



Wasa-at-COSY

ERBERHARD KARLS  
UNIVERSITÄT  
TÜBINGEN



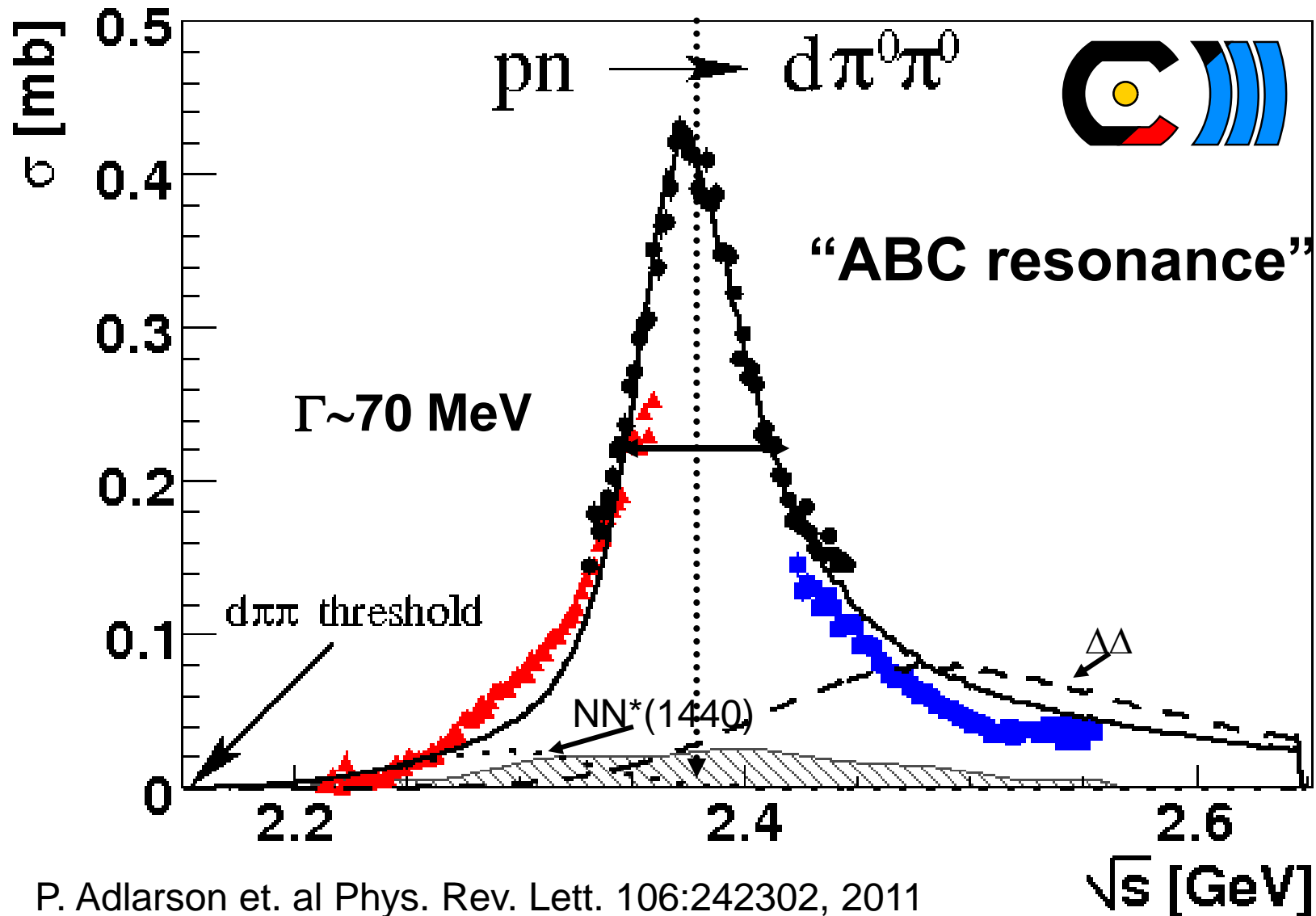
Observation of the  $d^*$  resonance in the  
 $pn \rightarrow d^* \rightarrow d\pi\pi$  and  $pn \rightarrow d^* \rightarrow pn$   
at WASA

Mikhail Bashkanov

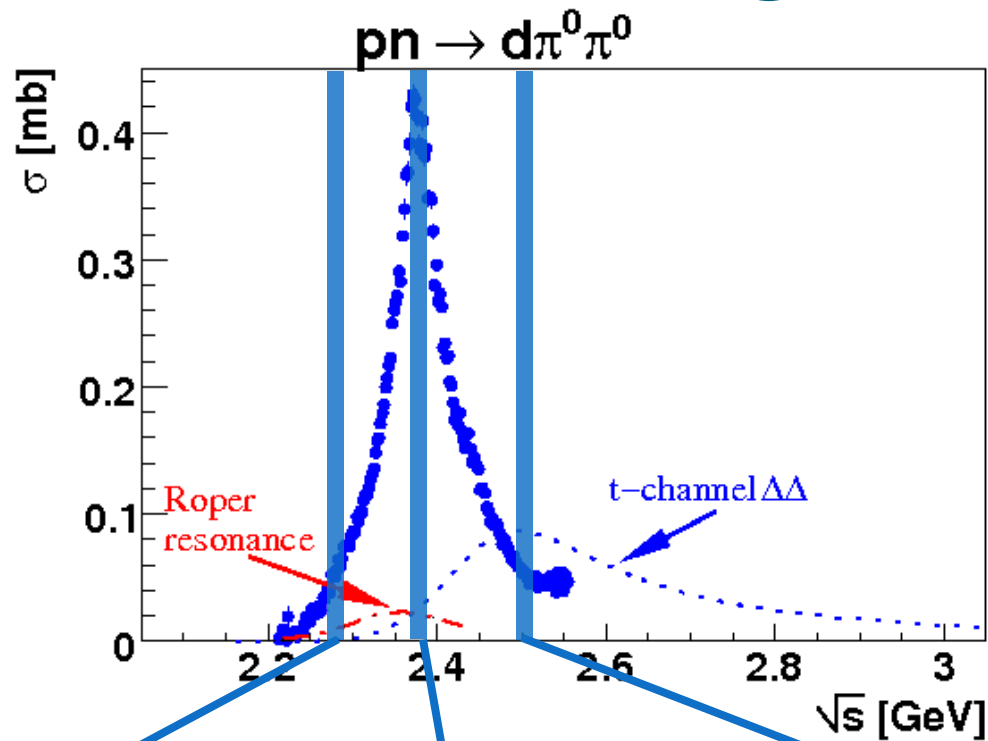
# Content

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

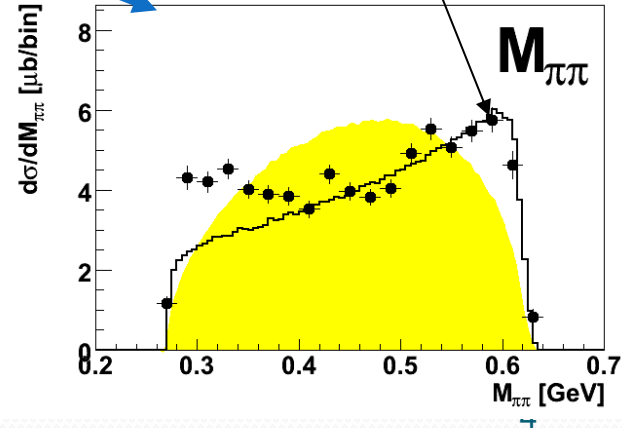
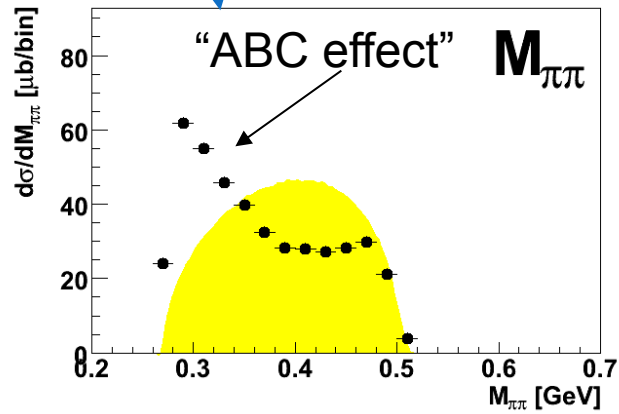
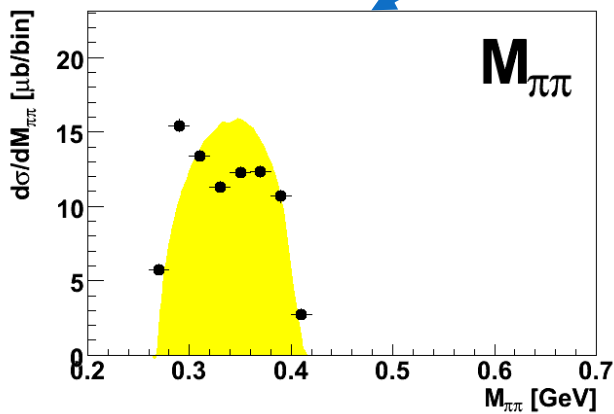
# Total cross section $pn \rightarrow d\pi^0\pi^0$



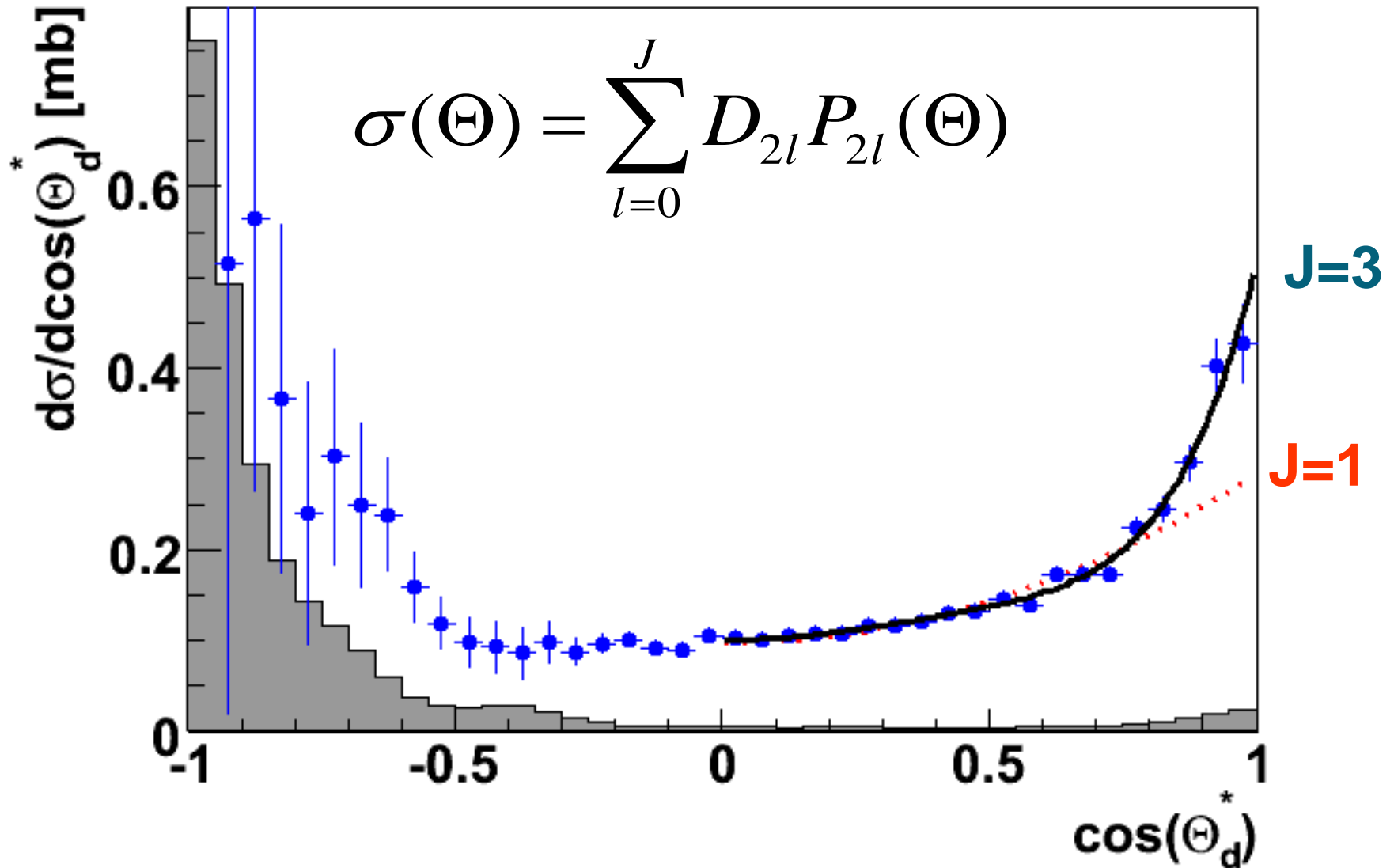
# $M_{\pi\pi}$ for different energies



t-channel  $\Delta\Delta$



# Angular distribution in the peak

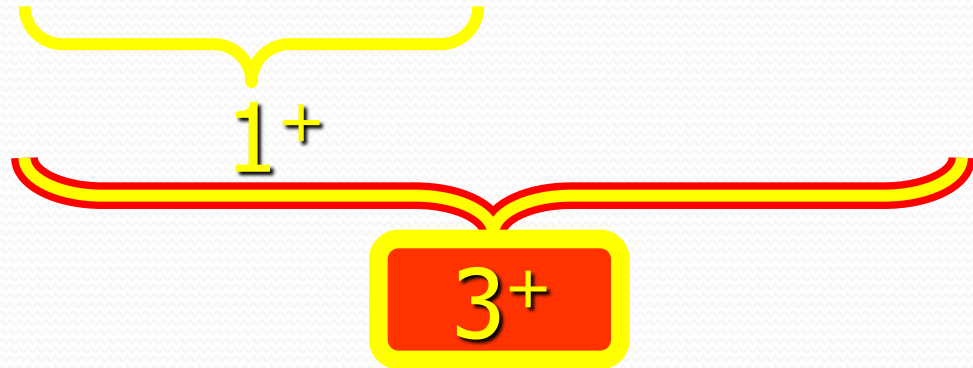


# Quantum numbers of the structure

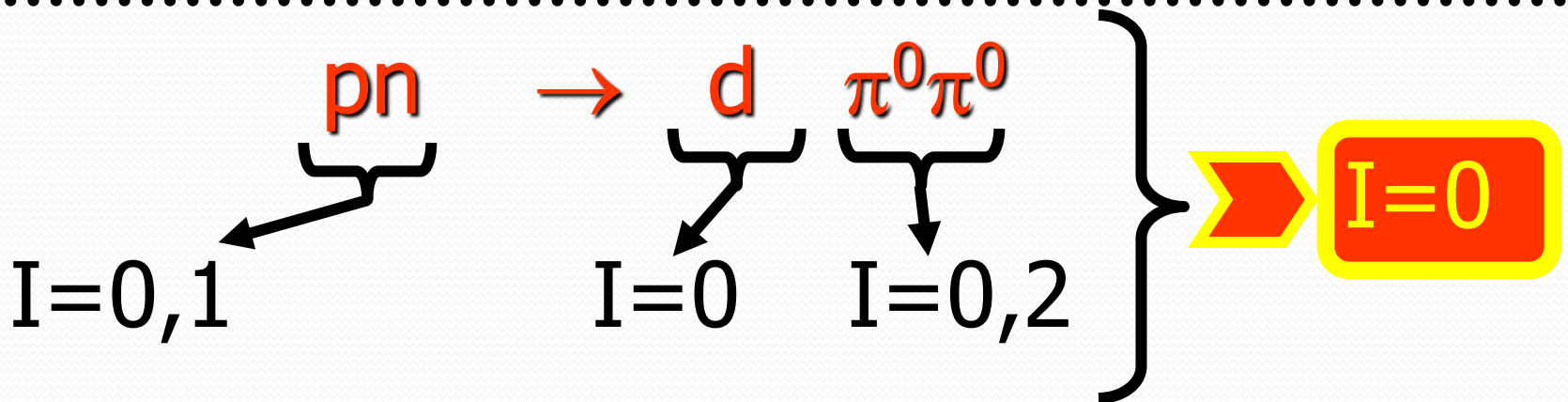
$$\mathbf{pn} \rightarrow \mathbf{R} \rightarrow \mathbf{d} \pi^0 \pi^0$$

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

$$\sigma(\cos \Theta_d^*) = D_0 P_0 + D_2 P_2 + D_4 P_4 + D_6 P_6$$

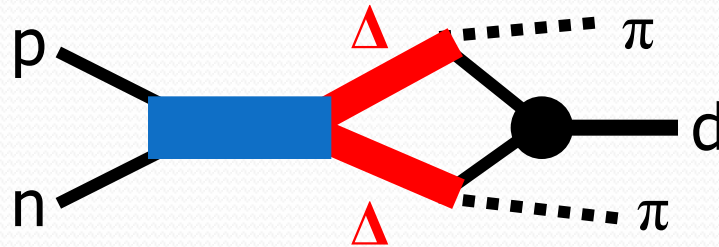


$1^+$  excluded by  $\sigma(\Theta)$ .  
 $3^+$  assigned



# Status of Theoretical Description

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



$$I(J^P) = 0(3^+)$$

# Isospin relations

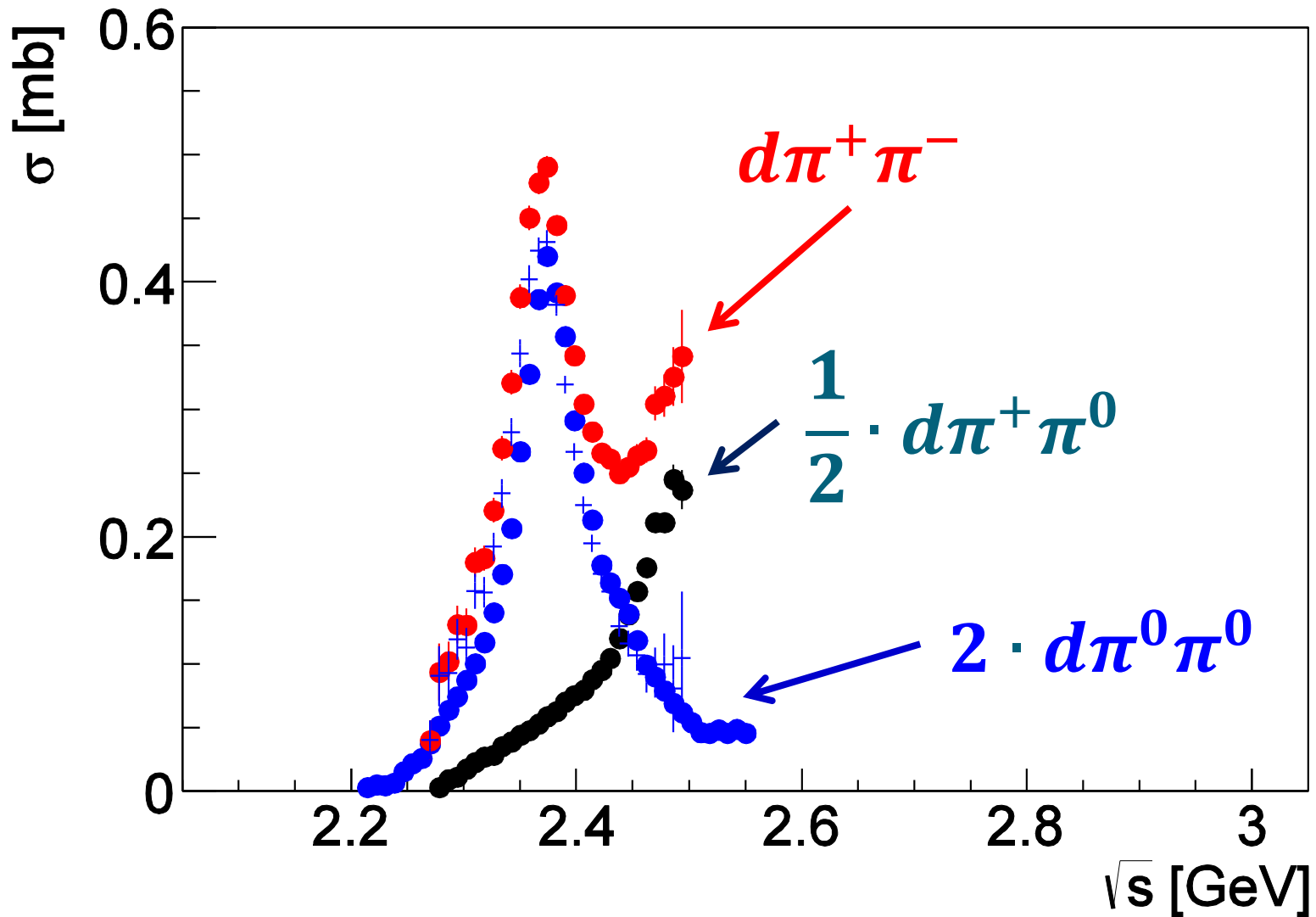
$$\sigma[pn \rightarrow d\pi^+\pi^-] = \frac{1}{2} \sigma[pp \rightarrow d\pi^+\pi^0] + 2\sigma[pn \rightarrow d\pi^0\pi^0]$$

