

Update on the analysis  
of  $J/\psi \rightarrow K^+ K^-$   
via  $\psi(2S) \rightarrow \pi^+ \pi^- J/\psi$   
without PID

Francesca De Mori

Università degli Studi di Torino, INFN sez. Di Torino

Corbis

# Outline

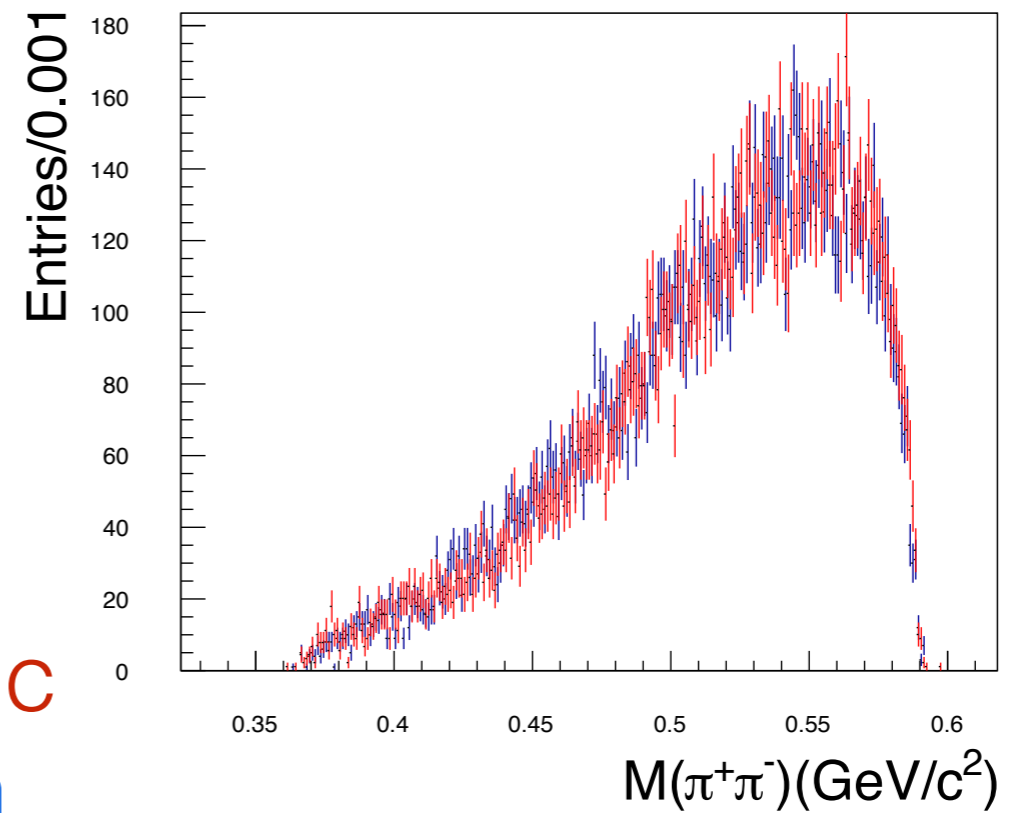
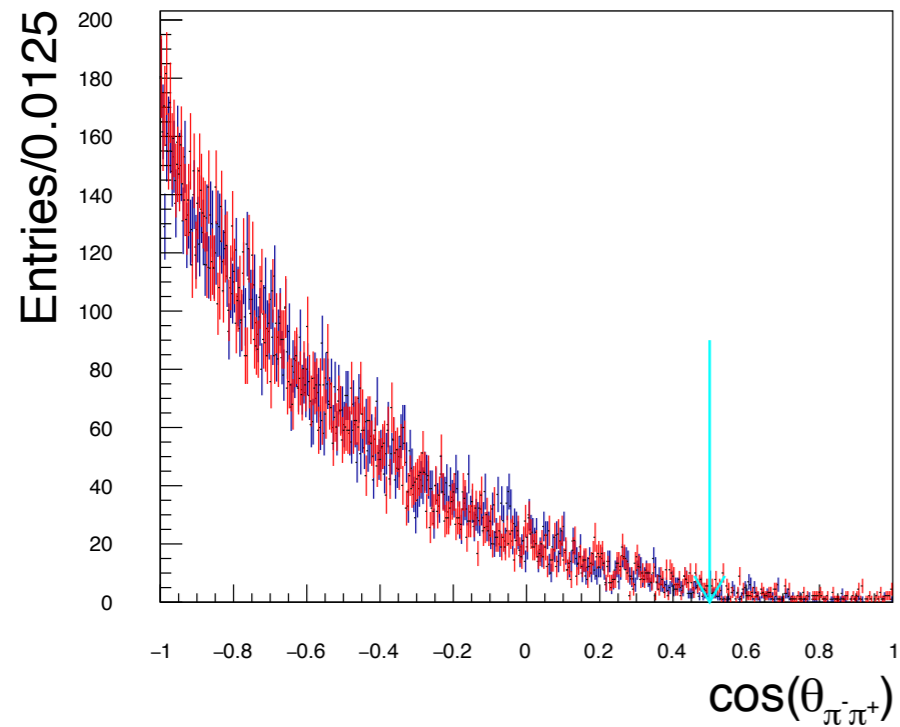
- 2009 sample processing and re-processing 2012 (updated algorithm)
- 2009 Inclusive-Data skimmed samples comparison
- 2009-2012 comparison
- Background evaluation 2009( 2012 comparison)
- Efficiency evaluation
- 2009 preliminary result and re-determination of 2012 preliminary
- result
- Outlook

✱ 2009 → successful processing(p01)

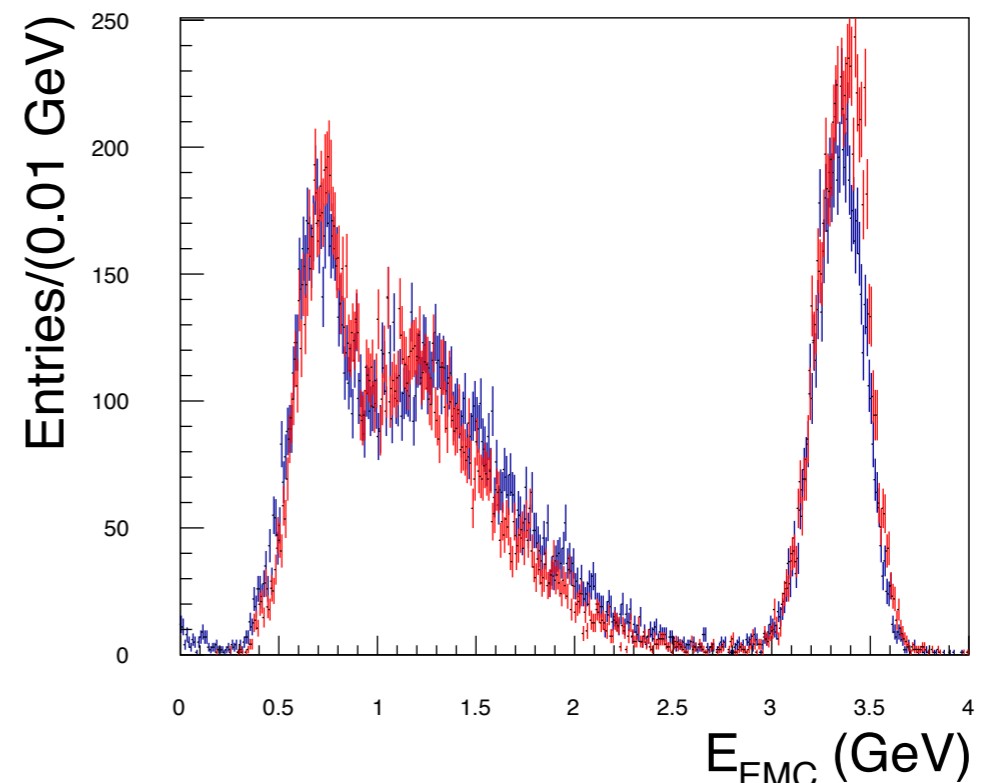
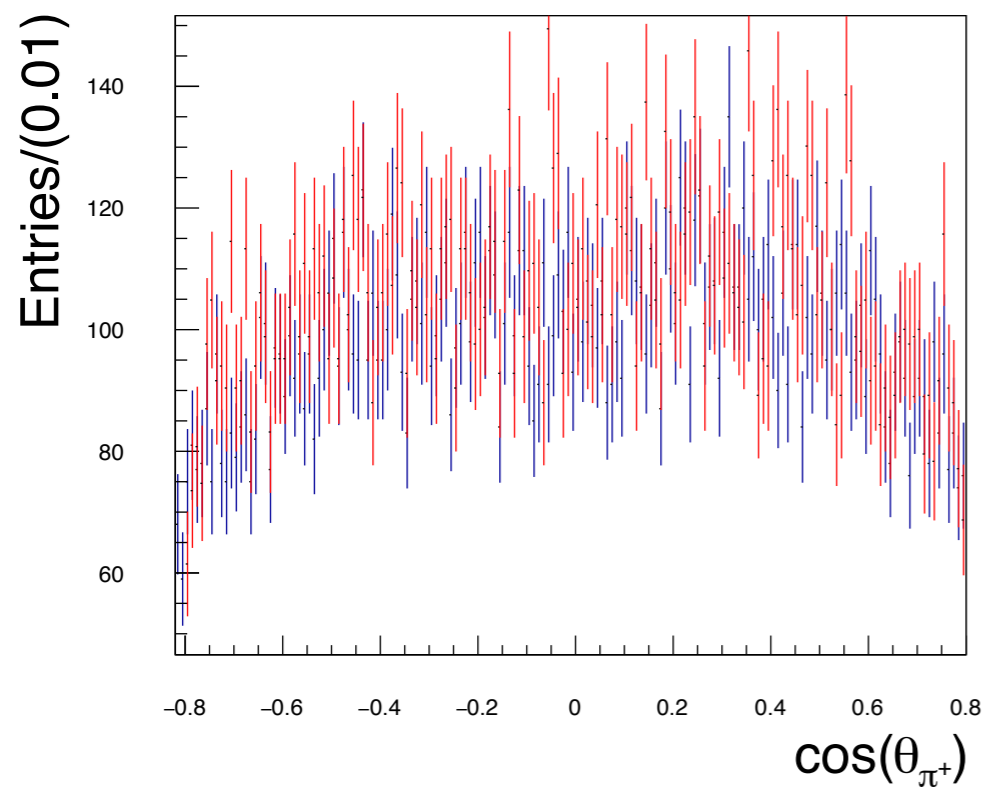
✱ Check of the analysis code → Reprocessing 2012 because of code update

