A measurement of Spin–TRansfer coefficients In the fusion reaction $D(\vec{d},\vec{p})^3H$

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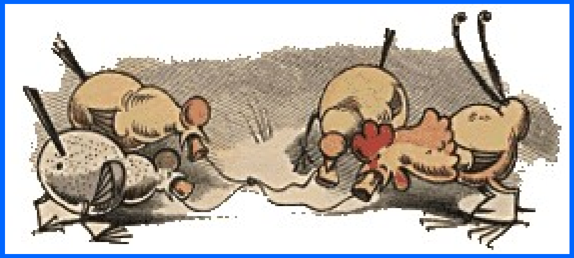
overview

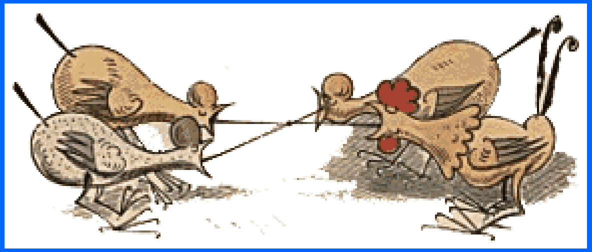
- motivation
- **polarization transfer**
- transfer polarimeter
  - setup
  - calibration
- double scattering experiment
  - experimental method
  - results
- comparison with others and theory

Information about the reaction mechanism

Many experimental challenges in the 4N-system but also theoretically…

„Max und Moritz" by W. Busch



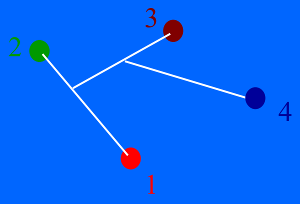


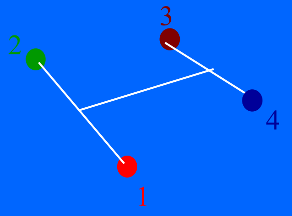
mathematical: Faddeev-Yakubovskiĭ- equations

A = 4 system as laboratory

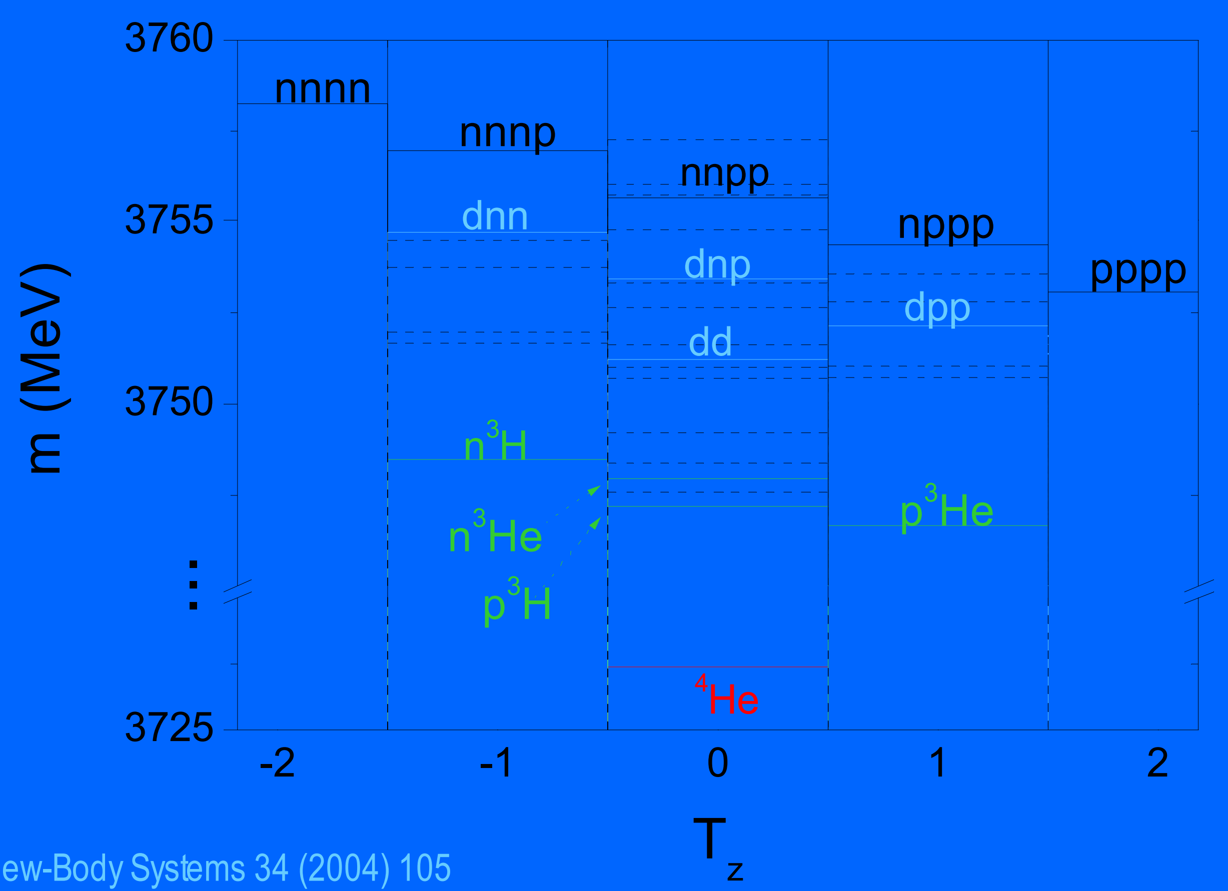
Test other dynamical aspects of NN potentials than A = 2, 3