**$I=1$**

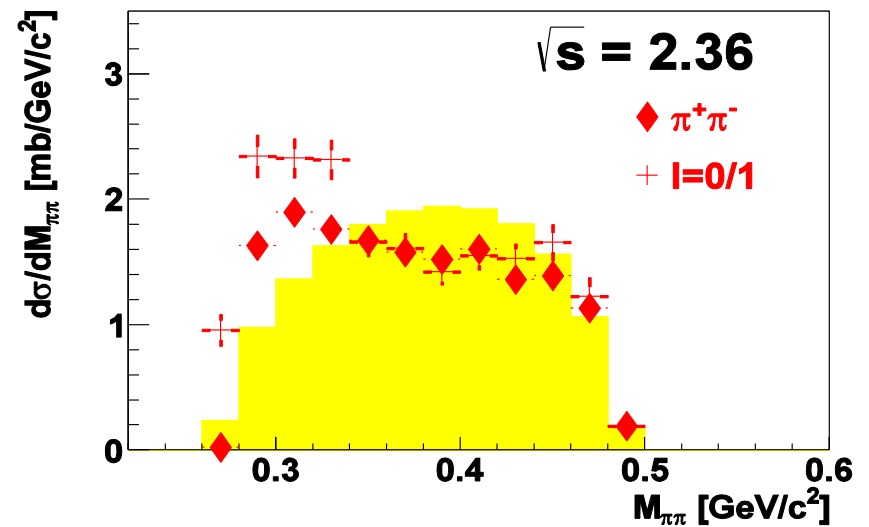
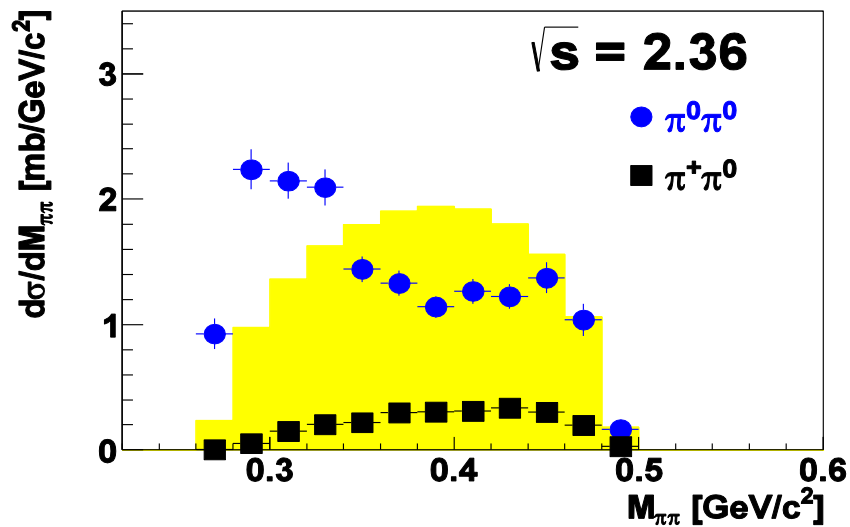
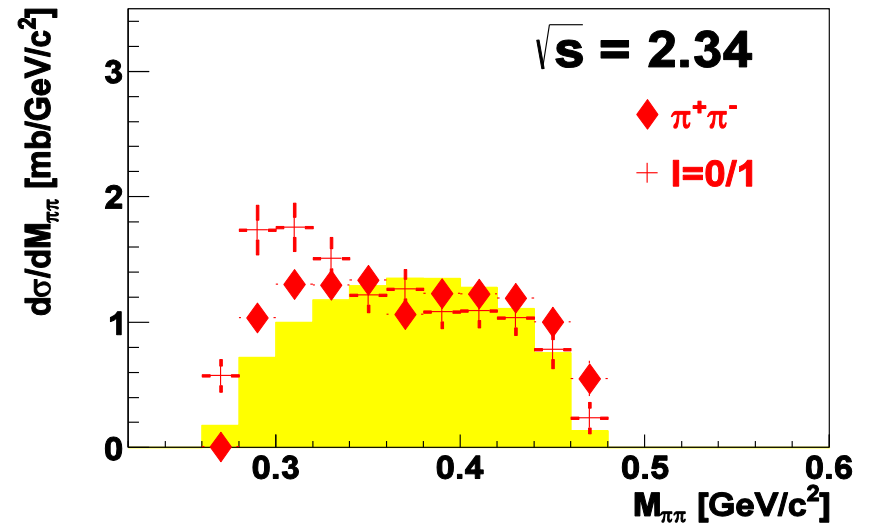
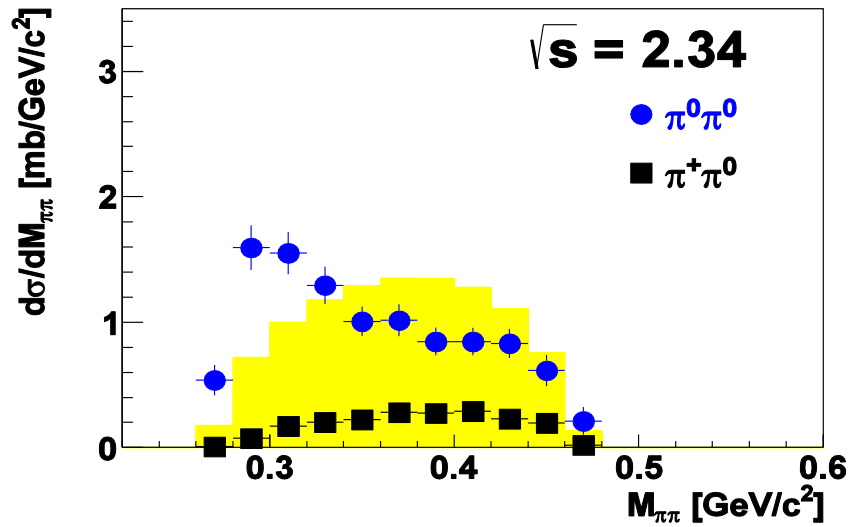
**$I=0$**



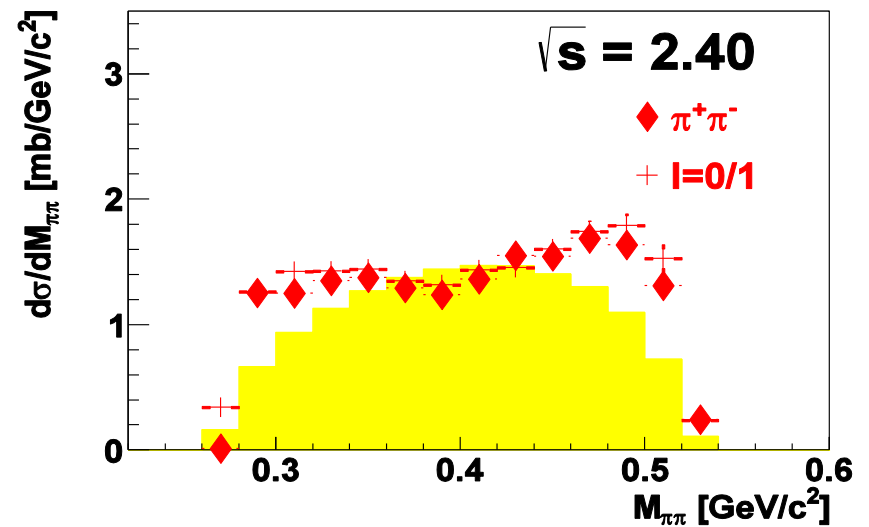
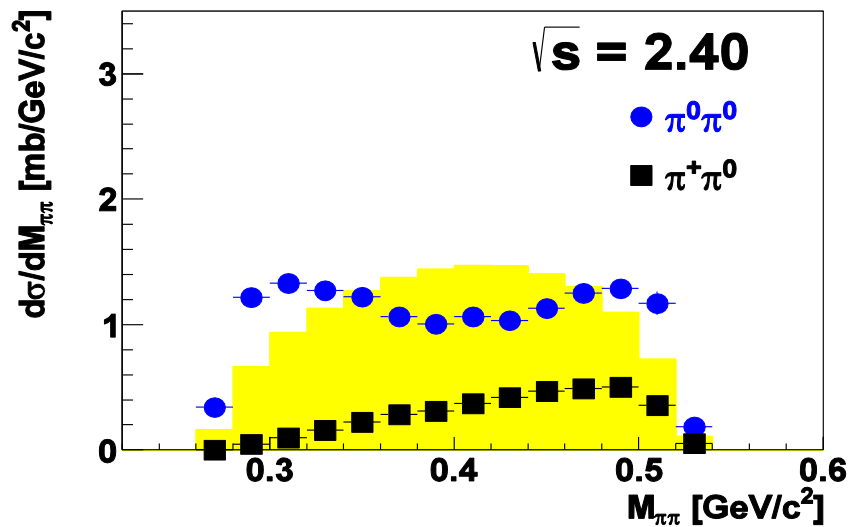
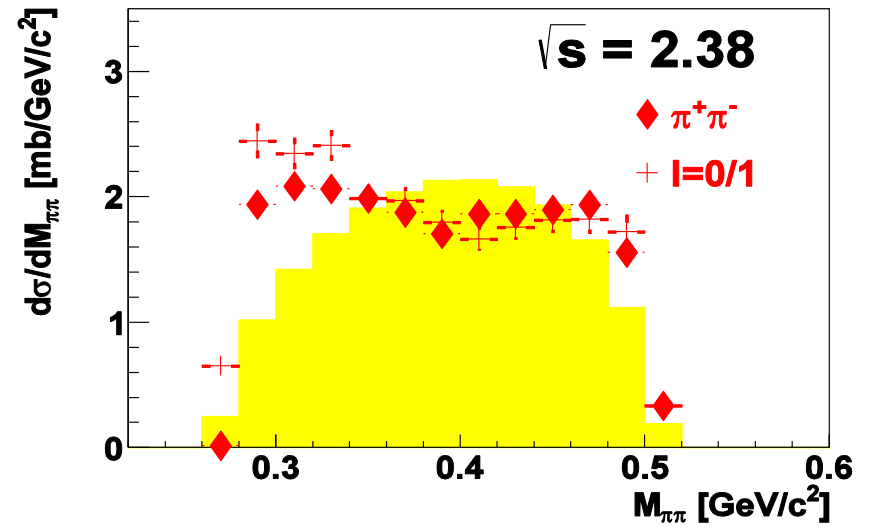
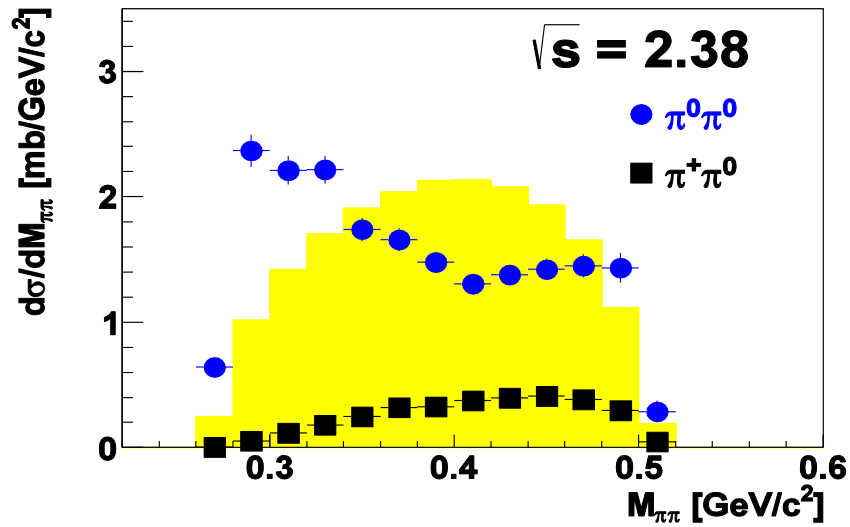
# Total cross section $pN \rightarrow d\pi\pi$



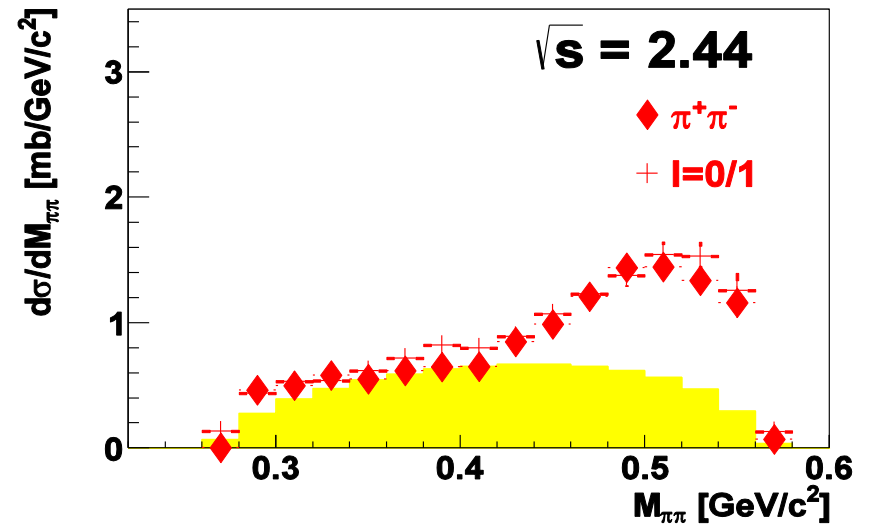
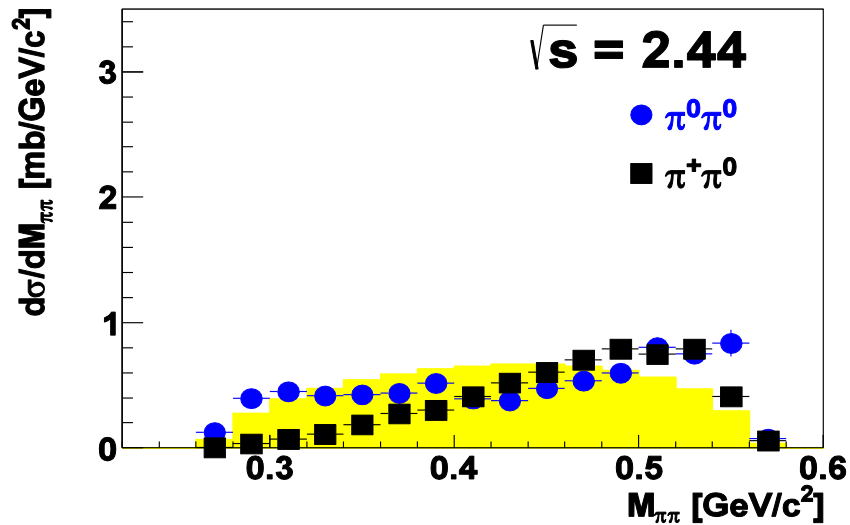
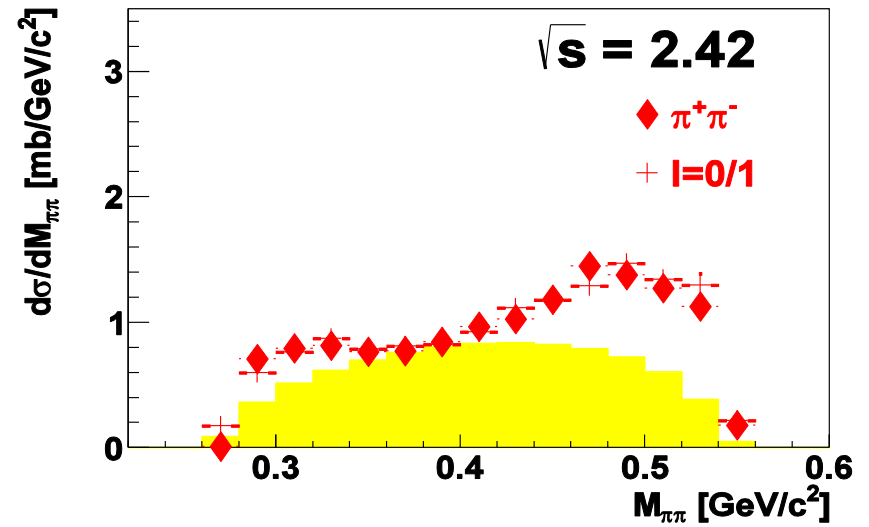
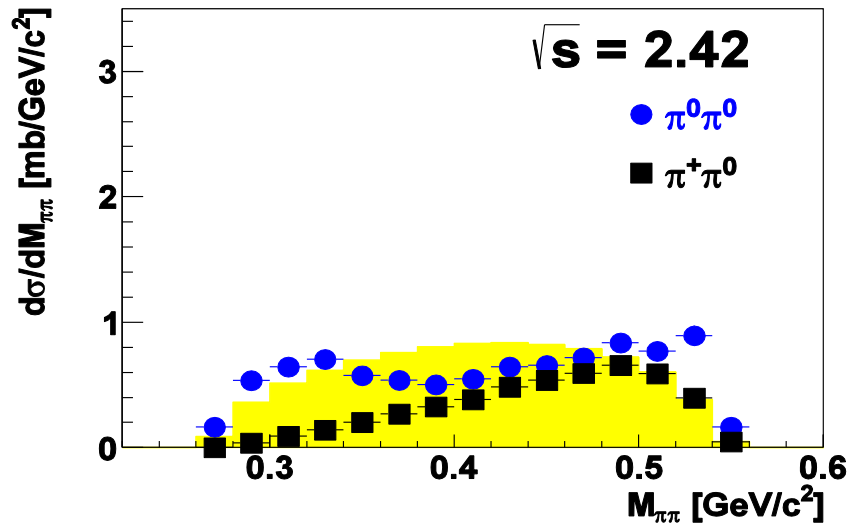
# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$



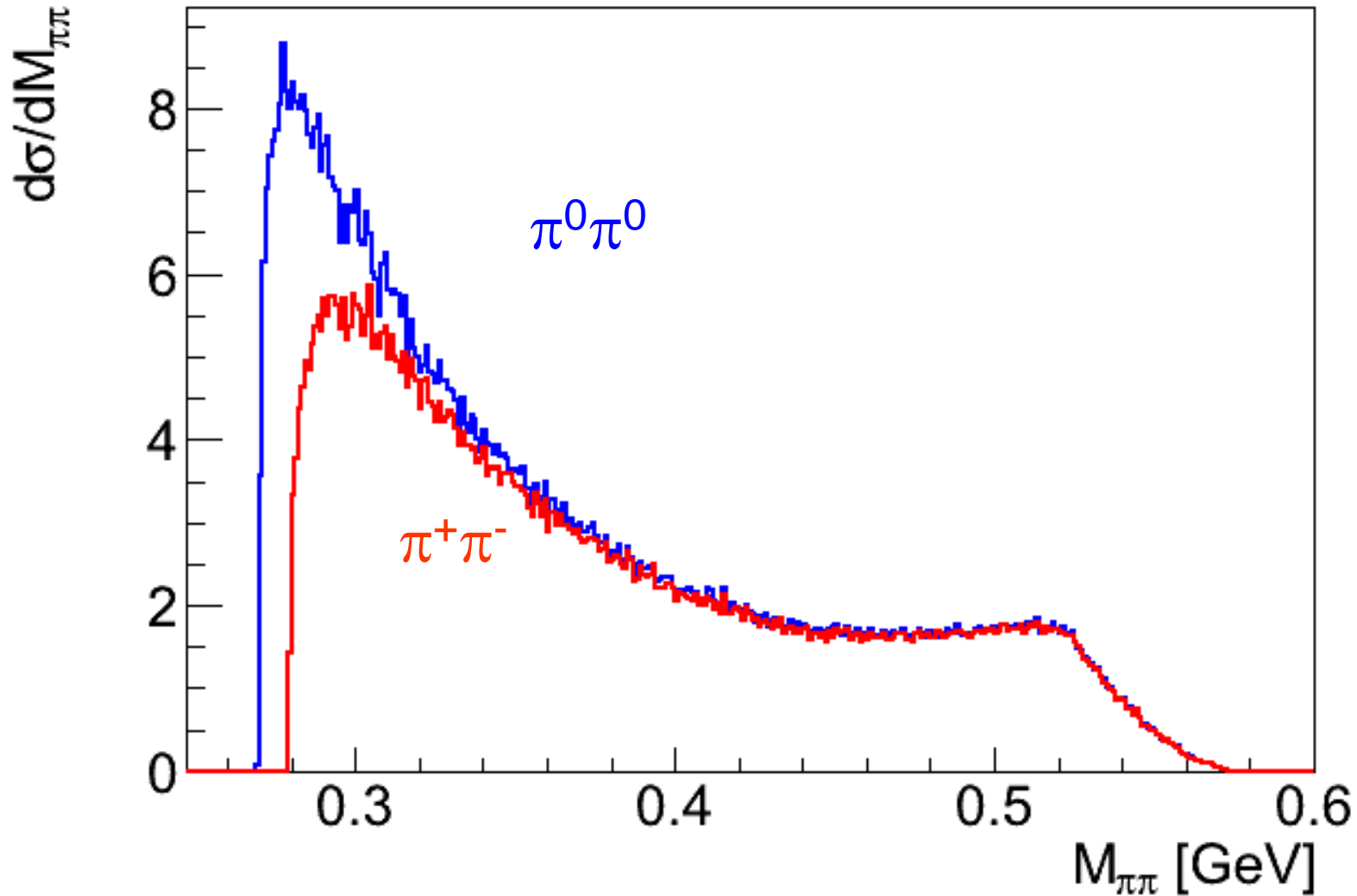
# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$



