Sensitivity studies on S/B for the channel $\bar{p}p \rightarrow D_{s0}^{*}(2317)^{+} D_{s}^{-}$

Analysis note v2 - A. Gillitzer, J. Ritman, E. Prencipe

September 9th, 2015 | Elisabetta Prencipe, Forschungszentrum Jülich | Charm meeting

Outline

- Motivation
- On the interference in $\bar{p}p \rightarrow D_{s0}^{*}(2317)^{+} D_{s}^{-}$
- Answers to the questions from the "outside world"
- Analysis strategy
- Background characterization
- Rate estimates
- Systematic uncertainties
- Summary and future plans → Publication as PLB?

Outline

Goals of this talk:

- answer to the main questions risen during the past one year, during public talks at workshop/conferences (2014/2015)

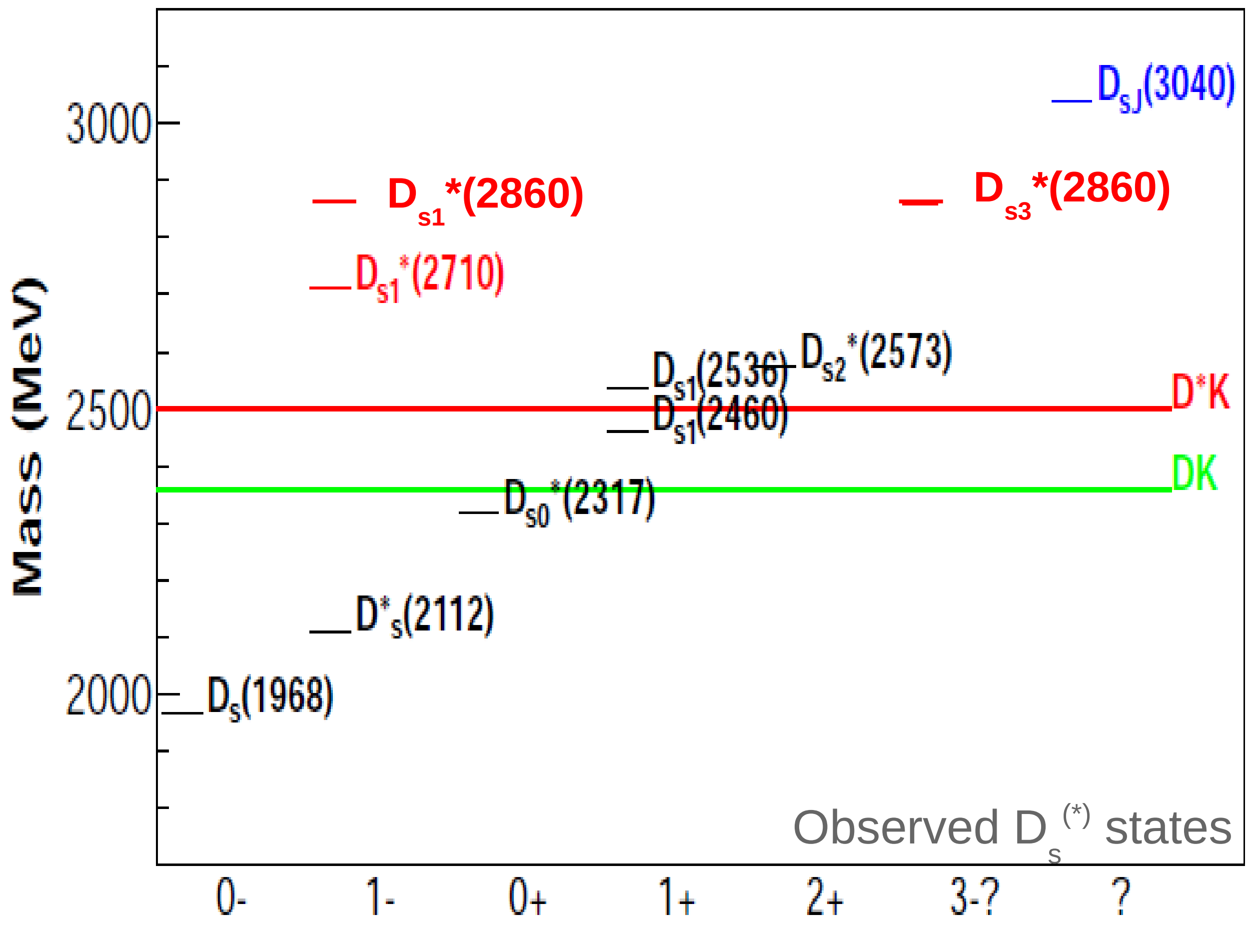
- show the status of the full simulation on the proposed channel

- summary of the published results during the past year (2014)

- discussion on how to proceed

- plan for the publication

D_s spectroscopy, today



Highlighted papers: $D_{s0}^{*}(2317)^{+}$

“Observation of a narrow meson decaying to $D^{+}_{s}\pi^{0}$ at a mass of 2.32-GeV/c^{2}“

Phys.Rev.Lett. 90 (2003) 242001

e-Print: hep-ex/0304021 | PDF

Experiment: SLAC-PEP2-BABAR

719 citations

BaBar: experiment optimized for CP violation, measurement of angles and sides of the CKM matrix. For comparison:

“Observation of CP violation in the B^{0} meson system”

Phys.Rev.Lett. 87 (2001) 091801

e-Print: hep-ex/0107013| PDF

Experiment: SLAC-PEP2-BABAR

720 citations

The more a paper is cited,
the more the topic is challenging!

My original plan:
- to work on $D_{s1}(2460)$ and $D_s(2536)$
- check the analysis strategy on $D_{s0}^*(2317)$, for consistency

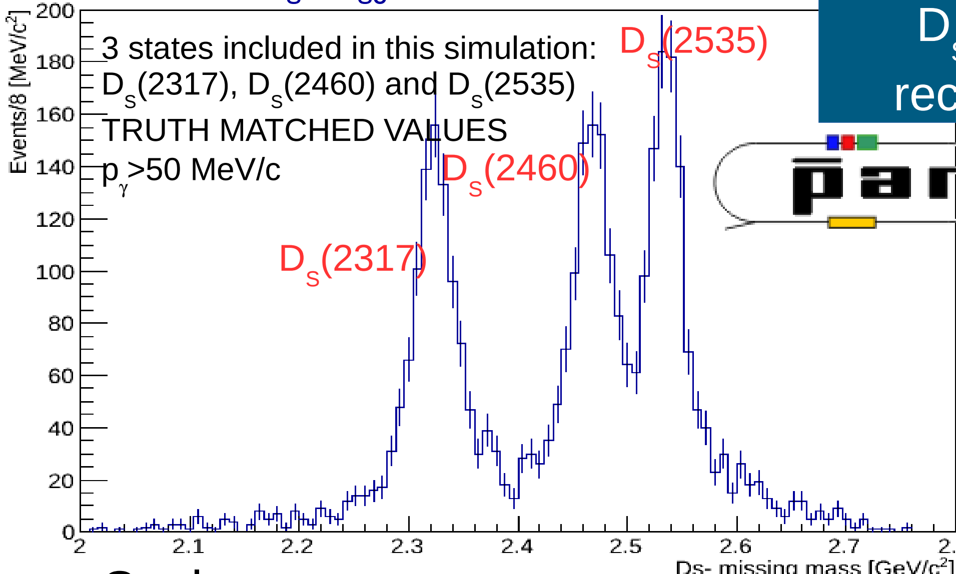
Since 1 year I have been working on the $D_{s0}^*(2317)$

This is the first full simulation performed with pandaroot on $D_{s0}^*(2317)$

D_s meson spectroscopy at $\bar{P}$ANDA

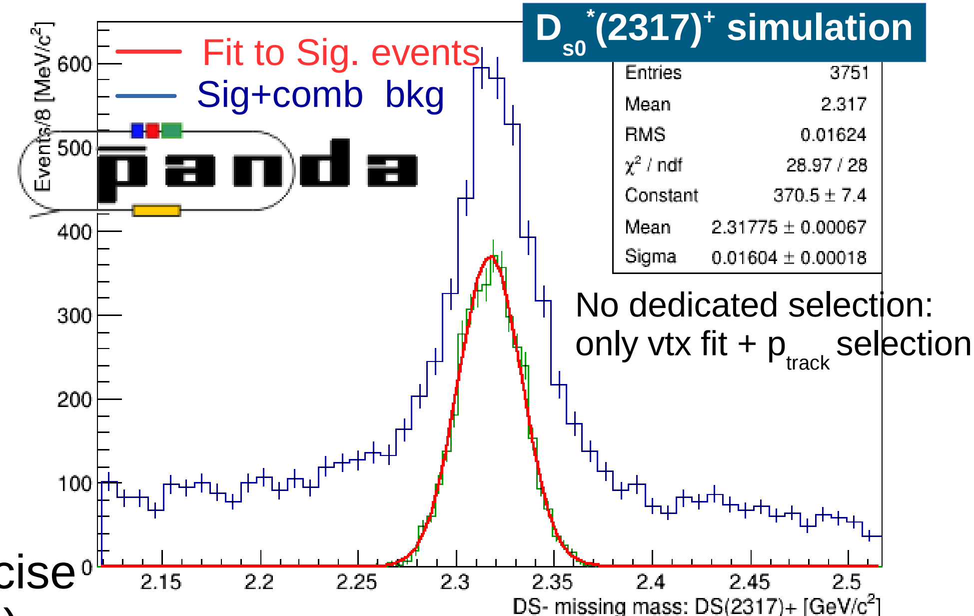
E.P., arXiv:1410.5201 [hep-ex]; EPJ Web of Conf 95 (2015) 04052

- $\bar{p}p \rightarrow D_s^- D_{sJ}^{(*)+}$



D_s^- recoil

- Recoil mass of D_s^-: improve mass resolution and efficiency
- D_{SJ} reconstructed exclusively to evaluate the width
- Bkg cross section > thousand times than expected on signal



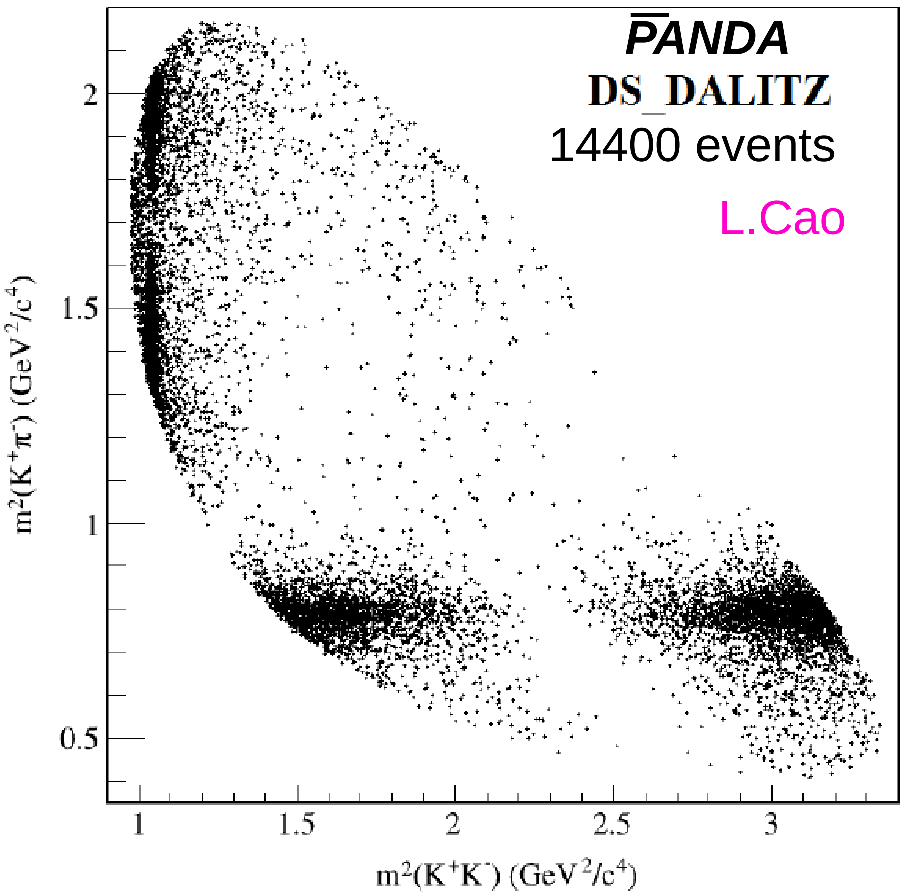
No dedicated selection: only vtx fit + p_{track} selection

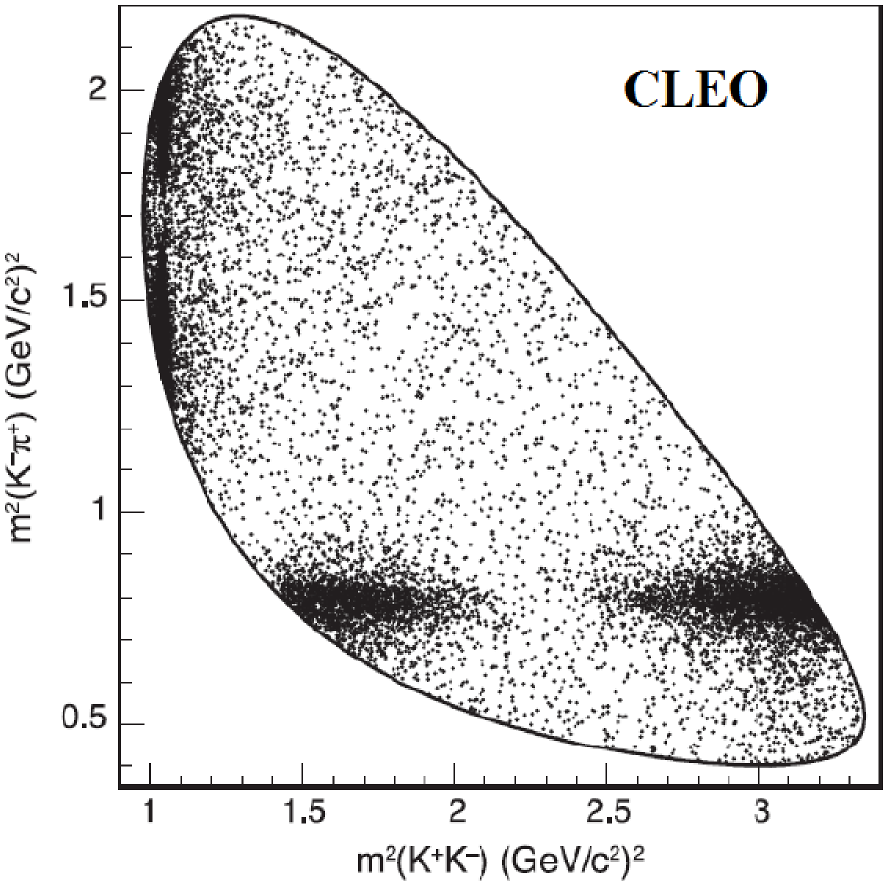
- Goals:

1. Cross section measurement in $\bar{p}p$ (unknown, difficult predictions: [1-100] nb)
2. Measurement of the width with mass scan and the excitation function of cross section
3. Mixing between D states with same J^P, e.g. $D_{S1}(2460)$ and $D_{S1}(2535)$
4. Chiral symmetry breaking, involving very precise mass measurement: $D_{S0}(2317)$ and $D_{S1}(2460)$ can be interpreted as chiral partners of the same heavy-light system
5. Study of the invariant mass system $D_s^- D_s^{*+}$

D_s recontruction: Dalitz model

EPJ Web of Conf 95 (2015) 04052

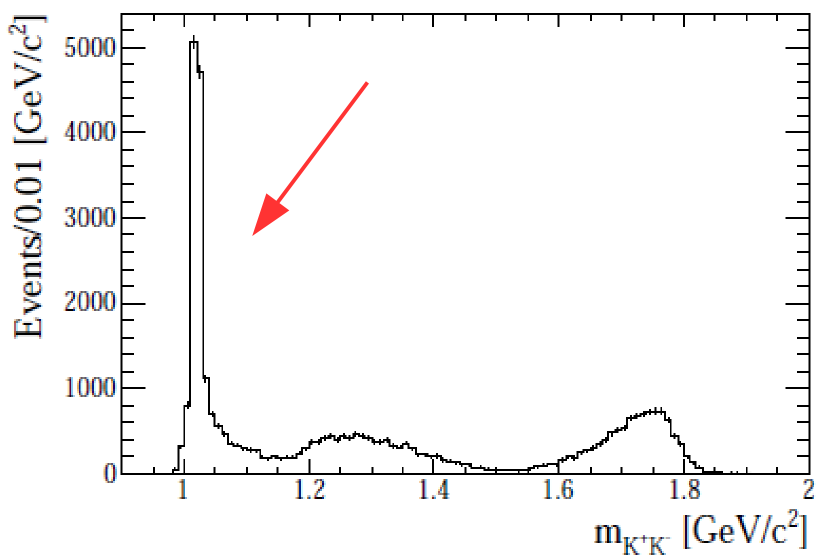


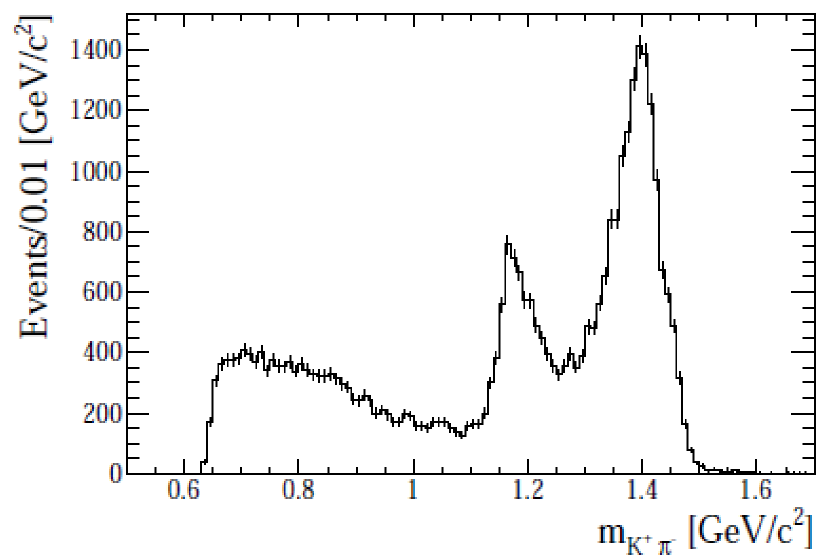


See poster session @ ICHEP 2014 (Lu Cao, selected poster on 15/234)

Realistic MC simulations!

