$B \to K^* \nu\nu$ vs HAD tag: energy smearing in FastSim

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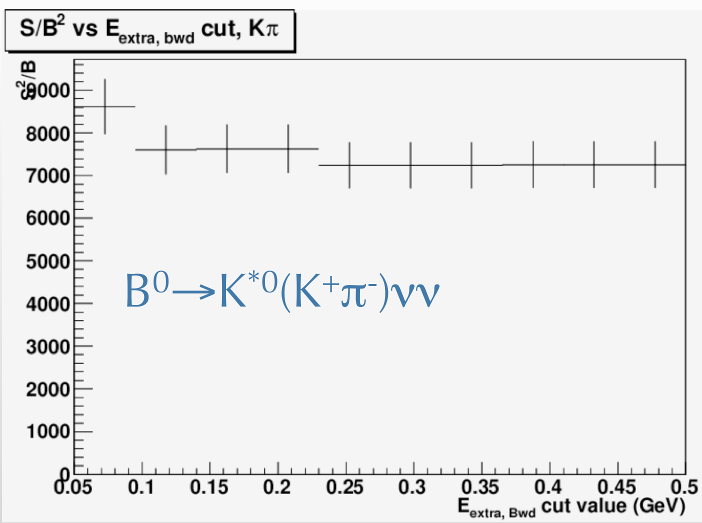
Outline

- Caltech results and analysis strategy
- Neutral energy smearing algorithm
- Patch validation
- Results on Bwd EMC veto impact

Caltech results

– Eextra_bwd < 0.05 GeV:

$B^0 \to K^{*0}\nu\bar{\nu}$					
Sample	N_{sel}	ε_{tot}	$N_{sel,Bwd}$	$\varepsilon_{tot,Bwd}$	$\delta\varepsilon/\varepsilon$
$B^0 \to K^{*0}\nu\bar{\nu}$	727	$(24.5 \pm 0.9) \times 10^{-5}$	719	$(24.2 \pm 0.9) \times 10^{-5}$	$(-1.1 \pm 0.4)\%$
B^0 had cocktail	76	$(20 \pm 2) \times 10^{-8}$	60	$(16 \pm 2) \times 10^{-8}$	$(-21 \pm 7)\%$
$S/\sqrt{B}$	83 ± 7		93 ± 9		
$B^+ \to K^{*+}(K_s\pi^+)\nu\bar{\nu}$					
Sample	N_{sel}	ε_{tot}	$N_{sel,Bwd}$	$\varepsilon_{tot,Bwd}$	$\delta\varepsilon/\varepsilon$
$B^+ \to K^{*+}\nu\bar{\nu}$	223	$(7.1 \pm 0.5) \times 10^{-5}$	222	$(7.0 \pm 0.5) \times 10^{-5}$	$(-0.5 \pm 0.4)\%$
B^+ had cocktail	48	$(12.0 \pm 1.7) \times 10^{-8}$	40	$(10.0 \pm 1.7) \times 10^{-8}$	$(-17 \pm 7)\%$
$S/\sqrt{B}$	32 ± 4		35 ± 5		



$$\delta\left(\frac{S}{\sqrt{(B)}}\right) = \frac{\left(\frac{S}{\sqrt{(B)}}\right)_{bwd} - \left(\frac{S}{\sqrt{(B)}}\right)_{nobwd}}{\left(\frac{S}{\sqrt{(B)}}\right)_{nobwd}} =$$

$$K\pi : (10 \pm 3)\%$$
$$K_s\pi : (8 \pm 3)\%$$

Motivations and analysis strategy

– September production ntuple: neutral energy smearing not applied

– @ Caltech: analysis of September sample to evaluate the impact of Bwd EMC used as veto device

→ without smearing, results can be too optimistic

– Need to re-compute impact of Bwd EMC veto including resolution effects:

- make a new production for the BBbar sample is too time consuming

→ apply smearing off-line

- validate smearing algorithm on signal and single particle MCs
- apply off line smearing on both BBbar and signal samples from September production
- repeat the analysis and compare S/sqrt(B+B) w and w/o Eextra_bwd veto

FastSim energy smearing algorithm (I)

- BaBar EMC energy resolution:

$$\sigma(E)/E = 2.35\%/E^{(1/4)} + 1.35\%$$

- Energy resolution parameterization in FastSim:
  gaussian component: $\sigma(E)/E = fa/E^{(ep)} + fb$
  + exponential tail: $\tau = cexp/E^{(pexp)} + dexp$

- parameter values :

par	fwd	brr	bwd
fa	0.0102	0.0102	0.14
fb	0.0	0.0	0.03
ep	0.264	0.264	0.5
cexp	0.0165	0.0165	0.0
dexp	0.0284	0.0284	0.0
pexp	0.05	0.050	0.0

FastSim energy smearing algorithm (II)

– Experimental effects accounted in FastSim:
  - global EMC calibration: apply scaling factor to recover part of the cluster not contained
  - background cluster effects: once the "physics" cluster has been reconstructed, switch on random crystals around the cluster
  - energy smearing due to finite resolution

↓

smearing parameter:

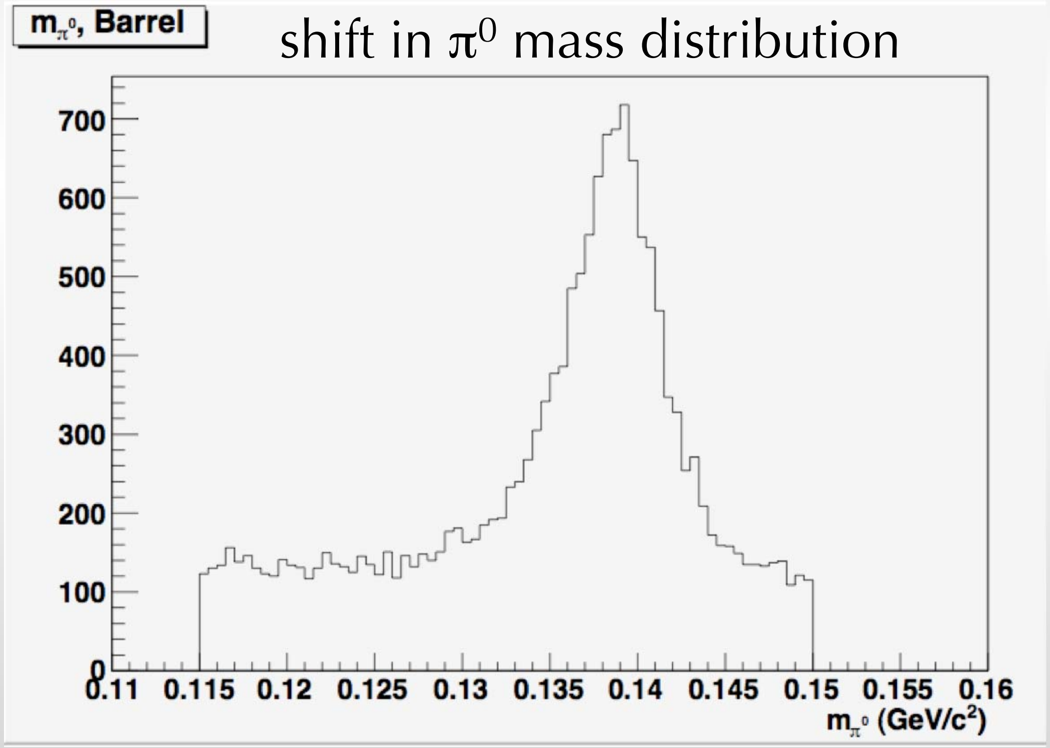
δE = gaussRnd $(0,\sigma(E))$ – expRnd$(\tau(E))$

gaussRnd/expRnd = random numbers generated according to gaussian/exponential distribution (function of resolution params)

→ smeared energy: $E_{meas} = E_0 * (1+\delta E)$

FastSim energy smearing algorithm (III)

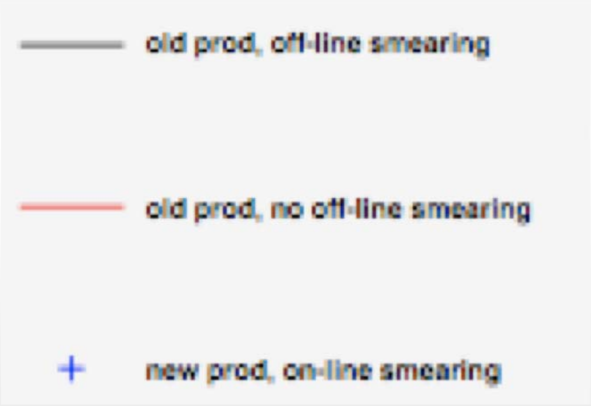
- September production:
  - global EMC calibration ON
  - background cluster effects ON
  - energy smearing due to finite resolution OFF



Patch validation

Strategy

- Compare "production with smearing turned on" and "production with smearing turned off + off-line smearing"
- samples: $B^0 \rightarrow K^{*0}\nu\nu$ signal, single-π^0 beam, single-γ beam MCs
- Legenda in the following plots:



1) Production without energy smearing + patch with smearing applied after reconstruction (algorithm we want to validate)

2) Production without energy smearing

3) Production with energy smearing

- 1) is obtained starting from 2) and applying the smearing algorithm, it aims to reproduce 3)

→ black histo and blue + should match

$B^0 \rightarrow K^{*0}\nu\nu$ signal MC: sample and selection

- sample:
  - ~3M events from September production (V0.2.5 FastSim release, smearing OFF)
  - ~10M events with V0.2.6 FastSim release (smearing ON)

