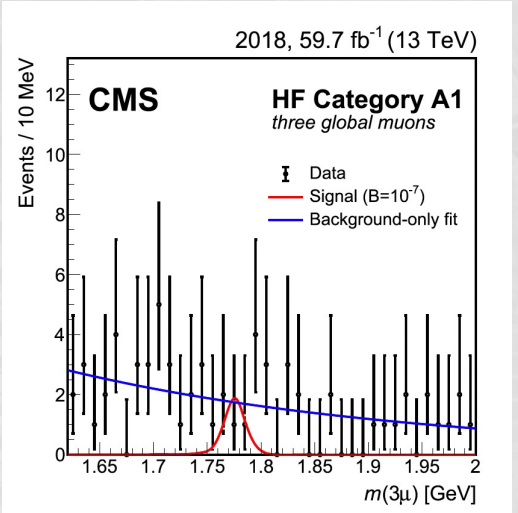
Limit on $\mathcal{B}(\tau \to 3\mu)$ in Heavy Flavour (B and D meson) and W boson decays

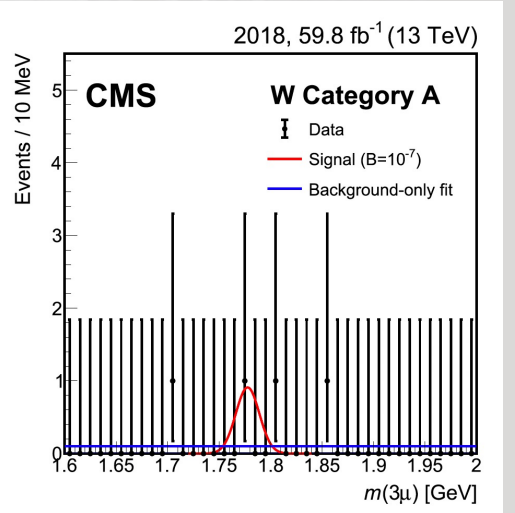
- $B, D \to \tau \to 3\mu$: high stats, lower p_T, more bkg.
- $W \to \tau \to 3\mu$: low stats, high purity

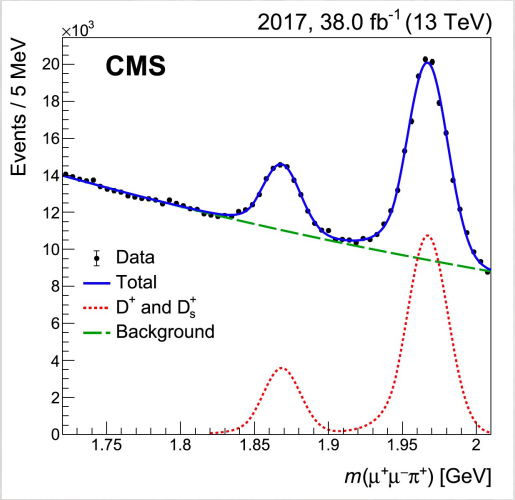
- Displaced 3μ vtx. w. $q = \pm 1$
- B, D channel: norm. channel: $D_s^+ \to (\varphi \to \mu^+\mu^-)\,\pi^+$
- split into ***m* resolution** categories (A, B, C), the 2 channels (B, D / W) and *year*, then analysis BDT regions (1, 2, 3)



Full run 2 (97.7 fb^{-1} in 2017 and 2018, combined with 2016 J. High Energ. Phys. 2021, 163 (2021))





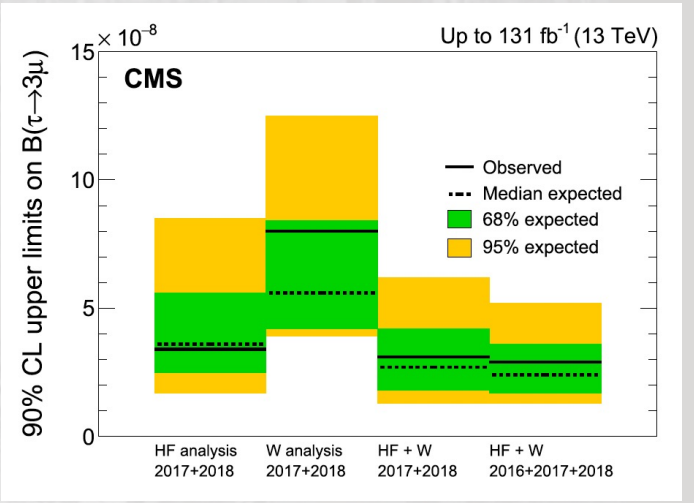


- Simultaneous maximum likelihood fit on $\boldsymbol{m_\tau}$ **distribution** in all regions
- statistically limited, major syst.: $K^\pm, \pi^\pm \to \mu^\pm$ mis-ID (major bkg., dedicated BDT), normalisation, $\mathcal{B}_r$, ϵ_μ, ϵ_{BDT}

Observed (expected) limit:

$\mathcal{B}(\tau \to 3\mu) < 2.9\ (2.4) \cdot 10^{-8}$ at 90% CL

$< 3.6\ (3.0) \cdot 10^{-8}$ at 95% CL



$R(J/\psi)$ at CMS

CMS-PAS-BPH-22-012

Flavour anomalies: deviations from LFU observed in $b \to c\,\ell\,\nu$ transition with $\boldsymbol{R(D^*), R(D)}$, …

$$R(J/\psi) = \frac{\mathcal{B}\left(B_c^{\pm} \to J/\psi\,\tau^{\pm}\nu_\tau\right)}{\mathcal{B}\left(B_c^{\pm} \to J/\psi\,\mu^{\pm}\nu_\mu\right)}$$

2018 (59.7 fb^{-1})

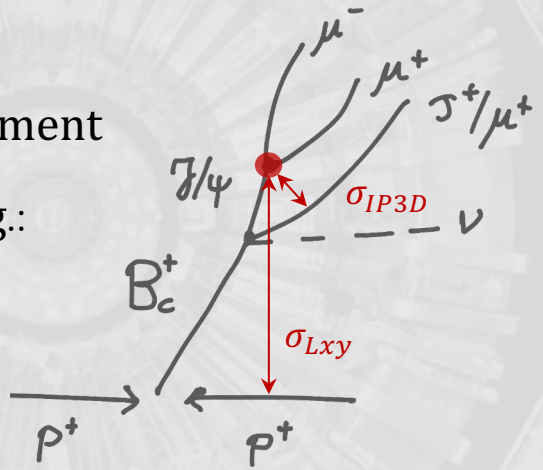
First measurement of $R(J/\psi)$ by CMS (complements LHCb measurement Phys. Rev. Lett. 120, 121801)

