Update on $\bar{p}p \rightarrow D_{s0}^{*}(2317)^{+}D_{s}^{-}$

In preparation for the analysis note v3

November 19th, 2015 | Elisabetta Prencipe, Forschungszentrum Jülich | Open-Charm meeting

Outline

- Excitation function of the cross section
- S/B sensitivity studies
- Background rejection studies: LK, NN, BDT methods

Master formula

- Excitation function of the cross section for $\bar{p}p \rightarrow D_s^- D_s^*(2317)^+$

$$\sigma(s) = \frac{|\mathcal{M}|^2}{64 \cdot \pi \cdot p_1^* \cdot s} \Phi(E)$$

$$\Phi(E) = \frac{1}{\pi} \sqrt{\frac{MM^*\Gamma^*}{M + M^*}} \int_{-\infty}^{\tilde{\tilde{E}}} d\delta \sqrt{\tilde{\tilde{E}} - \delta} \frac{1}{\delta^2 + 1}$$

$M = M(D_s^-)$

$M^* = M(D_s^*(2317)^+)$

$\Gamma^* = \Gamma(D_s^*(2317)^+)$

s = square energy in the center-of-mass system

p_1^* = momentum of the antiproton beam

$E = \sqrt{s} - M - M^*$

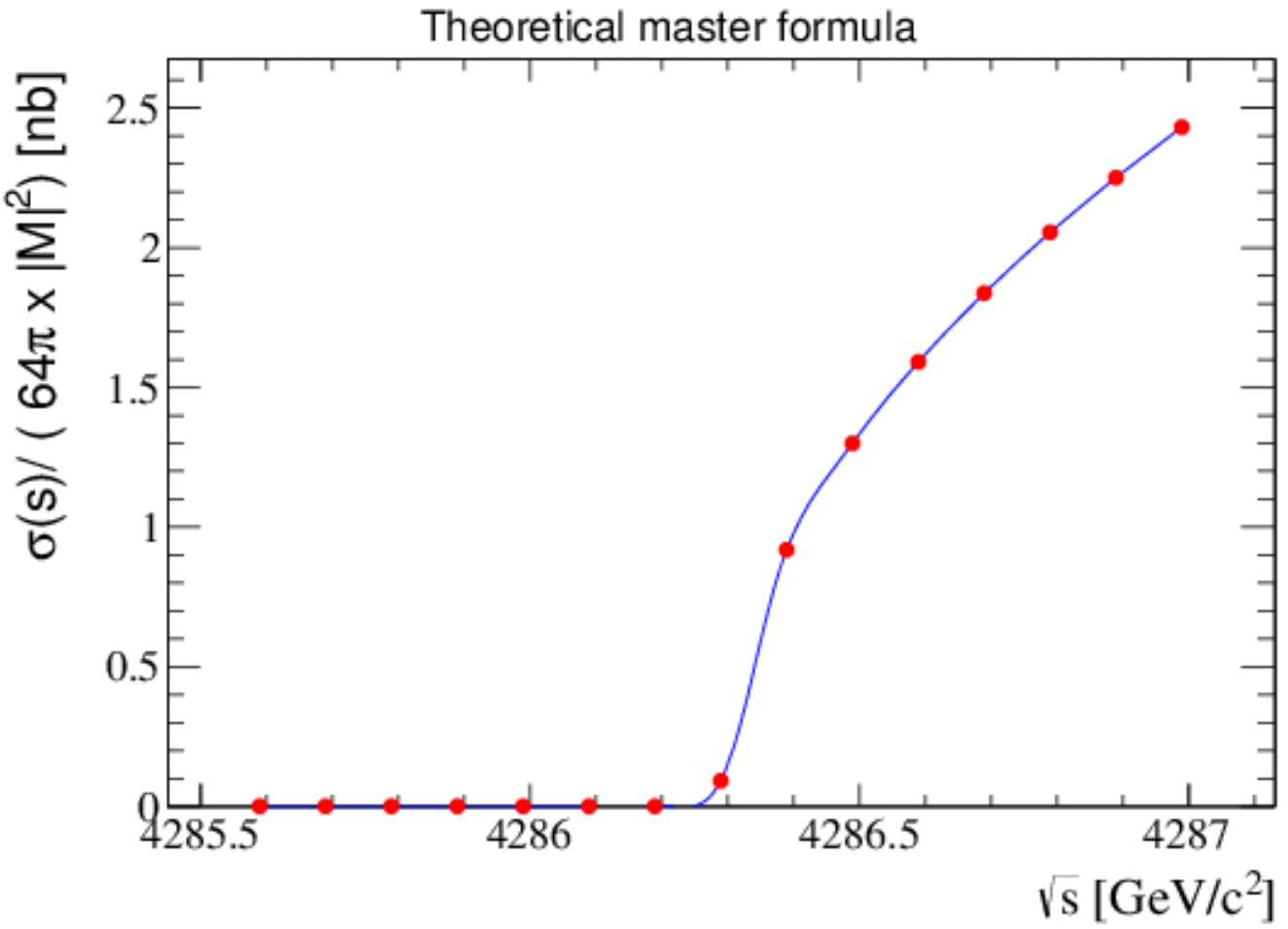
$\tilde{\tilde{E}} = 2\,E/\Gamma^*$

Many thanks to Christoph Hanhart for his extremely useful help!

$\mu = MM^*/(M+M^*)$

$$\sqrt{\tilde{\tilde{E}}} \cdot \int d\delta / (\delta^2+1) = \pi$$

$$\Phi(E) \rightarrow \sqrt{\mu\Gamma^*}\ \sqrt{2E/\Gamma^*} = p^{cm}_{Ds2317} \qquad \text{for } \tilde{\tilde{E}} >> 1$$



MC simulation – decay chain

noPhotos

Decay pbarpSystem
D_s0*+ D_s- PHSP;

Decay D_s+
K- K+ pi+ DS_DALITZ;

Decay D_s0*+
D_s+ pi0 PHSP;

- MC simulations: $D_s(2317)^+$ decays 100% to $D_s^+ \pi^0$
- Approach: D_s^- is reconstructed;
  $D_s(2317)^+$ is obtained as <u>recoil</u> of D_s^-
  because of the higher rate

