Mitglied der Helmholtz-Gemeinschaft

Determination of the D_{s0}*(2317) width with the $\bar{\mathrm{P}}$ANDA detector

EXA Wien, 8.9.2011 Marius C. Mertens

Overview

The Challenge

- The D-Meson: „Hydrogen of QCD“
- Theoretical Interpretation of the $D_{s0}^*(2317)$

The Approach

- Width Determination
  by Measuring the Excitation Function
- Influence of the Beam Momentum Spread
- Achievable $D_{s0}^*(2317)$ Width Resolution at PANDA

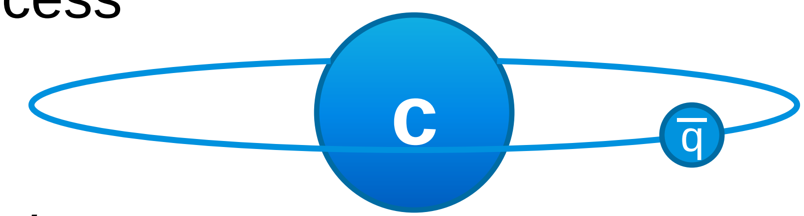
The Tool

- The PANDA Detector

The D-Meson: „Hydrogen of QCD“

General idea of spectroscopy:

- Measure the properties of the states
  to deduce the properties of the potential
- Has been done with great success
  for the QED with hydrogen
- D-Meson
  - *Heavy-light system, like hydrogen*
  - *The c-quark can be considered as a static color source*

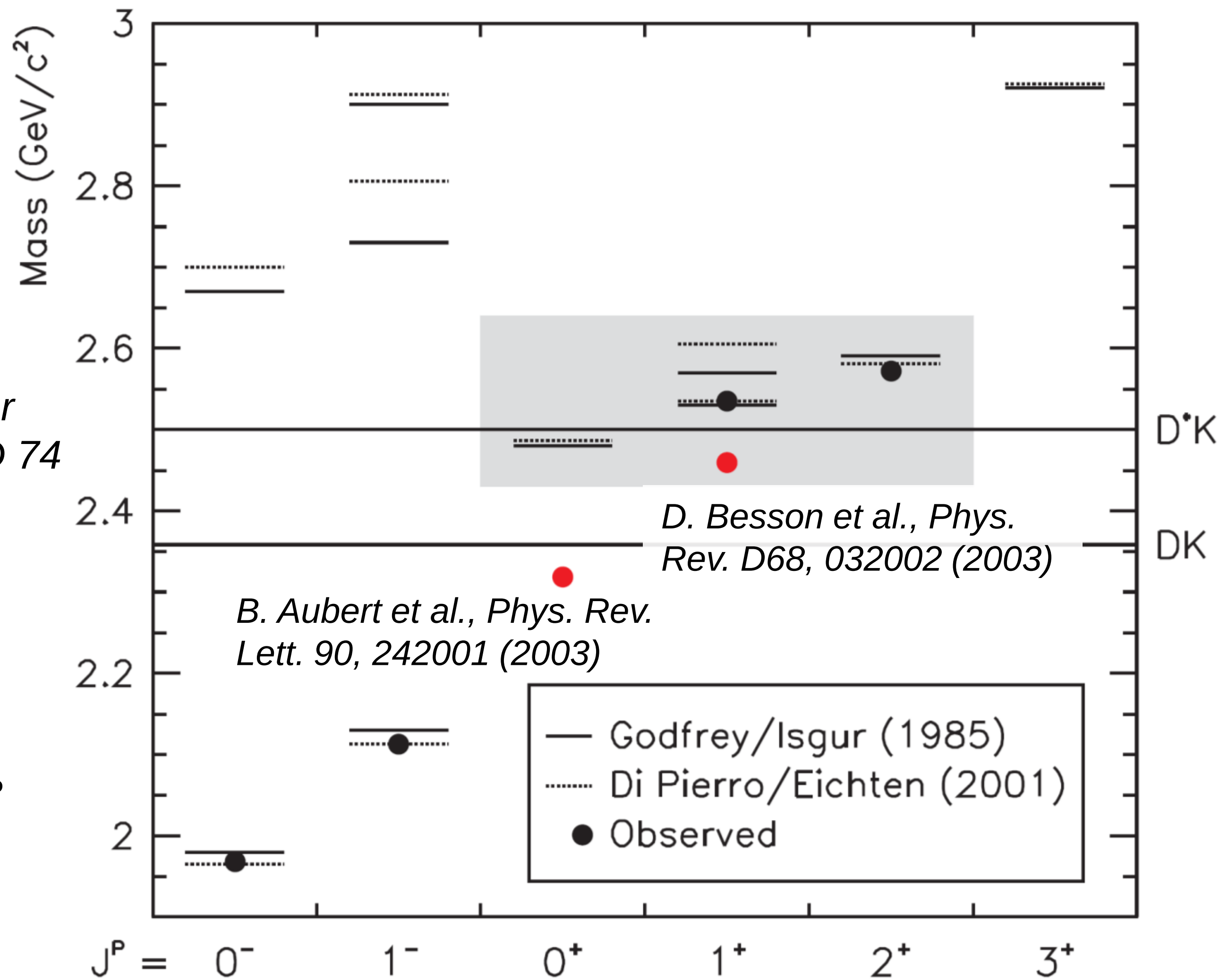


The spectroscopy of the pseudo scalar and vector D mesons is complete, and the masses are well measured. Three of the excited charmed mesons have been observed, although it will take further experiments to extract completely the individual particle properties.

Morrison, Witherell
Annu. Rev. Nucl. Part. Sci. 1989. 39: 183-230

D_s-Meson Spectrum

B. Aubert et al. (BaBar Collab.), Phys. Rev. D 74 (2006) 032007



Mind the notation:

$n^{2S+1}L_J \Leftrightarrow n^jL_J \Leftrightarrow J^P$

$S = s_h + s_l$

$J = L + S$

$P = (-1)^{L+1}$

Theoretical Interpretation of the D_{s0}*(2317)

- When the D_{s0}*(2317) and D_{s1}(2460) were found, their properties did not fit the quark model predictions
  - *~150 MeV below the calculations*
  - *Very narrow*
- Two basic lines of interpretation
  - *Not a quark-antiquark system, but: Molecule, Tetraquark, …*
  - *States can be explained by the quark model with changes to the potential*
- Precise knowledge of the parameters needed to distinguish between interpretations
  - *Current world average: mass: 2317.8* ***± 0.6*** *MeV/c^2, width:* ***< 3.8*** *MeV/c^2*
  - *PANDA's goal: σ_{Width}* ***< 0.1 MeV/c^2***

Theoretical Interpretation of the $D_{s0}^*(2317)$

Approach	$\Gamma(D_{s0}^*(2317) \rightarrow D_s\pi^0)$ (keV)
M. Nielsen, Phys. Lett. B 634, 35 (2006)	**6 ± 2**
P. Colangelo and F. De Fazio, Phys. Lett. B 570, 180 (2003)	**7 ± 1**
S. Godfrey, Phys. Lett. B 568, 254 (2003)	**10**
Fayyazuddin and Riazuddin, Phys. Rev. D 69, 114008 (2004)	**16**
W. A. Bardeen, E. J. Eichten and C. T. Hill, Phys. Rev. D 68, 054024 (2003)	**21.5**
J. Lu, X. L. Chen, W. Z. Deng and S. L. Zhu, Phys. Rev. D 73, 054012 (2006)	**32**
W. Wei, P. Z. Huang and S. L. Zhu, Phys. Rev. D 73, 034004 (2006)	**39 ± 5**
S. Ishida, M. Ishida, T. Komada, T. Maeda, M. Oda, K. Yamada and I. Yamauchi, AIP Conf. Proc. 717, 716 (2004)	**15 - 70**
H. Y. Cheng and W. S. Hou, Phys. Lett. B 566, 193 (2003)	**10 - 100**
A. Faessler, T. Gutsche, V.E. Lyubovitskij, Y.L. Ma, Phys. Rev. D 76 (2007) 133	**79.3 ± 32.6**
Y. I. Azimov and K. Goeke, Eur. Phys. J. A 21, 501 (2004)	**129 ± 43 (109 ± 16)**
M.F.M. Lutz, M. Soyeaur, arXiv: 0710.1545 [hep-ph]	**140**
Feng-Kun Guo, Christoph Hanhart, Siegfried Krewald, Ulf-G. Meißner Phys Lett. B 666 (2008) 251-255	**180 ± 40 ± 100**

