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

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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

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*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

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

$V(nS)$	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

Depending of the model, LFU violation for ψ(2S) at 95% C.L. is predicted to be:

$$R^{\psi(2S)}_{\tau/\ell} = 0.389 - 0.390.$$

LFU violation at BESIII?

Rinaldo's suggestion

BR7's talk in Perugia

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 ?**

Perugia 2018 April 16th 6

Analysis: event and track selection

Study of $\psi(2S)\rightarrow\tau\tau\rightarrow e\mu 4\nu$ decay

Charged tracks

- 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>0.2 GeV/c
- nCharged=2

Neutral candidates

- EMC time cut: $0<t_{TDC}<14(/50ns)$
- E_γ >0.025 GeV for the barrel (**$|\cos(\theta)|<0.8$**), and E_γ>0.050 GeV for the endcap (**$0.86<|\cos(\theta)|<0.92$**)
- Isolated γ: opening angle between photon and its nearest charged tracks $\theta_{\gamma\text{-}tr}$> 20°
- nGamma = 0
- Enel < 0.2 GeV

- Release 664p03
- 200000 events simulated: $\psi(2S)\rightarrow\tau\tau\rightarrow e^{\mp}\mu^{\pm}4\nu$
- 2009 MC inclusive $\psi(2S)$ sample
- 2009 $\psi(2S)$ data sample

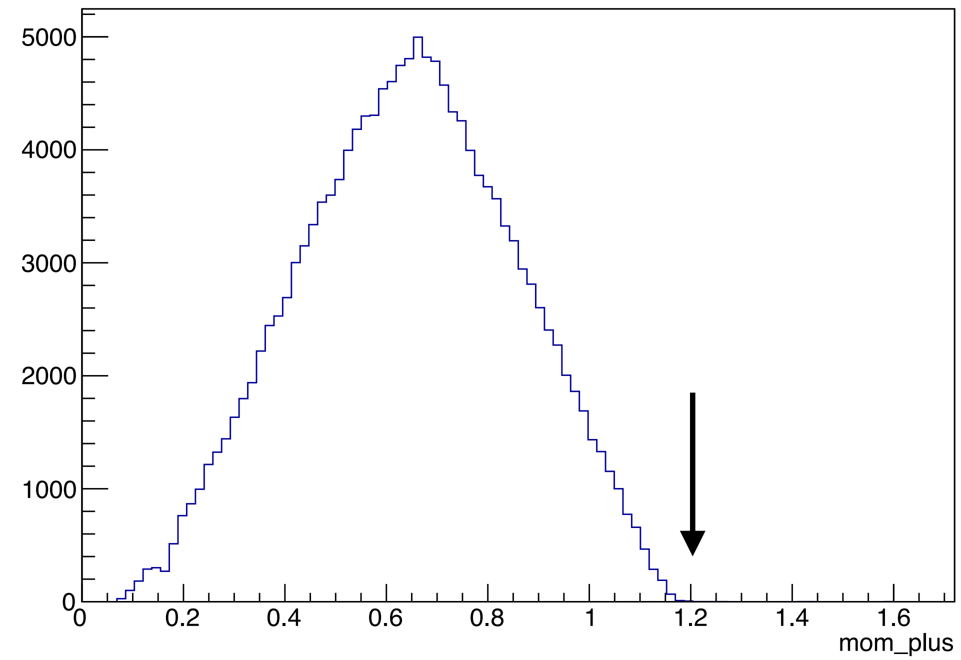
```
Decay psi(2S)
  1.0000    tau+  tau-              PHOTOS VLL;
Enddecay

Decay tau+
   1.0000 e+ nu_e anti-nu_tau      PHOTOS TAULNUNU;
Enddecay


Decay tau-
   1.0000 mu- anti-nu_mu nu_tau      PHOTOS TAULNUNU;
Enddecay


End
```

