Large, precise set of polarization observables of the deuteron-proton breakup at 130 MeV

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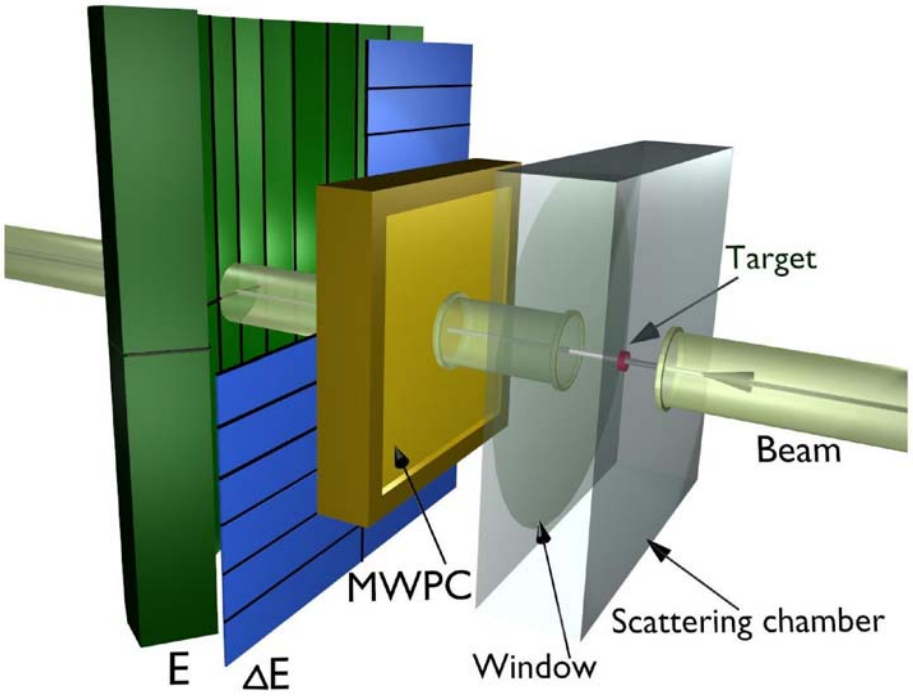
Why Do We Measure Analyzing Powers?

- A few times more additional data points (supplementing cross sections)
- Potentially stronger sensitivity to small ingredients (sums of interfering amplitudes)
- Small Coulomb effects - it can be easier to trace 3NF!
- Data measured for elastic scattering process in the similar range of energies show, that analyzing powers are more "troublesome" than cross section

$^1H(\vec{d},pp)n$ Measurement at 130 MeV
with vector and tensor polarized beam:



7 states:		ΔP_z	ΔP_{zz}
		0.008	0.05
P_z^{max}	P_{zz}^{max}	P_z	P_{zz}
+1/3	-1	0.265	-0.73
+2/3	0	0.480	-0.08
-2/3	0	-0.469	0.06
0	+1	-0.058	0.52
0	-2	0.009	-1.37
+1/3	+1	0.219	0.61
0	0		

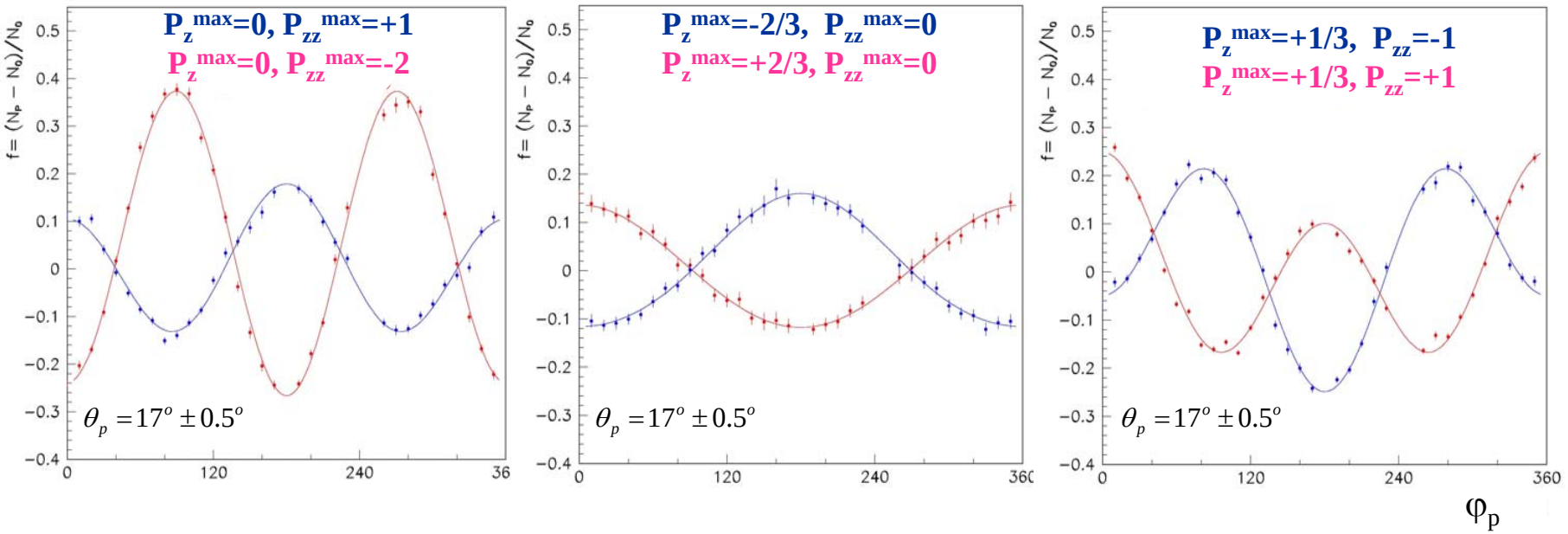
60-80%

Determination of the beam polarization

Analysis of the elastic scattering process:

