Fwd PID performance studies with K(*)nunu SL BReco

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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

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Outline

- Reminder: Semi-Lep-Breco ($B^+ \to K^+ \nu\nu$ and $B \to K^* \nu\nu$)
- $B^+ \to K^+ \nu\nu$ analysis
  - Background studies
  - Efficiency gains with Dec. Improvements (Fwd-PID)
- $B^+ \to K^* \nu\nu$ analysis
  - Background studies
  - Efficiency gains with Dec. Improvements (Fwd-PID)
- Summary

Semi-Leptonic Breco (I)

- D^0/D^+ reconstructed in 6 decays channels:
  - $D^0 \to K^-\pi^+, K^-\pi^+\pi^-\pi^+, K^-\pi^+\pi^0, K^0_S\pi^+\pi^-$
  - $D^+ \to K^-\pi^+\pi^-, K^0_S\pi^+$
- Also look also for D* decays:
  - $D^{*+} \to D^0\pi^+, D^+\pi^0$ (slow pions)
  - $D^{*0} \to D^0\pi^0, D^0\gamma$
- Look for $B^+ \to D^{0(*)} l\nu$ and $B^0 \to D^{+(*)} l\nu$ ($l = e/\mu$)

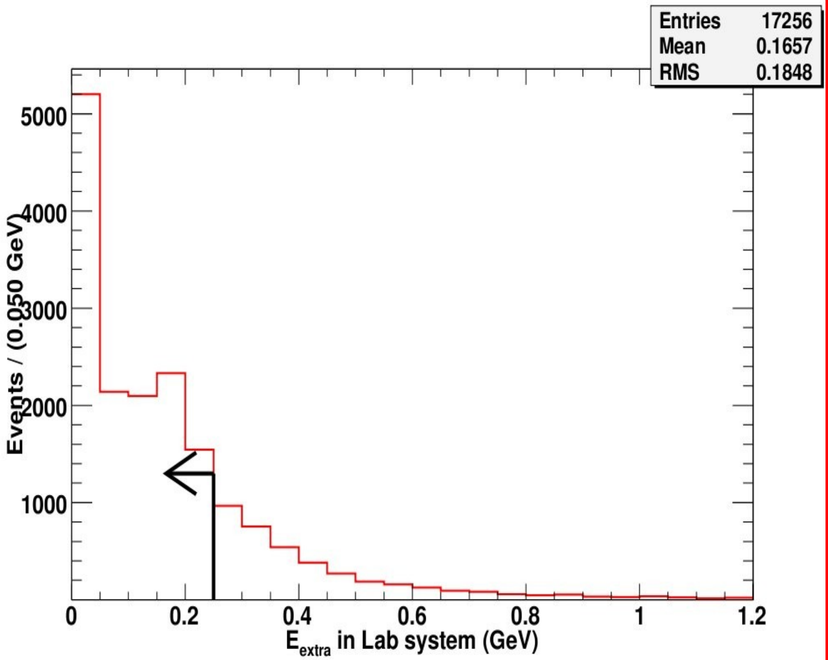
Semi-Leptonic Breco (II)

- $B^+ \to K^+ \nu\nu$:
  - Tag-Side cuts:
    - $|$Net charge$| < 2$
    - $-2.5 < \cos(B,Dl) < 1.1$
    - m_{D0} cut ($|$mass – PDG$| < 3\sigma$)
    - Dl vertex Prob > 0.04
    - $|p^*_l| > 1.35$GeV/c
    - $M_{miss} > 1.0$ GeV/c
    - $m_{Dl} > 3$GeV/c^2
    - $|p^*_D| > 0.5$GeV/c
  - Signal-Side cuts:
    - $|p^*_K| > 1.25$GeV/c
    - $|\cos(Dl,K)| < 0.8$

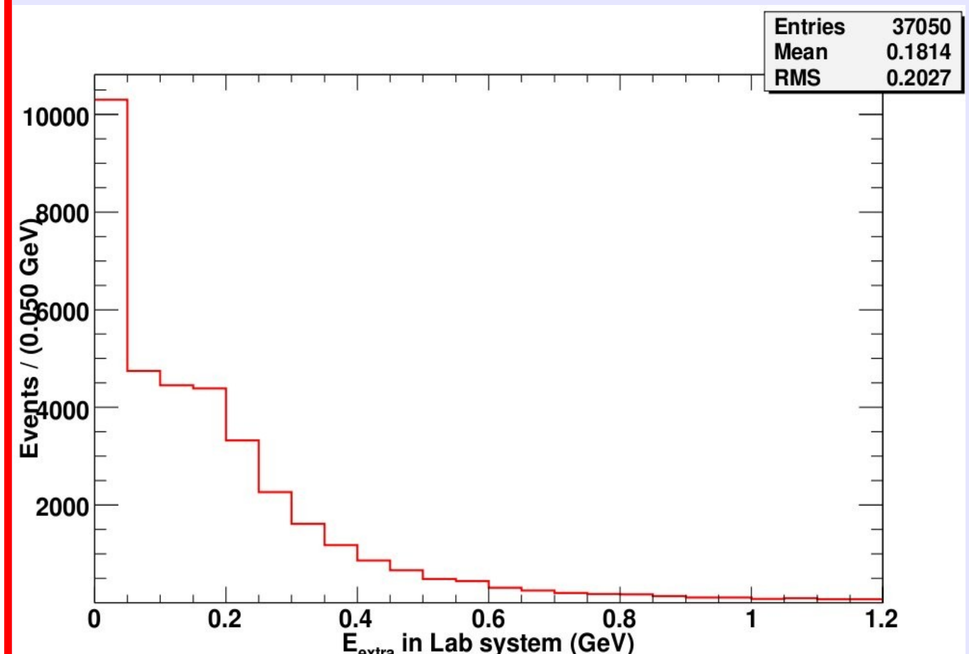
- $B \to K^* \nu\nu$:
  - Sig-side effic. ~10 smaller wrt $K^+\nu\nu$
  - Relaxed cuts ⇒ tag-side effic. ~twice $K^+\nu\nu$
  - Tag-Side cuts:
    - $|$Net charge$| < 2$
    - $-2.0 < \cos(B,Dl) < 1.1$
    - m_{D0} cut ($|$mass – PDG$| < 3\sigma$)
    - Dl vertex Prob > 0.04
    - $|p^*_l| > 0.8$GeV/c
  - Sig-Side cuts:
    - K* mass cut

Semi-Leptonic Breco (II)

- $B^+ \to K^+ \nu\nu$:



- $B \to K^* \nu\nu$:



- **Main discriminant variable:**
  - **Eextra Σ(energy of extra neutrals not tag/sig)**
  - **Peaks at zero for signal**

PID implementation in FastSim

- **Kaons, Pions and Muons:**
  - **still use Table-Based-Selectors (BaBar run6-r24c PiD tables)**

- **Electrons use NoDeDxFirstElectronSelector:**
  - **Mainly uses E/p**
  - **Only tunned for Barrel-Fwd EMC**

