ANALYSIS OF THE $pp \to \{pp\}_s\pi^0$ REACTION AT THE ENERGY RANGE 0.8–2.8 GeV

ANKE Collaboration,COSY-Jülich synchrotron(Germany)

Presented by :

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What to study $pp \to \{pp\}_s\pi^0$ process For?

$\{pp\}_s$ is a pp system with the excitation energy $E_{pp} < 3$ MeV, i.e mainly S-state of two protons(the admixture of the states with higher momenta $\approx 6\%$). Then such pp system having I=1,L=0 may have spin S=0 only and angular momentum of initial beam-target pp system can be odd.

Why is it interesting to study processes with its participation?

One example :

Assume that reaction near Δ_{1232} threshold goes via intermediate $\Delta_{1232}N$ state. Then angular momentum of such a system may be only only P,F,.. - only odd and its production is suppresessed due to centrifugal barrier. Then the other mechanisms may be more pronounced and suitable for its studies!

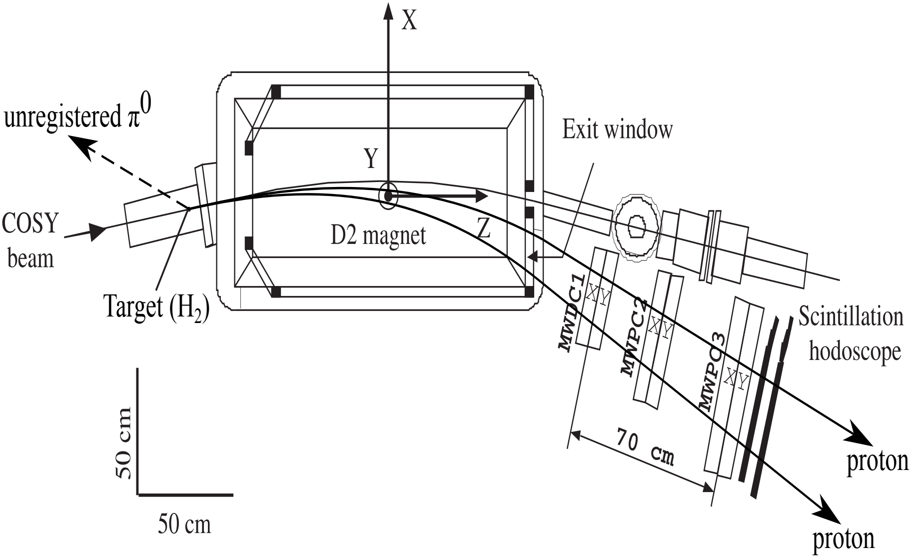
Also there is a well studied $pp \to d\pi^+$, where two nucleon system(deuteron) has quantum numbers S=1, I=0 and L=0,2 and a lot of analyses can be done comparing these two processes.

Bulk Of Data

Apparatus – ANKE setup,COSY-Jülich synchrotron(Germany).
Energy Range – 0.8–2.8 GeV range.
12 expositions(energies) were analysed:
1 Exposition in march 2013 - energy 0.8GeV(march13)
9 Expositions in june 2010 - energies 1.0,1.4,1.6 and up to 2.8 with step 0.2,all GeV(j10)
2 Expositions in october 2007 - energies 1.7 and 2.4 (pi07) - statistically most meaningful; ≈ 30 times more than in j10
Angular Range Analyzed - $0^\circ < \theta_{pp} \lesssim 18^\circ$,$pp$ is diproton

