EWP measurements at the *Super* Flavour Factories: Focus on Inclusive Signatures

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universitätbonn

Key Topics for SuperB/BelleII

- Radiative:
  - Inclusive Radiative: $\mathbf{B \to X_s \gamma}$, $\mathbf{B \to X_d \gamma}$
  - Semi-Inclusive Radiative: $\mathbf{B \to X_s \gamma}$ (X_s reconstructed in 40+ modes)
  - Exclusive suppressed: $\mathbf{B \to X_d \gamma}$, $\mathbf{X_d = \rho, \omega}$

- Semileptonic:
  - Inclusive Charged Semileptonic: $\mathbf{B \to Xll}$
  - Neutral Semileptonic $\mathbf{B \to X\nu\nu}$ (& invisible $\mathbf{B \to \nu\nu}$)

- Other topics:
  - (Semi)Tauonic: $\mathbf{B \to X\tau\tau}$ ($\mathbf{B \to \tau\tau}$)
  - Complementary, $\mathbf{B \to Xl\nu}$, exclusive&inclusive (e.g. constraints on C^R)
  - Studies of all the above with $\mathbf{B_s}$ @ $\mathbf{\Upsilon(5S)}$, **e.g.** $\mathbf{B_s \to X\gamma}$ ($B_{(s)} \to \gamma\gamma$)

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> ➢Focus on decays with **Missing-E**, **Neutrals**, or ***Inclusive***

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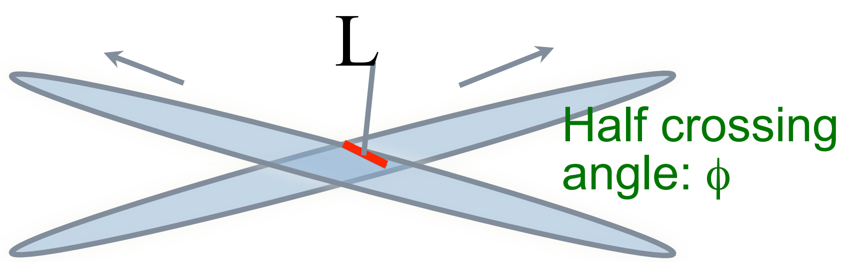
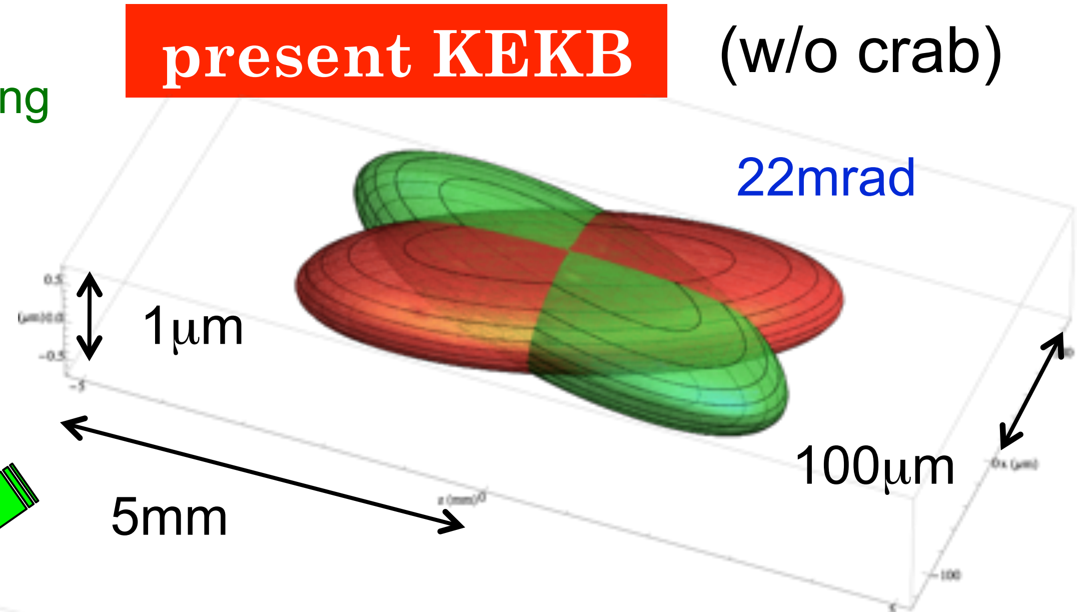
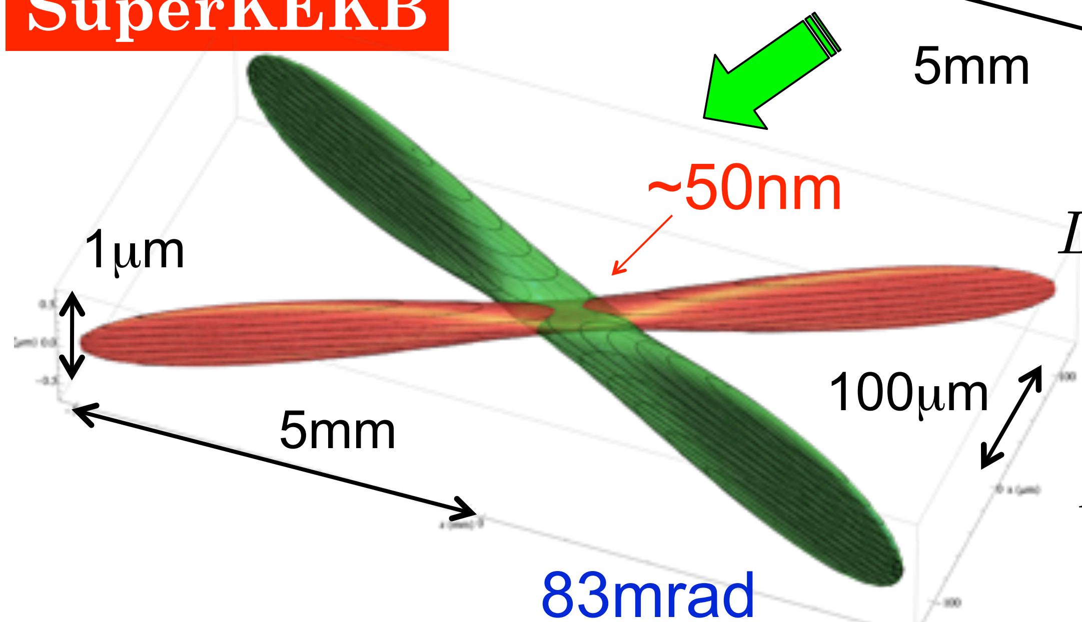
The Colliders: (SuperKEKB L×40)



Hourglass condition:

$\beta_y^* \gtrsim L = \sigma_x / \phi$



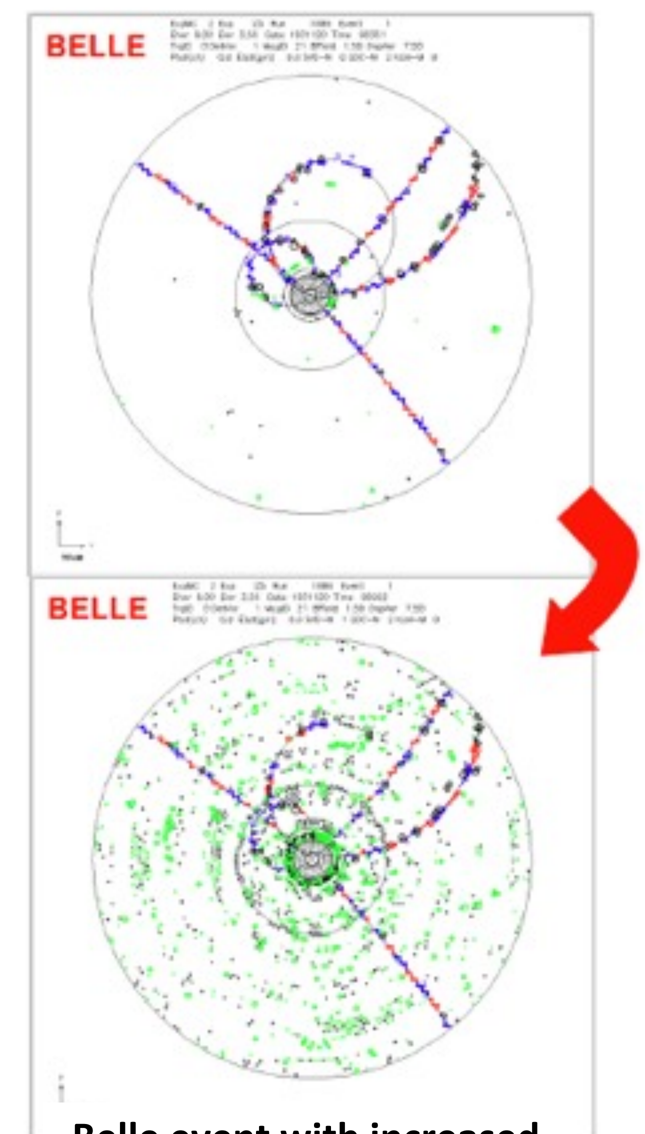


$L = 8 \cdot 10^{35}\ s^{-1} cm^{-2}$

$$L = \frac{\gamma_\pm}{2er_e}\left(1 + \frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

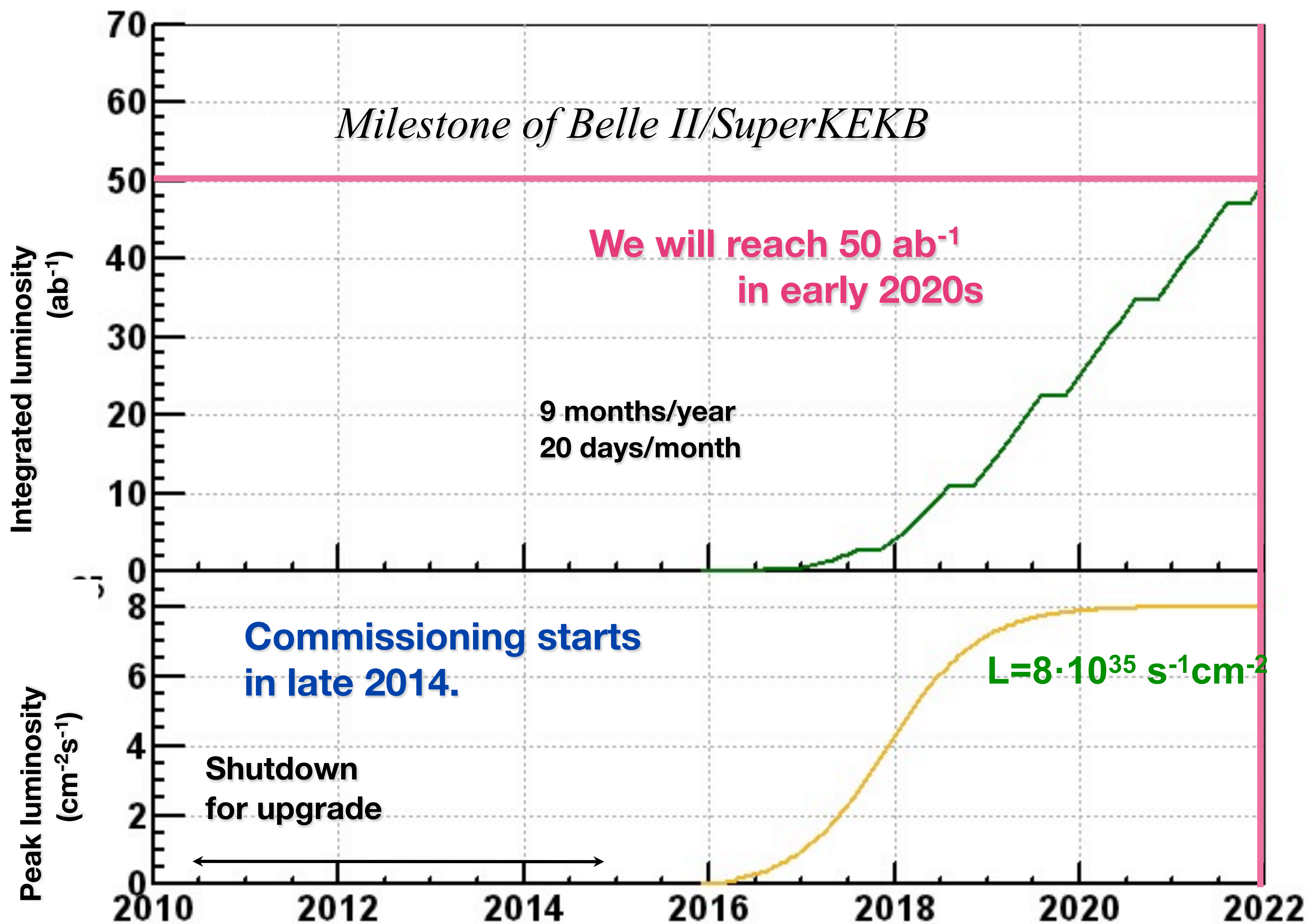
$$L = \frac{N_+ N_- f}{4\pi\sigma_x^*\sigma_y^*} R_L$$

- **Improvements**
  - Smaller beam profile(Improved background rejection?, Better Y(5S) resolution?)
  - Possibility for 80% polarisation of one of the beams.
- **Drawbacks:**
  - Likely to have multiple collisions in any readout window.
  - Higher backgrounds due to Touschek (x 20), higher occupancy and potentially degrades the "excess neutral energy" as a discriminant

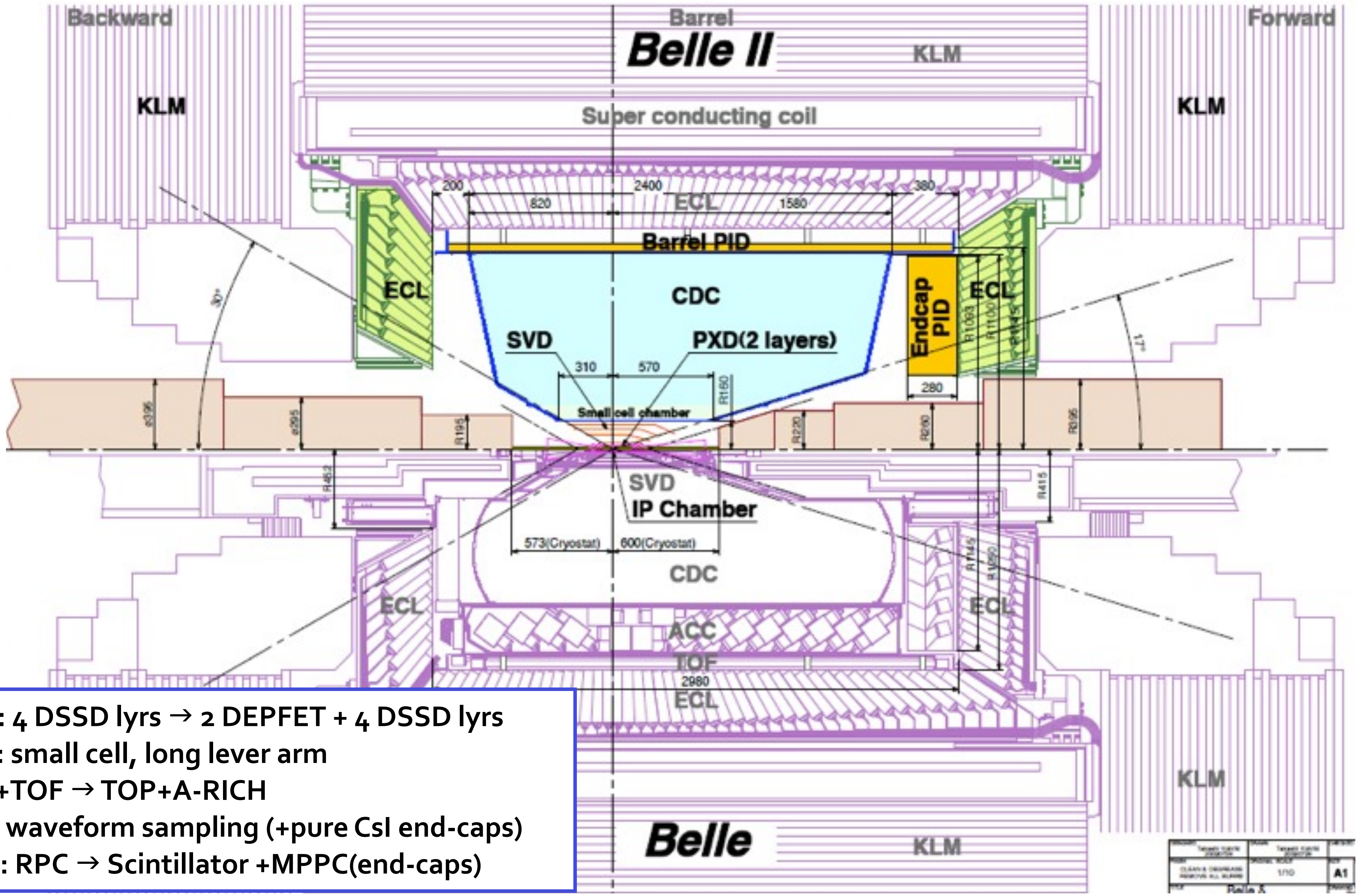


Belle event with increased background overlaid.

Luminosity Prospects SuperKEKB



The Detectors: (Belle→Belle II)

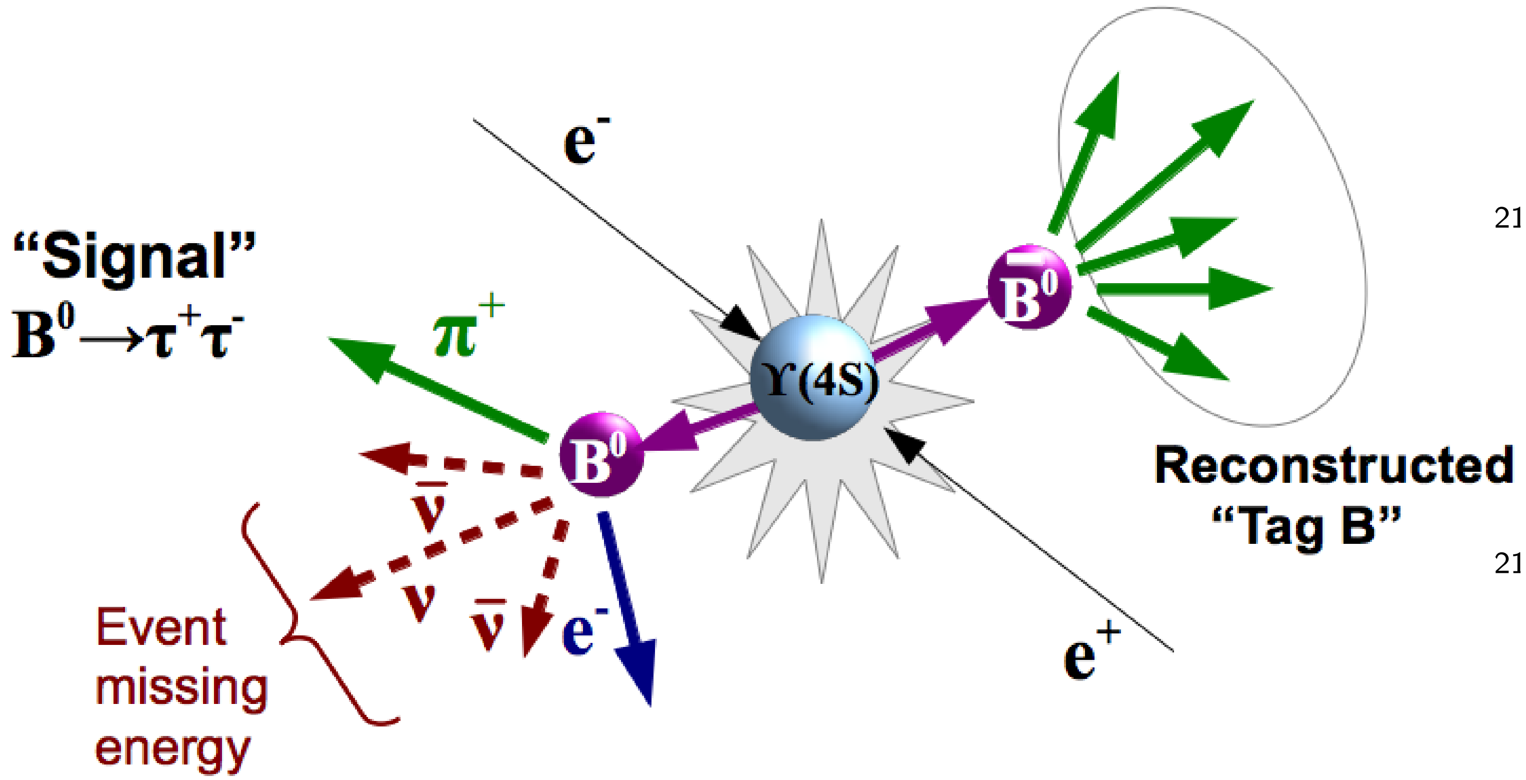


SVD: 4 DSSD lyrs → 2 DEPFET + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling (+pure CsI end-caps)
KLM: RPC → Scintillator +MPPC(end-caps)

- Improved hermeticity, detectors closer to beam-pipe
- Improved particle identification, coverage, vertexing
- Conclusion: there should be improvements in experimental systematic errors.

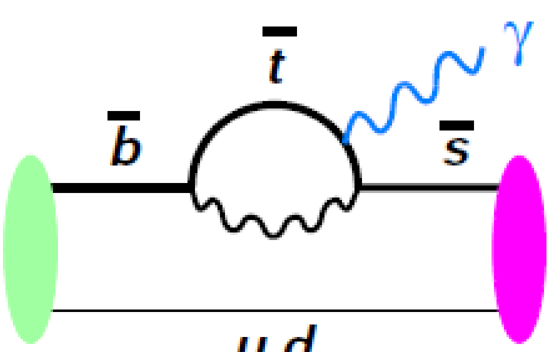
The Analysis Tool of BelleII's future: B tagging

- Many B-meson rare decays use the same technique.
- Use a "Tagged B" to define 4-momenta of "Signal B":
  - Tagged B Hadronic decays : Signal B momenta well-defined.
  - Tagged B Semi-leptonic decay : Signal B momenta defined in a cone.

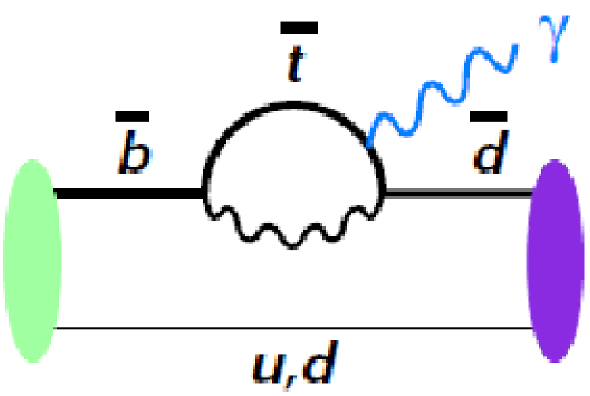


- Semi-leptonic tagged modes generally have higher efficiency but lower purity than hadronic (due to neutrino).
- The number of reconstructed B_{tag} decay modes can be >1000.
- Look for excess neutral energy ("E_{extra}") not assigned to tagged or signal B.

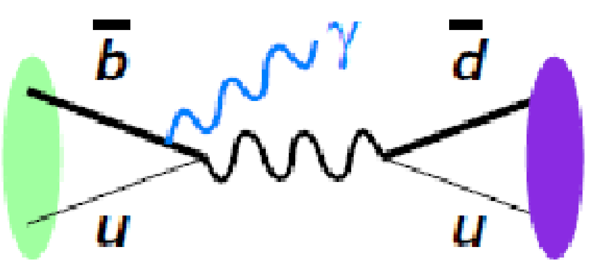
$b \to q\,\gamma$



b→sγ penguin



b→dγ penguin



b→dγ annihilation

Inclusive $b \to s\gamma$

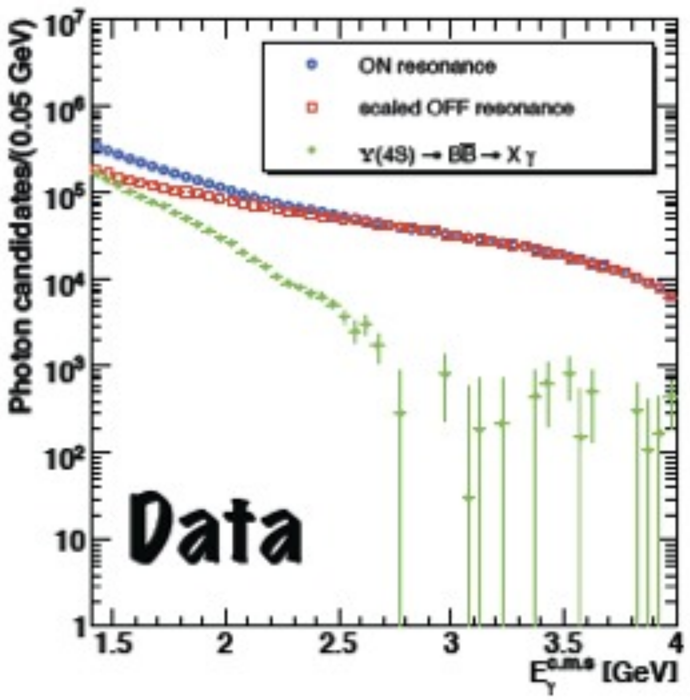
- In general, inclusive $B \to X s/d \gamma$ are theoretically clean but experimentally challenging compared to exclusive modes.
- $BF(B \to X_s \gamma)$: limit in charged Higgs mass
  - BR and SM expectation currently have 7% errors
- Energy Spectrum&Moments: Determine heavy quark parameters for V_{ub} extraction.
- $A_{CP}(B \to X_s \gamma)$: Direct CP asymmetry in inclusive decays have sizeable long-distance contributions. However these may be robust with up to 10% deviations in non-SM models.
- $BF(B \to X_d \gamma)/BF(B \to X_s \gamma)$: extract $|V_{td}/V_{ts}|$.

