$\psi(2S) \to \tau\tau$
A way to test Lepton Flavor Violation @ BESIII

I. Garzia
University of Ferrara - INFN Ferrara

X.H. Mo, J.Y.Zhang, B.X. Zhang
IHEP

CGEM-IT Ferrara meeting
Nov 8-9, 2021

LF Universality Violation

Lepton Flavor Universality violation accessed by BaBar and Belle studying the ratio:

$$R(D^{(*)}) \equiv \frac{\Gamma(B \to D^{(*)}\tau\nu)}{\Gamma(B \to D^{(*)}\ell\nu)}, \quad (\ell = e, \mu)$$

EXP: $R(D) = 0.403 \pm 0.047, \quad R(D^*) = 0.310 \pm 0.017,$

SM: $R(D) = 0.300 \pm 0.008, \quad R(D^*) = 0.252 \pm 0.003.$

The combined results show a deviation from SM prediction of a level of 3.9σ

- new physics only in the τ channel decay

<u>*JHEP **06** (2017) 019*</u>

IDEA: ψ(2S)→ττ

New observables for test the LFU violation: non-universality in leptonic decays of ψ and ϒ quarkonia

- same mechanism as for the $R(D^{(*)})$
- only the V→ττ decay is affected by NP

$$R^V_{\tau/\ell} \equiv \frac{\Gamma(V \to \tau^+\tau^-)}{\Gamma(V \to \ell^+\ell^-)}, \quad (V = \psi, \Upsilon; \ \ \ell = e, \mu),$$

$V(nS)$	SM prediction	Exp. value $\pm\sigma_{\text{stat}} \pm \sigma_{\text{syst}}$
$\Upsilon(1S)$	$0.9924 \pm \mathcal{O}(10^{-5})$	$1.005 \pm 0.013 \pm 0.022$
$\Upsilon(2S)$	$0.9940 \pm \mathcal{O}(10^{-5})$	$1.04 \pm 0.04 \pm 0.05$
$\Upsilon(3S)$	$0.9948 \pm \mathcal{O}(10^{-5})$	$1.05 \pm 0.08 \pm 0.05$
$\psi(2S)$	$0.390 \pm \mathcal{O}(10^{-4})$	0.39 ± 0.05

<u>*@ BES: hep-ex/0609023v1 (2006)*</u>

$$BF(\psi(2S) \to \tau^+\tau^-) = (3.1 \pm 0.21 \pm 0.38) \times 10^{-3}$$

? ?

with 550M of psi2S data

Analysis: event and track selection

Study of $\psi(2S)\to\tau\tau\to e\mu4\nu$ decay

Charged tracks

- **nCharged=2**
- Vertex cut: R... and R_z<10cm
- polar angle ... MDC: |cosθ|<0.93
- ptrk < 1.2 GeV (re... and dimuon events)
- **pt>0.05 GeV/c**
- **Vertex Fit**

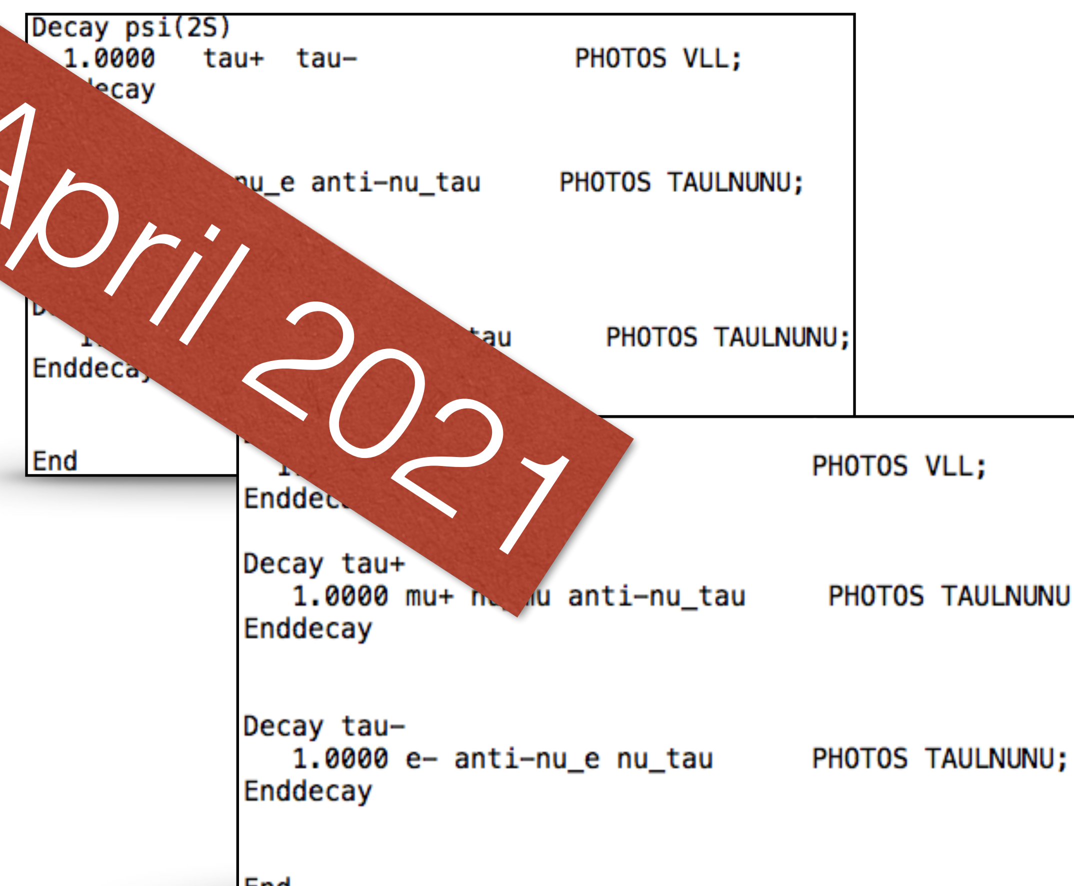
Neutral candidates

- EMC time cut: $0<t_{TDC}<14(/50ns)$
- E_γ >0.025 GeV for the barrel (**<u>|(cos(θ)|< 0.8)</u>**), and E_γ>0.050 GeV for the endcap (**<u>0.86<|(cos(θ)|<0.92</u>**)
- Isolated γ: opening angle between photon and its nearest charged tracks $\theta_{\gamma\text{-}tr}$> 10°
- nGamma = 0

Enel < 0.2 GeV

Last meeting in April 2021

- Release 664p03
- 240000 events simulated: $\psi(2S)\to\tau\tau\to e^{\mp}\mu^{\pm}4\nu$
- 2012 MC inclusive ψ(2S) sample
- 2012 ψ(2S) data sample



Analysis: event and track selection

Study of $\psi(2S)\to\tau\tau\to e\mu 4\nu/\pi e 3\nu/\pi\mu 3\nu/\pi\pi 2\nu$ decays

Charged tracks

- **nCharged=2**
- Vertex cut: R_{xy}<1cm and R_z<10cm
- polar angle of tracks in MDC: $|\cos\theta|<0.93$
- ptrk < 1.2 GeV (remove Bhabha and dimuon events)
- pt>0.05 GeV/c
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- EMC time cut: $0<t_{TDC}<14(/50ns)$
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- Isolated γ: opening angle between photon and its nearest charged tracks $\theta_{\gamma\text{-}tr}$> 10°
- nGamma = 0
- ~~Enel < 0.2 GeV~~

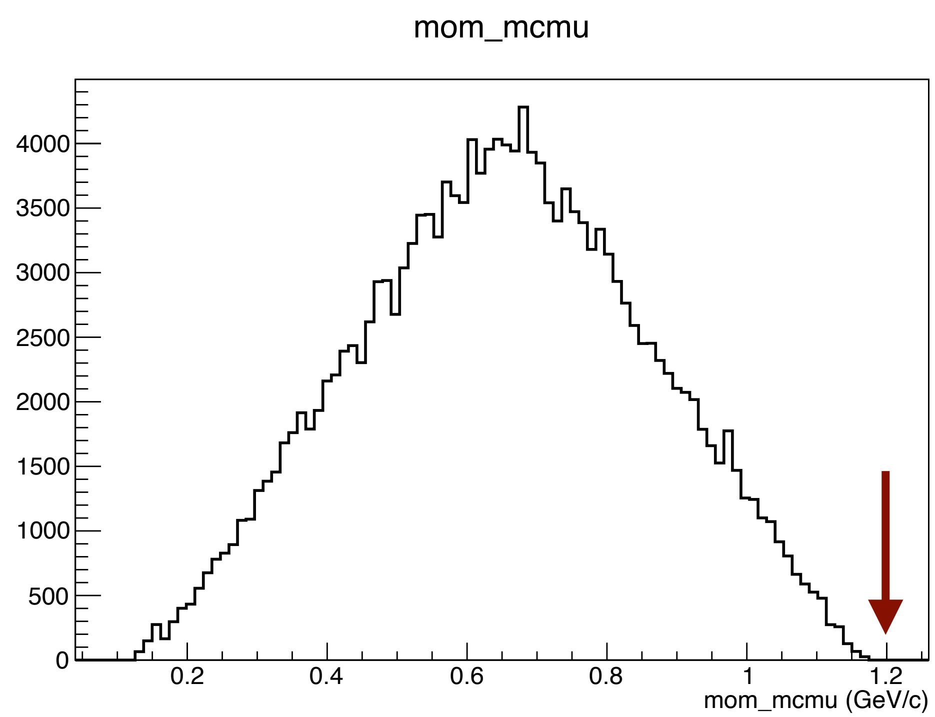
- Release 664p03
- 240000 events simulated: $\psi(2S)\to\tau\tau\to e^{\mp}\mu^{\pm}4\nu$ ......
- 2012 MC inclusive $\psi(2S)$ sample
- 2012 $\psi(2S)$ data sample

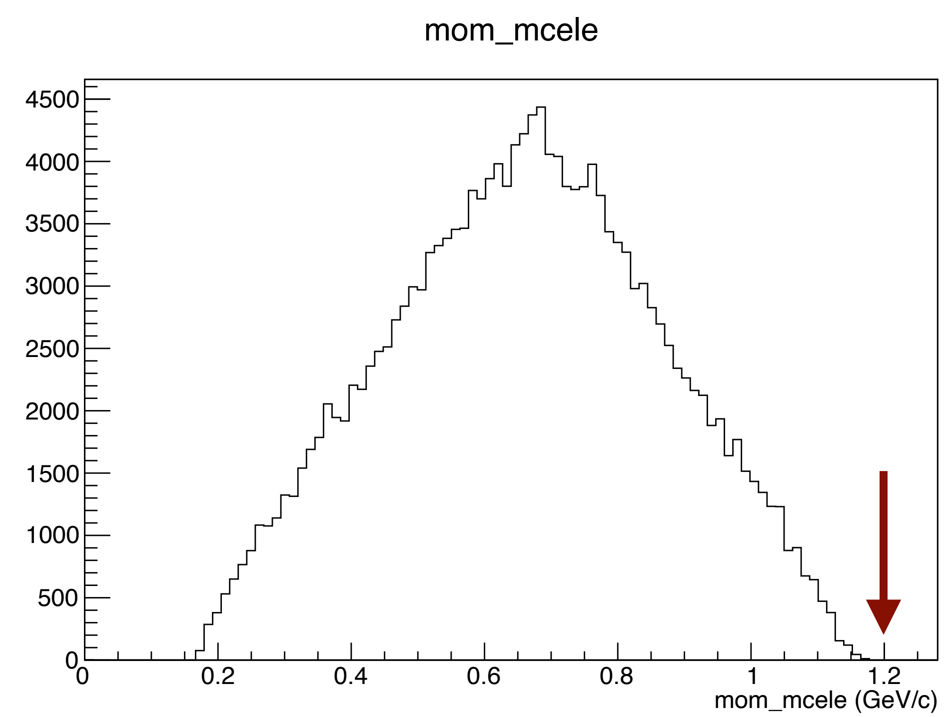
```
Decay psi(2S)
  1.0000    tau+  tau-                PHOTOS VLL;
Enddecay

Decay tau+
   0.3900 e+ nu_e anti-nu_tau         PHOTOS TAULNUNU;
   0.3900 mu+ nu_mu anti-nu_tau       PHOTOS TAULNUNU;
   0.2200 pi+  nu_tau                 TAUSCALARNU;
Enddecay


Decay tau-
   0.3900 e- anti-nu_e nu_tau         PHOTOS TAULNUNU;
   0.3900 mu- anti-nu_mu nu_tau       PHOTOS TAULNUNU;
   0.2200 pi-  nu_tau                 TAUSCALARNU;
Enddecay


End
```

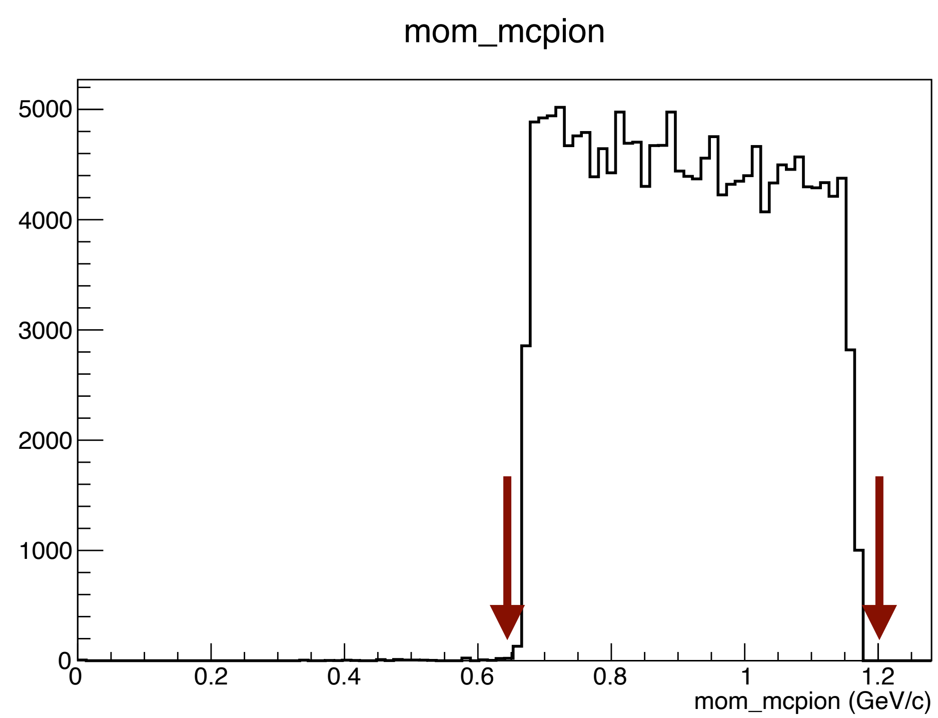
Signal MC: distributions I

ψ(2S)→ττ→eμ4ν/πe3ν/πμ3ν/ππ2ν signal

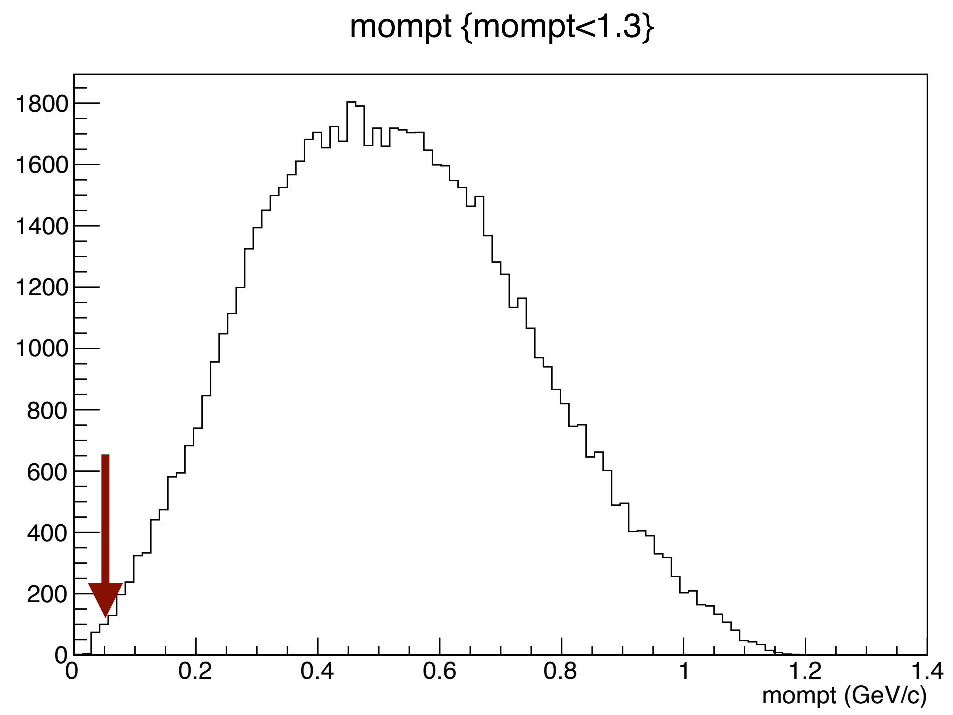
Momentum of charged tracks from MC truth

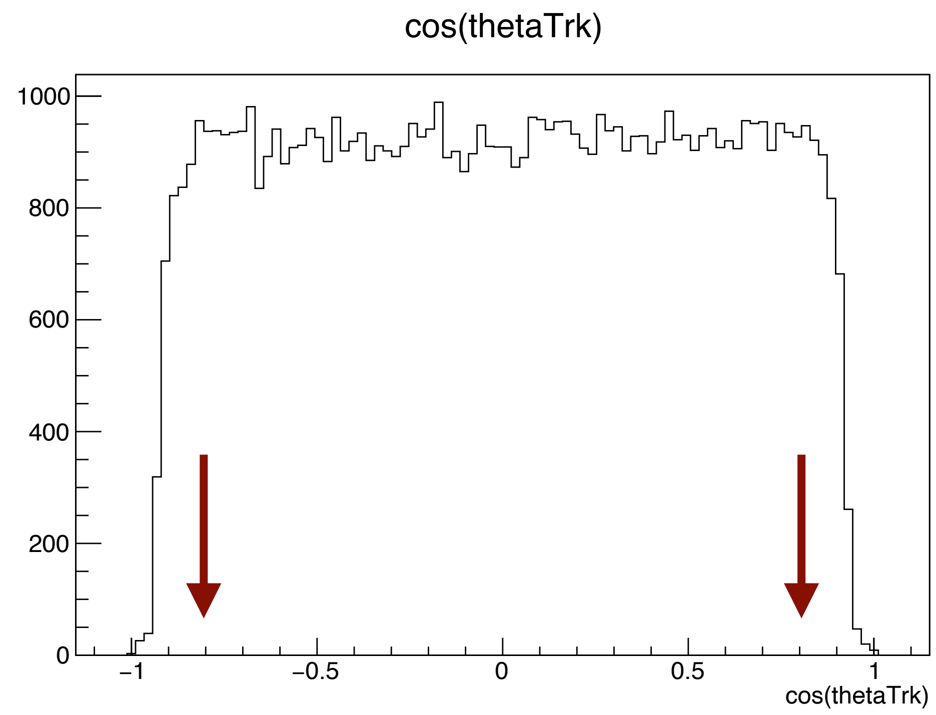


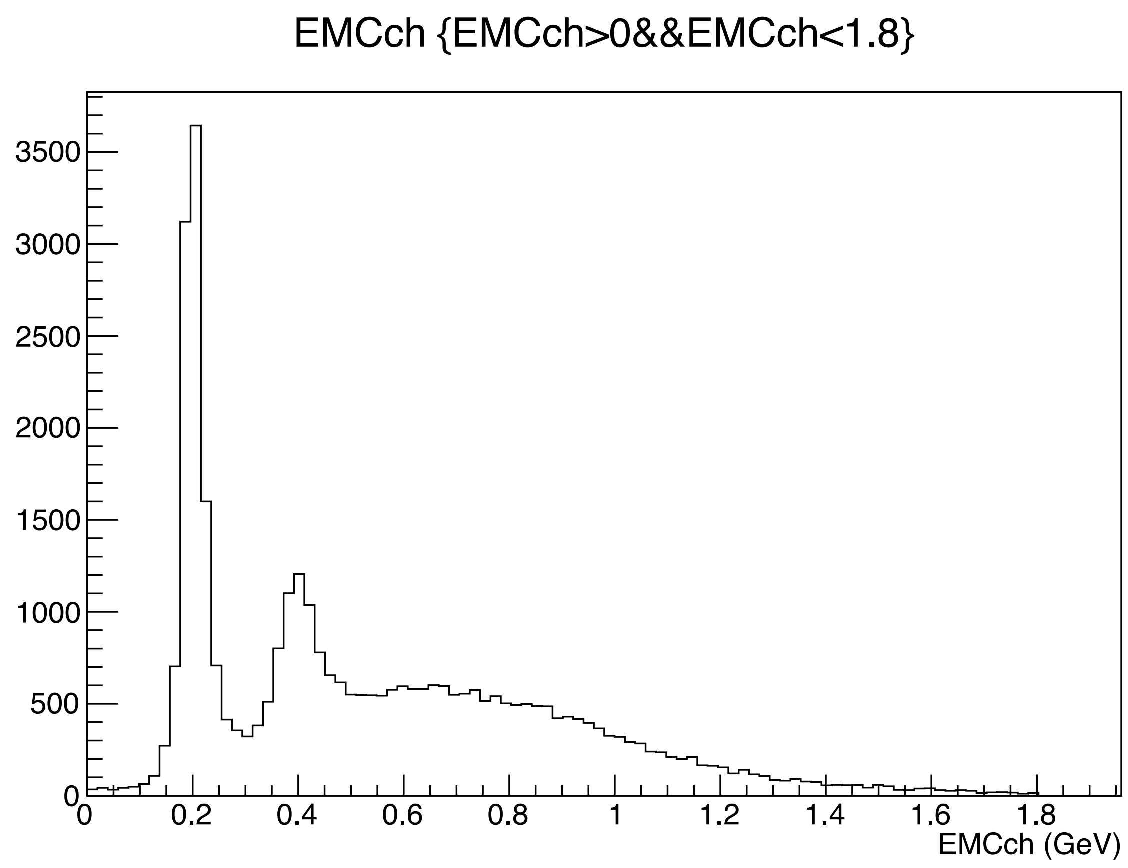




Signal MC: distributions I



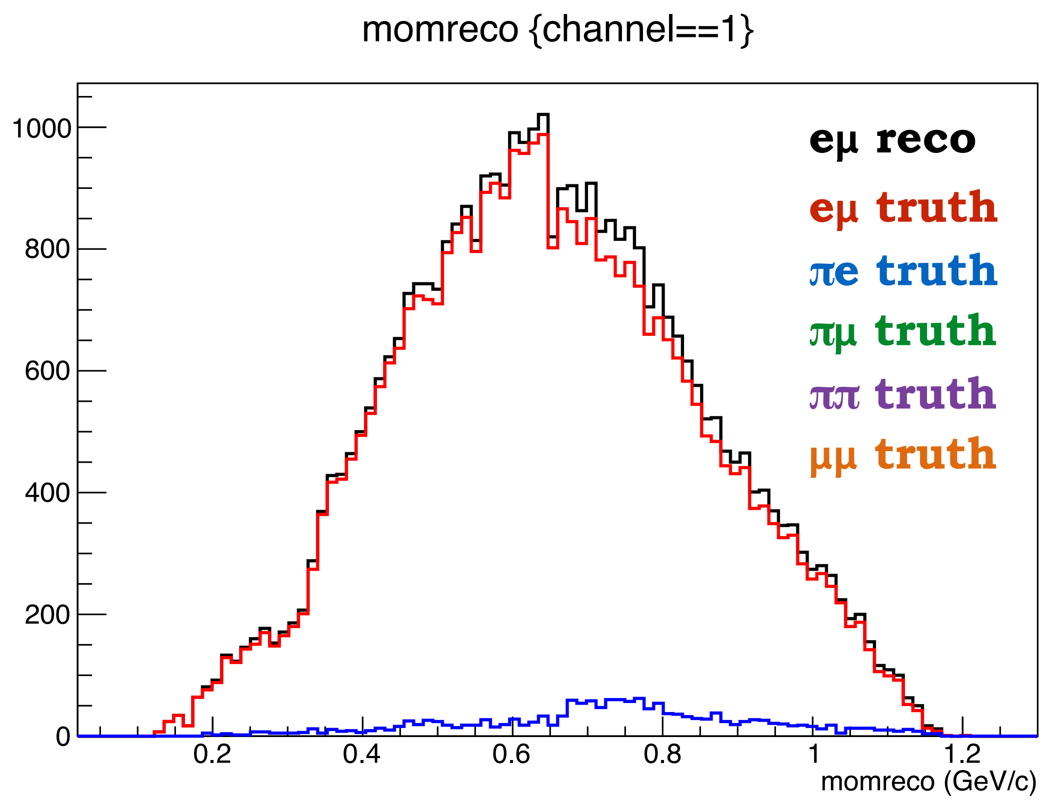


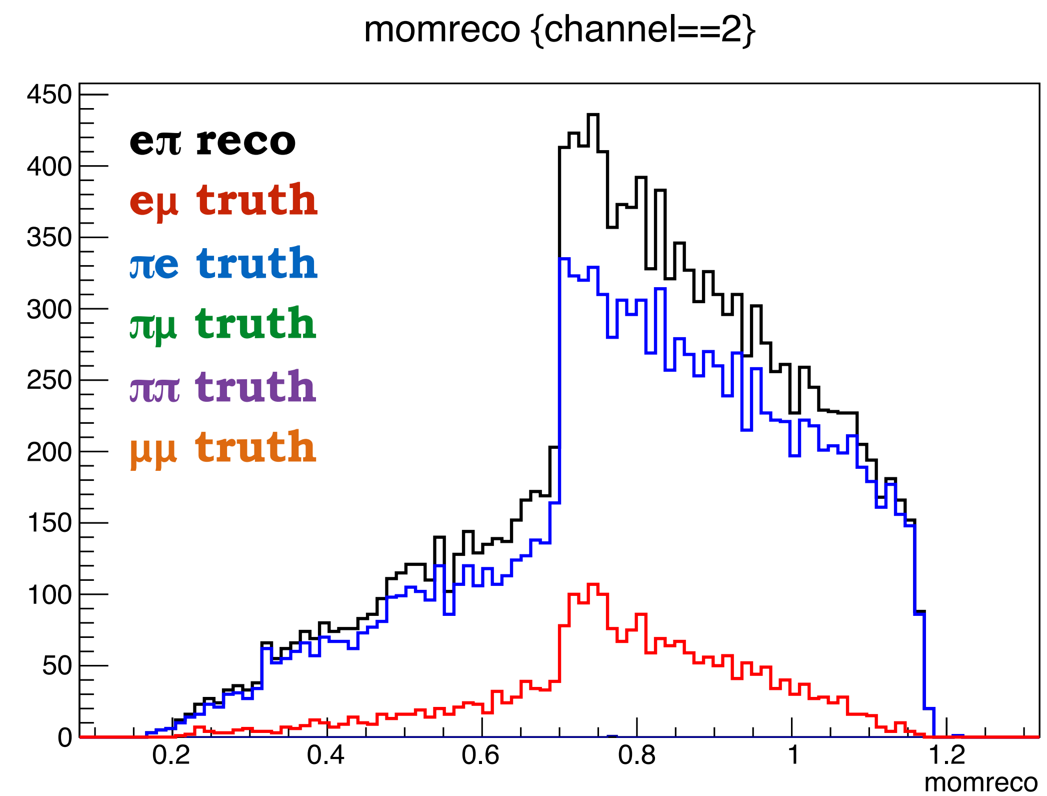


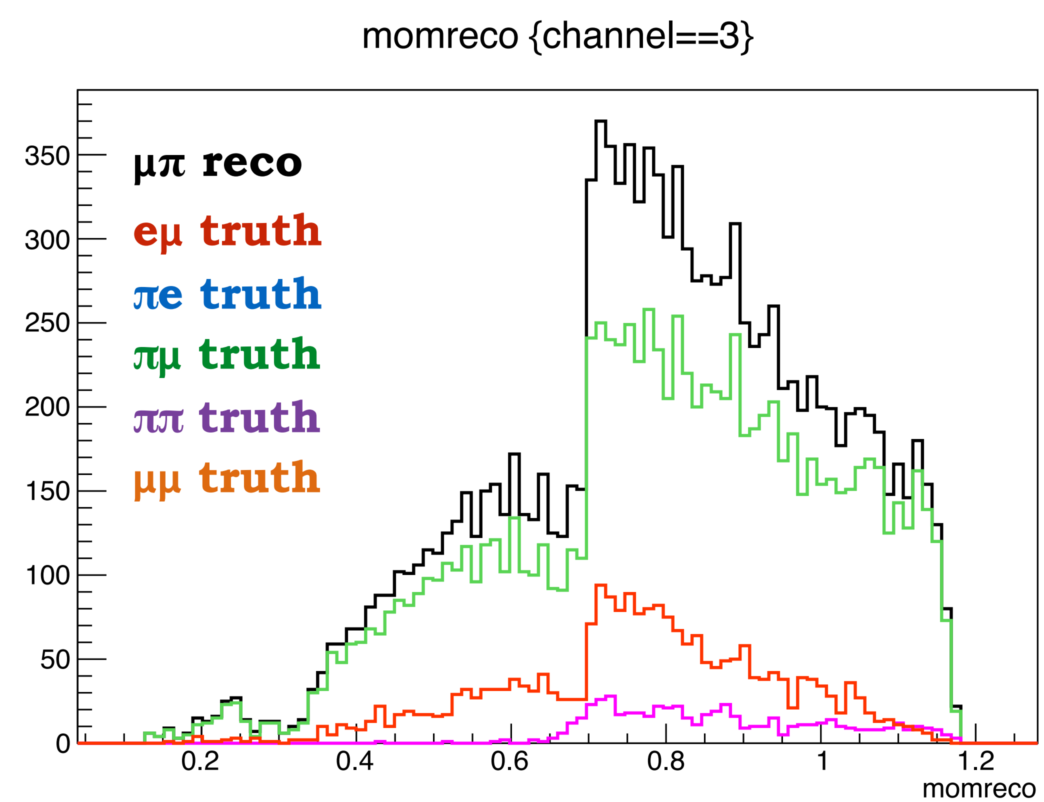
- Charged tracks energy deposit inside the EMC (sum of the two charged tracks)

