Cross section measurement of $\eta J/\psi$ and $\pi^0 J/\psi$ at $\sqrt{s}$= 4.009GeV

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What has this memo done?

- With 477pb^{-1} data sample collected at $\sqrt{s}$=4.009GeV, the production of $e^+e^- \rightarrow \eta J/\psi$ is observed with a statistical significance of greater than 10σ as well as its branch ratio
- The production of $e^+e^- \rightarrow \pi^0 J/\psi$ is searched for but no significance signal is observed only an upper limits of branch ratio is given

What does this memo achieved the goals?

- The Born-order cross section is calculated using the following formulism as well as branch ratio:

$$\sigma^B = \frac{N^{obs}}{\mathcal{L}_{int}(1+\delta)\epsilon\mathcal{B}}$$

$$(1+\delta) = \frac{\sigma^{obs}}{\sigma^B} = \frac{\int \mathrm{BW}(s(1-x))F(x,s)dx}{\mathrm{BW}(s)}$$

- π^0 and η are constructed by two γs and J/ψ are constructed by e^+e^- and $\mu^+\mu^-$ channels

Event Selection Criteria

- Normal event selection criteria has been applied
- Some special event selection criteria
  - ➢ For electron candidates: E/p ratio value larger than 0.8 of each track
  - ➢ For muon candidates: deposited energy of each track less than 0.4GeV

Event Selection Criteria

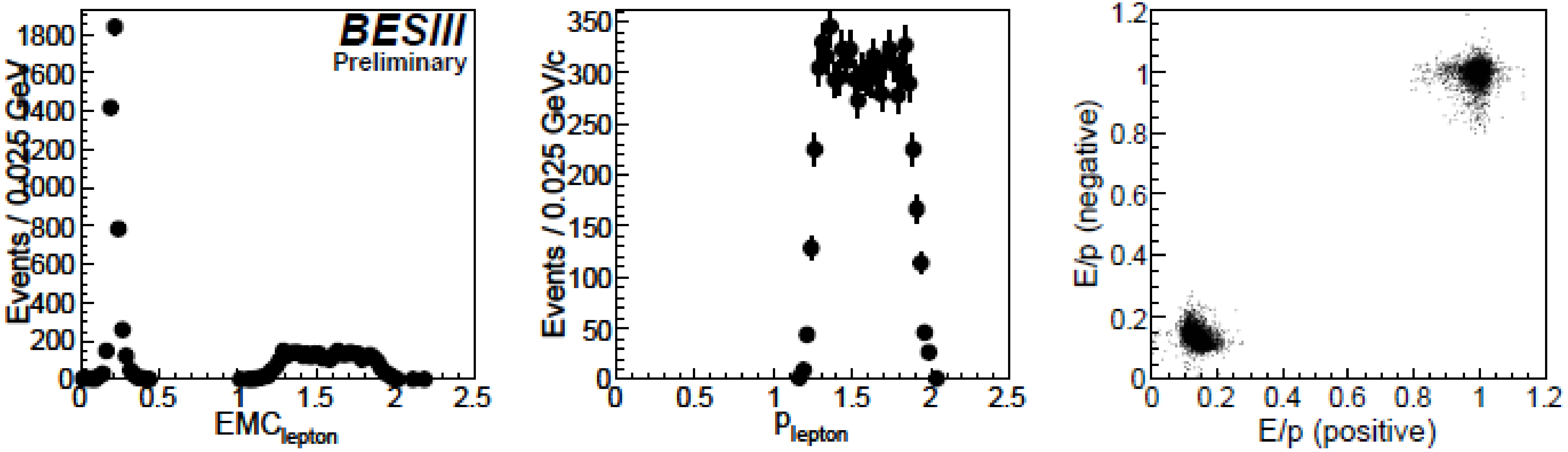


FIG. 1: (left) EMC deposit energy distribution, (middle) momentum distribution, and (right) E/p scatter plot of leptons in $\eta J/\psi$ signal MC sample. Electron events and muon events are separated clearly by EMC deposit energy and E/p ratio.

Event Selection Criteria

- To further separate events with one real photon and one low energy fake photon (for example $\gamma_{ISR} J/\psi$ events), three-constraint (3C) kinematic fits are also performed with the two charged tracks and two photon candidates (missing the energy of the low energy photon).