# 2009 INC-DATA comparison

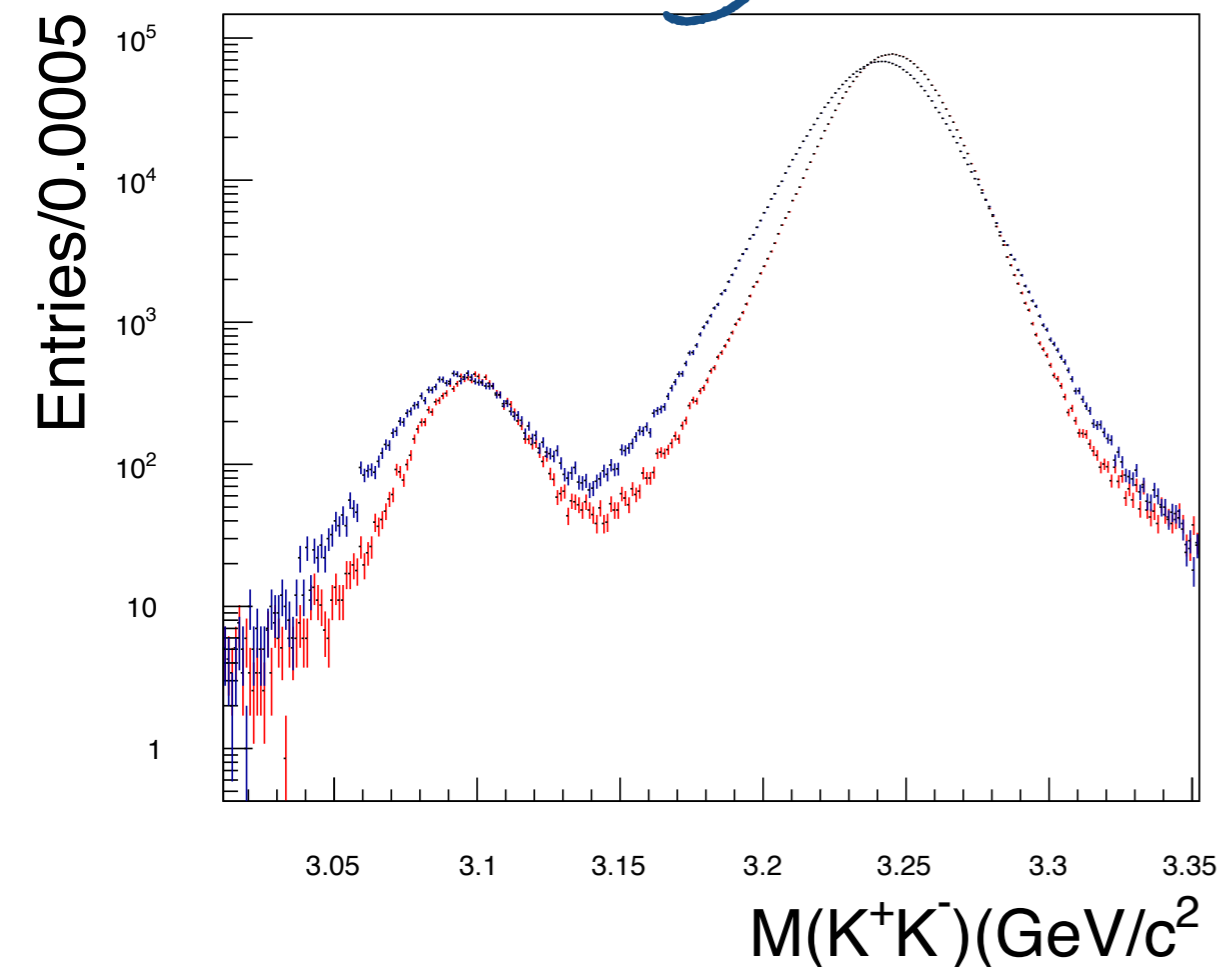
w/o the selection itself



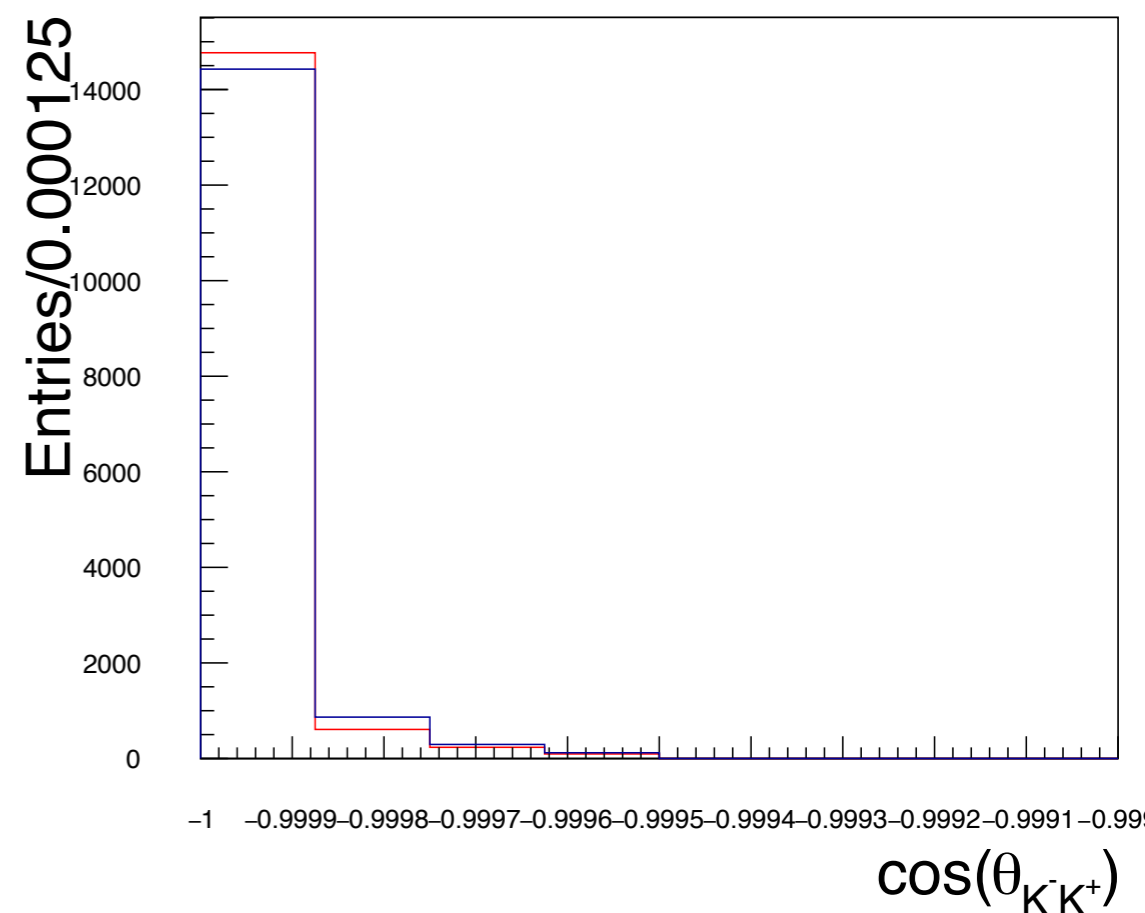
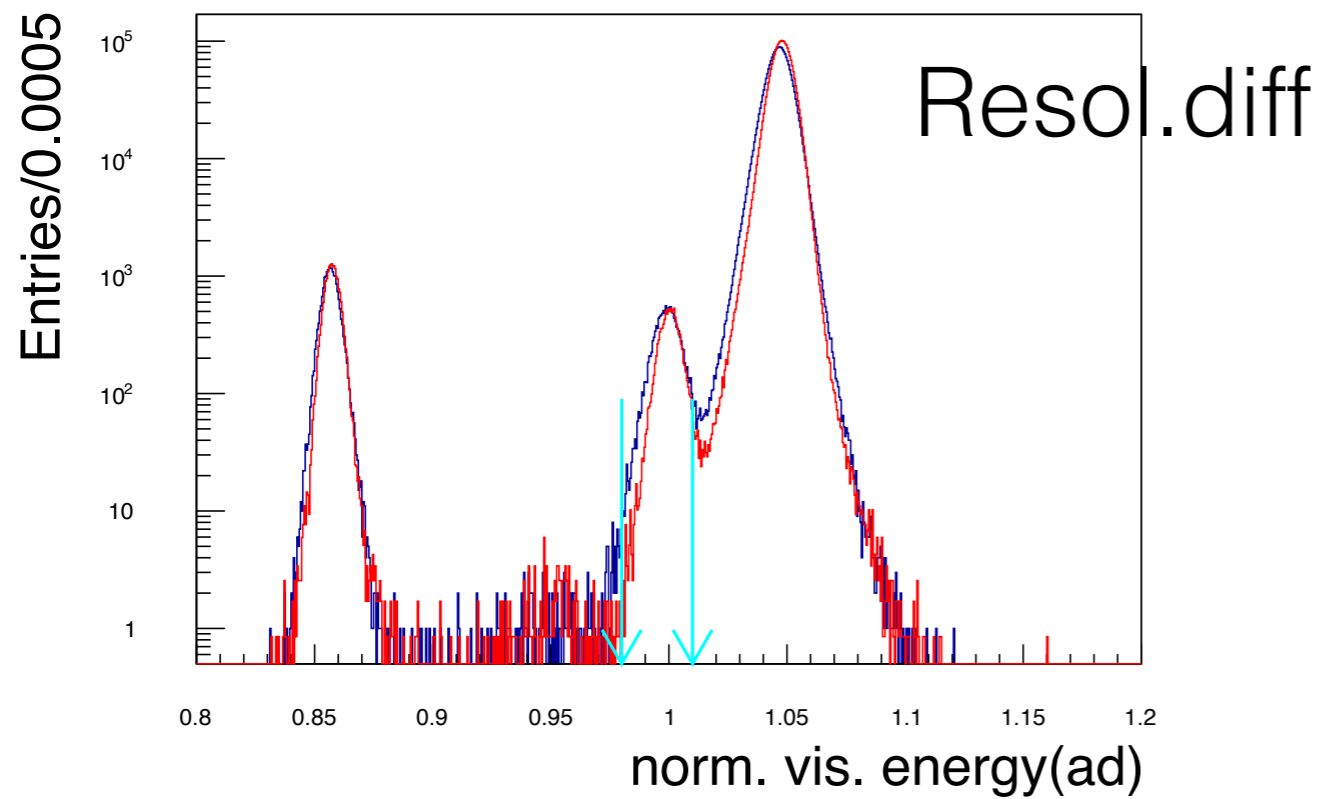
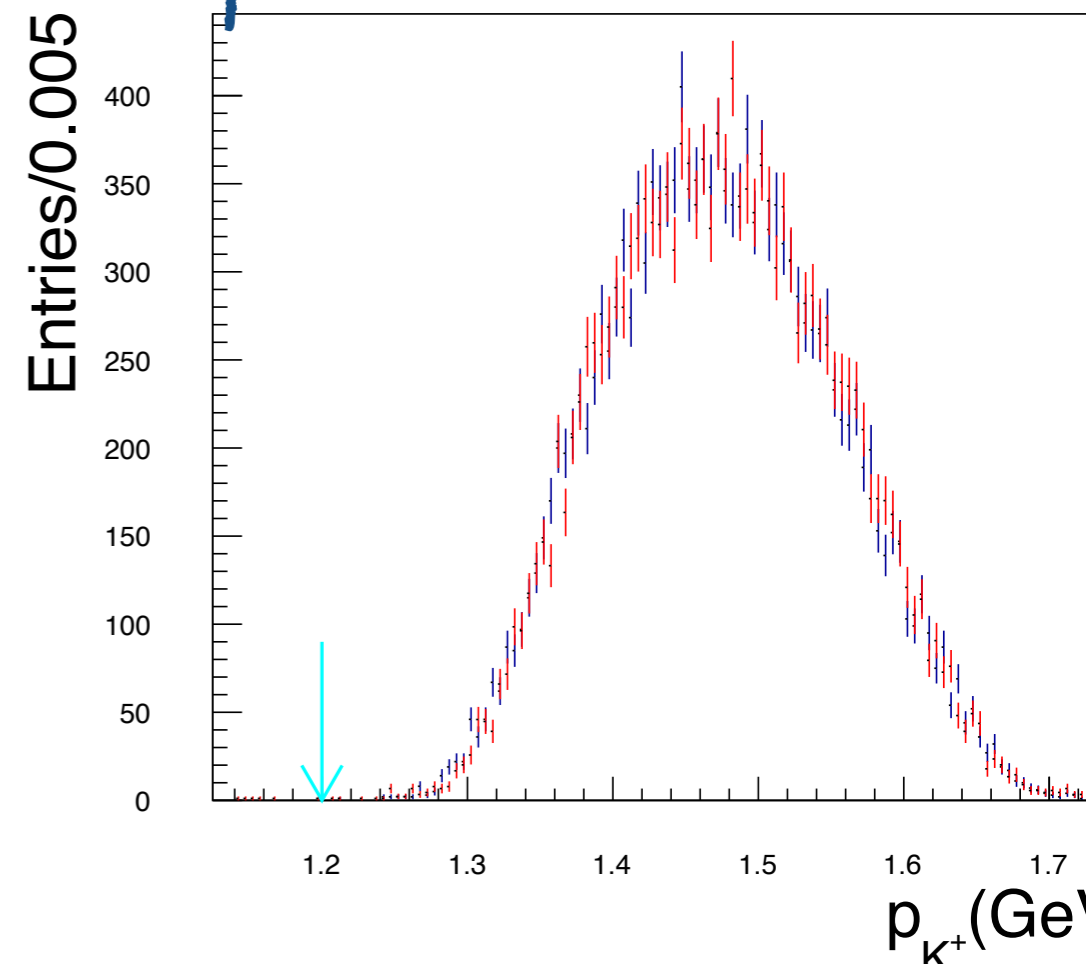
Inc-mc  
Data



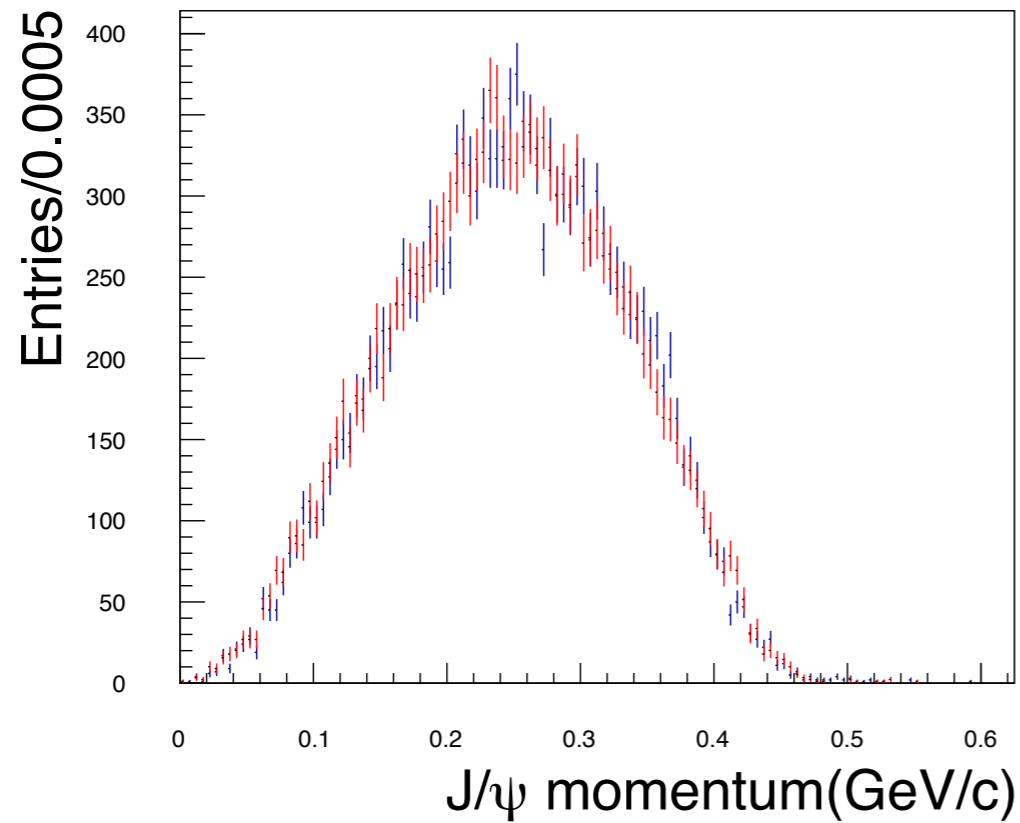
# 2009 INC-DATA COMPARISON



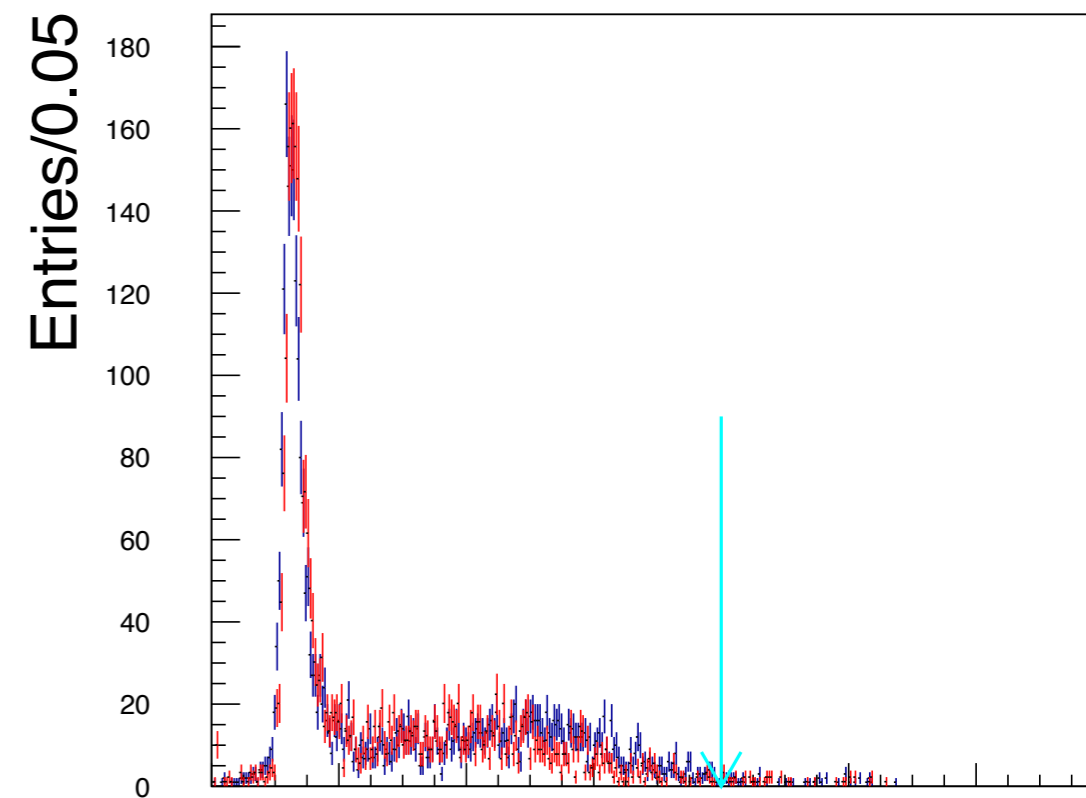
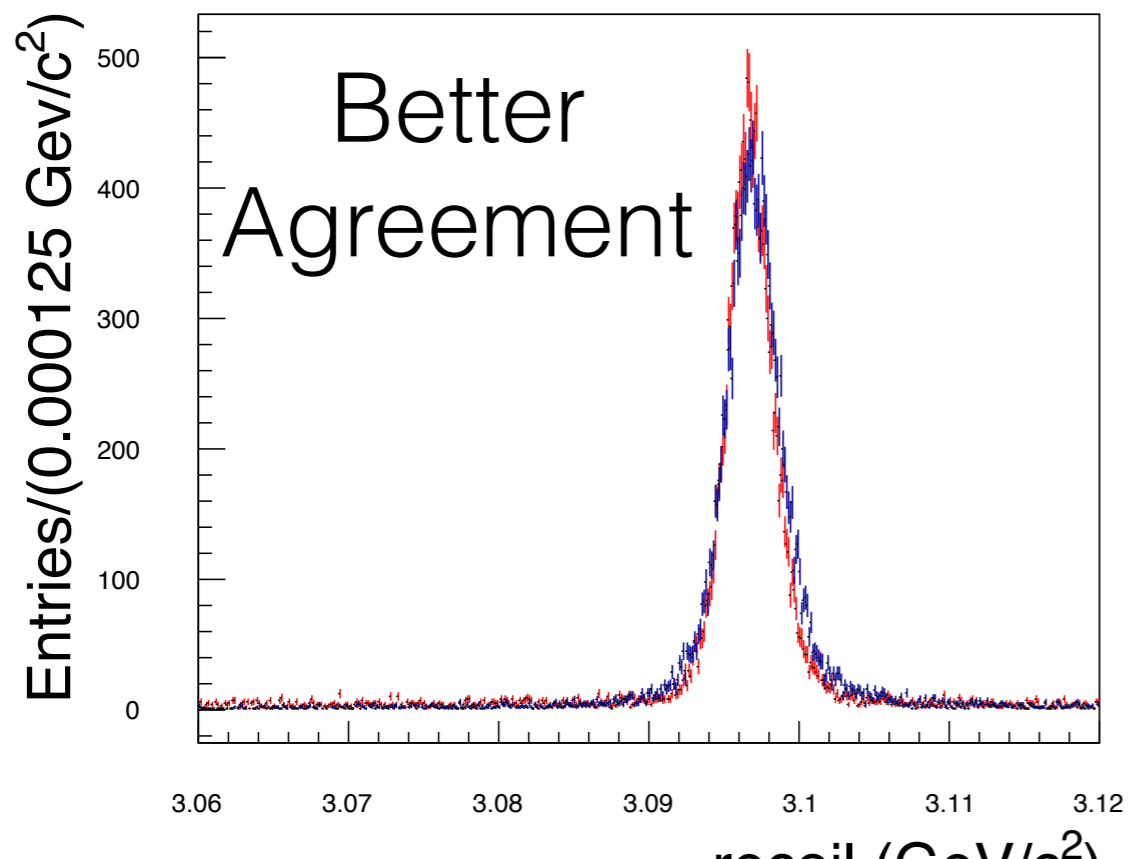
Inc-mc  
Data

