Two pion production in pp→ppππ -

do we see a sign of Delta(1600) excitation?

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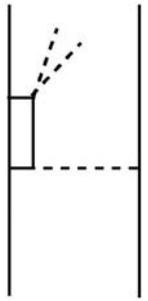
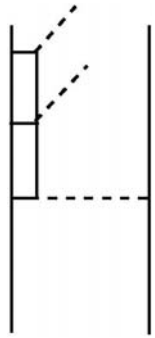
for CELSIUS-WASA

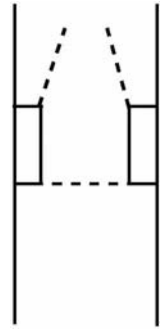
- experiment ↔ theory
- isospin decomposition
- conclusions



N* → Nσ

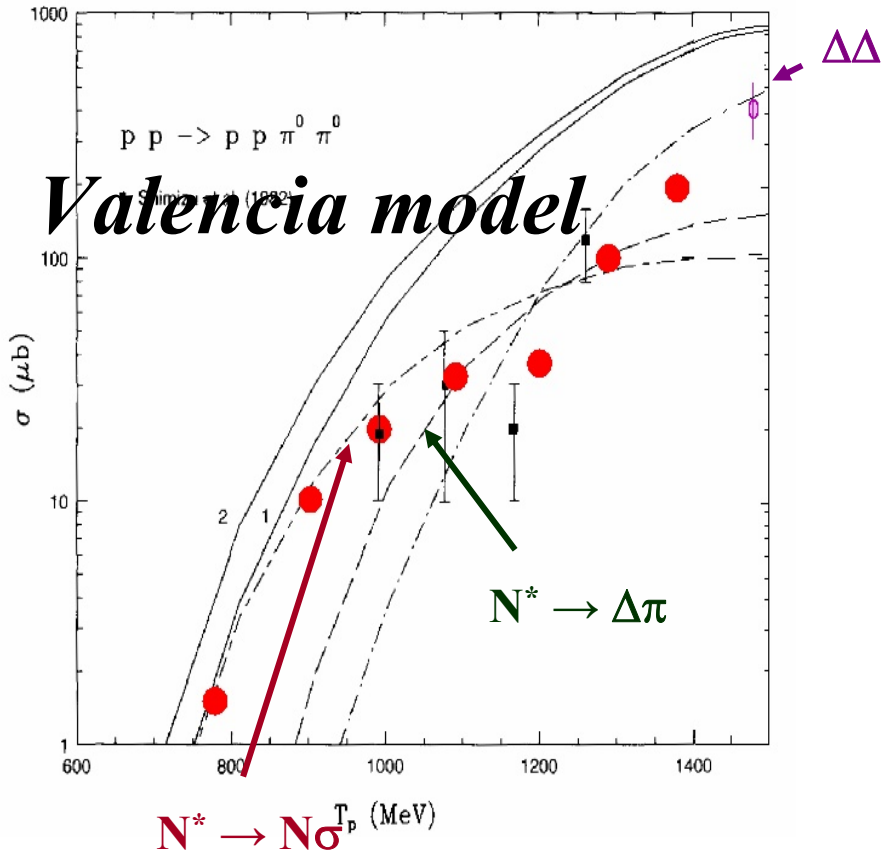


N* → Δπ



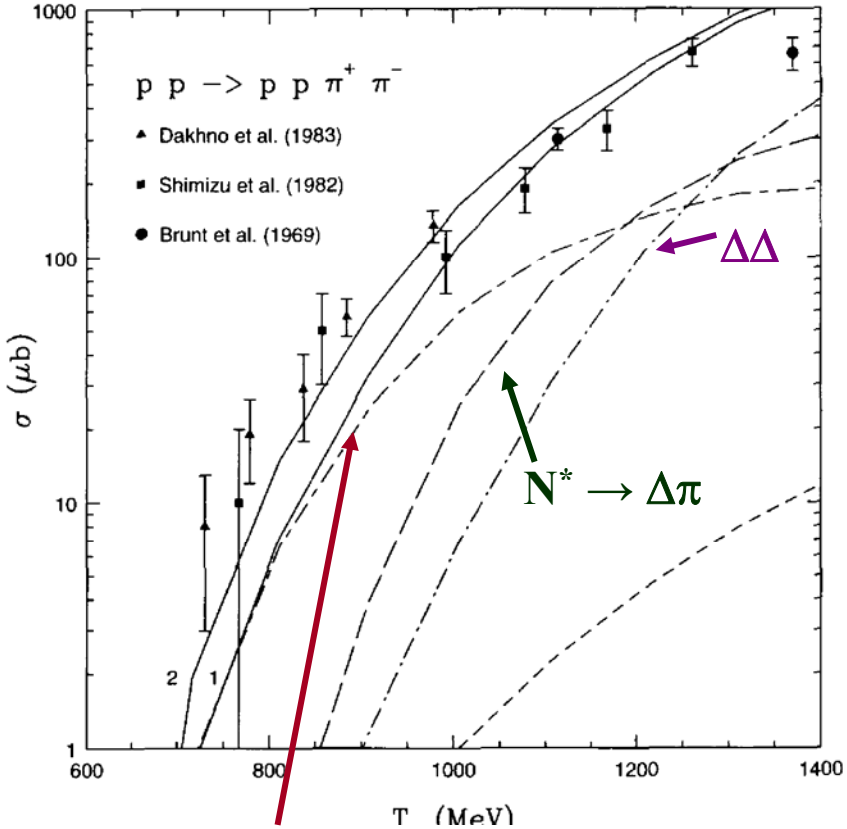
ΔΔ

$pp \rightarrow pp\pi^0\pi^0$



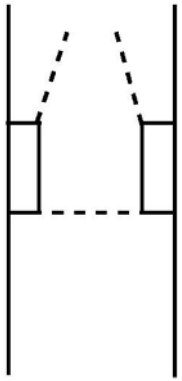
Total cross section

$pp \rightarrow pp\pi^+\pi^-$

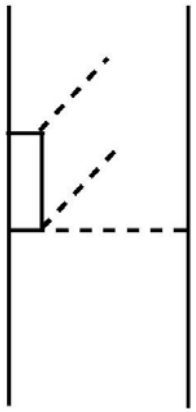


Total cross section

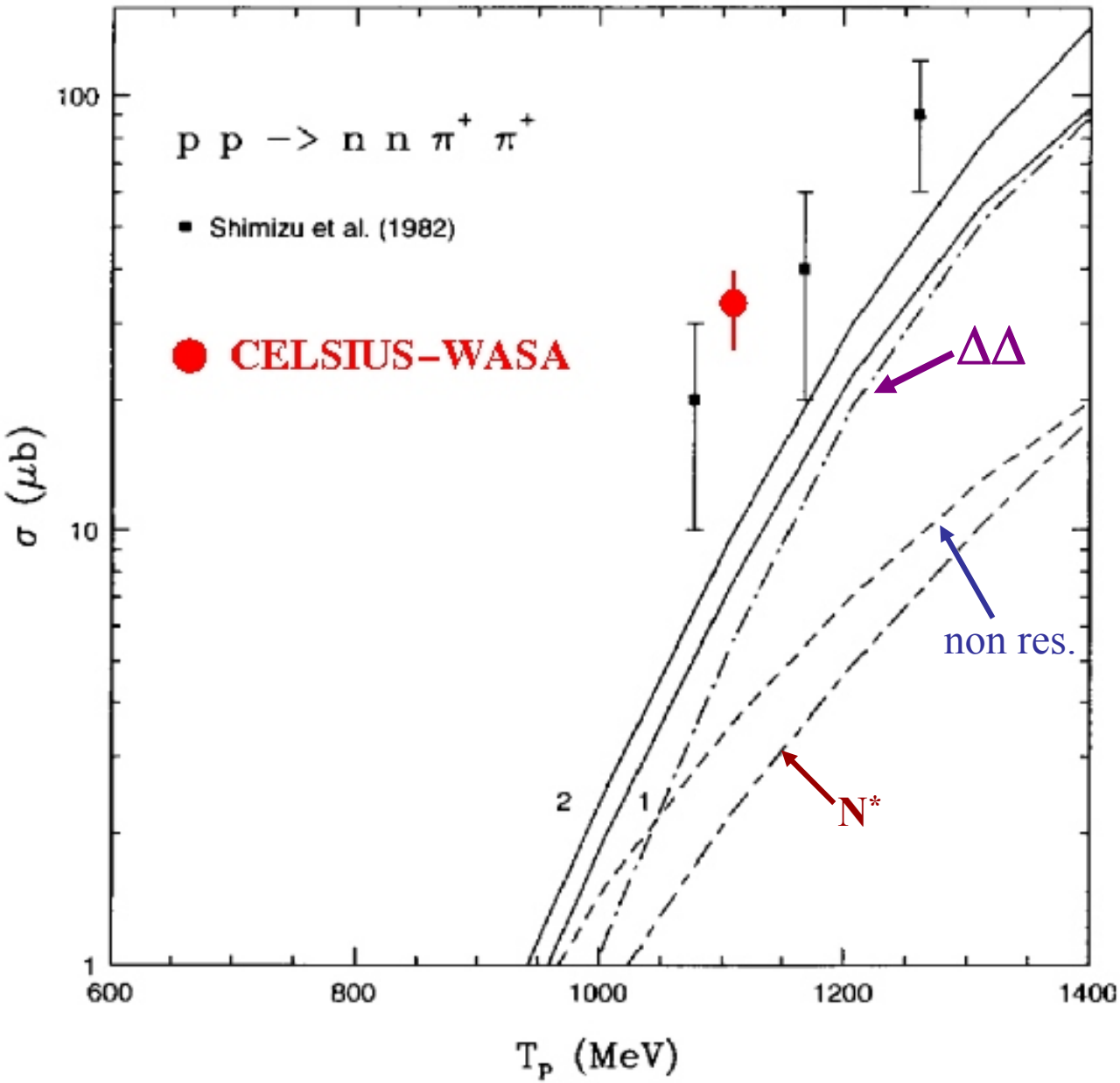
