Plans for Hadronic Recoil analysis and $B \rightarrow K^{(*)} \nu\nu$

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2nd Superb Collaboration Meeting – LNF

Physics Session, December 14th 2011

Outline

answers to John's questions

1) Broad outline of the analysis

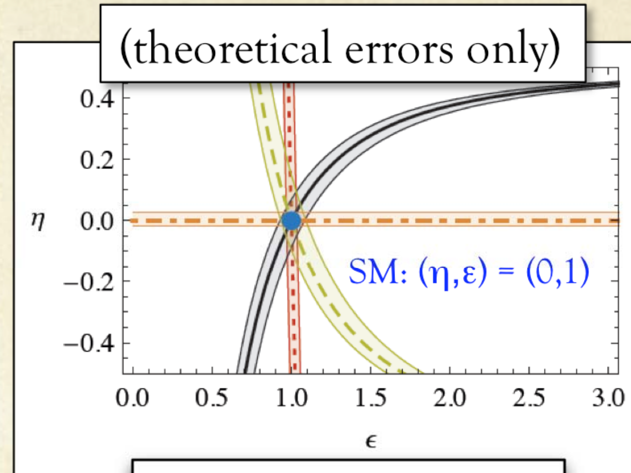
2) What does extrapolation from Babar (or other experiments) tell us, if anything?

3) What additional knowledge will be gained from a FastSim analysis?

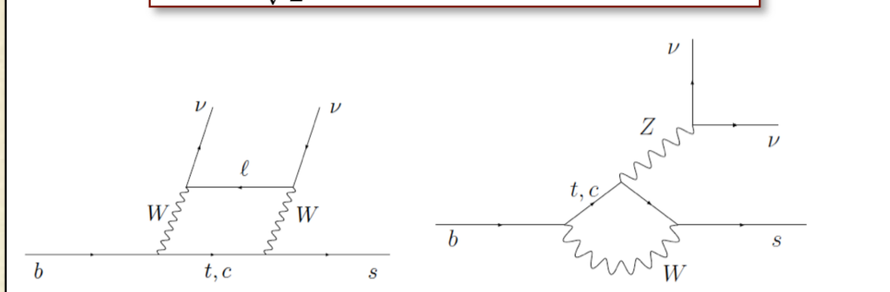
4) Tools - what specific tools are crucial to the analysis?

Theoretical motivations : $B \to K^{(*)}\nu\nu$

- Standard Model (SM) prediction (TUM-HEP-709-09) :
  - $\mathcal{B}(B \to K\nu\nu) = (4.5 \pm 0.7) \times 10^{-6}\ (1-2\eta)\epsilon^2$
  - $\mathcal{B}(B \to K^*\nu\nu) = (6.8 \pm 1.1) \times 10^{-6}\ (1+1.31\eta)\epsilon^2$
  - $F_L(B \to K^*\nu\nu) = (0.54 \pm 0.01)\ (1+2\eta)/(1+1.31\eta)$



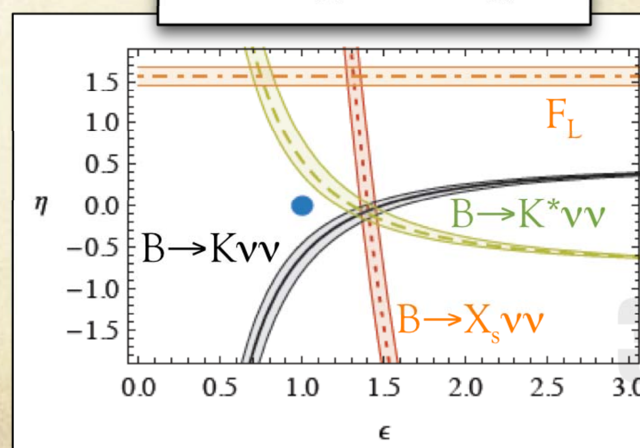
$$\mathcal{H} = -\frac{4G_F}{\sqrt{2}} V_{tb} V^*_{ts} (\mathcal{C}^\nu_L \mathcal{O}^\nu{}_L + \mathcal{C}^\nu_R \mathcal{O}^\nu{}_R) + h.c.$$