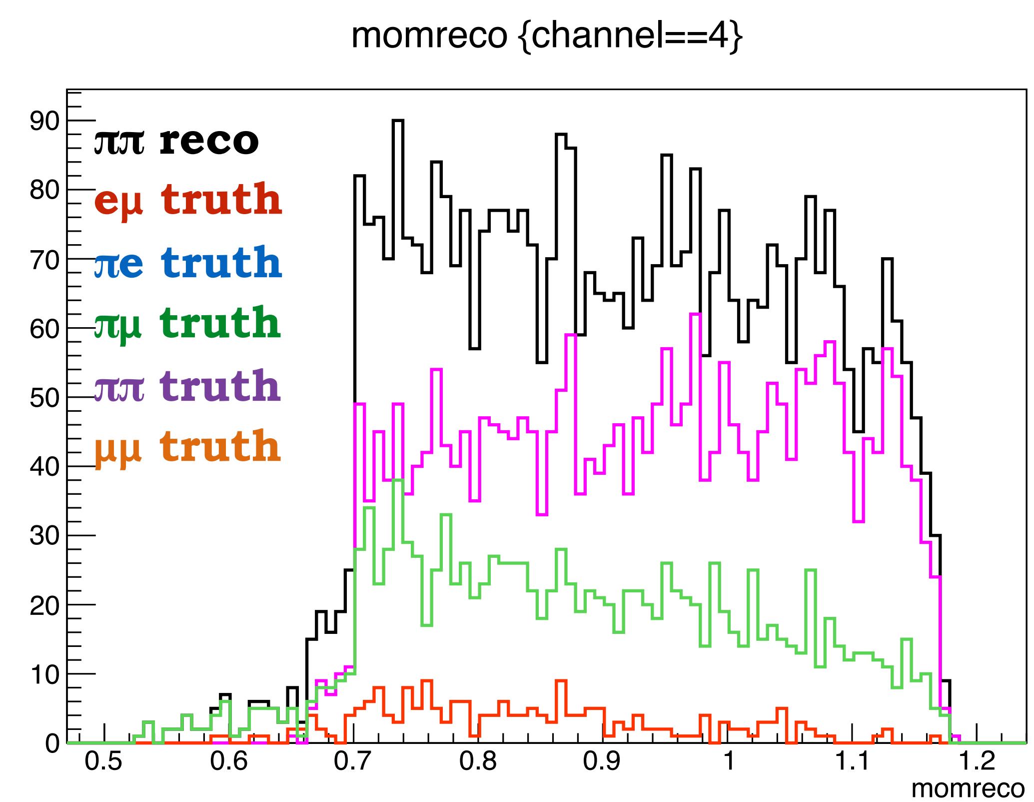
Signal MC: distributions I

$\psi(2S)\to\tau\tau\to e\mu 4\nu/\pi e 3\nu/\pi\mu 3\nu/\pi\pi 2\nu$ signal









PID studies

Electron PID

- $0.8 < E/p < 1.2$
- $\chi 2_{dE/dx}(e) < 4$
- $|\Delta tof(e)| < 0.3$ ns

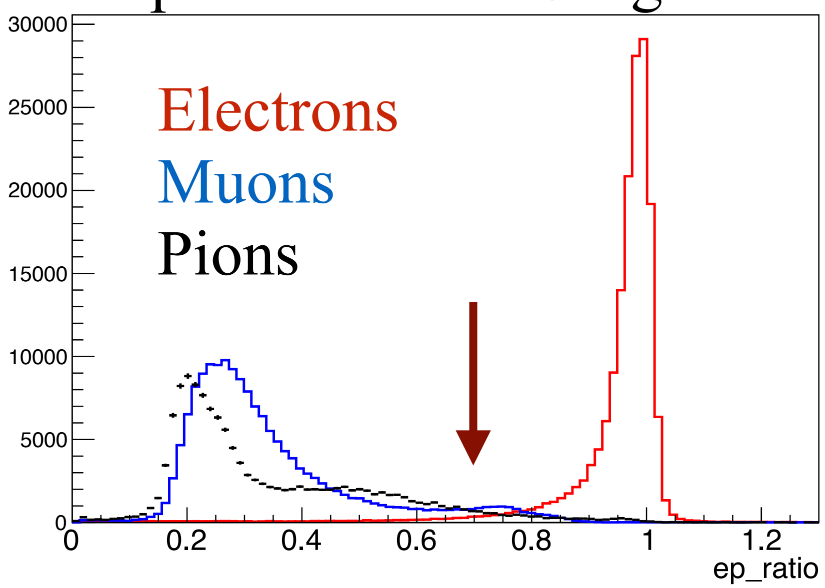
Muon PID

- $E/p < 0.7$
- $\chi 2_{dE/dx}(\mu) < 4$
- $|\Delta tof(\mu)| < 0.3$ ns
- **muc_dep>81*(ptrk-0.65)**

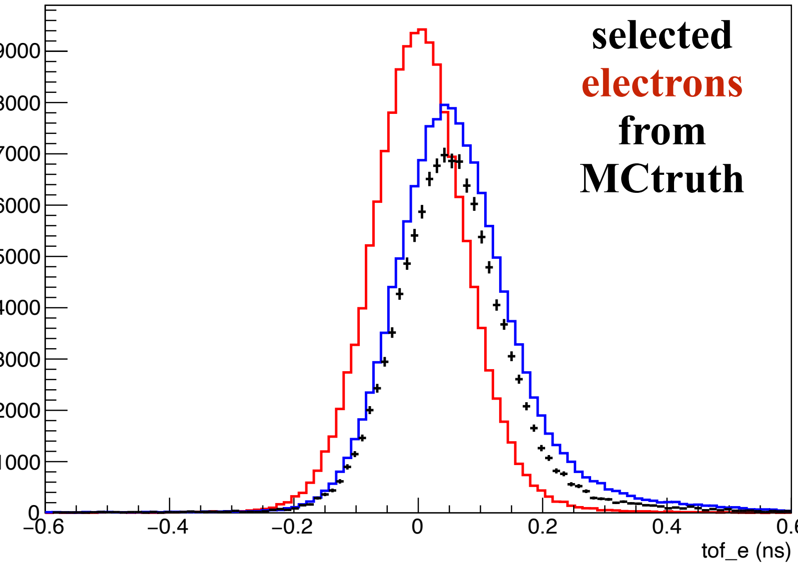
Pion PID

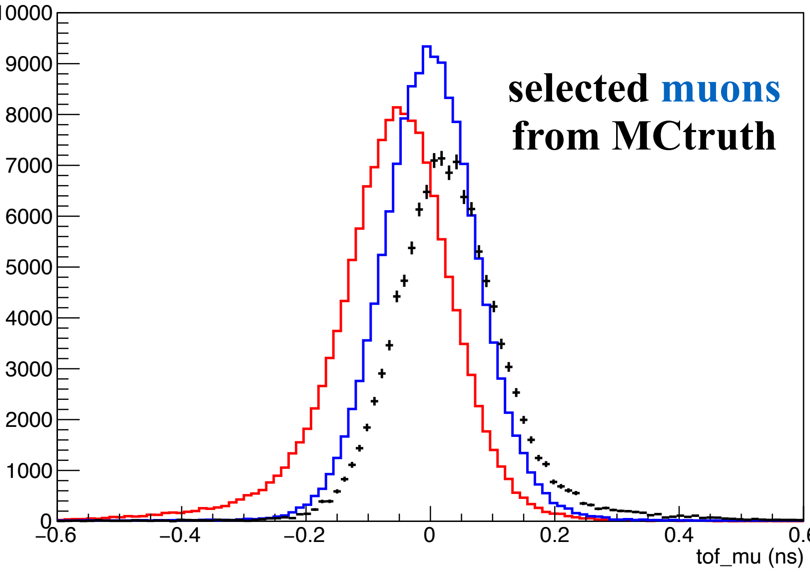
- $E/p < 0.7$
- $p > 0.7$ GeV/c
- $\chi 2_{dE/dx}(\pi) < 4$
- $|\Delta tof(\pi)| < 0.3$ ns
- **muc_dep<81*(ptrk-0.65)**

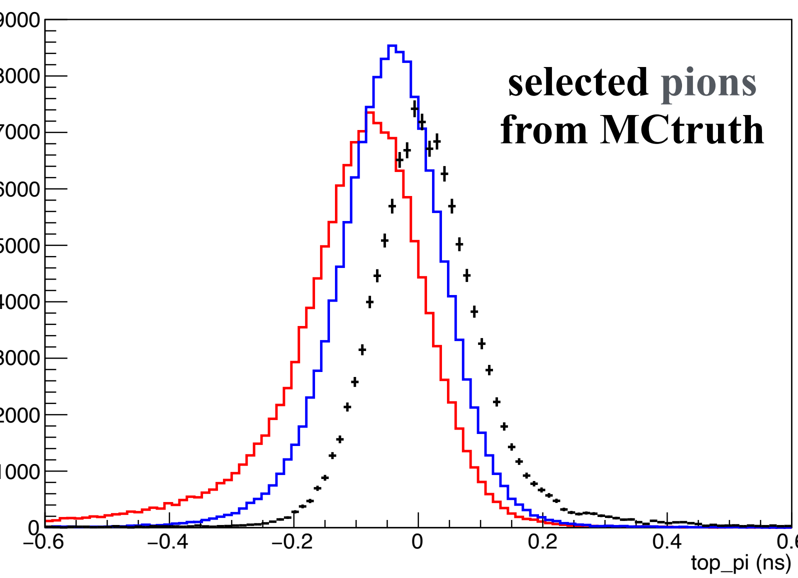
E/p ratio from MC signal



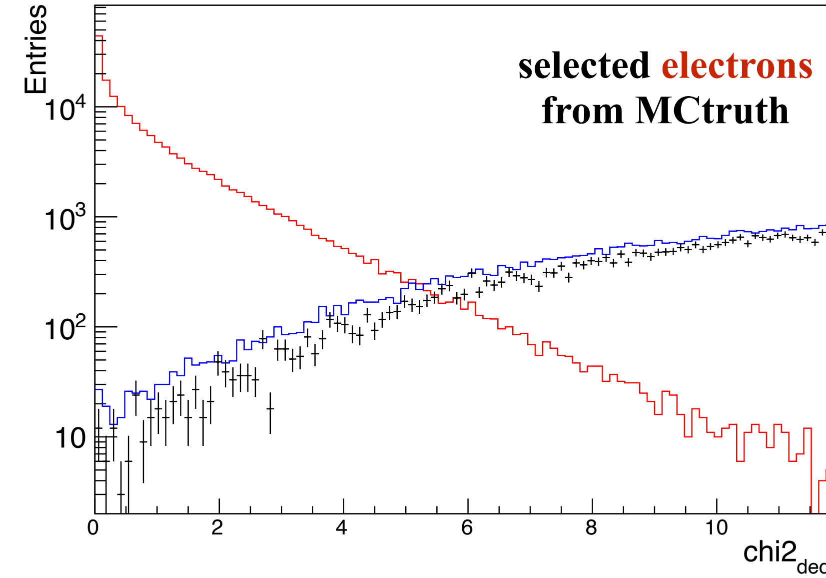
(exp-tof - tof_calc) from MC signal

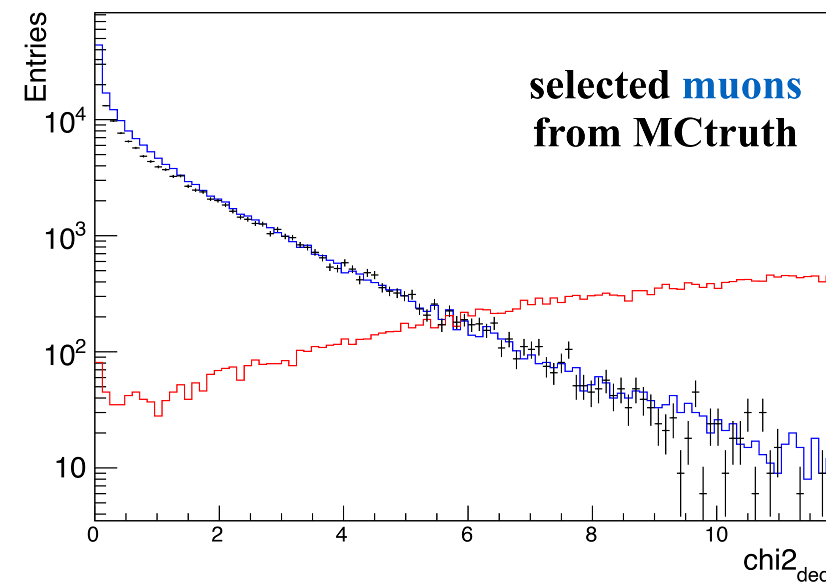


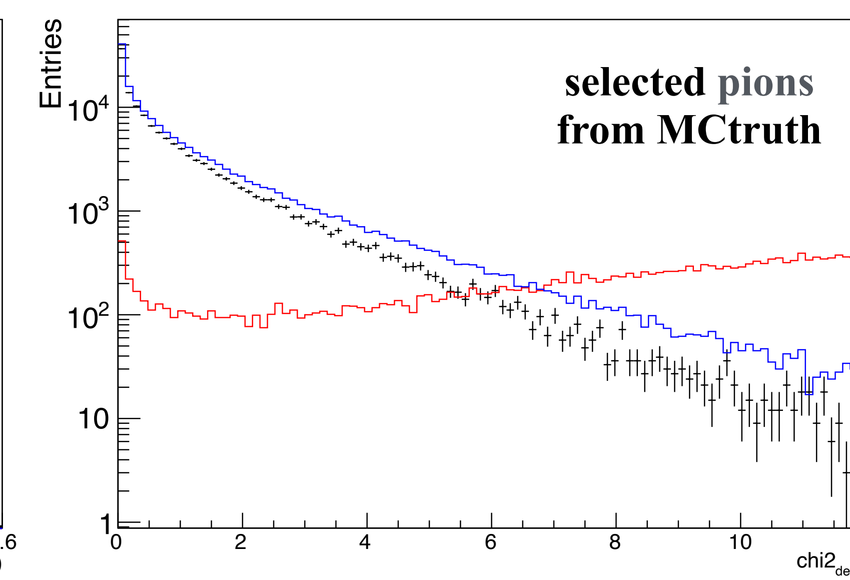




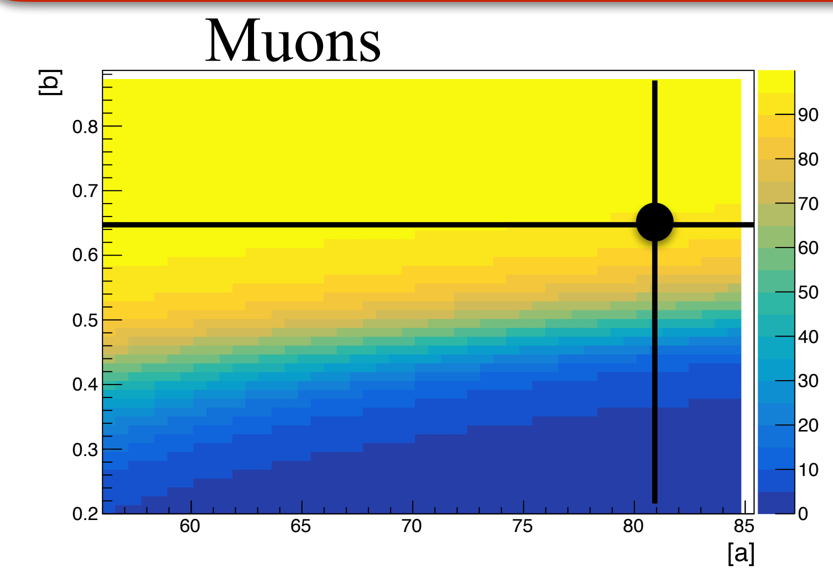
chi2-dEdx from MC signal







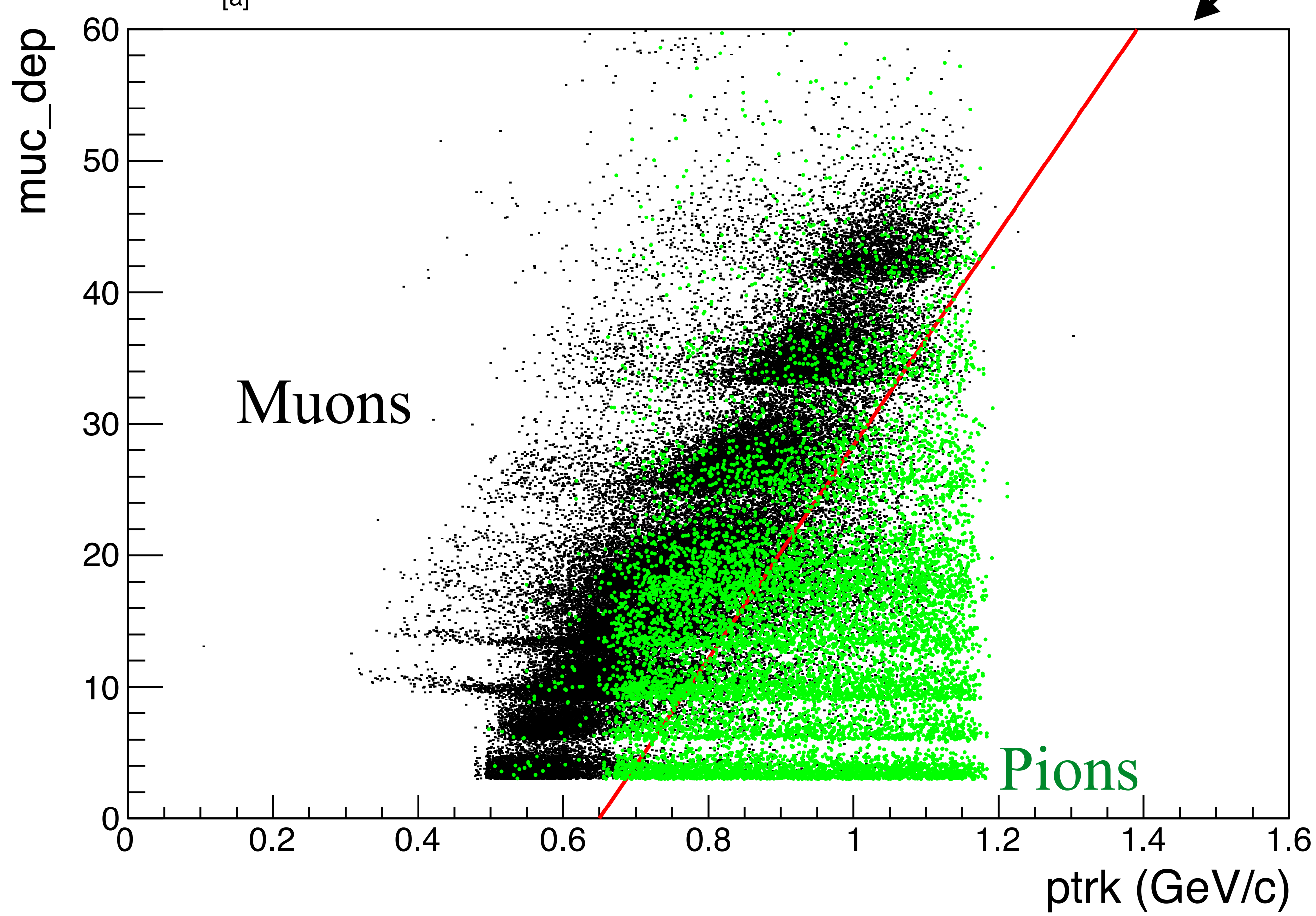
muc vs. ptrk from MC samples



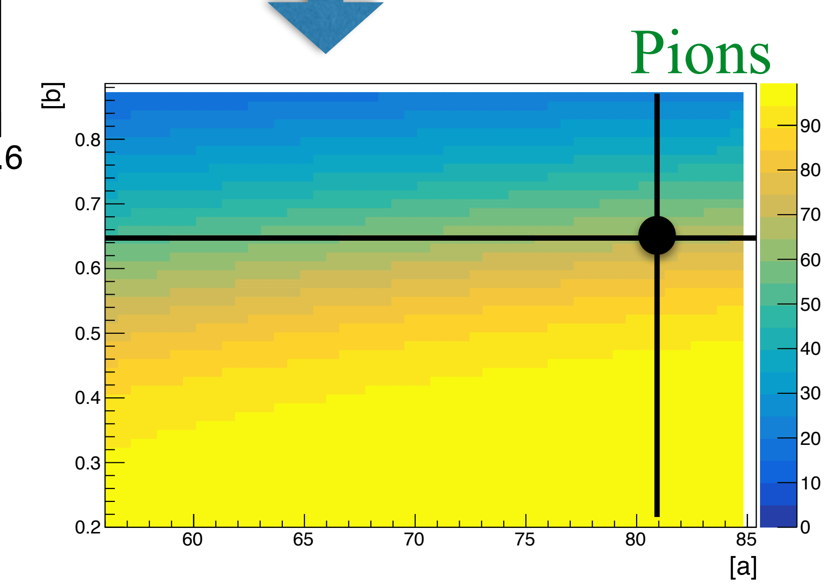
cut efficiency > 90% for muons selection

y = [a]*(x - [b])

y = 81*(x - 0.65) (optimized)



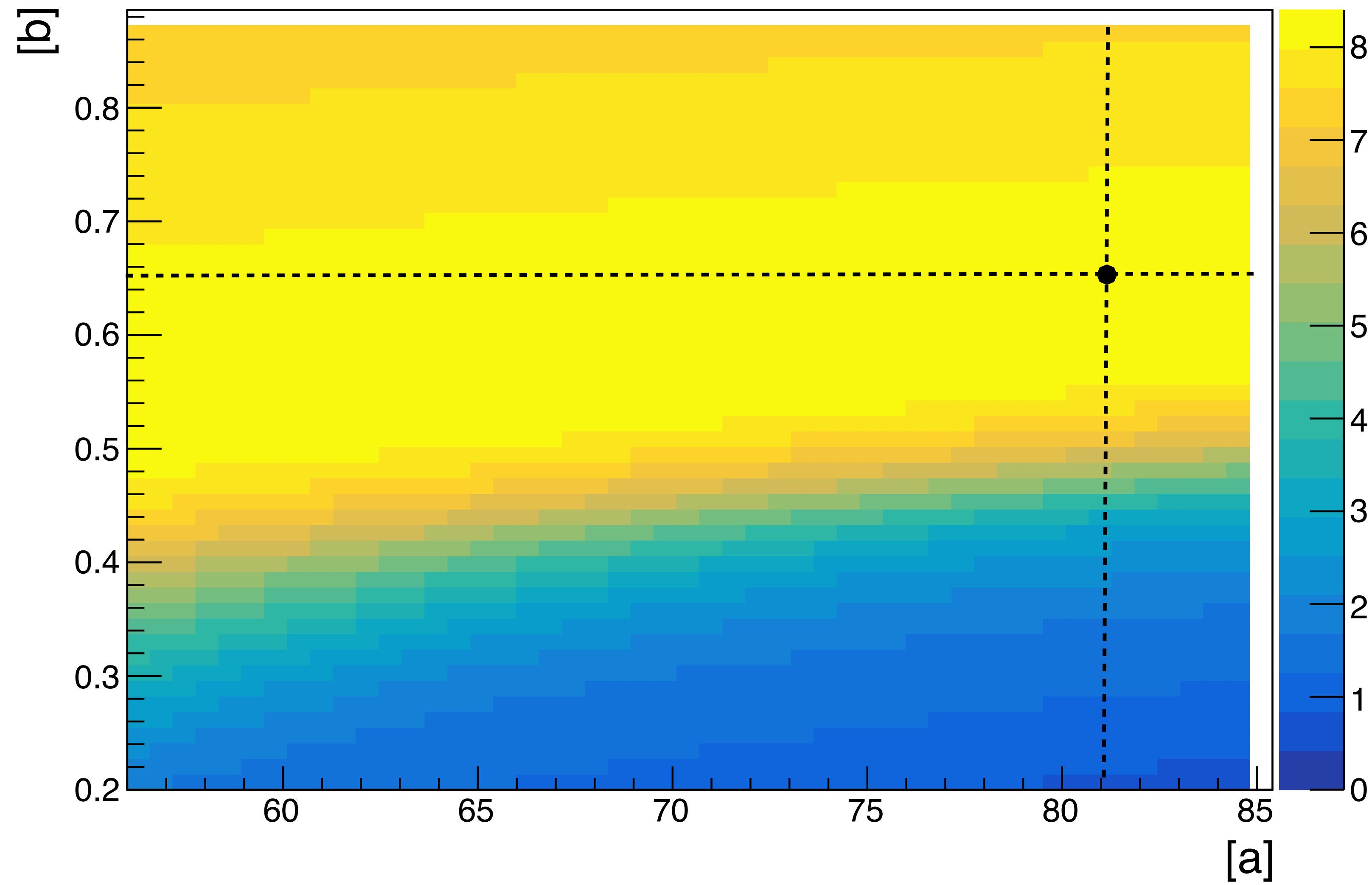
~70% of pions fall below the red line

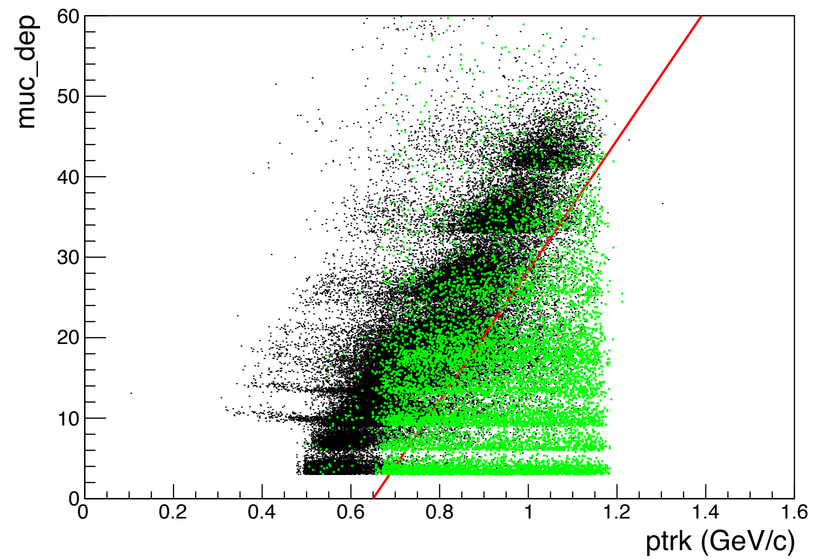


muc vs. ptrk from MC samples

$$\text{f.o.m.} = \frac{\text{S}}{\sqrt{\text{S}+\text{B}}}$$

- Scan for different value of parameters [a] and [b]
- Maximization of f.o.m.



