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

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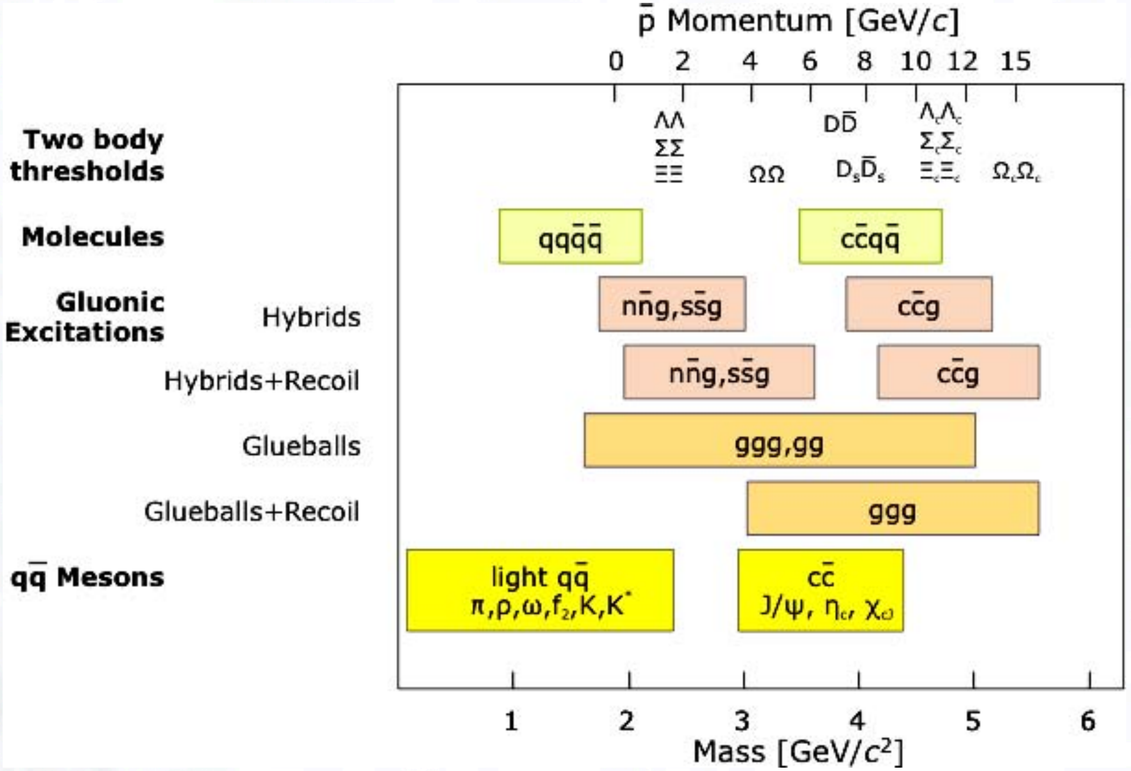
PANDA Collaboration Meeting 20/2

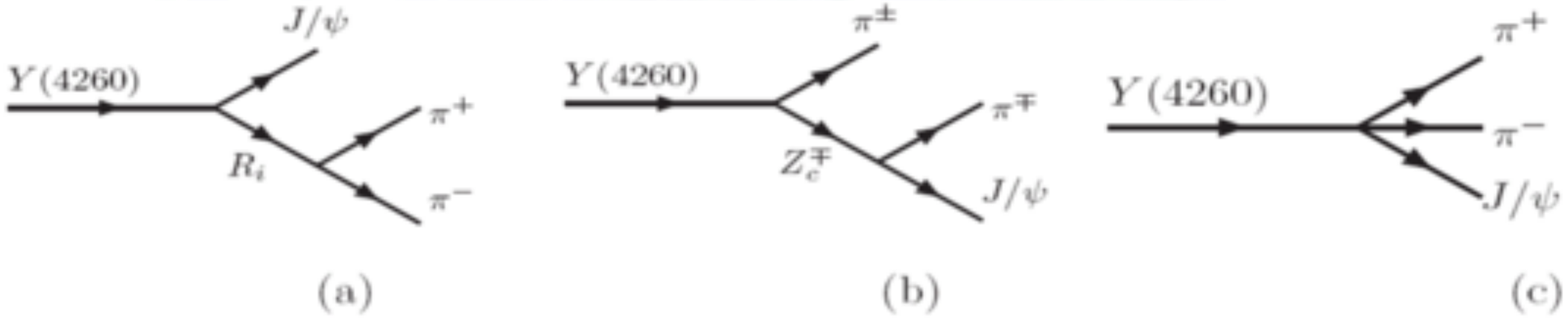
Introduction

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

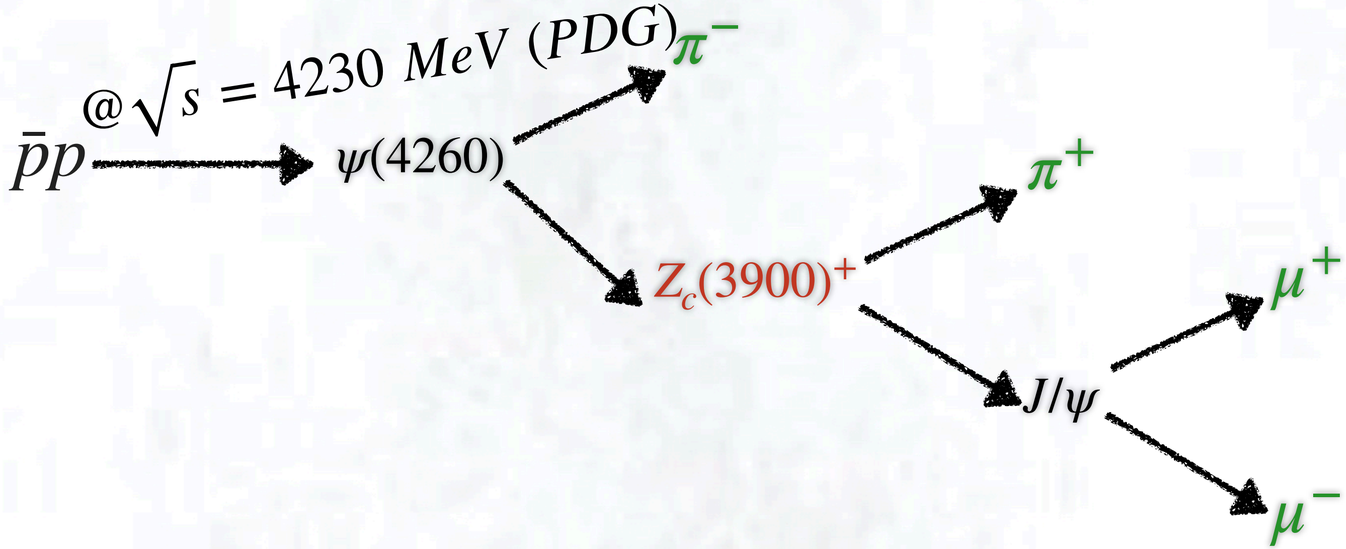


The Zc(3900)− was observed in π−J/ψ invariant mass distribution in the study of e+e− → π+π−J/ψ at BESIII and Belle experiments [M. Ablikim et al., C. Z. Yuan et al.].

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^-)

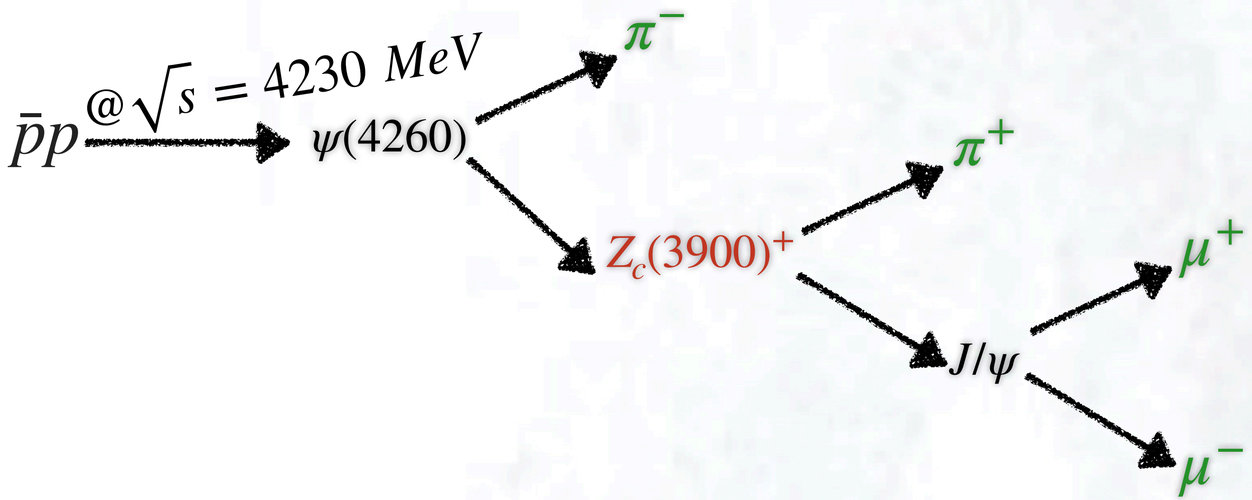
for event generation

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 (produced, not included in the talk)
- PHSP model was used for all event generations
- PHOTOS was turned off for simplicity

Strategy

Signal events was generated by

nev = 10k and pbeam = 8.59979 // for pbar = 4.230 GeV

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

pbarZ: 8.59979; Etot :9.58381;

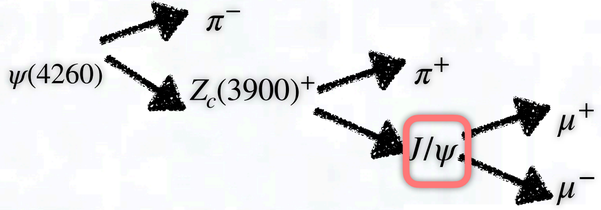
TLorentzVector ini(0, 0, pbarZ, Etot); // for pbar = 4.230 GeV

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

Strategy

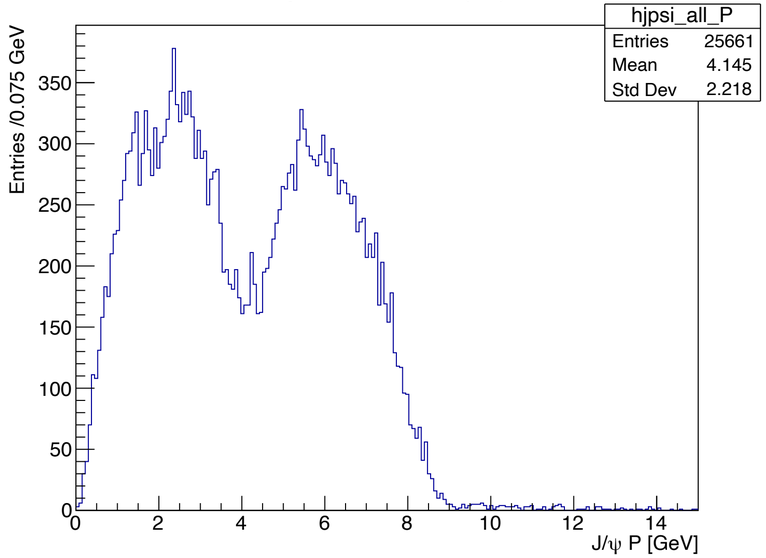
- Combine all μ candidates and accept them as J/ψ if their mass is within nominal range and apply a vertex fit with a mass constraint,
- Combine these with a π^+ and accept them as a candidate charmonium
- Then reconstruct the initial system, perform a 4-constraint fit and accept only those ones which 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

