Study of X(3872) $\rightarrow$ DD decays

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Motivation

To look for different charmonium-like states (conventional and exotic) in *pp\bar* annihilation to obtain complementary results to the ones from *e+e-* and *pp* collisions

Motivation

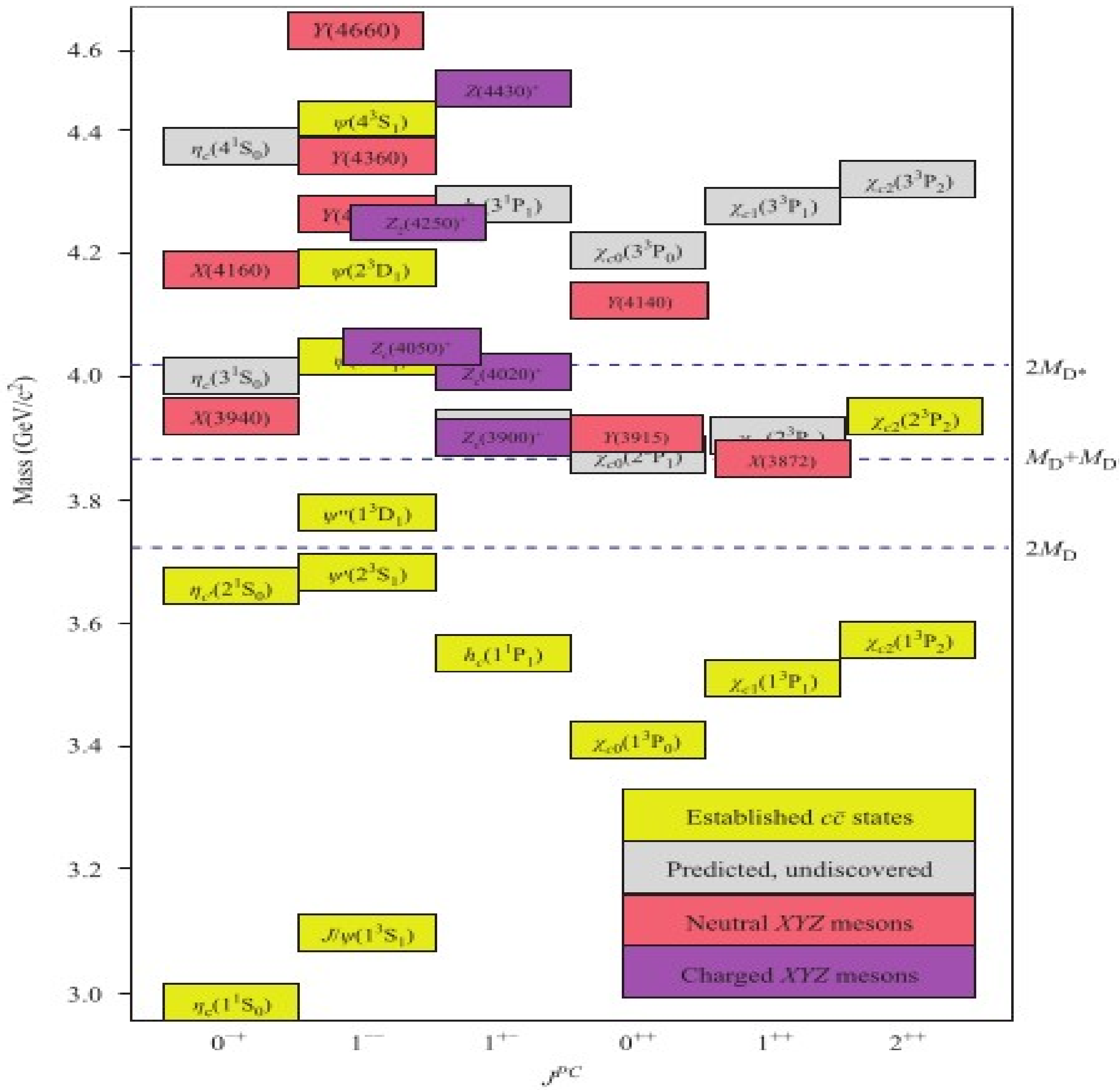


Fig. 4 The spectrum of charmonium and charmoniumlike mesons

S.L.Olsen
arXiv 1411.7738

- Below the open charm threshold the spectrum well understood
  - very good agreement between predicted and discovered states
- Above the threshold the situation in more complex
  - only few of the predicted states have been found
  - in the last decades many new states have been observed with properties that are not consistent with expectations for charmonium: X, Y, Z

X states:

- charmonium-like states with $J^{PC} \neq 1^{--}$
- Observed in B decays, pp and pp collisions

Y states:

