DGWG parallel session, December 15th 2010

Fwd-PID and Bwd-EMC Studies SL recoil analyses

Alejandro Pérez

INFN – Sezione di Pisa

A. Stocchi, N. Arnaud, L. Burmistrov

LAL – Université Paris XI

CALTECH SuperB Workshop

Istituto Nazionale di Fisica Nucleare
SEZIONE DI PISA

UNIVERSITÉ PARIS-SUD 11

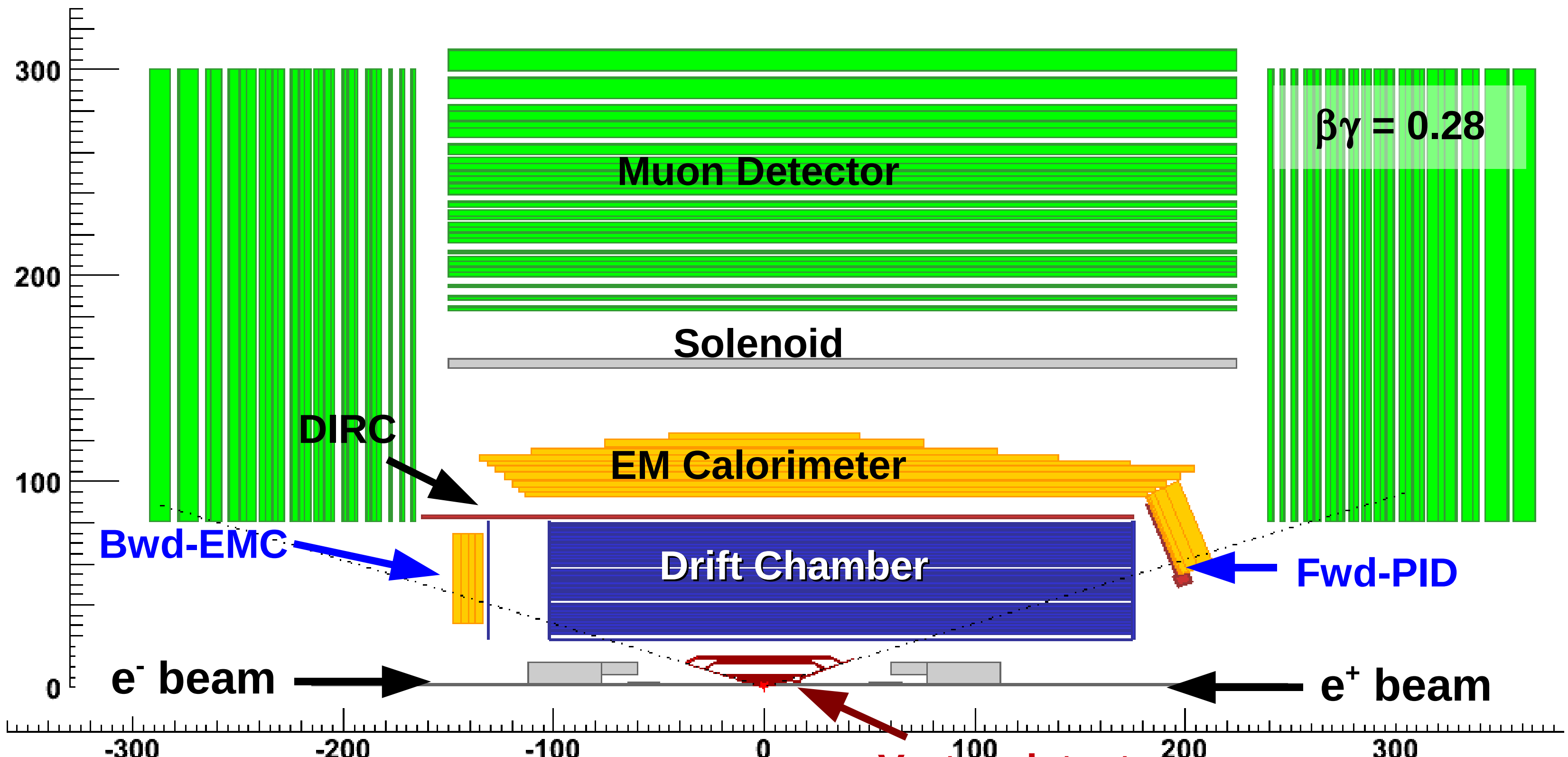
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

Outline

- **Detector Geometries**
- **Samples used**
- **Fwd-PID studies strategy**
- **Bwd-EMC studies strategy**
- **Results on boost reduction**
- **Results on Fwd-PID Studies**
- **Results on Bwd-EMC Studies**
- **Summary and outlook**

Detector Geometries

- BaBar ($\beta\gamma = 0.56$) (**DG_BaBar**)
- Baseline configuration: BaBar with reduced boost ($\beta\gamma = 0.24$)
- Generated geometries:
  - Baseline + Bwd-EMC + Fwd-PID (quartz) (**DG_4**)
  - Baseline + Bwd-EMC + Fwd-PID (air) (**DG_4a**)



Summer 2010 Production

- **Signal samples:**
  - $B^+ \to K^+ \nu\nu$ (DG_BaBar/DG_4/DG_4a): 3.00/4.02/3.03 M
  - $B^0 \to K^0 \nu\nu$ (DG_BaBar/DG_4/DG_4a): 3.00/3.00/3.00 M
  - $B^0 \to K^{*0} \nu\nu$ (DG_BaBar/DG_4/DG_4a): 3.00/3.00/2.94 M
  - $B^+ \to K^{*+} \nu\nu$ (DG_BaBar/DG_4/DG_4a): 3.00/2.97/3.00 M
  - $B^+ \to \tau^+ \nu$ (DG_BaBar/DG_4/DG_4a): 3.00/3.00/3.00 M
- **Background Samples:**
  - B^+B^- SL-cocktail (DG_BaBar/DG_4/DG_4a): 89.30/340.72/344.32 M
  - B^0B^0 SL-cocktail (DG_BaBar/DG_4/DG_4a): 71.90/284.00/284.56 M
- **All samples generated with bkg mixing NoPairs (V0.2.5 Rev 307)**
- **Checked that DG_4 and DG_4a are equivalent samples (variables distributions and efficiencies)**
- **DG_4 and DG_4a are merged together to perform the DGWG studies**

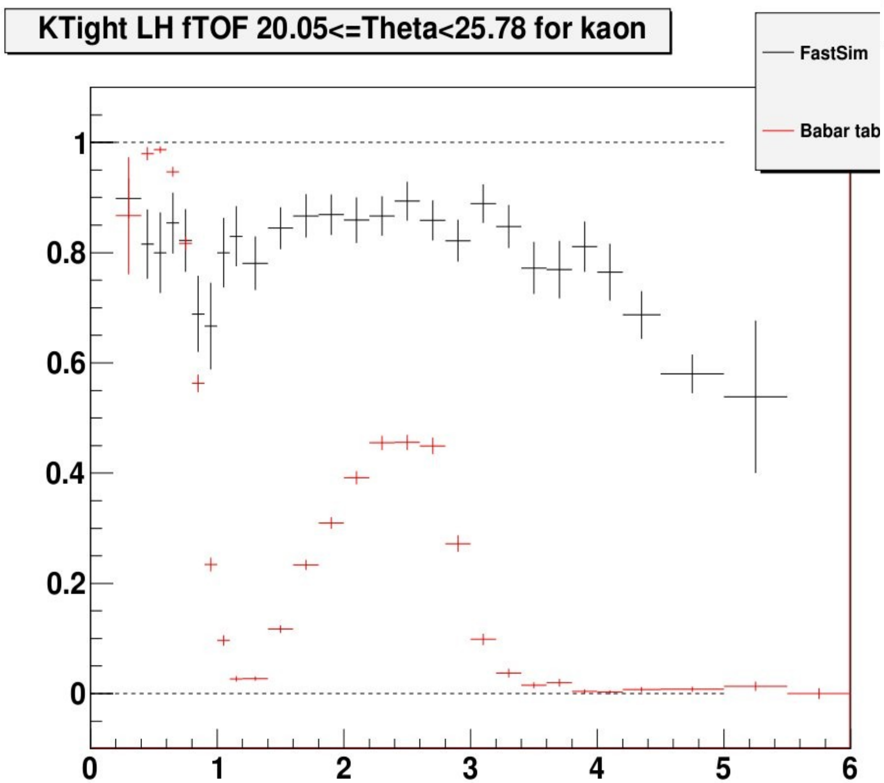
Fwd-PID Studies Strategy

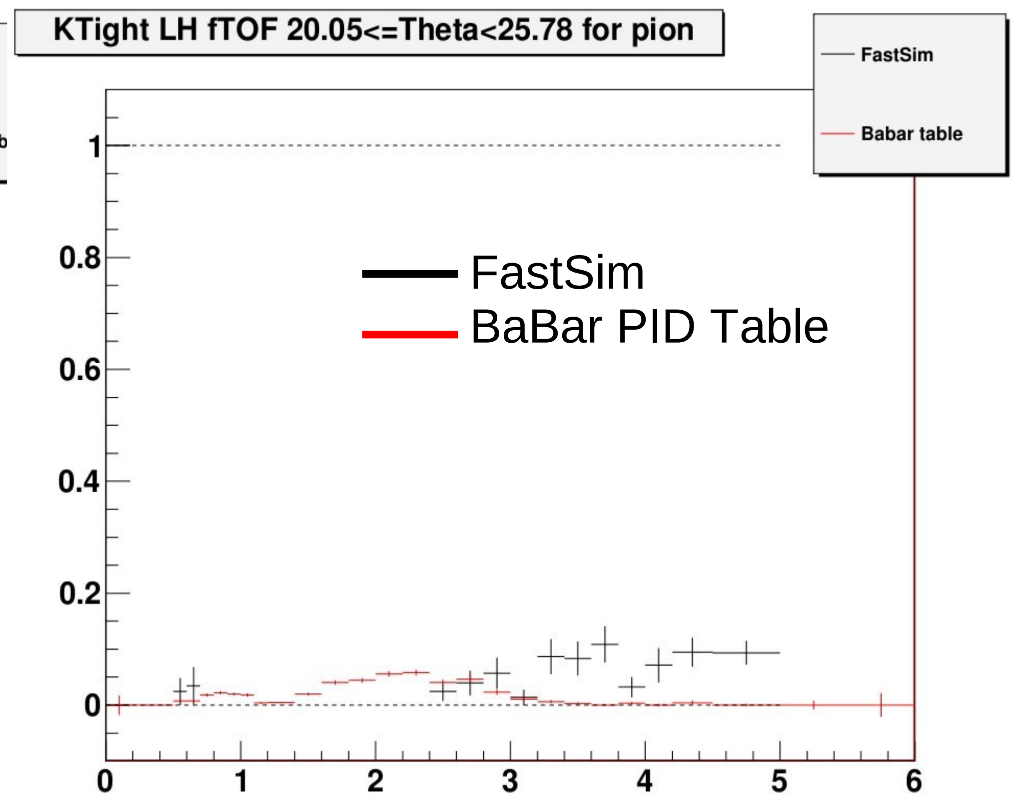
- **Latest studies from full simulation showed that fTOF material has negligible effect on Fwd-EMC**
- **Generate two samples to estimate Fwd-PID impact:** DG_4 and DG_4a
- **Compare DG_4 and DG_4a to estimate the effect of the fTOF material**

  Result: effect is negligible $\Rightarrow$ DG_4 and DG_4a samples equivalent
- **Store at the n-tuples two selectors for the same particle type and tightness (i.e.)**
  - KaonLHTightSelector (no use of timing information from fTOF)
  - KaonLHTight_fTOFSelector (use of timing information from fTOF when available)
- **Merge DG_4 and DG_4a samples (DG_4+DG_4a)**
- **Use this sample to estimate fTOF impact:**
  - **fTOF out place:** use KaonLHTightSelector
  - **fTOF in place:** use KaonLHTight_fTOFSelector
- **Gain due to fTOF will be the increase in efficiency**

PID requirements

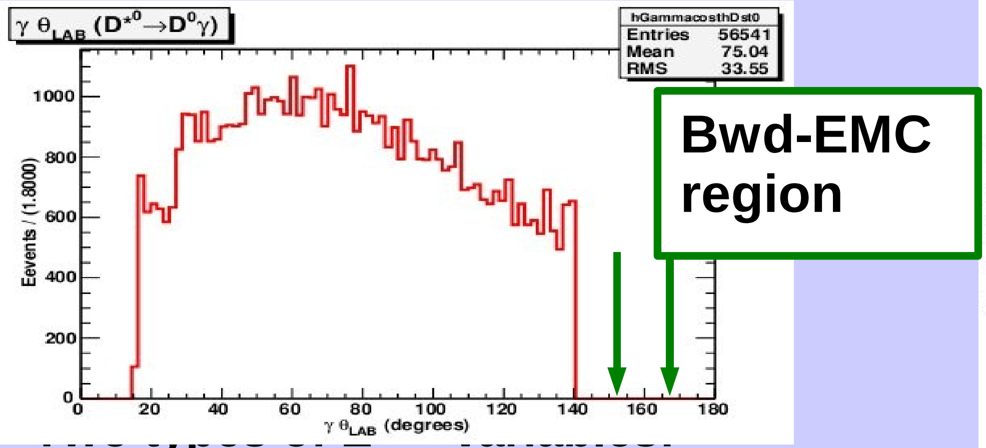
- **Tag-Side:**
  - Use KaonLHTight
- **Signal-Side:**
  - Use KaonLHTight

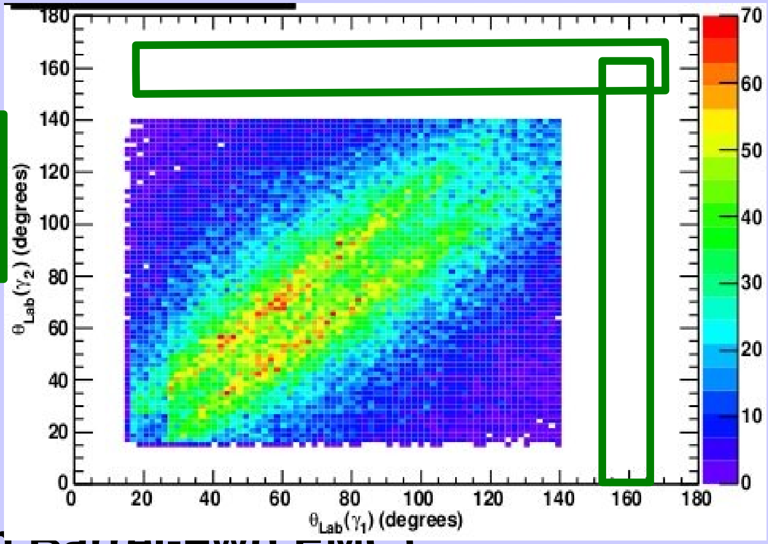




Bwd-EMC Studies Strategy: Veto device

- B_{tag} and B_{sig} candidates reconstructed without neutrals from Bwd-EMC

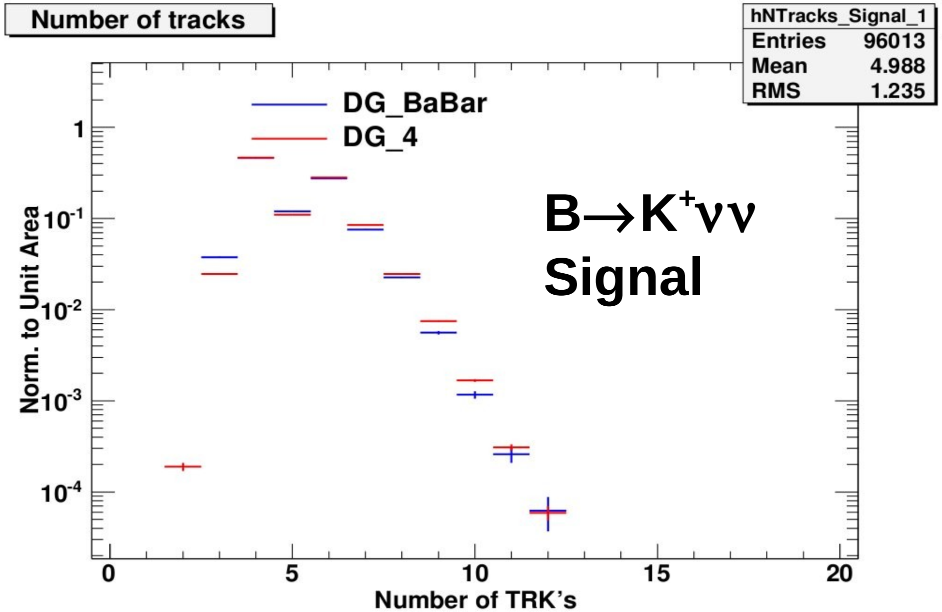


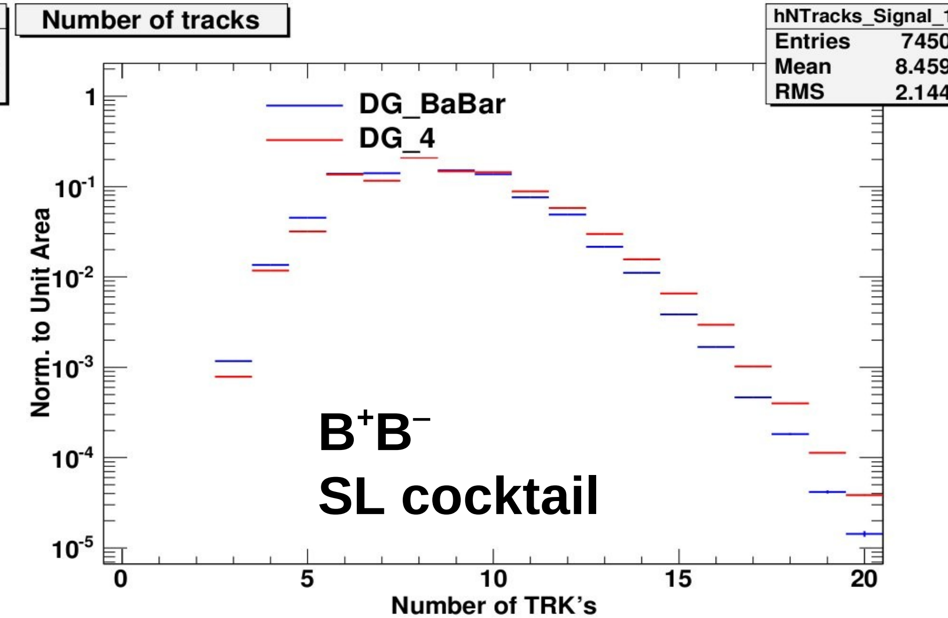


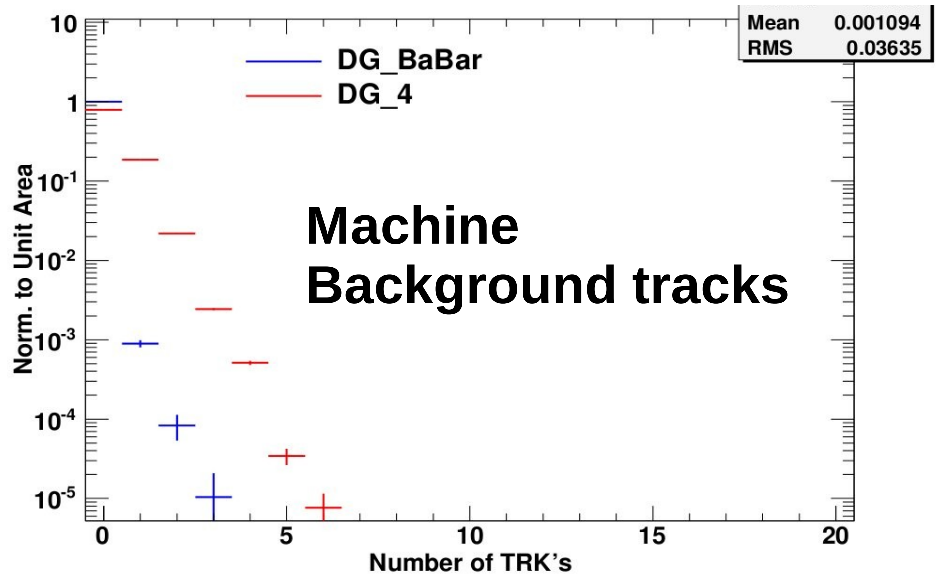
- Two types of E_{extra} variables:
  - E_{extra}(Barrel-Fwd) = Σ(extra neutrals on Barrel-Fwd EMC)
  - E_{extra}(Bwd) = Σ(extra neutrals on Bwd EMC)
- Can used E_{extra}(Bwd) to cut on and E_{extra}(Barrel-Fwd) to perform a fit
- Test different $E(\gamma)_{min}$ cut for Bwd-EMC photons (none, 30, 50, 70 MeV)
- Try to define an optimum cut that maximizes a figure of merits
  $\Rightarrow S/\sqrt{(S+B)}$

