New Experimental Method for a Precise Measurement of the Proton Charge Radius at the S-DALINAC *

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Introduction

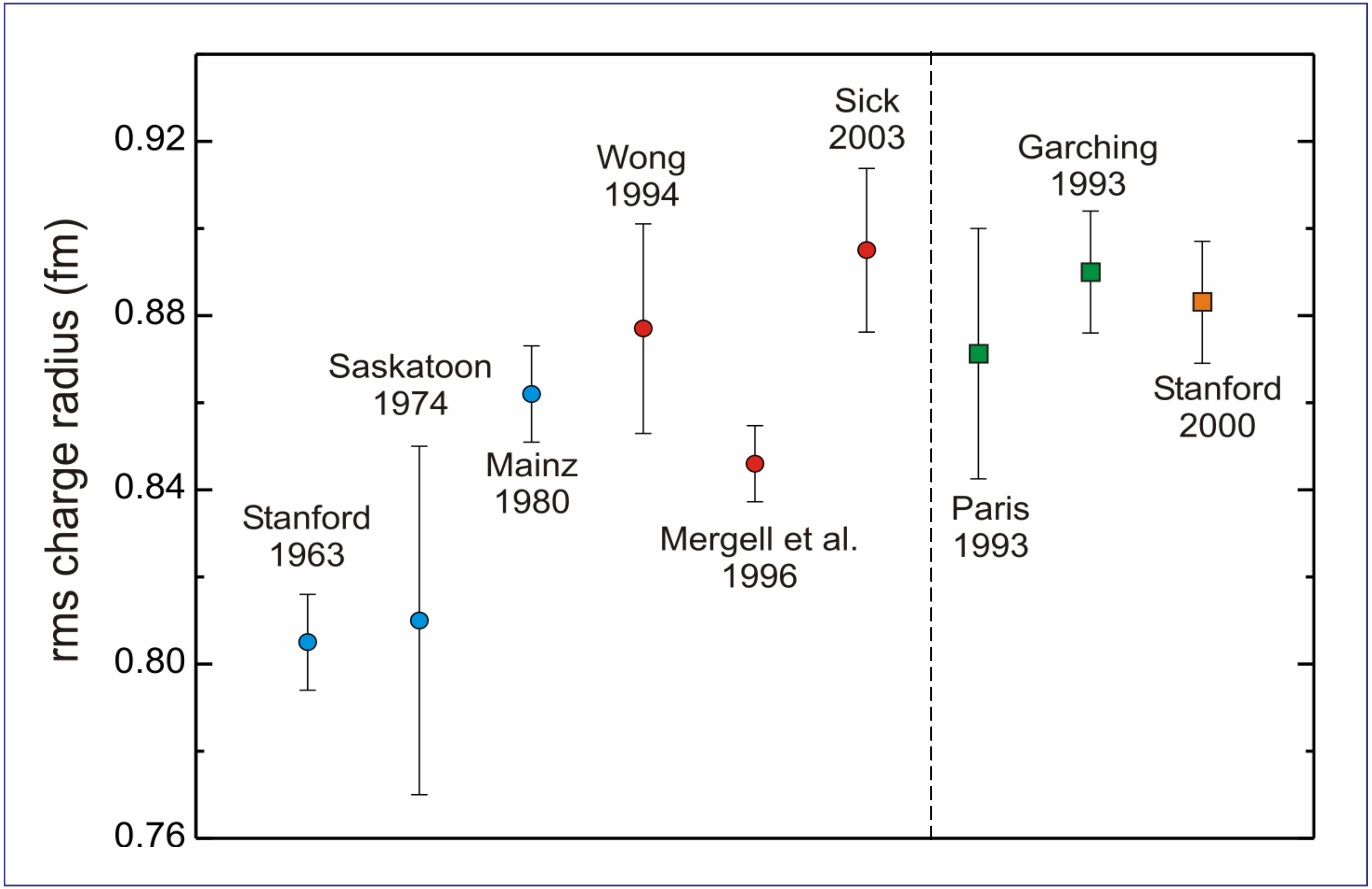
Proton charge radius –
one of the fundamental quantities in physics!

Its precise determination is very important -

- to understand its structure in terms of quark and gluon degrees of freedom of Quantum Chromodynamics.

- for high-precision tests of Quantum Electrodynamics using Lamb shift measurements .

