Measurement of $\psi(2s) \to \Delta^{++}\Delta^{--}$

Kexin Su, Hao Cai

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Outline

- Motivation
- Data Set
- Data Analysis
- Question

Motivation

- Precise Measurement:

	$\mathbf{B(\psi(2s) \to \Delta^{++}\Delta^{--})(\times\ 10^{-4})}$
PDG	1.28 ± 0.35

- 12% Rule:

$Q_h = \frac{B(\psi(2s) \to h)}{B(J/\psi \to h)}$

	$\mathbf{B(J/\psi \to \Delta^{++}\Delta^{--})}$	$\mathbf{Q_{\Delta^{++}\Delta^{--}}\ (\%)}$
PDG	$(1.1 \pm 0.29) \times\ 10^{-3}$	(11.6 ± 1.0)

Make a deeper understanding in perturbative QCD.

Data Set

- Working environment: boss.6.6.5.p01
- Data Set

	Data	**Inclusive MC**	**PHSP MC**
2009	**1.06**$\times 10^9$	**1.6**$\times 10^9$	**1.0**$\times 10^5$
2012	**3.41**$\times 10^9$	**4.0**$\times 10^9$	**1.0**$\times 10^5$
Total	**4.47**$\times 10^9$	**5.6**$\times 10^9$	**2.0**$\times 10^5$

- Signal MC:

$\psi(2s) \to \Delta^{++}\ \Delta^{--}$ PHSP
$\Delta^{++} \to P\ \pi^+$ PHSP
$\Delta^{--} \to \overline{P}\ \pi^-$ PHSP

Data Analysis

- Event Selection
- Further Cuts
- Background Analysis
- Sideband
- Fit for $\Delta^{++}\Delta^{--}$

Event Selection

- Protons selection:P^+,$\overline{P}$;

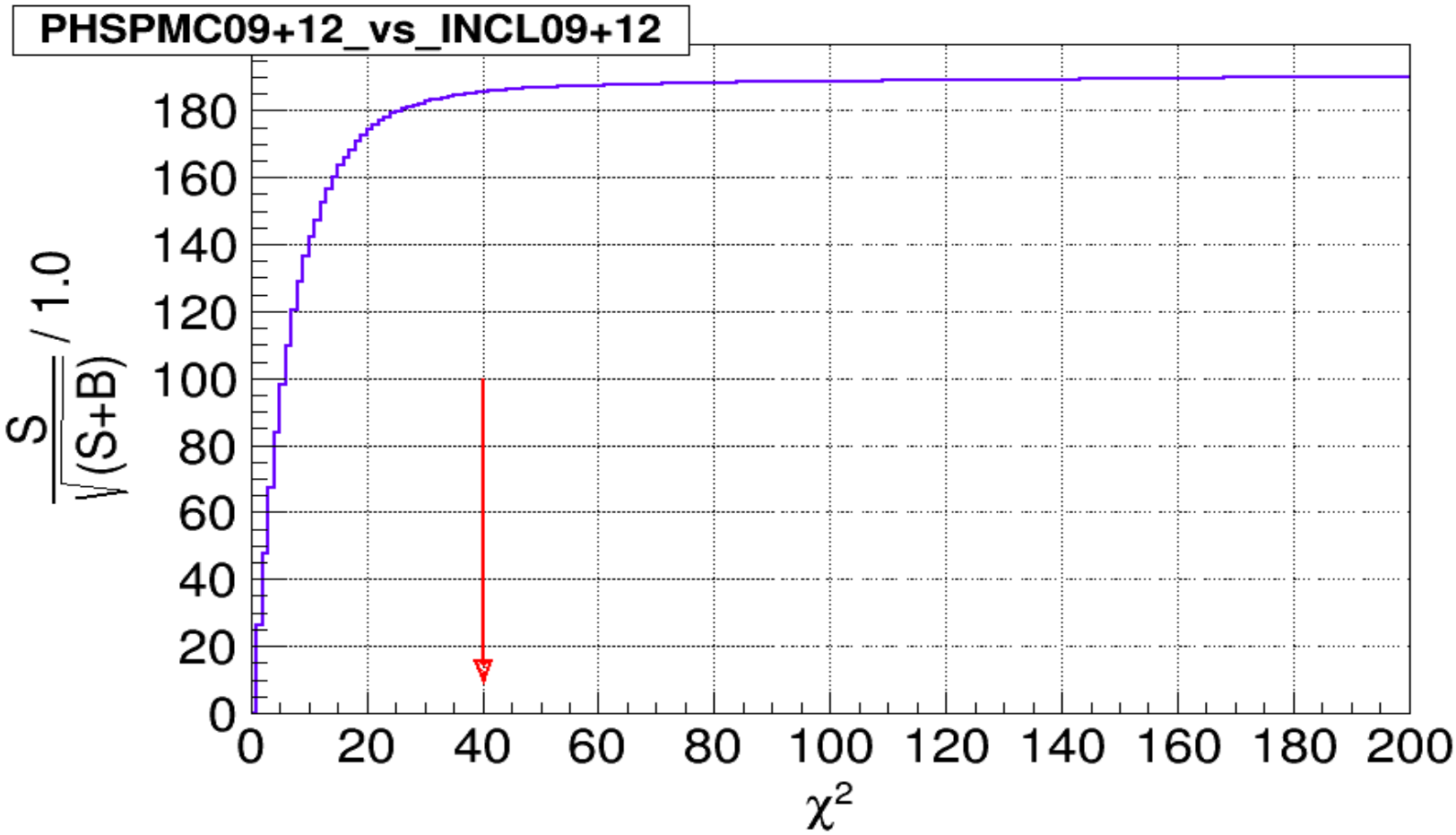
  Pions selection: π^+, π^-

- Define Δ^{++}, Δ^{--}

  $M_{\Delta^{++}} = m_P + m_{\pi^+}$;

  $M_{\Delta^{--}} = m_{\overline{P}} + m_{\pi^-}$.

