Search for new physics signals in rare B decays

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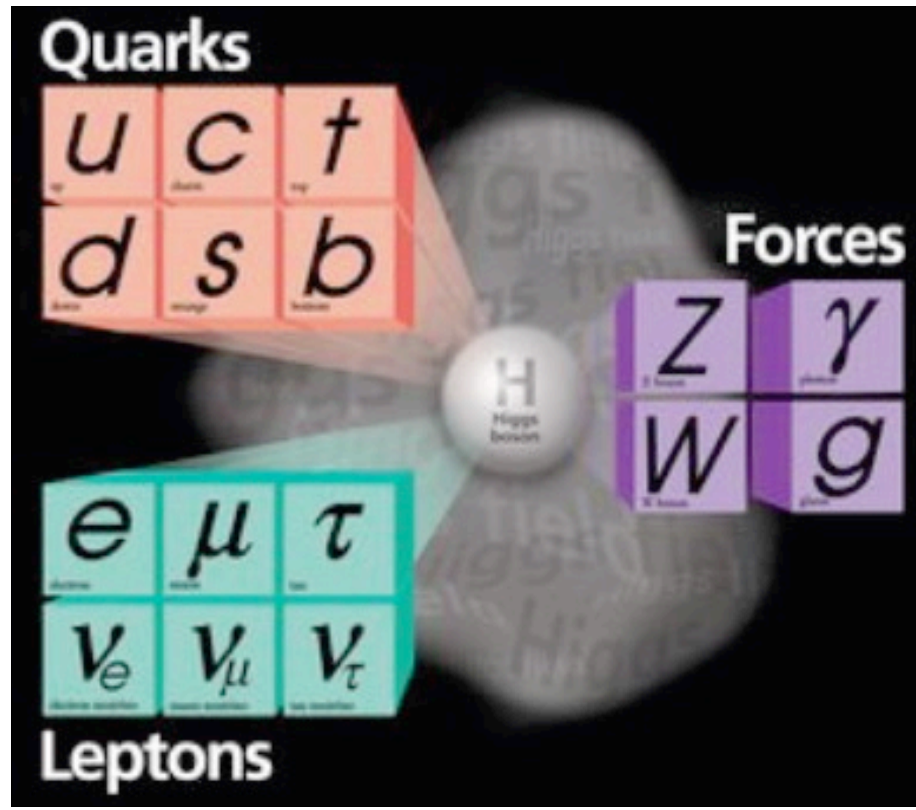
Higgs发现之后的粒子物理基本问题 —费米子“代”和“味道”之谜

- 为什么恰好有三代 ？
- 为什么有不同的质量?
- CP 破坏问题 ？
- 物质和反物质不对称



最小标准模型的61个基本粒子

粒子物理的相互作用有三部分：

- 规范相互作用—最清楚的部分
- Higgs场部分—LHC刚刚发现
- 味物理部分—不很清楚的部分

Higgs工厂？环形正负电子对撞机

2013年12月成立
－Center for Future High Energy Physics
(中科院高能所)

a future plan

TeV尺度的新物理

新粒子一定伴随着新的味道混合机制.

Almost all extensions of the SM have new sources of CPV & flavor conversion

已经有了很多的模型→ 它们最终需要实验的验证

- 在标准模型中，夸克与轻子通过Higgs机制和Yukawa相互作用获得质量，
- 但并没有给出质量的起源
- 理论本身无法预言质量的大小。
- 电子质量0.5 MeV，u、d夸克几个MeV, 而top夸克175GeV，相差30万倍。
- 为什么差别这么大？ 阶梯性、跷跷板

顶夸克的质量非常接近电弱能标破缺尺度，有希望找到新物理

- 但是顶夸克在现有实验产额太低
- 同为第三代夸克的b夸克便担负起了寻找新物理信号的重任。
- **近年来，重味物理一直是粒子物理的最重要研究方向之一**

高能物理实验发展方向

我听说过好多挺低能量的...

- 北京正负电子对撞机(BEPC)
- 大亚湾中微子实验
- B-工厂，好像还有两个?
- 还有人要造超级B-工厂 （Belle II）

任务是探索新粒子和新现象...

- 可以通过两种方式:直接或间接
- 我们有两个高能物理实验前沿:高能量和高精度 ...

超级B介子工厂

直接CP破坏的发现导致了
2008年的诺贝尔物理奖

Flavor physics is important

The origin of flavour is one of the big, unsolved mysteries of fundamental physics!

While the Standard Model (SM) ***describes*** flavour physics very accurately, it does not ***explain*** its mysteries:

- ✓ Why are there 3 generations in nature?
- ✓ What determines the extreme hierarchy of fermion masses?
- ✓ What determines the elements of the CKM matrix?
- ✓ What is the origin of the matter-antimatter asymmetry (CP violation)?

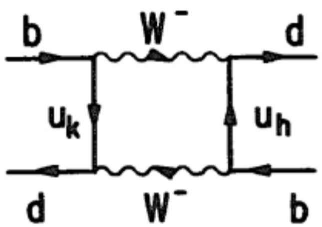
The SM CP-violation is insufficient to explain the matter/antimatter asymmetry
→ progress in flavour physics may help understand open questions in cosmology

History has shown that flavour physics often gives first evidence for new discoveries:

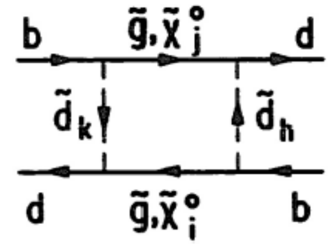
- ➢ Kaon mixing, BR($K^0_L \rightarrow \mu\mu$) & GIM → prediction of charm
- ➢ CP violation → prediction of third quark family
- ➢ B mixing → mass of top is very heavy
- ➢ rare B-decays → SUSY parameter space constrained

New Physics in FCNC processes

- Mixing

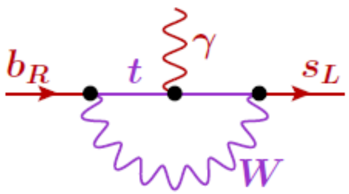


~~OR~~ ⇒ AND?

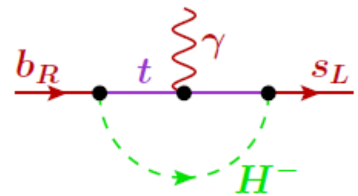


Simple parameterization for each neutral meson: $M_{12} = M_{12}^{\rm SM}\,(1 + h e^{2i\sigma})$

- Penguin decays



~~OR~~ ⇒ AND?

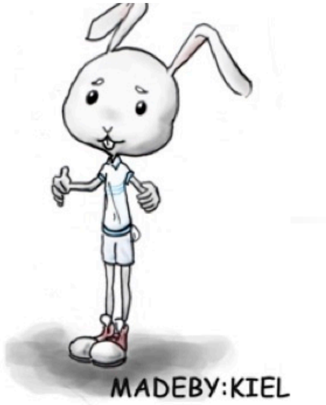


Many operators for $b \to s$ transitions — no simple parameterization of NP

- $V_{td,\,ts}$ only measurable in loops; likely also subleading couplings of new particles

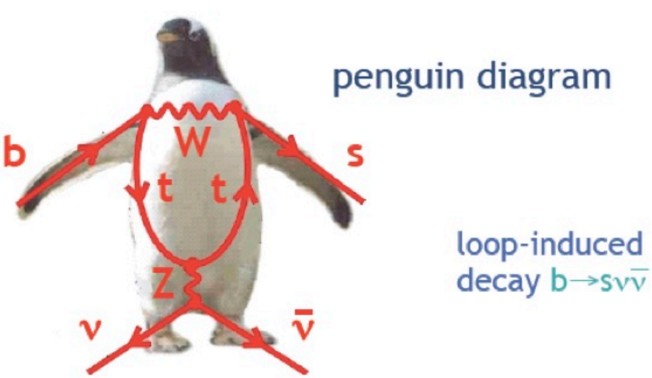
- Isolating modest NP contributions requires many measurements
  Compare NP-independent (tree) with NP-dependent (loop) processes

