Polarimetry at ANKE

David Chiladze
IHEPI, Tbilisi State University
IKP, Forschungszentrum Jülich

Outline

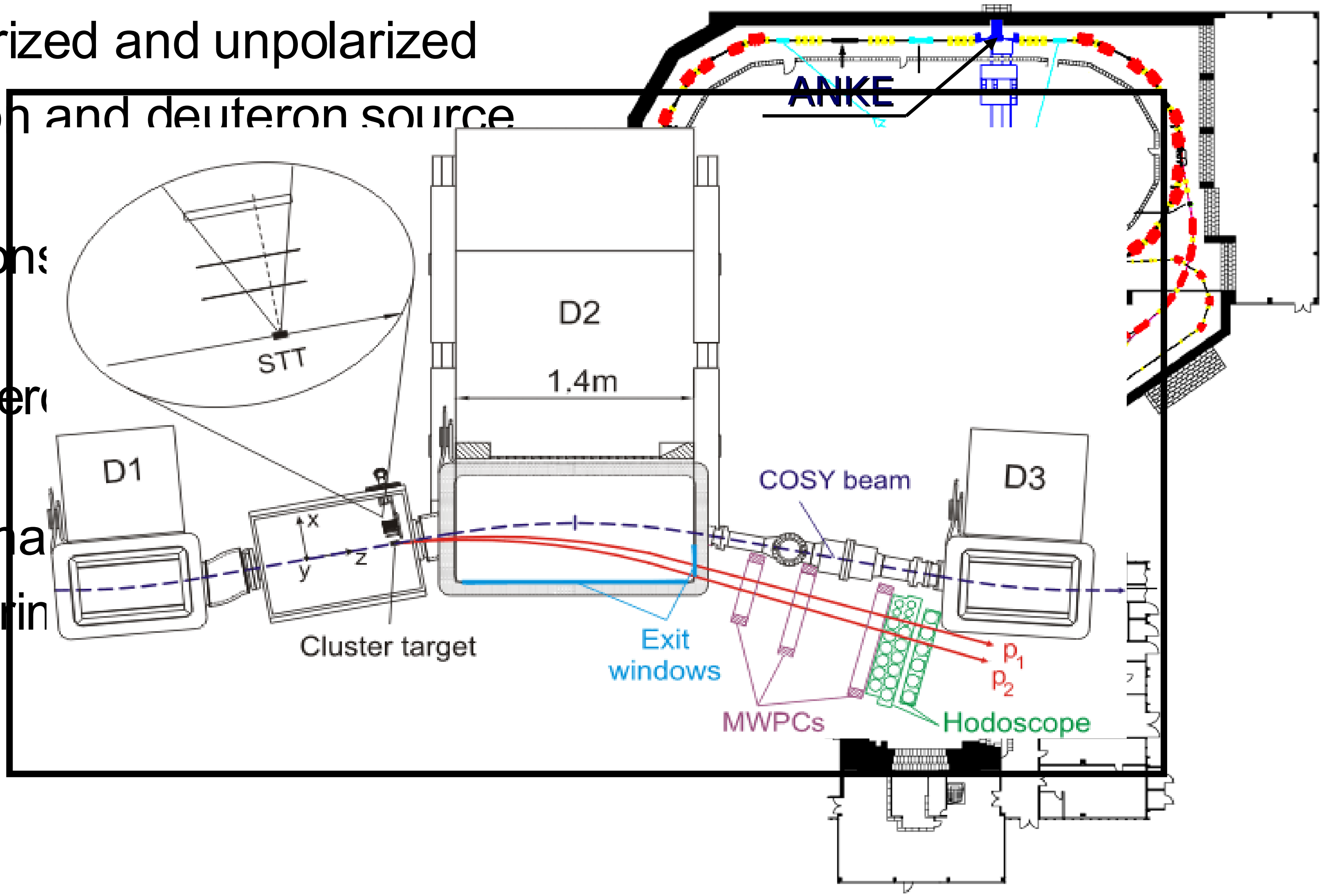
- Motivation
- Experimental tools
- Single polarized experiment T_d = 1.2 GeV (Nov `03)
- Polarization export T_d = 1.2, 1.6, 1.8 GeV (Feb `05)
- Double polarized experiment T_d =1.2 GeV (Jan `07)
- Summary

Motivation

- Reconstruction of spin dependent np amplitudes
- Single and double polarized CE reaction $dp \rightarrow (pp)_{^1S_0}\, n$
- Polarimetry of deuteron beam and hydrogen target is needed

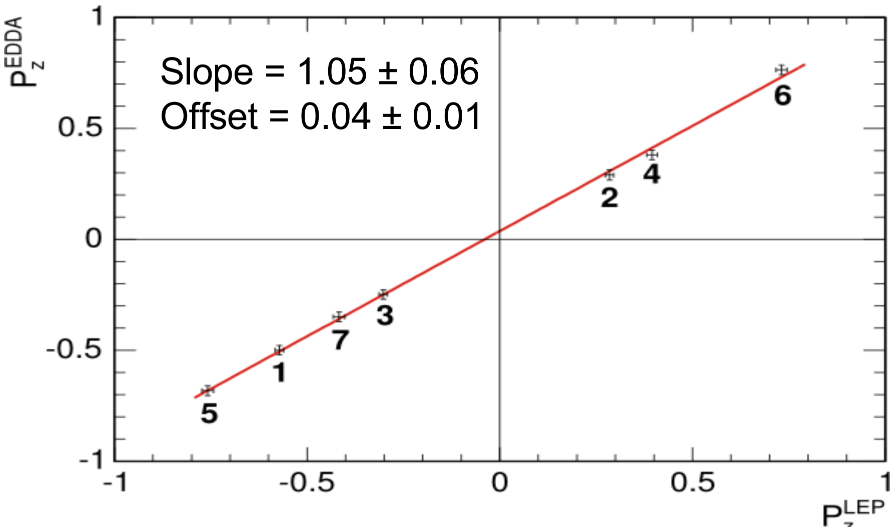
Experimental tools: COSY & ANKE

- Polarized and unpolarized proton and deuteron source
- Protons
- Deuter
- Interna experin



Single polarized experiment: Beam polarimetry

Spin mode	P_z ideal	P_{zz} ideal	Intensity $[I_0]$
0	0	0	1
1	-2/3	0	1
2	+1/3	+1	1
3	-1/3	-1	1
4	+1/2	-1/2	2/3
5	-1	+1	2/3
6	+1	+1	2/3
7	-1/2	-1/2	2/3



$P_z \approx 75$ % $P_{zz} \approx 60$ %

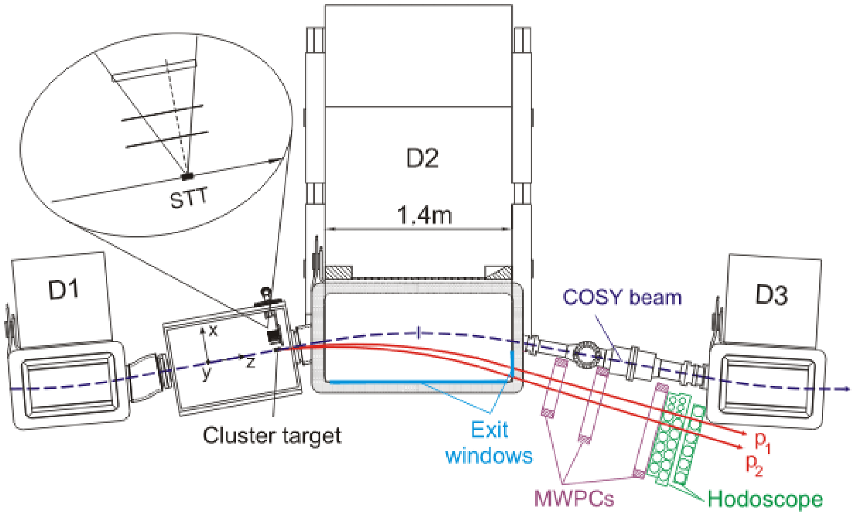
- $\vec{d}C \to dC$
  - T_d = 75.6 MeV
  - $A_y(40°)$ = 0.61 ± 0.04
    S.Kato et al.
    Nucl.Inst.Meth. A 238, 453 (1985)

