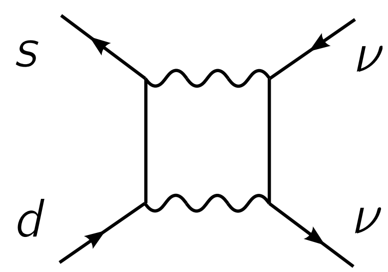
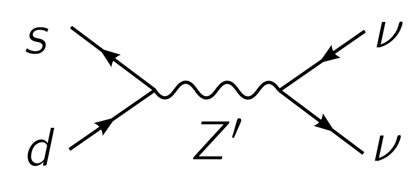
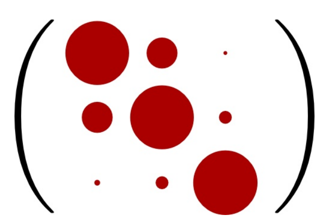
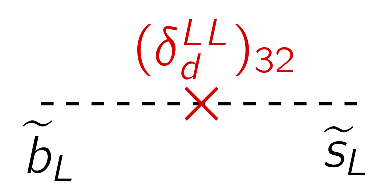
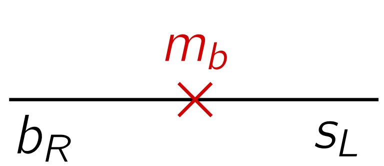
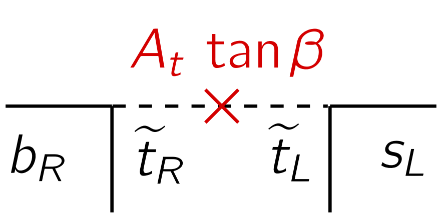
Summary from WGIII - Rare Decays

Mitesh Patel
(Imperial College London)

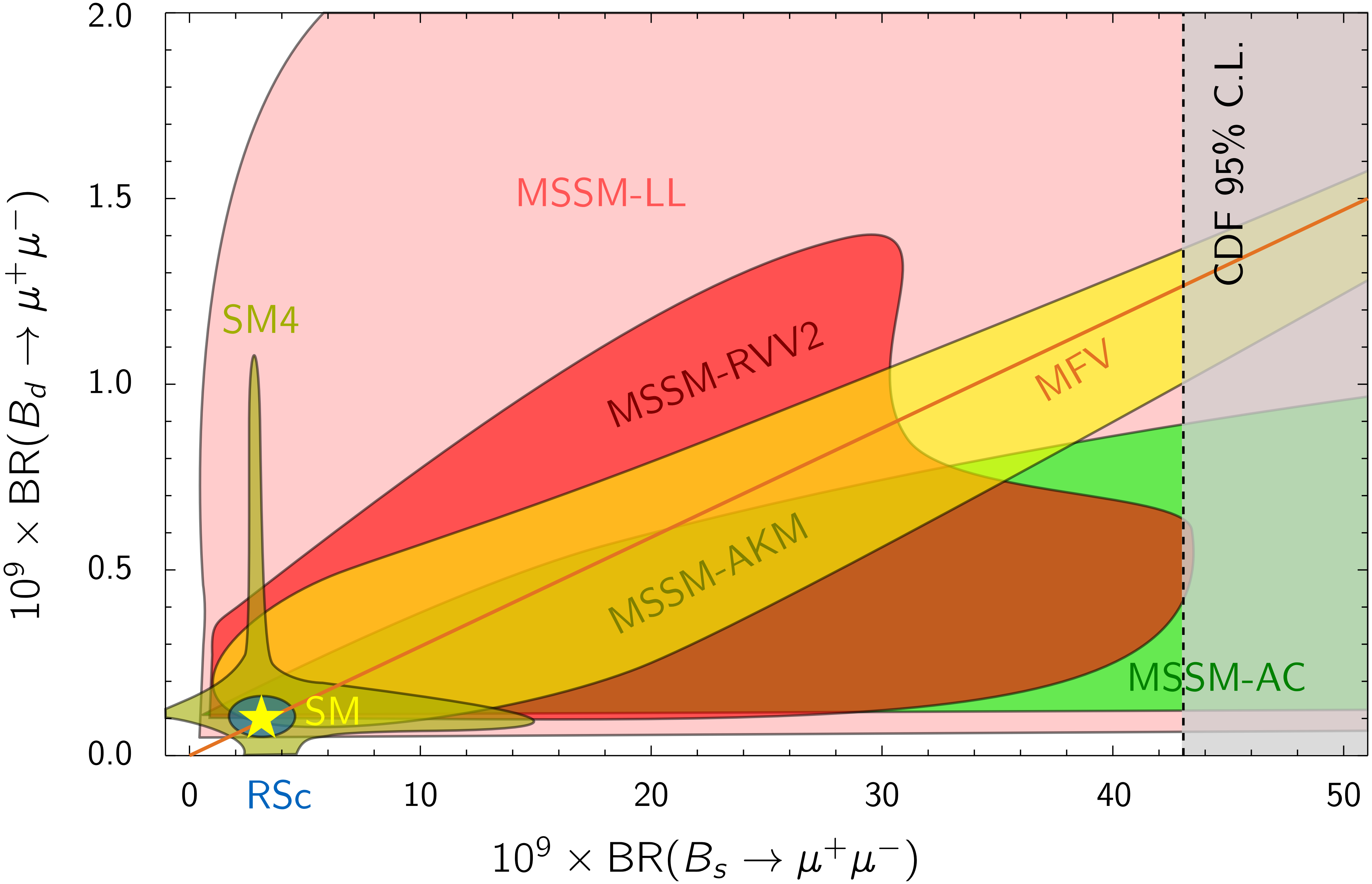
The Interest in Rare Decays

[Straub]

In the SM, FCNCs are suppressed		In the presence of NP, suppression can be lifted
Loop factor		
Hierarchy of CKM		
GIM mechanism	$O(m_c^2 - m_u^2) \ll m_W^2$	$O(m_{\tilde{c}}^2 - m_{\tilde{u}}^2) > m_W^2$
Chirality suppression		

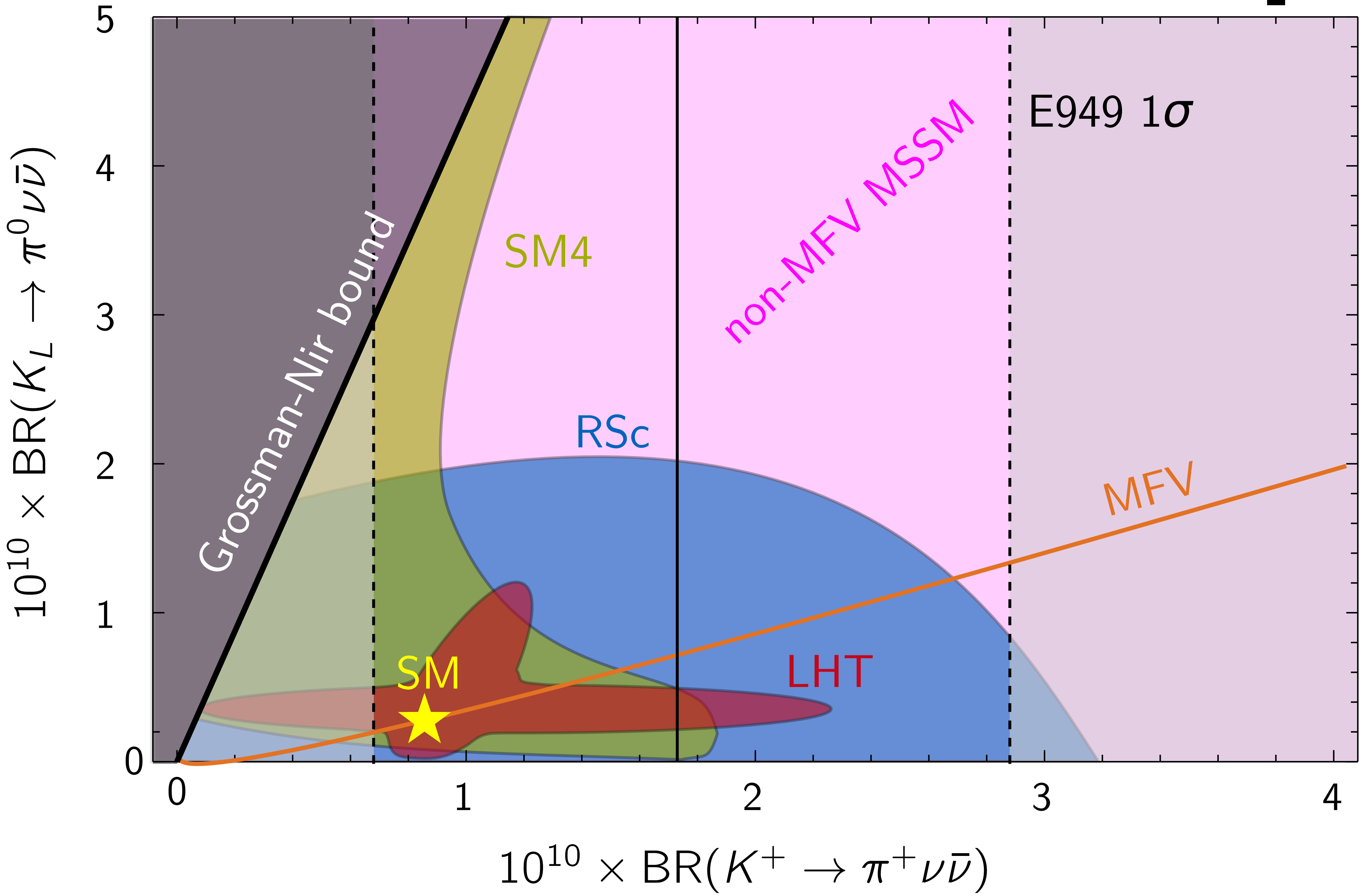
Rare Decays as Probes of NP models

[Straub]



Rare Decays as Probes of NP models

[Straub]



- While only a schematic picture :
  - Correlation between different measurements a powerful probe of NP models
  - Large number of potential channels ... will talk only about a few
  - RD have a bright future: final data sets from B-factories, LHCb, Super Flavour Factories, Kaon experiments...

B -> K* ll - Experimental Status

- Four-body final state with rich phenomenology
- Many observables: - A_{FB}, F_L, Isospin Asymmetry...

[Eigen]

Lepton Forward-Backward Asymmetry $\mathcal{A}_{FB}$

- BABAR, Belle and CDF measured $\mathcal{A}_{FB}$

BABAR: PRL 102, 091803 (2009)
CDF: Note 10047 (2010)
Belle: PRL 103, 171801 (2009)

- TM & © Ne

  $(0.1<q^2<6.25\ GeV^2/c^2)$

  $\mathcal{A}_{FB} = 0.24^{+0.18}_{-0.23} \pm 0.05$

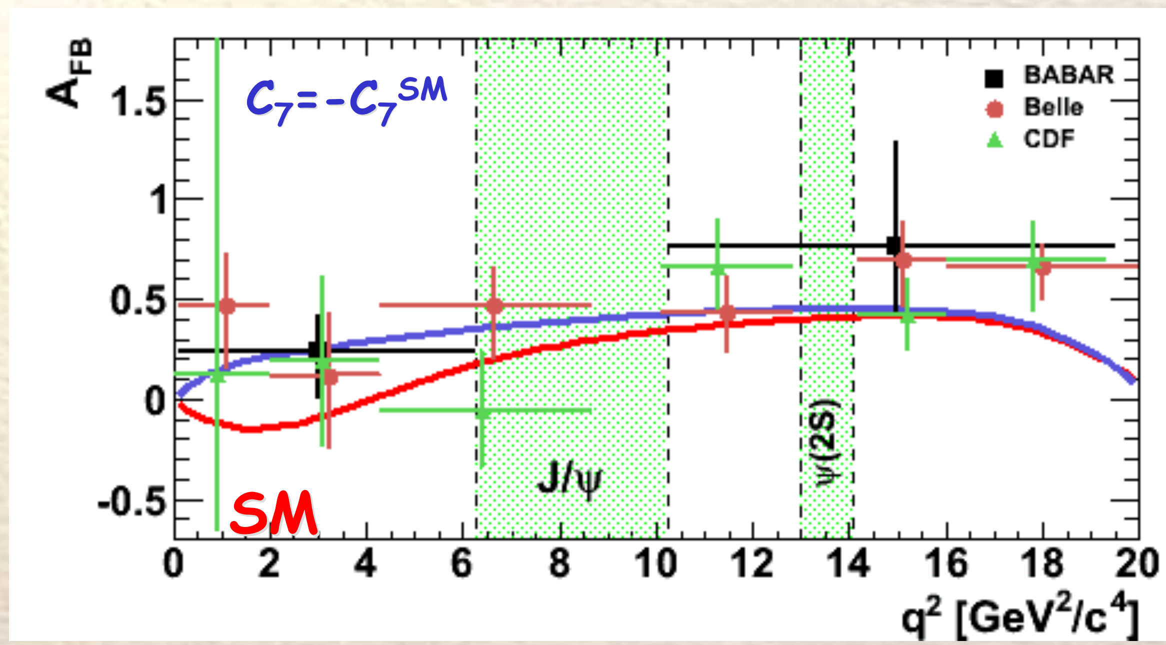
- BELLE

  $(1<q^2<6 GeV^2/c^2)$

  $\mathcal{A}_{FB} = 0.26^{+0.27}_{-0.30} \pm 0.07$

- $(1<q^2<6 GeV^2/c^2)$

  $\mathcal{A}_{FB} = 0.43^{+0.36}_{-0.37} \pm 0.06$



Ali et *al*. PRD 61, 074024 (2000)
Buchalla et *al*. PRD 63, 014015 (2000)
Ali et *al*. PRD 66, 034002 (2002)
Krüger et *al*. PRD 61, 114028 (2002)
Krüger & Matias PRD71, 094009 (2005)

- The measurements of the 3 experiments are in good agreement

- They are consistent with the SM prediction

$$\mathcal{A}_{FB}^{SM} = -0.05^{+0.03}_{-0.04} \quad (1 < q^2 < 6\ GeV^2)$$

C. Bobeth *et al.* arXiv:1006.5013

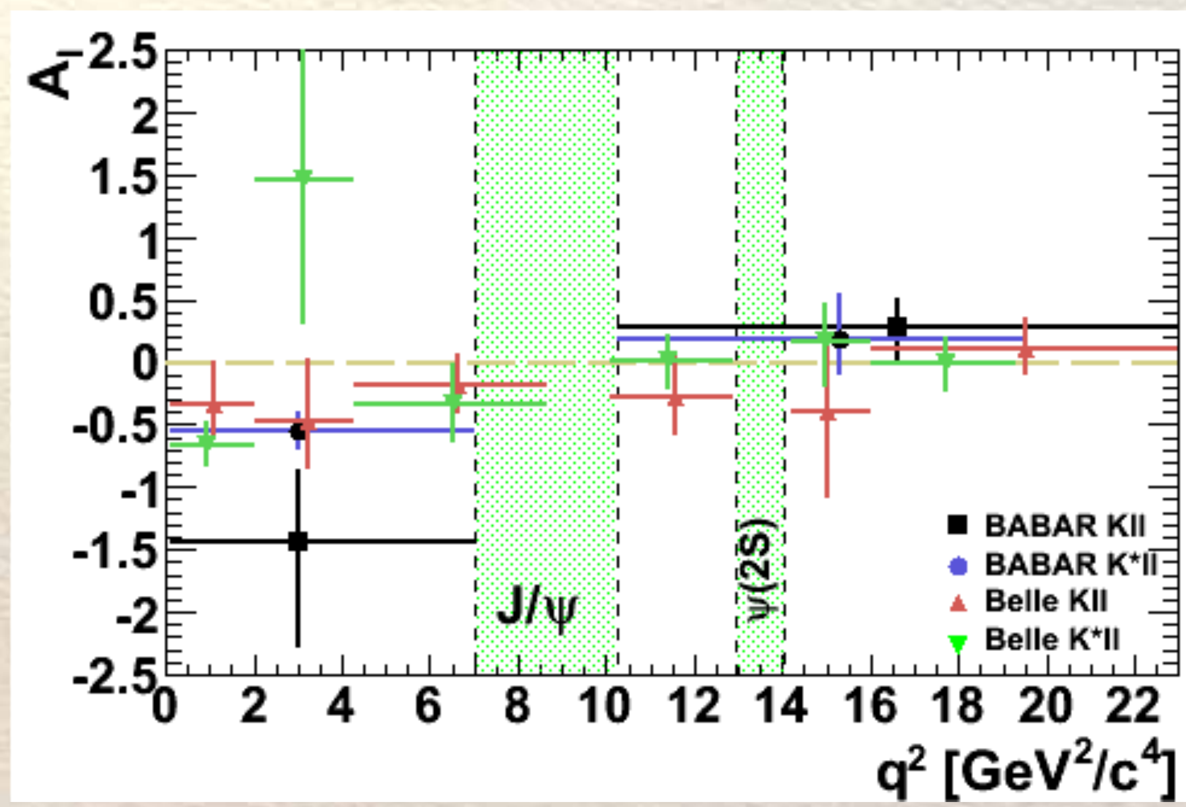
B -> K* ll - Experimental Status

- Four-body final state with rich phenomenology
- Many observables: - A_{FB}, F_L, Isospin Asymmetry...