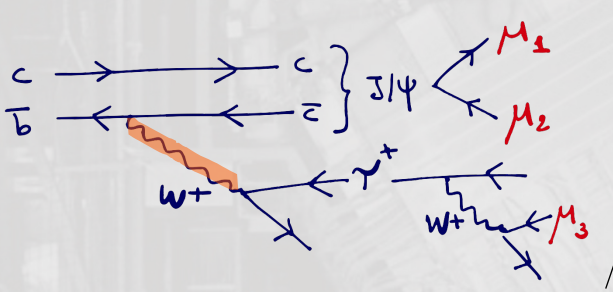
- 3μ events selected (2018 3μ trigger)
- J/ψ ***vertex*** (2μ with opposite charge) and ***m*** requirement
- exploit decay topology to distinguish signals and bkg.:

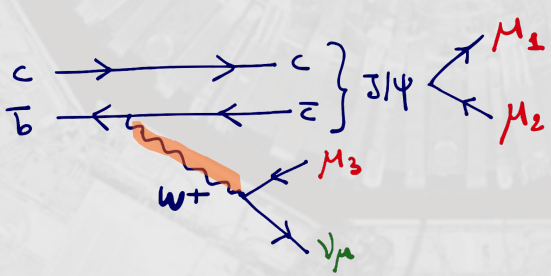
  significance of 3D IP between μ and J/ψ vtx: σ_{IP3D}

  significance of J/ψ vtx displacement : σ_{Lxy}

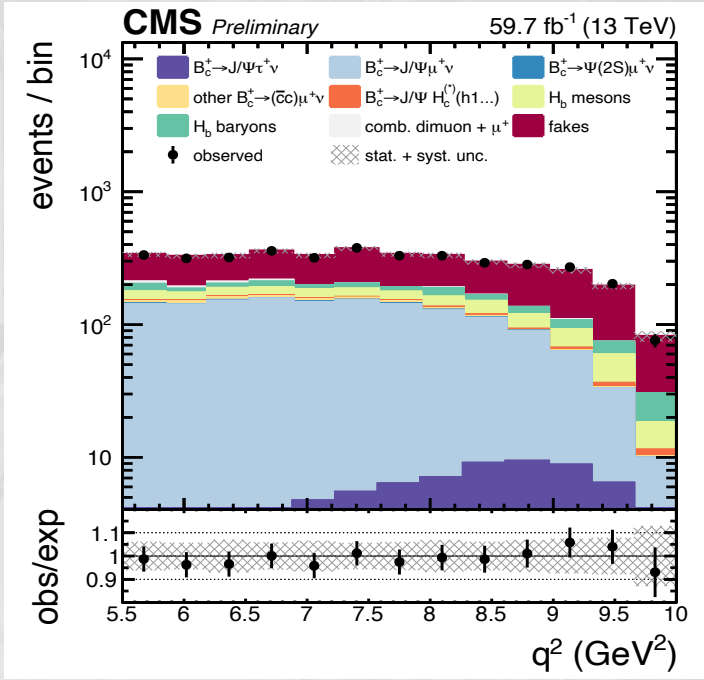
  transferred 4-momentum: $q^2 = (p_B - p_{J/\psi})$







3 μ visible final state



$R(J/\psi)$ at CMS

2018 (59.7 fb^{-1})

Simultaneous binned maximum likelihood template fit of 14 regions

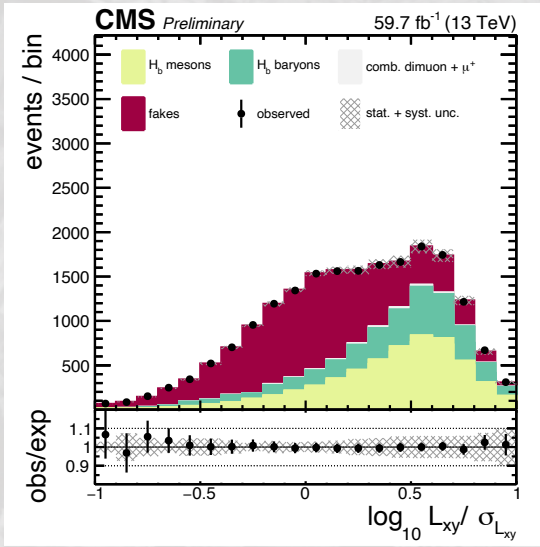
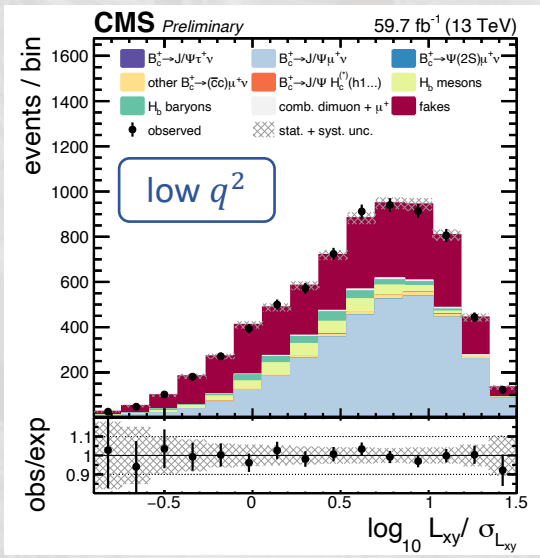
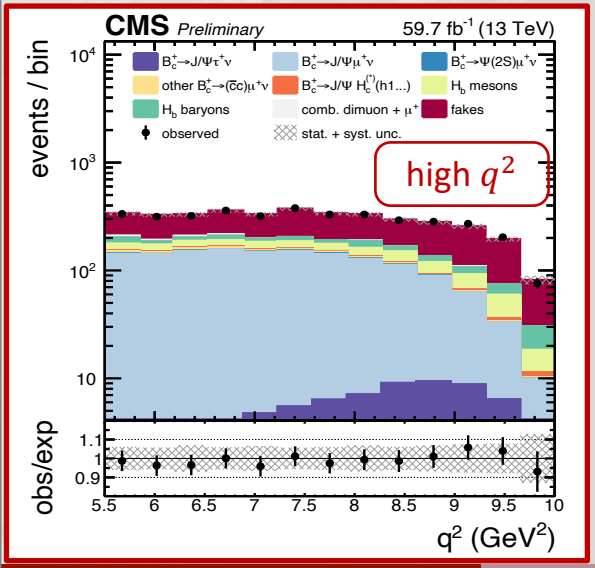
- bkg. w. J/ψ and $\mu^{\pm}$ from hadron decays simulated, and constrained in *high mass* control region (CR)
- ***misID***: in-flight decay of $K^{\pm},\pi^{\pm} \rightarrow \mu^{\pm}$ Neural Network weighting extrapolated from CRs
- combinatoric from $\mu^{+}\mu^{-}$ pair in J/ψ modelled from low dimuon mass