New, yet not solved, problems





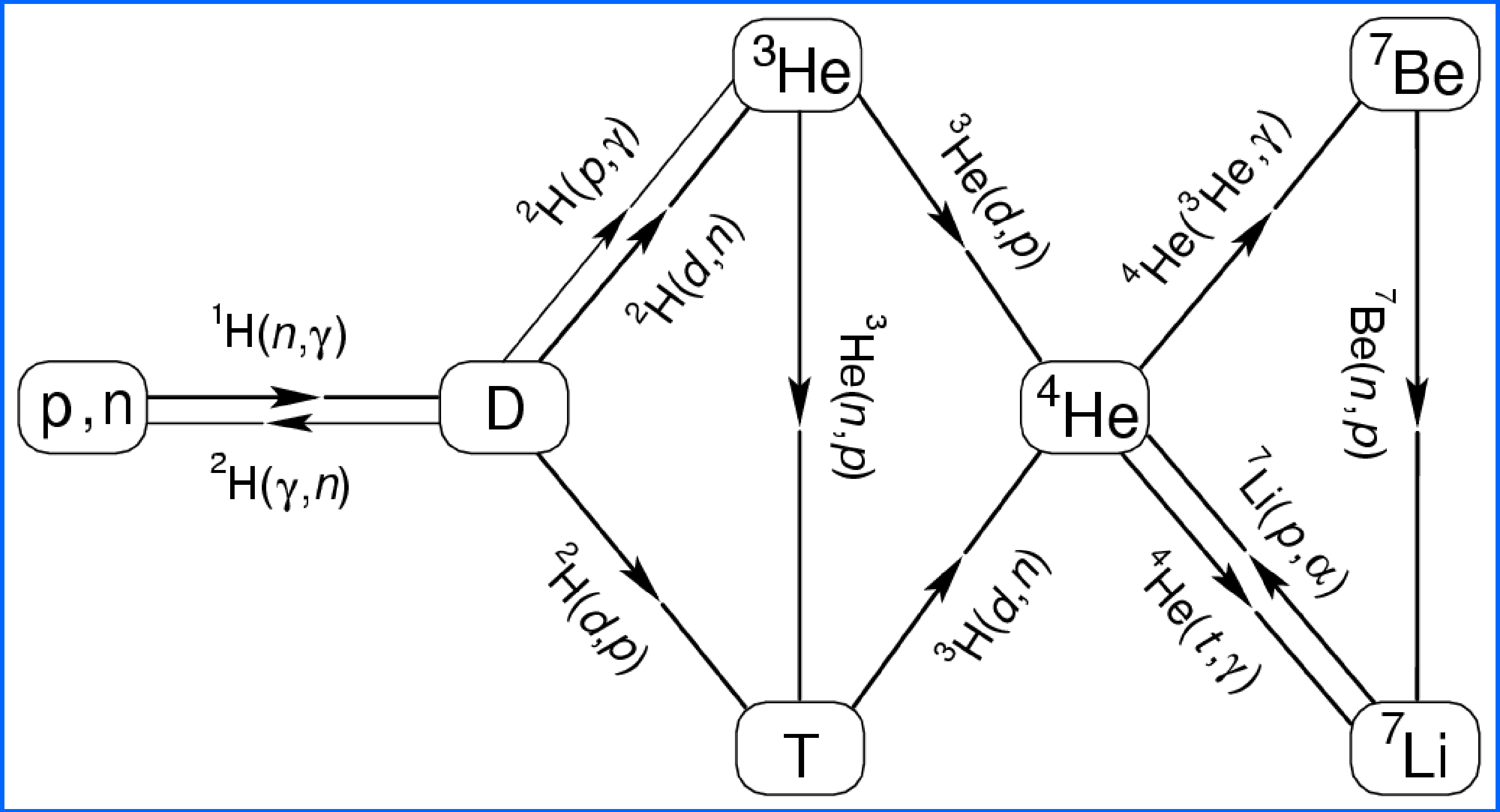
Complexity of the 4N-system



R. Lazauskas, Few-Body Systems 34 (2004) 105

Big Bang - Nucleosynthesis

primordial key reactions

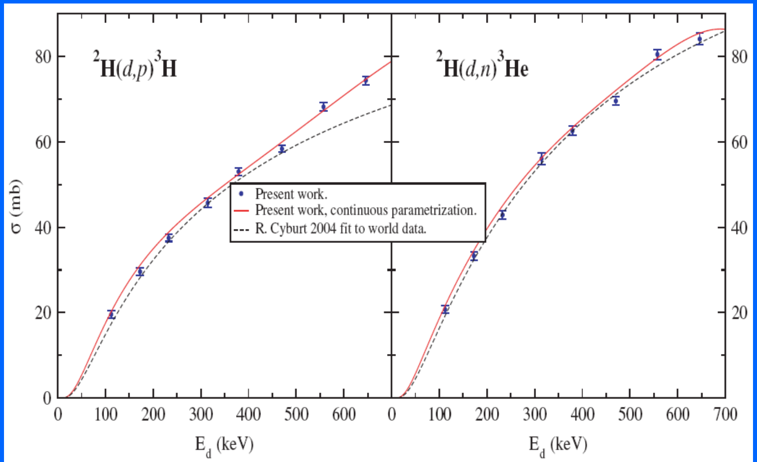


1934 First investigations of the mirror reactions

$d + D \rightarrow p + 3H$ Q = 4.033 MeV
$d + D \rightarrow n + 3He$ Q = 3.268 MeV

Important: cross sections

Precision measurements @ TUNL



D. Leonard et al., PRC 73 (2006) 045801

Why polarization physics …

… somewhat special,

but very instructive !

