Backward EMC for $B \to \tau\nu_\tau$ Decay With Hadronic Tag B

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Caltech

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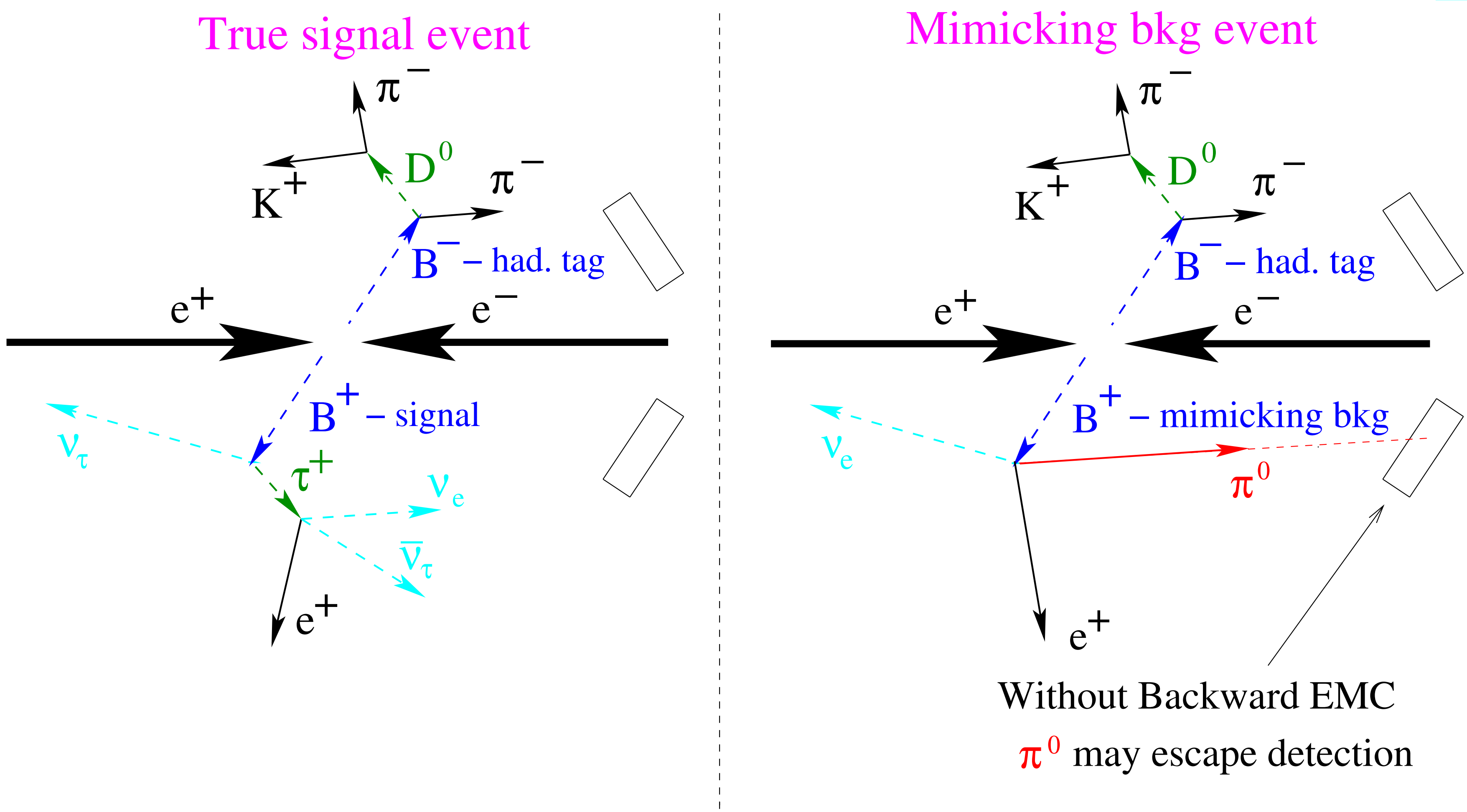
XVI SuperB General Meeting

$B \to \tau \nu_\tau$ Event



The purpose of Backward EMC is to help better distinguish between signal and background by detecting (otherwise lost) photons

Analysis Strategy

- Generate B^+B^- Monte Carlo with FastSim V0.2.6 (BAD energy smearing) and V0.2.7 (BETTER energy smearing) for DG_4 and MixSuperbBkg_NoPair for different decays of B_{tag} and B_{recoil}
- Reconstruct B_{tag} and B_{recoil} with `PacHadRecoilUser` package
- Ensure that B_{tag} reconstruction does not include bwd photons with $\cos\theta < -0.8$
- Select only B_{tag} with minimum ΔE (one or more per event)
- Plot $m_{ES}(B_{tag})$ and fit it to get the yield
- Obtain yields for signal (S) and mimicking background (B) decays of B_{recoil}
- Calculate S/B ratio and $S/\sqrt{S+B}$ at 75 ab^{-1} **without using Backward EMC info (reference values)**

Analysis Strategy - cont'd

- Ensure that B_{recoil} reconstruction does not include bwd photons with $\cos\theta < -0.8$
- Calculate E_{extra} in Bwd EMC for 6 different thresholds: none, $20, 30, 50, 70, 100$ MeV
  ☞ Thus every plot comes in 6 copies
- Obtain reconstruction efficiencies for signal and mimicking background decays of B_{recoil}, as well as S/B ratio and $S/\sqrt{S+B}$ at 75 ab^{-1} **as functions of cut on $\boldsymbol{E_{extra}}$**
- Compare to reference values from previous page, obtain 6 rel. differences in S/B and $S/\sqrt{S+B}$
- Quote maximum of these 6 numbers as final result for this combination of signal and mimicking background decays of B_{recoil} (for given decay of B_{tag})
- Repeat for different signal and mimicking background decays of B_{recoil}, present results as a table
- Repeat for different B_{tag} decays
- Repeat for V0.2.6 and V0.2.7 to see energy smearing effects

τ reconstruction

Signal $B_{sig} \to \tau\nu$ decay	τ BF from PDG	Mimicking bkg	Mimicking τ bkg
$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	17.36%	$B \to e\nu + X$	$B \to \tau\nu X, \tau \to e\nu\nu$
$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	17.85%	$B \to \mu\nu + X$	$B \to \tau\nu X, \tau \to \mu\nu\nu$
$B_{sig} \to \tau\nu, \tau \to \pi\nu$	10.91%	$B \to \pi + X$	$B \to \tau\nu X, \tau \to \pi\nu$
$B_{sig} \to \tau\nu, \tau \to \rho\nu$	25.51%	$B \to \rho + X$	$B \to \tau\nu X, \tau \to \rho\nu$
$B_{sig} \to \tau\nu, \tau \to a_1\nu$	9.32%	$B \to a_1 + X$	$B \to \tau\nu X, \tau \to a_1\nu$
$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	9.29%	$B \to \pi 2\pi^0 + X$	$B \to \tau\nu X, \tau \to \pi 2\pi^0\nu$
$\tau \to$ all 6	90.24%	$B \to$ anything	$B \to \tau\nu X, \tau \to$ all 6

- X - any lost particle(s). Rare loss of particles compensated by large relative BF
- Last column: Special sub-class of the mimicking bkg – bkg having real τ

Analysis Outline

Tag	Signal	Mimicking bkg		
		Simplest	Generic	Tauonic
$B_{tag} \to \pi D^0(K\pi)$	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	$B \to \pi^0 \mu\nu$	$B \to \mu\nu X$	$B \to \tau\nu X, \tau \to \mu\nu\nu$
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	$B \to \pi^0 e\nu$	$B \to e\nu X$	$B \to \tau\nu X, \tau \to e\nu\nu$
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$		$B \to X$	$B \to \tau\nu X, \tau \to \pi\nu$
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$		$B \to X$	$B \to \tau\nu X, \tau \to \rho\nu$
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$		$B \to X$	$B \to \tau\nu X, \tau \to a_1\nu$
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0 \nu$		$B \to X$	$B \to \tau\nu X, \tau \to \pi 2\pi^0 \nu$
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes		$B \to X$	$B \to \tau\nu X, \tau \to$ 6 modes
$B_{tag} \to$ hadrons	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	$B \to \pi^0 \mu\nu$	$B \to \mu\nu X$	$B \to \tau\nu X, \tau \to \mu\nu\nu$
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	$B \to \pi^0 e\nu$	$B \to e\nu X$	$B \to \tau\nu X, \tau \to e\nu\nu$
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$		$B \to X$	$B \to \tau\nu X, \tau \to \pi\nu$
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$		$B \to X$	$B \to \tau\nu X, \tau \to \rho\nu$
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$		$B \to X$	$B \to \tau\nu X, \tau \to a_1\nu$
	$B_{sig} \to \tau\nu, \tau \to \pi 2 pi^0 \nu$		$B \to X$	$B \to \tau\nu X, \tau \to \pi 2\pi^0 \nu$
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes		$B \to X$	$B \to \tau\nu X, \tau \to$ 6 modes

I use two kinds of MC samples for generic hadronic bkg: Caltech-generated (V0.2.6 and V0.2.7)

and offical CNAF-generated hadronic cocktail (September 2010 production, V0.2.4)

Simplest Hadronic Tag

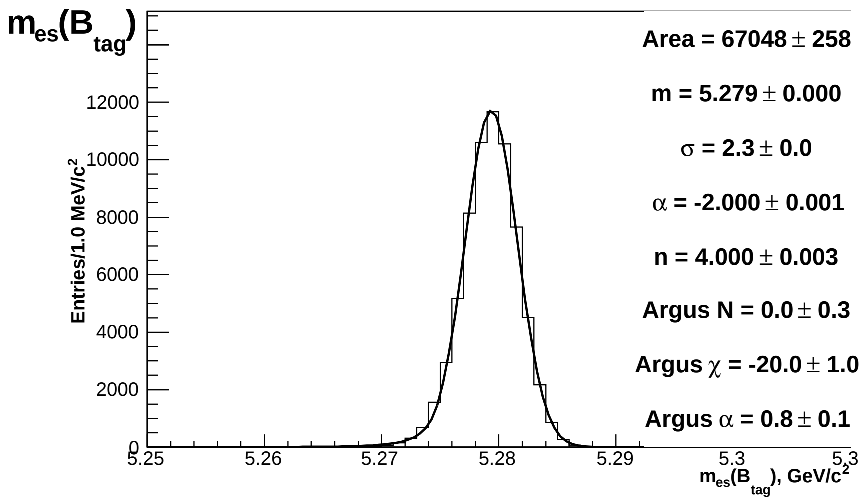
$$B_{tag} \rightarrow \pi D^0, D^0 \rightarrow K\pi$$

