Measurement of the analyzing powers in pd elastic and pn quasi-elastic scattering at small angles at ANKE-COSY

S. Dymov
(Ferrara University, Italy,   JINR, Dubna, Russia)

MOTIVATION: Nucleon-Nucleon (NN) interaction

Understand nuclear force in GeV region

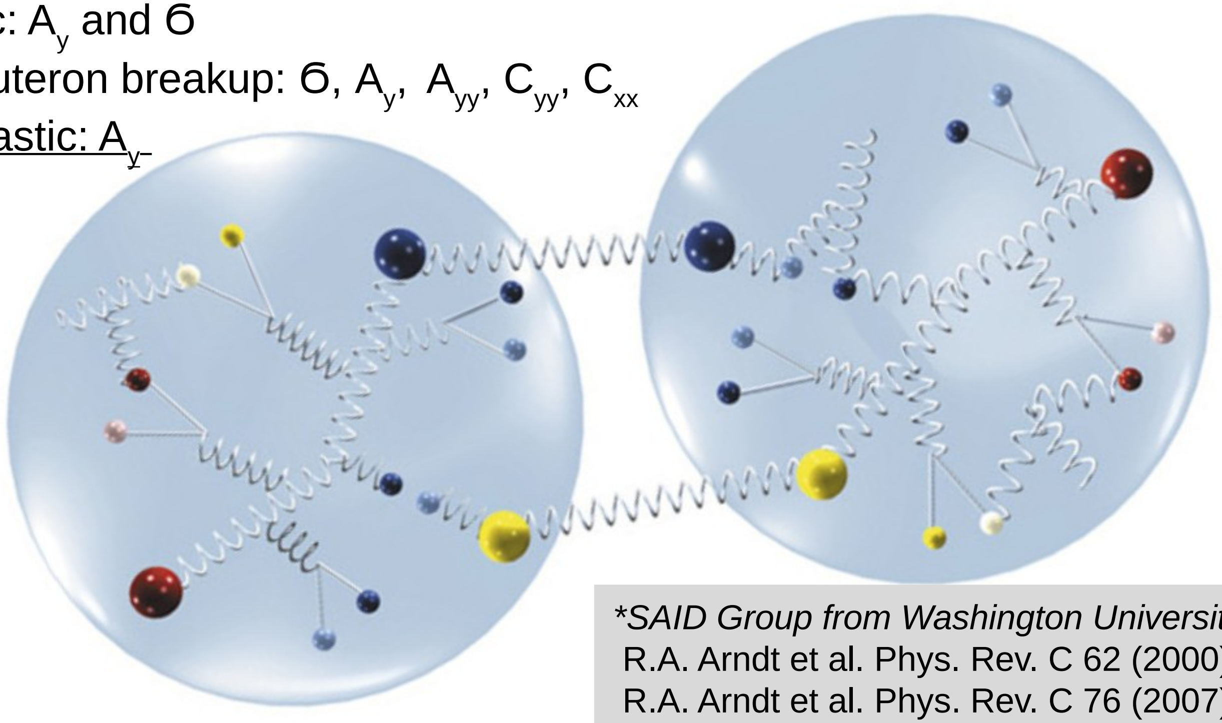
→ pp and np-amplitudes

→ Phase Shift Analysis*

ANKE

→ Spin observables

- Small angle pp-elastic: A_y and σ
- Charge-exchange deuteron breakup: σ, A_y, A_{yy}, C_{yy}, C_{xx}
- Small angle pn, pd-elastic: A_y



**SAID Group from Washington University:*
R.A. Arndt et al. Phys. Rev. C 62 (2000) 034005;
R.A. Arndt et al. Phys. Rev. C 76 (2007) 025209