味物理：研究不同“味”直接的转换



- 强相互作用和电磁作用过程味是守恒的
- 新物理的效会比较弱，比弱作用还弱...
- 理论上对弱相互作用的理解比较清楚

研究味转换过程中对理论的微小偏离，探索新物理！



第一次发现对称性守恒定律的破坏

-- 宇称(P)不守恒

首先由李政道和杨振宁1956提出，在弱作用中存在不守恒

θ– τ是同一种粒子

他们研究发现，在强相互作用和电磁相互作用过程中宇称守恒是得到了实验的判定性检验的，但是在弱相互作用过程中宇称守恒并没有得到实验的判定性检验

建议可以通过钴60的衰变实验来对这一点进行判定性检验

1957年诺贝尔奖

31岁-35岁

1957年吴健雄实验证明宇称不守恒

CP联合变换则守恒

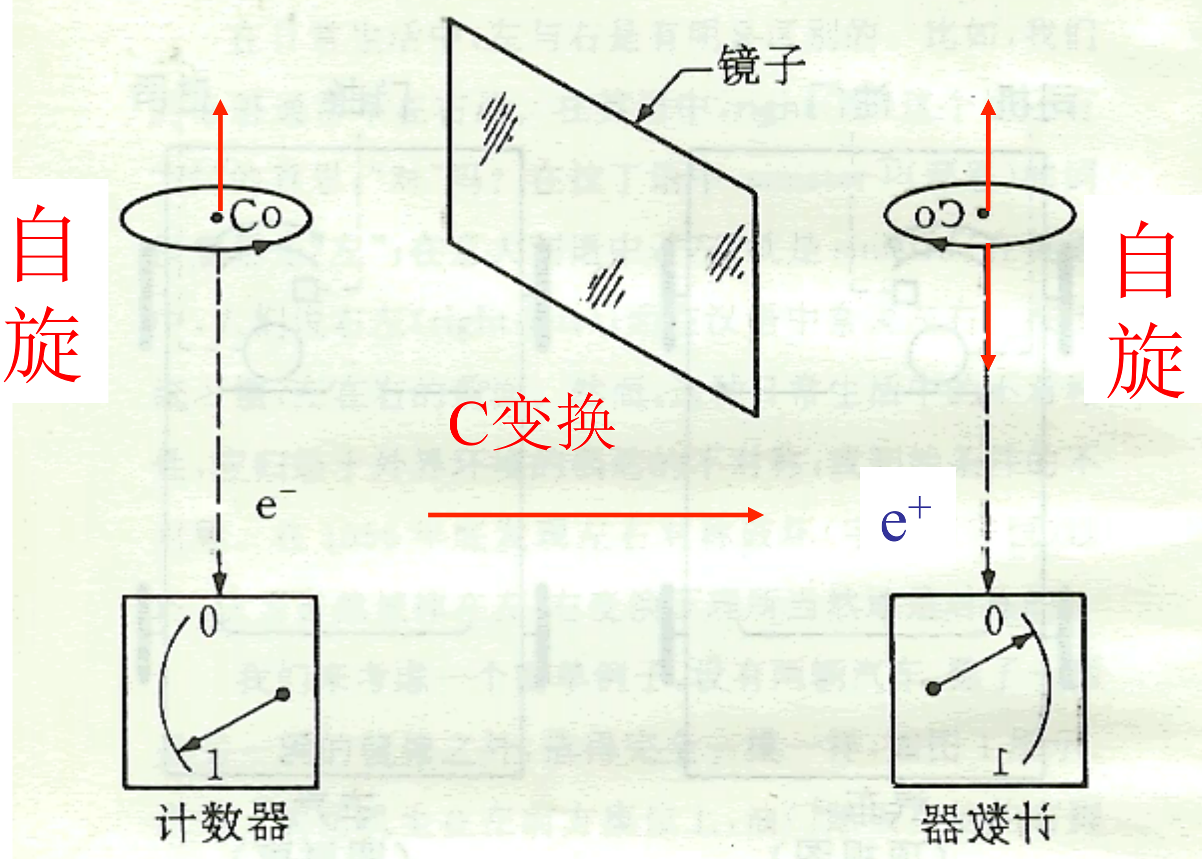


图 2 这两套 Co^{60} 衰变实验的初始装置是互为镜像的，

Experimental Discovery of CP Violation

VOLUME 13, NUMBER 4 PHYSICAL REVIEW LETTERS 27 JULY 1964

EVIDENCE FOR THE 2π DECAY OF THE K_2^0 MESON*†

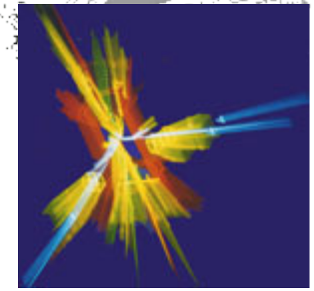
J. H. Christenson, J. W. Cronin,‡ V. L. Fitch,‡ and R. Turlay§
Princeton University, Princeton, New Jersey
(Received 10 July 1964)

This Letter reports the results of experimental studies designed to search for the 2π decay of the K_2^0 meson. Several previous experiments have served[1,2] to set an upper limit of 1/300 for the fraction of K_2^0's which decay into two charged pions. The present experiment, using spark chamber techniques, proposed to extend this limit.

In this measurement, K_2^0 mesons were produced at the Brookhaven AGS in an internal Be target bombarded by 30-BeV protons. A neutral beam was defined at 30 degrees relative to the circulating protons by a $1\frac{1}{2}$-in.$\times 1\frac{1}{2}$-in.$\times$48-in. collimator at an average distance of 14.5 ft. from

The analysis program computed the vector momentum of each charged particle observed in the decay and the invariant mass, m^*, assuming each charged particle had the mass of the charged pion. In this detector the K_{e3} decay leads to a distribution in m^* ranging from 280 MeV to ~536 MeV; the $K_{\mu 3}$, from 280 to ~516; and the $K_{\pi 3}$, from 280 to 363 MeV. We emphasize that m^* equal to the K^0 mass is not a preferred result when the three-body decays are analyzed in this way. In addition, the vector sum of the two momenta and the angle, θ, between it and the direction of the K_2^0 beam were determined. This

2×10^{-3} : *Too Small .... for Sakharov !*



Matter

Anti Matter

反物质到哪儿去了 ？

物质—反物质不对称的条件

Sakharov (1960s)

- 存在改变重子数的相互作用

  例如：大统一理论

- C和CP变换都不守恒
- 早期宇宙中存在过对热平衡的偏离

三条件缺一不可

问题相当麻烦！

Universire: $\frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}} = 10^{-9} \sim 10^{-10}$

Standard Model: $\frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}} = \sim 10^{-20}$

CP violation in the K and B meson decays can be explained by the Standard Model.

CP violation in the universe cannot be explained by the Standard Model.

New source for CP violation beyond the Standard Model in the particle world?

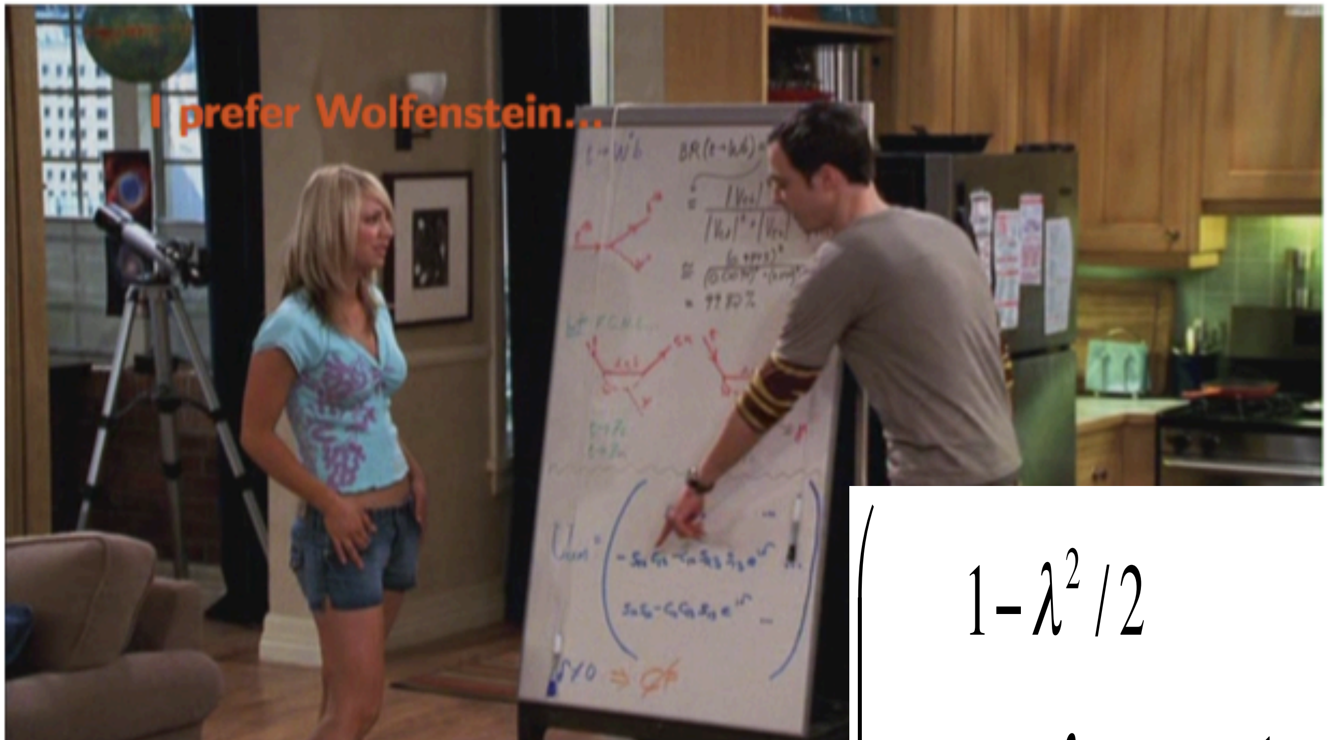
弱作用拉矢量

- 弱作用拉氏量：左手流 $W_\mu \bar{u}\gamma^\mu(1-\gamma^5)d'$
- 质量项： $m_u^2 \bar{u}u + m_d^2 \bar{d}d + \ldots$
- 质量本征态 ≠ 弱作用本征态
- 三代夸克需要**3x3 矩阵（CKM）描写混合**