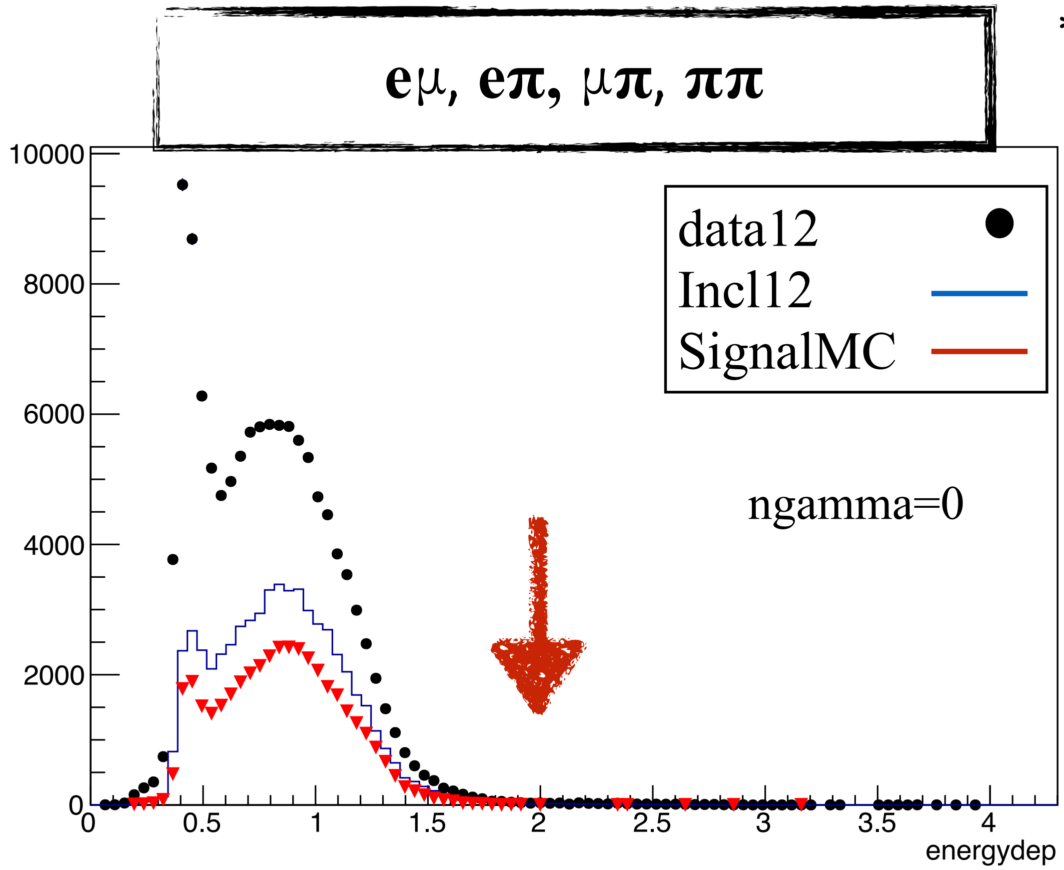


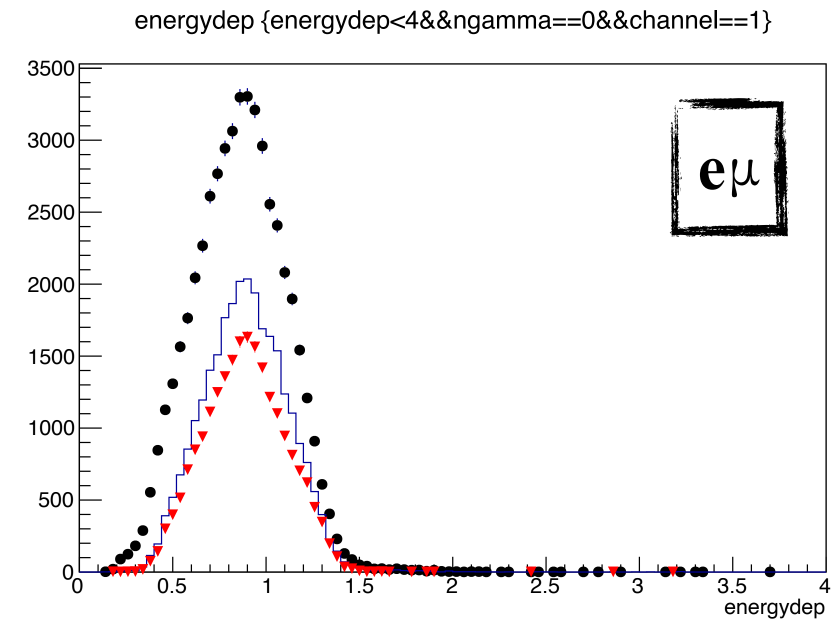
y = [a]*(x - [b])

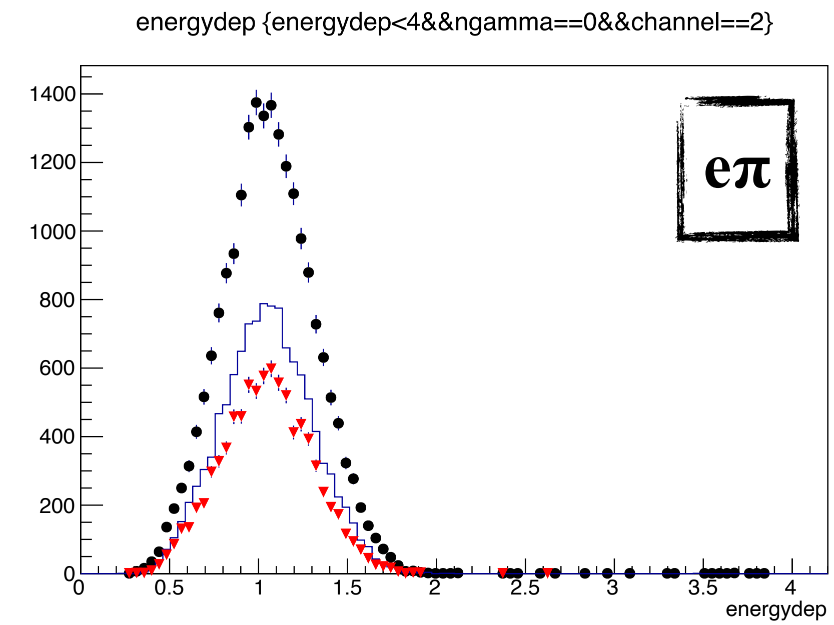
y = 81*(x - 0.65) (optimized)

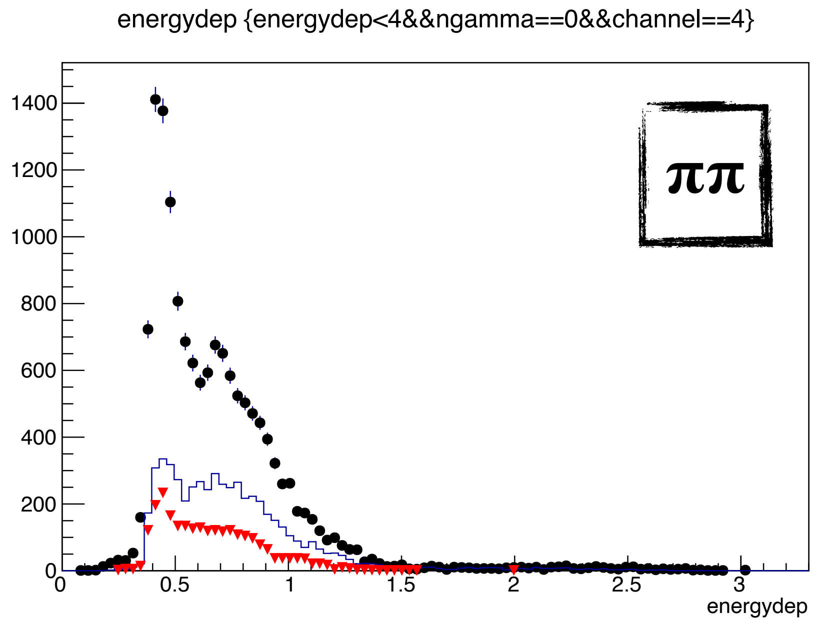
Additional cuts I

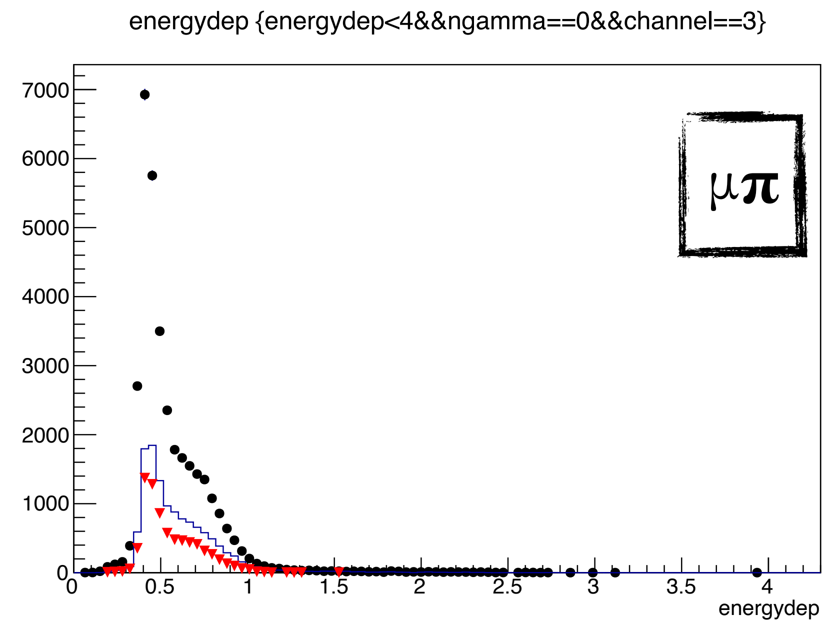
*signal arbitrary scale







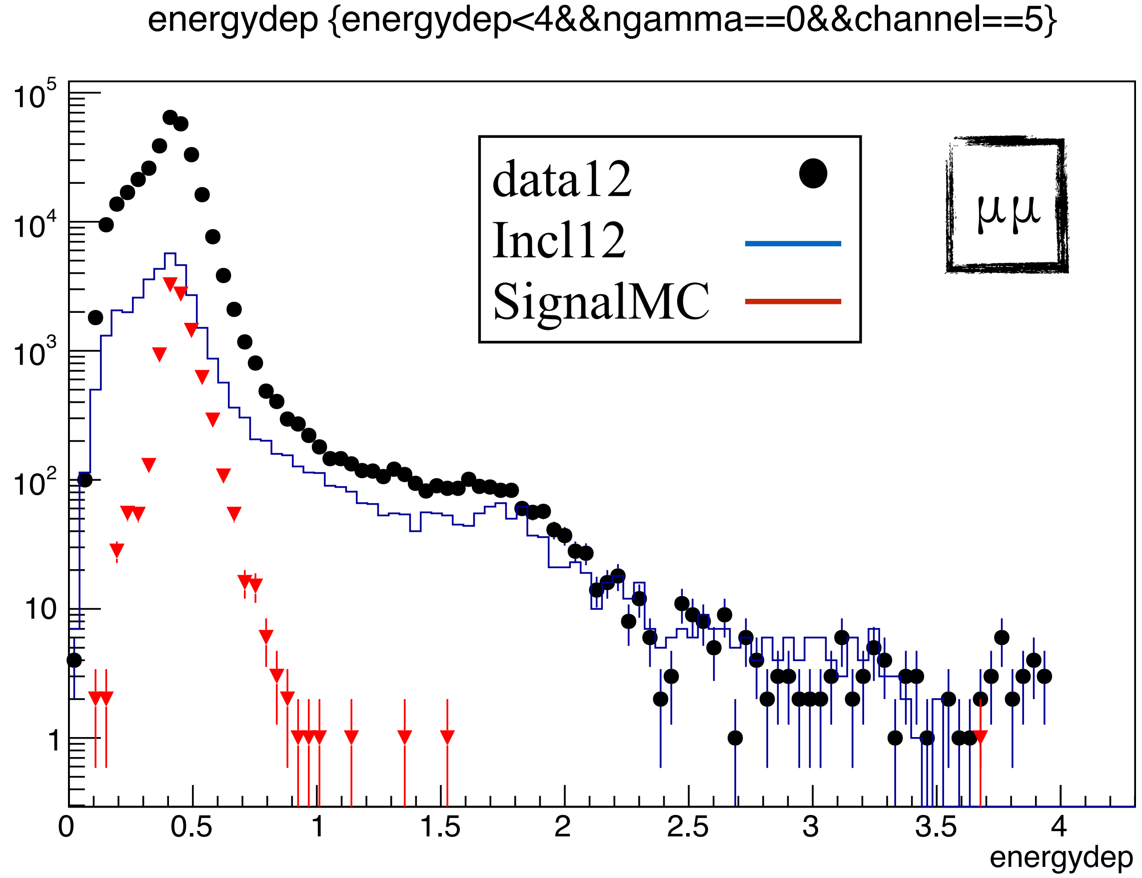


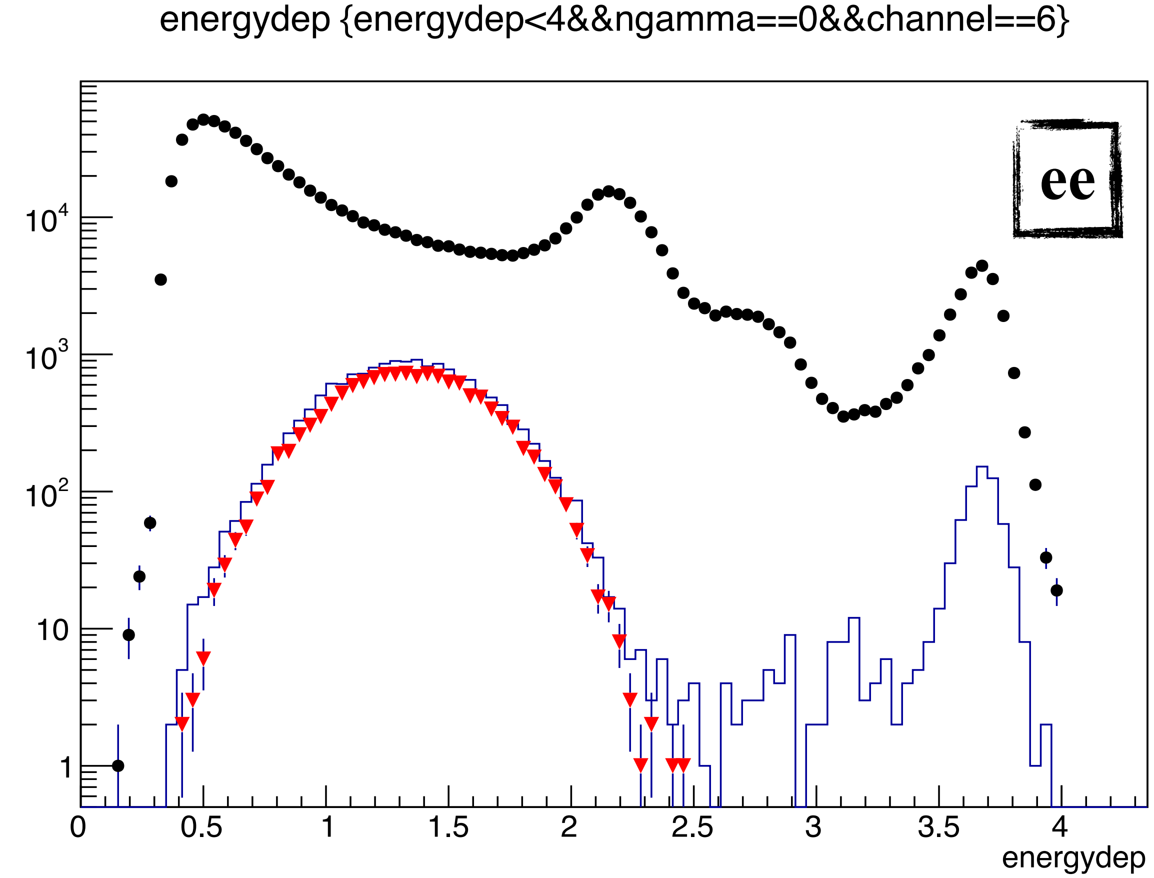


- energyDep < 2 (sum of deposit energy of the two tracks)

Additional cuts I

*signal arbitrary scale

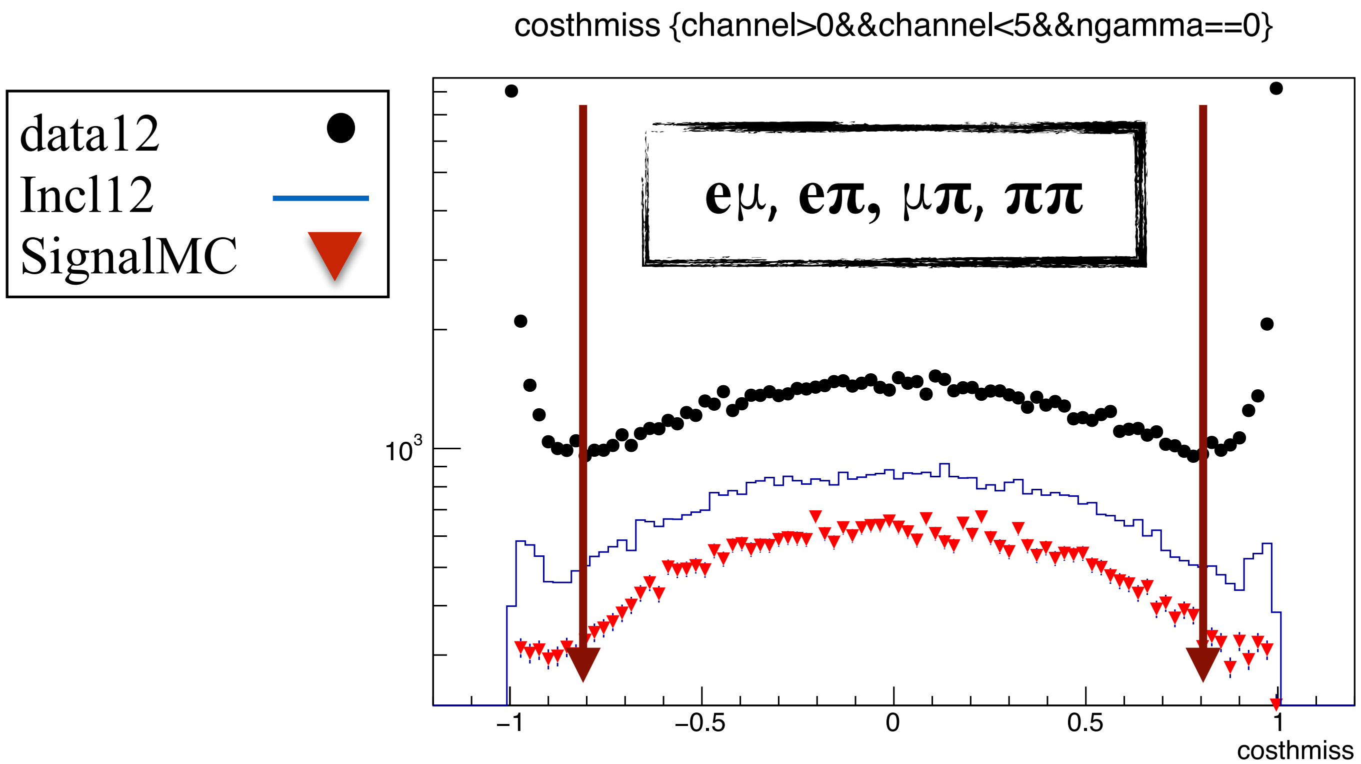




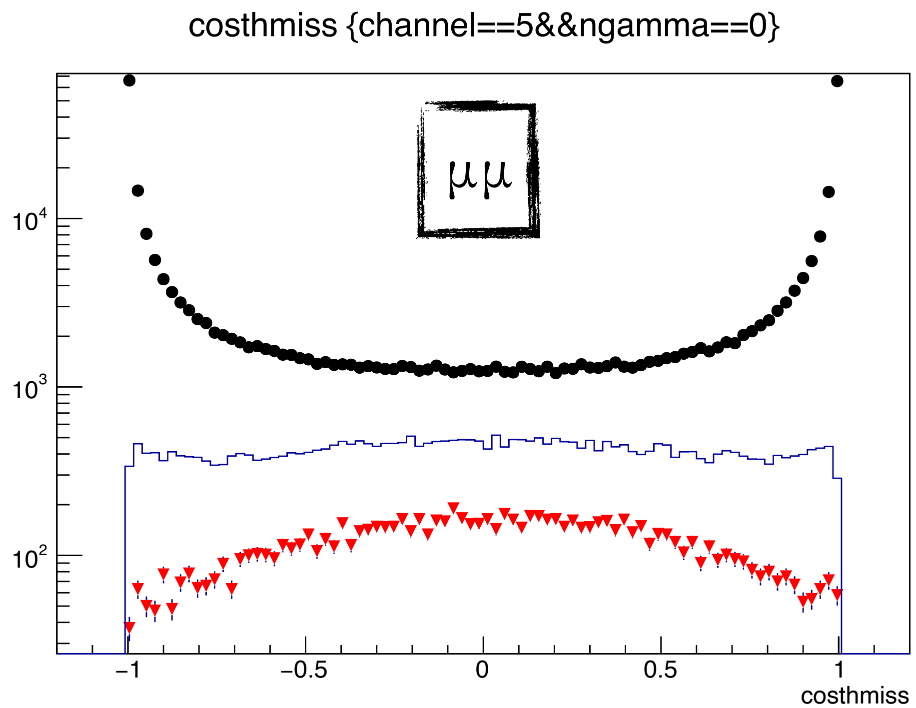
- Strong difference between data and MC

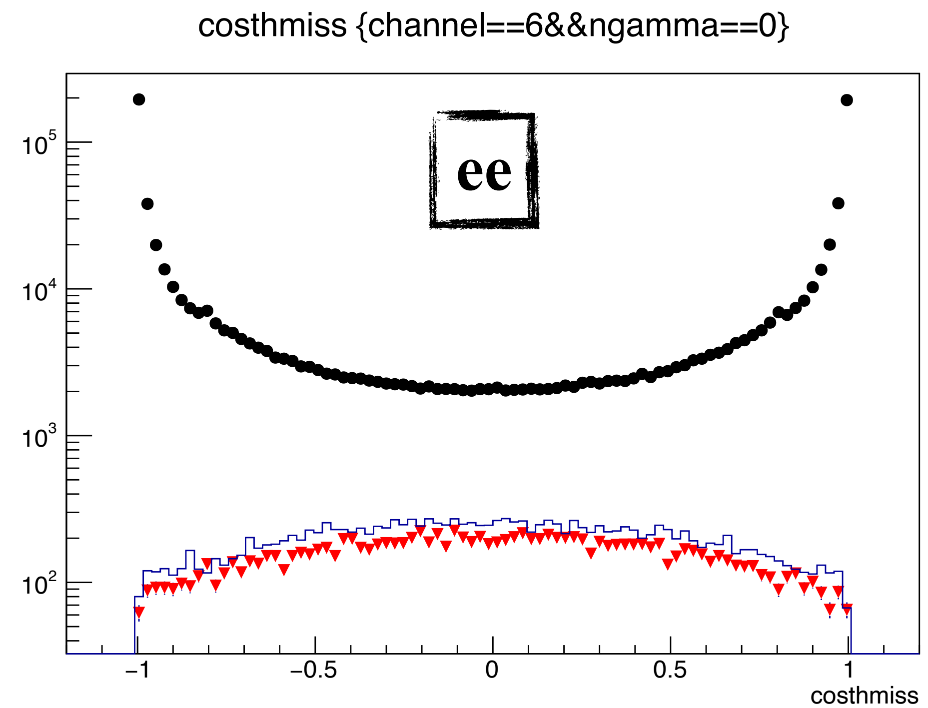
Additional cuts II

*signal arbitrary scale



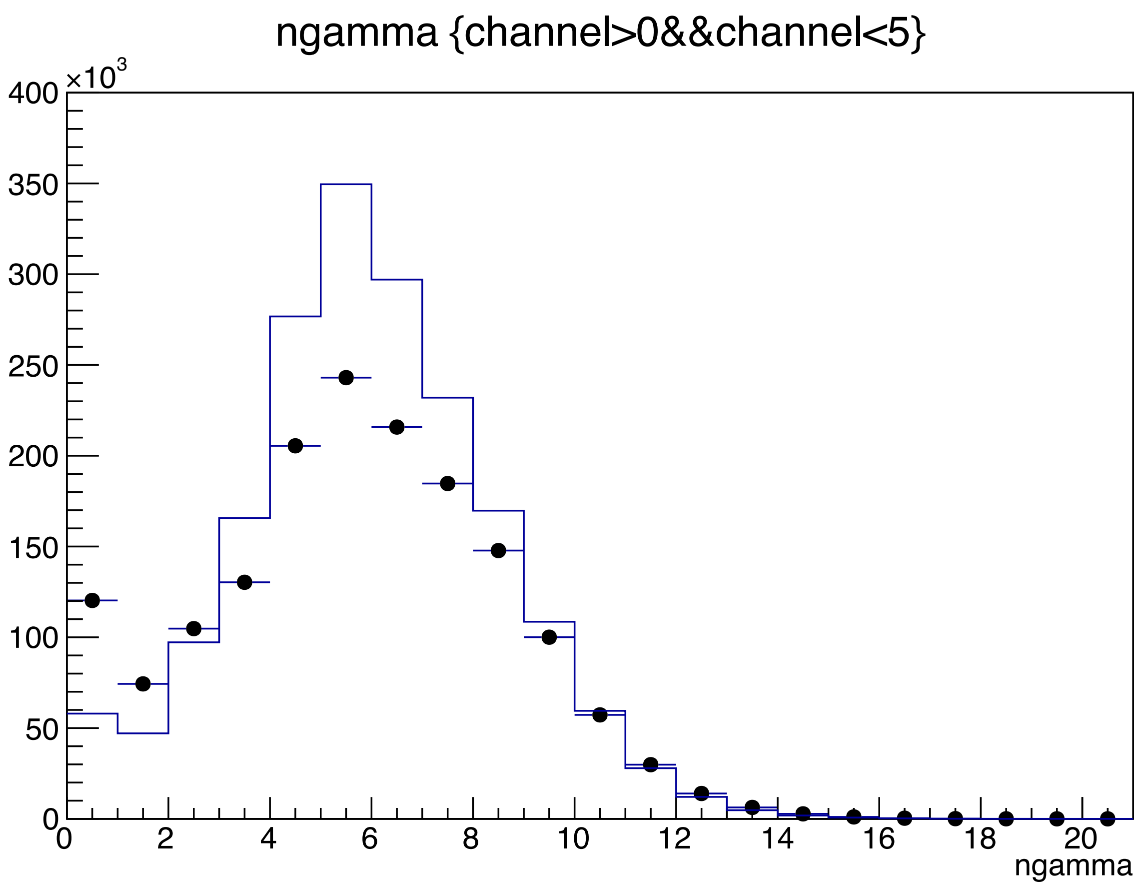
$$\cos\theta_{mis} = \frac{(\vec{p}_1+\vec{p}_2)_z}{|\vec{p}_1+\vec{p}_2|}$$

