Rare B decays potential of SuperB

ICHEP conference 2010

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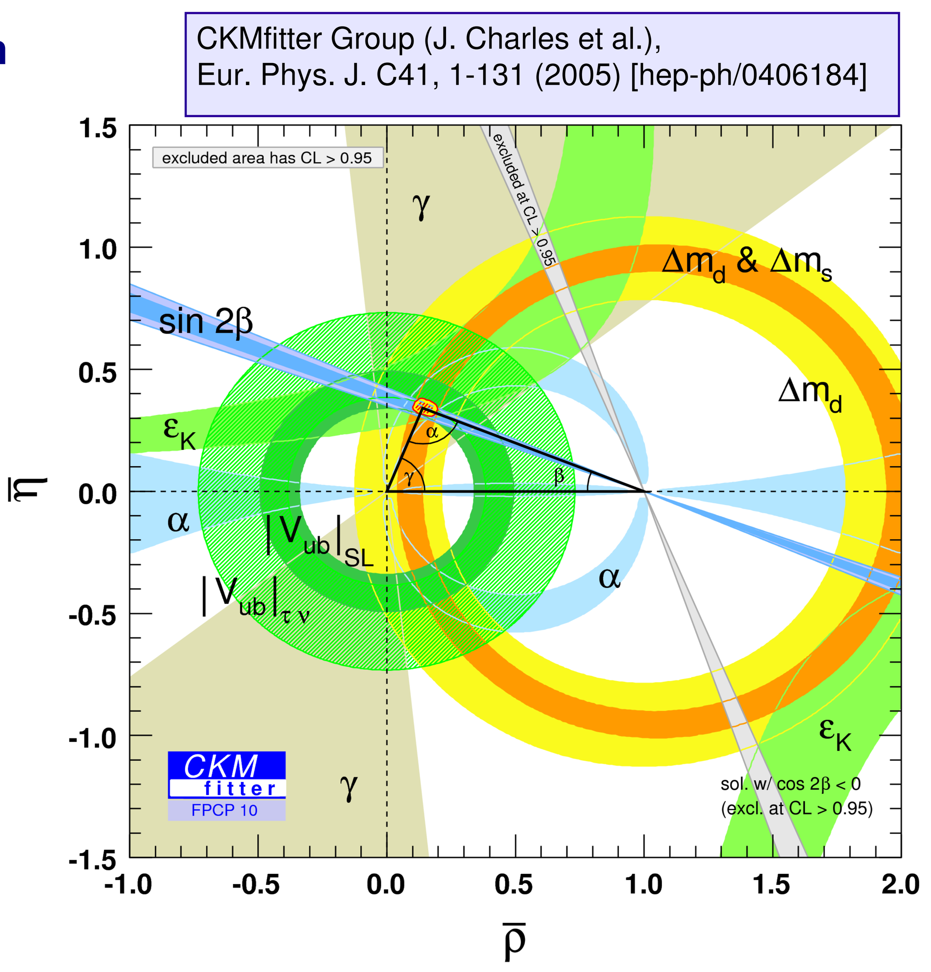
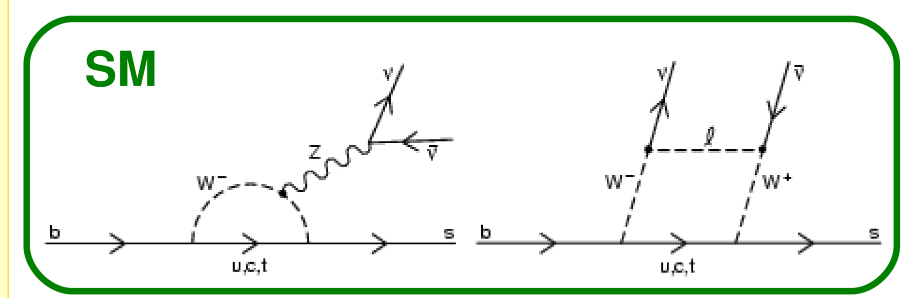
General Introduction to Rare decays