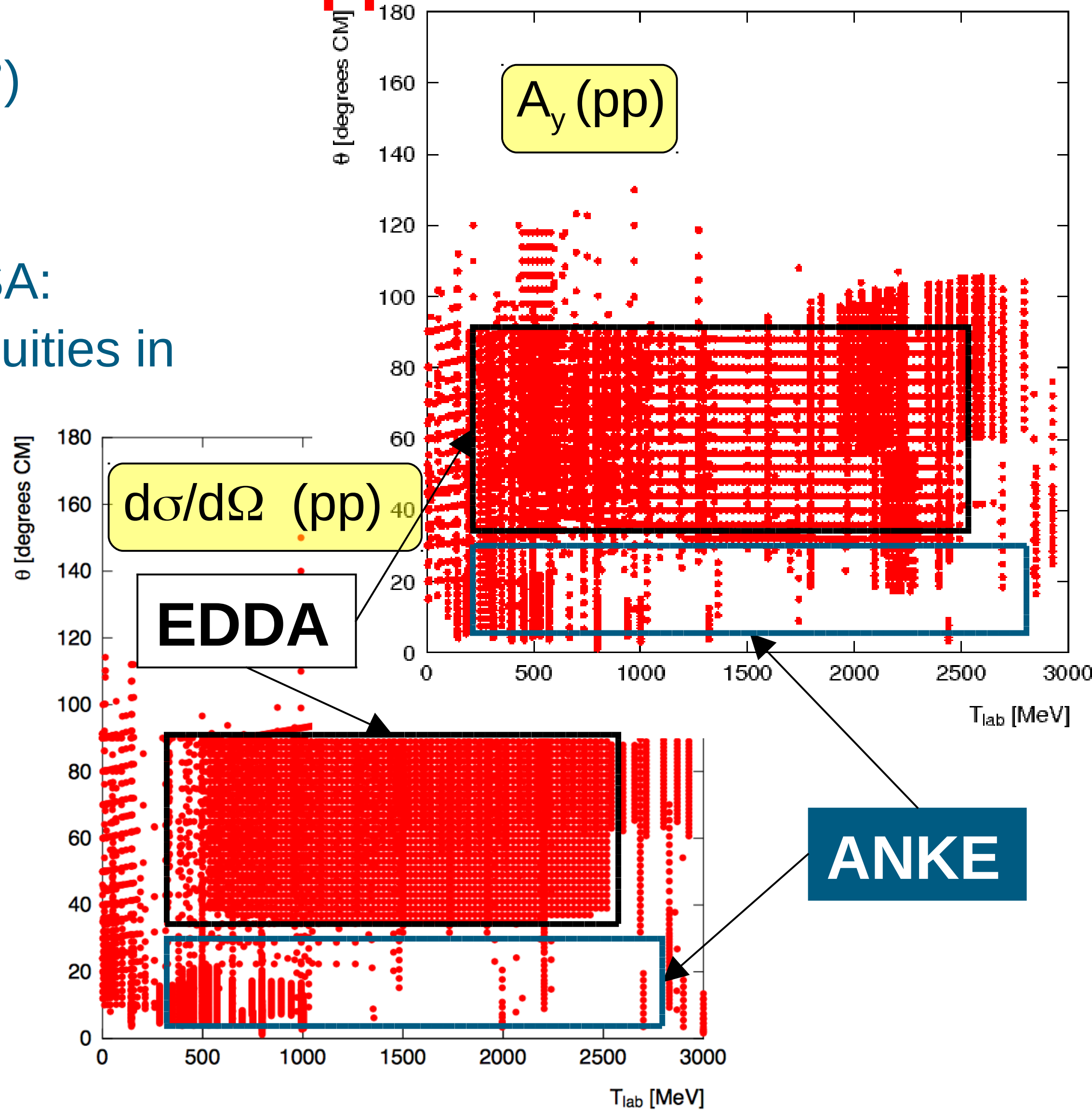
MOTIVATION: Where are we in pp elastic?

- Wealth of data ($35° < \theta_p < 90°$) $0.5 < T_p \leq 2.5$ GeV
- EDDA's large impact on PSA: significantly reduced ambiguities in phase shifts (I=1)

PRL 90, 142301 (2003)
PRL 85, 1819 (2000)

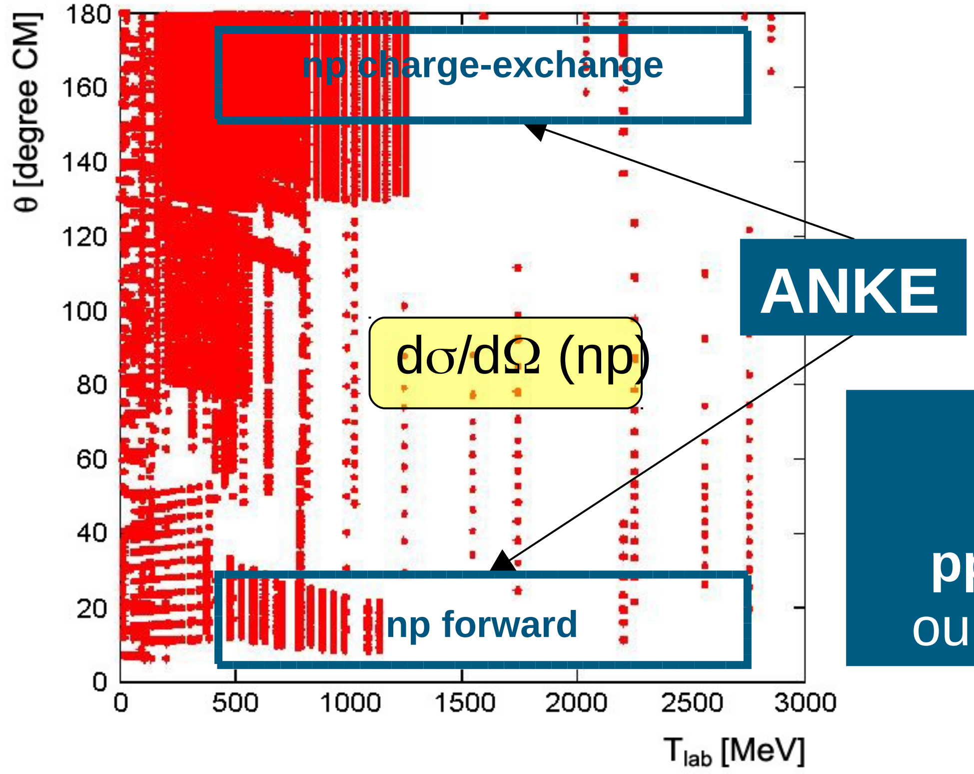
- No experimental data at smaller angles ($\theta_p < 35°$) above T_p=1.0 GeV

