Electron-deuteron scattering at Mainz

Michael O. Distler for the A1 collaboration

- Proposal MAMI A1/01-12
  - Motivation
  - Add-on: Breakup
  - March 2014 Beamtime
  - Online Spectra

JOHANNES GUTENBERG UNIVERSITÄT MAINZ

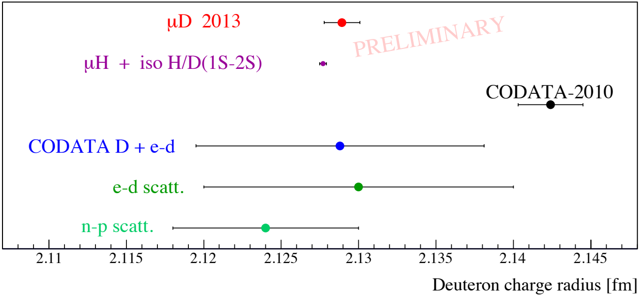
Deuteron radius from the H-D isotope shift, μH, and μD

Proton radius: The challenge continues

Combining H-D isotope shift and μH:

$$\left.\begin{aligned} r_d^2 - r_p^2 &= 3.82007(65)\,\mathrm{fm}^2 \\ r_p &= 0.84087(39)\,\mathrm{fm} \end{aligned}\right\} \Rightarrow r_d = 2.12771(22)\,\mathrm{fm}$$

A. Antognini *et al.*, Science 339 (2013) 417-420



Paul Indelicato, Mainz, 2013

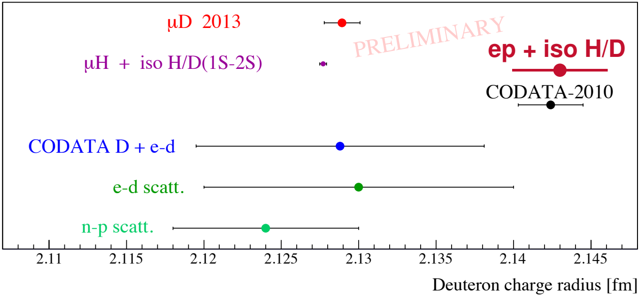
Deuteron radius from the H-D isotope shift, μH, and μD

Proton radius: The challenge continues

Combining H-D isotope shift and e-p elastic scattering:

$$\left.\begin{aligned} r_d^2 - r_p^2 &= 3.82007(65)\,\mathrm{fm}^2 \\ r_p &= 0.879(8)\,\mathrm{fm} \end{aligned}\right\} \Rightarrow r_d = 2.143(3)\,\mathrm{fm}$$

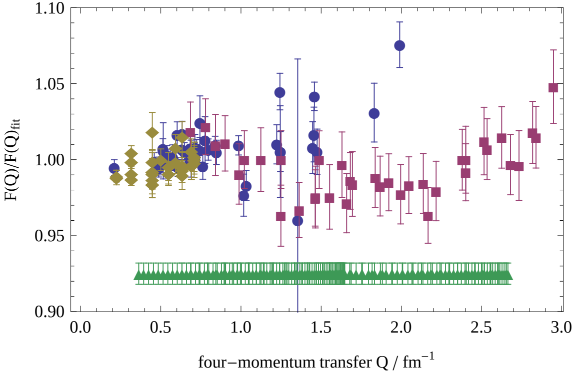
J.C. Bernauer *et al.*, Phys.Rev.Lett. 105 (2010) 242001



Paul Indelicato, Mainz, 2013

World low Q^2 data and predicted errors

D(e,e')D

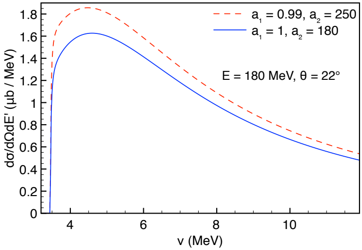


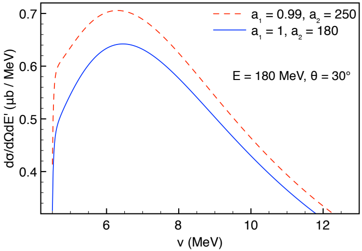
♦ Berard (1973), • Simon (1981), ■ Platchkov (1990), ▲ MAMI

MAMI A1 01/2012: Measurement of the elastic $A(q^2)$ form factor of the deuteron at very low momentum transfer

Add-on: Deuteron electro-desintegration

Carl E. Carlson, Mikhail Gorchtein, Marc Vanderhaeghen: *Nuclear structure contribution to the Lamb shift in muonic deuterium*, Phys. Rev. **A89**, 022504 (2014).