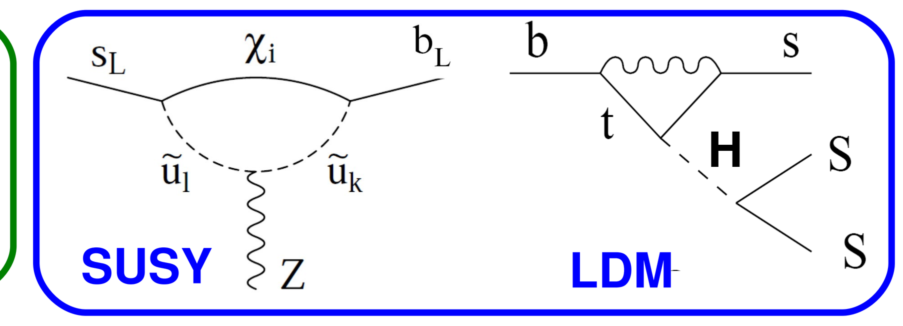
- The Standard Model (SM) has been able to explain coherently (almost) all the experimental evidence of electroweak and strong interactions
- Cabibbo-Kobayashi-Maskawa (CKM) picture has been able to explain all the measurements in the flavor sector
- BUT everybody is eager for New Physics (NP)
- Currently two complementary approaches:
  - Explore unopened energy frontiers (LHC)
  - Measure precisely virtual precesses which can test high energy scales (flavor factories)
- Rare decays are prolific ground and clean probes for this:
  - If a suppressed decay is observed above SM prediction ⇒ clean sign of NP
  - If an UL is set ⇒ NP scenarios are constrained



The B→K*νν and B→Kνν system

- Electroweak penguin (loop diagrams) radiated processes (b→s):
  - Flavor changing neutral current (FCNC) prohibited in SM at tree level
  - Sensitive to Higgs, SUSY particles, light dark matter (LDM)



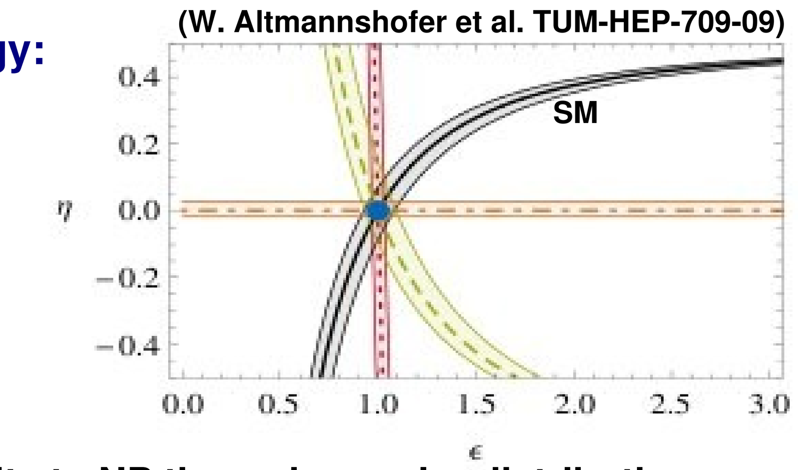


- b→sνν model independent phenomenology:
  - $BR(B\to K\nu\nu) = 4.5\times10^{-6}(1-2\eta)\varepsilon^2$
  - $BR(B\to K^*\nu\nu) = 6.8\times10^{-6}(1+1.31\eta)\varepsilon^2$
  - $F_L(B\to K^*\nu\nu) = 0.54(1+2\eta)/(1+1.31\eta)$

$$\frac{d\Gamma}{d\cos\theta} \propto \frac{3}{4}(1-\langle F_L\rangle)\sin^2\theta + \frac{3}{2}\langle F_L\rangle\cos^2\theta$$

θ = angle between:
- K* direction in B rest frame
- K direction in K* rest frame

(W. Altmannshofer et al. TUM-HEP-709-09)

