WIV2023
ZHUHAI CHINA

Lepton Flavor Universality Experimental Highlights

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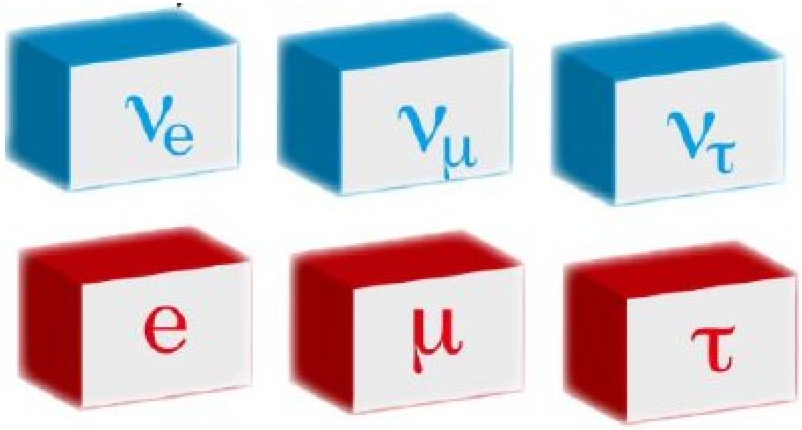
Wuhan University

LHCb BELLE BESIII

July/05/2023

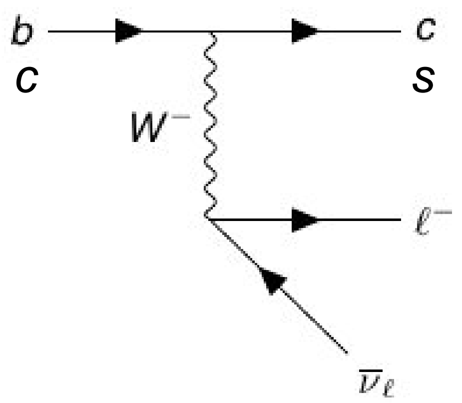
Outline

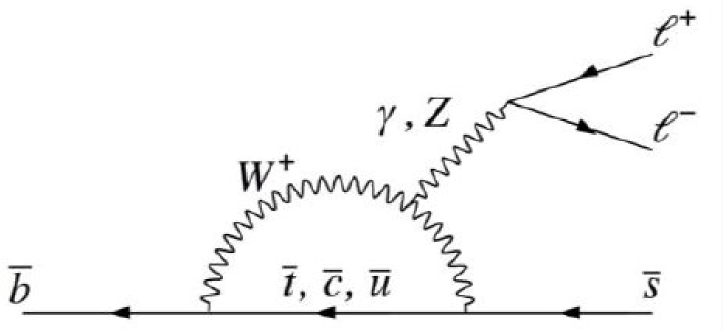
- LFU tests in (semi-)leptonic D decays (Charged currents)
- LFU tests in semi-leptonic B decays (Charged currents)
- LFU tests in rare B decays (Neutral currents)
- Summary



Disclaimer: A much biased personal selection of experimental results

Charged currents versus neutral currents

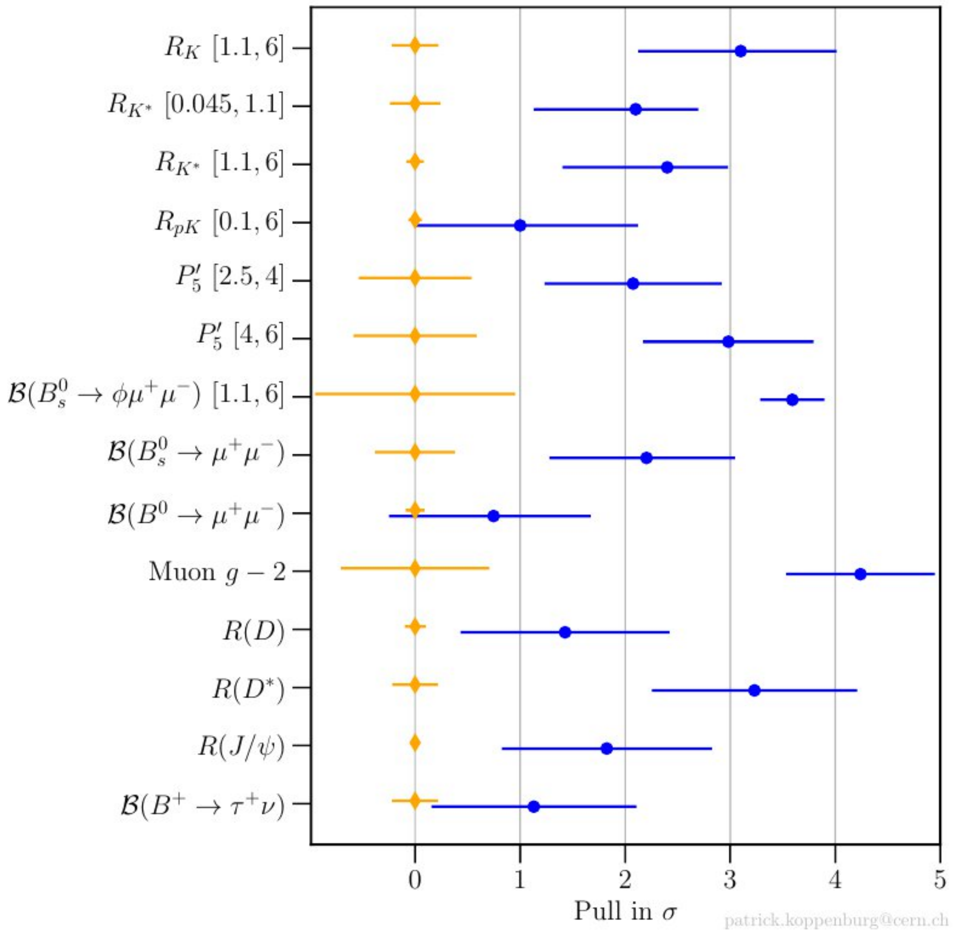




- One charged lepton in the final state
- Tree level
- Theoretically clean
- Abundance of data
- Experimentally challenging due to missing neutrino

- Dilepton final states
- Forbidden at tree level in SM
- Sensitive to NP
- Highly suppressed, statistically limited in experiments
- Mainly on e-μ asymmetry

Experimental status on B anomalies @ WIN2021



How coherent is the pattern of deviations?

[Scholarpedia, arXiv:1606.00999] [All plots]

R_K, R_{K*}: LHCb [arXiv:2103.11769] [JHEP 08 (2017) 055] vs [Bordone, Isidori, Pattori EPJC 76 (2016) 440].

R_{pK} LHCb [JHEP 05 (2020) 040].

P_5' my average of LHCb [PRL 125 (2020) 011802], CMS [PLB 781 (2018) 517], ATLAS [JHEP 10 (2018) 047] vs [Bharucha et al., JHEP 08 (2016) 098].

$B_s^0 \to \phi\mu^+\mu^-$ [LHCb-PAPER-2021-014] vs [Horgan et al.] via [FLAVIO].

$B \to \mu^+\mu^-$ combination [Hurth et al.] of LHCb [LHCb-PAPER-2021-007], CMS [JHEP 04 (2020) 188], ATLAS [JHEP 04 (2019) 098] vs [Beneke, Bobeth, Szafron, JHEP 10 (2019) 232].

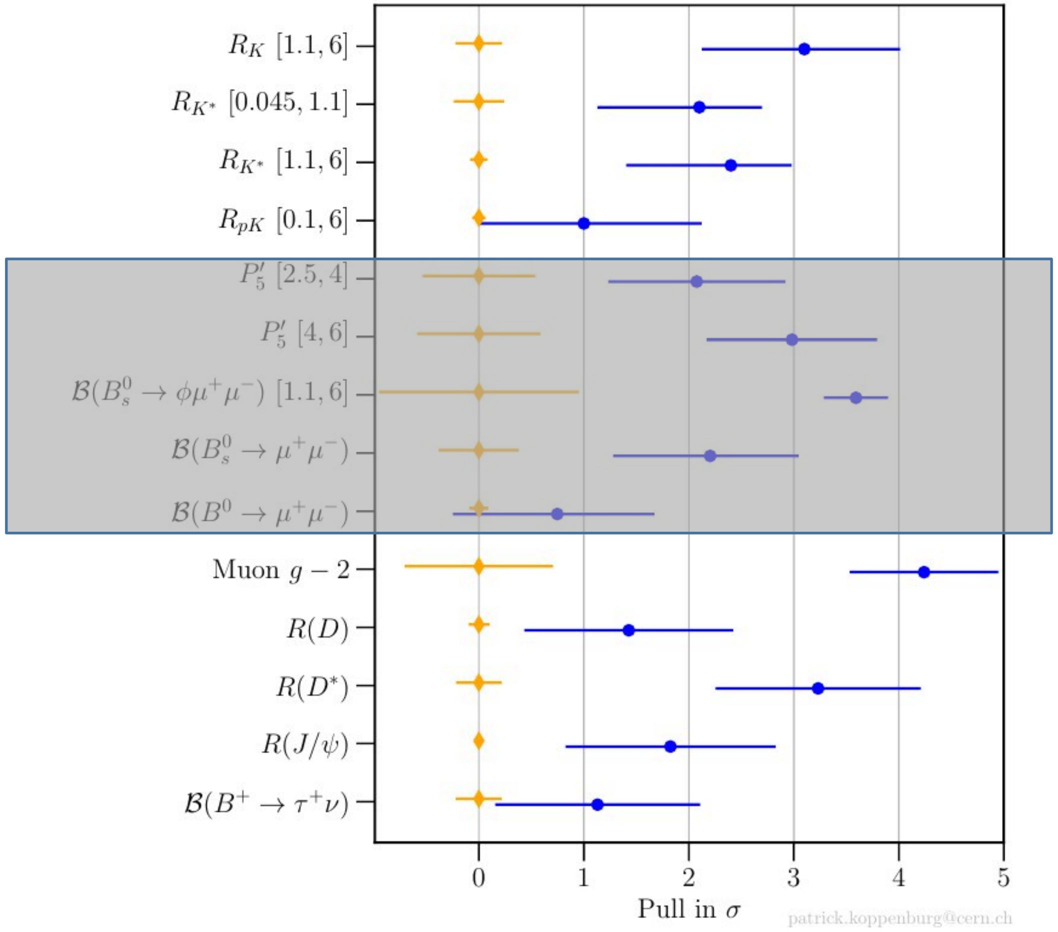
Muon $g-2$ [Muon $g-2$, PRL 126 (2021) 141801] vs [Aoyama et al., Phys. Rept. 887 (2020) 1].

$R(D^{(*)})$ [HFlav].

$\mathcal{B}(B^+ \to \tau\mu)$ [UTFit].

Experimental status on B anomalies @ WIN2021

A coherent pattern on LFU?



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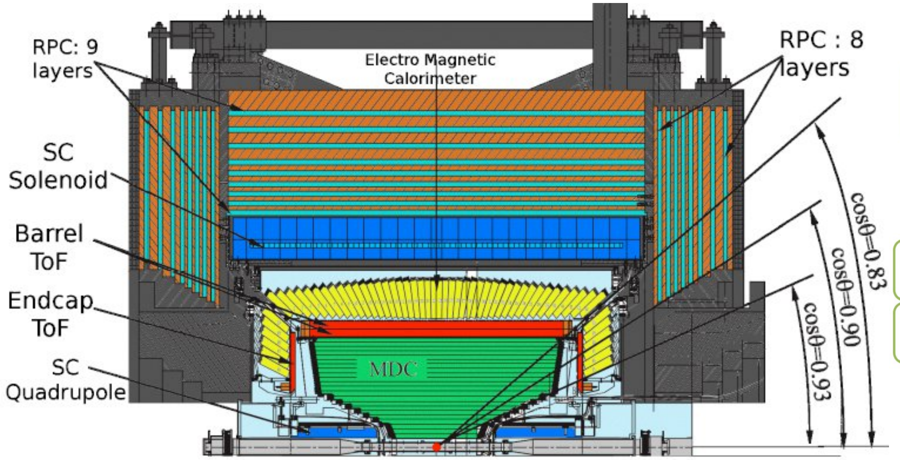
Major experiments for LFU tests

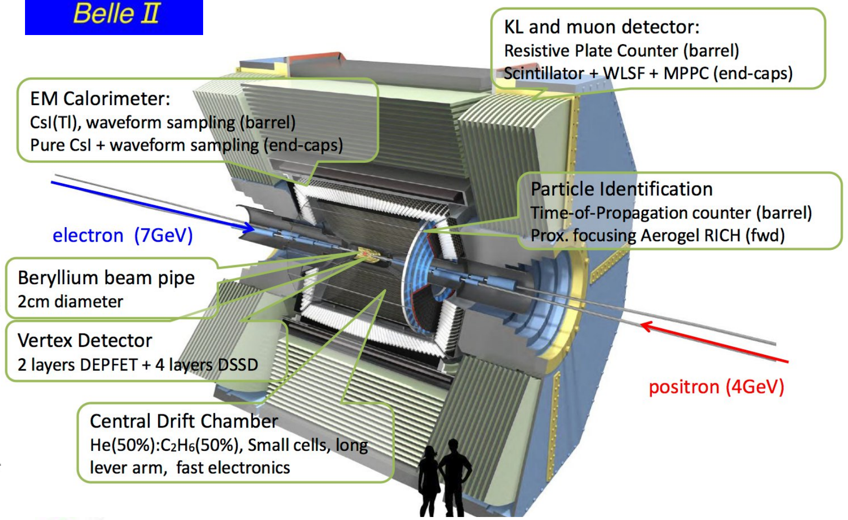
BESIII



Wire tracker (no Si); TOF + dE/dx for PID; CsI Ecal; RPC muon

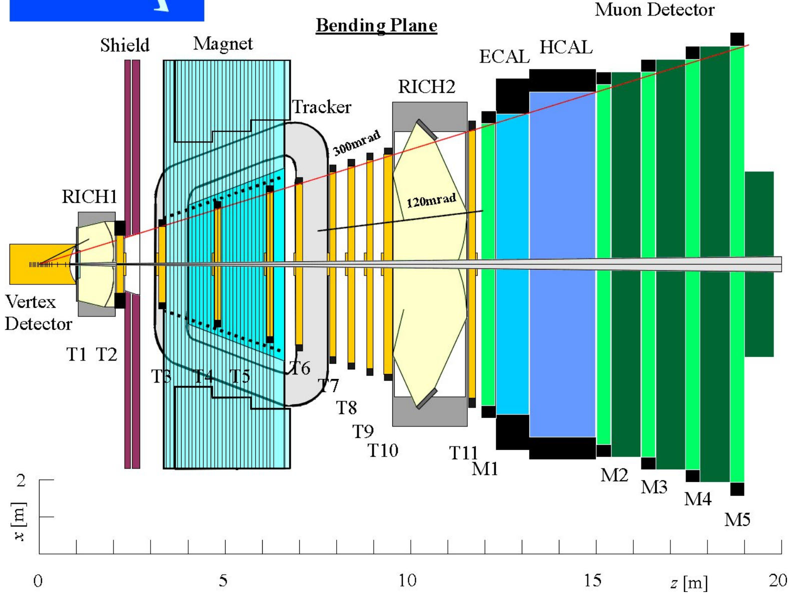
- ✓ double-tag method for bkg. suppr. & neutrino reco.
- ✓ extremely clean environment
- ✓ high efficiency detection on electrons/neutrals
- ✓ quantum coherence
- ● no CM boost, no T-dep analyses