Boost Reduction Results

Boost reduction results

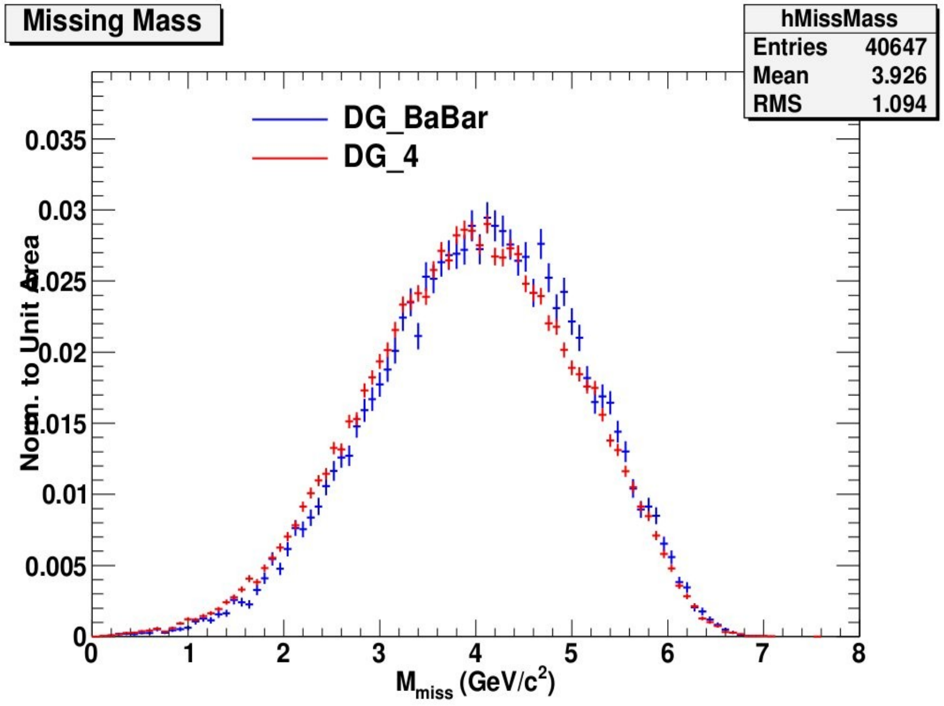


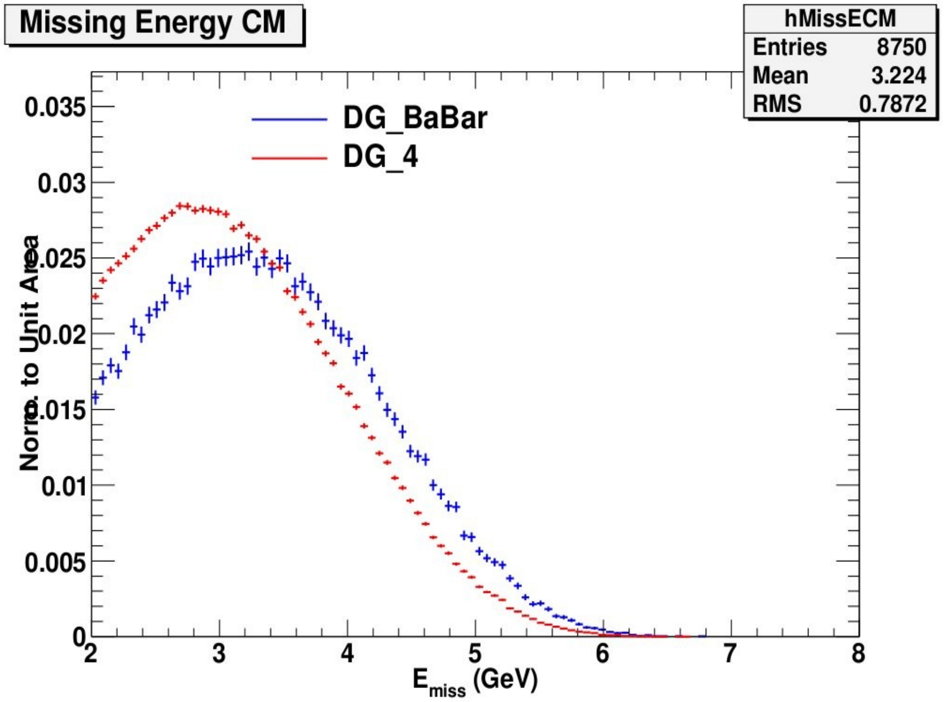




- Boost reduction increases detector acceptance
- Increase in N-tracks is due to:
  - Boost reduction
  - Increase in Machine bkg rate
- This increase can reduce the reconstruction efficiency

Boost reduction results



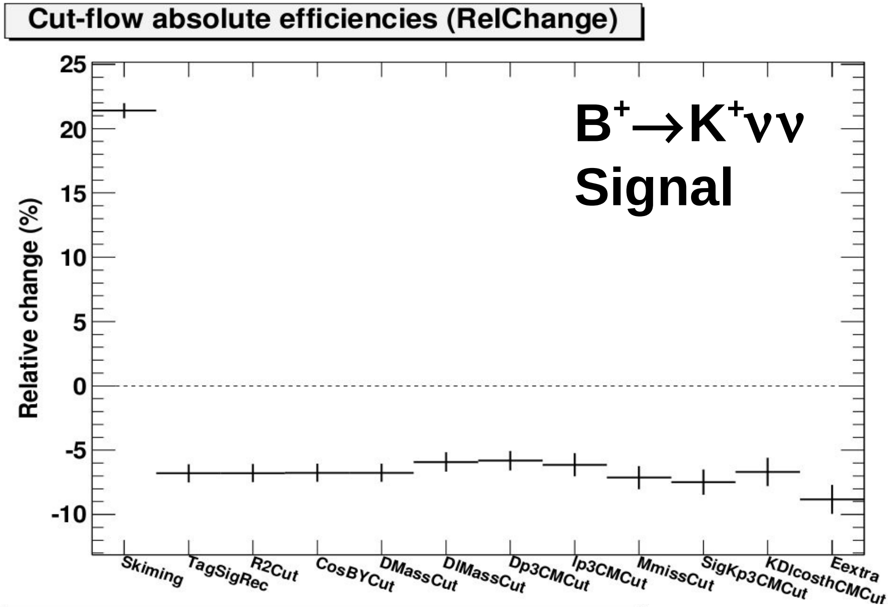


- **Boost reduction also modifies the Missing momentum variables**

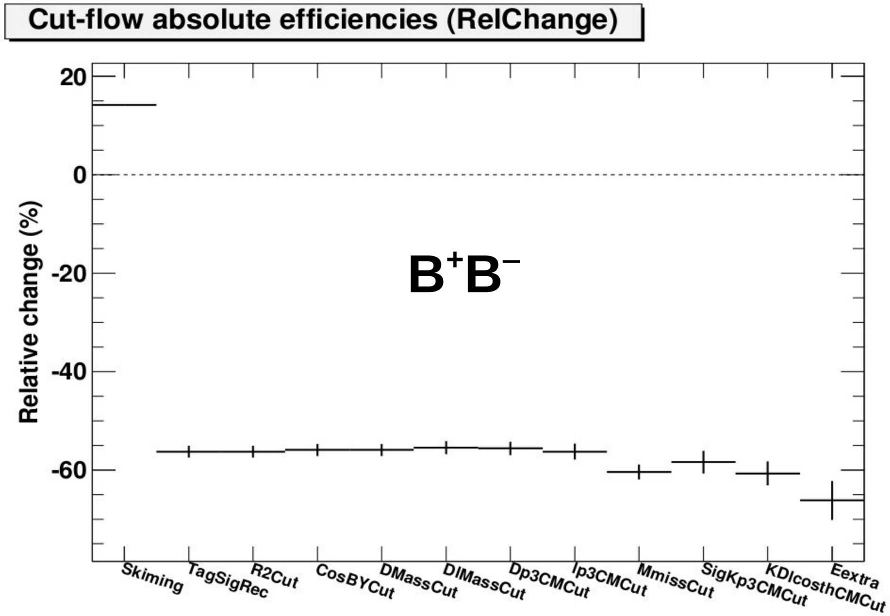
  - No change for signal

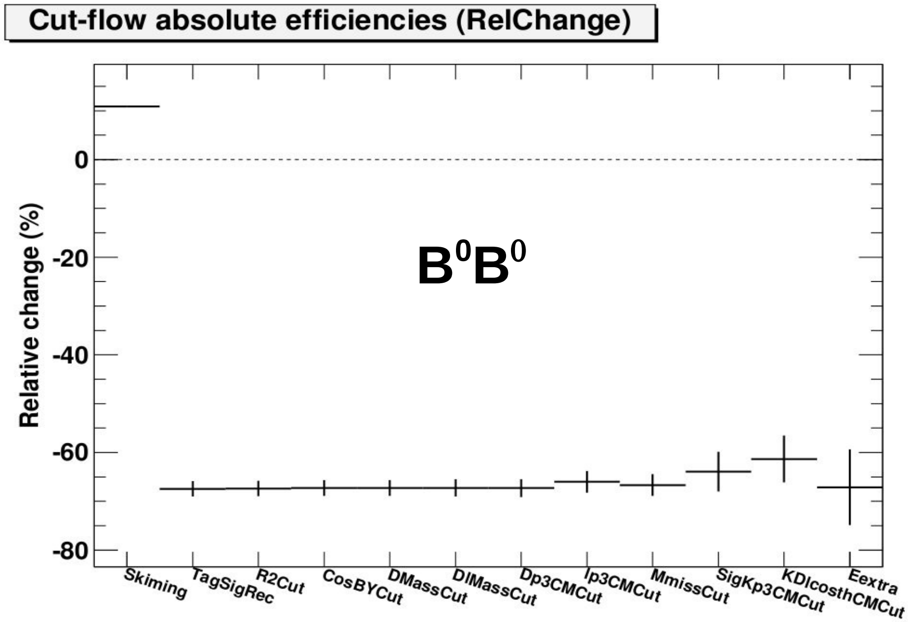
  - Bkg distributions get more discriminant (get shifted to zero)

