Coupled channel effects in pi-pi S-wave interaction

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Topical Seminar on Frontier of Particle Physics 2004

QCD and Light Hadrons

Outline

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- Coupled channel effects in I=2 pi-pi S-wave interaction
- Coupled channel effects in I=0 pi-pi S-wave interaction
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1. Motivation

I=0 $\pi\pi$ S-wave interaction

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I=0 $J^{PC}=0^{++}$ particles: σ, glueball

However, to really understand the I=0 $\pi\pi$ S-wave interaction, one must first understand the I=2 $\pi\pi$ S-wave interaction

Because: a, **simpler**. There are no known s-channel resonances and less coupled channels in I=2 pi pi system, so it is much simpler than the I=0 pi pi S-wave interaction;

b, **necessary input for extracting I=0 phase shifts from data.** To extract I=0 $\pi\pi$ S-wave phase shifts from experimental data obtained by pi +N → pi + pi +N reactions, one needs an input of the I=2 pi pi S-wave interaction.

However, in the previous analysis of I=2 amplitude, the feature of inelasticities η_0^2 which start to deviate from 1 for energies above 1.1 GeV often was overlooked.

In this report, we show in a K-matrix formalism that the features can be well reproduced by $\pi\pi - \rho\rho - \pi\pi$ coupled-channel effect. The same coupled channel effects in I=0 will also be discussed.

2.Coupled channel effects in I=2 pi-pi S-wave interaction

Coupled channel K-matrix formalism:

$$K = \begin{pmatrix} K_{11} & K_{12} \\ K_{12} & K_{22} \end{pmatrix}, \qquad \rho(s) = \begin{pmatrix} \rho_1(s) & 0 \\ 0 & \rho_2(s) \end{pmatrix},$$

$$K_{11} : \pi\pi \to \pi\pi,$$

$$K_{12} : \pi\pi \to \rho\rho,$$

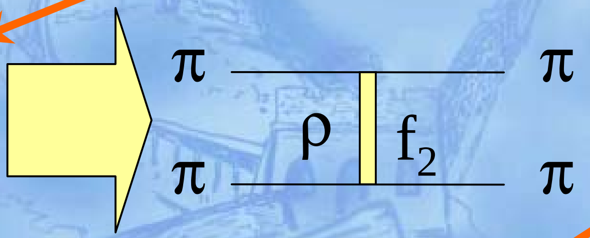
$$K_{22} : \rho\rho \to \rho\rho$$

$$T = \frac{K}{1 - i\rho K}$$

$$T_{11} = \frac{K_{11} - i\rho_2(K_{11}K_{22} - K_{12}K_{21})}{1 - i\rho_1 K_{11} - i\rho_2 K_{22} - \rho_1\rho_2(K_{11}K_{22} - K_{12}K_{21})},$$

If $K_{22} = 0$, $T_{11} = \dfrac{K_{11} + iK_{12}\rho_2 K_{21}}{1 - i\rho_1 (K_{11} + iK_{12}\rho_2 K_{21})}$,