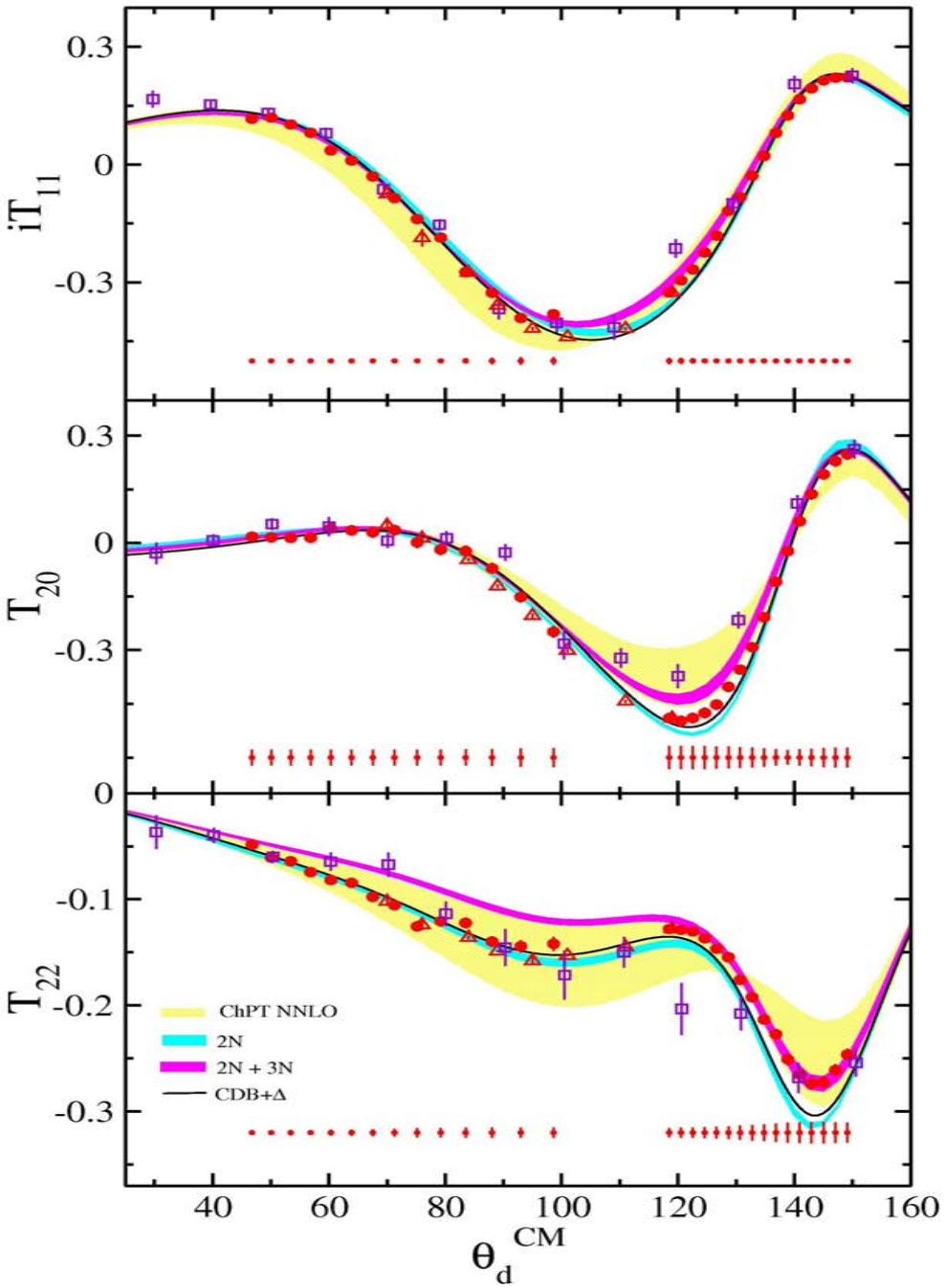
$$\sigma_p(\theta_p,\varphi_p)=\sigma_0(\theta_p)\cdot\left[1+\sqrt{3}\cdot iT_{11}(\theta_p)\cdot P_z\cdot\cos\varphi_p-\frac{\sqrt{3}}{2}\cdot T_{22}(\theta_p)\cdot P_{zz}\cdot\cos 2\varphi_p-\frac{\sqrt{2}}{4}\cdot T_{20}(\theta_p)\cdot P_{zz}\right]$$

$$\frac{N_P-N_0}{N_0}=a\cdot\cos\varphi+b\cdot\cos 2\varphi+c$$



iT_{11}, T_{20}, T_{22} : H. Mardanpour et al., Eur. Phys. J. 31, 383 (2007)

Analyzing Powers of Elastic Scattering



● **$^1H(\vec{d},d)p$**
$^1H(\vec{d},dp)$
E. Stephan et al., accepted for publ. in Phys. Rev. C BR

△ H. Mardanpour et al., Eur. Phys. J. 31, 383 (2007)

□ H. Witała et al., Few-Body Systems 15, 67-85 (1993)