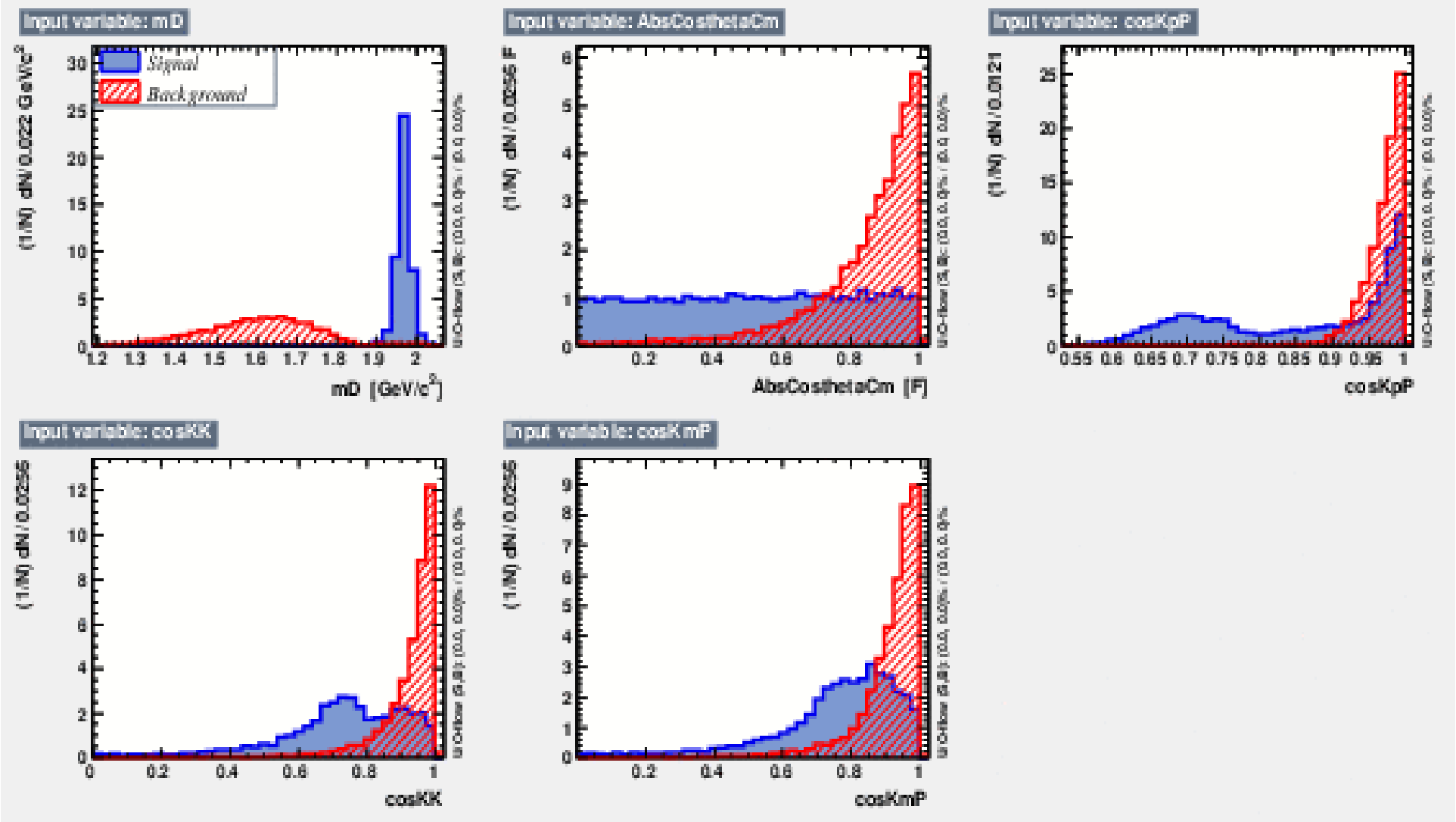
$$m_{recoil} = \sqrt{(M_{tot} - E^*_{D_s})^2 - p^{*2}_{D_s}}$$

- MC simulation: the approach works by definition....
- DATA: everything allowed, on the D_s^- recoil;
  need to fix selection criteria to identify $D_s(2317)^+$

Selection

Pre-selection	PID PndKinVxt fitter (prob, χ^2) Track momentum Photon momentum
selection	ϕ mass range ΔE signal range Ds. Ds2317 mass range 3 charged track – Ds daug. BDT, NN, LK, F (5 var)

Sig/Bkg discriminant: 5 variables

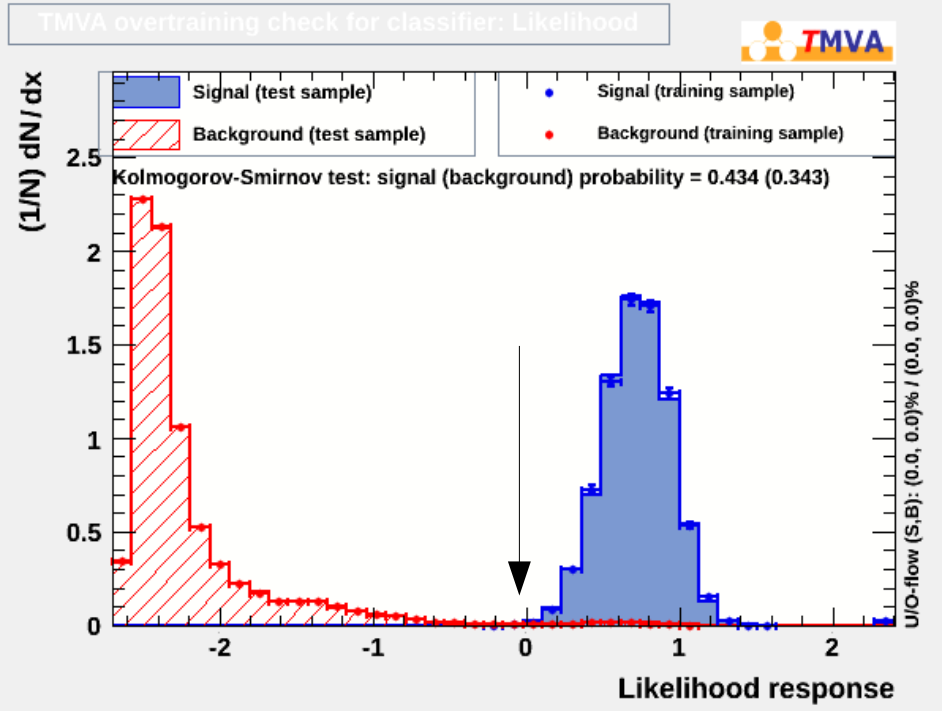


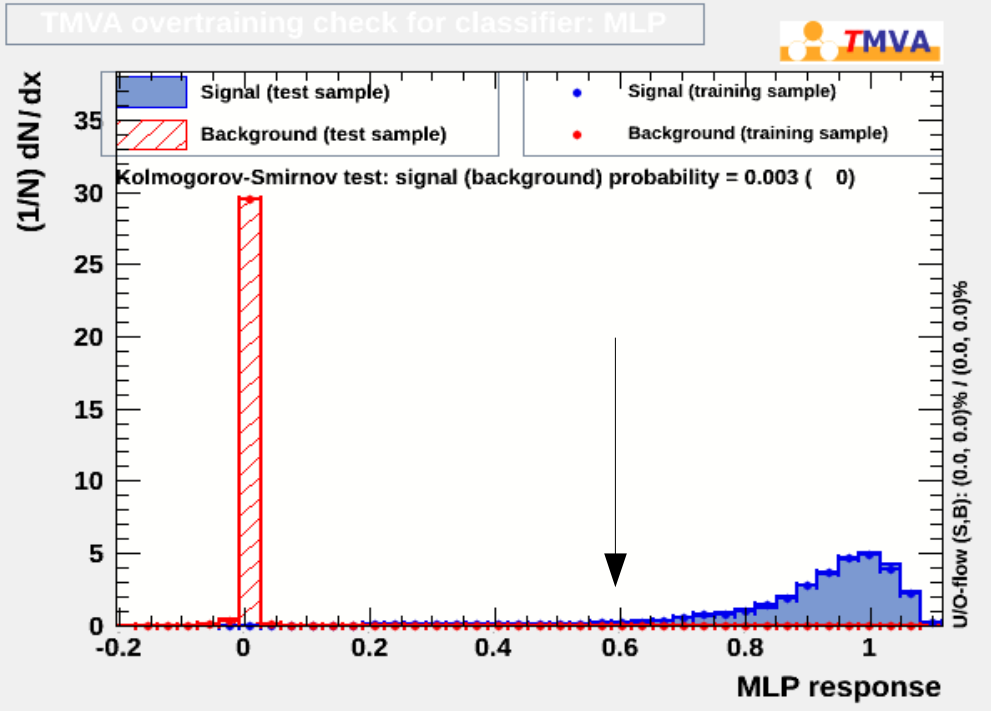
Sig/Bkg discriminants

- 4 attempts: F, LK, MLP, BDT
- Macro used: /tutorial/analysis/TMVATrainer.C
  /tutorial/analysis/TMVATester.C (new trunk)

