Feasibility Study of $Z_c(3900)^+$ with PANDA

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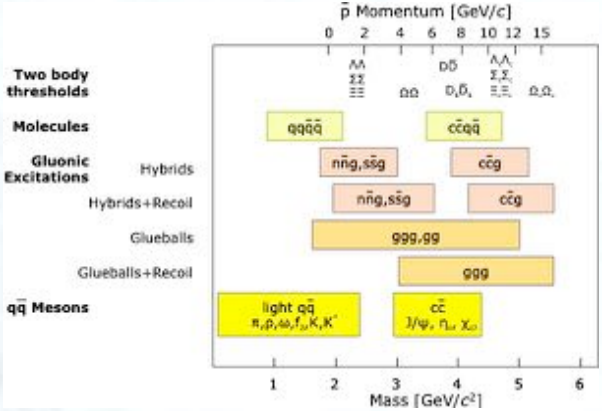
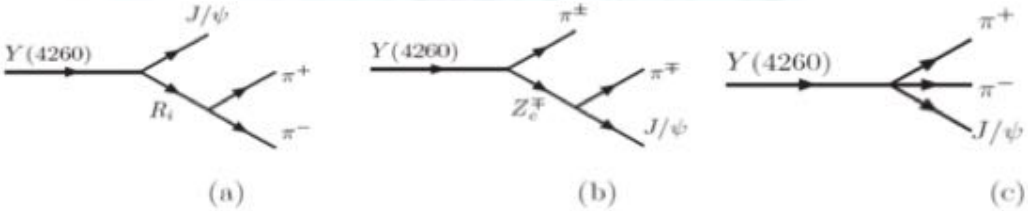
Introduction

Mass range of hadrons that will be accessible at PANDA. The upper scale indicates the corresponding antiproton momenta required in a fixed-target experiment.



The HESR will provide 1.5 to 15 GeV/c antiprotons, which will allow charmonium spectroscopy, the search for charmed hybrids and glueballs, the production of D meson pairs and the production of baryon pairs for hypernuclear studies. [PANDA-TDR]

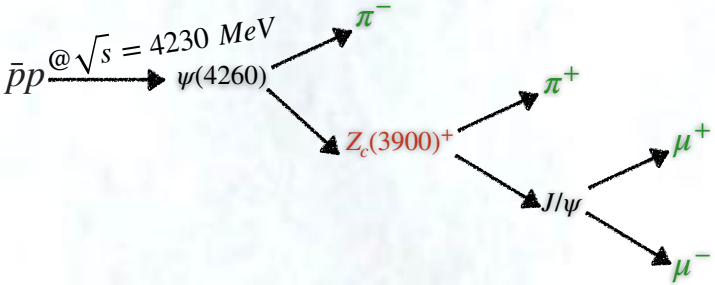
Introduction



The Zc(3900)− was observed in π−J/ψ invariant mass distribution in the study of e+e− → π+π−J/ψ at BESIII and Belle experiments [M. Ablikim et al., C. Z. Yuan et al.].

MC simulation: Decay Tree

exotic charmonium hybrid
spin-parity quantum numbers $J^{PC} = 1^{++}$



three intermediate resonances ($\psi(4260), Z_c(3900)^+$ and J/ψ),
four final state particles (μ^+, μ^-, π^+ and π^-)

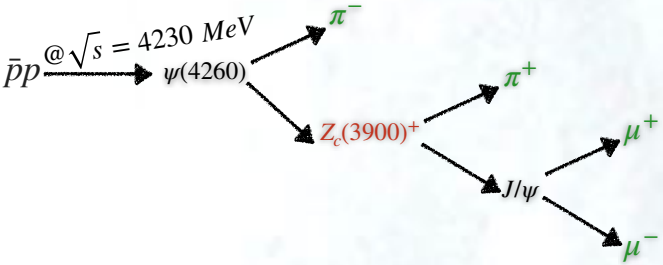
for event generation

Since Added/Moved XYZ states, by K. Goetzen 02.04.2020 for PANDA, now we can define the dec file

evt.pdl

name	id	mass/GeV	width/GeV	max_Dm/GeV	3*charge	2*spin	lifetime*c/mm	PythiaId
psi(4260)	99100443	4.2300000e+00	5.5000000e-02	5.5000000e-01	0	2	0.0000000e+00	99100443
Z_c(3900)+	99010443	3.8872000e+00	2.8200000e-02	2.8200000e-01	3	2	0.0000000e+00	99010443

psi4260_Zc3900Plus_Jpsi2pi_Jpsi_mumu.dec"; decay file specifying the signal decay channel




```
noPhotos

Decay psi(4260)
  1.0  Z_c(3900)+ pi-     PHSP;
Enddecay
Decay Z_c(3900)+
  1.0  J/psi   pi+        PHSP;
Enddecay

Decay J/psi
  1.0   mu+ mu-           VLL;
Enddecay

End
```

for event generation

- 10000 for signal
- 10000 for DPM events (needs to produced)
- PHSP model was used for all event generations
- PHOTOS was turned off for simplicity

