中国科学院大学
University of Chinese Academy of Sciences

Flavor & Precision Physics Summary

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The 29th International Workshop on Weak Interactions and Neutrinos
SYSU, Zhuhai, 03-08 July 2023

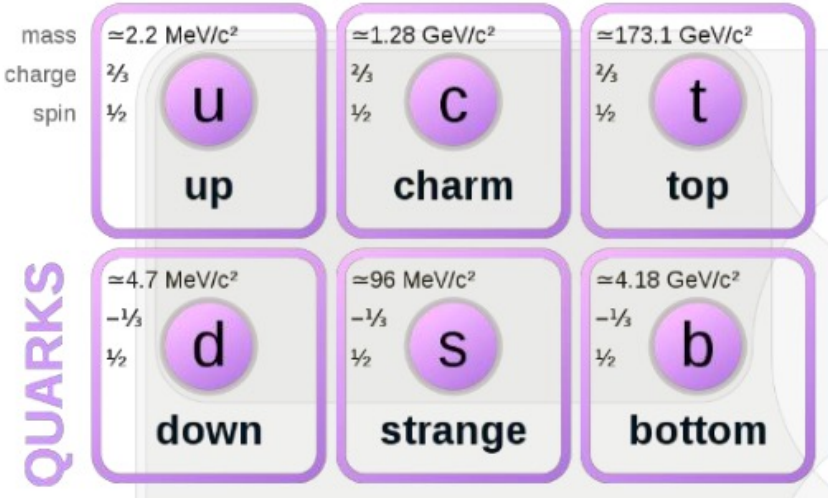
Talk statistics

- **Six plenary talks: 2 theory overviews + 4 experiment summaries, covering CKM, LFV/LFU, g-2 etc**
- **Six sessions of parallel talks: 25 talks (8 from theory)**

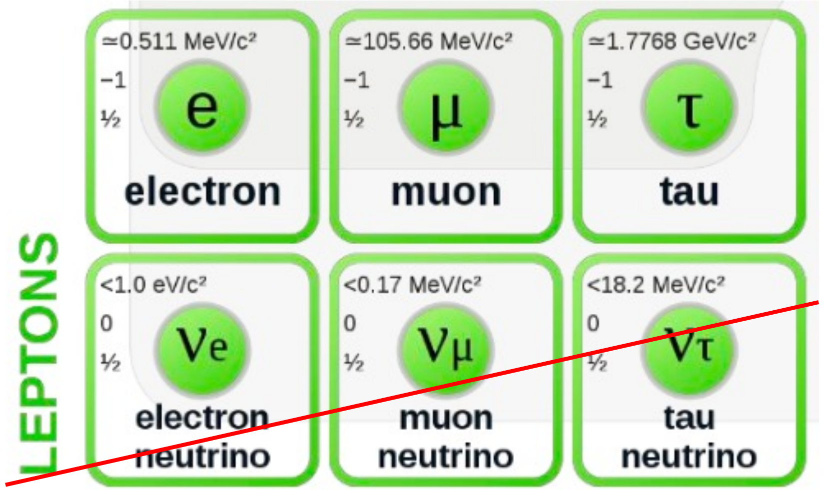
Talk	Speaker	Room	Time
Charm meson decays at BESIII	Zehui Lu	Haiqin Building #6	14:00 - 14:25
CPV measurement in Bs2PhiPHi decay	Kechen Li	A280, Haiqin Building #6	14:25 - 14:50
CP Violation Induced by Neutral Meson Mixing Interference	Yin-Fa Shen	A280, Haiqin Building #6	14:50 - 15:15
Recent Results of B Mesogenesis and Dark Sector at $BABAR$	Dexu Lin	A280, Haiqin Building #6	15:15 - 15:40
Search for Rare Neutral Kaon Decays at JPARC KOTO Experiment	Prof. Yee Bob Hsiung	A280, Haiqin Building #6	16:10 - 16:35
Precision measurements with Kaons at CERN	Cristina Biino	A280, Haiqin Building #6	16:35 - 17:00
Searches for lepton flavour universality violation with the ATLAS detector	Hao Pang	A280, Haiqin Building #6	17:00 - 17:25
Models for the Muon EDM	Yuichiro Nakai	A280, Haiqin Building #6	17:25 - 17:50
Current Status of the COMET Experiment	Dr Yu Xu	A631, Haiqin Building #6	14:00 - 14:25
Expected Direct Search Charged Lepton Flavor Violation Sensitivity in μ^+ and π^+ Decays at Rest	Shihua Huang	A631, Haiqin Building #6	14:25 - 14:50
The Mu3e experiment: physics and status	Yifeng Wang	A631, Haiqin Building #6	14:50 - 15:15
Higgs LFV decays	Avelino Vicente	A631, Haiqin Building #6	15:15 - 15:40

Talk	Speaker	Room	Time
Hyperon physics at BESIII	Hong-Fei Shen	A280, Haiqin Building #6	16:10 - 16:35
Recent results of the exotic hadron studies at CMS	Zhen Hu	A280, Haiqin Building #6	16:35 - 17:00
Recent results of the exotic states studies at LHCb	Dongliang Zhang	A280, Haiqin Building #6	17:00 - 17:25
TMD wave functions and soft functions at one-loop in LaMET	Zhifu Deng	A280, Haiqin Building #6	17:25 - 17:50
Search for rare charm decays at BESIII	Yonghua Zhan	A280, Haiqin Building #6	17:50 - 18:15
Charmed baryon physics at BESIII	Lei Li	A280, Haiqin Building #6	14:00 - 14:25
Recent results from the Belle II experiment	Chengping Shen	A280, Haiqin Building #6	14:25 - 14:50
The heavy flavor rare decays at CMS	Chuqiao Jiang	A280, Haiqin Building #6	14:50 - 15:15
Light quark decays of doubly heavy baryons in light front approach	Chang Yang	A280, Haiqin Building #6	15:15 - 15:40
New physics interpretations of $R(D^{(*)})$ anomaly and their exciting predictions	Teppei Kitahara	A631, Haiqin Building #6	16:10 - 16:35
Testing Lepton Flavor Universality at Future Z Factories	Tsz Hong Kwok	A631, Haiqin Building #6	16:35 - 17:00
Muon g-2 experiment at Fermilab	Mr Cheng Chen	A631, Haiqin Building #6	17:00 - 17:25
A quark and lepton model with flavor specific DM and muon $g-2$ in modular A_4 and hidden $U(1)$ symmetries	Takaaki Nomura		

Flavor physics



The world made by Fermions



- **Focus on quarks and charged leptons**
- **To understand matter anti-matter asymmetry (CP violation), new forces or new particles coupled to fermions through quantum fluctuation, dark matter etc.**
- **Colored quarks confined inside hadron, QCD crucial**
- **QCD extremely interesting on its own (low energy behaviors)**

Precision physics

Talk by H. Yin

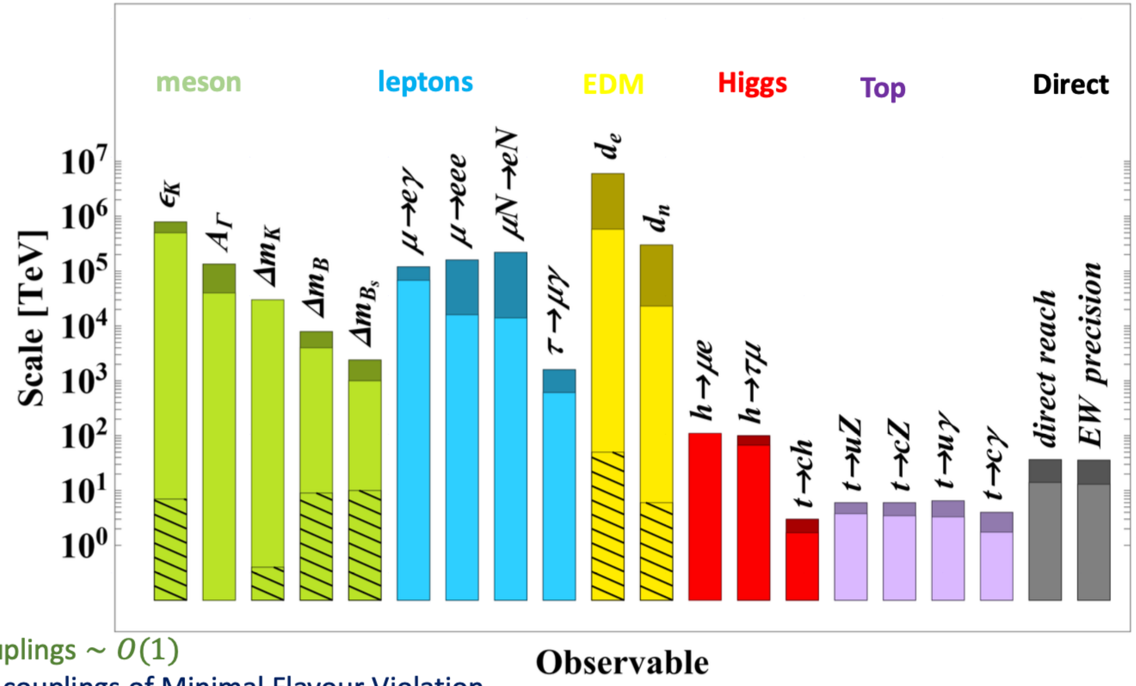
Sensitivity

arXiv: 1910.11775

CERN-ESU-004
10 January 2020

Physics Briefing Book

Input for the European Strategy for Particle Physics Update 2020



Light region: couplings ~ $O(1)$
Shadow regions: couplings of Minimal Flavour Violation

7/3/2023 Flavour and Precision Physics, Hang Yin 13

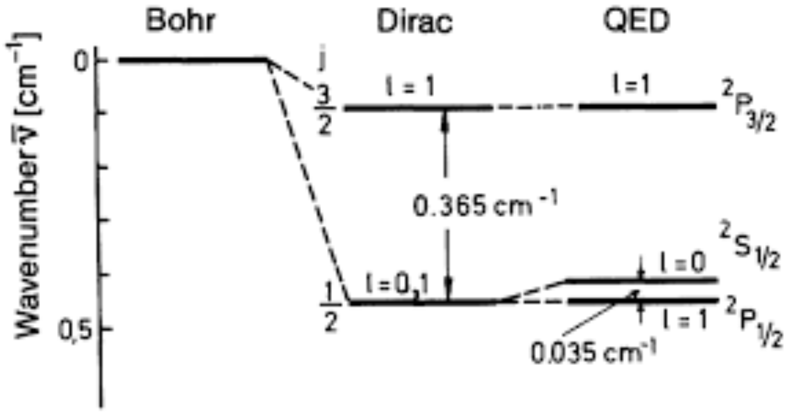
$$\mathcal{A}(\psi_i \to \psi_j + X) = \mathcal{A}_0\left(\frac{c_{\mathrm{SM}}}{v^2} + \frac{c_{\mathrm{NP}}}{\Lambda^2}\right)$$

Energy scale for SM: v ~100 GeV

NP scale: Λ

Indirect searches

Trojan horse



Lamb shift

Outline

- **CKM physics**
- **New physics searches with leptons**

Spectroscopy

Disclaimer: material selected based on personal taste, my apologies if your favorites are not shown

Outline

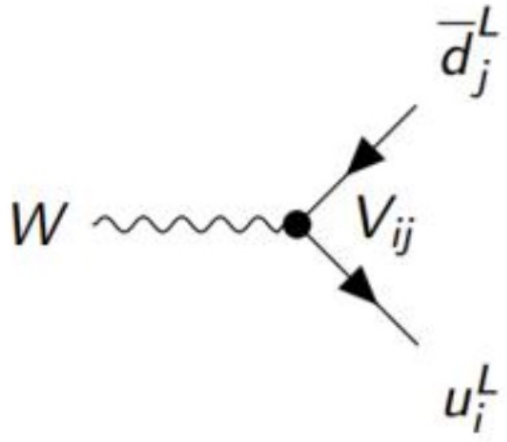
- CKM physics
- New physics searches with leptons
- Spectroscopy

CKM matrix

Talk by H. Yin, X. He

$$\begin{pmatrix} d^I \\ s^I \\ b^I \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

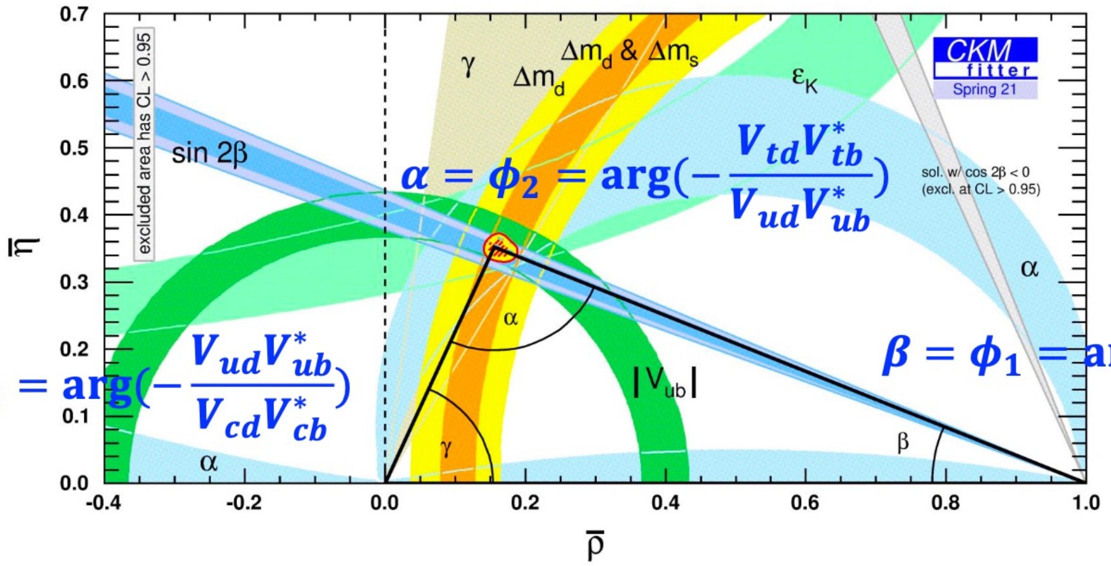
Interaction eigenstates **Mass eigenstates**



- **Unitary condition implies:** $\sum_i V_{ij}^* V_{ij} = 1$ $\sum_i V_{ij}^* V_{ik} = 0$

Four free parameters

Over constraining through different measurements, looking for discrepancies



$$\alpha = \phi_2 = \arg\left(-\frac{V_{td}V_{tb}^*}{V_{ud}V_{ub}^*}\right)$$

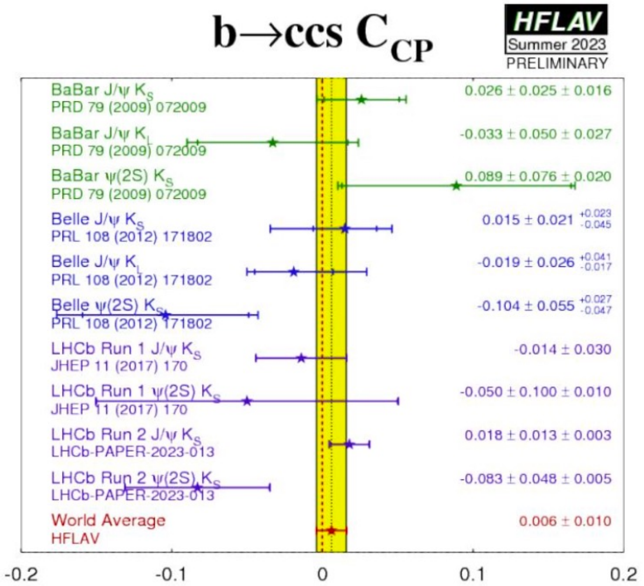
$$\beta = \phi_1 = \arg\left(-\frac{V_{cd}V_{cb}^*}{V_{td}V_{tb}^*}\right)$$

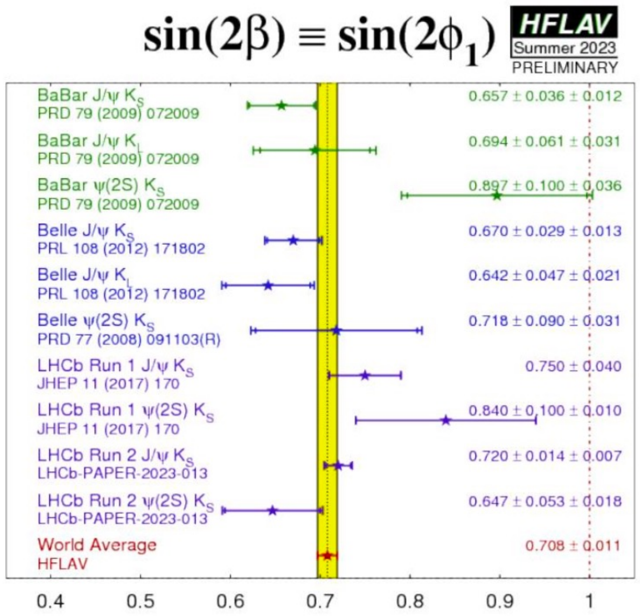
$$\gamma = \phi_3 = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$

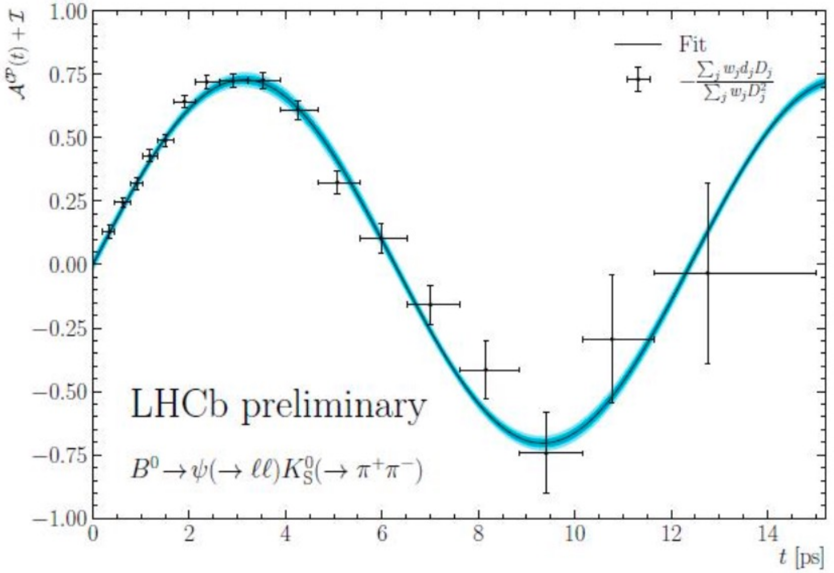
α, β, γ all related to the single weak phase, response for CPV

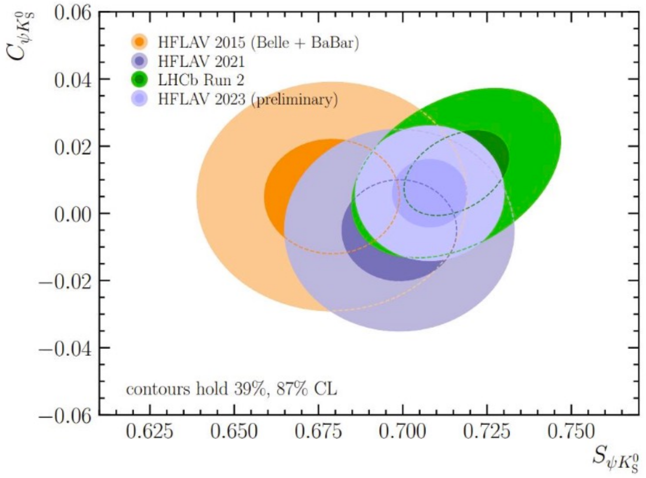
Angle β

Talk by K. Li









[HFLAV to update]

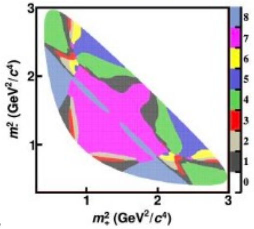
$$\mathcal{A}^{CP}(t) = \frac{\Gamma(\overline{B}^0(t) \to \psi K^0_S) - \Gamma(B^0(t) \to \psi K^0_S)}{\Gamma(\overline{B}^0(t) \to \psi K^0_S) + \Gamma(B^0(t) \to \psi K^0_S)} \approx \underbrace{D_{\Delta t} D_{FT}}_{\text{Experimental dilution factors}} S \sin(\Delta m_d t)$$

$$S^{\text{Run 2}}_{\psi K^0_S} = 0.716 \pm 0.013\,(\text{stat}) \pm 0.008\,(\text{syst})$$

$$C^{\text{Run 2}}_{\psi K^0_S} = 0.012 \pm 0.012\,(\text{stat}) \pm 0.003\,(\text{syst})$$