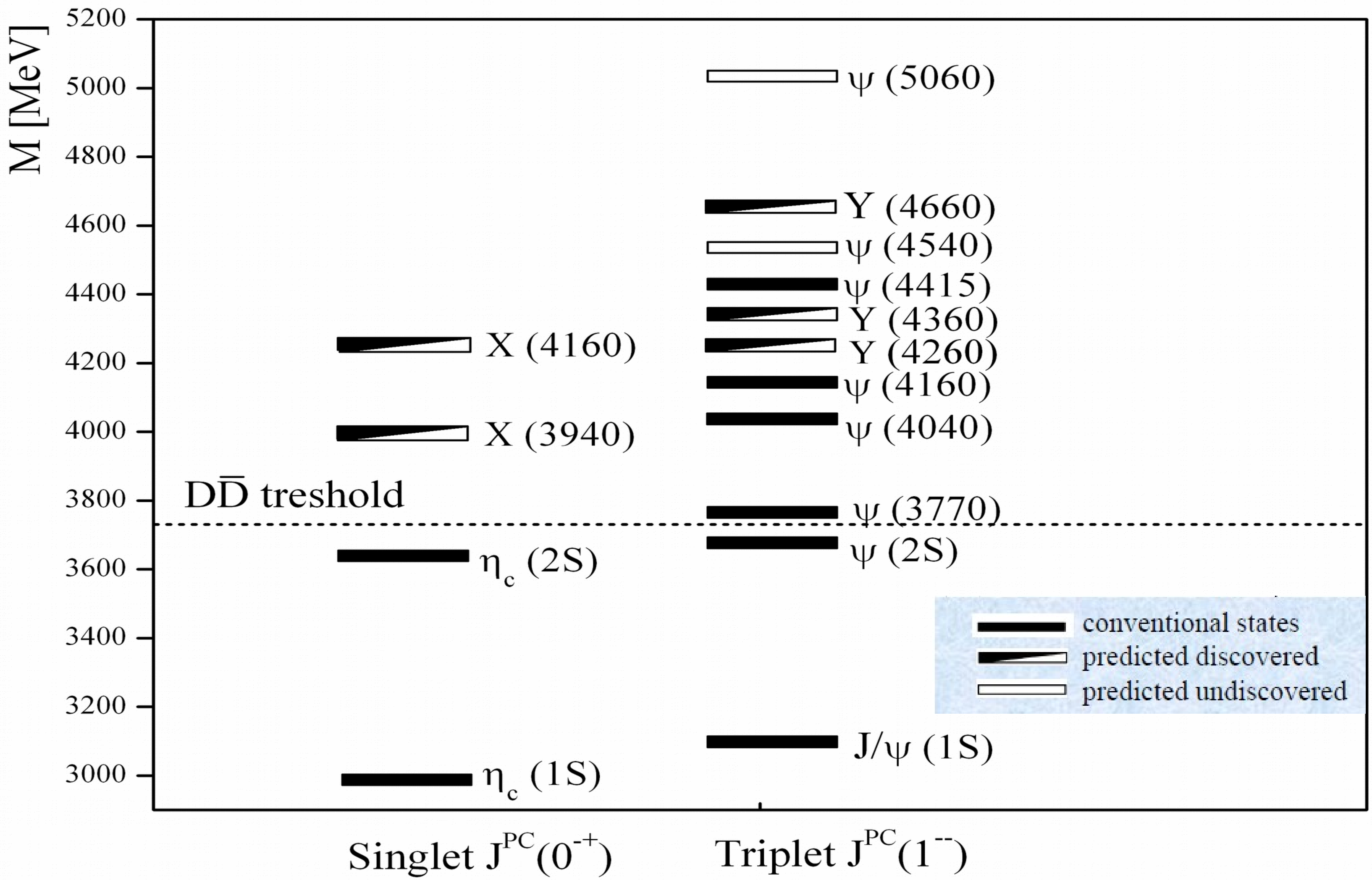
- charmonium-like states with $J^{PC} = 1^{--}$
- Observed in direct e + e - annihilation or in ISR

Z states:

- Must contain at least a cc and a light qq pair

Motivation

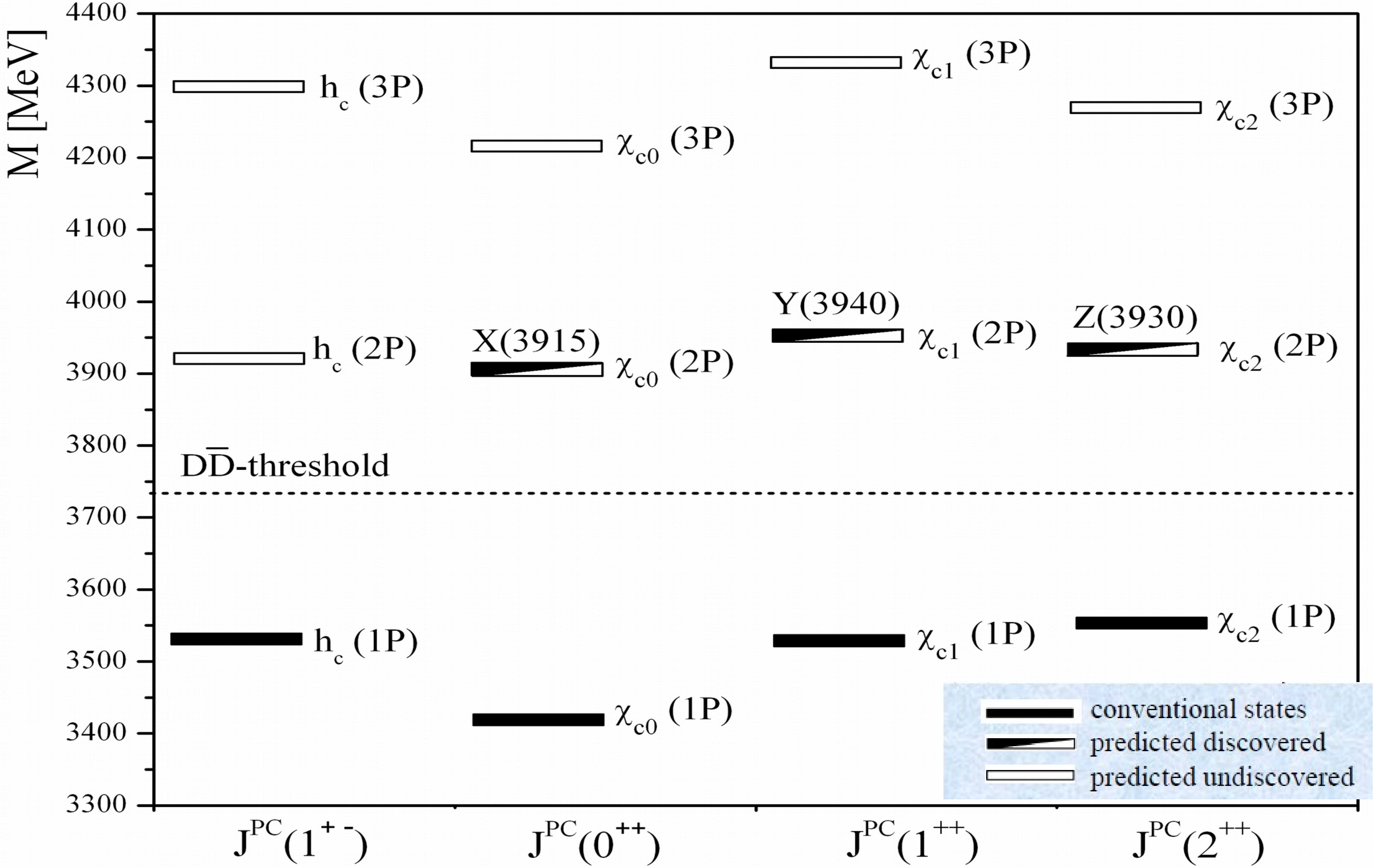
THE SPECTRUM OF SINGLET ($^1S_0$) AND TRIPLET ($^3S_1$) STATES OF CHARMONIUM



