JÜLICH
FORSCHUNGSZENTRUM

Simulation of Ds semileptonic decay

Lu Cao

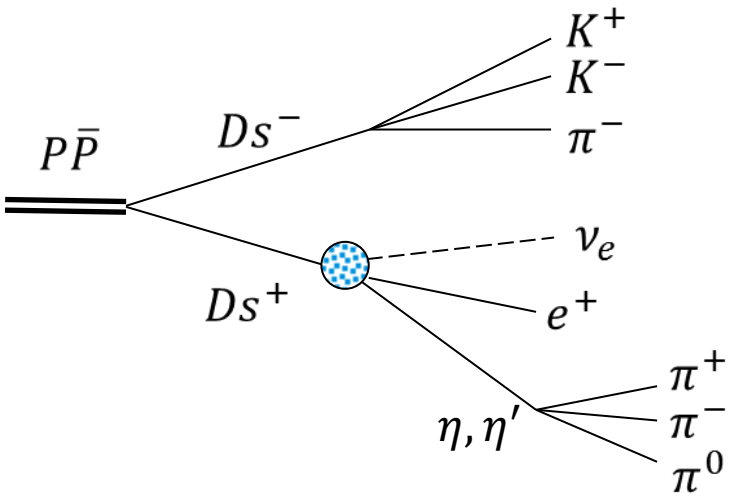
June 26th, 2013

Outline

- Introduction & significance
- Check the decay models with MC truth
- Reconstruction (ongoing)
- Summary & outlook

Introduction & significance

- Semileptonic decays Ds-> e + v + η,η' are an excellent environment for precision measurements of the CKM matrix element $|V_{cd}|$ and $|V_{cs}|$.



- Form factor encapsulates QCD bound-state effects; relates to the probability of forming final state at given q^2.

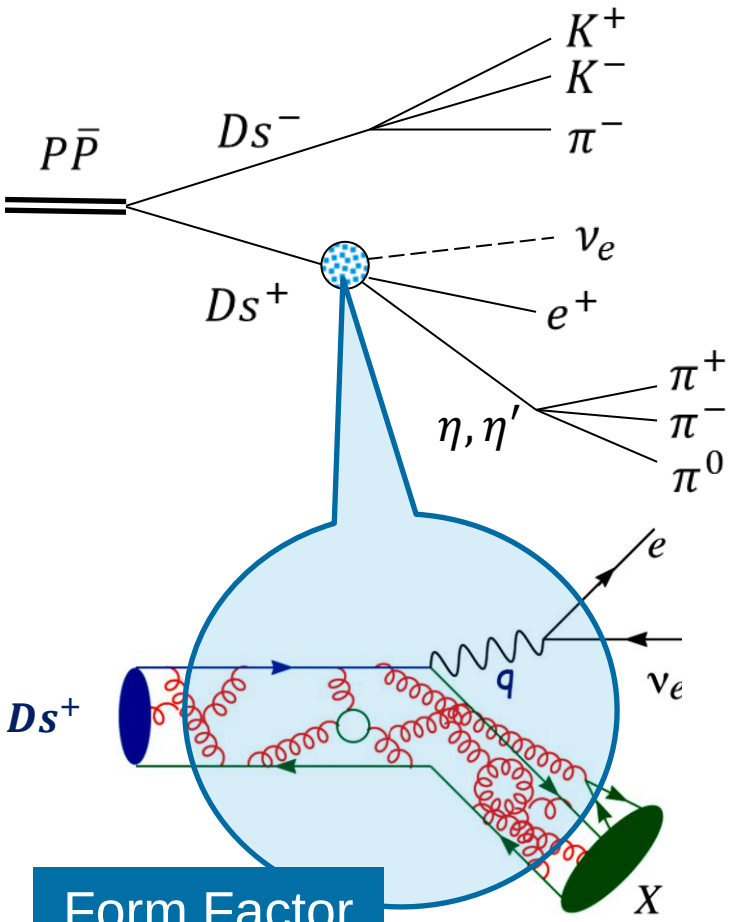
- The investigation opens a new approach to improve the measurement of mixing angle for η and η'.

Introduction & significance

- Semileptonic decays Ds-> e + v + η,η' are an excellent environment for precision measurements of the CKM matrix element $|V_{cd}|$ and $|V_{cs}|$.

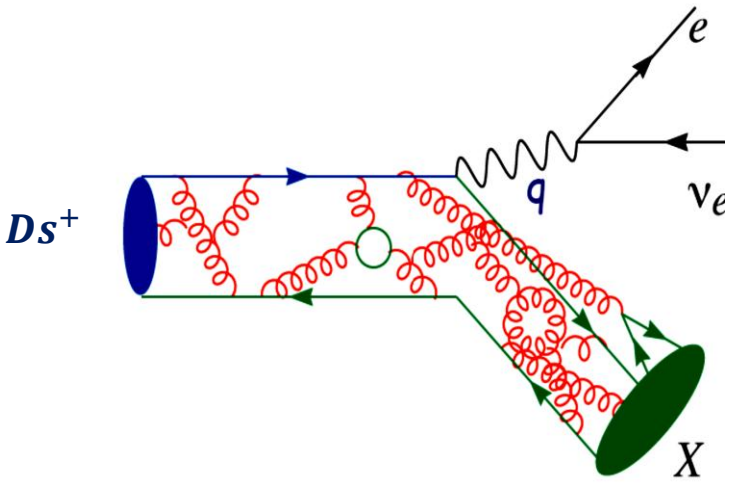
- Form factor encapsulates QCD bound-state effects; relates to the probability of forming final state at given q^2.

- The investigation opens a new approach to improve the measurement of mixing angle for η and η'.



Form Factor
$f_+(q^2)$

pbarpSystem	
-> Ds- Ds+	BR_{PDG}
| |-> eta e+ nu_e	2.67%
|-> K- K+ pi-	5.49%



Production Rate of Ds pair

$$R = \mathcal{L} \cdot \sigma \cdot \varepsilon \cdot t \cdot \mathcal{BR}$$

$$= 10^{32}(cm^2) \cdot \mathbf{10}(nb) \times 10^{-24}(cm^2/b) \cdot 5 \times 10^{-2} \cdot 3 \times 10^{6}(s) \cdot 2.67\% \times 5.49\%$$

$$\backsimeq 220$$

Previous measurements have been carried on CLEO-c, BaBar, etc..

Partial Rate of Ds semileptonic decay

$$\frac{d\Gamma(Ds \to vlX)}{dq^2} = \frac{{G_F}^2}{24\pi^3} |V_{cx}|^2 {p_x}^3 |f_+(q^2)|^2$$

Check the decay models with MC truth

pbarp system	**noPhotos**
-> Ds- Ds+	
| |-> eta e+ nu_e	**PHOTOS ISGW2**
| | -> pi+ pi- pi0	**ETA_DALITZ**
|-> K- K+ pi-	**?**

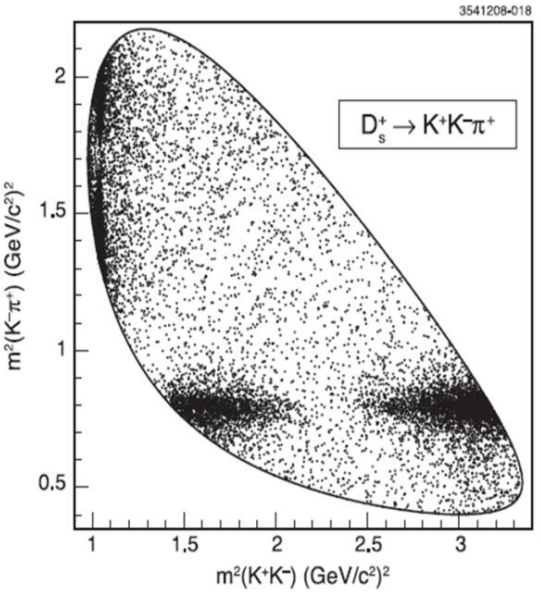
- D_DALITZ

  in EvtGen of the released PANDAROOT

  provides Dalitz amplitude for three-body $K\pi\pi$ D decays: $D^+ \rightarrow K^-\pi^+\pi^+$, $D^0 \rightarrow K^-\pi^+\pi^0$,etc..

