Recent BaBar highlights on B-meson physics

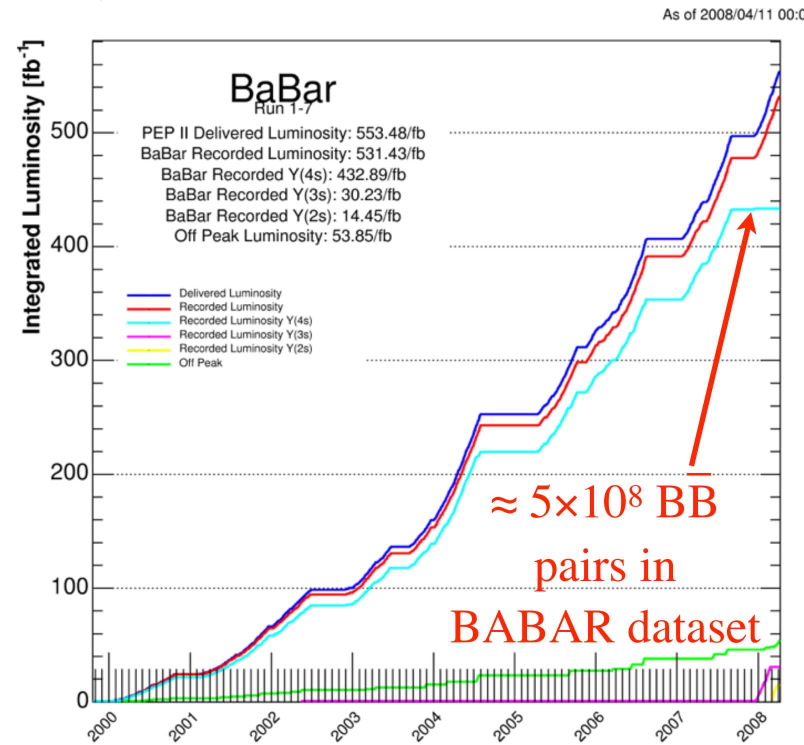
Yury Kolomensky
UC Berkeley/LBNL

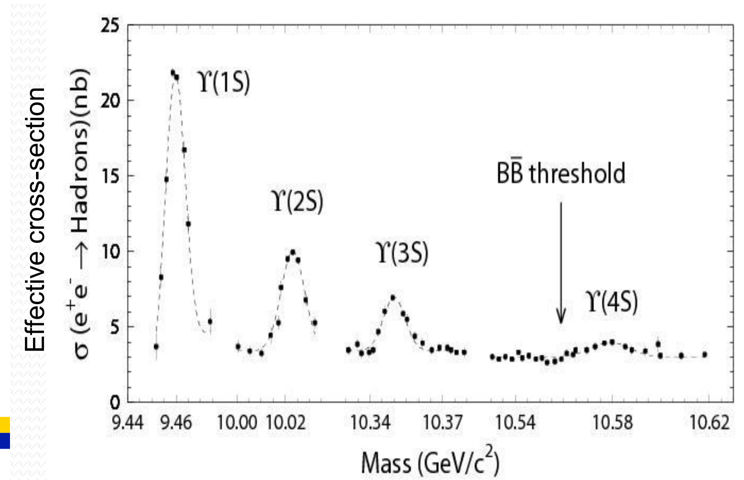
For the BABAR Collaboration

XXXth International Workshop
on High Energy Physics
Protvino, June 24, 2014

Recent Results from BABAR

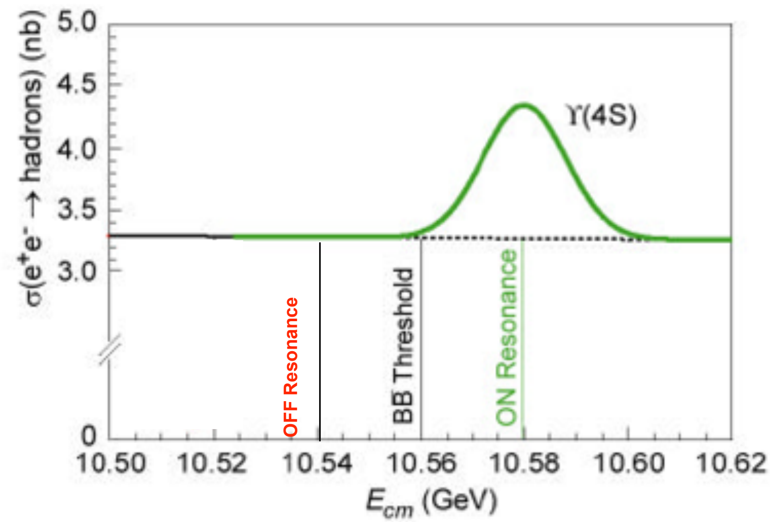
- BaBar still produces a lot of results
  - ☞ 531 published papers and counting
- Rare decays and symmetry violations: complementary to the LHC
- Most recent highlights:
  - ❑ Probes of New Physics in Penguin Decays
  - ❑ Lepton Number Violation
  - ❑ CP Violation in $B^+ \to K_S \pi^+ \pi^0$

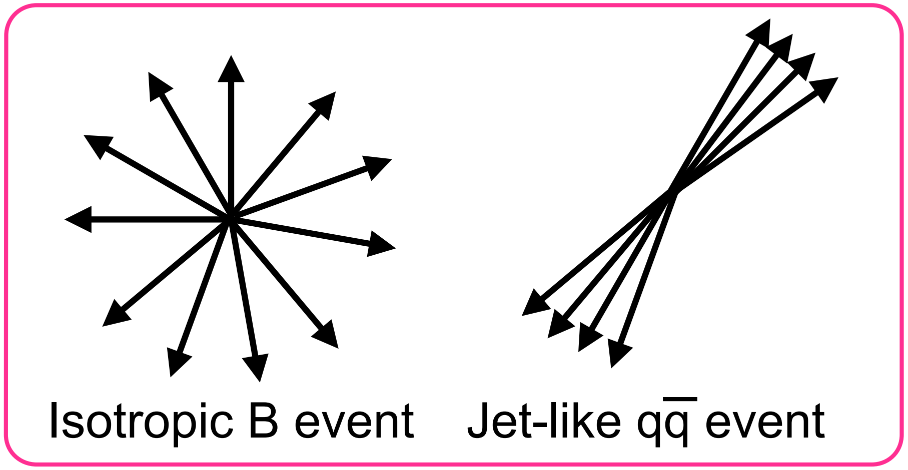




Analysis Techniques at B Factories

- B decay data collected at $\Upsilon(4S)$ resonance
  - Near threshold: spherically symmetric
- Largest background from "continuum" QED udsc production
  - "Jetty" events
- Discriminate using topological "event shape" variables
  - Measure in "off-resonance" data

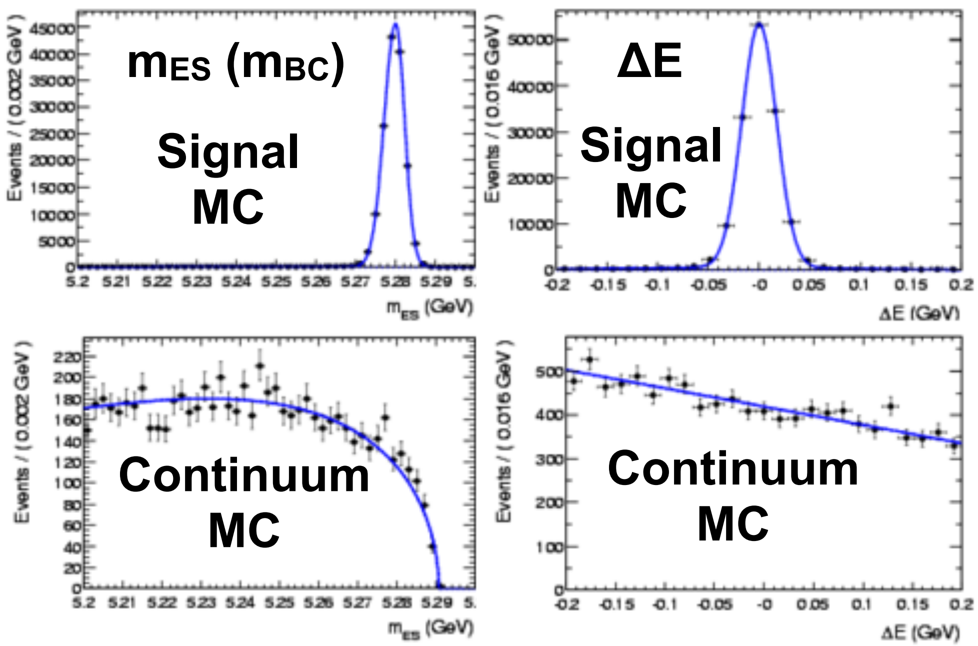




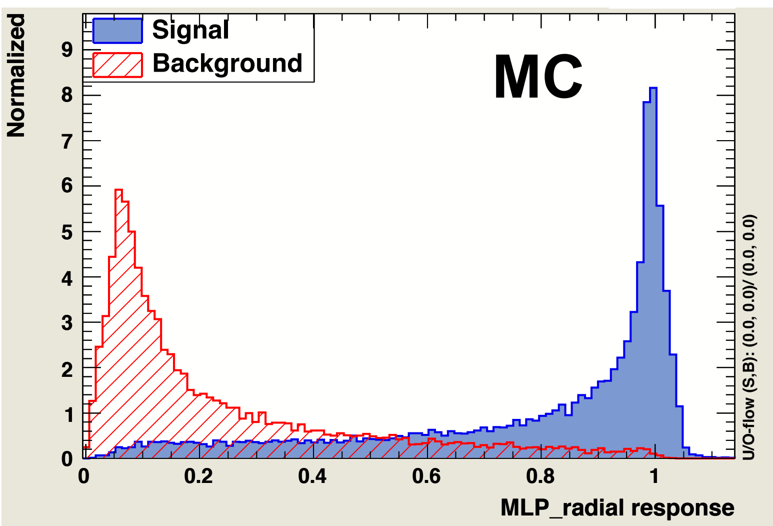
Analysis Techniques at B Factories

- Multi-variate discriminating techniques common
  - ☞ Fisher, Likelihood, BDT, ANN, …
- Precise kinematic discrimination: m_{ES} and ΔE
- Multivariate max likelihood fits to extract parameters of interest

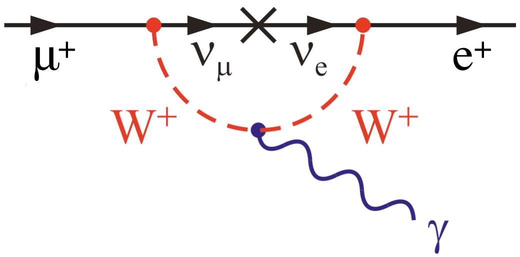
$$m_{ES(BC)} = \sqrt{E^{*2}_{\text{beam}} - p^{*2}_{B}} \qquad \Delta E = E^{*}_{B} - E^{*}_{beam}$$

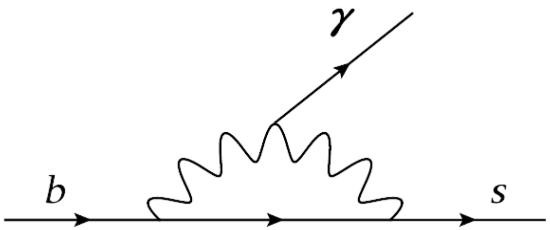


Example MVA

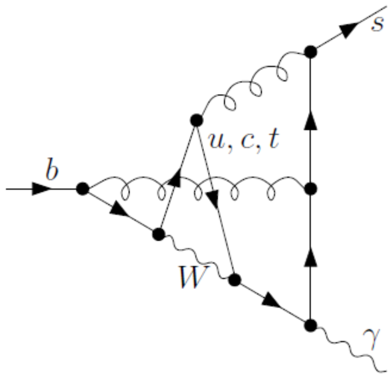


Flavor Changing Neutral Currents



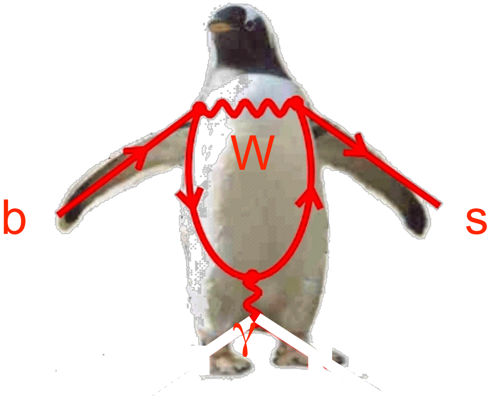


- FCNC: precision test of the Standard Model
  - For example μ→eγ
    - ☞ Sensitive to lepton mass differences in SM
  - Heavy quark transitions: b→sγ
    - ☞ Sensitive to effective quark mass differences
    - ☞ Rates and spectra: precision test of QCD
    - ☞ CP Asymmetry: sensitivity to New Physics



