The N(1440) Revisited Using SAID Facility

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Based on work in collaboration with
R. Arndt, W. Briscoe, R. Workman

- What we know about N(1440) [phenom/exp]
  - πN PWA
  - direct measurements
  - πPR PWA
- How much we can learn from πEPR PWA
- Summary

User Group Meeting 2005, June 22, 2005

N(1440) bio

- N(1440) was born in 1963 (M = 1485 MeV)

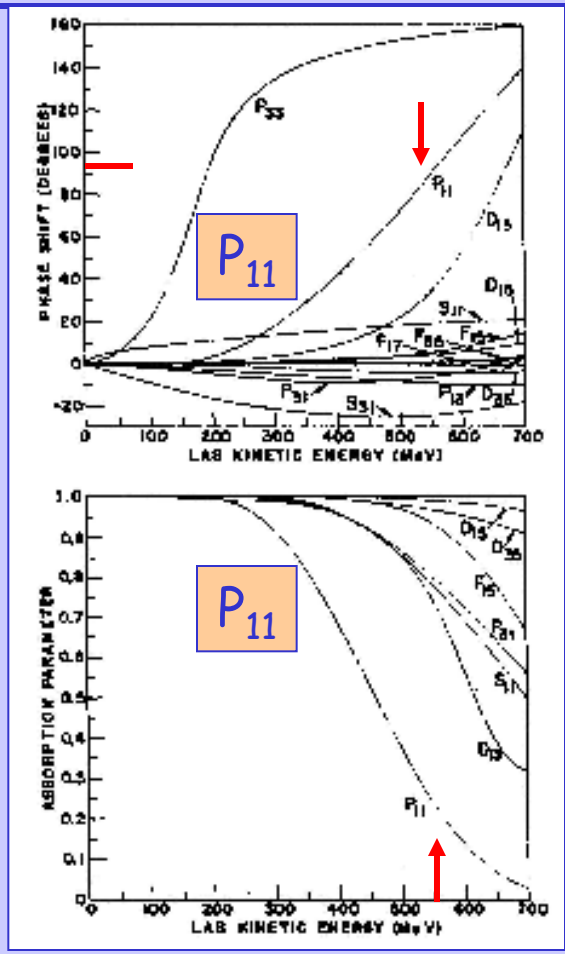
  [B.T. Feld and L.D. Roper, Proc of the Siena Intern Conf on Elem Part (Italian Phys Soc, Bologna, Italy, 1963), p. 400]

- The first official report is

  [L.D. Roper, Phys Rev Lett **12**, 340 (1964)]

- More bio details are in

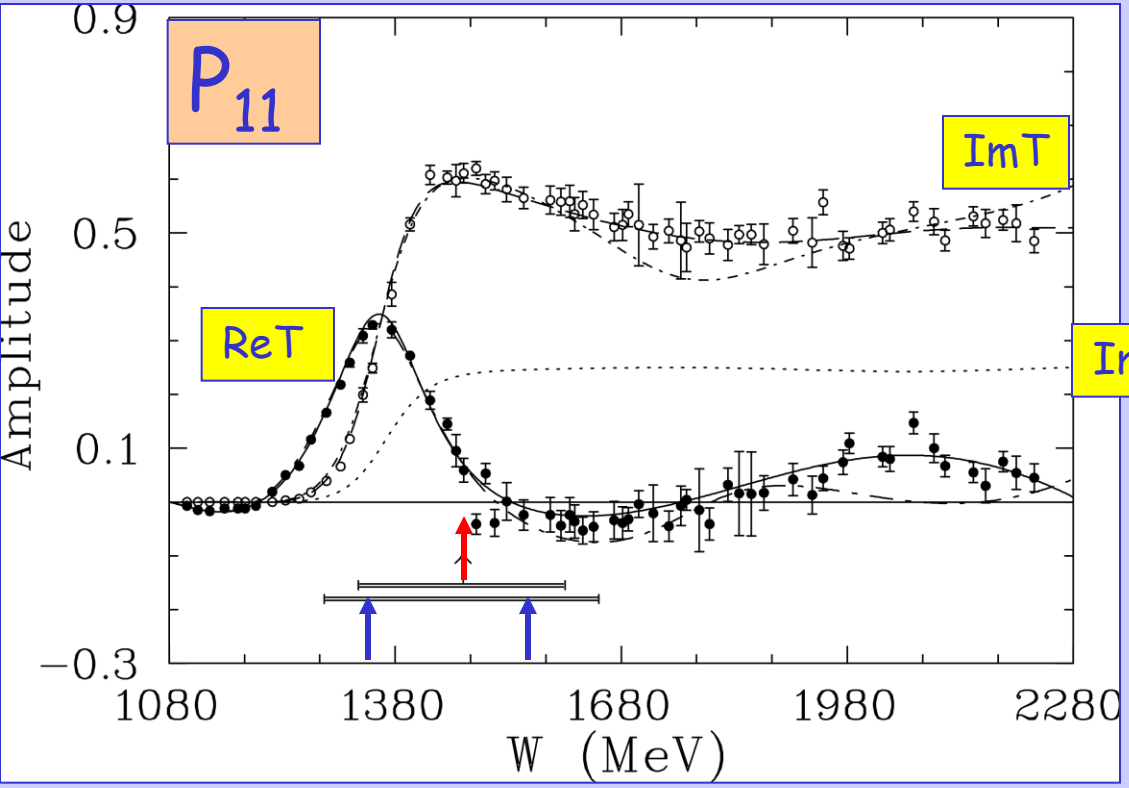
  [http://arts.bev.net/roperldavid/roperres.htm]



$N(1440)P_{11}$ within πN PWA

[R. Arndt, W. Briscoe, IS, R. Workman, M. Pavan, Phys Rev C **69**, 035208 (2004)]

- One of the most convincing ways to study N*s and Δ*s is πN PWA

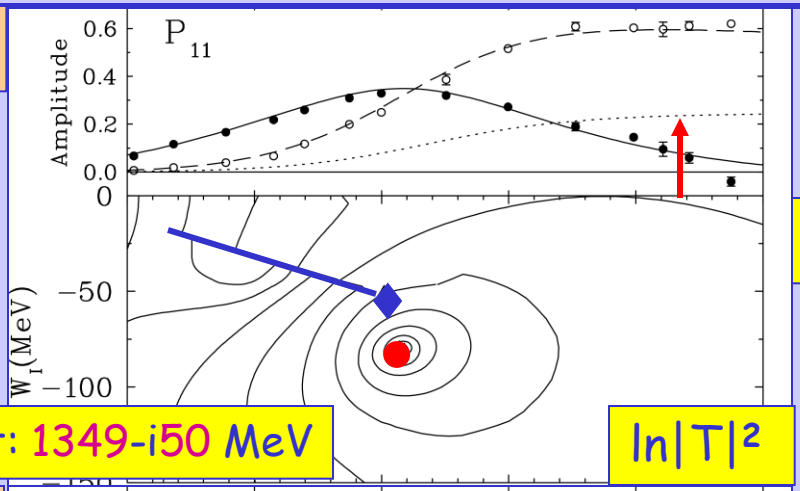


ImT-T*T < ImT [unitarity limit]

