Cross section Measurements of $e^+e^- \to D^{*+}D^{*-}$ at BESIII

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Outline

- Motivation
- Analysis strategy
- Data sets
- Event selection
- Background analysis
- 2-D fit method
- Cross section measurement
- Summary

1.Motivation

- 1. Vector states above open-charm threshold are not fully understood. Vector charmonium-like， $Y(4260)$, $Y(4360)$， only observed in hidden charm channel， different with conventional charmonium. The coupling with open-charm channels is key to understand all the charmonium.
- 2.Belle measured the cross section of $e^+e^- \rightarrow D^{(*)+}D^{*-}$ with ISR, but the precision is not enough.

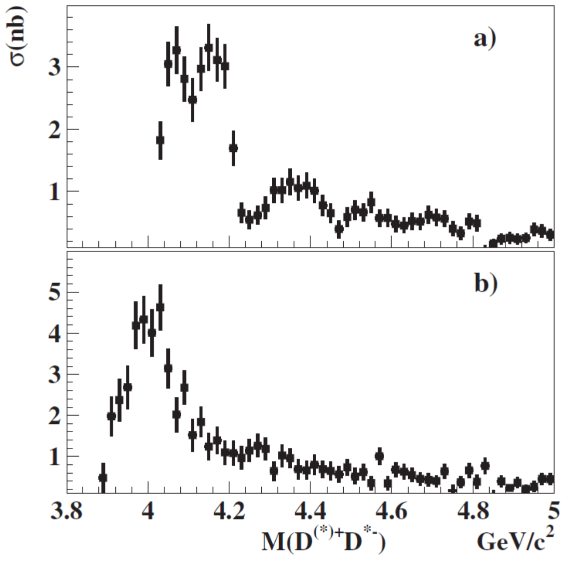
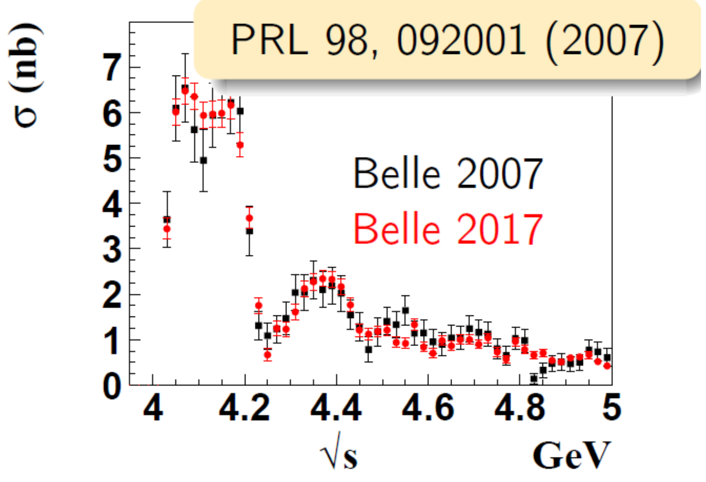
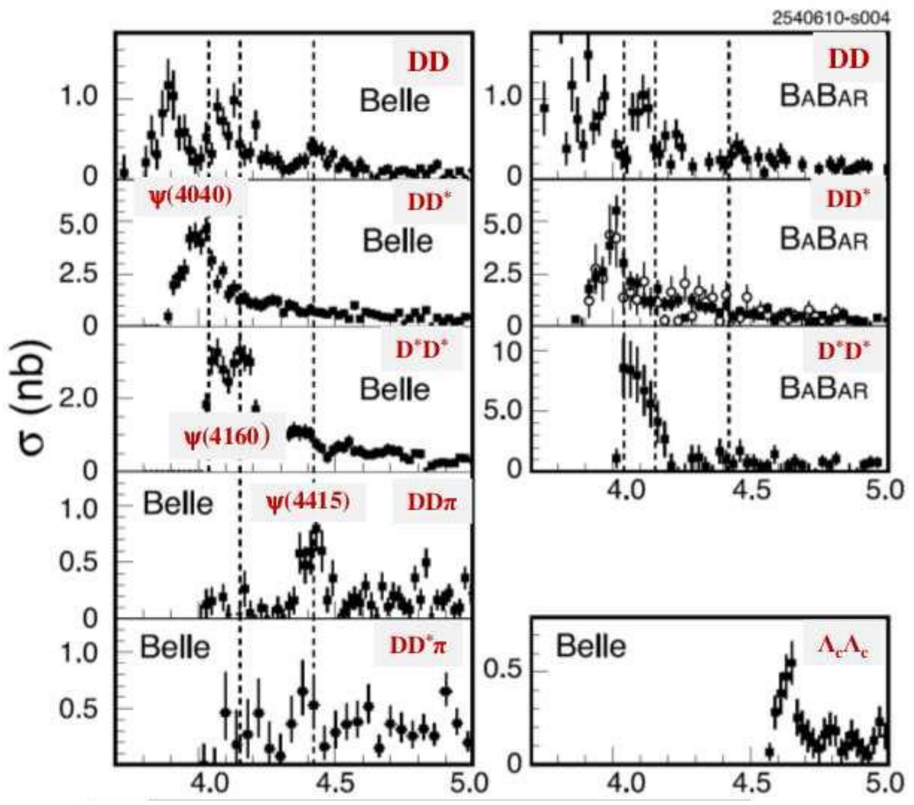


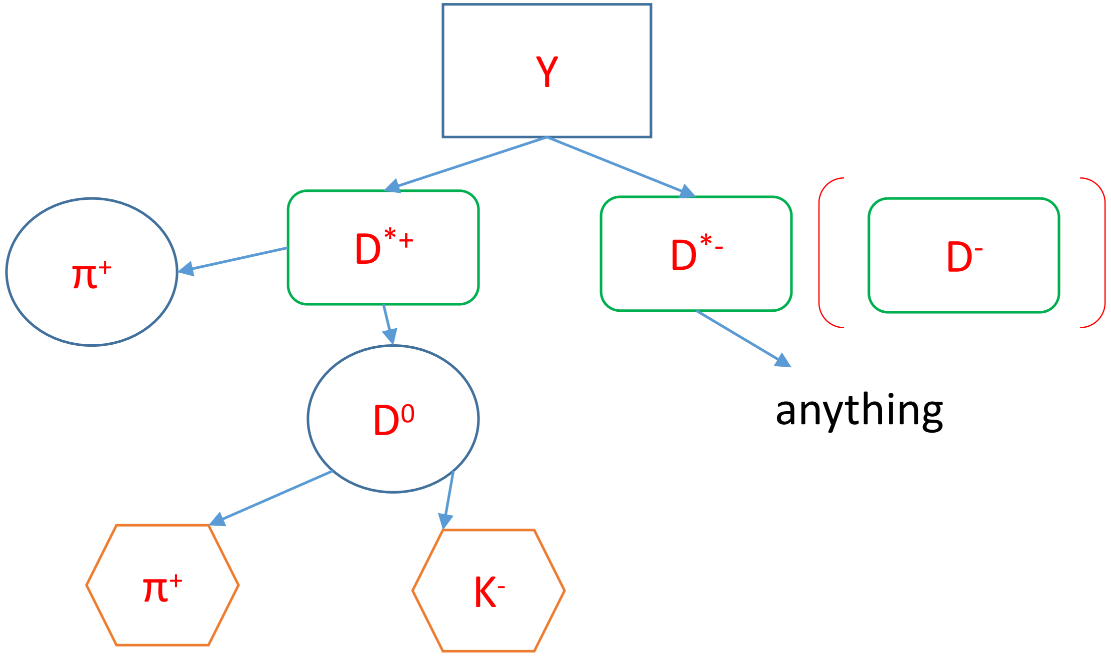
FIG. 2. The exclusive cross sections for (a) $e^+e^- \rightarrow D^{*+}D^{*-}$ and (b) $e^+e^- \rightarrow D^+D^{*-}$.





2. Analysis strategy

- **Only reconstruct D^{*+}**, via $D^{*+} \to \pi^+ D^0$, $D^0 \to K^- \pi^+$
- Then, the $\mathbf{D^{*-}}$ signals are searched for in the $\mathbf{D^{*+}}$ recoil mass spectra
- The mass of $(K^- \pi^+)$ is constrained to mass D^0
- Only a combination of $(\pi^+ K^- \pi^+)$ with minimum χ^2 is kept for further study.
- Using two dimensional (2D) fit to extract the number of signal events.
- (With the same method, the $\mathbf{D^-}$ signals are also searched for in the $\mathbf{D^{*+}}$ recoil mass spectra.)



3. Data sets

All the xyz data samples above 4.02 GeV.

- **MC samples are generated with ConExc (ISR is contained)**
- **each MC sample contains 200,000 events**

  - BOSS version: 703 && 704

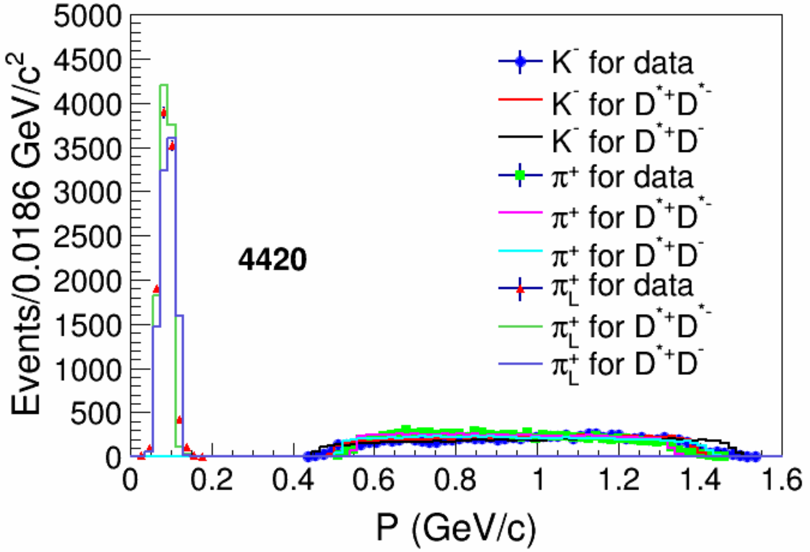
BOSS	Energy (GeV)	Luminosity (pb-1)	Energy (GeV)	Luminosity (pb-1)
703	4180	3160	4280	175.7
	4190	566.23	4360	543.9
	4200	525.2	4420	1043.9
	4210	572.15	4600	586.9
	4220	568.0	4090	52.86
	4230	1100.94	4310	45.08
	4237	530.0	4390	55.57
	4246	538.1	4470	111.09
	4260	828.4	4530	112.12
	4270	531.1	4575	48.93
704	4130	400	4340	500
	4160	400	4380	500
	4290	500	4400	500
	4315	500	4440	570

