Search for $J/\psi \to \gamma\eta\ /\gamma\eta'$ $\eta\ /\eta' \to e^+e^-\mu^+\mu^-$、$\mu^+\mu^-\mu^+\mu^-$

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CONTENTS

1 Investigate

- $J/\psi \to \gamma\eta\ /\gamma\eta'$

The branching fraction of $J/\psi \to \gamma\eta$、$\gamma\eta'$ is large ,which can offer us a clear and sufficient η、η'events to study decay more precisely.

- $\eta\ /\eta' \to e^+e^-\mu^+\mu^-$、$\mu^+\mu^-\mu^+\mu^-$

The double Dalitz decays proceeds through two virtual photons intermediate state with internal photon conversion to $\ell^+\ \ell^-$pairs. These processes are of great interest for understanding the pseudoscalar transition form factor and the interactions between pseudoscalars and virtual photons.

	$\mathcal{B}_{PDG}(10^{-3})$
$J/\psi \to \gamma\eta$	1.085 ± 0.018
$J/\psi \to \gamma\eta'$	5.25 ± 0.07

	J_{pc}	$Mass$	Γ
η	0^{-+}	$547.853 \pm 0.024 MeV$	$1.30 \pm 0.07\ keV$
η'		$957.78 \pm 0.06\ MeV$	$0.204 \pm 0.015\ MeV$

1 Current status - Theory

- Theory 1 : Vector meson dominance (VMD)

Theory 1: arXiv:1010.2378v1 [nucl-th] 12 Oct 2010

	$\mathcal{B}_{th1}$
$\eta \to e^+e^-\mu^+\mu^-$	$(5.465 \pm 0.079) \times 10^{-6}$
$\eta \to \mu^+\mu^-\mu^+\mu^-$	$(9.634 \pm 0.163) \times 10^{-9}$
$\eta' \to e^+e^-\mu^+\mu^-$	$(3.458 \pm 0.160) \times 10^{-7}$
$\eta' \to \mu^+\mu^-\mu^+\mu^-$	$(9.47 \pm 0.067) \times 10^{-8}$

- Theory 2 : the data driven approach

Theory 2 : Chinese Physics C Vol. 42, No. 2 (2018) 023109

	$\mathcal{B}_{th2}$
$\eta \to e^+e^-\mu^+\mu^-$	$(2.39 \pm 0.7) \times 10^{-6}$
$\eta \to \mu^+\mu^-\mu^+\mu^-$	$(3.98 \pm 0.15) \times 10^{-9}$
$\eta' \to e^+e^-\mu^+\mu^-$	$(6.39 \pm 0.91) \times 10^{-7}$
$\eta' \to \mu^+\mu^-\mu^+\mu^-$	$(1.69 \pm 0.36) \times 10^{-8}$

1 Current status - Experiment

II. THE EXPERIMENT

The experiment was performed at the CELSIUS storage ring in Uppsala, using the WASA detector setup (fig. 2) [22]. Protons with a kinetic energy of 893 MeV interacted with frozen droplets of deuterium [23]. The η mesons were produced in the reaction $pd \rightarrow {}^3\mathrm{He}\,\eta$ close to the η production threshold. The detection of ^{3}He ions in a zero-degree spectrometer (tagging detector) provided a clean η trigger independent of decay channel [24]. The

BR_{exp} : M. Berlowski et al.,Phys.Rev, D 77 (2008) 032004

	$\mathcal{B}_{PDG}$	$\mathcal{B}_{exp}$	TECN
$\eta \rightarrow e^+e^-\mu^+\mu^-$	$< 1.6 \times 10^{-4}$(CL=90%)	$< 1.6 \times 10^{-4}$(CL=90%)	WASA
$\eta \rightarrow \mu^+\mu^-\mu^+\mu^-$		$< 3.6 \times 10^{-4}$(CL=90%)	WASA
$\eta' \rightarrow e^+e^-\mu^+\mu^-$		not seen	
$\eta' \rightarrow \mu^+\mu^-\mu^+\mu^-$		not seen	

2 Data set

- BESIII Offline Software System version: 7.0.8
- decay :

$J/\psi \to \gamma\eta\ /\gamma\eta'$	HELAMP
$\eta \to e^+e^-\mu^+\mu^-$	DIY_etaemu
$\eta' \to e^+e^-\mu^+\mu^-$	DIY_etapemu
$\eta \to \mu^+\mu^-\mu^+\mu^-$	DIY_eta4mu
$\eta' \to \mu^+\mu^-\mu^+\mu^-$	DIY_etap4mu

- job : data +signalMC+ inclusiveMC (09+12)

2 Initial event selection

$$\eta\,/\eta' \to e^+e^-\mu^+\mu^-、\ \mu^+\mu^-\mu^+\mu^-$$

Good charged track

- $|R_{zo}|\leq 10cm$, $|R_{xy0}|\leq 1cm$
- $|\cos\theta|\leq 0.93$
- nCharge = 0, nGood = 4
- nGood_p = 2, nGood_m = 2

Good photon

- Baeeel : $E \geq 25MeV$, $|\cos\theta| \leq 0.8$
- Endcap : $E \geq 50MeV$, $0.86< |\cos\theta| \leq 0.92$
- $0 \leq TDC_{EMC} \leq 14$ (x50ns)
- nGam ≥ 1

4mu 4pi pid&&kmfit

- pid-> useDedx && useTofCorr
- 4 charge tracks to do vertex fit
- 4c done to constraint J/ψ mass

