Study of $e^+e^- \to \gamma D_s^+ D_s^-$ at BESIII

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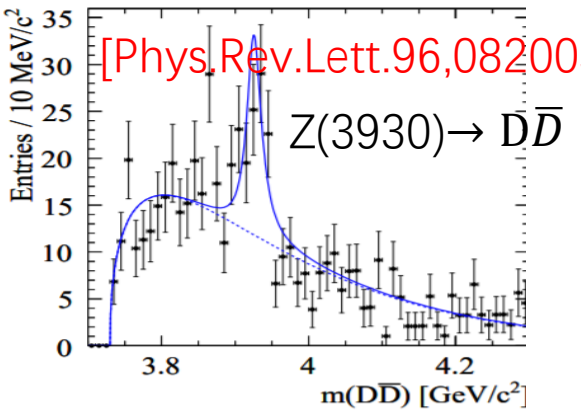
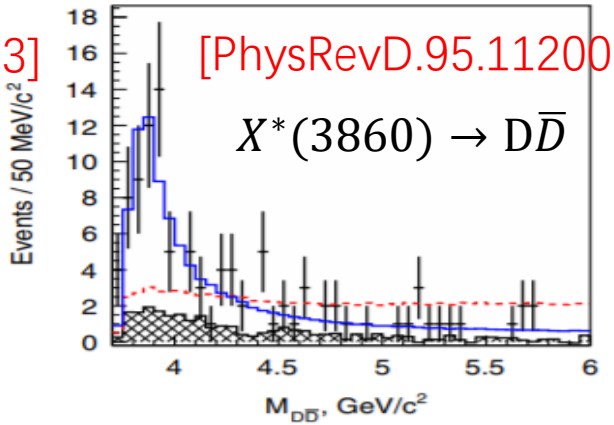
Outline

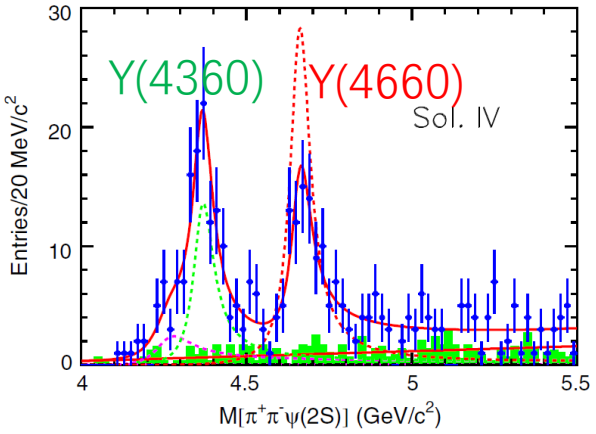
- Motivation and introduction
- BESIII data samples
- General selections
- Signals and background study
- Summary and plan

Motivations

- Z(3930) was discovered by Belle in $\gamma\gamma \to \mathrm{D}\bar{D}$ process is asigned to be $\chi_{c2}(2\mathrm{P})$.
  - M=$(3929 \pm 5 \pm 2)$MeV/c^2 and Γ=$(29 \pm 10 \pm 2)$MeV
- $X^*(3860)$ was discovered by Belle in $e^+e^- \to J/\psi + D\bar{D}$, which agrees with $\chi_{c0}(2\mathrm{P})$.
  - M = (3862^{+26+40}_{-32-13}) MeV/c^2 and Γ=$(201^{+154+88}_{-67-82})$ MeV
- The highest charmoniumlike vector Y(4660) state was discovered in $f_0(980)\psi'$ final states, where $f_0(980)$ could contain ssbar components.
- How about replacing $D\bar{D}$ with ${D_s}^+{D_s}^-$?
- The radiative decay Y(4660)→ $\gamma{D_s}^+{D_s}^-$ should be allowed, and a $\chi_{cJ}(\mathrm{nP})$–like state may exist in ${D_s}^+{D_s}^-$, since there should ssbar in Ds^+Ds^- system.
- BESIII is taking data on Y(4660), which allows the search.
- We have Y(4360) data right now, which can be used for preliminary study.







BESIII data/MC samples and MC simulation I

- XYZ Data(Boss 703) at Ecms=4.36GeV
- Signal MC:
  - 0.1 M events at √s=4.36GeV and √s=4.66GeV
  - The channel:
    - $e^+e^- \to \gamma$X(3.94),(via PHSP) X(3.94)→ Ds^+Ds^-(via PHSP)
    - $Ds^+ \to K^+K^-\pi^+$, (via D_DALITZ)
    - $Ds^- \to K^+K^-\pi^-$, (via D_DALITZ)
- Inclusive MC: MC-703(hadron) at √s=4.36GeV
- Bkg MC:
  - 0.1 M events at √s=4.36GeV
  - The channel:
    - $e^+e^- \to Y \to {D_s}^{*-}{D_s}^+$ (via HELAMP 1.0 0.0 0.0 0.0 -1.0 0.0)

    Case1:

    - ${D_s}^{*-} \to \gamma Ds^-$(93.5±0.7) % (via VSP_PWAVE), $Ds^{*-} \to \pi^0 Ds^-(5.8\pm0.7)\%$(via VSS), $Ds^{*-} \to e^+e^-Ds^-(6.7\pm1.6)\times 10^{-3}$(via PHSP), $Ds^- \to$anything
    - ${D_s}^+ \to K^+K^-\pi^+$ (via D_DALITZ)

BESIII data/MC samples and MC simulation II

- Case2:

  $D_s^{*-} \to \gamma Ds^-$(93.5±0.7) % (via VSP_PWAVE), $Ds^{*-} \to \pi^0 Ds^-(5.8\pm0.7)\%$(via VSS), $Ds^{*-} \to e^+e^-Ds^-(6.7\pm1.6)\times 10^{-3}$(via PHSP), $Ds^- \to K^+K^-\pi^-$(via D_DLITZ)

  $Ds^+ \to anything$

- 0.1 M events at √s=4.36GeV
- The channel:

  $e^+e^- \to Y \to Ds^{*+}Ds^{*-}$(via PHSP), $Ds^{*+} \to \gamma Ds^+$(via VSP_PWAVE), $Ds^{*-} \to \gamma Ds^-$(via VSP_PWAVE), $Ds^+ \to K^+K^-\pi^+$(via D_DLITZ)

- 0.1 M events at $\sqrt{s}$= 4.36GeV
- The channel :

  $e^+e^- \to Y \to \gamma_{ISR} Ds^+Ds^-$(via VSS), $Ds^+ \to K^+K^-\pi^+$(via D_DLITZ)

