Charmed meson reconstruction with the PANDA detector

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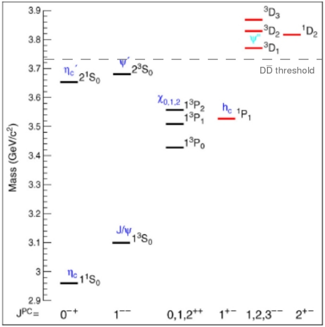
Outline

Overview

Physics motivation

Rich physics program: a selective list

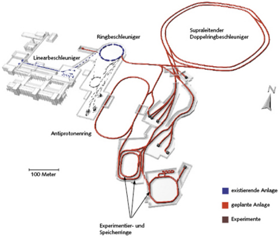
- ...
- charmonium above $D\bar{D}$ thresholds
- search for charmed hybrids
- open charm spectroscopy
- charm in medium, modifications of basic properties (mass, width)?
- investigation of rare decays and CP violation in D meson sector
- ...

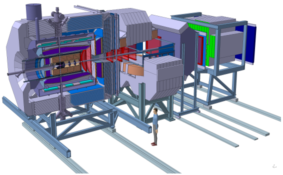


→ plenary talk on Monday:
S.Lange *"PANDA - Hadron Physics with Antiprotons at FAIR"*

HESR - a storage and cooler ring

- 5×10^{10} antiprotons; beam momentum range of $p_{beam,\bar{p}} = 1.5 \ldots 15 GeV/c$
- high luminosity and high resolution mode:
  - high lumi mode: $L = 10^{32} cm^{-2} s^{-1}$ with $\Delta p/p = 10^{-4}$
  - high reso mode: $L = 10^{31} cm^{-2} s^{-1}$ with $\Delta p/p = 3 \times 10^{-5}$



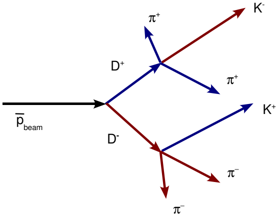


PANDA - a combined solenoid and forward spectrometer

- excellent PID and track reconstruction abilities
- good solid angle coverage (nearly 4π)
- high interaction rate and untriggered readout (continuous beam), $1 - 2 \times 10^{7}$ interactions/s

Overview

List of basic benchmark channels



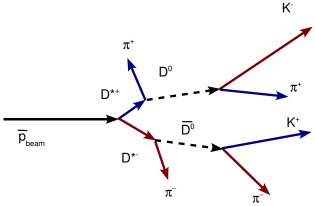
Large scale simulation study

$\bar{p}p \longrightarrow D^+D^-$

- only charged decay considered $D^+ \longrightarrow K^-\pi^+\pi^+$ (+cc)
- production at $\sqrt{s} = 3.77\,GeV$, $p_{beam} = 6.57\,GeV/c$

$\bar{p}p \longrightarrow D^{*+}D^{*-}$

- $D^{*+} \longrightarrow D^0\pi^+$, $D^0 \longrightarrow K^-\pi^+$
- production at $\sqrt{s} = 4.04\,GeV$, $p_{beam} = 7.70\,GeV/c$
- slow pion from $D^{*\pm}$ decay



Selection criteria

common selection criteria for both channels

- loose mass window cut before vertex fitting
  - D^+D^-: $m_D = 1.7 \ldots 2.1 GeV/c^2$
  - $D^{*+}D^{*-}$: $m_{D^*} = 1.8 \ldots 2.3 GeV/c^2$
- minimum 6 charged tracks
- constraints: decay particles have to form a common vertex
- kinematic fit to constrain beam energy and momentum (c.l.$> 5 \times 10^{-2}$)
- K/π selection (LH $>= 0.3$), different PID cuts can be used to reject background
- additional constraint on D meson momentum

Estimation of $\bar{D}D$ cross sections

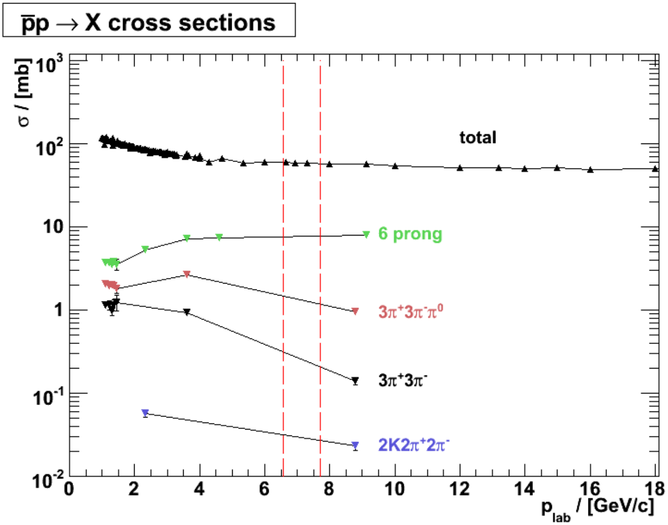
- $\sigma(\bar{p}p \to \bar{D}D)$ unknown
- cross section of a resonance via Breit-Wigner

