Status Update on the analysis of feasibility study of $Z_c(3900)^+$

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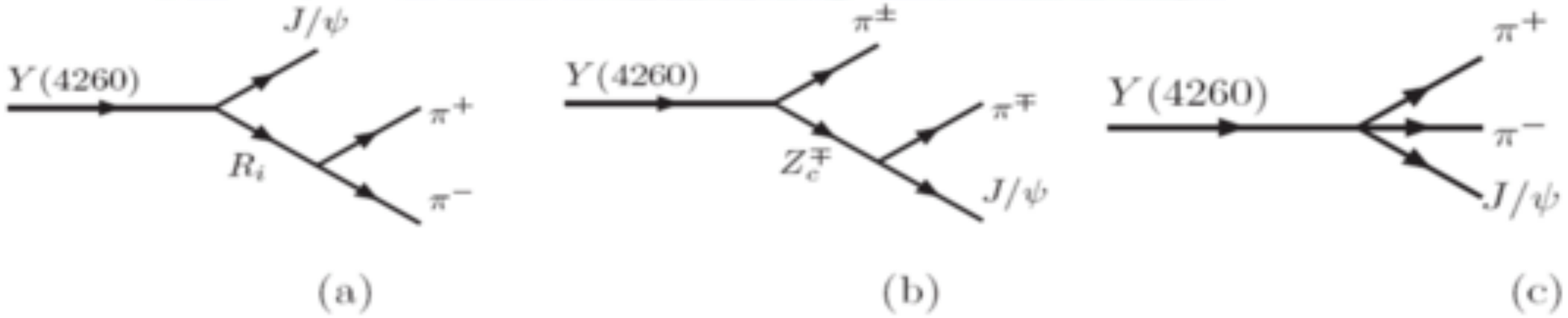
Introduction

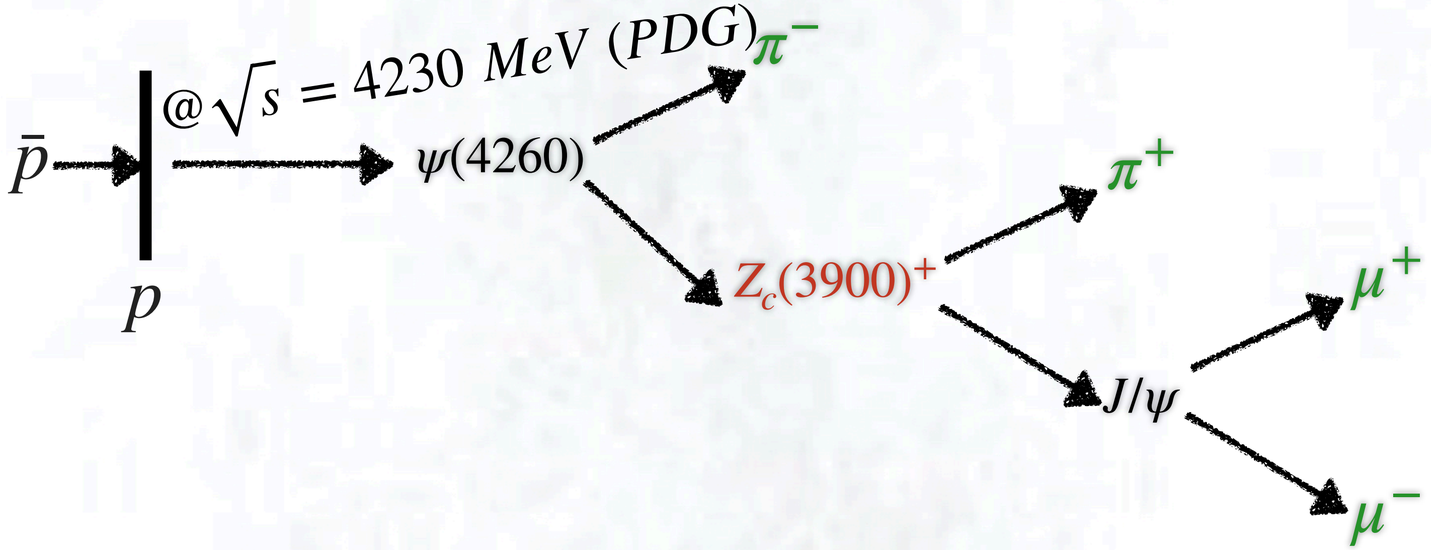


The Zc(3900)- was observed in π^-J/ψ invariant mass distribution in the study of $e^+e^- \to \pi^+\pi^-J/\psi$ at BESIII and Belle experiments [M. Ablikim et al., C. Z. Yuan et al.].

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^-)

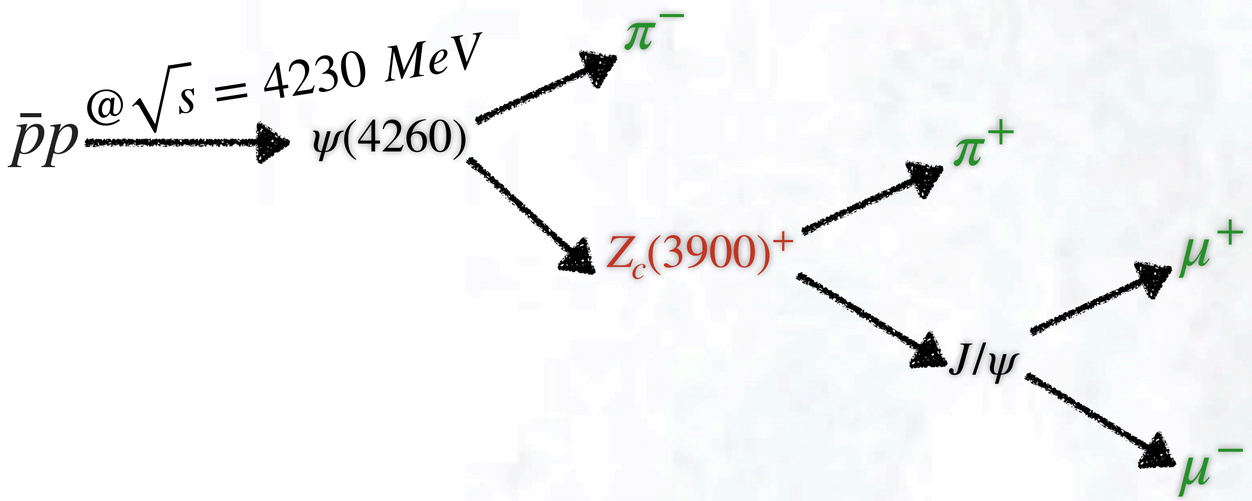
for event generation

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




```
noPhotos


Decay pbarpSystem1
  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

- 600K for signal
- 2.68M for DPM events
- PHSP model was used for all event generations
- PHOTOS was turned off for simplicity

Strategy

Signal events was generated by