Sig: $B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$

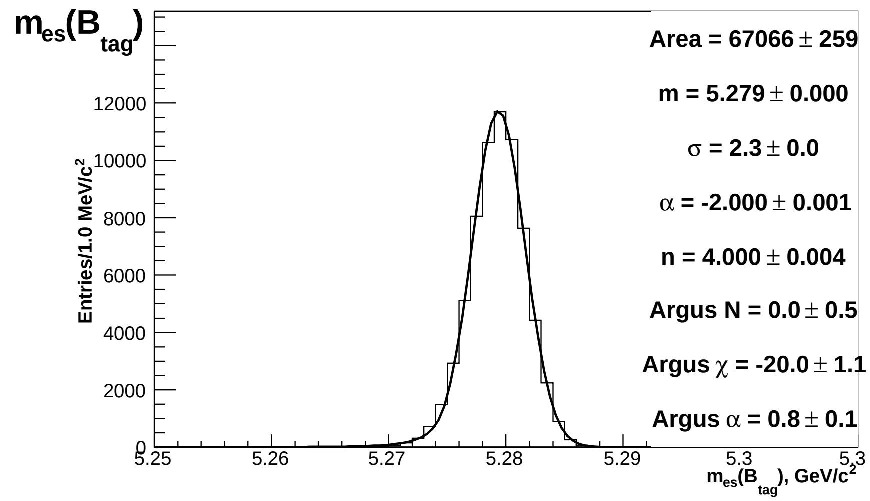
Bkg: $B \to \pi^0\mu\nu$

Bkg: very special case with almost the same branching and only two extra photons

m_{es} in signal sample

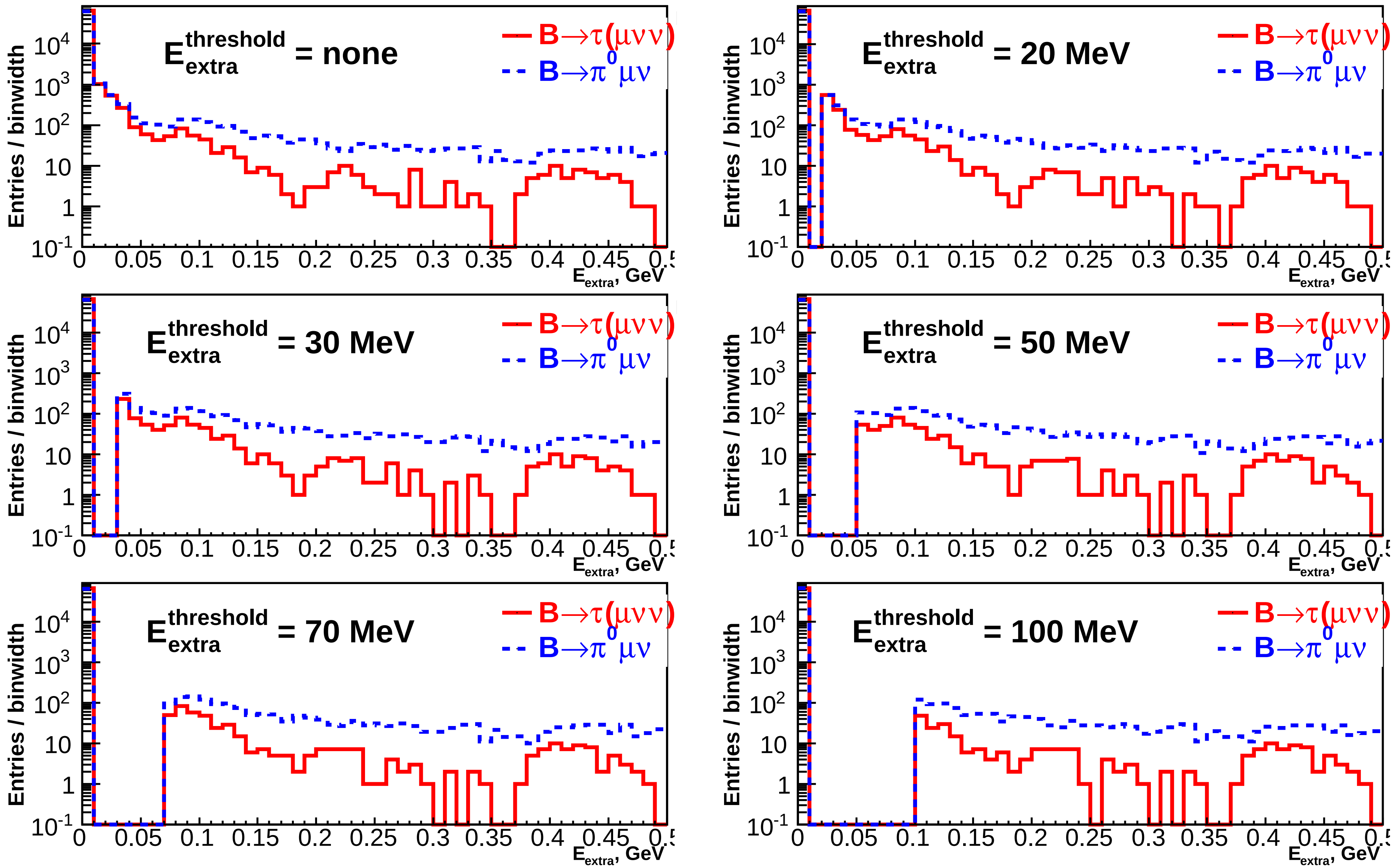


m_{es} in bkg sample



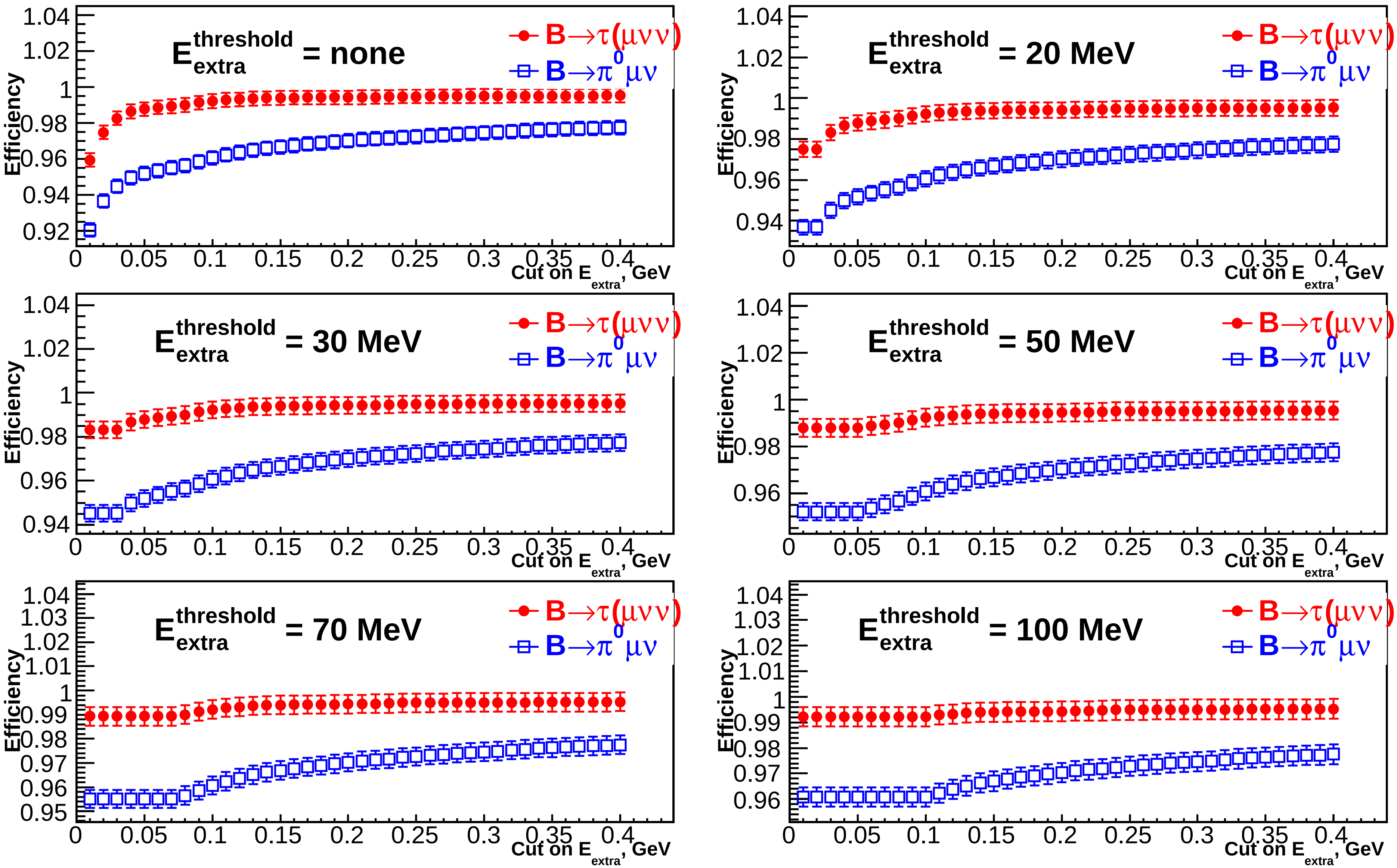
- Cut on different values of E_{extra} in Backward EMC
- Fit for the peak yield after each cut
- Plot peak yields vs. cut values

E_{extra}



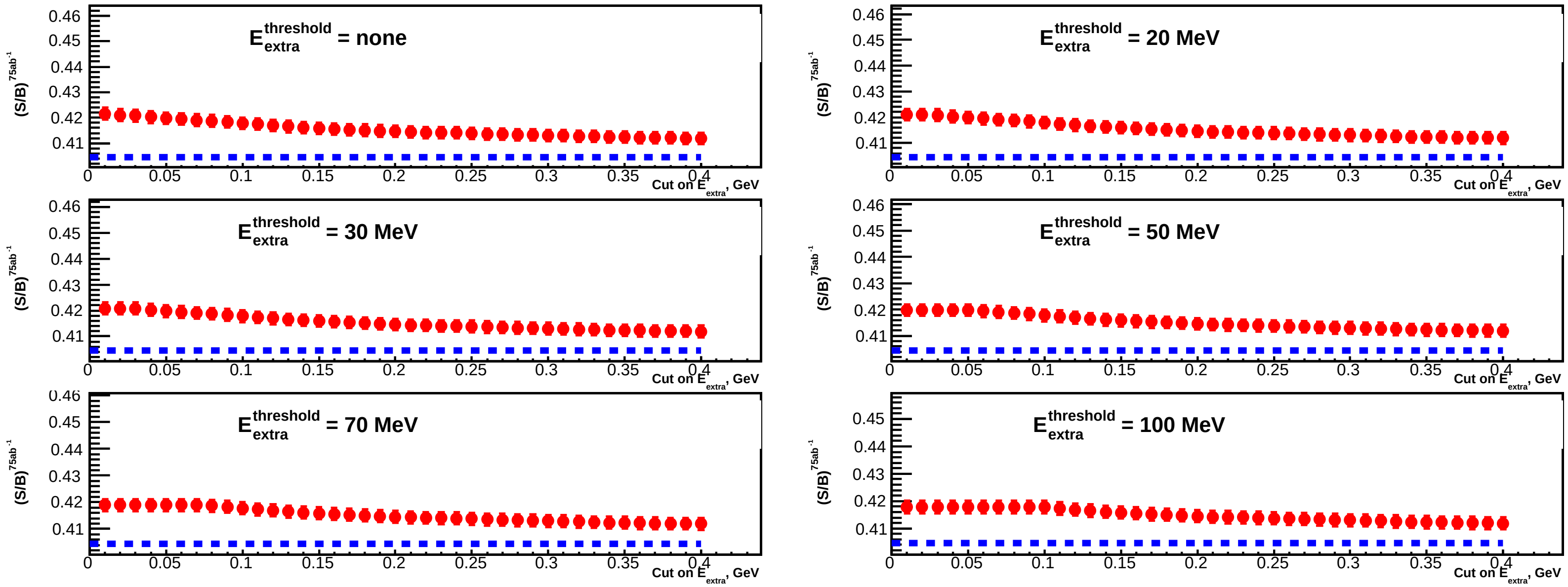
$E_{extra}^{threshold}$ = none
$E_{extra}^{threshold}$ = 20 MeV
$E_{extra}^{threshold}$ = 30 MeV
$E_{extra}^{threshold}$ = 50 MeV
$E_{extra}^{threshold}$ = 70 MeV
$E_{extra}^{threshold}$ = 100 MeV
$B\to\tau(\mu\nu\nu)$
$B\to\pi^0\mu\nu$
Entries / binwidth
E_{extra}, GeV

