Novel Technique to Measure the Polarizability of the Nucleon*

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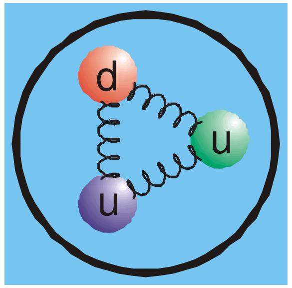
- Motivation
- Experimental Setup
- Experiments
- Results
- Summary and Outlook

SFB 634

*Supported by the DFG within SFB 634

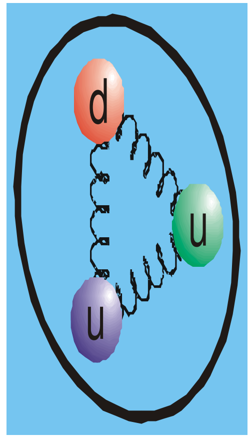
Motivation



α, β - electric and magnetic polarizabilities

$$\vec{d} = \alpha\vec{E}$$

$$\vec{\mu} = \beta\vec{B}$$



$\vec{E}$
$\vec{B}$

describe the response of the nucleon internal structure to applied electric and magnetic fields

$$\bar{\alpha}_p = (11.9 \pm 0.5 \mp 1.3) \times 10^{-4}\, fm^3$$

$$\bar{\beta}_p = (1.2 \pm 0.7 \pm 0.3) \times 10^{-4}\, fm^3$$

V. Olmos de Leon *et al.*, Eur. Phys. J. 10 (2001) 207

$$\bar{\alpha}_n = (8.8 \pm 2.4) \times 10^{-4}\, fm^3$$

$$\bar{\beta}_n = (6.5 \mp 2.4) \times 10^{-4}\, fm^3$$

M. Lundin *et al.*, Phys. Rev. Lett. 90 (2003) 192501

Goal: better accuracy of these constants

Motivation

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Low energy Compton scattering (E < 140 MeV)

Low Energy Theorem:

$$\frac{d\sigma(E_\gamma,\theta)}{d\Omega} = \left[\frac{d\sigma(E_\gamma,\theta)}{d\Omega}\right]_{Point} - \rho + 0(E_\gamma^4)$$

$$\left[\frac{d\sigma(E_\gamma,\theta)}{d\Omega}\right]_{Point}$$

Powell cross section for the point like proton with anomalous magnetic moment

$$\rho \sim \left[\frac{\bar{\alpha}+\bar{\beta}}{2}(1+\cos\theta)^2 + \frac{\bar{\alpha}-\bar{\beta}}{2}(1-\cos\theta)^2\right]E_\gamma^2$$