- BW: **M** = 1468±4.5 MeV
  Γ/2 = 180±13 MeV
  X = 0.750±0.024

Complex Energy Plane for P_{11}

1st sheet

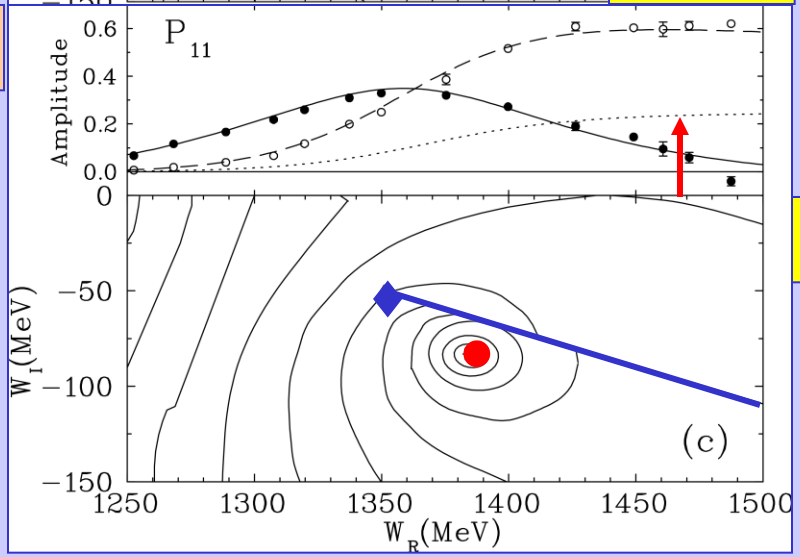


Pole : 1357-i80 MeV

Branch point: 1349-i50 MeV

ln|T|²

2nd sheet

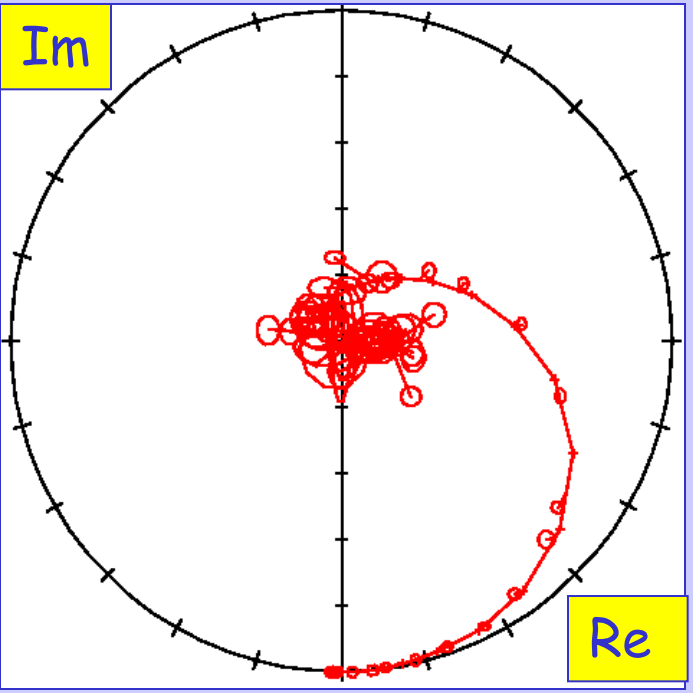


Pole: 1385-i83 MeV

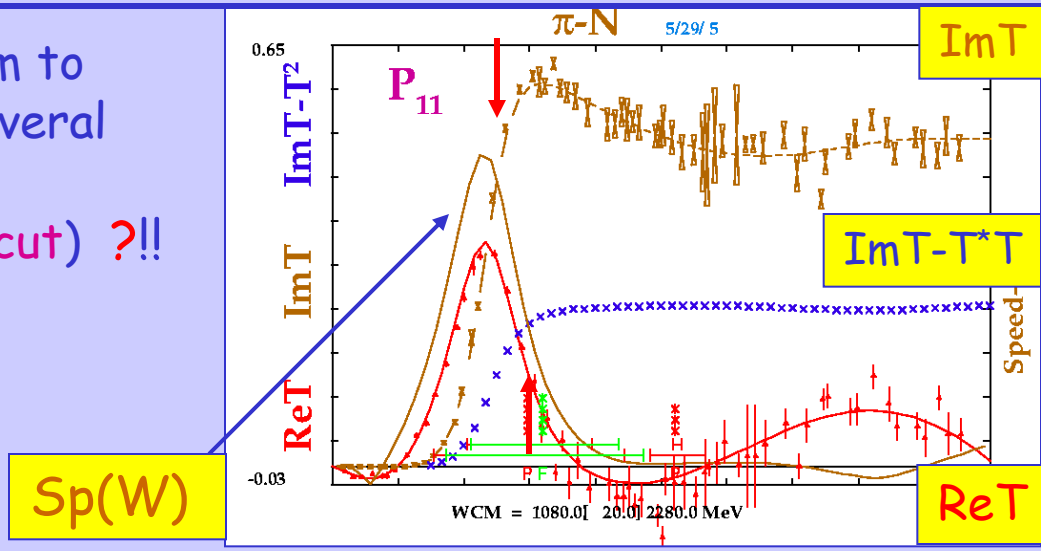
- ● - Pole of the P_{11} amplitude
- ◆ - Branch point [πΔ threshold]
- ——— - πΔ branch cut

P_{11} via Argand and Speed plots

- Is standard BW an appropriate form to extract N(1440) from the set of several nearby singularities (2 poles and $\pi\Delta$ branch point with a very prominent cut) ?!!



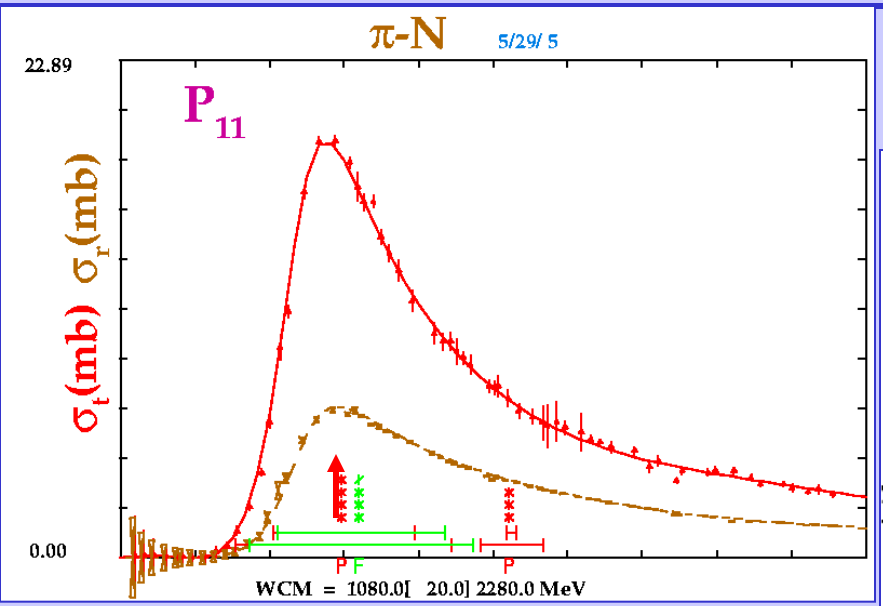
W = 1080 [20] 2280 MeV



- Sp(W) = |dT/dW|
  - ⟶ peak at W=M (pole)
  - at NR ⟶ 0

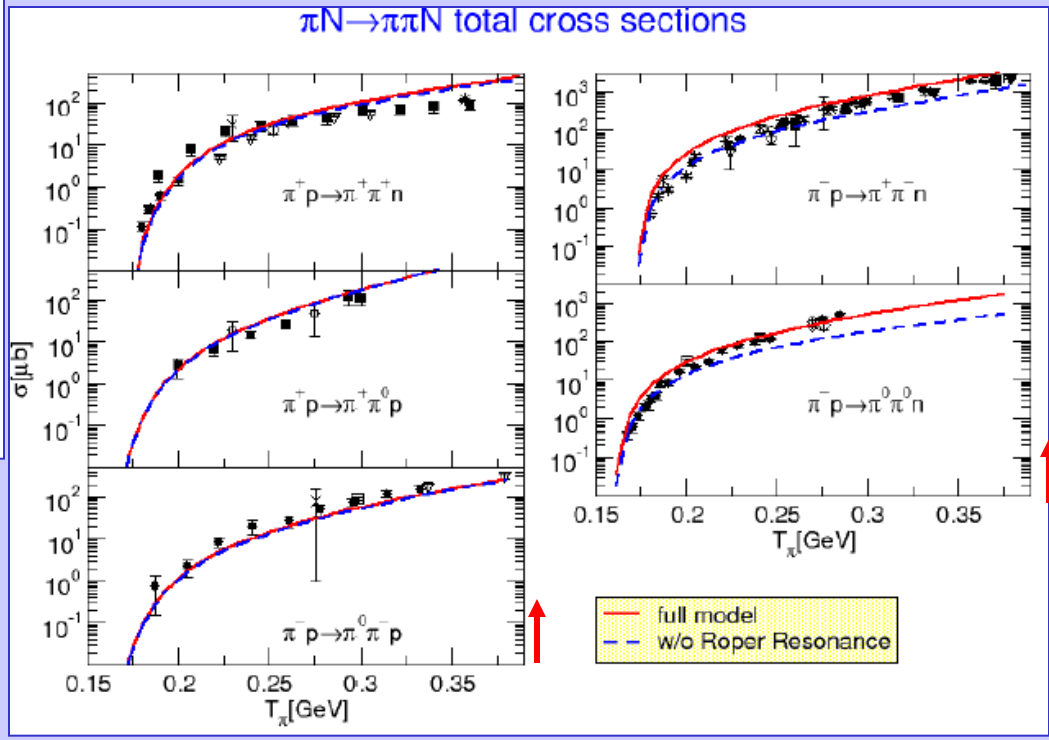
[G. Hoehler,]

Inelastic πN→ππN



- For P_{11}, $\sigma_r \sim \sigma_e$ (X=0.75)
- ηN does not help because N(1440) is below thr