Boost reduction results: $B^+ \to K^+ \nu\nu$

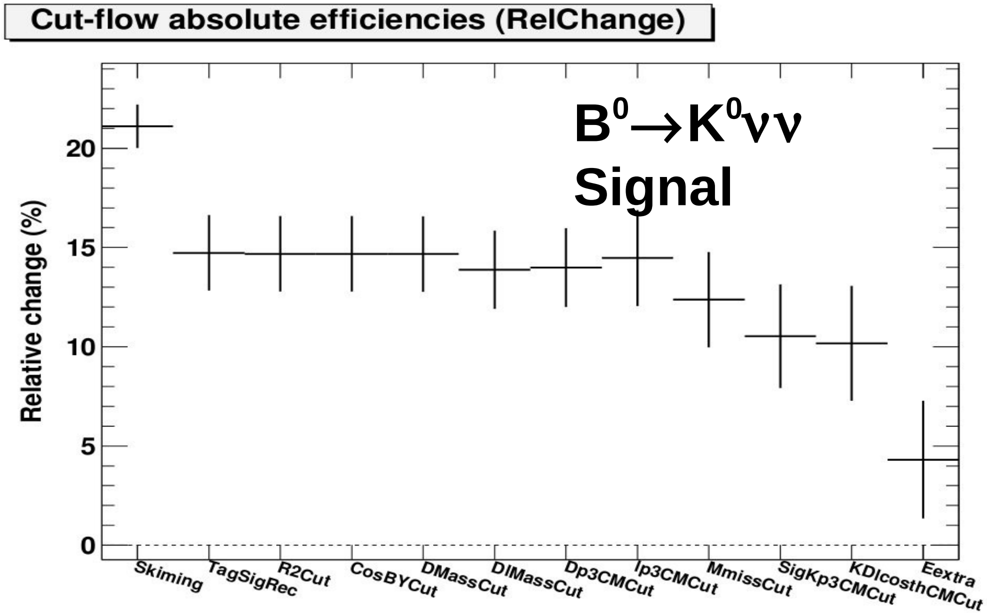


- **Signal:** ~ -8.0 %
- **B^+B^-:** ~ -60.0 %
- **B^0B^0:** ~ -65.0 %

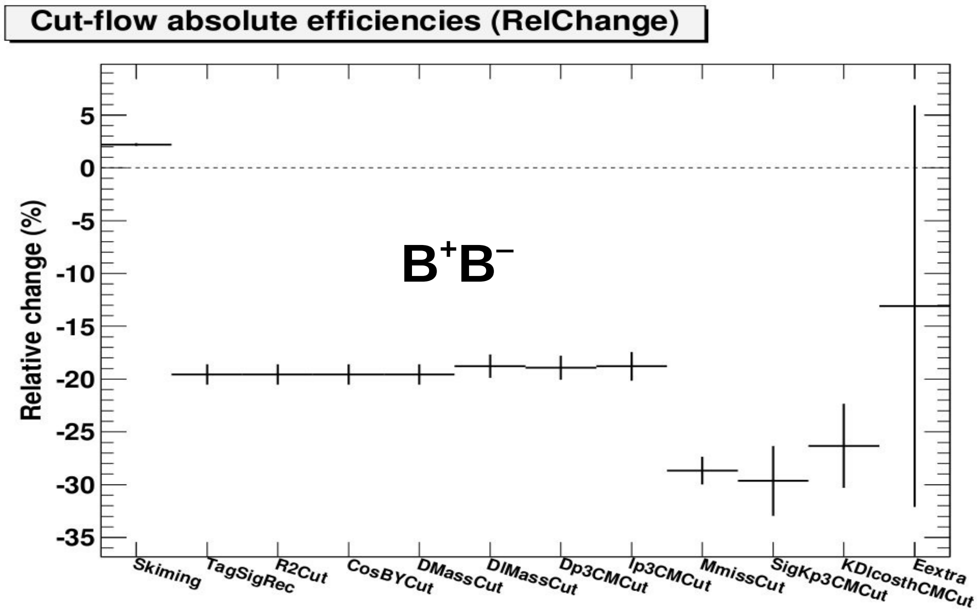


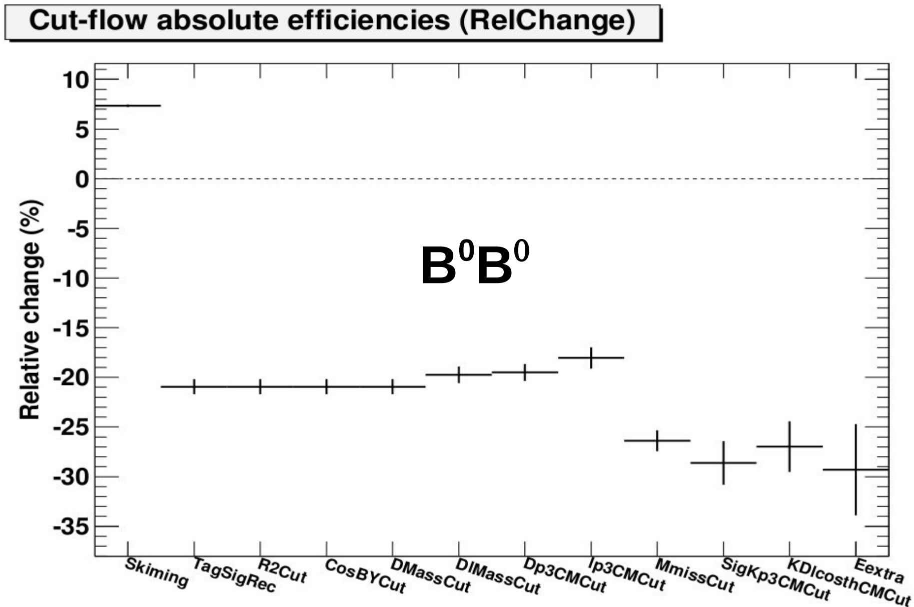


Boost reduction results: $B^0 \to K^0 \nu\nu$

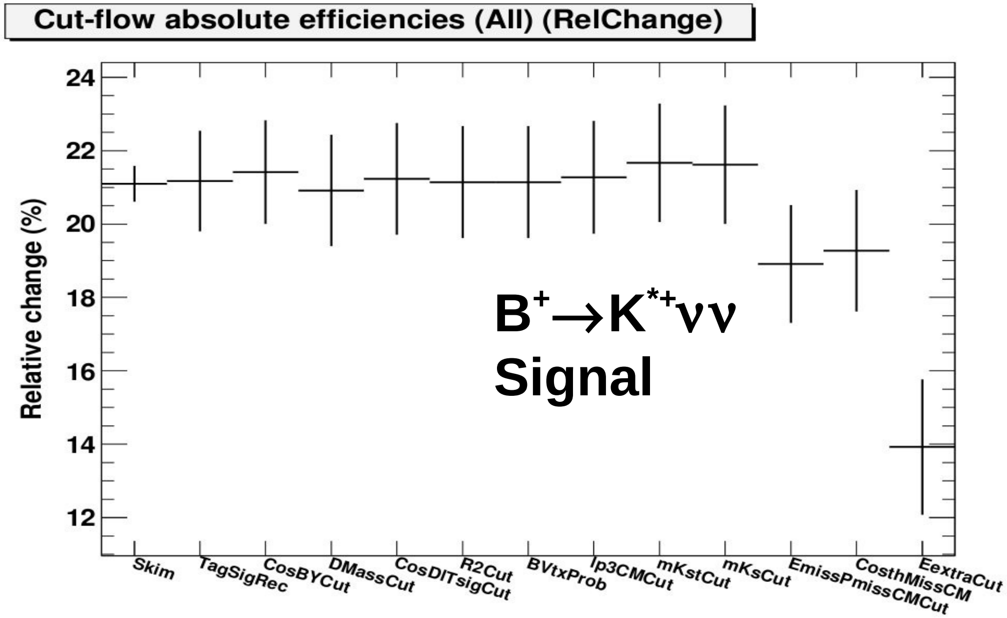


- **Signal:** ~ +15.0 %
- **B^+B^-:** ~ -30.0 %
- **B^0B^0:** ~ -28.0 %

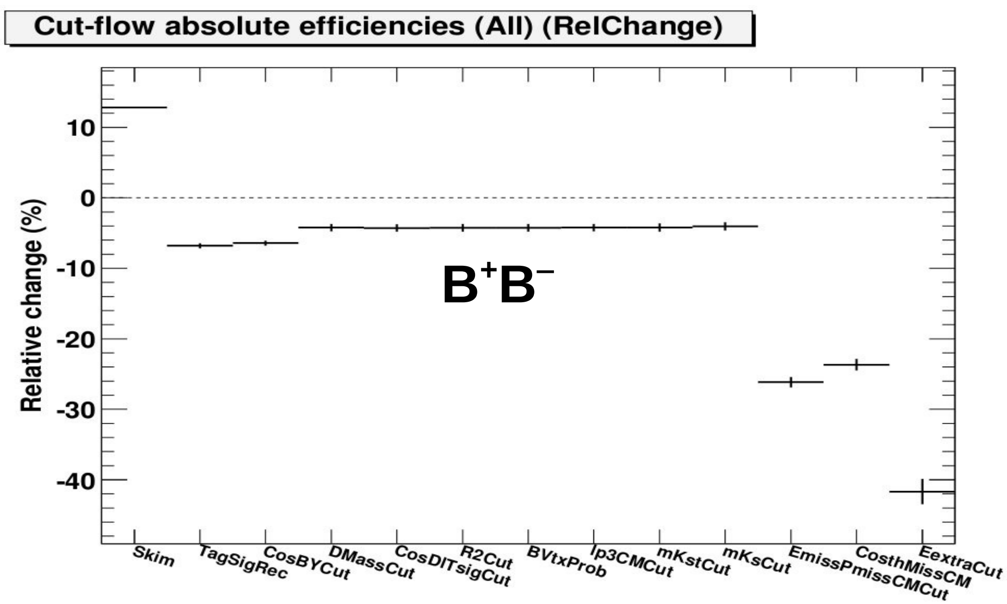


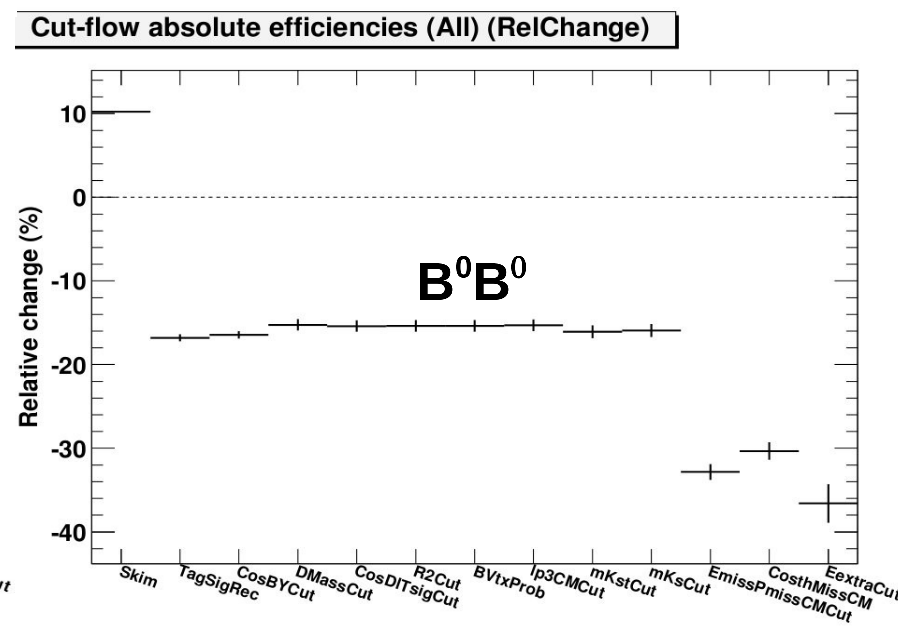


Boost reduction results: $B^+ \to K^{*+}\nu\nu$

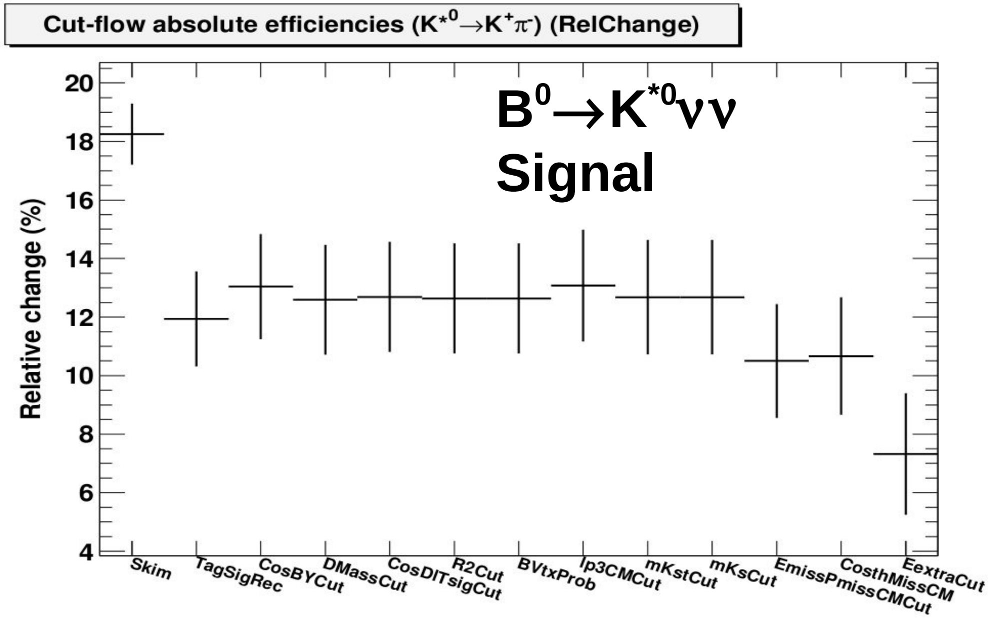


- **Signal:** ~ +21.0 %
- **B^+B^-:** ~ -28.0 %
- **B^0B^0:** ~ -32.0 %

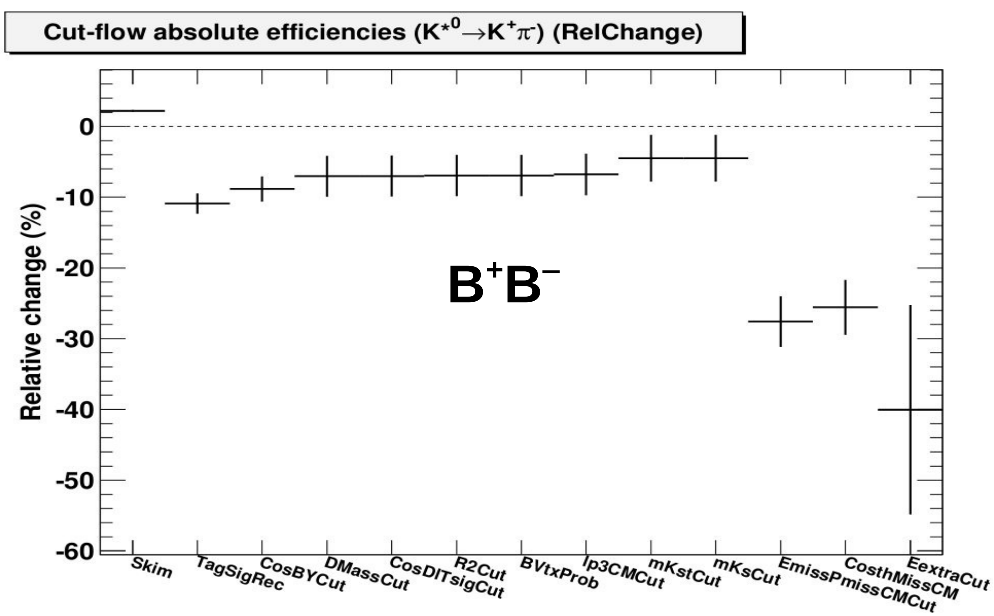


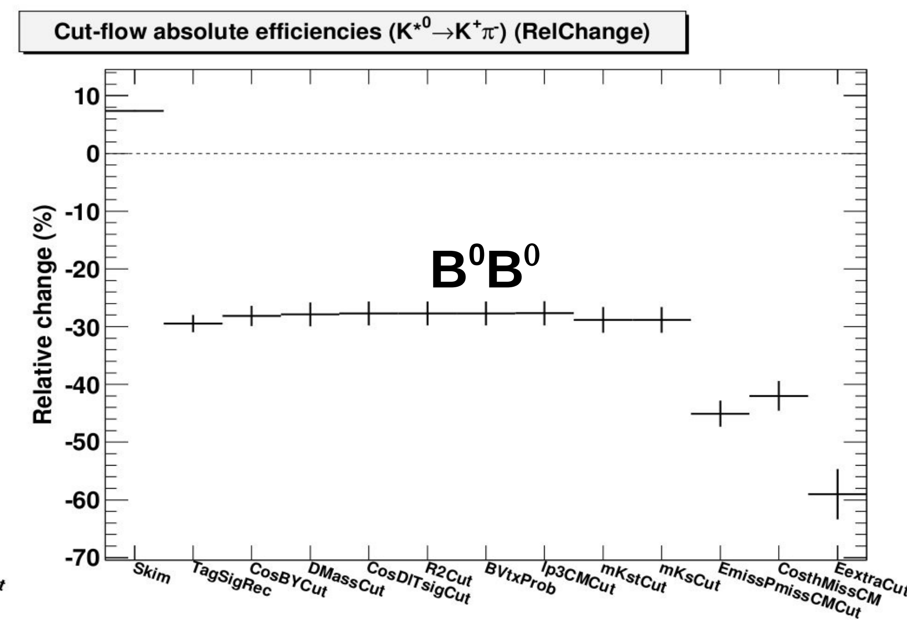


Boost reduction results: $B^0 \to K^{*0} \nu\nu$

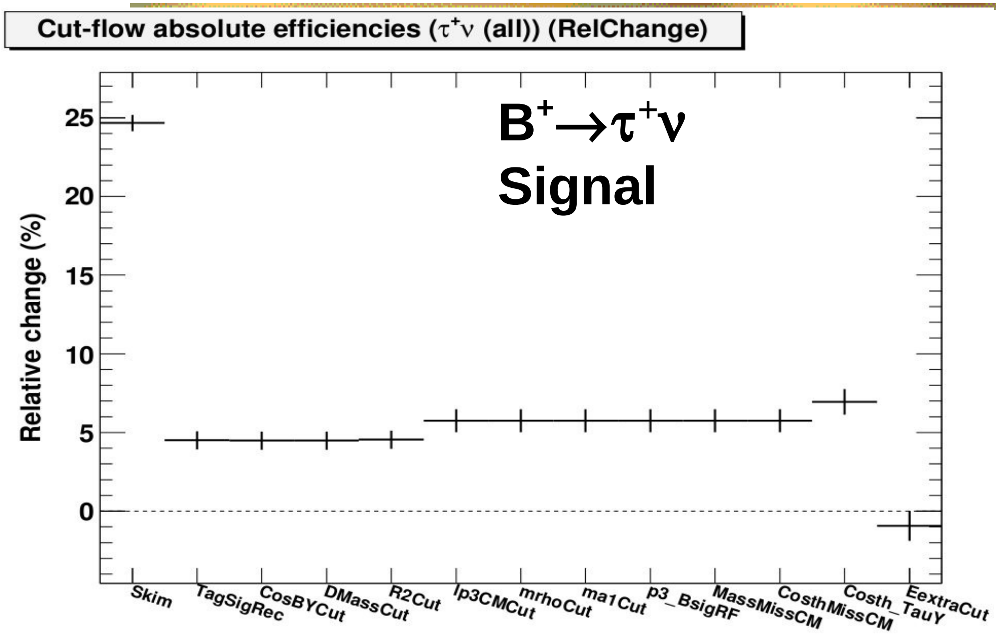


- **Signal:** ~ +12.0 %
- **B^+B^-:** ~ -28.0 %
- **B^0B^0:** ~ -40.0 %

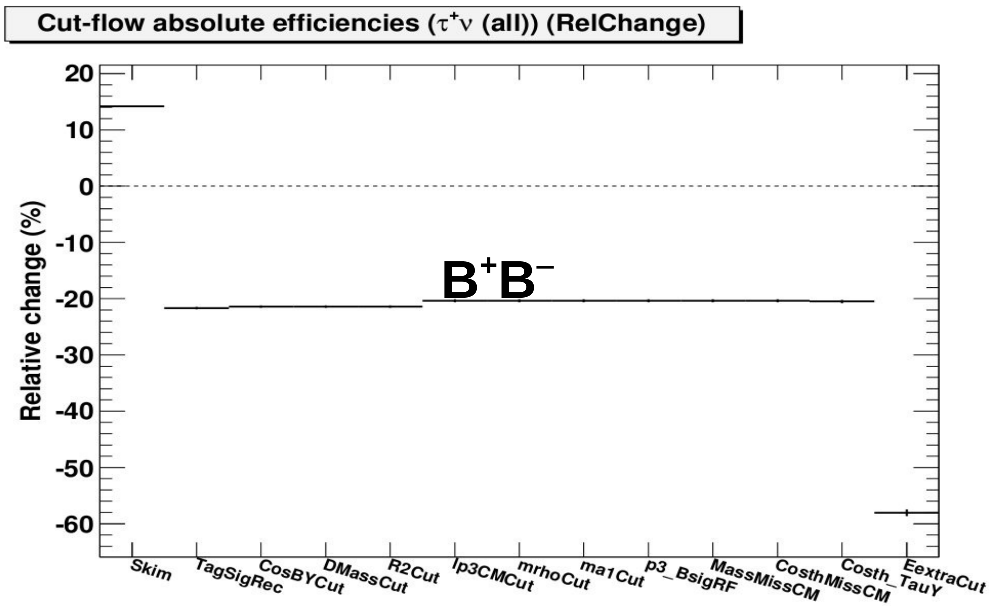


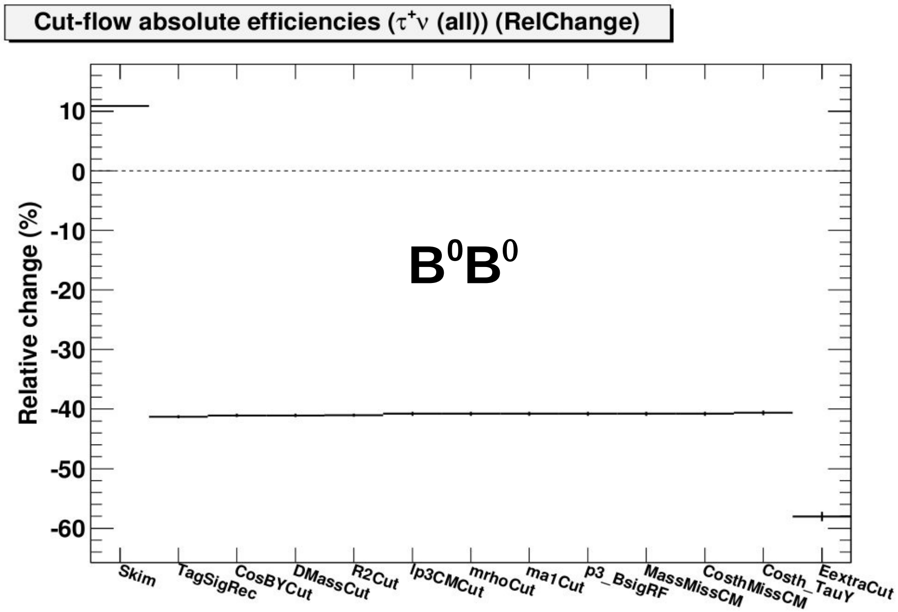


Boost reduction results: $B^+ \to \tau^+ \nu$



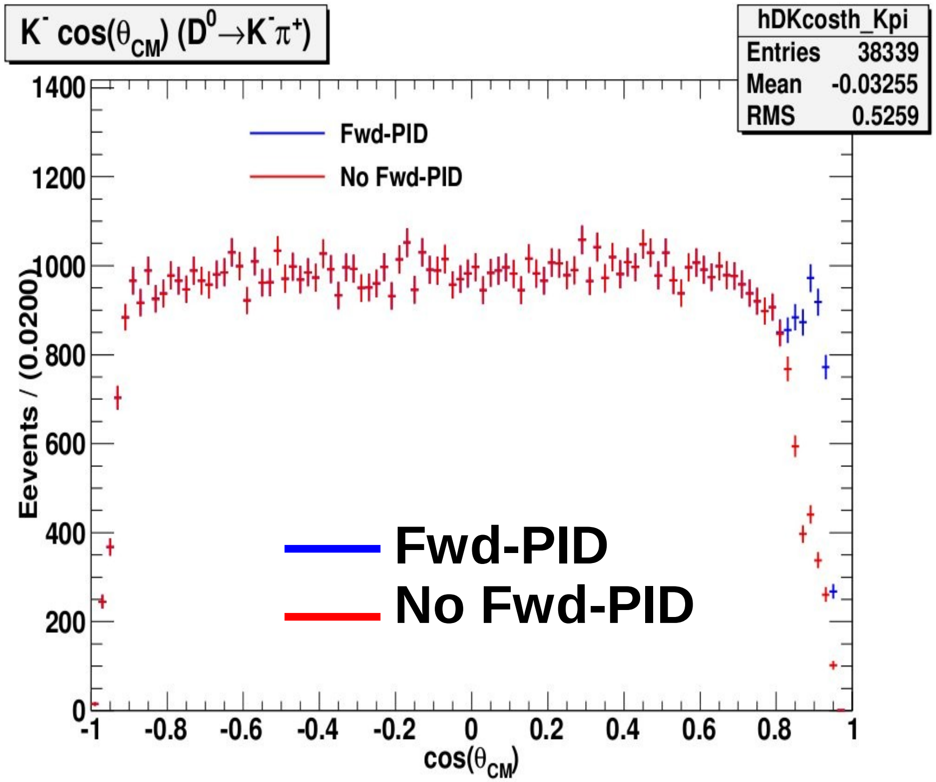
- **Signal:** ~ +5.0 %
- **B^+B^-:** ~ -20.0 %
- **B^0B^0:** ~ -40.0 %