4.*Event Selection*

- *At least three good charged tracks in final states.*

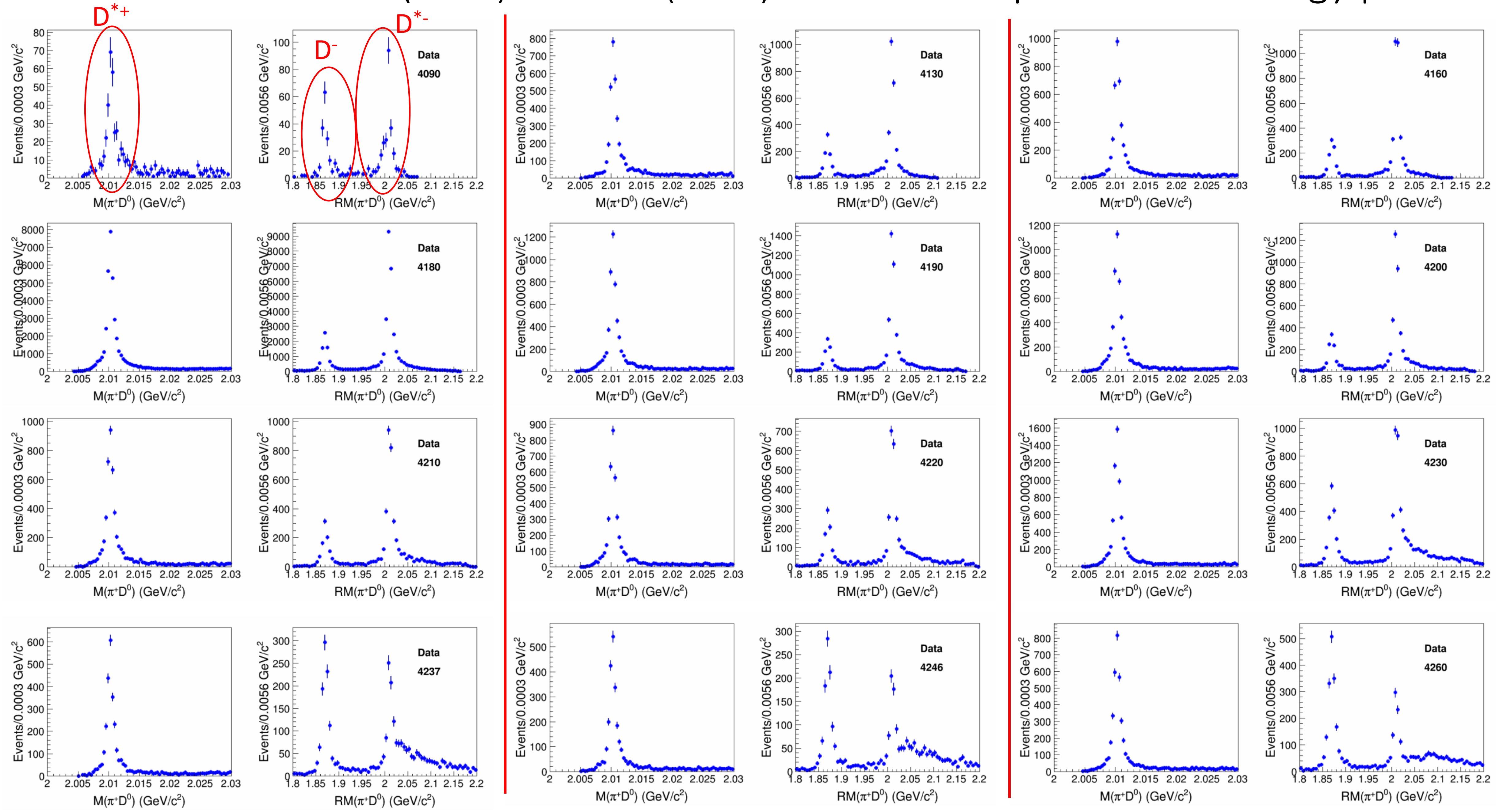
- *Charged tracks:*
- *Rxy < 1cm, |Rz |< 10cm;* $|cos\theta| < 0.93$;

- *Use momentum and PID to separate the* π_L *and* π_H
- π_L: P_{mdc}<0.3 && ($Prob_\pi$>$Prob_K$) && ($Prob_\pi > 0.001$)
- K_H: P_{mdc}>0.3 &&($Prob_K$>$Prob_\pi$)&&($Prob_K$>0.001)
- π_H: P_{mdc}>0.3 && ($Prob_\pi$>$Prob_K$) && ($Prob_\pi$>0.001)
- $N_{\pi_L} \geq 1$ $N_{\pi_H} \geq 1$ $N_{K_H} \geq 1$

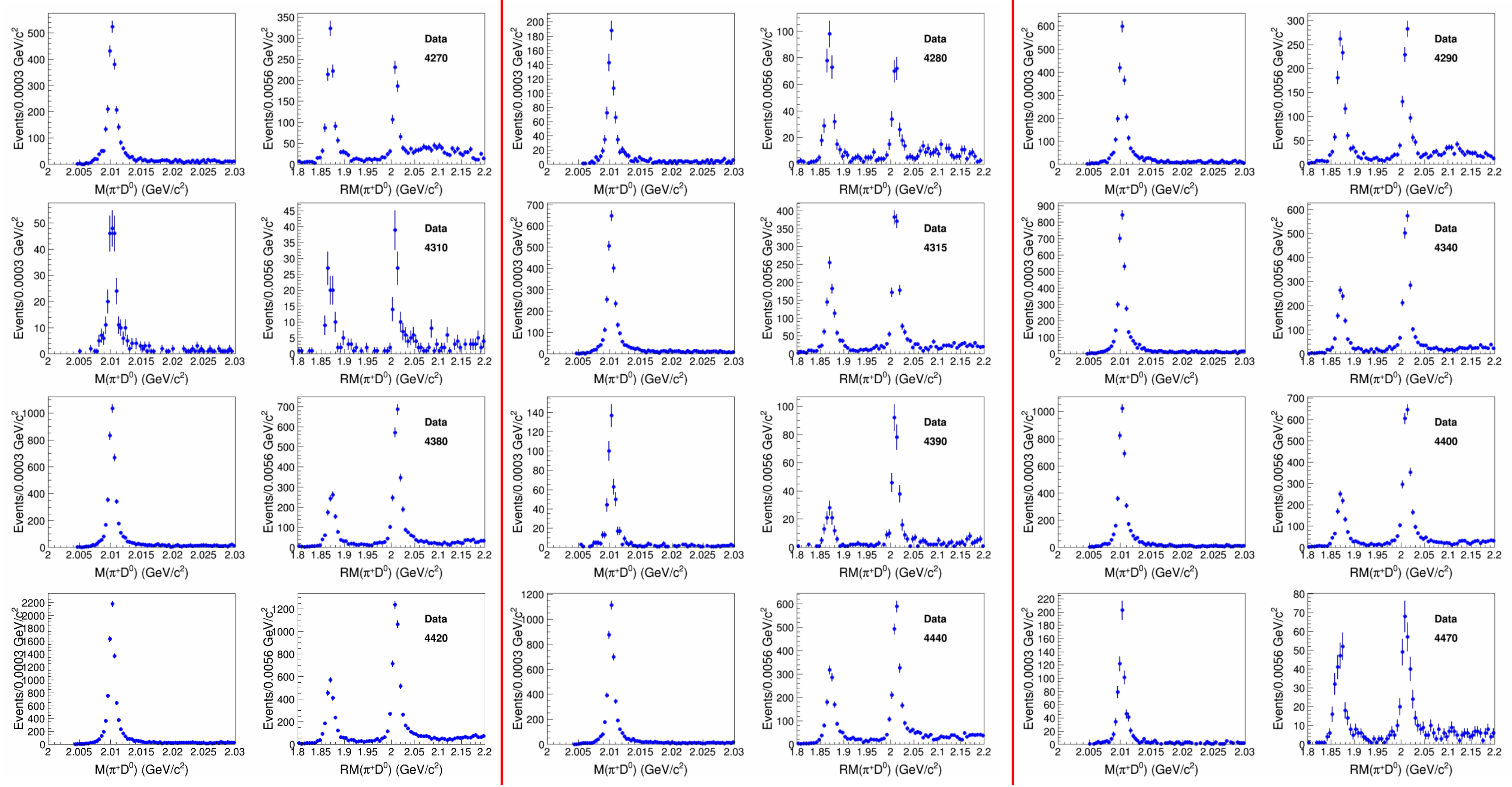


- *kinematic fit:*
- The mass of the combination of ($K^-\pi^+$) with the higher momentum is constrained to mass D^0
- Only a combination of ($\pi^+K^-\pi^+$) with minimum χ^2 is kept for further study

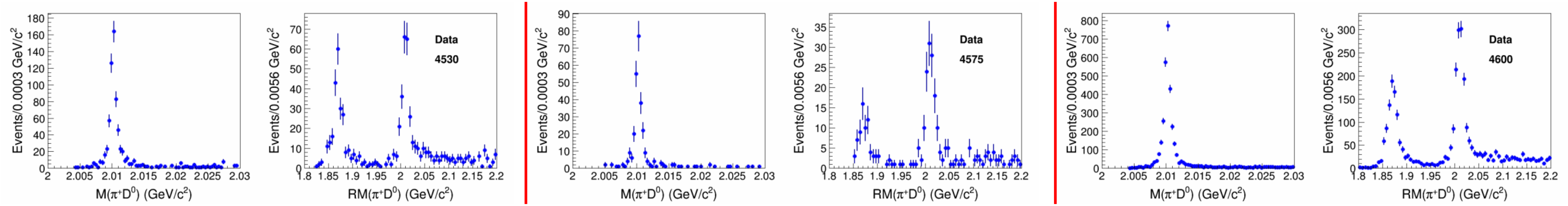
2-D distribution of $M(\pi^+D^0)$ and $RM(\pi^+D^0)$ for data sample at each energy point



2-D distribution of $M(\pi^+D^0)$ and $RM(\pi^+D^0)$ for data sample at each energy point

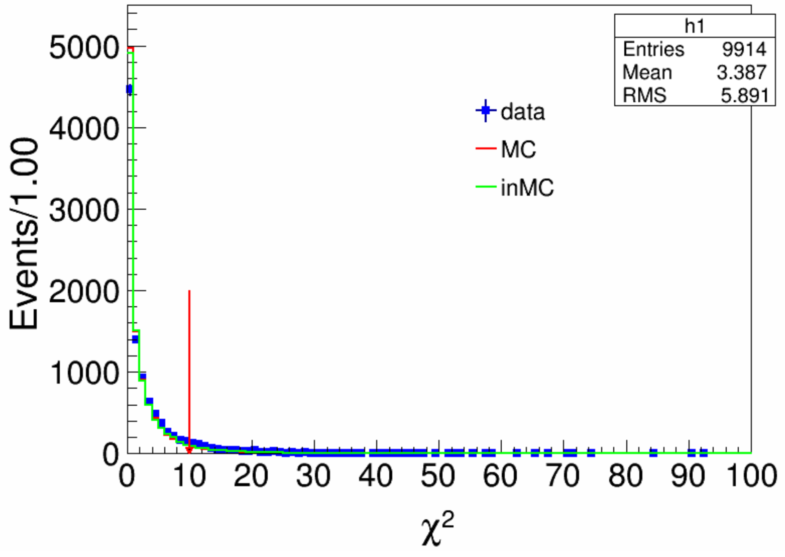


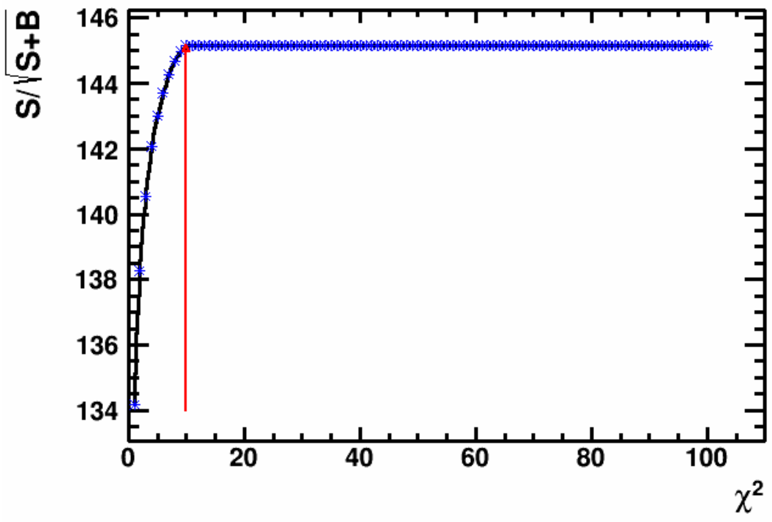
2-D distribution of M(π^+D^0) and RM(π^+D^0) for data sample at each energy point