$$\epsilon = \frac{\sqrt{|C^\nu_L|^2 + |C^\nu_R|^2}}{|(C^\nu_L)^{SM}|}$$

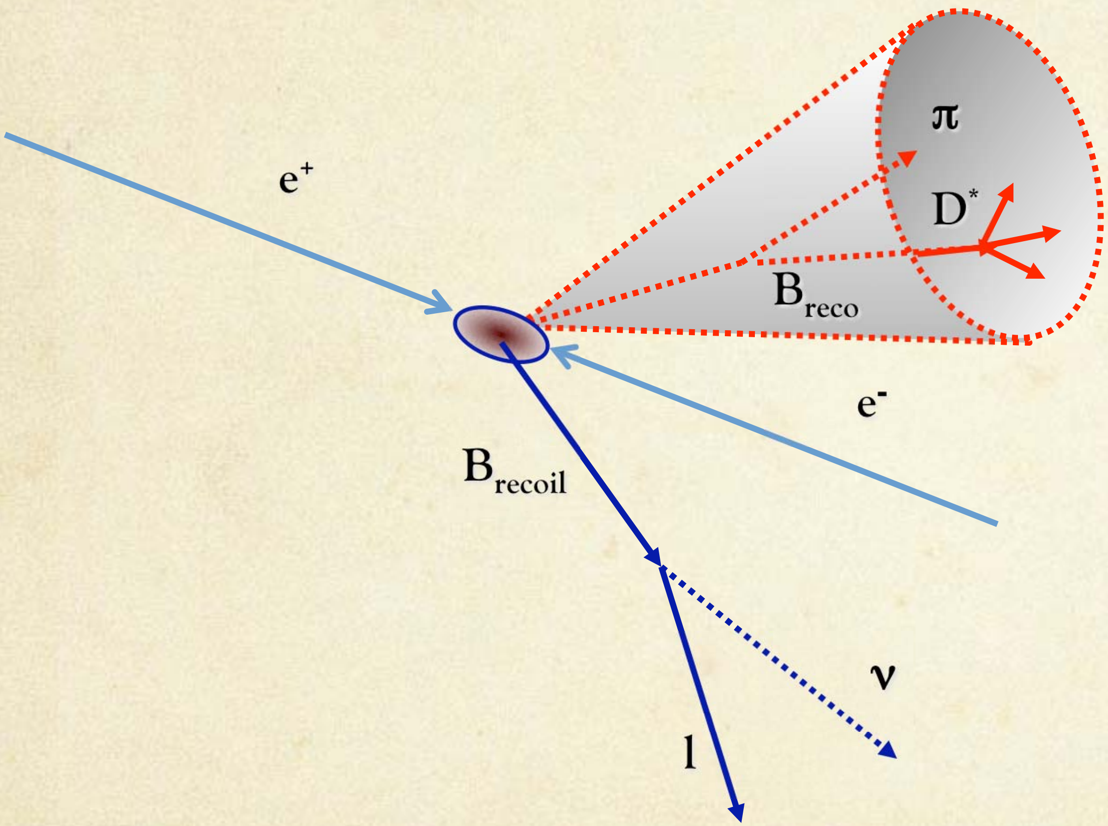
$$\eta = \frac{-Re(C^\nu_L C^{\nu *}_R)}{|C^\nu_L|^2 + |C^\nu_R|^2}$$

- New Physics (NP) effects
  - Non Standard Z-couplings
  - New sources of missing energy



1) Broad outline of the analysis

Recoil analysis



- Fully reconstruct one of the two Bs in hadronic modes...

  ...and do it with "high" efficiency

- The remaining of the event is the other B

- Single B beam, search for rare B decays (i.e. invisible particles in the finale state)

n.b.: same applies to Semileptonic reconstruction in $B_{reco} \rightarrow D^{(*)} l\nu$ final states

