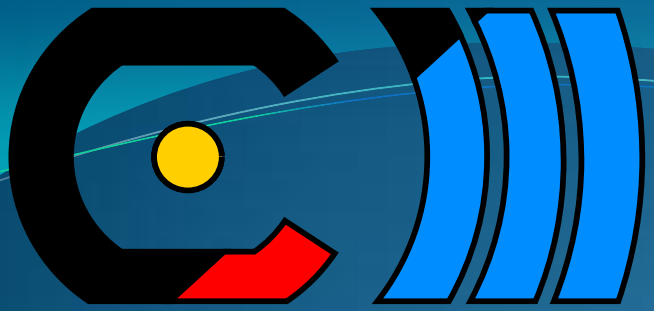


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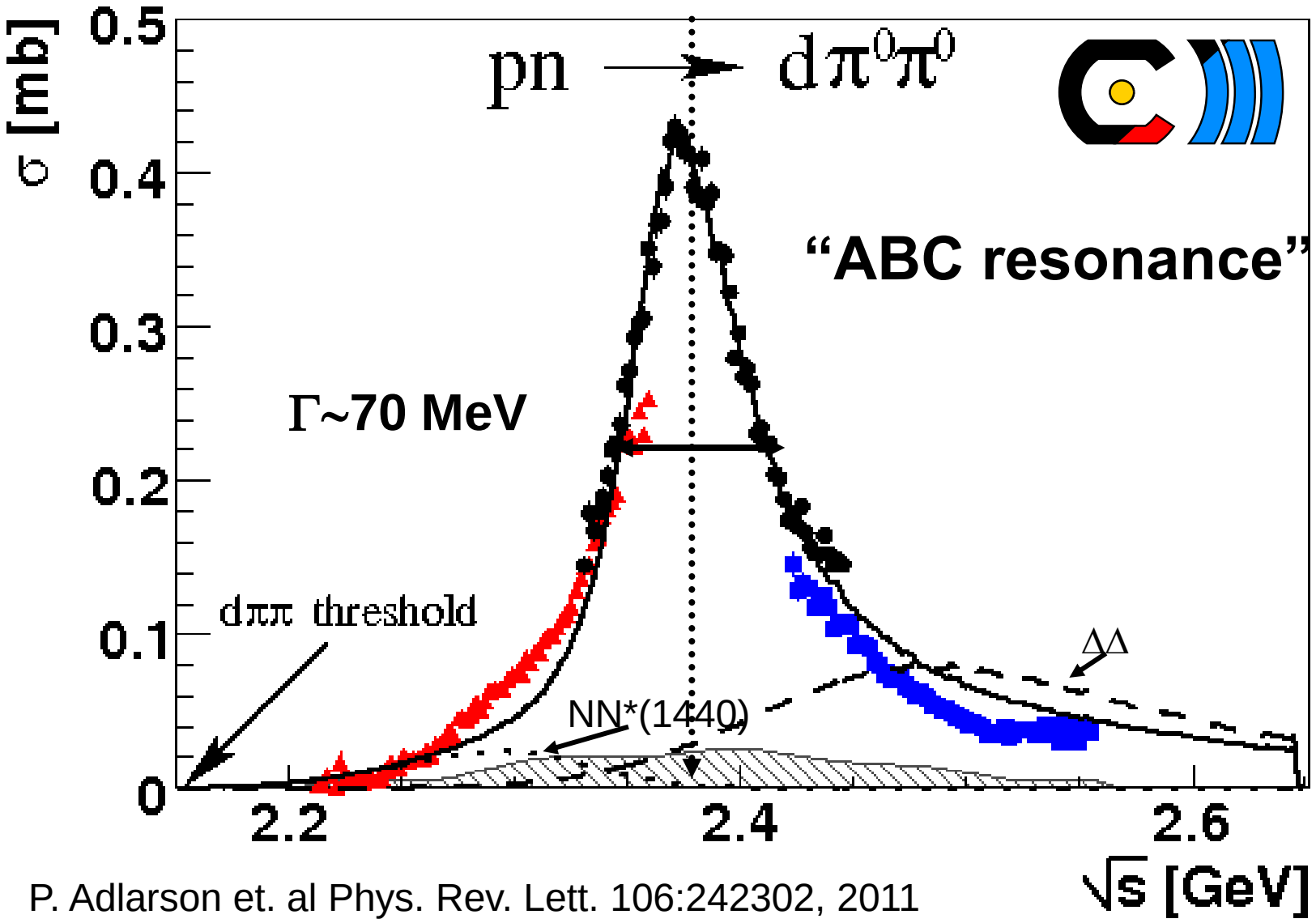
# Observation of the d* resonance in the $pn \rightarrow d^* \rightarrow d\pi\pi$ and $pn \rightarrow d^* \rightarrow pn$ at WASA

Mikhail Bashkanov

# Content

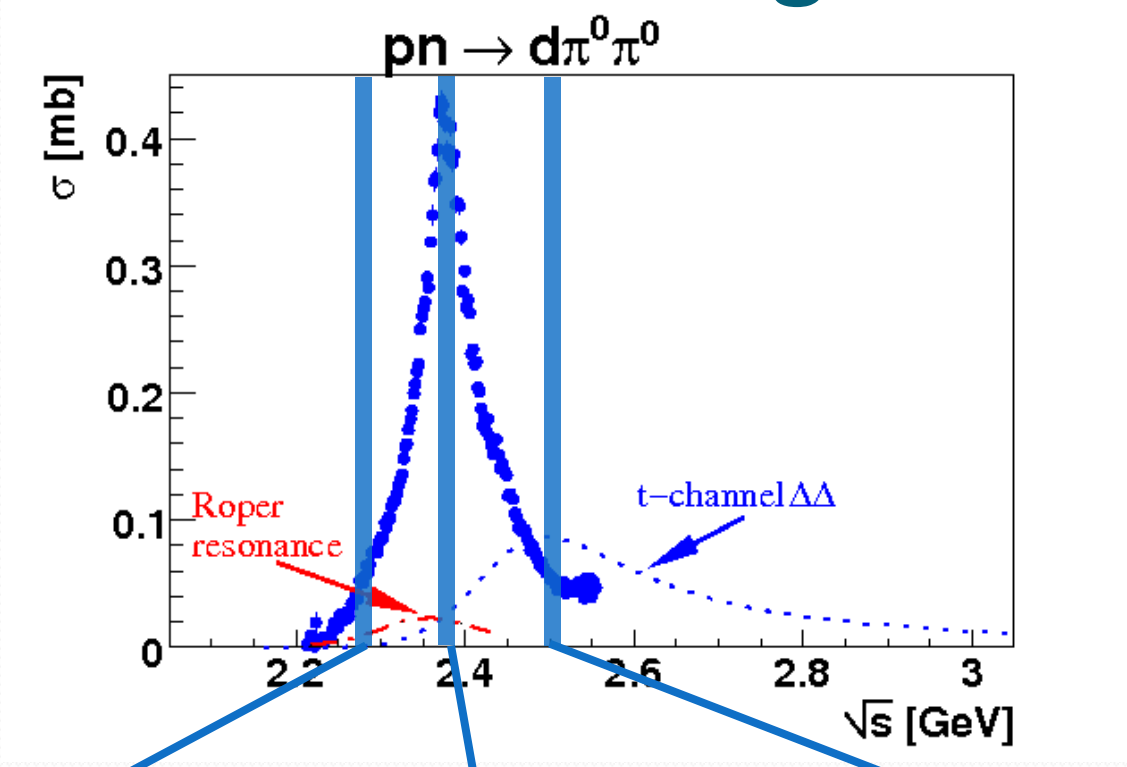
- ABC Resonance in $pn \to d\pi^0\pi^0$
  - Quantum numbers
- Isospin decomposition
  - $pn \to d\pi^0\pi^0$, $pn \to d\pi^+\pi^-$, $pp \to d\pi^+\pi^0$
- Resonance in elastic scattering $pn \to R \to pn$

# Total cross section $pn \rightarrow d\pi^0\pi^0$

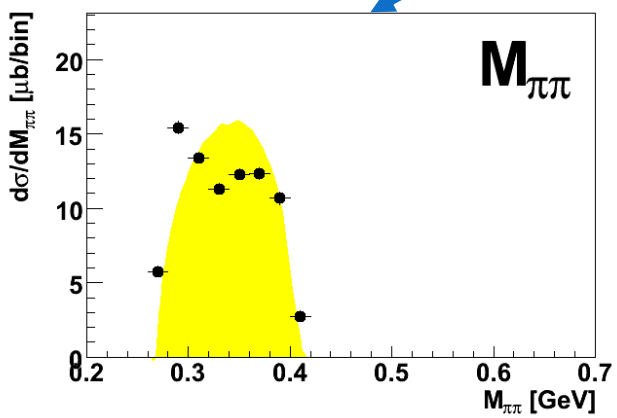


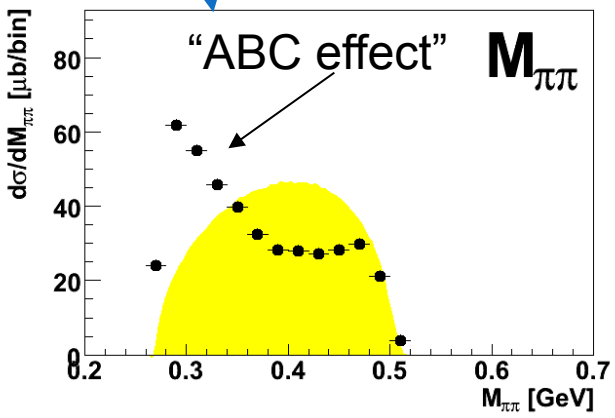

P. Adlarson et. al Phys. Rev. Lett. 106:242302, 2011

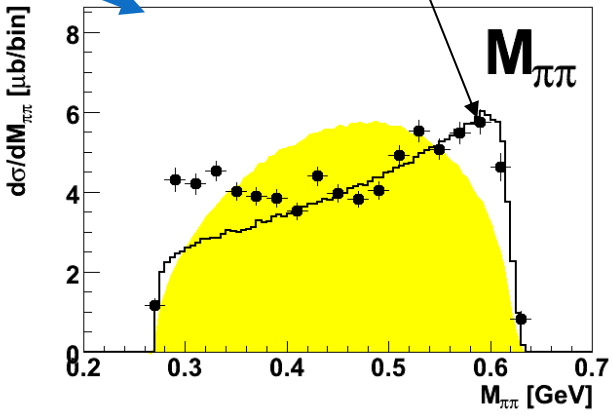
# $M_{\pi\pi}$ for different energies



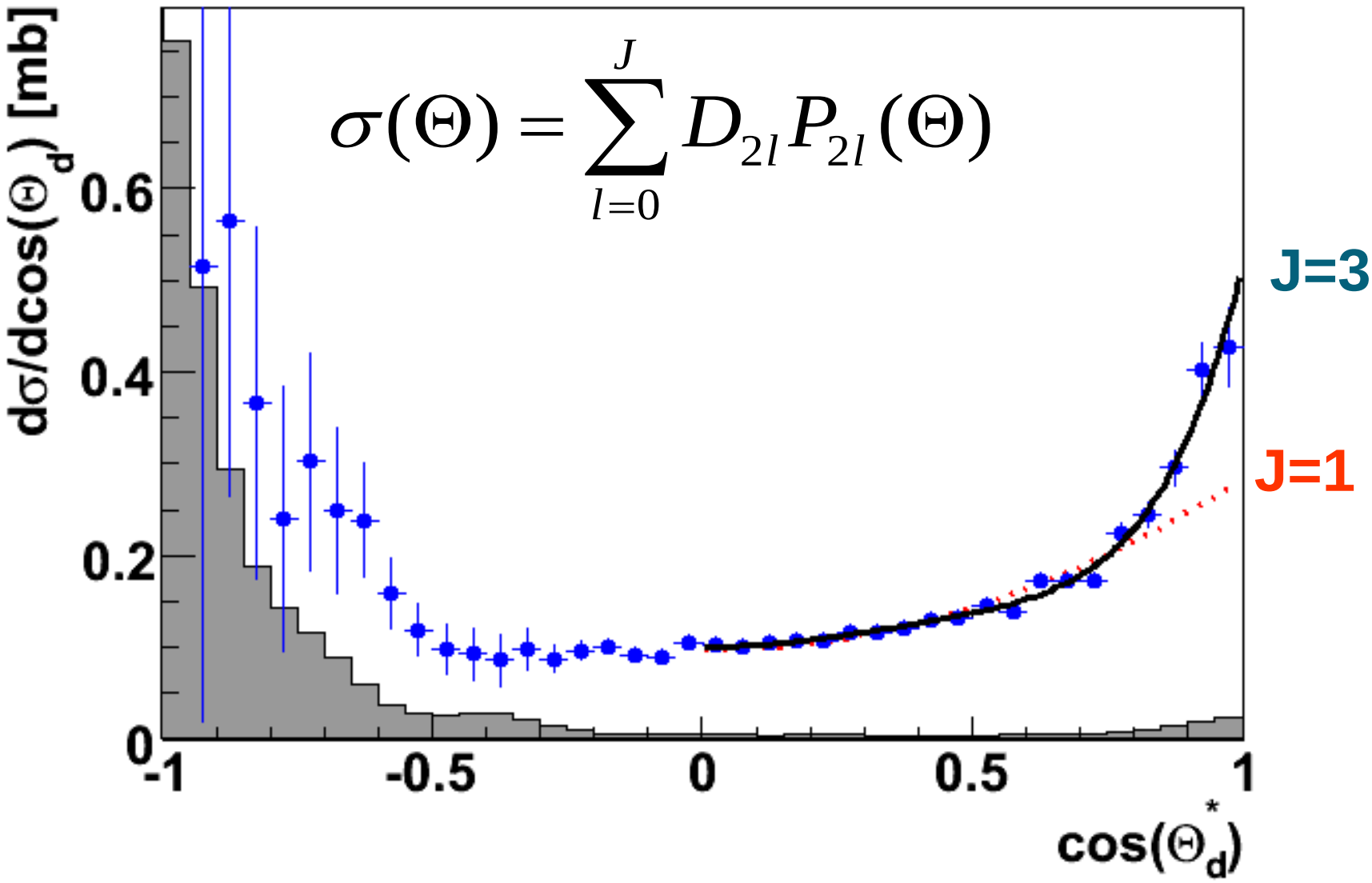

t-channel ΔΔ



# Angular distribution in the peak



# Quantum numbers of the structure

## $pn \rightarrow R \rightarrow d\ \pi^0\pi^0$

Antisymmetrization: $J^P = 1^+$ or $3^+$ : if $L_{\Delta\Delta} = 0$

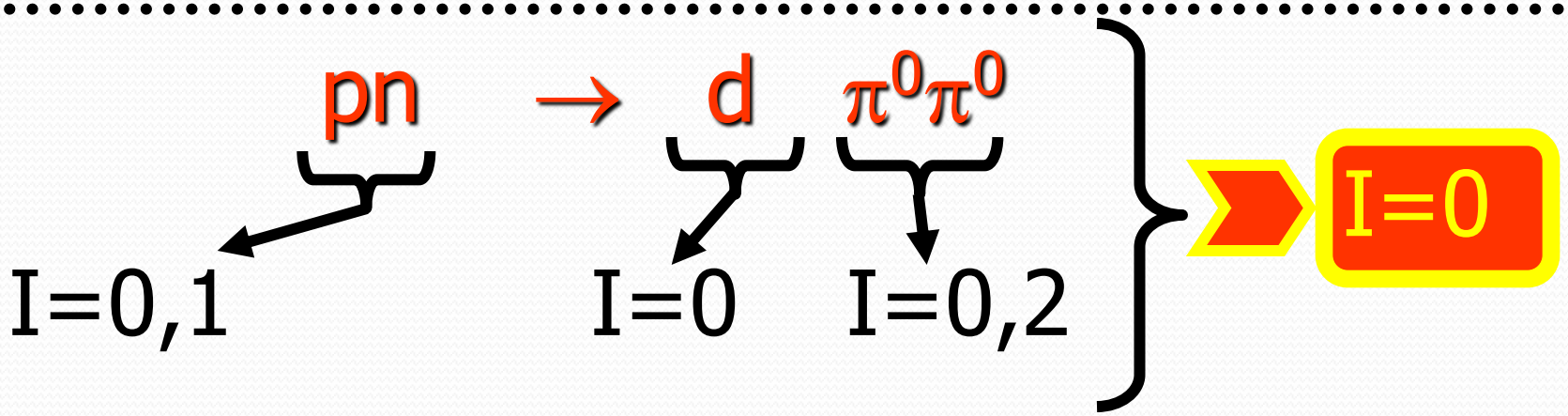
$$\sigma(\cos\Theta^*_d) = D_0P_0 + D_2P_2 + D_4P_4 + D_6P_6$$

$D_0P_0 + D_2P_2$ : $1^+$

$1^+$ excluded by $\sigma(\Theta)$.

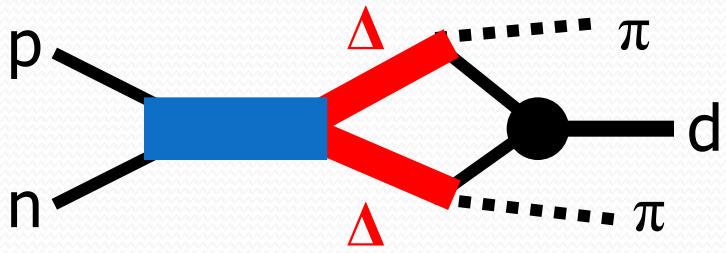
$3^+$ assigned

$3^+$



# Status of Theoretical Description

- $pn \rightarrow R \rightarrow \Delta\Delta \rightarrow d\pi^0\pi^0$

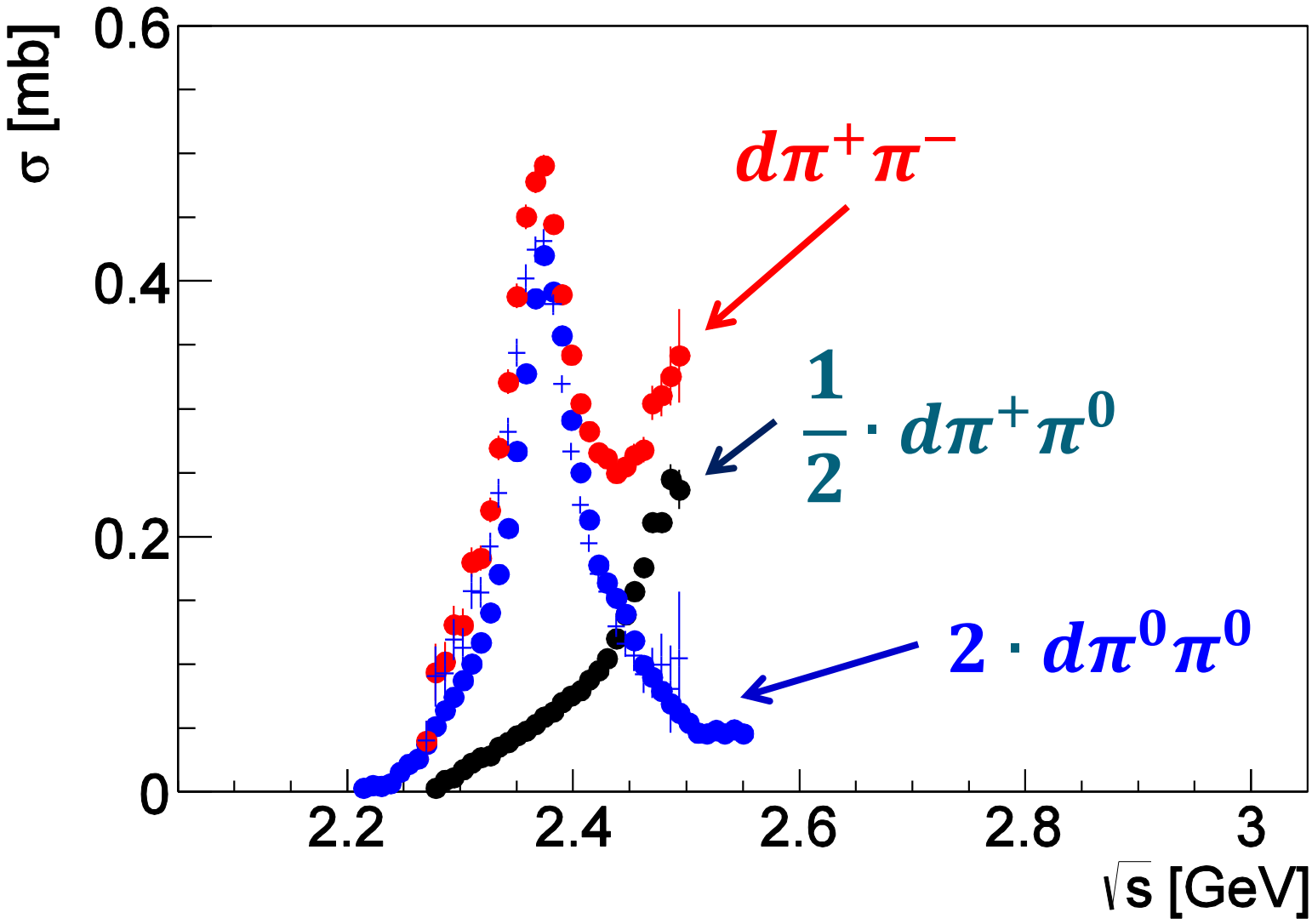



**$I(J^p) = 0(3^+)$**

# Isospin relations

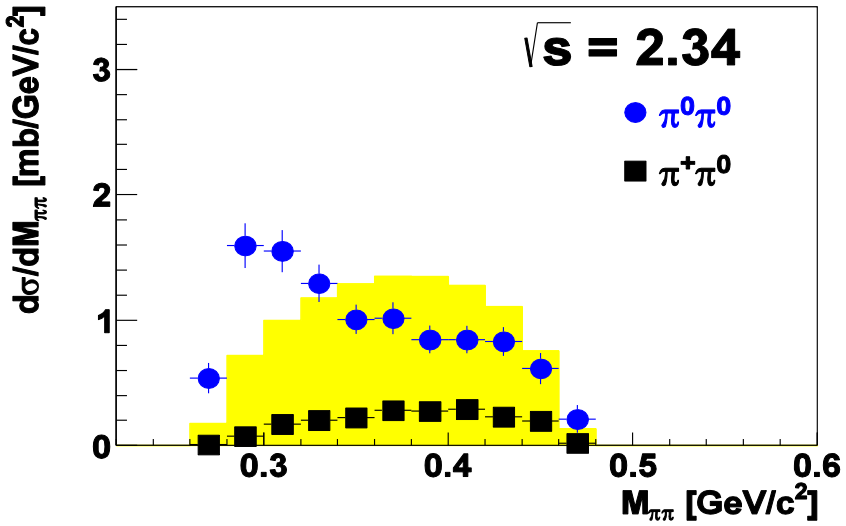
$$\sigma[pn \to d\pi^+\pi^-] = \overbrace{\frac{1}{2}\sigma[pp \to d\pi^+\pi^0]}^{I=1} + \underbrace{2\sigma[pn \to d\pi^0\pi^0]}_{I=0}$$