M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen, Yadernaya Fizica, V.77, N.1, pp. 1 - 5 (2014) / Phys. At. Nucl., V.77, N.1, pp. 126 -130 (2014)

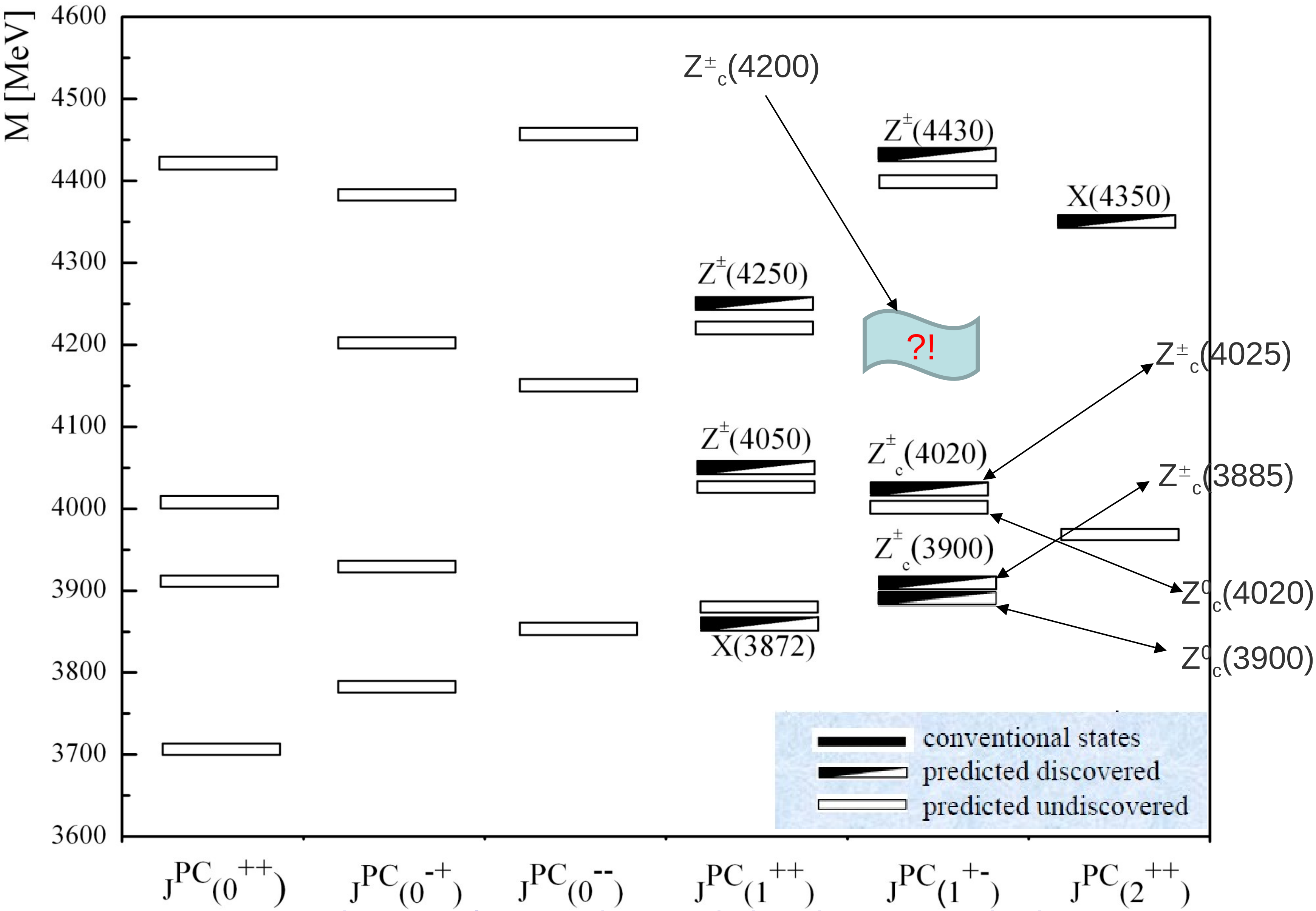
Motivation

THE SPECTRUM OF SINGLET ($^1P_1$) AND TRIPLET (^3P_J) STATES OF CHARMONIUM



M.Yu. Barabanov, A.S. Vodopyanov, S.L. Olsen , Yadernaya Fizica, V.77, N.1, pp. 1 - 5 (2014) / Phys. At. Nucl., V.77, N.1, pp. 126 -130 (2014)

THE SPECTRUM OF TETRAQUARKS WITH THE HIDDEN CHARM



M.Yu. Barabanov, S. L. Olsen, A.S. Vodopyanov, Physica Scripta, T166 014019 (2015)

M.Yu. Barabanov, S. L. Olsen, A.S. Vodopyanov, A.I. Zinchenko, Yad. Fiz., V.79, N.1, pp. 1-4 (2016) / Phys. At. Nucl., V.79, N.1, pp. 126 – 179 (2016)