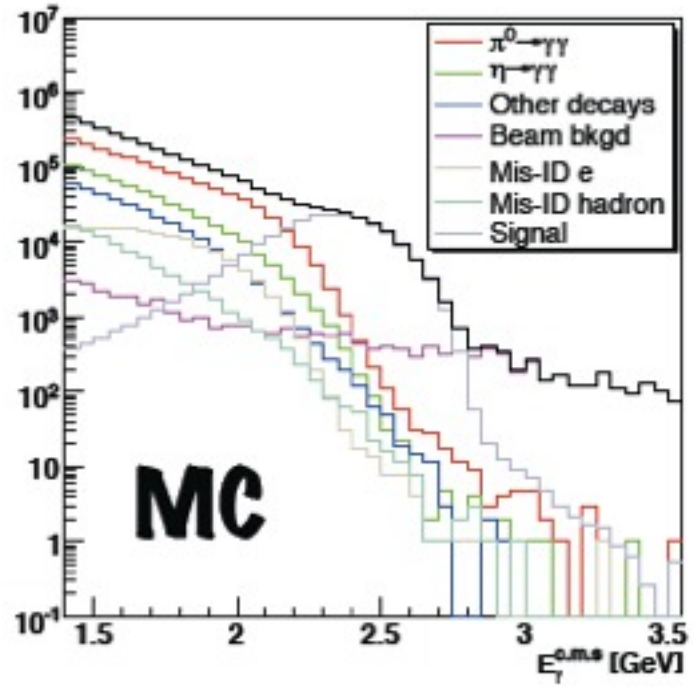
BF($B \to X_s\gamma$)

- **Three methods for inclusive analysis for $B \to X_s\gamma$ (in chronological order)**
- **Fully inclusive**
  - **Subtract the on-resonance photon energy spectrum by the continuum spectrum.**
  - Free from the model uncertainty of hadronic system (Xs).
  - Generally, has large backgrounds.
  - Lepton tag is sometimes used for background suppression and flavor tagging.
- **Sum of exclusive modes (semi-inclusive; pseudo-reconstruction).**
  - **Reconstruct hadronic system (Xs) as a sum of exclusive modes.**
  - Signal is cleaner than using the fully inclusive method.
  - Model uncertainty of hadronic system; missing modes.
  - Separation of Xs and Xd.
- **Recoil tag (full reconstruction).**
  - **Fully reconstruct the other side B.**
  - Very low efficiency (<1%), but very clean (continuum bkg becomes negligible).
  - Measurement in B frame. Access to flavour information etc.

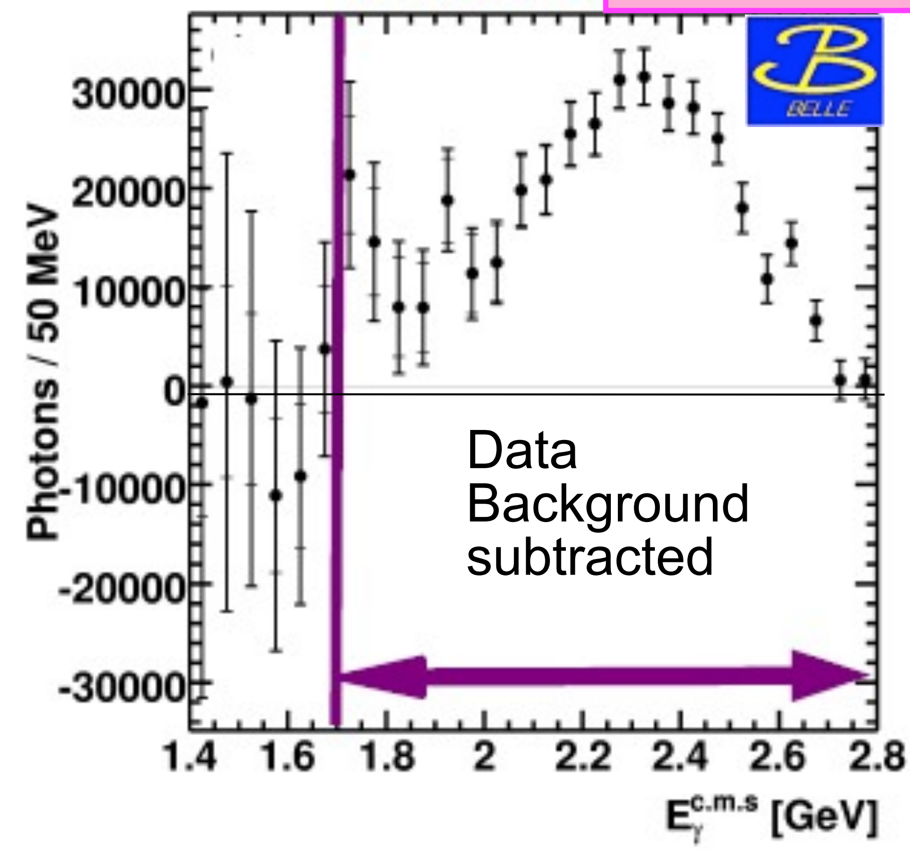
Experimental Status: Inclusive b→sγ

Fully Inclusive measurement





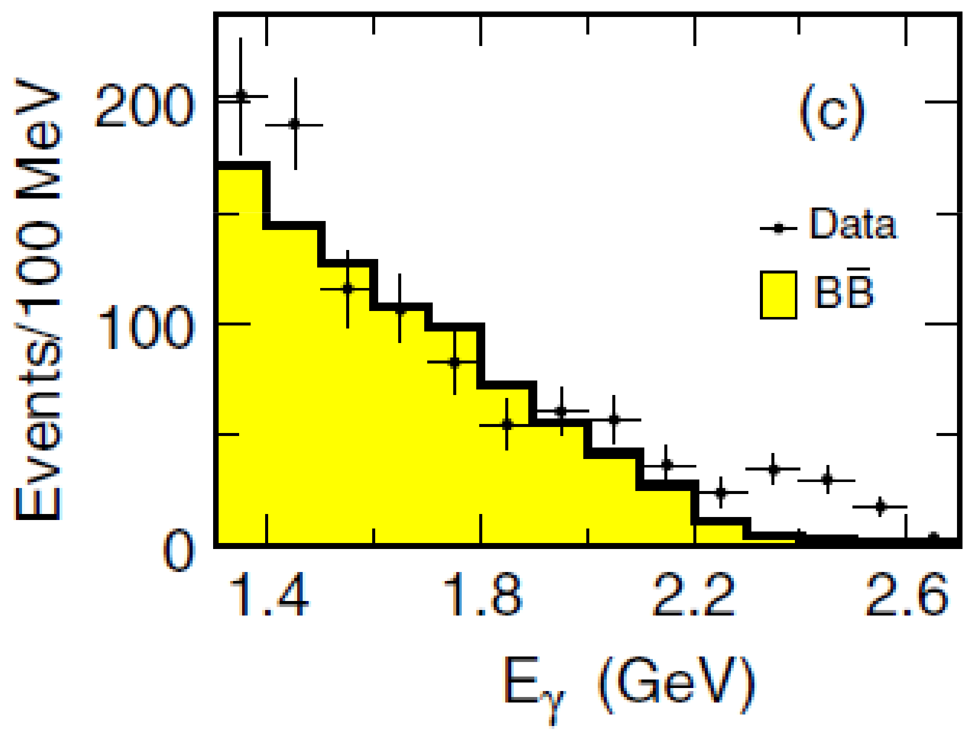
657M $B\bar{B}$

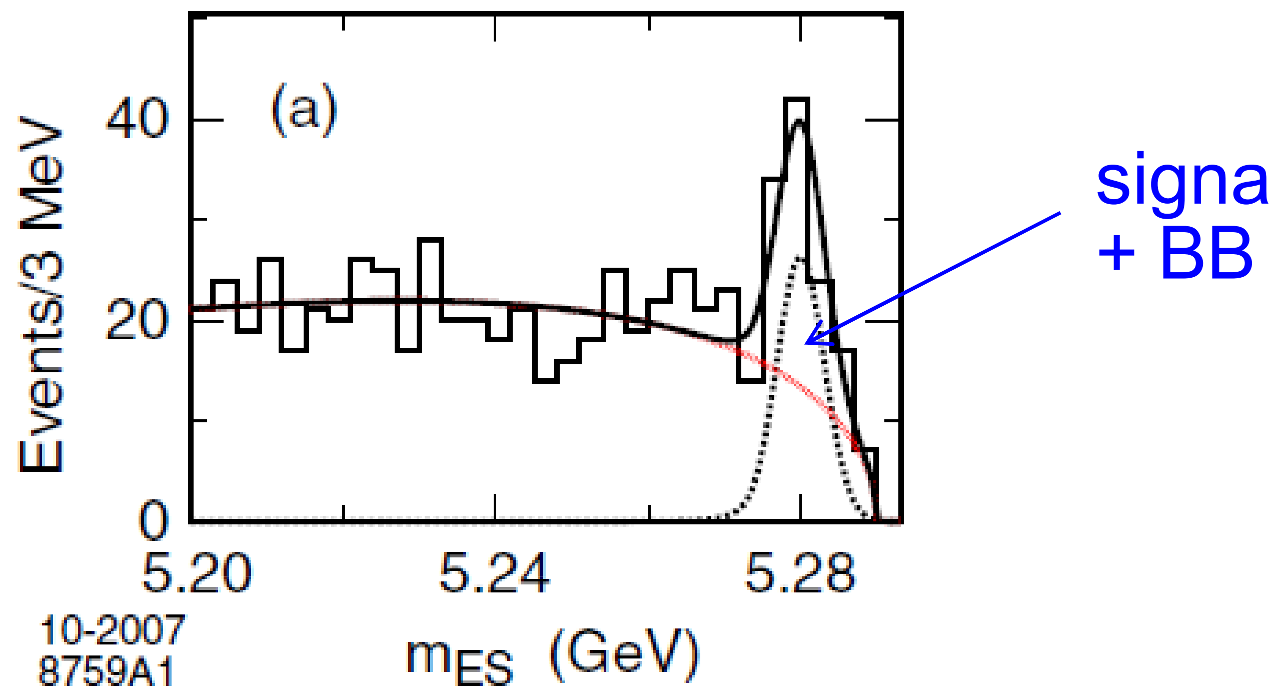


Recoil tag BF($B \to X_s \gamma$)

[Phys. Rev., D77, 051103 (2008)]

- Babar Analysis with 210 fb^{-1}
- 0.68 M tagged BB events with ~0.3% full recon. efficiency
- 23% statistical error.
  - By scaling the stat., get 3% stat. error at 10 ab^{-1}
- BB background subtraction using MC





1.6<E_γ<1.7 [GeV] charged B

Status of BF($B \to X_s \gamma$)

Mode	BF	E_{min}	$B(E_\gamma > E_{min})$	$B_{cnv.}(E_\gamma > 1.6)$
CLEO Inc.	$321 \pm 43 \pm 27^{+18}_{-10}$	2.0	$306 \pm 41 \pm 26$	$327 \pm 44 \pm 28 \pm 6$
Babar Inc.		1.9	$367 \pm 29 \pm 34 \pm 29$	$390 \pm 31 \pm 47 \pm 4$
Belle Inc.	-	1.7	$345 \pm 15 \pm 40$	$347 \pm 15 \pm 40 \pm 1$
Babar Full Inc.	$391 \pm 91 \pm 64$	1.9	$366 \pm 85 \pm 60$	$389 \pm 91 \pm 64 \pm 4$
Belle Semi.	$336 \pm 53 \pm 42^{+50}_{-54}$	2.24	-	$369 \pm 58 \pm 46^{+56}_{-60}$
Babar Semi.	$335 \pm 19^{+56+4}_{-41-9}$	1.9	$327 \pm 18^{+55+4}_{-40-9}$	$349 \pm 20^{+59+4}_{-46-3}$

- At Belle/Babar, the fully inclusive method, or the sum of exclusive methods have given the most precise results, but they are already systematics dominated. This is due to **continuum** and B backgrounds.
  - **L(off-resonance)/L(on-resonance)~0.1**
- In the future (with > 10 ab^{-1}), recoil tag method will be most promising.
  - **or a much longer off-resonance run**

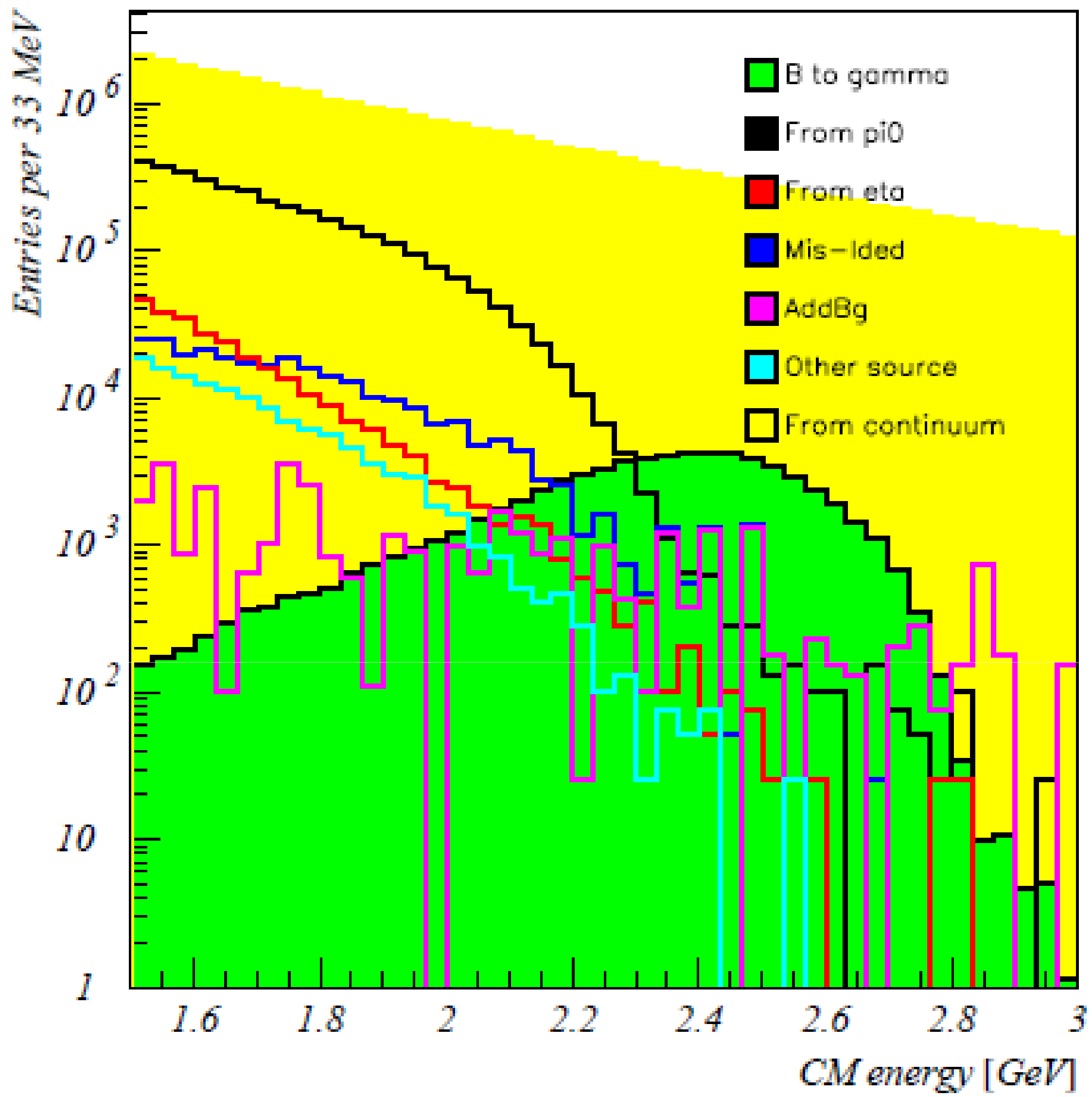
BF(B→Xsγ)

- **Other B decays are the main background source.**
  - Decay of π^0, η : largest, but can be calibrated with control sample.
  - Other decay (ω, η′, J/ψ), and hadronic interactions of neutral particles in the calorimeter..

- According to Belle inclusive analysis, 6-7% systematic error is assigned to B background (excluding π^0, η decay)

- The effect might be less for full reconstruction, but still around 3-5% systematic expected.

- This might be adequate with the current theory prediction.



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

In the SM:

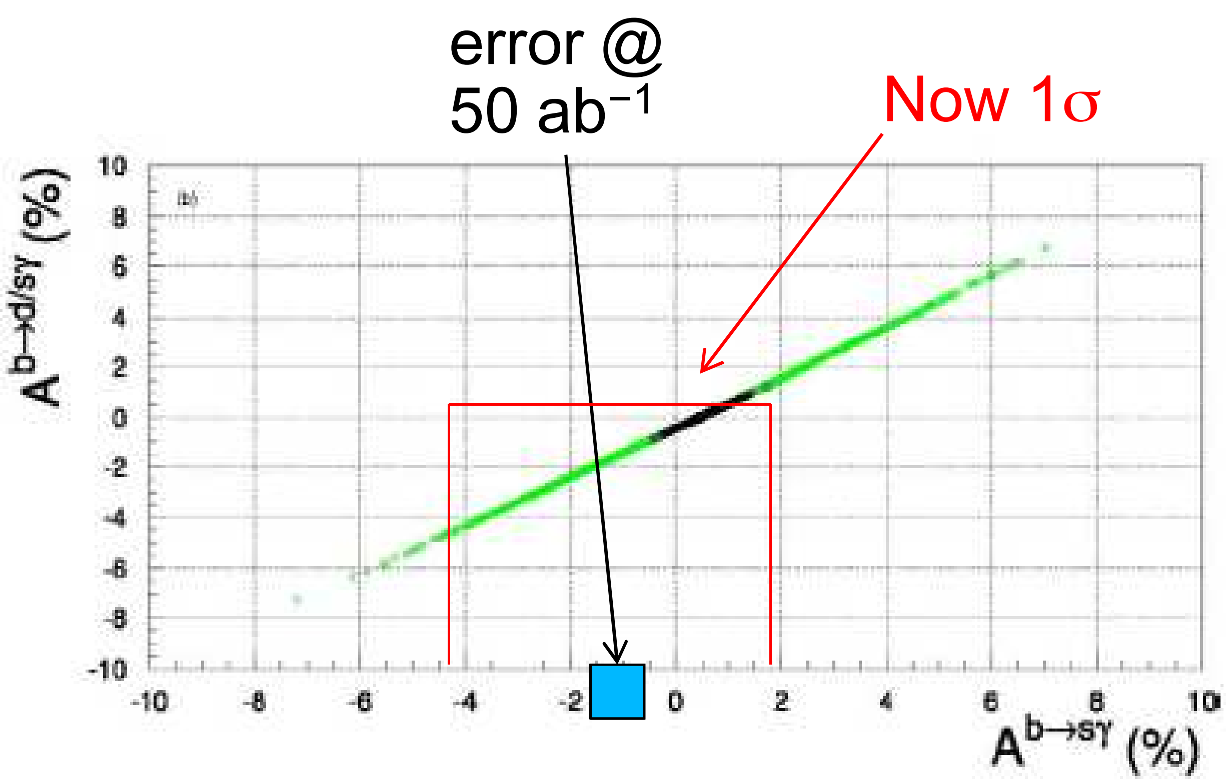
$$-0.006 < A_{CP}(B\to X_s\gamma) < 0.028$$
$$-0.62 < A_{CP}(B\to X_d\gamma) < 0.14$$
$$A_{CP}(B\to X_{s/d}\gamma) \sim 0$$

Some New Physics models predict larger asymmetry for $B\to X_s\gamma$ or $B\to X_{s/d}\gamma$.

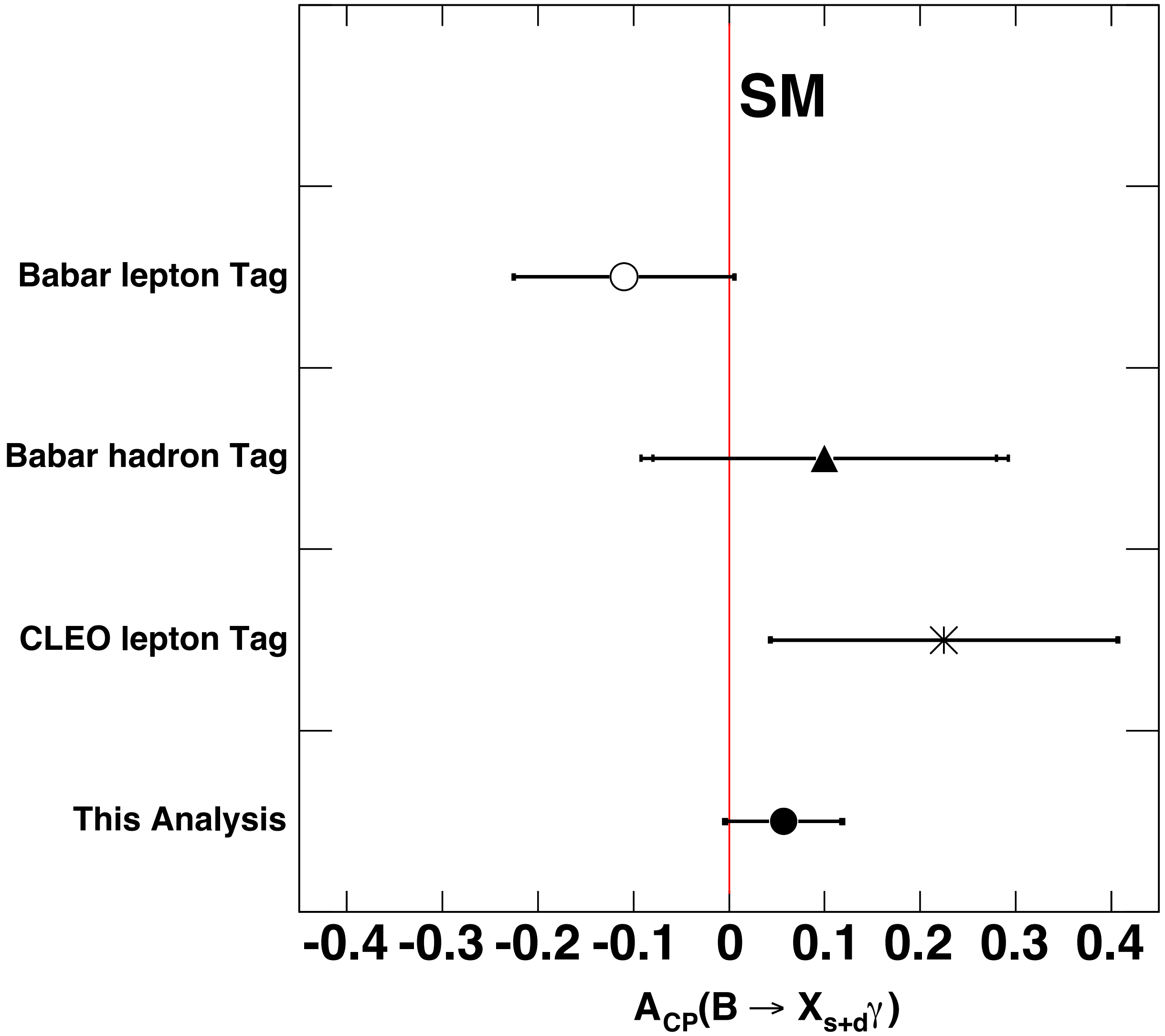
- **Sum of exclusives** give $A_{CP}(B\to Xs\gamma)$,
  - $A_{CP}(B\to X_s\gamma$:Belle 140 fb^{-1}) = 0.002 ± 0.050 ± 0.030
  - $A_{CP}(B\to X_s\gamma$:Babar 383 M BB) = −0.011 ± 0.030 ± 0.014
- Most systematic errors are limited by the control sample statistics, and can be reduced in the future.
- Scaled 140 fb^{-1} from Belle results:
  - $\delta A_{CP}(B\to X_s\gamma)$[@5ab^{-1}]=±0.009(stat)±0.006(syst),
  - $\delta A_{CP}(B\to X_s\gamma)$[@50ab^{-1}]=±0.003(stat)±0.002(syst)± 0.003(model)
  - Sensitivity to O(1%) asymmetry.
- Question: how to estimate the model error due to missing modes?