- Release oct14:
  ~ 800k DPM jobs, 500 events/each , ~29Mb/each → >23 Tb (*pid.root)
  200k signal events, produced with EvtGen

Likelihood vs NN



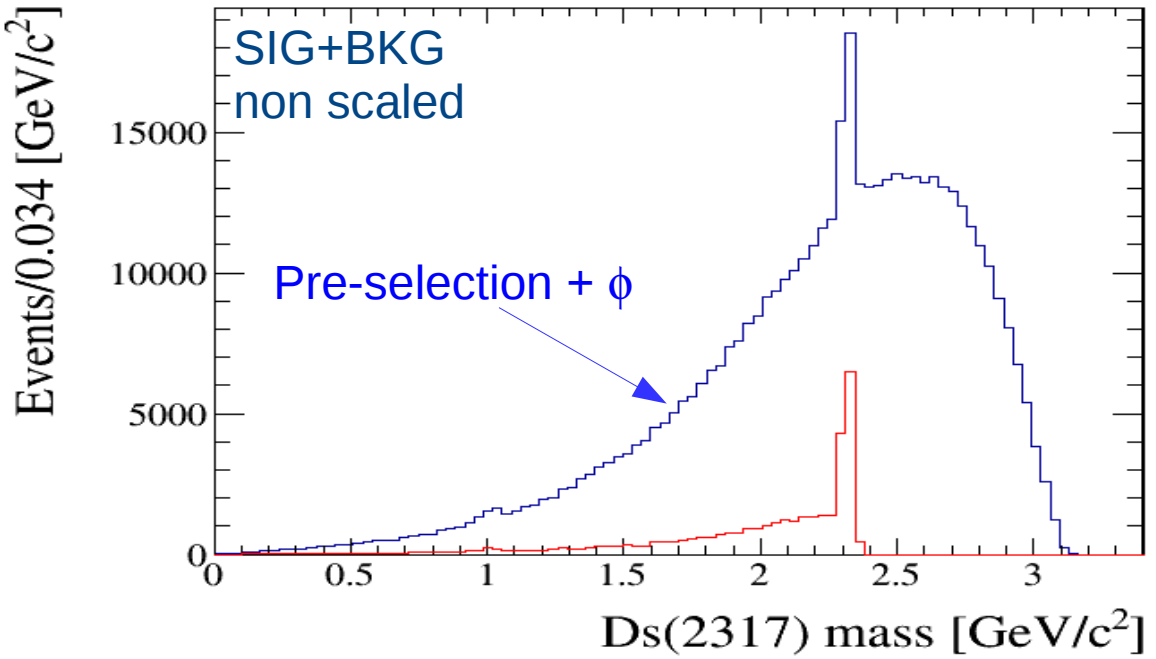


- Test: 200k sig, 45M DPM events
- PID
- PndKinFit
- Prob χ^2>0.01; χ^2<14

- Training: 5 variables

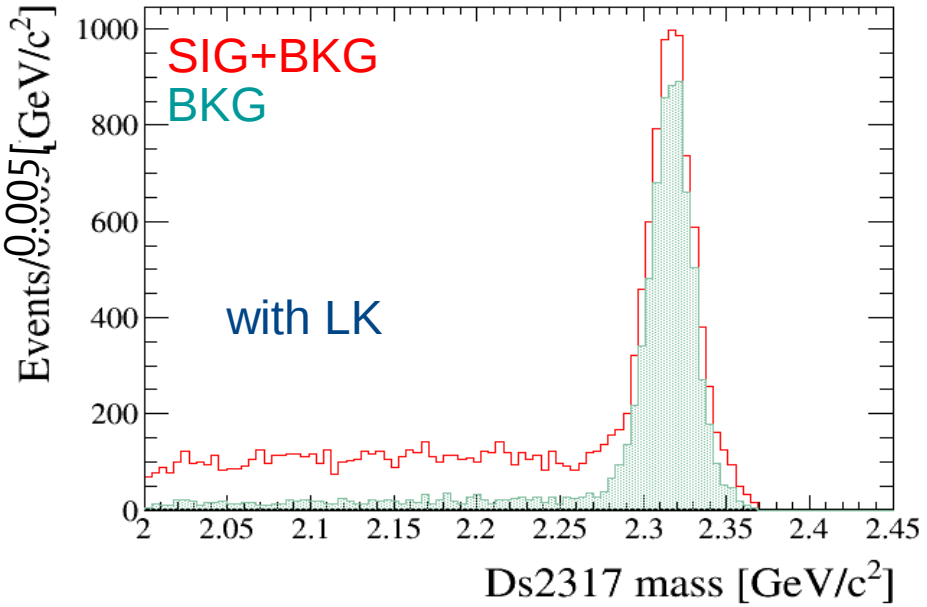
Pre-selection

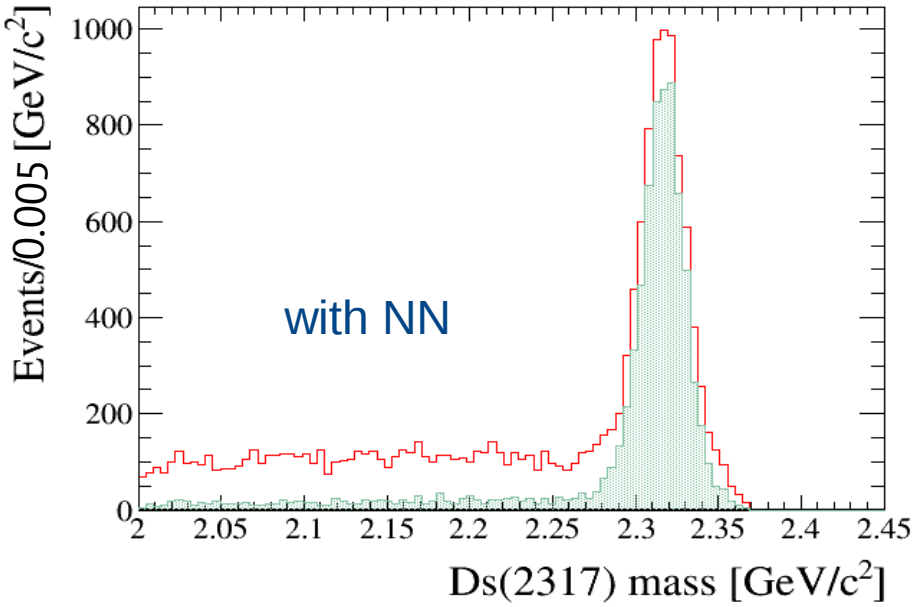
- Pre-selection + |ΔE| + ϕ cut

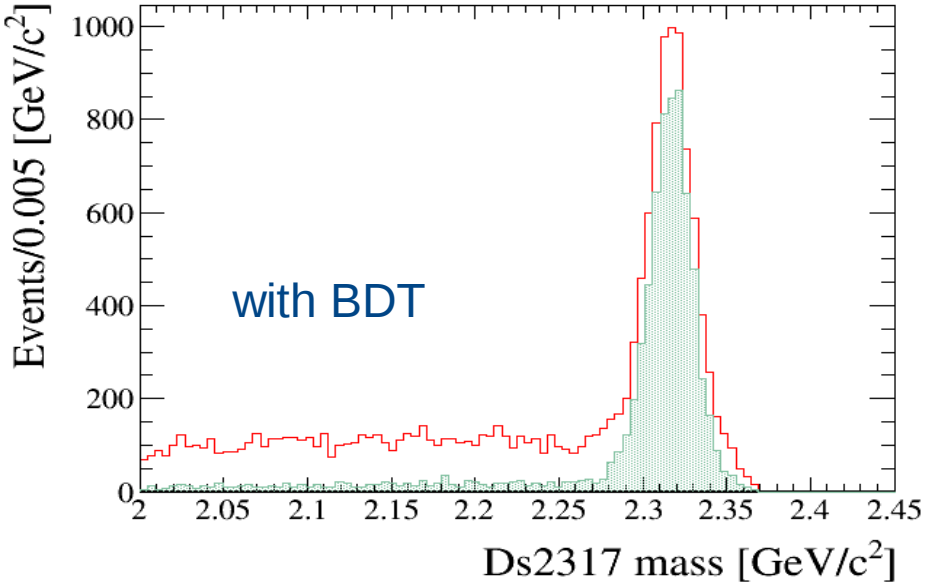


- |ΔE| < 50 MeV
- 1.004< ϕ mass < 1.034 GeV/c^2

LK, NN, BDT: mass distribution - comparison







Pre-selection+ |DE| + LK/NN/BDT +

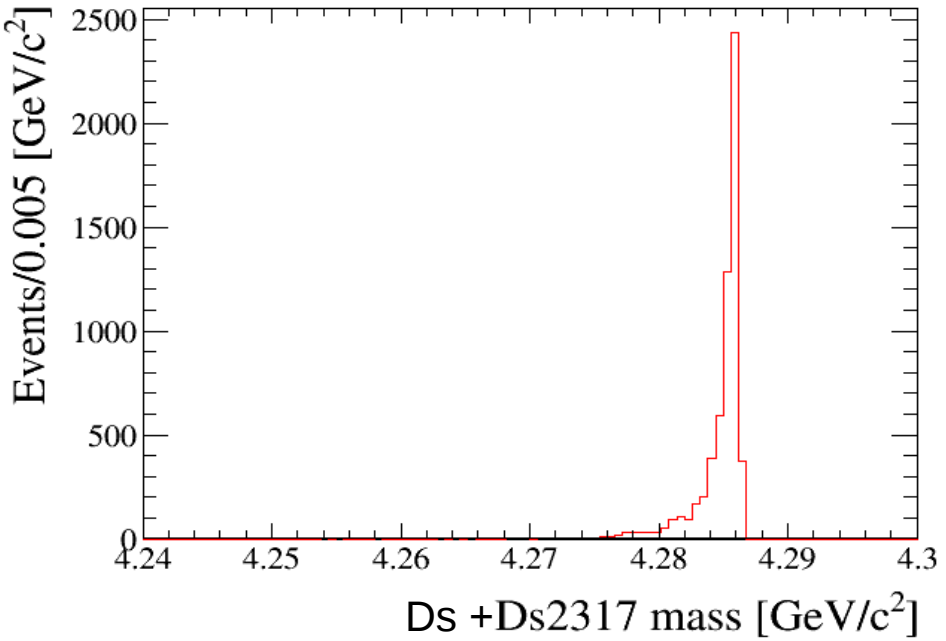
- Vertex cuts:
  |x|, |y| < 2 mm
  |z| < 3 mm

LK, NN, BDT comparison

- Remaining DPM events, after Ds(2317) mass cuts: [2.24;2.38] GeV/c^2

LK	NN	BDT
143	138	118

- With BDT cut, Nsig = 6326/200000 ~ 3.2%
- With Fisher discriminant, ε ~ 2.2%