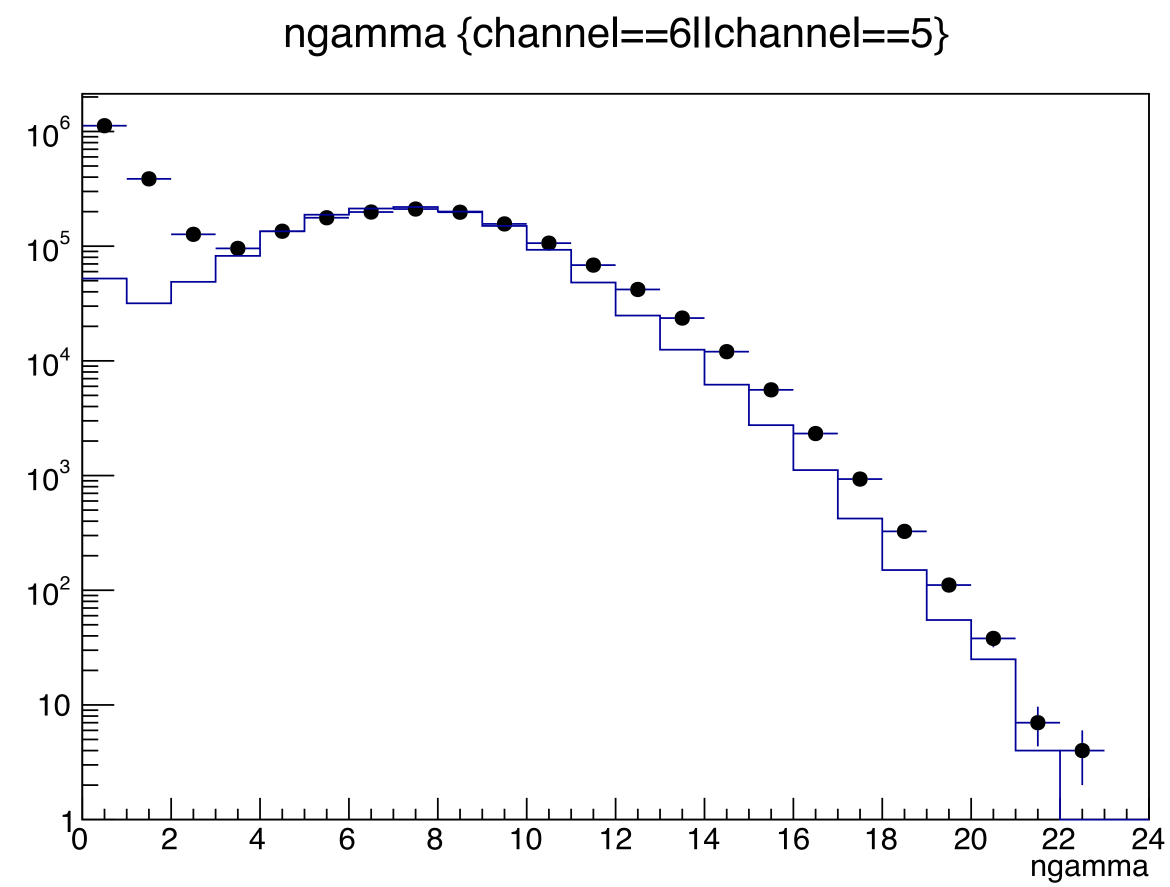




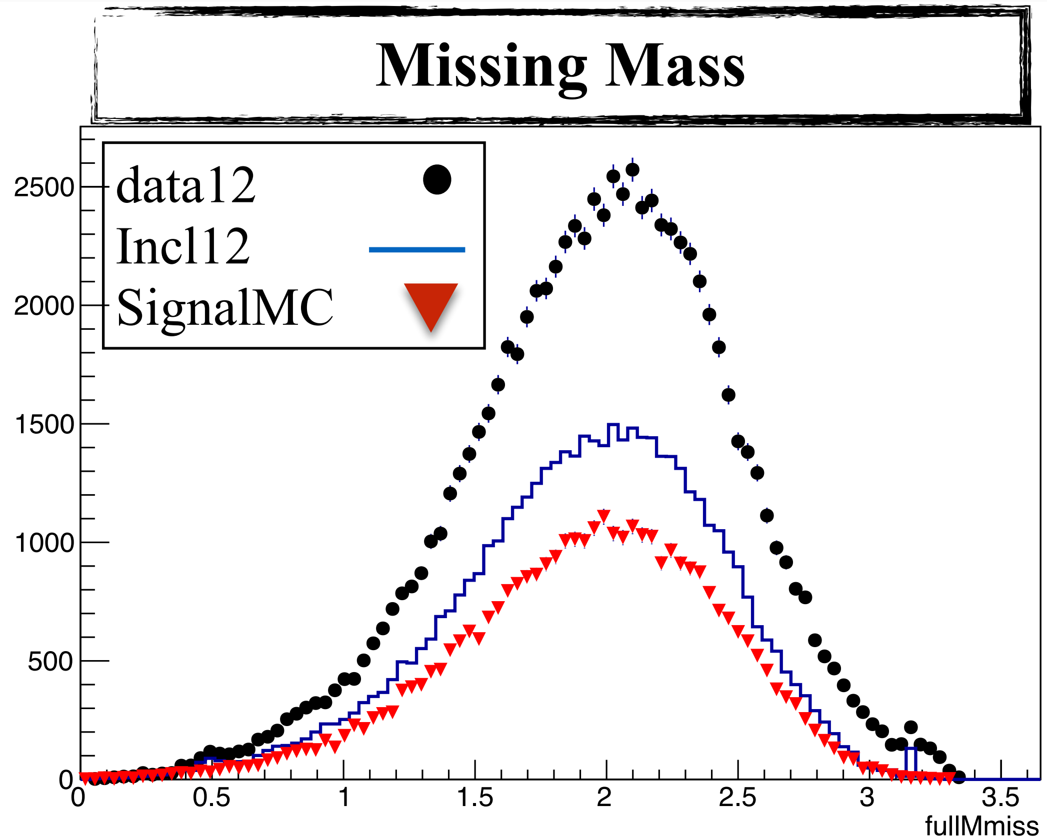
- |cosθ_miss| < 0.8

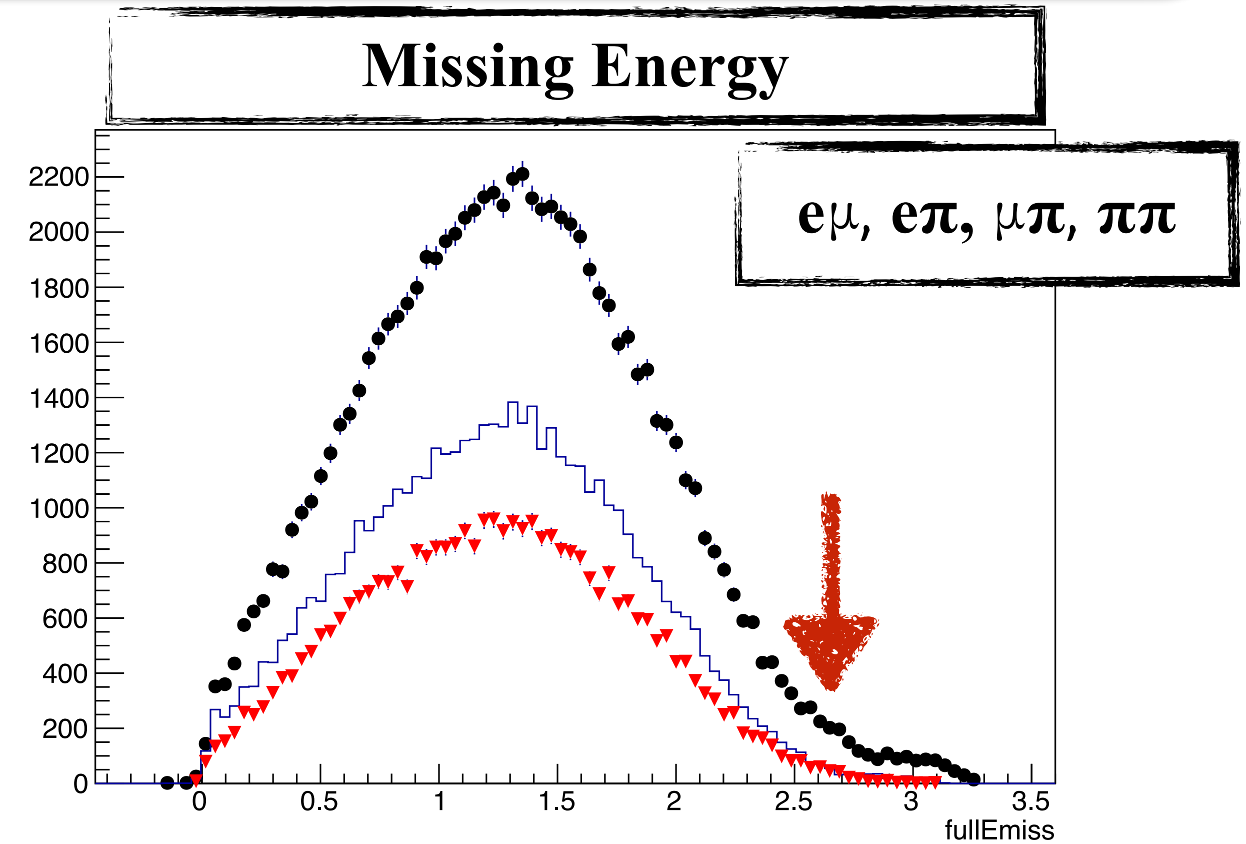
Difference between data and MC

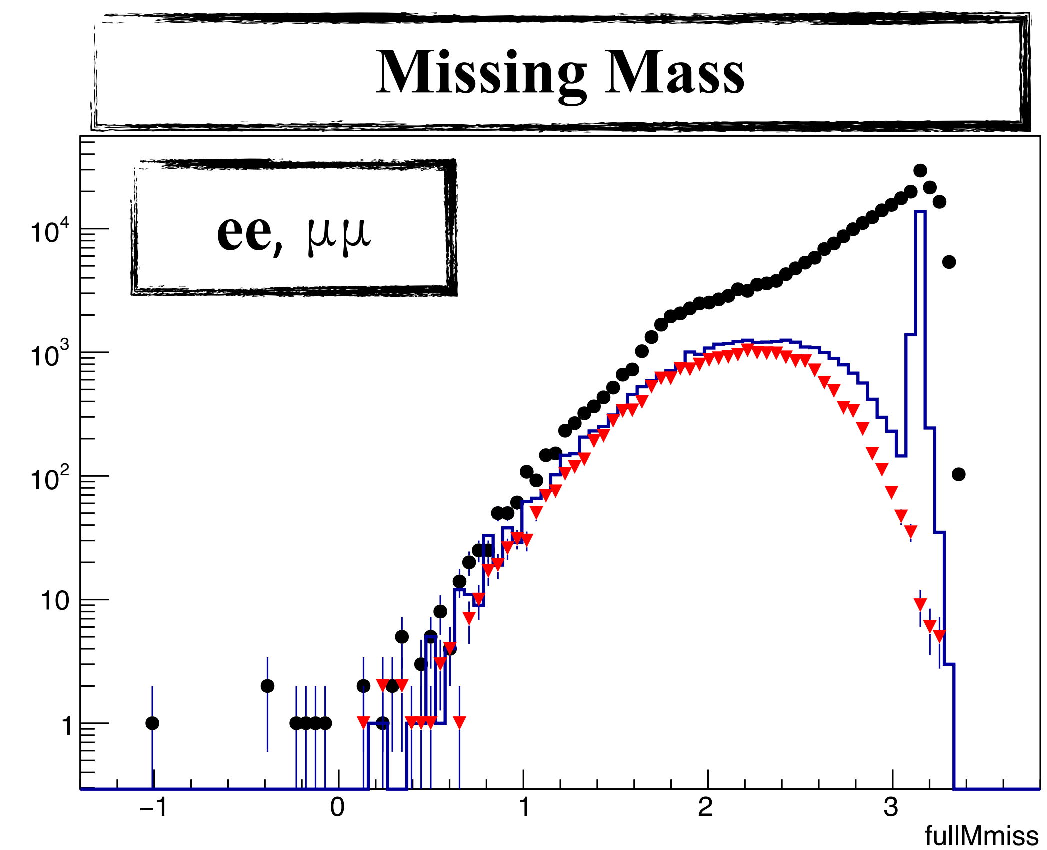


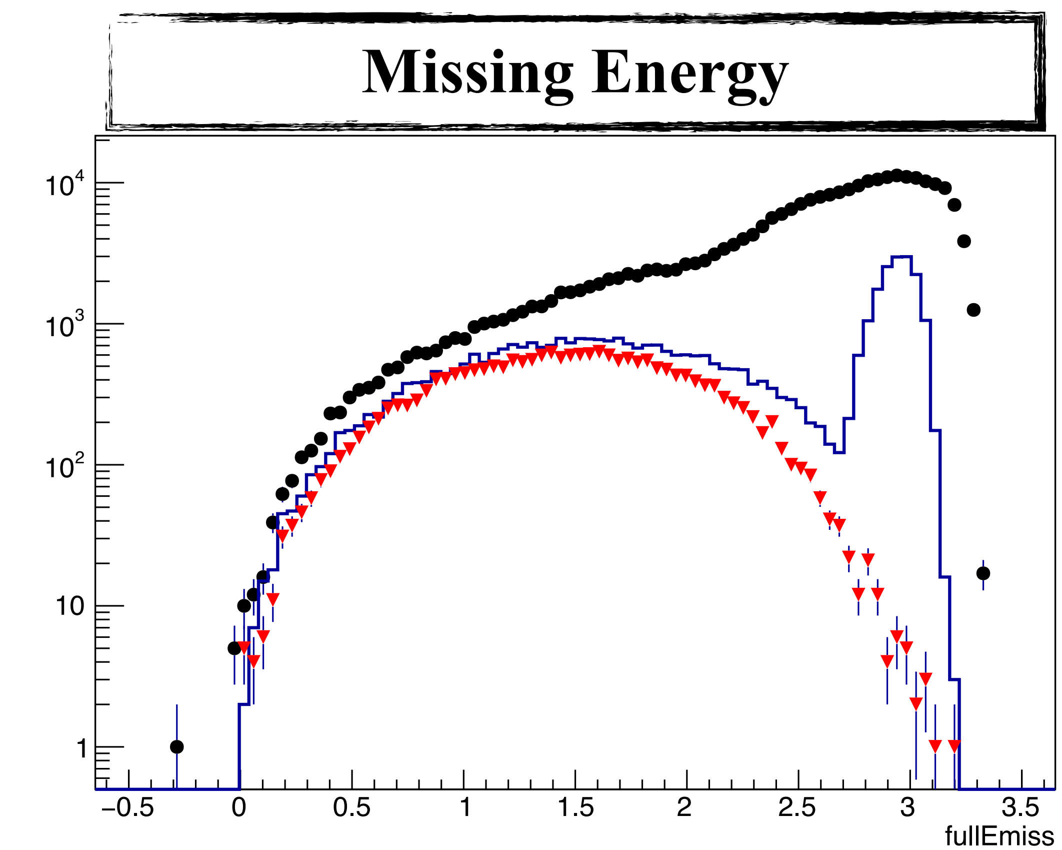


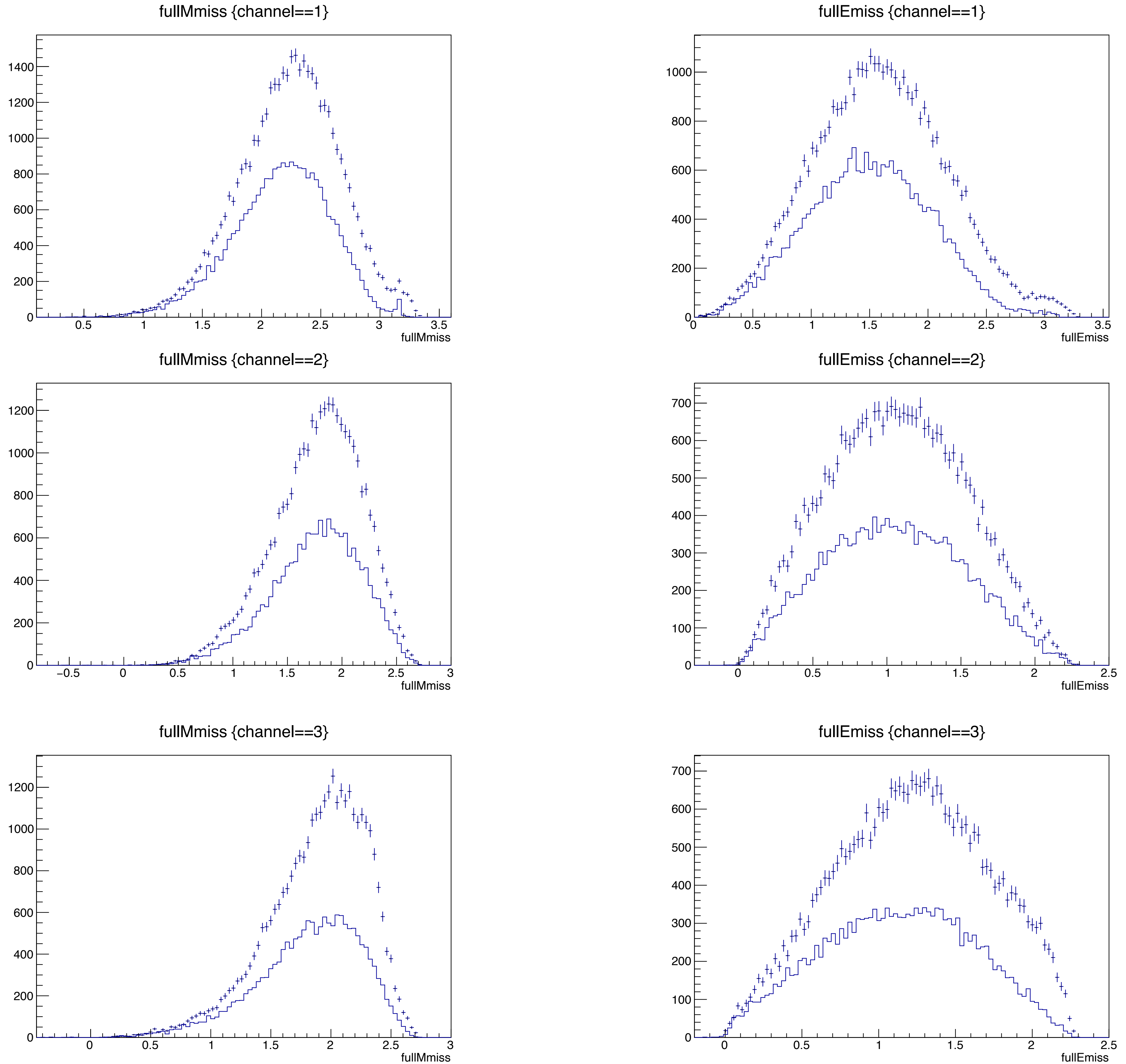
Additional cuts II










fullMmiss {channel==1}
fullMmiss
fullEmiss {channel==1}
fullEmiss
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fullEmiss {channel==2}
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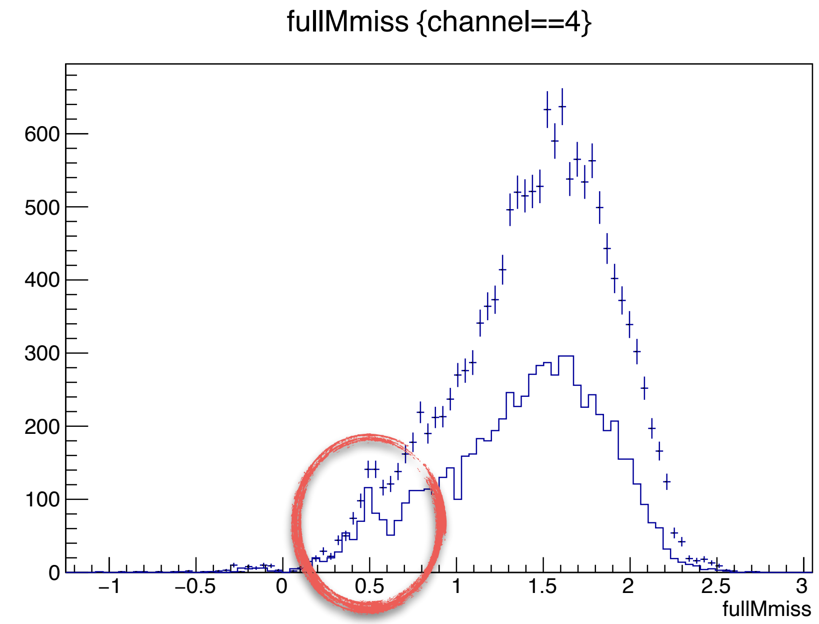
fullEmiss {channel==3}
fullEmiss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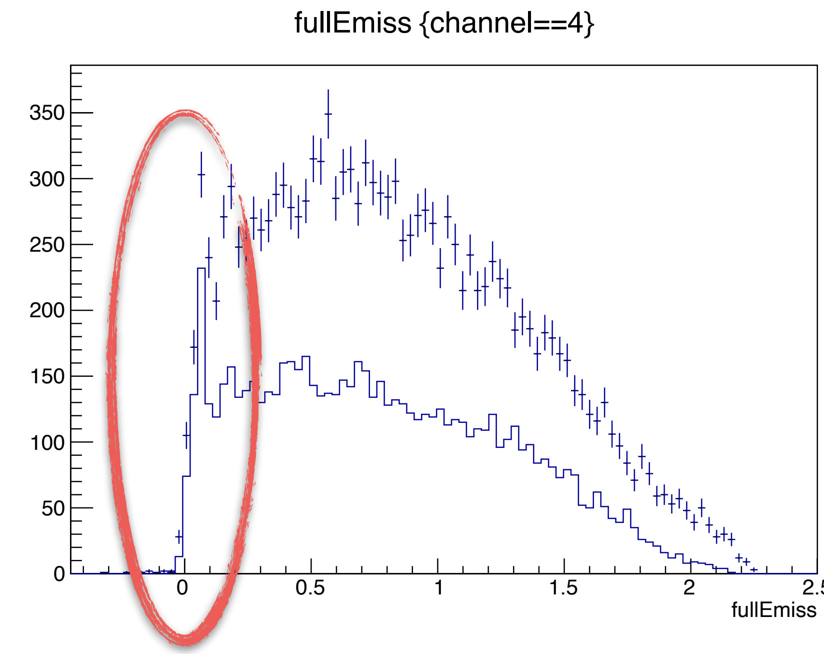
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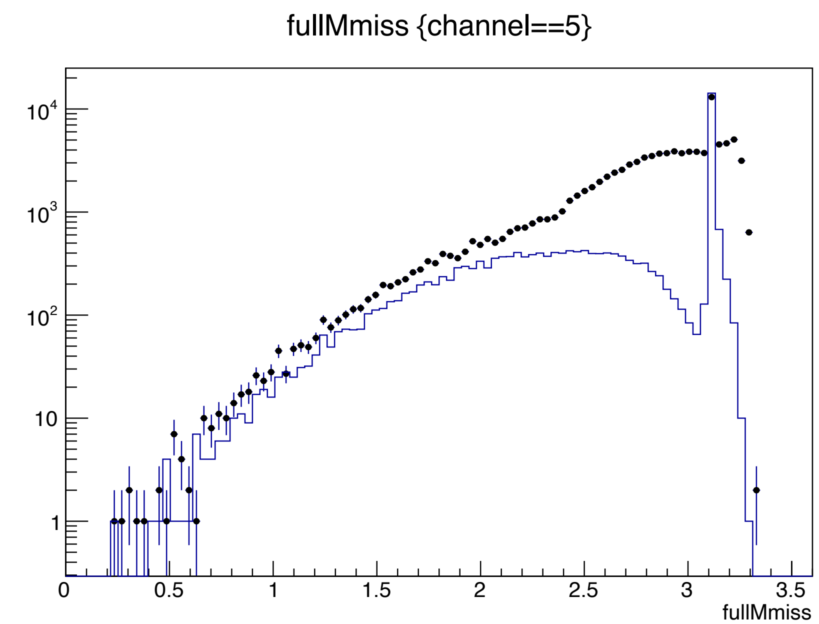
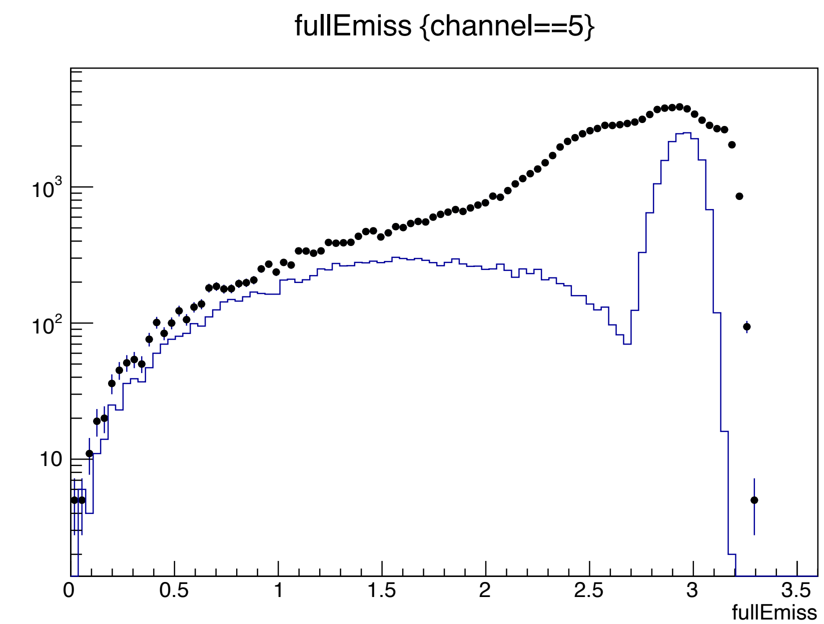
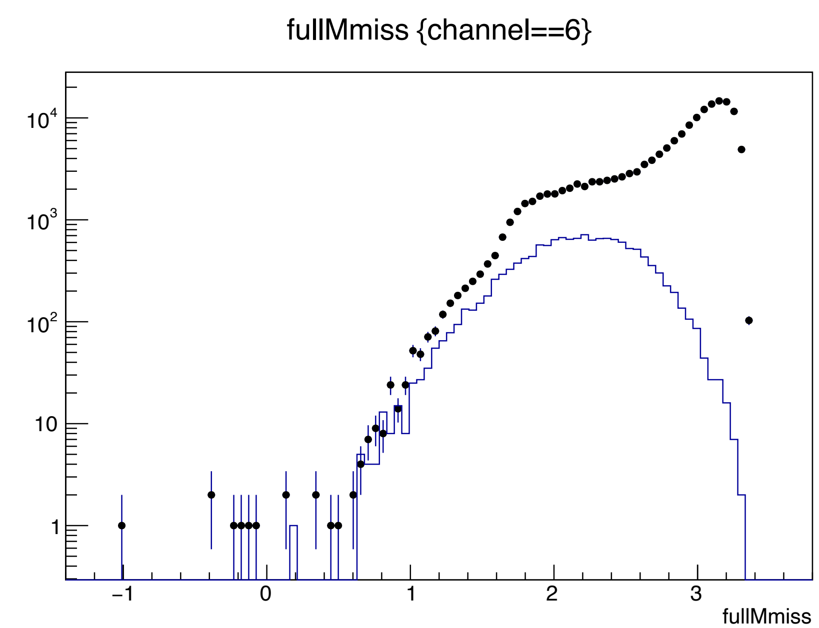
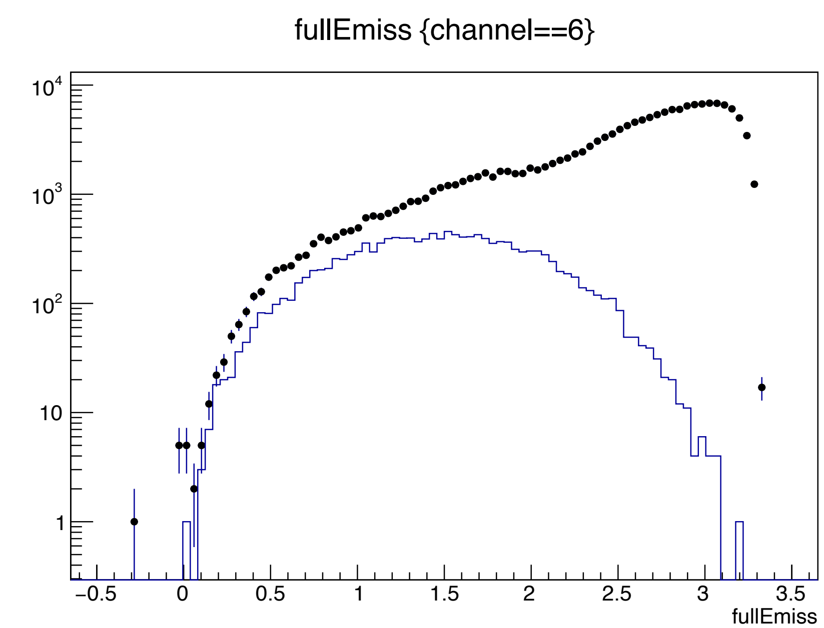