Strategy

Signal events was generated by

nev = 10k and pbeam = 8.73556 // for pbar = 4.260 GeV

- tut_sim.C :: full simulation of the events;
  (sim.root, par.root files)

pbarZ: 8.73556; Etot :9.71893;

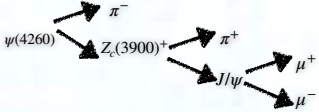
TLorentzVector ini(0, 0, pbarZ, Etot); // for pbar = 4.260 GeV

- tut_ana.C :: analysis of full sim events;
  (ana.root)

Strategy

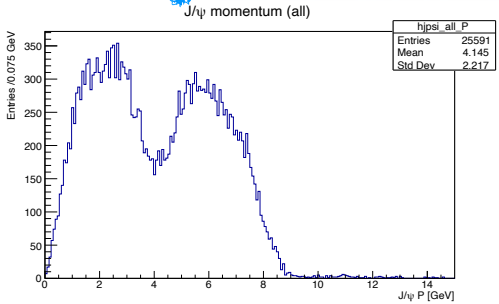
- Combine all μ candidates and accept them as J/ψ if their mass is within nominal range and apply a vertex fit with a mass constraint,
- Combine these with a π^+ and accept them as a candidate charmonium
- Then reconstruct the initial system, perform a 4-constraint fit and accept only those ones which have a probability > 0.01
- Perform mass constraint fits on all intermediate states except the charmonium and a new 4-constraint fit on the system created from the fitted states - a probability > 0.01 is required at every step