- With mass cut DsDs2317 >4.25 GeV/c^2, 0 DPM events remains



Need x10000 DMP stat

Background sources

Channel: $\bar{p}p \rightarrow D_s^{\pm} D_{s0}^{*}(2317)^{\mp}$

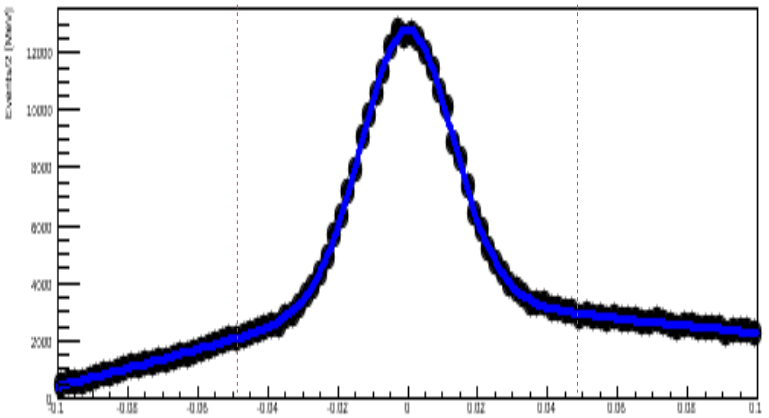
$D_s^{\pm} \rightarrow \phi\pi^{\pm}, \quad \phi \rightarrow K^+K^-$

$D_{s0}^{*}(2317)^{\mp} \rightarrow$ anything

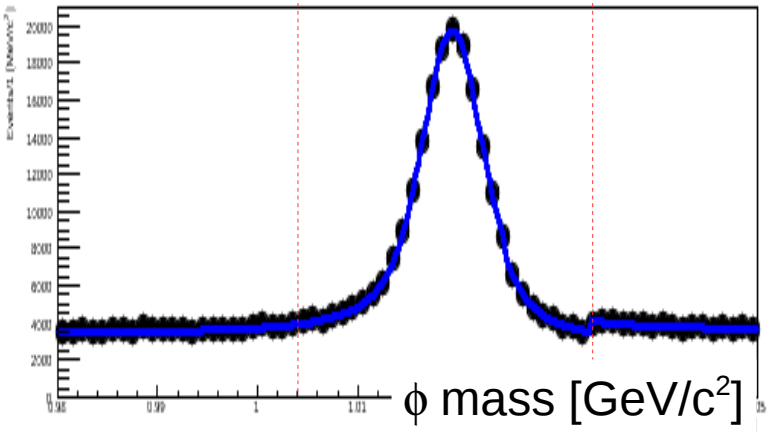
x ~10

Channel		
$\bar{p}p \rightarrow KK\pi$ + anything	~400M	σ = 53 mb /3 = 17.67 mb
$\bar{p}p \rightarrow D_s^{\pm} D_s^{\mp} \pi^0$	100k	σ same as signal
$\bar{p}p \rightarrow D_s^{\pm} D_s^{\mp} 2\pi^0$		
$\bar{p}p \rightarrow D_s^{\pm} D_s^{\mp} \pi^+\pi^-$		
$\bar{p}p \rightarrow D_s^{\pm} D_s^{*\mp}$		
$\bar{p}p \rightarrow D_s^{\pm} D_s^{*\mp} \pi^0$		
$\bar{p}p \rightarrow D_s^{\pm} D_s^{\mp} \gamma$		
$\bar{p}p \rightarrow D_s^{\pm} D_s^{*\mp} \gamma$		

ToyMC studies

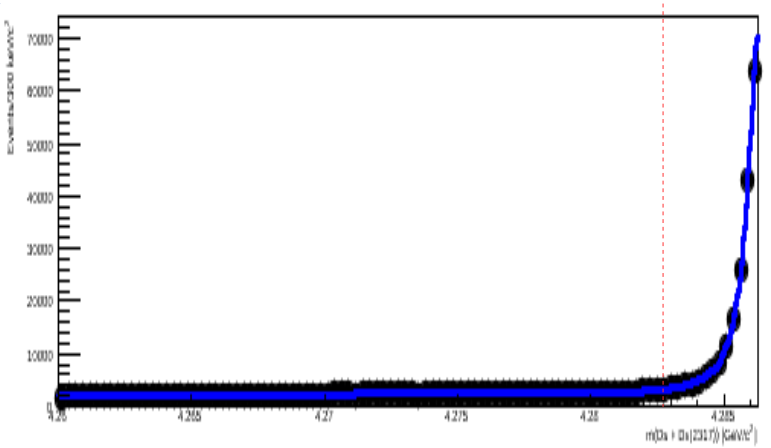


ΔE [GeV/]