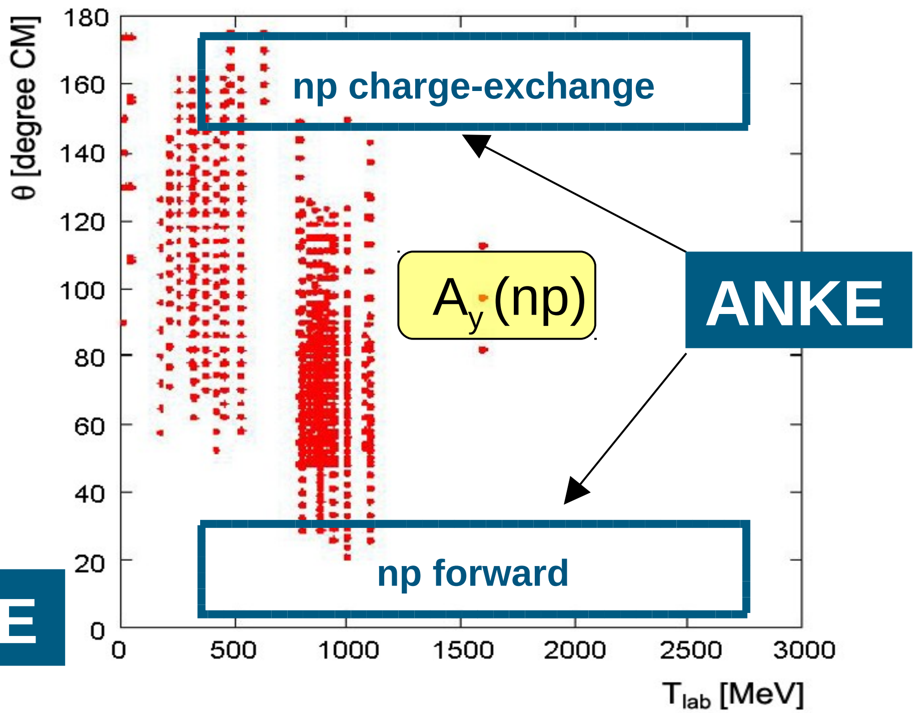
Source: http://nn-online.org/NN



MOTIVATION: Where are we in pn?

R. Arndt: ***Gross misconception within the community that np amplitudes are known up to a couple of GeV. np data above 800 MeV is a DESERT for experimentalists."***



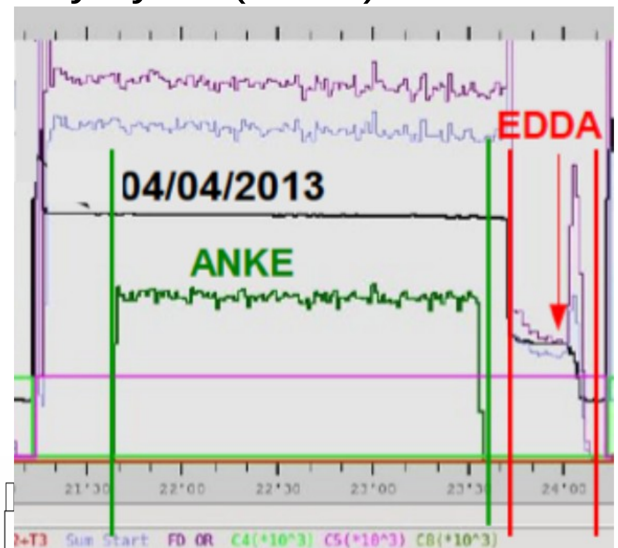


ANKE is able to provide the experimental data for both: **pp and np systems** and improve our understanding of NN interaction

Source: http://nn-online.org/NN

Experiment: ANKE at COSY

Polarized proton beam: T_p=0.8, 1.6, 1.8, 2.0, 2.2, 2.4 GeV,
Beam polalization : Py~50%, spin flipped every cycle (5 min)
D_2 cluster jet target: *$d=5\cdot10^{14}$ cm^{-2}*

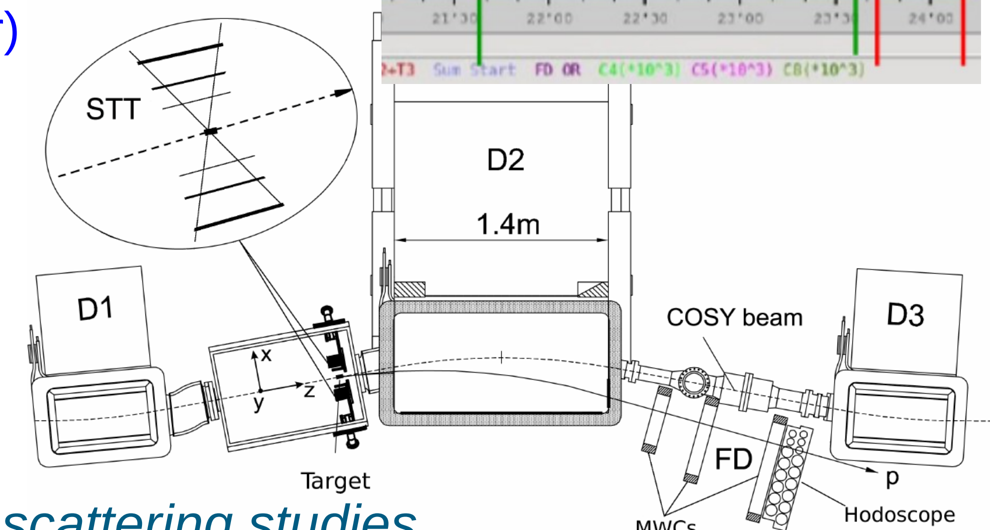


Polarimetry: EDDA detector

Forward detector (FD):
fast proton @ 0-15^0

*Silicon Tracking Telescope **(STT)***:
low energy proton (spectator)
($5^\circ < \Theta^p_{cm} < 30^\circ$)