Outline

1. Software used.

2. Decay X(3872) $\rightarrow$ D+D- $\rightarrow$ $(K\pi\pi)^2$.

3. Decay X(3872) $\rightarrow$ D0antiD0 $\rightarrow$ $(K\pi)^2$.

4. Yield considerations.

5. Background estimates.

6. Summary and outlook.

Software used

- *FairSoft may16p1*
- *FairRoot v-16.06*
- *PandaRoot trunk 29531 (updated on 6/10/2016)*

1. EvtGen and DPM generators

2. prod/prod_sim.C, prod/prod_aod.C (for simulation & reconstruction)

3. Rho analysis package (for applying cuts and reconstructing M inv)

Generated events

```
noPhotos

Decay pbarpSystem
  1.0       D+ D-            PHSP;
Enddecay

Decay D+
  1.0   K- pi+ pi+    D_DALITZ;
Enddecay

Decay D-
  1.0   K+ pi- pi-      D_DALITZ;
Enddecay

End
```

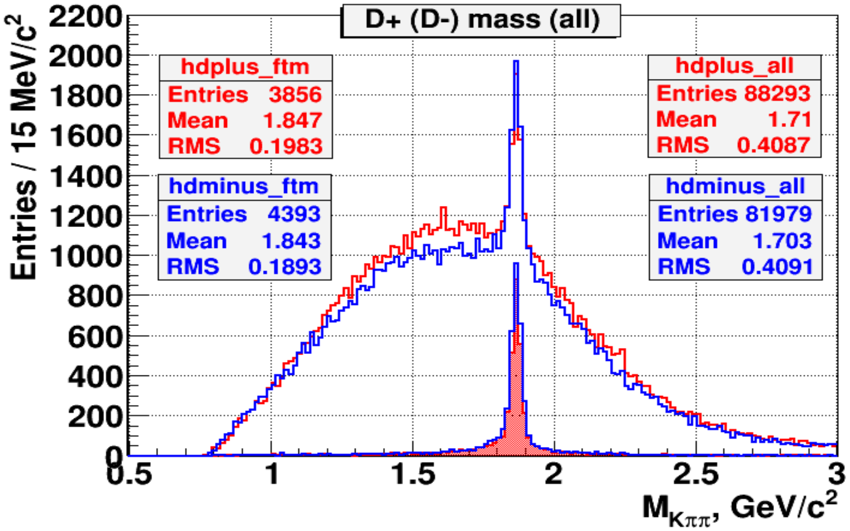
10k events

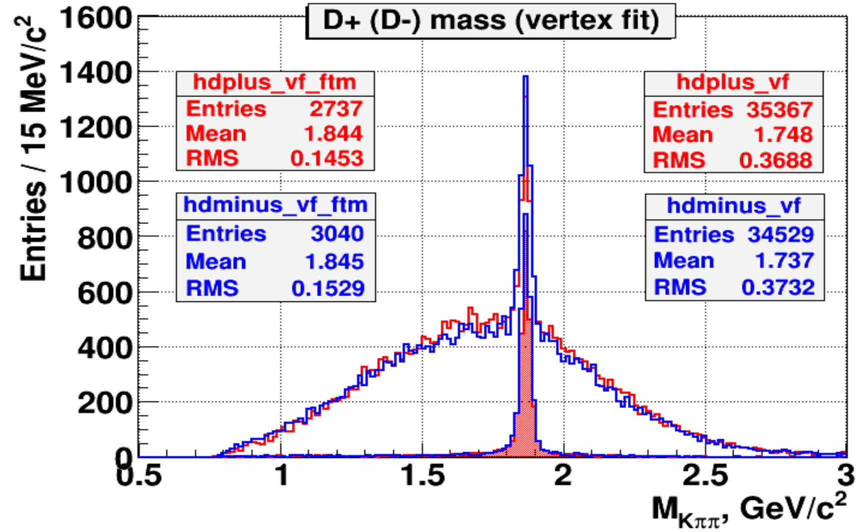
```
noPhotos

Decay pbarpSystem
  1.0       D0 anti-D0    PHSP;
Enddecay

Decay D0
  1.0   K- pi+          PHSP;
Enddecay

Decay anti-D0
  1.0   K+ pi-          PHSP;
Enddecay

End
```