- **Still need to switch to “real selectors”**

Scenarios: Detector Configurations

- **Test addition only FwdPiD SuperB baseline**

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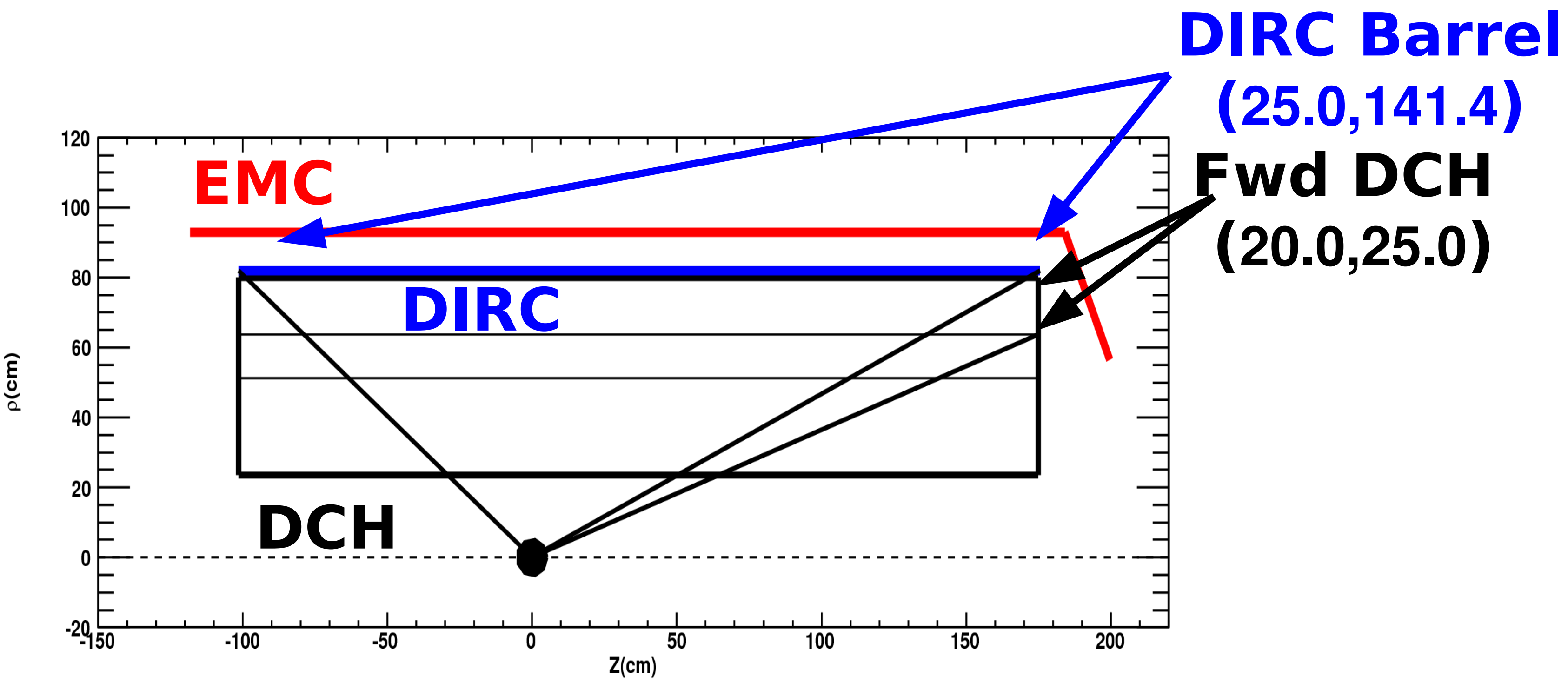
- **BaBar ($\beta\gamma$ = 0.56)**

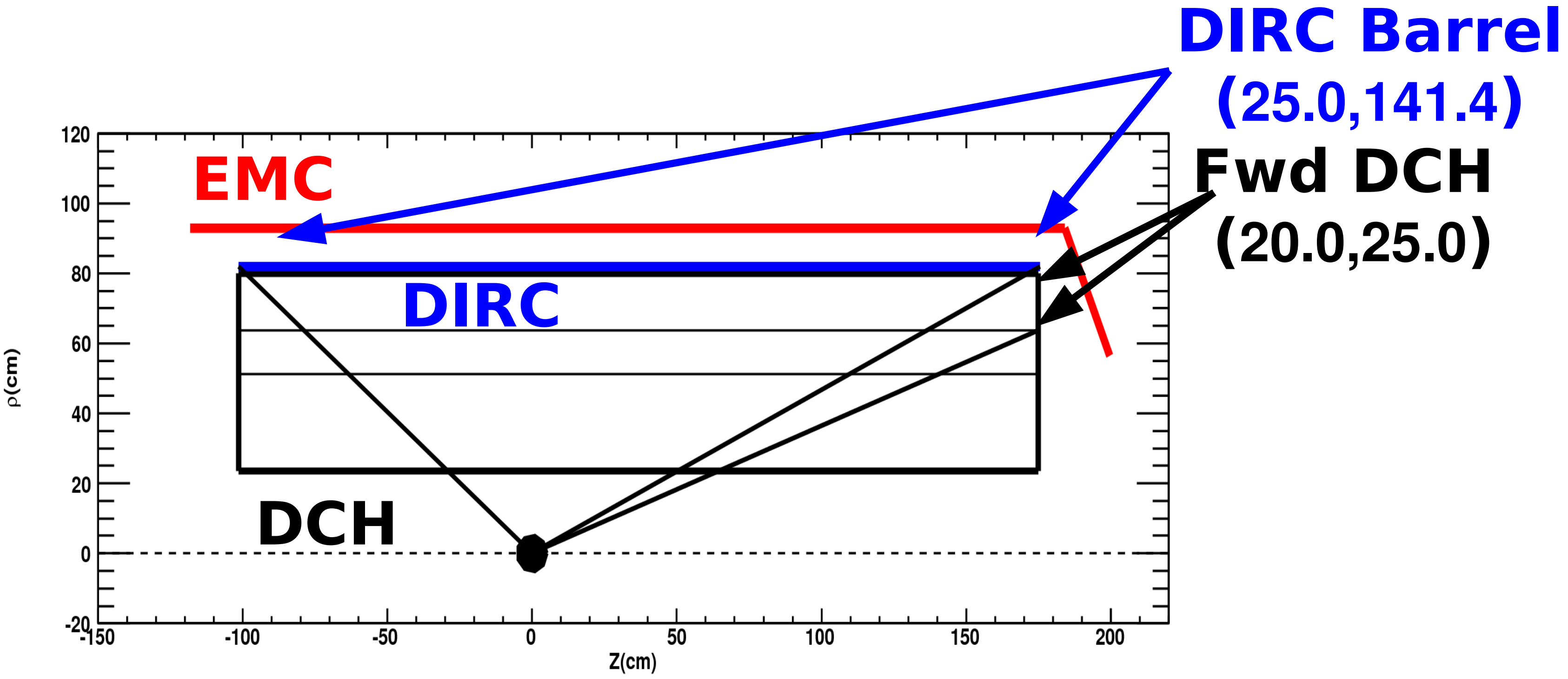
- PID in (20.0,141.4) (includes Fwd DCH)



Scenarios: Detector Configurations

- Test addition only FwdPiD SuperB baseline
- SuperB baseline (DG0) ($\beta\gamma$ = 0.28)