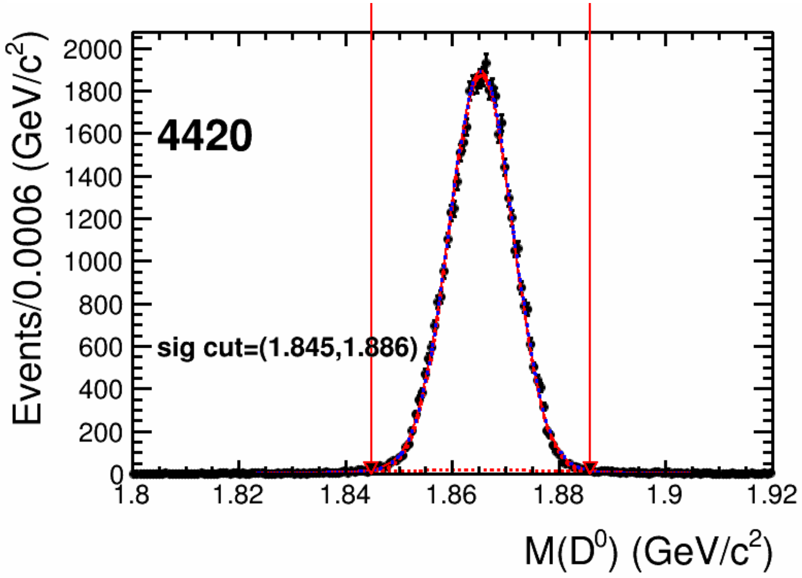


Further events selection

- χ^2 distribution and D^0 mass distribution

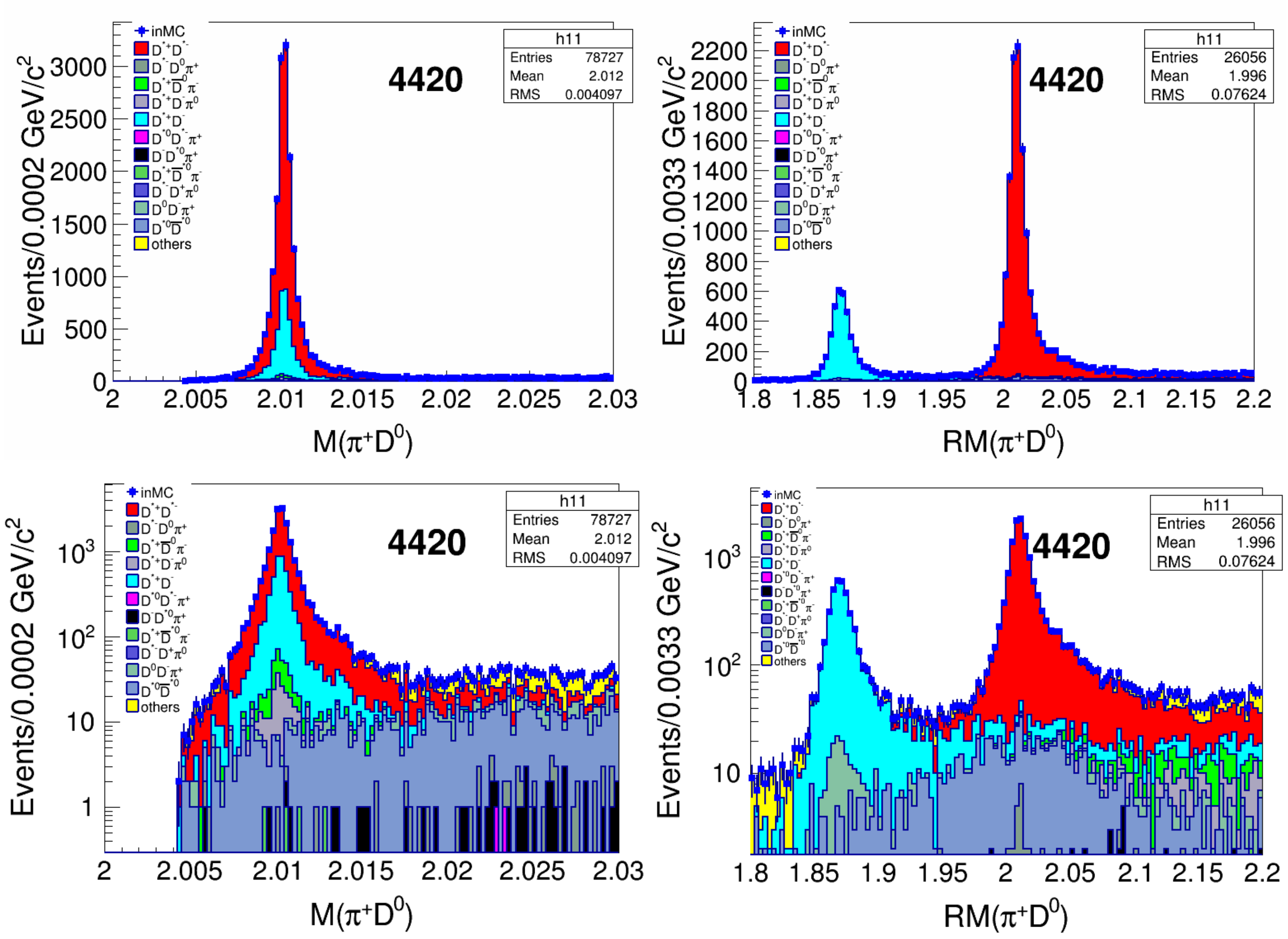






Use Double-Gaussion function to obtain the signal region of M(D^0)

5.Background analysis



The $\pi^{+}D^{0}$ mass and recoil mass distribution of different MC samples from inclusive MC sample at 4.42 GeV.

Background processes which have the decay channel $D^{*+} \rightarrow \pi^{+}D^{0}$ or $D^{0} \rightarrow K^{-}\pi^{+}$

- The signal processes:
- $e^+e^- \to D^{*+}D^{*-},\ D^{*+} \to \pi^+D^0,\ D^0 \to K^-\pi^+$
- $e^+e^- \to D^{*+}D^{-},\ D^{*+} \to \pi^+D^0,\ D^0 \to K^-\pi^+$
- The possible background processes:
- $e^+e^- \to D^{*+}\ \bar{D}^0\pi^-,\ D^{*+} \to \pi^+D^0,\ D^0 \to K^-\pi^+$
- $e^+e^- \to D^{*-}\ D^0\pi^+,\ \ D^0 \to K^-\pi^+$

conjugated

- $e^+e^- \to D^{*+}\ D^-\pi^0,\ D^{*+} \to \pi^+D^0,\ D^0 \to K^-\pi^+$
- ($e^+e^- \to D^{*-}\ D^+\pi^0$, efficiency ~0.001% , neglect)

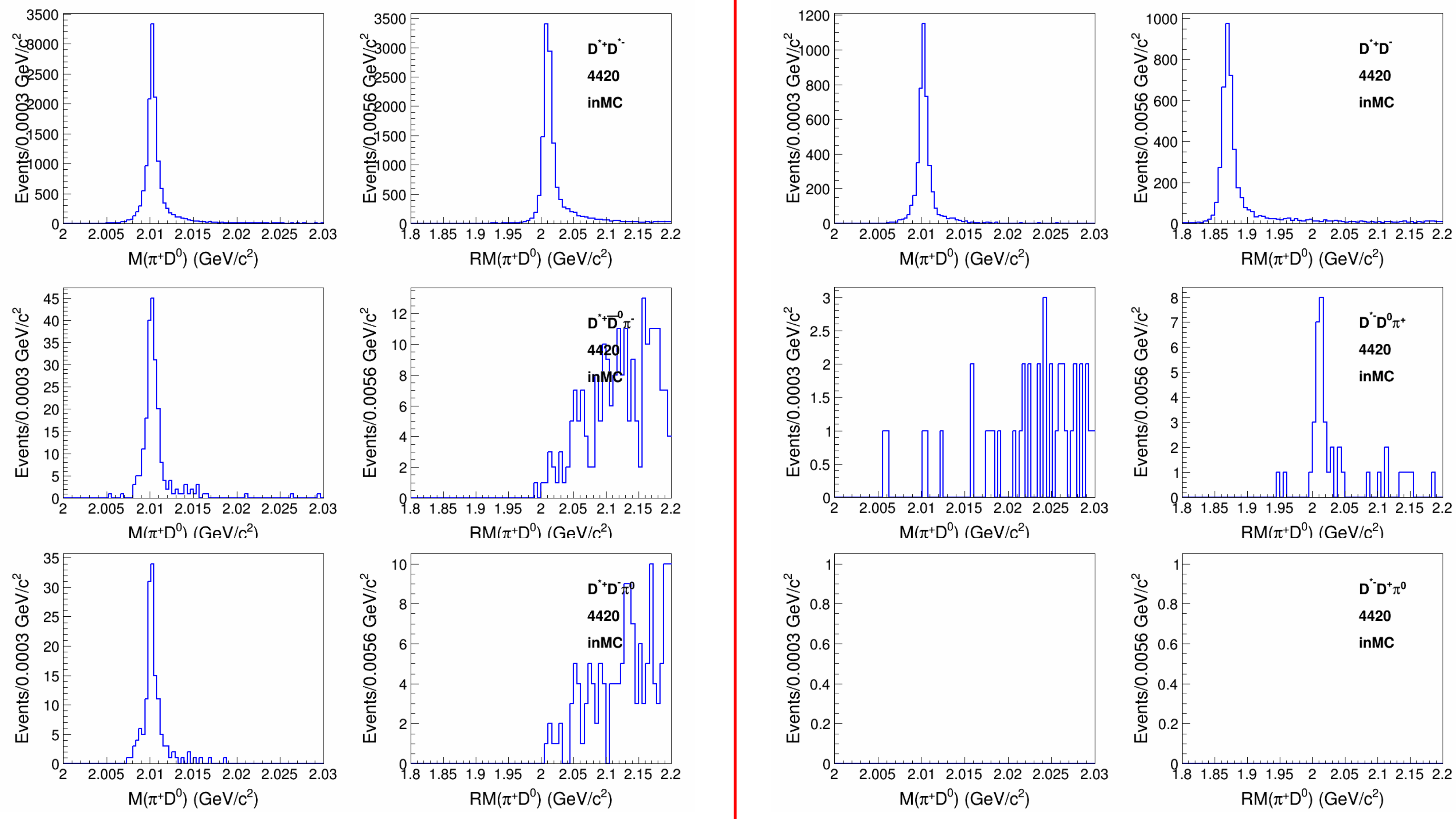
conjugated

- $e^+e^- \to D^{*+}\bar{D}^{*0}\pi^-,\ D^{*+} \to \pi^+D^0,\ D^0 \to K^-\pi^+$
- $e^+e^- \to D^{*-}\ D^{*0}\pi^+, D^{*0} \to\ D^0\pi^0,\ D^0 \to K^-\pi^+$ (smooth)

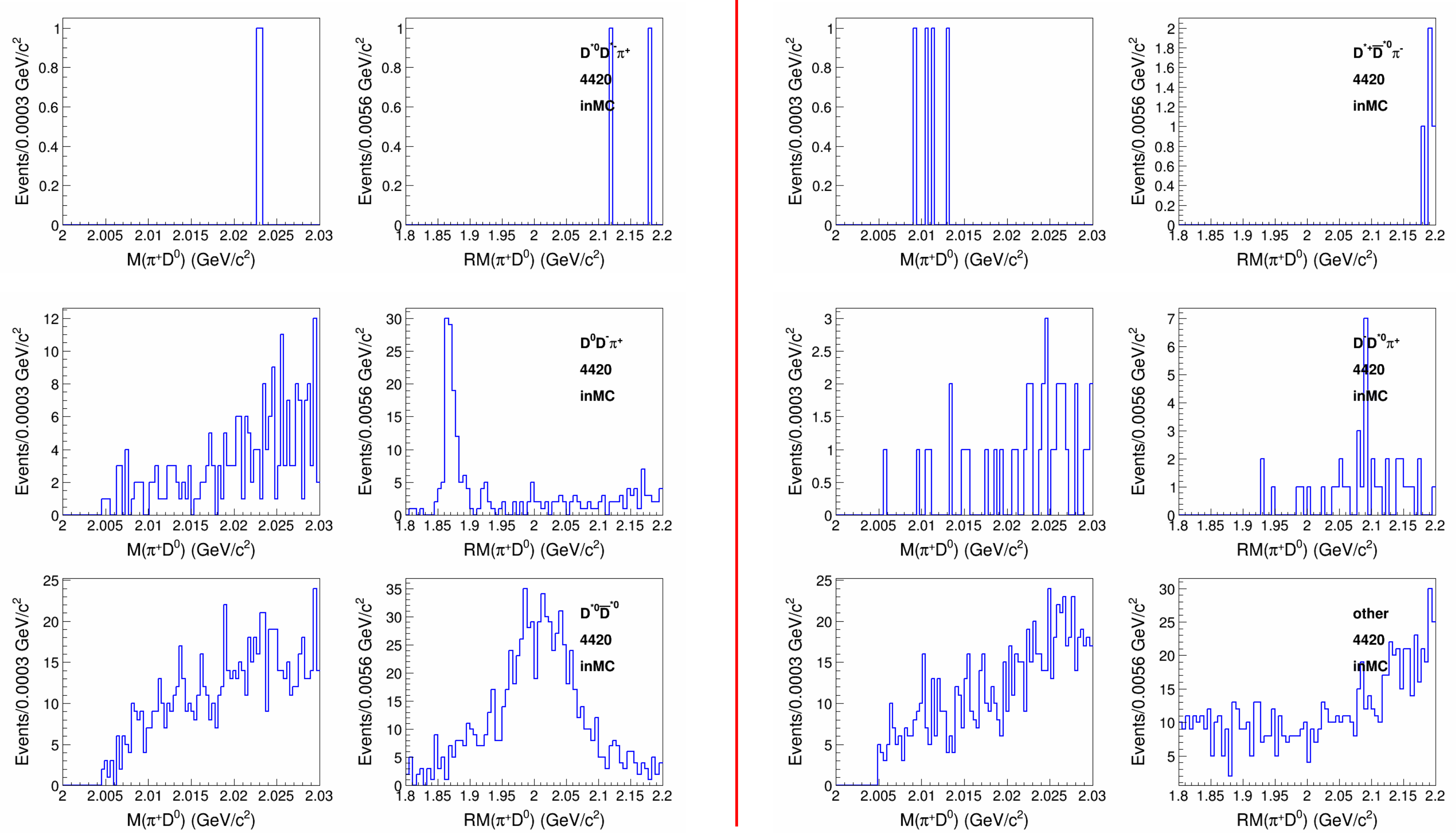
conjugated

- $e^+e^- \to D^{*0}\bar{D}^{*0}$
- $e^+e^- \to D^-\ D^0\pi^+,\ D^0 \to K^-\pi^+$
- $e^+e^- \to D^-\ D^{*0}\pi^+, D^{*0} \to D^0\pi^0, D^0 \to K^-\pi^+$ (smooth)