Part of this table from A. Faessler, et al. Phys. Rev. D 76 (2007) 014005

… and More Puzzle Pieces for the Spectrum

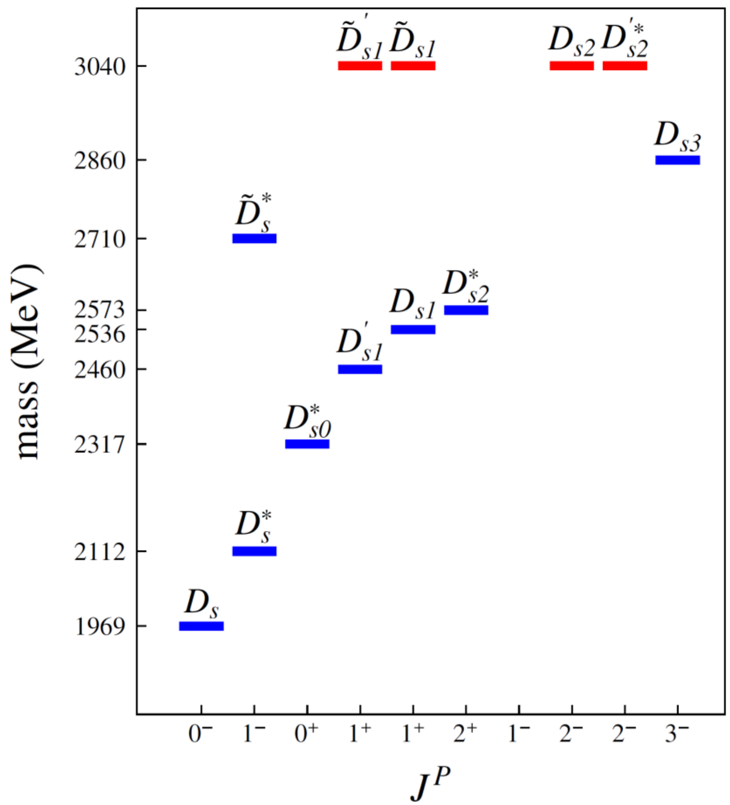


FIG. 1 (color online). Spectrum of the $c\bar{s}$ system. All observed D_{sJ} states, with mass indicated on the y axis, are assigned to a level with J^P and proper name. The four assignments discussed for $D_{sJ}(3040)$ are shown in correspondence to the mass value $M = 3040$ MeV.

Colangelo, De Fazio, Phys. Rev. D 81 (2010) 094001

Width Determination by Measuring the Excitation Function

- Reaction:

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

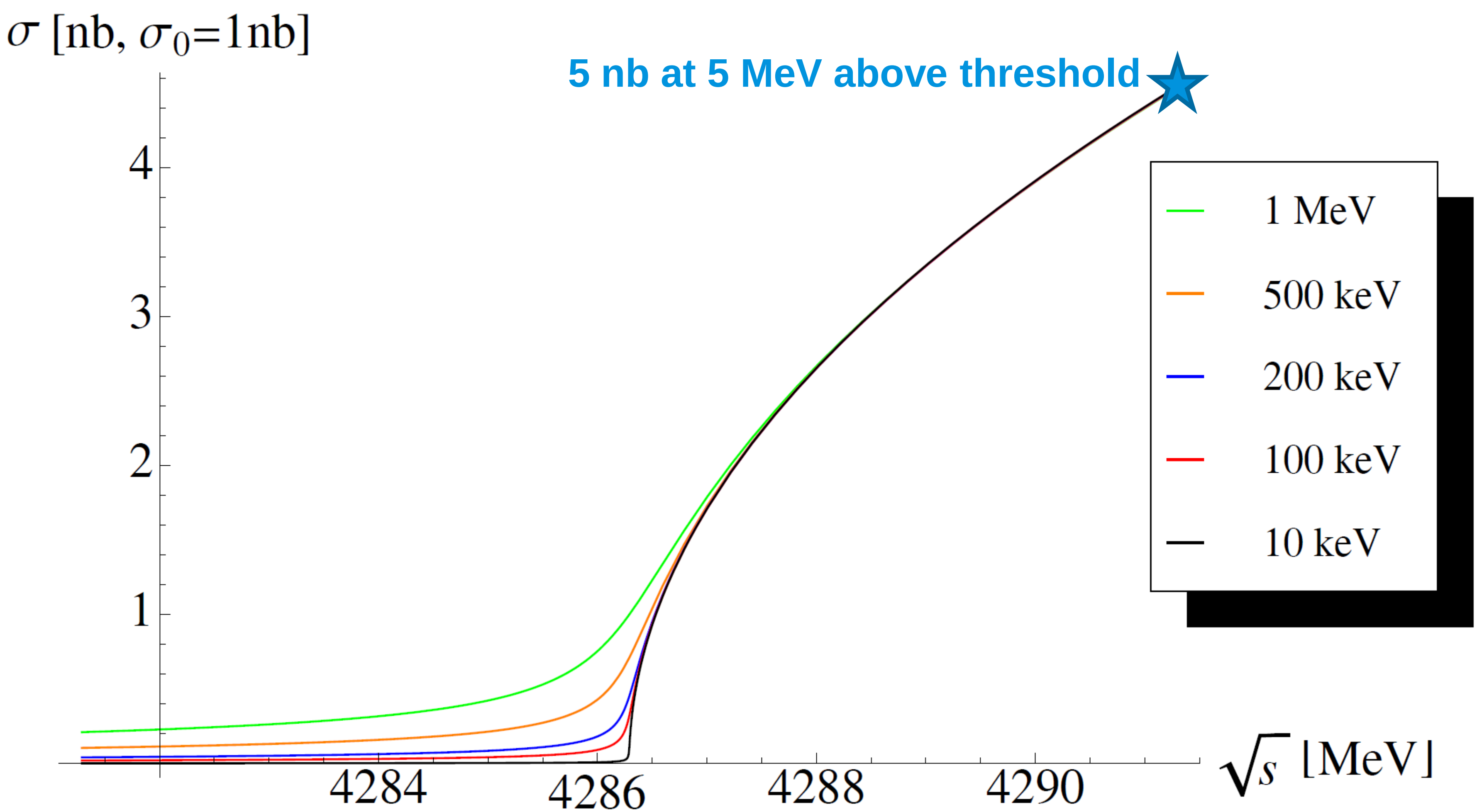
$$D_s^{\pm} \rightarrow \phi\pi^{\pm}, \quad \phi \rightarrow K^{+}K^{-}$$