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

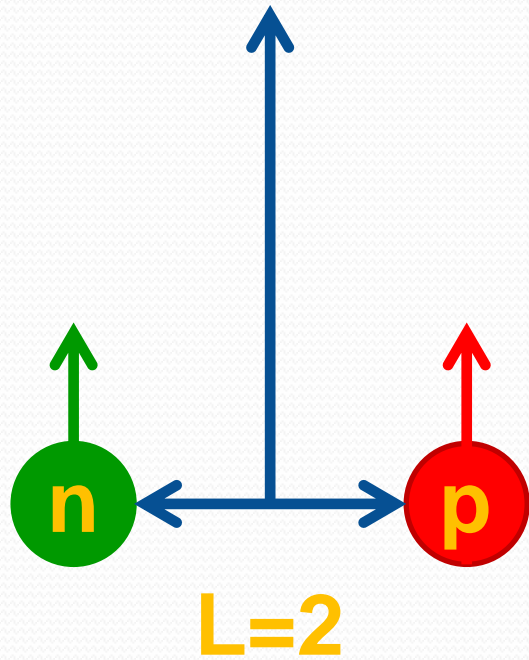


# Isospin violation

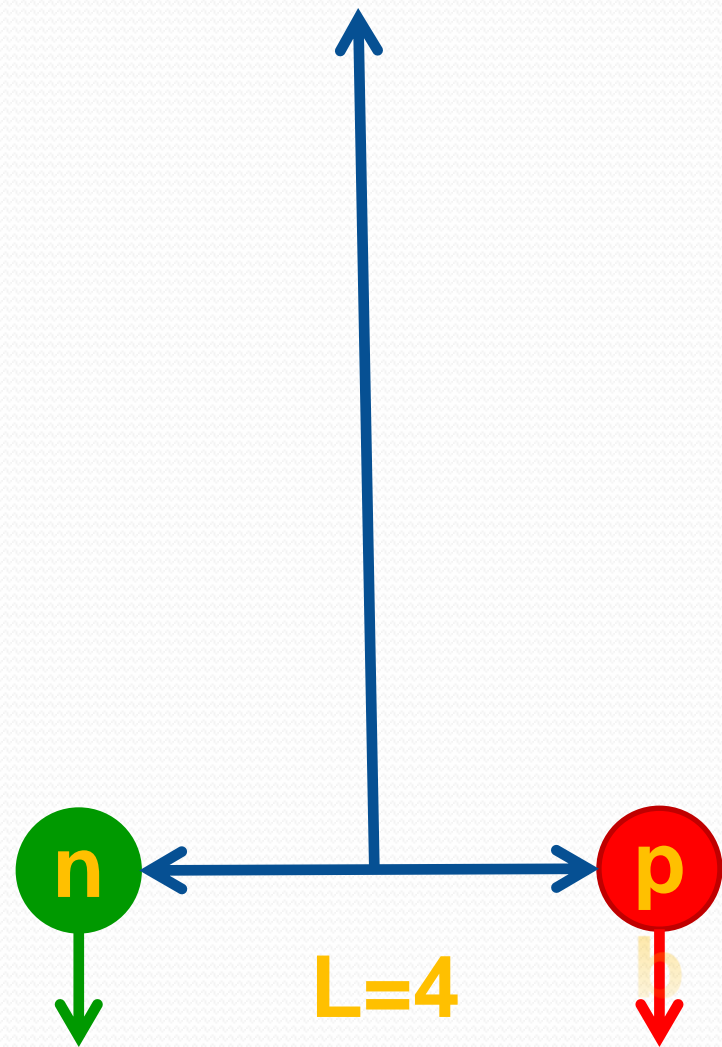


# Elastic channel

# 3<sup>+</sup> Resonance in pn

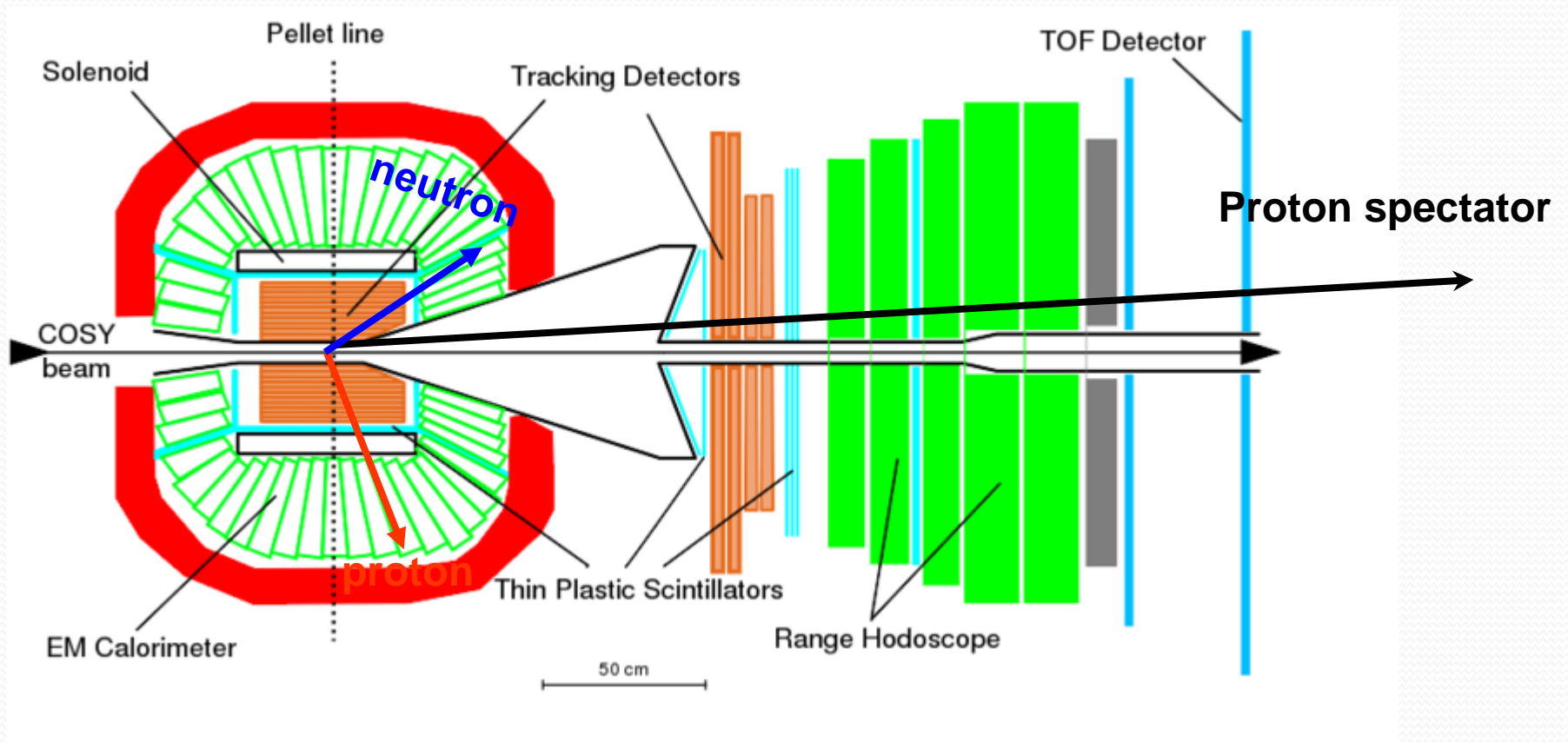
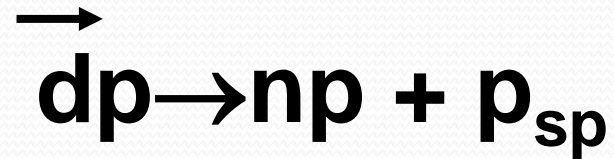


${}^3D_3$



${}^3G_3$

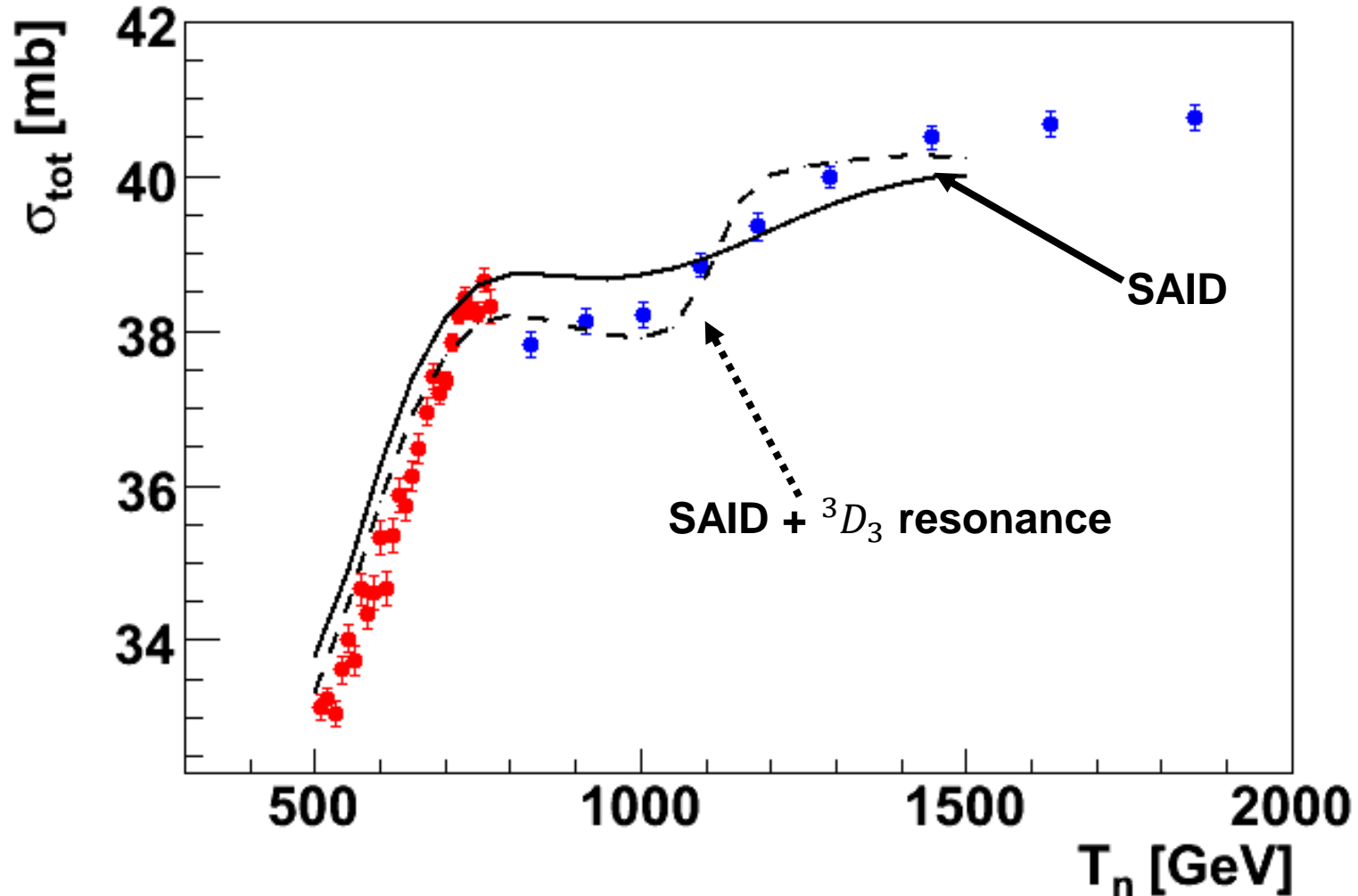
# Kinematics





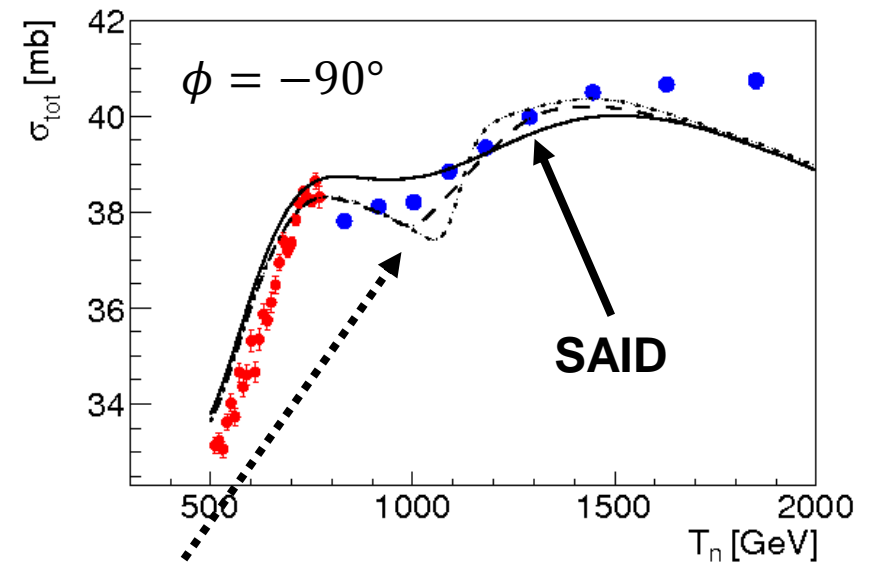
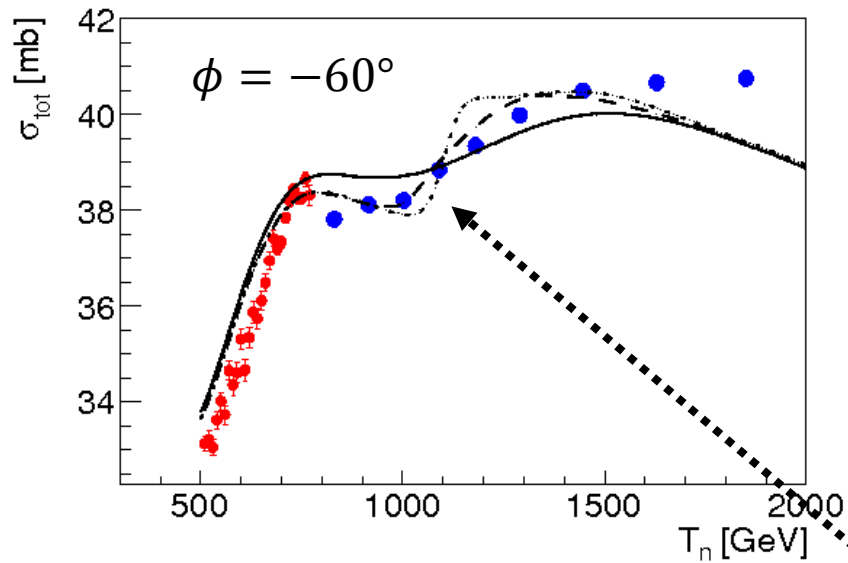
# Total pn cross-section

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



# Total pn cross-section

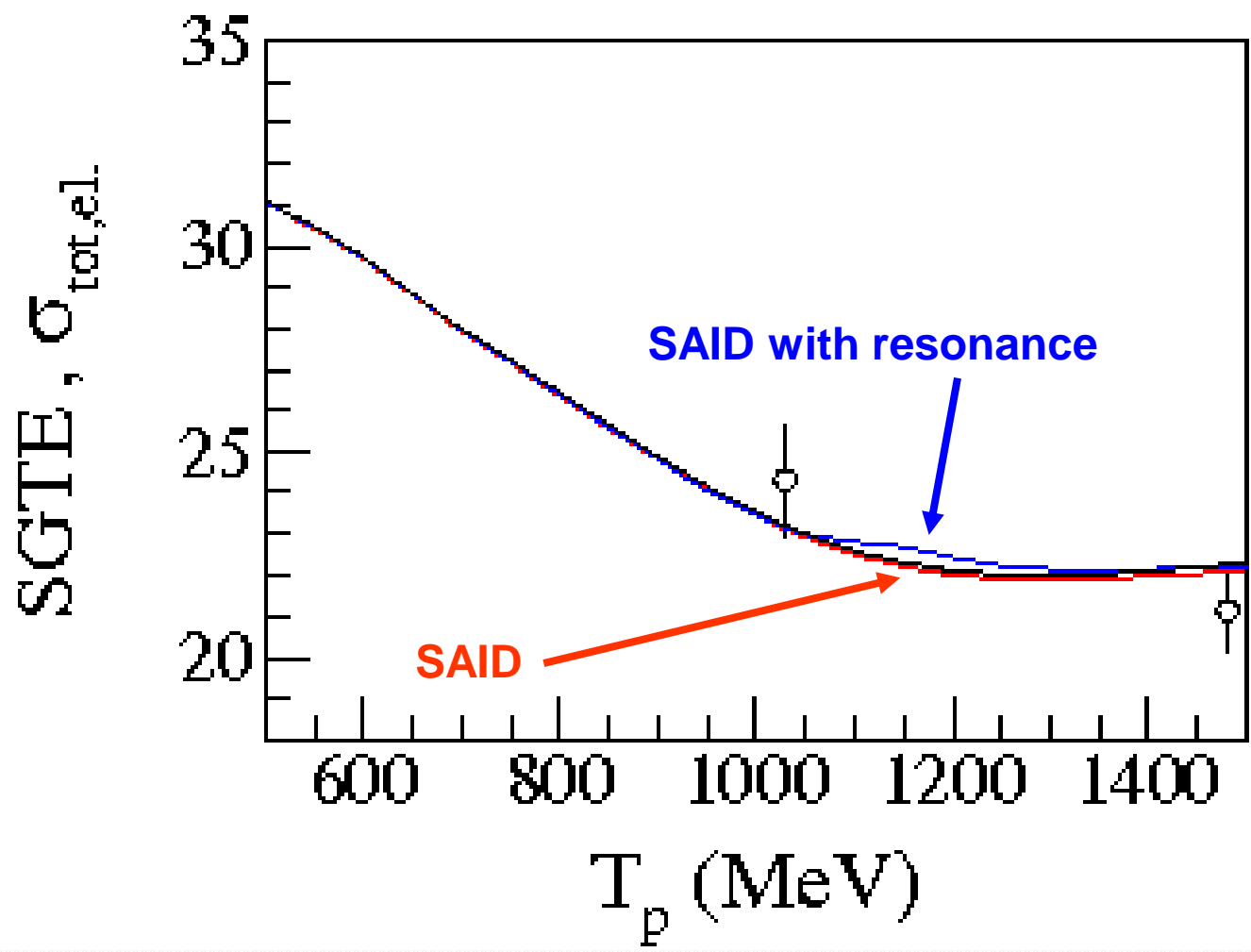
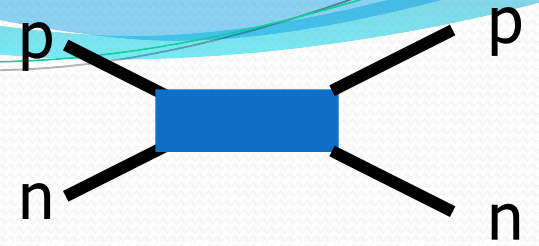
- Devlin et al, PRD8, 136 (73)
- Lisowski et al, PRL49, 255(82)