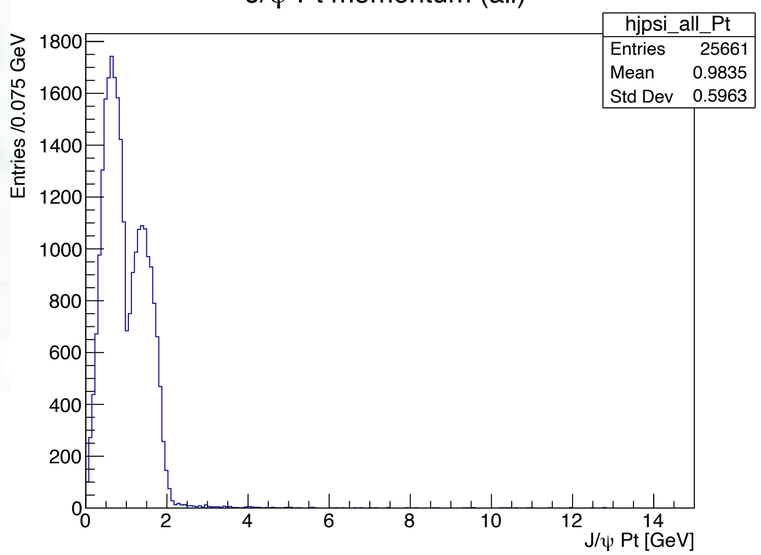


Reconstructed particles

J/ψ momentum (all)

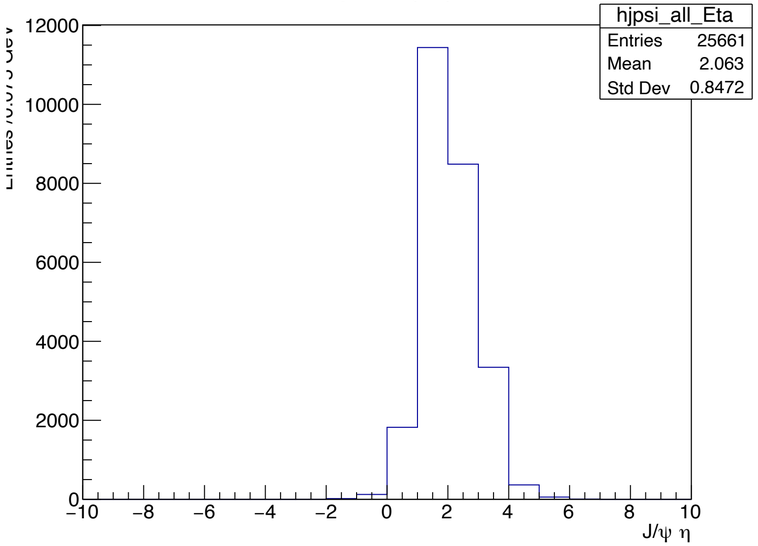


J/ψ Pt momentum (all)

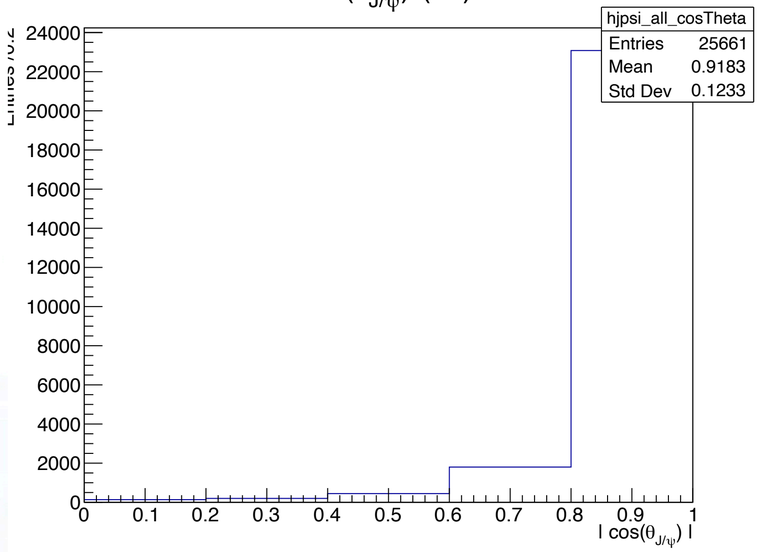


all

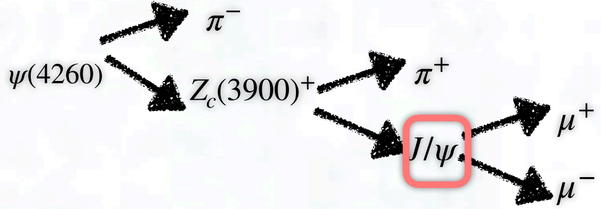
J/ψ eta (all)



$\cos(\theta_{J/\psi})$ (all)

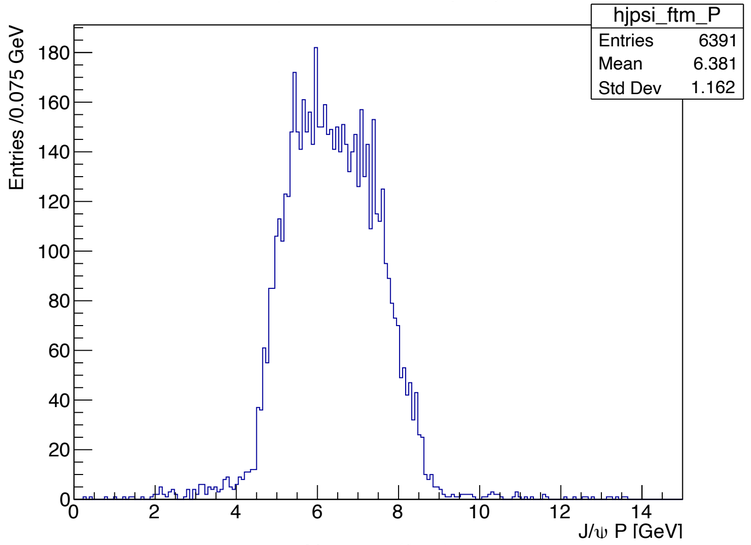


Analysis: kinematics



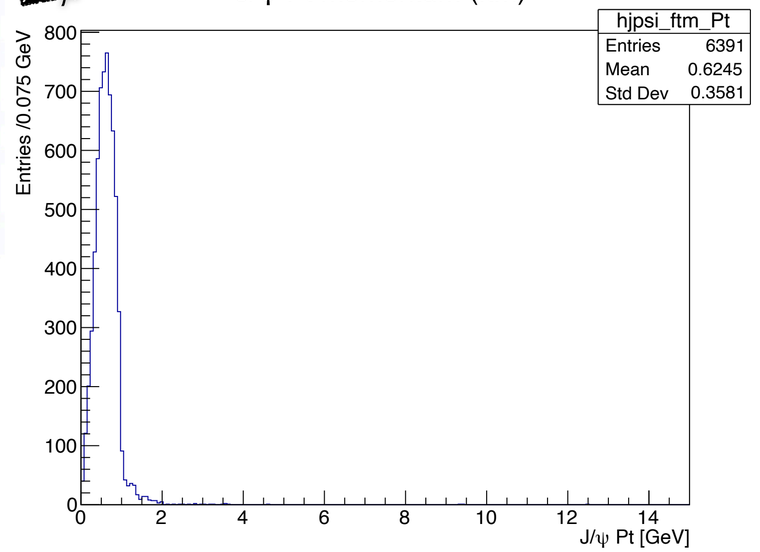
Reconstructed particles

J/ψ momentum (ftm)

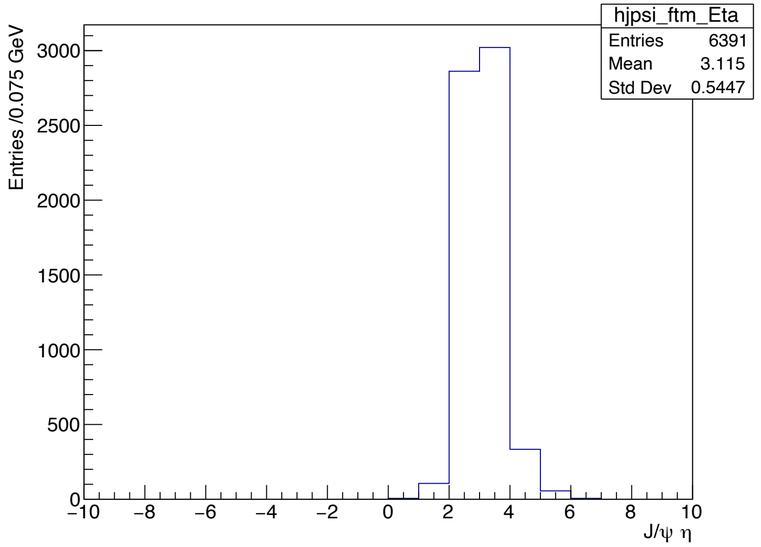


ftm

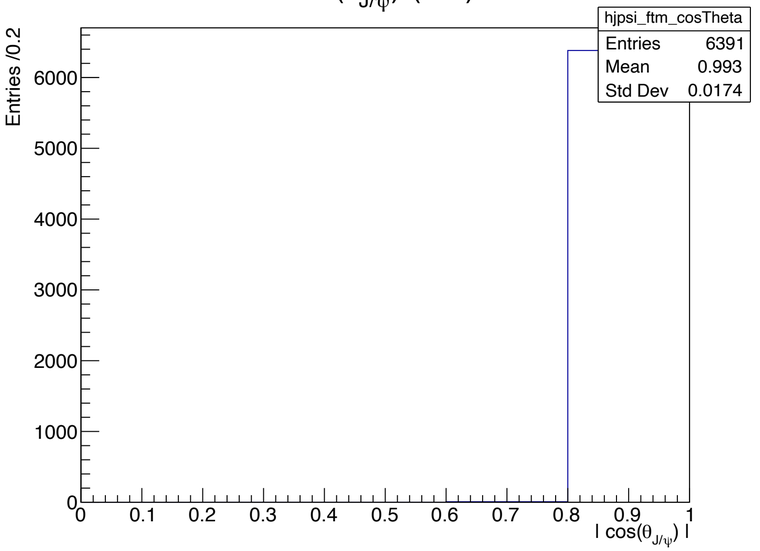
J/ψ Pt momentum (ftm)



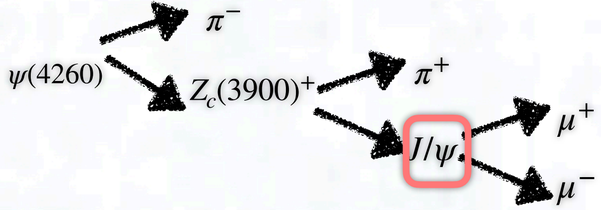
J/ψ eta (ftm)



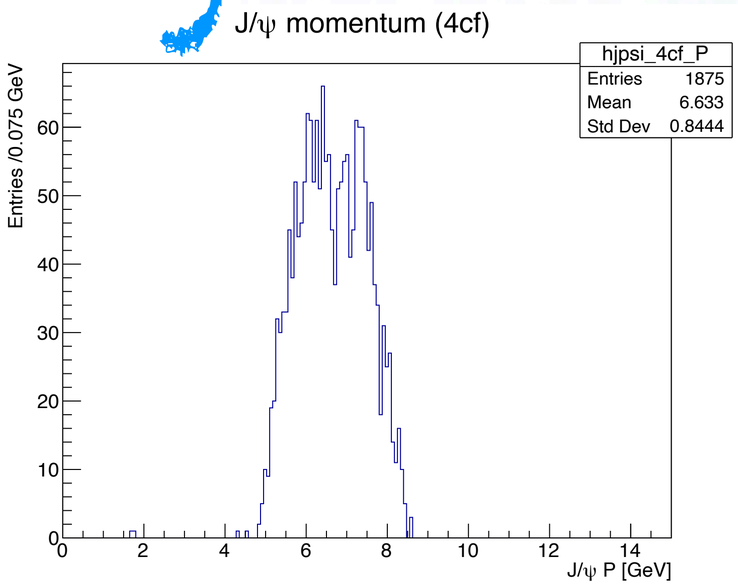
$\cos(\theta_{J/\psi})$ (ftm)