Belle II Detector



- ✓ clean event environment
- ✓ high trigger efficiency
- ✓ high-efficiency detection of neutrals
- ✓ many high-statistics control samples
- ✓ time-dependent analysis
- ● smaller cross-section than hadron colliders

LHCb

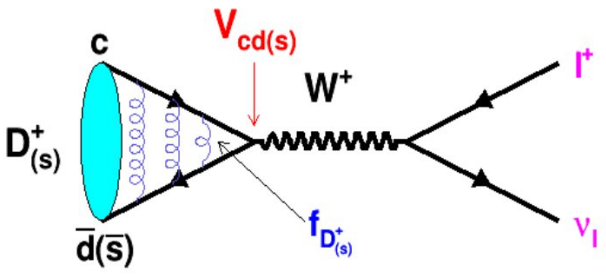


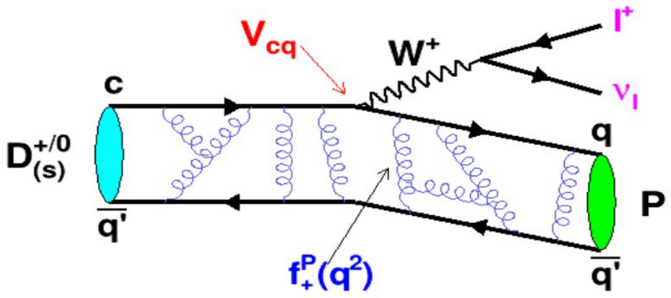
- ✓ large production cross-section
- ✓ large boost: excellent time res
- ● dedicated trigger required
- ● hard to do neutrals and neutrinos

Experimental challenges for LFU tests

- Hadronic part: most of uncertainties cancel in the ratio at 1st order
- Missing neutrinos for (semi-)leptonic processes:
  - e^+e^- machines: inferred using beam condition & mising info
  - Hadron machines: more difficult, using info such as decay vertices, isolation info, kinematics of visible part, etc
- Electron: generally more difficult in experiments such as LHCb
- Muon: difficuties in μ/π separation for low-P tracks @ BESIII
- Tau lepton: short lifetime, decaying into final states with $\geq 1\nu$
  - e^+e^- machines: $\tau \to e\bar{\nu}\nu, \mu\bar{\nu}\nu, \pi(\pi^0)\nu$
  - Hadron machines: $\tau \to \mu\bar{\nu}\nu, \pi\pi\pi(\pi^0)\nu$

LFU tests in (semi-)leptonic D decays @ BESIII



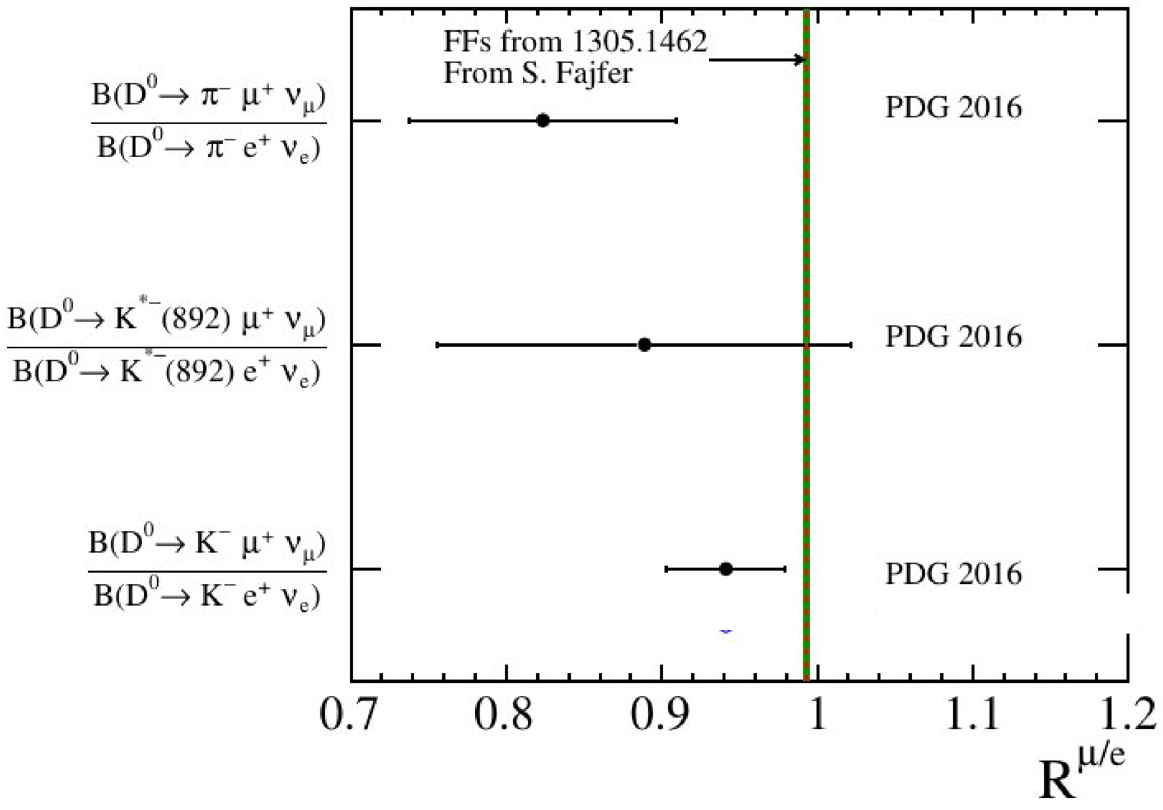


Details can also be found in Zehui's talk "Charmed mesons decays at BESIII"

Situation before BESIII

- Tension in charm sector

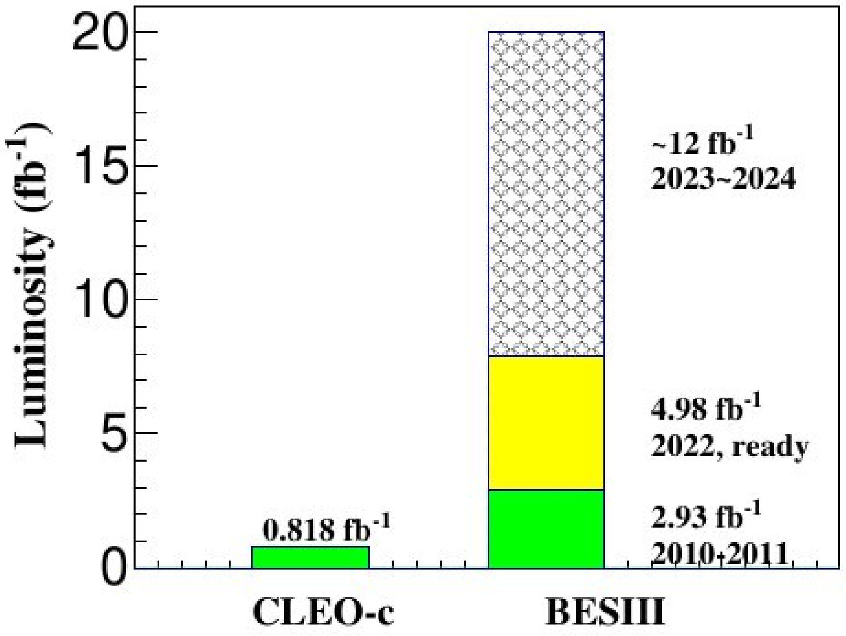
adapted from PoS CKM2016 (2017) 025

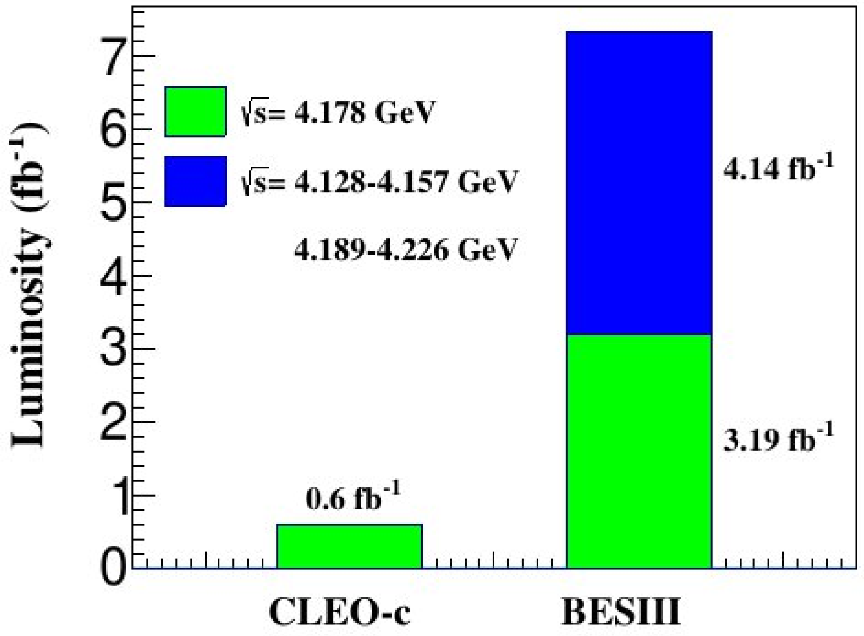


- Poor knowledge in semimuonic charm decays

	D^0		D^+		D_s^+	
$c \to s l^+ \nu$	K^-	4%[Belle]	$\bar{K}^0$	7%[FOCUS]	η	NA
	K^{*-}	13%[FOCUS]	$\bar{K}^{*0}$	3%[CLEOc]	η'	NA
					ϕ	NA
					f_0	NA
$c \to d l^+ \nu$	π^-	10%[Belle]	π^0	NA	K^0	NA
	ρ^-	NA	ρ^0	17%[FOCUS]	K^{*0}	NA
			ω	NA		
			η	NA		
			η'	NA		

World's largest threshold D meson samples

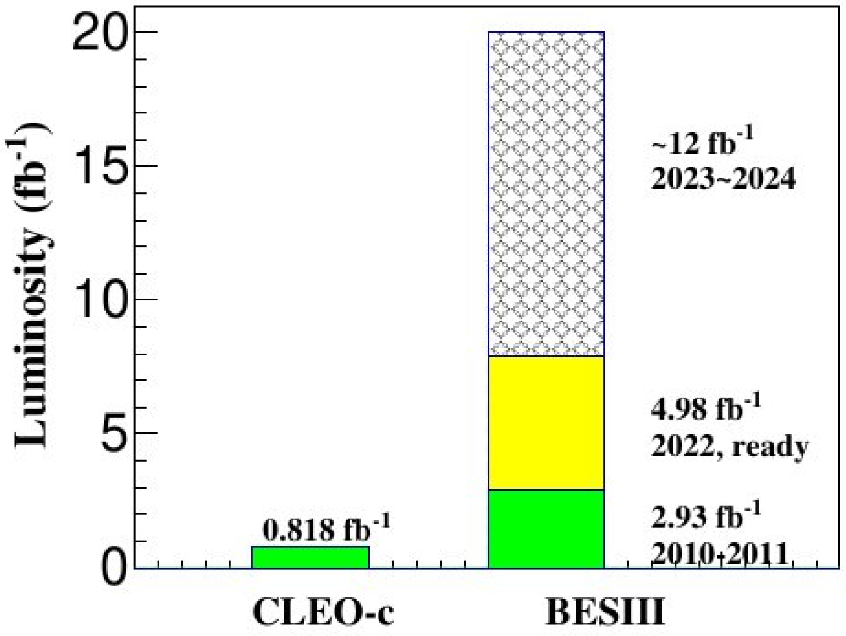


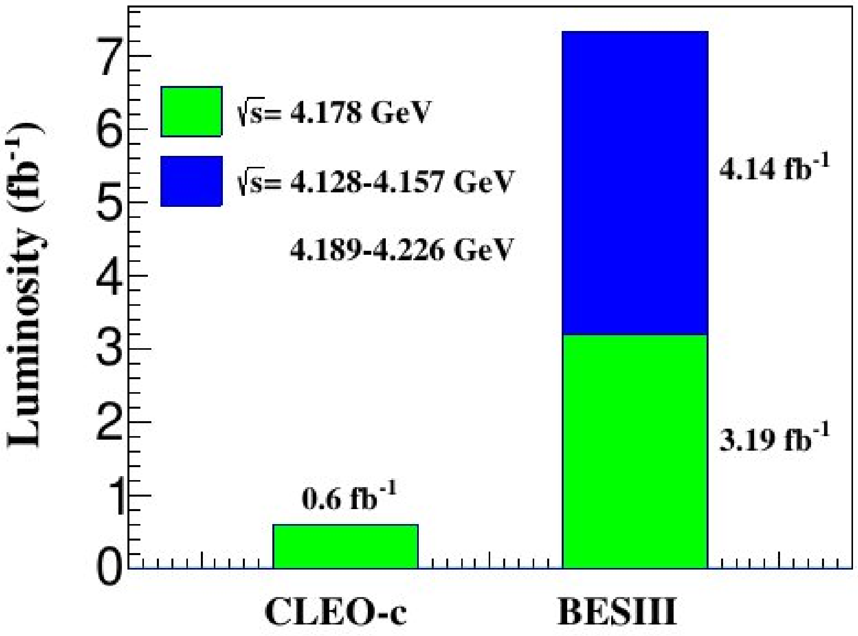


- $e^+e^- \to \psi(3770) \to D\bar{D}$, $\mathcal{L}_{\rm int}$ =2.93+4.98 (+12) fb^{-1}
- $e^+e^- \to D_s D_s^*$, $\sqrt{s} = 4.128 - 4.226$ GeV, $\mathcal{L}_{\rm int}$=7.33 fb^{-1}
- Advantages: Clean, double tag method

BESIII

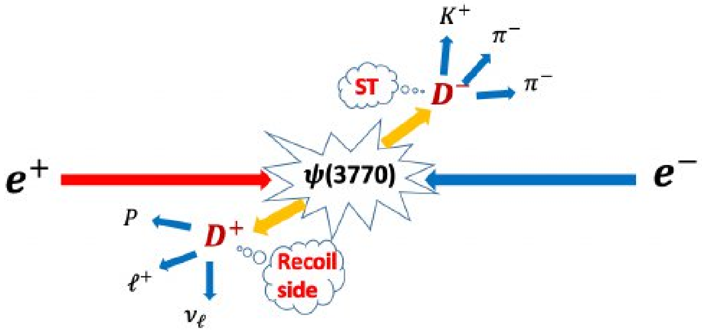
World's largest threshold D meson samples

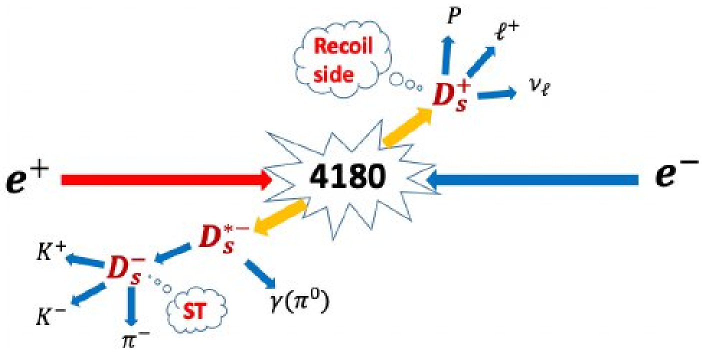




- $e^+e^- \to \psi(3770) \to D\bar{D}$, $\mathcal{L}_{\rm int}$ =2.93+4.98 (+12) fb^{-1} Not used in any results shown today
- $e^+e^- \to D_sD_s^*$, $\sqrt{s} = 4.128 - 4.226$ GeV, $\mathcal{L}_{\rm int}$=7.33 fb^{-1}
- Advantages: Clean, double tag method

Double-tag method for (semi-)leptonic decays





Tag modes

- $\bar{D}^0 \to K^+\pi^-$, ...
- $D^- \to K^+\pi^-\pi^-$, ...
- $D_s^- \to K^+K^-\pi^-$, ...