fullMmiss {channel==5}
fullMmiss

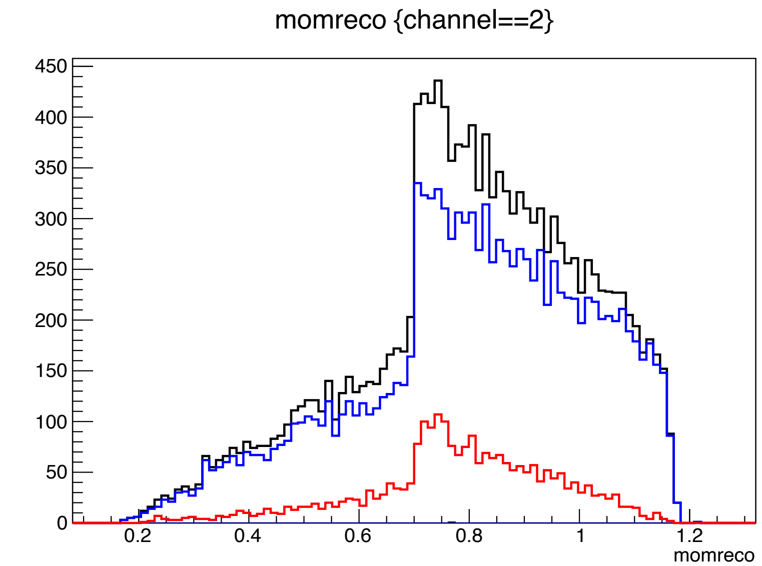

fullEmiss {channel==5}
fullEmiss

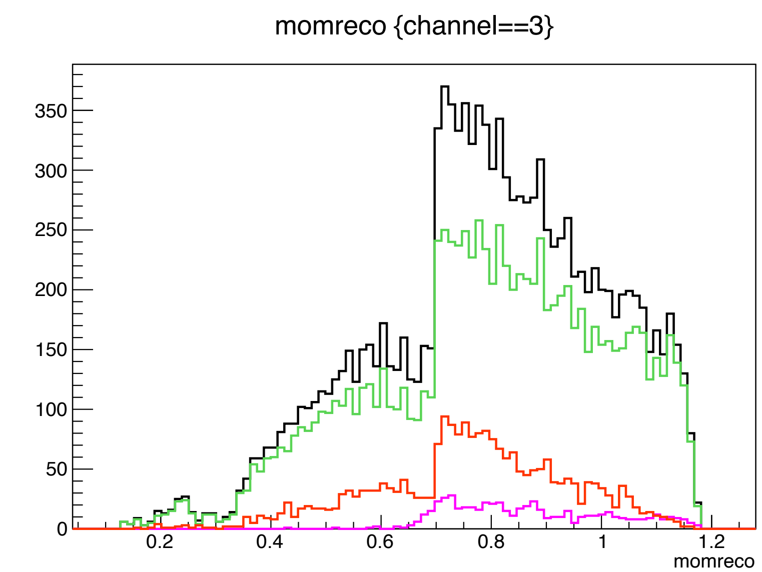

fullMmiss {channel==6}
fullMmiss


fullEmiss {channel==6}
fullEmiss

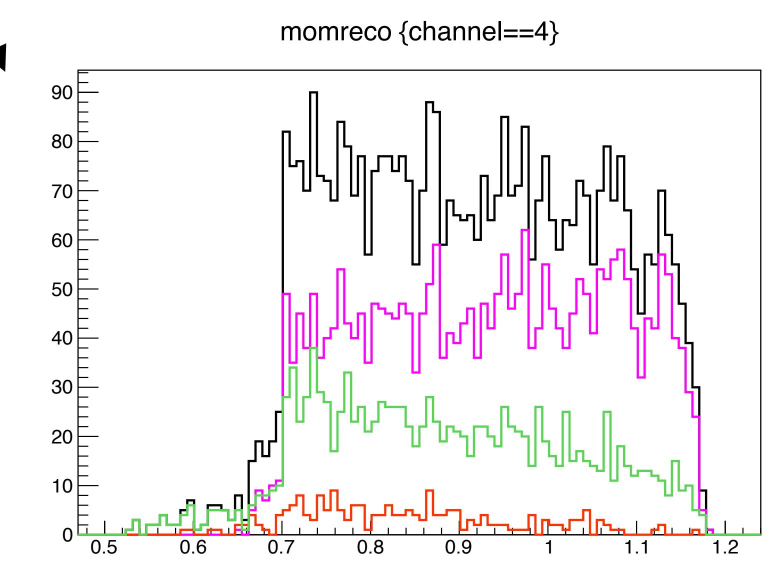
Conclusion from this new event and track selection

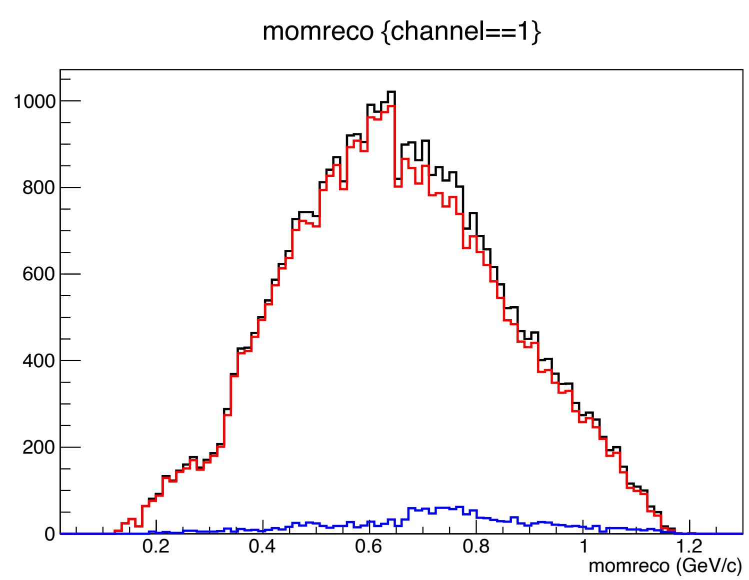
$\psi(2S)\to\tau\tau\to e\mu4\nu/\pi e3\nu/\pi\mu3\nu/\pi\pi2\nu$





- Huge contamination form other signal channels
- Unfolding procedure should be necessary to disentangle each channel
  - increase the uncertainties
- We decide to use only **$e\mu4\nu$** channel as "signal" (cleanest channel)





eμ reco
πe truth
~4/5% of background contamination

Summary table of cuts $\psi(2S)\to\tau\tau\to e\mu 4\nu$

Charged tracks

- **nCharged=2**
- Vertex cut: R_{xy}<1cm and R_z<10cm
- polar angle of tracks in MDC: |cosθ|<0.93
- ptrk < 1.2 GeV (remove Bhabha and dimuon events)
- pt>0.05 GeV/c
- **Vertex Fit**

Neutral candidates

- EMC time cut: 0<t_{TDC}<14(/50*ns*)
- E_γ >0.025 GeV for the barrel (**|(cos(θ)|< 0.8)**, and E_γ>0.050 GeV for the endcap (**0.86<|(cos(θ)|<0.92**)
- Isolated γ: opening angle between photon and its nearest charged tracks $\theta_{\gamma\text{-tr}}$> 10°
- nGamma = 0

Electron PID

- 0.8 < E/p < 1.2
- $\chi2_{dE/dx}$ (e)< 4
- |Δtof(e)|<0.3 ns

Pion PID

- E/p < 0.7
- p > 0.7 GeV/c
- $\chi2_{dE/dx}$ (π)< 4
- |Δtof(π)|<0.3 ns
- **muc_dep<81*(ptrk-0.65)**

Muon PID

- E/p < 0.7
- $\chi2_{dE/dx}$ (μ)< 4
- |Δtof(μ)|<0.3 ns
- **muc_dep>81*(ptrk-0.65)**

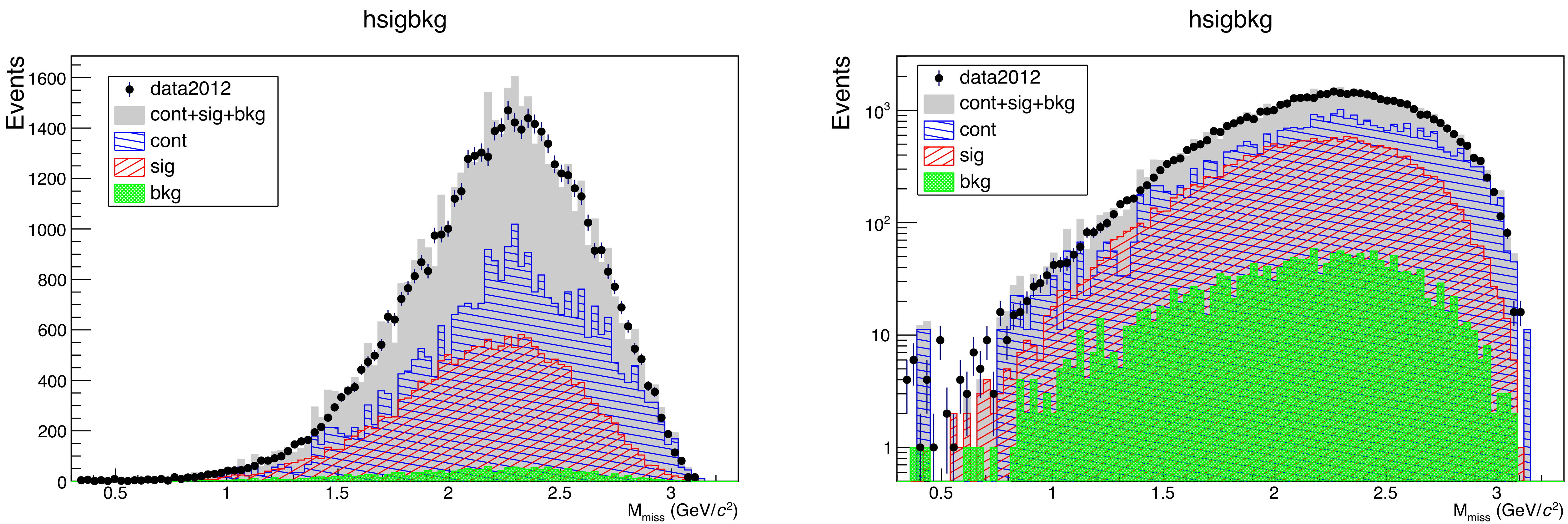
- |cosθ_miss| < 0.8
- energyDep < 2 (sum of deposit energy of the two tracks)

- MissingEnergy<2.65 GeV/c2
- 2.5<tof < 5 (ns)

Study of inclusive sample

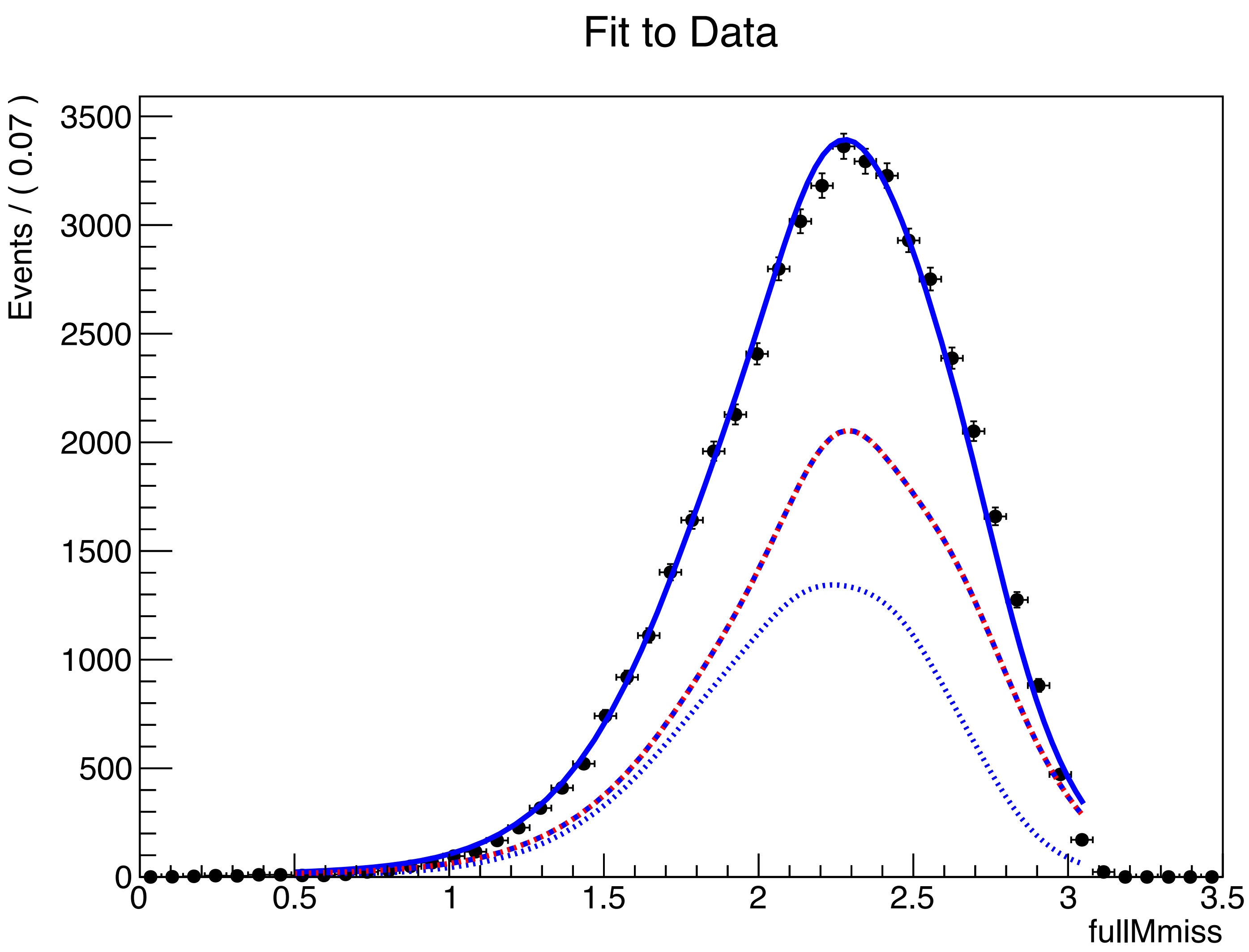
@ 3.650 GeV (L ~ 44.5 pb^{-1})

Continuum
2012 data



- Signal shape form inclusive MC (MCtruth)
- Background shape from inclusive MC (check MC truth info different from emu signal)
- Continuum from data, rescaled for the right luminosity factor

Extraction of number of signal



- Signal+background shape form inclusive MC
  - background fraction ~ 10% from inclusive MC sample
- Continuum from data, rescaled for the right luminosity factor (fixed)
- Nsig = 17237 ± 195
- ε = 0.30

$$Br_{\tau\tau} = \frac{\frac{N^{obs} - N^{obs}_{cont} - N^{norm}_{bg}(Br_{\tau\tau})}{\varepsilon_{e\mu} \cdot Br(e\mu)} - \sigma^{\tau\tau}_{Int}(Br_{\tau\tau}) \cdot L_{3.686}}{N_{\psi(2S)}}$$

$=(2.72 \pm 0.05) \times 10^{-3}$

LFU violation at BESIII?

Rinaldo's suggestion

BESII/BESIII on ψ (2S) -> ττ

BESII : arXiv:hep-ex/0609023v1 13 Sep 2006 ***(PRD74,112003)***

- BESII:
  - 14 M ψ (2S)
  - Looking to ττ -> μ e not aligned events
  - BR (ψ (2S) -> ττ) = $(3.1 \pm 0.21_{stat} \pm 0.38_{syst}) \times 10^{-3}$
  - Systematic error mostly due to lack of continuum data ***(10%)***

6 times lower

- **BESIII:**
  - **550 M ψ (2S)**
  - **BR (ψ (2S) -> ττ) ≈ $(3.1 \pm 0.03_{stat} \pm ?) \times 10^{-3}$ [0.03/3.1 ≈ 1 %]**
  - **Looking also to other τ decay modes**
  - **ψ (2S) scan -> systematic error more under control**
  - **can we achieve ≈ 1 % , testing LFU violation ?**

$(2.72 \pm 0.05) \times 10^{-3}$
with only 2012 data set

From Zhang Bingxin (IHEP)

X. H. Mo, J. Y. Zhang, B.X. Zhang (IHEP)

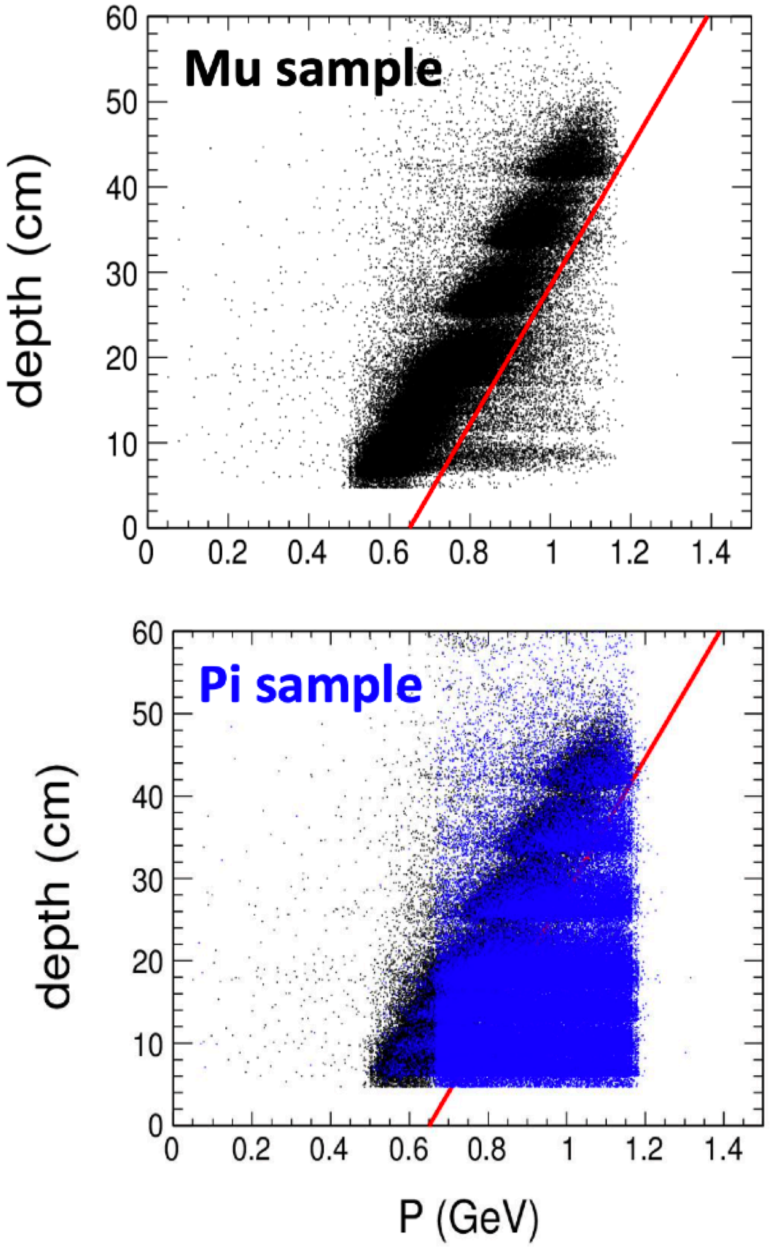
Events selection

◆ **Charged track**
- nCharged=2
- Vr<1cm,|Vz|<10cm
- |cosθ|<0.93
- ptrk<1.2 GeV
- Vertex Fit

◆ **Neutral track**
- Emc>0.025GeV(barrel),Emc>0.050 GeV(Endcap)
- $0<T_{EMC}<14$(x50ns)
- $\theta(\gamma,trk)>10^0$

◆ PID electron
- 0.8<E/p<1.2
- $\chi 2_{dE/dx}<4$
- Δtof(e) <0.3 ns

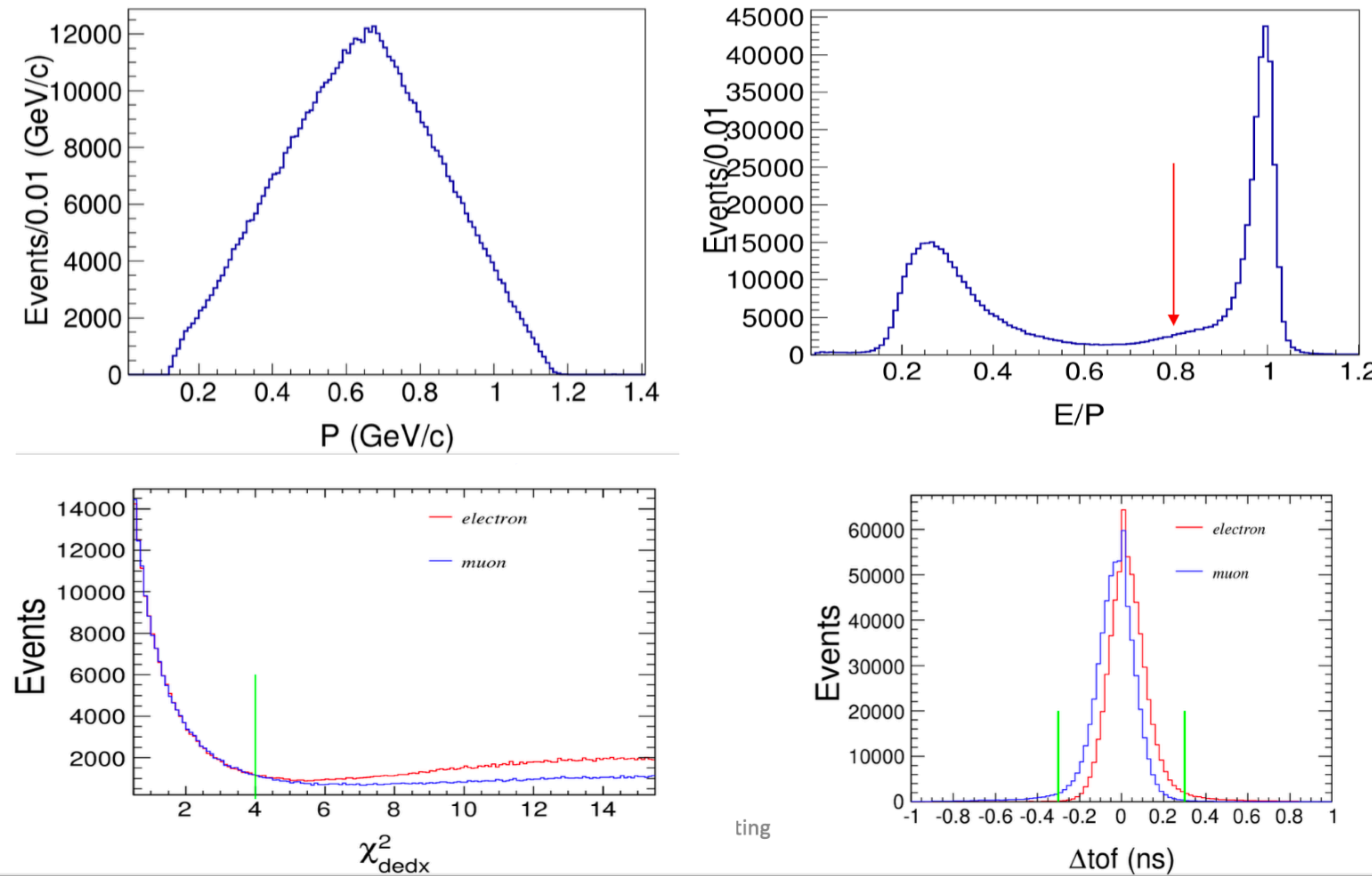
◆ PID muon
- E/p<0.7
- $\chi 2_{dE/dx}<4$
- Δtof(mu) <0.3 ns
- muc_dep>81*(ptrk-0.65)