Check the decay models with MC truth

pbarp system	noPhotos
-> Ds- Ds+	
| |-> eta e+ nu_e	PHOTOS ISGW2
| | -> pi+ pi- pi0	ETA_DALITZ
|-> K- K+ pi-	DS_DALITZ

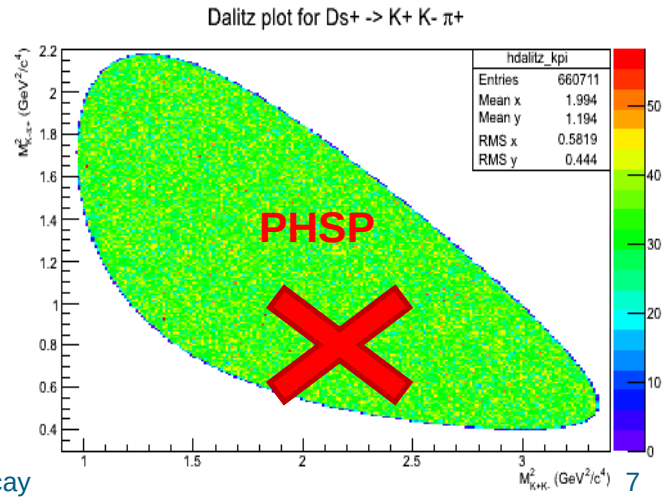


CLEO Collaboration,
Phys.Rev.D79:072008,2009

- D_DALITZ

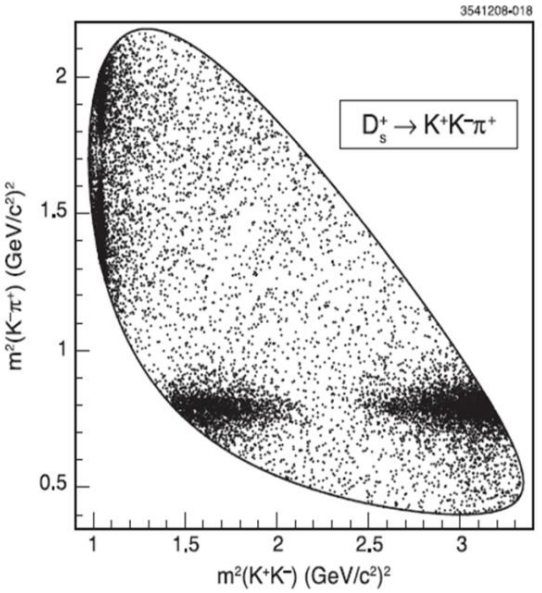
  in EvtGen of the released PANDAROOT

  provides Dalitz amplitude for three-body $K\pi\pi$ D decays: $D^+ \to K^-\pi^+\pi^+$, $D^0 \to K^-\pi^+\pi^0$,etc..



Check the decay models with MC truth

pbarp system	noPhotos
-> Ds- Ds+	
| |-> eta e+ nu_e	PHOTOS ISGW2
| | -> pi+ pi- pi0	ETA_DALITZ
|-> K- K+ pi-	DS_DALITZ



CLEO Collaboration,
Phys.Rev.D79:072008,2009

- D_DALITZ

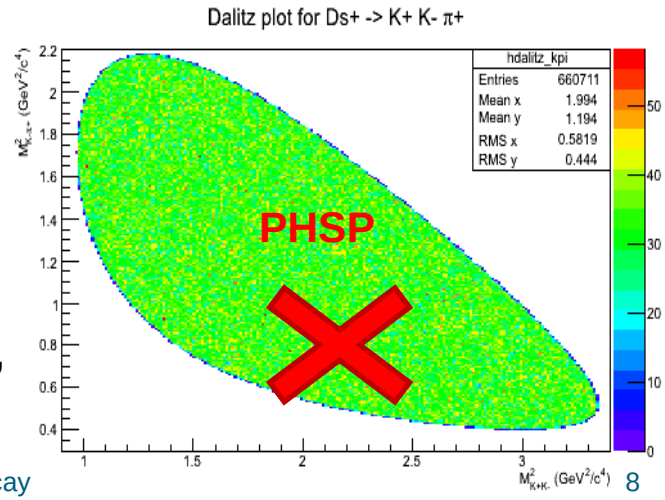
  in EvtGen of the released PANDAROOT

  provides Dalitz amplitude for three-body *Kππ* D decays: $D^+ \to K^-\pi^+\pi^+$, $D^0 \to K^-\pi^+\pi^0$,etc..

- DS_DALITZ

  for *Ds->KKπ* mode, with the resonance contributions of

  $K^*(892)K^+$, $K^*_0(1430)\,K^+$, $f_0(980)\,\pi^+$, $\Phi(1020)\,\pi^+$, $f_0(1370)\,\pi^+$, $f_0(1710)\,\pi^+$.