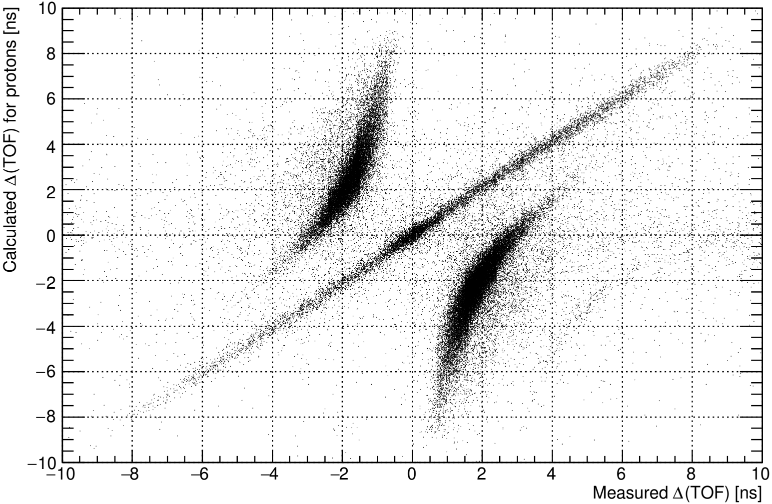
Experimental Setup

ANKE,Experimental setup



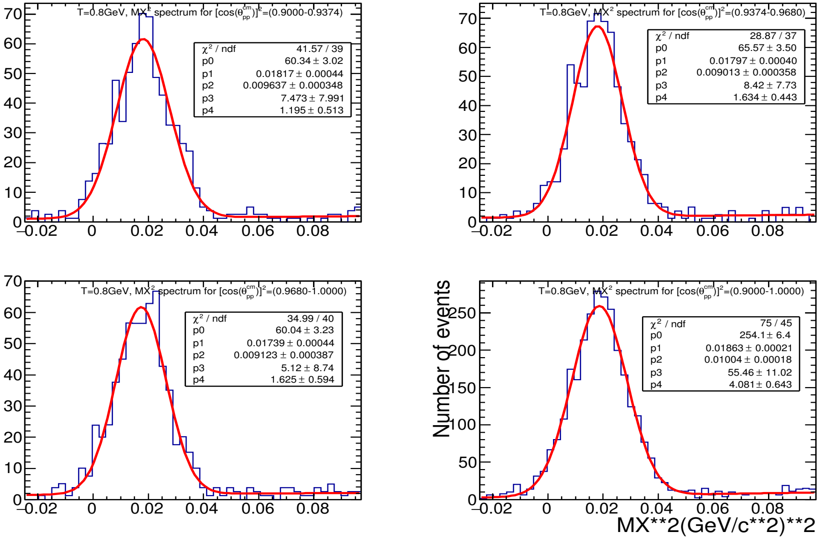
Data Processing,Time criterium

Time Difference Criterium :

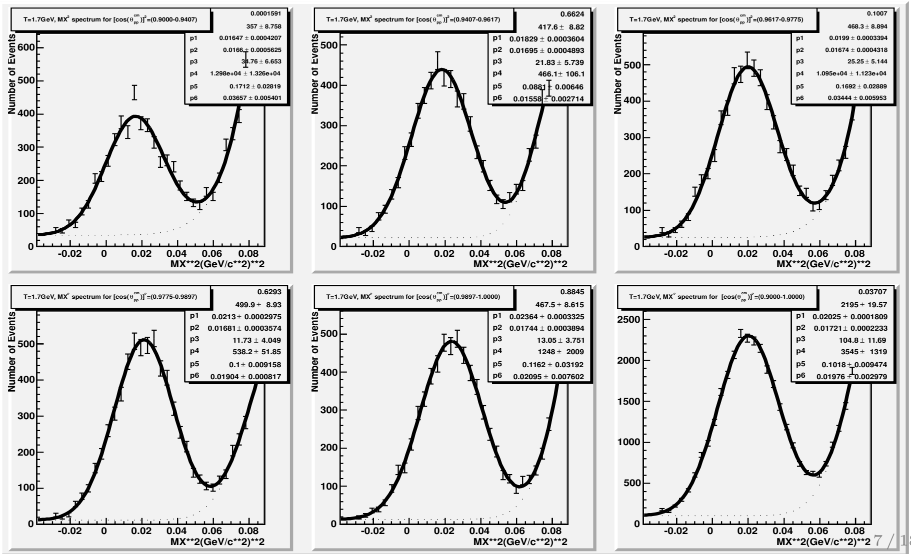


Data Processing,Missing Mass criterium - one

Missing Mass Criterium, Low Energy :



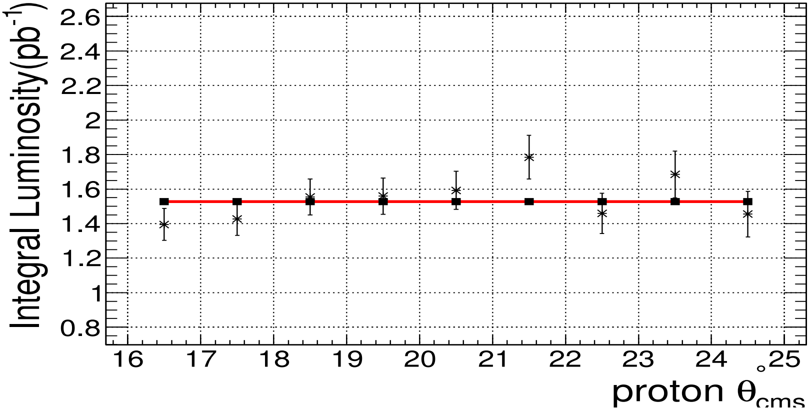
Missing Mass Criterium, Higher Energy :