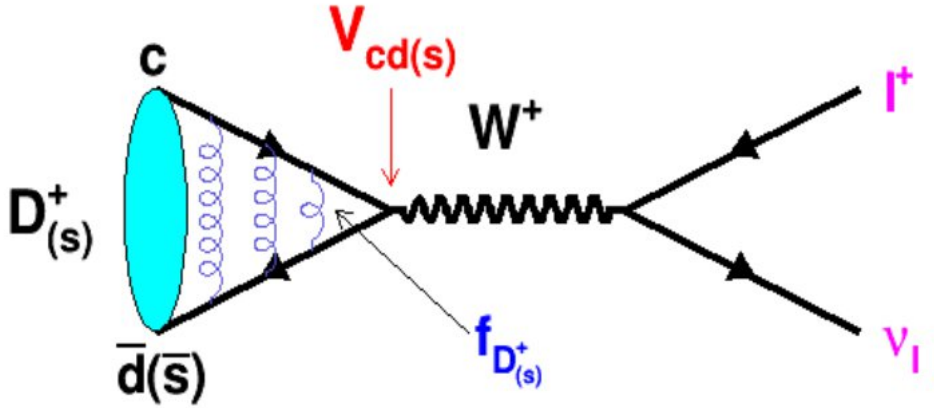
Branching fraction

- $N_{\rm tag} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\epsilon_{\rm tag}$
- $N_{\rm DT} = 2N_{D\bar{D}}\mathcal{B}_{\rm tag}\mathcal{B}_{\rm sig}\epsilon_{\rm DT}$
- $\mathcal{B}_{\rm sig} = \frac{N_{\rm DT}}{N_{\rm tag}\epsilon_{\rm DT}/\epsilon_{\rm tag}}$

Missing neutrino is determined by

- $U_{\rm miss} = E_{\rm miss} - |\vec{p}_{\rm miss}|$
- $E_{\rm miss} = E_{\rm cm} - E_{\rm tag} - E_P - E_{\ell+}$
- $M^2_{\rm miss} = E^2_{\rm miss} - |\vec{p}_{\rm miss}|^2$
- $\vec{p}_{\rm miss} = -\vec{p}_{\rm tag} - \vec{p}_P - \vec{p}_{\ell+}$

LFU tests with $D_{(s)}^{+} \to \ell^{+}\nu_{\ell}$

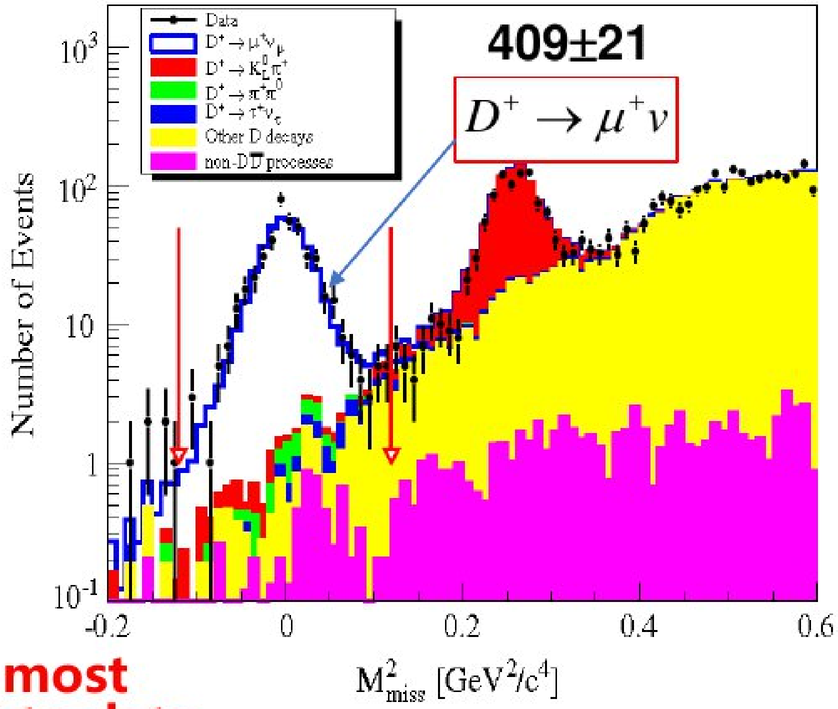


$$\Gamma(D_{(s)}^{+} \to \ell^{+}\nu_{\ell}) = \frac{G_F^2}{8\pi} f_{D_{(s)}^{+}}^2 |V_{cd(s)}|^2 m_{\ell}^2 m_{D_{(s)}^{+}} \left(1 - \frac{m_{\ell}^2}{m_{D_{(s)}^{+}}^2}\right)^2$$

- The electron channels are strongly suppressed due to mass
- The branching ratios $R_{\tau/\mu}$ are determined by the lepton and D masses in the SM

LFU test with $D^+ \to \ell^+ \nu_\ell, \ell = \mu, \tau$

PRD89(2014)051104



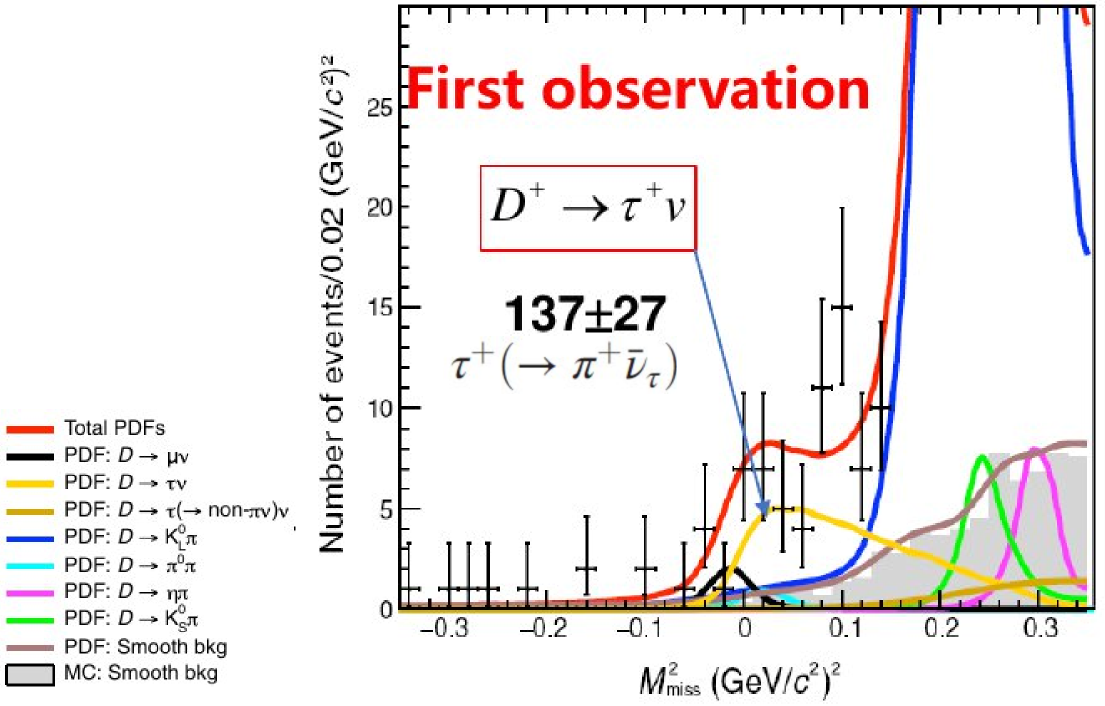
The most precise to date

$B[D^+ \to \mu^+ v] = (3.71 \pm 0.19 \pm 0.06) \times 10^{-4}$

$\mathbf{f_{D^+}|V_{cd}| = 46.7 \pm 1.2 \pm 0.4}$ **MeV**

$$R_{\tau/\mu} = \frac{\Gamma(D^+ \to \tau^+\nu_\tau)}{\Gamma(D^+ \to \mu^+\nu_\mu)} = \frac{m_\tau^2\left(1-\frac{m_\tau^2}{M_{D^+}^2}\right)^2}{m_\mu^2\left(1-\frac{m_\mu^2}{M_{D^+}^2}\right)^2} = 2.67$$

PRL123(2019)211802



$B[D^+ \to \tau^+ v] = (1.20 \pm 0.24 \pm 0.12) \times 10^{-3}$

$\mathbf{f_{D^+}|V_{cd}| = 50.4 \pm 5.0 \pm 2.5}$ **MeV**

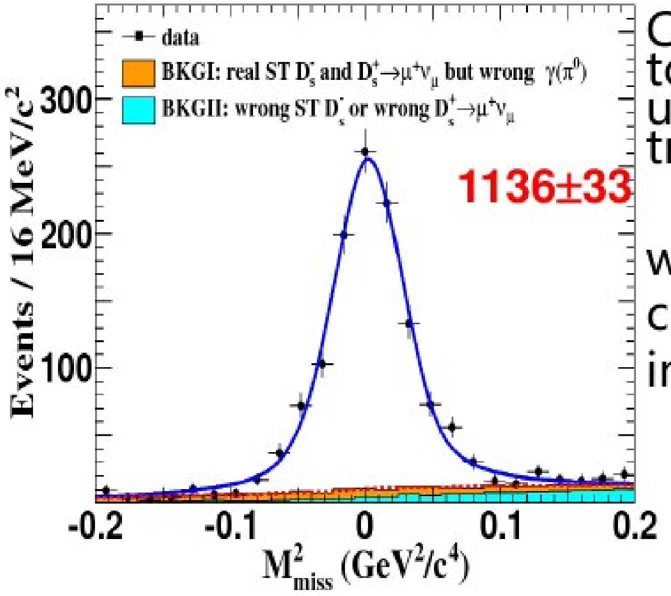
$R_{\tau/\mu} = 3.21 \pm 0.64_{stat} \pm 0.43_{syst}$.

Consistent with SM prediction

Studies of $D_s^+ \to \mu^+ \nu_\mu$

3.19 fb^{-1}@4.18 GeV

PRL122(2019)071802



Constrained fit to matched and un-matched transition $\gamma(\pi^0)$

with μ counter information

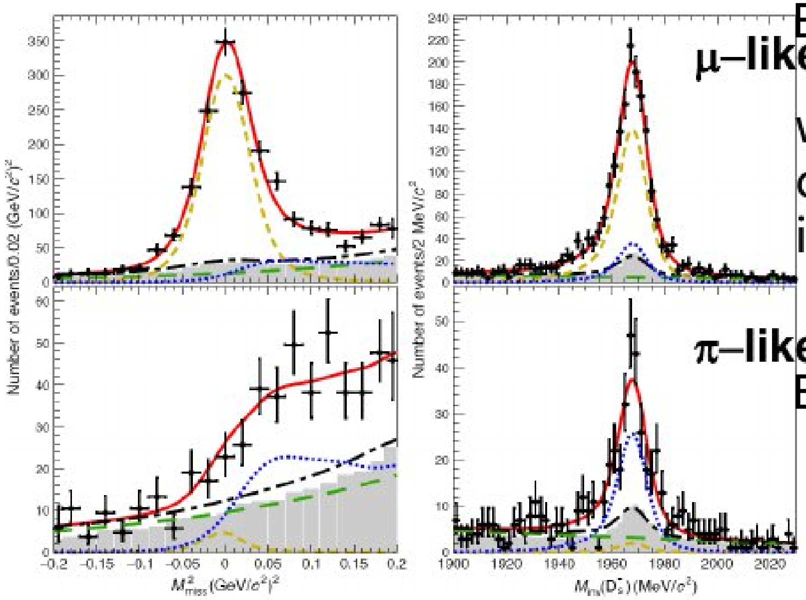
$$B[D_s^+ \to \mu^+ \nu] = (5.49 \pm 0.16 \pm 0.15) \times 10^{-3}$$

$f_{D_s^+}|V_{cs}| = (246.2 \pm 3.6 \pm 3.5)$ MeV

Precision~2.1%

6.3 fb^{-1}@4.18-4.23GeV

PRD104(2021)052009



E_{EMC} < 300 MeV

without μ counter information

E_{EMC} > 300 MeV

$D_s^+ \to \mu\nu$

$D_s^+ \to \tau\nu$

2198±55

$$B[D_s^+ \to \mu^+ v] = (5.35 \pm 0.13 \pm 0.16) \times 10^{-3}$$

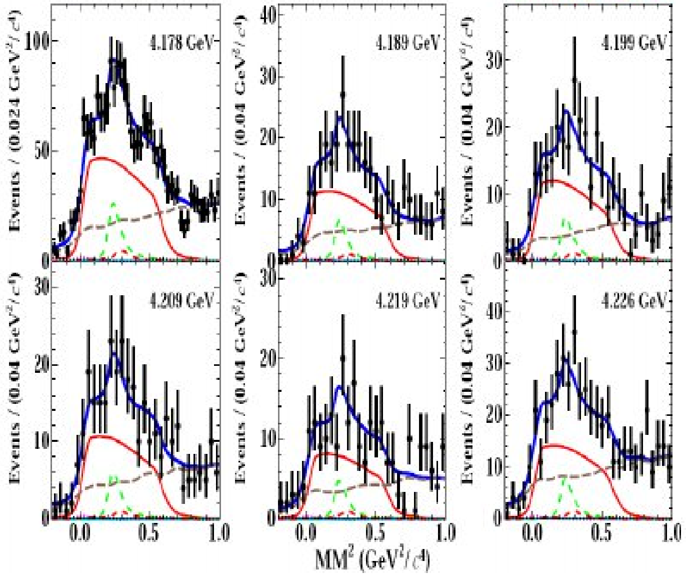
$f_{D_s^+}|V_{cs}| = (243.1 \pm 3.0 \pm 3.7)$ MeV