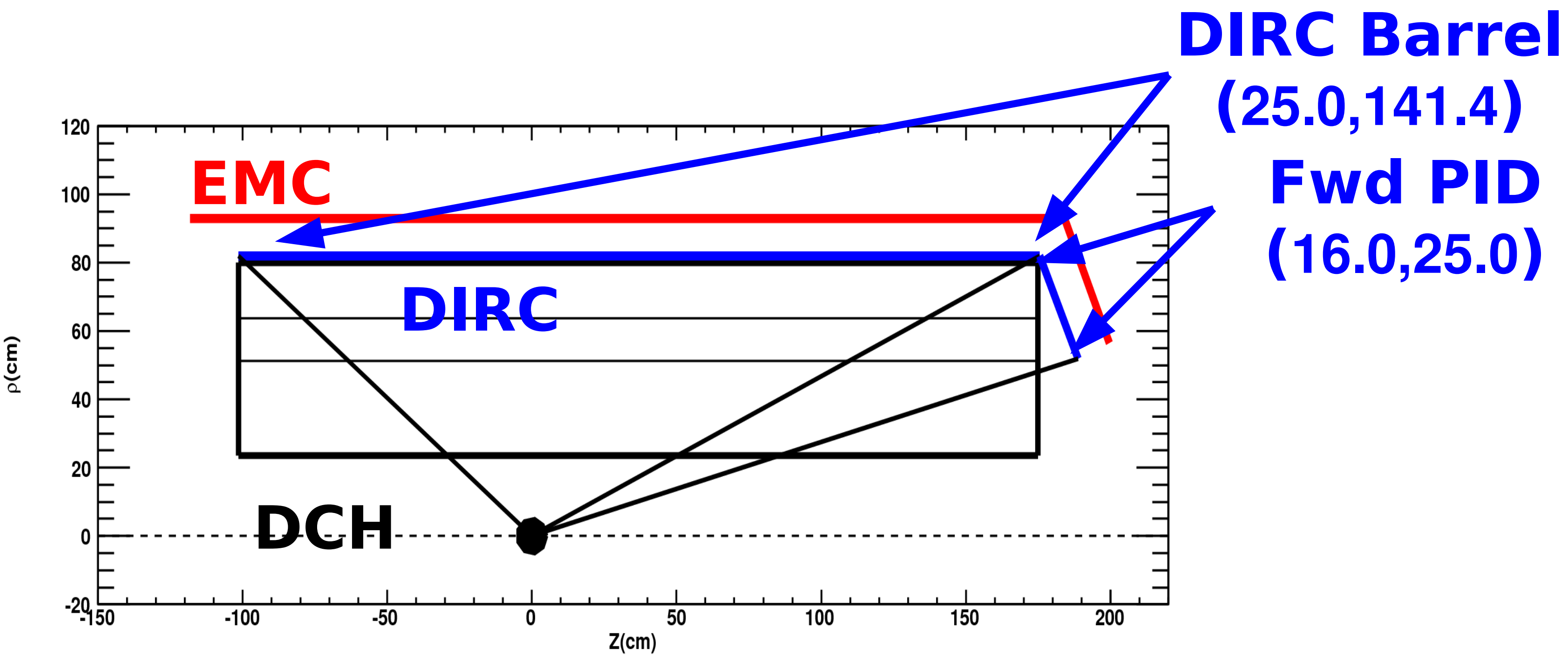
  - PID in (20.0,141.4) (includes Fwd DCH)



Scenarios: Detector Configurations

- Test addition only FwdPiD SuperB baseline
- SuperB baseline + FwdPiD (DGX) ($\beta\gamma$ = 0.28)

 - PID in (16.0,141.4) (increase Fwd coverage by ~5°)



$K^+\nu\nu$ Analysis

$B \to K^+\nu\nu$ (SL): Bkg decomposition

- Assuming: $BF(K^+\nu\nu) = 4.0\times10^{-6}$ and Signal-effic ~ 0.17%, obtain ($1ab^{-1}$)
  - 7.6 signal events
  - 85 bkg events (latest BaBar $K^+\nu\nu$ SL, doesn't include peaking components)

- Charged BB-Backgrounds: ⇒ ~47 events

- Neutral BB-Backgrounds: ⇒ ~10 events

- Qqbar:
  - ccbar ⇒ ~24 events
  - uds ⇒ ~4 events

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  - 7.6 signal events
  - 85 bkg events (latest BaBar $K^+\nu\nu$ SL, doesn't include peaking components)

- Charged BB-Backgrounds: ⇒ ~47 events
  - Double-SL (BF~4.0%, effic~2.0×10^{-6}) ⇒ ~44 events (Non-peaking)
  - $B^+ \to K^{*+}\nu\nu$ (BF~1.3×10^{-5}, effic~7.3×10^{-5}) ⇒ ~1.0 events (Non-peaking)
  - $B^+ \to \tau^+\nu$ (BF~1.5×10^{-4}, effic~2.4×10^{-5}) ⇒ ~4.0 events (Peaking)

- Neutral BB-Backgrounds: ⇒ ~10 events
  - Double-SL (BF~4.0%, effic~4.0×10^{-7}) ⇒ ~ 9 events (Non-peaking)
  - $B^0 \to K^{*0}\nu\nu$ (BF~1.3×10^{-5}, effic~1.9×10^{-5}) ⇒ ~0.3 events (Peaking)

- Qqbar:
  - ccbar ⇒ ~24 events (Non-peaking)
  - uds ⇒ ~4 events (Non-peaking)

$B \to K^+\nu\nu$ (SL): Bkg decomposition

- Assuming: $BF(K^+\nu\nu) = 4.0\times10^{-6}$ and Signal-effic ~ 0.17%, obtain ($1ab^{-1}$)
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- Qqbar:
  - ccbar ⇒ ~24 events (Non-peaking)
  - uds ⇒ ~4 events (Non-peaking)

$B \to K^+\nu\nu$ (SL): MC samples

- $B^+ \to K^+\nu\nu / B^- \to$ generic (Signal): ⇒ ~10M events

- Charged BB-Backgrounds:
  - $B^+ \to D^{(*,1,2)} l\nu / B^- \to D^{(*,1,2)} l\nu$ (Double-SL) ⇒ ~100M events
  - $B^+ \to K^{*+}\nu\nu / B^- \to$ generic ⇒ ~50M events
  - $B^+ \to \tau^+\nu / B^- \to$ generic ⇒ ~50M events

- Neutral BB-Backgrounds:
  - $B^0 \to D^{(*,1,2)} l\nu / B^0 \to D^{(*,1,2)} l\nu$ (Double-SL) ⇒ ~100M events
  - $B^0 \to K^{*0}\nu\nu / B^0 \to$ generic ⇒ ~50M events

- Addition of Fwd-PID:
  - Signal: efficiency increase (shown previously)
  - Bkgs: expect slower efficiency increase

$B \to K^+ \nu\nu$ (SL): Bkg studies

- Tag-Side-Kaon (Tight), Tag-Side-Pion (Loose),Sig-Side-Kaon (Tight)
- Use SuperB-baseline (DG0) configuration to study mis-ID

Tag-Side Kaon

Bkg Sample	$K \leftrightarrow \pi$	$K \leftrightarrow \mu$	$K \leftrightarrow e$
Double-SL (ch)	~2.5%	~2.5%	~0.1%
$K^{*+}\nu\nu$	~0.2%	~0%	~0%
$K^{*0}\nu\nu$	~8.0%	~0%	~0%
$\tau^+\nu$	~1.0%	~0.5%	~1.0%

Tag-Side Pion

Bkg Sample	$\pi \leftrightarrow K$	$\pi \leftrightarrow \mu$	$\pi \leftrightarrow e$
Double-SL (ch)	~0.5%	~11%	~8.6%
$K^{*+}\nu\nu$	~0.2%	~11%	~9.1%
$K^{*0}\nu\nu$	~0%	~2.5%	~0.6%
$\tau^+\nu$	~0%	~3.0%	~1.6%