- **statistical close to syst.**, main syst.: B_c^+ form factors, *misID*, MC stats, kinematic modelling

$$R(J/\psi) = \mathbf{0.17 \pm 0.33}$$
$$= 0.17\ ^{+0.18}_{-0.17}(stat.)\ ^{+0.21}_{-0.22}(syst.)\ ^{+0.19}_{-0.18}(th.)$$

Consistent with SM and LHCb measurement

SM:	$R(J/\psi) = 0.2582(38)$
LHCb:	$R(J/\psi) = 0.71 \pm 0.17(\text{stat}) \pm 0.18(\text{syst})$

	$low - q^2$	$high - q^2$
$m_{reco}(B) > m_{B_c}$		
$m_{reco}(B) < m_{B_c}$		

- Separated into $high - q^2$ and $low - q^2$ ($q^2 < 4.5$ GeV)
- *High mass* region $m_{reco}(B) > (M_{B_c} = 6.27 GeV)$ used to constrain bkgs.
- In $high - q^2$ 4 σ_{Lxy} bins further binned in q^2
- 2 bins of σ_{Lxy} in $low - q^2$

$R(K)$ at CMS

arXiv:2401.07090

$$R(K) = \frac{\mathcal{B}(B^{\pm} \to \mu^{\pm}\mu^{\mp}K^{\pm})}{\mathcal{B}(B^{\pm} \to e^{\pm}e^{\mp}K^{\pm})} = \frac{\frac{\mathcal{B}(B^{\pm} \to \mu^{\pm}\mu^{\mp}K^{\pm})}{\mathcal{B}(B^{\pm} \to (J/\psi \to \mu^{\pm}\mu^{\mp})K^{\pm})}}{\frac{\mathcal{B}(B^{\pm} \to e^{\pm}e^{\mp}K^{\pm})}{\mathcal{B}(B^{\pm} \to (J/\psi \to e^{\pm}e^{\mp})K^{\pm})}}$$

measured on ***tag-side***

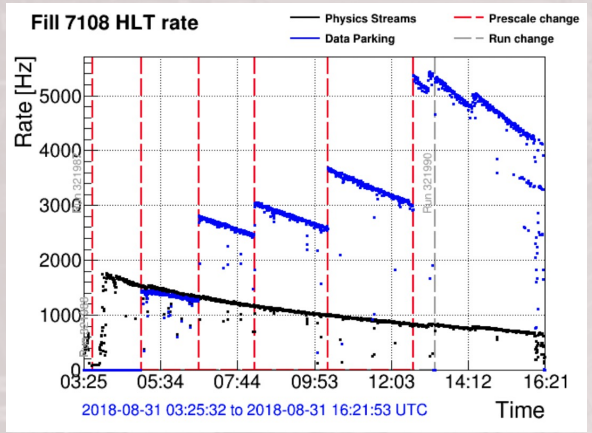
- $\epsilon_{trig.}$ do not cancel in ratio ☹
- more stats in $B^{\pm} \to \mu^{\pm}\mu^{\mp}K^{\pm}$ channel ☺

measured on ***probe-side***

2018 B-parking (41.6 fb^{-1})

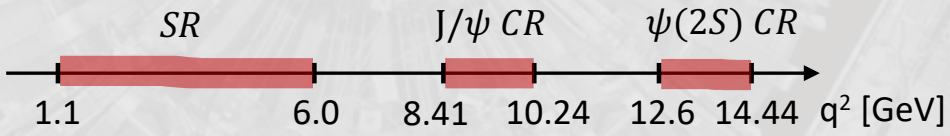
2018 *B*–parking dataset

- trigger **displaced μ** to tag B decays $(\mathcal{B}(b\bar{b} \to \mu + X) \approx 40\%)$
- gradually adjusted → exploit spare rate during LHC $\mathcal{L}$ drop

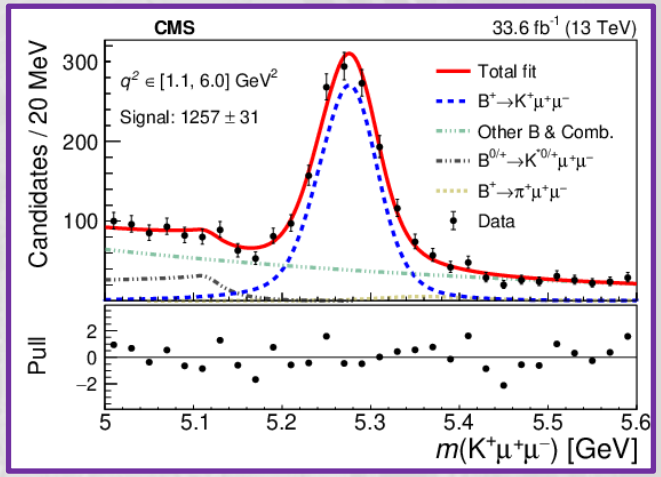


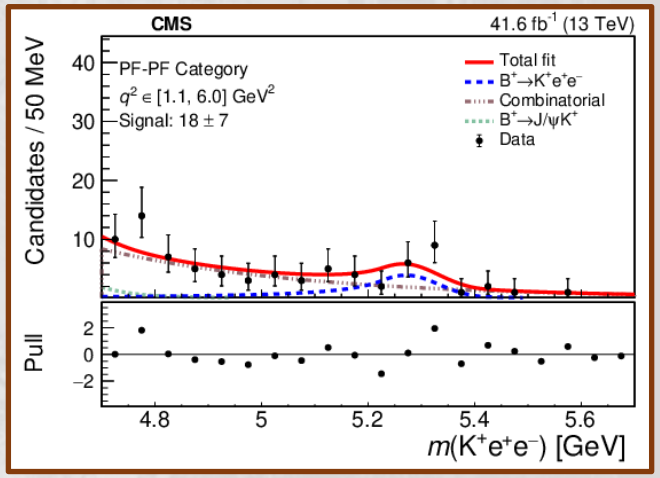
- **~10 billion** unbiased B decays (paper: arXiv:2403.16134)

- Dedicated low-p_T $e^{\pm}$ reconstruction and ID down to 1 GeV
- 3 q^2 regions: measurement is **double ratio in *SR* and J/ψ *CR*** *(control with ratio in J/ψ CR and $\psi(2S)$ CR)*



- Main bkg.: combinatorial, partially reco. $B^{*0/+} \to K^{*0/+}(892)\ell^{\pm}\ell^{\mp}$, $B^{\pm} \to \pi^{\pm}\ell^{\pm}\ell^{\mp}$ (simulated), leakage from resonant J/ψ and $\psi(2S)$, $B^{+} \to K^{+}h_1h_2$ (<10^{-3}, 6% unc.)