[Eigen]

$B \to K^{(*)} \ell^+ \ell^-$ Isospin Asymmetry

- $\mathcal{A}_I$ is consistent with zero for all q^2 and in the high-q^2 region
- In the low-q^2 region $\mathcal{A}_I$ shows a significant deviation from zero
- BABAR measures a significant $\mathcal{A}_I$ in the low q^2 region
  ➔ $K\ell^+\ell^-$ and $K^*\ell^+\ell^-$ modes modes differ from the SM prediction by 3.9σ
- Belle and BABAR results are consistent
- Belle is also consistent with SM prediction



BABAR: PRL 102, 091803 (2009)
Belle: PRL 103, 171801 (2009)

G. Eigen, CKM10 Warwick, 07-09-2010

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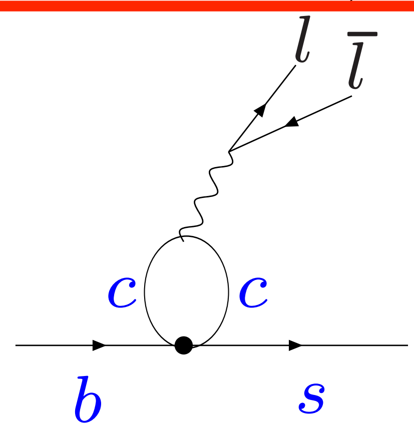
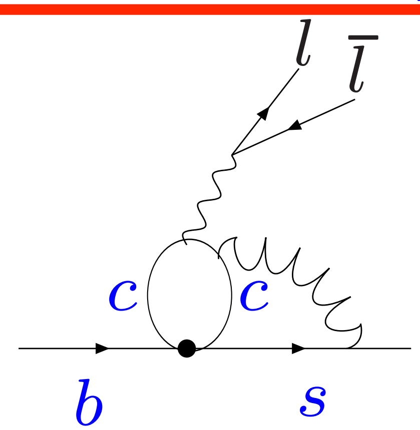
B -> K* ll - Long Distance Effects

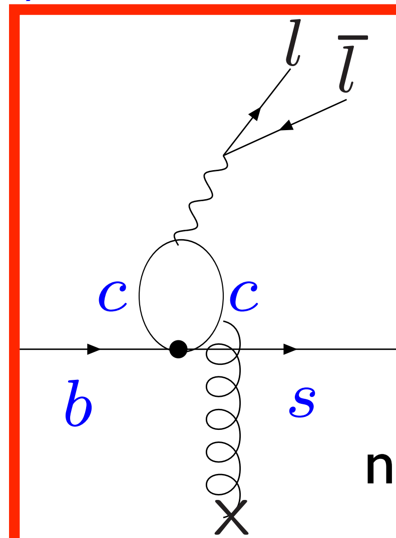
Charm-loops in $B \to K^{(*)}\ell^+\ell^-$

- Charm-loop effect: a combination of the $(\bar{s}c)(\bar{c}b)$ weak interaction ($O_{1,2}$) and e.m.interaction $(\bar{c}c)(\bar{\ell}\ell)$



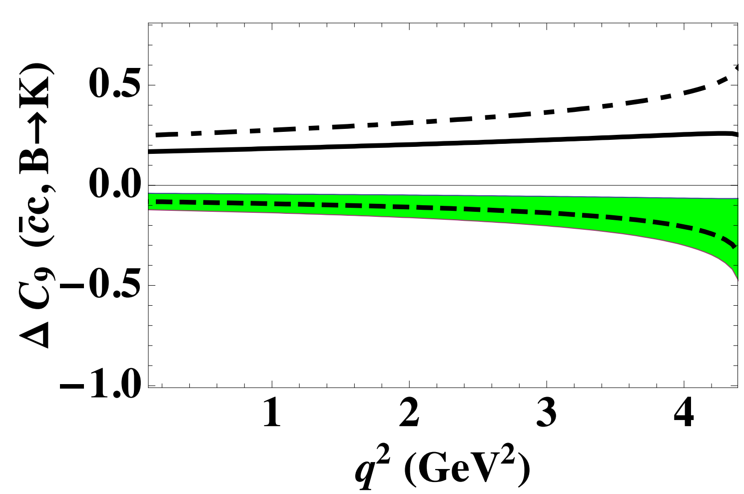


accounted for using QCD factorisation
[Beneke, Feldmann, Seidel]



new: soft gluon contribution
[Khodjamirian]

► correction to the effective coefficient of O_9 operator, $B \to K\ell^+\ell^-$:



B -> K* ll - Status of Form Factors

- to reach $<20\%$ accuracy of the form factors we need QCD calculation !

[Khodjamirian]

Combined analysis of $B \to K$ and $B \to K^*$ form factors

[A.Bharucha, Th.Feldmann, M.Wick, 1004.3249[hep-ph].

- use LCSR (Ball-Zwicky (2005)) and some lattice results $\oplus$ series parameterization
- typical uncertainties: $\pm(12-15)\%$ for $B \to P$, $\sim \pm 20\%$ for $B \to V$ form factors
- an example: $B \to K$ form factor $f^+_{BK}(q^2) \equiv A_{V,0}(q^2)$

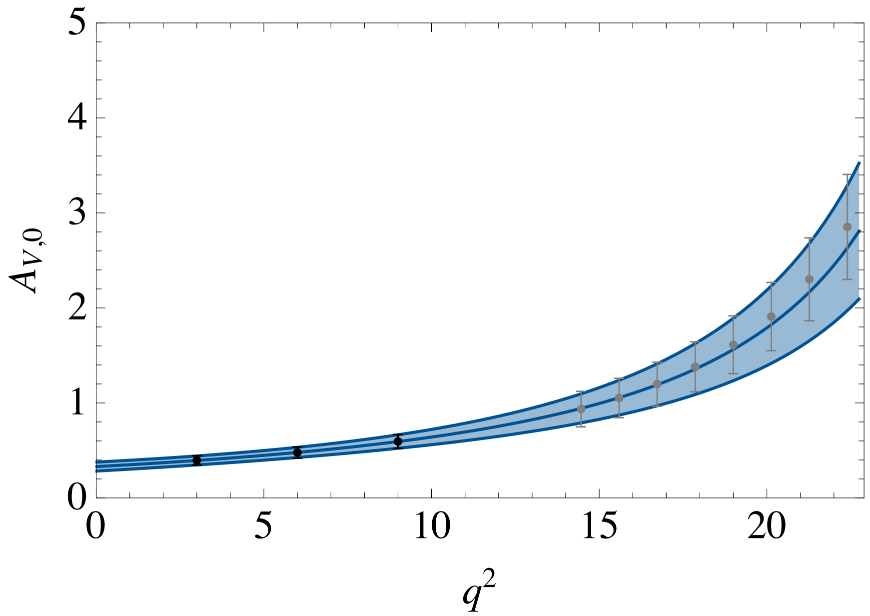


fig. from the above paper

B -> K* ll - Future prospects for Form Factors

[Khodjamirian]

- $B \to P$ form factors needed for $B \to P\ell^+\ell^-$ are accessible both on the lattice and with LCSR, future accuracy:
  $\sim$ 5% (lattice, [App.A SuperB report '07]
  $\sim$ 10% (LCSR)
- $B \to V$ form factors:
  difficulties of "unquenching" on the lattice
- LCSR techniques combined with series parameterization may play a decisive role in providing $B \to V$ form factors in future, very optimistically, with 10-15% accuracy

[Liu]

- Lattice calculations of form factors at high q^2
  - Difficulty extrapolating from q^2_{max} to lower q^2

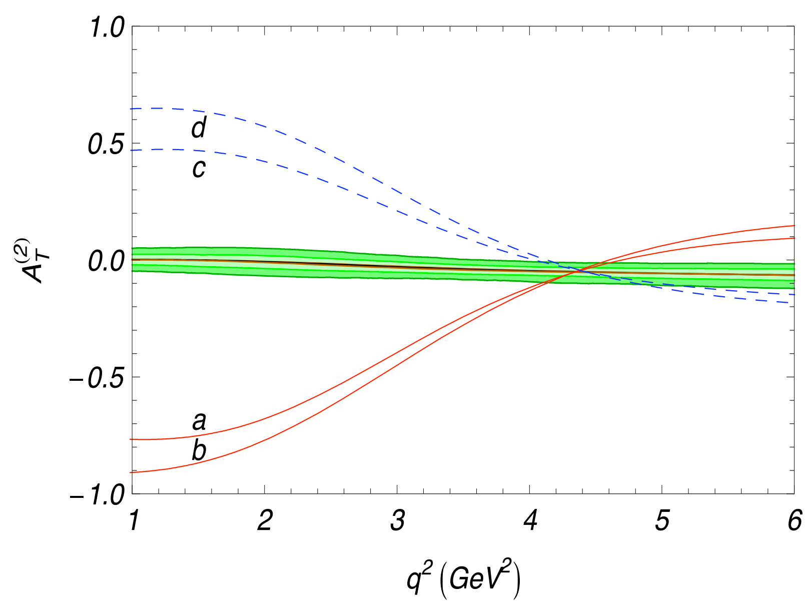
B -> K* ll - New Observables : A_T^2

[Matias]

- Find observables where have reduced dependence on form factors

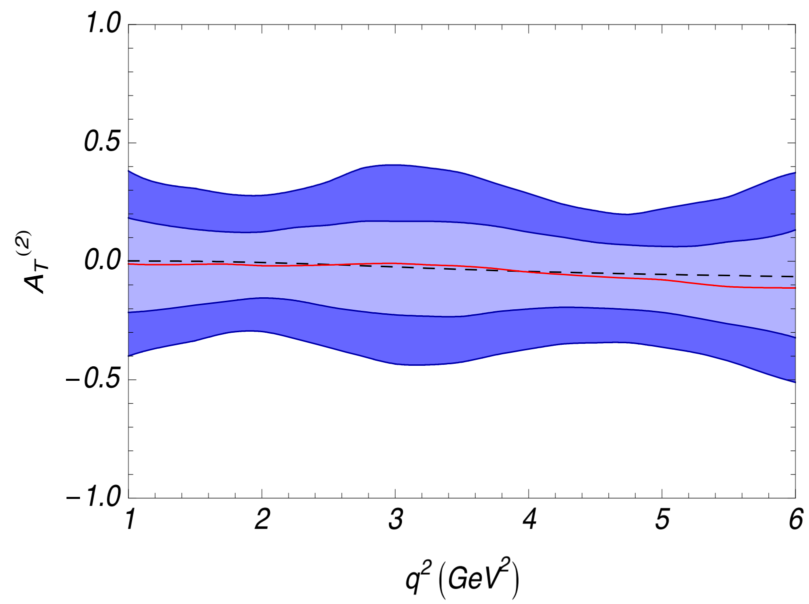
$$A_T^2 = \frac{|A_\perp|^2 - |A_\parallel|^2}{|A_\perp|^2 + |A_\parallel|^2} = -2\frac{\mathrm{Re}H_+^* H_-}{|H_+|^2 + |H_-|^2}$$

- Physics Sensitivity: Deviation from SM left-handed structure: $A_T^2\Big|_{SM} \sim 0$.
- Cleanliness: Soft form factor ($\xi_\perp(0)$) dependence cancel exactly at LO and very mild dependence at NLO.
- Domain: Low-Region $1 \le q^2 \le 6\ \mathrm{GeV}^2$ (High region, see G. Hiller et al.)



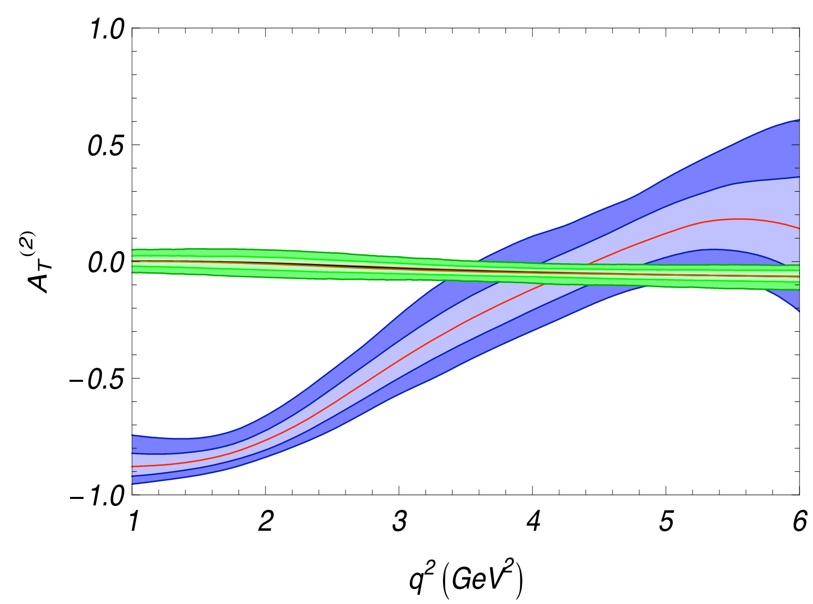
Theoretical sensitivity

Λ/m_b: light(dark) green $\pm 5\%$ ($\pm 10\%$)



Exper. sensitivity SM ($10\mathrm{fb}^{-1}$)

light(dark) blue 1σ (2σ)



Exper. SUSY sens.

(Egede et al. 08)

B -> K* ll - New Observables : A_T^5

[Matias]

- Find observables where have reduced dependence on form factors

$$A_T^{(5)} = \frac{|A_\parallel^{R*} A_\perp^L + A_\parallel^L A_\perp^{R*}|}{|A_\parallel|^2 + |A_\perp|^2}$$

a) It probes spin amplitudes $A_\perp$ and $A_\parallel$ differently from A_T^2.
b) No angular coefficient mixes L/R with $\perp / \parallel$ simultaneously.
c) In the large recoil limit

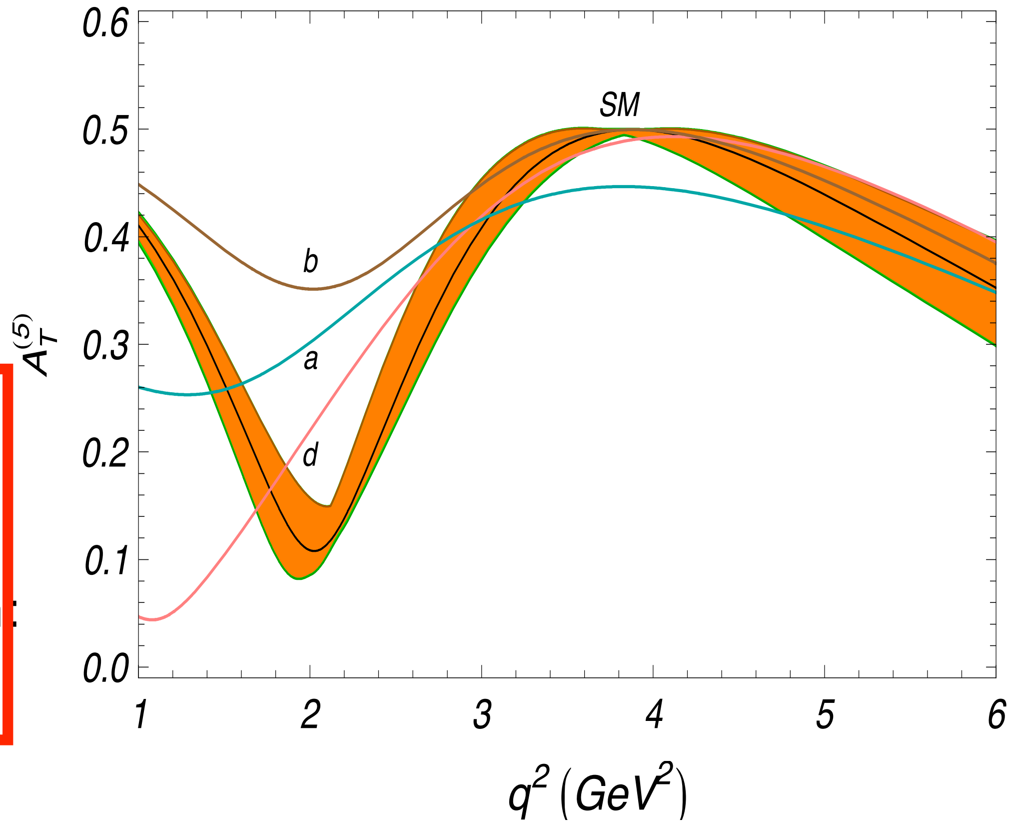
$$A_T^{(5)}\Big|_{SM} = \frac{\left|-C_{10}^2 + (2m_b M_B C_7^{eff}/q^2 + C_9^{eff})^2\right|}{2\left[C_{10}^2 + (2m_b M_B C_7^{eff}/q^2 + C_9^{eff})^2\right]},$$