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

Decay tau+
   1.0000 mu+ nu_mu anti-nu_tau      PHOTOS TAULNUNU;
Enddecay


Decay tau-
   1.0000 e- anti-nu_e nu_tau      PHOTOS TAULNUNU;
Enddecay


End
```

Some distributions I

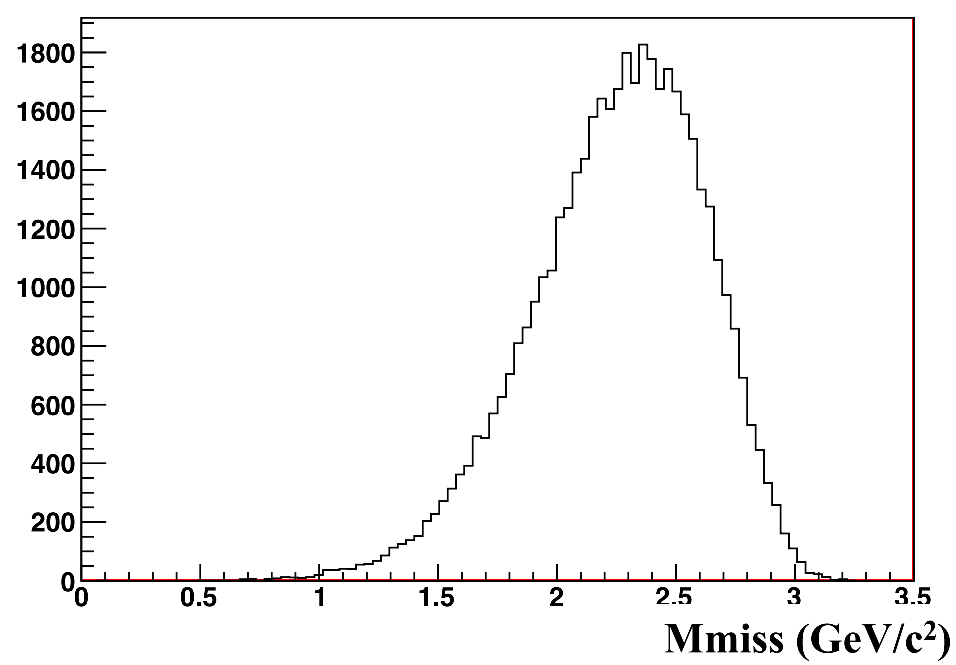
$\psi(2S) \rightarrow \tau\tau \rightarrow e\mu 4\nu$ signal

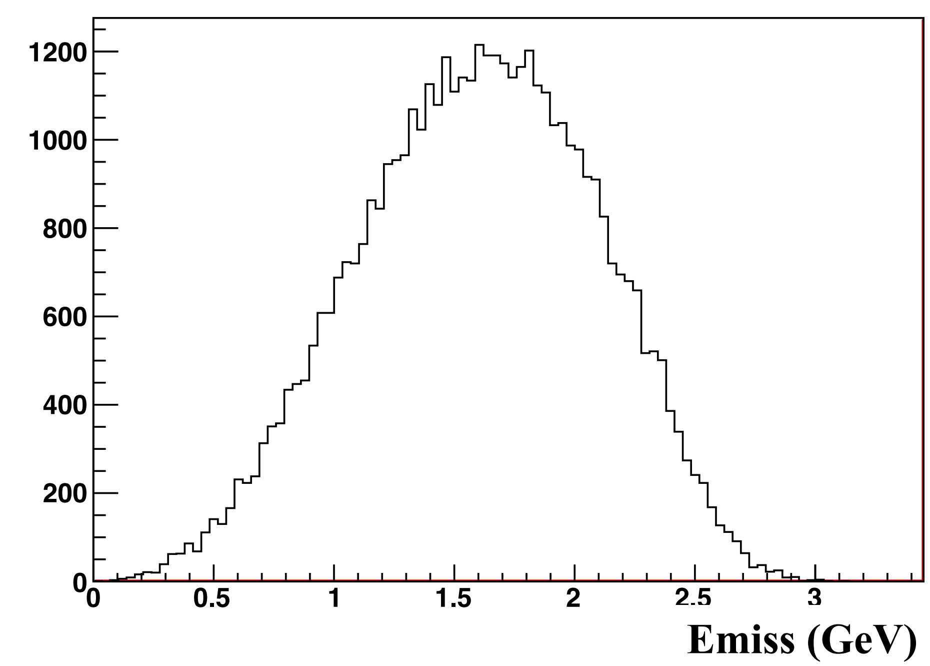
Momentum of charged tracks