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

- Lepton tag
  Wrong tag due to **mixing** (9%), lepton from **non-B** (3%), **fakes**.
- $B \to X_d\gamma$ is included in the signal.
- By simple extrapolation, 1% statistical error @ 10 ab^{-1}
  - Challenging due to detector bias, fitting systematics etc.

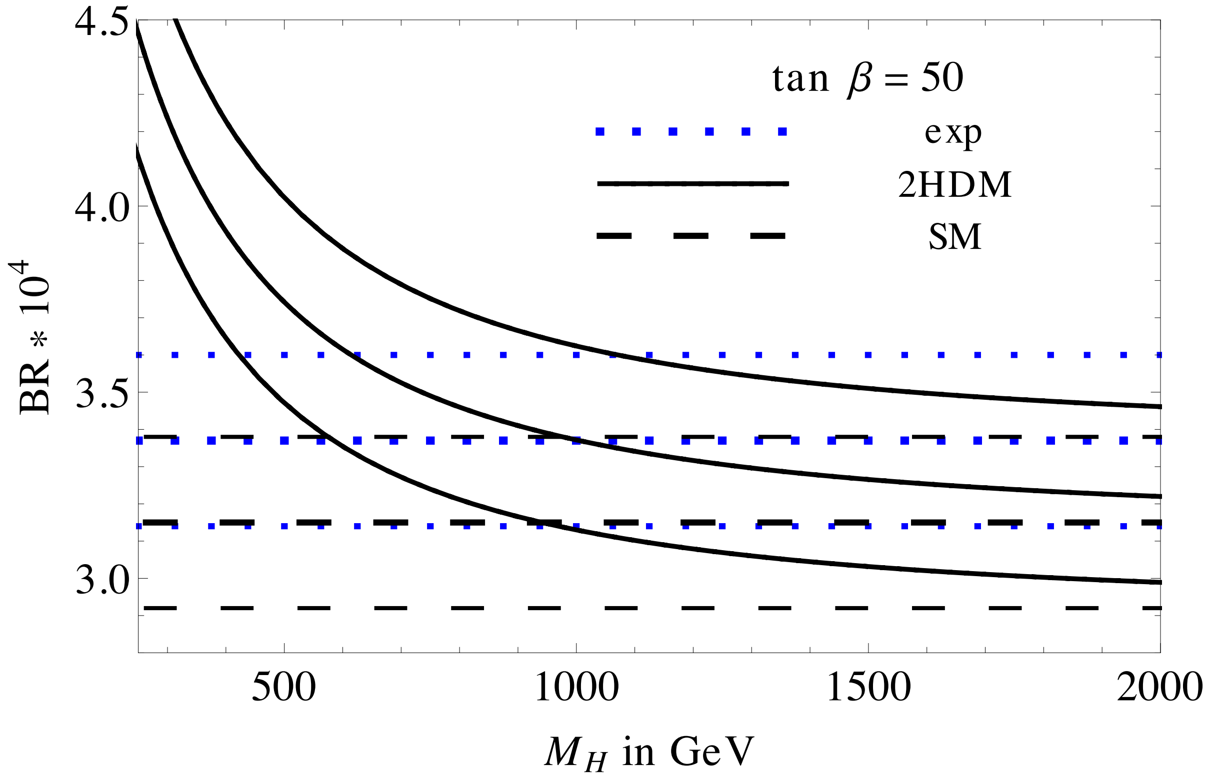


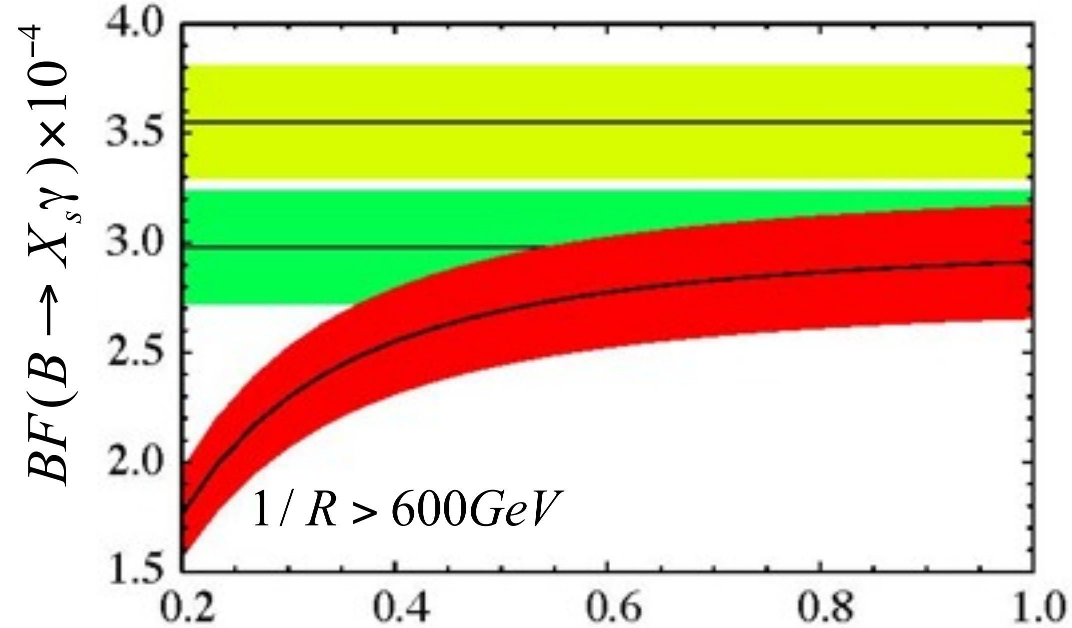
- Lepton tag



Recoil tag also useful for $A_{CP}(B \to X_s\gamma)$, $A_{CP}(B \to X_{s+d}\gamma)$

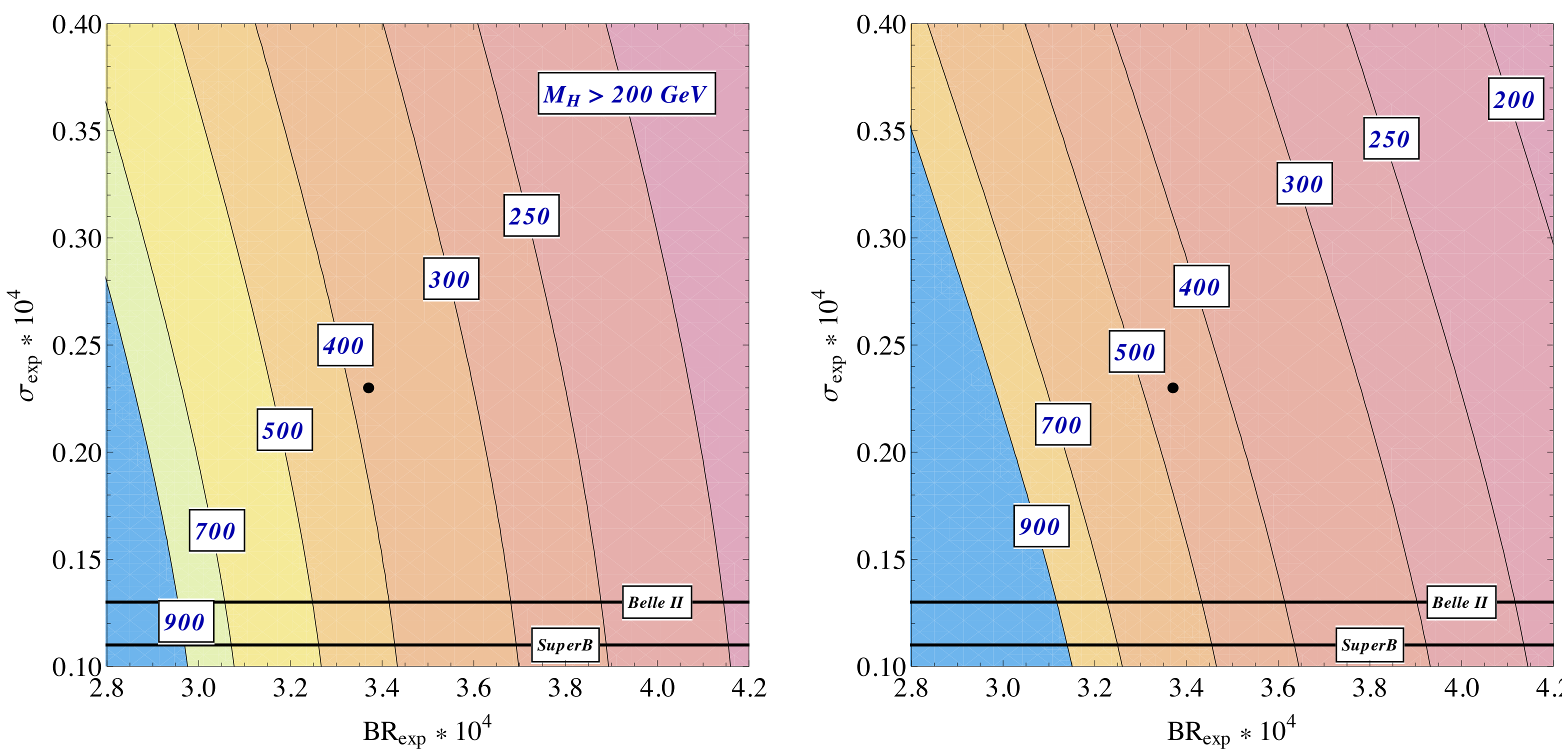
Current limits from current B→$X_s\gamma$ measurements





1/(R = Compactification radius in minimal universal extra dimension (mUED) models)

Lower bounds on M_{H^+} at the 95% C.L. as a function of the experimentally determined branching ratio (abscissa) and the corresponding uncertainty (ordinate). The current theory uncertainty has been used in panel (a), while panel (b) presents a future projection with assumed reduction of the theory uncertainty by a factor of two.

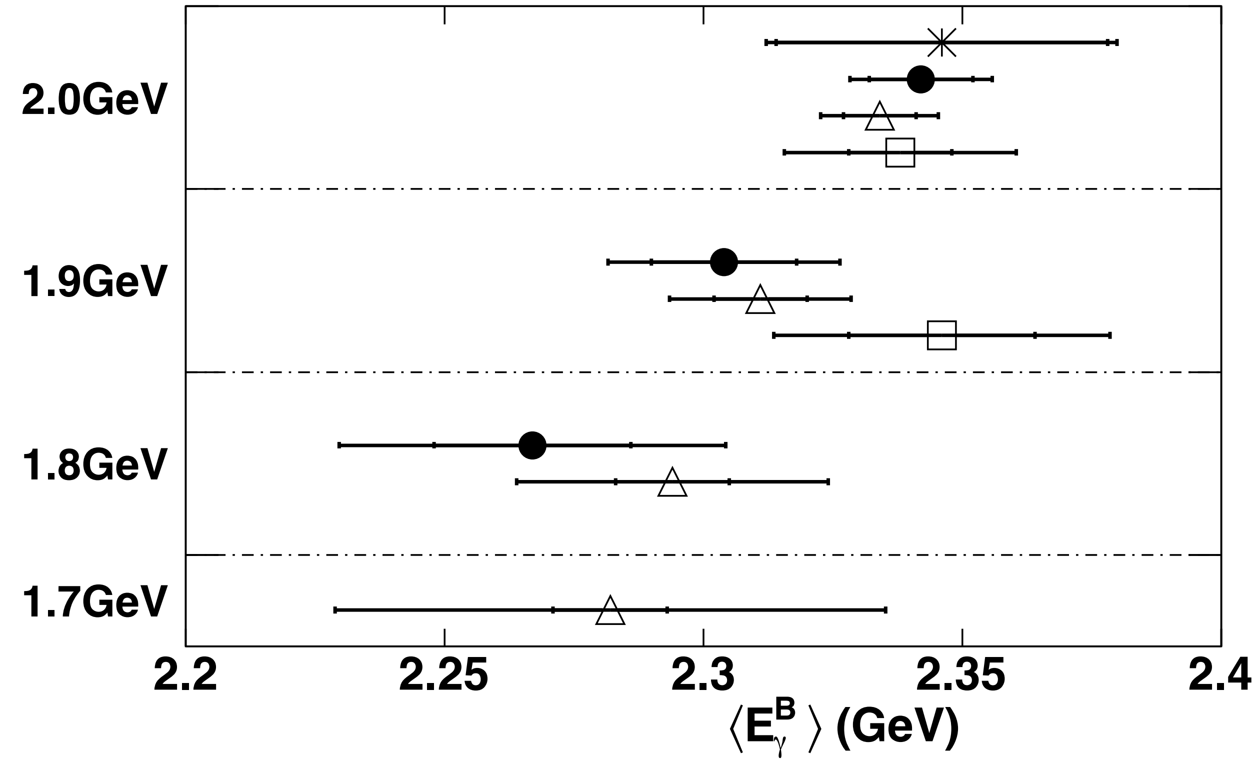


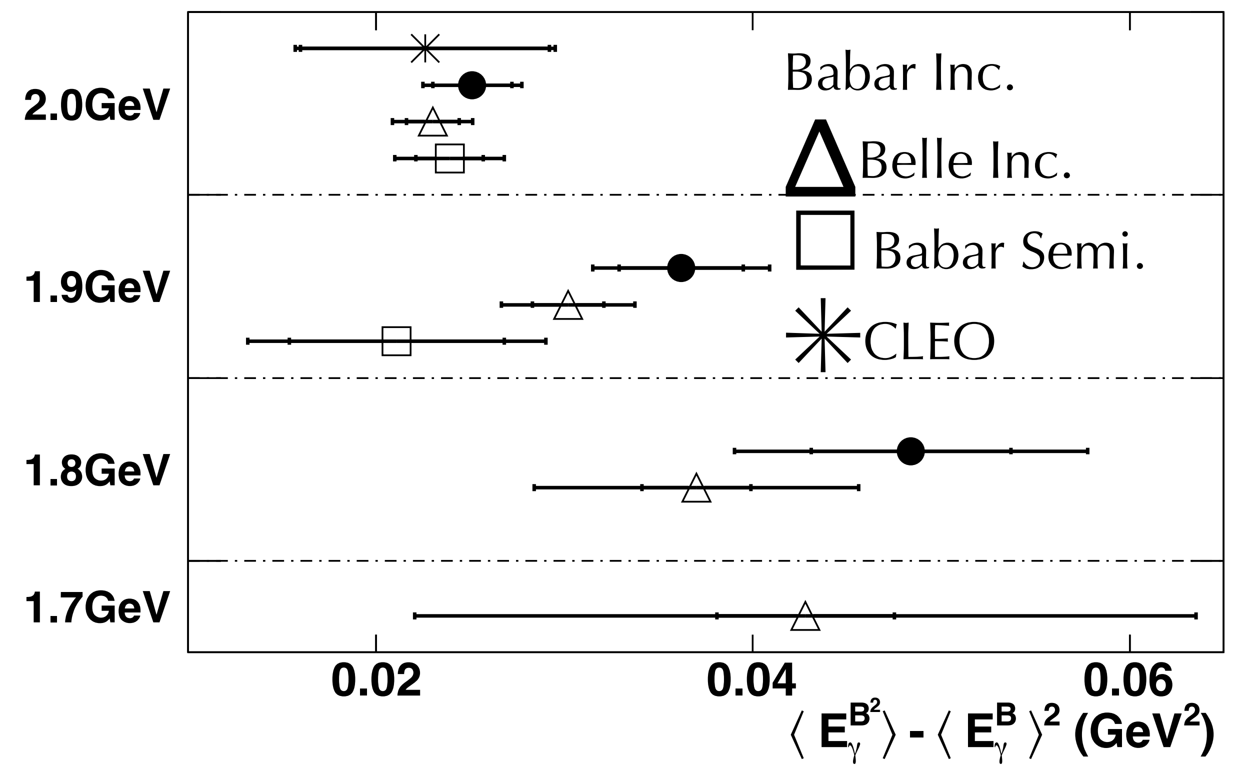
Energy spectrum&moments of $B \to X_s\gamma$

- Spectrum&Moments are used to determine Heavy quark parameters, m_b and b-Fermi motion kinetic energy (e.g. μ_π^2, l_1)
  - Important for precise $|V_{ub}|$
  - Insensitive to NP

- Energy moments from BABAR, Belle and CLEO for different Eg selection are consistent.
  - Belle: PRL 103, 241801 (2009), BABAR: arXiv: 1207.5772(2012) ,BABAR: PRD 72, 052004 (2005), CLEO: PRL 87, 251807 (2001)

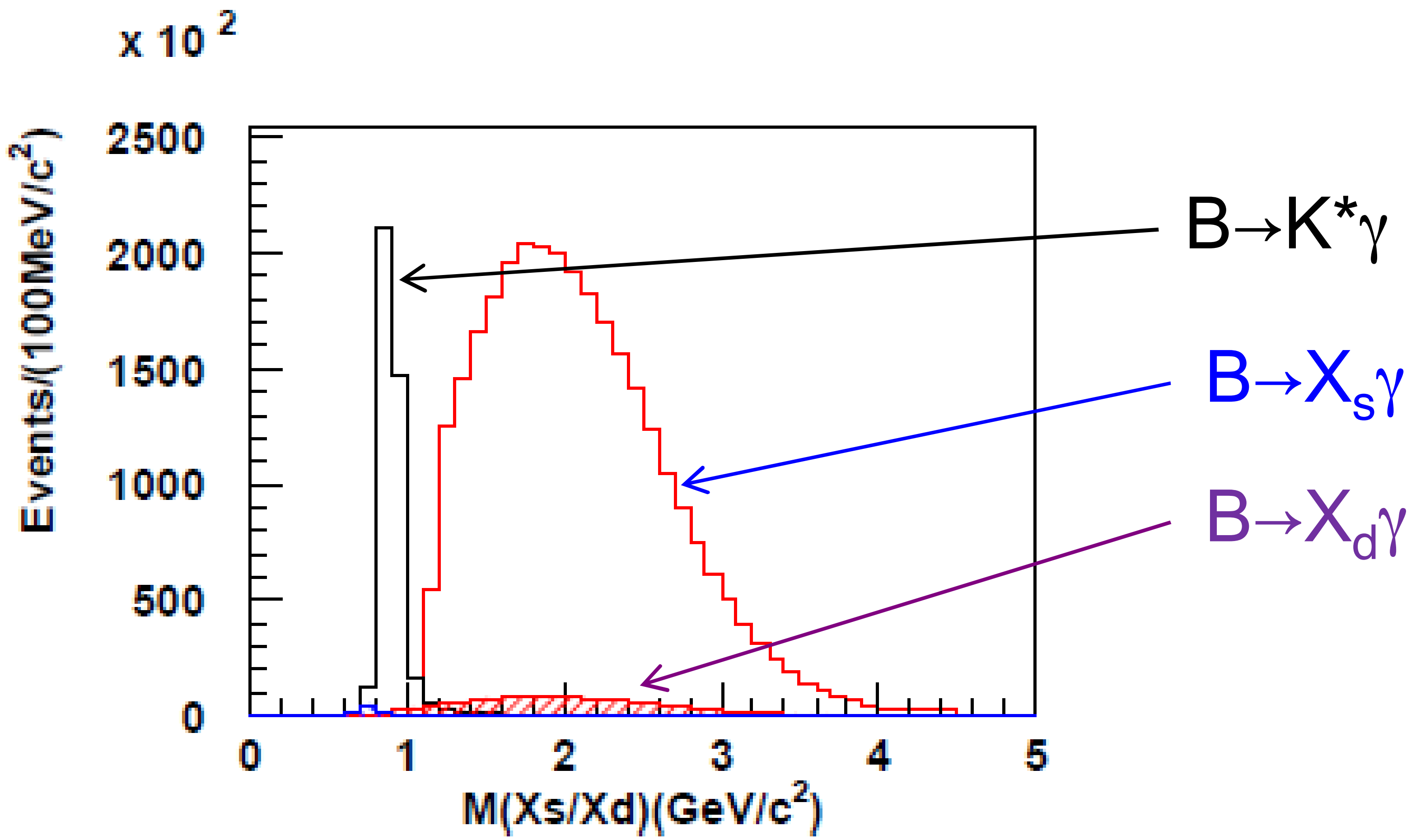
- **HFAG 2012 (1S, using SL & radiative)**
  Radiative provide very strong constraints
  - m_b=4.696 +/- 0.043 GeV, l_1=-0.354 +/- 0.072 GeV^2
- **(1S, using SL)**
  - m_b=4.595 +/- 0.110 GeV, l_1=-0.428 +/- 0.099 GeV^2

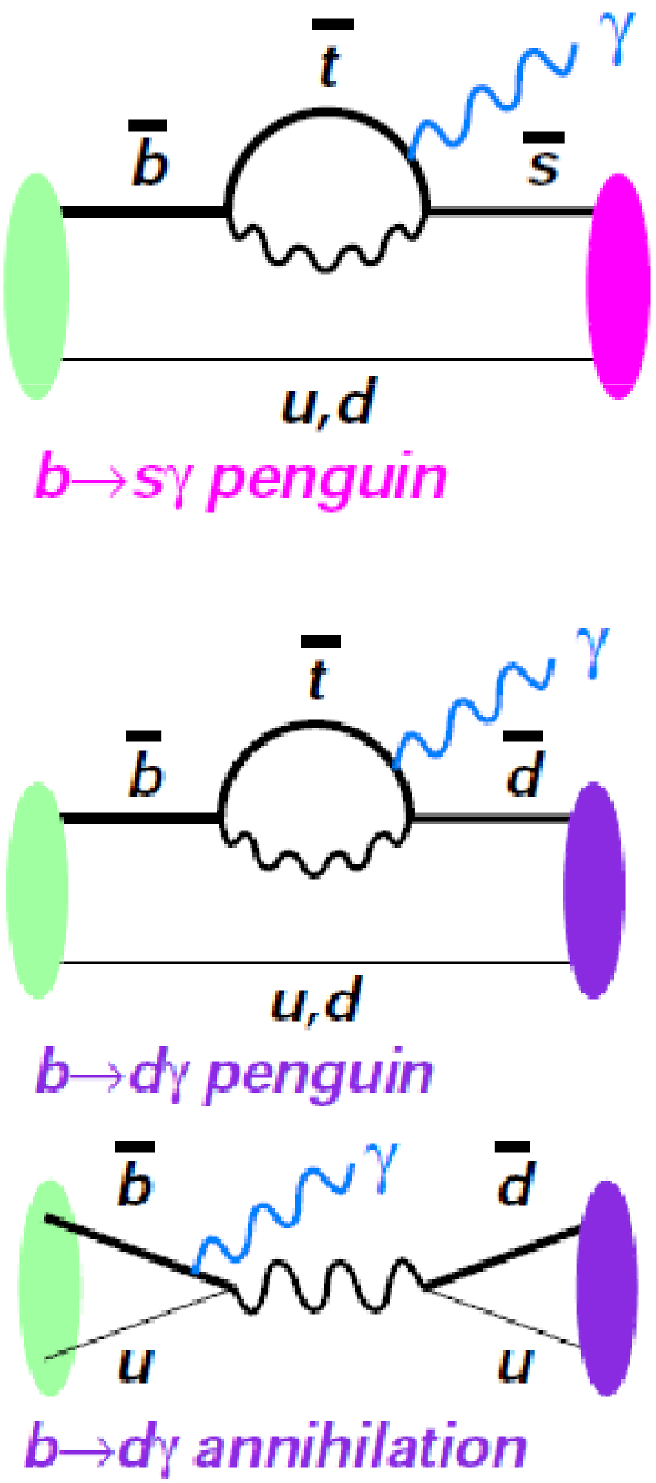




BF($B \to X_d\gamma$)

- $B \to X_d\gamma$: $|V_{td}/V_{ts}|$
- Huge background from $B \to X_s\gamma$
- To suppress $b \to s\gamma$,
  - sum of exclusive methods and
  - strangeness tagging (find K in the event)
    - New tree level $b \to s\gamma$ calculations may shed some light on ssbar popping backgrounds: arXiv1209.0965