χ^2_{4c} Optimization



S: the events of signal MC

S+B: the events of signal and background of inclusive MC

We choose $\chi^2_{4c} < 40$ for 2009 and 2012 events.

Further Cuts

- $M_{P\overline{P}} > 3.15 \parallel M_{P\overline{P}} < 3.05(cut J/\psi)$
- $M_{P\pi^-} < 1.11 \parallel M_{P\pi^-} > 1.33(cut \Delta^0 and \Lambda^0\ )$
- $M_{\overline{P}\pi^+} < 1.11 \parallel M_{\overline{P}\pi^+} > 1.33(cut \overline{\Delta^0} and \overline{\Lambda^0})$
- $M_{\Delta^{++}} < 1.731 \&\& M_{\Delta^{++}} > 0.731$
- $M_{\Delta^{--}} < 1.731 \&\& M_{\Delta^{--}} > 0.731$

	Data	**Inclusive MC**	**PHSP MC**	**rate(%)**
Total	2.0×10^{11}	1.97×10^{11}	2.0×10^{5}	**100**
After 4c	**327537**	**543581**	**104425**	**52.2**
$0 < \chi^2 < 40$	**270715**	**463731**	**93702**	**46.9**
J/ψ	**117228**	**279482**	**86572**	**43.3**
Δ^{++}	**90135**	**192380**	**83847**	**41.9**
Δ^{--}	**64205**	**106422**	**81005**	**40.5**
$\Delta^0 and \Lambda^0$	**49368**	**86935**	**69488**	**34.7**
$\overline{\Delta^0} and \overline{\Lambda^0}$	**38096**	**69561**	**59014**	**29.5**

Further Cuts

- The invariant quality diagram of the Δ^{++}andΔ^{--} after cut.

