Cross section measurement of $e^+e^- \to \gamma_{ISR}\gamma X(3872), X(3872) \to \pi^+\pi^- J/\psi, J/\psi \to l^+l^-$

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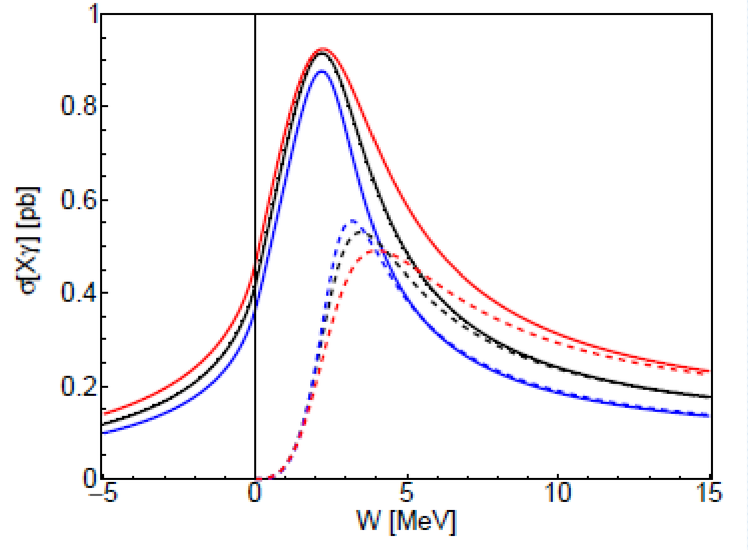
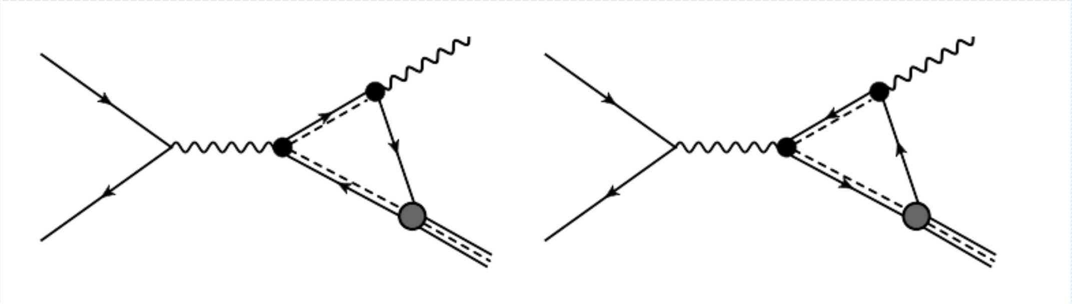
Introduction

From the paper arXiv:1904.12915v1, it hypothesis that X(3872) is a weakly bound charm-meson molecule, it can be produced in e^+e^- annihilation by the creation of $D^{*0}\bar{D}^{*0}$ from a virtual photon followed by the rescattering of the charm-meson pair into X and a photon.

The largest value of the cross section and the branching fraction into $J/\psi\ \pi^+\pi^-$ was about 0.5 pb. Upper and lower bounds can be put on the branching fraction for the decay of X into $J/\psi\ \pi^+\pi^-$: $3\% < Br < 33\%$. Thus the height of the peak from the triangle singularity at 4.016 GeV could be a significant fraction of the cross section measured in this higher energy region.

And the peak from the triangle singularity is large enough that it could be observed by the BESIII detector.





Feynman diagrams for $e^+e^- \rightarrow \gamma X$ from rescattering of $D^{*0}\bar{D}^{*0}$. The X is represented by a triple line consisting of two solid lines and a dashed line. The spin-0 charm mesons D^0 and $\bar{D}^0$ are represented by solid lines with an arrow

Data Sets

- Decay channel: $e^+e^- \to \gamma_{ISR}\gamma X(3872)$, $X(3872) \to \pi^+\pi^- J/\psi, J/\psi \to l^+l^-$
- Boss version: BOSS 703
- Signal MC: 100K at 4.180GeV
- Inclusive MC: generated at 4.180 GeV (bhabha, di-γ, di-μ, di-τ, resDD, two-γ, hadron, ISR, qqbar)
- Data:
  - ECM: 4.178GeV
  - Run number: 43716-45105 and 45418-47066
  - Luminosity(pb^-1): 3194.5 ±0.2 ±31.9

Event Selection

- **Charged Tracks:**

  $|V_z|$ <10cm && $|V_{xy}|$<1 cm && $|\cos\theta|$ <0.93 ; Ngood =4;

  Numner of total Charge =0 ; 1C for J/ψ ;

- **Identification π and Lepton:**

  P_{moment}< 1.0GeV/c => π ; P_{moment}> 1.0Gev/c => lepton

- **Identification μ and e :**

  E_{EMC} >1.0 GeV => e ; E_{EMC} < 0.4 GeV => μ ;