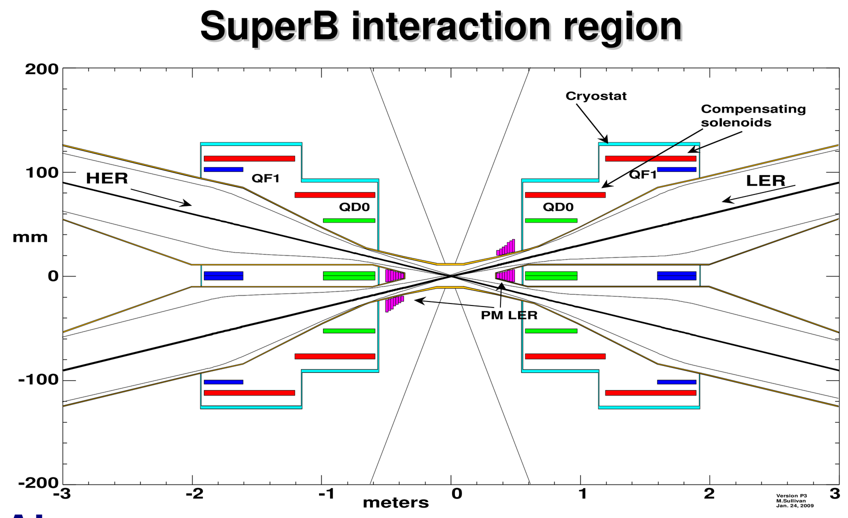


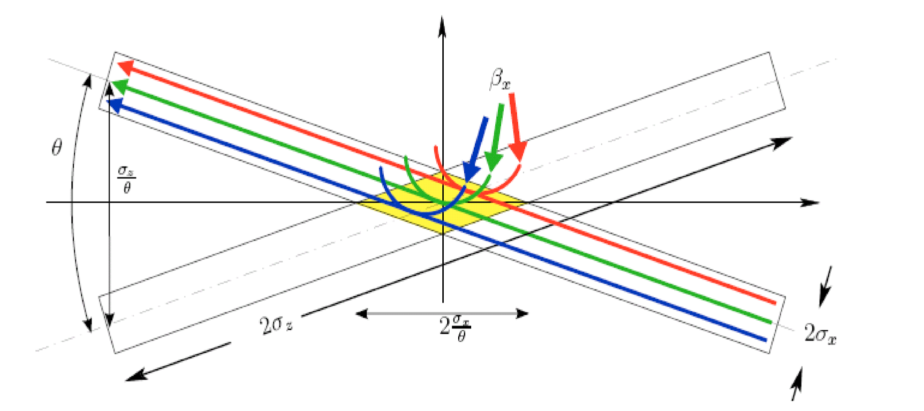
- Good sensitivity to NP through angular distribution

What is the SuperB project?

- SuperB aims at the construction of a very high luminosity asymmetric e^+e^- flavor factory:

SuperB interaction region



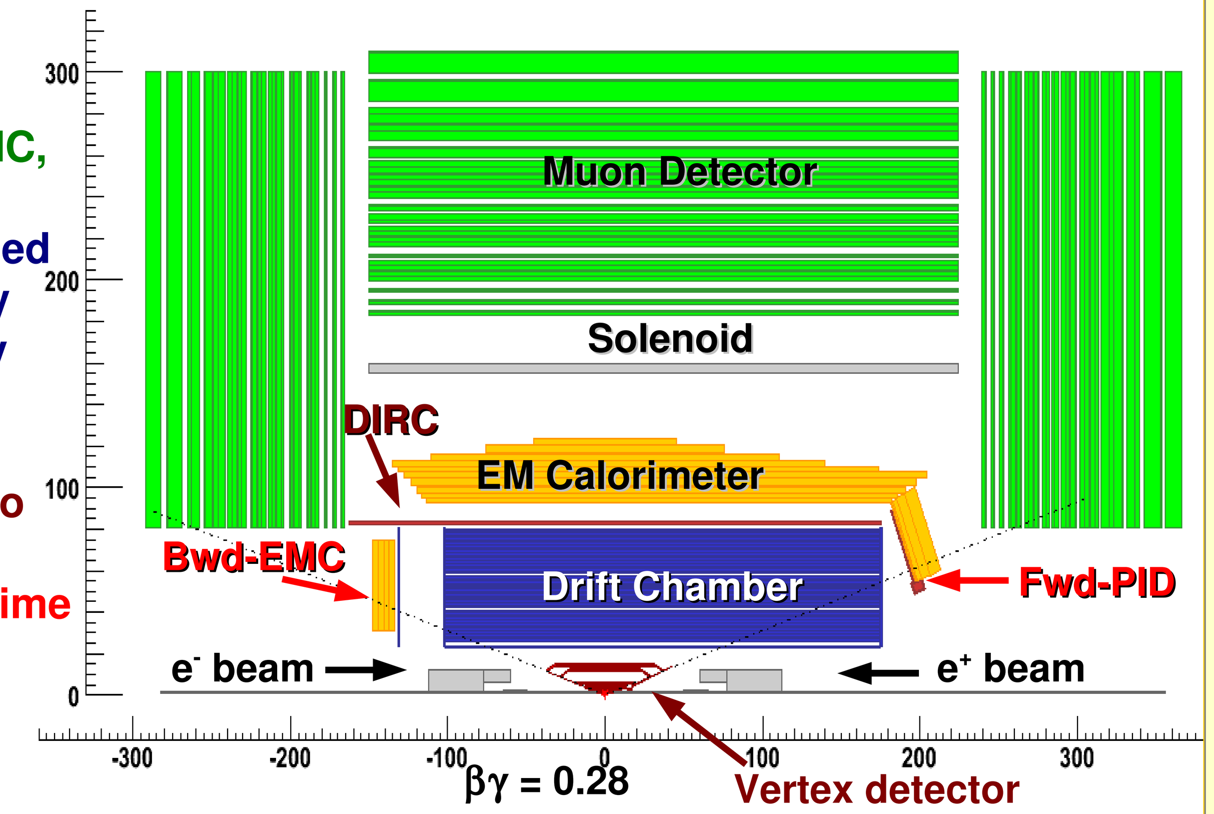


Large Piwinski angle and crabbed waist scheme

- Aims:
  - Operate with a reduced boost βγ = 0.28 (BaBar/Belle is 0.56) ⇒ higher hermeticity
  - Very high luminosity of $1\times10^{36}cm^{-2}s^{-1}$ or more (100 more than BaBar/Belle)
  - High reliability
  - Polarized e^- beam at interaction point ⇒ τ physics
  - Ability to collide at the Υ(4S) and at J/ψ masses ⇒ B and D physics