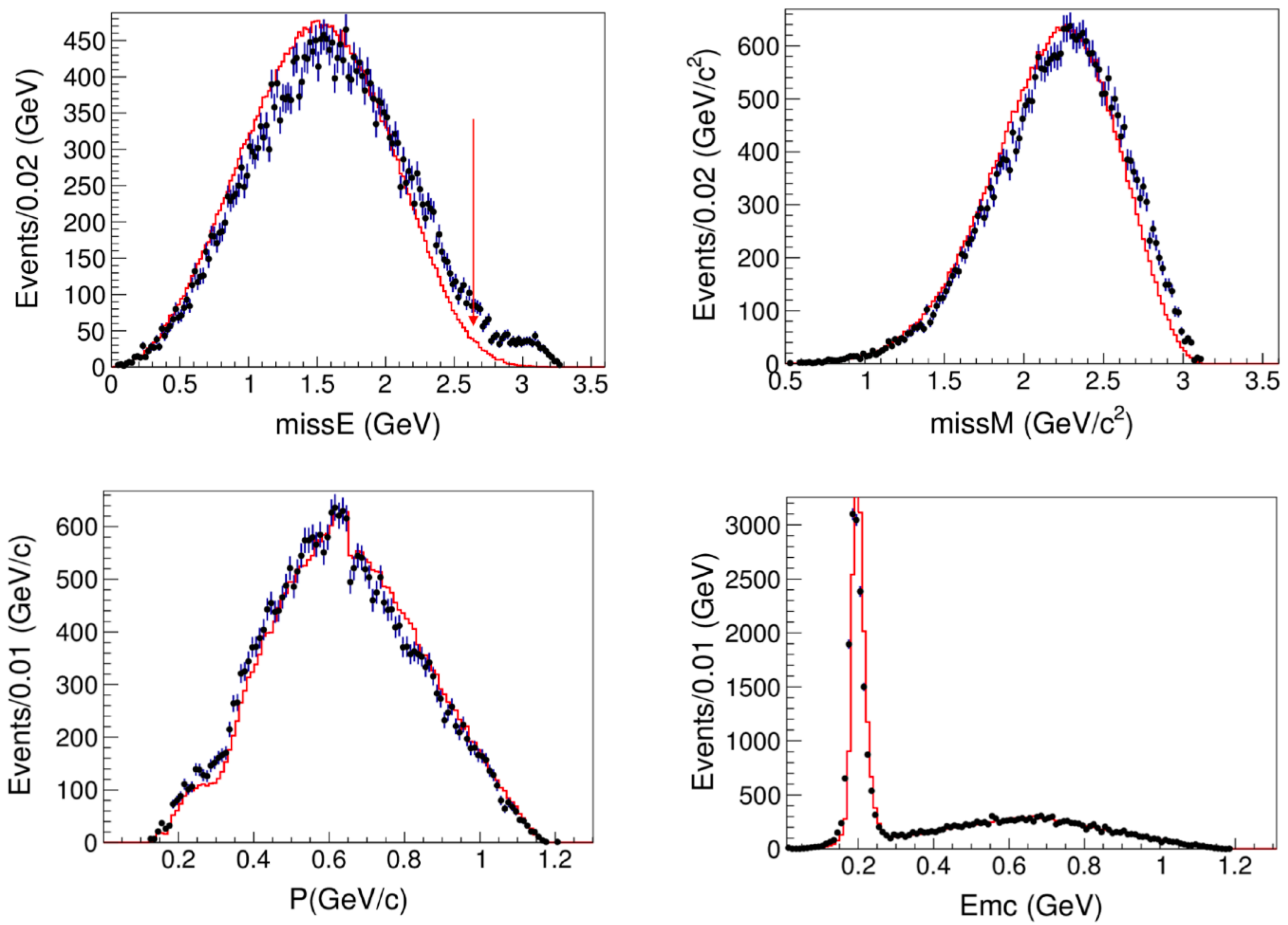
From Zhang Bingxin (IHEP)

X. H. Mo, J. Y. Zhang, B.X. Zhang (IHEP)

Signal MC distribution (I)



MC & Data distribution comparison(II)



X. H. Mo, J. Y. Zhang, B.X. Zhang (IHEP)

From Zhang Bingxin (IHEP)

X. H. Mo, J. Y. Zhang, B.X. Zhang (IHEP)

$$B(\tau\tau) = \frac{\frac{N_{e\mu} - N_{bg}}{B\varepsilon} - \sigma_{Q+I}L}{N_{\psi(2S)}}$$

This term is estimated by continuum data at energy point （3.65 GeV）

- B fraction of τ+τ- events yielding the eμ topology. 0.6190（PDG）
- $N_{e\mu}$, N_{bg} , $N_{\psi(2S)}$ Events number of eu, background and ψ(2S)
- ε detection efficiency
- σ_{Q+I} *QED production* cross section 2.230nb
- L the accumulated luminosity ψ(2S)

Branching fraction calculation

Item/ Year	Nobs	Nbkg	Lum.	ε	$N_{\psi'}(10^6)$	$Br(10^{-3})$
2009	11535	835	161.63	0.2304	107.0	3.63±0.006
2012	31006	2821	506.92	0.2433	341.1	2.17±0.003 IT: $(2.72\pm0.05)\times10^{-3}$
Combine			$(2.40\pm0.006)X10^{-3}$			

(3.1 ± 0.4) X 10^{-3} (PDG)

Plans and Conclusions

- Very nice collaboration started
  - cross check and code debugging done
- to do list:
  - check the number of background evaluation
  - 2009 data set and consistency check
  - how to estimate interference between signal and background
  - Systematic uncertainties

Thanks for your attention

Background analysis (inclusive MC)

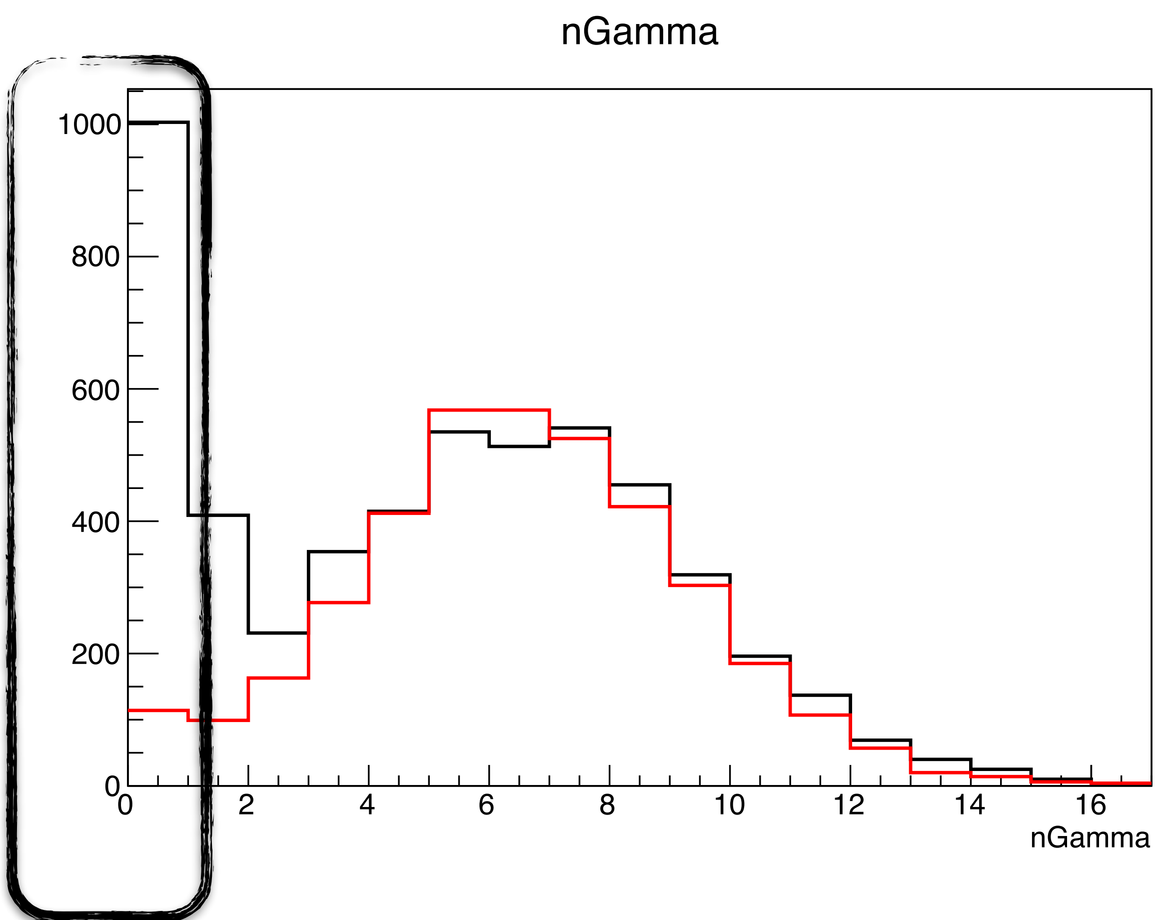
No.	decay chain	final states	iTopology	nEvt	nTot
0	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$	$e^+\bar{\nu}_\mu\bar{\nu}_\tau\nu_e\mu^-\nu_\tau$	0	8018	8018
1	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau$	$\bar{\nu}_e\mu^+\bar{\nu}_\tau e^-\nu_\mu\nu_\tau$	1	7939	15957
2	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to \pi^-\nu_\tau$	$e^+\bar{\nu}_\tau\pi^-\nu_e\nu_\tau$	2	735	16692
3	$\psi' \to \tau^+\tau^-, \tau^+ \to \pi^+\pi^0\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau$	$\bar{\nu}_e\bar{\nu}_\tau e^-\pi^0\nu_\tau\pi^+$	7	664	17356
4	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau\gamma_{FSR}$	$e^+\bar{\nu}_\mu\bar{\nu}_\tau\nu_e\mu^-\nu_\tau$	3	568	17924
5	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}$	$\bar{\nu}_e\mu^+\bar{\nu}_\tau e^-\nu_\mu\nu_\tau$	4	556	18480
6	$\psi' \to \tau^+\tau^-, \tau^+ \to \pi^+\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}$	$\bar{\nu}_e\bar{\nu}_\tau e^-\nu_\tau\pi^+$	12	55	18535
7	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau\gamma_{FSR}, \tau^- \to \pi^-\pi^0\nu_\tau$	$e^+\bar{\nu}_\tau\pi^-\pi^0\nu_e\nu_\tau$	13	40	18575
8	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to \pi^-\pi^-\pi^+\nu_\tau$	$e^+\bar{\nu}_\tau\pi^-\pi^-\nu_e\nu_\tau\pi^+$	16	25	18600
9	$\psi' \to \tau^+\tau^-, \tau^+ \to \pi^+\pi^+\pi^-\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau$	$\bar{\nu}_e\bar{\nu}_\tau\pi^-e^-\nu_\tau\pi^+\pi^+$	5	24	18624
10	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}\gamma_{FSR}$	$\bar{\nu}_e\mu^+\bar{\nu}_\tau e^-\nu_\mu\nu_\tau$	15	23	18647
11	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to K^{*-}\nu_\tau, K^{*-} \to \bar{K}^0\pi^-, \bar{K}^0 \to K_L$	$e^+\bar{\nu}_\tau\pi^-\nu_e K_L\nu_\tau$	14	23	18670
12	$\psi' \to \tau^+\tau^-, \tau^+ \to K^{*+}\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau, K^{*+} \to K^0\pi^+, K^0 \to K_L$	$\bar{\nu}_e\bar{\nu}_\tau e^-K_L\nu_\tau\pi^+$	17	23	18693
13	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau\gamma_{FSR}\gamma_{FSR}, \tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$	$e^+\bar{\nu}_\mu\bar{\nu}_\tau\nu_e\mu^-\nu_\tau$	9	19	18712
14	$\psi' \to \tau^+\tau^-\gamma_{FSR}, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$	$e^+\bar{\nu}_\mu\bar{\nu}_\tau\nu_e\mu^-\nu_\tau$	8	8	18720
15	$\psi' \to J/\psi\pi^+\pi^-, J/\psi \to e^+e^-\gamma_{FSR}$	$e^+\pi^-e^-\pi^+$	28	7	18727
16	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$	$\mu^+\bar{\nu}_\mu\bar{\nu}_\tau\mu^-\nu_\mu\nu_\tau$	11	4	18731
17	$\psi' \to \tau^+\tau^-, \tau^+ \to \pi^+\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}\gamma_{FSR}$	$\bar{\nu}_e\bar{\nu}_\tau e^-\nu_\tau\pi^+$	35	4	18735
18	$\psi' \to \tau^+\tau^-, \tau^+ \to K^{*+}\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}, K^{*+} \to K^0\pi^+, K^0 \to K_L$	$\bar{\nu}_e\bar{\nu}_\tau e^-K_L\nu_\tau\pi^+$	21	3	18738
19	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to K^{*-}\nu_\tau, K^{*-} \to \bar{K}^0\pi^-, \bar{K}^0 \to K_S, K_S \to \pi^+\pi^-$	$e^+\bar{\nu}_\tau\pi^-\pi^-\nu_e\nu_\tau\pi^+$	33	3	18741
20	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau, \tau^- \to K^-\nu_\tau$	$e^+\bar{\nu}_\tau K^-\nu_e\nu_\tau$	24	3	18744
21	$\psi' \to \tau^+\tau^-\gamma_{FSR}, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to e^-\bar{\nu}_e\nu_\tau$	$\bar{\nu}_e\mu^+\bar{\nu}_\tau e^-\nu_\mu\nu_\tau$	44	3	18747
22	$\psi' \to \tau^+\tau^-, \tau^+ \to \pi^+\pi^0\bar{\nu}_\tau, \tau^- \to \pi^-\pi^0\nu_\tau$	$\bar{\nu}_\tau\pi^-\pi^0\pi^0\nu_\tau\pi^+$	29	2	18749
23	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau\gamma_{FSR}, \tau^- \to \pi^-\pi^-\pi^+\nu_\tau$	$e^+\bar{\nu}_\tau\pi^-\pi^-\nu_e\nu_\tau\pi^+$	18	2	18751
24	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau\gamma_{FSR}\gamma_{FSR}, \tau^- \to \pi^0\pi^0\pi^-\nu_\tau$	$e^+\bar{\nu}_\tau\pi^-\pi^0\pi^0\nu_e\nu_\tau$	25	2	18753
25	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau, \tau^- \to \pi^-\pi^0\nu_\tau$	$\mu^+\bar{\nu}_\tau\pi^-\pi^0\nu_\mu\nu_\tau$	37	2	18755
26	$\psi' \to J/\psi\pi^+\pi^-, J/\psi \to e^+e^-\gamma_{FSR}\gamma_{FSR}$	$e^+\pi^-e^-\pi^+$	6	2	18757
27	$\psi' \to \tau^+\tau^-, \tau^+ \to \mu^+\nu_\mu\bar{\nu}_\tau\gamma_{FSR}, \tau^- \to e^-\bar{\nu}_e\nu_\tau\gamma_{FSR}\gamma_{FSR}$	$\bar{\nu}_e\mu^+\bar{\nu}_\tau e^-\nu_\mu\nu_\tau$	27	1	18758
28	$\psi' \to \tau^+\tau^-, \tau^+ \to e^+\nu_e\bar{\nu}_\tau\gamma_{FSR}, \tau^- \to K^{*-}\nu_\tau, K^{*-} \to \bar{K}^0\pi^-, \bar{K}^0 \to K_L$	$e^+\bar{\nu}_\tau\pi^-\nu_e K_L\nu_\tau$	10	1	18759
29	$\psi' \to \pi^0\pi^0\omega, \omega \to \pi^-\pi^+\pi^0$	$\pi^-\pi^0\pi^0\pi^0\pi^+$	22	1	18760

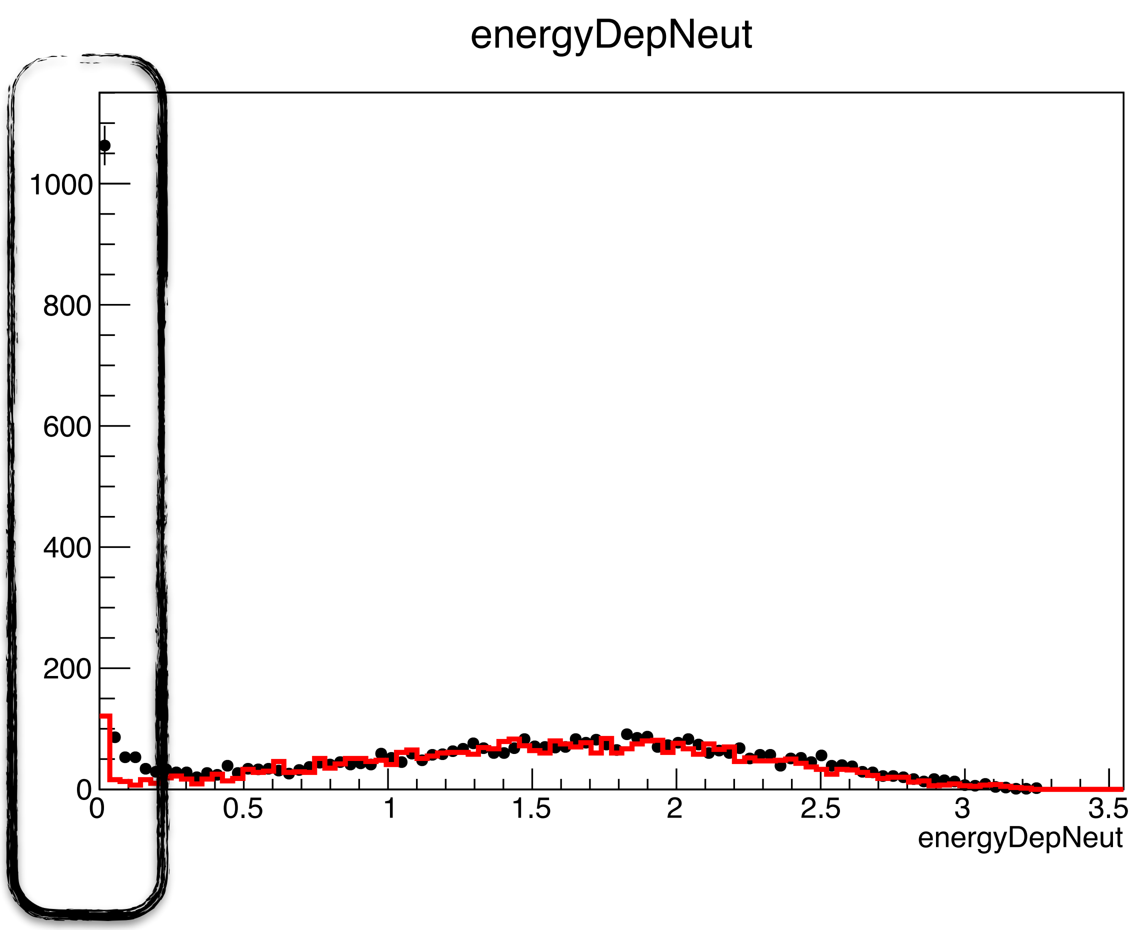
Mainly background come from eπ and eK events with same intermediate state ττ and ππJ/ψ (J/ψ to electron pairs)

Check the difference between data and inclusive MC

RUN 25338

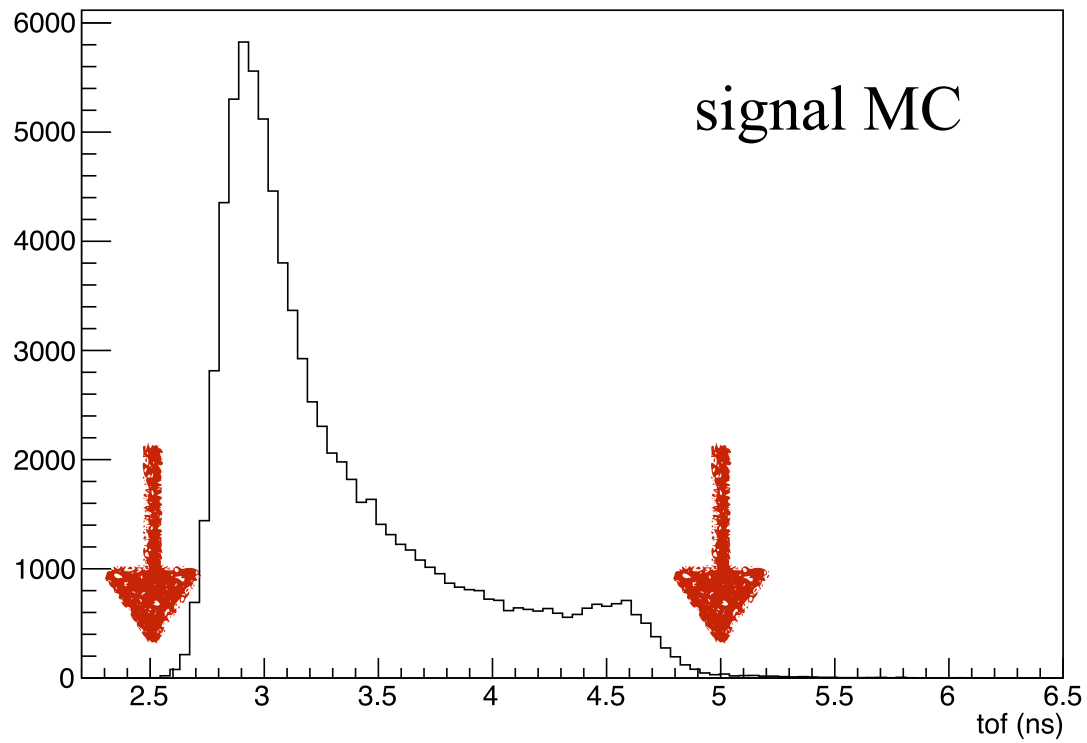
- Comparison between data and inclusive MC distributions





Our signal region!!!

Additional cuts II



- 2.5<tof < 5 (ns)

Missing mass and missing energy:

- *4mom_miss = 4mom_ψ2s - 4mom_ll*
- *U = E_miss = 4mom_miss.e()-|4mom_miss .p()|*

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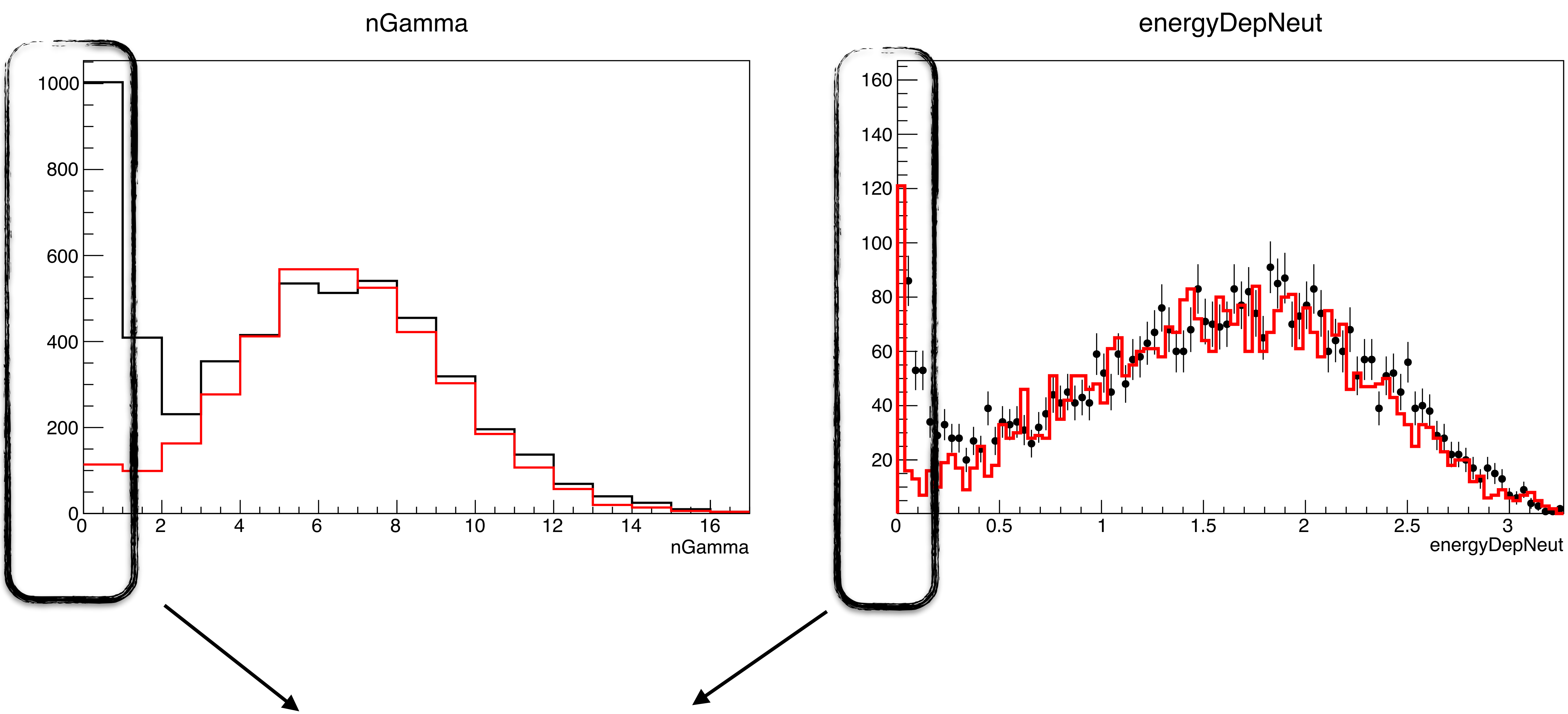
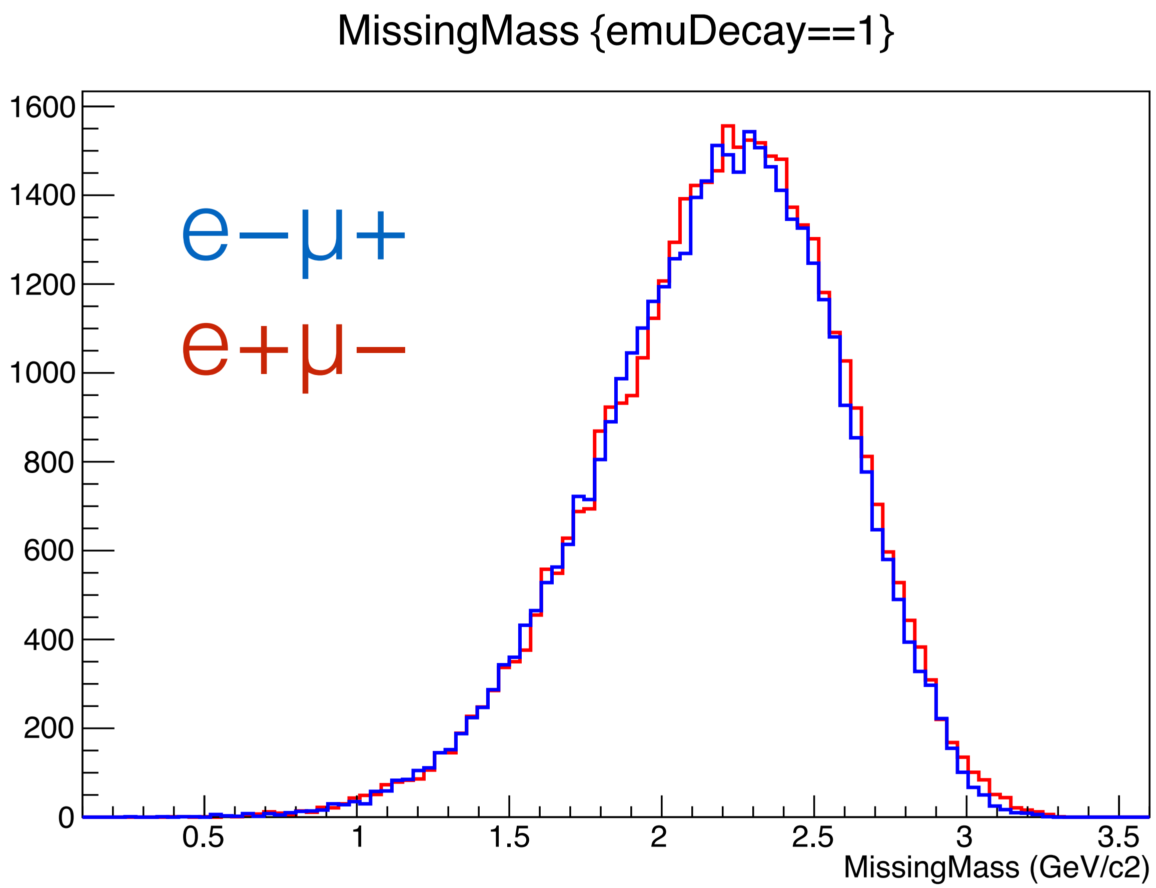


Our signal region!!!

