HADRON 2023
June 5-9, 2023
Genova, Italy

Further evidence for the lower-lying vector meson ρ(1250) in the $e^+e^- \to \omega\pi^0$ process

Presenter:
Toshihiko Komada (Nihon Univ.)

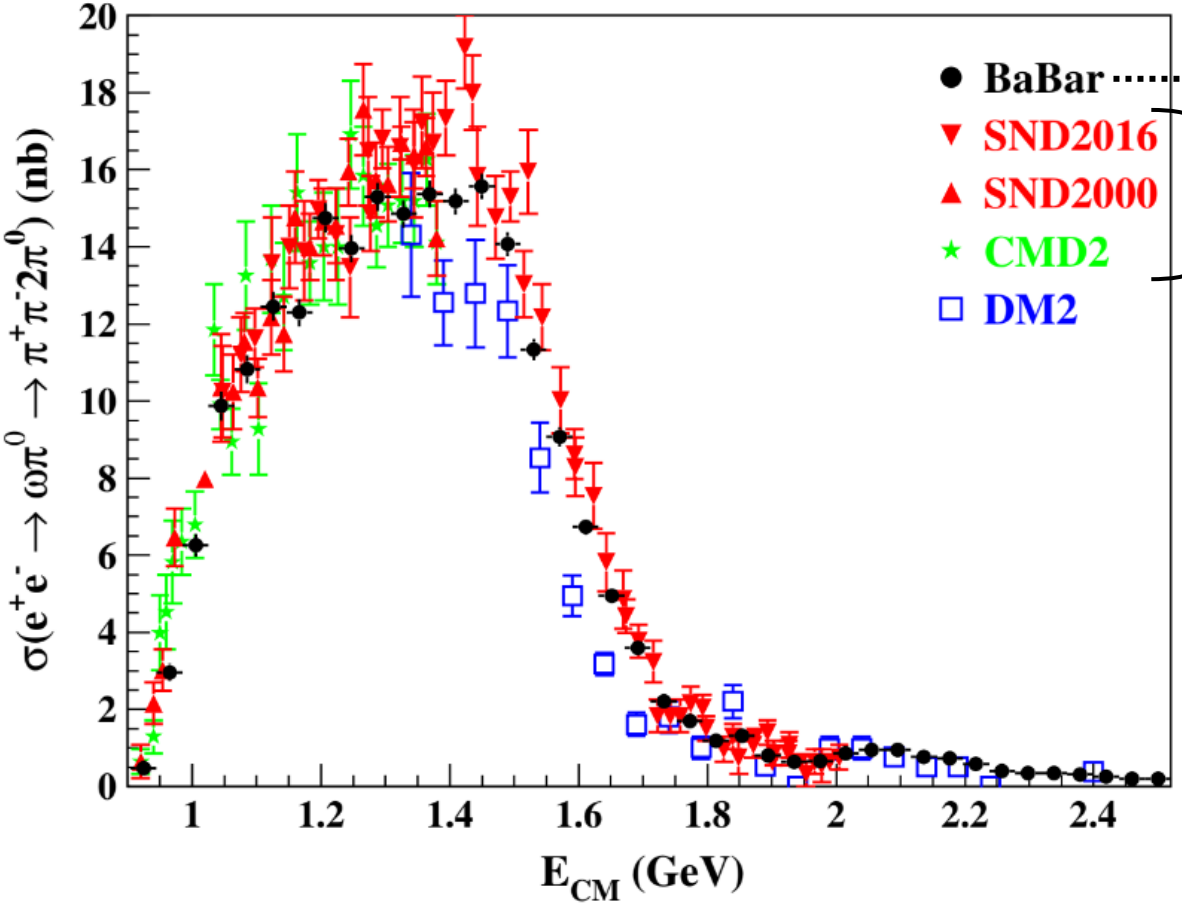
Collaborators:
Tomohito Maeda, Tsuneaki Tsuru, Kenji Yamada (Nihon Univ.)

Introduction

- The existence of the low-mass "$\rho(1250)$" was strongly suggested in the analysis of $\pi\pi$ phase shift (N. Hammoud et al.,PRD102(2020)054029).