Minimum at LO of $A_T^5 \Rightarrow$ **NEW** relation:

$$C_{10}^2 = (2m_b M_B C_7^{eff}/q_1^2 + C_9^{eff})^2$$

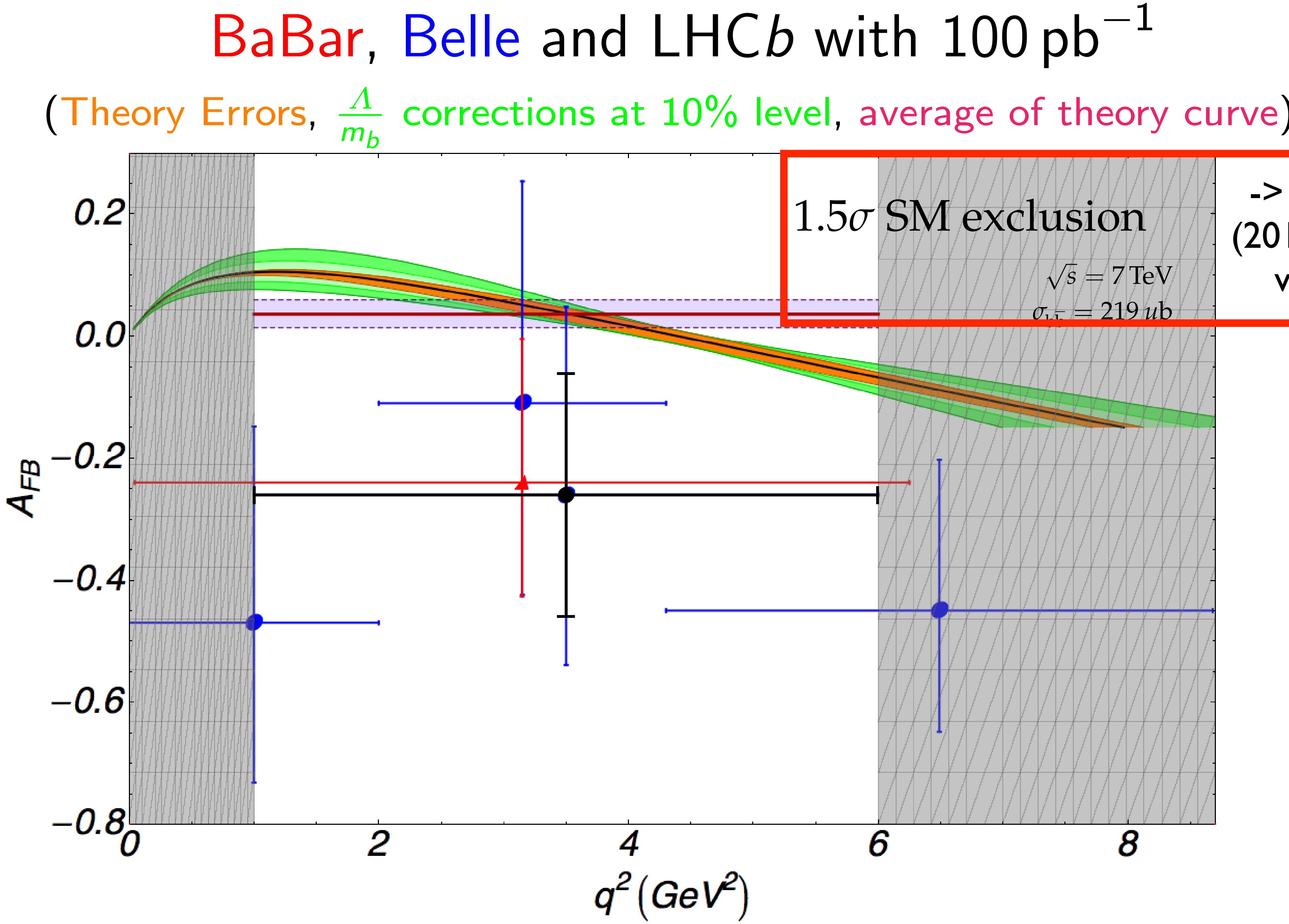
Maximum at LO of $A_T^5 \Rightarrow$ by **OLD** (A_{FB}-zero) relation:

$$-C_9^{eff} = 2m_b M_B C_7^{eff}/q_0^2$$



B -> K* ll - LHCb Prospects

[Soomro]

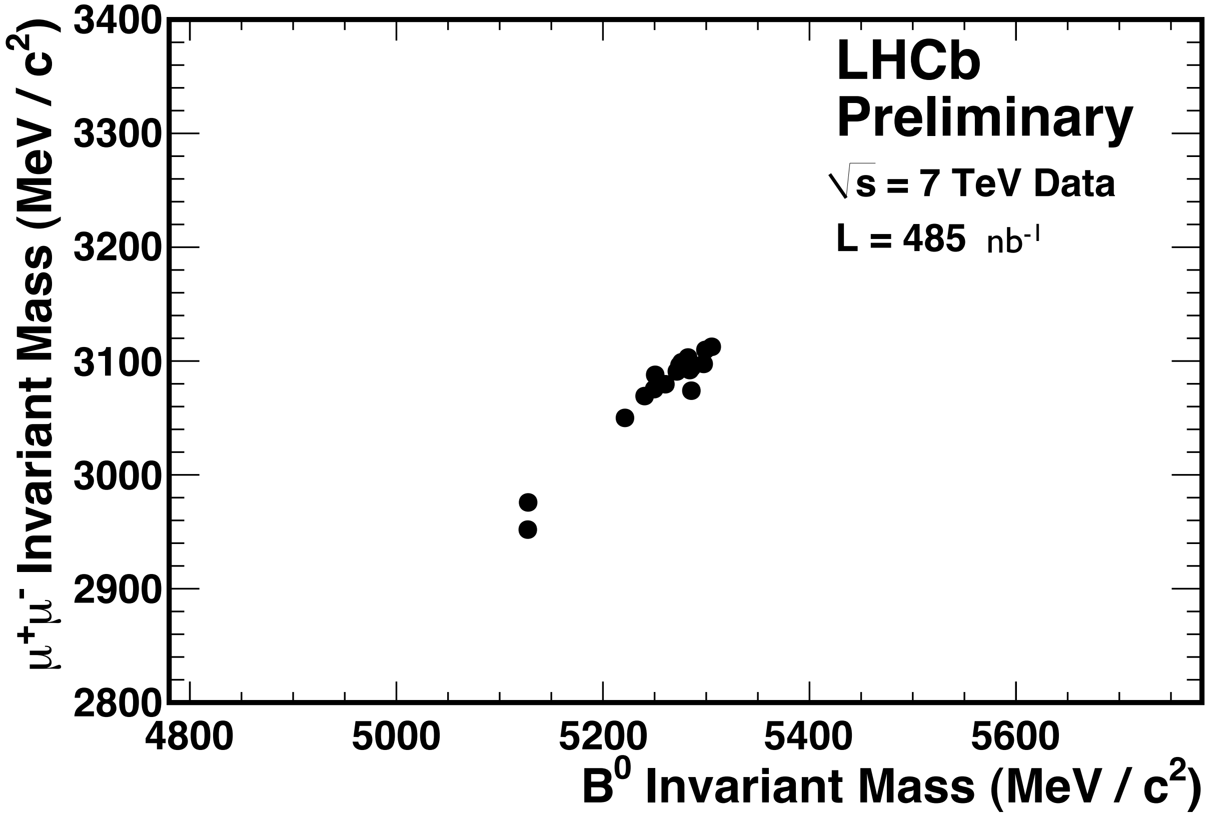


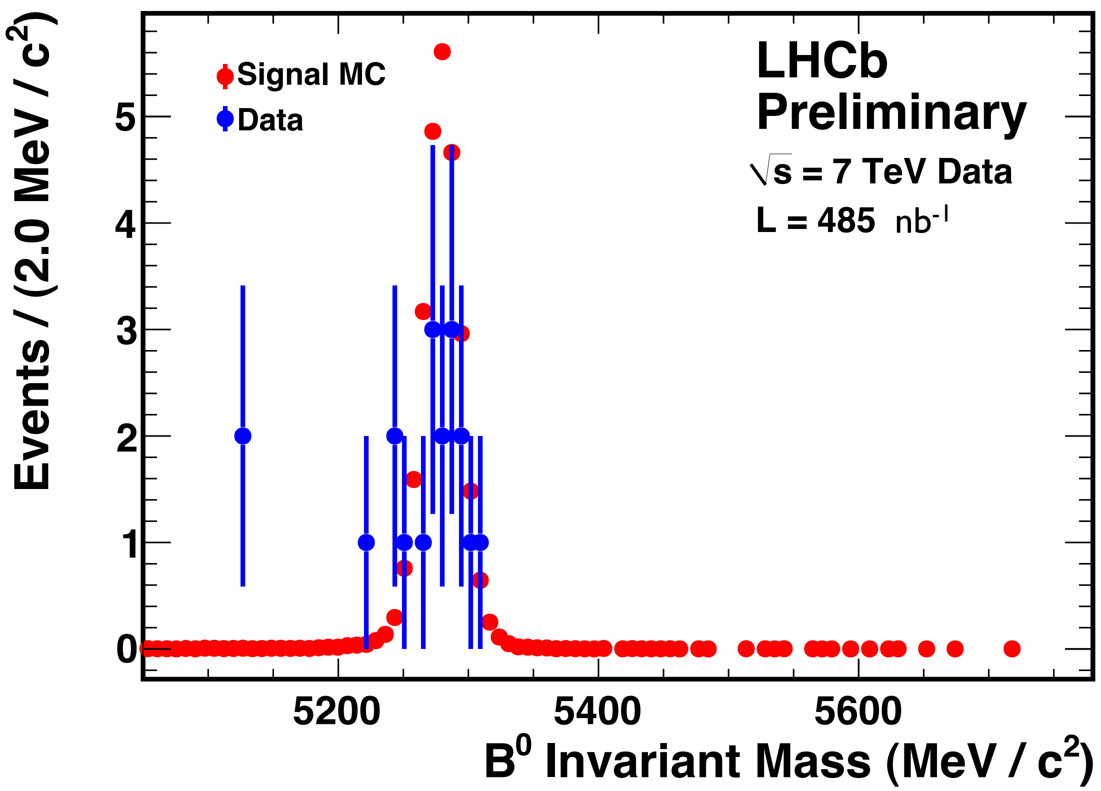
-> 5sigma with 1fb^{-1} (2011?) if Belle central value maintained

B -> K* ll - LHCb Prospects

[Soomro]

- B -> K* J/Psi control channel





Clear signal of $B_d \rightarrow K^* J/\psi$ with $B_d \rightarrow K^* \mu^+ \mu^-$ cuts

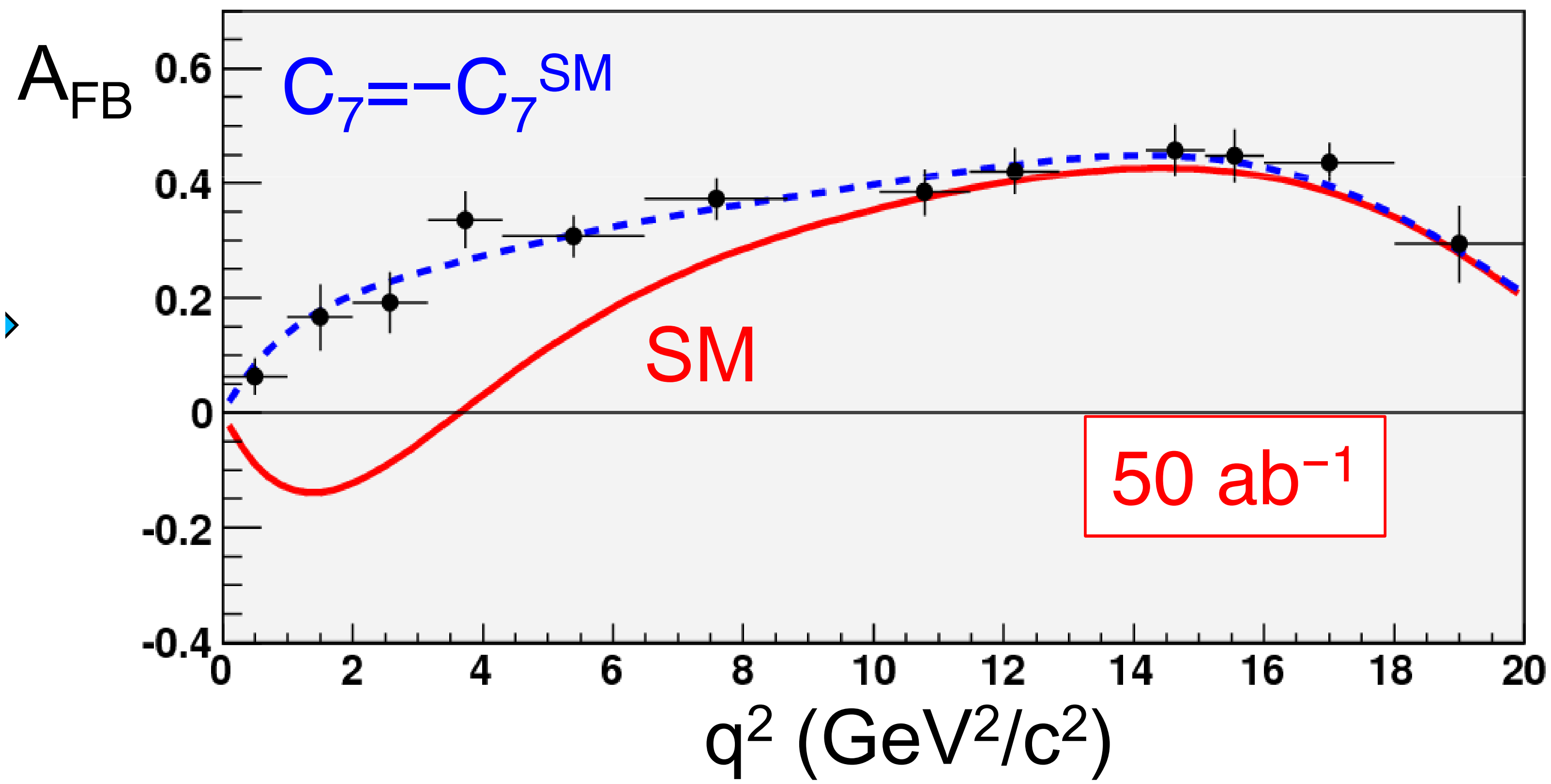
$\Rightarrow$The data and MC are normalized to the measured $\sigma_{b\bar{b}}$

$\Rightarrow$Efficiency estimates from MC are reliable

B -> K* ll - The Future

[Nishida, Ciuchini]

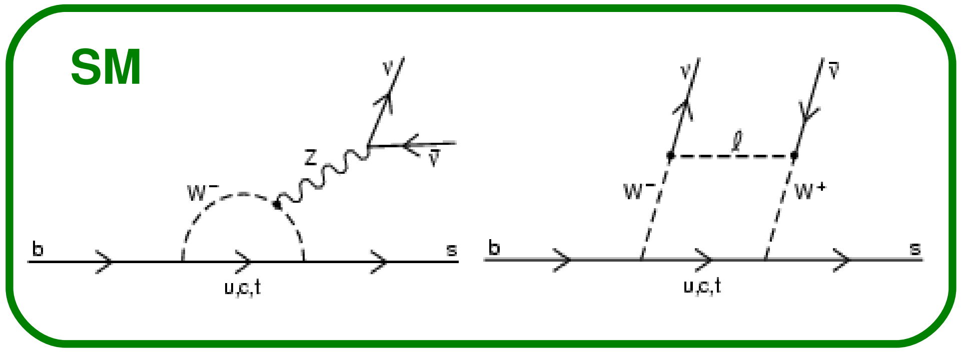
- 1 year of LHCb data-taking s_0~ 13% uncertainty
- 5 years at Super Flavour Factory s_0~ 5% uncertainty

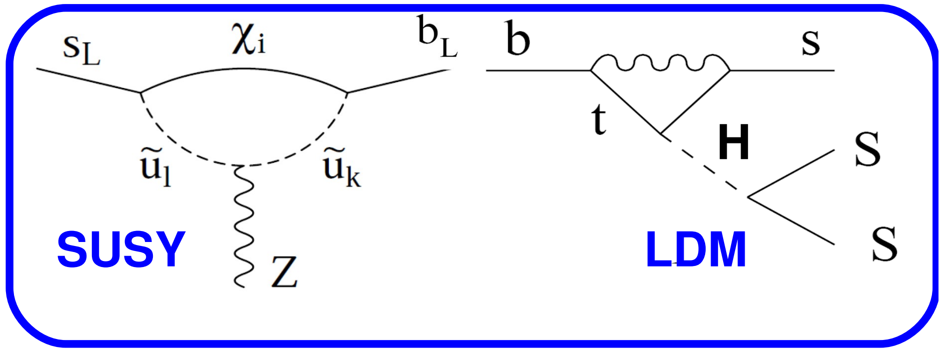


B -> K$^{(*)}$nunu

- **Electroweak penguin (loop diagram) radiated processes ($b \to s$):**
  - **Flavor changing neutral current (FCNC) prohibited in SM at tree level**
  - **Sensitive New Physics (NP): Susy particles, light dark matter (LDM), ...**

[Perez, Kamenik]





• Branching ratio of a large number of such channels has been constrained by B factories

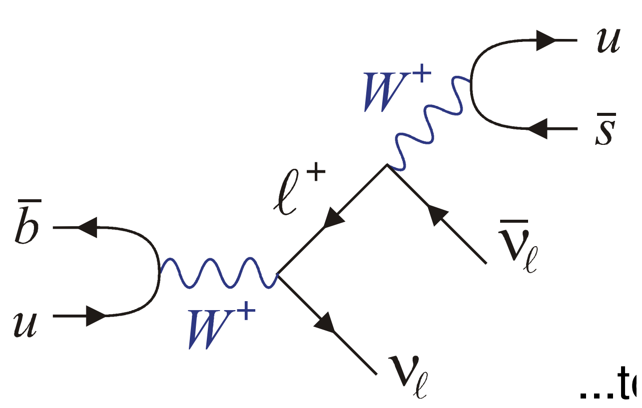
[Chen]