Semi-inclusive Measurement of b→sγ CP Asymmetry

arXiv:1406.0534, submitted to PRD
(Preliminary)



Semi-inclusive Measurement of b→sγ

- Reconstruct $B \to X_s \gamma$ decays in 16 exclusive final states

Final State
$B^+ \to K_S \pi^+ \gamma$
$B^+ \to K^+ \pi^0 \gamma$
$B^0 \to K^+ \pi^- \gamma$
$B^+ \to K^+ \pi^+ \pi^- \gamma$
$B^+ \to K_S \pi^+ \pi^0 \gamma$
$B^+ \to K^+ \pi^0 \pi^0 \gamma$
$B^0 \to K^+ \pi^- \pi^0 \gamma$
$B^+ \to K_S \pi^+ \pi^- \pi^+ \gamma$
$B^+ \to K^+ \pi^+ \pi^- \pi^0 \gamma$
$B^+ \to K_S \pi^+ \pi^0 \pi^0 \gamma$
$B^0 \to K^+ \pi^+ \pi^- \pi^- \gamma$
$B^0 \to K^+ \pi^- \pi^0 \pi^0 \gamma$
$B^+ \to K^+ \eta(\to \gamma\gamma) \gamma$
$B^0 \to K^+ \eta(\to \gamma\gamma) \pi^- \gamma$
$B^+ \to K^+ K^- K^+ \gamma$
$B^0 \to K^+ K^- K^+ \pi^- \gamma$

Measure Direct CP Asymmetry:

$$A_{CP} = \frac{\Gamma(b \to s\gamma) - \Gamma(\bar{b} \to \bar{s}\gamma)}{\Gamma(b \to s\gamma) + \Gamma(\bar{b} \to \bar{s}\gamma)}$$

Dominated by long-distance effects in SM: prediction $0.6\% < A_{CP} < 2.8\%$

NP loop effects can enhance ACP up to 15% and induce <10% difference between B^+ and B^0

NP B704, 56; PRL 73, 2809; PRD 60, 014003

Semi-inclusive b→sγ: Results

B Sample	$A_{\rm peak}$	D	$A_{\rm det}$	A_{CP}
All B	$+(0.33 \pm 1.87)\%$	$\pm 0.88\%$	$-(1.40 \pm 0.49 \pm 0.51)\%$	$+(1.73 \pm 1.93 \pm 1.02)\%$
Charged B	$+(3.14 \pm 2.86)\%$	$\pm 0.80\%$	$-(1.09 \pm 0.67 \pm 0.51)\%$	$+(4.23 \pm 2.93 \pm 0.95)\%$
Neutral B	$-(2.48 \pm 2.47)\%$	$\pm 0.97\%$	$-(1.74 \pm 0.72 \pm 0.51)\%$	$-(0.74 \pm 2.57 \pm 1.10)\%$

$A_{CP} = (1.7 \pm 1.9 \pm 1.0)\%$

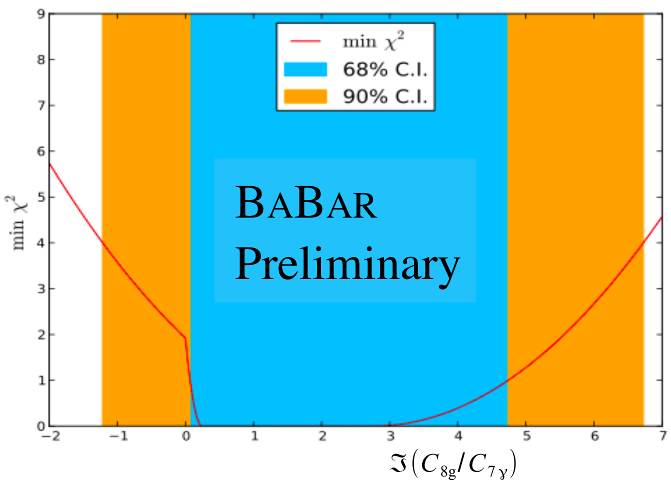
$\Delta A_{X_s\gamma} = (5.0 \pm 3.9 \pm 1.5)\%$

arXiv:1406.0534
(Preliminary)

$$\Delta A_{X_s\gamma} = A_{X_s^-\gamma} - A_{X_s^0\gamma}$$

First Measurement !
In agreement with SM

Systematics dominated by measurements of bkg dilution D and detector asymmetry $A_{\rm det}$



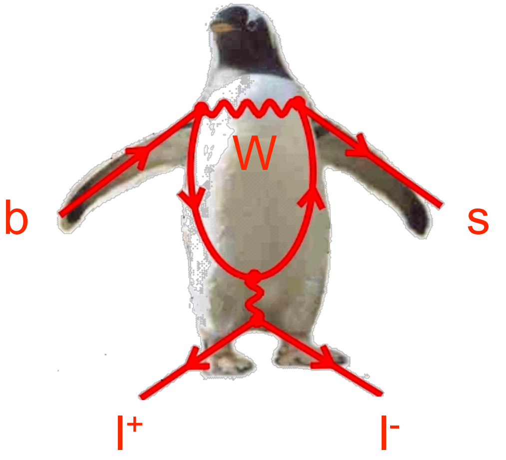
$\Delta A_{X_s\gamma}$ provides limits on a poorly constrained Wilson coefficient C_{8g}:

$$\Im(C_{8g}/C_{7\gamma}) \in [-1.64, 6.52] \text{ @ 90\%CL}$$

PRL 106, 141801; JHEP 1204 008

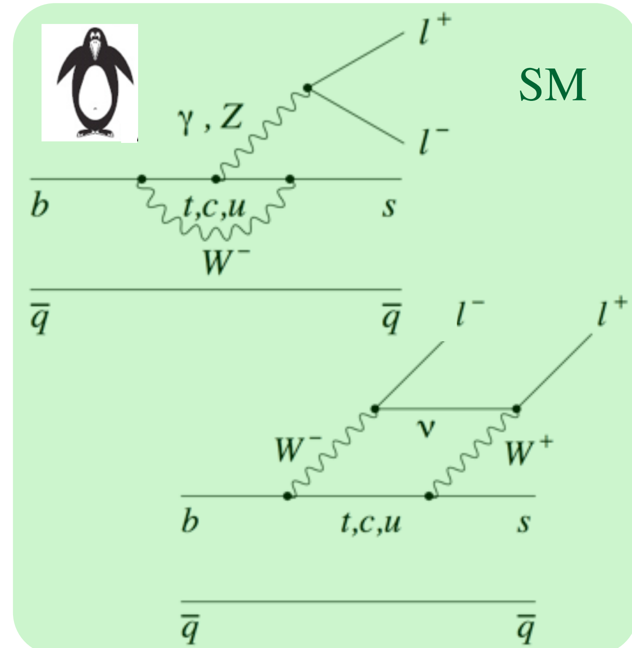
$B \rightarrow X_s\, l^+l^-$ Branching Fraction and Direct CP Asymmetry

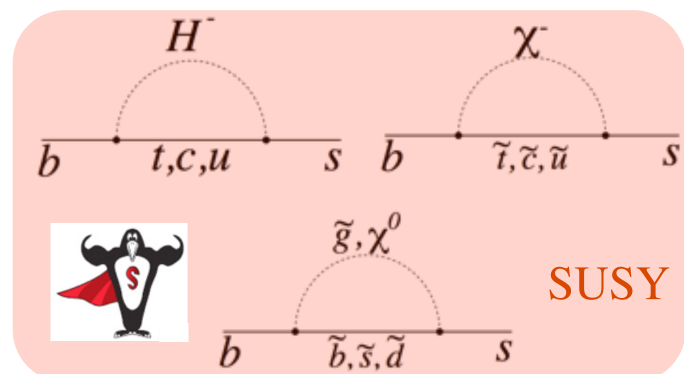
PRL 112, 211902 (2014)



Electroweak Penguins: $B \rightarrow X_s ll$

- FCNC Rare decays (BF ~ 10^{-6})
- Sensitive to TeV-scale physics, e.g. SUSY
  - Direct CP asymmetry A_{CP} suppressed in SM to ~1% level (PRD **54**, 882)
  - NP may enhance the value, especially at high q^2 (c.f. PRD **79**, 034017)
- Existing puzzles
  - ☞ Large isospin asymmetries
  - ☞ Forward-backward asymmetries
  - ☞ LHCb angular analysis (L. Pescatore)

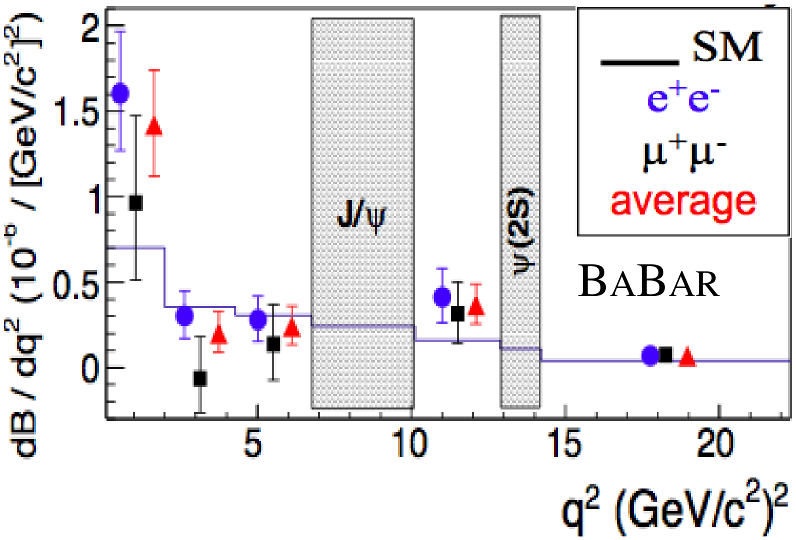


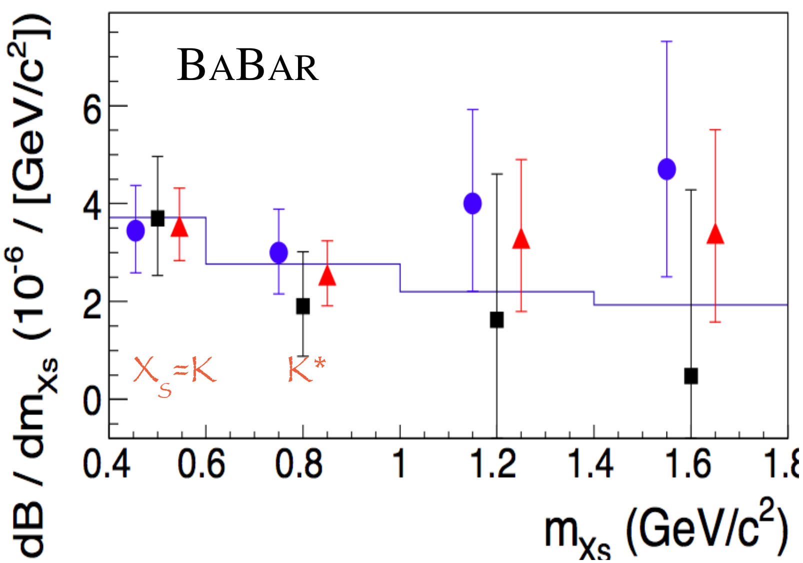


$B \to X_s\, l^+ l^-$

- Semi-inclusive measurement using the sum of 20 exclusively reconstructed modes
  - MC-assisted extrapolation to the total rate
    - ☞ About 70% of inclusive rate with M(Xs)<1.8 GeV reconstructed
    - ☞ Complementary to (and competitive with) LHCb
- Final states:
  - 0 pions: K^+, K_S
  - 1 pion: $K^+\pi^0$, $K^+\pi^-$, $K_S\pi^0$, $K_S\pi^+$
  - 2 pions: $K^+\pi^-\pi^0$, $K^+\pi^+\pi^-$, $K_S\pi^+\pi^0$, $K_S\pi^+\pi^-$
    - ☞ CP-symmetric modes not used in measurement of A_{CP}
- Well-identified leptons ($l=e,\mu$)
- Extract results by likelihood fit to distribution of kinematic variable m_{ES} and event topology likelihood ratio L_R