pbarp system **noPhotos**

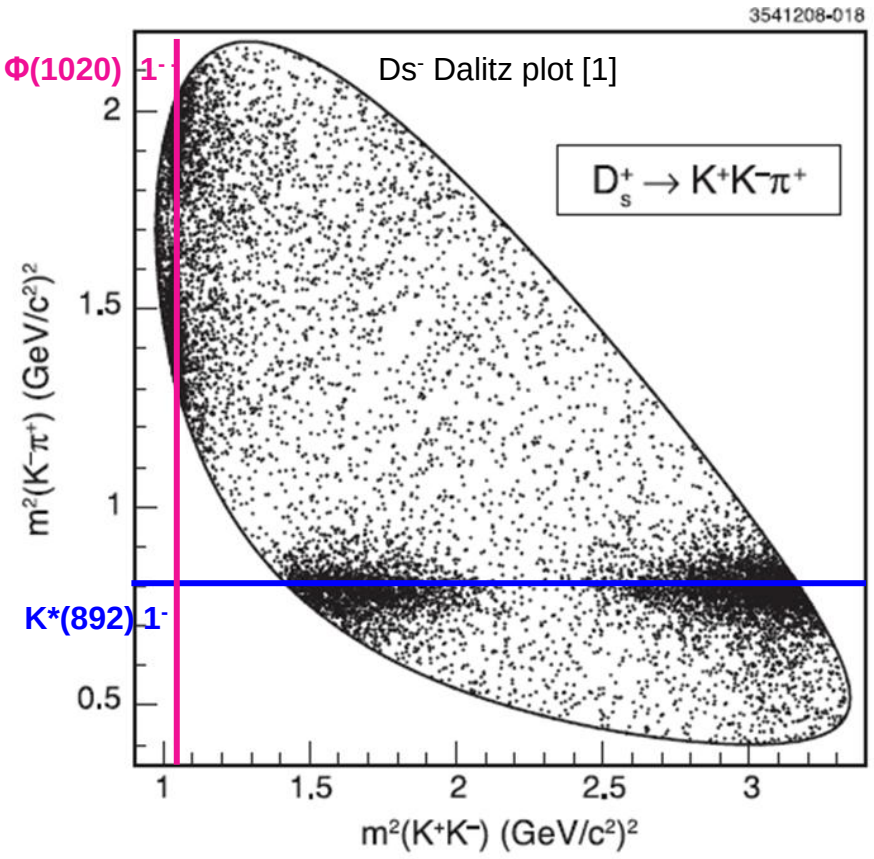
-> Ds- Ds+

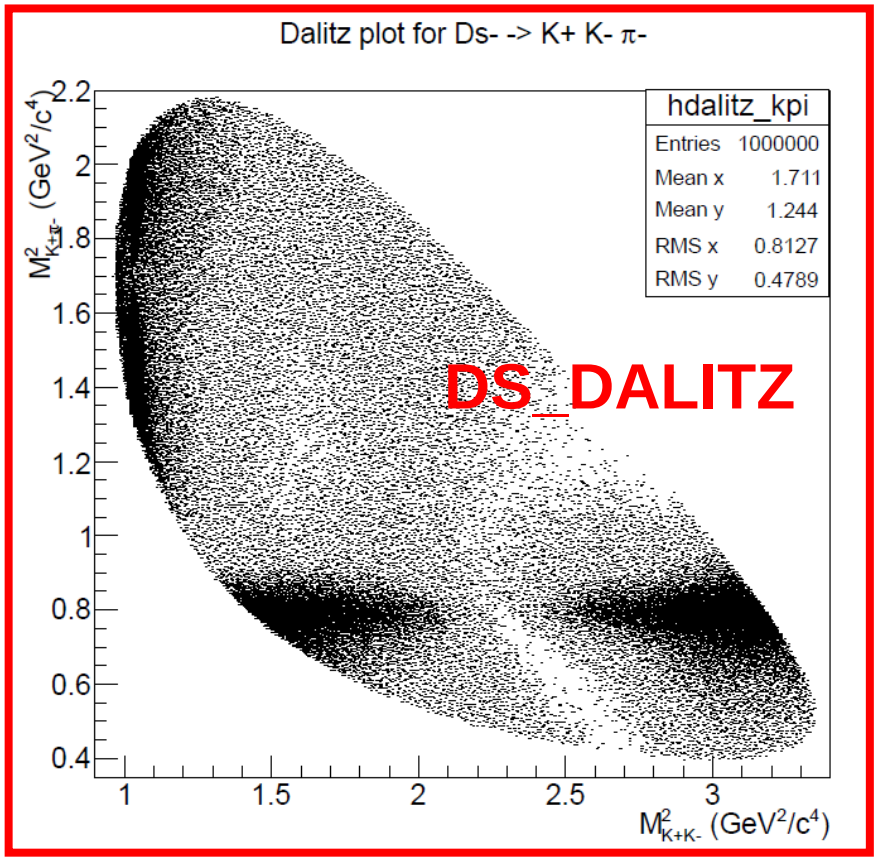
| |-> eta e+ nu_e **PHOTOS ISGW2**

| | -> pi+ pi- pi0 **ETA_DALITZ**

|-> K- K+ pi- **DS_DALITZ**

Our Dalitz analysis has repeated the experimental data [1,2].