ϕ mass [GeV/c^2]

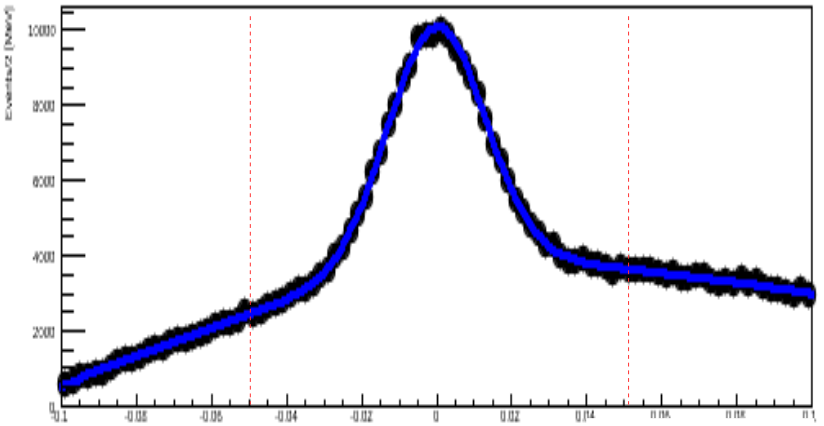
Generated events: 550000
S/B ~ 5:1 (signal area)
M_{tot} = 4286.430 ± 0.021 MeV/c^2



- ϕ mass resolution ~ 4 Mev/c^2\;
- ΔE resolution ~ 15 MeV;
- M_{tot} resolution ~ 0.9 MeV/c^2.

Loose cuts

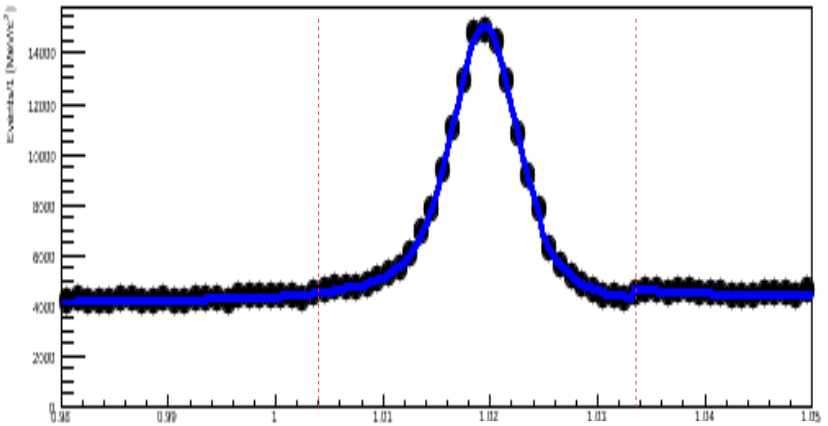
ToyMC studies



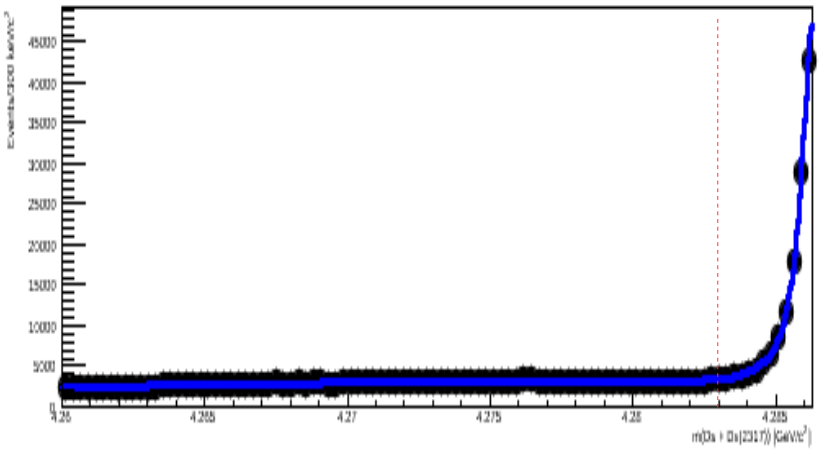
ΔE [GeV/]

S/B ~ 2:1 (signal area)

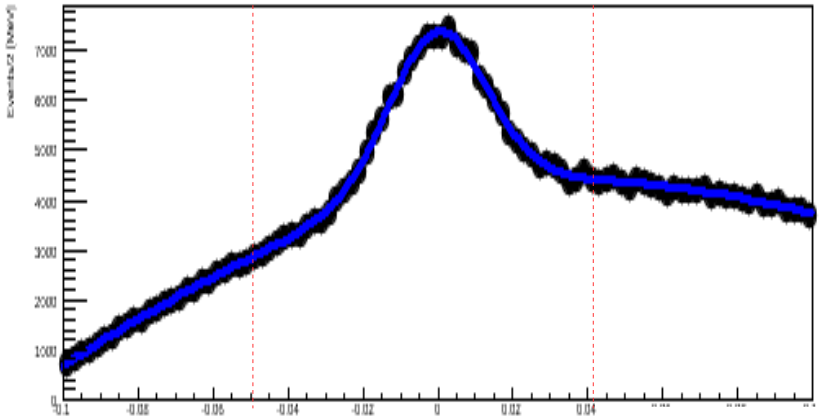
M_{tot} = 4286.520 ± 0.026 MeV/c^2



ϕ mass [GeV/c^2]



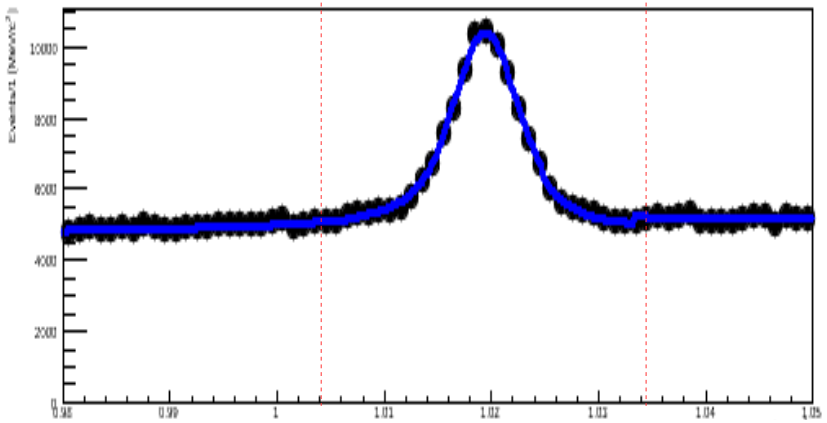
ToyMC studies



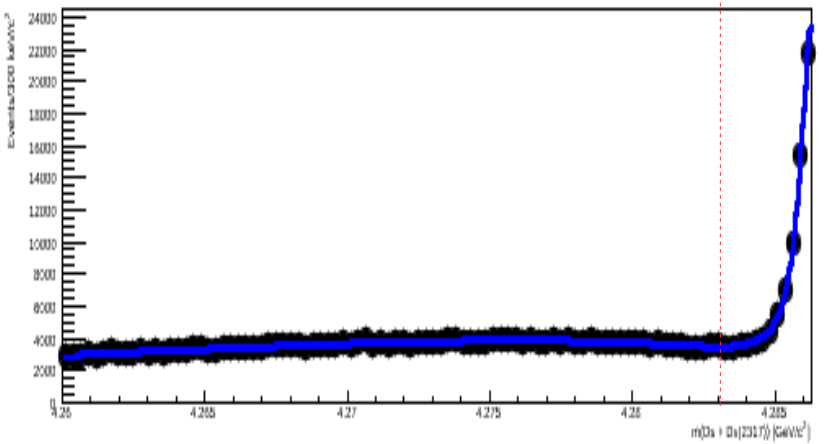
ΔE [GeV/]