D_s recontruction: Dalitz model

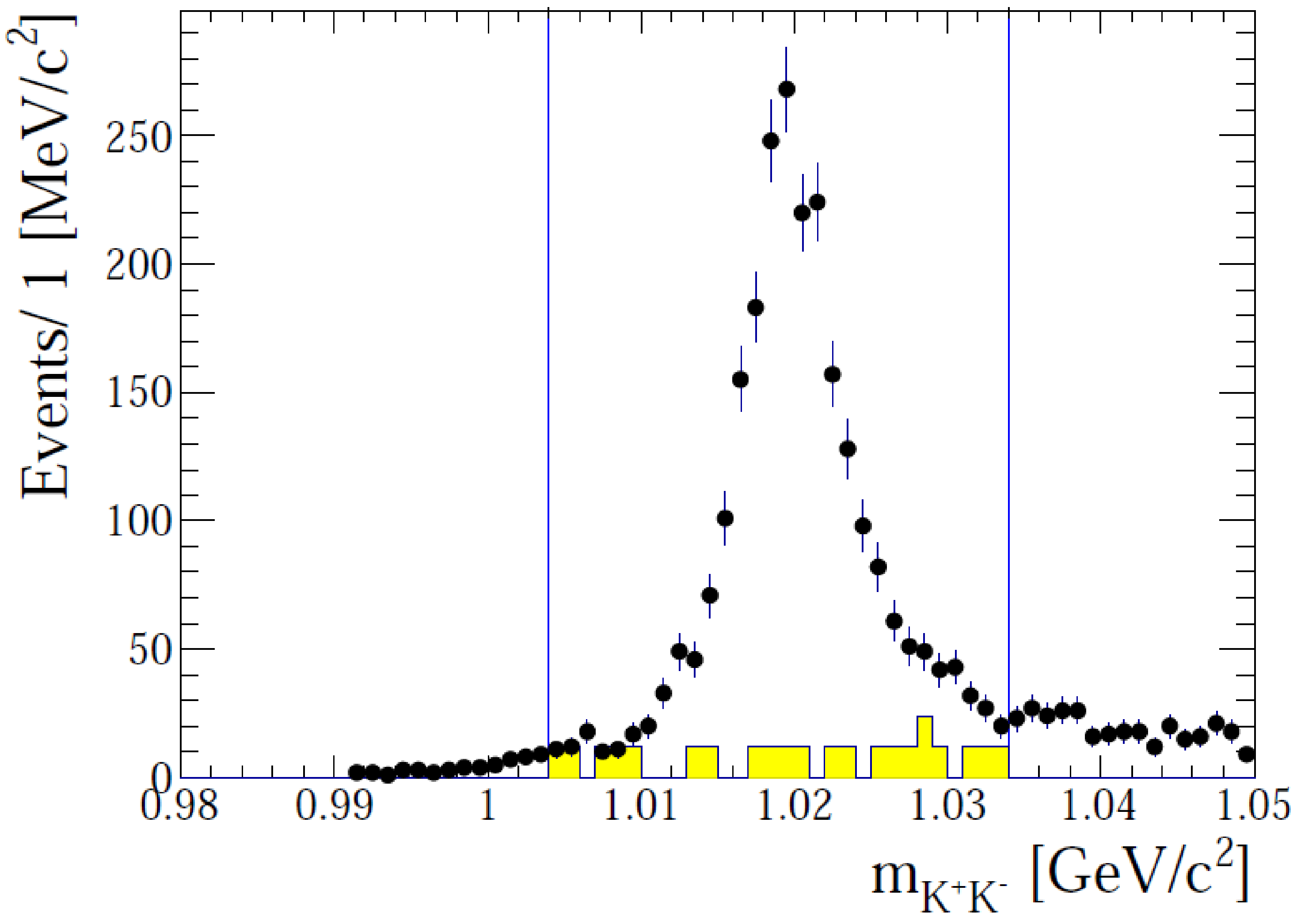




- $D_s^- \rightarrow K^+K^-\pi^-$
- Several structures inside the Dalitz plot: this is not smooth PHSP!
- K^+K^- invariant mass will be restricted to the ϕ signal area

consequence: efficiency decreases ~ 3 times; but bkg drastically reduced

ϕ signal area

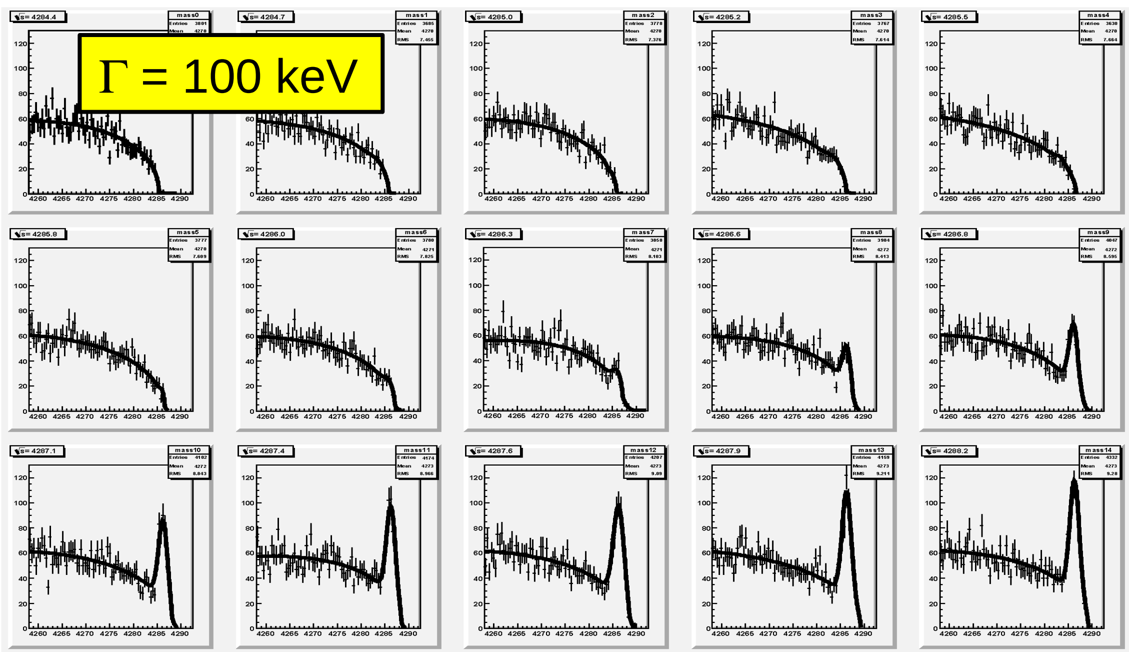


Zoomed figure

DPM bkg scaled to arbitrary number: it is linear

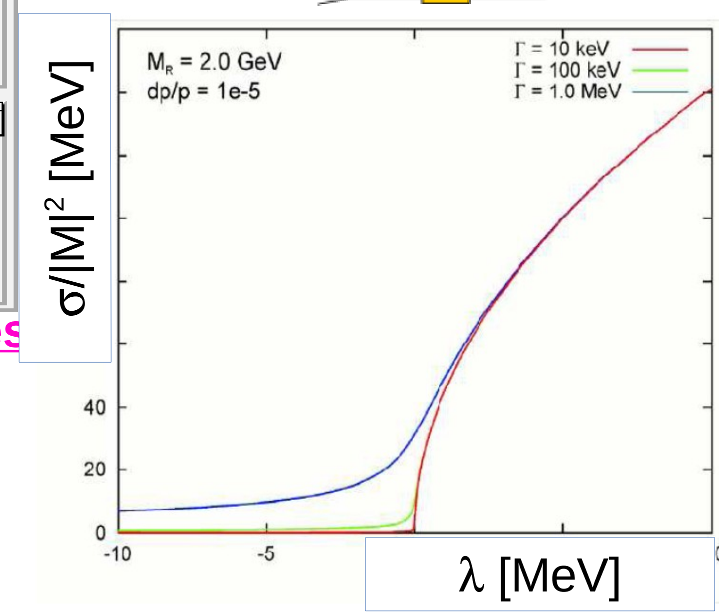
Width of the $D_{s0}^{*}(2317)^{+}$ with $\bar{P}$ANDA

- $D_{s0}^{*}(2317)^{+} \rightarrow D_s^{+} \pi^0$



PhD thesis, M. Mertens, based on **ToyMC studies**

What do we want to measure?
How?



- PDG: Γ <3.8 MeV at 95% c.l.
- Excitation function of the cross section(*):

$$\sigma(\lambda) = \sqrt{m_R \Gamma} |M^2| \frac{1}{\pi} \int_{-\infty}^{\lambda} \mathrm{d}x, \frac{\sqrt{\lambda - x}}{x^2 + 1}$$

$$\sigma(0) = \sqrt{\frac{m_R \Gamma}{2}} |M^2| \qquad \lambda = \sqrt{s} - 2m_R$$

$\bar{p}p \rightarrow D_s(2317)^{+} D_s(2317)^{-}$

(*) easy formula, assuming identical final states: $\bar{p}p \rightarrow D(2317)^{-} D(2317)^{+}$

First question:

What is the formula of the excitation function of the cross section when the final state is composed by 2 different particles?

Ongoing discussion since February 2015 with theorists:
the calculation was done again.
The difference is not too big, due to the similar mass values of D_s and $D_s(2317)$

$\sqrt{m_R/2}$	$\sqrt{M_R M_{Ds2317} / (m_R + m_{Ds2317})}$
0.9921	1.0316

This calculation is only related to the term in front of the matrix element

Width of the $D_{s0}^{*}(2317)^{+}$

$\bar{p}p \rightarrow D_s(2317)^+ D_s^-$, $D_s(2317) \rightarrow D_s^+ \pi^0$

$$\sigma \propto |\mathcal{M}|^2 \sqrt{2\mu}\,\Gamma^* \frac{1}{\sqrt{s}} \times \int_{-\infty}^{\lambda} dx \frac{1}{x^2 + \frac{\Gamma^2}{m^2}} \sqrt{(\lambda+1)^{\frac{1}{2}} - (x+1)^{\frac{1}{2}}}$$

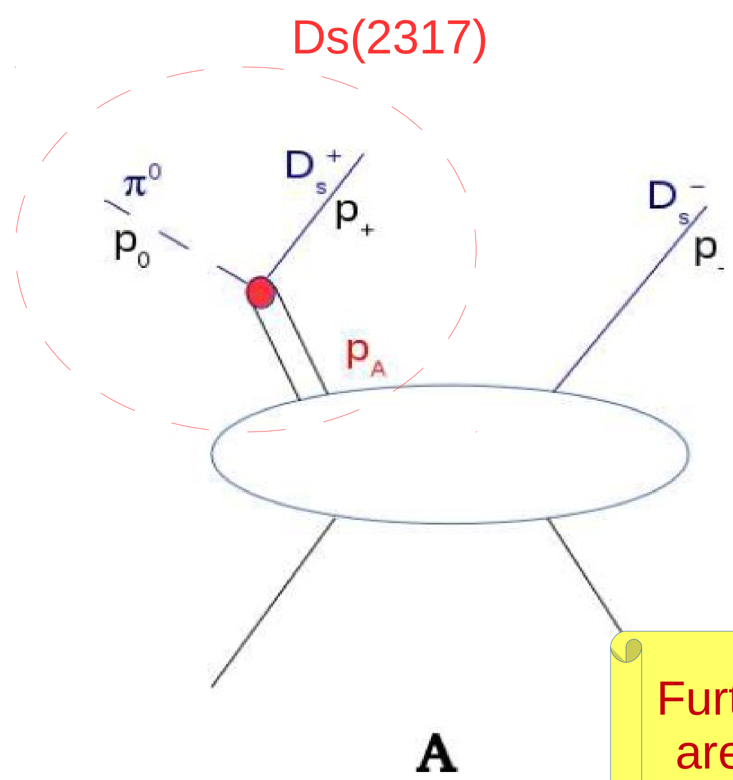
Γ^* = width of the D_s

Γ = width of the $D_s(2317)$

$$\mu = \frac{m \cdot m_{Ds}}{m + m_{Ds}} \approx \frac{m \cdot m_{Ds}}{\sqrt{s}}$$

$$\bar{\lambda} = \sqrt{s} - M_{Ds}$$

$$\lambda = \frac{\bar{\lambda}^2 - M^2_{Ds2317}}{M^2_{Ds2317}}$$

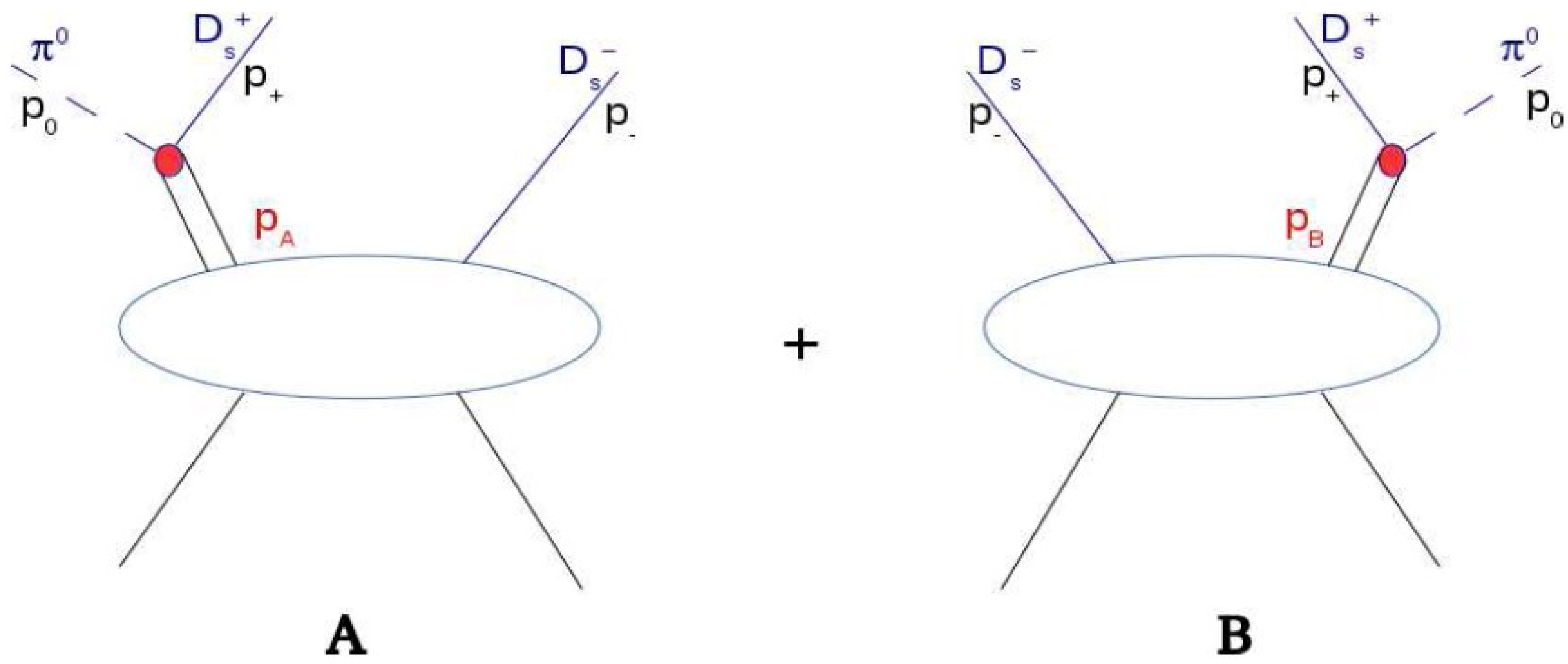


- Calculation is performed in absence of interference effects

Further checks are ongoing...

Interference effects: graphs

How the formula changes in case of interference in $D_s^- D_s^+ \pi^0$?



$D_s^- D_{s0}^*(2317)^+$ and $D_s^+ D_{s0}^*(2317)^-$ systems decay to $D_s^- D_s^+ \pi^0$

$$(2317 - 135 - 1968)\ \mathrm{MeV}/c^2 = 214\ \mathrm{MeV}/c^2 \Rightarrow \frac{\Gamma}{2 \cdot E_R} \ll 1$$

$D_s(2317)^+$ π^0 D_s^+

$$\sigma \sim 4\pi \int d\phi(E, p_+, p_-)\delta^{(1)}(E - p_-^2, E - p_+^2) \times \left| \frac{g}{2M*(E - \frac{p_+^2}{2\mu}) + iM*\Gamma*} + \frac{g}{2M*(E - \frac{p_-^2}{2\mu}) + iM*\Gamma*} \right|^2$$

- In case interference enters in the calculation, it is challenging to extract the width of the $D_{s0}^*(2317)$: no clue from theorists

- We assume <u>interference does not occur</u>: how can we justify this assumption?

Interference effects: question

Do $D_{s0}^{*}(2317)^{+}$ and D_{s}^{-} interfere, in $\bar{p}p \rightarrow D_{s0}^{*}(2317)^{+} D_{s}^{-}$?

NO, because they have different spin parity, and

NO, because PANDA is a 4π experiment

BUT....