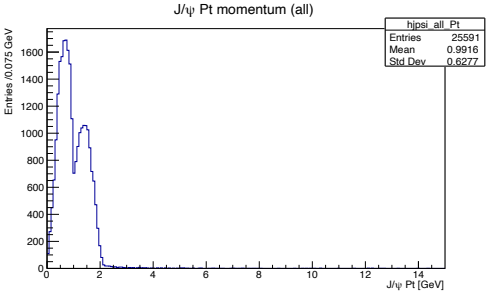
Analysis: kinematics

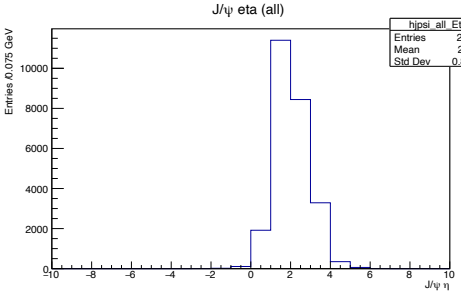


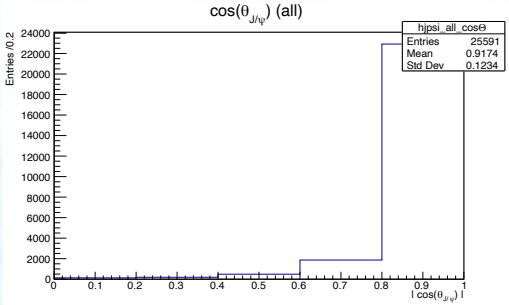
Reconstructed particles

all

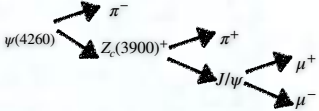




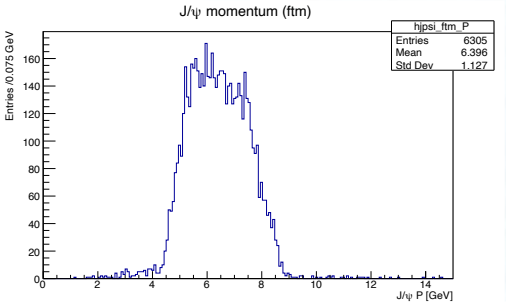




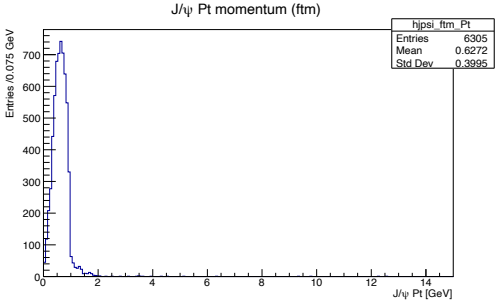
Analysis: kinematics

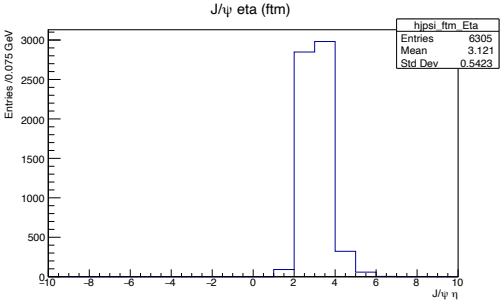


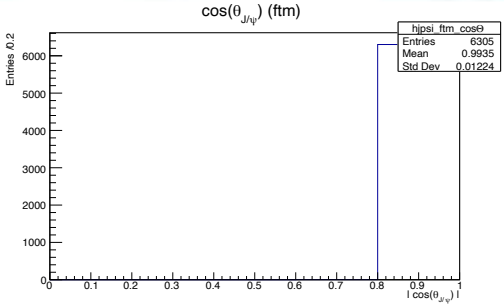
Reconstructed particles



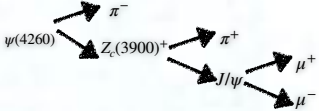
ftm



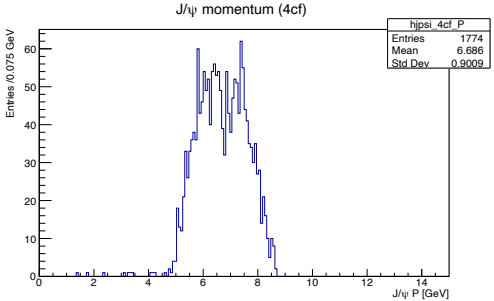




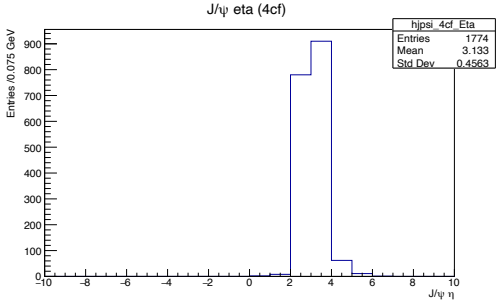
Analysis: kinematics

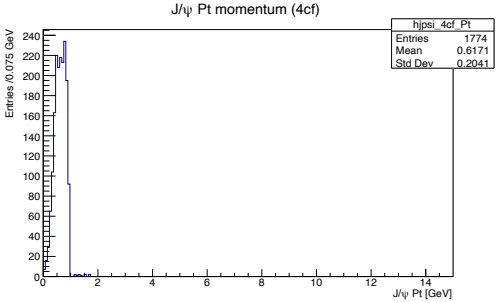


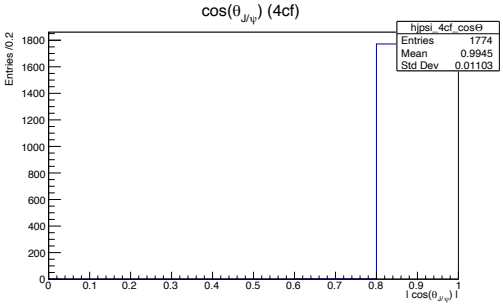
Reconstructed particles



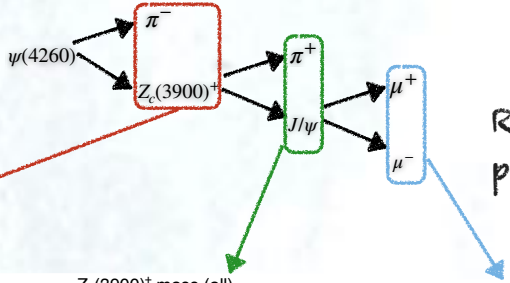
4cf



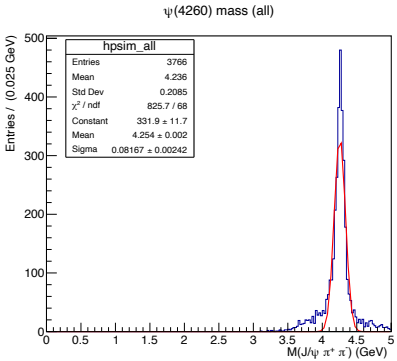