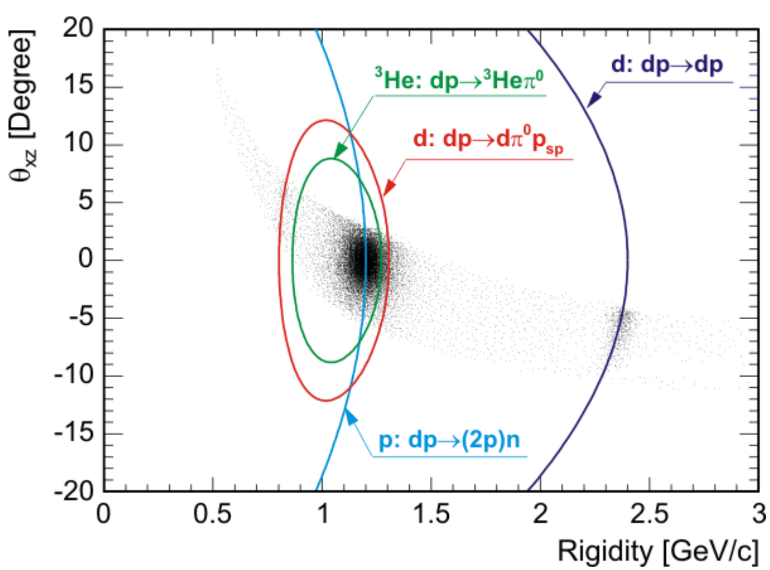
LEP

- $\vec{d}p \to dp$
  - T_d = 270 MeV
  - A_y, A_{yy} $(65° – 95°)_{c.m.}$
    K. Sekiguchi et al.
    Phys.Rev. C 65, 034003 (2002)

EDDA

Single polarized experiment: ANKE acceptance



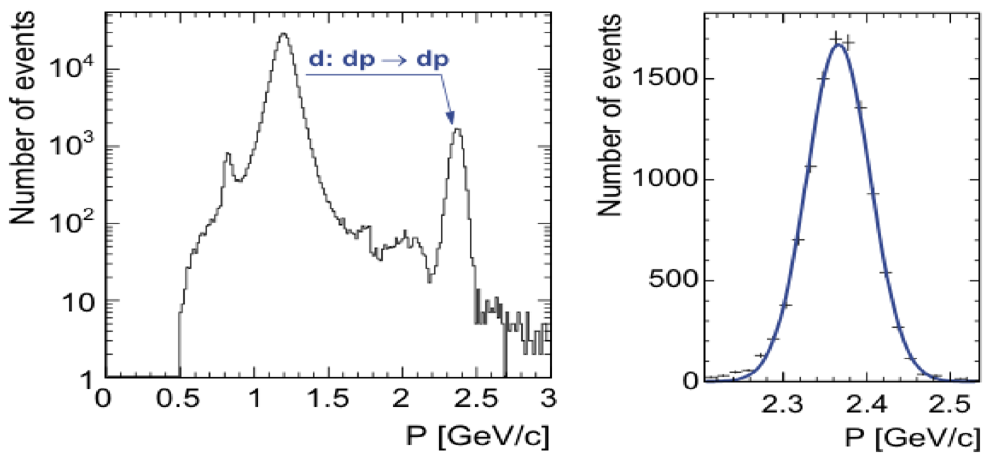


T_d = 1170 MeV

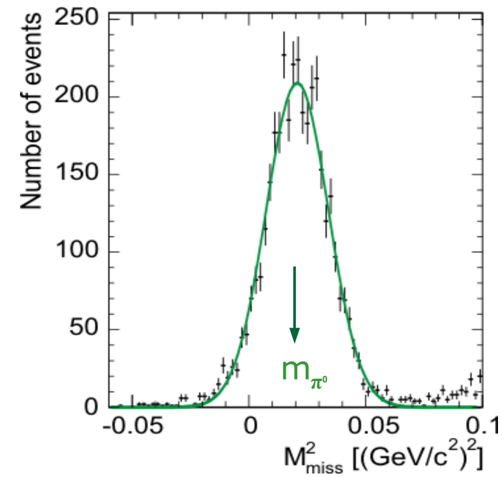
- $\vec{d}p \to dp$
- $\vec{n}p \to d\pi^0$
- $\vec{d}p \to {}^3He\pi^0$
- $\vec{d}p \to (pp)n$