"when you will run real data, you will see: you must cut at some angles, because of nasty noisy low energetic photons. This might lead to an interference effect. Nobody studies those effects up to now. Are these effects studied somehow in PANDA?" (A.B.)

1. We reconstruct $D_{s0}^{*}(2317)^{+}$ on the recoil of D_{s}^{-};
2. We have studied possible interference effects in the system $D_{s}^{-}D_{s}^{+}\pi^{0}$

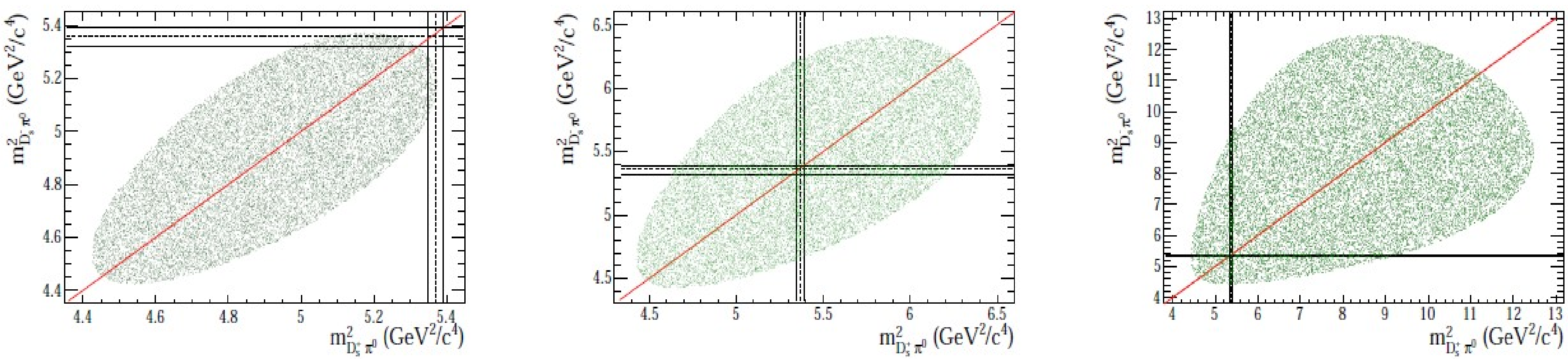
Interference effects: $D_s^+ D_s^- \pi^0$ Dalitz

JÜLICH FORSCHUNGSZENTRUM

$\bar{p}p \rightarrow D_s(2317)^+ D_s^-$, $D_s(2317) \rightarrow D_s^+ \pi^0$

Interference occurs if $m(D_s^+\pi^0) = m(D_s^-\pi^0) = m(D_{s0}^*(2317))$

$\sqrt{s_1}$ and $\sqrt{s_2}$: the higher and lower energy limits → Interference occur!



(a) $\sqrt{s} = 4.286$ GeV (b) $\sqrt{s} = 4.500$ GeV (c) $\sqrt{s} = 5.500$ GeV

- $\sqrt{s} < \sqrt{s_1}$: no interference
- $\sqrt{s_1} \leq \sqrt{s} \leq \sqrt{s_2}$: interference can occur
- $\sqrt{s} > \sqrt{s_2}$: no interference

$$\sqrt{s_1} - \sqrt{s_{th}} = 12.027 \text{ MeV}$$

$$\sqrt{s_2} - \sqrt{s_{th}} = 6.777 \text{ GeV}$$

Interference in our case does not occur [4.28629 -4.28699 GeV]

Technique validation

“How can you be sure that the shape of the excitation function of the cross section will be not affected from any interference effect?” (A.B.)

1. We study a final state composed by particles with different spin parity.
2. In the $D_s^+ D_s^- \pi^0$ 3-body PHSP no interference effects occur, in the energy range under study [4.28629 – 4.28699] GeV.
3. We will measure the excitation function of the cross section of $D_s(2536)^+$, in the process $\bar{p}p \rightarrow D_s(2536)\, D_s$; this is know and measured (PDG).

$$\Gamma = (0.92 \pm 0.35)\ \mathrm{MeV}$$

Ir we can confirm this PDG measurement, this channel could validate our proposed technique, on data, and the measurement of the $D_{s0}^*(2317)$ width is believable.

...on the $\bar{p}p$ coupling

"How do you perform your simulation?
Did you study different couplings to the $\bar{p}p$ system?"
(from several people in the audience)

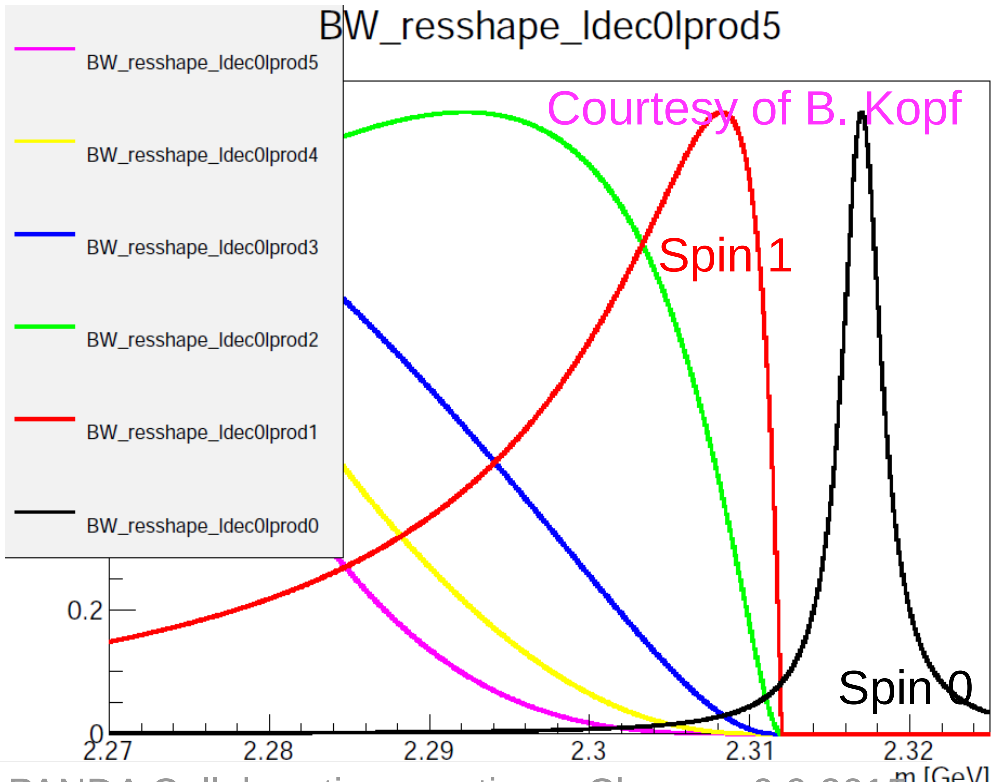
1. A full simulation $\bar{p}p \rightarrow D_s(2317)D_s$ in PANDA is ongoing (S-wave: spin = 0)
2. Tracking, PID, full detector geometry is in this framework
3. Different couplings to the $\bar{p}p$ system have been under study: this can affect <u>of course</u> the shape of the excitation function of the cross section

<u>BUT</u>

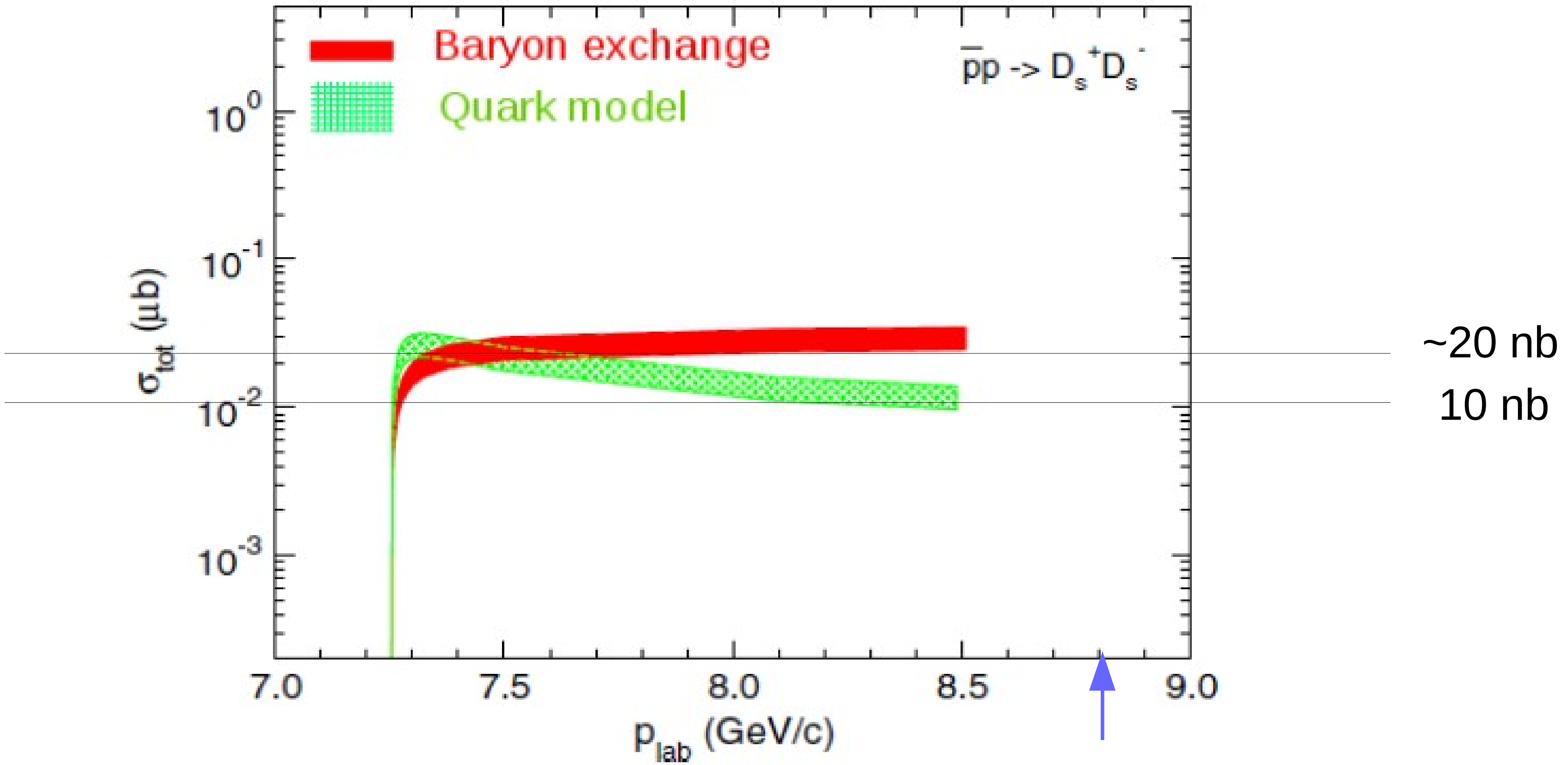
as we run at the threshold production of the $D_s(2317)D_s$ system, we assume that spin-0 or spin-1 can be the only cases that can occur. It is a <u>reasonable assumption</u>.

p ϵ [8.80235 (threshold) – 8.80557] GeV/c

$D_s + D_s(2317) = 4.28629$ Gev/c^2



Theoretical cross section estimate



J. Heidenbauer, G. Krein, Phys. Rev. D **89**, 114003 (2014)

Hypothesis: SU(4) symmetry is valid

Nothing is known about $D_{s0}^{*}(2317)$

Assumption: $1<\sigma<20$, p ≥8.80225 Gev/c

“Do not take it too simple: this analysis is complicated!” (A.B.)

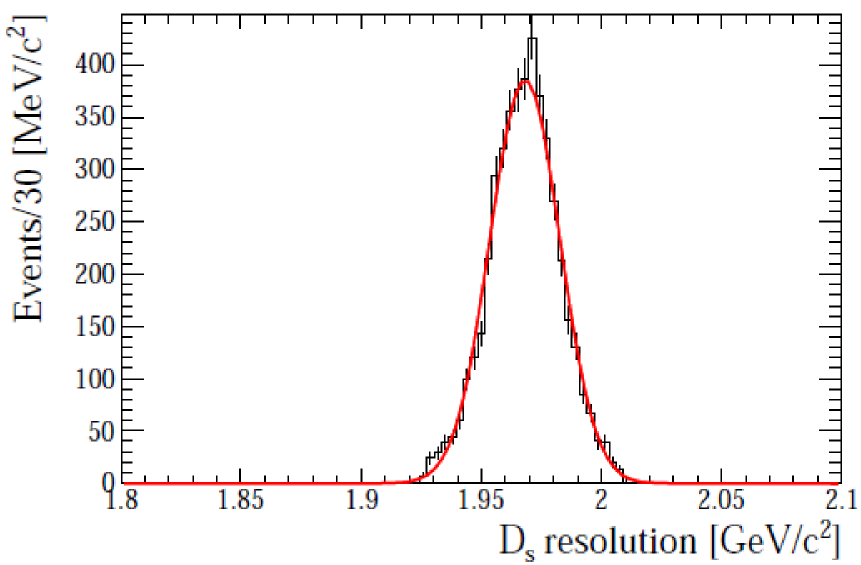
We do not

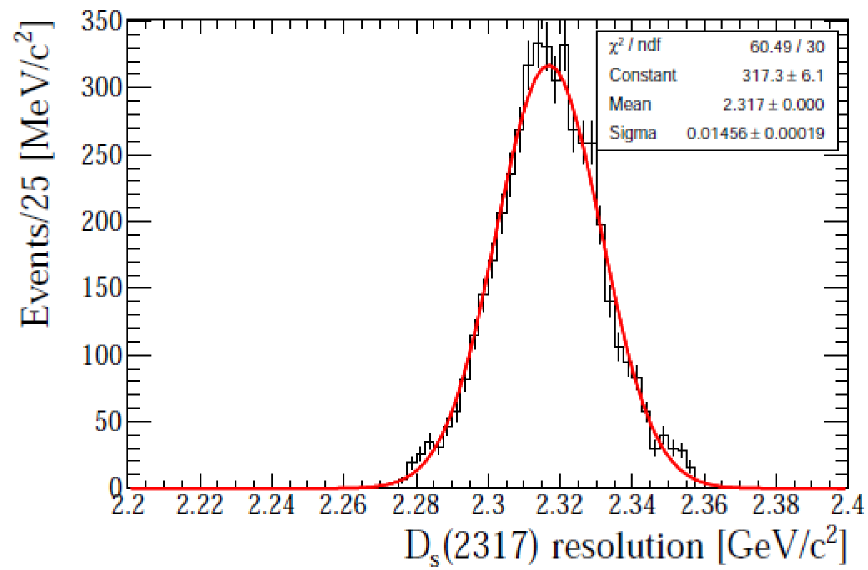
Strategy

- (semi)inclusive analysis Single tag mode
- p_{beam} $\geq$8.8 GeV/c. 8 scan points!
  $p_{beam} = 8.80235$ GeV/c, $M_{tot} = 4.28629$ GeV/c^2
- *Geant3*
- Monte Carlo (MC) generator EvtGen: 200k signal events, each scan point
- Dual Parton Model (DPM) : 40M bkg events
- reconstruction chain under study is $\bar{p}p \to D_s^- D_{s0}^*(2317)^+$
  $D_s^- \to K^+ K^- \pi^-$
- model used to simulate D_s events: DS-DALITZ
- PandaRoot release: *oct*14
- PID: “best”
- Fisher, Likelihood or Neutral Network discriminant to suppress the background

$D_{s0}^{*}(2317)^{+}$ as recoil of D_s^-

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

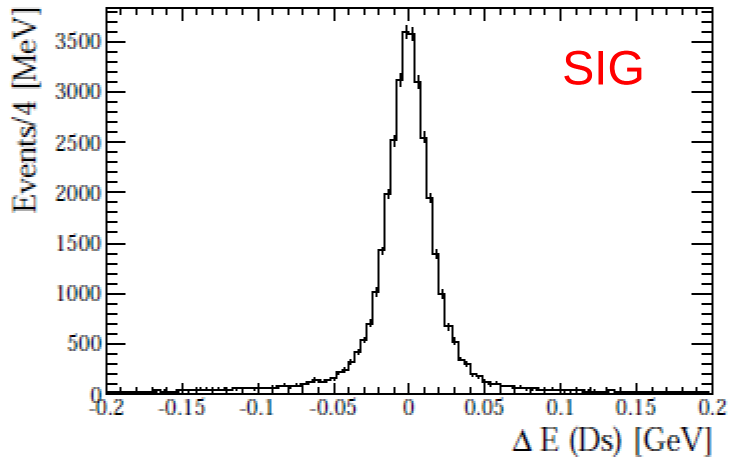


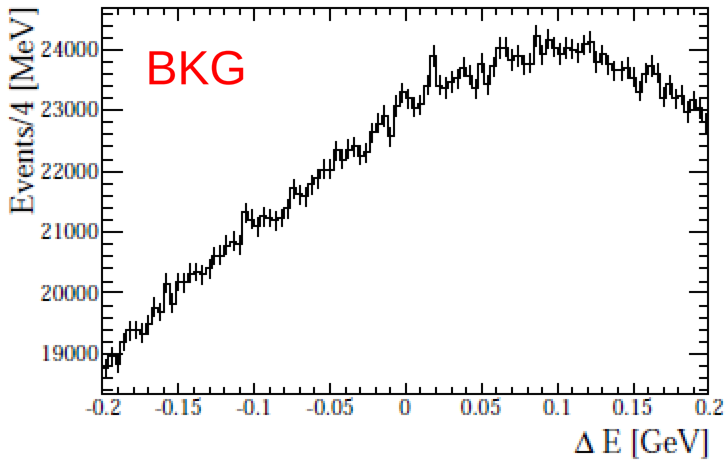


$$D_s^- \rightarrow K^+ K^- \pi^-$$

- Mass resolution: 14.56 MeV/c^2
- P_{beam} is fixed. No smearing in pandaroot:
  some studies presented at Coll meeting Mar2014 when applying smearing
  $\Delta p/p \sim 10^{-4}$