Background analysis for inclusive MC sample at 4.42 GeV



Background analysis for inclusive MC sample at 4.42 GeV



6. 2-D fit method

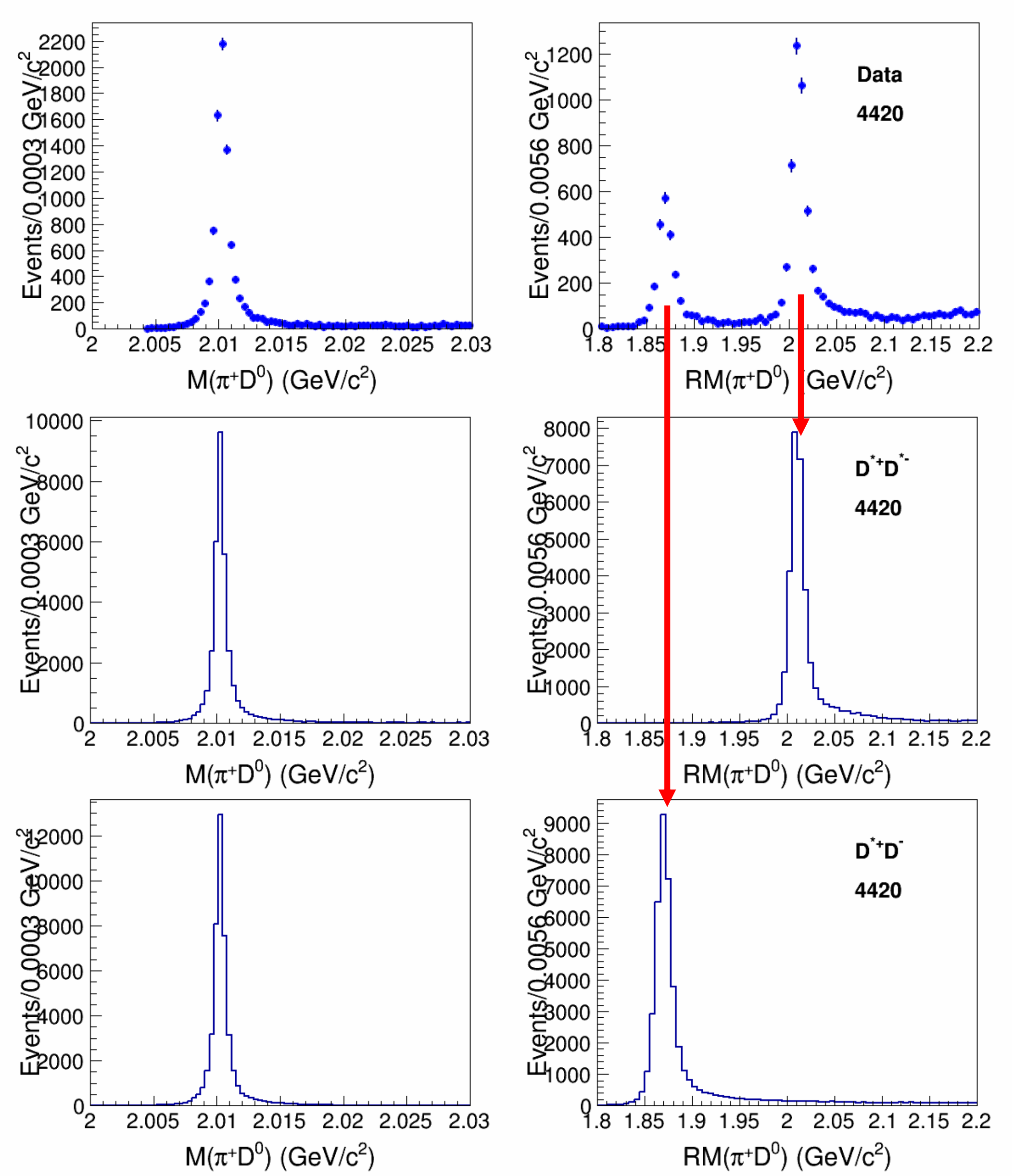
Use the 2-d MC distribution and Argus × Chebyshev functions to fit the M(D^{*+}) and RM(D^{*+}) 2-d mass spectra.

Signal components: $D^{*+} D^{-} + D^{*+} D^{*-}$

Peaking background components: $D^{*+}\bar{D}^{0}\pi^{-} + D^{*-}D^{0}\pi^{+} + D^{*+} D^{-} \pi^{0} + D^{-}D^{0}\pi^{+} + D^{*0}\bar{D}^{*0}$

Smooth background components: use Argus function to fit M(D^{*+}) and use Chebyshev function to fit RM(D^{*+}), then, generate 2-D PDF with Argus × Chebyshev .