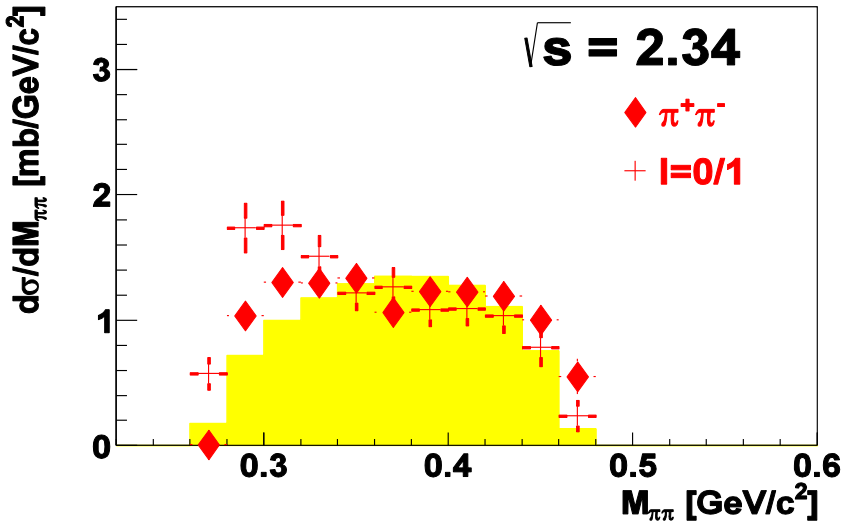
# Total cross section pN → dππ

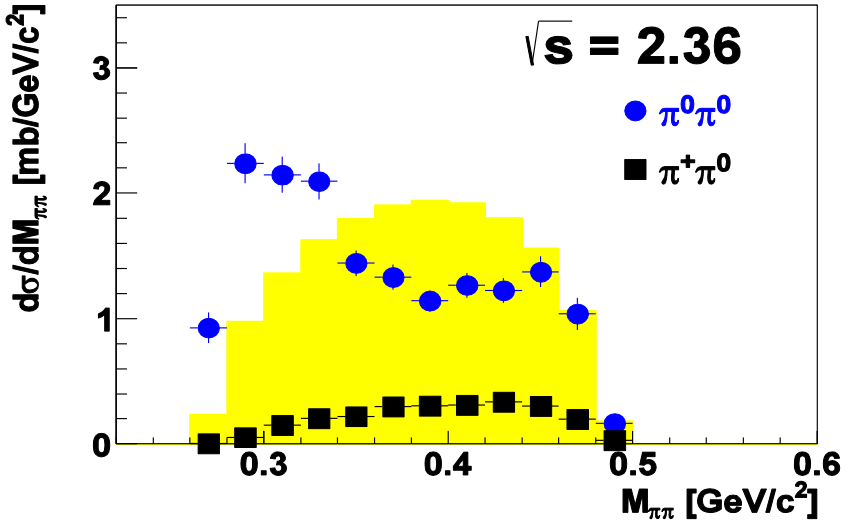


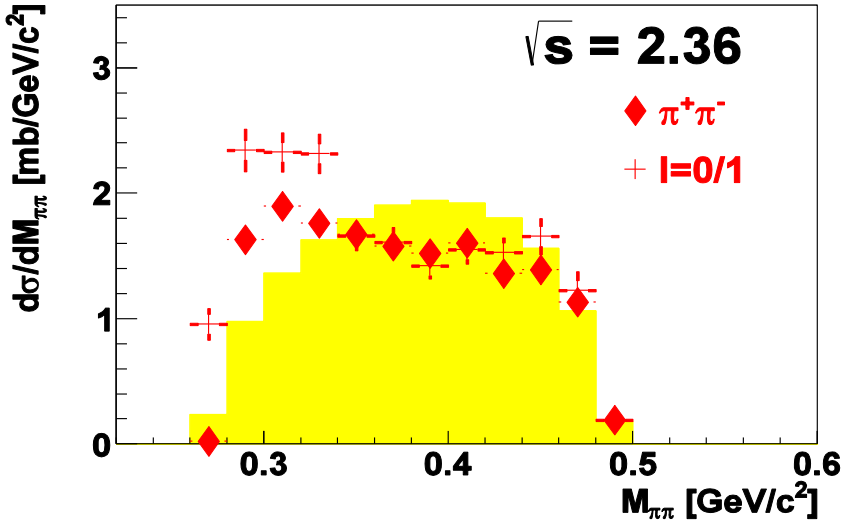

P. Adlarson et. al arXiv:1212.2881

# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

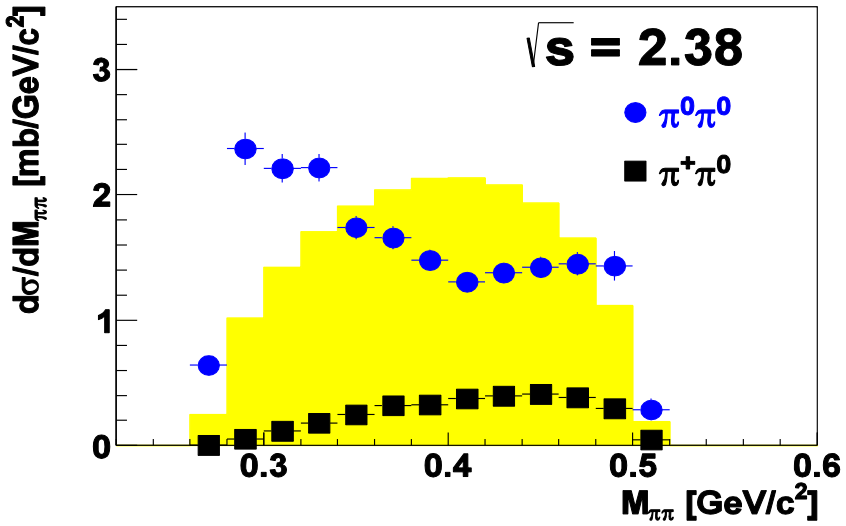


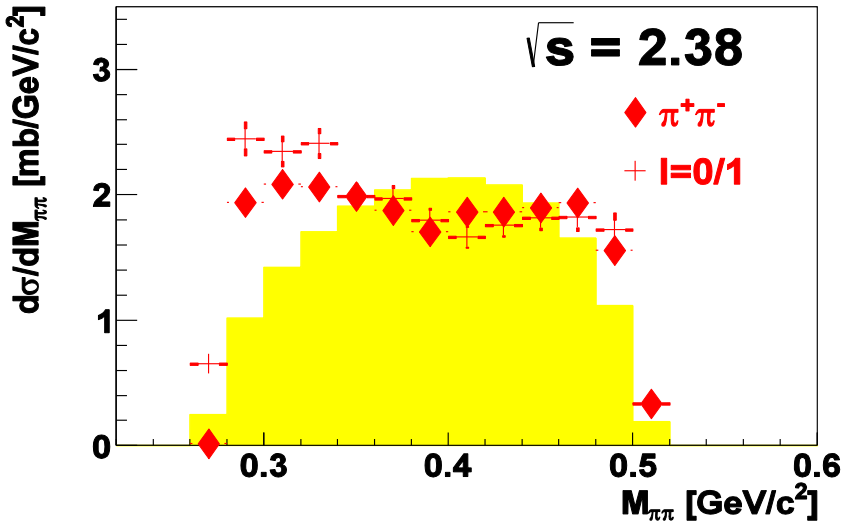



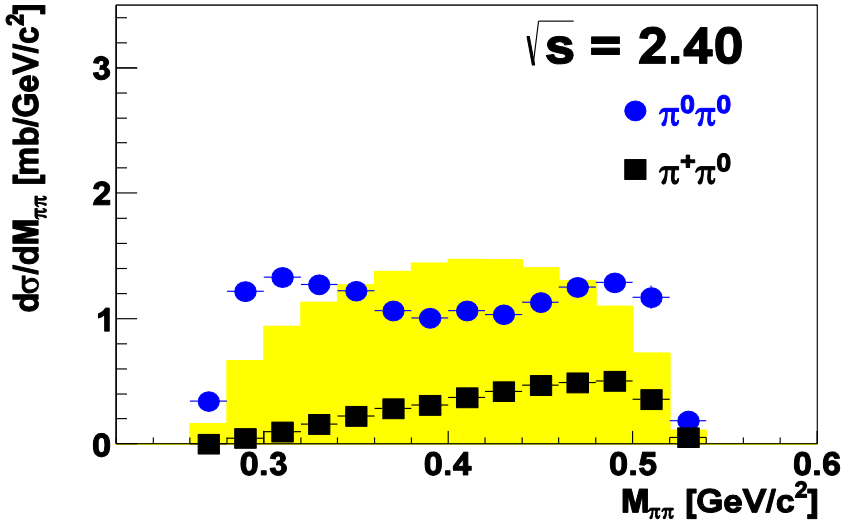



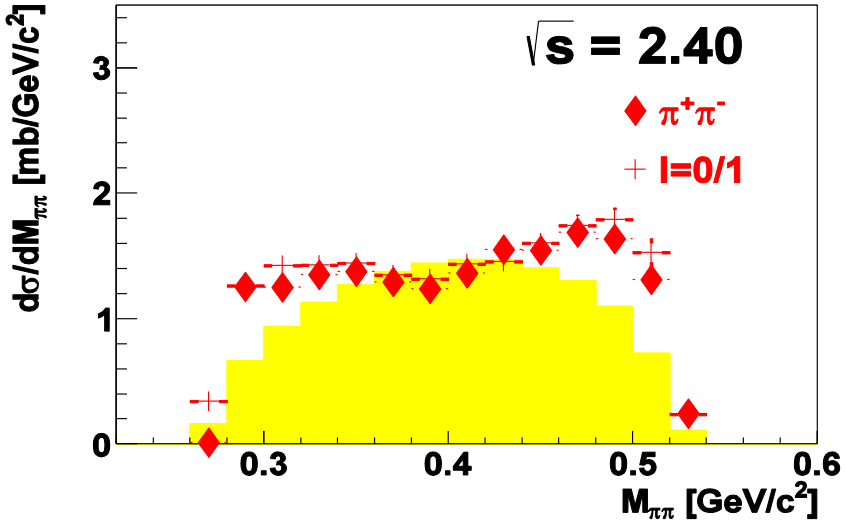



# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

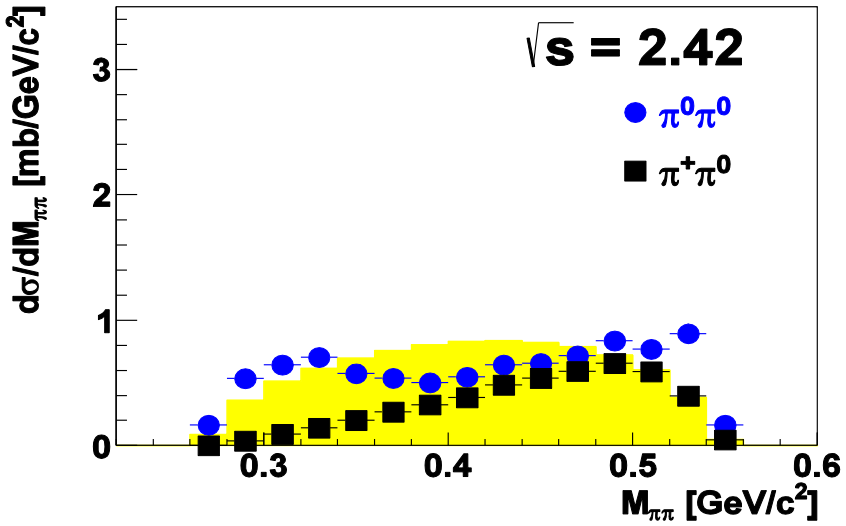


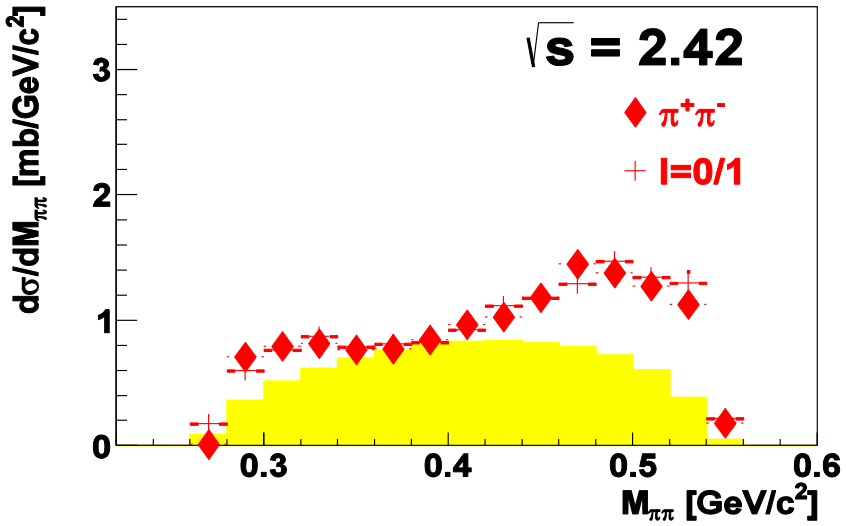



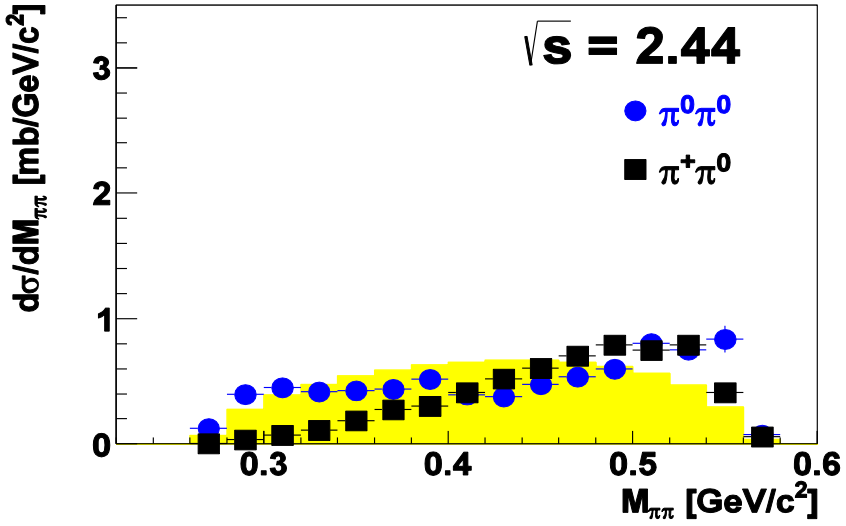



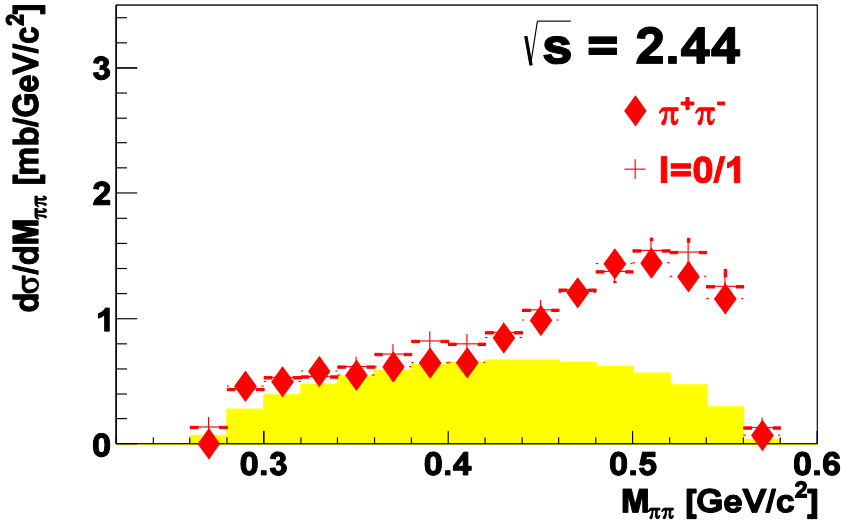



# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

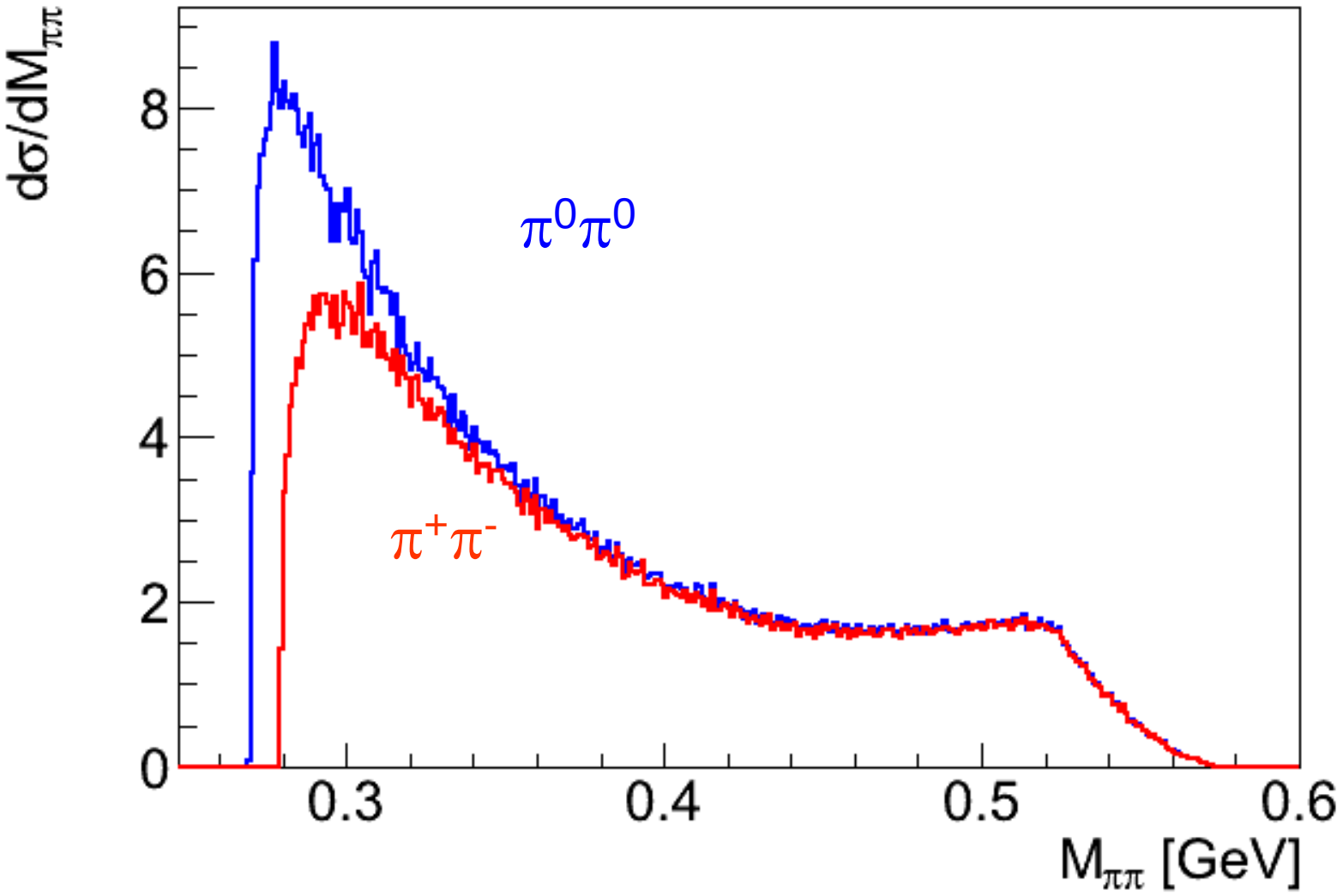


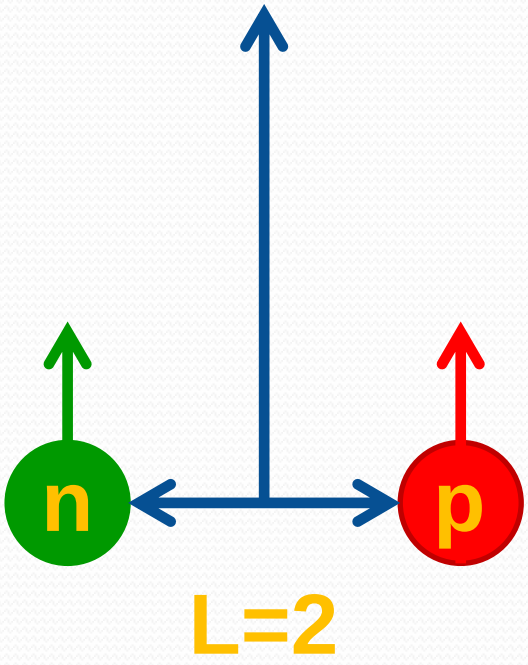



# Isospin violation

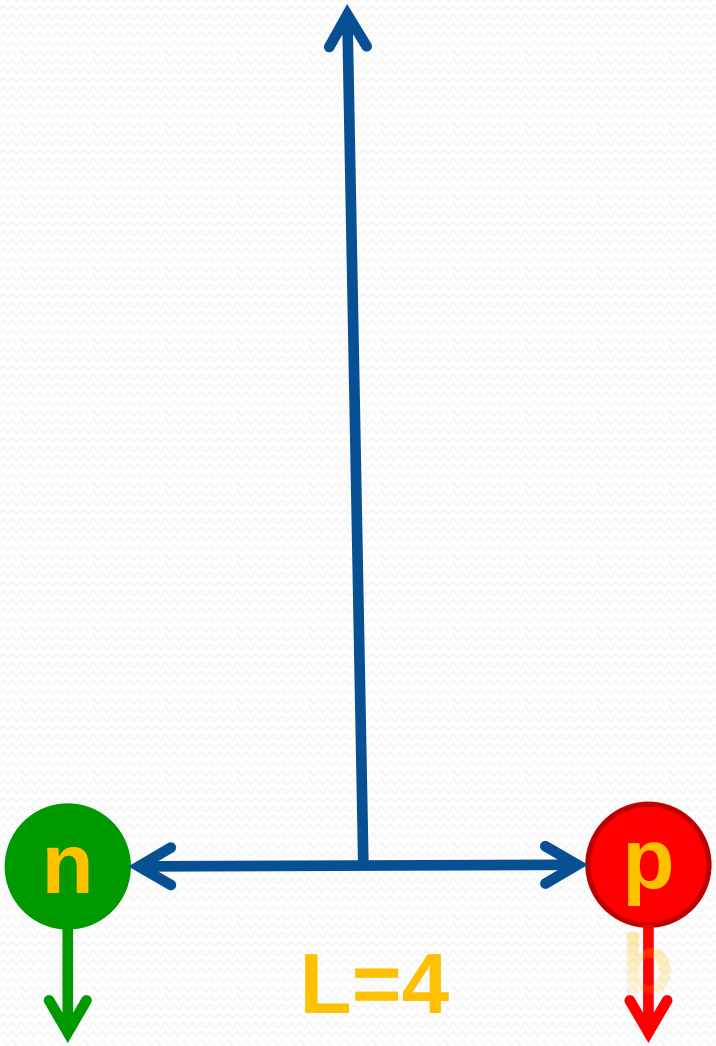


# Elastic channel

# $3^+$ Resonance in pn



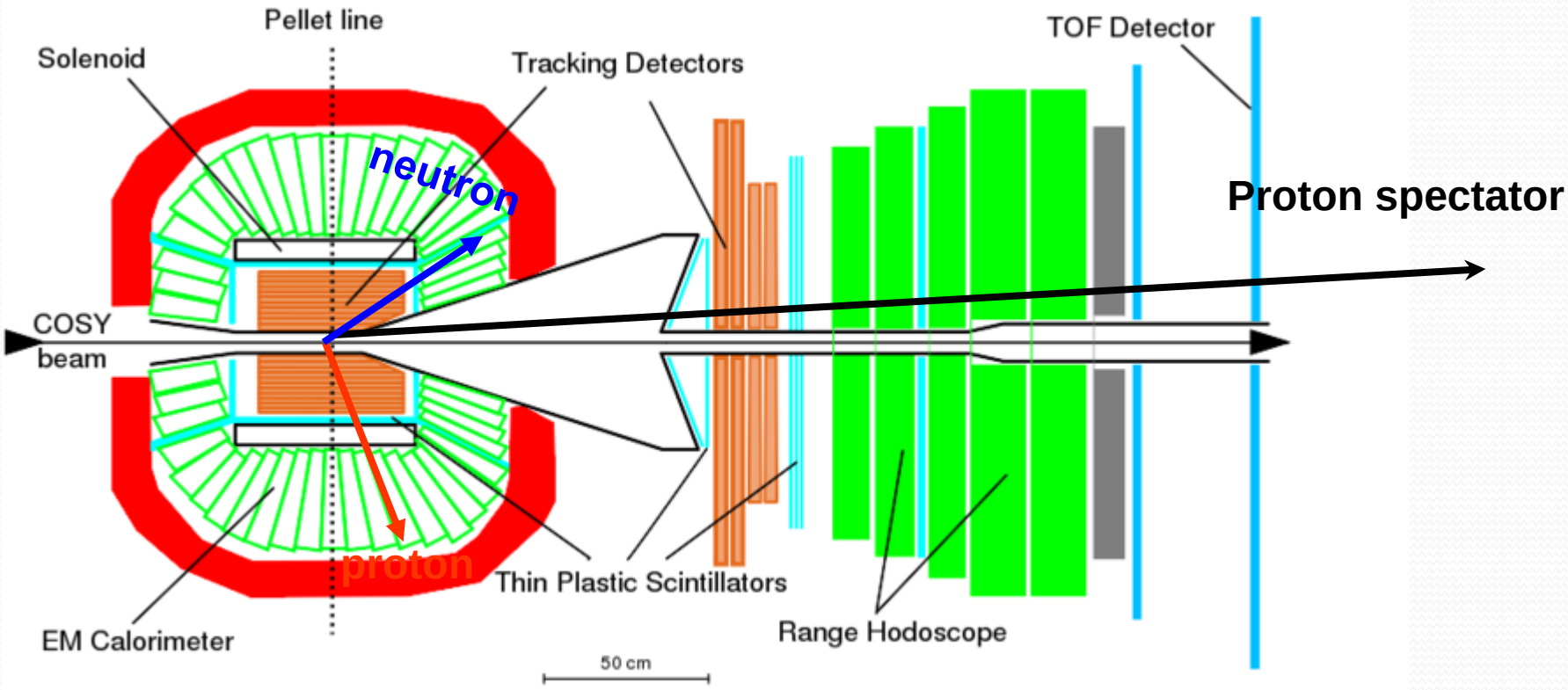

$^3D_3$



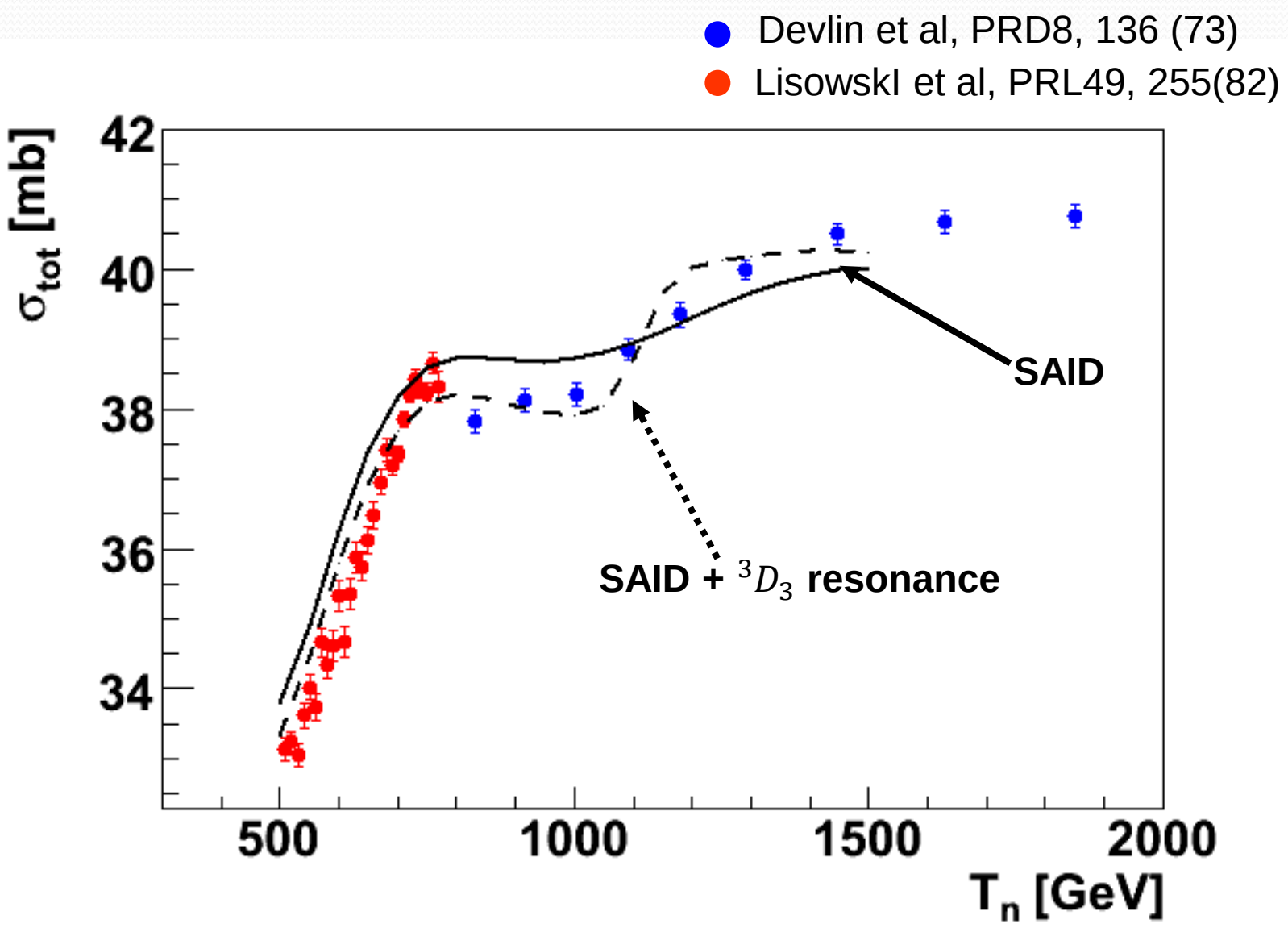

$^3G_3$

# Kinematics

$$\vec{d}p \rightarrow np + p_{sp}$$

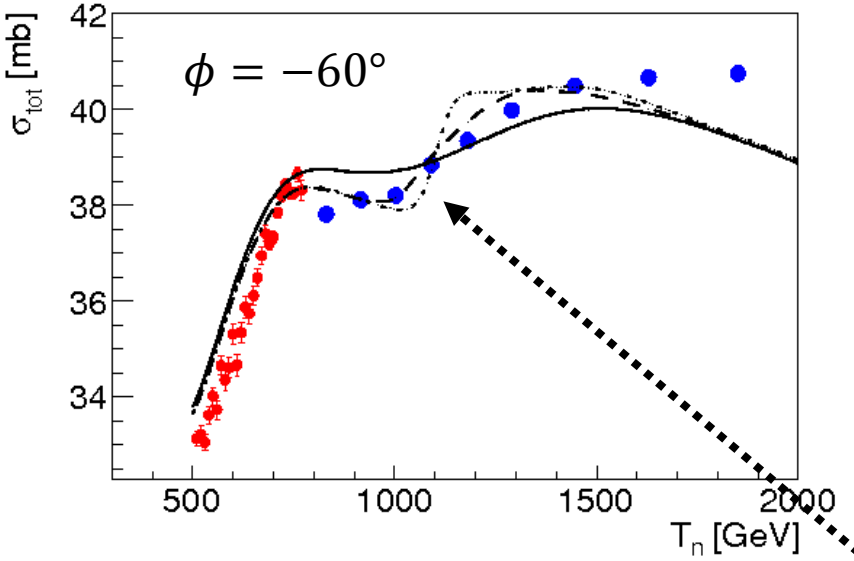


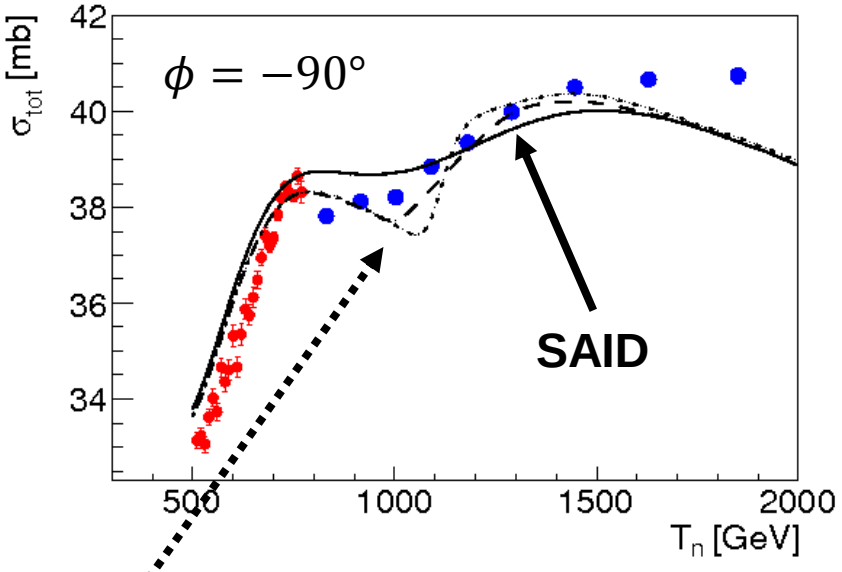
# Total pn cross-section



# Total pn cross-section

- Devlin et al, PRD8, 136 (73)
- Lisowskl et al, PRL49, 255(82)