Single polarized experiment: Reaction identification

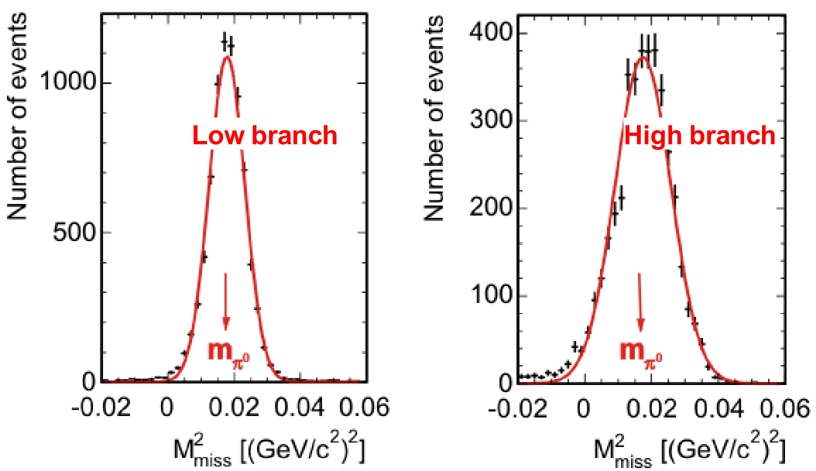
dp → dp



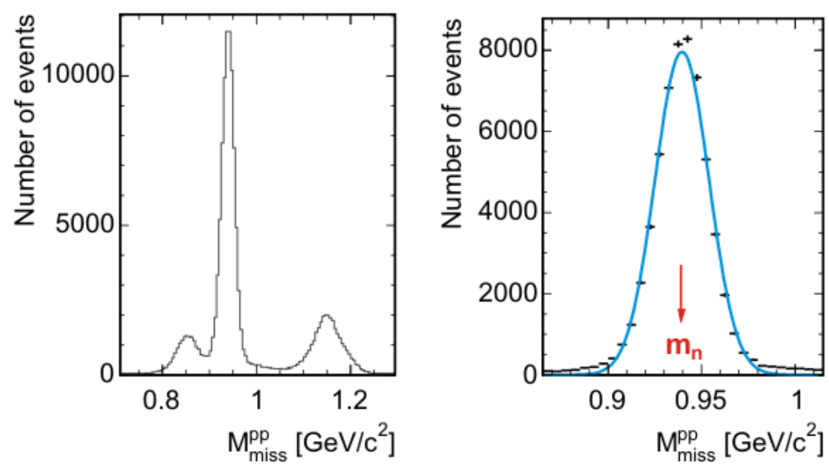
dp → ^{3}Heπ^0



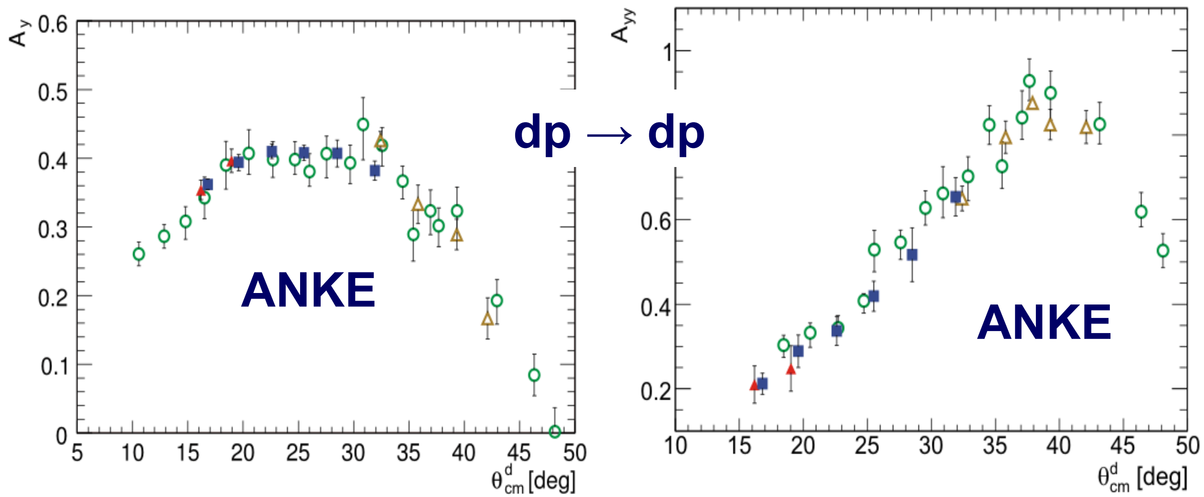
dp → dp$_{sp}$ π^0

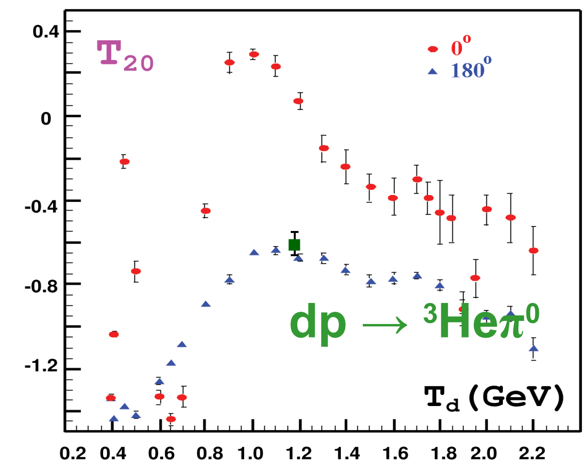


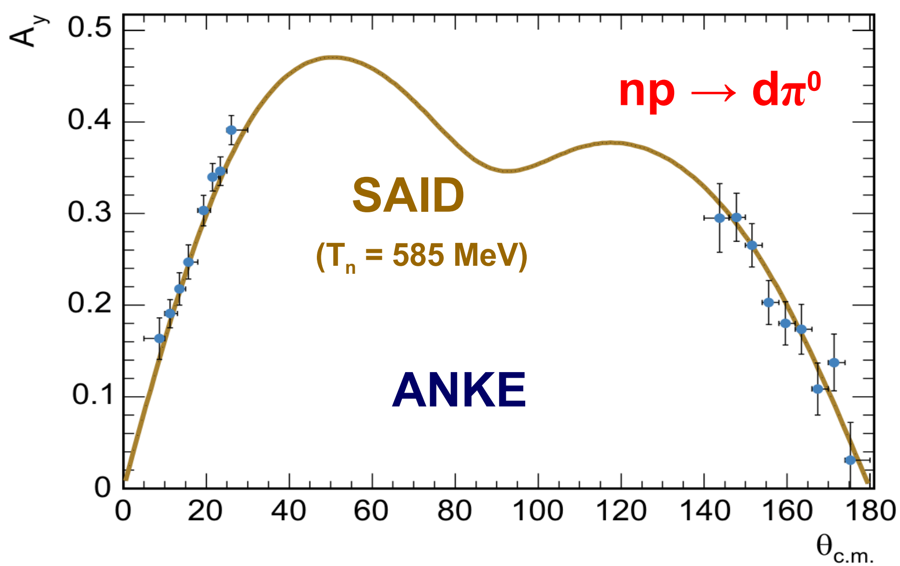
dp → (pp)n

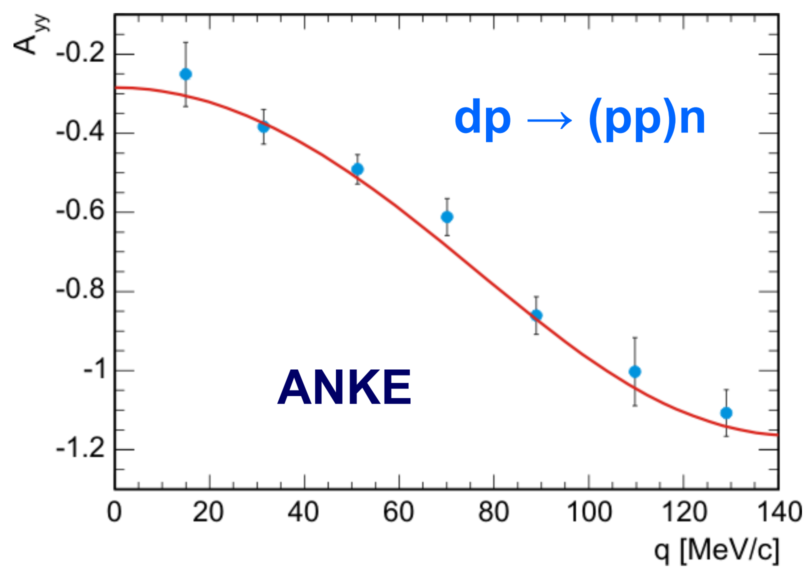


Single polarized experiment: A_y, A_{yy} measurement









Depolarization less then 4%

D. Chiladze et al. Phys. Rev. STAB 9, 050101 (2006)

Single polarized experiment: CE reaction

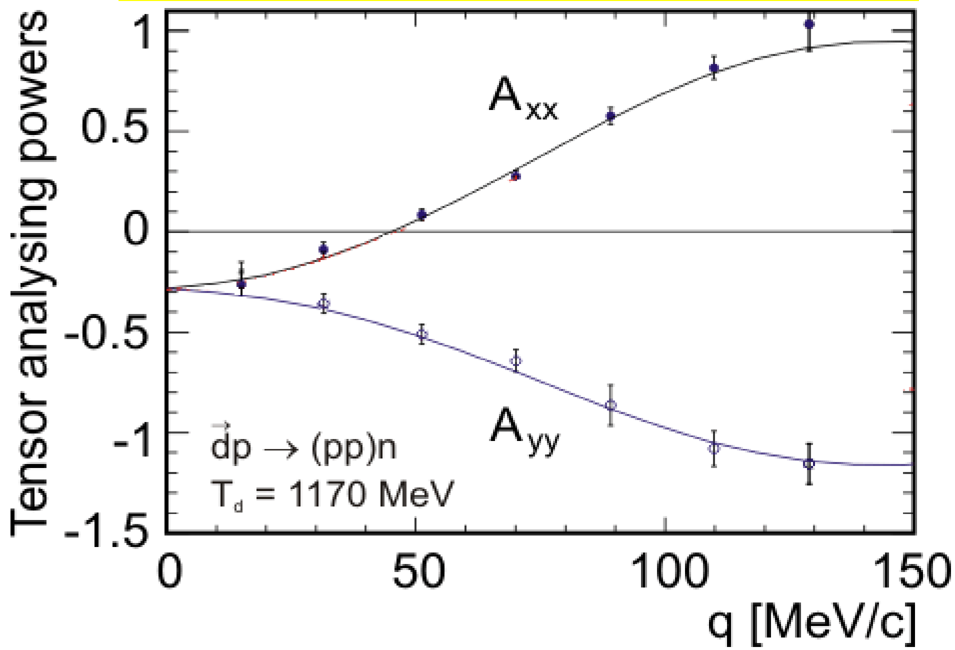
$\vec{d}p \rightarrow (pp)_{^1S_0}\, n$

Transition from deuteron to $(pp)_{^1S_0}$: pn → np spin flip

Obtain np elementary spin-dependent amplitudes:

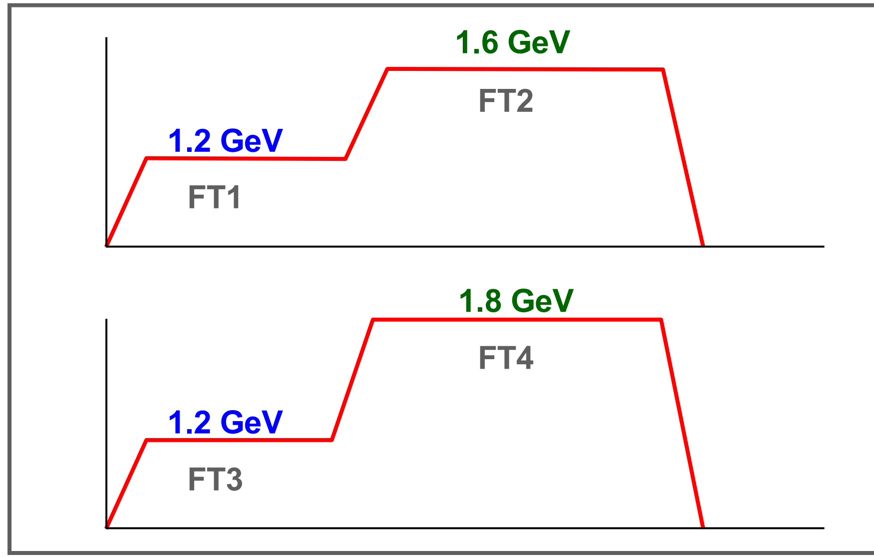
$$\frac{d\sigma}{dt}, A_{yy}, A_{xx} \Rightarrow |\gamma|^2 + |\beta|^2, |\delta|^2, |\varepsilon|^2$$