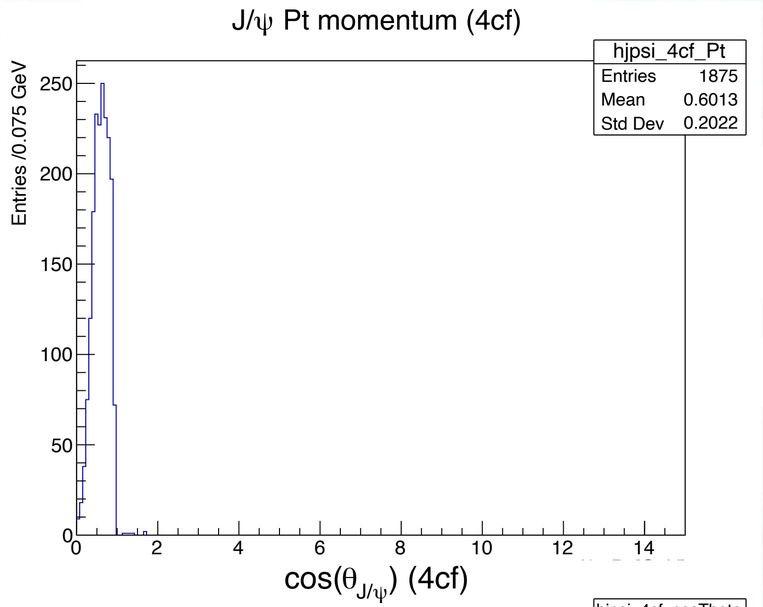
Analysis: kinematics

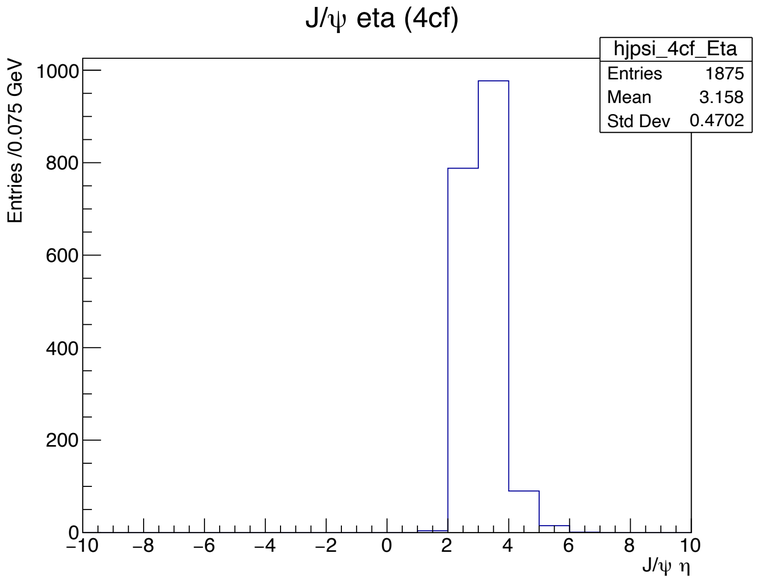


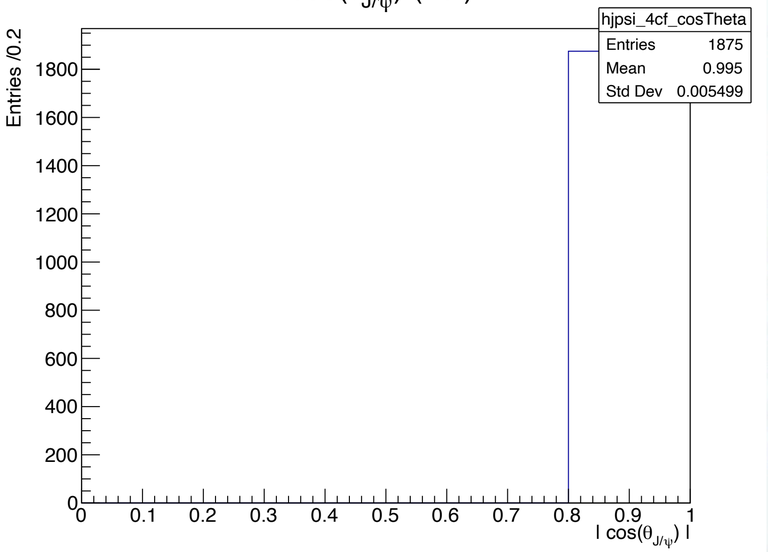
Reconstructed particles



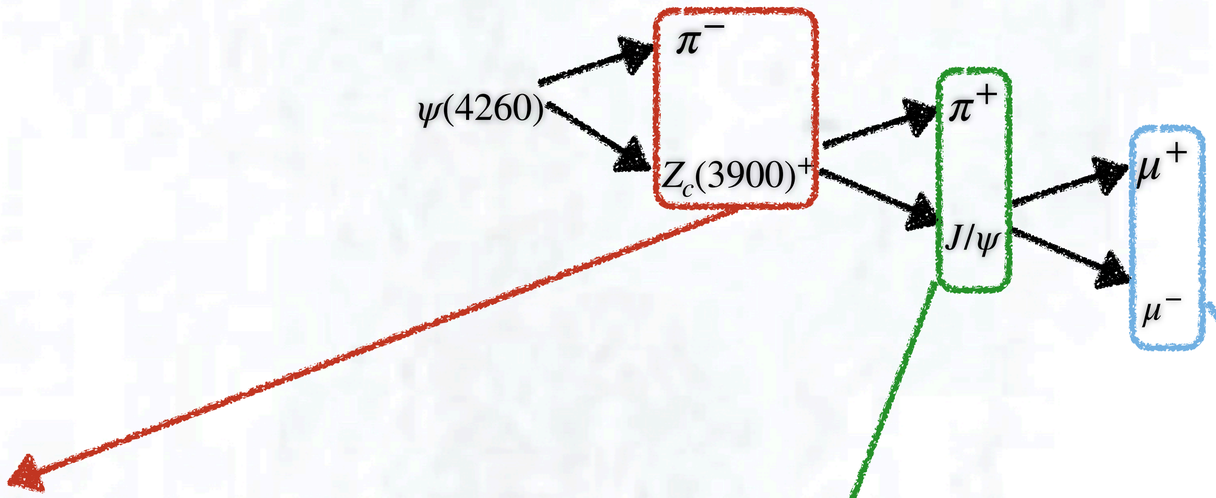
4cf





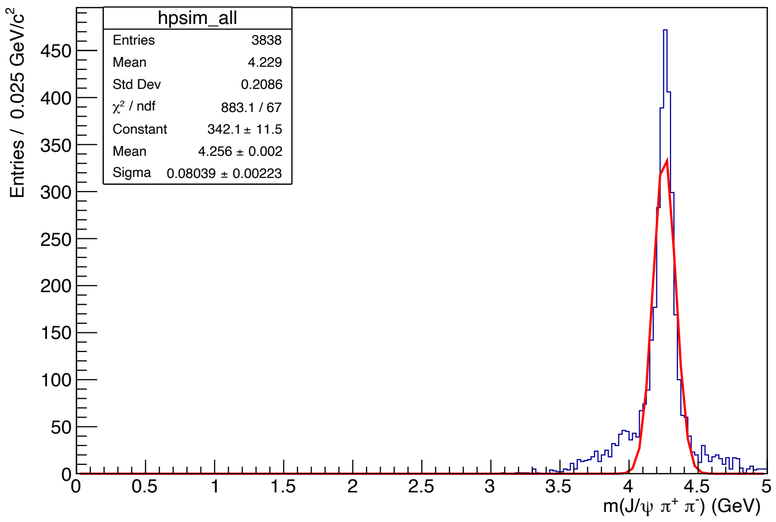


Analysis: mass: all

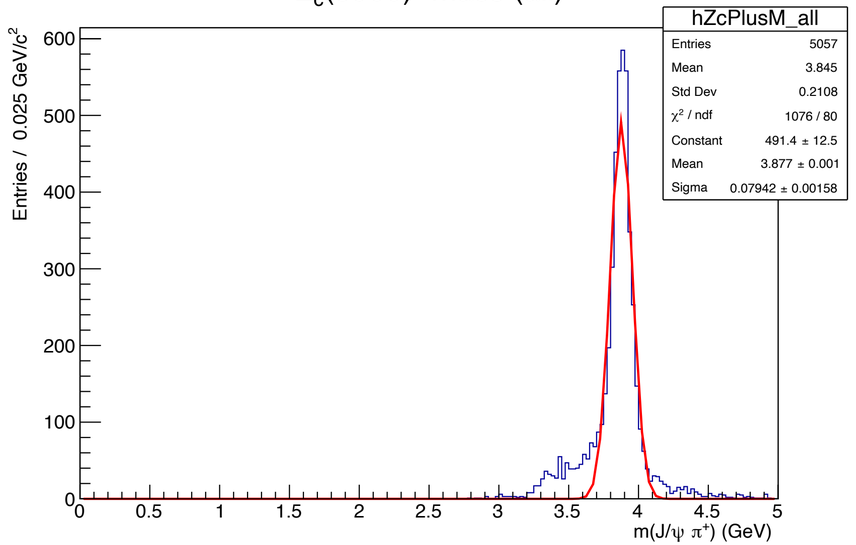


Reconstructed all particles

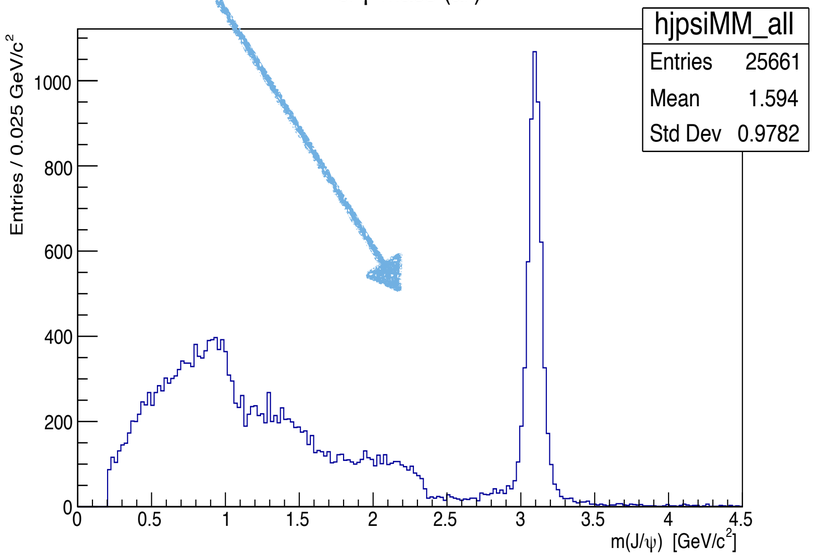
$\psi(4260)$ mass (all)



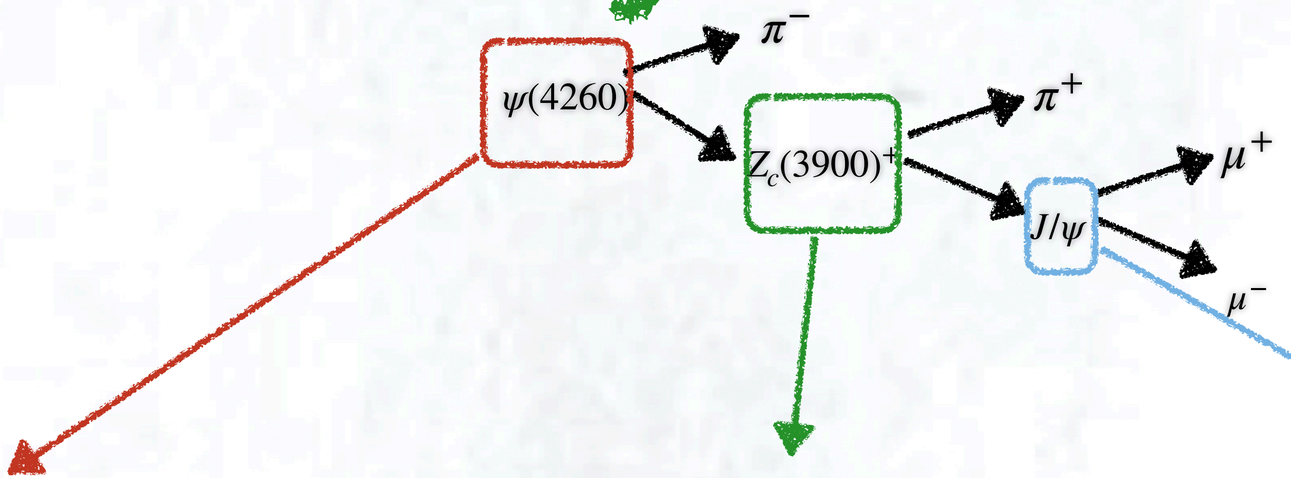
$Z_c(3900)^+$ mass (all)