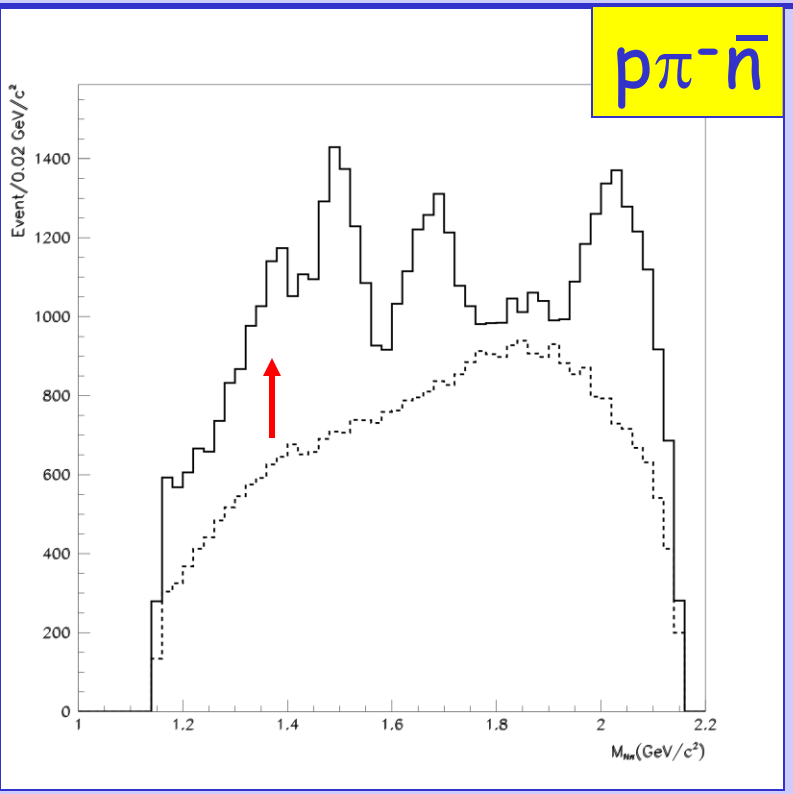
- S. Schneider and S. Krewald [Bad Honnef, July 2003]

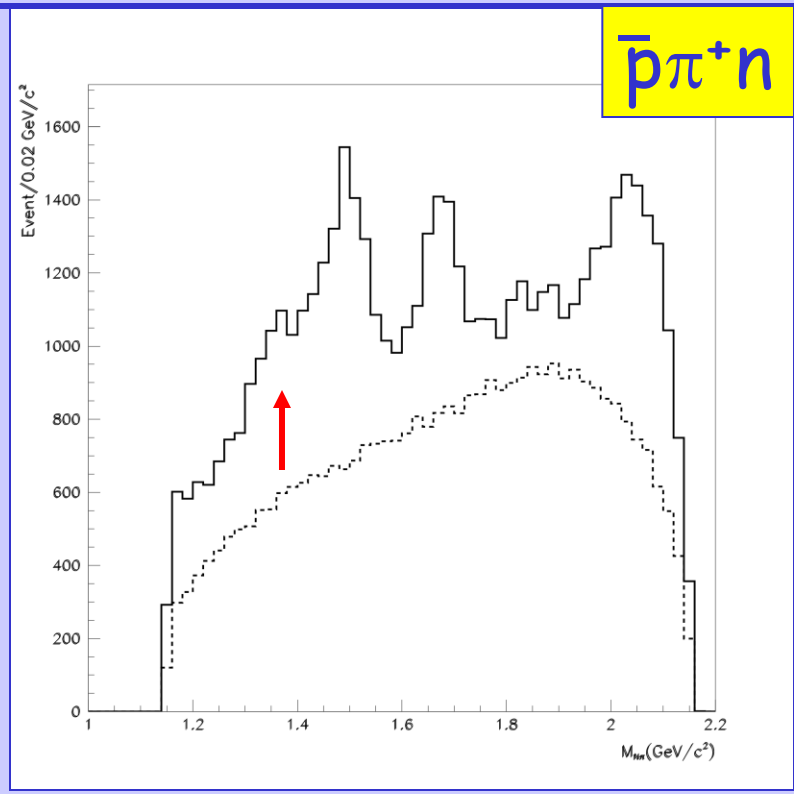


- $\pi^-p \to \pi^+\pi^-n$ and $\pi^0\pi^0n$ are essential but not critical

Direct Measurement: $e^+e^- \to J/\psi \to p\pi^-\bar{n} + \bar{p}\pi^+n$

[M. Ablikim *et al.* (BES Collaboration), hep-ex/0405030]



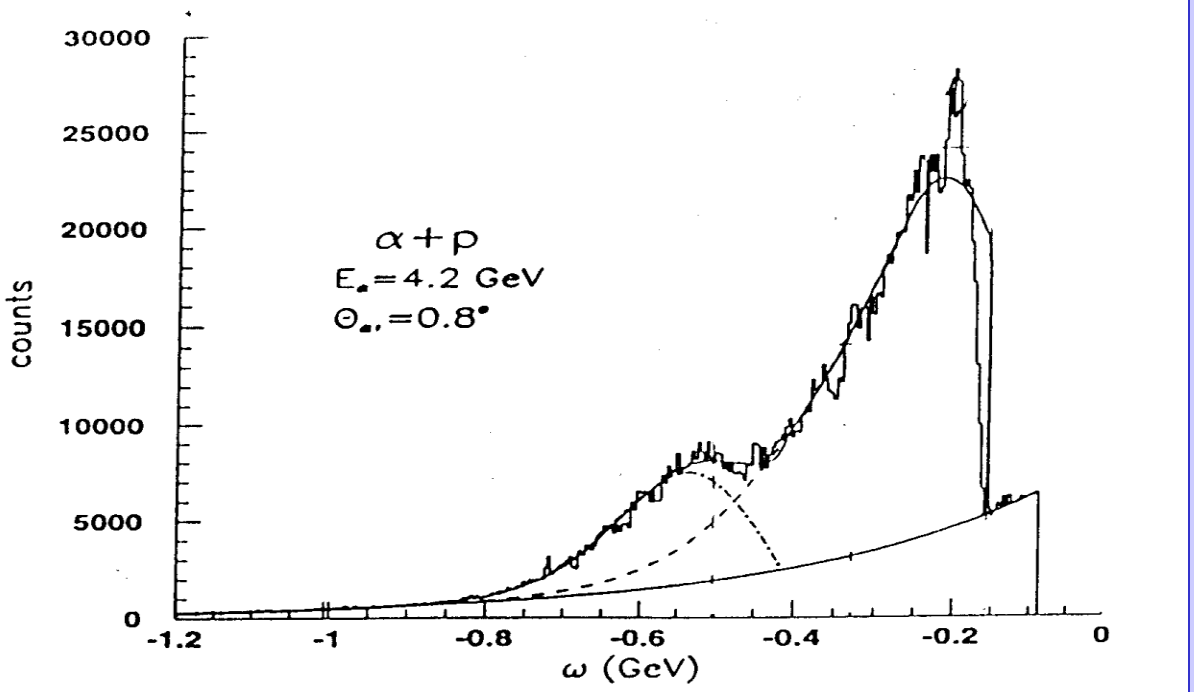


- PWA: $J^P=1/2^+$
  $M=1358\pm 6\pm 16$ MeV
  $\Gamma= 179\pm 26\pm 50$ MeV

- Looks similar as pole in πN

Direct Measurement at SATURNE II: αp→α'X

[H.P. Morsch and P. Zupranski, Phys Rev C **61**, 024002 (2000)]