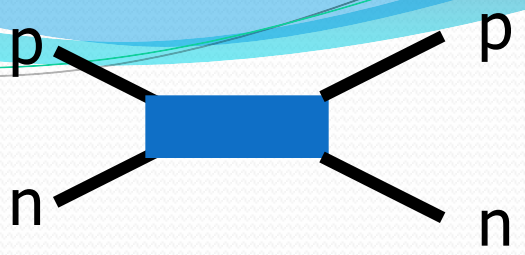


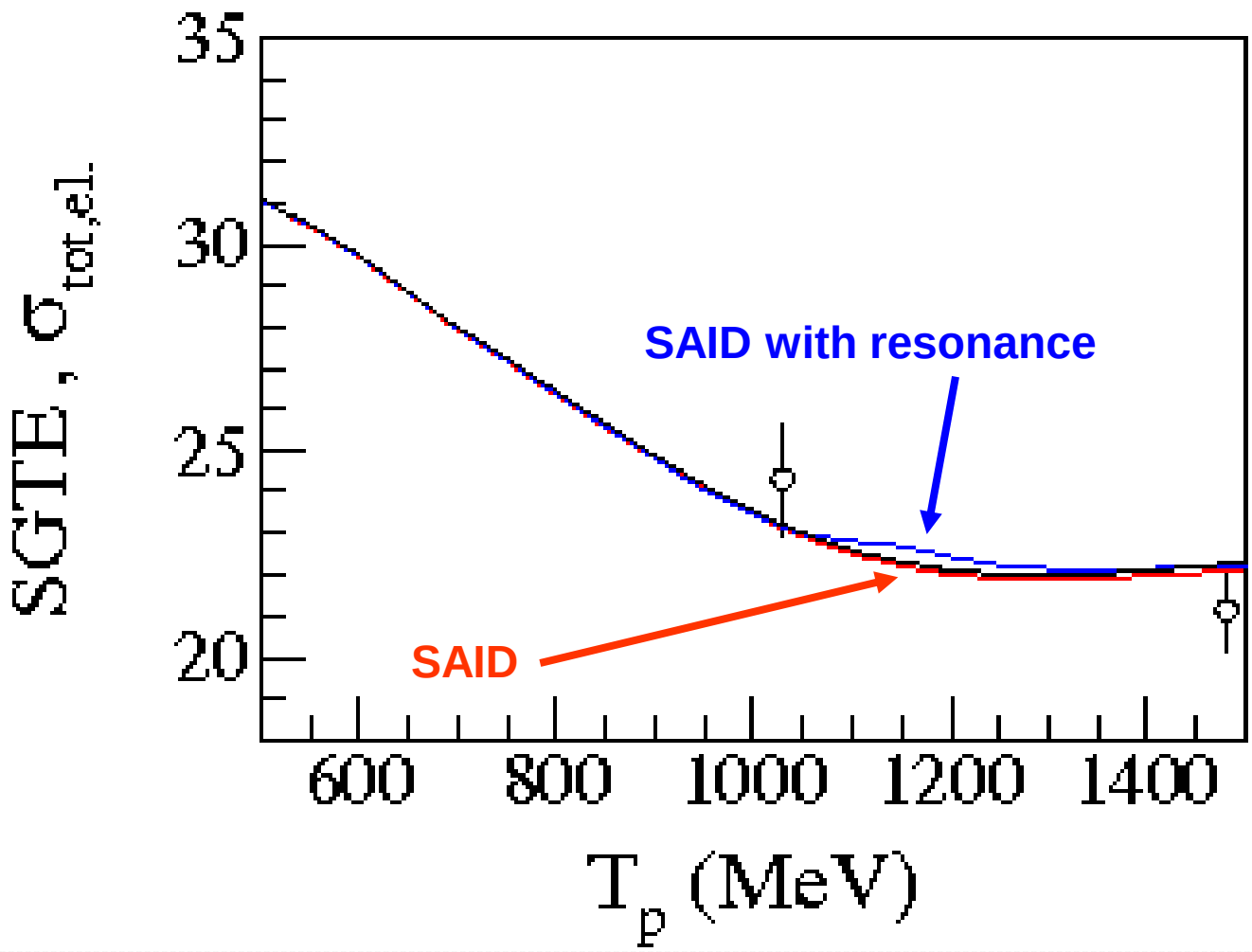




**SAID + $^3G_3$ resonance**

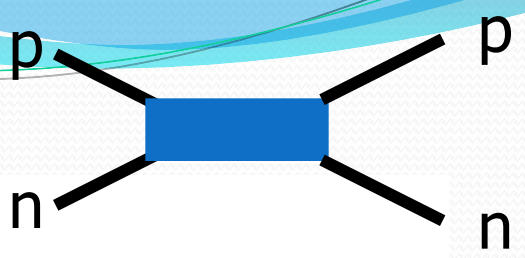
# Expectations

$$pn \rightarrow R \rightarrow pn$$

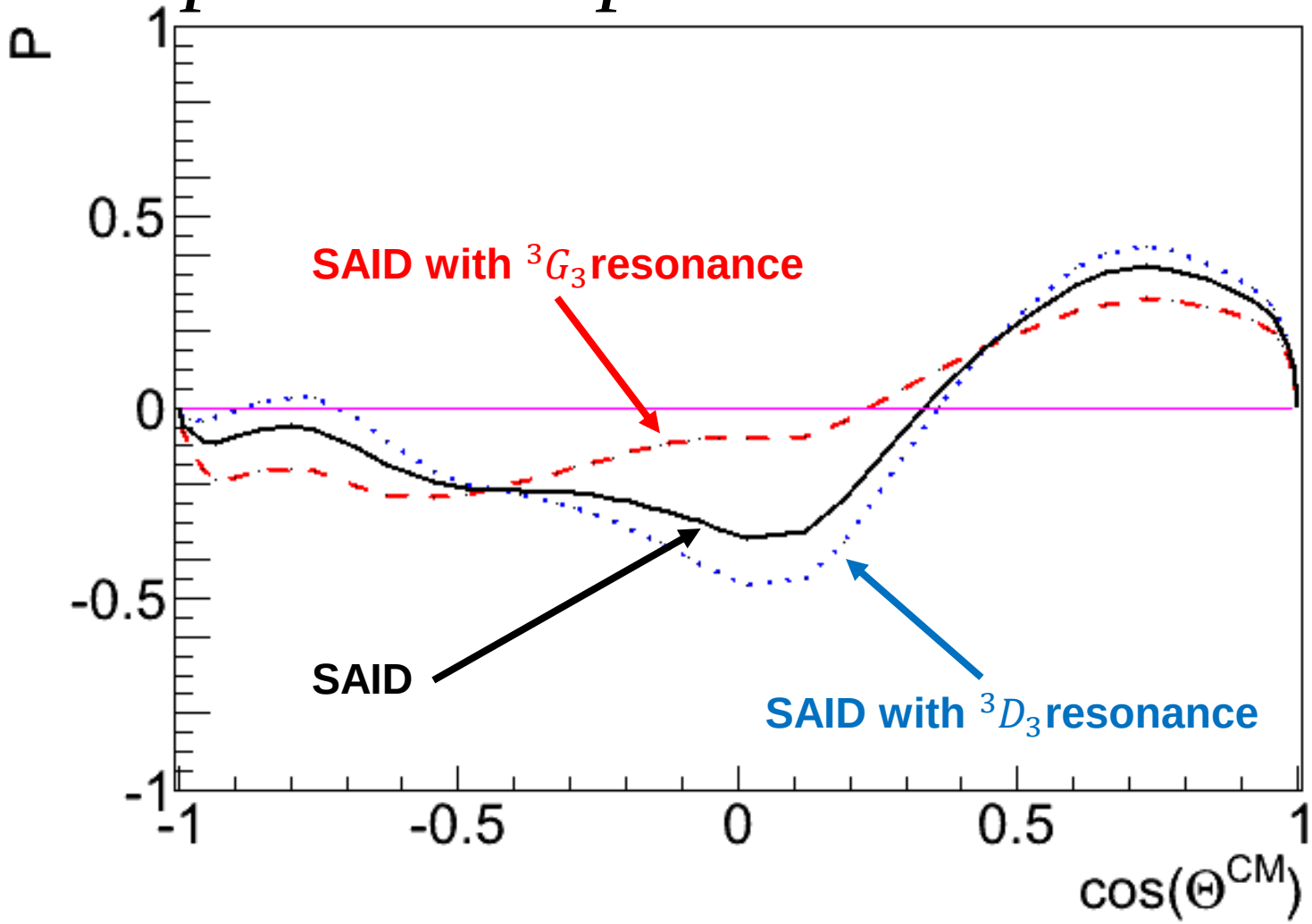


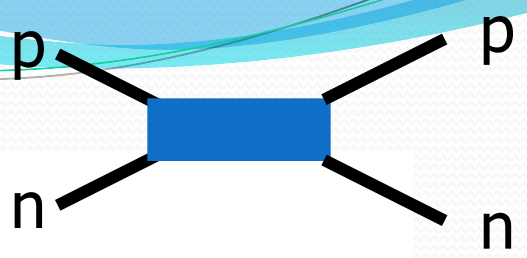
# Expectation



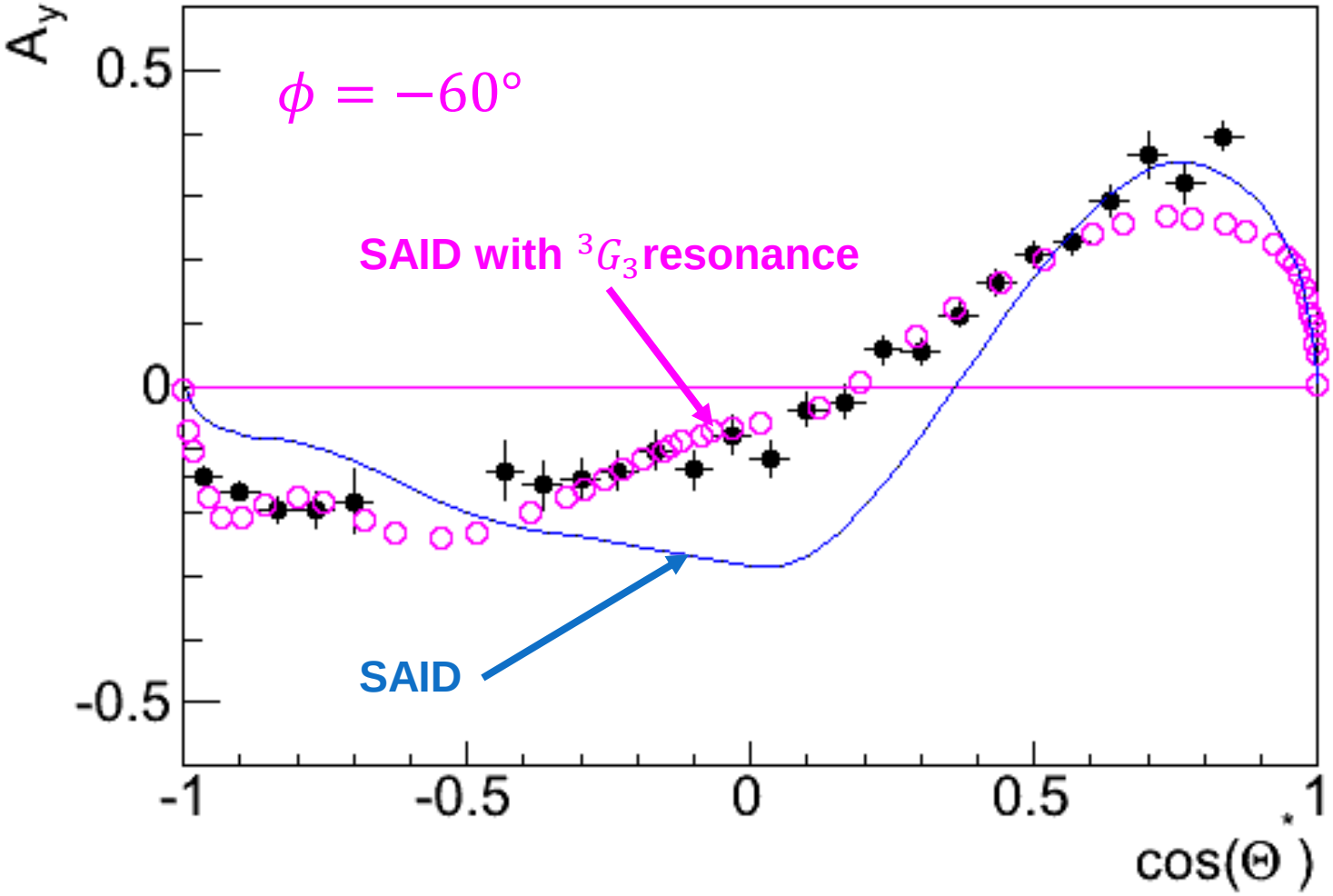

$$pn \rightarrow R \rightarrow pn$$



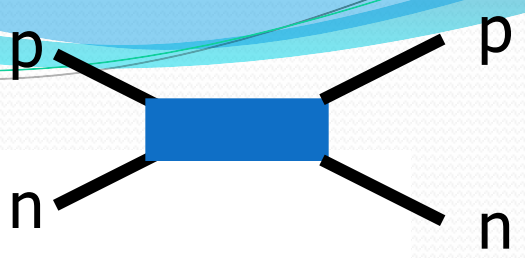
# Reality



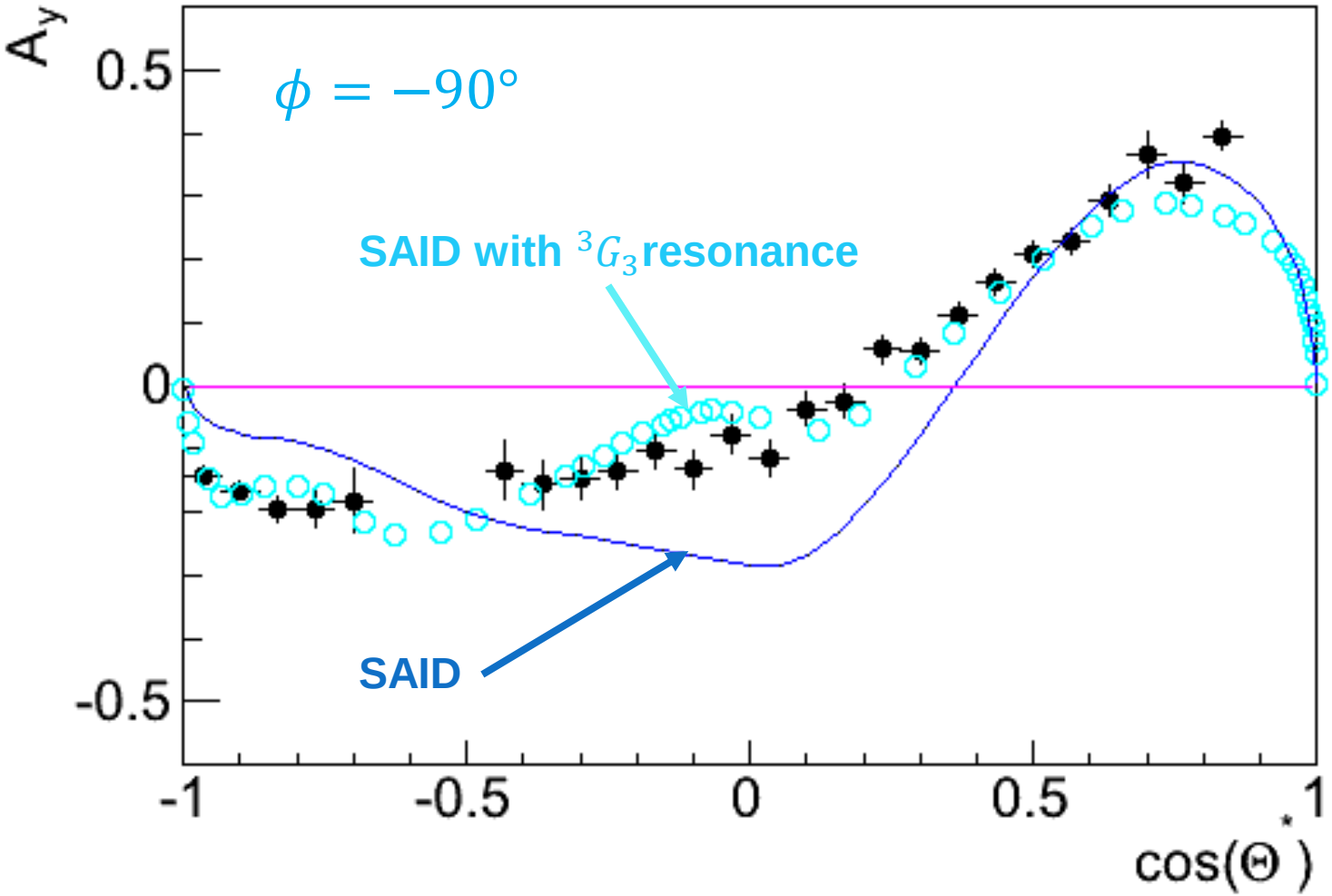

$$pn \rightarrow R \rightarrow pn$$



# Reality

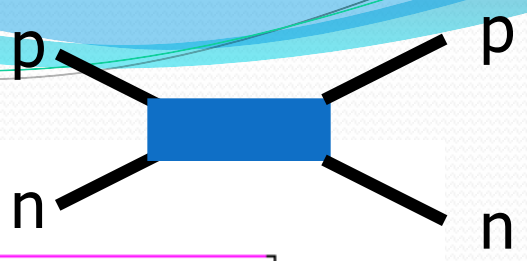


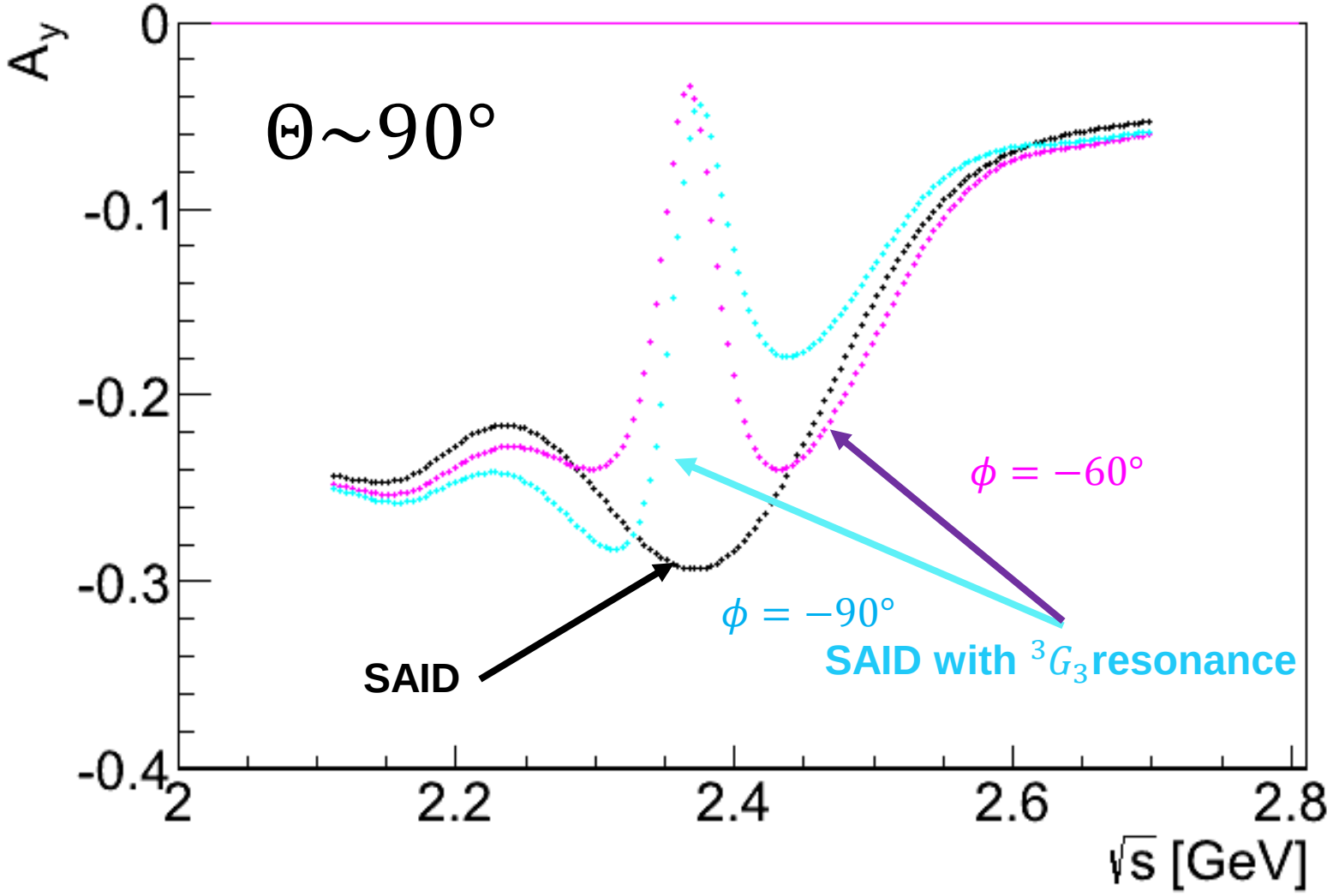

$$pn \rightarrow R \rightarrow pn$$



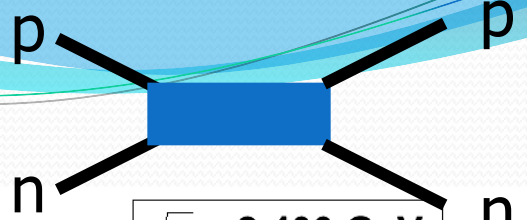
# Expectation

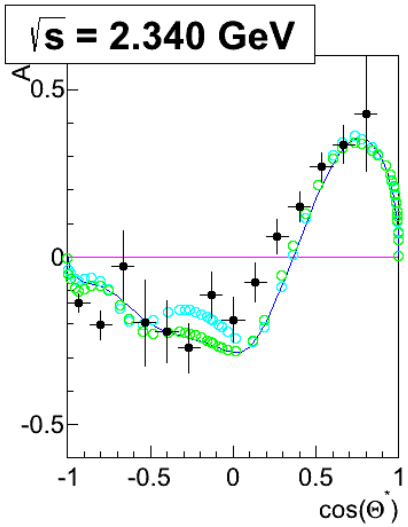
$$pn \rightarrow R_0 \rightarrow pn$$

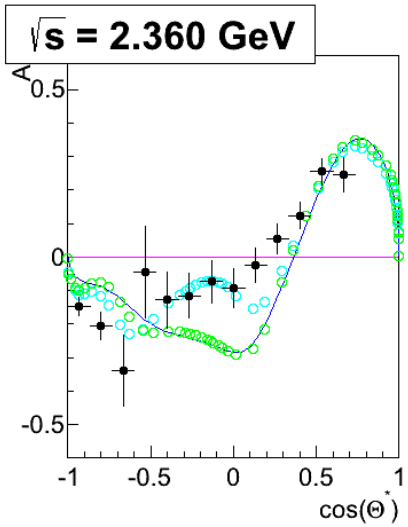


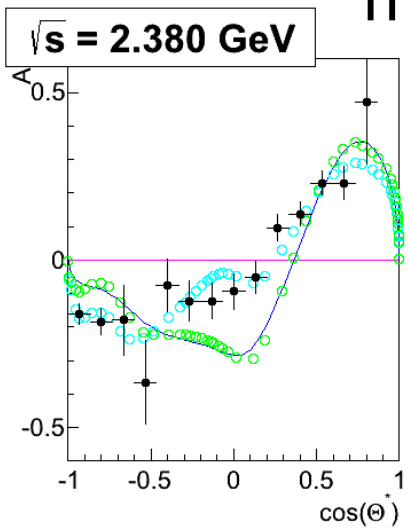



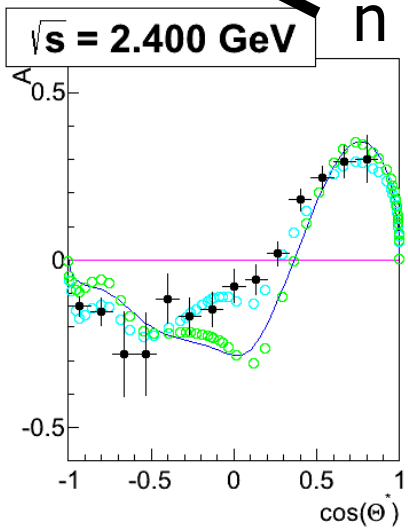
$$pn \to R \to pn$$

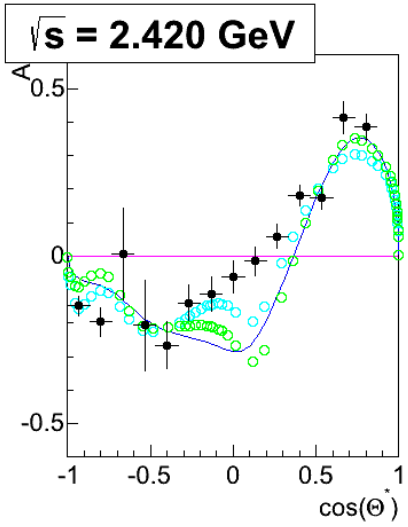

p
p
n
n

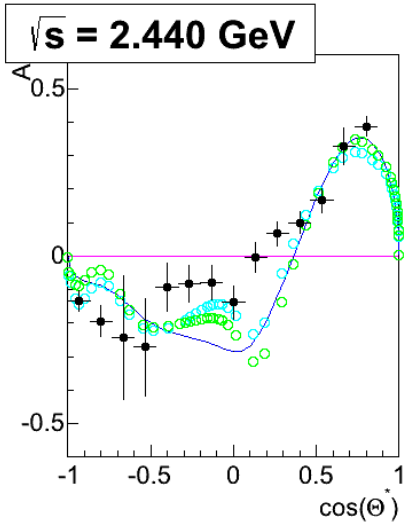

√s = 2.340 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)