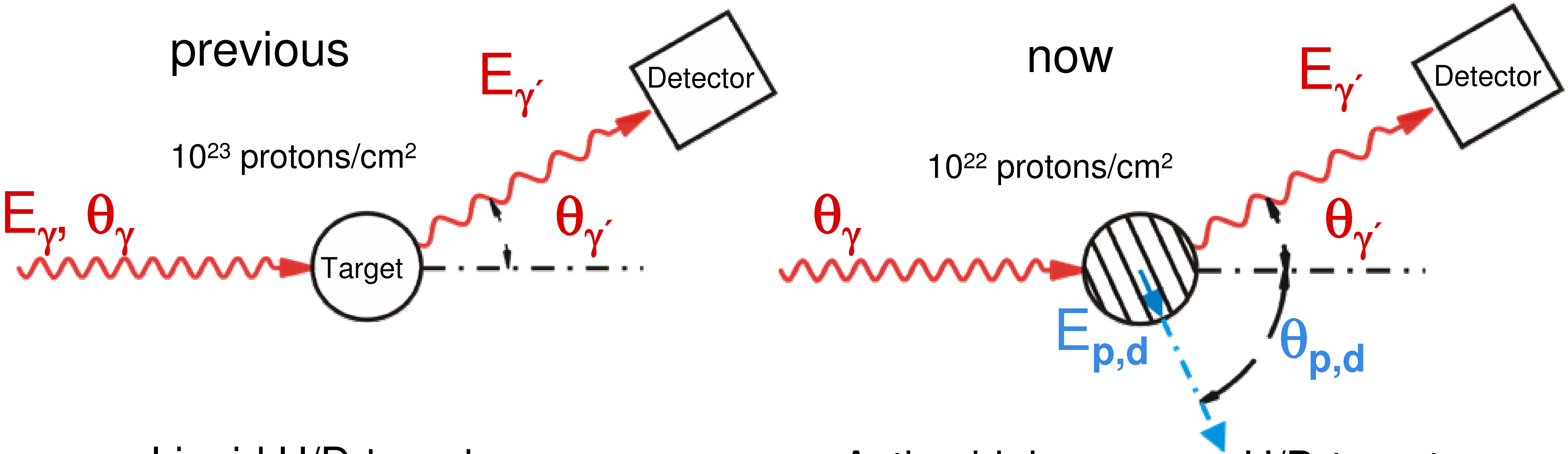
Structure term

$$0(E_\gamma^4)$$

Terms of higher order structure constants

V. Petrun'kin et al., Sov. J. Part. Nucl. 12 (1981) 278

Experiment with Compton Scattering



Liquid H/D-target

Active high pressure H/D-target

$E_p = 0.4 - 8$ MeV

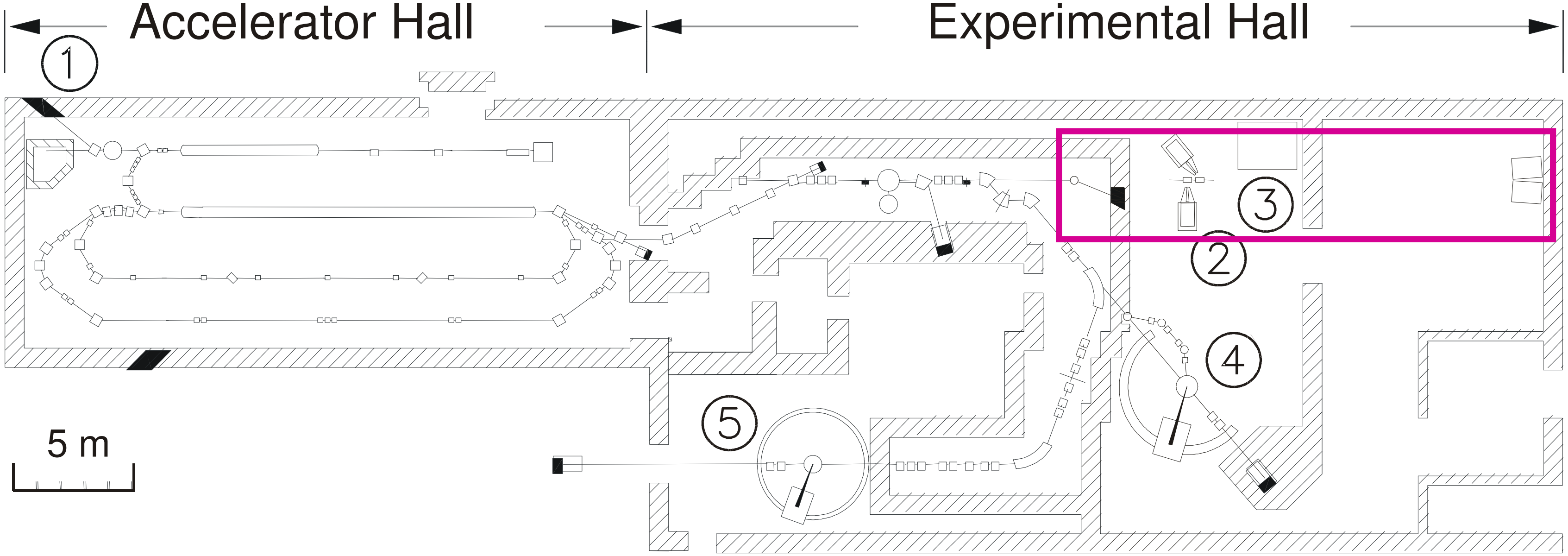
- high luminosity:

10^6 γ/MeV/s $\quad$ 10^9 γ/MeV/s

- background suppression:
redundancy of kinematic values

- Bremsstrahlung spectrum has to be known

S-DALINAC

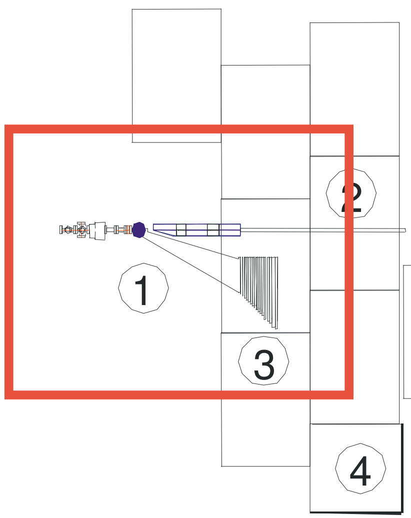


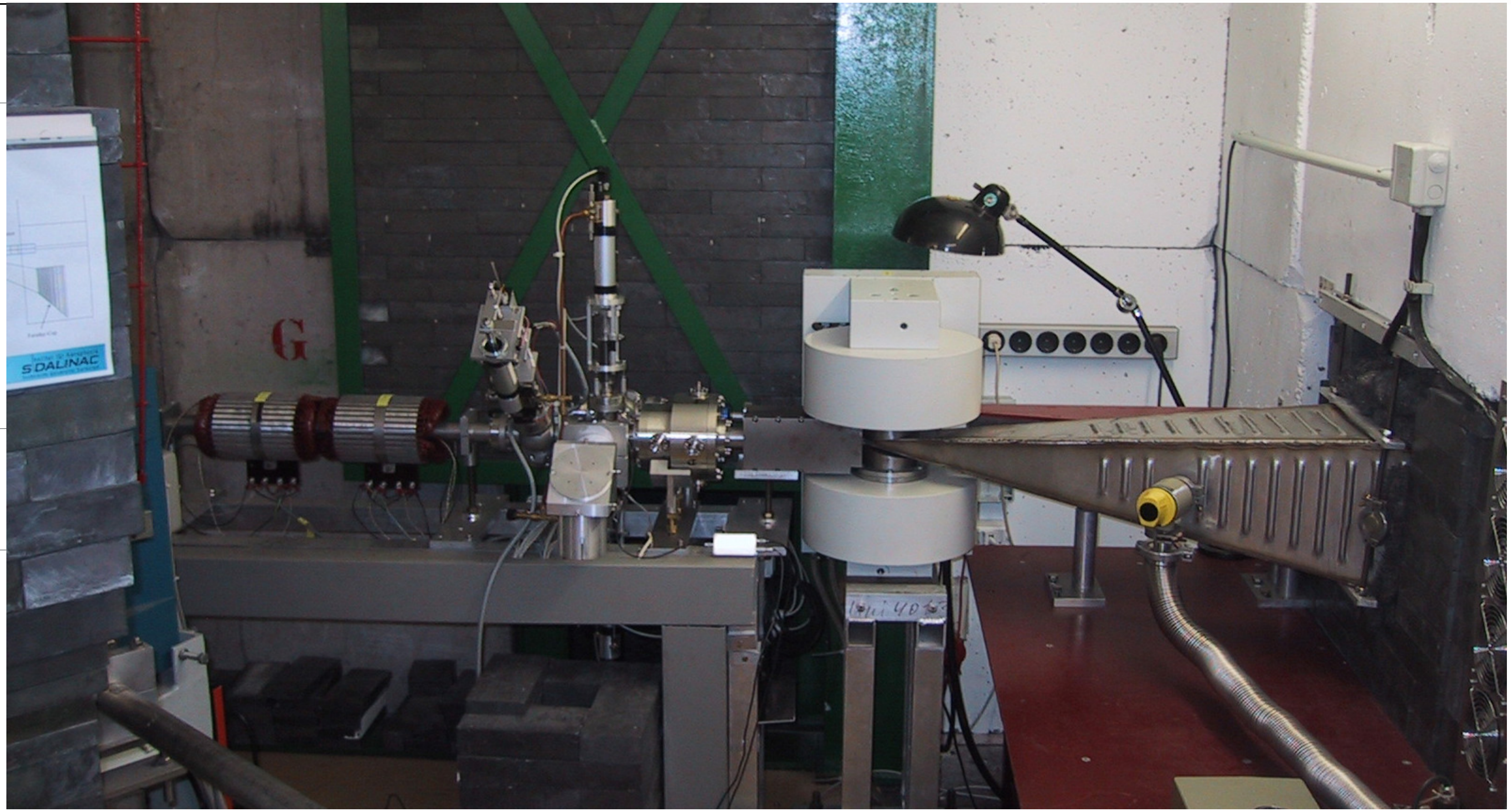
Design Parameters

Maximum energy:	130 MeV
Energy spread :	10^{-4}
Maximum current:	20 μA
Material:	Niobium
Temperature:	2K

1. (γ,γ') & (γ,n) - Experiments
2. Compton Scattering on Nucleon
3. $(\gamma,\gamma' x)$- Experiments at NEPTUN Tagger
4. $(e,e' x)$ & 180°- Experiments at QCLAM Spectrometer
5. (e,e') - Experiments at Lintott Spectrometer