E_{extra} cut efficiency

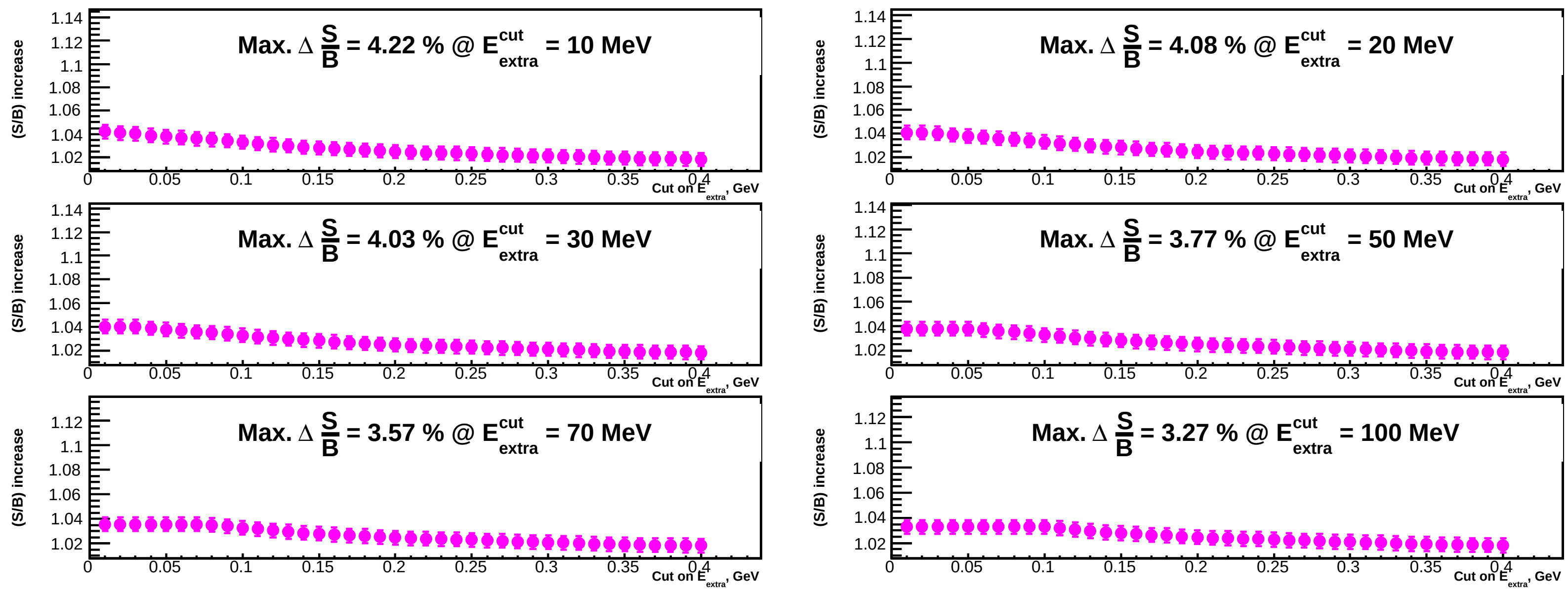


S/B ratio at 75 ab^{-1}

Absolute value

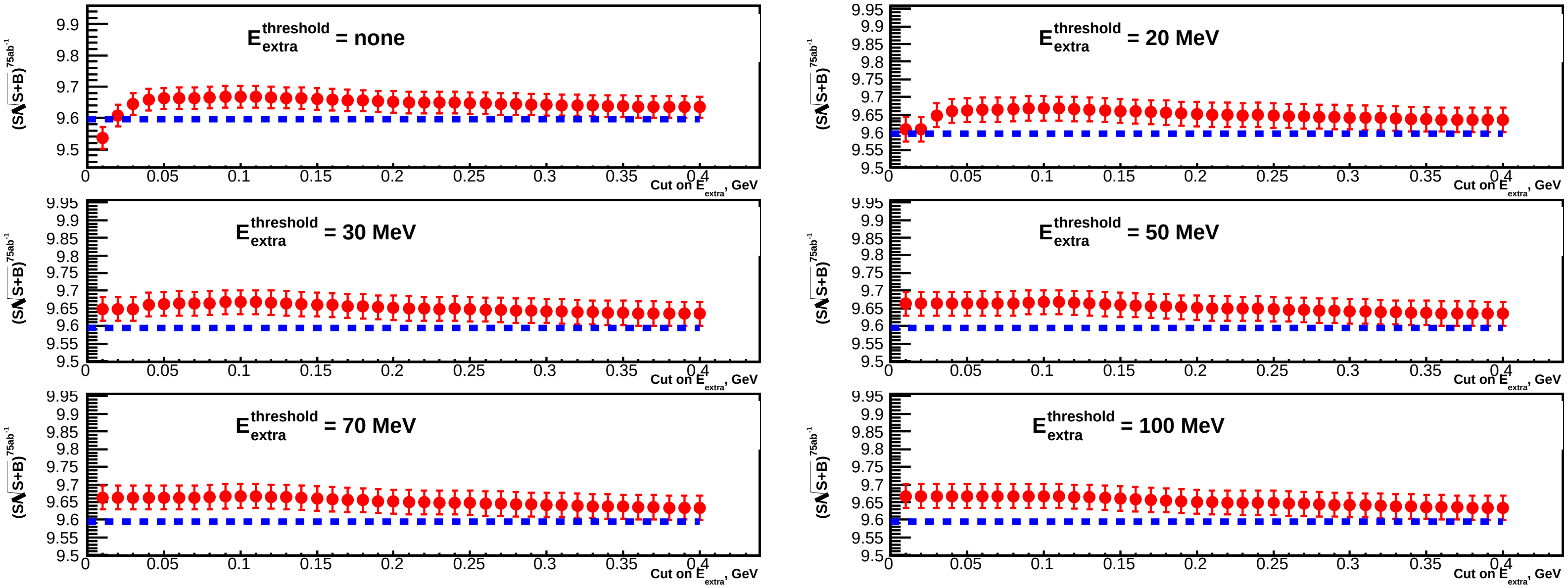


Relative increase

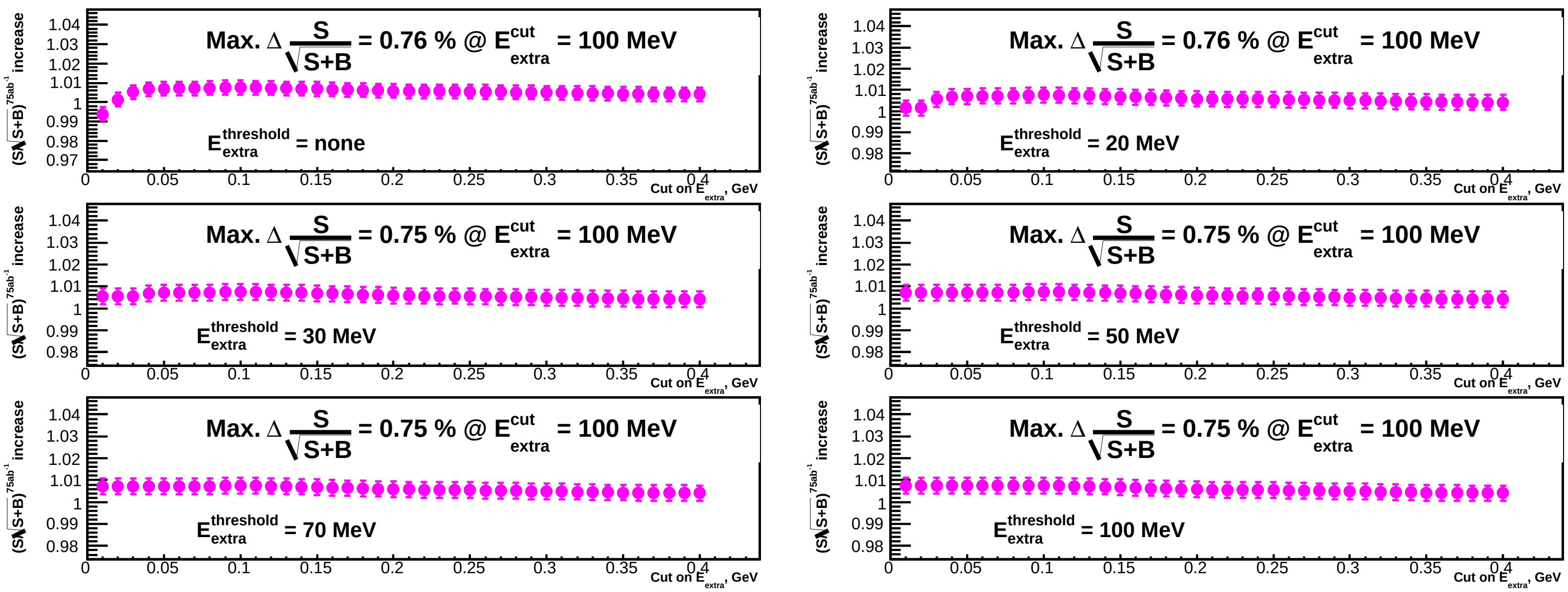


$S/\sqrt{S+B}$ at 75 ab^{-1}

Absolute value



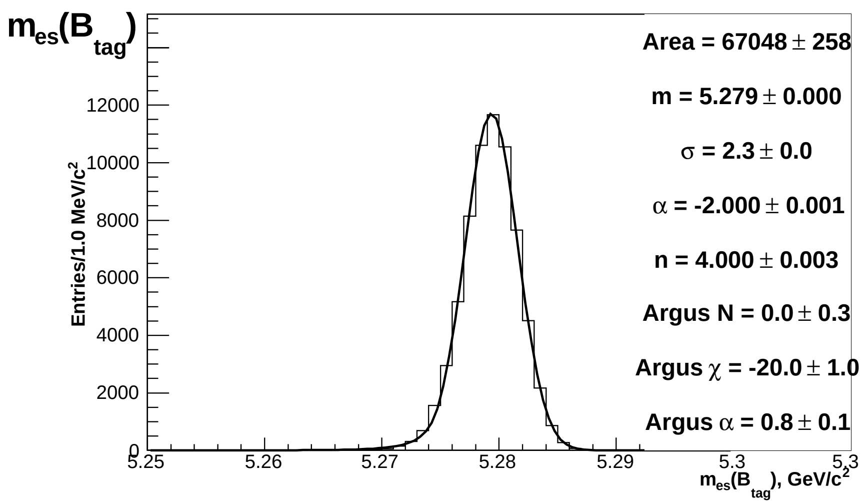
Relative increase



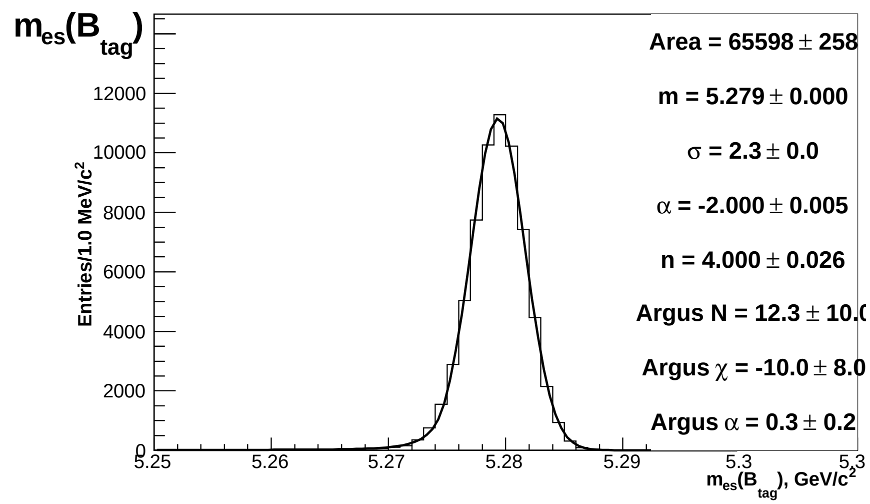
Sig: $B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$