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

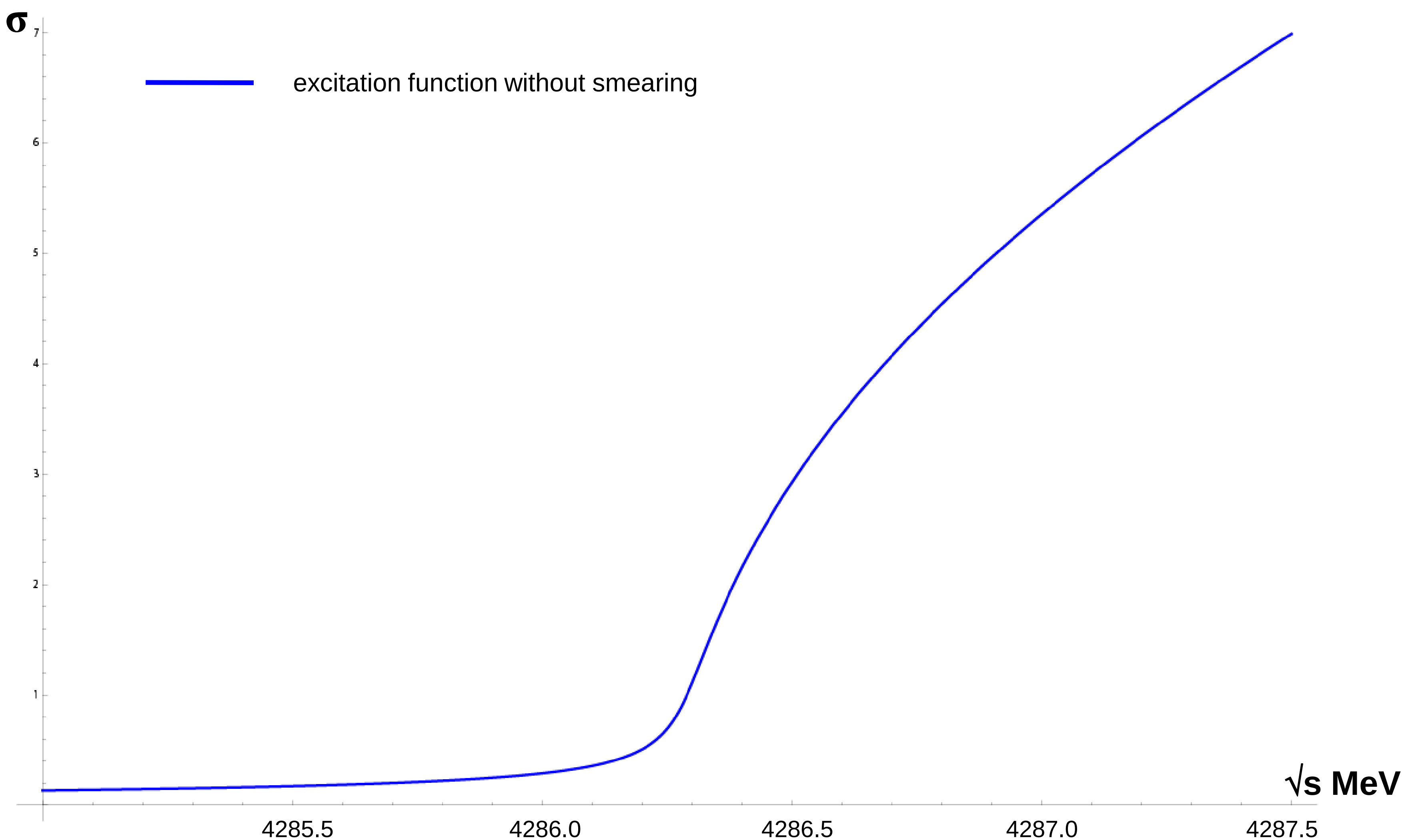
- Excitation function:

$$\frac{\sigma(s)}{|M|^2} = \frac{\boxed{\Gamma}}{4\pi * \sqrt{s}} \cdot \int_{-\infty}^{\sqrt{s}-m_{D_s}} \frac{\sqrt{\left(s-\left(m+\boxed{m_{D_s}}\right)^2\right)\cdot\left(s-\left(m-\boxed{m_{D_s}}\right)^2\right)}}{\left(m-\boxed{m_{D2317}}\right)^2+\left(\frac{\boxed{\Gamma}}{2}\right)^2}\, dm$$

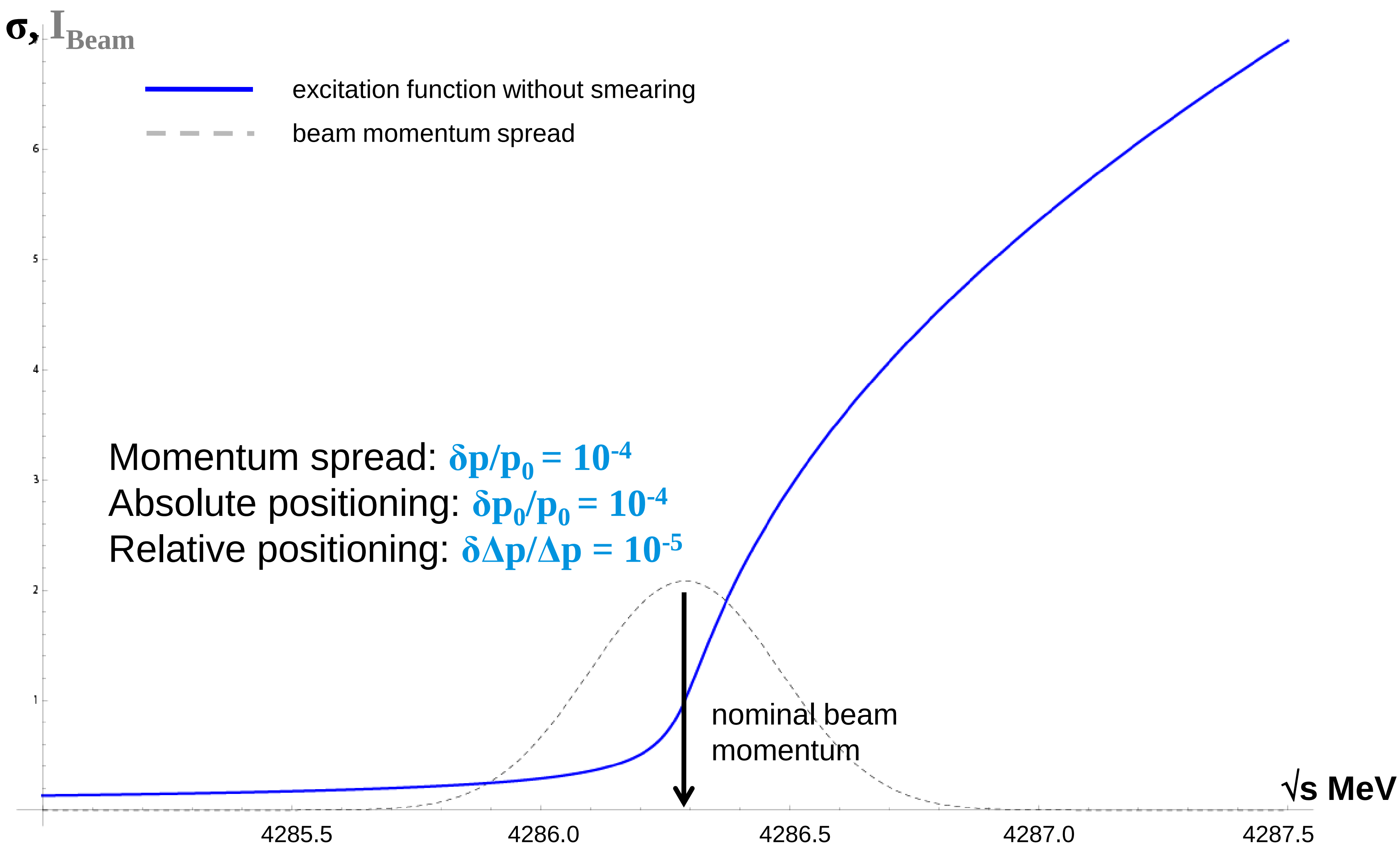
Excitation function of the $D_{s0}^*(2317)$