S/B ~1:2 (signal area)

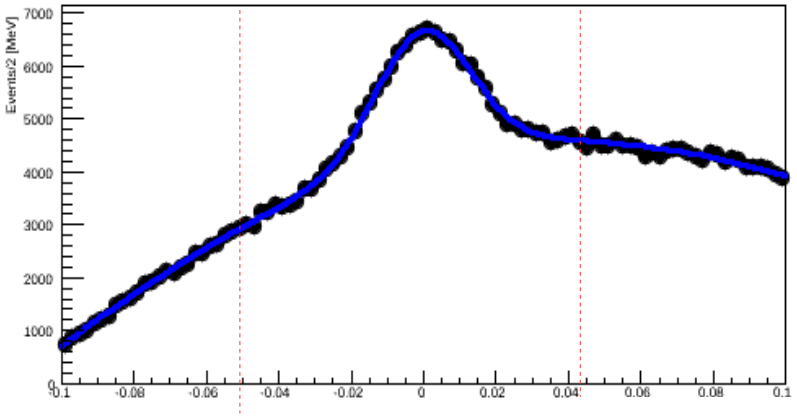
M_{tot} = 4286.530 ± 0.043 MeV/c^2



ϕ mass [GeV/c^2]



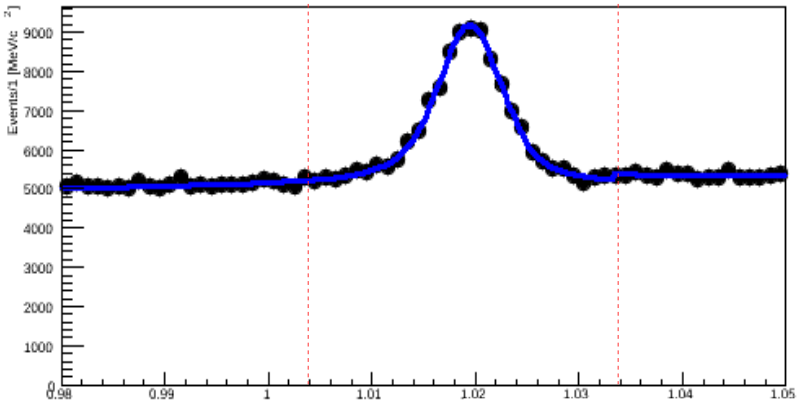
ToyMC studies



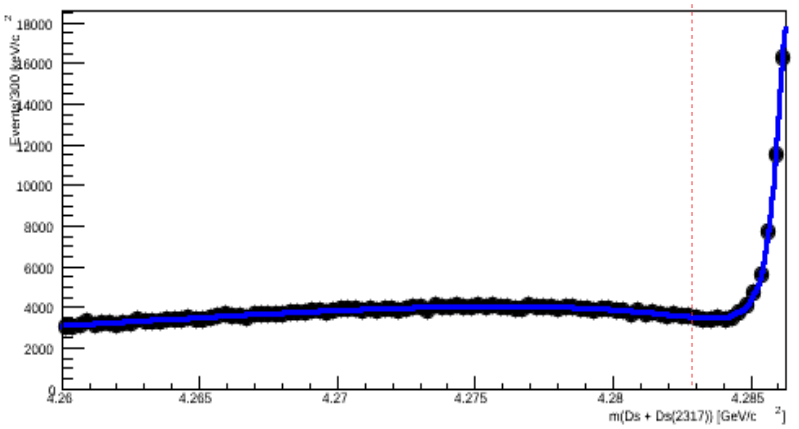
ΔE [GeV/]

S/B ~1:3 (signal area)

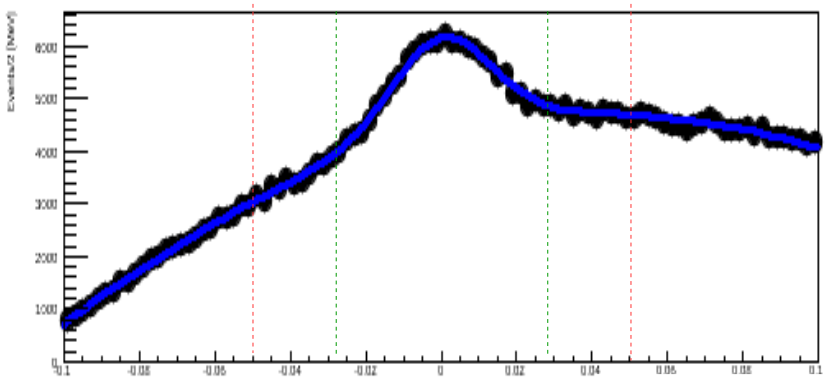
M_{tot} = 4286.530 ± 0.049 MeV/c^2



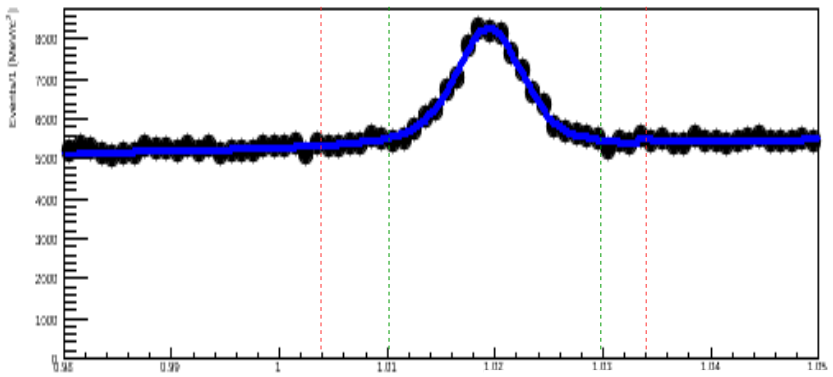
ϕ mass [GeV/c^2]



ToyMC studies



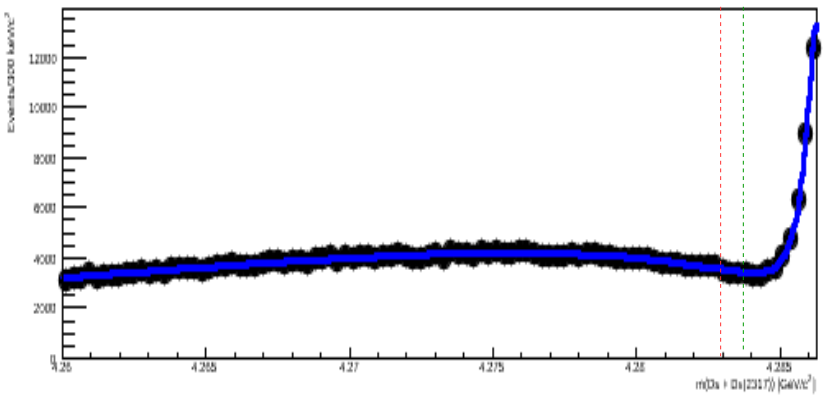
ΔE [GeV/]



ϕ mass [GeV/c^2]

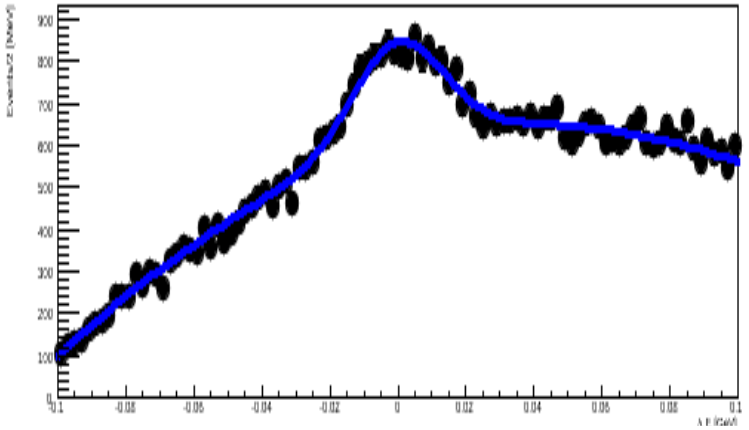
S/B ~1:5 (signal area)

M_{tot} = 4286.350 ± 0.061 MeV/c^2



...work in progress...