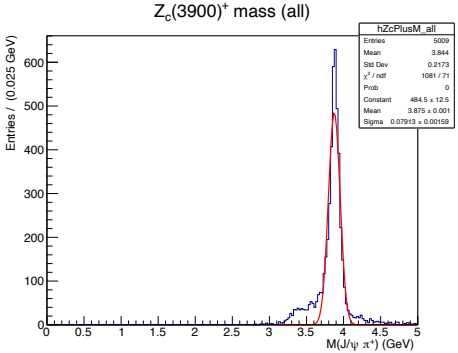


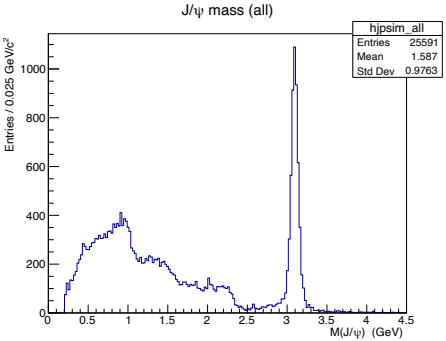
Analysis: mass: all



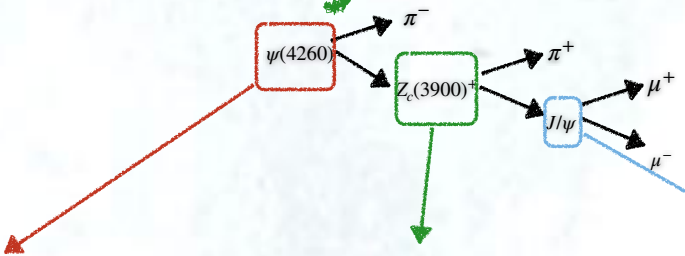
Reconstructed all particles



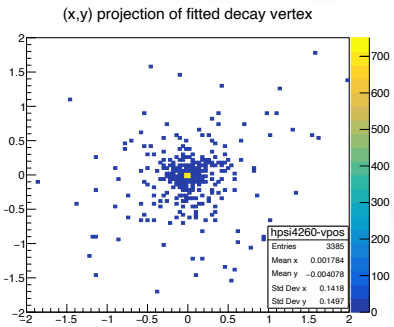


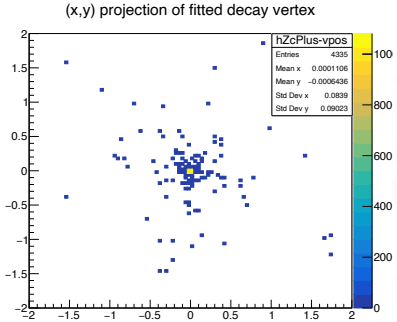


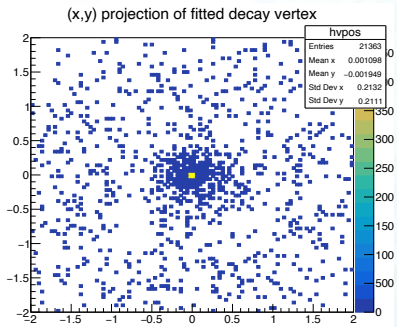
Analysis: decay vertex



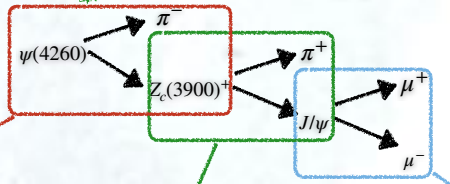
Resonant particles decay vertexes





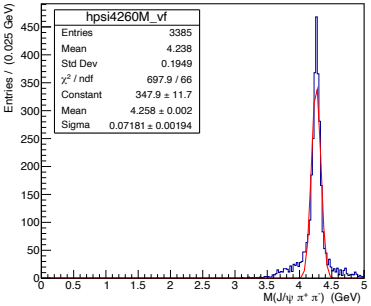


Analysis: decay vertex fit

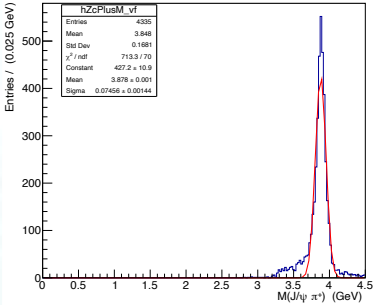


InvMass for particles coming from vertex

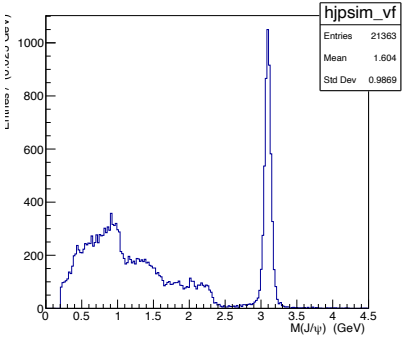
$\psi(4260)$ mass (vertex fit)



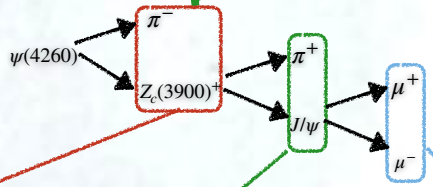
$Z_c(3900)^+$ mass (vertex fit)



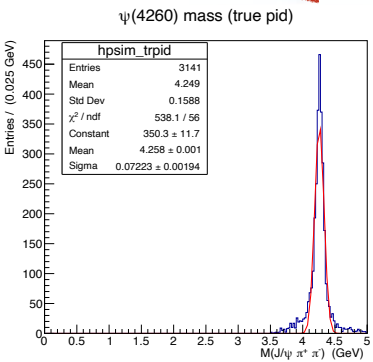
J/ψ mass (vertex fit)