Experimental Setup





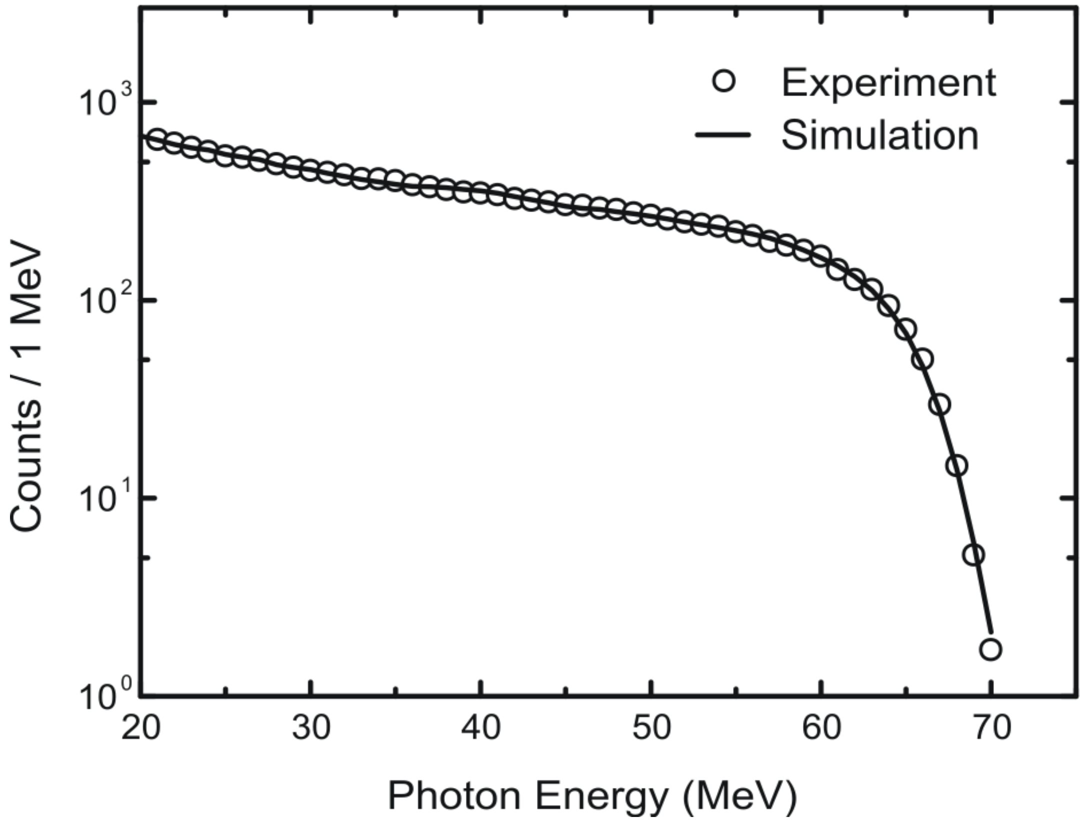
1 – Bremsstrahlung facility
2 – Collimator system
3 – Faraday cup
4 – Concrete shield

5 – High pressure ionisation cahmber
6 – NaI(Tl) spectrometer (10“x14“)
7 – Collimator system
8 – BPM, Quantameter
9 – NaI(Tl) spectrometer (10“x10“)