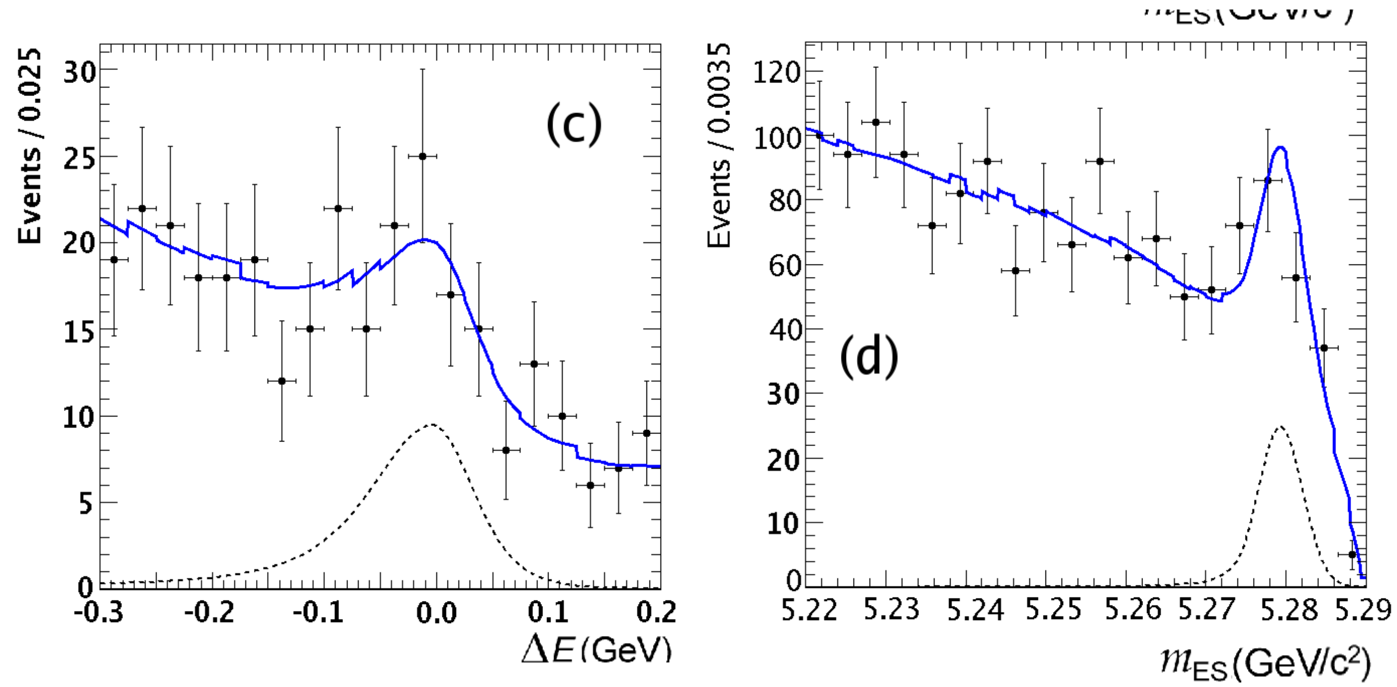




BF($B \rightarrow X_d \gamma$)

BaBar 471M BB [arXiv:1005.4087]

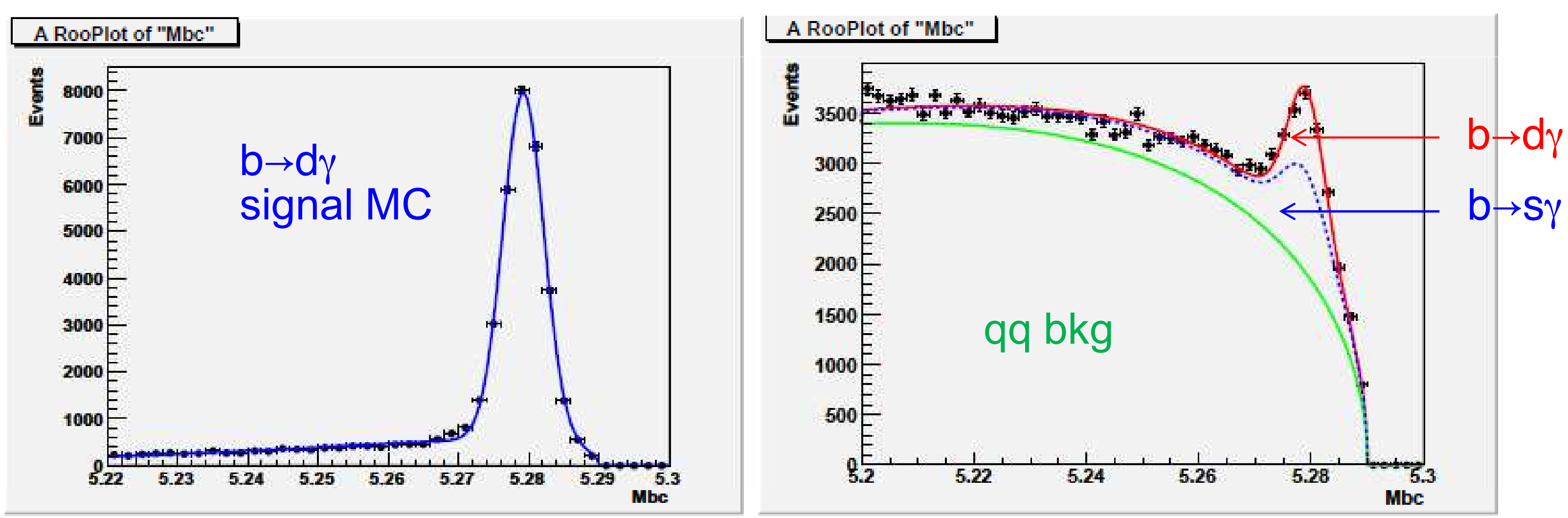
$B \to X_d\gamma$	$B \to X_s\gamma$
$B^0 \to \pi^+\pi^-\gamma$	$B^0 \to K^+\pi^-\gamma$
$B^+ \to \pi^+\pi^0\gamma$	$B^+ \to K^+\pi^0\gamma$
$B^+ \to \pi^+\pi^-\pi^+\gamma$	$B^+ \to K^+\pi^+\pi^-\gamma$
$B^0 \to \pi^+\pi^-\pi^0\gamma$	$B^0 \to K^+\pi^-\pi^0\gamma$
$B^0 \to \pi^+\pi^-\pi^+\pi^-\gamma$	$B^0 \to K^+\pi^-\pi^+\pi^-\gamma$
$B^+ \to \pi^+\pi^-\pi^+\pi^0\gamma$	$B^+ \to K^+\pi^-\pi^+\pi^0\gamma$
$B^+ \to \pi^+\eta\gamma$	$B^+ \to K^+\eta\gamma$



BF($B \to X_d\gamma$, $0.5 < M_{Xd} < 2.0$) = $(9.2 \pm 2.0 \pm 2.3) \times 10^{-6}$,
BF($B \to X_s\gamma$, $0.5 < M_{Xs} < 2.0$) = $(23.0 \pm 0.8 \pm 3.0) \times 10^{-5}$,
$|V_{td}/V_{ts}| = 0.199 \pm 0.022(\text{stat}) \pm 0.024(\text{syst}) \pm 0.002(\text{th})$

- MC study for Belle II
  - sum up 2 to 4 pions, including up to 1 π^0 for $M(X_d) < 2.0$ GeV
- 5% stat error @ 5 ab^{-1}
- 20% systematics, mainly from $b \to s\gamma$ normalisation

$(4.2 \pm 0.2(\text{stat}) \pm 0.9(\text{fit})) \times 10^3$ events



BF($B \to X_d \gamma$)

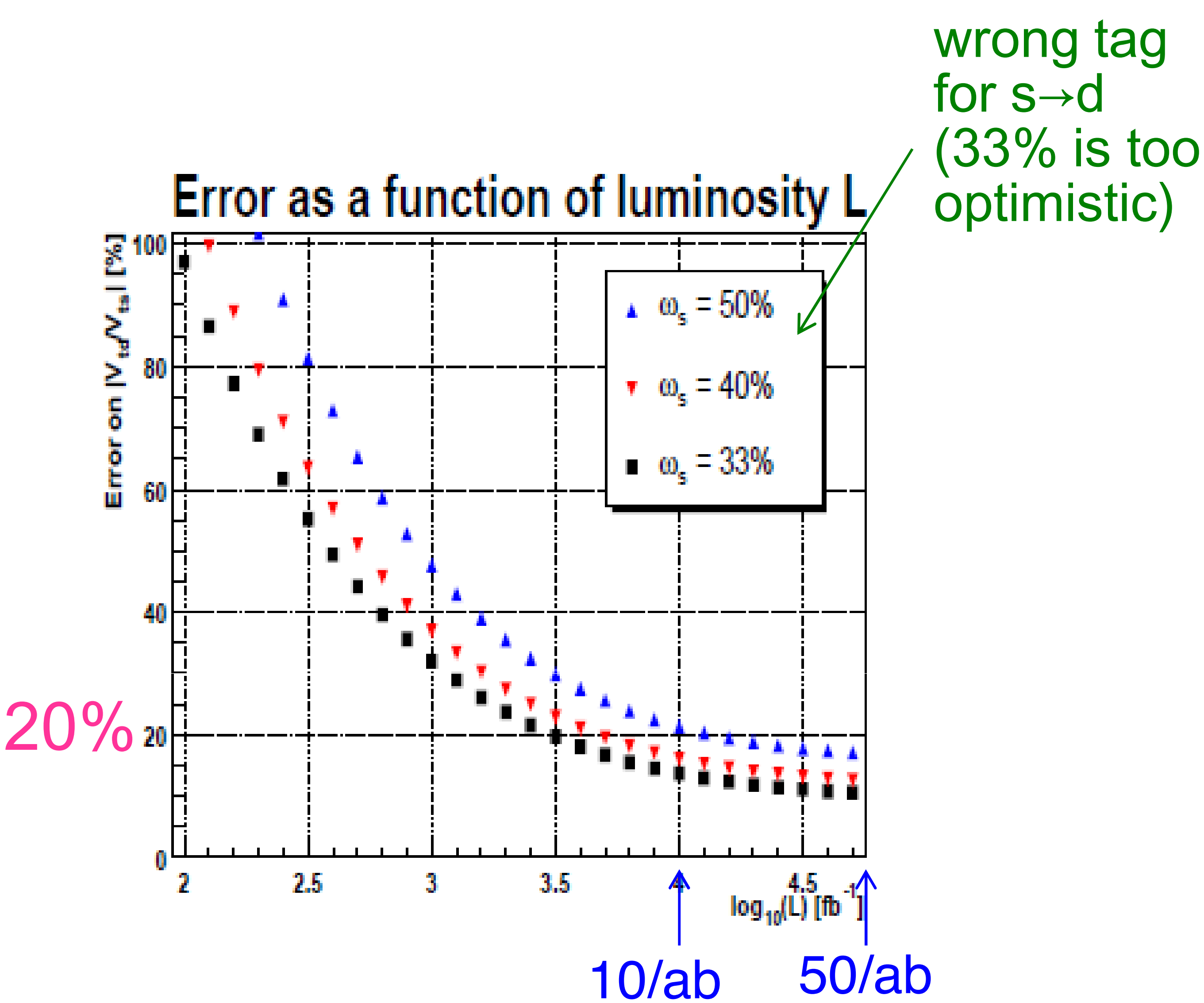
[arXiv:1005.4087]

Systematic Error Source	$M(X_s)$ 0.5-1.0	$M(X_s)$ 1.0-2.0	$M(X_d)$ 0.5-1.0	$M(X_d)$ 1.0-2.0
Track selection	0.3%	0.4%	0.3%	0.4%
Photon reconstruction	1.8%	1.8%	1.8%	1.8%
π^0/η reconstruction	0.9%	1.1%	1.4%	1.6%
Neural network	1.1%	4.9%	1.1%	4.9%
B counting	0.6%	0.6%	0.6%	0.6%
PID (*)	2.0%	2.0%	2.0%	2.0%
Fit bias (*)	0.1%	0.9%	4.9%	6.5%
PDF shapes (*)	2.3%	0.6%	3.7%	3.4%
Histogram binning (*)	0.8%	0.2%	1.8%	1.8%
Background (*)	0.8%	1.2%	5.9%	7.0%
Fragmentation (*)	-	3.3%	-	5.1%
Signal model	-	5.8%	-	6.0%
Error on partial $\mathcal{B}$	4.0%	9.0%	9.3%	14.2%
Missing ≥ 5 body		9.6%		18.2%
Other missing states		7.5%		15.3%
Spectrum Model		1.8%		1.6%
Error on inclusive $\mathcal{B}$	4.0%	15.2%	9.3%	27.7%

- A large part of the systematic error comes from missing modes or fragmentation.
- These will be improved by statistics (e.g. more reconstruction modes), but only slightly.
  - What can we learn from $B \to X_s \gamma$?

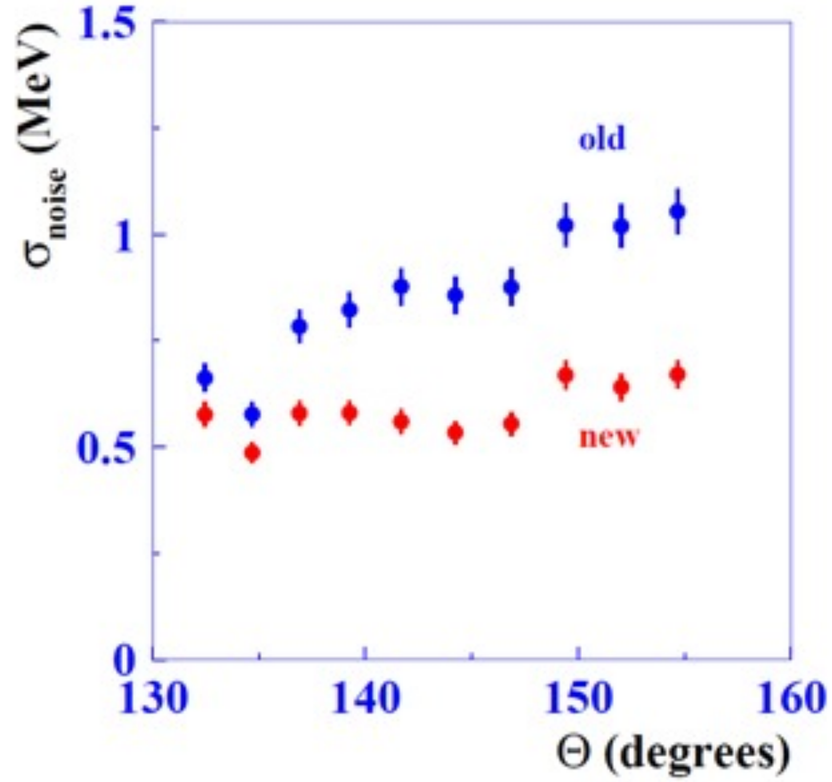
BF($B \to X_d\gamma$)

- Another possibility: full reconstruction + strangeness tag
- Strangeness tag : not so straightforward
  - Will fail for $K_S \to \pi^0\pi^0$, K_L :33% of K
  - Baryonic decay (Λ: ok, but Σ ?)
  - ssbar popping (e.g. $B \to KK\gamma$)
- A study in SLAC-R-709 "The Discovery Potential of a Super B Factory"
  - Semi-leptonic tag is assumed.
  - 10-20% for $|V_{td}/V_{ts}|$@10 ab^{-1}.
  - If full reconstruction is necessary, need one order of magnitude
  - more statistics (program@50 ab^{-1})



Some detector improvements

- Photons: ECL (Calo.) waveform sampling. Improved energy resolution. CsI coverage extended to endcap.
- K/π: TOP+ARICH Significant improvement in discrimination.

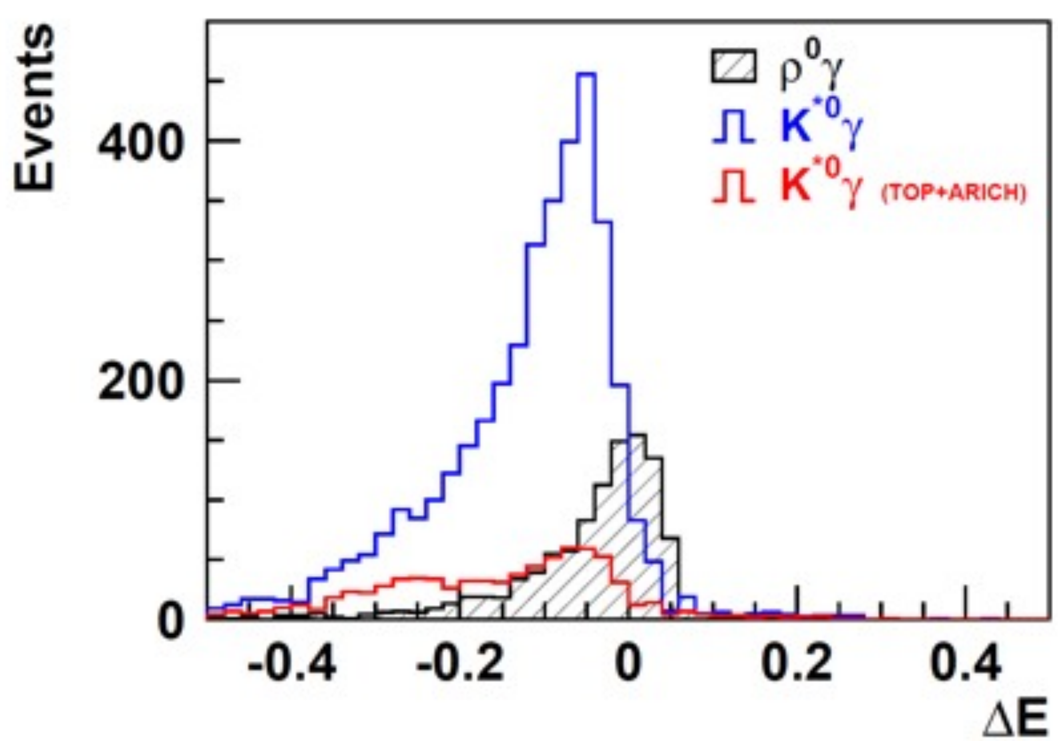


Luminosity Gain

$B^0 \rightarrow \rho^0 \gamma$

No upgrade BAD / Upgrade GOOD

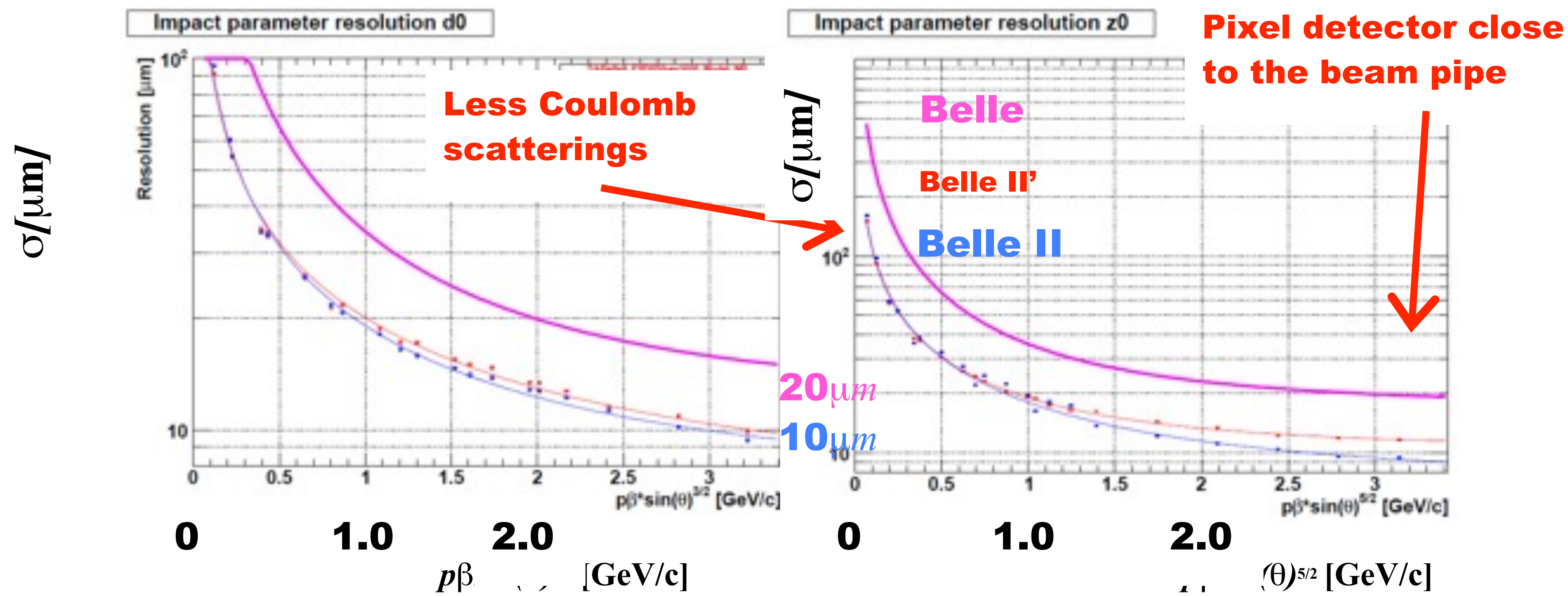
FWD / BRL	ACC only	dE/dx only	As good as Belle	A-RICH
TOF, dE/dx NA	–74%	–69%	–68%	–62%
TOF NA	–41%	–35%	–32%	–22%
As good as Belle	–10%	–4%	0% (definition)	+12%
TOP opt.0	+27%	+33%	+40%	+59%
TOP opt.2	+45%	+51%	+60%	+83%



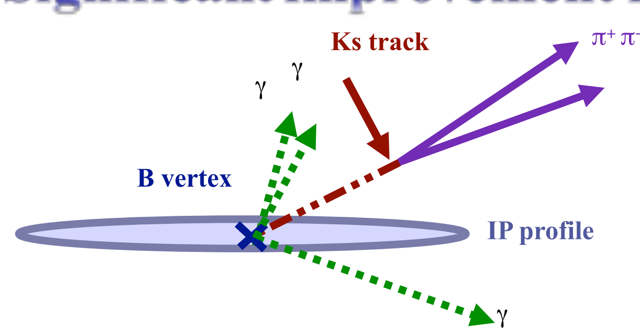
Exclusive Golden mode: $B \to K_S \pi^0 \gamma$

- Flavour factories will do time-dependent CP-violation in exclusive mode $B \to K_S \pi^0 \gamma$

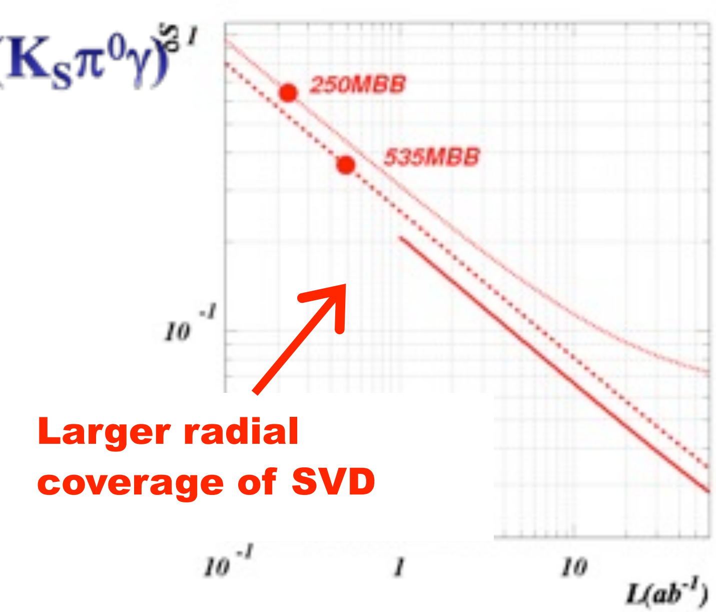
- New Vertexing layout: **PIXEL** +STRIPS resolution: 20μm to 10μm (large p).



