Observation of isovector dibaryon resonance-like states with a mass of 2.2 GeV/$c^2$

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Dibaryon resonance-like states

- Resonances with baryon number $B = 2$ — “dibaryons”
- Seen in partial wave analysis (PWA) of $pp \rightarrow pp$, $pp \rightarrow d\pi^+$
- Not observed directly
- Meson-baryon models: states of the nucleon–$\Delta(1232)$ channel
- Quark-gluon models employing also $\pi$, $\sigma$-meson fields
Why $pp \rightarrow \{pp\}_s \pi^0$ channel

Three main resonances:

$^1D_2$, $^3F_3$, $^3P_2$

($^{2S+1}L_J$ of the $pp$ pair)

$^1D_2$, $^3F_3$ — well defined from partial wave analysis

$^3P_2$ — the least intensive, large uncertainties

Final proton pairs in the $^1S_0$ state

Forbidden odd ($p$, $f$...) pion partial waves, forbidden even ($S$, $D$...) $\Delta N$ states

Of three dominant dibaryon resonances only the least well-defined $^3P_2$ allowed
Experimental setup

COSY synchrotron

ANKE spectrometer
Experiment

- **Forward detector** of the ANKE spectrometer
- **Transversely polarized** proton beam, internal hydrogen target

![Diagram of experimental setup]

Allows measuring

- Differential cross section \( \frac{d\sigma}{d\Omega} \)
- Vector analyzing power \( A_y \)
Fitting functions

\[
\frac{d\sigma}{d\Omega} = \frac{k}{4p} \left( a_0 + a_2 \cos^2 \theta_{pp} + a_4 \cos^4 \theta_{pp} + \ldots \right)
\]

\[
A_y \frac{d\sigma}{d\Omega} = \frac{k}{4p} \sin \theta_{pp} \cos \theta_{pp} \left( b_2 + b_4 \cos^2 \theta_{pp} + \ldots \right)
\]

Pion orbital momenta \( \ell \leq 2 \), new parametrization

\[
\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega} \left( 1 + \kappa \sin^2 \theta_{pp} \right)
\]

\[
A_y = \frac{A_y^{\text{max}} \sqrt{1 + \kappa \sin 2\theta_{pp}}}{1 + \kappa \sin^2 \theta_{pp}}
\]

- \( d\sigma_0 / d\Omega \) — cross section at 0 angle
- \( \kappa \) — cross section angular slope
- \( A_y^{\text{max}} \) — maximal analyzing power
Measured cross section $d\sigma/d\Omega$ and analyzing power $A_y$
Energy dependence of fit parameters

\[ \frac{\sigma}{d\Omega} = b/sr, \mu, \Omega/d, \sigma, d_0, \kappa \]

\[ T_p = 400, 600, 800, 1000 \text{ MeV} \]

\[ \kappa = 0, 5, 10 \]

- new ANKE data
- published ANKE data
- published WASA data
- Breit-Wigner fit
- 68% confidence interval
Further analysis

Features of the data

- **Resonance peak** in $d\sigma_0/d\Omega$
- $d\sigma/d\Omega$ angular dependence: **minimum** at zero angle
- Slowly varying angular slope parameter $\kappa$
- **Large** analyzing power

Partial wave analysis

- $\ell \leq 2$ — three possible transitions:
  - $^3P_0 \rightarrow ^1S_0s$, $^3P_2 \rightarrow ^1S_0d$, $^3F_2 \rightarrow ^1S_0d$
- Similarity to $pp \rightarrow d\pi^+$:
  - $^3F_2 \rightarrow ^1S_0d$ and momenta $\ell > 2$ neglected
- Two main transitions $^3P_0 \rightarrow ^1S_0s$, $^3P_2 \rightarrow ^1S_0d$
- $\{d\sigma_0/d\Omega, \kappa, A^\text{max}_y\} \longrightarrow \{|M^P_s|, |M^P_d|, \phi\}$
Partial waves energy dependence

![Graph of Partial Waves Energy Dependence](image)

- **$|M_p^2|$** vs. $T_p$ [MeV]
- **$\phi$** [deg] vs. $\sqrt{s}$ [MeV]

**Legend:**
- **with $A_y$**
- **phase $\phi$ fixed from $pp \rightarrow pp$**
- **excluded from fit**
- **modified Breit-Wigner fit**
- **68% confidence interval**
- **$pp \rightarrow pp M_s^P-M_d^P$ phase**
Comparable $^3P_0 \rightarrow ^1S_0s$ and $^3P_2 \rightarrow ^1S_0d$ amplitudes, peak in $d\sigma_0/d\Omega$, positive slope $\kappa$ and large $A_y$ originates from their interference

$^3P_2$ resonance parameters:
$E_R = 2195 \pm 8 \text{ MeV}/c^2$, $\Gamma = 134 \pm 22 \text{ MeV}/c^2$
with $\chi^2/\text{ndf} = 8/6$

Indication on resonant behaviour in $^3P_0s$, parameters:
$E_R = 2199 \pm 5 \text{ MeV}/c^2$, $\Gamma = 94 \pm 11 \text{ MeV}/c^2$, $c_{bg} = 2.4 \pm 0.2 \text{ \mu b/sr}$
with the $\chi^2/\text{ndf} = 6.5/6$

Article to be published

Thank you