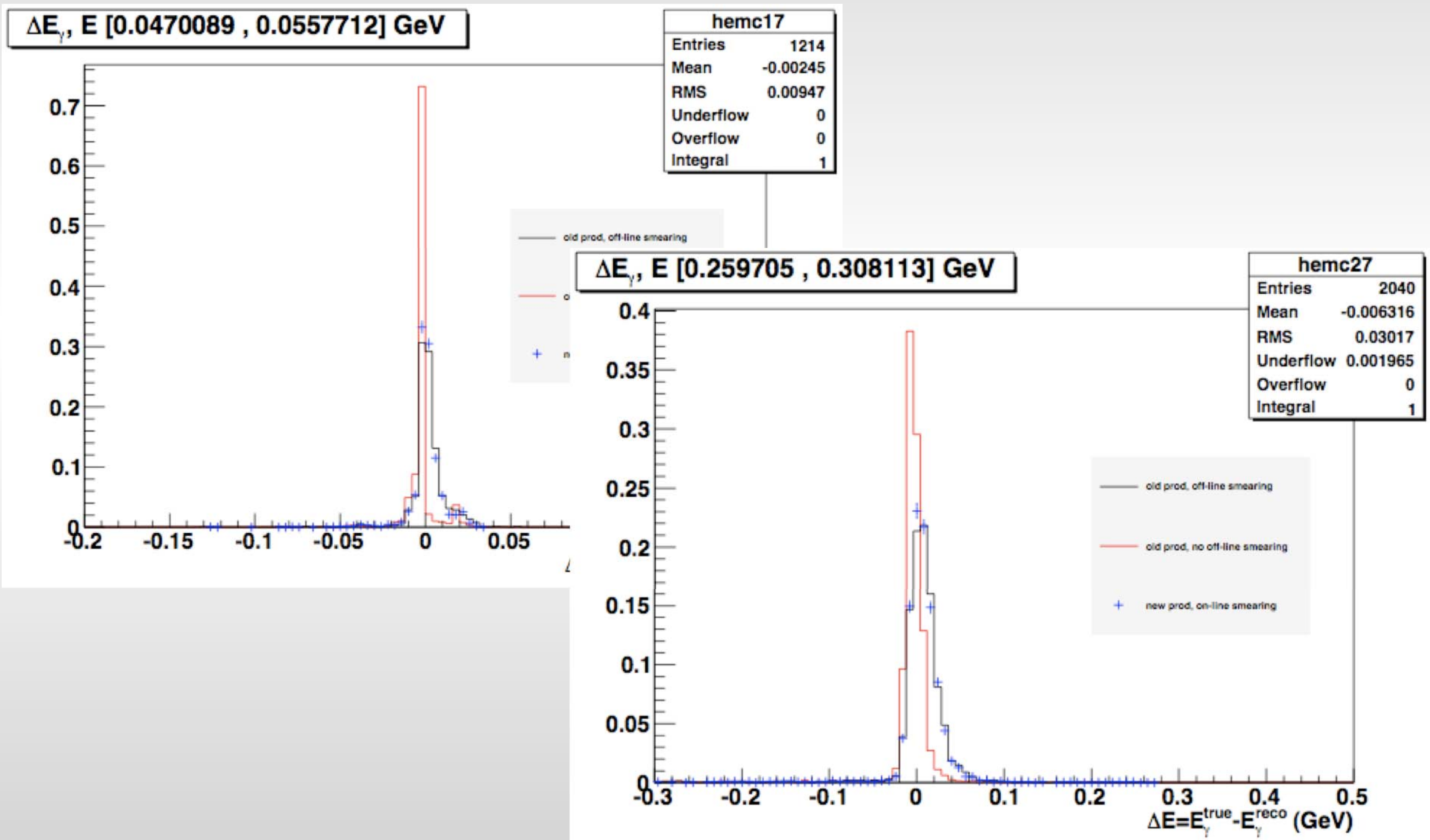
- generate $B^0 \rightarrow K^{*0}\nu\nu$ vs B^0bar→ hadronic modes

  reconstruct with PacHadRecoilUser package (FastSim package for hadronic Breco analysis)

- selection
  - examine all reconstructed γ (irrespective of their origin, i.e. γ from any decay product of both Breco and Bsig)
  - thruth matching: reco photons associated to one photon in the MC list

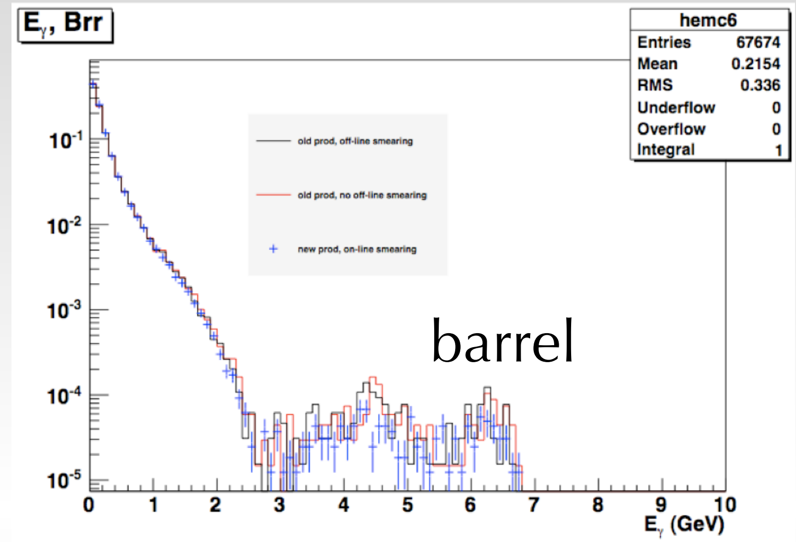
$B^0 \rightarrow K^{*0}\nu\nu$ signal MC : γ energy (I)

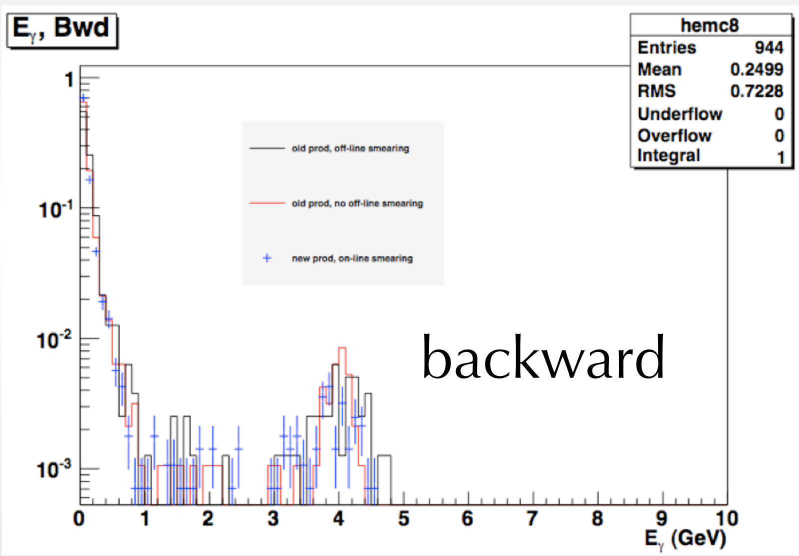
- $E_{true} - E_{reco}$ in bins of E_{true}, truth-matching required

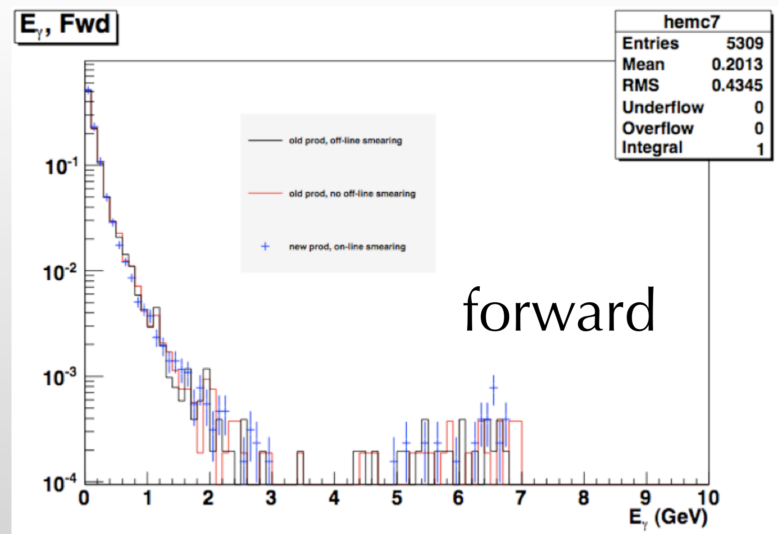


$B^0 \to K^{*0} \nu\nu$ signal MC : γ energy (II)