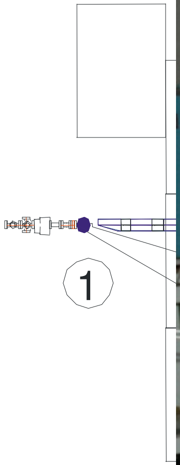
Bremsstrahlung

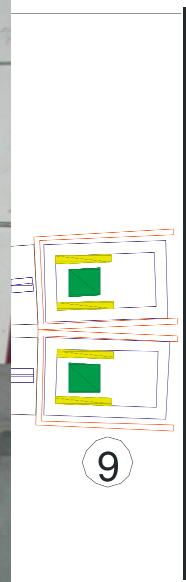
$E_e = 71.3$ MeV t = 40 min

$I_e = 200$ pA under 0°



Experimental Setup



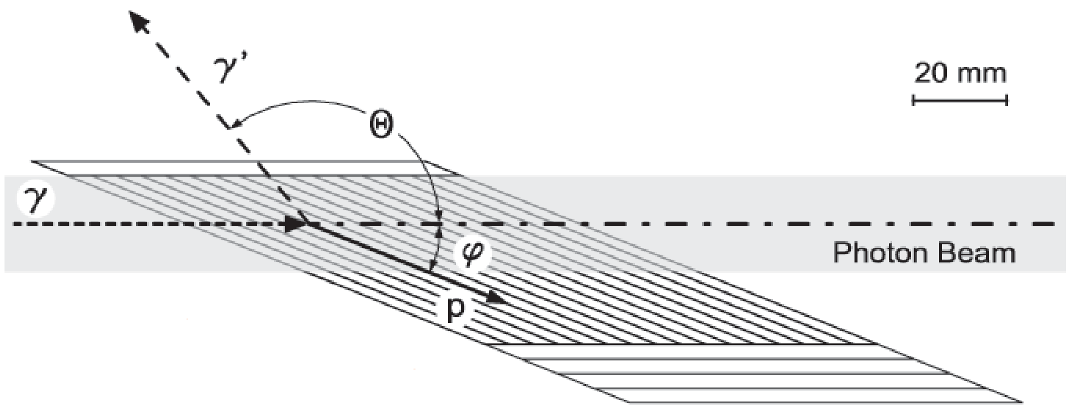


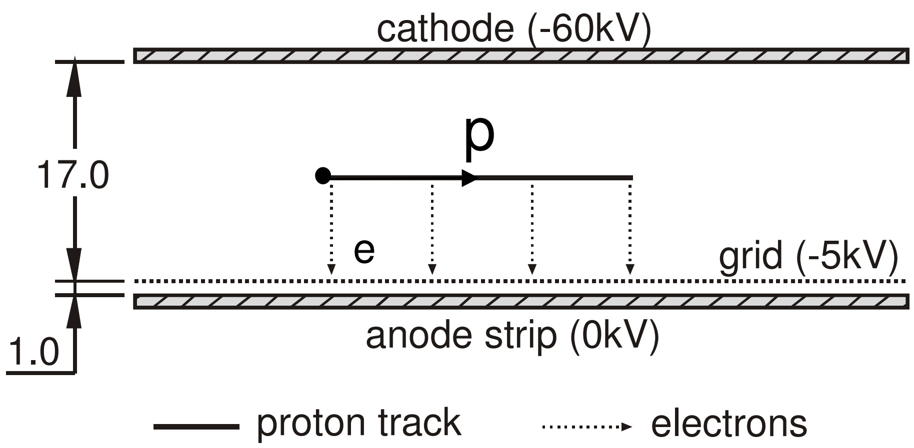
1 – B
2 – C
3 – F
4 – C
5 – H

High Pressure Ionisation Chamber