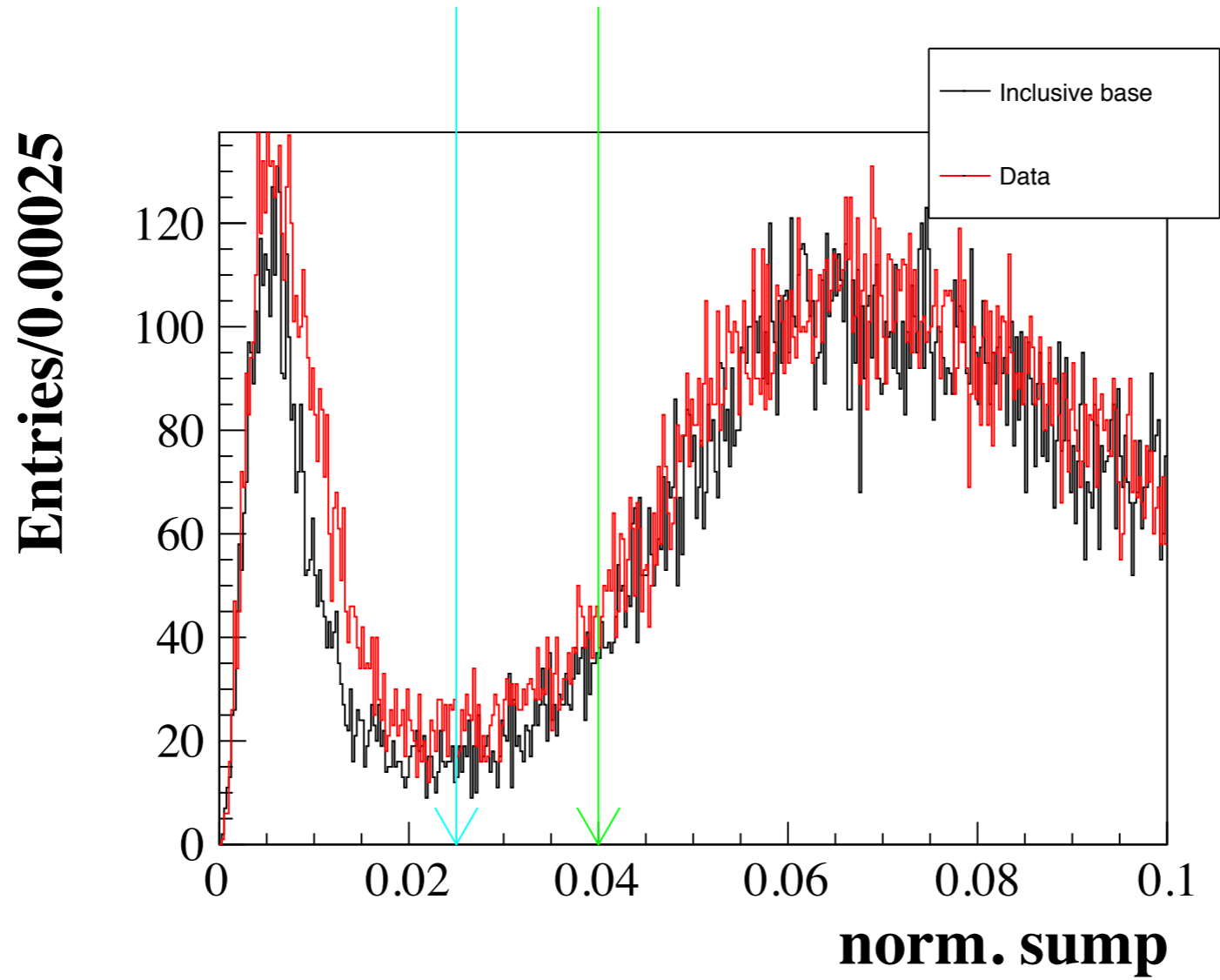


# 2009 INC-DATA comparison



Inc-mc  
Data





In KKrange

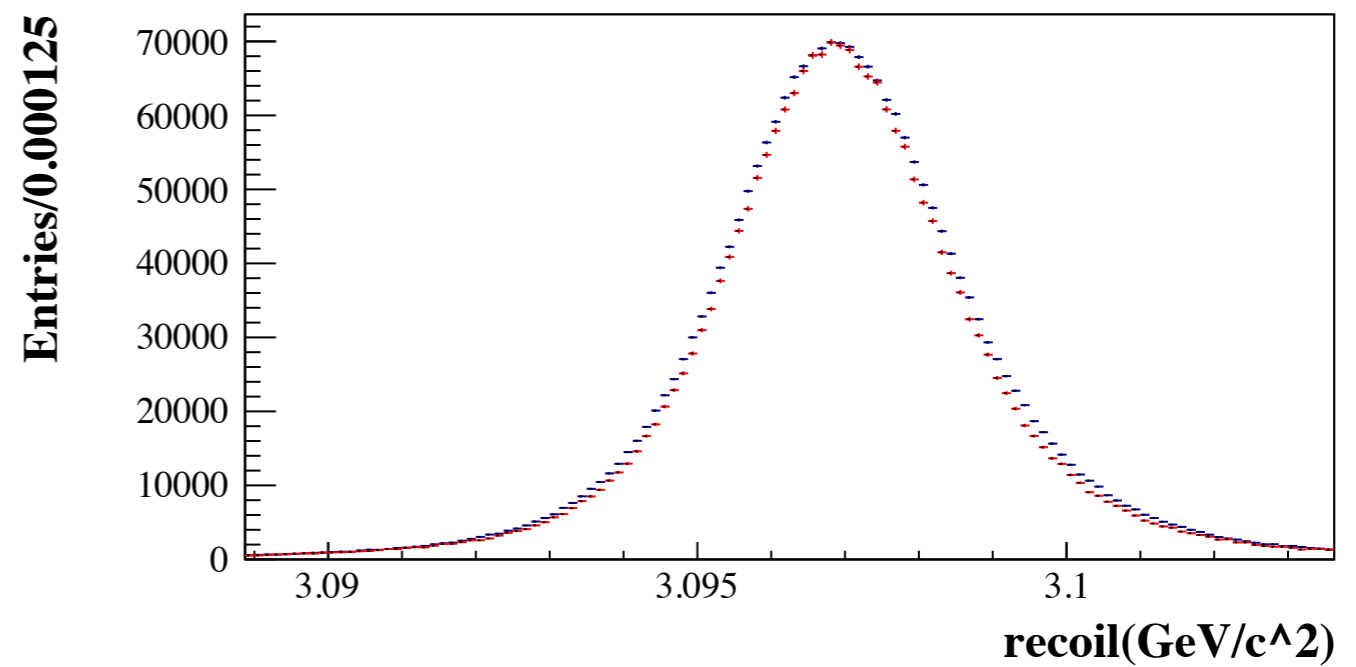
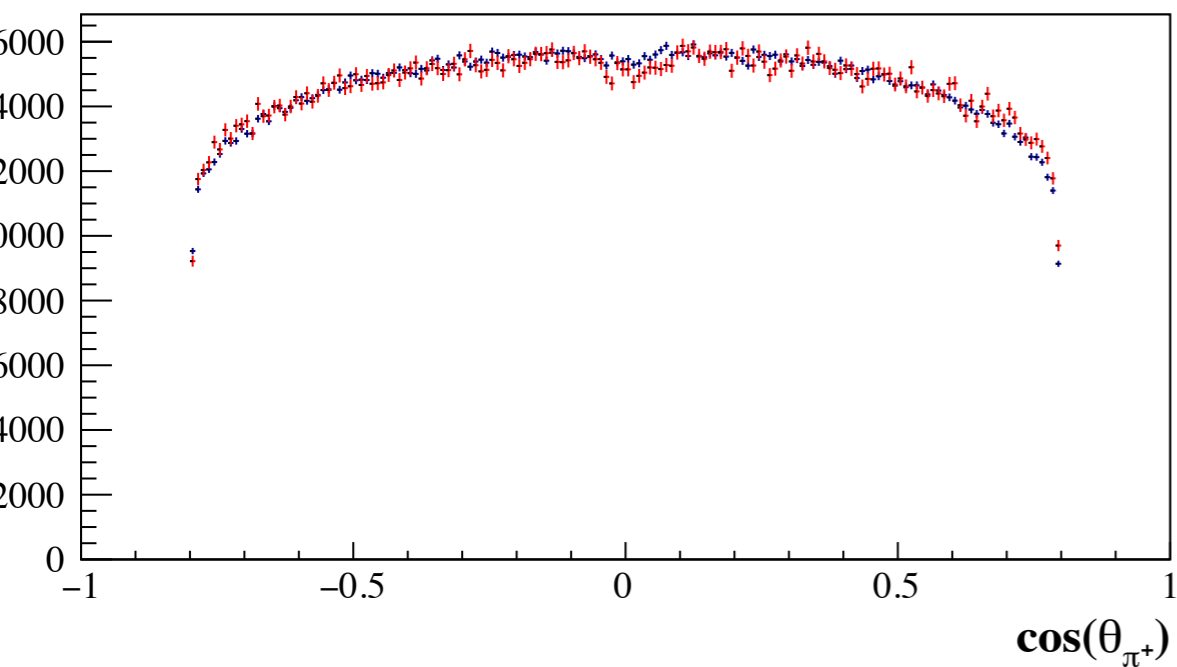
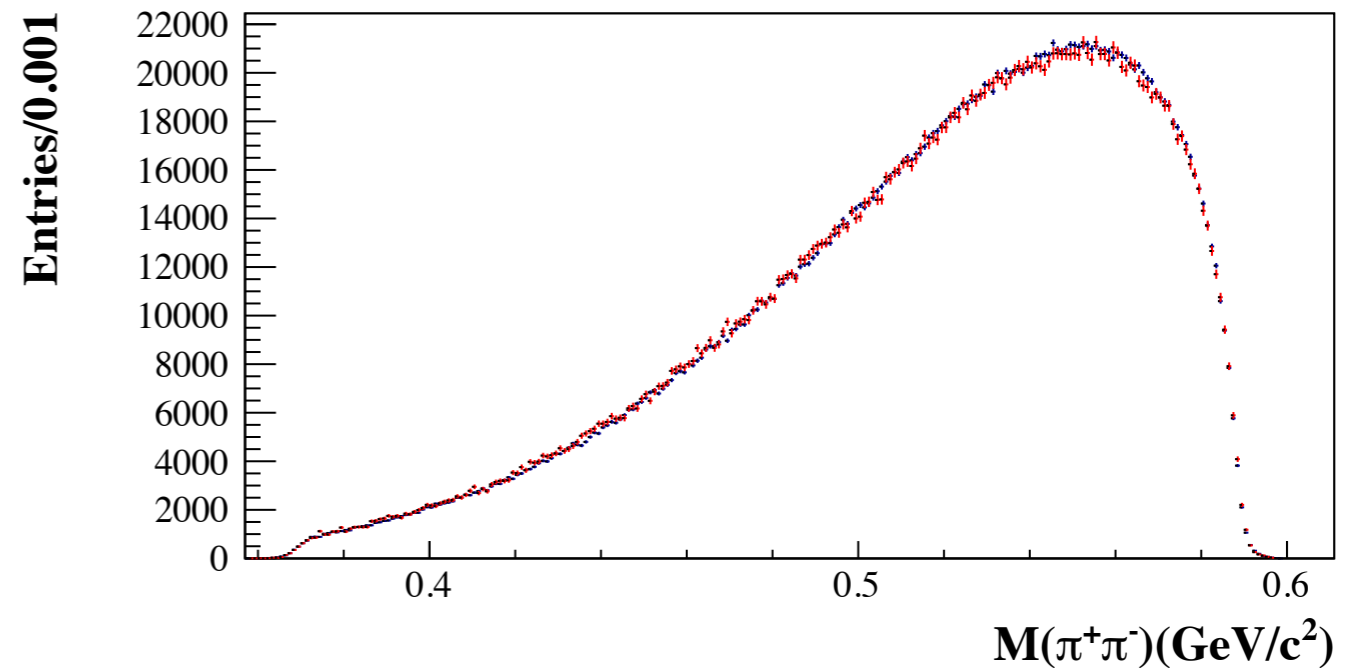
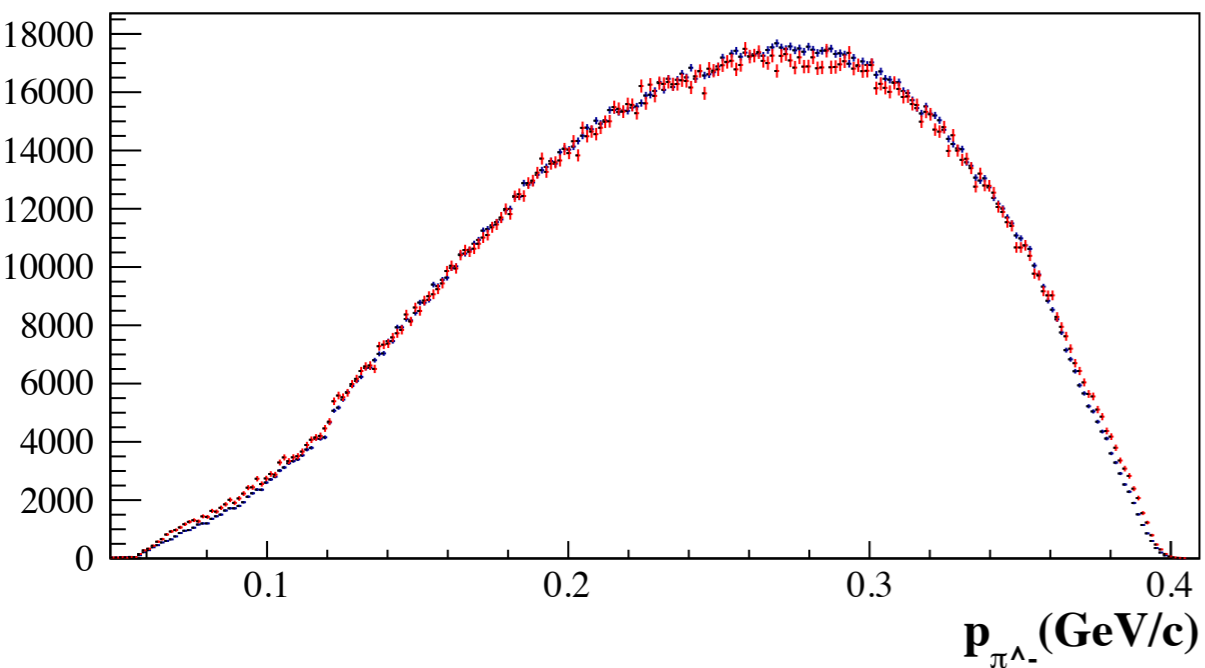
Improved..squeezed—>in 2012 as well

# Samples comparison

2009

2012

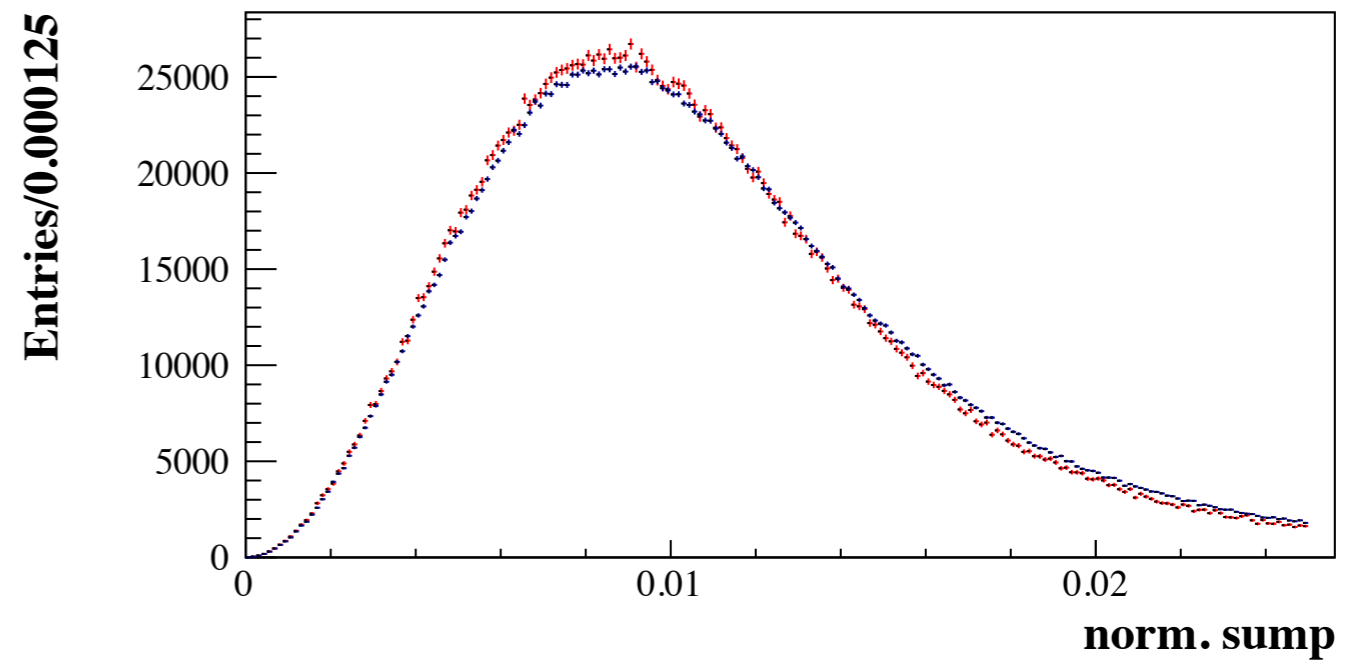
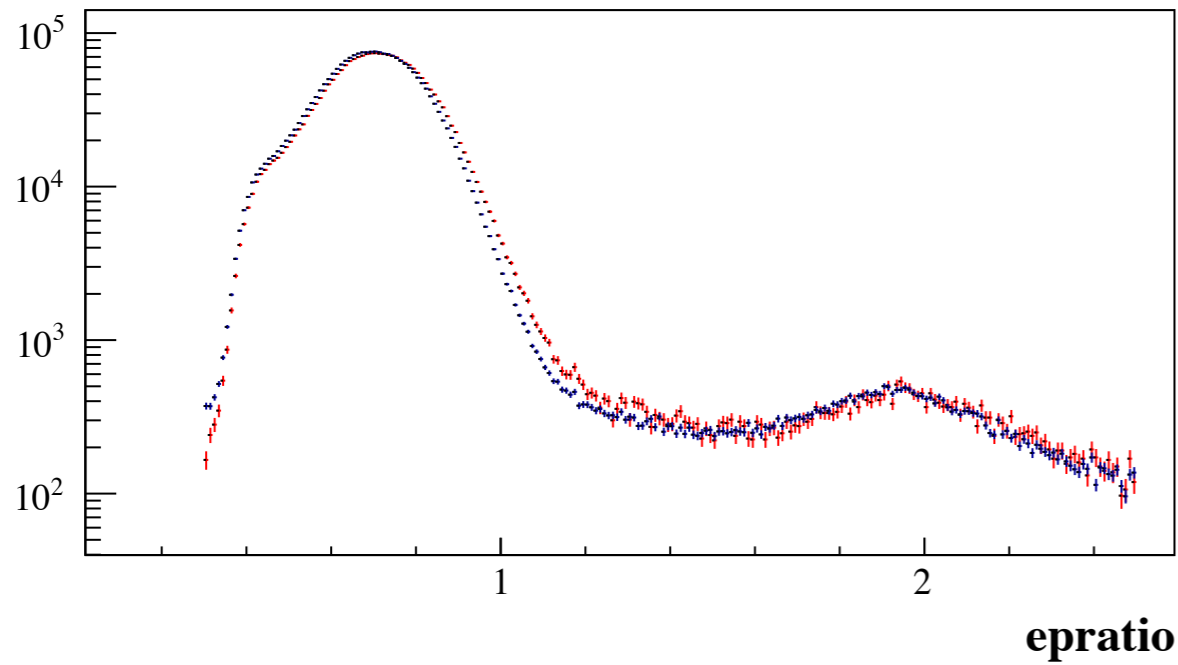
## Skimmed Data-noevis