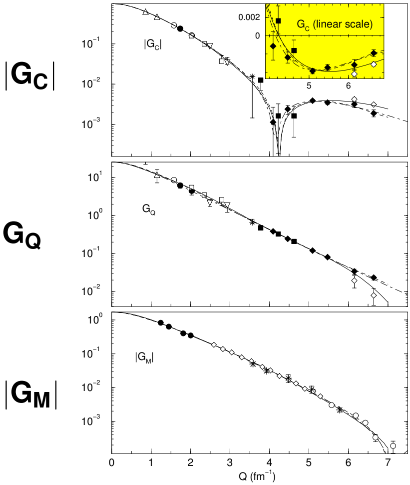
Quote: "The main source of the uncertainty of the dispersion analysis is due to lack of quasielastic data at low energies and forward angles. . . . a targeted measurement of the deuteron electro desintegration . . . can help quenching this uncertainty significantly."

Elastic scattering from the spin-1 deuteron

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\mathrm{Mott}} \left[A(Q^2) + B(Q^2)\tan^2\frac{\theta}{2}\right]$$

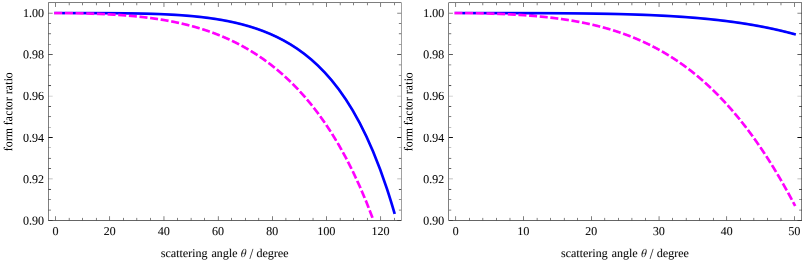
$$\begin{aligned} A(Q^2) &= \boxed{G_C^2(Q^2)} + \frac{8}{9}\eta^2 G_Q^2(Q^2) \\ &\quad + \frac{2}{3}\eta(1+\eta) G_M^2(Q^2) \\ B(Q^2) &= \frac{4}{3}\eta(1+\eta)^2 G_M^2(Q^2) \end{aligned}$$

Compilation of world's data



D. Abbott *et al.* [JLAB t20 Collaboration], "Phenomenology of the deuteron electromagnetic form-factors," Eur. Phys. J. A **7** (2000) 421 [nucl-ex/0002003].

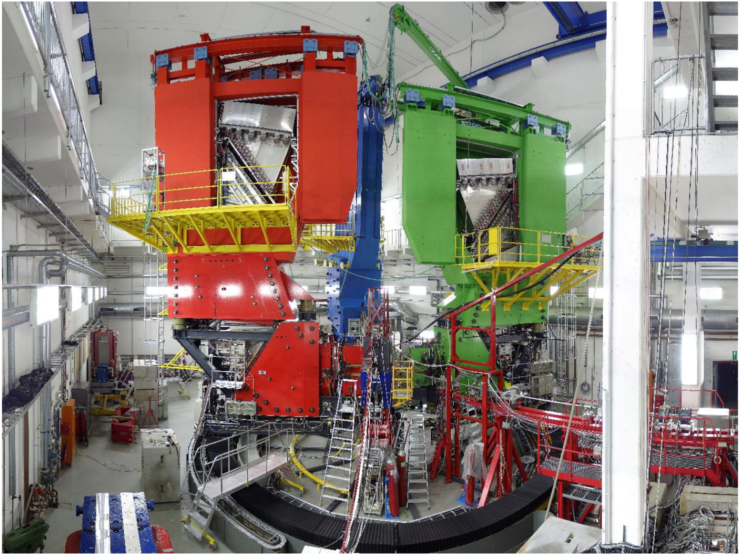
form factor ratio



$A(Q^2)$ form factor and the charge form factor $G_C^2(Q^2)$ divided by the normalized cross section $\frac{d\sigma}{d\Omega} / \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}}$ as a function of the scattering angle θ for two beam energies 180 MeV (left) and 450 MeV (right).