K_{11}

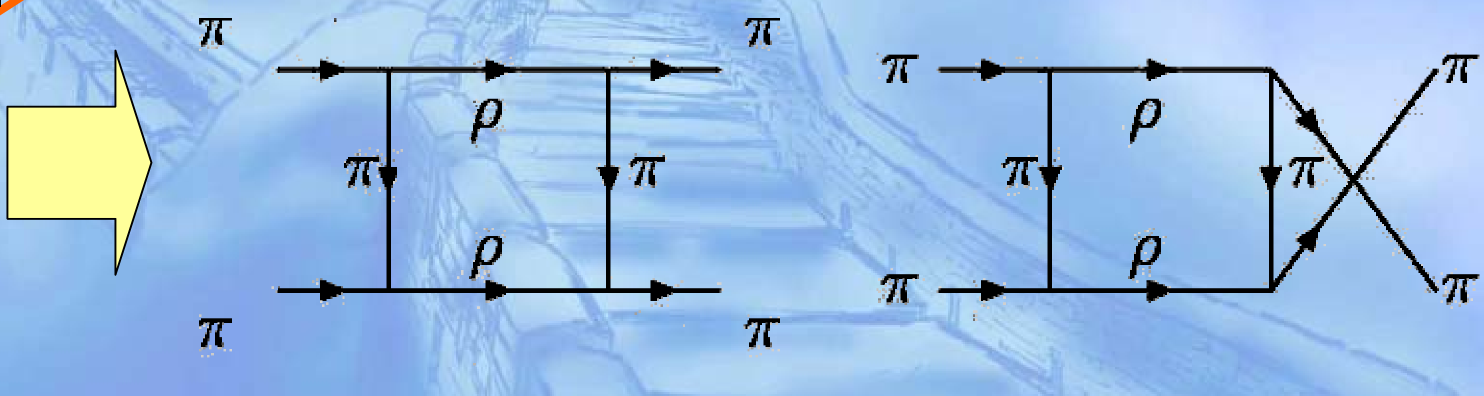


$V_{\rho\pi\pi} = g_{\rho\pi\pi}\, \varepsilon_\mu q^\mu \;\; \mathbf{I_\rho . (I_{\pi 1} * I_{\pi 2})}$

$V_{f2\pi\pi} = g_{f2\pi\pi}\, F_{\mu\nu} q^\mu q^\nu \mathbf{(} I_{\pi 1} \,.\, I_{\pi 2} \mathbf{)}$

In order to obtain $\mathbf{K_{11}}$, we incorporate the t-channe **f_2(1270)** contribution into the **rho** exchange term by the **Dalitz-Tuan method.**

$iK_{12}\rho_2K_{12}$



(a) (b)

Off-shell form factor:

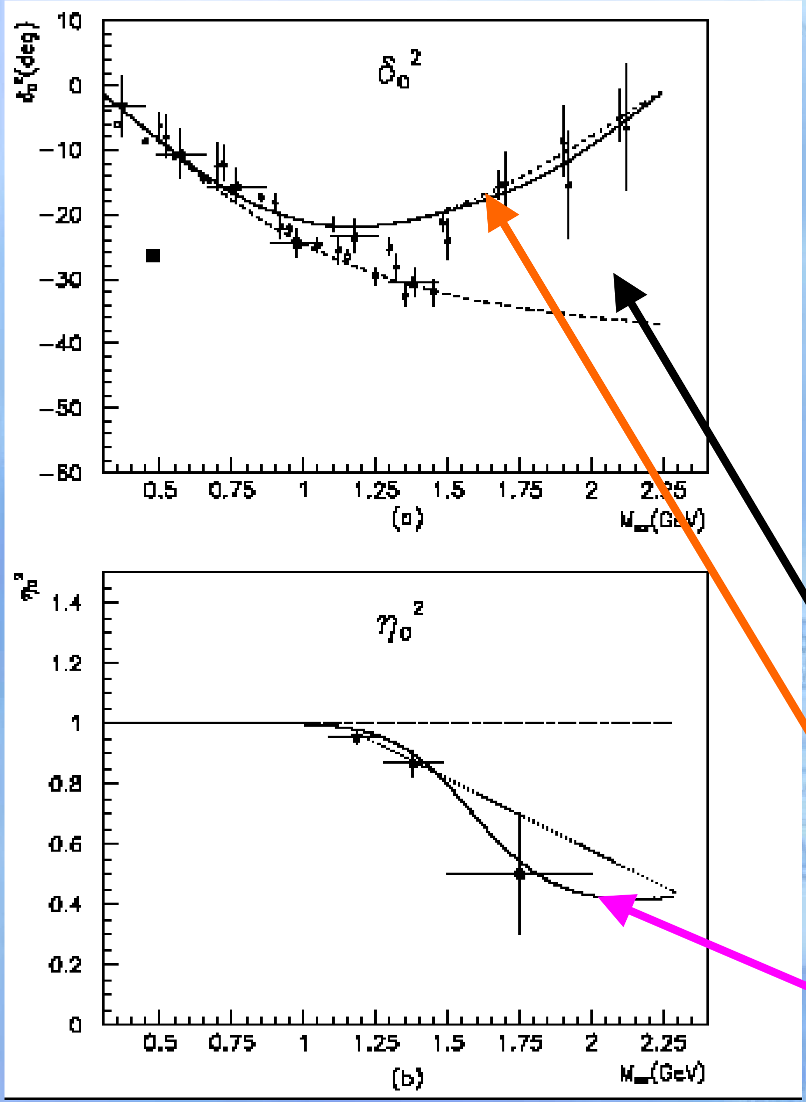
$$F(q^2) = \frac{\Delta^2 + m^2}{\Delta^2 + s^2} \qquad F(q^2) = \frac{\Delta^2 - m^2}{\Delta^2 - q^2}$$