Determination of the energy and the position of the recoiled protons

Strips in the direction of the recoiled protons



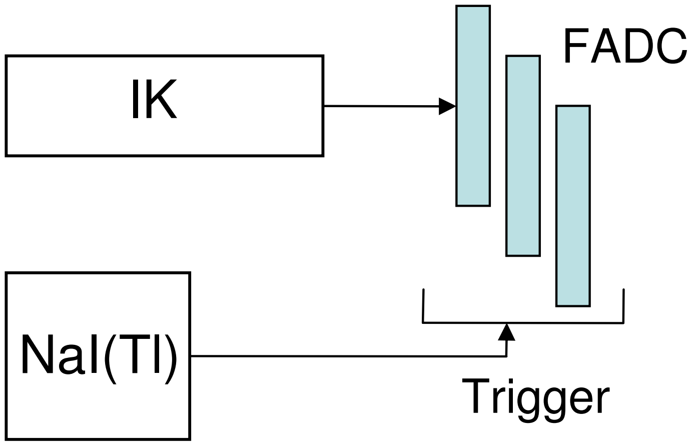


$$20\ \text{MeV} \le E_\gamma \le 90\ \text{MeV}$$

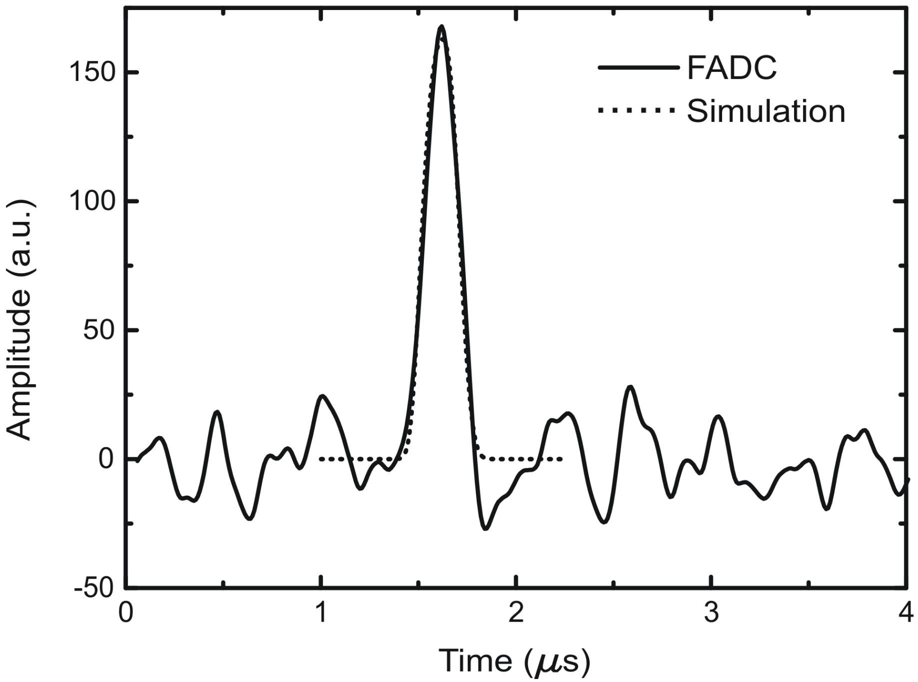
$$0.4\ \text{MeV} \le E_p \le 8\ \text{MeV}$$

Proton Signals

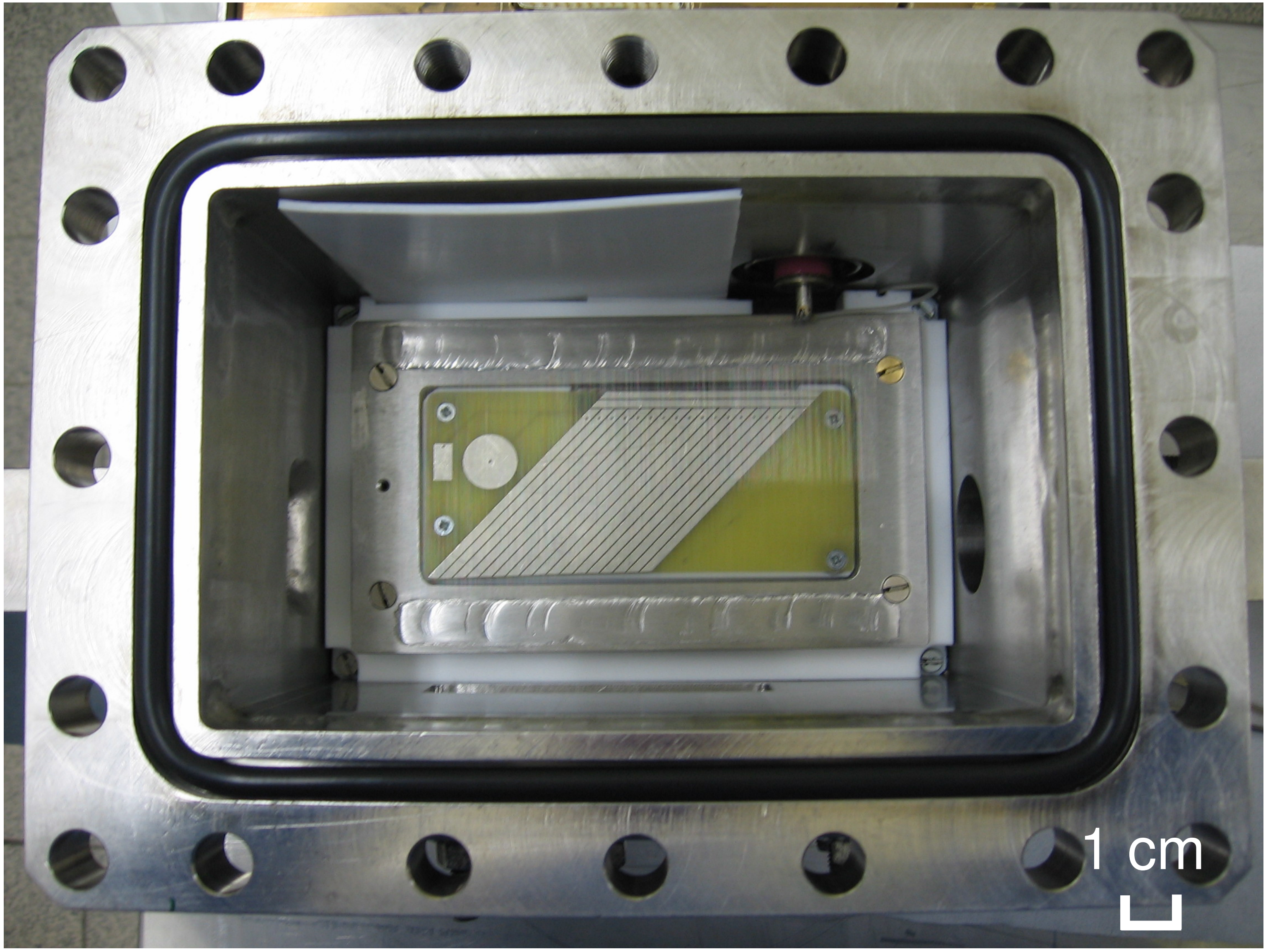
Flash ADC (FADC)