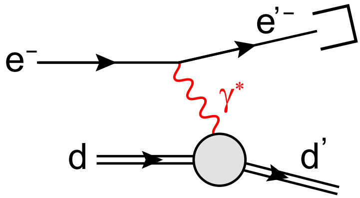
$\Rightarrow$ the contribution of the magnetic and quadrupole form factor is small at low Q^2

The Mainz high-precision p(e,e')p measurement: Three spectrometer facility of the A1 collaboration



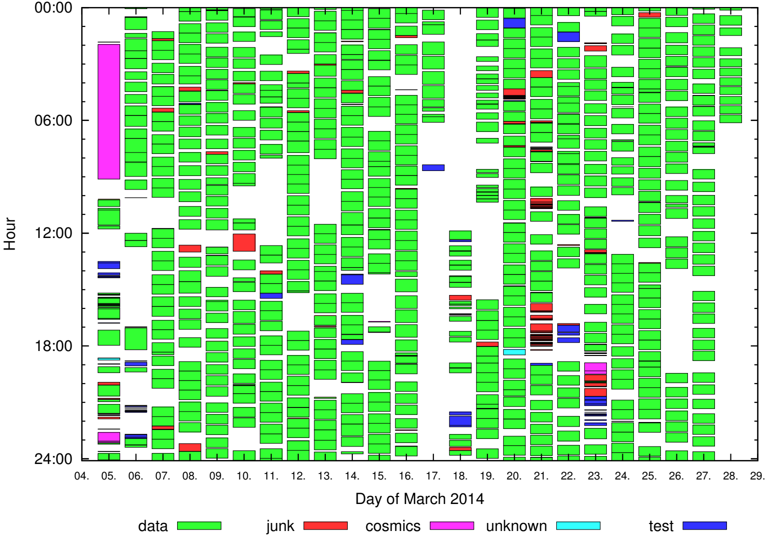
The Mainz high-precision d(e,e')d measurement

- same idea as p(e,e')p
- remote control of spectrometer movement
- improved (automated) pA-meter readout
- 200+ setup changes
- + empty target measurements



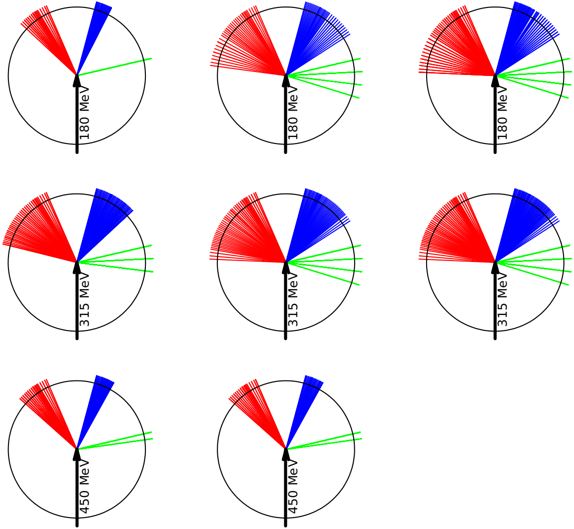
Ph.D. Student: Yvonne Kohl, Postdoc: Sören Schlimme

Beamtime overview



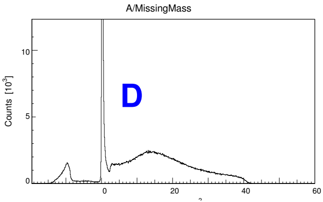
Setup overview

First weeks Cryo (Ice), Empty cell, Last weeks Cryo (without Ice)

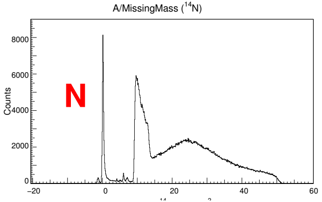


Nitrogen Ice Problem

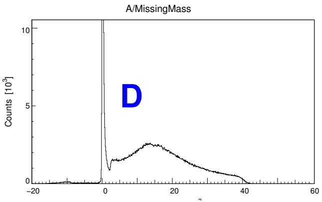
Missing Mass Spec A 41,8°, 315 MeV, 08.03.