Only two parameter in our theory:

$$\Delta_{\rho\pi\pi} = 1.5 Gev \qquad \Delta_{f_2\pi\pi} = 1.7 Gev$$

With t-channel ρ, **f_2(1270)** exchange, we reproduce the pion pion isotensor S-wave and D-wave scattering phase shifts up to 2.2 GeV quite well, but inelastici parameter η=1. **In order to reproduce this inelasticity, it is necessary to consider the pi pi→rho rho coupling channel effect.**

I=2 ππ S-wave phase shift δ and inelastic parameter η



Main features:

(1)the δ_0^2 goes down more and more negative as the pi pi invariant mass increases from pion pion threshold up to 1.1 GeV;(2) the δ_0^2starts to increase for energies above about1.1 GeV;(3) the η_0^2 starts to deviate from 1 for energies above 1.1 GeV.

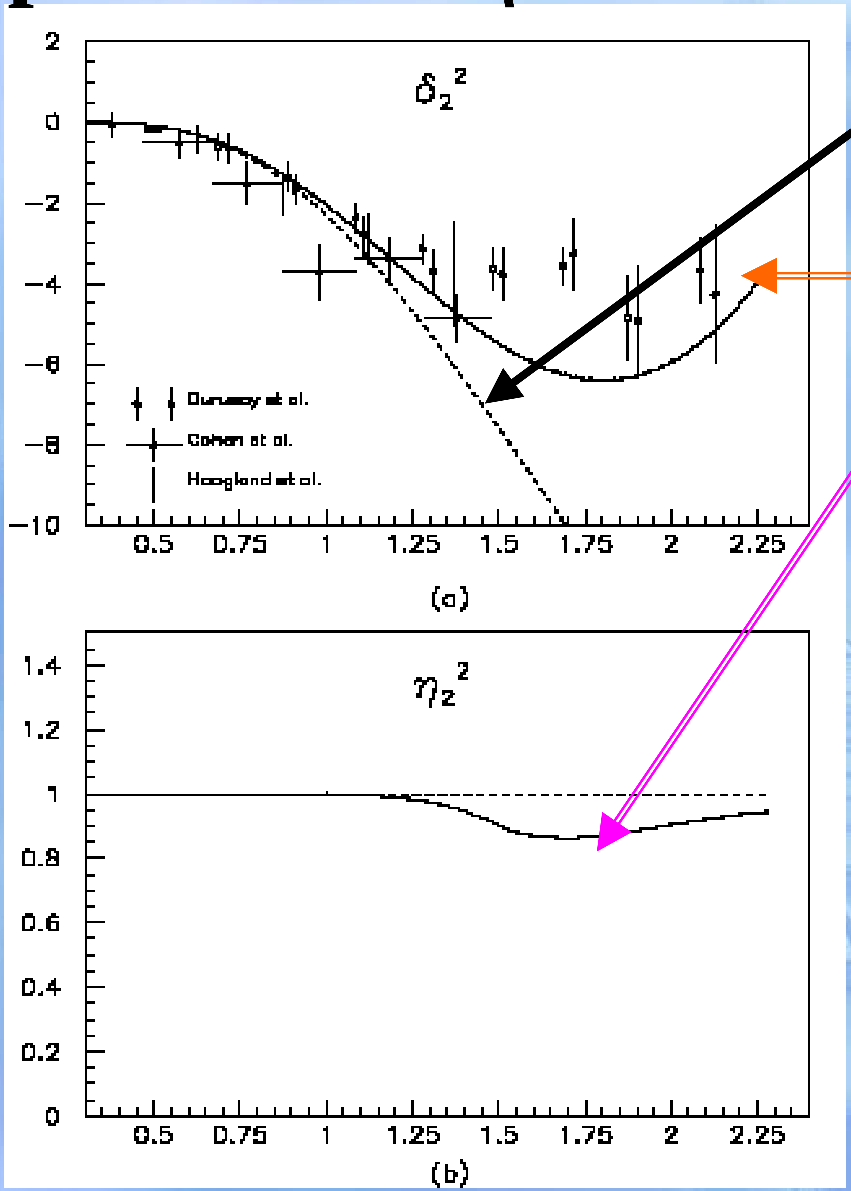
Explain :