$$W_\mu \bar{u}_i\gamma^\mu(1-\gamma^5)(V_{CKM})_{ij}d_j$$

The CKM (Cabibbo·Kobayashi·Maskawa) matrix

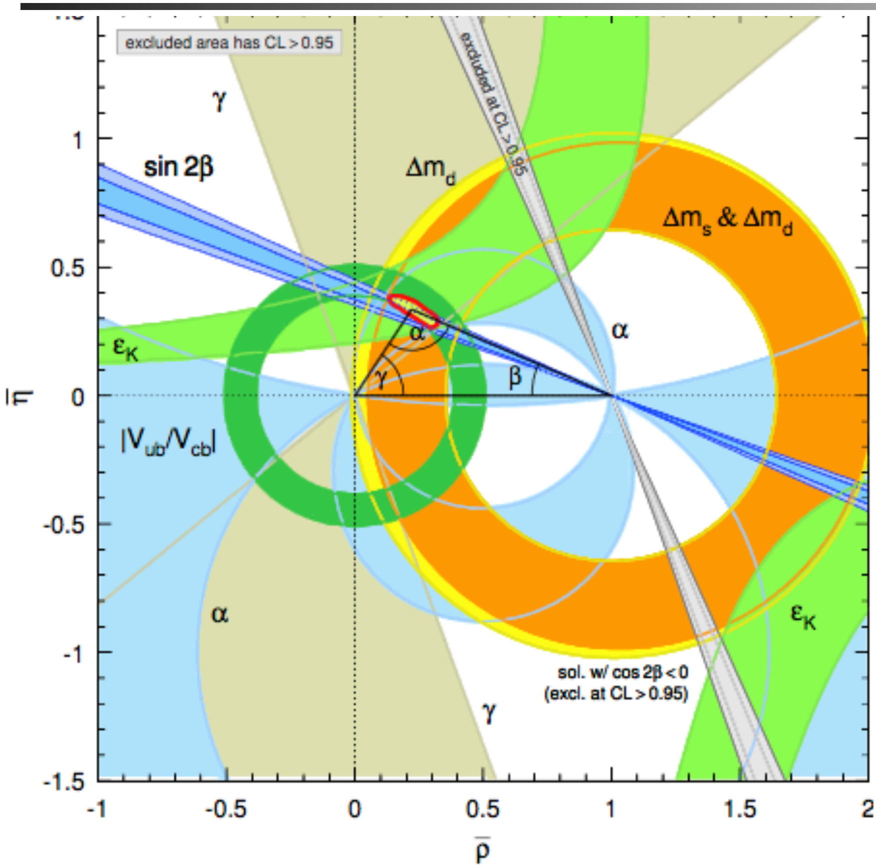
Another possible parametrisations (Chau and Keung parametrisation, adopted by PDG):



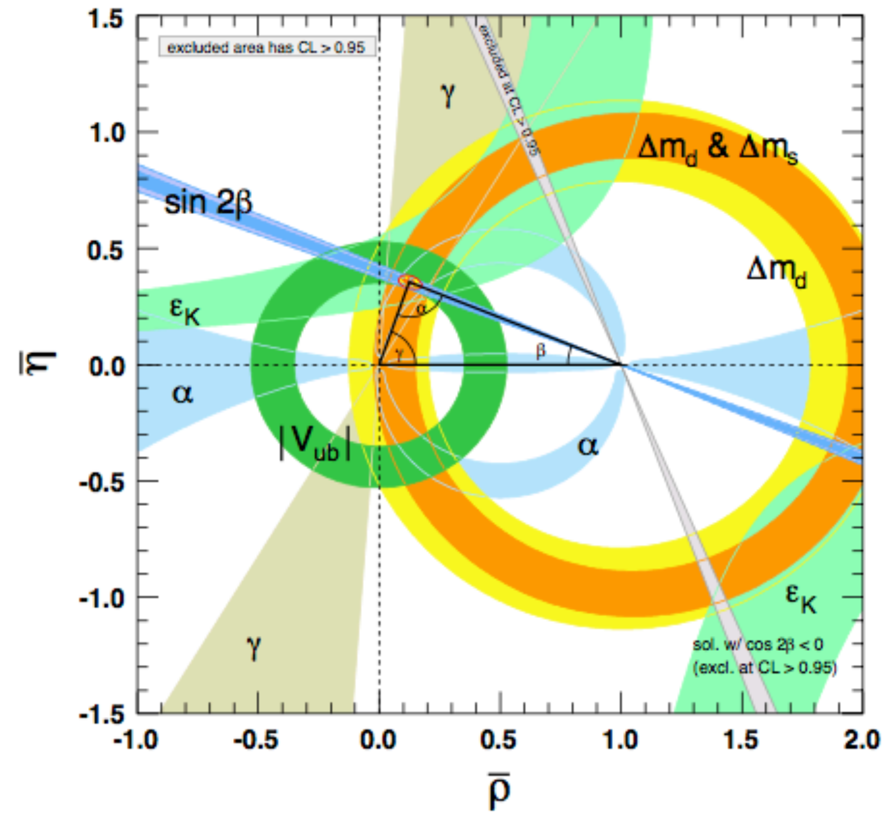
$$
\begin{pmatrix}
1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\
-\lambda & 1-\lambda^2/2 & A\lambda^2 \\
A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1
\end{pmatrix}
$$

科大

PDG2006 & 2016 Unitarity Triangle Comparison



2006



2016

CP破坏 的“重要意义”

- 沟通文明世界
- 在互相访问之前，应该首先搞清楚是否互为反物质 —非常重要
- 正反粒子的定义，以及电荷和左右的定义都是相对的
- 通过CP破坏才可以定义：

$$\frac{\Gamma(K_L \to \pi^- \mu^+ \nu) - \Gamma(K_L \to \pi^+ \mu^- \overline{\nu})}{\Gamma(K_L \to \pi^- \mu^+ \nu) + \Gamma(K_L \to \pi^+ \mu^- \overline{\nu})} = (0.64 \pm 0.08)\%$$

Flavor anomalies

$\sim 3.5\sigma$	$(g-2)_\mu$ anomaly	
$\sim 3.5\sigma$	non-standard like-sign dimuon charge asymmetry	
$\sim 3.5\sigma$	enhanced $B \to D^{(*)}\tau\nu$ rates	$R_{D^{(*)}}$
$\sim 3.5\sigma$	suppressed branching ratio of $B_s \to \phi\mu^+\mu^-$	
$\sim 3\sigma$	tension between inclusive and exclusive determination of $\lvert V_{ub}\rvert$	
$\sim 3\sigma$	tension between inclusive and exclusive determination of $\lvert V_{cb}\rvert$	
$2-3\sigma$	anomaly in $B \to K^*\mu^+\mu^-$ angular distributions	P_5'
$2-3\sigma$	SM prediction for ϵ'/ϵ below experimental result	
$\sim 2.5\sigma$	lepton flavor non-universality in $B \to K\mu^+\mu^-$ vs. $B \to Ke^+e^-$	R_K
$\sim 2.5\sigma$	non-zero $h \to \tau\mu$	

Wolfgang Altmannshofer (UC) | Theoretical Advances in Flavor Physics | January 14, 2016 | 18 / 34

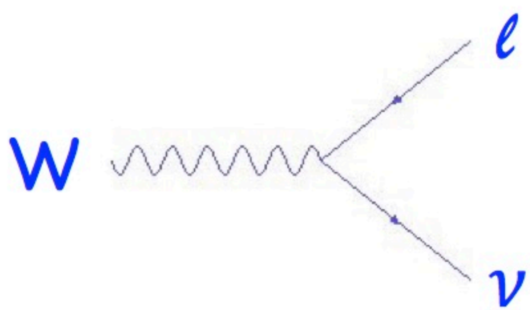
(Wolfgang Altmannshofer, Aspen Winter Conference on Particle Physics 2016)

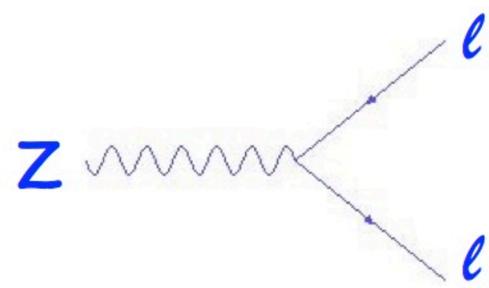
轻子－普适性

- 一个自然的问题是，弱相互作用耦合常数是否对所有的费米子都是一样的？或者说，是否所有的夸克和轻子都带有相同的弱作用的荷？
- 早期的实验答案是：对轻子来说，有普适性。强子（夸克）则没有。
- 对于纯轻子相互作用来说，例如，μ子和τ子的衰变。它们都是通过W粒子传播的短程相互作用。作用强度正比于费米耦合常数$G_F \sim g^2 / M_W^2$
- 因为弱耦合常数g是没有量纲的。因而费米常数就有质量量纲的$^{-2}$

Lepton Universality

- lepton couplings to gauge bosons in the SM are all the same
- very well tested, PDB averages:





$$\frac{B(W^+ \to \mu^+\nu)}{B(W^+ \to e^+\nu)} = 0.991 \pm 0.018$$

$$\frac{B(W^+ \to \tau^+\nu)}{B(W^+ \to e^+\nu)} = 1.043 \pm 0.024$$

$$\frac{B(W^+ \to \tau^+\nu)}{B(W^+ \to \mu^+\nu)} = 1.070 \pm 0.026$$

$$\frac{B(Z \to \mu^+\mu^-)}{B(Z \to e^+e^-)} = 1.0009 \pm 0.0028$$

$$\frac{B(Z \to \tau^+\tau^-)}{B(Z \to e^+e^-)} = 1.0019 \pm 0.0032$$

.9977 (SM)