Signal-Side Kaon

Bkg Sample	$K \leftrightarrow \pi$	$K \leftrightarrow \mu$	$K \leftrightarrow e$
Double-SL (ch)	~0%	~2.7%	~2.4%
$K^{*+}\nu\nu$	~2.3%	~0%	~0%
$K^{*0}\nu\nu$	~0.2%	~0%	~0%
$\tau^+\nu$	~31%	~1.4%	~2.8%

- Significant contribution of $\tau\nu$ due to $K \leftrightarrow \pi$ mis-ID
- Other channels less significant
- Need to study acceptance effect

$B^+ \to K^+ \nu\nu$ (SL): Signal efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight)

Tagging efficiency(%)

D^0 Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+$	0.132 ± 0.001	0.143 ± 0.002	0.149 ± 0.002
$K^-\pi^+\pi^-\pi^+$	0.100 ± 0.001	0.105 ± 0.001	0.114 ± 0.002
$K^-\pi^+\pi^0$	0.275 ± 0.002	0.295 ± 0.003	0.312 ± 0.003
Average	0.539 ± 0.003	0.577 ± 0.004	0.610 ± 0.004

Total efficiency (%)

D^0 Channel	BaBar	DG0	DGX(TOF)
------------	0.144 ± 0.001	0.163 ± 0.002	0.175 ± 0.002

$B^+ \to K^+ \nu\nu$ (SL): Signal efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight)

Tagging efficiency(%) Relative Gains

D^0 Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+$	0.132 ± 0.001	8.6%	4.3%
$K^-\pi^+\pi^-\pi^+$	0.100 ± 0.001	4.7%	8.7%
$K^-\pi^+\pi^0$	0.275 ± 0.002	7.4%	5.9%
Average	0.539 ± 0.003	10.0%	5.4%

Total efficiency (%) Relative Gains

D^0 Channel	BaBar	DG0	DGX(TOF)
------------	0.144 ± 0.001	17.0%	6.2%

$B^+ \to K^+\nu\nu$ (SL): Bkg efficiencies

- **Tag-Side: Kaon (Tight), Pion (Loose)**
- **Sig-Side: Kaon (Tight)**

Total efficiency (%)

Bkg Sample	BaBar	DG0	DGX(TOF)
Double-SL (char)	$(20 \pm 2)\times10^{-5}$	$(20 \pm 2)\times10^{-5}$	$(20 \pm 2)\times10^{-5}$
Double-SL (neut)	$(4 \pm 2)\times10^{-5}$	$(4 \pm 2)\times10^{-5}$	$(4 \pm 2)\times10^{-5}$
$K^{*+}\nu\nu$	$(61 \pm 1)\times10^{-4}$	$(70 \pm 1)\times10^{-4}$	$(75 \pm 7)\times10^{-4}$
$K^{*0}\nu\nu$	$(89 \pm 5)\times10^{-5}$	$(98 \pm 5)\times10^{-5}$	$(109 \pm 5)\times10^{-5}$
$\tau^+\nu$	$(205 \pm 7)\times10^{-5}$	$(224 \pm 7)\times10^{-5}$	$(226 \pm 7)\times10^{-5}$

$B^+ \to K^+\nu\nu$ (SL): Bkg efficiencies

- **Tag-Side: Kaon (Tight), Pion (Loose)**
- **Sig-Side: Kaon (Tight)**

Total efficiency (%) Relative Gain

Bkg Sample	BaBar	DG0	DGX(TOF)
Double-SL (char)	$(20 \pm 2)\times10^{-5}$	---------	---------
Double-SL (neut)	$(4 \pm 2)\times10^{-5}$	---------	---------
$K^{*+}\nu\nu$	$(61 \pm 1)\times10^{-4}$	15.1%	7.3%
$K^{*0}\nu\nu$	$(89 \pm 5)\times10^{-5}$	9.8%	11.5%
$\tau^+\nu$	$(205 \pm 7)\times10^{-5}$	9.4%	0.8%

$B^+ \to K^+ \nu\nu$ (SL): Extrapolation

- Re-scale Nsig and Nbkg for different Lumis

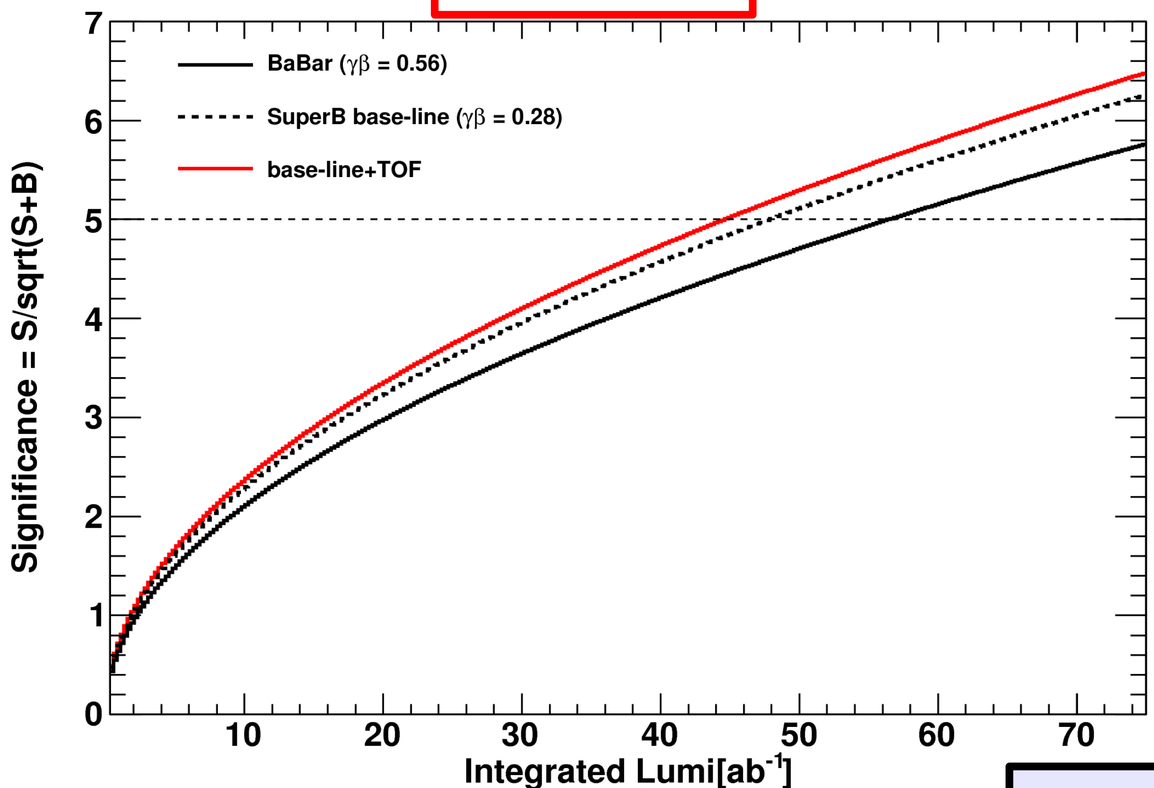
- Detector Configurations: re-scale Nsig and Nbkg for different efficiency gains obtained with FastSim
- Use signal and Bkg ($\tau^+\nu$, $K^{*(+,0)}\nu\nu$) gains in efficiency when adding Fwd-PID

- Assume that ratio of signal over other Bkg components (e.g. double-SL) stays constant (pessimistic assumption)