Proton charge radius – the data



Differential cross-section H(e,e)p

$$\frac{d\sigma}{d\Omega} = \left.\frac{d\sigma}{d\Omega}\right|_{Mott} F(q^2)$$

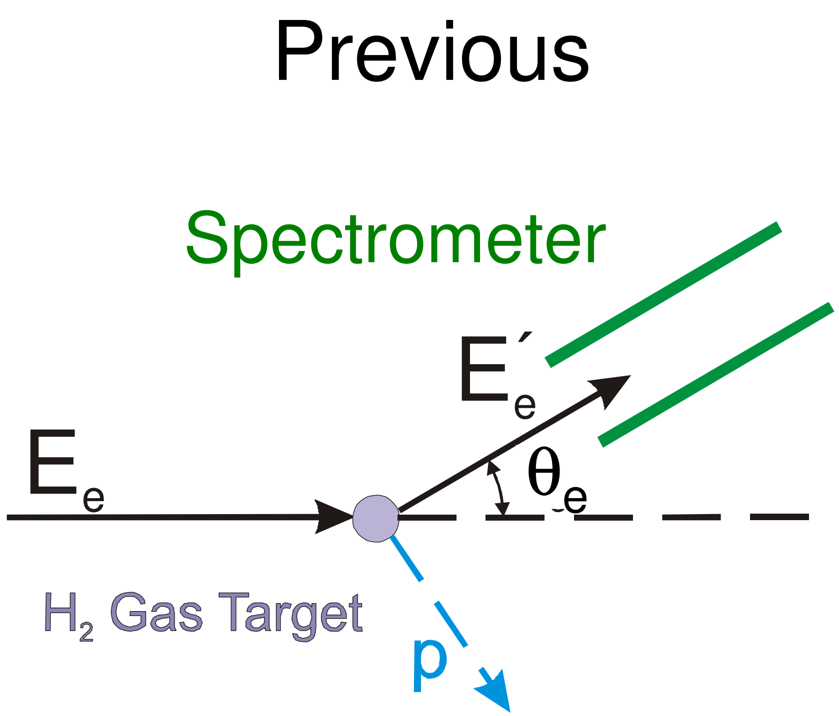
$$F(q^2) = \left\{\left(\frac{G_E{}^2 + \cancel{\tau G_M^2}}{1+\tau}\right) + \cancel{2\tau G_M^2} \tan^2\frac{\theta}{2}\right\}, \textit{with}\ \tau \equiv \frac{q^2}{4M^2}$$

At low q, $\tau \sim 0$

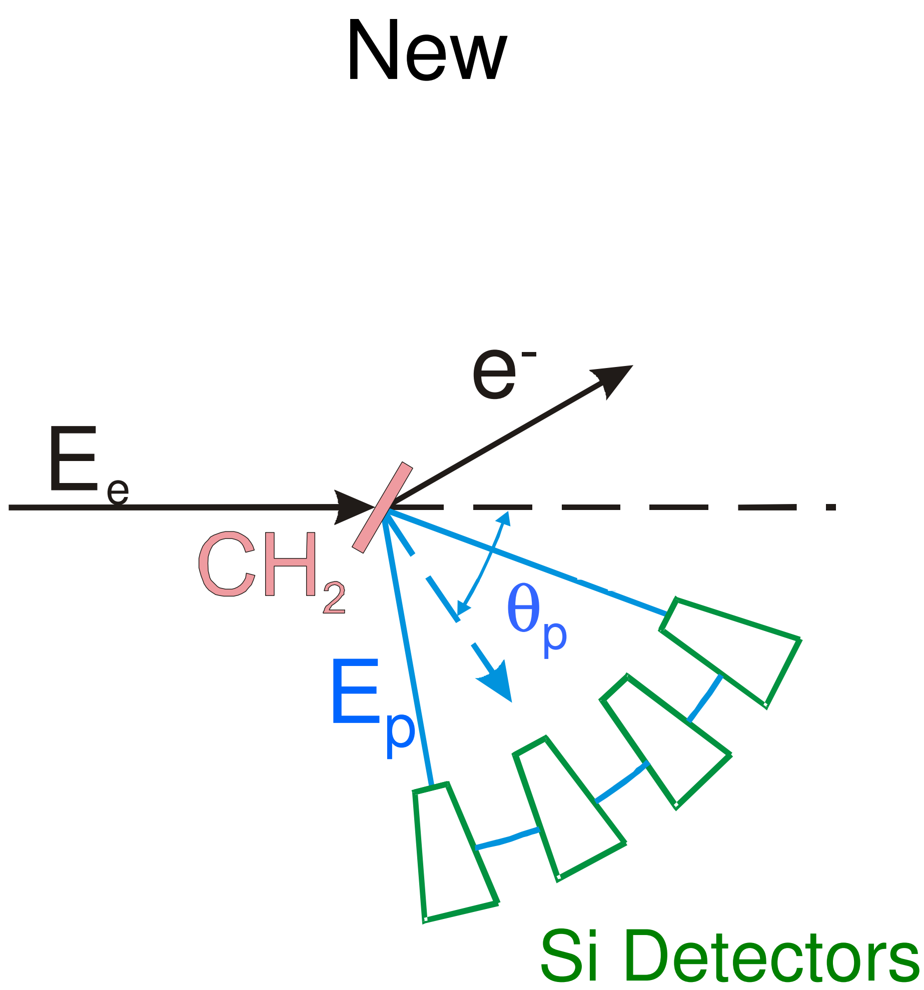
$$F(q^2) = \int e^{i\vec{q}\cdot\vec{r}} \rho(r)\, d^3 r$$