6. 2-D fit method

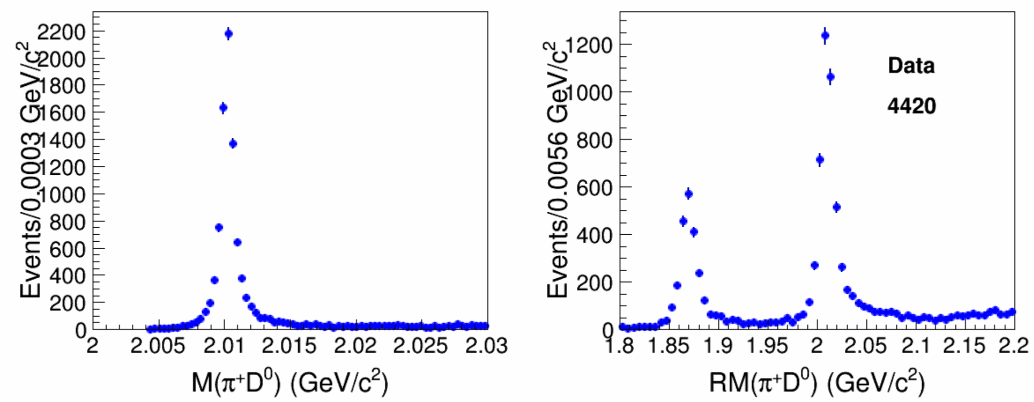


Data sample at 4.42 GeV

Signal component 1

Signal component 2

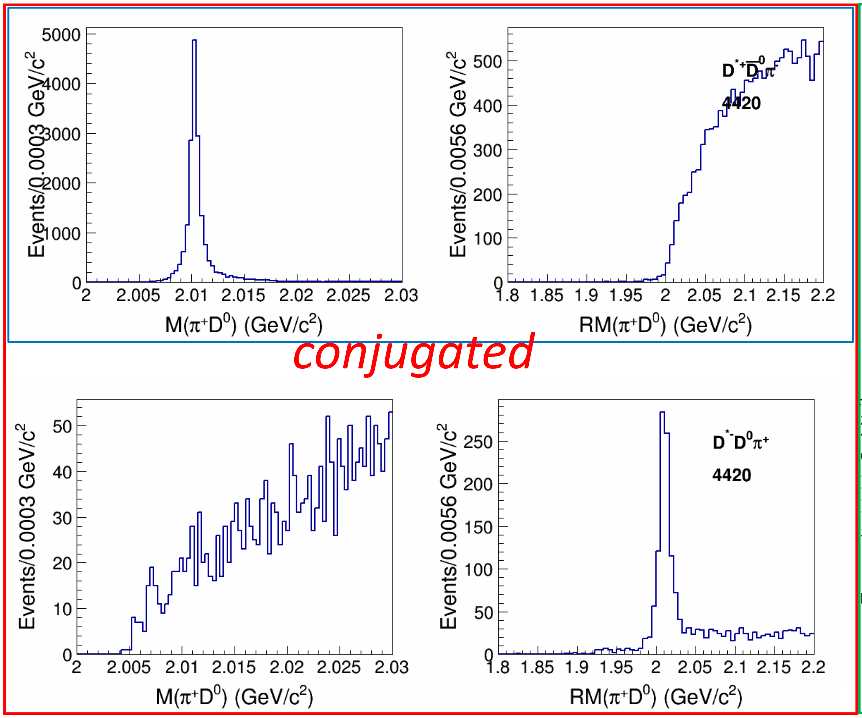
6. 2-D fit method

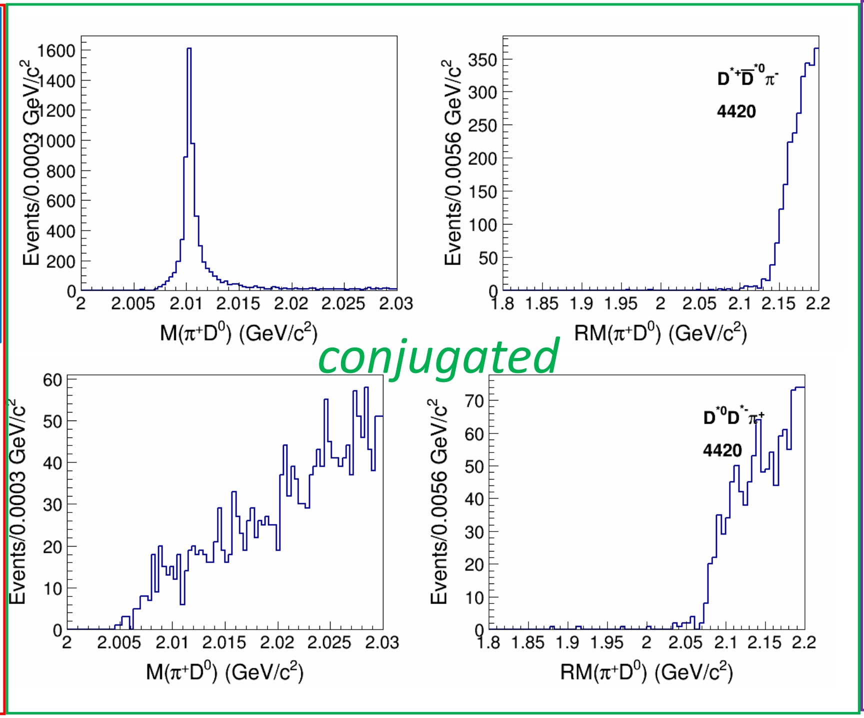


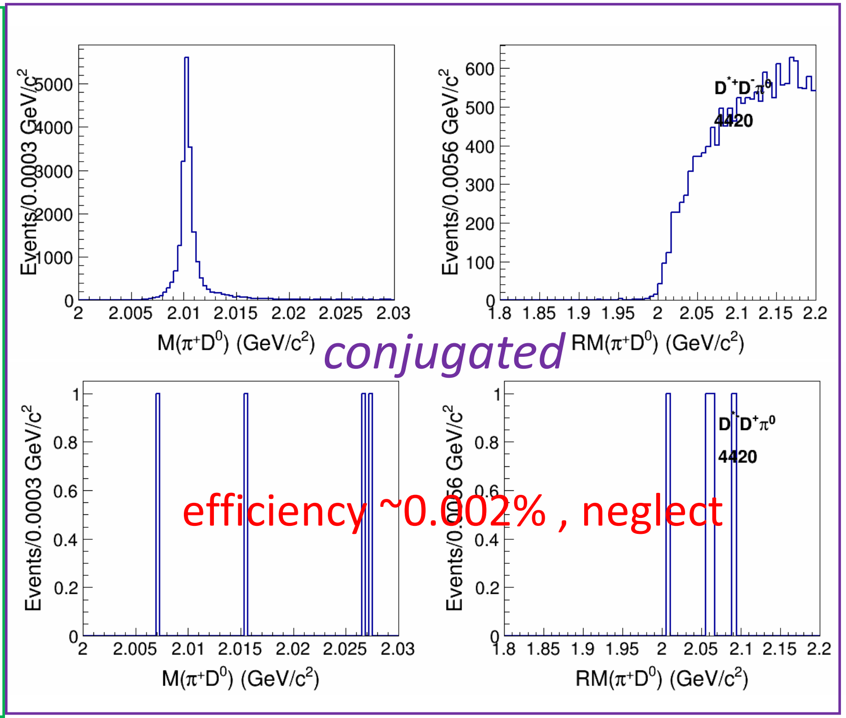
background component 1

background component 2

background component 3





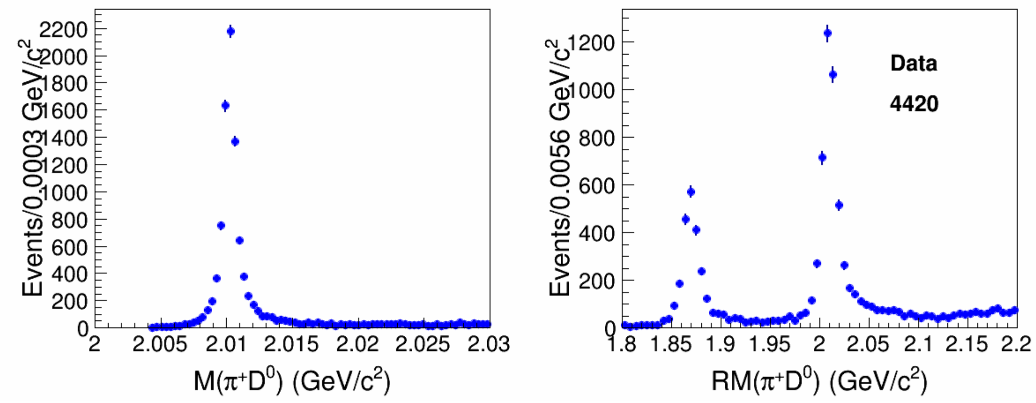


$D^{*+}\,\overline{D}^0\pi^-$
$D^{*-}\,D^0\pi^+$

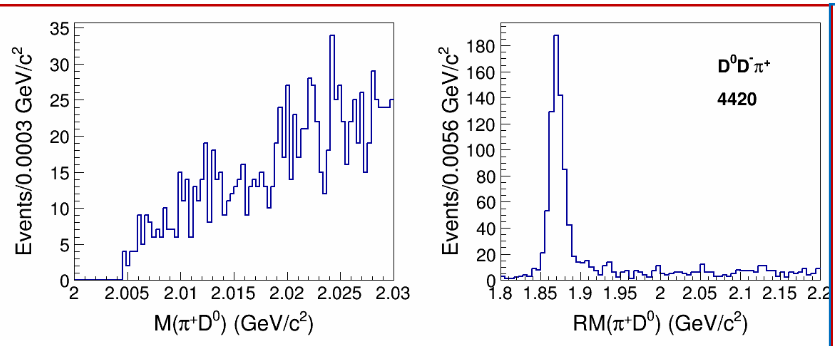
$D^{*+}\overline{D}^{*0}\pi^-$
$D^{*-}\,D^{*0}\pi^+$

$D^{*+}\,D^-\pi^0$
$D^{*-}\,D^+\pi^0$

6. 2-D fit method

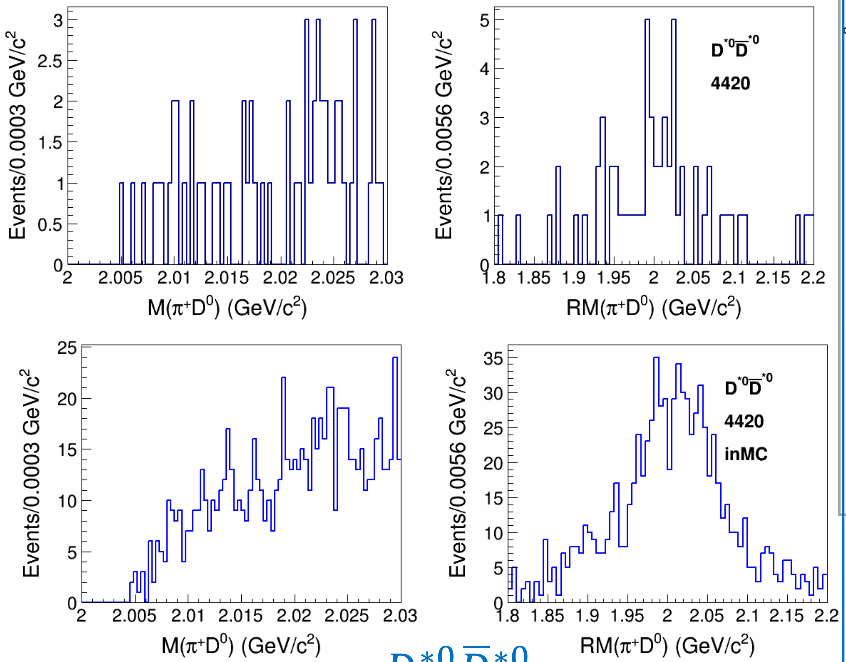


background component 4



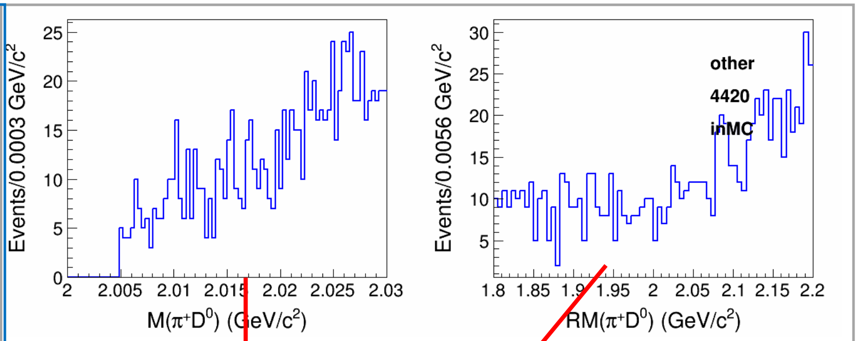
$D^- \, D^0\pi^+$

background component 5



$D^{*0}\overline{D}^{*0}$

background component 6

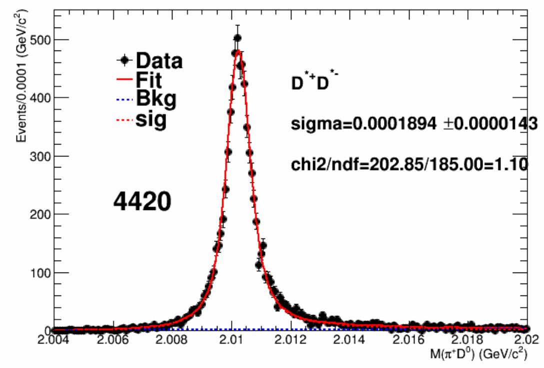


Argus × Chebyshev functions

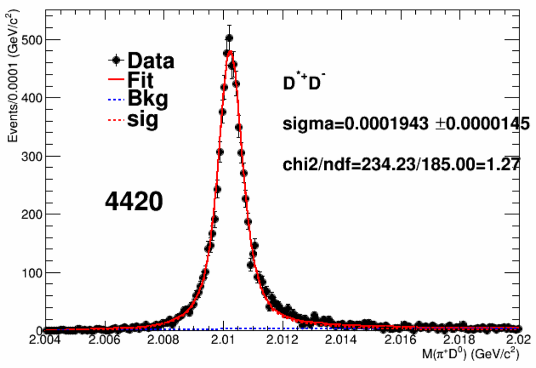
2D fit for XYZ data samples

1. Use 1-D MC distribution of M($\pi^+ D^0$) convoluted with Gaussion function to fit the 1-D mass distribution of ($\pi^+ D^0$) to get the sigma of Gaussion function(only the signal components).
The sigma of Gaussion function describes the distribution difference between MC and Data.
2. MC correction: for each event of MC sample, generate a set of random numbers following Gaussion distribution(mean=0).
3. Use the 2-D mass distribution (after MC correction) to generate a PDF to fit the 2-D mass distribution of data sample.