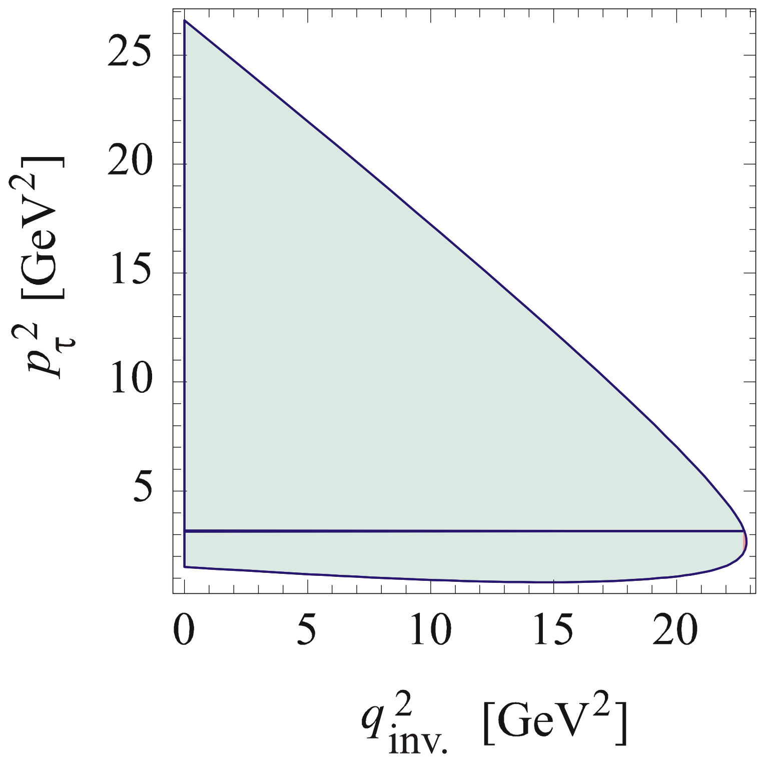
	Target Channel	Best B-factories Exp. Limits
$b \to s\nu\nu$	$B \to K^+\nu\nu$	$< 1.3 \times 10^{-5}$
	$B \to K^0\nu\nu$	$< 5.6 \times 10^{-5}$
	$B \to K^{*0}\nu\nu$	$< 12 \times 10^{-5}$
	$B \to K^{*+}\nu\nu$	$< 8 \times 10^{-5}$
$b \to d\nu\nu$	$B \to \pi^+\nu\nu$	$< 1.0 \times 10^{-4}$
	$B \to \rho^+\nu\nu$	$< 1.5 \times 10^{-4}$
	$B \to \rho^0\nu\nu$	$< 4.4 \times 10^{-4}$
	$B \to \pi^0\nu\nu$	$< 2.2 \times 10^{-4}$
others	$B \to \varphi\nu\nu$	$< 5.8 \times 10^{-5}$
	$B \to$ invisible	$< 2.2 \times 10^{-4}$
	$B \to \gamma\nu\nu$	$< 4.7 \times 10^{-5}$

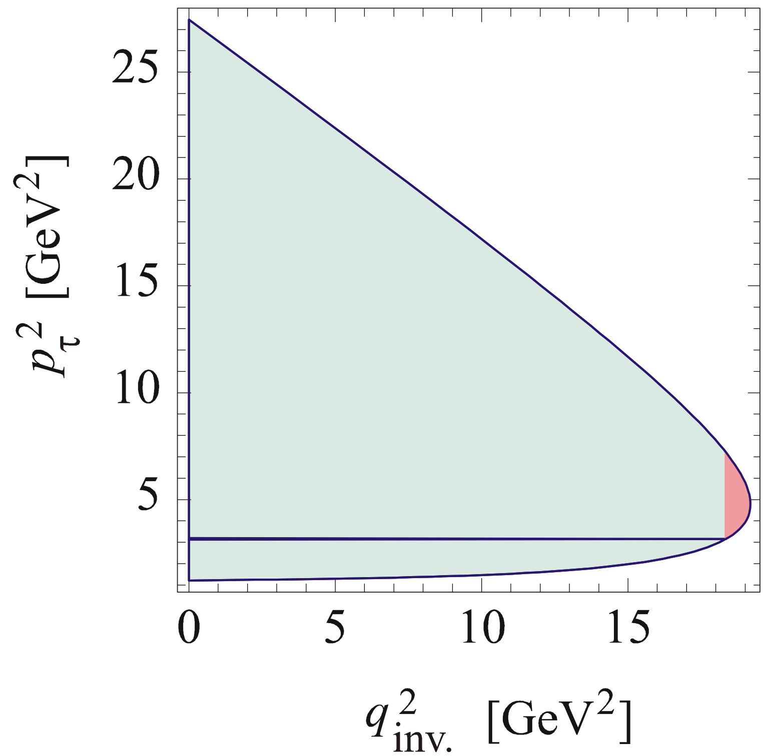
Background to B^+ -> $K^{(*)+}$nunu

[Kamenik, Smith]

- Important background from $B^+ \to \tau^+ \nu$ with tau decaying into $K^{(*)+} \nu$







- can be measured and subtracted

$$\mathcal{B}(B^+ \to K^+ \nu\bar{\nu})^{LD} \propto \mathcal{B}(B^+ \to \tau^+ \nu) \times \mathcal{B}(\tau^+ \to K^+ \bar{\nu})$$

(need a few % accuracy)

- or can be computed and added (V_{ub}, $f_{B,K}$)

(-> 3-4 % uncertainty)

B -> K$^{(*)}$nunu - Observables and Future Prospects

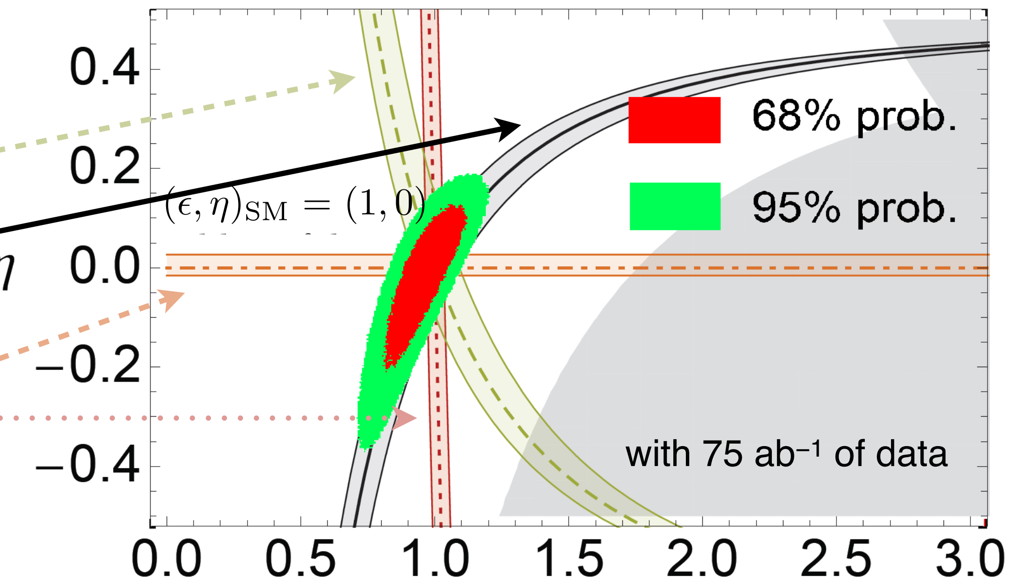
[Kamenik]

- Parametrize SM+NP in OPE: $\mathcal{H}_{\text{eff}} = -\frac{4\,G_F}{\sqrt{2}} V_{tb} V_{ts}^* \left(C_L^\nu \mathcal{O}_L^\nu + C_R^\nu \mathcal{O}_R^\nu\right) \; + \; \text{h.c.}$

- Only two independent combinations measurable with present observables

$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{\text{SM}}|}\,, \qquad \eta = \frac{-\text{Re}\,(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2}$$

$$\begin{aligned} R(B \to K^* \nu\bar{\nu}) &= (1 + 1.31\,\eta)\epsilon^2, \\ R(B \to K \nu\bar{\nu}) &= (1 - 2\,\eta)\epsilon^2, \\ R(\bar{B} \to X_s \nu\bar{\nu}) &= (1 + 0.09\,\eta)\epsilon^2, \\ \langle F_L \rangle / \langle F_L \rangle_{\text{SM}} &= \frac{(1 + 2\,\eta)}{(1 + 1.31\,\eta)}, \\ R(X) &= \mathcal{B}(X)/\mathcal{B}(X)_{\text{SM}} \end{aligned}$$



M. Wick, 0911.0297

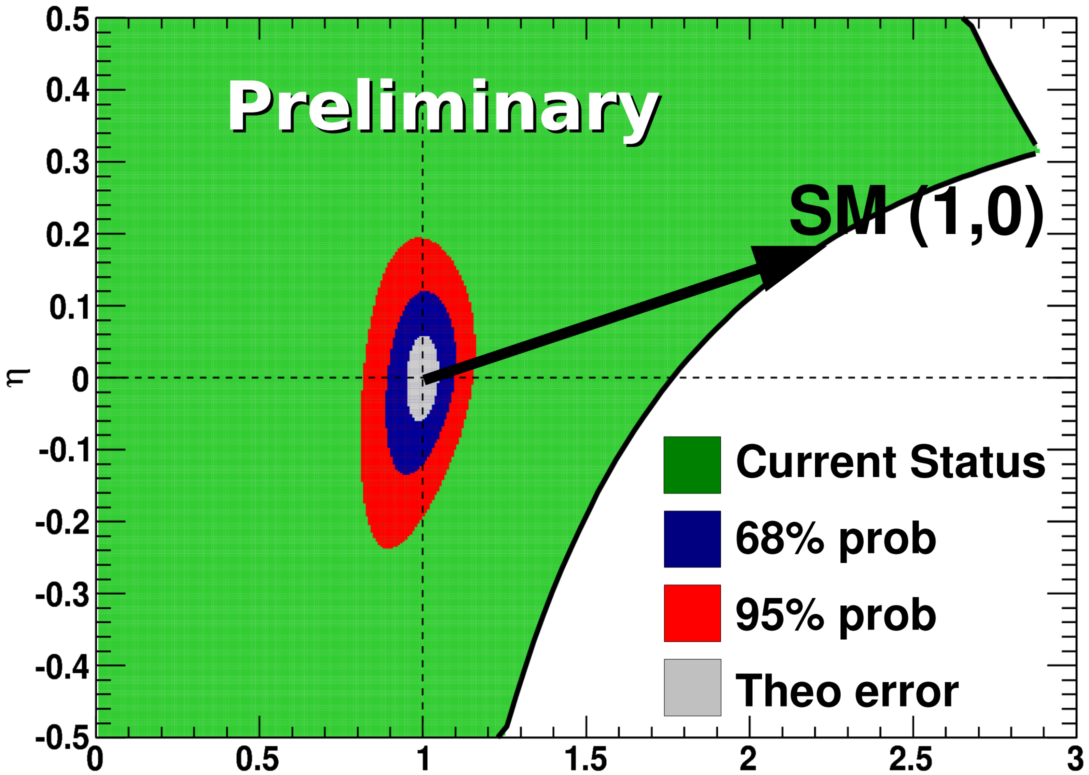
- important feature of F_L: only depends on η

  - Any deviation from SM would imply presence of right-handed currents

Altmannshofer et al., 0902.0160

B -> K$^{(*)}$nunu - Observables and Future Prospects

[Perez]



SuperB, 50 ab^{-1}

- **Warning: very preliminary results**
- **Still need to quantify the effect of:**
  - Bwd-EMC on background rejection
  - SuperB machine backgrounds rates

b -> s/d E_{Miss}

[Kamenik, Smith, Chen]

- Neutrinos not detected in experiments probing b → s/d νν

- Various NP contributions can mimic experimental signature

  very light scalar dark matter
  light neutralinos
  light NMSSM pseudoscalar Higgs
  light radions
  unparticles
  ...

C. Bird, et al., hep-ph/0401195.

R. Adhikari & B. Mukhopadhyaya, hep-ph/9411347.

H. K. Dreiner et al., 0905.2051.

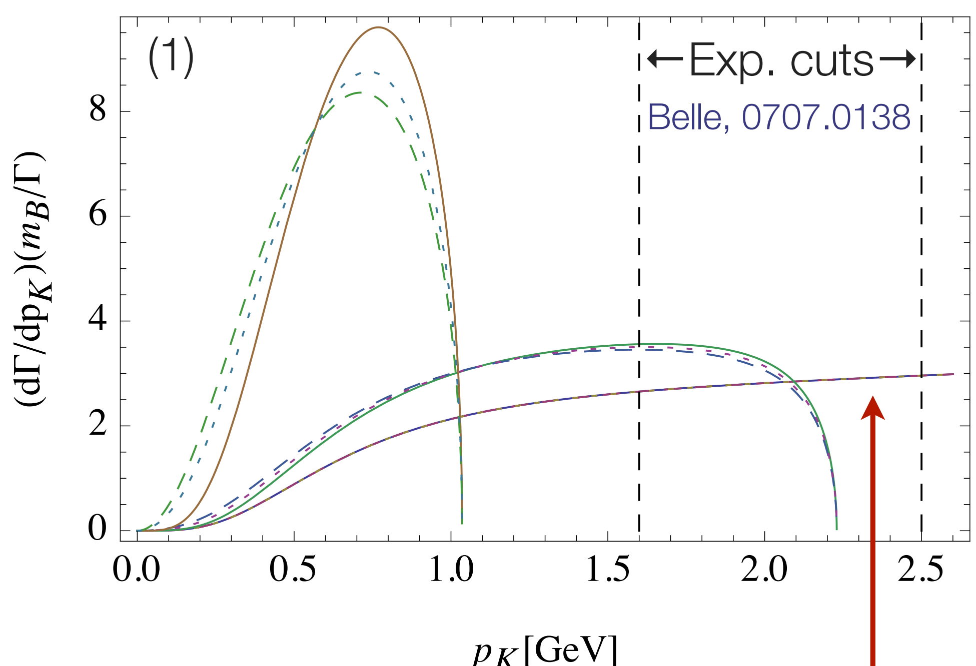
G. Hiller, hep-ph/0404220.

H. Davoudiasl and E. Ponton, 0903.3410.

T. M. Aliev, et al., 0705.4542

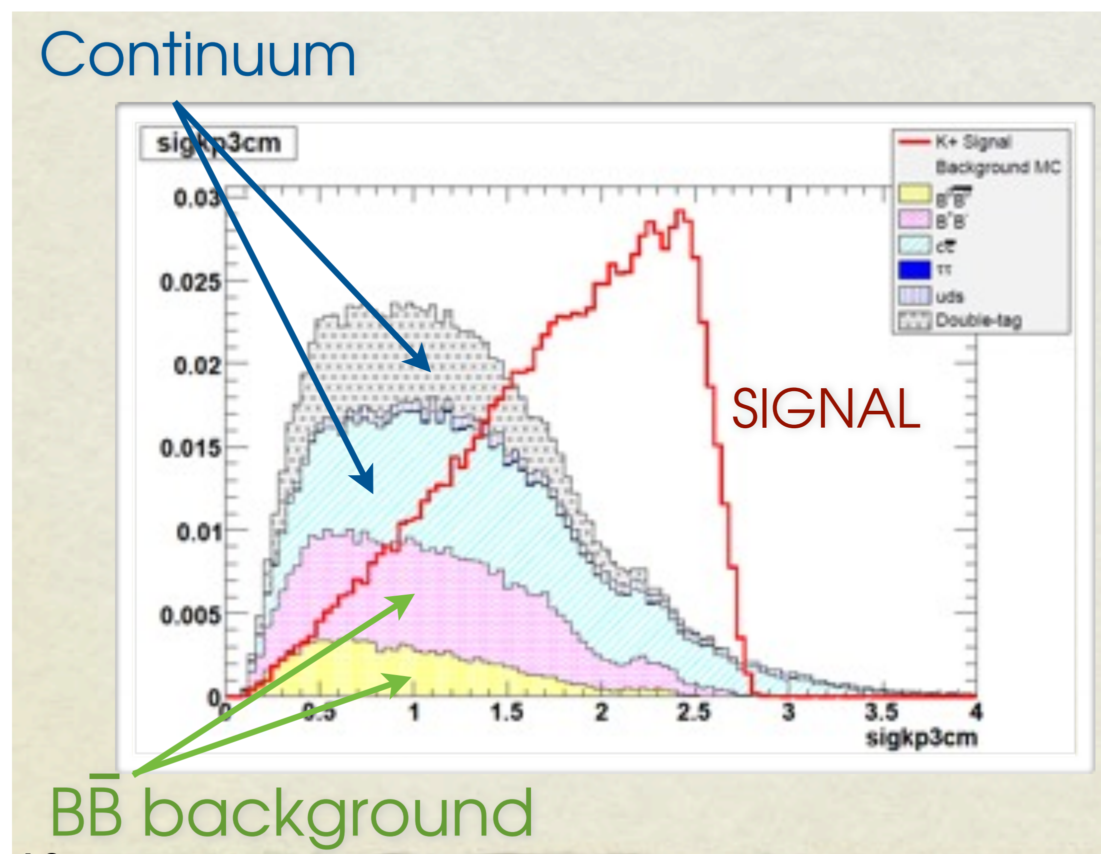
- Failure of the individual constraints on the ε-η plane meeting at a single point

- Kinematical distributions modified - need to be taken into account when interpreting experimental searches



axial, vector, chiral couplings
m_ψ=0, 1, 2 GeV

SM-like



B -> X_s gamma - Theory

[Paz]

- SM prediction at NNLO

  - Current (2006) value Misiak et. al. '06:

    $\Gamma(b \to s\gamma) = (3.15 \pm 0.23) \times 10^{-4}, \quad E_\gamma > 1.6\ \mathrm{GeV}$

    Four types of uncertainties:

    – nonperturbative (5%) from $\mathcal{O}\left(\frac{\Lambda_{\mathrm{QCD}}}{m_b}\right)$

    – parametric (3%)

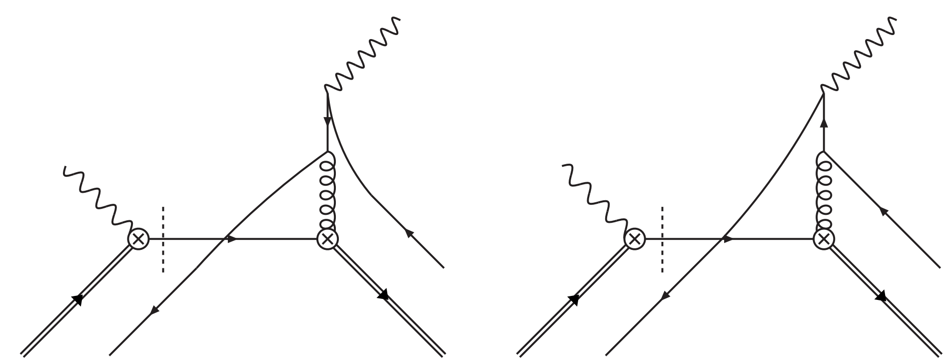
    – higher-order (3%)

    – m_c-interpolation ambiguity (3%)

  - New perturbative corrections $\sim 1\%$ for $\Gamma(\bar{B} \to X_s\gamma)$

Can we improve on the Non-perturbative error?