$$\frac{< r^2 >}{6} = -\left.\frac{dG_E{}^p(q^2)}{dq^2}\right|_{q \to 0}$$

Experimental method

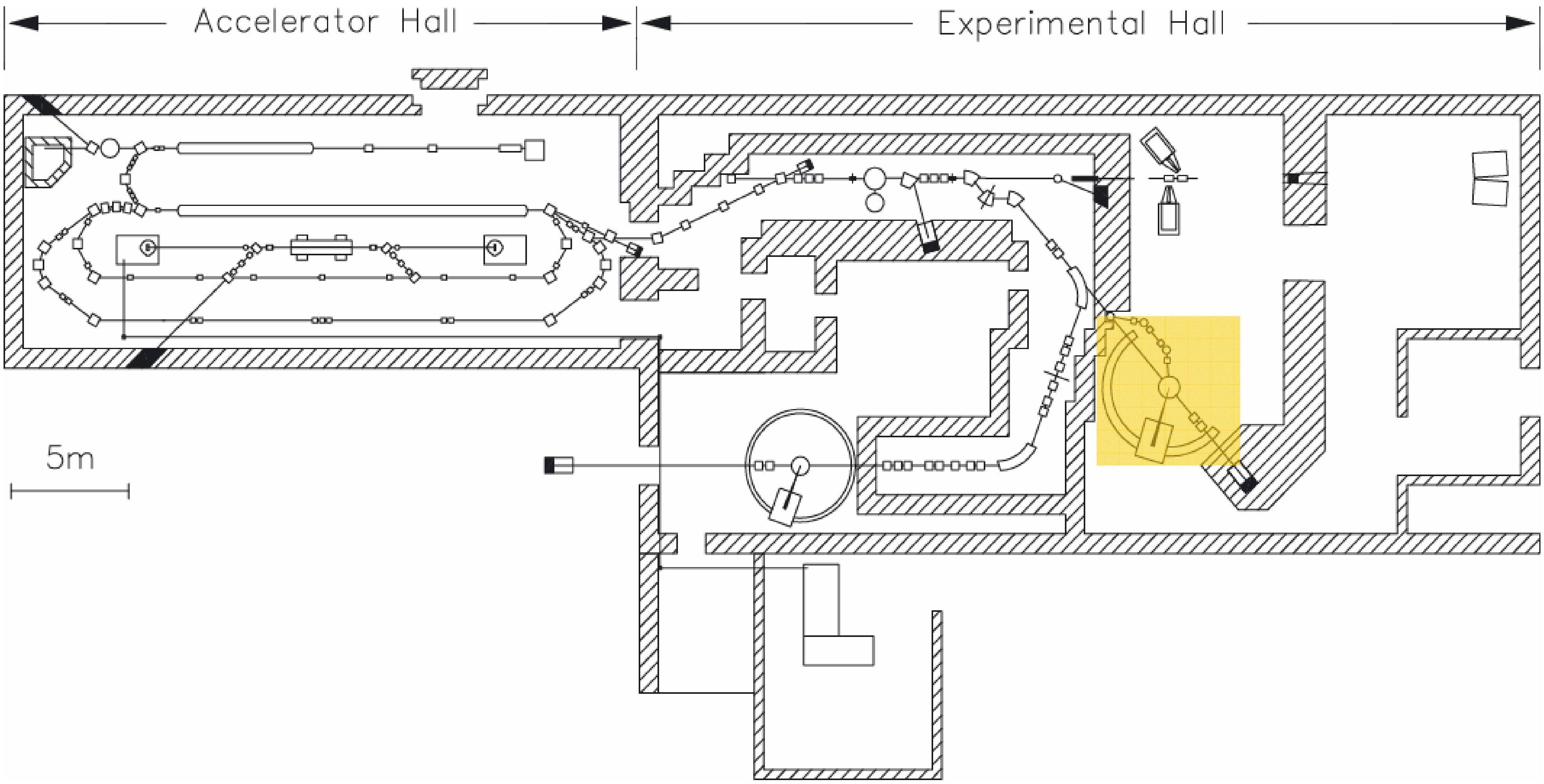


Stanford
Mainz

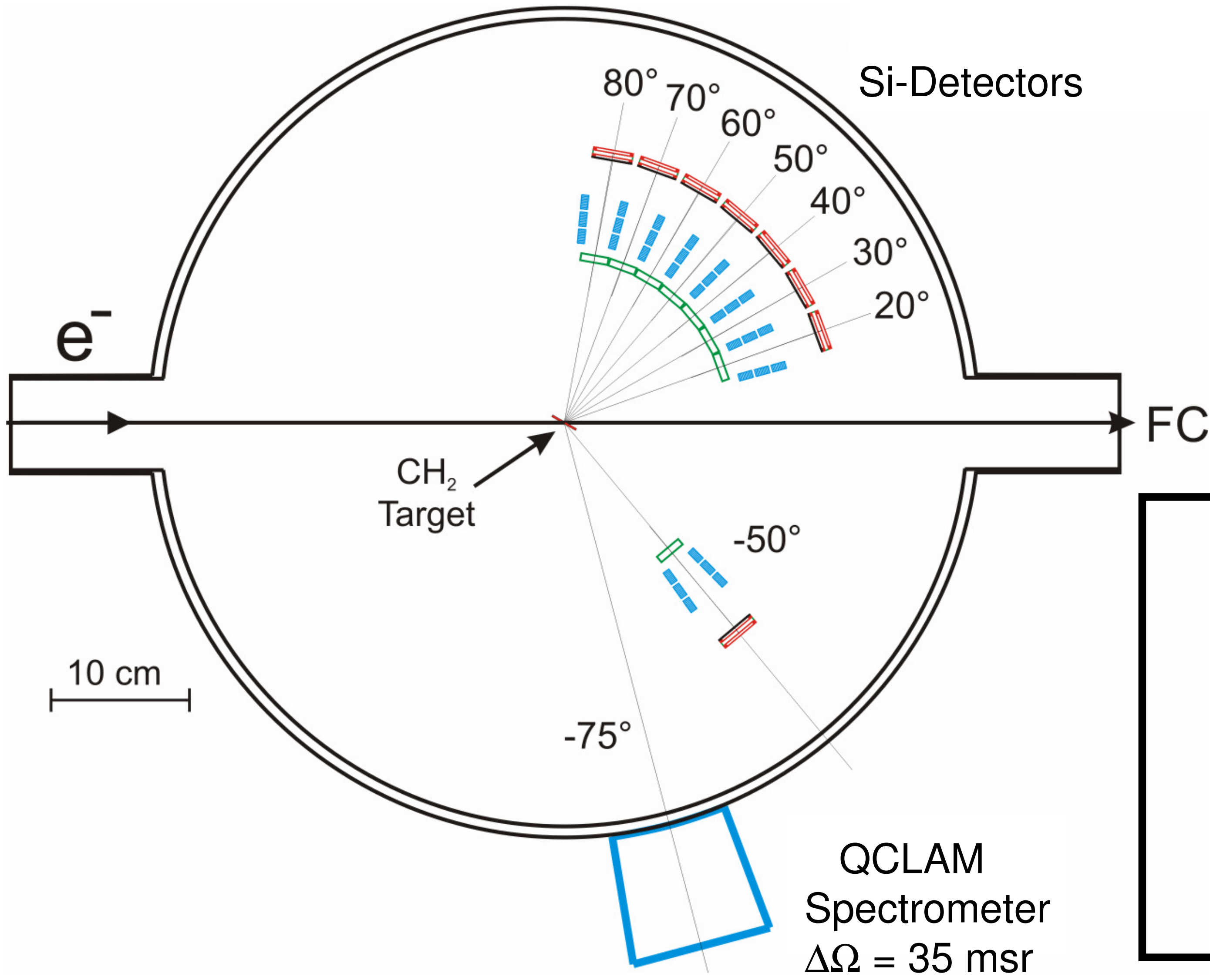


$\Delta r_p / r_p < 1\%$