Triggers:
- Self-triggering STT L2
- FD*STT coincidence



Ideal for small angle elastic scattering studies

Silicon tracking telescope at ANKE

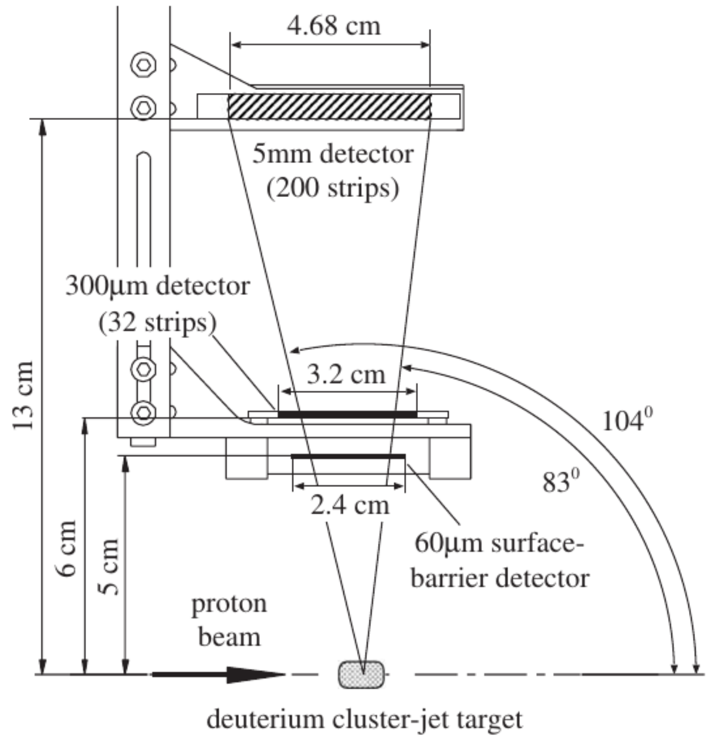
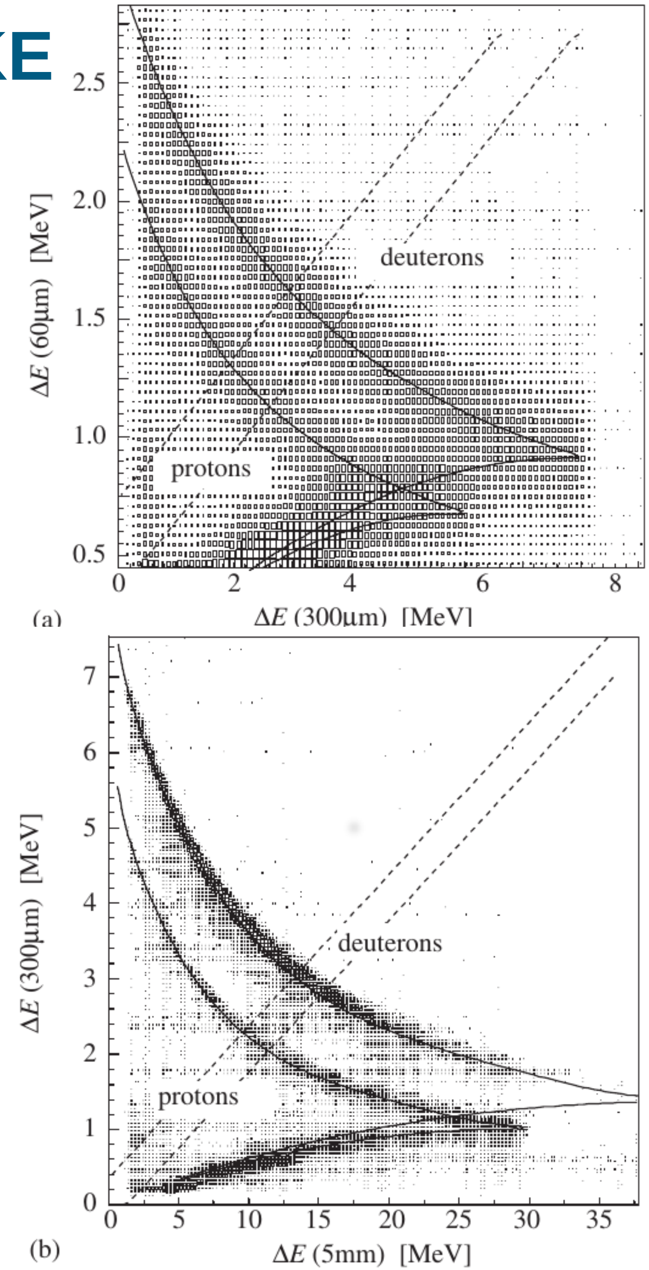


Fig. 1. Sketch of top view of the silicon telescope inside the ANKE target chamber showing the COSY beam, the cluster target and the telescope structure of three silicon detectors.