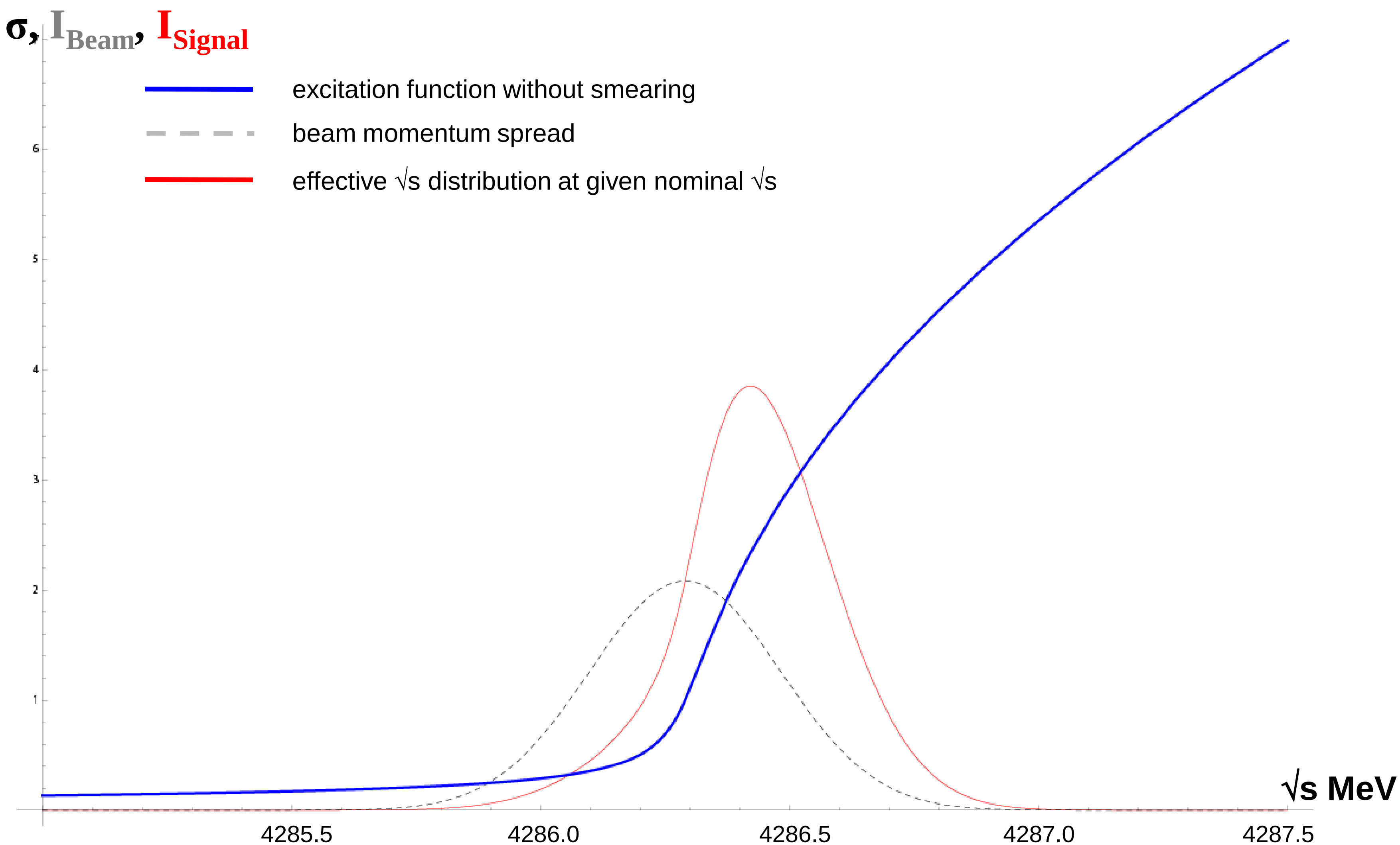
Influence of the Beam Momentum Spread



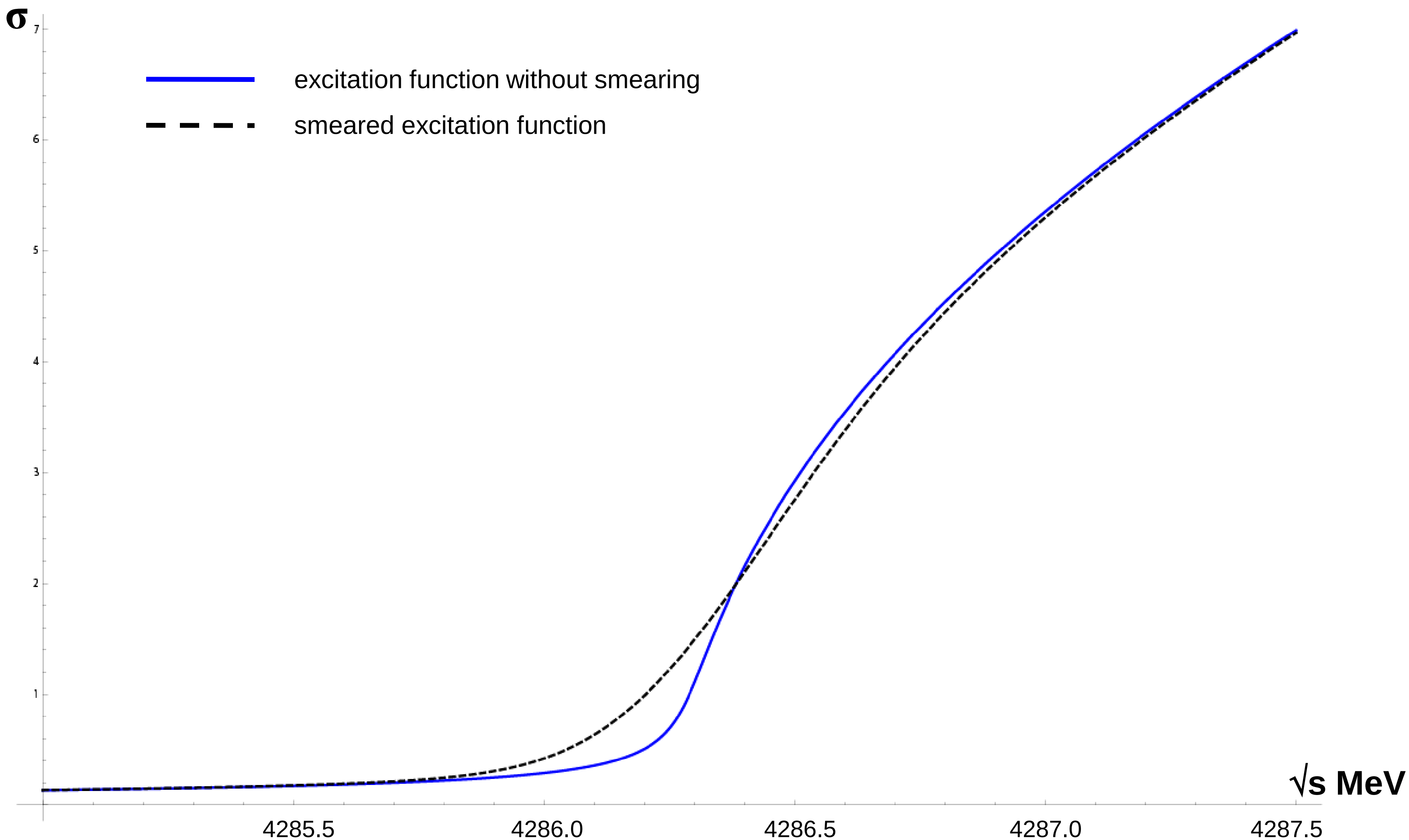
Influence of the Beam Momentum Spread



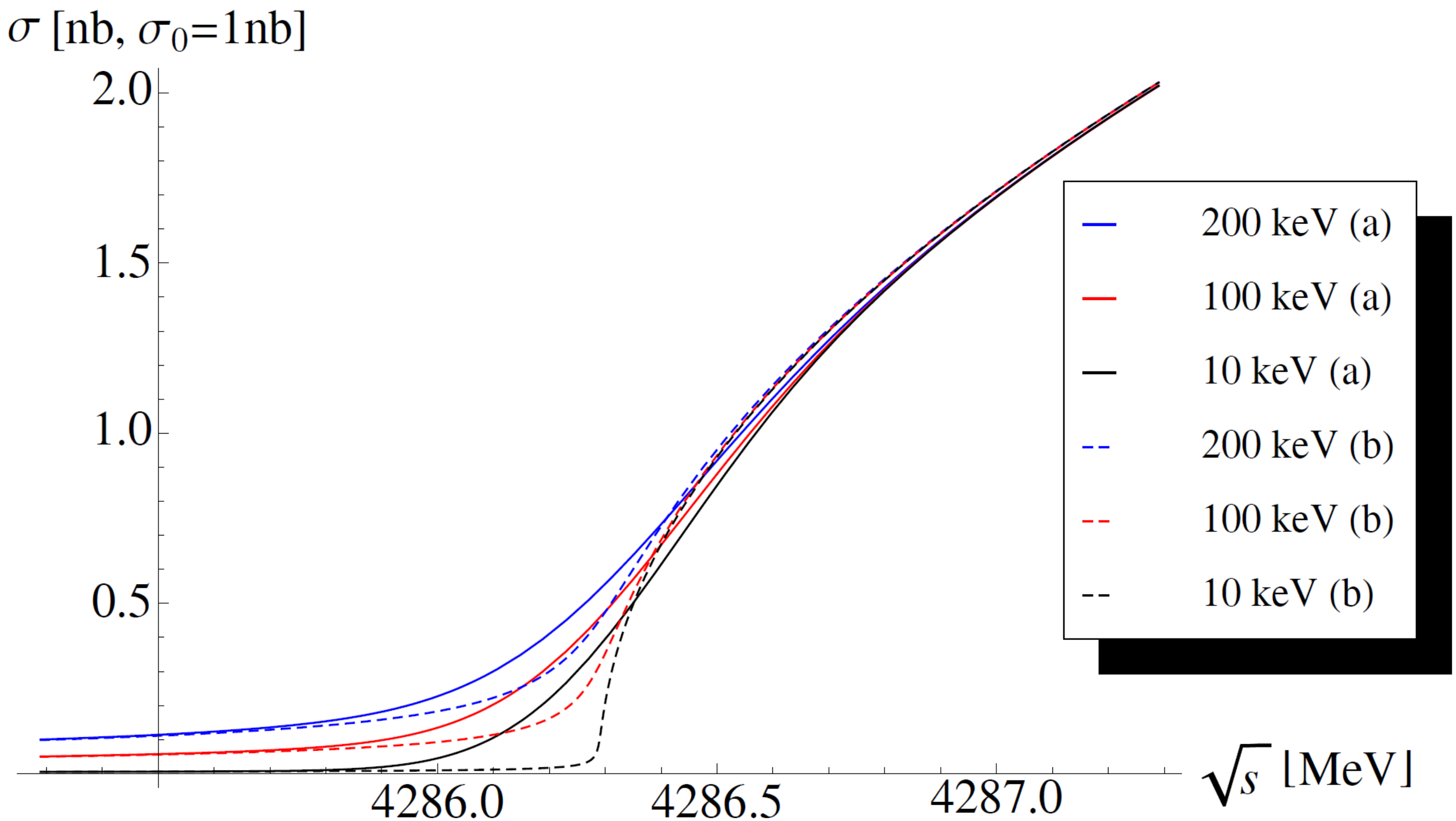
Influence of the Beam Momentum Spread



Influence of the Beam Momentum Spread