γ combination

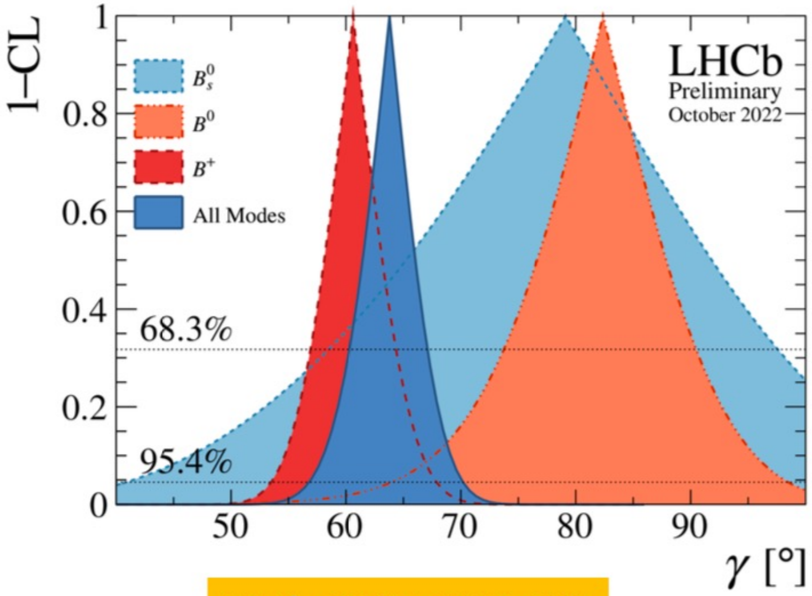
For the strong phase of D meson, we need input from BESIII
For example: $\psi(3770) \to D\bar{D}$ [PRD 101 (2020) 112002]



- Combining all LHCb results for γ

B decay	D decay	Ref.	Dataset	Status since Ref. [14]
$B^\pm \to Dh^\pm$	$D \to h^+h^-$	[29]	Run 1&2	As before
$B^\pm \to Dh^\pm$	$D \to h^+\pi^-\pi^+\pi^-$	[30]	Run 1	As before
$B^\pm \to Dh^\pm$	$D \to K^\pm\pi^\mp\pi^+\pi^-$	[18]	Run 1&2	**New**
$B^\pm \to Dh^\pm$	$D \to h^+h^-\pi^0$	[19]	Run 1&2	**Updated**
$B^\pm \to Dh^\pm$	$D \to K^0_S h^+h^-$	[31]	Run 1&2	As before
$B^\pm \to Dh^\pm$	$D \to K^0_S K^\pm\pi^\mp$	[32]	Run 1&2	As before
$B^\pm \to D^*h^\pm$	$D \to h^+h^-$	[29]	Run 1&2	As before
$B^\pm \to DK^{*\pm}$	$D \to h^+h^-$	[33]	Run 1&2(*)	As before
$B^\pm \to DK^{*\pm}$	$D \to h^+\pi^-\pi^+\pi^-$	[33]	Run 1&2(*)	As before
$B^\pm \to Dh^\pm\pi^+\pi^-$	$D \to h^+h^-$	[34]	Run 1	As before
$B^0 \to DK^{*0}$	$D \to h^+h^-$	[35]	Run 1&2(*)	As before
$B^0 \to DK^{*0}$	$D \to h^+\pi^-\pi^+\pi^-$	[35]	Run 1&2(*)	As before
$B^0 \to DK^{*0}$	$D \to K^0_S\pi^+\pi^-$	[36]	Run 1	As before
$B^0 \to D^\mp\pi^\pm$	$D^+ \to K^-\pi^+\pi^+$	[37]	Run 1	As before
$B^0_s \to D_s^\mp K^\pm$	$D_s^+ \to h^+h^-\pi^+$	[38]	Run 1	As before
$B^0_s \to D_s^\mp K^\pm\pi^+\pi^-$	$D_s^+ \to h^+h^-\pi^+$	[39]	Run 1&2	As before

Good agreement with CKM fitter
Limited by statistics



LHCb-CONF-2022-003

$(63.8^{+3.5}_{-3.7})$

Strong phase measurements

Already several Joint meetings and joint analyses ongoing

- $D^0 \to K^-\pi^+$ Eur. Phys. J. C 82, 1009 (2022)

$\delta_D^{K\pi} = (187.6^{+8.9+5.4}_{-9.7-6.4})^\circ$, most precise measurement

$$r_D^{K\pi} exp(-i\delta_D^{K\pi}) = \frac{\langle K^+\pi^- | D^0\rangle}{\langle K^+\pi^- | \bar{D}^0\rangle},$$

where $r_D^{K\pi}$ are $\delta_D^{K\pi}$ the ratio of amplitudes and phase difference, respectively, between the DCS and CF decays.

$A_{K\pi} = 0.132 \pm 0.001 \pm 0.007$, 30% more precision

$A_{K\pi}^{\pi\pi\pi^0} = 0.130 \pm 0.012 \pm 0.008$

$\mathscr{B}(D^0 \to K_L^0\pi^0) = (0.97 \pm 0.03 \pm 0.02) \times 10^{-2}$

$\mathscr{B}(D^0 \to K_L^0\omega) = (1.09 \pm 0.06 \pm 0.03) \times 10^{-2}$

$\mathscr{B}(D^0 \to K_L^0\pi^0\pi^0) = (1.26 \pm 0.05 \pm 0.03) \times 10^{-2}$.

- $D^0 \to \pi^+\pi^-\pi^+\pi^-$ Phys. Rev. D 106, 092004 (2022)

$F_+ = 0.735 \pm 0.015 \pm 0.005$,

$\to$ predominantly CP – even

most precise determination

- $D^0 \to K^+K^-\pi^+\pi^-$ Phys. Rev. D 107, 032009 (2023)

$F_+ = 0.730 \pm 0.037 \pm 0.021$,

$\to$ predominantly CP – even

first model-independent measurement of F_+ of this decay

- $D^0 \to K_S^0\pi^+\pi^-\pi^0$ arXiv:2305.03975

$F_+ = 0.235 \pm 0.010 \pm 0.002$,

$\to$ predominantly CP – odd

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QCD in flavor physics

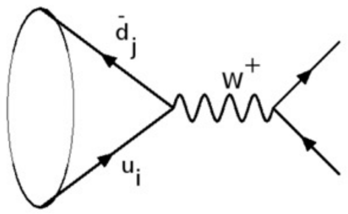
Physics of interest

Where Lattice/other QCD tools can help

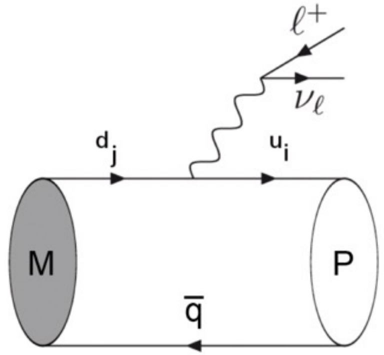
$$\Gamma = (\text{Weak})\,(\text{EM})\,(\text{QCD})$$

Experimental measurements

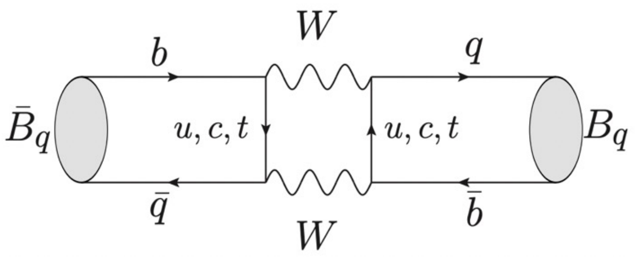
Precisely calculated by QED



Decay constant



Form factor



Decay constant, bag parameters

$$B[M \to \ell\nu_\ell]_{\text{SM}} = \frac{G_F^2 m_M m_\ell^2}{8\pi}\left(1 - \frac{m_\ell^2}{m_M^2}\right)^2 |V_{q_u q_d}|^2 f_M^2 \tau_M (1 + \delta_{em}^{M\ell 2})$$

Example of magnitude measurement

Talk by Z. Lu

(Semi-)Leptonic decays

Pure leptonic decays:

$D_s^+ \to \tau^+\nu_\tau, \tau^+ \to e^+\nu_e\bar{\nu}_\tau$, **Phys. Rev. Lett. 127, 171801 (2021)**

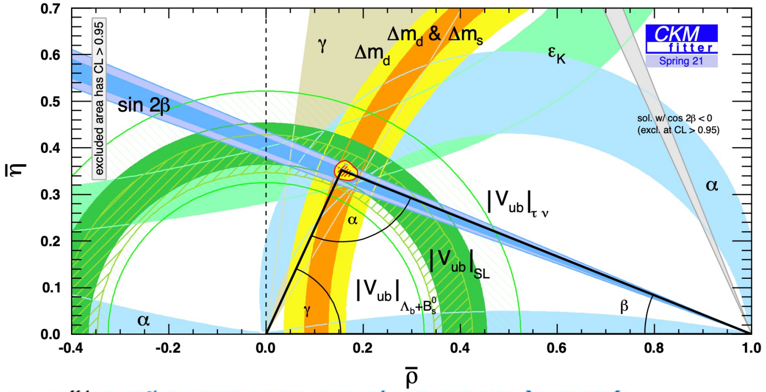
$D_s^+ \to \tau^+\nu_\tau, \tau^+ \to \pi^+\bar{\nu}_\tau$ & $D_s^+ \to \mu^+\nu_\mu$, **Phys. Rev. D 104, 052009 (2021)**

$D_s^+ \to \tau^+\nu_\tau, \tau^+ \to \pi^+\pi^0\bar{\nu}_\tau$, **Phys. Rev. D 104, 032001 (2021)**

$D_s^+ \to \tau^+\nu_\tau, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau$, **arXiv:2303.12468**

$D_s^+ \to \tau^+\nu_\tau, \tau^+ \to \pi^+\bar{\nu}_\tau$, **a**

$D_s^{*+} \to e^+\nu_e$, **arXiv:2304.**



Semi-leptonic decays:

$D^0 \to K_1(1270)^- e^+\nu_e$, **Ph**

$D_s^+ \to a_0(980)^0 e^+\nu_e$, **Phy**

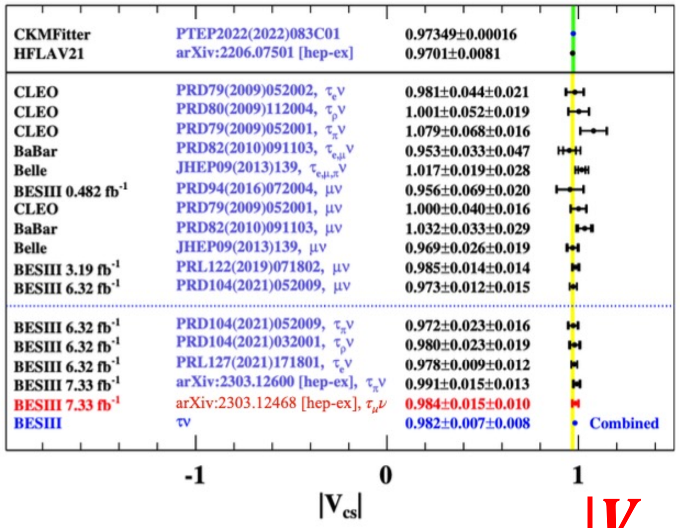
$D^0 \to K^- e^+\nu_e$ & $D^+ \to \bar{K}$

$D_s^+ \to \pi^0\pi^0 e^+\nu_e$ & $K_S^0K_S^0 e^+\nu_e$, **Phys. Rev. D 105, L031101 (2022)**

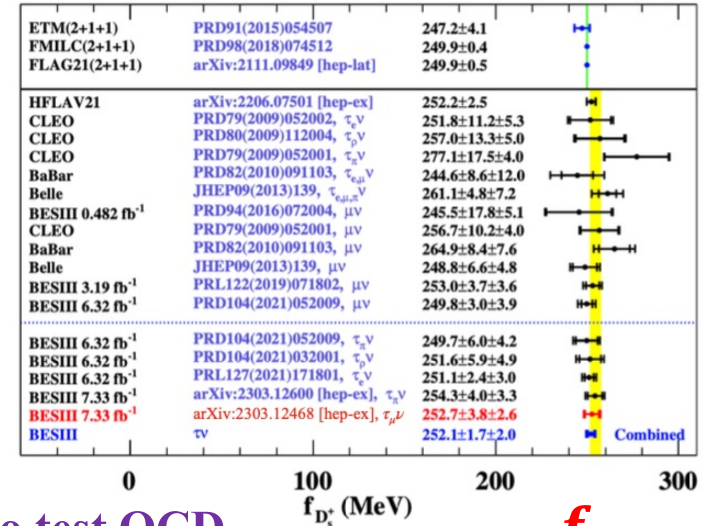
$D_s^+ \to \pi^0 e^+\nu_e$, **Phys. Rev. D 106, 112004 (2022)**

$D_s^+ \to \pi^+\pi^- e^+\nu_e$, **arXiv:2303.12927**

$D_s^+ \to \eta e^+\nu_e, \eta' e^+\nu_e$, **arXiv:2306.05194**



$|V_{cs}|$



$f_{D_s^+}$

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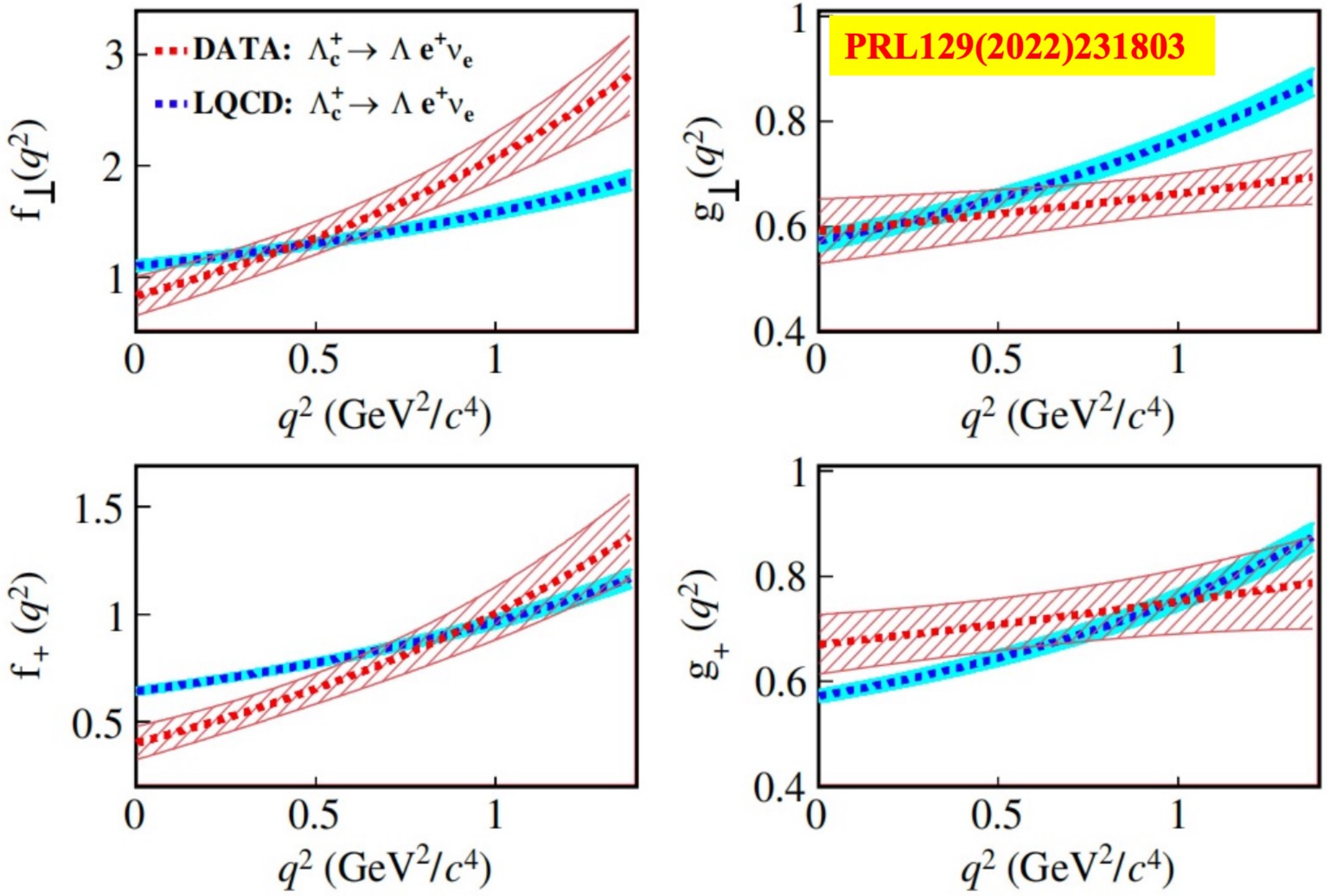
Gives the magnitudes of the triangles; could also be used to test QCD

Constraining QCD predictions

Talk by L. Li

Comparisons between data and LQCD prediction

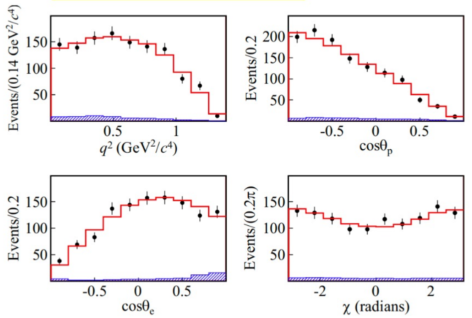


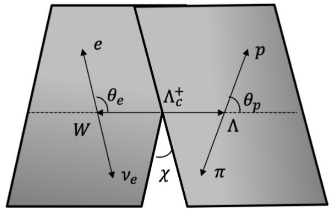
$\Lambda_c^+ \to \Lambda e^+ \nu_e$

Study of the kinematics in $\Lambda_c^+ \to \Lambda e^+ \nu_e$ decay:

$$\frac{d^4\Gamma}{dq^2 d\cos\theta_e d\cos\theta_p d\chi} = \frac{G_F^2|V_{cs}|^2}{2(2\pi)^4} \cdot \frac{Pq^2}{24M_{\Lambda_c}^2} \left\{ \frac{3}{8}(1-\cos\theta_e)^2 |H_{\frac{1}{2}1}|^2 (1+\alpha_\Lambda\cos\theta_p) + \frac{3}{8}(1+\cos\theta_e)^2 |H_{-\frac{1}{2}-1}|^2 (1-\alpha_\Lambda\cos\theta_p) \right.$$
$$+ \frac{3}{4}\sin^2\theta_e [|H_{\frac{1}{2}0}|^2 (1+\alpha_\Lambda\cos\theta_p) + |H_{-\frac{1}{2}0}|^2 (1-\alpha_\Lambda\cos\theta_p)] + \frac{3}{2\sqrt{2}}\alpha_\Lambda \cos\chi \sin\theta_e \sin\theta_p$$
$$\left. \times [(1-\cos\theta_e) H_{-\frac{1}{2}0} H_{\frac{1}{2}1} + (1+\cos\theta_e) H_{\frac{1}{2}0} H_{-\frac{1}{2}-1}] \right\}$$

PRL129(2022)231803





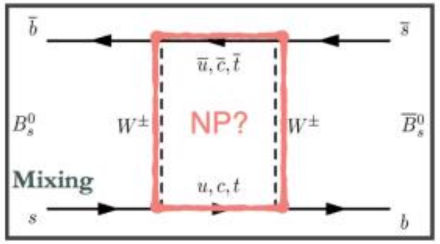
Parameters	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
Values	$1.43 \pm 2.09 \pm 0.16$	$-8.15 \pm 1.58 \pm 0.05$	$1.75 \pm 0.32 \pm 0.01$	$3.62 \pm 0.65 \pm 0.02$	$1.13 \pm 0.13 \pm 0.01$
Coefficients	$\alpha_1^{g_\perp}$	$\alpha_1^{f_\perp}$	r_{f_+}	$r_{f_\perp}$	r_{g_+}
$a_0^{g_\perp}$	−0.64	0.60	−0.66	−0.83	−0.40
$\alpha_1^{g_\perp}$		−0.63	0.62	0.53	−0.33
$\alpha_1^{f_\perp}$			−0.79	−0.67	−0.07
r_{f_+}				0.57	−0.09
$r_{f_\perp}$					0.39

❑ Helicity amplitude:

$$H^V_{\frac{1}{2}1} = \sqrt{2Q_-} f_\perp(q^2), \qquad H^A_{\frac{1}{2}1} = \sqrt{2Q_+} g_\perp(q^2),$$
$$H^V_{\frac{1}{2}0} = \sqrt{Q_-/q^2} f_+(q^2)(M_{\Lambda_c} + M_\Lambda),$$
$$H^A_{\frac{1}{2}0} = \sqrt{Q_+/q^2} g_+(q^2)(M_{\Lambda_c} - M_\Lambda),$$

- **Form factors obtained through full angular fit**
- **Quite some discrepancies found; need further understanding**

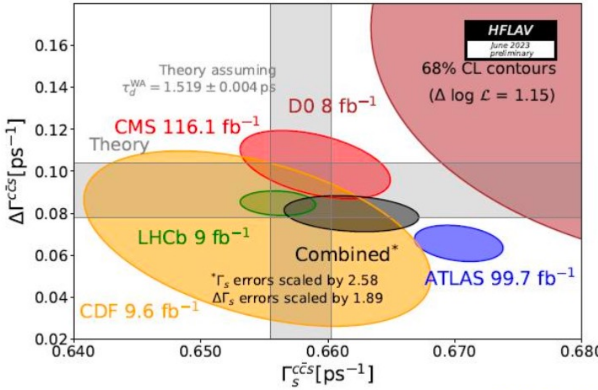
Search for new physics with precise CPV measurements