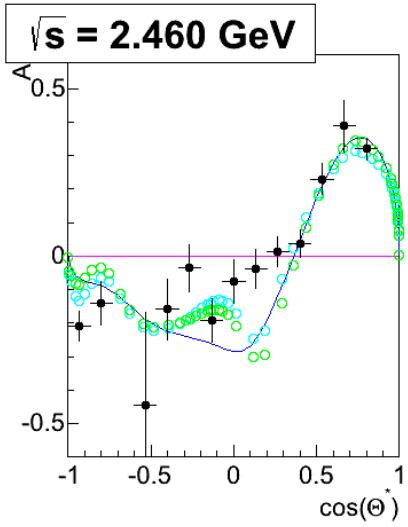

√s = 2.360 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)

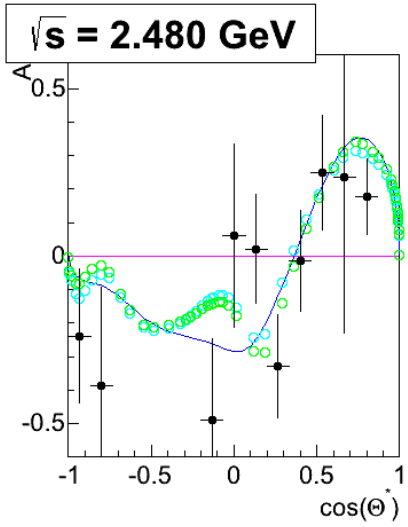

√s = 2.380 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)


√s = 2.400 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)


√s = 2.420 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)


√s = 2.440 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)


√s = 2.460 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)

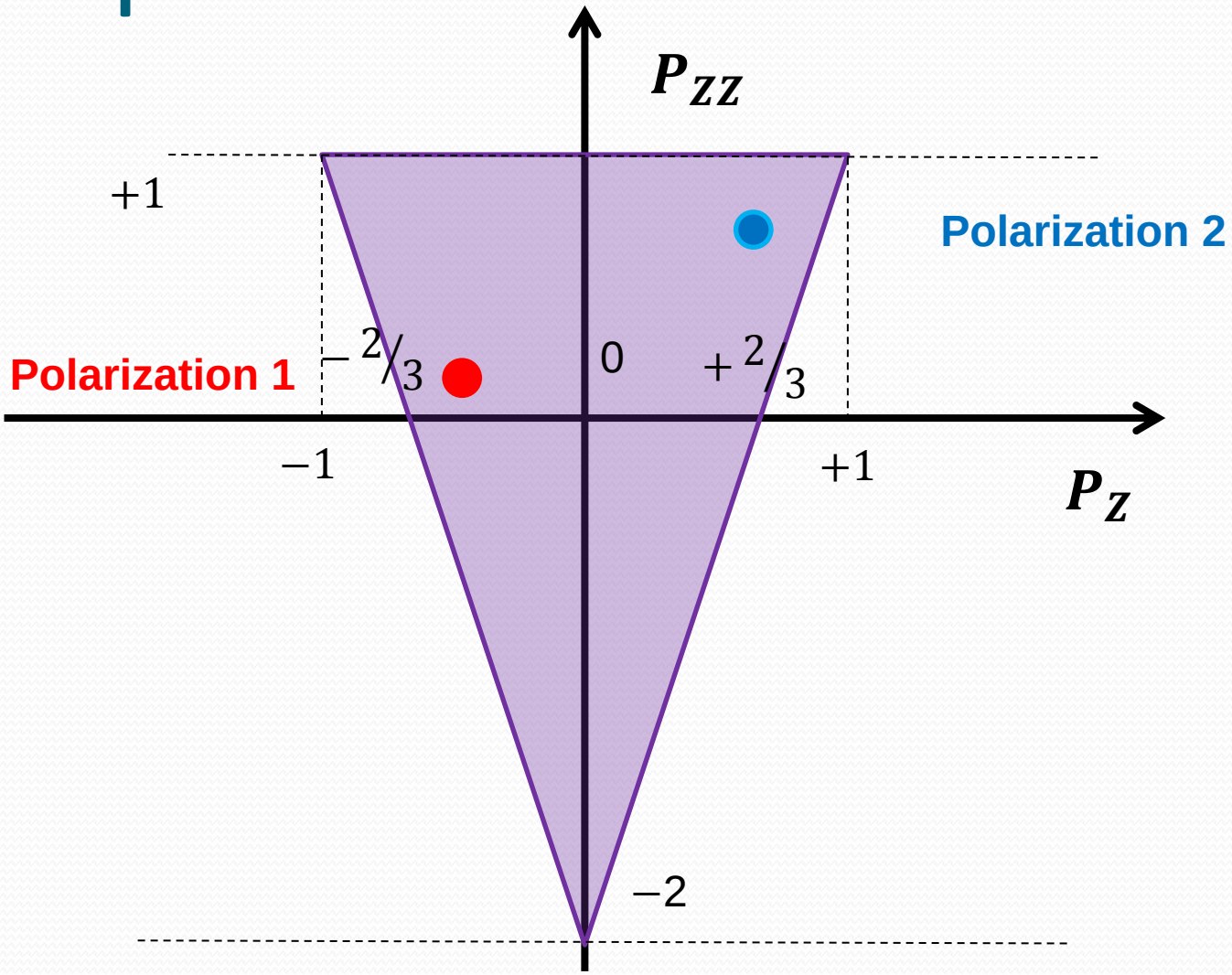

√s = 2.480 GeV
A
0.5
0
-0.5
-1
-0.5
0
0.5
1
cos(Θ*)

# Conclusion

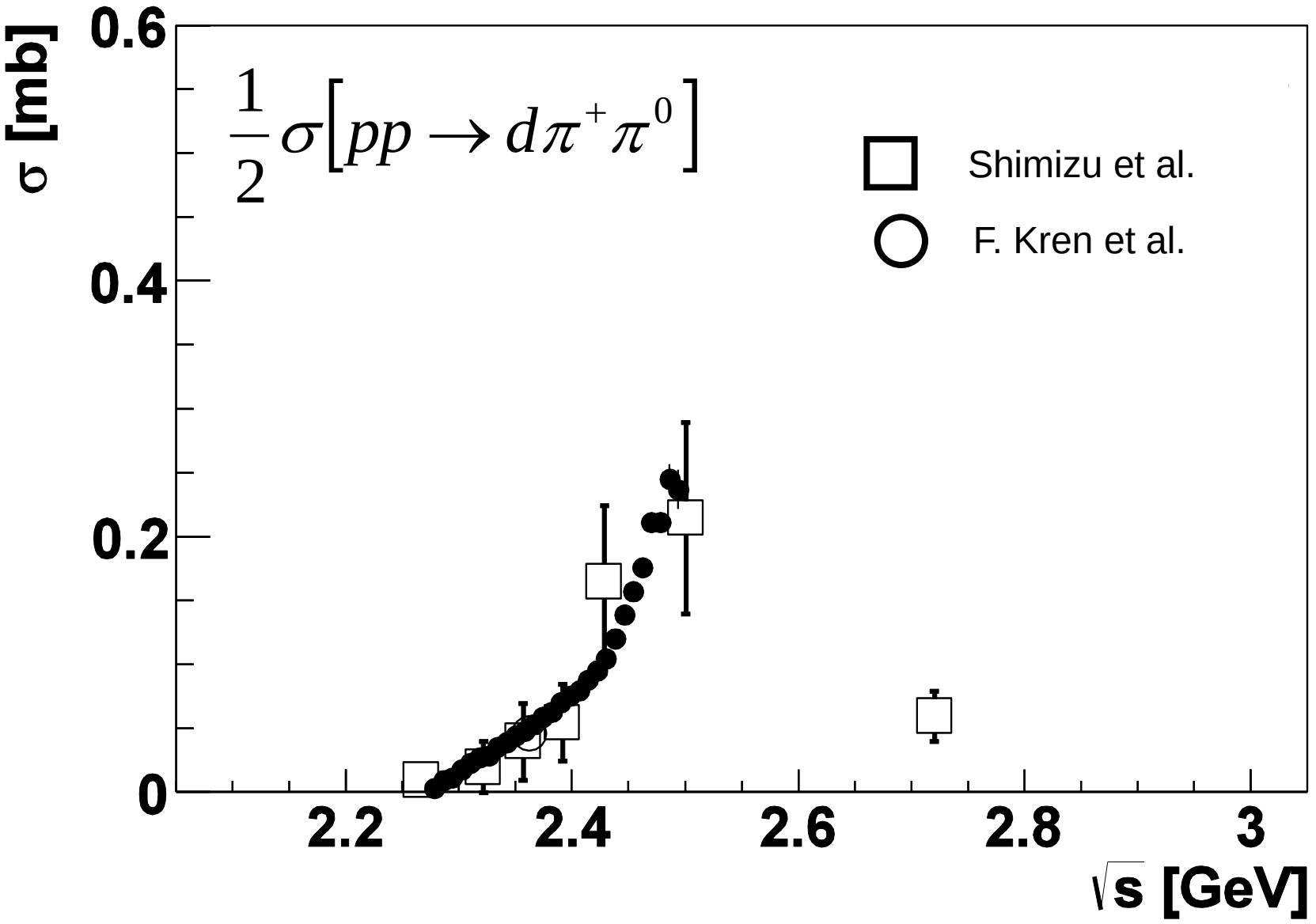
- ABC-resonance is seen in
  - $pn \to d\pi^0\pi^0$
  - $pn \to d\pi^+\pi^-$
  - $pn \to pp\pi^-\pi^0$
- pn-elastic scattering exhibits fast phase motion
  - Good hints for a resonance in elastic channel
- A discovery of a new resonance?
  - Dibaryon $d^*$: $M = 2.38\ GeV$, $\Gamma = 0.07\ GeV$, $\mathrm{I}(\mathrm{J}^{\mathrm{P}}) = 0(3^+)$, ${}^3G_3$ - partial wave.


Thank you

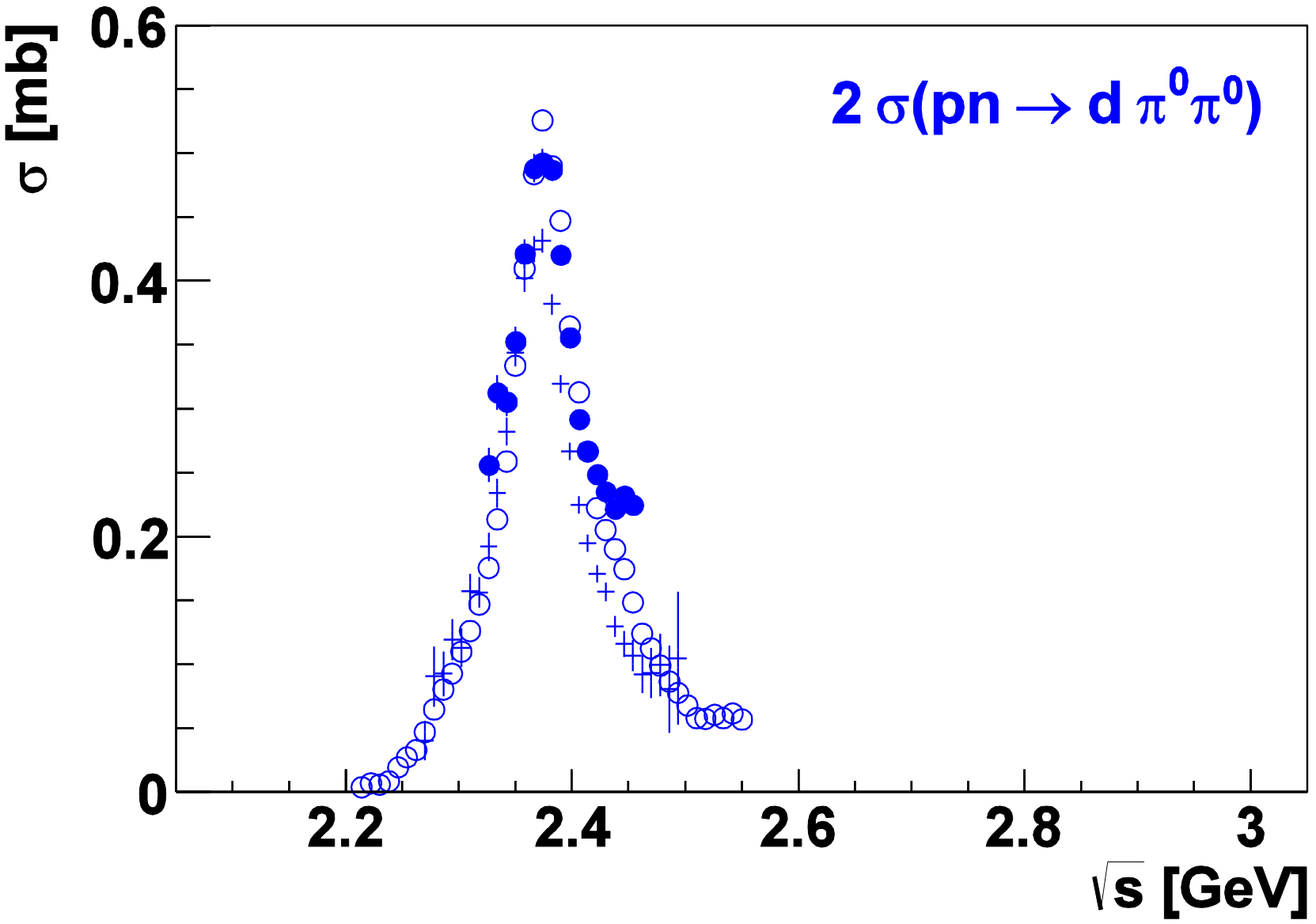
# Beam polarization



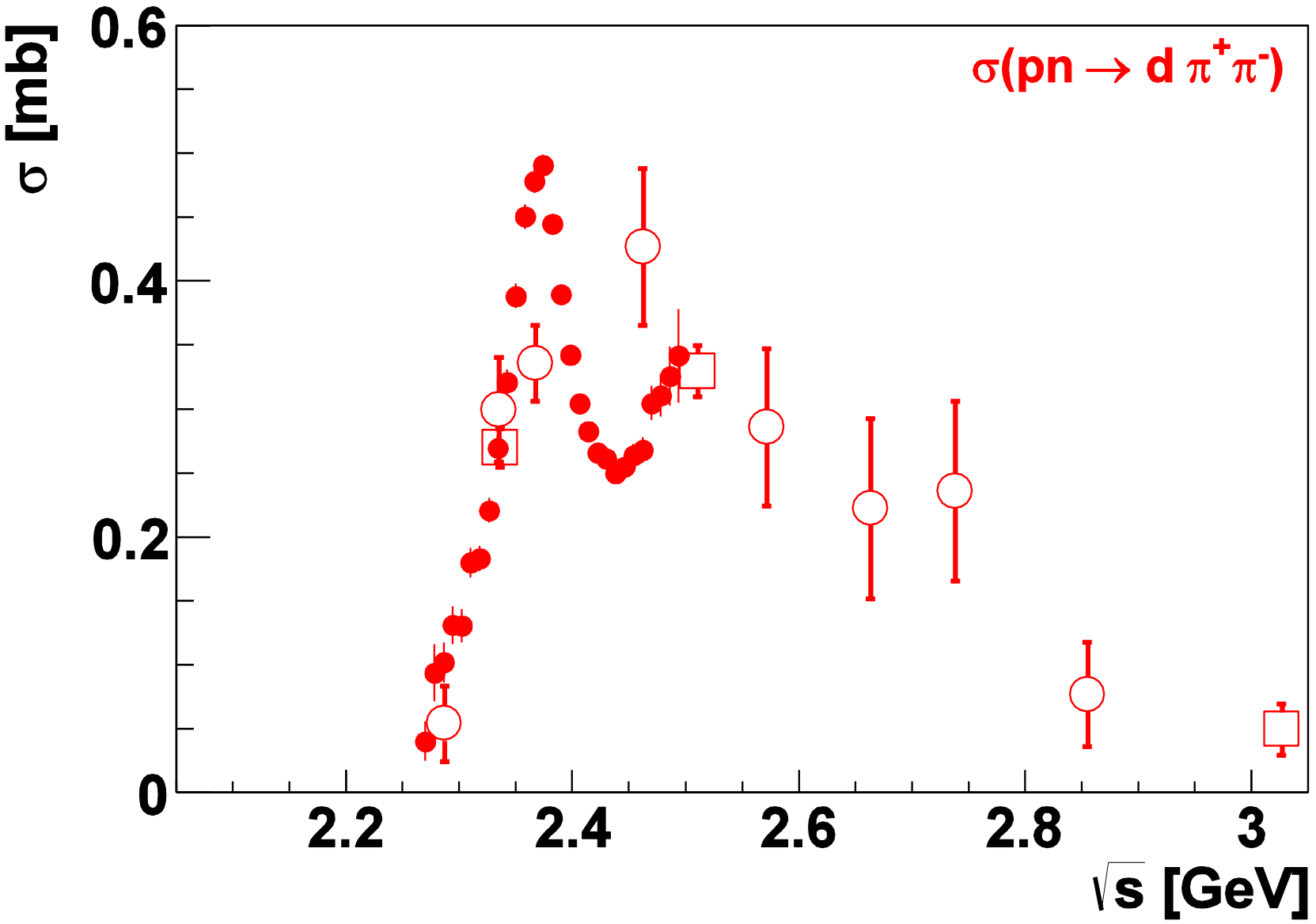
# Total cross section $pp \to d\pi^+\pi^0$