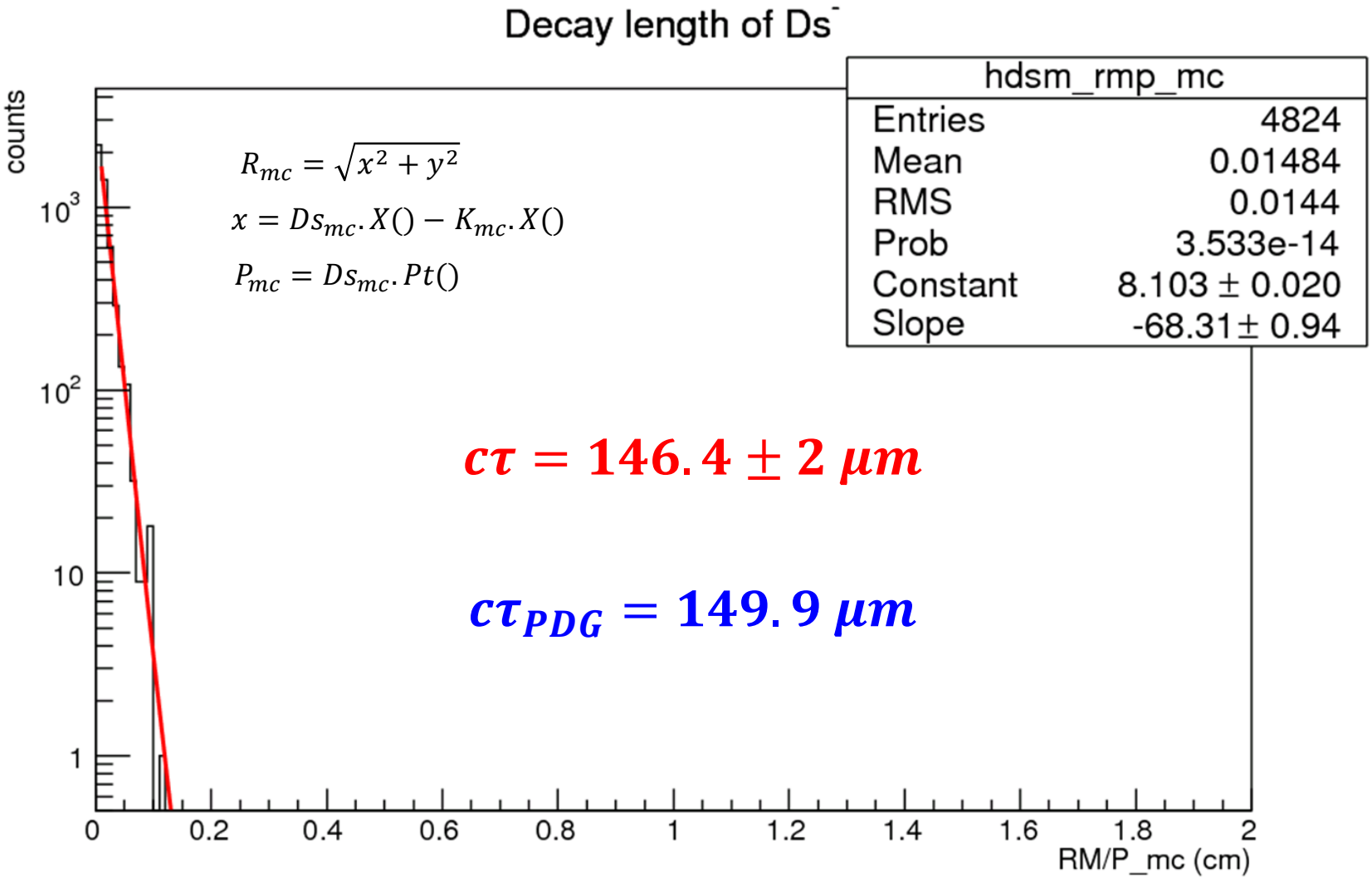


[1] CLEO Collaboration, Phys.Rev.D79:072008,2009

[2] BABAR Collaboration, Phys.Rev.D83:052001,2011

Decay length with MC truth

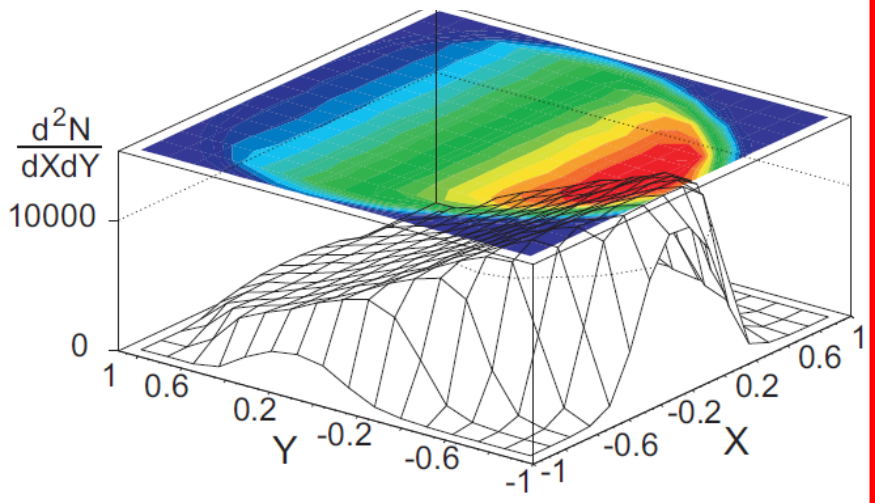
Evt=2k

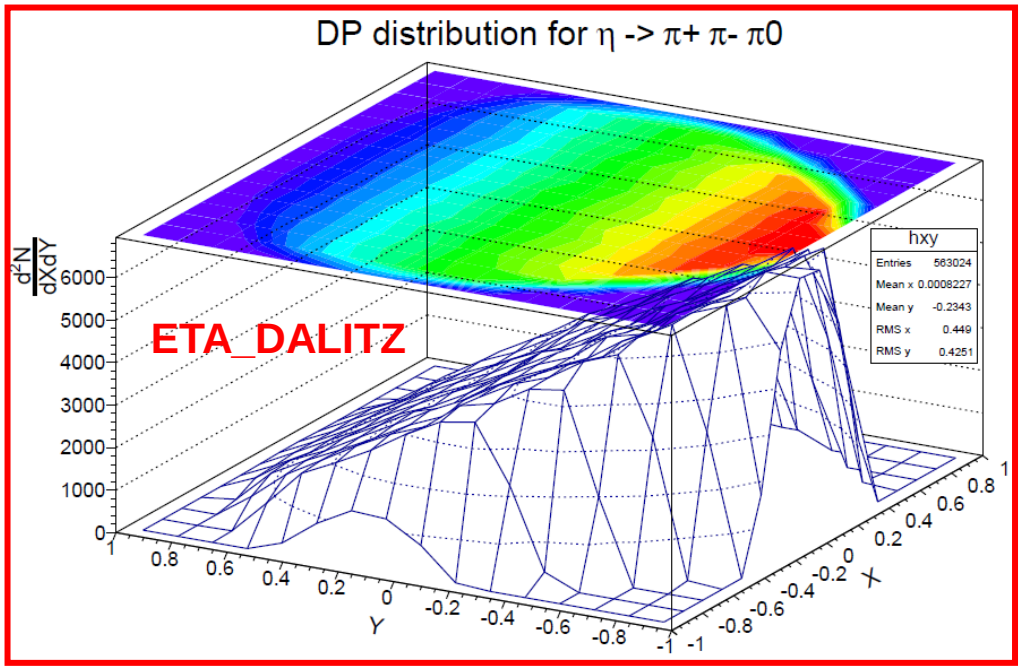


pbarp system	noPhotos
-> Ds- Ds+	
| |-> eta e+ nu_e	PHOTOS ISGW2
| | | -> pi+ pi- pi0	ETA_DALITZ
|-> K- K+ pi-	DS_DALITZ

Double-check with the Dalitz plot distribution

Dalitz plot distribution for eta[3]





The dalitz distribution plot agrees the experimental data [3] very well, then ensures the correctness of ETA_DALITZ in the present EvtGen reasonably.

[3] KLOE Collaboration, JHEP 05, 006 (2008).

pbarp system noPhotos

-> Ds- Ds+

| |-> eta e+ nu_e PHOTOS ISGW2

| | -> pi+ pi- pi0 ETA_DALITZ

|-> K- K+ pi- DS_DALITZ

No direct Dalitz information to compare with simulation because of the missing neutrino in this decay.

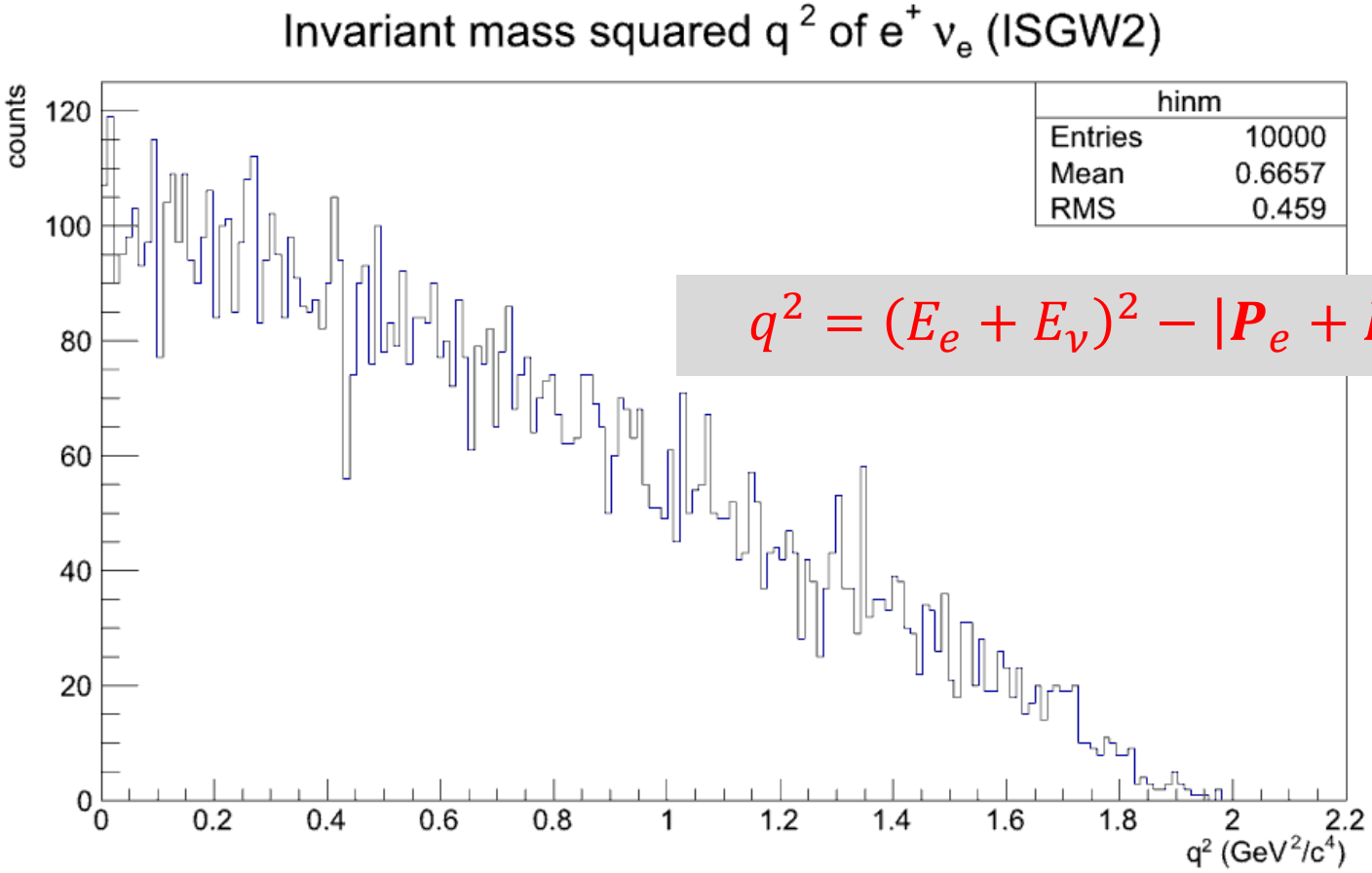
Possible semileptonic decay models in EvtGen:

Model	Description	Example channel
SLPole	implements a pole form parameterization	$B^0 \to \rho^- \mu^+ \nu_\mu$
ISGW	the first exclusive model [4] to calculate rates to channels other than the pseudoscalar and vector ground states	$\bar{B}^0 \to D^{*+} e\nu$
ISGW2	an updated version [5] of ISGW designed to make “best estimates” within the context of a constituent quark model that fully respects Heavy Quark Symmetry	$\bar{B}^0 \to D^{*+} e\nu$
HQET	pseudoscalar semileptonic decay to a vector meson	$B \to D^* l\nu$

[4] N. Isgur, D. Scora, B. Grinstein, and M.B. Wise, Phys. Rev. D39, 799 (1989).
[5] D. Scora and N. Isgur, Phys. Rev. D52, 2783 (1995).