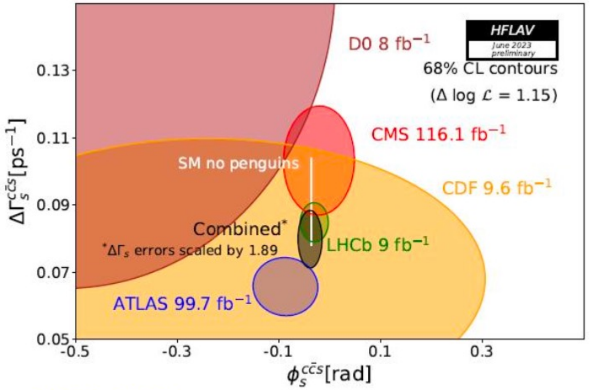


Talk by K. Li

CP violation in $B_s \to J/\psi KK$ decays

$$\phi_s = \phi_s^{tree} + \delta\phi_s^{penguin} + \delta\phi_s^{NP}$$





[LHCb-Paper-2023-016 In preparation]

$$\phi_s[\text{rad}] = -0.039 + 0.022 \pm 0.006$$
$$|\lambda| = 1.001 \pm 0.011 \pm 0.005$$

- Consistent with the prediction of Global fits assuming SM:[3]

$$\phi_s^{\text{CKMfitter}} \approx (-0.0368^{+0.0006}_{-0.0009})\ \text{rad},\ \phi_s^{\text{UTfitter}} = -0.0370 \pm 0.0010\ \text{rad}$$

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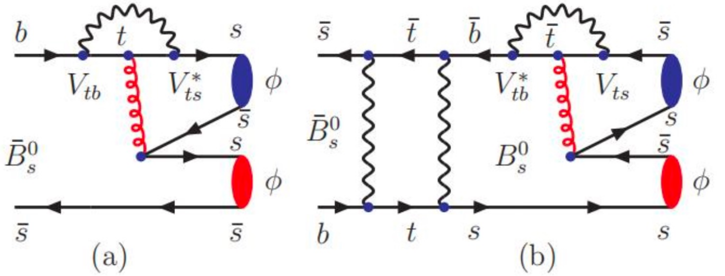
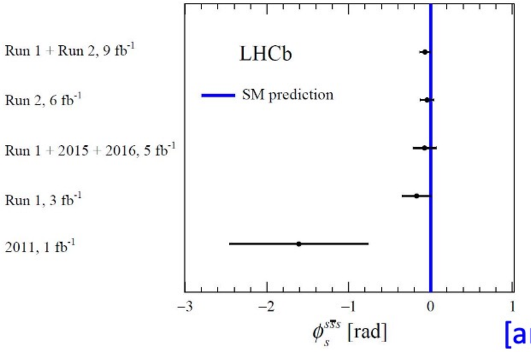
CP violation in $B_s \to \Phi\Phi$ decays

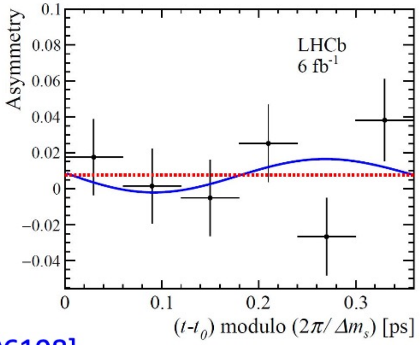


Fitting Result

$$\phi_s^{s\bar{s}s} = -0.042 \pm 0.077 \pm 0.010\ \text{rad}$$
$$|\lambda| = 1.004 \pm 0.030 \pm 0.009$$

- Consistent with SM expectation due to large uncertainty
- No sign of polarisation-dependence observed





[arxiv.2304.06198]

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- **Once precisely measured, can be used to give SM predictions**

FCNC: rare kaon decays

Talk by Y. Hsiung and C. Biino

Results of the 2016–18 Data Analysis

$K_L^0 \to \pi^0 \nu\bar{\nu}$

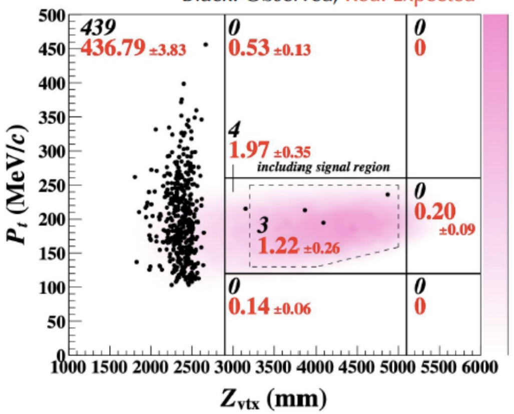
- Single Event Sensitivity:

$$SES = \frac{1}{N_{K_L} \times A_{signal}} = 7.2 \times 10^{-10}$$

- 3 events observed ==> consistent to #BG
- $BR(K_L \to \pi^0 \nu\bar{\nu}) < 4.9 \times 10^{-9}$ (90% C.L.)

Phys. Rev. Lett. 126, 121801 (Published in March 2021)

Black: Observed, Red: Expected



Background Table

Source		Number of events
K_L	$K_L \to 3\pi^0$	0.01 ± 0.01
	$K_L \to 2\gamma$ (beam halo)	0.26 ± 0.07[a]
	Other K_L decays	0.005 ± 0.005
$K^\pm$		0.87 ± 0.25[a]
Neutron	Hadron cluster	0.017 ± 0.002
	CV η	0.03 ± 0.01
	Upstream π^0	0.03 ± 0.03
Total		1.22 ± 0.26

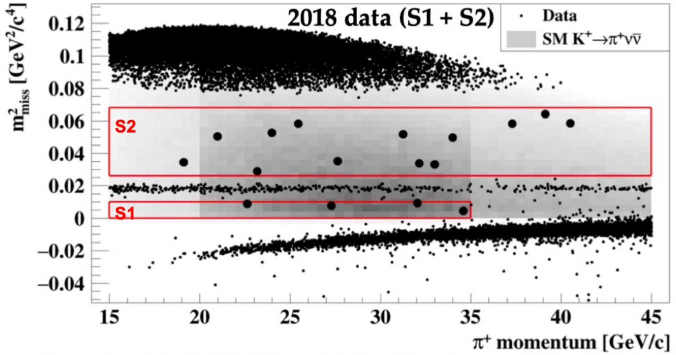
Total #BG = 1.22 ± 0.26

- Finalizing the analysis of the 2021 data
  - Single Event Sensitivity = 7.9×10^{-10} (preliminary)
  - #BG(total) = 0.325 $_{+0.069/-0.070}$ (preliminary)

$$BR(K_L \to \pi^0 \nu\bar{\nu})_{SM} = 3 \times 10^{-11}$$

NA62 results from Run 1 (2016-2018)

$K^+ \to \pi^+ \nu\bar{\nu}$



Channel	Background (2018)
$\pi^+\pi^0$	0.75 ± 0.05
$\mu^+\nu$	0.64 ± 0.08
$\pi^+\pi^- e^+\nu$	0.51 ± 0.10
$\pi^+\pi^+\pi^-$	0.22 ± 0.10
$\pi^+\gamma\gamma$	< 0.01
$\pi^0 l^+\nu$	< 0.001
Upstream	$3.30^{+1.00}_{-0.75}$
Total (2018)	$5.42^{+1.00}_{-0.75}$

- **20 events observed in the signal region - full Run1 data sample**
- Combining the complete Run 1 data set and assuming $BR_{SM}(8.4 \pm 1.0)\ 10^{-11}$:

$N^{exp}_{\pi\nu\nu} = 10.01 \pm 0.42_{syst} \pm 1.19_{ext}$

$N^{exp}_{background} = 7.03\ ^{+1.05}_{-0.82}$

$SES = (0.839 \pm 0.053_{syst}) \times 10^{-11}$

JHEP 06 (2021) 093

$SM: \sim 8 \times 10^{-11}$

$BR(K^+ \to \pi^+ \nu \bar{\nu}) = (10.6\ ^{+4.0}_{-3.4}|_{stat} \pm 0.9_{syst}) \times 10^{-11}$ **3.4σ significance**

WIN 2023 | K⁺ → π⁺ ν ν̄ | C. Biino 10

NA62 RUN2

- On-going: data taking foreseen at least until 2025 (included), +45-50% increase of intensity vs RUN1

$\mathcal{O}(15\%)$ final precision expected on $BR(K^+ \to \pi^+\nu\nu)$

Future of physics with kaons at CERN SPS

HIKE project under discussion at CERN: K^+, K_L, dark sector searches

Letter of Intent: arXiv:2211.16586v1

Intensity × 4-6 with respect to NA62; Detectors with $\mathcal{O}(20\ ps)$ time resolution; Similar experimental layouts

- $K^+ \to \pi^+ \nu\bar{\nu}$ approaching SM theory expectation

Belle II

Talk by Y. Guan and C. Shen

TD CPV in $B^0 \to J/\psi K_S^0$

Angle β

- Tree-dominated $b \to c\bar{c}s$, golden mode
  - small theoretical uncertainty and clean experimental signature.
  - contribution of penguin diagrams with a different CKM phase is expected to be at less than 1% level.
- Fit ΔE distribution and subtract background.
- Fit the sWeighted Δt distribution to extract $\sin(2\beta)$ and A_{CP}.

$$\mathcal{A}(\Delta t) = S_{J/\psi K_S^0} \sin(\Delta m_d \Delta t) + A_{J/\psi K_S^0} \cos(\Delta m_d \Delta t)$$

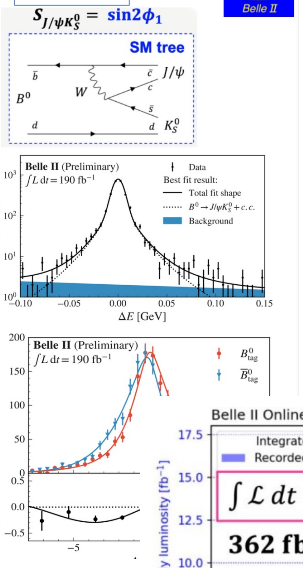
$$S_{CP} = 0.720 \pm 0.062(\text{stat}) \pm 0.016(\text{syst}).$$

$$A_{CP} = 0.094 \pm 0.044(\text{stat})^{+0.042}_{-0.017}(\text{syst}).$$

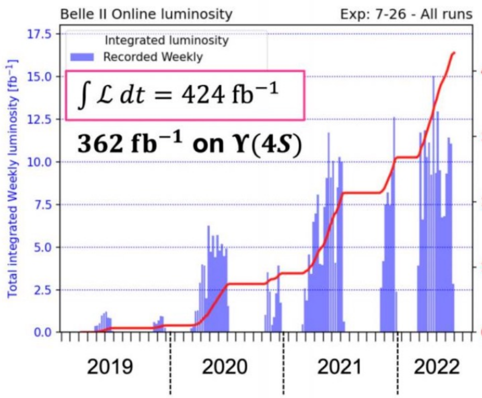
- Consistent with the world-average. Statistical uncertainty is twice that of the current most precise determination (from Belle), consistent with a four-times smaller data set.

arXiv:2302.12898

Belle II 190 fb^{-1}



Similar as Belle

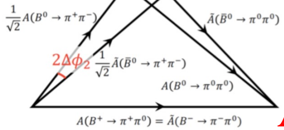


CPV in $B^+ \to \pi^+\pi^0$ and $B^0 \to \pi^0\pi^0$

- The CKM angle ϕ_2 measurement is based on $b \to u$ processes. Significant contributions from penguins ($b \to d$): $\phi^{\text{eff}}_2 = \phi_2 + \Delta\phi_2$.
- Penguin and tree contributions can be disentangled using the isospin relations

$$A^{+0} = \frac{1}{\sqrt{2}} A^{+-} + A^{00} \quad \text{and} \quad \bar{A}^{-0} = \frac{1}{\sqrt{2}} \bar{A}^{+-} + \bar{A}^{00},$$

M. Gronau and D. London, Phys Rev. Lett. **65**, 3381 (1990).

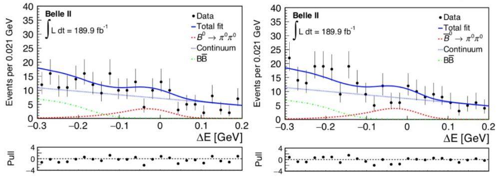


Angle α

$A_{CP}(B^+ \to \pi^+\pi^0) = -0.08 \pm 0.05(stat) \pm 0.01(syst)$

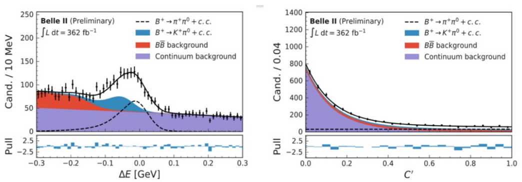
arXiv:2303.08354

Belle II 189 fb^{-1}



$$A_{CP}(B^0 \to \pi^0\pi^0) = 0.14 \pm 0.46 \pm 0.07.$$

Belle (772M $B\bar{B}$) : $A_{CP} = +0.14 \pm 0.36\ (\text{stat.}) \pm 0.10\ (\text{syst.})$



$$A_{CP}(B^+ \to \pi^+\pi^0) = -0.08 \pm 0.05 \pm 0.01$$

Belle (772M $B\bar{B}$) : $A_{CP} = +0.025 \pm 0.043 \pm 0.007$

CPV in $B^0 \to K_S^0\pi^0$

$K\pi$ puzzle

arXiv:2305.07555

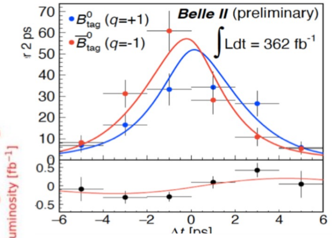
Belle II 362 fb^{-1}

- $B^0 \to K_S^0\pi^0$ proceeds mainly via $b \to sd\bar{d}$ loop amplitude.
- Sensitive to effective value of $\sin 2\phi_1$ and providing inputs to isospin sum-rule

$$I_{K\pi} = \mathcal{B}r(K^+\pi^-)\mathcal{A}_{K^+\pi^-} + \mathcal{A}_{K^0\pi^+}\mathcal{B}r(K^0\pi^+)\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^+\pi^0}\mathcal{B}r(K^+\pi^0)\frac{\tau_{B^0}}{\tau_{B^+}} - 2\mathcal{A}_{K^0\pi^0}\mathcal{B}r(K^0\pi^0); \quad I^{SM}_{K\pi} = 0$$

M. Gronau, Phys. Lett. B **627**, 82(2005).

- Time dependent $B^0 \to K_S^0\pi^0$: main challenge is the decay vertex reconstruction.
- Validated on $B^0 \to J/\psi K_S^0$ events reconstructed w/o J/ψ vertex.
- Simultaneous time-integrated (40% events without Δt) and time-dependent fit to maximize the sensitivity on A_{CP}.
- Competitive with world's best results with less (60-80%) luminosity.



$A_{CP} = 0.04 \pm 0.15 \pm 0.05 \qquad A^{w.a.}_{CP} = 0.00 \pm 0.13$

$S_{CP} = 0.75^{+0.20}_{-0.23} \pm 0.04 \qquad S^{w.a.}_{CP} = 0.58 \pm 0.17$

combine time-integrated and time-dependent results:

$\mathcal{A}^{K_S^0\pi^0}_{CP} = -0.01 \pm 0.12 \pm 0.05 \qquad w.a. = -0.0 \pm 0.13$

- Combining all $B \to K\pi$ final states at Belle II:

$I_{K\pi} = -0.03 \pm 0.13 \pm 0.05 \qquad w.a. = 0.13 \pm 0.11$

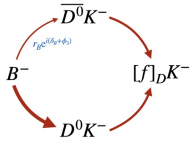
11

CPV in $B^+ \to DK^+$ (towards ϕ_3/γ)

ϕ_3/γ is the phase between b → u and b →c transitions.

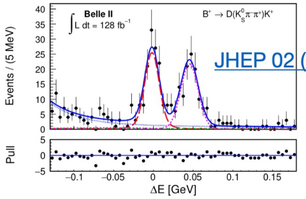
- The absence of the loop contribution allows extremely clean theoretical prediction of ϕ_3
- Various approaches with different D final states:
  - Self-conjugate final states $D^0 \to K_S h^+h^-$
  - singly Cabibbo-suppressed $D^0 \to K_S K^+\pi^-$.
  - CP eigenstates: $D^0 \to K^+K^-$, $K_S^0\pi^0$
  - CF and DCS decays: $D^0 \to K^+\pi^-$

Interference between two decays to same final state gives access to phase:



Angle γ

$$\frac{\mathcal{A}^{\text{suppr.}}(B^- \to \bar{D}^0K^-)}{\mathcal{A}^{\text{favor.}}(B^- \to D^0K^-)} = r_B e^{i(\delta_B+\gamma)}$$



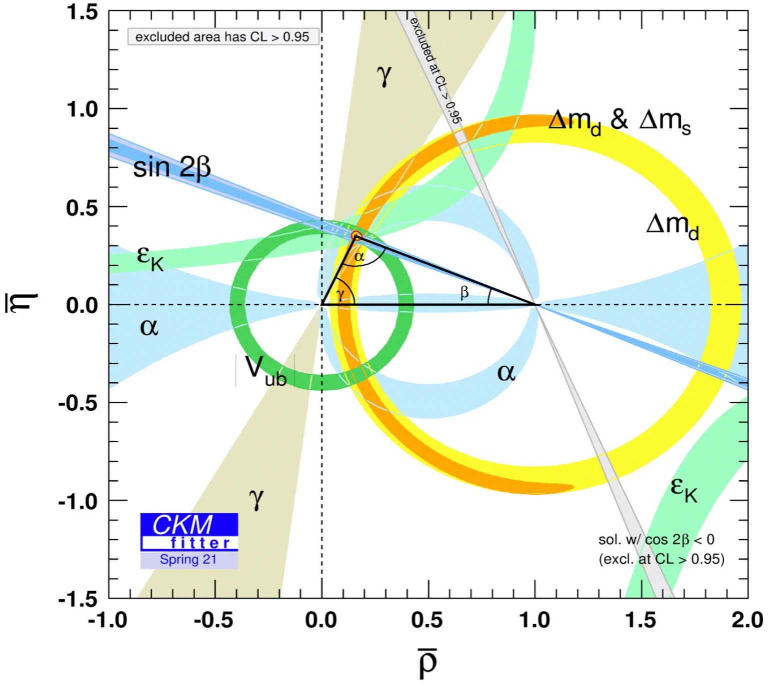
JHEP 02 (2022) 063

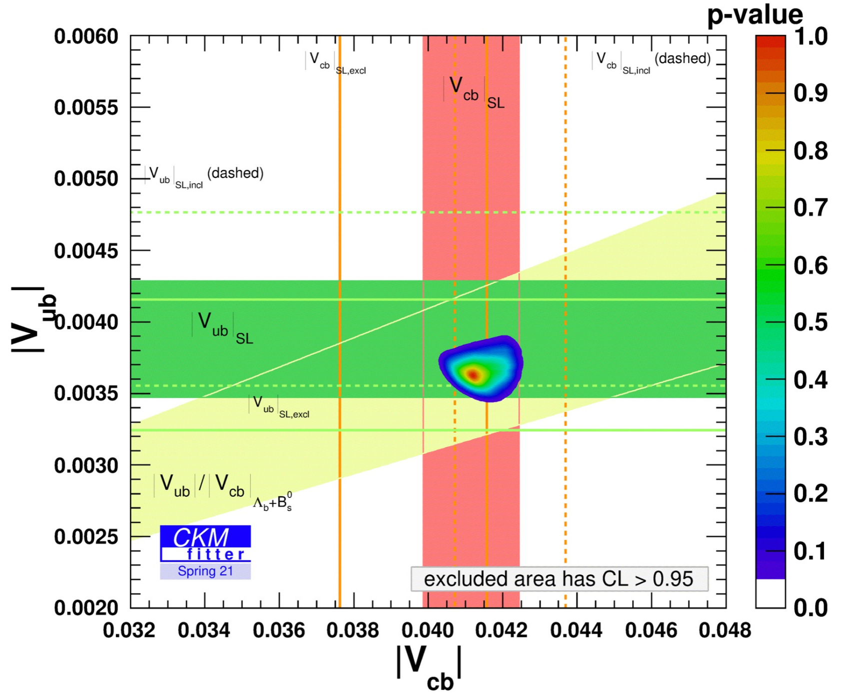
$$\phi_3 = (78.4 \pm 11.4 \pm 0.5 \pm 1.0)^\circ$$

Good at final states with π^0 and missing particles

12

Is the precision enough?





$$10^{-5}$$

$$V_{ud}V_{ud}^{*}+V_{us}V_{us}^{*}+V_{ub}V_{ub}^{*}-1$$

$$=-0.00230^{+0.00218}_{-0.00023}\ (1\sigma)$$
$$-0.00230^{+0.00237}_{-0.00044}\ (2\sigma)$$
$$-0.00230^{+0.00242}_{-0.00065}\ (3\sigma)$$

Direct measurements:

$$\alpha+\beta+\gamma=(179^{+7}_{-6})^{\circ}$$

Global fits:

$$\alpha+\beta+\gamma=(179.9^{+1.9}_{-1.7})^{\circ}$$

Disaster for new physics searches if we don't understand CKM elements precisely

Changing $|V_{cb}|$: $39\cdot10^{-3}\Rightarrow 42\cdot10^{-3}$

changes $|V_{cb}|^2$: **by 16%** $(B_{s,d}\to\mu^+\mu^-,\ \Delta M_{s,d})$

$|V_{cb}|^3$: **by 25%** $(K^+\to\pi^+\nu\bar{\nu},\varepsilon_K)$

$|V_{cb}|^4$: **by 35%** $(K_L\to\pi^0\nu\bar{\nu},K_S\to\mu^+\mu^-)$

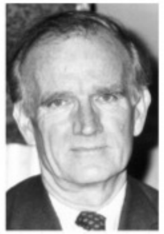
From A. Buras

CP violation in hyperon decays

Talk by Y. Guan and H. Shen

P violation	*K* meson *CPV*	*B* meson *CPV*	*D* meson *CPV*	Baryon ?
1957	1964	2001	2019	

James Watson Cronin



Val Logsdon Fitch

General Partial Wave Analysis of the Decay of a Hyperon of Spin $\frac{1}{2}$

T. D. Lee* and C. N. Yang

Institute for Advanced Study, Princeton, New Jersey

(Received October 22, 1957)

Phys. Rev. 108, 1645 (1957)

The decay parameters are defined as:

$$\alpha_Y = \frac{2\,\mathrm{Re}\,(S^* P)}{|S|^2 + |P|^2}, \quad \beta_Y = \frac{2\,\mathrm{Im}\,(S^* P)}{|S|^2 + |P|^2}, \quad \gamma_Y = \frac{|S|^2 - |P|^2}{|S|^2 + |P|^2}$$

- $J/\psi \rightarrow \Lambda\bar{\Lambda}$ Phys.Rev.Lett. 129 (2022) 131801 **SM ~10^{-5}, need STCF**
  - 1×10^{10} J/ψ events

$$A_{CP} = (\alpha_- + \alpha_+)/(\alpha_- - \alpha_+) = -0.0025 \pm 0.0046 \pm 0.0012$$

- $J/\psi \rightarrow \Sigma^+\bar{\Sigma}^-$ arXiv:2304.14655
  - 1×10^{10} J/ψ events
  - First study to test CP symmetry in the hyperon to neutron decay, and result is consistent with CP-conservation.