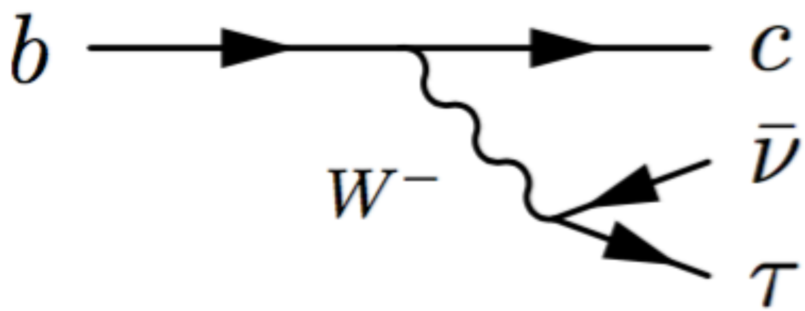
$\bar{B} \to D^{(*)}\tau\bar{\nu}$ Br ~ 0.7+1.3 % in the SM

Not rare, but two or more missing neutrinos

Data available since 2007 (Belle, BABAR, LHCb)

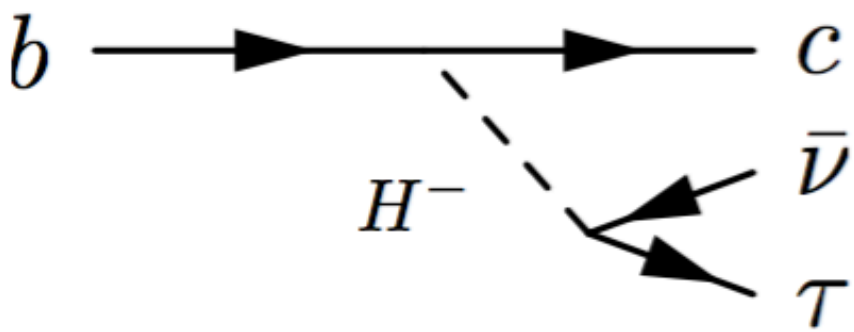
Theoretical motivation

W.S. Hou and B. Grzadkowski (1992)



SM: gauge coupling

lepton universality



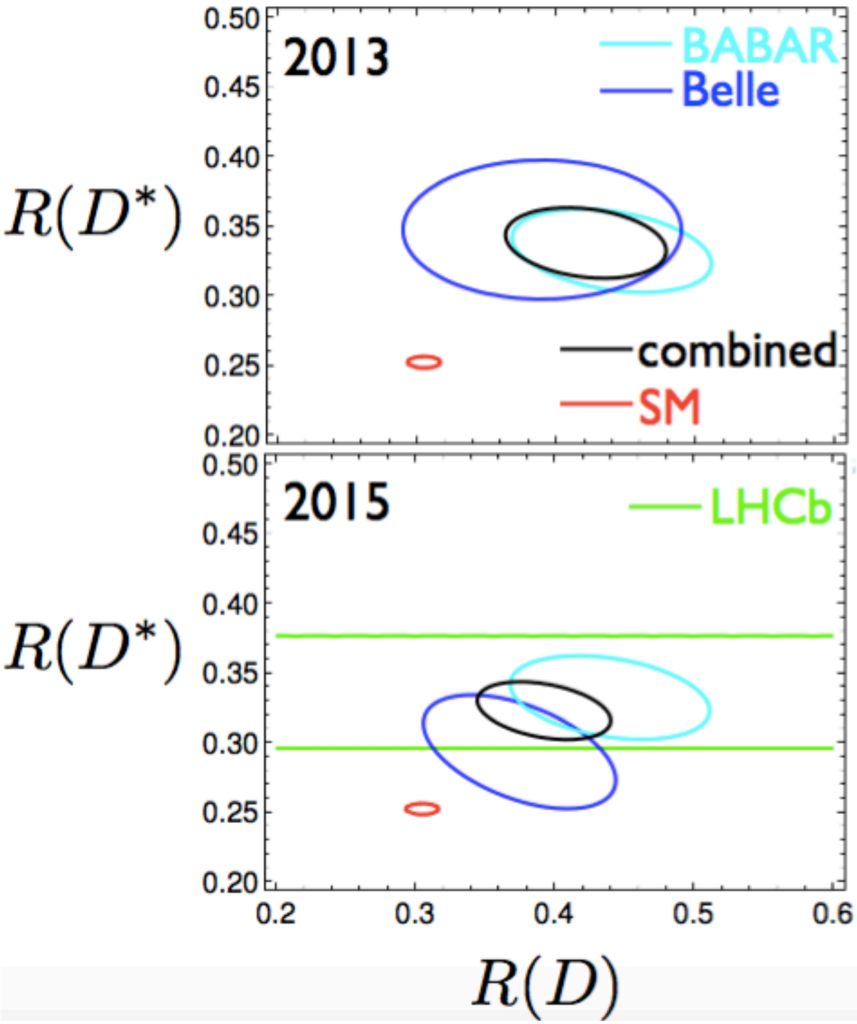
Type-II 2HDM (SUSY)

Yukawa coupling

$\propto m_b m_\tau \tan^2\beta$

Enhanced $B \to D^{(*)}\tau\nu$ decay rates

Experiments



$$R(X) = \frac{\Gamma(B \to X\tau\bar{\nu})}{\Gamma(B \to X(e/\mu)\bar{\nu})}$$

$$R(D) = 0.421 \pm 0.058$$
$$R(D^*) = 0.337 \pm 0.025$$

~3.5σ

Y. Sakaki, MT, A. Tayduganov, R. Watanabe

$$R(D) = 0.391 \pm 0.041 \pm 0.028$$
$$R(D^*) = 0.322 \pm 0.018 \pm 0.012$$

~3.9σ **HFAG**

Standard model predictions

Theoretical uncertainty: form factors

data from $\bar{B} \to D^{(*)}\ell\bar{\nu}$ $(\ell = e, \mu)$

+ HQET or pQCD

+ lattice QCD

$R(D) = 0.296 \pm 0.016$ (Fajfer, Kamenik, Nisandzic)

0.302 ± 0.015 (Sakaki, MT, Tayduganov, Watanabe)

0.299 ± 0.011 (Bailey et al.)

$0.337^{+0.038}_{-0.037}$ (Fan, Xiao, Wang, Li)

$0.391 \pm 0.041 \pm 0.028$ (Exp. HFAG)

$R(D^*) = 0.252 \pm 0.003$ (Fajfer, Kamenik, Nisandzic)

0.252 ± 0.004 (Sakaki, MT, Tayduganov, Watanabe)

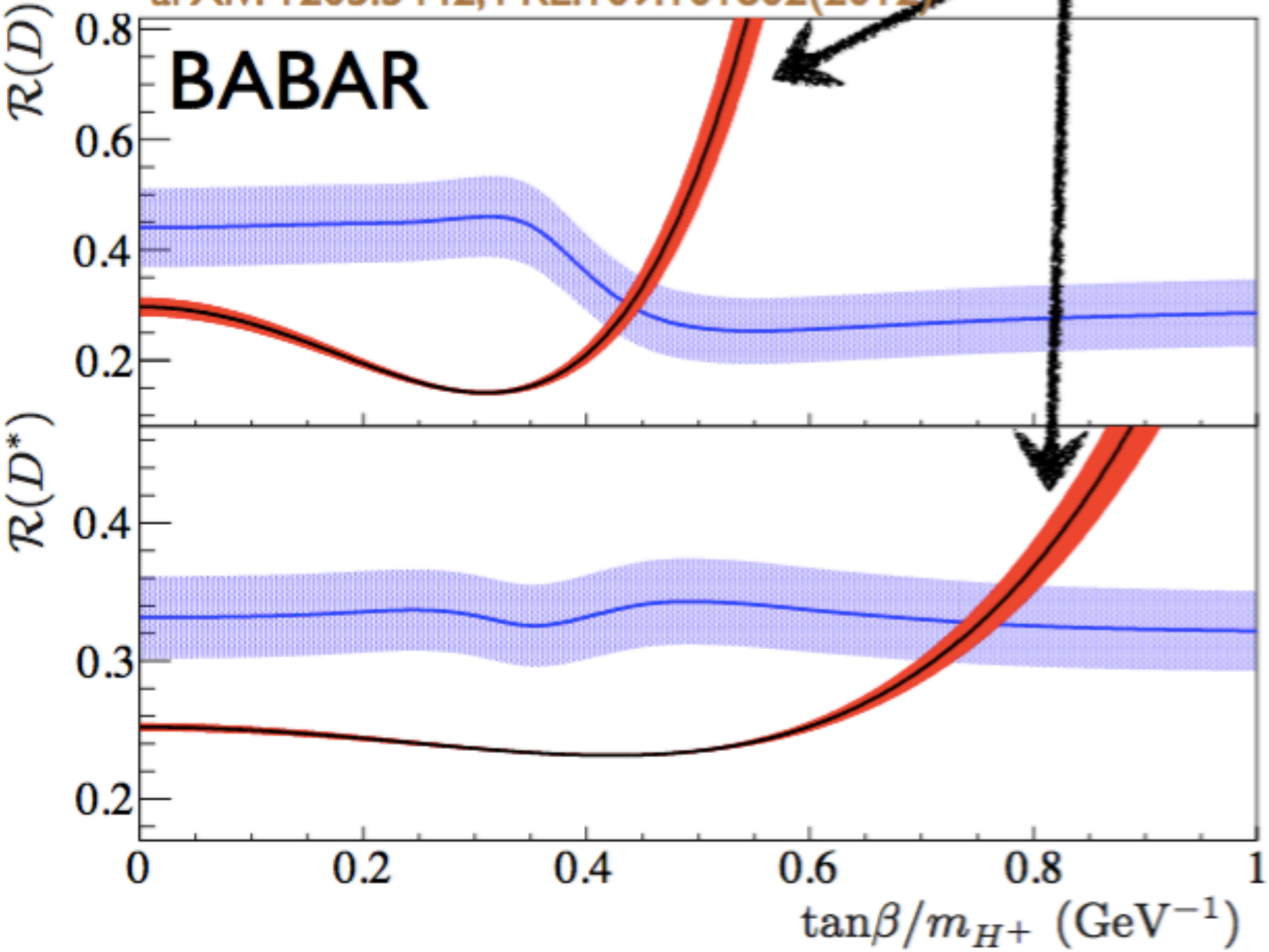
$0.269^{+0.021}_{-0.020}$ (Fan, Xiao, Wang, Li)