Generic μ bkg: $B \to \mu\nu X$

m_{es} in signal sample



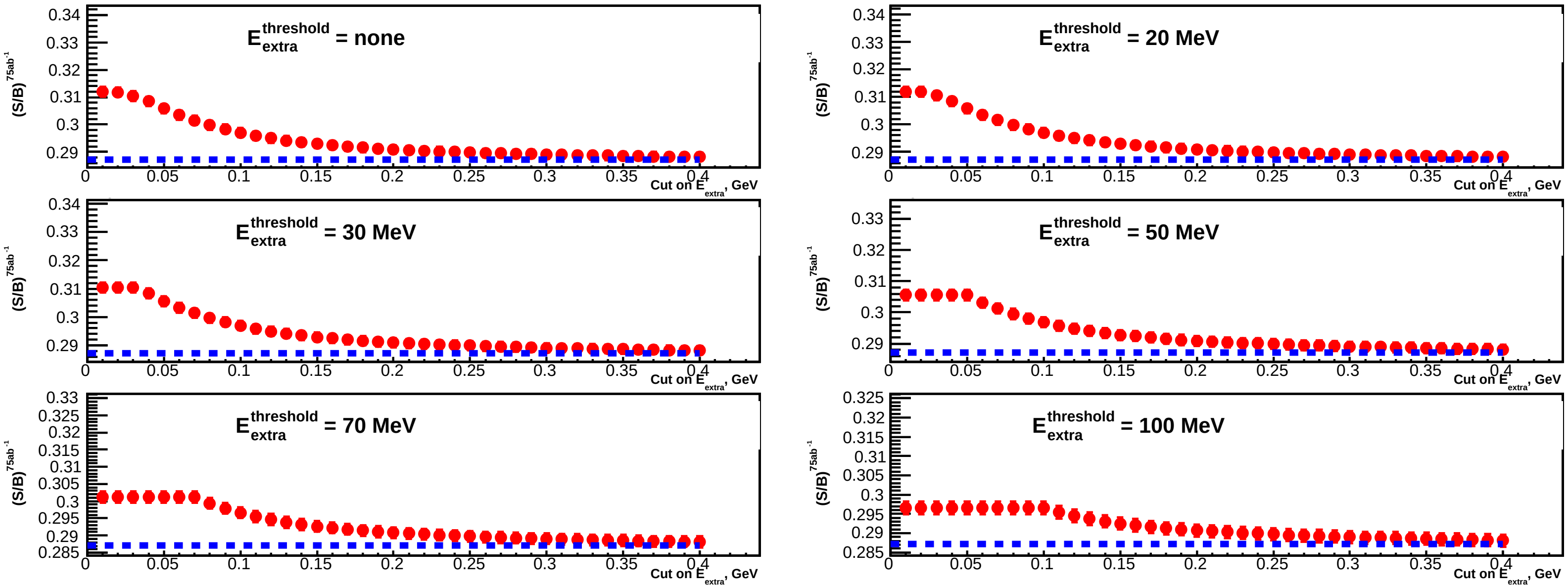
m_{es} in bkg sample



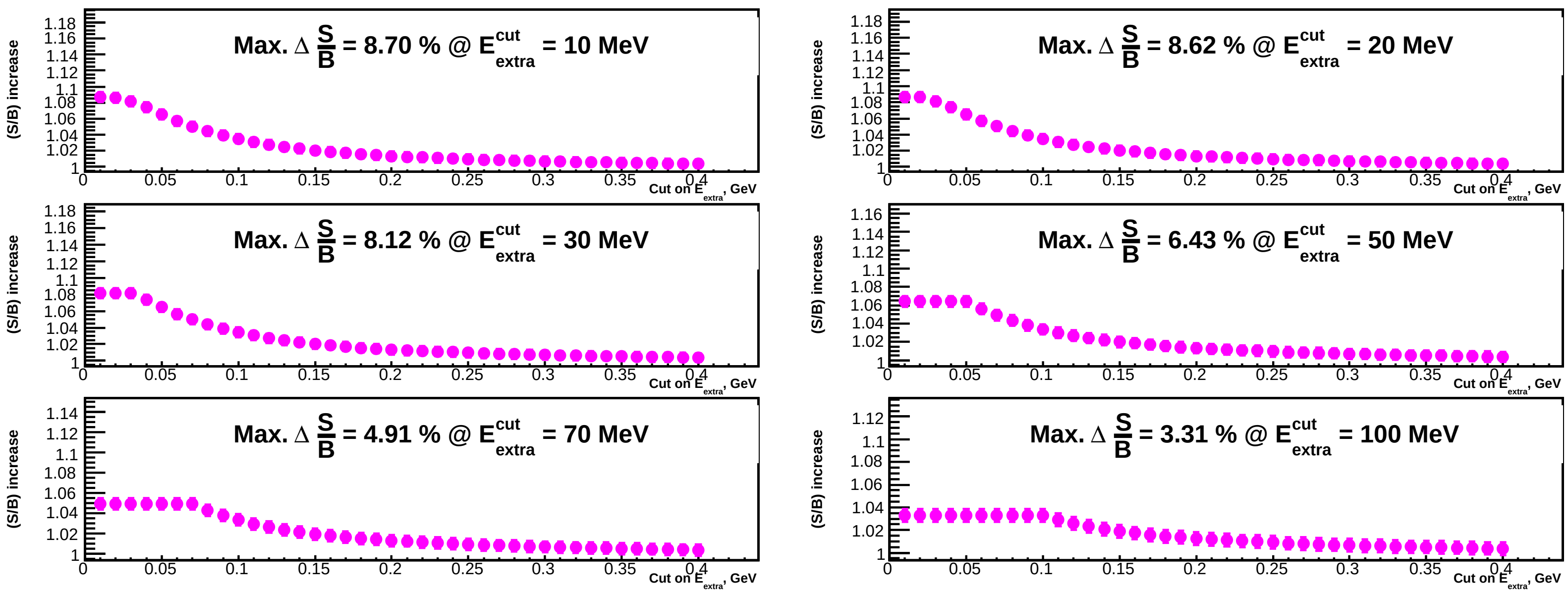
- Cut on different values of E_{extra} in Backward EMC
- Fit for the peak yield after each cut
- Plot peak yields vs. cut values