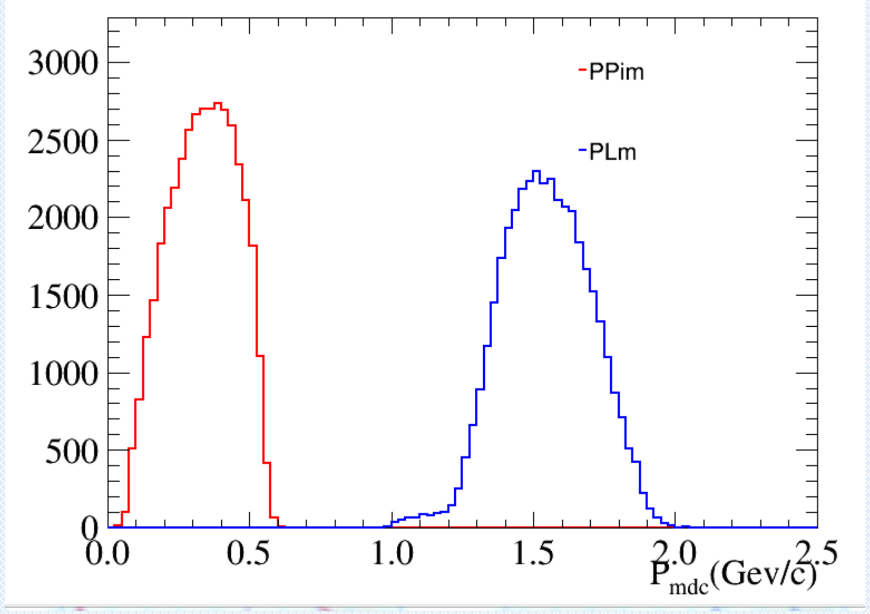
- **Good Photons:**

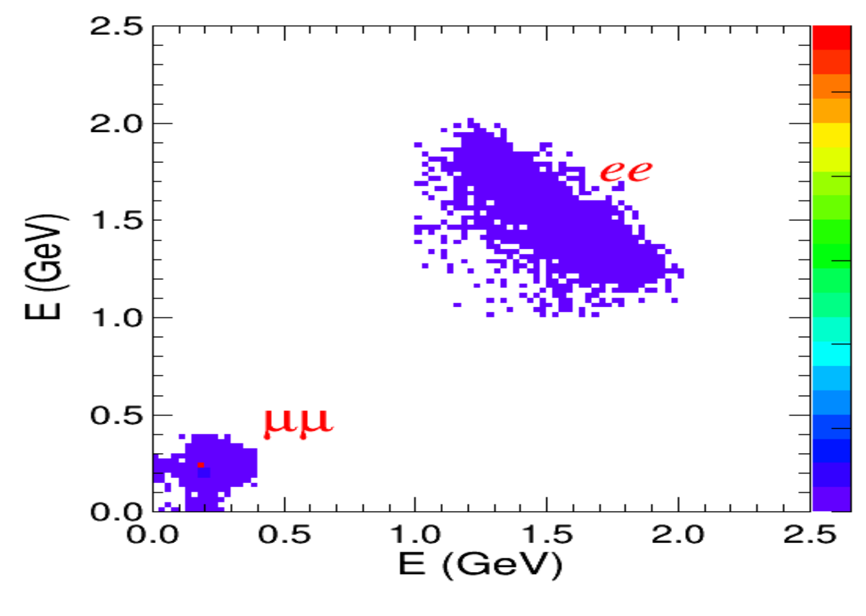
  Ngood >= 1 ; Ebarrel >25 MeV ; Eendcap > 50MeV;

  $\theta_{\min}$ $(\gamma, \text{charge}) > 20°$

Event Selection

Momentum and EMC deposit Energy distribution





Momentum distribution of pion and lepton :

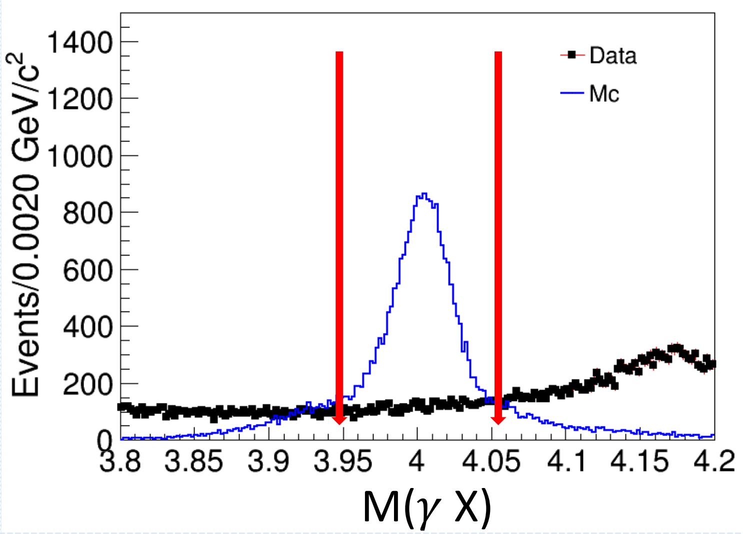
- P_{π}<1.0GeV/c
- P_{L}>1.0GeV/c

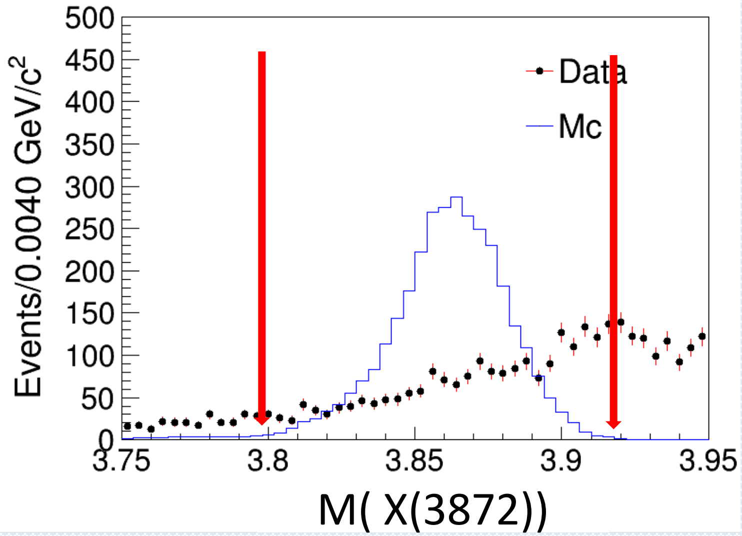
EMC deposit Energy of muon and electron :

- E_{μ}<0.4GeV
- E_{e}>1.0GeV

Event Selection

The invariant mass distribution





With all preselection criterion we get the invariant mass distribution of X(3872) and $\gamma X(3872)$. And we get the signal region.