J/ψ mass (all)

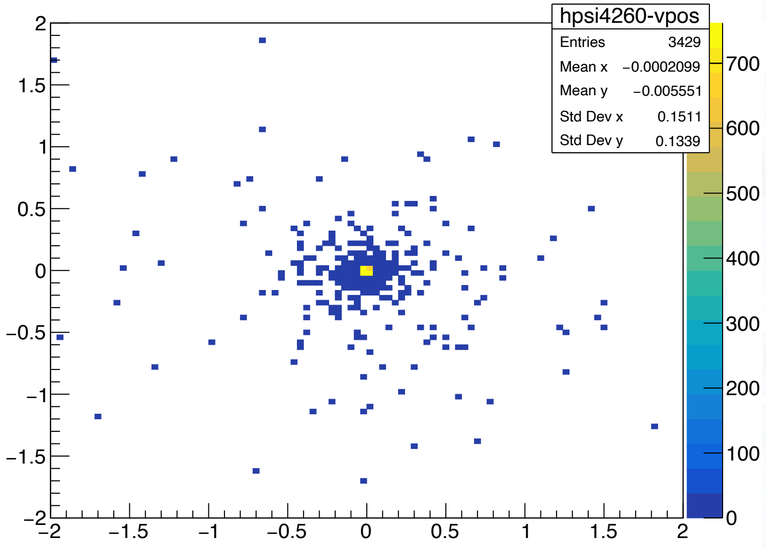


Analysis: decay vertex

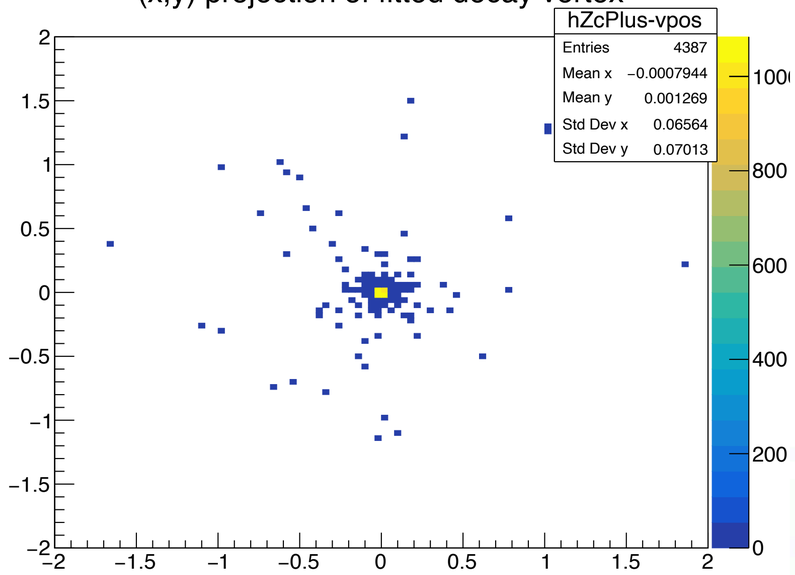


Resonant particles decay vertexes

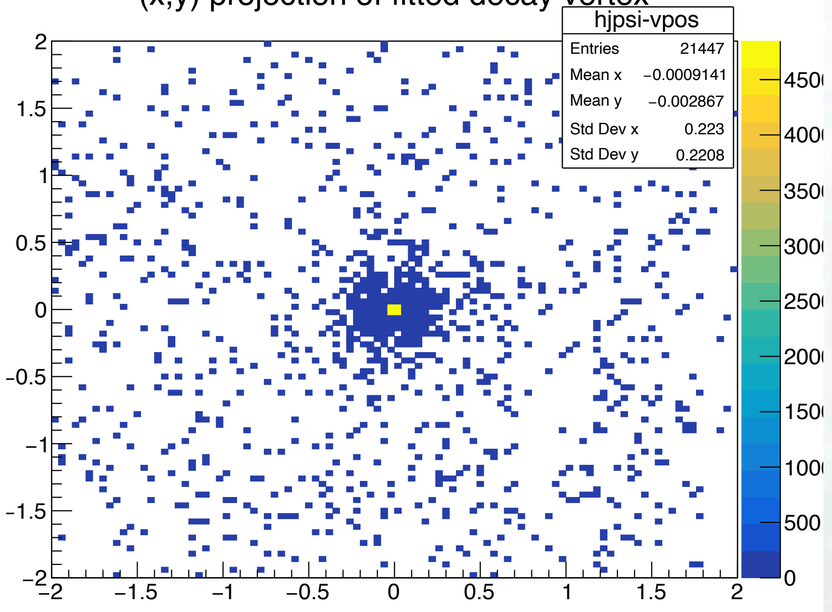
(x,y) projection of fitted decay vertex



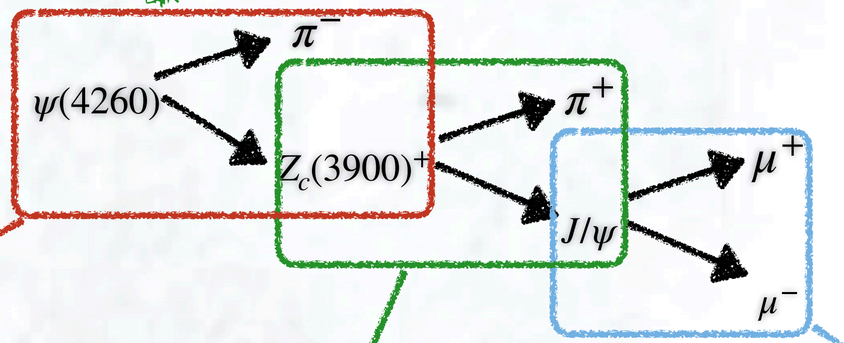
(x,y) projection of fitted decay vertex



(x,y) projection of fitted decay vertex

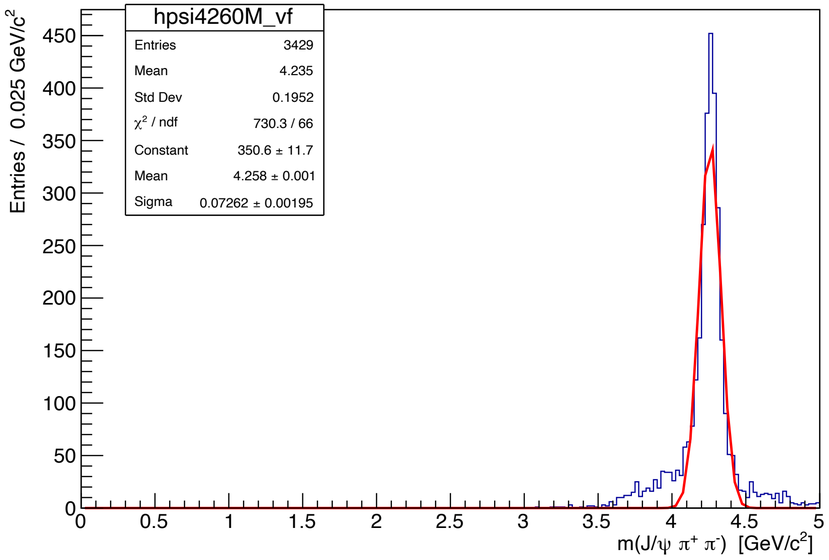


Analysis: decay vertex fit

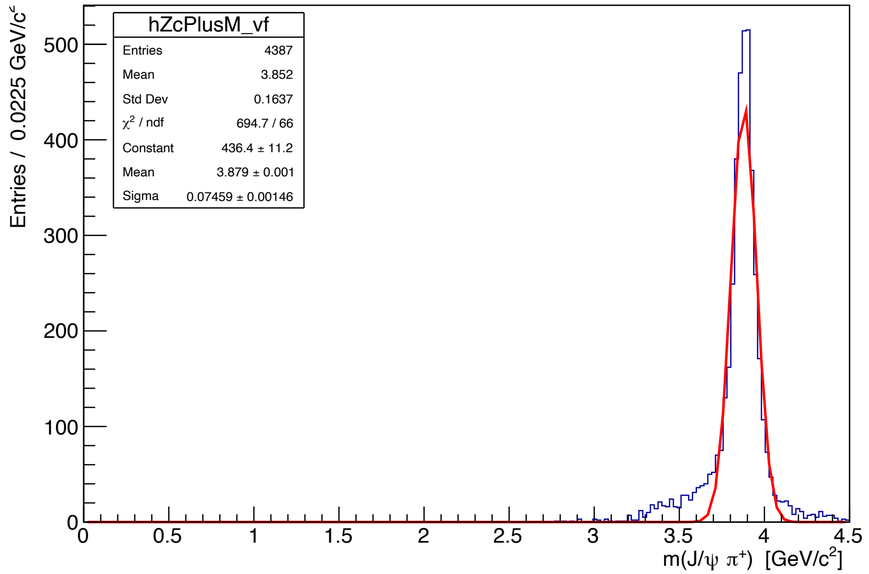


InvMass for particles coming from vertex

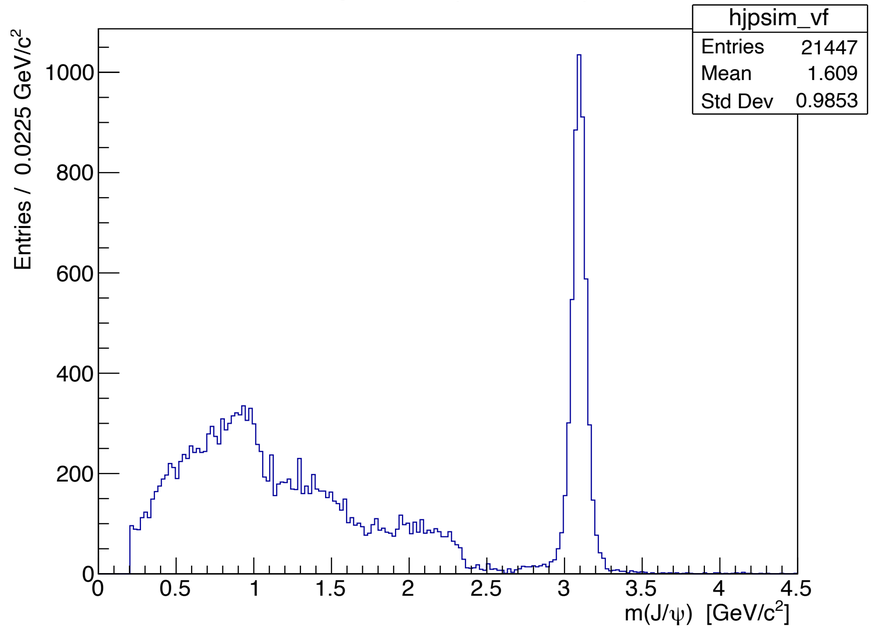
$\psi(4260)$ mass (vertex fit)



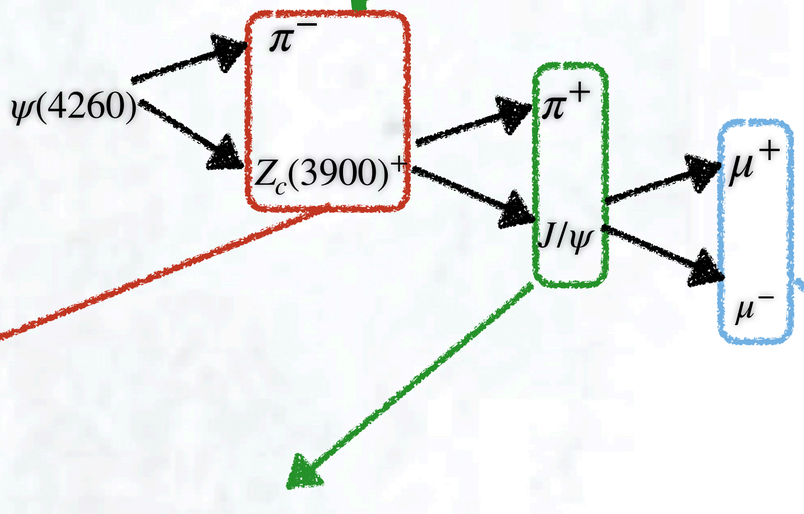
$Z_c(3900)^+$ mass (vertex fit)