2e2mu pid&&kmfit

- set 12 group
- vertex and 4c fit for 12 group
- vertex and 4c fit for 2e2mu

2 Initial event selection -> 2e2mu

about 12 group		
$e^+\mu^+e^-\mu^-$	$\mu^+e^+\mu^-e^-$	$\pi^+e^+\pi^-e^-$
$e^+\mu^+\mu^-e^-$	$\mu^+e^+e^-\mu^-$	$\pi^+e^+e^-\pi^-$
$e^+\pi^+e^-\pi^-$	$\mu^+\pi^+\mu^-\pi^-$	$\pi^+\mu^+\pi^-\mu^-$
$e^+\pi^+\pi^-e^-$	$\mu^+\pi^+\pi^-\mu^-$	$\pi^+\mu^+\mu^-\pi^-$

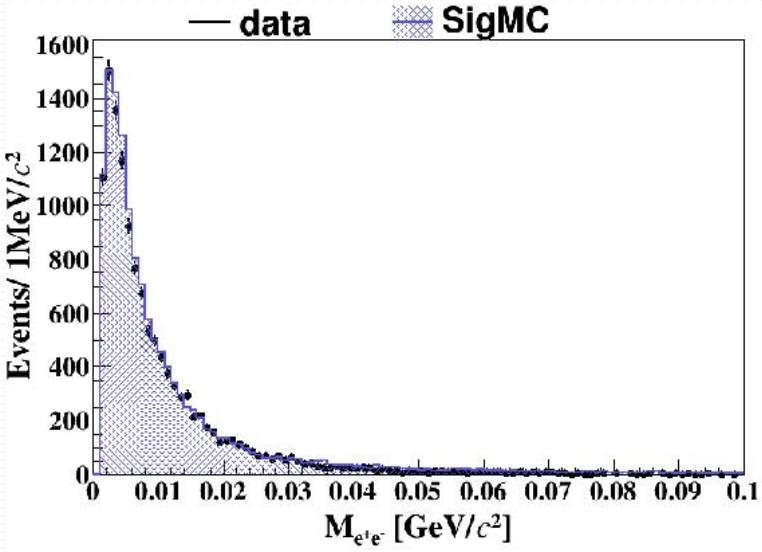
set 12 group

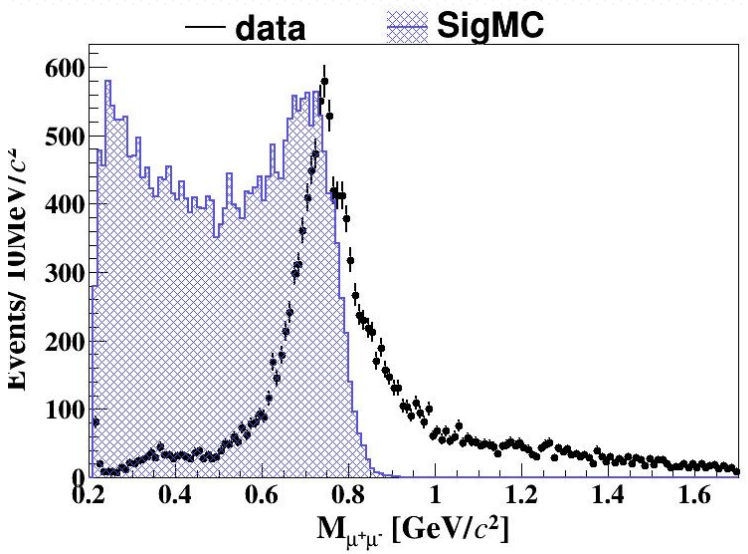
1. set p1 : e^+ μ^+ π^+ ->3case
2. set p1p2 : $e^+\mu^+$ $e^+\pi^+$ μ^+e^+ $\mu^+\pi^+$ π^+e^+ $\pi^+\mu^+$ ->6case

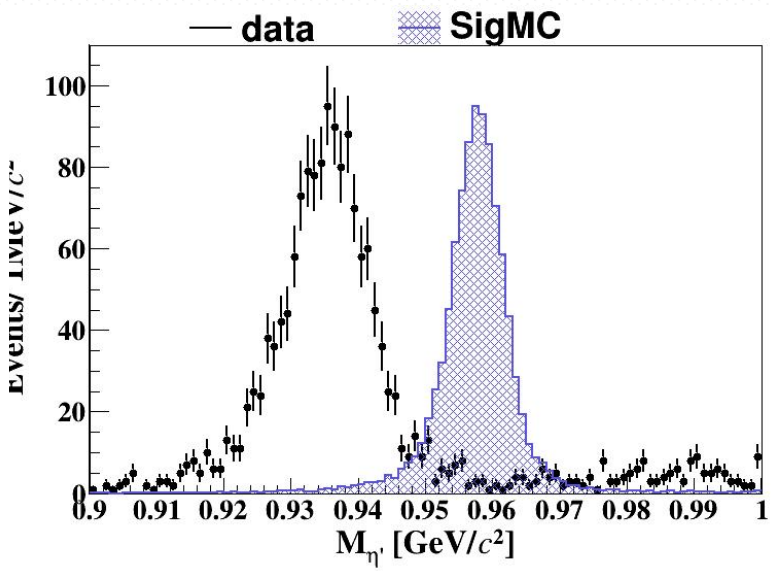
3. set p1p2m1m2 : $e^+\mu^+$ -> $e^+\mu^+e^-\mu^-$
   -> $e^+\mu^+\mu^-e^-$ -> 2 x 6 = 12 case