$B \to X_s l^+l^-$: Results





Perturbative region: $1<q^2<6$ GeV^2

$$\left.\begin{array}{ll} X_s\,\mu^+\mu^- & 0.66^{+0.82}_{-0.76}{}^{+0.30}_{-0.24} \pm 0.07 \\ X_s\,e^+e^- & 1.93^{+0.47}_{-0.45}{}^{+0.21}_{-0.16} \pm 0.18 \\ X_s\,\ell^+\ell^- & 1.60^{+0.41}_{-0.39}{}^{+0.17}_{-0.13} \pm 0.18 \end{array}\right\} \times 10^{-6}$$

(Average $X_s l^+l^-$ consistent with SM)

Above $\psi(2S)$:

$$\left.\begin{array}{ll} X_s\,\mu^+\mu^- & 0.60^{+0.31}_{-0.29}{}^{+0.05}_{-0.04} \pm 0.00 \\ X_s\,e^+e^- & 0.56^{+0.19}_{-0.18}{}^{+0.03}_{-0.03} \pm 0.00 \\ X_s\,\ell^+\ell^- & 0.57^{+0.16}_{-0.15}{}^{+0.03}_{-0.02} \pm 0.00 \end{array}\right\} \times 10^{-6}$$

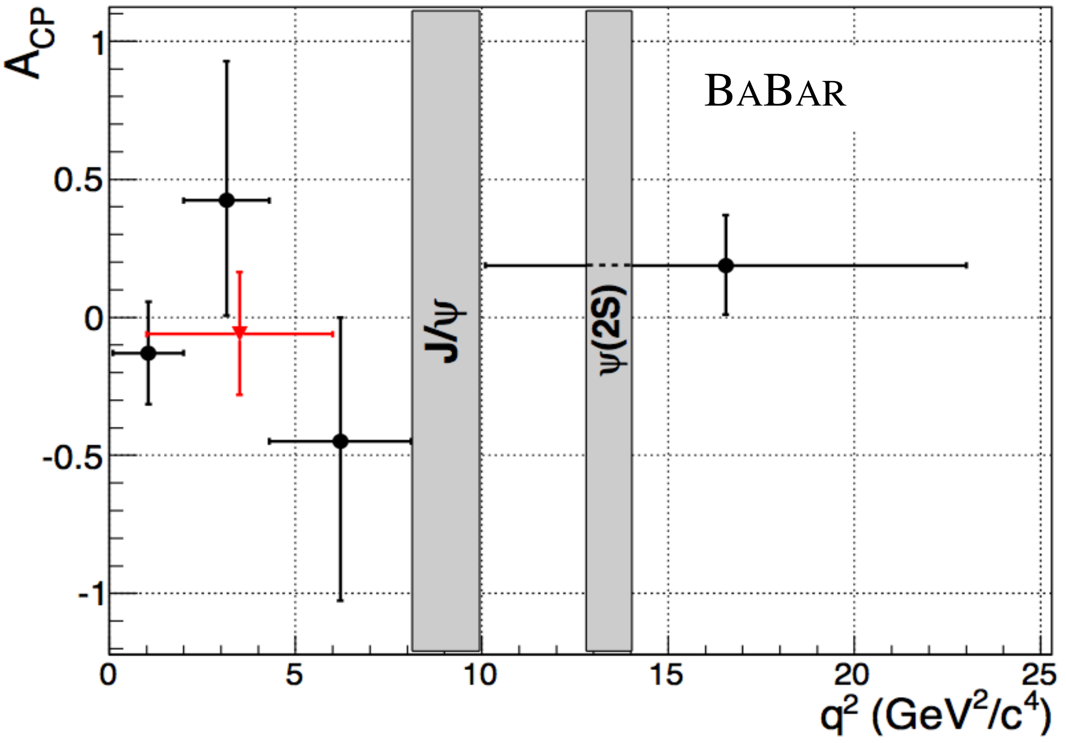
About 2σ above SM expectation

$$\mathcal{B}(\bar{B} \to X_s\mu\mu)_{\rm high} = (2.40^{+0.69}_{-0.62}) \times 10^{-7}$$

T. Huber, T. Hurth and E. Lunghi, Nucl. Phys. B 802, 40 (2008).

Opposite direction compared to evidence for deviation from SM observed at LHCb (see L. Pescatore's talk and backup)

$B \to X_s l^+l^-$: Results



$$A_{CP} = \frac{BF_B - BF_{\bar{B}}}{BF_B + BF_{\bar{B}}}$$

Measure A_{CP} in q^2 bins, for e,μ final states separately and on average

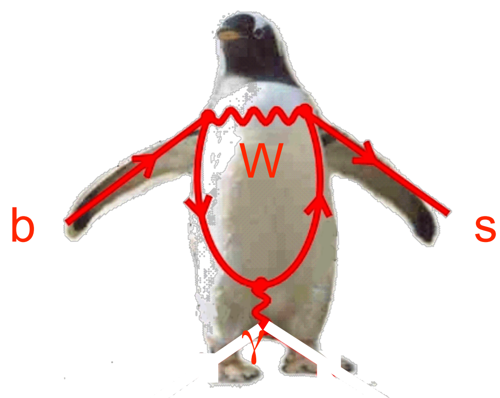
No model-dependent extrapolation of signal rates for A_{CP}

A_{CP} (q^2>0.1 GeV^2) = 0.04 ± 0.11 (stat) ± 0.01 (syst)

(in agreement with the Standard Model)

Time-dependent CP Asymmetry in $B \rightarrow K\pi\pi\gamma$

(Preliminary)



CP Asymmetry in B→Kππγ

$$A_{CP}(\Delta t) = \frac{\Gamma(\bar{B}^0(\Delta t)\to f_{CP}\gamma) - \Gamma(B^0(\Delta t)\to f_{CP}\gamma)}{\Gamma(\bar{B}^0(\Delta t)\to f_{CP}\gamma) + \Gamma(B^0(\Delta t)\to f_{CP}\gamma)} = S_{f_{CP}} \sin(\Delta m_d \Delta t) - C_{f_{CP}} \cos(\Delta m_d \Delta t)$$

(Δt is the proper time difference between B decays)

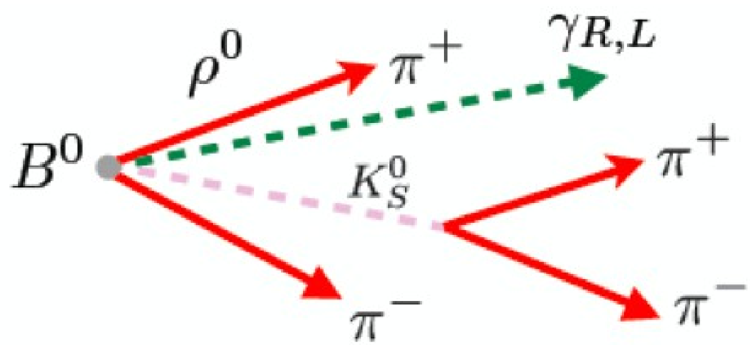
SM prediction $S_{f_{CP}} = m_s / m_b = 0.02$

Non-zero asymmetry is a sign of new physics effects (e.g. RH currents)
Complementary to photon polarization measurements (c.f. LHCb)

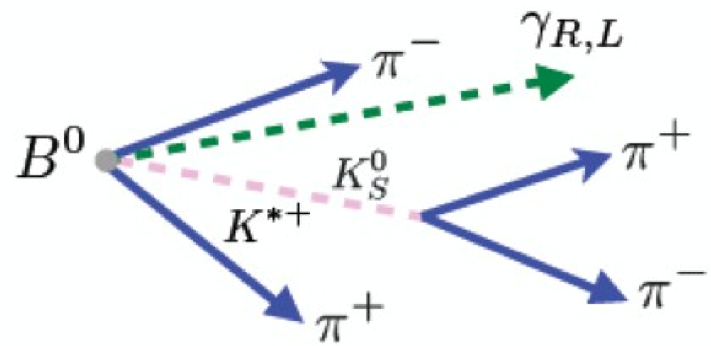
Experimental technique: time-dependent CP analysis of CP eigenstate B0→$K_S^0\rho\gamma$

Complication: dilution from irreducible background of non-CP eigenstate $B^0\to K^*[K_S^0\pi]\pi\gamma$. Measure dilution from amplitude analysis of $B^+\to K^+\pi^-\pi^+\gamma$

CP eigenstate B0→$K_S^0\rho\gamma$

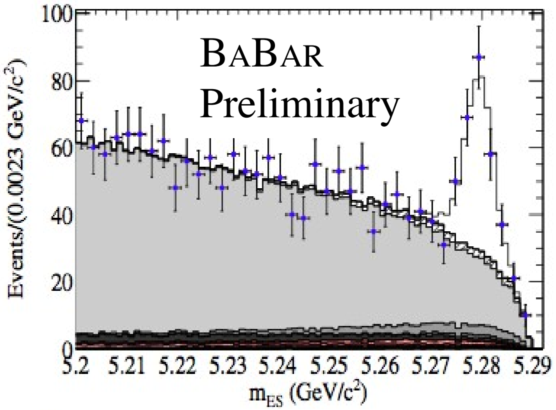


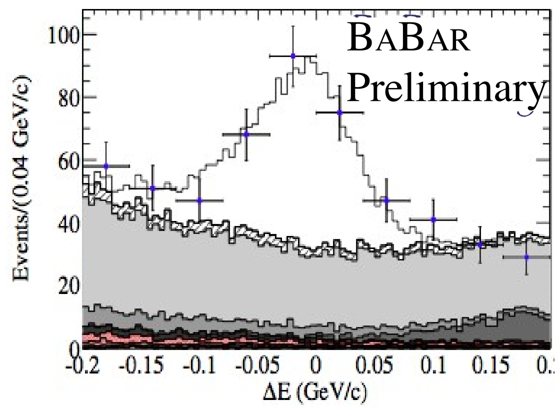
Non-CP eigenstate B0→$K^*[K_S^0\pi]\pi\gamma$

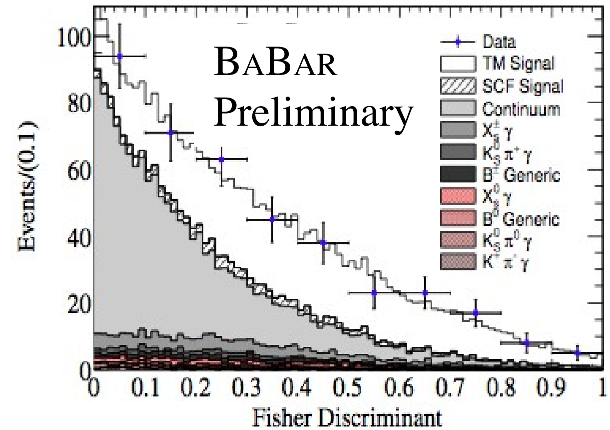


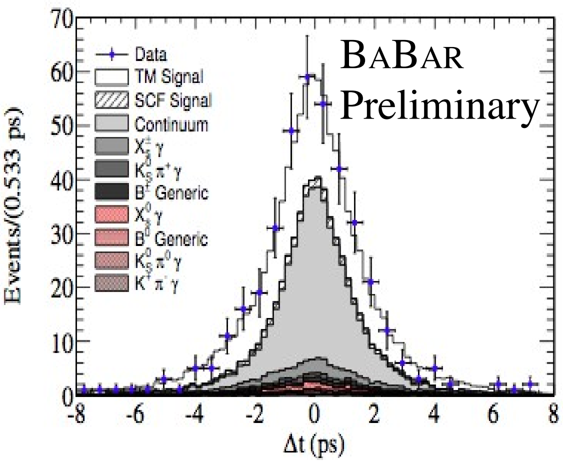
CP Asymmetry in B→Kππγ

Max-likelihood fit to 4 variables: m_{ES}, ΔE, event shape Fisher, Δt









Branching Fraction measurement:

$$\mathcal{B}(B^0 \to K^0\pi^+\pi^-\gamma) = (23.9 \pm 2.4^{+1.6}_{-1.9}) \times 10^{-6}$$

CP Observables:

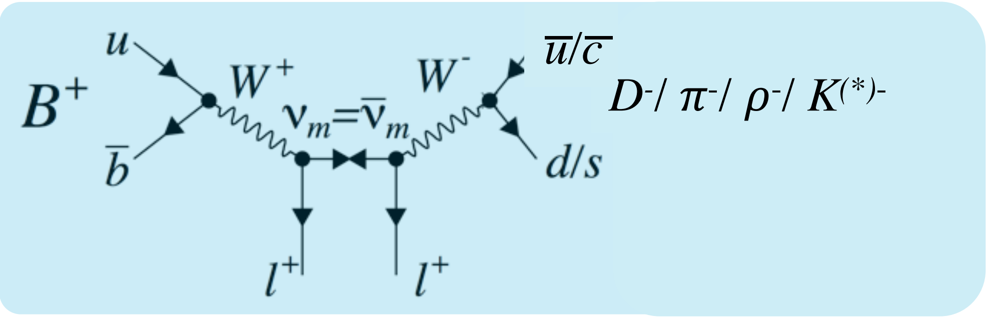
$$\mathcal{S}_{K^0_S\pi^+\pi^-\gamma} = 0.14 \pm 0.25(\text{stat.})^{+0.04}_{-0.03}(\text{syst.}) \ ,$$

$$\mathcal{C}_{K^0_S\pi^+\pi^-\gamma} = -0.39 \pm 0.20(\text{stat.}) \pm 0.05(\text{syst.}) \ ,$$

Correcting for dilution: $\mathcal{S}_{K^0_S\rho\gamma} = 0.25 \pm 0.46(\text{stat.})^{+0.08}_{-0.06}(\text{syst.})$

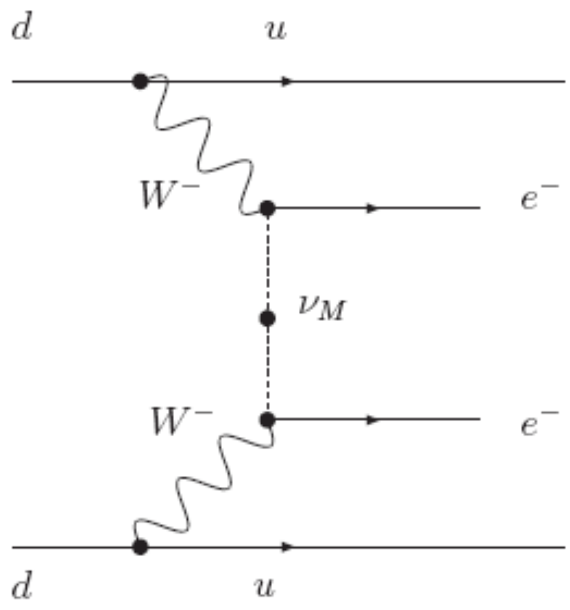
Search For Lepton-Number Violating Processes in $B^+ \to h^- l^+ l^+$

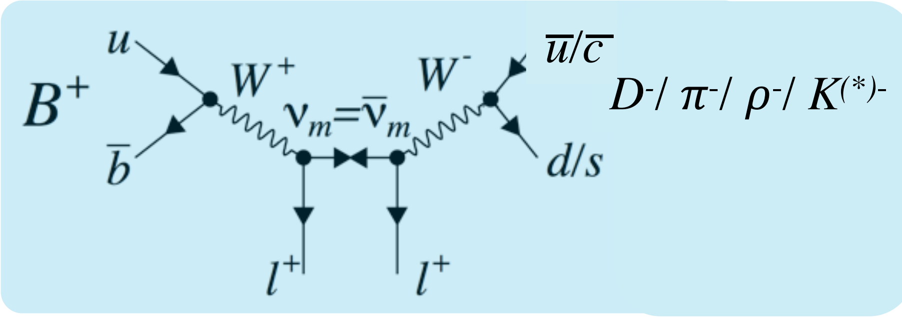
PRD **89**, 011102(R) (2014)



Lepton Number Violation

- Nuclear Physics: Neutrinoless double-beta decay $0\nu\beta\beta$ probes Majorana nature of neutrinos
- LNV in B decays: another probe
  - Access to 2nd and 3rd (and possibly 4th) generation
    - Different effective neutrino mass
    - Additional Majorana phases accessible
    - Or new physics in 2nd and 3rd generation

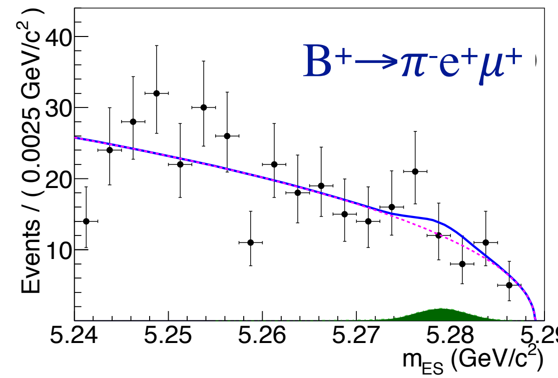


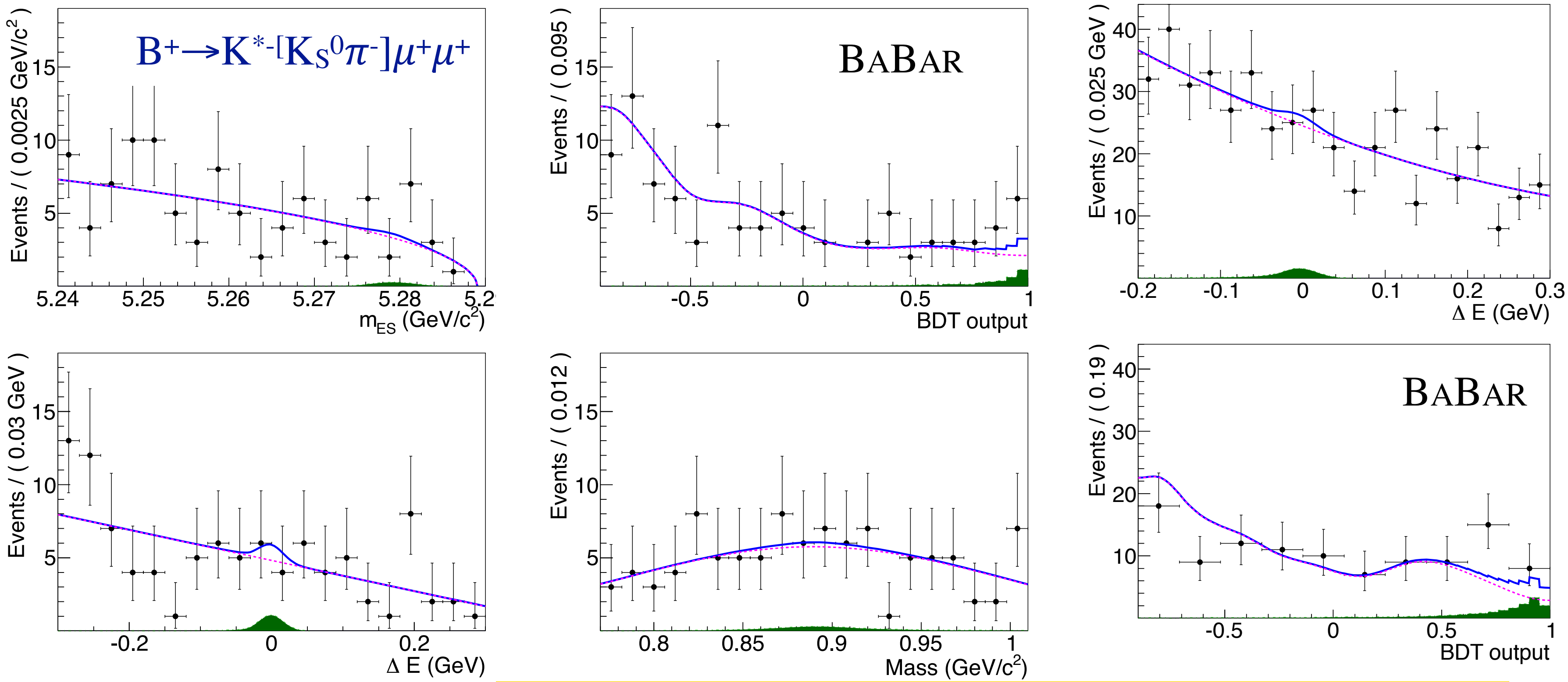


LNV: $B^+ \to h^- l^+ l^+$

- 14 decay channels
- Multivariate background suppression (BDT)
- Maximum-likelihood fit to 3 (or 4) variables
  - ☞ m_{ES}, ΔE, BDT [and $D/K^*/\rho$ mass]

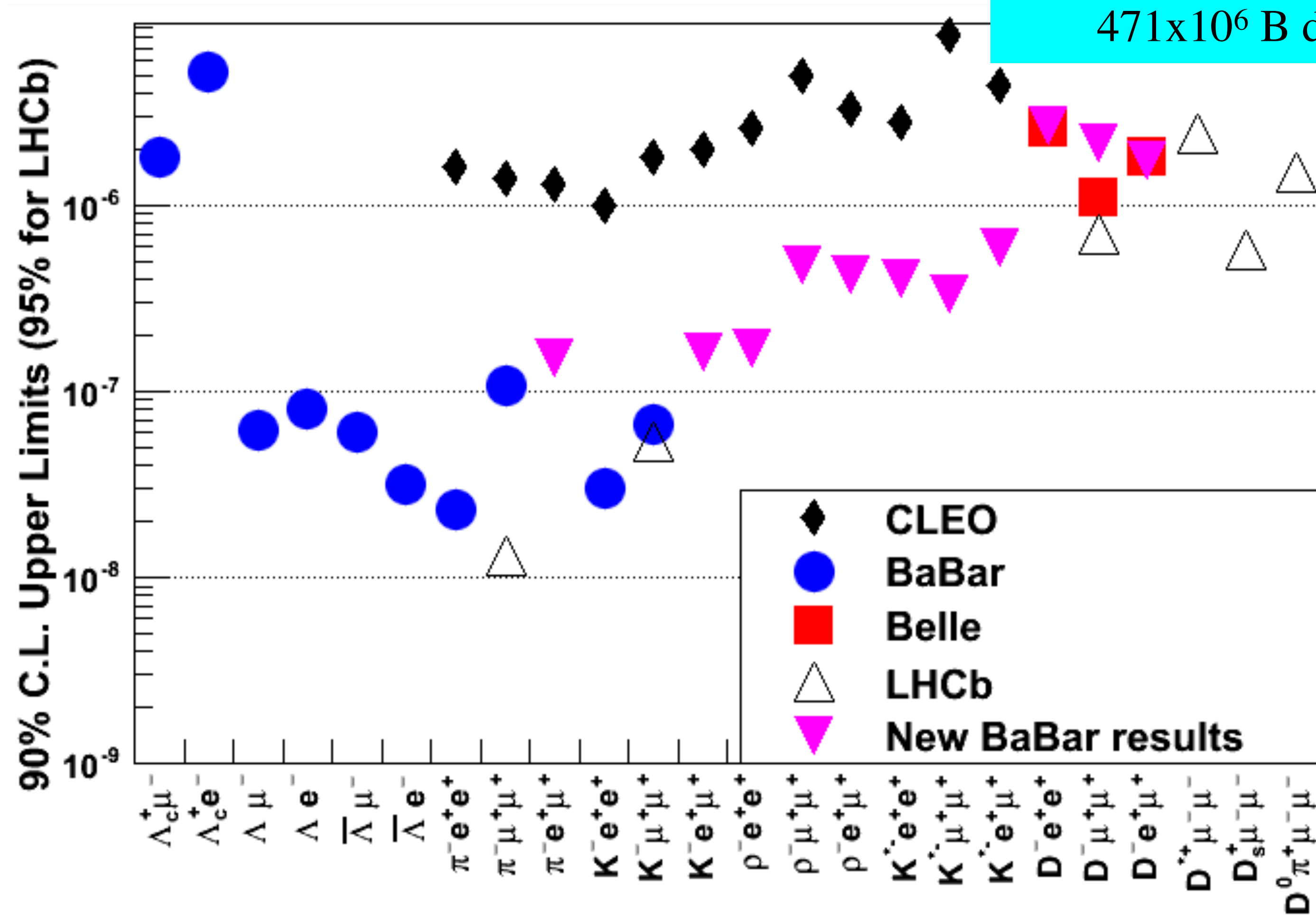
No significant signal observed





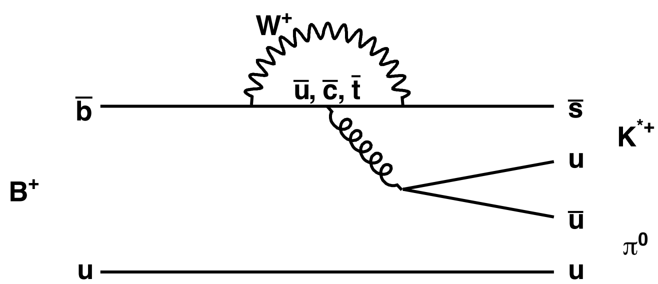
LNV: $B^+ \to h^- l^+ l^+$ Results

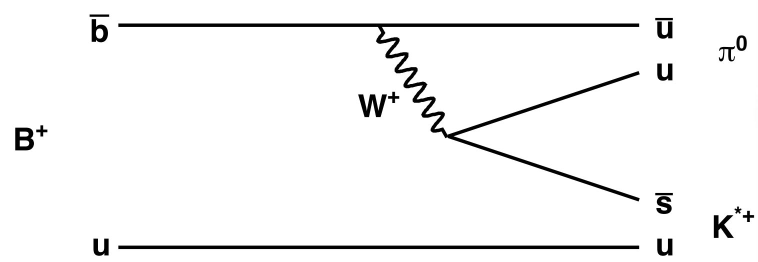
PRD **89**, 011102(R) (2014)
471x10^6 B decays