Identification of stopped protons of 2.5 - 30 MeV, deuterons of 3.5 – 40 MeV

I. Lehmann et al., NIM A 530 (2004) 275

Beam polarization measurement by EDDA

- Carbon fibre target (pC)
- Known effective pC analyzing power
- Scintillator semi-rings (φ asymmetry)

Beam Energy T_kin [MeV]	Av. Polarisation P [%]	Statistical Error P_er [%]
796	55.4	0.8
1600	50.4	0.3
1800	- 50.8	1.1
1965	- 42.9	0.8
2157	- 50.1	1.0
2368	43.5	1.5

- LEP: P~90% at injection
- EDDA: P~50% at experiment energy
- ~1% statistic and 3% systematic error

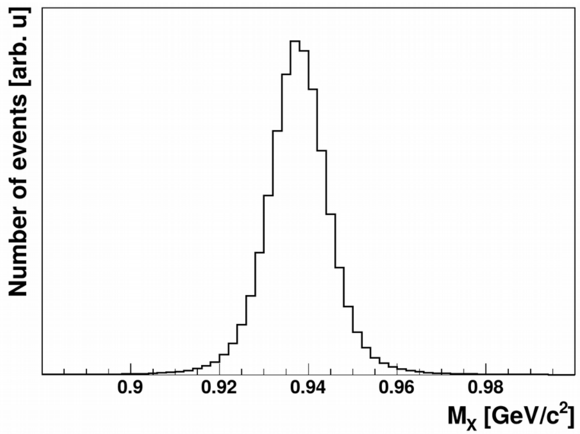
Analyzing power in $\vec{p}$d elastic

Cross ratio method: Syst. errors suppressed in first order

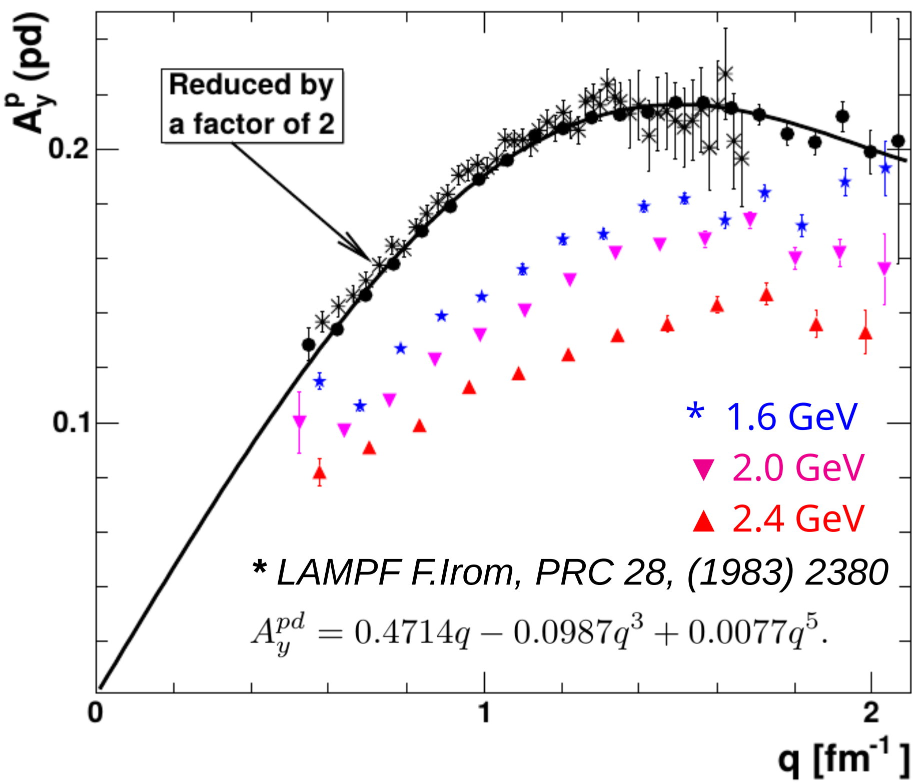
$$\varepsilon = \frac{L-R}{L+R} = PA \qquad L = \sqrt{L_1 L_2} = \sqrt{L\uparrow R\downarrow} \qquad R = \sqrt{R_1 R_2} = \sqrt{L\downarrow R\uparrow}$$

Deuteron detected in STT (STT trigger)

Angle defined from deuteron energy
$\sigma\Theta<0.2^0$, $\sigma E_d<2\%$

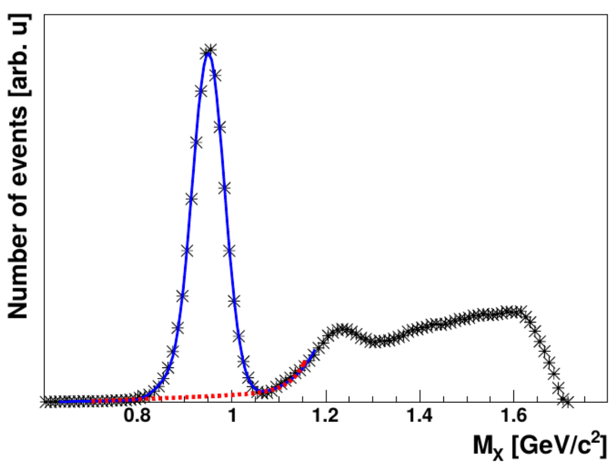


Missing mass Mx in pd→dX, STT

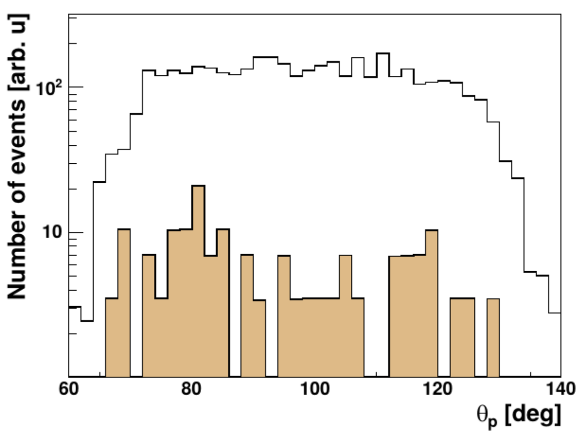


Analyzing power in pn quasi-free elastic (1)