S/B ratio at 75 ab^{-1}

Absolute value

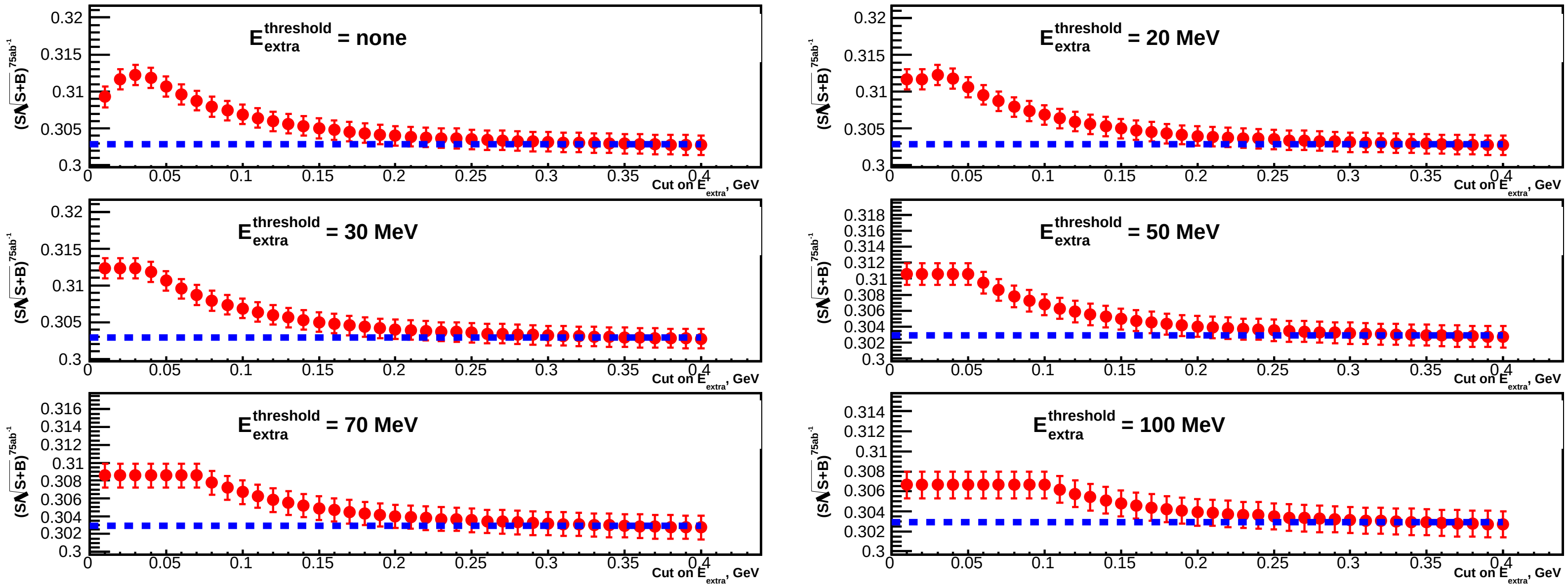


Relative increase

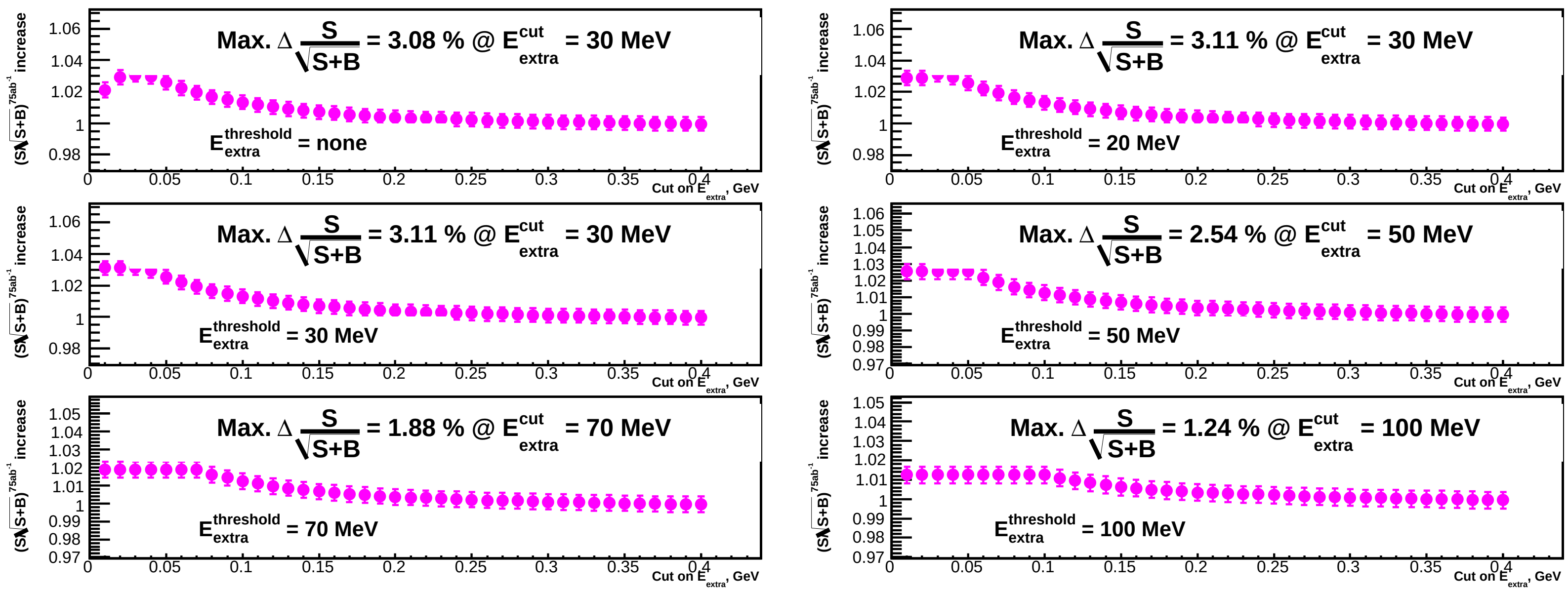


$S/\sqrt{S+B}$ at 75 ab^{-1}

Absolute value



Relative increase

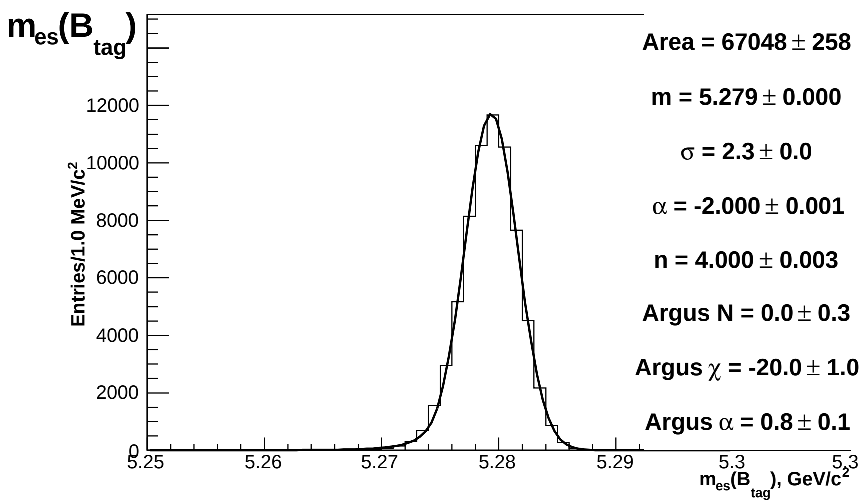


Sig: $B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$

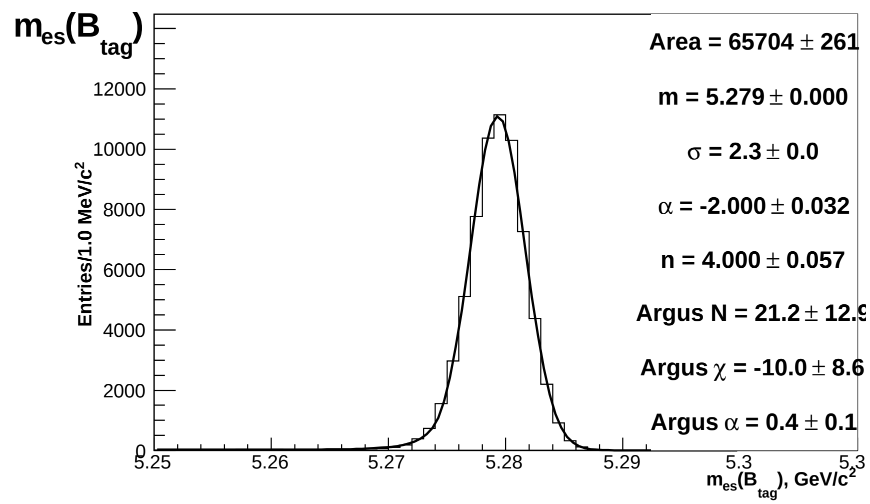
Generic $\tau(\mu\nu\nu)$ bkg:

$B \to \tau\nu X, \tau \to \mu\nu\nu$

m_{es} in signal sample



m_{es} in bkg sample



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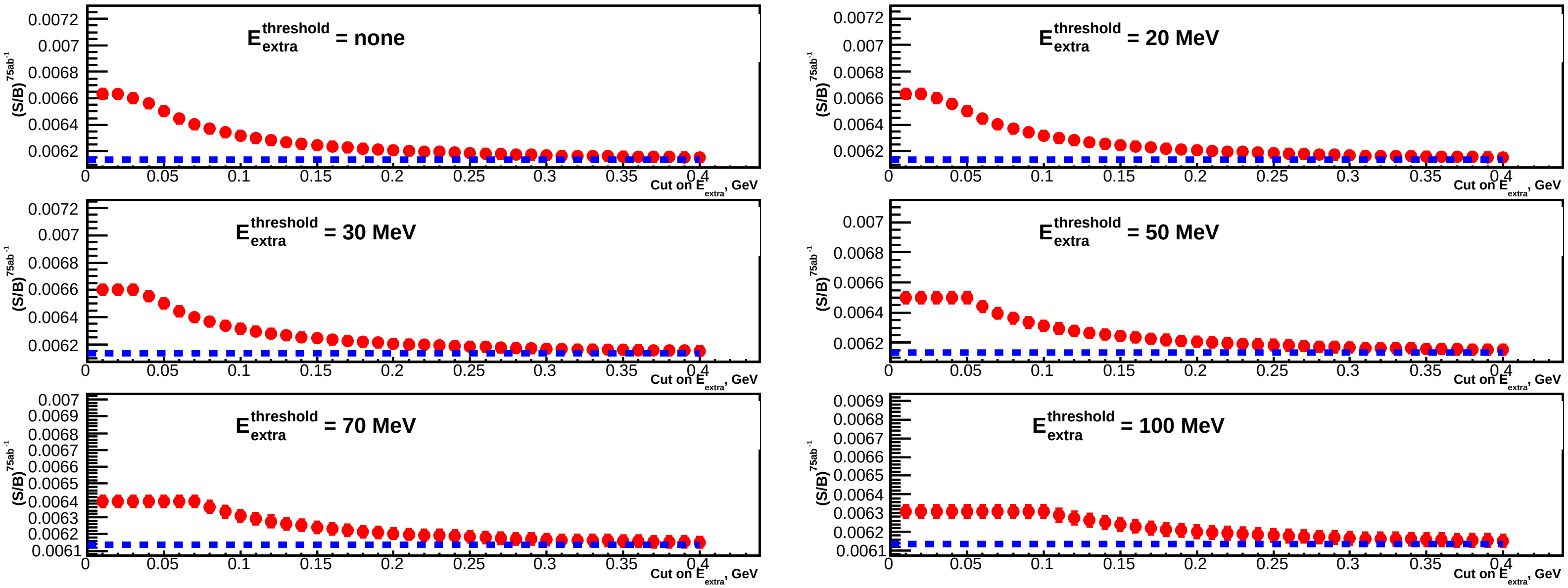
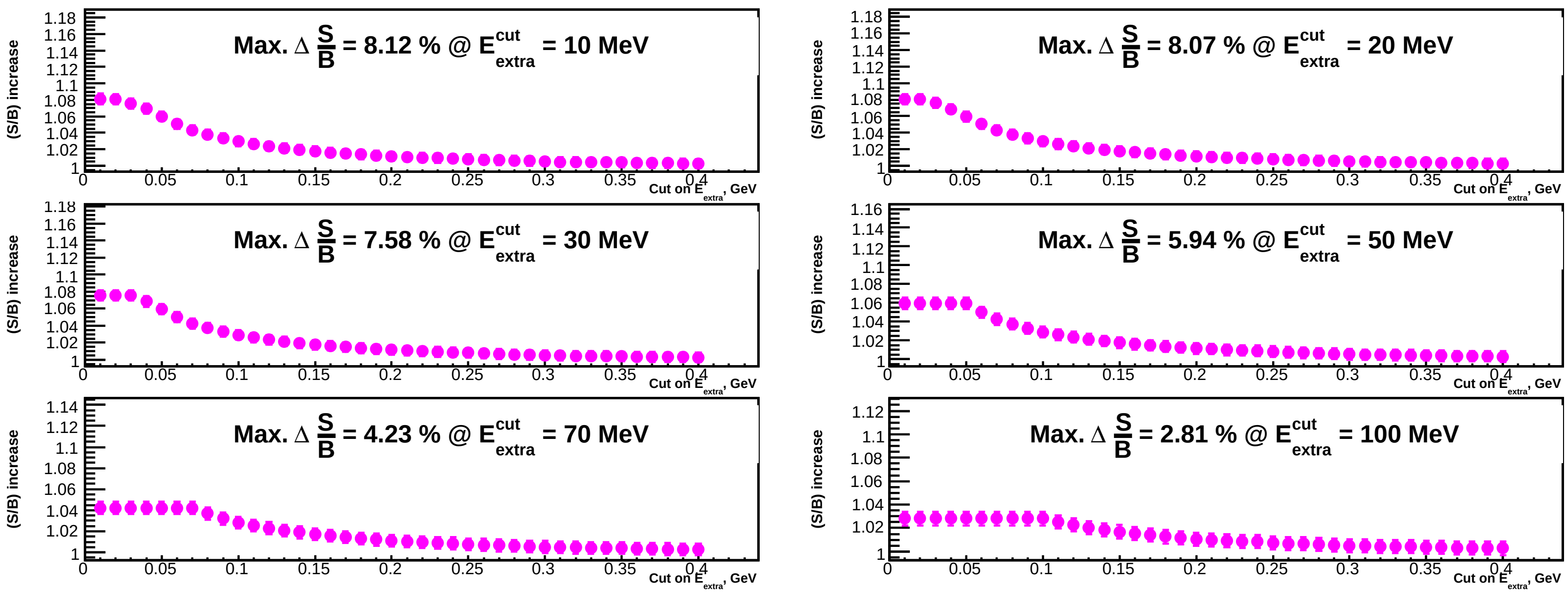
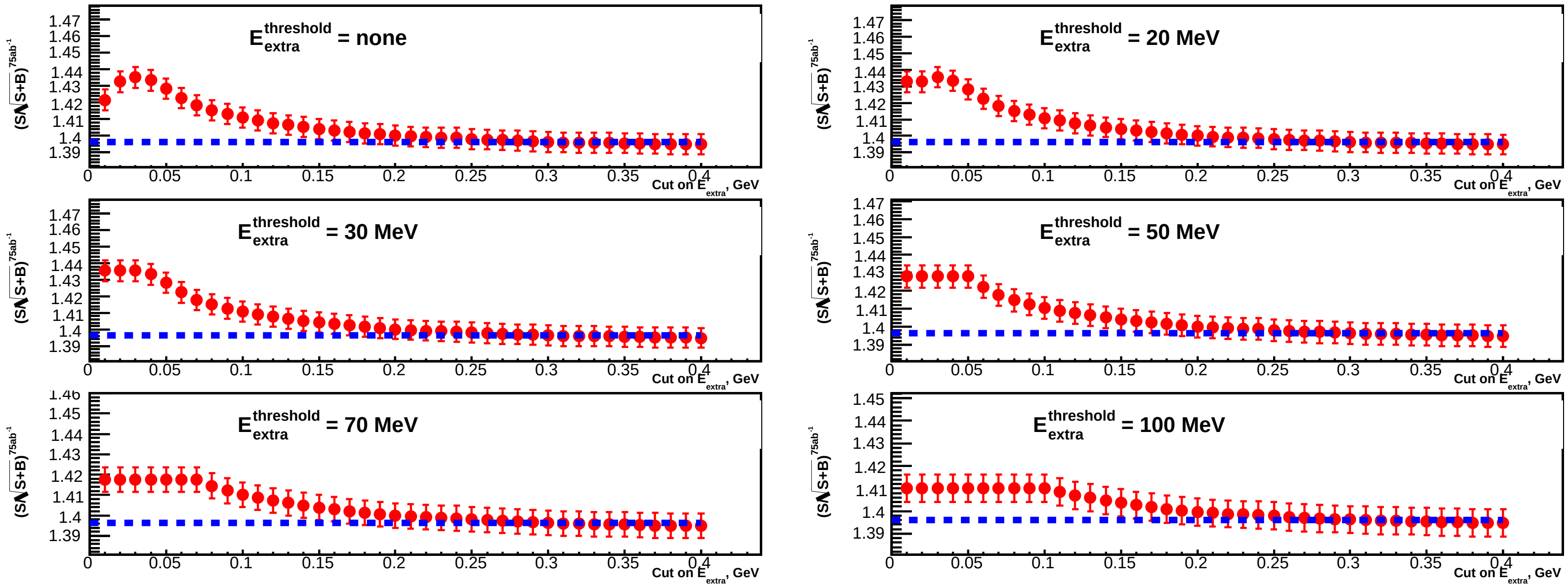