nev = 10k and pbeam = 8.5454 // for pbar = 4.230 GeV

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

pbeam: 8.5454, Ecm: 4.23, Etot: 9.53503

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

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

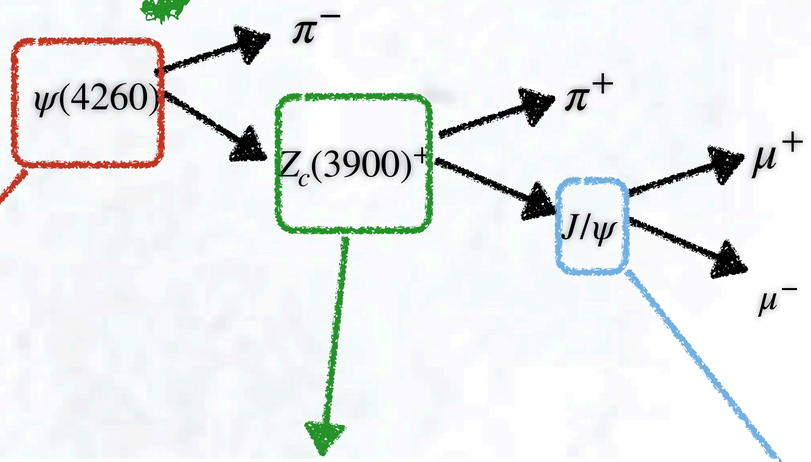
Strategy

- Get all final state particles (μ^+, μ^-, π^+ and π^-)
- Select true particle id
- Combine all μ candidates and assign the type id for J/psi then
- accept them as J/ψ if they pass truth match algorithm
- apply a vertex fit and accept only those ones which a probability > 0.01
- Select J/ψ if their mass is within nominal range (rough mass select)
- Combine these with a π^+ and accept them as a candidate charmonium and set its type id and apply true particle id selection algorithm

Strategy