$pp \rightarrow nn\pi^+\pi^+$



ΔΔ



N*



Isospin decomposition

$$M_{(I_{NN})_f\, I_{\pi\pi}\, (I_{NN})_i}$$

$$\sigma_{nn\,\pi^+\pi^+} = \frac{3}{20}\,|\,M_{121}\,|^2$$

$$\sigma_{pp\pi^0\pi^0} = \frac{1}{60}|M_{121} - \sqrt{5}M_{101}|^{\,2} =$$

$$\frac{1}{60}|M_{121}|^2 + \frac{1}{12}|M_{101}|^2 - \frac{1}{\sqrt{180}}|M_{121}||M_{101}|\cos\varphi$$

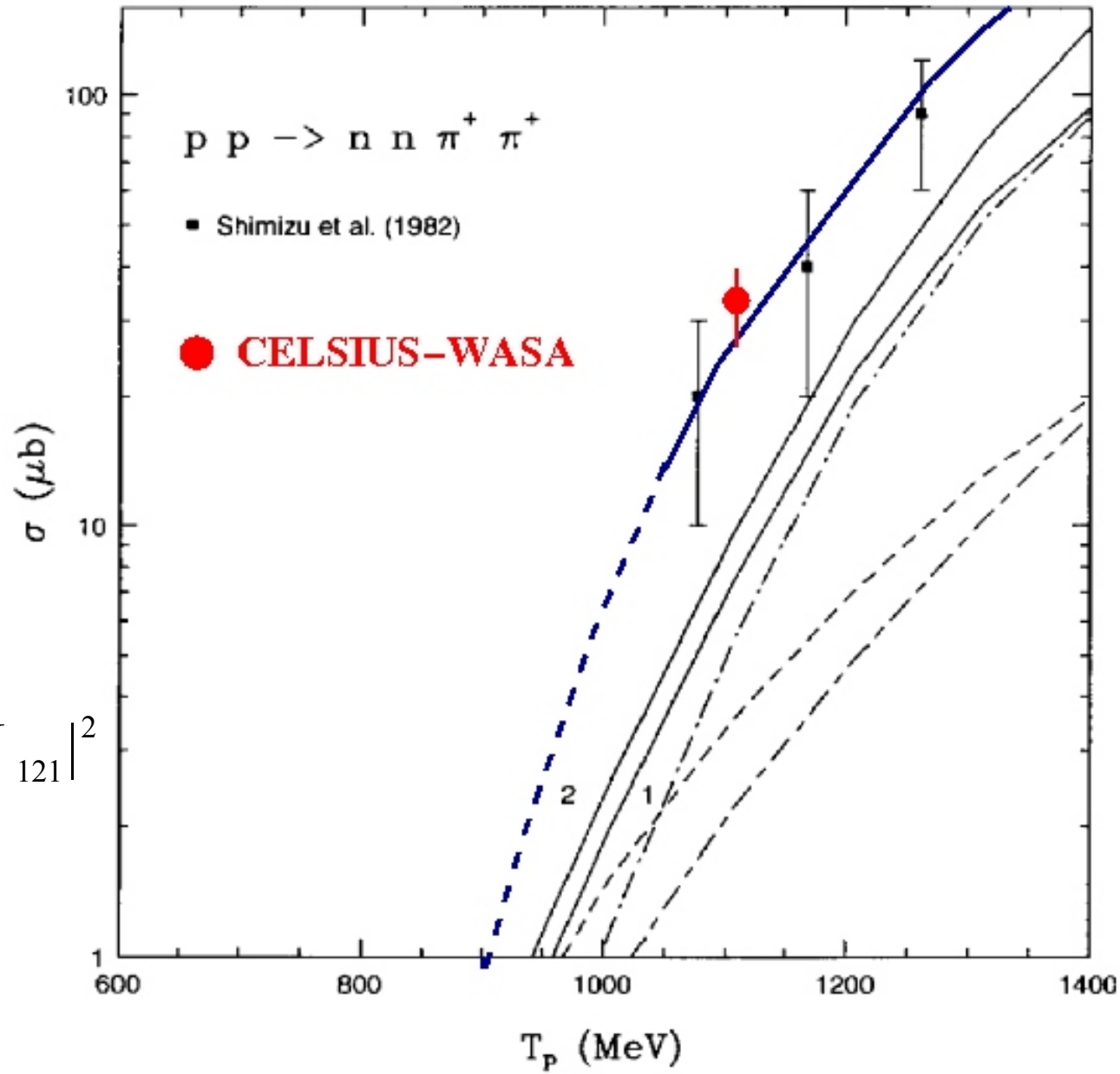
$$\sigma_{pp\pi^-\pi^+} = \frac{1}{120}\,|\,M_{121} + 2\sqrt{5}M_{101}\,|^2 + \frac{1}{8}\,|\,M_{111}\,|^2 =$$

$$|\,M_{111}\,|^2 + \frac{1}{120}\,|\,M_{121}\,|^2 + \frac{1}{6}\,|\,M_{101}\,|^2 + \frac{1}{\sqrt{180}}\,|\,M_{121}\,||\,M_{101}\,|\cos\varphi$$