Influence of the Beam Momentum Spread



Solid lines (a) with beam momentum spread
Dashed lines (b) without beam momentum spread

D_{s0}*(2317) Energy Scan

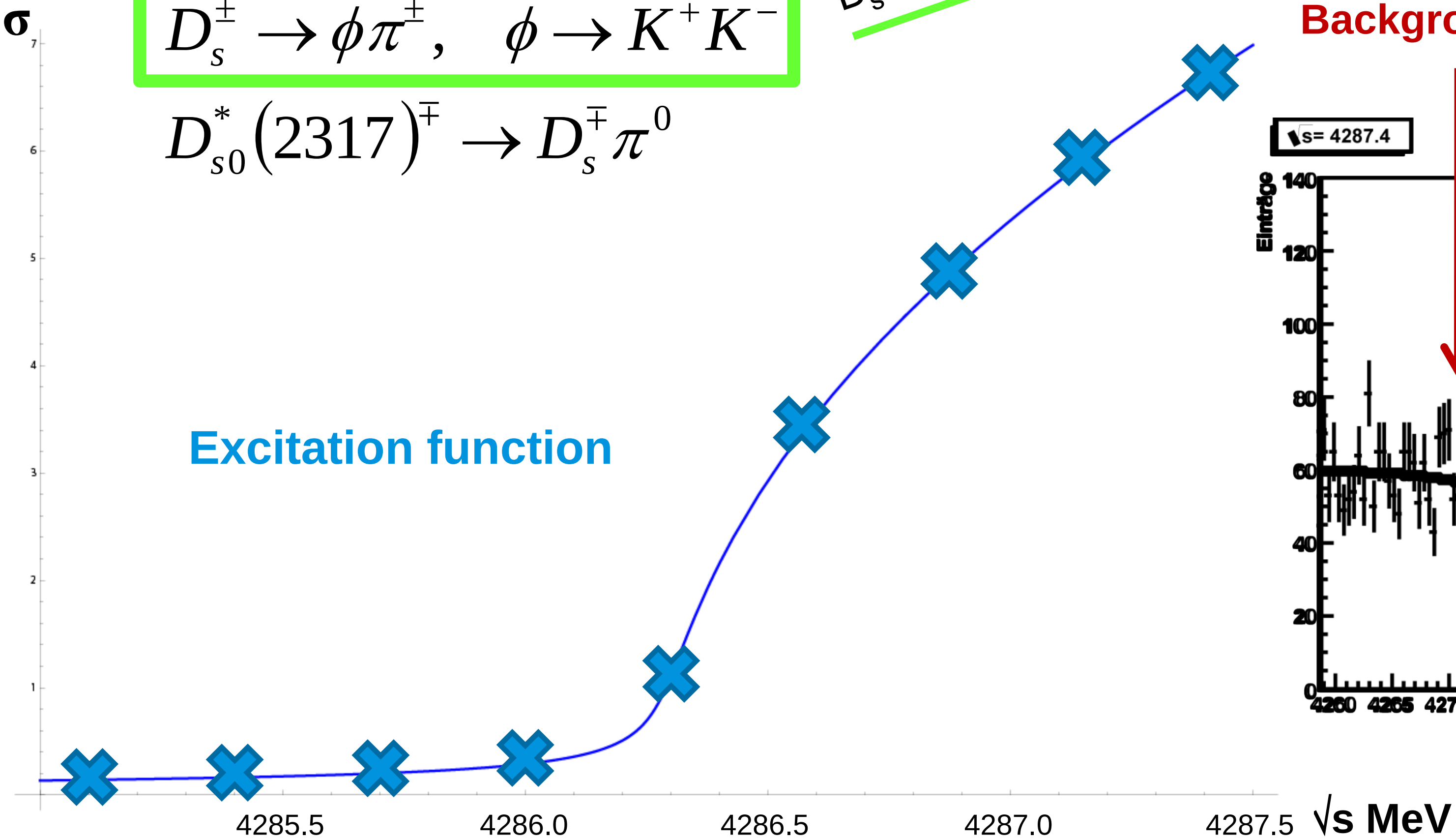
$$\bar{p}p \rightarrow D_s^{\pm} D_{s0}^{*}(2317)^{\mp}$$