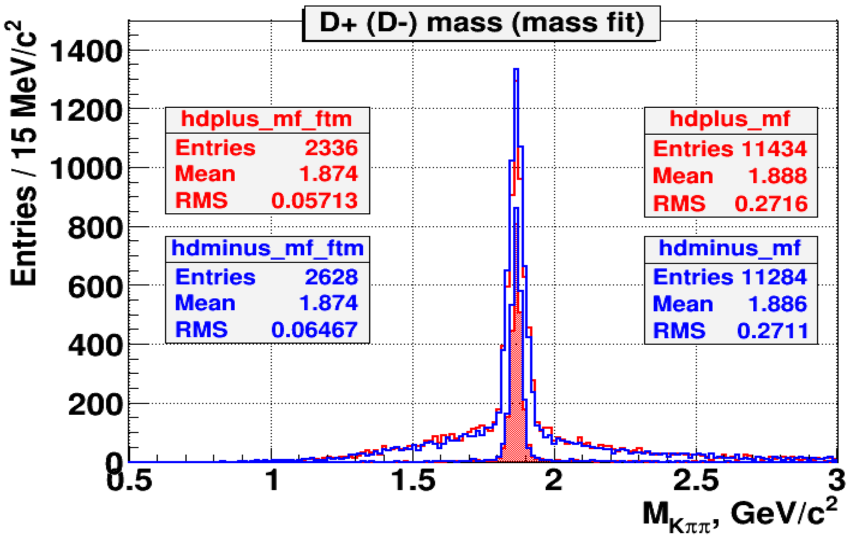
10k events

X(3872) → D+D-

D+ → K-π+π+ and D- → K+π-π- invariant mass





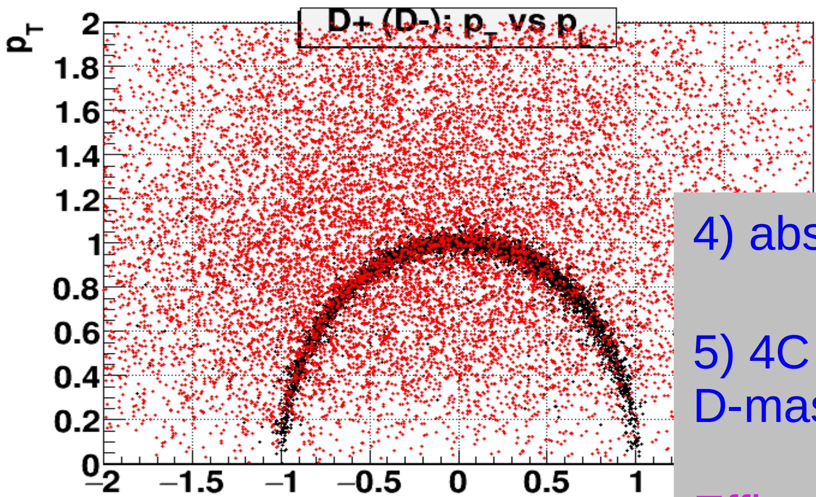


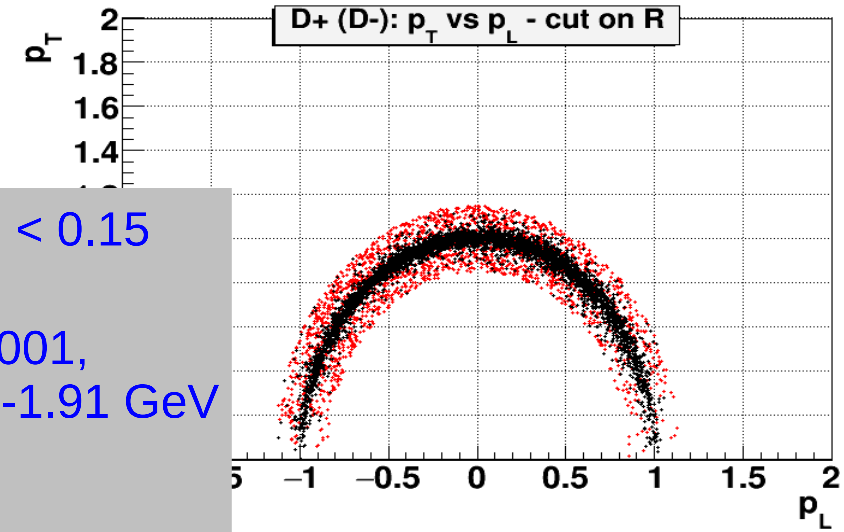
Applied different cuts and looked at M inv mass distributions to estimate signal & background. Started from selection of charged particles without PID.