$$\sigma_R(s) = \frac{4\pi\hbar^2 c^2}{s - 2m_p^2 c^4} \frac{B_{in} B_{out}}{1 + \left(2(\sqrt{s} - M_R c^2)/\Gamma_R\right)^2}$$

- e.g. $\sigma(\bar{p}p \to \Psi(3770) \to D^+D^-) \approx 3.25nb$
- worst case: cross section for direct production of $D\bar{D}$ pair assumed to be in the same order of magnitude at the resonant position, close to threshold (no data yet)
- total cross section at $p_{beam} = 6.5\ GeV/c$:
  $\sigma(\bar{p}p \to X) = 60mb$

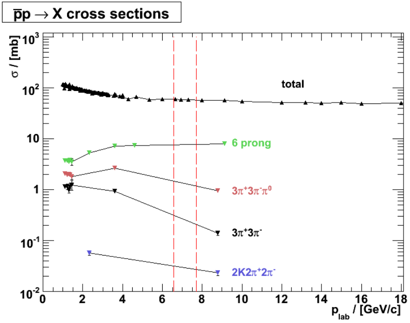
channel	D^+D^-	$D^{*+}D^{*-}$
decay	$D^{\pm} \to K^{\mp}\pi^{\pm}\pi^{\pm}$ (9.2%)	$D^{*+} \to D^0\pi^+$ (67.7 %) $D^0 \to K^-\pi^+$ (3.8 %)
rel. branching	5×10^{-10}	1×10^{-11}

some data from the 70's and early 80's for possible background reactions



Background sources for $D\bar{D}$ channels

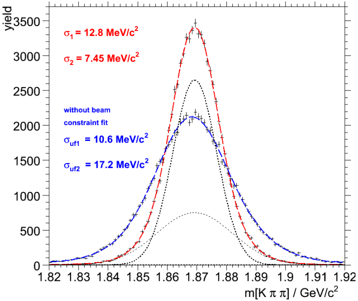
- assumption: signal suppressed by $10^{10} - 10^{11}$
- general background
  - DPM (dual parton model) describes $\bar{p}p$ annihilation processes
  - test for apparative effects
  - tested down to level of 10^{-7}
- specific background reactions
  - $\frac{\sigma(\bar{p}p \to 3\pi^+ 3\pi^- \pi^0)}{\sigma(\bar{p}p \to X)} \approx 2.5 \times 10^{-2}$
  - $\frac{\sigma(\bar{p}p \to 3\pi^+ 3\pi^-)}{\sigma(\bar{p}p \to X)} \approx 5 \times 10^{-3}$
  - $\frac{\sigma(\bar{p}p \to 2K^\mp 4\pi^\pm)}{\sigma(\bar{p}p \to X)} \approx 5 \times 10^{-4}$

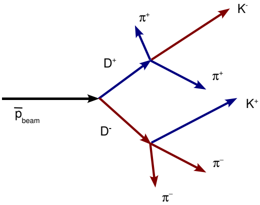


complete detector simulation

- $\bar{p}p \to 3\pi^+ 3\pi^- \pi^0$: (400×10^6)
- $\bar{p}p \to 3\pi^+ 3\pi^-$: (70×10^6)
- $\bar{p}p \to 2K^\mp 4\pi^\pm$: 10×10^6