One-spin observables: Analyzing powers

Many experiments @ very low energies

B. Becker et al., Few-Body Systems 13 (1992) 19

Until 2001:

No two-spin observables ≤ 6 MeV

Zero-Spin observable σ

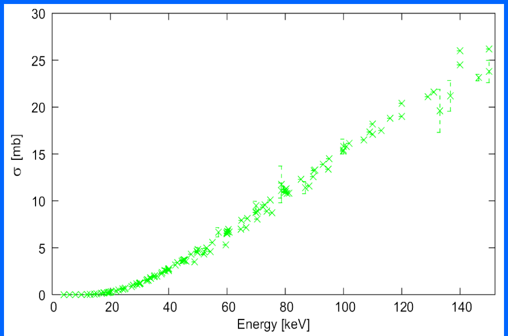
Spin 1 – Spin ½ transfer :

One-Spin observables $A_y, A_{xz}, A_{zz}, A_{xx-yy}$

Two-Spin observables $K_y^{y'}, K_x^{x'}, K_z^{x'}, K_z^{z'}, K_x^{z'}$

$K_{xy}^{x'}, K_{yz}^{x'}, K_{xz}^{y'}, K_{xx-yy}^{y'}, K_{zz}^{y'}, K_{xy}^{z'}, K_{yz}^{z'}$

↪ low count rate



D(d,p)T

Remedy:

- thick targets
- large solid angles of detectors
- entrance aperture in front of polarimeter

but :

- attenuation of A_y

Analyzer depends on energy range

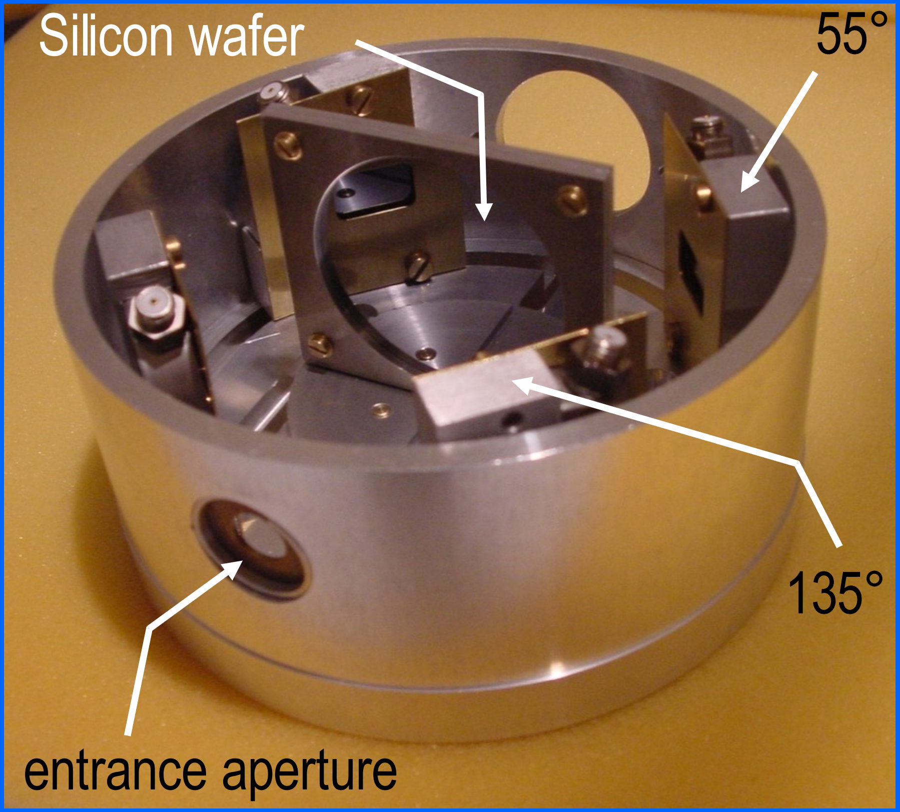
figure of merit : $A_y^2 \cdot \left(\frac{d\sigma}{d\Omega}\right)_0$

protons @ E_p = 3 – 4 MeV :

$Si(\vec{p},p)Si$

detectors : θ = 55°

θ = 135°



Results of the calibration:

Polarimeter 1 $A_y = -0.278 \pm 0.002$

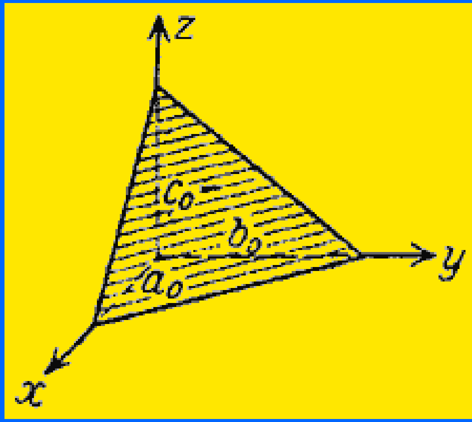
Polarimeter 2 $A_y = -0.151 \pm 0.002$

Efficiency of the polarimeters

$$3\text{-}4 \cdot 10^{-5}$$

Other polarimeters :

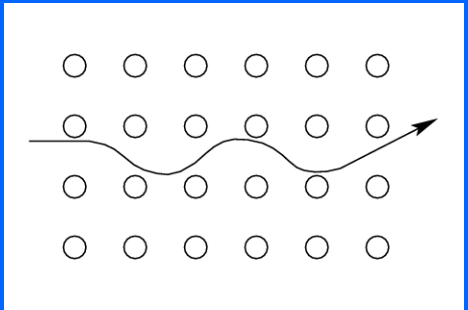
A.I.	(2001)	^{28}Si	$3.8 \cdot 10^{-6}$	Diplomarbeit
Katabuchi	(2001)	^{28}Si	$9.7 \cdot 10^{-6}$	Phys. Rev. C 64 (2001) 047601
Sydow	(1992)	^{12}C	$3.4 \cdot 10^{-5}$	
Vohl	(1995)	^{3}He	$1.4 \cdot 10^{-6}$	