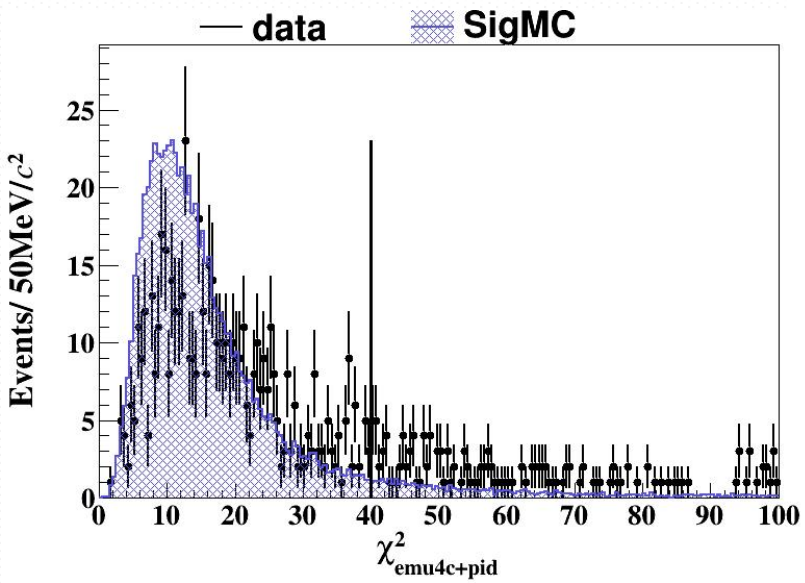
3 Background study

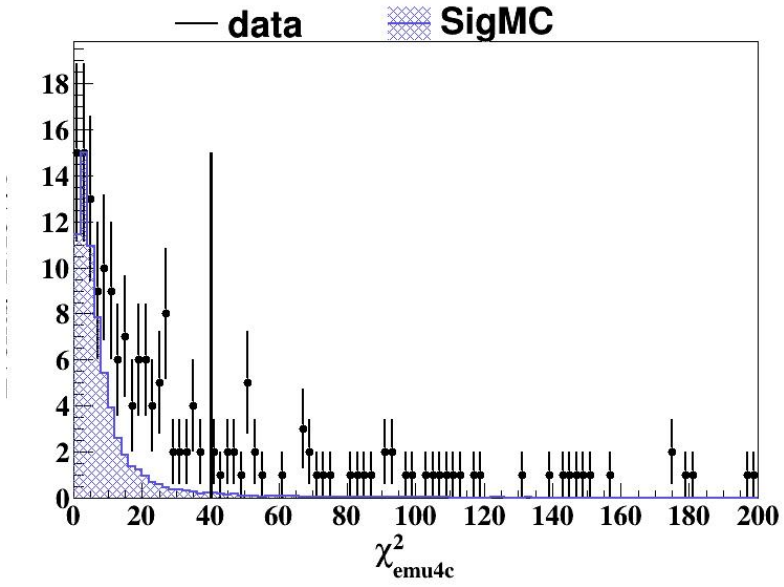
■ $\eta' \to e^+e^-\mu^+\mu^-$:

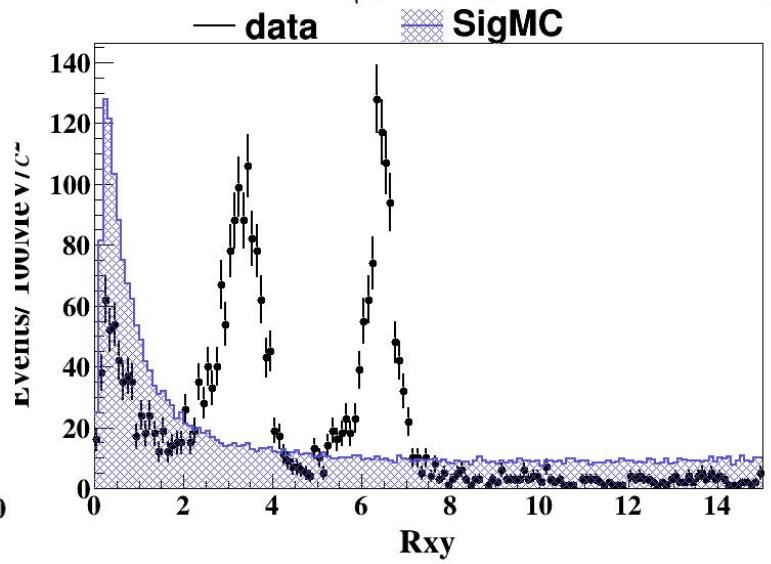












3 Background study

■ $\eta' \to e^+e^-\mu^+\mu^-$:

Table 1: Decay trees and their respective final states.

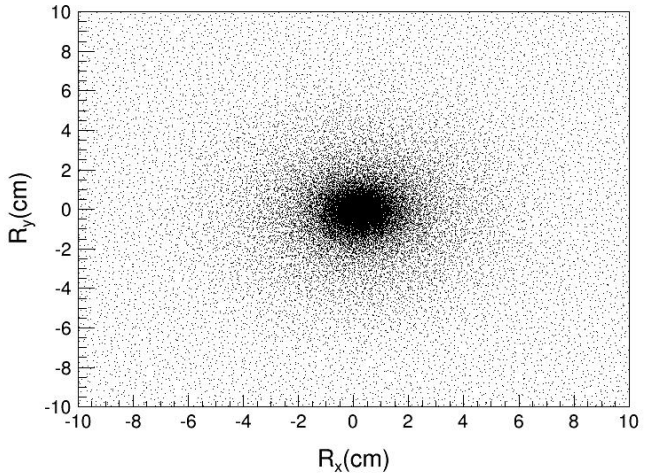
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F$	$\pi^+\pi^-\gamma^F\gamma$	0	1371	1371
2	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-$	$e^+e^-\pi^+\pi^-\gamma$	1	41	1412
3	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F\gamma^f$	$\pi^+\pi^-\gamma^F\gamma\gamma^f$	2	3	1415
4	$J/\psi \to \pi^0\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^-$	3	3	1418
5	$J/\psi \to \eta'\gamma, \eta' \to \mu^+\mu^-\gamma^F$	$\mu^+\mu^-\gamma^F\gamma$	6	3	1421
6	$J/\psi \to e^+e^-\gamma^f\gamma^f$	$e^+e^-\gamma^f\gamma^f$	7	2	1423
7	$J/\psi \to e^+e^-\gamma^f$	$e^+e^-\gamma^f$	4	1	1424
8	$J/\psi \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^-$	5	1	1425
9	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-\gamma^f$	$e^+e^-\pi^+\pi^-\gamma\gamma^f$	8	1	1426