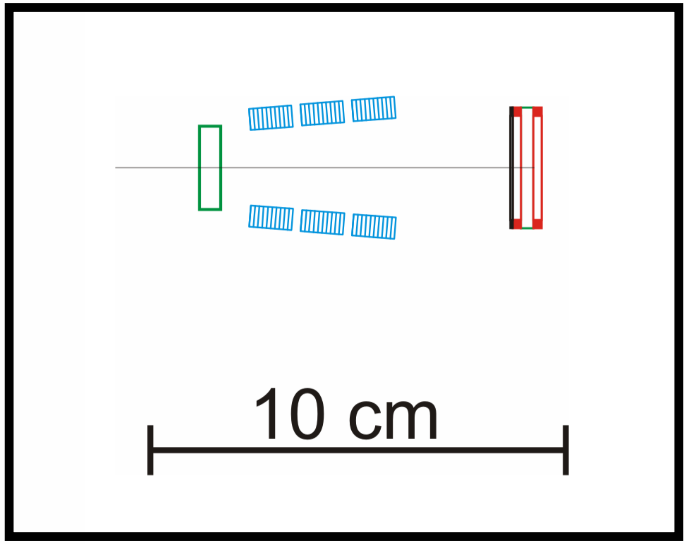
S-DALINAC



Set-up

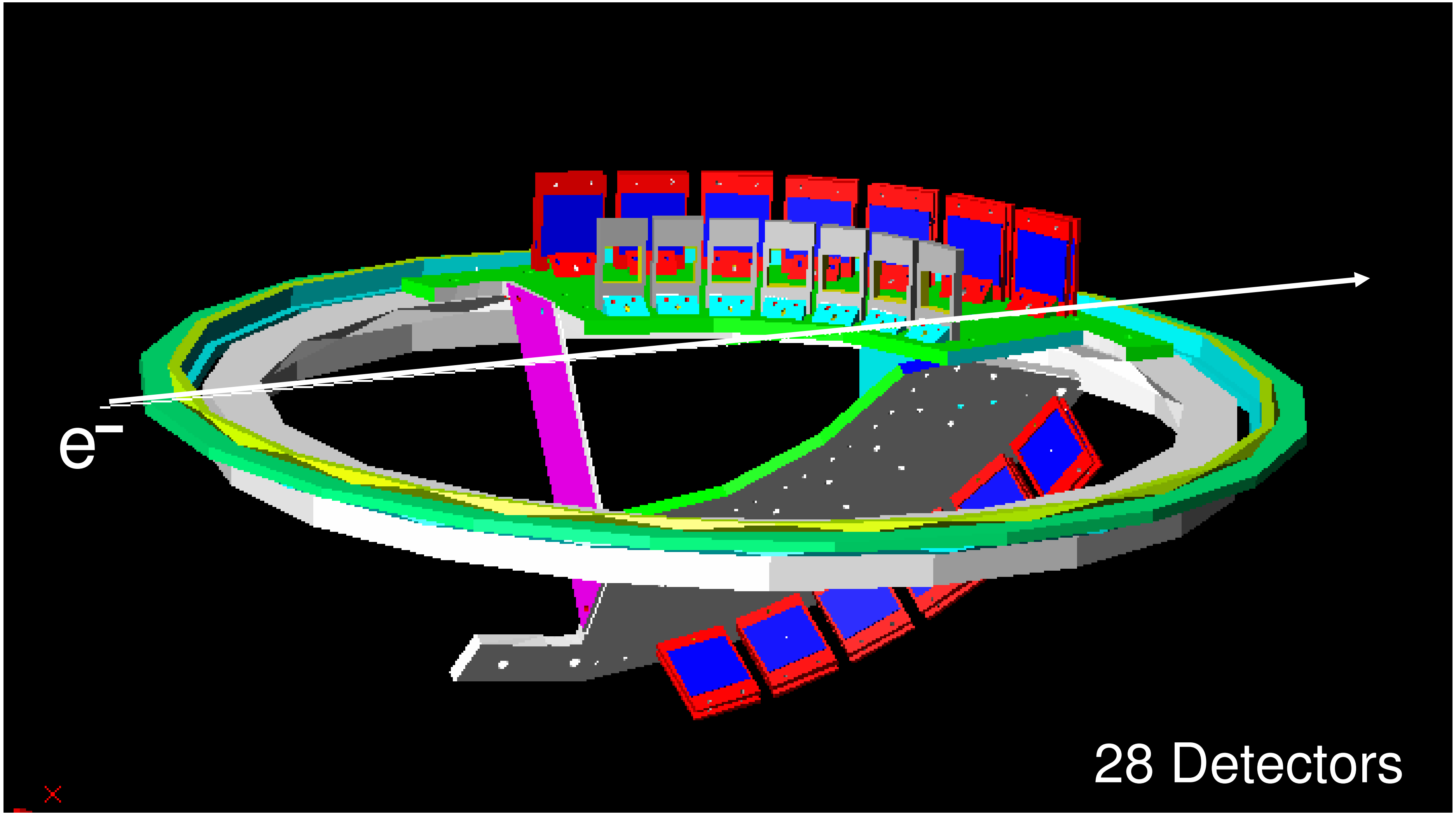


Si-Detectors
80°
70°
60°
50°
40°
30°
20°
e-
FC
CH2
Target
-50°
-75°
10 cm
QCLAM
Spectrometer
ΔΩ = 35 msr