Signal region:

3.95GeV <M(γX(3872))<4.05GeV

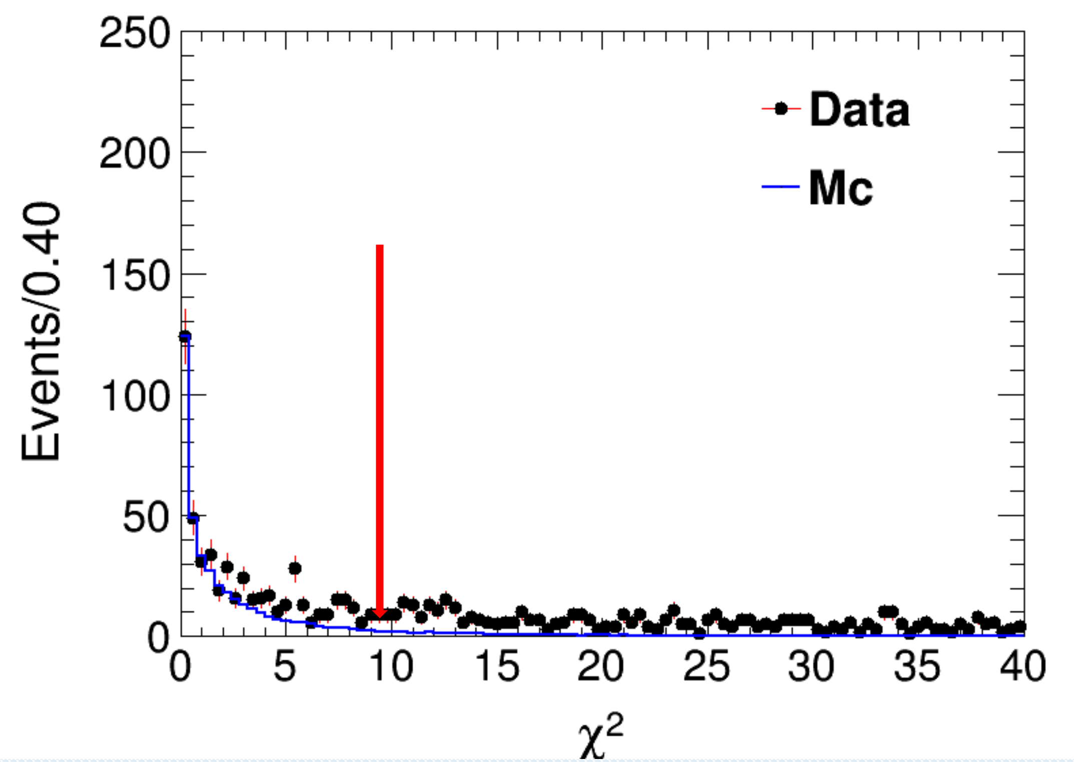
In γ X(3872) signal region, we constraint the X(3872) invariant mass distribution:

X(3872):