– E_{reco} in different EMC regions

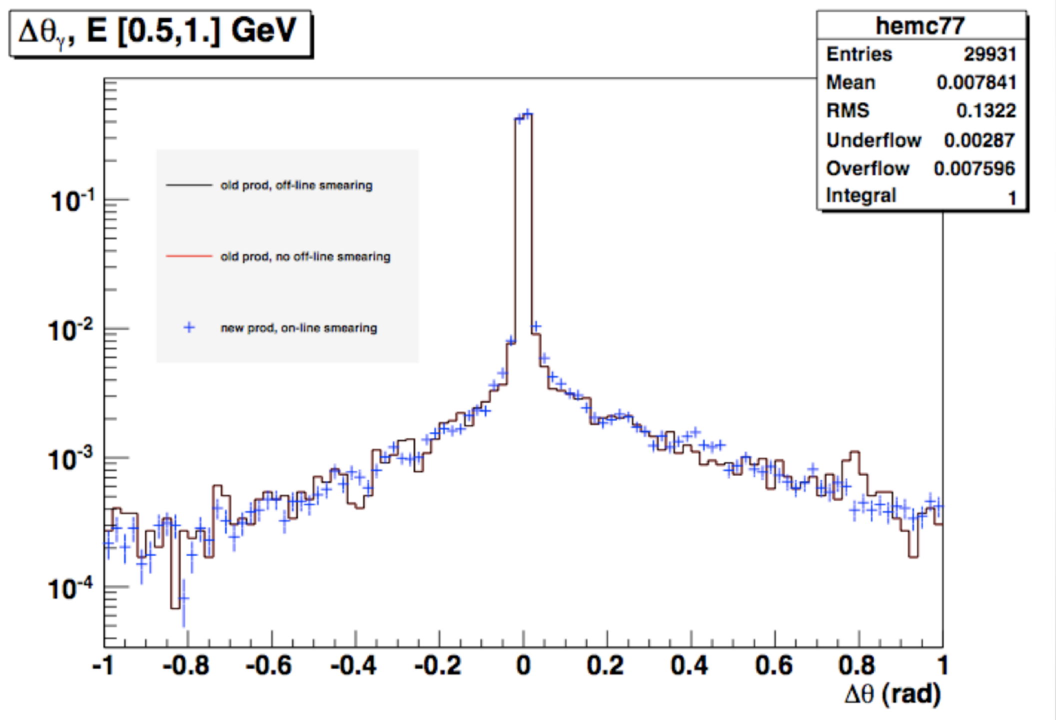






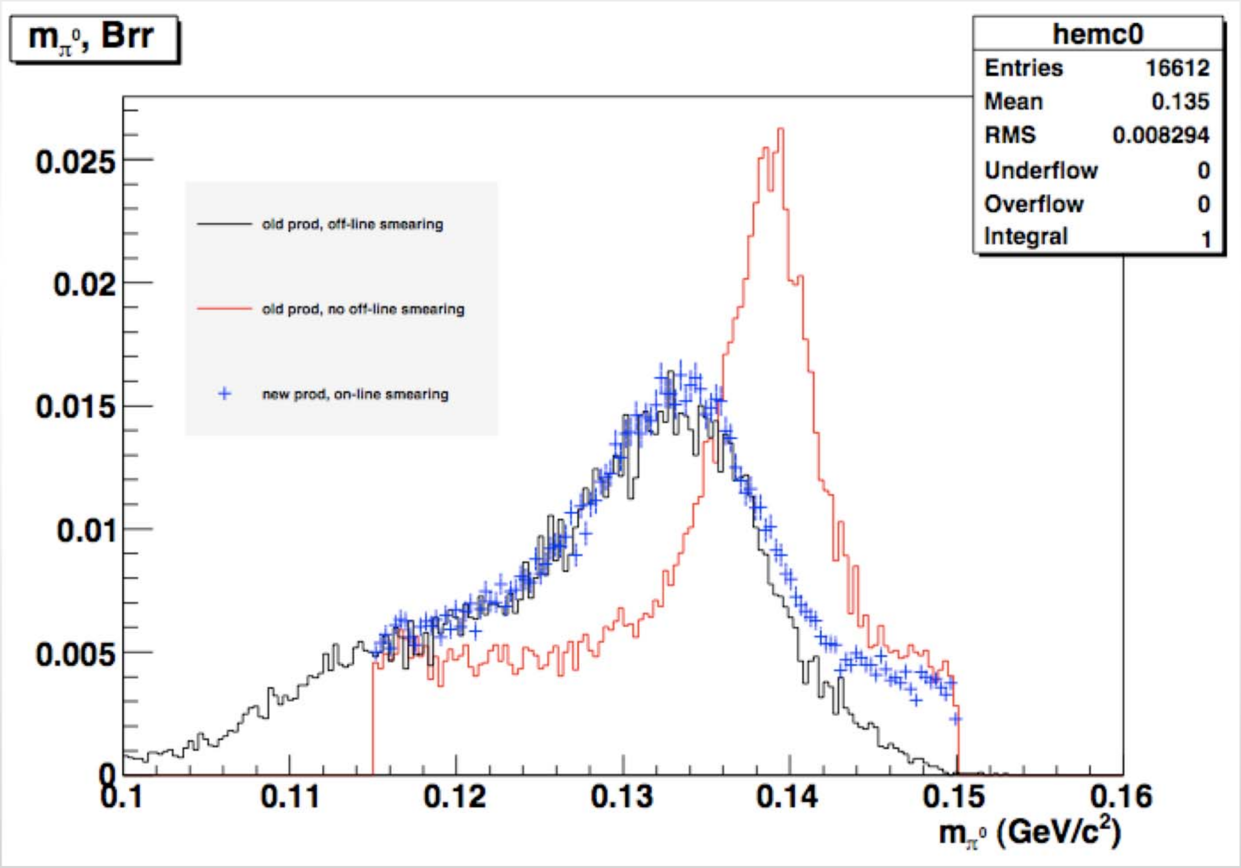
$B^0 \rightarrow K^{*0} \nu\nu$ signal MC : γ angle

- $\theta_{true} - \theta_{reco}$ in bins of E_{true}, truth-matching required
- NO ANGULAR SMEARING APPLIED: red and black matches (same sample)
- large tails due to reco gamma not correctly matched (probably associated to bremmstrahlung – γ produced after $\gamma \rightarrow e^+e^-$ conversion), improvements in single particle tests with more stringent matching requirements (slide 16)



$B^0 \to K^{*0} \nu\nu$ signal MC : π^0 mass

– list-level cuts and fit constraints not reproduced applying smearing after reconstruction, see slide 18 for single π^0 beam results



Single π^0 : sample and selection

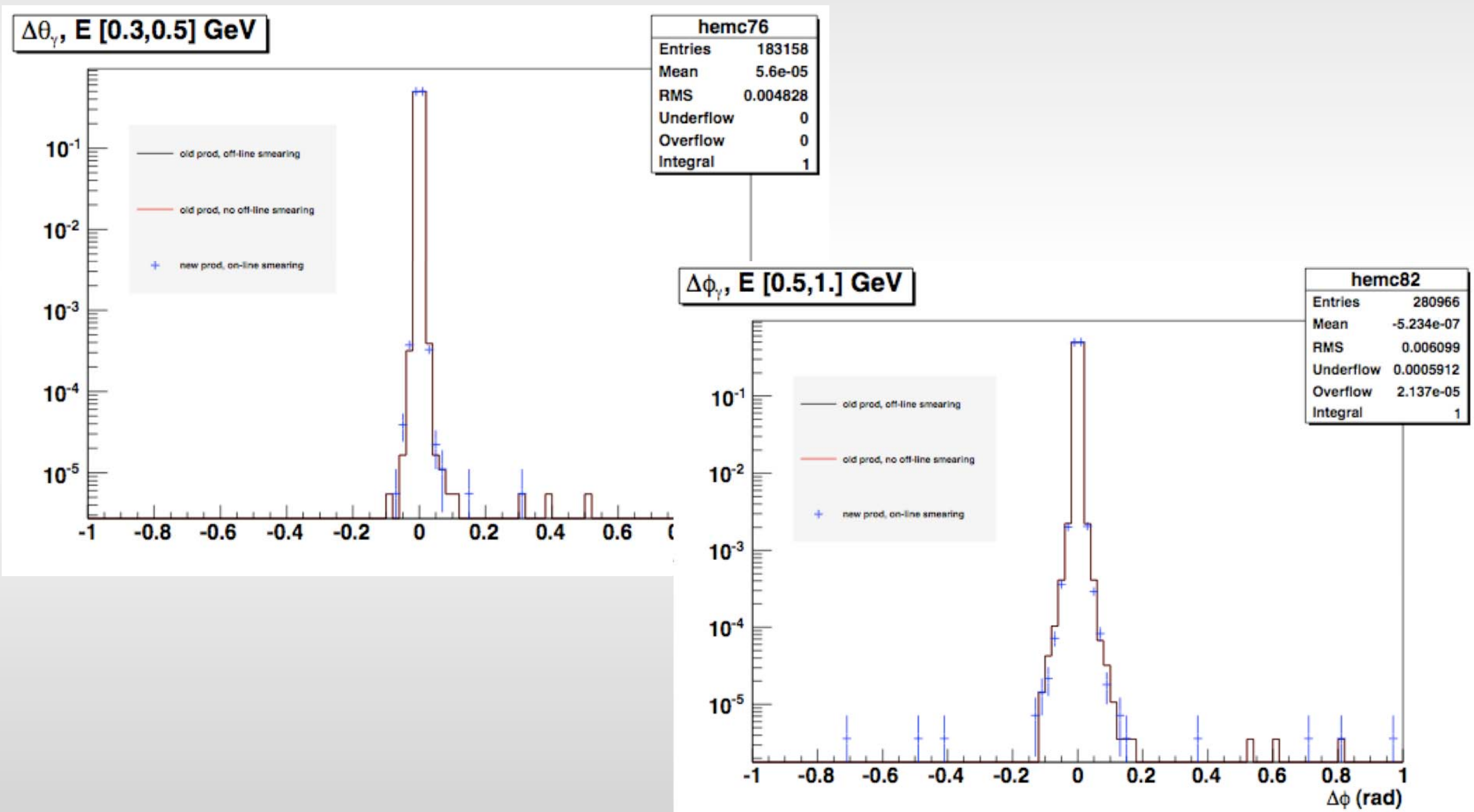
- sample:
  - 500K events with V0.2.6 FastSim release and smearing OFF
  - 500K events with NOMINAL V0.2.6 FastSim release (smearing ON)

- π^0 list
  - γs from CalorNeutral list,
  - $\gamma\gamma$ invariant mass cut: [0.090,0.165] GeV
  - Pmin set 0.05 GeV, Pmax set 4.0 GeV
  - CosThetamin set -1, CosThetamax set 1

- selection
  - 1 reco π^0
  - thruth matching: π^0 reco daughters associated to 2nd and 3rd particle in the MC list (to cut reco γ matched with bremmstrahlung γ produced after $\gamma \rightarrow e^+e^-$ conversion)

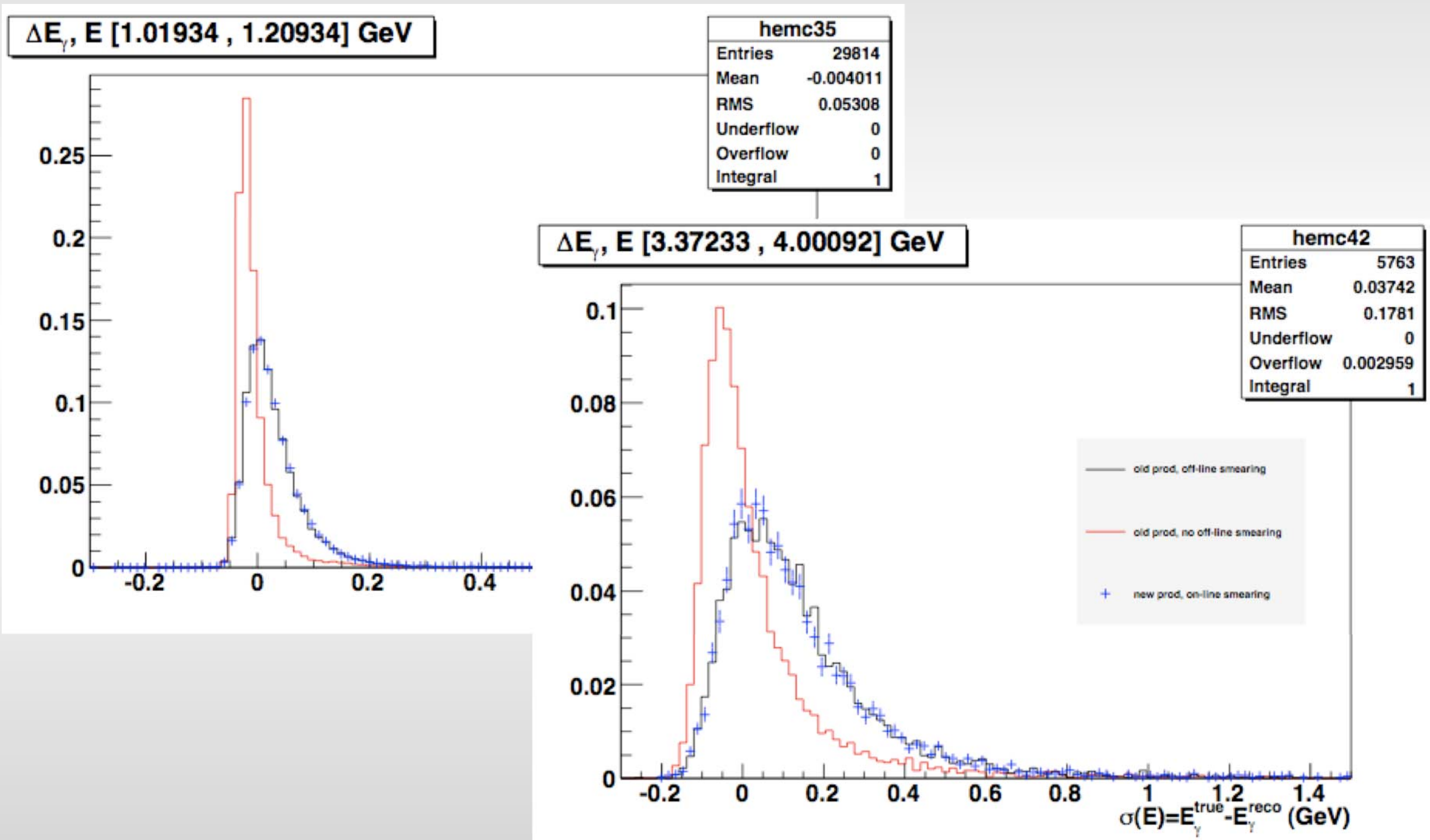
Single π^0 : γ angle

– $\theta_{true} - \theta_{reco}$ and ϕ_{true}-ϕ_{reco} in bins of E_{true}, truth-matching required