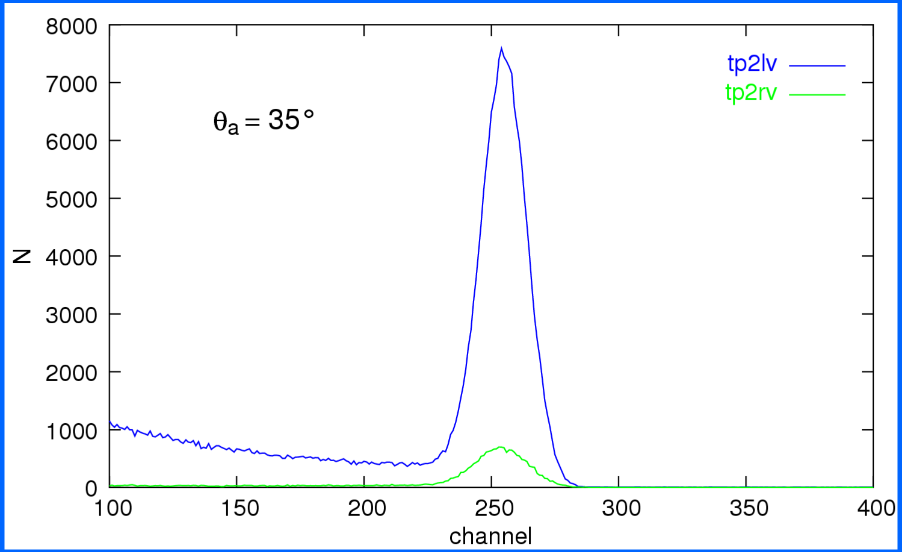


Targets : analyzer reaction

Effects of the crystal structure in Silicon

↪ Channeling