SCET analysis [Benzke, Lee, Neubert, Paz]



new: Q_7 - Q_8 at tree-level !
=> irreducible 5% uncertainty

B -> X_s gamma - Experiment

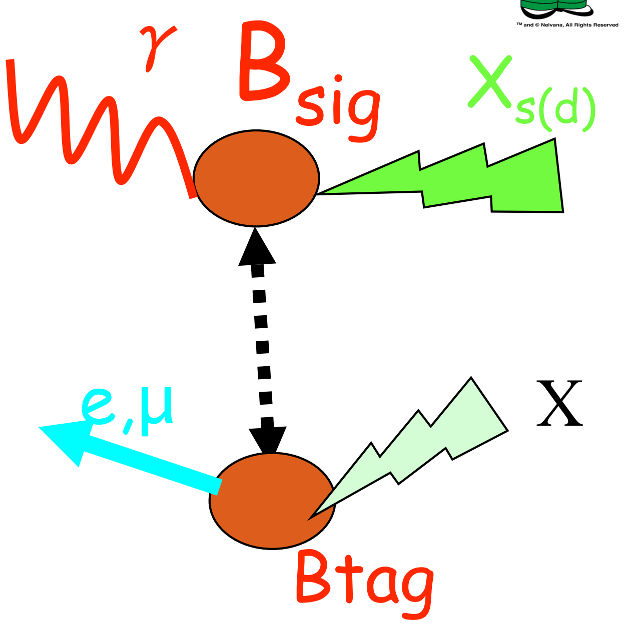
[Wang]

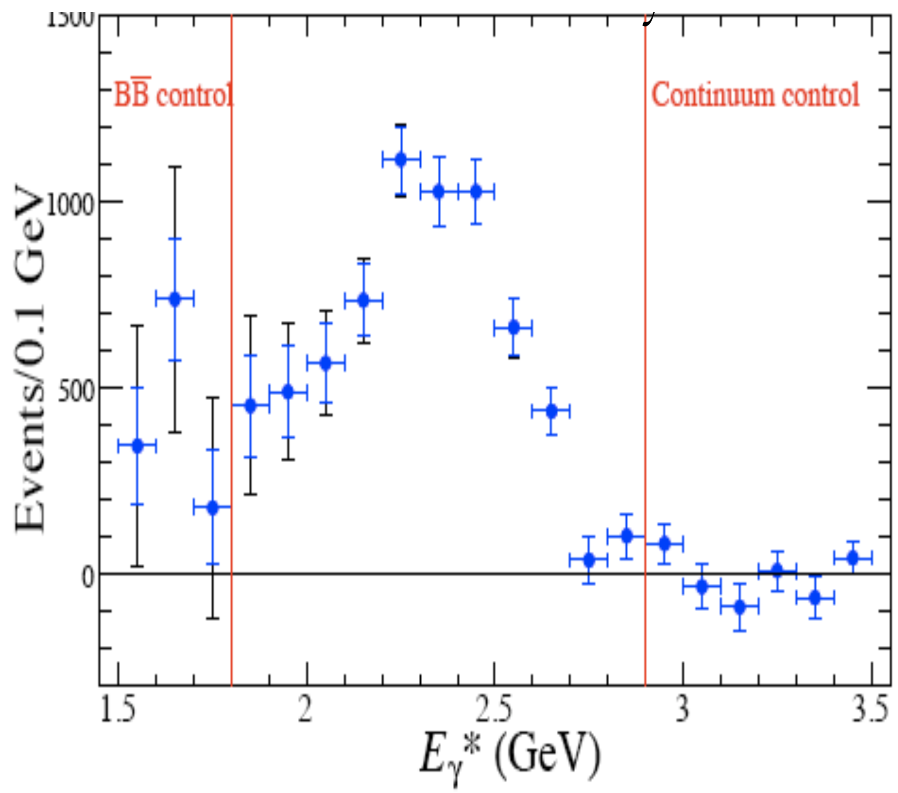
Babar: $B \to X_s \gamma$ (New, preliminary)

347 fb^{-1} $\Upsilon(4S)$ Data and 36 fb^{-1} Off resonance Data

- ❖Signal signature:
  One isolated High Energy photon (γ_{HE}), do not reconstruct the hadronic system. Veto γ_{HE} from π^0/η.

- ❖Lepton tag and event topology criteria used to suppress continuum.





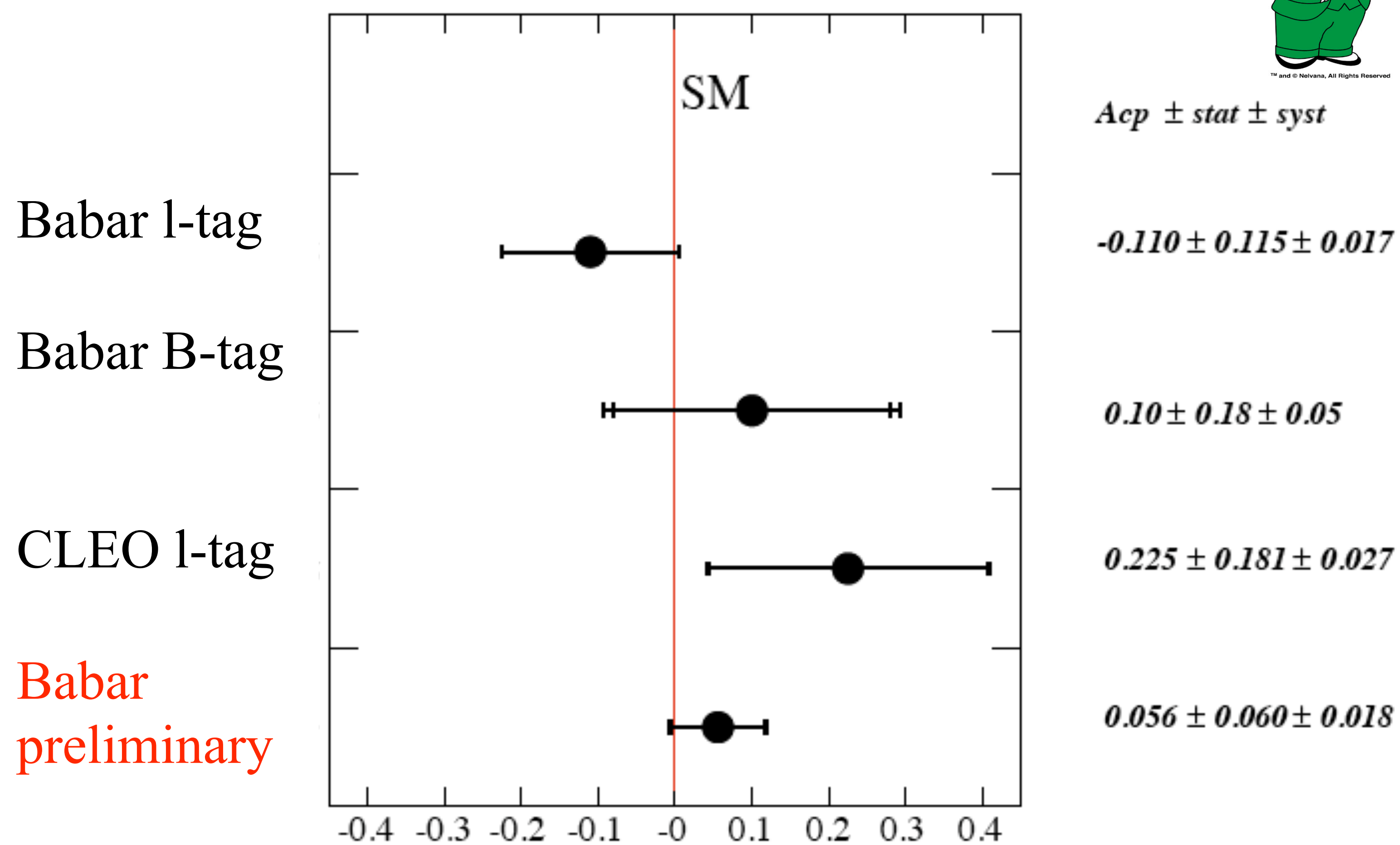
B -> X_s gamma - Experiment - A_{CP}

[Wang]

$A_{CP}(B \to X_{s+d}\gamma)$ preliminary

$N(l^+) = 2623 \pm 158$
$N(l^-) = 2397 \pm 151$

Babar preliminary
$A_{CP} = 0.056 \pm 0.060 \pm 0.018$



- ✓ No significant asymmetry is observed, most precise to date.
- ✓ Consistent with SM and previous measurements.
- ✓ All measurements dominated by statistical uncertainty.

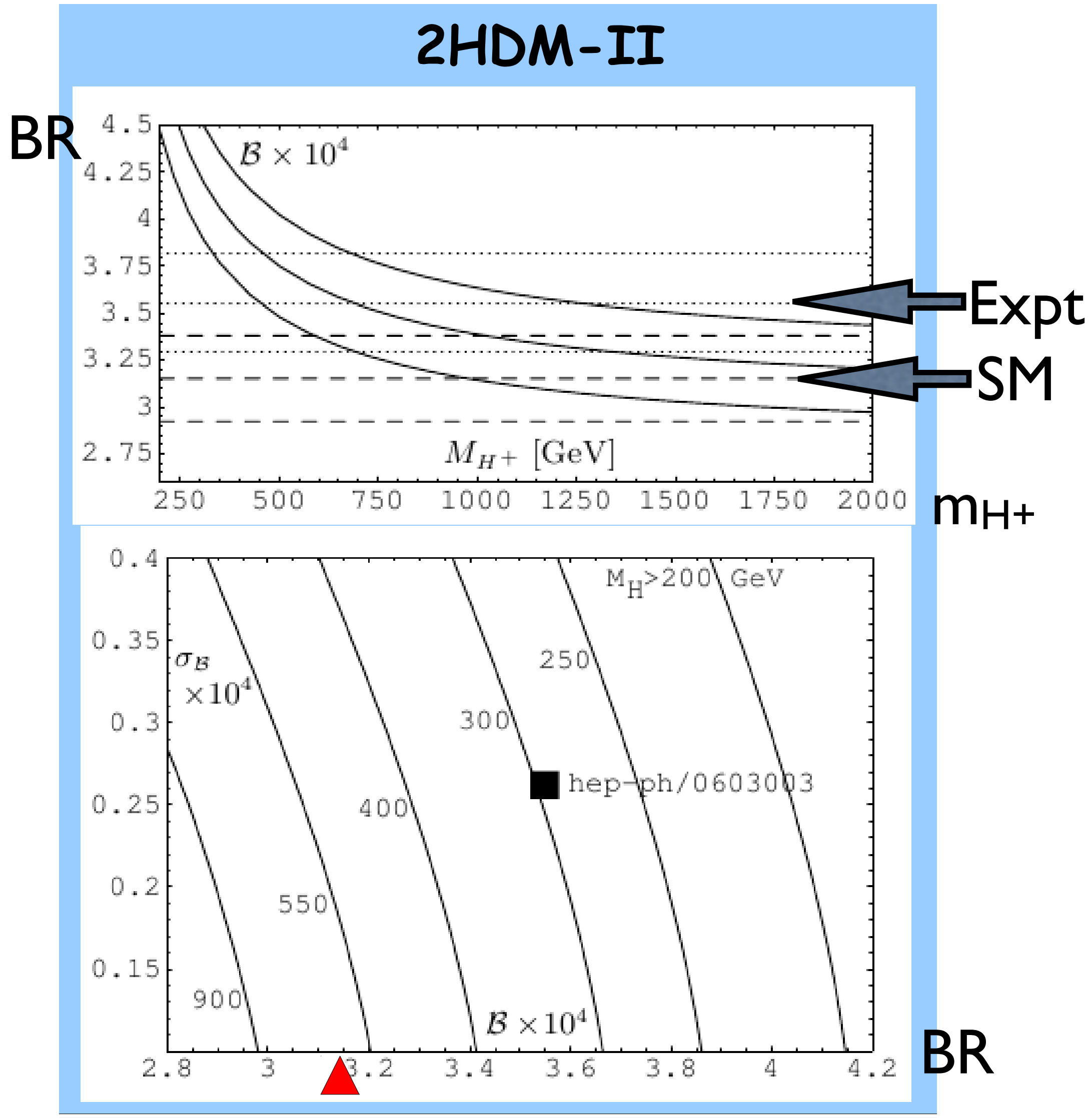
B -> X_s gamma - Experiment - Branching Fraction

[Wang, Ciuchini]

	E gamma	BR
HFAG average (2010)	**1.6** (extrap.)	3.55±0.24±0.09
SM NNLL	**1.6**	3.15±0.23

1.2 σ

❖Good agreement with SM prediction.



SM prediction: $E_\gamma > 1.6$ GeV   M. Misiak et al., hep-ph/0609232

$$\mathcal{B}(\bar{B} \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$$

World average:

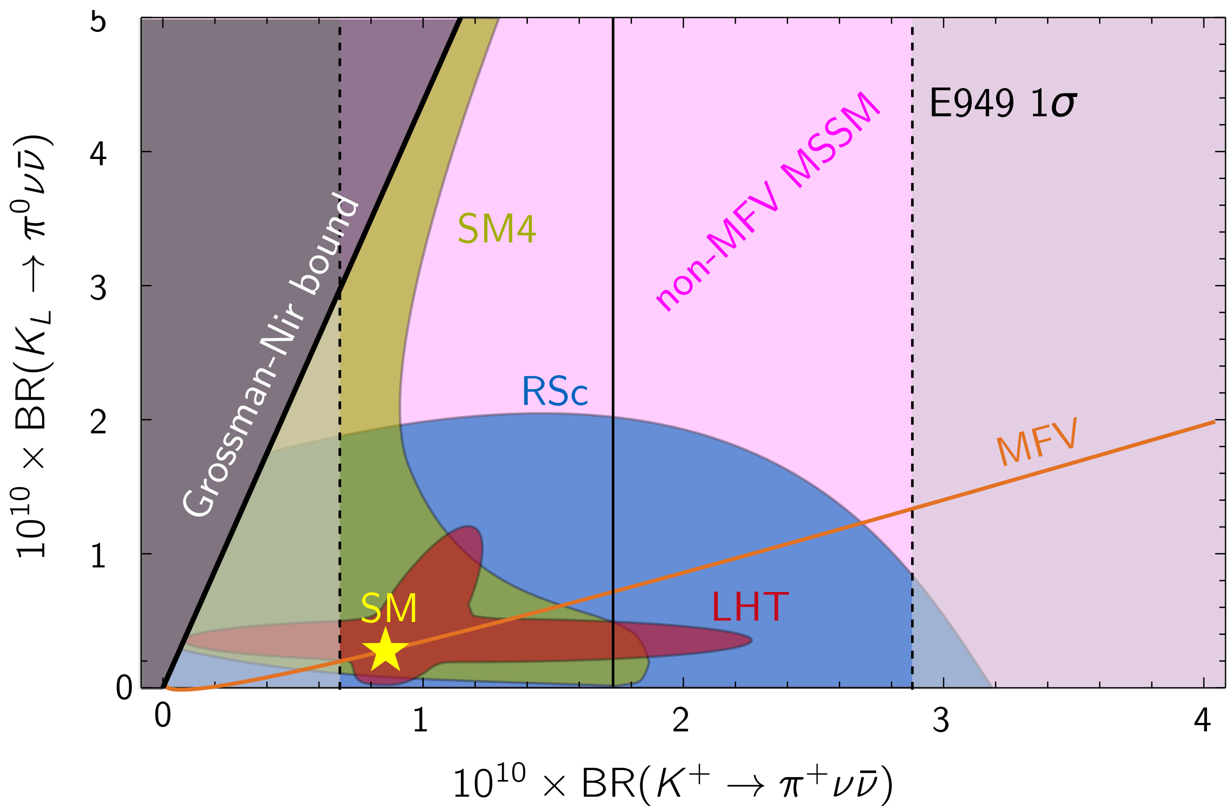
$$B(\bar{B} \to X_s\gamma) = (3.52 \pm 0.23 \pm 0.09) \times 10^{-4}$$

Already gives the best lower limit on the charged Higgs mass:

$M_{H^+} > 295$ GeV@95%CL

- Given power of this, still important to improve expt'al error... ?