$0.322 \pm 0.018 \pm 0.012$ (Exp. HFAG)

Charged Higgs boson

predictions of 2HDM II

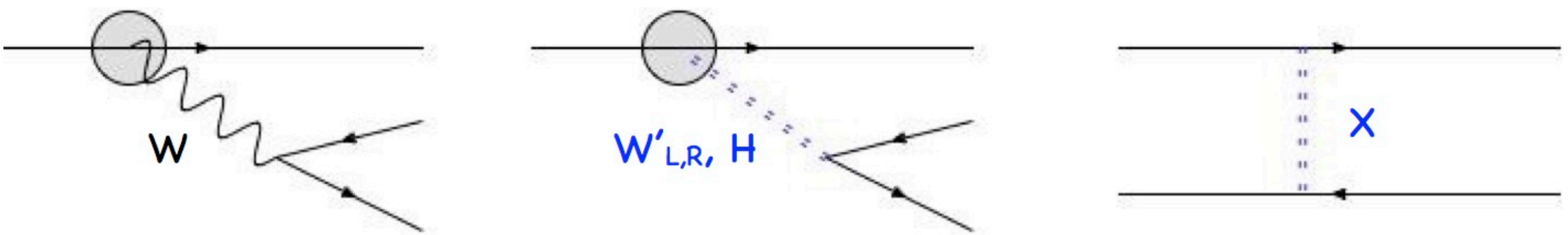
arXiv: 1205.5442, PRL.109.101802(2012)



Charged Higgs *excluded* at 99.8% CL

first surprise in b → c τ ν

- apparently the τ has a stronger coupling
- at tree level, several possible other couplings



- new W gauge boson with non-universal couplings (our model W_R)
- leptoquark - need very specific flavour structure
- charged Higgs, seems a natural explanation but the simple models do not work

Nothing seen in other meson decay

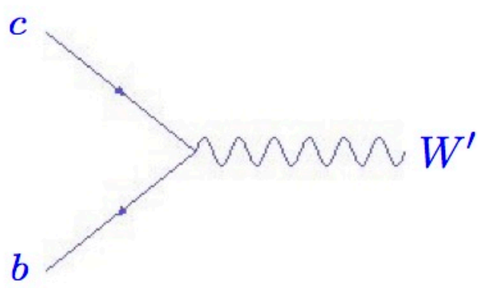
	Exp. (PDB)	SM
$\frac{B(K^+ \to \pi^0 \mu^+ \nu)}{B(K^+ \to \pi^0 e^+ \nu)}$	0.6608±0.0029	0.6631±0.0042 (Cirigliano et al)
$\frac{B(K^+ \to e^+ \nu)}{B(K^+ \to \mu^+ \nu)}$	2.488±0.009(10^{-5})	2.477±0.001 (10^{-5}) (Cirigliano et al)
$\frac{B(\pi^+ \to e^+ \nu(\gamma))}{B(\pi^+ \to \mu^+ \nu(\gamma))}$	1.2327±0.0023(10^{-4})	1.2352±0.0005(10^{-4}) (Marciano, Sirlin)

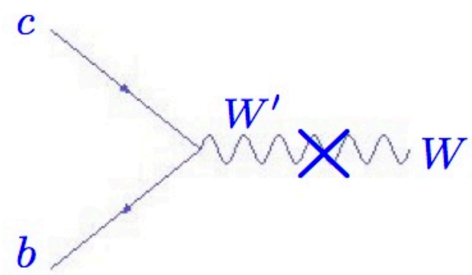
- no simple models
- need to arrange the flavour structure to single out this family: b, τ

- Very large new-physics effect, considering these are CKM -favored decay modes occurring at tree level in the SM
- SM gauge interactions do not distinguish between lepton generations
- Phase-space differences due to large τ mass taken into account
- Different form factors contribute when the final-state lepton is massive, but their contributions are suppressed by $(m_\tau/m_B)^2$ and constrained by heavy-quark symmetry (uncertainties enter only in power corrections)
- SM prediction **rather clean**, but worthwhile to keep improving it!

W′ and semileptonic B decay to tau

quark sector





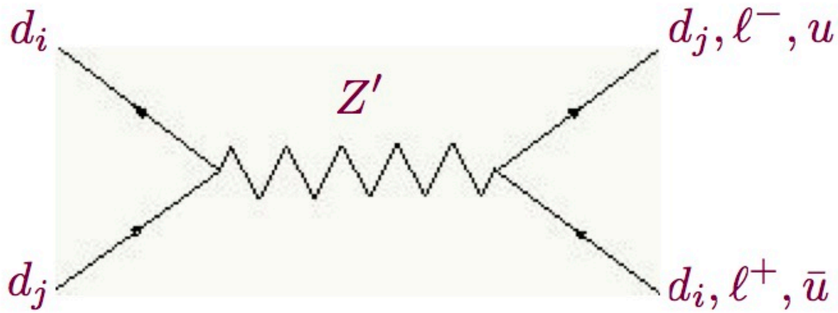
$$
\begin{aligned}
\mathcal{L}_W \quad = \quad & -\frac{g_L}{\sqrt{2}} \bar{U}_L \gamma^\mu V_{KM} D_L (\cos\xi_W W_\mu^+ - \sin\xi_W W_\mu^{\prime +}) \\
& -\frac{g_R}{\sqrt{2}} \bar{U}_R \gamma^\mu V_R D_R (\sin\xi_W W_\mu^+ + \cos\xi_W W_\mu^{\prime +}) \; + \; \text{h. c.},
\end{aligned}
$$

- two (sets) of parameters come into play
- mixing between W and W′
- right handed analog of CKM matrix

previously worked out constraints

*HFAG-2012

*From $b \to s\gamma$ = $(3.55 \pm 0.25) \times 10^{-4}$ $\quad -0.0013 \le \frac{g_R}{g_L}\xi_W \le 0.0027$



strongest constraints from meson mixing

FCNC constraints can be summarised by $\quad V^d_{Rbi} \sim \delta_{bi}$

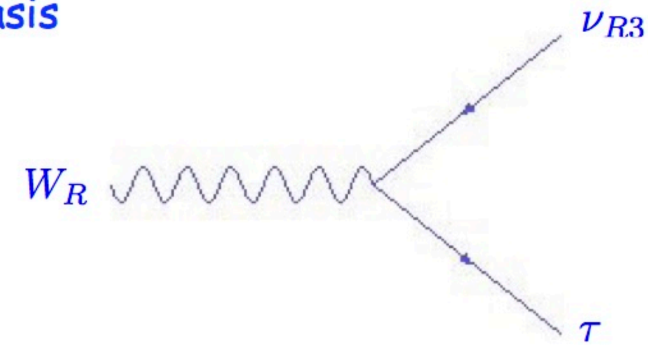
with $\quad V_L^{u,d} = V_R^{u,d},\ V_L^{u\dagger} V_L^d = V_{CKM}$ this allows us to predict

$$V_R = (V_{Rij}) = (V^{u*}_{Rti} V^d_{Rbj}) \qquad V_R \sim \begin{pmatrix} 0 & 0 & A\lambda^3 \\ 0 & 0 & A\lambda^2 \\ 0 & \lambda^4 & 1 \end{pmatrix}$$

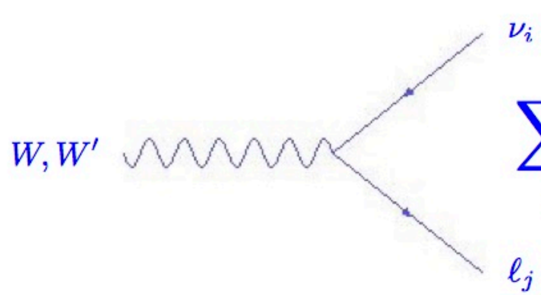
$$V^u_{Rtc} \sim V_{cb}, V^u_{Rtu} \sim V_{ub}$$

W′and semileptonic B decay to tau

lepton sector



- need the new right-handed neutrino to be light
- it is possible to have a scalar sector that gives an acceptable neutrino mass spectrum and mixing



no interference if neutrino mass << charged lepton mass

$$\sum_i |M_{\rm lepton}|^2 \propto \begin{cases} 1 & \text{for } \ell_L \\ |V^\ell_{R3j}|^2 & \text{for } \ell_R. \end{cases} \quad \sim 1 \text{ for } j = \tau$$

rotates RH charged lepton to mass eigenstate

$B \to \tau\ \nu$

CKMfitter

$$B(B^+ \to \tau^+\nu) = \begin{cases} \text{with meas.} & 0.851^{+0.035}_{-0.038} \times 10^{-4} \\ \text{without} & 0.821^{+0.034}_{-0.028} \times 10^{-4} \end{cases}$$

Heavy Flavor Averaging Group - October 2016

Compilation of B^+ and B^0 Leptonic Branching Fractions ($\times 10^{-6}$) - UL at 90% CL

