

# Simulation of Charmonium-like Resonance States in PANDAROOT

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# Plan of Talk

Motivation

PANDAROOT Simulation

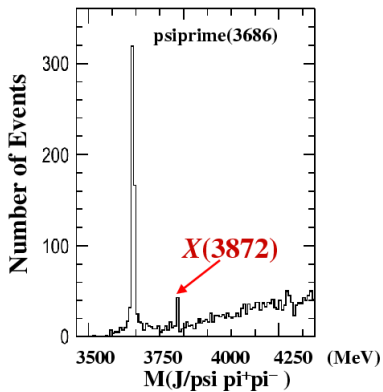
Summary

# Charmonium Studies

- ▶ Mainly Studies in  $e^+e^-$  and  $\bar{p}p$  collider
- ▶  $e^+e^- \rightarrow J^{PC} = 1^{--}$
- ▶  $\bar{p}p \rightarrow$  Direct formation with any quantum number
- ▶ PANDA:  $\bar{p}$  beam suitable for Charmonium Studies
- ▶ Better momentum resolution and PID
- ▶ Able to obtain high precision data

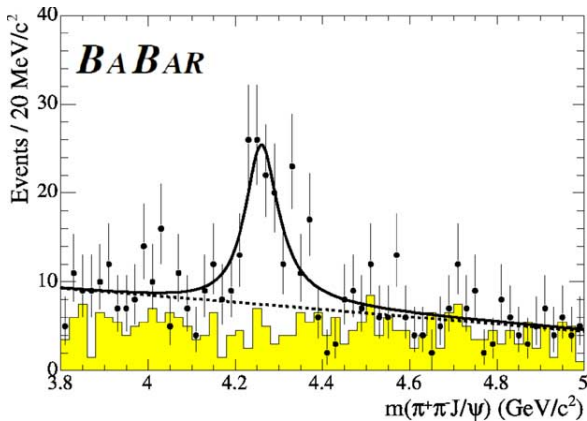
# X(3872) STATE

- ▶ BELLE:  $B^\pm \rightarrow K^\pm \pi^+ \pi^- J/\psi$
- ▶ CDF, D0 and BABAR



# Y(4260) STATE

- ▶ BABAR
- ▶ CLEO, BELLE



# Y(4140) state

## ► CDF Result

- $\bar{p}p$  collisions @  $\sqrt{s} = 1.96$  TeV
- $B^\pm \rightarrow J/\psi \phi K^\pm$
- $M_{Y(4140)} = 4143.4^{+2.9}_{-3.0}(\text{stat}) \pm 0.6(\text{syst})$  MeV
- $\Gamma_{Y(4140)} = 15.3^{+10.4}_{-6.1}(\text{stat}) \pm 2.5(\text{syst})$  MeV

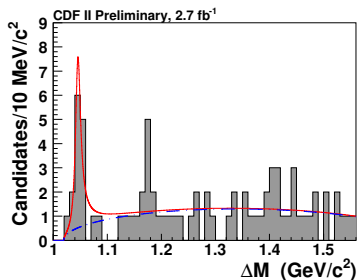
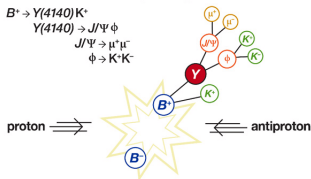
### Production of Y(4140)

$$B^+ \rightarrow Y(4140) K^+$$

$$Y(4140) \rightarrow J/\psi \phi$$

$$J/\psi \rightarrow \mu^+ \mu^-$$

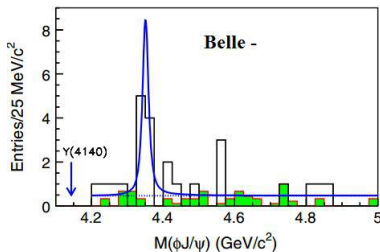
$$\phi \rightarrow K^+ K^-$$



# Y(4140) state

## ▶ BELLE Result

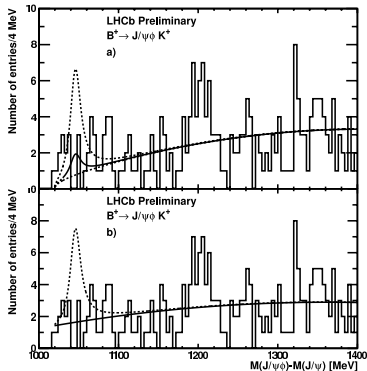
- ▶  $e^+e^-$  collisions
- ▶  $\gamma\gamma \rightarrow \phi J/\psi$
- ▶ No significant signal was found