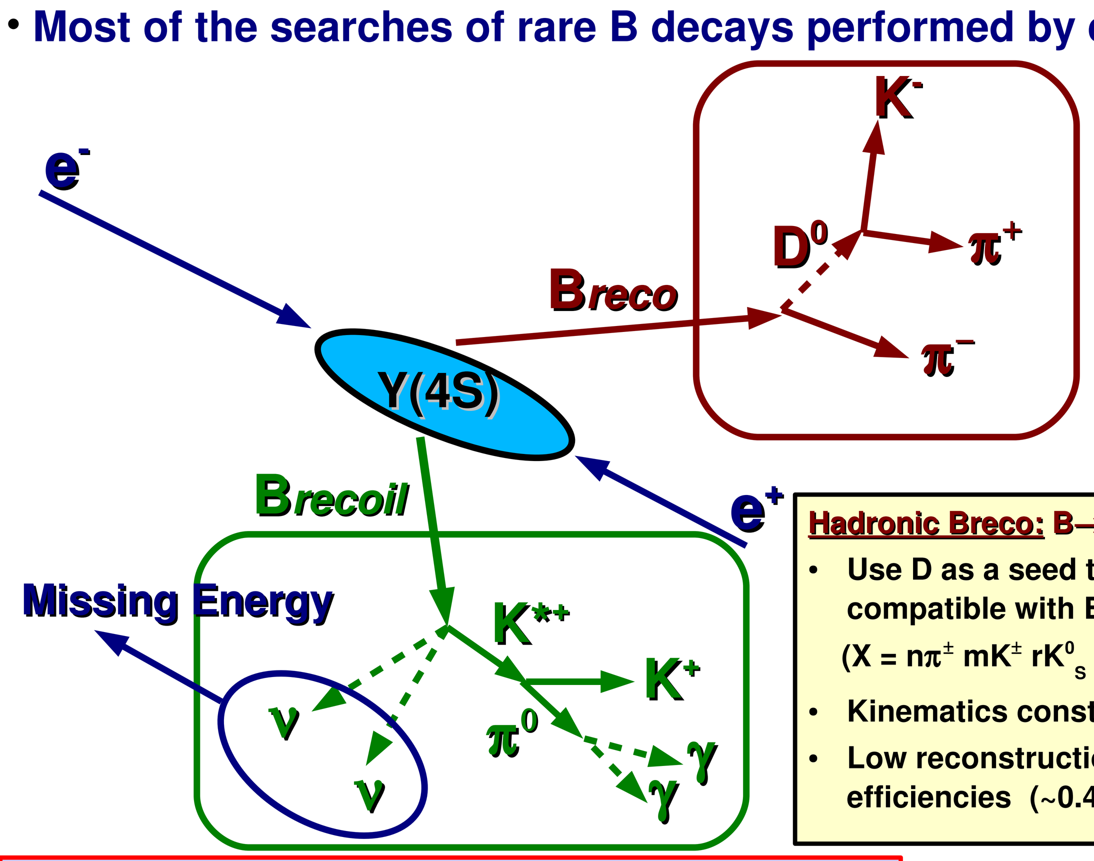
The conception of the SuperB detector

- SuperB detector concept is based on BaBar
  - Silicon vertex detector (SVT) } Tracking system
  - Drift Chamber (DCH)
  - Cherenkov detector (DIRC) ⇒ K/π identification
  - Electromagnetic Calorimeter (EMC)
  - Instrumented Flux Return (IFR)
- Reuse a number of components from BaBar: flux-return-steel, Super conducting coil, barrel EMC, DIRC fused silica radiators
- Other components will be replaced with new ones which can reliably operate at the SuperB luminosity and lower boost
- Two new devises are proposed to further improve the hermiticiy:
  - a forward PID devise based on time of flight measurements (fTOF)
  - a backward EMC (Bwd-EMC)



The experimental technique and current status

- Most of the searches of rare B decays performed by exploiting the Recoil Technique:



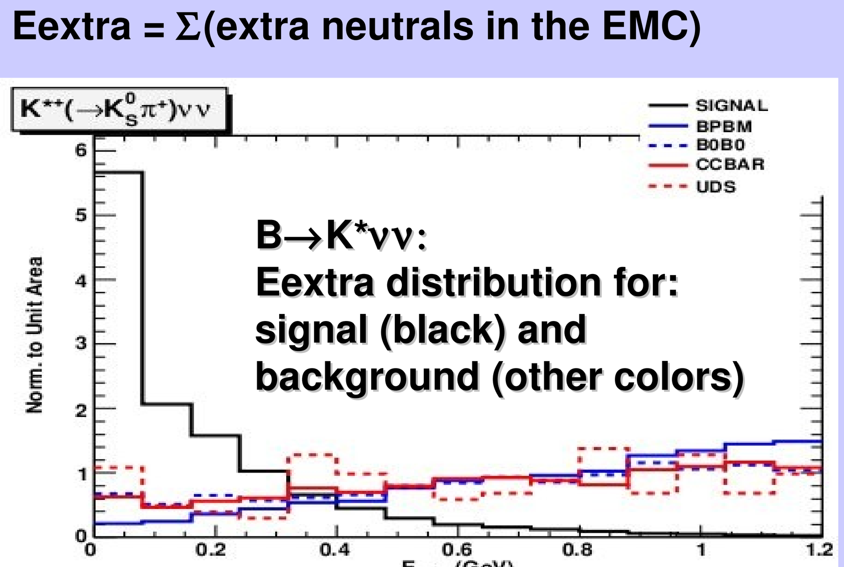
***Breco*: full (partial) reconstruction of one B into a hadronic (semi-leptonic) final state**