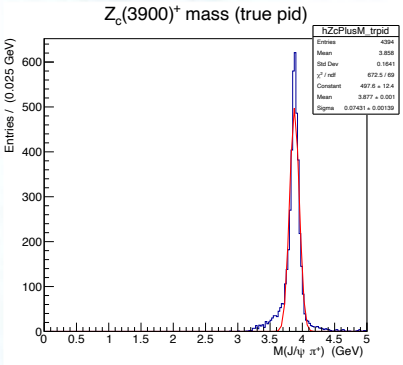


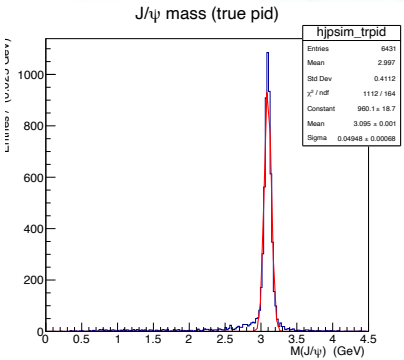
Analysis: mass: trpid



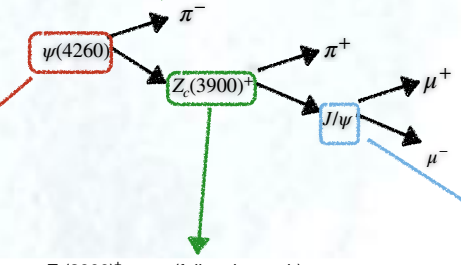
particles with true particle id





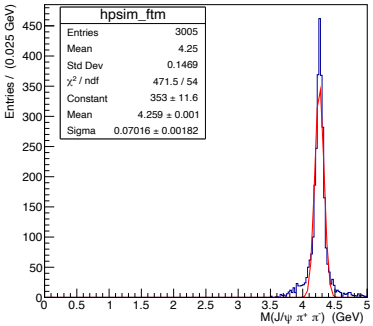


Analysis: mass: ftm

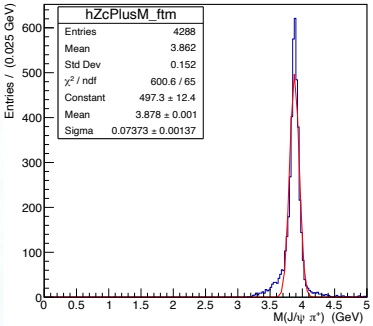


Full truth match for the particles (dec file & vertex & trpid)

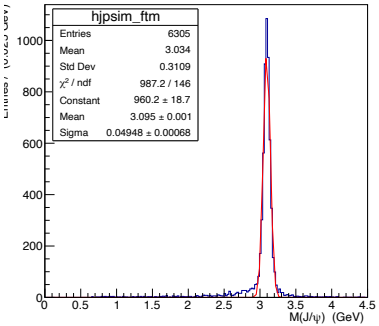
ψ(4260) mass (full truth match)



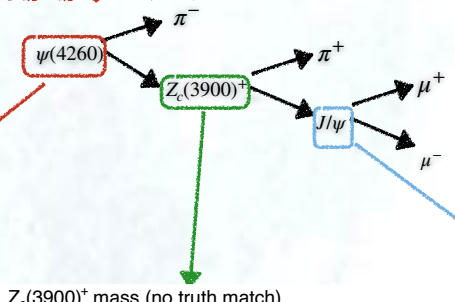
$Z_c(3900)^+$ mass (full truth match)



J/ψ mass (full truth match)

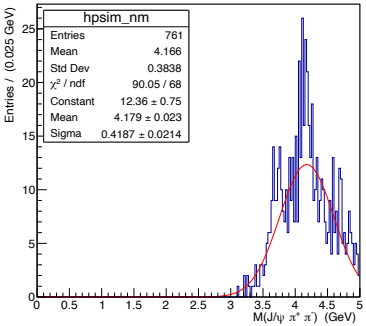


Analysis: mass: nm

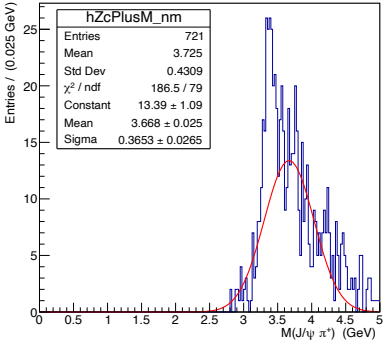


not matched particles (dec file & vertex & trpid)

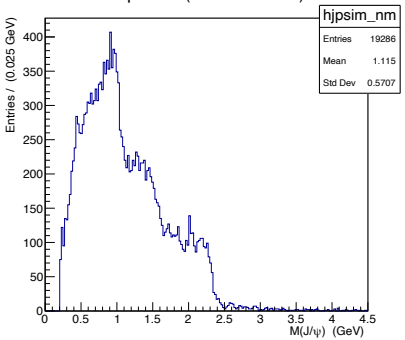
$\psi(4260)$ mass (no truth match)



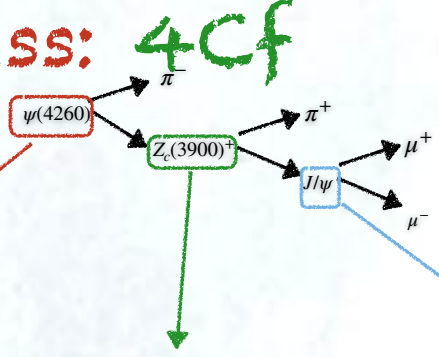
$Z_c(3900)^+$ mass (no truth match)