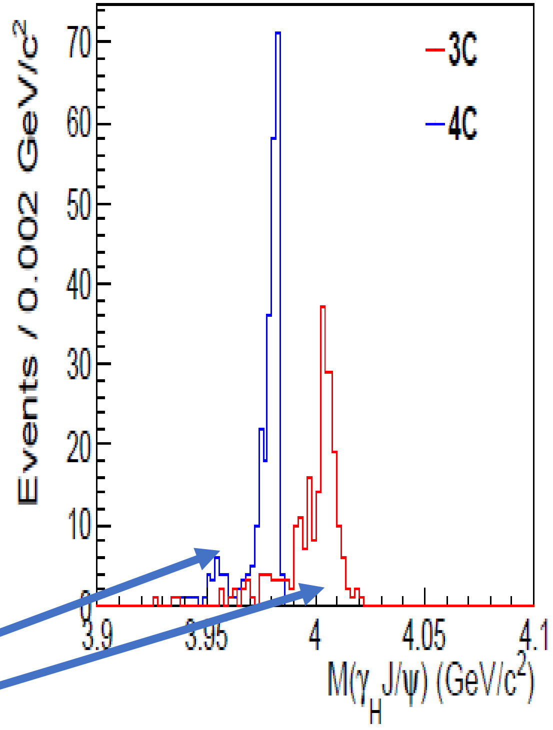


FIG. 3: The $M(\gamma J/\psi)$ mass distribution of 4C kinematic fit vs. 3C kinematic fit from $\gamma_{ISR} J/\psi$ MC sample. Mass of 4C fit is lowered due to the inclusion of one low energy fake photon but 3C fit is not affected.

Question from Hao: what are 3C and 4C fit? Why the peak from 4C is a little lower than that from 3C

Event Selection Criteria

- In order to veto $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ background in $\pi^0 J/\psi$ search, at least one charged track have MUC hit depth larger than 30 cm.

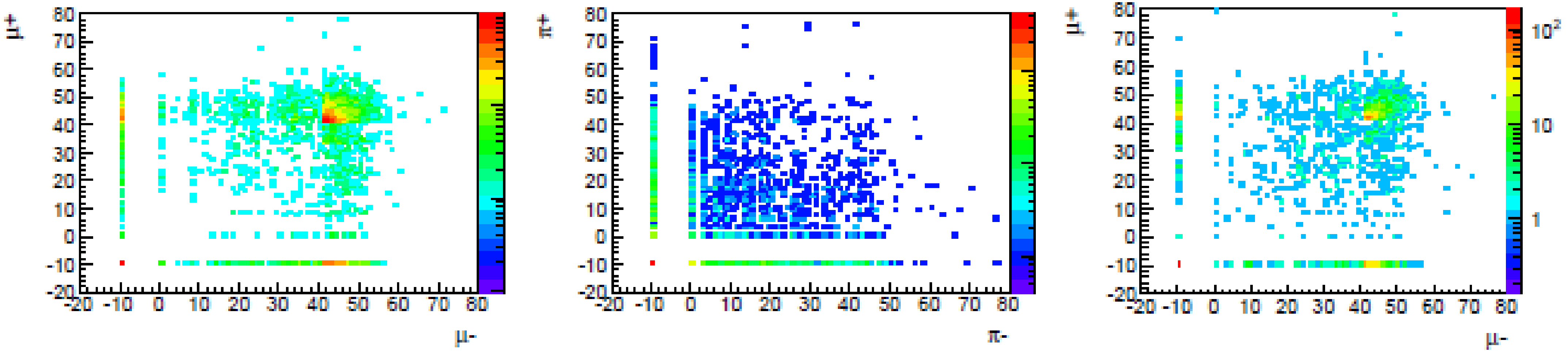


FIG. 5: Scatter plot of MUC hit depth distribution for $\pi^0 J/\psi$ MC events (left), $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ MC events (middle) and $\psi' \rightarrow \eta J/\psi$ data events (right).

Fit of M(γγ) spectra

- Fit to the $M(\ell^+\ell^-)$ invariant mass distribution of $\eta J/\psi$ MC sample with double Gaussian function

Yields a J/ψ mass of 3100.0+/-0.8 MeV/c^2 with a resolution of 14 MeV/c^2 for lepton pairs

the J/ψ mass window is determined to be between 3.075 GeV/c^2 and 3.125 GeV/c^2 for both modes