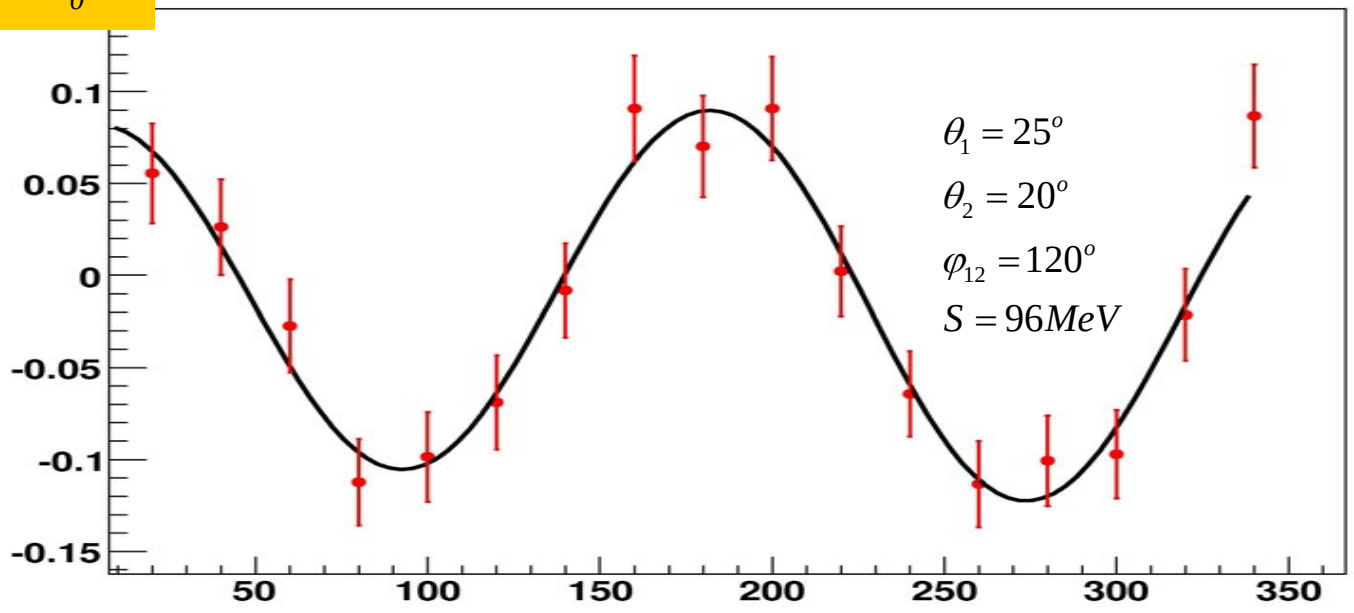
Breakup process

$$\sigma_p(\varsigma,\varphi_1)=\sigma_0(\varsigma)\cdot\left[1+P_z\cdot\left(-\frac{3}{2}\sin\varphi_1 A_x+\frac{3}{2}\cos\varphi_1 A_y\right)+\right.$$
$$\left.P_{zz}\cdot\left(-\sin\varphi_1\cos\varphi_1 A_{xy}\right)+P_{zz}\cdot\left(\frac{1}{2}\sin^2\varphi_1 A_{xx}+\frac{1}{2}\cos^2\varphi_1 A_{yy}\right)\right]$$

$$\varsigma=(\theta_1,\theta_2,\varphi_{12},S)$$

$$a=-\frac{3}{2}P_z A_x(\varsigma)$$
$$b=\frac{3}{2}P_z A_y(\varsigma)$$
$$c=-P_{zz}A_{xy}(\varsigma)$$
$$d=\frac{1}{2}P_{zz}A_{xx}(\varsigma)$$
$$e=\frac{1}{2}P_{zz}A_{yy}(\varsigma)$$

$$\frac{N_P-N_0}{N_0}=a\cdot\sin\varphi_1+b\cdot\cos\varphi_1+c\cdot\sin\varphi_1\cdot\cos\varphi_1+d\cdot\sin^2\varphi_1+e\cdot\cos^2\varphi_1$$



$^1H(\vec{d},pp)n$ Measurement at 130 MeV

Analyzing Power Results – Summary

- ✓ Vector (A_x, A_y) and tensor analyzing powers (A_{xx}, A_{yy}, A_{xy}) determined in the large part of the phase space
- ✓ Nearly 1000 data points per observable
  - θ_1, θ_2 = 15° – 30°; grid 5° ; $\Delta\theta$ = **±2°**
  - φ_{12} = 40° – 180°; grid 20° ; $\Delta\varphi$ = **±10°**