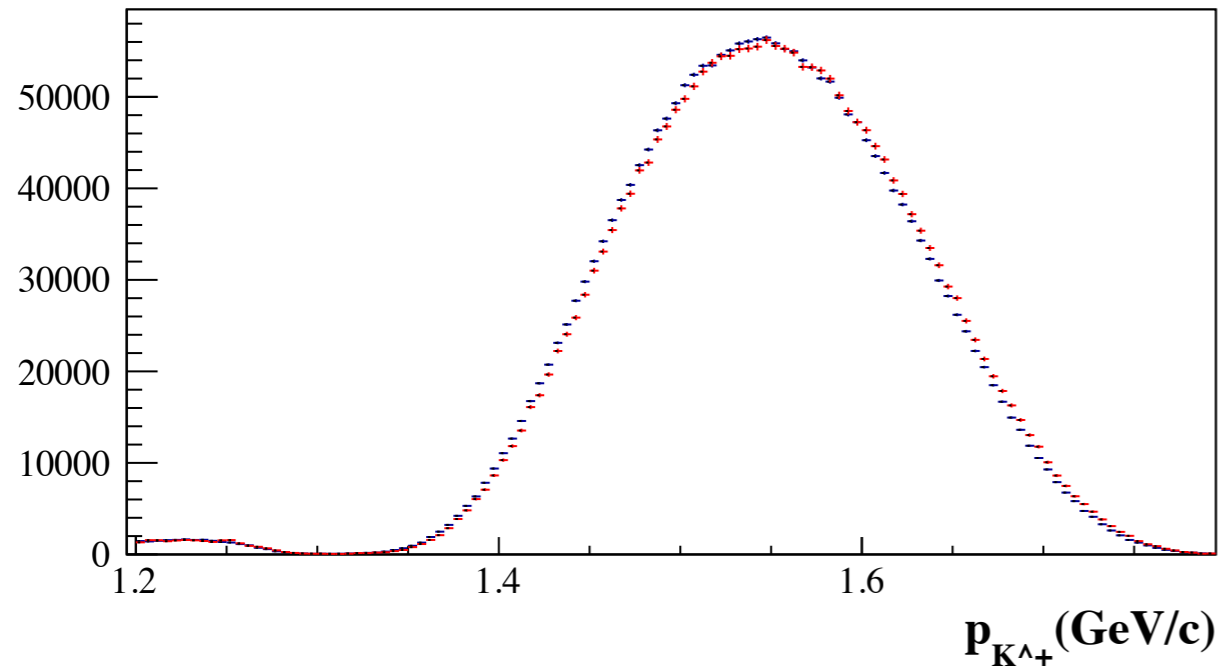
normalized



# Samples comparison

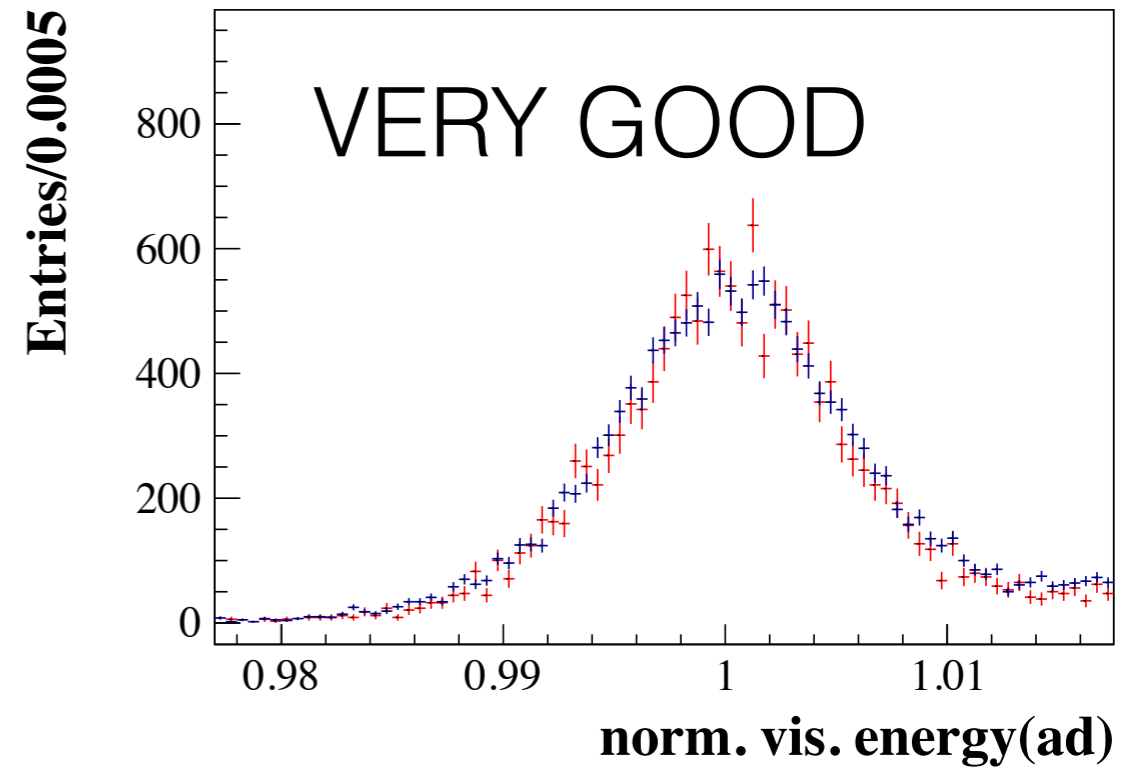
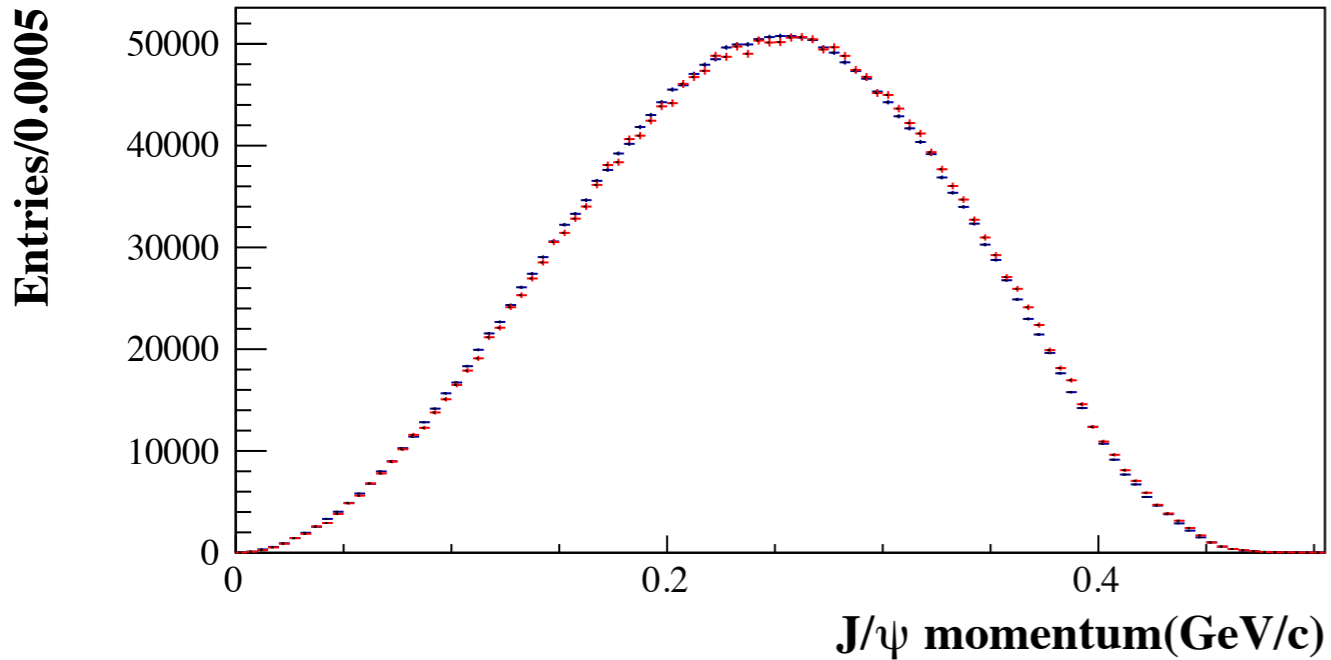
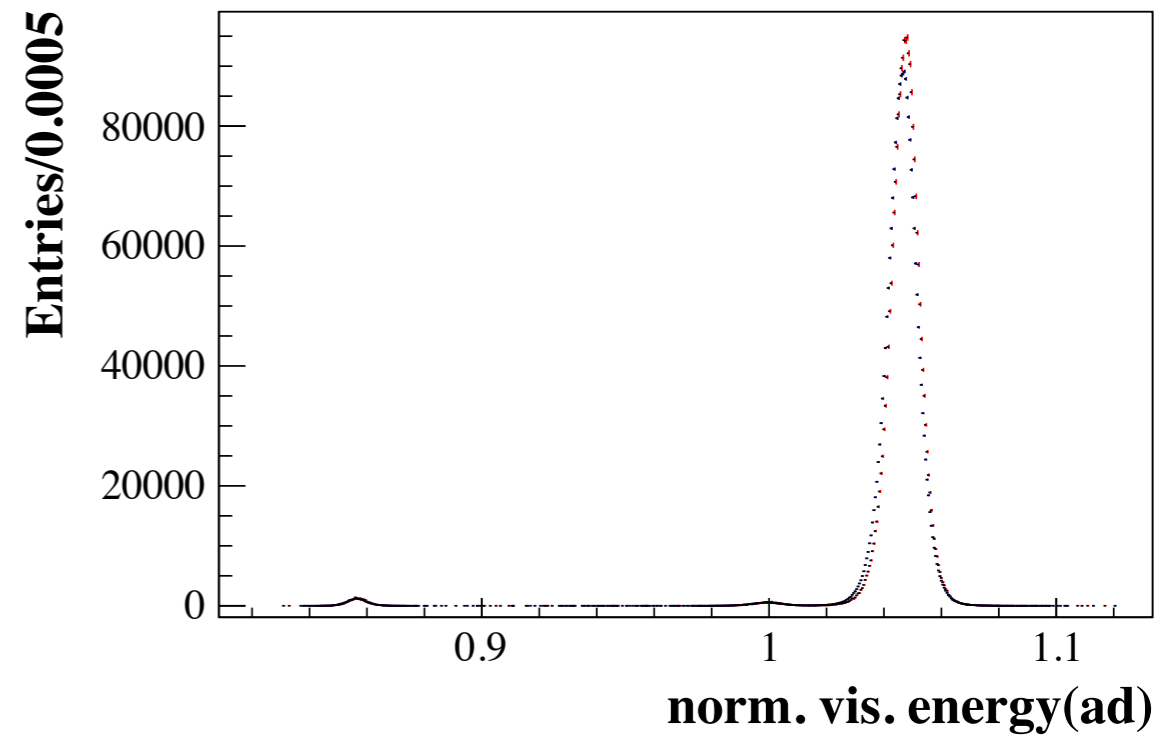



# Samples comparison



2009

2012





**Background analysis 2009**

# Background analysis 2009

in kkrange (for fraction determination)

No.	decay chain	final states	iTopo	nEvt	nTot
0	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow K^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	0	3242	3242
1	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \mu^- \mu^+$	$\psi' \rightarrow \pi^+ \mu^+ \mu^- \pi^-$	1	70	3312
2	$\psi' \rightarrow K^- K_1(1270)^+, K_1(1270)^+ \rightarrow \pi^+ K_0(1430)^*0, K_0(1430)^*0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	2	31	3343
3	$\psi' \rightarrow K_1(1270)^- K^+, K_1(1270)^- \rightarrow \bar{K}_0(1430)^*0 \pi^-, \bar{K}_0(1430)^*0 \rightarrow K^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	4	27	3370
4	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow e^- e^+$	$\psi' \rightarrow \pi^+ e^+ e^- \pi^-$	3	18	3388
5	$\psi' \rightarrow K^- K_1(1270)^+, K_1(1270)^+ \rightarrow \pi^+ K^*(892)^0, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	12	14	3402
6	$\psi' \rightarrow \bar{K}^*(892)^0 K^*(892)^0, \bar{K}^*(892)^0 \rightarrow K^- \pi^+, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	13	10	3412
7	$\psi' \rightarrow \bar{K}^*(892)^0 \pi^- K^+, \bar{K}^*(892)^0 \rightarrow K^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	14	10	3422
8	$\psi' \rightarrow K_1(1270)^- K^+, K_1(1270)^- \rightarrow \bar{K}^*(892)^0 \pi^-, \bar{K}^*(892)^0 \rightarrow K^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	10	9	3431
9	$\psi' \rightarrow K^- K_1(1270)^+, K_1(1270)^+ \rightarrow \pi^- \pi^+ K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	17	7	3438
10	$\psi' \rightarrow K_1(1270)^- K^+, K_1(1270)^- \rightarrow K^- \pi^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	6	6	3444
11	$\psi' \rightarrow K^- \pi^+ K^*(892)^0, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	5	6	3450
12	$\psi' \rightarrow K_2^{*0} K^*(892)^0, K_2^{*0} \rightarrow K^- \pi^+, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	9	5	3455
13	$\psi' \rightarrow K_1(1270)^- K^+, K_1(1270)^- \rightarrow K^- \rho^0, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	18	5	3460
14	$\psi' \rightarrow K^- \pi^- \pi^+ K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	7	4	3464
15	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \rho^- \pi^+, \rho^- \rightarrow \pi^- \pi^0$	$\psi' \rightarrow \pi^+ \pi^+ \pi^0 \pi^- \pi^-$	16	4	3468
16	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \pi^- \rho^+, \rho^+ \rightarrow \pi^0 \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^0 \pi^- \pi^-$	22	3	3471
17	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	8	2	3473
18	$\psi' \rightarrow \eta J/\psi, \eta \rightarrow \pi^- \gamma \pi^+, J/\psi \rightarrow K^- K^+$	$\psi' \rightarrow \gamma K^+ \pi^+ \pi^- K^-$	11	1	3474
19	$\psi' \rightarrow K^- \rho^0 K^+, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	19	1	3475
20	$\psi' \rightarrow \pi^- \pi^- \pi^0 \pi^+ \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^0 \pi^- \pi^-$	20	1	3476
21	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \pi^0 \rho^0, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^0 \pi^- \pi^-$	21	1	3477
22	$\psi' \rightarrow \bar{K}_0(1430)^*0 K^*(892)^0, \bar{K}_0(1430)^*0 \rightarrow K^- \pi^+, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	15	1	3478
23	$\psi' \rightarrow K^- \pi^+ K_2^{*0}, K_2^{*0} \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	23	1	3479
24	$\psi' \rightarrow \gamma, \rightarrow K^- \pi^+ K_S, K_S \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- K^-$	24	1	3480
25	$\psi' \rightarrow K^- K_1(1270)^+, K_1(1270)^+ \rightarrow \rho^0 K^+, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	25	1	3481
26	$\psi' \rightarrow \bar{K}^*(892)^0 K_2^{*0}, \bar{K}^*(892)^0 \rightarrow K^- \pi^+, K_2^{*0} \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^- K^-$	26	1	3482

3242 KK 142 no pipijpsi 4.1+-0.4% 13597 in kkregion(3482+-59 kk)

2.0+-0.2 di muon

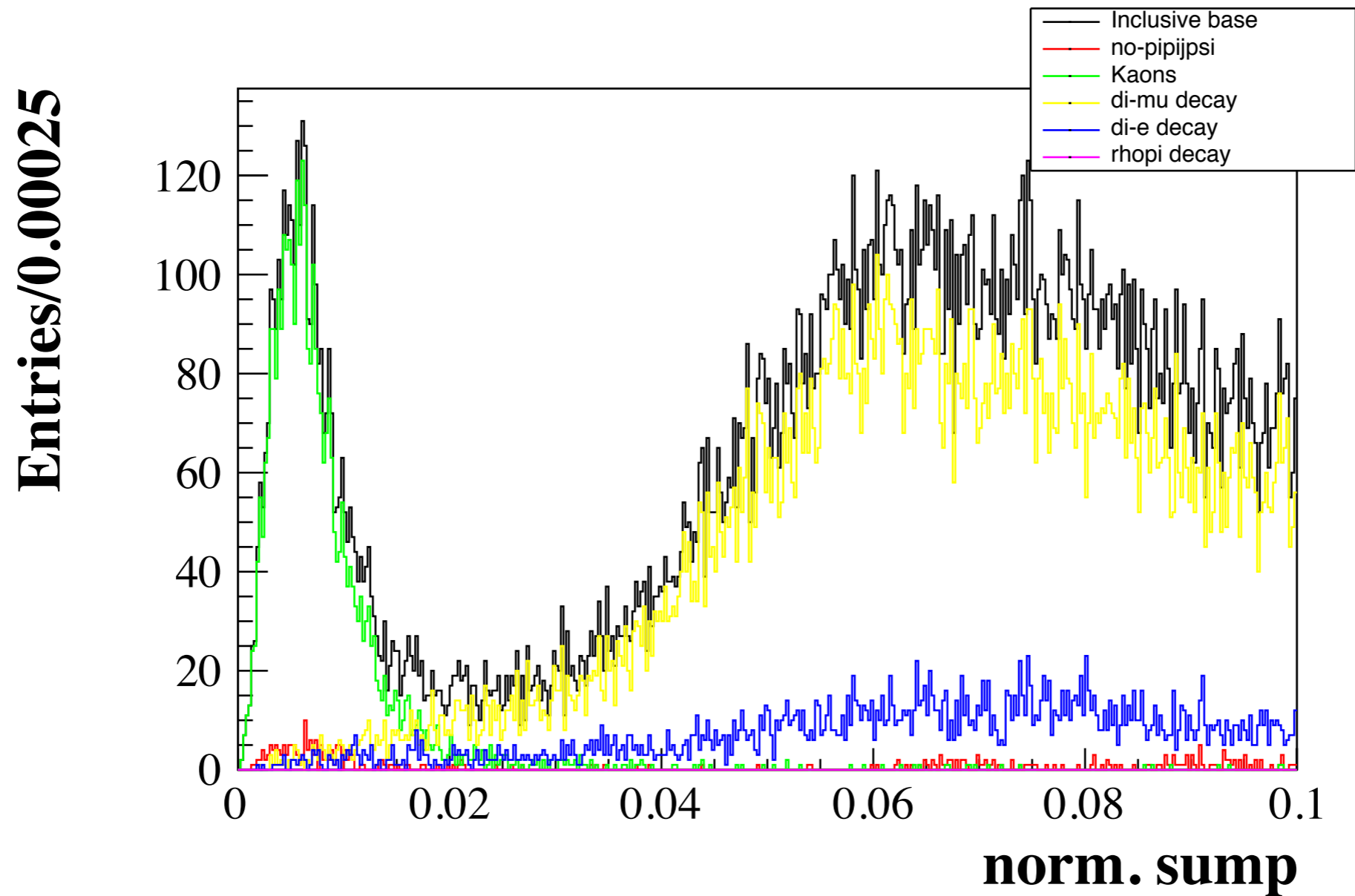
# Background analysis 2009

Di-muon range (for fraction determination)