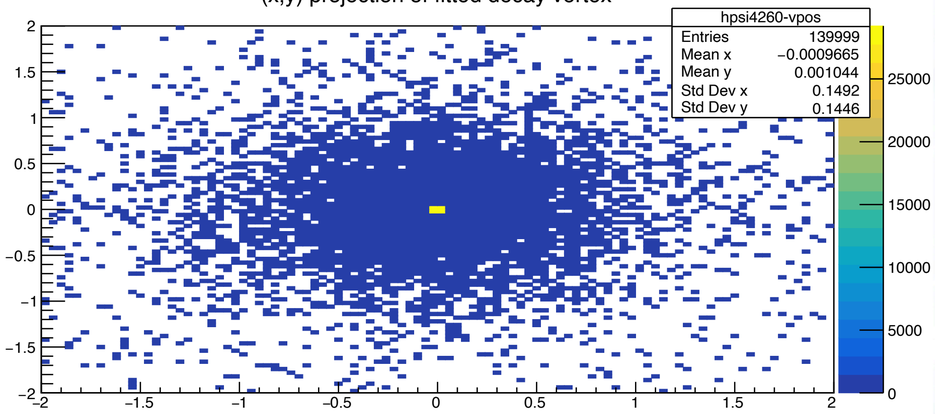
- then accept Zc(3900) if they pass truth match algorithm
- apply a vertex fit and accept only those ones which a probability > 0.01
- Select Zc(3900) if their mass is within nominal range (rough mass select)
- Then reconstruct the initial pbarpSystem1 system and set type id,
- then accept pbarpSystem1 if they pass truth match algorithm
- apply a vertex fit and accept only those ones which a probability > 0.01
- perform a 4-constraint fit and accept only those ones which have a probability > 0.01

Analysis: decay vertex

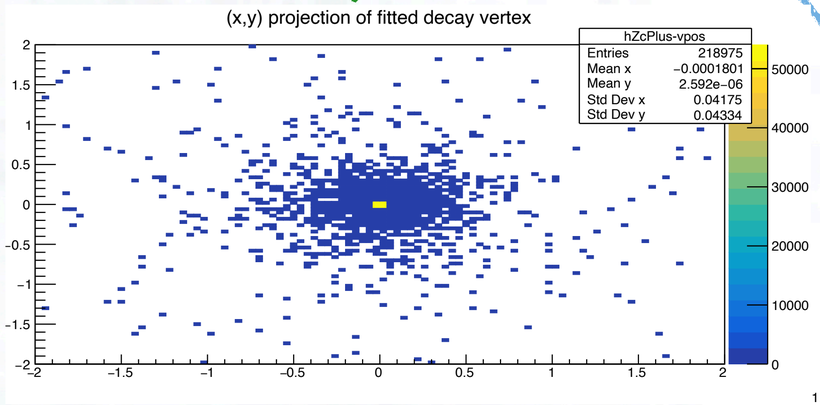


Resonant particles decay vertexes

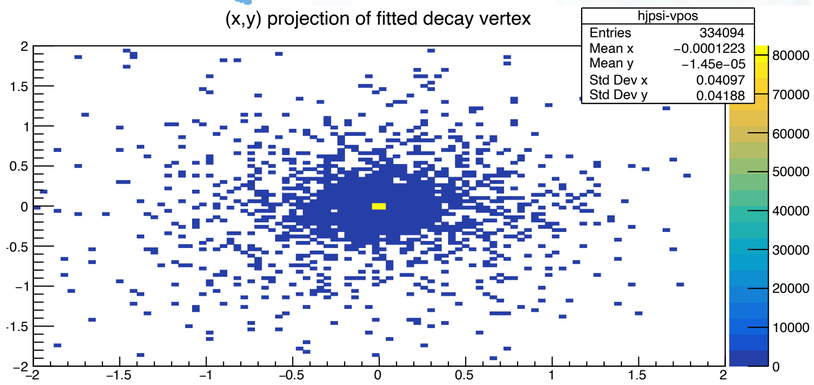
(x,y) projection of fitted decay vertex



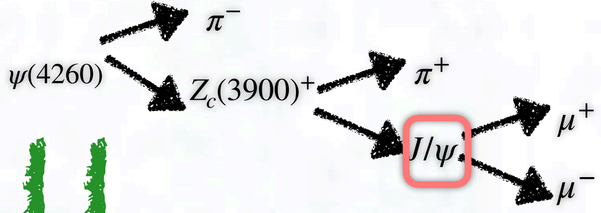
(x,y) projection of fitted decay vertex



(x,y) projection of fitted decay vertex