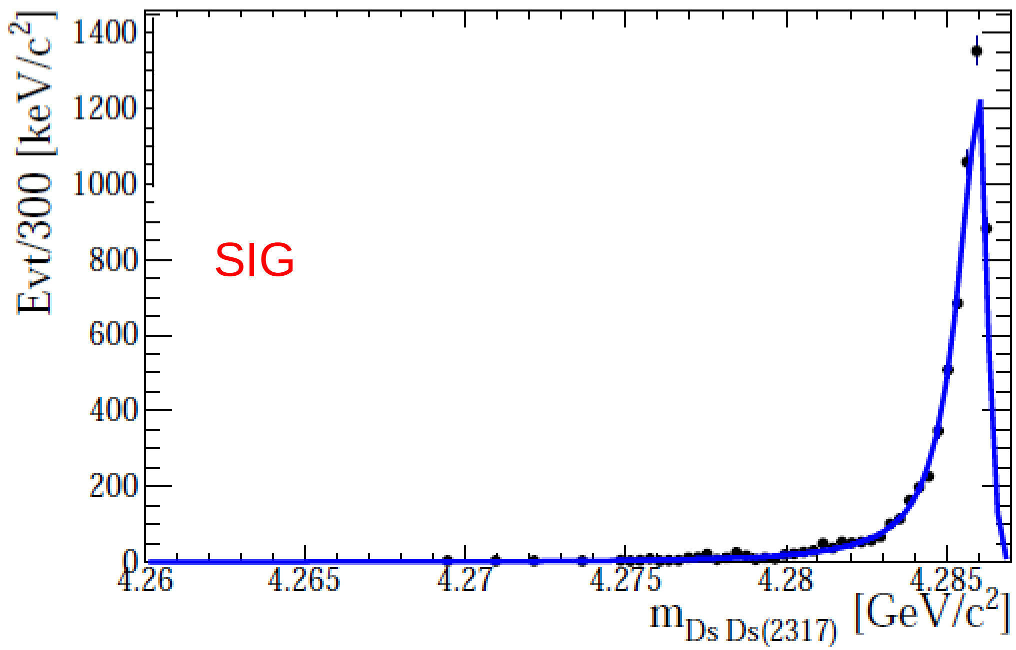
Interesting variable: ΔE





- Difference between the energy of the D_s in the c.m. and its nominal value
- Expected a distribution centered in 0.
- Double gaussian parametrization for signal; polynomial for bkg

Interesting variable: $D_s + D_s(2317)$



$$\frac{dn}{dm} = \frac{q}{(m_r^2 - m^2)^2 + m_R^2 \times G^2}$$

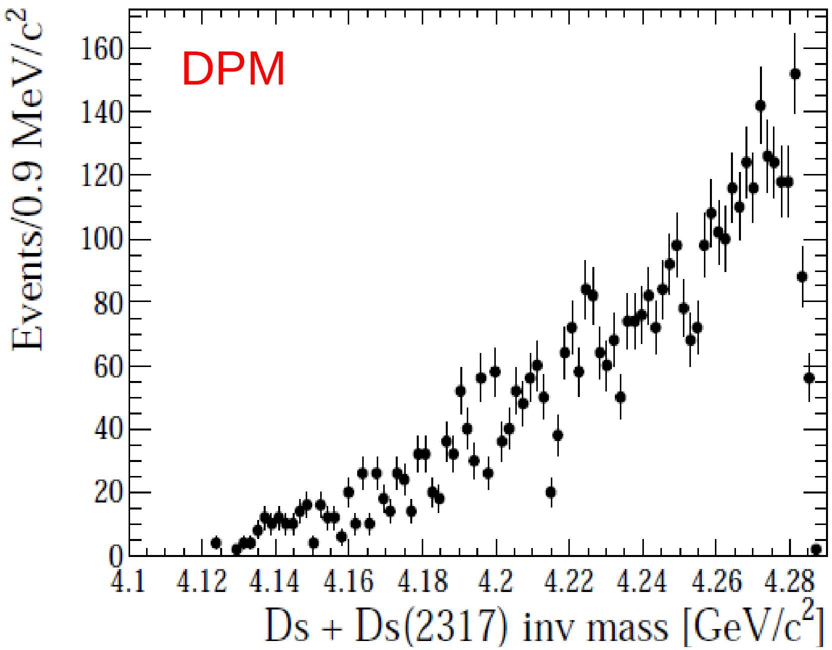
This is simplified for spin = 0

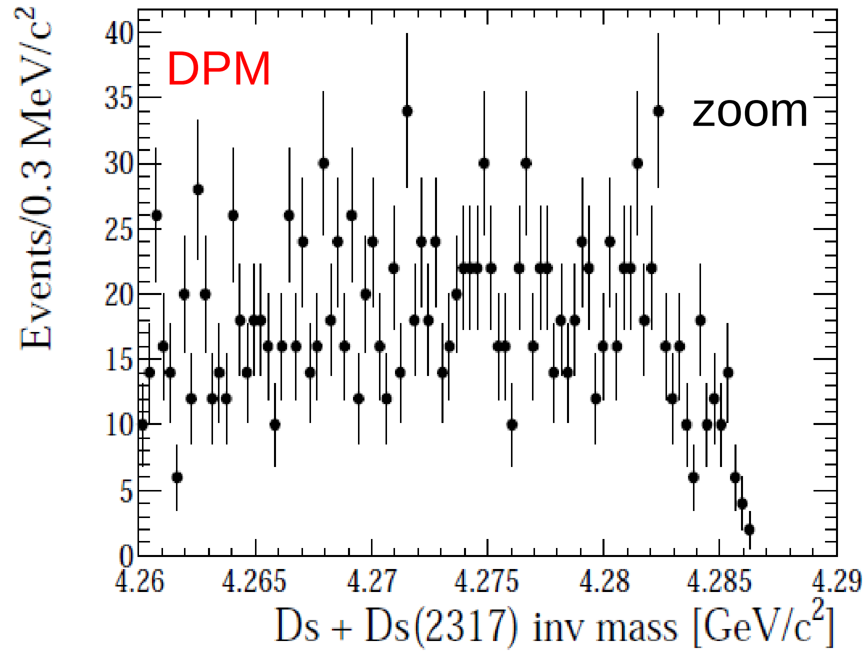
$$q = [m^2 - (m_{Ds} + m_{Ds(2317)})^2]^2 \cdot [m^2 - (m_{Ds} - m_{Ds(2317)})^2]^2$$

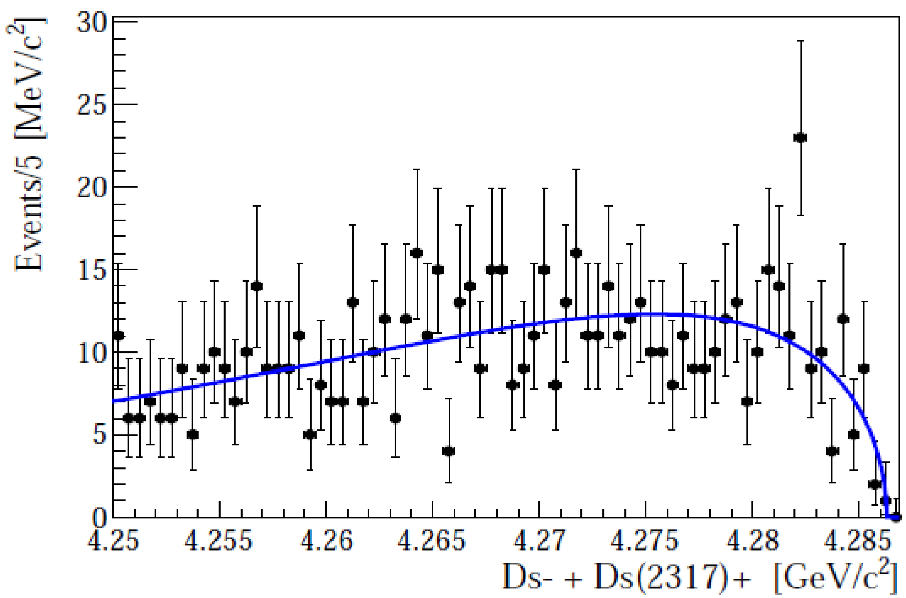
$$G = [G(R) \times \frac{q}{m} \cdot \frac{m_R}{q(R)}]$$

$$\mathrm{R} = \text{resonant state} = D_s D_{s0}^*(2317)$$

Interesting variable: $D_s + D_s(2317)$

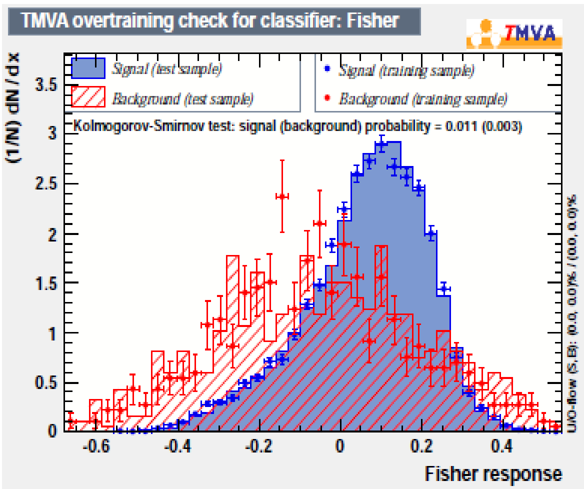


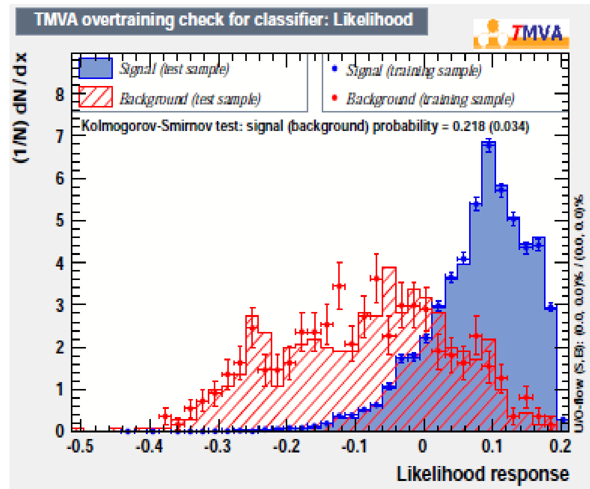


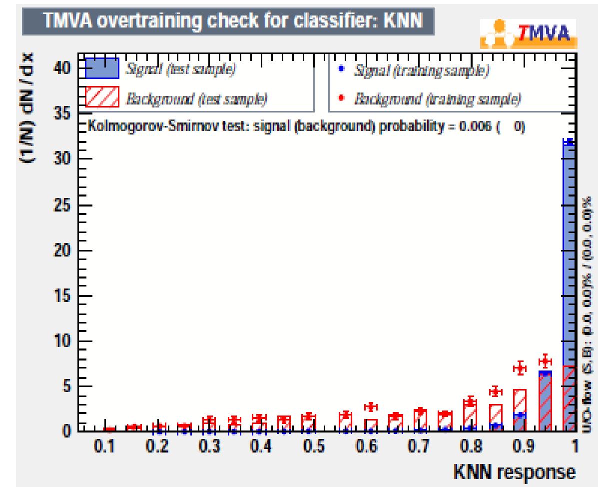


After selection, bkg scaled
ARGUS is used...

Interesting variable: Fisher discr.







<u>5 variables</u>:

D_s mass

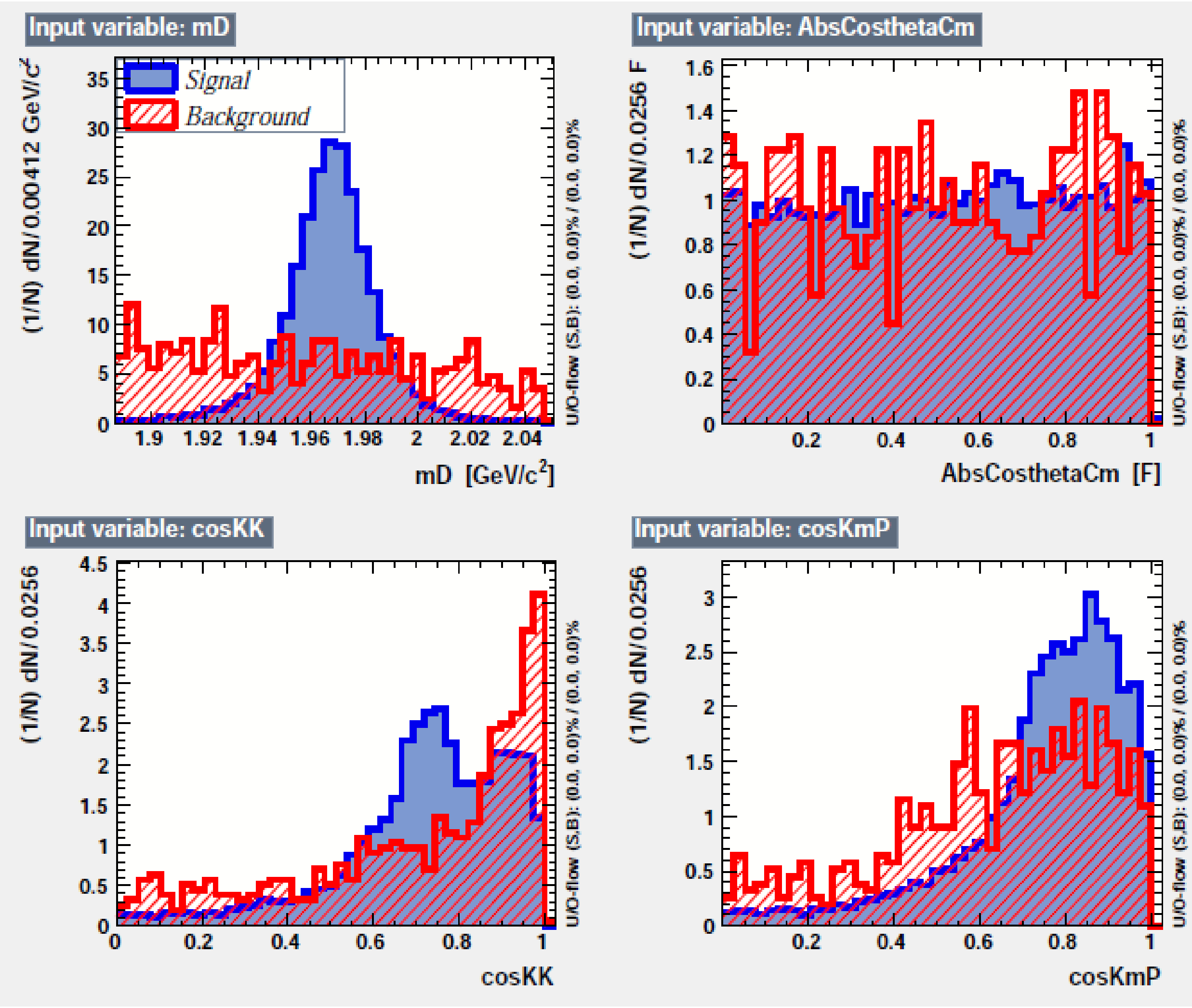
absolute value of the cosine of the polar angle of the D_s

absolute values of the cosine of the angle $\widehat{K^+K^-}$

absolute values of the cosine of the angle $\widehat{K^+\pi^-}$

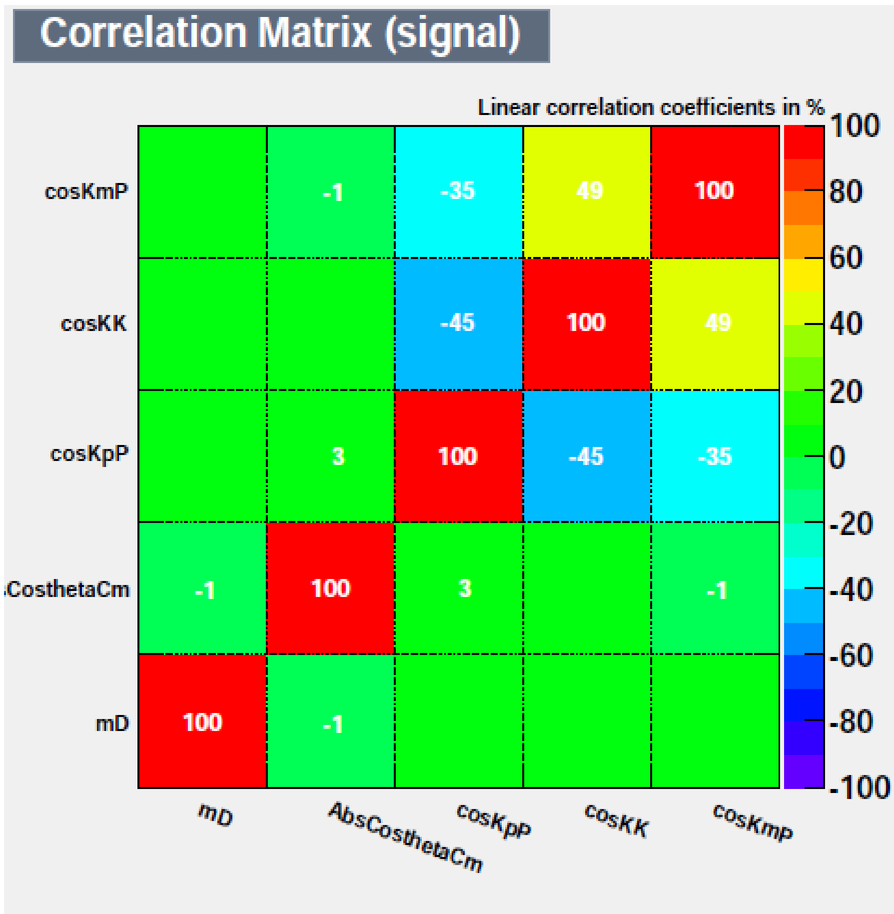
absolute values of the cosine of the angle $\widehat{K^-\pi^-}$