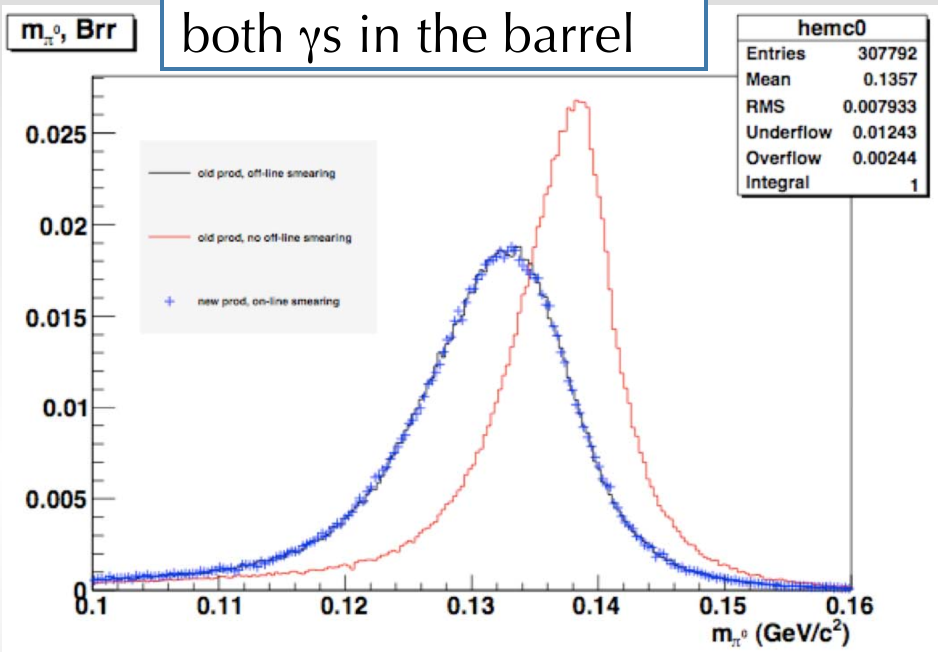
Single π^0 : γ energy

- $E_{true} - E_{reco}$ in bins of E_{true}, truth-matching required

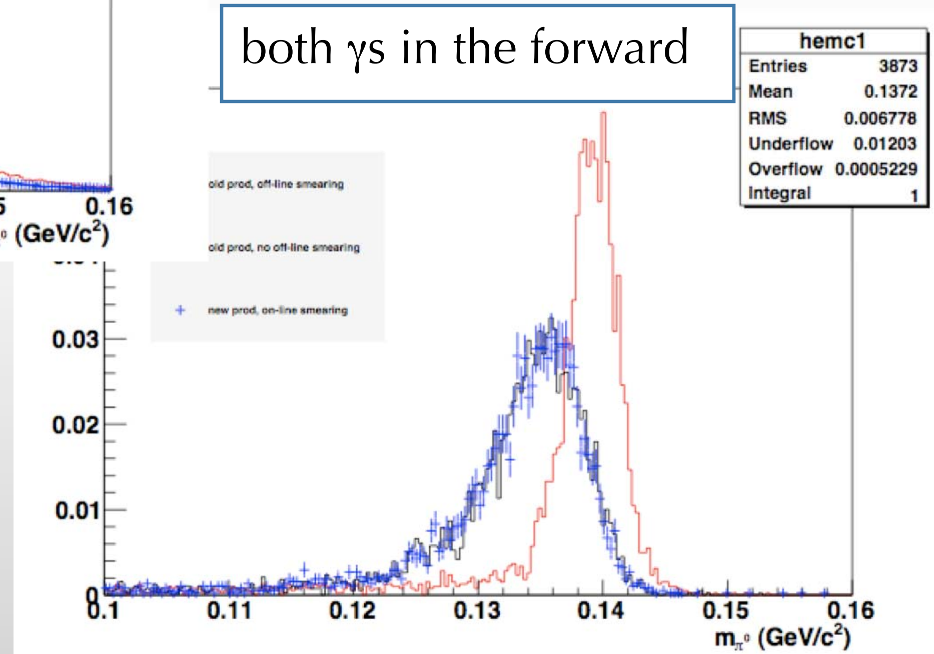


Single π^0 : π^0 mass

both γs in the barrel



both γs in the forward

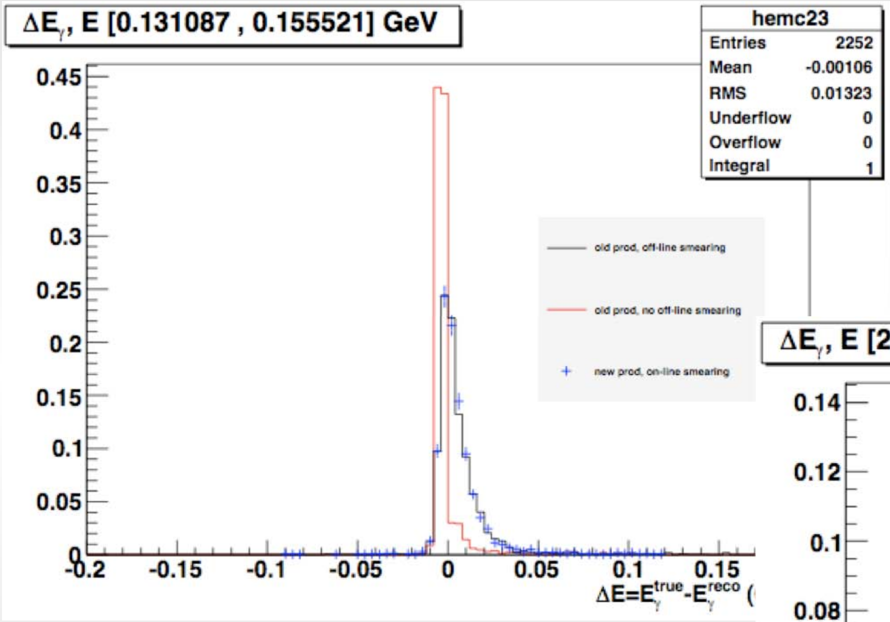


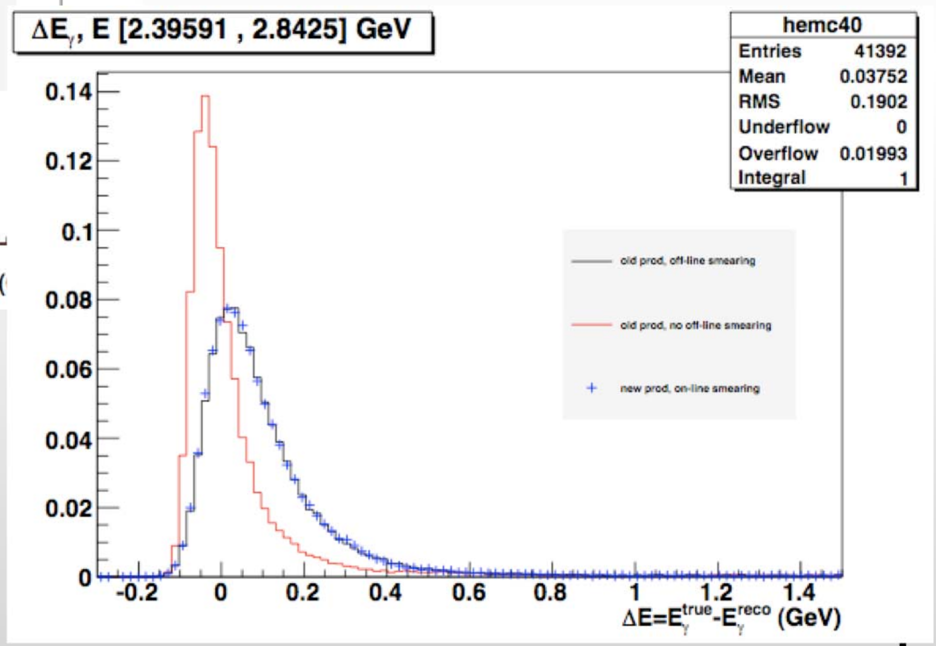
Single γ : sample and selection

- sample:
  - 500K events with V0.2.6 FastSim release and smearing OFF
  - 500K events with NOMINAL V0.2.6 FastSim release (smearing ON)
- γ list
  - CalorNeutral list
  - Pmin set 0.05 GeV , Pmax set 4.0 GeV
  - FULL ANGULAR COVERAGE : CosThetamin set -1, CosThetamax set 1
  - BWD REGIONS: CosThetamin set -1, CosThetamax set -0.9
    CosThetamin set -0.9615, CosThetamax set -0.8815
- selection
  - 1 reco photon
  - thruth matching: reco photon associated to 1st particle in the MC list (to cut reco γ matched with bremmstrahlung γ produced after $\gamma \to e^+e^-$ conversion)

Single γ – full angular coverage : γ energy (I)

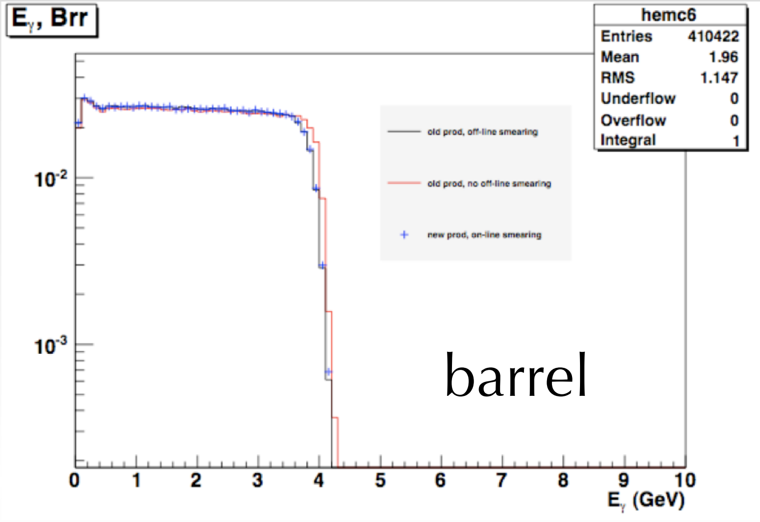
– $E_{true} - E_{reco}$ in bins of E_{true}, truth-matching required