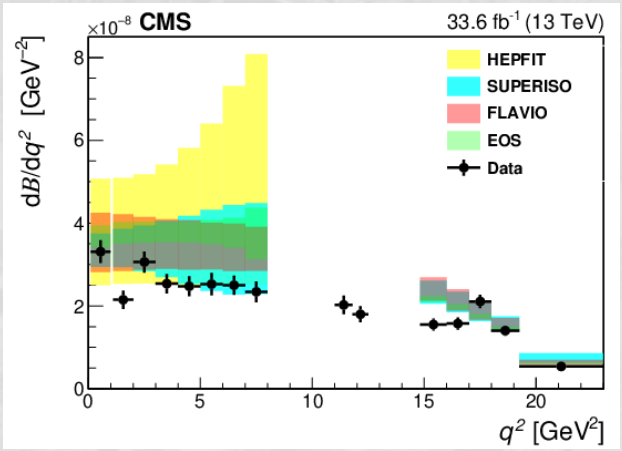


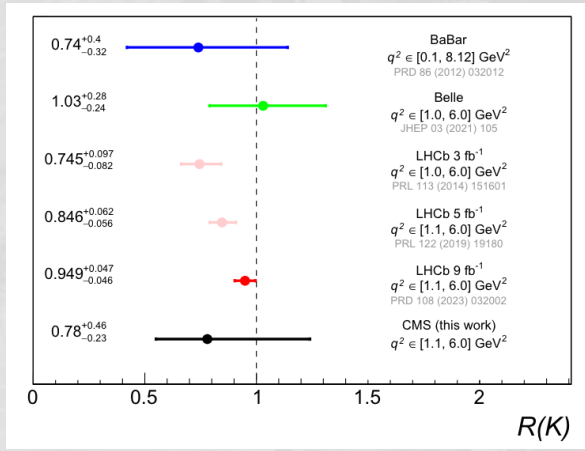
$R(K)$ at CMS

Unbinned maximum likelihood fit on m_B with analytic functional (templates from MC) shapes

- yields floating in fit
- shape parameters as nuisances (Gaussian constraints in likelihood function)
- validated in J/ψ and $\psi(2S)$ control regions
- **statistically dominated (*ee* channel)**, main syst.: MC stats., bkg. description (low-q², J/ψ *CR*), trigger turn-on

2018 B-parking (41.6 fb^{-1})





$$\mathcal{B}(B^\pm \to \mu^\pm\mu^\mp K^\pm)[1.1, 6.0]\text{GeV} = (12.42 \pm 0.68) \cdot 10^{-8}$$
$$= ((12.42 \pm 0.54\,(stat.) \pm 0.11\,(MC) \pm 0.40\,(syst.)) \cdot 10^{-8}$$

Consistent with world average and LHCb measurement

World avg: $\mathcal{B}(B^\pm \to \mu^\pm\mu^\mp K^\pm)[1.0, 6.0]\text{GeV} = (12.6 \pm 1.2) \cdot 10^{-8}$
LHCb: $\mathcal{B}(B^\pm \to \mu^\pm\mu^\mp K^\pm)[1.1, 6.0]\text{GeV} = (11.86 \pm 0.68) \cdot 10^{-8}$

Separate fit in bins of q^2 simultaneously for differential measurement of $\mathcal{B}(B^\pm \to \mu^\pm\mu^\mp K^\pm)$

- main syst.: bkg. description, trigger turn-on

$$R(K) = 0.78\,^{+0.46}_{-0.23}(stat.)\,^{+0.09}_{-0.05}(syst.) = 0.78\,^{+0.47}_{-0.23}$$

Within 1σ of SM expectation (≈ 1) and compatible with previous measurements

Summary and conclusion

	LFV	LFUV
TOP	$\mathcal{B}(t \to \mu\,\tau\,q_{c,u}) < 8.7 \cdot 10^{-7}$ at 95% CL $\mathcal{B}(t \to e\,\mu\,u) < 0.32 \cdot 10^{-7}$ at 95% CL $\mathcal{B}(t \to e\,\mu\,c) < 4.98 \cdot 10^{-7}$ at 95% CL • No signs from LFV coupling involving t quark • However, *stats. limited* → ***HL LHC* will tell more**!	$R_W^{\mu/e} = \frac{\mathcal{B}(W \to \mu\nu)}{\mathcal{B}(W \to e\nu)} = 0.9995 \pm 0.0045$ $R_W^{\tau/\mu} = \frac{\mathcal{B}(W \to \tau\nu)}{\mathcal{B}(W \to \mu\nu)} = 0.992 \pm 0.013$ • LFU well in established in W decays (at sub-% level)
B	$\mathcal{B}(\tau \to 3\mu) < 3.6\ (2.9) \cdot 10^{-8}$ at 95% (90%)CL • No enhancement of $\mathcal{B}(\tau \to 3\mu)$ beyond 10^{-8} • However, *stats. limited*, sensitivity only started eating into most optimistic NP models → **still a long way to go to rule it out**!	$R(J/\psi) = 0.17 \pm 0.33$ $R(K) = 0.78\ ^{+0.47}_{-0.23}$ • First measurements from CMS in $b \to c\,\ell\,\nu$ and $b \to s\,\ell\ell$ • Neither confirm/infirm previous measurements nor SM

Thank you for your attention!

Further questions?

marc.huwiler@cern.ch

Backup

$R(W)\ \tau/\mu$ at ATLAS

Nature Phys. 17 (2021) 813

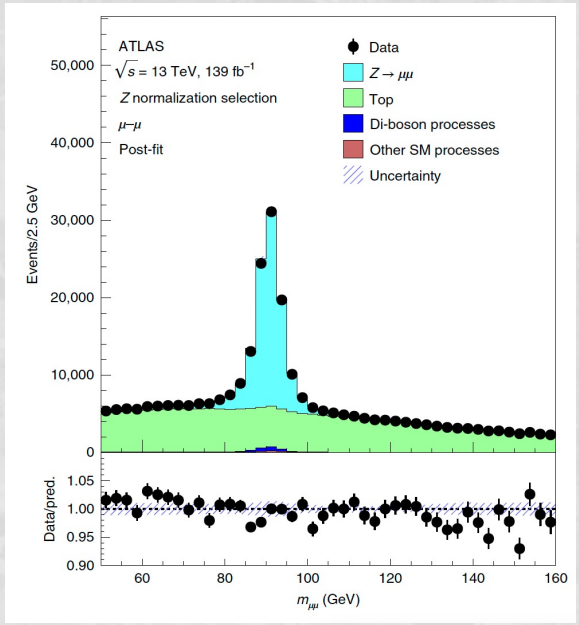
$$R(\tau/\mu) = \frac{\mathcal{B}(W\to\tau\nu)}{\mathcal{B}(W\to\mu\nu)} \qquad \tau \to \mu\,\nu_\tau\nu_\mu$$