Missing energy and missing mass:

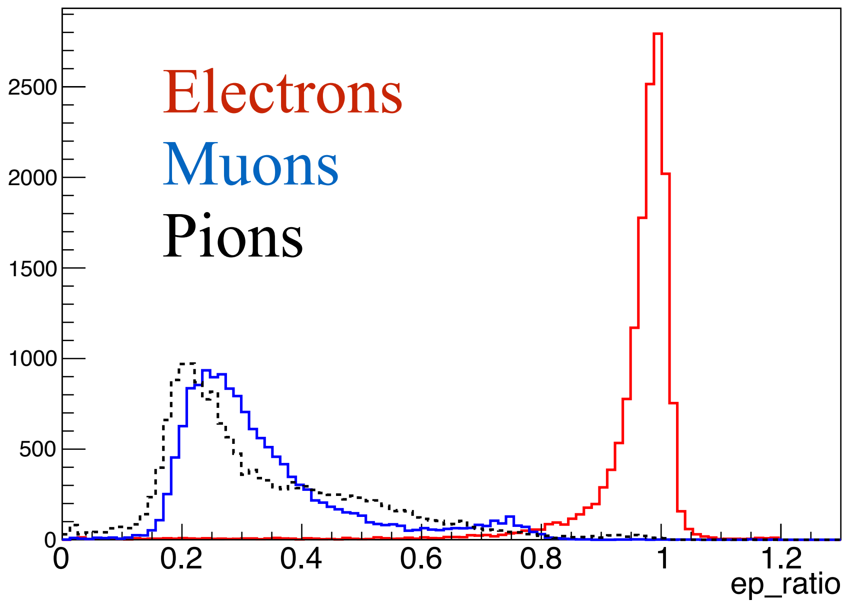
- *4mom_miss = 4mom_ψ2s - 4mom_ll*
- *U = E_miss = 4mom_miss.e()- |4mom_miss .p()|*



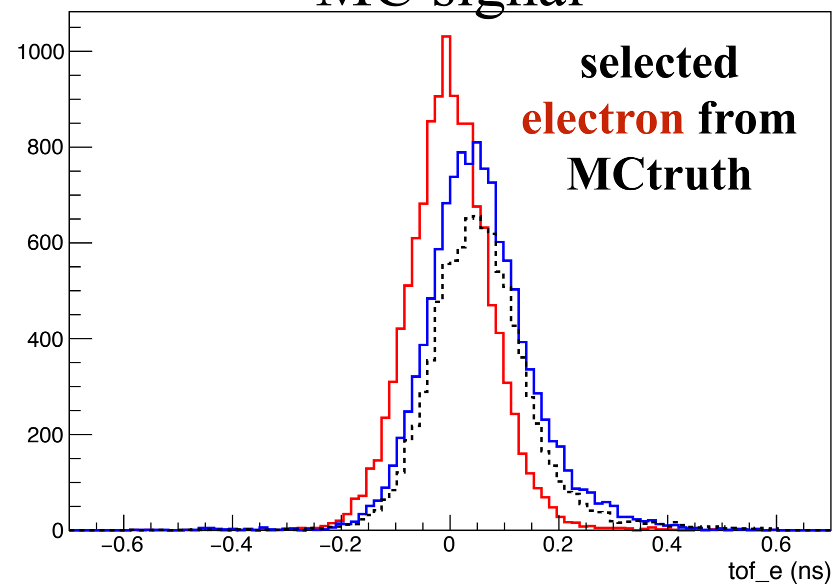


PID studies

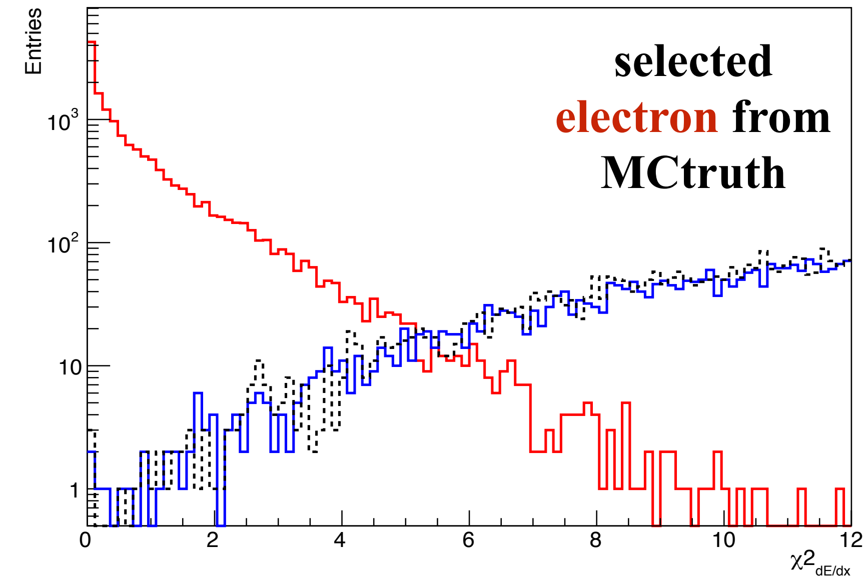
E/p ratio from MC signal



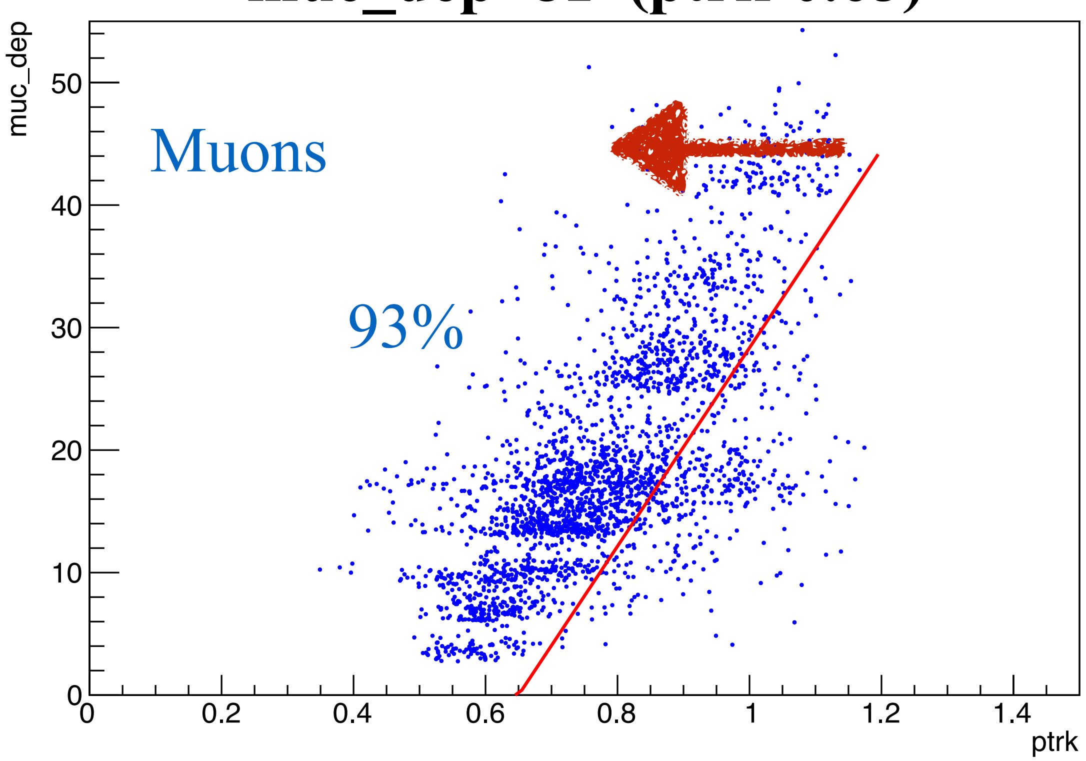
(exp-tof - tof_calc) from MC signal

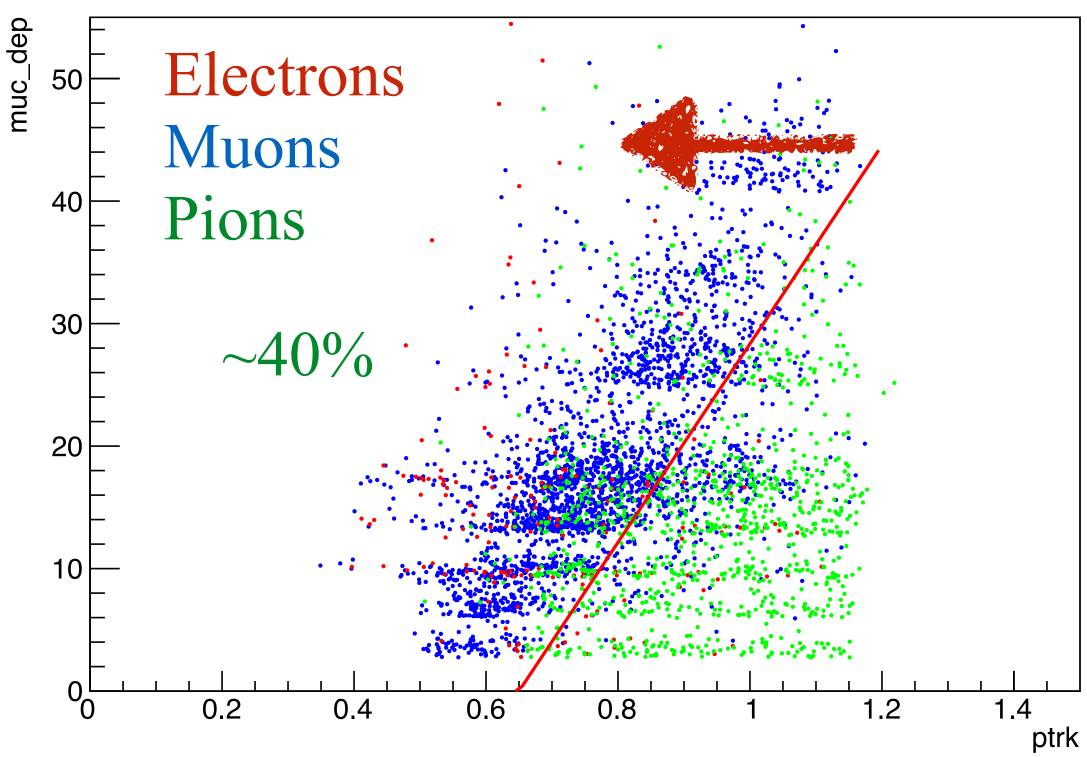