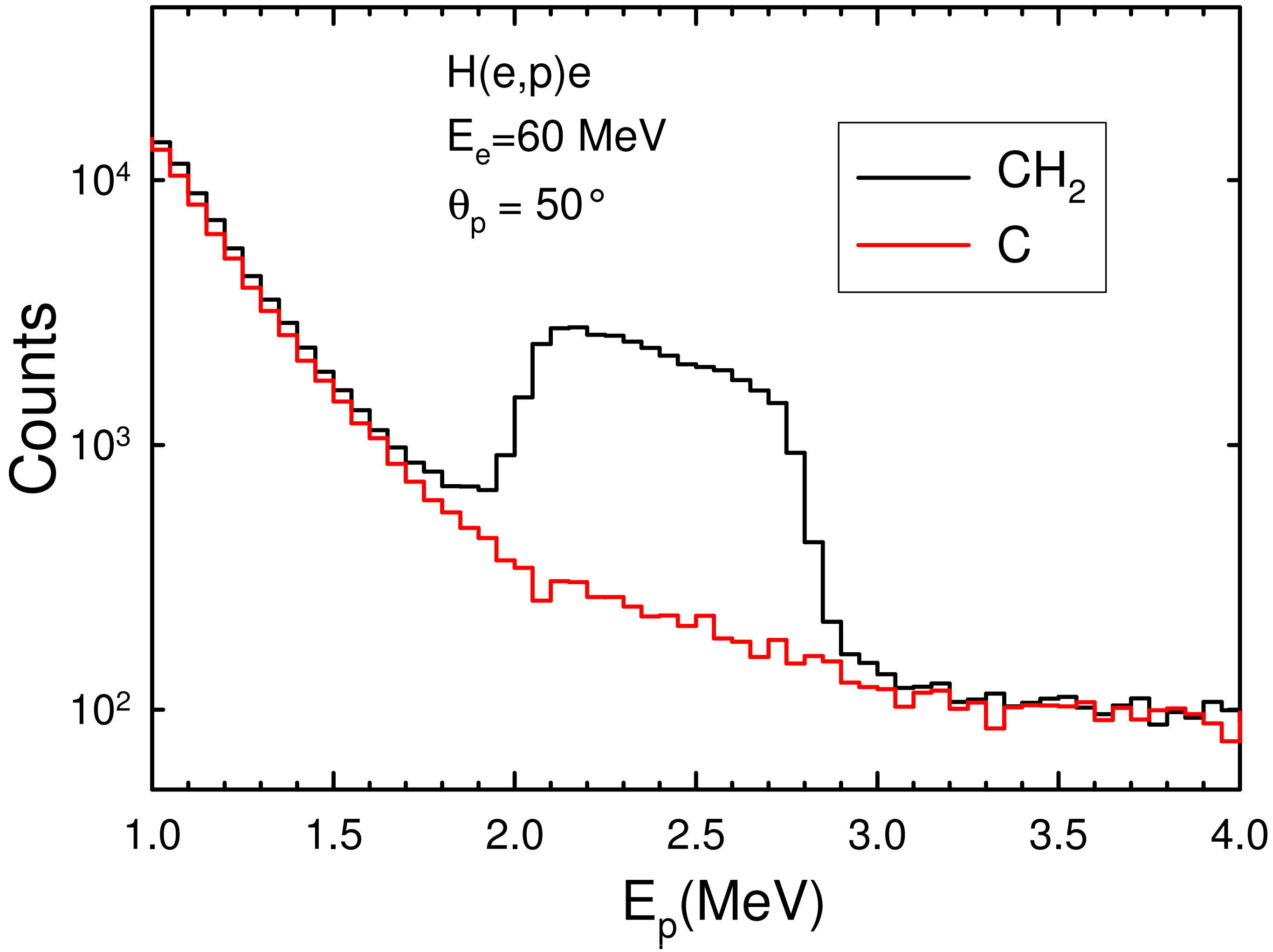
10 cm

Setup

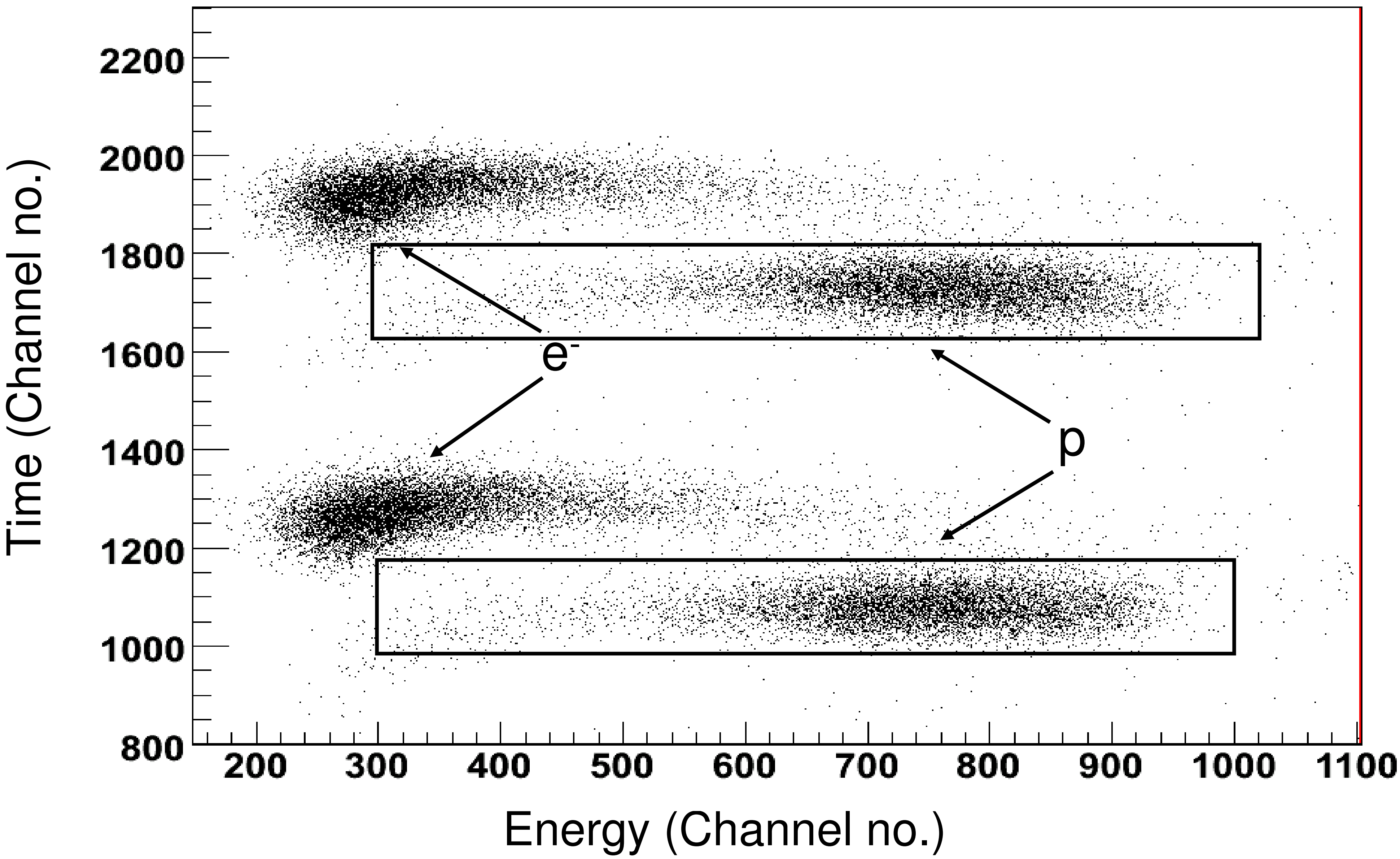