1, repulsive force by t-channel ρ

2, attractive force by f_2 (1270)

3, inelasticity by ππ -ρρ- ππ box

I=2 ππ D-wave phase shift δ and inelastic parameter η



Explain：

1， repulsive force by t-channel ρ

2, attractive force by f_2 (1270)

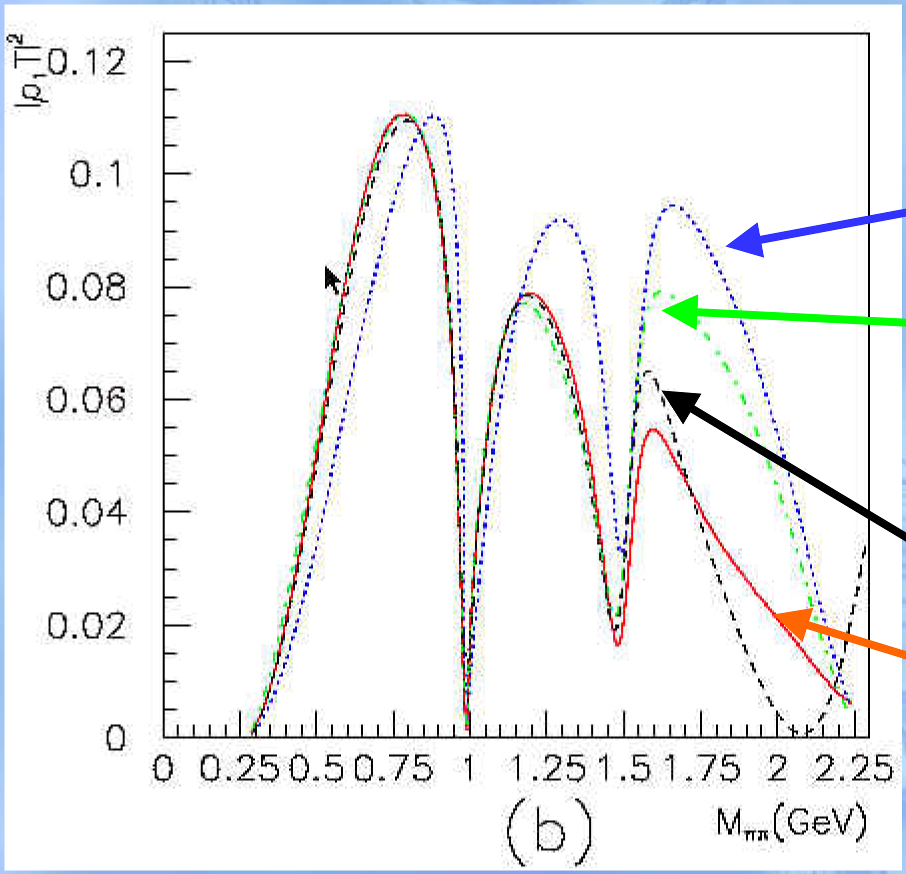
3, inelasticity by ππ -ρρ- ππ box

the δ_2^2 data around 1.7 GeV has the largest discrepancy with our theoretical result. **Main reason** may be they assume $\eta^2{}_2 = 1$, when they disposal the experimental data .