Significant improvement in $\delta S(K_S\pi^0\gamma)$



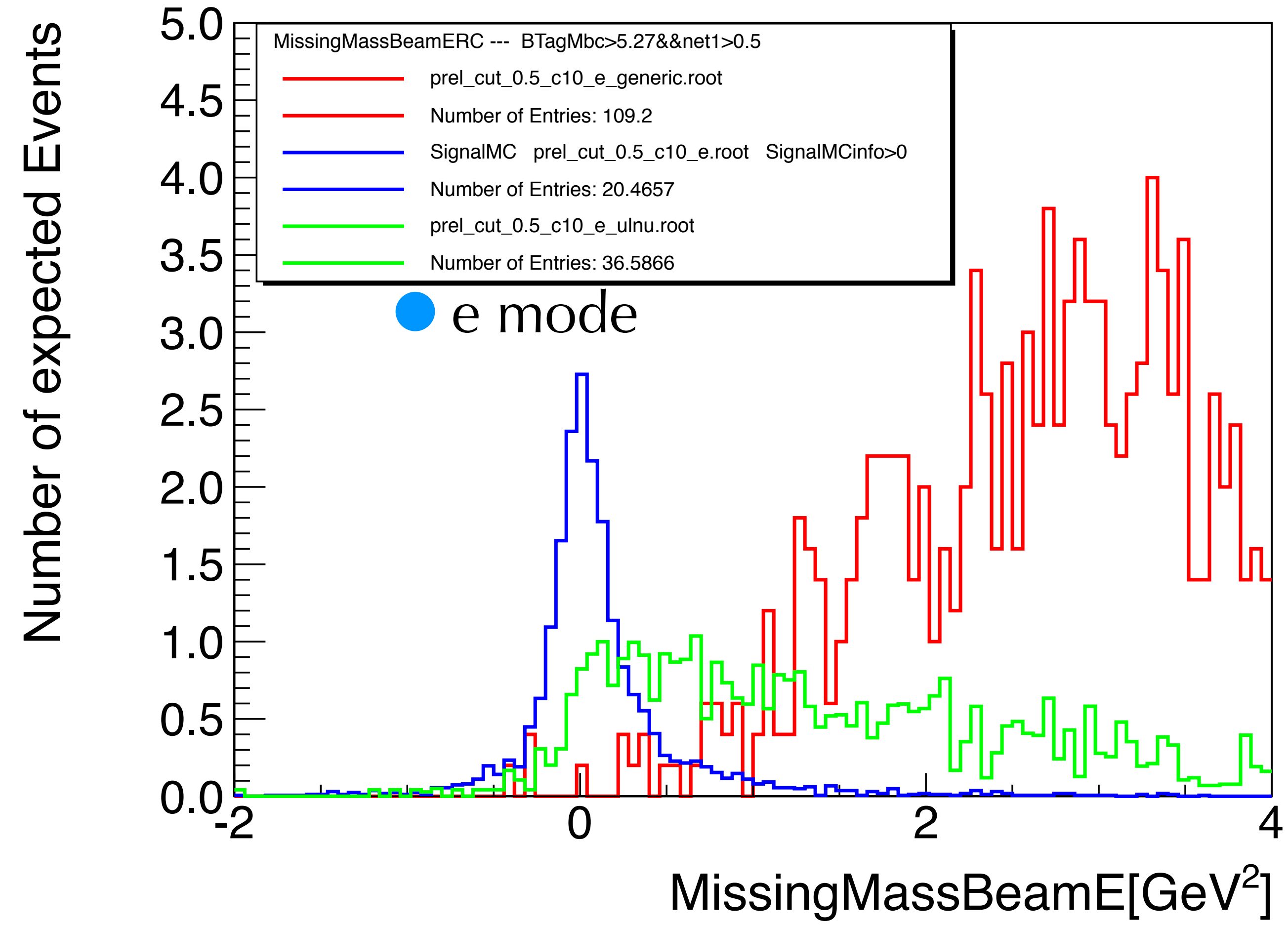
B decay point reconstruction with K_S trajectory



Radiative leptonic $B^+ \to e^+(\mu^+)\nu\,\gamma$

- Access to B distribution function parameter, λ_B
  - $B_{SM}(B^+ \to e^+(\mu^+)\nu\,\gamma) = 5.0 \times 10^{-6}$
- BaBar limits at 90% CL:
  - Model independent:
    - $< 17 \times 10^{-6}$ (electrons),
    - $< 26 \times 10^{-6}$ (muons)
  - Model specific:
    - $< 8.4 \times 10^{-6}$ (electrons),
    - $< 6.7 \times 10^{-6}$ (muons)
- Belle: Results in preparation. Expect limits close to the SM value.
- It will be a Super FF precision measurement ~**25 signal events per e and μ modes per 1 ab^{-1} with hadron tagging!**

- MC study, ~703 fb^{-1}



$B \rightarrow X_s l^+ l^-$ & $B \rightarrow X_u l \nu$

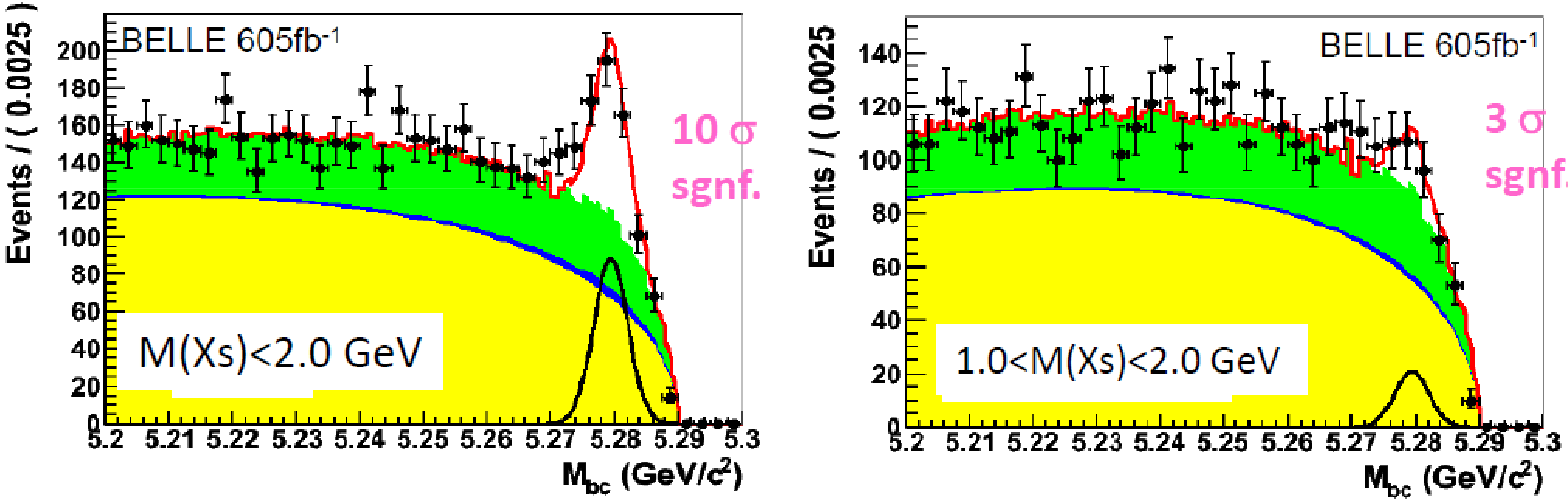
Inclusive $B \to X_s l^+ l^-$

- Theoretically clean compared to exclusive, error <5% at $A_{FB}=0$
- More challenging than $B \to X_{s/d}\gamma$ (two orders of magnitudes lower B.F.), BR error ~25%.
- **Measurements: Branching fraction, forward backward asymmetry etc. (similar to exclusive $B \to K^*$ ll).**
- Study possible only in e^+e^- B factories.
  - But, So far, all the analyses at BaBar and Belle are based on the sum of exclusive modes method.
  - Acceptance for electron and muons very similar allowing comparison, test of lepton universality, and CP violation
- Theoretical error on BF($B \to X_s l^+ l^-$) in high q^2 (>14.4GeV) region may be reduced by using information from $B \to X_u l^+ \nu$.
  - Estimate error would decrease from 30% to 15%. In low q^2 region errors are ~10%.
- "Sum of exclusive modes" has been used at B Factories. "Recoil method" will become increasingly useful at Flavour factories (efficiency ~0.5% but improves rejection of semi-leptonic background).

Inclusive $B \to X_{s/d} l^+ l^-$ (Sum of Excl.)

Belle 605 fb^{-1} result

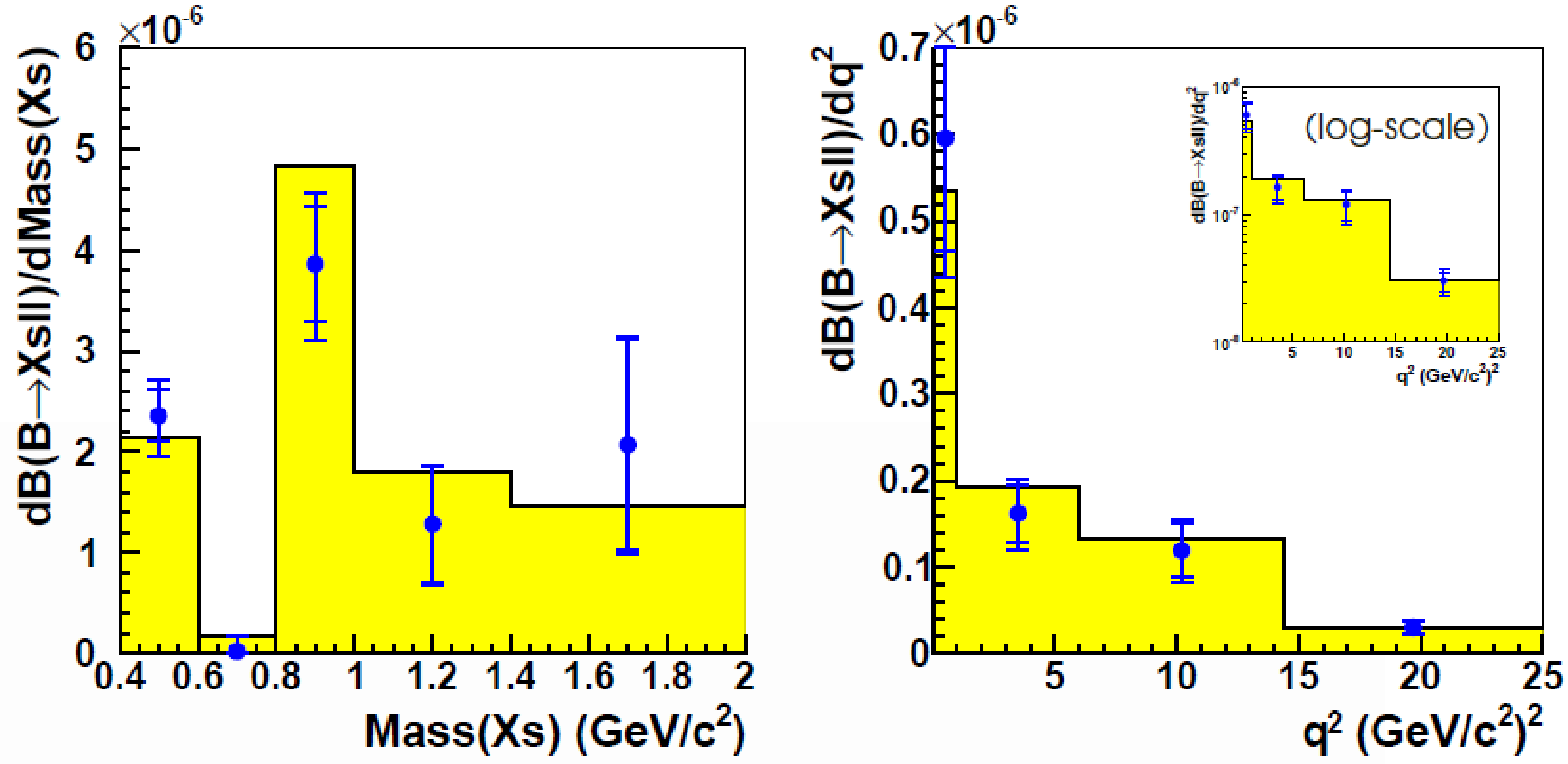
[LP09]



- 283.2±26.4±2.3 events : $B(B \to X_s l^+ l^-) = 3.33 \pm 0.80^{+0.19}_{-0.24}$) 10^{-6}
- 18 X_s modes used, fraction of the Xs decay states covered by this semi- inclusive method is approximately 62% (41 % and 21 % for $K^\pm$ and K_S^0 states, respectively)
  - $K^\pm$, $K^\pm\pi^0$, $K^\pm\pi^\mp$, $K^\pm\pi^\mp\pi^0$, $K^\pm\pi^\mp\pi^\pm$, $K^\pm\pi^\mp\pi^\pm\pi^0$, $K^\pm\pi^\mp\pi^\pm\pi^\mp$, $K^\pm\pi^\mp\pi^\pm\pi^\mp\pi^0$, $K^\pm\pi^\mp\pi^\pm\pi^\mp\pi^\pm$, K_S^0 , $K_S^0\,\pi^0$, $K_S^0\,\pi^\pm$, $K_S^0\,\pi^\pm\,\pi^0$, $K_S^0\pi^\pm\pi^\mp$, $K_S^0\pi^\pm\pi^\mp\pi^0$, $K_S^0\pi^\pm\pi^\mp\pi^\pm$, $K_S^0\pi^\pm\pi^\mp\pi^\pm\pi^0$, and $K_S^0\pi^\pm\pi^\mp\pi^\pm\pi^\mp$.

Inclusive $B \to X_{s/d} l^+ l^-$

- So far, M_{Xs} and q^2 dependence for a few bins are obtained.
- Still statistics dominated.
- **Main systematic error sources**
  - assumed Kll, K*ll fraction (6%)
  - hadronisation + missing mode (5%)



analysis improves with statistics

comparison with Xsγ

- Belle& Babar still **yet** to publish their results.

Inclusive $B \rightarrow X_{s/d} l^+ l^-$

$X_s \ell\ell$

Sum of exclusive

Recoil Mass

		BABAR (425 fb^{-1})				SuperB (75 ab^{-1})			
Observable	q^2 region [GeV^2/c^4]	Stat. SE	Sys. SE	Stat. RM	Sys. RM	Stat. SE	Sys. SE	Stat. RM	Sys. RM
$\sigma\mathcal{B}/\mathcal{B}$	all	0.11	0.056	0.26	0.06	0.008	0.03-0.05	0.019	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	0.1–1	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	1–4	0.23	0.06	0.53	0.06	0.017	0.03-0.05	0.040	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	4–7.84	0.18	0.06	0.43	0.06	0.014	0.03-0.05	0.032	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96	0.31	0.07	0.73	0.07	0.024	0.04-0.06	0.055	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	>14.06	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06

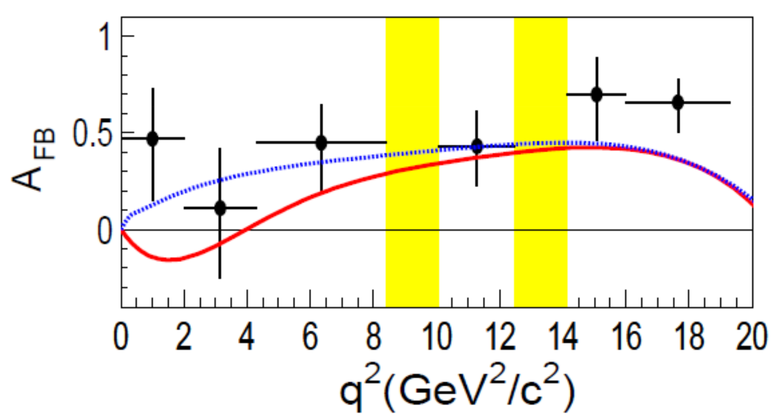
(hadronic uncertainty ~10% not included)

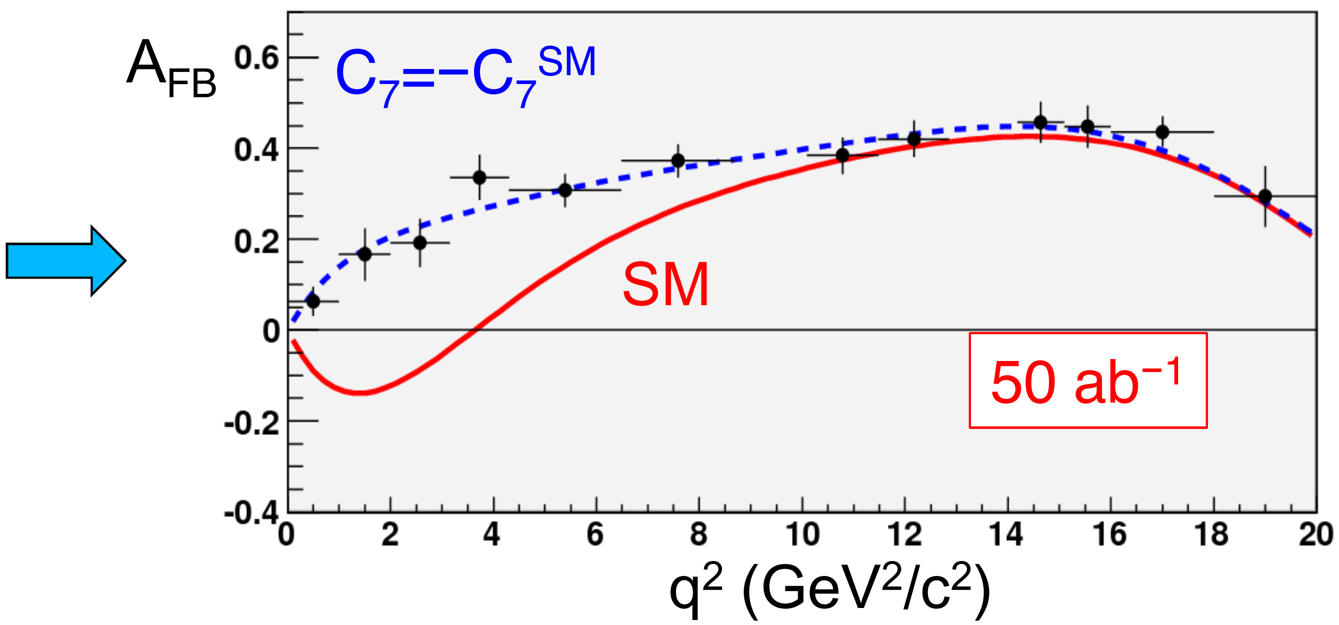
Measurement with a few % precision possible at 75 ab^{-1}

A_{FB} $B \to X_{s/d} l^+ l^-$

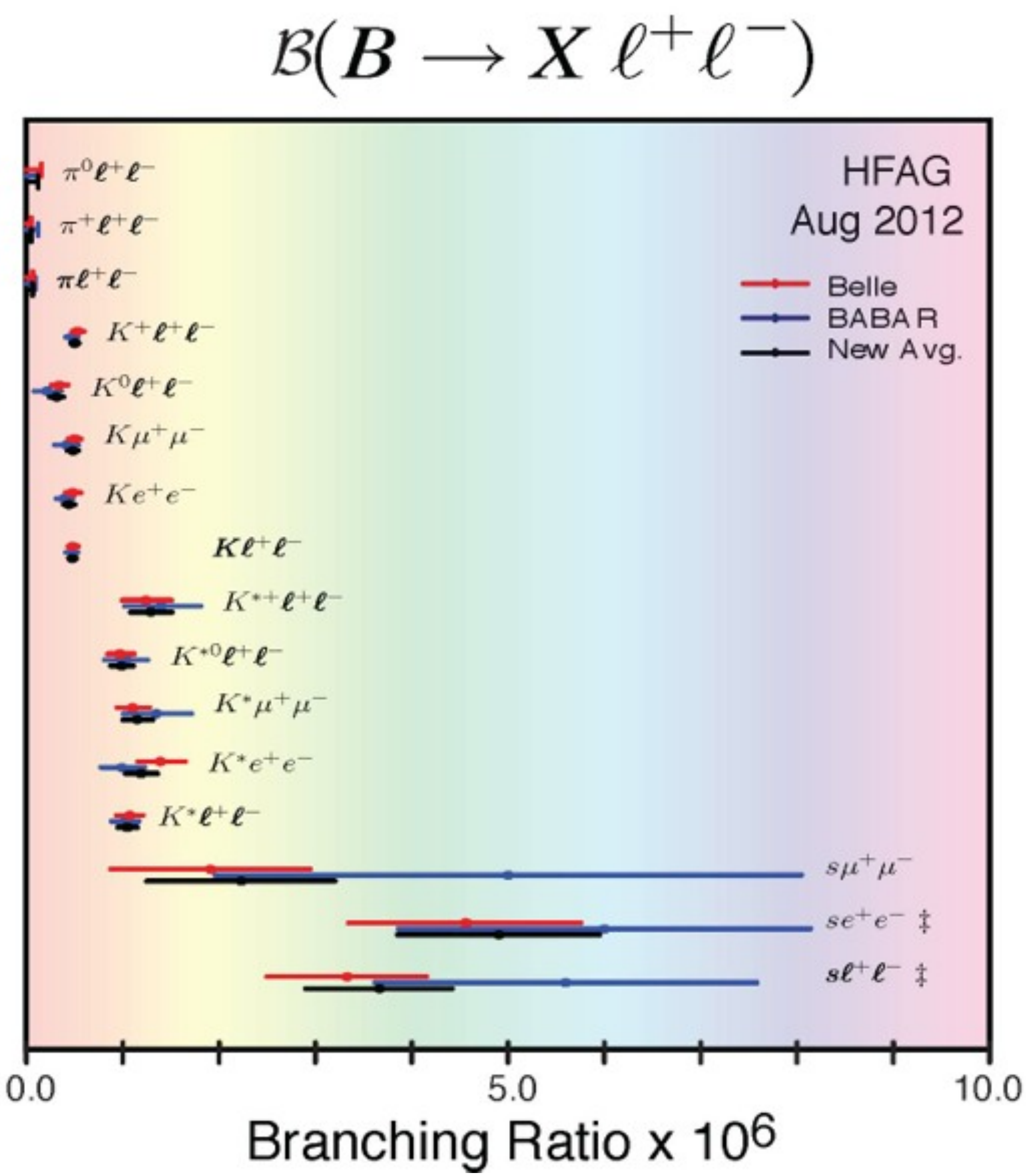
- Next Step: Forward-backward asymmetry, isospin asymmetry
  - But, results & feasibility study exist only for exclusive modes.
  - No estimation of forward backward asymmetry for inclusive mode
  - One order of magnitude luminosity required to get reasonable uncertainties.
  - Considering theoretical precision of exclusive modes, perhaps inclusive modes may not be competitive for some time.

exclusive K*ℓℓ



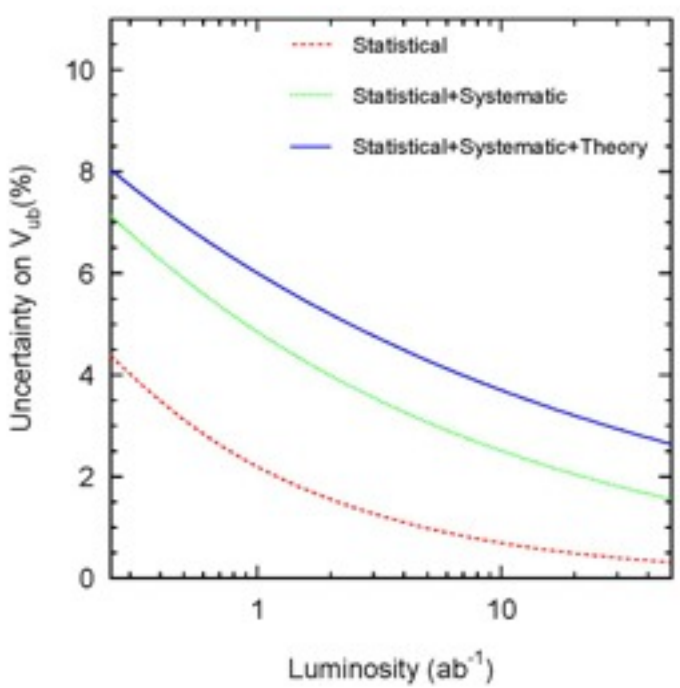


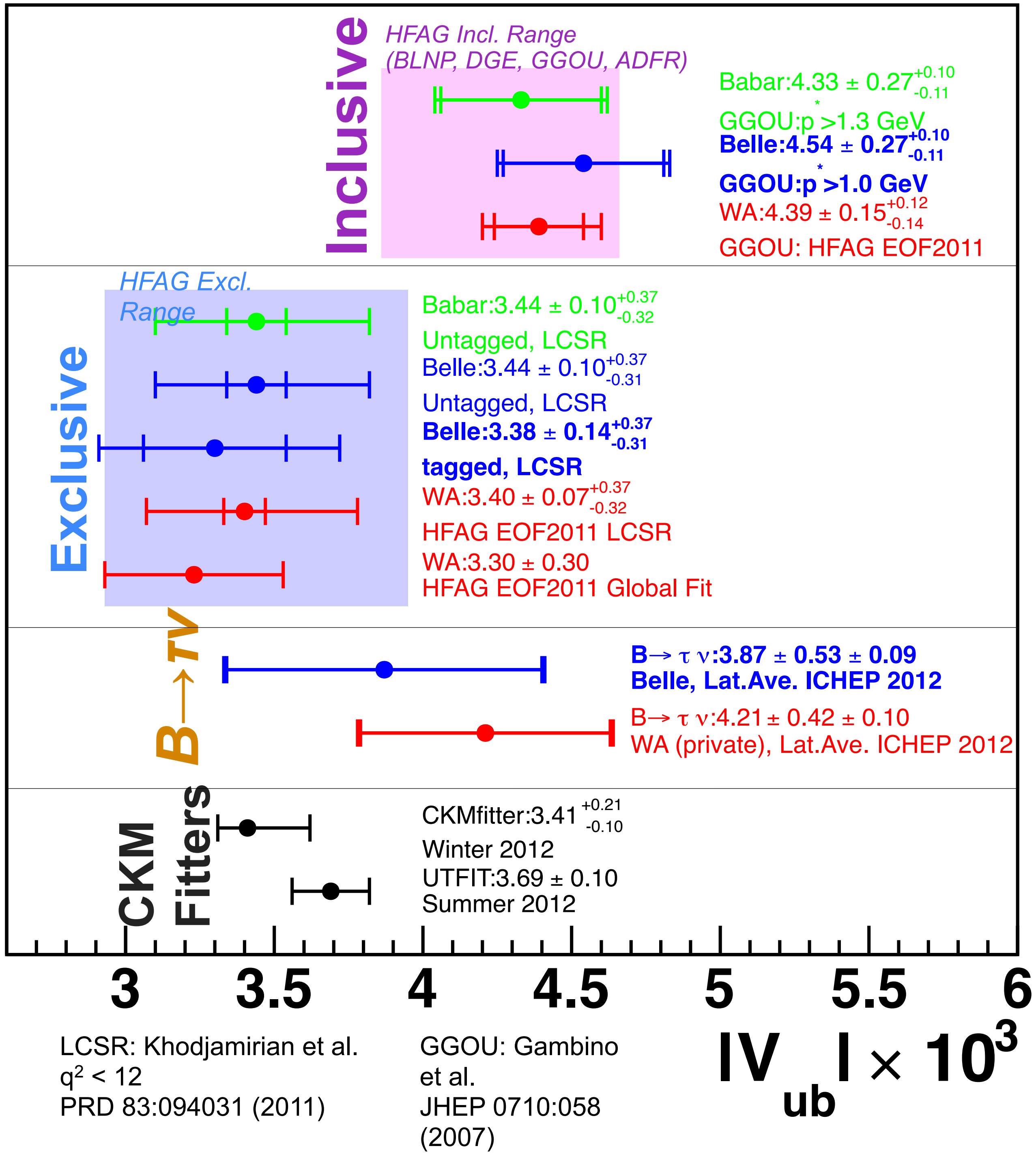
Current HFAG inclusive/exclusive results