Selection criteria I

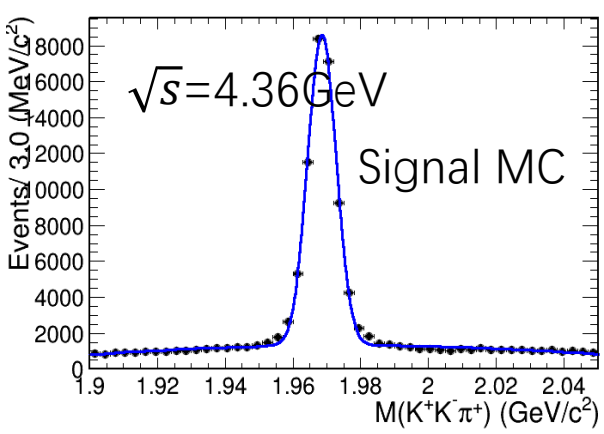
- Reconstruction:
  - $e^+e^- \to \gamma Ds^+Ds^-$, $Ds^+ \to K^+K^-\pi^+/\phi\pi^+$, $\phi \to K^+K^-$
- Charged tracks:
  - N(trk)≥ 3
  - V_{xy}=$\sqrt{Vx^2 + Vy^2}$<1 cm and $|Vz| < 10cm$
  - $|cos\theta| < 0.93,$ in the active region of MDC
- Photon(s):
  - E_barrel > 25 MeV or E_endcap > 50 MeV
  - N(γ)≥ 1
  - >$5°$ away from any good charged track
  - t < 700ns after T0 of one event

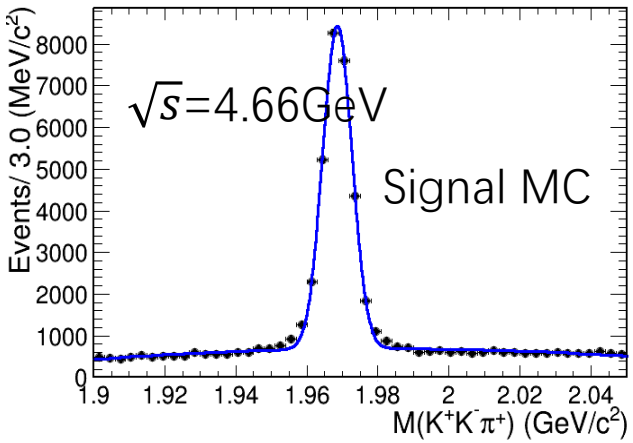
Selection criteria II

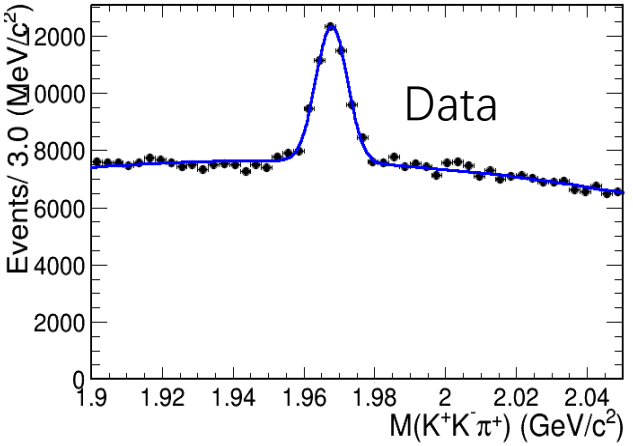
- PID:
  - Prob(K)>Prob(π) and Prob(K)>0.001 for Kaon
  - Otherwise, it is a pion.
- Kinematic constrain
  - 4C kinematic fit
  - $M_{rec}(\gamma Ds)$ constraint to Ds nominal mass
- Mass windows:
  - $|M(K^+K^-\pi^+) - m(Ds)| < 15$ MeV for D_s signal
  - $|M_{rec}(\gamma D_s) - m(Ds)|$<15 MeV for another D_s
  - **Ds^* veto:** $|M(\gamma D_s) - m(Ds^*)| > 15$MeV and $|M_{rec}(K^+K^-\pi^+) - m(Ds*)| > 15$MeV
- Efficiencies:
  - $e^+e^- \to \gamma Ds^+Ds^-$, $Ds^+ \to K^+K^-\pi^+$: $\varepsilon = 32.28\%$ at Ecms=4.36 GeV
  - $e^+e^- \to \gamma Ds^+Ds^-$, $Ds^+ \to K^+K^-\pi^+$: $\varepsilon = 19.61\%$ at Ecms=4.66 GeV

D_s signals in M($K^+K^-\pi^+$)

PDF: Gaussian + second-order polynomial







M = (1968.6±0.2) MeV /c^2
$\sigma = (4.2 \pm 0.2)$ MeV/c^2

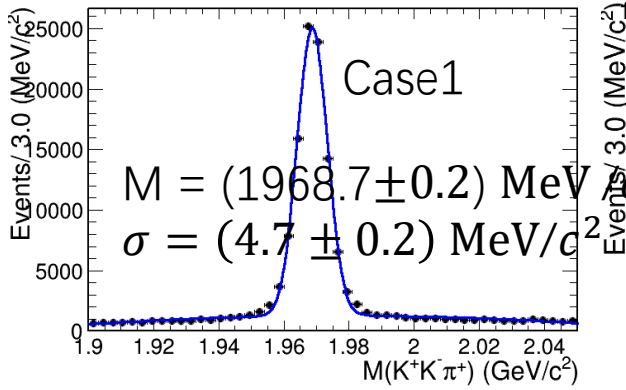
M = (1968.6±0.3) MeV /c^2
$\sigma = (4.1 \pm 0.3)$ MeV/c^2

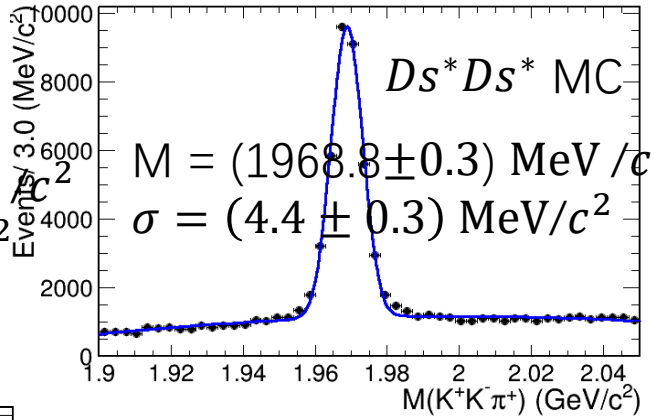
M = (1967.8±0.1) MeV /c^2
$\sigma = (4.4 \pm 0.1)$ MeV/c^2

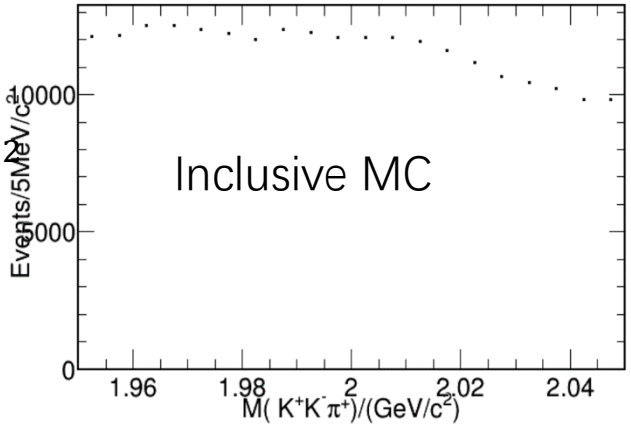
- $\sigma \approx 4$ MeV/c^2
- Signal region: $|M(K^+K^-\pi^+) - m(Ds)| < 15$ MeV