In PDG2014 New since PDG2014 (preliminary) New since PDG2014 (published)

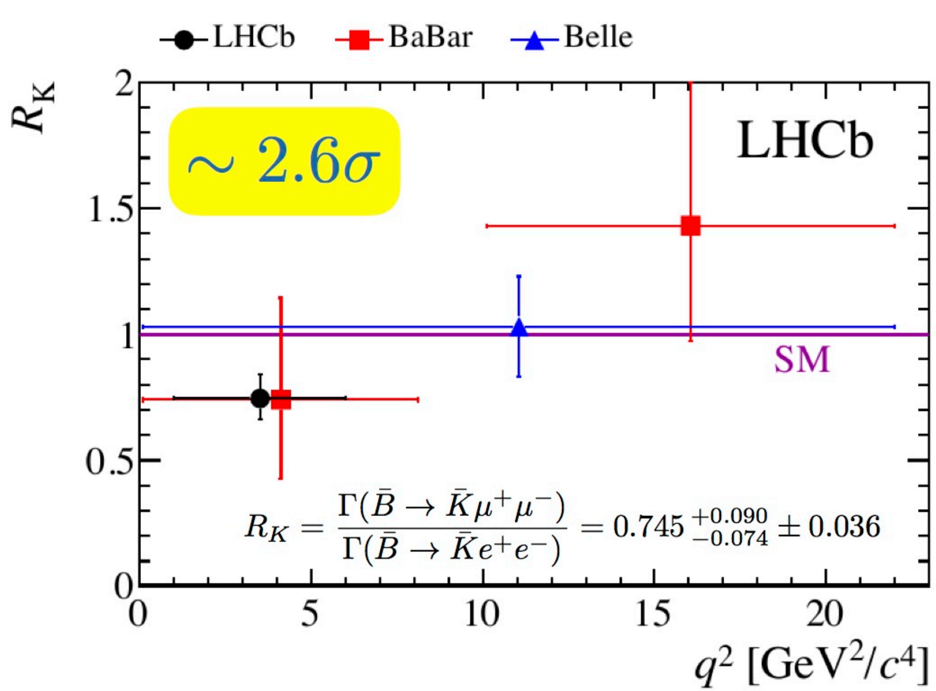
Mode	PDG2014 Avg.	BABAR	Belle
$e^+\nu$	< 0.98	< 1.9	< 0.98 †
$\mu^+\nu$	< 1.0	< 1.0	< 1.7 †
$\tau^+\nu$	114 ± 27	179 ± 48 ‡	$91 \pm 19 \pm 11$ ‡

$$\frac{\Gamma(B^- \to \tau^-\nu)}{\Gamma(B^- \to \tau^-\nu_\tau)_{SM}} = F^u_{W'} - 2\, F^u_{\rm Mix} \quad \sim 1.3 \quad \text{with} \frac{V_{Rub}}{V_{ub}} \sim \frac{V_{Rcb}}{V_{cb}}$$

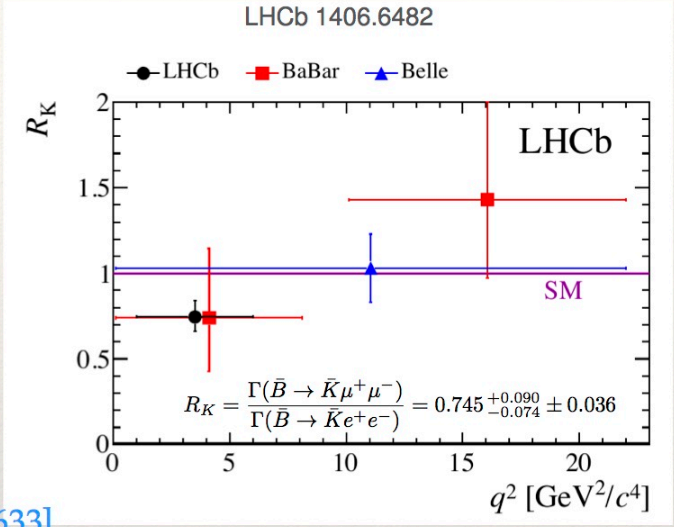
Non-universal B→Kμμ/ee rates

- LHCb observation of a violation of lepton universality in the rare decays B→Kμμ vs. B→Kee — if confirmed — would be the most spectacular LHC discovery after the Higgs boson:

LHCb 1406.6482

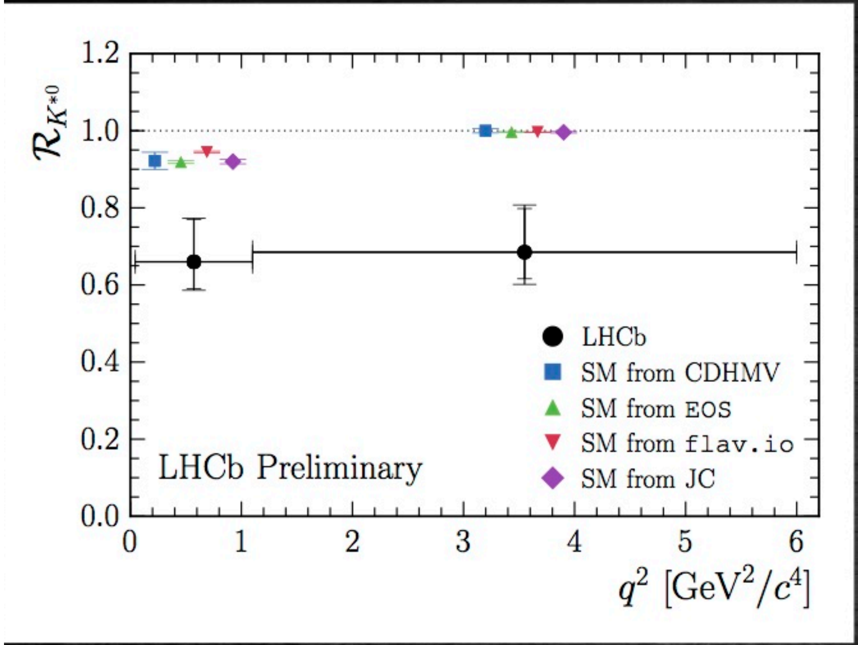


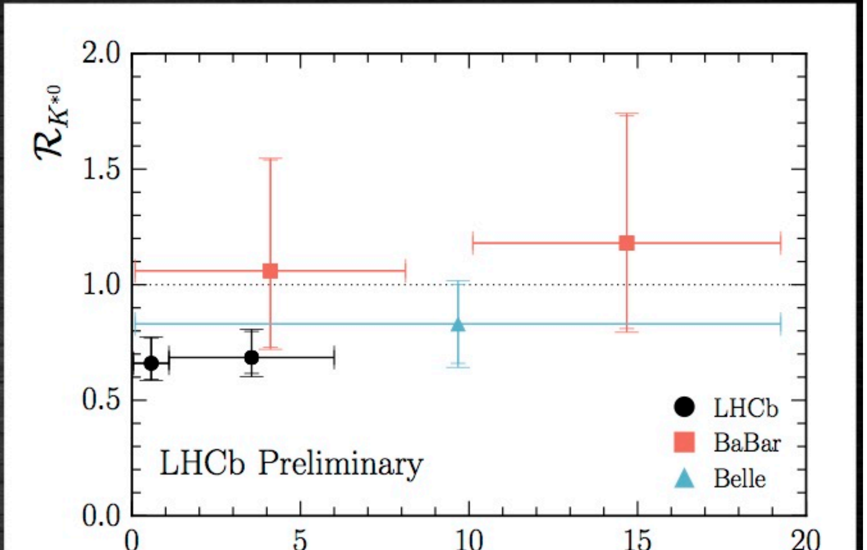
Non-universal B→Kμμ/ee rates



- In SM this ratio equals 1 to high accuracy
- Leading deviations arise from QED corrections, giving rise to large logarithms involving the ratio $m_B/m_{\mu,e}$
- The effects have been estimated and were found to be of O(1%) [Bordone, Isidori, Pattori: 1605.07633]
- SM prediction **very clean**!
- Eagerly awaiting an update from LHCb (electron reconstruction efficiency is rather different from that for muons)…
- Teaser on R_{K^*} (but no results yet) presented by LHCb at Moriond-EW