Luminosity

Estimated by $pp \to pp$ reaction,delayed by the absence of information at 1.7,2.4 energies in our angular range. New ANKE data in 2016. It ranged from few tens nb^{-1} to few pb^{-1}

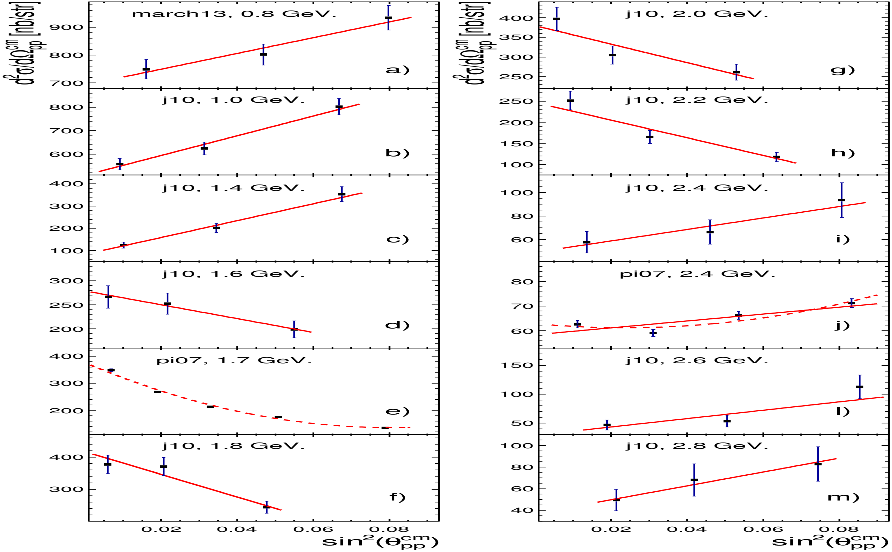
Luminosity for pi07,1.7GeV as an example:



Data

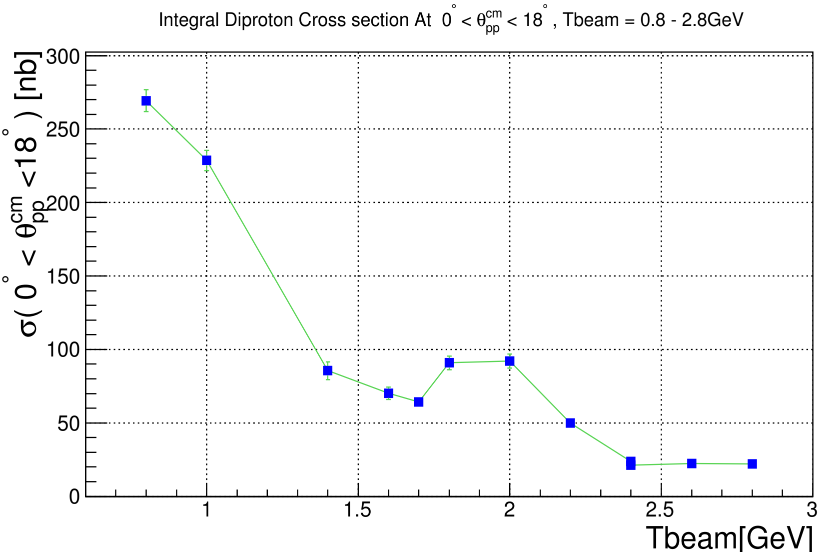
Everywhere where needed we used kinematical fitting technique. The results were obtained in the form $d\sigma/d\Omega_{pp}$, where Ω_{pp} - is the solid angle of pp system in the center of mass of the reaction. Only the proton pairs with the excitation energy $E_{pp} < 3MeV$ were selected. The accuracy was $\sigma_{(\delta(E_{pp})/E_{pp})} \approx 0.3$. Systematic errors were estimated to be $\approx 8\%$.
Fitting by :
$d\sigma/d\Omega = d\sigma/d\Omega(0) * (1 + k * sin^2(\theta_{pp}^{cm}))$ – for j10, march13 beam times.
$d\sigma/d\Omega = d\sigma/d\Omega(0) * (1 + k * sin^2(\theta_{pp}^{cm}) + k1 \cdot (sin^2(\theta_{pp}^{cm}))^2)$– for pi07 beam time.