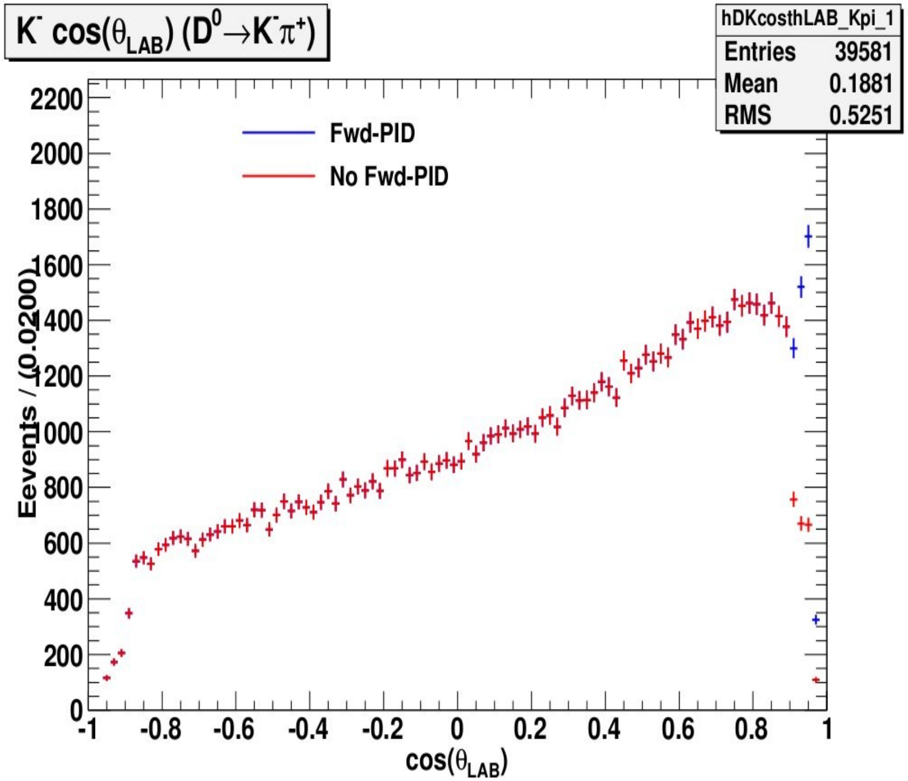




Results on Fwd-PID Studies

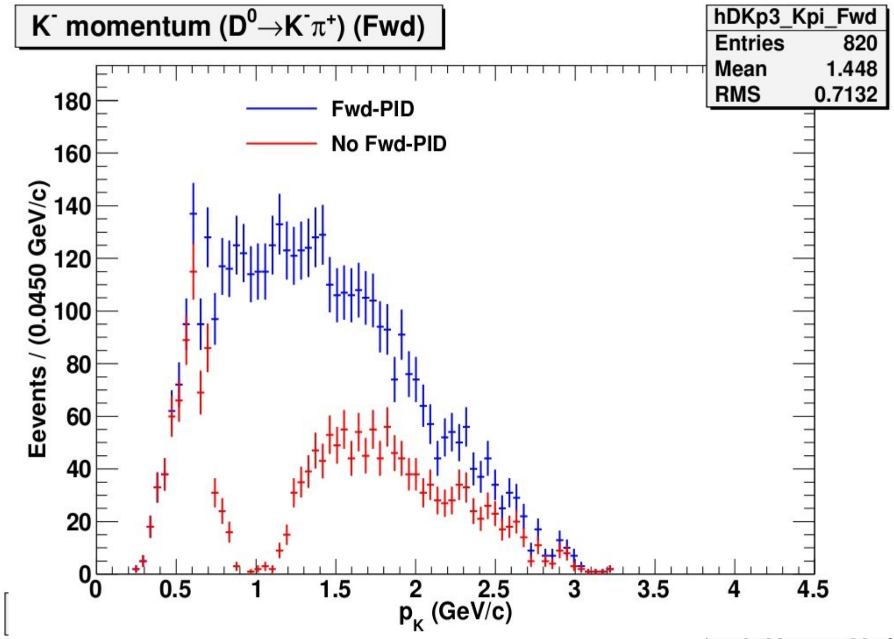
Fwd-PID studies: $B^+ \to K^+ \nu\nu$

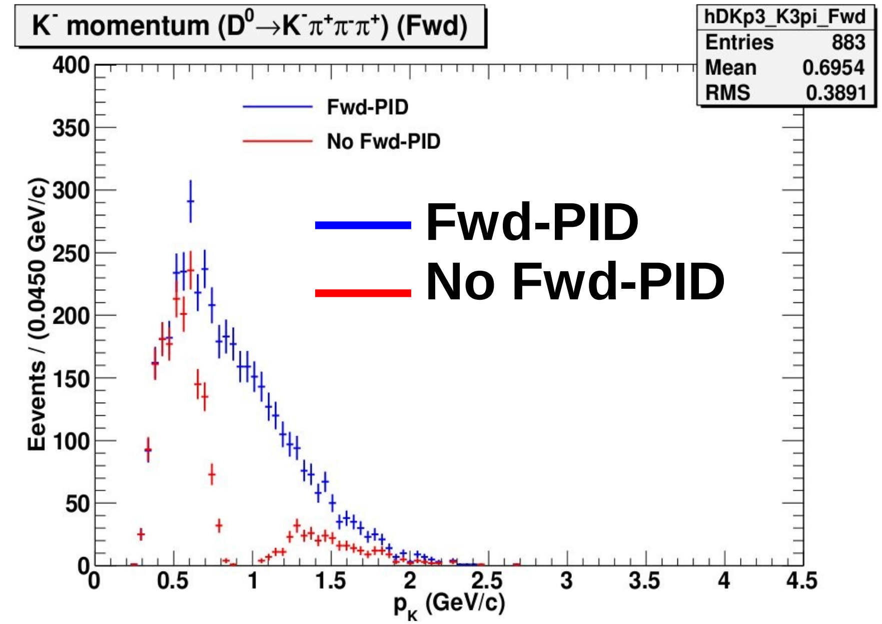


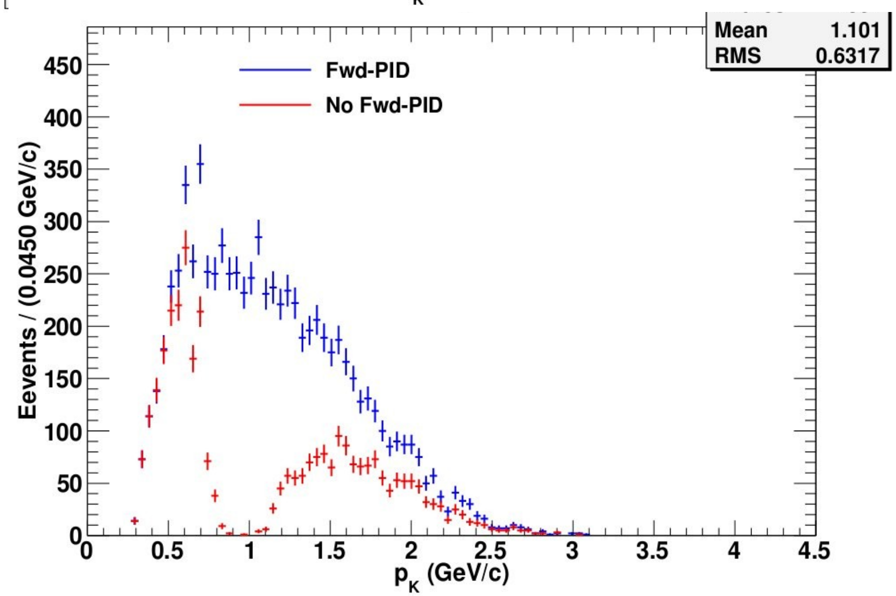


- Events in the Fwd region (15-25 degrees) are 5% of the total sample if cos(θ) (CM) is flat
- f-TOF seems to recover the events in the Fwd
- Gain from fTOF not expected to be higher than 5% for each identified kaon

Fwd-PID studies: $B^+ \to K^+ \nu\nu$



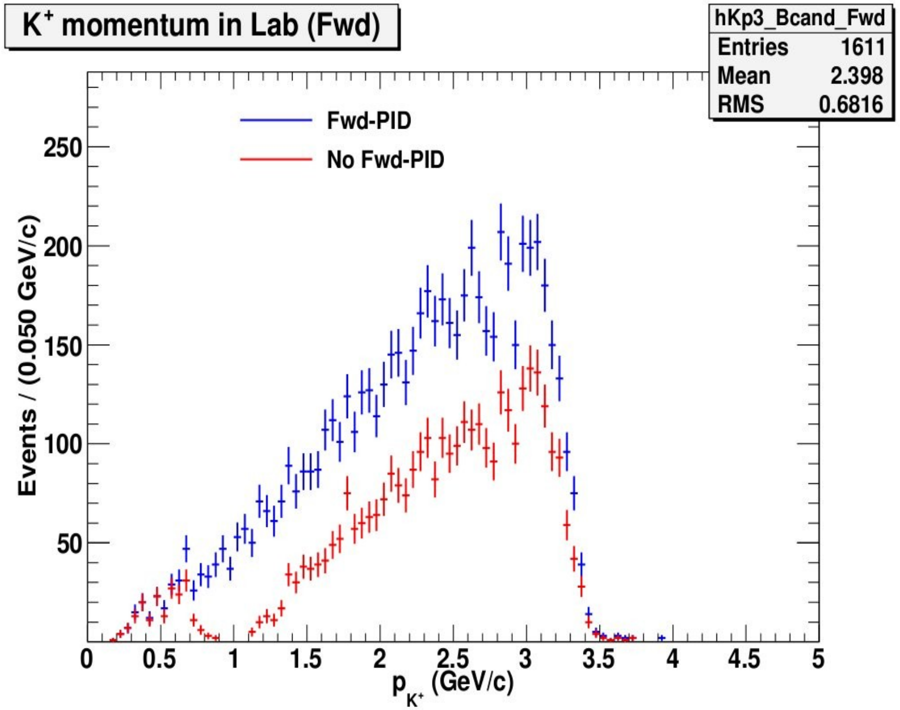


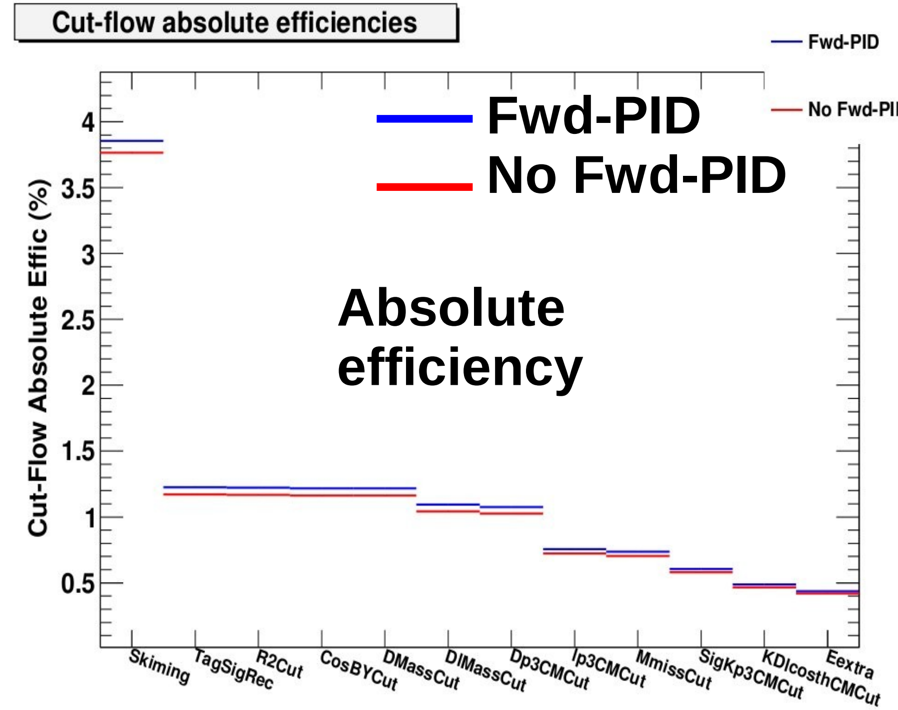


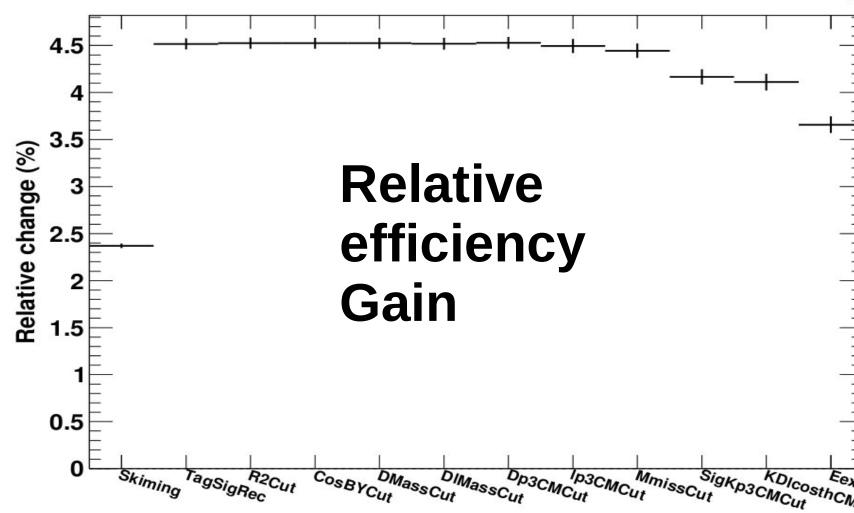
- **fTOF in: number of events in the Fwd gets doubled**

  ⇒ gain on tag-side side ~2.5%

Fwd-PID studies: $B^+ \to K^+ \nu\nu$



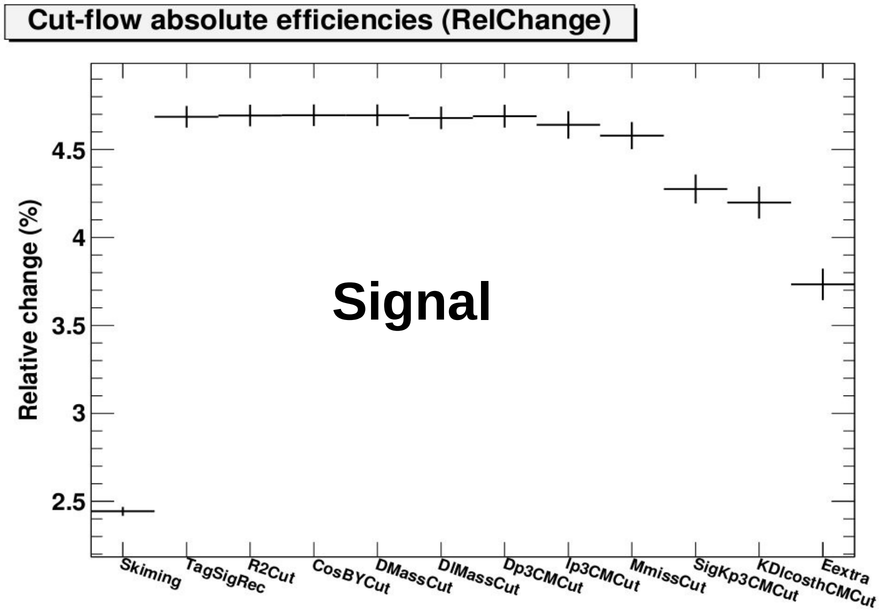




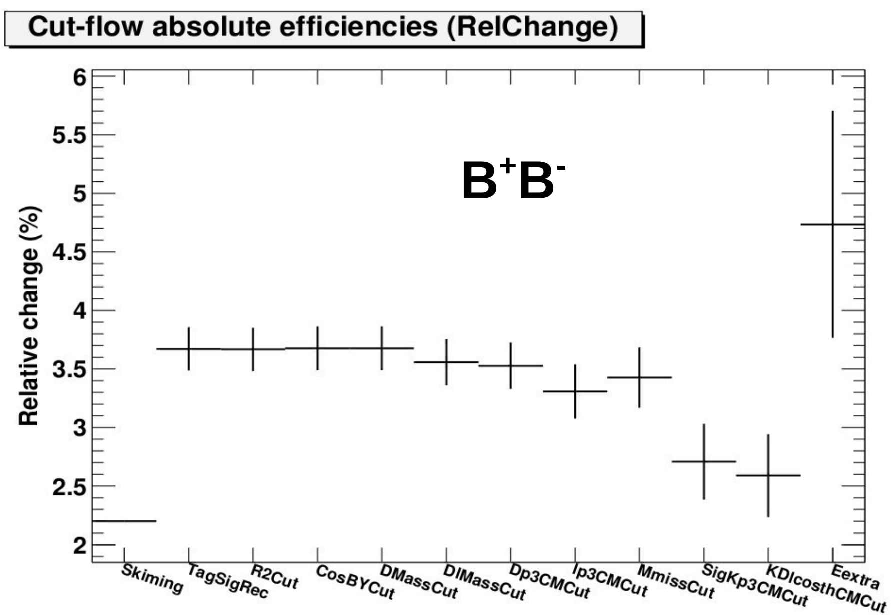
- **Different gain is obtained on the signal-side due to the different Kaon momentum spectrum (harder w.r.t tag-side)**

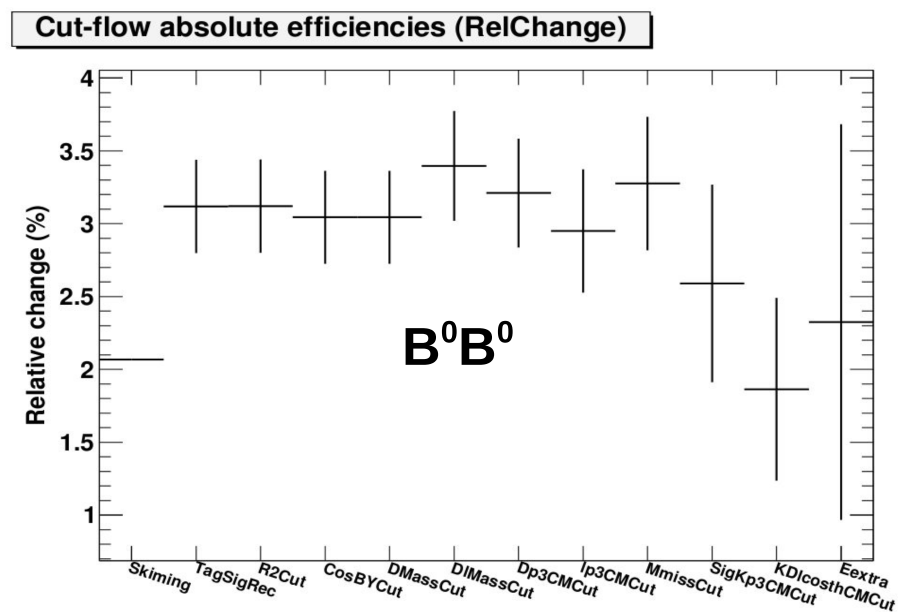
  ⇒ gain in signal-signal side ~2%

Fwd-PID studies: $B^+ \to K^+ \nu\nu$

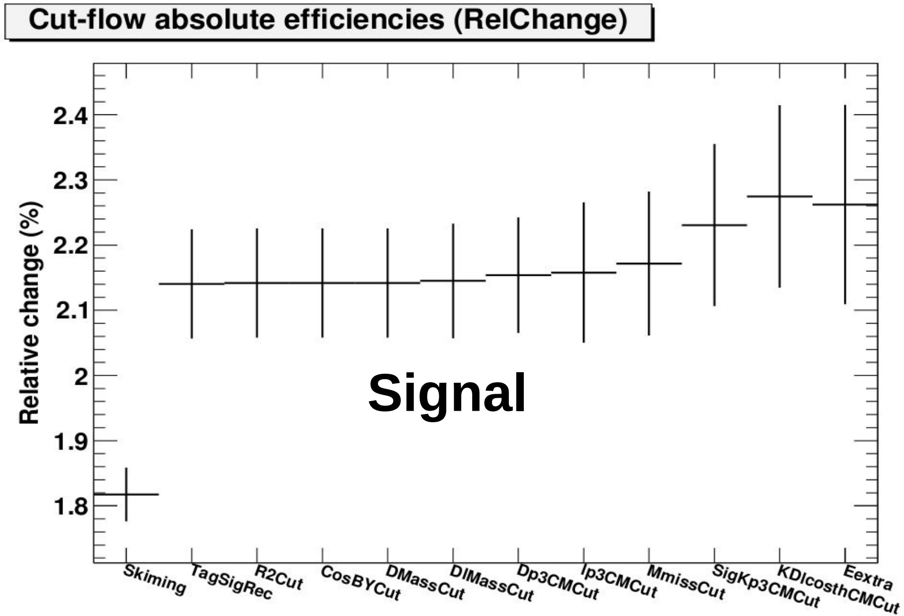


- **Signal: -** Tag-side: 2.4 %
  - Sig-side: 2.1 ± 0.1%
- **B^+B^-:** - Tag-side: 2.0 %
  - Sig-side: 3.3 ± 2.1%
- **B^0B^0:** - Tag-side: 2.0 %
  - Sig-side: 3.5 ± 4.0%