- Plot the significance Nsig/sqrt(Nsig+Nbkg) as a function of Lumi
- **Warning:** Not include systematic extrapolation

$B^+ \to K^+\nu\nu$ (SL): Extrapolation

$K^+\nu\nu$



- **5σ significance (stat-only):**
- **BaBar: ~55ab^{-1}**
- **SuperB-base line: ~48ab^{-1}**
- **+TOF: ~44ab^{-1}**

$K^{*(+/0)}\nu\nu$ Analysis

$B\to K^*\nu\nu$ (SL): MC samples

- $B^+\to K^{*+}\nu\nu/B^-\to$generic (charged-Signal): ⇒ ~5M events
- $B^0\to K^{*0}\nu\nu/B^0\to$generic (neutral-Signal): ⇒ ~5M events

- Charged BB-Backgrounds:
  - $B^+\to D^{(*,1,2)}l\nu/B^-\to D^{(*,1,2)}l\nu$ (Double SL) ⇒ ~100M events
  - $B^+\to K^+\nu\nu/B^-\to$generic ⇒ ~50M events
  - $B^+\to\tau^+\nu/B^-\to$generic ⇒ ~50M events
- Neutral BB-Backgrounds:
  - $B^0\to D^{(*,1,2)}l\nu/B^0\to D^{(*,1,2)}l\nu$ (Double SL) ⇒ ~100M events

- **Any other expected physical bkg?**

- When adding Fwd-PID:
  - Signal: efficiency increase (shown previously)
  - Bkgs: expect slower efficiency increase

$B \to K^{*+}\nu\nu$ (SL): Bkg decomposition

- Assuming: $BF(K^{*+}\nu\nu) = 1.3\times10^{-5}$ and Signal-effic ~ 0.08%, obtain (1ab^{-1})
  - ~12 signal events
  - ~4228 bkg events (latest BaBar $K^{*+}\nu\nu$ SL, doesn't include peaking components)

- Charged BB-Backgrounds: ⇒ ~2354 events
  - Double-SL (BF~4.0%, effic~1.8×10^{-5}) ⇒ ~413 events (Non-peaking)
  - $B^+ \to K^+\nu\nu$ (BF~1.3×10^{-5}, effic~2.6×10^{-4}) ⇒ ~1.1 events (Peaking)
  - $B^+ \to \tau^+\nu$ (BF~1.5×10^{-4}, effic~2.6×10^{-5}) ⇒ ~5.6 events (Peaking)

- Neutral BB-Backgrounds: ⇒ ~974 events
  - Double-SL (BF~4.0%, effic~3.7×10^{-6}) ⇒ ~156 events (Non-Peaking)
  - $B^0 \to K^{*0}\nu\nu$ (BF~1.3×10^{-5}, effic~3.6×10^{-5}) ⇒ ~0.5 events (Non-Peaking)

- Qqbar:
  - ccbar ⇒ ~833 events (Non-peaking)
  - uds ⇒ ~65 events (Non-peaking)

$B^+ \to K^{*+} \nu\nu$ (SL): efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight), Pion (Loose)

Tagging efficiency(%)

D^0 Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+$	0.223 ± 0.002	0.246 ± 0.003	0.254 ± 0.003
$K^-\pi^+\pi^-\pi^+$	0.162 ± 0.002	0.174 ± 0.002	0.185 ± 0.002
$K^-\pi^+\pi^0$	0.591 ± 0.004	0.650 ± 0.004	0.672 ± 0.004
Average	1.067 ± 0.005	1.160 ± 0.005	1.208 ± 0.005

Total efficiency (%)

D^0 Channel	BaBar	DG0	DGX(TOF)
------------	0.075 ± 0.001	0.079 ± 0.001	0.083 ± 0.001

$B^+ \rightarrow K^{*+} \nu\nu$ (SL): efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight), Pion (Loose)

Tagging efficiency(%) Relative gain

D^0 Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+$	0.223 ± 0.002	10.3%	3.3%
$K^-\pi^+\pi^-\pi^+$	0.162 ± 0.002	7.4%	6.3%
$K^-\pi^+\pi^0$	0.591 ± 0.004	10.0%	3.4%
Average	1.067 ± 0.005	8.7%	4.1%

Total efficiency (%) Relative gain

D^0 Channel	BaBar	DG0	DGX(TOF)
------------	0.075 ± 0.001	5.3%	5.1%

$B \to K^{*0} \nu\nu$ (SL): Bkg decomposition

- Assuming: $BF(K^{*0}\nu\nu) = 1.3\times10^{-5}$ and Signal-effic ~ 0.042%, obtain ($1 ab^{-1}$)
  - ~10 signal events
  - ~1584 bkg events (latest BaBar $K^{*0}\nu\nu$ SL, doesn't include peaking components)

- Charged BB-Backgrounds: ⇒ ~234 events
  - Double-SL (BF~4.0%, effic~0.002%) ⇒ ~25 events (Non-peaking)
  - $B^+ \to K^+\nu\nu$ ($BF\sim4.0\times10^{-6}$, effic~0.02%) ⇒ ~0.02 events (Peaking)
  - $B^+ \to K^{*+}\nu\nu$ ($BF\sim1.3\times10^{-5}$, effic~0.02%) ⇒ ~0.03 events (Non-peaking)
  - $B^+ \to \tau^+\nu$ ($BF\sim1.5\times10^{-4}$, effic~0.003%) ⇒ ~0.12 events (Non-peaking)

- Neutral BB-Backgrounds: ⇒ ~1093 events
  - Double-SL (BF~4.0%, effic~4.0×10^{-7}) ⇒ ~77 events (Non-peaking)

- Qqbar:
  - ccbar ⇒ ~231 events (Non-peaking)
  - uds ⇒ ~24 events (Non-peaking)

$B^0 \to K^{*0}\nu\nu$ (SL): efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight), Pion (Loose)

Tagging efficiency(%)

D^+ Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+\pi^-$	0.180 ± 0.002	0.193 ± 0.002	0.204 ± 0.002
$K_s\pi^+$	0.053 ± 0.001	0.057 ± 0.001	0.057 ± 0.001
Average	0.233 ± 0.002	0.250 ± 0.002	0.261 ± 0.002

Total efficiency (%)

D^+ Channel	BaBar	DG0	DGX(TOF)
-----------	0.042 ± 0.001	0.048 ± 0.001	0.053 ± 0.001

$B^0 \to K^{*0} \nu\nu$ (SL): efficiency

- Tag-Side: Kaon (Tight), Pion (Loose)
- Sig-Side: Kaon (Tight), Pion (Loose)

Tagging efficiency(%)