Inclusive $|V_{ub}|$

- Unique to flavour factories.
- Measurement of $|V_{ub}|$ allows comparison of length of $|V_{ub}|$ side (tree) of Unitarity triangle and $\sin(2\beta)$ (loop).
- $B \to X_c l\nu$ ~50 x larger than signal $B \to X_u l\nu$.
- Normalisation of decay spectra determines $|V_{ub}|$ while shape sensitive to m_b and Fermi motion.
    - Important feedback to $B \to X_{s/d}\, \gamma / l^+ l^-$
- **Extra statistics at flavour factories will help to reduce theoretical and experimental systematic errors.**

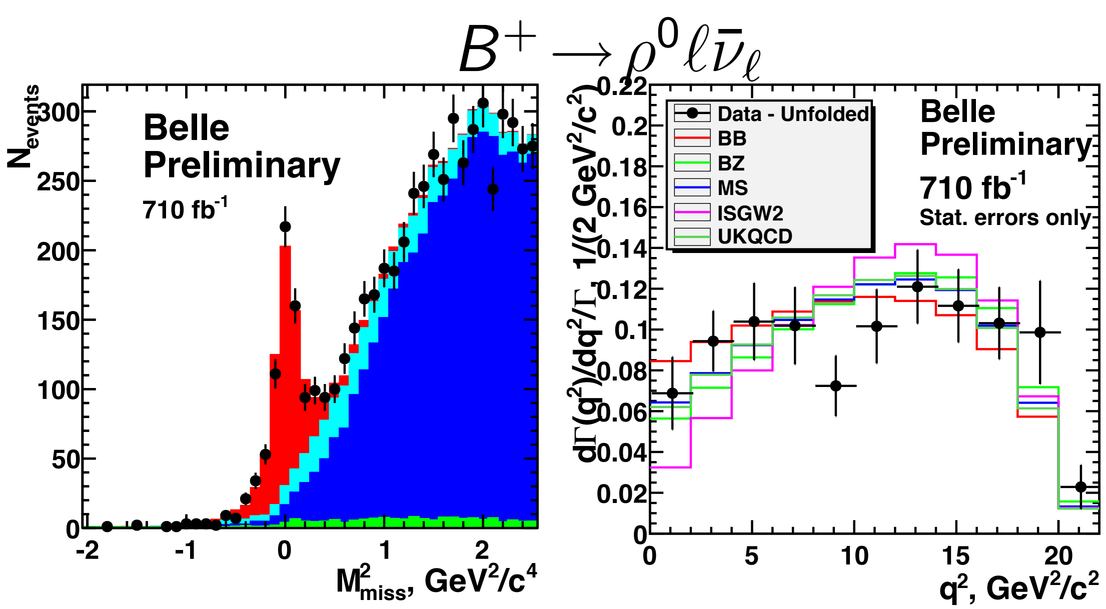




Exclusive $|V_{ub}|$ Double Ratios

- Can we learn something from Exclusive $B \to X_u l \nu$ or use $K^{(*)}ll$ to improve V_{ub}?, e.g. can double ratios cancel form factor errors? e.g. hep-ph/9711248 , or pQCD calculations in arXiv:1207.0265,
- **K^* & ρ $l\nu$ will be studied to test for current chirality:** complementary to EWP modes.

Belle Full Recon. 2012



Exclusive V_{ub} projection

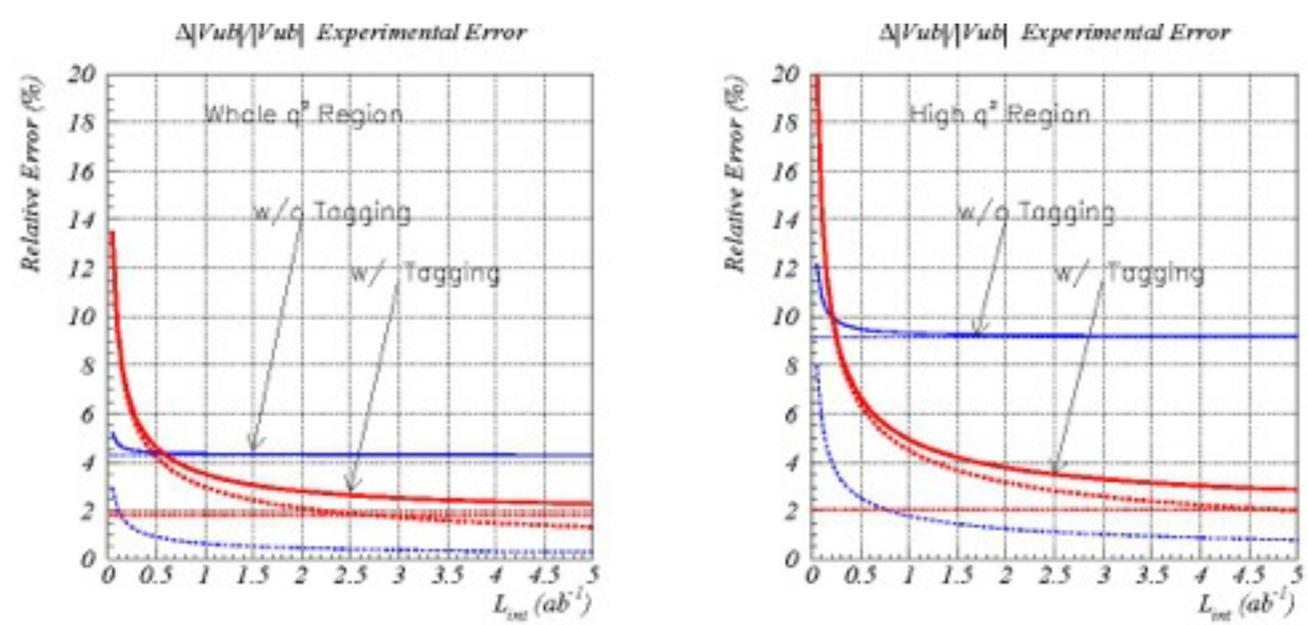


Figure 5.50: Expected improvement of the experimental error in $|V_{ub}|$ (solid lines) as a function of the integrated luminosity L, (left) for the whole q^2 and (right) the high q^2 regions.

“Inclusive” $B \to X\nu\nu$, $B \to \nu\nu$(invisible)

B → X ν ν

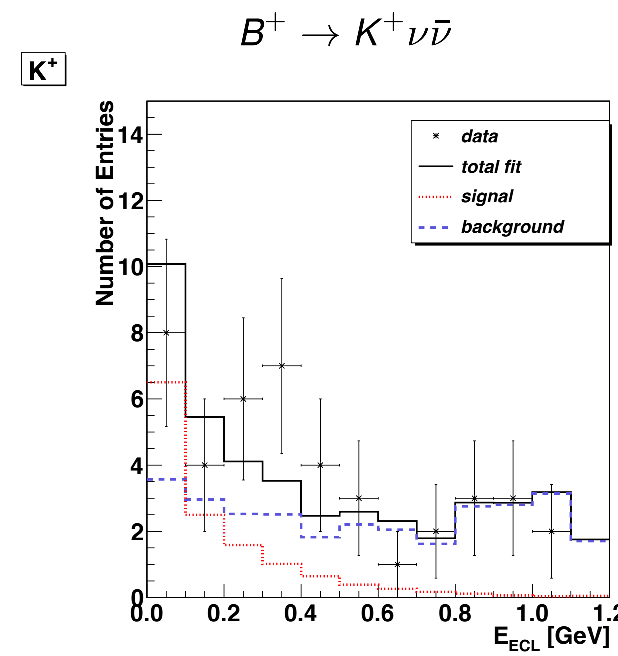
- Precise theoretical predictions (only one hadron in the final state, no charged leptons)
- Experimentally very challenging, Best constraints come from exclusive B→K$^{(*)}$ν ν-bar.
- Peaking backgrounds from B→τν

TABLE VI: SM predictions and experimental 90% C.L. upper bounds for the four $b \to s\nu\bar{\nu}$ observables.

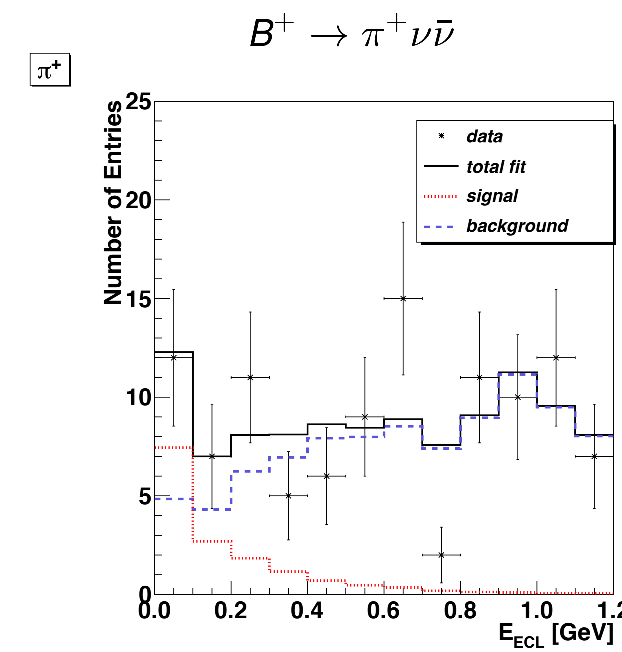
Observable	SM prediction	Experiment
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	$(6.8^{+1.0}_{-1.1}) \times 10^{-6}$ [63]	$< 80 \times 10^{-6}$ [65]
$\mathcal{B}(B^+ \to K^+\nu\bar{\nu})$	$(3.6 \pm 0.5) \times 10^{-6}$ [66]	$< 14 \times 10^{-6}$ [67]
$\mathcal{B}(\bar{B} \to X_s\nu\bar{\nu})$	$(2.7 \pm 0.2) \times 10^{-5}$ [63]	$< 64 \times 10^{-5}$ [68]
$\langle F_L(B \to K^*\nu\bar{\nu})\rangle$	0.54 ± 0.01 [63]	–

New Belle hadron tagging results

Channel	Branching ratio limit at 90% CL **Belle 2012**	Branching ratio limit at 90% CL previous Belle analysis	PDG limit at 90% CL
$B^+ \to K^+\nu\bar{\nu}$	5.5×10^{-5}	1.4×10^{-5}	1.3×10^{-5}
$B^+ \to K^{*+}\nu\bar{\nu}$, $K^{*+} \to K^+\pi^0$	3.3×10^{-5}	14×10^{-5}	8×10^{-5}
$B^+ \to K^{*+}\nu\bar{\nu}$, $K^{*+} \to K^0_s\pi^+$	2.9×10^{-5}	14×10^{-5}	8×10^{-5}
$B^+ \to \pi^+\nu\bar{\nu}$	9.8×10^{-5}	17×10^{-5}	10×10^{-5}
$B^+ \to \rho^+\nu\bar{\nu}$	21.4×10^{-5}	44×10^{-5}	15×10^{-5}
$B^0 \to K^0_s\nu\bar{\nu}$	9.4×10^{-5}	16×10^{-5}	5.6×10^{-5}
$B^0 \to K^{*0}\nu\bar{\nu}$, $K^{*0} \to K^+\pi^-$	5.4×10^{-5}	34×10^{-5}	1.2×10^{-5}
$B^0 \to \pi^0\nu\bar{\nu}$	6.9×10^{-5}	22×22^{-5}	22×10^{-5}
$B^0 \to \rho^0\nu\bar{\nu}$	20.8×10^{-5}	44×10^{-5}	44×10^{-5}
$B^0 \to \phi\nu\bar{\nu}$	12.5×10^{-5}	5.8×10^{-5}	5.8×10^{-5}



$N_{Sig} = 13.3^{+7.4}_{-6.6}$
$S_{stat} = 2.1\sigma$
$S_{stat+syst} = 2.0\sigma$



$N_{Sig} = 15.2^{+7.1}_{-6.2}$
$S_{stat} = 2.8\sigma$
$S_{stat+syst} = 2.6\sigma$

B → X ν ν

- K^* channel sensitive to longitudinal polarization fraction $F_L(q^2)$. Which is theoretically clean.
  - Inclusive decay rates (and FL) depend on 2 independent combinations of Wilson coeff's $C^{\nu}_{L,R}$
  - F_L only depends on η. Observation would imply right-handed currents. By measuring inclusive and exclusive, η-ε plane can be over-constrained.
- Non-MFV MSSM can have effects up to 35%. Non-universal Z′ models can have large effects; if Z′ may couple more strongly to ν than l+

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

$$(\varepsilon, \eta)_{SM} = (1, 0)$$

$$\frac{R(B \to K^* \nu\bar{\nu})}{R(B \to K^* \nu\bar{\nu})_{SM}} = (1 + 1.31\eta)\varepsilon^2$$

$$\frac{R(B \to K \nu\bar{\nu})}{R(B \to K \nu\bar{\nu})_{SM}} = (1 - 2\eta)\varepsilon^2$$

$$\frac{R(B \to X_S \nu\bar{\nu})}{R(B \to X_S \nu\bar{\nu})_{SM}} = (1 + 0.09\eta)\varepsilon^2$$

$$\langle F_L \rangle / \langle F_L \rangle_{SM} = \frac{(1 + 2\eta)}{(1 + 1.31\eta)}$$

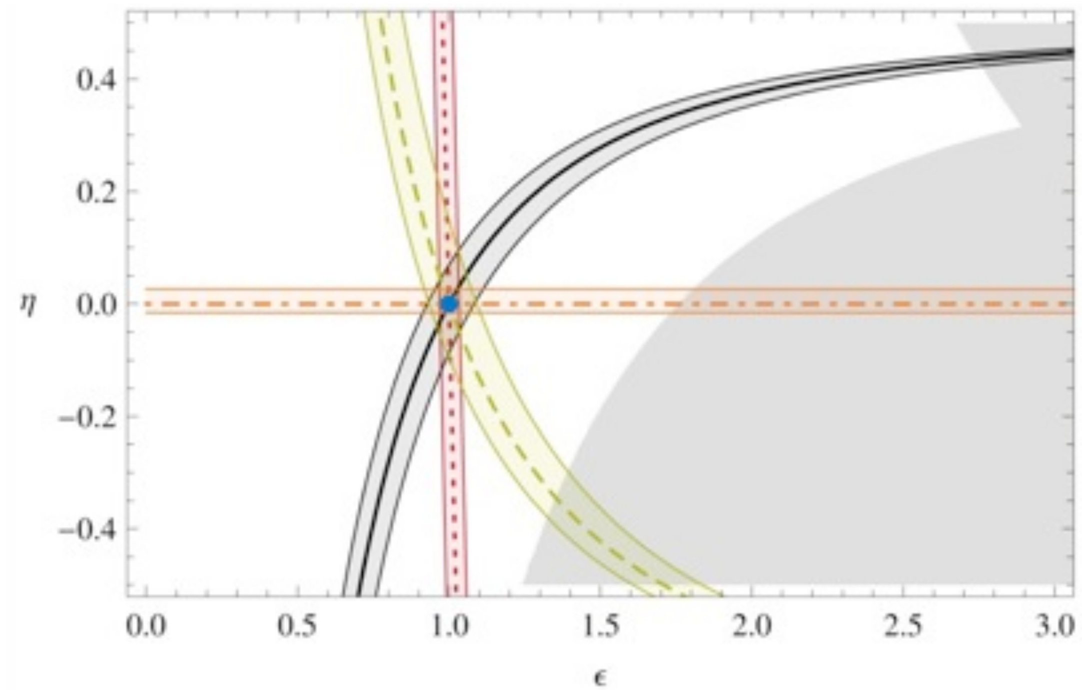
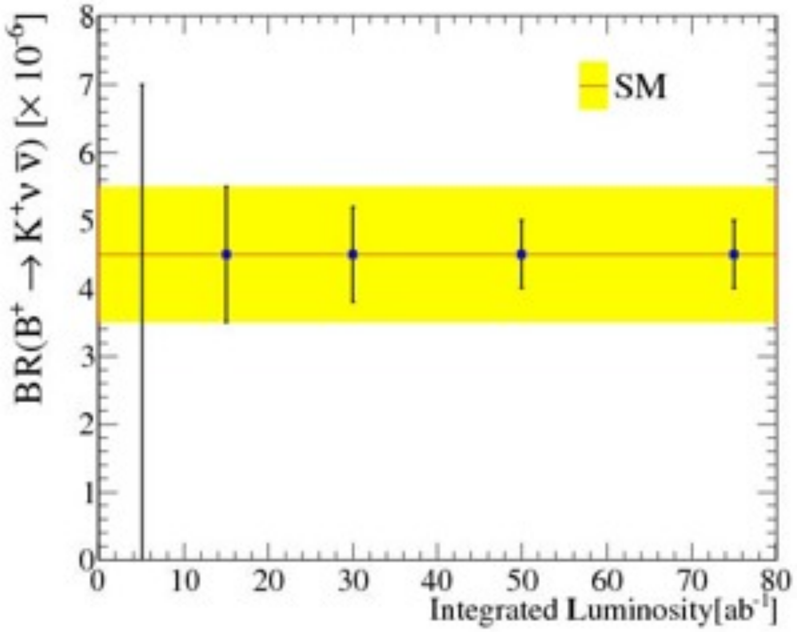


FIG. 5: Hypothetical constraints on the ϵ-η-plane, assuming all four observables have been measured with infinite precision. The error bands refer to theory uncertainties only. The green band (dashed line) represents $\mathcal{B}(B \to K^* \nu\bar{\nu})$, the black band (solid line) $\mathcal{B}(B \to K \nu\bar{\nu})$, the red band (dotted line) $\mathcal{B}(B \to X_s \nu\bar{\nu})$ and the orange band (dot-dashed line) $\langle F_L \rangle$. The shaded area is ruled out experimentally at the 90% confidence level.

B→K$^{(*)}$νν-bar predictions



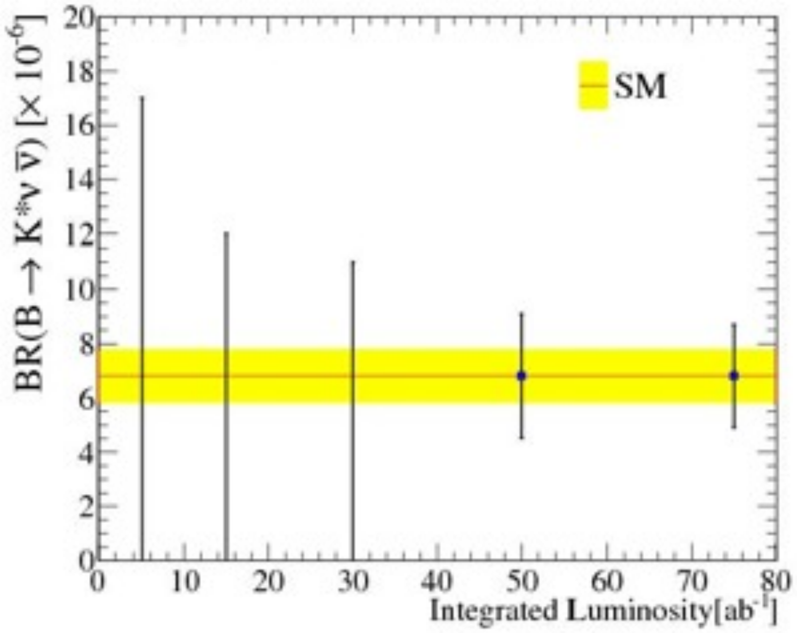


FIG. 9: Expected precision of the measurements of the branching fractions of (top) $B^+ \to K^+\nu\overline{\nu}$ and (bottom) $B^* \to K^*\nu\overline{\nu}$ evaluated as a function of the integrated luminosity.

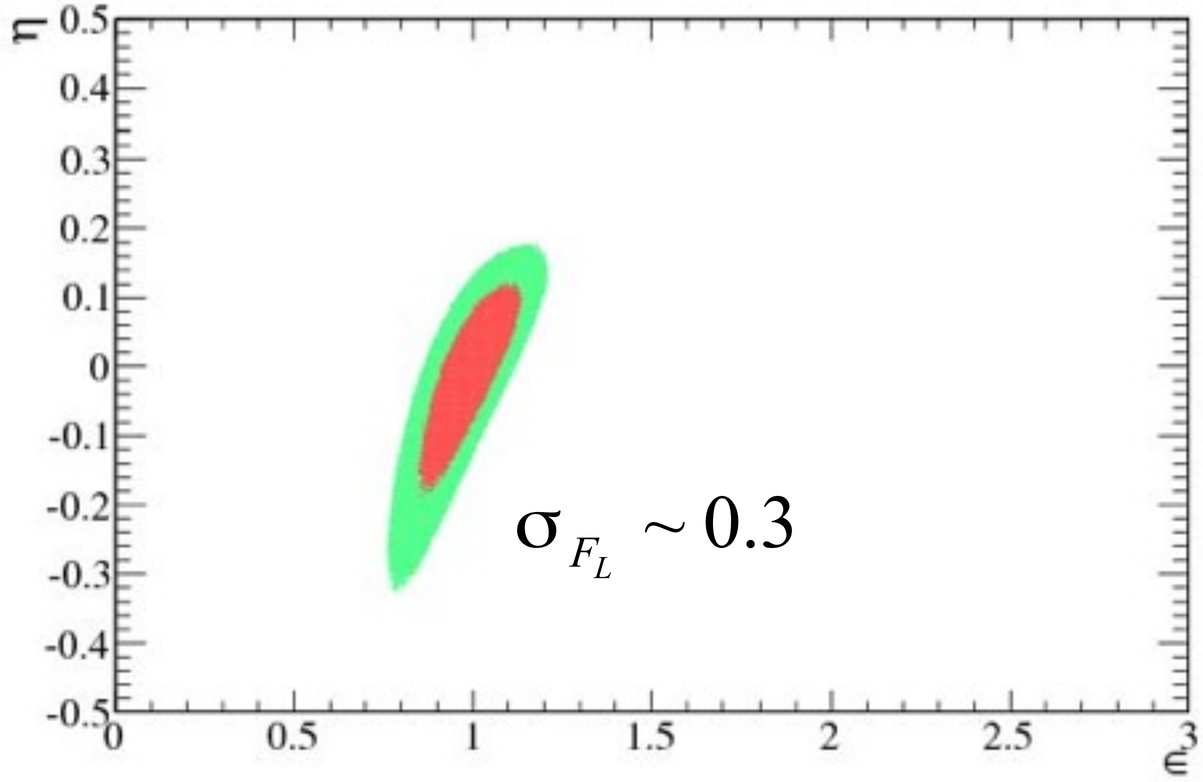


FIG. 10: Expected constraint on the (ϵ, η) plane discussed in Section 3 B 1, from the measurement of the Branching Ratios of $B \to K^{(*)}\nu\overline{\nu}$ and the angular analysis of $B^0 \to K^{*0}\nu\overline{\nu}$ at 75 ab^{-1} (See Figure 9).