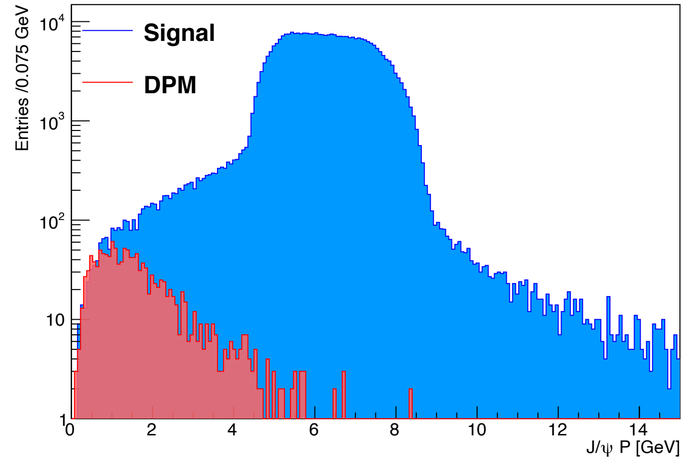


Analysis: kinematics all

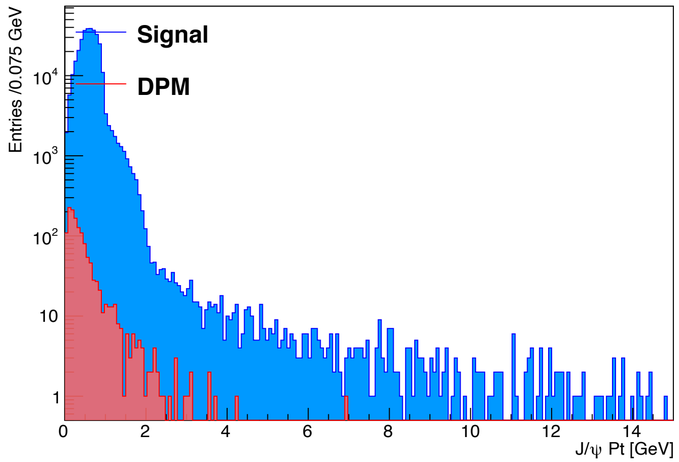


Reconstructed particles

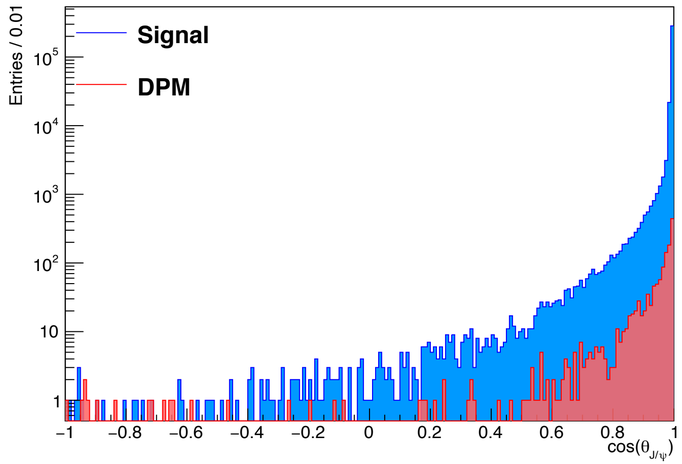
J/ψ momentum (all)



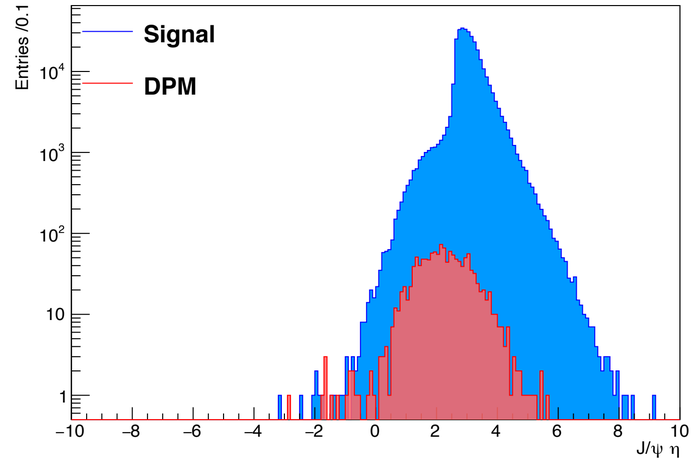
J/ψ Pt momentum (all)



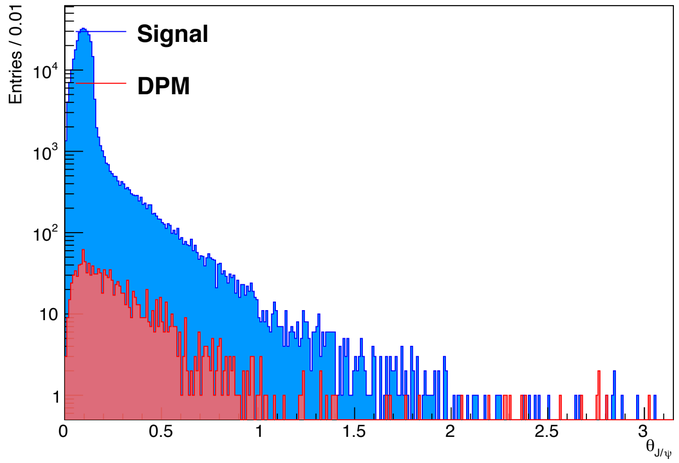
cos($\theta_{J/\psi}$) (all)



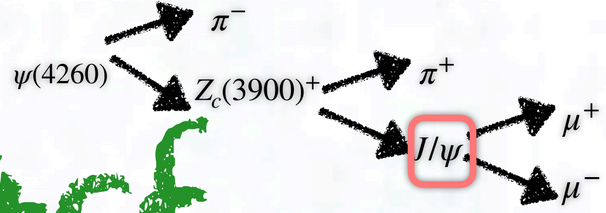
J/ψ eta (all)



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



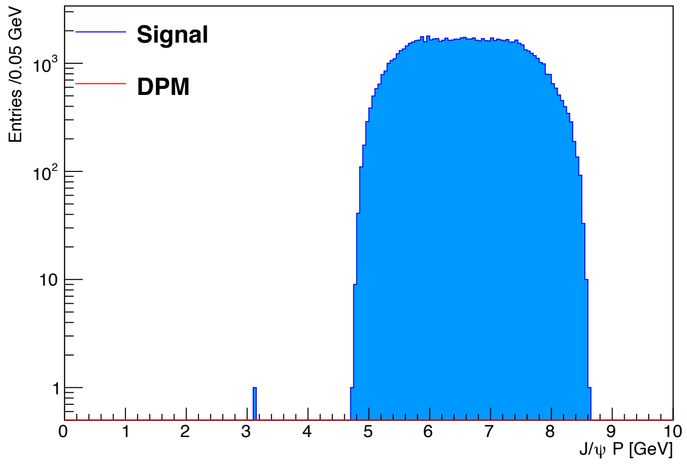
Analysis: kinematics



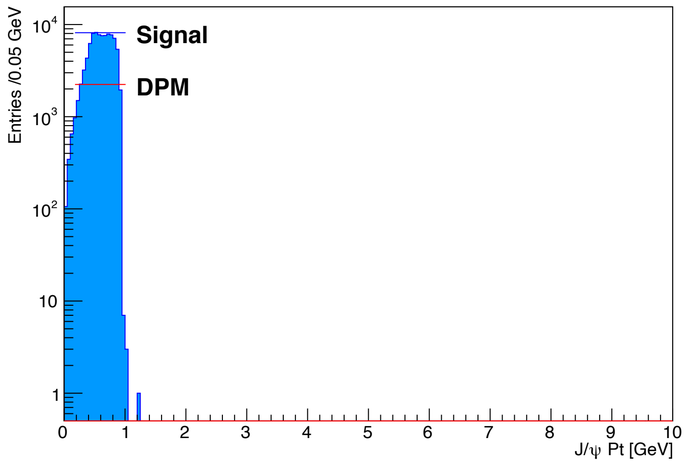
4cf

Reconstructed particles

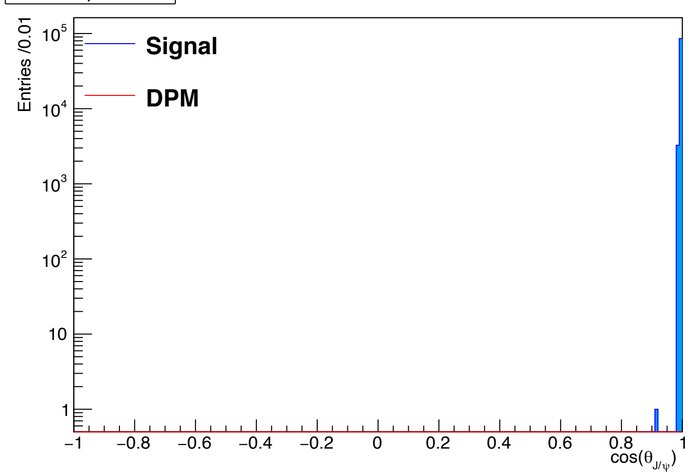
J/ψ momentum (4cf)



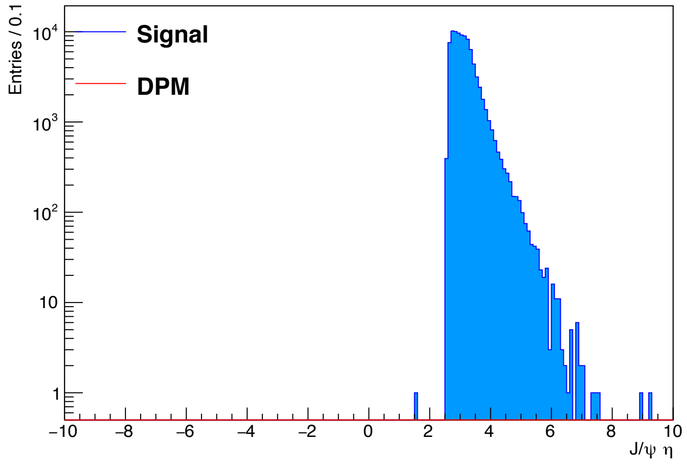
J/ψ Pt momentum (4cf)



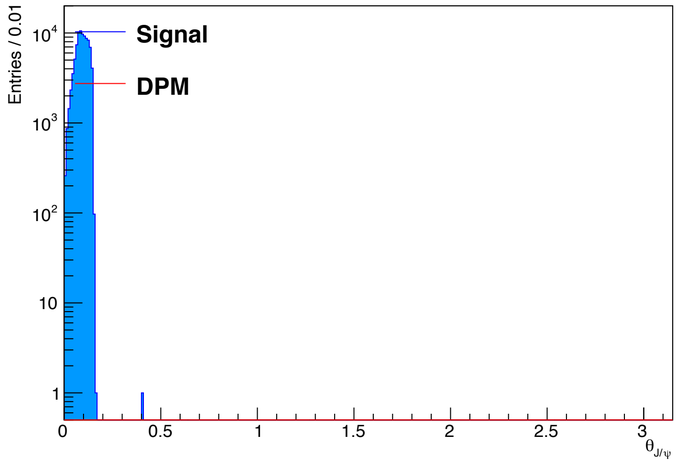
cos($\theta_{J/\psi}$) (4cf)



J/ψ eta (4cf)



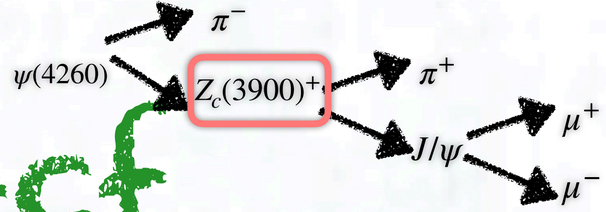