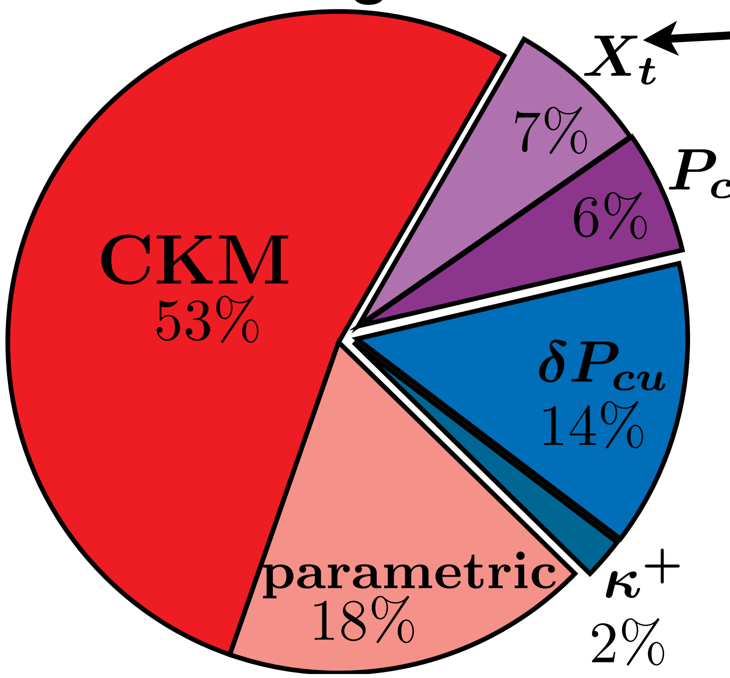
K -> pinunu - Theory



[Stamou, Straub]

- Sensitive to new physics
- Precise theory prediction

K$^+$ -> pi$^+$nunu - error budget



Improved theory prediction

$$\mathrm{Br}^{exp} = 1.73^{+1.15}_{-1.05} \times 10^{-10}$$

$$\mathrm{Br}^{the} = 8.22^{+0.74}_{-0.65} \pm 0.29 \times 10^{-10}$$

[Brod, Gorbahn, ES 10]

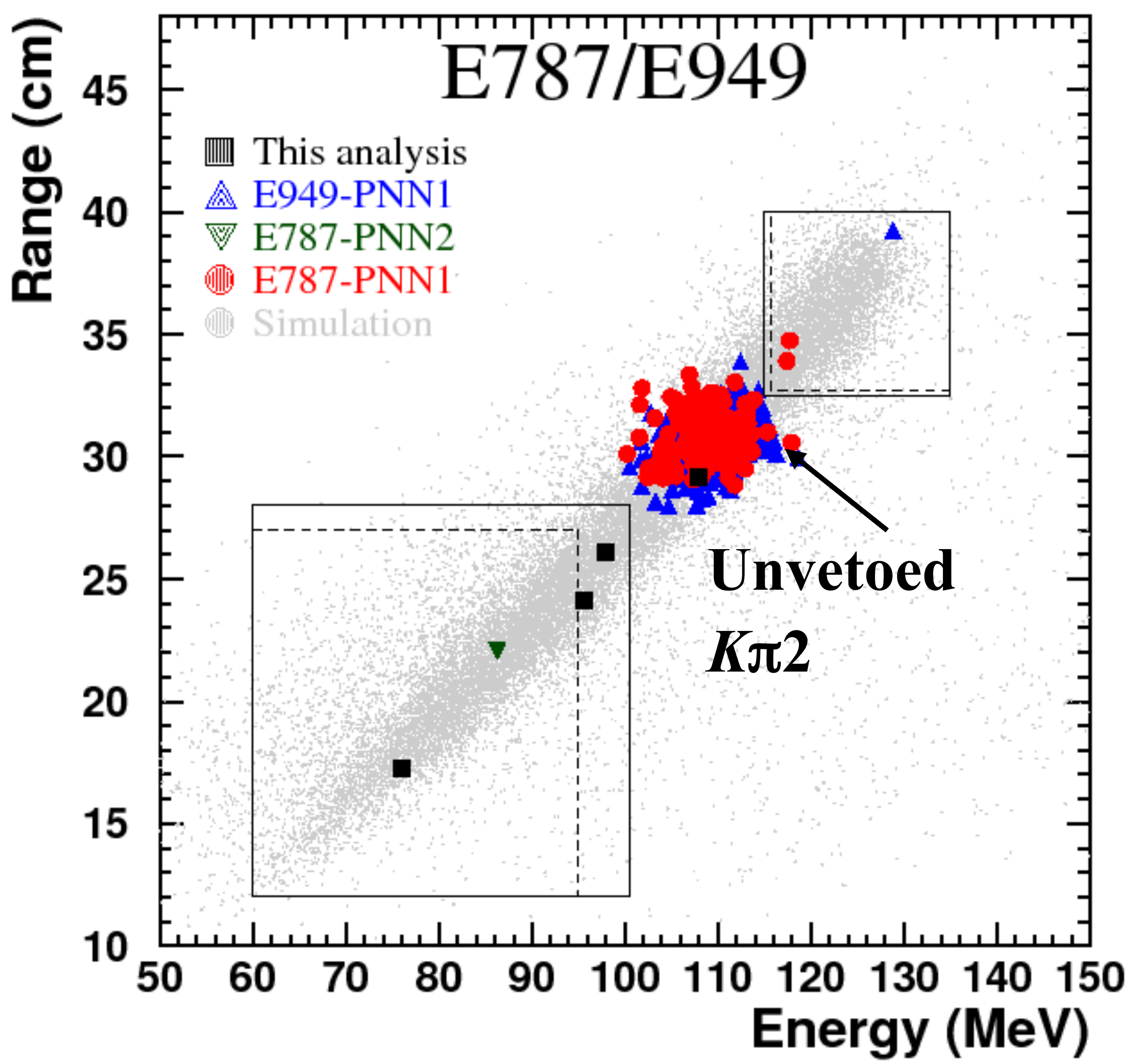
K^+ -> pi^+nunu - Experiment

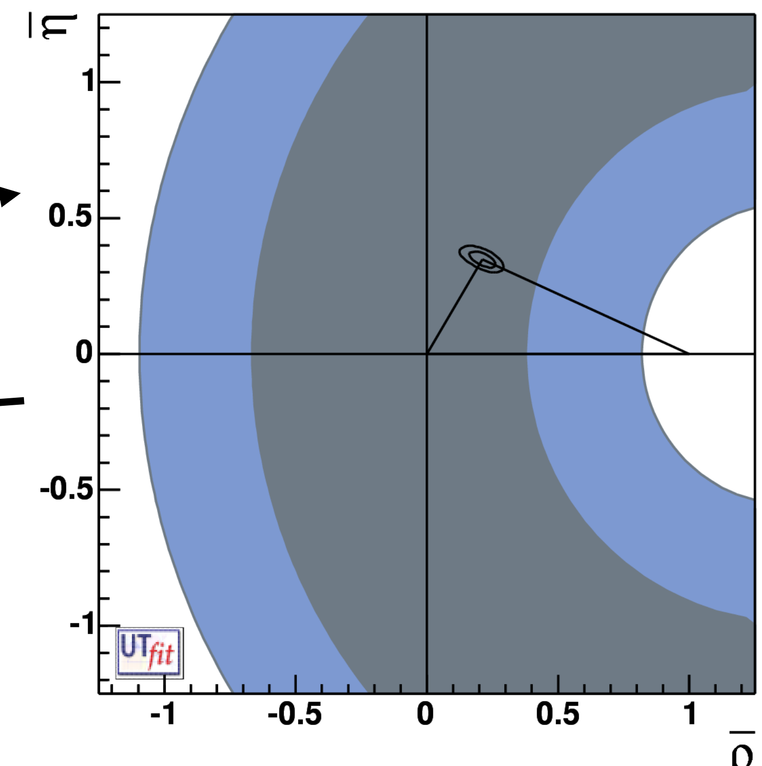
[Spadaro]

Final results from E787/E949 (2008)

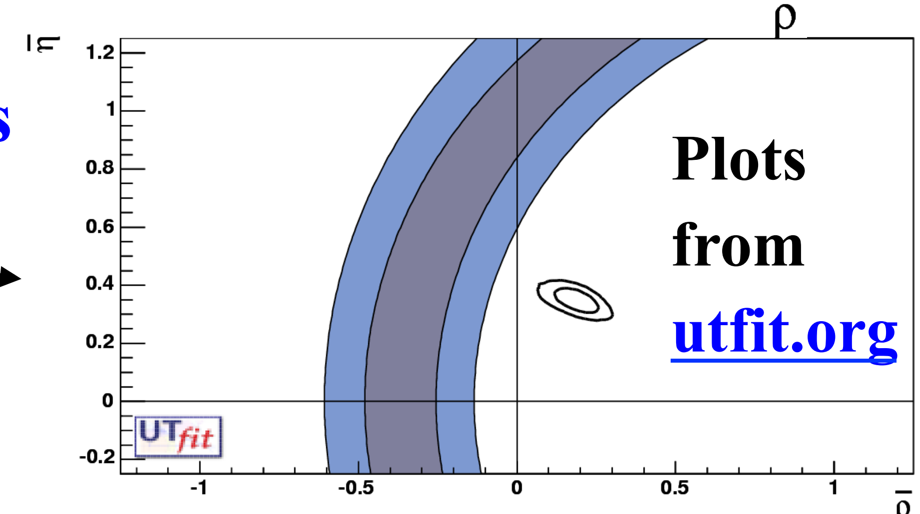
Combined results, from E787 (1995-8 runs) & E949 (12-weeks run in 2001)

$$BR(K^+ \rightarrow \pi^+ \nu\nu) = (1.73^{+1.15}_{-1.05}) \times 10^{-10}$$





Same central value, 100 evts

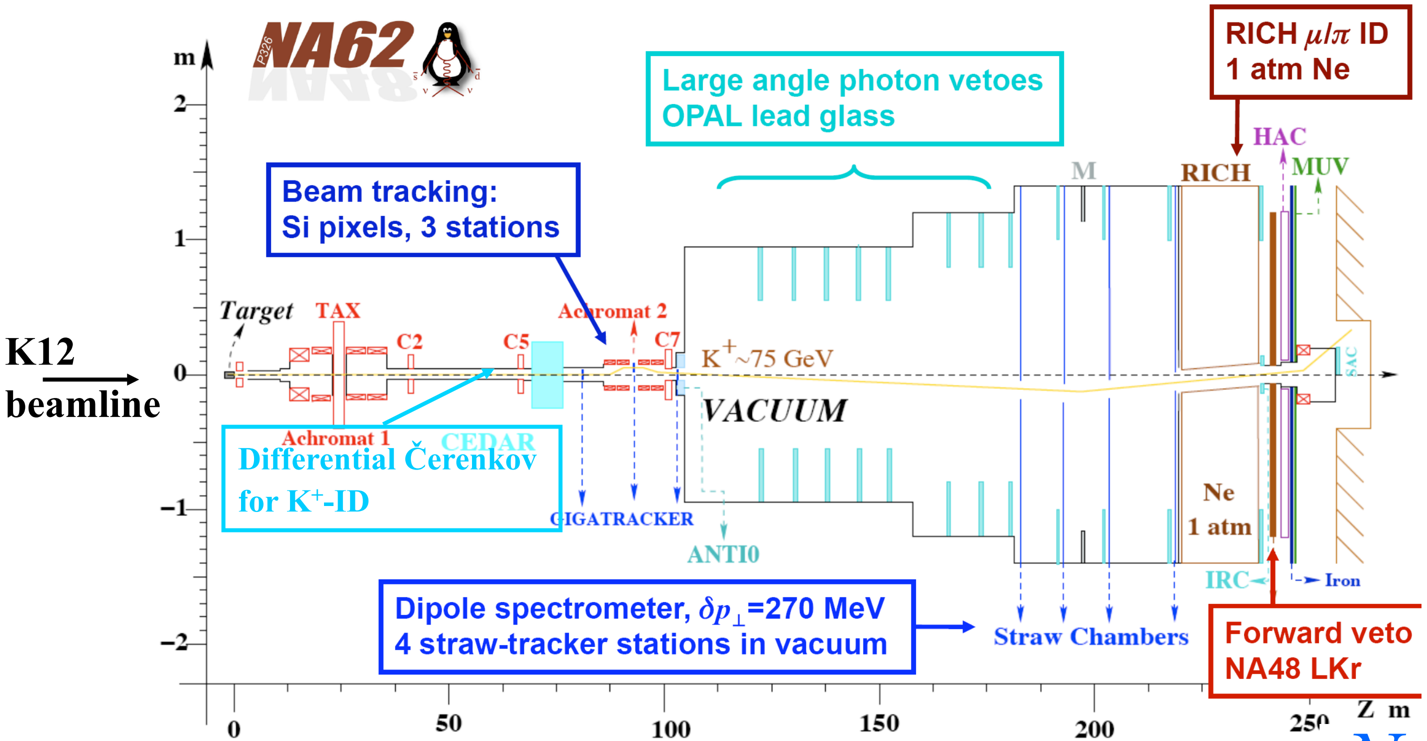


Prob. all 7 obs. evts are bkg is ~10^{-3}

K$^+$ -> pi$^+$nunu - Experiment

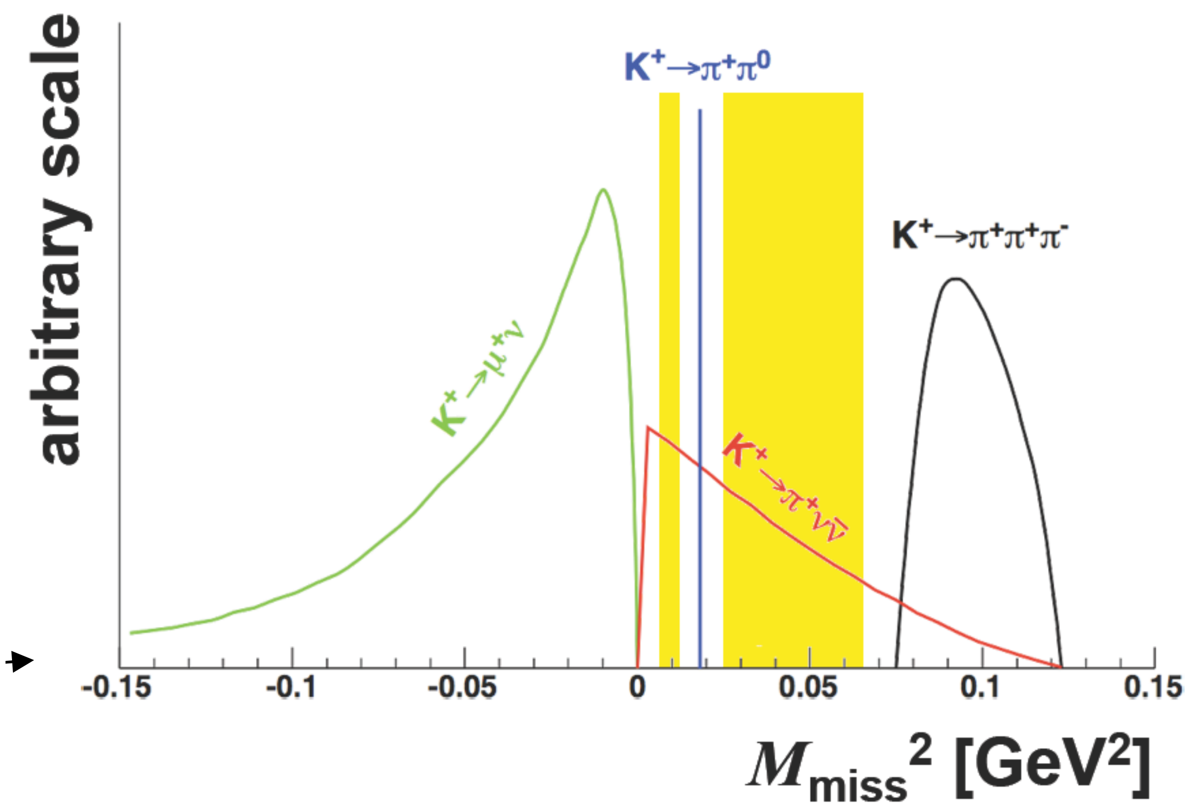
The in-flight approach: NA62 @ CERN

[Spadaro]



NA62 expected sensitivity

Decay Mode	Events
Signal: $K^+ \to \pi^+\nu\nu$ *[flux = 4.8×10^{12} decay/year]*	*55 evt/year*
$K^+ \to \pi^+\pi^0$ *[$\eta_{\pi 0} = 2\times10^{-8}$ (3.5×10^{-8})]*	4.3% (7.5%)
$K^+ \to \mu^+\nu$	2.2%
$K^+ \to e^+\pi^+\pi^-\nu$	≤3%
Other 3 – track decays	≤1.5%
$K^+ \to \pi^+\pi^0\gamma$	~2%
$K^+ \to \mu^+\nu\gamma$	~0.7%
$K^+ \to e^+(\mu^+)\,\pi^0\nu$, others	negligible
Expected background	≤13.5% (≤17%)



Aim to obtain O(~10%) signal acceptance with <10% background

Theorists Point of View on LFV, RPV and Invisible States

[Smith]

Lepton flavor violation: $P \to P'\nu^I \bar{\nu}^J$

Within MFV, $P \to P'\nu^I \bar{\nu}^J$ and $P \to P'\ell^I \bar{\ell}^J$ are both tightly constrained by $\ell^I \to \ell^J \gamma$, making them too suppressed to be seen.