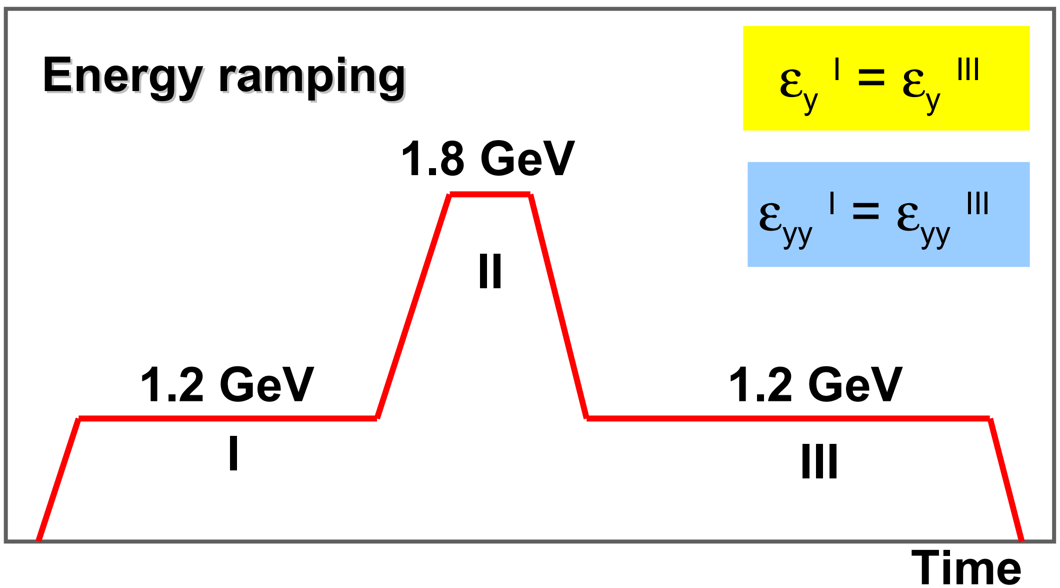
D.Chiladze et al. Phys. Let. B 637, 170 (2006)



Polarization export

- Polarized deuteron beam
- T_d = 1.2, 1.6, 1.8 GeV
- N_d = 1.8×10^{10} , 1.6×10^{10}





Results

$\varepsilon_y^{\,I} = -0.213 \pm 0.005$

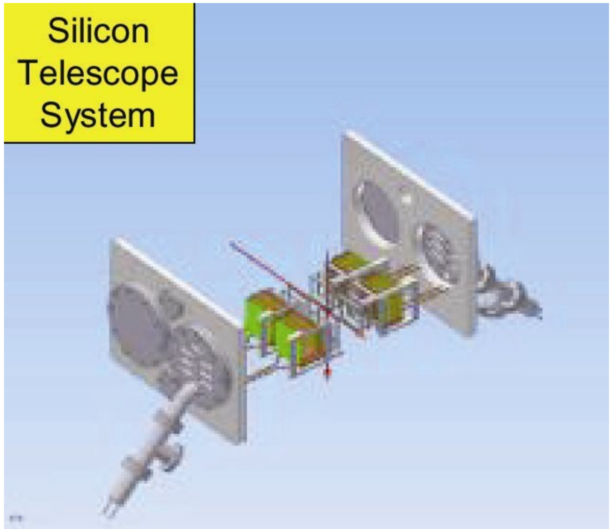
$\varepsilon_y^{\,III} = -0.216 \pm 0.006$

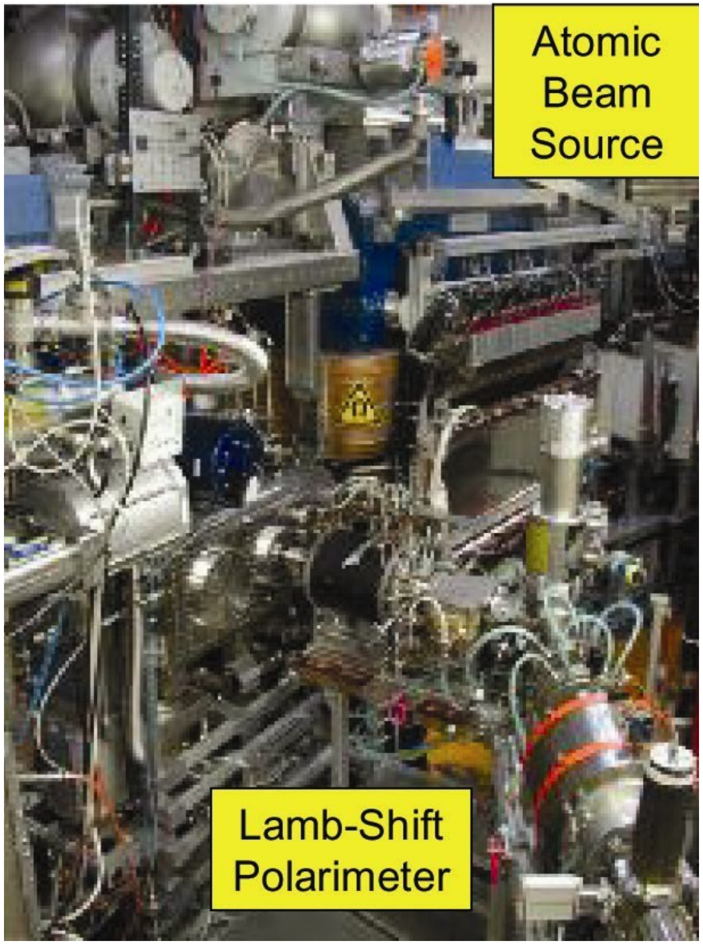
$\varepsilon_{yy}^{\,I} = 0.057 \pm 0.003$

$\varepsilon_{yy}^{\,III} = 0.059 \pm 0.003$

Double polarized experiment: New tools

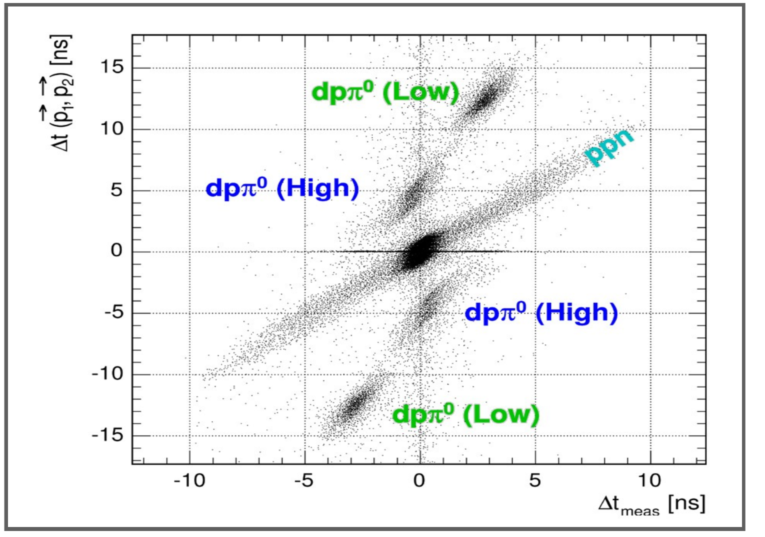
- Polarized deuteron beam
- Polarized H cell target
- Silicon Tracking Telescope