- J/ψ ($\psi(3686)$) $\rightarrow \Xi^0\,\bar{\Xi}^0$
  - 1×10^{10} J/ψ events; 4×10^{8} $\psi(3686)$ events
  - Results are consistent with CP-conservation.

arXiv:2305.09218

A_{CP}^{Ξ}	$(-5.4 \pm 6.5 \pm 3.1) \times 10^{-3}$
$\Delta\phi_{CP}^{\Xi}$(rad)	$(-0.1 \pm 6.9 \pm 0.9) \times 10^{-3}$
A_{CP}^{Λ}	$(6.9 \pm 5.8 \pm 1.8) \times 10^{-3}$

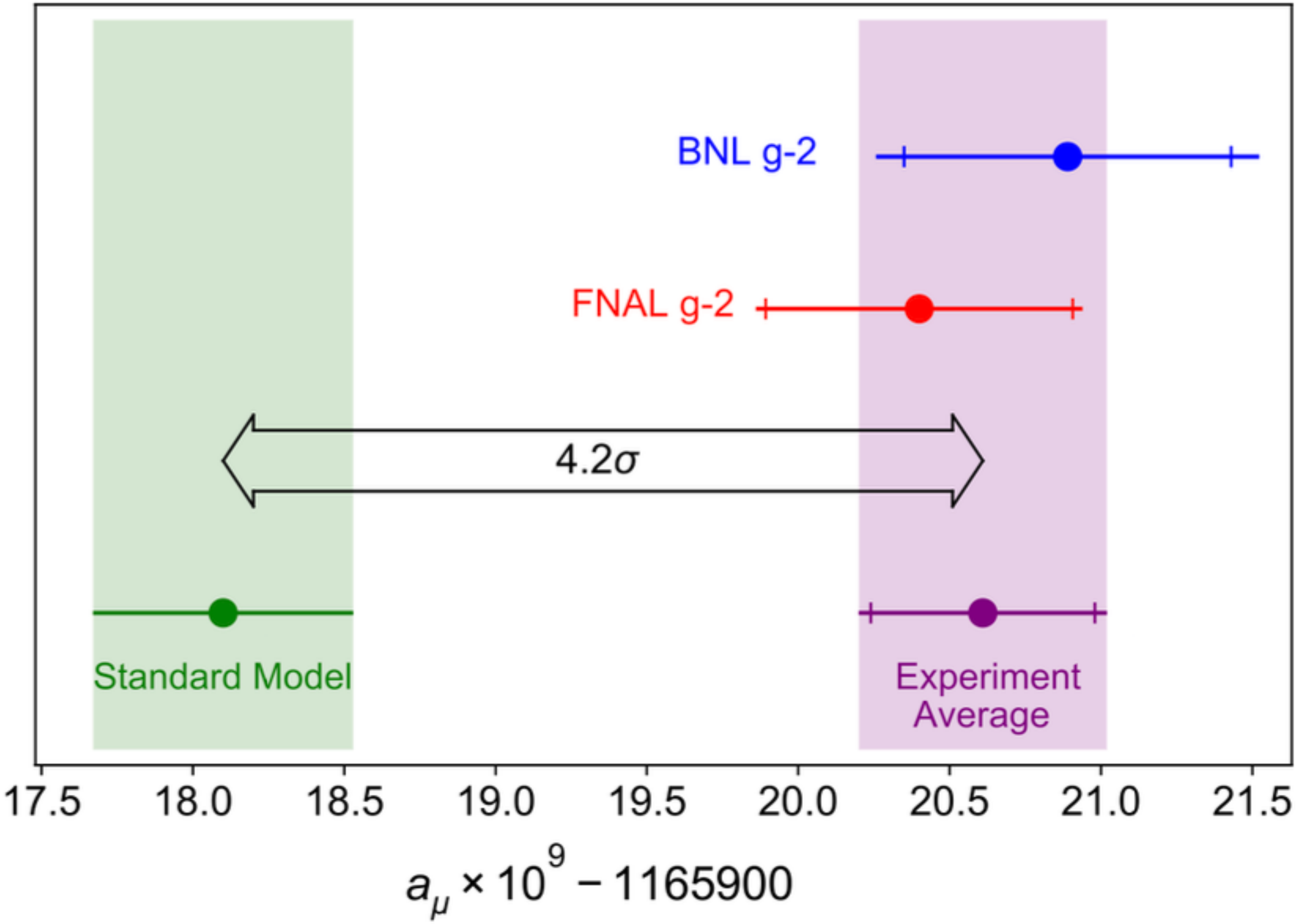
arXiv:2302.09767

A_{CP}^{Ξ}	$-0.007 \pm 0.082 \pm 0.025$
$\Delta\phi_{CP}^{\Xi}$	$-0.079 \pm 0.082 \pm 0.010$

Outline

- CKM physics
- New physics searches with leptons
- Spectroscopy

g-2

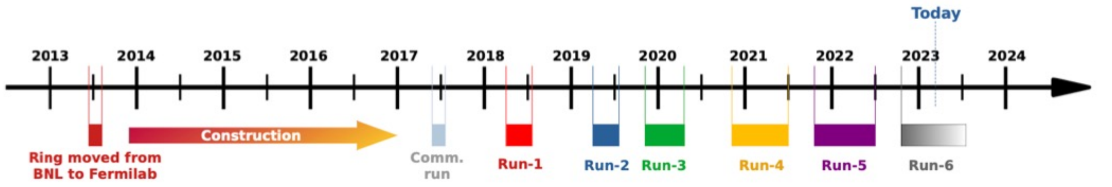

BNL g-2
FNAL g-2
4.2σ
Standard Model
Experiment Average
17.5
18.0
18.5
19.0
19.5
20.0
20.5
21.0
21.5
$a_\mu \times 10^9 - 1165900$

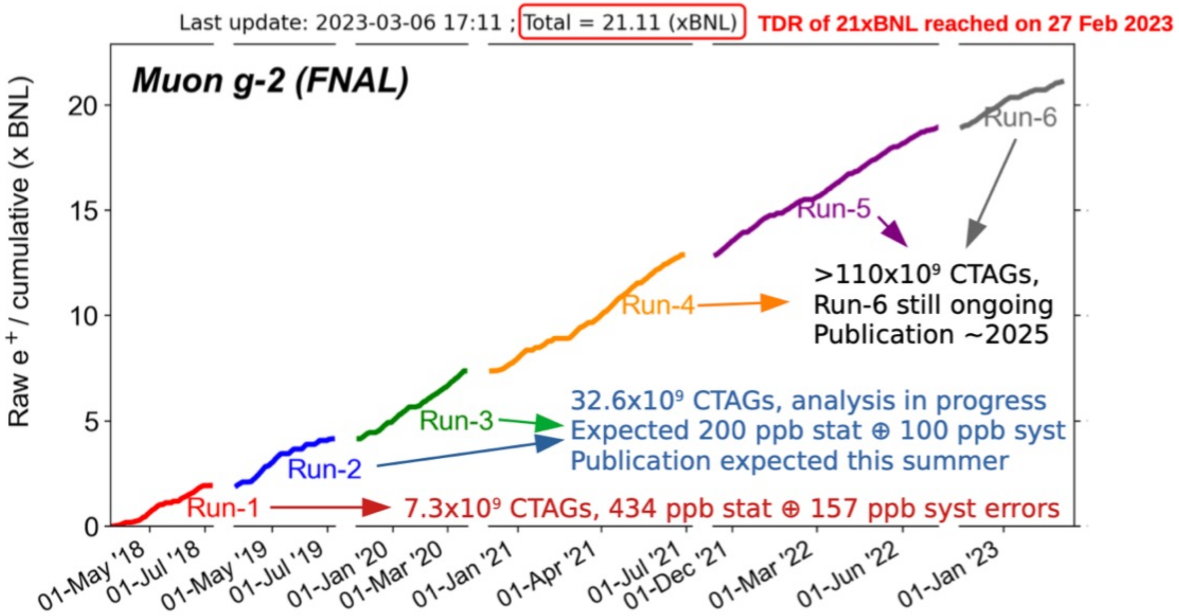
Experiment updates in the near future

Talk by C. Chen

From BNL to FNAL Run-6

- Run-1 is only ~5% of the final dataset
  - ✓434 ppb stat ⊕ 157 ppb syst
  - ✓Finalized in April 2021
- Run-2/3 analysis is about to finalize
  - ✓200 ppb stat ⊕ 100 ppb syst (expected)
  - ✓Publication this summer (expected)
- Run-6 is still ongoing
  - ✓21.11xBNL in total
  - ✓150 billion of raw e^+ in total





TSUNG-DAO LEE INSTITUTE 以天之语 解物之道 32

Theoretical focus

Talk by L. Jin

Muon $g-2$ from the Standard Model

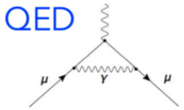
6 / 37

Muon $g-2$ Theory Initiative White paper posted 10 June 2020.

132 authors from worldwide theory + experiment community. [Phys. Rept. 887 (2020) 1-166]

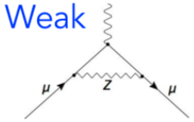
$$a_\mu = a_\mu(\text{QED}) + a_\mu(\text{Weak}) + a_\mu(\text{Hadronic})$$

QED



$+\ldots$ $116\,584\,718.9\,(1) \times 10^{-11}$ 0.001 ppm

Weak

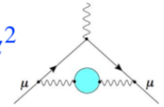


$+\ldots$ $153.6\,(1.0) \times 10^{-11}$ 0.01 ppm

Hadronic…

…Vacuum Polarization (HVP)

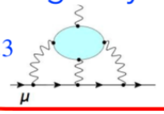
α^2



$+\ldots$ $6845\,(40) \times 10^{-11}$ [0.6%] 0.34 ppm

…Light-by-Light (HLbL)

α^3



$+\ldots$ $92\,(18) \times 10^{-11}$ [20%] 0.15 ppm

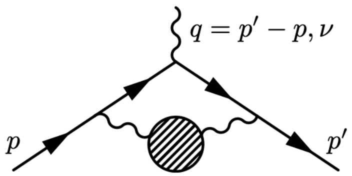
- Two methods: dispersive + data ↔ lattice QCD

From Aida El-Khadra's theory talk during the Fermilab $g-2$ result announcement.

Tension in HVP prediction

Talk by L. Jin and C. Chen

Muon $g-2$ HVP: Data driven approach (New CMD-3 results) 12 / 37



$$a_\mu^{\text{HVP LO}} = 693.1(2.8)_{\text{exp}}(2.8)_{\text{sys}}(0.7)_{\text{DV+QCD}} \times 10^{-10}$$
$$= 693.1(4.0) \times 10^{-10}\,.$$

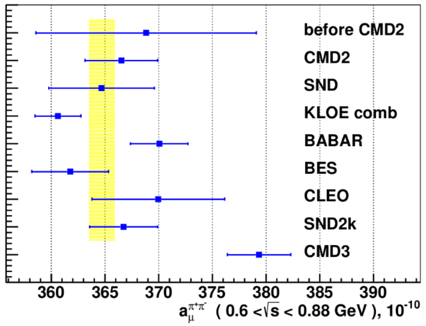


Figure 36: The $\pi^+\pi^-(\gamma)$ contribution to $a_\mu^{had,LO}$ from energy range $0.6 < \sqrt{s} < 0.88$ GeV obtained from this and other experiments.

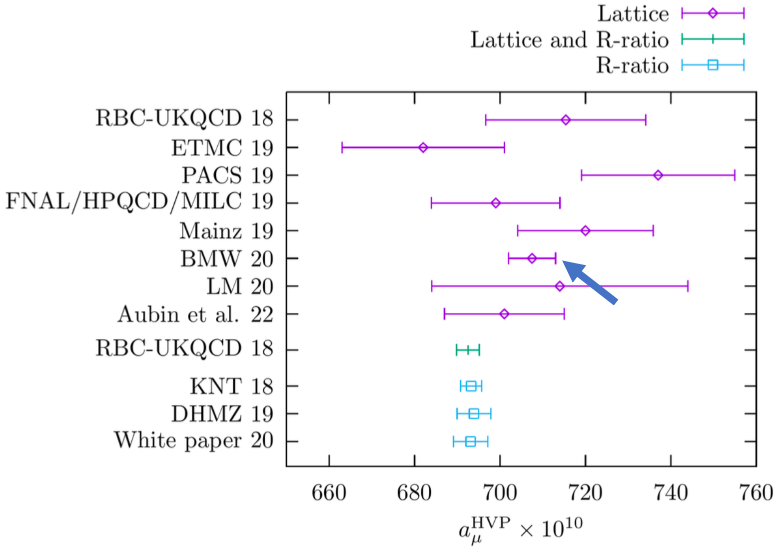
Experiment	$a_\mu^{\pi^+\pi^-,LO}$, 10^{-10}
before CMD2	368.8 ± 10.3
CMD2	366.5 ± 3.4
SND	364.7 ± 4.9
KLOE	360.6 ± 2.1
BABAR	370.1 ± 2.7
BES	361.8 ± 3.6
CLEO	370.0 ± 6.2
SND2k	366.7 ± 3.2
CMD3	379.3 ± 3.0

Table 4: The $\pi^+\pi^-(\gamma)$ contribution to $a_\mu^{had,LO}$ from energy range $0.6 < \sqrt{s} < 0.88$ GeV obtained from this and other experiments.

The source of this difference is unknown at the moment. 08834

Muon $g-2$ HVP: overview 25 / 37

- Dispersive method via R-ratio (red points) is mature and reproducible.
- Lattice (blue points) errors are limited by statistics.
  Except for BMW, which beats down the statistical error, result is limited by systematic error:
  BMW 20: $707.5(2.3)_{\text{stat}}(5.0)_{\text{sys}}$
- Lattice-QCD calculations of comparable precision needed.
- Consistency is needed to claim new physics.



✓ 4.2 σ (dispersion) → 1.5 σ (lattice-QCD)

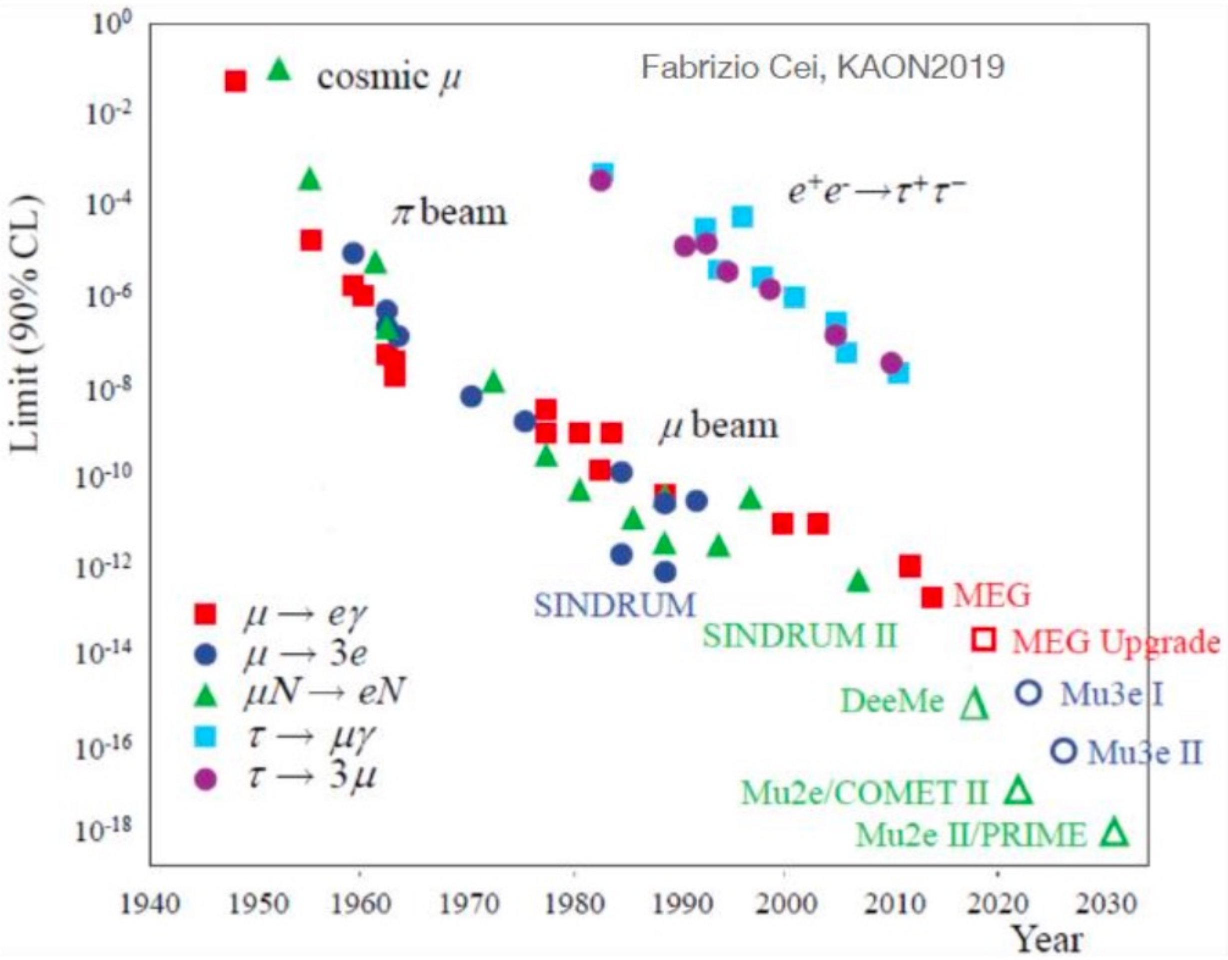
– Middle window (W) part: Consensus is reached among lattice QCD calculations. However, there is more than 3σ tension between:
  - ∗ lattice QCD consensus and previous data driven results,
  - ∗ new CMD-3 and previous data driven results.

– Long distance (LD) part and its QED corrections: Some tension ($\sim 2\sigma$) between BMW 20 and previous data driven results. BMW 20 appears to be consistent with the new CMD-3 results. Results from other lattice collaborations are coming.

CLFV: muon

Talk by C. Wu, Y. Xu, S. Huang and Y. Wang

Glimpse on history and future



$\mu \to e\gamma$

- MEG II: 2021~2026, aims at 4×10^{-14}

$\mu \to eee$

- Mu3e aims at $\sim 10^{-15}$ sensitivity.