J/ψ mass (vertex fit)

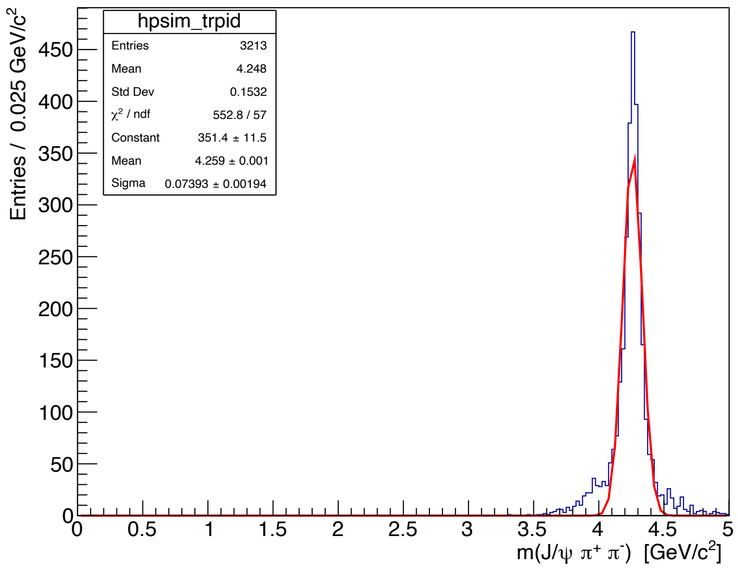


Analysis: mass: trpid

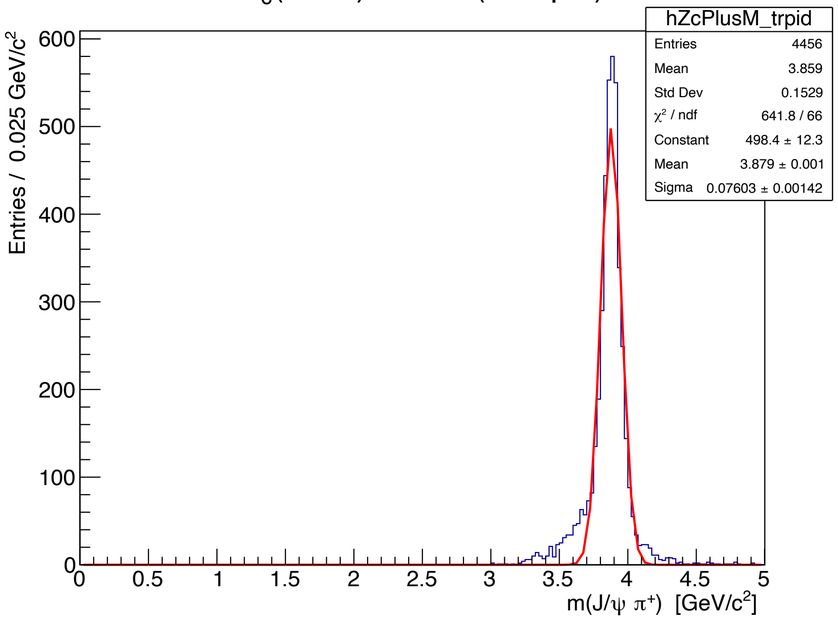


particles with true particle id

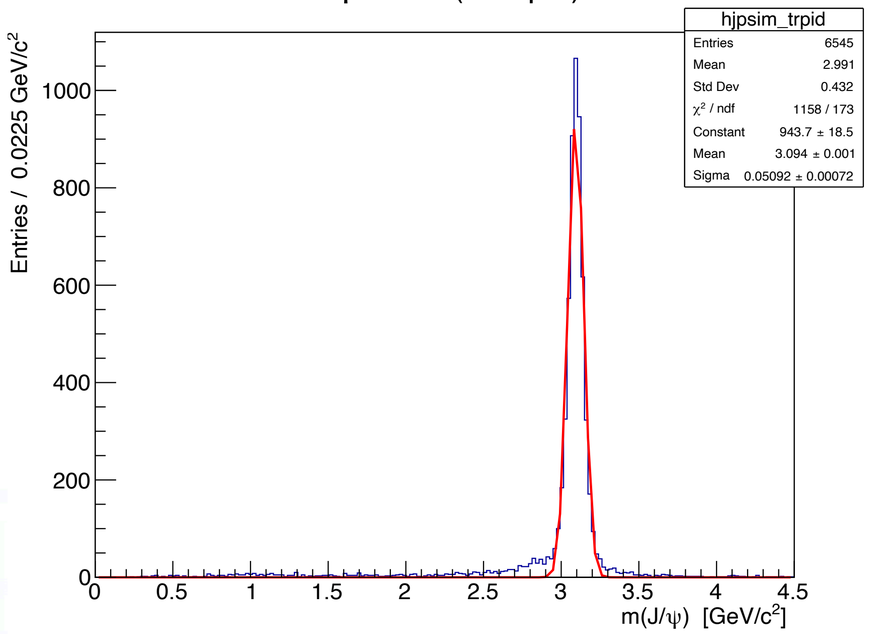
$\psi(4260)$ mass (true pid)



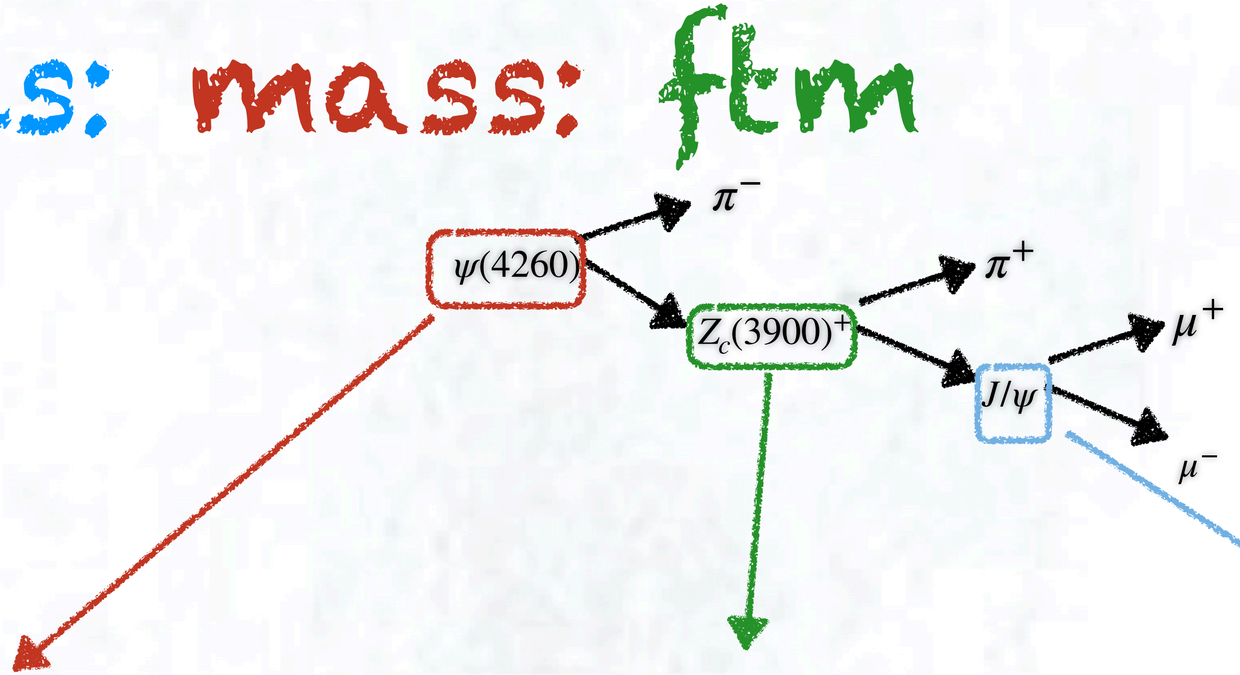
$Z_c(3900)^+$ mass (true pid)



J/ψ mass (true pid)

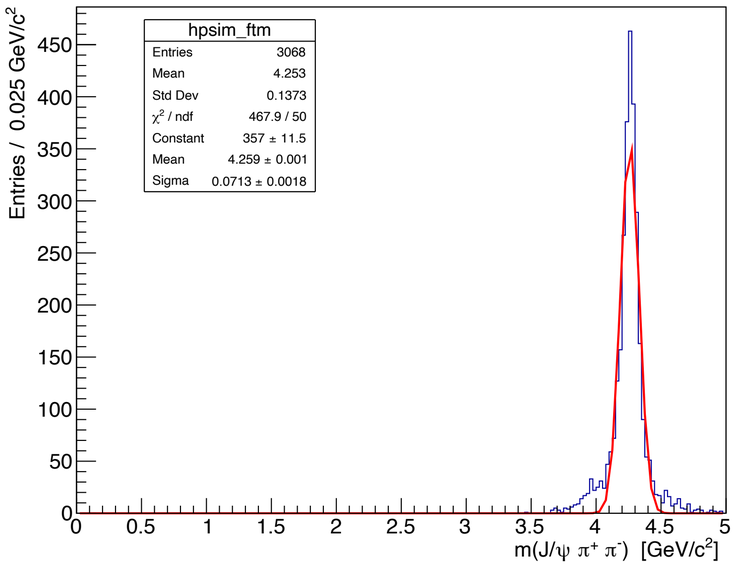


Analysis: mass: ftm

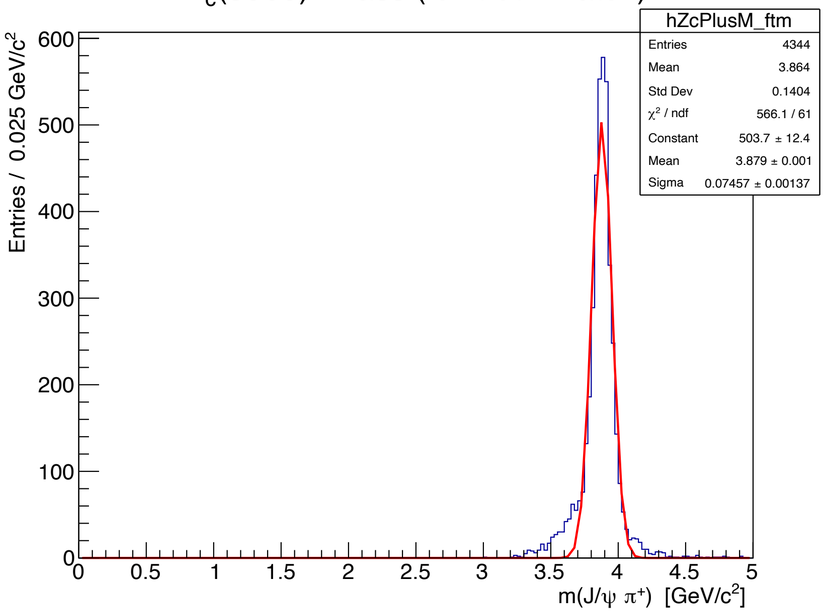


Full truth match for the particles (dec file & vertex & trpid)

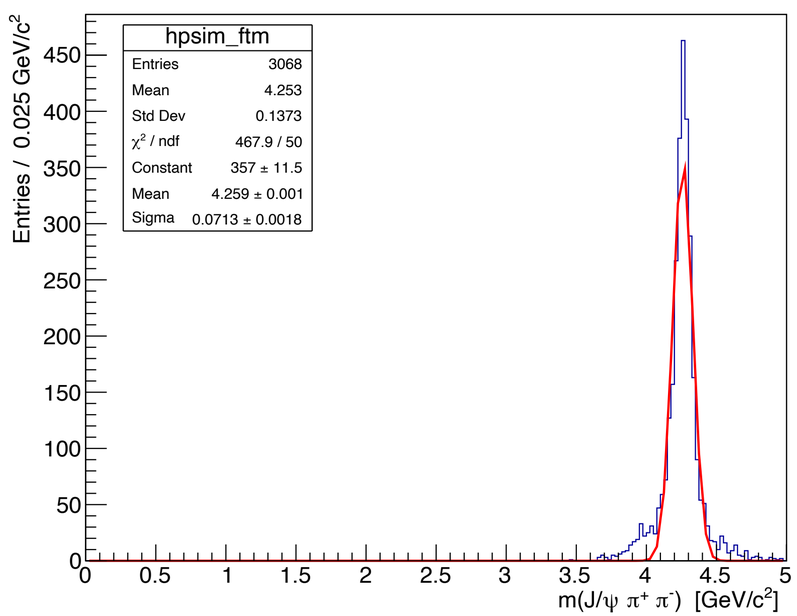
$\psi(4260)$ mass (full truth match)