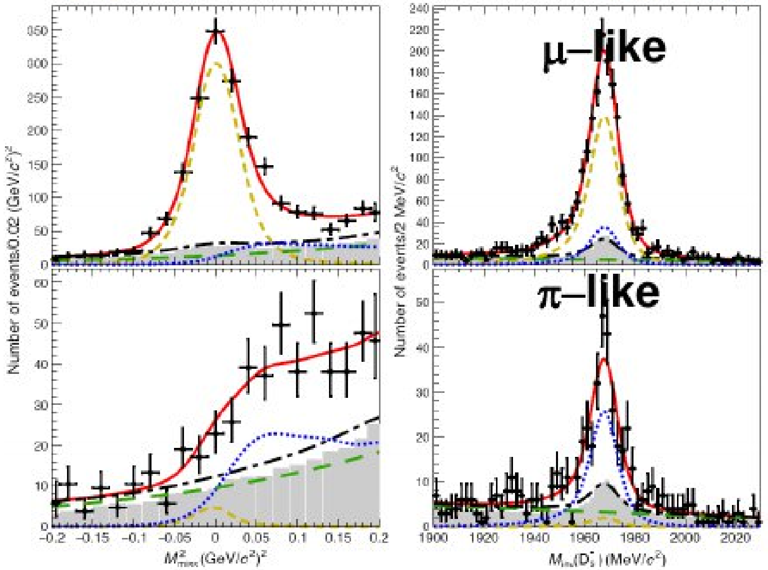
Precision~2.0%

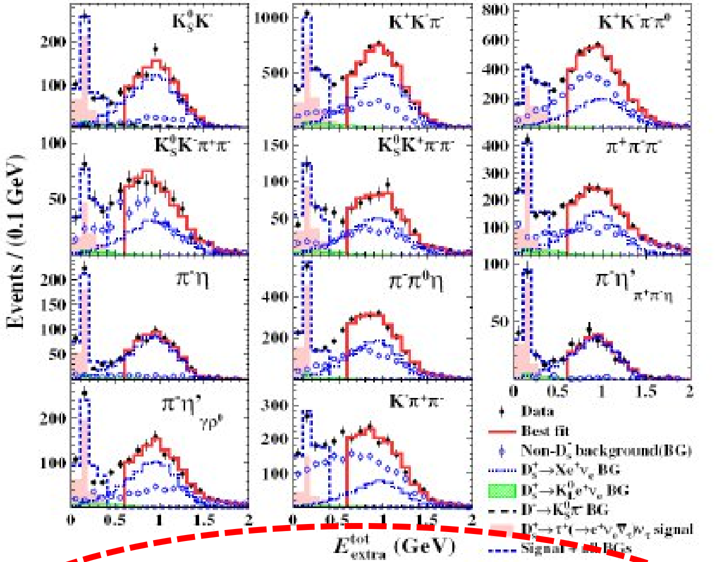
Studies of $D_s^+ \to \tau^+ \nu_\tau$ (I)

E_{extra}^{tot}: total energy of good EMC showers not associated with e^+

PRD104(2021)032001	PRD104(2021)052009	PRL127(2021)171801
$D_s^+ \to \tau^+(\rho^+ \nu)\nu$	$D_s^+ \to \tau^+(\pi^+ \nu)\nu$	$D_s^+ \to \tau^+(e^+ \nu\nu)\nu$
6.3 fb^{-1} 1745±84	6.3 fb^{-1} 946±46	6.3 fb^{-1} 4940±97







$B[D_s^+ \to \tau^+ \nu] = (5.29 \pm 0.25 \pm 0.20)\%$

$f_{D_s^+}|V_{cs}| = (244.8 \pm 5.8 \pm 4.8)$ MeV

$B[D_s^+ \to \tau^+ \nu] = (5.21 \pm 0.25 \pm 0.17)\%$

$f_{D_s^+}|V_{cs}| = (243.0 \pm 5.8 \pm 4.0)$ MeV

$B[D_s^+ \to \tau^+ \nu] = (5.27 \pm 0.10 \pm 0.12)\%$

$f_{D_s^+}|V_{cs}| = (244.4 \pm 2.3 \pm 2.9)$ MeV

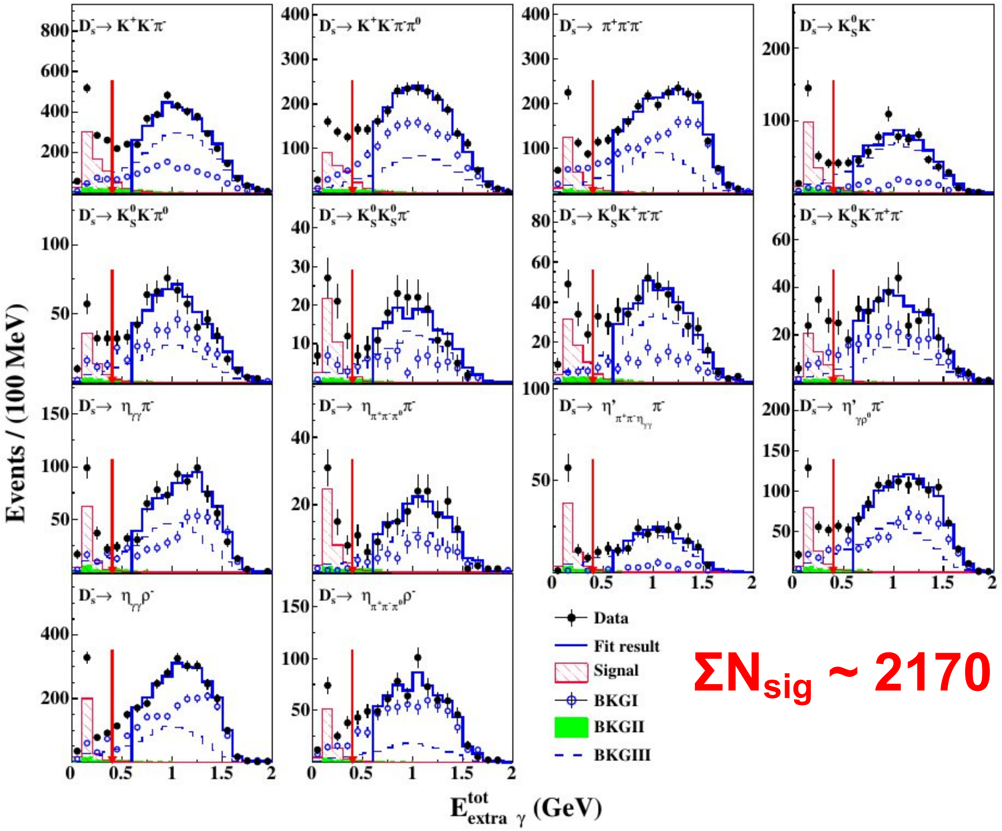
The most precise to date

Studies of $D_s^+ \to \tau^+ \nu_\tau$ (II)

arXiv:2303.12468

7.33 fb^{-1}

$D_s^+ \to \tau^+(\mu^+ \nu_\mu \bar{\nu}_\tau)\nu_\tau$



$\Sigma N_{sig} \sim 2170$

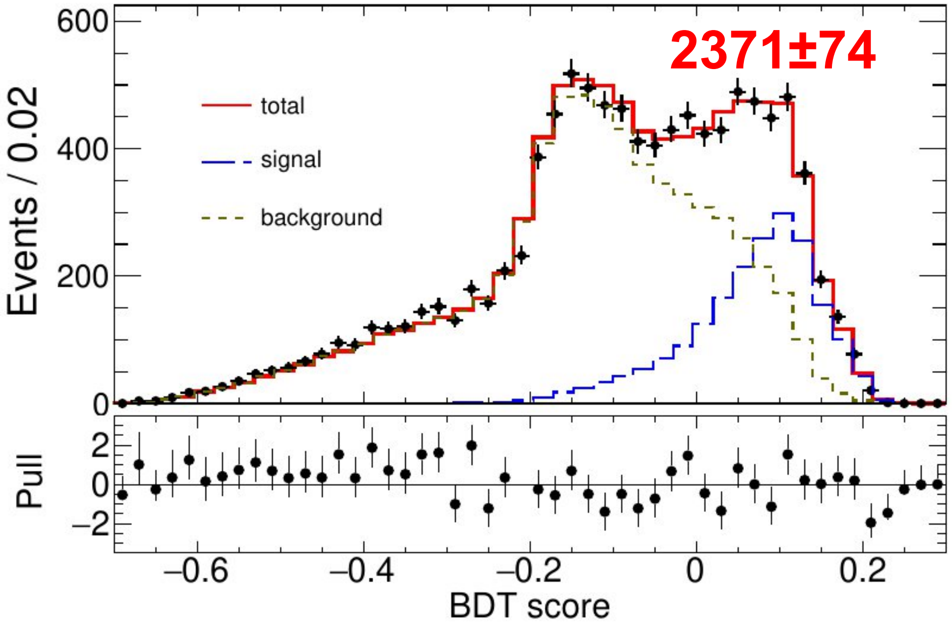
$$\mathcal{B}_{D_s^+ \to \tau^+ \nu_\tau} = (5.34 \pm 0.16_{\rm stat} \pm 0.10_{\rm syst})\%$$

$$f_{D_s^+}|V_{cs}| = (246.2 \pm 3.7_{\rm stat} \pm 2.5_{\rm syst})\ {\rm MeV}$$

arXiv:2303.12600

7.33 fb^{-1}

$D_s^+ \to \tau^+(\pi^+ \bar{\nu}_\tau)\nu_\tau$



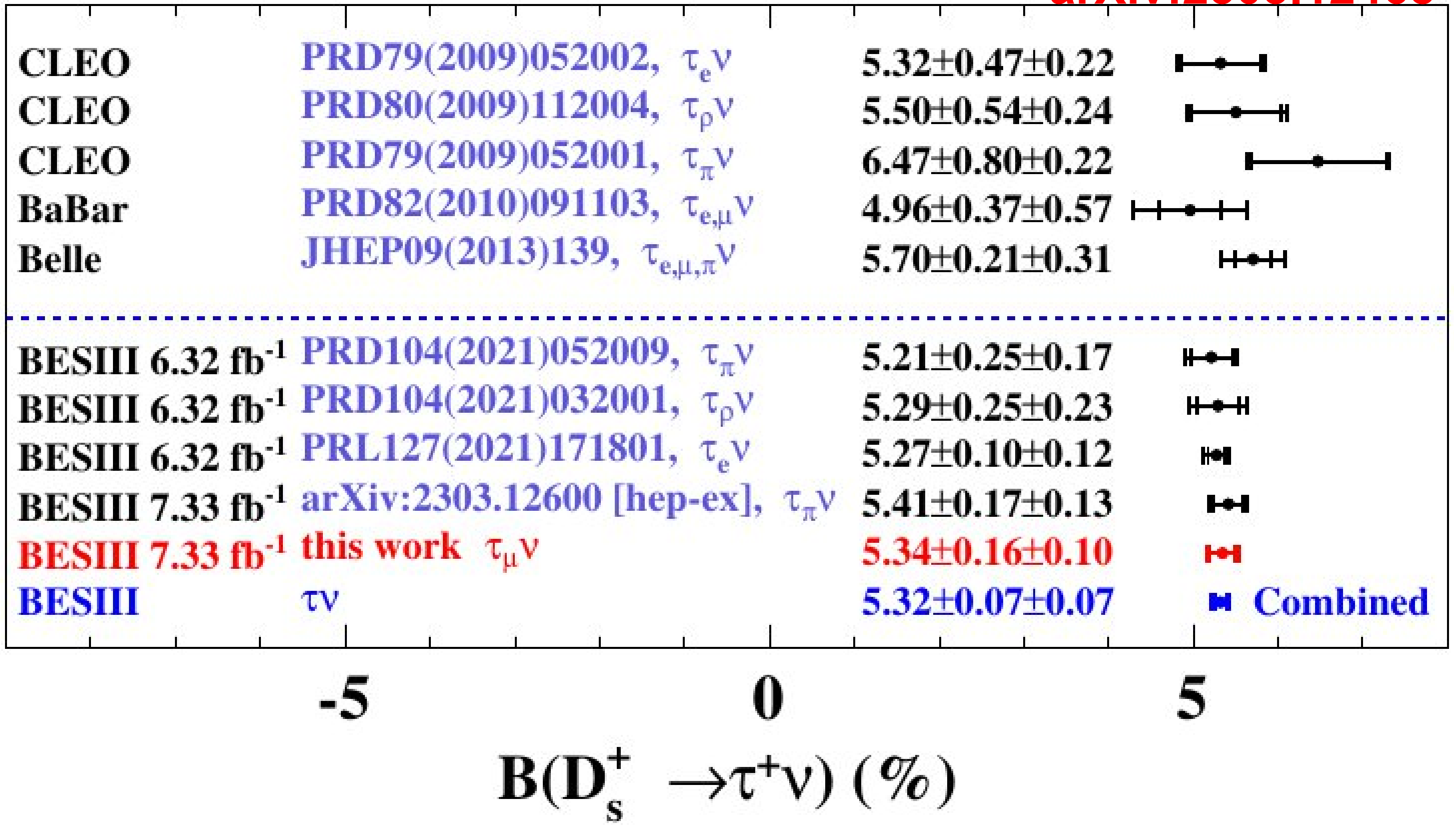
Updated with BDT selection

$$\mathcal{B}_{D_s^+ \to \tau^+ \nu_\tau} = (5.41 \pm 0.17_{\rm stat} \pm 0.13_{\rm syst})\%$$

$$f_{D_s^+}|V_{cs}| = (247.6 \pm 3.9_{\rm stat} \pm 3.2_{\rm syst} \pm 1.0_{\rm input})\ {\rm MeV}$$

arXiv:2303.12600

Summary of LFU test with $D_s^+ \to \ell^+ \nu_\ell$



$$\mathcal{R}_{\tau/\mu} = \frac{\mathcal{B}_{D_s^+\to\tau^+\nu_\tau}}{\mathcal{B}_{D_s^+\to\mu^+\nu_\mu}} = \frac{m_{\tau^+}^2\left(1-\frac{m_{\tau^+}^2}{m_{D_s^+}^2}\right)^2}{m_{\mu^+}^2\left(1-\frac{m_{\mu^+}^2}{m_{D_s^+}^2}\right)^2}$$

$$R_{\tau/\mu}^{SM} = 9.75 \pm 0.01$$

With PDG input of $B(D_s^+ \to \mu^+\nu_\mu)$ we have:

BESIII only result:

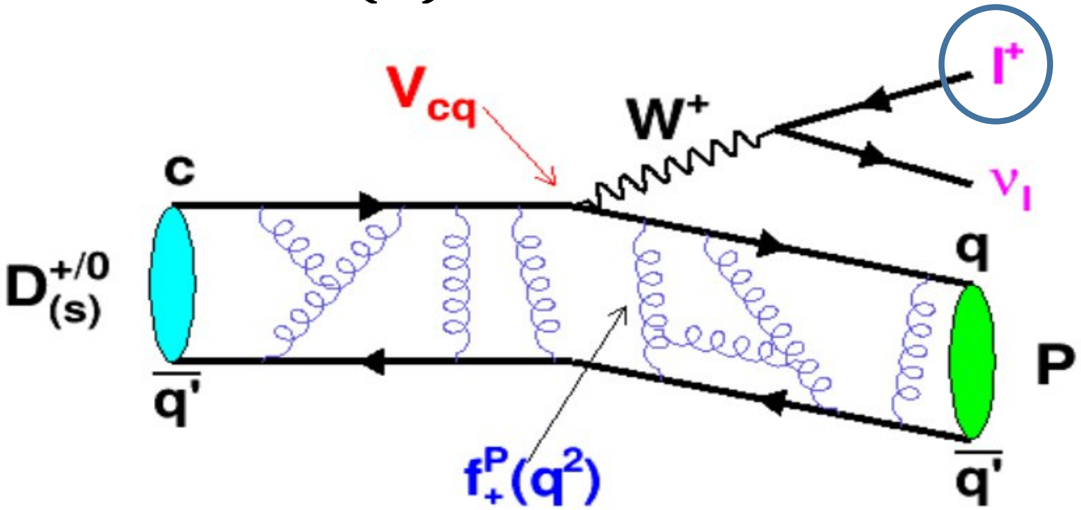
$$R_{\tau/\mu}^{BESIII} = 9.79 \pm 0.33$$

All included:

$$R_{\tau/\mu}^{Exp} = 9.86 \pm 0.32$$

Good agreement with SM value

LFU tests with $D_{(s)} \to (P,V)\ell^+\nu_\ell$

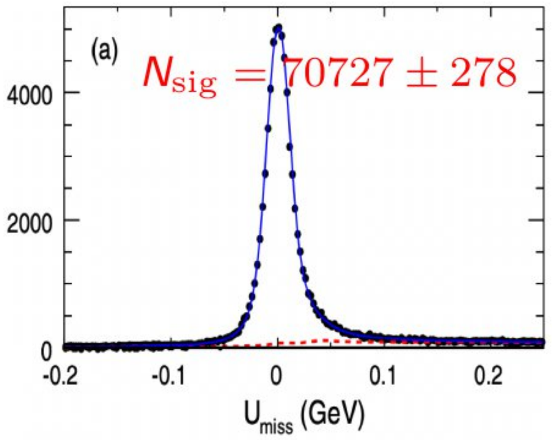


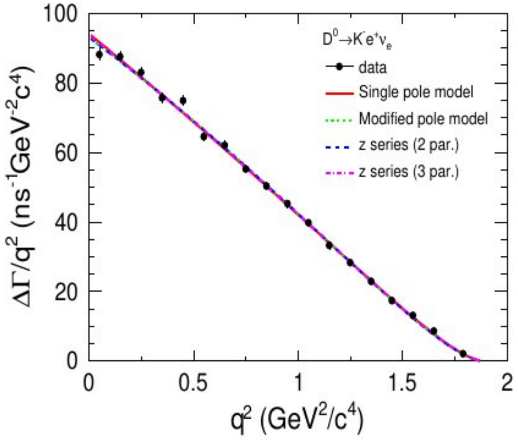
$$\frac{d\Gamma}{dq^2} = X\frac{G_F^2}{24\pi^3}|f_+^h(0)|^2|V_{cq}|^2|\vec{p}_h|^3$$

- Test of light lepton universality with branching ratios of e/μ

LFU tests with $D^0 \to K^-\ell^+\nu_\ell$

$D^0 \to K^- e^+ \nu_e$ PRD92(2015)072012



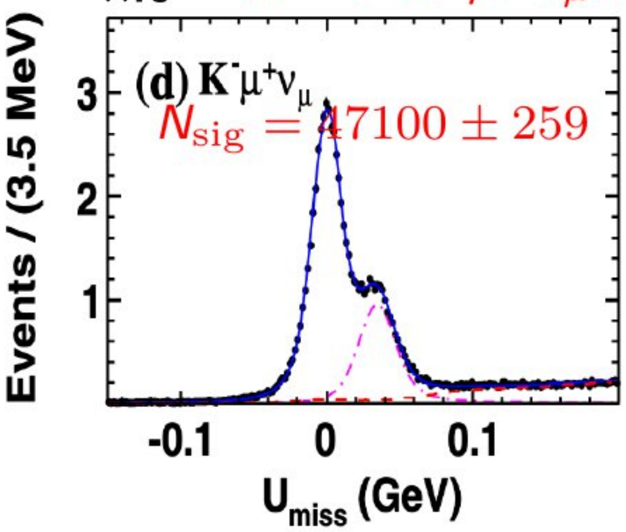


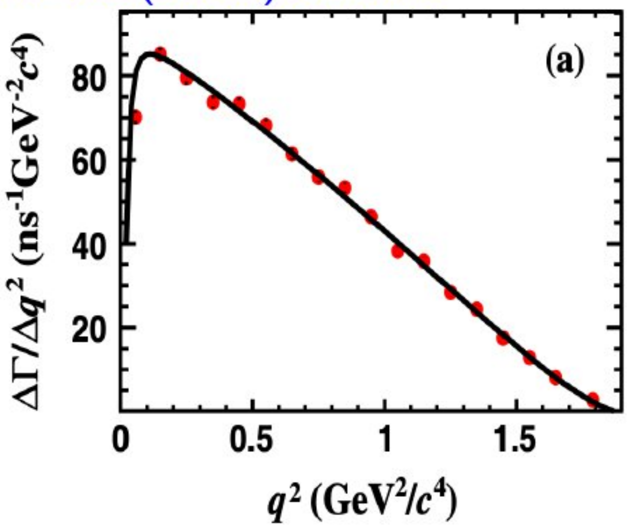
LFU tested at a precision ~1%

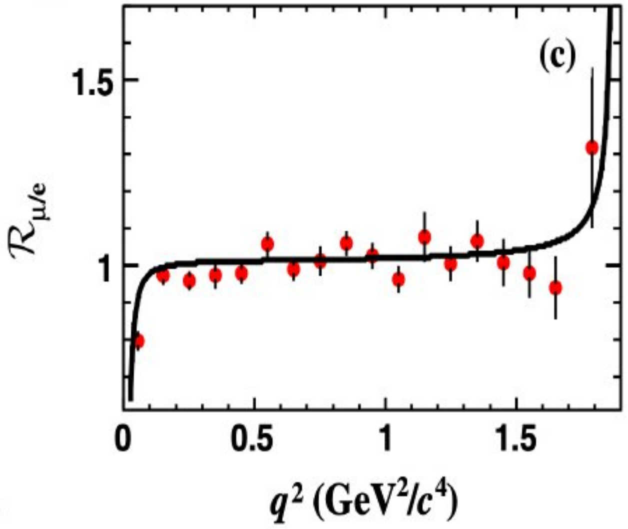
$$\mathcal{R}_{\mu/e} = 0.974 \pm 0.007 \pm 0.012$$

$$\mathcal{R}^{\rm SM}_{\mu/e} = 0.975 \pm 0.001$$

$D^0 \to K^- \mu^+ \nu_\mu$ PRL122(2019)011804





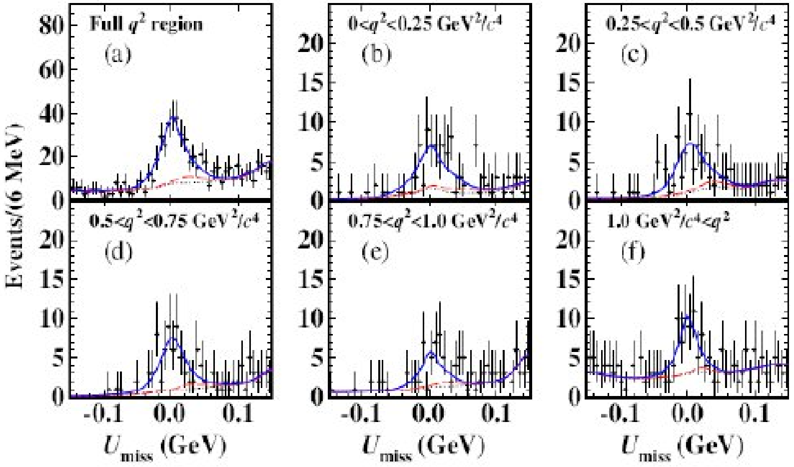


BESIII

Studies of $D \to (P,V)\mu^+\nu_\mu$

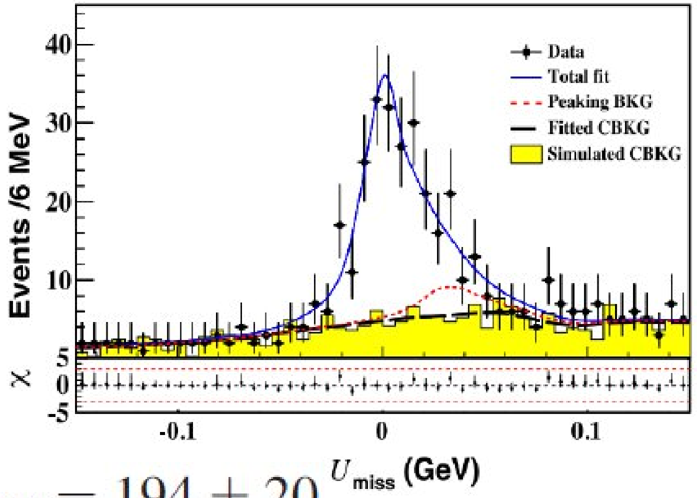
First observations

$D^+ \to \eta\mu^+\nu$	$D^+ \to \omega\mu^+\nu$	$D^0 \to \rho^-\mu^+\nu$
PRL124(2020)231801	PRD101(2020)072005	PRD104(2021)L091103



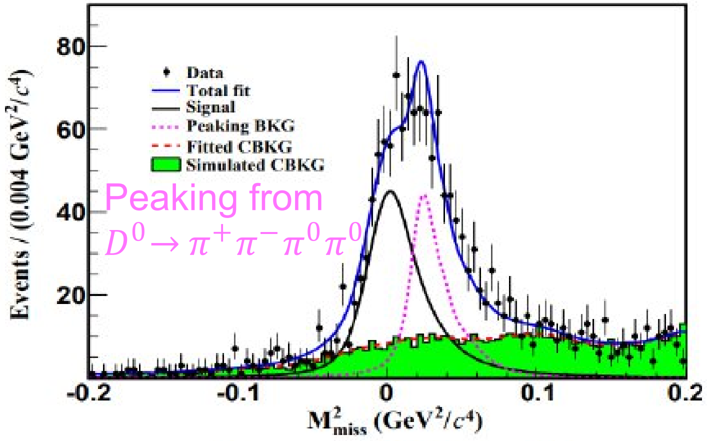
$N_{DT} = 234 \pm 22_{stat}$

$B[D^+ \to \eta\mu^+\nu] = (0.104 \pm 0.010 \pm 0.005)\%$



$N_{DT} = 194 \pm 20$

$B[D^+ \to \omega\mu^+\nu] = (0.177 \pm 0.018 \pm 0.011)\%$



$N_{DT} = 570 \pm 40$

$B[D^0 \to \rho^-\mu^+\nu] = (0.135 \pm 0.009 \pm 0.009)\%$

$$R_{D\eta} = \frac{\Gamma[D^+ \to \eta\mu^+\nu]}{\Gamma[D^+ \to \eta e^+\nu]} = 0.91 \pm 0.13$$

$$R_{D\omega} = \frac{\Gamma[D^+ \to \omega\mu^+\nu]}{\Gamma[D^+ \to \omega e^+\nu]} = 1.05 \pm 0.14$$

$$R_{D\rho} = \frac{\Gamma[D^0 \to \rho^-\mu^+\nu]}{\Gamma[D^0 \to \rho^- e^+\nu]} = 0.90 \pm 0.11$$

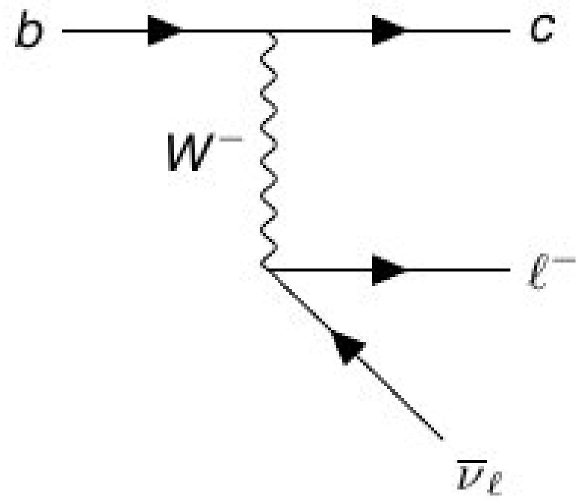
BESIII

LFU tests with $D_{(s)} \to (P,V)\ell^+\nu_\ell$: summary

		BF ratios	SM	References
μ/e	$D^0 \to K^-$	$0.978 \pm 0.007 \pm 0.012$	0.975	PRL122(2019)011804
	$D^0 \to \pi^-$	$0.922 \pm 0.030 \pm 0.022$	0.985	PRL121(2018)171803
	$D^0 \to \rho^-$	0.90 ± 0.11	0.93-0.96	PRD104(2021)091003
	$D^+ \to \bar{K}^0$	1.00 ± 0.03	0.975	EPJC76(2016)369
	$D^+ \to \pi^0$	$0.964 \pm 0.037 \pm 0.026$	0.985	PRL121(2018)171803
	$D^+ \to \omega$	1.05 ± 0.14	0.93-0.99	PRD101(2020)072005
	$D^+ \to \eta$	0.91 ± 0.13	0.97-0.98	PRL124(2020)231801
	$D_s^+ \to \eta$	0.86 ± 0.29	0.97-0.98	PRD97(2018)012006
	$D_s^+ \to \eta'$	1.14 ± 0.68	~0.95	
	$D_s^+ \to \phi$	1.05 ± 0.24	0.92-0.95	
	$\Lambda_c^+ \to \Lambda$	$0.96 \pm 0.16 \pm 0.04$	0.97	PLB767(2017)42

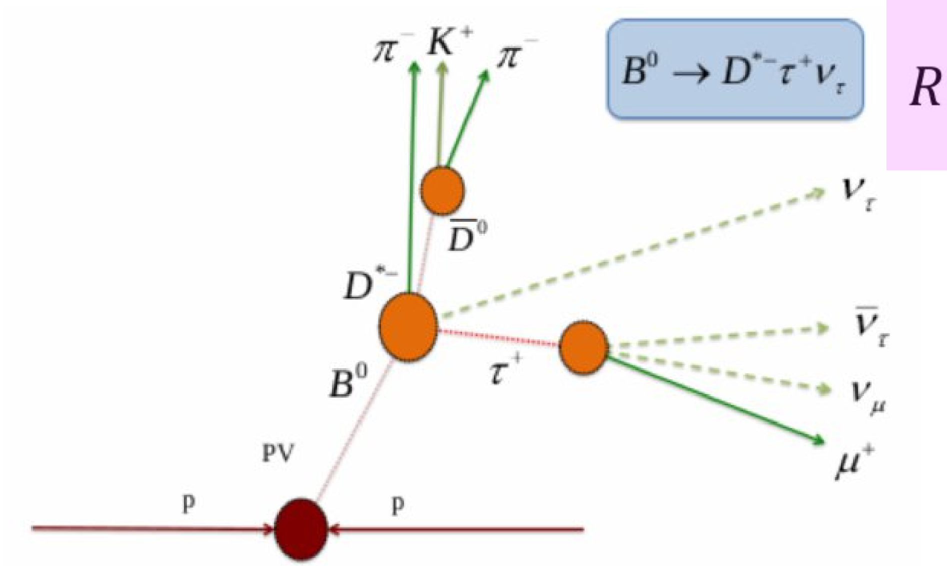
H.L. Ma, Mini-Workshop on BESIII Physics-- 500 Publications