- Fast proton in FD in coincidence with spectator proton in STT
- No detector Left-Right symmetry – cross ratio not applicable
- Must define ratio of luminosity with beam spin up and down: use ratio of deuterons from pd-elastic taken with STT-trigger $(L_d^{\uparrow} \cdot R_d^{\uparrow})/(L_d^{\downarrow} \cdot R_d^{\downarrow})$
- Very low and unpolarized background in Mx spectra, except 800 MeV, where deuterons from $pd \rightarrow d\pi^0 + p_{spec}$ in FD suppressed by dE/dX
- Only the right STT was used to suppress quasi-free pp-elastic



Missing mass Mx in $pd \rightarrow pX + p_{spec}$



Simulation: pn-quasi (empty histogram) and pp-quasi elastic counts.
Left STT in coincidence with FD

Analyzing power in pn quasi-free elastic (2):
Results at 800 MeV

<u>800 Mev is a test energy</u>:
compare with SAID SP07, data

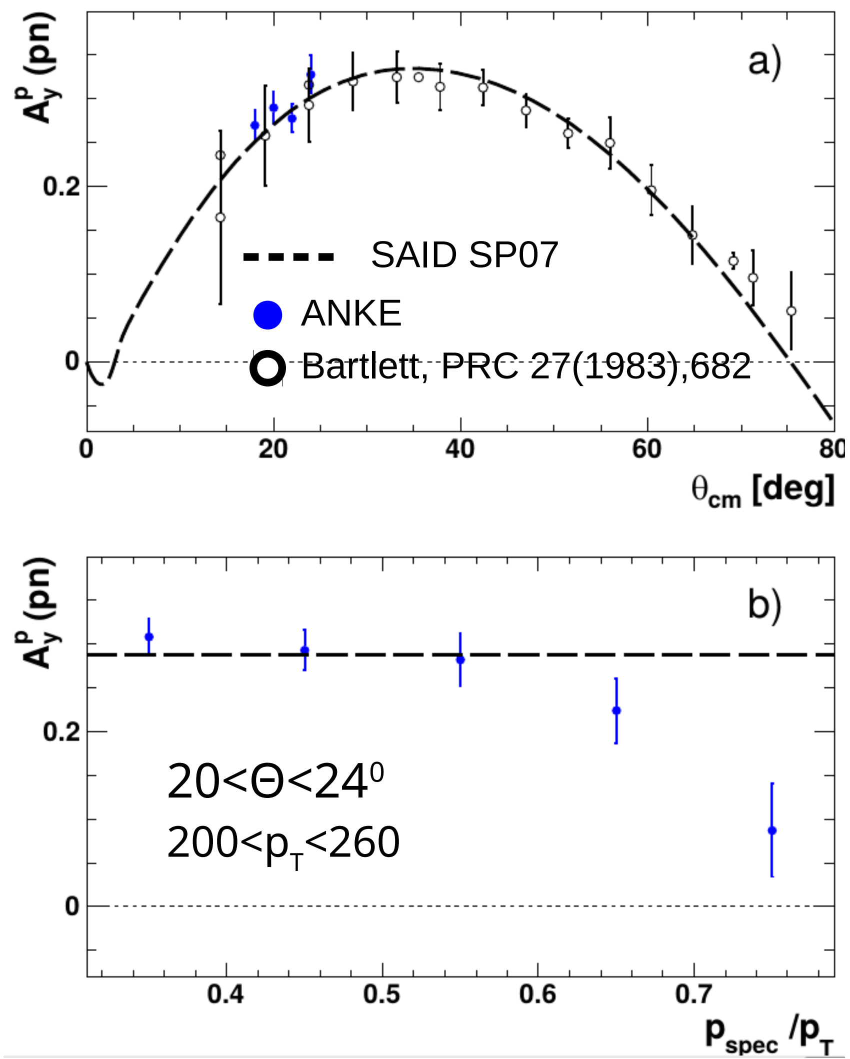
Quasi-free kinematics: $p_T > p_{spec}$

Smallest p_T are at 800 MeV $100 < p_T < 260$ MeV/c

Cuts for quasi-free scenario:

$p_{spec}/p_T < 0.5$, $p_T > 190$ MeV/c

→ $\Theta_{cm} > 17^0$ at 800 MeV,
full acceptance at higher energies



Analyzing power in pn quasi-free elastic (3):
Results at 1600 and 2200 MeV

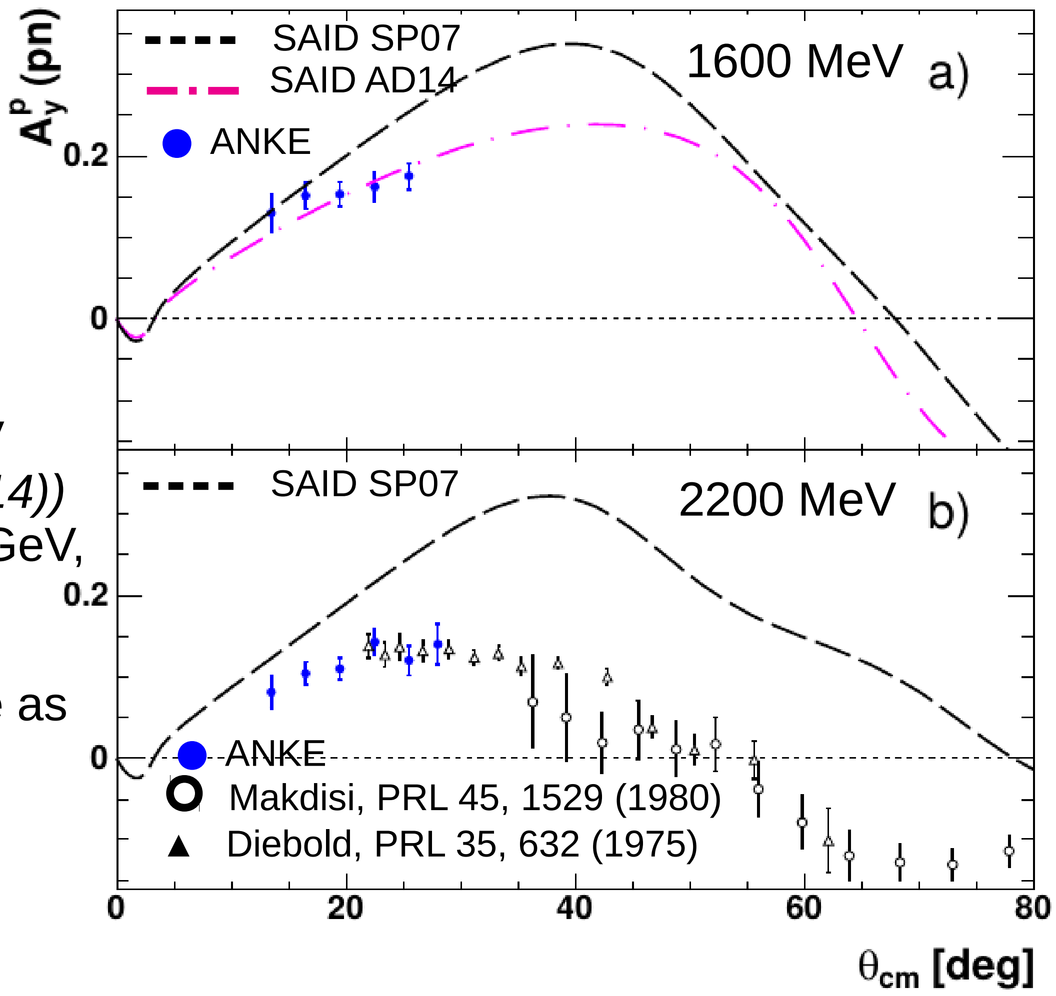
SAID SP07:

based on data < 1.5 GeV,
fails at T_p=1.6-2.4 GeV

SAID AD14:

Includes WASA data at ~1.1 GeV
(Adlarson, PRL 112, 202301 (2014))
Expected to work only up to 1.5 GeV,
But fits ANKE data at 1.6 GeV

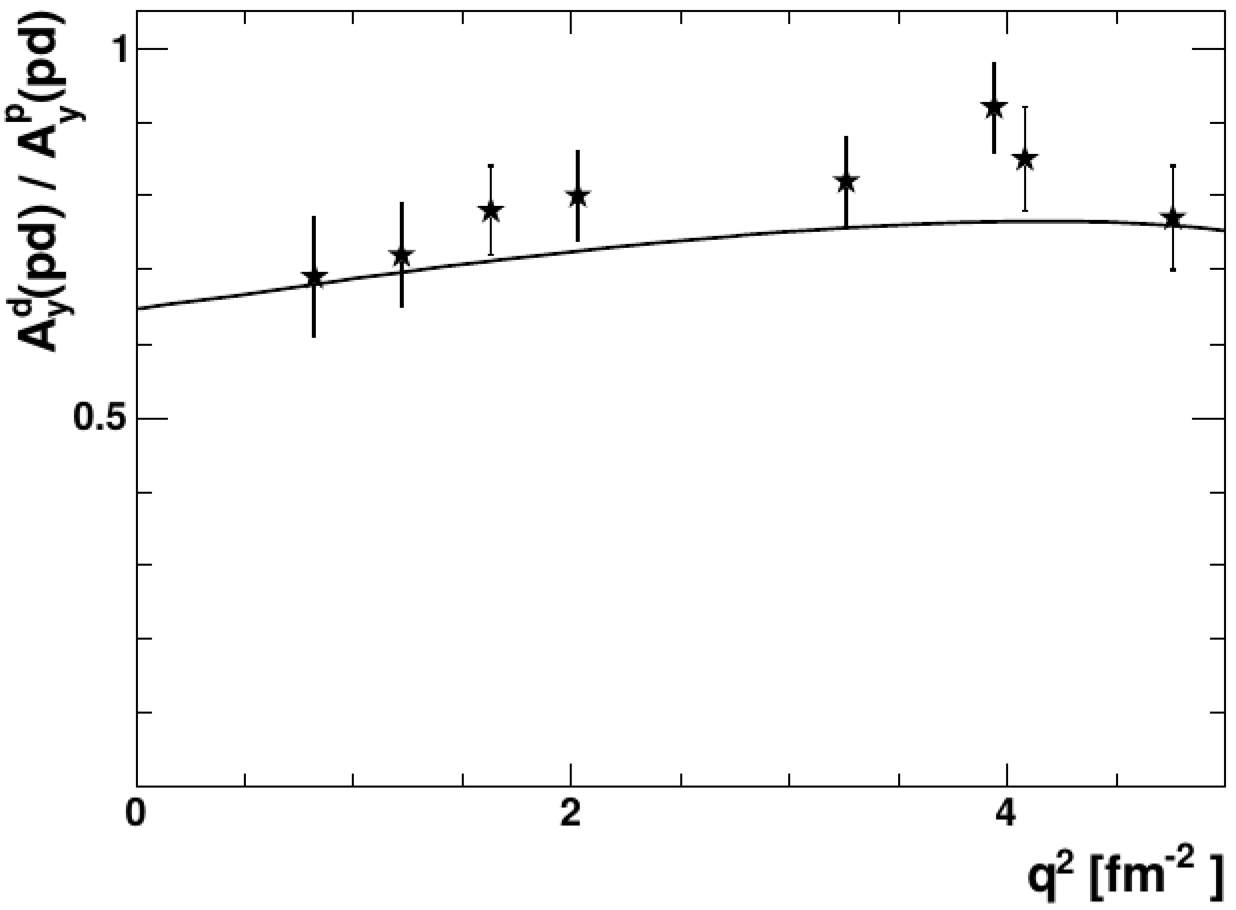
A_y^p decreasing with energy same as in pd-elastic