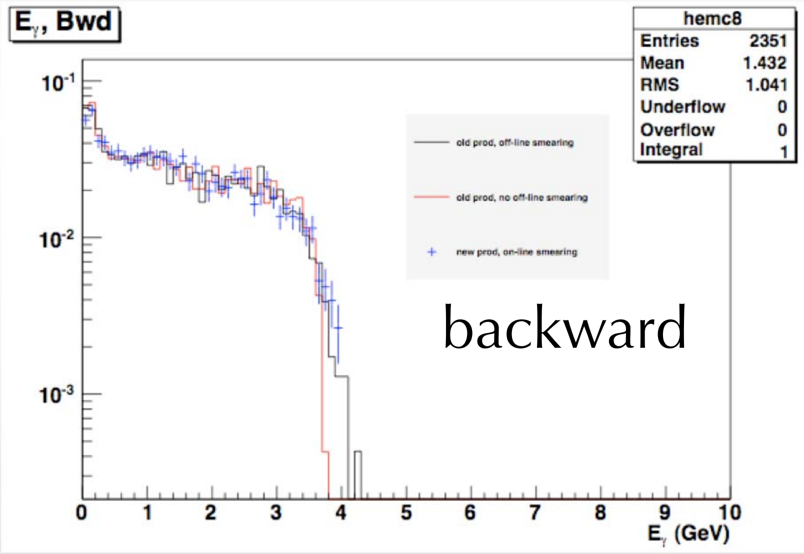


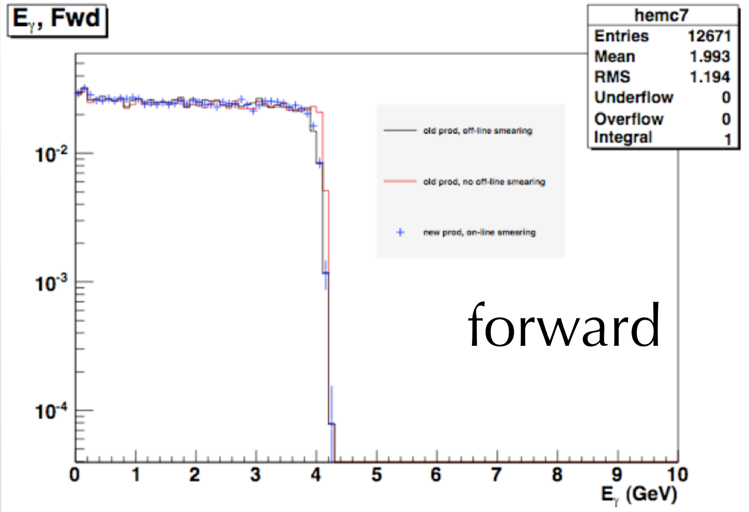


Single γ – full angular coverage : γ energy (II)

– E_{reco} in different EMC regions

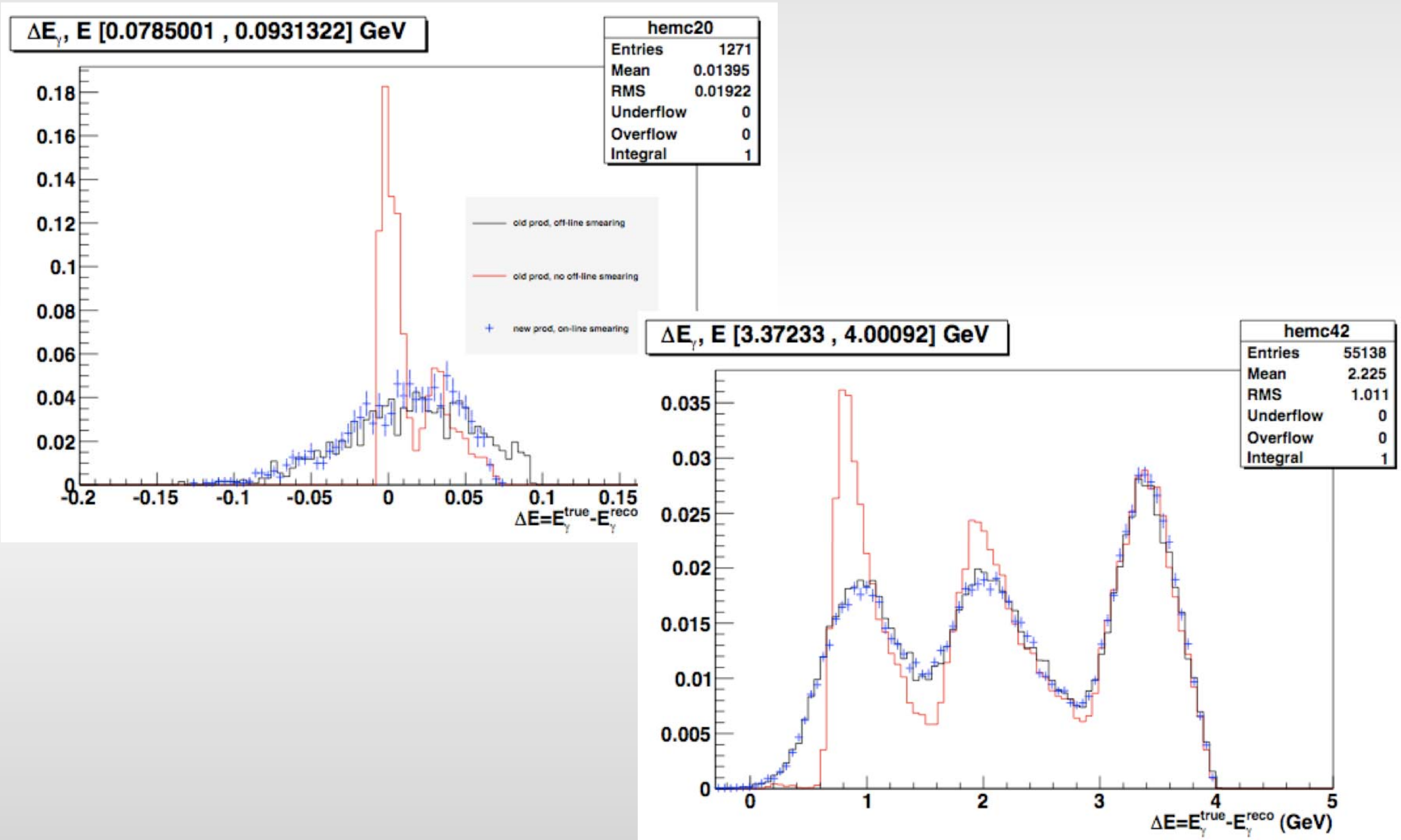






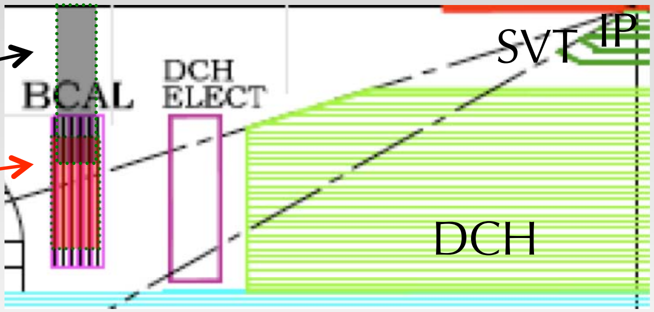
Single γ – BWD angular coverage : γ energy (I)

– $E_{true} - E_{reco}$ in bins of E_{true}, truth-matching required

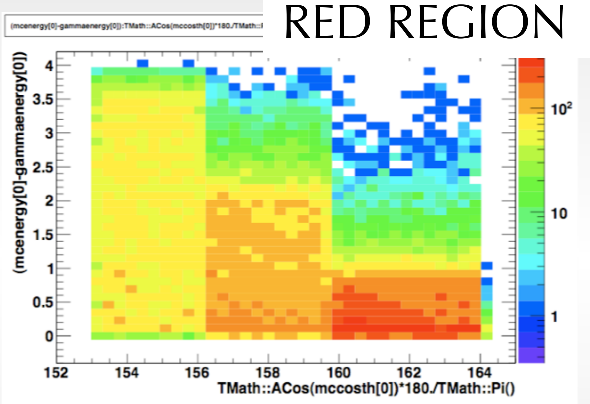


Single γ – BWD angular coverage : γ energy (II)

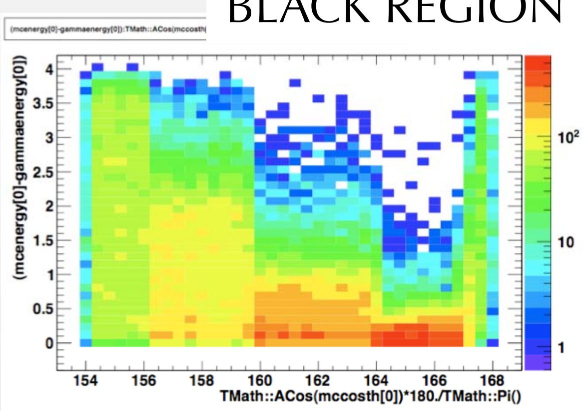
- Angular coverages:
  - CosTheta [-1,-0.9] (BLACK)
  - CosTheta [-0.9615,-0.8815] (RED)