3.80GeV<M(x(3872))<3.92GeV

Event Selection

1C(constrain) fit for J/ψ

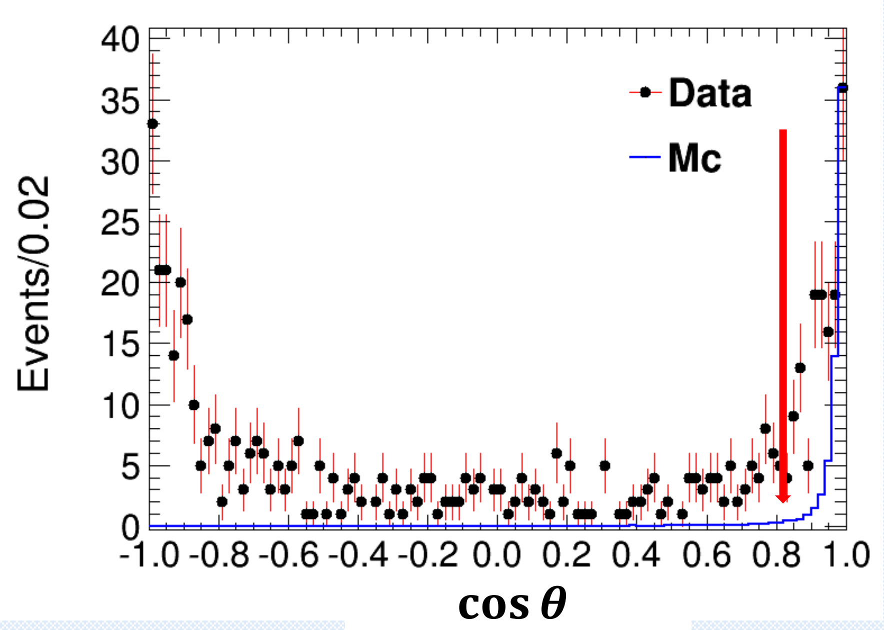


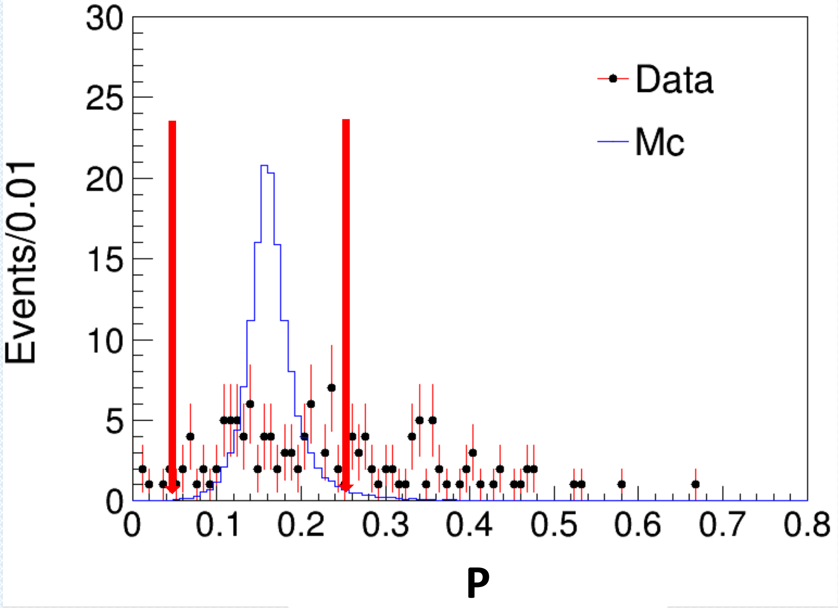
With preselection and the difference between data and MC, we need the 1C for J/ψ :

χ^2**<10.0**

Background analysis

The angle and momentum distribution of recoil γ_{ISR}



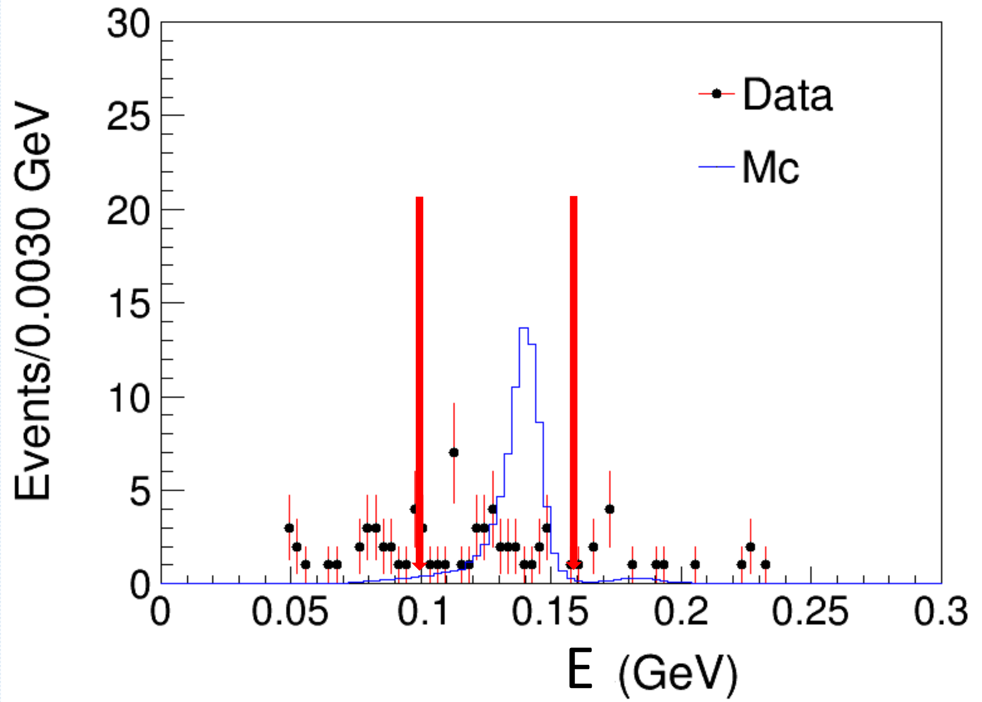


Comparing with MC, we ask for the angle and momentum for recoil γ(γ_{ISR}):