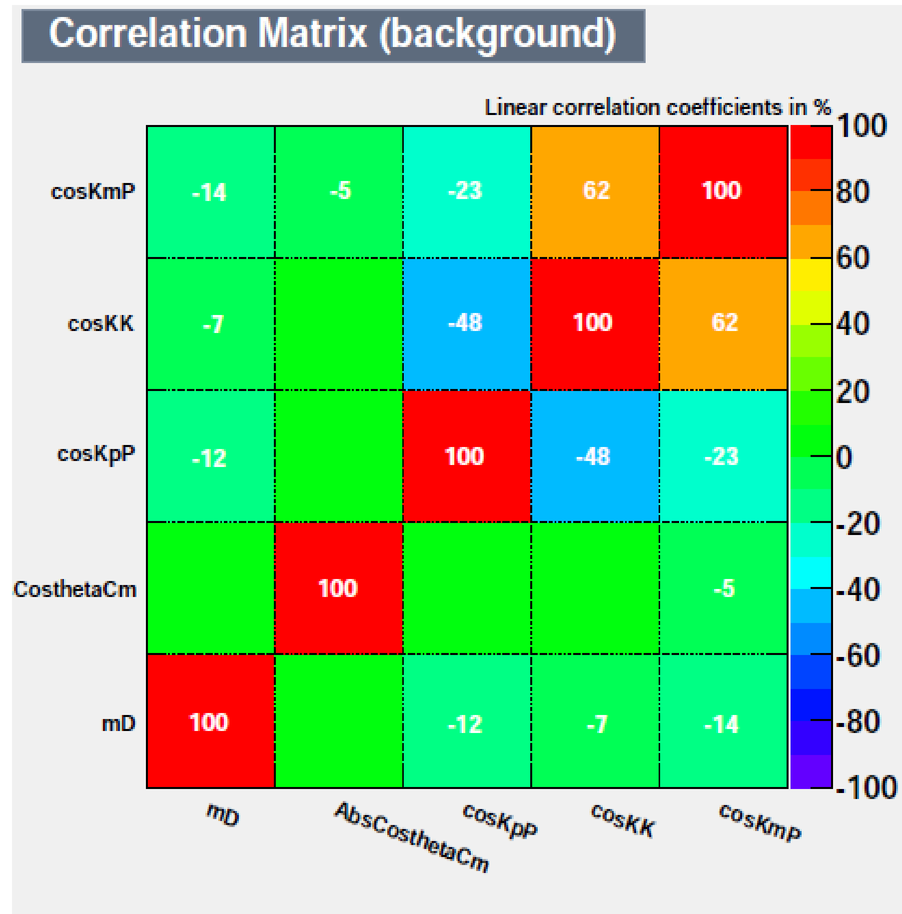
Input variables of the Fisher discr.



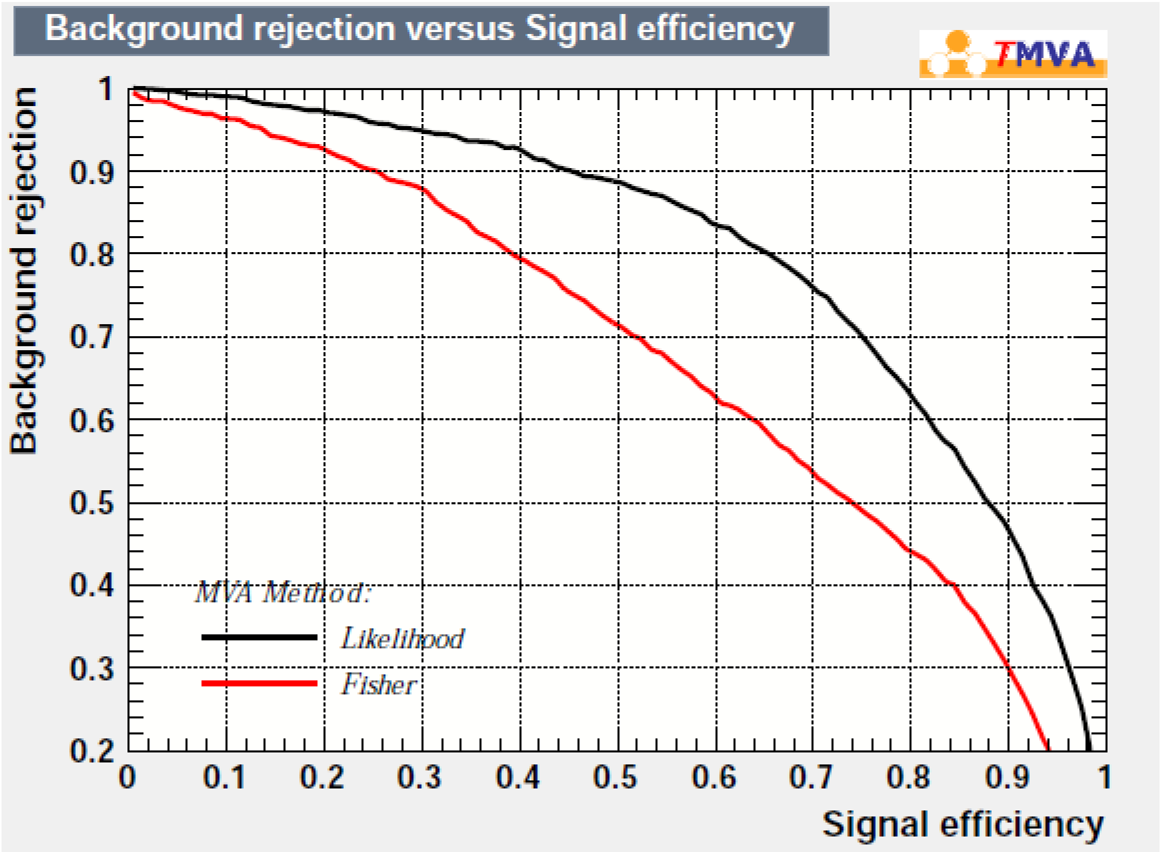
Input variable distributions

Interesting variable: Fisher discr.





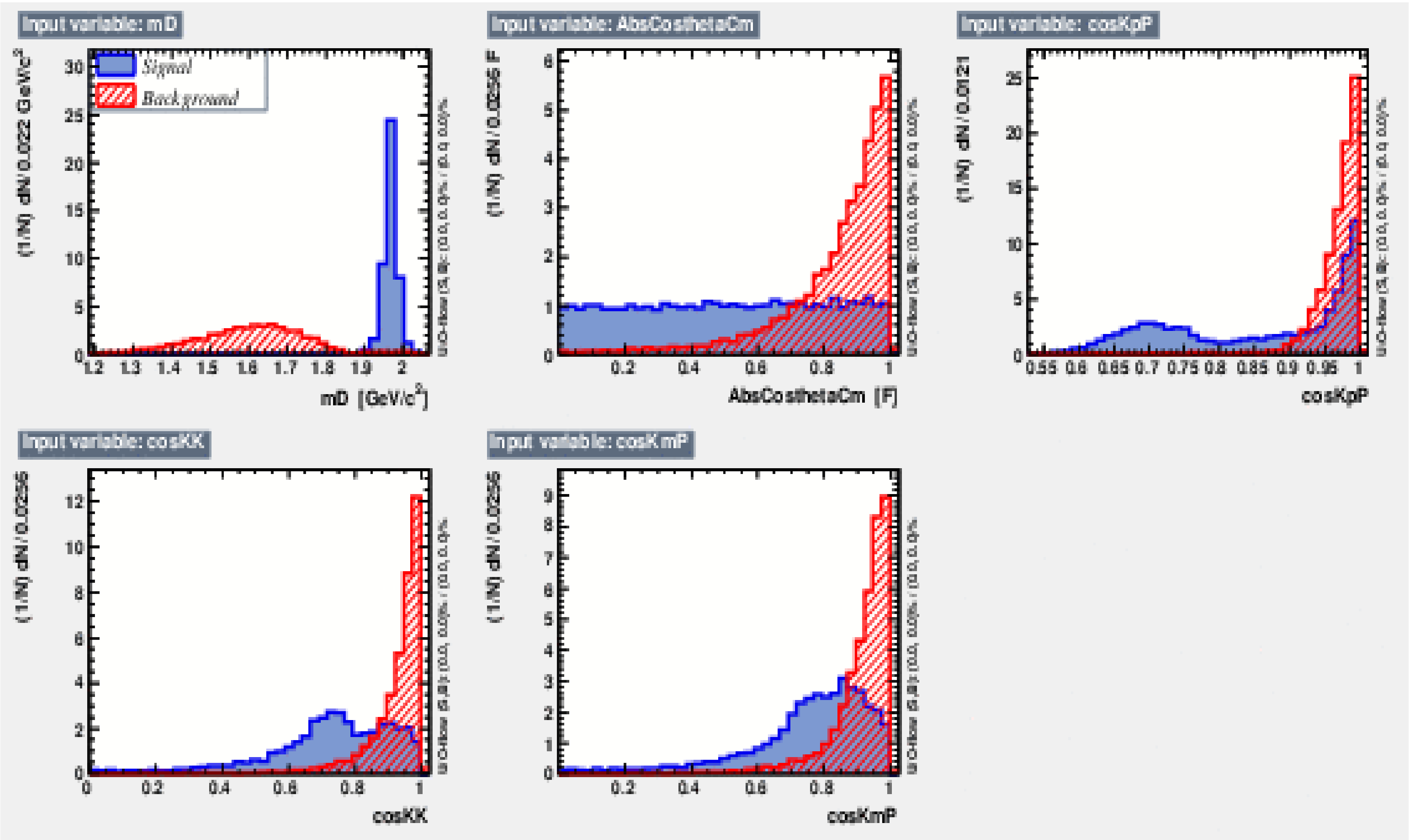
Fisher discr.: bgk-sig rejection power



$$\mathcal{F} = 4.293 \cdot m_{Ds} + 0.014 \cdot |Cos\theta| + 0.195 \cdot |Cos\widehat{K^+K^-}| + 0.217 \cdot |Cos\widehat{K^+\pi^-}| + 0.776 \cdot |Cos\widehat{K^-\pi^-}|$$

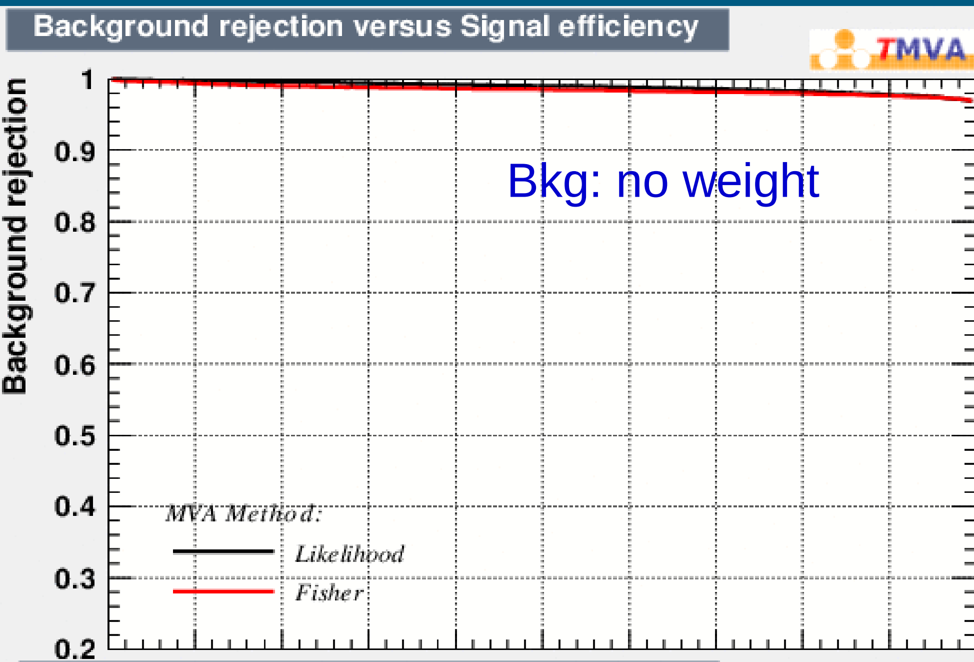
Optimized cut: -0.038

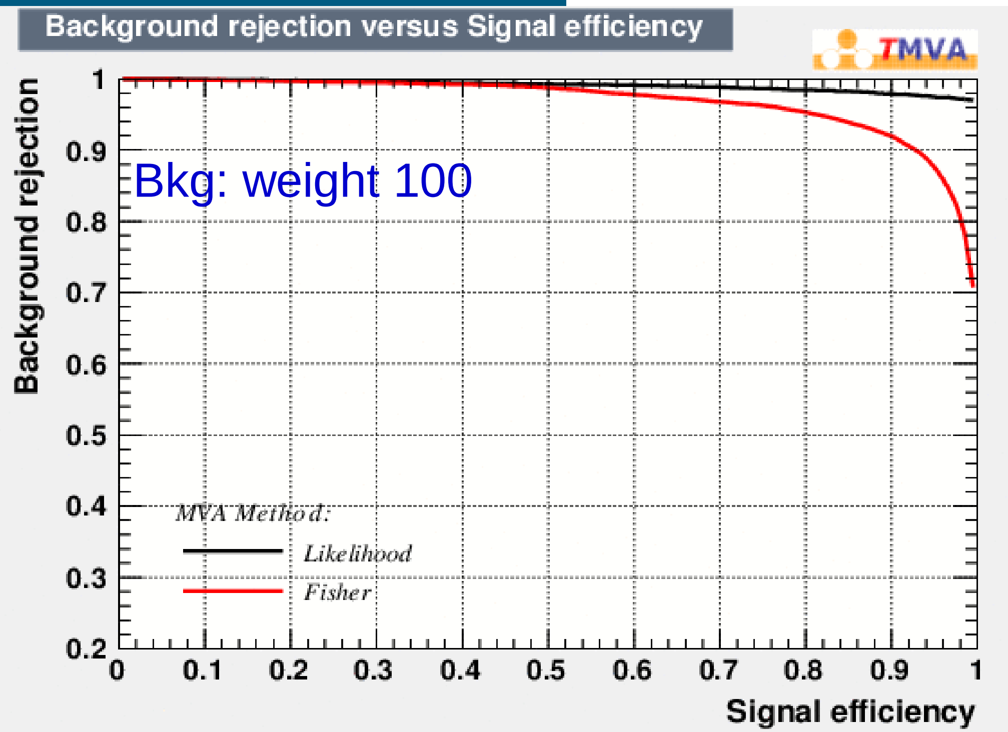
Fisher discriminant (2)

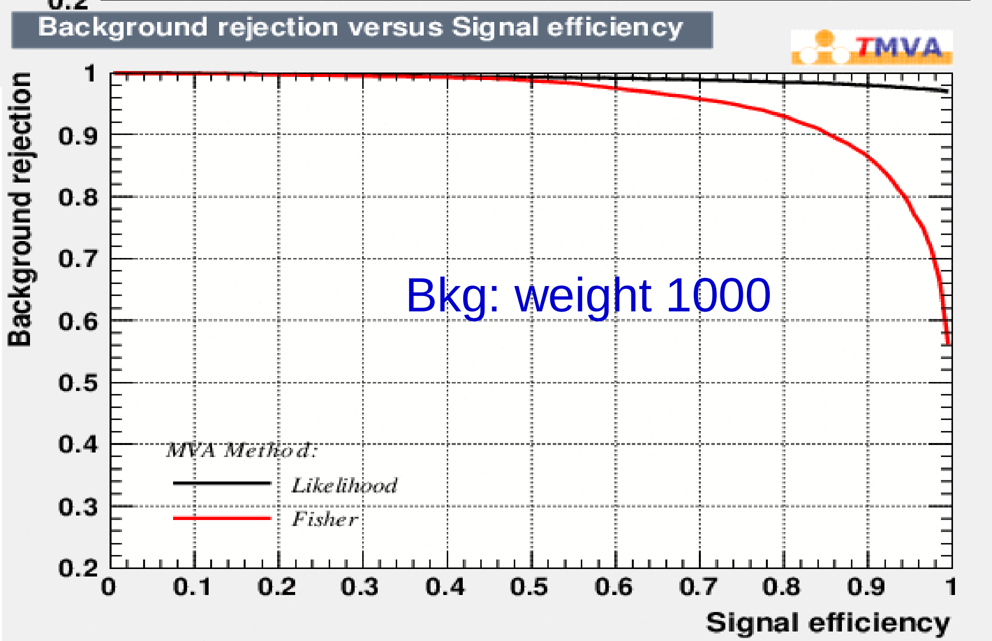


Enlarge selection cuts, then train the Fisher method

Fisher discriminant (2)







Samples: signal (200k), bkg (20M)
Bkg cross section: 57 mb (elastic + inelastic)
DPM filtet: at least 3 charged tracks⇨
100/270 events pass the filter⇨
108M equivalent bkg events