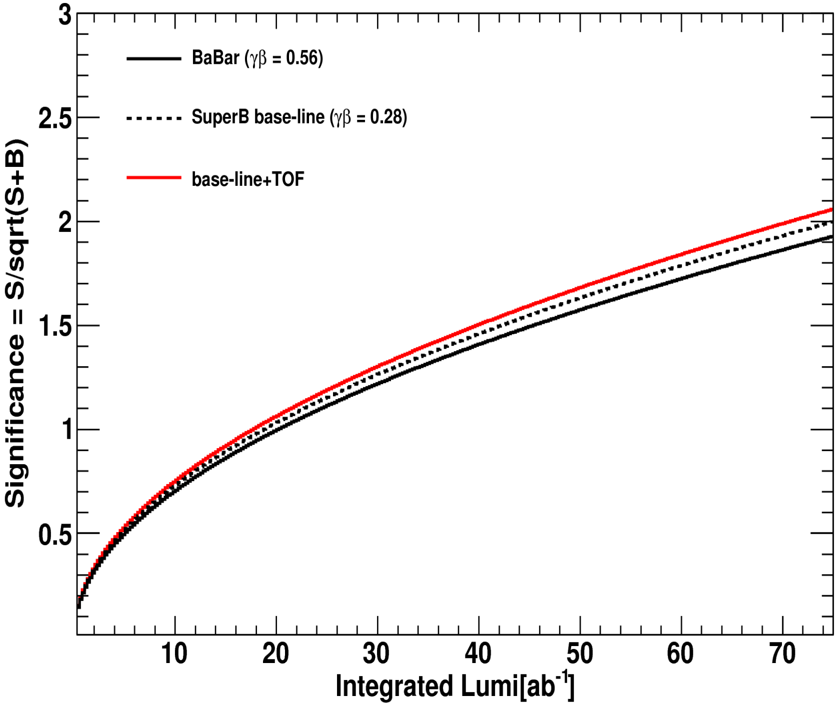
D^+ Channel	BaBar	DG0	DGX(TOF)
$K^-\pi^+\pi^-$	0.180 ± 0.002	7.2%	5.7%
$Ks\pi^+$	0.053 ± 0.001	6.3%	0.0%
Average	0.233 ± 0.002	7.2%	4.4%

Total efficiency (%)

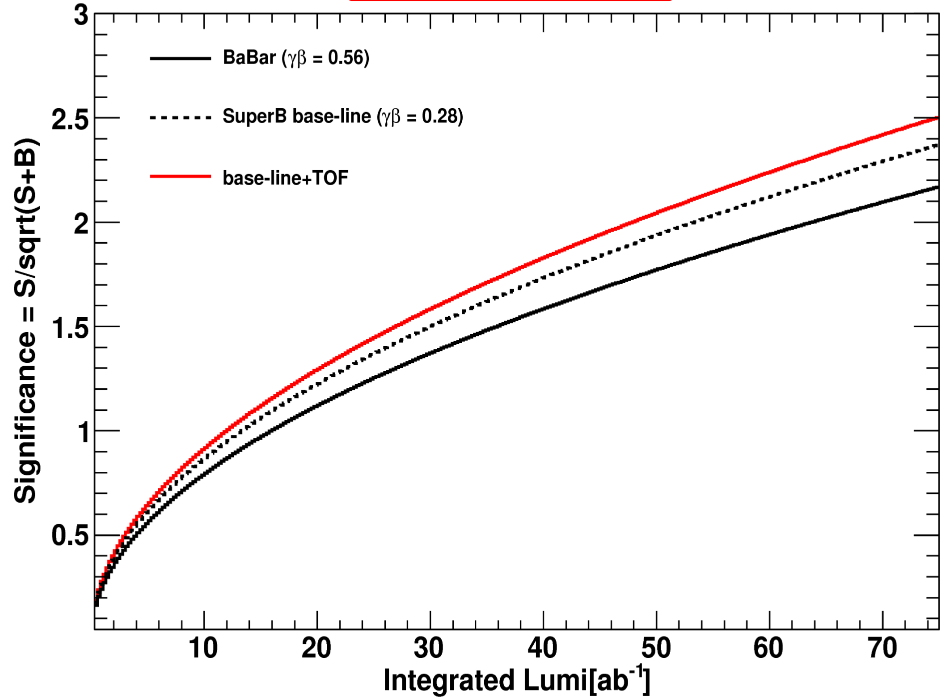
D^+ Channel	BaBar	DG0	DGX(TOF)
-----------	0.042 ± 0.001	15.0%	10.6%

$B \to K^{*(+,0)}\nu\nu$ (SL): Extrapolation

$K^{*+}\nu\nu$



$K^{*0}\nu\nu$

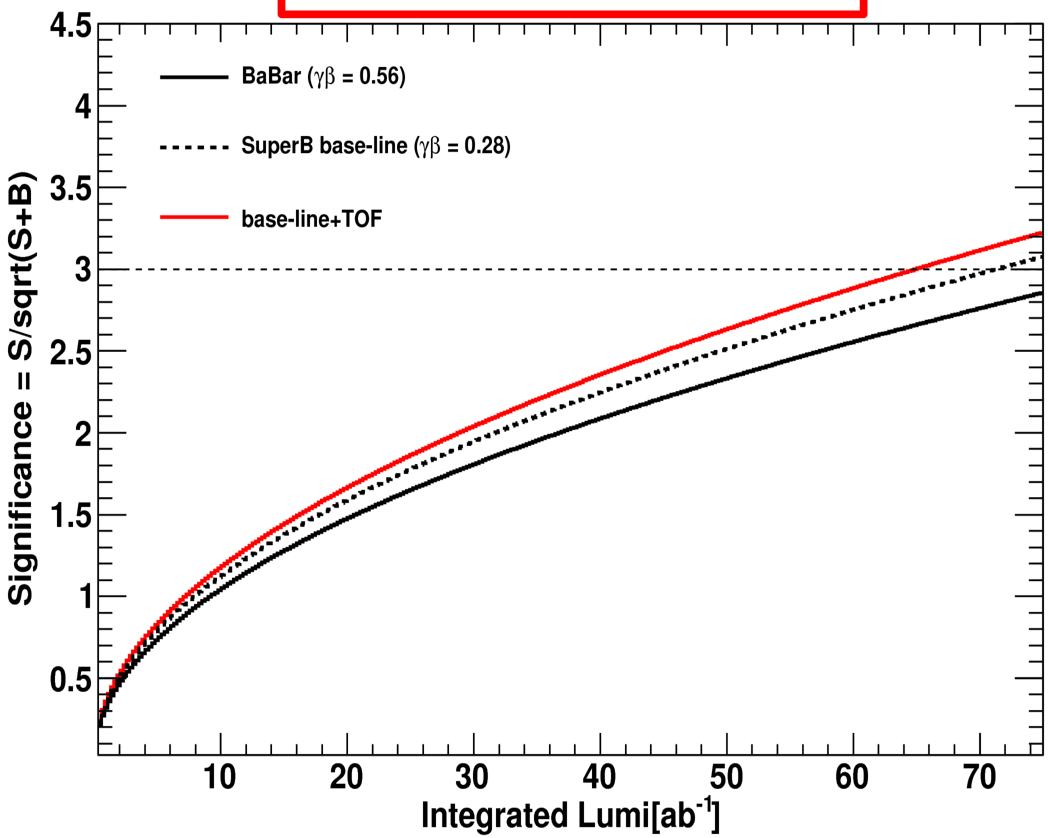


- **Neutral channel has a higher S/B ratio, and is more sensitive to Fwd-PID inclusion**
- **None of the channel reach the 3σ significance**

$B \to K^{*(+,0)}\nu\nu$ (SL): Extrapolation

- It is expected that both neutral and charged $K^{*}\nu\nu$ channels to have the same BF (no isospin asymmetry)
- We combine the results from both channels

Combined $K^{*(0,+)}\nu\nu$



- **3σ significance (stat-only):**
- BaBar: > 75ab^{-1}
- SuperB-base line: ~71ab^{-1}
- +TOF: ~64ab^{-1}

Summary

- $K^+\nu\nu$ (SL) Analysis:
  - Backgrounds studies:
    - Main contribution to BB-bkg is due to Double-SL
    - Only $\tau^+\nu$ contributes due to significant $K \leftrightarrow \pi$ mis-ID (30% of the events)
    - Others components must contribute due detector acceptance