LFU tests in semi-leptonic B decays

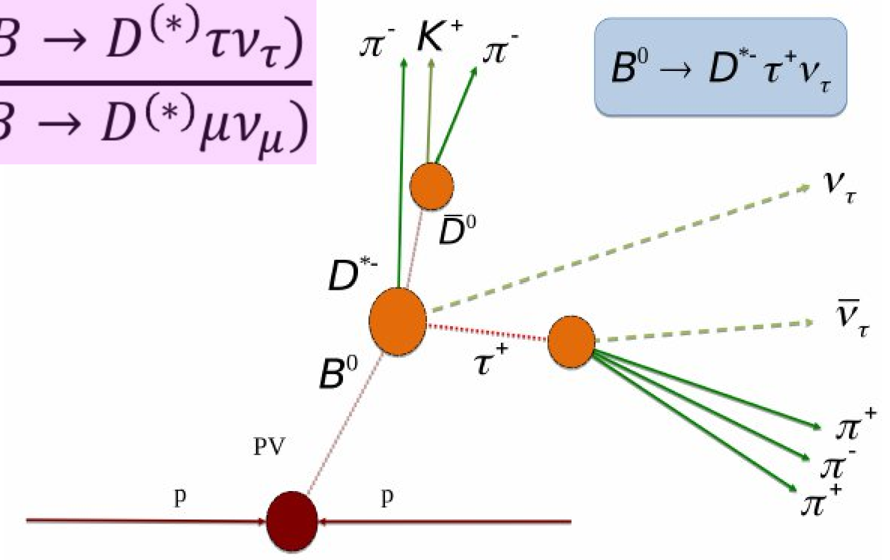


arXiv:2302.02886
arXiv:2305.01463

$R(D^{(*)})$ measurements @ LHCb



$$R(D^{(*)}) = \frac{\mathcal{B}(B \to D^{(*)}\tau\nu_\tau)}{\mathcal{B}(B \to D^{(*)}\mu\nu_\mu)}$$



Muonic $\tau \to \mu\bar{\nu}\nu$:

- Large statistics
- Study of τ and μ modes in one dataset
- Can measure R(D) and R(D*) simultaneously

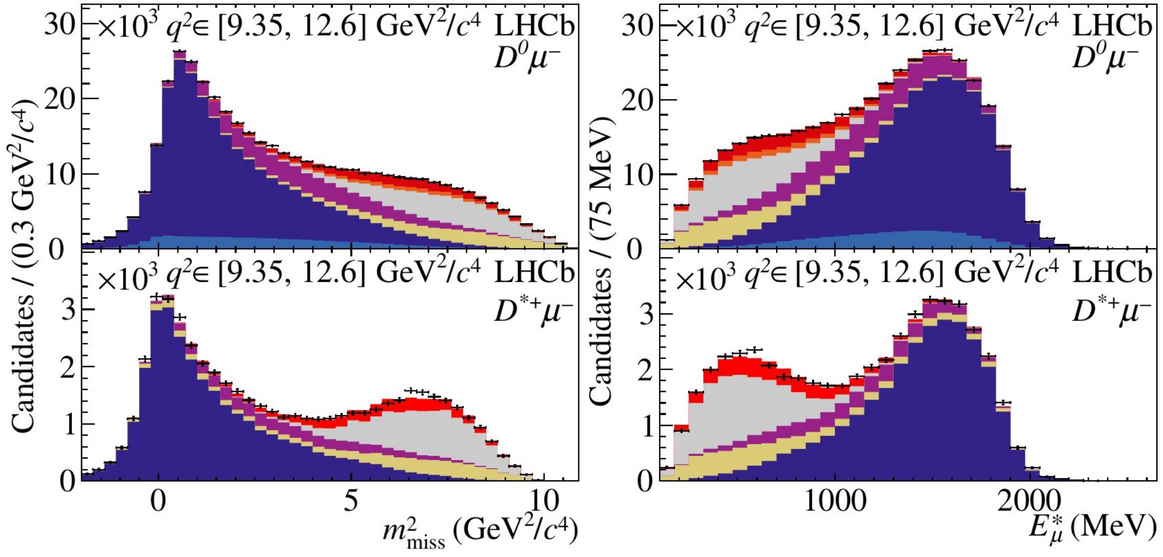
Hadronic $\tau \to \pi\pi\pi(\pi^0)\bar{\nu}$:

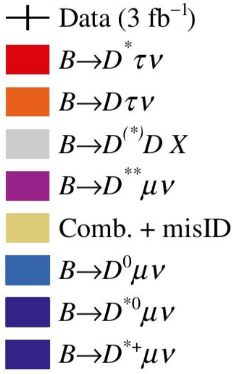
- Relatively high purity
- External BR measurement for normalization
- Decay vertex of τ well measured to suppress dominant backgrounds
- 3π dynamics important for the separation of B-> D*DX backgrounds

arXiv:2302.02886
arXiv:2305.01463

R(D$^{(*)}$) measurements @ LHCb

Muonic $\tau \to \mu\bar{\nu}\nu$





Using Run1 3 fb^{-1} data:

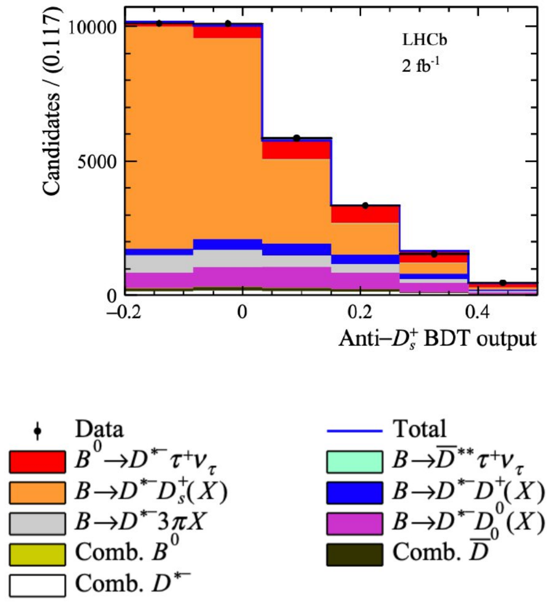
$$R(D^*) = 0.281 \pm 0.018\,(\text{stat.}) \pm 0.024\,(\text{syst.})$$

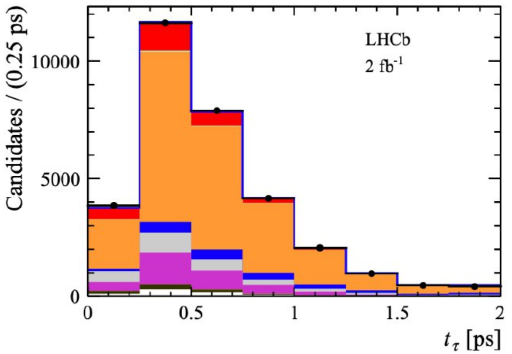
$$R(D) = 0.441 \pm 0.060\,(\text{stat.}) \pm 0.066\,(\text{syst.})$$

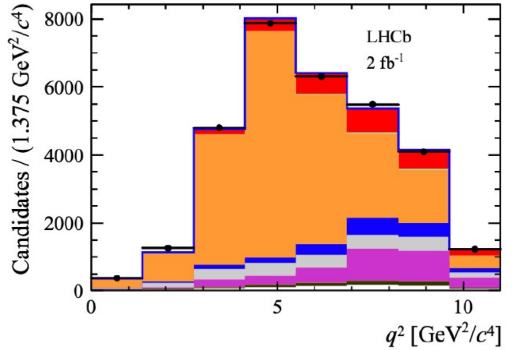
$$\rho = -0.43$$

1.9σ deviation from SM

Hadronic $\tau \to \pi\pi\pi(\pi^0)\nu$







Using Run1+2
5 fb^{-1} data:

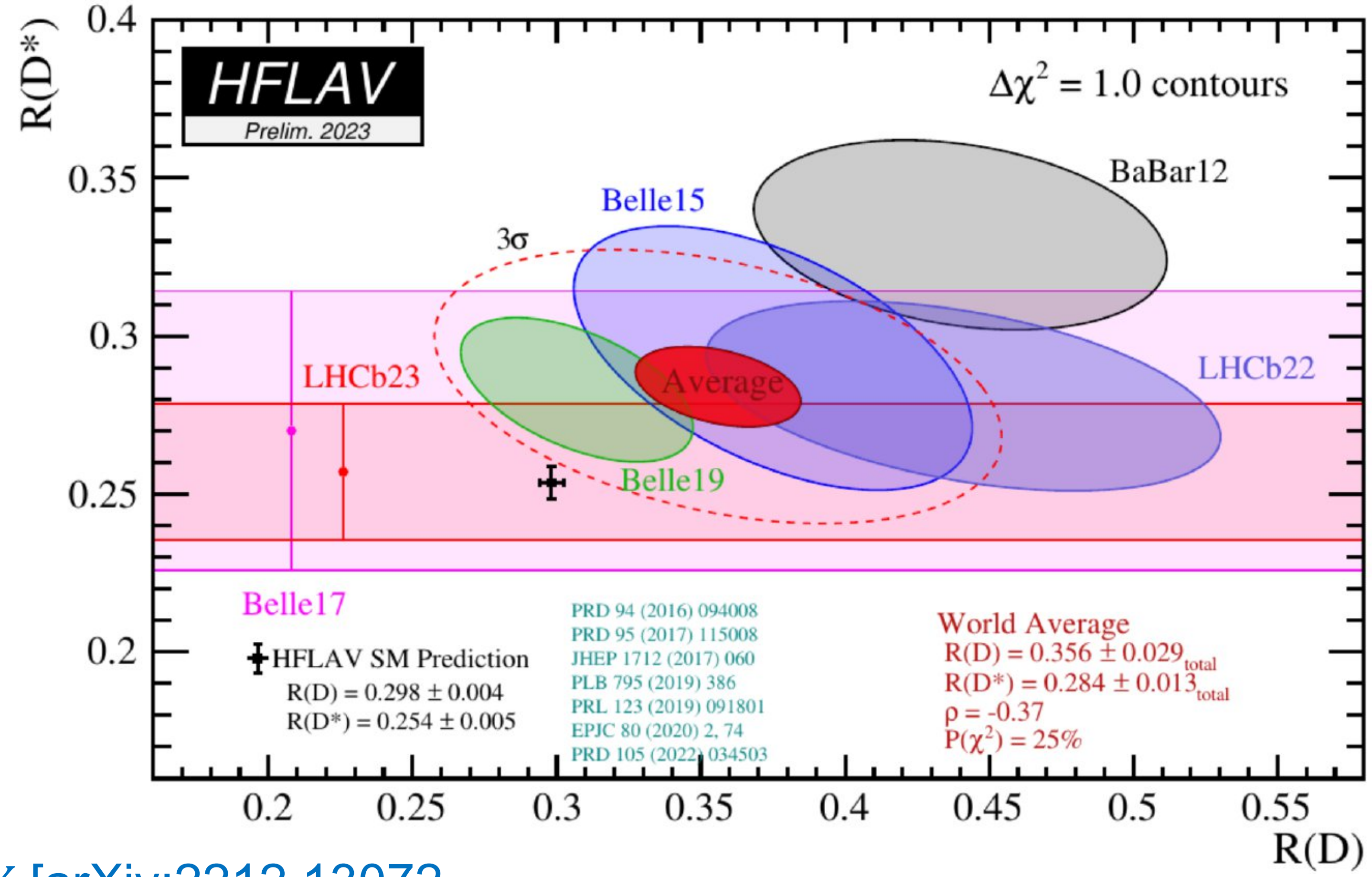
Agreement w/ SM <1σ

$$R(D^*) = 0.257 \pm 0.012\,(stat) \pm 0.014\,(syst) \pm 0.012\,(ext)$$

Considerable systematic uncertainty due to limited sample sizes

Updated $R(D^{(*)})$ world averages

- Updates with inclusion of two new results (LHCb22, LHCb23):
  - $R(D^*) = 0.284 \pm 0.013$
  - $R(D) = 0.356 \pm 0.029$
- Deviation from SM for combined R(D) − R(D*) now moves from 3.3σ to 3.2σ

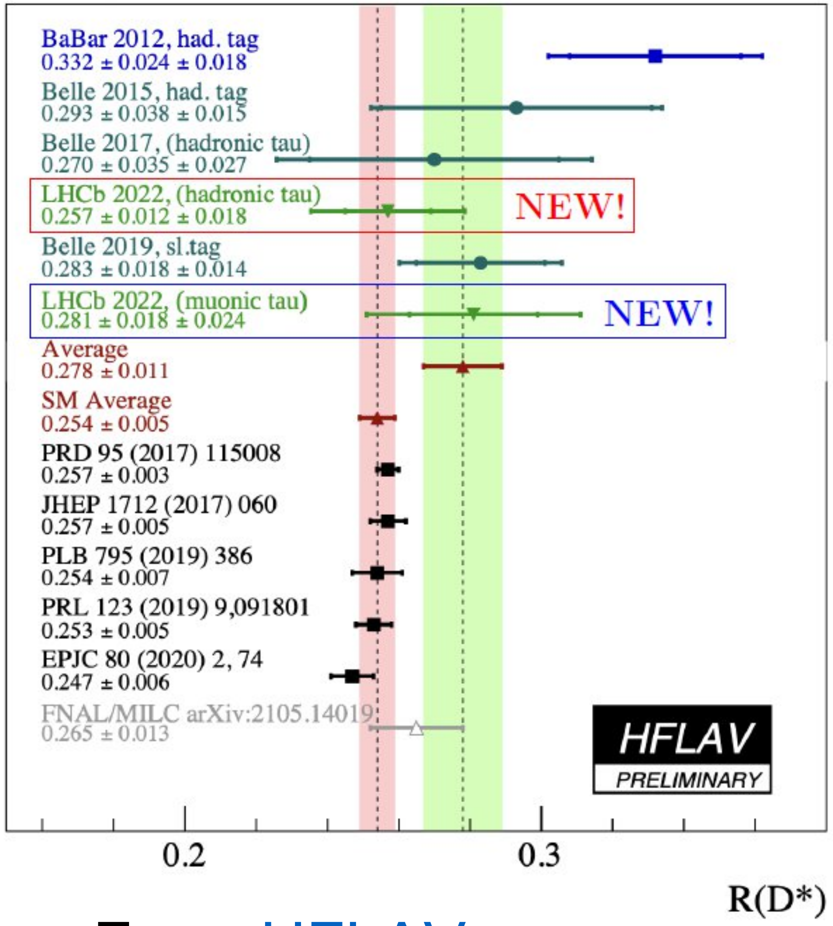


From HFLAV

Recent BESIII measurements on $D_{(s)} \to 3\pi X$ [arXiv:2212.13072, arXiv:2301.03214] could be helpful in understanding double-charm backgrounds in hadronic R(D*) measurements