RED REGION

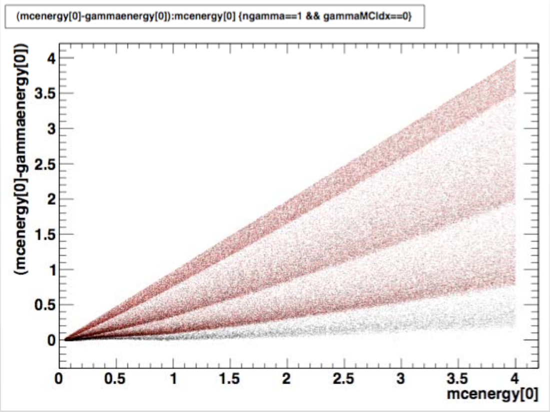


BLACK REGION



- $E_{true} - E_{reco}$ vs $Theta_{true}$

- $E_{true} - E_{reco}$ vs E_{true}, truth-matching required



Physics results

Eextra distributions, before Bsig selection

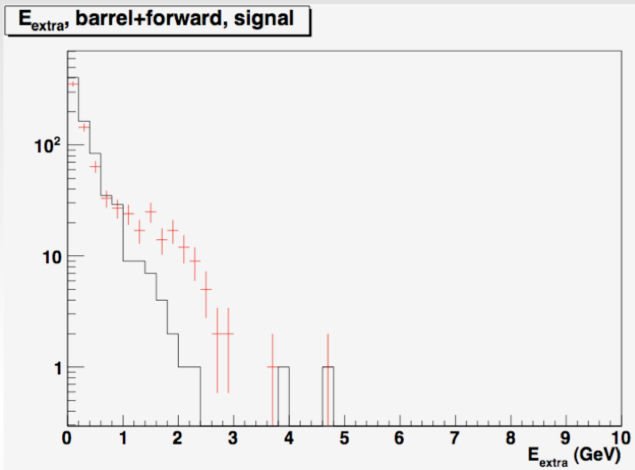
– $B^+ \to K^{*+}(K_s\pi)\nu\nu$

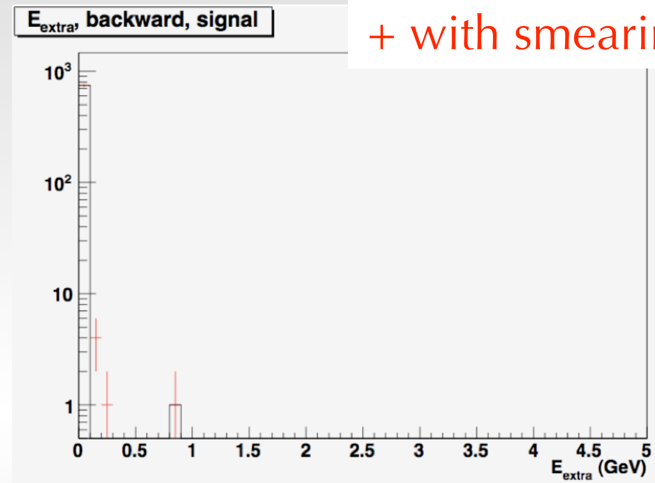
barrel+fwd

bwd

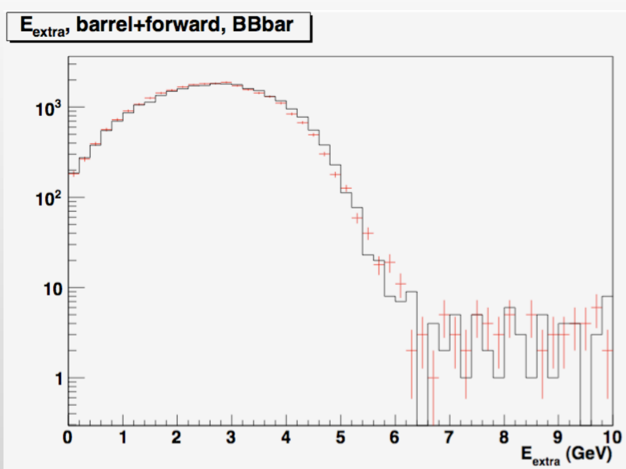
- without smearing
+ with smearing

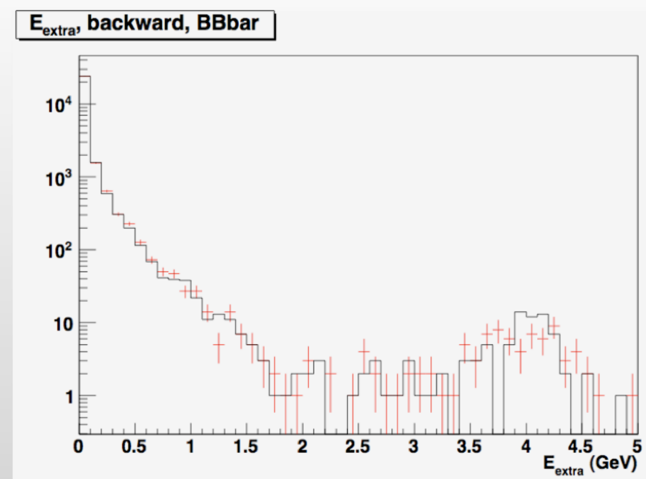
signal





BB cocktail





Eextra distributions, before Bsig selection

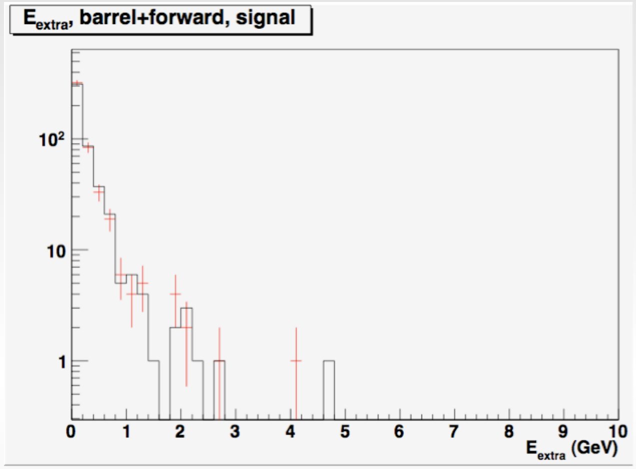
– $B^+ \to K^{*+}(K\pi^0)\nu\nu$

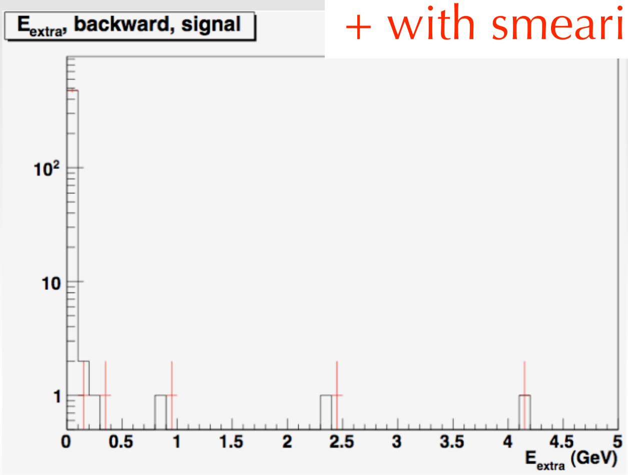
barrel+fwd

bwd

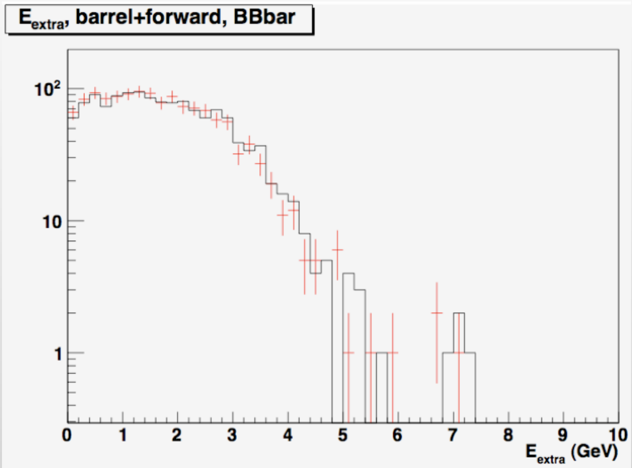
- without smearing
+ with smearing

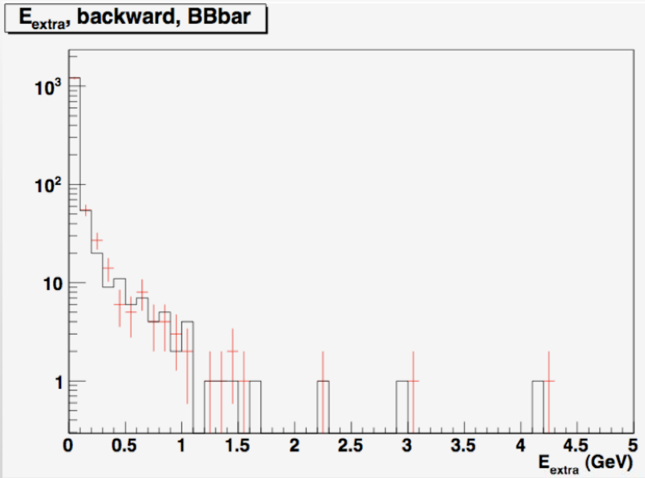
signal





BB cocktail





Eextra distributions, before Bsig selection

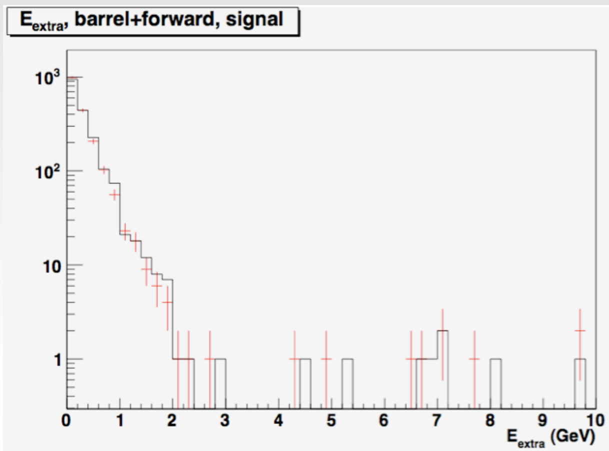
– $B^0 \to K^{*0}(K\pi)\nu\nu$

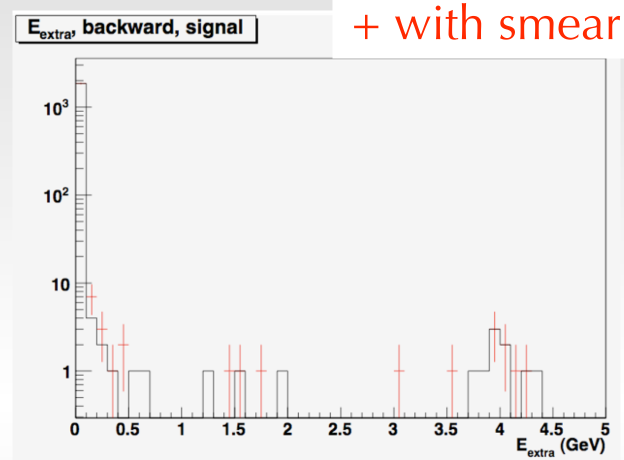
barrel+fwd

bwd

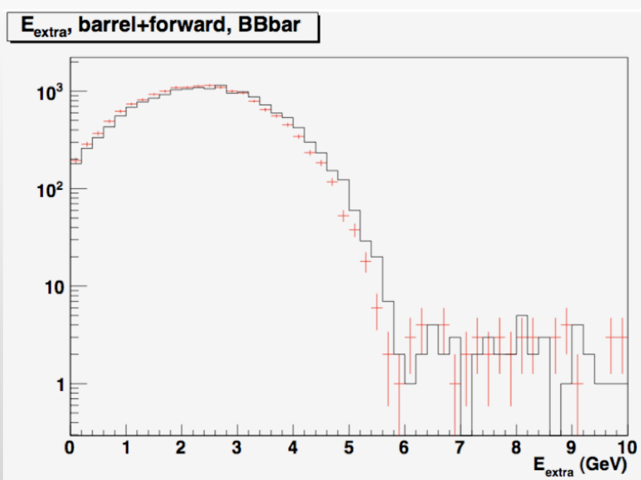
- without smearing
+ with smearing

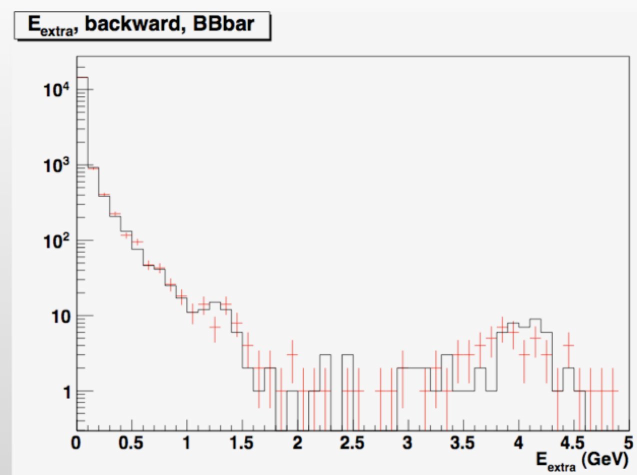
signal





BB
cocktail





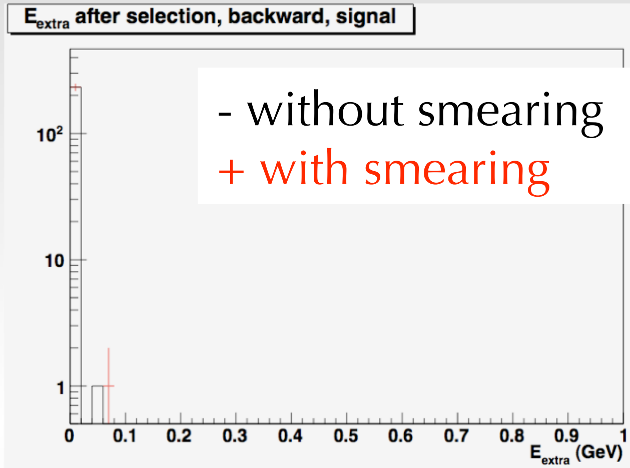
Eextra BWD distributions, after Bsig selection