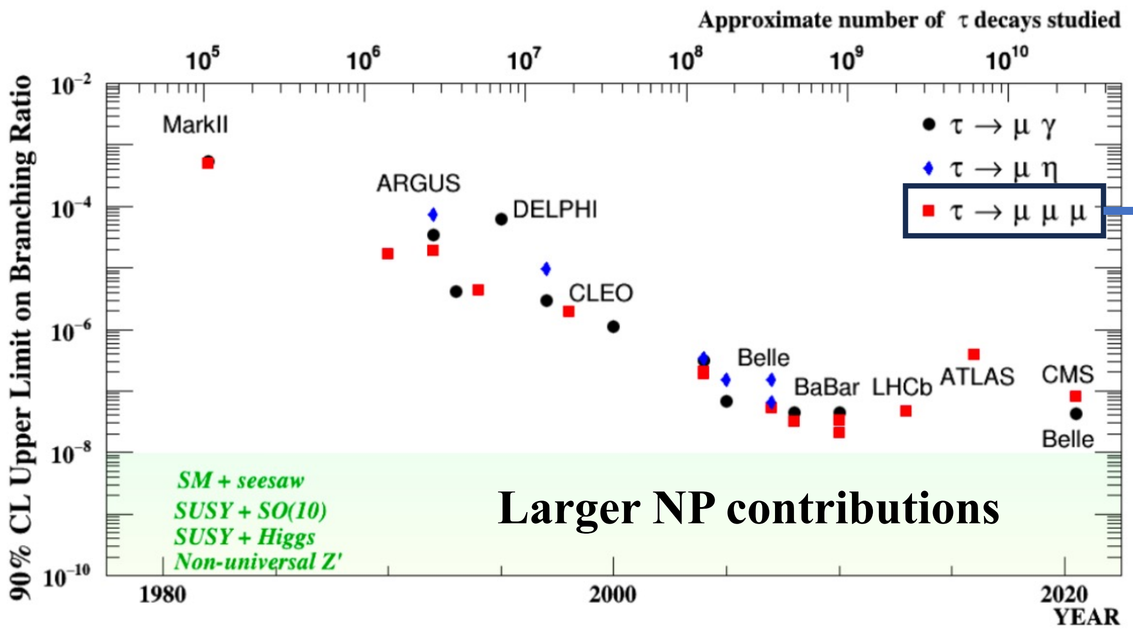
(~ 3 years)

$\mu N \to eN$

- **Mu2e aims at 8×10^{-17} with data from 2025~2026**
- **COMET 7×10^{-15} with data from 2024~2025 and then 4.6×10^{-17} with phase II (~10^{-18} with optimization)**
- **Many complementary studies from collider experiments (BESIII, LHCb, Belle/Belle II, NA62 etc.), sensitive to different new physics scenarios**

CLFV: tau

Talk by C. Wu and C. Jiang



Swagato Banerjee, CIPANP2022

arXiv:2203.14919

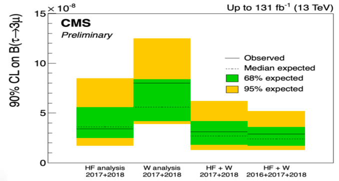
$\tau^- \to$	Observed Limits: Experiment	Luminosity	UL (obs)	Expected Limits: Experiment	Luminosity	UL (exp)
$\mu^-\mu^+\mu^-$	Belle [102]	782 fb^{-1}	2.1×10^{-8}	Belle II [54]	50 ab^{-1}	3.6×10^{-10}
	BaBar [103]	468 fb^{-1}	3.3×10^{-8}			
	LHCb [61]	3 fb^{-1}	4.6×10^{-8}	LHCb [76]	300 fb^{-1}	$\mathcal{O}(10^{-9})$
	CMS [67]	33 fb^{-1}	8.0×10^{-8}	CMS [77]	3 ab^{-1}	3.7×10^{-9}
	ATLAS [68]	20 fb^{-1}	3.8×10^{-7}	ATLAS [78]	3 ab^{-1}	1.0×10^{-9}
				STCF [74]	1 ab^{-1}	1.4×10^{-9}
				FCC-ee [87,91]	150 ab^{-1}	$\mathcal{O}(10^{-10})$

2.9×10^{-8} with 131 fb^{-1} data (17 + 18)

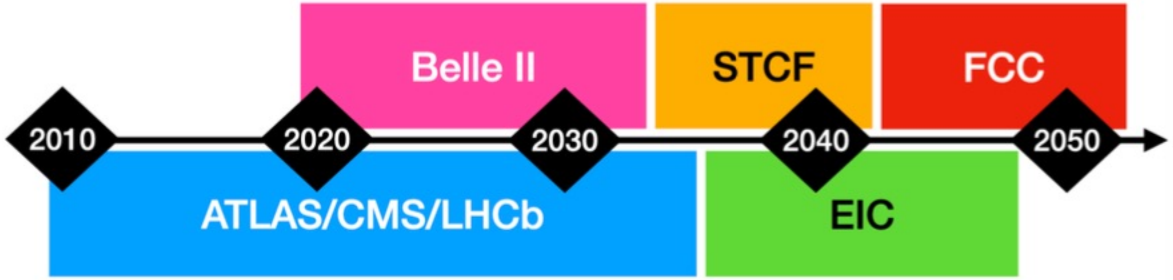
Search for τ → 3μ at CMS: results

CMS BPH-21-005

- The HF and W analyses, together with the previously published 2016 data result, are combined
- Events that pass the final selections of both analyses are removed from the HF analysis
- Systematics are assumed to be uncorrelated between the HF analysis and the W analysis
- Results dominated by statistical uncertainty



The observed (expected) upper limit is 2.9x10-8 (2.4x10-8) at 90% CL



Tentative timeline for data-taking arXiv:2203.14919

Future: $10^{-9} \sim 10^{-10}$

LFU: $R(D^{(*)})$, two new measurements from LHCb

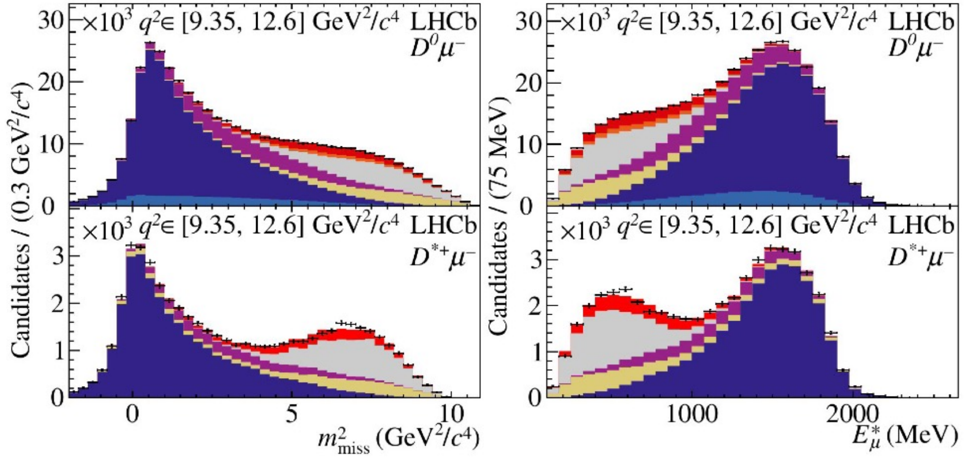
Talk by L. Sun

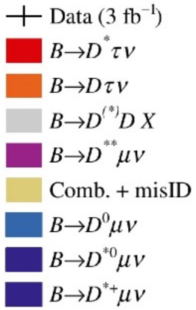
$$R(D^{(*)}) = \frac{\mathcal{B}(B \to D^{(*)}\tau\nu_\tau)}{\mathcal{B}(B \to D^{(*)}\mu\nu_\mu)}$$

arXiv:2302.02886
arXiv:2305.01463

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

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





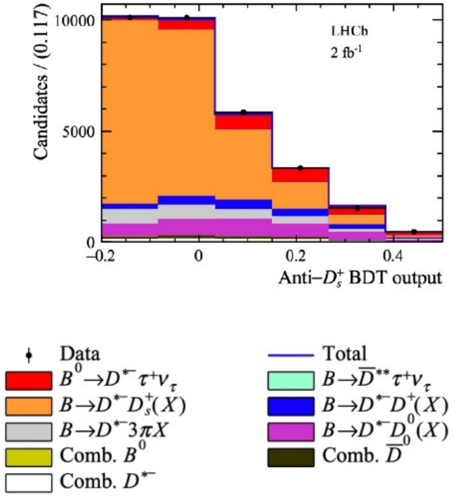
Using Run1 3 fb^{-1} data:

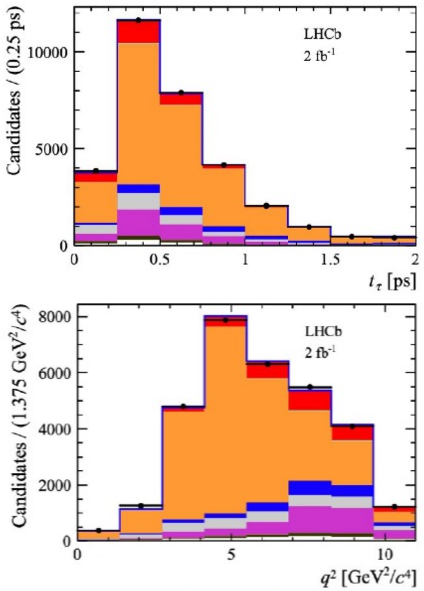
$$R(D^*) = 0.281 \pm 0.018\,(\text{stat.}) \pm 0.024\,(\text{syst.})$$
$$R(D) = 0.441 \pm 0.060\,(\text{stat.}) \pm 0.066\,(\text{syst.})$$

$\rho = -0.43$

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

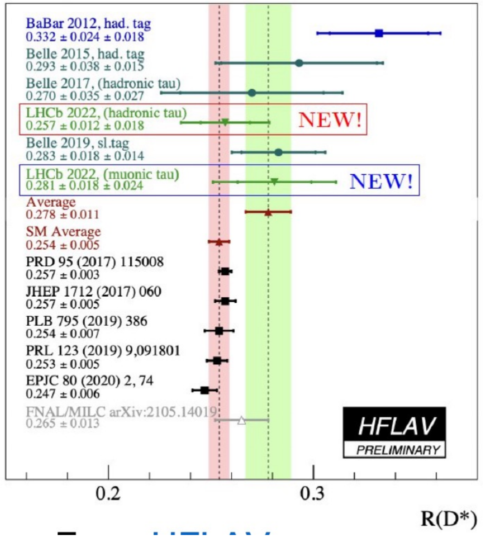
25

LFU: $R(D^{(*)})$, tension remained

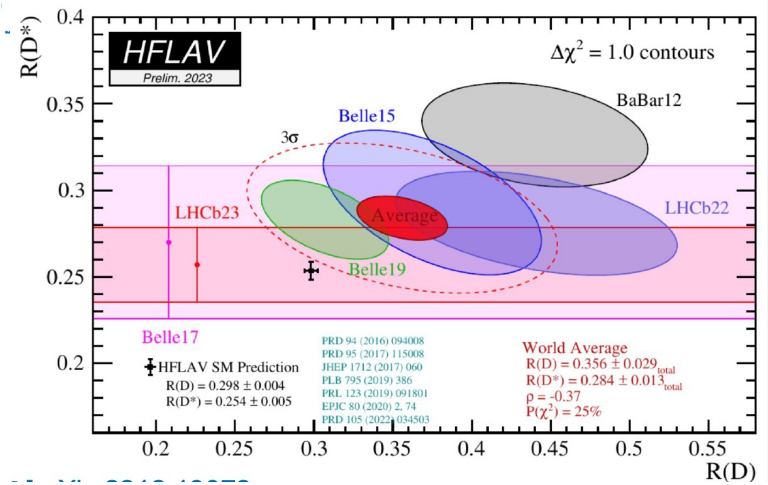
Talk by L. Sun

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



- Deviation from SM for combined R(D) − R(D*) now moves from 3.3σ to 3.2σ

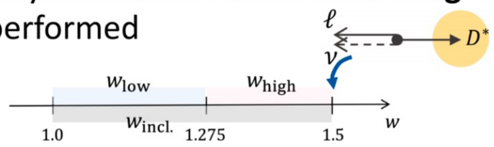


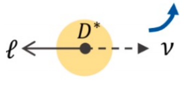
Complete set of angular asymmetries

Talk by C. Shen

$B^0 \to D^* \ell \nu$ angular asymmetries

- Light lepton universality tested by comparing **five angular asymmetries** of e and μ, $\Delta\mathcal{A}_x = \mathcal{A}_x^e - \mathcal{A}_x^\mu$ using $B^0 \to D^{*-}\ell^+\nu$ decays.
- The simultaneous determination of all asymmetries in **different w ranges** is performed





Define a set of 5 asymmetries for angular observables x

w : Recoil parameter $\quad w = \frac{m_B^2 + m_{D^*}^2 - q^2c^2}{2 m_B m_{D^*}}$

$$\mathcal{A}_x(w) = \left(\frac{d\Gamma}{dw}\right)^{-1} \left[\int_0^1 - \int_{-1}^0\right] dx \frac{d^2\Gamma}{dw dx}$$

$A_{FB}(w)$: $dx = d(\cos\theta_\ell)$

$S_3(w)$: $dx = d(\cos 2\chi)$

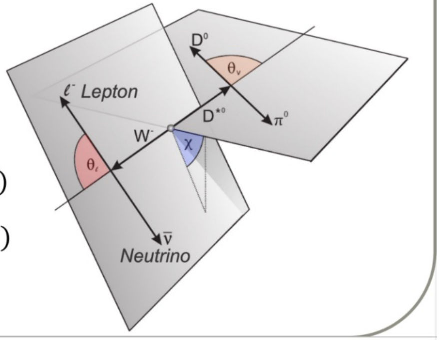
$S_5(w)$: $dx = d(\cos\chi \cos\theta_V)$

Highly sensitive to lepton universality violation

$S_7(w)$: $dx = d(\sin\chi \cos\theta_V)$

$S_9(w)$: $dx = d(\sin 2\chi)$

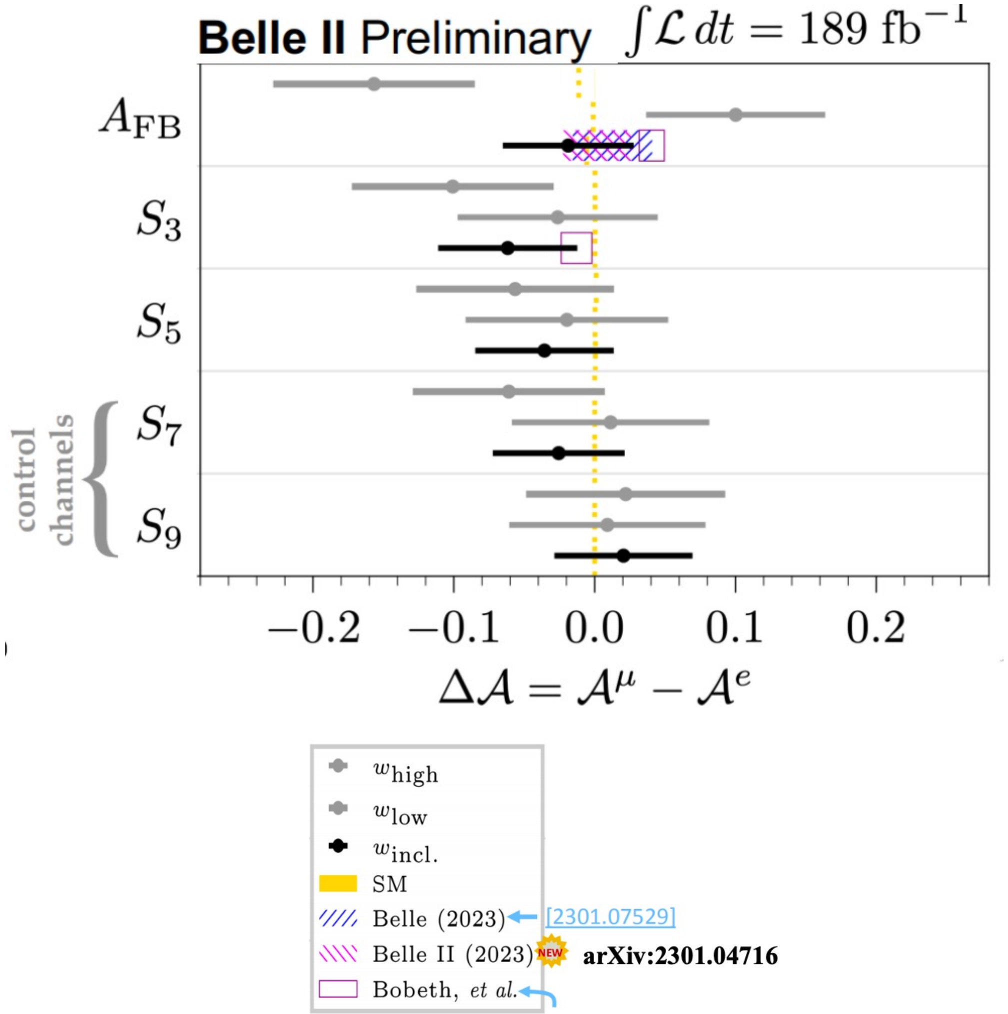
Less sensitive or insensitive to NP. Control tests of the analysis method



$S_7(w)$ 0 in SM and NP

$S_9(w)$ 0 in SM and ~0 in NP

- Asymmetries $\mathcal{A}$ are **experimentally clean** (most systematics cancel)
- $\Delta\mathcal{A}$ difference is **theoretically well-known** (form factors uncertainty cancel)



[2301.07529]

arXiv:2301.04716

EPJC **81**, 984 (2021)

Consistent with SM predictions

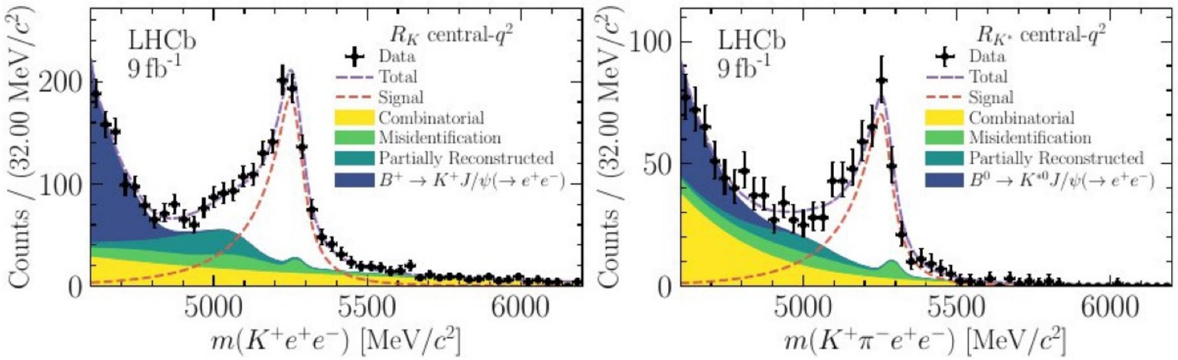
LFU: $R(K^{(*)})$, some tension disappeared

Talk by L. Sun

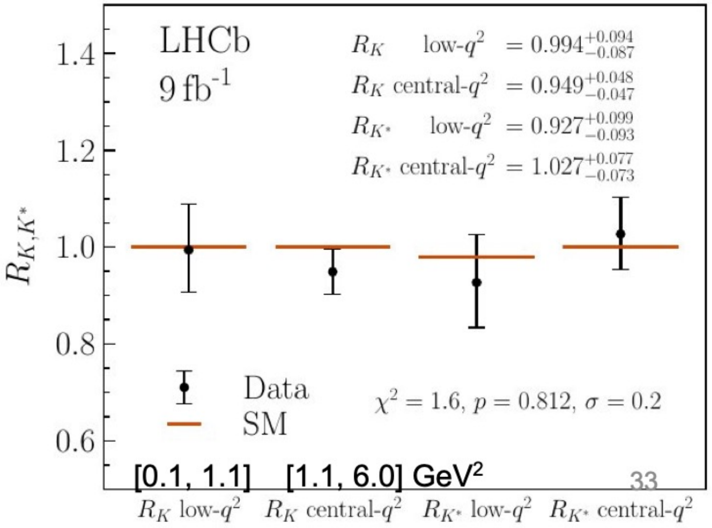
$$R_X = \frac{\mathcal{B}(B_q \to X_s \mu^+\mu^-)}{\mathcal{B}(B_q \to X_s J/\psi(\mu^+\mu^-))} \cdot \frac{\mathcal{B}(B_q \to X_s J/\psi(e^+e^-))}{\mathcal{B}(B_q \to X_s e^+e^-)}$$

arXiv:2212.09152
arXiv:2212.09153

R(K^(*)) results @ LHCb



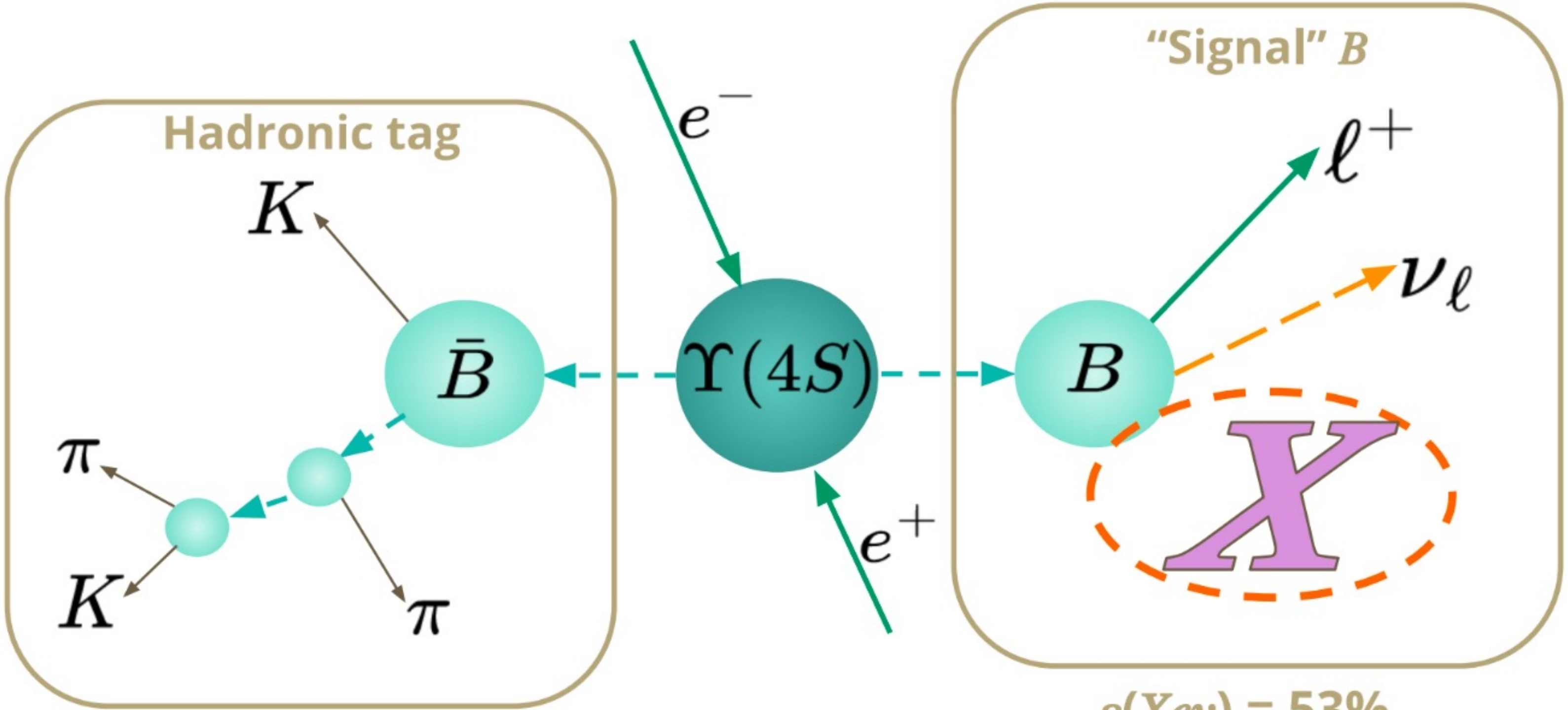
- Most precise LFU test in $b \to s\ell^+\ell^-$ decays
- Supersedes previous results
- Improved systematics of mis-IDed hadronic background in electron mode
- Now compatible with SM predictions at 0.2σ level
- Uncertainties statistically dominated