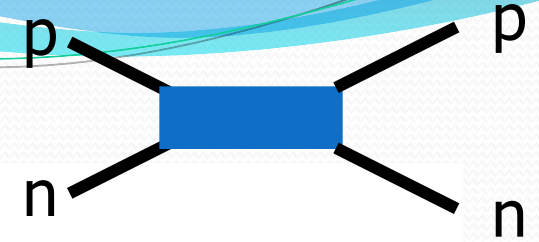
**SAID +  ${}^3G_3$  resonance**

# Expectations

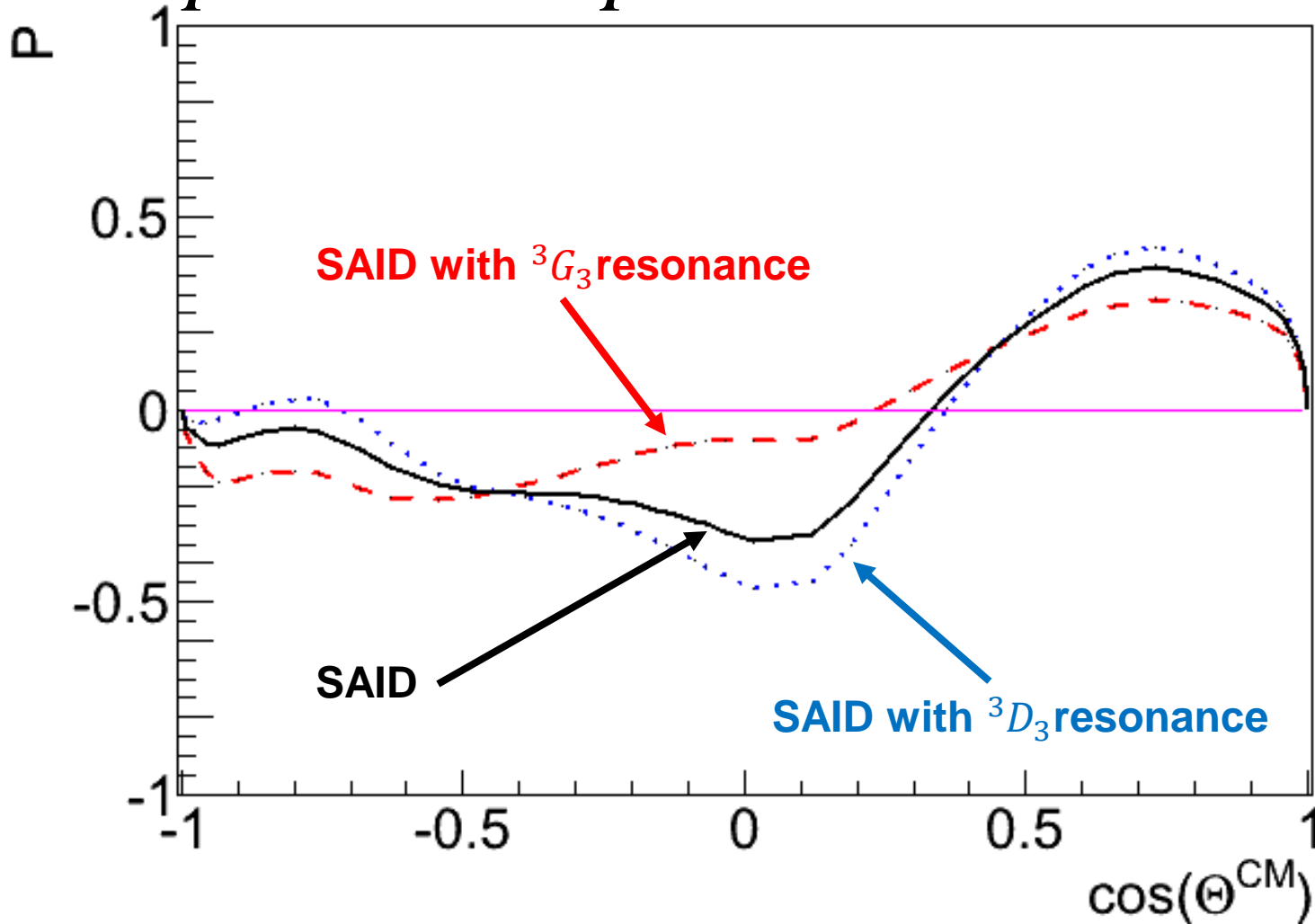
$$pn \rightarrow R \rightarrow pn$$



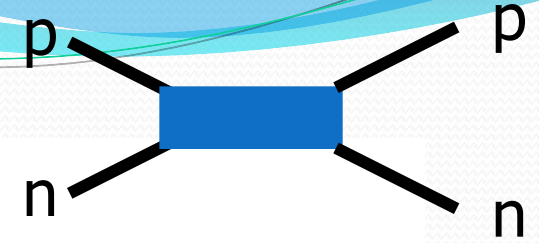
# Expectation



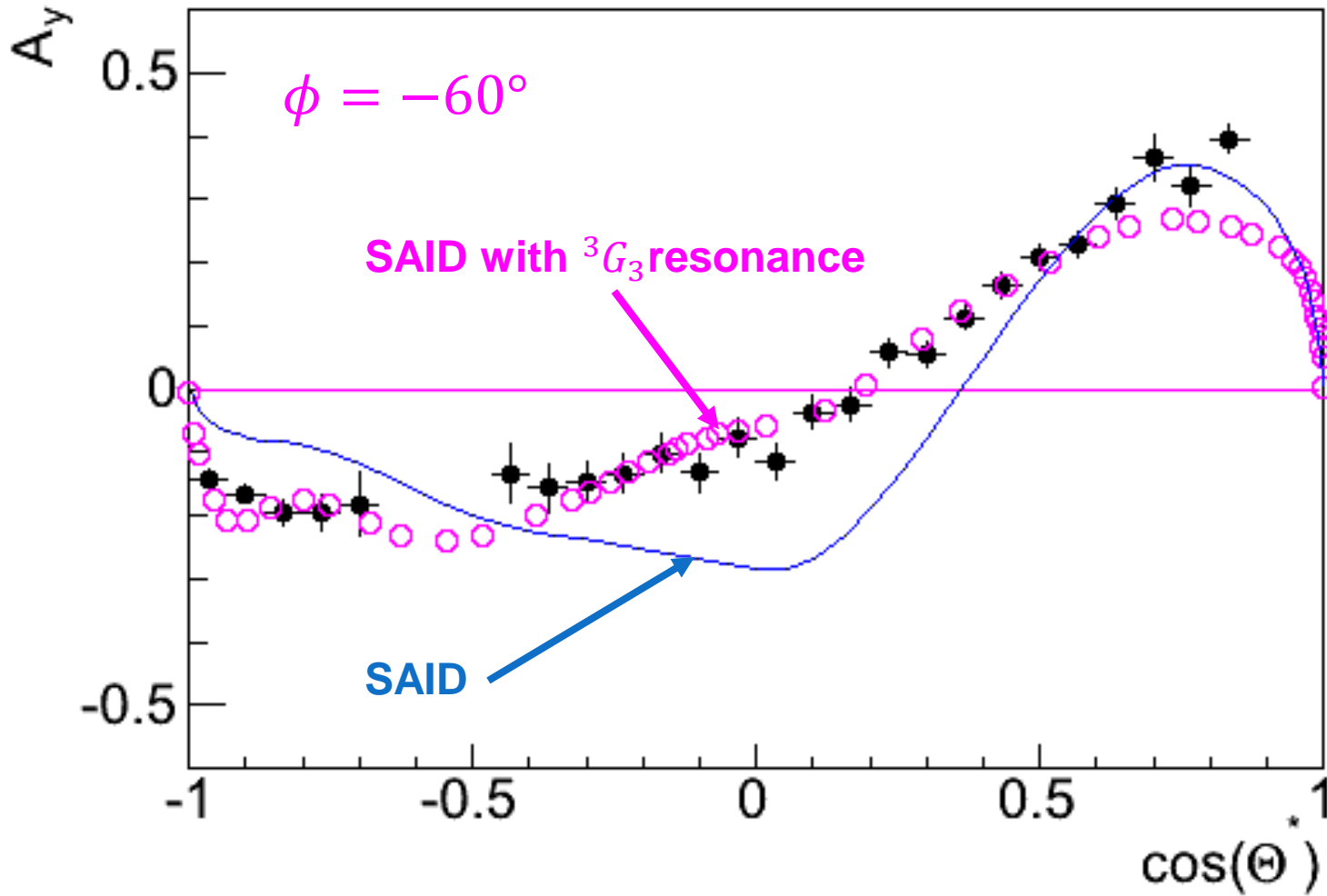
$$pn \rightarrow R \rightarrow pn$$



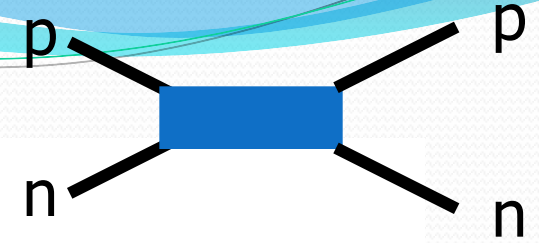
# Reality



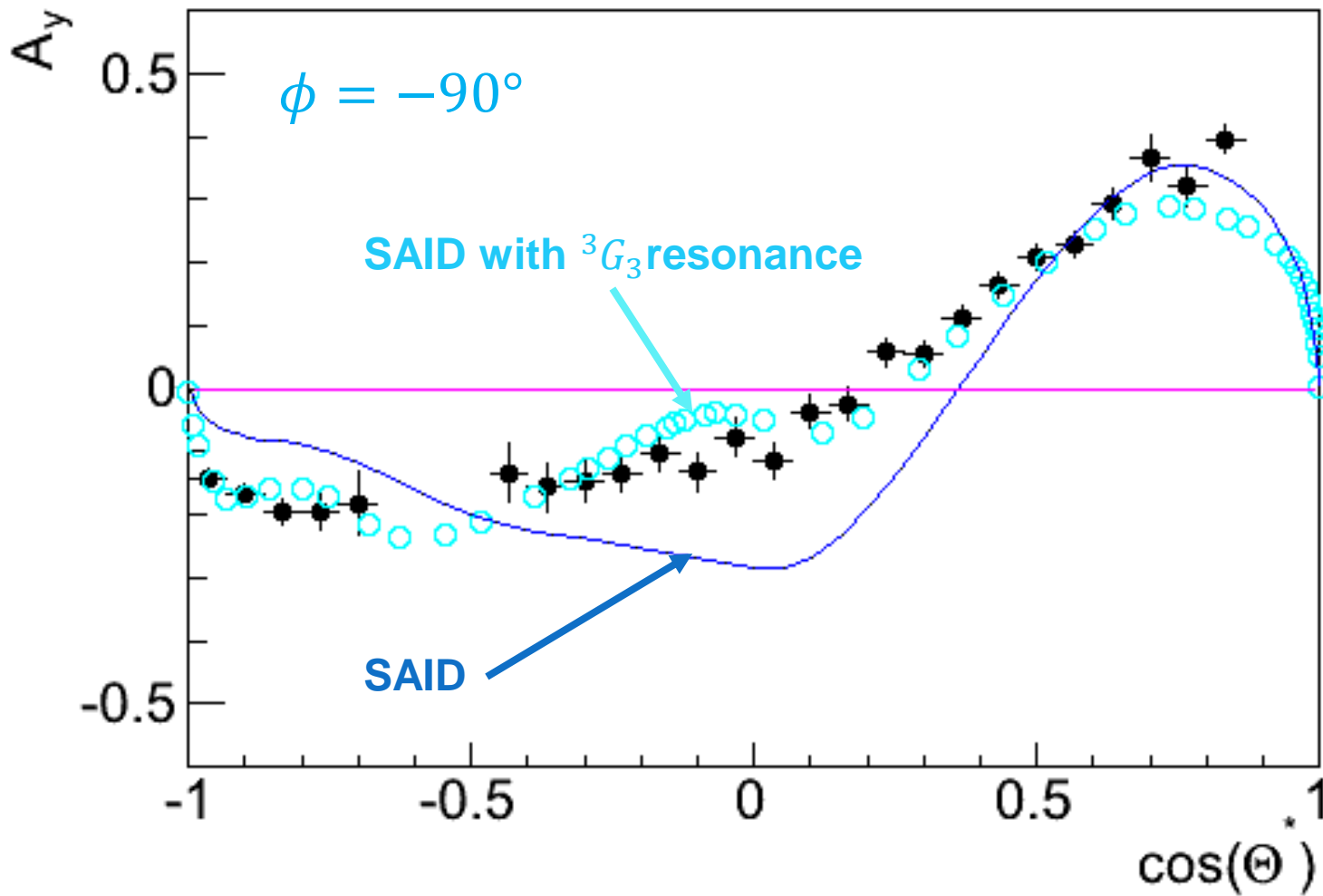
$$pn \rightarrow R \rightarrow pn$$



# Reality

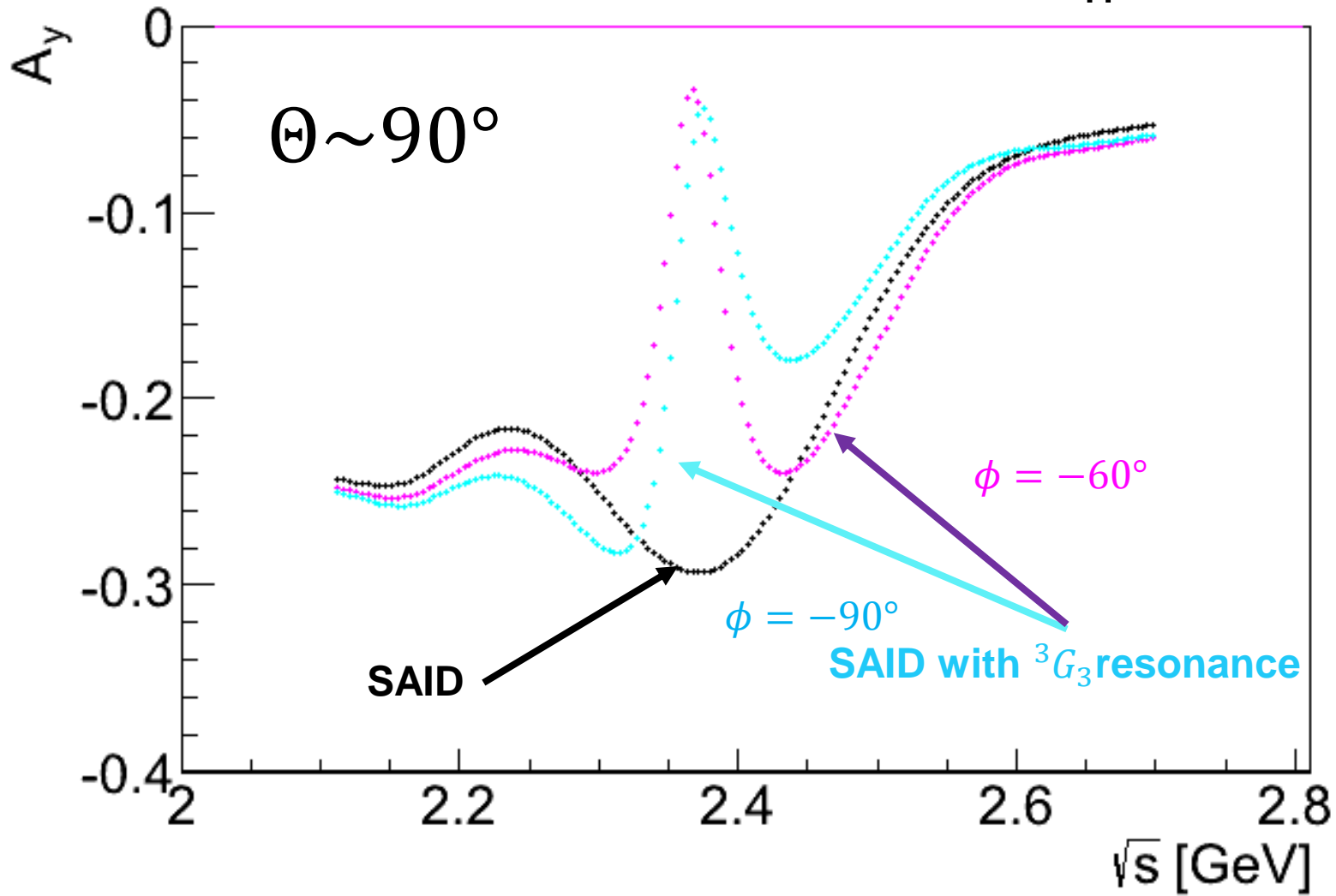
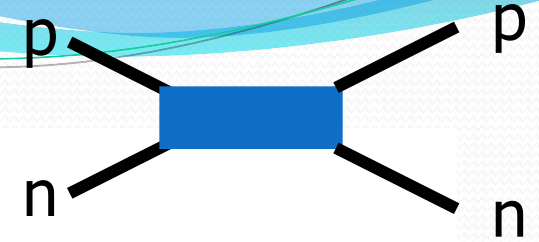