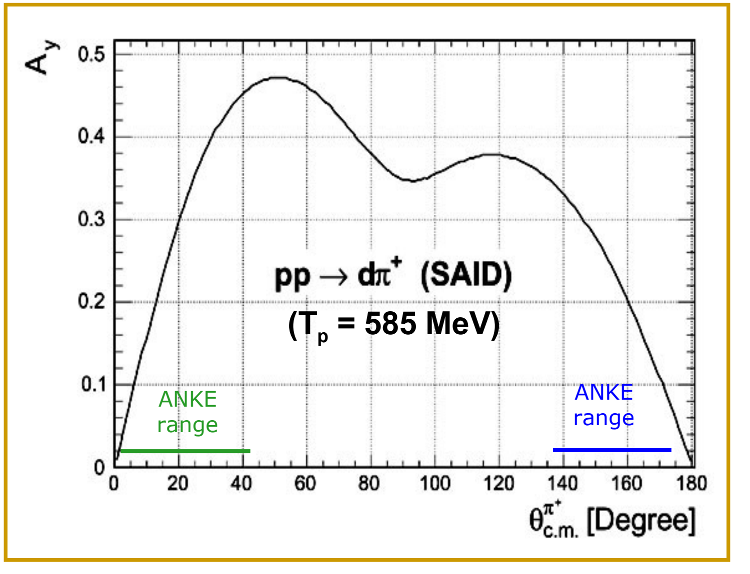




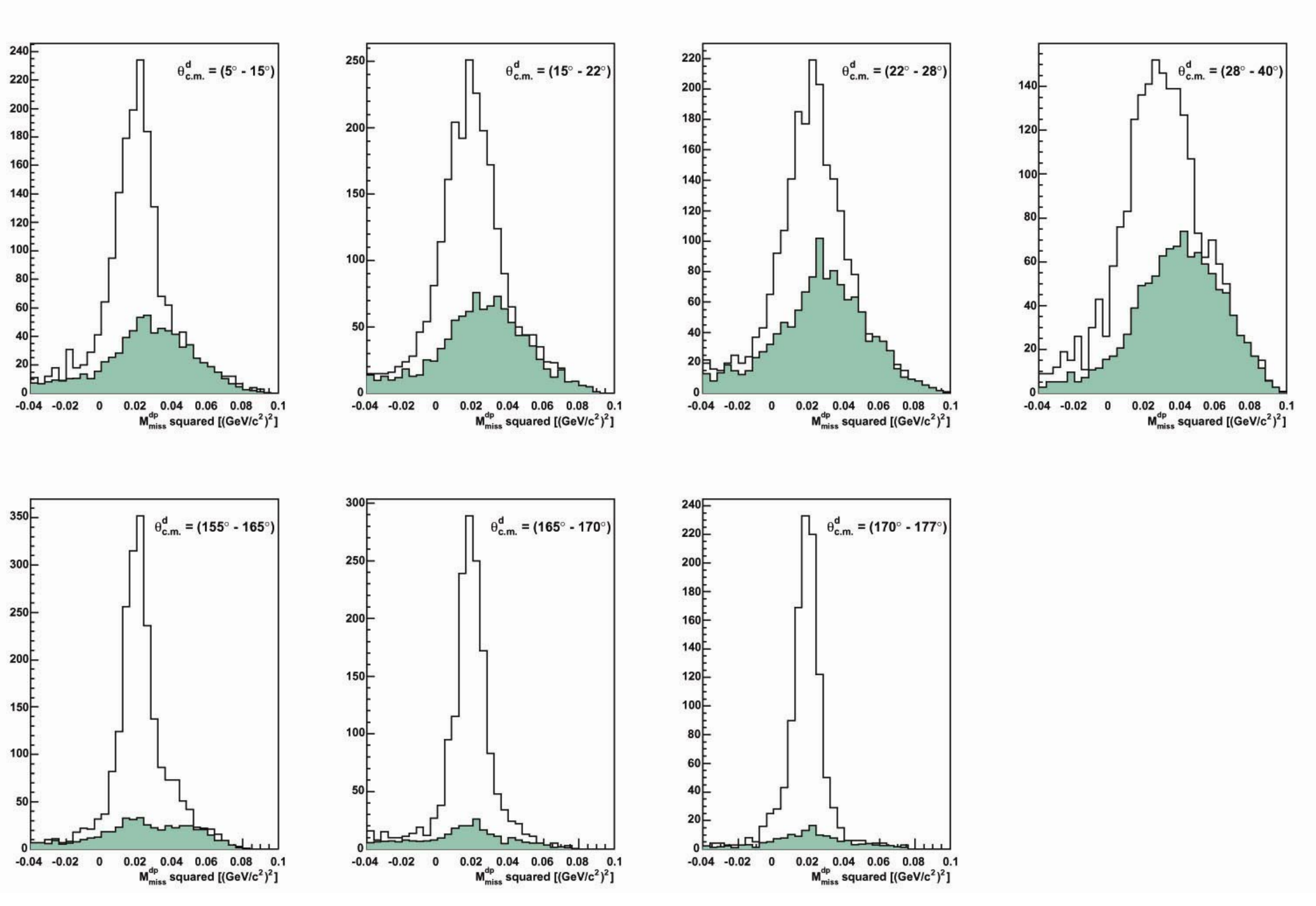
Double polarized experiment: Target polarization

- Unpolarized deuteron beam
- Target polarization "spin-up", "spin-down" flipping in every 5 sec.
- $d\vec{p} \rightarrow dp_{sp}\,\pi^0$
  - $A_y(pp\rightarrow dp^+)$ from SAID

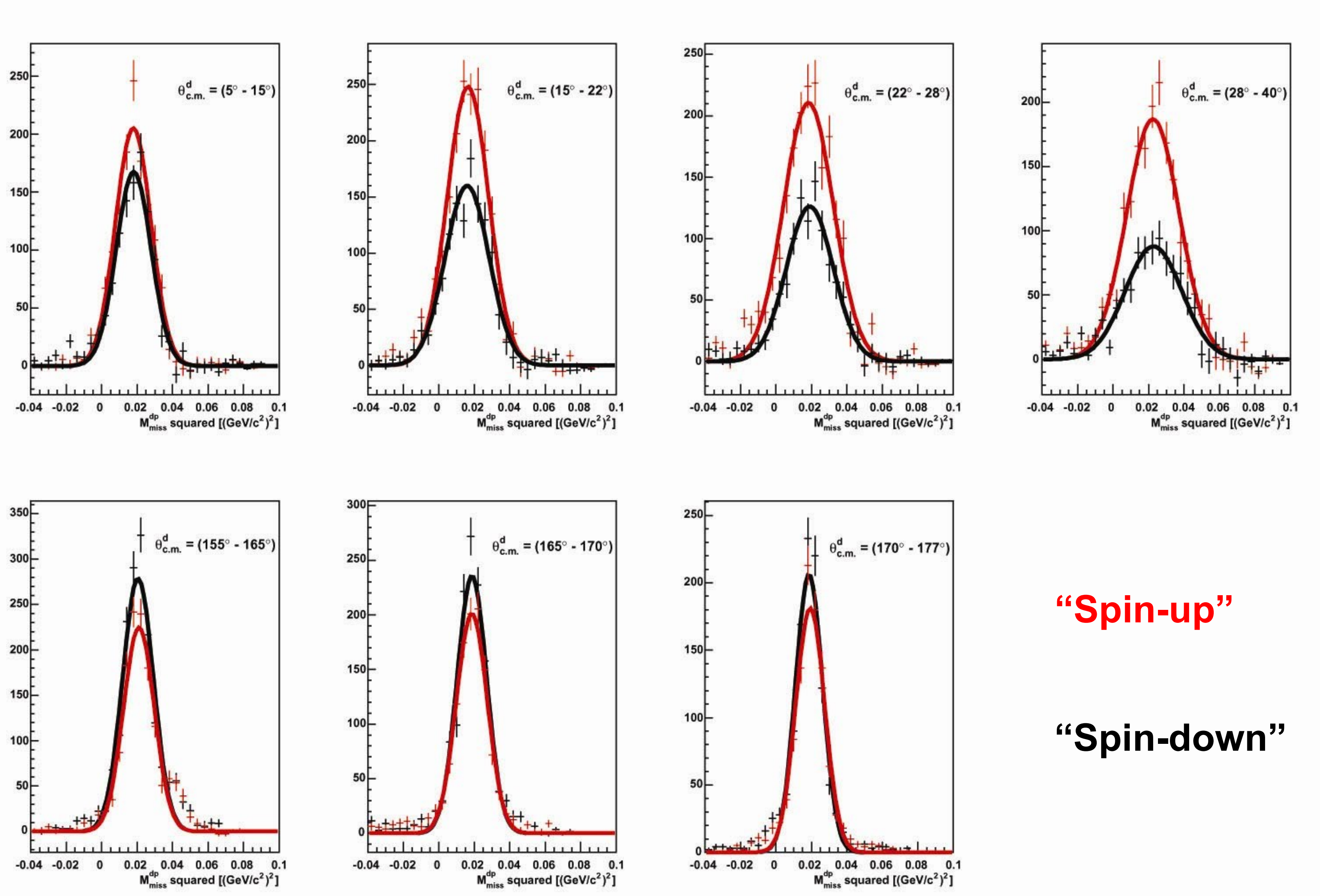




Double polarized experiment: Target polarization



Double polarized experiment: Target polarization



"Spin-up"