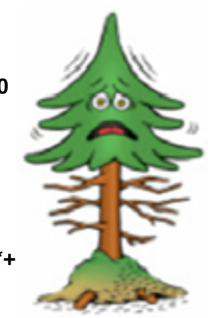


Dalitz Analysis and CP Asymmetry in $B^+ \to K_S \pi^+ \pi^0$

To be submitted to PRD
(Preliminary)

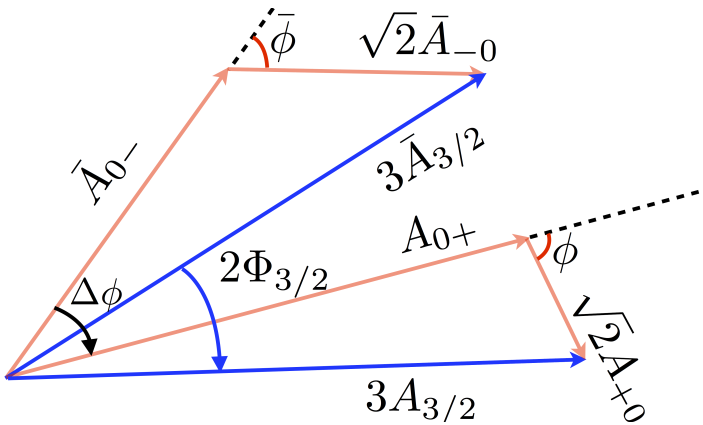






Dalitz and CP Analysis in $B^+ \to K_S \pi^+ \pi^0$

- Dalitz analysis can be used to measure CP angle γ
  - Requires full amplitude and CP analysis of $K^*\pi$ system
- $K\pi$ puzzle: isospin asymmetry ΔA_{CP} in $K\pi$ system
  - Look for insights in $K^*\pi$



Phys. Rev. **D74**, 051301 (2006)
Phys. Rev. **D75**, 014002 (2007)

$$\Delta A_{\rm CP} = A_{\rm CP}\left(K^{*+}\pi^0\right) - A_{\rm CP}\left(K^{*+}\pi^-\right)$$

$$A_{\rm CP}\left(B^+ \to K^{*+}\pi^0\right) = -0.06 \pm 0.24$$

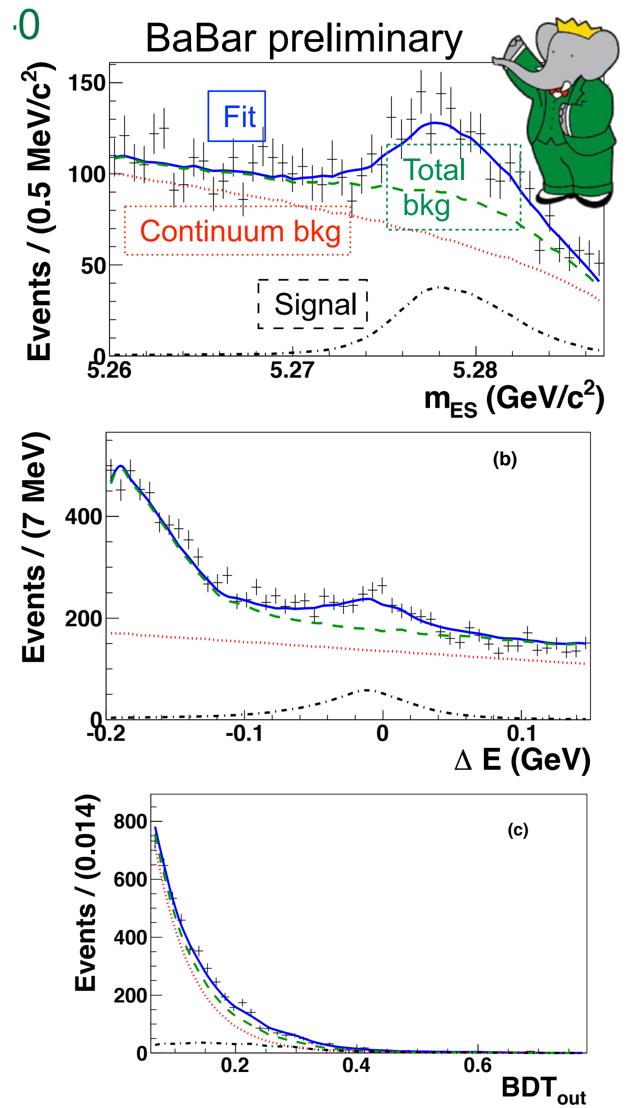
BaBar: Phys. Rev. **D84**, 092007 (2011)

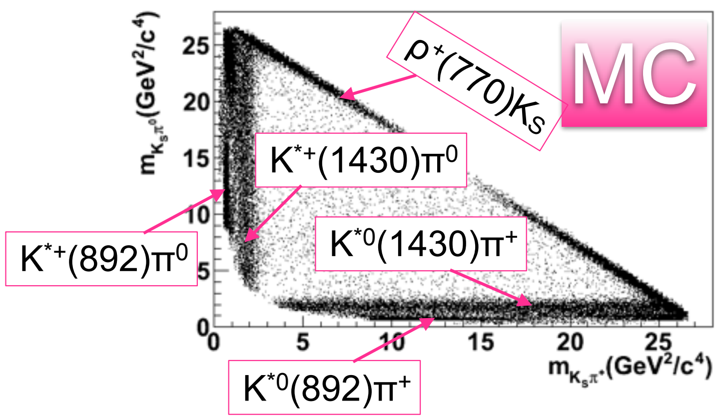
$$A_{CP}(B^0 \to K^{*+}\pi^-) = -0.23 \pm 0.06$$

HFAG, arXiv:1207.1158 [hep-ex]

$B^+ \to K_S \pi^+ \pi^0$ Analysis

- Extract event yields from max-likelihood fit to 3 variables
  - ☞ m_{ES}, ΔE, BDT
  - ☞ 1014±63 signal events over 31k background
- Dalitz analysis to measure individual contributions
  - ☞ Resonant contributions, strong and CP phases





$$\overset{(-)}{A} = \sum \overset{(-)}{A}_i = \sum \overset{(-)}{c}_i F\left(m^2_{K_S\pi^+}, m^2_{\pi^0\pi^+}\right)$$

complex coefficients

decay dynamics

$B^+ \to K_S \pi^+ \pi^0$ Results

First measurements

BABAR Preliminary

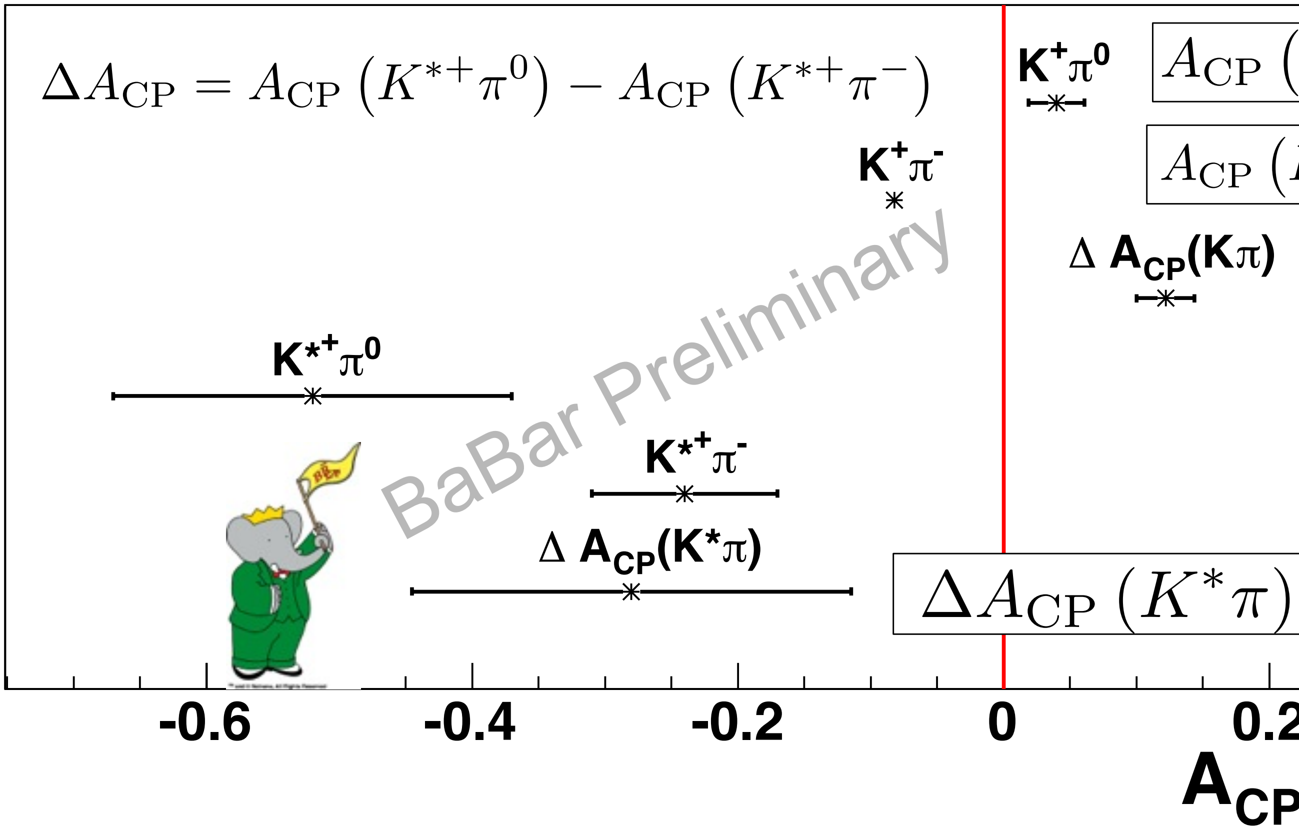
Decay channel	$\mathcal{B}\ (10^{-6})$	A_{CP}
$K^0\pi^+\pi^0$	$45.9 \pm 2.6 \pm 3.0 \pm 8.6$	$0.07 \pm 0.05 \pm 0.03 \pm 0.04$
$K^{*0}(892)\pi^+$	$14.6 \pm 2.4 \pm 1.3 \pm 0.5$	$-0.12 \pm 0.21 \pm 0.08 \pm 0.11$
$K^{*+}(892)\pi^0$	$9.2 \pm 1.3 \pm 0.6 \pm 0.5$	$-0.52 \pm 0.14 \pm 0.04 \pm 0.04$
$K_0^{*0}(1430)\pi^+$	$50.0 \pm 4.8 \pm 6.0 \pm 4.0$	$0.14 \pm 0.10 \pm 0.04 \pm 0.14$
$K_0^{*+}(1430)\pi^0$	$17.2 \pm 2.4 \pm 1.5 \pm 1.8$	$0.26 \pm 0.12 \pm 0.08 \pm 0.12$
$\rho^+(770)K^0$	$9.4 \pm 1.6 \pm 1.0 \pm 2.6$	$0.21 \pm 0.19 \pm 0.07 \pm 0.30$

Stat, syst, and model-dependent uncertainties

5.4σ significance (first observation)

3.4σ significance (first evidence)