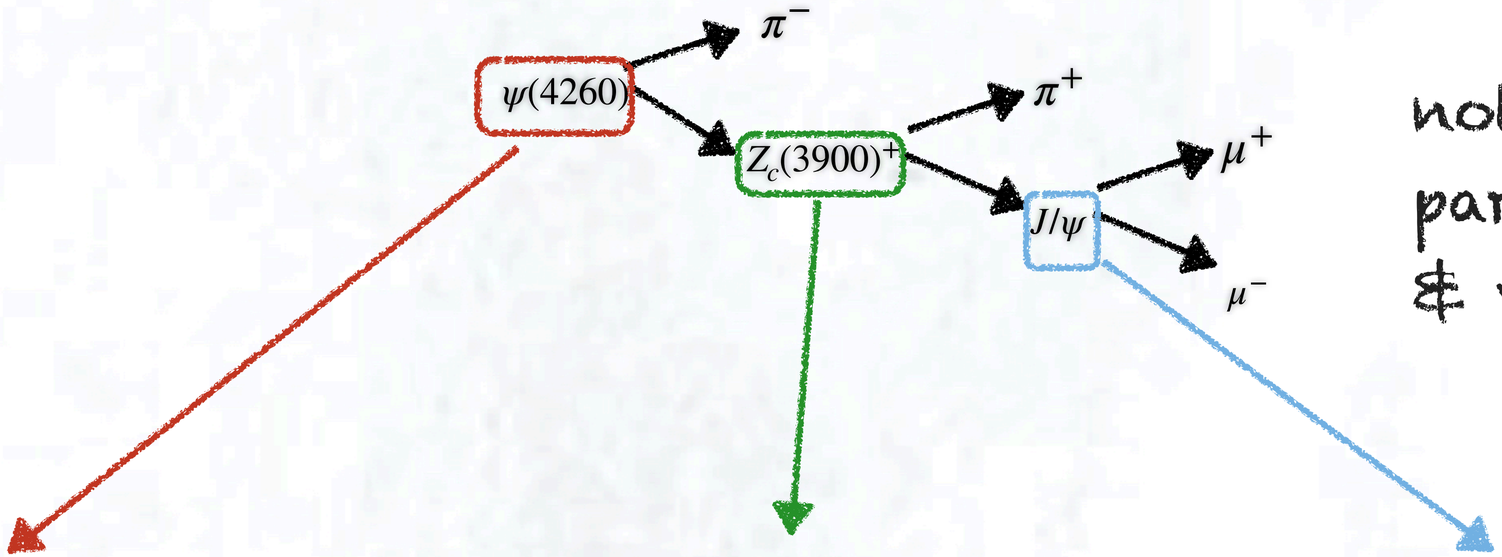
$Z_c(3900)^+$ mass (full truth match)



$\psi(4260)$ mass (full truth match)

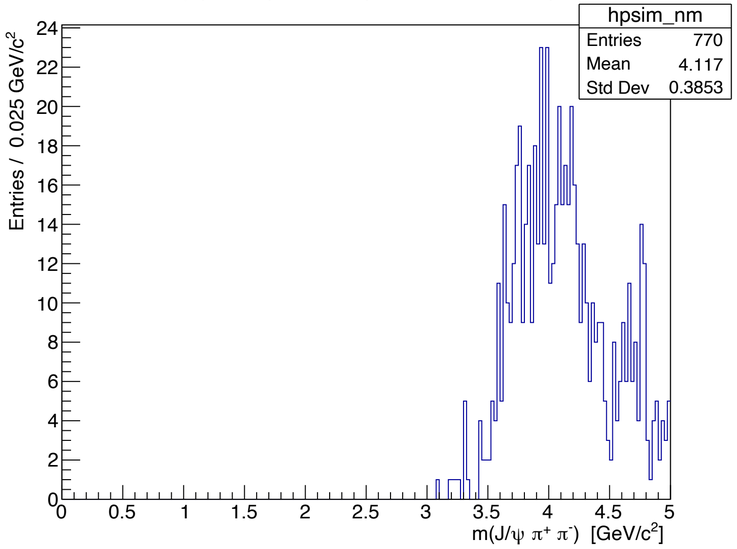


Analysis: mass: nm

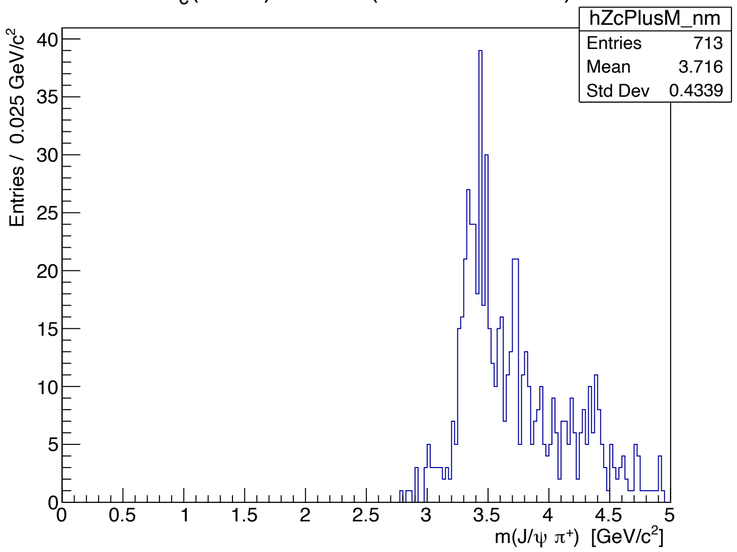


not matched particles (dec file & vertex & trpid)

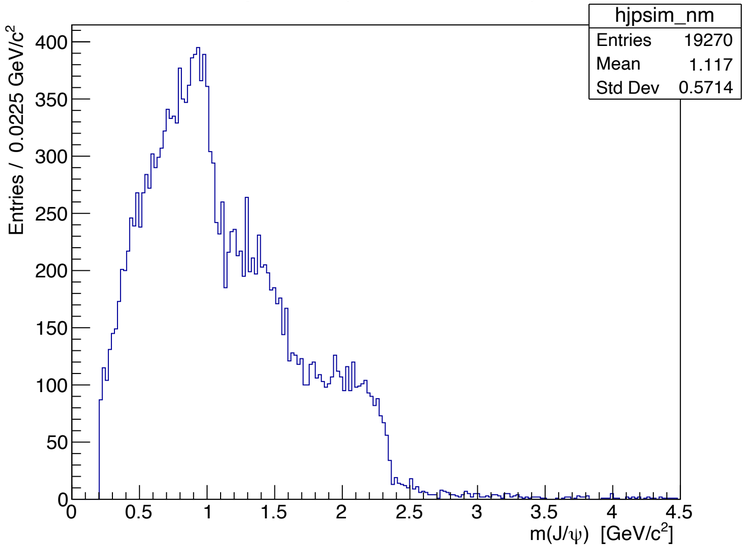
$\psi(4260)$ mass (no truth match)



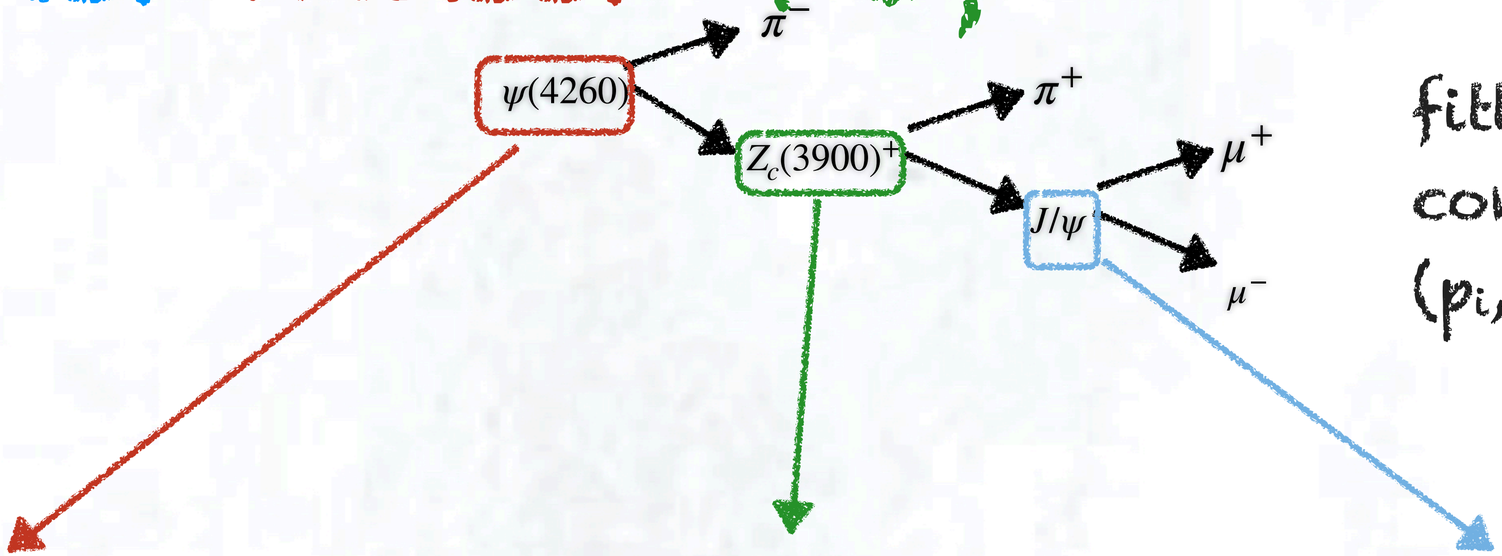
$Z_c(3900)^+$ mass (no truth match)



J/ψ mass (no truth match)



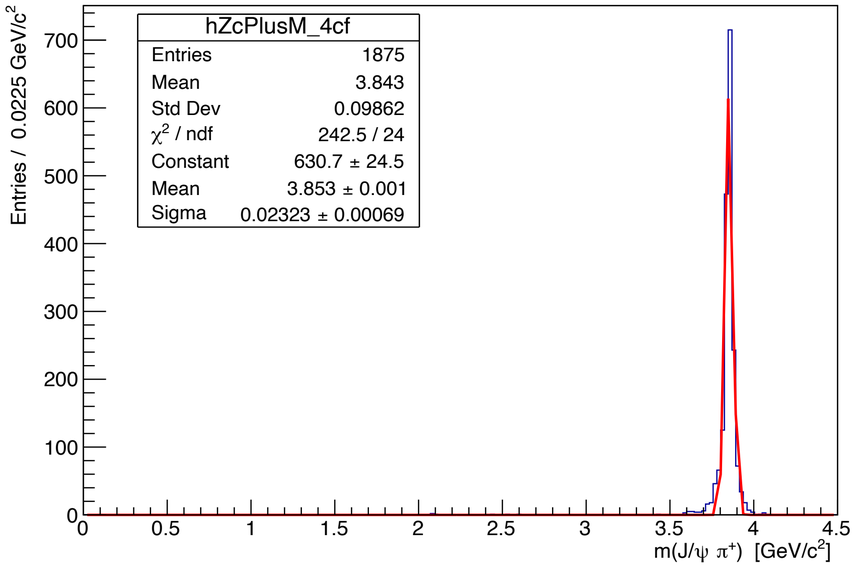
Analysis: mass: 4Cf



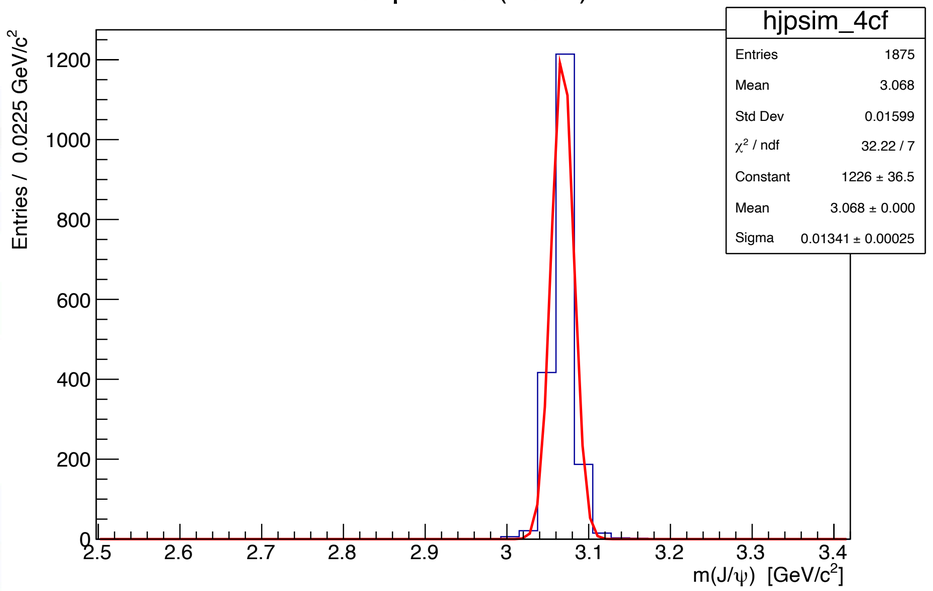
fitting with 4 constraint (4C) (p_i, E)