472 mm

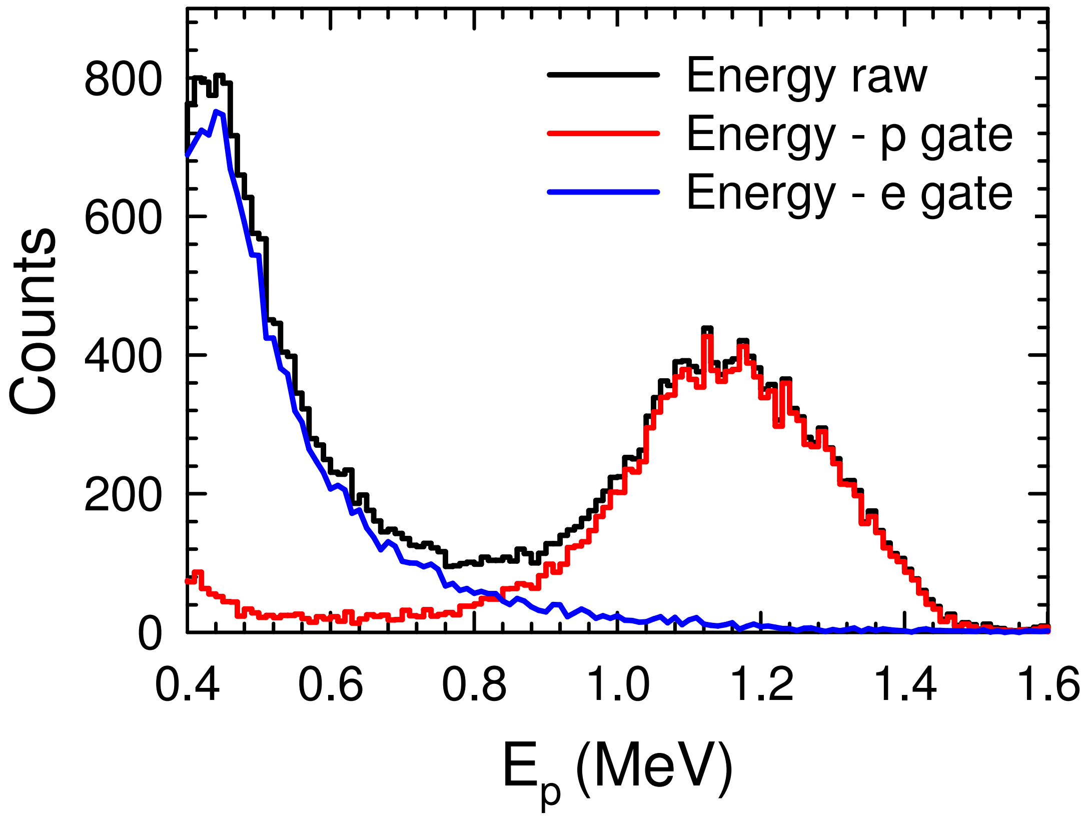
Experimental energy spectrum and background