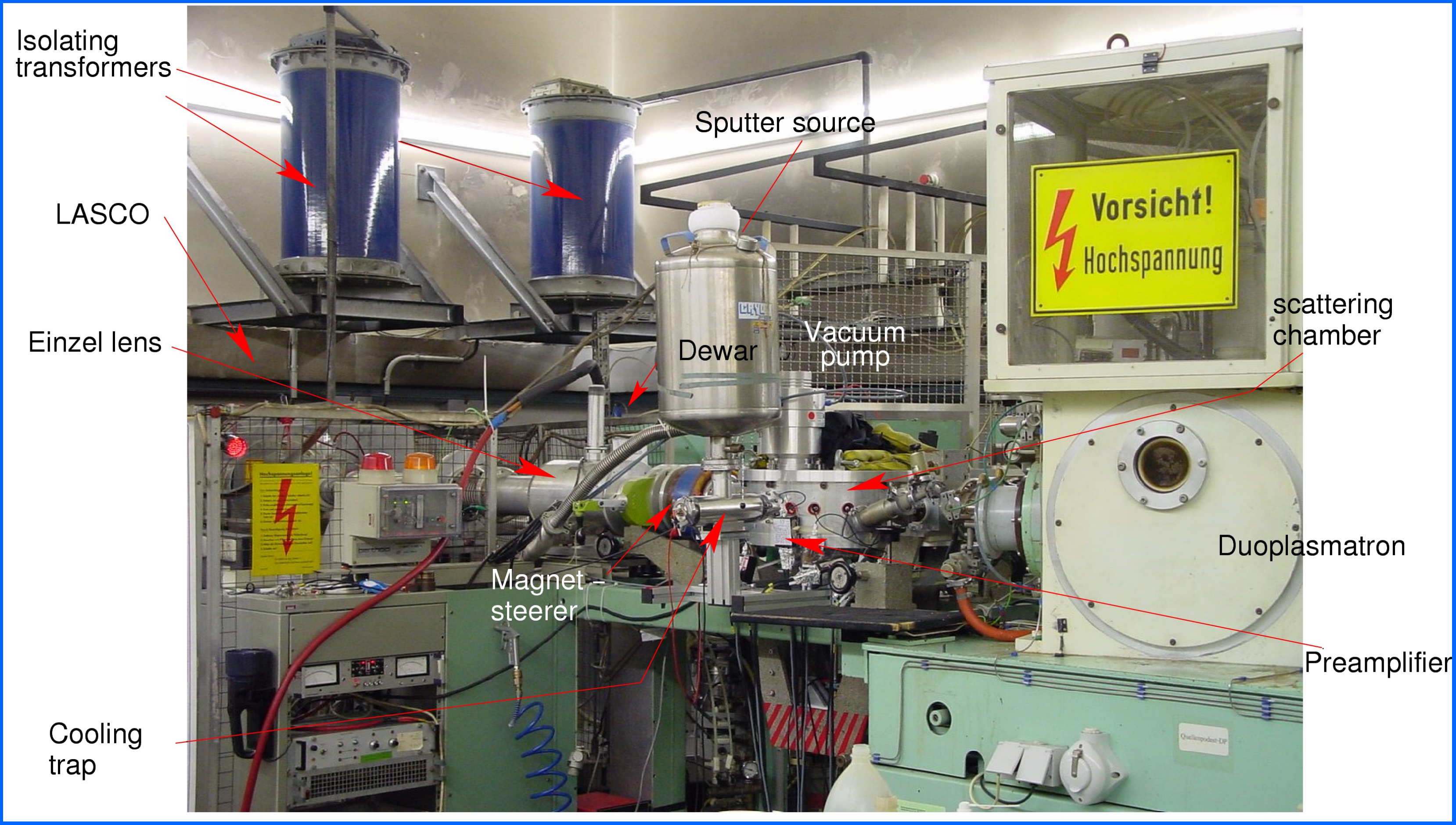




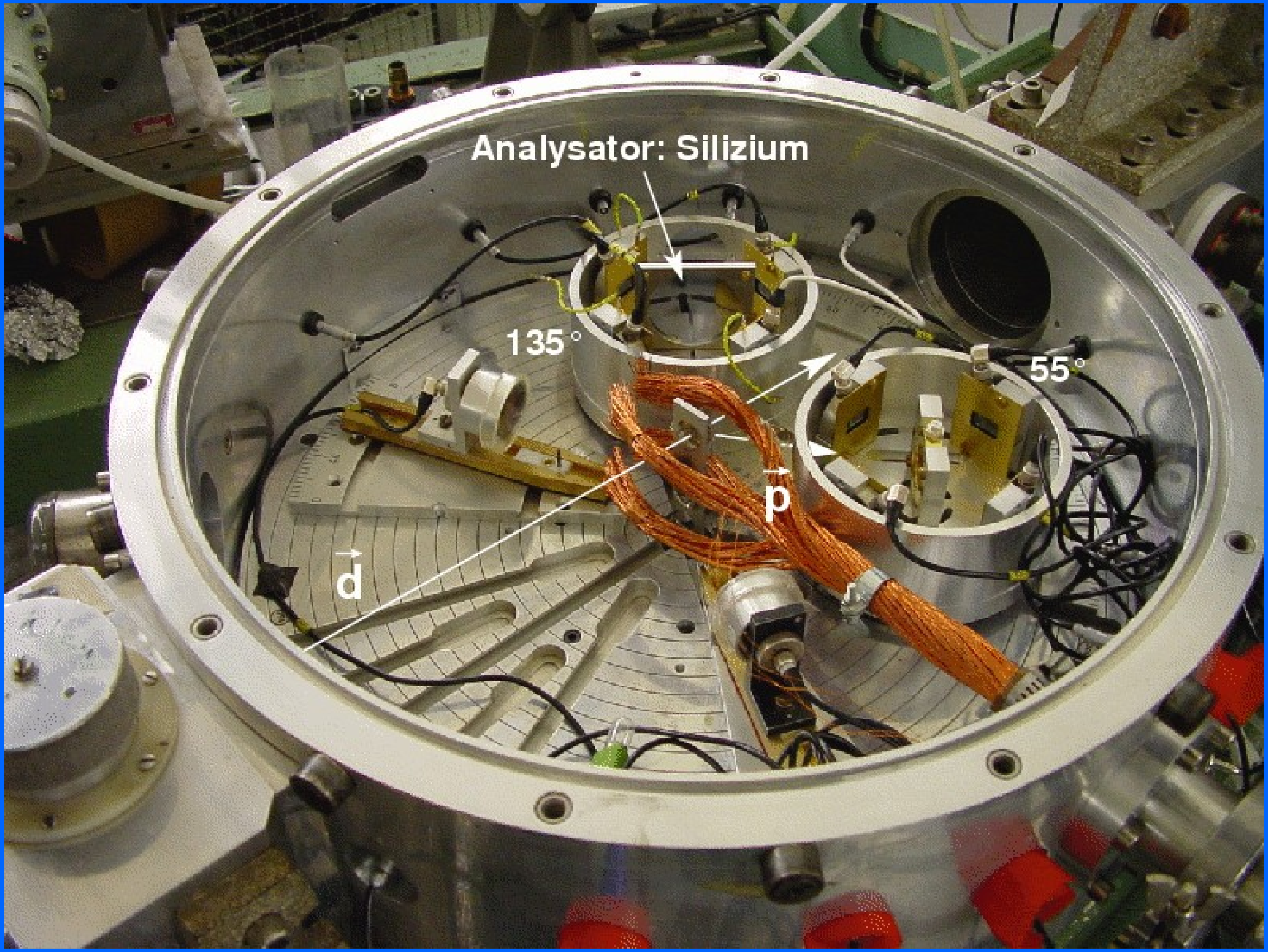
Difference only $\theta_a = 10°$

Unpolarized beam –
should be symmetric!