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

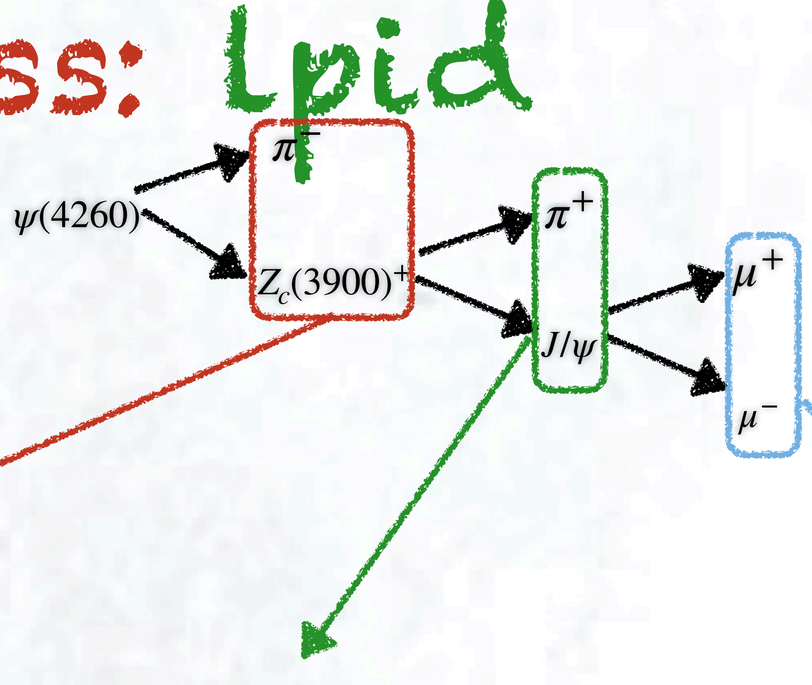
$Z_c(3900)^+$ mass (4C fit)



J/ψ mass (4C fit)

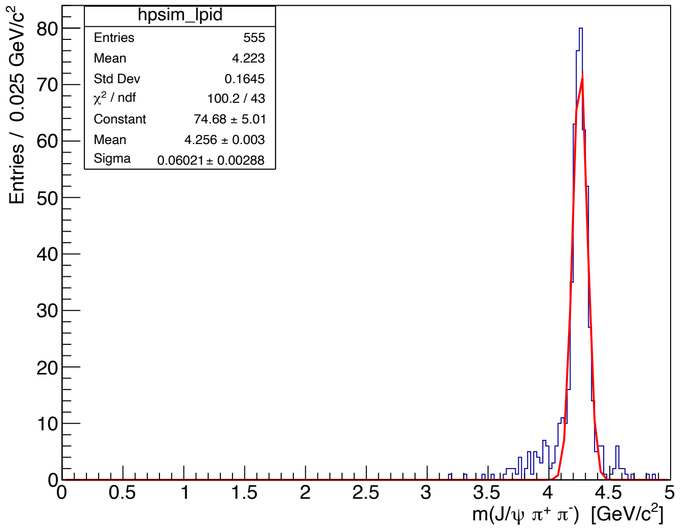


Analysis: mass: lpid

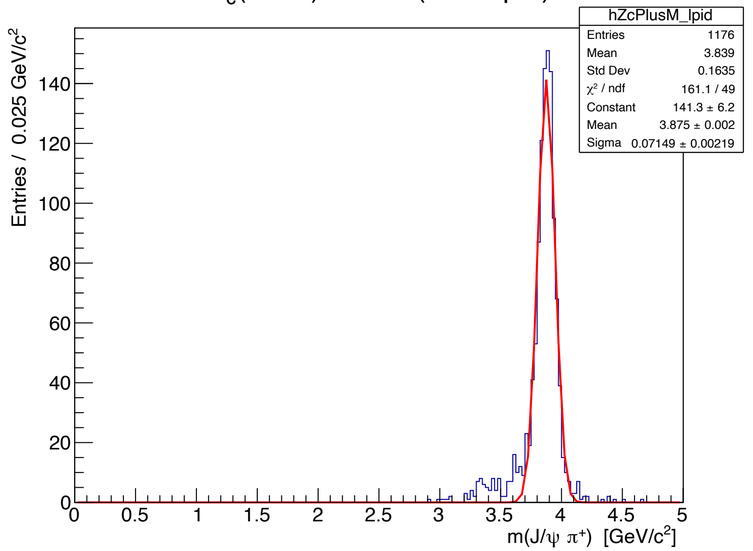


loose particle id

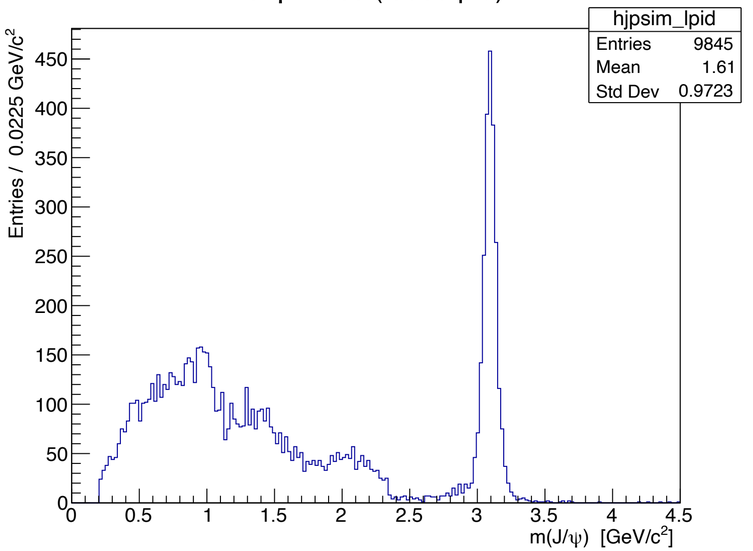
$\psi(4260)$ mass (loose pid)



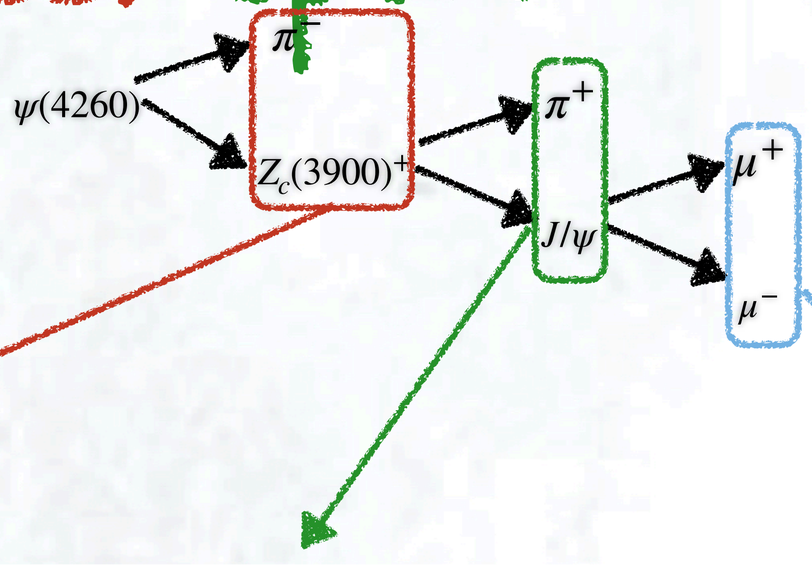
$Z_c(3900)^+$ mass (loose pid)



J/ψ mass (loose pid)

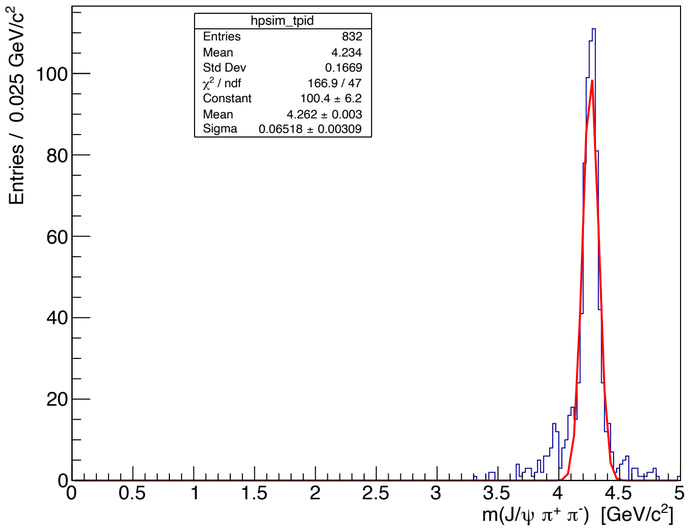


Analysis: mass: tpid

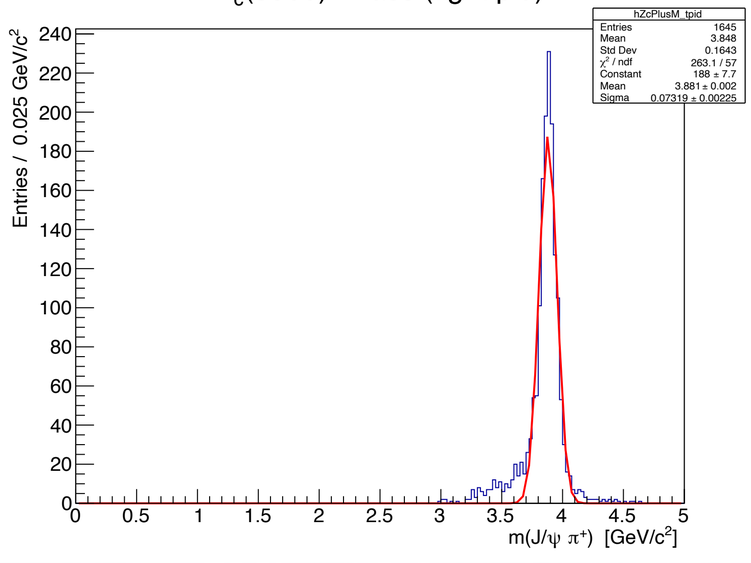


tight particle id

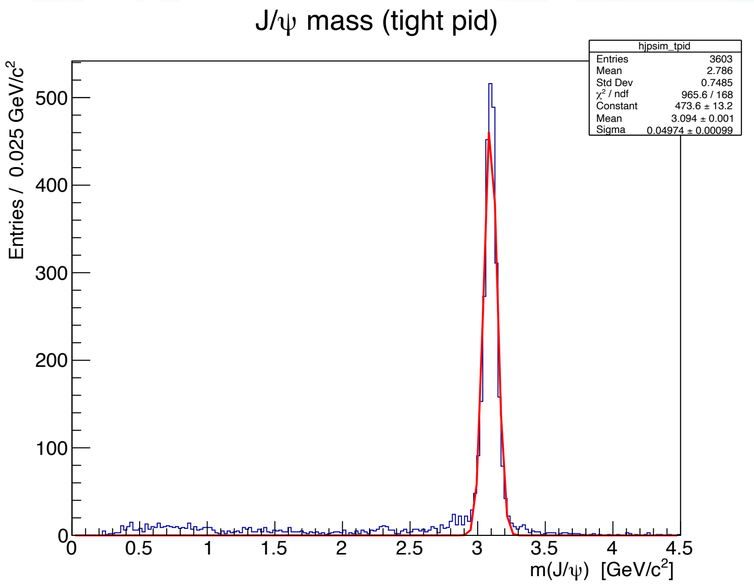
$\psi(4260)$ mass (tight pid)