R-parity violation: Tree-level effects possible from $\Delta\mathcal{L} = 1$ couplings.

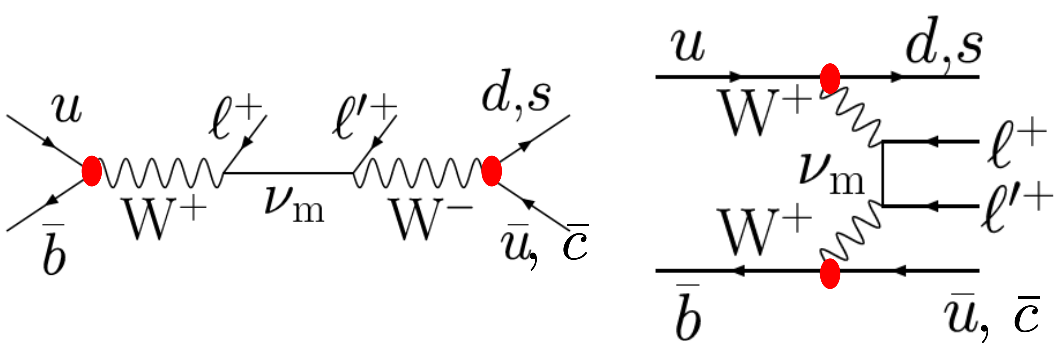
Within MFV, $\Delta\mathcal{L}$ couplings are negligible, and loop-level FCNC from $\Delta\mathcal{B}$ couplings are very suppressed (except maybe for $b \to s$).

New invisible states: $P \to P' + \text{missing energy}$

Competitive bounds if these states have flavor-breaking interactions, or if they couple to top quarks (?), but not if they couple to light quarks.

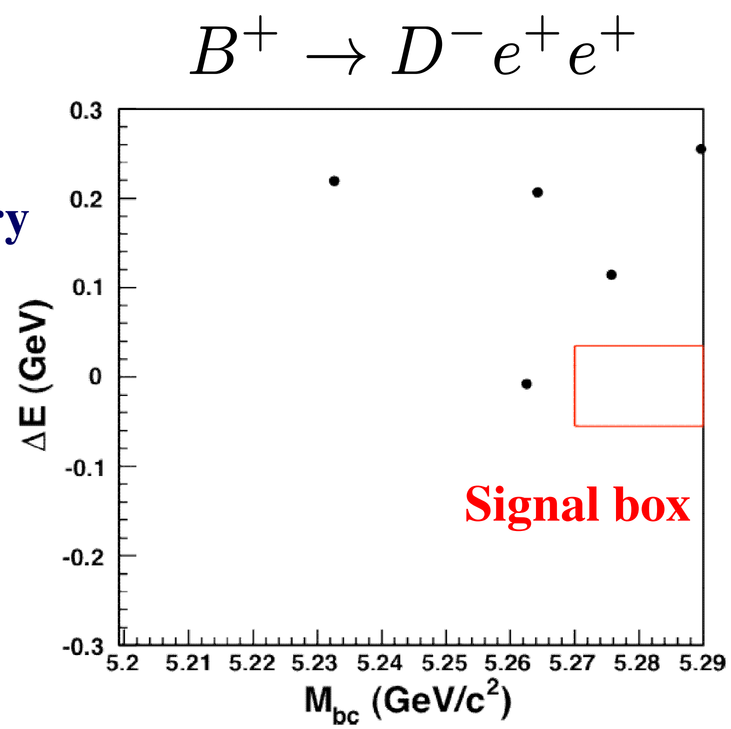
LFV and LNV Decays at B factories

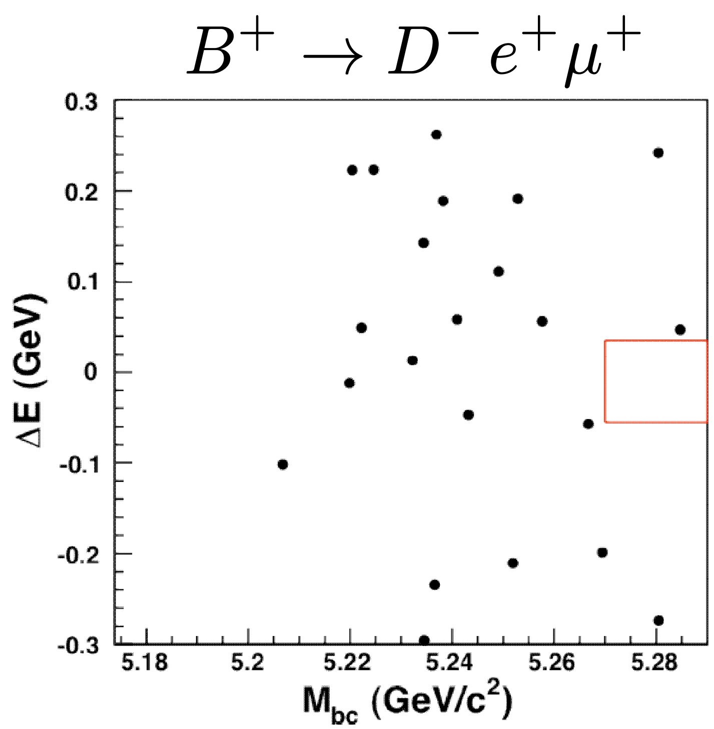
[Mohanty]

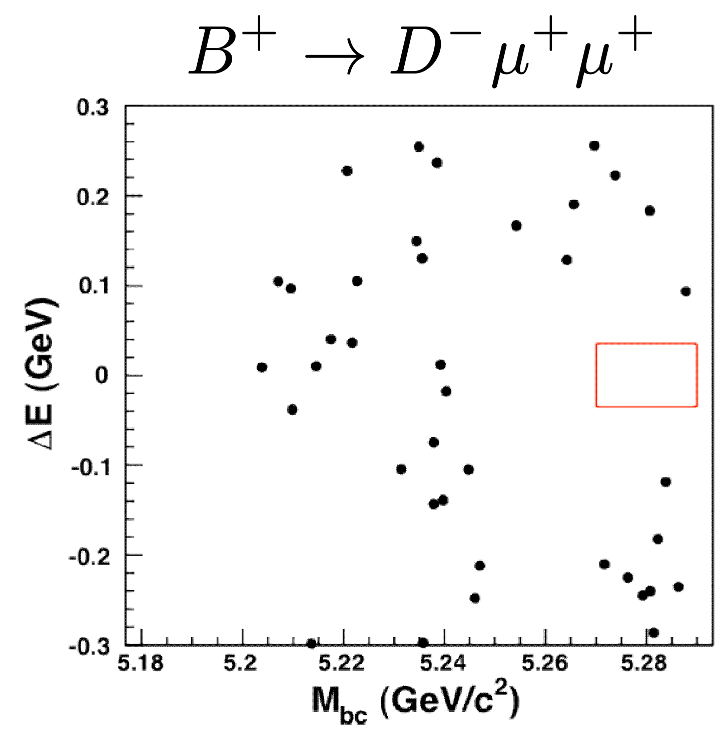


- Both lepton flavor violating (LFV) and lepton number violating (LNV) decay, involving Majorana ν's ➡ strongly suppressed in the SM

Preliminary







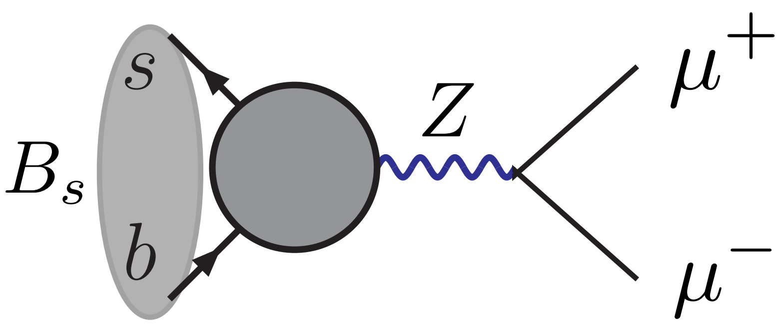
- No evidence for a signal ➡ derive 90% CL upper limits on BF

Decay mode	Eff.	$N_{\rm bkg}$	UL on BF
$B^+ \to D^- e^+ e^+$	1.2%	0.18 ± 0.13	2.7×10^{-6}
$B^+ \to D^- e^+ \mu^+$	1.3%	0.83 ± 0.29	1.9×10^{-6}
$B^+ \to D^- \mu^+ \mu^+$	1.8%	1.44 ± 0.43	1.1×10^{-6}

Large number of tau LFV decay modes also limited...

B->mumu - Theory

[Jager]

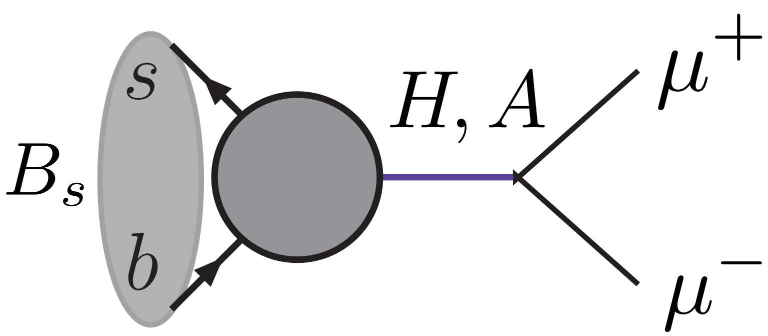


$$\propto \frac{m_\mu^2}{M_W^2}$$

loop and helicity suppressed in SM

$\mathcal{B}(B_s \to \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$

Buras et al 2010



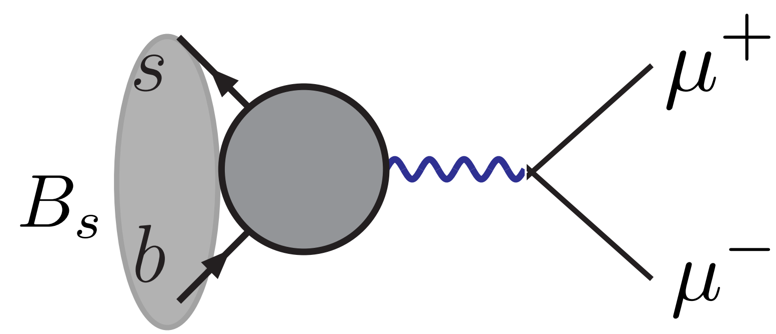
$$\propto \frac{m_b^2 m_\mu^2}{M_W^4} \tan^6 \beta$$

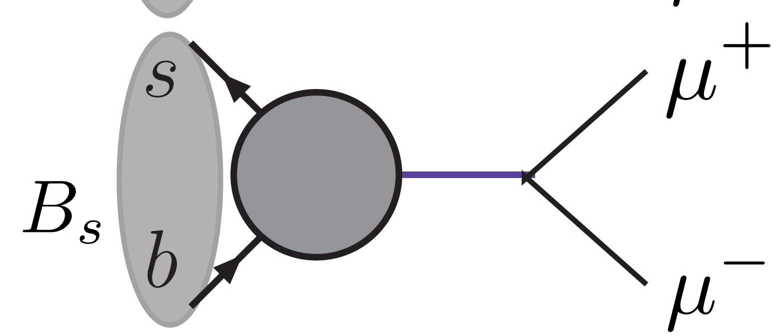
Yukawa suppressed in SM

in 2HDM (or MSSM) Yukawas can be very large

- New physics can modify the Z penguin ....

  ... induce a Higgs penguin ...

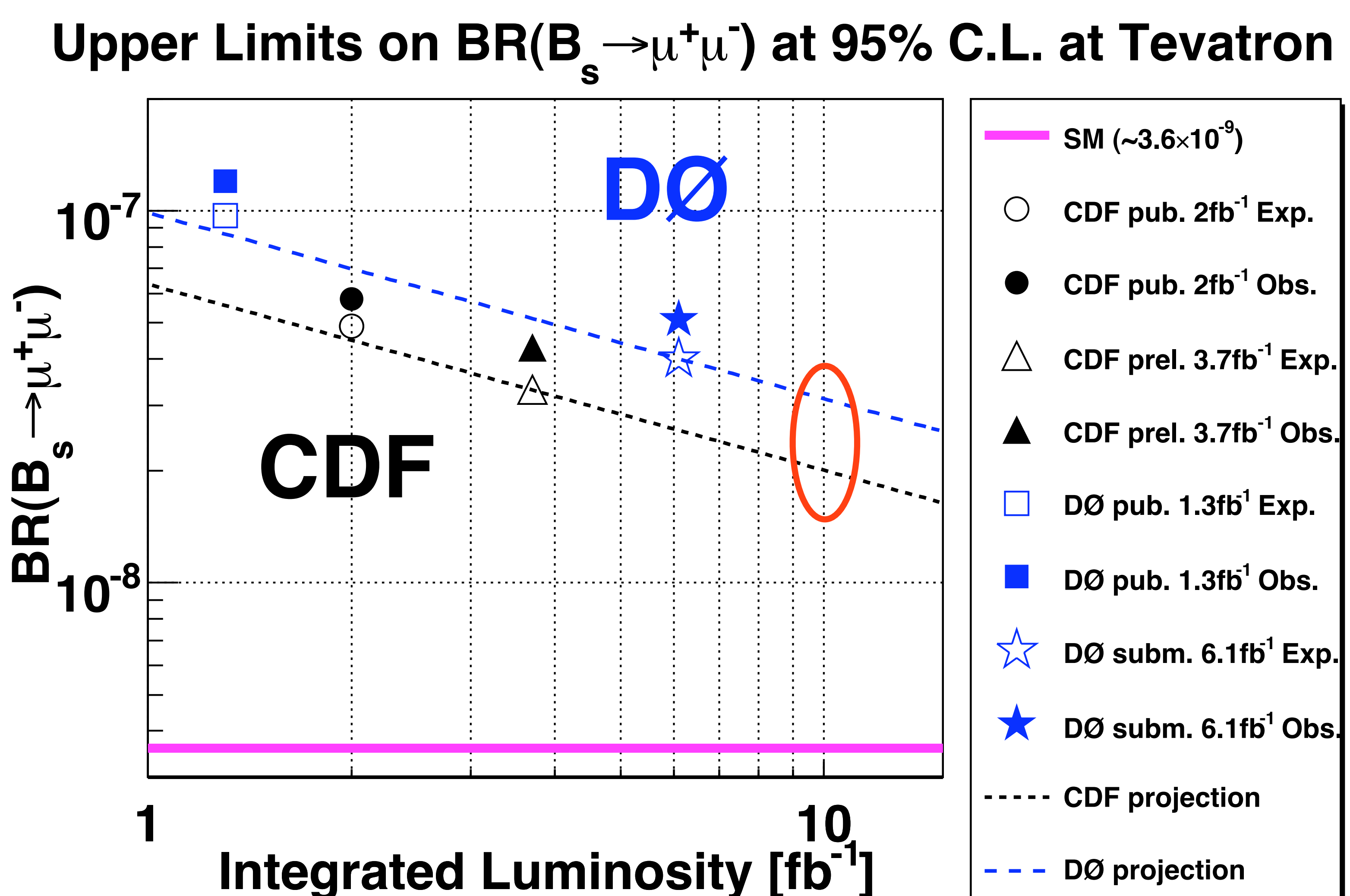




B_s->mumu - Status and Future at Tevatron

[Bertram]

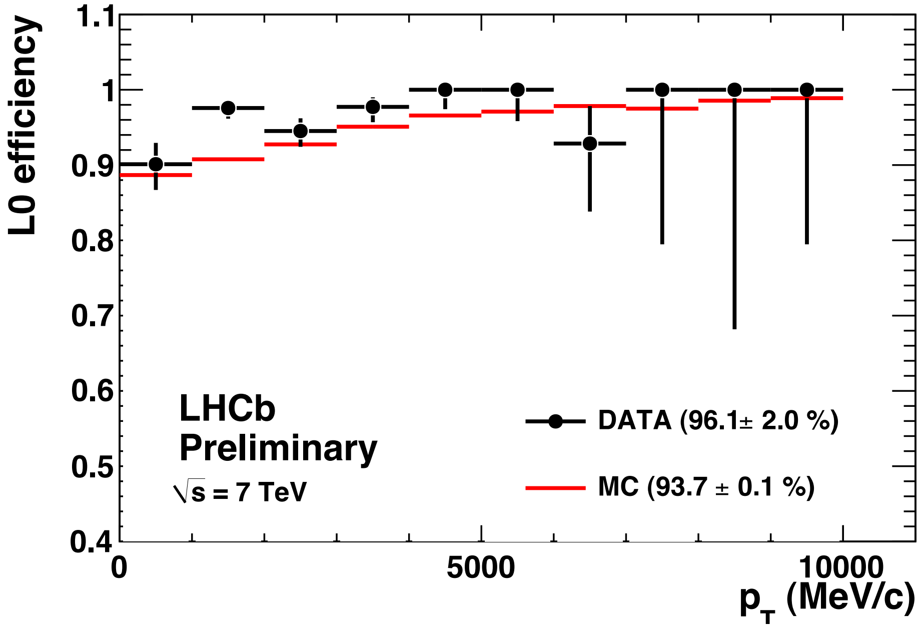
- B→μμ (D0 new result 6.1fb^{-1}) B(Bs) < 51 x 10^{-9}
  - ➡ CDF World Best 3.7fb^{-1} B(Bs) < 43 x 10^{-9}
  - ➡ No evidence of Physics beyond the SM
- Additional data being collected, 8fb^{-1} on tape
  - ➡ Expect 10fb^{-1} by Summer 2011, and possibly 16fb^{-1} in 2014.