Relative increase

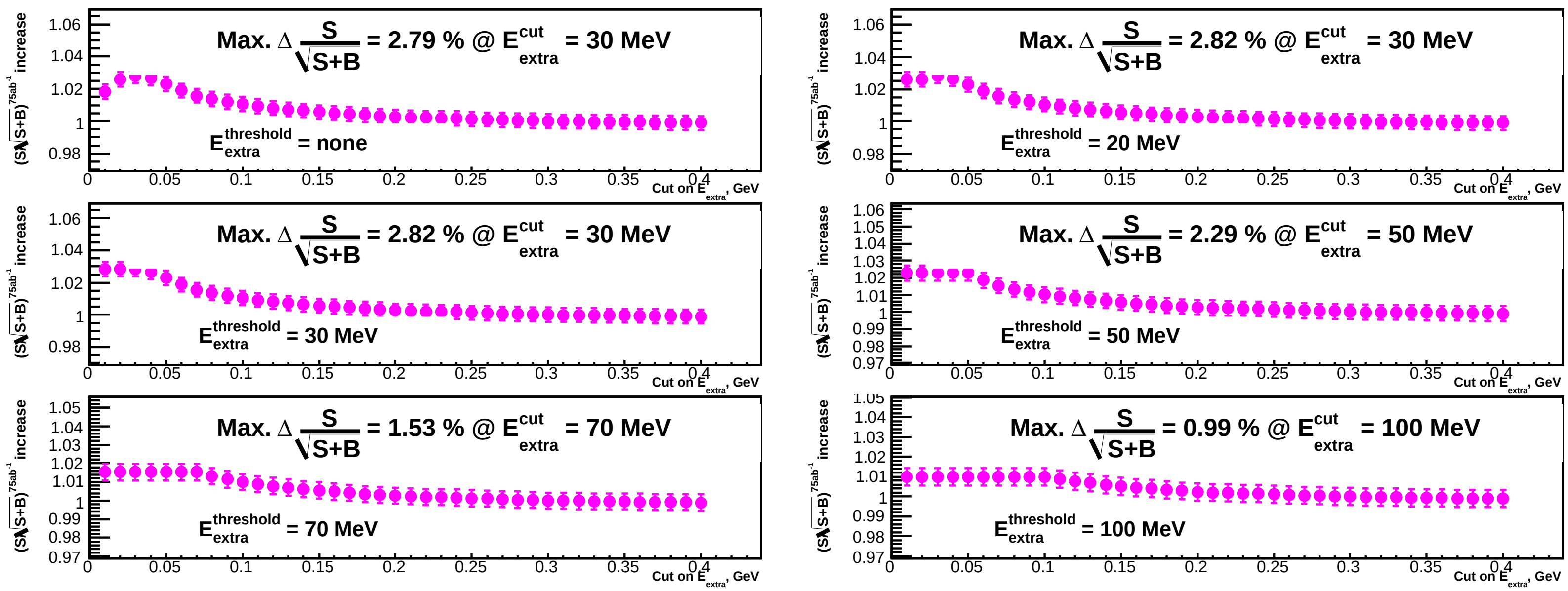


$S/\sqrt{S+B}$ at 75 ab^{-1}

Absolute value



Relative increase



Generic Hadronic Tag

Sig: $B_{sig} \rightarrow \tau\nu, \tau \rightarrow \mu\nu\nu$

Bkg: $B \rightarrow \pi^0\mu\nu$

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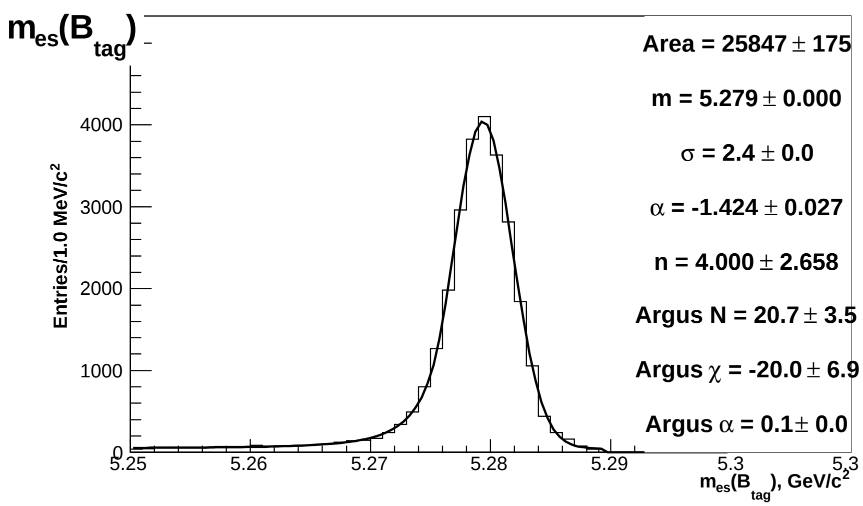
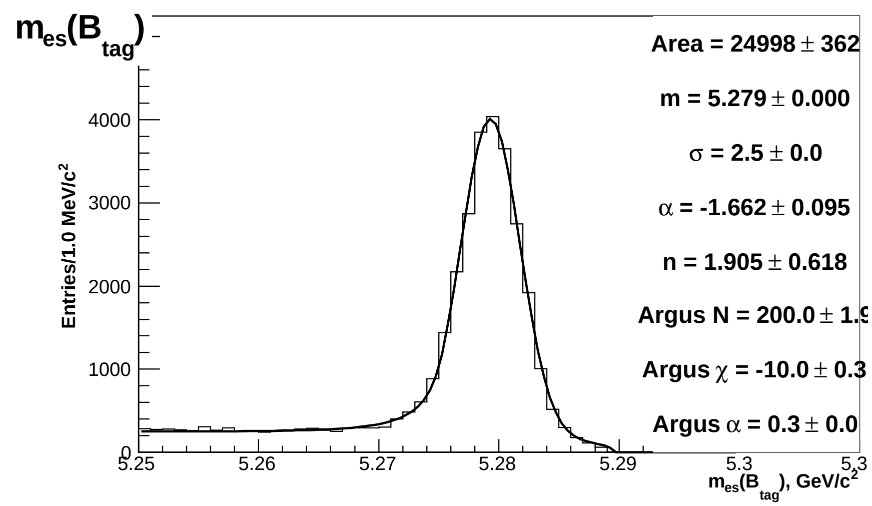
m_{ES} in signal sample