Cut	SigMC Efficiency
$M_{2e2\mu} \in (0.9, 1.0)$	118357/450000 = 26.30%
$\chi^2_{2e2\mu} < 40$	107044/450000 = 23.79%
$M_{2e} \in (0, 0.1)$	83946/450000 = 18.65%
$R_{xy}<2$	23607/450000 = 5.25%

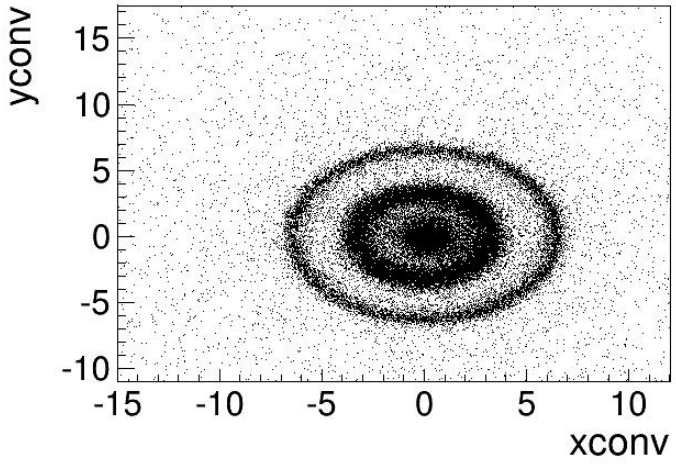
3 Background study->Gamma conversion

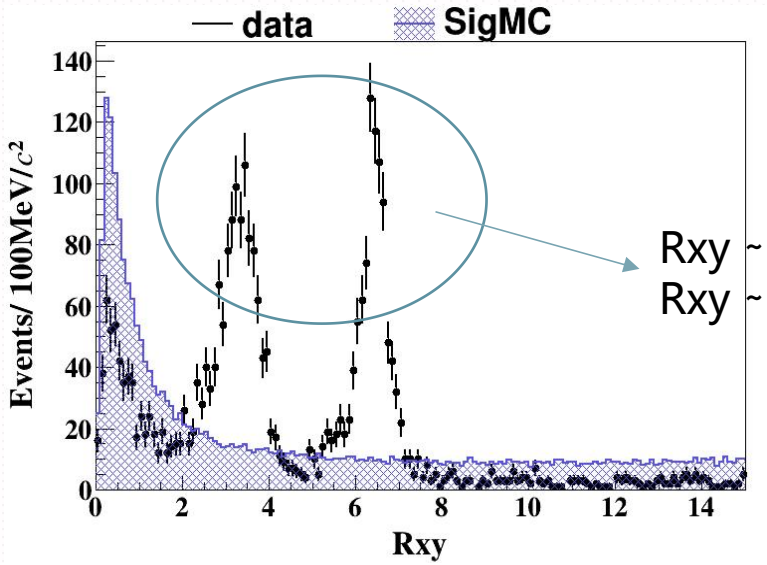
- The primary peaking background comes from the decay J/ψ → γη′, η′ → γμ+μ−, where the photon converts to an e+e-pairs in the beam pipe or the inner wall of the drift chamber.

SignalMC



Data





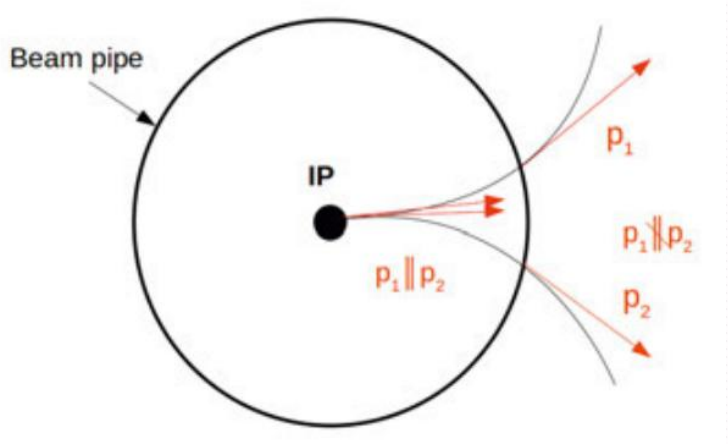
Rxy ~ 3cm, for beam pipe;
Rxy ~ 6cm, for inner wall;

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F$	$\pi^+\pi^-\gamma^F\gamma$	0	1371	1371
2	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-$	$e^+e^-\pi^+\pi^-\gamma$	1	41	1412
3	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F\gamma^f$	$\pi^+\pi^-\gamma^F\gamma\gamma^f$	2	3	1415
4	$J/\psi \to \pi^0\rho^0, \rho^0 \to \pi^+\pi^-$	$\pi^0\pi^+\pi^-$	3	3	1418
5	$J/\psi \to \eta'\gamma, \eta' \to \mu^+\mu^-\gamma^F$	$\mu^+\mu^-\gamma^F\gamma$	6	3	1421
6	$J/\psi \to e^+e^-\gamma^f\gamma^f$	$e^+e^-\gamma^f\gamma^f$	7	2	1423
7	$J/\psi \to e^+e^-\gamma^f$	$e^+e^-\gamma^f$	4	1	1424
8	$J/\psi \to \pi^0\pi^+\pi^-$	$\pi^0\pi^+\pi^-$	5	1	1425
9	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-\gamma^f$	$e^+e^-\pi^+\pi^-\gamma\gamma^f$	8	1	1426