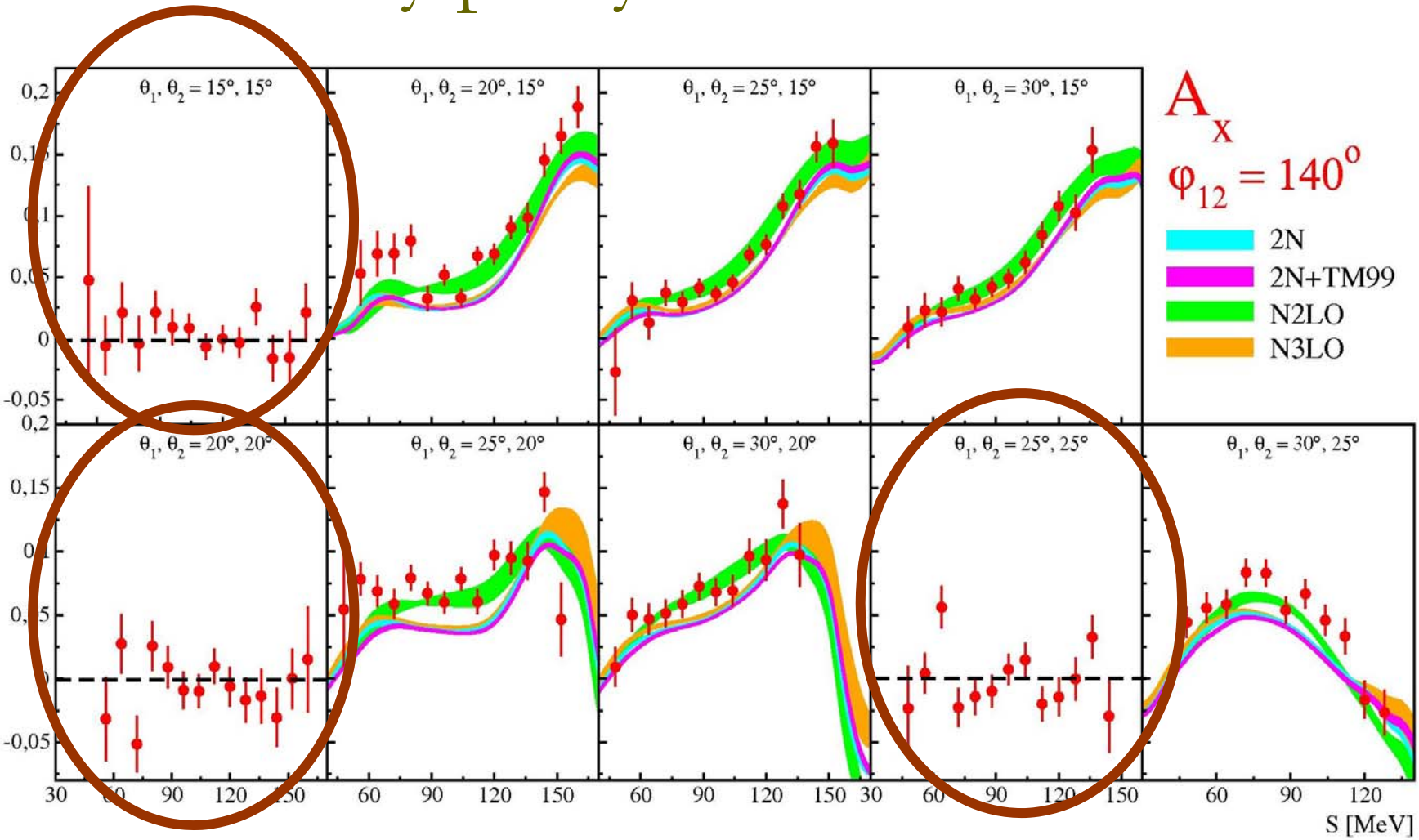
  } non-negligible averaging!
  - S [MeV] = 40 – 160; grid 4; ΔS = ±2
  - ➢ Statistical accuracy 0.01 – 0.05
  - ➢ Systematic errors – analyzis under way
- ✓ Global comparisons with theory (χ^2 test)

PhD Th's: Aleksandra Biegun, Rafał Sworst

Studies of the possible sources of systematic effects:

- Determination of proton emmission angles
  - Control over geometry - kinematics of the elastic scattering process.
  - Phase of φ – asymmetry distributions for elastic scattering, uncertainty below 0.5°.
- Uncertainty of polarization determination
  - well under control, systematic error of about 3 %.
- General consistency of the data –
  - do they fulfill constrains of parity conservation?

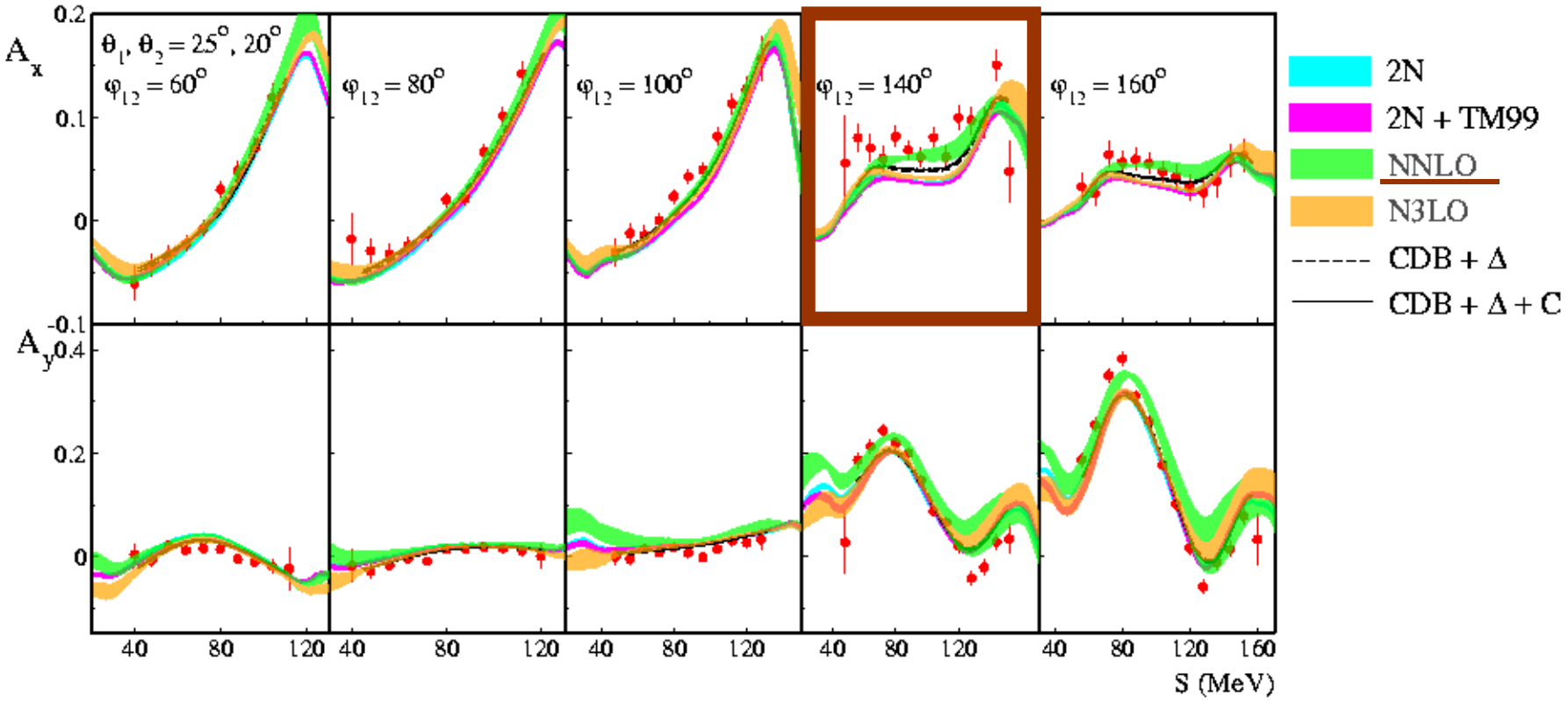
Constrains on the breakup analyzing powers set by parity conservation