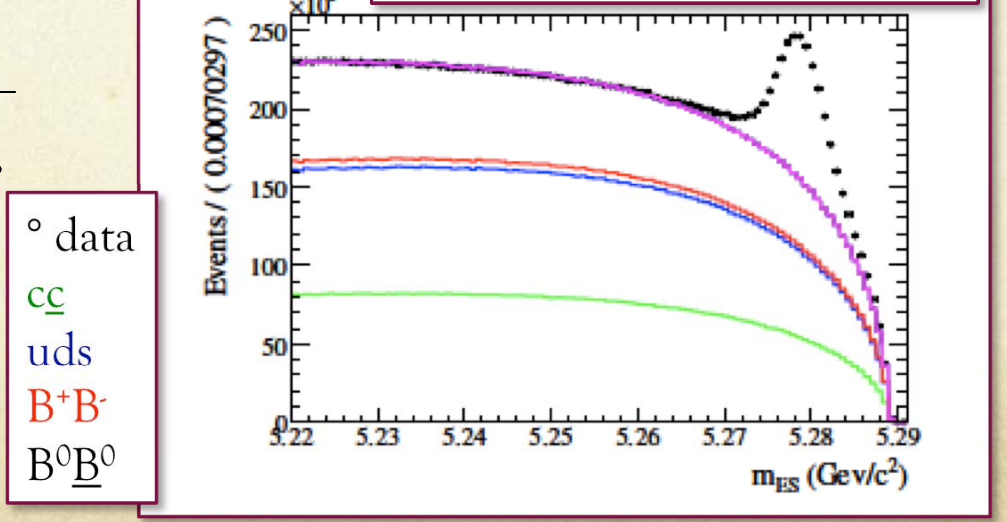
B_{reco} reconstruction

- Reconstruct $B_{reco} \to D^{(*)}\, n_1\pi\, n_2K\, n_3K_s\, n_4\pi^0$ with $n_1 + n_2 < 6$, $n_3 < 3$, and $n_4 < 3$
  - semi-exclusive reconstruction: don't mind about intermediate resonances of the hadronic final state
  - about 1000 B final states reconstructed (typical reconstruction efficiency for *neat+clean+dirty* modes : $O(10^{-3})$)
  - most discriminant variables from B_{reco} (closed) kinematics

$$\Delta E = E_{beam} - E_{B_{reco}}$$

$$m_{ES} = \sqrt{E_{beam}^2 - p_{B_{reco}}^2}$$

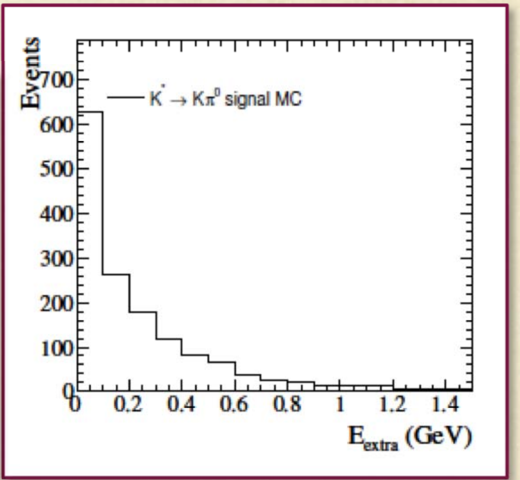
m_{ES} for reconstrcted $B^0{}_{reco}$, BaBar data

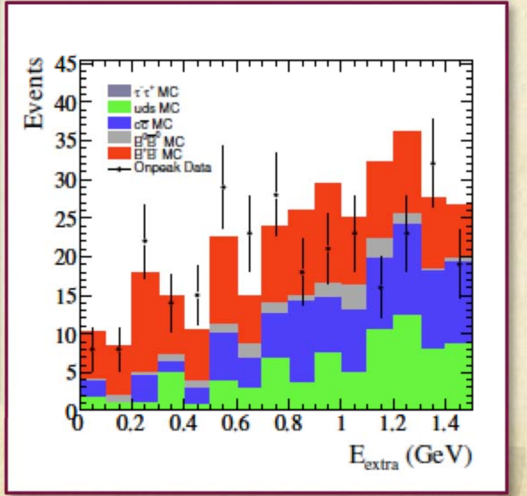


B_{sig} reconstruction and selection

- Search for the signal signature in the rest of the events
  - veto on extra-tracks
  - cut on event-shape and kinematic variables
  - most discriminant variables
    - P_{miss}= E_{beam} – E(reco neutrals and tracks)
    - E_{extra} = Extra neutral energy in Elettromagnetic Cal (EMC) not associated to B_{sig} / B_{reco}
- Signal yield extraction
  - Cut-and-count analysis
  - Fit to E_{extra}
  - combine discriminant variables in a Neural Network and fit output distribution
- Systematics
  - largely dominated by MC statistics (i.e. PDF modeling)

E_{extra}, BaBar data and MC, $B^0 \to K^{*0}(K^+\pi^-)\nu\nu$ analysis





Experimental state of the art

- $B \to K^* \nu\nu$: BaBar HAD+SL recoil combined (PRD78,072007,2008) (used for SuperB extrapolation)