Updated $R(D^{(*)})$ world averages

- Updates with inclusion of two new results (LHCb22, LHCb23):
  - $R(D^*) = 0.284 \pm 0.013$
  - $R(D) = 0.356 \pm 0.029$
- Deviation from SM for combined $R(D^*)$ now at 1.9σ



From HFLAV

Recent BESIII measurements on $D_{(s)} \to 3\pi X$ [arXiv:2212.13072, arXiv:2301.03214] could be helpful in understanding double-charm backgrounds in hadronic R(D*) measurements

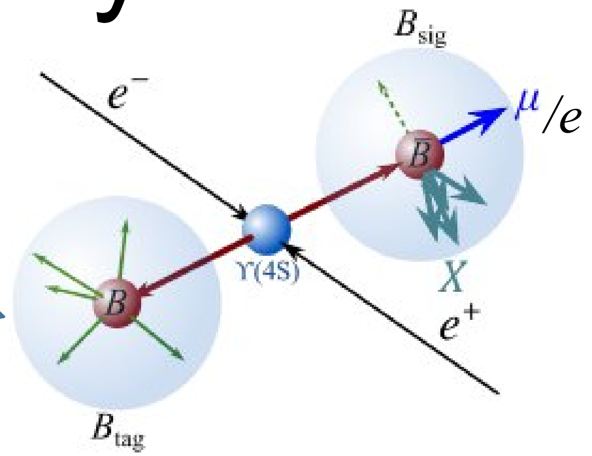
arXiv:2301.08266

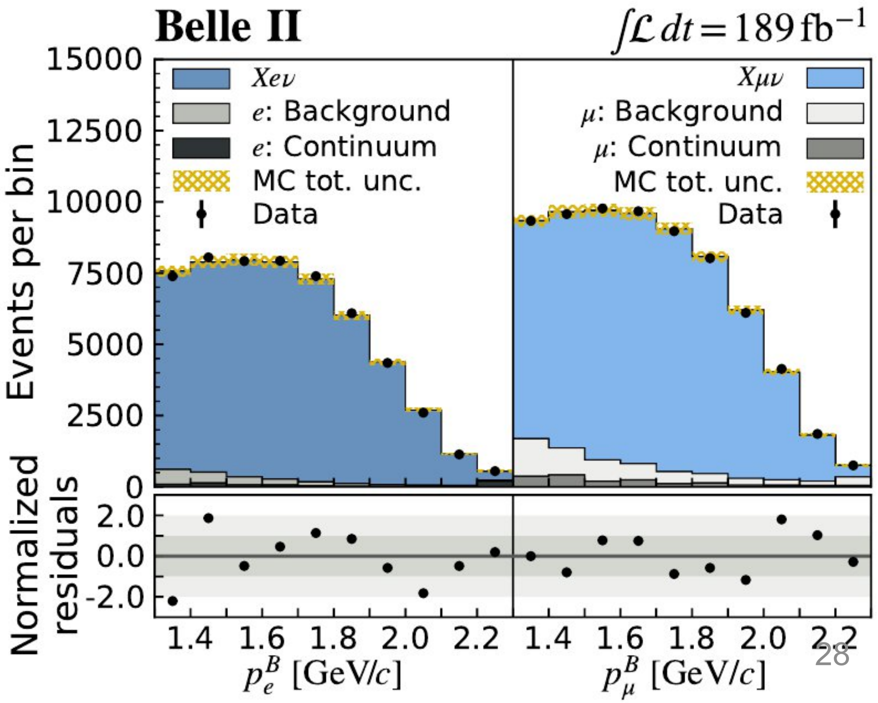
$R(X_{e/\mu})$ in semileptonic B decays

- Hadronic tagging with a fully reco'ed B_{tag}
- Distribution of lepton momentum in B_{sig} rest frame fitted to extract signals
- Most precise LFU result in b-sector:

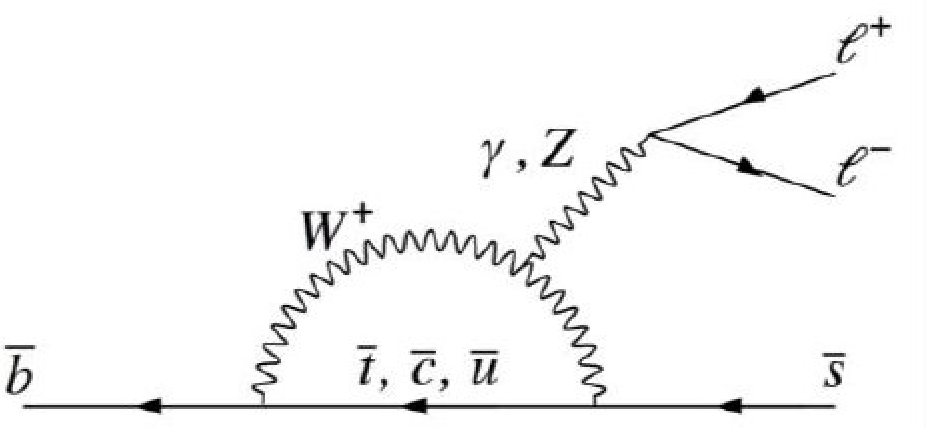
$$R(X_{e/\mu}) = 1.007 \pm 0.009\ (\text{stat}) \pm 0.019\ (\text{syst})$$

  - In agreement with SM based prediction of 1.006 ± 0.001 [arXiv:2207.03432]
  - In agreement with BELLE measurements in exclusive $D^*\ell\nu$ channels [e.g. arXiv:2301.07529]
- Also e/μ difference in angular asymmetries in $B^0 \to D^{*-}\ell\nu$ reported here

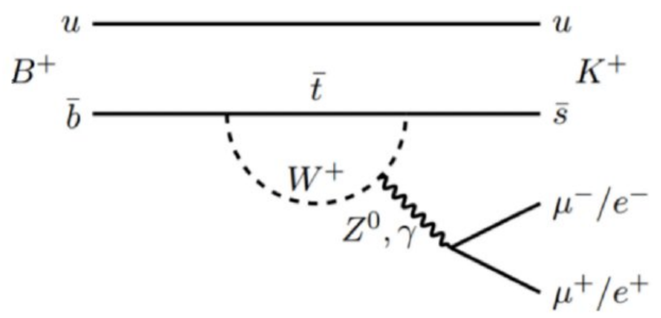


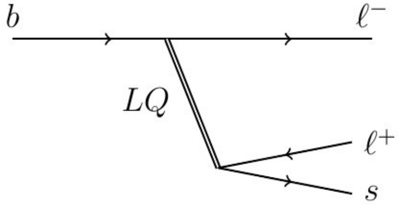


LFU tests in rare b-hadron decays



LFU tests in $b \to s\ell^+\ell^-$ decays



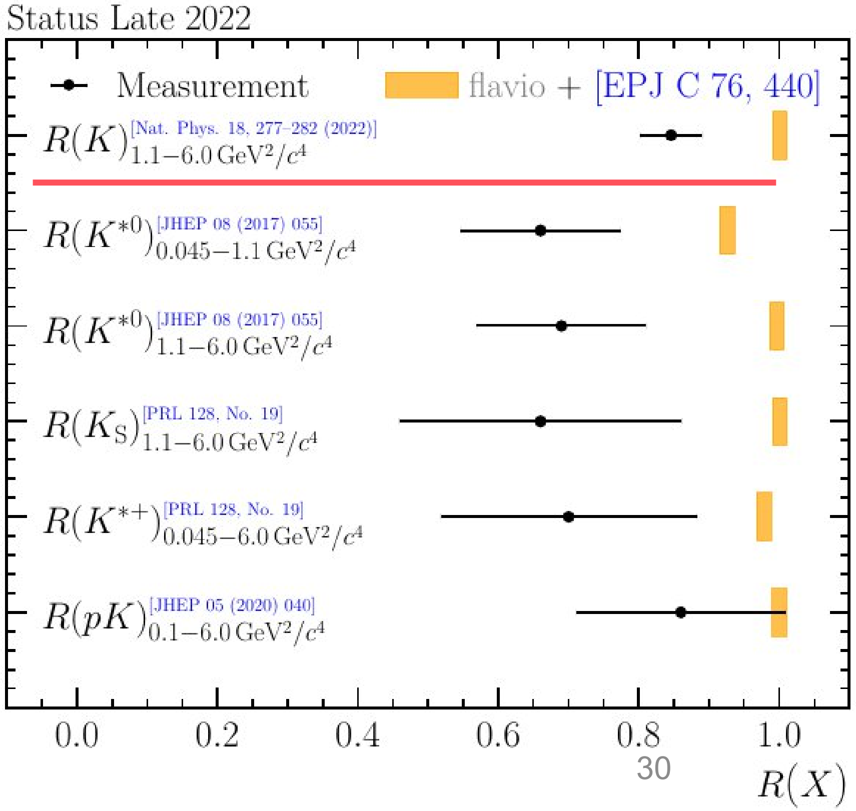


- $b \to s\ell^+\ell^-$ FCNC processes highly suppressed in SM
- NP may manifest in the loops and cause LFU violation
- LFU tests use

$$q^2 = m(\ell^+\ell^-)^2$$

$$R_X = \frac{\int_{q^2_{min}}^{q^2_{max}} \frac{d\mathcal{B}(B_q \to X_s \mu^+\mu^-)}{dq^2} dq^2}{\int_{q^2_{min}}^{q^2_{max}} \frac{d\mathcal{B}(B_q \to X_s e^+e^-)}{dq^2} dq^2} = 1 \pm \mathcal{O}(1\,\%)$$

  - Cancellation of hadronic uncertainties in the ratio => precise prediction of R_X

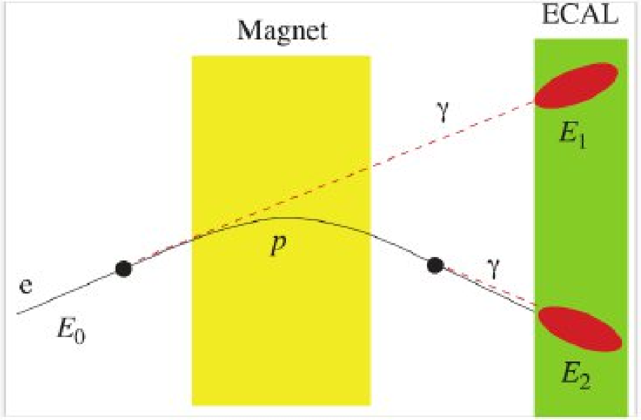


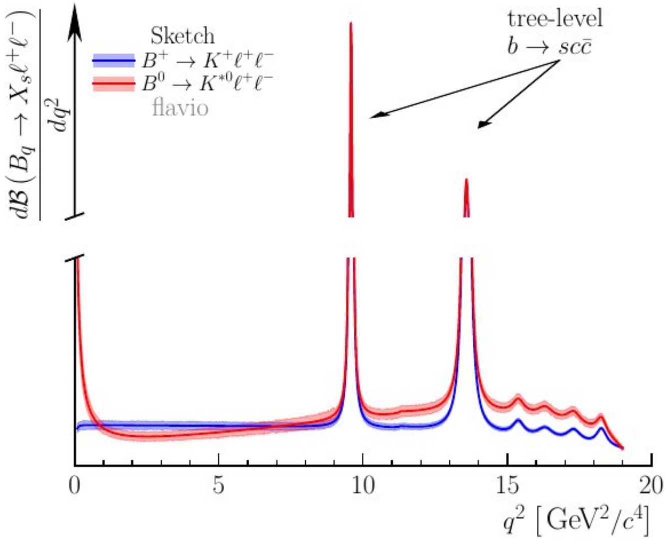
R(K$^{(*)}$) measurements @ LHCb

- Electrons & muons behave quite differently in the LHCb detector
- Lower efficiencies & worse resolution (energy loss) for electrons
- Double-ratio of branching fractions:

$$R_X = \frac{\mathcal{B}(B_q \to X_s \mu^+\mu^-)}{\mathcal{B}(B_q \to X_s J/\psi(\mu^+\mu^-))} \cdot \frac{\mathcal{B}(B_q \to X_s J/\psi(e^+e^-))}{\mathcal{B}(B_q \to X_s e^+e^-)}$$

  - Most of systematic uncertainties cancel to 1st order
  - LFU in $J/\psi \to \ell^+\ell^-$ well established at ‰ level [BESIII, PRD 88, 032007 (2013)]
  - Validated in $\psi(2S)$ mode

