SFB 634 - Teilprojekt C2 -"Few Nucleon Systems"





SFB 634





TECHNISCHE UNIVERSITÄT DARMSTADT

Programme



Basic properties of the nucleon

- Polarizability of the nucleon
- Charge radius of the proton

Electron-beam induced break-up reactions

- Break-up of the deuteron
- Experimental developments
 - Helium gas target
 - new Si detector array
- Break-up of ³He and ⁴He

Polarizability of the nucleon



<u>Low energy Compton</u> <u>scattering</u> (E < 140 MeV) on the proton (deuteron)





α, β - electric and magnetic polarizabilities ... fundamental properties of the nucleon

Experiment and results





Perspectives ...



BUT:

Current values:

$$\alpha_p = (12.0 \pm 0.6) \cdot 10^{-4} \,\mathrm{fm}^3 \qquad \beta_p = (1.9 \pm 0.5) \cdot 10^{-4} \,\mathrm{fm}^3$$

Review of Particle Physics Phys. Lett. B 667, 1 (2008), p. 77

Aim:

Improvement to $\Delta \alpha = 0.3$ and $\Delta \beta = 0.4$ would require integrated charge of 2.5·10⁴ μ Ah, hence with a beam intensity of 5 μ A ... 5000 h or 208 d of beam time!!!

... it seems currently not realistic to perform such a measurement 😕 🎗

Charge radius of the proton



Basic property which is suprisingly poorly determined ...



New measurement at MAMI claims error < 1% (preliminary)

Charge radius of the proton





Absolute cross sections are needed

Problem: Normalistion of measurements with spectrometer

> New method: <u>Measurement</u> <u>of recoiling proton</u>

Background suppression / PID (I)





Background suppression / PID (II)



Particle identification by pulse shape discrimination (PSD):

- dE/dx different for electrons and protons
- drift velocity of produced electrons and holes is different

Can be used also to identify p, d, t, and α



Measured spectra





Primordial nucleosynthesis







⁷Li abundance





Results and comparison with theory



Inclusive measurement of electron-beam induced breakup of ²H (180° scattering ... selective on M1 excitation)



- Excellent agreement with potential model using Bonn CD (H. Arenhövel)
- Deviations from pionless EFT at higher momentum transfer (H. Griesshammer)
- Extrapolation to photon point \rightarrow equivalent ($\gamma d \rightarrow np$) cross sections

Impact on **BBN**





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Helium gas target

• thickness 10¹⁹ He/cm²





Si detector array



Previous "Si-Ball" design

- electronics ✓
- detectors (Si surface barrier) ... production at TUD failed 222

New Si detector array

<u>Aim</u>:

• large solid angle (around 2 π)

... angular correlations of fragments in coincidence with electrons Important: cover large <u>phase space</u>

- angular resolution: 10° (20° acceptable for certain kinematics)
- particle identification

New design based on detectors available for a first experiment

- single sided Si strip detectors: 30x30 mm² (8 strips) and 50x50 mm² (16 resistive strips)
- array of PIN diodes (10x10 mm²)

New Si detektor array UNIVERSITÄT DARMSTADT (Nearly) same Silicon detector array set-up should Array of PIN diodes suit also TP A2 8.5 cm e to QCLAM e,p,d,t,α Target Electron beam • PID - TOF (improved by new source TP E4) - PSD (low energy p, d, t, α) or dE/E J. Birkhan Detector stacks to identify electrons TK Low energy Møller electrons are a problem??? **PvNC**

TECHNISCHE

1. April 2010 | SFB 634 - Workshop | TP C2 - Few Nucleon Systems | Thorsten Kröll (TUD) | 19

New Si detektor array (MC simu)





50x50 mm² (16 resistive strips)

Length of target L Distance of detector from target h Width of beam spot $\,\sigma\,$



New Si detektor array (MC simu)





Strip: Theta 900 800 700 Strip 1-3 600 500 11-13 400 6-8 300 200 100 80 70 80 90 100 110 120

50x50 mm² (16 resistive strips)

Length of target L Distance of detector from target h Width of beam spot σ

Lesson learnt: With a 10 mm target we can reach about 10° angular resolution ...

Inclusive/Exclusive Measurements





Exclusive measurement (electron in coincidence with two protons)

$$\frac{\mathrm{d}^{8}\sigma}{\mathrm{d}\hat{k_{0}}\mathrm{d}\hat{k_{1}}\mathrm{d}\hat{k_{2}}\mathrm{d}S} = \sigma_{Mott} \{V_{L}R_{L} + V_{T}R_{T} + V_{TT}R_{TT} + V_{TL}R_{TL}\}\rho$$

Interference terms

J. Golak et al. Phys. Rep. 415, 89 (2005)

Break-up of ³He

At low momentum transfer only scarce data available

Inclusive measurement ³He(e,e')

Dotted line: full FSI Dashed line: full FSI +MEC Solid line: full FSI + MEC + 3NF

- correct treatment of FSI is absolutely necessary
- MEC and 3NF play a minor role, but more important compared to higher q

Theory: J. Golak, et al., Phys. Rep. 415, 89 (2005) 0.00 Data: G. A. Retzlaff et al., Phys. Rev. C 49, 1263 (1994)





Exclusive break-up of ³He



Aim: Test EFT's at low momentum transfer

dotted = FSI dashed = FSI + MEC full = FSI + MEC + 3NF



⁴He - longitudinal response function R_L





Exclusive break-up reactions



Measurement ⁴He(e,e´p)t ... dominated near threshold by quasi bound 0⁺ state at 20.2 MeV

Clean measurement of R_{τ} at Θ_{e} =180° and subtraction from data obtained for other angles.

Cleaner than the commonly used Rosenbluth separation ...

Exclusive break-up reactions

(e,e´p) – explore large phase space

(e,e´pp) – explore small phase space, higher sensitivity to individual contributions, selected by particular kinematics

... guidance from theory needed WHERE to measure

!!! Will help to determine low energy constants (LECs) of EFT better !!!

Break-up of deuteron revisited ...

Exclusive mesurement 30%-45% deviation from theory (CD Bonn + FSI + MEC + ...) found for the LT contribution P. von Neumann-Cosel et al., Phys. Rev. Lett. 88, 202304 (2002)

New data points needed for different kinematical conditions covering a large phase space ... as it will be possible with the new Si detector array

Separation of the response functions: R_⊤ measured at 180°

Will allow to pin down reason for discrepancy observed







Summary



- "Few Nucleon Systems" are an interesting test ground for NN potentials (mainly determined from NN scattering ... hence, unbound systems) and modern EFT's. Importance for the primorial nucleosynthesis.
- Experimental developments:
 - Helium gas target currently under test
 - new Si detector array under design
- Break-up of ³He, ⁴He, (and ²H) at low momentum transfer
 - inclusive and exclusive measurements
 - cover large phase space and/or pp angular correlations
 - measurement with polarised electrons ...
 - ... help to fix LECs of EFT's (or ChEFT's)
- heavier nuclei like ^{6,7}Li: (e,e´p) ... guidance from theory needed
- Beam time in 2010: test of set-up, study of background, ...

QCLAM / 180° set-up





Spectra and decomposition





Absolute and relative normalization agree within 5 %

Neuer Si-Detektor