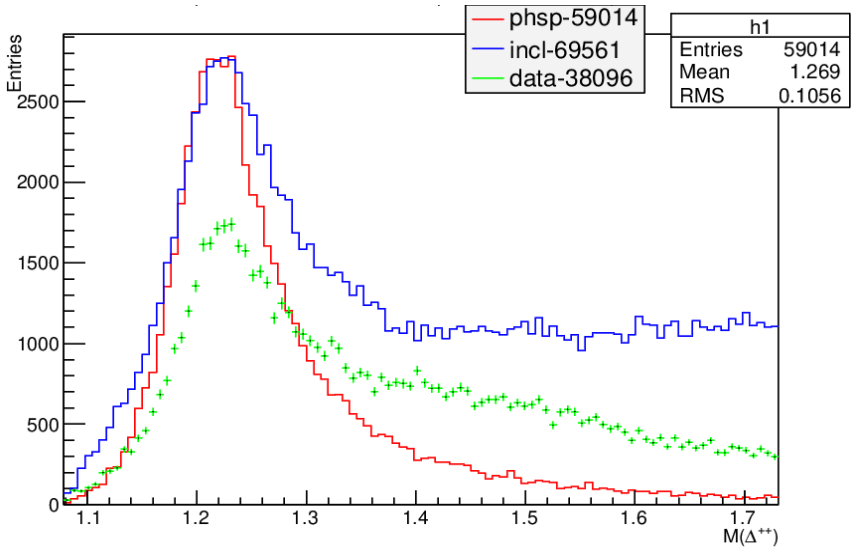


Figure: Δ^{++}

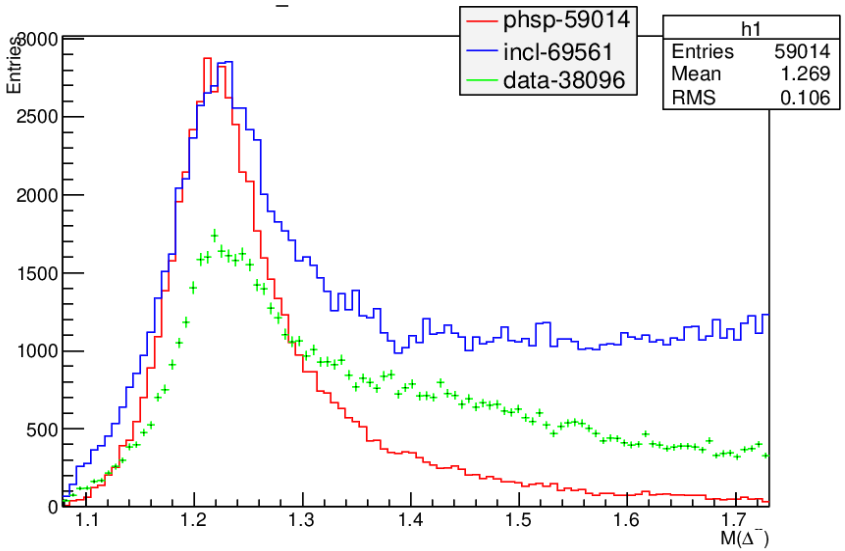


Figure: Δ^{--}

Fit the Signal MC

- Probability density function :Bilateral crystal ball function

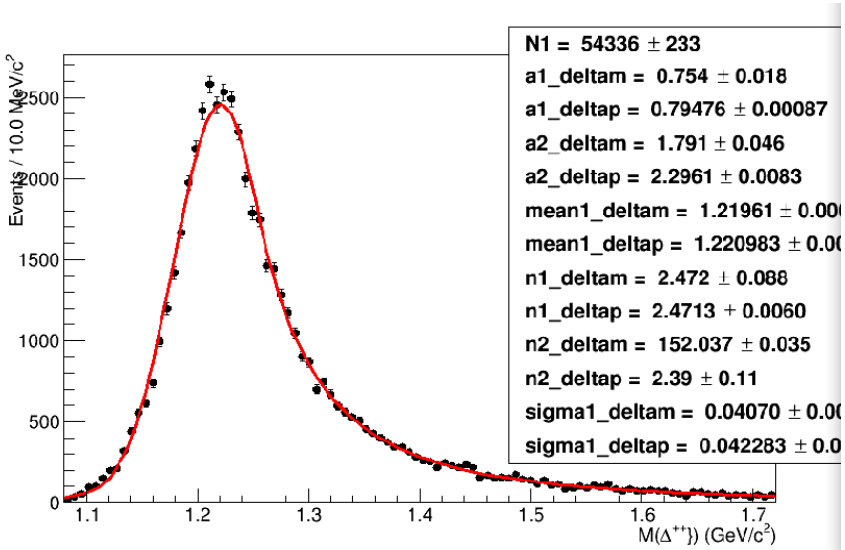


Figure: Δ^{++}

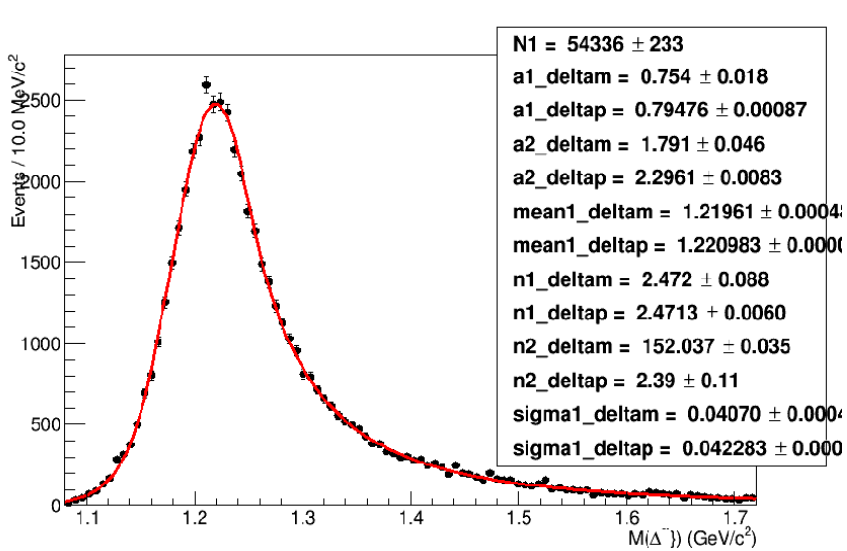


Figure: Δ^{--}

- Asymmetric width due to phase space variation over resonance.

Background Analysis

After all cuts, by doing the topology, we find out the backgrounds.

No.	Decay Chain	Final States	Event Number
0	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\pi^-\bar{p}$	$\bar{p}\pi^- ce^-\pi^+ p$	27086
1	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\Delta^{--}, \Delta^{++} \to p\pi^+, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\pi^+ p$	14650
2	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	7971
3	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\pi^-\bar{p}, \Delta^{++} \to p\pi^+$	$\bar{p}\pi^- ce^-\pi^+ p$	6821
4	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\Delta^{--}, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\pi^+ p$	6652
5	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\Delta^{--}, \Delta^{++} \to p\pi^+, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	4335
6	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\rho^0\bar{p}, \rho^0 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\pi^+ p$	2131
7	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\pi^-\bar{p}, \Delta^{++} \to p\pi^+$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	1952
8	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\Delta^{--}, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	1936
9	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to pf_2\bar{p}, f_2 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\pi^+ p$	1735
10	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	1142
11	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\Delta^{--}, \Delta^{++} \to p\pi^+, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	636
12	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\rho^0\bar{p}, \rho^0 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	632
13	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to pf_2\bar{p}, f_2 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	516
14	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\Delta^{--}, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	292
15	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\pi^-\bar{p}, \Delta^{++} \to p\pi^+$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	284
16	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^0\pi^+\bar{p}, \Delta^0 \to p\pi^-$	$\bar{p}\pi^- ce^-\pi^+ p$	254
17	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^-\Delta^{0-}, \Delta^{0-} \to \pi^+\bar{p}$	$\bar{p}\pi^- ce^-\pi^+ p$	211
18	$0 \to Z^0 \gamma\gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\gamma\pi^+ p$	140
19	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to f_0(1370)p\bar{p}, f_0(1370) \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\pi^+ p$	123
20	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\eta'\bar{p}, \eta' \to \rho^0\gamma, \rho^0 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	94
21	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\rho^0\bar{p}, \rho^0 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	80
22	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Lambda^0\bar{\Lambda}^0, \Lambda^0 \to p\pi^-, \bar{\Lambda}^0 \to \pi^+\bar{p}$	$\bar{p}\pi^- ce^-\pi^+ p$	79
23	$0 \to Z^0 \gamma\gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^{++}\Delta^{--}, \Delta^{++} \to p\pi^+, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\gamma\pi^+ p$	73
24	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^-\Delta^{0-}, \Delta^{0-} \to \pi^+\bar{p}$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	62
25	$0 \to Z^0 \gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to pf_2\bar{p}, f_2 \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\gamma\pi^+ p$	62
26	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to \Delta^0\pi^+\bar{p}, \Delta^0 \to p\pi^-$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	62
27	$0 \to Z^0 e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\omega\bar{p}, \omega \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\pi^+ p$	51
28	$0 \to Z^0 \gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to f_0(1370)p\bar{p}, f_0(1370) \to \pi^+\pi^-$	$\bar{p}\pi^- ce^-\gamma\pi^+ p$	47
29	$0 \to Z^0 \gamma\gamma\gamma e^-, Z^0 \to c\bar{c}, \bar{c} \to cluster, cluster \to \psi(2S), \psi(2S) \to p\pi^+\Delta^{--}, \Delta^{--} \to \pi^-\bar{p}$	$\bar{p}\pi^- ce^-\gamma\gamma\gamma\pi^+ p$	35