ππ S-wave full amplitude squared

$$\pi^+\pi^+ \to \pi^0\pi^0$$

The same $T^{I=0}$ plus various input Of $T^{I=2}$



various $T^{I=2}$:

1, $T^{I=2} = 0$

2, $T^{I=2} = \frac{a_0 q}{1 - i a_0 q}$

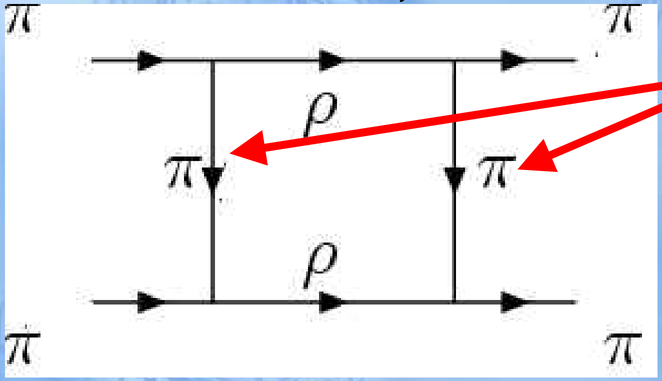
t-channel ρ exchange

3, include ρ， f_2 (1270) exchange

4, include ρ， f_2， ππ -ρρ- ππ box diagram.

Discussion：

A，In our calculation of the ππ -ρρ- ππ box diagram, besides π, we also consider



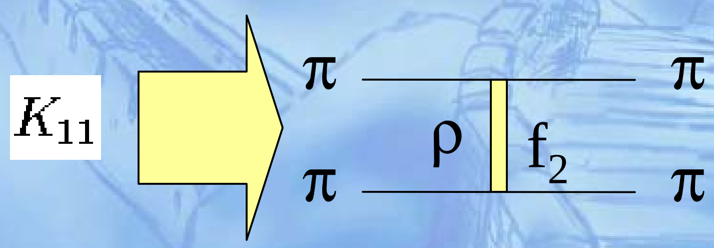
$\omega(783), a_1(1260), \pi(1300), a_2(1320)$

Which have large coupling to ρπ, The result show these contribution is about a quarter of what we get from the pi exchange and will possible cancel each other.

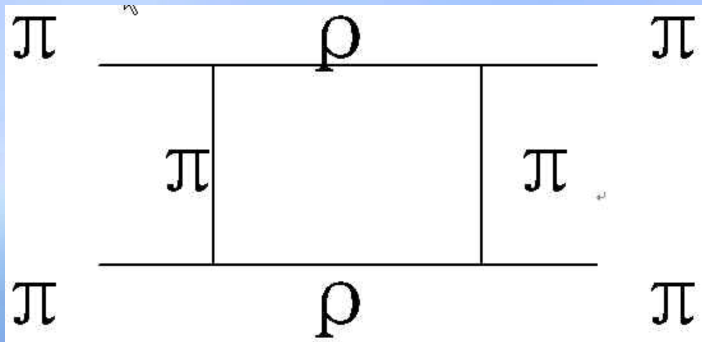
B，About $K_{22}=0$ assumption。The interaction of $\rho\rho \to \rho\rho$ channel is not clear up to now, by assuming $K_{22}=xK_{11}$, with x a constant. It is found that for $x \le 5$ the results are still within the experimental error bars. For $x \le 10$ by adjusting off-shell cutoff parameter,the data can still be well reproduced

3. Coupled channel effects in pi-pi I=0 S-wave interaction

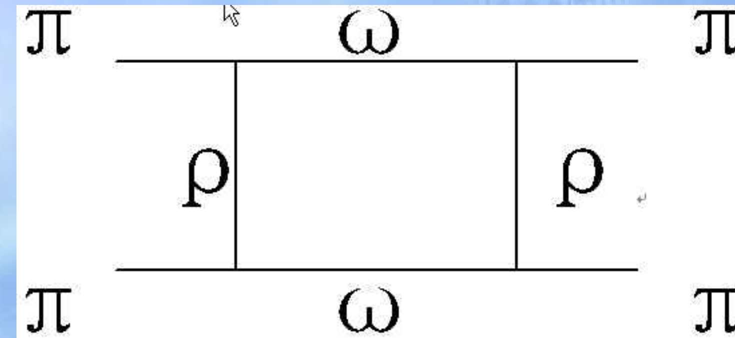
Without including s-channel resonances, we only consider the effect of ρ, f_2 exchanges and various coupled channel box diagram $K_{ab}\rho_{bb}K_{ba}$ upon pi pi inelastic parameter.