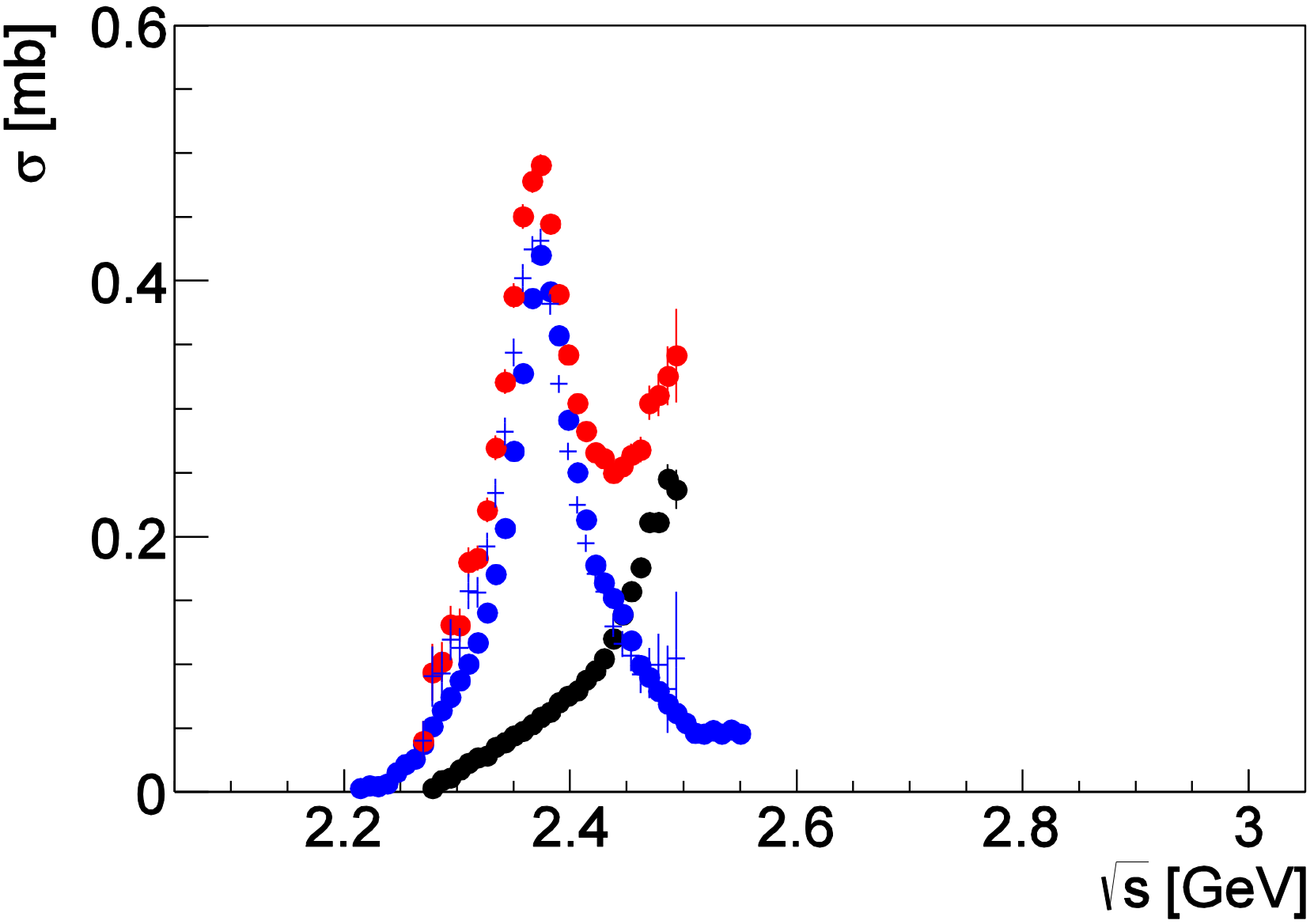
# Total cross section $pn \rightarrow d\pi^0\pi^0$



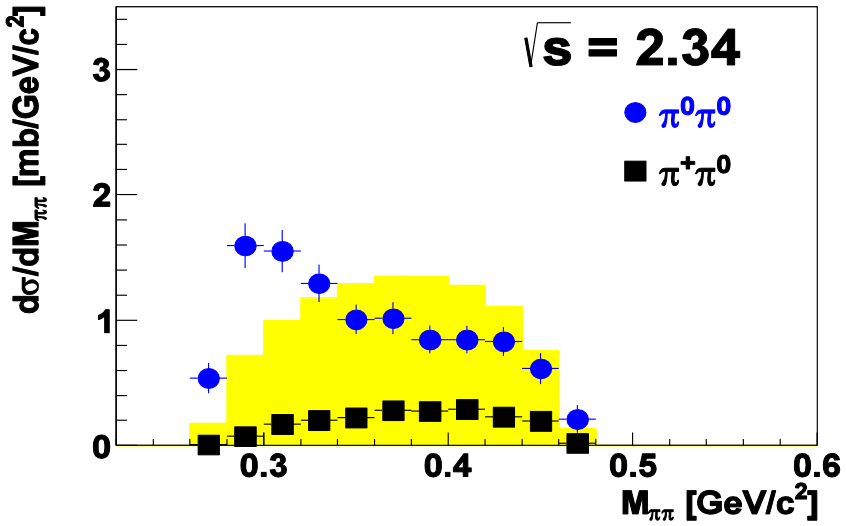
# Total cross section $pn \rightarrow d\pi^+\pi^-$

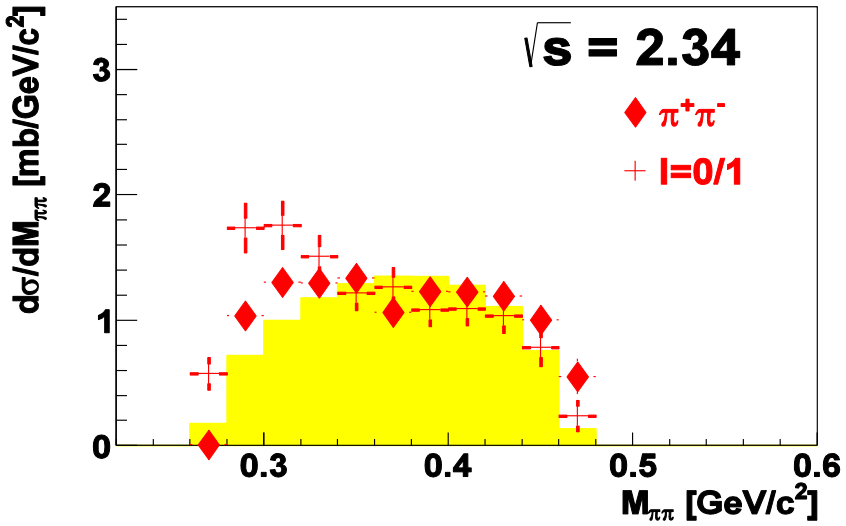


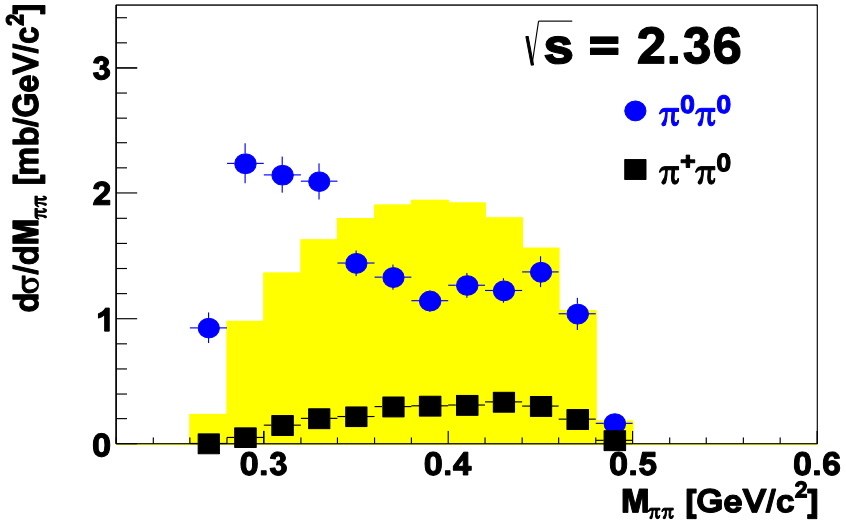
# Total cross section $pn \rightarrow d\pi^+\pi^-$