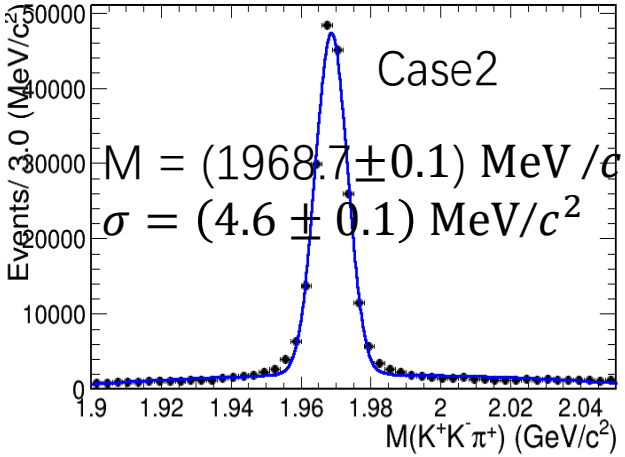
D_s in M($K^+K^-\pi^+$) from bkgs

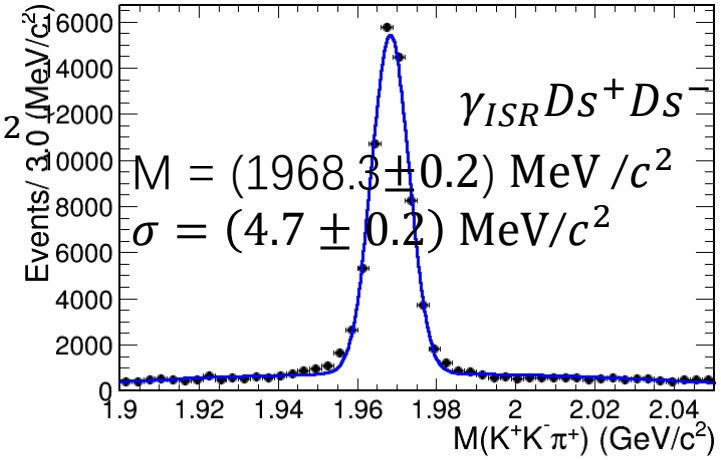
PDF: Gaussian + second-order polynomial







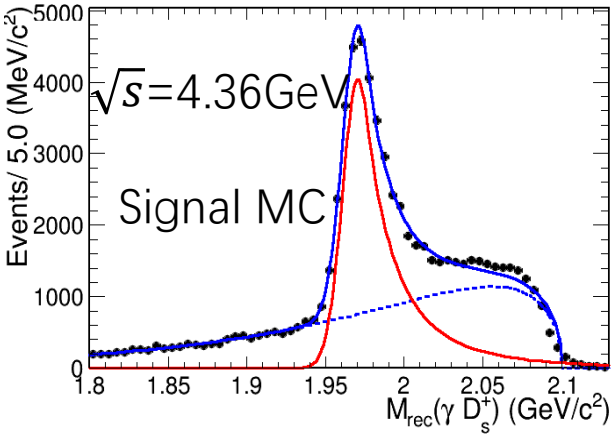


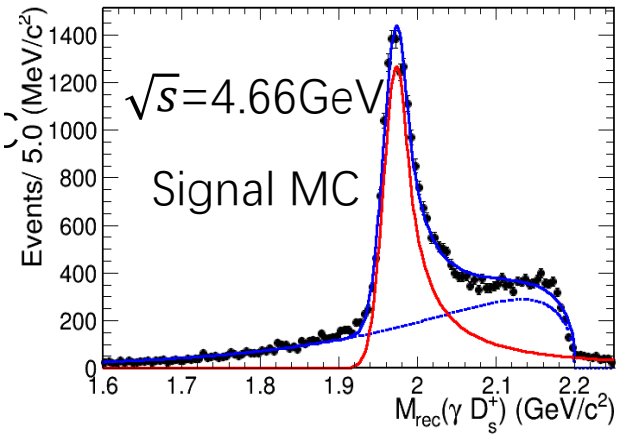


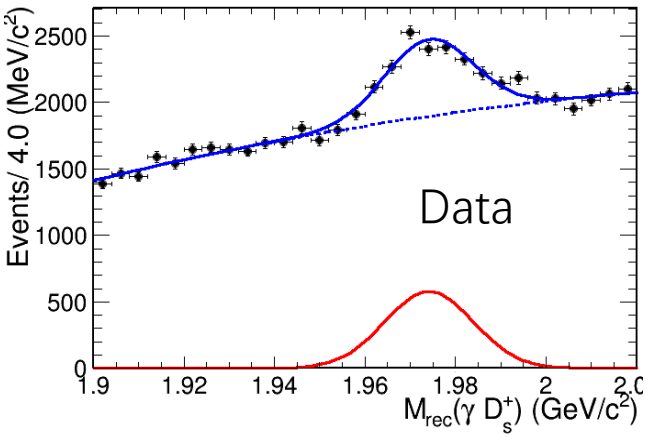
- The mass resolution is similar to the one from signal MC simulation

Resolutions of $M_{rec}(\gamma Ds^{+})$

PDF: Gaussian/Crystal_ball + second-order polynomial/Agus







M = (1963.8±0.2) MeV $/c^2$
$\sigma = (9.6 \pm 0.3)\mathrm{MeV}/c^2$

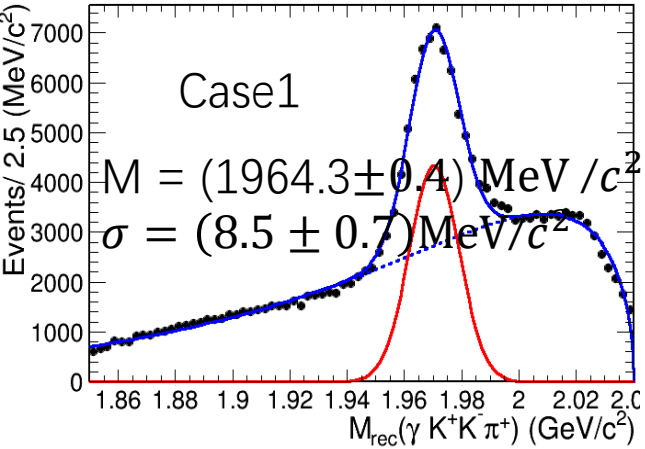
M = (1976.1±0.3) MeV $/c^2$
$\sigma = (14.5 \pm 0.5)\mathrm{MeV}/c^2$