"Spin-down"

Double polarized experiment: Target polarization

$$N_{pol}(\theta,\varphi) = N_0(\theta)\left(1 + Q_y \cdot A_y(\theta) \cdot \cos\varphi\right)$$

$$N^{\uparrow}(\theta,\varphi) = N_0(\theta)\left(1 + |Q_y| \cdot A_y(\theta) \cdot \cos\varphi\right)$$

$$N^{\downarrow}(\theta,\varphi) = N_0(\theta)\left(1 - |Q_y| \cdot A_y(\theta) \cdot \cos\varphi\right)$$

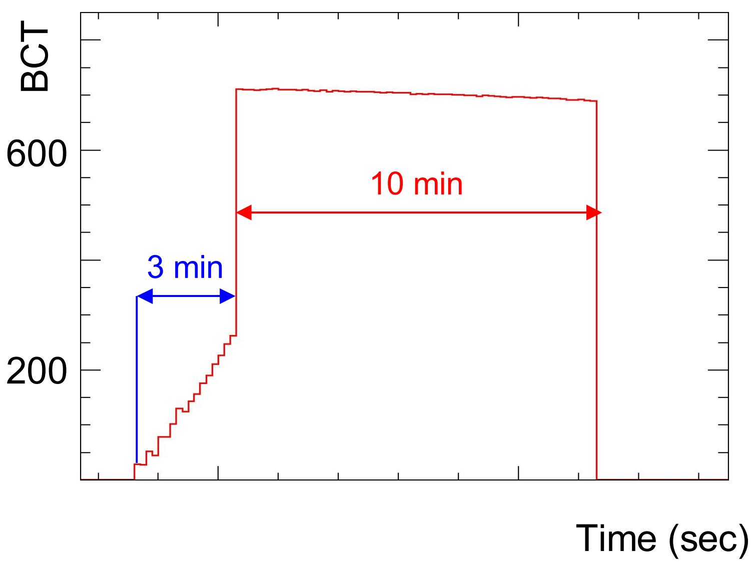
$$\varepsilon(\theta) = \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}} = |Q_y| A_y(\theta) \langle \cos\varphi \rangle$$

$$|Q_y| = 0.79 \pm 0.07$$

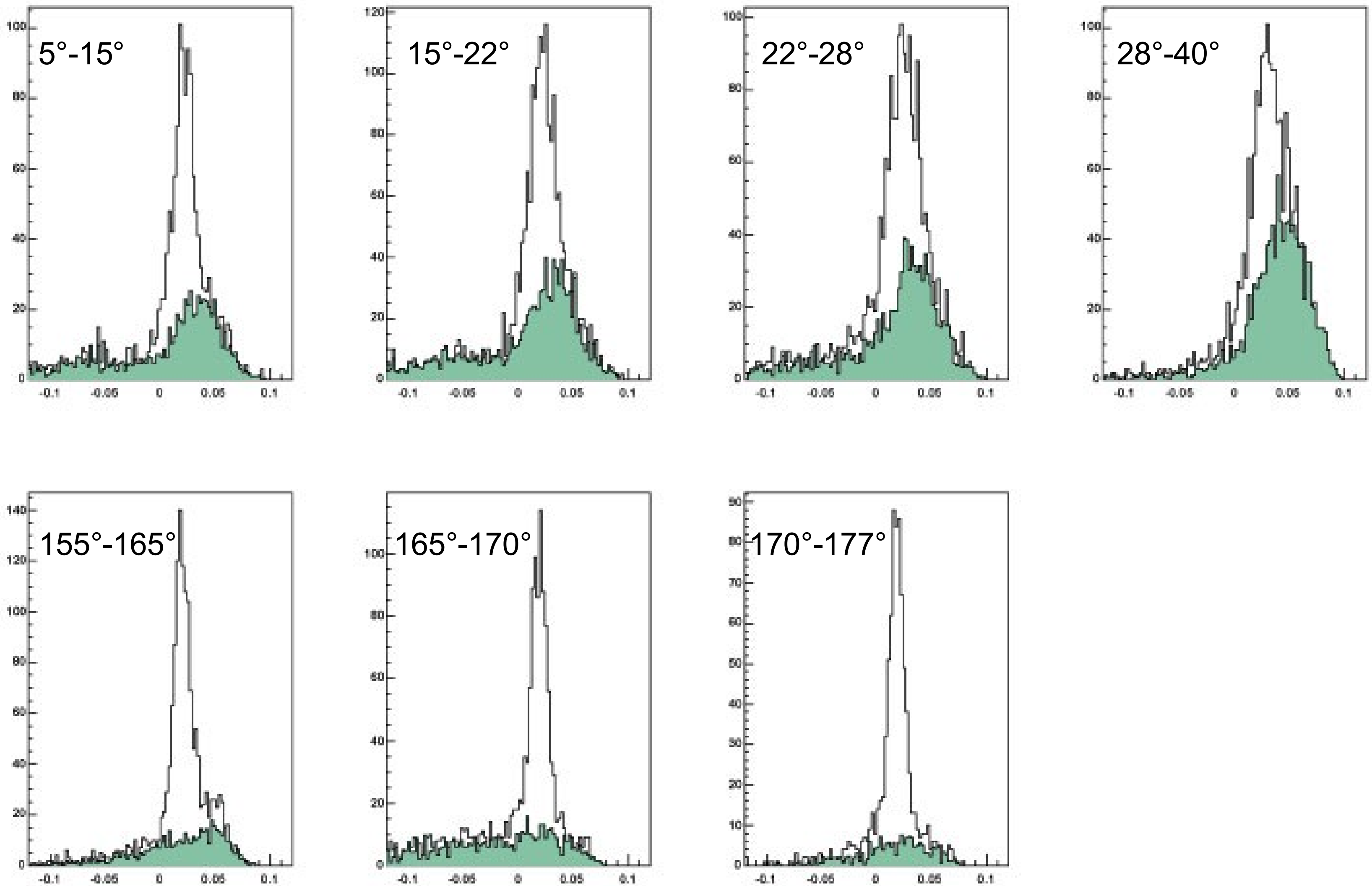
Double polarized experiment: Beam polarization

- Polarized deuteron beam
- Cell target
- Injection with stacking
- $dp \rightarrow dp_{sp}\,\pi^0$ for P_z
- $dp \rightarrow dp$ for P_z and P_{zz}

Spin mode	P_z ideal	P_{zz} ideal	Intensity $[I_0]$
1	-2/3	0	1
2	+1/3	-1	1
3	-1	+1	2/3
4	+1	+1	2/3
5	0	0	1