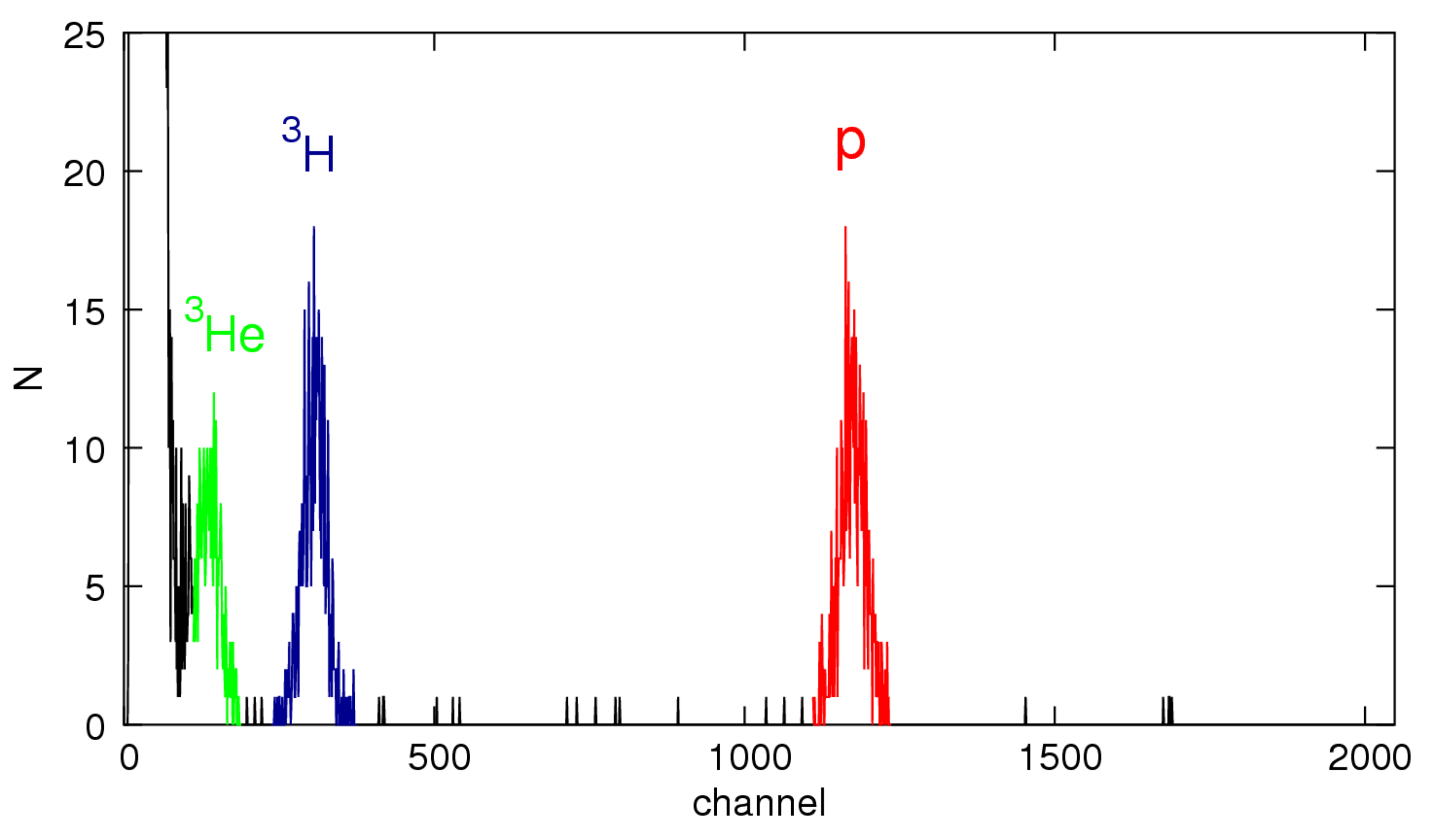
Double scattering



Double scattering



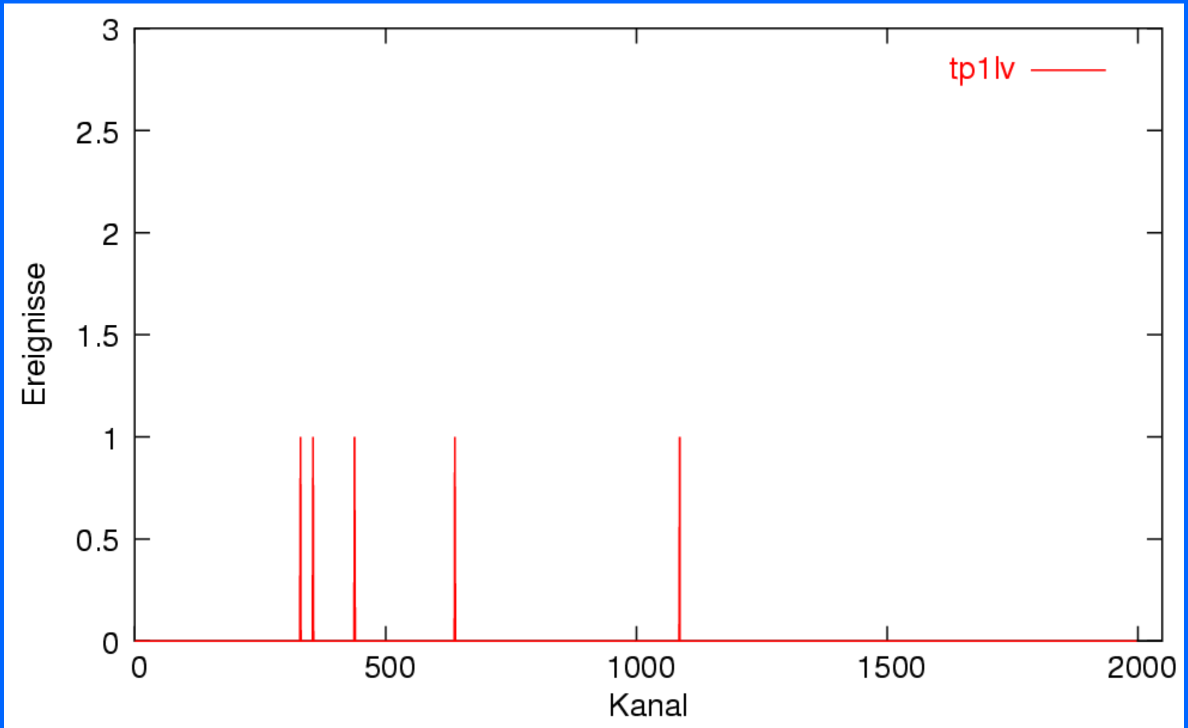
spectrum after first reaction



separation of ^{3}H and ^{3}He by Hostaphan foil

spectrum after second reaction

Where are the protons ?