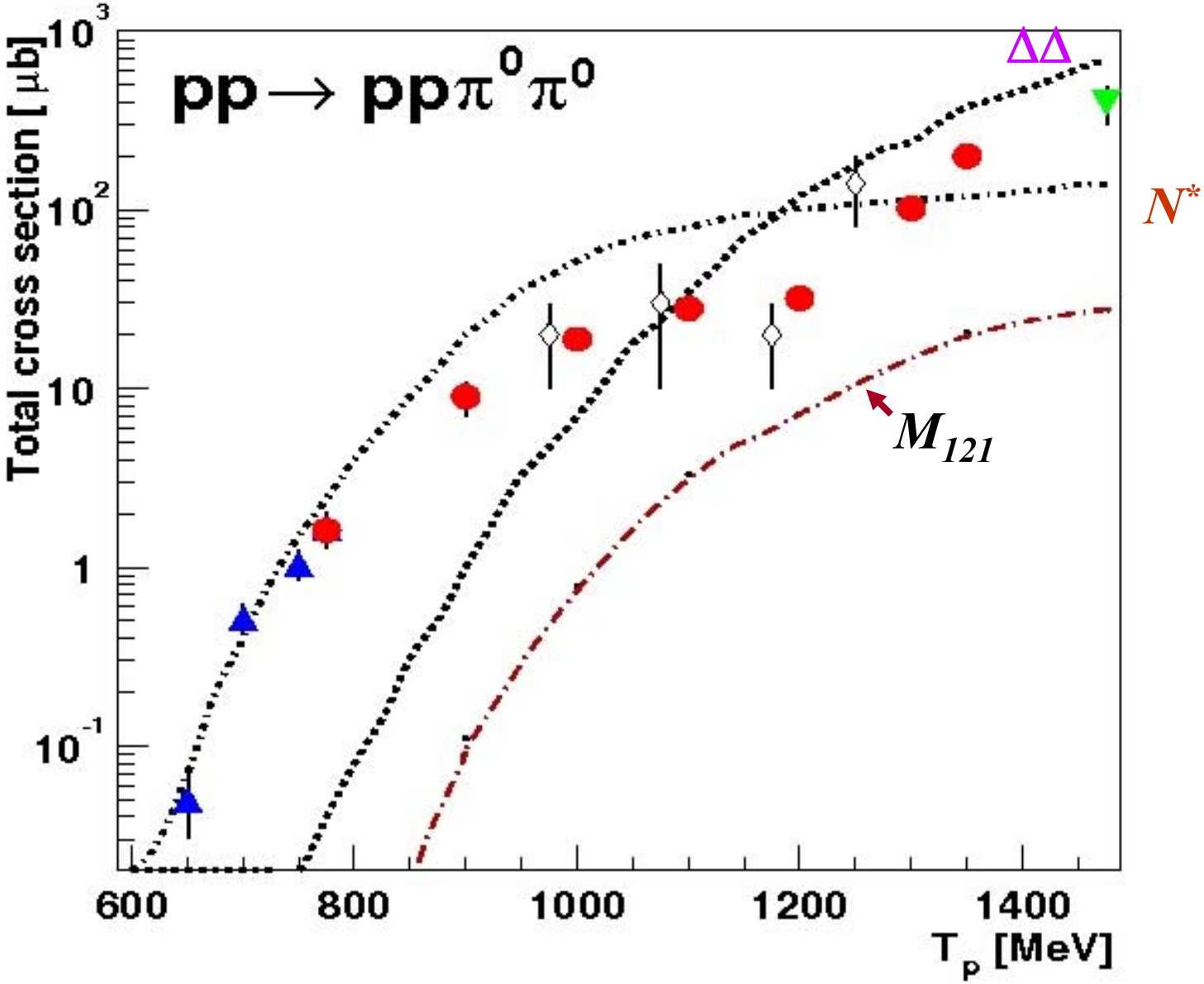
Total cross section

$pp \to nn\pi^+\pi^+$

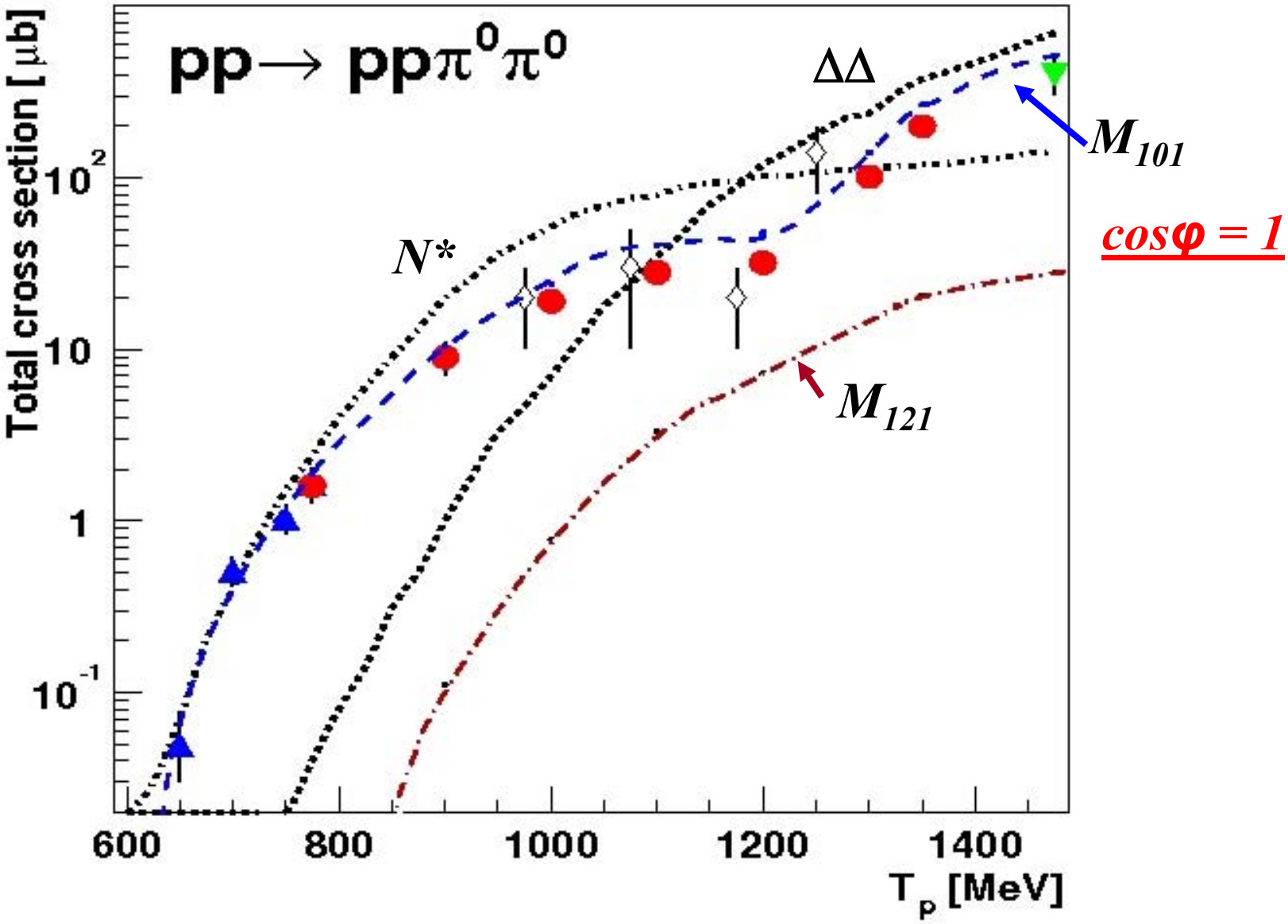
$$\sigma_{pp\pi^+\pi^+} = \frac{3}{20}|M_{121}|^2$$



Total cross section

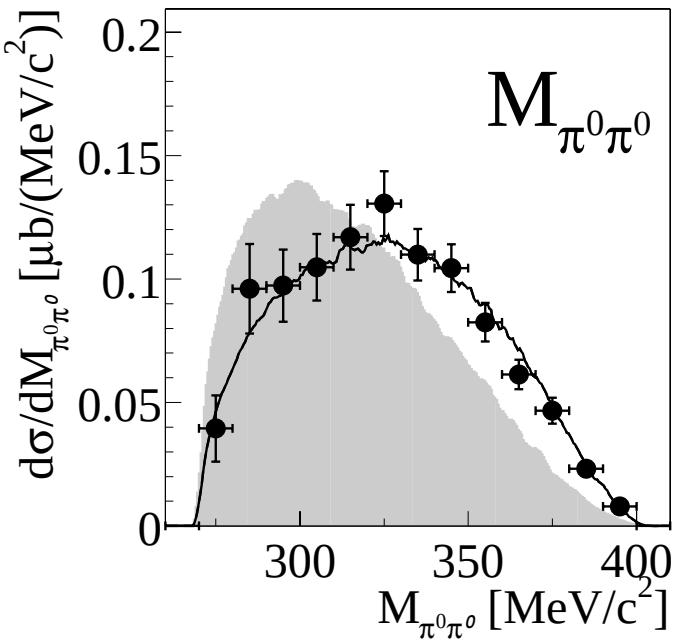


Total cross section

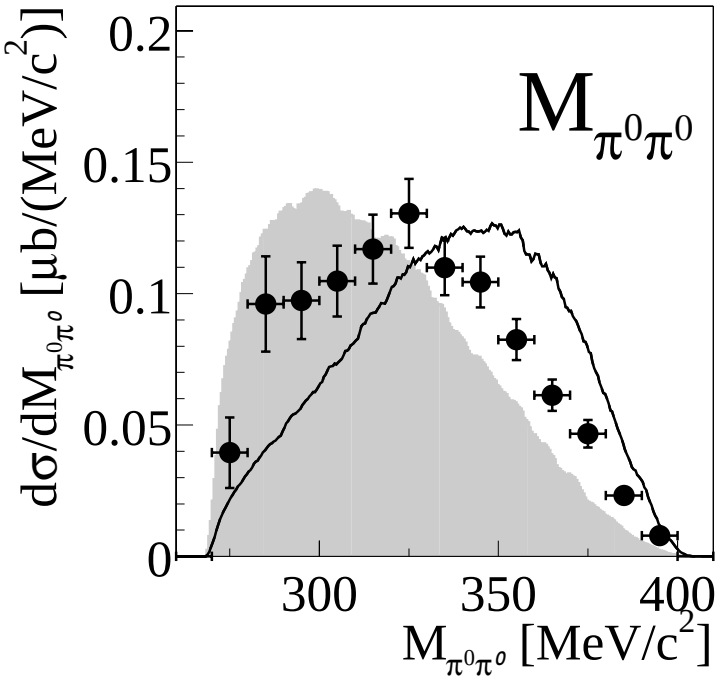


$$|M_{101}| = |M_{101}^{N^*} + M_{101}^{\Delta\Delta}|$$

$$|M_{101}^{N^*}| = |M_{101}| - |M_{101}^{\Delta\Delta}| \qquad |M_{101}^{N^*}| = |M_{101}| + |M_{101}^{\Delta\Delta}|$$