B→K$^{(*)}\pi$ Results



$$\Delta A_{\rm CP} = A_{\rm CP}\left(K^{*+}\pi^0\right) - A_{\rm CP}\left(K^{*+}\pi^-\right)$$

$$A_{\rm CP}\left(K^+\pi^0\right) = 0.040 \pm 0.021$$

$$A_{\rm CP}\left(K^+\pi^-\right) = -0.082 \pm 0.006$$

$$\Delta A_{\rm CP}\left(K^*\pi\right) = -0.29 \pm 0.16$$

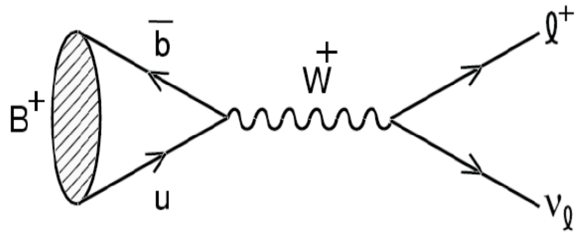
Summary

- Unique sensitivity to new physics in B decays
  - Complementary to LHC in SUSY parameter space
  - In case of discoveries, shed light on flavor structure of New Physics
  - Complementary to other rare decays and precision measurements
    - ☞ Muon g-2, $\mu\to e$ conversion, $\mu\to e\gamma$, $0\nu\beta\beta$
- High-multiplicity, inclusive and semi-inclusive final states accessible at B Factories
- Few puzzles and smoking guns
  - Belle-II can improve sensitivities by 1-2 orders of magnitude

Backup

Rare B Decays

- Powerful (indirect) probe of New Physics
  - (Old) smoking gun: $B^+ \to \tau^+ \nu$, sensitive to charged Higgs



$$\mathcal{B}(B^- \to \ell^- \bar{\nu}) = \frac{G_F^2 m_B}{8\pi} m_l^2 \left(1 - \frac{m_l^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

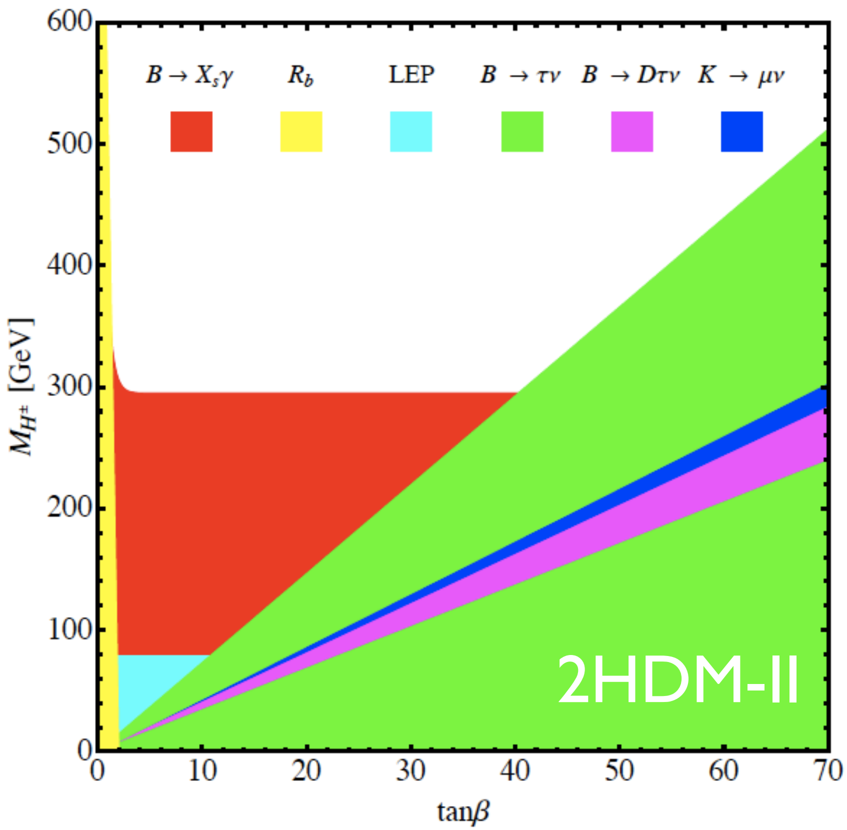
$$\mathcal{B}_{SM}(B^+ \to \tau^+ \nu) = (0.80 \pm 0.20) \times 10^{-4}$$

(using f_B=190±13 MeV and V_{ub}=(3.5±0.4)×10^{-3}

Charged Higgs contribution:

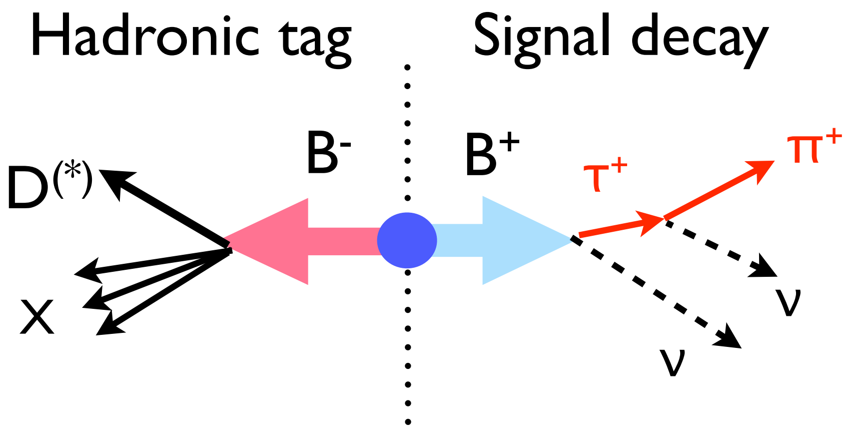
$$\mathcal{B}(B \to \tau\nu) = \mathcal{B}(B \to \tau\nu)_{\mathrm{SM}} \times r_H$$

$$r_H = (1 - \frac{m_B^2}{m_H^2} \tan^2\beta)^2$$



$B^+ \to \tau^+\nu$: Hadronic Tag Technique

- Reconstruct "the tag B" completely
  - ☞efficiency 0.28%
- Reconstruct leptonic and hadronic τ decay modes (~70% BF)
- Key discriminant: unassociated neutral energy E_{extra}
  - ❑ Look for excess of events @ E_{extra}~0



$$B^- \to D^{(*)0} X^-$$

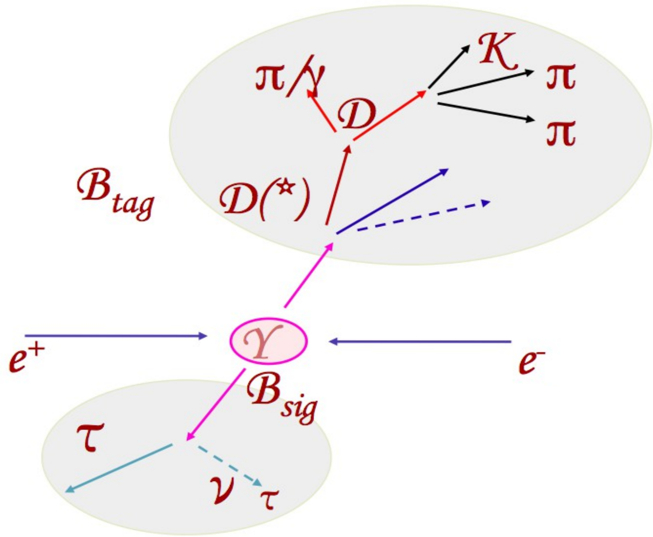
$$\begin{aligned} D^0 &\to K^-\pi^+, K^-\pi^+\pi^0, K^-\pi^+\pi^-\pi^+, \\ & \quad K^0_s\pi^0, K^0_s\pi^+\pi^-, K^0_s\pi^+\pi^-\pi^0 \\ & \quad K^+K^-, \pi^+\pi^- \\ D^{*0} &\to D^0\pi^0, D^0\gamma \end{aligned}$$

$$X = n\pi^\pm + mK + p\pi^0 + qK^0$$
$$n + m \leq 5, \quad m, p, q \leq 2$$

$B \to \tau\nu$

[PRD-RC 88, 031102 (2013)]

- Events selected on the recoil of fully reconstructed $B \to D^{(*)} X$, $J/\psi X$ with Tag Efficiency ≈ 0.28 %



- Events reconstructed in the $e^+\nu\nu$, $\mu^+\nu\nu$, $\pi^+\nu$, $\rho^+(\pi^+\pi^0)\nu$ channels requiring a single charged track
- BKG from continuum & combinatorial reduced by means of a likelihood ratio exploiting topological variables.

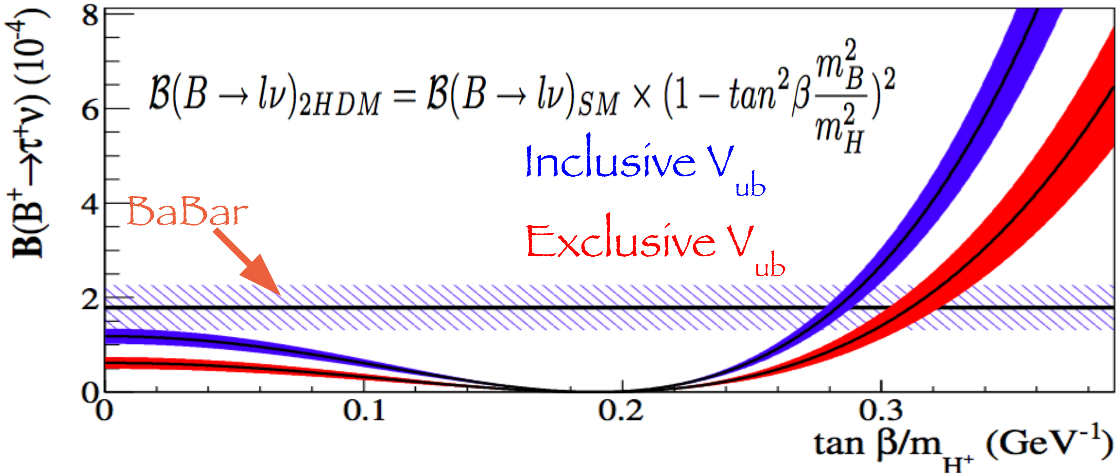
- From E_{Extra} fit:

$BR(B \to \tau\nu) = (1.83^{+0.53}_{-0.49}(stat) \pm 0.24(syst))10^{-4}$ (significance 3.8 σ)

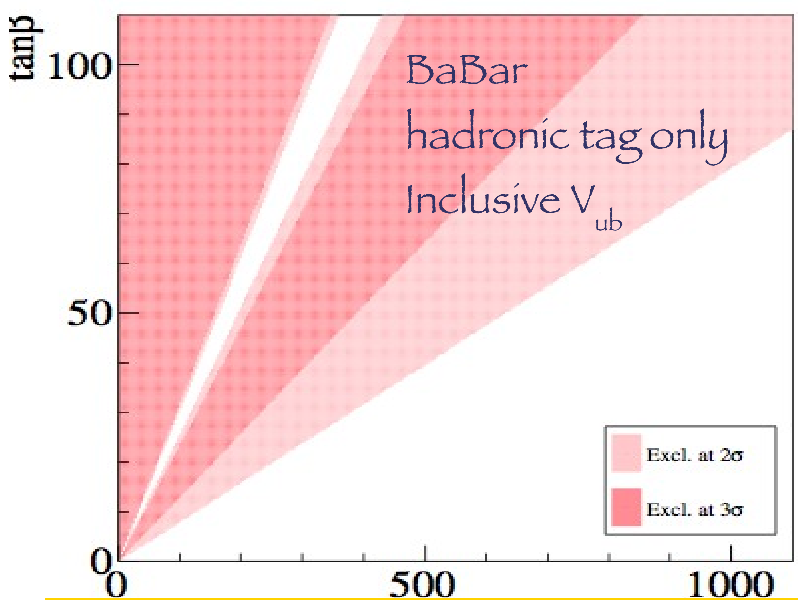
- Exceeds the SM prediction by 2.4σ (1.6σ) using V_{ub} from the exclusive (inclusive) charmless semileptonic B decays

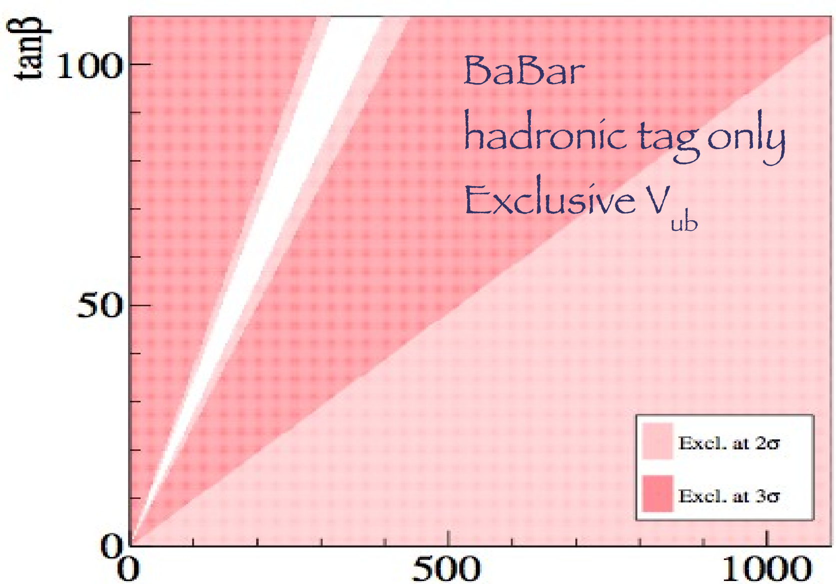
$B \to \tau\nu$ [PRD-RC 88, 031102 (2013)]