J/ψ mass (no truth match)



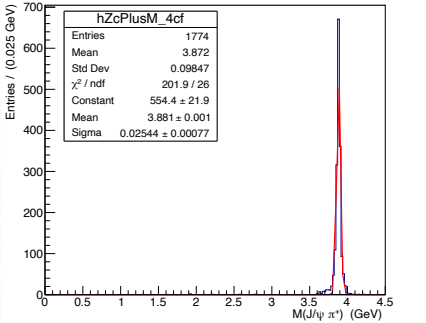
Analysis: mass: 4Cf



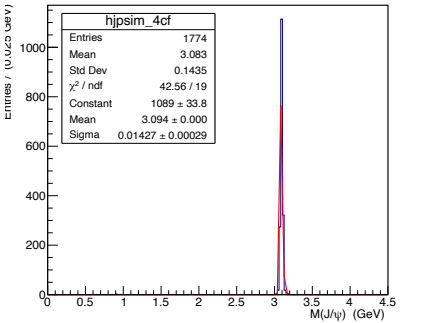
fitting with 4 constraint (4C) (p_i, E)

Searching in the initial cond. of psi4260 (p_i, E)

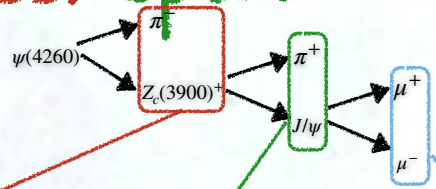
$Z_c(3900)^+$ mass (4C fit)



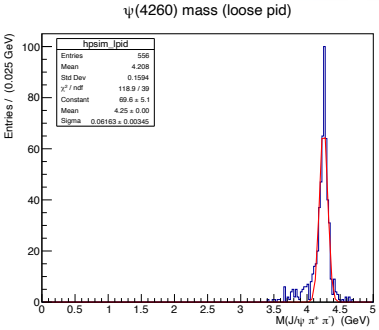
J/ψ mass (4C fit)

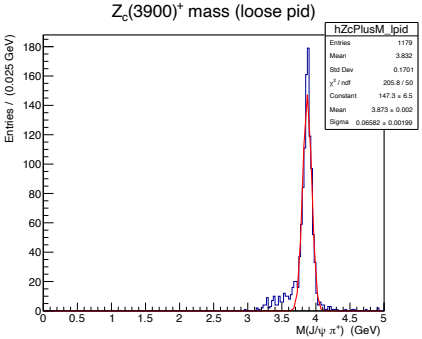


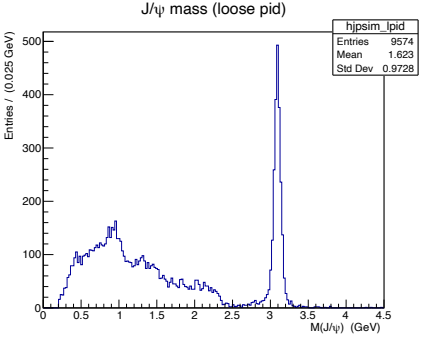
Analysis: mass: lpid



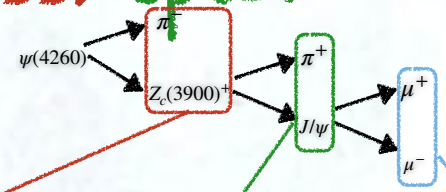
loose particle id





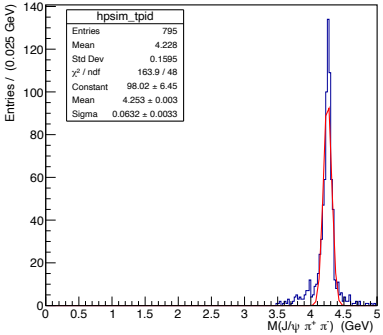


Analysis: mass: tpid

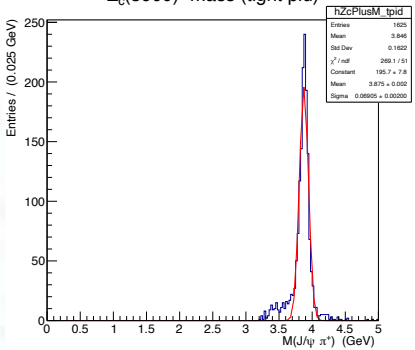


tight particle id

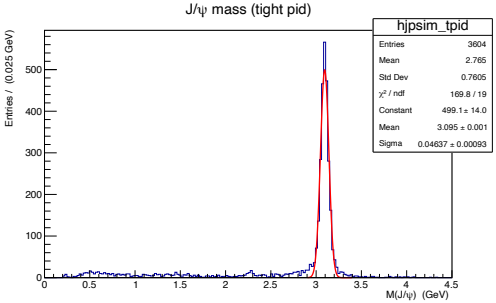
$\psi(4260)$ mass (tight pid)