  $\mathcal{B}(B^+ \to K^{*+} \nu\nu) < 80 \times 10^{-6}$

  $\mathcal{B}(B^0 \to K^{*0} \nu\nu) < 120 \times 10^{-6}$

- $B \to K \nu\nu$: Belle HAD recoil (PRL99,221802,2007)

  $\mathcal{B}(B^+ \to K^+ \nu\nu) < 14 \times 10^{-6}$

  - used for SuperB extrapolation: BaBar SL Recoil Analysis (PRD82,112002,2010)

  $\mathcal{B}(B^+ \to K^+ \nu) < 56 \times 10^{-6}$

2-3) Extrapolation from BaBar to SuperB using FastSim

Tools, Samples and detector geometry

- Hadronic recoil analysis impelented in `PacHadRecoilUser` FastSim package
- Sample: 2010 September FastSim production
  - Signal MC samples
  - Hadronic cocktails
  - Machine backgrounds: BhaBha and radiative BhaBha
- DGWG studies:
  - Consider default SuperB detector geometry
  - Switch on/off detector options (FWD PID, BWD EMC) and study their impact on physics

Extrapolation strategy

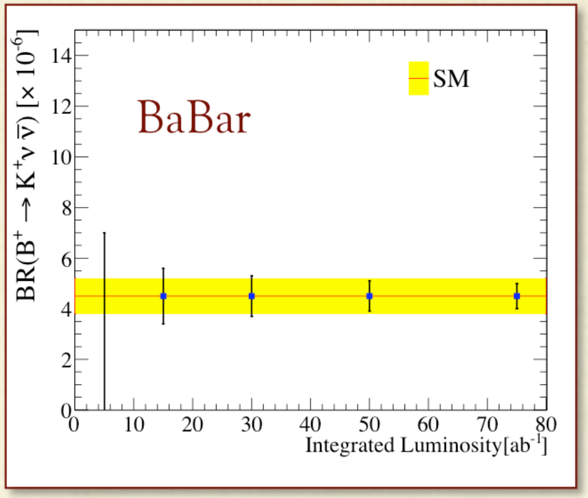
- Apply cut-and-count analysis "a-la-BaBar"
  - use SuperB Fast Simulation, most relevant machine backgrounds (BhaBha and radiative BhaBha) included
- Evaluate gain on signal efficiency and background rejection due change in boost
- Evaluate gain in efficiency due to improvements in detector (FWD PID, BWD EMC)
- Consider BaBar results
  - signal and background yields, signal efficiencies, normalizations
- Extrapolate to SuperB luminosity (75 ab^{-1} ~ 5 years of data taking)
  - account for efficiency changes
  - assume syst error ~ stat error

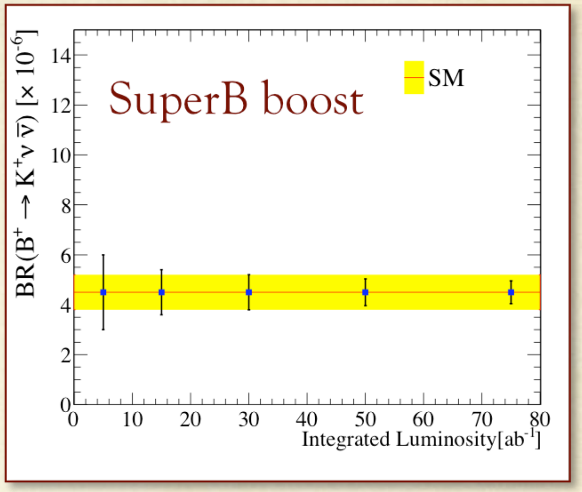
$B^+ \to K^+ \nu\nu$: SuperB expected sensitivity