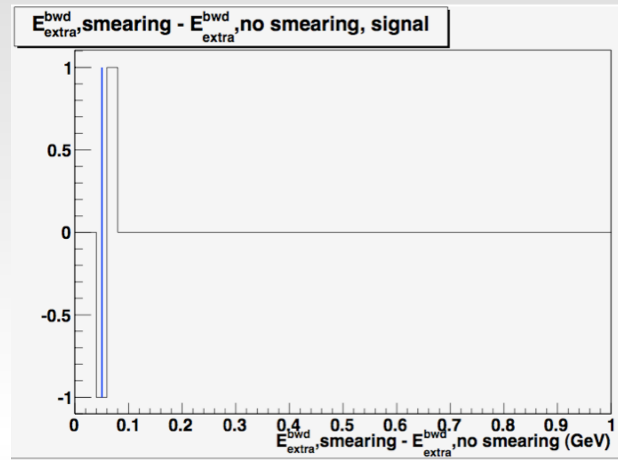
– $B^+ \to K^{*+}(K_s\pi)\nu\nu$

bwd

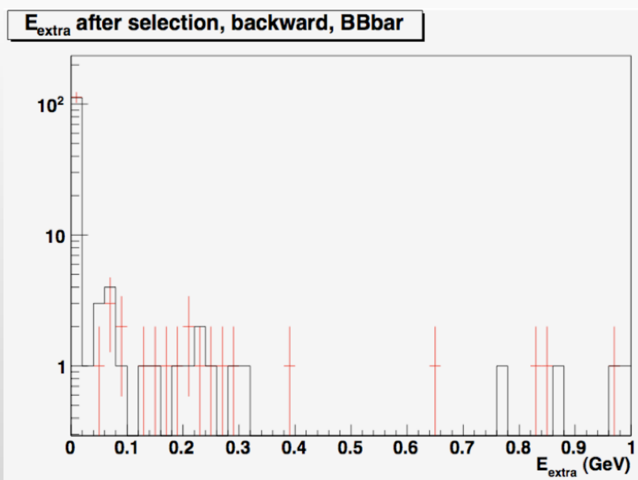
Eextra bwd w smearing - Eextra bwd w/o smearing

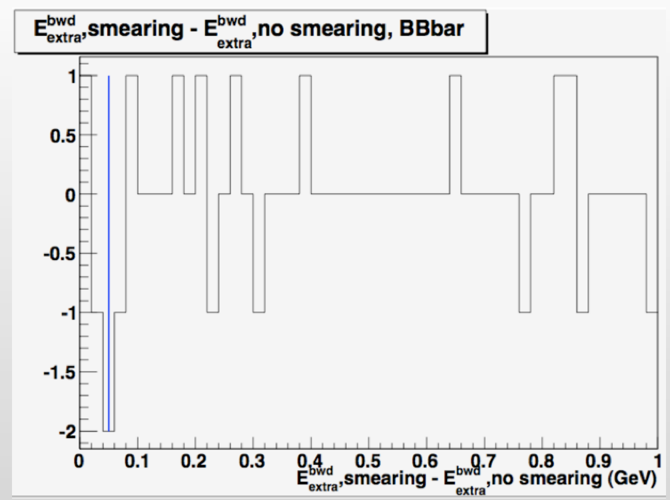
signal





BB cocktail





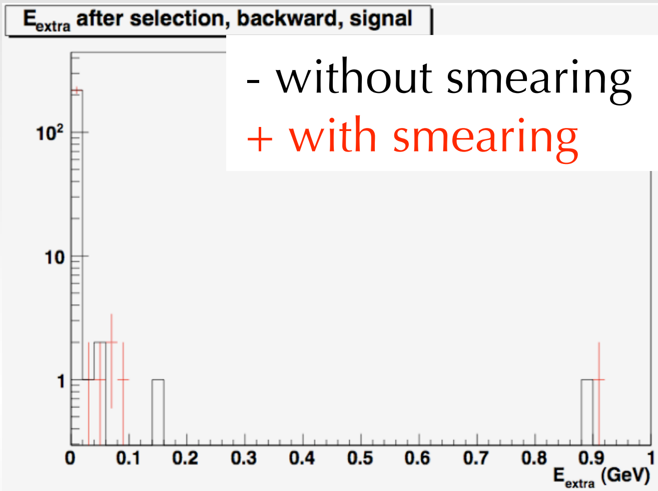
Eextra BWD distributions, after Bsig selection

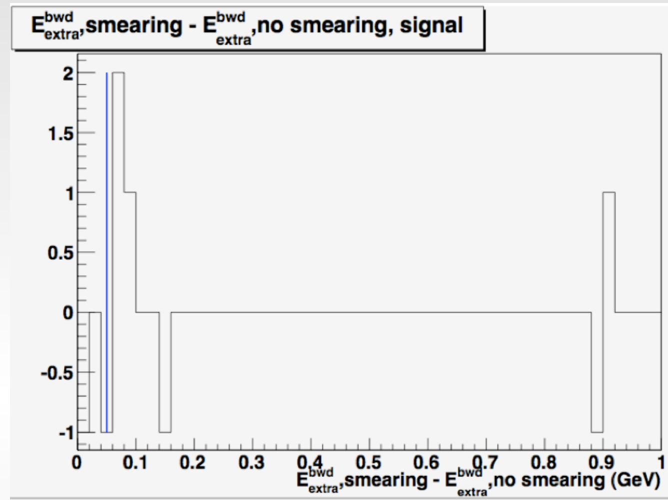
– $B^+ \rightarrow K^{*+}(K\pi^0)\nu\nu$

bwd

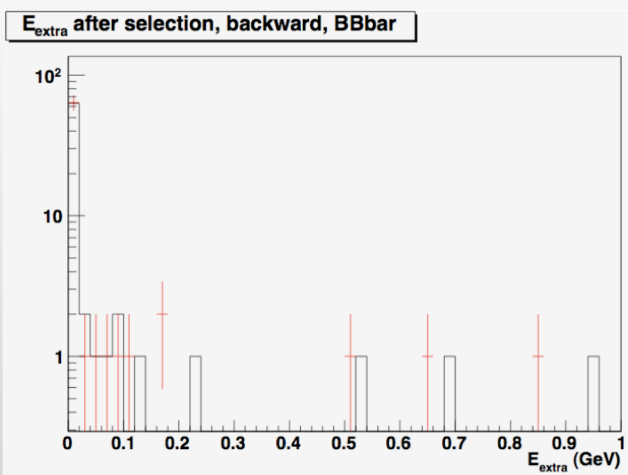
Eextra bwd w smearing - Eextra bwd w/o smearing

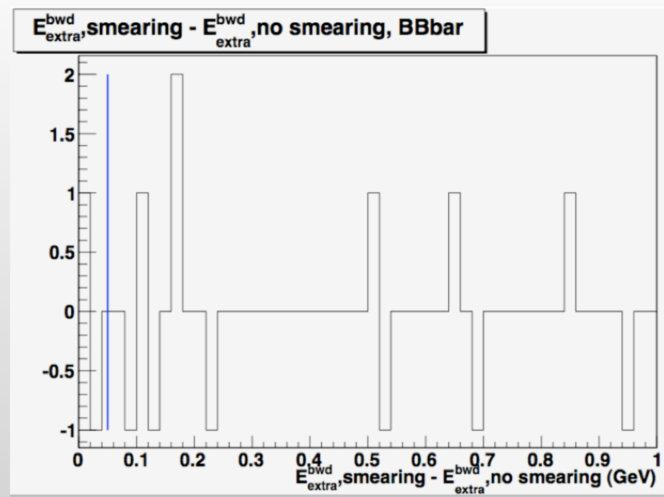
signal





BB cocktail





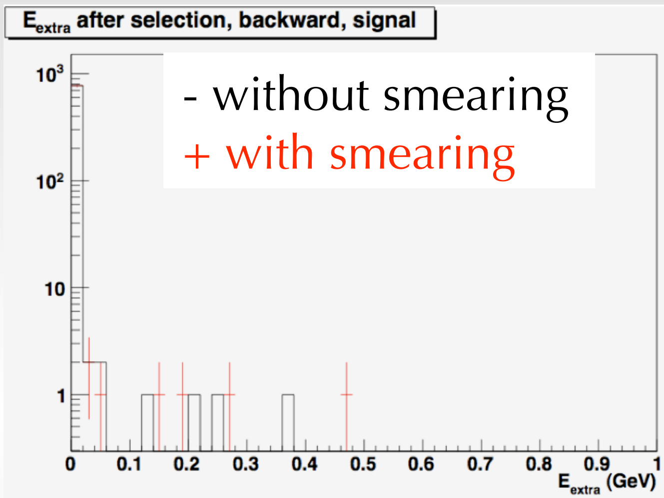
Eextra BWD distributions, after Bsig selection