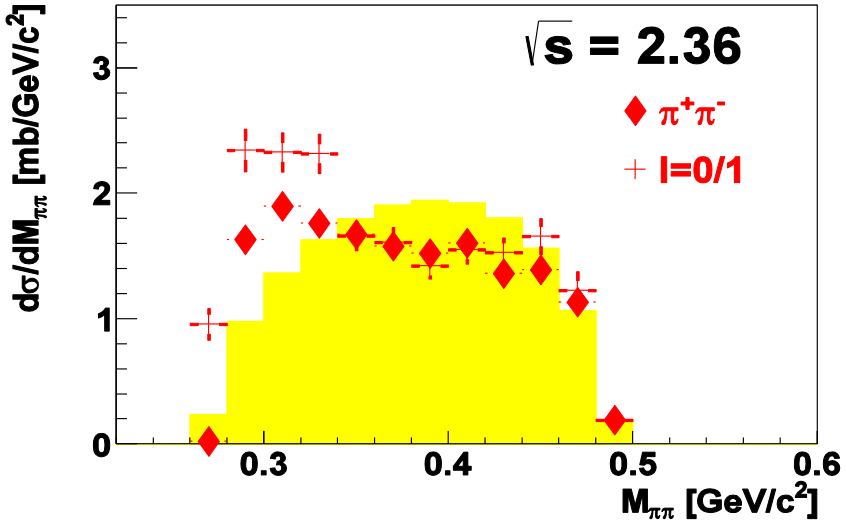


# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

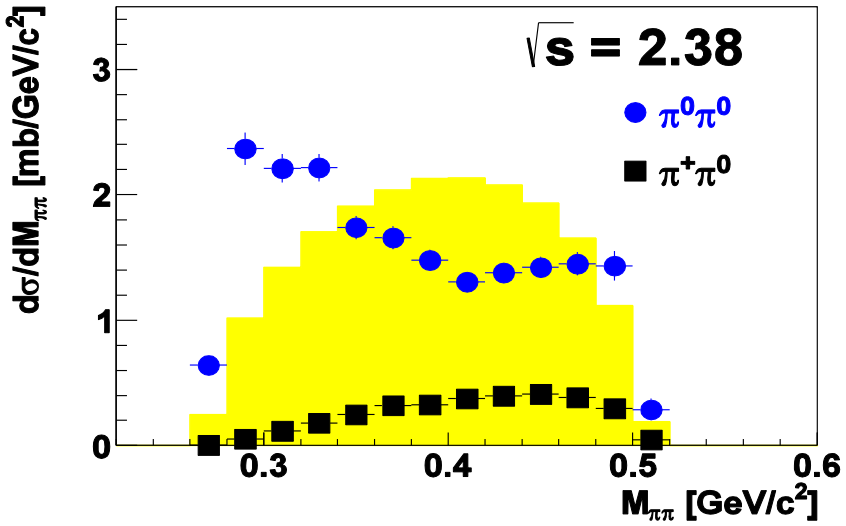


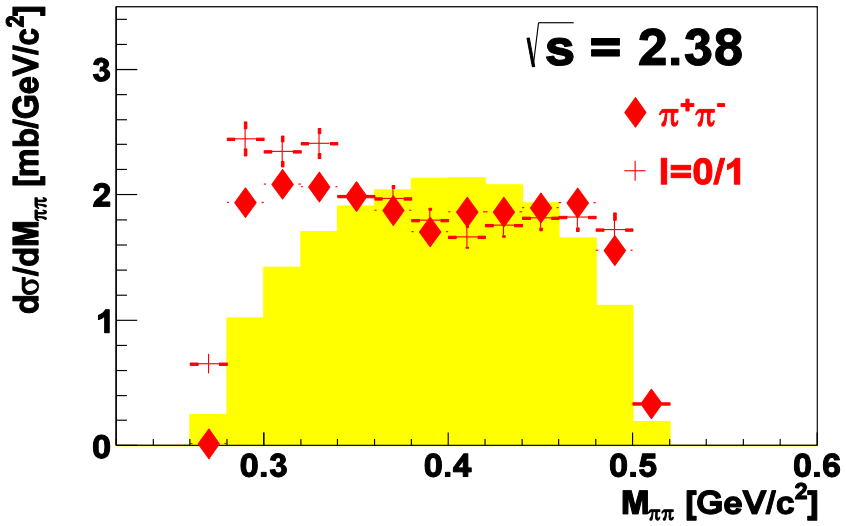



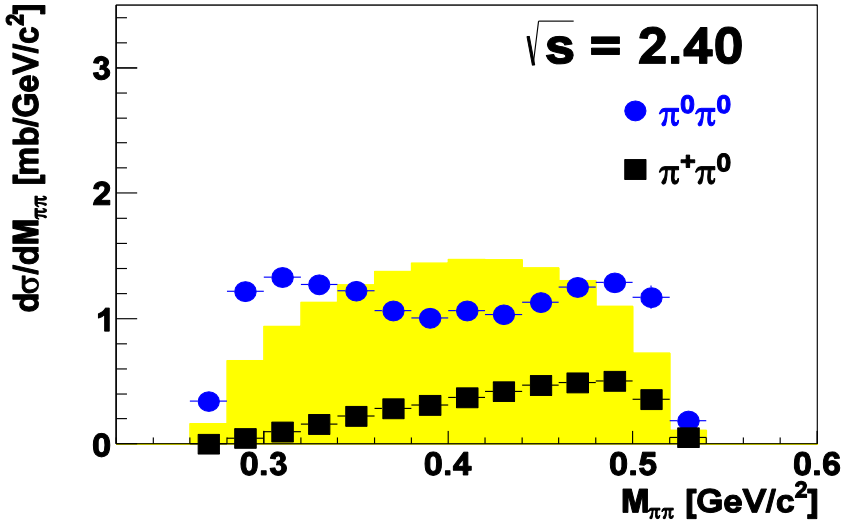



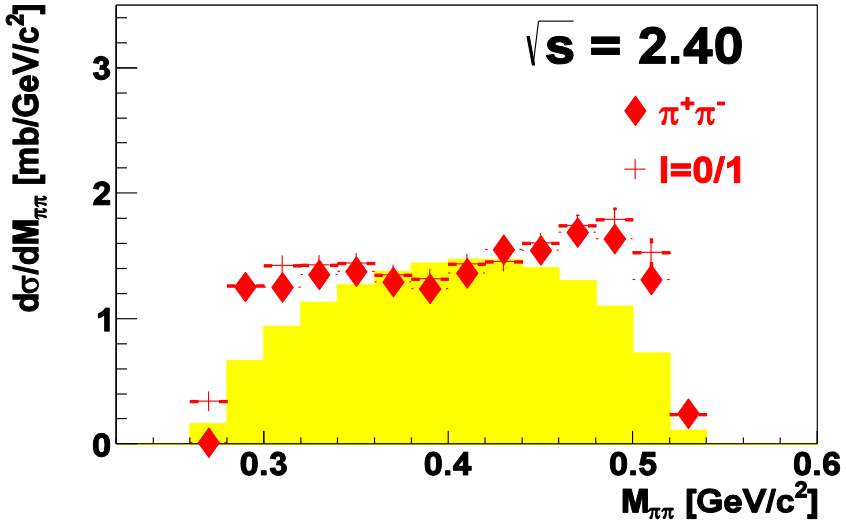



# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

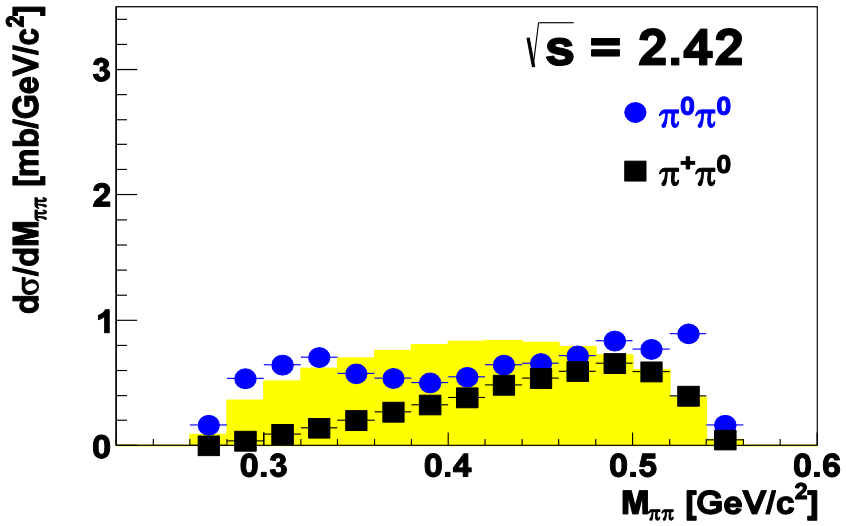


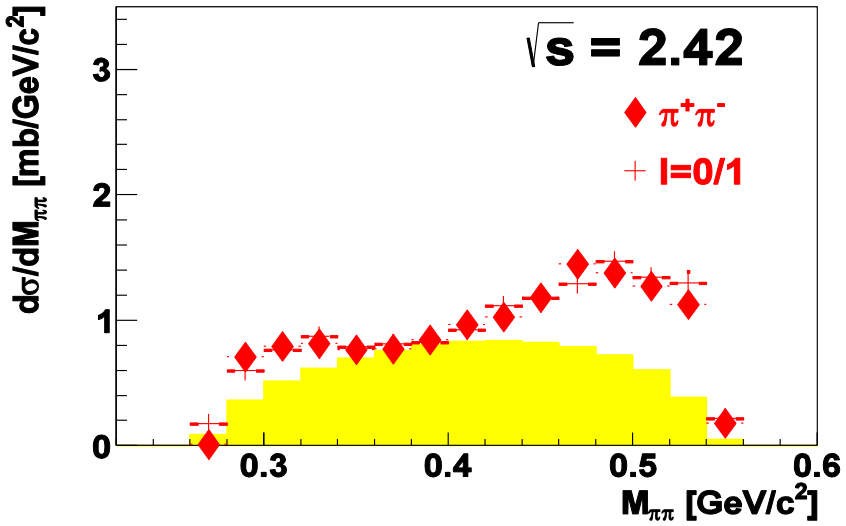



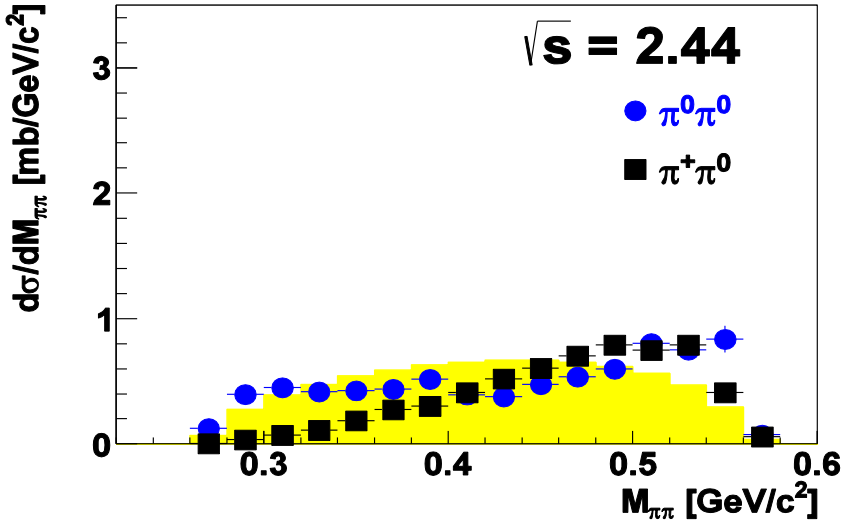



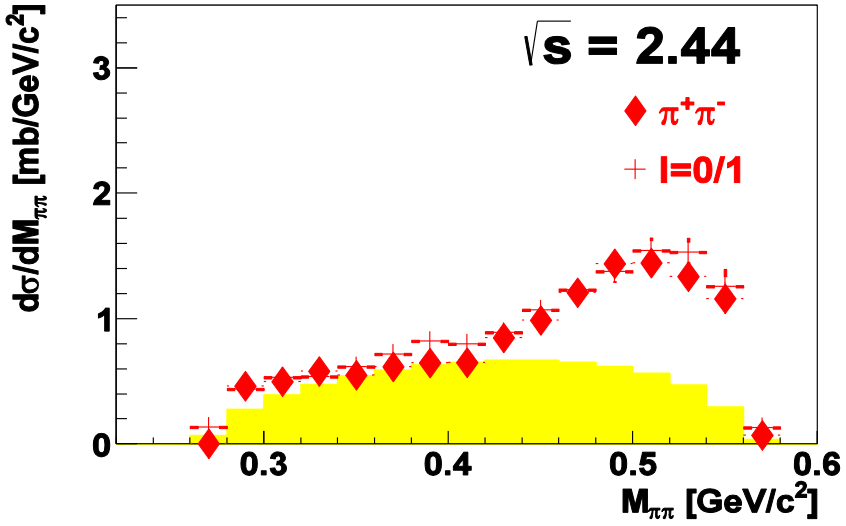



# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