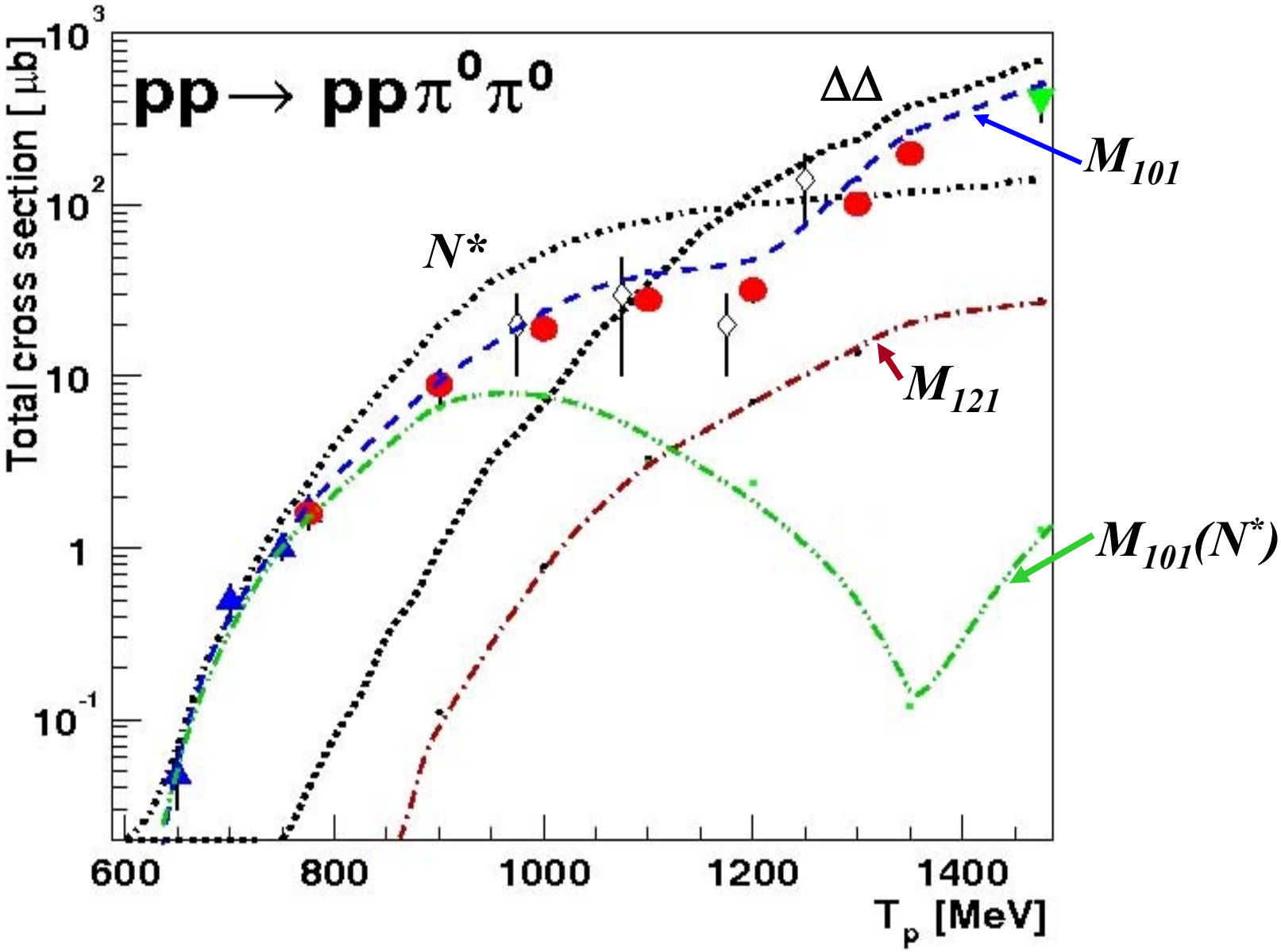


T_p=900 MeV



$$M_{101}^{N^*} = M_{101} - M_{101}^{\Delta\Delta}$$

Total cross section

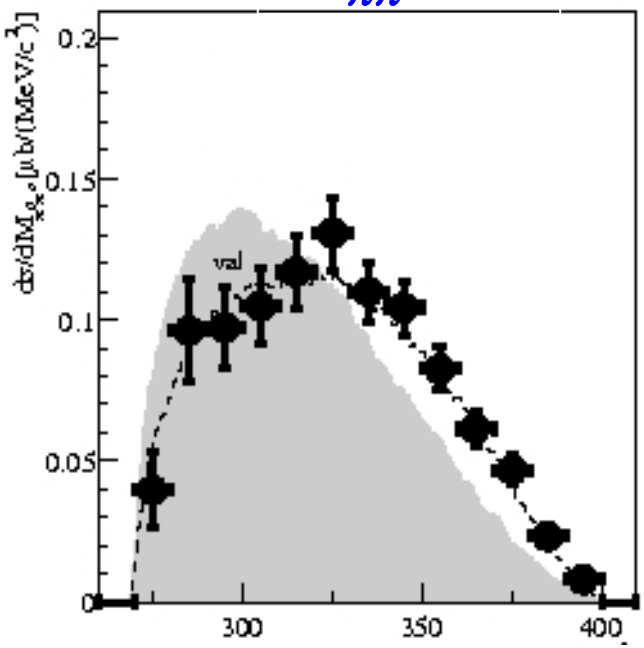


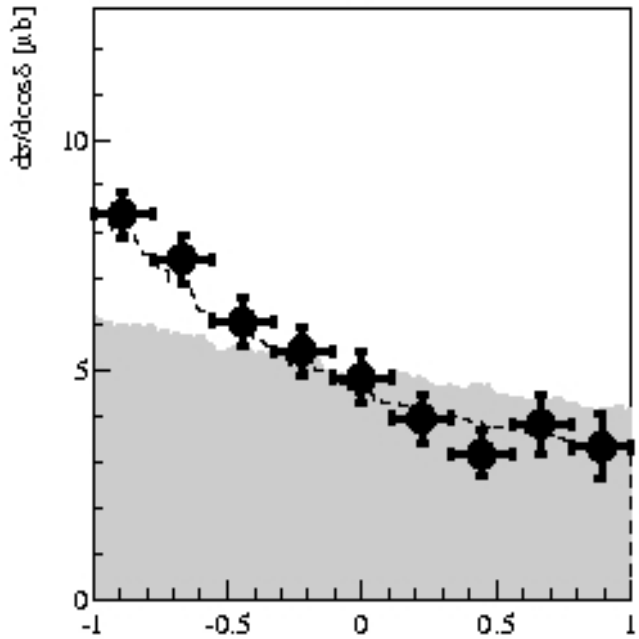
$pp \rightarrow pp\pi^0\pi^0$

$M_{\pi\pi}$

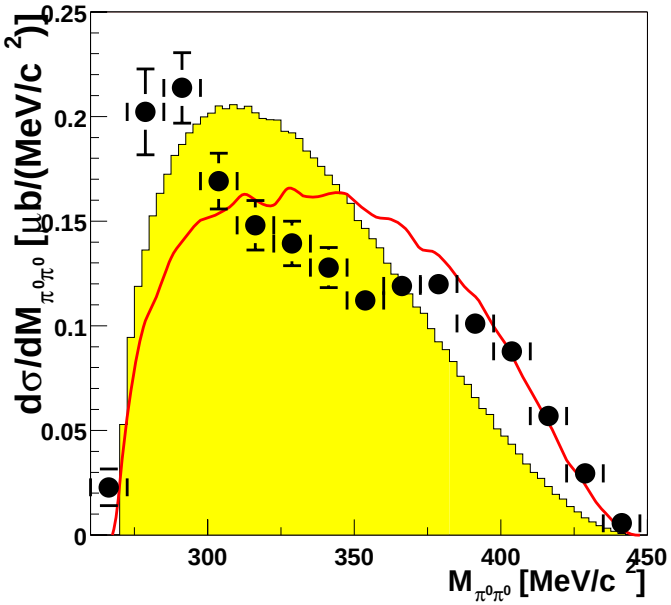
$\delta_{\pi\pi}$

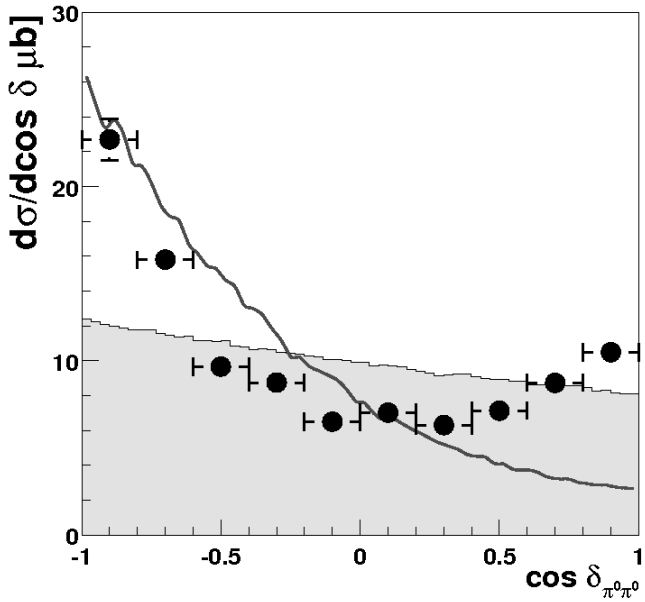