chi2-dEdx from MC signal



muc_dep>81*(ptrk-0.65)





Some numbers

Electron PID

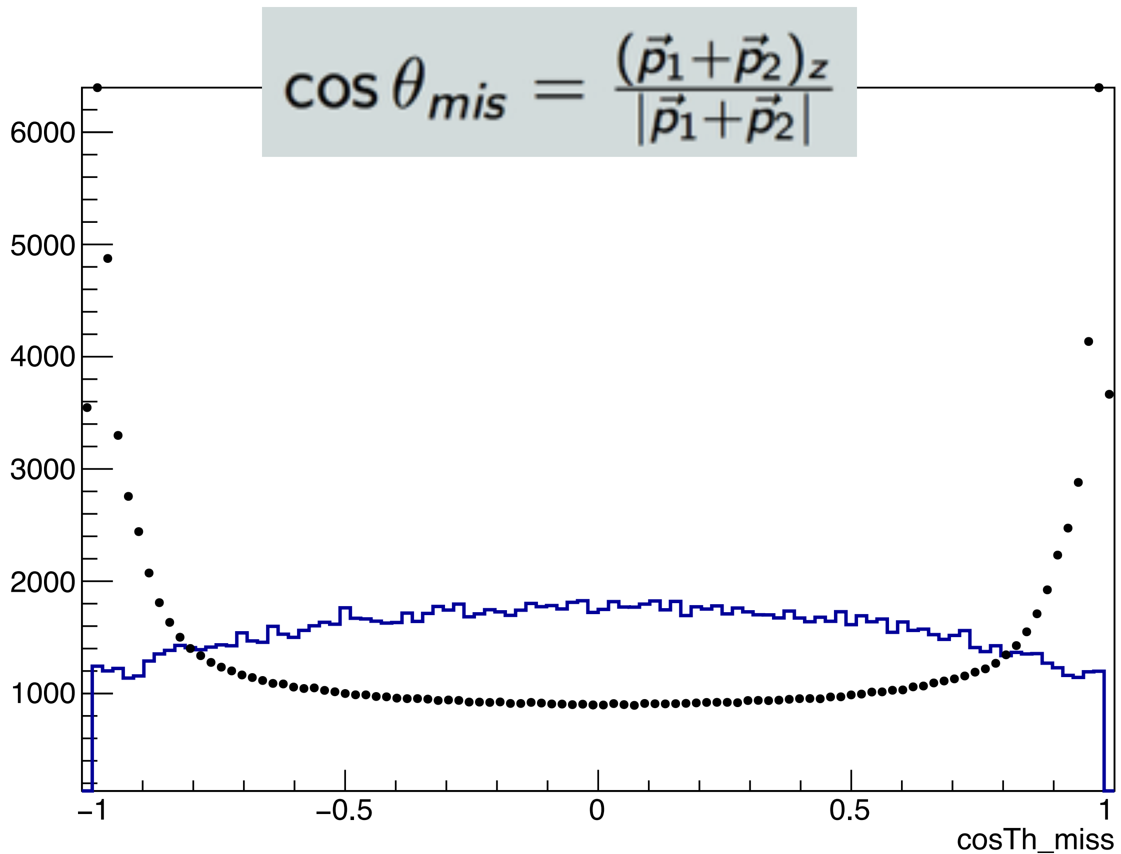
- 0.8 < E/p < 1.1
- $\chi2_{dE/dx}$ (e)< 4
- |Δtof(e)|<0.3 ns

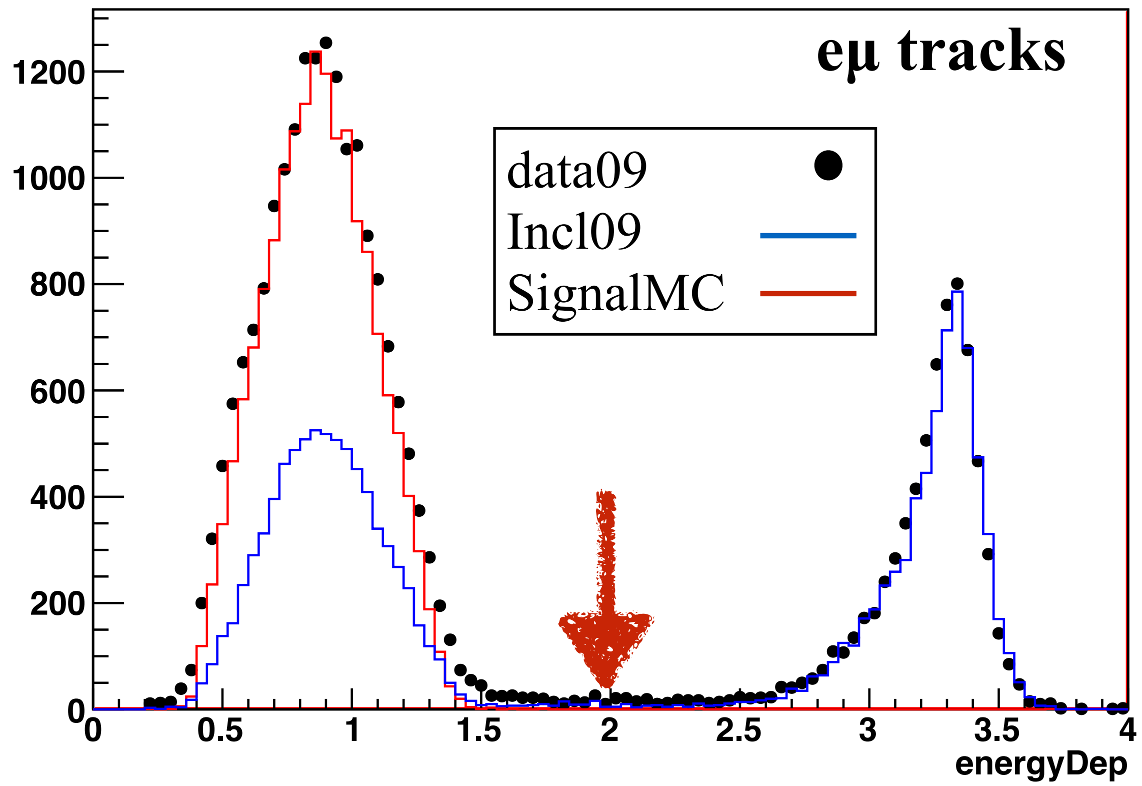
Muon PID

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

	numbers after each cut: MC signal	numbers after each cut: data09 subsample	numbers after each cut: InclMC09 subsample