m_{ES} in bkg sample



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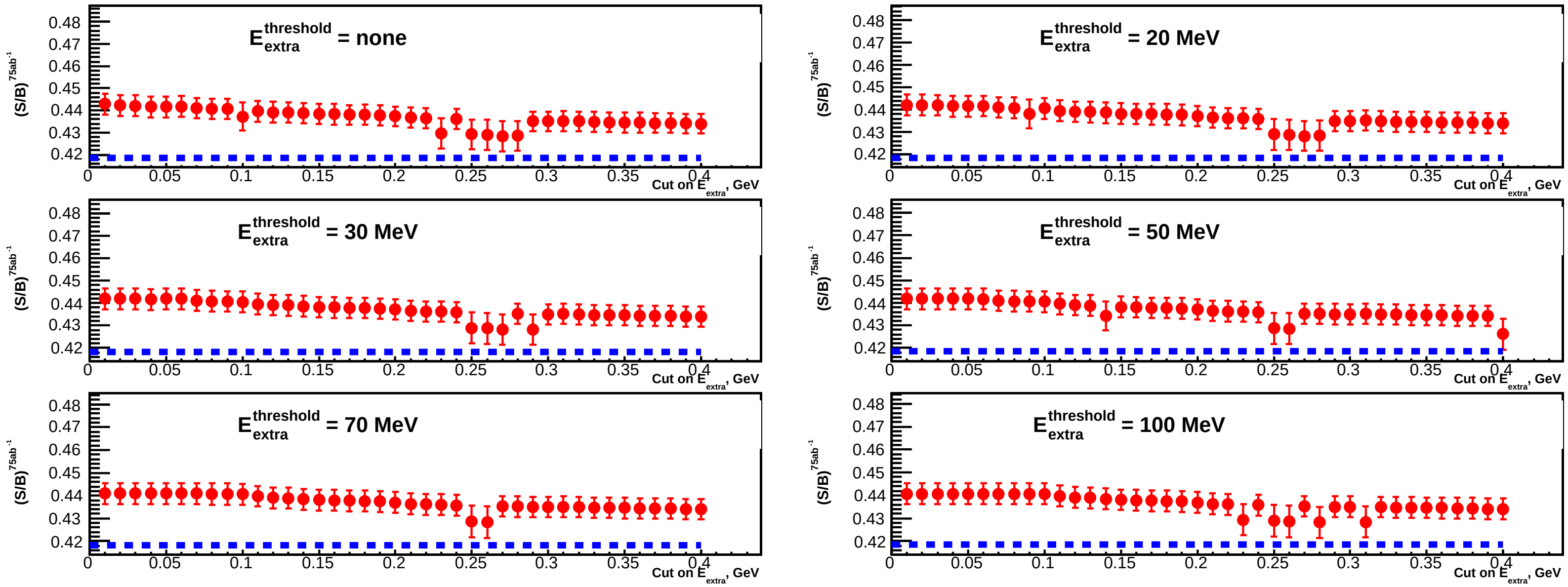
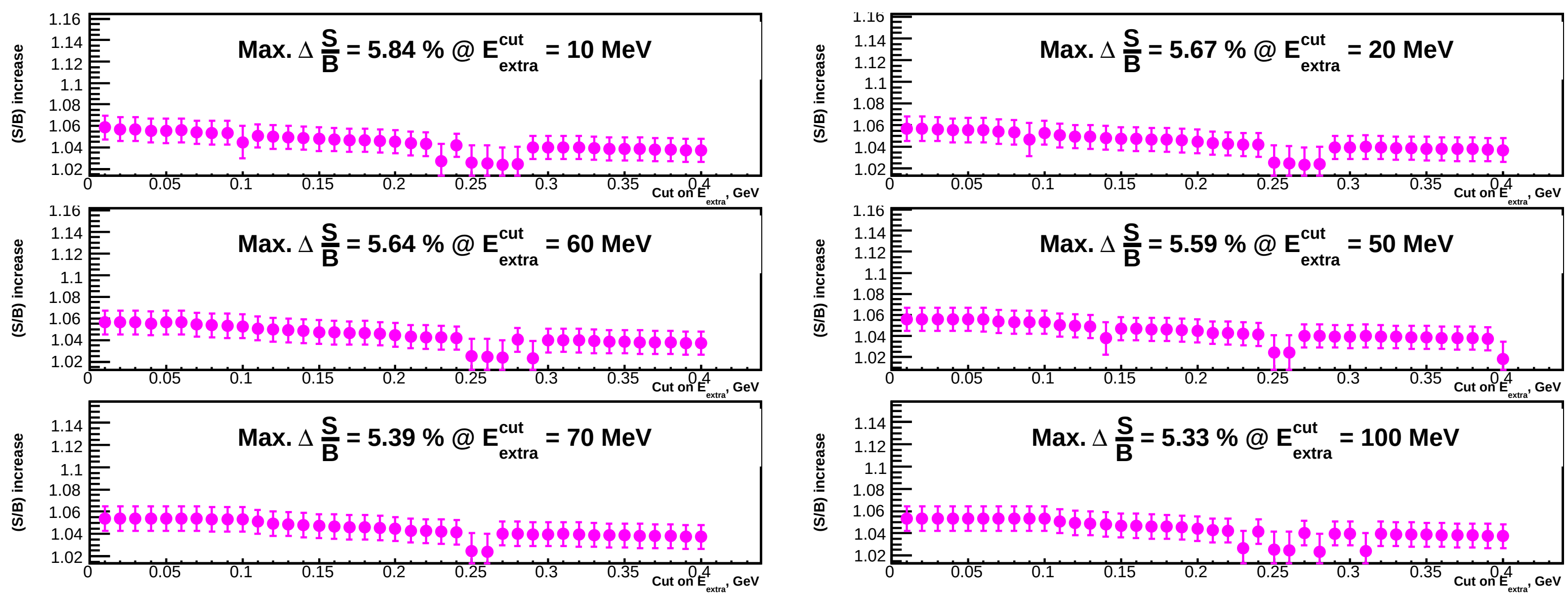
S/B ratio at 75 ab^{-1}

Absolute value

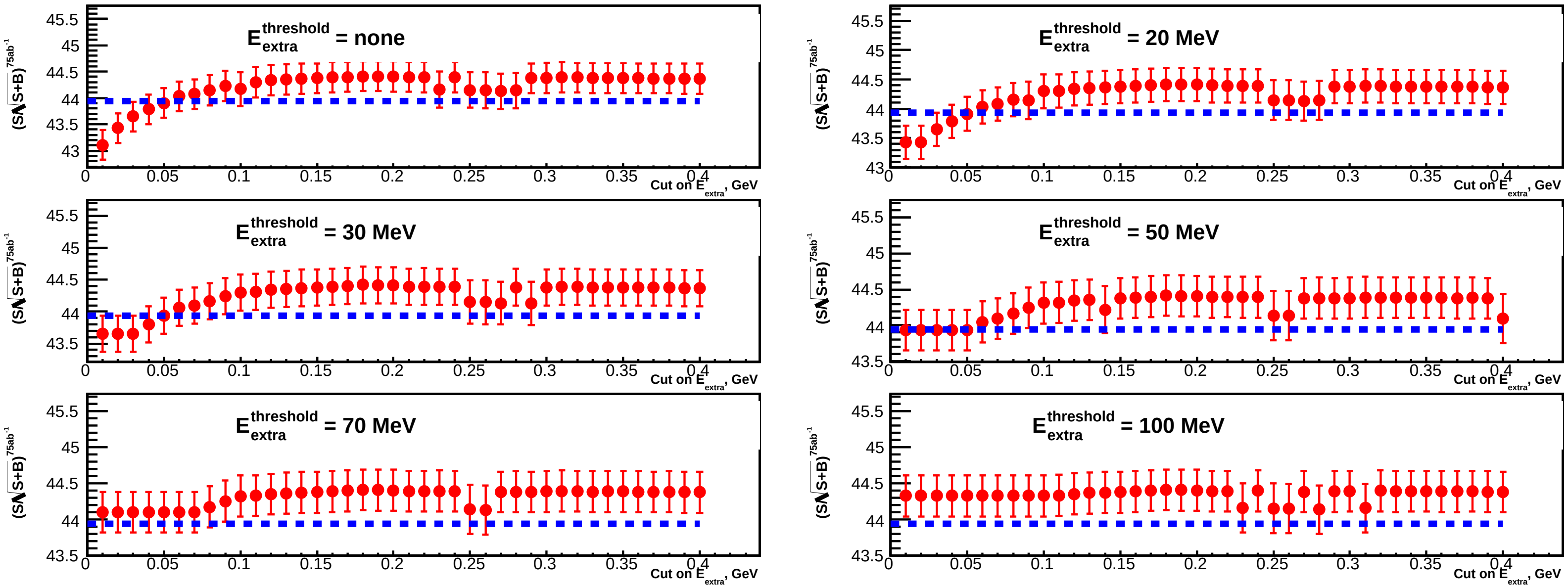


Relative increase

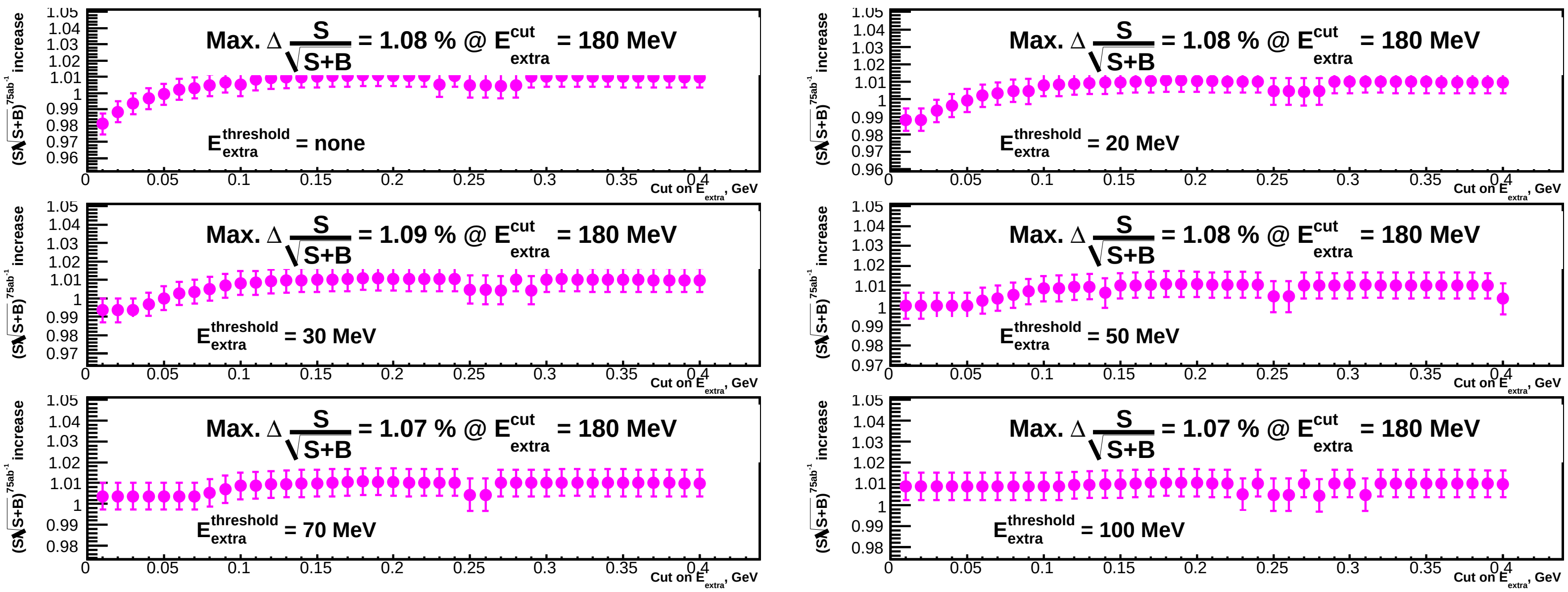


$S/\sqrt{S+B}$ at 75 ab^{-1}

Absolute value



Relative increase



V0.2.6 Analysis Results

Maximum relative increase in S/B (in percent):

Tag	Signal	Mimicking bkg			
		Simplest	Caltech Generic	Tauonic	CNAF Cocktail (V0.2.4)
$B_{tag} \to \pi D^0 (K\pi)$	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	4.22 ± 0.59	8.70 ± 0.65	8.12 ± 0.62	–
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	4.09 ± 0.58	8.52 ± 0.63	8.02 ± 0.62	–
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	11.68 ± 0.66	7.88 ± 0.61	–
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	7.67 ± 0.64	8.51 ± 0.64	–
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	11.51 ± 0.66	7.99 ± 0.64	–
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0 \nu$	–	3.23 ± 0.62	8.77 ± 0.67	–
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	8.79 ± 1.08	7.45 ± 1.06	–
$B_{tag} \to$ hadrons	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	5.84 ± 1.13	15.14 ± 1.83	12.26 ± 1.94	16.75 ± 0.81
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	4.97 ± 1.35	14.21 ± 1.88	12.39 ± 1.98	16.66 ± 0.81
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	21.71 ± 0.97	12.08 ± 1.85	16.95 ± 0.81
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	16.61 ± 1.26	13.05 ± 2.18	12.10 ± 1.12
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	21.10 ± 1.10	15.91 ± 2.62	16.30 ± 0.95
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0 \nu$	–	12.84 ± 1.53	17.19 ± 2.57	8.67 ± 1.41
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	**18.99 ± 1.01**	12.87 ± 2.00	**14.63 ± 0.86**