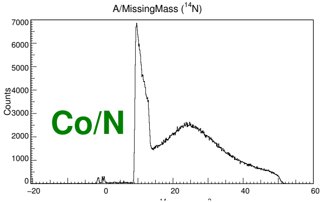
Missing Mass N Spec A 41,8°, 315 MeV, 08.03.



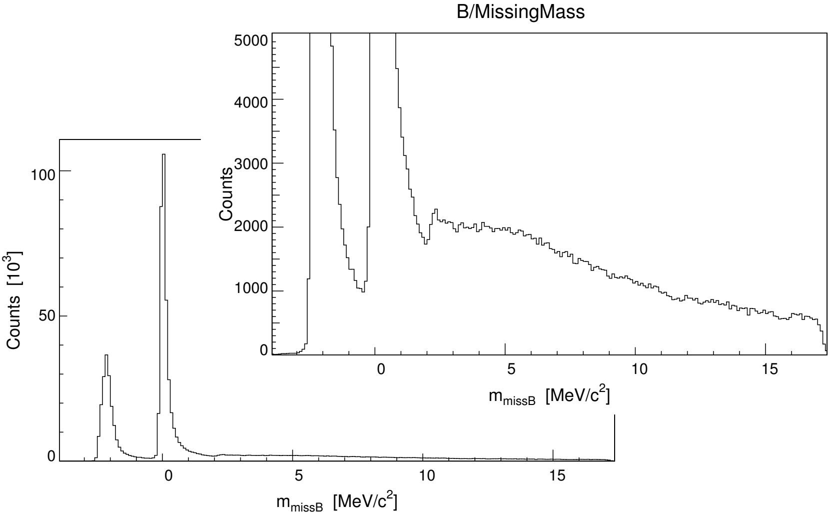
Missing Mass Spec A 41,8°, 315 MeV, 25.03.



Missing Mass N Spec A 41,8°, 315 MeV, 25.03.

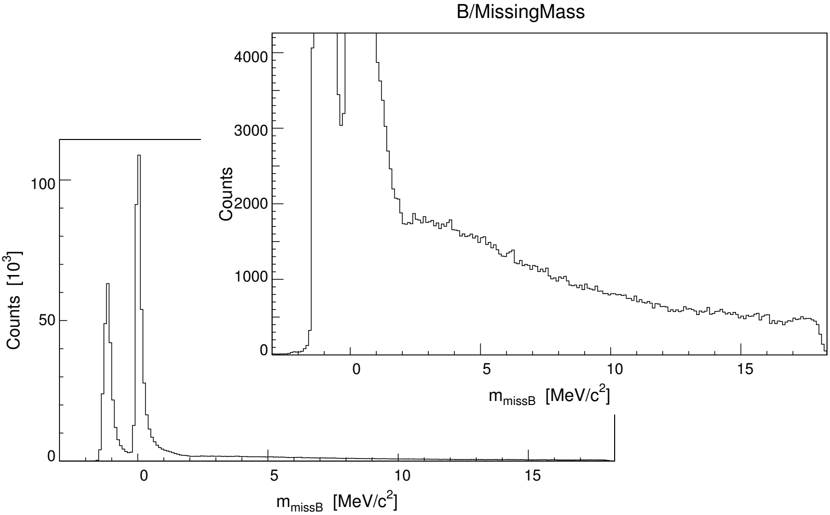


Breakup, 180 MeV, 30° (online)