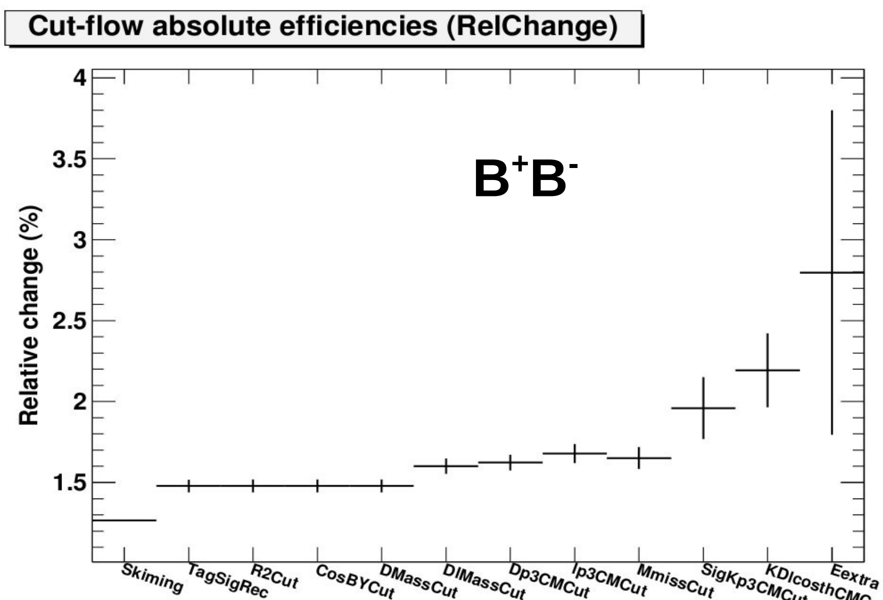


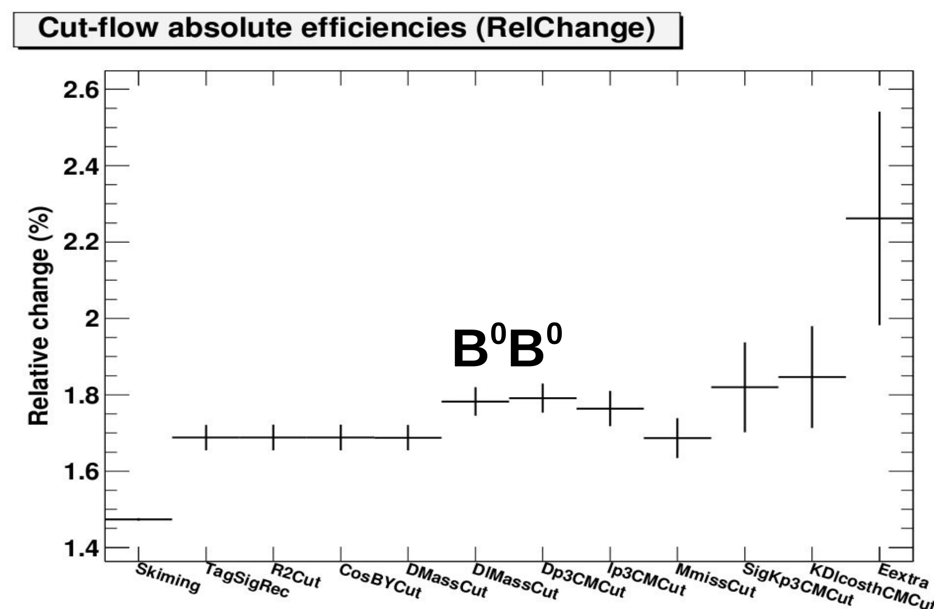


Fwd-PID studies: $B^0 \to K^0 \nu\nu$

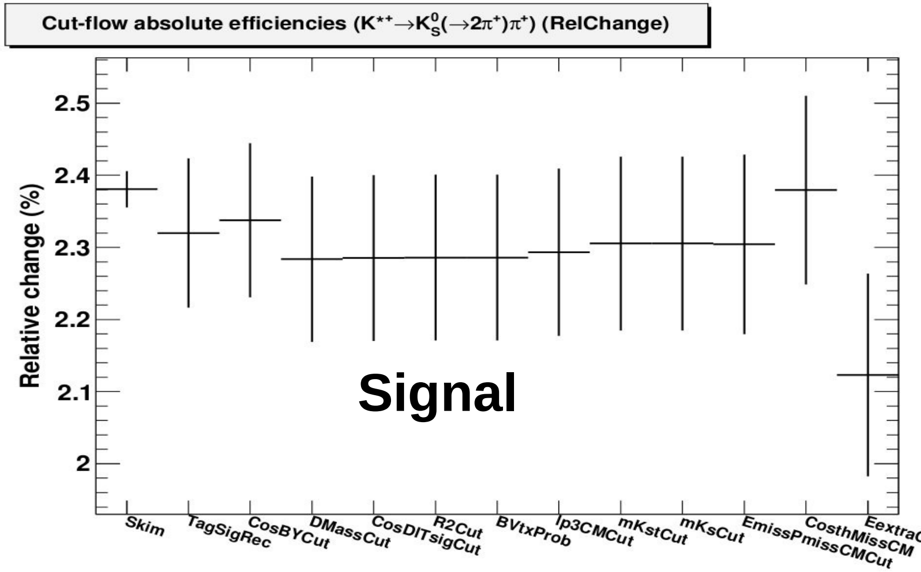


- **Signal: -** Tag-side: 1.8 %
  - Sig-side: 2.1 ± 0.1%
- **B^+B^-:** - Tag-side: 1.3 %
  - Sig-side: 0.2 ± 0.1%
- **B^0B^0:** - Tag-side: 1.5 %
  - Sig-side: 0.2 ± 0.1%



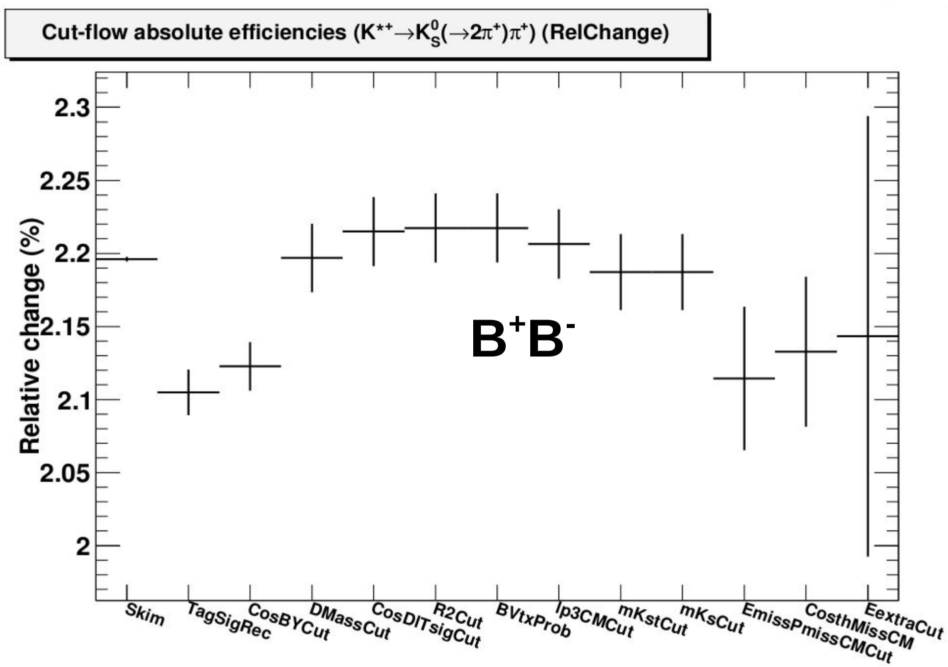


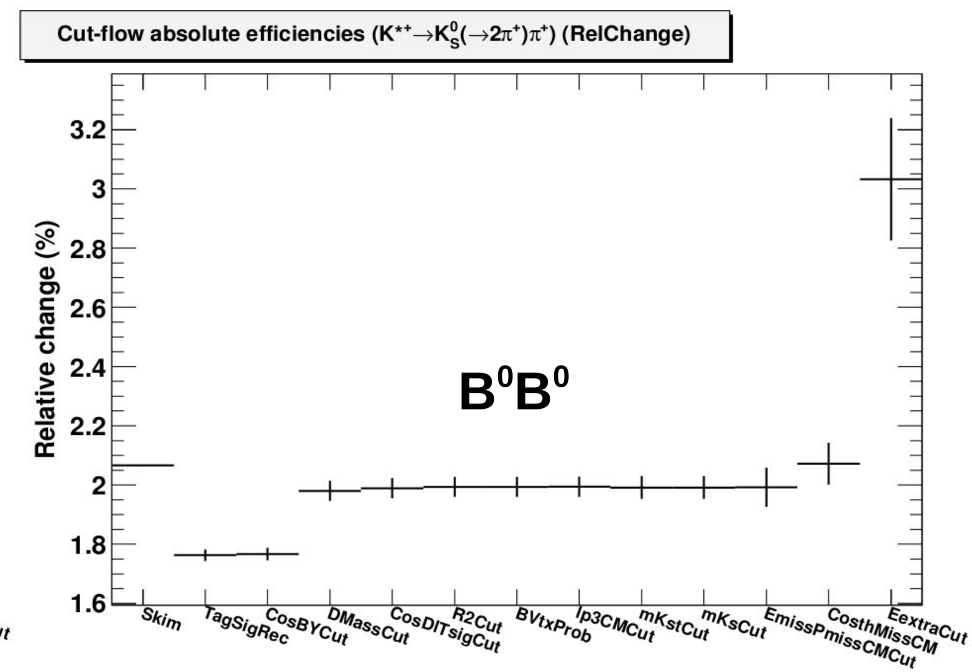
Fwd-PID studies: $B \to K^{*+} \nu\nu$



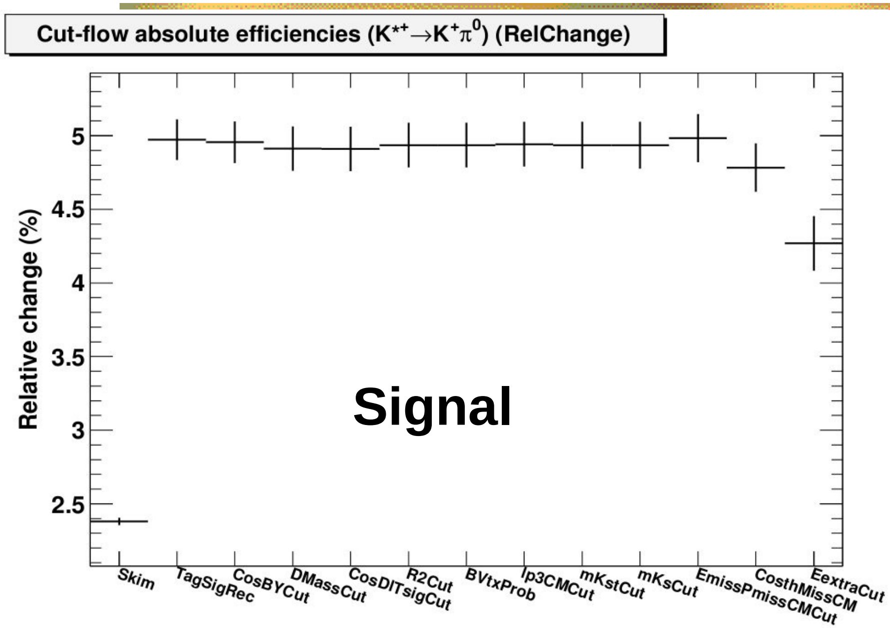
$K^{*+} \to K^0_S(\to 2\pi^+)\pi^+$

- **Signal:** - Tag-side: 2.4 %
  - Sig-side: 0.0 ± 0.15%
- **B^+B^-:** - Tag-side: 2.2 %
  - Sig-side: -0.1 ± 0.2%
- **B^0B^0:** - Tag-side: 2.0 %
  - Sig-side: -0.2 ± 0.1%



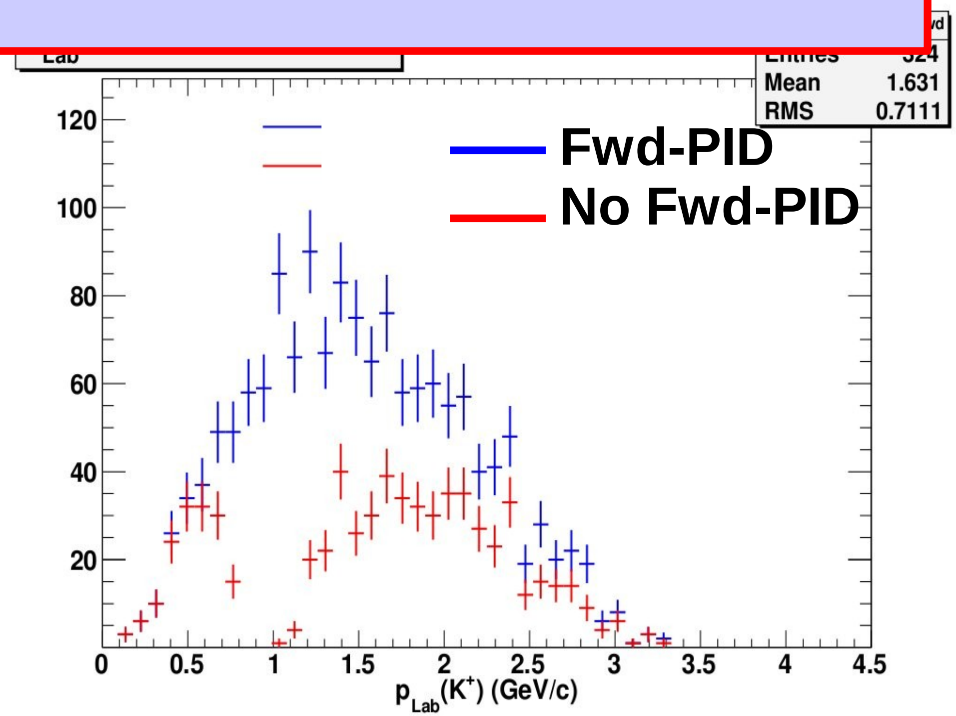


Fwd-PID studies: $B \to K^{*+} \nu\nu$

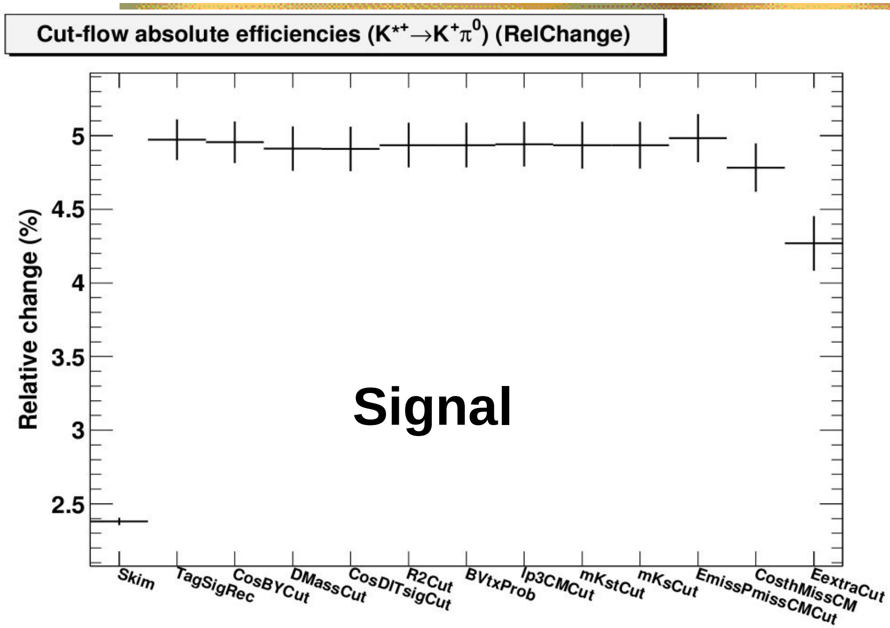


$K^{*+} \to K^+\pi^0$

- **Signal: -** Tag-side: 2.4 %
  - Sig-side: 2.6 ± 0.1%
- **B^+B^-:** - Tag-side: 2.3 %
  - Sig-side: 2.1 ± 0.1%
- **B^0B^0:** - Tag-side: 2.0 %
  - Sig-side: 0.0 ± 0.1%

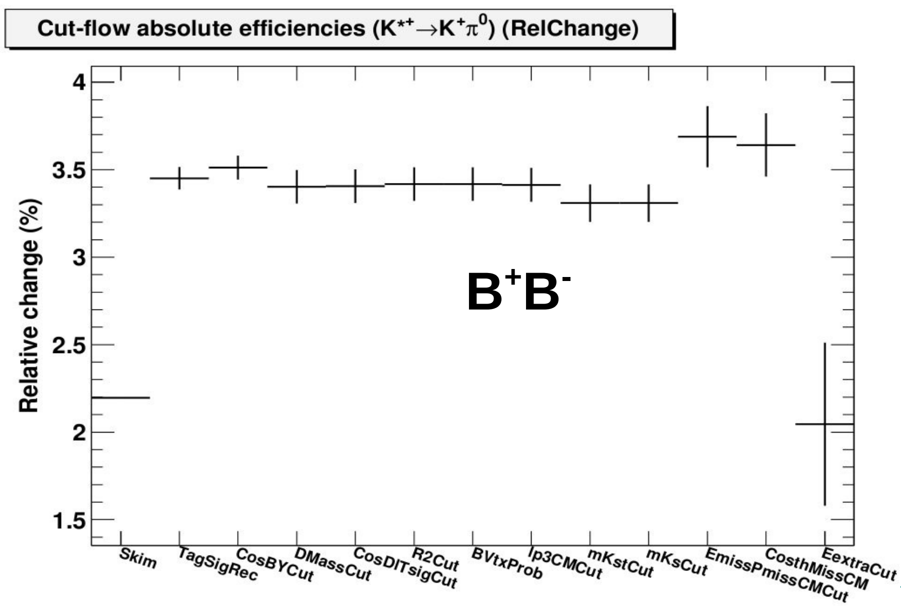


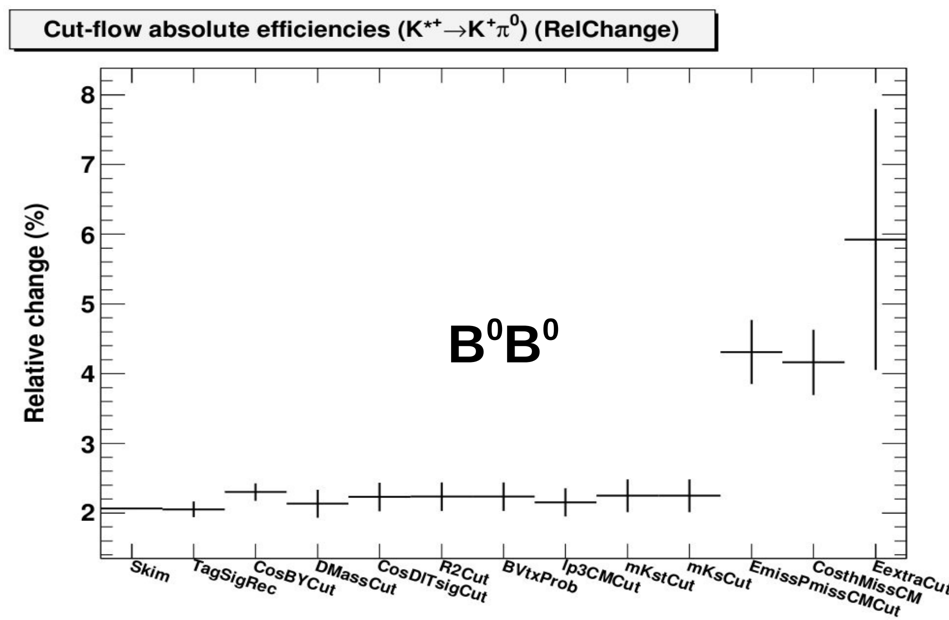
Fwd-PID studies: $B\to K^{*+}\nu\nu$



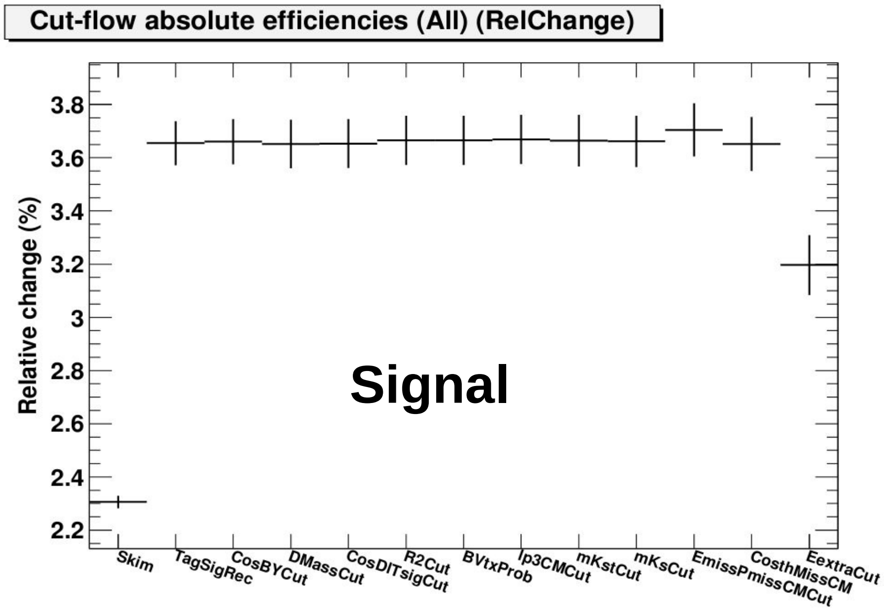
$K^{*+}\to K^+\pi^0$

- **Signal:** - Tag-side: 2.4 %
  - Sig-side: 2.6 ± 0.1%
- **B^+B^-:** - Tag-side: 2.3 %
  - Sig-side: 2.1 ± 0.1%
- **B^0B^0:** - Tag-side: 2.0 %
  - Sig-side: 0.0 ± 0.1%