LFU from Belle II

Talk by C. Shen

$$R(X_{e/\mu}) = \frac{\mathrm{Br}(B \to Xe\nu)}{\mathrm{Br}(B \to X\mu\nu)}$$



$\varepsilon_{tag} = \mathcal{O}(0.1\%)$

$\varepsilon(Xe\nu) = 53\%$
$\varepsilon(X\mu\nu) = 66\%$

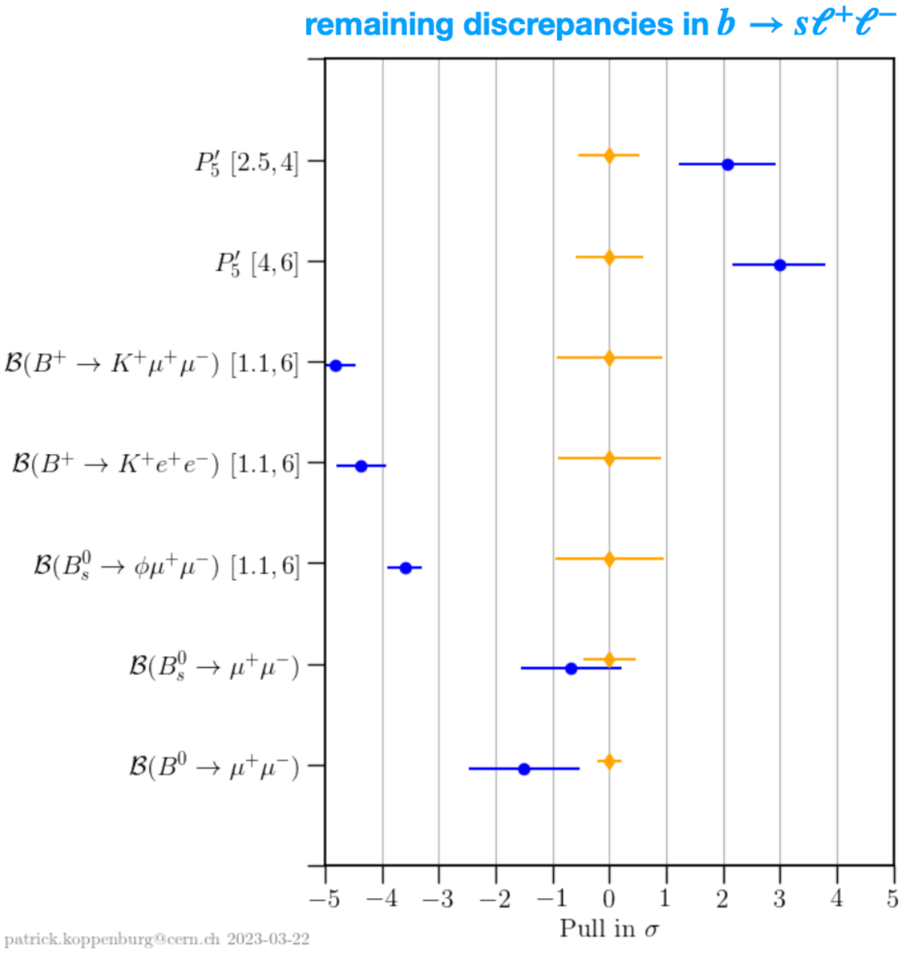
$$R(X_{e/\mu}) = 1.033 \pm 0.010(\mathrm{stat}) \pm 0.019(\mathrm{syst})$$

$R(X_{e/\mu})_{SM} = 1.006 \pm 0.001$
JHEP11(2022)007

New global fit results on NP

Talk by X. Yuan, T. Kitahara and T. Nomura

- **Many tensions still remains, but do we understand QCD tools used to predict well?**
- **NP favors in $C_{9\mu}^{NP}$ only, and prefers $C_{9\mu}^{NP} = C_{9e}^{NP}$**
- **Build models based on anomalies (charged higgs, leptoquarks**



$b \to s\ell\ell$ anomalies@mid.2023

Recent Global Fit

Ciuchini et al 2212.10516
Alguero et al 2304.07330
Qiaoyi Wen, Fanrong Xu 2305.19038

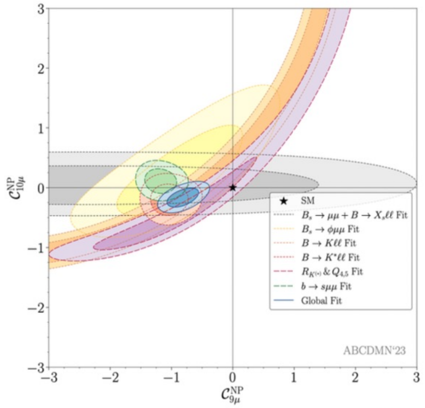
1D Hyp.	Best fit	All $1\sigma/2\sigma$	Pull_{SM}	p-value
$\mathcal{C}_{9\mu}^{\text{NP}}$	-0.67	$[-0.82, -0.52]$ $[-0.98, -0.37]$	4.5	20.2 %
$\mathcal{C}_{9\mu}^{\text{NP}} = -\mathcal{C}_{10\mu}^{\text{NP}}$	-0.19	$[-0.25, -0.13]$ $[-0.32, -0.07]$	3.1	9.9 %

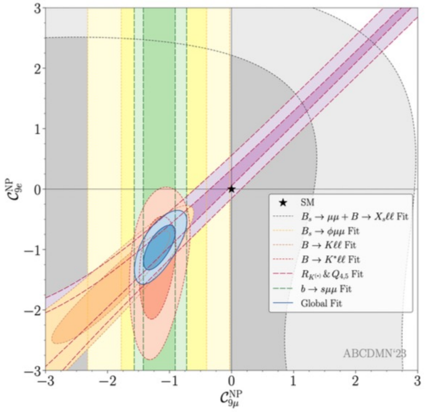
← $\mathcal{B}(B_s \to \mu^+\mu^-)$ consistent with SM

2D Hyp.	All Best fit	Pull_{SM}	p-value
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10\mu}^{\text{NP}})$	$(-0.82, -0.17)$	4.4	21.9%
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{7'})$	$(-0.68, +0.01)$	4.2	19.4%
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9'\mu})$	$(-0.78, +0.21)$	4.3	20.7%
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{10'\mu})$	$(-0.76, -0.12)$	4.3	20.5%
$(\mathcal{C}_{9\mu}^{\text{NP}}, \mathcal{C}_{9e}^{\text{NP}})$	$(-1.17, -0.97)$	5.6	40.3%

Scenario		Best-fit point	1σ	Pull_{SM}	p-value
Scenario 0	$\mathcal{C}_{9\mu}^{\text{NP}} = \mathcal{C}_{9e}^{\text{NP}} = \mathcal{C}_9^{\text{U}}$	−1.17	$[-1.33, -1.00]$	5.8	39.9 %
Scenario 5	$\mathcal{C}_{9\mu}^{\text{V}}$ $\mathcal{C}_{10\mu}^{\text{V}}$ $\mathcal{C}_9^{\text{U}} = \mathcal{C}_{10}^{\text{U}}$	−1.02 −0.35 +0.19	$[-1.43, -0.61]$ $[-0.75, -0.00]$ $[-0.16, +0.58]$	4.1	21.0 %
Scenario 6	$\mathcal{C}_{9\mu}^{\text{V}} = -\mathcal{C}_{10\mu}^{\text{V}}$ $\mathcal{C}_9^{\text{U}} = \mathcal{C}_{10}^{\text{U}}$	−0.27 −0.41	$[-0.34, -0.20]$ $[-0.53, -0.29]$	4.0	18.0 %
Scenario 7	$\mathcal{C}_{9\mu}^{\text{V}}$ $\mathcal{C}_9^{\text{U}}$	−0.21 −0.97	$[-0.39, -0.02]$ $[-1.21, -0.72]$	5.6	40.3 %
Scenario 8	$\mathcal{C}_{9\mu}^{\text{V}} = -\mathcal{C}_{10\mu}^{\text{V}}$ $\mathcal{C}_9^{\text{U}}$	−0.08 −1.10	$[-0.14, -0.02]$ $[-1.27, -0.91]$	5.6	41.1 %

← No R_K, R_{K^*} anomalies now !





U = LFU, V = LFUV

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LFV, LNV, BNV, dark sector

Talk by Y. Zhan and D. Lin

$J/\psi \to e\tau$
Phys. Rev. D 103,112007 (2021)

$\mathcal{B}(J/\psi \to e\tau) < 7.5 \times 10^{-8}$ @90% C.L.

$J/\psi \to e\mu$

$\mathcal{B}(J/\psi \to e\mu) < 4.5 \times 10^{-9}$ @90% C.L.

$D^0 \to pe$
Phys. Rev. D 105, 032006 (2022)

$\mathcal{B}(D^0 \to e^+\bar{p}) < 1.2 \times 10^{-6}$ @90% C.L.

$\mathcal{B}(D^0 \to pe^-) < 2.2 \times 10^{-6}$ @90% C.L.

$D \to ne$
Phys. Rev. D 106, 112009 (2022)

$\mathcal{B}(D^+ \to e^+\bar{n}) < 1.43 \times 10^{-5}$ @90% C.L.

$\mathcal{B}(D^+ \to ne^-) < 2.92 \times 10^{-5}$ @90% C.L.

$e^+e^- \to \gamma\gamma'$

coupling ε are $(1.6 - 5.7)\times10^{-3}$

$\Lambda_c^+ \to p\gamma'$

$\mathcal{B}(\Lambda_c^+ \to p\gamma') < 8.0\times10^{-5}$

$J/\psi \to \gamma a, a \to \gamma\gamma$

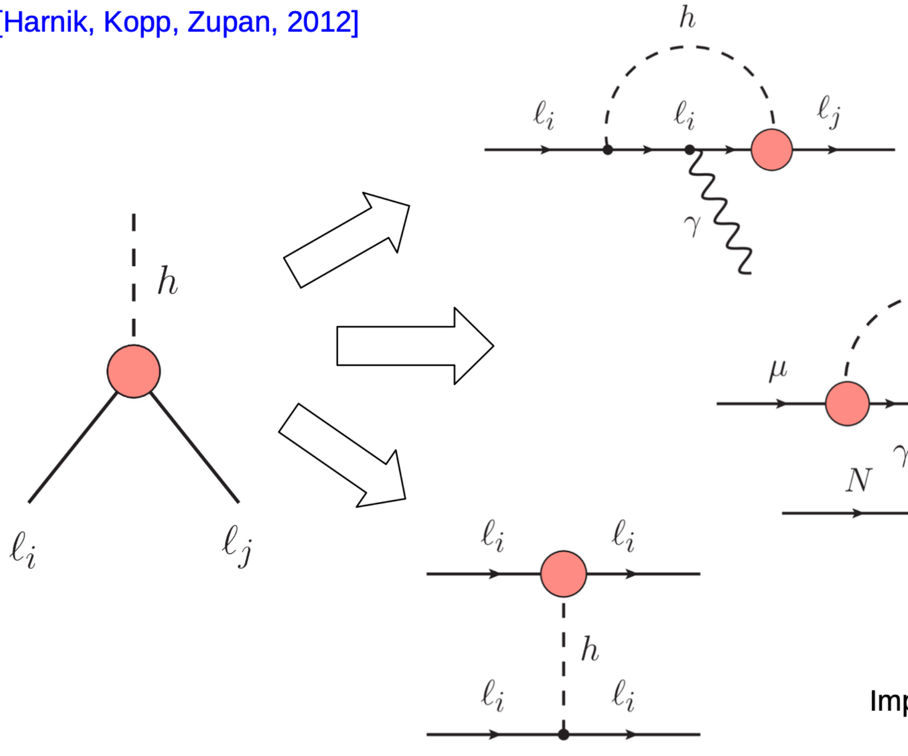
$8.3 \times 10^{-8}$to 1.8×10^{-6}

- **Also interesting studies from Babar on dark sectors in $B \to \Lambda\psi_D, p\psi_D, Ka(\gamma\gamma)$**

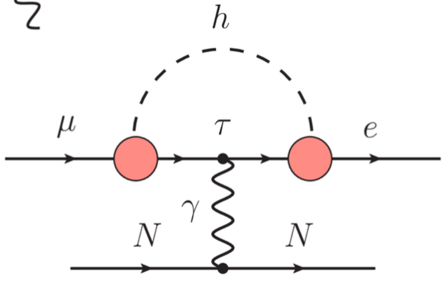
Complementary high energy searches

Talk by A. Vicente

[Harnik, Kopp, Zupan, 2012]

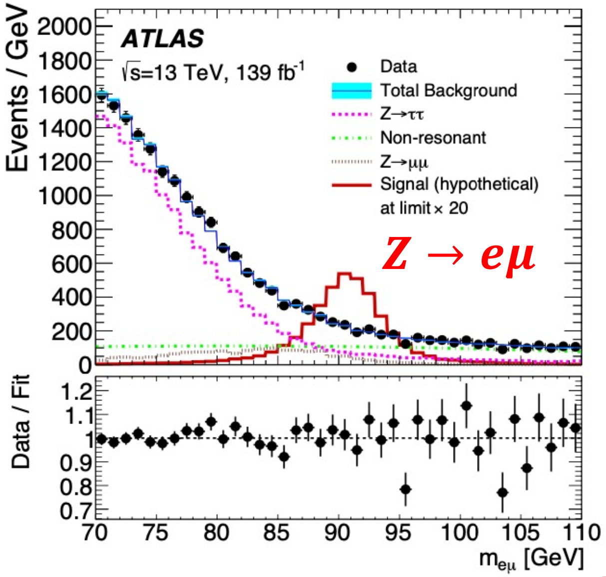


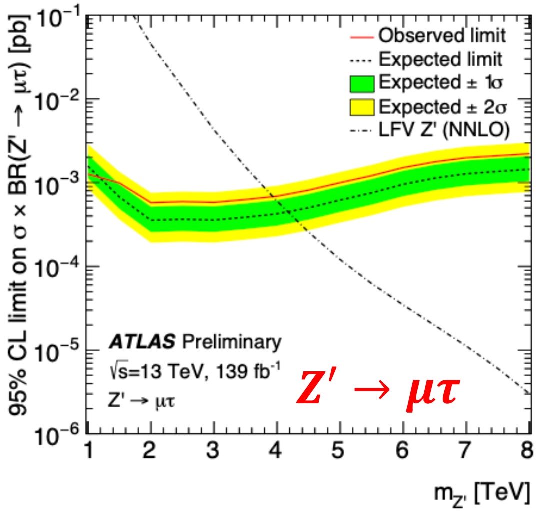
Indirect bounds



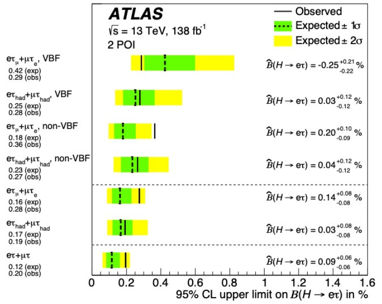
For this reason:

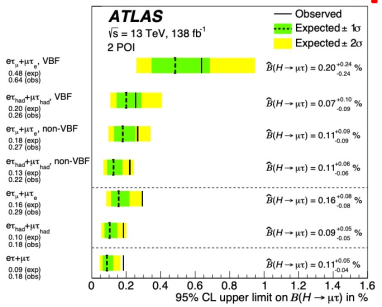
Impossible to observe $h \to \mu e$

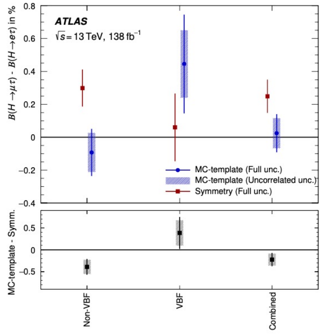




$H \to e\tau, \mu\tau$







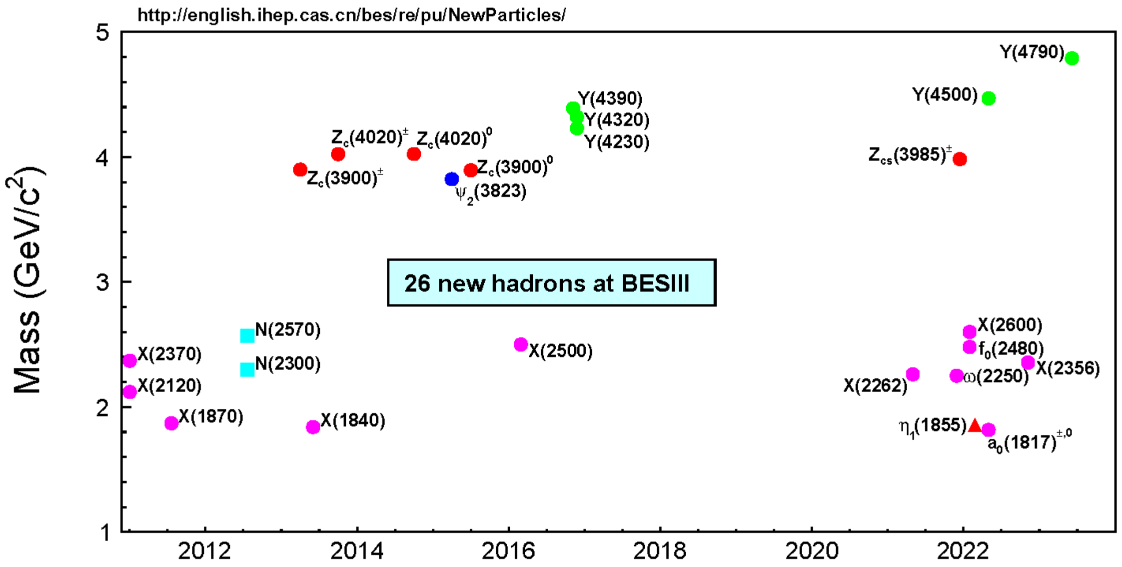
- **Synergy between low energy searches and high energy observables in Z and H decays**