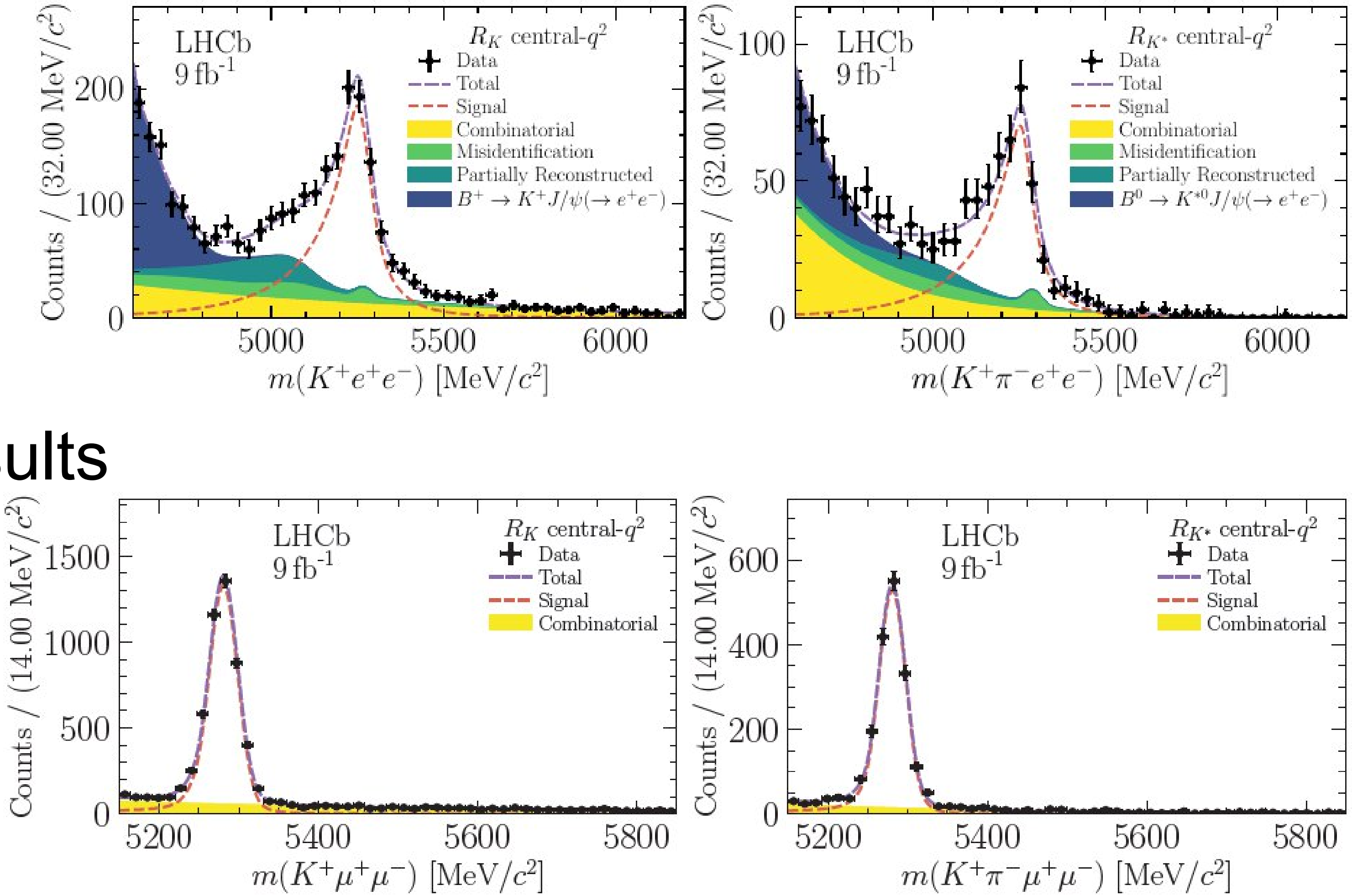




arXiv:2212.09152
arXiv:2212.09153

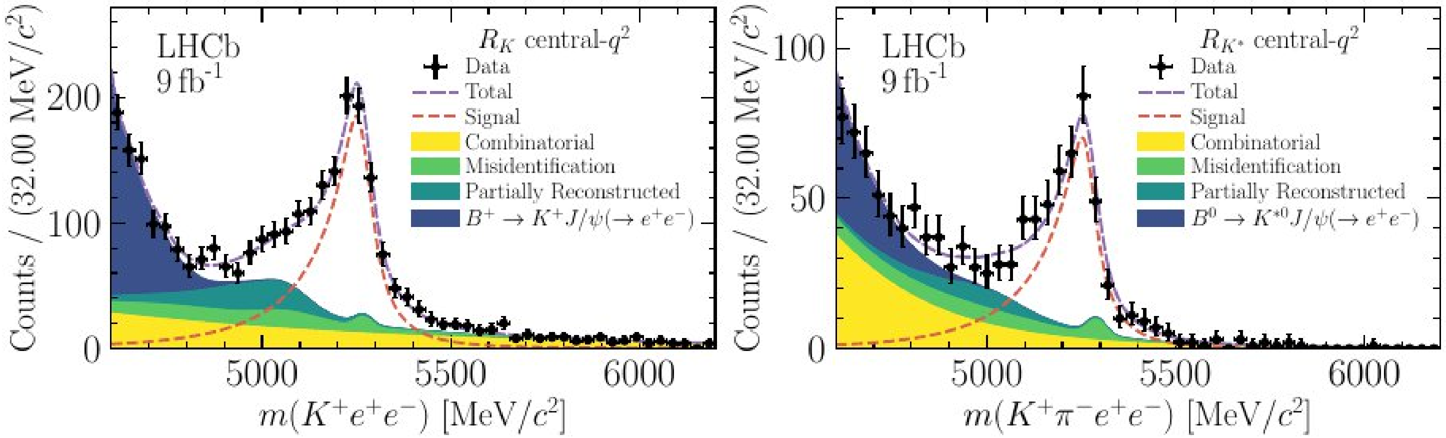
R(K$^{(*)}$) results @ LHCb

- Most precise LFU test in $b \to s\ell^+\ell^-$ decays
- Supersedes previous results

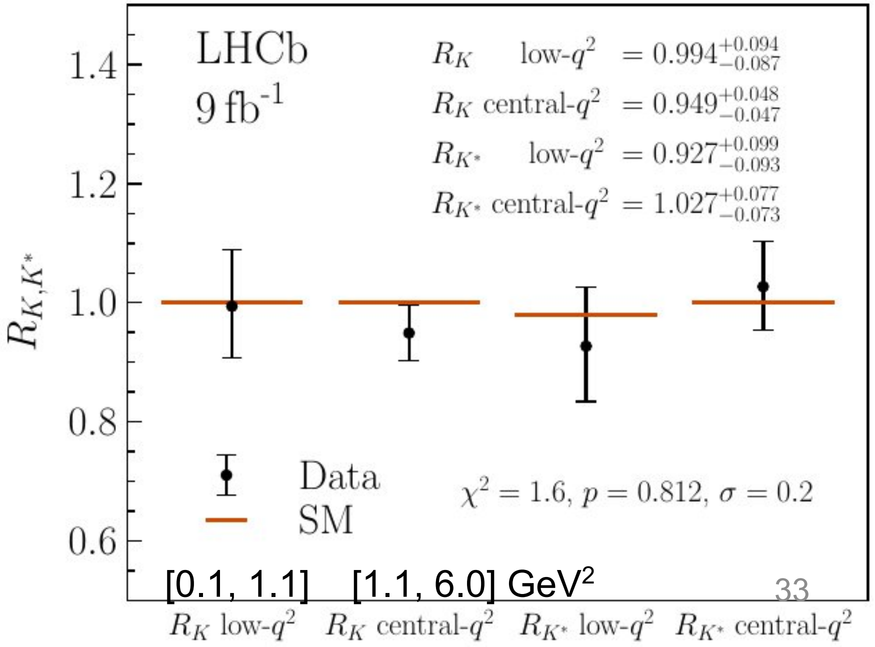


arXiv:2212.09152
arXiv:2212.09153

$R(K^{(*)})$ results @ LHCb



- Most precise LFU test in $b \to s\ell^+\ell^-$ decays
- Supersedes previous results
- Improved systematics of mis-IDed hadronic background in electron mode
- Now compatible with SM predictions at 0.2σ level
- Uncertainties statistically dominated



Recent LFU results not covered here ...

- LFU tests in semileptonic decays of light hadrons
  - See talk “Hyeron physics at BESIII” by Hong-Fei Sun)
- LFU tests with $\mathrm{B}(W \to \ell\nu)$

CMS, PRD 105, 072008 (2022)

	CMS	LEP	ATLAS	LHCb	CDF	D0
$R_{\mu/e}$	1.009 ± 0.009	0.993 ± 0.019	1.003 ± 0.010	0.980 ± 0.012	0.991 ± 0.012	0.886 ± 0.121
$R_{\tau/e}$	0.994 ± 0.021	1.063 ± 0.027	...	...	...	...
$R_{\tau/\mu}$	0.985 ± 0.020	1.070 ± 0.026	0.992 ± 0.013	...	...	...
$R_{\tau/\ell}$	1.002 ± 0.019	1.066 ± 0.025	...	...	...	...

- cLFV searches closely related to LFU

  See the talk by Chen Wu after the coffee break

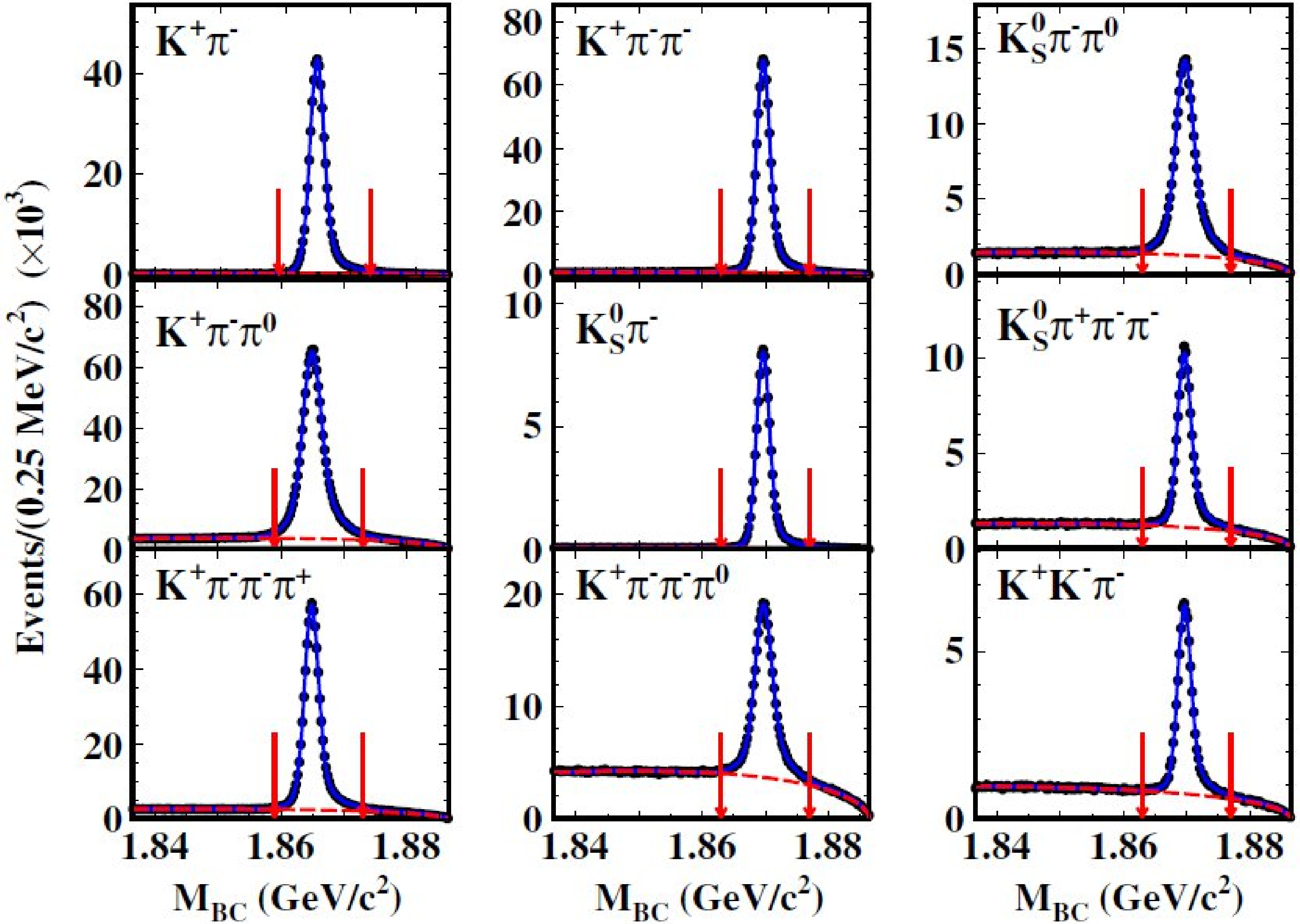
Summary & outlook

- LFU tests in a large range of decay channels have been performed recently by BESIII, BELLE(II), LHCb, etc.
    - Focused on beauty/charm sectors
- With improved precision or being first measurements, all results show good agreement with LFU
- $R(D^{(*)})$ results still show tension with SM, while R(K) now moves closer to SM expectation
- With new $R(K^{(*)})$ results, LF universal NP in $C_{9\ell}$ now favored over LFU violation according to global fits [arXiv:2304.07330]
- Synergy of different experiments important to improve precision
- Still excitements ahead: LHC Run3 ongoing / more BELLEII data / BESIII taking 7x ψ(3770) data / STCF on the horizon / ...

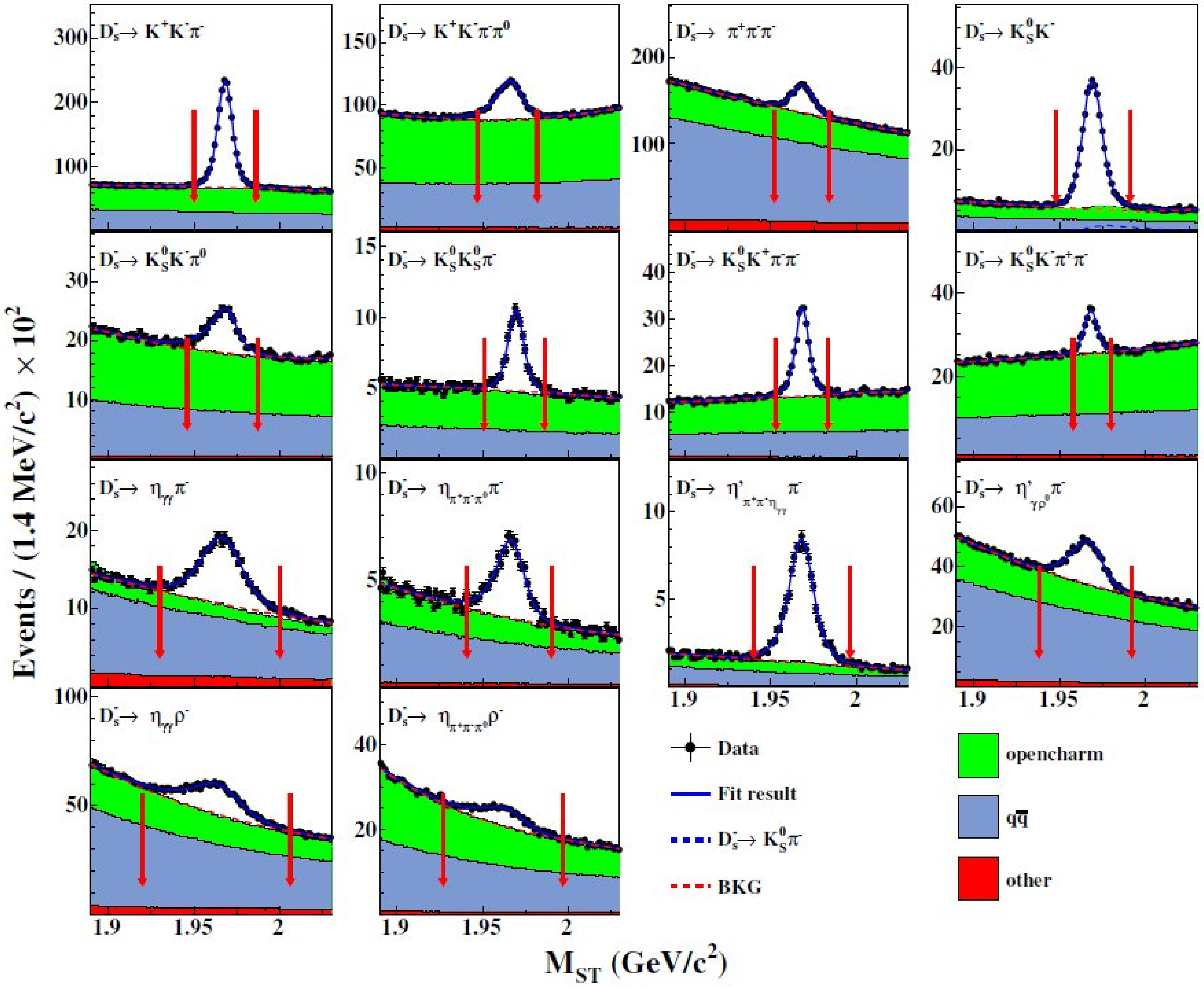
Backup Slides

D tags @ BESIII

PHYSICAL REVIEW LETTERS **121**, 171803 (2018)



D_s tags @ BESIII



arXIv:2303.12468

3.19 fb^{-1} @ 4178 MeV