$\theta_{J/\psi}$ (4cf)



Analysis:

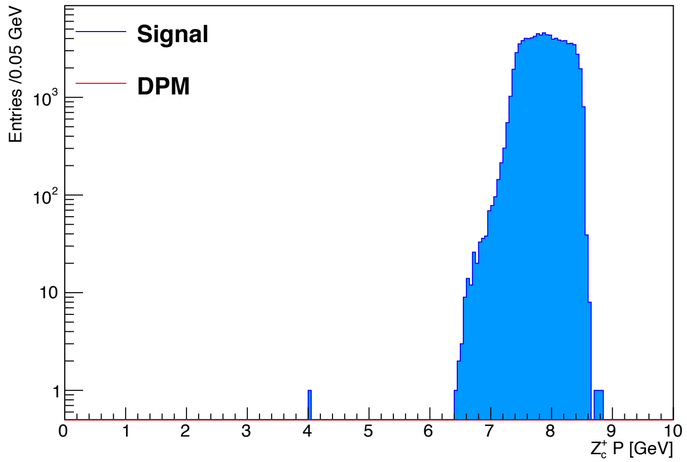
kinematics

4cf

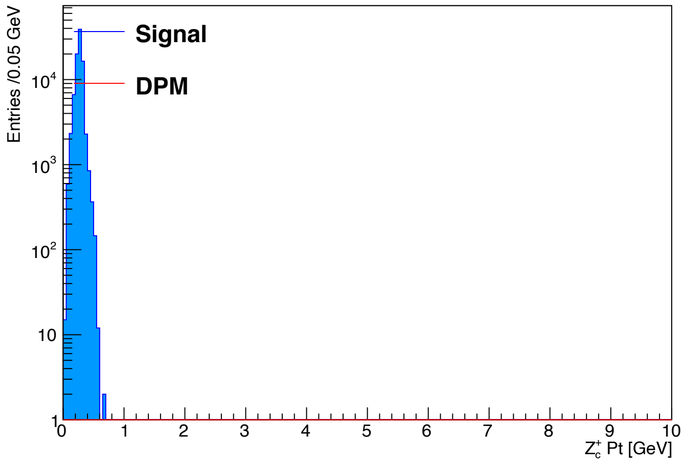


Reconstructed particles

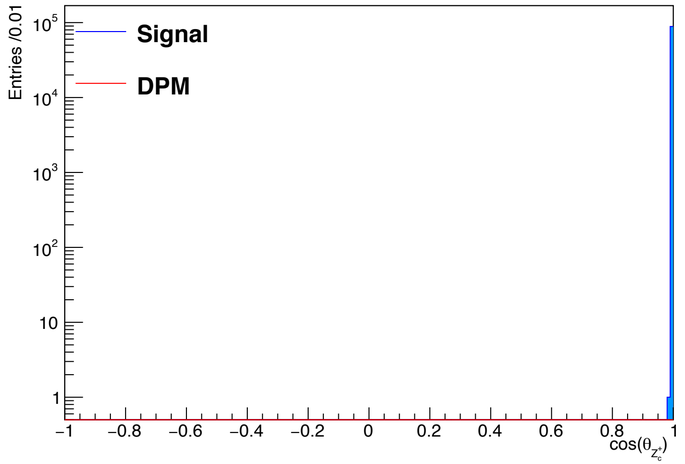
$Z_c(3900)^+$ momentum (4cf)



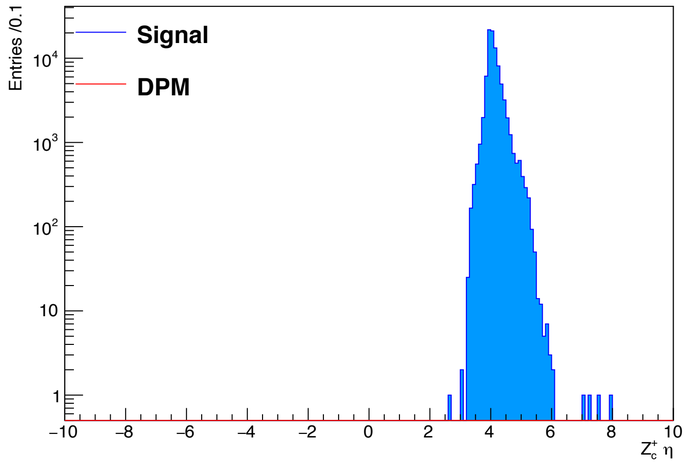
$Z_c(3900)^+$ Pt momentum (4cf)



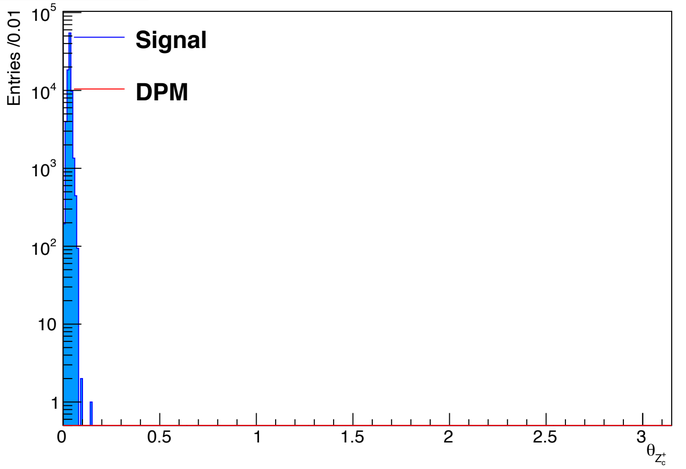
$\cos(\theta_{Z_c(3900)^+})$ (4cf)



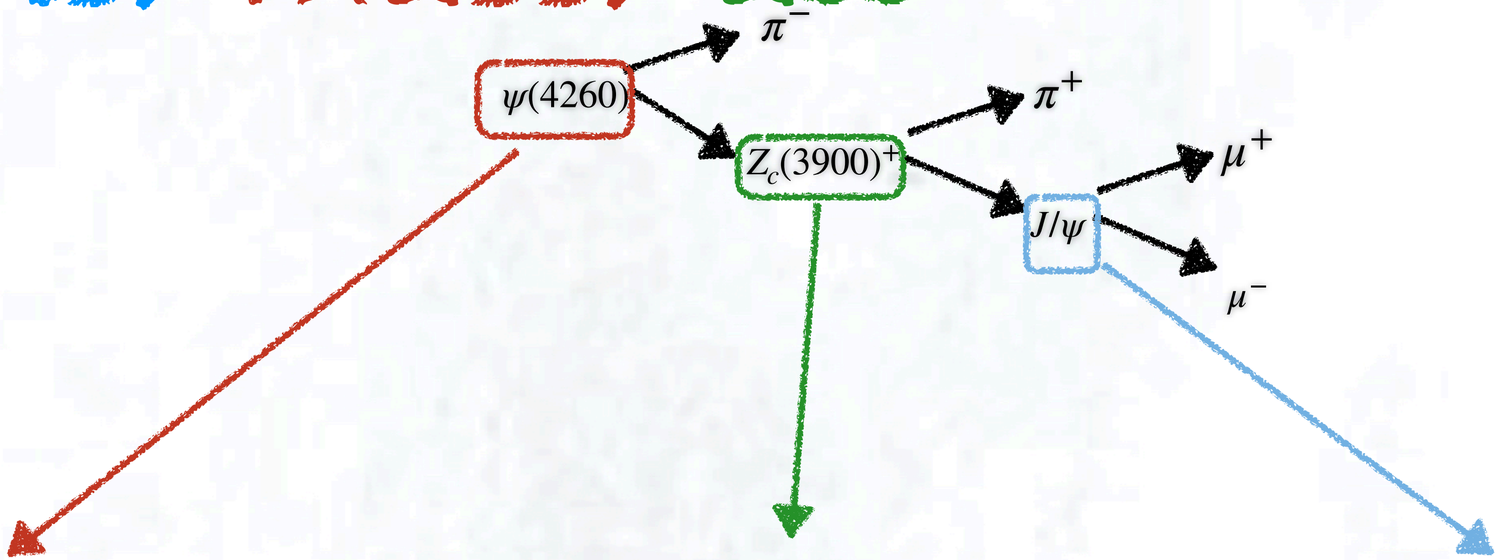
$Z_c(3900)^+$ eta (4cf)



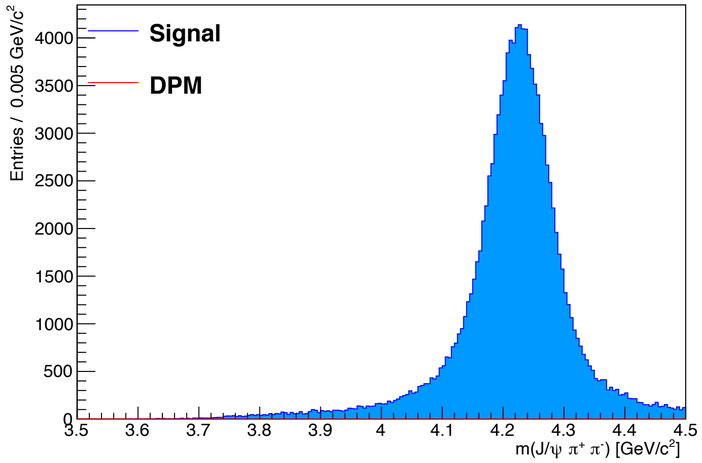
$\theta_{Z_c(3900)^+}$ (4cf)



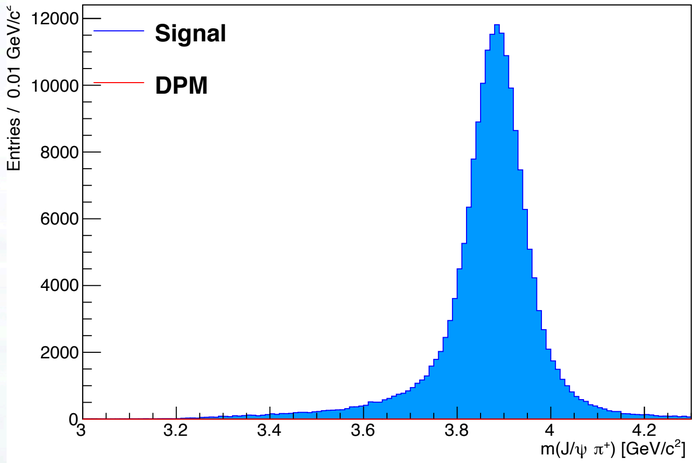
Analysis: mass: all



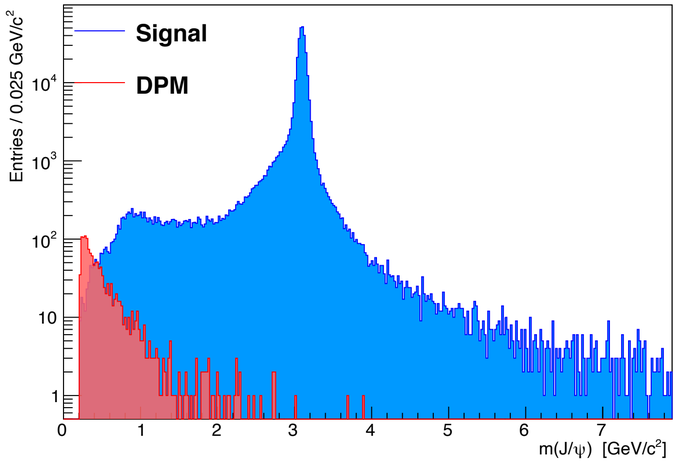
$\psi(4260)$ mass (all)



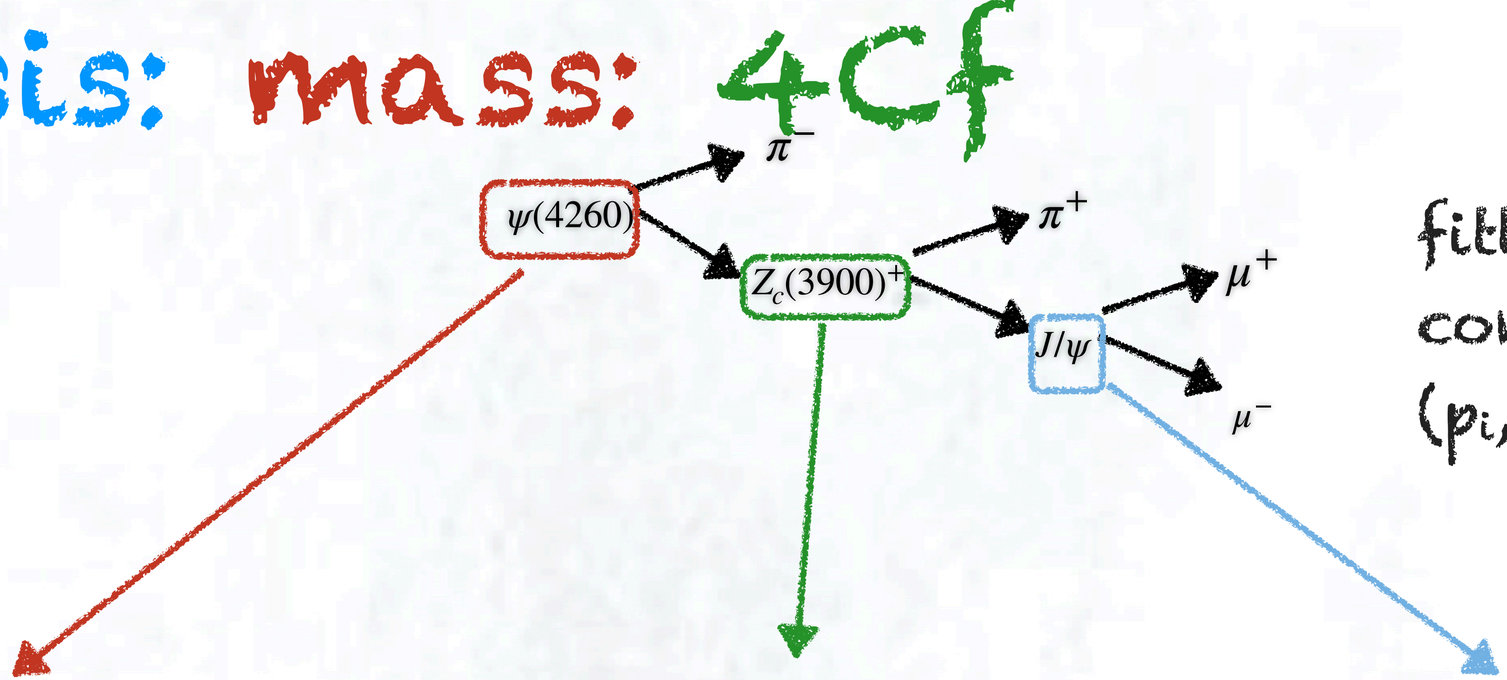
$Z_c(3900)^+$ mass (all)



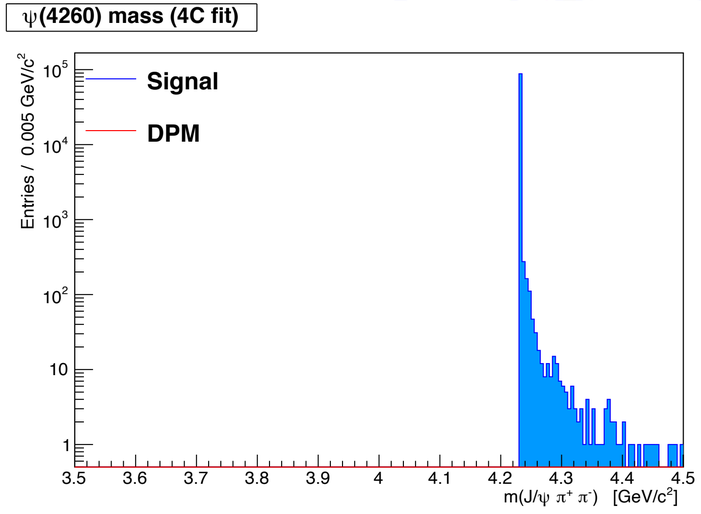
J/ψ mass (all)

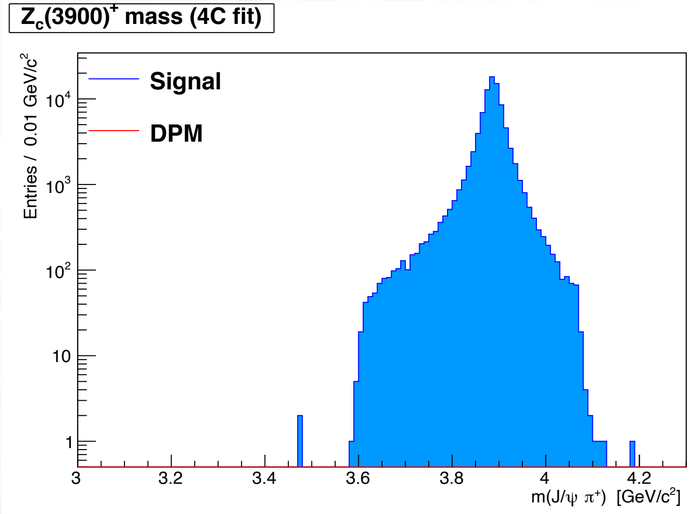