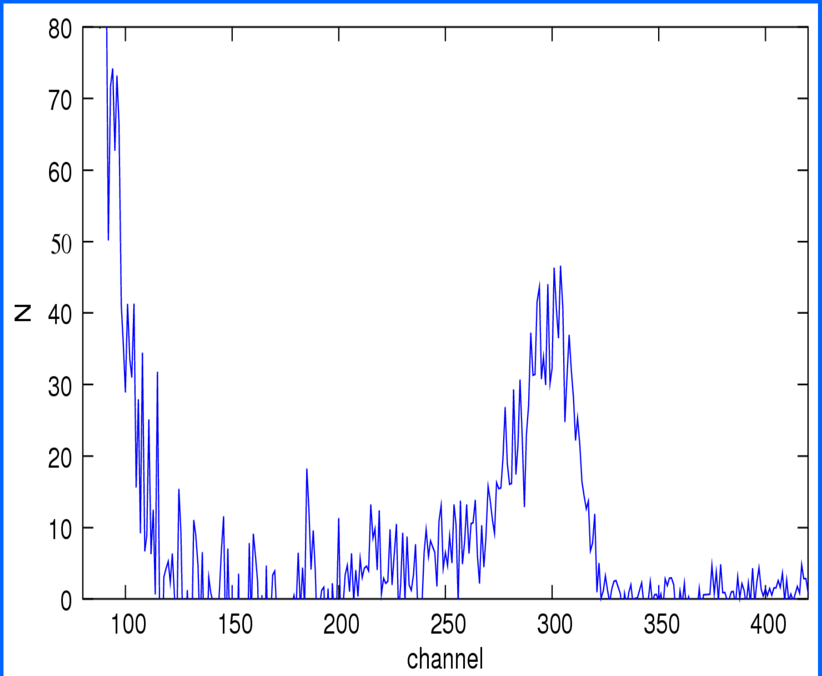


Double scattering

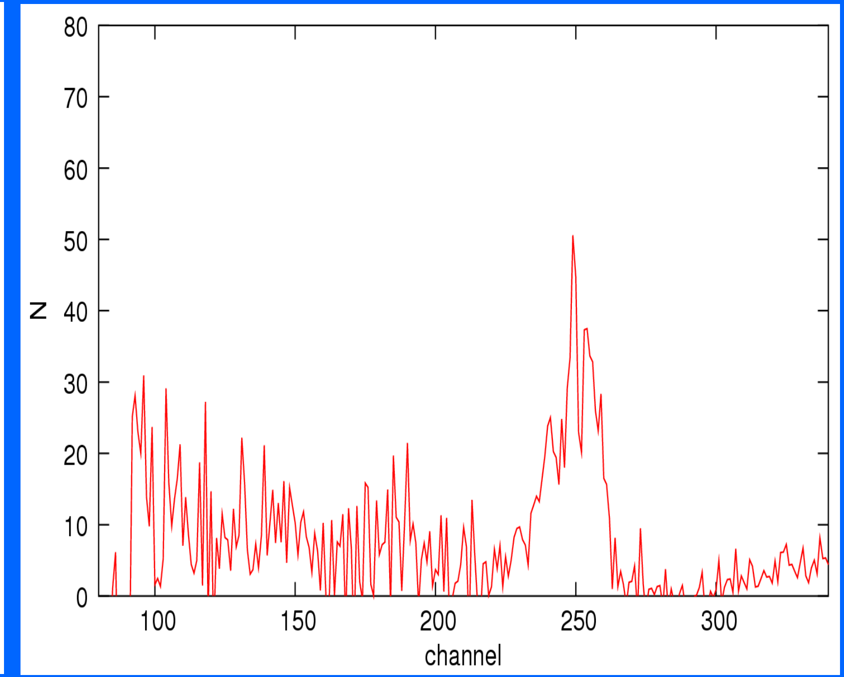
spectrum after second reaction

sum spectra after background reduction

polarimeter 1



polarimeter 2



comparison: experiment – experiment

Katabuchi — incident energy : E_d = 90 keV, θ = 0°

mean reaction energy : $\overline{E_R}$ = 68 keV

$(CD_2)_n$

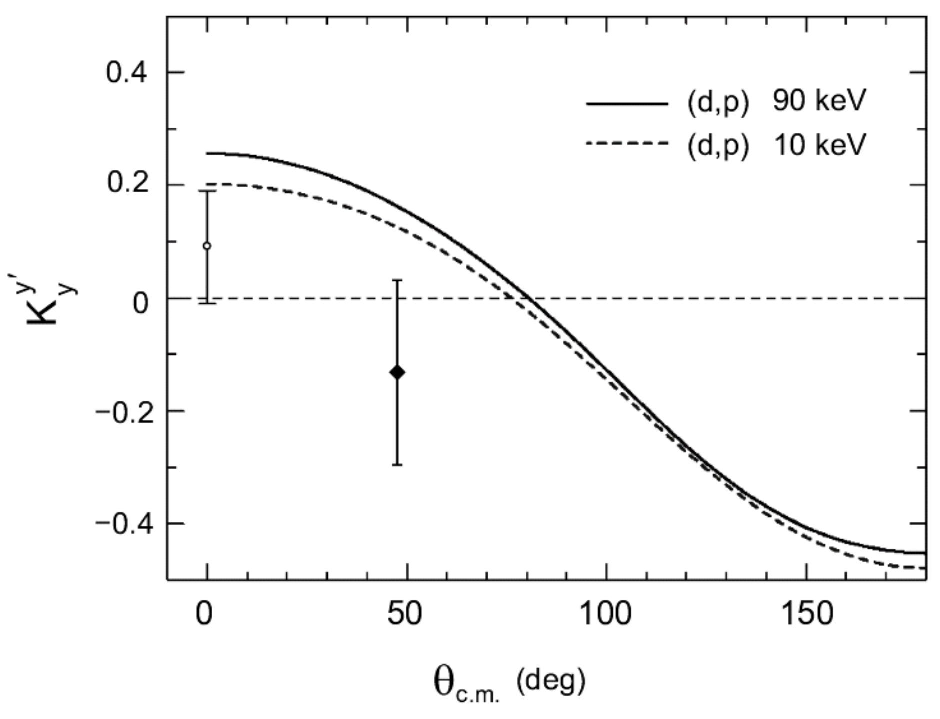
A.I. — E_d = 78 keV

$\overline{E_R}$ = 58 keV

θ = 45°

TiD_2

$$K_y^{y'} = -0.126 \pm 0.186$$

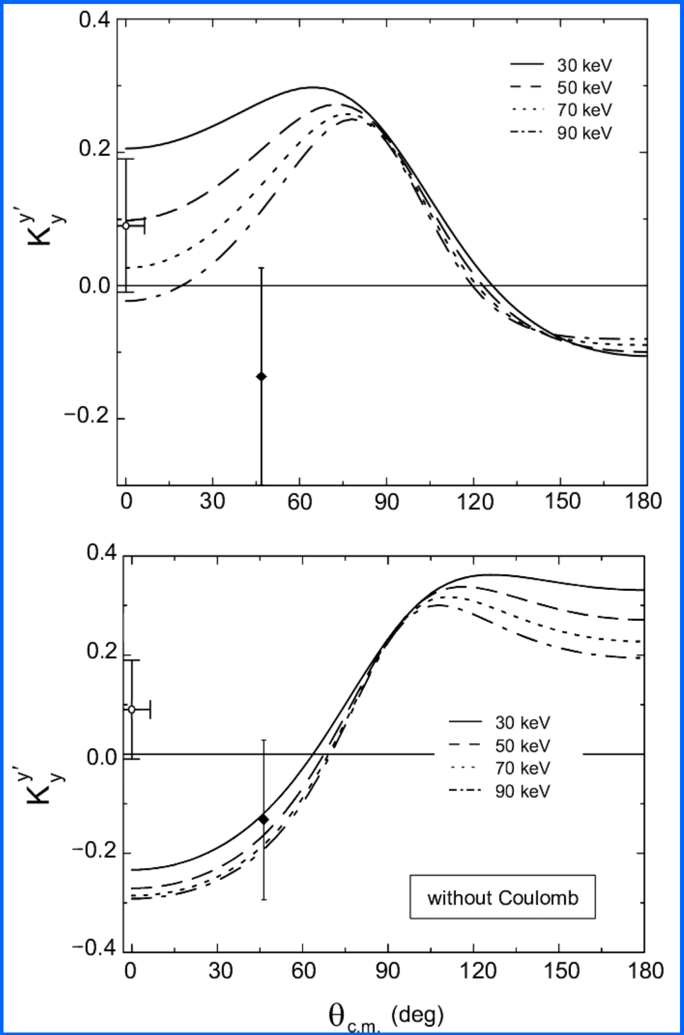


Fit over world data set with reaction matrix elements

comparison: experiment – theory

A.I. et al., Phys. Rev. C 73 (2006) 024001

T. Katabuchi et al., Phys. Rev. C 64 (2001) 047601