$$pn \rightarrow R \rightarrow pn$$

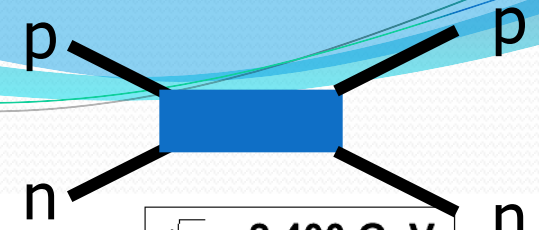


# Expectation

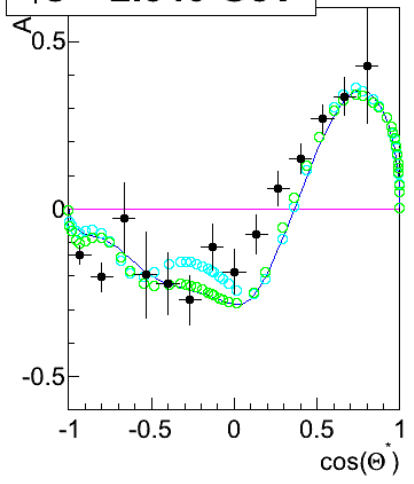
$$pn \rightarrow R_0 \rightarrow pn$$



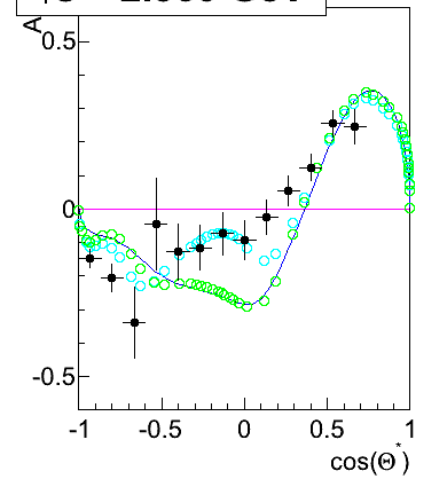
$$pn \rightarrow R \rightarrow pn$$



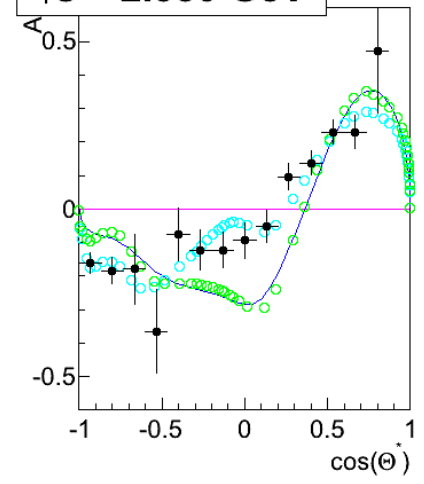
$\sqrt{s} = 2.340 \text{ GeV}$



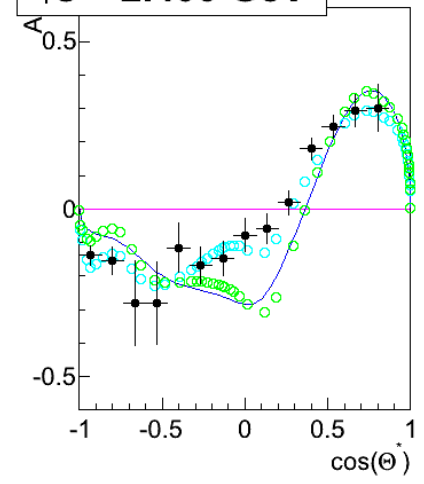
$\sqrt{s} = 2.360 \text{ GeV}$



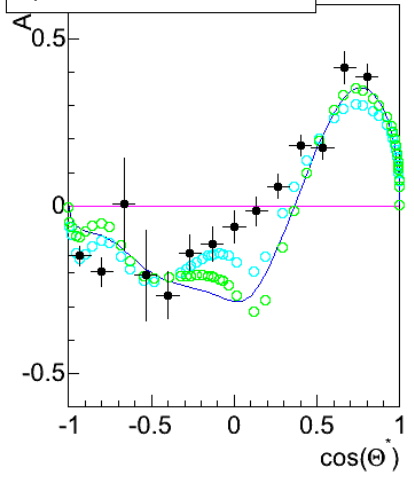
$\sqrt{s} = 2.380 \text{ GeV}$



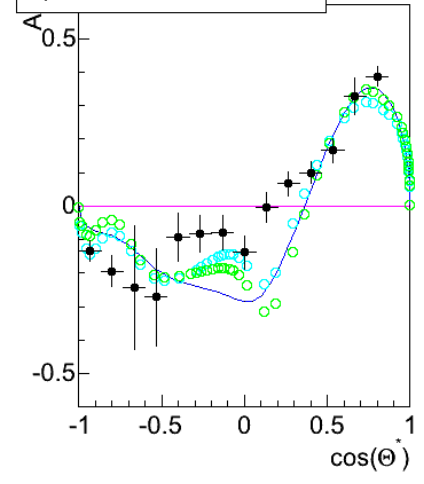
$\sqrt{s} = 2.400 \text{ GeV}$



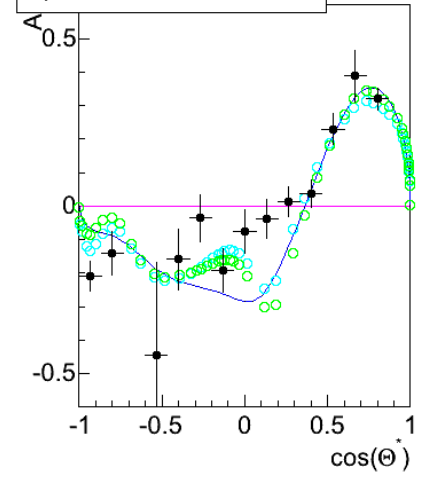
$\sqrt{s} = 2.420 \text{ GeV}$



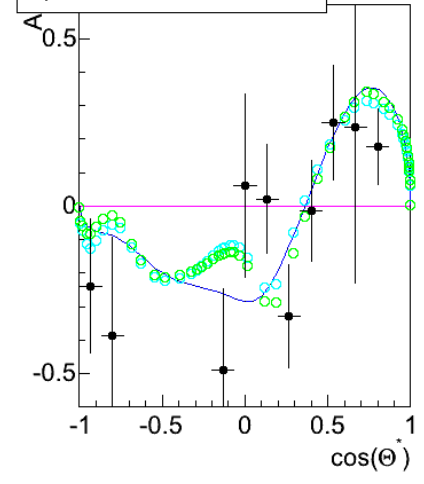
$\sqrt{s} = 2.440 \text{ GeV}$



$\sqrt{s} = 2.460 \text{ GeV}$



$\sqrt{s} = 2.480 \text{ GeV}$



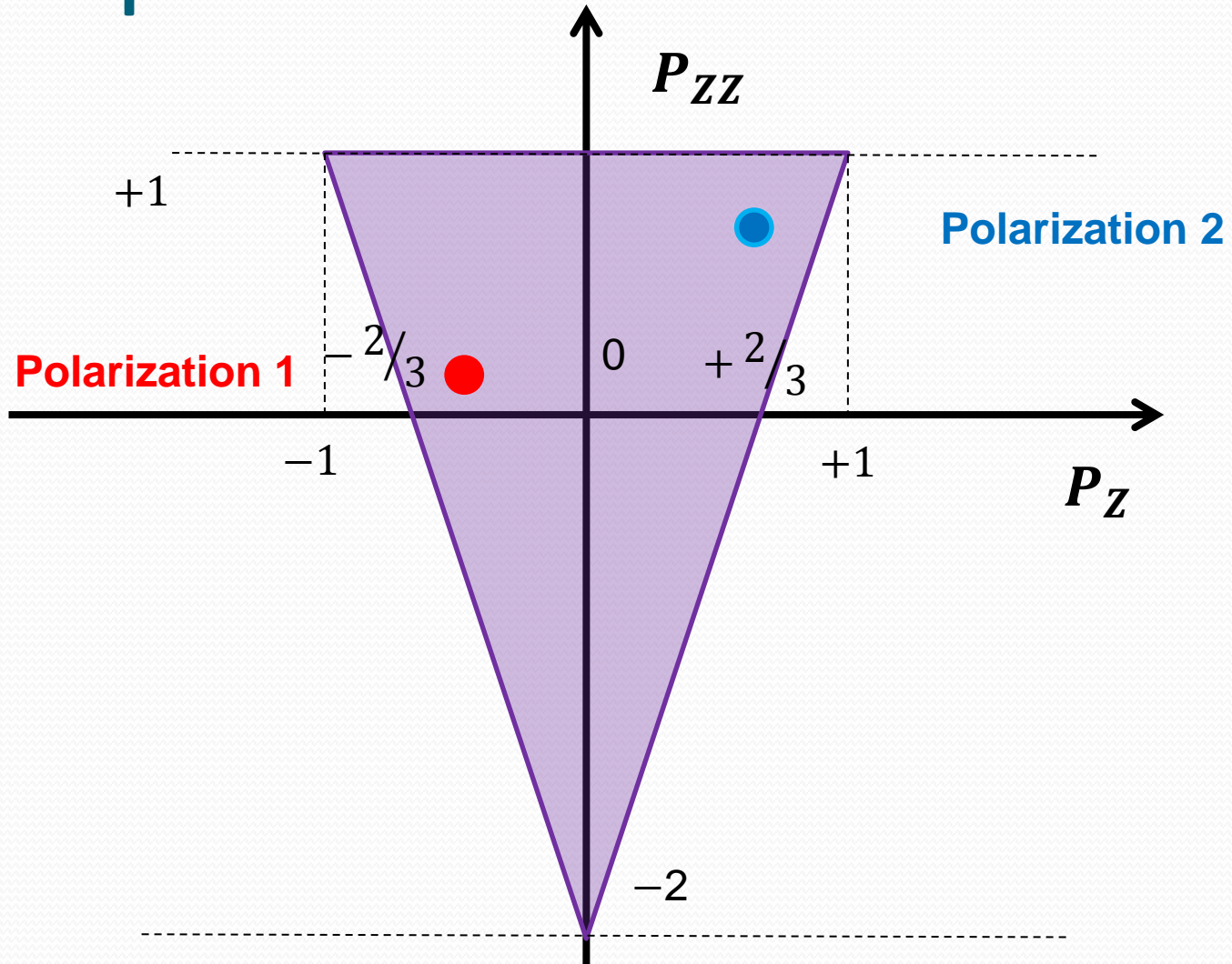


# Conclusion

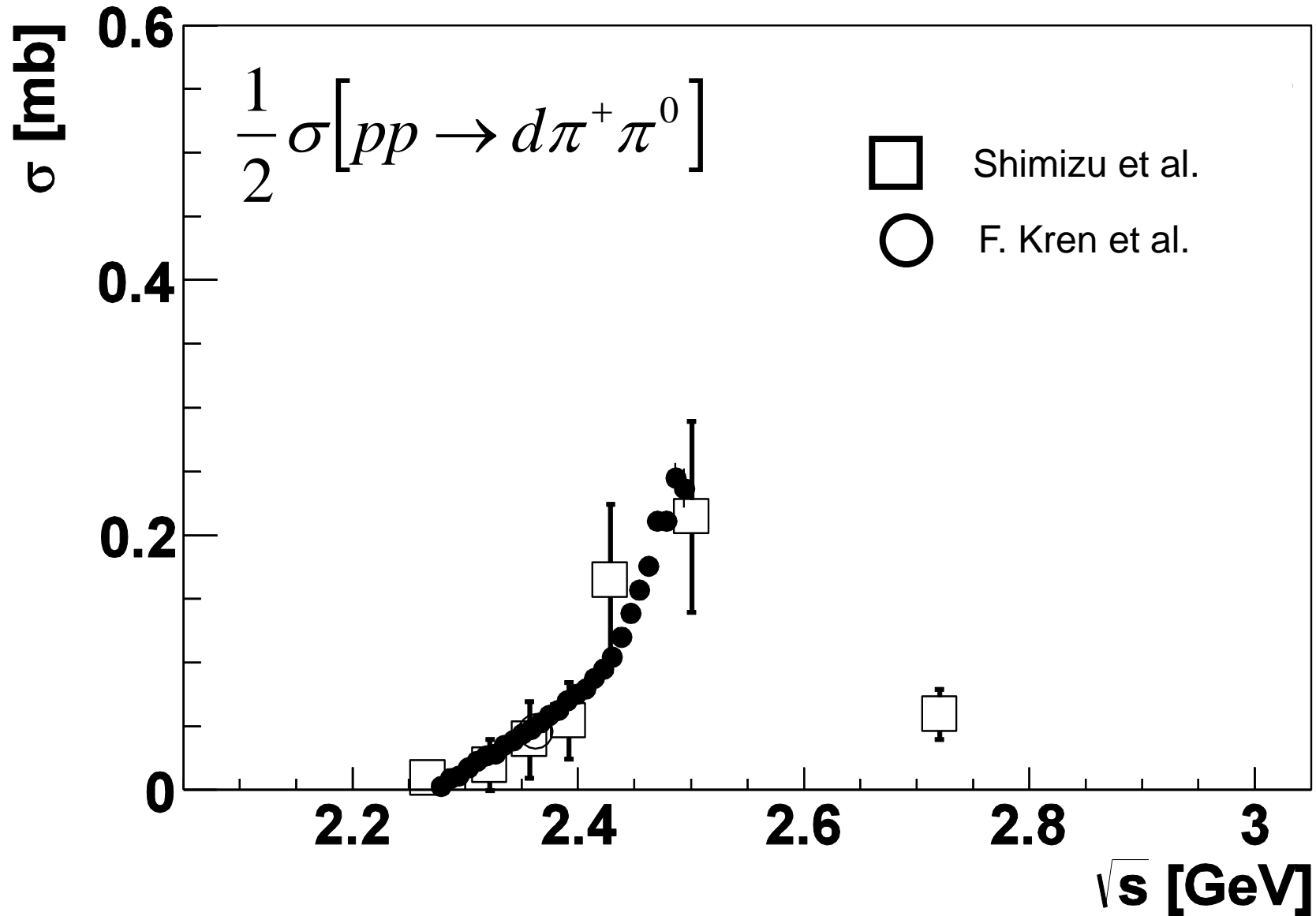
- ABC-resonance is seen in
  - $pn \rightarrow d\pi^0\pi^0$
  - $pn \rightarrow d\pi^+\pi^-$
  - $pn \rightarrow pp\pi^-\pi^0$
- pn-elastic scattering exhibits fast phase motion
  - Good hints for a resonance in elastic channel
- A discovery of a new resonance?
  - Dibaryon  $d^*$ :  $M = 2.38 \text{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

Thank you

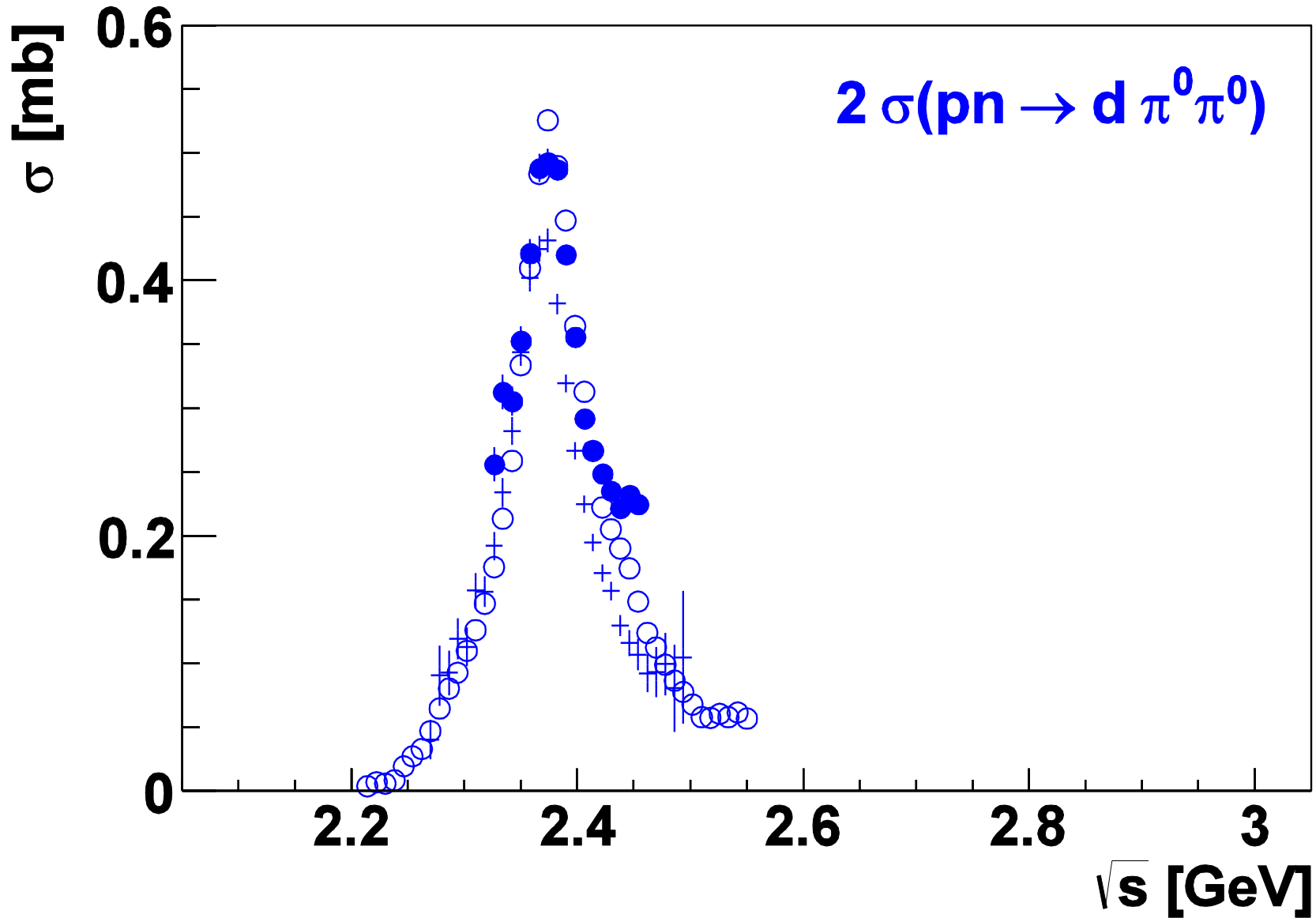
# Beam polarization



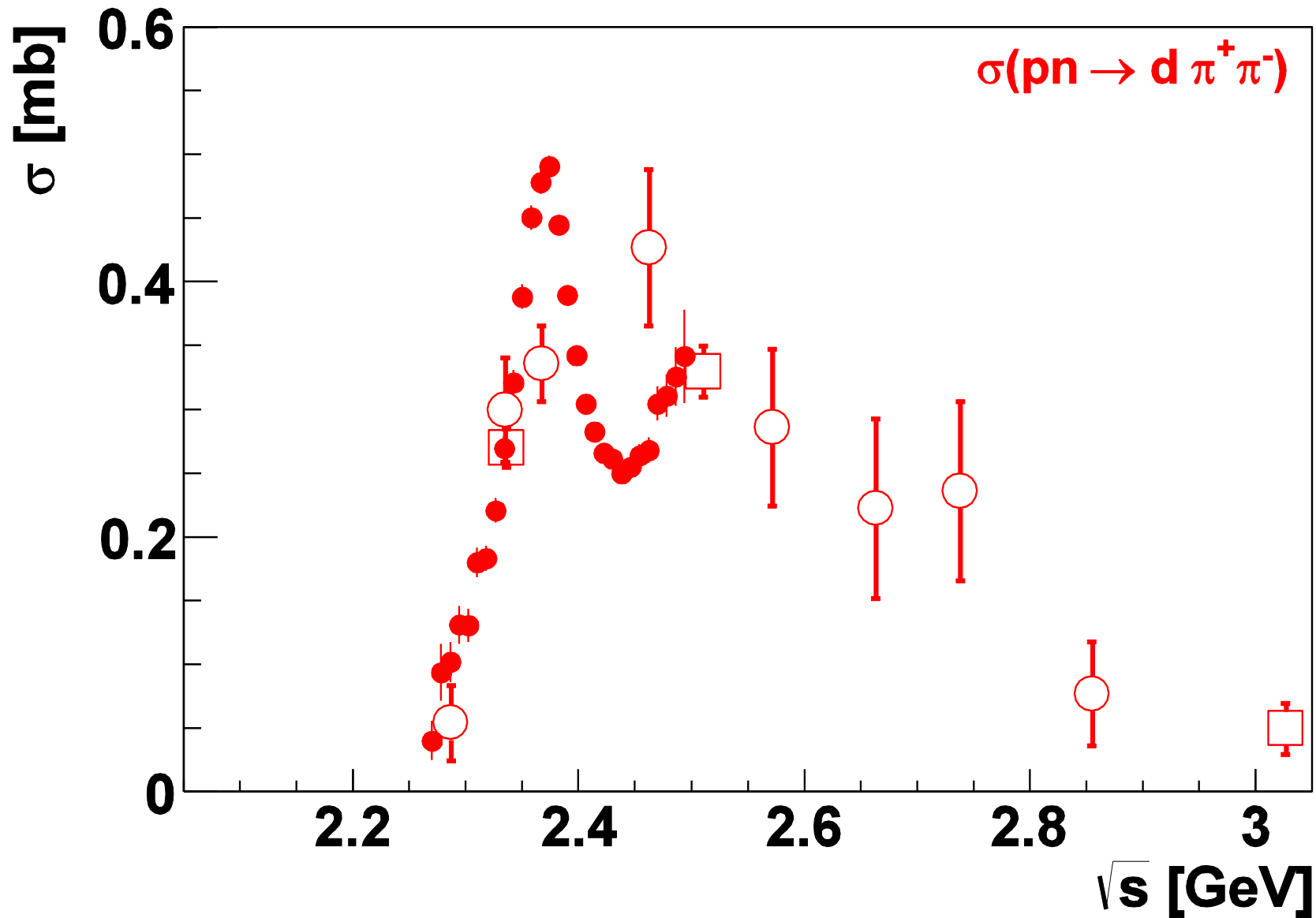
# Total cross section $pp \rightarrow d\pi^+\pi^0$



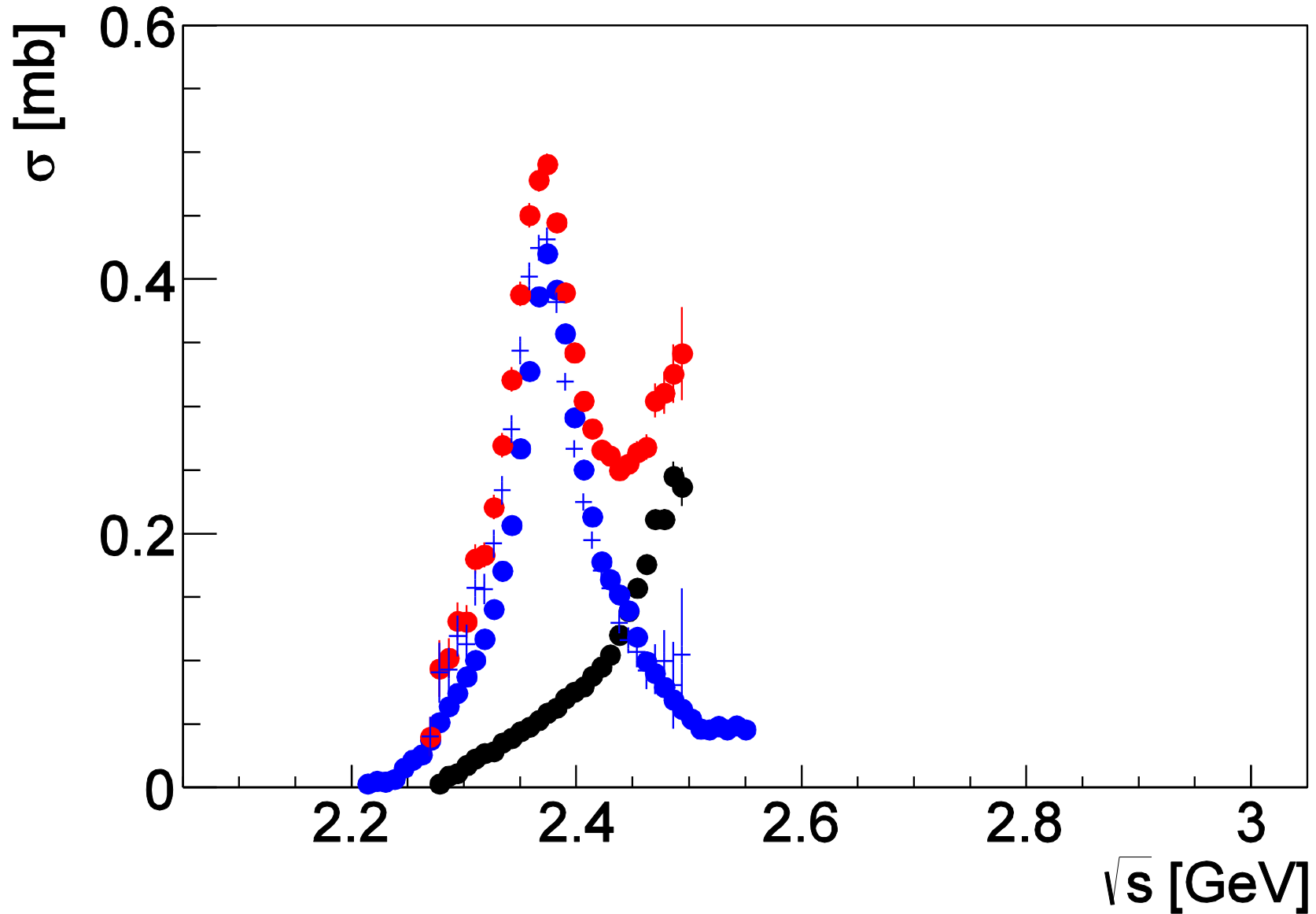
# Total cross section $pn \rightarrow d\pi^0\pi^0$