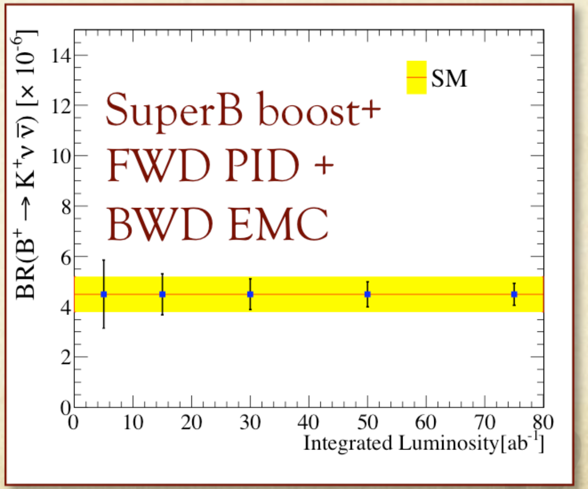
- assume SM branching fraction
- 3σ significance @
  - BaBar : 8 ab^{-1}
  - SuperB-boost : 5 ab^{-1}
  - SuperB+boost+ PID +EMC : 4 ab^{-1}

with ~ 30% precision on $\mathcal{B}$

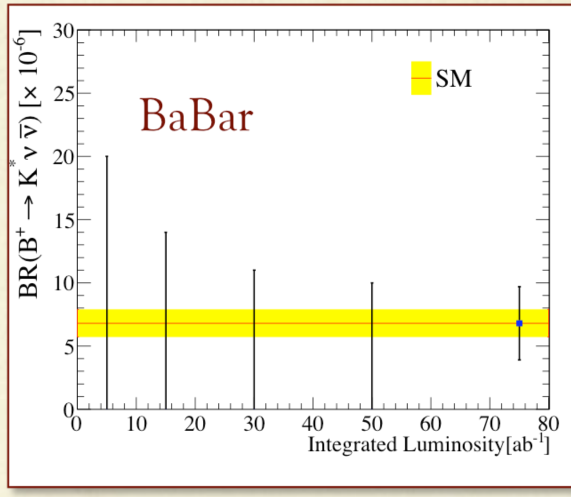
- 75 ab^{-1} SuperB boost + PID + EMC precision : ~ 10%

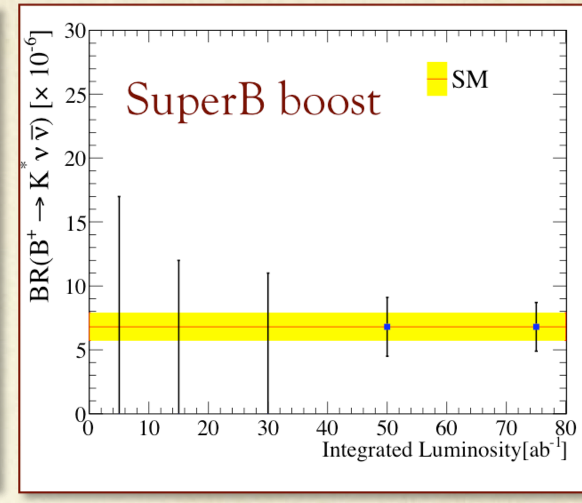






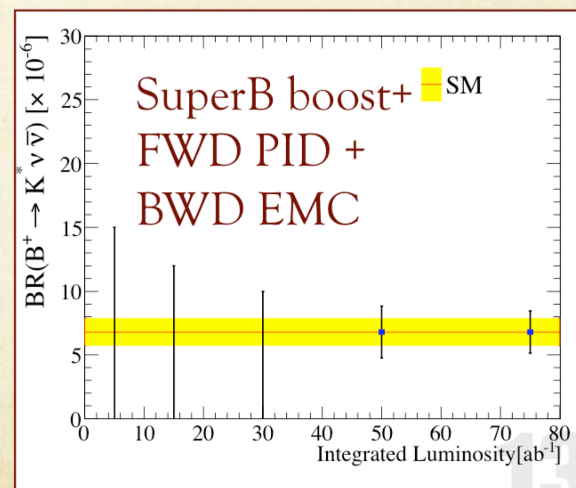
B→K*νν: SuperB expected sensitivity





- assume SM branching fraction
- 3σ significance @
  - BaBar : 75 ab^{-1}
  - SuperB-boost : 50 ab^{-1}
  - SuperB+boost+ PID +EMC : 42 ab^{-1}

with ~ 30% precision on $\mathcal{B}$



- 75 ab^{-1} SuperB boost + PID + EMC precision : ~ 25%

4) Tools

K-PID and PacHadRecoilUser

- PID: Kaon selectors already implemented in FastSim
- PacHadRecoilUser: package, inherited from BaBar code, running in the SuperB FastSim framework
  - allow to study $B \rightarrow K^{(*)}\nu\nu$, $B \rightarrow \tau\nu$ in the Had recoil (possibility of adding new B_{sig} modes)
  - code included in the past FastSim producition series
  - physics channels used in the DGWG studies to quantify impact of BWD EMC and FWD PID
  - PacSemilepRecoilUser: twin package for SL recoil analysis
  - Documentation

http://mailman.fe.infn.it/superbwiki/index.php/FastSimDoc/Tutorial_PacHadRecoilUser

http://agenda.infn.it/getFile.py/access?contribId=0&resId=0&materialId=slides&confId=4278