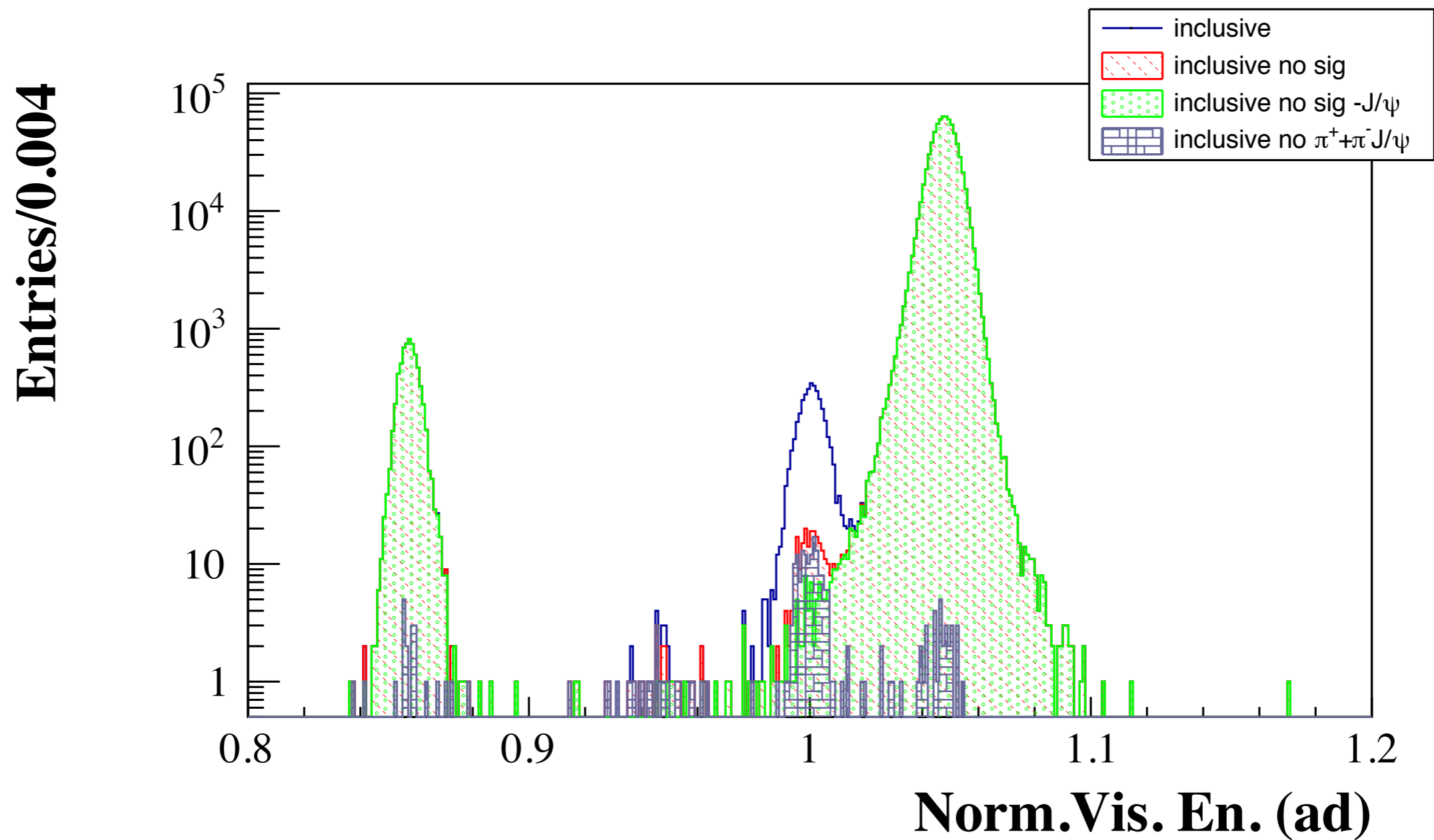
No.	decay chain	final states	iTopo	nEvt	nTot
0	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \mu^- \mu^+$	$\psi' \rightarrow \pi^+ \mu^+ \mu^- \pi^-$	0	727134	727134
1	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow e^- e^+$	$\psi' \rightarrow \pi^+ e^+ e^- \pi^-$	1	2790	729924
2	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	2	2194	732118
3	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \gamma f_4(2050), f_4(2050) \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- \pi^-$	3	32	732150
4	$\psi' \rightarrow \eta J/\psi, \eta \rightarrow \pi^- \gamma \pi^+, J/\psi \rightarrow \mu^- \mu^+$	$\psi' \rightarrow \gamma \pi^+ \mu^+ \mu^- \pi^-$	5	13	732163
5	$\psi' \rightarrow \pi^- \rho^0 \pi^+, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	4	8	732171
6	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \gamma f_2(1950), f_2(1950) \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- \pi^-$	6	5	732176
7	$\psi' \rightarrow \eta J/\psi, \eta \rightarrow e^- e^+ \gamma, J/\psi \rightarrow \mu^- \mu^+$	$\psi' \rightarrow \gamma \mu^+ e^+ e^- \mu^-$	8	4	732180
8	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \gamma f_0(1710), f_0(1710) \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- \pi^-$	13	2	732182
9	$\psi' \rightarrow \pi^- \pi^- \pi^+ \pi^+ \eta, \eta \rightarrow \gamma \gamma$	$\psi' \rightarrow \gamma \gamma \pi^+ \pi^+ \pi^- \pi^-$	9	1	732183
10	$\psi' \rightarrow K_1(1270)^- K^+, K_1(1270)^- \rightarrow \rho^- K_L, \rho^- \rightarrow \pi^- \pi^0$	$\psi' \rightarrow K^+ K_L \pi^0 \pi^-$	10	1	732184
11	$\psi' \rightarrow \pi^0 \pi^0 J/\psi, J/\psi \rightarrow K^- \pi^- \pi^0 \pi^+ K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^0 \pi^0 \pi^- K^-$	11	1	732185
12	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \omega f_1(1420), \omega \rightarrow \pi^- \pi^0 \pi^+, f_1(1420) \rightarrow K^- K_L \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^+ K_L \pi^0 \pi^- \pi^- K^-$	12	1	732186
13	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \gamma f_2(1270), f_2(1270) \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- \pi^-$	7	1	732187
14	$\psi' \rightarrow \pi^- \pi^+ J/\psi, J/\psi \rightarrow \phi f_2, \phi \rightarrow K^- K^+, f_2 \rightarrow K_L K_L$	$\psi' \rightarrow K^+ \pi^+ K_L K_L \pi^- K^-$	14	1	732188
15	$\psi' \rightarrow \gamma \chi_{c2}, \chi_{c2} \rightarrow \pi^- \pi^0 b_1^+, b_1^+ \rightarrow \pi^+ \omega, \omega \rightarrow \pi^- \pi^- \pi^+ \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^+ \pi^0 \pi^- \pi^- \pi^-$	15	1	732189
16	$\psi' \rightarrow \gamma \chi_{c0}, \chi_{c0} \rightarrow \pi^- \pi^- \pi^+ \pi^+$	$\psi' \rightarrow \gamma \pi^+ \pi^+ \pi^- \pi^-$	16	1	732190
17	$\psi' \rightarrow K^- \pi^0 \pi^+ K^*(892)^0, K^*(892)^0 \rightarrow \pi^- K^+$	$\psi' \rightarrow K^+ \pi^+ \pi^0 \pi^- K^-$	17	1	732191
18	$\psi' \rightarrow \bar{\Delta}^{--} \Delta^{++}, \bar{\Delta}^{--} \rightarrow \bar{p} \pi^-, \Delta^{++} \rightarrow \pi^+ p$	$\psi' \rightarrow p \pi^+ \pi^- \bar{p}$	18	1	732192
19	$\psi' \rightarrow \pi^- a_1^+, a_1^+ \rightarrow \rho^0 \pi^+, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	19	1	732193
20	$\psi' \rightarrow a_2^- \pi^+, a_2^- \rightarrow \pi^- \rho^0, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	20	1	732194
21	$\psi' \rightarrow \pi^- a_2^+, a_2^+ \rightarrow \rho^0 \pi^+, \rho^0 \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	21	1	732195
22	$\psi' \rightarrow \omega f_2(1270), \omega \rightarrow \pi^- \pi^+, f_2(1270) \rightarrow \pi^- \pi^+$	$\psi' \rightarrow \pi^+ \pi^+ \pi^- \pi^-$	22	1	732196

73216 mumu, 2790 ee +2194 pipi (6.9+-0.7 per mille)