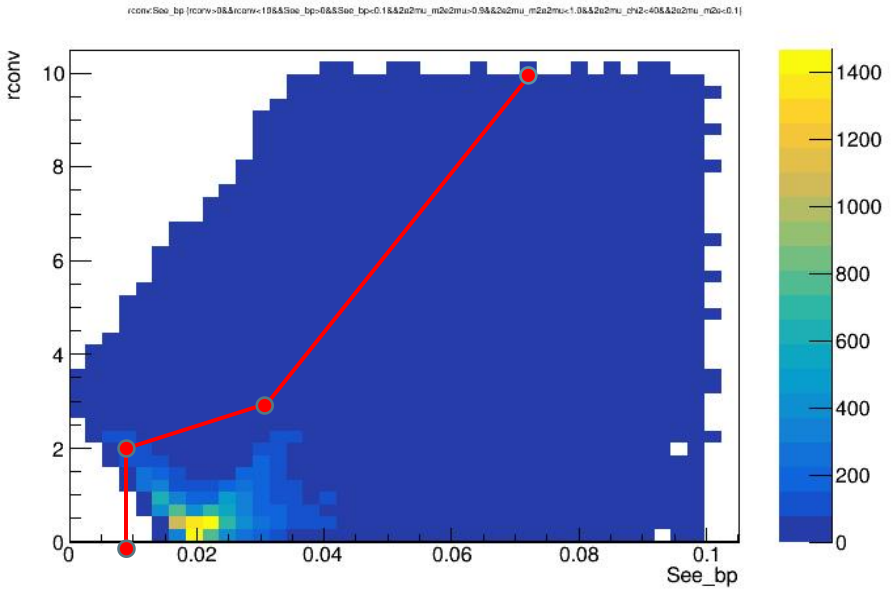
3 Background study->Gamma conversion

R_{xy} && M_{2ebp}

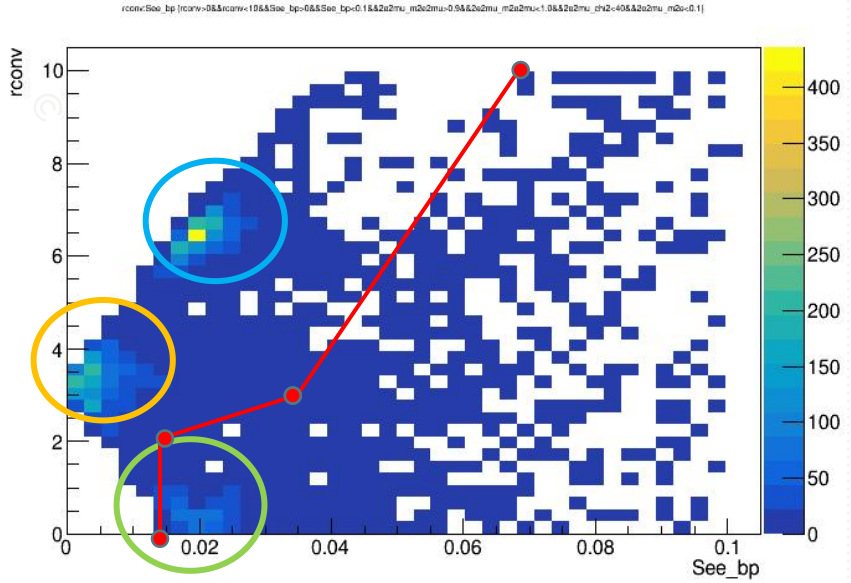


- By changing the reference point of the helices of all $e^{\pm}$ tracks to their respective points of intersection with the beam pipe. This procedure changes the direction of the vectors, but not their magnitudes.

Signal MC



Data



- green: IP point
- yellow: beam pipe
- blue: inner wall

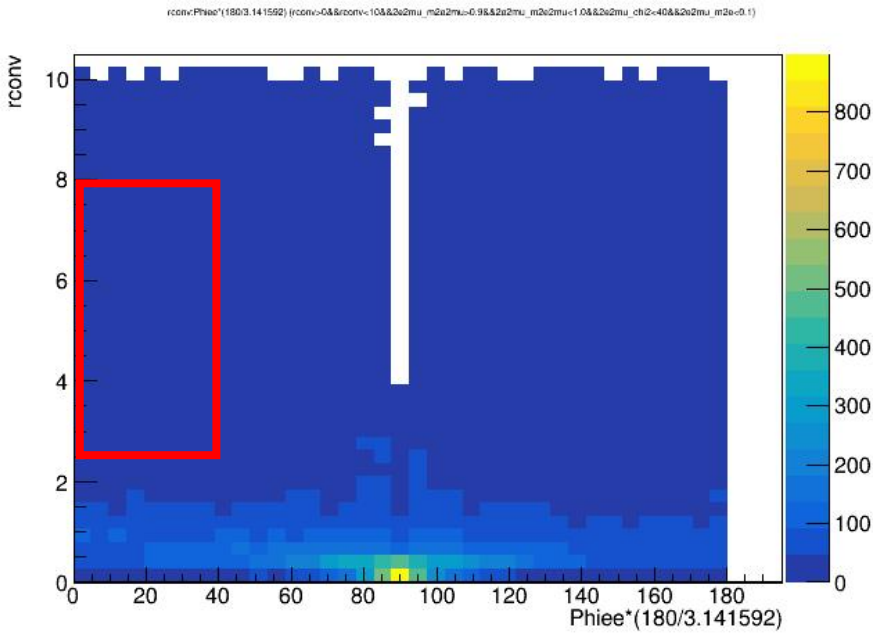
(0.005GeV/c2, 0cm)
(0.005GeV/c2, 2cm)
(0.02GeV/c2, 4cm)
(0.07GeV/c^2, 10cm)