***Brecoil*: look for the signal signature, e.g. $K^{(*)}$ not accompanied by additional (charged+neutral) particles + Missing Energy**

Hadronic Breco: B→DX
- Use D as a seed to add X system compatible with B hypothesis ($X = n\pi^\pm\ mK^\pm\ rK^0_s\ q\pi^0$ and n+m+r+q<6)
- Kinematics constrained completely ☺
- Low reconstruction efficiencies (~0.4%) ☹

Semi-Leptonic Breco: B→Dlν
- Use D as a seed and a lepton to form a Dl pair ($l = e^\pm,\mu^\pm$)
- Kinematics is unconstrained due to neutrino ☹
- Higher reconstruction efficiencies (~2.0%) ☺

B→K(*)νν Analysis strategy:
- B→Kνν: look for single K^+ or K^0_s in Brecoil
- B→K*νν: look for $K^{*(+/0)}$ in Brecoil. Several modes: $K^{*+}\to K^0_s\pi^+$ and $K^+\pi^0$, $K^{*0}\to K^+\pi^-$
- Require opposite charges of *Breco* and B*recoil* for charged modes
- Additional cuts on other kinematic variables (K^0_s and K* mass) and missing energy
- Main discriminant variable: Eextra = Σ(extra neutrals in the EMC)



Recoil technique at B-Factories:
- search for rare decays (10^{-5}) with missing energy (Not possible at hadronic machines)
- Several benchmark channels at SuperB: B→τν, $B\to K^{(*)}\nu\nu$, ...

Current Status

BaBar

SL Recoil (90 million BB pairs)[2]:
$BF(B^+\to K^+\nu\nu) < 5.2\times10^{-5}$

Had Recoil (351 million BB pairs)[3]:
$BF(B^+\to K^+\nu\nu) < 4.2\times10^{-5}$

Had+SL Recoil (454 million BB pairs)[4]:
$BF(B^+\to K^{*+}\nu\nu) < 8.0\times10^{-5}$
$BF(B^0\to K^{*0}\nu\nu) < 12.0\times10^{-5}$

Belle

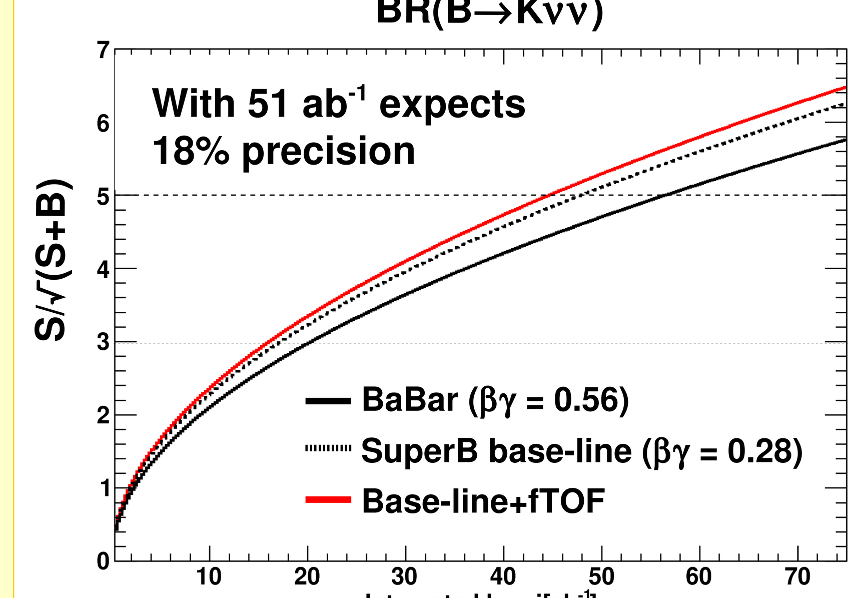
Had Recoil (535 million BB pairs)[1]:
$BF(B^+\to K^+\nu\nu) < 1.4\times10^{-5}$
$BF(B^0\to K^0_s\nu\nu) < 1.6\times10^{-4}$
$BF(B^+\to K^{*+}\nu\nu) < 1.4\times10^{-4}$
$BF(B^0\to K^{*0}\nu\nu) < 3.4\times10^{-4}$