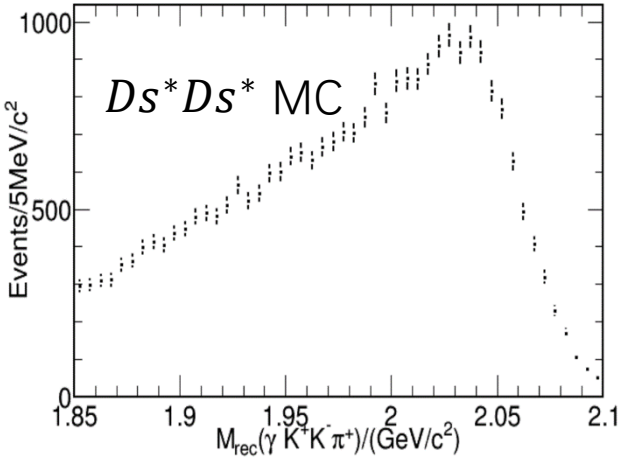
M = (1974.8±0.6) MeV $/c^2$
$\sigma = (9.7 \pm 0.7)\mathrm{MeV}/c^2$

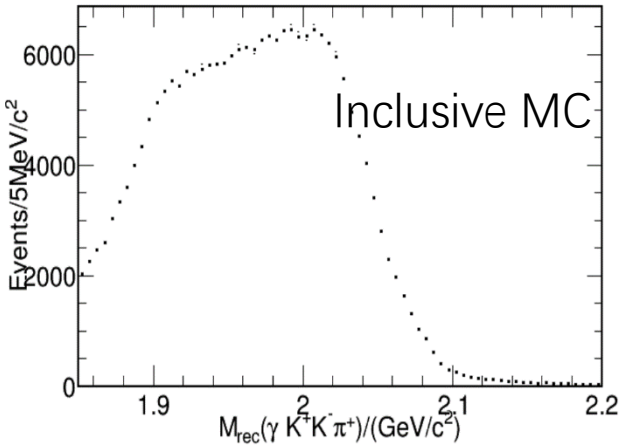
- $M_{rec}(\gamma D_s) = M(D_s)$ for signal
- Mass resolution increases from Ecms=4.36 GeV to 4.66 GeV, becoming worse
- Mass window for another Ds:
  - $|M_{rec}(\gamma K^+K^-\pi^+) - 1.968| < 30$ MeV, 4.36 GeV data used currently

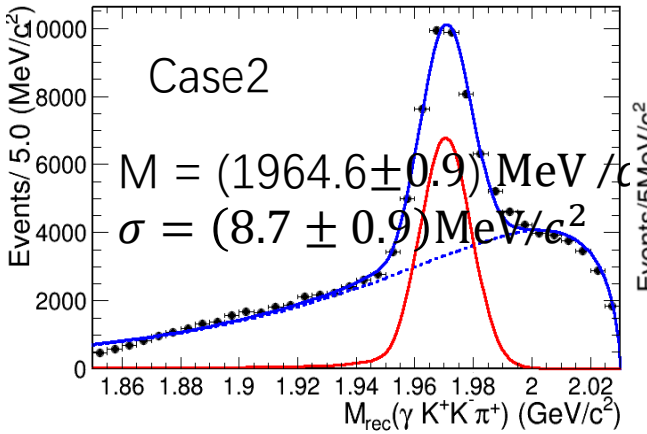
$M_{rec}(\gamma D_s{}^+)$ from bkgs in MC samples

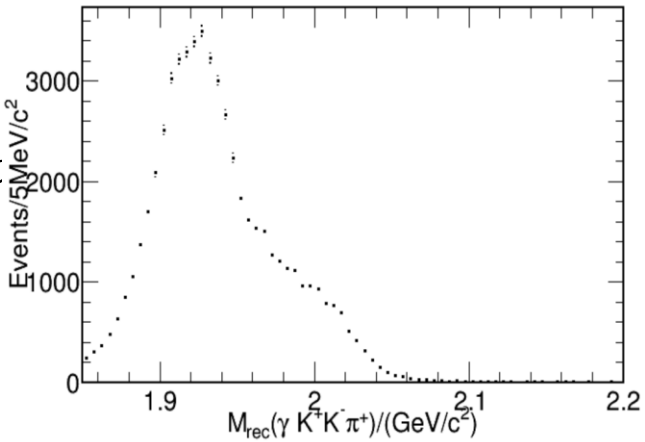
PDF: Crystal ball + Agus







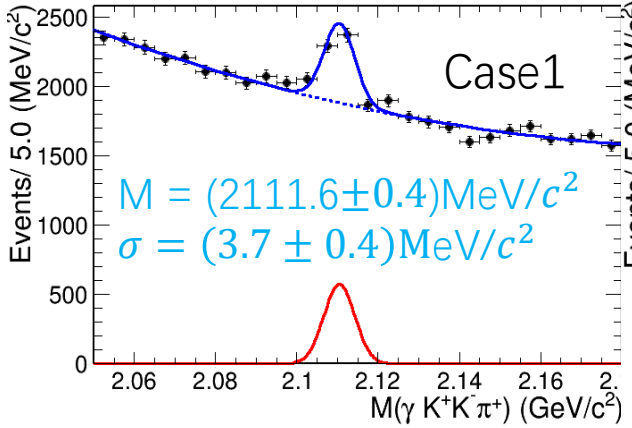


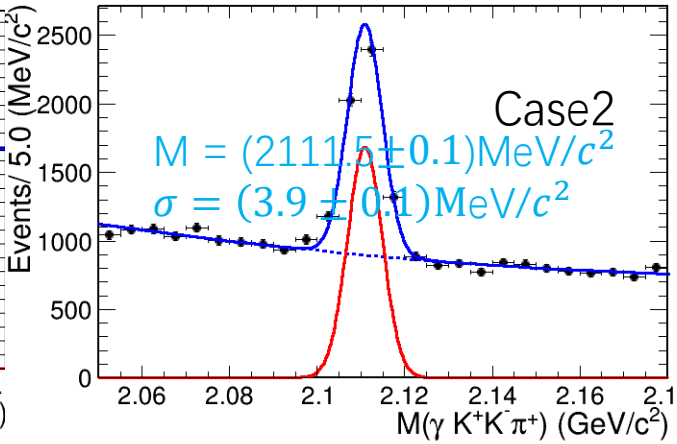


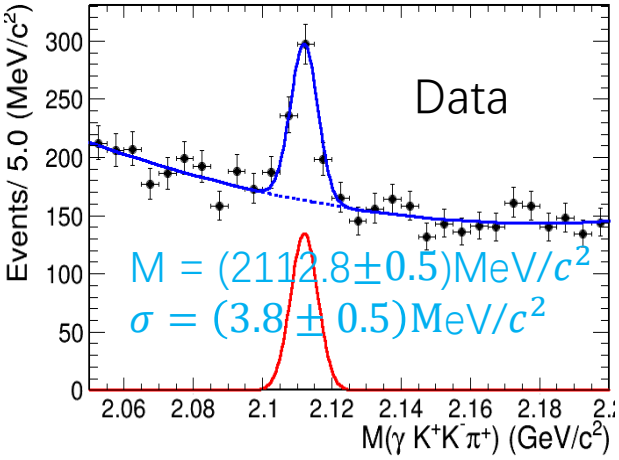
➢ Only bkgs from Ds^*D_s have clear D_s singal in $M_{rec}(\gamma D_s{}^+)$