ToyMC studies

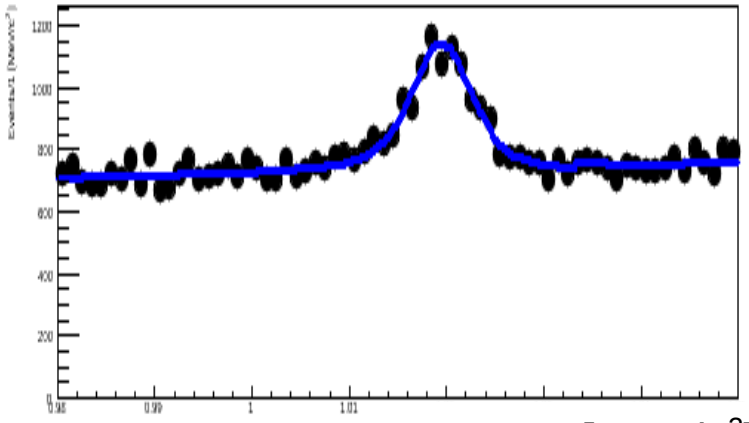


ΔE [GeV/]

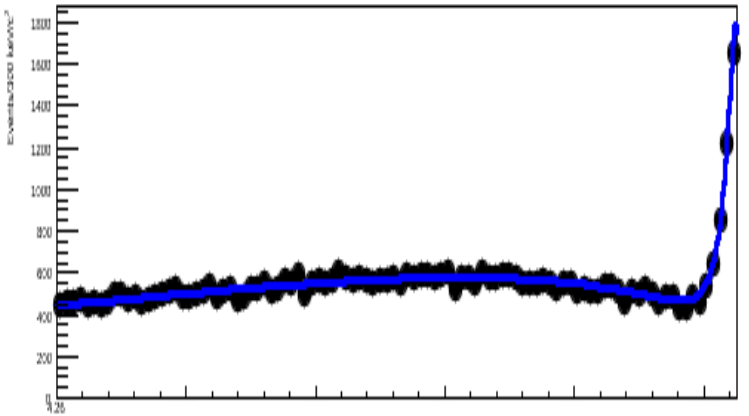
S/B ~1:5 (signal area)

55000 Toy-events produced

M_{tot} = 4286.350 ± 0.097 MeV/c^2



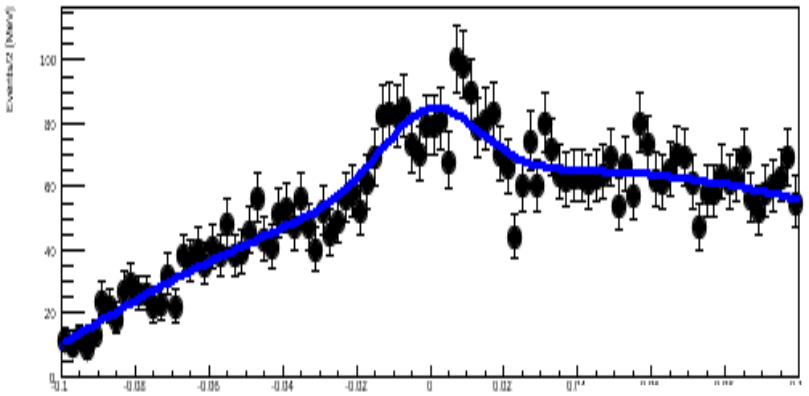
ϕ mass [GeV/c^2]



Ds + Ds2317 mass [GeV/c^2]

...work in progress...

ToyMC studies

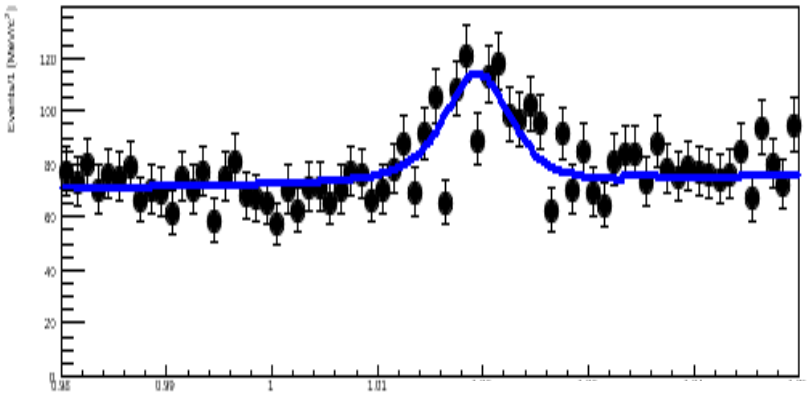


ΔE [GeV/]

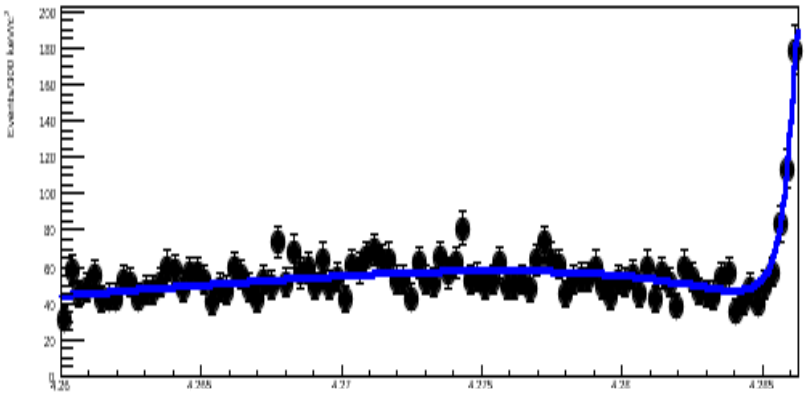
S/B ~1:5 (signal area)
5500 Toy-events produced