Total number of signal is 17875,and the number of peaking backgrounds of Δ^{++} is 8043 and Δ^{--} is 7885.

Background Analysis

- Any background picked out by topological analysis except for the signal.

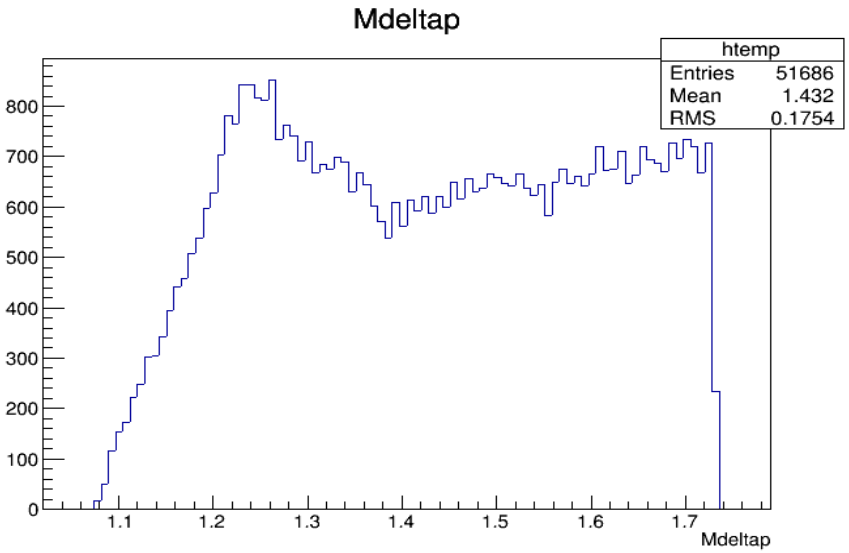


Figure: Background of Δ^{++}

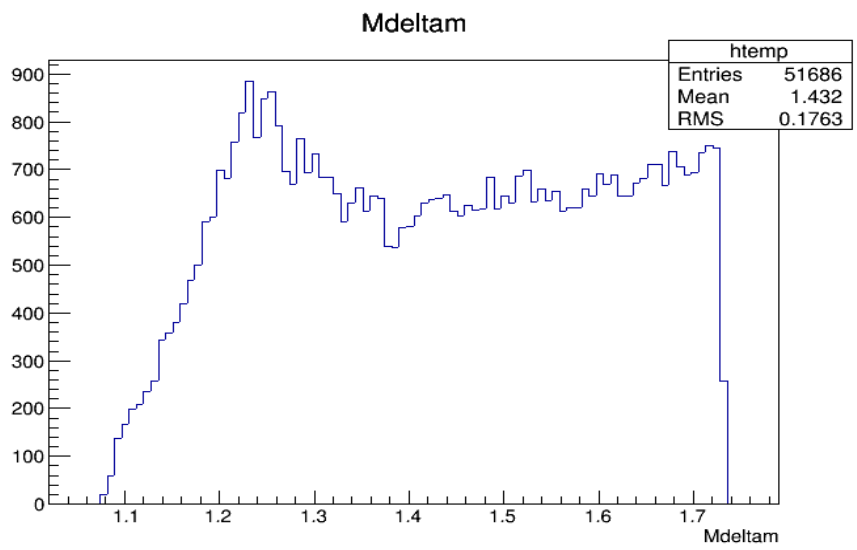


Figure: Background of Δ^{--}

Background Analysis

- In the following two pictures, each color represents a different decay chain.
  —$\psi(2s) \to P\ \overline{P}\ \pi^+\ \pi^-(36339)$ —$\psi(2s) \to P\ \overline{P}\ \rho^0(2524)$
  —$\psi(2s) \to \Delta^{++}\ \overline{P}\ \pi^-(8043)$ —$\psi(2s) \to P\ \overline{P}\ f_2\ (1793)$
  —$\psi(2s) \to \Delta^{--}\ P\ \pi^+(7885)$