$\cos\theta$ > 0.8 and 0.05GeV/c<P<0.25GeV/c

Background analysis

The Ecm deposited energy distribution of Good photons

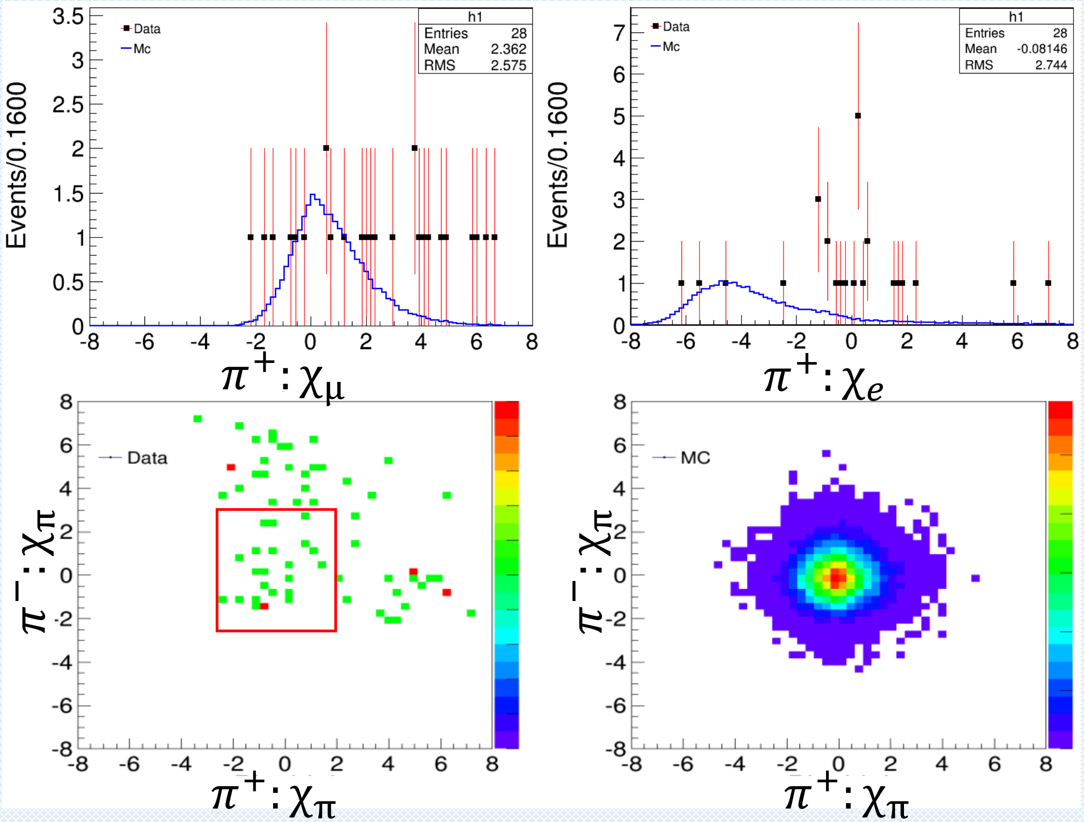


Comparing with MC, we require for the Ecm depsited energy of Good photons:

0.1GeV<E_γ<0.15GeV

Background analysis

Misidentifying of leptons and pion



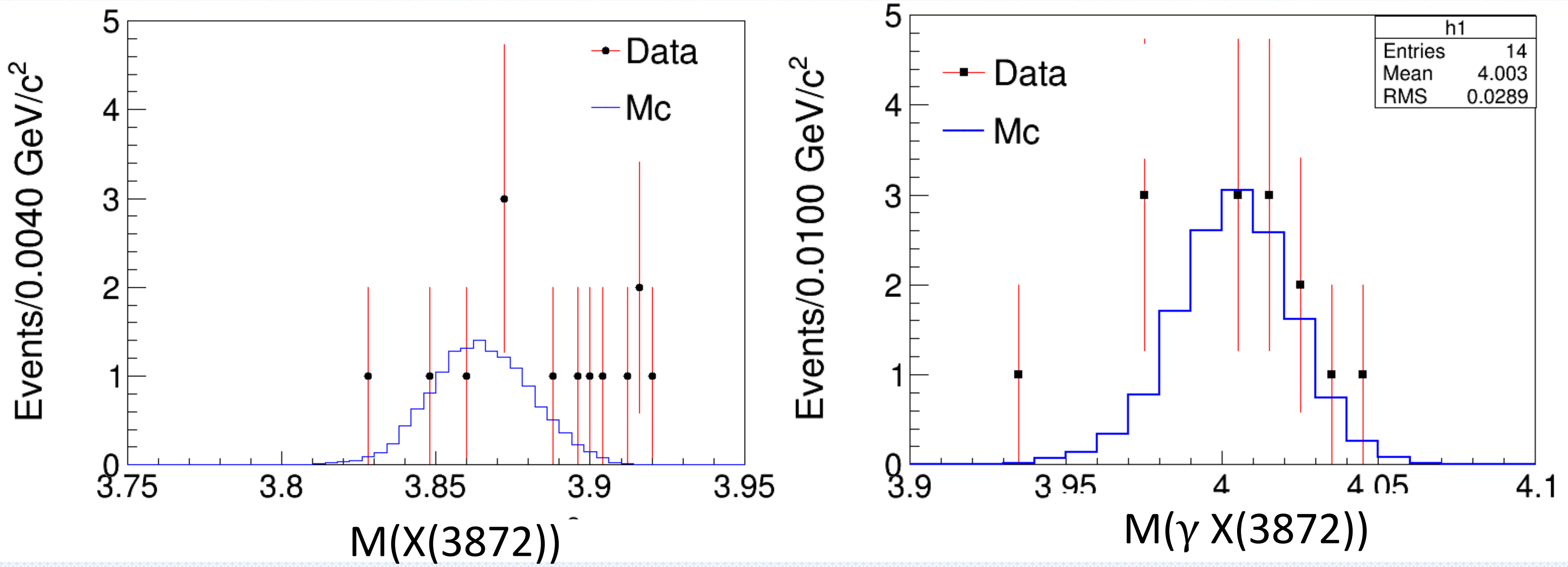
From the dE/dX χ distribution, we can see clearly misidentification of pion and electrons.

From our analysis, we found that the cut on two dimensional distribution of $\pi^+:\chi_\pi$ and $\pi^-:\chi_\pi$ will get a better results.