V0.2.6 Analysis Results

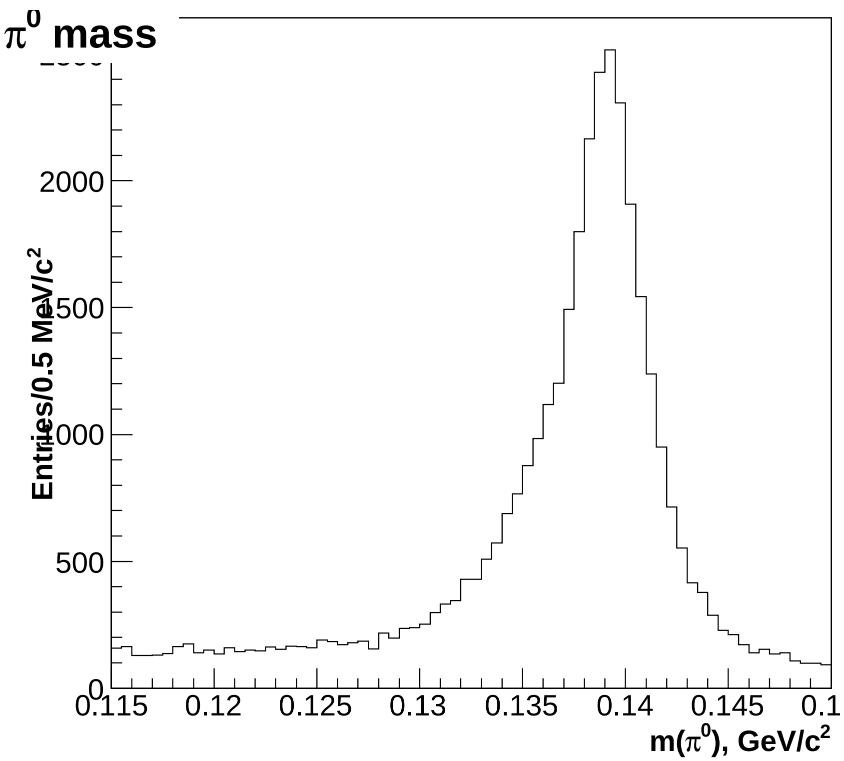
Maximum relative increase in $S/\sqrt{S+B}$ (in percent):

Tag	Signal	Mimicking bkg: Simplest	Mimicking bkg: Caltech Generic	Mimicking bkg: Tauonic	Mimicking bkg: CNAF Cocktail (V0.2.4)
$B_{tag} \to \pi D^0(K\pi)$	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	0.76 $\pm$ 0.36	3.11 $\pm$ 0.45	2.82 $\pm$ 0.45	–
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	0.57 $\pm$ 0.36	2.94 $\pm$ 0.45	2.65 $\pm$ 0.45	–
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	4.26 $\pm$ 0.46	2.50 $\pm$ 0.45	–
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	0.78 $\pm$ 0.45	1.13 $\pm$ 0.45	–
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	4.22 $\pm$ 0.47	2.58 $\pm$ 0.46	–
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	-0.90 $\pm$ 0.43	-0.81 $\pm$ 0.45	–
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	1.73 $\pm$ 0.92	1.12 $\pm$ 0.91	–
$B_{tag} \to$ hadrons	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	1.09 $\pm$ 0.65	3.97 $\pm$ 1.02	2.34 $\pm$ 1.03	4.76 $\pm$ 0.73
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	0.53 $\pm$ 0.73	3.47 $\pm$ 1.04	2.47 $\pm$ 1.07	4.68 $\pm$ 0.73
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	6.69 $\pm$ 0.77	2.82 $\pm$ 1.04	4.94 $\pm$ 0.73
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	2.31 $\pm$ 1.03	0.98 $\pm$ 1.29	0.59 $\pm$ 1.00
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	6.10 $\pm$ 0.89	3.98 $\pm$ 1.37	4.35 $\pm$ 0.86
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	-0.72 $\pm$ 1.20	1.10 $\pm$ 1.53	-1.37 $\pm$ 1.18
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	**4.57 $\pm$ 0.81**	1.74 $\pm$ 1.10	**2.86 $\pm$ 0.77**

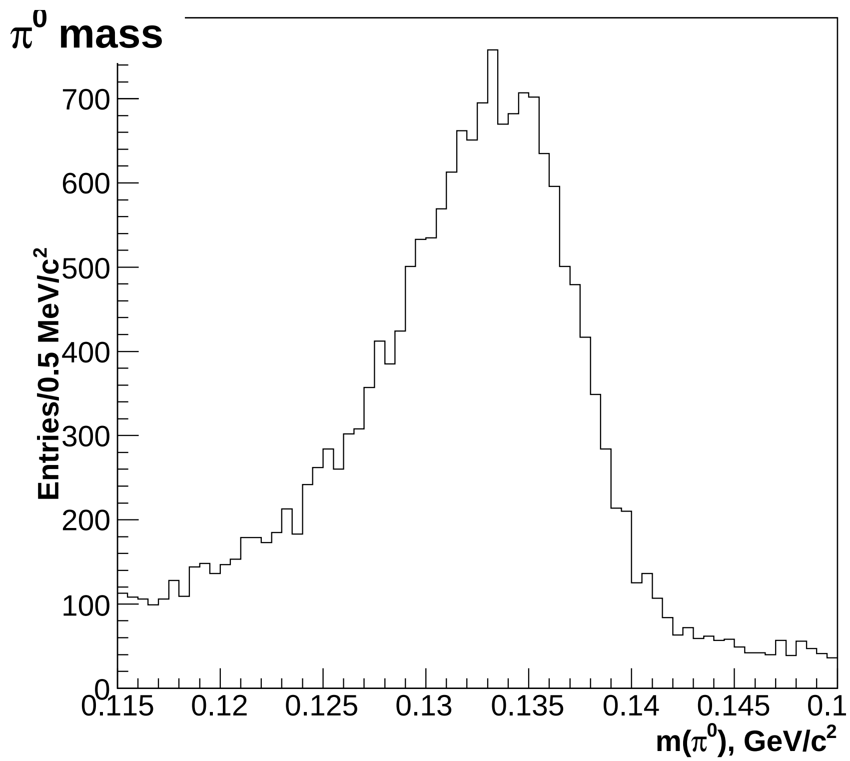
Let me remind you that B_{recoil} reconstruction does not include bwd photons with $\cos\theta < -0.8$

π^0 Mass

V0.2.6



V0.2.7



V0.2.7 Analysis Results

Maximum relative increase in S/B (in percent):

Tag	Signal	Mimicking bkg			
		Simplest	Caltech Generic	Tauonic	CNAF Cocktail (V0.2.4)
$B_{tag} \to \pi D^0(K\pi)$	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	4.02 $\pm$ 0.57	7.81 $\pm$ 0.59	7.29 $\pm$ 0.60	–
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	3.77 $\pm$ 0.57	7.62 $\pm$ 0.60	7.08 $\pm$ 0.59	–
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	10.82 $\pm$ 0.63	7.12 $\pm$ 0.61	–
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	6.71 $\pm$ 0.61	7.60 $\pm$ 0.61	–
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	10.42 $\pm$ 0.63	7.00 $\pm$ 0.60	–
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	2.67 $\pm$ 0.59	7.67 $\pm$ 0.63	–
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	7.93 $\pm$ 1.06	6.45 $\pm$ 1.04	–
$B_{tag} \to$ hadrons	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	4.04 $\pm$ 1.49	15.31 $\pm$ 3.15		16.61 $\pm$ 1.05
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	3.79 $\pm$ 1.94			15.92 $\pm$ 1.06
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	21.01 $\pm$ 1.06		16.50 $\pm$ 0.92
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	16.96 $\pm$ 1.24		12.60 $\pm$ 1.11
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	20.43 $\pm$ 1.48		15.95 $\pm$ 1.35
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	11.57 $\pm$ 1.81		7.42 $\pm$ 1.69
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	**18.25 $\pm$ 1.04**	12.65 $\pm$ 2.05	**13.85 $\pm$ 0.90**

Comparison to non-energy-smeared CNAF Monte Carlo is not entirely legitimate...

V0.2.7 Analysis Results

Maximum relative increase in $S/\sqrt{S+B}$ (in percent):

Tag	Signal	Mimicking bkg			
		Simplest	Caltech Generic	Tauonic	CNAF Cocktail (V0.2.4)
$B_{tag} \to \pi D^0(K\pi)$	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	0.79 $\pm$ 0.35	2.28 $\pm$ 0.44	2.05 $\pm$ 0.44	–
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	0.51 $\pm$ 0.35	1.96 $\pm$ 0.44	1.72 $\pm$ 0.43	–
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	3.50 $\pm$ 0.44	1.89 $\pm$ 0.43	–
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	0.10 $\pm$ 0.44	0.42 $\pm$ 0.43	–
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	3.27 $\pm$ 0.44	1.82 $\pm$ 0.43	–
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	-0.94 $\pm$ 0.42	-0.98 $\pm$ 0.42	–
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	1.39 $\pm$ 0.93	0.82 $\pm$ 0.94	–
$B_{tag} \to$ hadrons	$B_{sig} \to \tau\nu, \tau \to \mu\nu\nu$	0.62 $\pm$ 0.84	4.27 $\pm$ 1.62		5.11 $\pm$ 0.94
	$B_{sig} \to \tau\nu, \tau \to e\nu\nu$	0.09 $\pm$ 0.87			4.22 $\pm$ 0.93
	$B_{sig} \to \tau\nu, \tau \to \pi\nu$	–	6.61 $\pm$ 0.85		5.10 $\pm$ 0.82
	$B_{sig} \to \tau\nu, \tau \to \rho\nu, \rho \to \pi\pi^0$	–	3.26 $\pm$ 1.07		1.95 $\pm$ 1.03
	$B_{sig} \to \tau\nu, \tau \to a_1\nu, a_1 \to 3\pi$	–	6.15 $\pm$ 1.24		4.53 $\pm$ 1.18
	$B_{sig} \to \tau\nu, \tau \to \pi 2\pi^0\nu$	–	-0.89 $\pm$ 1.50		-1.61 $\pm$ 1.48
	$B_{sig} \to \tau\nu, \tau \to$ 6 modes	–	**4.33 $\pm$ 0.84**	2.08 $\pm$ 1.14	**2.81 $\pm$ 0.80**

Comparison to non-energy-smeared CNAF Monte Carlo is not entirely legitimate...

Conclusion

- Cutting on E_{extra} in Backward EMC for V0.2.6 increases:
  - ☞ S/B by $\sim$15-20% depending on τ decay mode
  - ☞ $S/\sqrt{S+B}$ by $\sim$3-5%
- Proper energy smearing (V0.2.7) lowers these numbers insignificantly