Inclusive MC sample is not reliable

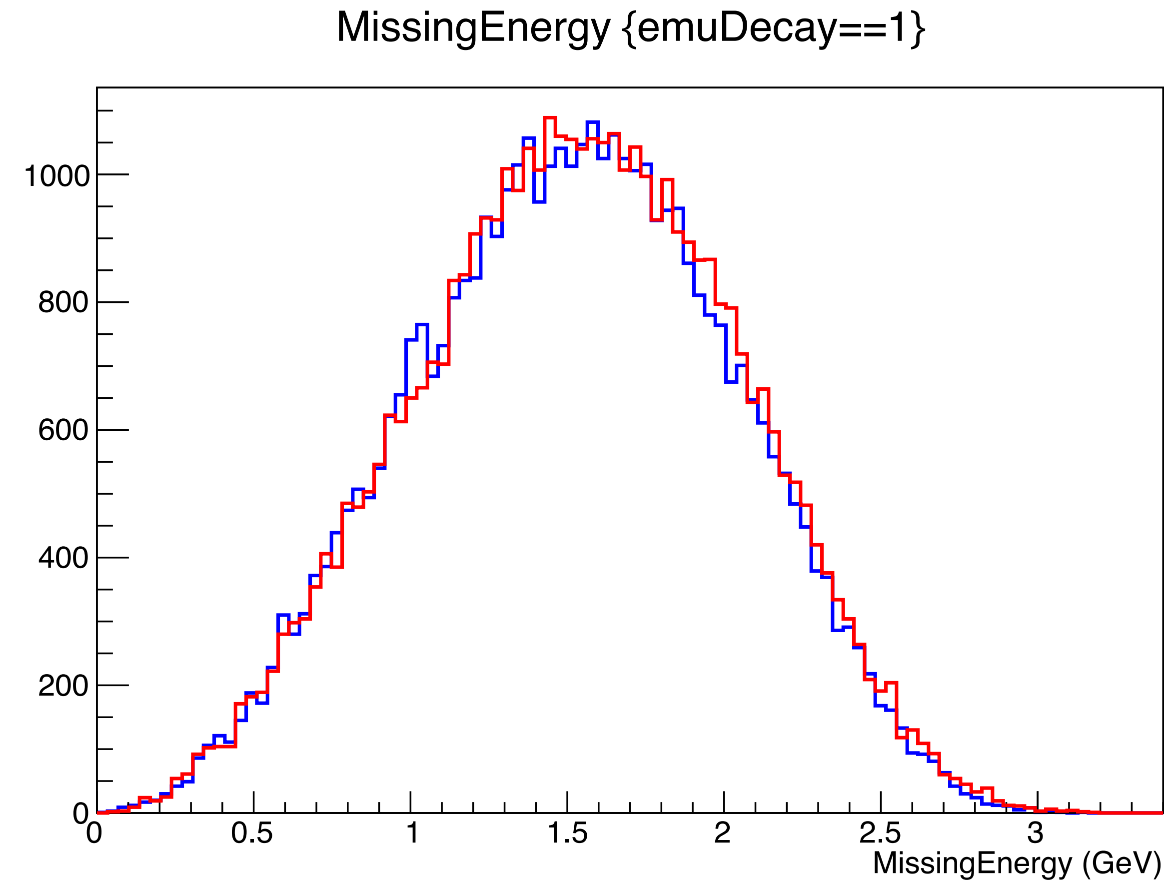
Signal MC: distributions III



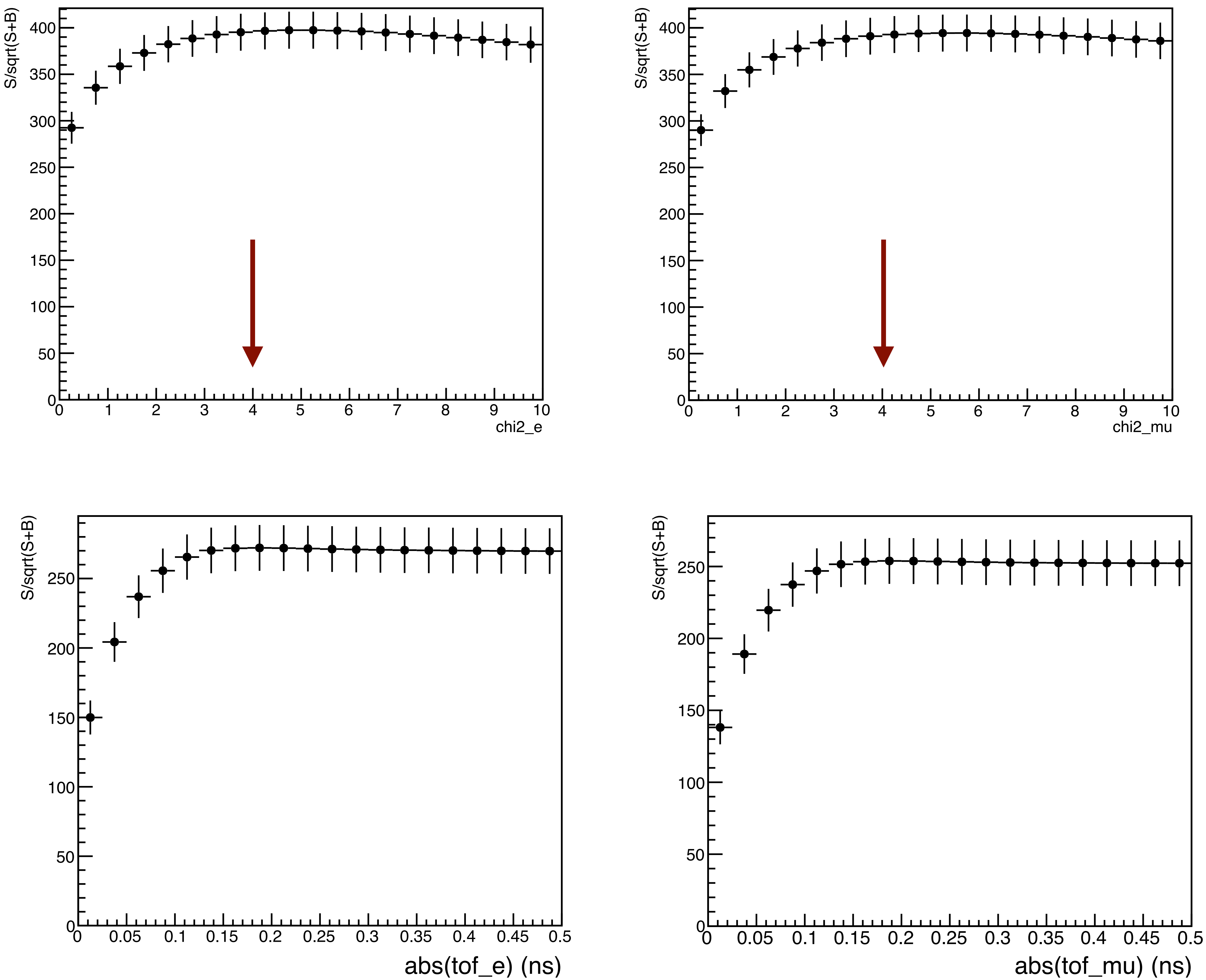
Missing energy and missing mass:

- *4mom_miss = 4mom_ψ2s - 4mom_ll*
- *U = E_miss = 4mom_miss.e()-|4mom_miss .p()|*

Distributions after cuts and PID selection



Cuts Optimization



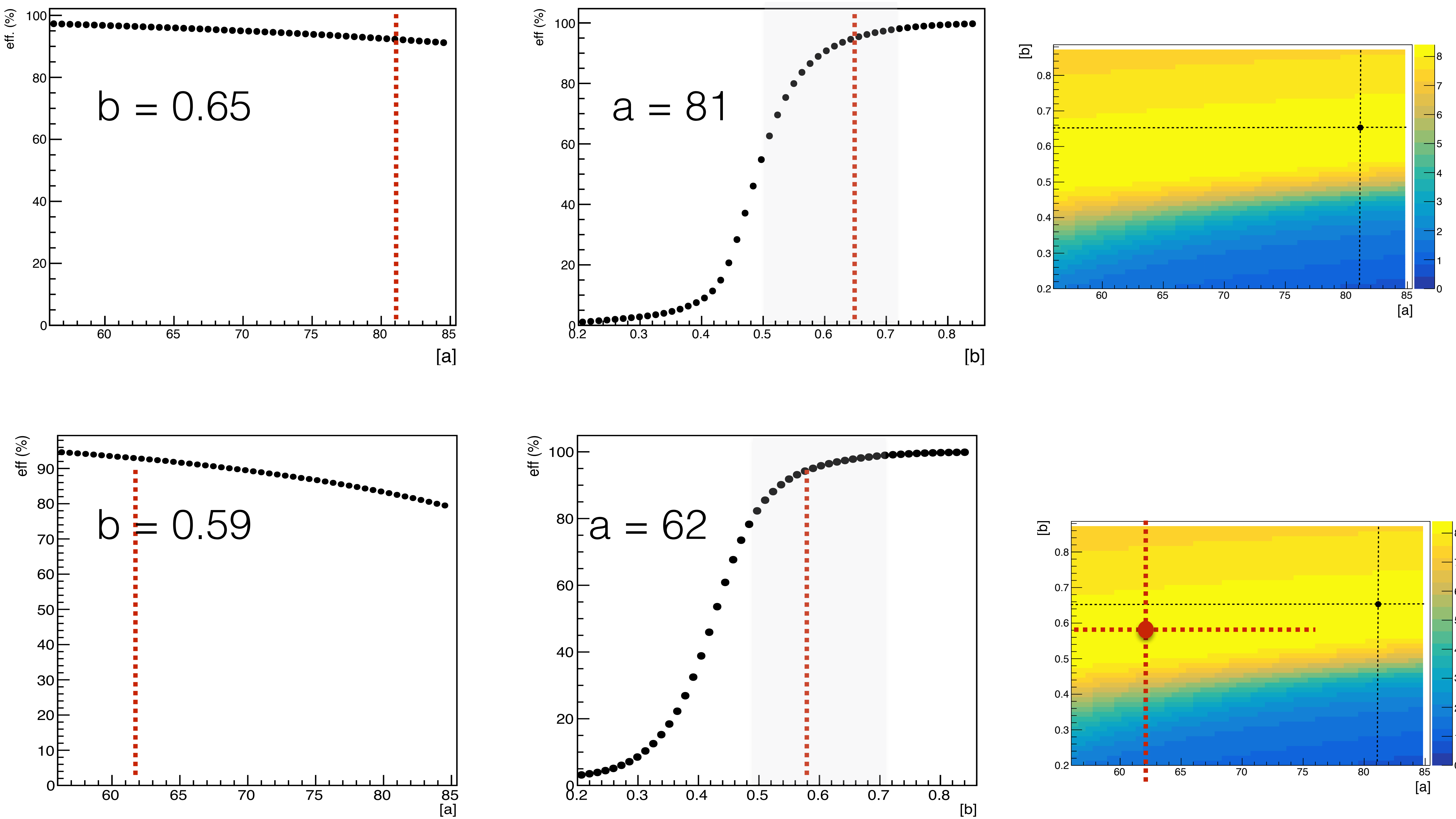
Background studies

Several background taken into account:

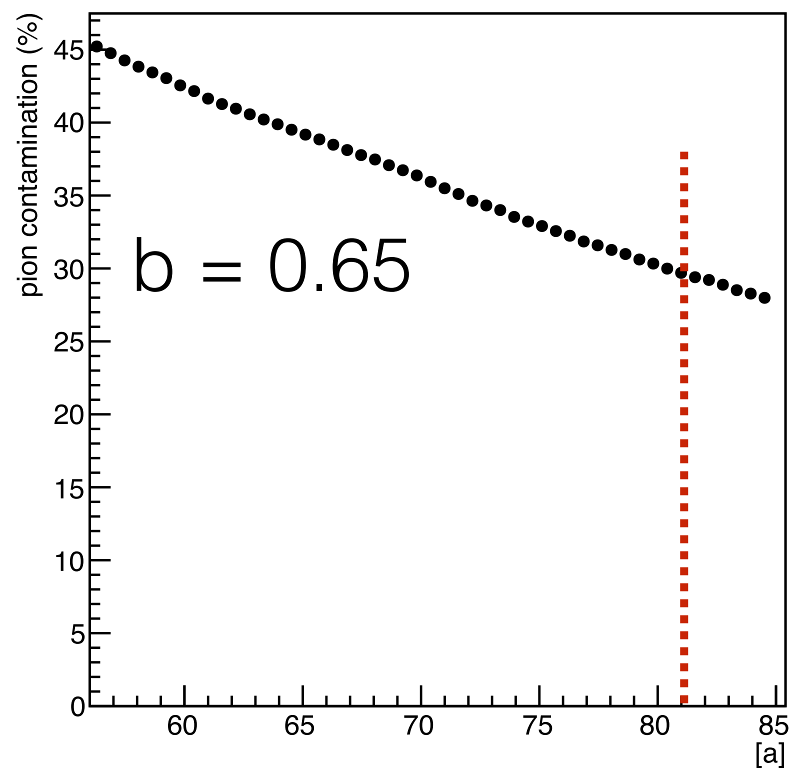
CUTS	$\psi(2S)\rightarrow\pi^{+}e^{-}3\nu$	$\psi(2S)\rightarrow\pi^{-}e^{+}3\nu$	$\psi(2S)\rightarrow\pi^{+}\mu^{-}3\nu$	$\psi(2S)\rightarrow\pi^{-}\mu^{+}3\nu$	$\psi(2S)\rightarrow\pi^{-}\pi^{+}3\nu$	SIGNAL $\psi(2S)\rightarrow e\mu 4\nu$
Tot number	40000	40000	40000	40000	100000	240000
good trk = 2	32368	32531	32744	32750	82762	195993
EMCch > 25 MeV	32336	32499	32703	32712	82647	195847
Ngamma = 0	23505	22618	25732	24870	54505	167455
eμDecay	1005	943	1	1	0	84176
μμDecay	1	0	1119	1074	38	2
eeDecay	4	2	0	0	0	16

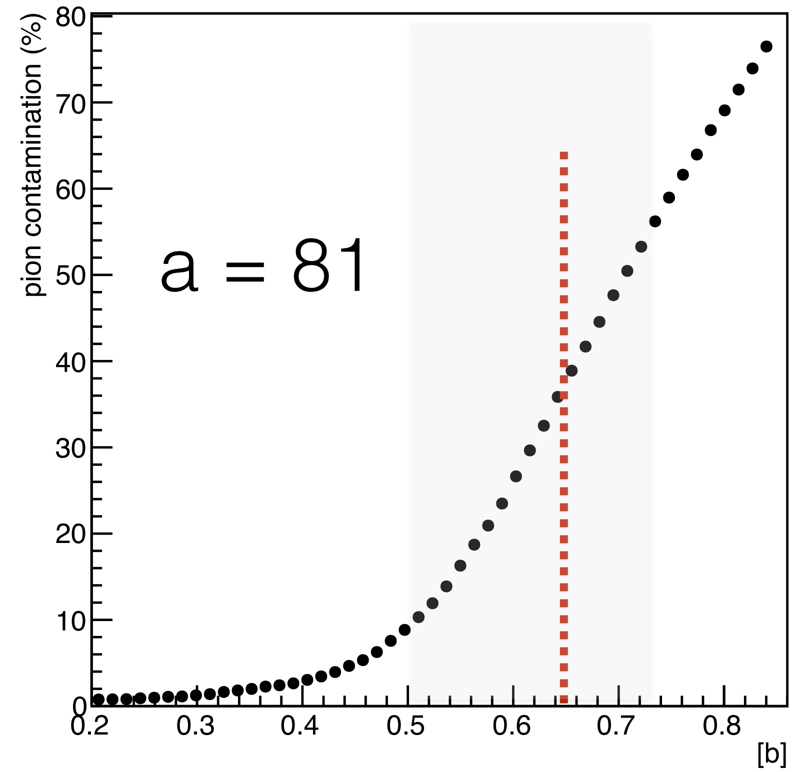
$\psi(2S)\rightarrow\pi e 3\nu$ non-negligile contribution

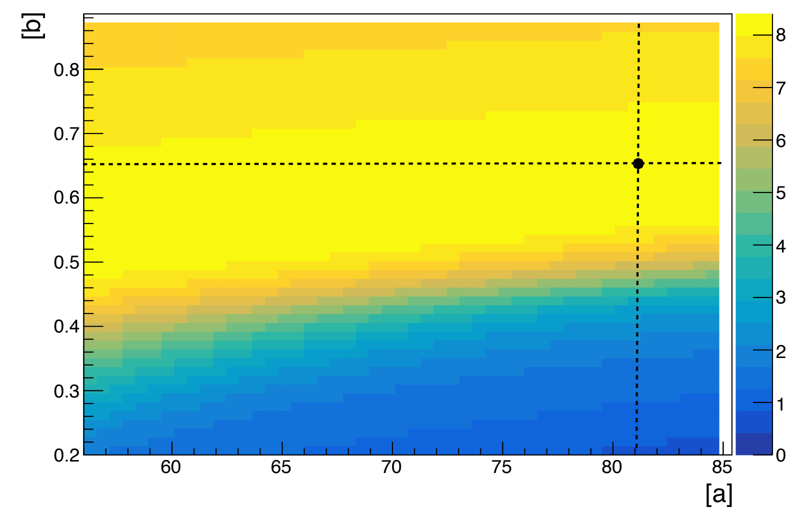
Signal Efficiency

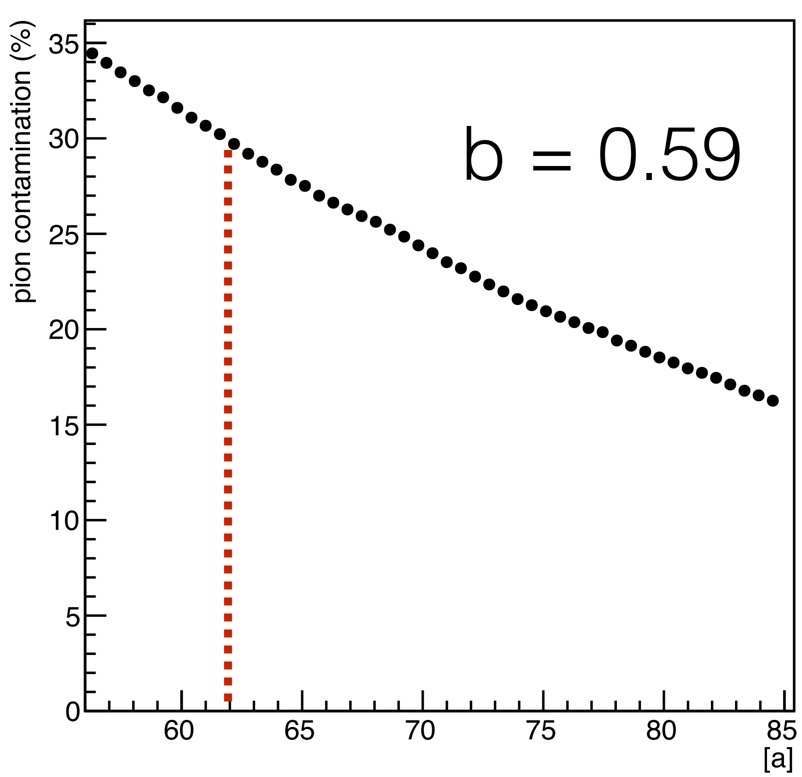


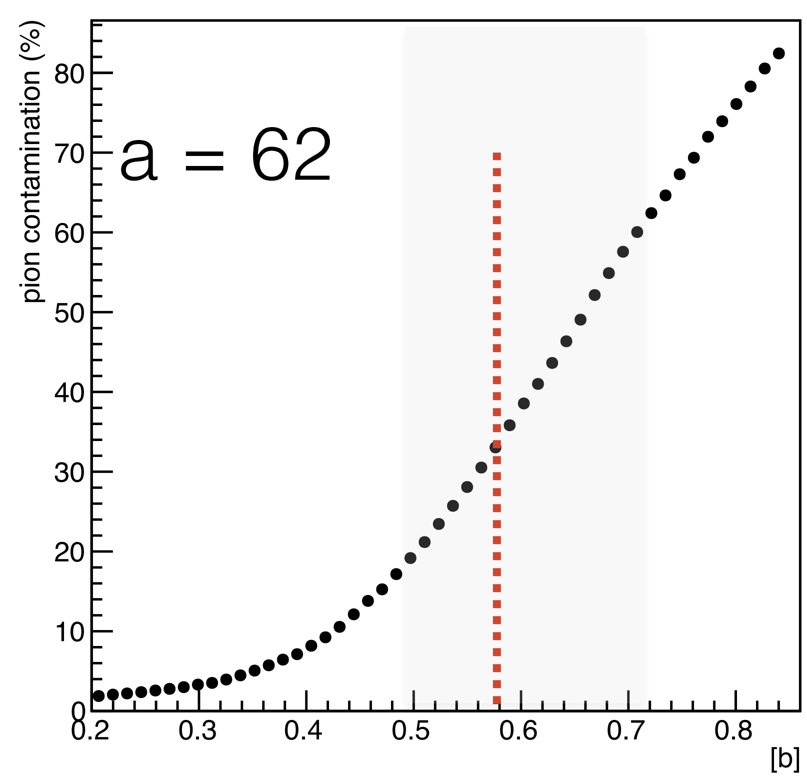
Pions contamination

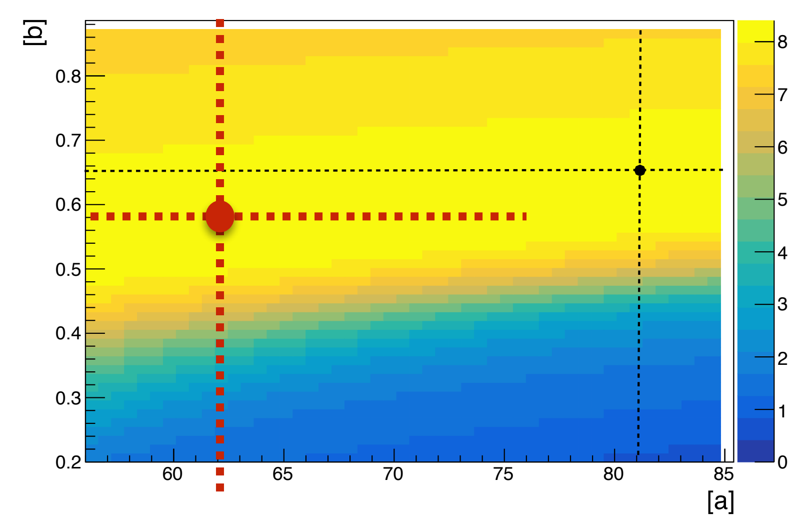












LFU violation at BESIII?