1) K all
2) P(vtx fit) > 0.001
3) P (D-mass fit) > 0.001

X(3872) → D+D-

D+ → K-π+π+ and D- → K+π-π-

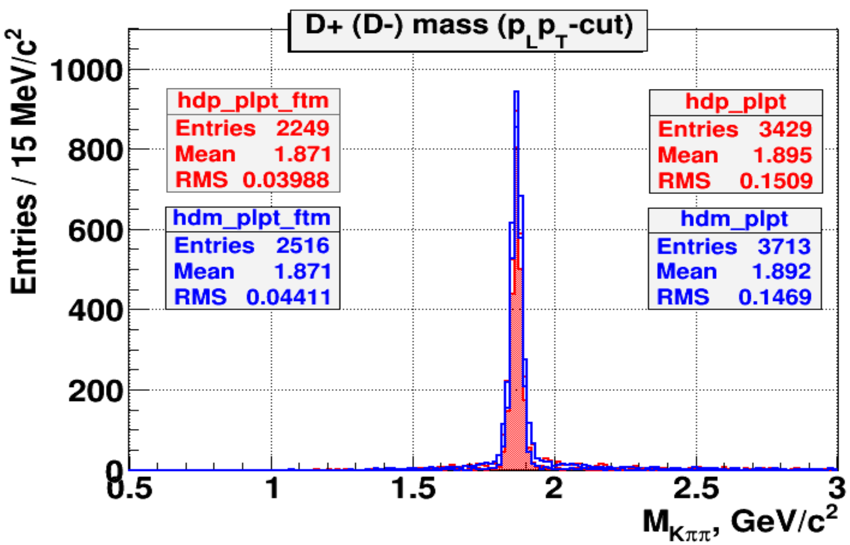


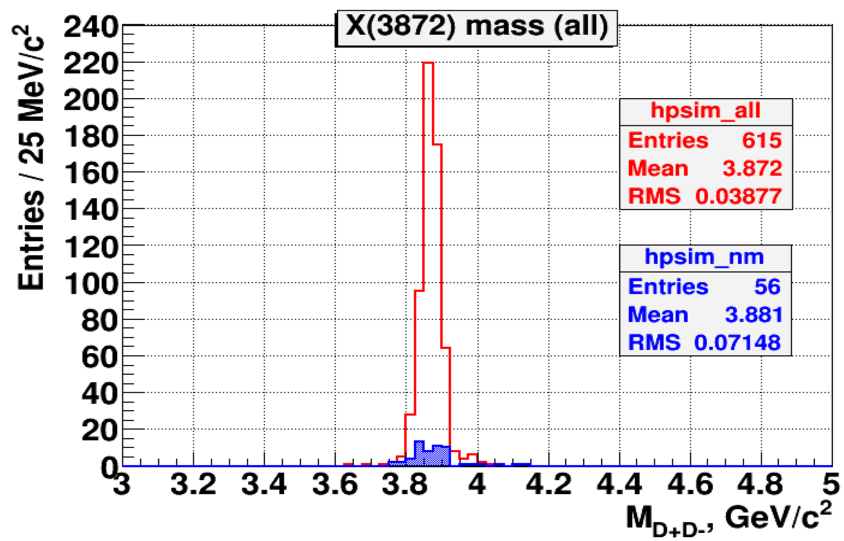


4) abs(Rp_Lp_T-1) < 0.15

5) 4C fit: P > 0.001,
D-mass = 1.83-1.91 GeV

Effic. = 5.6%





X(3872) → D+D-

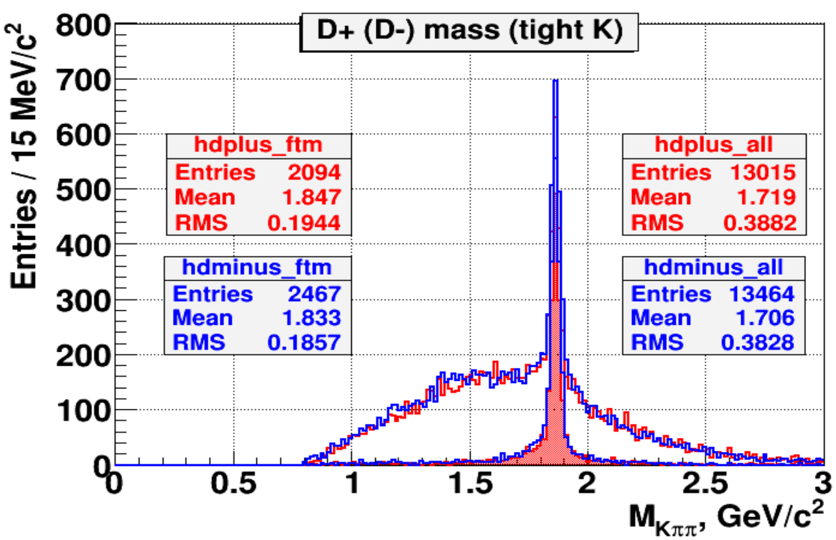
D+ → K-π+π+ and D- → K+π-π- (tight K)

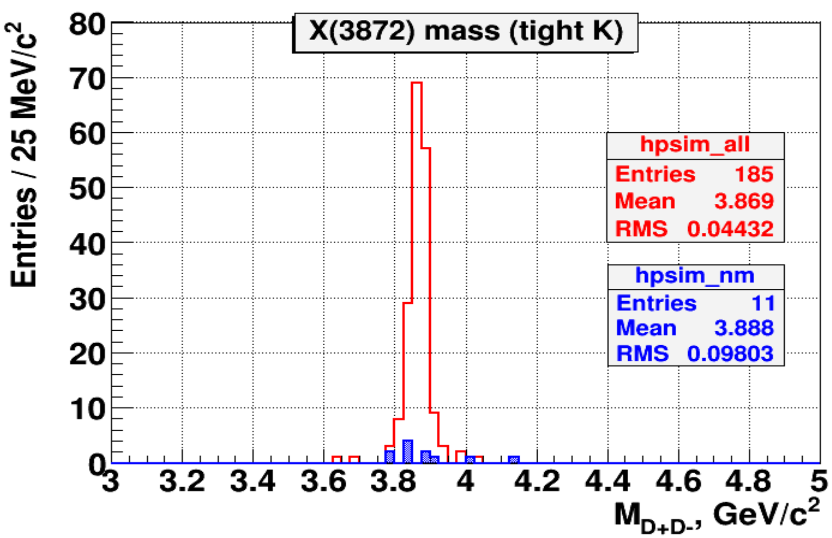
we can try reduce more background and apply PID for kaons
require tight ID with combination of algorithms and detectors

theAnalysis->FillList(kplus, "KaonTightPlus", "PidAlgoDisc;PidAlgoStt;PidAlgoDrc");

theAnalysis->FillList(kminus, "KaonTightMinus“ ,"PidAlgoDisc;PidAlgoStt;PidAlgoDrc");

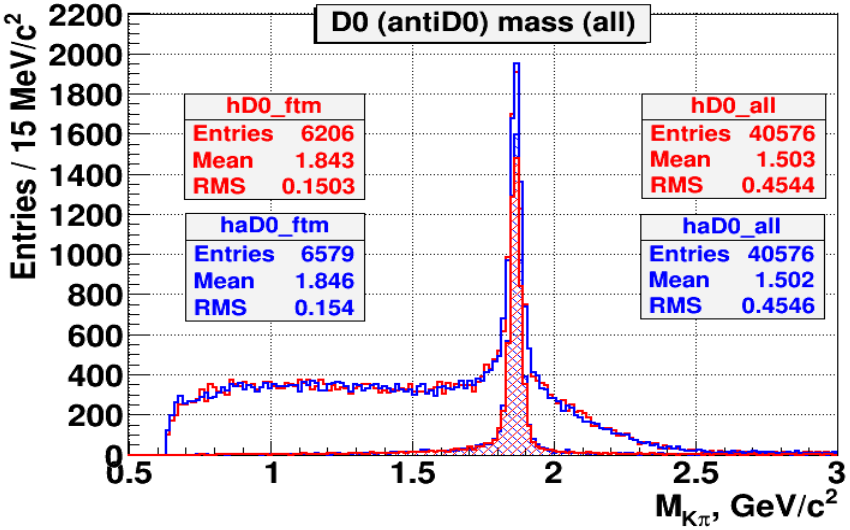
PID need or no at this stage – is not clear, it should be looked later with full background;