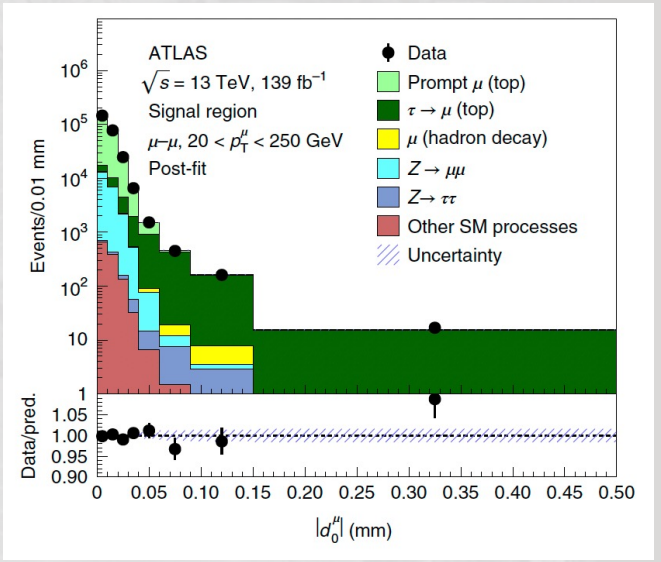
Full run 2 (139 fb^{-1}, 2015-2018)

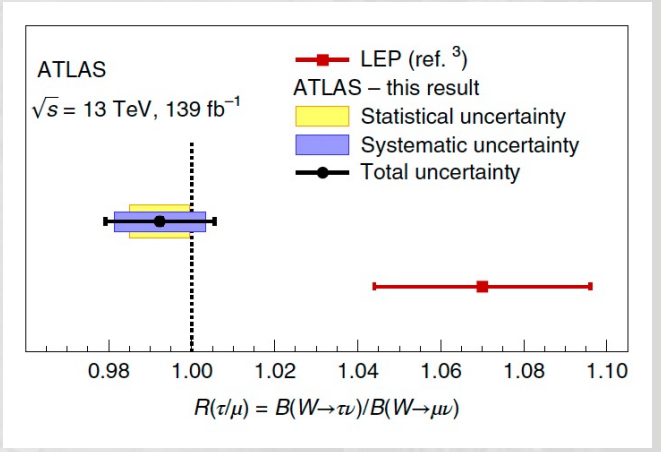
Comparing $\mu\mu$ and $e\mu$ final states in leptonically tagged $t\bar{t}$ events

Profile likelihood fit extracts the ratio in 3 p_T and 8 $|d_0^\mu|$ (muon displacement) bins

- shape of $|d_0^\mu|$ obtained from a Z $\to \ell\ell$ CR
- main bkg.: $t\bar{t} \to B \to \mu$, in-flight decay of $K^\pm,\pi^\pm \to \mu^\pm$
- **statistically dominated**, main syst.: data-driven modelling, theory, reconstruction







$$R(\tau/\mu) = 0.992 \pm 0.007\,(stat.) \pm 0.011\,(syst.) = 0.992 \pm 0.013$$

W branching ratios at CMS

Phys. Rev. D **105**, 072008

Full run 2 (2016-2018, 138 fb^{-1})

Measurement of W branching fractions in e, μ, τ and hadrons

- 21 categories using W from $t\bar{t}$ (90%), Wt (4.4%), WW (1.4%) and W+jets (4.1%) events
- Binned maximum likelihood fit in all categories extracts the 4 $\mathcal{B}_r$, as well as CKM elements
- Major bkg: $t\bar{t} \to B \to \mu$

$$\mathcal{B}(W \to e\nu_e) = (10.83 \pm 0.10) \cdot 10^{-2}$$

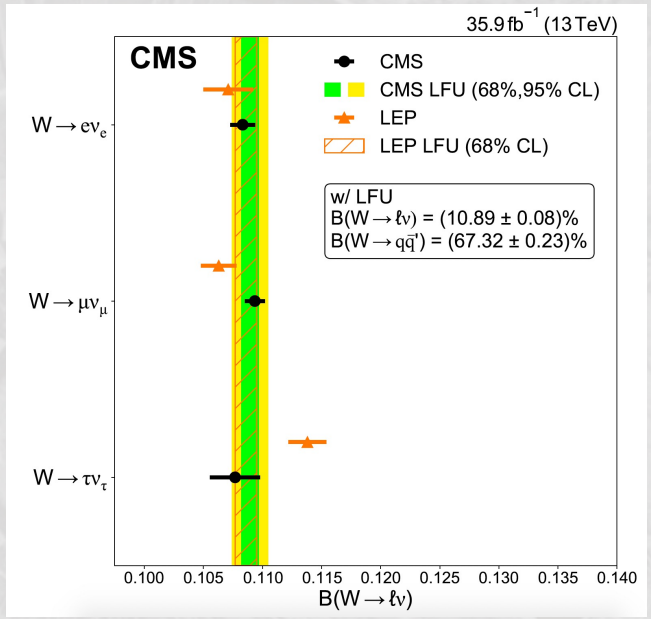
$$\mathcal{B}(W \to \mu\nu_\mu) = (10.94 \pm 0.08) \cdot 10^{-2}$$

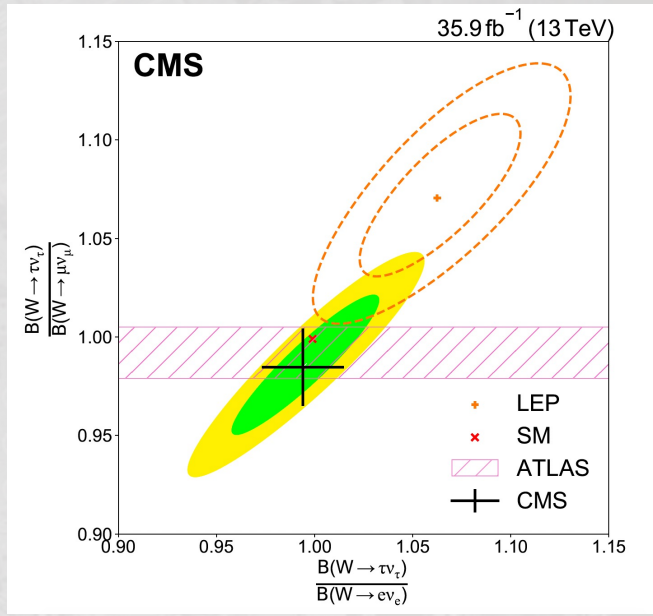
$$\mathcal{B}(W \to \tau\nu_\tau) = (10.77 \pm 0.21) \cdot 10^{-2}$$