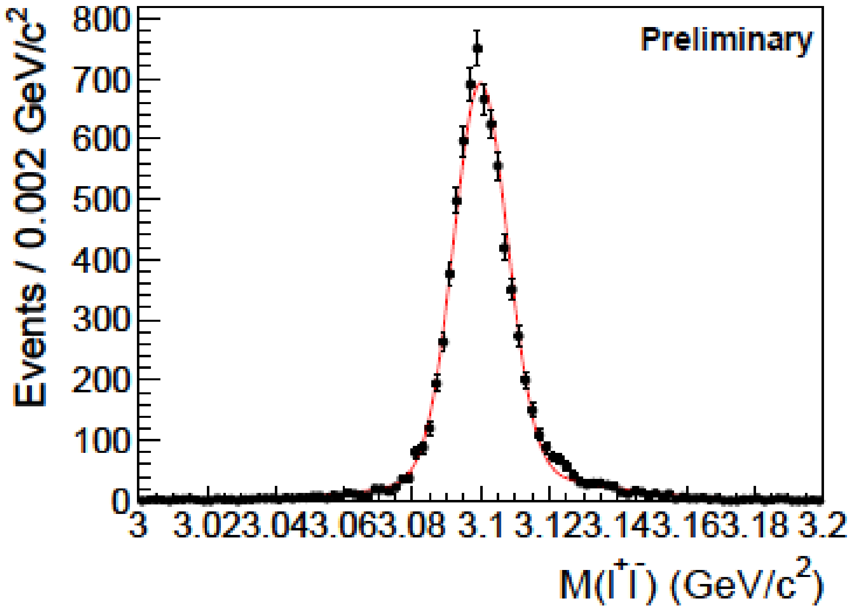


FIG. 7: Fit $M(\ell^+\ell^-)$ invariant mass distribution of $\eta J/\psi$ MC sample with double Gaussian function. The fit yields $M(J/\psi) = 3100 \pm 0.8$ MeV/c^2 with resolution $\sigma = 14$ MeV/c^2.

To reduce the uncertainty of background estimation, J/ψ mass sideband is chosen to be $2.95 < M(\ell^+\ell^-) < 3.05$ GeV/c^2 and $3.15 < M(\ell^+\ell^-) < 3.25$ GeV/c^2, which is 4 times of the signal region.

Fit of M(γγ) spectra

- Fit of M(γγ) spectra

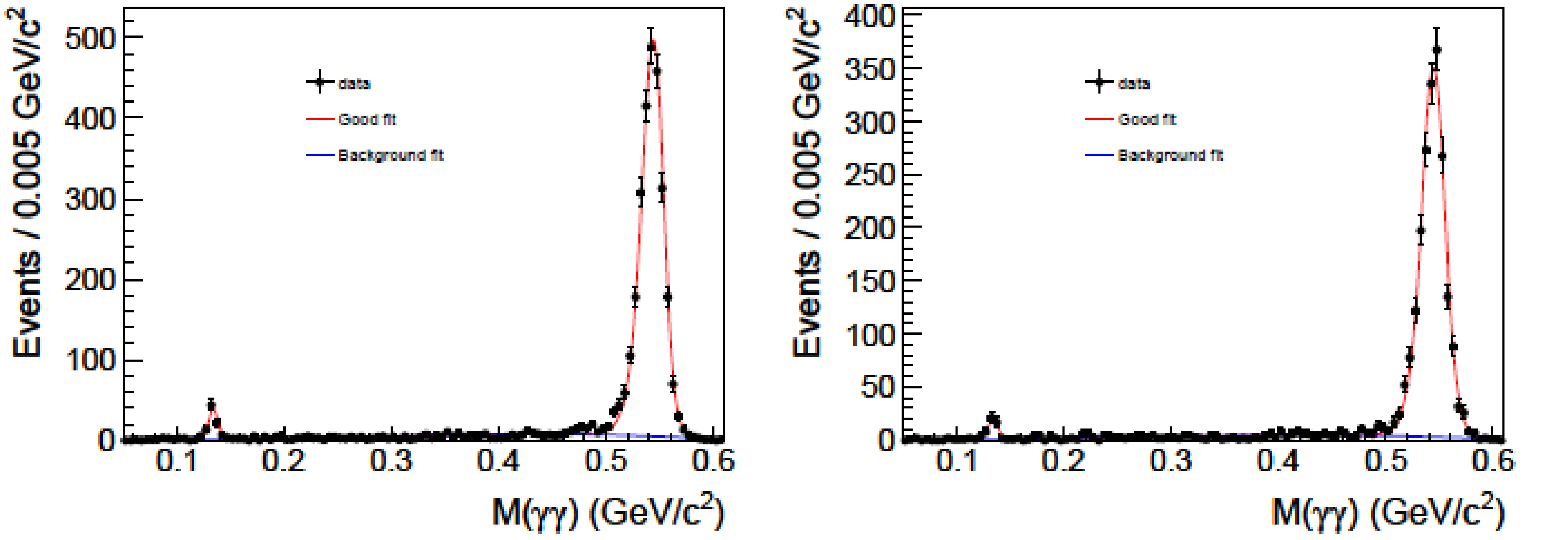


FIG. 8: Fit $M(\gamma\gamma)$ invariant mass distribution in $\mu^+\mu^-$ mode (left) and e^+e^- mode (right) for $\psi' \to \eta/\pi^0 J/\psi$ control sample with MC histogram convolving free Gaussian functions.