q^2 of the lepton-neutrino syst. in MC truth

$$Ds^+ \rightarrow \eta + e^+ + \nu_e$$ Evt=10k

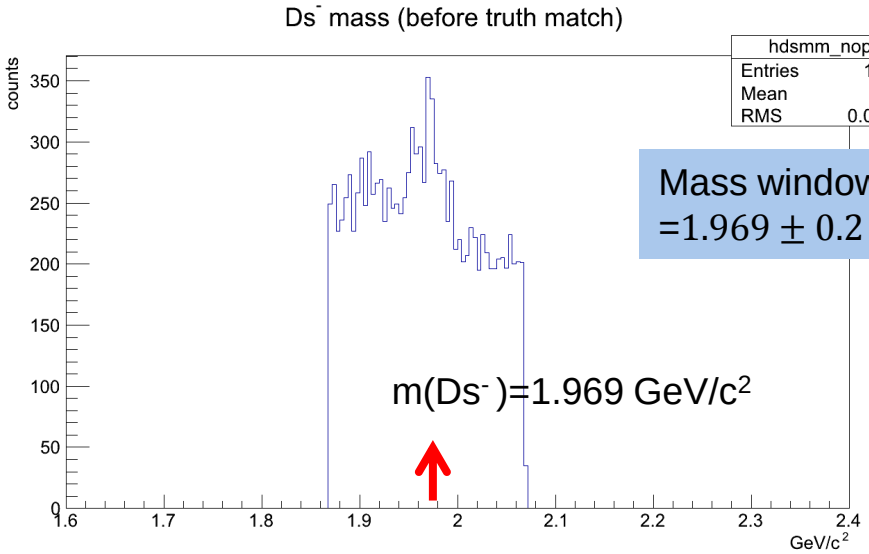


$$q^2 = (E_e + E_\nu)^2 - |\boldsymbol{P}_e + \boldsymbol{P}_\nu|^2$$

Reconstruction: $Ds^- \rightarrow K^+ K^- pi^-$

Evt = 2k

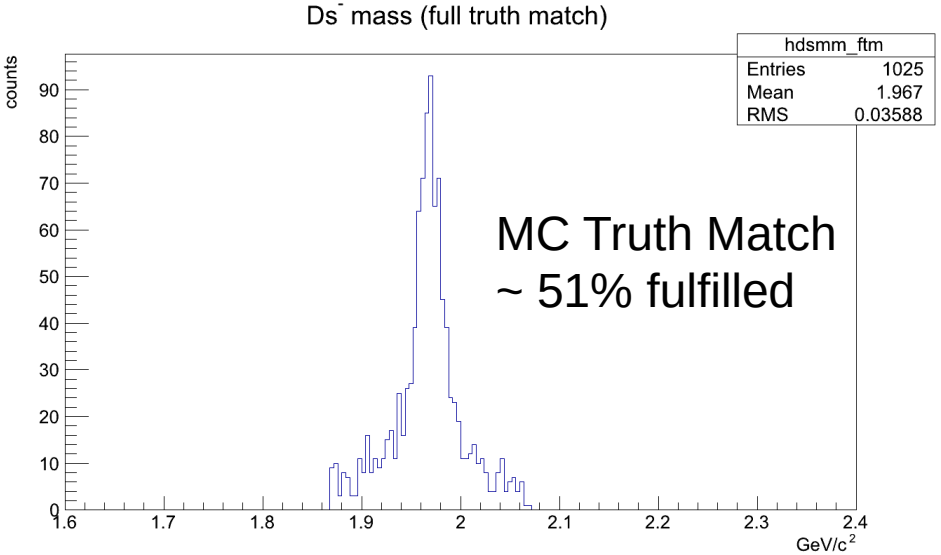
pbarp system **noPhotos**
-> Ds- Ds+
| |-> eta e+ nu_e PHOTOS ISGW2
| | -> pi+ pi- pi0 ETA_DALITZ
|-> K- K+ pi- DS_DALITZ



Mass window
=1.969 ± 0.2 GeV/c²

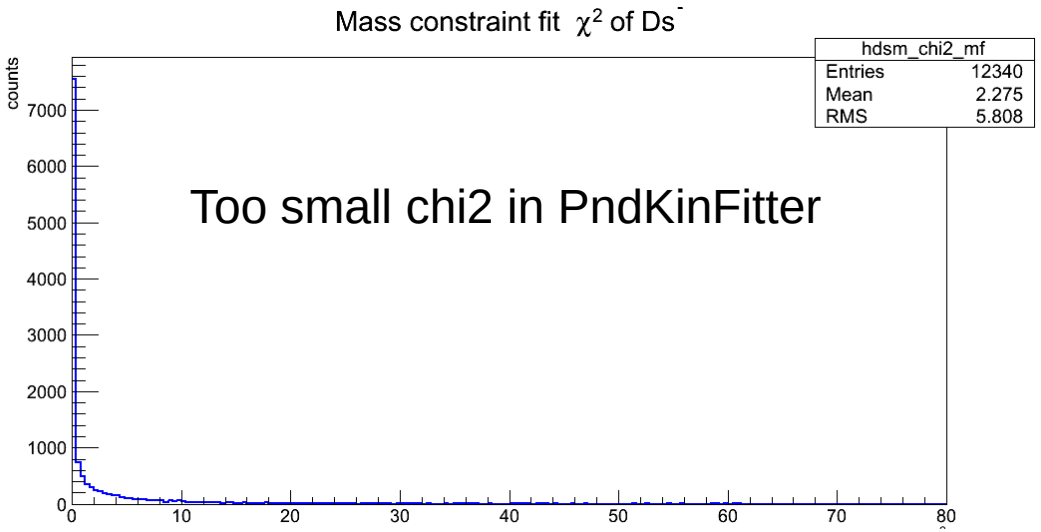
Strategy for Ds-

- Combine the final particles ($K^+ K^- pi^-$) and filter with mass window
- Mass Constraint Fit
- Vertex Fit
- Get resolution of selected candidates