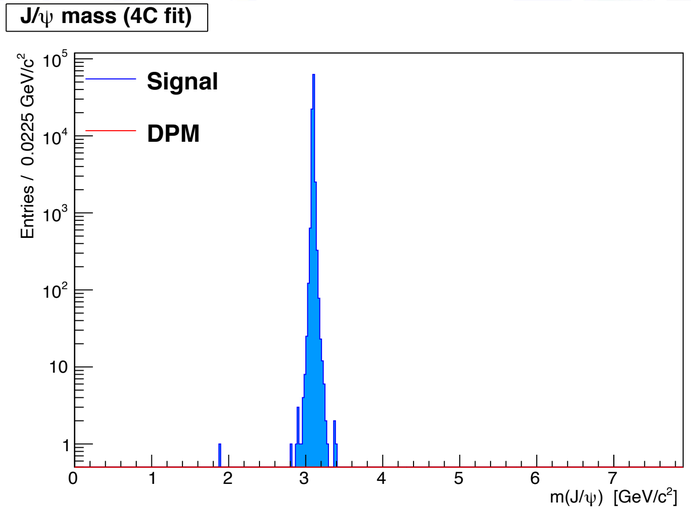
Analysis: mass: 4Cf



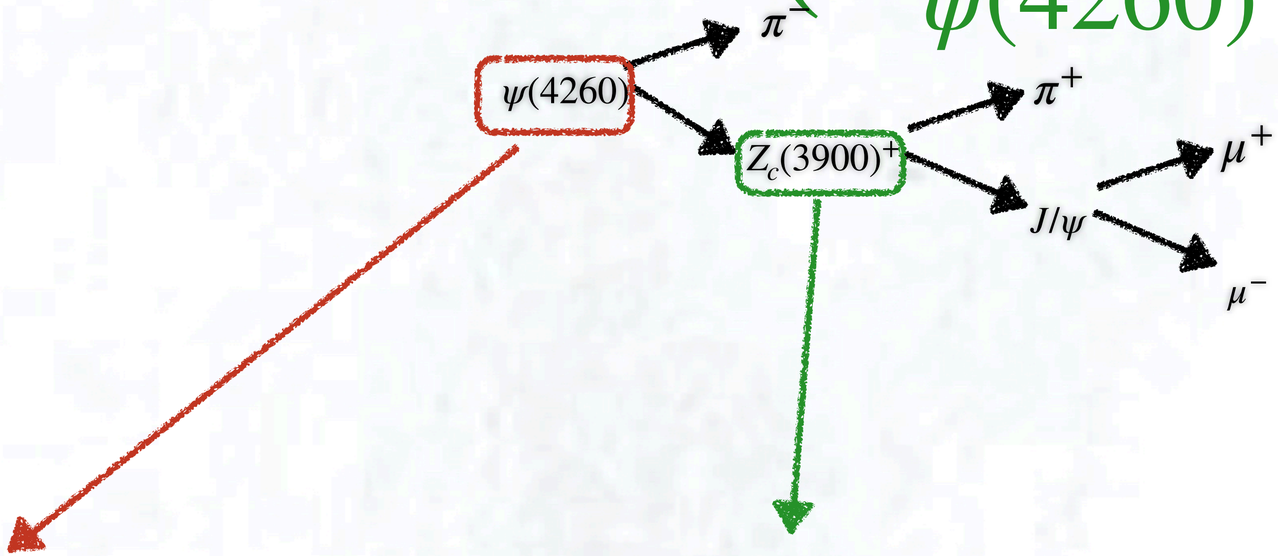
fitting with 4 constraint (4C) (p_i, E)

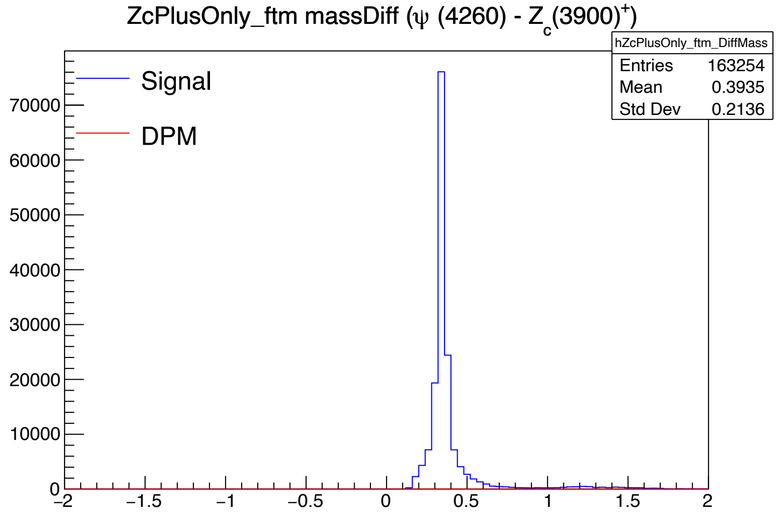


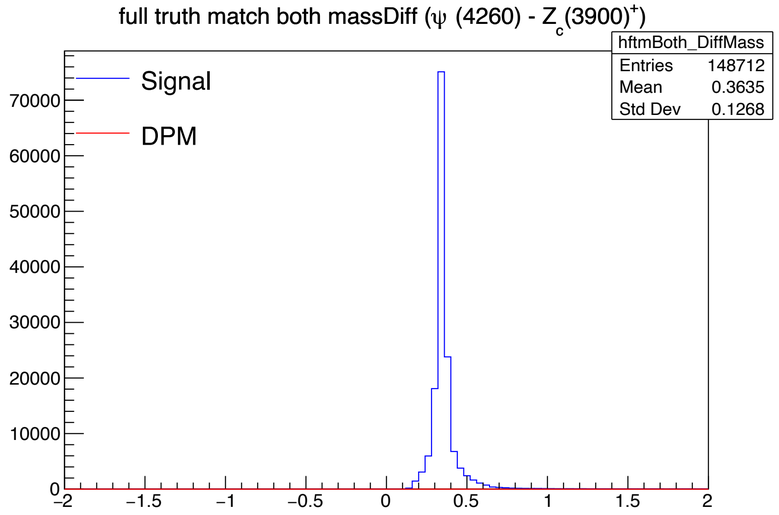


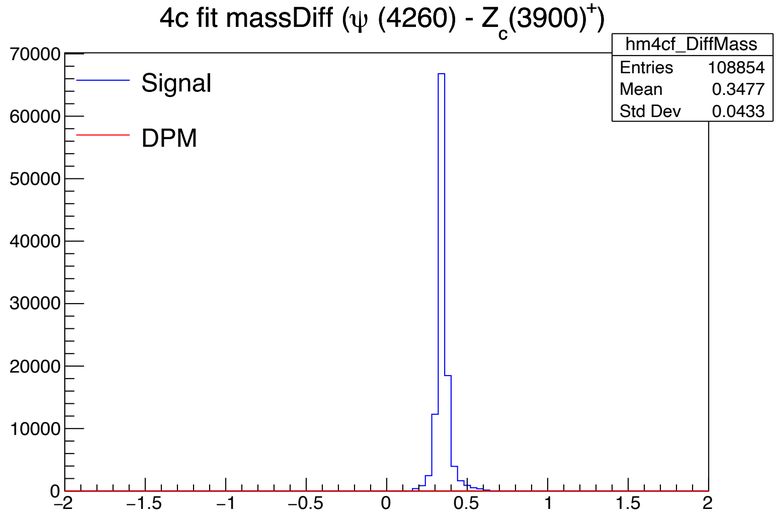


Analysis: mass: $\Delta m(m_{\psi(4260)} - m_{Z_c(3900)})$

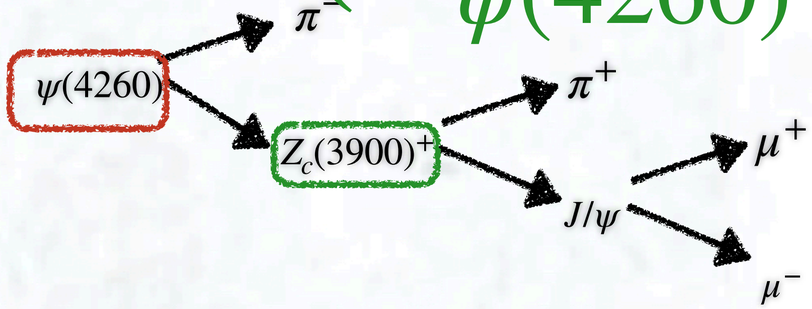








Analysis: mass: $\Delta m(m_{\psi(4260)} - m_{Z_c(3900)})$

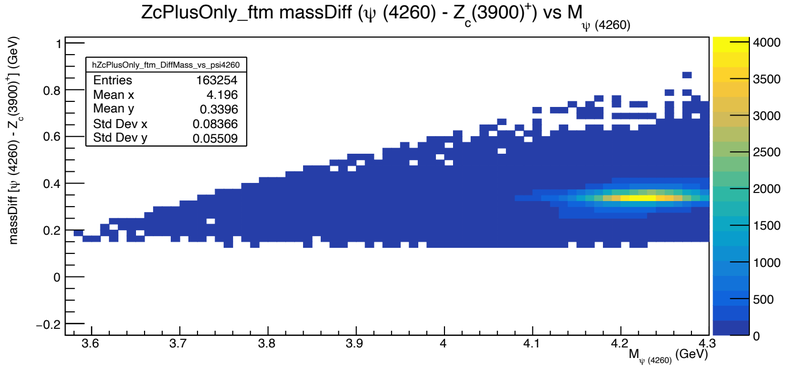


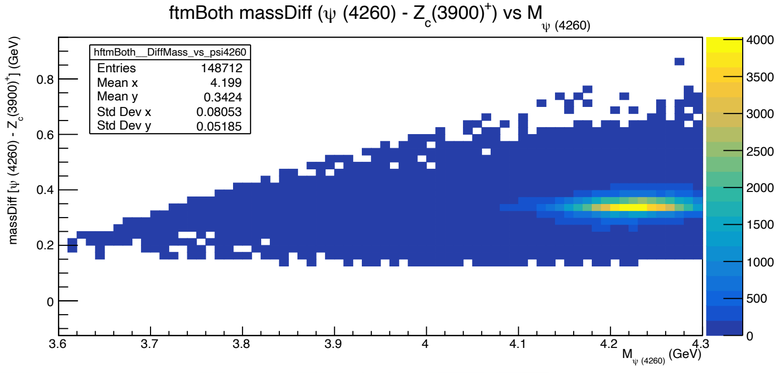
2d

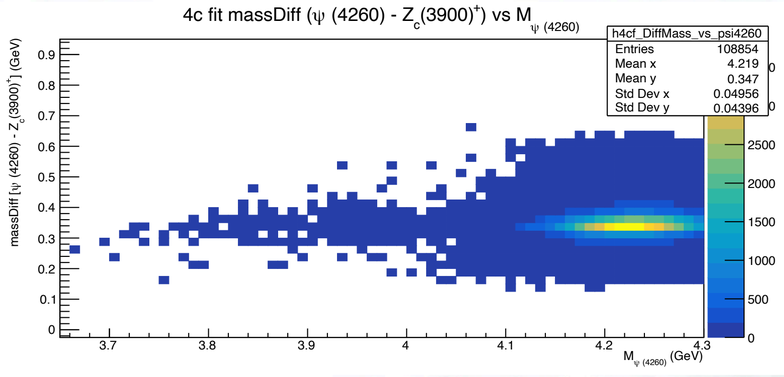
only $Z_c(3900)^+$ passed ftm

both of them passed ftm

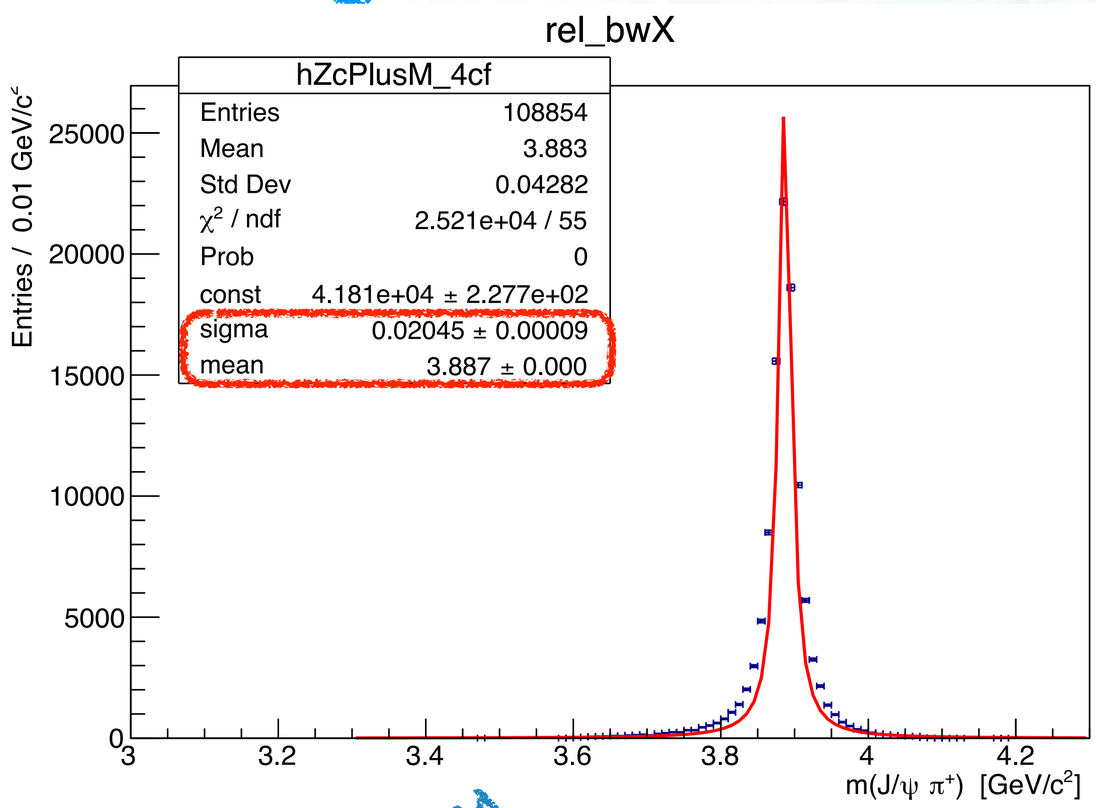
both of them passed ftm+4C

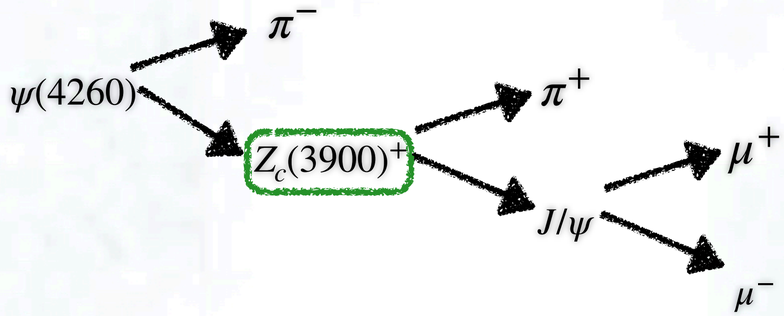






Analysis: mass: result





evt.pdl — Git Config

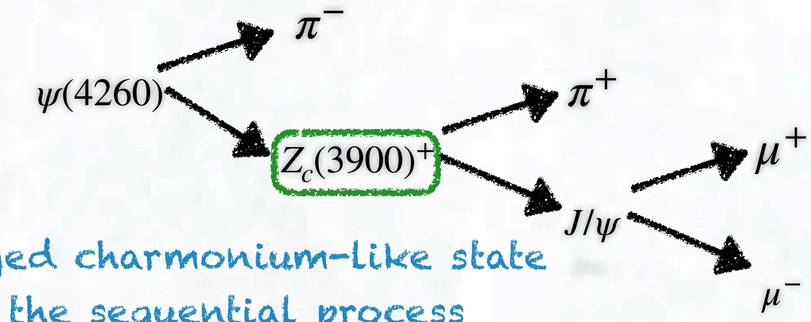