S [MeV]

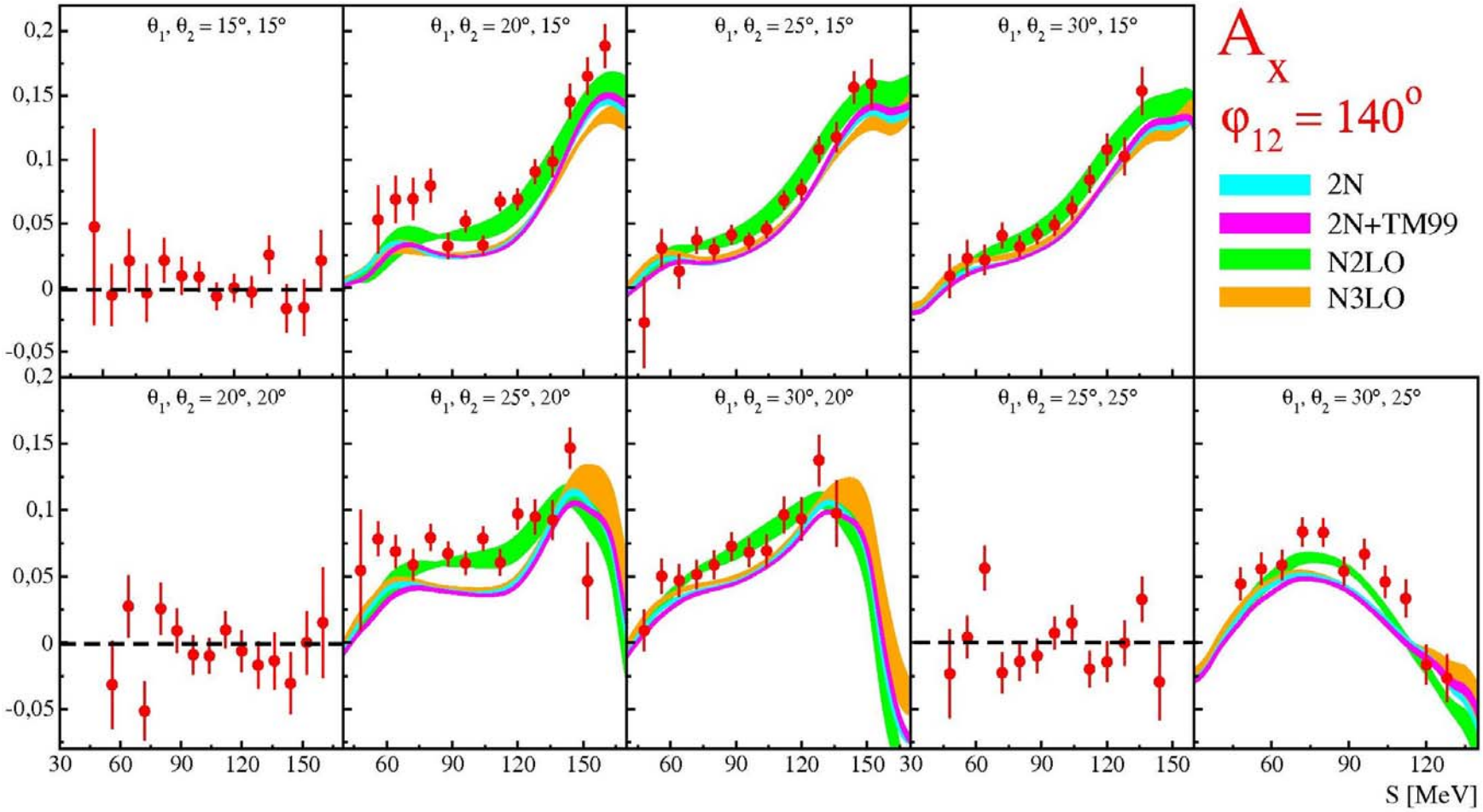
Vector Analyzing Power Results

example for proton polar angles θ_1=25°, θ_2=20°, various φ_{12} :