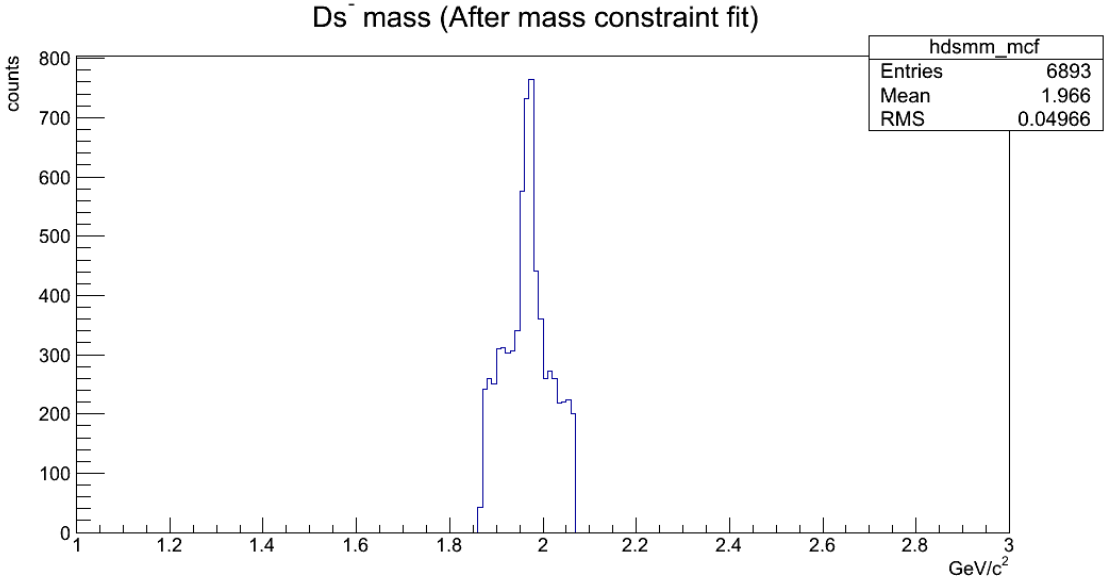
Mass constraint fit

Evt = 2k



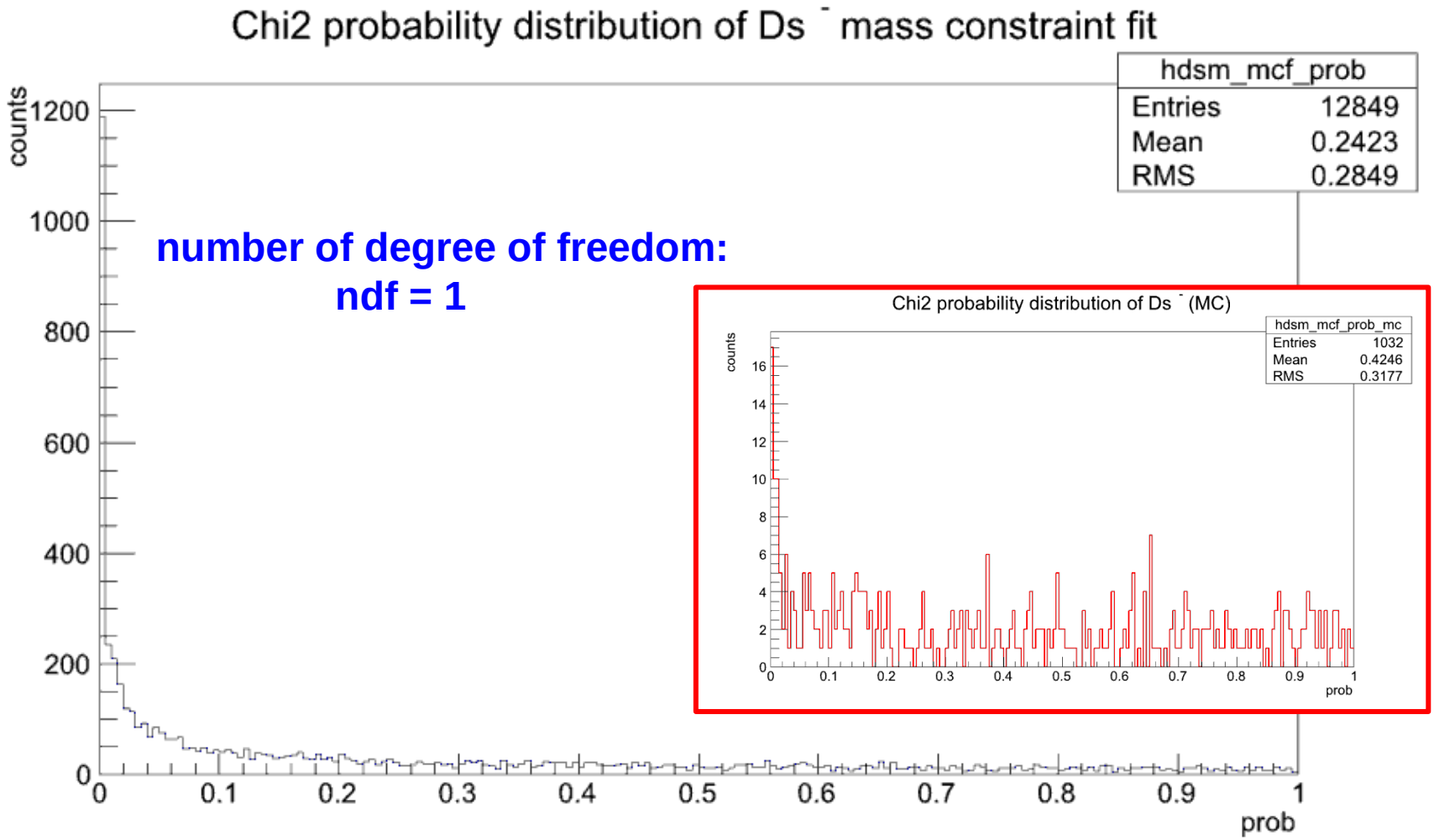
~ 55.9% survived with Chi2<0.2

Chi2 cutting removes some background, however, the Ds- mass after fitting is far away from an expected delta function.