total number	80000	16960604	6616952
iGood.size()==2	60390	224222	1142300
EMCch > 25 MeV	60383	222152	1136424
nGamma = 0	54312	26847	41251
n_emu	19975	258	901
n_mumu	0	1367	3186
n_ee	6	2130	288 ?

Additional cuts I



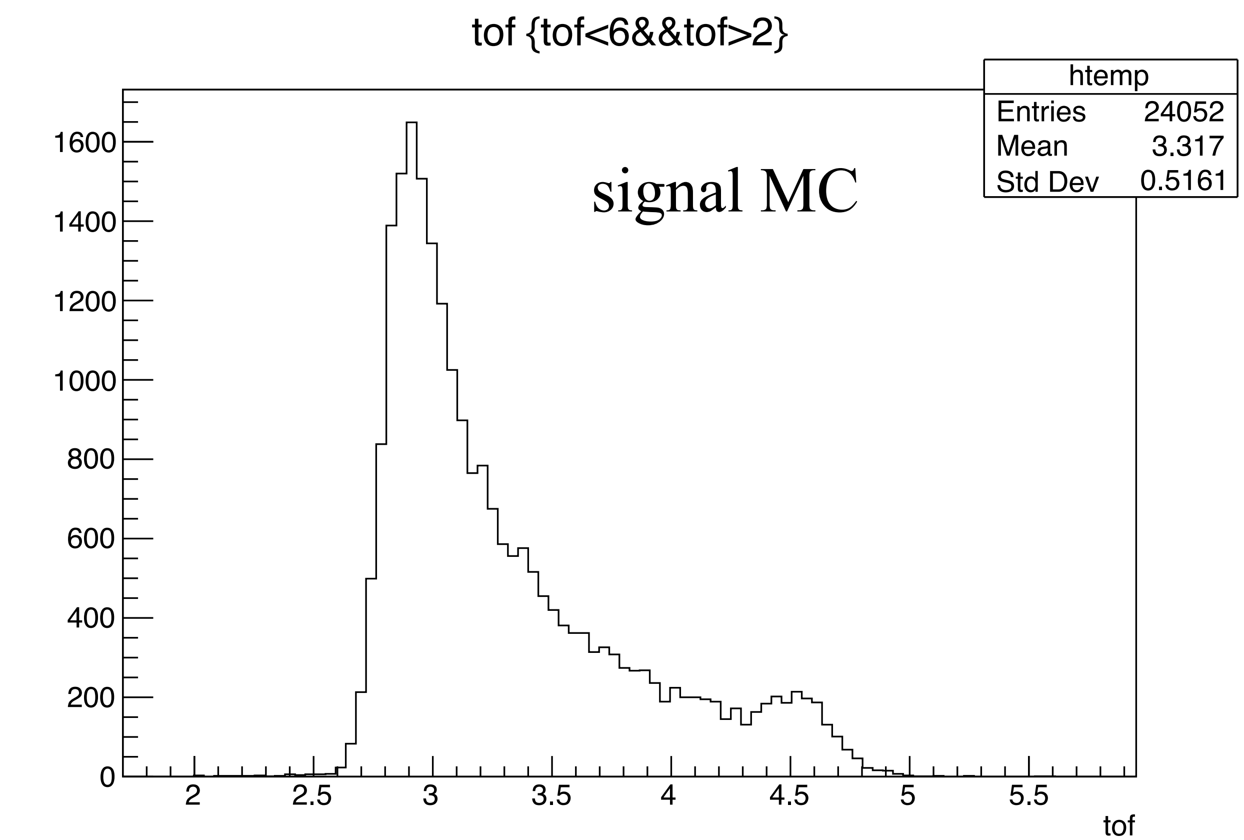


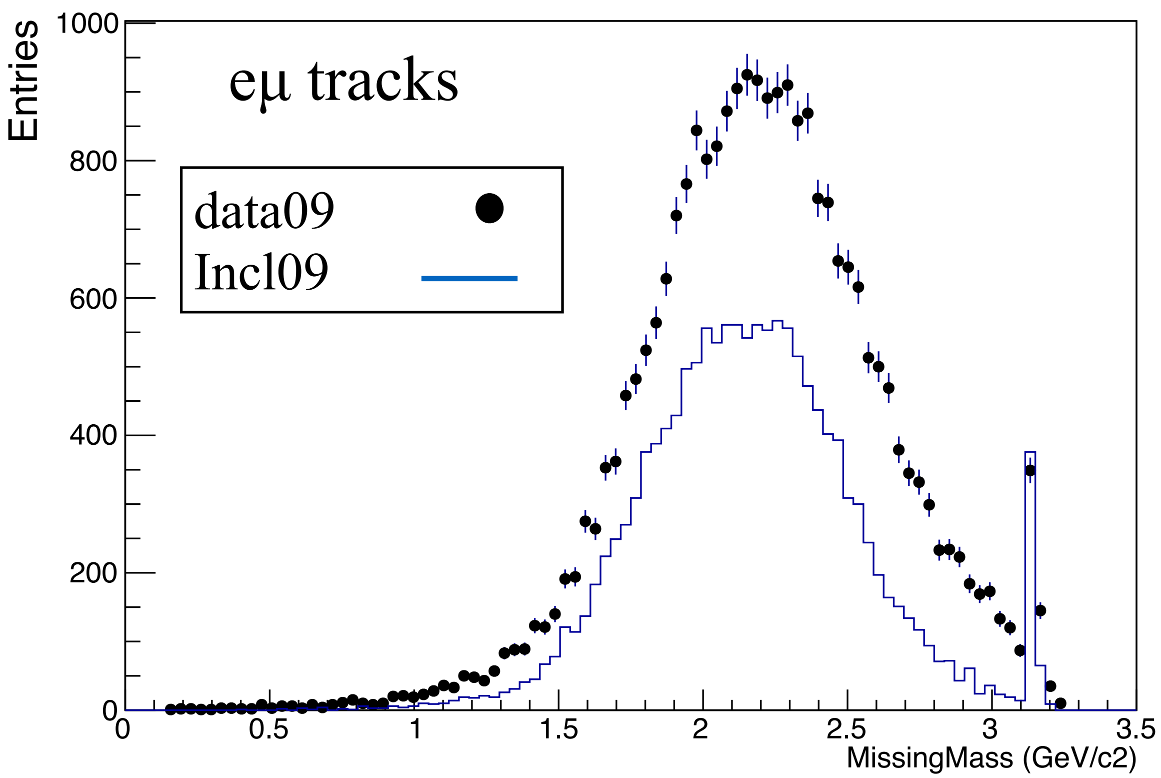
- $|\cos\theta\_miss| < 0.8$ or $0.86 < |\cos\theta\_miss| < 0.92$