Data



$d^2\sigma/d\Omega_{pp}^{cm}$ [nb/str]
march13, 0.8 GeV.
a)
j10, 1.0 GeV.
b)
j10, 1.4 GeV.
c)
j10, 1.6 GeV.
d)
pi07, 1.7 GeV.
e)
j10, 1.8 GeV.
f)
j10, 2.0 GeV.
g)
j10, 2.2 GeV.
h)
j10, 2.4 GeV.
i)
pi07, 2.4 GeV.
j)
j10, 2.6 GeV.
l)
j10, 2.8 GeV.
m)
$\sin^2(\theta_{pp}^{cm})$

Integral Data



AtZero, Fit by Breight-Wigner

Solid curve - is a fit by formula $p0/((\sqrt{(}s) - p1)^2 + p2^2)$

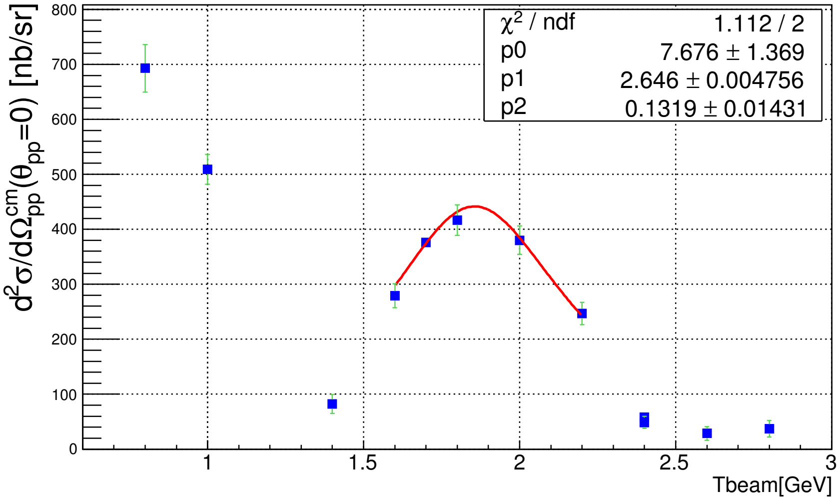
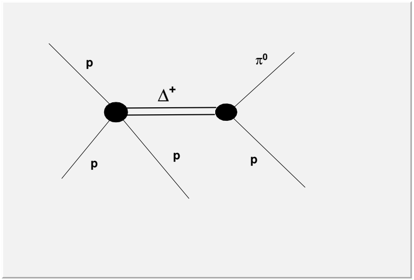
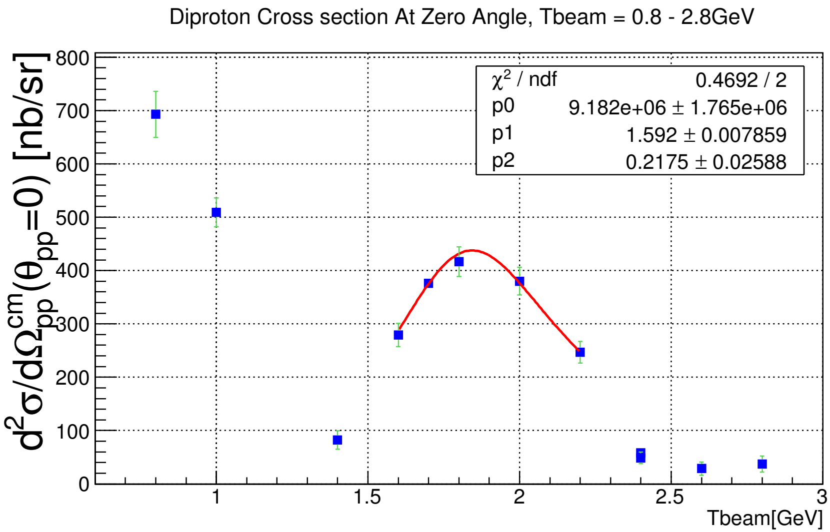