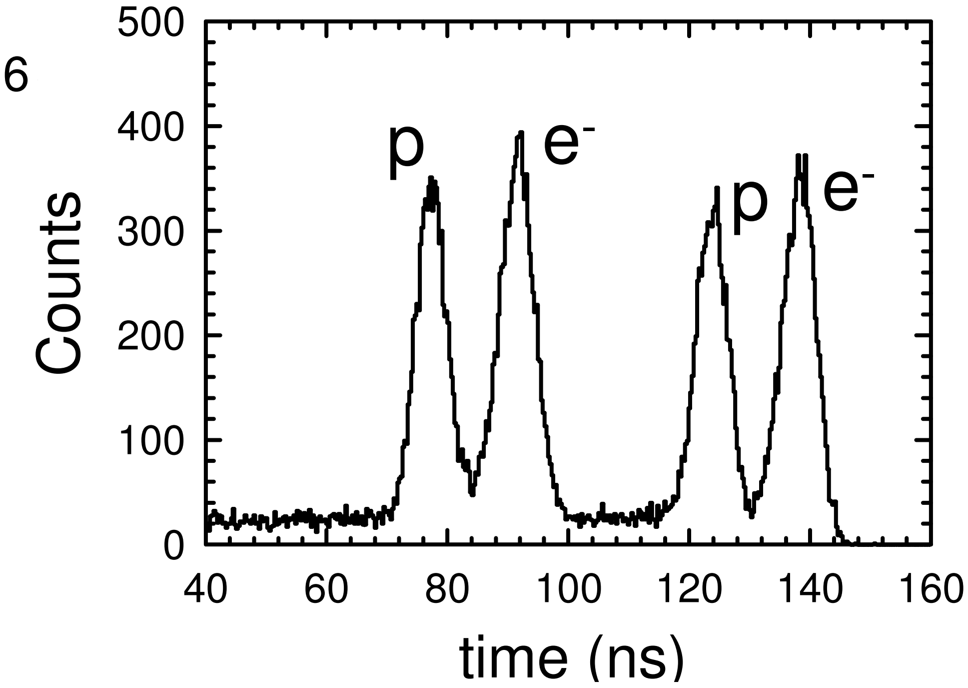
Linearised spectrum



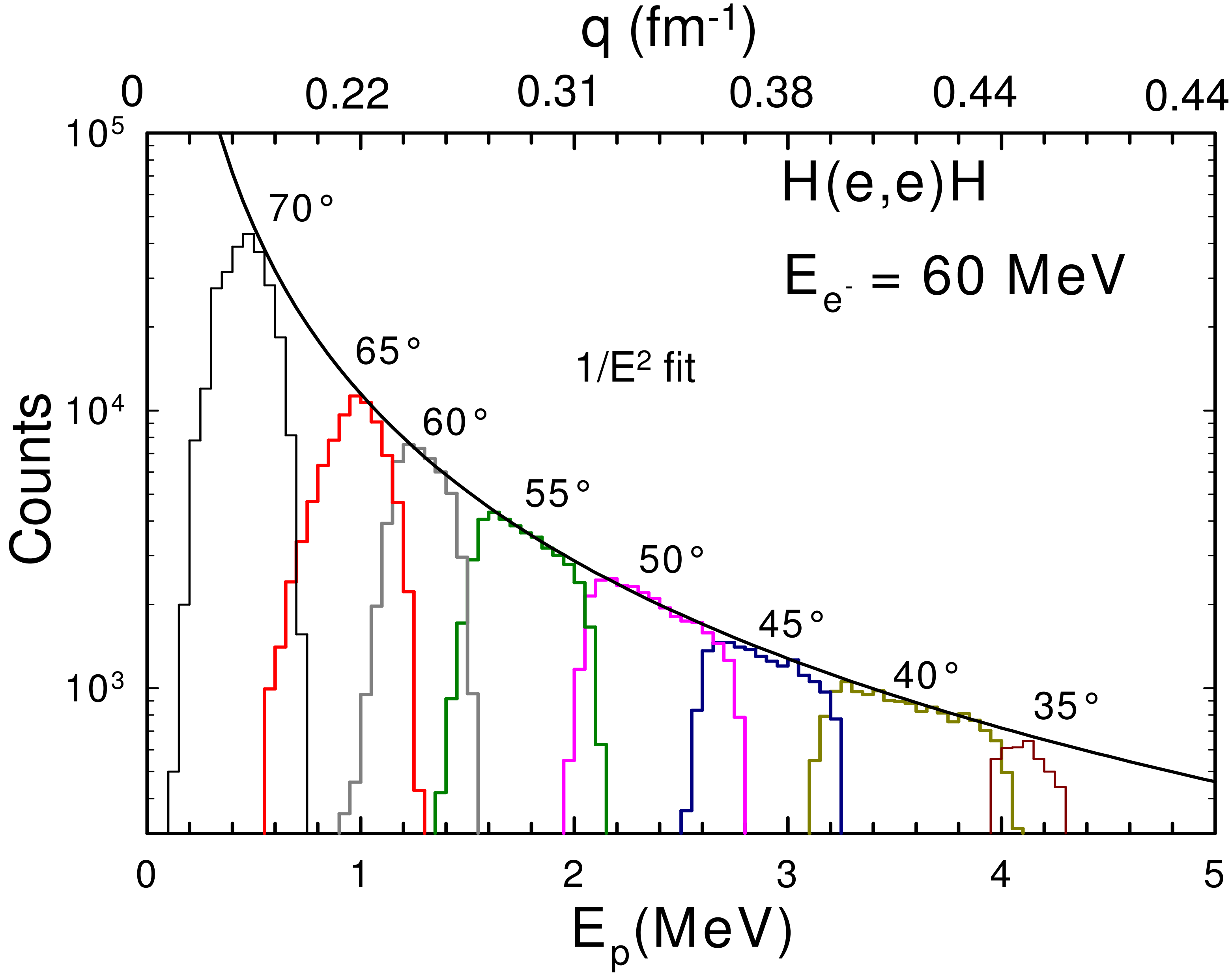
Projected spectra



Time Resolution ~ 5 ns