3 Background study->Gamma conversion

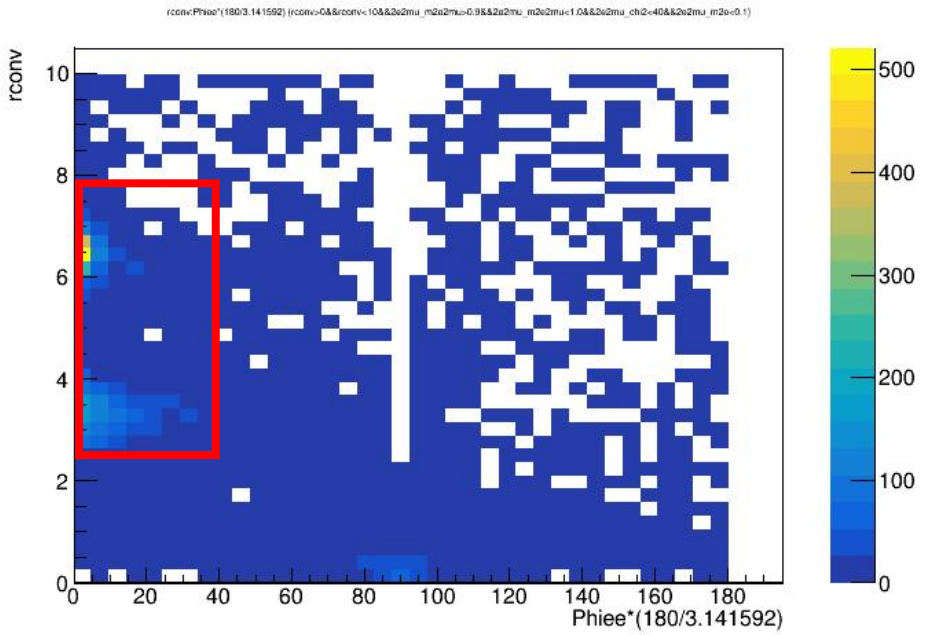
R_{xy} && Φ_{ee}

- For Gamma conversion : Φee is expected to be close to zero
- For Signal : any Angle

Signal MC



Data



for Backgroup :

$2.5 < R_{xy} < 8$

$0 < \Phi_{ee} < 40$

3 Background study->Gamma conversion

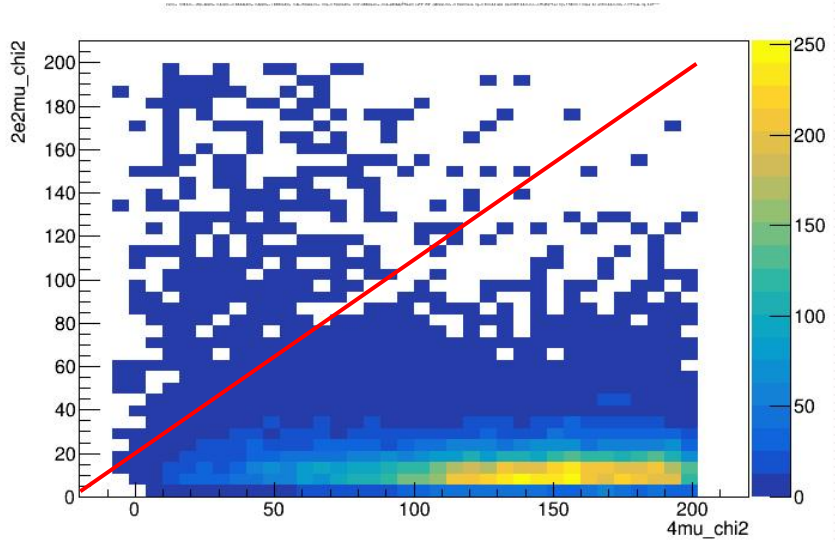
■ $\eta' \to e^+e^-\mu^+\mu^-$:

cut	Efficiency
$M_{2e2\mu} \in (0.9,\ 1.0)$	118357/450000 = 26.30%
$\chi^2_{2e2\mu} < 40$	107044/450000 = 23.79%
$M_{2e} \in (0,\ 0.1)$	83946/450000 = 18.65%
R_{xy} && Φ_{ee}	81794/450000 = 18.18%
R_{xy} && M_{2ebp}	75180/450000 = 16.71%

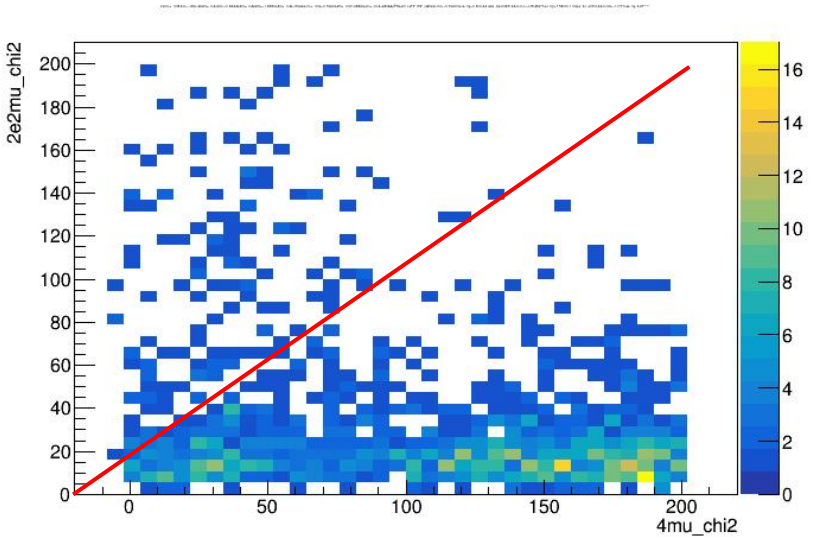
Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F$	$\pi^+\pi^-\gamma^F\gamma$	0	458	458
2	$J/\psi \to \eta'\gamma, \eta' \to e^+e^-\pi^+\pi^-$	$e^+e^-\pi^+\pi^-\gamma$	1	34	492
3	$J/\psi \to e^+e^-\gamma^f\gamma^f$	$e^+e^-\gamma^f\gamma^f$	3	2	494
4	$J/\psi \to e^+e^-\gamma^f$	$e^+e^-\gamma^f$	2	1	495
5	$J/\psi \to \eta'\gamma, \eta' \to \pi^+\pi^-\gamma^F\gamma^f$	$\pi^+\pi^-\gamma^F\gamma\gamma^f$	4	1	496