- Constraints on 2HDM type II model



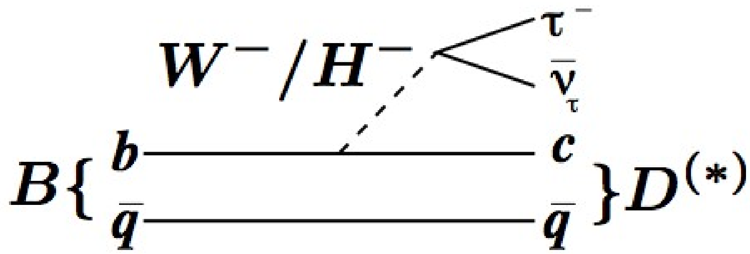
- Stringent limits set in the (tanβ , m_{H+}) plane:





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

- Tree level decay less model dependent, several observables sensitive to NP



- BRs for the different lepton species are predicted to be different in the SM:

$$\mathcal{R}(D^{(*)}) \equiv \frac{\mathcal{B}(B \to D^{(*)}\tau\nu)}{\mathcal{B}(B \to D^{(*)}\ell\nu)} \qquad \begin{aligned} \mathcal{R}(D)_{\rm SM} &= 0.297 \pm 0.017, \\ \mathcal{R}(D^{*})_{\rm SM} &= 0.252 \pm 0.003. \end{aligned}$$

  - Theoretical & experimental uncertainties (V_{cb}, Form Factors, Particle identification, reconstruction effects) reduced in the BRs ratio
  - D, D^* affected differently by charged Higgs exchange (different helicity)

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

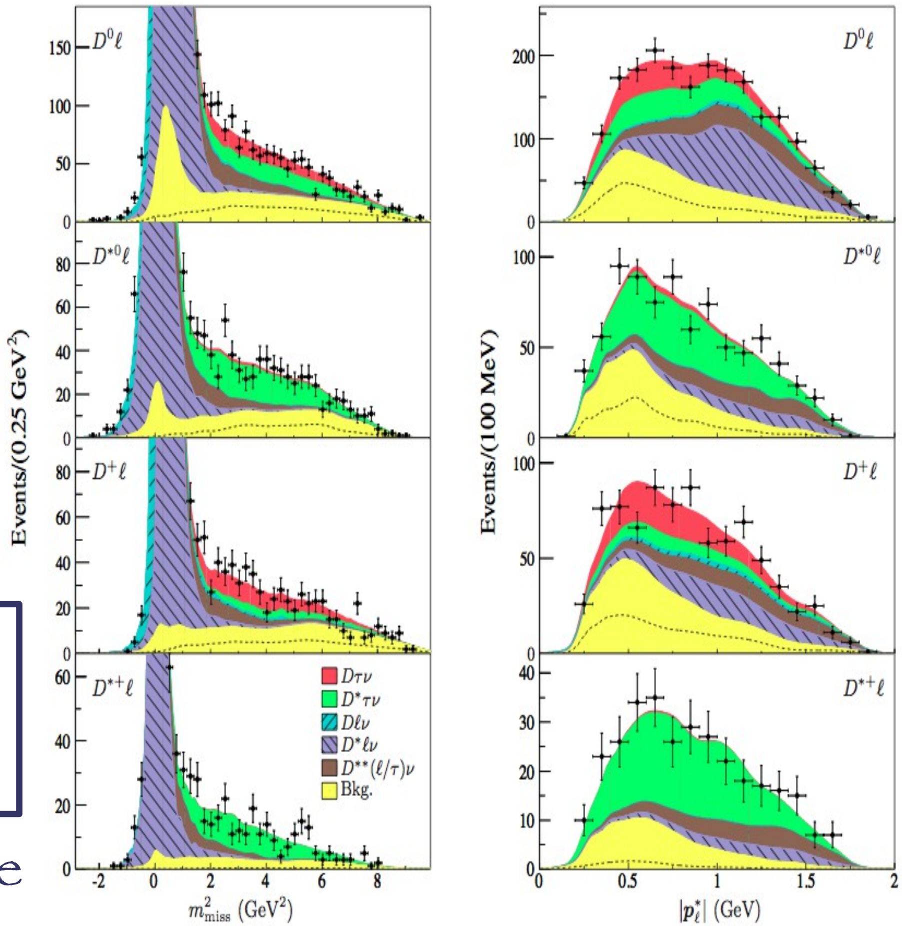
[PRD 88, 072012 (2013)]

- $D^{(*)}l$ events selected on the recoil of reconstructed hadronic B decays
- Use only leptonic τ decays
- Yields extracted by means of a simultaneous fit to:
  - Lepton momentum in the B rest frame
  - $M^2_{miss} = (P_{e+e-} - P_{Btag} - P_{D(*)} - P_l)^2$

R(D)=0.440±0.058±0.042

R(D*)=0.332±0.024±0.018

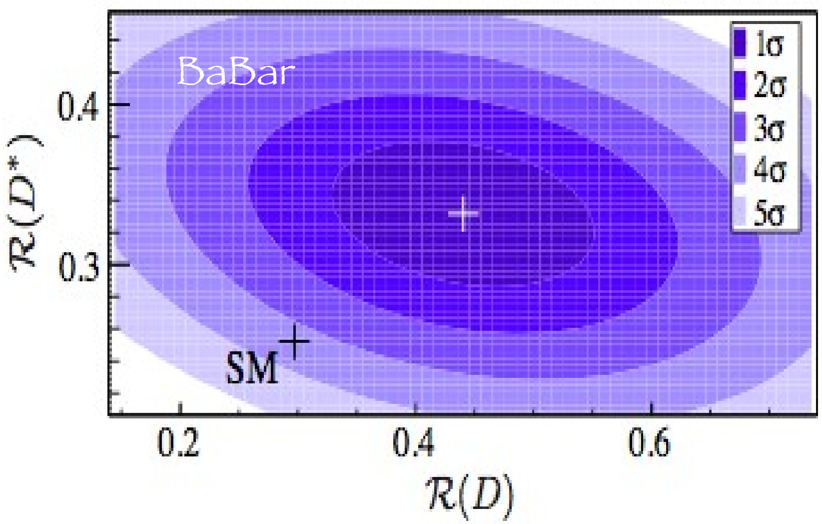
- Systematics from BKG PDF shape

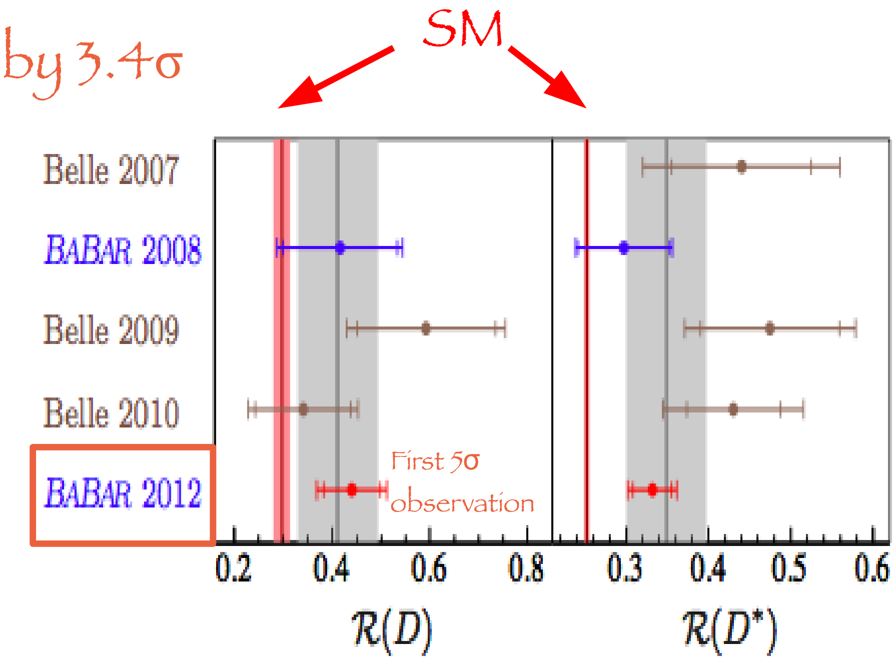


$B \to D^{(*)}\tau\nu$

[PRD 88, 072012 (2013)]

- Results above the SM prediction by 3.4σ





- Adding Belle results:

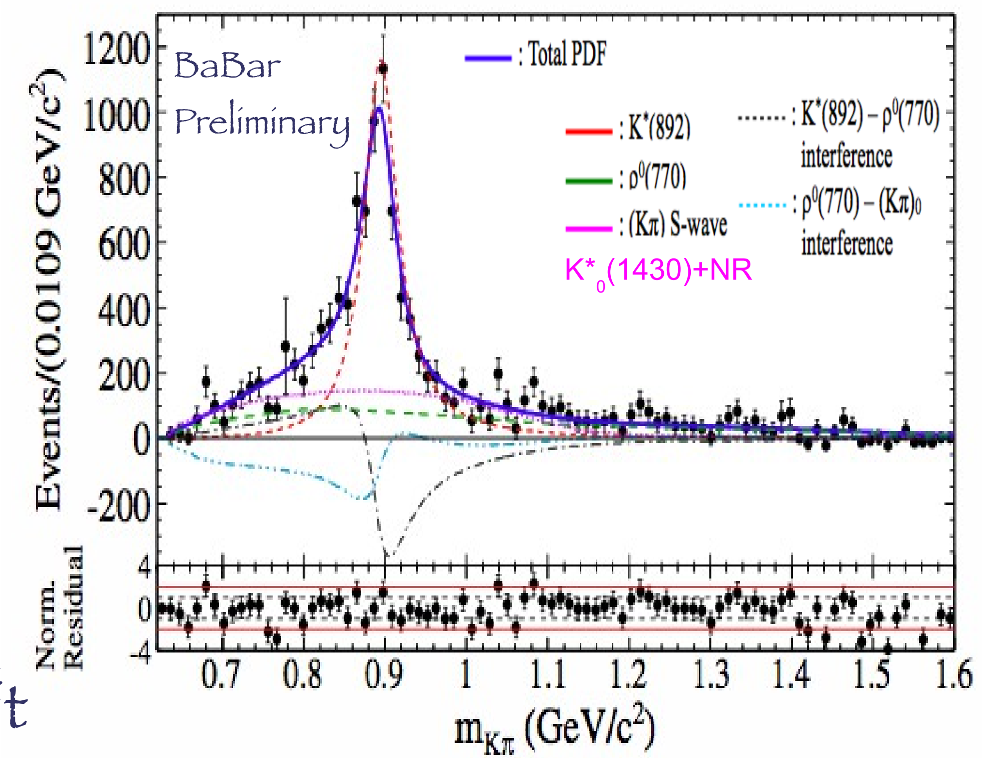
[PRL 99 191807, PRD 82 072005]

Deviation from SM prediction at 4.8σ

Belle & BaBar	Deviation
$\mathcal{R}(D)$	2.4σ
$\mathcal{R}(D^*)$	3.8σ
Combined	4.8σ

Amplitude Analysis of $B^+ \to K\pi\pi\gamma$

- Extraction of the dilution from amplitudes of intermediate states decaying to $K\pi$ and $\pi\pi$
- Full amplitude analysis in the $m(K\pi)$-$m(\pi\pi)$ difficult due to small statistics
  - Perform a 1D fit to $m(K\pi)$ using as inputs the BRs obtained from the $m(K\pi\pi)$ fit



$$\mathcal{D}_{K^0_S\rho\gamma} = F(A_\rho, A_{K^*}, A_{(K\pi)S\text{-wave}}) = 0.549^{+0.096}_{-0.094}$$