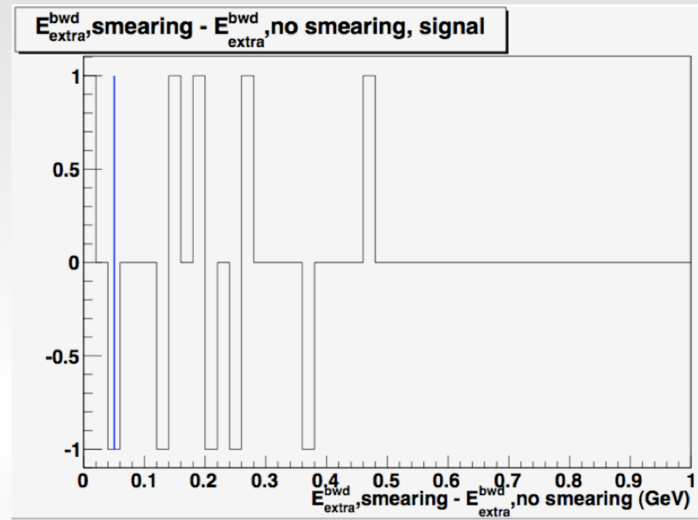
– $B^0 \to K^{*0}(K\pi)\nu\nu$

bwd

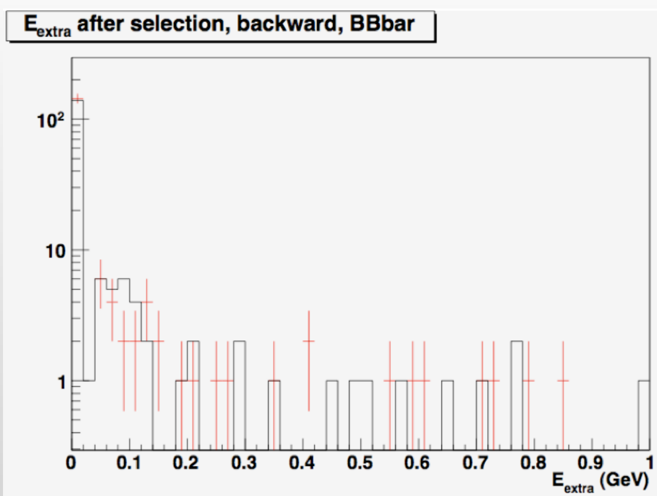
Eextra bwd w smearing - Eextra bwd w/o smearing

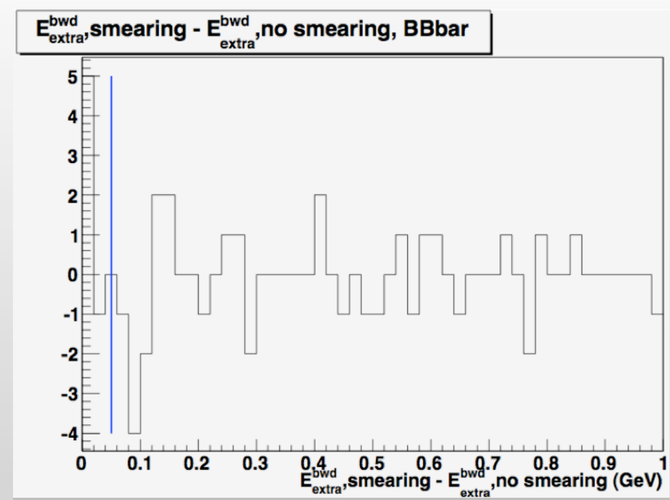
signal





BB cocktail





Result (I)

– Eextra_bwd < 50 GeV, $E_{min,\gamma}$ = 30 MeV

– Changes wrt to Preliminary results shown in

http://agenda.infn.it/getFile.py/access?contribId=2&resId=0&materialId=slides&confId=3464

- fixed bug in Bwd-Barrel angular coverage
- fixed bug in extra-photon finding algorithm (some of the Breco modes where not incorporated in the study)
- remove cut on Eextra_barrel+fwd (uncorrelated to Eextra_bwd) to increase the statistics

– Figure of Merit

- Significance =S/sqrt(S+B)
- ΔSignificance/Significance = (Sig_bwd-Sig_nobwd)/Sig_nobwd
- in the limit S<<B:

ΔSignificance/Significance = (ε_sig/sqrt(ε_bb)) - 1

being ε_sig (ε_bb) the marginal efficiency of the Eextra_bwd cut in signal (BBbar) MC sample

Result (II)

SMEARING OFF			
$B^0 \to K^{*0}\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^0 \to K^{*0}\nu\bar{\nu}$	786	778	$(99.98 \pm 0.36)\%$
B^0 had cocktail	181	143	$(79.0 \pm 3.0)\%$
$\Delta Sign/Sign$	$(11.4 \pm 1.9)\%$		
$B^+ \to K^{*+}(K_S\pi^+)\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	233	232	$(99.57 \pm 0.43)\%$
B^+ had cocktail	136	114	$(83.8 \pm 3.2)\%$
$\Delta Sign/Sign$	$(8.7 \pm 1.9)\%$		
$B^+ \to K^{*+}(K^+\pi^0)\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	227	222	$(97.8 \pm 1.0)\%$
B^+ had cocktail	75	65	$(86.7 \pm 3.9)\%$
$\Delta Sign/Sign$	$(5.0 \pm 2.4)\%$		

SMEARING ON			
$B^0 \to K^{*0}\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^0 \to K^{*0}\nu\bar{\nu}$	786	778	$(99.98 \pm 0.36)\%$
B^0 had cocktail	181	146	$(80.7 \pm 2.9)\%$
$\Delta Sign/Sign$	$(10.2 \pm 1.8)\%$		
$B^+ \to K^{*+}(K_S\pi^+)\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	233	232	$(99.57 \pm 0.43)\%$
B^+ had cocktail	136	114	$(83.8 \pm 3.2)\%$
$\Delta Sign/Sign$	$(8.7 \pm 1.9)\%$		
$B^+ \to K^{*+}(K^+\pi^0)\nu\bar{\nu}$			
Sample	N_{sel}	$N_{\text{sel,Bwd}}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	227	221	$(97.4 \pm 1.1)\%$
B^+ had cocktail	75	65	$(86.7 \pm 3.9)\%$
$\Delta Sign/Sign$	$(4.6 \pm 2.4)\%$		

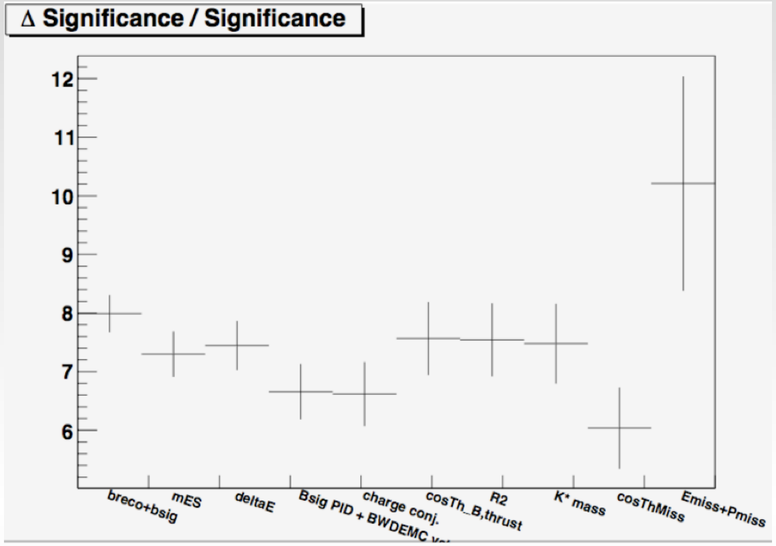
Conclusion

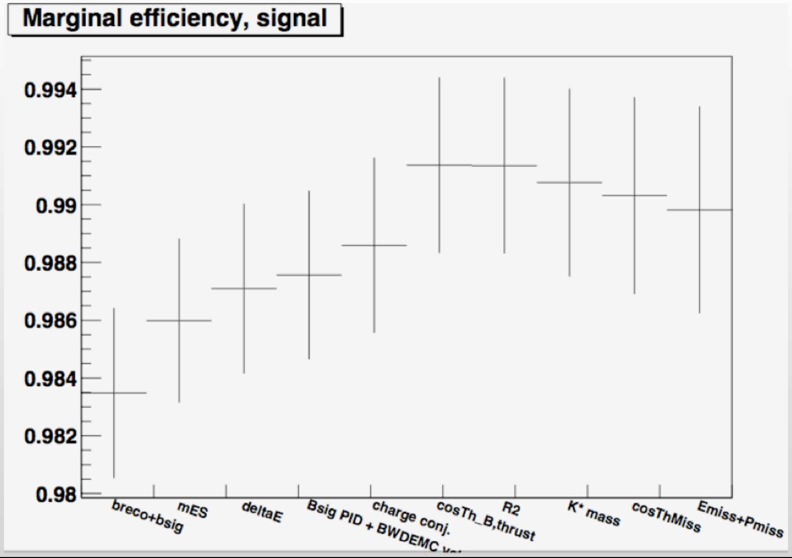
- Algorithm to apply off-line neutral energy smearing in place
- algorithm validated on gamma and π^0 single particle beams and signal MC

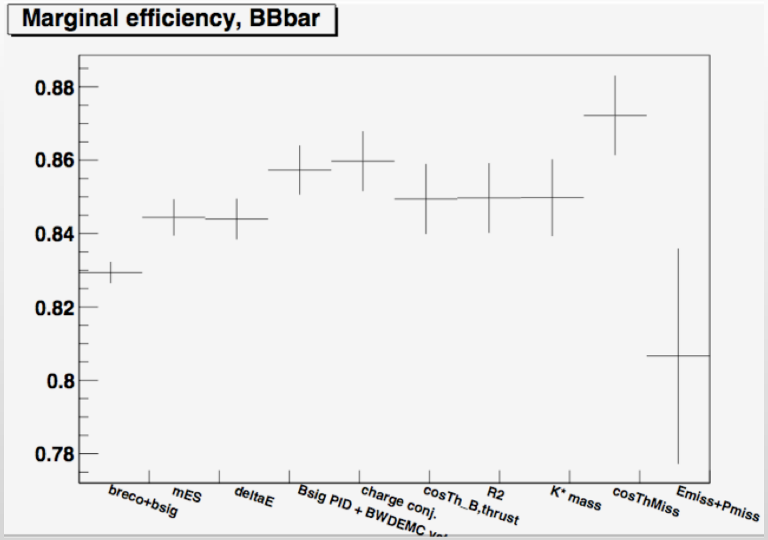
- Negligible effect of smearing on physics result:
  5-10% gain in significance with Eextra,bwd veto

Back-up slides

Significance-flow in Kπ







Results with Eextra_brrfwd cut

SMEARING ON, E_{extra}^{brrfwd} cut			
$B^0 \to K^{*0}\nu\bar{\nu}$			
Sample	$N_{\rm sel}$	$N_{\rm sel,Bwd}$	ε
$B^0 \to K^{*0}\nu\bar{\nu}$	735	727	$(98.91 \pm 0.38)\%$
B^0 had cocktail	91	75	$(82.4 \pm 4.0)\%$
$\Delta Sign/Sign$	$(8.9 \pm 2.4)\%$		
$B^+ \to K^{*+}(K_S\pi^+)\nu\bar{\nu}$			
Sample	$N_{\rm sel}$	$N_{\rm sel,Bwd}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	191	190	$(99.48 \pm 0.52)\%$
B^+ had cocktail	76	66	$(86.8 \pm 3.9)\%$
$\Delta Sign/Sign$	$(6.7 \pm 2.3)\%$		
$B^+ \to K^{*+}(K^+\pi^0)\nu\bar{\nu}$			
Sample	$N_{\rm sel}$	$N_{\rm sel,Bwd}$	ε
$B^+ \to K^{*+}\nu\bar{\nu}$	214	208	$(97.2 \pm 1.1)\%$
B^+ had cocktail	40	33	$(82.5 \pm 6.0)\%$
$\Delta Sign/Sign$	$(7.0 \pm 3.7)\%$		