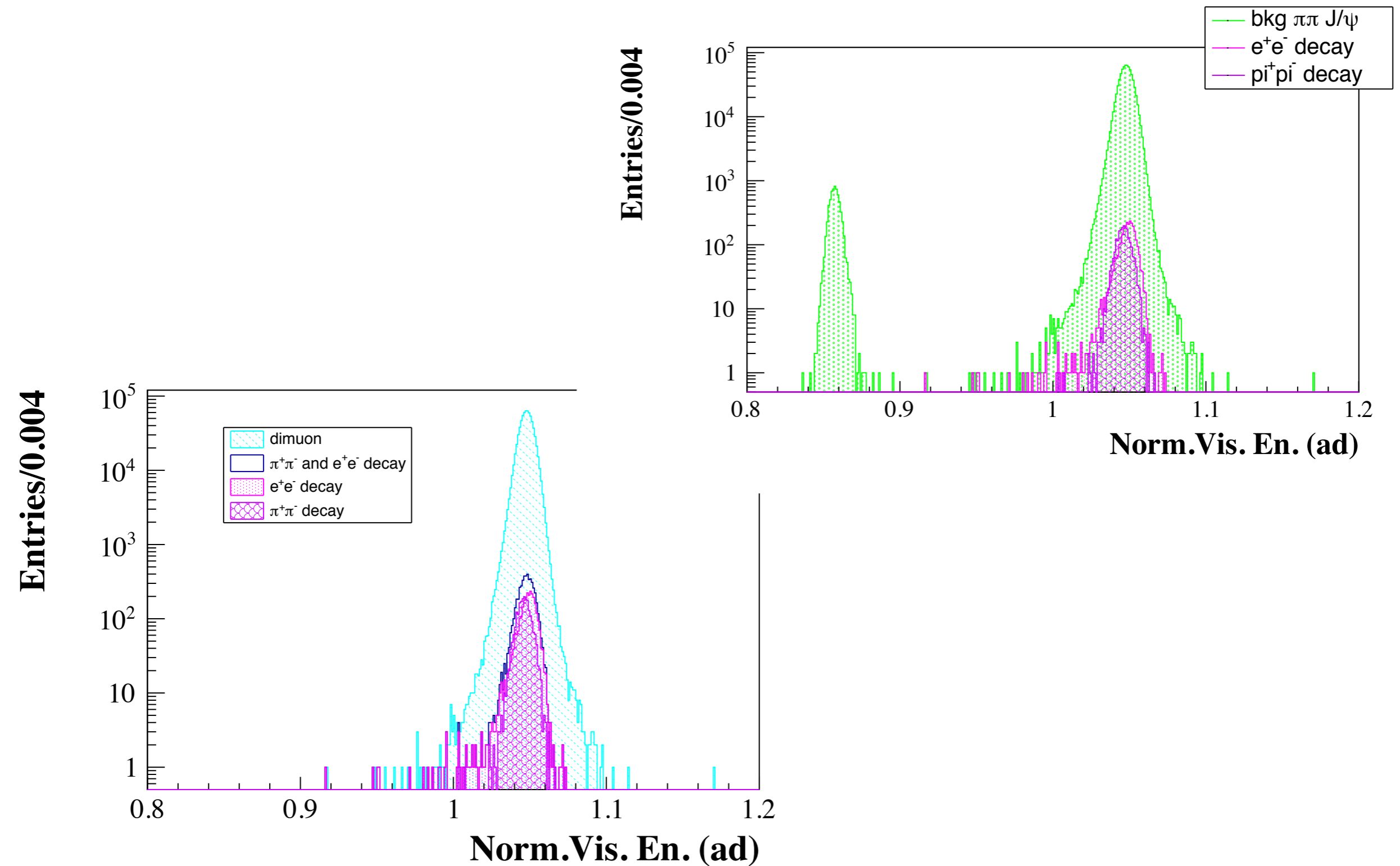
# Background analysis 2009



# Background analysis 2009



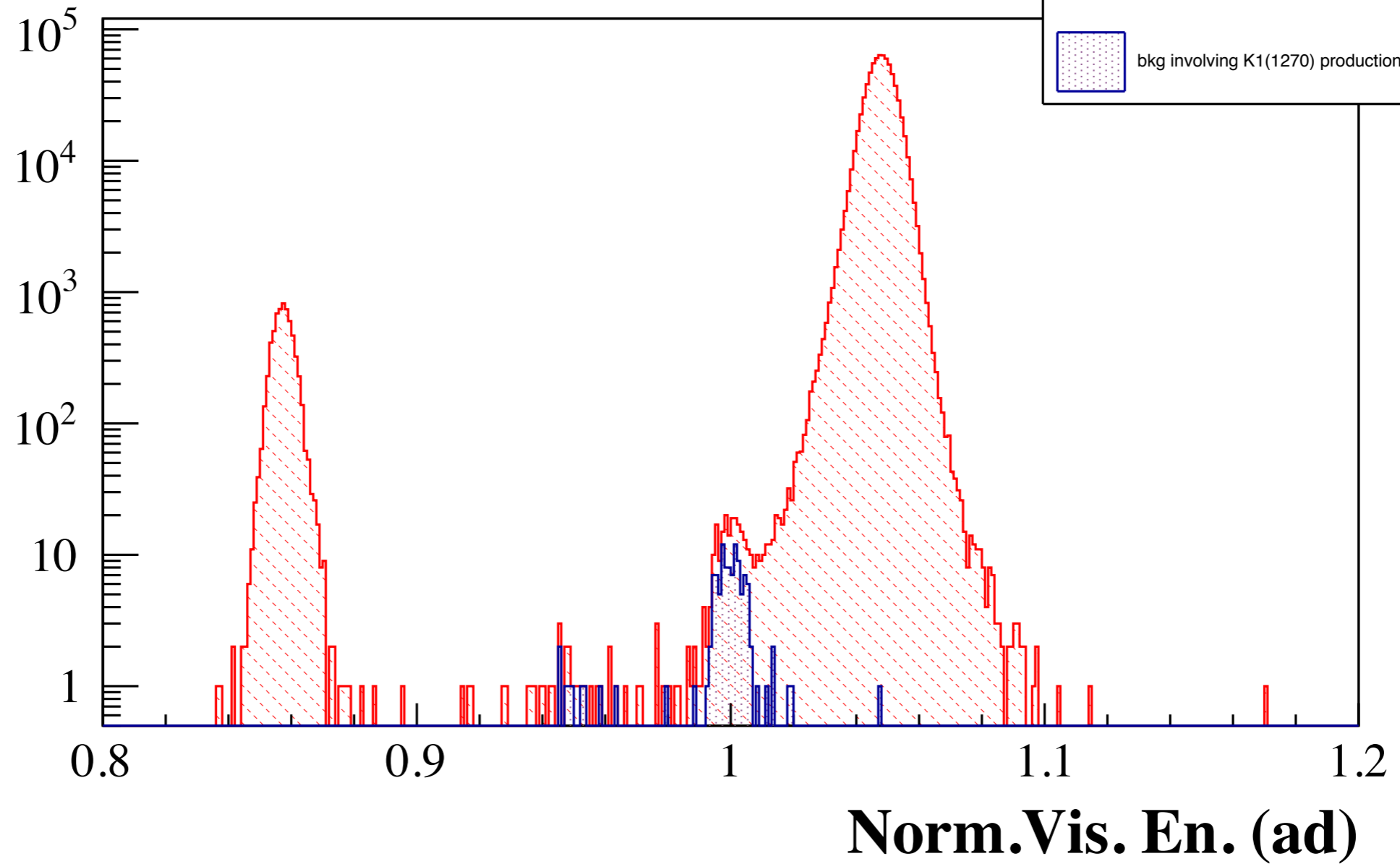
# Background analysis 2009



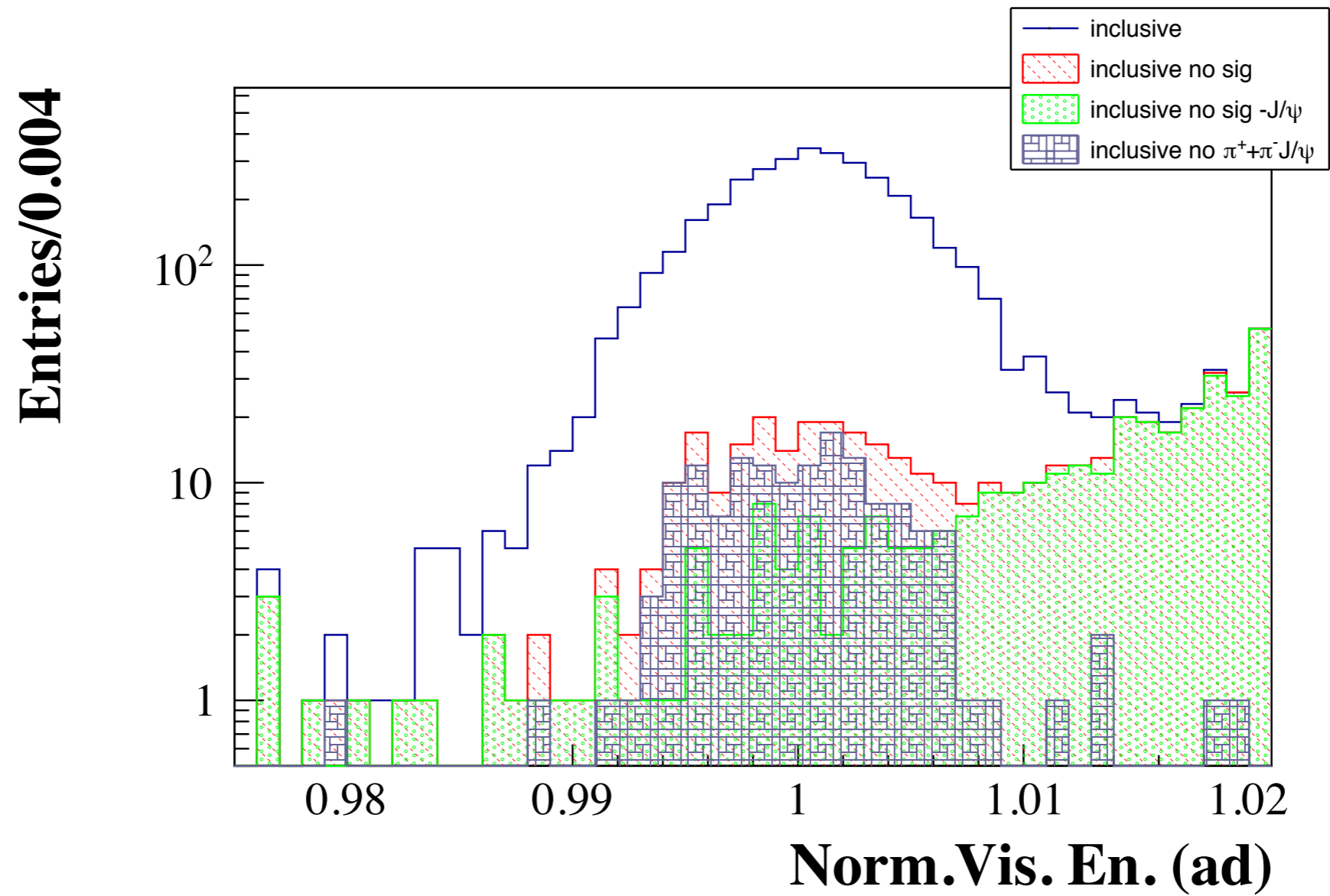


# Background analysis 2009

**Entries/0.004**

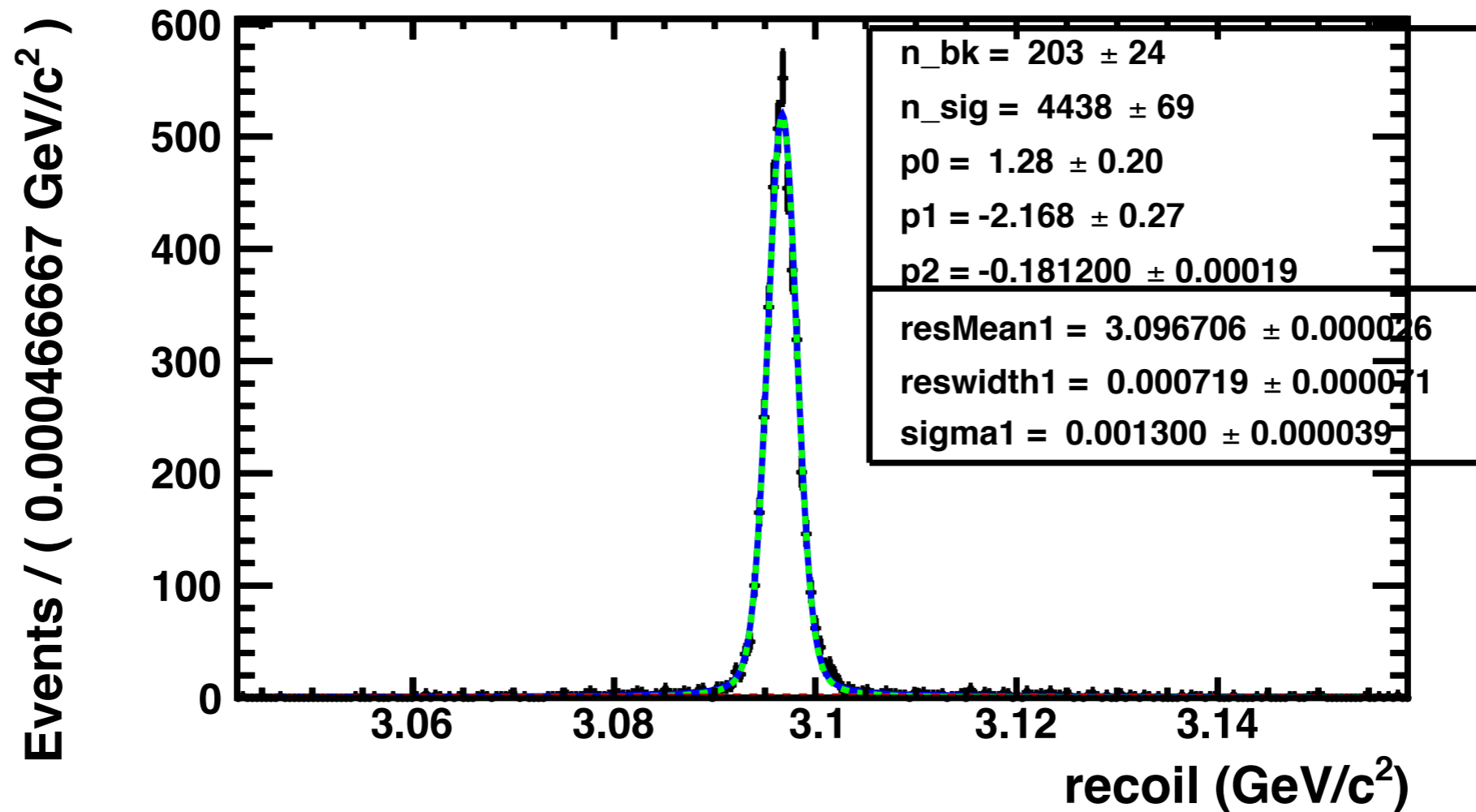


let's look to our channel range!!!



# Data-driven bkg evaluation 2009

UML voigtian+2nd order Chebichev



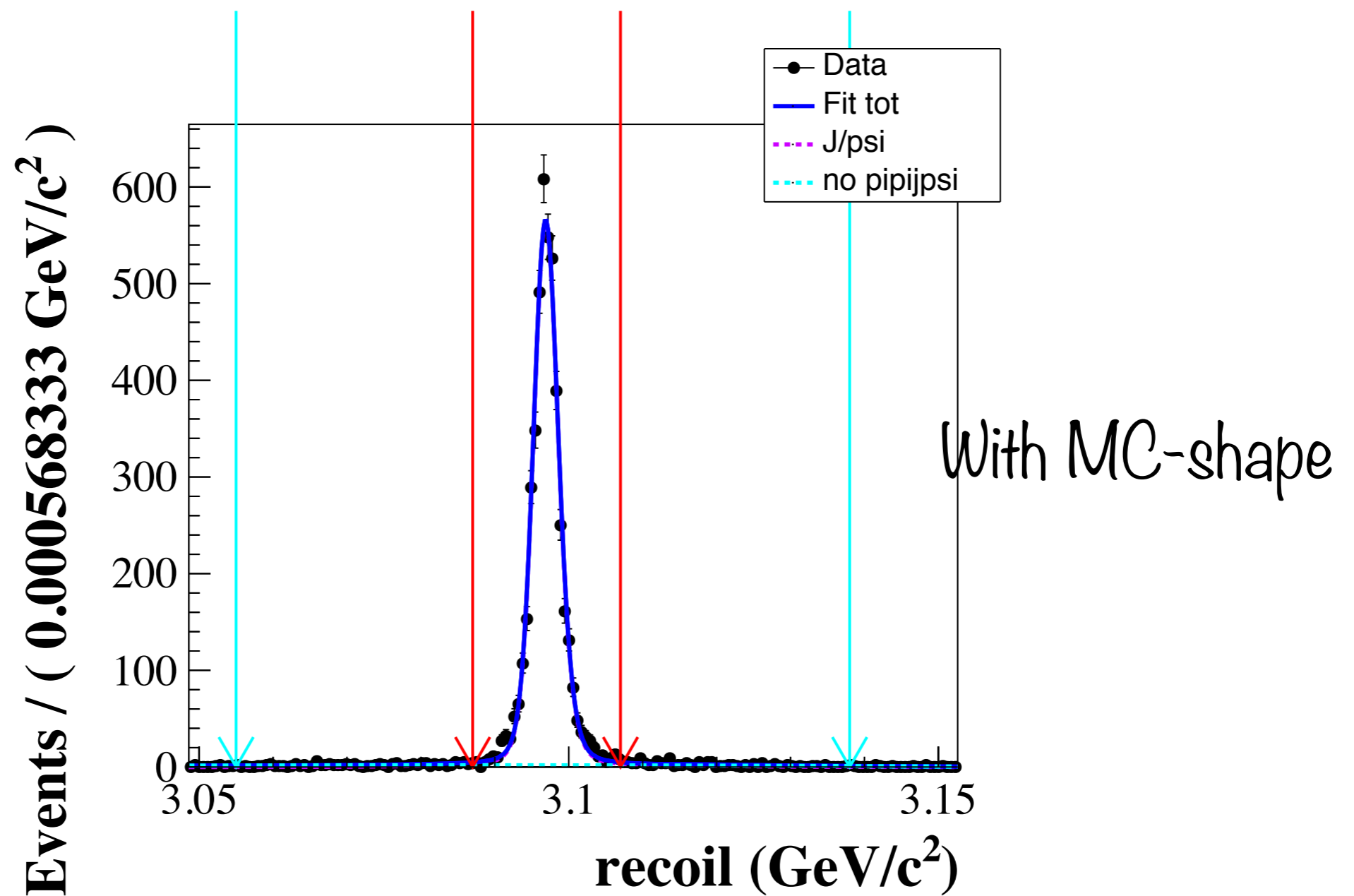
$55 \pm 7$  bkg event in KK range

$(1.26 \pm 0.19)\%$

to be compared with 2012

(In the signal range  $(0.80 \pm 0.10)$  of bkg)

# Data-driven bkg estimate 2009



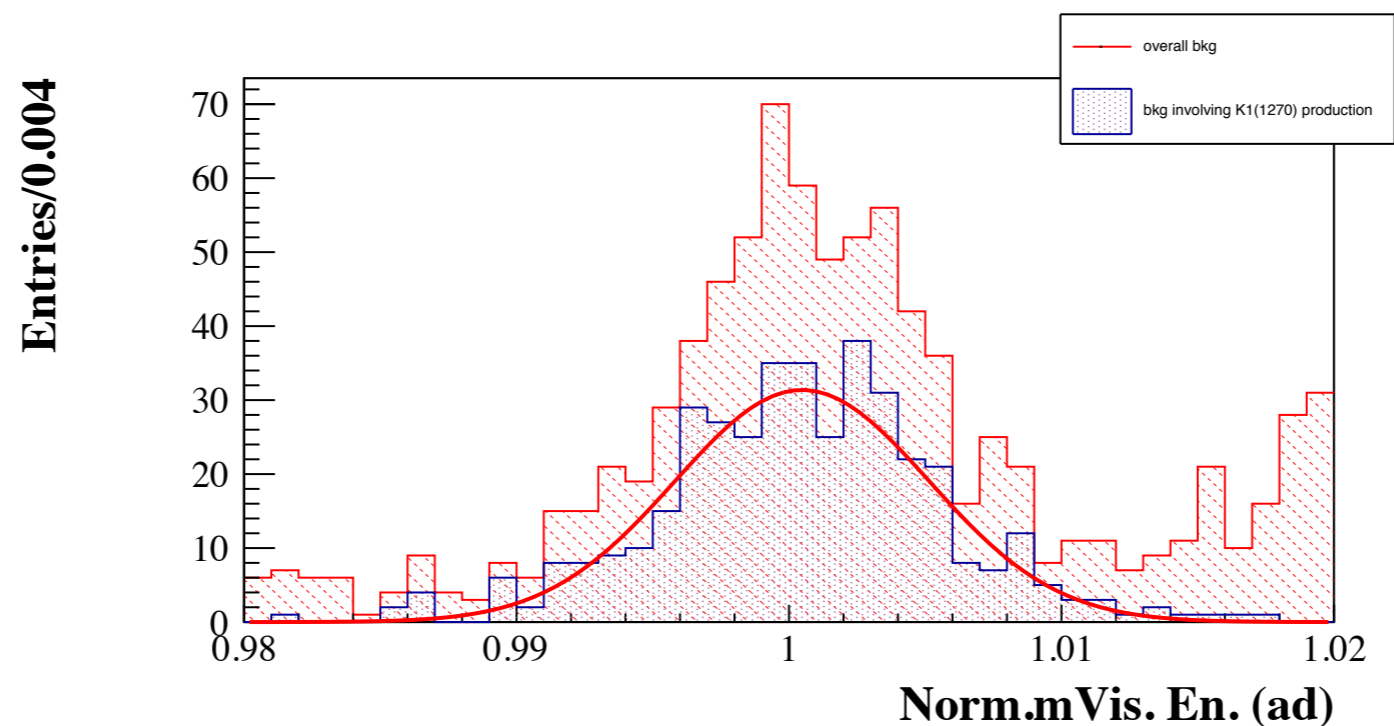
$59 \pm 8$  (4469 signal)  $\rightarrow$   $(1.3 \pm 0.2)\%$

Fair agreement!!!

# Non-pípijpsi gauss parameters 2009

...due to the low statistics...refer to 2012

# How to model the peaking backgrounds (2012)?



Gaussian fit to INC-MC data—>Parameters fixed

Fitted with a gaussian function:

Mean compatible with signal mean—>FIXED TO THAT

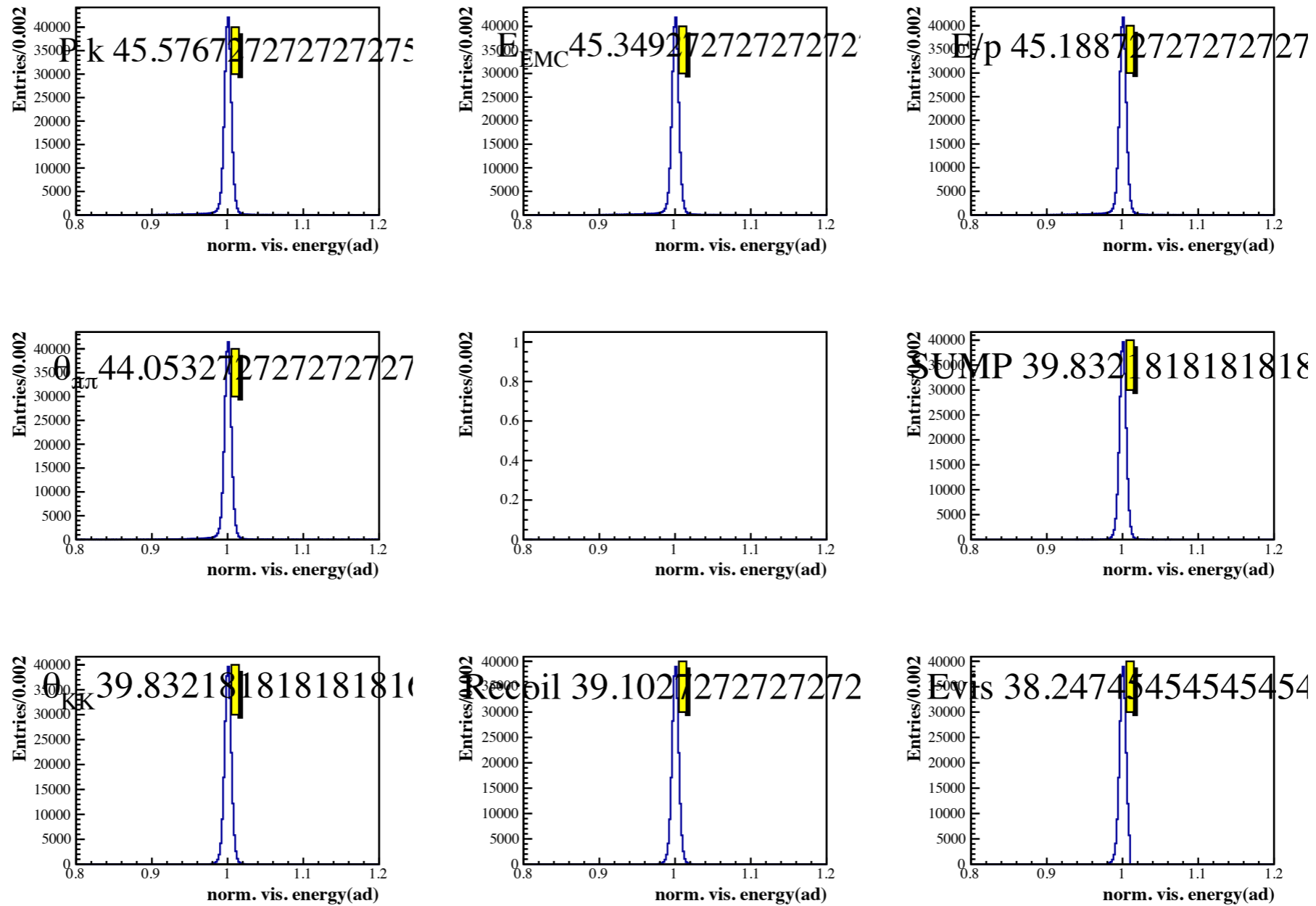
Sigma= $(4.720 \pm 0.239) \times 10^{-3}$  (wider than signal)



cut flow 2009

# Cutflow 2009

Kk

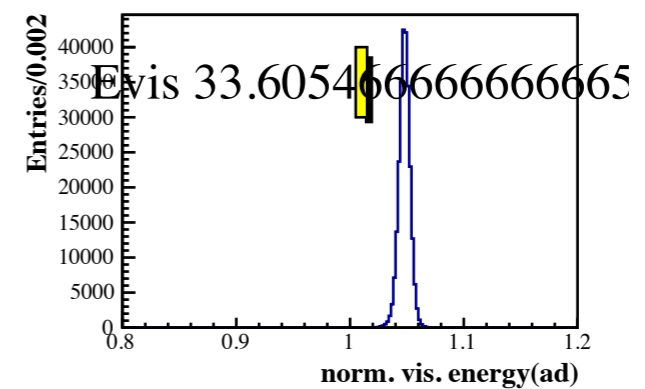
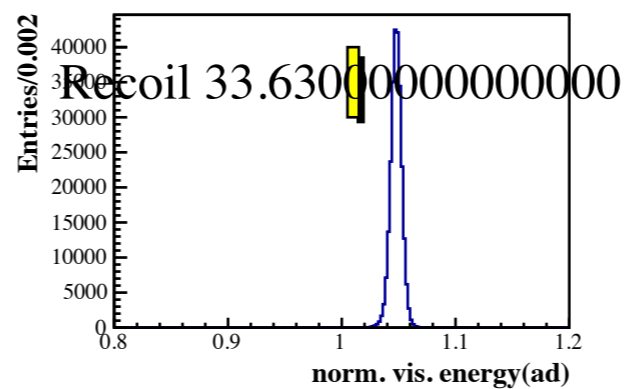
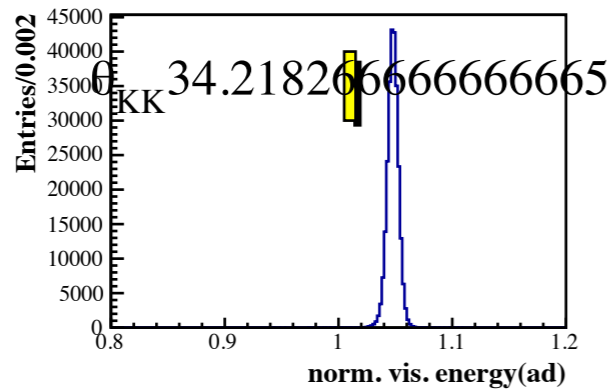
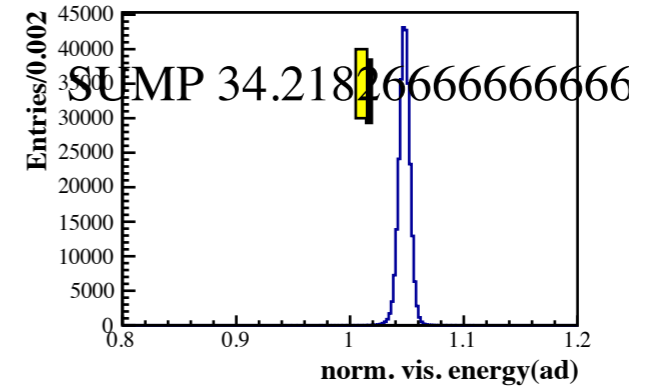
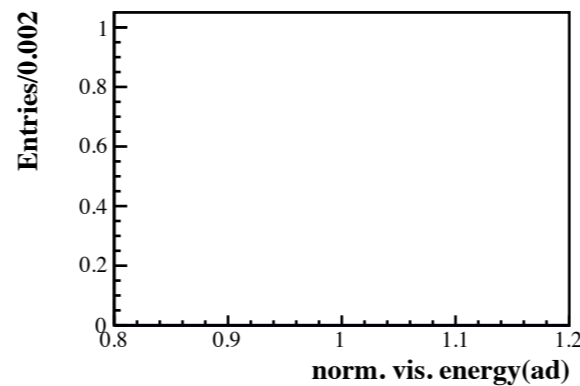
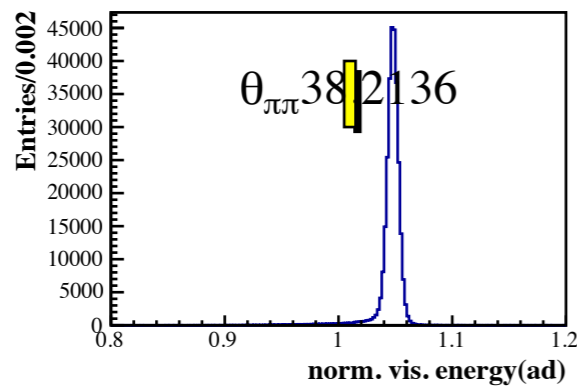
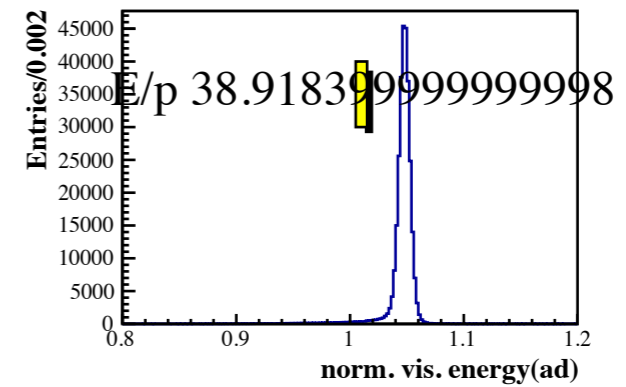
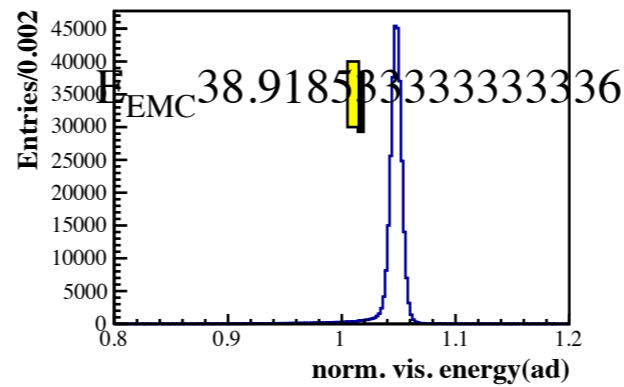
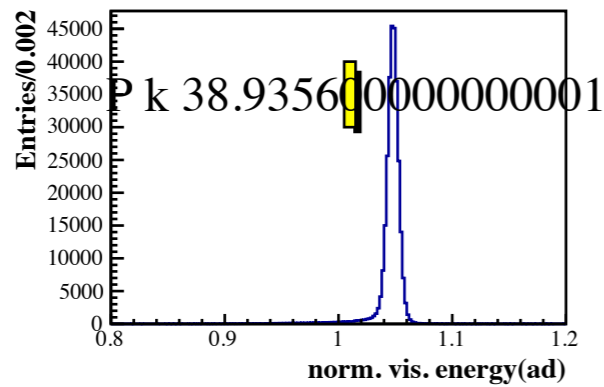