$T_p = 895\ MeV$





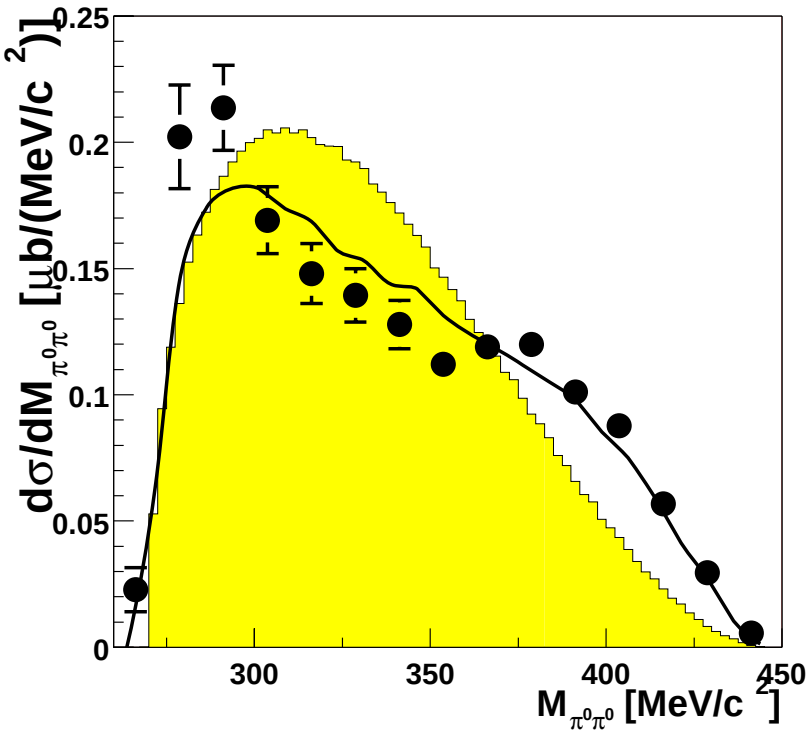
$T_p = 1000\ MeV$



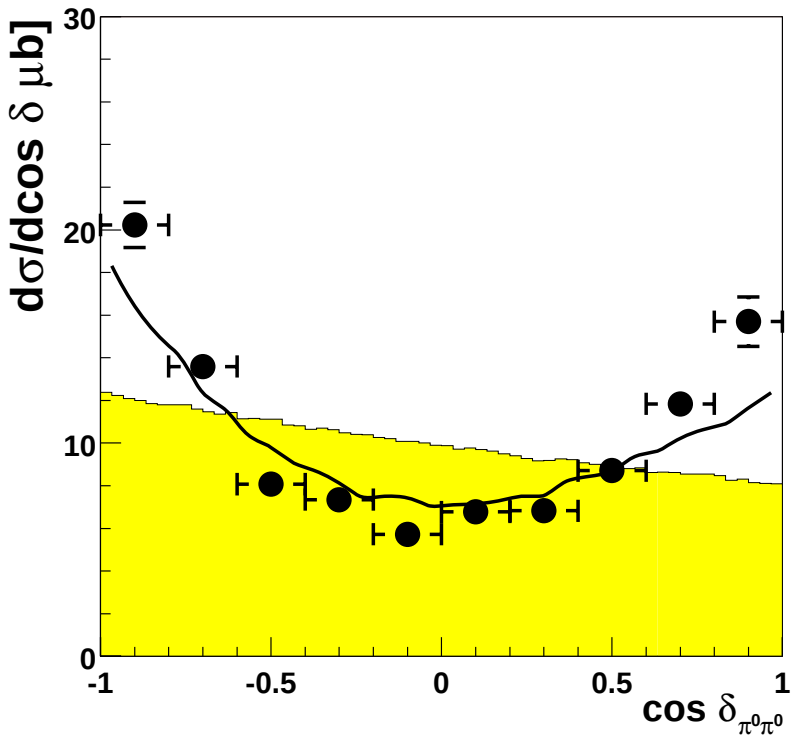


$pp \rightarrow pp\pi^0\pi^0 \quad T_p = 1000\ MeV.$

$M_{\pi\pi}$

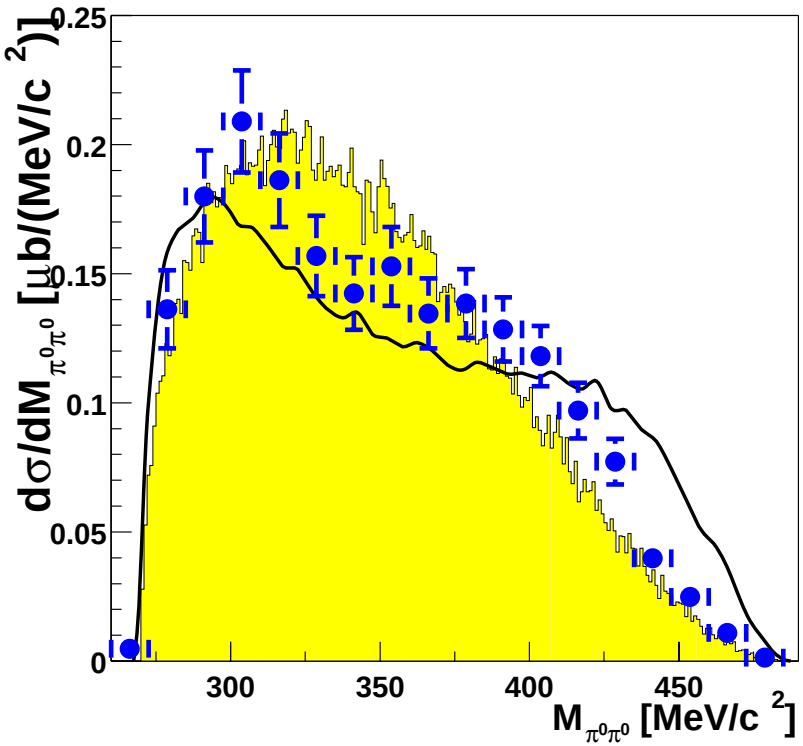


$\delta_{\pi\pi}$

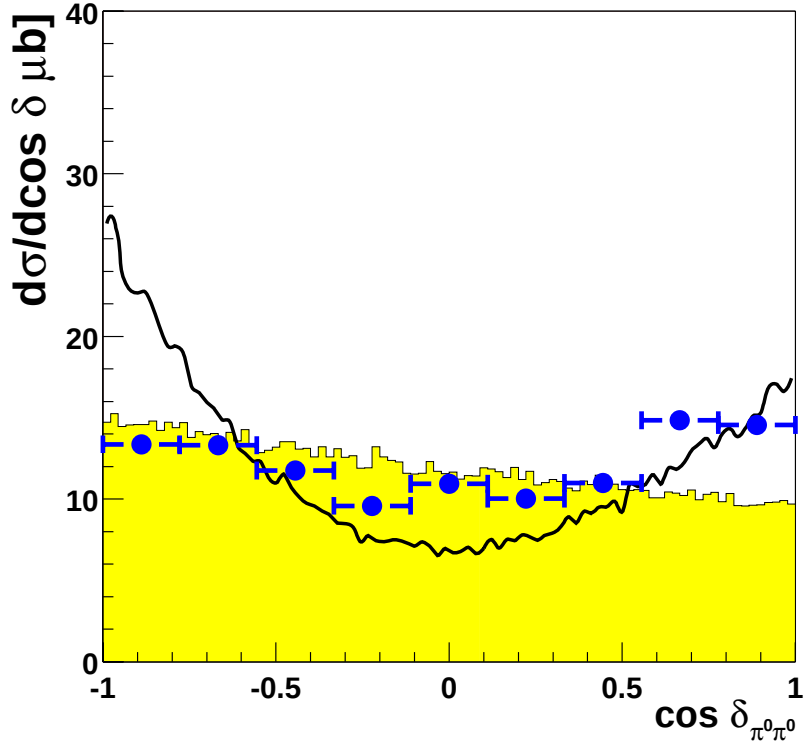


$$pp \rightarrow pp\pi^0\pi^0 \quad T_p = 1100\ MeV.$$

$M_{\pi\pi}$