Selection

Selection cut	$\sigma=20$ (bkg)	$\sigma=10$ (bkg)	$\sigma=5$ (bkg)	$\sigma=2$ (bkg)	$\sigma=1$ (bkg)	signal events	signal ϵ (%)
pre-selection	$1.2\cdot10^{10}$	$2.4\cdot10^{10}$	$4.5\cdot10^{11}$	$1.2\cdot10^{11}$	$2.4\cdot10^{11}$	36478	$(18.23\pm0.09)\%$
|POCA radius| <0.1	$9.0\cdot10^{9}$	$1.8\cdot10^{10}$	$3.6\cdot10^{10}$	$9.0\cdot10^{10}$	$1.8\cdot10^{11}$	24463	$(12.23\pm0.07)\%$
|POCA z| <0.2	$7.1\cdot10^{9}$	$1.4\cdot10^{10}$	$1.9\cdot10^{10}$	$7.1\cdot10^{10}$	$1.4\cdot10^{11}$	20214	$(10.11\pm0.06)\%$
➤ $m_{Ds\ Ds(2317)}>4.25$	$9.2\cdot10^{8}$	$1.8\cdot10^{9}$	$3.6\cdot10^{9}$	$9.2\cdot10^{9}$	$1.8\cdot10^{10}$	19815	$(9.91\pm0.06)\%$
$\mathcal{F}>-0.038$	$6.7\cdot10^{8}$	$1.3\cdot10^{8}$	$2.7\cdot10^{8}$	$6.7\cdot10^{9}$	$1.3\cdot10^{9}$	18301	$(9.15\pm0.06)\%$
➤ $\|\Delta E\|<0.04$	$8.6\cdot10^{7}$	$1.7\cdot10^{8}$	$3.4\cdot10^{8}$	$8.6\cdot10^{8}$	$1.7\cdot10^{8}$	16866	$(8.43\pm0.06)\%$
$\|p_z^*\|<0.1$	$4.5\cdot10^{7}$	$9.0\cdot10^{7}$	$1.8\cdot10^{8}$	$4.5\cdot10^{8}$	$9.0\cdot10^{8}$	16549	$(8.27\pm0.06)\%$
$1.92< m_{D_s} <2.01$	$4.1\cdot10^{7}$	$8.2\cdot10^{7}$	$1.6\cdot10^{8}$	$4.1\cdot10^{8}$	$8.2\cdot10^{8}$	16549	$(8.27\pm0.05)\%$
$p_t\ (D_s)<0.2$	$2.7\cdot10^{7}$	$5.4\cdot10^{7}$	$1.1\cdot10^{8}$	$2.7\cdot10^{8}$	$5.4\cdot10^{8}$	16547	$(8.27\pm0.05)\%$
➤ $1.004< m_{K^+K^-} <1.04$	49346	98692	197383	$4.9\cdot10^{5}$	$9.9\cdot10^{5}$	4536	$(2.27\pm0.05)\%$

- Preselection:
  p_{track} cut, POCA volume, Kin fitter
- Background is scaled assuming a signal cross section = 20 nb
- ϕ mass resolution: 5 MeV/c^2

Signal box: M(DsDs2317) > 4.282 GeV/c^2
Only 5 DPM events survive/ 40 millions

S/B ~ 1/110 (rescaled to 19mb DPM equivalent)

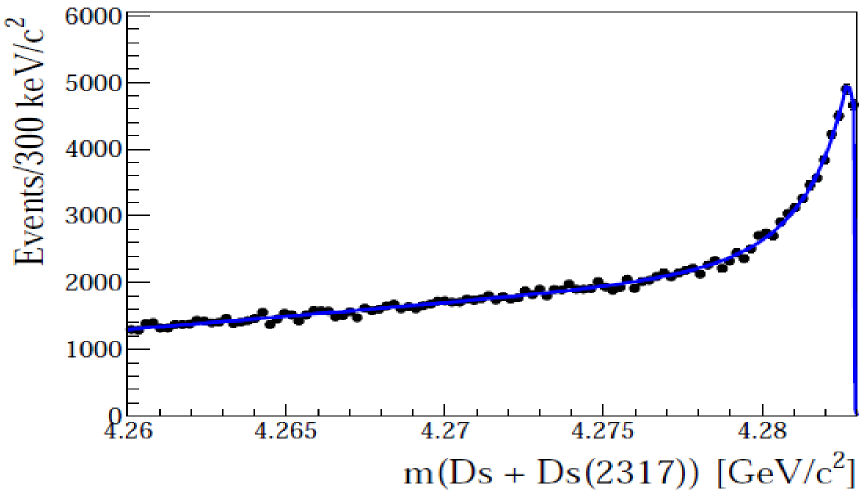
Check: background samples

Table 5: DPM consistency check. Selection (1) shows the number of events, surviving to the pre-selection, before the χ^2 cut is applied. Selection (2) shows the number of events, surviving to the pre-selection, with Prob(χ^2)>1%. The first skim column shows the efficiency of our pre-selection skim. The skim column with mass cut shows the efficiency of our pre-selection skim, with the additional requirement that the invariant mass of the $K^+K^-\pi^-$ system (i.e., m_{D_s}) is restricted in 500-MeV-window from the D_s nominal value: $|m_{D_s}^{reco} - m_{D_s}^{PDG}| < 500$ MeV$/c^2$.

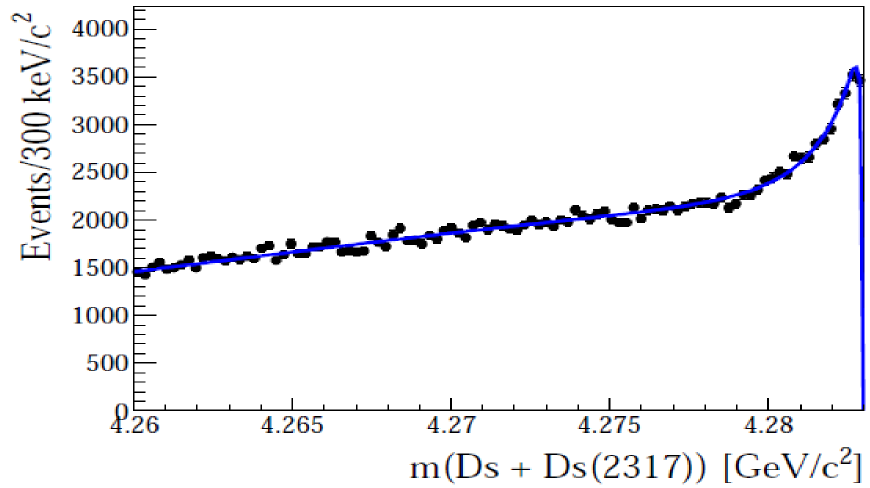
Sample ID	Generated events	Selection (1)	Selection (2)	skim efficiency (%)	skim efficiency (%) (with mass cut)
A	5 143 500	1 927 141	663 512	13%	7%
B	4 966 000	1 675 052	614 790	12%	6%
C	2 922 500	1 343 355	362 683	12%	6%
D	1 633 000	329 520	210 494	13%	7%
E	5 263 000	2 375 941	841 939	16%	8%
F	4 968 000	1 738 805	552 794	12%	6%
G	4 761 500	1 733 178	556 487	12%	6%
H	1 489 500	509 402	163 845	11%	6%
I	4 032 500	1 358 953	514 964	13%	7%
L	5 439 000	2 077 698	673 414	12%	6%

2.8M skimmed over 40M DPM events, with our pre-selection!

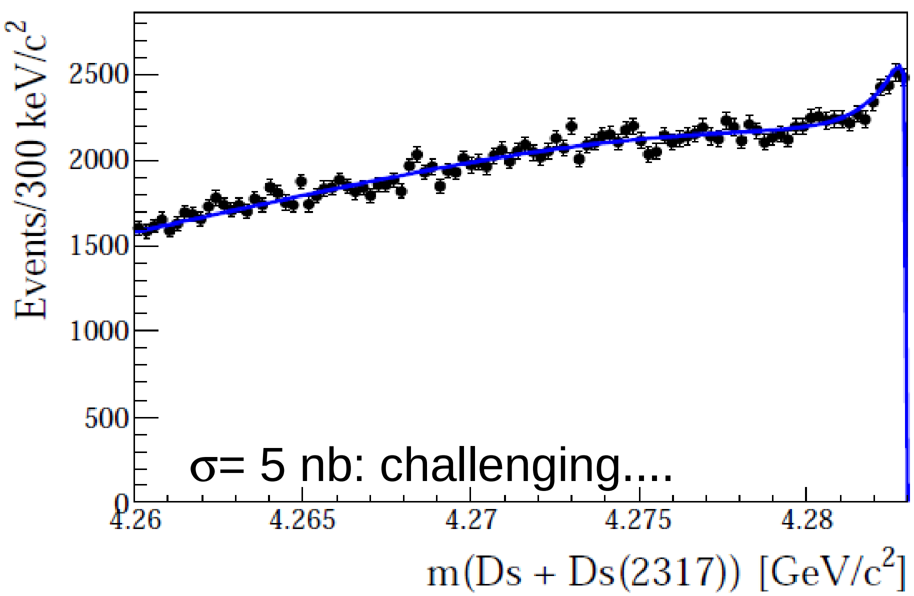
Preliminary mass fits: SIG + BKG



(a) input σ = 20 nb



(b) input σ = 10 nb



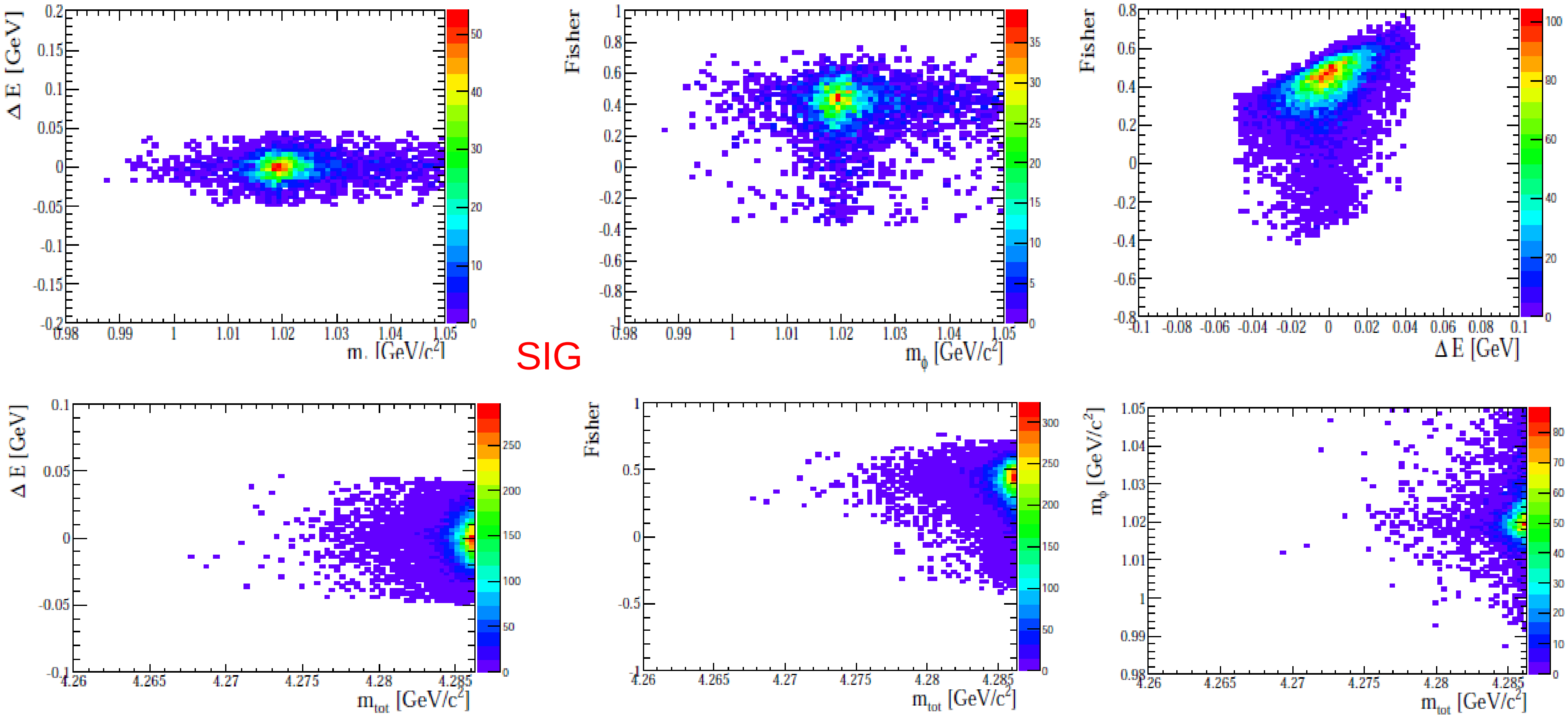
Threshold distributions, after selection

Assuming: S/B = 1/12:

For σ =1, or 2 nb, not feasible
Need to study a better strategy
in these 2 cases.

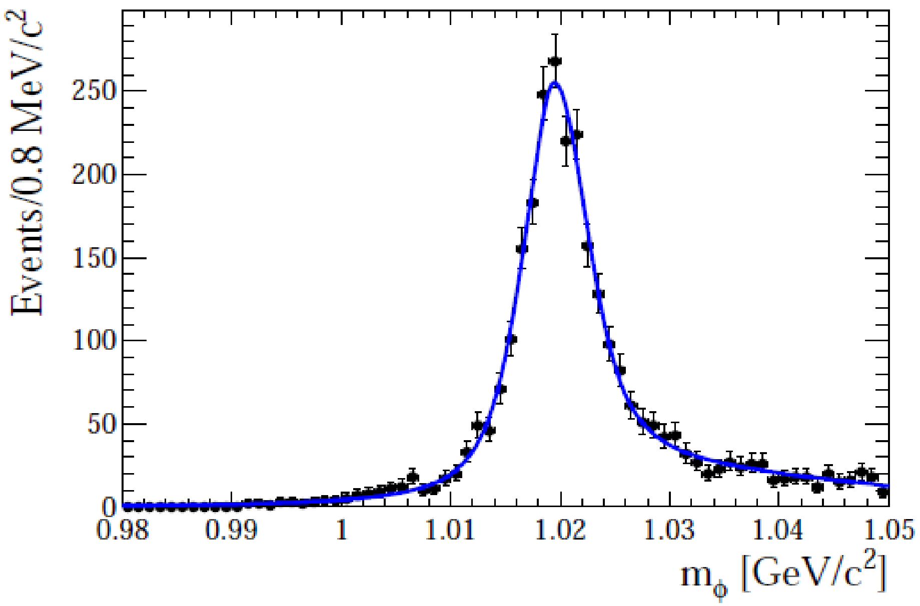
4D-likelihood fit

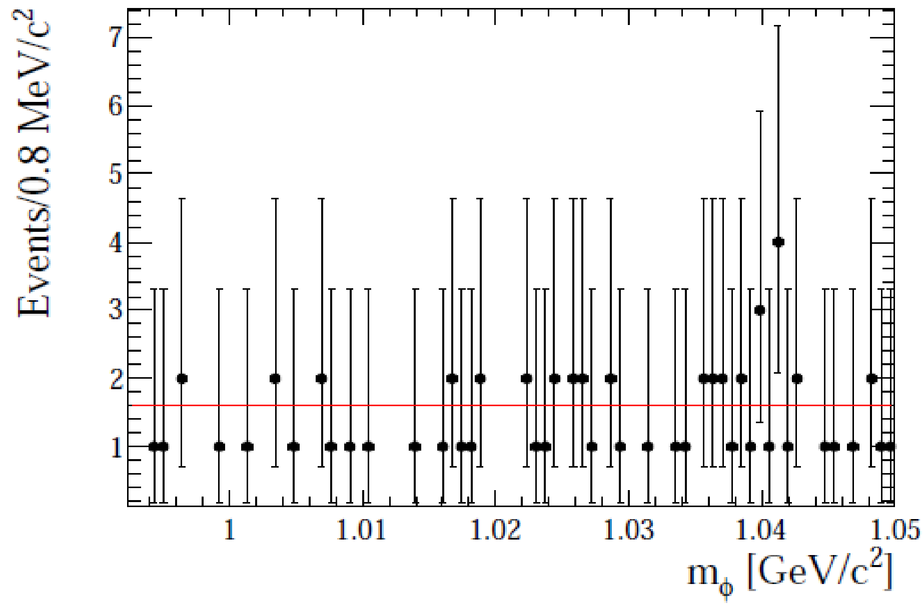
The signal-bkg discrimination, in case of σ(signal) =1, or 2 nb, is not good.
We propose a 4-Dim fit, writing likelihood, build with ΔE, F, M, ϕ



Need to parameterize the sig. and bkg. variable distributions!