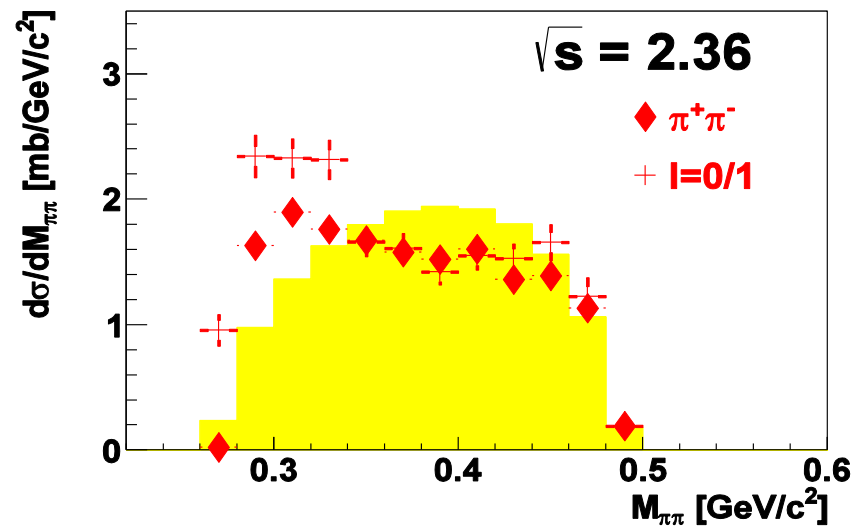
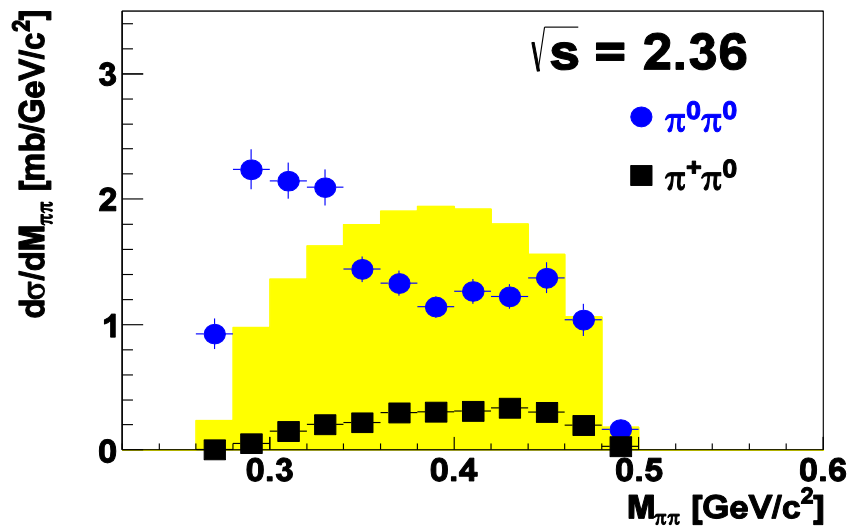
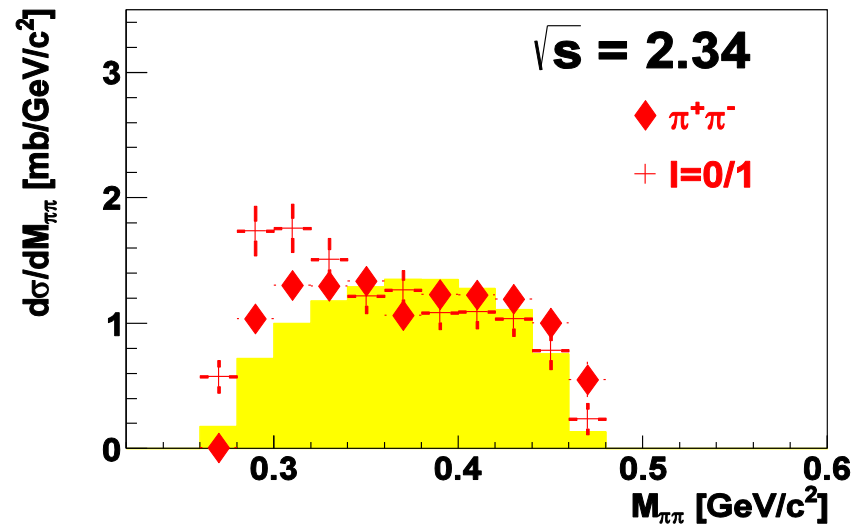
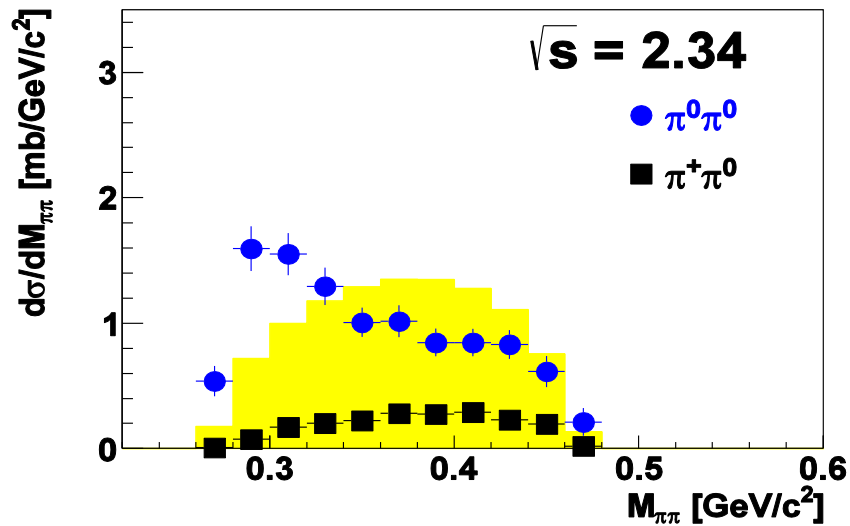
# Total cross section $pn \rightarrow d\pi^+\pi^-$



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

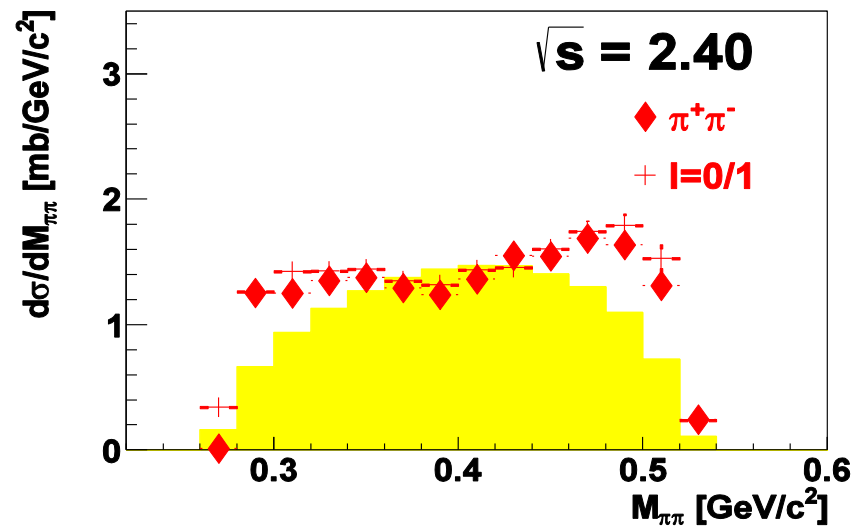
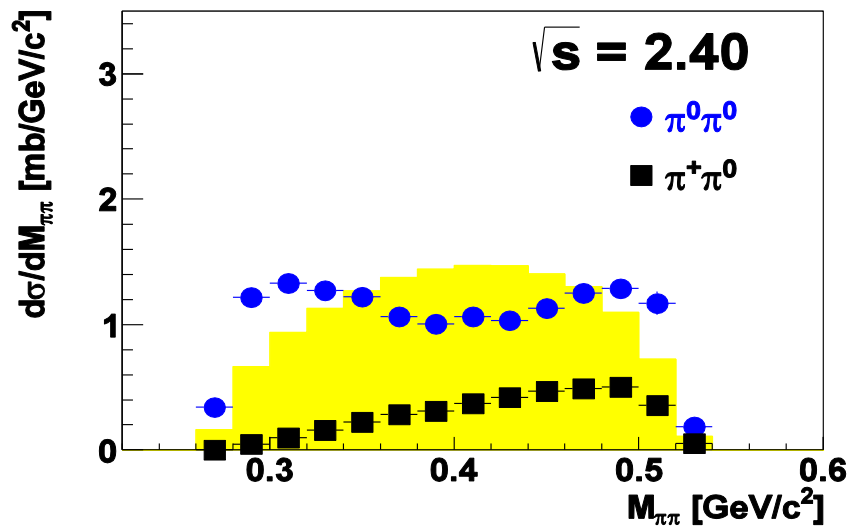
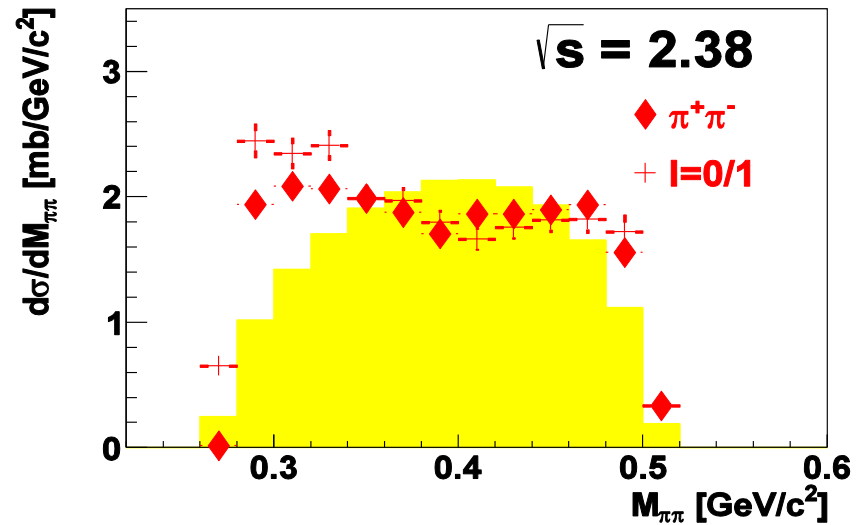
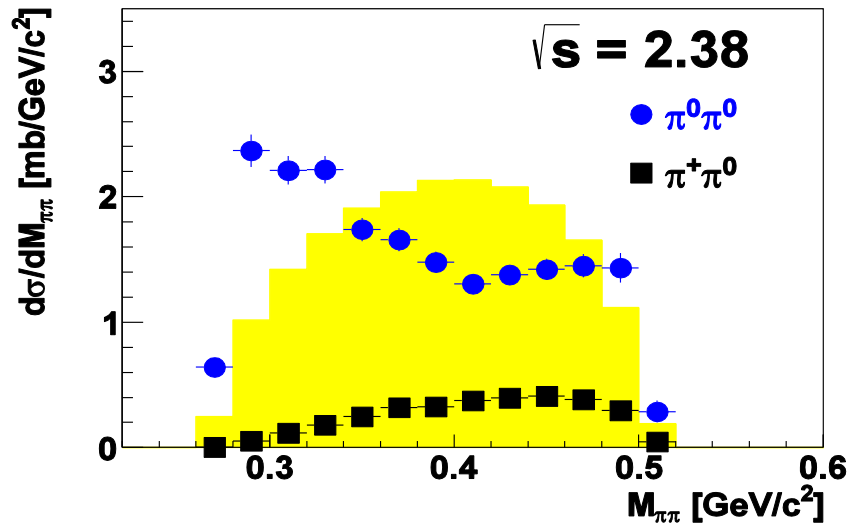


# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$

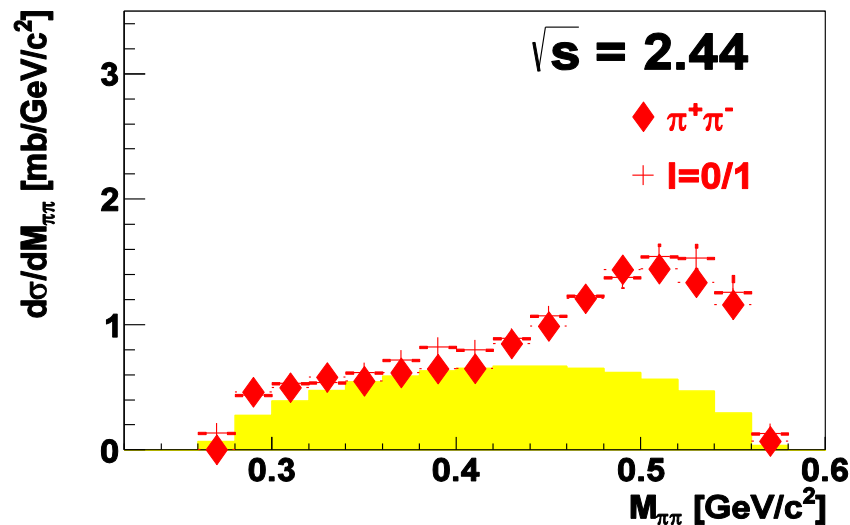
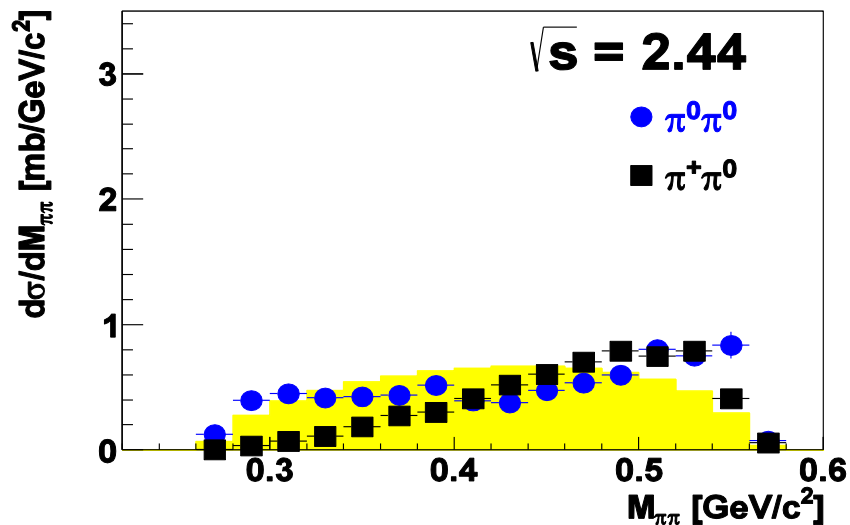
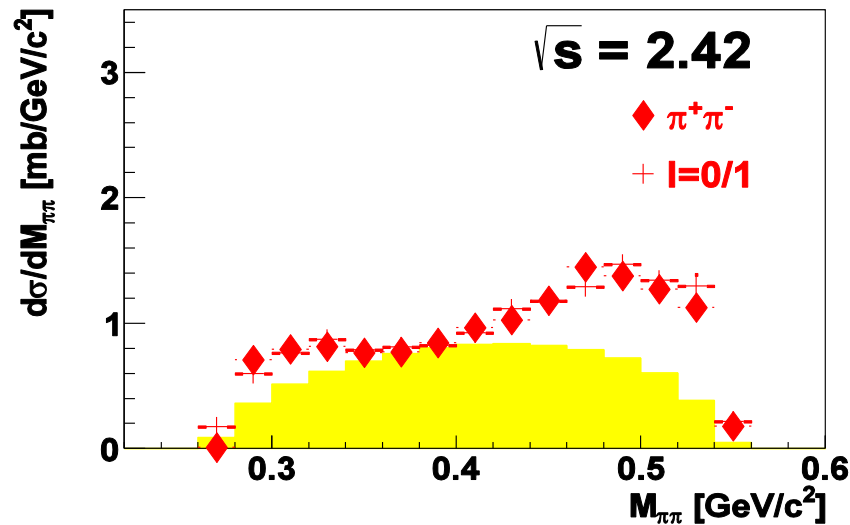
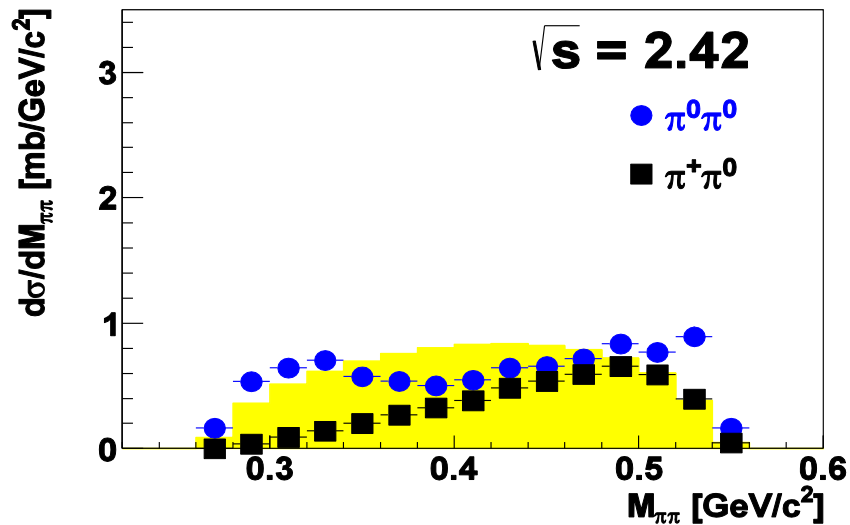




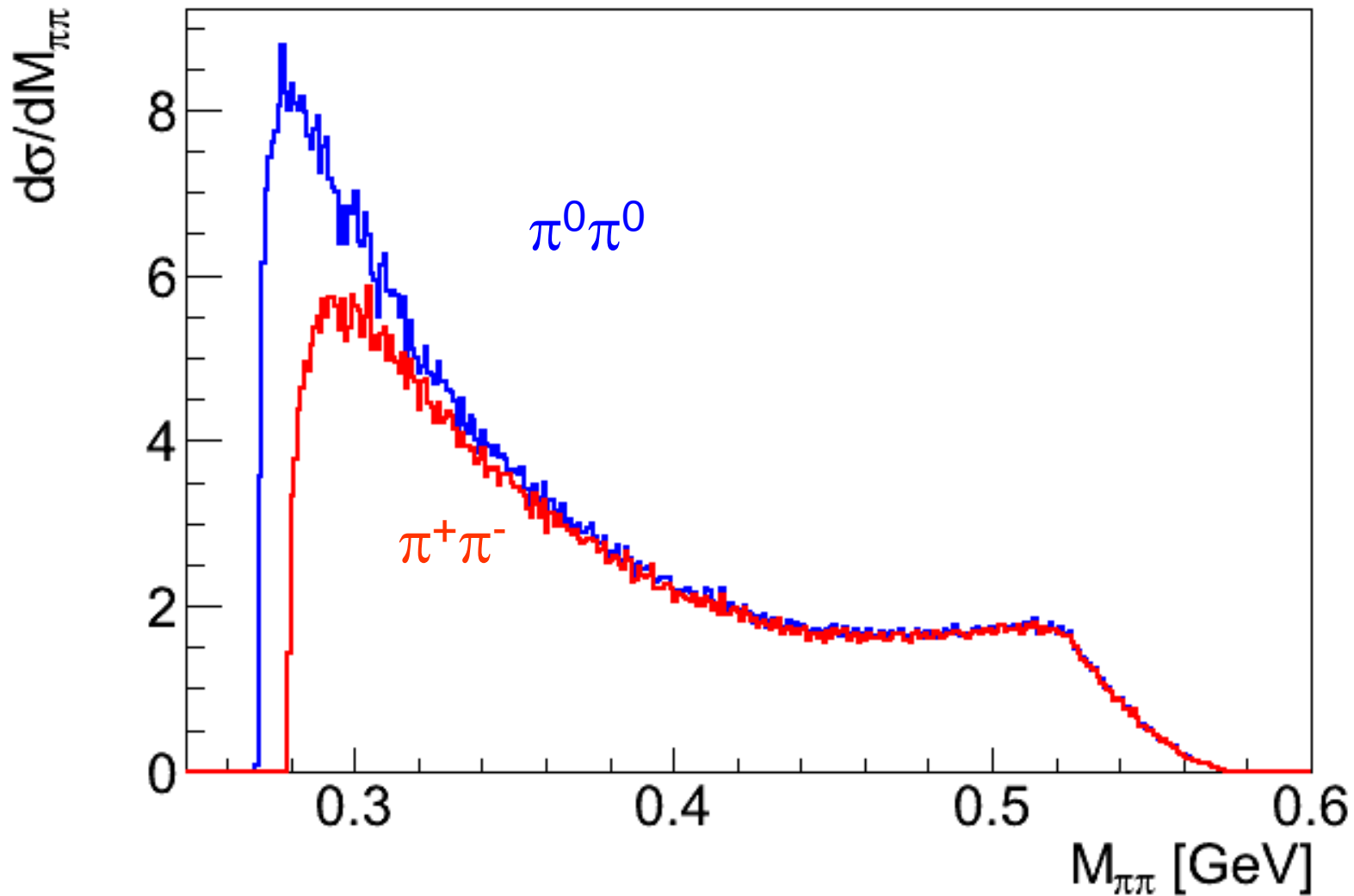
# $M_{\pi\pi}$ in $pN \rightarrow d\pi\pi$