C. P. Shen et al. Phys. Rev. Lett. 104 (2010) 112004.

# Y(4140) state

- ▶ LHCb Result
  - ▶  $pp$  collisions @  $\sqrt{s} = 7$  TeV
  - ▶  $B^+ \rightarrow J/\psi \phi K^+$
  - ▶ No evidence for this state is found
  - ▶ Not confirm the existence of Y(4140) state



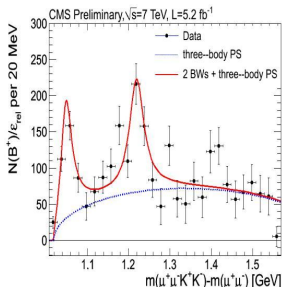
R. Aaij et al. Phys. Rev. D 85(2012) 091103.



# Y(4140) state

## ► CMS Result

- $pp$  collisions @  $\sqrt{s} = 7 \text{ TeV}$
- $B^+ \rightarrow J/\psi \phi K^+$
- Observed two structure
- $M_{Y(4140)} = 4148.2 \pm 2.0(\text{stat}) \pm 4.6(\text{syst}) \text{ MeV}$
- $M_{\text{other}} = 4316.7 \pm 3.0(\text{stat}) \pm 7.3(\text{syst}) \text{ MeV}$



CMS - Results:

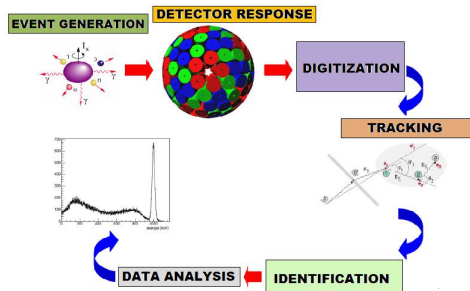
<https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsBPH11026>

(Nov 2012)

# Y(4140) state

- ▶ Interesting Case
- ▶ Possibilities for the structure:
  - ▶  $c\bar{c}$  state
  - ▶ Tetraquark state
  - ▶ Molecular structure
  - ▶ Hybrid charmonium
- ▶ PANDA can study this state with more precision
- ▶ Monte Carlo Simulation using PANDAROOT

# Monte Carlo Simulation

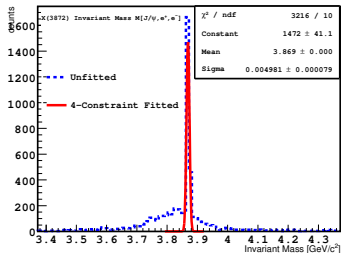
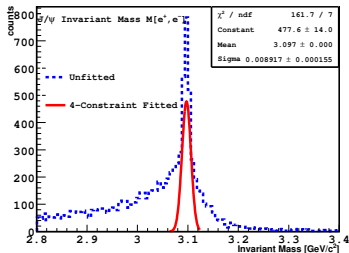


- ▶ EVTGEN : PHSP
- ▶ Geant3
- ▶ Full Simulation:
  - ▶ Simulation
  - ▶ Digitization
  - ▶ Reconstruction
  - ▶ PID

▶ Invariant Mass =  $\sqrt{(\sum E)^2 - (\sum p_x)^2 - (\sum p_y)^2 - (\sum p_z)^2}$

# Test Case: X(3872) State

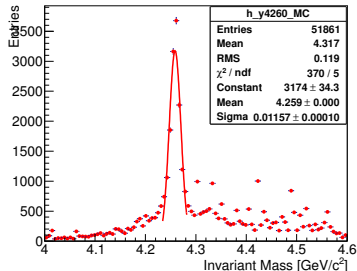
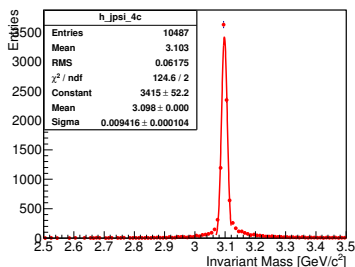
- ▶  $p\bar{p} \rightarrow J/\psi\pi^+\pi^- \rightarrow e^+e^-\pi^+\pi^-$
- ▶ 15000 events
- ▶  $\sqrt{s} = 3.872 \text{ GeV}$



Proceedings of the DAE Symp. on Nucl. Phys. 56 (2011).