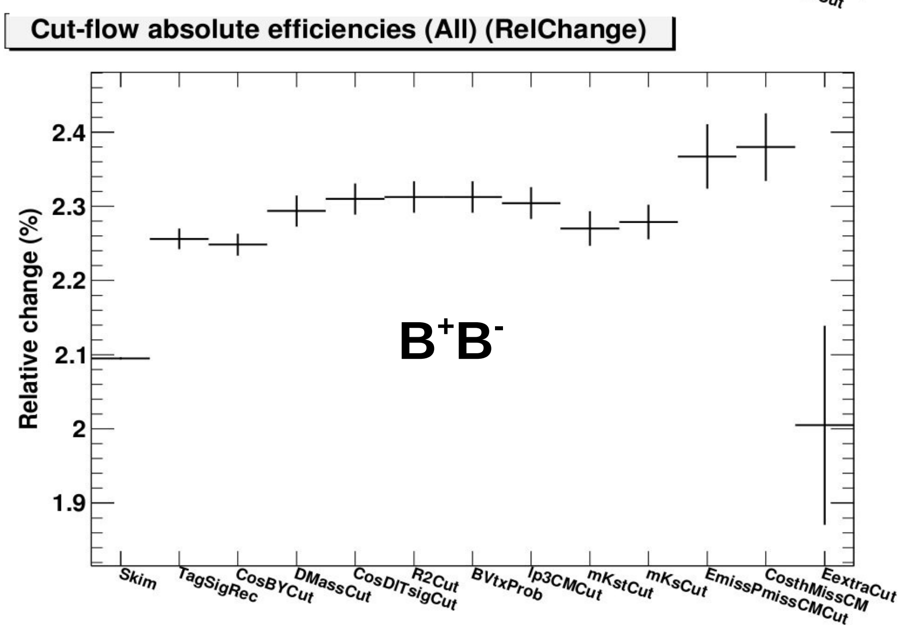


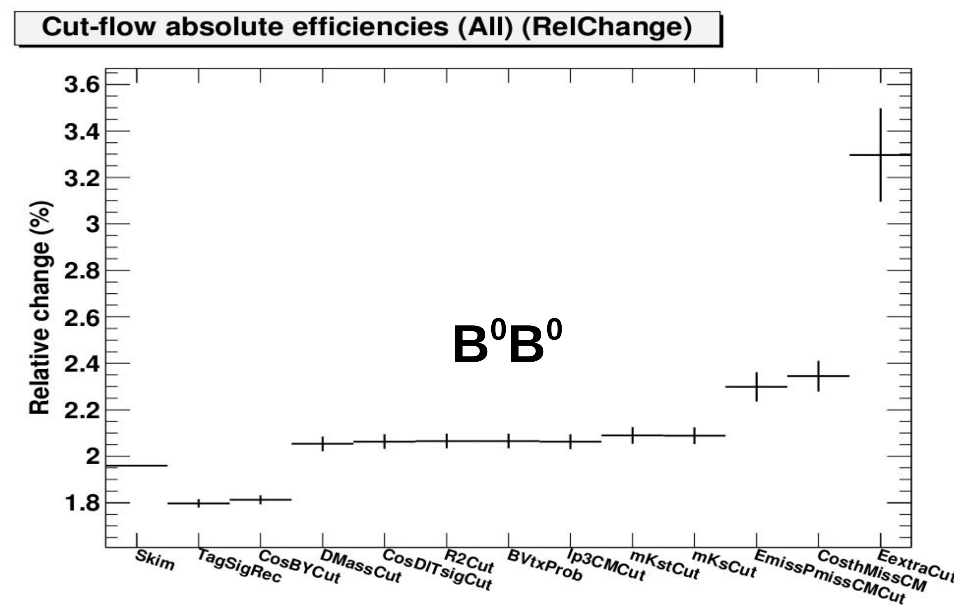
Fwd-PID studies: $B \to K^{*+} \nu\nu$



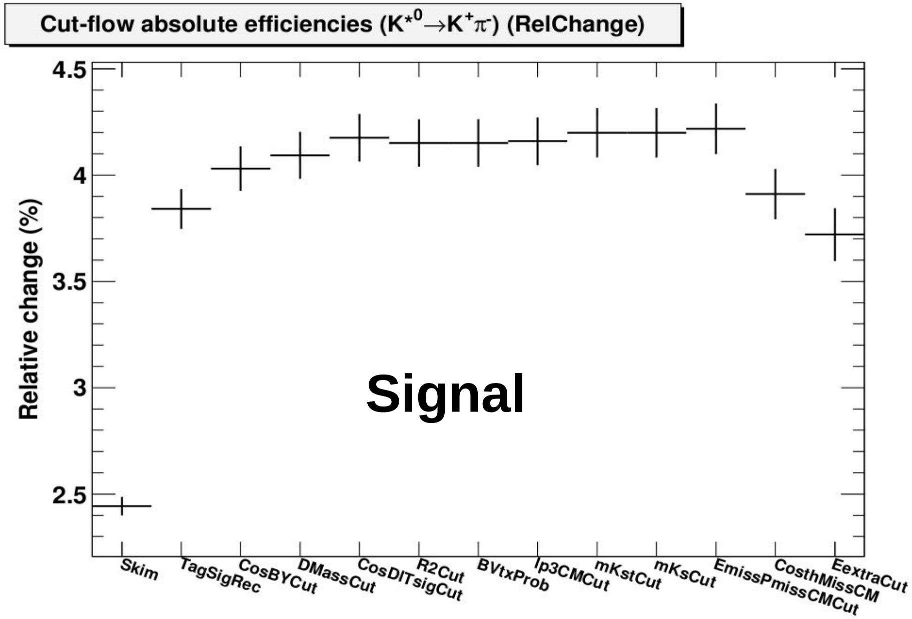
All K^{*+} modes

- **Signal: -** Tag-side: 2.3 %
  - Sig-side: 1.4 ± 0.3%
- **B^+B^-:** - Tag-side: 2.1 %
  - Sig-side: 0.2 ± 0.2%
- **B^0B^0:** - Tag-side: 2.0 %
  - Sig-side: 0.2 ± 0.1%



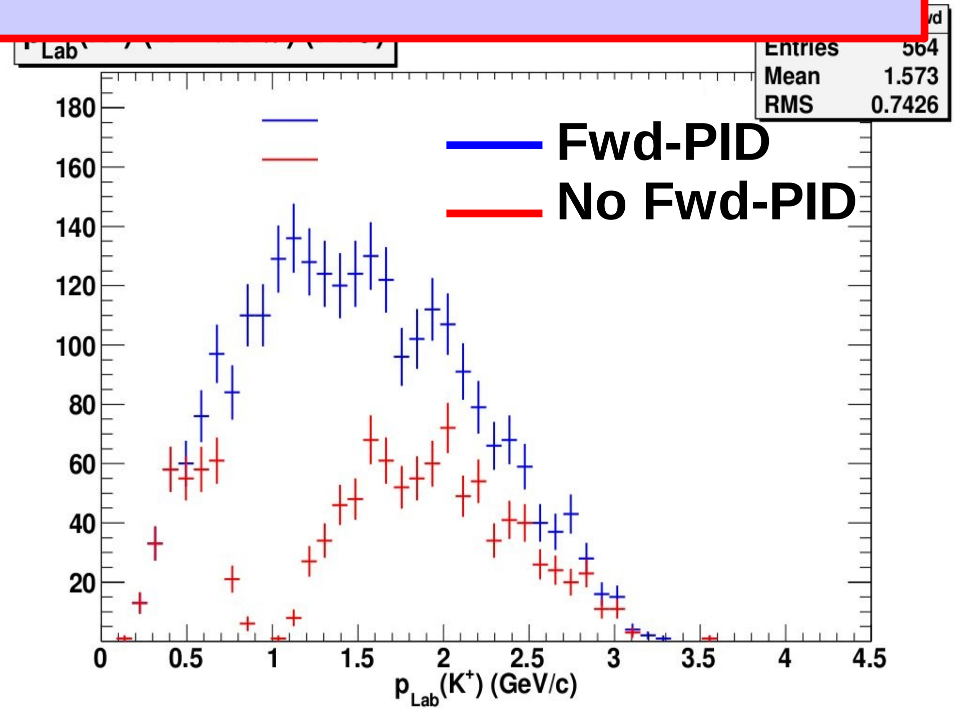


Fwd-PID studies: $B \to K^{*0} \nu \nu$

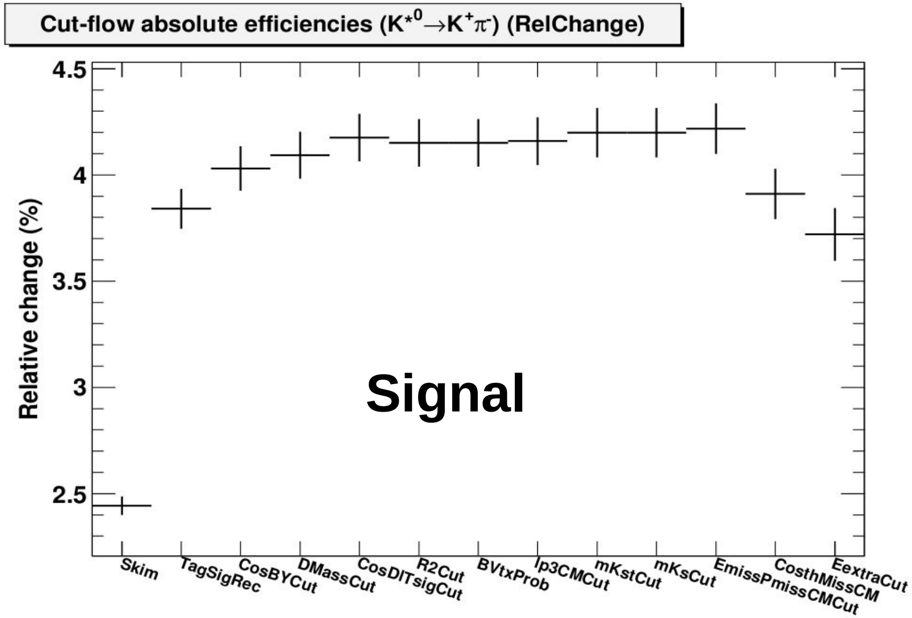


$K^{*0} \to K^+ \pi^-$

- **Signal: -** Tag-side: 2.5 %
  - Sig-side: 1.4 ± 0.1%
- **B^+B^-:** - Tag-side: 1.2 %
  - Sig-side: 2.8 ± 0.1%
- **B^0B^0:** - Tag-side: 1.6 %
  - Sig-side: 1.4 ± 0.1%

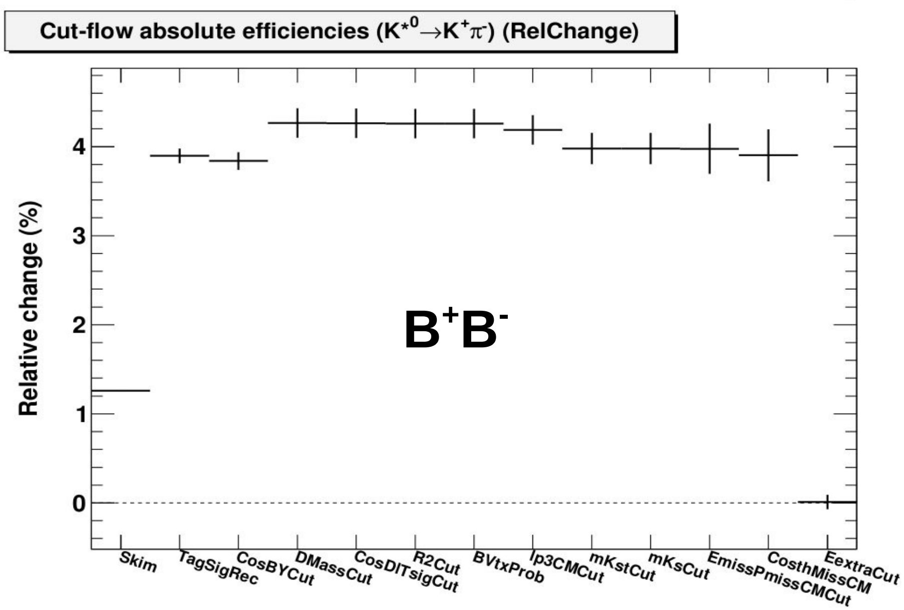


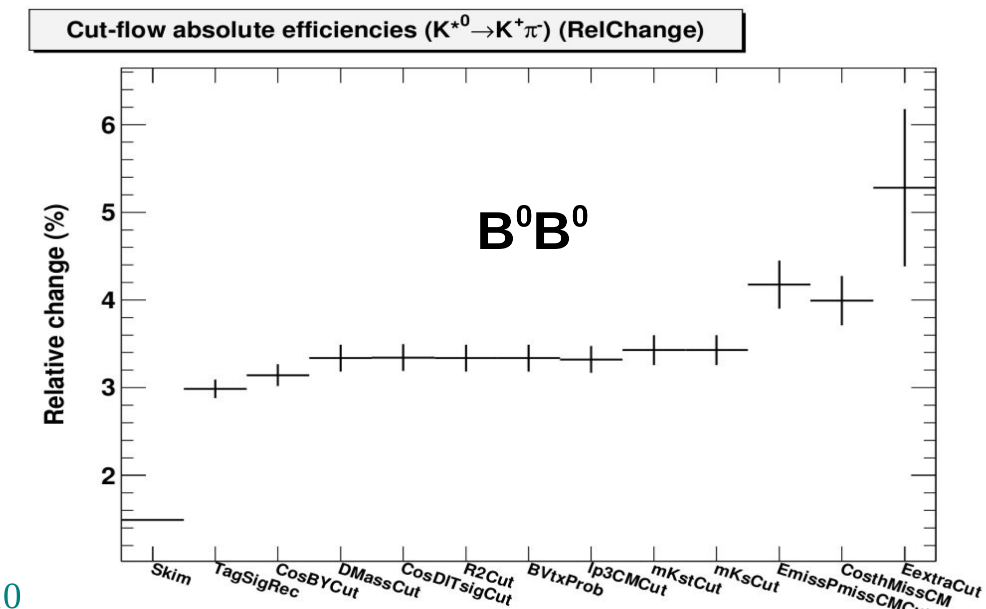
Fwd-PID studies: $B \to K^{*0} \nu\nu$



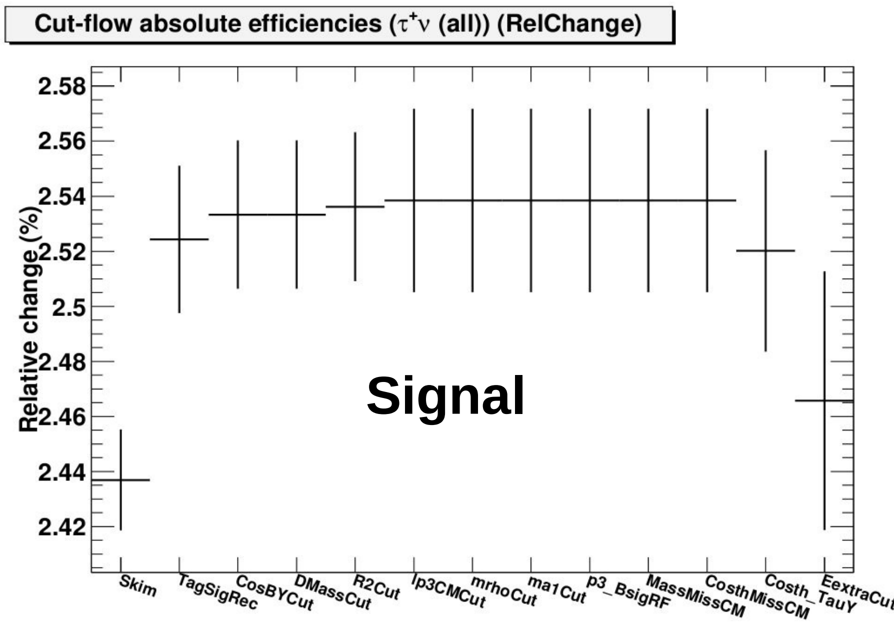
$K^{*0} \to K^+ \pi^-$

- **Signal:** - Tag-side: 2.5 %
  - Sig-side: 1.4 ± 0.1%
- **B^+B^-:** - Tag-side: 1.2 %
  - Sig-side: 2.8 ± 0.1%
- **B^0B^0:** - Tag-side: 1.6 %
  - Sig-side: 1.4 ± 0.1%

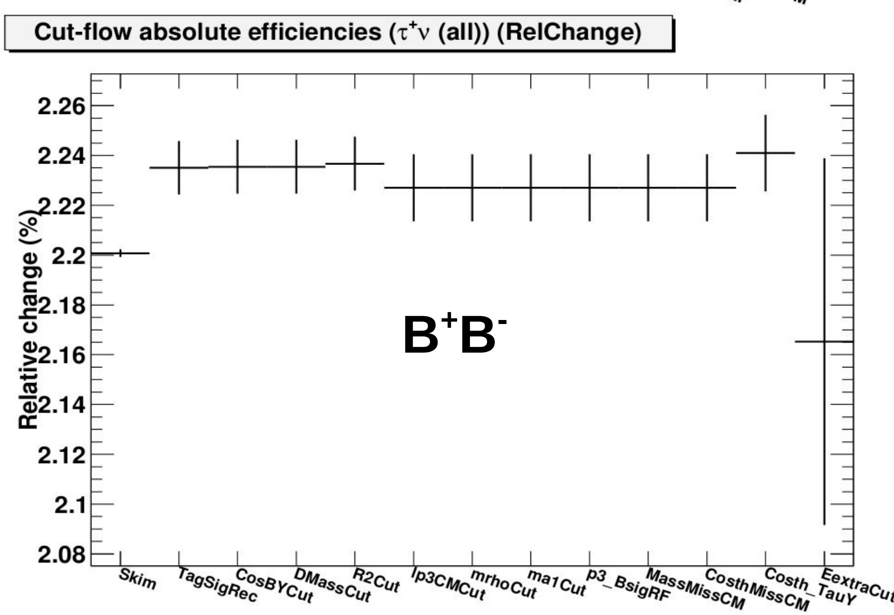


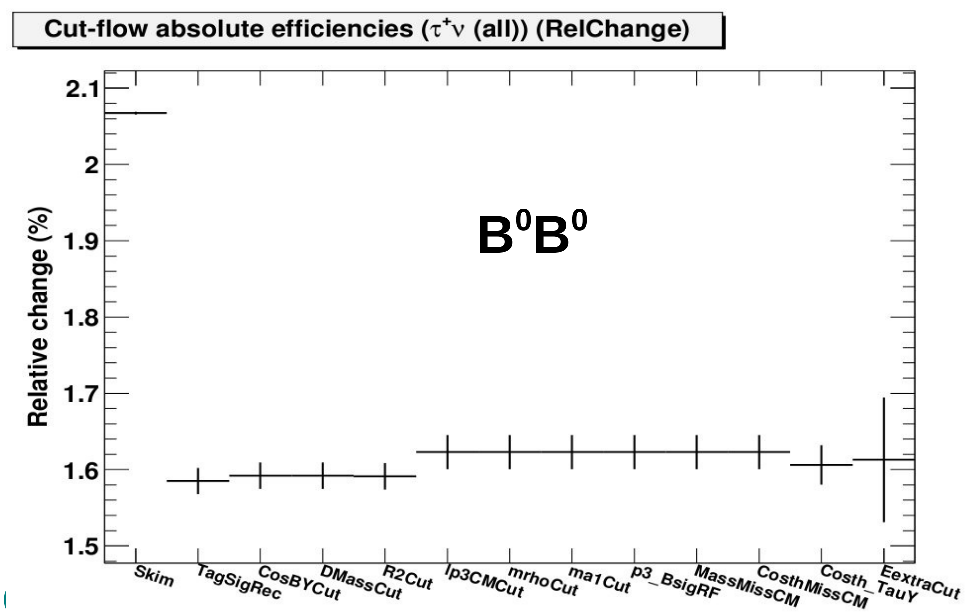


Fwd-PID studies: $B \to \tau^+ \nu$



- **Signal:** - Tag-side: 2.4 %
  - Sig-side: 0.1 ± 0.02%
- **B^+B^-:** - Tag-side: 2.1 %
  - Sig-side: 0.04 ± 0.02%
- **B^0B^0:** - Tag-side: 2.1 %
  - Sig-side: -0.4 ± 0.1%