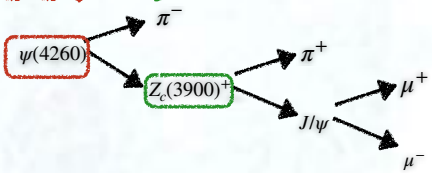
$Z_c(3900)^+$ mass (tight pid)



J/ψ mass (tight pid)



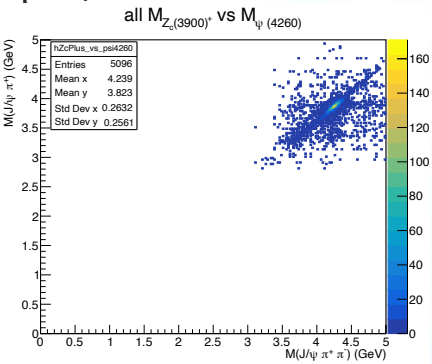
Analysis: mass: 2d

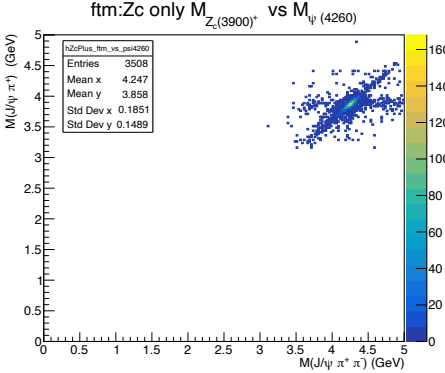


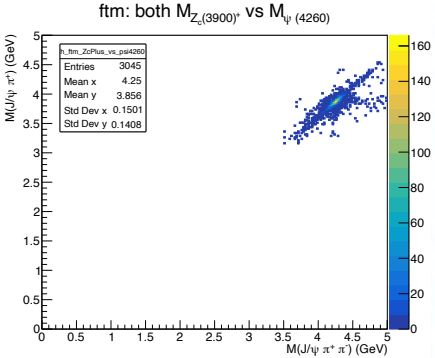
no ftm all events in psi4260

only $Z_c(3900)^+$ passed ftm

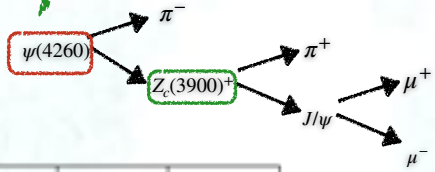
both of them passed ftm

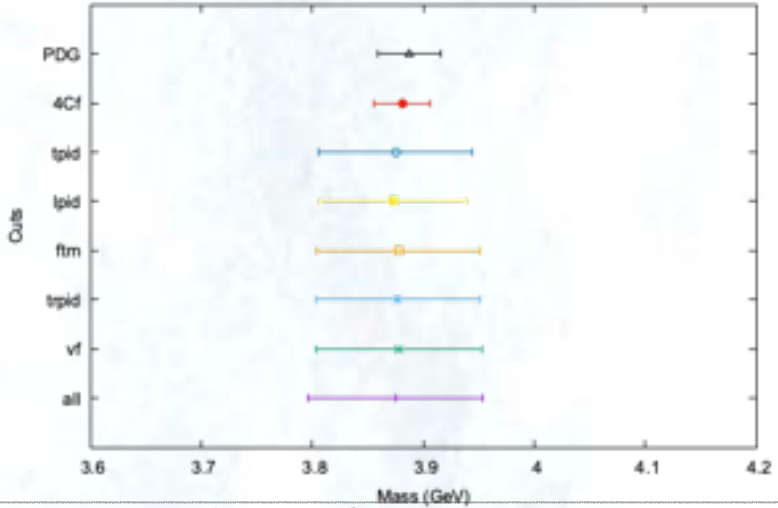




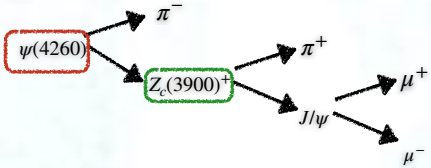


Analysis: mass: cut flow





Conclusion:



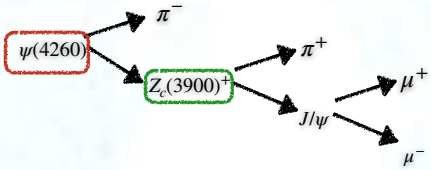
- the production of the exotic charged charmonium-like state $Z_c(3900)^+$ in $p\bar{p}$ collisions through the sequential process $\psi(4260) \to Z_c^+(3900)\pi^-, Z_c^+(3900) \to J/\psi\pi^+$.