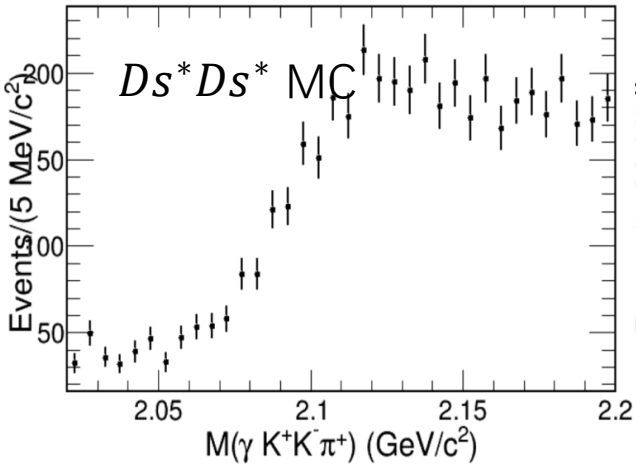
Distributions of M(γD_s^+)

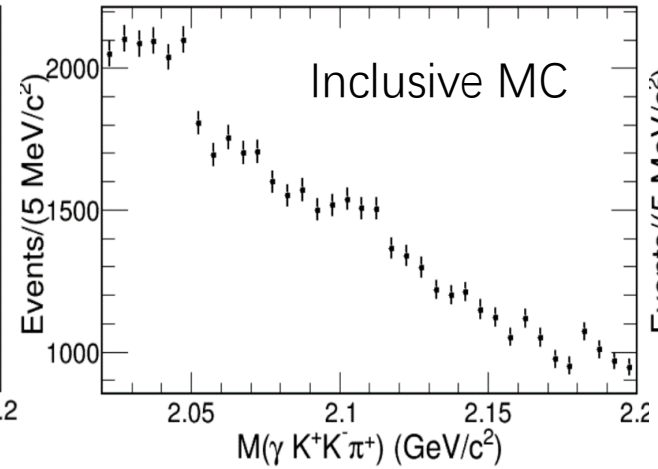
PDF: Gaussian + second-order polynomial

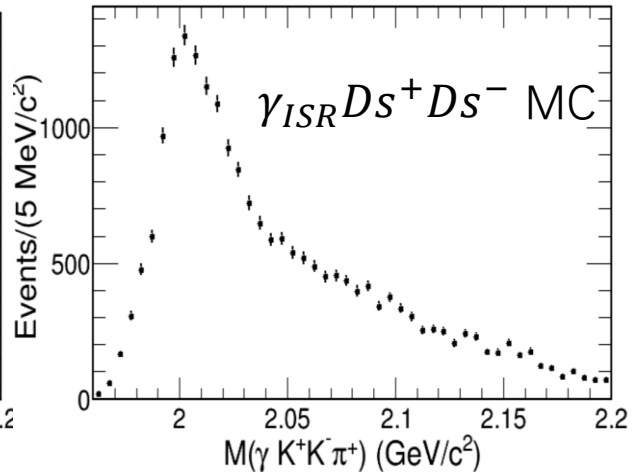








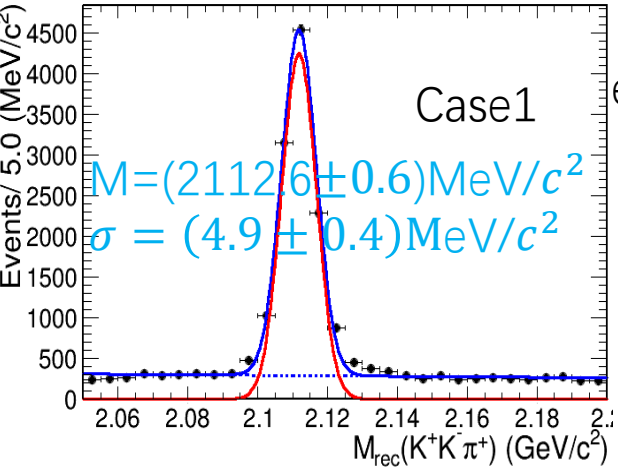


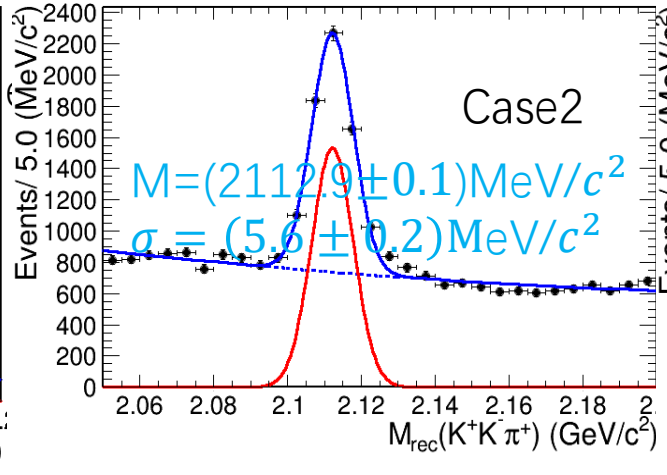


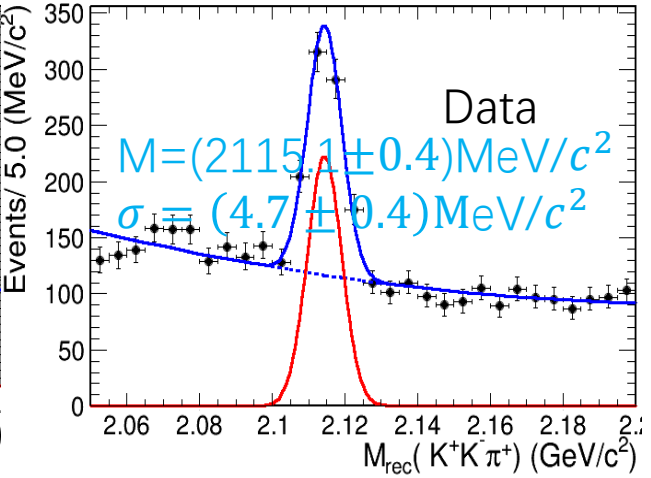
- The data show clear D_s* component from e+e- -> D_s*D_s, which can be simulated.
- **D_s* veto**: $|M(\gamma K^+K^-\pi^+) - m(Ds^*)| > 15$ MeV