Double polarized experiment: Beam polarization



Double polarized experiment: Beam polarization

$$N_{pol}(\theta,\varphi) = N_0(\theta)\left(1 + P_z \cdot A_y(\theta)\cdot\cos\varphi\right)$$

$$\varepsilon(\theta) = \frac{N_{pol} - N_0}{N_0} = P_z A_y(\theta)\langle\cos\varphi\rangle$$

$$P_z^{ANKE} = 0.51\% \pm 0.040$$

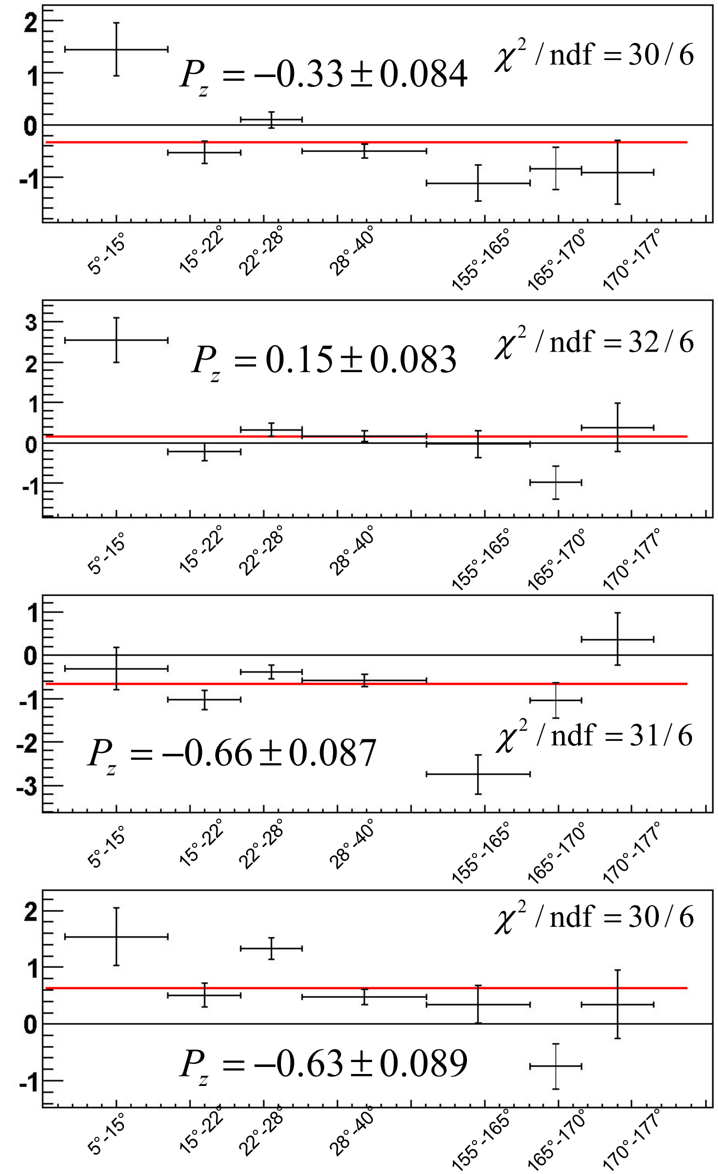
$$P_z^{LEP} = 0.66\% \pm 0.003$$

P_z = -2/3

P_z = +1/3

P_z = -1

P_z = +1



Summary & Outlook

- Polarisation standard at 1.2 GeV
- Polarisation export technique
- Double polarized $dp \rightarrow (2p)n$ reaction

- Analyse Feb`05, Nov`06 and Jan`07 data
- Polarimetry for $\vec{d}p \rightarrow {}^{3}He\eta$

Introduction: np amplitudes

$\vec{d}p \rightarrow (pp)_{^1S_0}\, n$

$$I = |\gamma|^2 + |\beta|^2 + |\varepsilon|^2 + |\delta|^2 R^2, \quad R = \frac{S^+(k,q/2)}{S^-(k,q/2)}; \qquad \frac{d^4\sigma}{dt\,d^3k} = \frac{1}{3} I \left[S^-(k,q/2)\right]^2;$$

$$IT_{20} = \frac{1}{\sqrt{2}}\left[|\gamma|^2 + |\beta|^2 + |\delta|^2 R^2 - 2|\varepsilon|^2\right]; \qquad IT_{22} = \frac{\sqrt{3}}{2}\left[|\gamma|^2 + |\beta|^2 - |\delta|^2 R\right];$$

$$IC_{y,y} = -2\Re(\varepsilon^* \delta)R; \quad IC_{x,x} = -2\Re(\beta^* \varepsilon); \quad IC_{z,z} = -2\Re(\delta^* \beta)R.$$

$\frac{d\sigma}{dt}, T_{20}, T_{22} \Rightarrow |\gamma|^2 + |\beta|^2, |\delta|^2, |\varepsilon|^2$ **over a range in** t

Bugg, Wilkin; NP A467(1987) 575

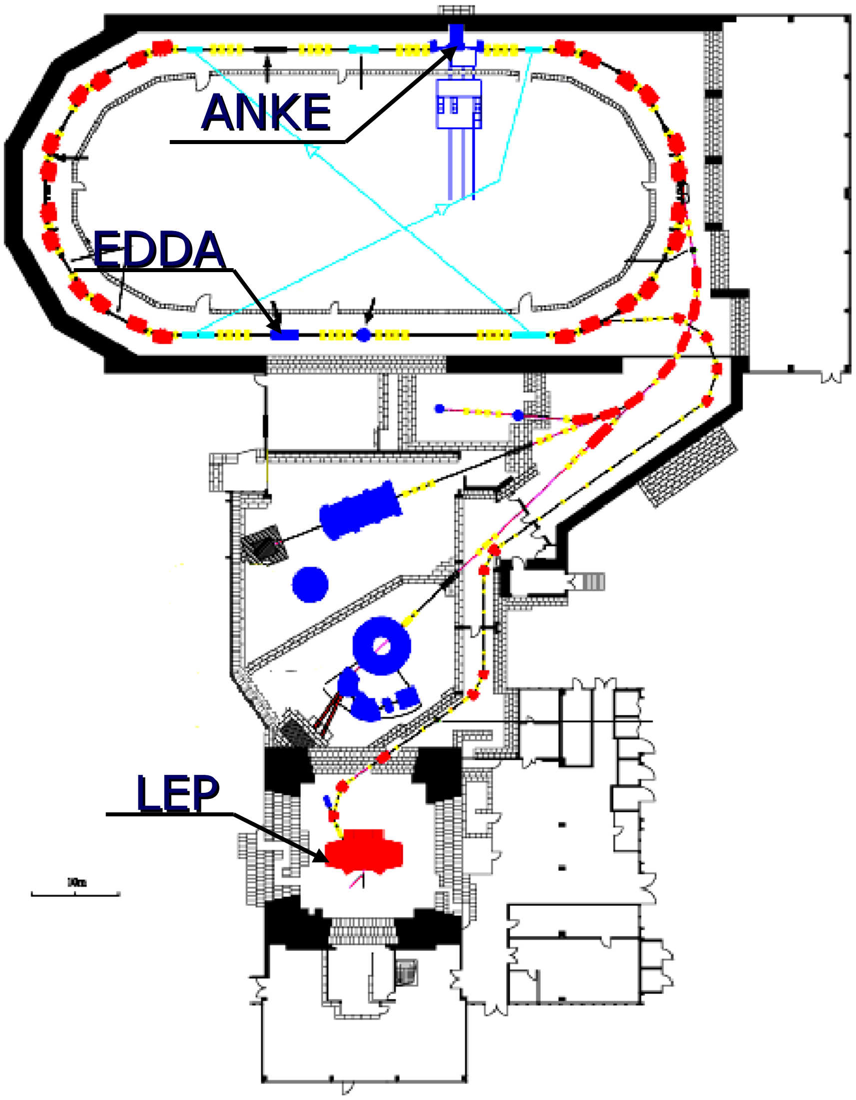
In collinear kinematics $\Rightarrow$

$$I = 2|\beta|^2 + |\varepsilon|^2; \quad IT_{20} = \sqrt{2}\left[|\beta|^2 - |\varepsilon|^2\right] \Rightarrow |\beta|, |\varepsilon|$$

$$IC_{y,y} = -2\Re(\varepsilon\beta^*); IC_{xz,y} = -3\Im(\beta\varepsilon^*) \Rightarrow \cos(\varphi_\varepsilon - \varphi_\beta)$$