reconstructed events in PANDA

M_{tot} = 4286.38 ± 0.13 MeV/c^2



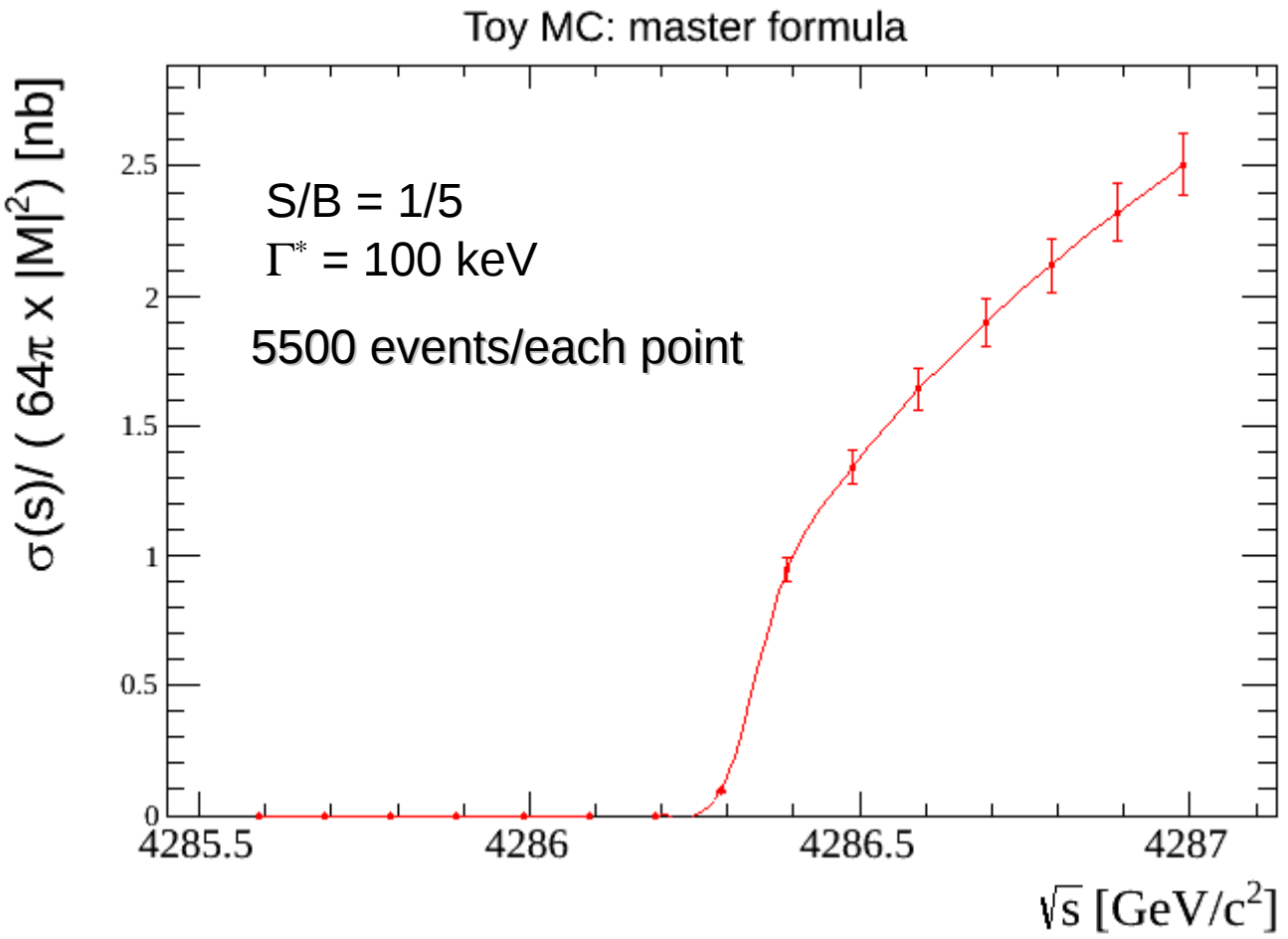
ϕ mass [GeV/c^2]



Ds + Ds2317 mass [GeV/c^2]

...work in progress...

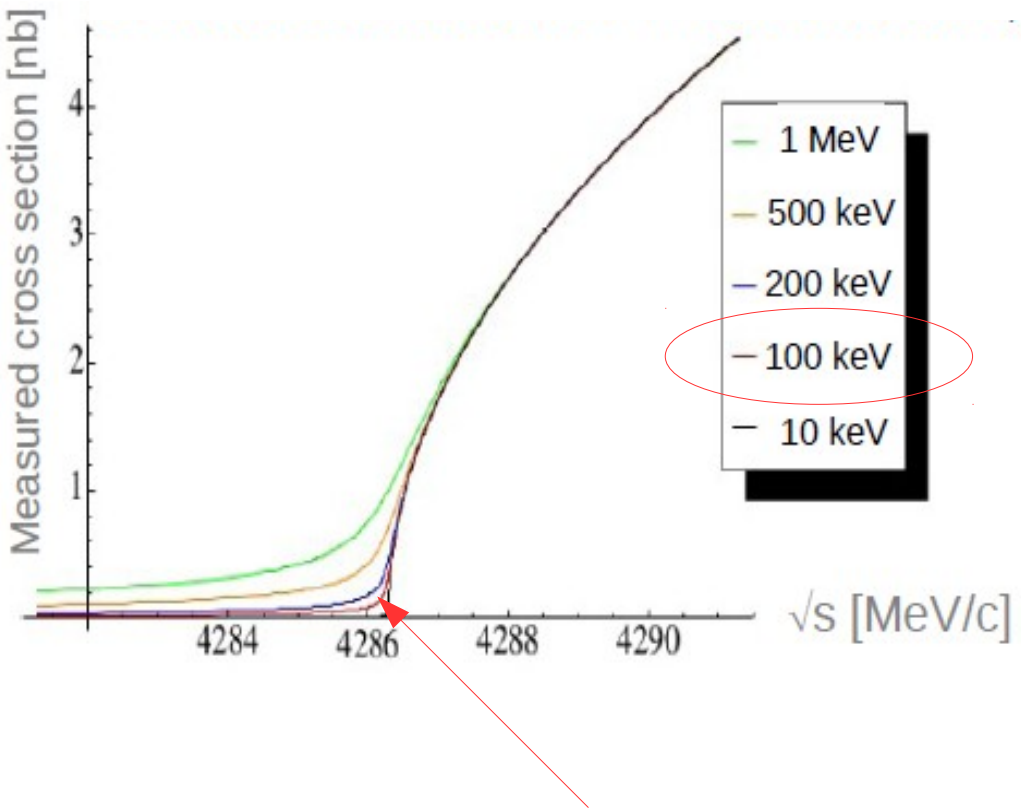
ToyMC studies



Only indetermination due to the M_{tot} fit is included, for now.

...work in progress...

Marius' plot



- Formula here is valid for same particles in the final state
- Small differences with the correct formula for different particles in the final state, due to mass difference

- Critical question: which precision we need (e.g. how long we have to run) to distinguish among different hypothesis?

Full simulation needed to understand

Expected produced events

Input σ (nb)	Produced events per day (HL)	Produced events per day (HR)
20	172 800	17 280
10	86 400	8640
5	43 200	4320
2	17 280	1728
1	8 640	864

- Conservative range: σ [1 – 100] nb
- With **L = 10^{31} cm^{-2} s^{-1}** (average), **864** produced events/day (hyp: **σ = 1nb**)
- B factories:
  S/B ~ 5/1, ε = 8.2% in $e^+e^- \rightarrow D_s D_{s0}^*(2317)$;
  S/B ~ 2/1, ε ∈[0.42-2.75] $\cdot 10^{-4}$ through B decays.
  } Belle, Phys. Rev. Lett. 92, 012002 (2004) Phys. Rev. Lett. 91, 262002 (2003)

  Belle II will collect 43750 $D_{s0}^*(2317)$ in 10 years ($\mathscr{L}$ = 50 ab^{-1})

Up to know I got 3.2% reconstruction efficiency.....

Open-issues

- Mass fit constraint to Ds mass: still to try, when I can run again jobs at GSI/prometheus
- Theoretical work on the master formula: how to publish that?
- PID: “best” and “VeryLoose” lists give comparable results.
- New cut, not still included: distance between the vertex of Ds and Ds2317.
- BDT is part on the analysis macro: it will be used in the analysis procedure.
  need to try on the full 400M DPM statistics.
- Optimization of the pdfs ongoing: need the full DPM statistics
- Need to optimize the χ^2 cut.
- Expected efficiency: a few point per cent!
- Need to select the best Ds candidate, yet.
- Only one Ds channel considered: KKπ.
- A new version of the document will be uploaded, with the new ToyMc studies.

That's all for today!