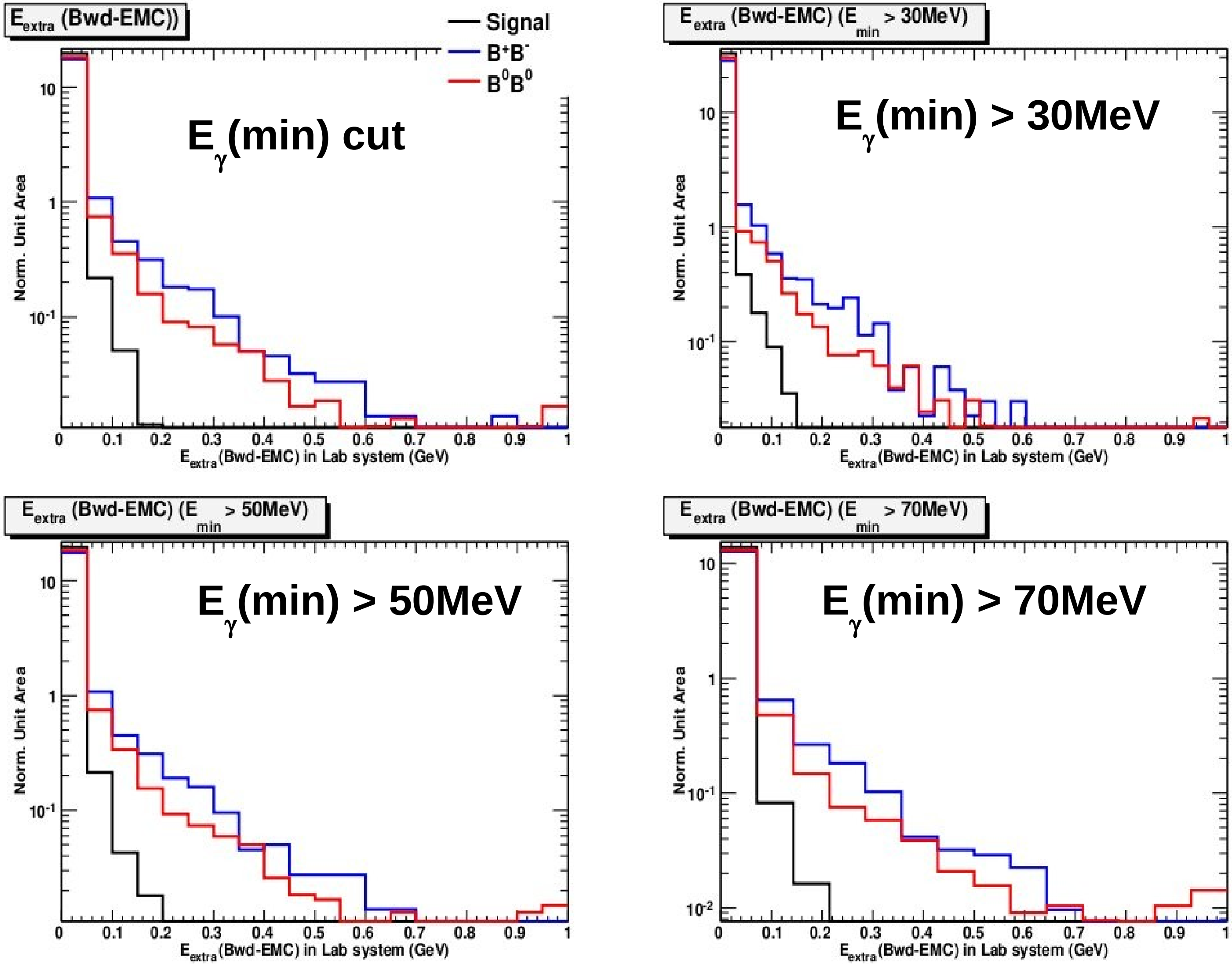




Results on Bwd-EMC Studies

Bwd-EMC studies: B→Kνν

Signal
B^+B^-
B^0B^0

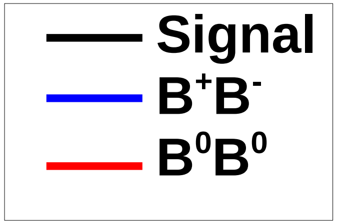


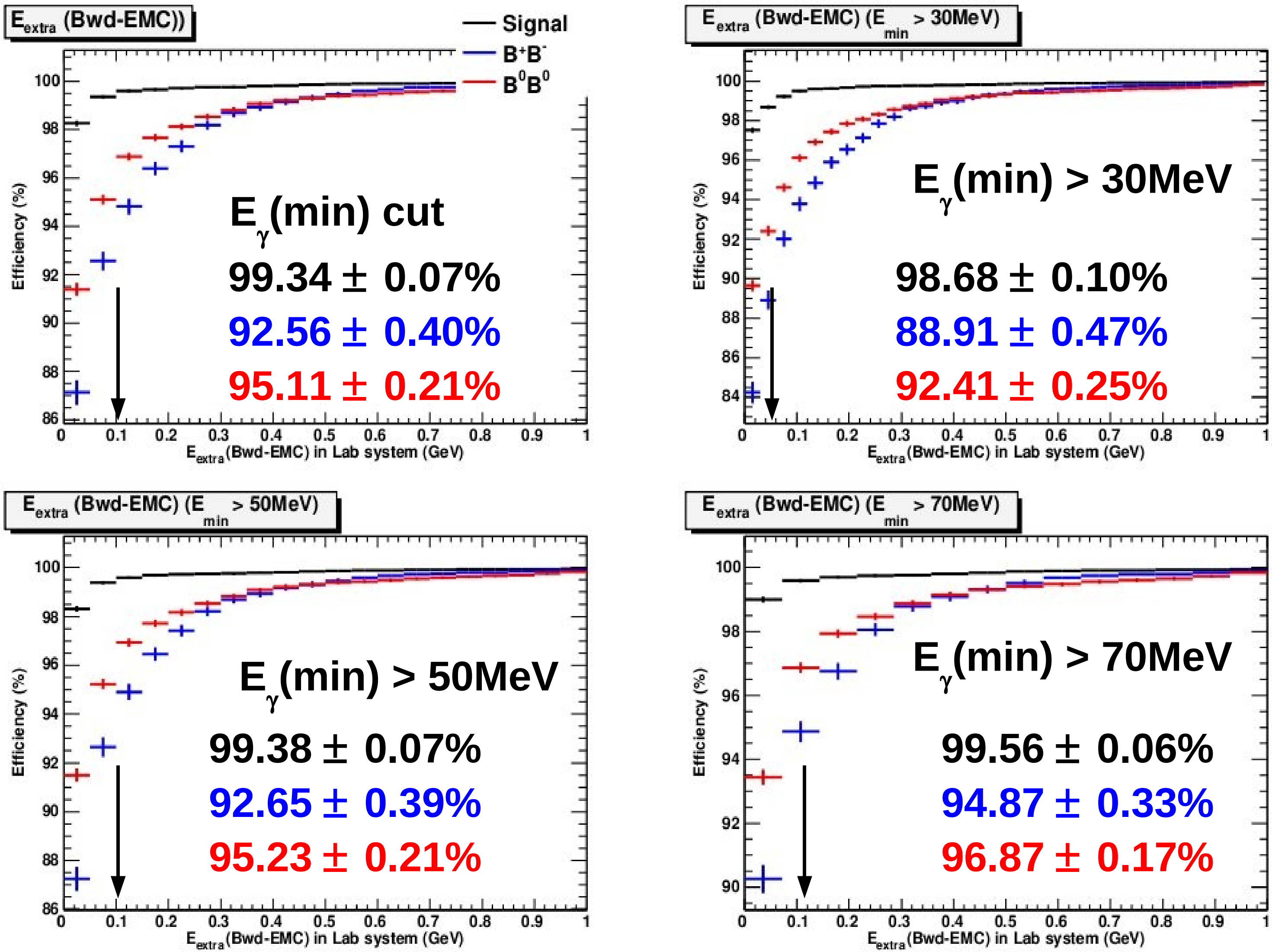
E_{extra}(Bwd-EMC) (GeV)

Warning: log-scale in the vertical scale

Backgrounds have longer tails to high values w.r.t signal

Bwd-EMC studies: B→Kνν



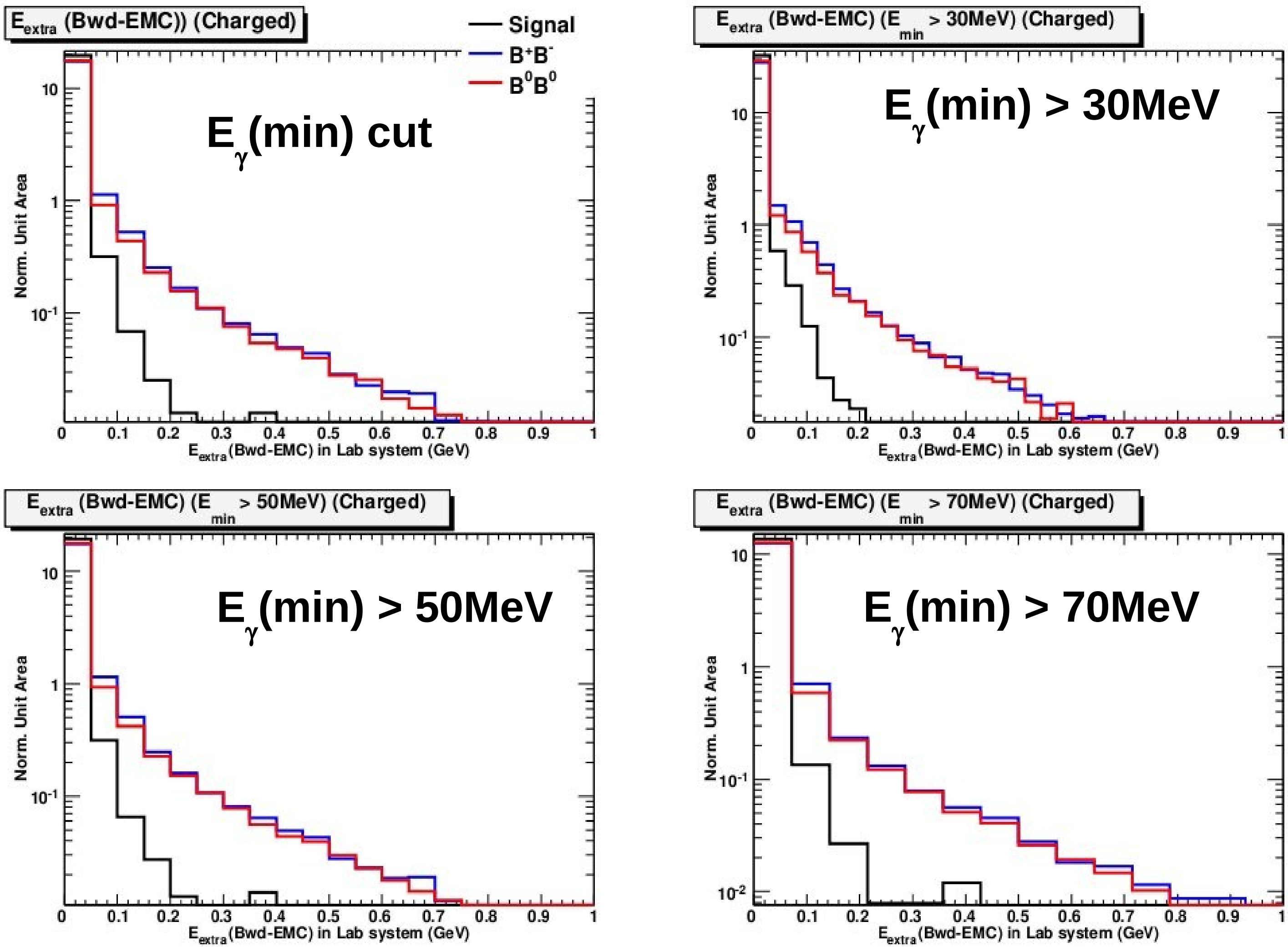


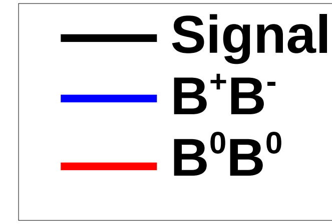
Seems that it is better to use E_γ(min) > 30MeV

Could reduce backgrounds by around 10%

E_{extra}(Bwd-EMC) (GeV)

Bwd-EMC studies: $B \to K^{*} \nu \nu$



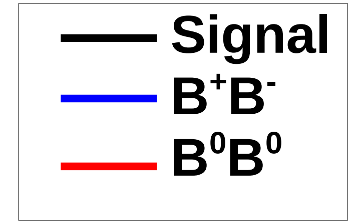


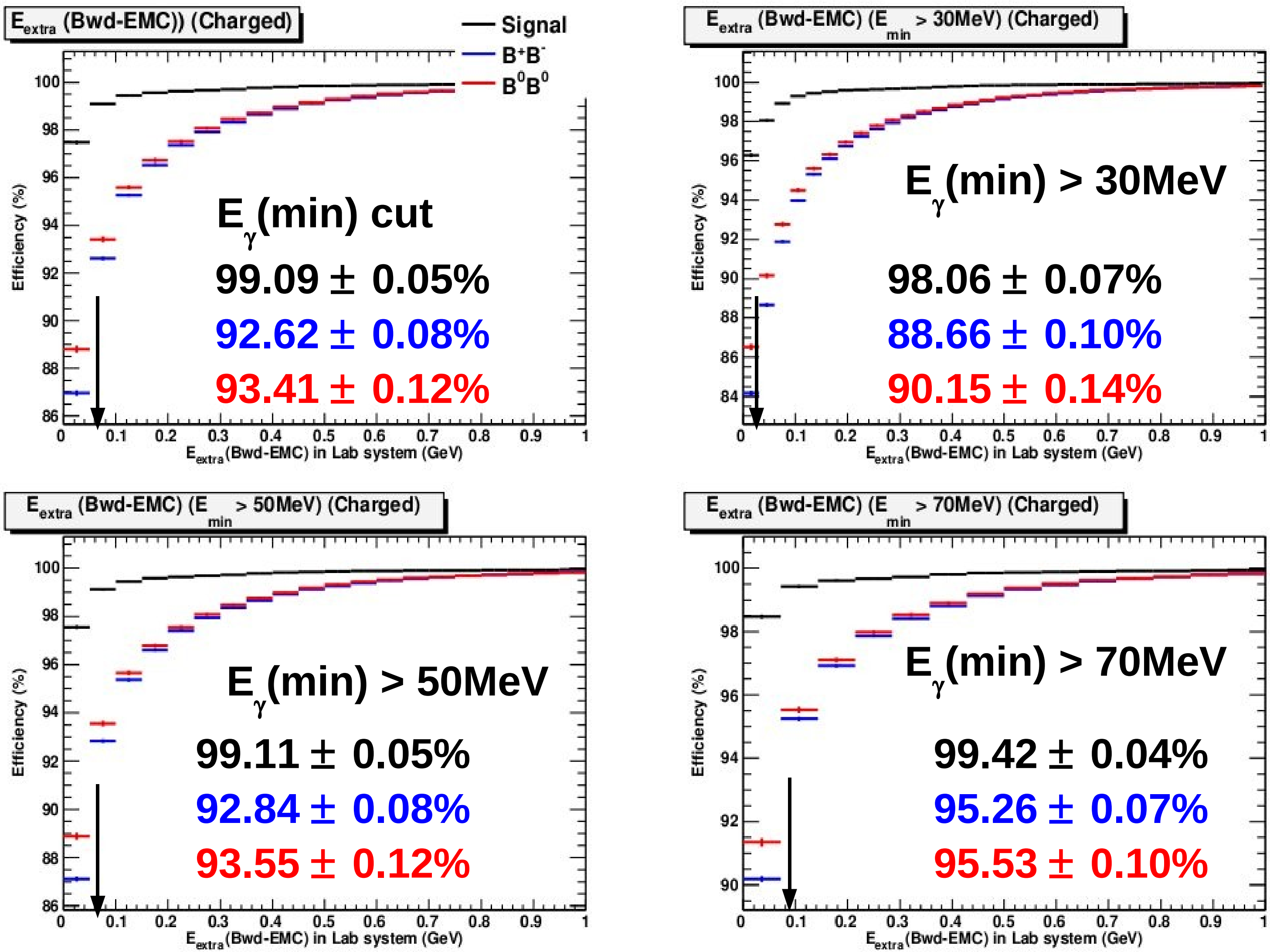
E_{extra}(Bwd-EMC) (GeV)

Warning: log-scale in the vertical scale

Backgrounds have longer tails to high values w.r.t signal

Bwd-EMC studies: $B \to K^* \nu\nu$



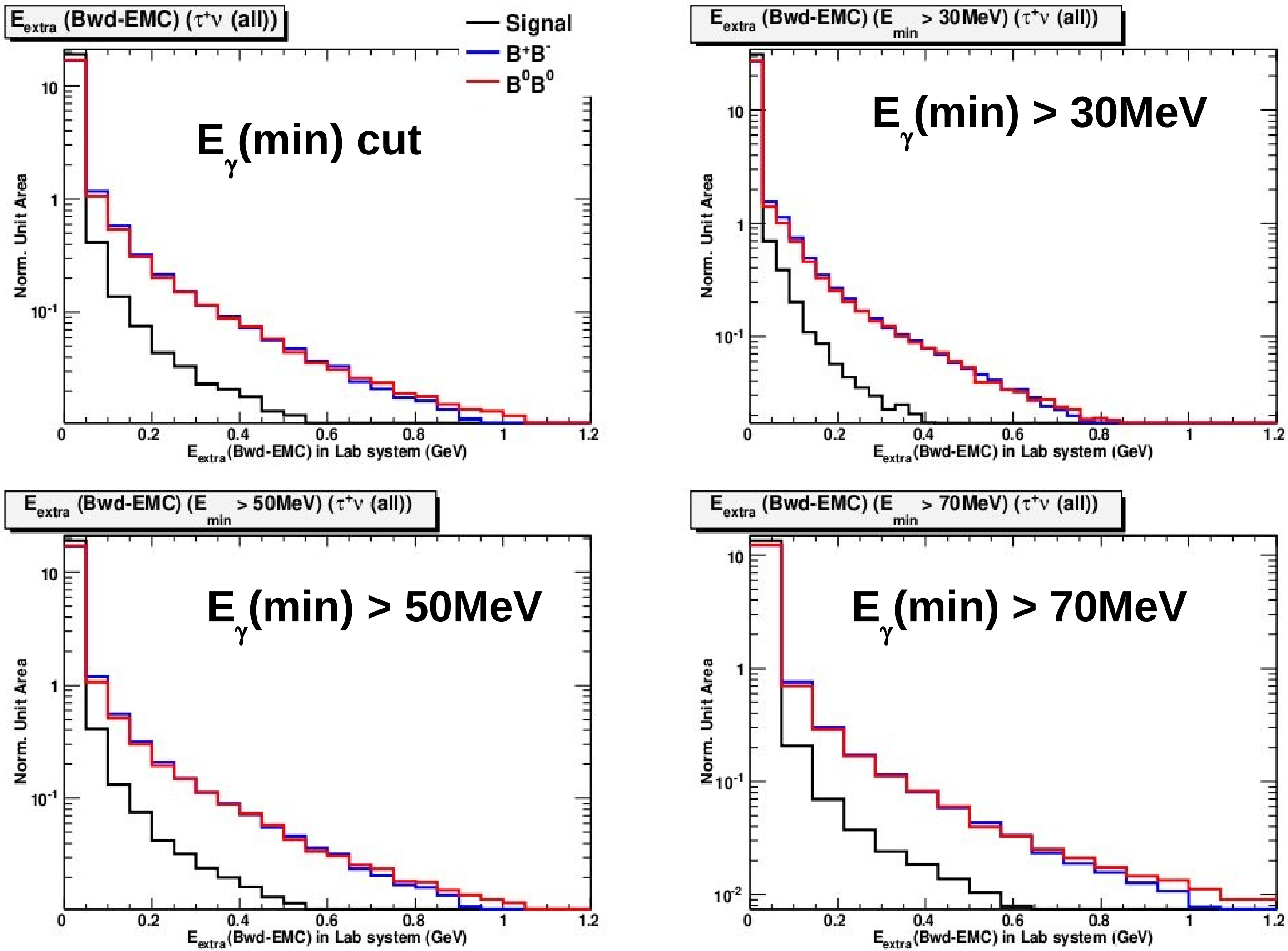


E_{extra}(Bwd-EMC) (GeV)