- In this work, we will study the existence of $\rho(1250)$ by reanalyzing the cross section data for the $e^+e^- \to \omega\pi^0$ decay process.

Cross Section Data of $e^+e^- \to \omega\pi^0$



$e^+e^- \to \omega\pi^0 \to \pi^+\pi^-\pi^0\pi^0$

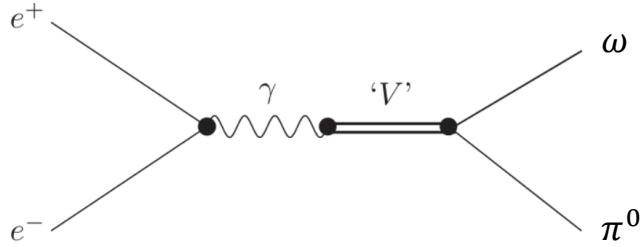
$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$

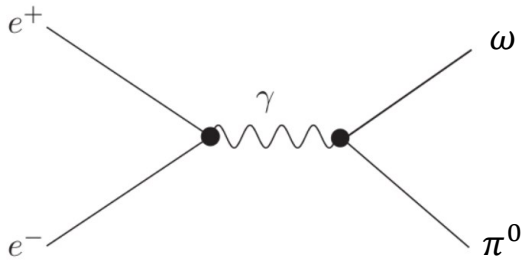
SND2016, PR**D94** (2016) 112001
SND2000, PL**B486** (2000) 29
CMD2, PL**B562** (2003) 173

BABAR, Phys. Rev. **D96** (2017), 092009

Analysis Method

Diagrams for the $e^+e^- \to 'V' \to \omega\pi^0$





$'V' = \rho(770), \rho(1250), \rho(1450), \rho(1600), \rho(1800)$

Vector Meson Dominance

Direct decay

Cross Section Formula

$$\sigma(s) = \frac{4\pi\alpha^2}{s^{\frac{3}{2}}} \times \left(\frac{g_{\rho\omega\pi}}{f_\rho}\right)^2 \left| \frac{m_\rho^2\sqrt{F_\rho(s)}}{m_\rho^2 - s - i\sqrt{s}\Gamma_\rho(s)} + \sum_{i=1}^{4} A_i \frac{e^{i\theta_{\rho(i)}} m_{\rho(i)}^2 \sqrt{F_{\rho(i)}(s)}}{m_{\rho(i)}^2 - s - i m_{\rho(i)}\Gamma_{\rho(i)}} + A_{dir}\frac{e^{i\theta_{dir}}}{s} \right|^2 P_f(s)$$

ρ: $\rho(770), \rho^{(1)}$: $\rho(1250), \rho^{(2)}$: $\rho(1450), \rho^{(3)}$: $\rho(1600), \rho^{(4)}$: $\rho(1800)$

Fitting parameters

- $m_{\rho(i)}$, $\Gamma_{\rho(i)}$: Fitting parameters with constraint
- $m_{\rho(770)}$, $\Gamma_{\rho(770)}$: Fixed to PDG values
- $\theta_{\omega(i)}$: $0°$ *or* $180°$
- $g_{\rho\omega\pi}, A_{\rho(i)}, A_{dir}, \theta_{dir}$: Free parameter

s dependence of $\rho(770)$

$$\Gamma_\rho(s) = \left(m_\rho \Gamma\rho \frac{p_\pi^3(s)}{s} \frac{m_\rho}{p_\pi^3(m_\rho^2)} + \frac{g_{\rho\omega\pi}^2}{12\pi} p_\omega^3(s) \right) \frac{2m_\rho^2}{m_\rho^2 + s}$$

Input parameters

TABLE II. Pole positions on various Riemann sheets, for $\sqrt{s_r} = E_r - i\Gamma_r/2$, of the unitary amplitude fitted to experimental data and GKPY equations.