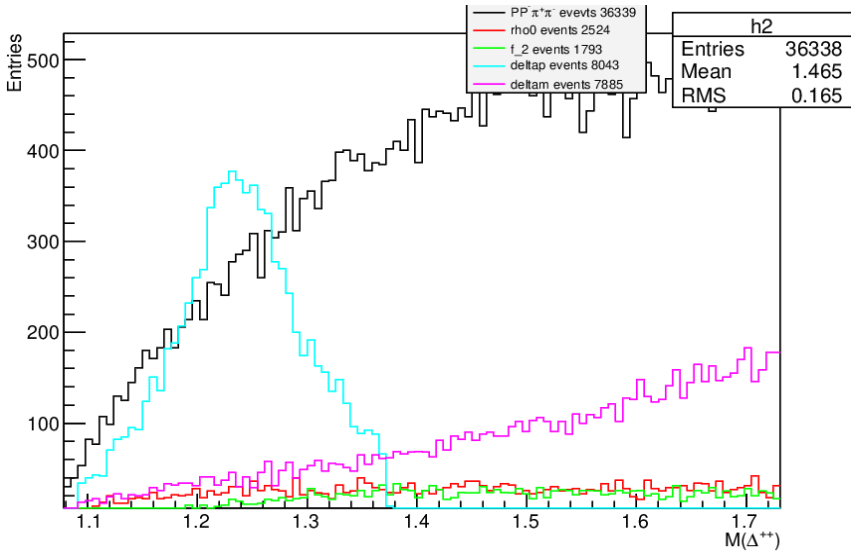


Figure: Δ^{++}

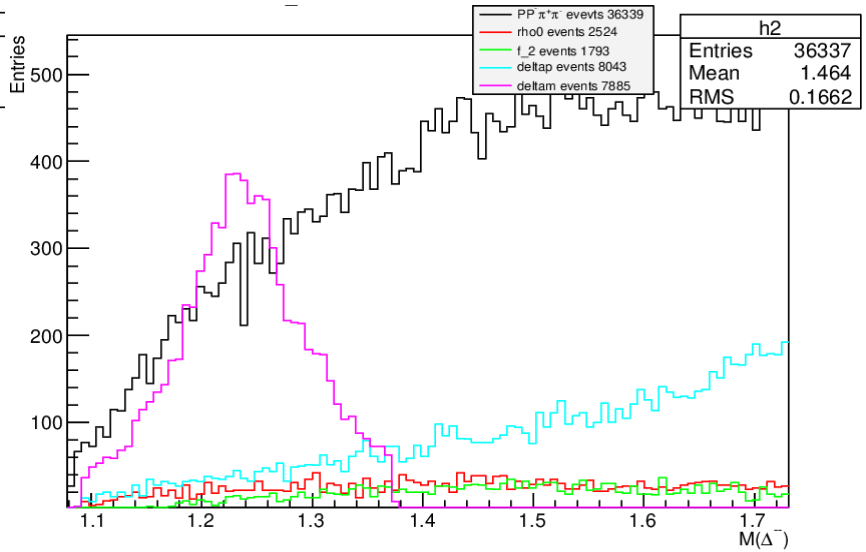


Figure: Δ^{--}

Background Analysis

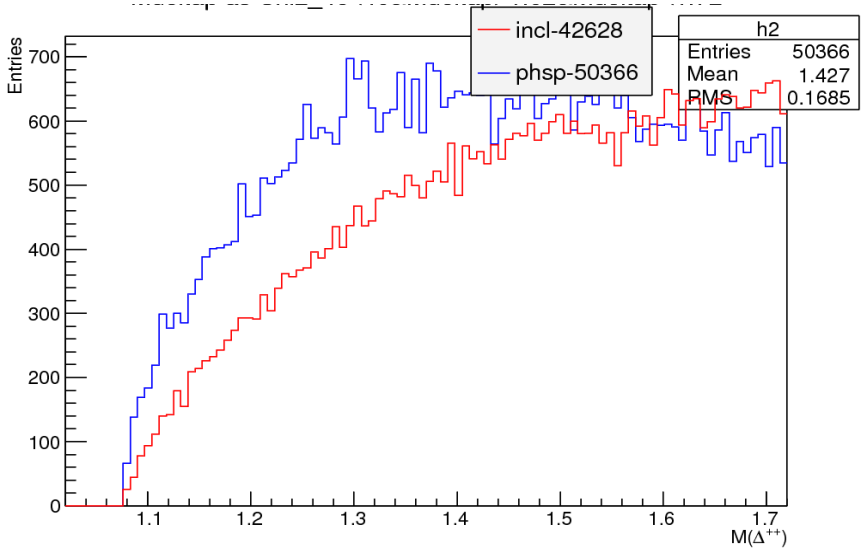


Figure: Δ^{++}

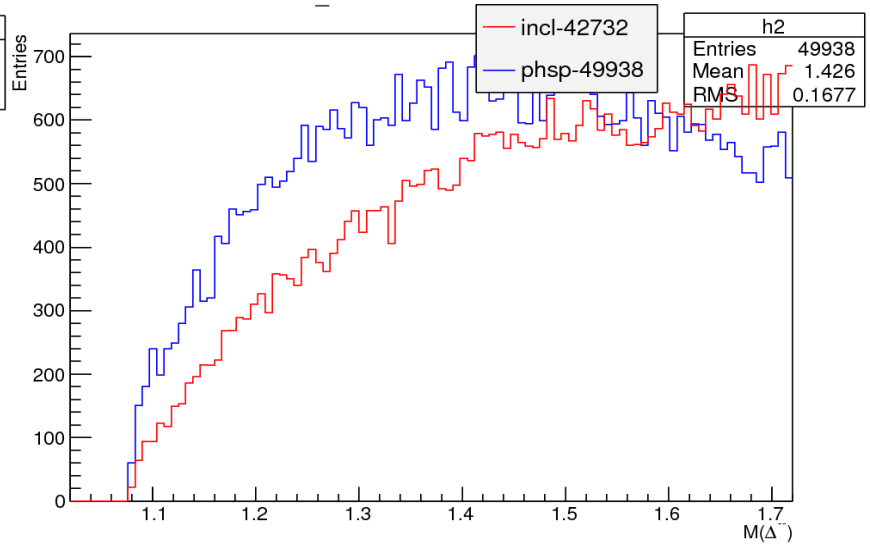


Figure: Δ^{--}

Sideband

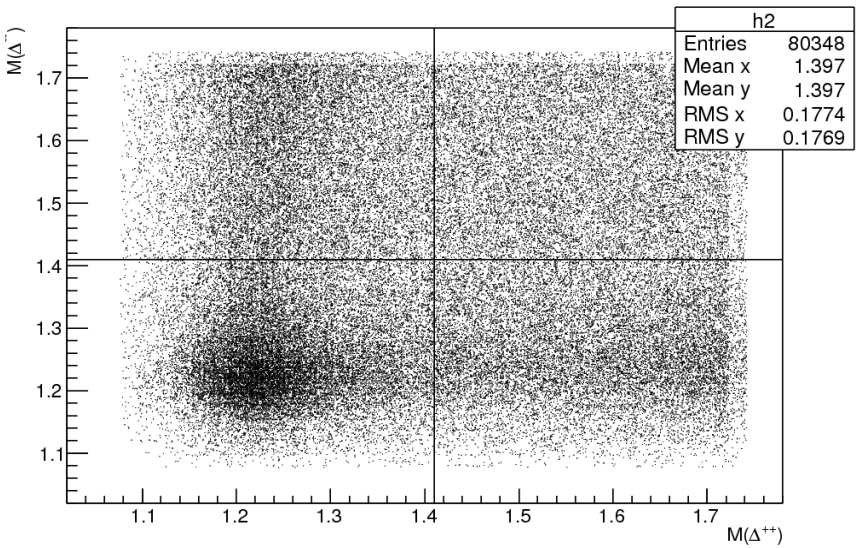