$\pi^+:\chi_\pi$<3.0 && $\pi^-:\chi_\pi$<3.0

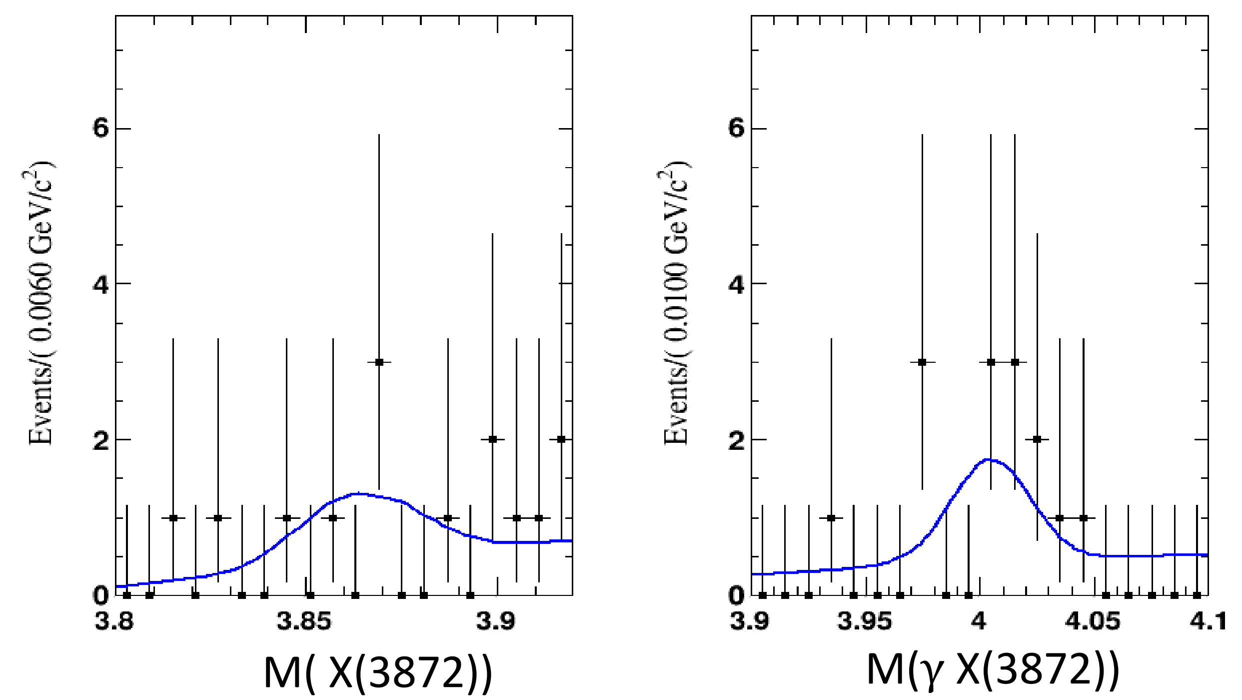
$\pi^+:\chi_\mu$: after selection condition , we believe it is π^+,and see its χ_μ of dE/dX, Same as $\pi^+:\chi_e$, $\pi^+:\chi_\pi$.

X(3872) and γX(3872) invariant mass



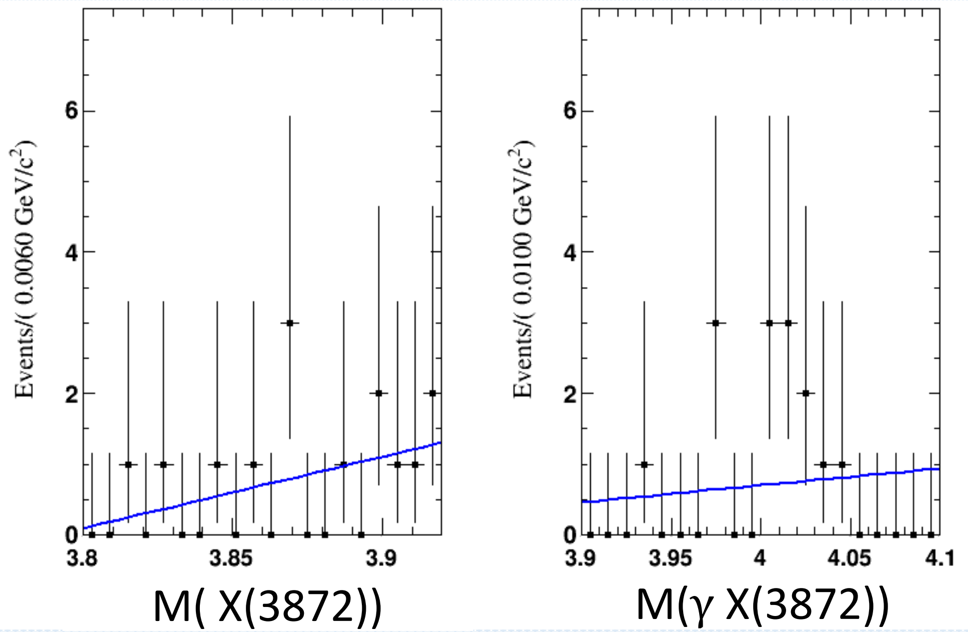
With all the background analysis and cut criterion, we give the invariant mass distribution of ***M(X(3872))*** and ***M(γX(3872))***

Fitting the invariant mass

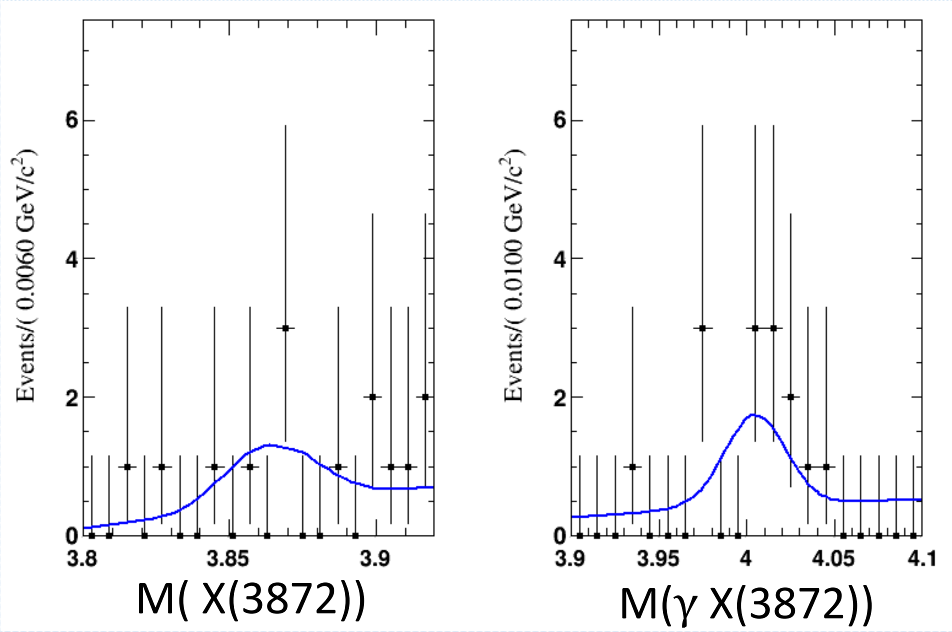


We apply two-dimensional fitting on the data, and the fitting variables are $M_{X(3872)}$ and $M_{\gamma X(3872)}$.
Here we use MC shape to describe the signal and first-order polynomial to describe the background. nsig=6.0606$\pm$3.1204 nbkg=7.93977$\pm$3.39417