$(37.25 \pm 0.06)\%$   $(38.25 \pm 0.06)\%$  2009



# Cutflow 2009

Mumu

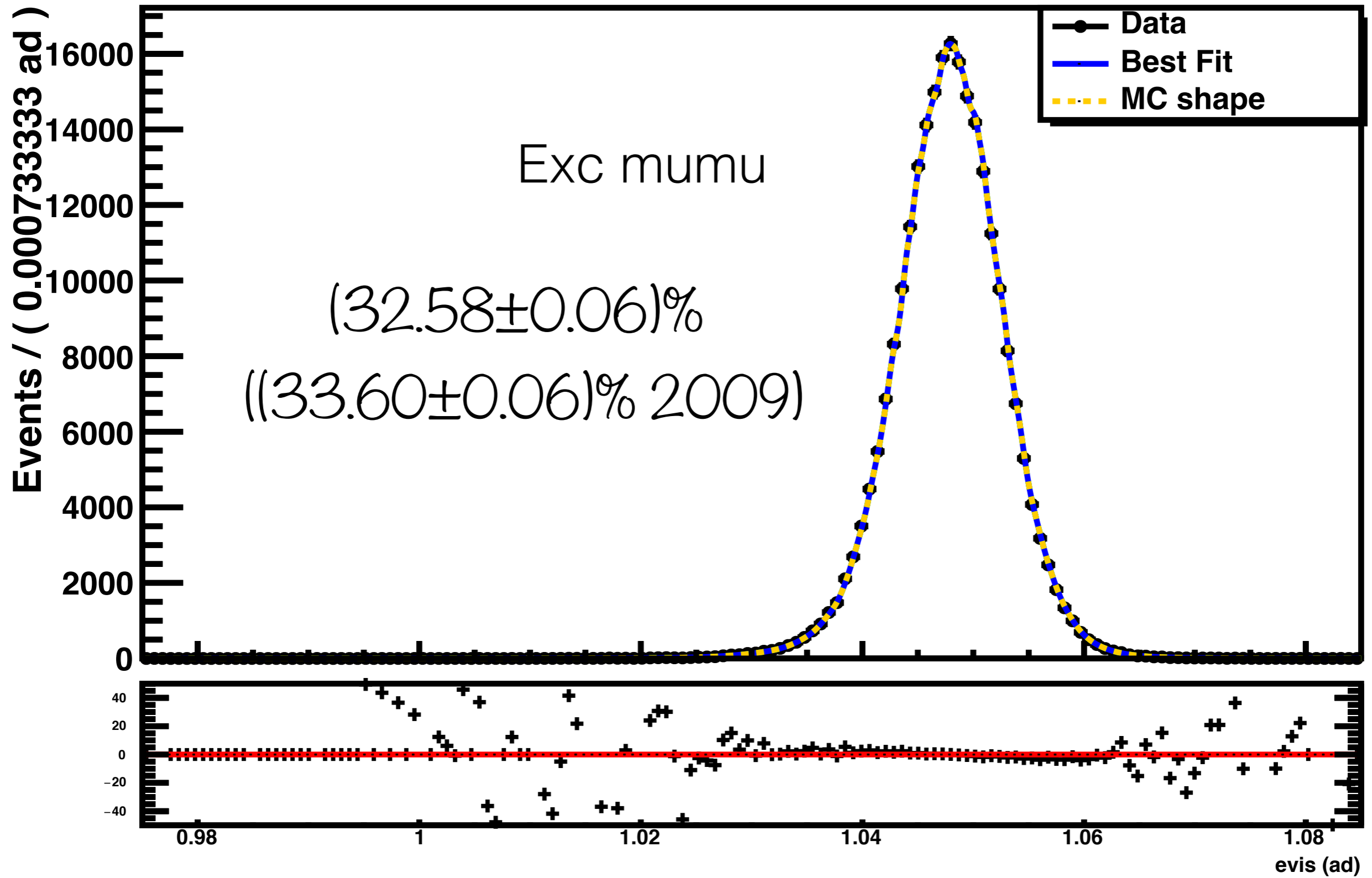


$(32.58 \pm 0.06)\%$   $(33.60 \pm 0.06)\%$  2009



Efficiencias 2009

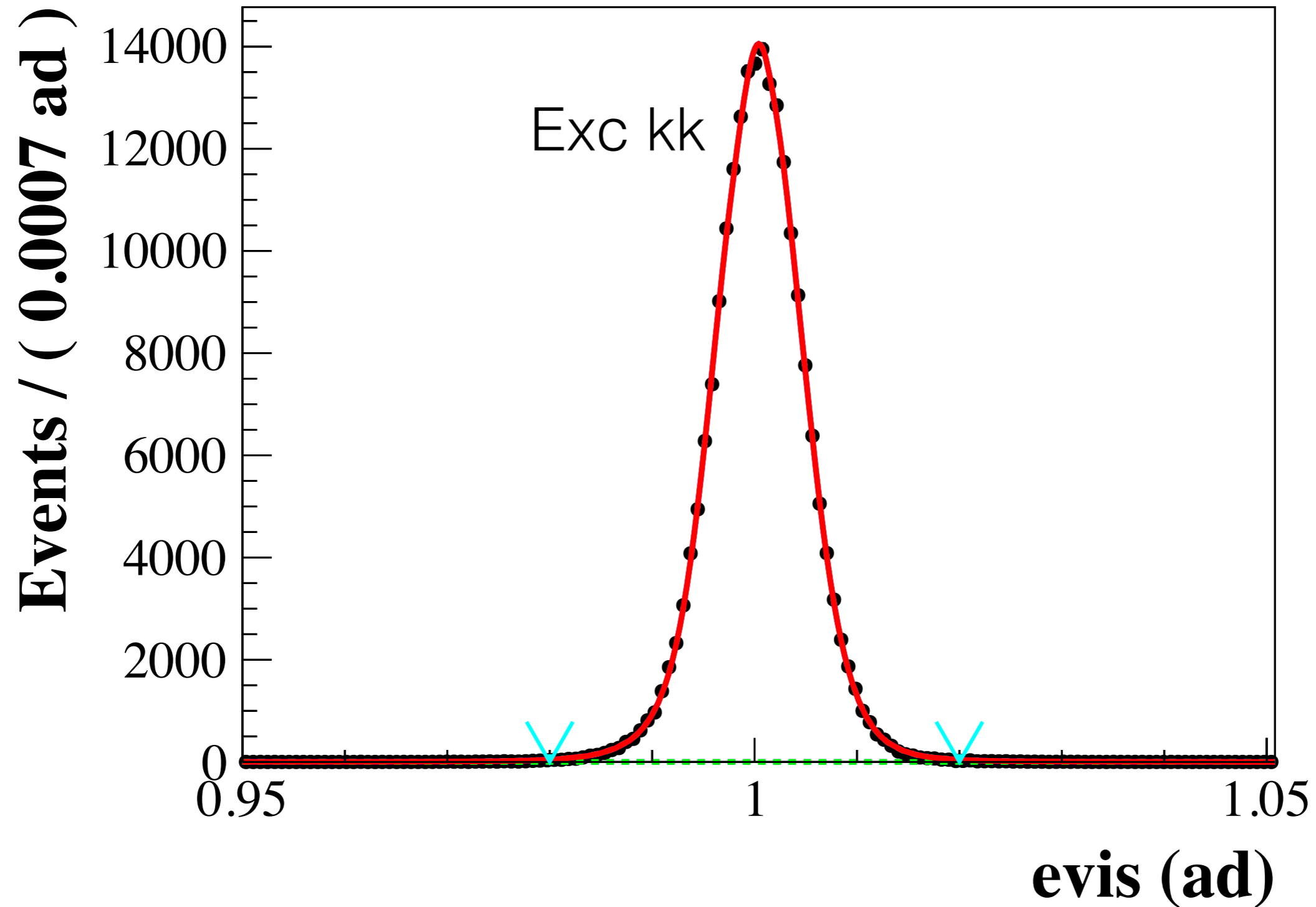
# Efficiências evaluation 2009



# Efficiències evaluation 2009

$(37.25 \pm 0.06)\%$

$((38.25 \pm 0.06)\% \text{ 2009})$



Also the efficiencies are compatible between

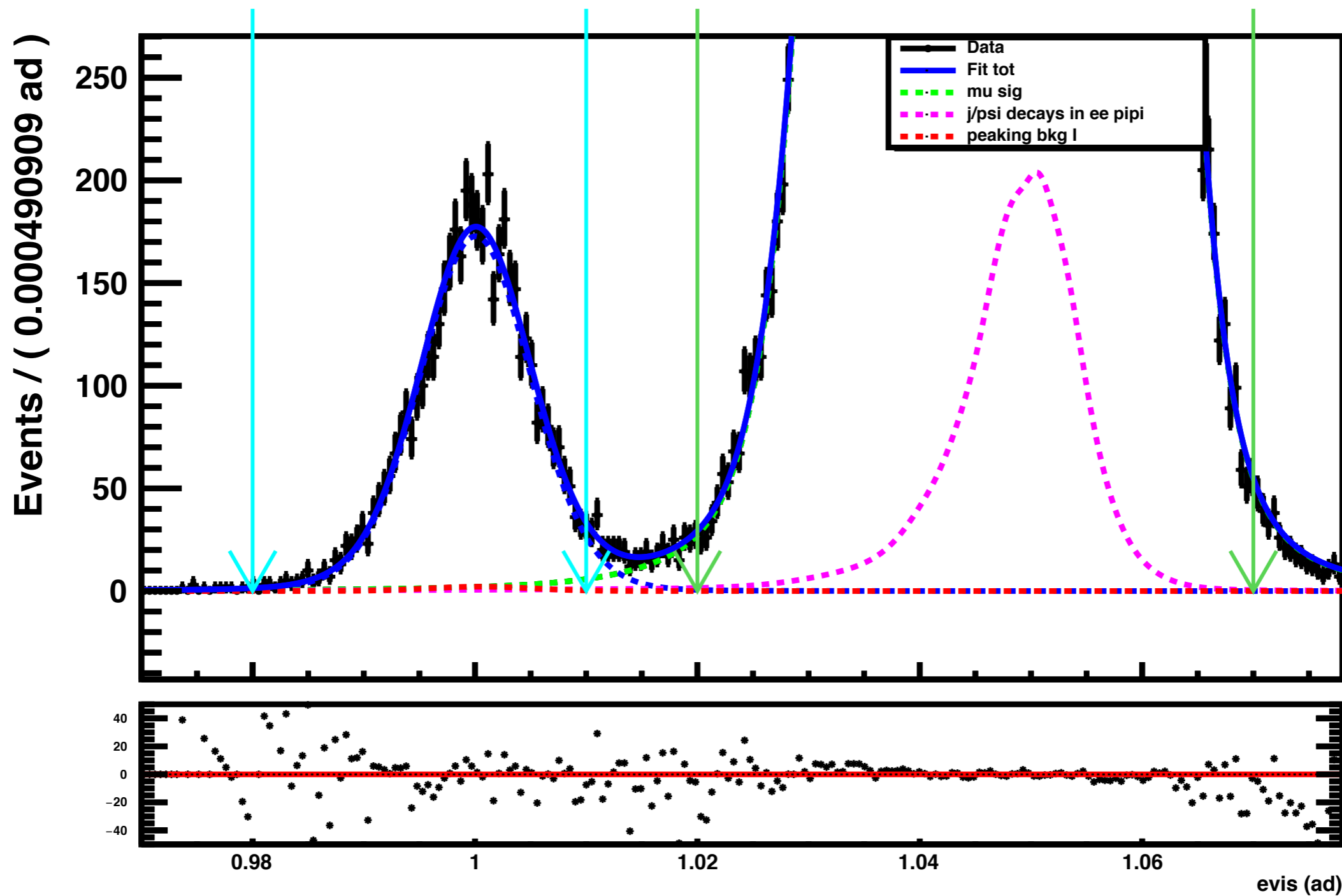
2009 and 2012

!!!

The image is a complex abstract drawing on a yellow background. It features a variety of geometric and organic shapes. In the top left, there is a dark blue five-pointed star. A large red circle is positioned in the upper right quadrant. A blue wavy line runs across the bottom of the page. The drawing is filled with thin black lines, some forming triangles and circles, and others creating a sense of movement or flow. There are also several small, scattered dots and a cluster of small black crosses. The overall composition is dense and layered, with various elements overlapping and interacting. The text "Preliminary results 2009" is centered in the middle of the drawing in a bold, black, sans-serif font.

**Preliminary results 2009**

# Yields determination 2009



$$N_{KK} = 4328 \pm 64$$

Fixed ranges

$$N_{\mu\mu} = 736592 \pm 858$$

# BR determination 2009

from PDG

$$BR_{KK} = R * BR_{\mu\mu} = (3.08 \pm 0.05 \pm 0.06) \times 10^{-4}$$

$$R_{\text{eff}} = 0.8786 \pm 0.0018$$

$$N_{KK} = 4328 \pm 64$$

$$R = 0.00516 \pm 0.000007$$

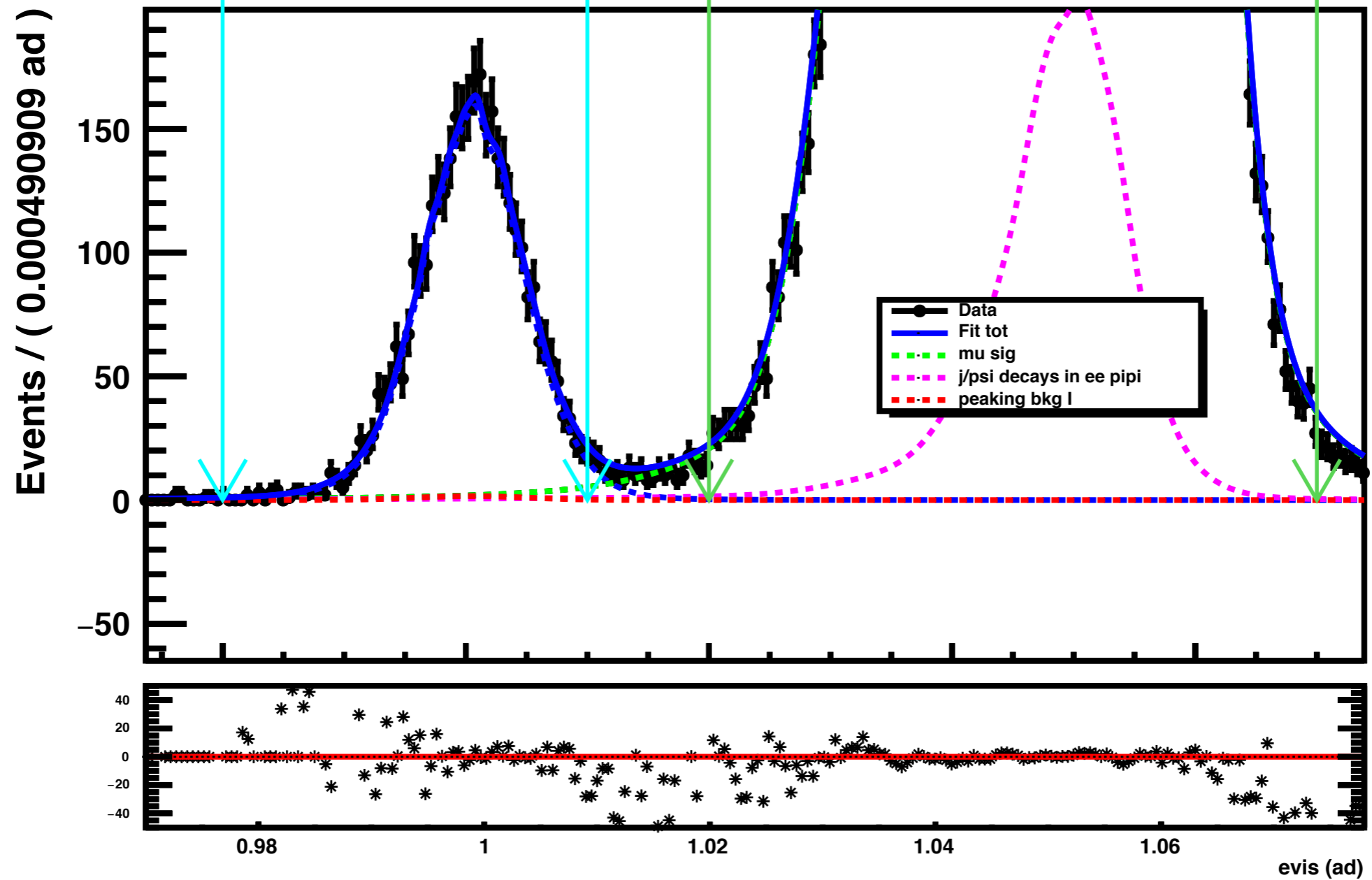
$$N_{\mu\mu} = 736592 \pm 858$$

$$BR_{\mu\mu} = (5.961 \pm 0.033)$$

Systematics to be further studied (this from previous analysis)