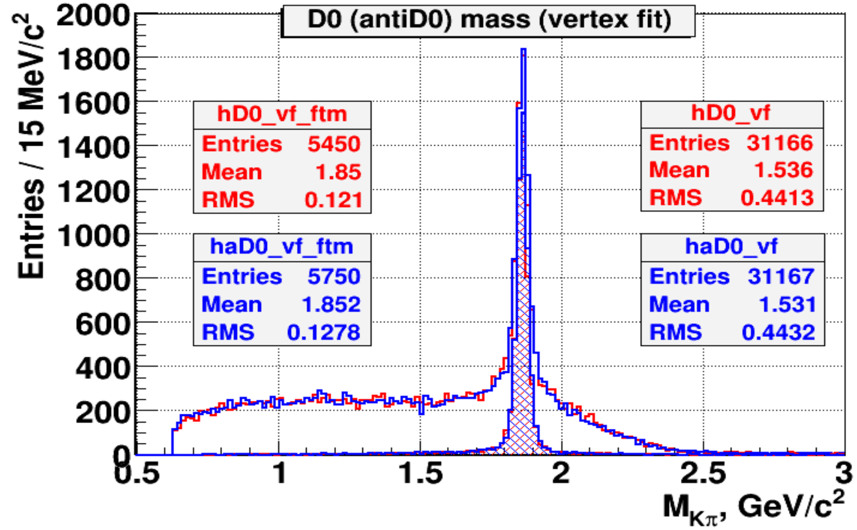


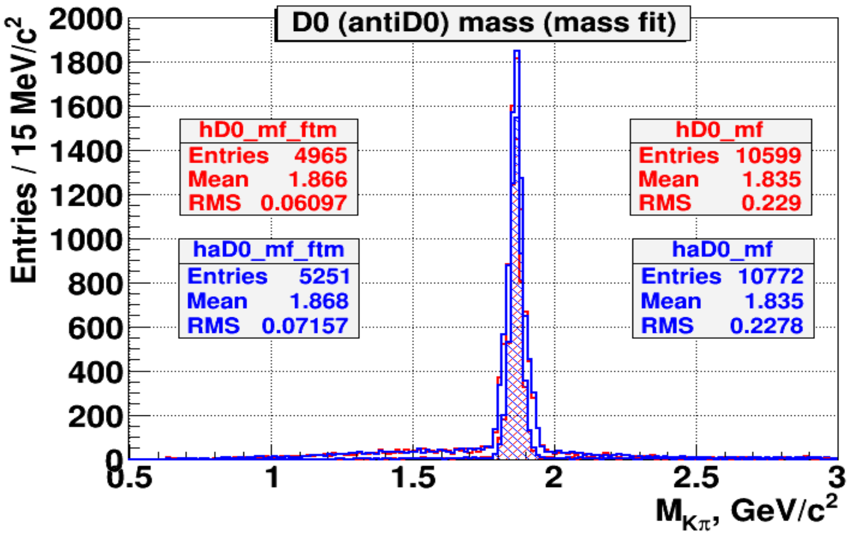


X(3872) → D0antiD0

D0 → K-π+ and antiD0 → K+π- invariant mass







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1) K all
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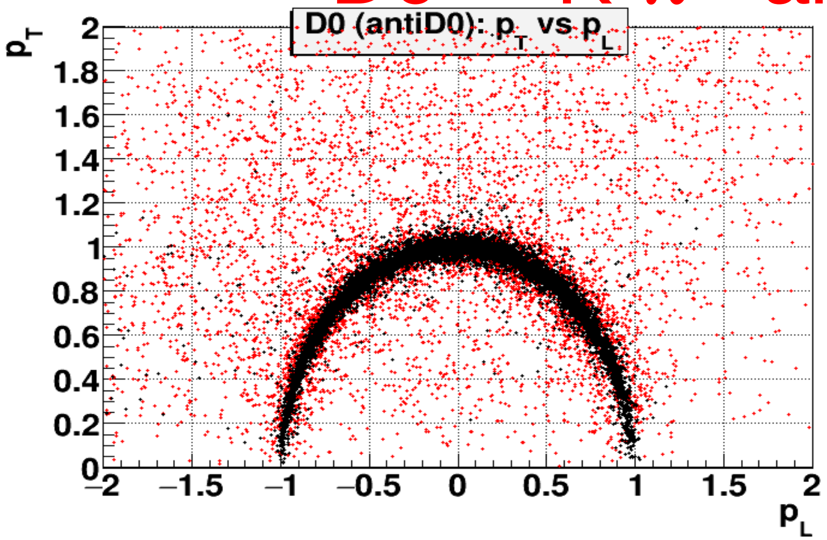
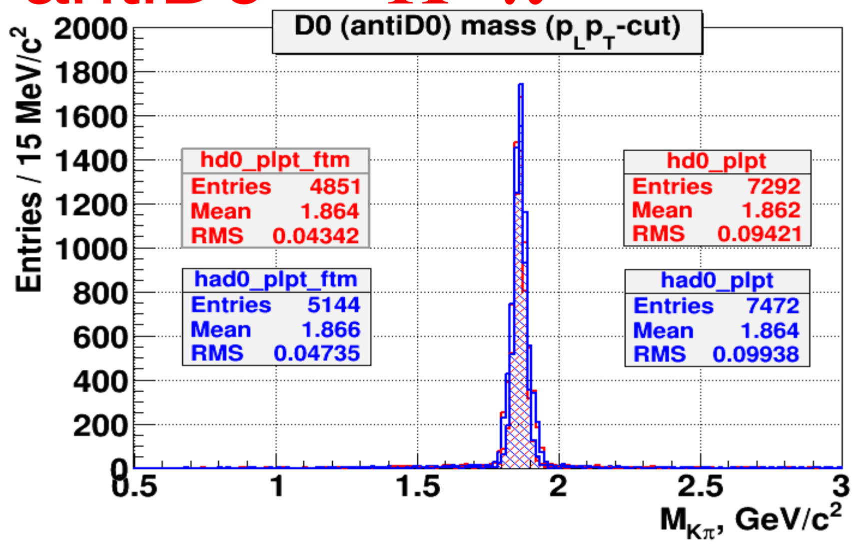
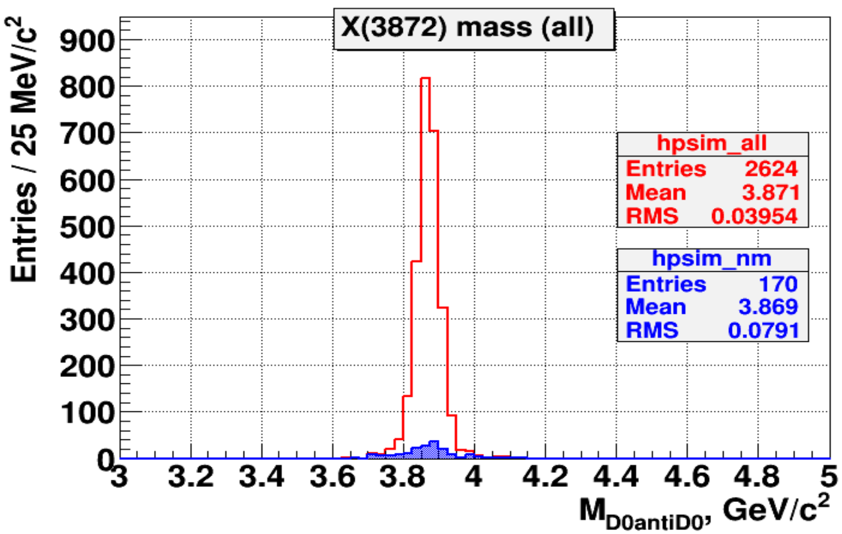
X(3872) → D0antiD0