Resonance	Riemann Sheet	E_r, $\Gamma_r/2$ (MeV)
$\rho(770)$	II	$765.2 \pm 0.4,\ 73.1 \pm 0.3$
$\rho(1250)$	III	$1264.1 \pm 33,\ 146.7 \pm 12$
$\rho(1450)$	III	$1424.7 \pm 26,\ 104.9 \pm 24$
$\rho(1600)$	IV	$1595.1 \pm 5,\ 69.5 \pm 4$
$\rho(1800)$	VI	$1779.2 \pm 14,\ 121.9 \pm 16$

N. Hammoud et al., Phys. Rev. D102(2020)054029

Upper and lower limit of BW mass and width as fitting parameters

	Mass (MeV)	Width (MeV)
$\rho(1250)$	$1153.7 \sim 1357.2$	$258.4 \sim 332.5$
$\rho(1450)$	$1339.8 \sim 1501.5$	$137.8 \sim 283.1$
$\rho(1600)$	$1578.3 \sim 1608.9$	$127.1 \sim 151.2$
$\rho(1800)$	$1731.2 \sim 1818.7$	$196.0 \sim 292.8$

In this analysis, we set the range to be within 3σ of the error in the results obtained from PRD 102(2020)054029

Fit Results

Obtained values of parameters

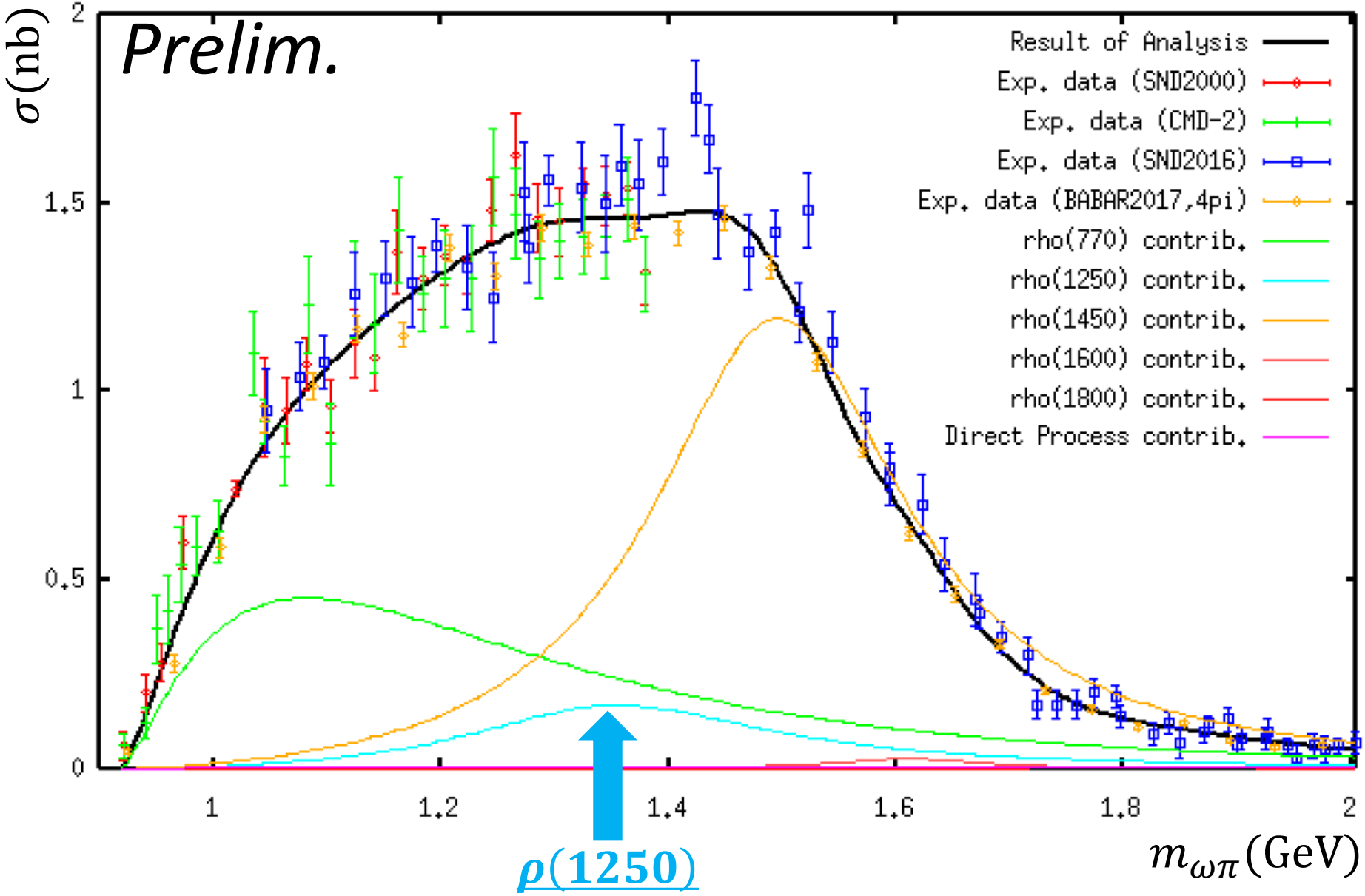
Prelim.