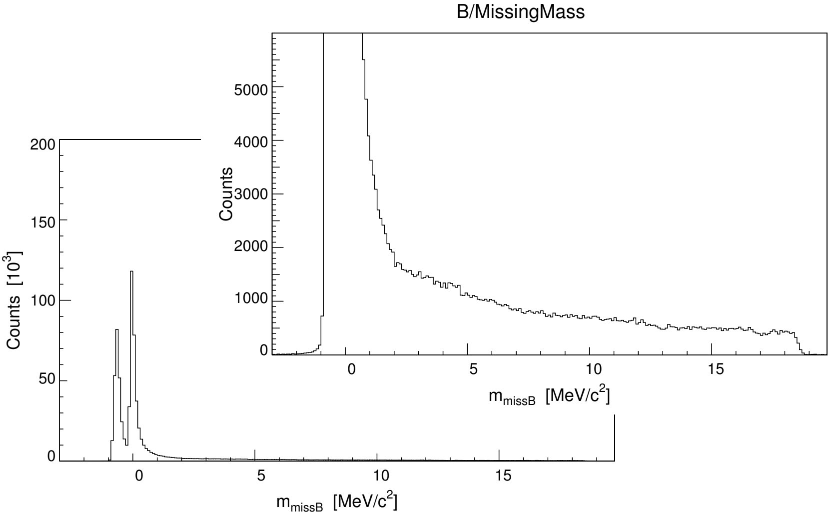
1% extraction seems possible

Breakup, 180 MeV, 22° (online)



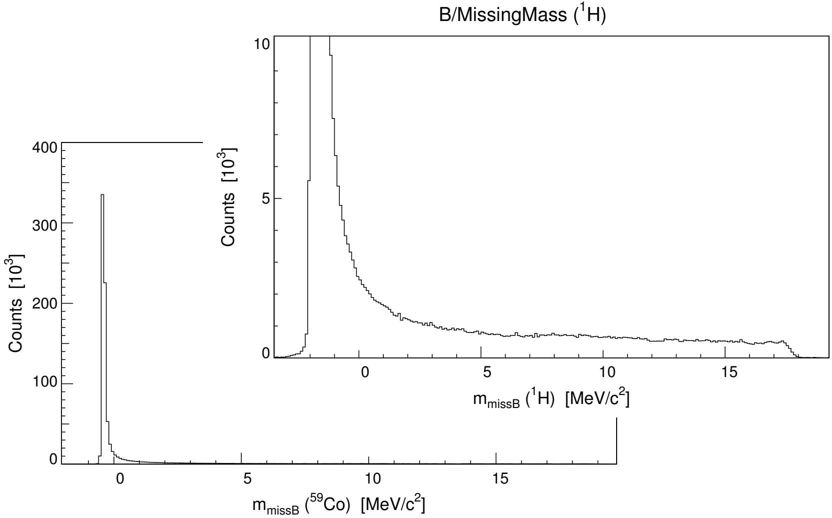
3% extraction seems possible

Breakup, 180 MeV, 16° (online)



dedicated experiment needed

Empty target, 180 MeV, 15.1° (online)



empty target data can be used to cross check Mainz ep-data

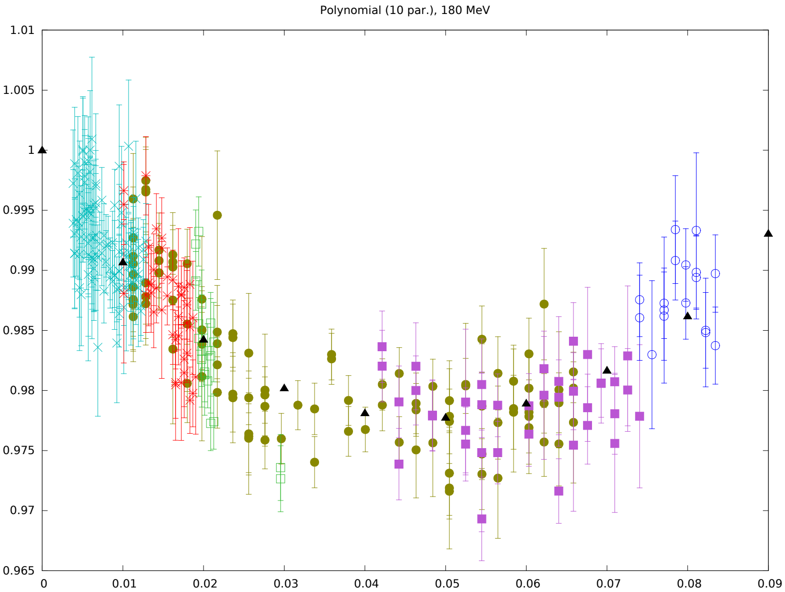
Summary

We performed a high precision measurement of the elastic cross section in the reaction ^{2}H(e,e')d at very low 4-momentum transfer squared, Q^2.