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- Systematic error mostly due to lack of continuum data ***(10%)***

6 times lower

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- **550 M ψ (2S)**
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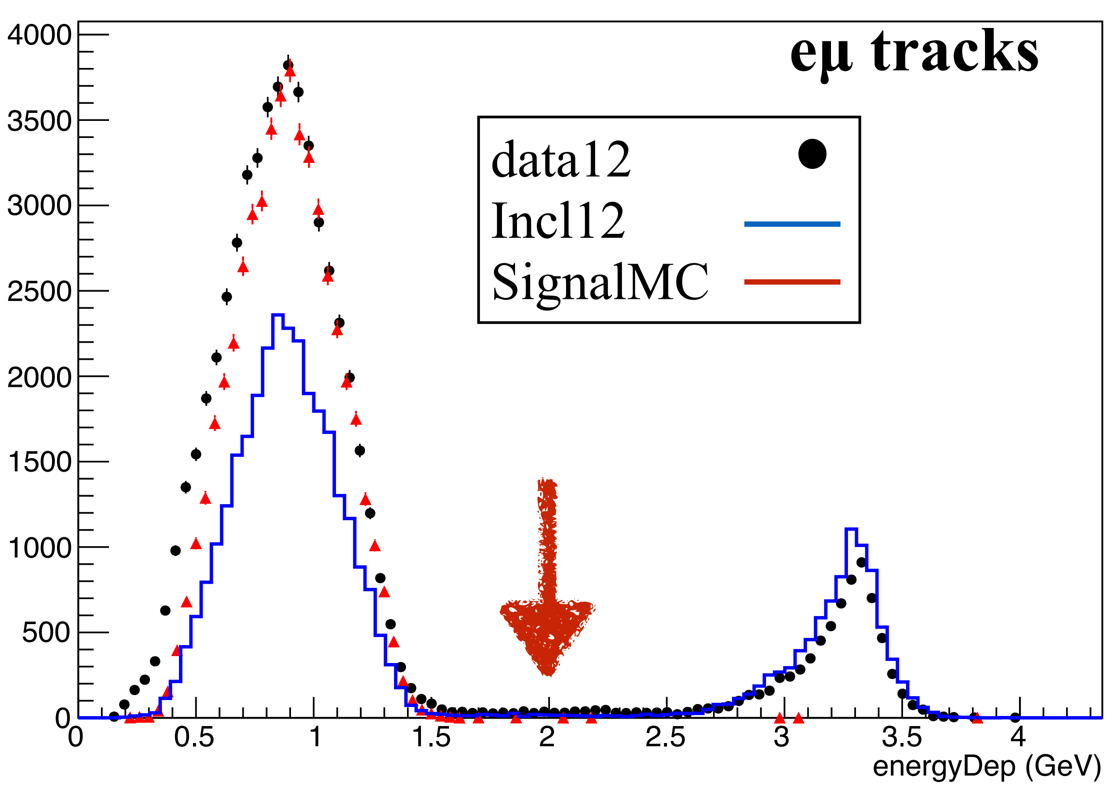
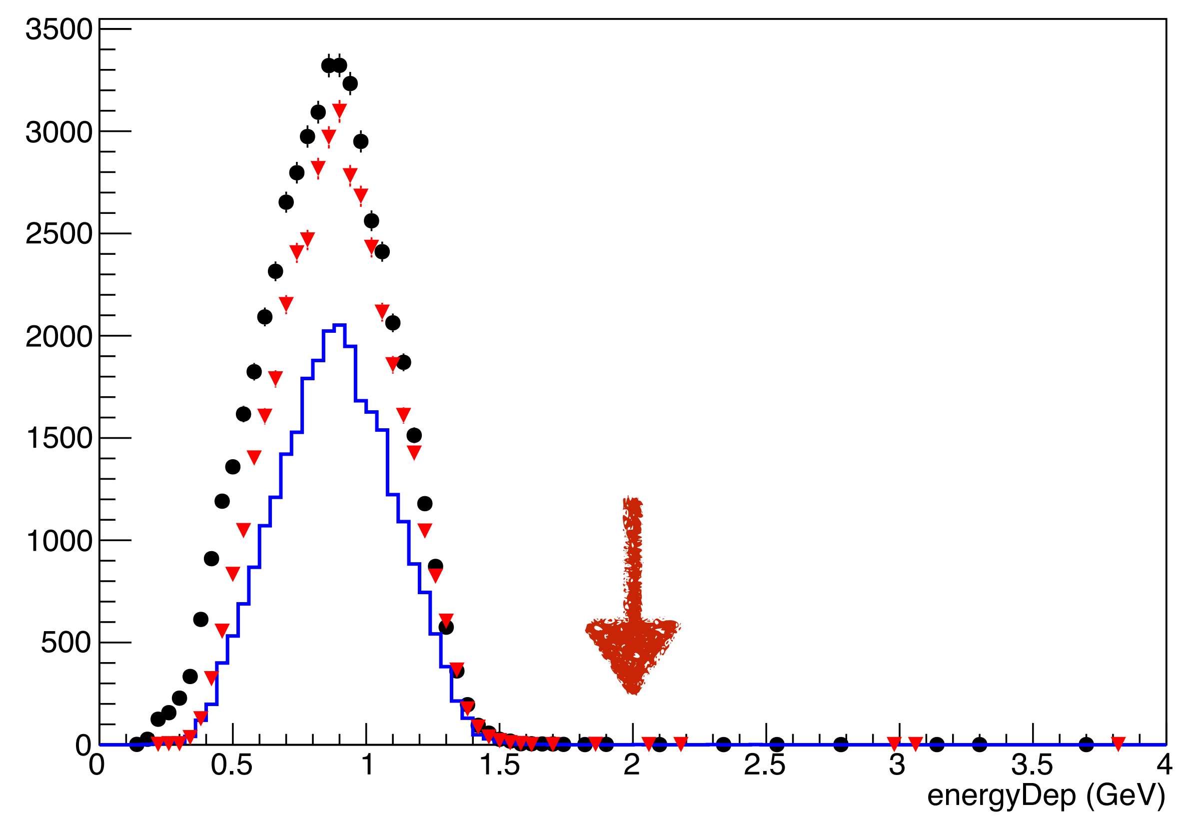
- **Looking also to other τ decay modes**
- **ψ (2S) scan -> systematic error more under control**
- **can we achieve ≈ 1 % , testing LFU violation ?**

Additional cuts I

*signal arbitrary scale



NgoodTracks ==2

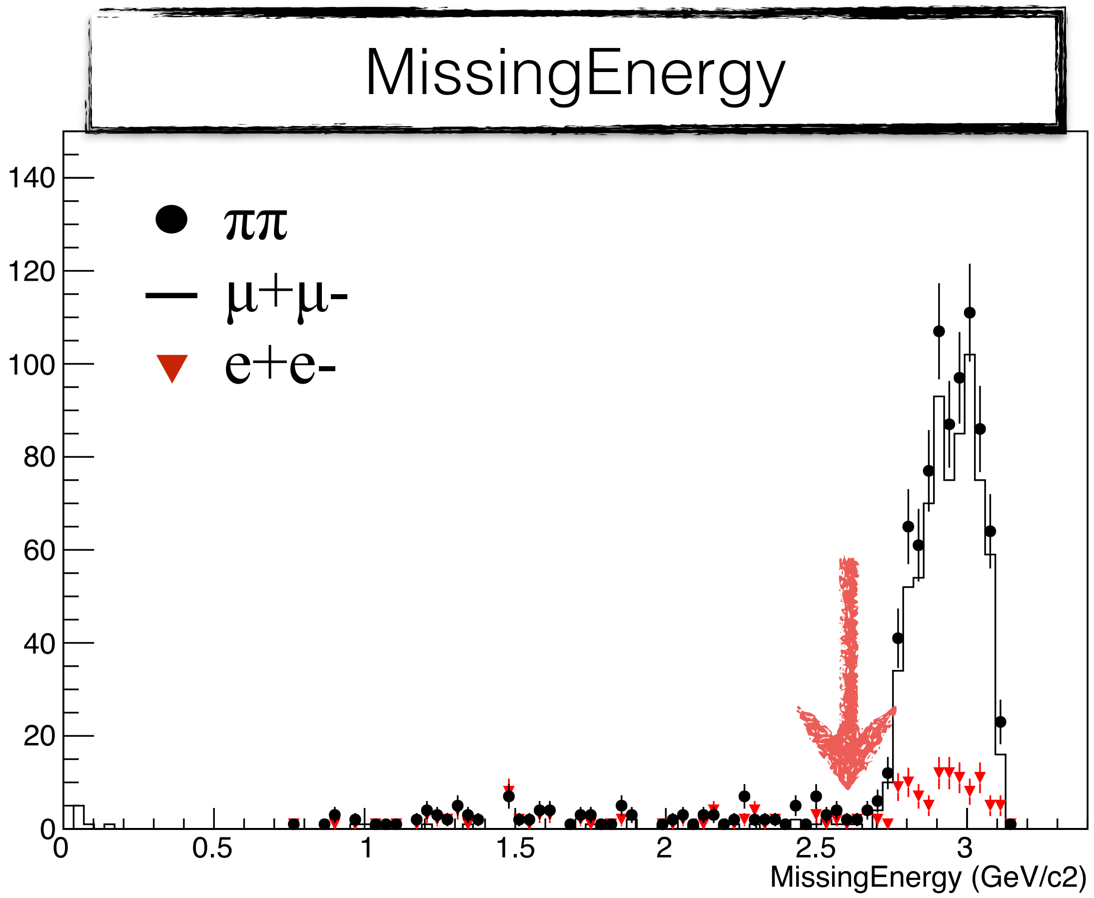


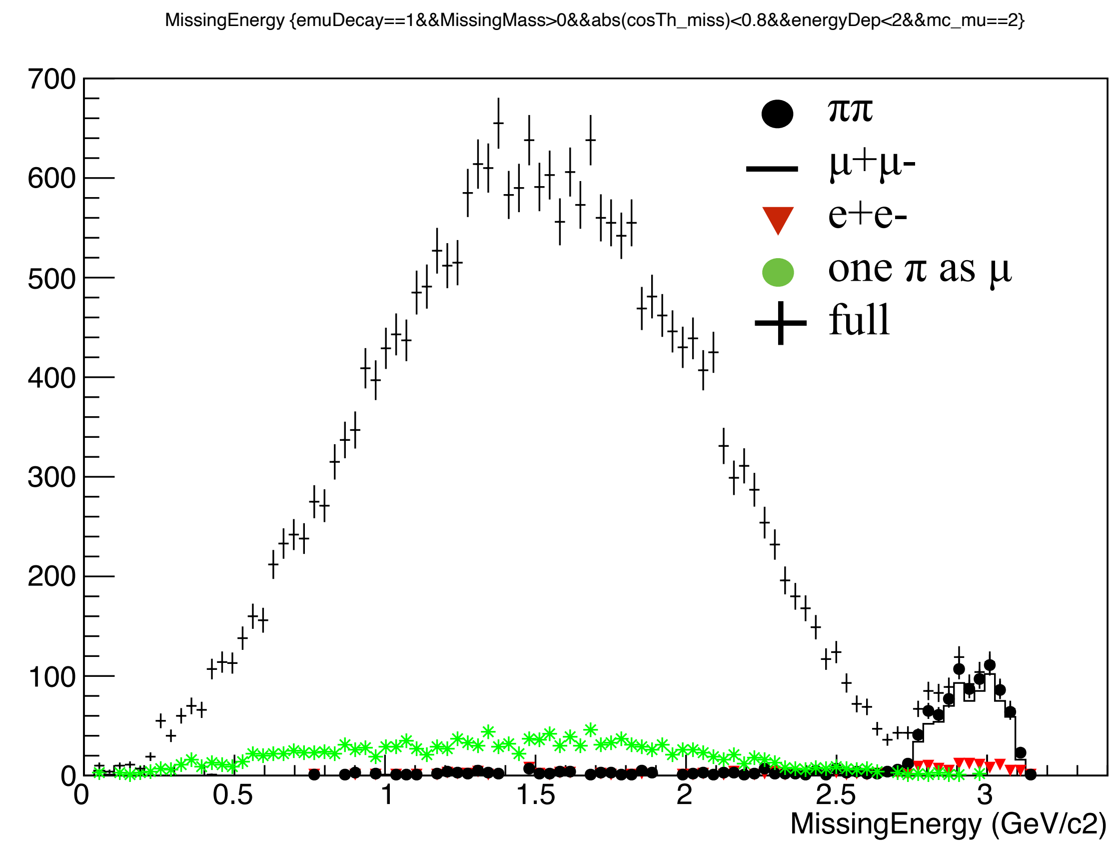
NTracks ==2

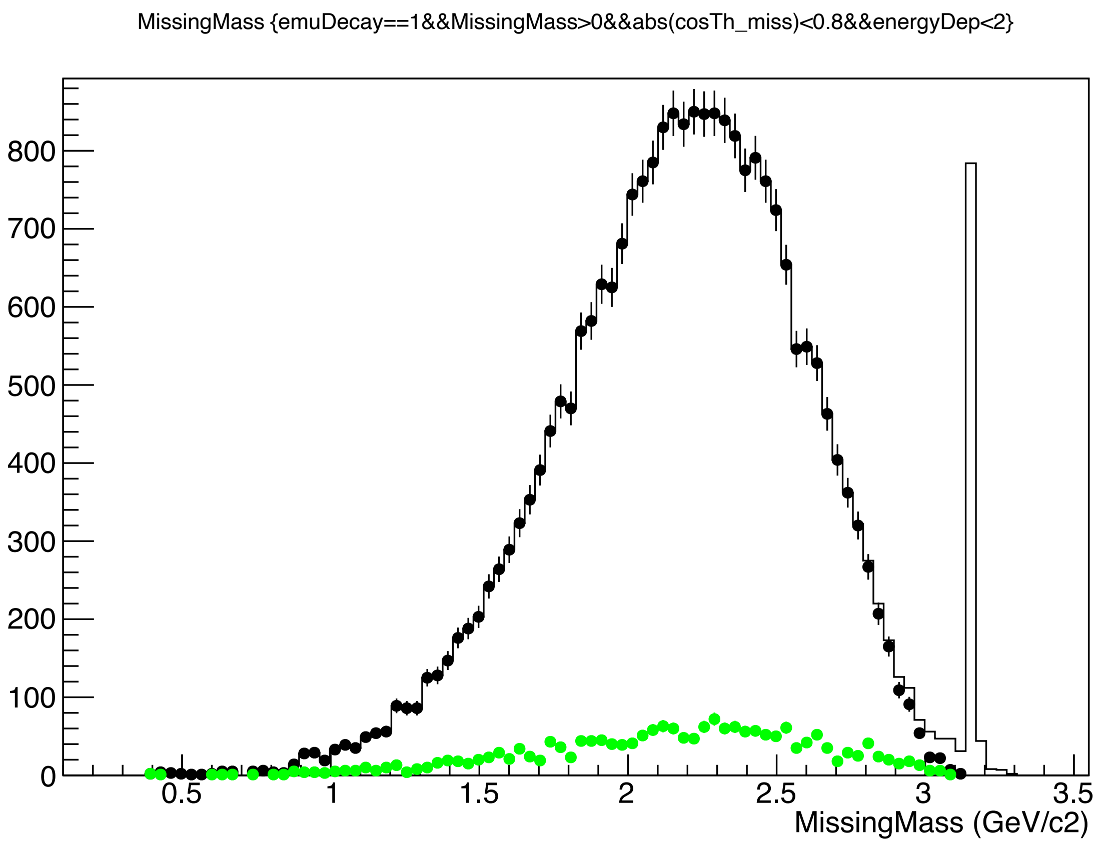
Full data-2012 and inclusive-2012 MC sample analyzed

- evident discrepancy between the two samples in the signal region
- the peak above 3 GeV (due to Psi2S decay to pipiJpsi) is removed after selecting events with charged tracks equal to 2

Additional cuts II

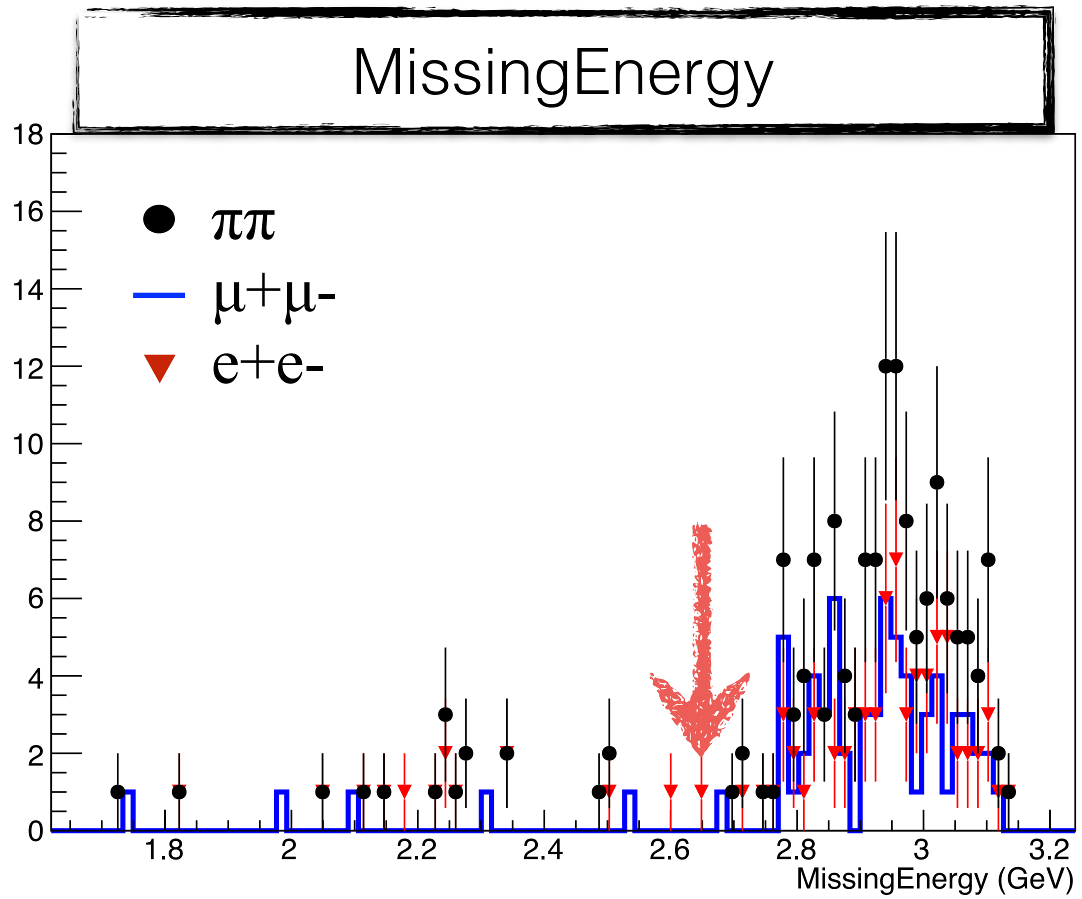


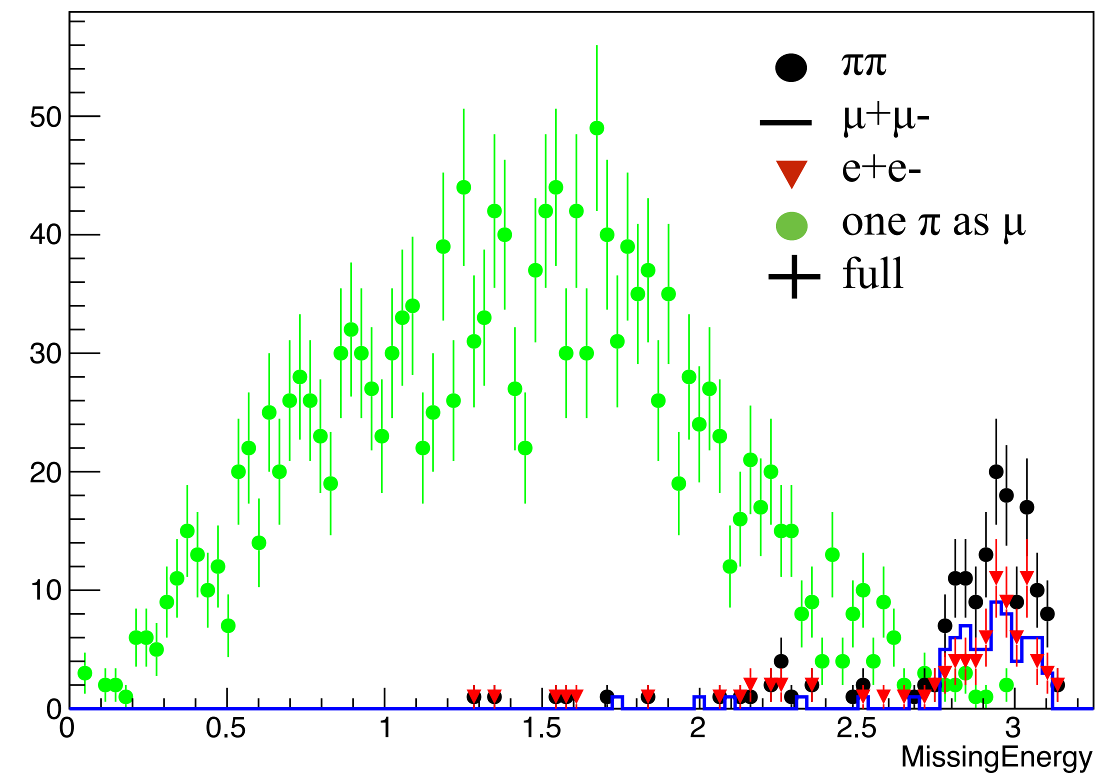


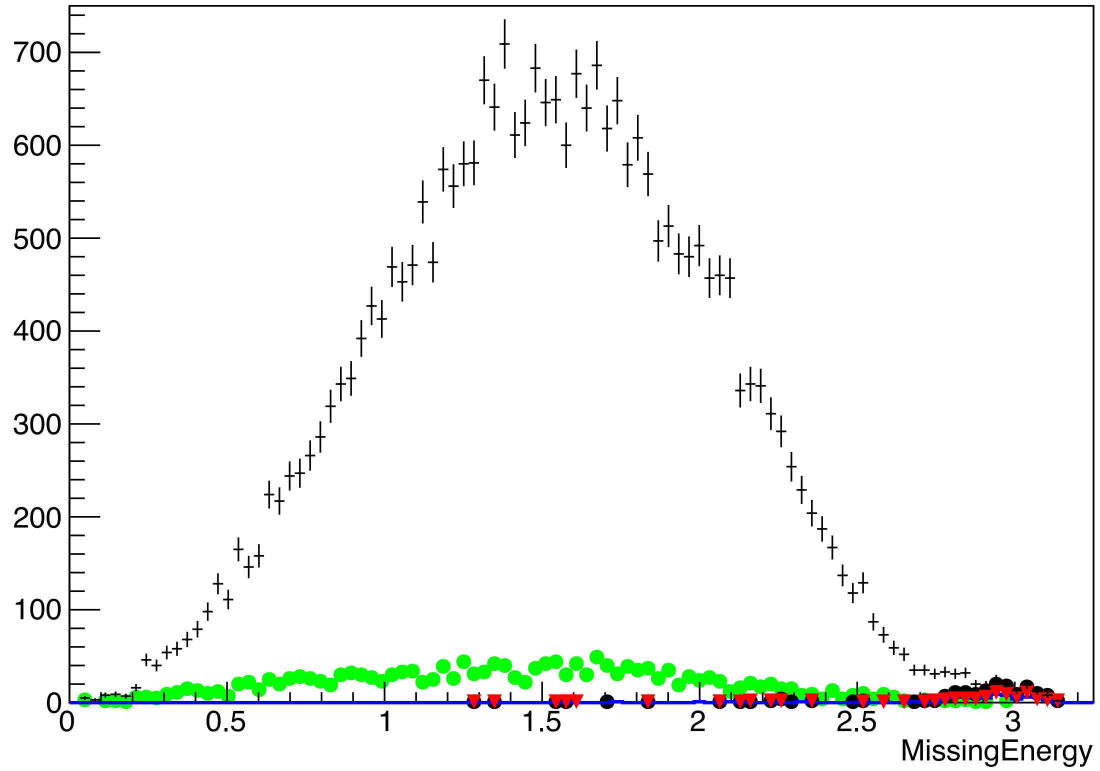


— no cut in MissingEnergy
● MissingEnergy<2.65 GeV
● pion contamination

Additional cuts II

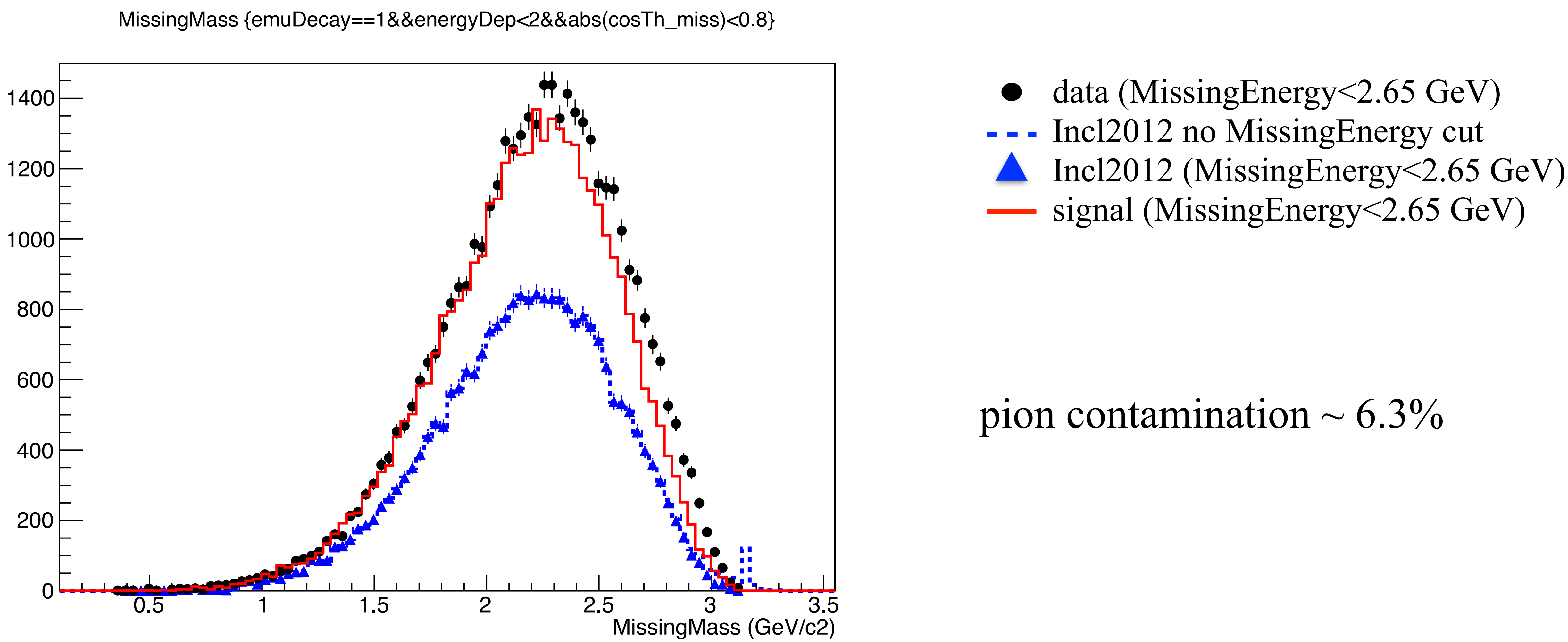






MissingEnergy < 2.65 GeV

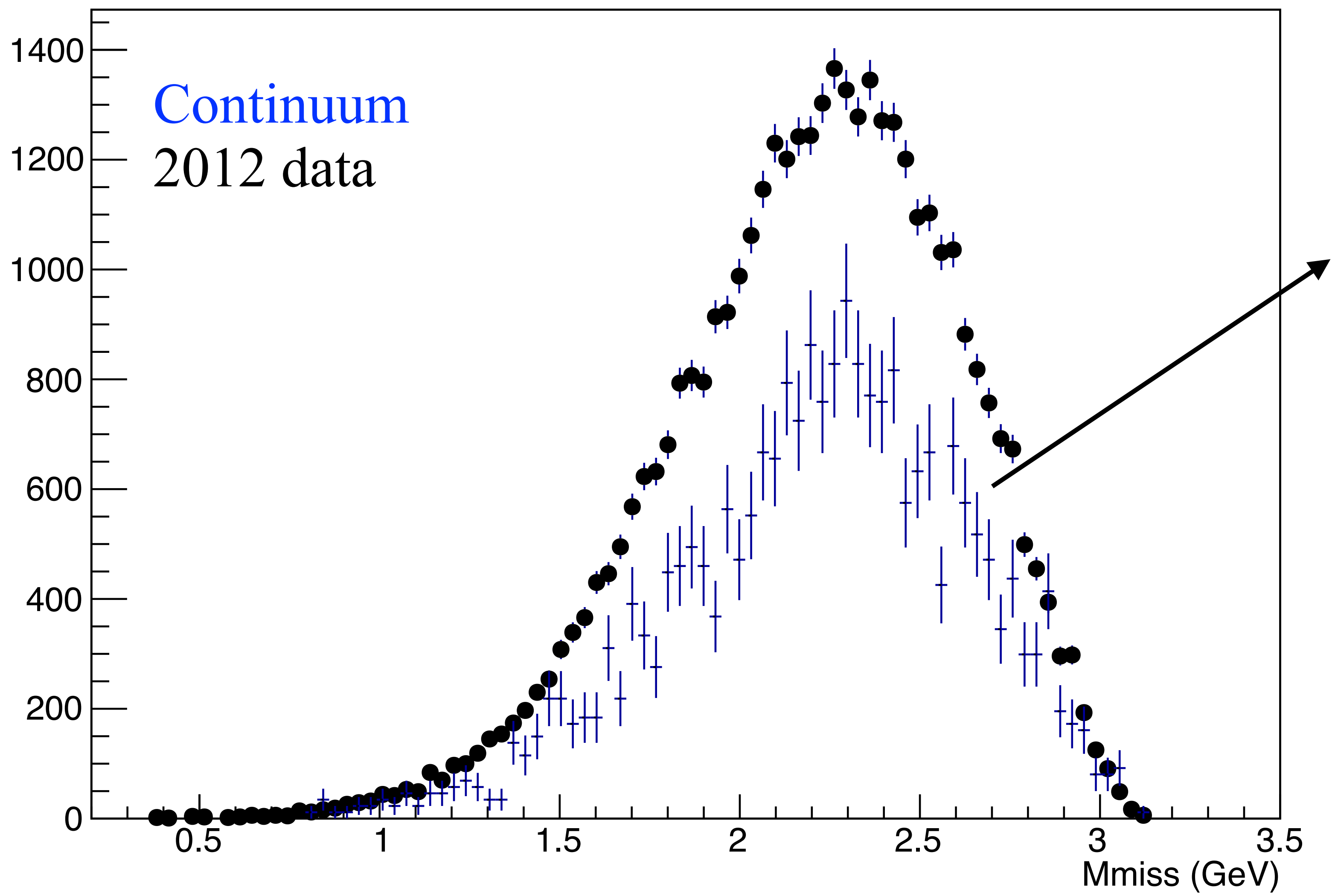
Additional cuts II



pion contamination ~ 6.3%

Continuum

@ 3.650 GeV (L ~ 44.5 pb^{-1})



Normalized