Amplitude Analysis in $B^+ \to K_S \pi^+ \pi^0$

BaBar Preliminary

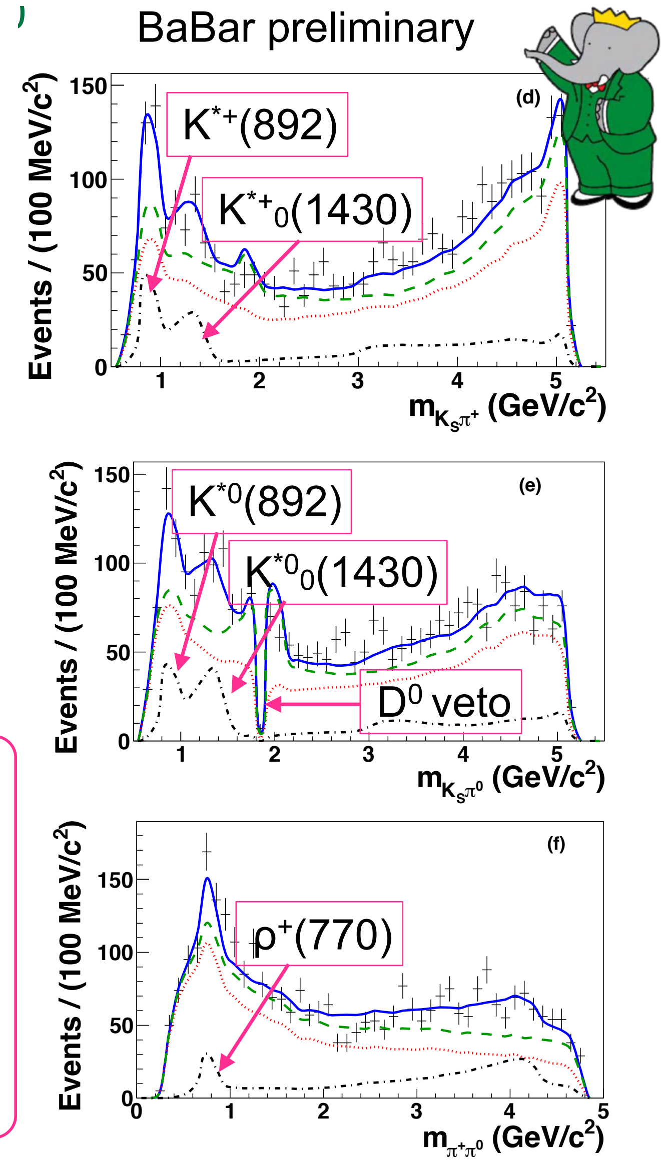
Decay channel	$\mathcal{B}\ (10^{-6})$
$K^0\pi^+\pi^0$	$45.9 \pm 2.6 \pm 3.0 \pm 8.6$
$K^{*0}(892)\pi^+$	$14.6 \pm 2.4 \pm 1.3 \pm 0.5$
$K^{*+}(892)\pi^0$	$9.2 \pm 1.3 \pm 0.6 \pm 0.5$
$K_0^{*0}(1430)\pi^+$	$50.0 \pm 4.8 \pm 6.0 \pm 4.0$
$K_0^{*+}(1430)\pi^0$	$17.2 \pm 2.4 \pm 1.5 \pm 1.8$
$\rho^+(770)K^0$	$9.4 \pm 1.6 \pm 1.0 \pm 2.6$

First uncertainty is statistical, second systematic, and third due to the signal model

BaBar Preliminary

Reference amplitude \ Resonances	Relative phases (°) $K^{*0}(892)\pi^+$	$K^{*+}(892)\pi^0$	$(K\pi)_0^{*0}\pi^+$	$(K\pi)_0^{*+}\pi^0$	$\rho^+(770)K_S^0$
$B^+ \to K^{*0}(892)\pi^+$	0	-96 ± 44	174 ± 11	-91 ± 43	-122 ± 38
$B^+ \to K^{*+}(892)\pi^0$	–	0	-90 ± 42	6 ± 10	-27 ± 26
$B^+ \to (K\pi)_0^{*0}\pi^+$	–	–	0	95 ± 42	64 ± 37
$B^+ \to (K\pi)_0^{*+}\pi^0$	–	–	–	0	-32 ± 25
$B^+ \to \rho^+(770)K_S^0$	–	–	–	–	0

Uncertainty is statistical only



Implications from $B \to X_s l^+ l^-$ Partial BFs on LHCb "anomaly"

- A recent LHCb paper essentially claims a ~4 sigma observation of a non-SM signal from one of an ensemble of 24 quasi-independent observables
  - PRL 111, 191801 (2013)
- There are, however, a number of caveats
  - ~4 sigma is a local significance; globally, assuming all 24 observables are independent, there is ~1 in 200 chance that this is a statistical fluctuation
  - However, all 24 observables are not, in fact, independent and are tied together by the transversity amplitudes which underlie the choice of angular projections here, P'4 and P'5
  - This implicit correlation also requires that other related observables, which are also dependent on the same underlying Wilson coefficients and/or transversity amplitudes, show an effect (albeit possibly smaller), **but this is not seen in LHCb's AFB analysis or other experiments' angular analyses or, more importantly, in the form-factor free inclusive B->Xsll analysis**
- Many theorists are "explaining" this singular LHCb result as a BSM contribution to C9, δC9
  - A few are also exploring the implications of this on other RadPen observables
  - The next page shows change in B->Xsll BF if δC9 is interpreted in the context of an MFV scenario

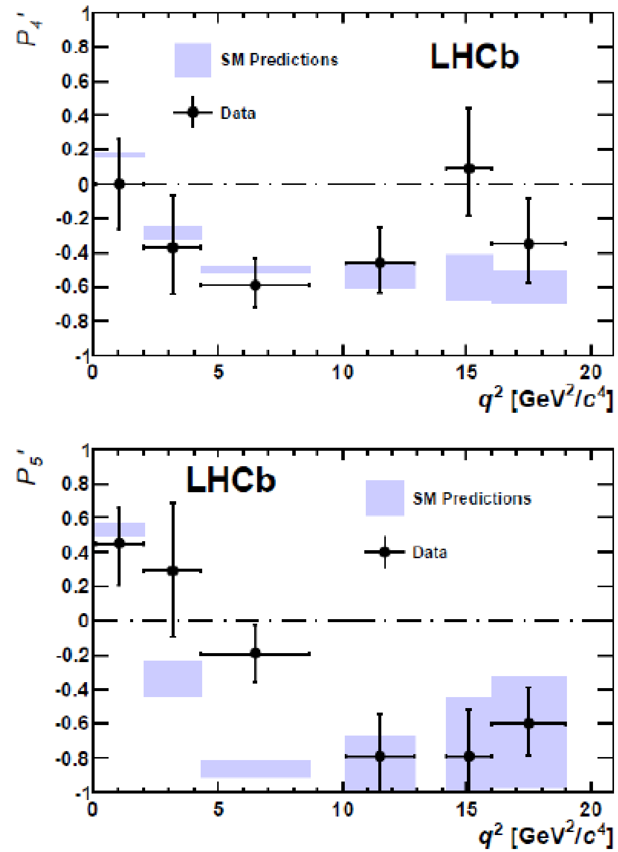


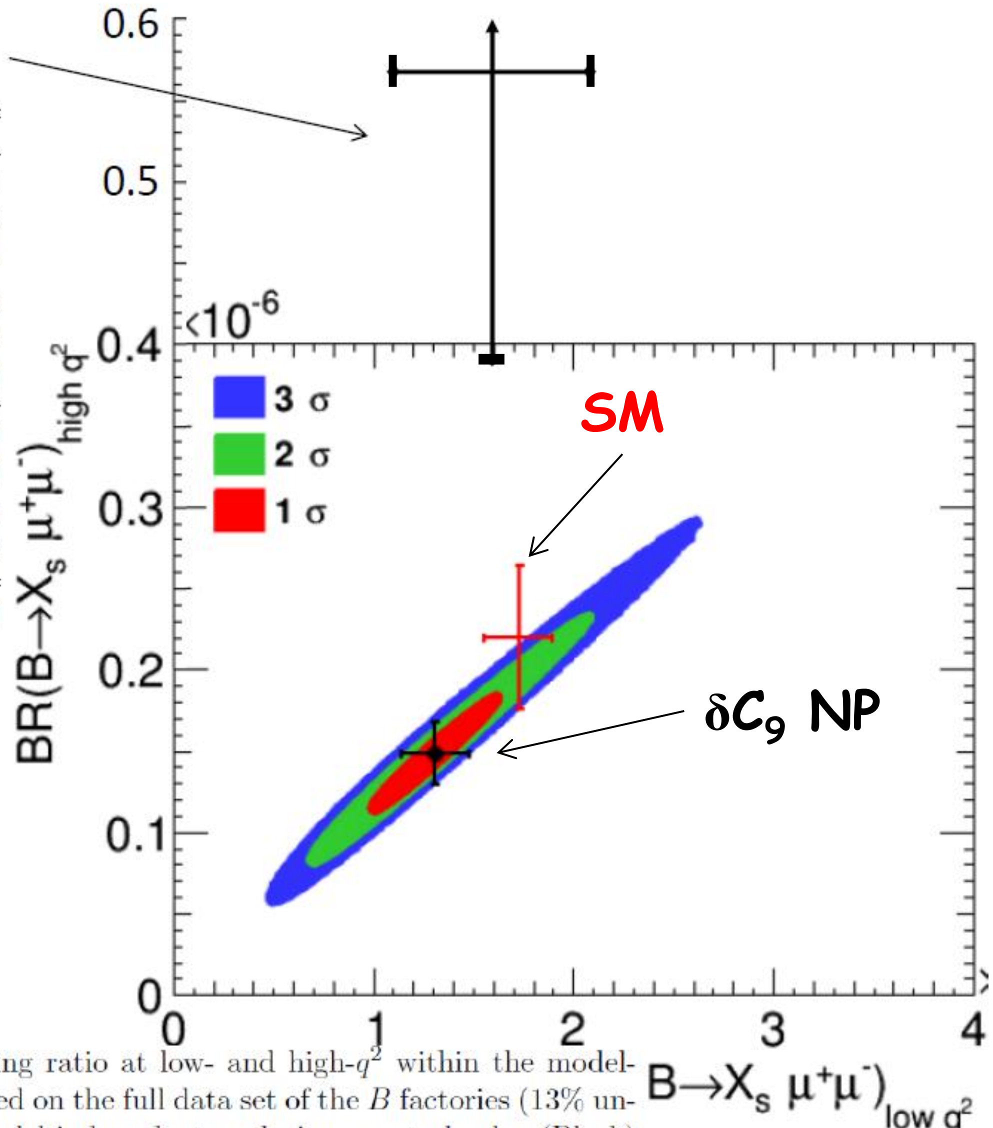
Figure 1: Measured values of P_4' and P_5' (black points) compared with SM predictions from Ref. [11] (blue bands).

8

Implications from $B\to X_s l^+l^-$ Partial BFs on LHCb "anomaly"

Our result

Bin	Range	$B \to X_s \ell^+\ell^-$
q_0^2	$1.0 < q^2 < 6.0$	$1.60^{+0.41+0.17}_{-0.39-0.13} \pm 0.18$
q_1^2	$0.1 < q^2 < 2.0$	$2.70^{+0.45+0.21}_{-0.42-0.16} \pm 0.35$
q_2^2	$2.0 < q^2 < 4.3$	$0.46^{+0.26+0.10}_{-0.23-0.06} \pm 0.07$
q_3^2	$4.3 < q^2 < 6.8$	$0.60^{+0.27+0.10}_{-0.25-0.08} \pm 0.05$
q_4^2	$10.1 < q^2 < 12.9$	$1.02^{+0.32+0.10}_{-0.30-0.07} \pm 0.04$
q_5^2	$14.2 < q^2$	$0.57^{+0.16+0.03}_{-0.15-0.02} \pm 0.00$
$m_{X_s,1}$	$0.4 < m_{X_s} < 0.6$	$0.71^{+0.15+0.03}_{-0.14-0.03} \pm 0.00$
$m_{X_s,2}$	$0.6 < m_{X_s} < 1.0$	$1.02^{+0.27+0.06}_{-0.25-0.05} \pm 0.00$
$m_{X_s,3}$	$1.0 < m_{X_s} < 1.4$	$1.32^{+0.61+0.19}_{-0.58-0.15} \pm 0.05$
$m_{X_s,4}$	$1.4 < m_{X_s} < 1.8$	$1.36^{+0.67+0.50}_{-0.63-0.34} \pm 0.12$
Total	$0.1 < q^2$	$6.73^{+0.70+0.34}_{-0.64-0.25} \pm 0.50$



T. Hurth and F. Mahmoudi, arXiv:1312.5267

Figure 3: 1-,2-,and 3-σ ranges for the branching ratio at low- and high-q^2 within the model-independent analysis. Future measurement based on the full data set of the B factories (13% uncertainty) assuming the best-fit point of the model-indpendent analysis as central value (Black) and the SM predictions (Red).

9