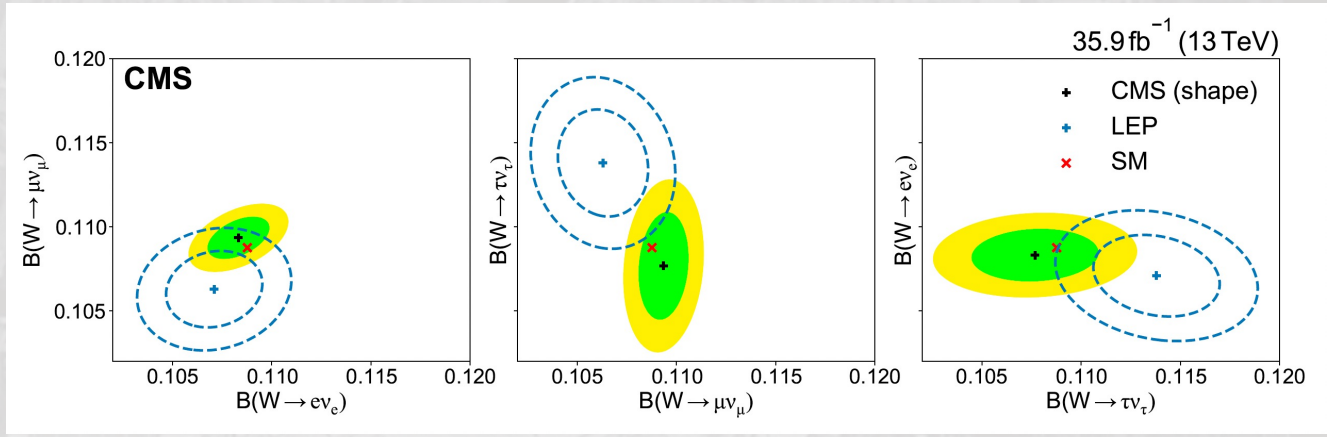
$$\mathcal{B}(W \to Nh) = (67.32 \pm 0.23) \cdot 10^{-2}$$

$$\sum_{ij} |V_{ij}^2| = 1.984 \pm 0.021$$

$$|V_{cs}| = 0.967 \pm 0.011 \qquad \alpha_s(m_W^2) = 0.095 \pm 0.033$$







$R(W)$ μ/e at ATLAS

$$R_W^{\mu/e} = \frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)} = \frac{\frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)}}{\sqrt{\frac{\mathcal{B}(Z\to\mu\mu)}{\mathcal{B}(Z\to ee)}}} \cdot \sqrt{\frac{\mathcal{B}(Z\to\mu\mu)}{\mathcal{B}(Z\to ee)}}$$

$= R_{WZ}^{\mu/e}$ measured

$= R_Z^{\mu\mu/ee} = 1.0009 \pm 0.0028$ taken from LEP2 and SLD

Comparing $\sigma_{t\bar{t}}$ in ee, $e\mu$, and $\mu\mu$ final states in semileptonically decaying $t\bar{t}$ events → cancel syst.

Simultaneous maximum likelihood fit of all regions

- extract all POI: $R_{WZ}^{\mu/e}$, $R_Z^{\mu\mu/ee}$, $\sigma_{t\bar{t}}$ and $\sigma_{Z\to\ell\ell}$

$$R_{WZ}^{\mu/e} = 0.9990 \pm 0.0022\,(stat.) \pm 0.0036\,(syst.) = 0.9990 \pm 0.0042$$

$$R_Z^{\mu\mu/ee} = 0.9913 \pm 0.0002\,(stat.) \pm 0.0045\,(syst.) = 0.9913 \pm 0.0045$$

$$R_W^{\mu/e} = \frac{\mathcal{B}(W\to\mu\nu)}{\mathcal{B}(W\to e\nu)} = 0.9995(stat.) \pm 0.0022 \pm 0.0036\,(syst.) \pm 0.0014\,(ext.) = 0.9995 \pm 0.0045$$

Cross sections $\sigma_{t\bar{t}}$ and $\sigma_{Z\to\ell\ell}$ also extracted:

$$\sigma_{t\bar{t}} = 809.5 \pm 1.1\,(stat.) \pm 20.1\,(syst.) \pm 7.5\,(lumi.) \pm 1.9\,(\sqrt{s})\ pb$$

$$\sigma_{Z\to\ell\ell} = 2019.4 \pm 0.2\,(stat.) \pm 20.7\,(syst.) \pm 16.8\,(lumi.) \pm 1.8\,(\sqrt{s})\ pb$$

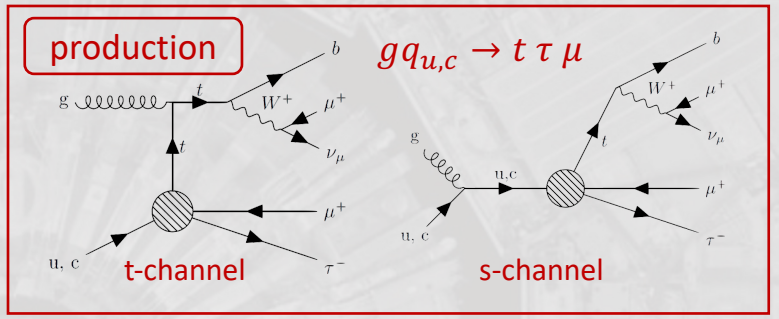
$\mu\tau qt$ coupling at ATLAS

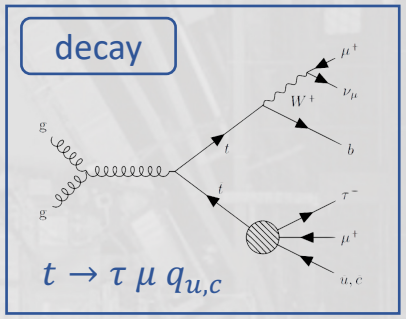
Full run 2 (140 fb^{-1}, 2015-2018)