```
452  * Added/Moved XYZ states, by K. Goetzen 02.04.2020 for PANDA (PDG 2019)
453  * tried to follow PDG rules: 99ab044c: where b=0,1,2 -> (J-1,J,J+1), c = 2J+1, 44=ccbar meson, a = sequential count when code identical
454  *-------------------------------------------------------------------------------------------------------------------------------
455  *
456  * [xyz cc-like]  name                 id          mass/GeV      width/GeV     max_Dm/GeV    3*charge 2*spin lifetime*c/mm  Pythiaid
477  add  p Particle  Z_c(3900)0          98010443    3.8872000e+00 2.8200000e-02 2.8200000e-01  0        2     0.0000000e+00   98010443
478  add  p Particle  Z_c(3900)+          99010443    3.8872000e+00 2.8200000e-02 2.8200000e-01  3        2     0.0000000e+00   99010443
479  add  p Particle  Z_c(3900)-         -99010443    3.8872000e+00 2.8200000e-02 2.8200000e-01  -3       2     0.0000000e+00  -99010443
```

preliminary

MASS: 3.887 GeV

WIDTH: 0.024078 GeV

Summary:



- 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^-).

- $\dfrac{Z_c(3900)_{reco}}{N_{events} : (generated)} = \dfrac{108854}{600K} = 18{,}14\,\%$ after 4C in signal channel

- $\dfrac{Z_c(3900)_{reco}}{N_{events} : (generated)} = \dfrac{0}{2.68M}$ after 4C for DPM bkg

- The current limit in evt.pdl Mass: 3.8872, Width: 0.0282 GeV and we obtained the Mass: 3.887, Width: 0.024078 GeV after 4Cf.

Outlook:

- Since the PHSP model is averaging the all spins of particle in the initial and final state,
- taken into account the VVS_PWave model to force $\psi(4260), Z_c^+(3900)$ in pure S-wave

- Improve the obtained mass and width limits via voigt fit

Thank you...