$N(\eta)_{\mu+\mu-}$=111.4+/-11.0; $N(\eta)e^+e^-$=61.4+/-10.5

Results

- The Born-order cross section is calculated using the following formulism:

$$\sigma^B = \frac{N^{obs}}{\mathcal{L}_{int}(1+\delta)\epsilon\mathcal{B}}$$

$$(1+\delta) = \frac{\sigma^{obs}}{\sigma^B} = \frac{\int \mathrm{BW}(s(1-x))F(x,s)dx}{\mathrm{BW}(s)}$$

Results

TABLE I: Summary of the systematic errors (%) in $\mu^+\mu^-$ mode and e^+e^- mode.

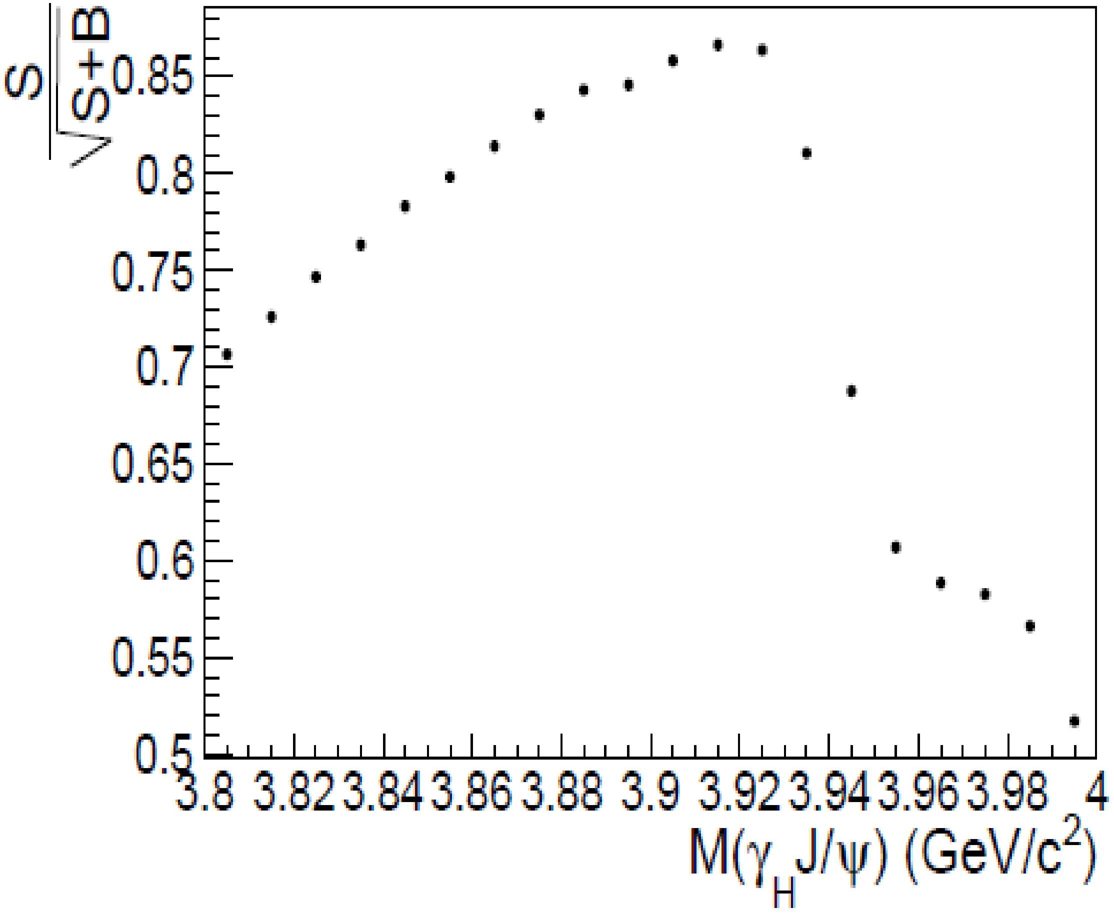
Source	$\eta\mu^+\mu^-$	ηe^+e^-	$\pi^0\mu^+\mu^-$
Luminosity	1.1	1.1	1.1
Track finding	2	-	2
Photon detection	2	2	2
Lepton pair mass resolution	1.6	2.4	1.6
Kinematic fit	1.9	1.9	1.9
Background shape	1.5	3.0	9.4
$\psi(4040)$ parameters and line shape	2.0	3.3	4.0
Branching ratios	1.2	1.2	1.0
Others	1.0	1.0	1.0
Total	5.0	6.1	11.1