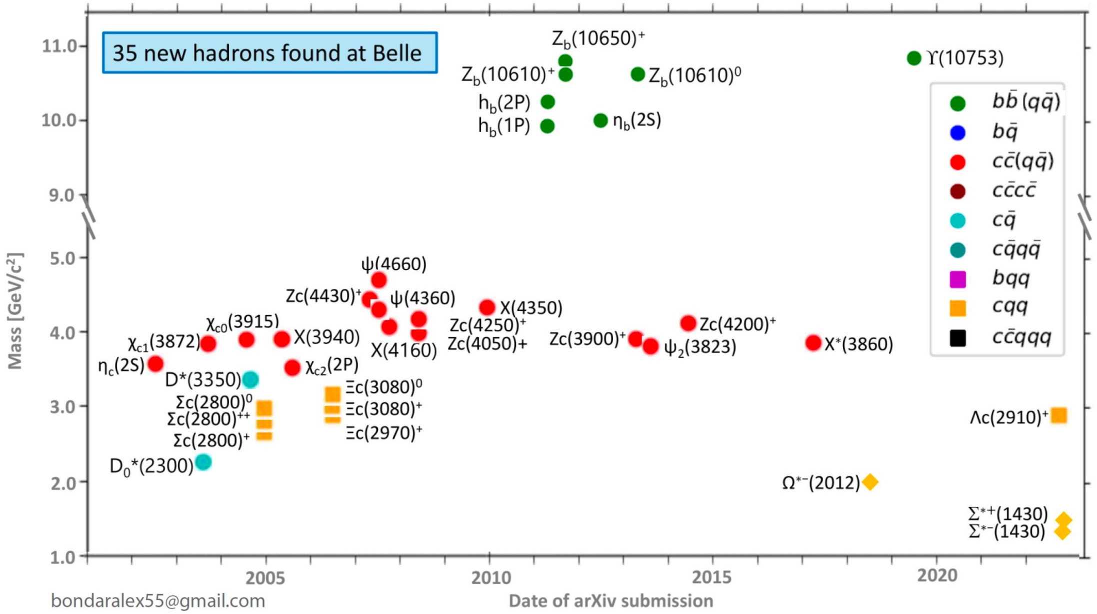
Outline

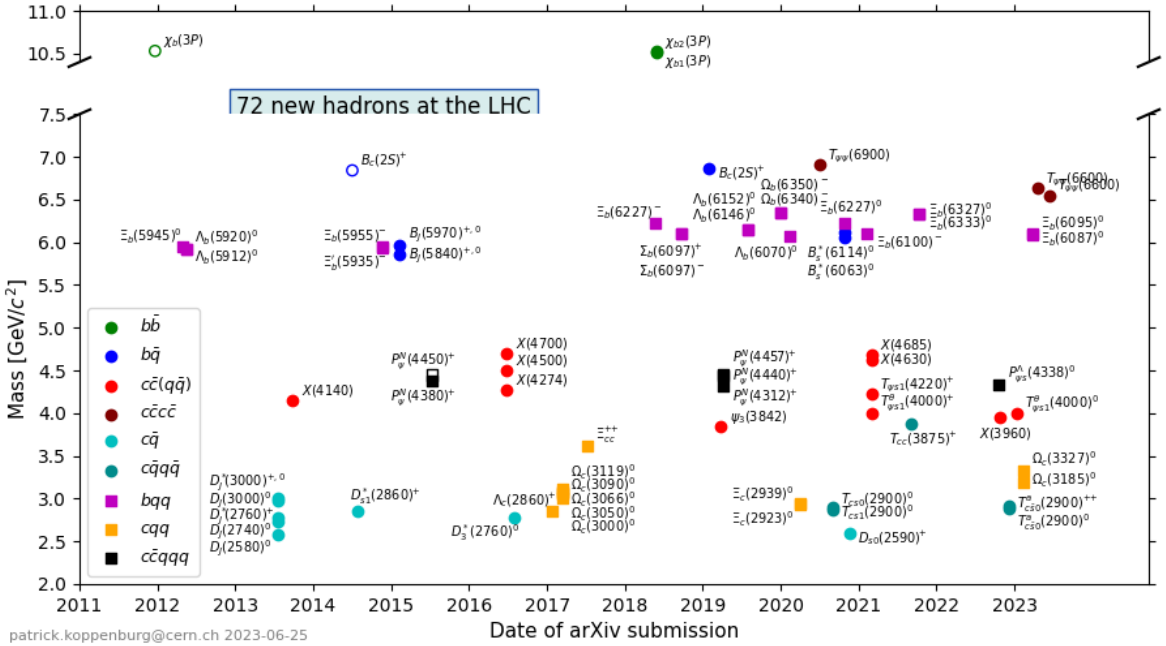
- **CKM physics**
- **New physics searches with leptons**
- **Spectroscopy**

New hadrons

Talks by D. Zhang and C. Shen







Still missing summary from BaBar, CDF, D0 etc

Particle Zoo 2.0

20 years ago

Observation of a narrow charmonium-like state in exclusive $B^{\pm} \to K^{\pm}\pi^{+}\pi^{-}J/\psi$ decays

Belle Collaboration • S.K. Choi (Gyeongsang Natl. U.) Show All(174)

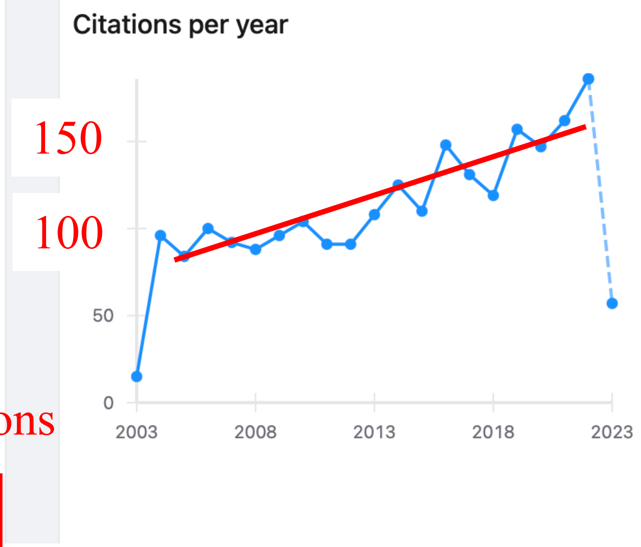
Sep, 2003 Sep, 2003

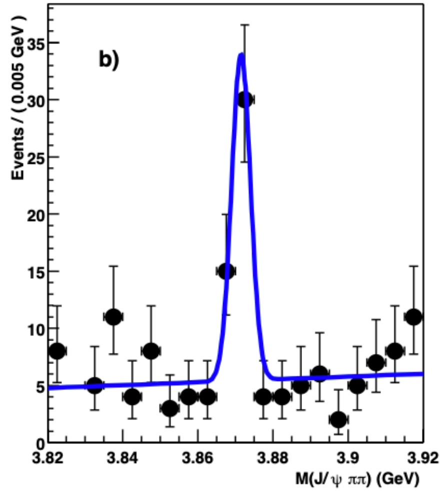
10 pages

Published in: *Phys.Rev.Lett.* 91 (2003) 262001
e-Print: hep-ex/0309032 [hep-ex]
DOI: 10.1103/PhysRevLett.91.262001
PDG: chi_c1(3872) --> pi+ pi- J/psi(1S) Show All(5)
Experiments: KEK-BF-BELLE
View in: ADS Abstract Service

pdf links cite claim reference search 2,307 citations

2307 citations





- **First heavy exotic candidate containing $c\bar{c}$, opening a new field of research ($D^*_{s0}(2317)$ and $D^*_{s1}(2460)$ at the same year)**

Particle X = $c\bar{c}$ + $c\bar{c}qq$ + cq $\bar{c}q$ + $c\bar{c}$ qq + …

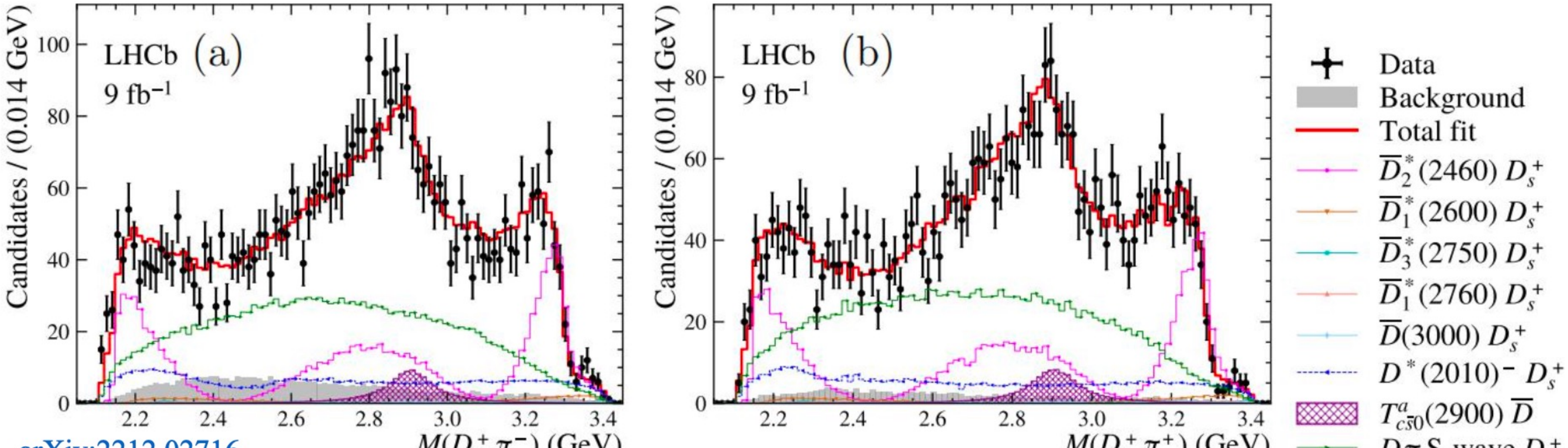
Highlights: doubly charged exotic

Talk by D. Zhang

Discovery of $T^a_{c\bar{s}0}(2900)^0$ and $T^a_{c\bar{s}0}(2900)^{++}$

- In $B^0 \to \overline{D}^0 D_s^+ \pi^-$ and $B^+ \to D^- D_s^+ \pi^+$
  - Isospin symmetry
- First observation of a doubly charged open-charm tetraquark

$m = 2.908 \pm 0.011 \pm 0.020$ GeV
$\Gamma = 0.136 \pm 0.023 \pm 0.011$ GeV
$J^P = 0^+$

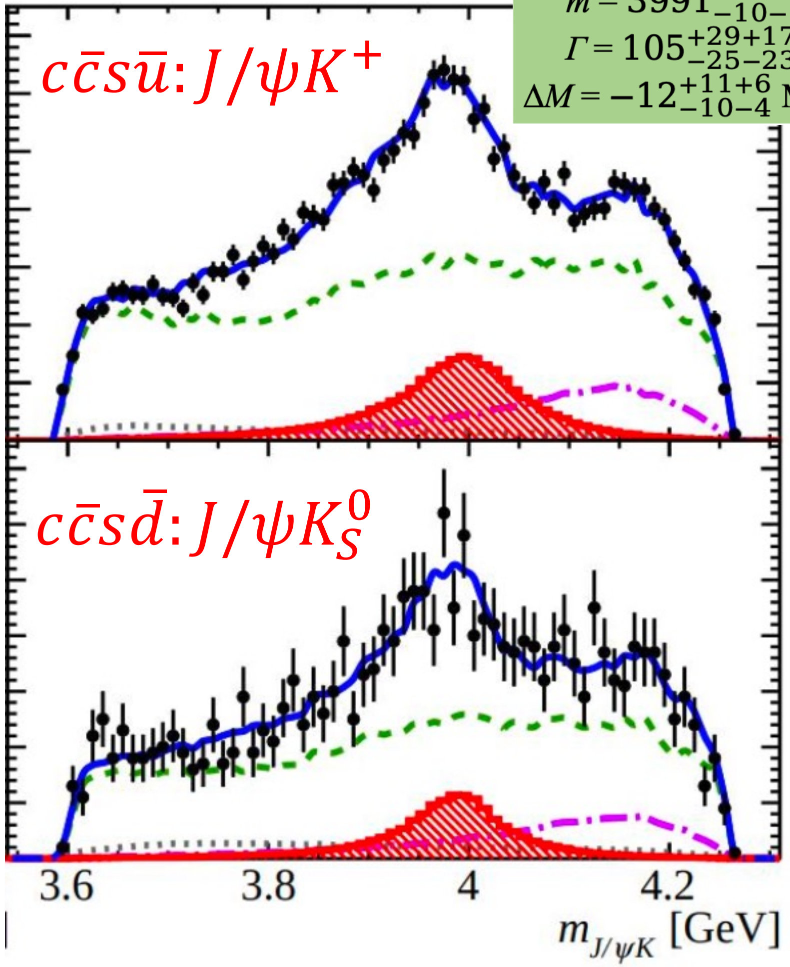


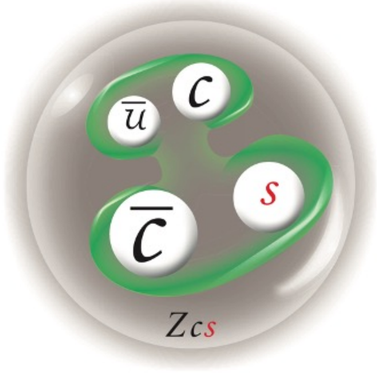
arXiv:2212.02716

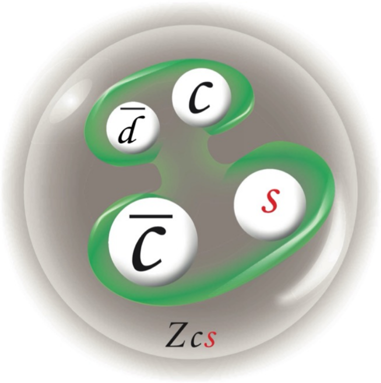
Highlights: hidden charm exotic with strangeness

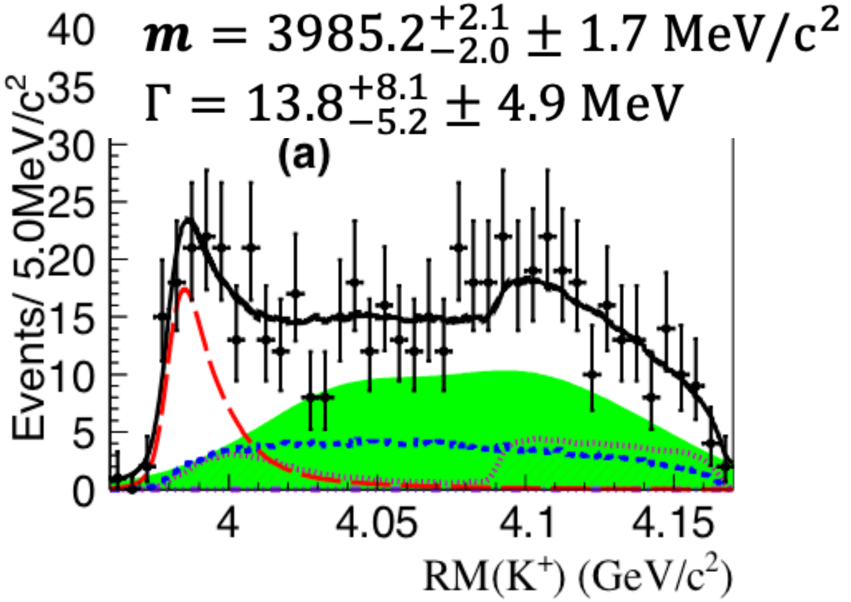
Talk by D. Zhang

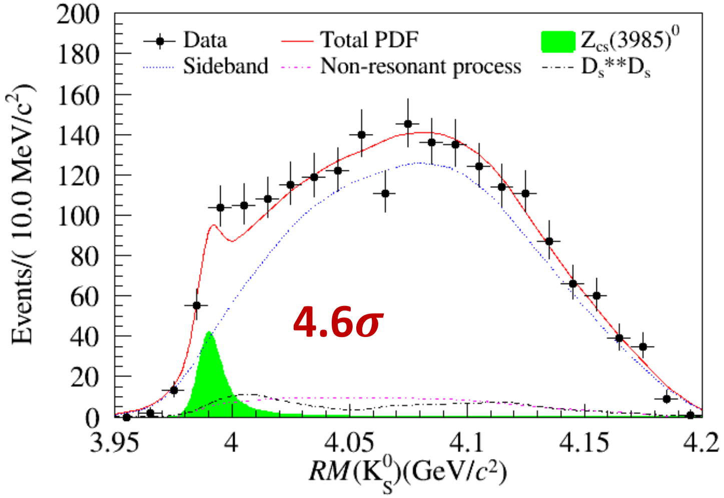
New neutral state:
$m = 3991^{+12+9}_{-10-17}$ MeV
$\Gamma = 105^{+29+17}_{-25-23}$ MeV
$\Delta M = -12^{+11+6}_{-10-4}$ MeV











- Similar masses but very different width, nature still under unknown

Highlights: hidden charm exotic with strangeness

Talk by D. Zhang

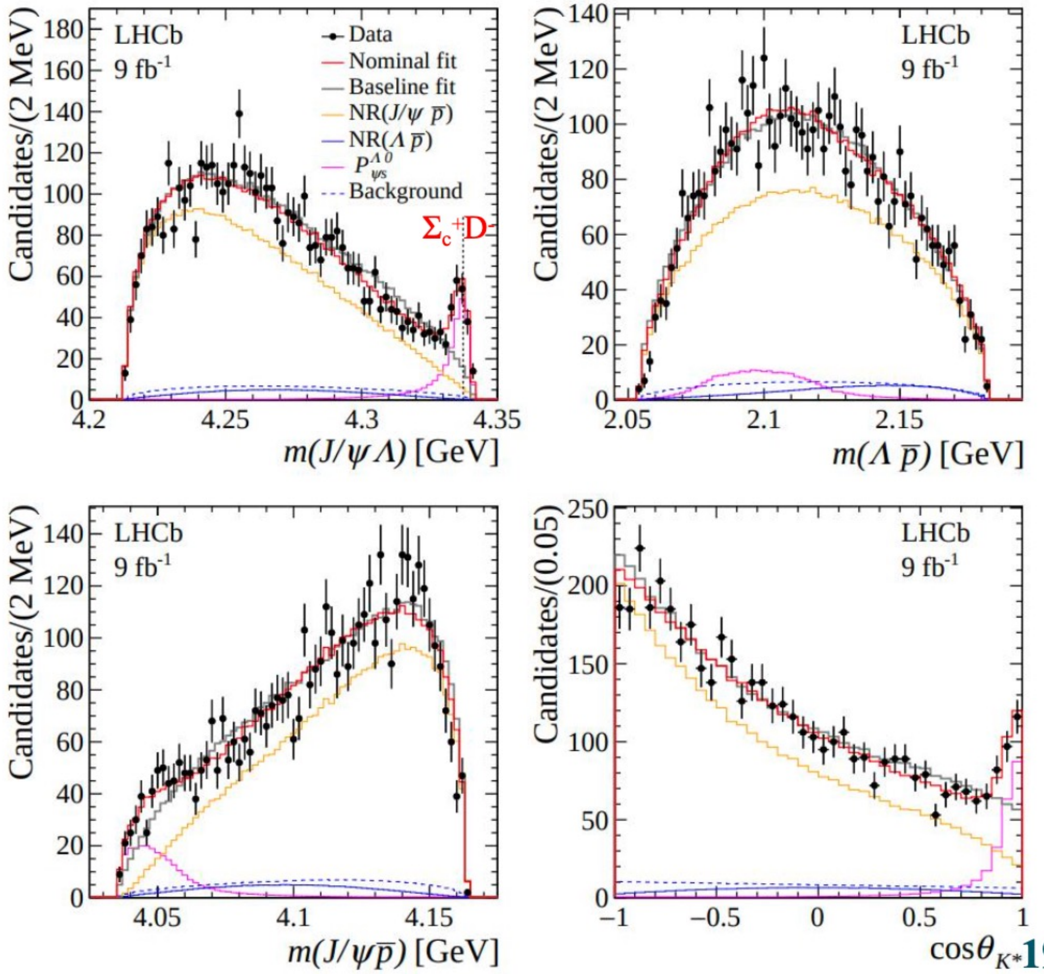
Discovery of $P^{\Lambda}_{\psi s0}(4338)^0 \to J/\psi\Lambda$