3 Background study->4μ, 4π

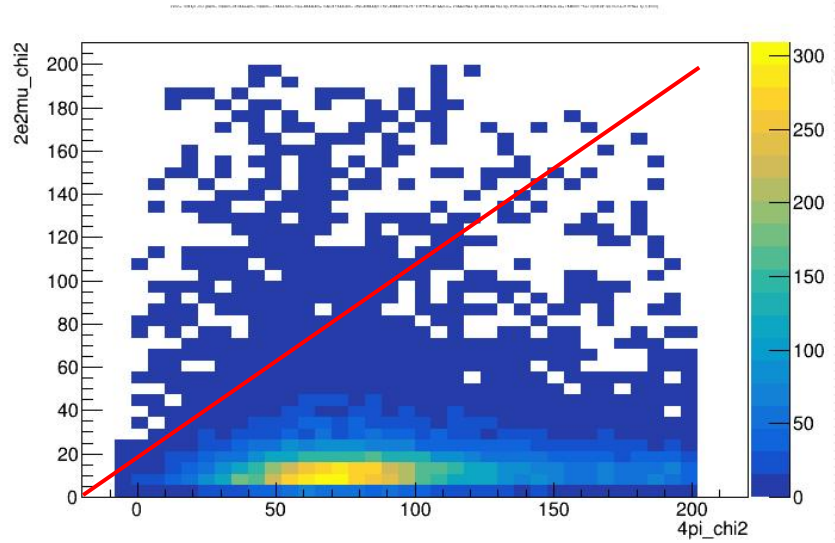


SigMC 2e2mu<chi2 : 4mu_chi2

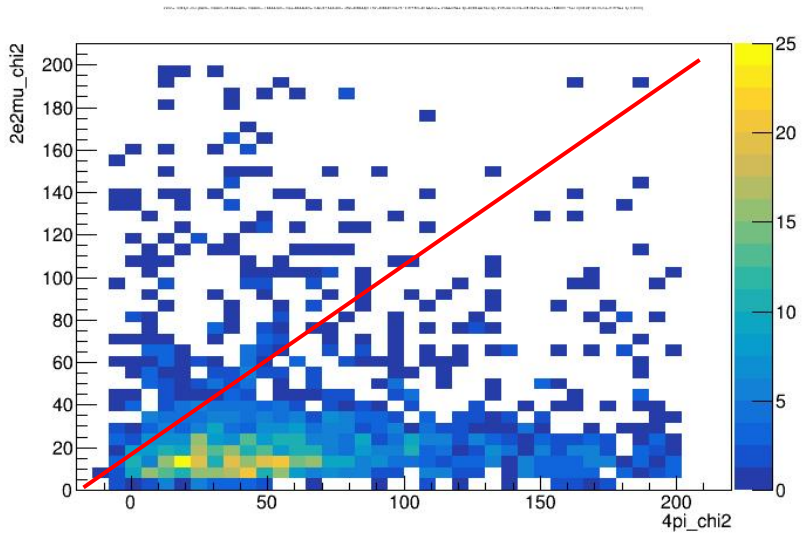


Data 2e2mu<chi2 : 4mu_chi2

$\chi^2(2e2\mu) < \chi^2(4\mu)$



SigMC 2e2mu<chi2 : 4pi_chi2



Data 2e2mu<chi2 : 4pi_chi2

$\chi^2(2e2\mu) < \chi^2(4\pi)$

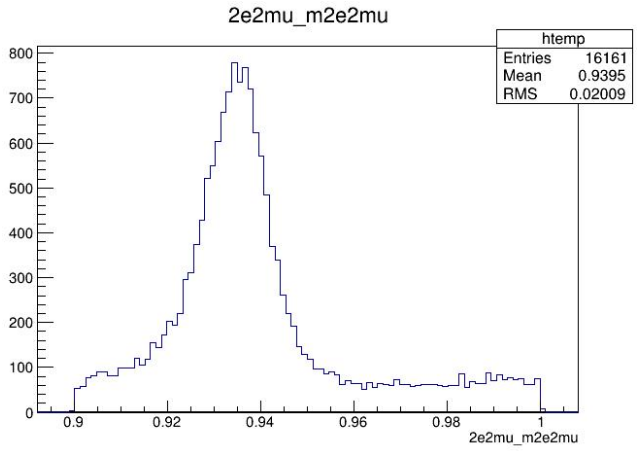
3

Background study->4μ, 4π

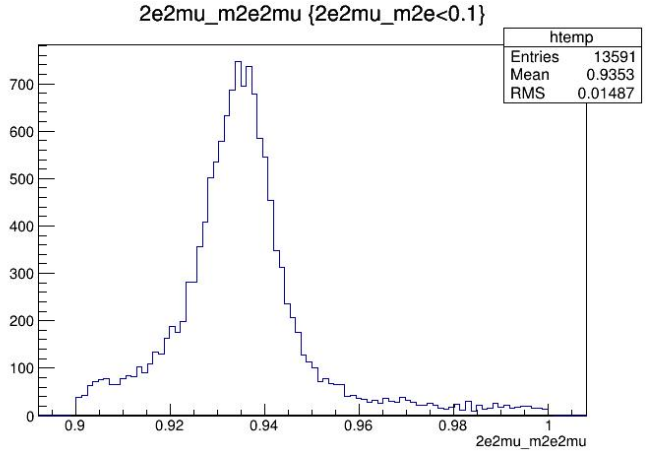
■ $\eta' \to e^+e^-\mu^+\mu^-$: SigMC

cut	Efficiency
$M_{2e2\mu} \in (0.9, 1.0)$	118357/450000 = 26.30%
$\chi^2_{2e2\mu} < 40$	107044/450000 = 23.79%
$M_{2e} \in (0, 0.1)$	83946/450000 = 18.65%
R_{xy} && Φ_{ee}	81794/450000 = 18.18%
R_{xy} && M_{2ebp}	75180/450000 = 16.71%
$\chi^2_{2e2\mu} < \chi^2_{4\mu}$	74950/450000 = 16.66%
$\chi^2_{2e2\mu} < \chi^2_{4\pi}$	74628/450000 = 16.58%