      $\Rightarrow$ need to study inclusion of Bwd-EMC (under study)
  - Efficiency gains:
    - Signal: Increases about ~6.2% when adding TOF
    - Studied bkg channels ($K^{*(+,0)}\nu\nu$, $\tau^+\nu$) show a slower increase
      - considered channels give small contribution to total BB-bkg
      - small gain on S/B ratio
    - Need to study inclusion of Bwd-EMC
  - Extrapolation:
    - Not assume any more S/B constant
    - With boost+Fwd-PID expect to have 5σ (stat) significance with $44ab^{-1}$ instead of $55ab^{-1}$(~20% effect)
    - Need to include systematic uncertainties

Summary

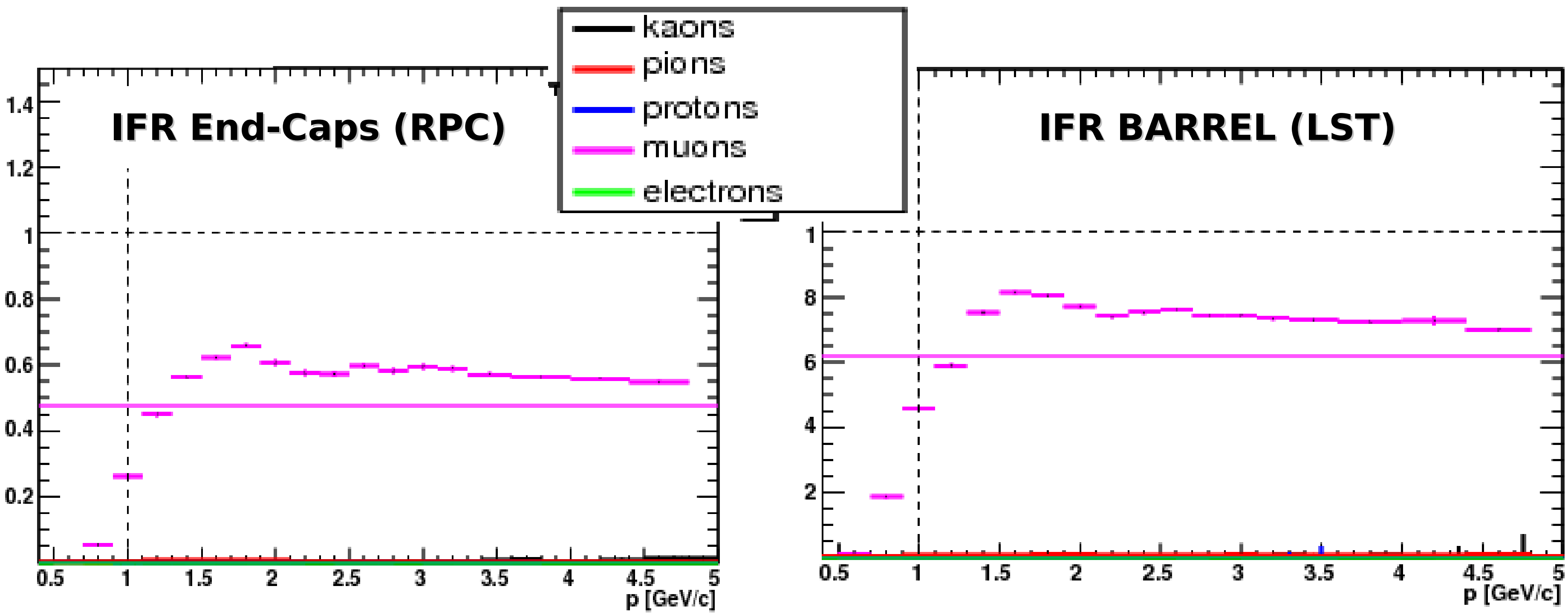
- $K^*\nu\nu$ (SL) Analysis:
  - Backgrounds studies:
    - None of the considered channels give a significant contribution to BB-bkg
    - Is there any other physical bkg to consider?
    - Need to perform the same studies as with the $K^+\nu\nu$ (under study)
  - Efficiency gains:
    - Signal: Increases about ~5.0% (charged) and ~10.0% (neutral) when adding TOF
    - Need to study efficiency gains for different bkg contributions
    - Need to study inclusion of Bwd-EMC
  - Extrapolation:
    - Assume S/B constant
    - With boost+Fwd-PID, none of the channels (charged and neutral) reach the 3σ (stat) significance with $75ab^{-1}$ statistics
    - When both channels are combined boost+Fwd-PID configuration reach 3σ (stat) significance with ~$64ab^{-1}$ statistics (BaBar needs more than ~$75ab^{-1}$)
    - Need to include systematic uncertainties

Backup

Semi-Leptonic Breco (II)

- **PID: still use TableBasedXXXSelection selectors for Kaons, pions and muons (BaBar run6-r24c PiD tables)**

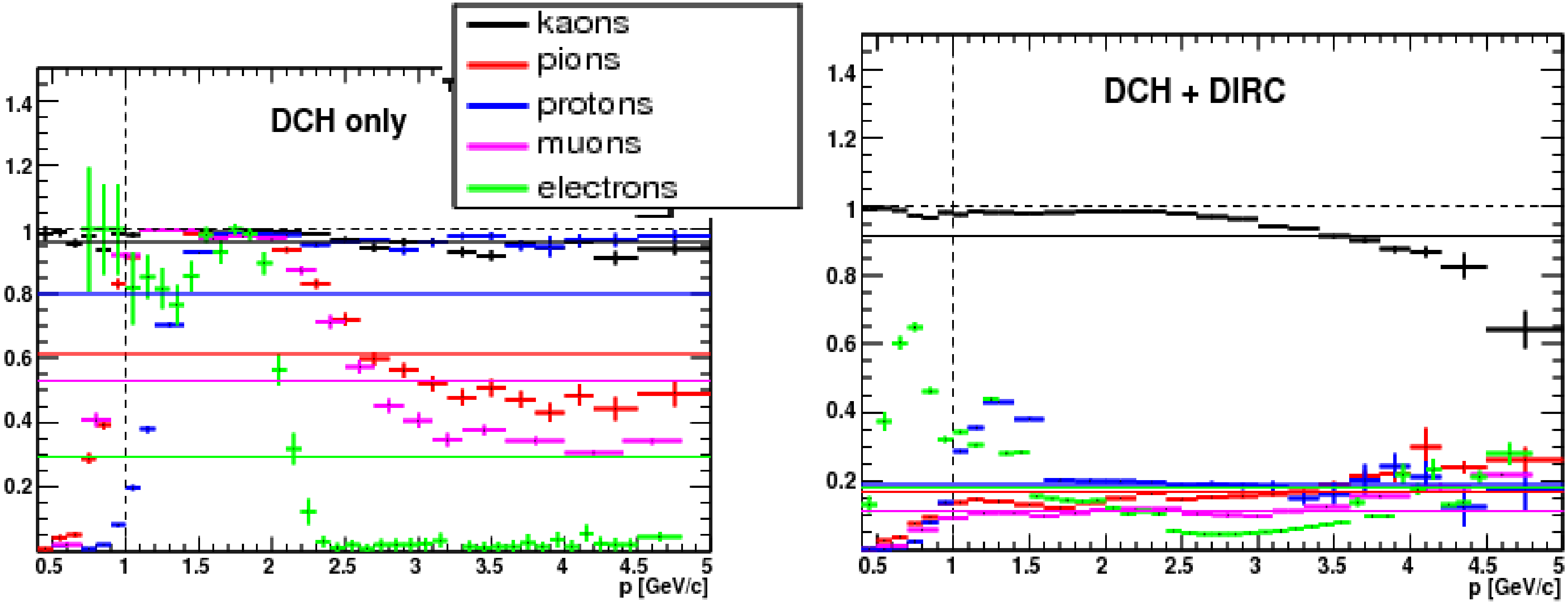
- Muon ⇒ MuonNNTight



Semi-Leptonic Breco (II)