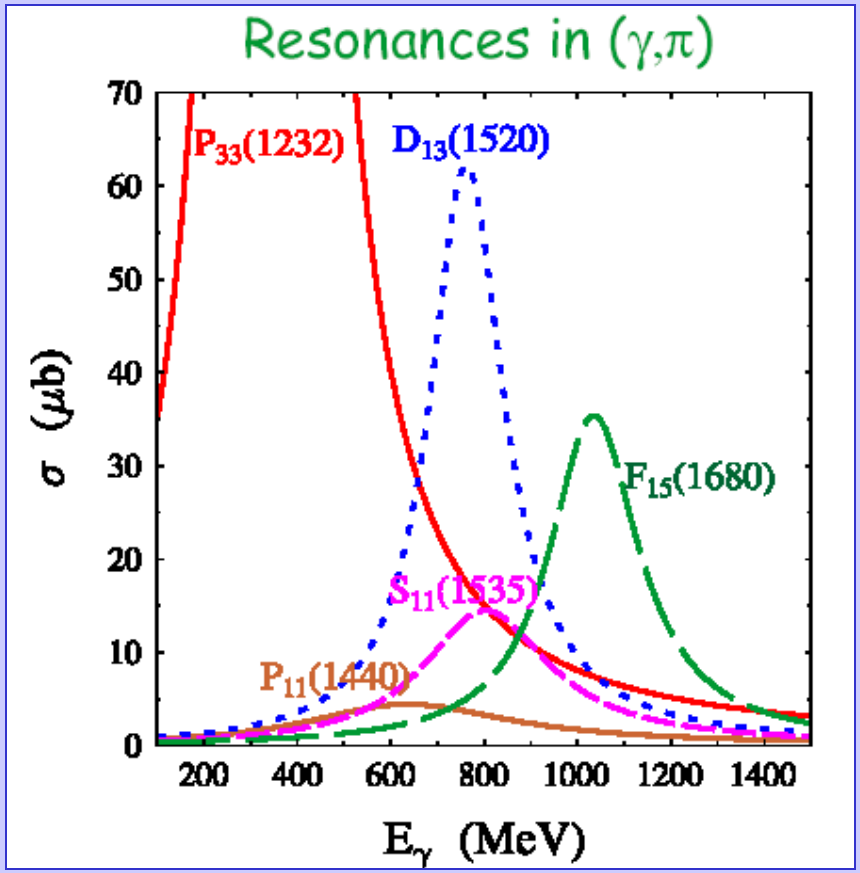
$\omega = E_{\alpha'} - E_{\alpha}$

- M=1390±20 MeV
  Γ= 190±30 MeV

- Looks similar as pole in πN

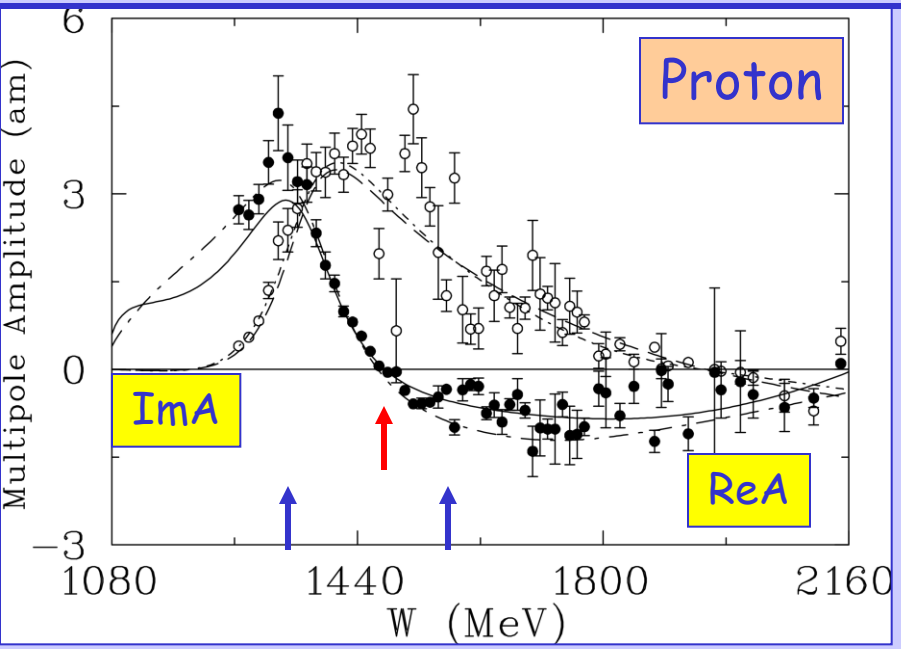
N(1440) within πPR PWA

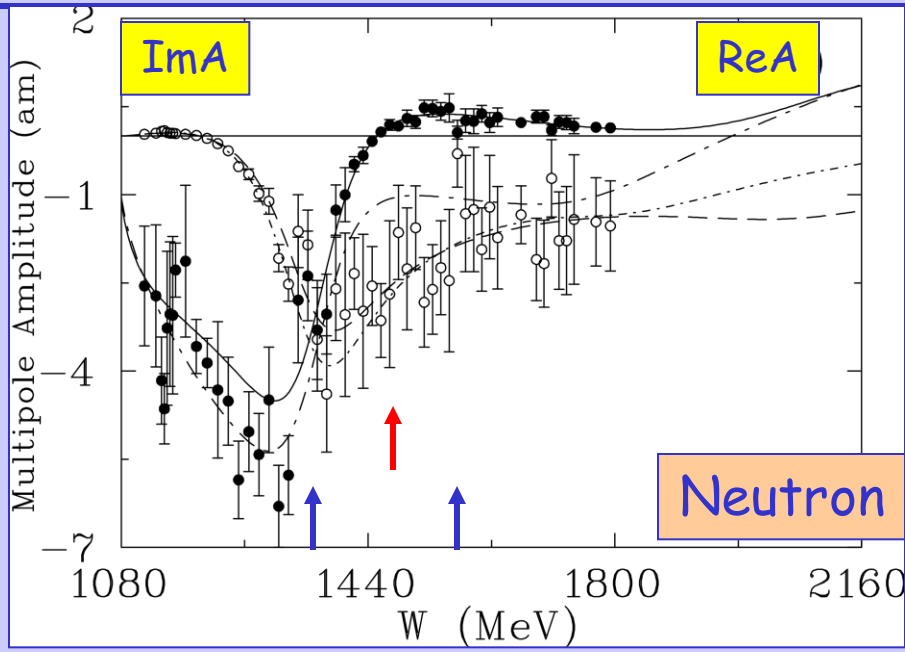
[R. Arndt, W. Briscoe, IS, R. Workman, Phys Rev *C* **66**, 055213 (2002)]



- P_{11} is less prominent within dominant waves

P_{11} ($M_{1-}^{1/2}$) within πPR PWA





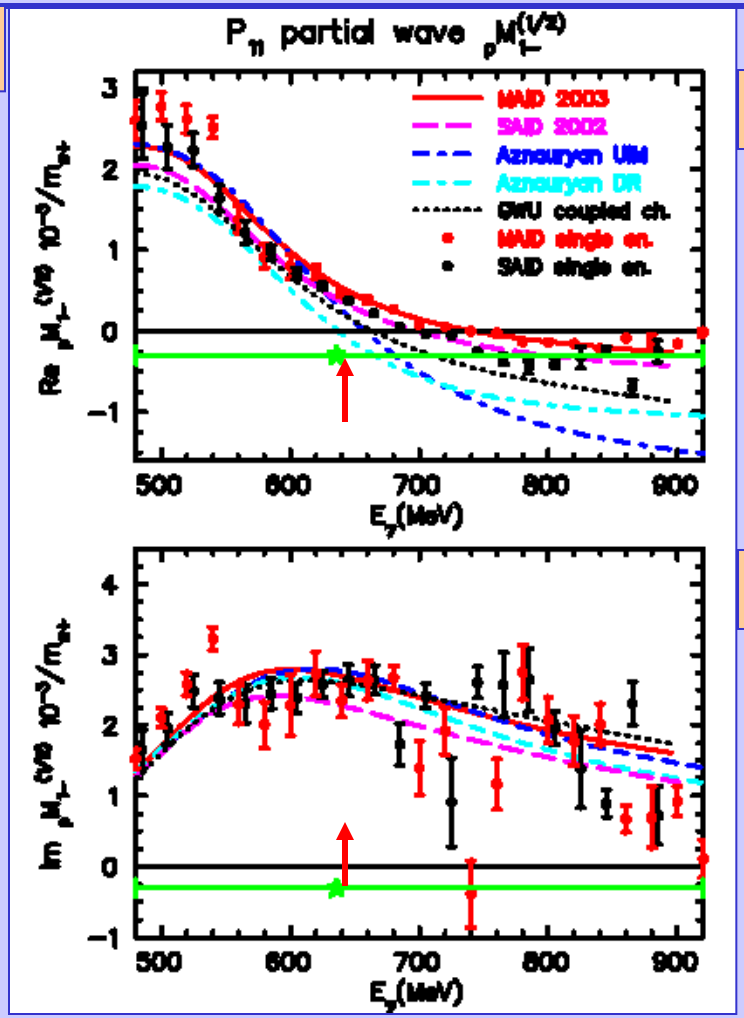
- ${}_pA_{1/2}$=-67±2 10^{-3} $GeV^{-1/2}$
  PDG =-65±4

- ${}_nA_{1/2}$= 47± 5 10^{-3} $GeV^{-1/2}$
  PDG = 40±10

P_{11} ($M_{1-}^{1/2}$) in Different Approaches

[L. Tiator *et al.* Nstar2004, March 2004]