Results – II





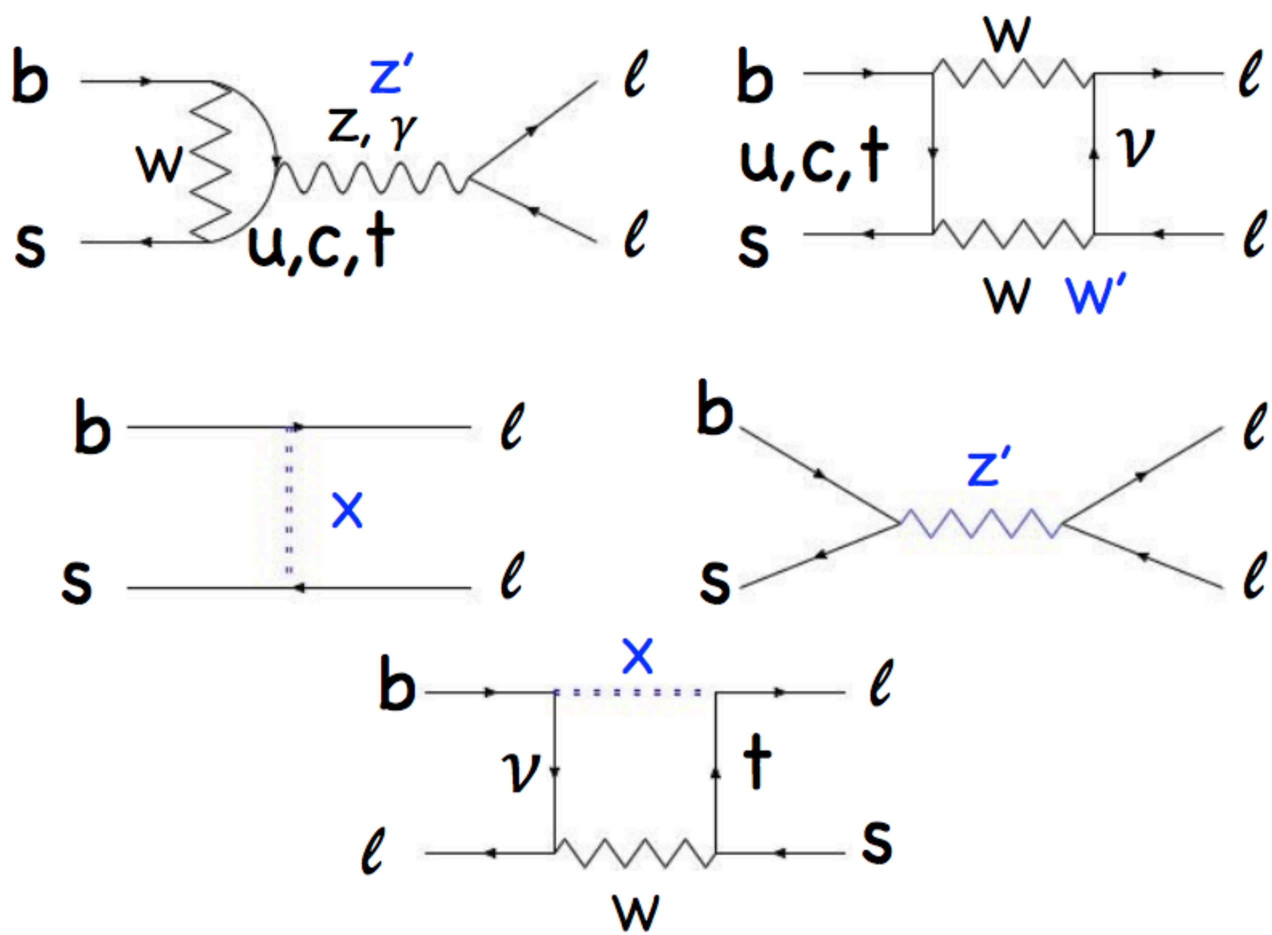
- PRD 86 (2012) 032012
- PRL 103 (2009) 171801

› The compatibility of the result in the **low-q²** with respect to the SM prediction(s) is of **2.2-2.4** standard deviations

› The compatibility of the result in the **central-q²** with respect to the SM prediction(s) is of **2.4-2.5** standard deviations

second surprise in b→ s *l*+*l*-

apparently the μ has a weaker coupling than the electron at tree and loop level, many possible other NP couplings



Flavour anomalies and New Physics

If confirmed by future analyses, what does this point to?

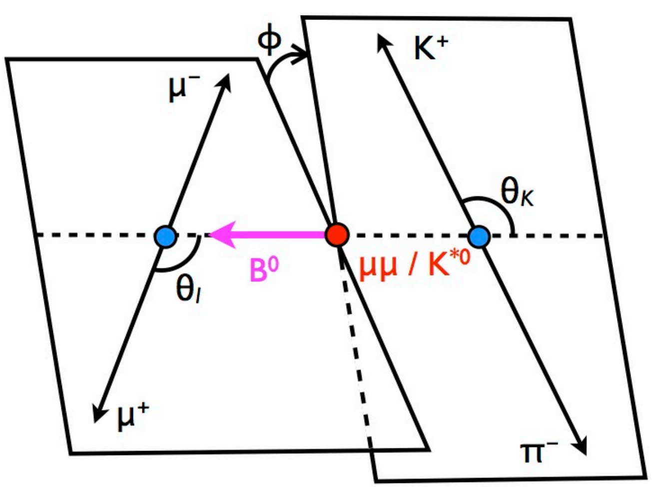
$$R_{D^{(*)}} \Leftrightarrow \tau \neq e, \mu \qquad\qquad R_K \Leftrightarrow \mu \neq e$$

SM gauge interactions do not distinguish between different leptons, and Higgs exchange is irrelevant; hence need new particles beyond the SM with new types of interactions

- $U(1)_{\tau-\mu}$ → new Z' boson coupling with opposite sign to μ/τ
- New particles with Yukawa-like interactions, leptoquarks (better: lepto-quark-bosons)

Angular analysis of B→K*μμ decays

- Rare B→K*μμ decays offer a rich laboratory for new-physics searches via differential angular distributions as a functions of lepton invariant mass:



$$\frac{1}{d\Gamma/dq^2}\frac{d^4\Gamma}{dq^2 d\cos\theta_l d\cos\theta_K d\phi}$$

S-wave and S&P-wave interference

$$= \frac{9}{8\pi}\left\{\frac{2}{3}\left[(F_S + A_S\cos\theta_K)(1-\cos^2\theta_l) + A_S^5\sqrt{1-\cos^2\theta_K}\sqrt{1-\cos^2\theta_l}\cos\phi\right] + (1-F_S)\left[2F_L\cos^2\theta_K(1-\cos^2\theta_l) + \frac{1}{2}(1-F_L)(1-\cos^2\theta_K)(1+\cos^2\theta_l) + \frac{1}{2}P_1(1-F_L)(1-\cos^2\theta_K)(1-\cos^2\theta_l)\cos 2\phi + 2P_5'\cos\theta_K\sqrt{F_L(1-F_L)}\sqrt{1-\cos^2\theta_K}\sqrt{1-\cos^2\theta_l}\cos\phi\right]\right\}$$

P-wave

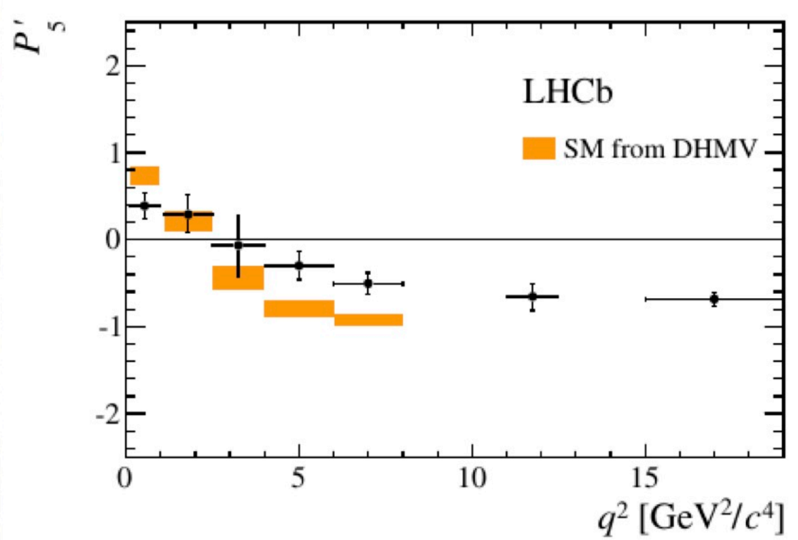
Angular analysis of $B \to K^* \mu\mu$ decays

- It is useful to construct observables which are less sensitive for hadronic uncertainties related to form factors

[Descotes-Genon, Matias, Ramon, Virto: 1207.2753]

- One particular such observable — called P_5' — shows a large discrepancy with the SM prediction in a particular q^2 range:

LHCb 1512.04442



2.8σ deviation in q^2 bin between [4, 6] GeV^2
(3.0σ in bin [6, 8] GeV^2)

Global fits

- from J. Matias, Moriond EW 2017:

Global analysis of $b \to s\mu\mu$ anomalies

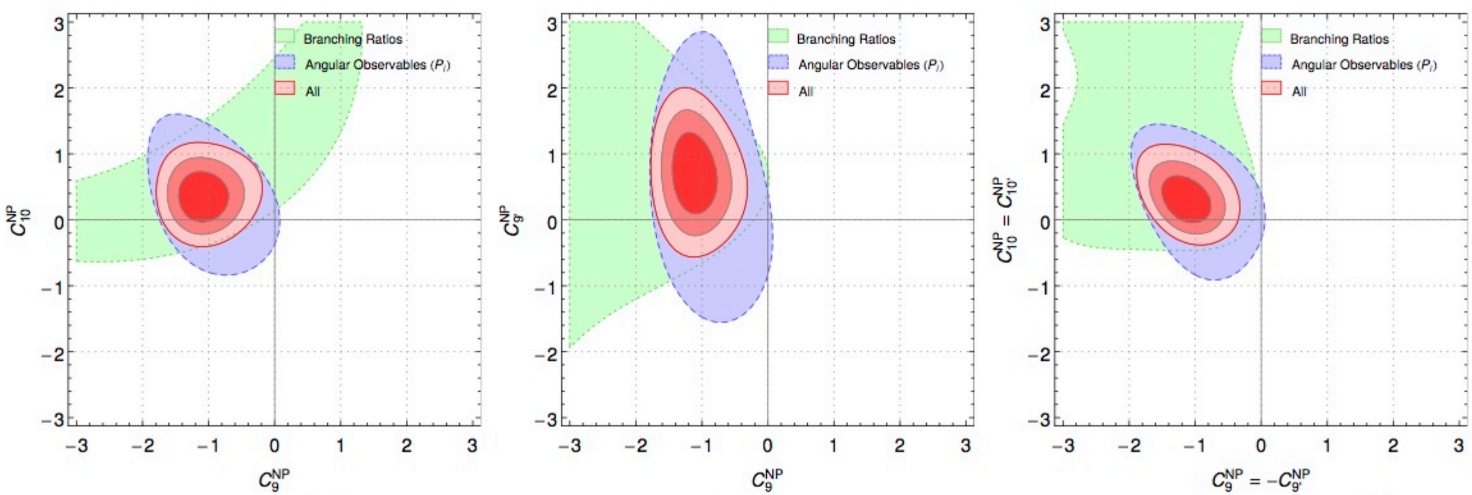
[Descotes, Hofer, JM, Virto]