Diagram of “Isobar” Model

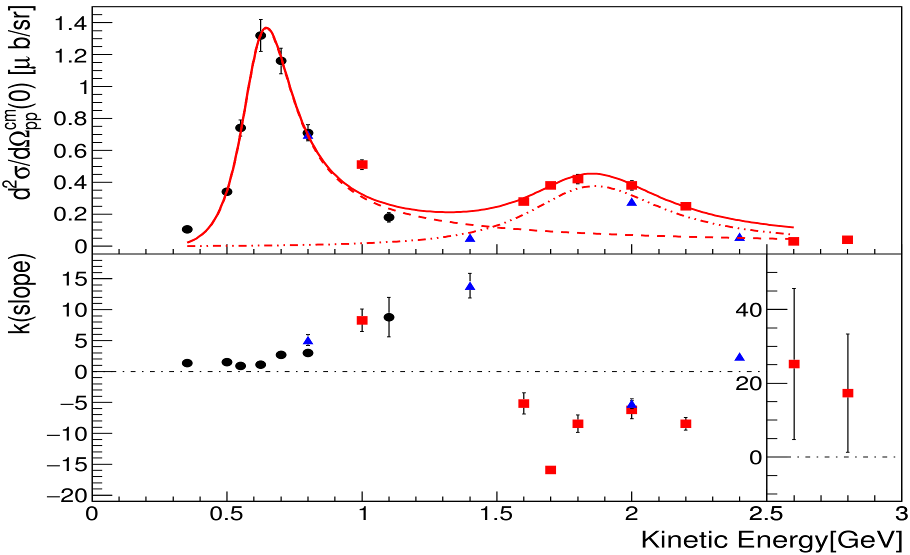


Matrix element is $A \approx q_\pi/((s_\Delta - s_\Delta^0) - i \cdot (s_\Delta^0)^{1/2} \cdot \Gamma_t)$
where s_Δ,q_π - current values of Δ mass squared and pion momentum in its rest frame;s_Δ^0 - central value of its mass squared, the width
$\Gamma_t = \Gamma_0 \left(\frac{q_\pi}{q_0}\right)^{2l+1} \cdot \frac{\rho(s_\Delta)}{\rho(s_\Delta^0)}$, where pion momentum is equal q_0 for isobar mass s_Δ^0 squared. l - is orbital momentum of the isobar and
$\rho(x) = 1/((x + m_\pi^2 - m_p^2)/(2\sqrt{x}))$.

Fit by "Isobar" Model



Previous and current data Combined



Explanation of Previous Picture

Higher Panel - all the results obtained by our group, including current one. Solid curve is the result of fitting - for fit we used 5 points for the energies 0.5,0.55,0.6,0.7,0.8GeV and 5 points, obtained in the current analysis- energies 1.6,1.7,1.8,2.0,2.2GeV. Low one - parameter k.
Fitting function was as a sum :
$|A|^2 = |A_{1232}(g_{1232}, M_{1232}, \Gamma_{1232})|^2 + |A_{1620}(g_{1620}, M_{1620}, \Gamma_{1620})|^2$
Here $A_{1620}(g_{1620}, M_{1620}, \Gamma_{1620})$ - the expression,used for the description of the region 1.6-2.2GeV and $A_{1232}(g_{1232}, M_{1232}, \Gamma_{1232})$ for low energy region. Dashed curve is the contribution of Δ_{1232}, dot-dashed of Δ_{1620}.
In a table 1 we show the value of fitted parameters

Table: The values of parameters

parameter	Values(GeV)	Values(GeV) (separate fit)
M_{1232}	1.225 ± 0.002	...
Γ_{1232}	0.095 ± 0.006	...
M_{1620}	1.606 ± 0.008	1.592 ± 0.008
Γ_{1620}	0.175 ± 0.031	0.218 ± 0.026

Comment on 1-st peak in a picture

Phenomenological(partial wave) analysis of differential cross sections and vector analyzing powers in the region of left peak(energy range of beam proton 0.5÷0.8 GeV) → paper **V.Komarov et al, Phys Rev C93,065206(2016)**:
All the data are explained as an interplay of two dibaryon resonances with close masses and widths $^3P_0$ and $^3P_2$; transitions $^3P_0 \to ^1 S_0 s$, $^3P_2 \to ^1 S_0 d$

Yesterday's Uzikov talk : calculations for zero-angle diff. cross section in his isobar model($0.4 \div 1.8 GeV$) requires inclusion of $^3F_2 d$ transition also.

Summary

- The differential cross section $d\sigma/d\Omega_{pp}$ for diproton production in the reaction $\boldsymbol{pp \to \{pp\}_s \pi^0}$ at the energy range $0.8 \div 2.8$GeV is obtained. Angular range analyzed - $0^\circ < \theta_{pp}^{cm} \lesssim 18^\circ$
- The results show "unusual" behavior of cross section in the region 1.6–2.2GeV: unlike the energies outside this interval it grows to zero angle.Fit of the angular dependence of cross section at 1.7GeV requires quadratic term $(sin^2(\theta_{pp}^{cm}))^2$ what signals about more complex form compared with lower energies.
- All the results for zero-angle differential cross section,obtained by ANKE group in Dubna for period 2006-2018, qualitatively can be explained as noncoherent sum of two isobar production