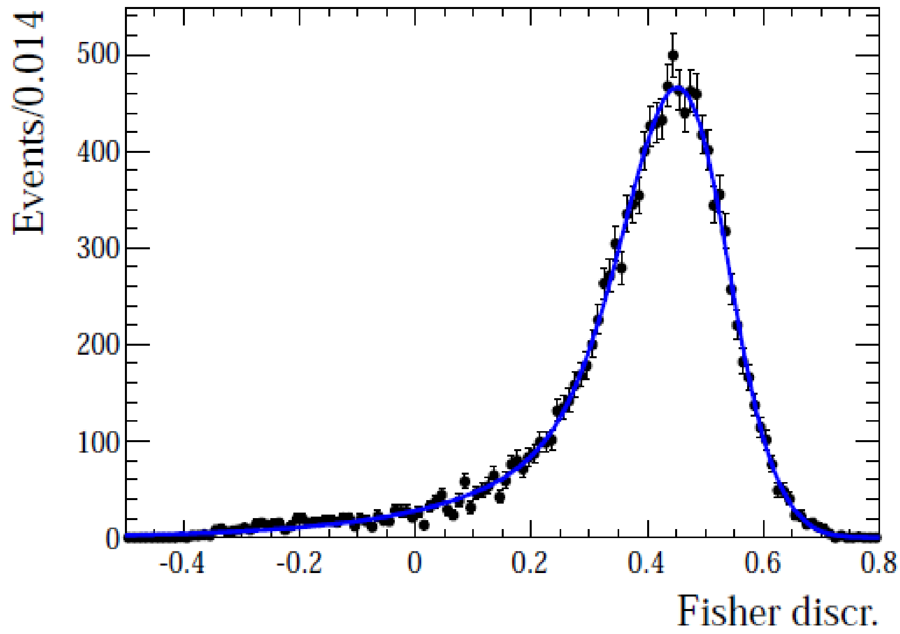
ϕ mass parameterization for the 4D-fit

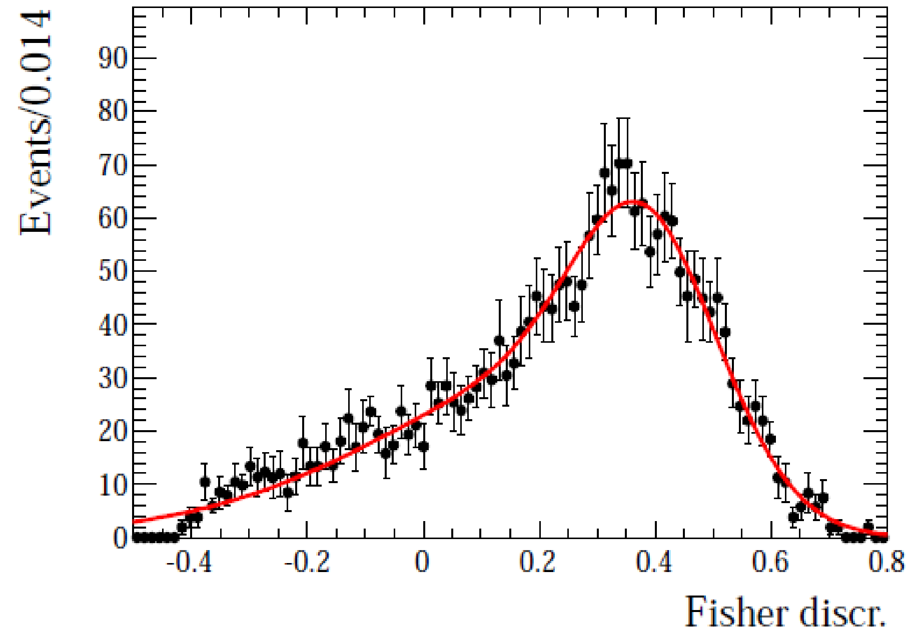




Parameter	Signal sample	Background sample
$\bar{x}_V$	fixed to 1.01945 GeV$/c^2$	-
σ_V	0.0247 ± 0.0036	-
Γ_V	0.00438 ± 0.00035	-
p_0	-	1.67 ± 0.09

F discr. parameterization for the 4D-fit





Parameter	Signal sample	Background sample
$\bar{x}_1$	0.406 ± 0.023	0.385 ± 0.012
$\bar{x}_2$	0.4632 ± 0.0051	0.200 ± 0.018
σ_1	0.600 ± 0.080	0.098 ± 0.083
σ_2	0.068 ± 0.021	0.185 ± 0.051
Γ_1	0.143 ± 0.015	0.1227 ± 0.0091
Γ_2	0.0925 ± 0.0019	0.268 ± 0.014
fraction	0.396 ± 0.049	0.392 ± 0.038

ΔE parameterization for the 4D-fit

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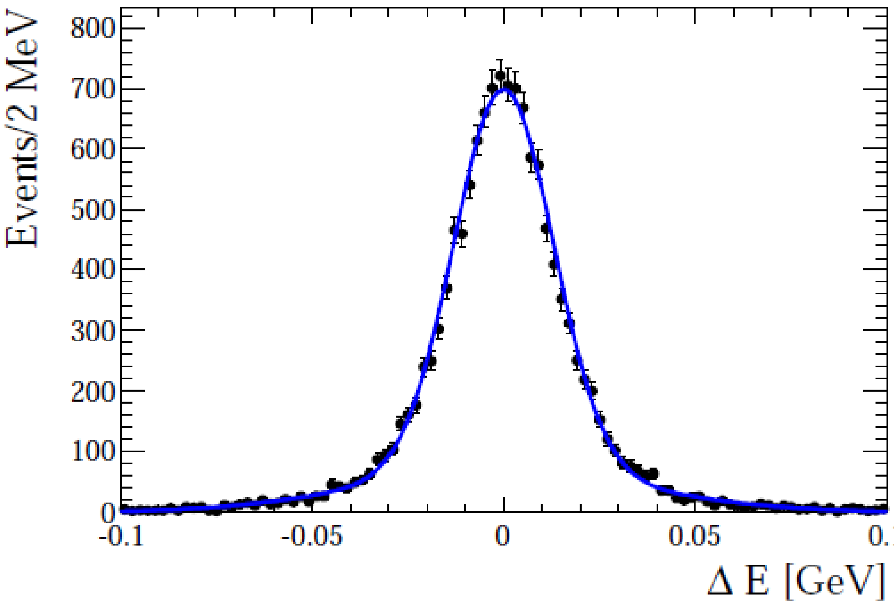

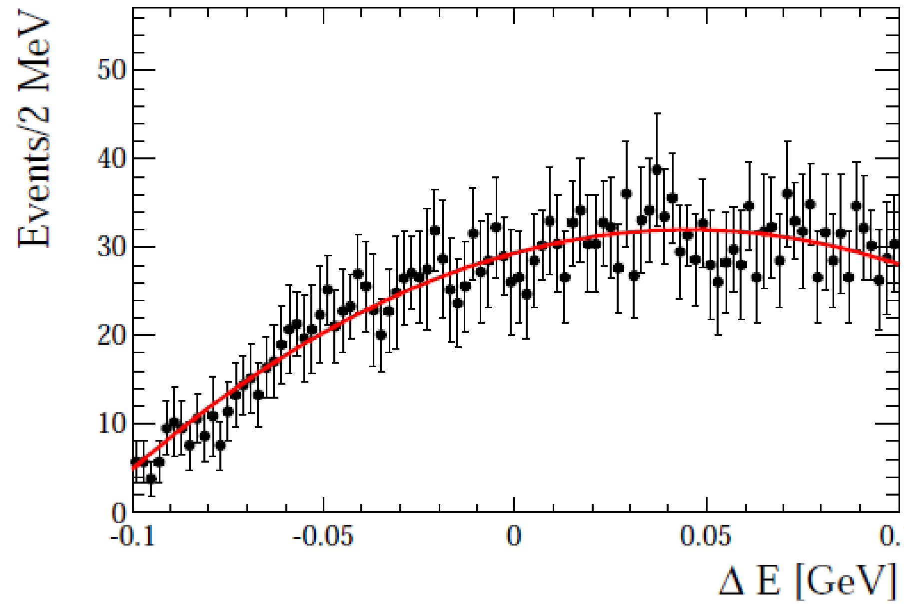

Parameter	Signal sample	Background sample
$\bar{x}_1$	$(-1.3 \pm 1.6)10^{-3}$	-
$\bar{x}_2$	$(-1.11 \pm 0.78)10^{-3}$	-
σ_1	0.01299 ± 0.00020	-
σ_2	0.0372 ± 0.0010	-
fraction	0.772 ± 0.013	-
p_0	-	3.95 ± 0.29
p_1	-	-44 ± 4

Mass parameterization for the 4D-fit

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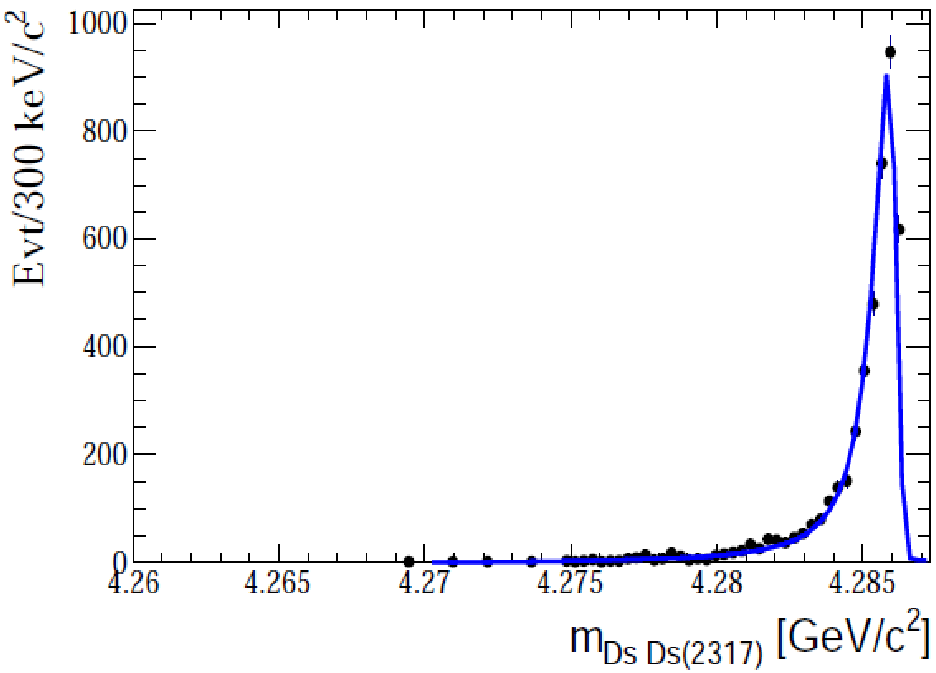
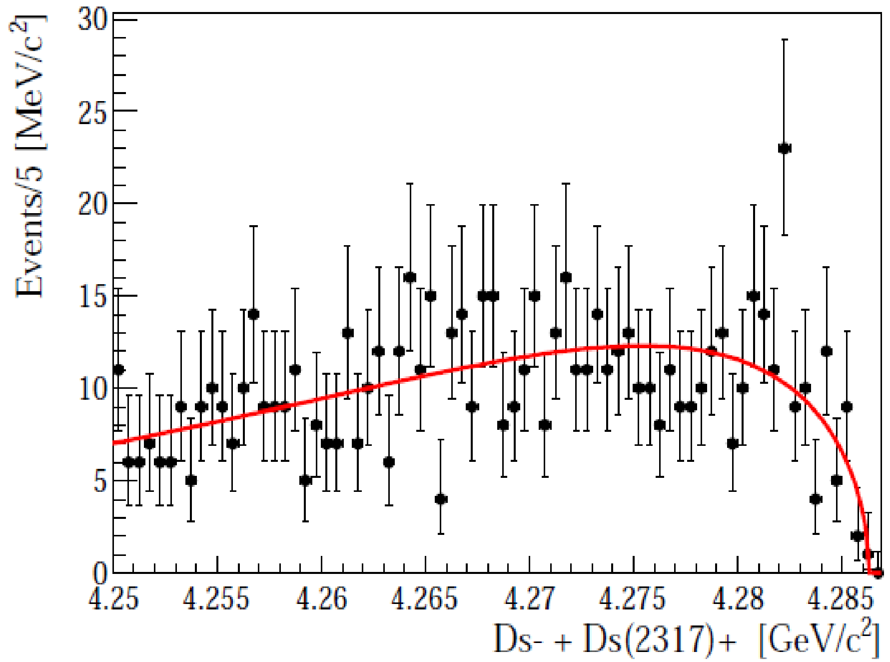




$$\frac{dn}{dm} = \frac{q}{(m_r^2 - m^2)^2 + m_R^2 \times G^2}$$

ARGUS: c = 98± 7

$$M_{system} \quad (4285.670 \pm 0.013)\ \text{MeV}/c^2$$
$$\Gamma_{system} \quad (0.894 \pm 0.026)\ \text{MeV}$$

4D-fit: likelihood

- A likelihood function is built, with ϕ, M, F (5 variables), ΔE

$$\mathcal{L} = \mathcal{P}(N) \times$$

$$\Pi_{i=1}^{N} \alpha_{sig} P_{SIG}(m_{\phi}^{i}, m_{DsDs2317}^{i}, \mathcal{F}^{i}, \Delta E^{i}) +$$

$$+ \alpha_{DPM} P_{DPM}(m_{\phi}^{i}, m_{DsDs2317}^{i}, \mathcal{F}^{i}, \Delta E^{i})$$

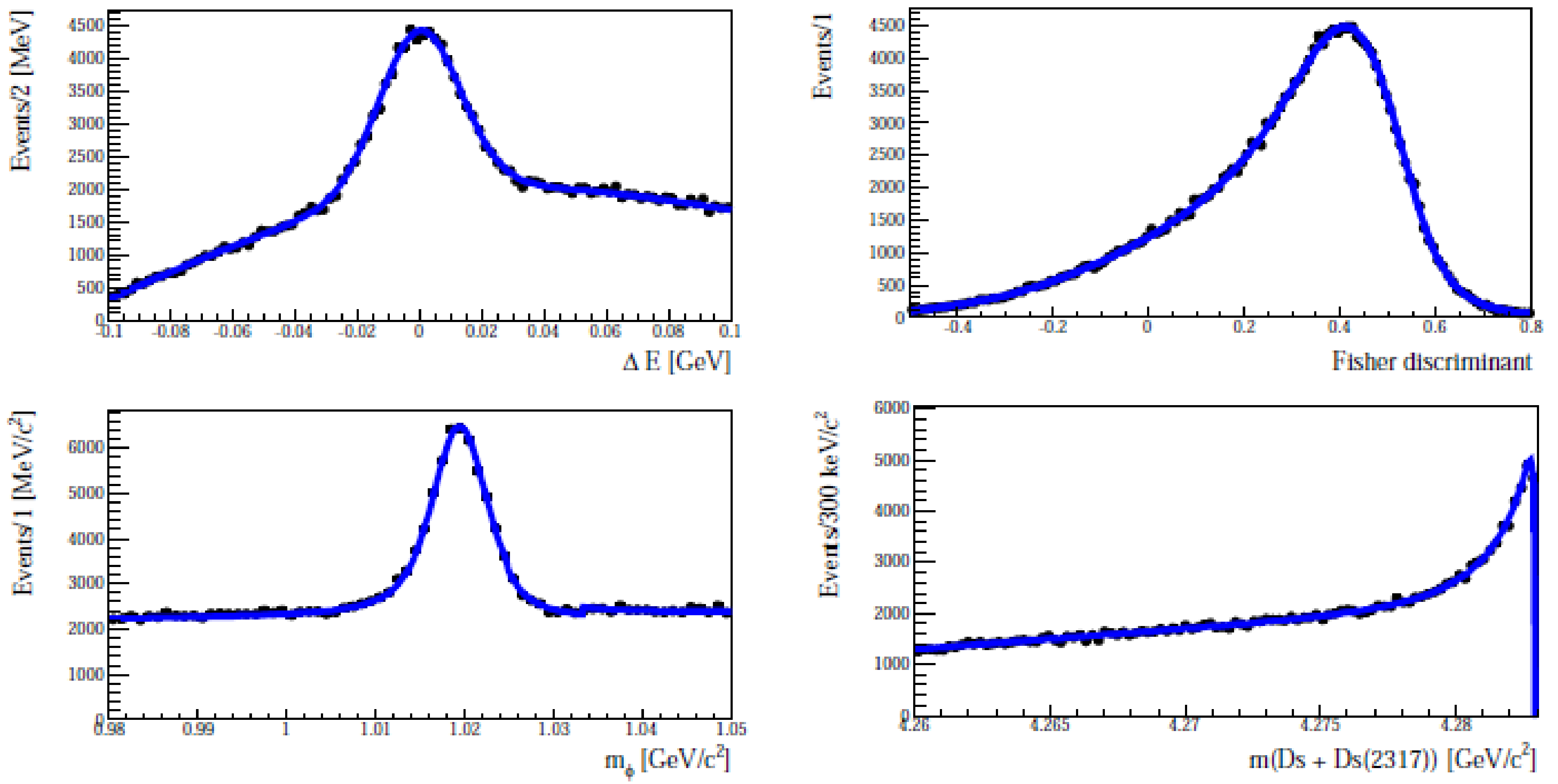
- 2 hypotheses: 1. signal, and 2. DPM bkg
- 4 variables

$$\mathcal{P}(N) = \frac{e^{-N \Sigma n_j}}{N!} \cdot (\Sigma N_j)^N$$

Poissonian prob. to observe N events

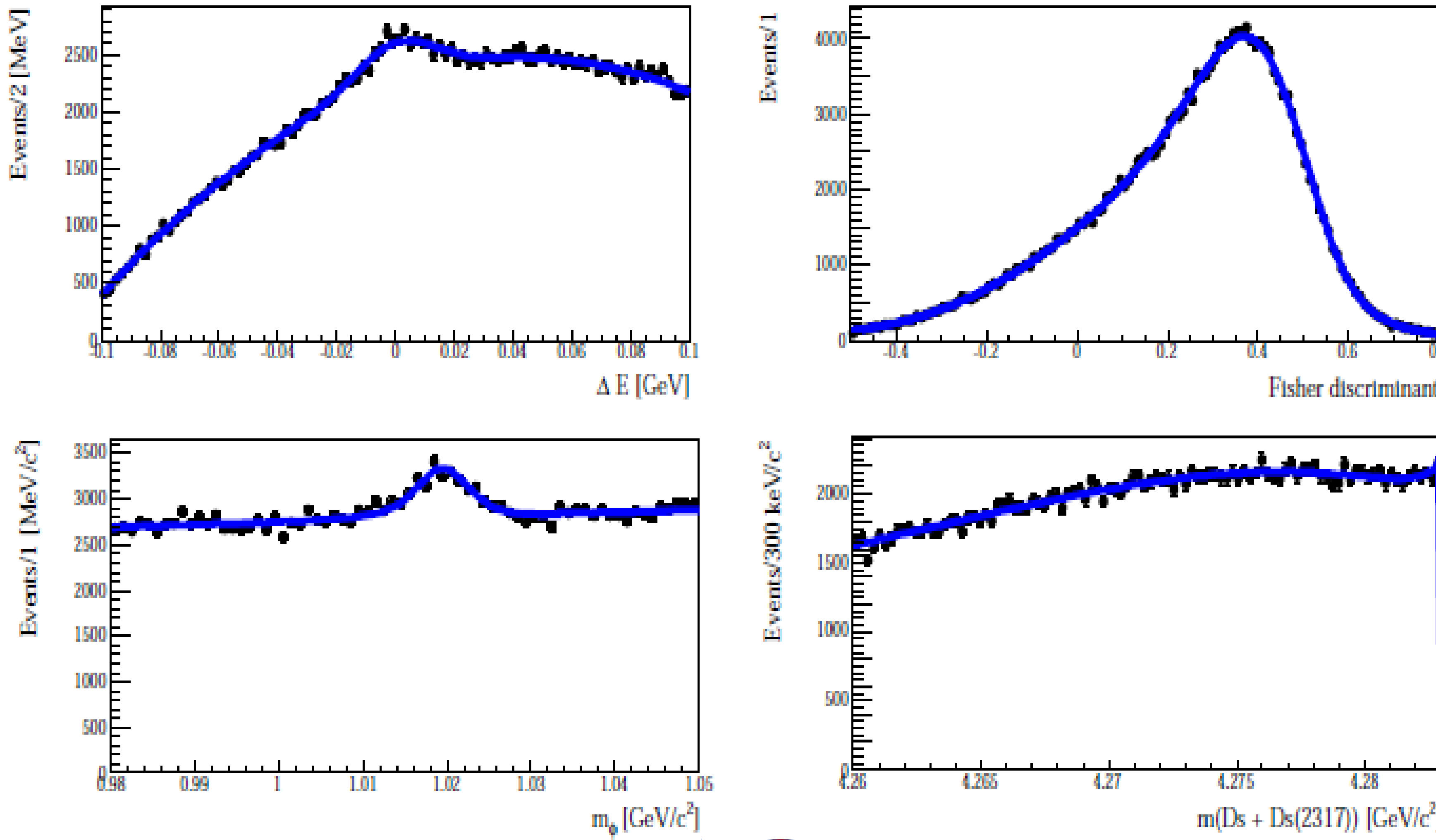
4D-fit: likelihood projections

Does it work? ToyMC study is performed, assuming S/B = 1/12



Input signal: N = 4401; measured: (4621 ± 85)
Parameterization is fixed; signal and bkg events are floating