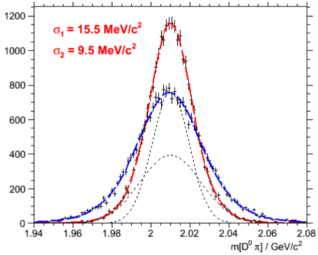
Signal efficiency

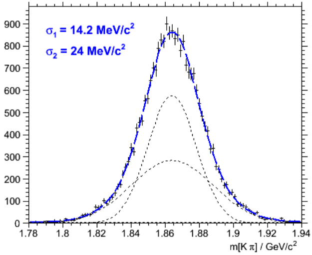


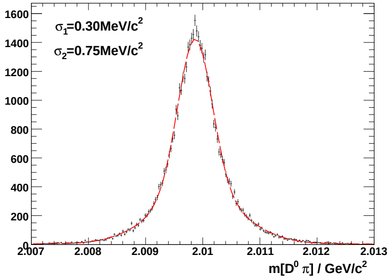


$\bar{p}p \rightarrow D^+D^-$

- efficiency $\epsilon = 40\%$
- kinematic fit (4C) improves resolution by $\approx 50\%$ (red curve)
- $m_D - m_{gen} = 0.5 \times 10^{-4} MeV/c^2$







$\bar{p}p \rightarrow D^{*+}D^{*-}$, $D^{*\pm} \rightarrow D^0\pi^\pm$

- efficiency $\epsilon = 27\%$
- 4C-fit improves resolution by $\approx 50\%$ (red curve)
- lower left: 5C-fit: $m_{D^0} = m_{D^0,PDG}$

Suppression of non strange background

$3\pi^+3\pi^-$, $3\pi^+3\pi^-\pi^0$

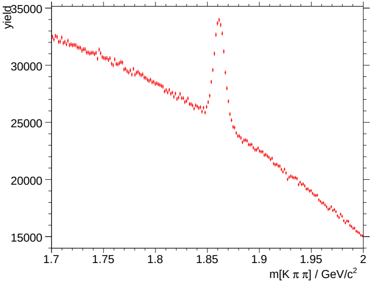
- distribution of K, π momenta from D decay in range from hundreds of MeV/c to few GeV/c
- using dE/dx information from the tracking system for low momentum tracks
- DIRC information for higher momentum particles
- kinematics very restrictive
- require higher K probability rejects remaining background

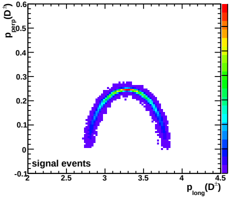
→ good PID neccessary to reject non strange background

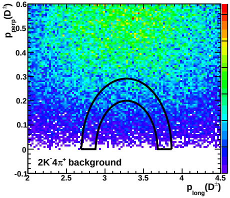
	signal efficency [%]		S/N
LH cut	D^+D^-	$D^{*+}D^{*-}$	$\bar{D}D$
0.2	39.9	27.4	1:5
0.3	25.4	14.3	1:1 (or better)

preliminary

$2K^{\mp}4\pi^{\pm}$ background







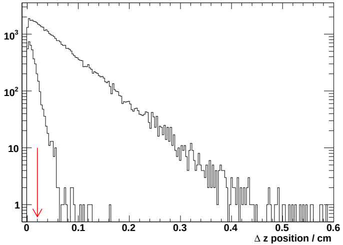
D^+D^-

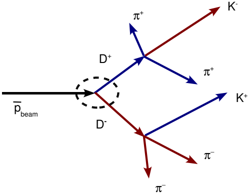
- constraining allowed momentum region for $D^{\pm}$ candidate
- cut on $D^{\pm}$ momentum rejects over 90% of the $2K^{\mp}4\pi^{\pm}$ background
- additional cut on Δz of $D^{\pm}$ decay vertex

Δz cut [μm]	S/N
200	1:160
400	1:20
600	1:2

preliminary

$2K^{\mp}4\pi^{\pm}$ background





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preliminary

$2K^{\mp}4\pi^{\pm}$ background

$D^{*+}D^{*-}$ channel

- better background suppression due to kinematics
  - additional vertex constraint from D^0 decay
  - slow pion from the $D^{*\pm}$ decay
- without D^0 mass constraint in $D^{*\pm}$ fit: background suppression worse
- no additional explicit vertex cut used

D^0 mass	signal efficiency [%]	S/N
no mass constraint	27.4	1:200
$M_{PDG}(D^0)$	24.9	$\approx$ 1:1 (or better)

Overview

Conclusions

- proposed detector setup shows good performance to reconstruct charmed mesons
- good signal reconstruction, using kinematic fitting
- excellent suppression of multi pion background using PID informations ($\approx 10^8$)
- sufficient suppression of strange background ($\approx 10^5$) using extended target region

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- good signal reconstruction, using kinematic fitting
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PANDA will facilitate precision study of many physics aspects in the charmed region using $\bar{p}p$ interactions