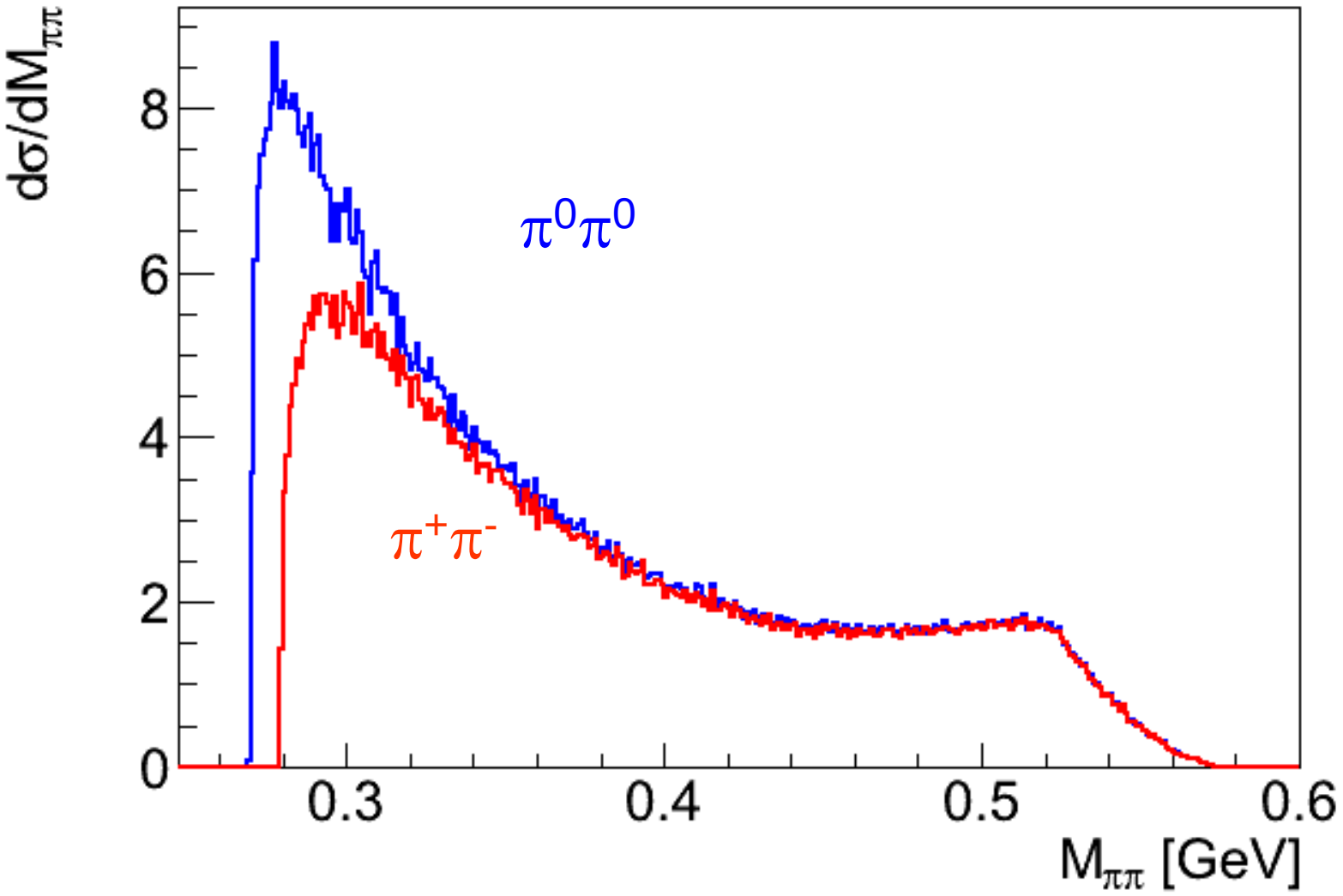


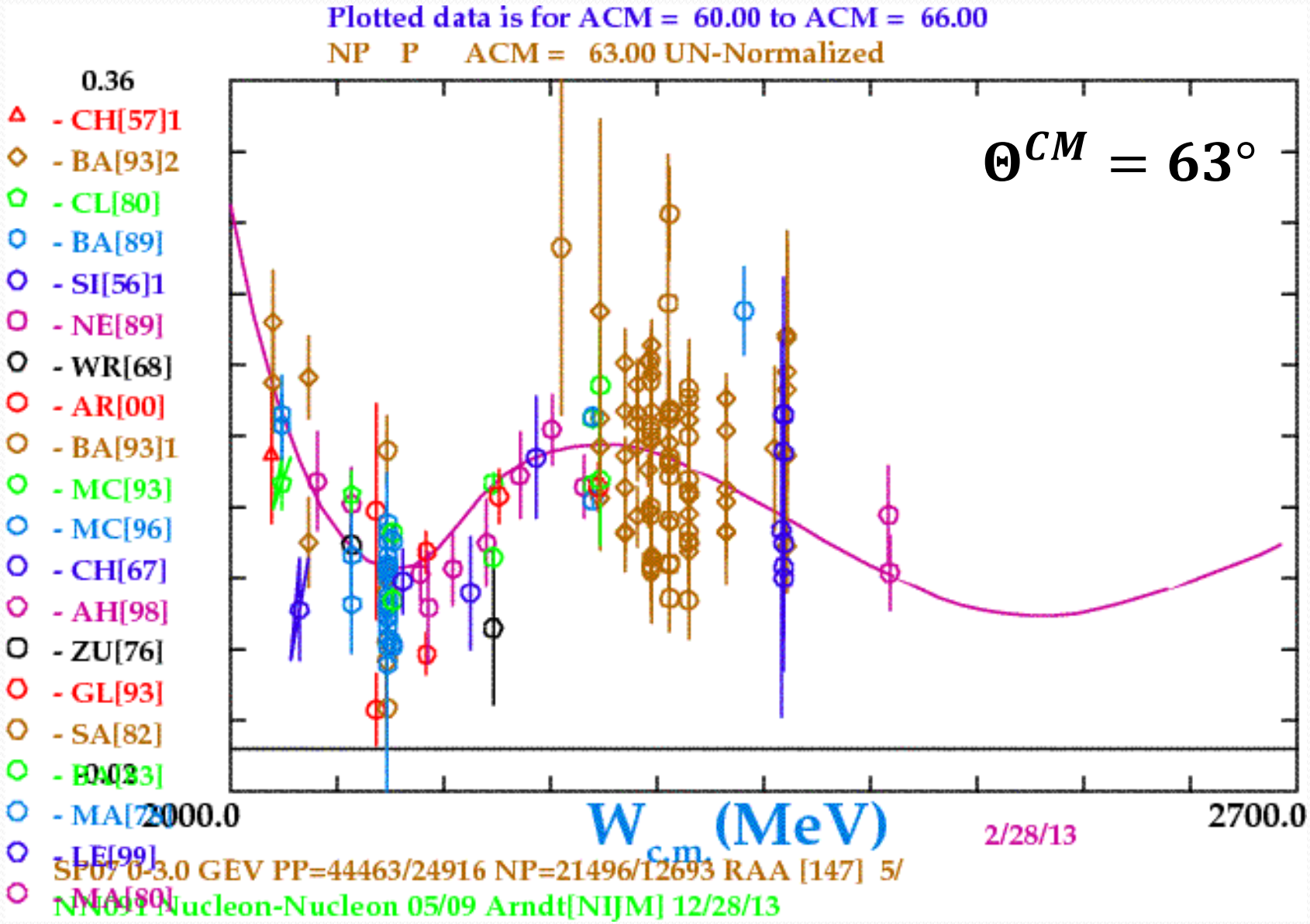



# Isospin violation



# pn Vector Analysing power



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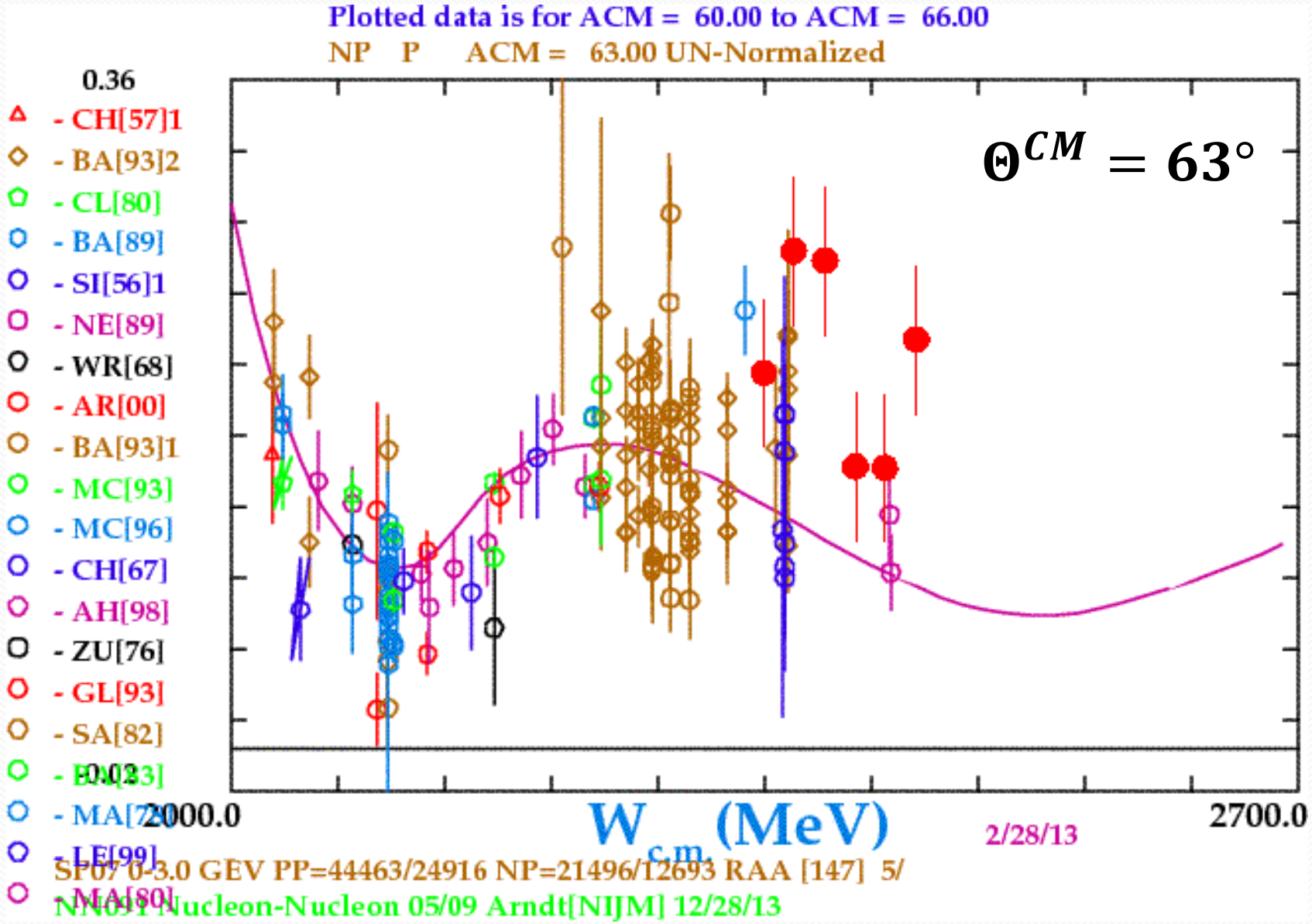

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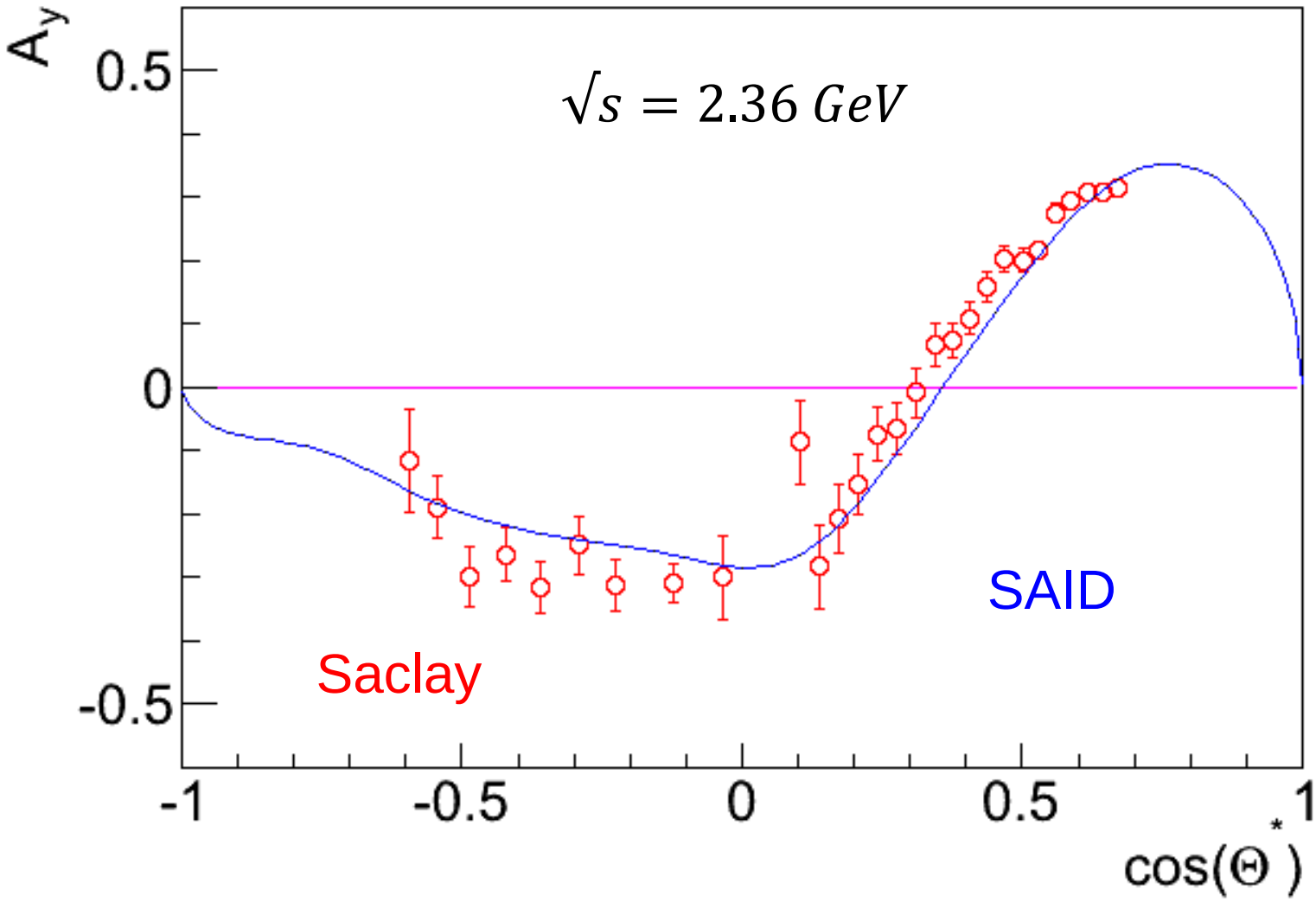

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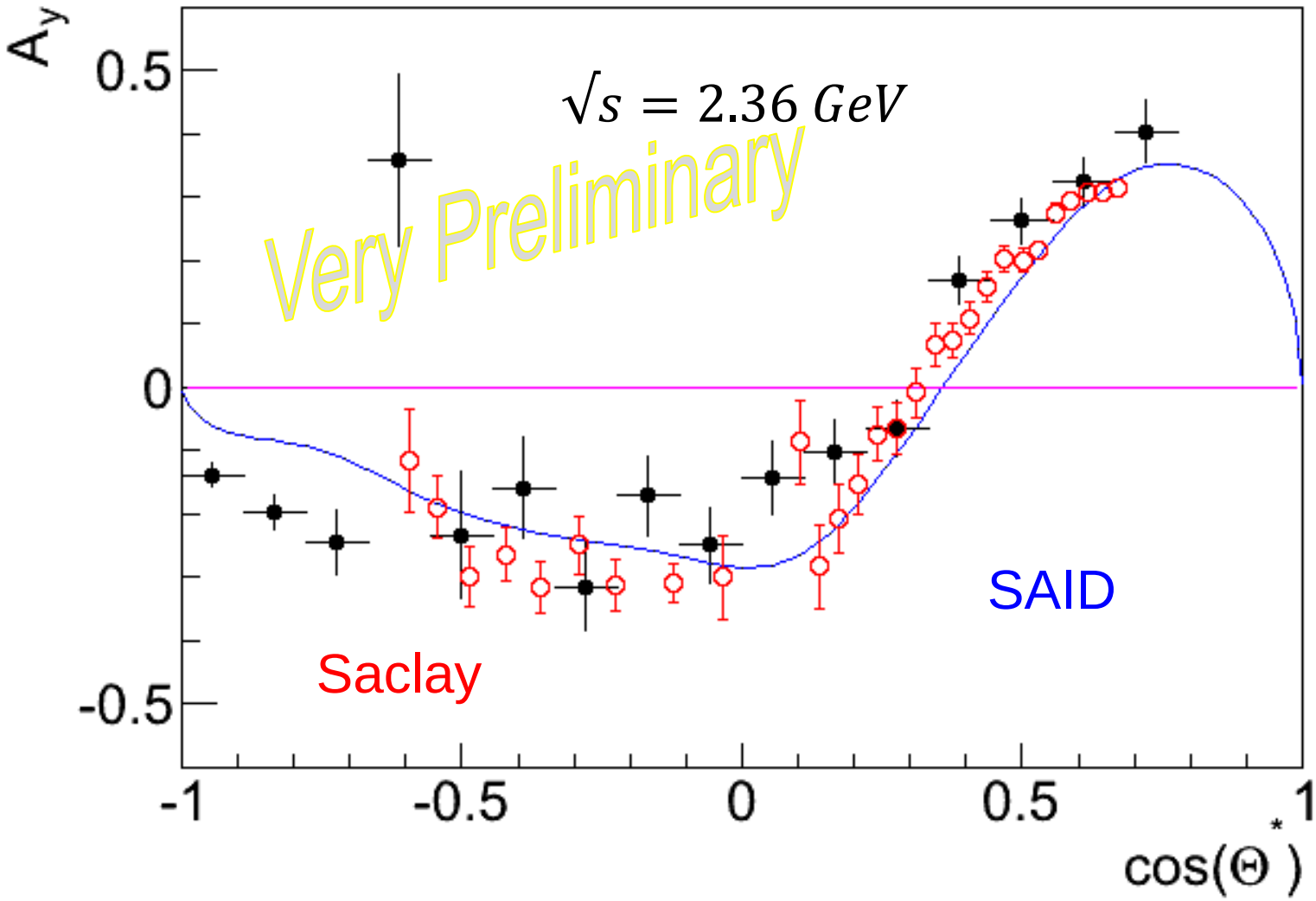

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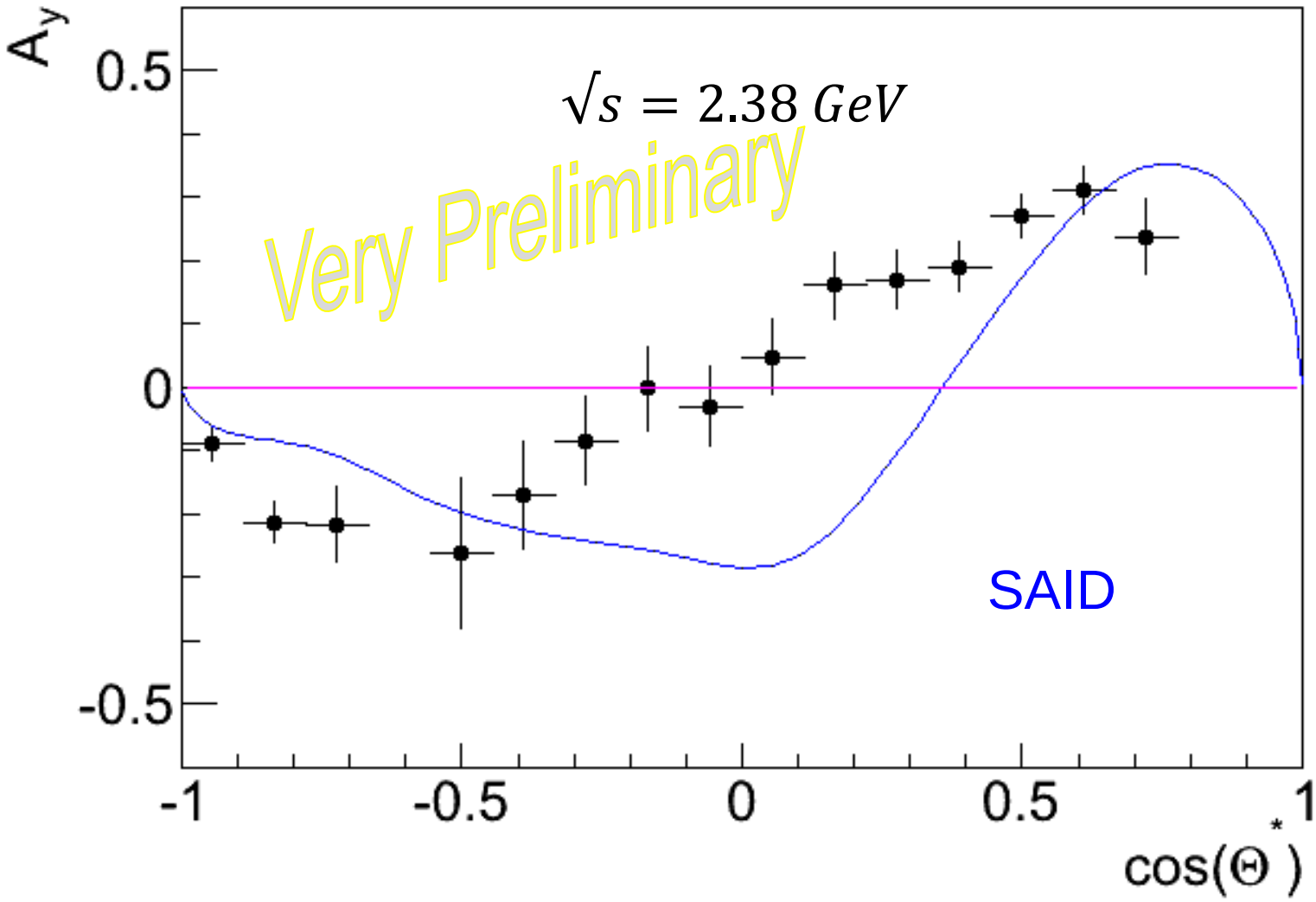