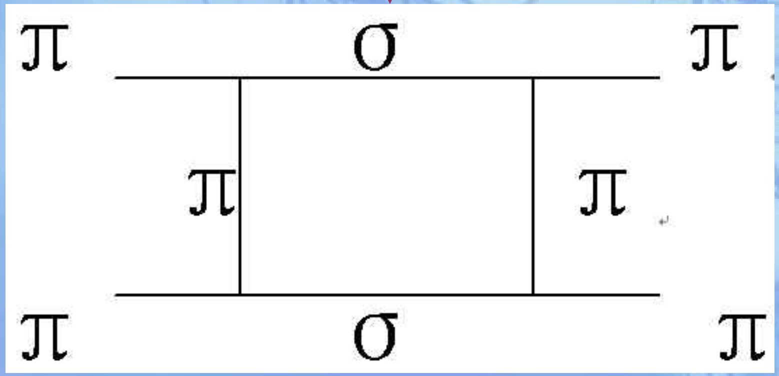
$$\pi\pi \to \rho\rho \to \pi\pi$$



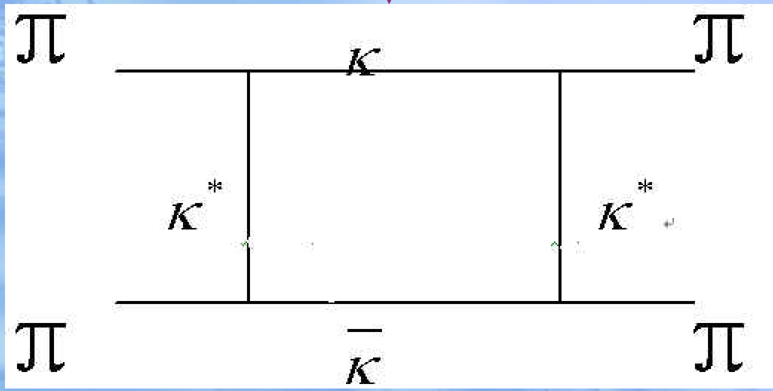
$$\pi\pi \to \omega\omega \to \pi\pi$$



$$K_{ab}\rho_{bb}K_{ba}$$

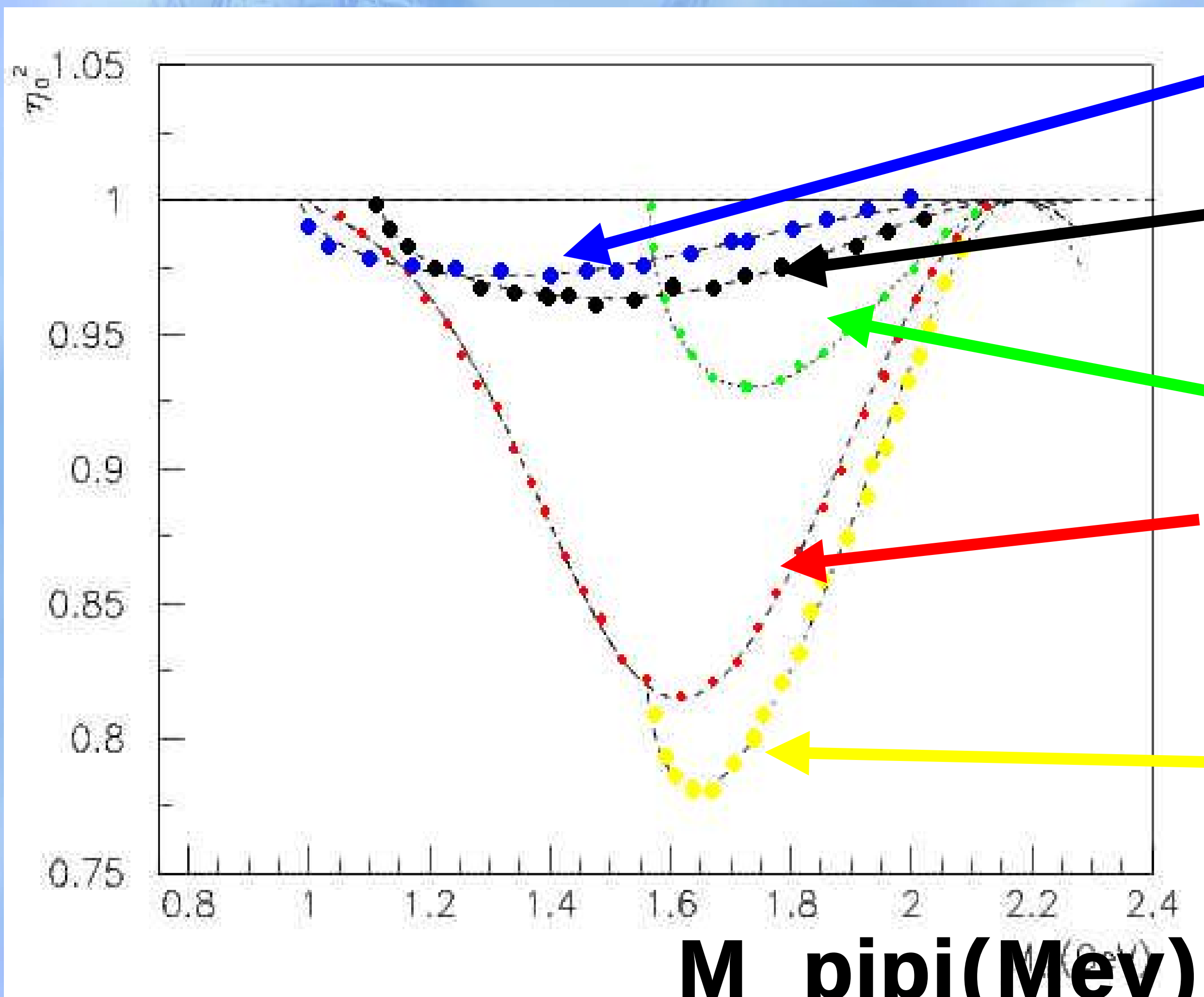


$$\pi\pi \to \sigma\sigma \to \pi\pi$$



$$\pi\pi \to \mathrm{KK} \to \pi\pi$$

I = 0 π π S-wave inelastic parameter (without s-channel resonances)



$\pi\pi \to KK \to \pi\pi$

$\pi\pi \to \sigma\sigma \to \pi\pi$

$\pi\pi \to \omega\omega \to \pi\pi$

$\pi\pi \to \rho\rho \to \pi\pi$

three channel $\left\{ \begin{array}{l} \pi\pi \to \omega\omega \\ \pi\pi \to \rho\rho \end{array} \right.$

4. Summary and Outlook

1) Three basic features of I=2 ππ scattering phase shifts and inelasticities can be well reproduced by the t-channel (ρ, f_2) meson exchange and the ππ –ρρ coupled-channel effect.

2) A correct description of I=2 ππ scattering has significant impact on the extraction of I=0 scattering amplitudes from $\pi^+\pi^- \to \pi^+\pi^-$ and $\pi^+\pi^- \to \pi^0\pi^0$ data, especially for energies above 1.2 GeV .

3) The t-channel (ρ,f_2) meson exchange and the $\pi\pi-\rho\rho$ coupled-channel effect should also be important in I=0 $\pi\pi$ scattering.

4) Further study of other channels like $K\overline{K} \to K\overline{K}$ will make more clear of pi pi interaction.

谢谢！

Thanks!