Questions

- From Ryuta: the center of mass energy = 4.009GeV differs from the mass of ψ(3686), so that the momentum/energy of the muons from J/ψ might be somehow different, but can we still expect that the MUC response is the same between these two?
- Answers from me: I think they are the same because when the detector detects a muon, for example, we can't distinguish whether it is from continuum process or from a resonance, we just detect a muon. To be honestly, I haven't any paper aimed at that. This judgment just based on my understanding of some papers I've read.

Questions

- From Suyu: what's S/sqrt(S+B)?
- Answers from me: basically, S are the events from signal MC S+B are the events from data. I don’ t know how the formula is got, but the function of it is to show the ratio of signal events by varying some variable to determine a cut for it



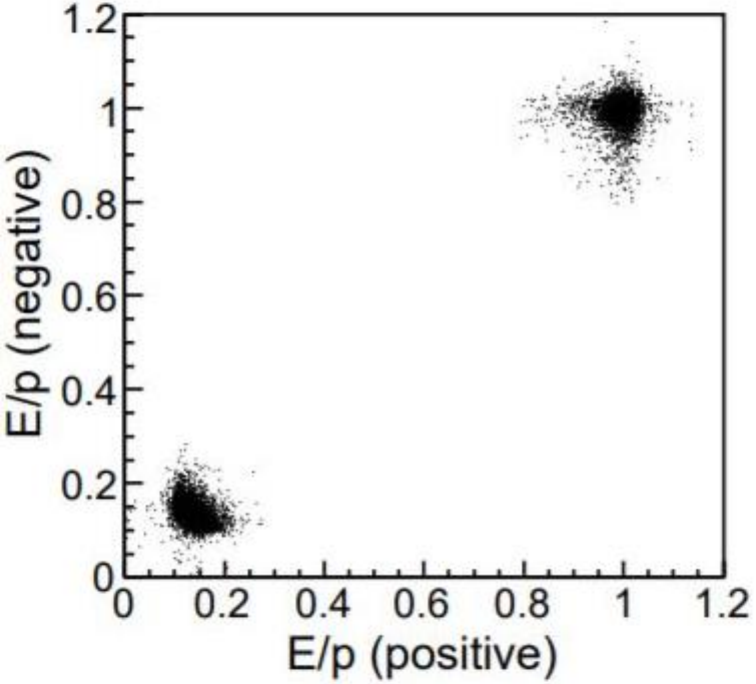
Questions

- From Kai:
  - By assuming $\eta J/\psi$, $\pi^0 J/\psi$ are all from $\psi(4040)$ decays. What kind of interactions are these two processes, strong interaction, electromagnetic, or weak interaction, explain your choice
  - When selecting electron/positron candidates from J/ψ decay, why they require E/q to be around 1(>0.8 in this paper based on the distribution shape)?
- Answers from me:
  - For the first question: sorry, I can't answer that
  - For the second question: this is also the question I want to ask

Questions

- From Tao: Could you please make a simple explanation the pictures below? Especially the E-P ratio

- Answers from me: I especially want to know why we can consider E/p ratio as a selection criteria?



Questions

- From Xin: How to explain the largest systematic uncertainty of $\pi^0\mu^+\mu^-$: 9.4%?

C. Background shape

The systematic uncertainty from background shape is estimated through varying the background shape from 3rd order polynomial to 2nd order or 4th order and the difference is 1.5% in $\mu^+\mu^-$ mode and 3.0% in e^+e^- mode for $\eta J/\psi$. For $\pi^0 J/\psi$, the uncertainty from background shape is mainly due to peaking background estimation, which gives 9.4% in $\mu^+\mu^-$ mode.

- Answers from me: Sorry, there are too many details to understand and I'm too exhausted when I came to that point

- From Hao: Displayed in former slide

Thanks!