Magnetic

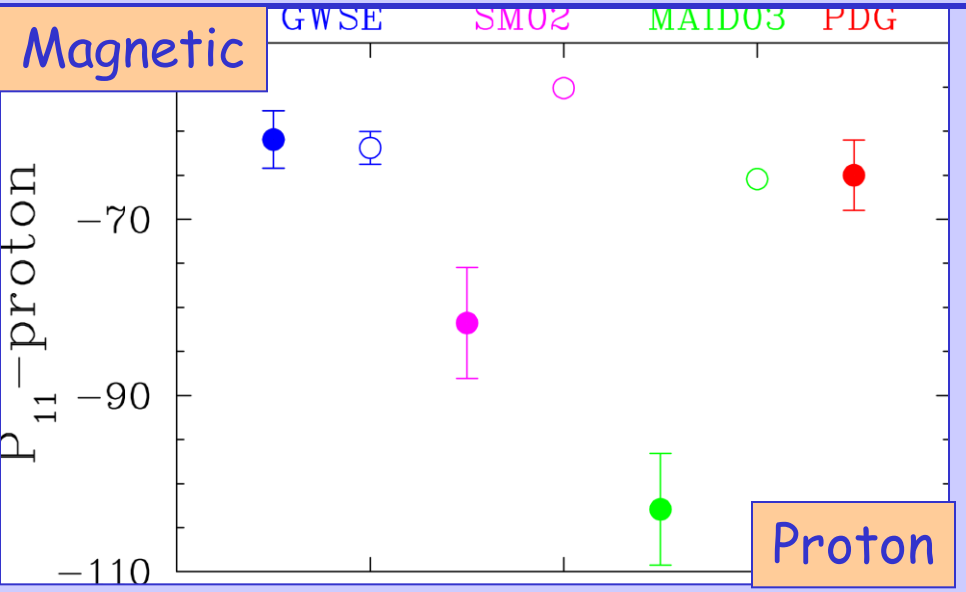


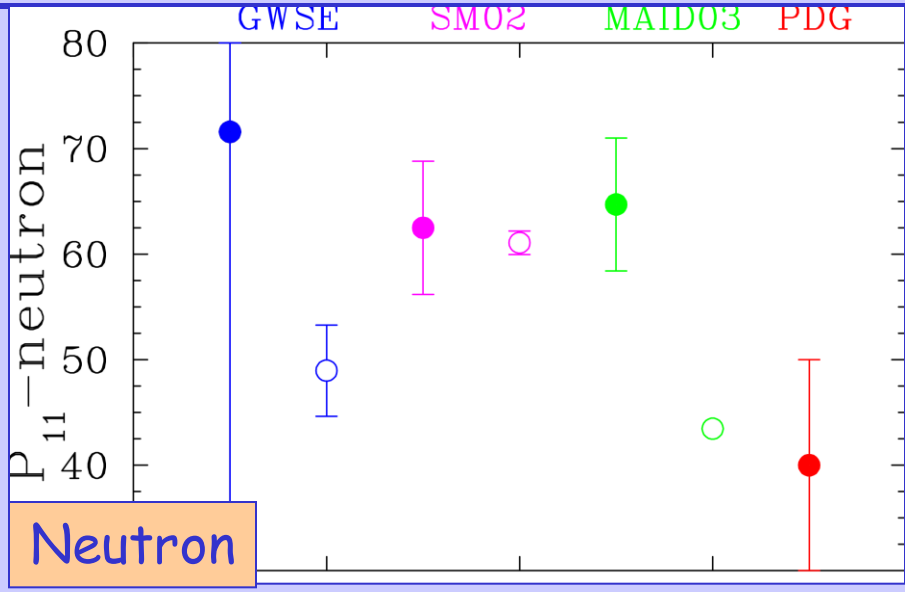
ReA

ImA

Sensitivity of the EM Couplings Extraction

[R. Arndt, W. Briscoe, IS, R. Workman, L. Tiator, in progress]





W = 1350 – 1550 MeV

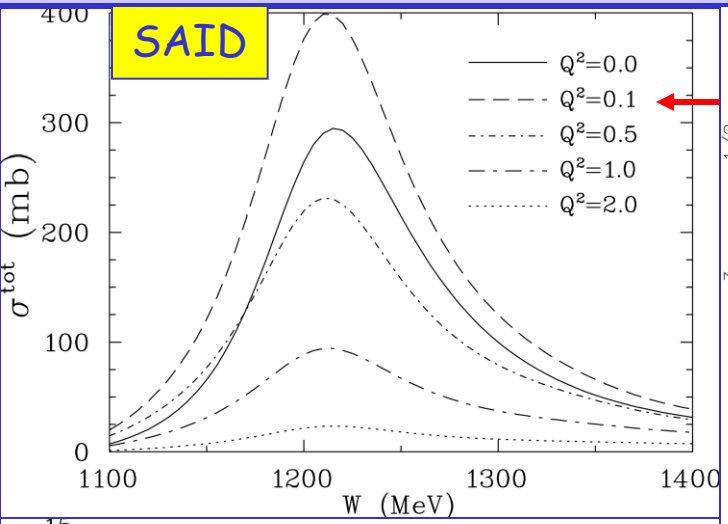
- A-form: $T=(1+it_{\pi N})(Born+A)+Rt_{\pi N}+(C+iD)(Imt_{\pi N}-|t_{\pi N}|^2)$
- C-form: $T=(1+it_{\pi N})(Born+A)+Rt_{\pi N}e^{i\phi}$

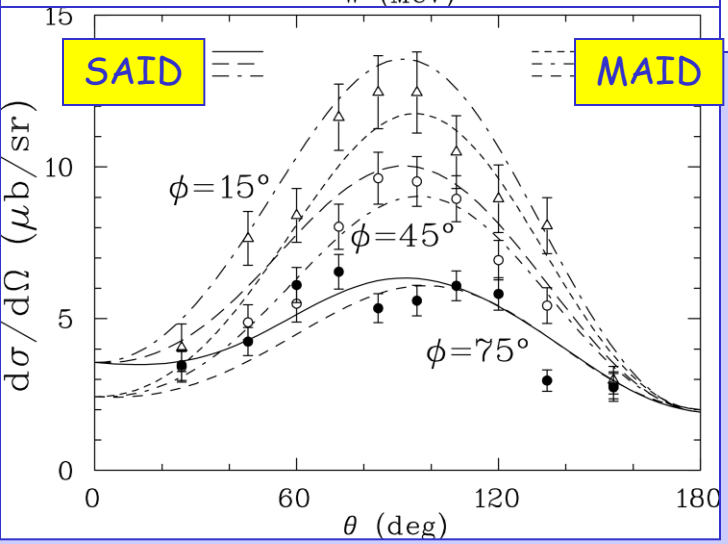
Some Conclusion about Sensitivity

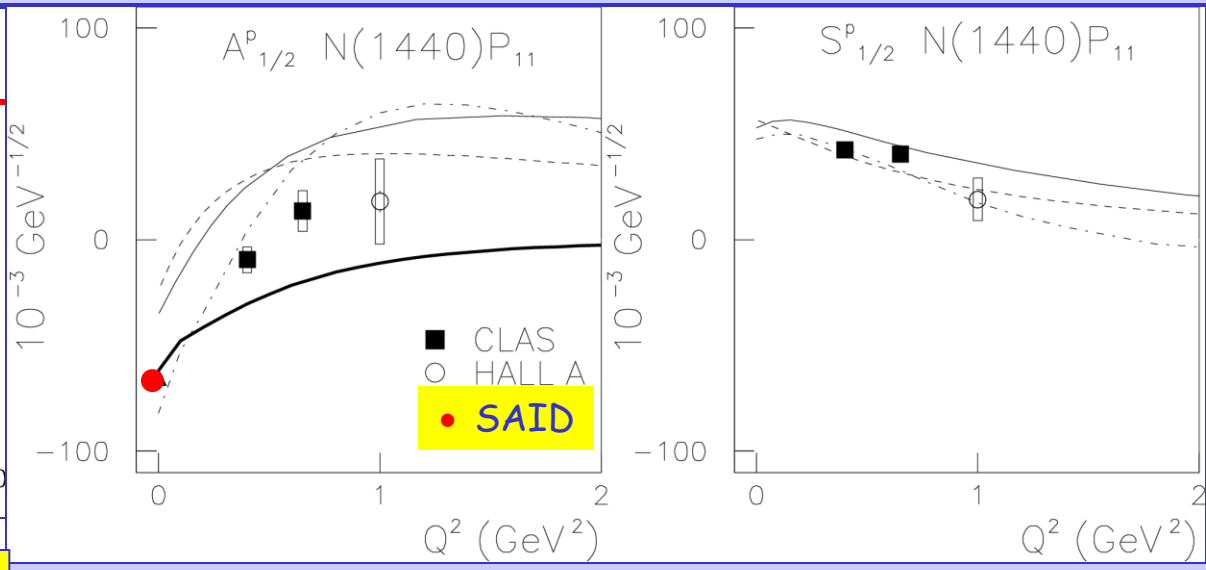
- PionPR does allow to determine EM couplings at fixed M, Γ, and X came from πN PWA
- Uncertainties of EM couplings depend from:
  - W range used in the BW fit (same as in πN PWA)
  - NR parameterization
  - Fitting procedure (data, amps, *etc*)
  - Exp data errs (both stat and syst)

$\pi^0 p$ Xsection variations within πEPR

[R. Arndt, W. Briscoe, IS, R. Workman, Nstar2002, Oct 2002]







CLAS: [K. Joo *et al*/ nucl-ex/0504027]

CLAS: W = 1300 MeV Q^2 = 0.4 GeV^2

[K. Joo *et al*/ PRL **88**, 122001 (2002)]