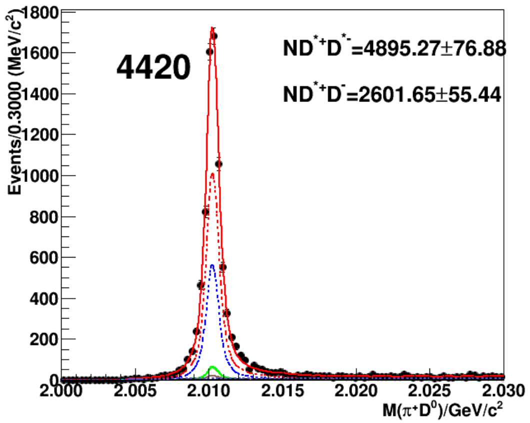
$D^{*+}D^{*-}$ MC correction

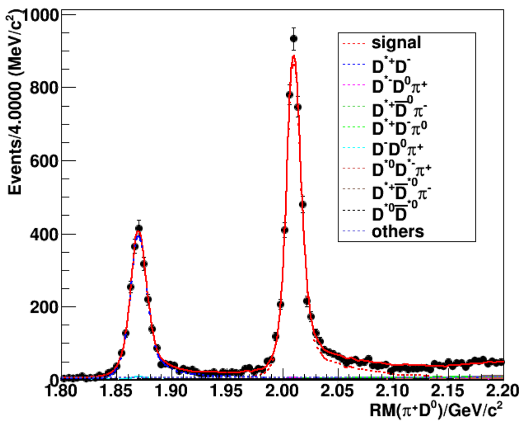


$D^{*+}D^{-}$ MC correction

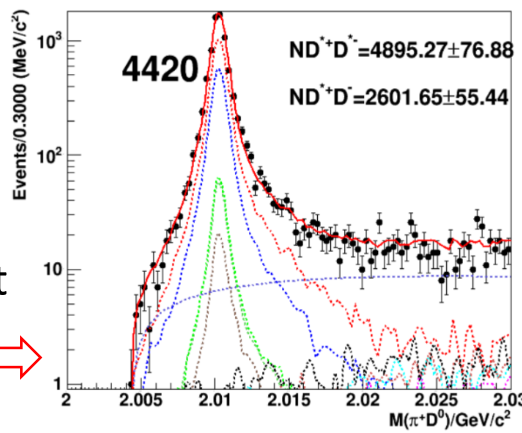


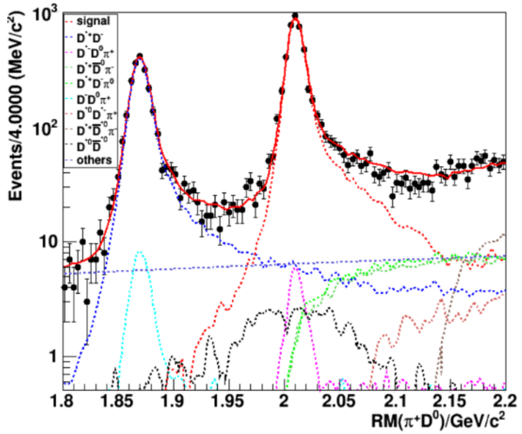
2D fit





Log plot

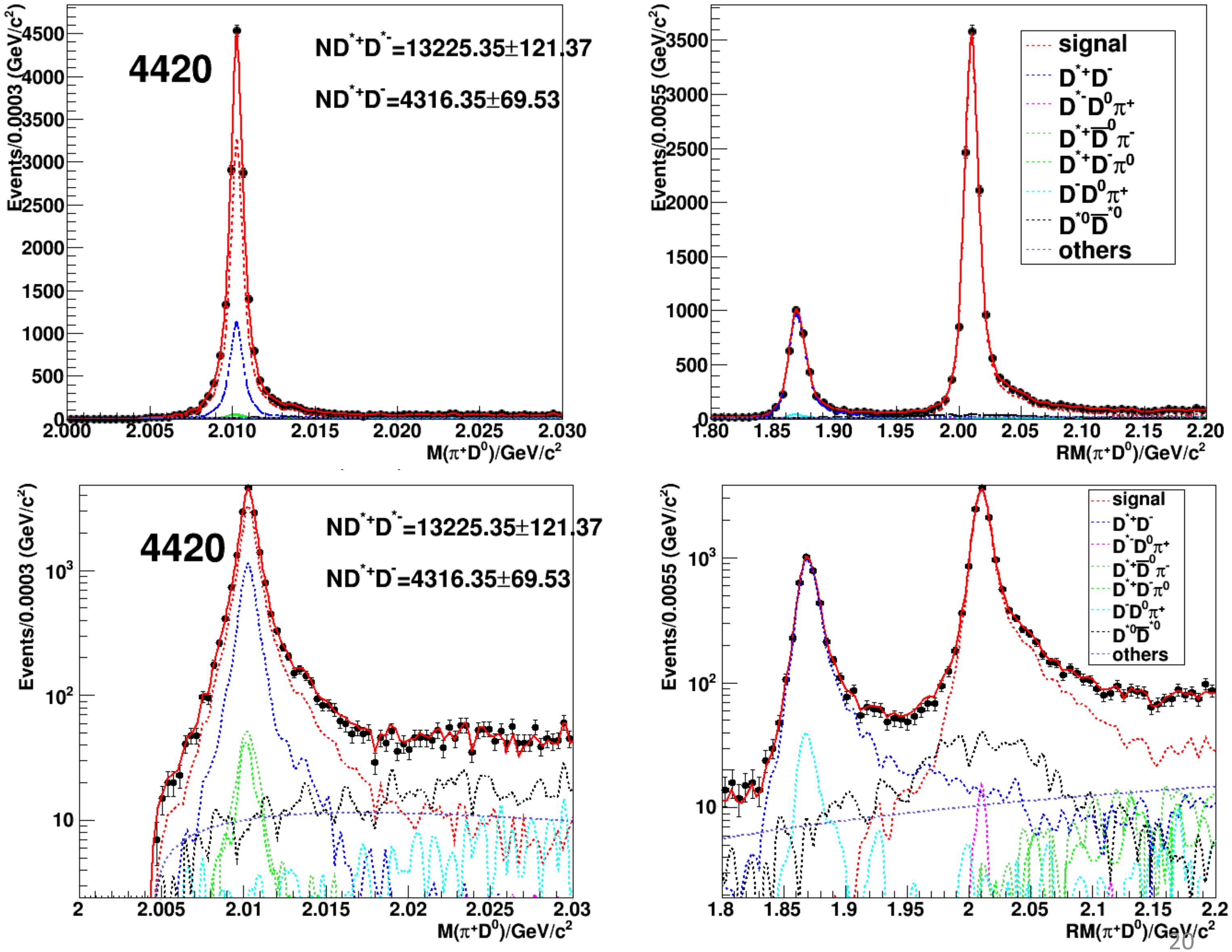




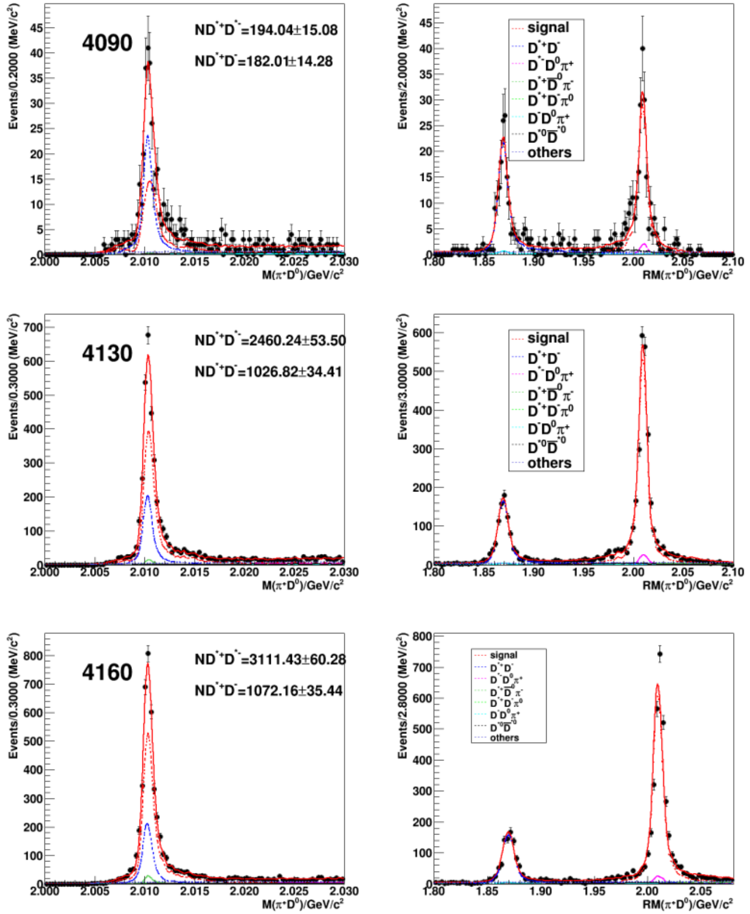
Test 2-D fit with inclusive MC sample at 4.42 GeV

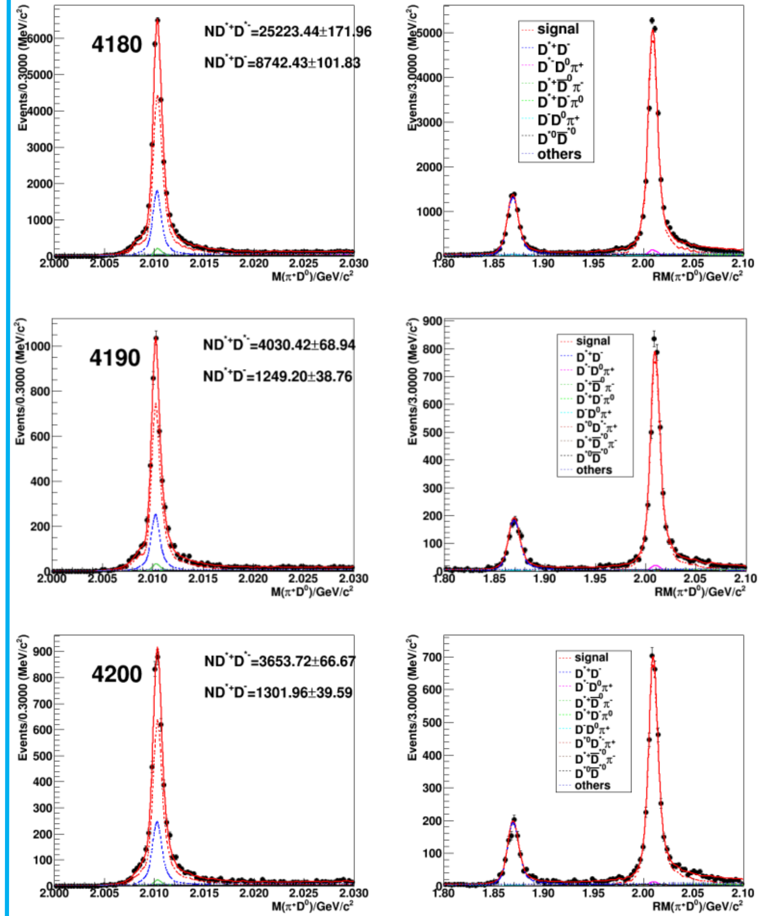
Mode	number	Fitting result
$D^{*+}D^{*-}$	13334	13225 ± 121
$D^{*+}D^{-}$	4321	4316 ± 70
$D^{*+}\overline{D}^{0}\pi^{-}$	214	243±36
$D^{*-}D^{0}\pi^{+}$	38	45±36
$D^{*+}D^{-}\pi^{0}$	144	171 ±29
$D^{0}D^{-}\pi^{+}$	223	261 ± 21
$D^{*0}\overline{D}^{*0}$	802	932 ± 42
Others	845	749 ± 41

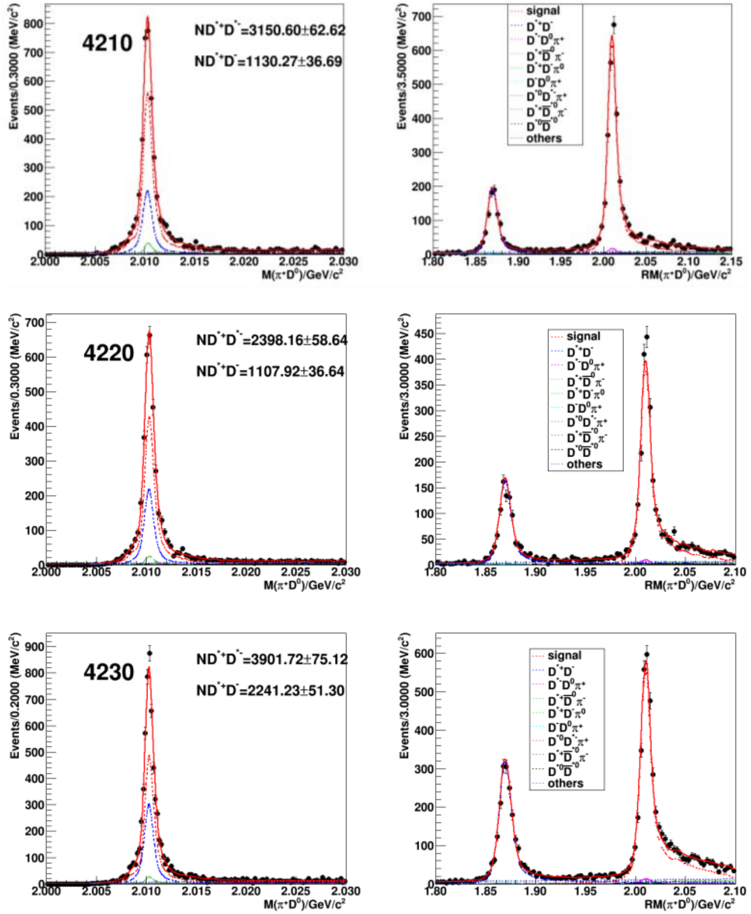
Match well for the different processes events.