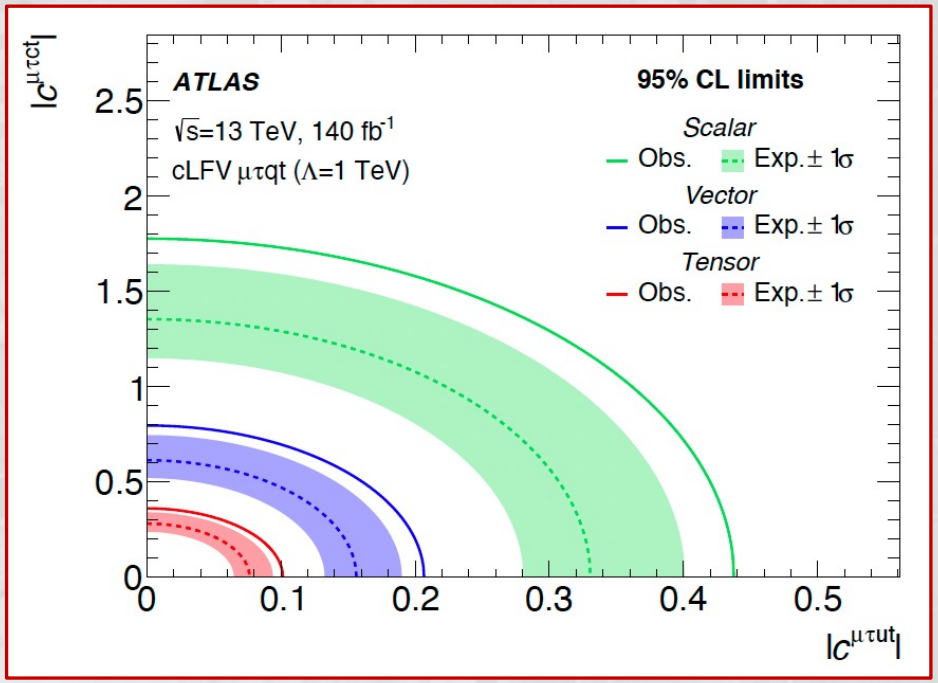
Details about EFT operators tested and limits set

Operator	Interaction	Lorentz Structure
$O_{lq}^{1(ijkl)}$	$(\bar{l}_i\gamma^\mu l_j)(\bar{q}_k\gamma_\mu q_l)$	Vector
$O_{lq}^{3(ijkl)}$	$(\bar{l}_i\gamma^\mu\sigma^I l_j)(\bar{q}_k\gamma_\mu\sigma_I q_l)$	Vector
$O_{eq}^{(ijkl)}$	$(\bar{e}_i\gamma^\mu e_j)(\bar{q}_k\gamma_\mu q_l)$	Vector
$O_{lu}^{(ijkl)}$	$(\bar{l}_i\gamma^\mu l_j)(\bar{u}_k\gamma_\mu u_l)$	Vector
$O_{eu}^{(ijkl)}$	$(\bar{e}_i\gamma^\mu e_j)(\bar{u}_k\gamma_\mu u_l)$	Vector
$O_{lequ}^{1(ijkl)}$	$(\bar{l}_i e_j)\varepsilon(\bar{q}_k u_l)$	Scalar
$O_{lequ}^{3(ijkl)}$	$(\bar{l}_i\sigma^{\mu\nu} e_j)\varepsilon(\bar{q}_k\sigma_{\mu\nu} u_l)$	Tensor

	95% CL upper limits on $\lvert c\rvert/\Lambda^2$ [TeV^{-2}]					
	$c_{lq}^{-(ijk3)}$	$c_{eq}^{(ijk3)}$	$c_{lu}^{(ijk3)}$	$c_{eu}^{(ijk3)}$	$c_{lequ}^{1(ijk3)}$	$c_{lequ}^{3(ijk3)}$
Previous (u) [34]	12	12	12	12	18	2.4
Expected (u)	0.33	0.31	0.3	0.32	0.33	0.08
Observed (u)	0.43	0.41	0.4	0.42	0.44	0.10
Previous (c) [34]	14	14	14	14	21	2.6
Expected (c)	1.3	1.2	1.2	1.2	1.4	0.28
Observed (c)	1.6	1.6	1.6	1.6	1.8	0.36





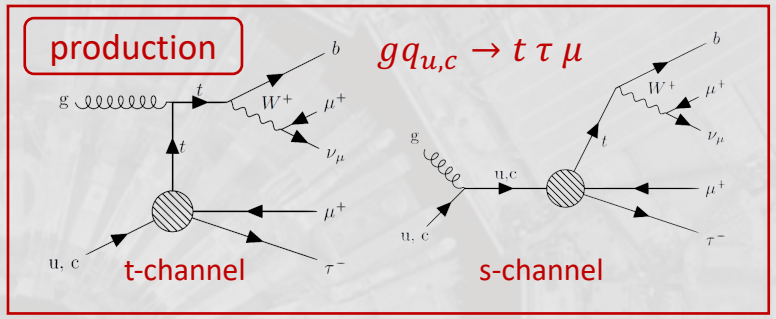


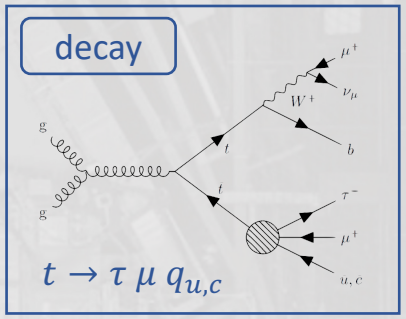
$\mu\tau qt$ coupling at ATLAS

Full run 2 (140 fb^{-1}, 2015-2018)

Breakdown of limits according to mediator scenario

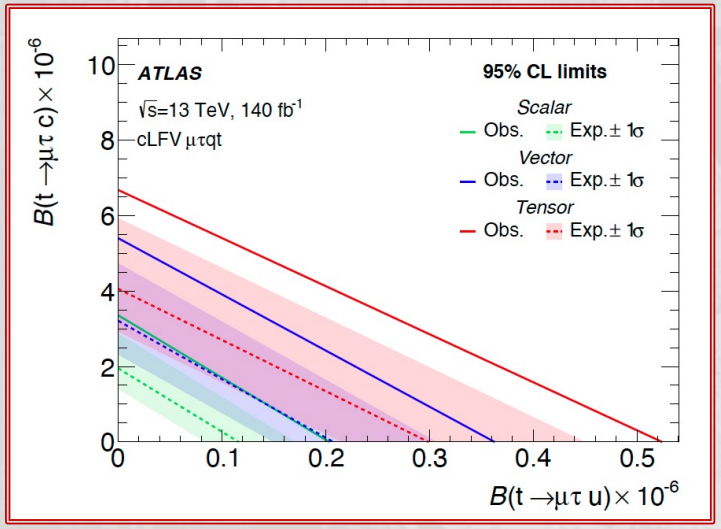
	95% CL upper limits on $\mathcal{B}(t \to \mu\tau q)$ ($\times 10^{-7}$)					
	$c_{lq}^{-(ijk3)}$	$c_{eq}^{(ijk3)}$	$c_{lu}^{(ijk3)}$	$c_{eu}^{(ijk3)}$	$c_{lequ}^{1(ijk3)}$	$c_{lequ}^{3(ijk3)}$
Expected (u)	2.3	2.0	1.9	2.2	1.2	3.0
Observed (u)	4.0	3.6	3.3	3.8	2.0	5.2
Expected (c)	33	32	32	33	20	41
Observed (c)	56	54	53	54	34	67





EFT flavour structure assumption for inclusive limit:

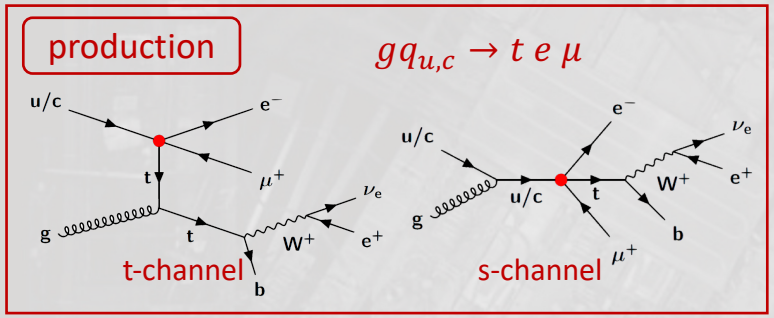
$$\lambda_{ki} \in \begin{pmatrix} \lambda_{t\tau} & \lambda_{c\tau} & \lambda_{u\tau} \\ \lambda_{t\mu} & \lambda_{c\mu} & \lambda_{u\mu} \\ \lambda_{te} & \lambda_{ce} & \lambda_{ue} \end{pmatrix} \equiv \lambda^{\mathrm{LQ}} \begin{pmatrix} 10 & 1 & 0.1 \\ 1 & 0.1 & 0.01 \\ 0.1 & 0.01 & 0.001 \end{pmatrix}$$

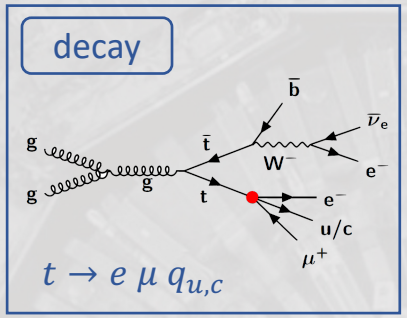


Inclusive limit (w. EFT flavour structure assumption) at 95% CL:

Observed: $\mathcal{B}(t \to \mu\,\tau\,q_{c,u}) < 8.7 \cdot 10^{-7}$ (expected $< 5 \cdot 10^{-7}$)

$e\mu qt$ coupling at CMS



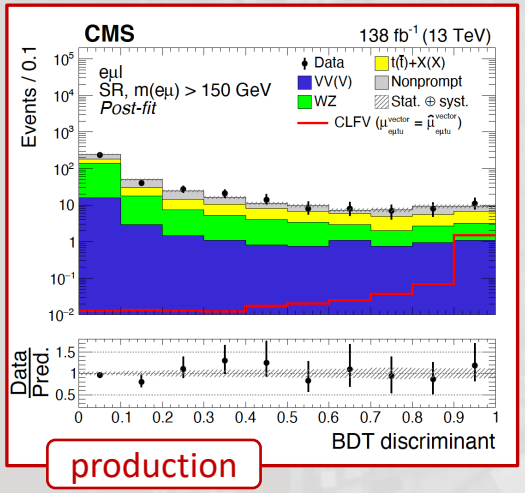


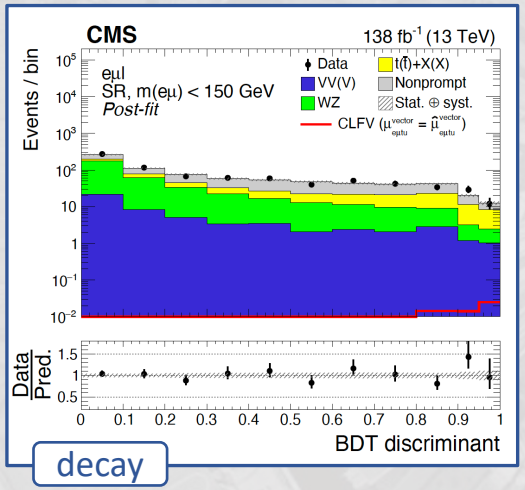
Full run 2 (2016-2018, 138 fb^{-1})

Limit on *Wilson coefficients* and $\mathcal{B}_r$ extracted with a *maximum likelihood fit* of the BDT discriminants

	(scalar)	(vector)	(tensor)
$\mathcal{B}(t \rightarrow e\,\mu\,u)$	$< 1.2 \cdot 10^{-8}$,	$< 2.2 \cdot 10^{-8}$,	$< 3.2 \cdot 10^{-8}$
$\mathcal{B}(t \rightarrow e\,\mu\,c)$	$< 2.16 \cdot 10^{-7}$,	$< 3.67 \cdot 10^{-7}$,	$< 4.98 \cdot 10^{-7}$

at 95% CL





CLFV coupling	Lorentz structure	$C_{e\mu tq}/\Lambda^2$ (TeV^{-2}) Exp. (68% CL range)	Obs.	$\mathcal{B}(t \rightarrow e\mu q) \times 10^{-6}$ Exp. (68% CL range)	Obs.
$e\mu tu$	Tensor	0.022 (0.018–0.026)	0.024	0.027 (0.018–0.040)	0.032
	Vector	0.044 (0.036–0.054)	0.048	0.019 (0.013–0.028)	0.022
	Scalar	0.093 (0.077–0.114)	0.101	0.010 (0.007–0.016)	0.012
$e\mu tc$	Tensor	0.084 (0.069–0.102)	0.094	0.396 (0.272–0.585)	0.498
	Vector	0.175 (0.145–0.214)	0.196	0.296 (0.203–0.440)	0.369
	Scalar	0.385 (0.318–0.471)	0.424	0.178 (0.122–0.266)	0.216

Bibliography

*Search for **charged-lepton flavor violation** in the **production and decay of top quarks** using trilepton final states in proton-proton collisions at $\sqrt{s}$ = 13 TeV* (CERN-EP-2023-258)

*Search for the **lepton flavor violating $\tau \rightarrow 3\mu$ decay** in proton-proton collisions at $\sqrt{s}$ = 13 TeV* (CMS-PAS-BPH-21-005)

*Test of **lepton flavor universality** violation in **semileptonic B_c^+** meson decays at CMS* (CMS-PAS-BPH-22-012)

*Test of lepton **flavor universality in $B^\pm \rightarrow K^\pm \mu^+ \mu^-$ and $B^\pm \rightarrow K^\pm \mu^+ \mu^-$** decays in proton-proton collisions at $\sqrt{s}$ = 13 TeV* (CERN-EP-2023-297)

*Precise test of **lepton flavour universality in W-boson** decays into **muons** and **electrons** in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector* (CERN-EP-2024-063)

*Search for **charged-lepton-flavour violating μτqt interactions** in **top-quark production and decay** in pp collisions at $\sqrt{s}$=13 TeV with the ATLAS detector at the LHC* (CERN-EP-2024-061)