Sampling: 105 MHz, 10 ns
Time window: 4.5 μs



High Pressure Ionisation Chamber



Normalisation

- Compton kinematics

$$E_{\gamma'} = \frac{E_\gamma}{1 + \frac{E_\gamma}{m}(1 - \cos\theta)}$$

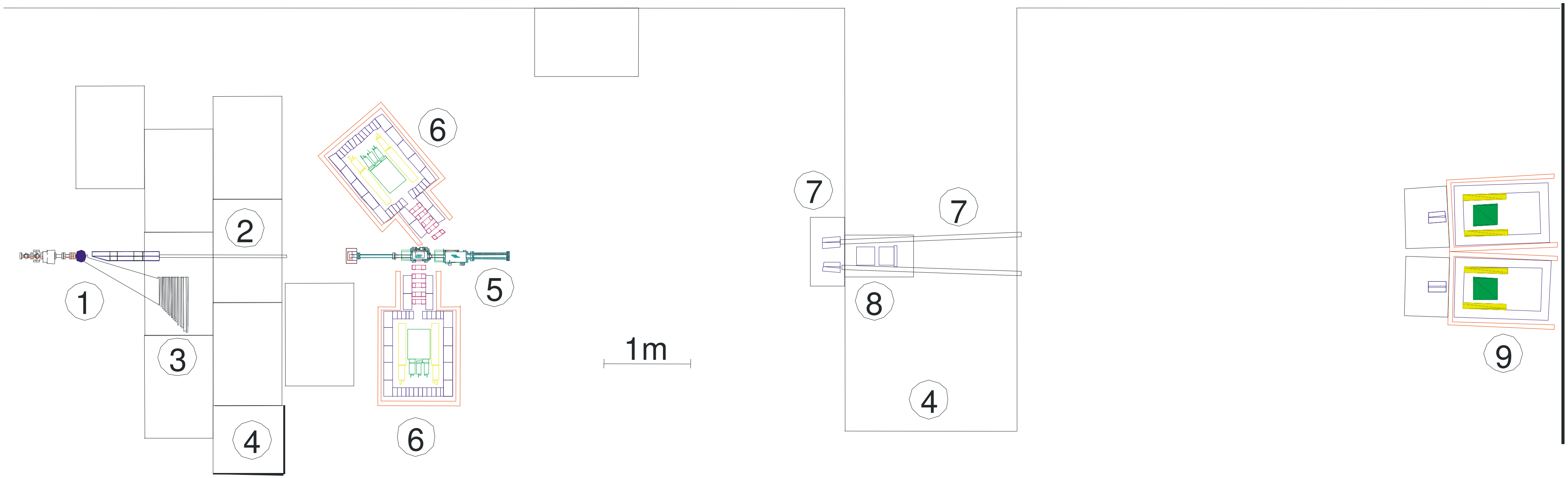
- Proton vs. electron

$$\frac{1 - \cos\theta_{(p)}}{m_p} = \frac{1 - \cos\theta_{(e)}}{m_e}$$

- Arrange θ and mass → identical kinematics

$$\theta_p = 90° \qquad 130°$$
$$\theta_e = 1.89° \qquad 2.42°$$

Experimental Setup



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Normalisation

$$N_{\gamma'} = N_\gamma N_T \varepsilon \Delta\Omega \frac{d\sigma}{d\Omega}$$

$$\frac{N^p_{\gamma'}}{N^e_{\gamma'}} = \frac{N^p_\gamma}{N^e_\gamma} \frac{N^p_T}{N^e_T} \frac{\Delta\Omega^p}{\Delta\Omega^e} \frac{\frac{d\sigma^p}{d\Omega}}{\frac{d\sigma^e}{d\Omega}}$$