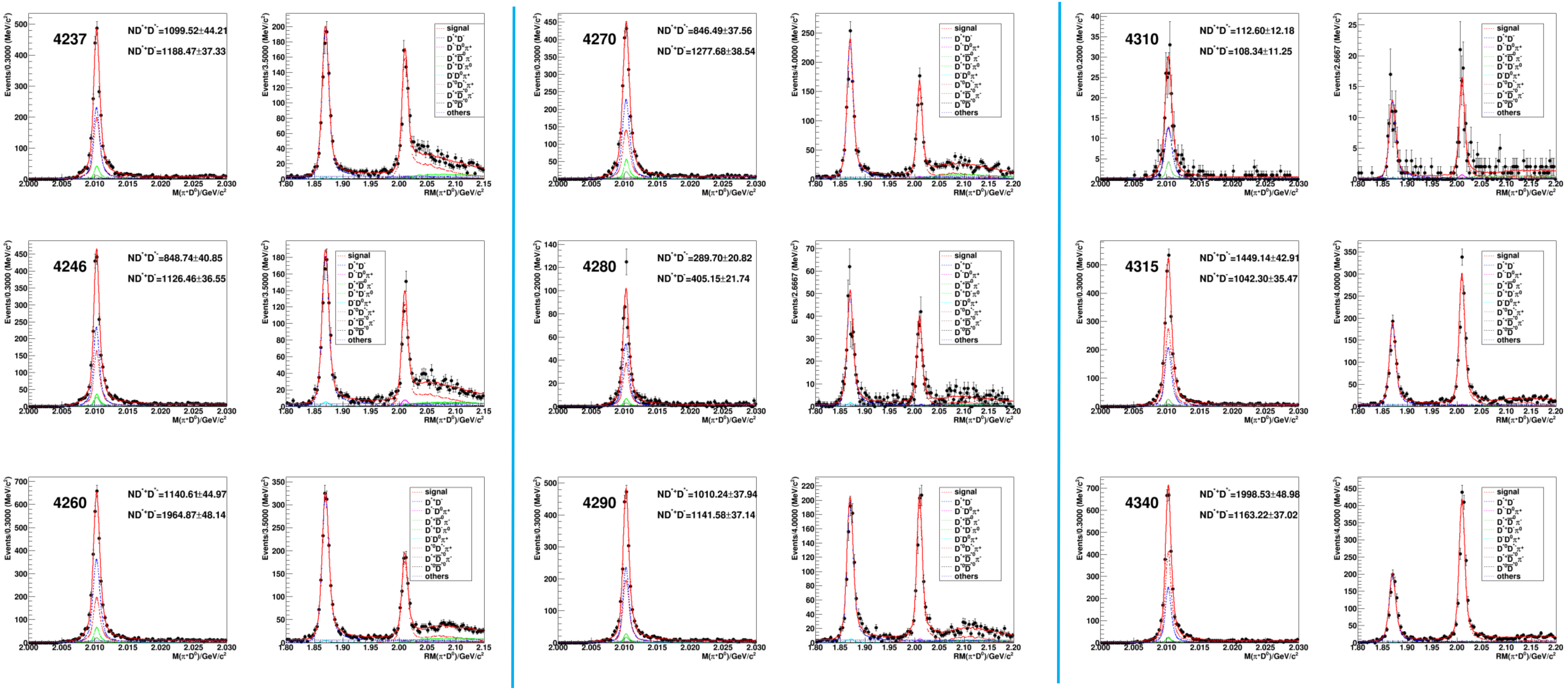
2D fit for XYZ data samples



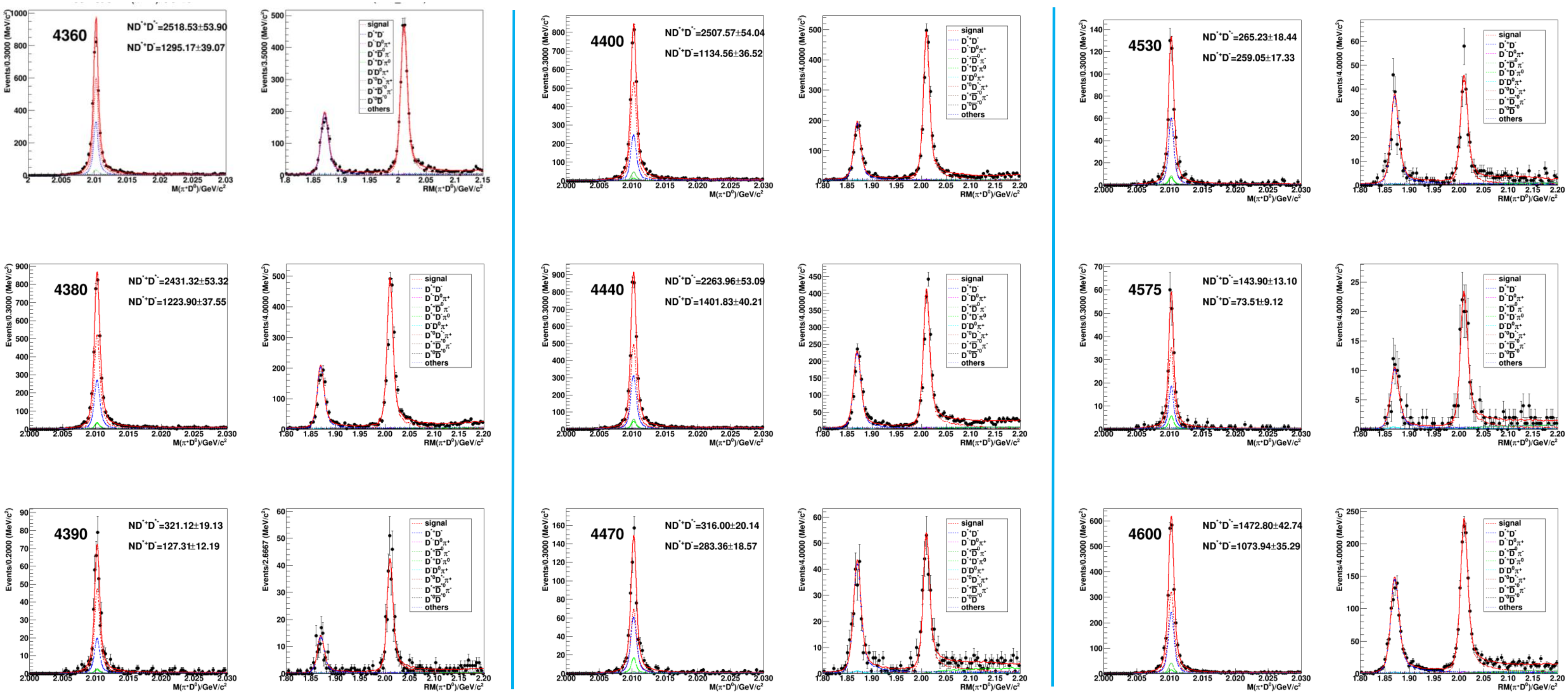




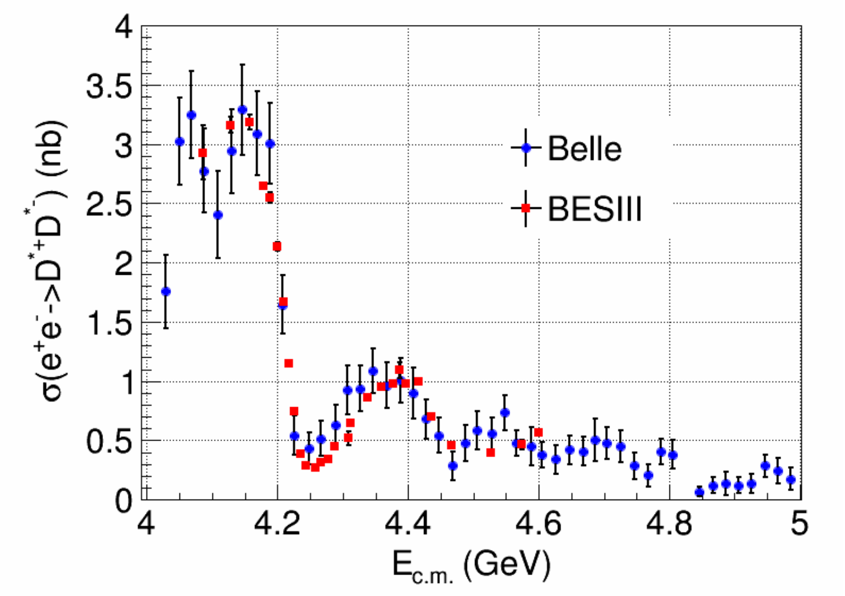
2D fit for XYZ data samples

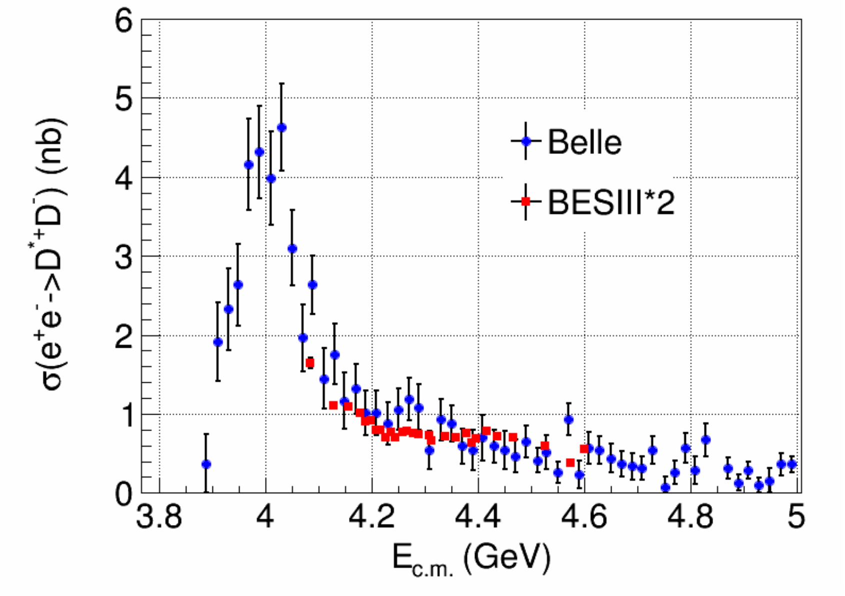


2D fit for XYZ data samples



7.Cross section measurement





$$\sigma^{Born} = \frac{N_{obs}}{L_{int} B \epsilon (f_{VP} \times f_{isr})}$$

$f_{VP} \times f_{isr}$ is obtained by ConExc

Samples	Energy (GeV)	Luminosity (pb^{-1})	$f_{VP} \times f_{isr}$	efficiency	Number($D^{*+}D^{*-}$)	$\sigma(D^{*+}D^{*-})$	$f_{VP} \times f_{isr}$	efficiency	Number($D^{*+}D^{-}$)	$\sigma(D^{*+}D^{-})$
4090	4.0854	52.86	0.846	0.056	194.04 ± 15.08	2926.68 ± 227.45	1.012	0.155	182.01 ± 14.28	823.91 ± 64.64
4130	4.1285	400.00	0.871	0.084	2460.24 ± 53.50	3160.85 ± 68.74	1.094	0.159	1026.82 ± 34.41	555.99 ± 18.63
4160	4.1574	400.00	0.875	0.105	3111.43 ± 60.28	3184.67 ± 61.70	1.064	0.172	1072.16 ± 35.44	549.30 ± 18.16
4180	4.1780	3189.00	0.891	0.124	24816.18 ± 171.02	2646.84 ± 18.24	1.096	0.185	8681.84 ±101.23	504.72 ± 5.88
4190	4.1886	526.70	0.908	0.124	4030.42 ± 68.94	2546.60 ± 43.56	1.089	0.182	1249.20 ± 38.76	450.18 ± 13.97
4200	4.1989	526.00	0.957	0.128	3653.72 ± 66.67	2135.59 ± 38.97	1.083	0.188	1301.96 ± 39.59	458.11 ± 13.93
4210	4.2092	517.10	1.037	0.132	3150.60 ± 62.62	1668.13 ± 33.16	1.080	0.191	1130.27 ± 36.69	399.22 ± 12.96
4220	4.2171	514.60	1.190	0.128	2398.16 ± 58.64	1153.56 ± 28.21	1.078	0.189	1107.92 ± 36.64	396.22 ± 13.10
4230	4.2263	1091.74	1.348	0.133	3901.72 ± 75.12	747.19 ± 14.39	1.077	0.204	2241.23 ± 52.30	351.01 ± 8.19
4237	4.2357	530.30	1.500	0.135	1099.52 ± 44.21	384.39 ± 15.46	1.076	0.204	1188.47 ± 37.33	383.93 ± 12.06
4245	4.2438	538.10	1.505	0.136	848.74 ± 40.85	289.50 ± 13.93	1.076	0.206	1126.46 ± 36.55	354.21 ± 11.49
4260	4.2580	828.40	1.364	0.142	1140.61 ± 44.97	266.88 ± 10.52	1.076	0.215	1964.87 ± 48.14	385.60 ± 9.45
4270	4.2668	531.10	1.280	0.149	846.49 ± 37.56	314.67 ± 13.96	1.077	0.214	1277.68 ± 38.54	393.05 ± 11.86
4280	4.2777	175.70	1.198	0.150	289.70 ± 20.82	344.80 ± 24.78	1.078	0.214	405.15 ± 21.74	375.40 ± 20.14
4290	4.2879	500.00	1.146	0.148	1010.24 ± 37.94	446.35 ± 16.76	1.111	0.207	1141.58± 37.14	373.07± 12.14
4310	4.3079	45.08	1.062	0.171	112.60 ± 12.18	518.02 ± 56.03	1.085	0.229	108.34 ± 11.25	364.24 ± 37.82
4315	4.3121	500.00	1.055	0.159	1449.14 ± 42.91	650.58 ± 19.26	1.091	0.217	1042.30 ± 35.47	330.30 ± 11.24
4340	4.3374	500.00	1.008	0.172	1998.53 ± 48.98	867.19 ± 21.25	1.072	0.228	1163.22 ± 37.02	358.14 ± 11.40
4360	4.3583	543.90	0.996	0.183	2518.53 ± 53.90	954.04 ± 20.42	1.095	0.234	1295.17 ± 39.07	349.47 ± 10.54
4380	4.3774	500.00	1.009	0.185	2431.32 ± 53.32	981.49 ± 21.52	1.048	0.234	1223.90 ± 37.55	374.95 ± 11.50
4390	4.3874	55.57	1.017	0.196	321.12 ± 19.13	1091.91 ± 65.05	1.104	0.243	127.31 ± 12.19	320.66 ± 30.70
4400	4.3964	500.00	1.034	0.186	2507.57 ± 54.04	980.24 ± 21.12	1.039	0.241	1134.56 ± 36.52	341.34 ± 10.99
4420	4.4156	1043.90	1.068	0.165	4895.27 ± 76.88	999.10 ± 15.69	1.109	0.216	2601.65 ± 55.44	390.68 ± 8.33
4440	4.4362	570.00	1.122	0.190	2263.96 ± 53.09	698.72 ± 16.39	1.025	0.252	1401.83 ± 40.21	357.92 ± 10.27
4470	4.4671	111.09	1.207	0.191	316.00 ± 20.14	462.65 ± 29.49	1.123	0.244	283.36 ± 18.57	350.09 ± 22.94
4530	4.5271	112.12	1.084	0.208	265.23 ± 18.44	394.26 ± 27.41	1.133	0.255	259.05 ± 17.33	300.79 ± 20.12
4575	4.5745	48.93	1.109	0.214	143.90 ± 13.10	465.13 ± 42.34	1.138	0.262	73.51 ± 9.12	189.08 ± 23.46
4600	4.5995	586.90	1.120	0.148	1472.80 ± 42.74	570.53 ± 16.56	1.142	0.217	1073.94 ± 35.29	277.61 ± 9.12