- **PID: still use TableBasedXXXSelection selectors for Kaons, pions and muons (BaBar run6-r24c PiD tables)**

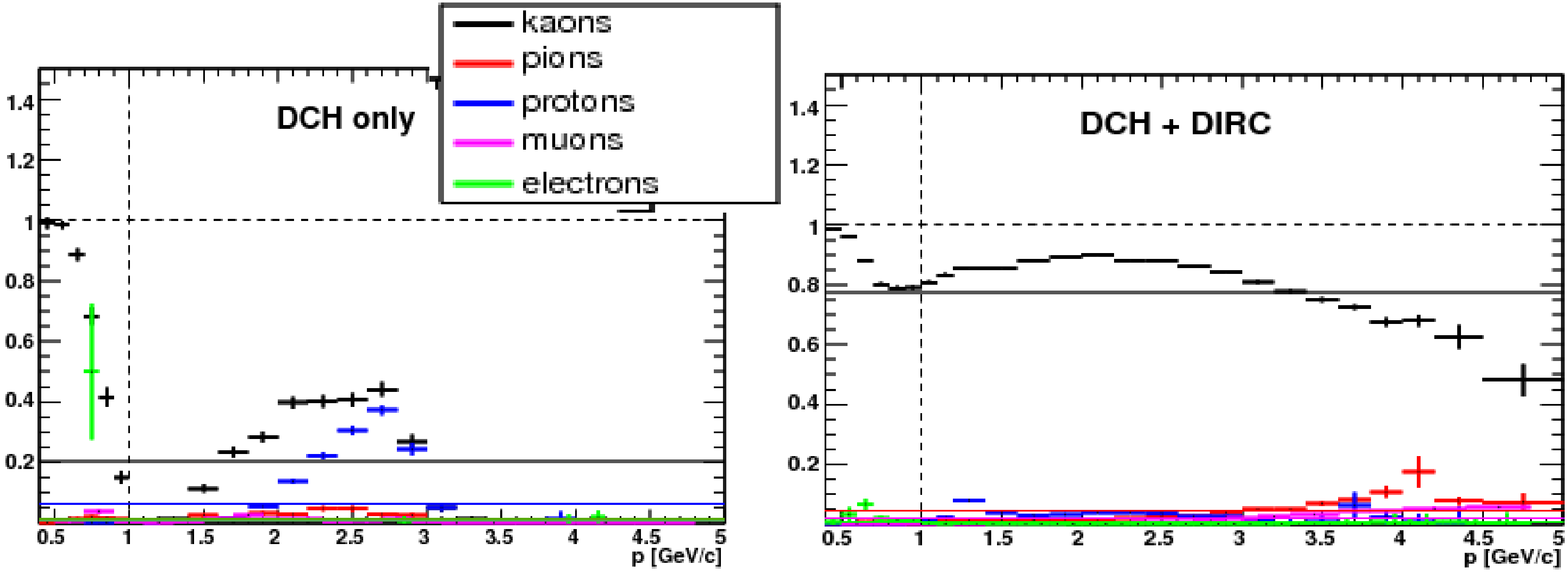
- Kaon ⇒ KaonNotPion



Semi-Leptonic Breco (II)

- **PID: still use TableBasedXXXSelection selectors for Kaons, pions and muons (BaBar run6-r24c PiD tables)**

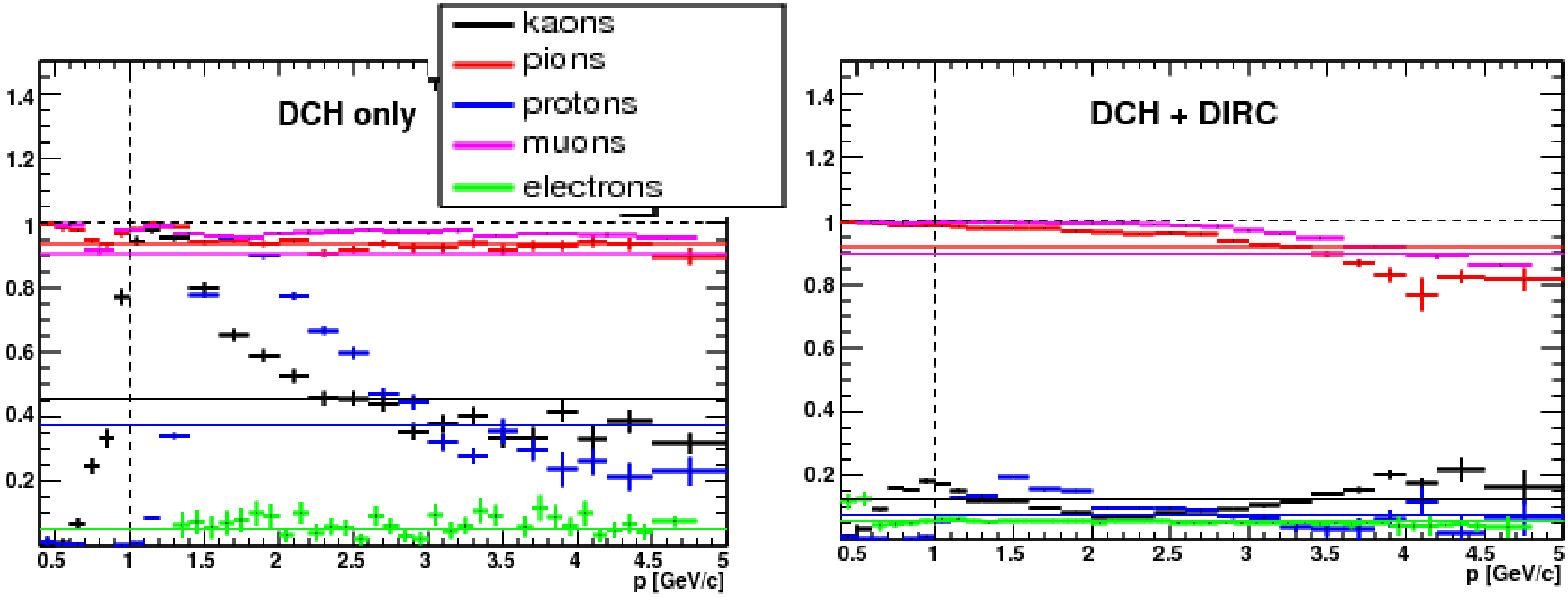
- Kaon ⇒ KaonTight



Semi-Leptonic Breco (II)

- PID: still use TableBasedXXXSelection selectors for Kaons, pions and muons (BaBar run6-r24c PiD tables)

- Pion ⇒ **Pion Not a Kaon (test PionLoose)**



Semi-Leptonic Breco (II)

- PID: still use TableBasedXXXSelection selectors for Kaons, pions and muons (BaBar run6-r24c PiD tables)

- Electron ⇒ NoDeDxFirstElectronSelector

- Uses Mainly E/p
- Only tuned for Barrel Emc