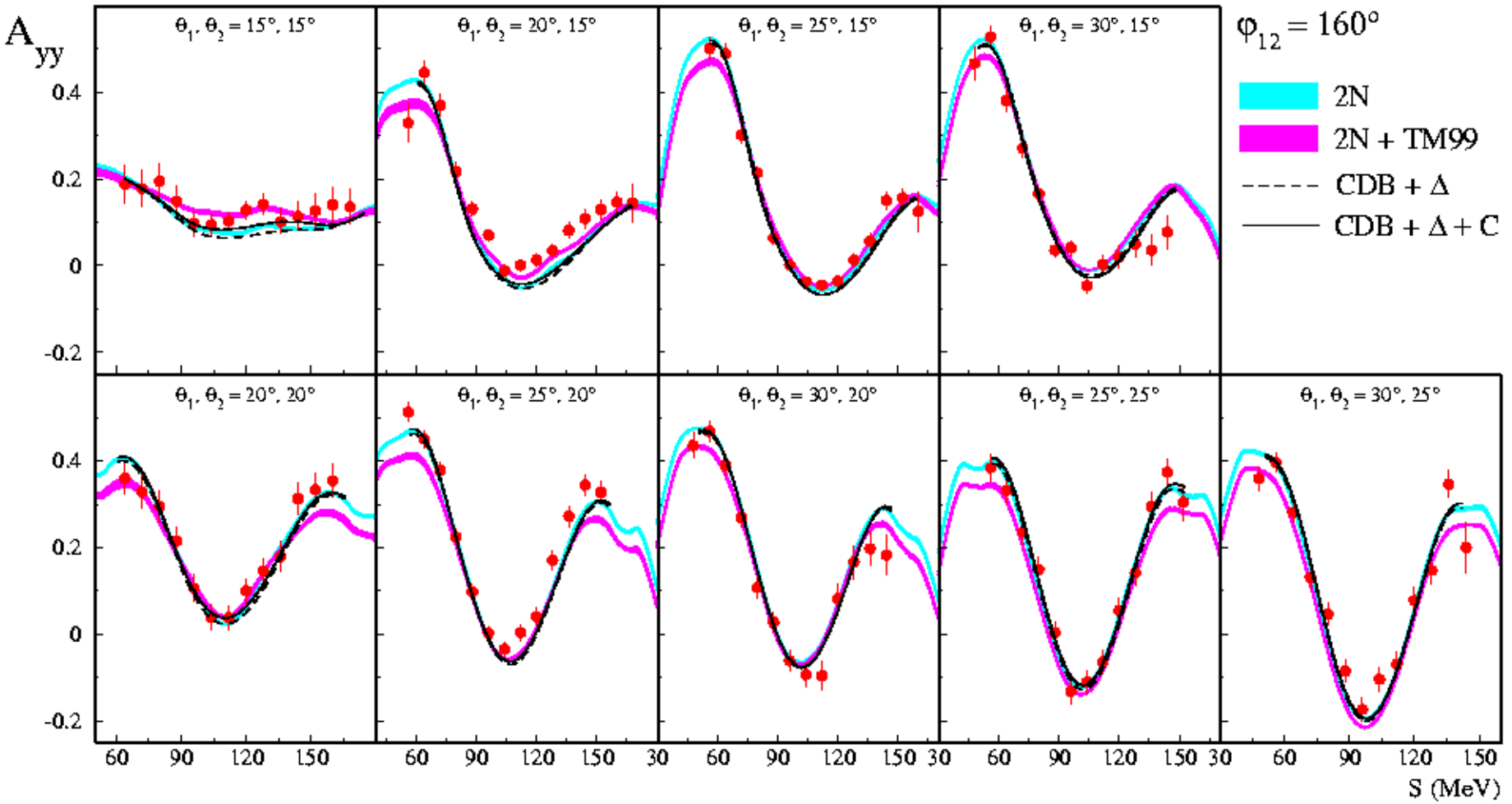
Vector Analyzing Power Results

example for relative azimuthal angle φ_{12} =140:



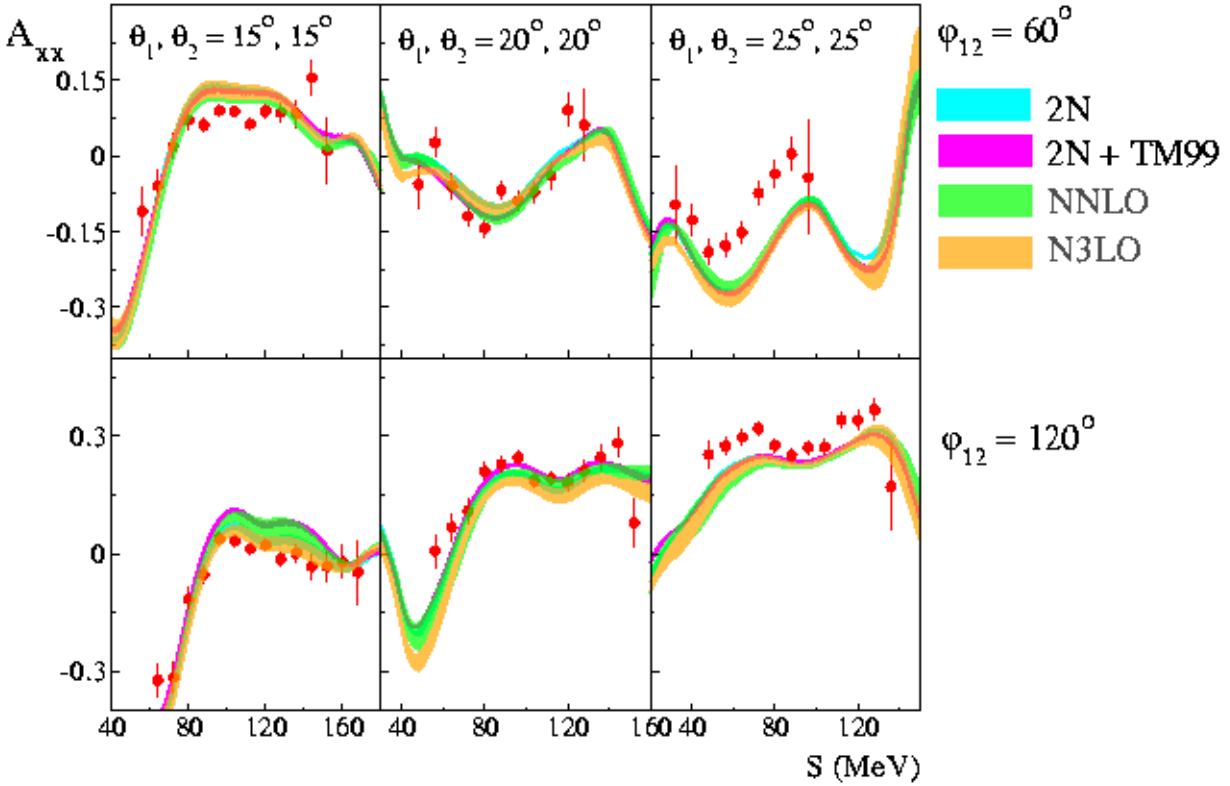
Tensor Analyzing Power Results

example for A_{yy}, various configurations with $\varphi_{12}=160^{o}$



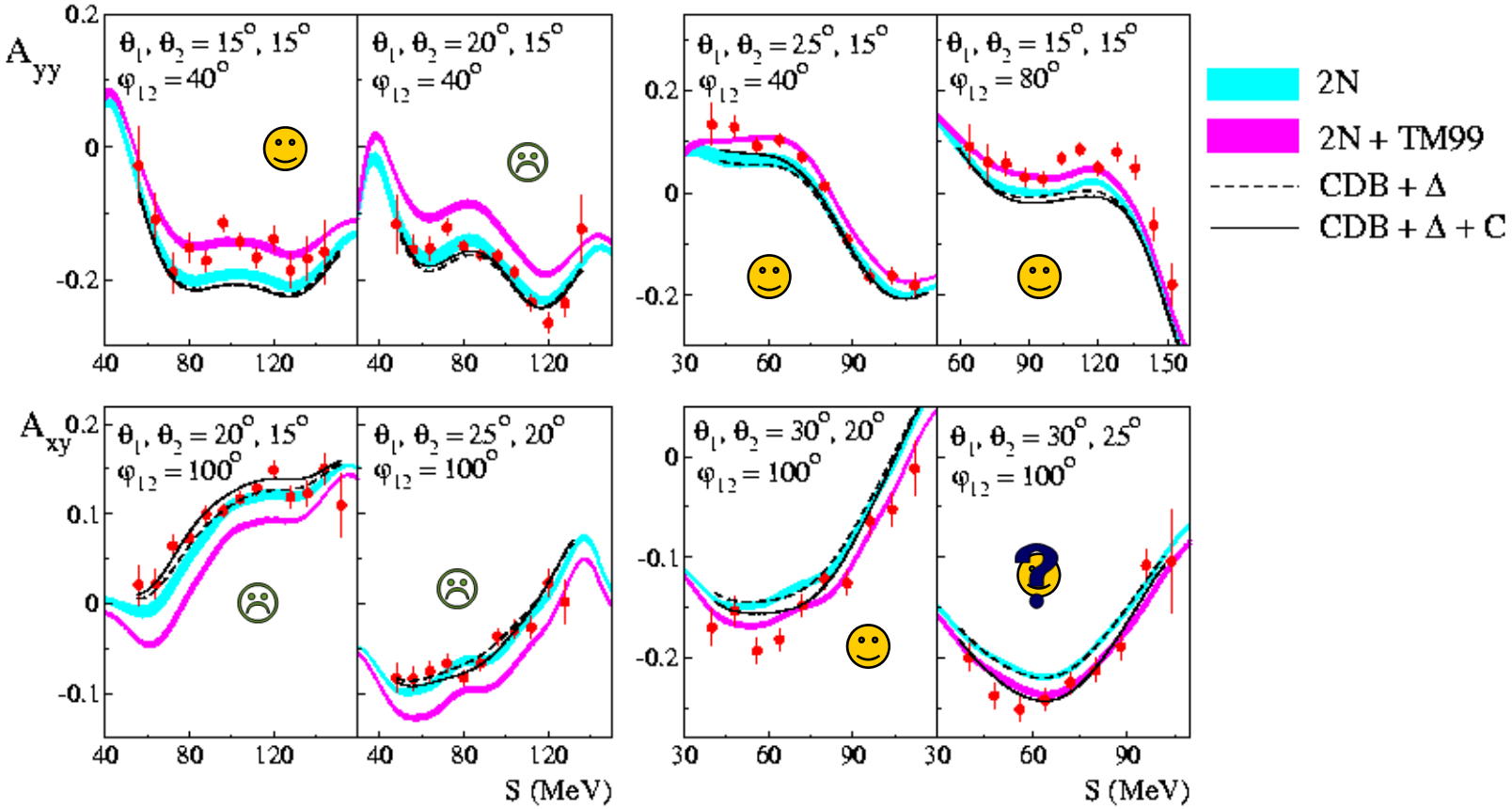
Tensor Analyzing Power Results

examples of A_{xx}, symmetric configurations with $\varphi_{12}=60^o$, 120^o



Tensor Analyzing Power Results

examples of configurations with predicted strong 3NF effects



Summary of analyzing power results:

- Generally no big discrepancies between data and theoretical predictions
- Large, precise basis for comparing description provided by various approaches:
  - Coulomb effects are rather small, but not so strongly "localized" in particular ranges of phase space as in the case of cross section.
  - predicted 3NF effects not large, in some cases confirmed by data, but in other cases discrepancy remains, why?
    - **relativistic effects? doubtful...**
  - results of ChPT N2LO calculations very promising for A_x
    - **will the full N3LO predictions confirm that?**
- Furher developments in theories are very important!
- New data at different energies (e.g. 100 MeV) and covering still larger part of phase space are being analyzed

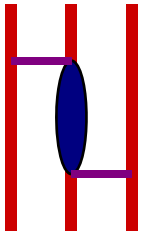
Spin observables are interesting !

Studies of the $^1H(\vec{d},pp)n$ Breakup at 130 MeV

University of Silesia, Katowice, Poland

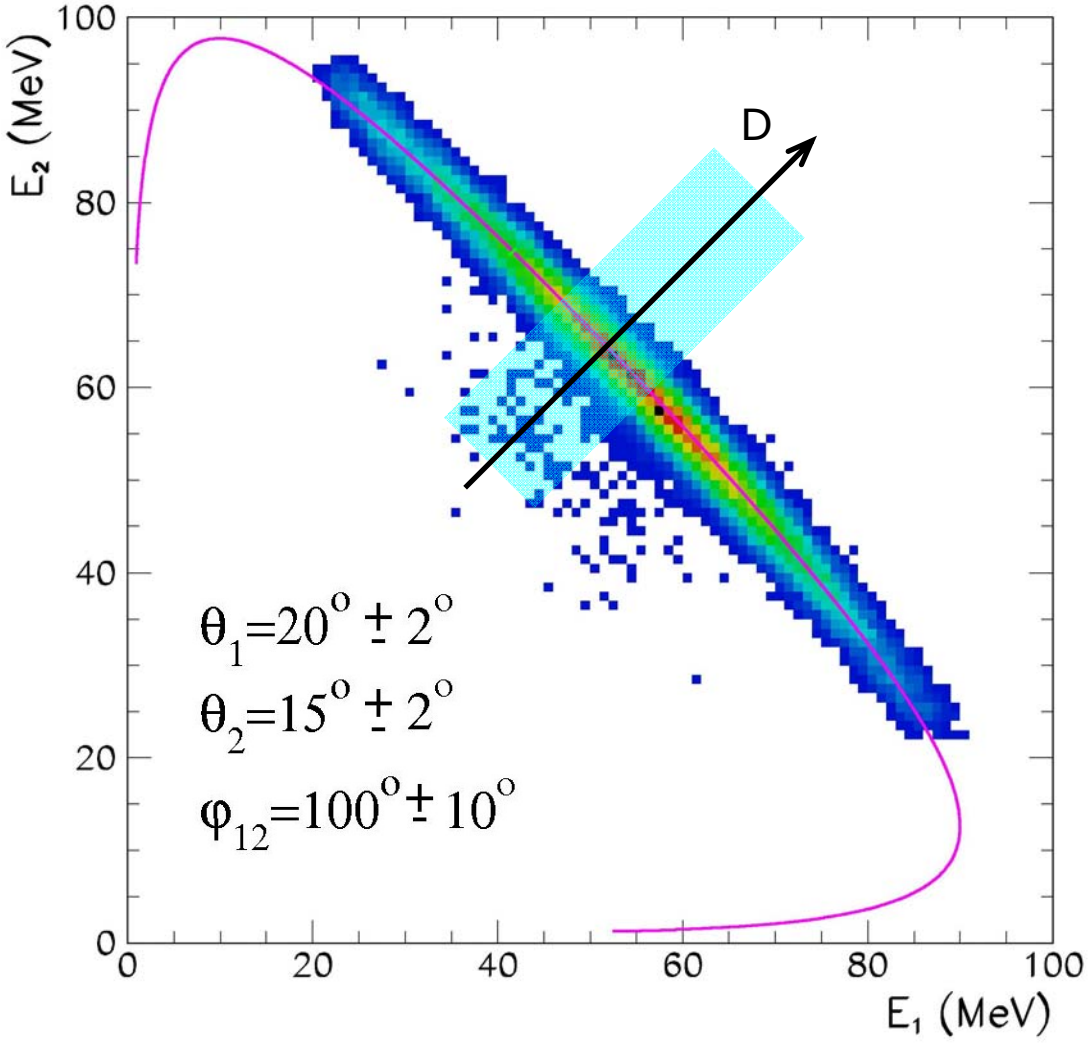
Jagiellonian University, Kraków, Poland

KVI, Groningen, The Netherlands



Kraków-Bochum Group
EFT/ChPT Group
Hannover/Lisboa Group

} Theory Support


E₂ (MeV)
E₁ (MeV)
0
20
40
60
80
100
D
θ1=20° ± 2°
θ2=15° ± 2°
φ12=100° ± 10°