8.Summary

Born cross section of $\boldsymbol{e^+e^-} \rightarrow \boldsymbol{D^{*+}D^{*-}}$ and $\boldsymbol{e^+e^-} \rightarrow \boldsymbol{D^{*+}D^{-}}$ are measured precisely with 28 xyz data samples at $\sqrt{s}$=4.09−4.60GeV.
Results of BESIII match well with those of Belle.

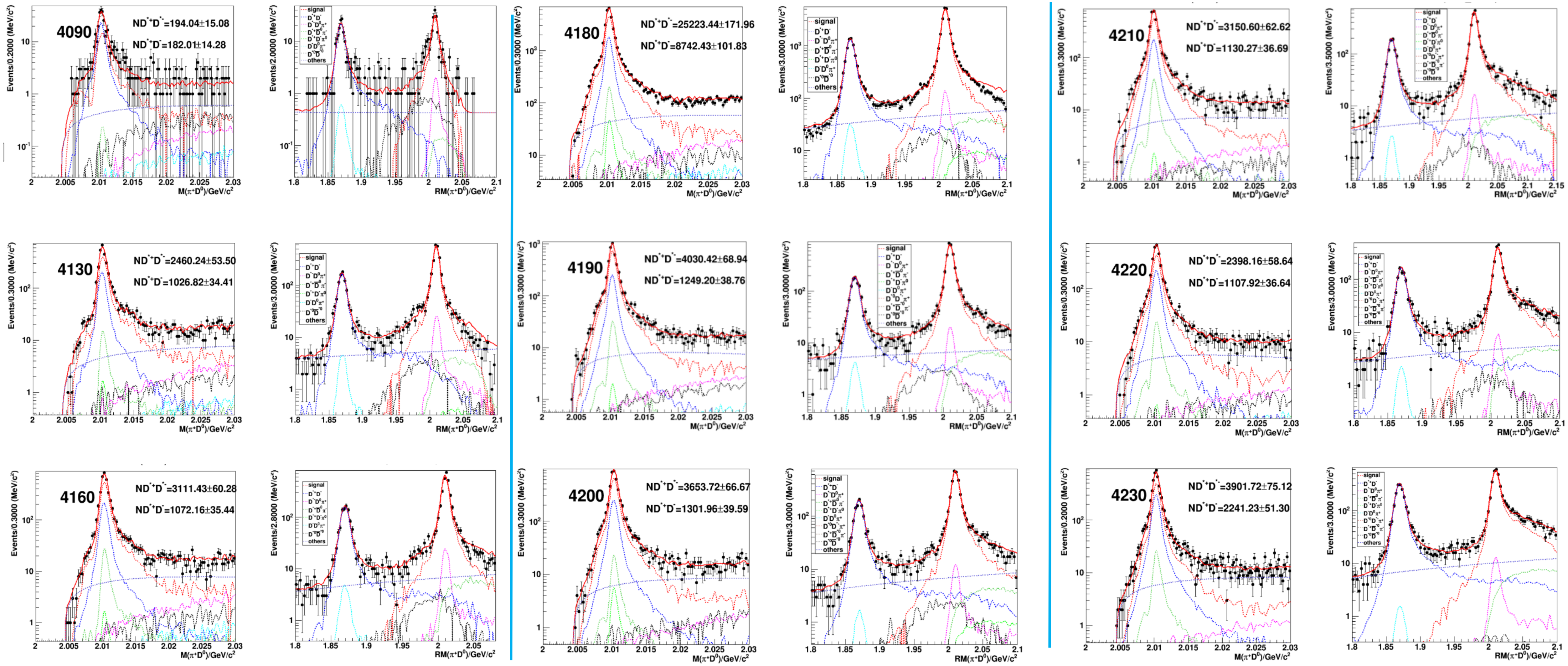
To do

- Events selection criteria optimization
- Cross section iteration
- The study of scan data samples
- System uncertainty

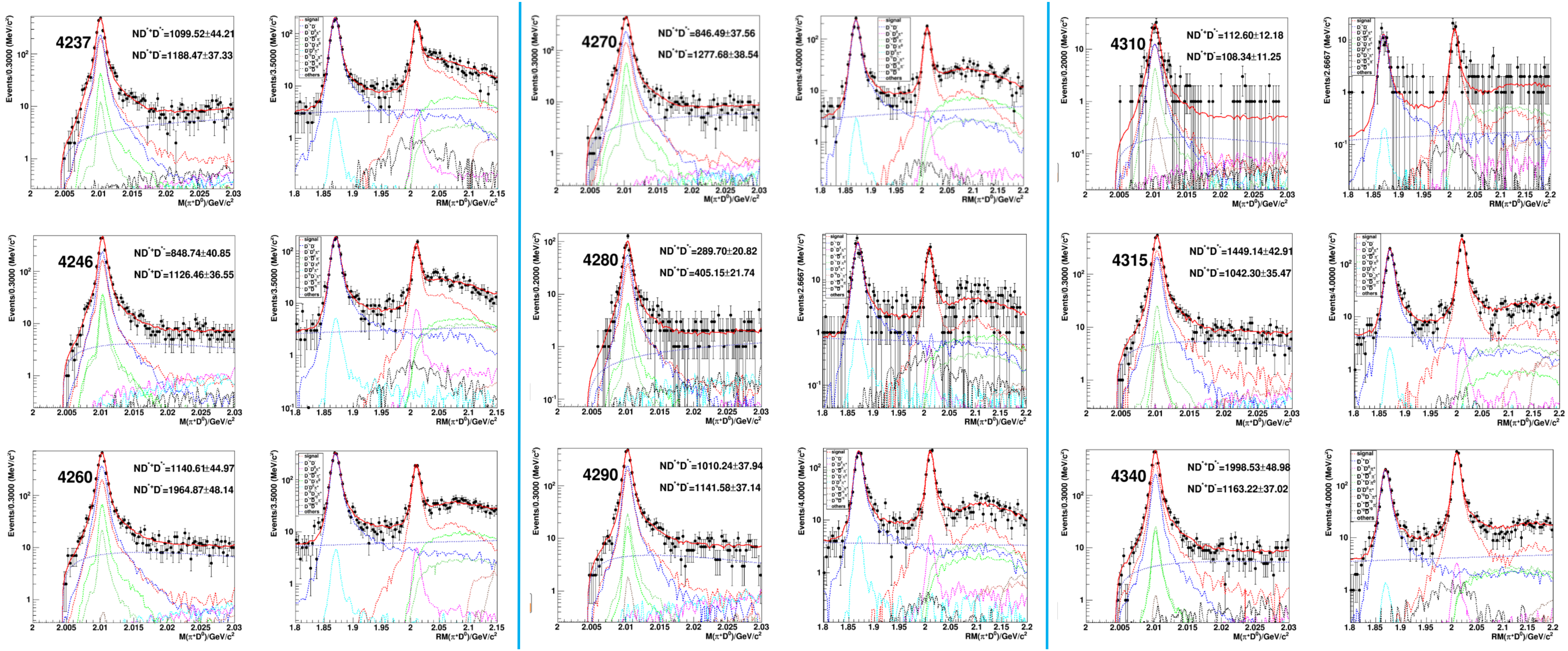
Thank you for your attention!

Back up

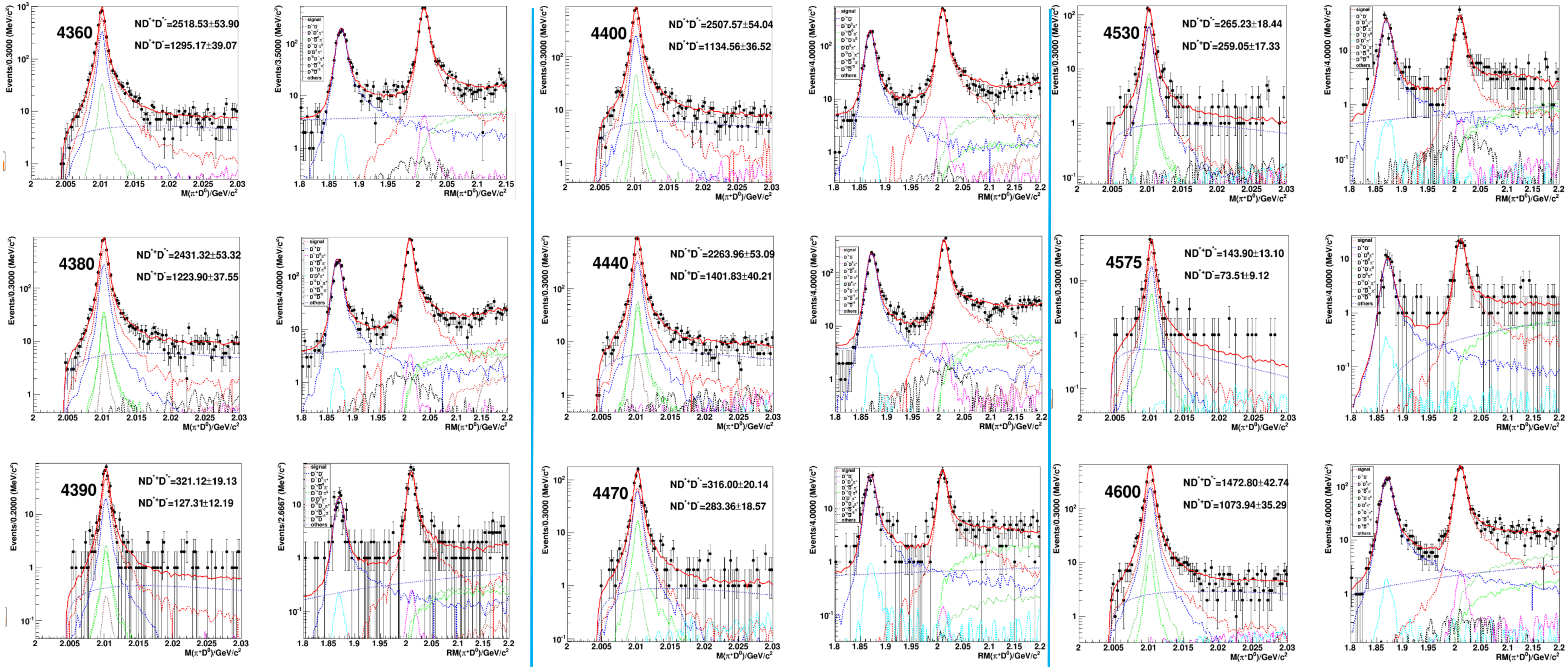
2D fit for XYZ data samples (log plots)



2D fit for XYZ data samples (log plots)



2D fit for XYZ data samples (log plots)



Distribution of $B\epsilon(f_{VP} \times f_{isr})$