D0 → K-π+ and antiD0 → K+π-







4) abs(Rp_Lp_T-1) < 0.15

5) 4C fit: P > 0.001,
D-mass = 1.83-1.90 GeV

Effic. = 24.5%

X(3872) yield considerations

Cross-section X(3872) = 100 nb [1]

From Pythia8:

Br ψ(3770)	$\rightarrow$ *D+D-:*	*42.43%*		
	$\rightarrow$ *D0antiD0:*	*57.23%*		
	$\rightarrow$ *J/ψ π+π- :*	*0.34%*		
Br X(3872)	$\rightarrow$ *J/ψ π+π- :*	*5% [1]*	*efficiency:*	*~10% [1]*
Br X(3872)	$\rightarrow$ *D+D-:*	*40.45%*	*efficiency:*	*5.6%*
	$\rightarrow$ *D0antiD0:*	*54.55%*	*efficiency:*	*24.5%*

Br D+- $\rightarrow$ K$\pi\pi$: *9.40%*
Br D0 $\rightarrow$ Kπ: *3.83%*

"Visible" cross-sections (i.e taking into account branches and efficiencies):
X(3872) $\rightarrow$ J/ψ π+π- : *100 * 0.05 * 0.06 * 0.10 = 0.030 nb (1 decay mode)*
X(3872) $\rightarrow$ D+D-: *100 * 0.4045 * 0.094 * 0.094 * 0.056 = 0.020 nb*
X(3872) $\rightarrow$ D0antiD0: *100 * 0.5455 * 0.038 * 0.038 * 0.245 = 0.019 nb*
Totally D+D- & D0antiD0 decays give a comparable contribution as J/ψ π+π-

[1] K.Goetzen et al, "Simulation Study of the Width and Line Shape of the X(3872)"

DPM background estimates

To evaluate background we need to look general background which can be simulated in DPM.

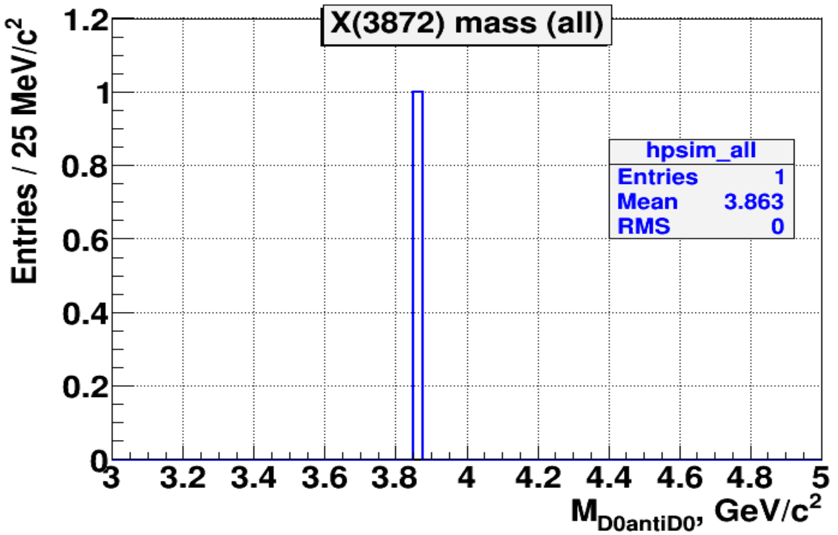
Sig_inelastic approx 46 mb -> 1million events was produced

Generator-level filter of inelastic DPM (available in PANDA Root):

D0antiD0: 1) >= 4 charged particles; 2) K-pi+ inv. mass combinations (1.5-2.2 GeV) >= 1; 3) K+pi- inv. mass combinations (1.5-2.2 GeV) >= 1: rejection factor ~ 6.

D+D-: 1) >= 6 charged particles; 2) K-pi+pi+ inv. mass combinations (1.5-2.2 GeV) >= 1; 3) K+pi-pi- inv. mass combinations (1.5-2.2 GeV) >= 1: rejection factor ~ 7.

170k filtered events - equivalent of ~1 mil.



Summary and outlook

1. X(3872) decays to D+D- (D goes to $K\pi\pi$): efficiency 5.6%
2. X(3872) decays to D0antiD (D goes to $K\pi$): efficiency 24.5%
3. Combined yield from both modes ~ yield from $J/\psi\pi\pi$ mode
4. DPM background – low statistics & we need much more events
5. What else? - Suggestions are welcome.