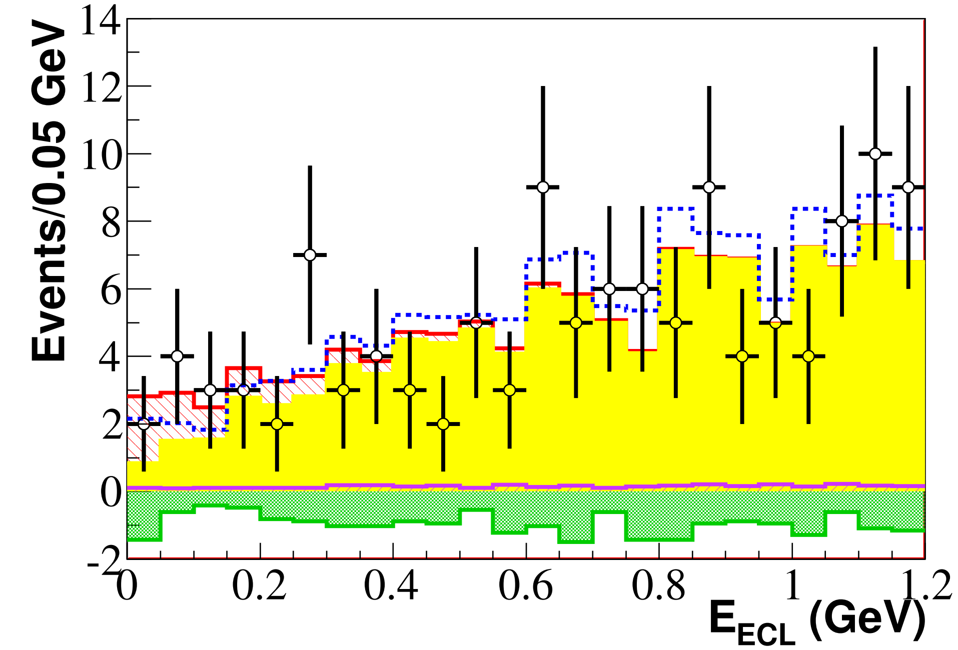
Invisible (+γ) decays

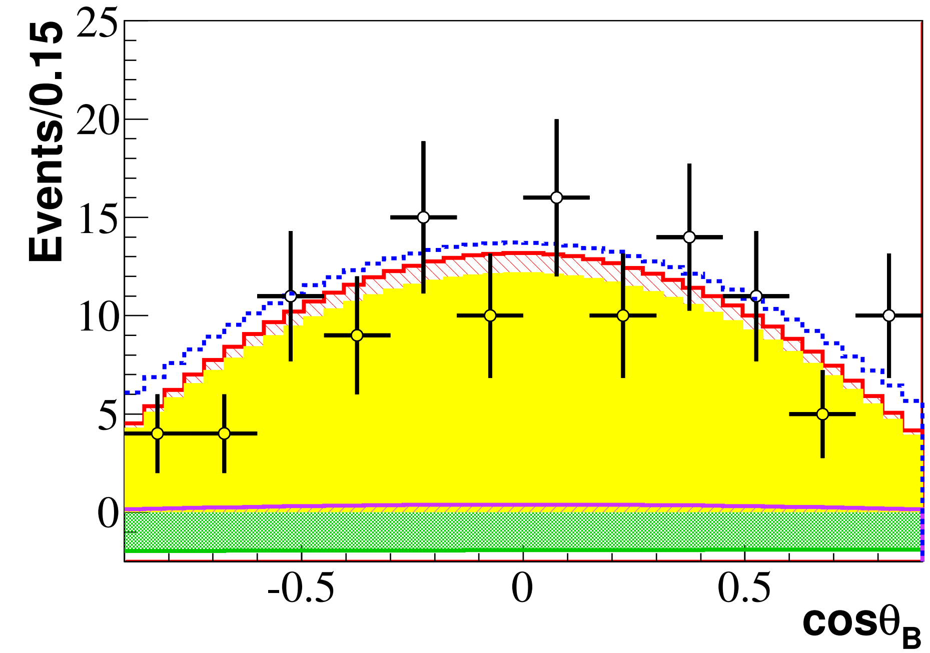
- B→invisible (+γ) includes searches for Dark Matter candidates.
- Models include R-parity violating SUSY and large EDMs.
  - $BF(B^0 \rightarrow \bar{\nu} \chi^0) \sim O(10^{-6} - 10^{-7})$
- Can use recoil method and semi-leptonic/hadronic tagged B at Υ(4S) or lower mass Υ(nS).
  - **Current best limit from semileptonic tag $BF<2.4\times10^{-5}$.**
- Upper limits likely to scale somewhere between sqrt(L) and L at B Factories.

- Belle PhysRevD.86.032002
- Hadron tagging

$N_{sig} = 8.9^{+6.3}_{-5.5}$

Upper limit: $\mathcal{B}(B \rightarrow \text{invisible}) < 1.3 \times 10^{-4}$





Other Topics

Tauonic, B_s, and Charm

(Semi)**Tauonic**: $B \to X\tau\tau$, $B \to \tau\tau$

- A design goal of the SFF's is good tau reconstruction.
- Don't expect to see these via SM due to limited reconstruction efficiency, rather as NP search modes (particularly with an extended Υ(5S) run)
- However very few searches done to date.
  - ...enough stats could allow polarisation studies.

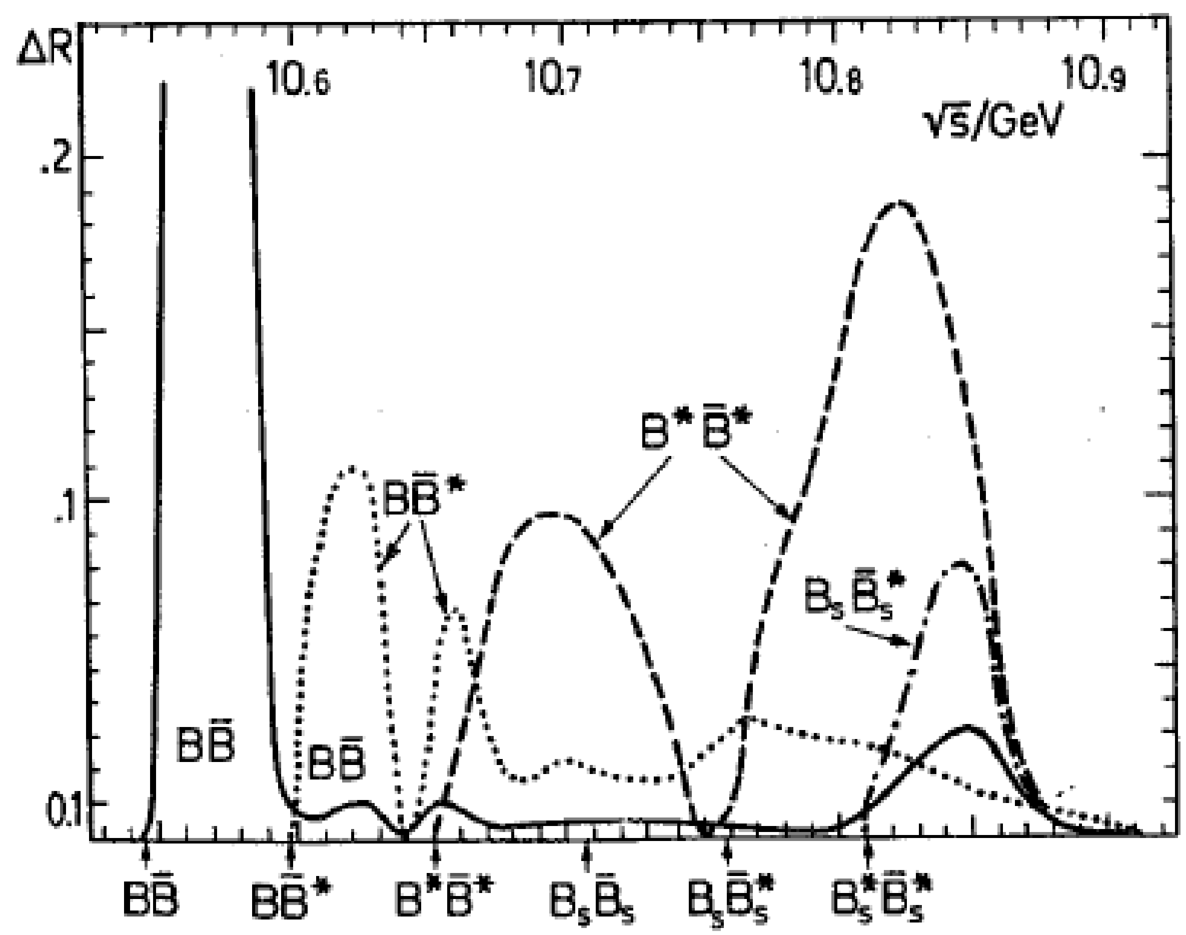
	SM~	**Limit**
$B \to X_s\tau\tau$	4×10^{-7}	-
$B \to \tau\tau$	1×10^{-7}	$< 4.1 \times 10^{-3}$
$B_s \to \tau\tau$	1×10^{-6}	-

B_s system

- If flavour factories run at ϒ(5S) would exclusive $B_s \to X\gamma$ be of interest e.g. $B_s \to \varphi\gamma$? Could generate about ~10^9 ϒ(5S) with one year full running.
- Even if statistical error is worse than LHCb, absolute BF rather than a ratio could be important as a reference point.
- (A program of rare decays will be pursued $\mathbf{B_s \to \gamma\gamma}$, $B_s \to \tau\tau$)
- Challenging:
  - $\sigma_{\Upsilon(5S)}/\sigma_{\Upsilon(4S)}$ ~0.3, f_s~0.2
  - Excited modes complicate the environment

Belle: PhysRevLett.100.121801, 23.6 fb^{-1}

Mode	ϵ (%)	$S_{B_s^0\bar{B}_s^0}$	$S_{B_s^*\bar{B}_s^0}$	$S_{B_s^*\bar{B}_s^*}$	$\mathcal{B}$ (10^{-6})	Sig.
$\phi\gamma$	24.7	$-0.7^{+2.5}_{-1.6}$	$0.5^{+2.9}_{-1.9}$	18^{+6}_{-5}	57^{+18+12}_{-15-11}	5.5
$\gamma\gamma$	17.8	$-4.7^{+3.9}_{-2.8}$	$-0.8^{+4.8}_{-3.8}$	$-7.3^{+2.4}_{-2.0}$	< 8.7	–



$D \to X l^+ l^-$, $D \to X\gamma$?

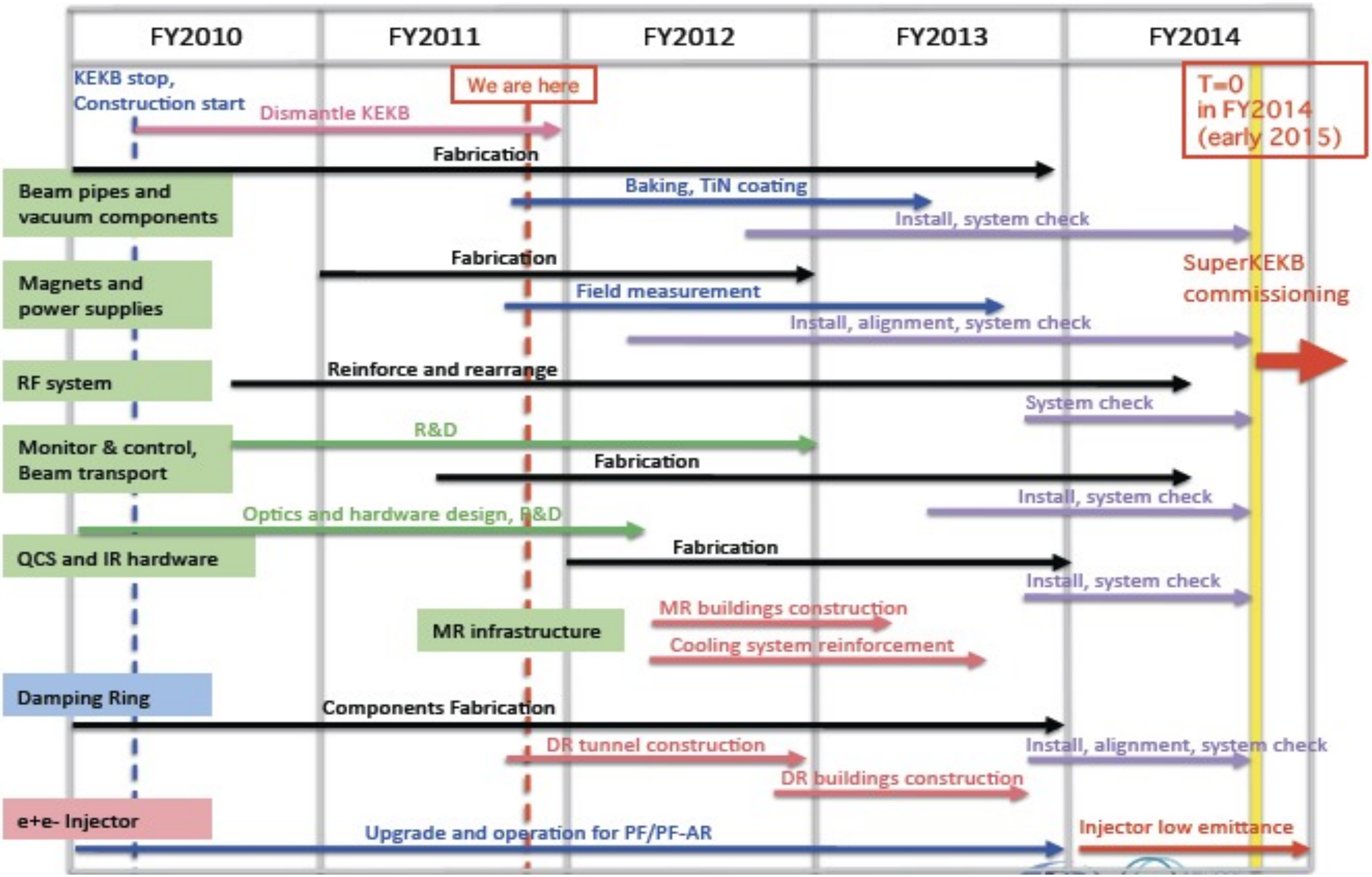
- Can these be of interest? Less likely to reveal NP due to long-distance non-perturbative effects.
- Some measurements from CLEO/BaBar/Belle. Current B factory limits 10 x higher than theoretical calculations.
- Requires Super Flavour Factories
  - SuperB can run at charm threshold
  - 0.5 ab^{-1} in about 4 months (700×10^6 charm pairs).

SuperKEKB EWP

Observable	Belle 2006	SuperKEKB		†LHCb	
	(~0.5 ab^{-1})	(5 ab^{-1})	(50 ab^{-1})	(2 fb^{-1})	(10 fb^{-1})
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K_S^0 \pi^0 \gamma}$	0.32	0.10	0.03	-	-
$\mathcal{B}(B \to X_s \gamma)$	13%	7%	6%	-	-
$A_{CP}(B \to X_s \gamma)$	0.058	0.01	0.005	-	-
C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-	11%	4%		
C_{10} from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-	13%	4%		
C_7/C_9 from $\overline{A}_{\rm FB}(B \to K^* \ell^+ \ell^-)$	-		5%		7%
R_K		0.07	0.02		0.043
$\mathcal{B}(B^+ \to K^+ \nu \nu)$	†† $< 3\ \mathcal{B}_{\rm SM}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0} \nu \bar{\nu})$	†† $< 40\ \mathcal{B}_{\rm SM}$		35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho \gamma}$	-	0.3	0.15		
$\mathcal{B}(B \to X_d \gamma)$	-	24% (syst.)		-	-
$\lvert V_{ub} \rvert$ (inclusive)	6%	5%	3%	-	-
$\lvert V_{ub} \rvert$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
B_s physics	(25 fb^{-1})	(5 ab^{-1})			
$\mathcal{B}(B_s \to \gamma \gamma)$	$< 8.7 \times 10^{-6}$	0.25×10^{-6}		-	-

see arXiv:1002.5012: "Physics at Super B Factory"

Timeline Belle II



Summary

- Recoil tag method is promising for $B \to X_s\gamma$
  - $\delta BF(B \to X_s\gamma)$~6% @ 50 ab–1 (Belle2); maybe less. , $\delta BF(B \to X_s\gamma)$~3%@75ab–1 (SuperB)
  - Theoretical prediction clean.
- Less than 1% precision for $A_{CP}(B \to X_s\gamma)$
  - $\delta A_{CP}(B \to X_s\gamma) \sim 0.005$ @ 50 ab^{-1} (Belle2)
  - $\delta A_{CP}(B \to X_{s+d}\gamma) \sim 0.01$ (?)
- Sum of exclusive modes for $X_d\gamma$, $X_s ll$.
  - Vastly improved PID will help X_d measurements.
  - Hadronic uncertainty, missing modes are the issue.
  - Calibration using $B \to X_s\gamma$.
  - Recoil tag method may be used for more inclusive approach when data samples>5 ab^{-1}.
    - Need (MC) studies (Software still in developmental phase)
- Numerous complementary measurements:
  - Excellent prospects for $K^{(*)}ee$, and NP with tau modes.
  - Distribution function from leptonic decays.
  - Interplay with V_{ub}
  - B_s studies with tagging techniques.

Backup

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[4] SuperB Progress Reports – The Physics, arXiv:1008.1541, Aug 2010

[5] SuperB CDR – The Physics, arXiv:1008.1541, Aug 2010

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[8] Physics at BES-II, IHEP-Physics-Report-BES-III-2008-001

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B-factory Approaches to Measuring $B \to X_u l \nu$

Eff. **Purity**

High **Low** **Lumi.**

Untagged

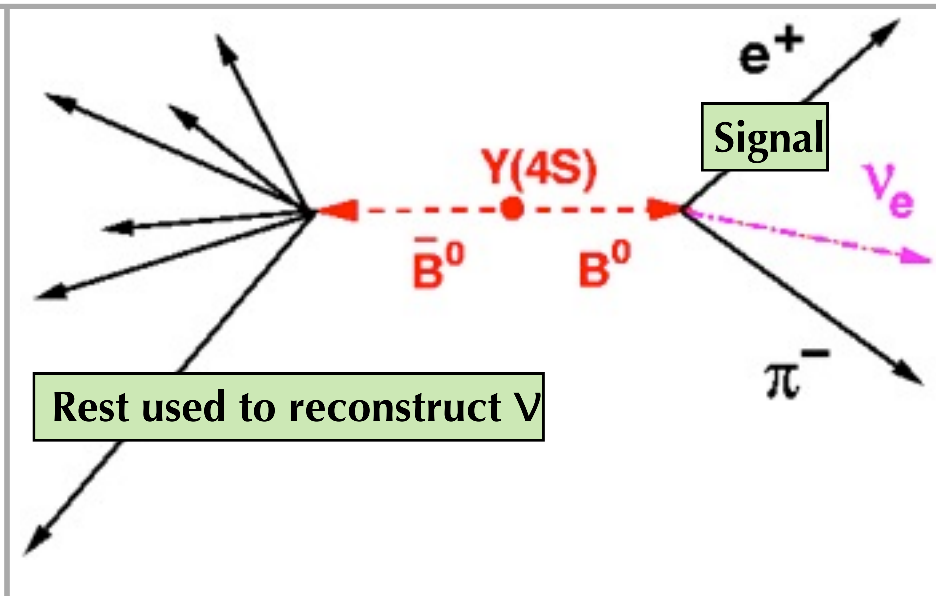
Initial 4-momentum known

missing 4-momentum = one ν

Reconstruct $B \to X_q\, l\, \nu$

using m_B (beam-constrained)

and $\Delta E = E_B - E_{beam}$

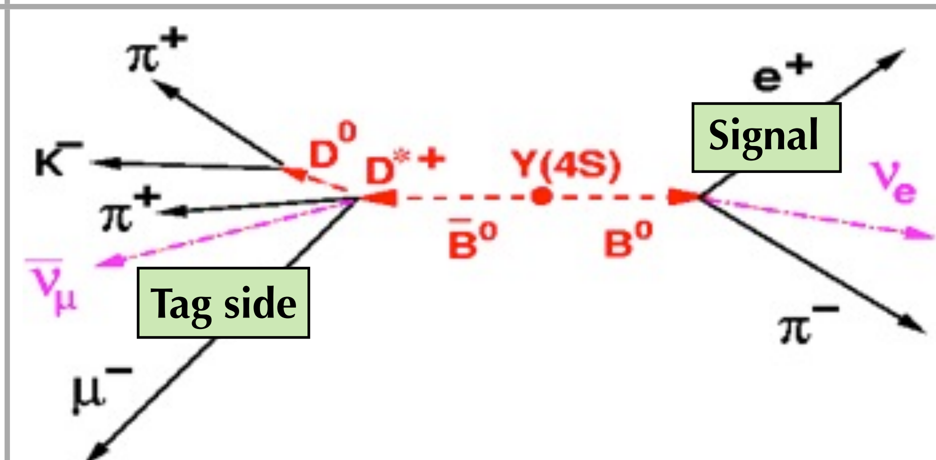


< 0.5 ab^{-1}

Semileptonic Tag

One B reconstructed in $D^{(*)}\, l\, \nu$ modes.

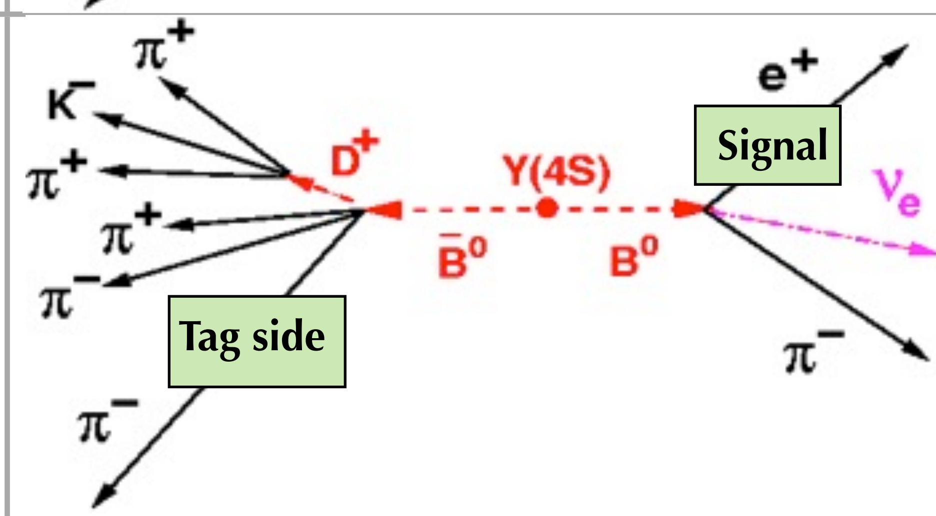
Two missing ν in event.



< 1 ab^{-1}

Full Reconstruction Tag

One B reconstructed completely in a known $b \to c$ mode without ν.



> 1 ab^{-1}

Low **High**

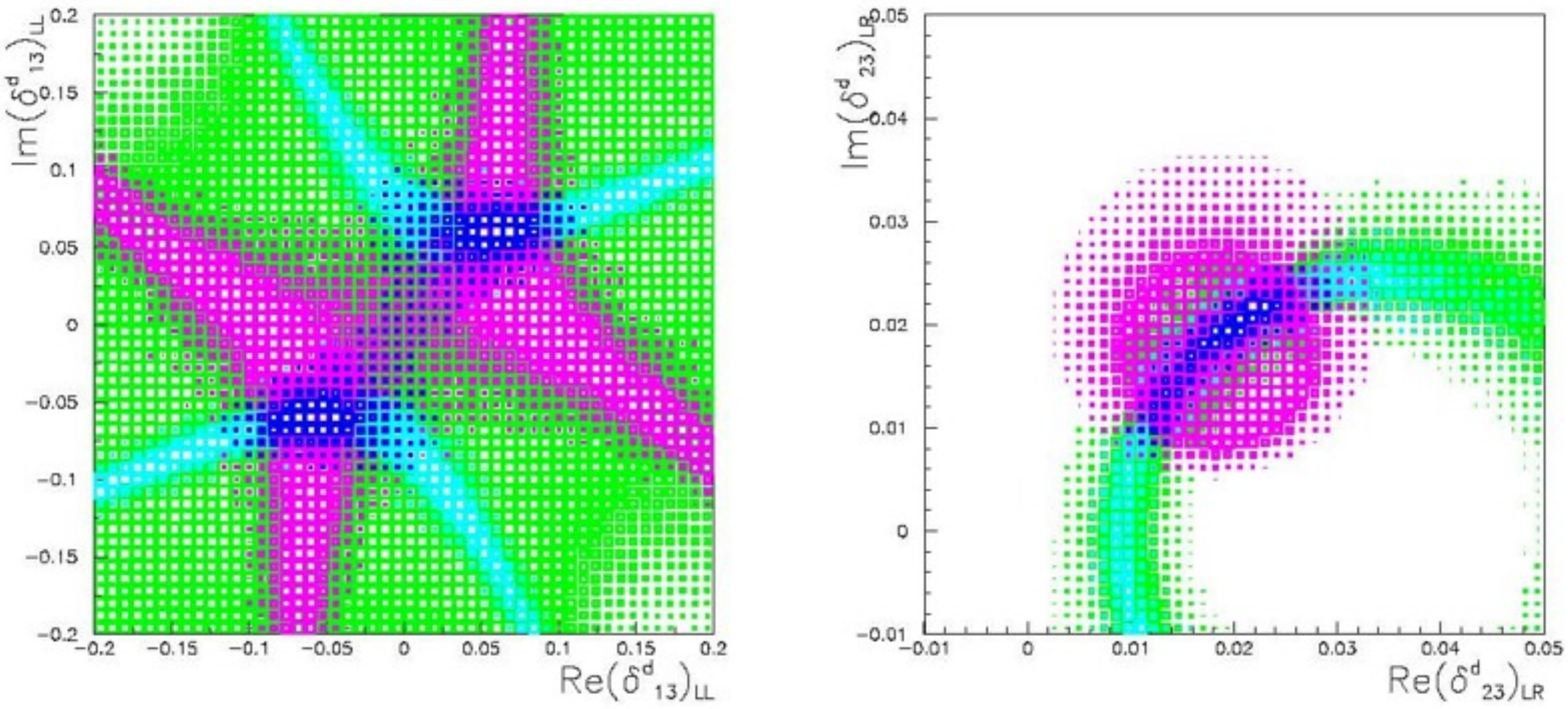


FIG. 31: Left: Density plot of the selected region in the $Re(\delta^d_{13})_{LL} - Im(\delta^d_{13})_{LL}$ for $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV and $(\delta^d_{13})_{LL} = 0.085e^{i\pi/4}$ using Super$B$ measurements (namely, 1-3 generation transitions). Different colors correspond to different constraints: $A^d_{\rm SL}$ (green), β (cyan), Δm_d (magenta), all together (blue). Right: Density plot of the selected region in the $Re(\delta^d_{23})_{LR} - Im(\delta^d_{23})_{LR}$ for $m_{\tilde{q}} = m_{\tilde{g}} = 1$ TeV and $(\delta^d_{23})_{LR} = 0.028e^{i\pi/4}$ using Super$B$ measurements (namely, 2-3 generation transitions). Different colors correspond to different constraints: $\mathcal{B}(B \to X_s\gamma)$ (green), $\mathcal{B}(B \to X_s l^+ l^-)$ (cyan), $A_{CP}(B \to X_s\gamma)$ (magenta), all together (blue).