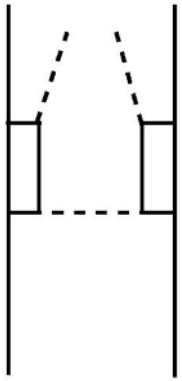


$\delta_{\pi\pi}$

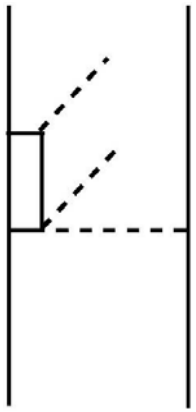


Total cross section

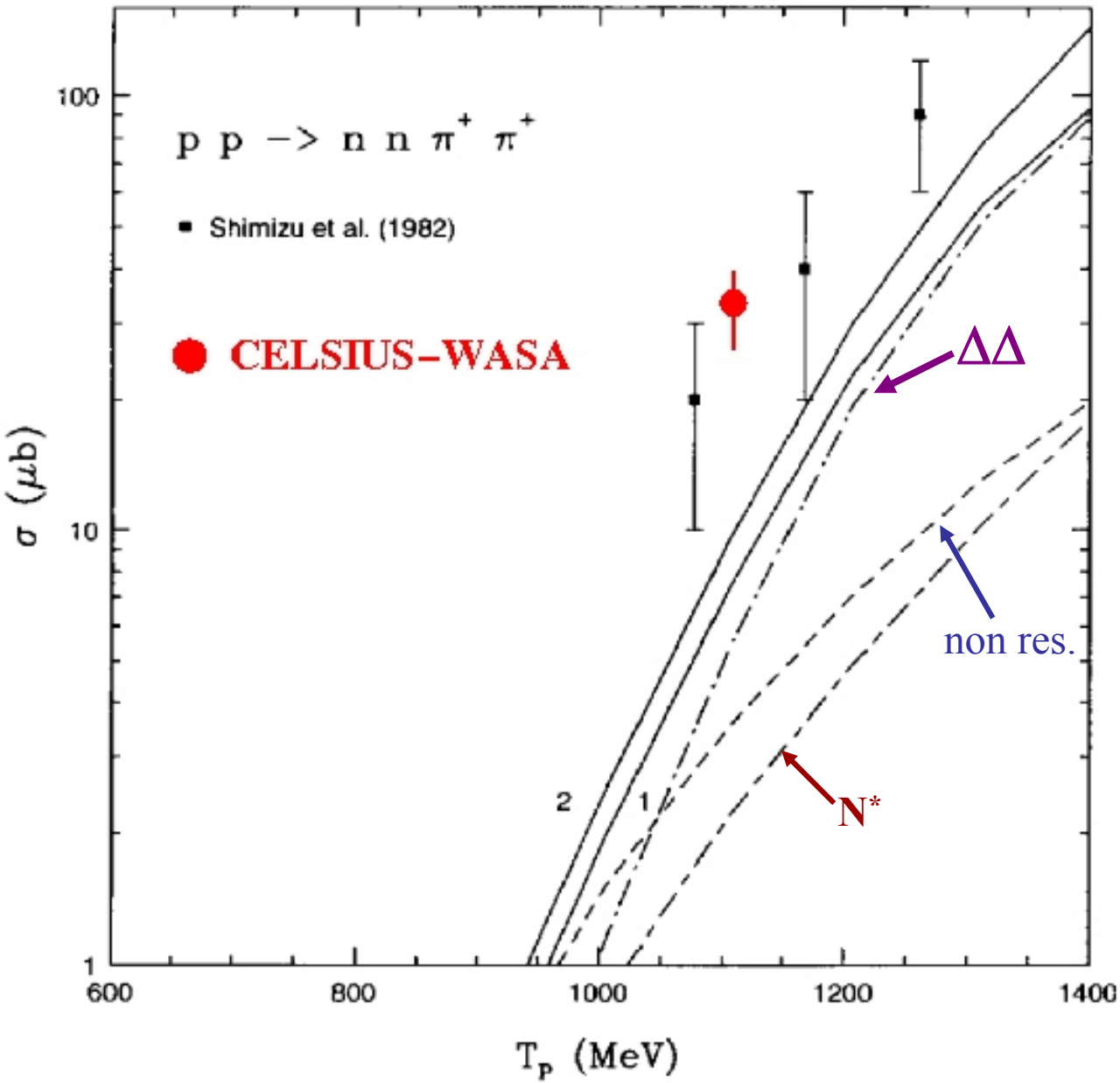
$pp \rightarrow nn\pi^+\pi^+$



ΔΔ



N*



M_{121}

$$M_{121} = M_{121}^{\Delta\Delta} \Rightarrow$$

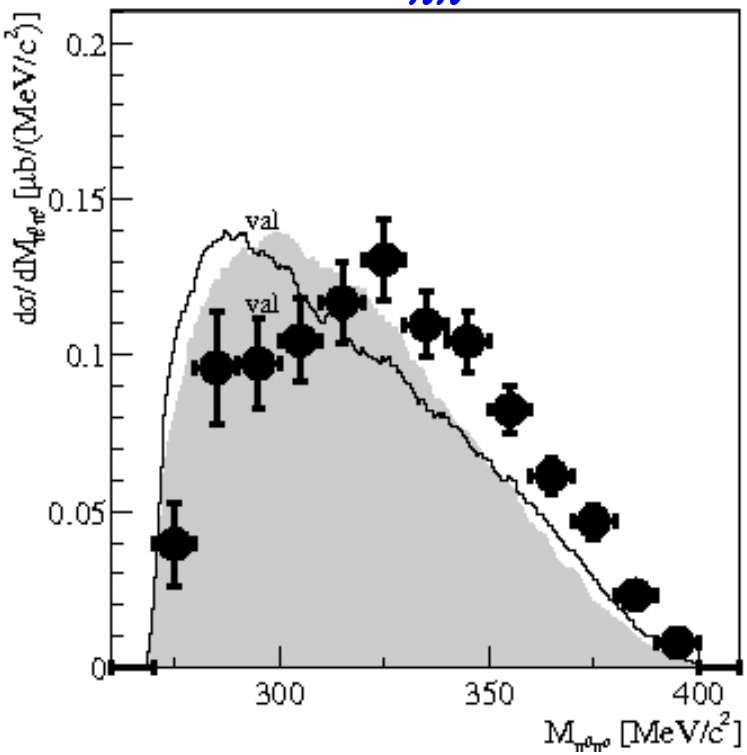
in 4 times bigger ΔΔ cross section in $pp\pi^0\pi^0$