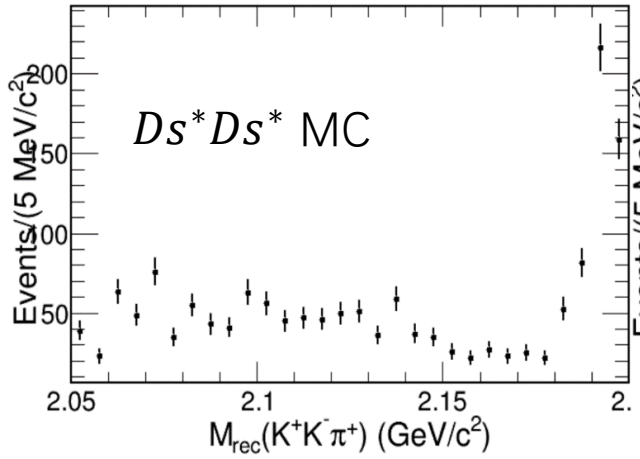
D_s^* in $M_{rec}(K^+K^-\pi^+)$

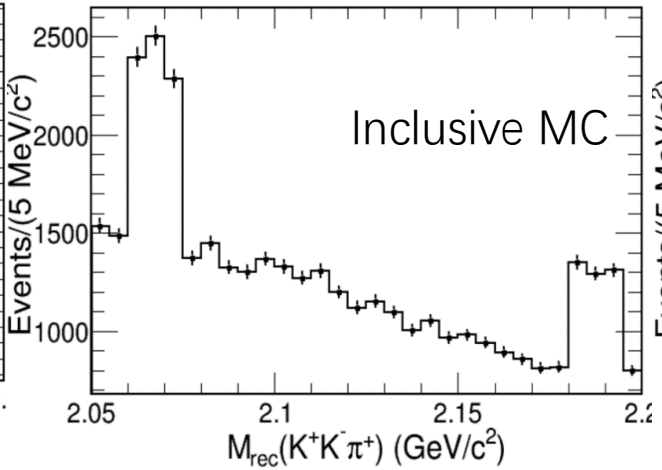
PDF: Gaussian + second-order polynomial

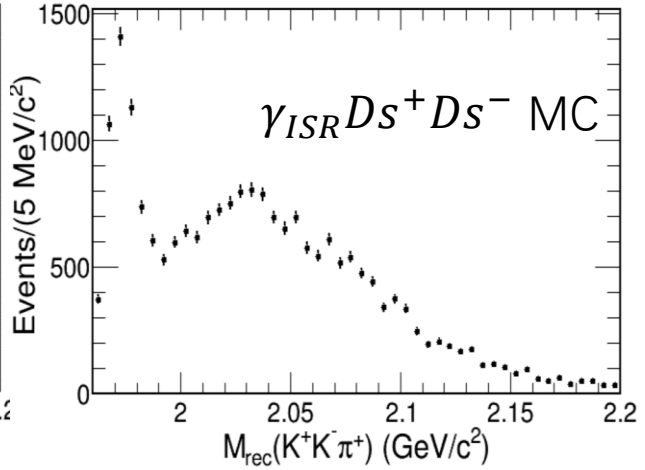






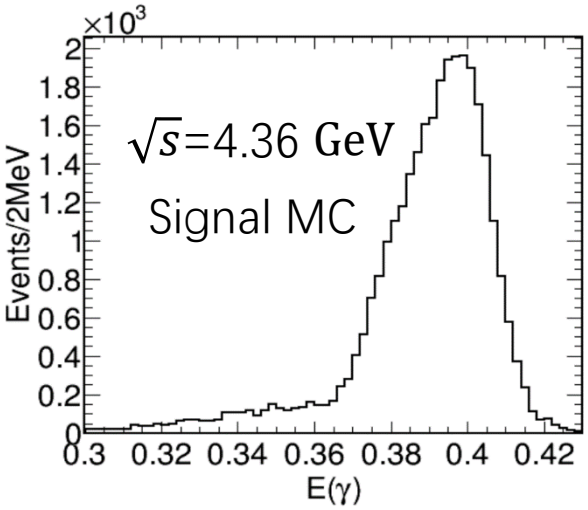


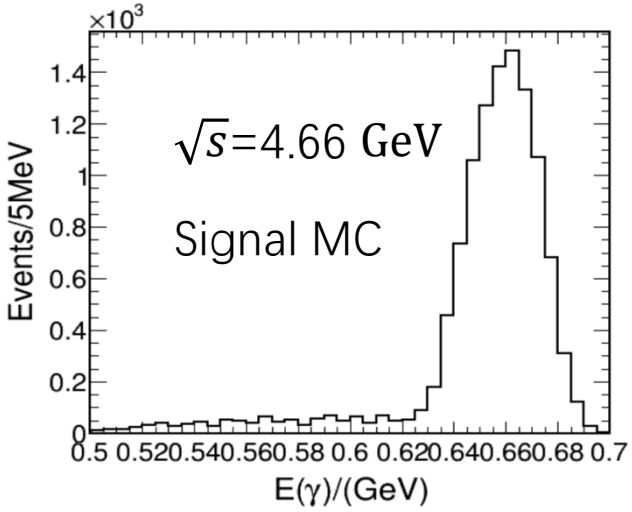


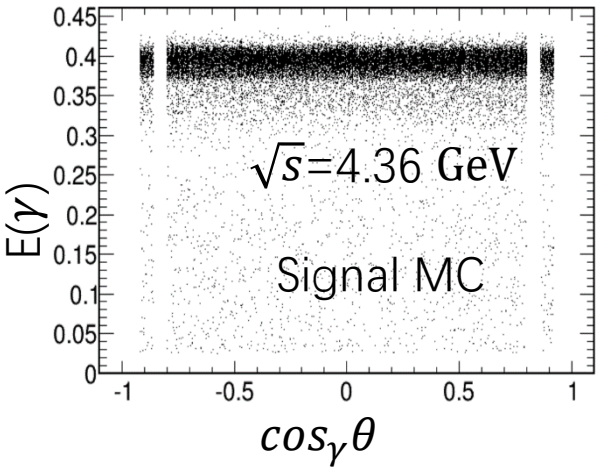


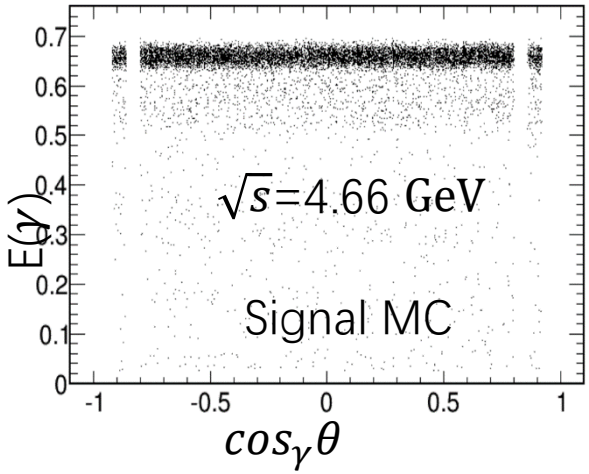
- **Second D_s^* veto:** $|M(K^+K^-\pi^+) - m(Ds^*)| > 15$ MeV