Figure: incl MC

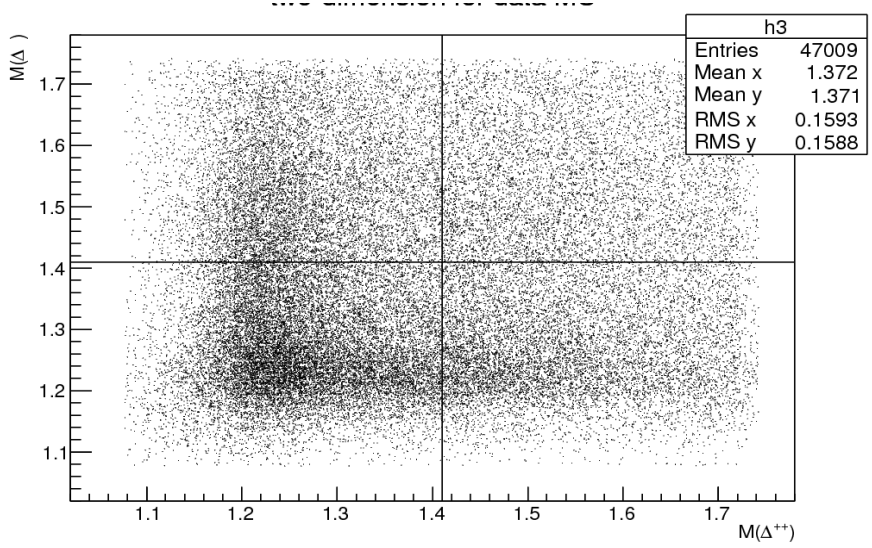


Figure: data

- $Mass_{\Delta^{++}} = Mass_{\Delta^{--}} = 1.232$Gev Width $= 0.112$Gev
- Line of incl: Horizontal (1.41, 1.02, 1.41, 1.78) Ordinate(1.02,1.41 ,1.78 ,1.41)
- Line of data: Horizontal (1.41,1.02, 1.41, 1.78) Ordinate (1.02,1.41 ,1.78 ,1.41)