	Solution I	Solution II	Solution III	Solution IV
χ^2/DoF	212.6/117=1.82	215.2/117=1.84	219.3/117=1.87	233.6/117=2.00
$m_{\rho(1250)}$ (MeV)	1,330.4	1,343.6	1,312.0	1,342.9
$\Gamma_{\rho(1250)}$ (MeV)	332.5	325.3	332.5	332.5
$A_{\rho(1250)}$	6.50×10^{-2}	5.95×10^{-2}	7.79×10^{-2}	7.37×10^{-2}
$\theta_{\rho(1250)}$ (deg)	180	180	180	180
$m_{\rho(1450)}$ (MeV)	1,486.4	1,493.9	1,470.4	1,494.5
$\Gamma_{\rho(1450)}$ (MeV)	275.7	271.4	283.1	283.1
$A_{\rho(1450)}$	1.10×10^{-1}	1.28×10^{-1}	8.91×10^{-2}	1.02×10^{-1}
$\theta_{\rho(1450)}$ (deg)	180	180	180	180
$m_{\rho(1600)}$ (MeV)	1,608.9	1,608.9	1,604.1	1,595.5
$\Gamma_{\rho(1600)}$ (MeV)	151.2	151.2	145.5	127.1
$A_{\rho(1600)}$	7.46×10^{-3}	9.38×10^{-3}	$\simeq 0$	$\simeq 0$
$\theta_{\rho(1600)}$ (deg)	180	180	0	0
$m_{\rho(1800)}$ (MeV)	1,818.7	1,805.6	1,731.2	1,818.7
$\Gamma_{\rho(1800)}$ (MeV)	196.0	283.9	196.0	196.0
$A_{\rho(1800)}$	2.13×10^{-3}	$\simeq 0$	3.67×10^{-3}	3.37×10^{-4}
$\theta_{\rho(1800)}$ (deg)	180	0	0	180
$g_{\rho\omega\pi}$ (GeV $^{-1}$)	16.0	14.7	18.5	16.8
A_{direct}	7.71×10^{-2}	2.67×10^{-1}	1.85×10^{-1}	2.49×10^{-2}
θ_{direct} (deg)	318.2	294.0	106.3	30.0