- energyDep < 2 (sum of deposit energy of the two tracks)

Full data09 and incl09 MC sample analyzed

- evident discrepancy between the two samples in the signal region

Additional cuts II





- |cosθ_miss| < 0.8 or 0.86<|cosθ_miss| < 0.92
- energyDep < 2 (sum of deposit energy of the two tracks)
- 2.5 < tof < 5 ns

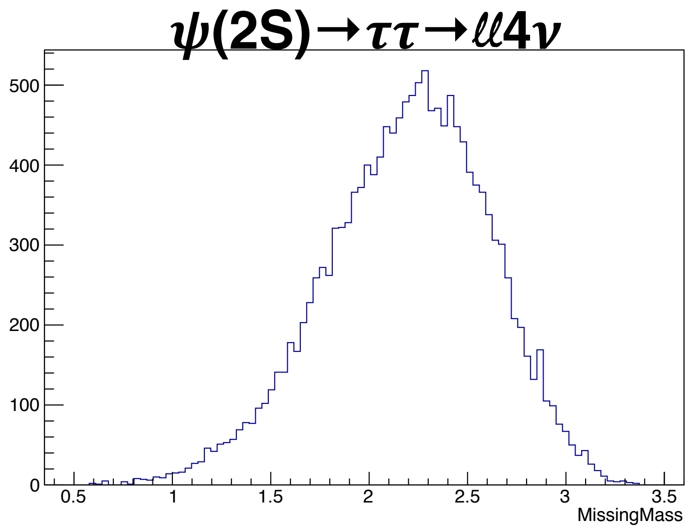
- MissingMass<3.1
- 2.5<tof < 5 (ns)

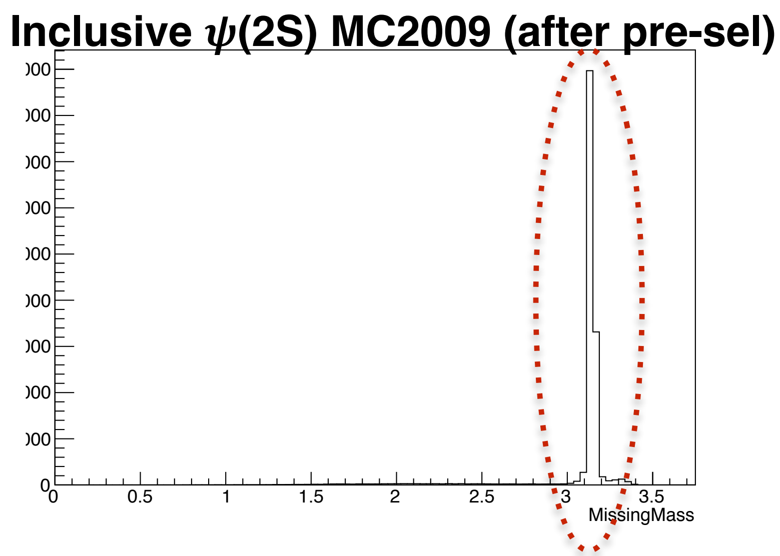