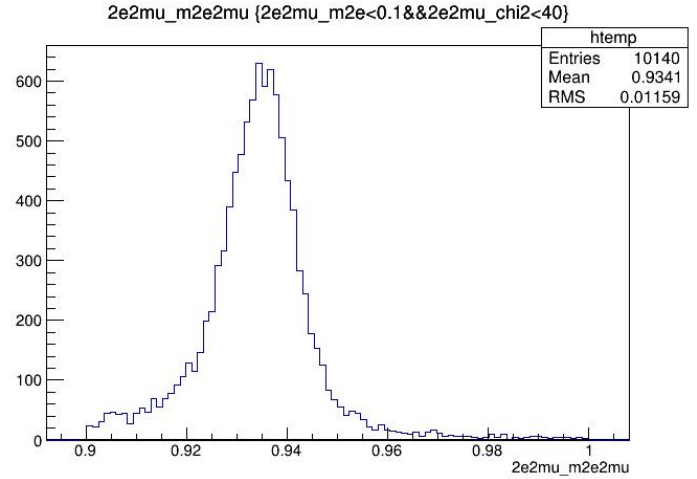
■ $\eta' \to e^+e^-\mu^+\mu^-$: data



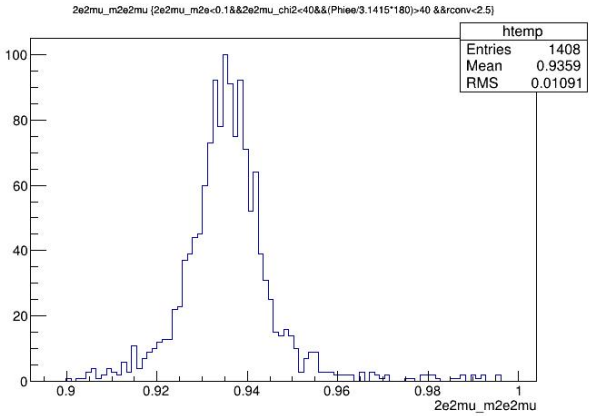
cut:Metap



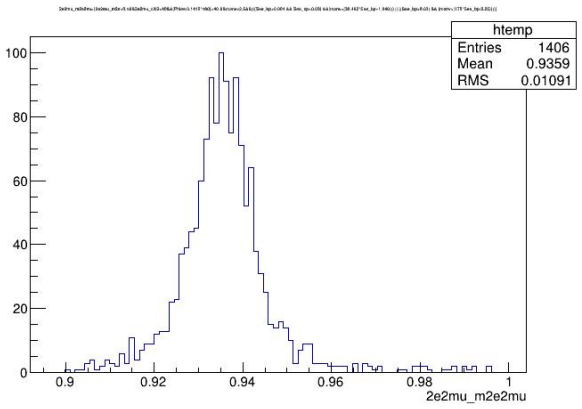
cut:Metap+Mee



cut:Metap+Mee+chi2



cut:Metap+Mee+chi2+
Rxy&Phiee



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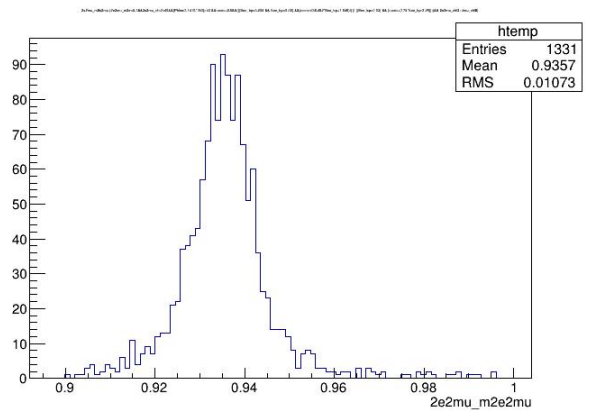
+Rxy&Phiee+Rxy&M
eebp



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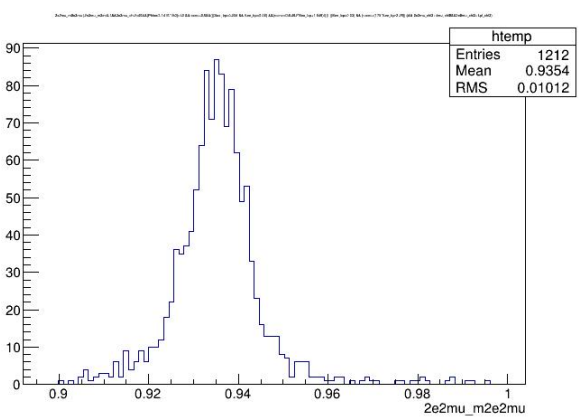
+chi24mu



cut:Metap+Mee+chi2
+Rxy&Phiee+Rxy&Meebp
+chi24mu+chi24pi

4 To do list

- for $\eta' \to e^+e^-\mu^+\mu^-$:
  add exclusiveMC ($\eta' \to \pi^+\pi^-e^+e^-$、$\eta' \to \gamma\pi^+\pi^-$)

- for $\eta \to e^+e^-\mu^+\mu^-$、$\eta\,/\eta' \to \mu^+\mu^-\mu^+\mu^-$:
  determine the final selection conditions

THANK YOU FOR WATCHING!

HTU Group Meeting,
October.22,2022