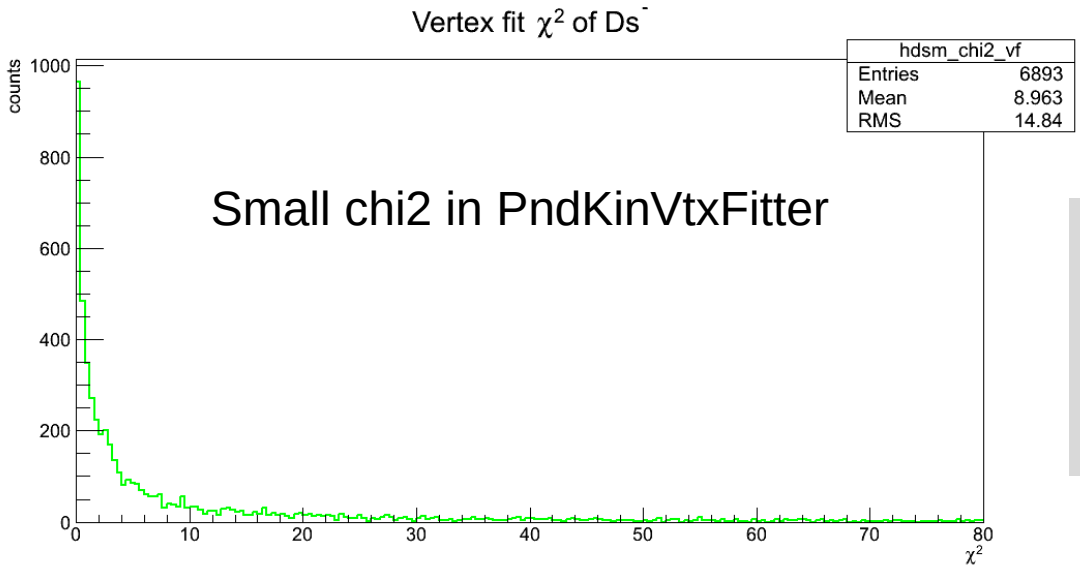
χ^2 probability distribution

Evt = 2k



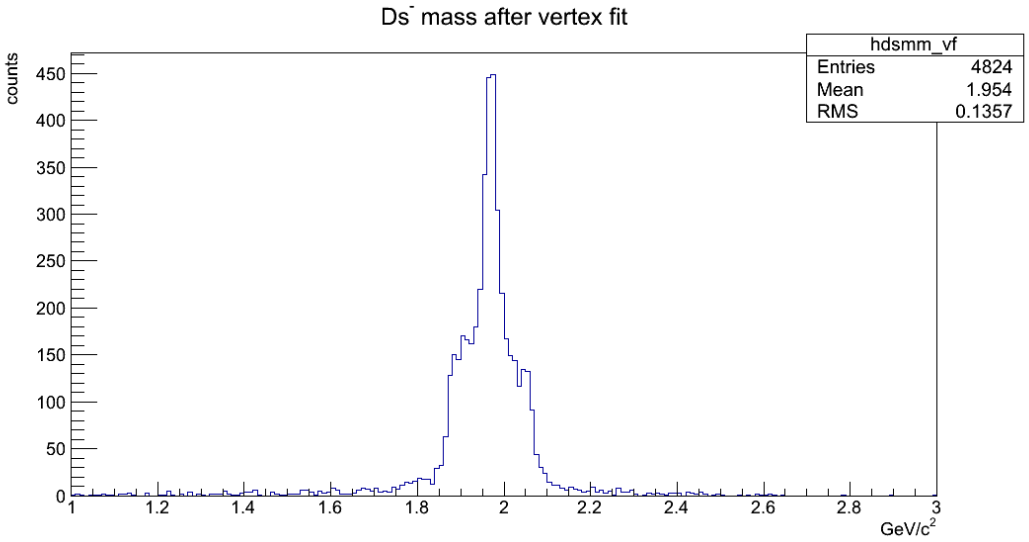
Vertex Fit

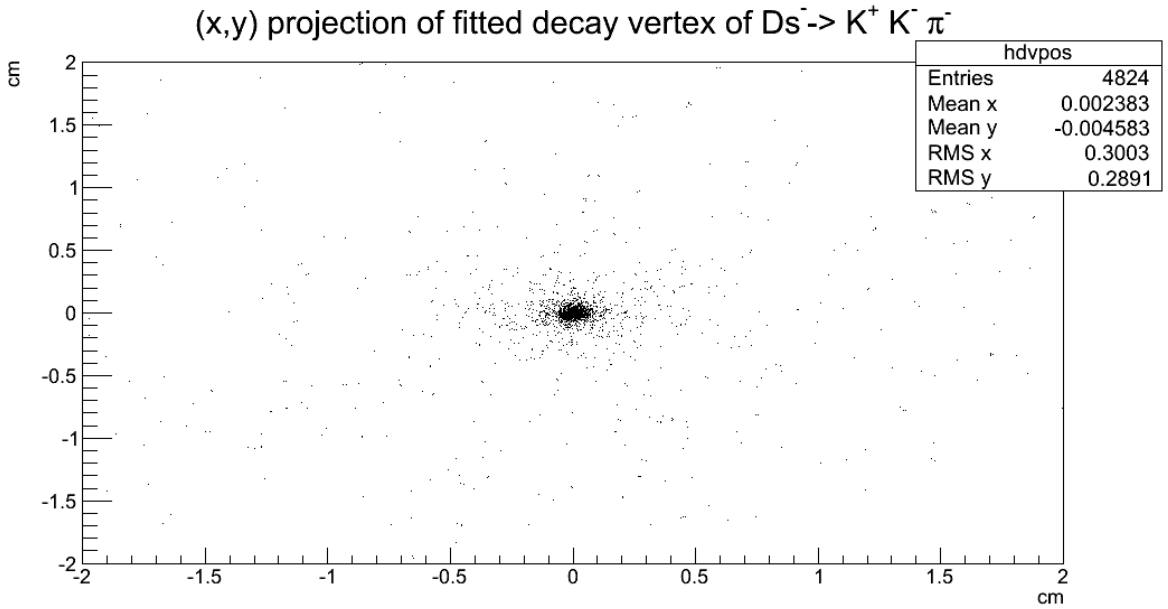
Evt = 2k

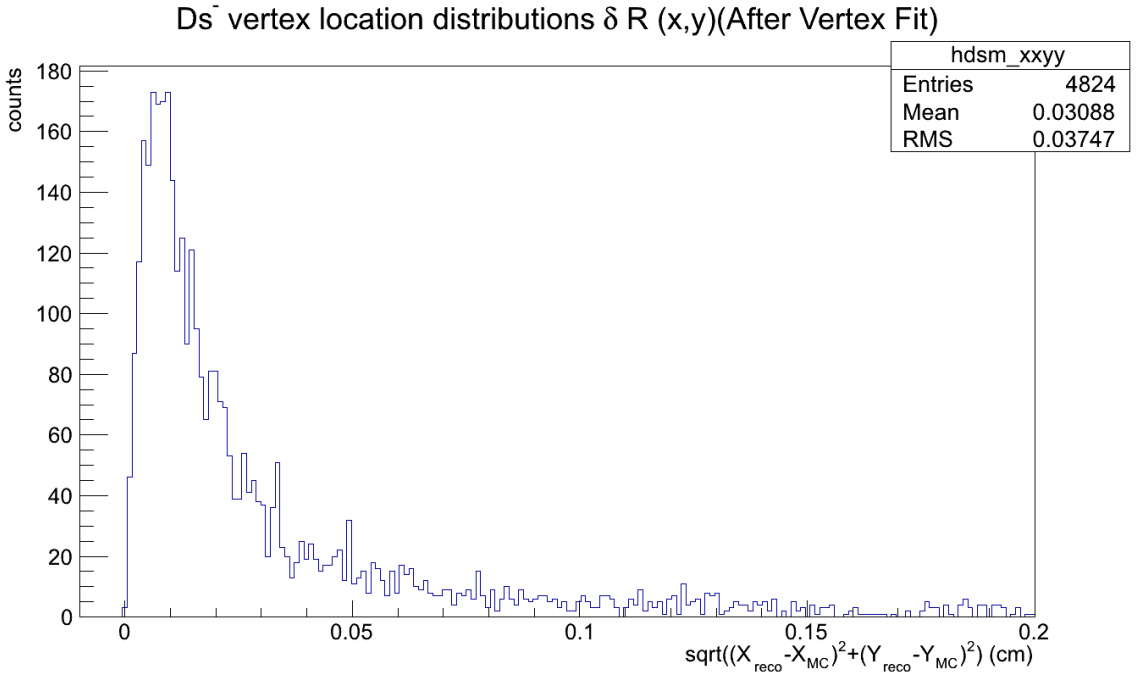


~ 70.0% survived in vtx fit with Chi2<20,
and 39.1% if combine with the mass constraint fit.

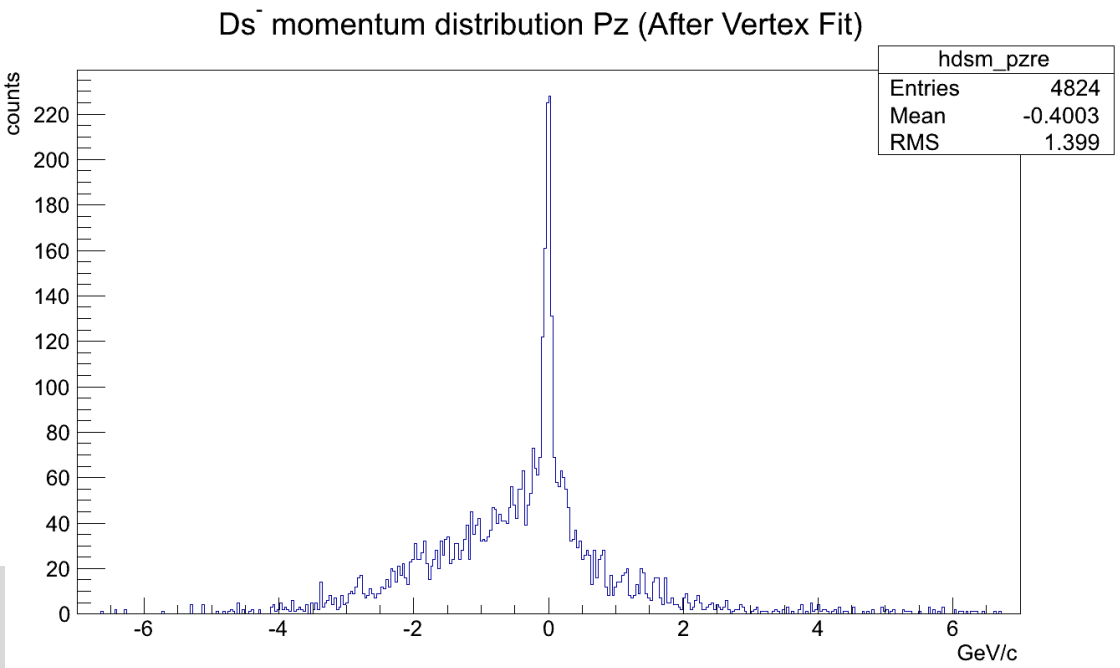
Probability distribution will bring a more reasonable chi2 cut