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



# Isospin violation



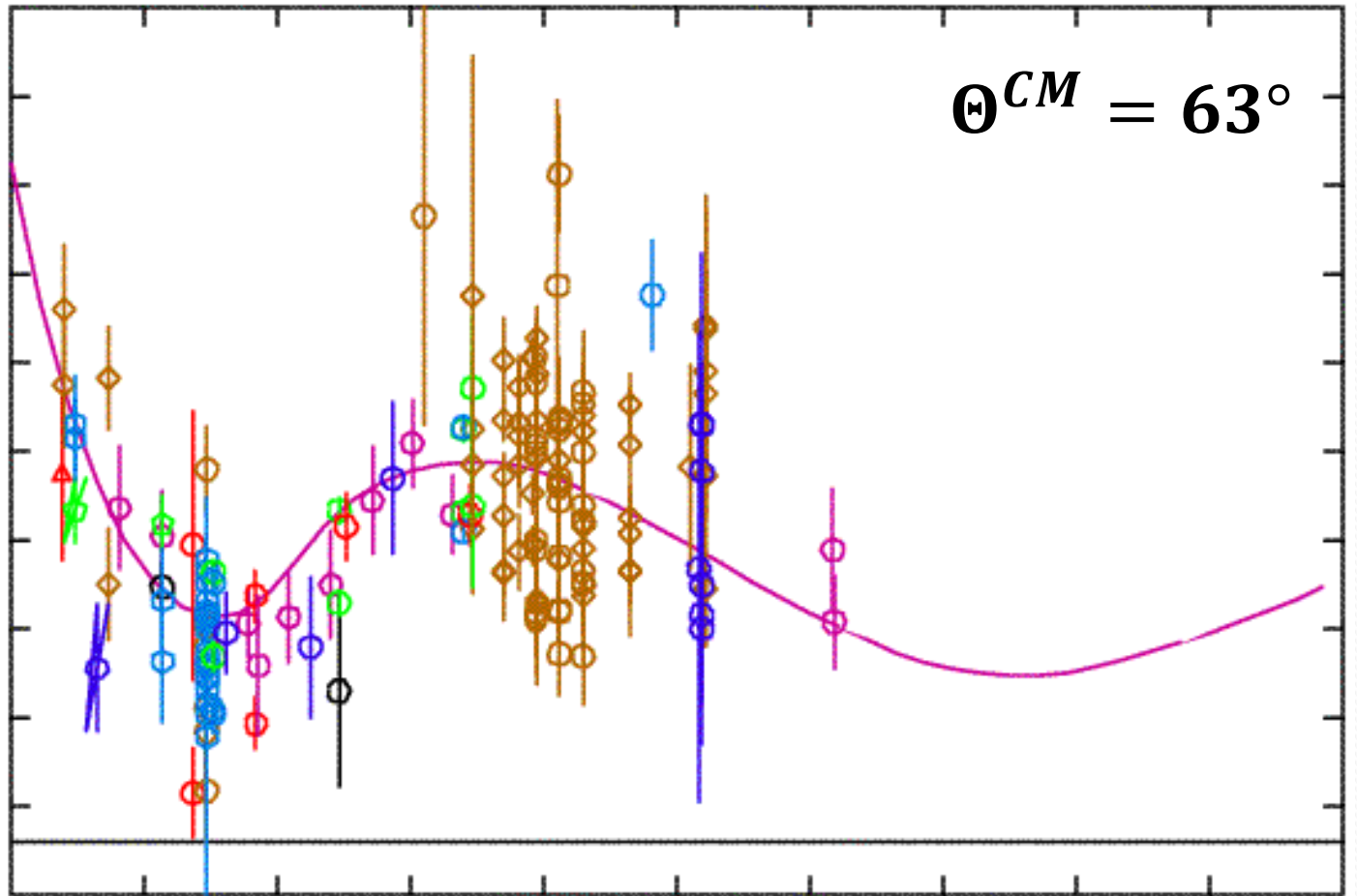
# pn Vector Analysing power

Plotted data is for ACM = 60.00 to ACM = 66.00

NP P ACM = 63.00 UN-Normalized

0.36

- △ - CH[57]1
- ◇ - BA[93]2
- - CL[80]
- - BA[89]
- - SI[56]1
- - NE[89]
- - WR[68]
- - AR[00]
- - BA[93]1
- - MC[93]
- - MC[96]
- - CH[67]
- - AH[98]
- - ZU[76]
- - GL[93]
- - SA[82]
- - EA[83]
- - MA[70]
- - LE[99]
- - NA[80]



$\theta^{CM} = 63^\circ$

2000.0

$W_{c.m.}$  (MeV)

2/28/13

2700.0

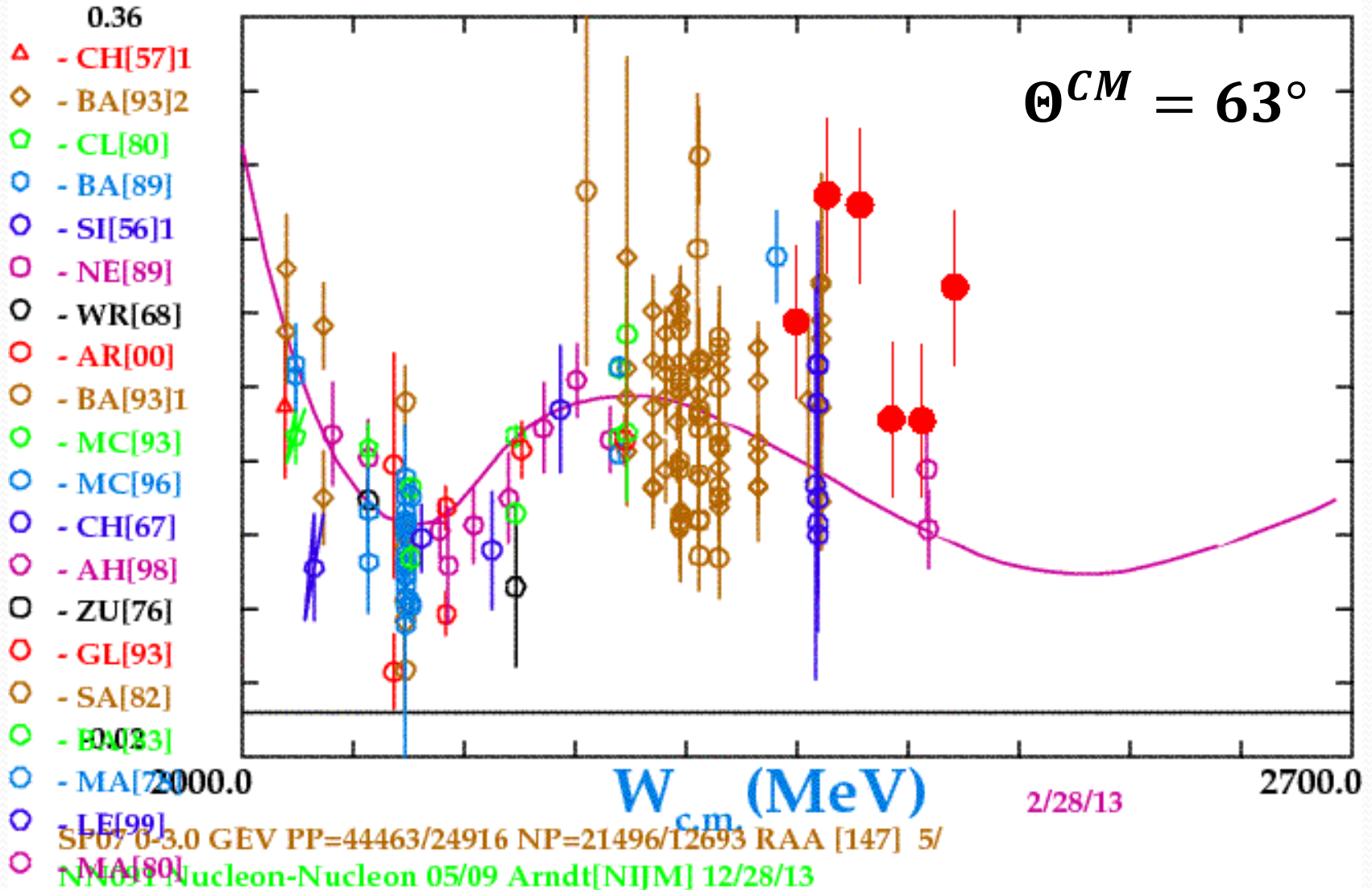
SP07 0-3.0 GEV PP=44463/24916 NP=21496/12693 RAA [147] 5/