$N_{\gamma'}$ – number of Compton events

N_γ – number of incoming photons

N_T – number of target nuclei

ε – detector efficiency

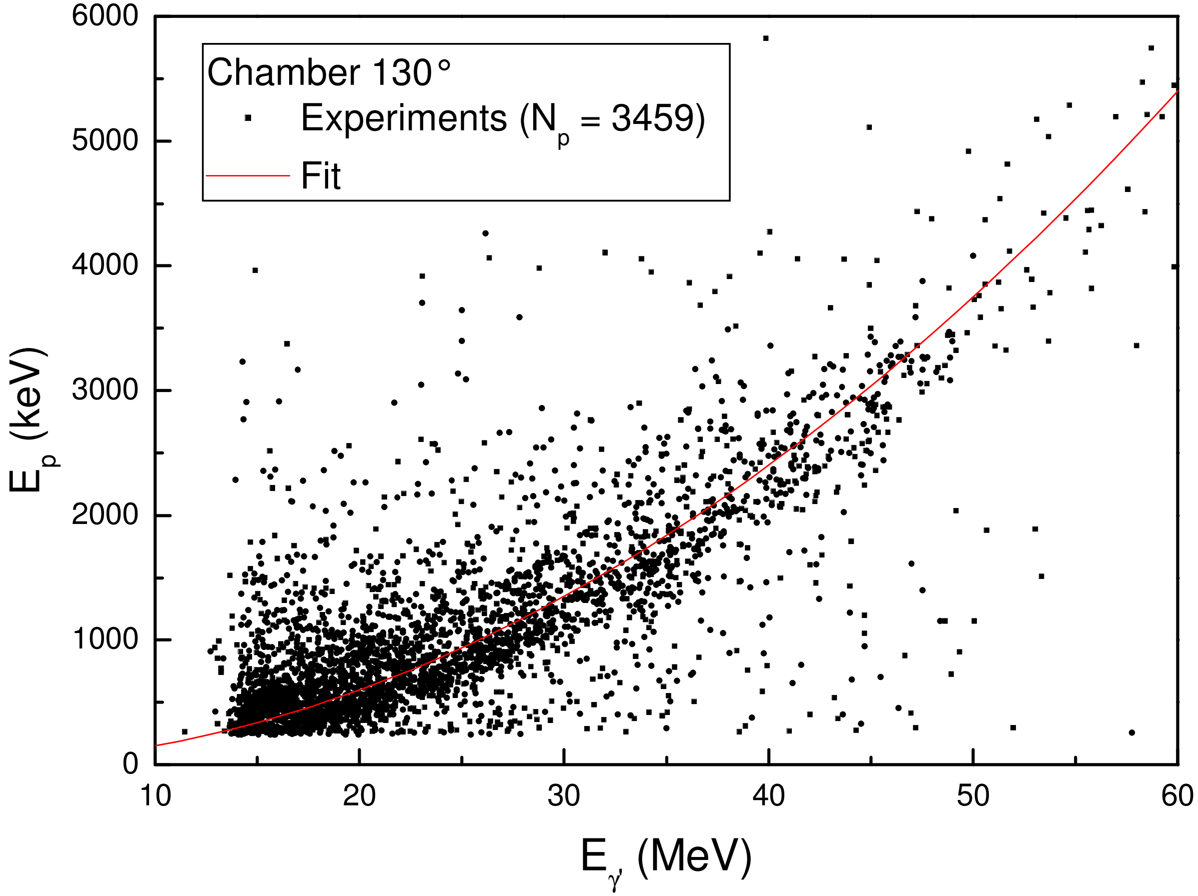
$\Delta\Omega$ – solid angle

$$\frac{N^p_{\gamma'}}{N^e_{\gamma'}} = C \frac{\frac{d\sigma^p}{d\Omega}(\alpha,\beta)}{\frac{d\sigma^e}{d\Omega}}$$

Experiments

	August 2006	April-May 2007
Current I_e, μA	1-7	1-3* *pulsed beam
Energy E_e, MeV	60	79
Charge, μAh	1116.4	333.54
Pressure, bar	73.5	73.5
Voltage, kV	$V_C = 39$, $V_G = 3.5$	$V_C = 39$, $V_G = 3.5$

First Results



$$E_p = E_\gamma - E_{\gamma'}$$

$$E_{\gamma'} = \frac{E_\gamma}{1 + \frac{E_\gamma}{m_p}(1 - \cos\theta)}$$

Summary and Outlook

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- Experiments were performed
- Preliminary results were shown

- Analysis is running
- Simulations with GEANT4
- Better statistics
- Experiment with deuteron

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