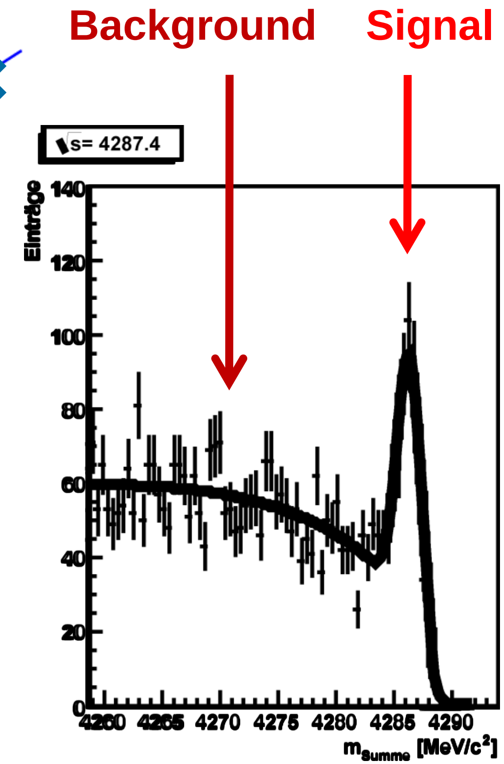
$$\boxed{D_s^{\pm} \rightarrow \phi\pi^{\pm}, \quad \phi \rightarrow K^{+}K^{-}}$$