PacHadRecoilUser : to do list

- Documentation pagere recently written
  - comments / suggestions to improve it are welcome
- code clean-up: remove parts inherited from BaBar and inessential to SuperB purposes
- code for validation: code to make histograms and efficiency computation to validate FastSim releases and pre-production cycles; part of the code already exists, needs to be refined
  - FastSim - BaBar FullSim comparison with HAD Breco discussed at tomorrow "Computing + Phys - Physics Tools" session
- study Breco properties: changes wrt BaBar algorithm are needed?

Conclusions

- $B \to K^{(*)} \nu\nu$ in the SuperB rare B decays shop list
  - Most stringent limits reported to-date:

$\mathcal{B}(B^+ \to K^{*+} \nu\nu) < 8.0 \times 10^{-5}$, $\mathcal{B}(B^0 \to K^{*0} \nu\nu) < 12.0 \times 10^{-5}$

$\mathcal{B}(B^+ \to K^+ \nu\nu) < 1.4 \times 10^{-5}$

- Extrapolation @ 75ab^{-1} using FastSim with FWD PID + BWD EMC
  - $B \to K^+ \nu\nu$: evidence @ 4 ab^{-1} with 30% precision on $\mathcal{B}$
  - $B \to K^* \nu\nu$: evidence @ 42 ab^{-1} with 30% precision on $\mathcal{B}$

- Main tools needed
  - Kaon PID
  - `PacHadRecoilUser`

in good shape and already used in previous FastSim production.