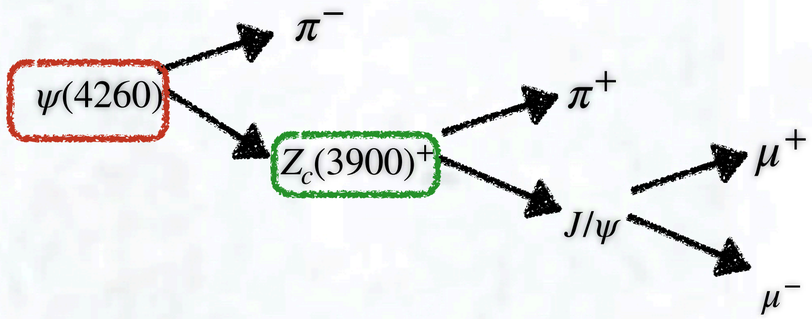
$Z_c(3900)^+$ mass (tight pid)



J/ψ mass (tight pid)



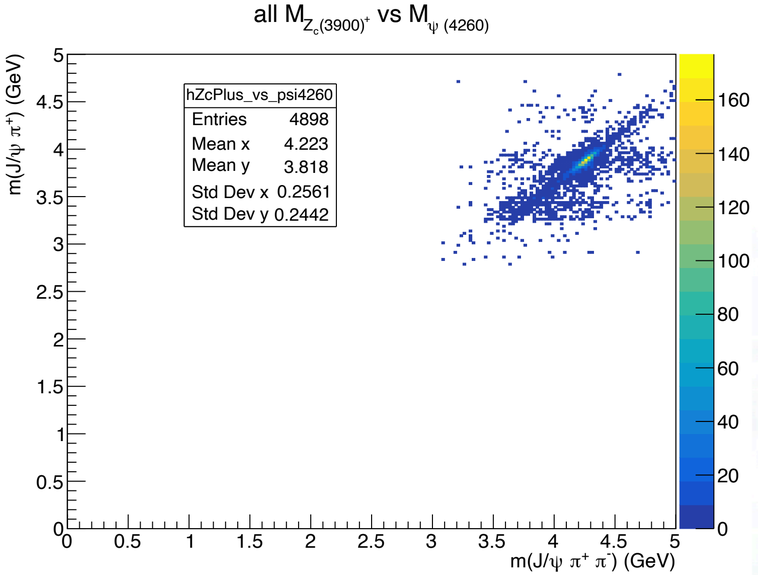
Analysis: mass: 2d

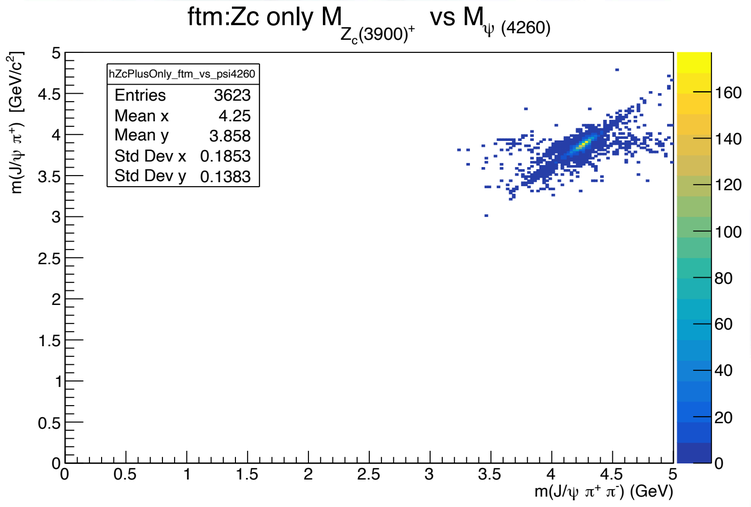


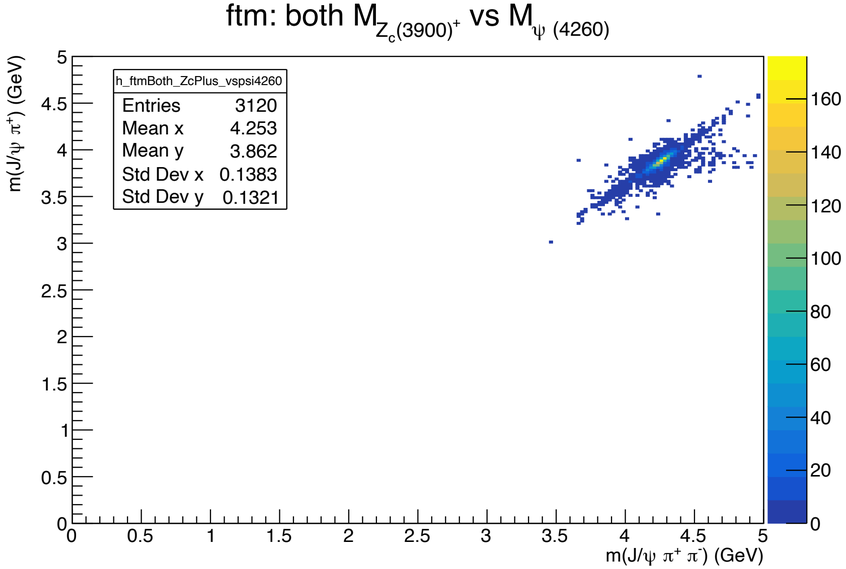
no ftm all events in psi4260

only $Z_c(3900)^+$ passed ftm

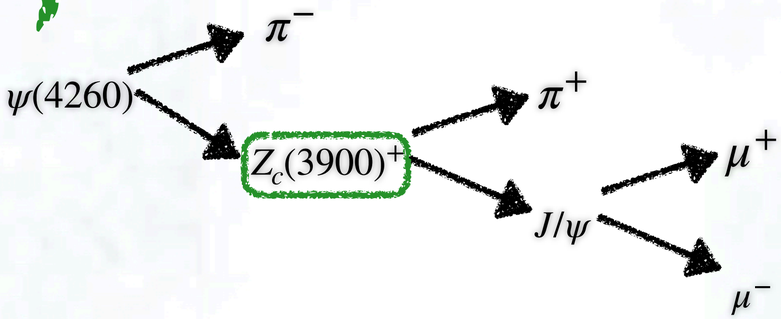
both of them passed ftm

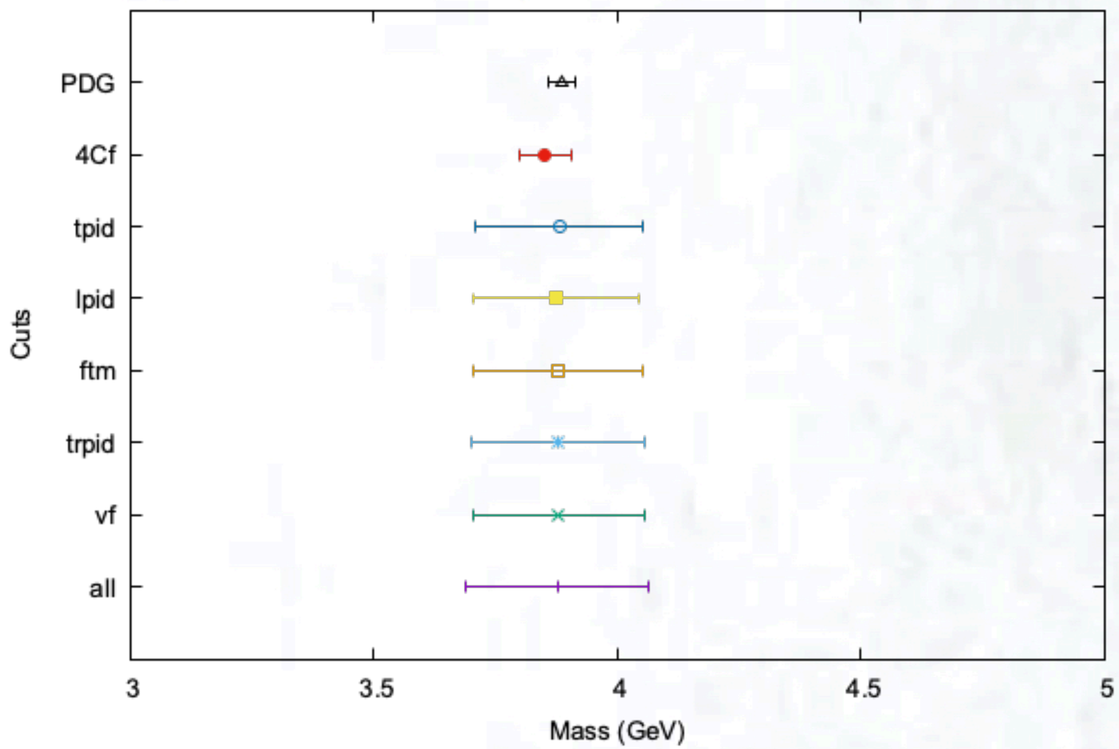






Analysis: mass: cut flow



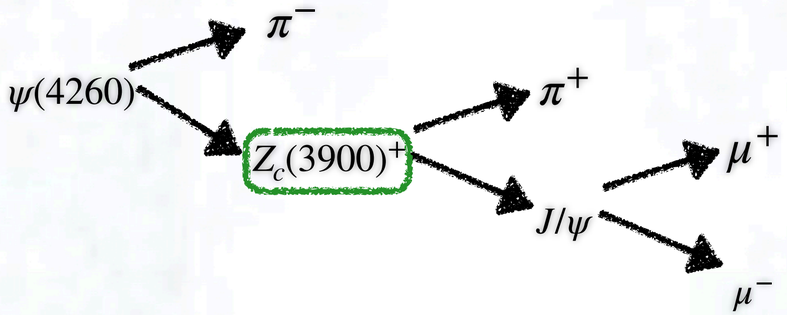


points represents the mean value of the gaussian fit to the Zc(3900) mass distribution

error bars computed sigma value of gaussian fit times 2.355 (=FWHM)

PDG : average mass and width

Conclusion:



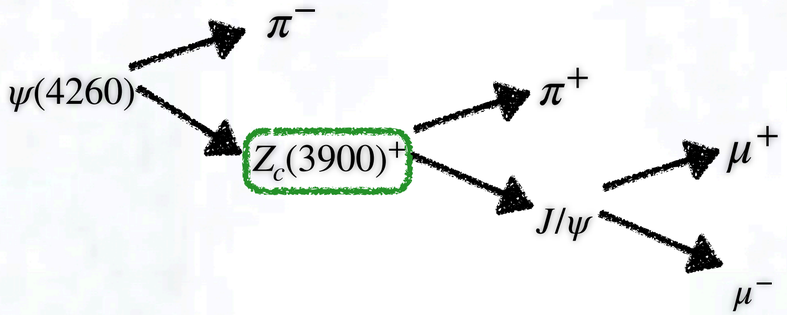
- the production of the exotic charged charmonium-like state $Z_c(3900)^+$ in $p\bar{p}$ collisions through the sequential process $\psi(4260) \rightarrow Z_c^+(3900)\pi^-, Z_c^+(3900) \rightarrow J/\psi\pi^+$.

- 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 (3.853 ± 0.02323 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)

Thank you...