- A new resonance is needed in the amplitude fit
- First pentaquark containing strange quark

$$B^- \to J/\psi \Lambda \bar{p}$$

$m = 4338.2 \pm 0.7 \pm 0.4$ MeV
$\Gamma = 7.0 \pm 1.2 \pm 1.3$ MeV

$J^P = \frac{1}{2}^-$ preferred

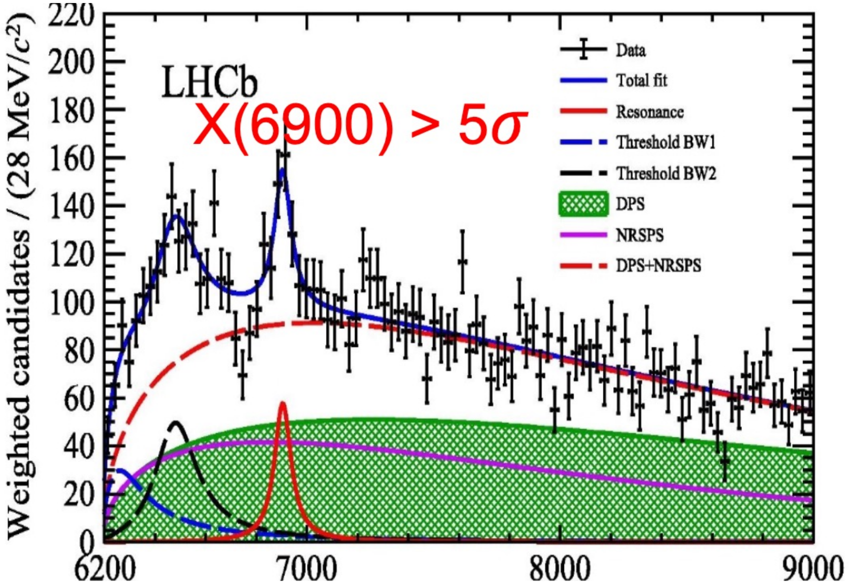


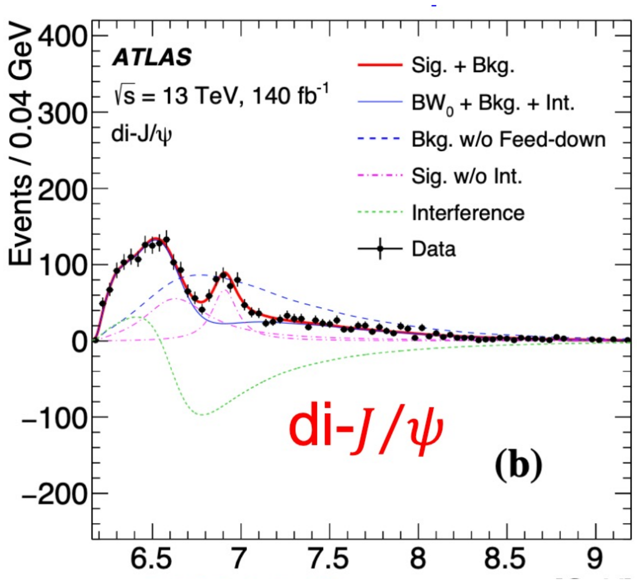
arXiv:2210.10346

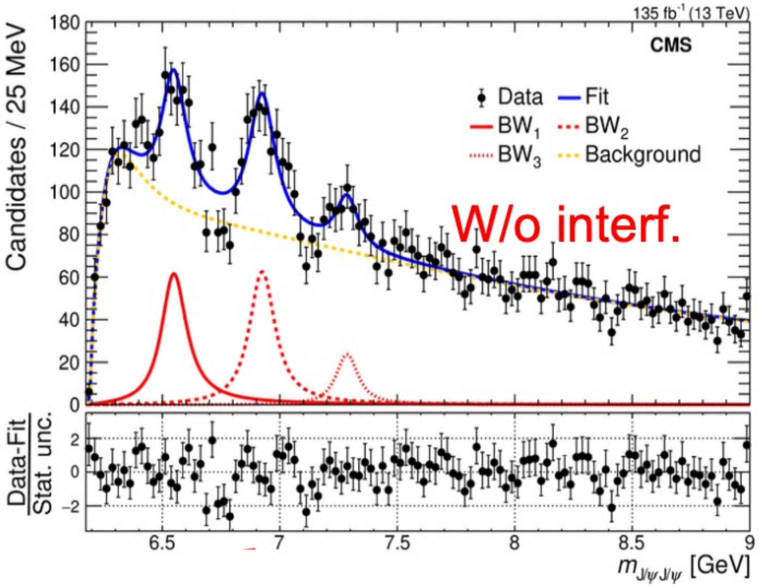
7/4/2023

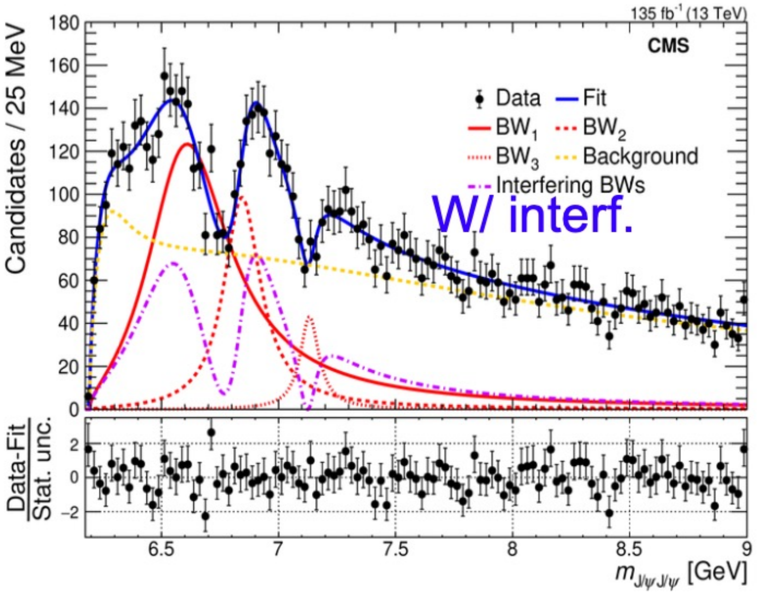
Highlights: exotic with 4c

Talk by Z. Hu



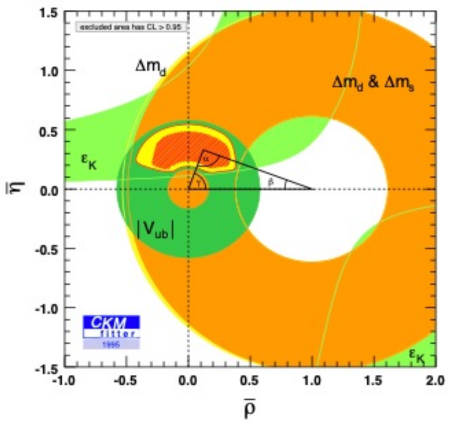




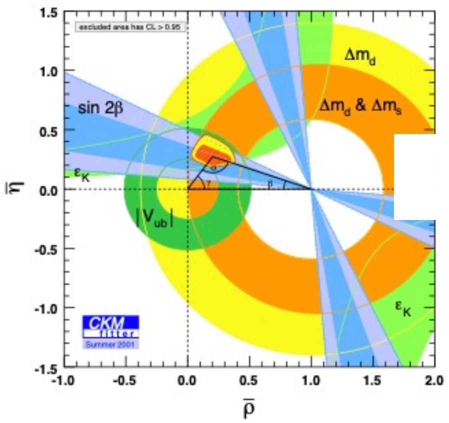


- **All three LHC experiments (LHCb, ATLAS, CMS) see resonances in di-J/ψ mass**
- **Existence of two resonances established, one with evidence**
- **Long waited, extremely interesting**

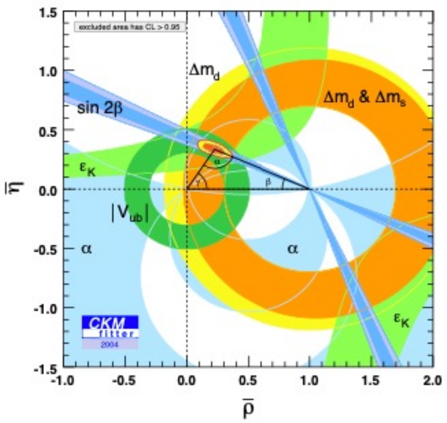
Summary of a summary



1995



2001



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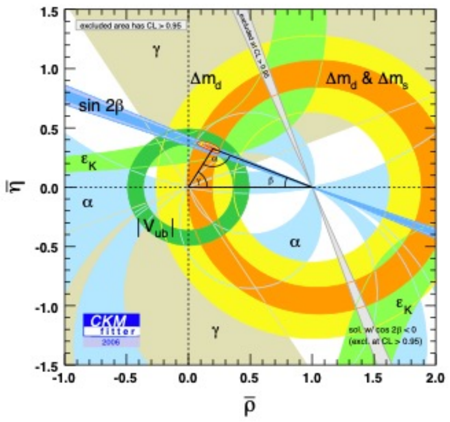

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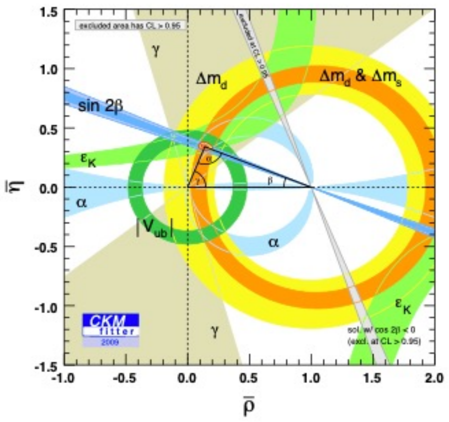

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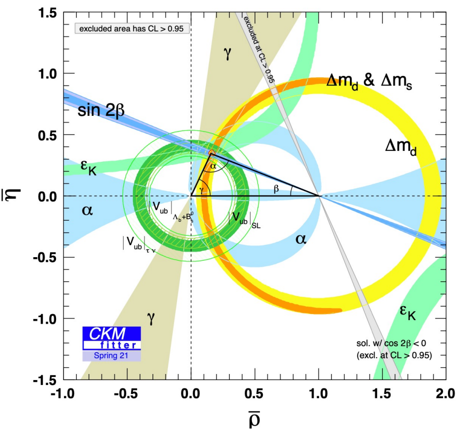

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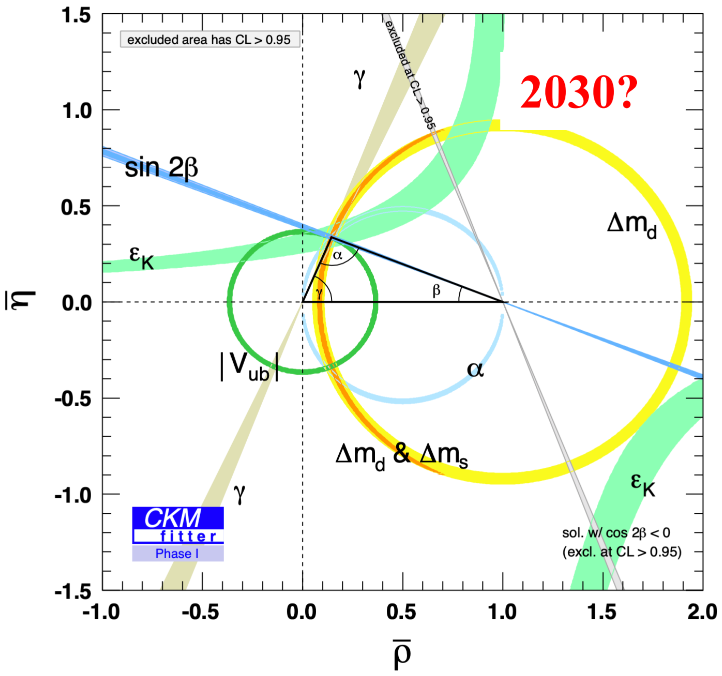
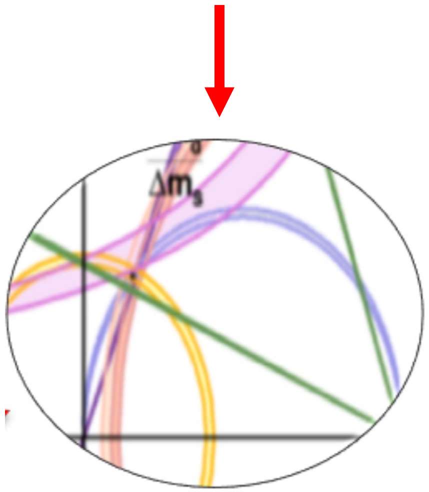
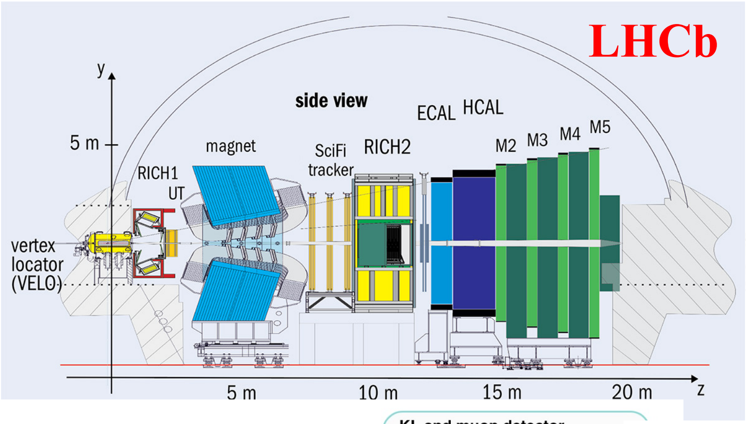
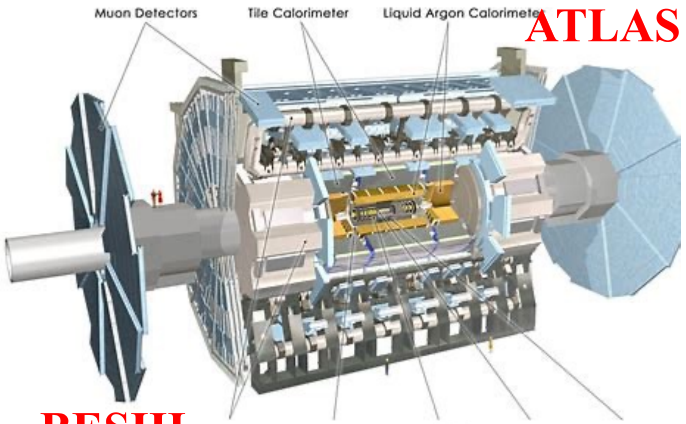
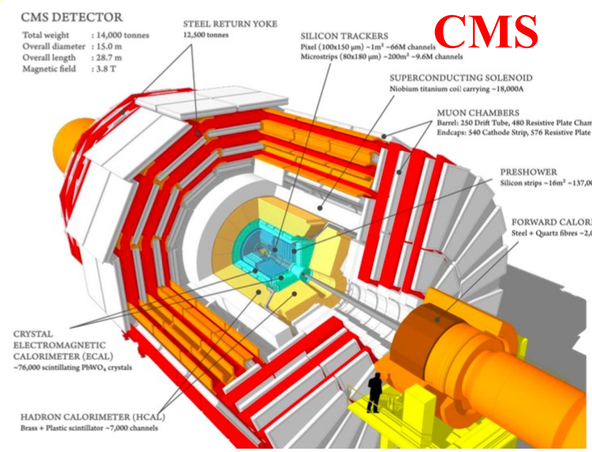




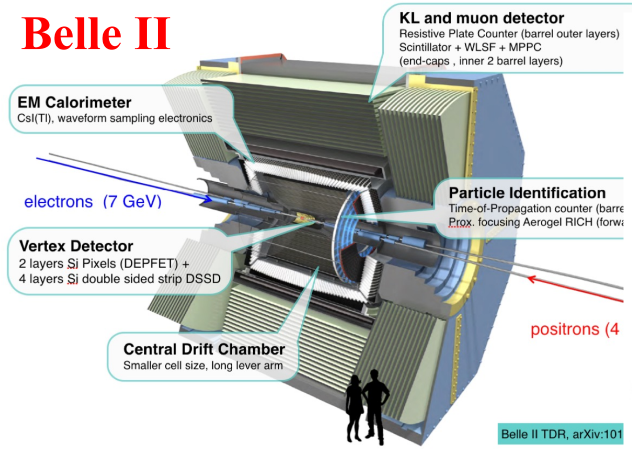
Bright Future

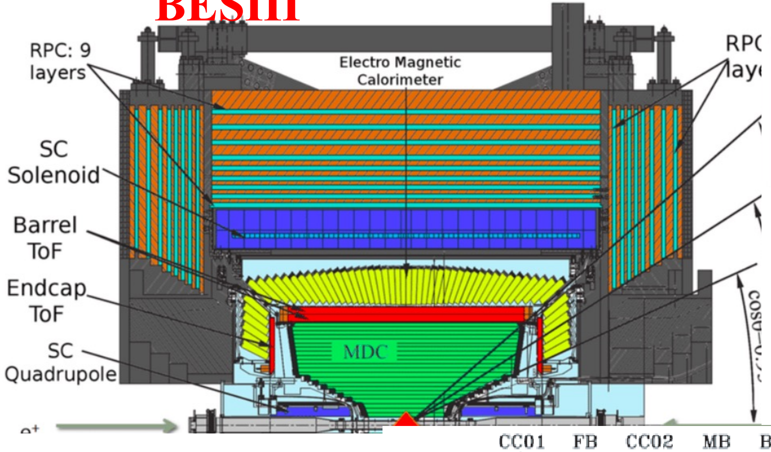


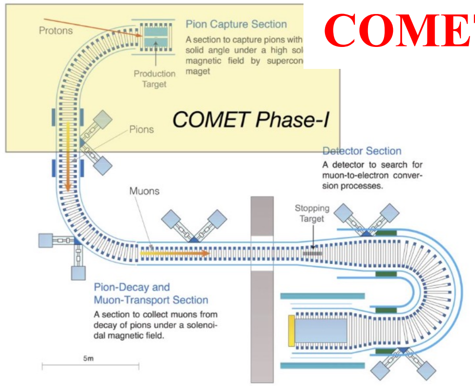


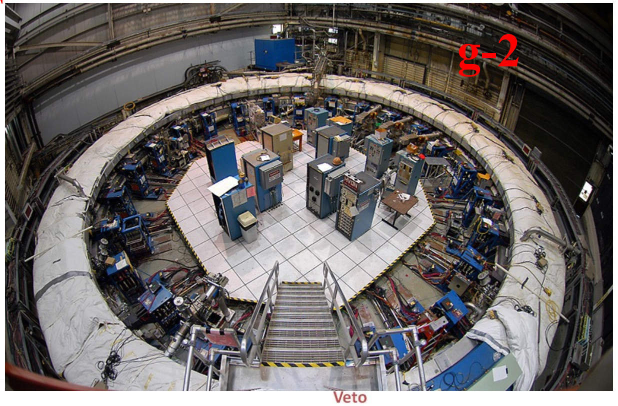


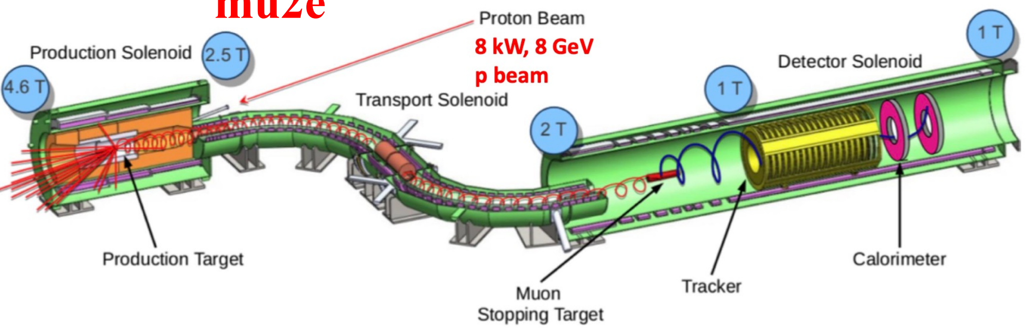
+ Mu3e
STCF
CEPC
FCC-ee/hh
SHiP
……

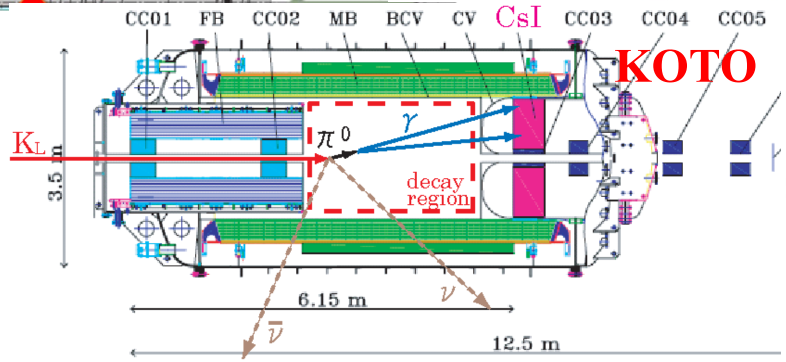


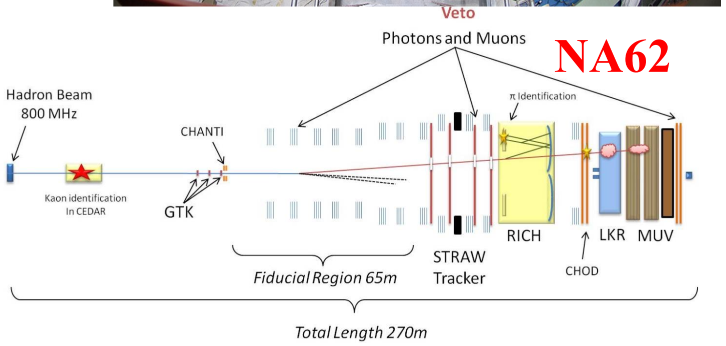












Thank you for your attention

Synergy between LHCb and BESIII (1)

Talk by Z. Lu

Quantum correlation $D^0\bar{D}^0$: $|\psi(3770)\rangle \rightarrow \frac{1}{\sqrt{2}}(|D^0\rangle|\bar{D}^0\rangle - |\bar{D}^0\rangle|D^0\rangle)$

➡ Provide direct access to the $D^0 - \bar{D}^0$ strong-phase difference

✔ Important input in CKM γ measurement

✔ Precise test of perturbative QCD calculations in charm decays, mixing and CPV

Different methods depending on the final states of D decays

- GLW : D decaying to CP eigenstates
- ADS : D decaying to CF/DCS eigenstates
- GGSZ : D decaying to self-conjugate eigenstates

Flavour	$K^\pm\pi^\mp\pi^\mp\pi^-$, $K^\pm\pi^\mp\pi^0$, $K^\pm\pi^\mp$, ...
CP-even	K^+K^-, $\pi^+\pi^-$, $\pi^0\pi^0$, $K^0_S\pi^0\pi^0$, $K^0_L\pi^0$, $K^0_L\omega$, $\pi^+\pi^-\pi^{0\dagger}$
CP-odd	$K^0_S\pi^0$, $K^0_S\eta$, $K^0_S\omega$, $K^0_S\eta'$, $K^0_S\phi$, $K^0_L\pi^0\pi^0$
Self-conjugate	$K^0_S\pi^+\pi^-$, $K^0_SK^+K^-$, ...