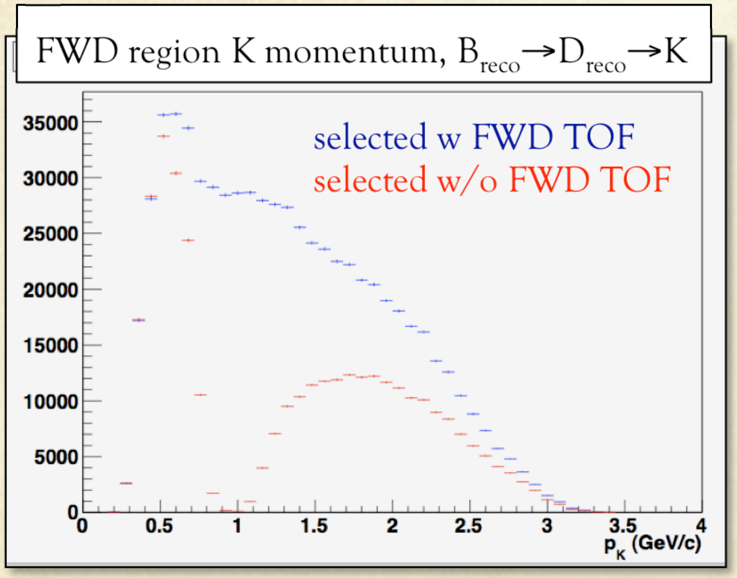
Extra Slides

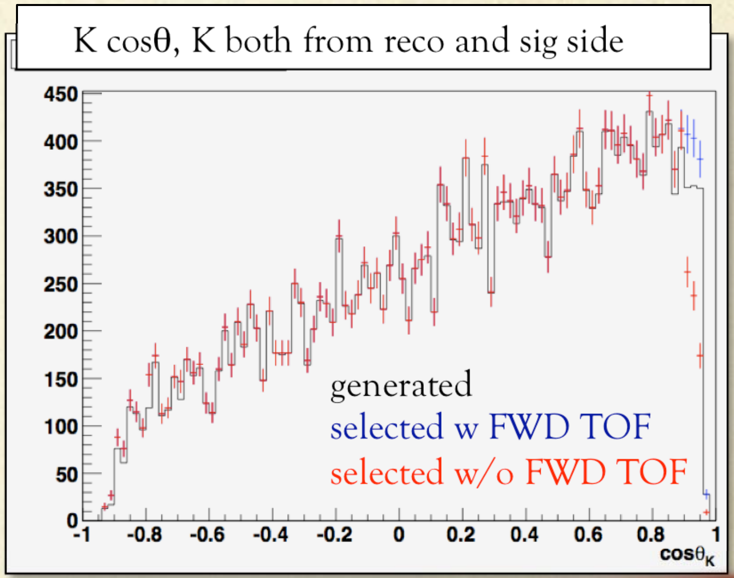
Variables used for DGWG studies

- The code allow to evaluate the impact of the BWD EMC and the FWD PID at analysis level
- Bwd EMC: used a veto device
  - variable that allow to remove candidates reconstructed in the BWD EMC (YSigB_IsBwdEMC)
  - extra neutral energy and missing momentum computed separately for barrel+FWD and BWD calorimeter
- Fwd PID:
  - main impact on Kaons from B_{reco} and B_{sig} sides
  - ntuples contain info to switch on/off FWD PID device and the same set of data can be used to evaluate efficiencies and physics reach w/o FWD PID

What's new in SuperB: FWD PID

- Possibility of PID device in the FWD region under study
  - one option : FWD Time Of Flight (TOF)
  - Single channel time resolution σ_t ~ 50 ps
  - Expect 3-4σ K-π separation @ 3 GeV
- Impact of FDW TOF
  - ~ 5% Kaons in the Fwd region, recuperate K with p_K>0.6 GeV



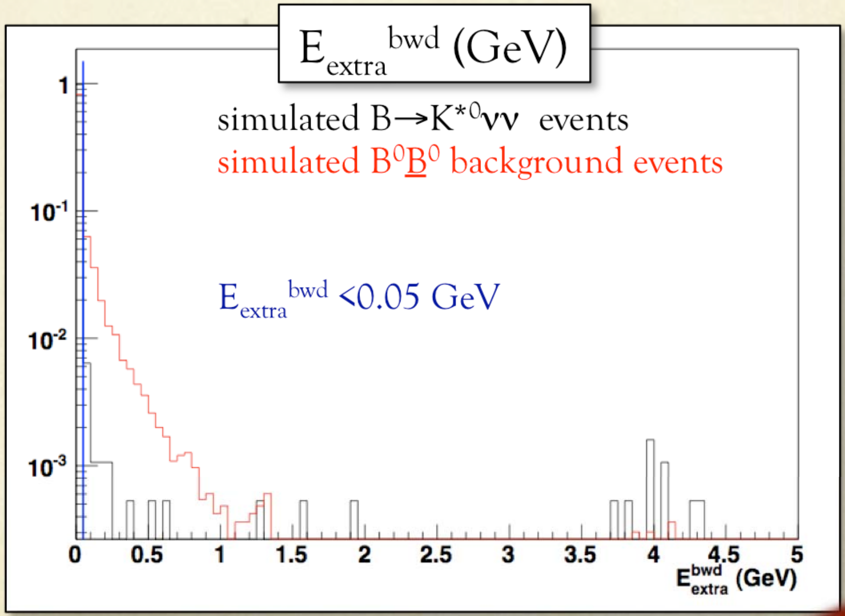


PRELIMINARY

  - +2.5-5% gain in signal selection efficiency, background efficiency ~ unchanged

What's new in SuperB: BWD EMC

- Possibility of EMC device in the BWD region under study
  - PB-scintillator sandwich (12 X0)
  - Resolution $\sigma(E)/E = 14\%/(E(GeV))^{1/2} \oplus 3.0\%$
- Use as veto device
  - reject B_{sig} and B_{reco} candidates with daughters hitting Bwd EMC
  - cut on E_{extra} compute with extra neutrals in the bwd region



- -2% reduction in signal selection efficiency

  -15% reduction in background selection efficiency

Some numbers for production

- To speed-up production: Purity cut : 50%, B cocktail : 60-70% of BB generics events surviving mES – delatE cut

- September 2010 production
  - Generated: 370x10^6 B0B0bar and 72x10^6 B+B- cocktail events
  - Surviving selection (all cuts but Eextra_BrrFwd) :

181 B0B0bar events for the B0->K^*0 (Kpi) nunubar events

136 B+B- events for the B+->K^*+ (Kspi+) nunubar events

75 B+B_ events for the B+->K^*+ (K+pi0) nunubar events.

- In the same production configuration, 20-25 x 10^9 events in the SuperB configuration would be a good amount of data also to make detailed syst studies.