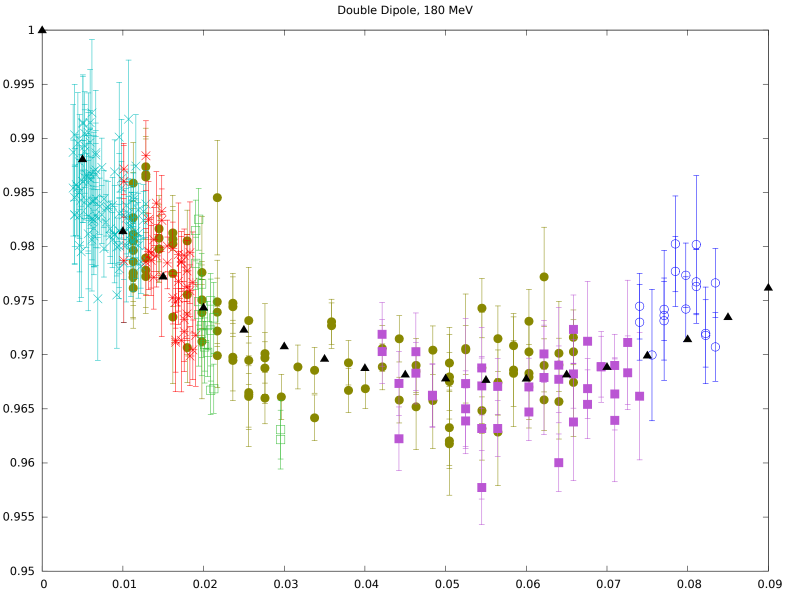
- beam energies: 180, 315, (450) MeV
- angular range: $15.1^\circ \ldots 107.0^\circ$
- Q^2 range: $0.0023 \ldots 0.21$ $(\ldots 0.4)$ $(\mathrm{GeV/c})^2$
- q range: $0.238 \ldots 2.3$ $(\ldots 3.2)$ fm^{-1}
- meaningful extraction of the breakup seems possible
- extensive empty target data

- **analysis ongoing**

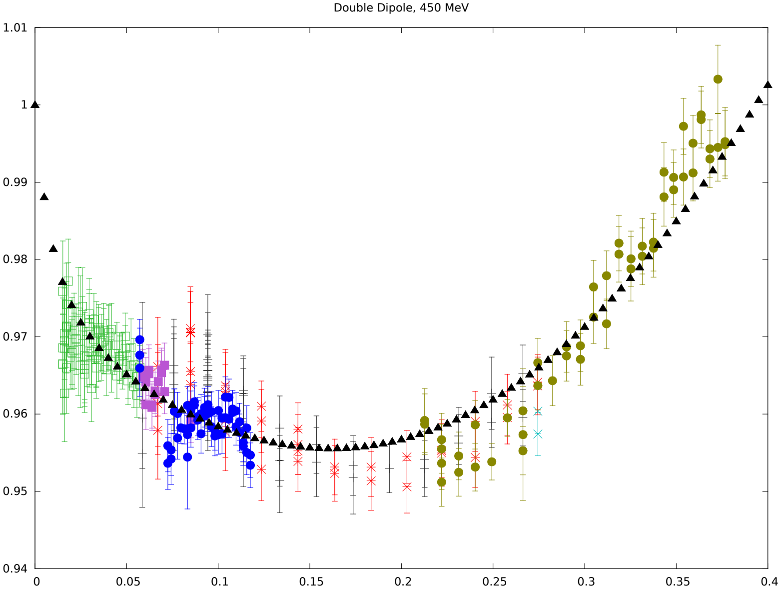
Slides shown during Wednesday discussion



Polynomial (10 par.), 180 MeV
1.01
1.005
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09



Double Dipole, 180 MeV
1
0.995
0.99
0.985
0.98
0.975
0.97
0.965
0.96
0.955
0.95
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09



Double Dipole, 450 MeV
1.01
1
0.99
0.98
0.97
0.96
0.95
0.94
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4