Significance of the signal



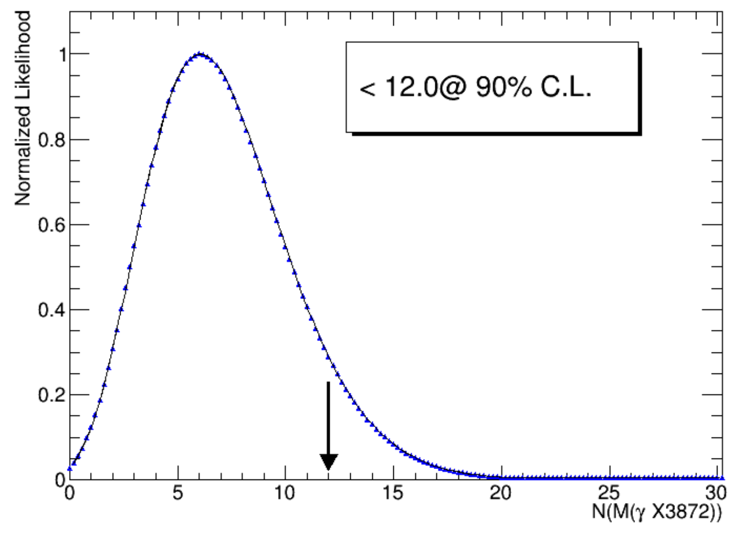
We hypothesis there are no signal and use a first-order polynomial to describe the sample and get the fitting result.
FCN=-77.220
NpEaramter = 3



Then we use the MC shape to describe the signal,and a first-order polynomial to describe the background and get the fitting result.
FCN=-80.765   Nparamter= 4

-deltaln(L) =1.77   nParam=1   significance= 1.88

Upper limit



$$\sigma = \frac{N}{\mathcal{L}_{eff}\varepsilon B(X \to \pi^+\pi^- J/\psi) B(J/\psi \to l^+l^-)}$$

$B(X \to \pi^+\pi^- J/\psi) = 3\% - 33\%$
$B(J/\psi \to l^+l^-) = 11.932 \pm 0.005\%$

ε =25.66%
$\mathcal{L}_{eff}$=1329.57pb^{-1}

For the Significance of the signal is only 1.88, and we just give the upper limit of the events.

The result is : 12.0 @90% C.L(confidence limit).

The Cross section is:

0.893-9.826 pb

Summary

From our analysis, we eliminate the background as much as possible and get the relatively purity signal events, and apply two-dimensional fitting method to get the upper limit of the signal, but there are only 1.88 sigma.

We will improve our analysis method to see if we can have a more significant signal.

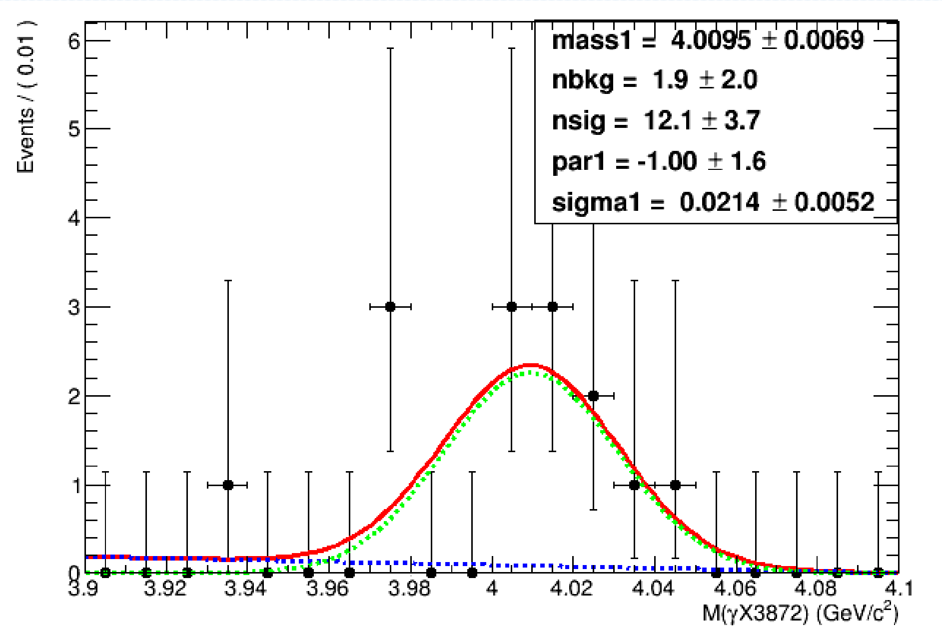
Next to do:

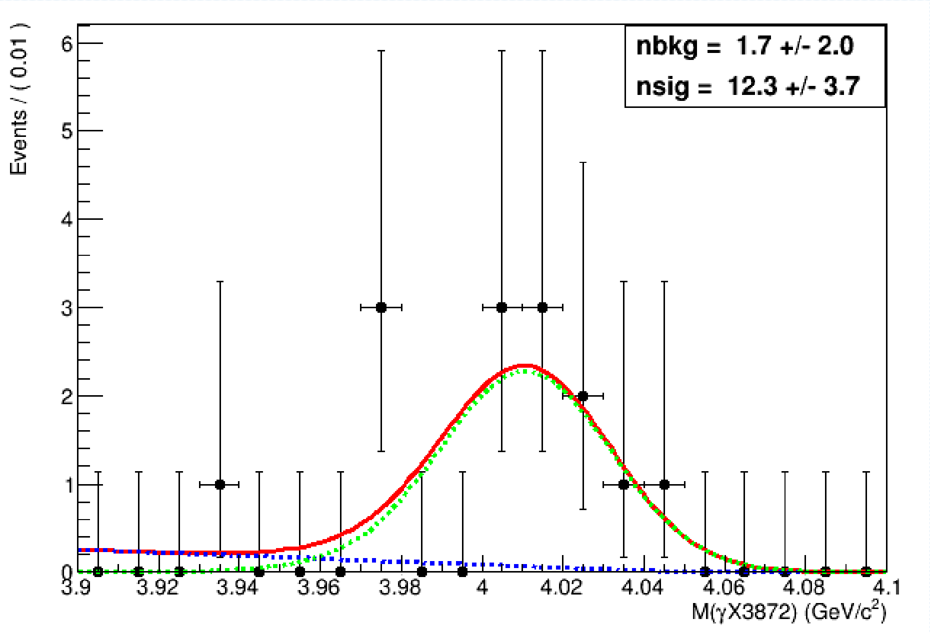
- Systematic uncertainties
- Other XYZ energy points above 4.18GeV

Thank you!

Backup

Fitting the invariant mass



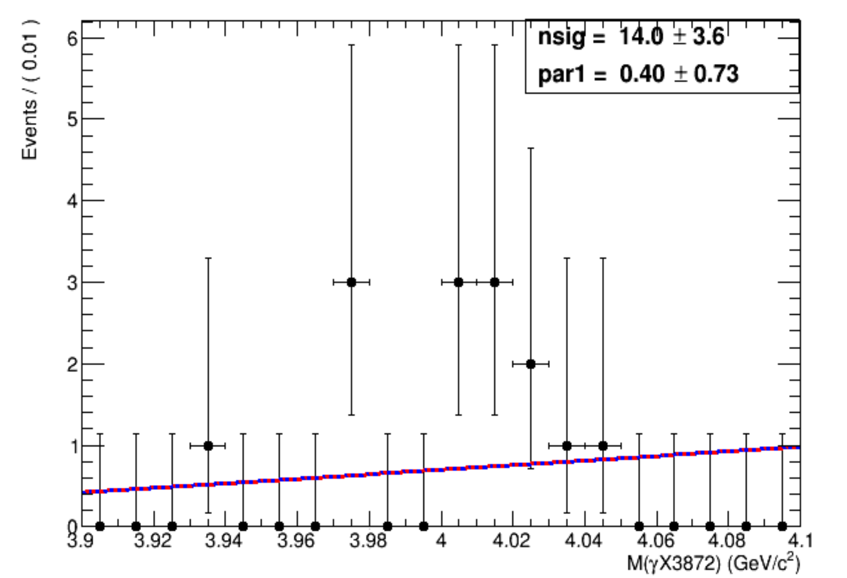


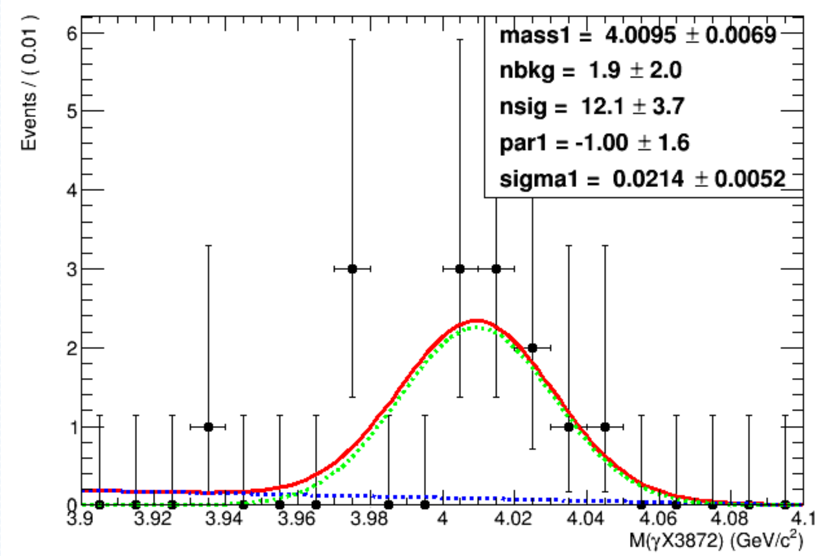
Signal: Gaussian
Background: first-order polynomial
FCN=-53.5343

Signal: MC shape convolute Gaussian
Background: first-order polynomial
FCN==53.4047

For the background are main the misidentification of pion and electron and we describe it with a first-order polynomial .

Significance of the signal





Fit with a first-order polynomial
FCN=-45.58
Nparameter=2

Signal: Gaussian
Background: first-order polynomial
FCN=-53.8136
Nparameter =5

-deltaln(L) =3.97 nParam=3 significance= 1.98

Effctive luminosity

$$\frac{dL_{\rm LO}}{d\sqrt{s'}} = L_{ee}\frac{dW_{\rm LO}}{d\sqrt{s'}}\left(\frac{\alpha(s')}{\alpha(0)}\right)^2,$$

$$\frac{dW_{\rm LO}}{d\sqrt{s'}} = \frac{\alpha(0)}{\pi x}\left[(2-2x+x^2)\ln\frac{1+c}{1-c} - x^2 c\right]\frac{2\sqrt{s'}}{s},$$

$\frac{dL_{LO}}{d\sqrt{s'}}$:effctive luminosity

L_{ee}:integral luminosity

$(\frac{\alpha(s')}{\alpha(0)})^2$: vacuum polarization factor

X=1-s'/s

C:$cos\theta^*_{min}$