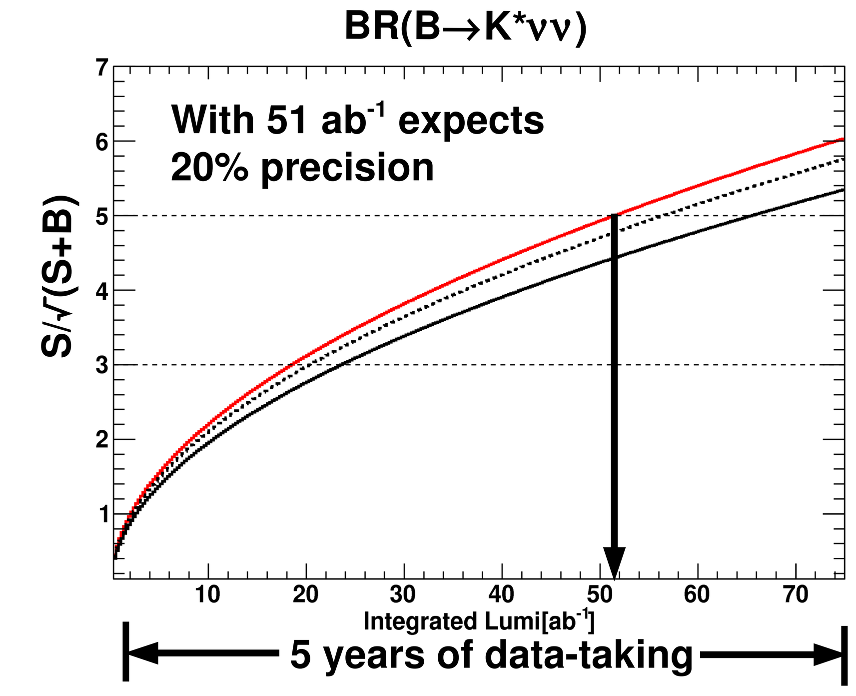
[1] K. F. Chen et al. [BELLE Collaboration], Phys. Rev. Lett. 99, 221802 (2007).
[2] B. Aubert et al. [BaBar collaboration], Phys.Rev. Lett. 101801 (2005)
[3] H.Kim on behalf of the BaBar collaboration, arXiv:hep-ex/08052365 (2008).
[4] B. Aubert et al. [BaBar collaboration], Phys.Rev.D78:072007,2008

All measurements (all upper limits!) still consistent with SM expectation

Some preliminary results

- Use SuperB fast simulation to quantify the potential on rare B decays of different Detector Geometries (DG)
- Current DG's tested:
  - BaBar detector with previous boost of βγ = 0.56
  - SuperB baseline (lower boost βγ = 0.28 for higher hermeticity)
  - SuperB base line + fTOF
- Currently, dominant systematic is MC statistics. Systematics rescaled with luminosity
- Results: fTOF effect is to reduce statistics needed for observation by a factor of ~5%. Expects observation (5σ) with a luminosity of
  - B→Kνν (left bottom plot): ~43 ab^{-1}
  - B→K*νν (right bottom plot): ~51 ab^{-1}





- Warning: no machine background included
- Right plot: constrain on ε-η plane for SuperB expected performances after ~3.4 years of data-taking (51 ab^{-1})
- Current status only set very weak constrains on NP
- With a reduced fraction of its expect total dataset SuperB will be able significantly reduce parameter space of NP
- Hopefully NP effects will be spotted after a couple years of running!