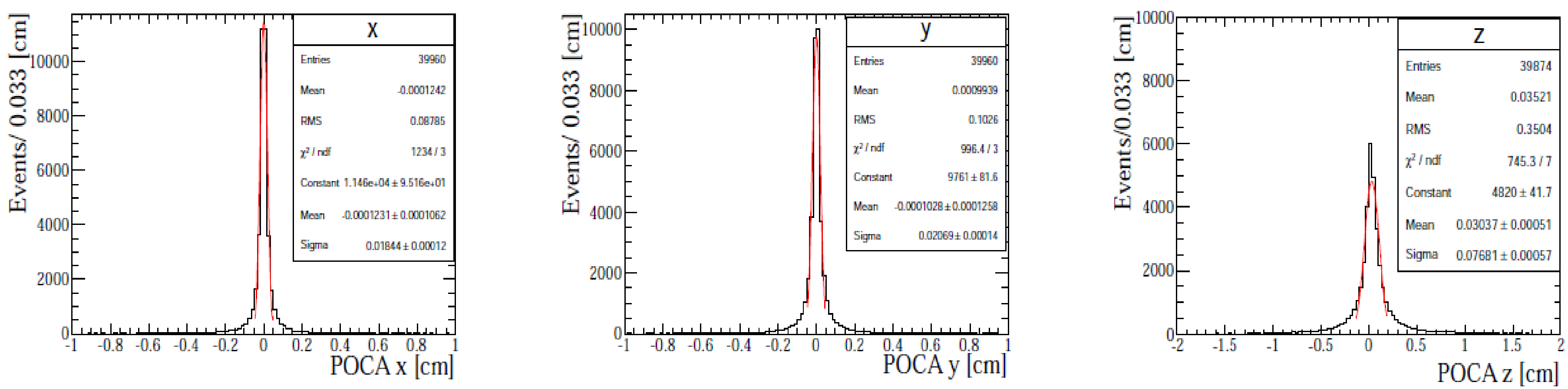
What happens if S/B = 1/110?



Vertexing

- <u>NOT GOOD</u>! Can we improve S/B? YES: <u>VERTEXIG</u> and <u>TRACKING</u>
- Signal efficiency is low.
- Problem: degraded vertex resolution
- In the studied selection: S/B = 1/110 (analysis not feasible!)

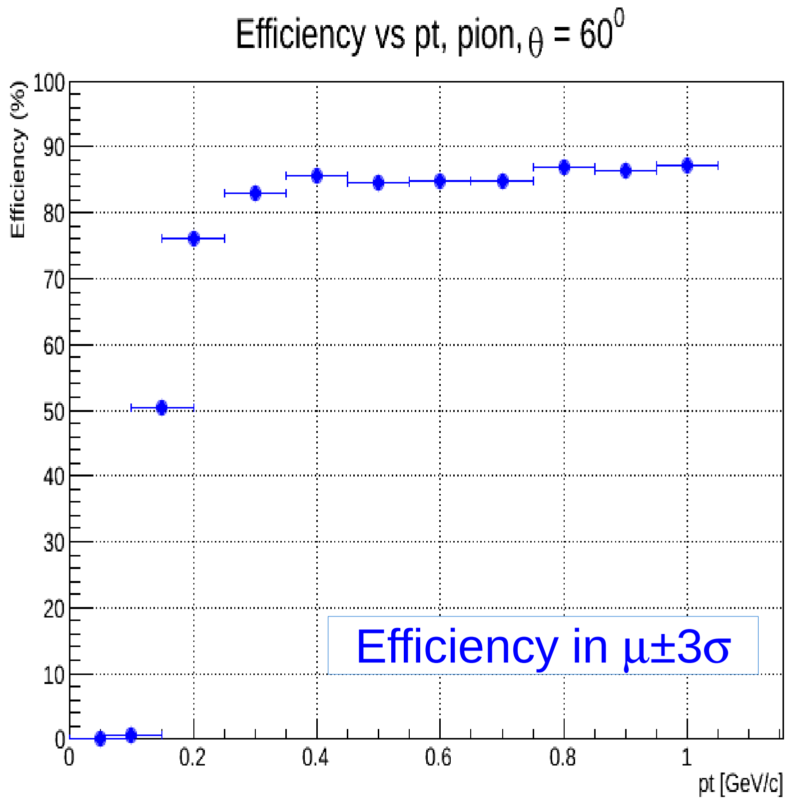
If S/B ~ 1/10, analysis feasible (a factor 10 missing...)



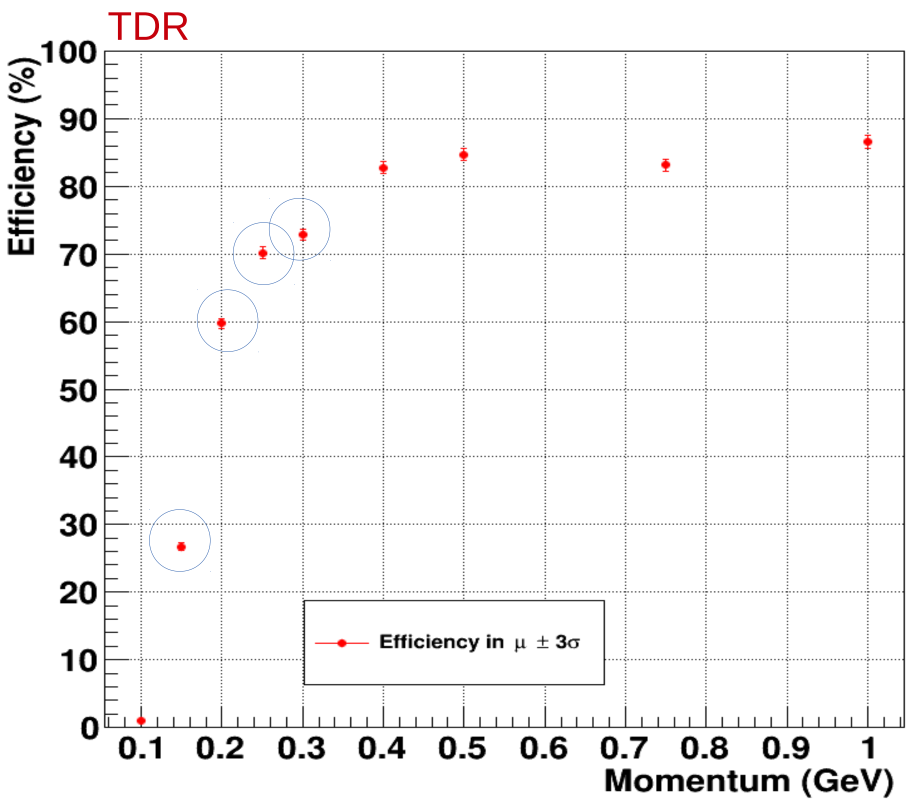
- Vtx resolution much larger than expected. If we could cut x, y, z <100 µm, 0 DPM events survive over 40 million. Need much higher DPM statistics to study the problem.

Tracking

GENFIT2

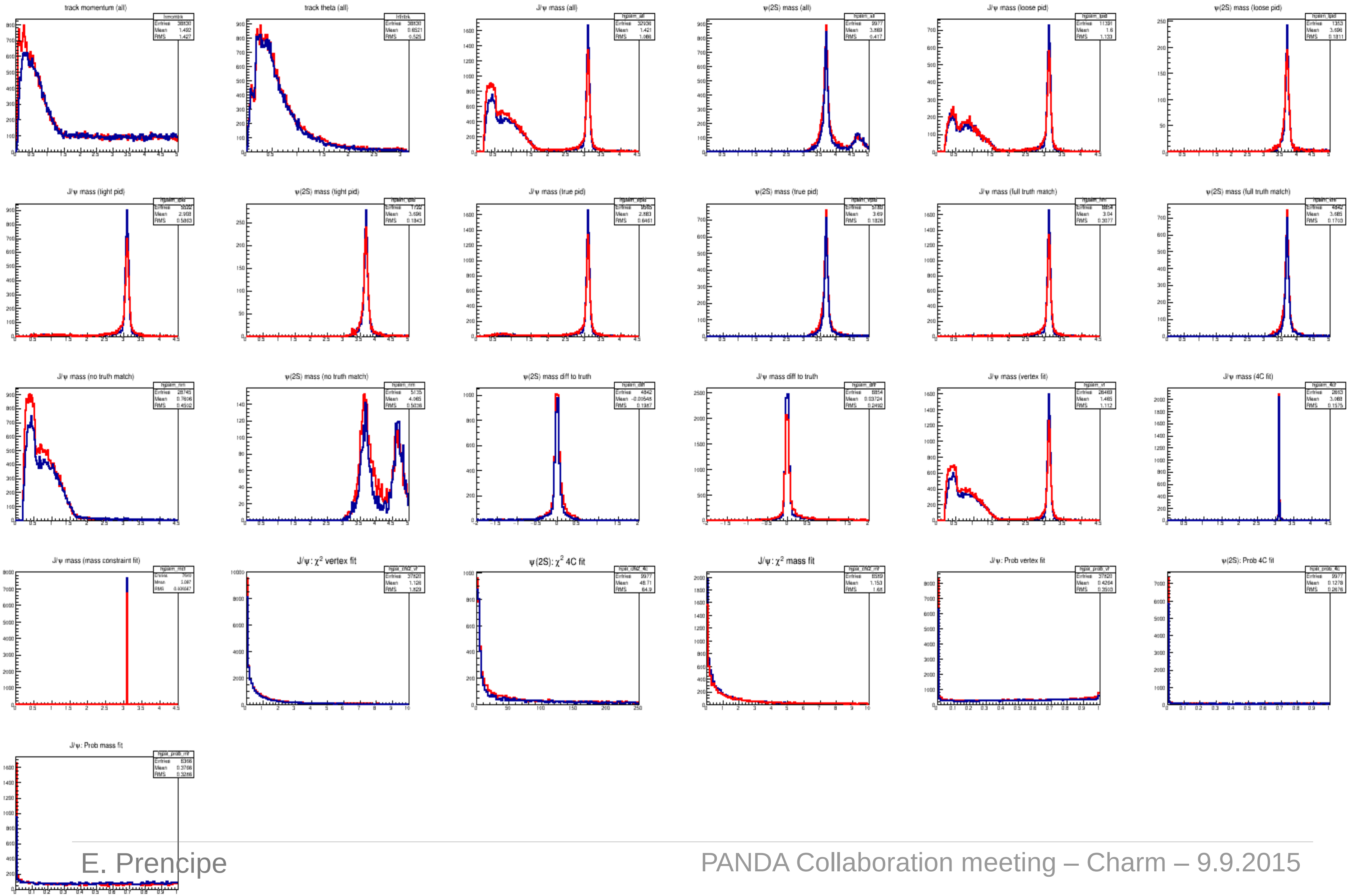


GENFIT1



Great improvement for low momentum tracks!

Courtesy of S. Spataro: genfit tests



Expectations with $\overline{\text{P}}$ANDA

JÜLICH FORSCHUNGSZENTRUM

SCRUT14

- General remarks:
  ① analysis proposed: single-tag mode (D_s^- is tagged to $K^+K^-\pi^-$);
  ②(semi-)inclusive approach;
  ③ unknown cross section, but σ expected in **[10-100] nb**;
- ④ if ε = **100%**, in $\overline{\text{P}}$ANDA $\mathscr{L}$= **0.864** pb^{-1}/day N = $\mathscr{L} \cdot \sigma \cdot \varepsilon \in$ [864-86400]/day
  ❺ but we need to scale by BR($D_s \rightarrow KK\pi$) = 5.34% ⇨ [46-4610] D_s events/day!

- Specific simulation of this talk:
- Proposed 15 scan points;

  Pre-selection

  assuming σ = **[1-100] nb**, ε = **17.5%** and $\mathscr{L}$= **0.864** pb^{-1}/day,
  $D_s^- \rightarrow K^+K^-\pi^-$ only (PID, vertexing, tracking, dedicated selection)
  BR($D_s \rightarrow KK\pi$)~ 5.34% ⇨ **[8-807] events/day**

- For comparison, at B factories:
  BABAR: in $e^+e^- \rightarrow c\bar{c}X$, $\mathscr{L}$=91 fb^{-1}, **1267** D_s(2317) selected;
  BELLE II (future): expected on $\mathscr{L}$=10 ab^{-1} **87 000** D_s(2317) in 2020.

Expectations with $\overline{\text{P}}$ANDA

OCT14, this work

Table 8: Sensitivity study to evaluate the number of produced and reconstructed events per day, for different input cross section values. The calculation is done in the assumpion to run in high luminosity mode (HL, $\mathcal{L} = 8.640\ pb^{-1}/\text{day}$) and high resolution mode (HR, $\mathcal{L} = 0.864\ pb^{-1}/\text{day}$). BR($D_s \rightarrow K^+K^-\pi^-$) = 5.34% [10].

Input σ (nb)	Produced events per day (HL)	Produced events per day (HR)	Reco. events per day (HL)	Reco. events per day (HR)
20	172 800	17 280	203	20
10	86 400	8640	103	10
5	43 200	4320	52	5
2	17 280	1728	20	2
1	8 640	864	10	1

62 days (HR) to reach what BaBar achieved in 4 years (σ = 20 nb)!

Summary

OCT14, this work

- General remarks:
  ① analysis proposed: single-tag mode (D_s^- is tagged to $K^+K^-\pi^-$);
  ②(semi-)inclusive approach;
  ③ unknown cross section, but σ expected in **[1-100] nb**;
- ④ if ε = **100%**, in PANDA $\mathscr{L}$= **0.864** pb^{-1}/day N = $\mathscr{L} \cdot \sigma \cdot \varepsilon \in$ [864-86400]/day
  ❺ but we need to scale by BR($D_s \to KK\pi$) = 5.34% ⇨ [46-4610] D_s events/day!

Pre-selection

- Specific simulation of this talk:
- Proposed 15 scan points;

  assuming σ = **[1-100] nb**, ε = **18.23%** and $\mathscr{L}$= **0.864** pb^{-1}/day,

  $D_s^- \to K^+K^-\pi^-$ only (PID, vertexing, tracking, dedicated selection)

  BR($D_s \to KK\pi$)~ 5.34% ⇨ [8 – 840] **events/day**

- If ε = 2.3%, then **[1-100]** events/day

- For comparison, at B factories:
  BABAR: in $e^+e^- \to ccX$, $\mathscr{L}$=91 fb^{-1}, **1267** $D_s(2317)$ selected;
  BELLE II (future): expected on $\mathscr{L}$=10 ab^{-1} **87 000** $D_s(2317)$ in 2020.

Puzzling....

In the PB (2008), ε = 20% using a pre-selection similar to that of this work.
I obtain since 1 year, in several pandaroot releases ~ 18%

Then, I have worked hard to fix a selection, to bring S/B = 10^{-6}, 10^{-7} to S/B = 10^{-2}.

This selection lowers ε to 2.2% (still best D_s candidate not selected)

How is it possible with only a pre-selection to suppress S/B = 10^{-6}, 10^{-7}?

My understanding: it is not possible!

A dedicated selection has to be performed

Window of improvement to decrease B: vertexing

My understanding: good vertex resolution definitively needed to suppress B!

→ then the analysis is feasible

Ongoing study: systematics

- indetermination of the model

  Simulations with $\bar{p}p$ system spin =1 are performed;
  Simulation with a resonant state in the DsDs(2317) invariant mass are performed

- tracking

- PID method

- efficiency. $\Delta\epsilon = \sqrt{\epsilon(1-\epsilon)/N_{gen}}$

"The greatest danger for most of us lies not in setting our aim too high and falling short; but in setting our aim too low, and achieve our mark."
(Michelangelo, 1475 - 1564)

THANK YOU
for your attention!