Sideband-upper-right

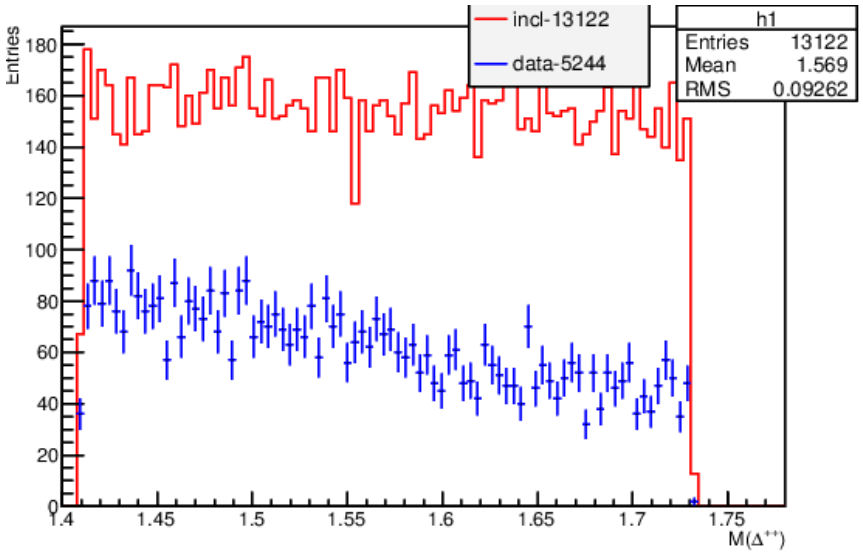


Figure: $M(\Delta^{++})$

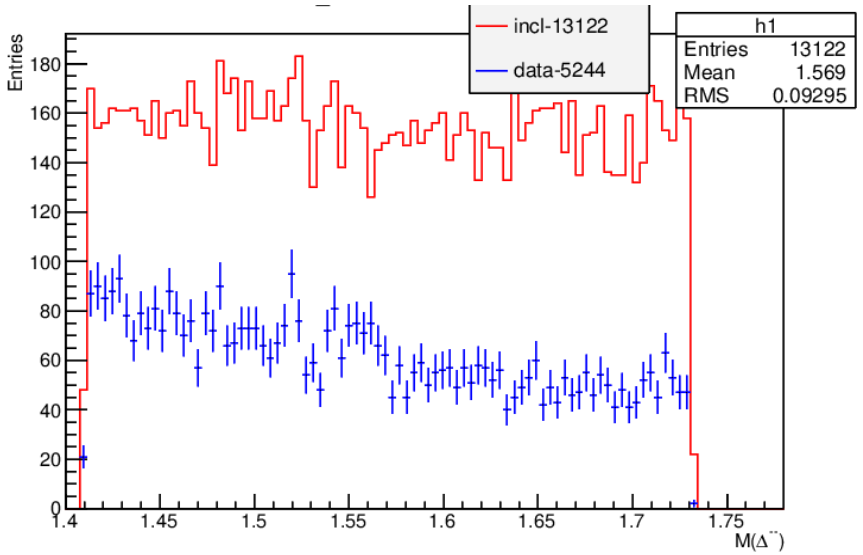
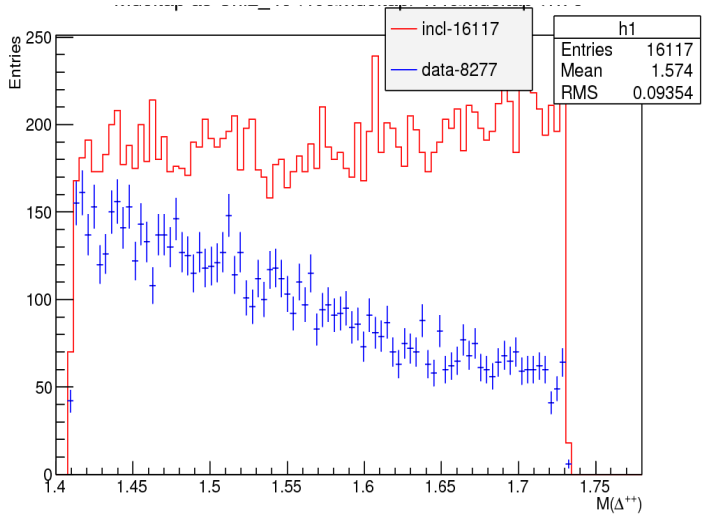
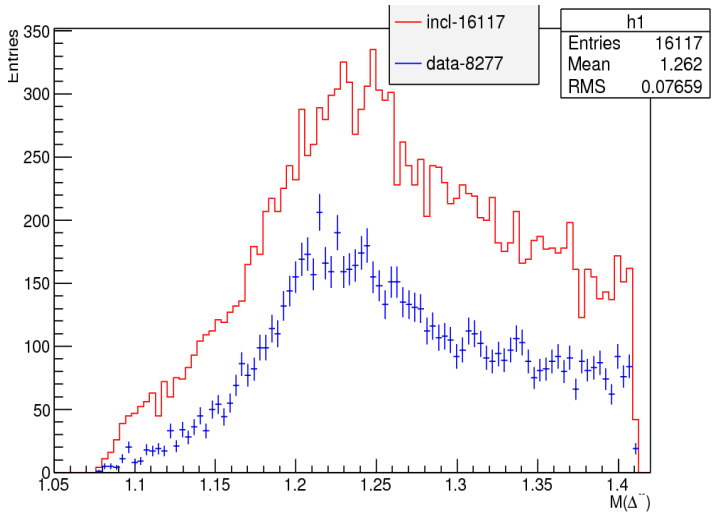