Summary

- Analyzing power A_y^p was measured in pd-elastic and pn quasi-elastic scattering in the forward angles at T_p=0.8 -2.4 GeV
- In pd-elastic A_y^p at 800 MeV consistent with LAMPF data. At 1.6 GeV A_y^p is about 2 times smaller than at 800 MeV, and descreases with energy.
- Resuls on pn quasi-elastic coincide well with available data at 800 MeV and 2200 MeV, and with SAID SP07 solution at 800 MeV. Data at 1600 MeV agree with SAID AD14 solution.
- The energy dependence in pn quasi-elastic scattering is similar to that in pd-elastic.
- The results obtained will be used in the PSA.

Thank you!



$A_y^d(pd) / A_y^p(pd)$
1
0.5
0
2
4
q^2 [fm^{-2}]

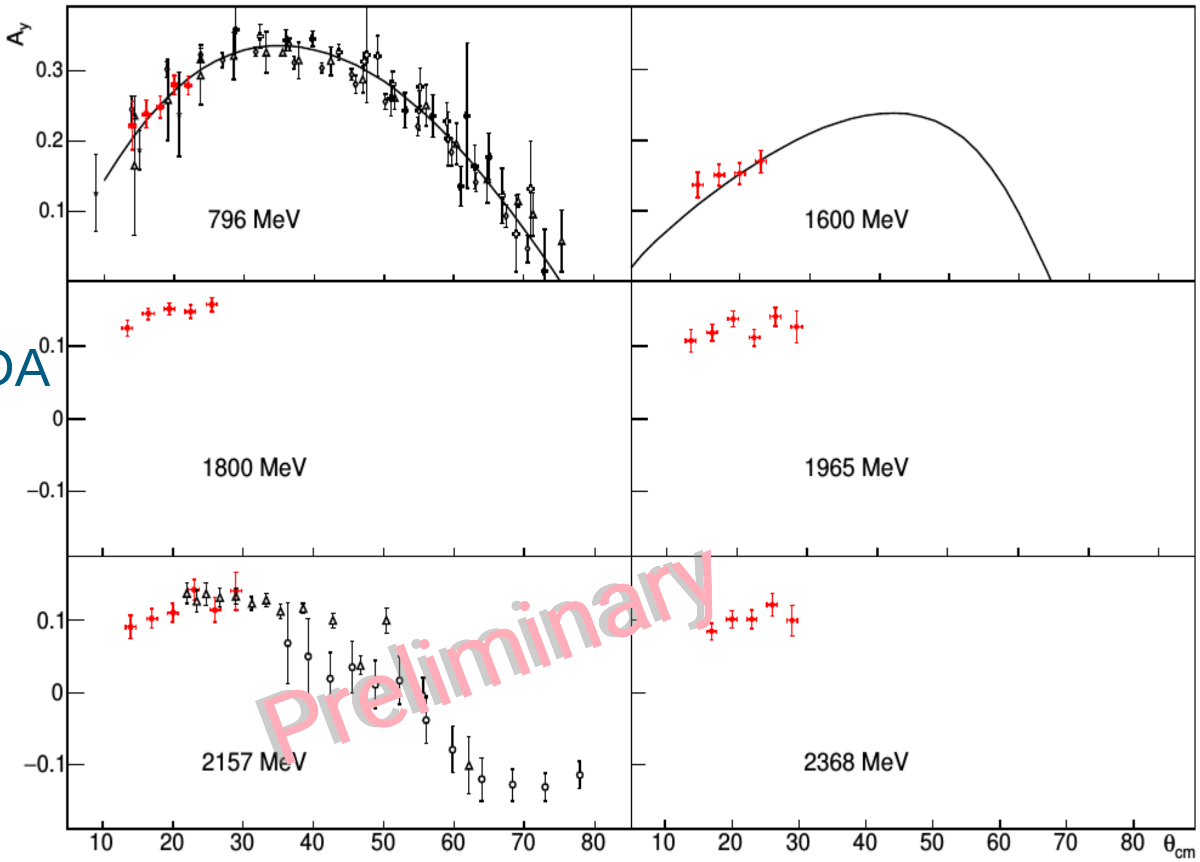
np program: quasi-elastic pn

$\vec{p}d \rightarrow ppn$

T_p = 0.8, 1.6, 1.8, 2.0, 2.2, 2.4 GeV

Polarization with EDDA

- Fast proton in FD
- Slow proton in STT



Compatible with existing data

SAID SP07 describes well at 796 MeV. Dedicated SAID solution at 1.6 GeV