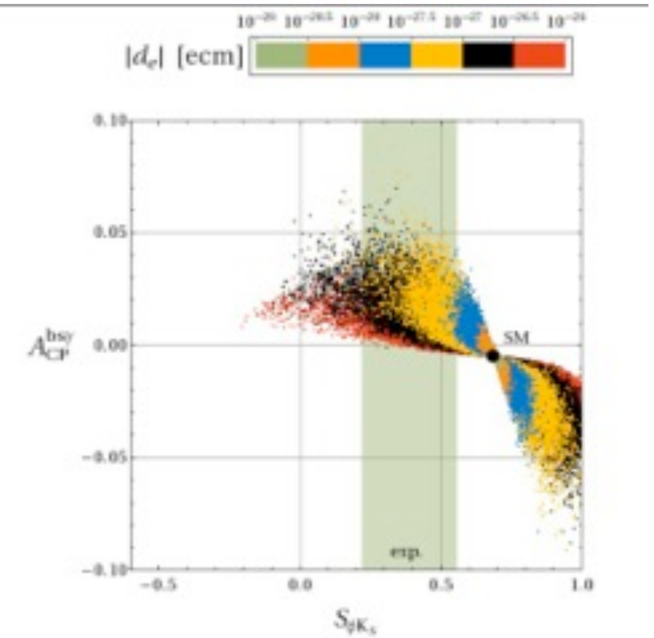


FIG. 33: Correlation between the CP asymmetries $A_{CP}^{b\to s\gamma}$ and $S_{\phi K_S}$ in the FBMSSM [420]. The various colors indicate the predicted lower bound on the electron EDM.

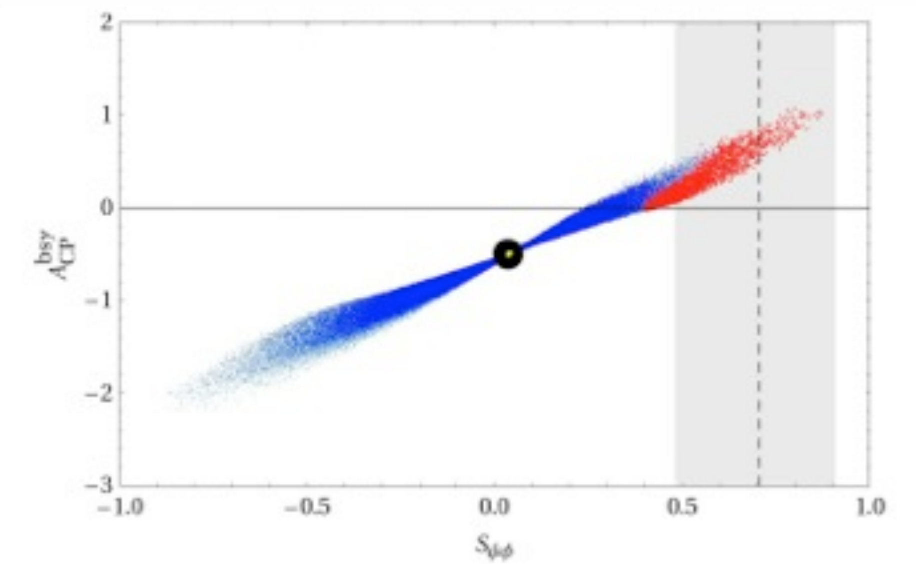


FIG. 35: Correlation between the *CP* asymmetries $A_{CP}^{b\to s\gamma}$ and $S_{\psi\phi}$ in the SM4 [424].

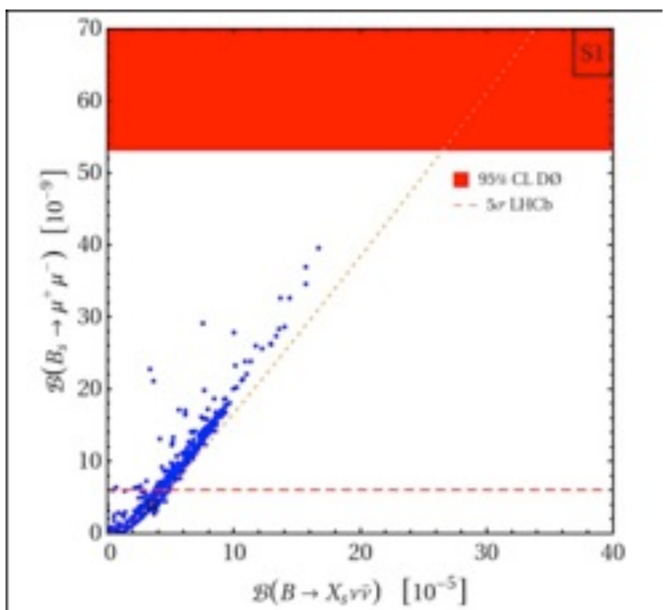


FIG. 36: Correlation between the branching ratios for $B_s\to\mu^+\mu^-$ and $B\to X_s\nu\bar{\nu}$ in the minimal RS model [428].

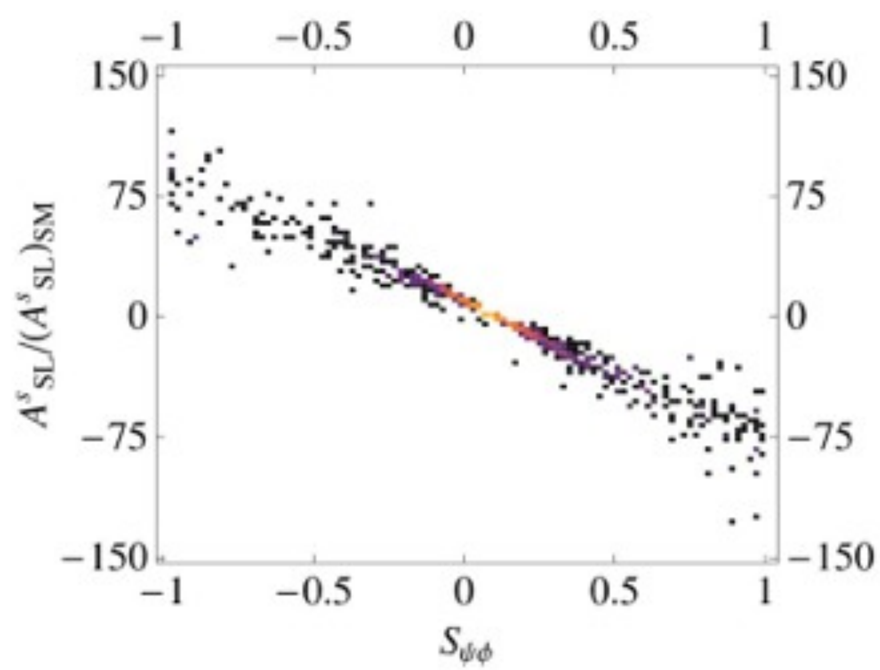


FIG. 37: Correlation between the *CP* asymmetries A^s_{SL} and $S_{\psi\phi}$ in the RSc model [427].

Observable	SM Theory	Current Expt.	Super Flavor Factories
$S(B \to \phi K^0)$	0.68	0.56 ± 0.17	± 0.03
$S(B \to \eta' K^0)$	0.68	0.59 ± 0.07	± 0.02
γ from $B \to DK$		$\pm 11^\circ$	$\pm 1.5^\circ$
$A_{\rm SL}$	-5×10^{-4}	-0.0049 ± 0.0038	± 0.001
$S(B \to K_S \pi^0 \gamma)$	< 0.05	-0.15 ± 0.20	± 0.03
$S(B \to \rho\gamma)$	< 0.05	-0.83 ± 0.65	± 0.15
$A_{\rm CP}(B \to X_{s+d}\gamma)$	< 0.005	0.06 ± 0.06	± 0.02
$\mathcal{B}(B \to \tau\nu)$	1.1×10^{-4}	$(1.64 \pm 0.34) \times 10^{-4}$	$\pm 0.05 \times 10^{-4}$
$\mathcal{B}(B \to \mu\nu)$	4.7×10^{-7}	$< 1.0 \times 10^{-6}$	$\pm 0.2 \times 10^{-7}$
$\mathcal{B}(B \to X_s\gamma)$	3.15×10^{-4}	$(3.55 \pm 0.26) \times 10^{-4}$	$\pm 0.13 \times 10^{-4}$
$\mathcal{B}(B \to X_s \ell^+\ell^-)$	1.6×10^{-6}	$(3.66 \pm 0.77) \times 10^{-6}$	$\pm 0.10 \times 10^{-6}$
$\mathcal{B}(B \to K\nu\overline{\nu})$	3.6×10^{-6}	$< 1.3 \times 10^{-5}$	$\pm 1 \times 10^{-6}$
$A_{\rm FB}(B \to K^* \ell^+\ell^-)_{q^2<4.3\,{\rm GeV}^2}$	-0.09	0.27 ± 0.14	± 0.04

Table 2-3. *A summary of the reach of the planned super flavor factory experiments for some key B decay measurements, in comparison to Standard Model theory and the current best experimental results. Normally Belle II assumes 50 ab^{-1} for such comparisons, while SuperB assumes 75 ab^{-1}. For this table, 50 ab^{-1} has been assumed.*

Inclusive: Experimental Challenges

- Ideally must be as inclusive as possible to exploit OPE (not using Non-pert. shape function)
- Previously used "sum of exclusive modes" but large systematic errors mean not competitive at flavour factories.
- Sum of exclusive modes can measure $A_{CP}(B \to X_s\gamma)$ but difficult to interprete results as only 50% of modes included.
- Acp systematic errors are already quite small. Statistical could scale with sqrt(Lumi) ~ factor 10

TABLE VII: Selected experimental results on A_{CP} from the B-factories. The first uncertainty listed is statistical, the second systematic.

Quantity	Result
$A_{CP}(\bar{B} \to X_s\gamma)$	$-0.011 \pm 0.030 \pm 0.014$ [139]
	$0.002 \pm 0.050 \pm 0.030$ [140]
$A_{CP}(B \to X_{s+d}\gamma)$	$-0.11 \pm 0.12 \pm 0.02$ [137]
	$0.10 \pm 0.18 \pm 0.05$ [138]
$A_{CP}(B \to K^*\gamma)$	$-0.003 \pm 0.017 \pm 0.007$ [141]

Flavour Factory Predictions

TABLE XI: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, partial branching fractions, CP asymmetries, isospin asymmetries, lepton flavor ratio, and angular observables for $B \to X_s \ell^+ \ell^-$. The first two columns show the results for the sum of exclusive modes (SE), the second two columns those for the recoil method (RM), respectively. The sum of exclusive modes including 28 final states has an additional uncertainty of $\sim 10\%$ from the decay model.

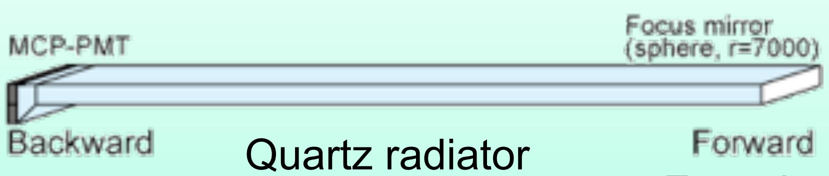
		BABAR (425 fb^{-1})				Super$B$ (75 ab^{-1})			
Observable	q^2 region [GeV^2/c^4]	Stat. SE	Sys. SE	Stat. RM	Sys. RM	Stat. SE	Sys. SE	Stat. RM	Sys. RM
$\sigma\mathcal{B}/\mathcal{B}$	all	0.11	0.056	0.26	0.06	0.008	0.03-0.05	0.019	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	0.1–1	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	1–4	0.23	0.06	0.53	0.06	0.017	0.03-0.05	0.040	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	4–7.84	0.18	0.06	0.43	0.06	0.014	0.03-0.05	0.032	0.03-0.05
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96	0.31	0.07	0.73	0.07	0.024	0.04-0.06	0.055	0.04-0.06
$\sigma\mathcal{B}/\mathcal{B}$	>14.06	0.29	0.07	0.69	0.07	0.022	0.04-0.06	0.052	0.04-0.06
$\mathcal{R}_{X_s}$	all	0.21	0.06	0.50	0.06	0.016	0.03-0.05	0.038	0.03-0.05
$\mathcal{R}_{X_s}$	0.1–7.84	0.25	0.06	0.58	0.06	0.019	0.03-0.05	0.044	0.03-0.05
$\mathcal{A}_{CP}$	all	0.06	0.01	0.14	0.01	0.004	0.005-0.008	0.011	0.005-0.008
$\mathcal{A}_{CP}$	0.1–7,84	0.07	0.01	0.16	0.01	0.005	0.005-0.008	0.012	0.005-0.008
$\mathcal{A}_I$	all	0.05	0.06	0.12	0.06	0.004	0.03-0.05	0.009	0.03-0.05
$\mathcal{A}_I$	0.1–7.84	0.06	0.06	0.14	0.06	0.005	0.03-0.05	0.011	0.03-0.05
$\mathcal{H}_L$	0.1–1	0.17	0.04	0.40	0.04	0.013	0.02-0.03	0.030	0.02-0.03
$\mathcal{H}_L$	1–4	0.17	0.04	0.40	0.04	0.013	0.02-0.03	0.030	0.02-0.03
$\mathcal{H}_L$	4–7.84	0.13	0.04	0.27	0.04	0.009	0.02-0.03	0.021	0.02-0.03
$\mathcal{H}_A$	0.1–1	0.22	0.06	0.51	0.06	0.016	0.03-0.05	0.039	0.03-0.05
$\mathcal{H}_A$	1–4	0.22	0.06	0.51	0.06	0.016	0.03-0.05	0.039	0.03-0.05
$\mathcal{H}_A$	4–7.84	0.15	0.06	0.35	0.06	0.011	0.03-0.05	0.026	0.03-0.05

Super Flavour Factory Vs. Current Sensitivities

Observable	SFF sensitivity	Current sensitivity
$\sin(2\beta)$ $(J/\psi K^0)$	0.005-0.012	0.01
γ (DK)	1–2°	$\sim 31°$ (CKMFitter)
α $(\pi\pi, \rho\pi, \rho\rho)$	1–2°	$\sim 15°$ (CKMFitter)
$\|V_{ub}\|$(excl)	3-5%	$\sim$ 18% (PDG review)
$\|V_{ub}\|$(incl)	2-6%	$\sim 8(PDGreview)\%$
$\bar{\rho}$	1.7-3.4%	$^{+20\%}_{-12\%}$
$\bar{\eta}$	0.7-1.7%	$\pm$4.6%
$S(\phi K^0)$	0.02-0.03	0.17
$S(\eta' K^0$	0.01-0.02	0.07
$\mathcal{B}(B \to \tau\nu)$	$3-4\%$	30%
$\mathcal{B}(B \to \mu\nu)$	$5-6\%$	not measured
$\mathcal{B}(B \to D\tau\nu)$	$2-2.5\%$	31%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3-4%	16%
$A_{CP}(b \to s\gamma)$	0.004-0.005	0.037
$A_{CP}(b \to s\gamma + d\gamma)$	0.01	0.12
$S(K_S\pi^0\gamma)$	0.02-0.03	0.24
$S(\rho^0\gamma)$	0.08-0.12	0.67
$A^{FB}(B \to K^*\ell^+\ell^-)_{s0}$	4-6%	not measured
$\mathcal{B}(B \to K\nu\bar{\nu})$	16-20%	not measured
$\mathcal{B}(B \to s\ell^+\ell^-)_{s0}$		
$\mathcal{B}(B \to d\ell^+\ell^-)_{s0}$		not measured
ϕ_D (NP phase)	$\pm(1-2)°$	$\sim \pm 20°$
$\mathcal{B}(\tau \to \mu\gamma)$	$(2-8) \times 10^{-9}$	not seen, $< 5.0 \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$(0.2-1) \times 10^{-9}$	not seen, $< (2-4) \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\eta)$	$(0.4-4) \times 10^{-9}$	not seen, $< 5.1 \times 10^{-8}$

Particle ID: Belle II

Barrel PID: Time of Propagation Counter (TOP)

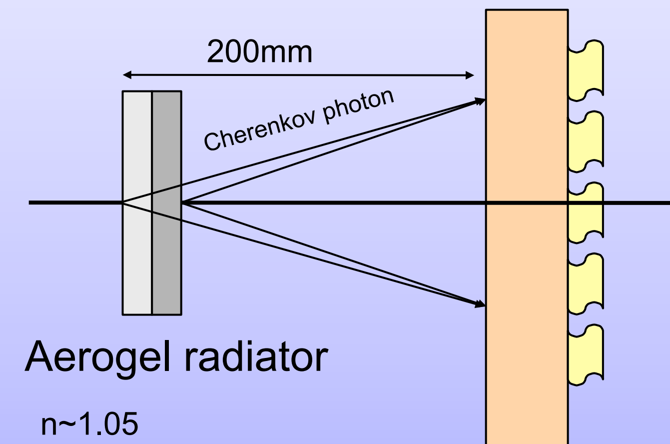


Quartz radiator

Focusing mirror

Small expansion block
Hamamatsu MCP-PMT (measure t, x and y)

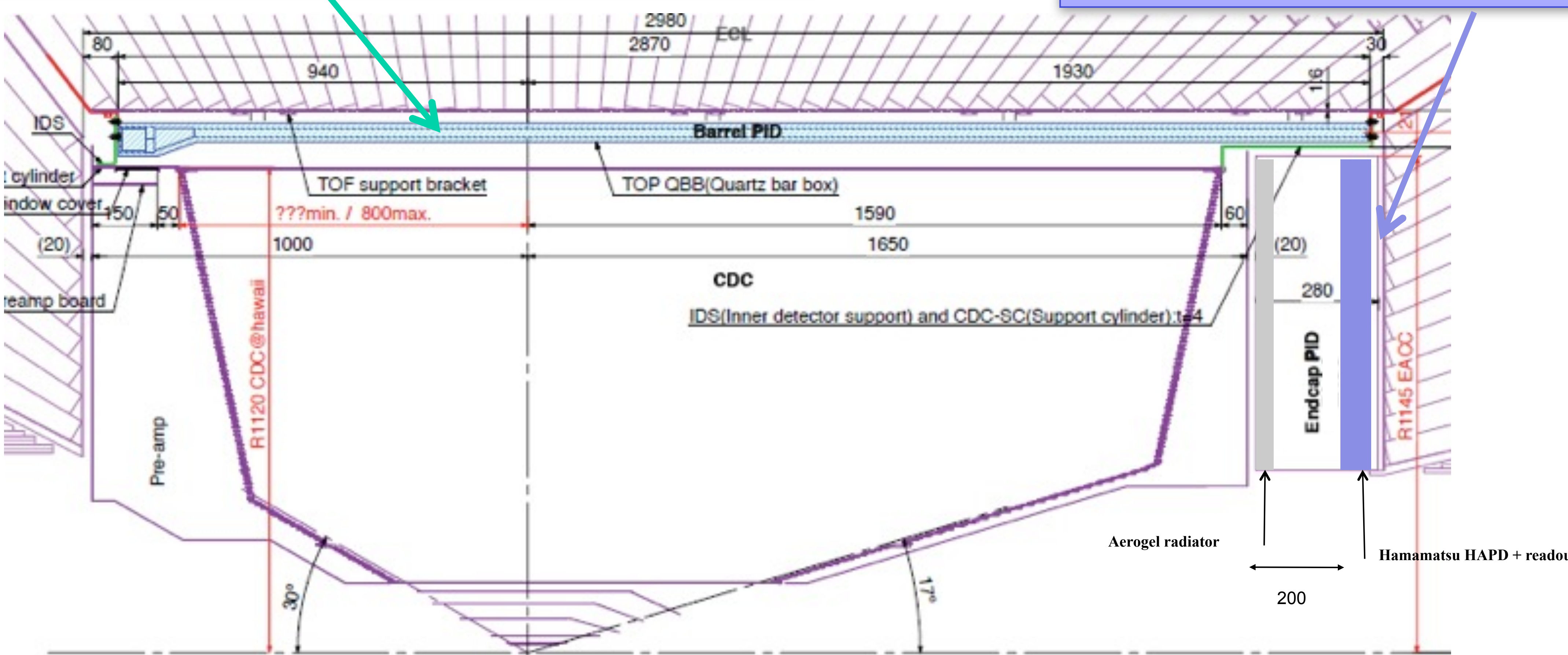
Endcap PID: Aerogel RICH(ARICH)



Aerogel radiator

n~1.05

Hamamatsu HAPD
+ new ASIC



Flavour Factory Predictions

TABLE VIII: Number of events for $B \to K\ell^+\ell^-$, $B \to K^*\ell^+\ell^-$, $B \to X_s\ell^+\ell^-$ via the sum of exclusive modes (SE) and $B \to X_s\ell^+\ell^-$ via the recoil method (RM) for luminosities of 425 fb^{-1} and 75 ab^{-1}. The signal yields are shown for the entire q^2 region, 0.1 $\text{GeV}^2/c^4 < q^2 <$ 7.84 GeV^2/c^4 and 1 $\text{GeV}^2/c^4 < q^2 <$ 6 GeV^2/c^4. Uncertainties in the yields are of the order of 20%.

	Number of events in 425 fb^{-1}			Expected number of events in 75 ab^{-1}		
Mode	all q^2	0.1–7.84	1–6	all q^2	0.1–7.84	1–6
$K\ell^+\ell^-$	90	42	26	15,900	7,340	4,600
$K^*\ell^+\ell^-$	110	46	24	19,400	8,200	4300
$X_s\ell^+\ell^-$ SL	270	171	101	47,500	30,000	17,900
$X_s\ell^+\ell^-$ RM	49	31	18	8,600	5,500	3250

Exclusive

Inclusive

TABLE IX: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, partial branching fractions, CP asymmetries, isospin asymmetries, lepton flavor ratio for $B \to K\ell^+\ell^-$ after combining e^+e^- and $\mu^+\mu^-$ modes as well as K^+ and K^0_S modes.

		BABAR (425 fb^{-1})		Super*B* (75 ab^{-1})	
Observable	q^2 region [GeV^2/c^4]	Stat.	Sys.	Stat.	Sys.
$\sigma\mathcal{B}/\mathcal{B}$	all	0.175	0.05	0.011	0.025-0.035
$\sigma\mathcal{B}/\mathcal{B}$	0.1–7.02	0.20	0.044	0.012	0.022-0.035
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96 and > 14.06	0.27	0.052	0.017	0.026-0.039
$\mathcal{R}_K$	all	0.34	0.05	0.021	0.025-0.038
$\mathcal{A}_{CP}$	all	0.18	0.01	0.012	0.008-0.01
$\mathcal{A}_I$	0.1–7.02	0.56	0.05	0.034	0.025-0.035

Exclusive

TABLE X: Present and extrapolated statistical and systematic uncertainties of the total branching fraction, partial branching fractions, CP asymmetries, isospin asymmetries, lepton flavor ratio, longitudinal polarization and lepton FBA for $B \to K^*\ell^+\ell^-$ after combining e^+e^- and $\mu^+\mu^-$ modes as well as K^{*+} and K^{*0} modes.

		BABAR (425 fb^{-1})		Super*B* (75 ab^{-1})	
Observable	q^2 region [GeV^2/c^4]	Stat.	Sys.	Stat.	Sys.
$\sigma\mathcal{B}/\mathcal{B}$	all	0.162	0.063	0.01	0.032-0.048
$\sigma\mathcal{B}/\mathcal{B}$	0.1–7.02	0.23	0.070	0.014	0.035-0.053
$\sigma\mathcal{B}/\mathcal{B}$	10.24–12.96 and > 14.06	0.24	0.071	0.015	0.036-0.054
$\mathcal{R}_{K^*}$	all	0.34	0.07	0.02	0.035-0.048
$\mathcal{A}_{CP}$	all	0.15	0.01	0.009	0.008-0.01
$\mathcal{A}_I$	0.1–7.02	0.17	0.03	0.01	0.015-0.023
$\mathcal{F}_L$	0.1–4	0.15	0.04	0.011	0.02-0.03
$\mathcal{F}_L$	4–7.84	0.14	0.04	0.011	0.02-0.03
$\mathcal{A}_{FB}$	0.1–4	0.14	0.05	0.011	0.025-0.038
$\mathcal{A}_{FB}$	4–7.84	0.14	0.05	0.011	0.025-0.038

Exclusive

Statistical precision ~1% for most observables