96 observables in total (LHCb for exclusive, no CP-violating obs)

- $B \to K^*\mu\mu$ ($P_{1,2}$, $P'_{4,5,6,8}$, F_L in 5 large-recoil bins + 1 low-recoil bin)+available electronic observables.
- $B_s \to \phi\mu\mu$ (P_1, $P'_{4,6}$, F_L in 3 large-recoil bins + 1 low-recoil bin)
- $B^+ \to K^+\mu\mu$, $B^0 \to K^0\ell\ell$ (BR) ($\ell = e, \mu$)
- $B \to X_s\gamma$, $B \to X_s\mu\mu$, $B_s \to \mu\mu$ (BR), $B \to K^*\gamma$ (A_I and $S_{K^*\gamma}$)

Beyond 1D several favoured scenarios

Allowing for more than one Wilson coefficient to vary different scenarios with pull-SM beyond 4σ pop-up:



(C_9, C_{10}) (C_9, C'_9) ($C_9 = -C'_9$ & $C_{10} = C'_{10}$)

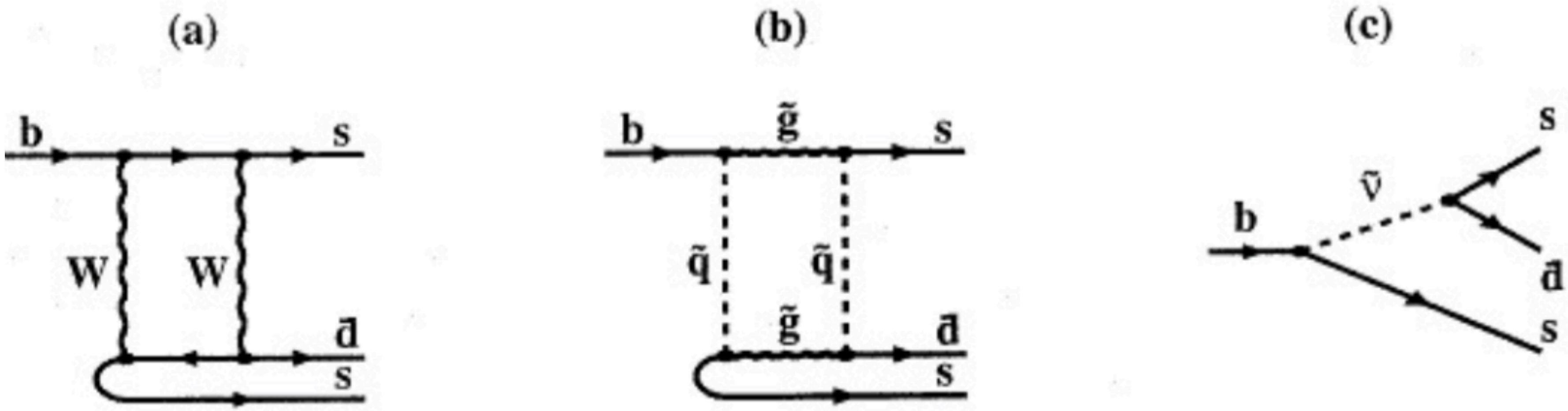
- BR and angular observables both favour $C_9^{\rm NP} \simeq -1$ in all 'good scenarios'.

best 2 parameter fit

- looks like fits prefer left-handed structure
- –previous model not favoured in this case?
- –tree-level FCNC are right-handed
- –one loop corrections of electroweak strength are left-handed also, could give the right size
- –full model is very complicated and would need a multi (>2) C_i fit
- another non-universal Z’ that is left handed

Search for new physics in hadronic B decays-1example

K. Huitu, C.D. Lü, P. Singer D.X. Zhang, **Phys. Rev. Lett. 81, 4313 (1998), hep-ph/9809566.**



$b \to s s \bar{d}$ transition (a) SM, (b) MSSM, (c) MSSM with R-parity violating coupling

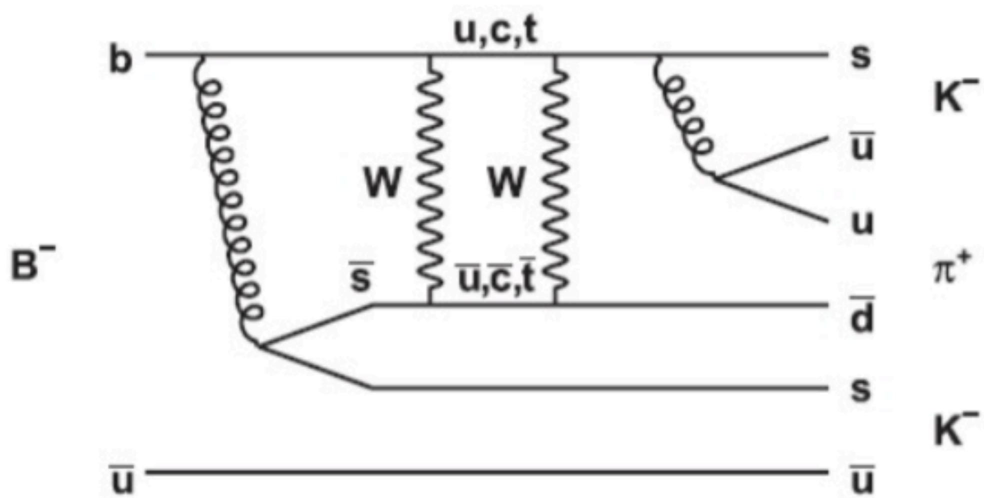
SM BRs: ~ 10^{-14},

Some New physics can reach 10^{-6}

Experimental search starting from OPAL @ LEP, phys. Lett. B 476 (2000) 233, later searched also by Belle/Babar

BABAR collaboration, Phys. Rev. D 78 (2008) 091102 [arXiv:0808.0900]

A search for the decay $B^- \to K^- K^- \pi^+$, Using a sample of $(467 \pm 5) \times 10^6$ $B\overline{B}$ pairs collected with the BABAR detector.



Result : No evidence for these decays was found and a upper limit was set as

$$\mathcal{B}(B^- \to K^- K^- \pi^+) < 1.6 \times 10^{-7}$$

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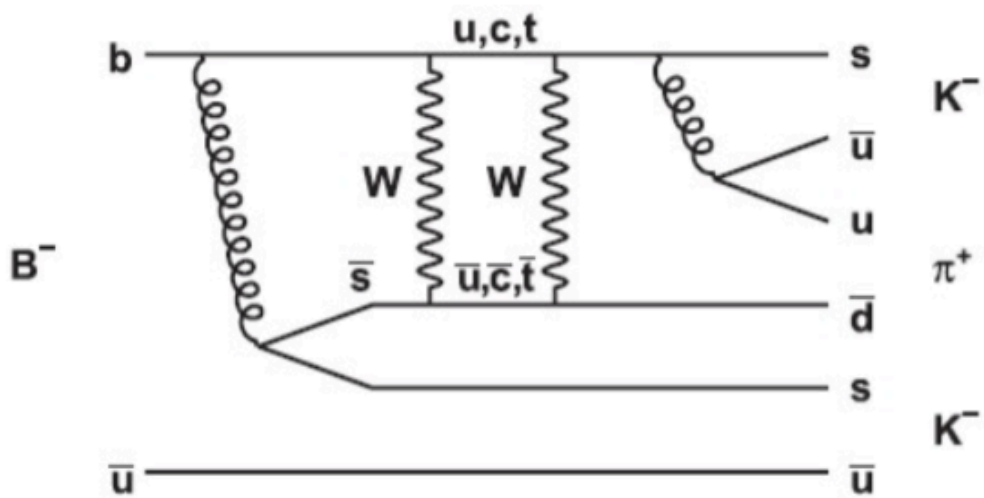

Similar channel $B^- \to \pi^- \pi^- K^+$

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Recent LHCb result:

Physics Letters B 765 (2017) 307–316

$$\mathcal{B}(B^+ \to K^+K^+\pi^-) < 1.1 \times 10^{-8}$$

$$\mathcal{B}(B^+ \to \pi^+\pi^+K^-) < 4.6 \times 10^{-8}.$$

Recent theoretical results in Randall-Sundrum model:

Chinese Physics C41 (2017) 053106

Br(b→ss d-bar) can reach to 10^{-10}

Summary

- No new physics so far at high energy at LHC
- B physics at LHCb combined with previous B factory results is slowly uncovering a conflict with SM
- **Flavor sector has only been tested at the 10% level and can be done much better**
- The pattern is not obvious, and the deviation from SM is large (> 5) when quantified by a global fit to many observables
- **We are still waiting for a clear New physics signal in the heavy flavor sector**

谢谢！