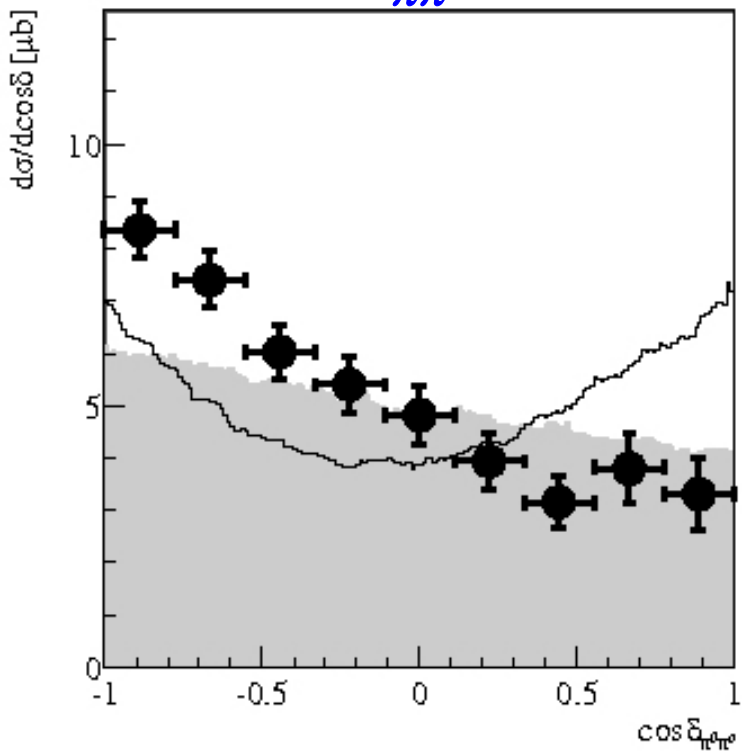
$$M_{101}^{\Delta\Delta} = -\sqrt{5} M_{121}^{\Delta\Delta}$$

$M_{\pi\pi}$

$\delta_{\pi\pi}$

T_p=900 MeV





$\mathbf{M_{121}}$

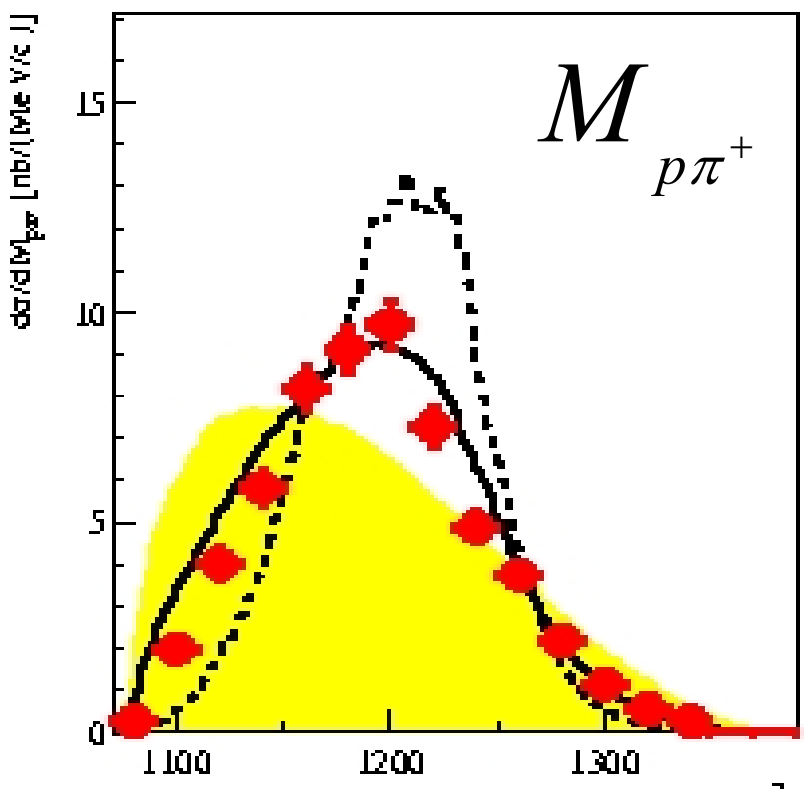
$$M_{121} = M_{121}^{\Delta\Delta} \quad \Rightarrow$$

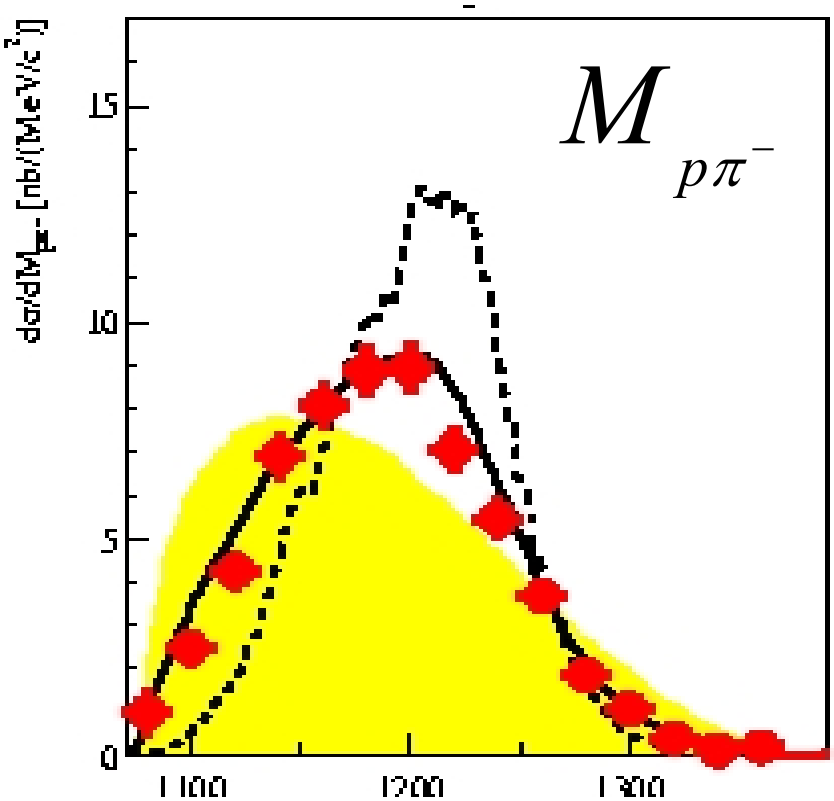
in 4 times bigger ΔΔ cross section in $pp\pi^0\pi^0$

$$|M_{121}| = |\sum M_{121}^{I=\frac{3}{2}}| \quad \Rightarrow$$

no contribution from ΔΔ

$pp \rightarrow pp\pi^+\pi^-$ T_p=1360





——— ΔΔ

$\mathbf{M_{121}}$

$$M_{121} = M_{121}^{\Delta\Delta} \quad \Rightarrow$$

in 4 times bigger ΔΔ cross section in $pp\pi^0\pi^0$

$$|M_{121}| = |\sum M_{121}^{I=\frac{3}{2}}| \quad \Rightarrow$$

no contribution from ΔΔ

$$|M_{121}| = |M_{121}^{\Delta\Delta} + \sum M_{121}^{I=\frac{3}{2}}|$$

$\mathbf{M_{121}}$

$$|M_{121}| = |M_{121}^{\Delta\Delta} + \sum M_{121}^{I=\frac{3}{2}}|$$

$\Delta(1232)$ $\qquad$ $\Delta(1600)$

very small amplitude

according to Valencia model

M_Δ***=1500–1700 MeV*** $\Rightarrow$

threshold energy $\approx$ ***threshold energy*** $\Delta\Delta$

Γ_Δ***=200–400 MeV*** $\Rightarrow$

can contribute at low energy

$$|M_{121}| = |M_{121}^{\Delta\Delta} + M_{121}^{\Delta_{1600}}|$$

~~$|M_{121}| = |M_{121}^{\Delta_{1600}}| + |M_{121}^{\Delta\Delta}|$~~

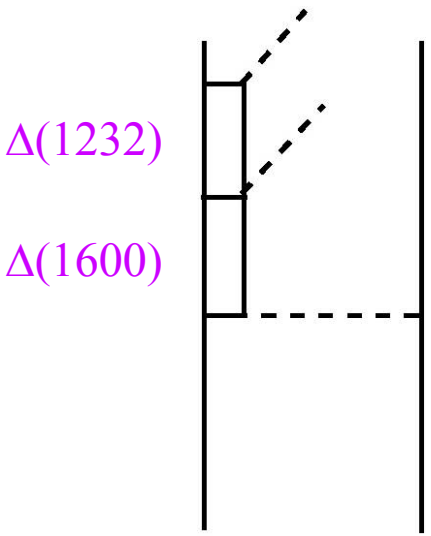
$|M_{121}| = |M_{121}^{\Delta_{1600}}| - |M_{121}^{\Delta\Delta}|$