- The decay file is modified to produce the ψ(4260) in the resonance (@$\sqrt{s} = 4230\ MeV$)

- $\psi(4260)$, $Z_c^+(3900)$ and J/ψ are reconstructed by the final state particles (μ^+, μ^-, π^+ and π^-).

- The current limit at PDG (3.8872± 0.0282 GeV) and we reached to (3.881 ± 0.02544 GeV) after 4Cf.

Future Works:



- produce DPM background (already produced $10k$ not included yet),
- increase stats. for both signal and DPM background,
- PWA analysis (Asiye Olgun already started to look into it)
- $Z_c(4430)$ study has been started (Umut Keskin, it will be his PhD thesis)

$Z_c(4430)$:

- We also started to analyze $Z_c(4430)$. The closest one to the PANDA detector is LHCb with pp collisions. So we taken the decay process from here and produced some data with a new decay file while using fairSoft and PANDAROOT softwares for productions and analysis.

Abstract

Resonant structures in $B^0 \to \psi'\pi^- K^+$ decays are analyzed by performing a four-dimensional fit of the decay amplitude, using pp collision data corresponding to 3 fb^{-1} collected with the LHCb detector. The data cannot be described with $K^+\pi^-$ resonances alone, which is confirmed with a model-independent approach. A highly significant $Z(4430)^- \to \psi'\pi^-$ component is required, thus confirming the existence of this state. The observed evolution of the $Z(4430)^-$ amplitude with the $\psi'\pi^-$ mass establishes the resonant nature of this particle. The mass and width measurements are substantially improved. The spin-parity is determined unambiguously to be 1^+.

In this Letter, we report a 4D model-dependent amplitude fit to a sample of $25\,176 \pm 174$ $B^0 \to \psi' K^+\pi^-$, $\psi' \to \mu^+\mu^-$ candidates reconstructed with the LHCb detector in pp collision data corresponding to 3 fb^{-1} collected at $\sqrt{s} = 7$ and 8 TeV. The ten-fold increase in signal yield over the previous measurement [27] improves sensitivity to exotic states and allows their resonant nature to be studied in a novel way. We complement the amplitude fit with a model-independent approach [24].

https://arxiv.org/pdf/1404.1903.pdf

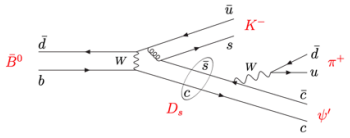


FIG. 1: Decay process through D_s: $\bar{B}^0 \to Z^+(4430)K^- \to \psi'\pi^+K^-$.

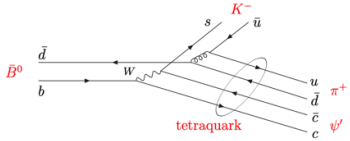


FIG. 2: Decay process through tetraquark: $\bar{B}^0 \to Z^+(4430)K^- \to \psi'\pi^+K^-$.

https://arxiv.org/pdf/0805.2442.pdf

$Z_c(4430)$:

- Here is the decay file for data production.

pp_B0_Zc4430_ee_nophot.dec 〉No Selec

```
noPhotos

Decay B0
  1.0    Z_c(4430)- K+  PHSP;
Enddecay

Decay Z_c(4430)-
  1.0    psi(3770) pi-  PHSP;
Enddecay

Decay psi(3770)
  1.0    e+ e-  VLL;
Enddecay

End
```

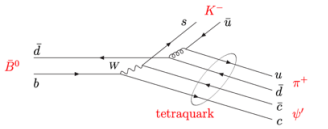
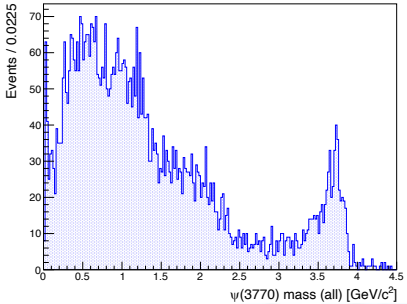


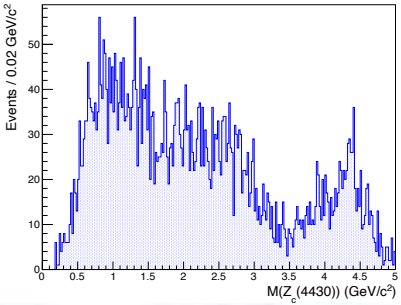
FIG. 2: Decay process through tetraquark: $\bar{B}^0 \to Z^+(4430)K^- \to \psi'\pi^+K^-$.

https://arxiv.org/pdf/0805.2442.pdf

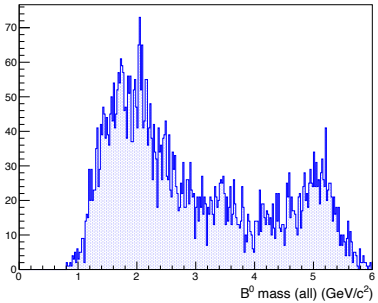
ψ'



M(Zc(4430))



M(B^0)



Thank you...