JLab Hall A proposal PR-05-010

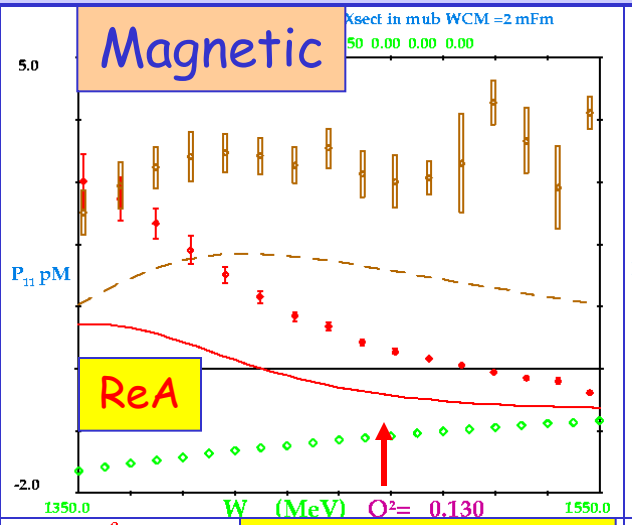
Structure of the Roper resonance from measurements of the double-polarization $p(\vec{e}, e'\vec{p})\pi^0$ reaction

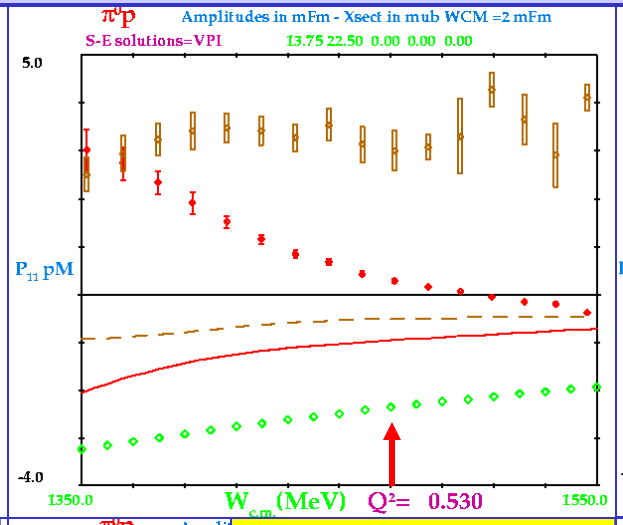
- W = 1380 – 1500 MeV
  Q^2 = 0.13 – 0.93 GeV^2
  Θ = 180^0 [parallel kinematics for the proton]

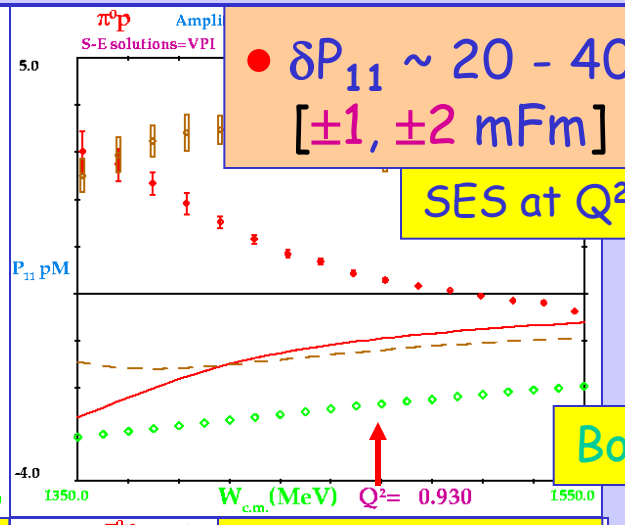
  Observables: P_y, P_x/h, and P_z/h [about 50data]
  Systematics = 3%

P_{11} ($M_{1-}^{1/2}$ and $S_{1-}^{1/2}$) within πEPR

[R. Arndt, W. Briscoe, IS, R. Workman, in progress]



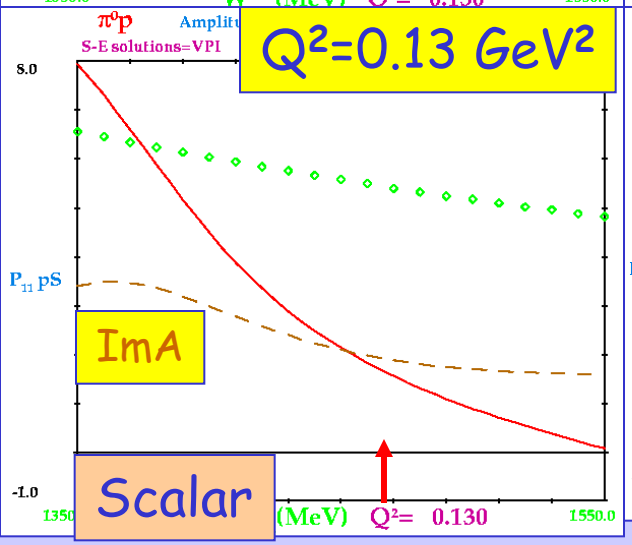


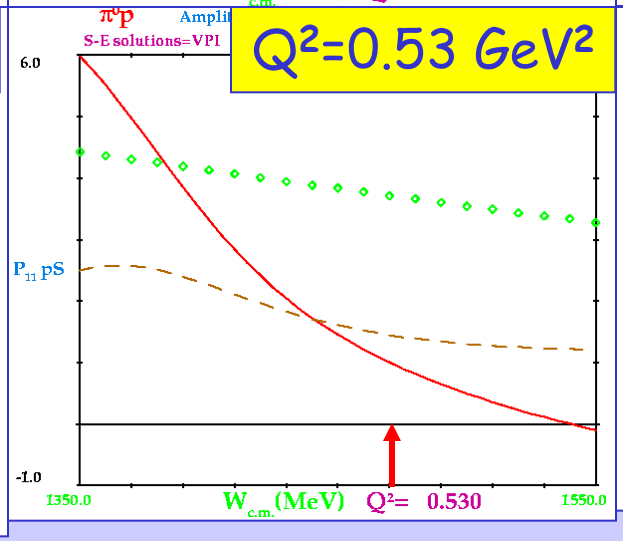


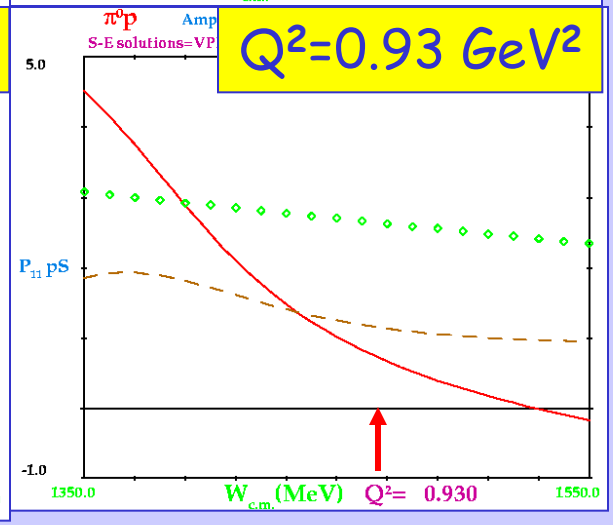
- δP_{11} ~ 20 - 40% [±1, ±2 mFm]