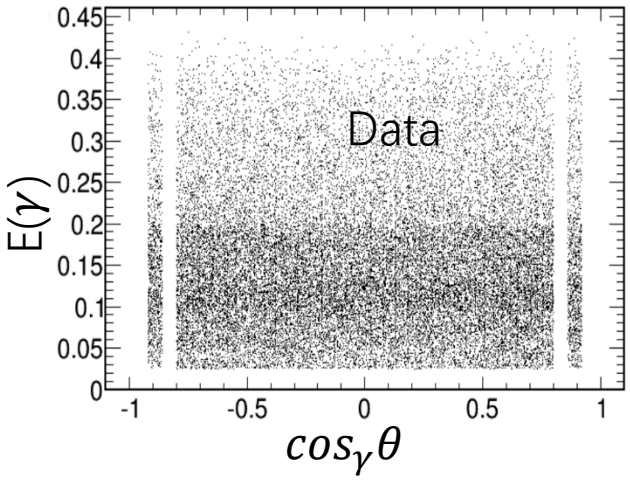
Energy and angle of γ





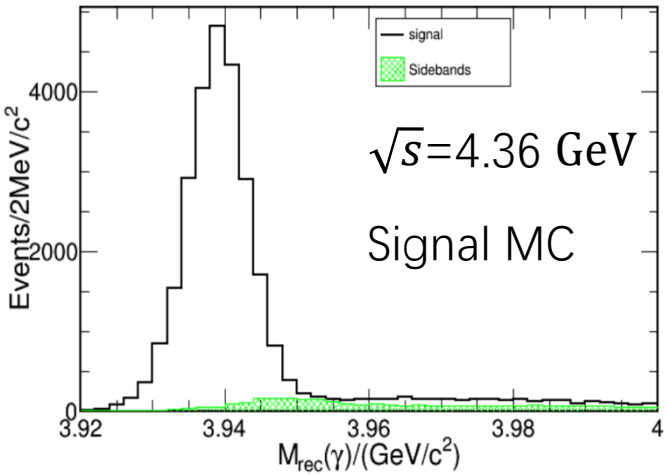


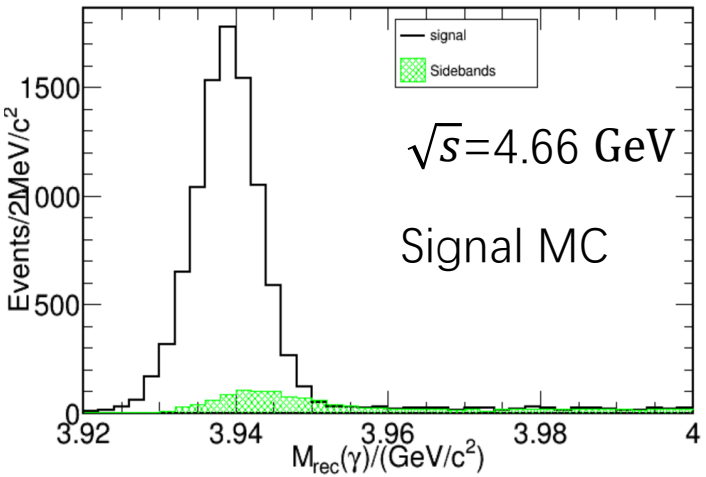


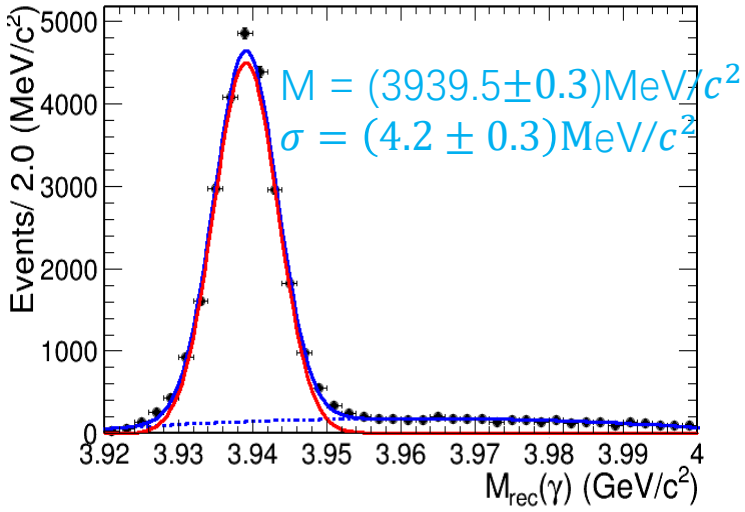


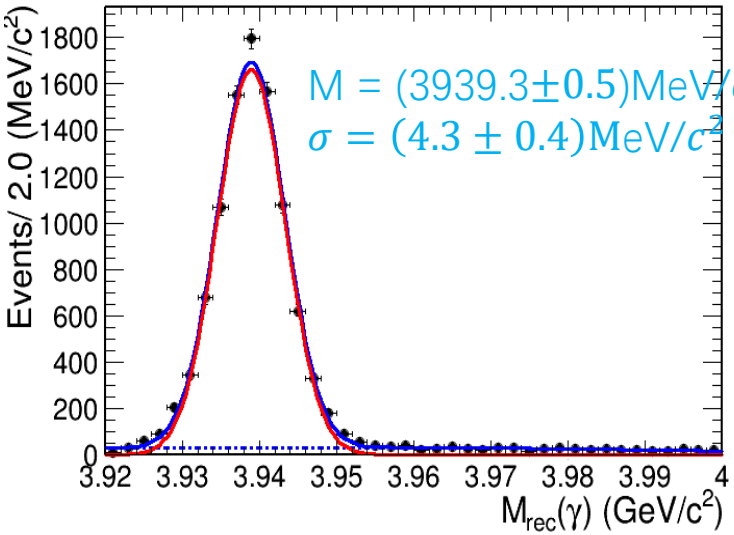
- E(γ) is related to the mass of X and $\sqrt{s}$ in signal MC