Figure: $M(\Delta^{--})$

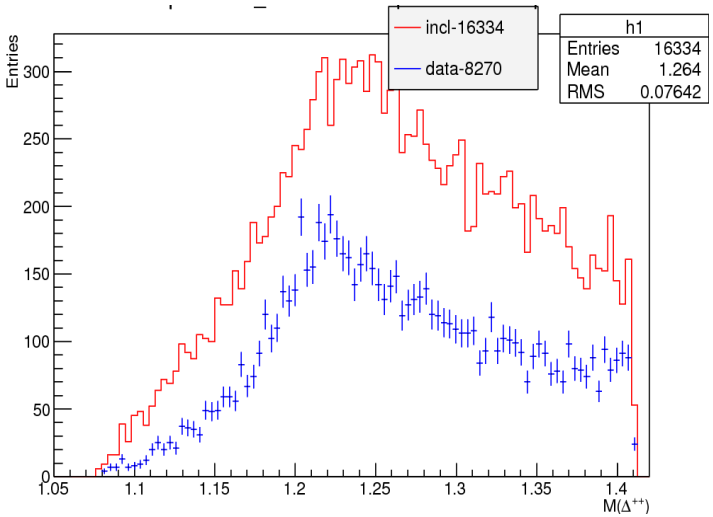
Sideband of lower-right and upper-left



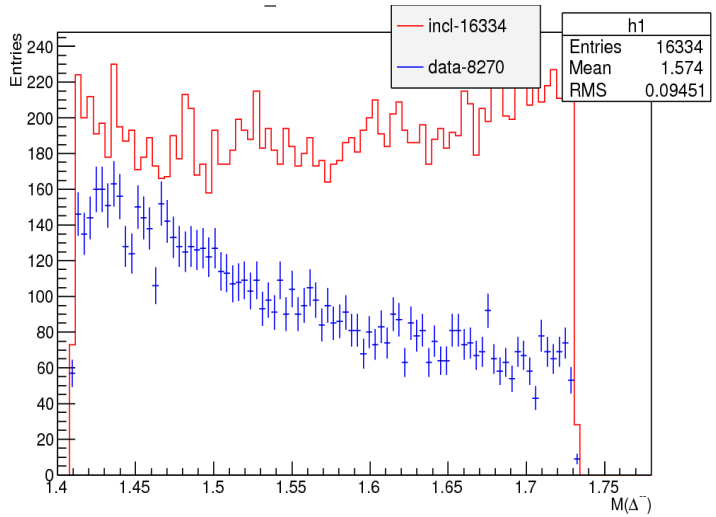
(a) $M(\Delta^{++})$



(b) $M(\Delta^{--})$



(c) $M(\Delta^{++})$



(d) $M(\Delta^{--})$

- Simultaneously Fit for Δ^{++} / Δ^{--}:
  Signal PDF: signal MC;
  Background PDF: 3rd order Chebyshev Polynomial;

- Fit model: $sig(\Delta^{++}) \times sig(\Delta^{--}) + sig(\Delta^{++}) \times bkg(\Delta^{--}) + bkg(\Delta^{++}) \times sig(\Delta^{--}) + bkg(\Delta^{++}) \times bkg(\Delta^{--})$.

Simultaneously Fit for $M(\Delta^{++})$ $M(\Delta^{--})$

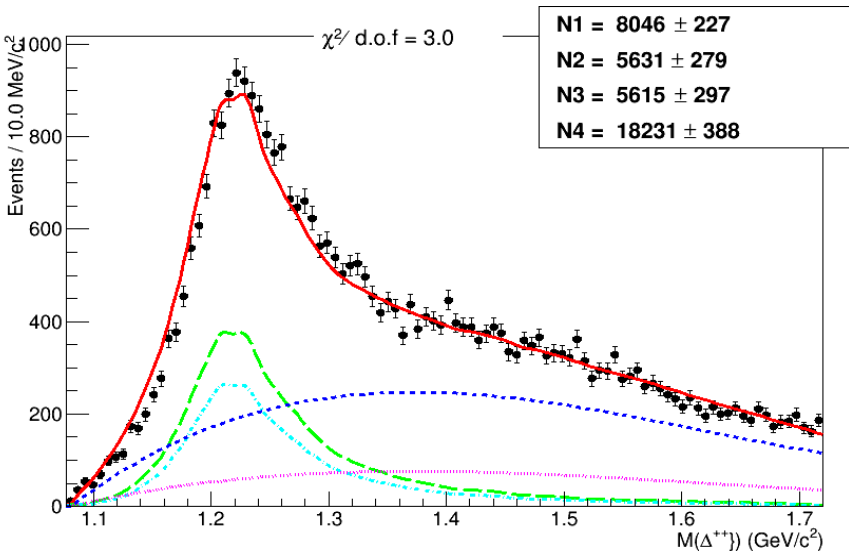


Figure: $M(\Delta^{++})$

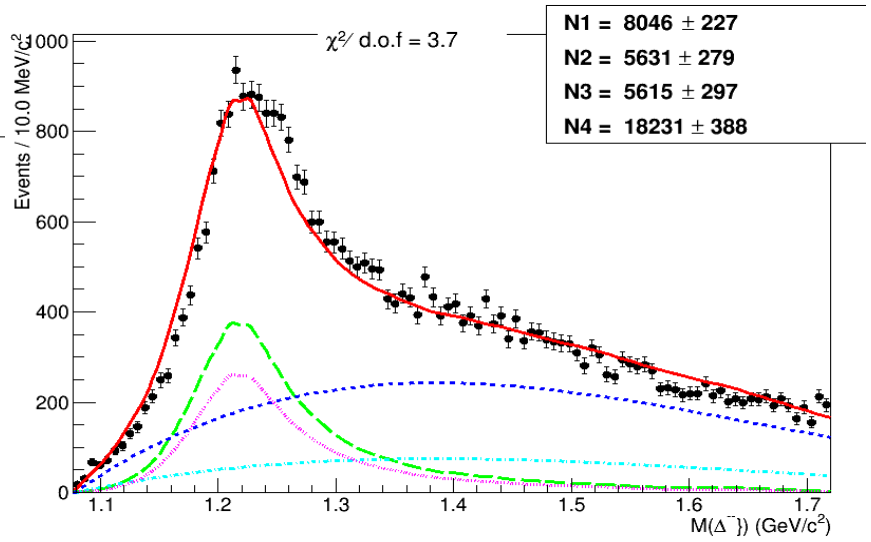


Figure: $M(\Delta^{--})$

- - - $sig_{\Delta^{++}} \times sig_{\Delta^{--}}$ - - - $sig_{\Delta^{++}} \times bkg_{\Delta^{--}}$

- - - $bkg_{\Delta^{++}} \times sig_{\Delta^{--}}$ - - - $bkg_{\Delta^{++}} \times bkg_{\Delta^{--}}$

Question

- How should I describle the background in data ?

THANK YOU