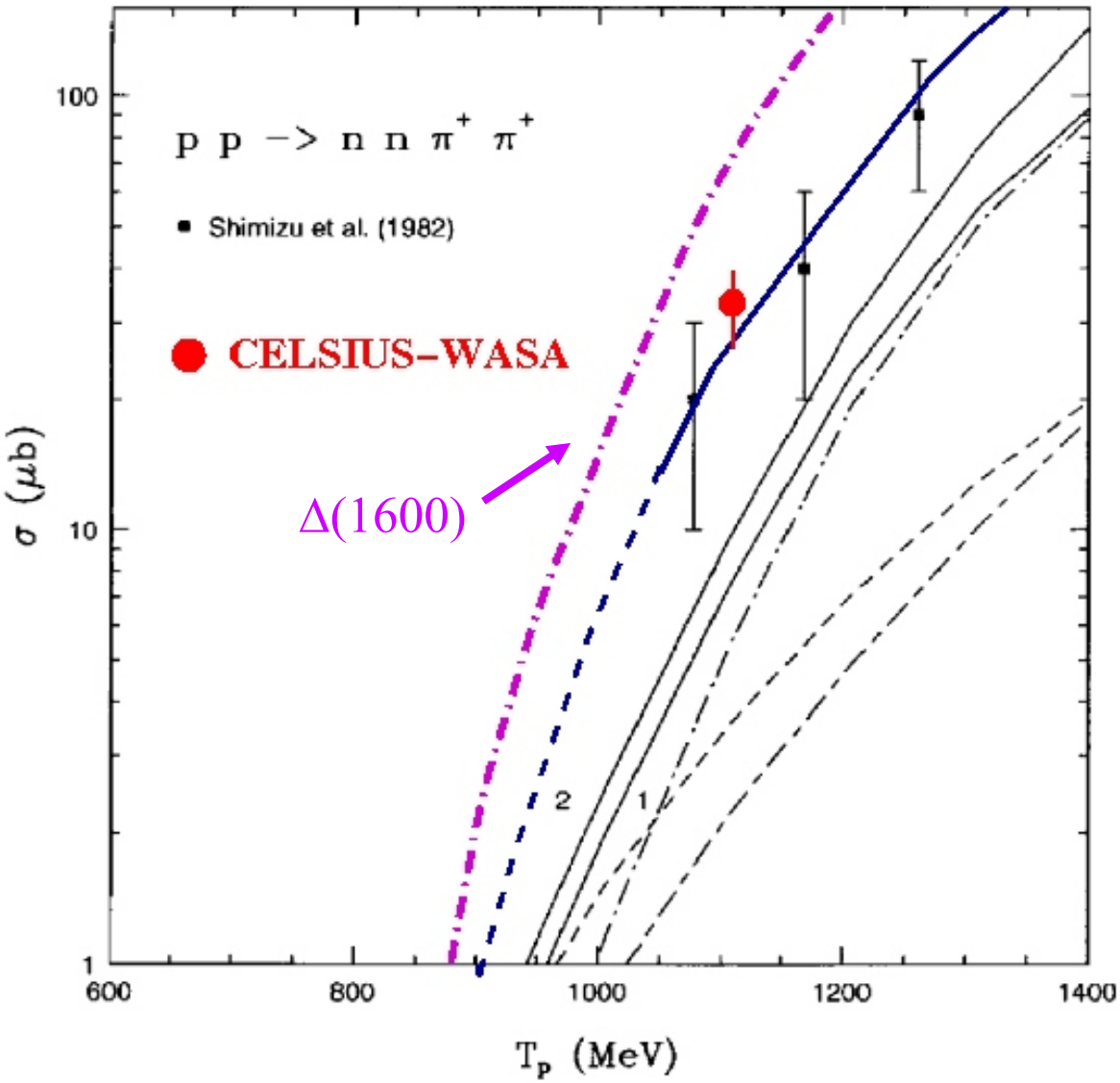
$\cos\varphi \approx +1$

$$M_{101}^{\Delta\Delta} = -\sqrt{5} M_{121}^{\Delta\Delta}$$

Total cross section

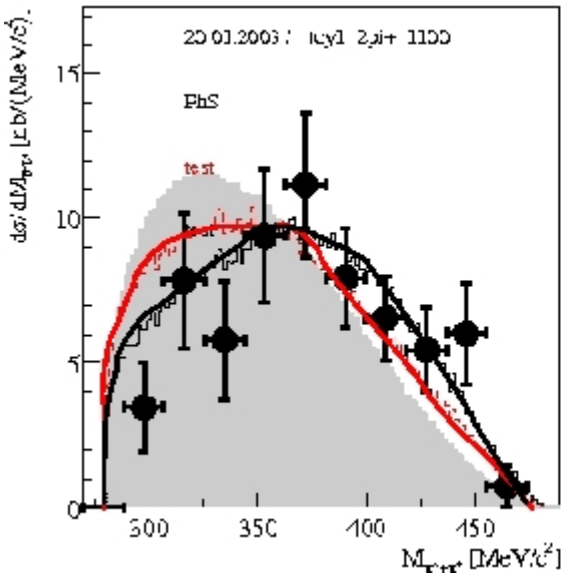
$pp \rightarrow nn\pi^+\pi^+$



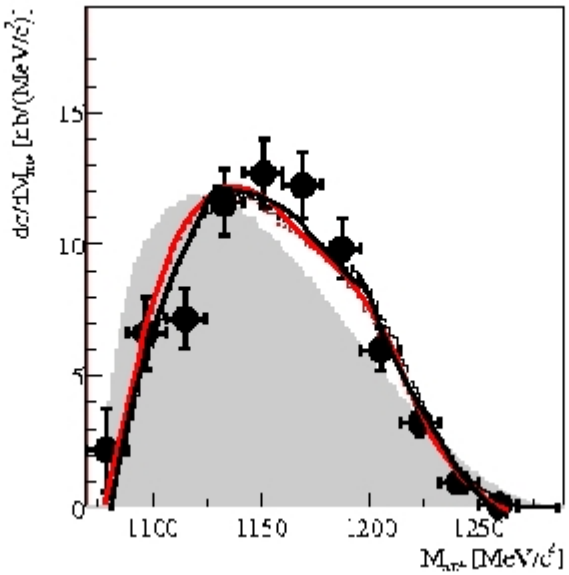


$pp \rightarrow nn\pi^+\pi^+$ $T_p = 1100\ MeV$

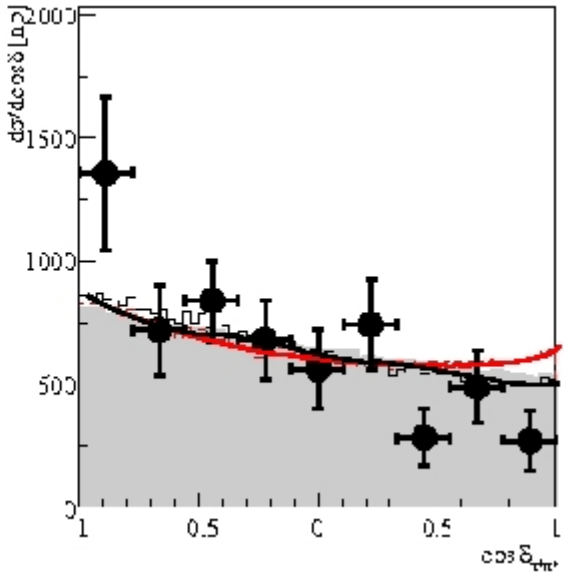
$M_{\pi\pi}$



$M_{n\pi}$



$\delta_{\pi\pi}$



Δ(1600)

Δ(1232)

Conclusions

- contribution from particle with spin 3/2 should be added in model description

  Δ(1600) – possible candidate

- $pp \rightarrow pn\pi^0\pi^+$