Seems that it is better to use E_γ(min) > 30MeV

Could reduce backgrounds by around 10%

Bwd-EMC studies: $B \to \tau^+ \nu$



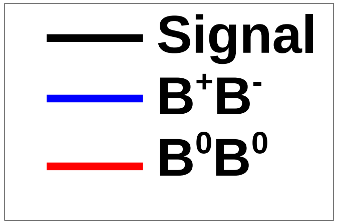
E_{extra}(Bwd-EMC) (GeV)

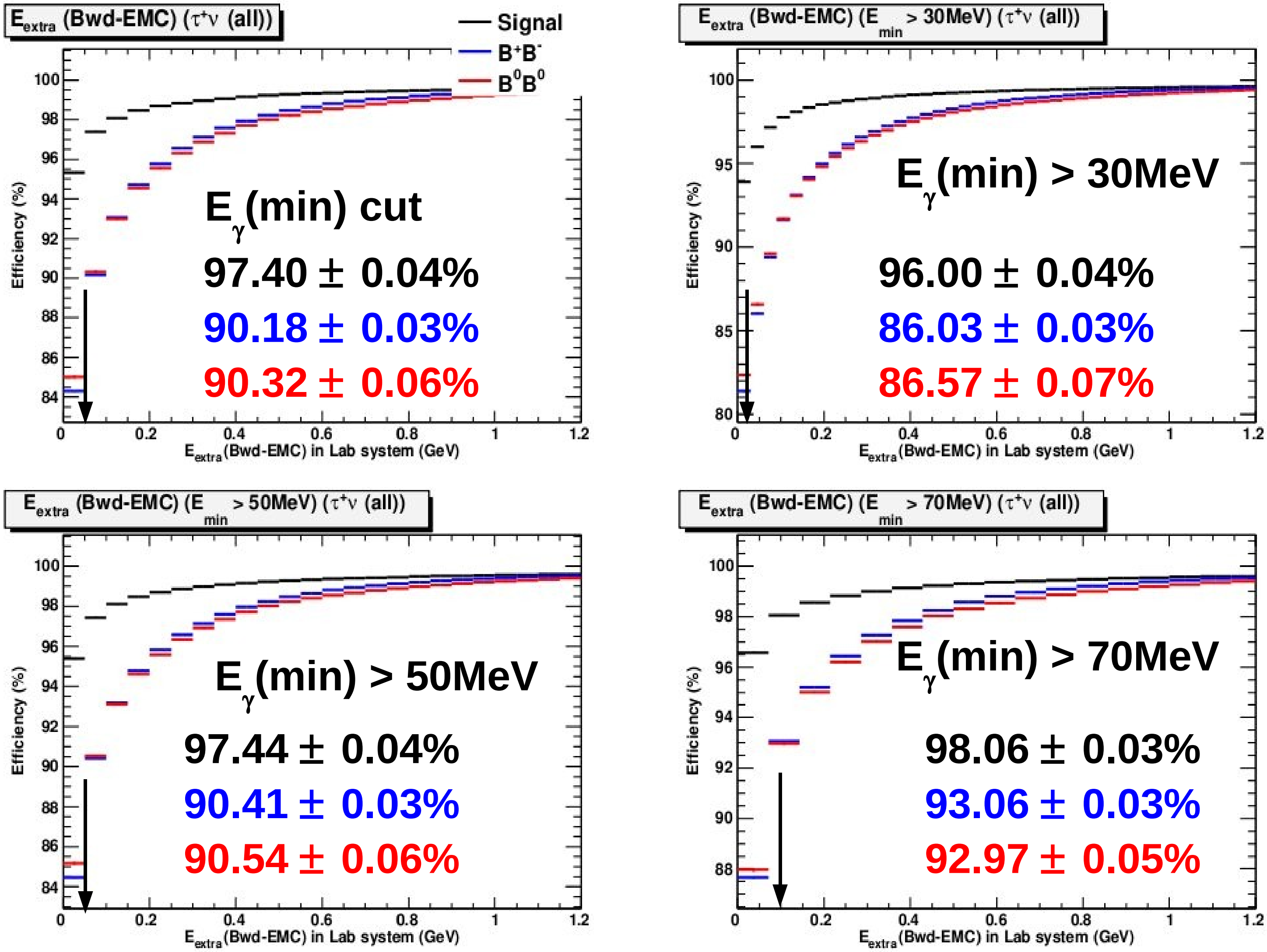
Signal
B^+B^-
B^0B^0

Warning: log-scale in the vertical scale

Backgrounds have longer tails to high values w.r.t signal

Bwd-EMC studies: $B \rightarrow \tau^+ \nu$





E_{extra}(Bwd-EMC) (GeV)

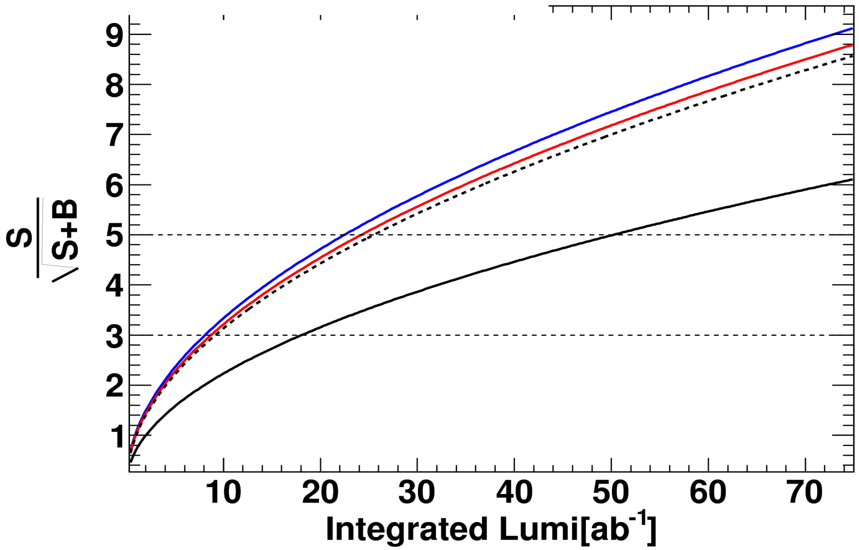
Seems that it is better to use E_γ(min) > 30MeV

Could reduce backgrounds by around 10-14%

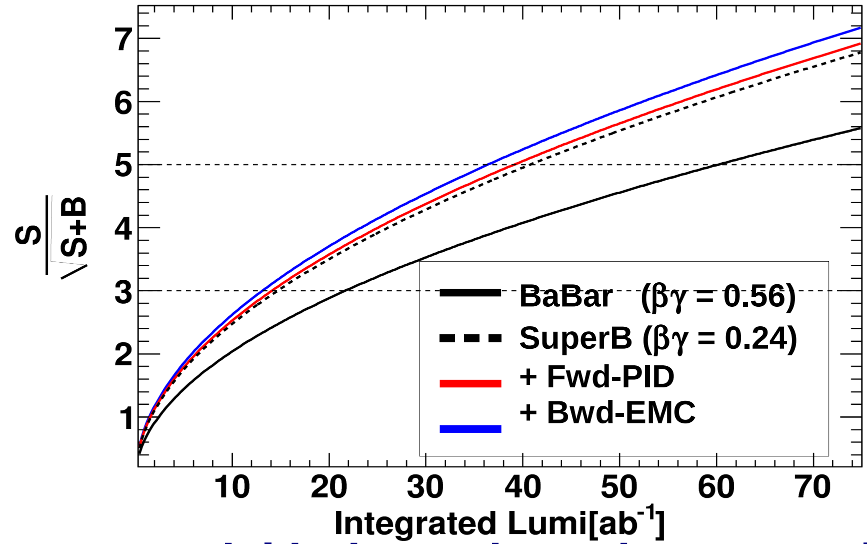
Expected SuperB Sensitivities

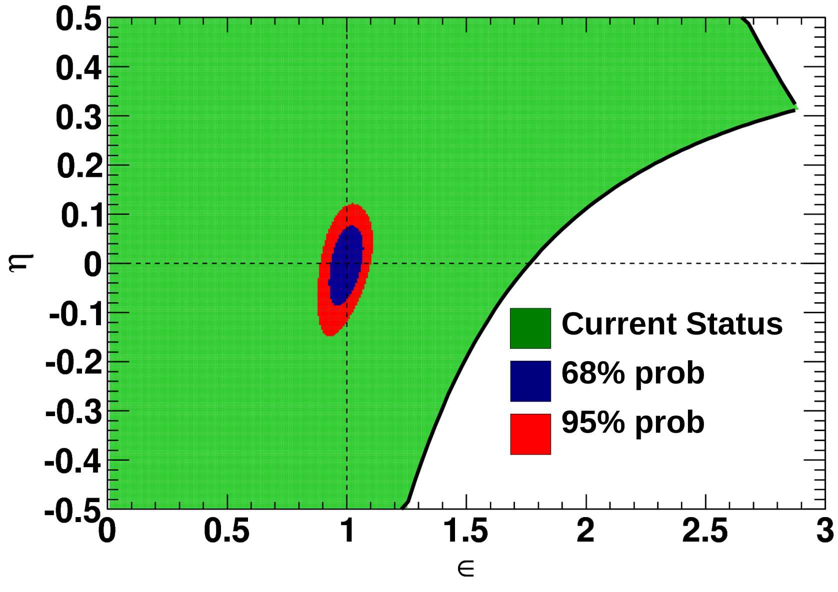
Expected sensitivities: $B \to K^{(*)}\nu\nu$

BR(B→Kνν)



BR(B→K*νν)





$b \to s\nu\nu$ model independent phenomenology:

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

- $BR(B \to K\nu\nu) = (4.5 \pm 0.7) \times 10^{-6}\,(1-2\eta)\varepsilon^2$
- $BR(B \to K^*\nu\nu) = (6.8 \pm 1.1) \times 10^{-6}\,(1+1.31\eta)\varepsilon^2$
- $F_L(B \to K^*\nu\nu) = (0.54 \pm 0.01)\,(1+2\eta)/(1+1.31\eta)$

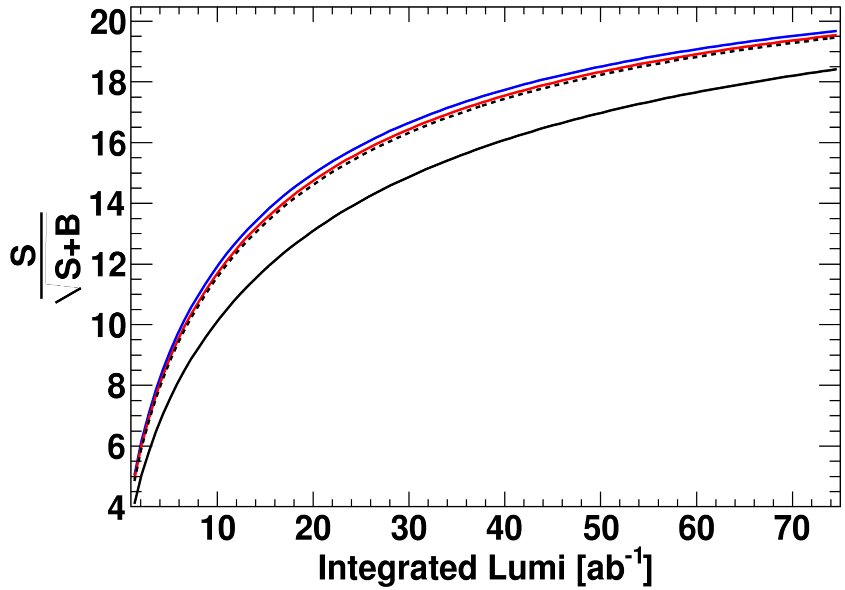
$$\frac{d\Gamma}{d\cos\theta} \propto \frac{3}{4}(1- < F_L >)\sin^2\theta + \frac{3}{2} < F_L > \cos^2\theta$$

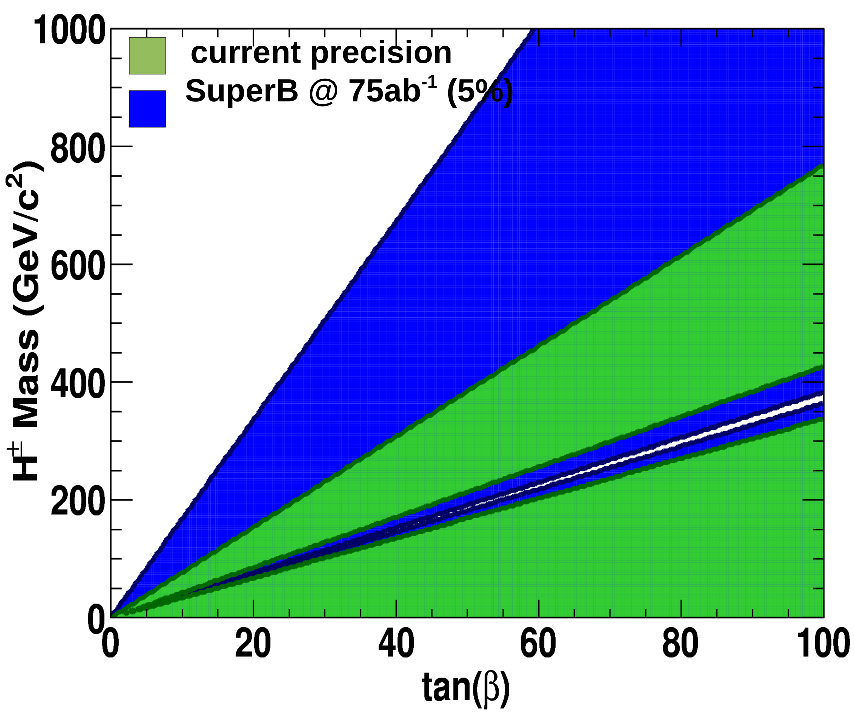
θ(helicity) = angle between:

- K* direction in B rest frame
- K direction in K* rest frame

Expected sensitivities: $B\to\tau^+\nu$

- **Assumptions:**
  - statistical error scales with luminosity
  - Main systematic error (E_{extra} bkg PDF) mainly due to MC statistics, ⇒ assume it scales with luminosity
  - Syst. on tag/signal efficiencies and BB counting (7%⊕5%⊕1.1% = 8.7%) seems to be irreducible. Suppose that it can be reduced by 50%





- **Assumptions:**

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

- BR_{exp} central value is SM value
- BR_{SM} = $(1.20\pm0.20)\times10^{-4}$ uncertainties mainly due to f_B = 190 ± 13 MeV, V_{ub} = $(4.32 \pm 0.16 \pm 0.29)\times10^{-3}$
- f_B error (lattice QCD): 1.0-1.5% for SuperB
- V_{ub}: 1st error is statistical (scales with lumi)
  2nd error is systematics (irreducible)

Summary and outlook

- **Boost reduction:**
  - Signal: efficiency decreases/increases from -8% to 20% depending on the mode
  - Bkg: efficiency get always reduced from -60% to -20% depending on the mode
- **Fwd-PID studies:**
  - Gain from 2.0 to 2.5% per identified kaon (depends on momentum spectrum)
  - Signal samples with (without) a charge kaon on signal-side get an overall relative increase on efficiency of ~4.5% (~2.5%)
  - Background samples efficiency increases due to better tag-side efficiency, not significant increase on signal-side efficiency (error bars still big)
- **Bwd-EMC studies:**
  - All analyses give similar performances for this device
  - It seems that we can reduce the two main background samples by about ~10% with negligible reduction on signal efficiency using $E\gamma(\text{min}) > 30\text{MeV}$
- **Many thanks to the production team who provided the samples needed for these studies**

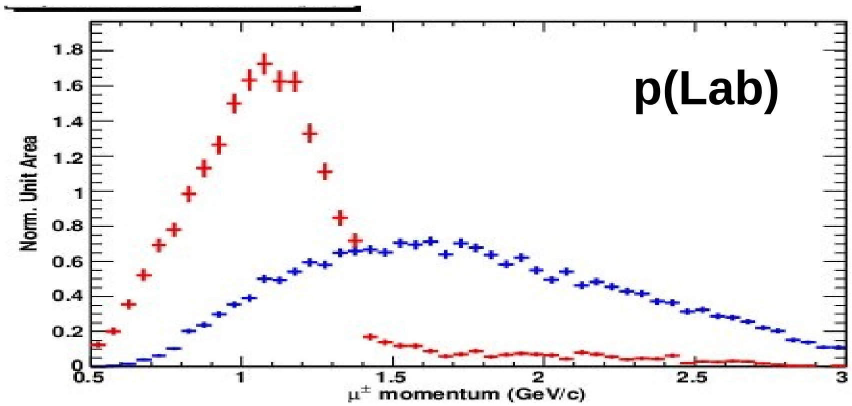
Backup

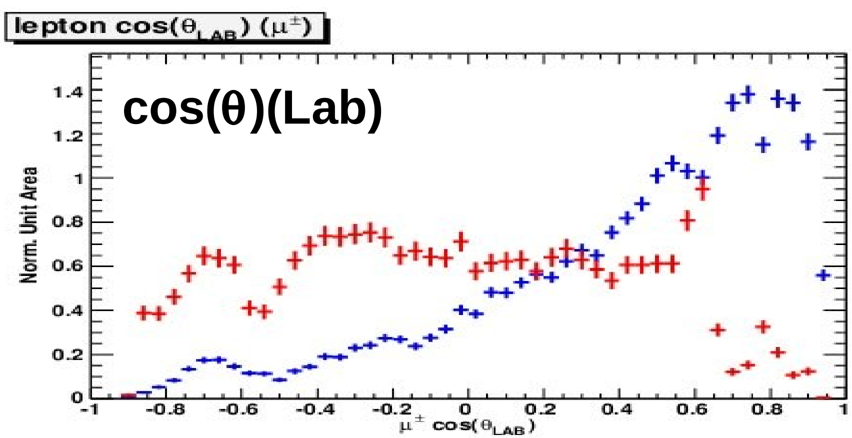
Full Sim

Fast Sim

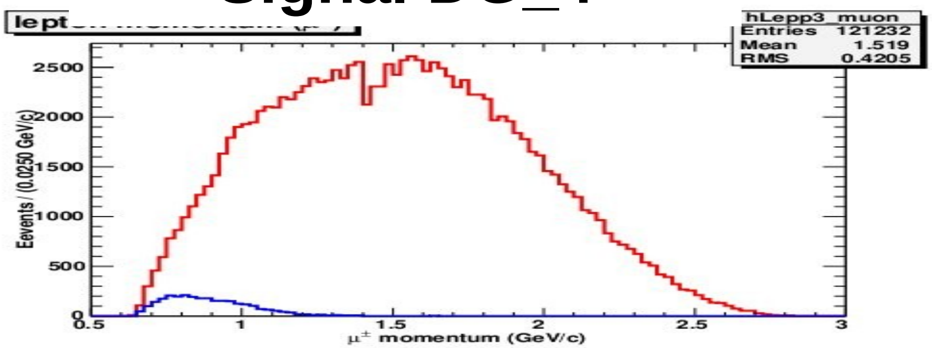
Variable: p*(muon)

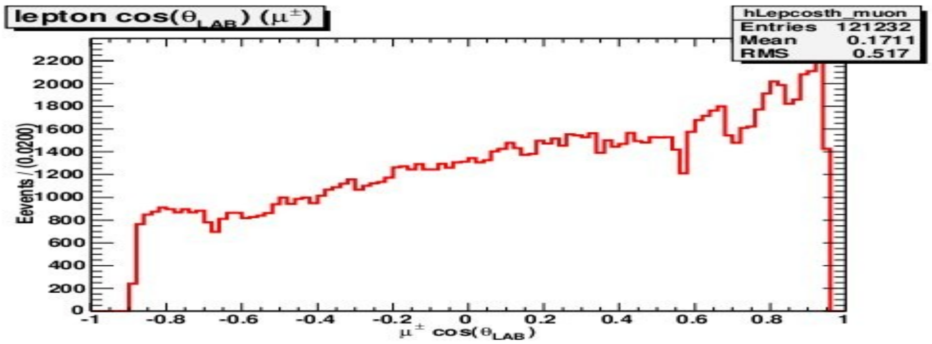
Signal DG_BaBar





Signal DG_4





Strange muon momentum and cos(θ) distribution only for DG_BaBar