Signal in $M_{rec}(\gamma)$ in MC simulation





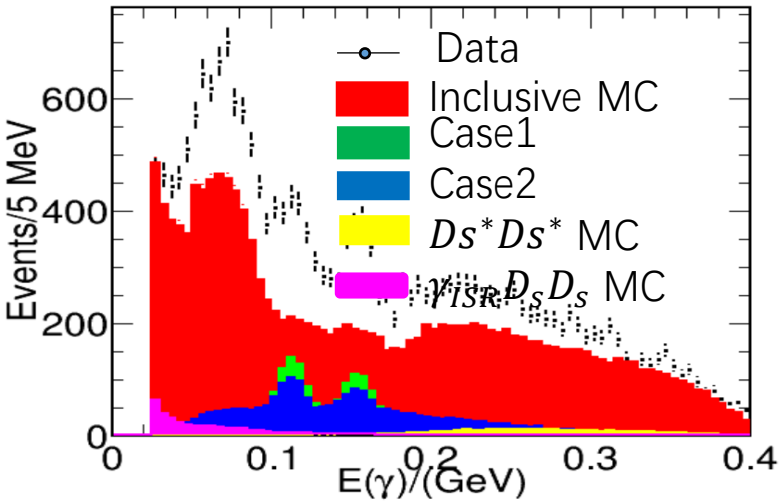


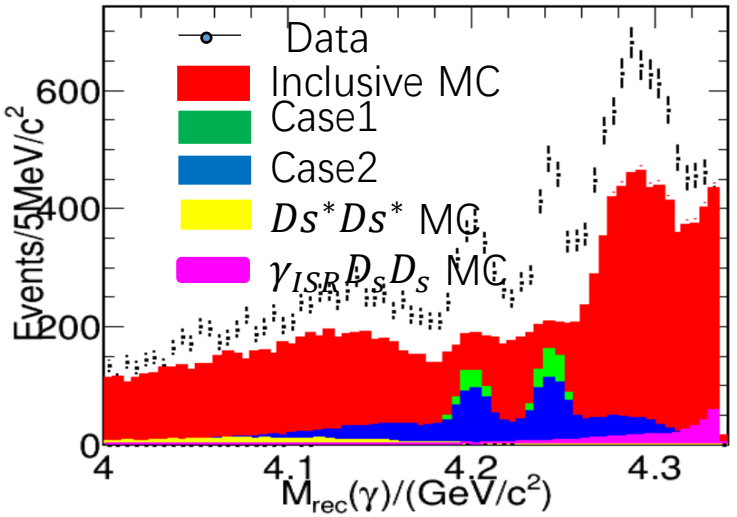


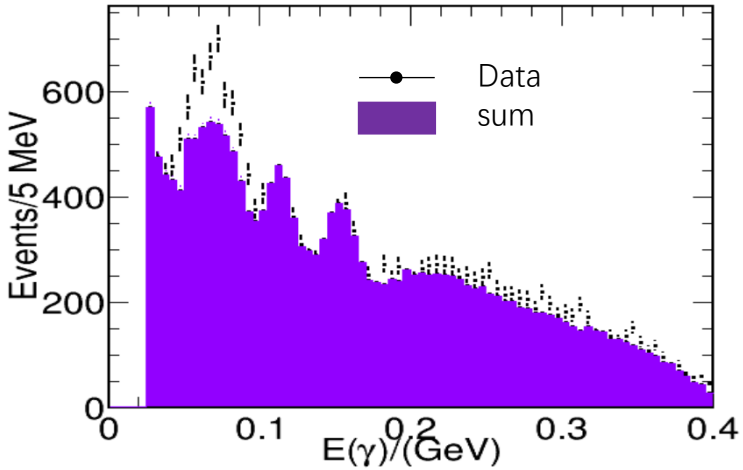
- $M_{rec}(\gamma)$ = M(DsDs)
- MC simulation shows very good resolution of M(DsDs) in $M_{rec}(\gamma)$:
  $\sigma = (4.2 - 4.3)$ MeV/c^2 !!!

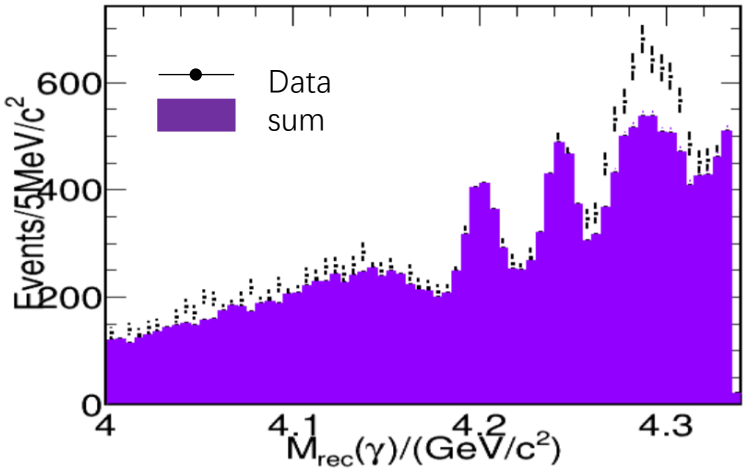
Distributions of E(γ) and $M_{rec}(\gamma)$

sum=inclusive MC+Case1+Case2+Ds^*Ds^* MC+$\gamma_{ISR}D_sD_s$









- Inclusive MC describes most of the events observed in data.
- Besides bkgs from inclusive MC, Ds^*D_S, $Ds^*Ds^*$and $\gamma_{ISR}D_SD_s$, there are still room from other contributions in data.
- Are they events of e+e- ->γ+DsDs directly?

Summary and plan

- Summary
  - We have studied the signal MC at √s=4.36GeV and √s=4.66GeV
  - We have researched for Data at √s=4.36GeV and have estimated backgrounds by inclusvie MC , $D_s Ds^*$, $Ds^* Ds^*$ and $\gamma_{ISR} D_s D_s$.

- Plan
  - To optimize general selections
  - To study more data and MC samples in different energy points.

Thank you !

Back up

Table 1: Decay trees and their respective initial-final states.

rowNo	decay tree (decay initial-final states)	iDcyTr	iDcyIFSts	nEtrs	nCEtrs
1	$e^+e^- \to \pi^0\pi^+\pi^- K^+K^-$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma\gamma)$	22	18	3631	3631
2	$e^+e^- \to \pi^0\pi^+\pi^- K^+K^-\gamma^I$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	5	0	3227	6858
3	$e^+e^- \to K^+K^-a_1^0\gamma^I, a_1^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	469	0	276	7134
4	$e^+e^- \to \pi^+\pi^-\eta K^+K^-\gamma^I, \eta \to \gamma\gamma$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	1312	0	274	7408
5	$e^+e^- \to K^+K^-a_1^0\gamma^I, a_1^0 \to \pi^+\rho^-, \rho^- \to \pi^0\pi^-$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	179	0	268	7676
6	$e^+e^- \to \pi^+\pi^-\eta K^+K^-, \eta \to \gamma\gamma$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma\gamma)$	100	18	267	7943
7	$e^+e^- \to f_2(1270)K^+K^-\gamma^I, f_2(1270) \to \pi^+\pi^-$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I)$	221	41	249	8192
8	$e^+e^- \to a_2^0K^+K^-\gamma^I, a_2^0 \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	54	0	245	8437
9	$e^+e^- \to a_2^0K^+K^-\gamma^I, a_2^0 \to \pi^+\rho^-, \rho^- \to \pi^0\pi^-$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma)$	58	0	239	8676
10	$e^+e^- \to \pi^+\pi^-\eta K^+K^-\gamma^I, \eta \to \pi^0\pi^0\pi^0$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma\gamma\gamma\gamma\gamma)$	231	7	224	8900
11	$e^+e^- \to \pi^+\pi^-\eta K^+K^-, \eta \to \pi^0\pi^0\pi^0$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma\gamma\gamma\gamma\gamma\gamma)$	334	80	204	9104
12	$e^+e^- \to K^+K^-b_1^0\gamma^I, b_1^0 \to \pi^0\omega, \omega \to \pi^0\pi^+\pi^-$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I\gamma\gamma\gamma\gamma)$	192	22	195	9299
13	$e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I)$	1955	41	187	9486
14	$e^+e^- \to \pi^+K^*K^-\gamma^I, K^* \to \pi^-K^+$ $(e^+e^- \to \pi^+\pi^- K^+K^-\gamma^I)$	533	41	183	9669
15	$e^+e^- \to D^{*+}D^{*-}, D^{*+} \to \pi^+D^0, D^{*-} \to \pi^-\bar{D}^0, D^0 \to \pi^0\pi^+K^-, \bar{D}^0 \to \pi^0\pi^-K^+$ $(e^+e^- \to \pi^+\pi^+\pi^-\pi^- K^+K^-\gamma\gamma\gamma\gamma)$	210	116	174	9843