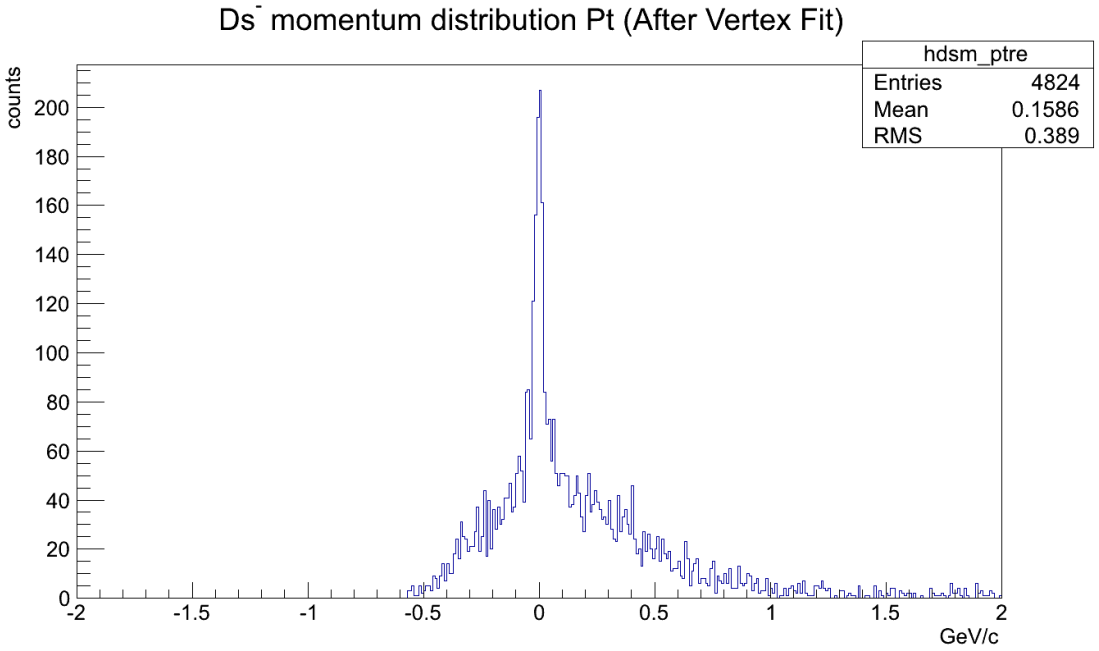


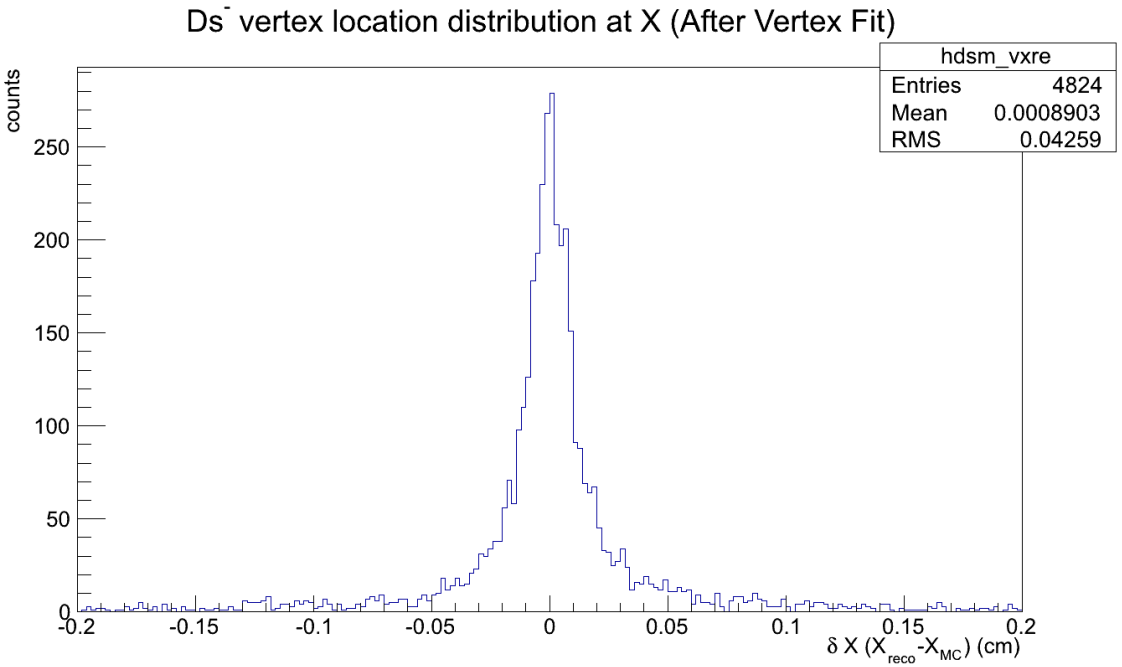

(x,y) projection of fitted decay vertex of Ds- -> K+ K- π-
hdvpos
Entries 4824
Mean x 0.002383
Mean y -0.004583
RMS x 0.3003
RMS y 0.2891
cm
cm

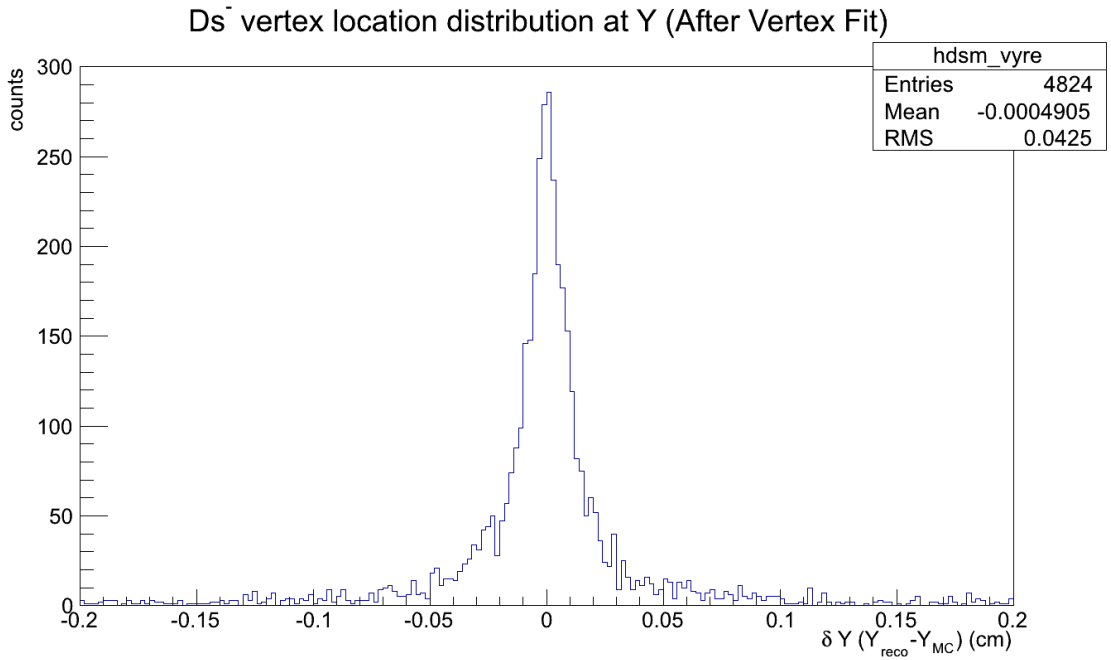

Ds- vertex location distributions δ R (x,y)(After Vertex Fit)
hdsm_xxyy
Entries 4824
Mean 0.03088
RMS 0.03747
counts
sqrt((X_reco-X_MC)^2+(Y_reco-Y_MC)^2) (cm)

Gaussian-fit will be performed and analyzed in coming steps






Ds⁻ vertex location distribution at X (After Vertex Fit)
hdsm_vxre
Entries 4824
Mean 0.0008903
RMS 0.04259
counts
δ X (X_reco-X_MC) (cm)


Ds⁻ vertex location distribution at Y (After Vertex Fit)
hdsm_vyre
Entries 4824
Mean -0.0004905
RMS 0.0425
counts
δ Y (Y_reco-Y_MC) (cm)

Reconstruction strategy for Ds^+

$P\bar{P}$

Ds^-

pi0

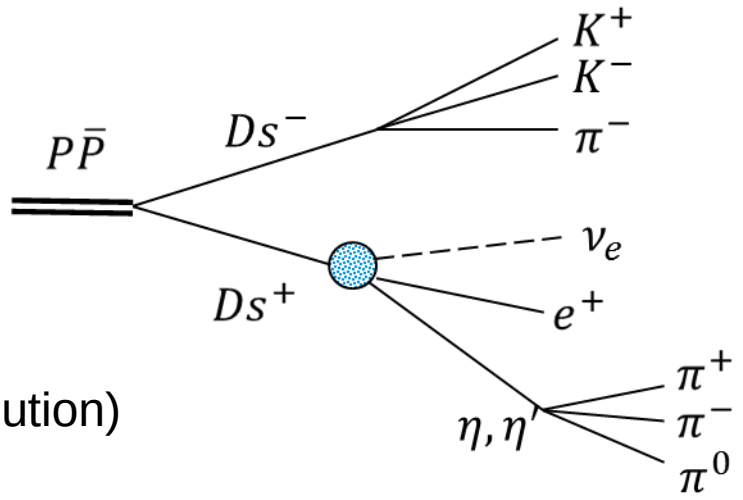
- combine 2 photons
- mass cut
- mass constraint fit (prob. distribution)

eta

- combine pi0 pi+ pi- (daughter of Ds^+)
- mass cut
- mass constraint fit (prob. distribution)
- Vtx fiting with tracks of pi+ and pi-

Ds^+

- 4-momentum conservation of pbar-p system to Ds- and Ds+



Summary & outlook

- ✓ Check and develop the decay models:

  ETA_DALITZ, ISGW2, DS_DALITZ

- ✓ Access MC truth for comparing
- ■ Reconstruct Ds- (ongoing)

  Improve the signal/background ratio

- □ Reconstruct Ds+
- □ Evaluate form factor and total reco. efficiency

photo cited from the internet resources

Thank you

l.cao@fz-juelich.de