Plans and Conclusions

- Event and track selection optimization almost finished
- Check on 2012 data set ongoing
  - Data-MC comparison: try to understand the observed discrepancies
- Study of background sources
  - Evaluation of continuum contribution

Thanks for your attention

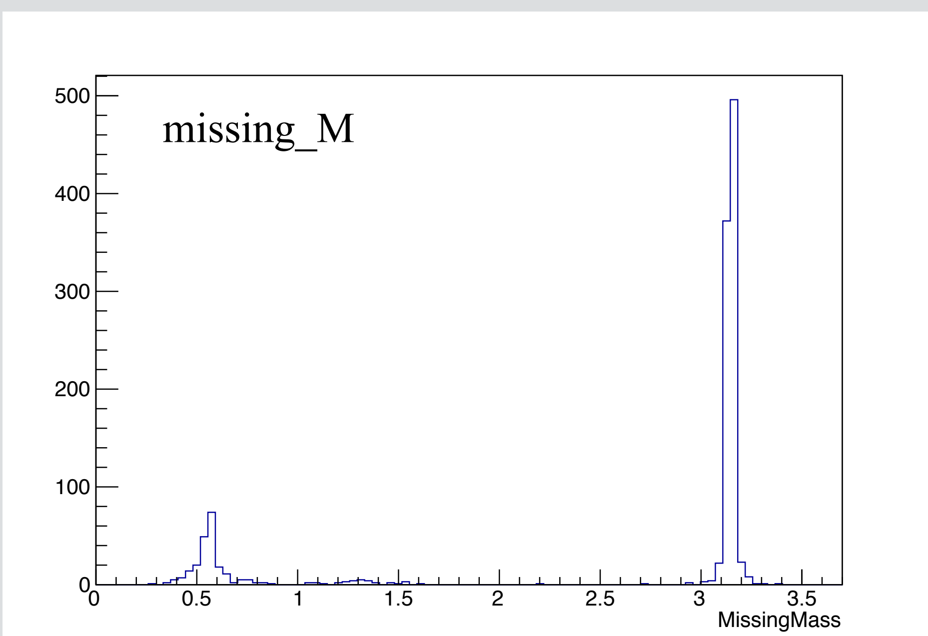
Background sources

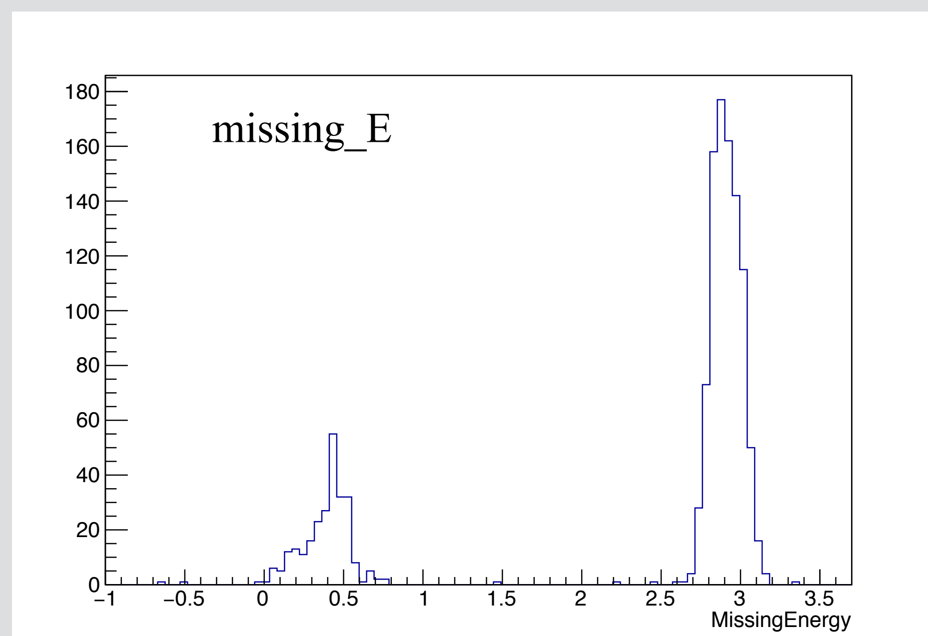




peak due to
$\boldsymbol{\psi}(2S)\to J/\psi\pi\pi$
$J/\psi\to \ell\ell$

In order to check what stated, we simulate a small MC sample of $\boldsymbol{\psi}(2S)\to J/\psi\pi\pi$, $J/\psi\to \ell\ell$ events. We applied the same event and track selection described before and we looked at the missing mass and energy distributions:





Other background sources:

$\psi(2S)\to\tau^+\tau^-\to e\nu\nu\pi\nu$