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

Inclusive reconstruction
D_s + missing mass

Simulated sum mass spectrum

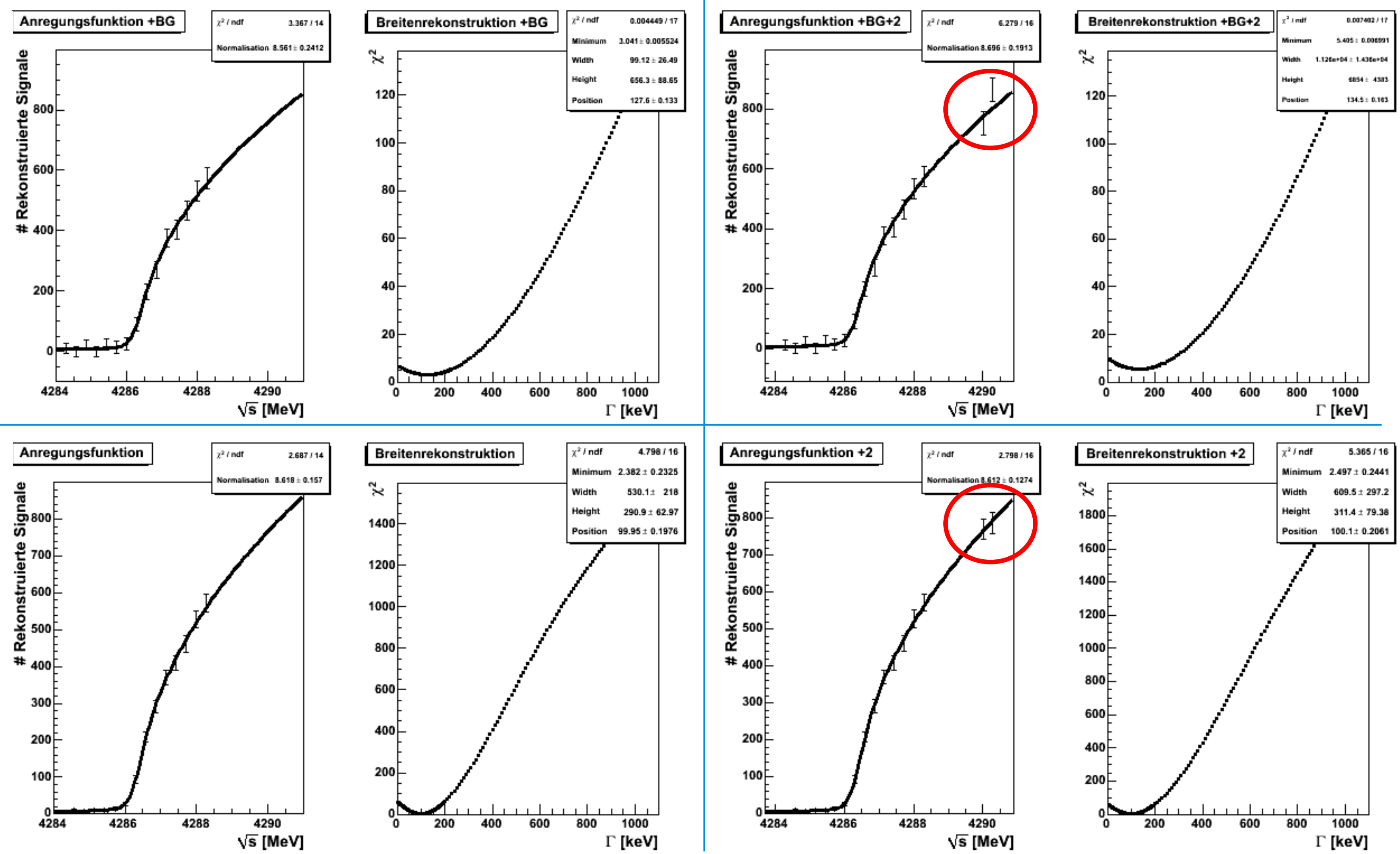




D_{s0}*(2317) Excitation Function – 100 keV Width

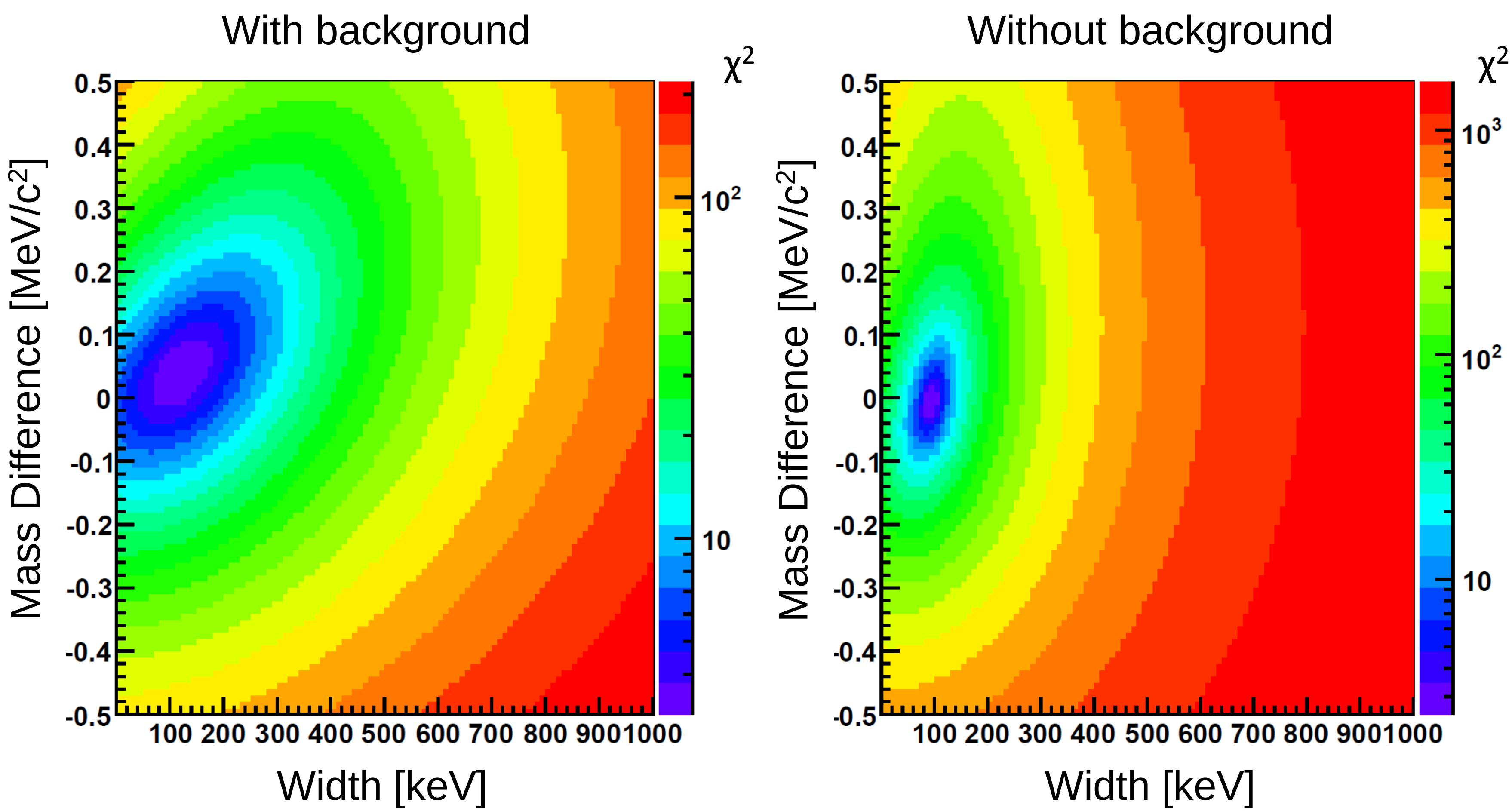
15 Scanpoints | 15+2 Scanpoints

With background / Without background

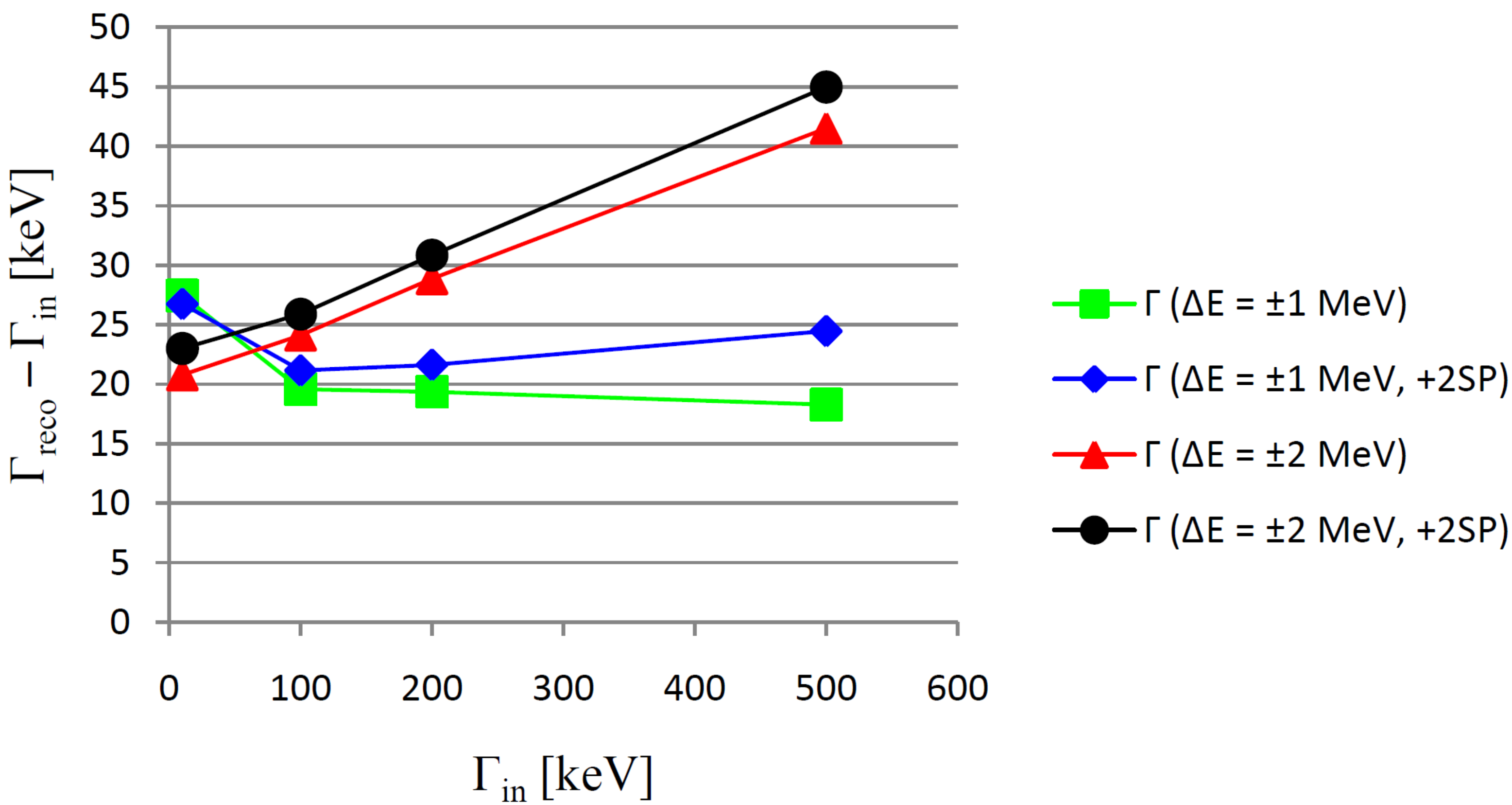


60·9000 nb^{-1}, 5 nb at 5 MeV above threshold, 2 scanpoint patterns

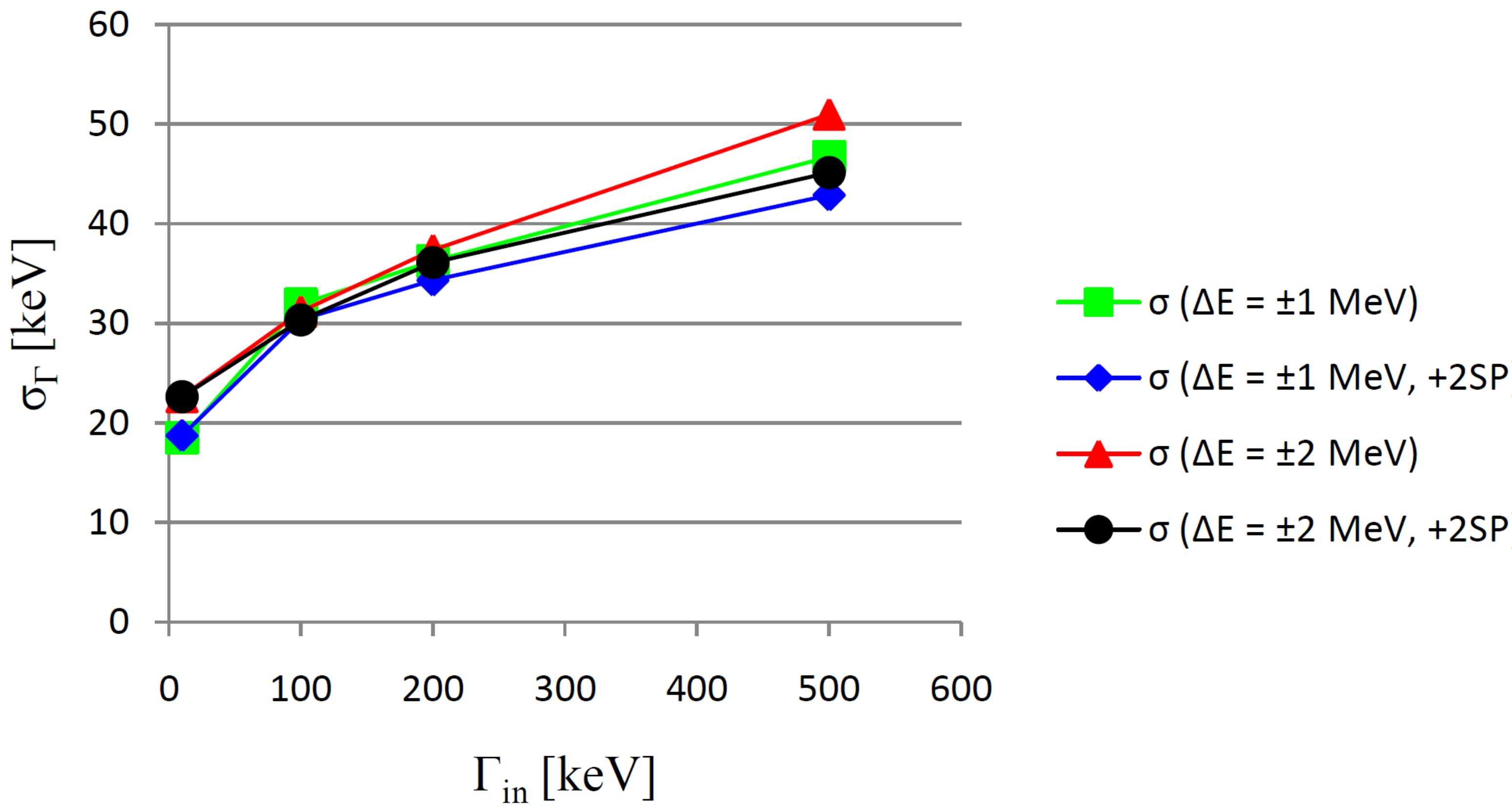
D_{s0}*(2317) χ^2 Distribution – 100 keV Width



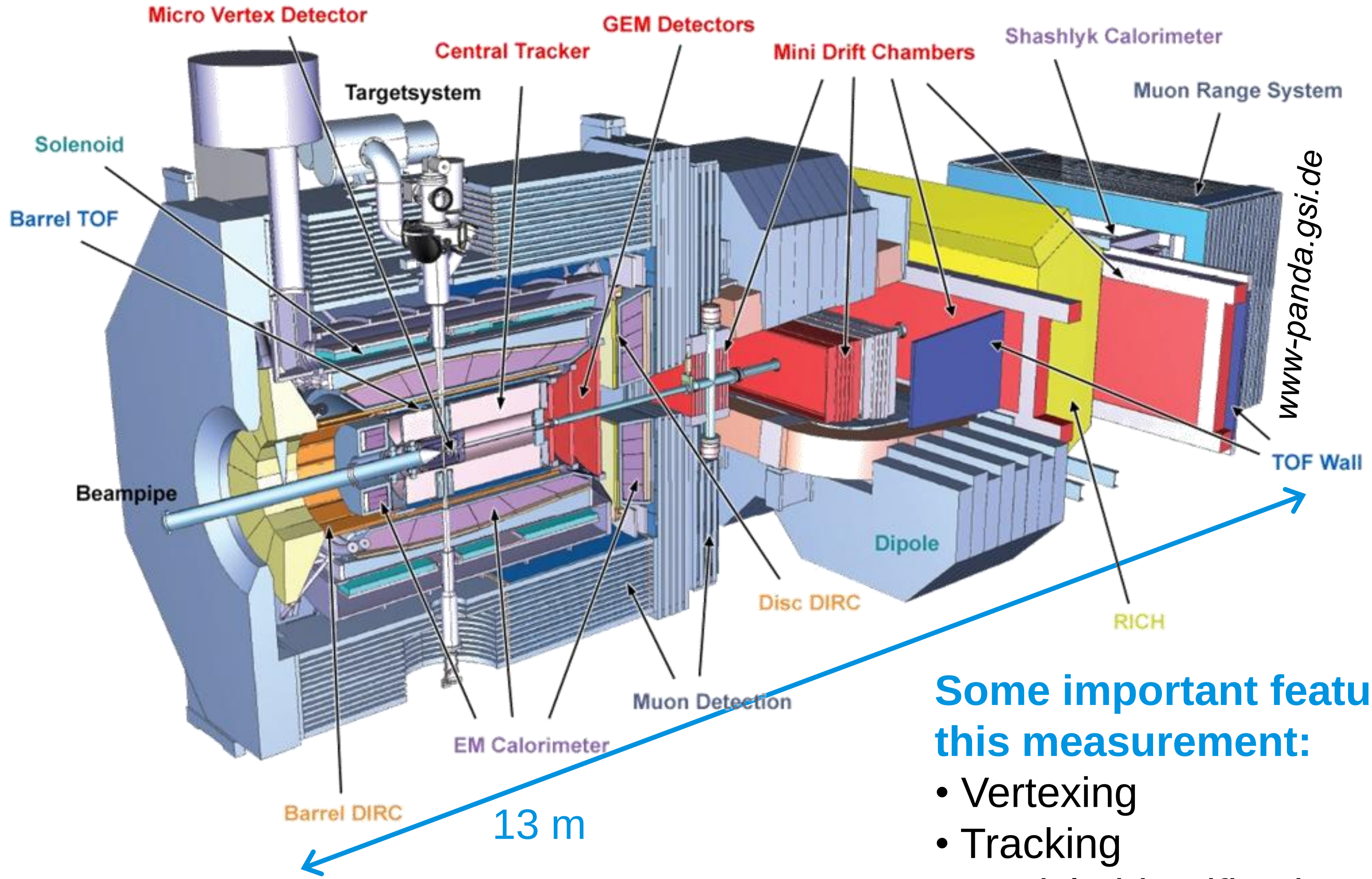
Systematic Shift of the Reconstructed Width



Resolution of the Reconstructed Width



The PANDA Detector



Some important features for this measurement:

- Vertexing
- Tracking
- Particle identification
- Calorimetry

Summary

Spectroscopy of the charmed mesons still exciting

- Particle properties not fully understood yet
- Precise data needed as input for theory
- $D_{s0}^*(2317)$ world average (PDG)
  - *Mass: 2317.8* **± *0.6*** *MeV/c²*
  - *Width:* ***< 3.8*** *MeV/c²*

Achievable PANDA performance

- Resolution of the width: **~ 0.1 MeV/c²**
- Sensitivity to background
  → Precision increases with higher production cross section
- Optimization of scanpoints
  → further improvement of results possible