NN09 Nucleon-Nucleon 05/09 Arndt[NIJM] 12/28/13

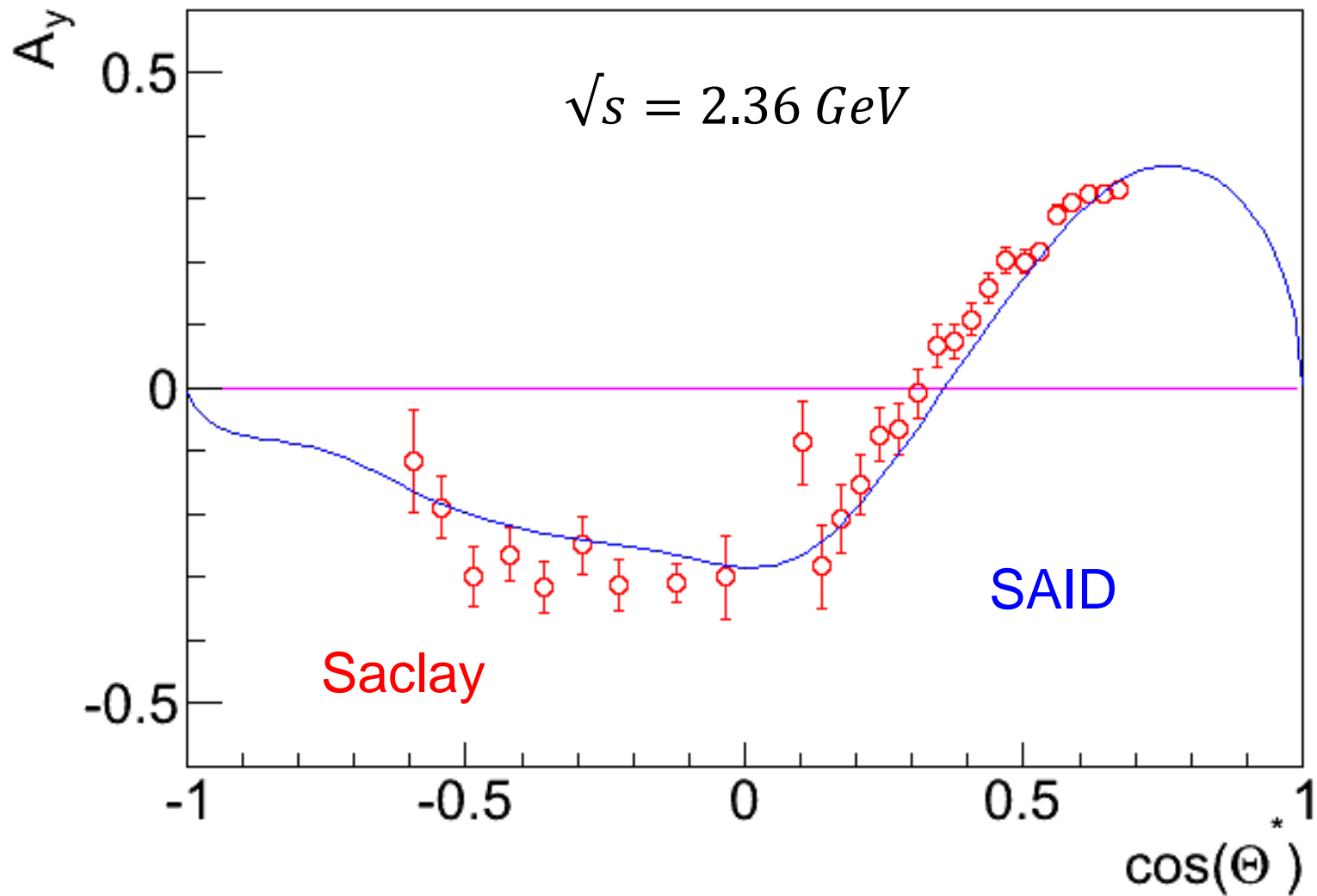
# pn Vector Analysing power

Plotted data is for ACM = 60.00 to ACM = 66.00

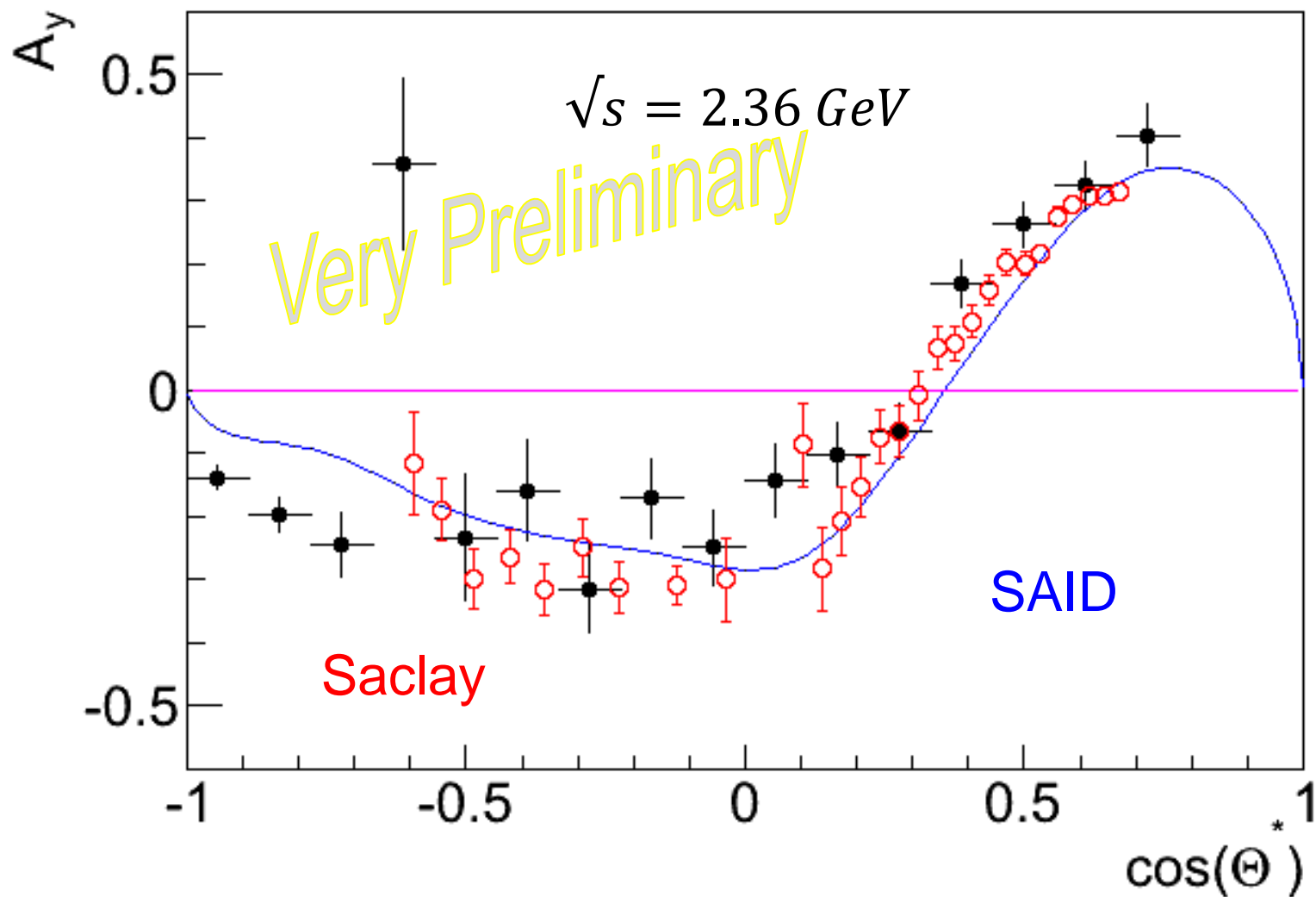
NP P ACM = 63.00 UN-Normalized



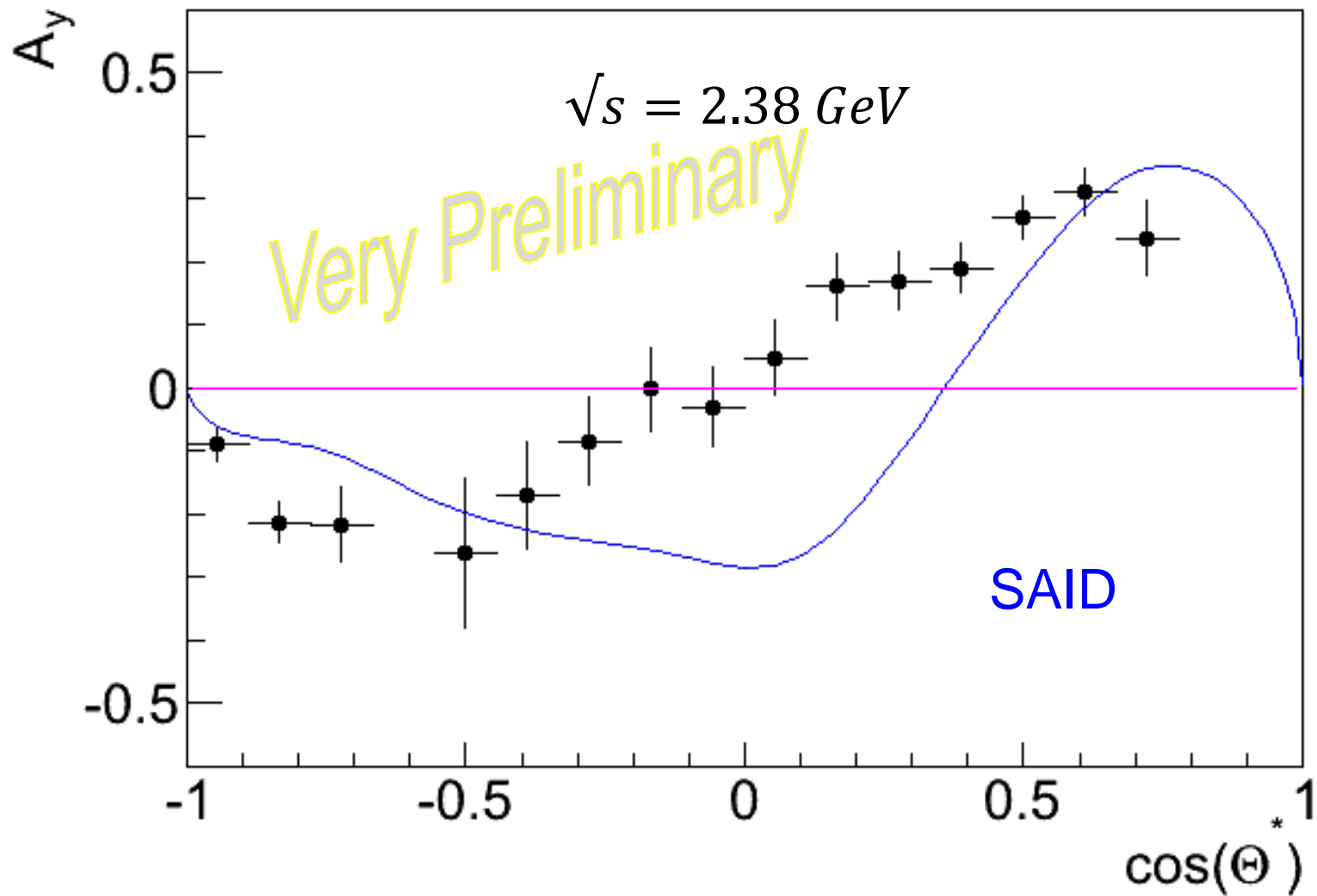
# pn Vector Analysing power



# pn Vector Analysing power

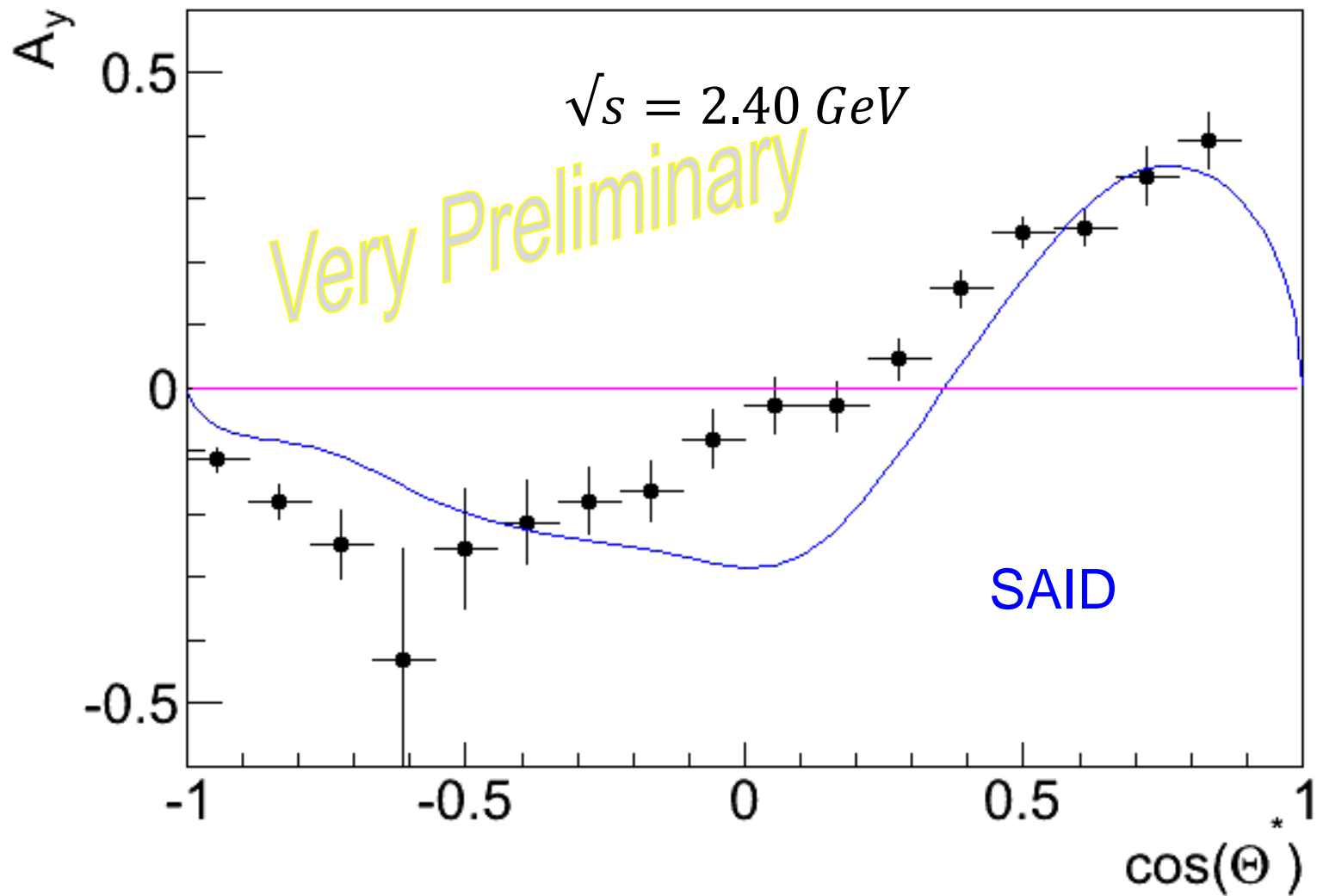


# pn Vector Analysing power

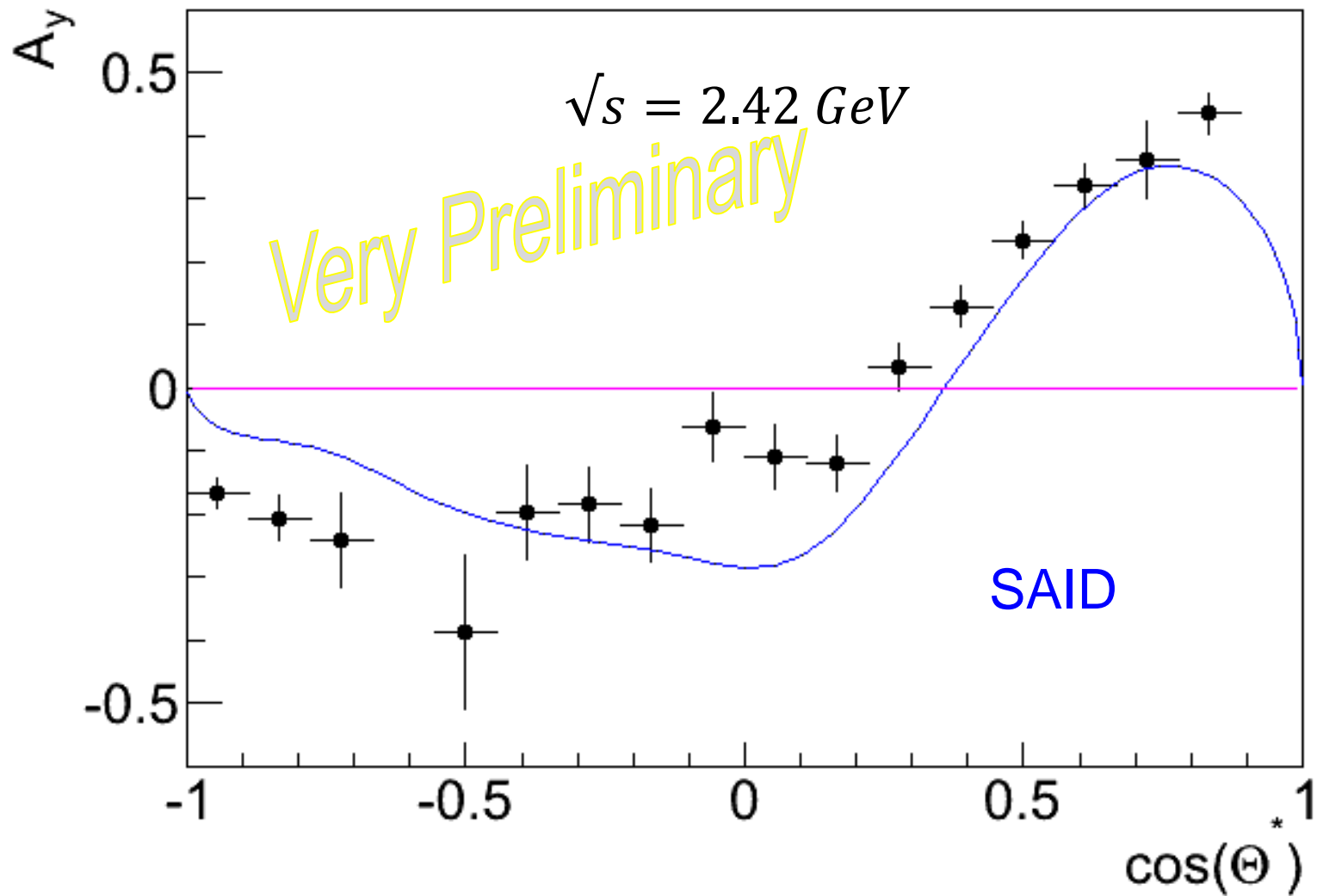




# pn Vector Analysing power

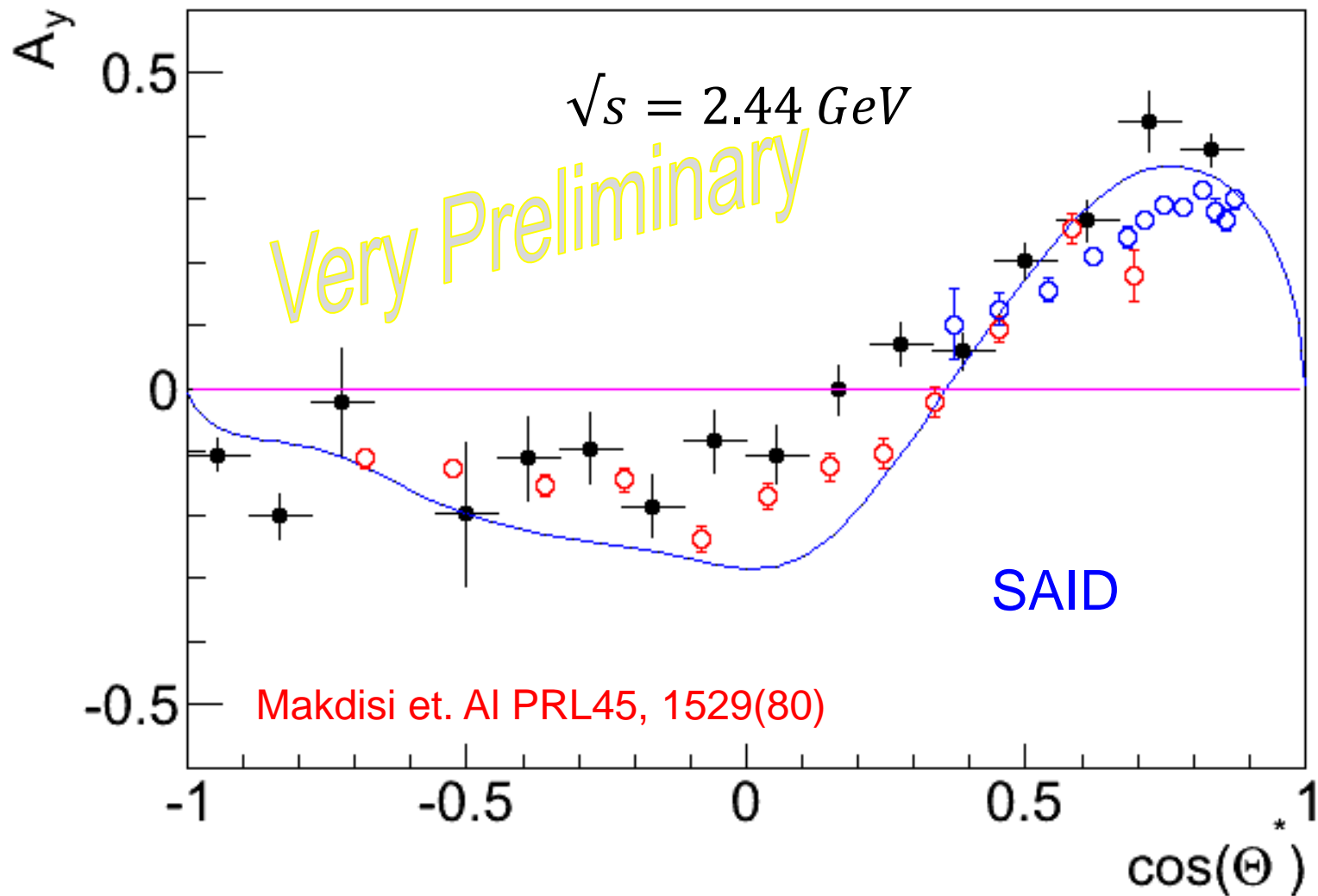


# pn Vector Analysing power



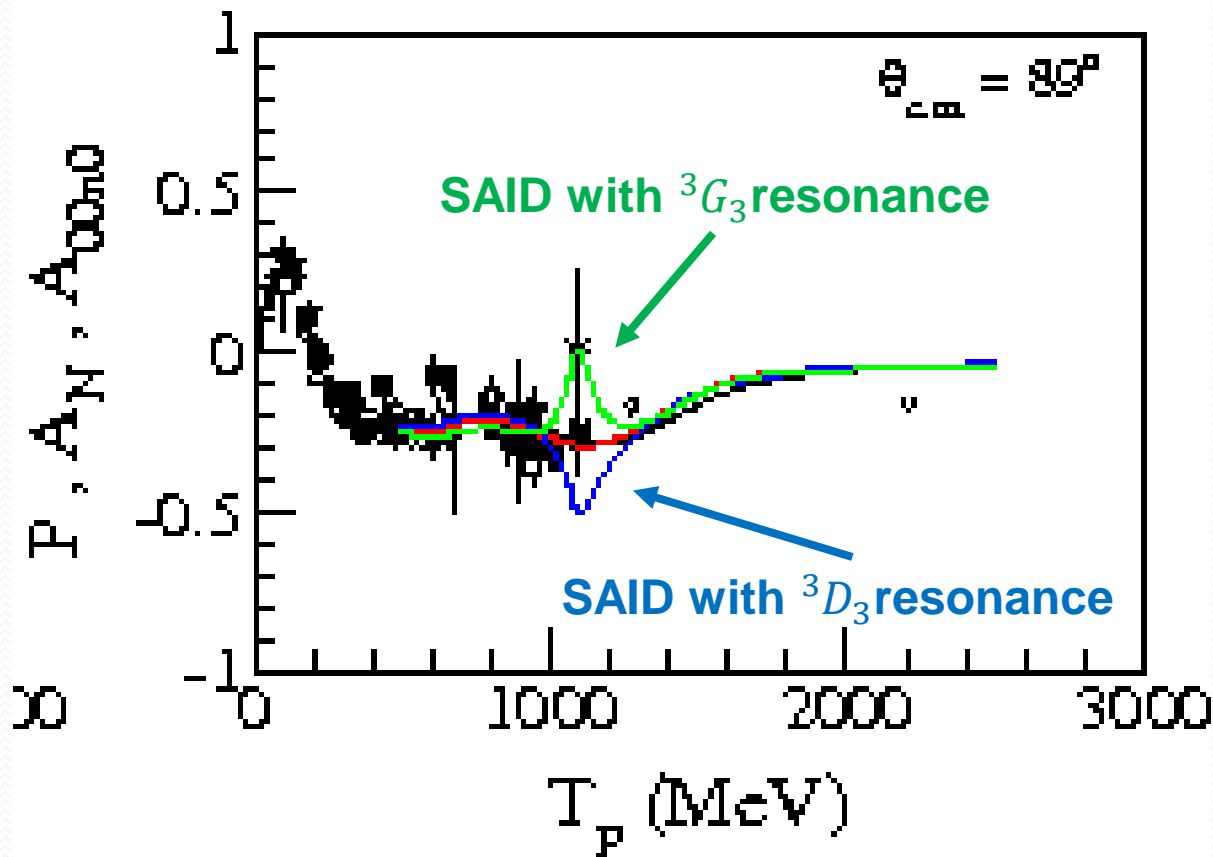
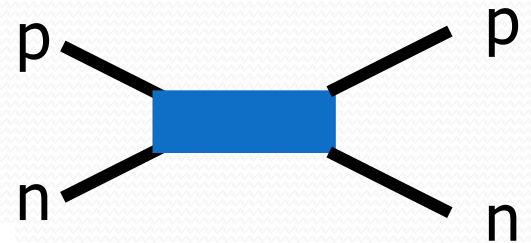
# pn Vector Analysing power

Diebold et. Al PRL35, 632(75)



# Expectations

$$pn \rightarrow R \rightarrow pn$$

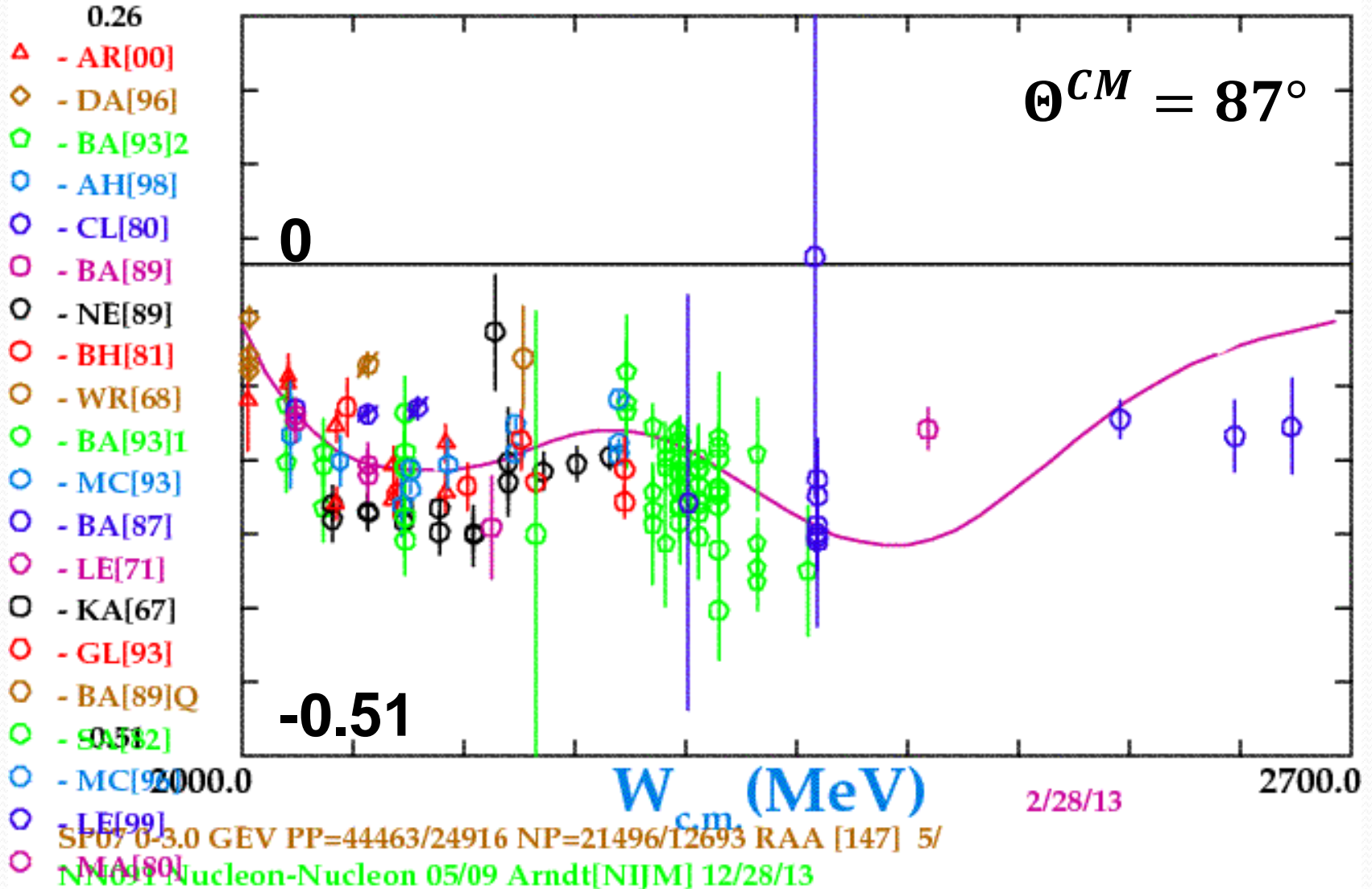


# pn Vector Analysing power

0.26

Plotted data is for ACM = 85.00 to ACM = 90.00

NP P ACM = 87.00 UN-Normalized



# pn Vector Analysing power

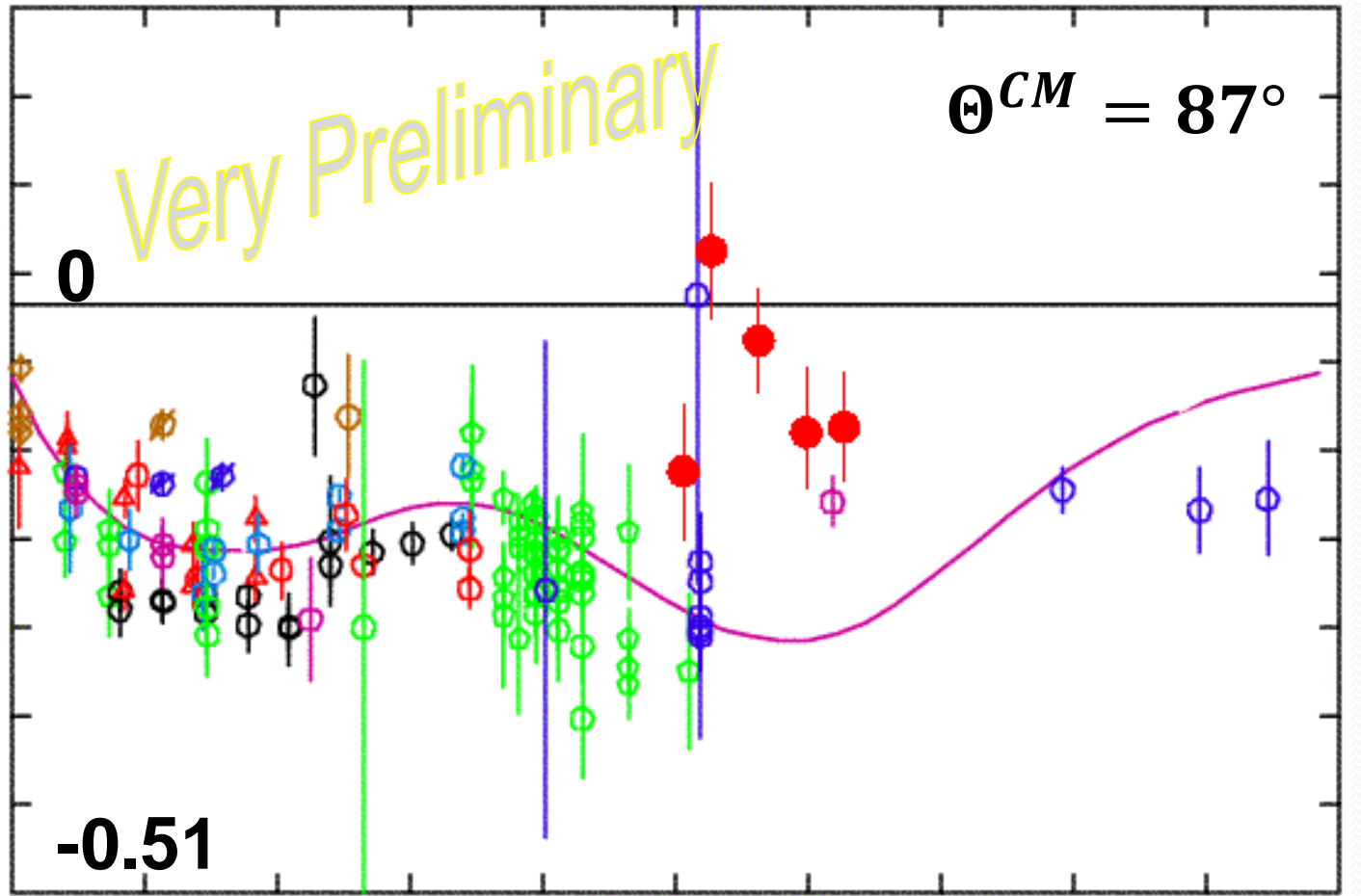
0.26

Plotted data is for ACM = 85.00 to ACM = 90.00

NP P ACM = 87.00 UN-Normalized

0.26

- △ - AR[00]
- ◇ - DA[96]
- ◊ - BA[93]2
- - AH[98]
- - CL[80]
- - BA[89]
- - NE[89]
- - BH[81]
- - WR[68]
- - BA[93]1
- - MC[93]
- - BA[87]
- - LE[71]
- - KA[67]
- - GL[93]
- - BA[89]Q
- - SA[58]
- - MC[92]
- - LE[99]
- - NA[80]



2000.0

$W_{cm}$  (MeV)

2/28/13

2700.0

SP07 0-3.0 GEV PP=44463/24916 NP=21496/12693 RAA [147] 5/  
 NN051 Nucleon-Nucleon 05/09 Arndt[NIJM] 12/28/13