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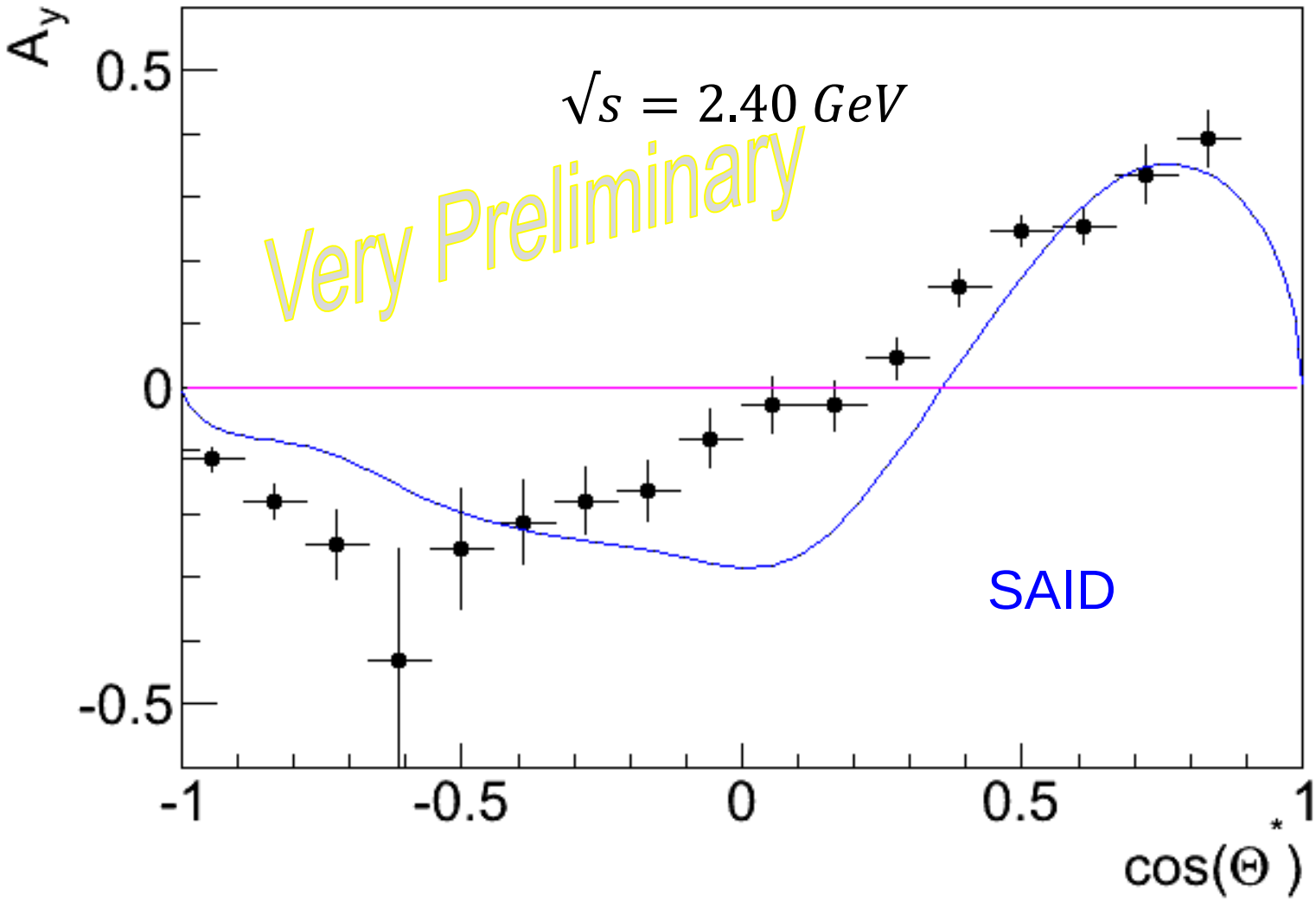

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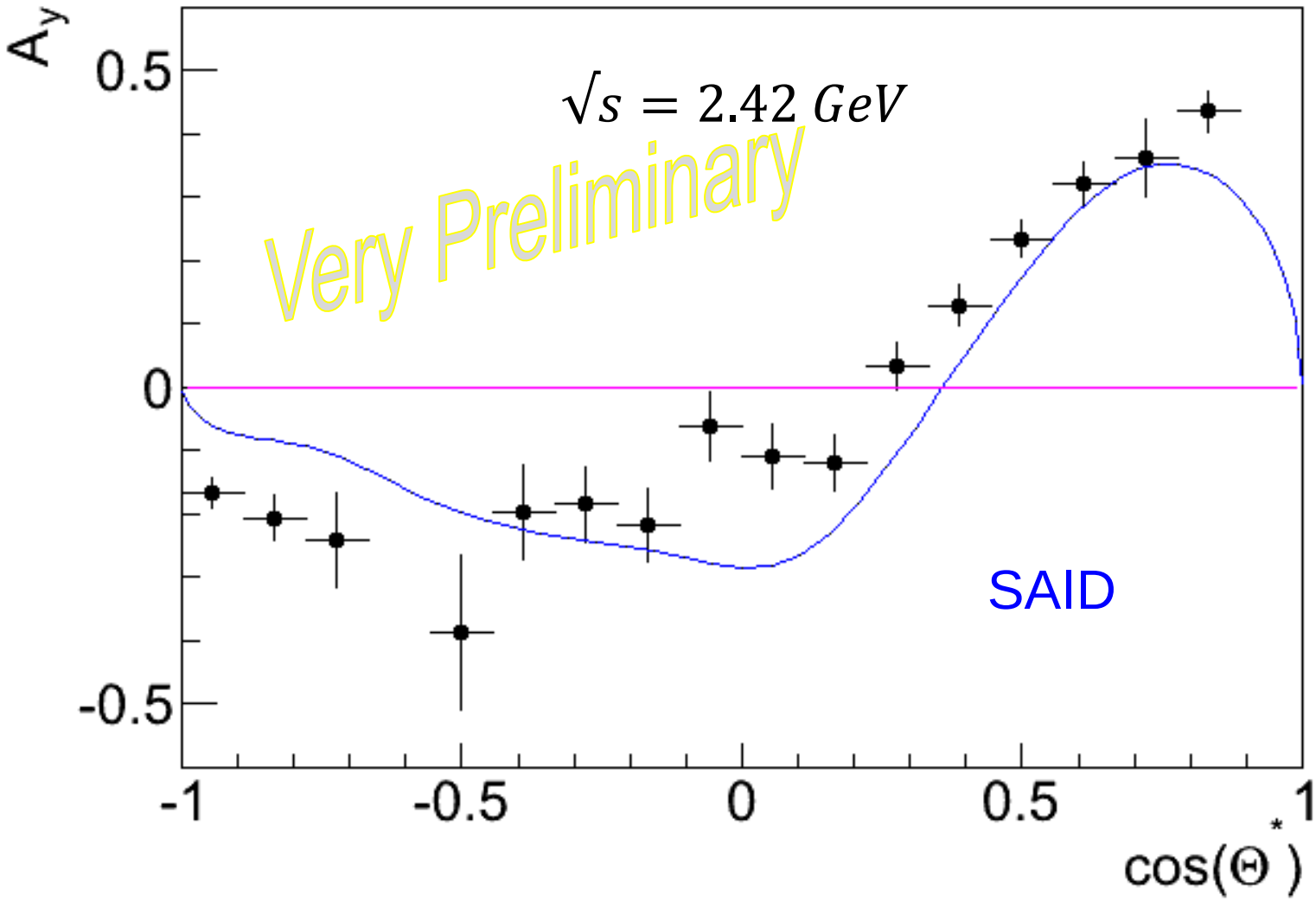

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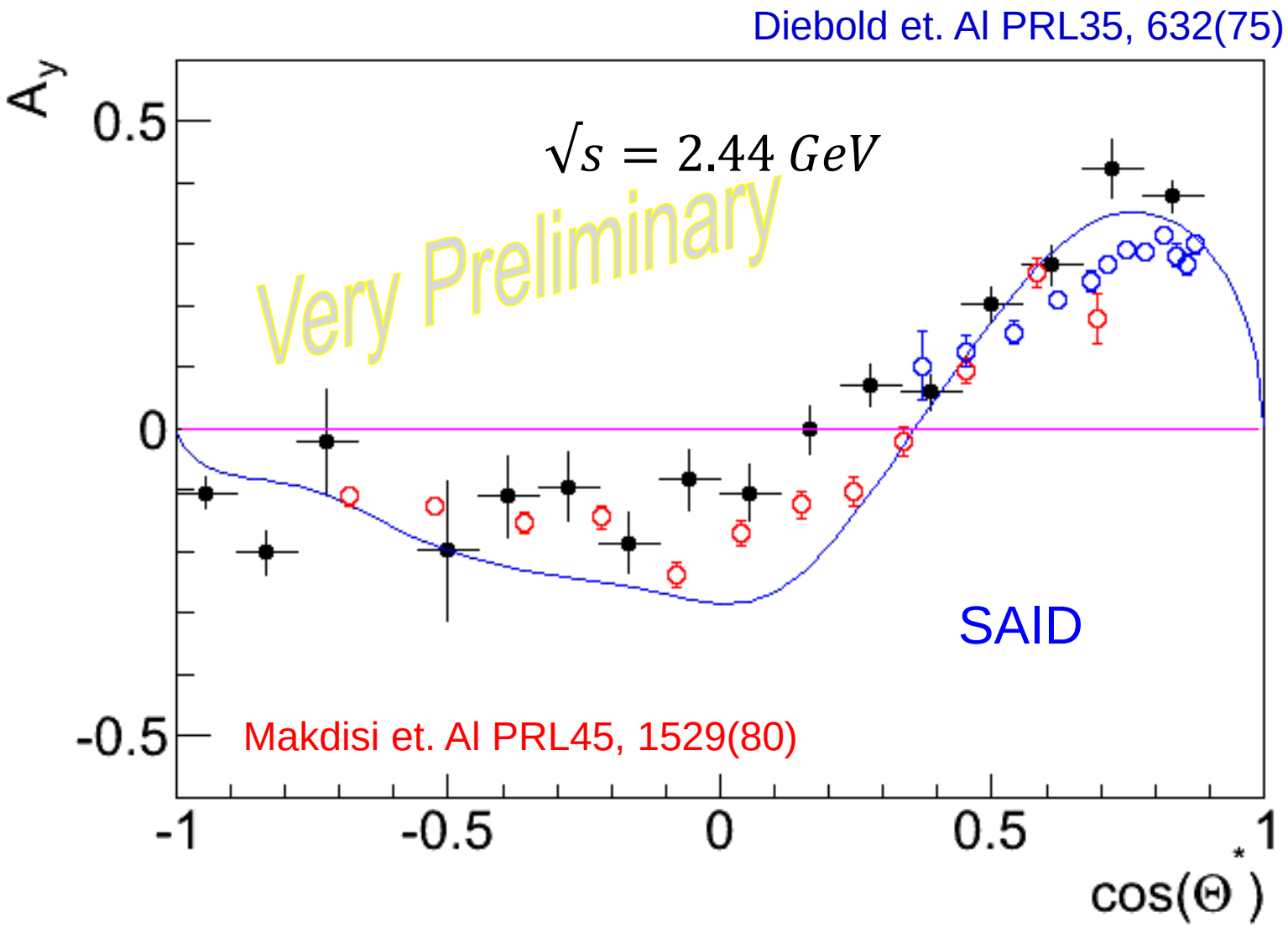
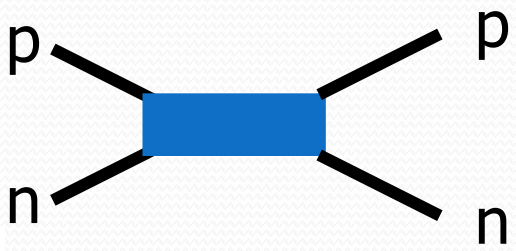
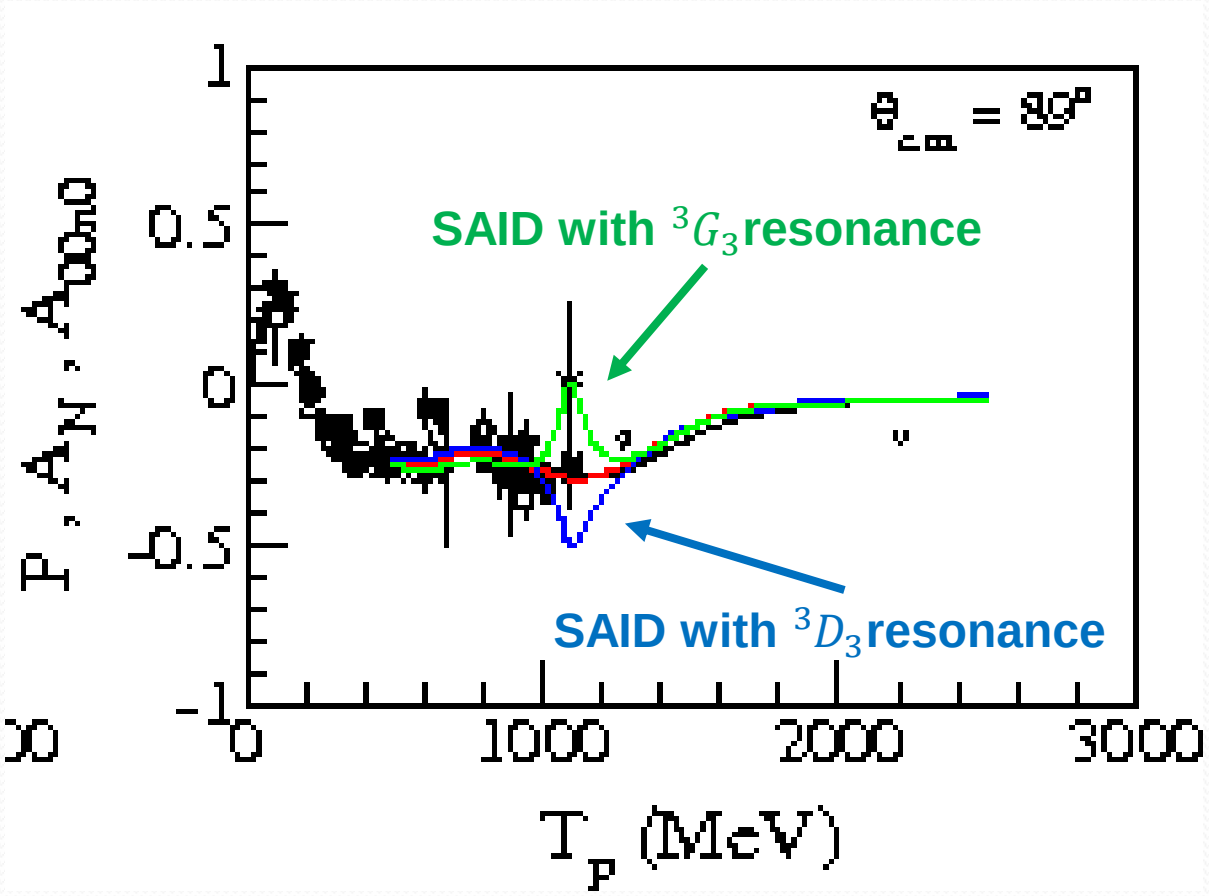


# Expectations

$$pn \rightarrow R \rightarrow pn$$



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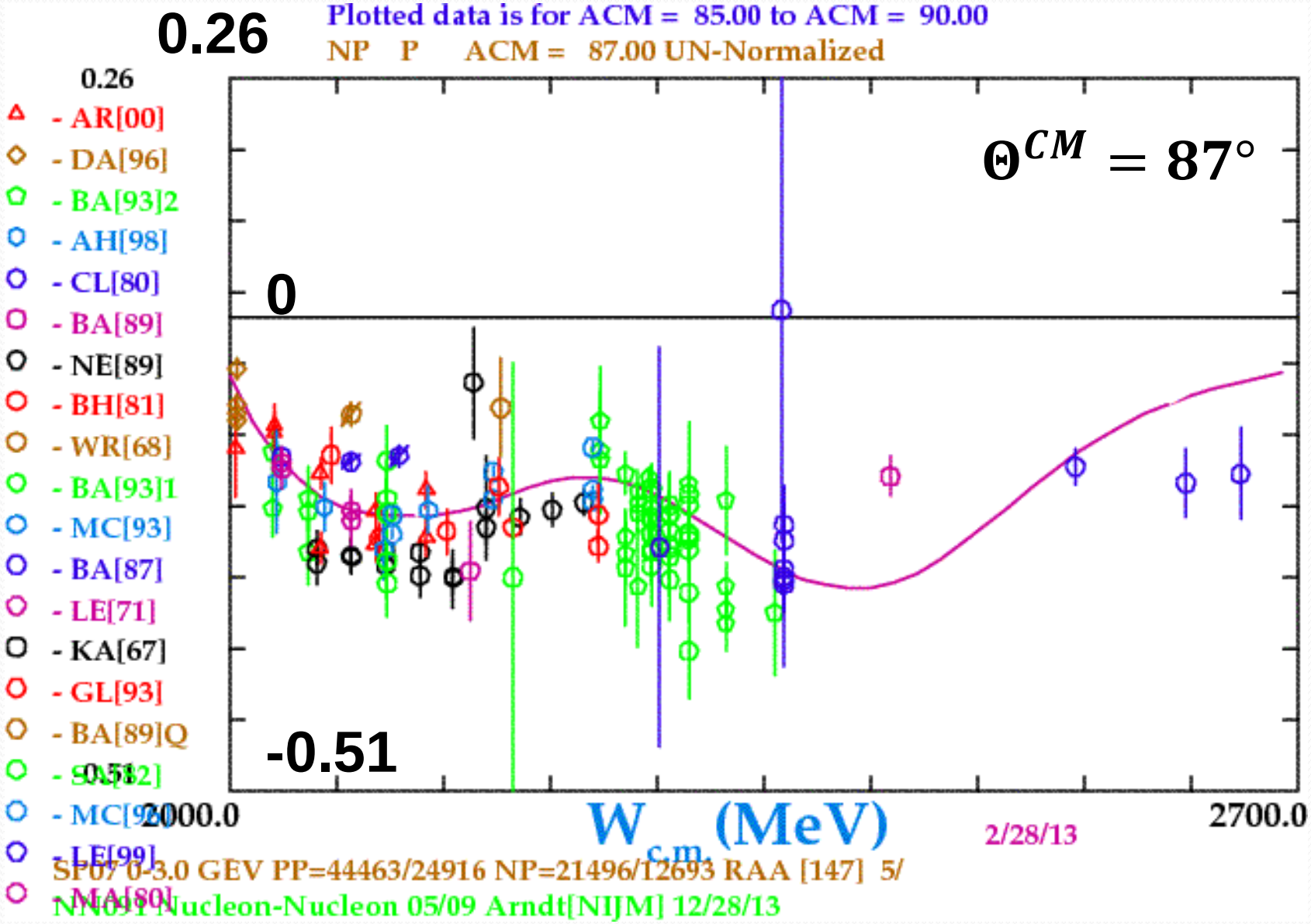

# pn Vector Analysing power