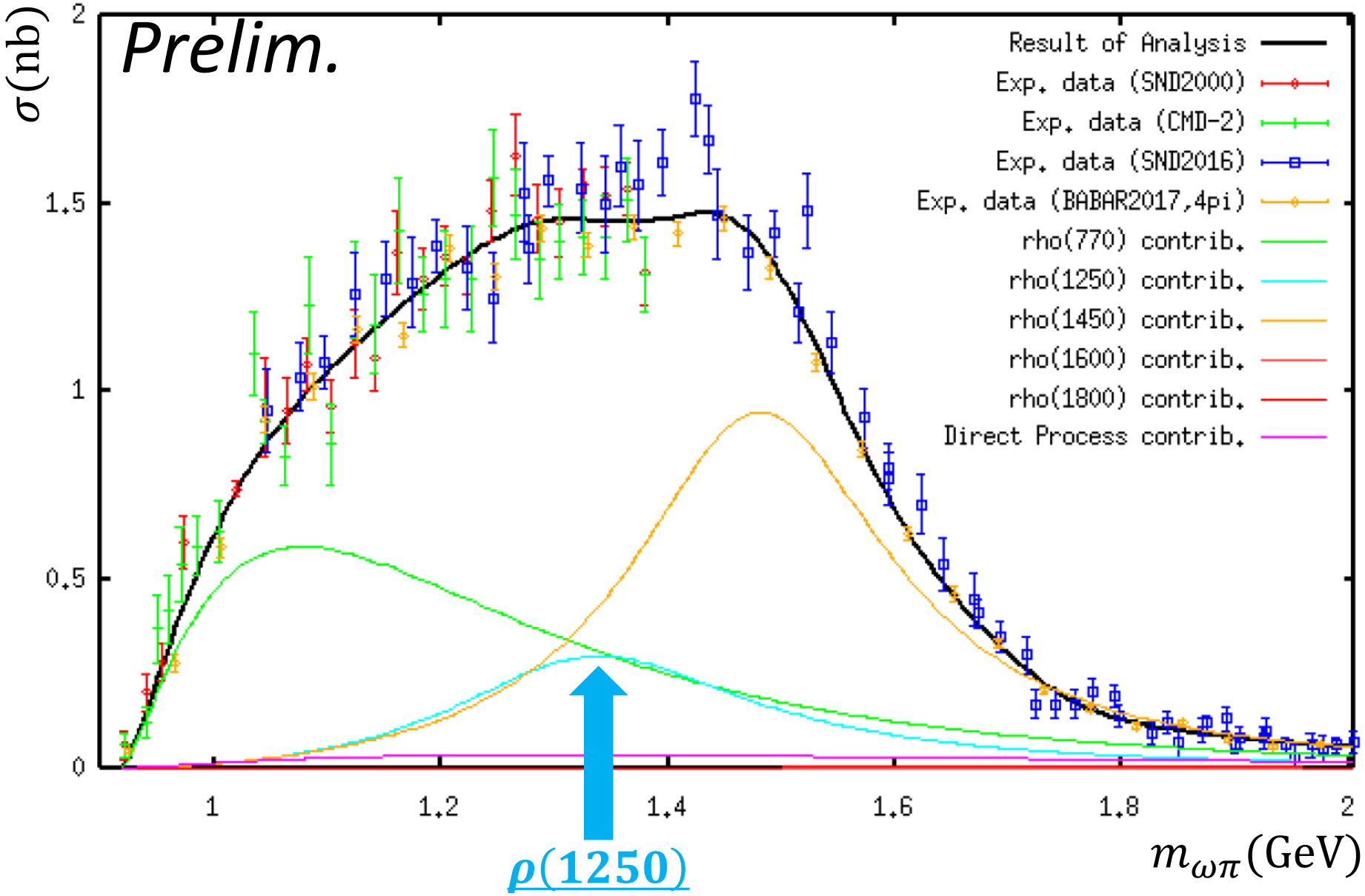
Reduced χ^2: χ^2 /DoF , ND=132, NF=15,DoF=132-15-1=117

$m_{\rho(770)}$, $\Gamma_{\rho(770)}$ were fixed to PDG

Solution I


Prelim.
σ(nb)
2
1.5
1
0.5
0
1
1.2
1.4
1.6
1.8
2
$m_{\omega\pi}$(GeV)
Result of Analysis
Exp. data (SND2000)
Exp. data (CMD-2)
Exp. data (SND2016)
Exp. data (BABAR2017,4pi)
rho(770) contrib.
rho(1250) contrib.
rho(1450) contrib.
rho(1600) contrib.
rho(1800) contrib.
Direct Process contrib.
$\rho(1250)$

Solution III



Statistical significance of each amplitude

Amplitude	χ^2	Significance
Best Solution	212.6	---
$\rho(1250)$	243.6	4.92 σ
$\rho(1450)$	359.6	> 10 σ
$\rho(1600)$	219.3	1.74 σ
$\rho(1800)$	215.2	0.74 σ
Direct Process	218.3	1.90 σ

Summary

- In this study, we reanalyze the $\omega\ \pi$ channel, which is different from the $\pi\pi$ channel, and confirm the existence of the $\rho(1250)$ with 4.92 σ significance.

- The relative phase of the $\rho(1250)$ referred to the $\rho(770)$ is obtained to be 180°.

- An indication of the $\rho(1600)$ with 1.74 σ significance is seen in the $e^+\ e^- \to \omega\ \pi^0$ process.

- The $\rho(1800)$ is not seen in the $e^+\ e^- \to \omega\ \pi^0$ process with 0.74 σ significance.