Experimental tools: COSY

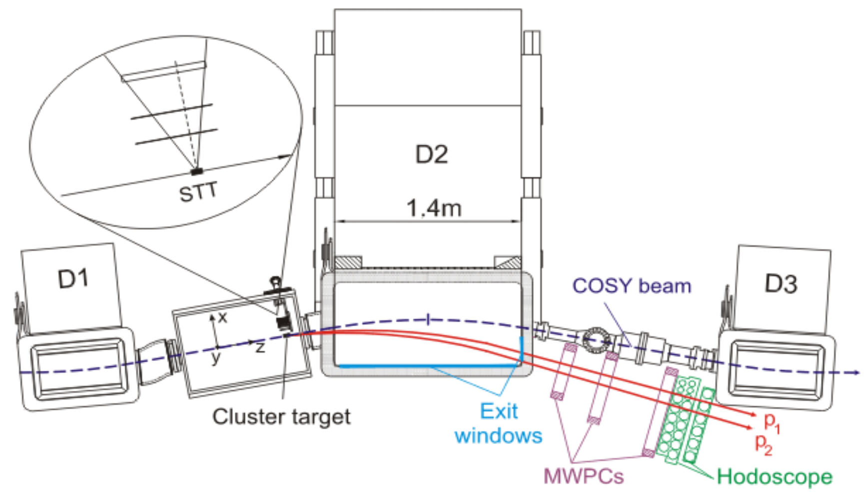
- Polarized and unpolarized proton and deuteron source
- Protons up to 2.88 GeV
- Deuterons up to 2.23 GeV
- Internal and external experiments

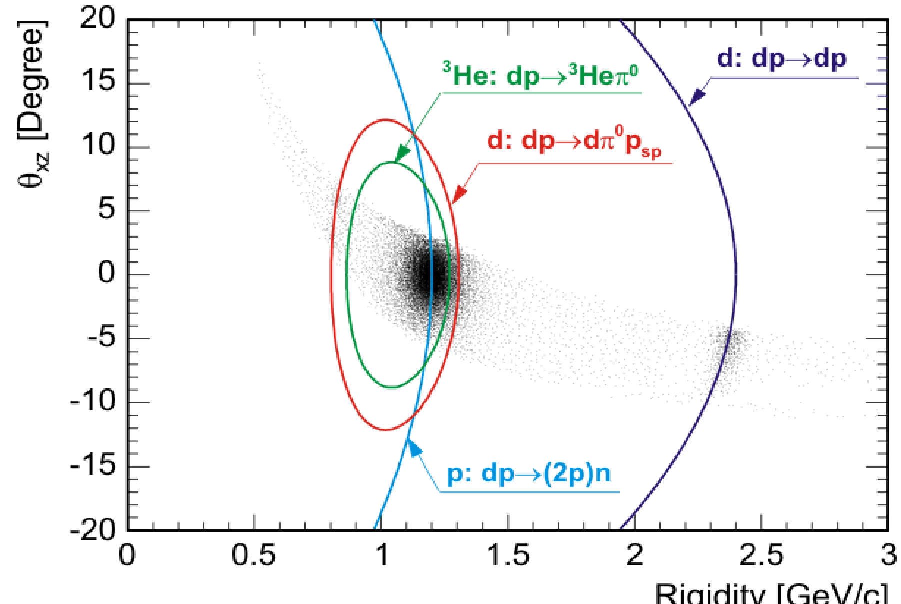


Experimental tools: ANKE setup

T_d = 1170 MeV

- $\vec{d}p \rightarrow dp$
- $\vec{d}p \rightarrow {}^3He\pi^0$
- $\vec{d}p \rightarrow dp_{sp}\,\pi^0$
- $\vec{d}p \rightarrow (pp)n$

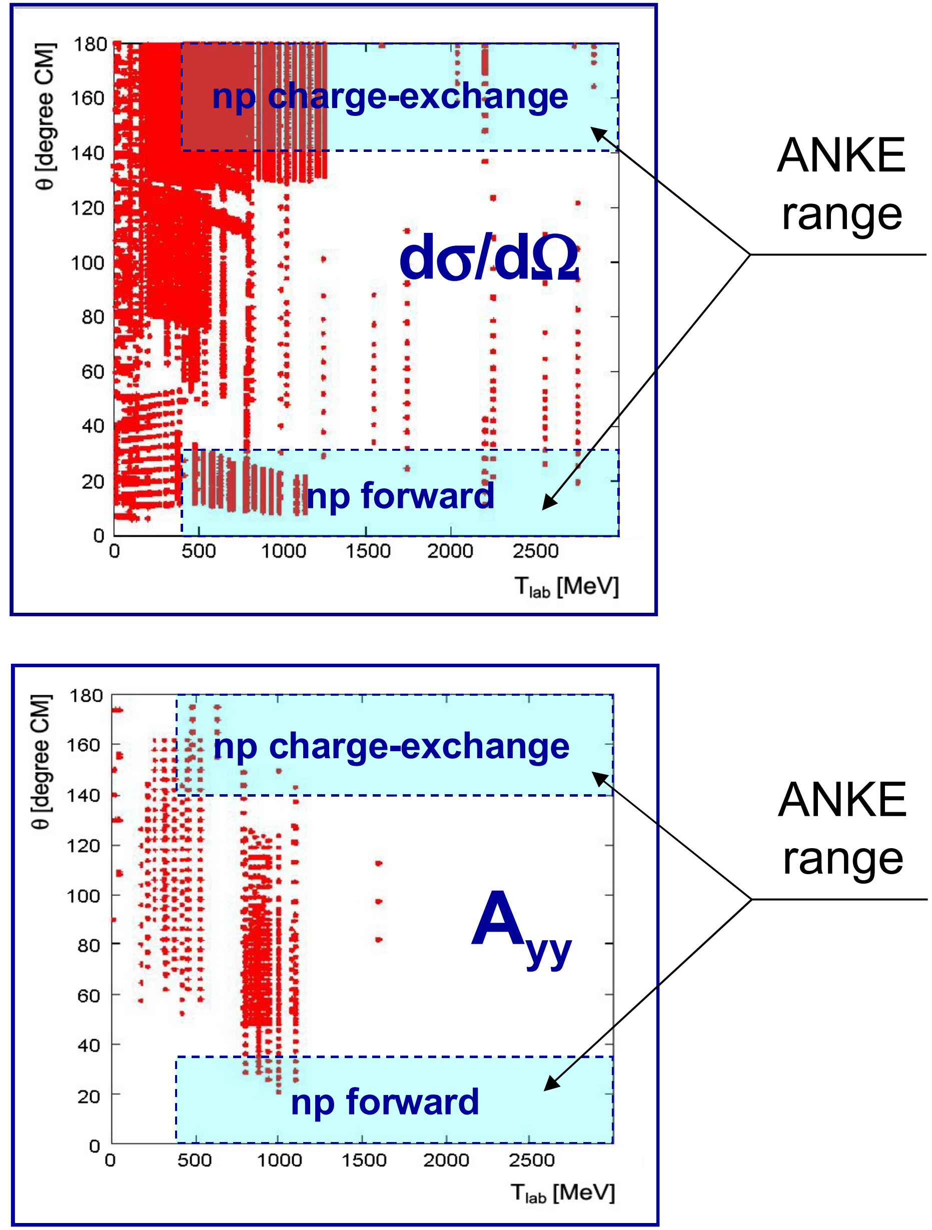




Introduction: NN Scattering

- Characterization requires precise data for Phase Shift Analyses

- Current experimental status of NN data:
  - pp system (I=1) well-known up to 2.5 GeV (EDDA): Majority of data on unpolarized, single, and double polarized observables
  - np system (I=0) poorly known → ANKE will provide high-quality data in forward/backward region



Introduction: np amplitudes

- The amplitude of the elementary np→pn reaction:

$$I_{np\to pn} = |\alpha|^2 + |\beta|^2 + 2|\gamma|^2 + |\delta|^2 + |\varepsilon|^2$$

- In the impulse approximation the deuteron charge-exchange amplitude:

$$I_{dp\to(pp)n} = |\gamma|^2 + |\beta|^2 + |\varepsilon|^2 + |\delta|^2 R^2, R = \frac{S^+(k,q/2)}{S^-(k,q/2)}$$

- Single polarized charge-exchange reaction $\vec{\mathrm{d}}\mathrm{p}\to(2\mathrm{p})\mathrm{n}$
  - Direct reconstruction of the spin-dependent *np* amplitudes

$$\frac{d\sigma}{dt}, A_{yy}, A_{xx} \Rightarrow |\gamma|^2 + |\beta|^2, |\delta|^2, |\varepsilon|^2$$

- Double polarized charge-exchange reaction $\vec{\mathrm{d}}\vec{\mathrm{p}}\to(2\mathrm{p})\mathrm{n}$
  - Measurement of spin-spin correlation parameters

$$C_{y,y}, C_{x,x} \Rightarrow \cos(\varphi_\varepsilon - \varphi_\beta)$$

Double polarized experiment: Target polarization