SES at Q^2=0

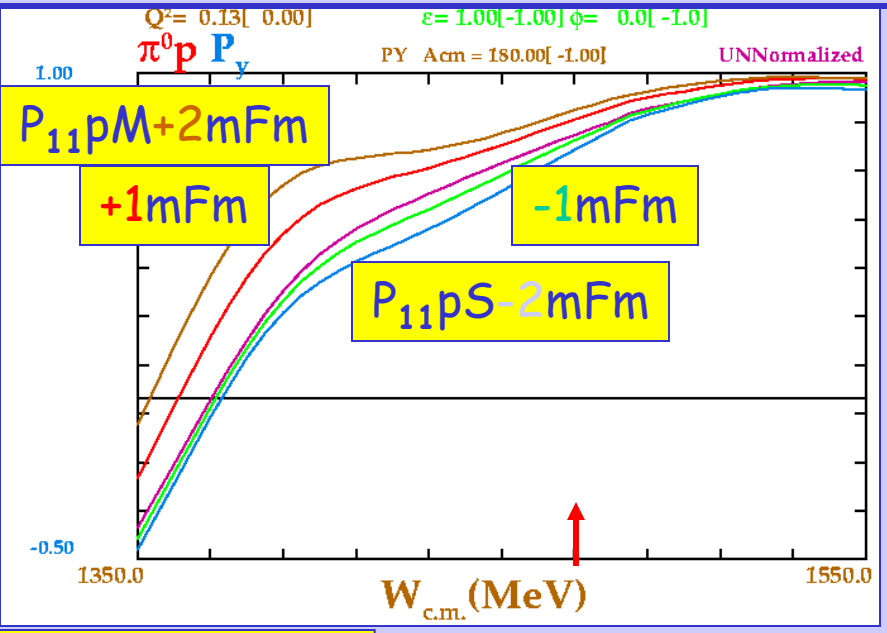
Born



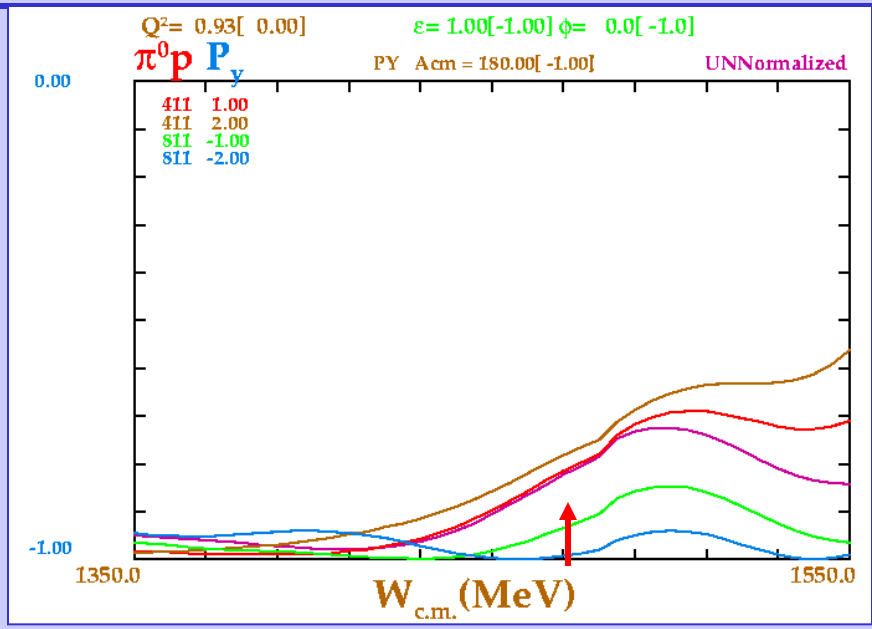




P_y vs P_{11} ($M_{1-}^{1/2}$ and $S_{1-}^{1/2}$)



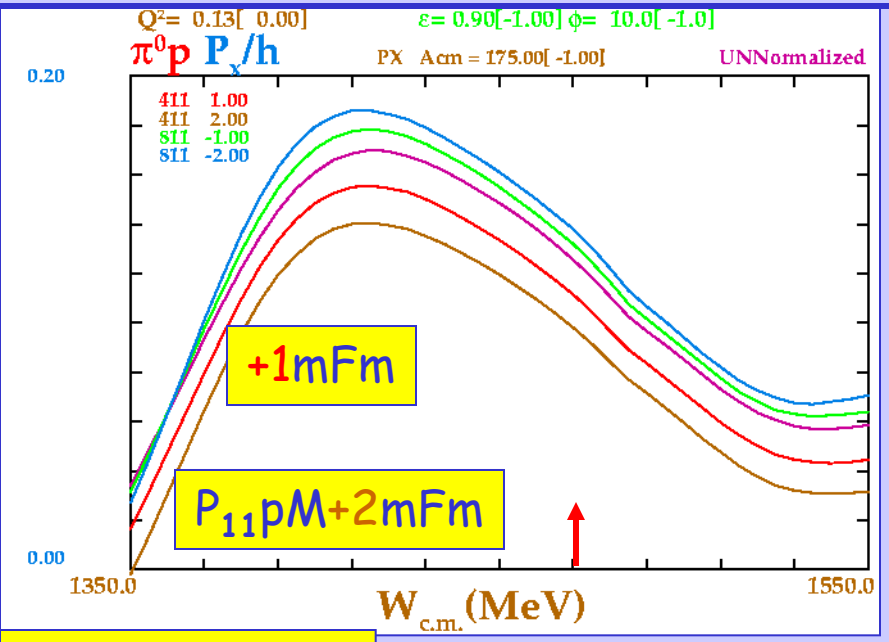
Q²=0.13 GeV²



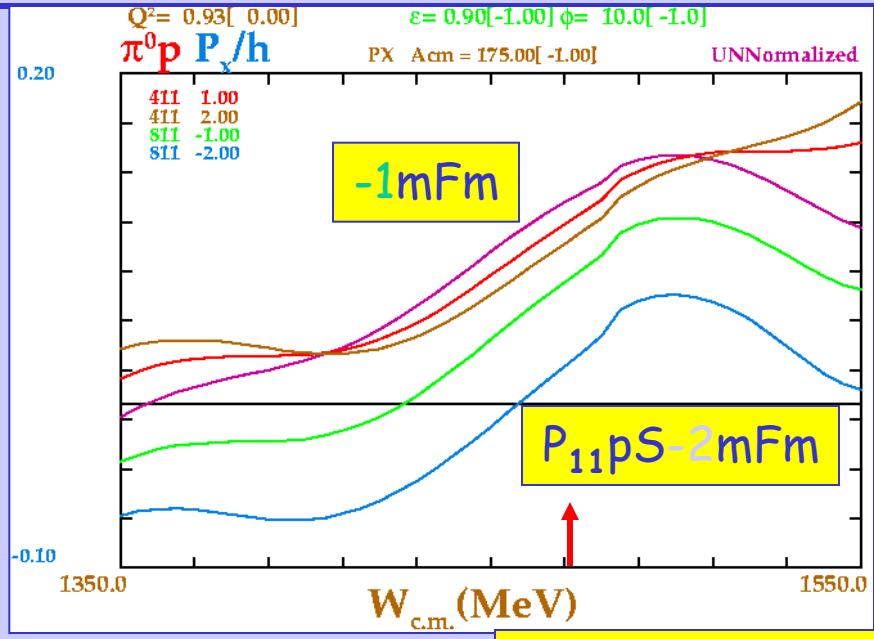
Q²=0.93 GeV²

- P_y at low W is sensitive to small Q^2
  high W is sensitive to large Q^2
- Scalar is less sensitive than magnetic
- Expected $\Delta Py = 0.02$

P_x/h vs P_{11} ($M_{1-}^{1/2}$ and $S_{1-}^{1/2}$)



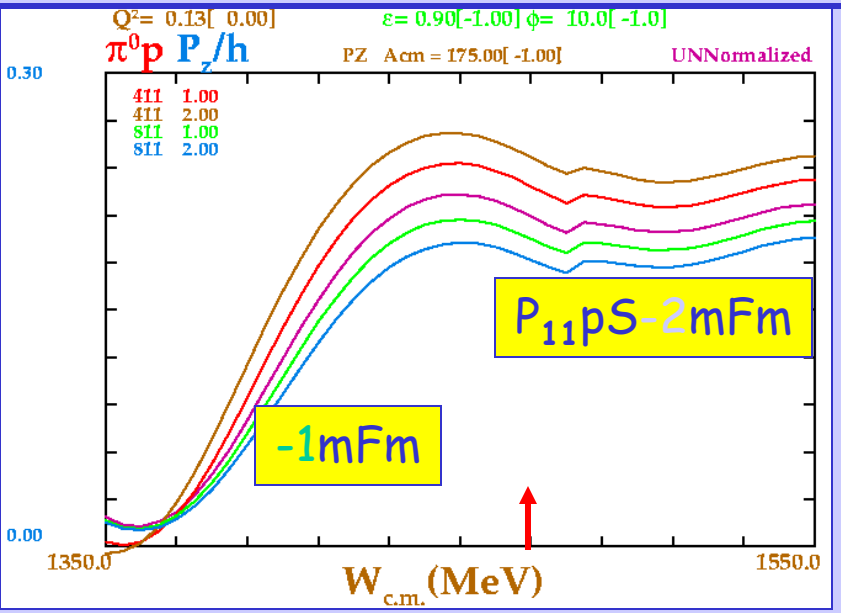
Q^2=0.13 GeV²



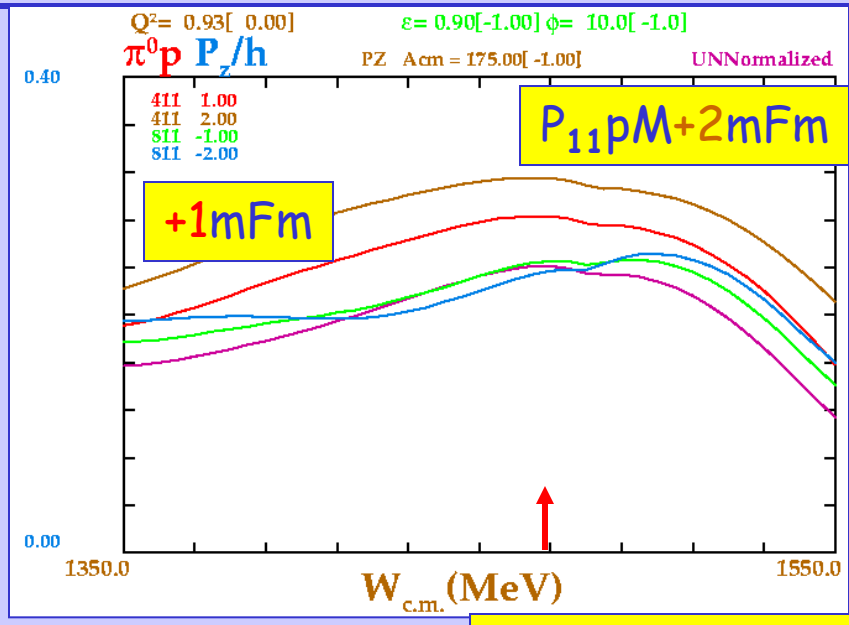
Q^2=0.93 GeV²

- Scalar is less sensitive than magnetic at low Q^2
- Expected $\Delta P_x/h$ = 0.01-0.02