calculations by Uzu

with and without Coulomb modifications

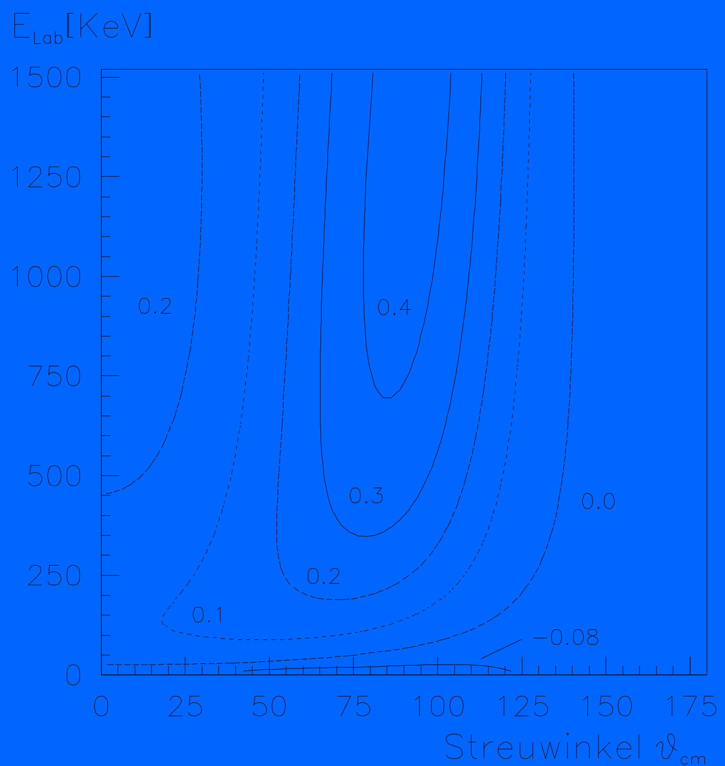
E. Uzu, arXiv: nucl-th/0210026 (2002)

Which could be the correct one ?

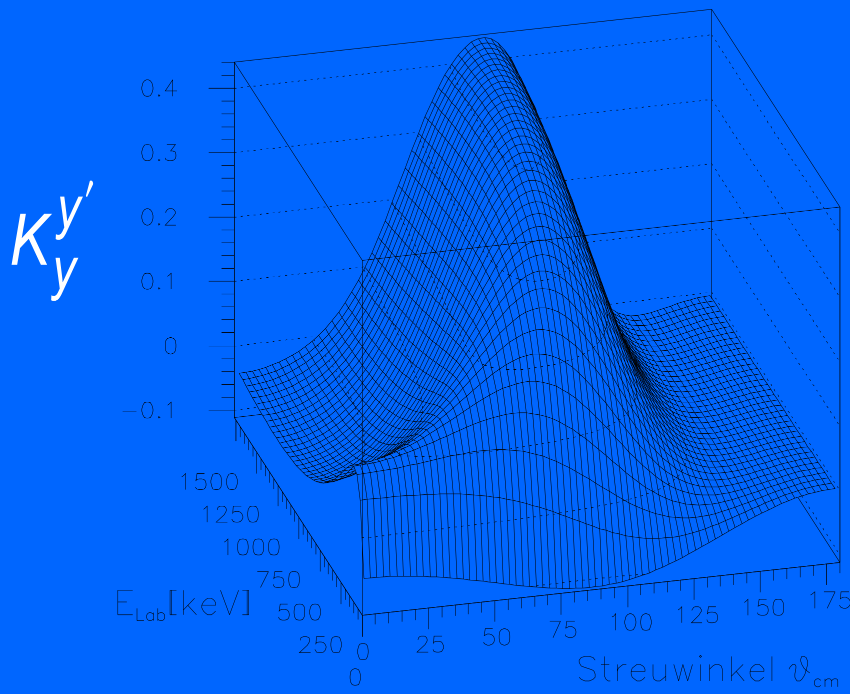
Analysis

Reaction-matrix analysis → predictions for all observables

New calculations are coming



O. Geiger et al., Nucl. Phys. A 586 (1995) 140



summary

- ✓ high efficiency polarimeter developed and calibrated
- ✓ new setup installed
- ✓ continuous experiment in parallel to tandem accelerator
- ✓ now : 3 PTCs for the reaction D(d,p)^{3}H
- ✓ repeat reaction matrix fit including new data

? **Theoretical description ?**

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