1/0 check 2009



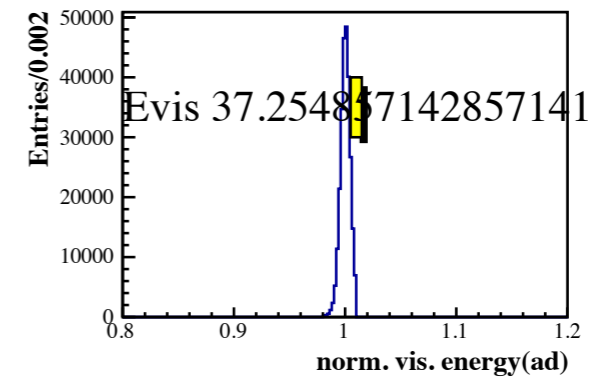
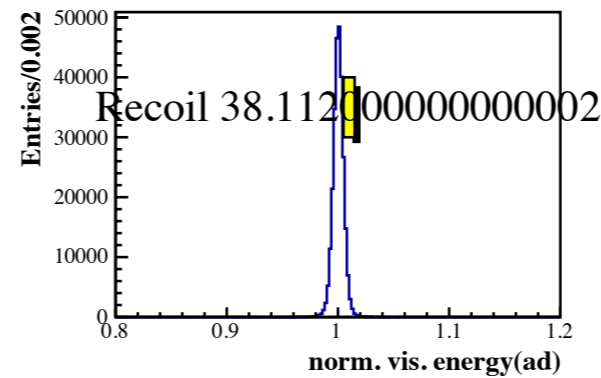
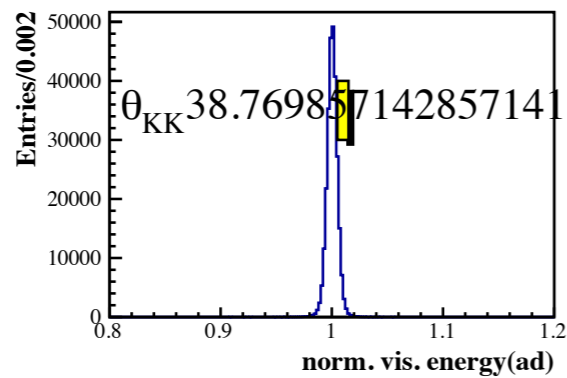
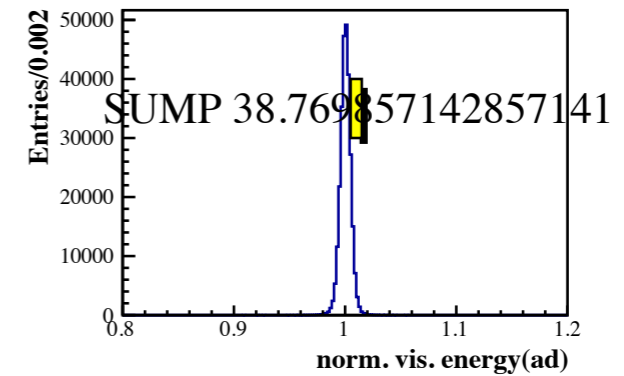
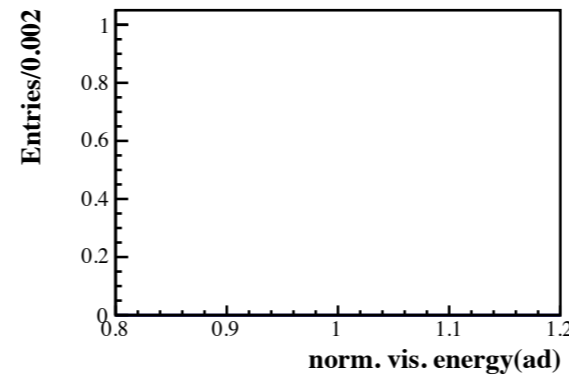
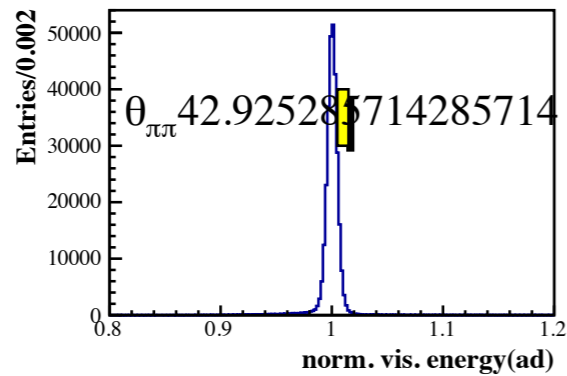
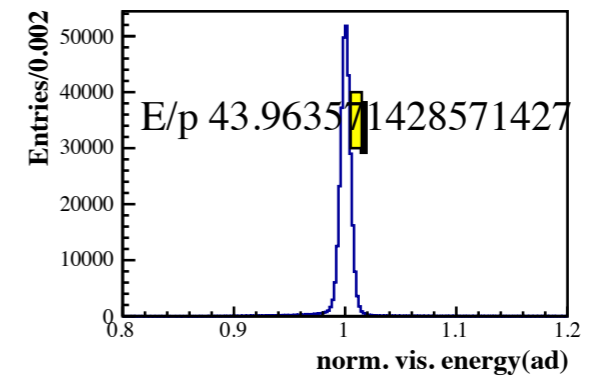
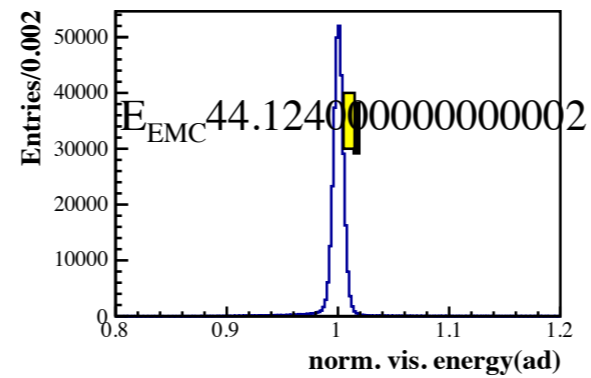
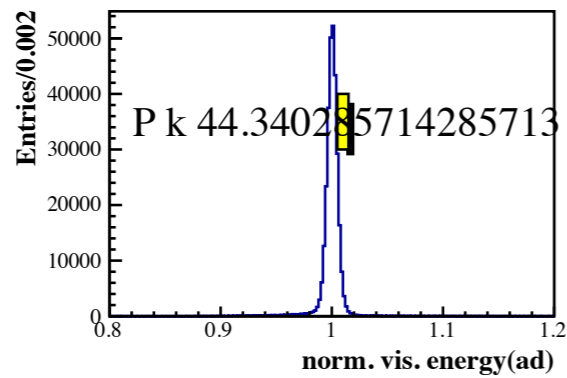
in agreement with pdf table.



New 2012

# Cutflow 2012

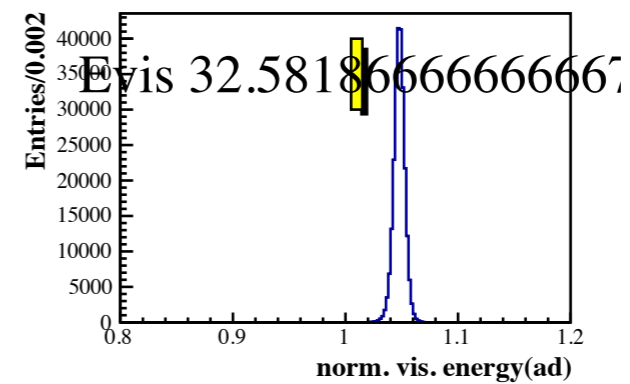
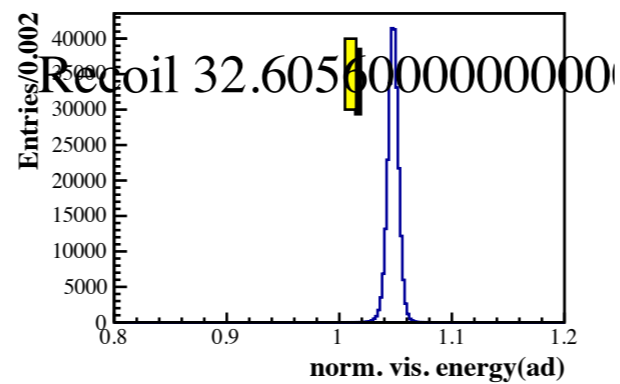
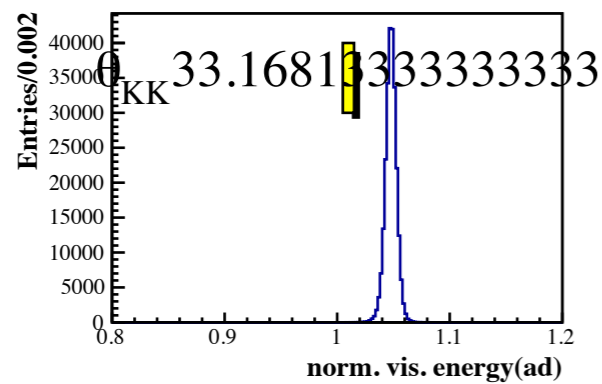
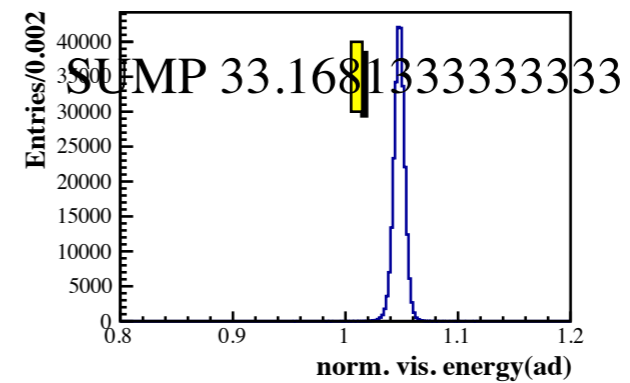
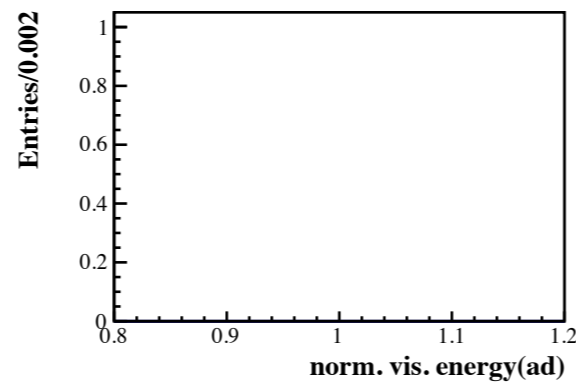
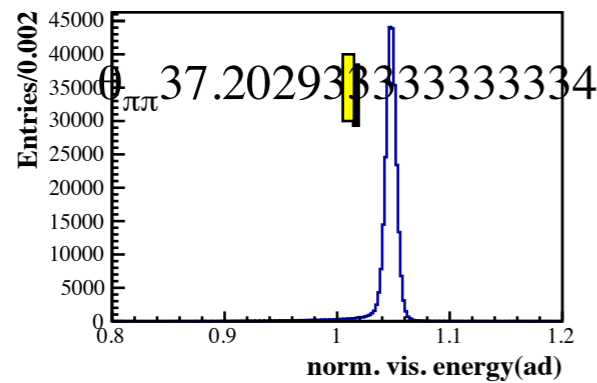
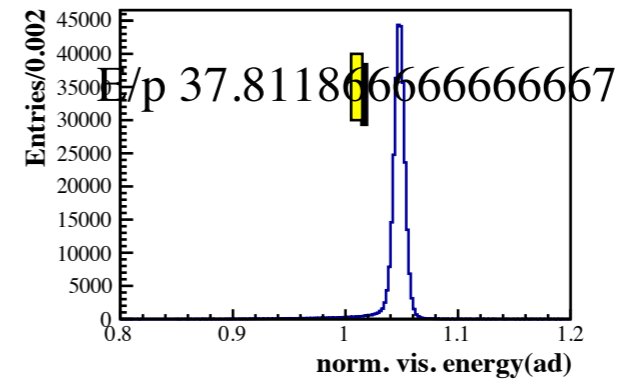
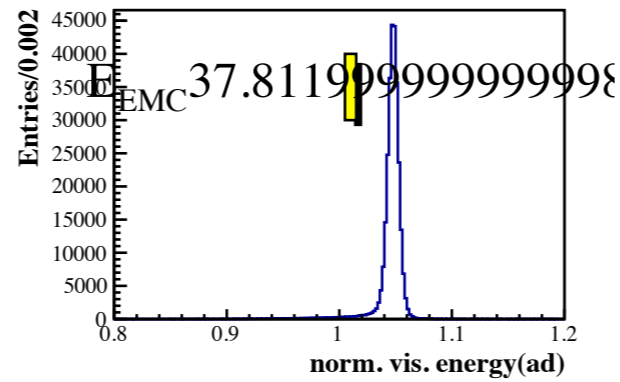
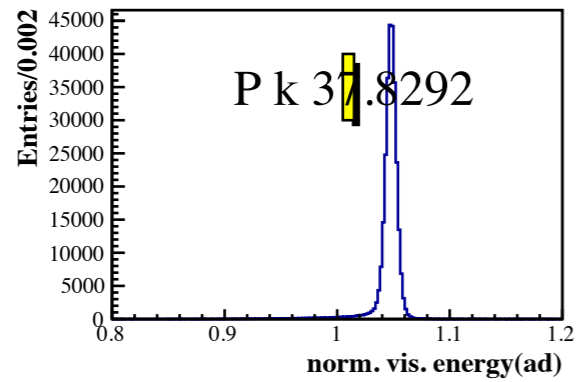
Kk



$(37.25 \pm 0.06)\% (38.25 \pm 0.06)\% 2009$

# Cutflow 2012

Mumu



$32.58 \pm 0.06\%$  ( $33.60 \pm 0.06\%$  2009)

# Efficiències evaluation 2012

$$R = \frac{BR_{KK}}{BR_{\mu\mu}} = \frac{N_{KK}}{\epsilon_{KK}} \cdot \frac{\epsilon_{\mu\mu}}{N_{\mu\mu}}$$

$$R_{\text{eff}} = 0.8746 \pm 0.0017$$

$$N_{KK} = 4364$$

$$(2.82 \pm 0.03) \cdot 10^{-4} \quad (2009)$$

# BR determination 2012

from PDG

$$BR_{KK} = R * BR_{\mu\mu} = (3.05 \pm 0.03 \pm 0.06) \times 10^{-4}$$

$$R_{\text{eff}} = 0.8754 \pm 0.0019$$

$$N_{KK} = 13409 \pm 116$$

$$R = 0.00511 \pm 0.000005$$

$$N_{\mu\mu} = 2293345 \pm 1514$$

$$BR_{\mu\mu} = (5.961 \pm 0.033)$$



ALL TOGETHER

$$BR_{KK} = R * BR_{\mu\mu} = (3.08 \pm 0.05 \pm 0.06) \times 10^{-4}$$

$$BR_{KK} = R * BR_{\mu\mu} = (3.05 \pm 0.03 \pm 0.06) \times 10^{-4}$$

The two BR are in fair agreement!!!

GREAT!!!!



# BR determination 2012+2009 weighted mean

$$BR_{KK} = (3.06 \pm 0.03 \pm 0.06) \times 10^{-4}$$

To be compared with PDG  $(2.86 \pm 0.21) \times 10^{-4}$

And to BABAR (PRD92,072008 (2015))  
 **$BR = (3.22 \pm 0.20 \pm 0.12) \times 10^{-4}$  with positive phase**  
 $= (3.50 \pm 0.20 \pm 0.12) \times 10^{-4}$  with negative phase

# BR determination 2012+2009 weighted mean

$$BR_{KK} = (3.06 \pm 0.03 \pm 0.06) \times 10^{-4}$$

To be compared with PDG  $(2.86 \pm 0.21) \times 10^{-4}$

And to BABAR (PRD92,072008 (2015))

$$BR = (3.22 \pm 0.20 \pm 0.12) \times 10^{-4} \text{ with positive phase} \\ = (3.50 \pm 0.20 \pm 0.12) \times 10^{-4} \text{ with negative phase}$$


...and to be compared to our PID analysis (same channel)

$$BR_{KK} = \frac{N_{KK}}{N_{J/\psi}} = \frac{N_{KKobs}/\epsilon_{KK}}{N_{\psi'} BR_{\pi\pi J/\psi}} \\ = (3.21 \pm 0.03 \pm 0.17) \times 10^{-4}$$

# BR determination 2012+2009 weighted mean

$$BR_{KK} = (3.06 \pm 0.03 \pm 0.06) \times 10^{-4}$$

...and to be compared to our phase fitting results:



$B_{out} \times 10^{-4}$	$\phi$	$\sigma_c(pb)$
$2.98 \pm 0.08$	$88.4 \pm 9.1$	$24.8 \pm 1.3$

BR determination 2012+2009

to be done!!

# Conclusions

- ★ 2009 samples (DATA+ONC+EXC) processed
- ★ 2012 reprocessed with updated algorithm
- ★ Comparison 2009/2012
- ★ Preliminary result 2009
- ★ Preliminary result 2012
- ★ Preliminary result 2009+2012 weighted mean

# Outlook / next to do / plans

- ☀ Preliminary result 2009+2012
- ☀ Dedicated systematics study
- ☀ memo update
- ☀ P&S presentation

Should be 1-2 month, we will see (boundary conditions very challenging)