P_z/h vs P_{11} ($M_{1-}^{1/2}$ and $S_{1-}^{1/2}$)



Q^2=0.13 GeV²



Q^2=0.93 GeV²

- P_z/h is less sensitive vs P_y and P_x/h
- Expected $\Delta P_z/h$ = 0.01-0.07

Summary

- Huge amount (more than 45 k data) of CLAS πEPR data included unpol and both single and double pol measurements is a critical source to determine $A(W,Q^2)$ and N* EM couplings
- There is no chance to get a model independent info about neutron couplings at $Q^2 > 0$ because of lack of data
- Scalar component of P_{11} is less sensitive to the double pol measurements than magnetic in Q^2 dependence
- Each pole found at πN PWA can provide different Q^2 dependence in pionEPR

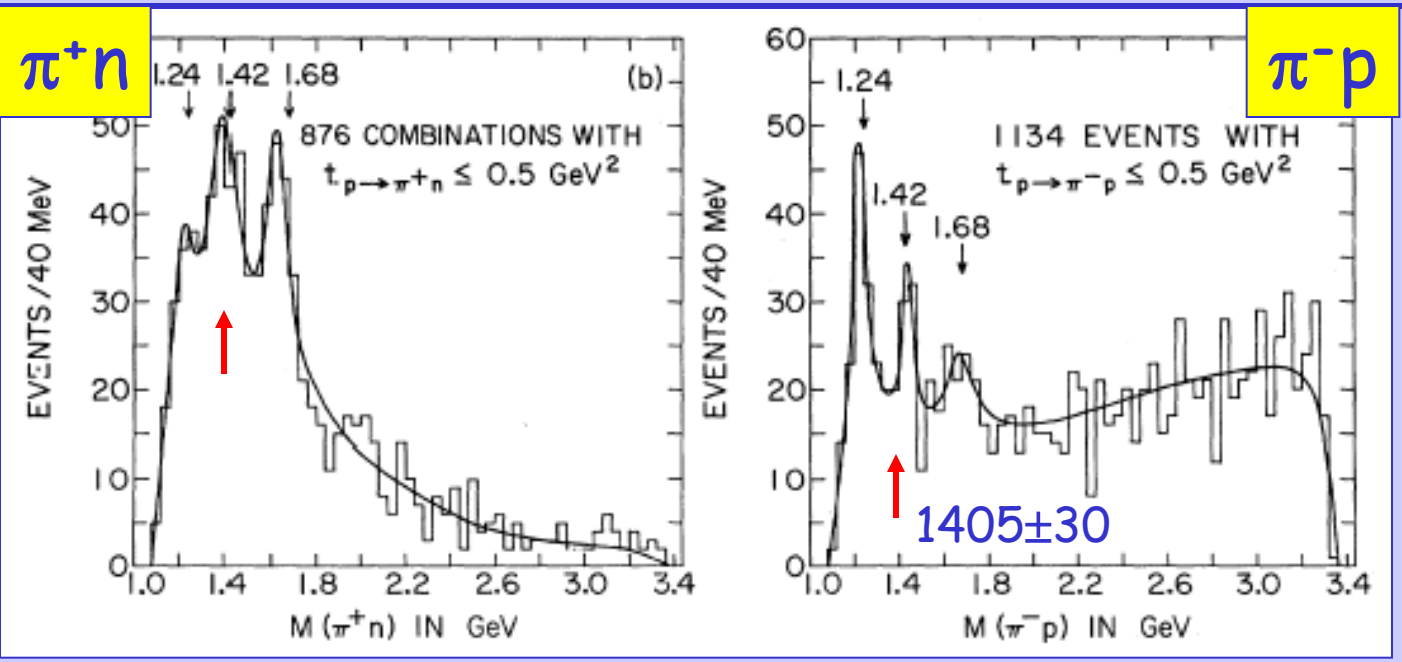
Thanks

I thank Dick Arndt, Yakov Azimov, Bill Briscoe, Cole Smith, and Ron Workman for very valuable discussions.

Backup

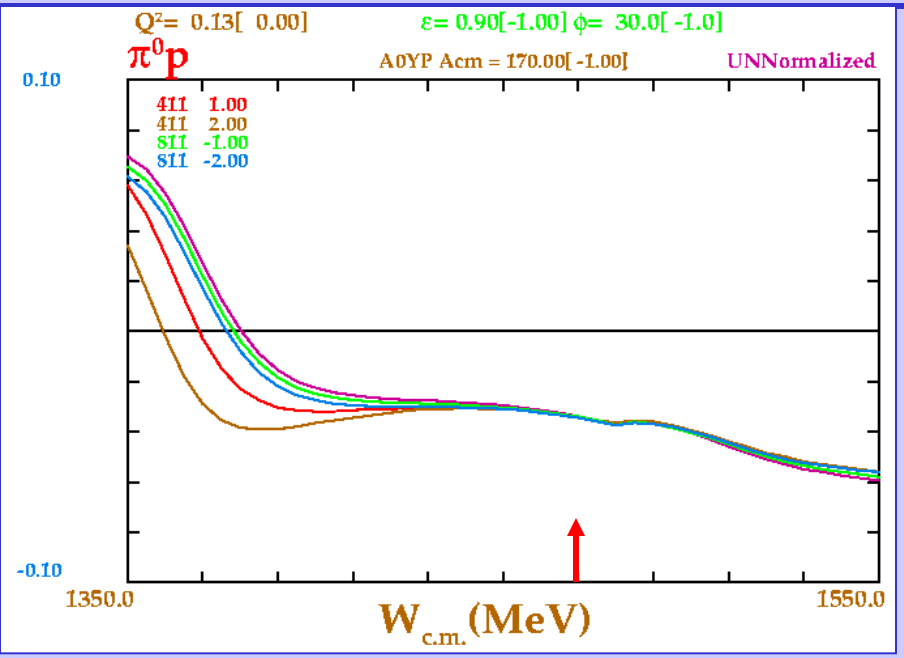
Prehistory of N(1440)

[found by C. Smith, June 2005]

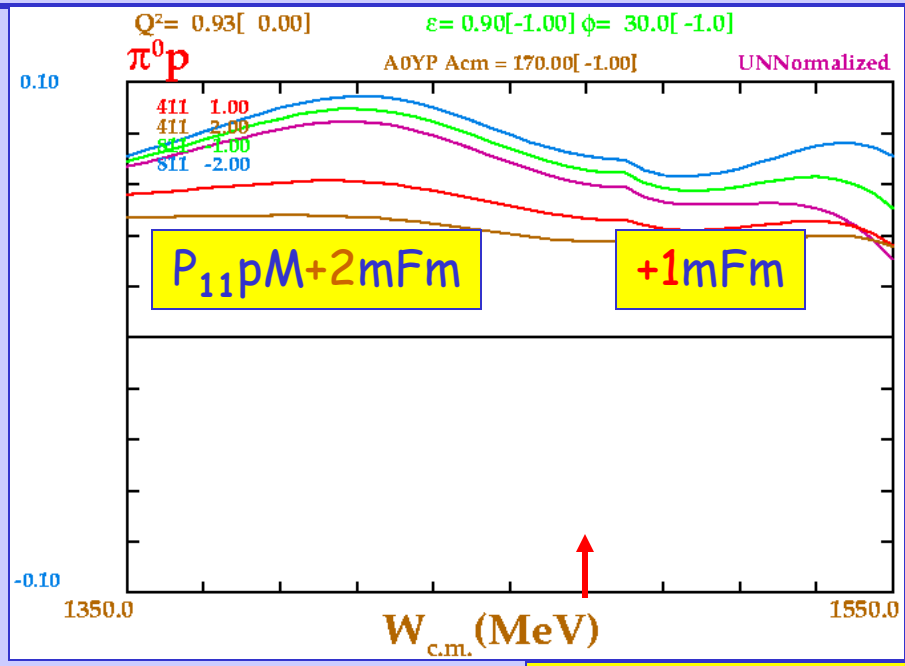


- BNL, LHBC: $\pi^{\pm}p$ at 6 GeV/c
  [R.B. Bell *et al* Phys Rev Lett **20**, 164 (1968)]
- π^+n: Significance$[N_s/\sqrt{(N_b+N_s)}]$= 3.1 σ
  π^-n: Significance$[N_s/\sqrt{(N_b+N_s)}]$= 2.8 σ

$A_{LT'}$ vs P_{11} ($M_{1-}^{1/2}$ and $S_{1-}^{1/2}$)



Q²=0.13 GeV²



Q²=0.93 GeV²

- $A_{LT'}$ requires a high accuracy measurements