# Test Case : Y(4260) State

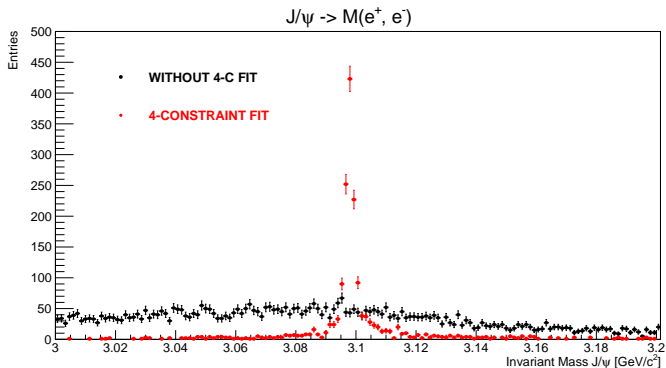
- ▶  $p\bar{p} \rightarrow J/\psi\pi^+\pi^- \rightarrow \mu^+\mu^-\pi^+\pi^-$
- ▶ 20000 events
- ▶  $\sqrt{s} = 4.260 \text{ GeV}$



Proceedings of the DAE Symp. on Nucl. Phys. 57 (2012)

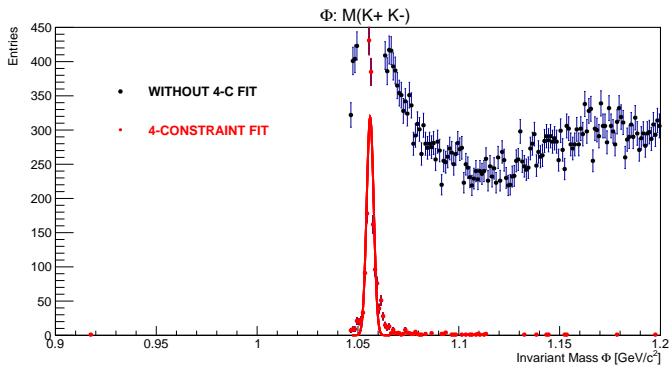
# Y(4140) State

- ▶  $p\bar{p} \rightarrow J/\psi\phi \rightarrow e^+e^-K^+K^-$
- ▶ 20000 events
- ▶  $\sqrt{s} = 4.140 \text{ GeV}$



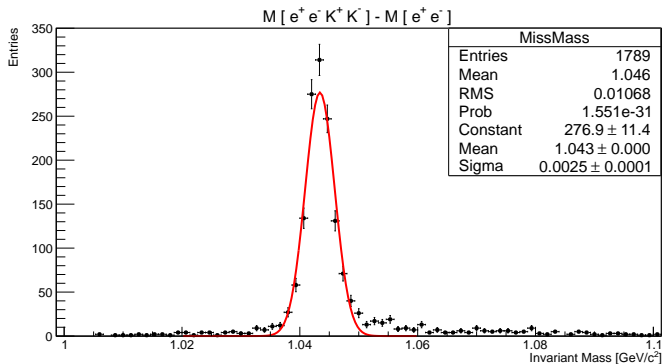
# Y(4140) State

$$p\bar{p} \rightarrow J/\psi\phi \rightarrow e^+e^-K^+K^-$$



# Missing Mass [Vertex Fit]

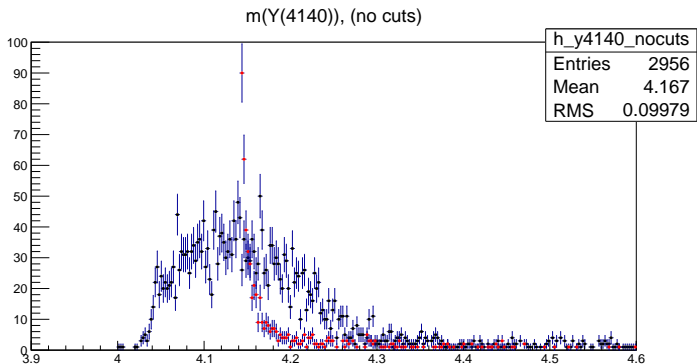
$$p\bar{p} \rightarrow J/\psi\phi \rightarrow e^+e^-K^+K^-$$





# Y(4140) State

$$p\bar{p} \rightarrow J/\psi\phi \rightarrow e^+e^-K^+K^-$$



# Summary

- ▶ We have made a small beginning in Monte Carlo simulation of X(3872) and Y(4260) states in PANDAROOT framework.
- ▶ The Y(4140) state is also simulated and obtained invariant mass of  $J/\psi$  and  $\phi$  using 4-Constraint and Vertex fitter
- ▶ Work to be done
  - ▶ Background study
  - ▶ Energy Scan
  - ▶ Resonance Scan

Thanks...