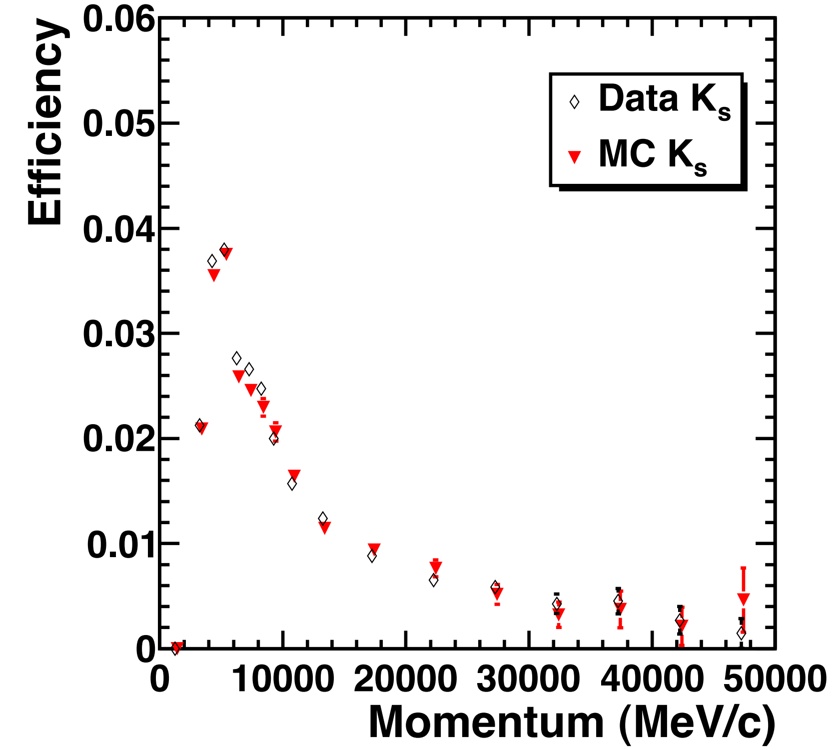
B_s->mumu - LHCb Prospects - road to a measurement

[Serra]

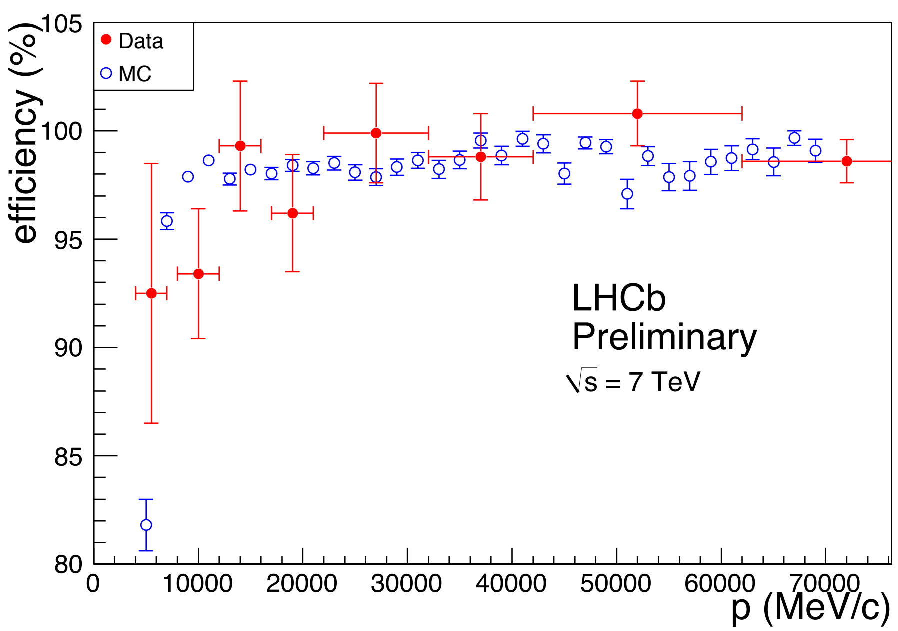
⇒ Efficient trigger: dedicated lines triggering on high PT muons



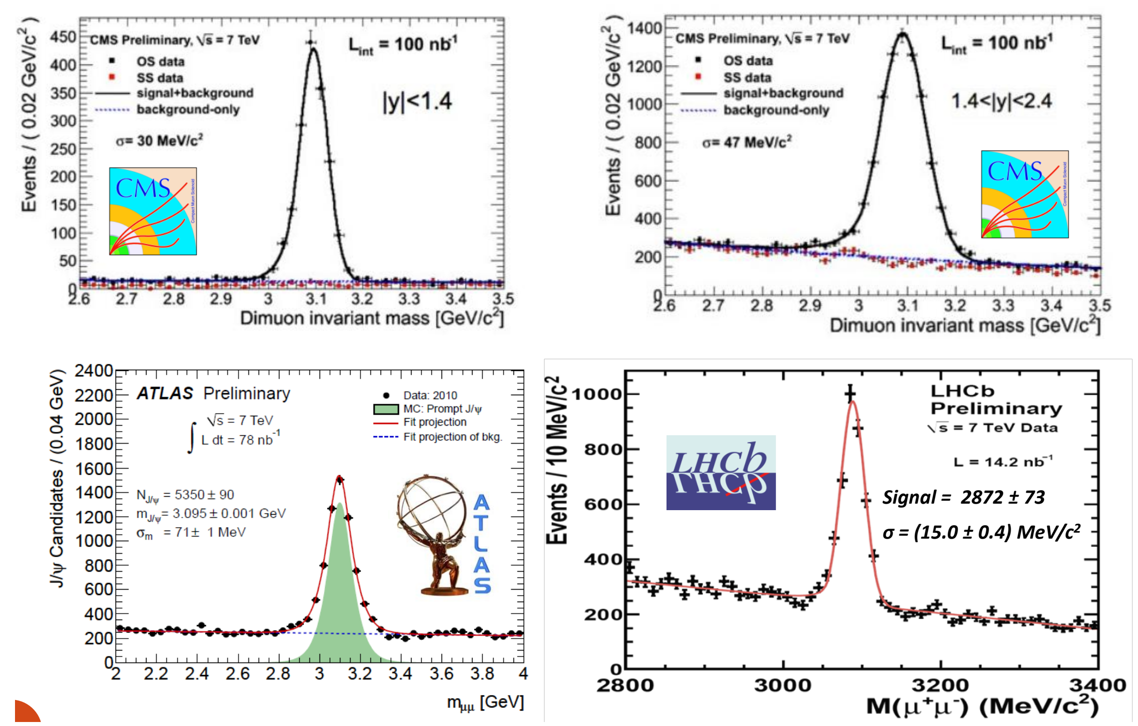
⇒ Low muon mis id rate



⇒ Positive identification of muons



J/ψ resolution with first data

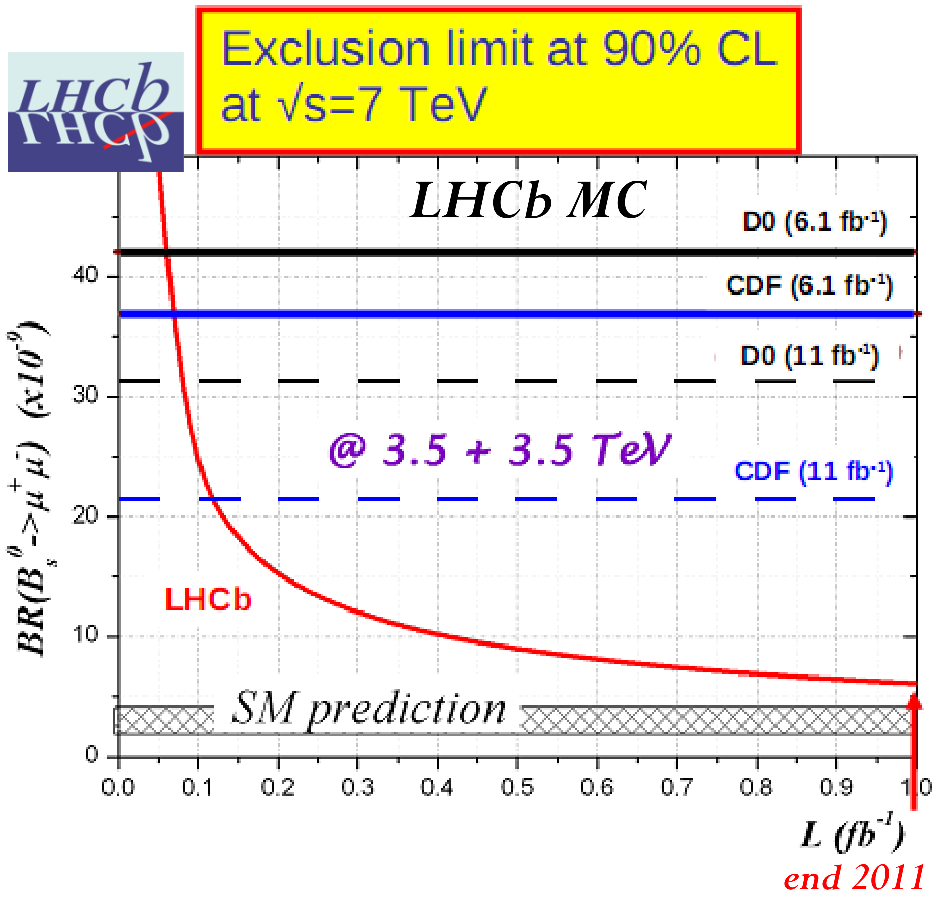


Mass resoln
ATLAS ~70MeV
CMS ~30MeV
LHCb ~15MeV

B_s->mumu - LHC Prospects

[Serra]

Experiment	Nsg	Nbg	Upper Limit 90%CL
ATLAS (10 fb^{-1} 14TeV)	5.6 events	14^{+13}_{-10} events (only bb→μμ)	-----------
CMS (1fb^{-1} 7TeV)	1.4	4.0 (1.25 only bb→μμ)	$15.8 \cdot 10^{-9}$ *private calculation*
LHCb (1fb^{-1} 7TeV)	6.3 (in the most significant region)	32.4 (in the most significant region)	$7 \cdot 10^{-9}$



- All the experiments plan to normalize to either $B_d \to J/\psi K^*$ or $B^+ \to J/\psi K^+$, LHCb is also studying the possibility to normalize to $B_s \to J/\psi\varphi$
- B_d BR are well known the need the measurement of fd/fs , LHCb plans to measure this parameter with the ratio $B \to D^- K^+$ and $B_s \to D_s^- \pi^+$
- Expected limit on $BR(B_s^0 \to \mu^+\mu^-) < 7 \cdot 10^{-9}$ with LHCb with 1fb^{-1} (corresponding to what we will get by the end of next year)
- Possibility to discover NP for $BR(B_s^0 \to \mu^+\mu^-) > 17 \cdot 10^{-9}$ with 1fb^{-1} .

Conclusions

- Large number of interesting contributions to WGIII

- Seems that rare decays will remain an essential tool to understanding physics beyond the SM :
  - Observables with precise (and improving) theoretical predictions
  - Lots of scope for improved experimental measurements

- In the future, hope they will help us to discriminate between different new physics models

B -> K* ll - Experimental Status

- Four-body final state with rich phenomenology
- Many observables: - A_{FB}, F_L, Isospin Asymmetry...

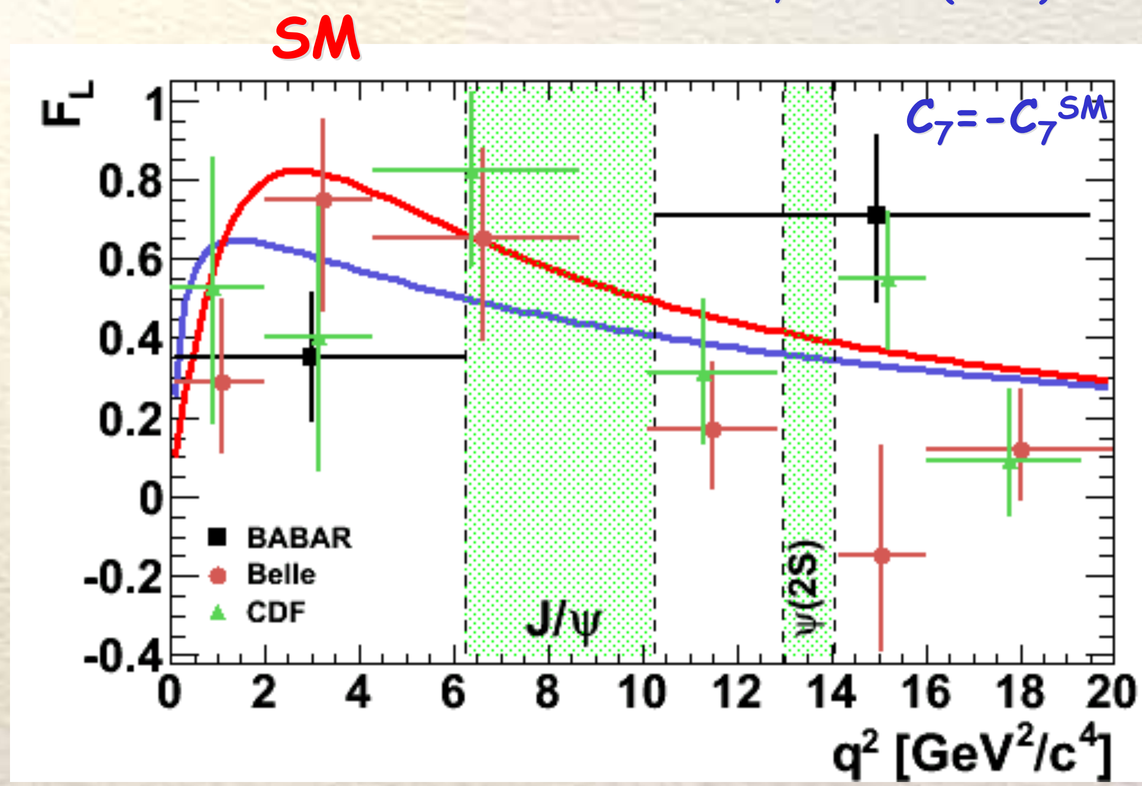
[Eigen]

K* Longitudinal Polarization $\mathcal{F}_L$

- BABAR, Belle and CDF measured $\mathcal{F}_L$

BABAR: PRL 102, 091803 (2009)
CDF: Note 10047 (2010)
Belle: PRL 103, 171801 (2009)

- $(0.1<q^2<6.25\ GeV^2/c^2)$ $\mathcal{F}_L = 0.35 \pm 0.16 \pm 0.04$
- $(1<q^2<6 GeV^2/c^2)$ $\mathcal{F}_L = 0.67 \pm 0.23 \pm 0.04$
- $(1<q^2<6 GeV^2/c^2)$ $\mathcal{F}_L = 0.50^{+0.27}_{-0.30} \pm 0.04$



Krüger & Matias PRD71, 094009 (2005)

- The 3 measurements are consistent with each other
- They are also consistent with the SM prediction

$$\mathcal{F}_L^{SM} = 0.73^{+0.13}_{-0.23} \quad (1 < q^2 < 6\ GeV^2)$$

C. Bobeth *et al.* arXiv:1006.5013

G. Eigen, CKM10 Warwick, 07-09-2010 20