Measured energy spectra



Outlook

Proton charge radius

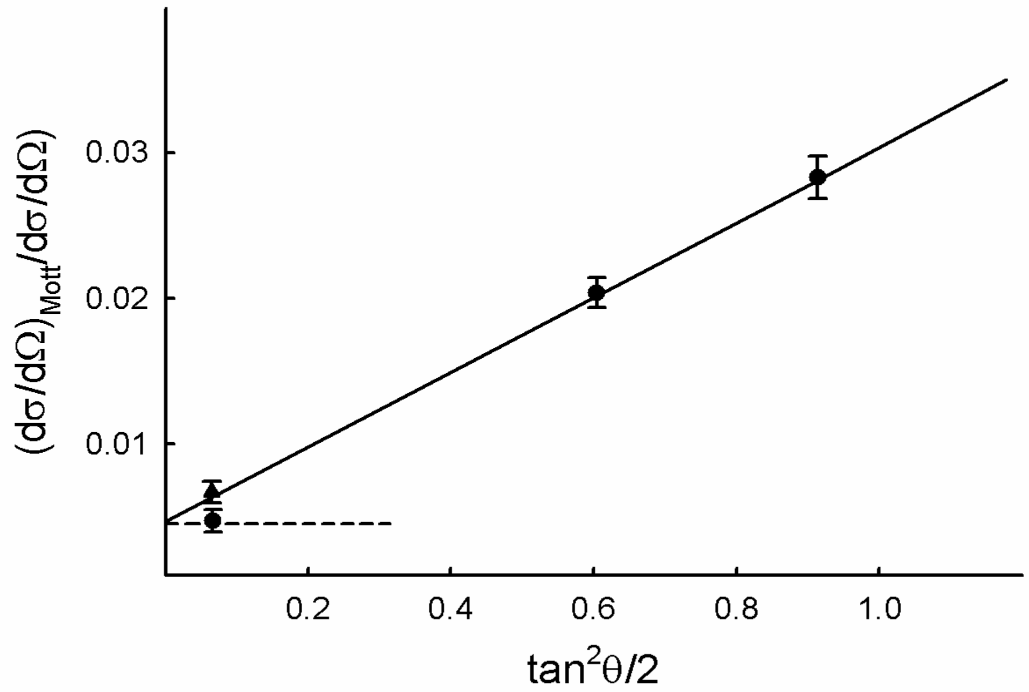
$$\frac{d\sigma}{d\Omega} \propto \frac{1}{q^4}\left\{1-\frac{<r^2>q^2}{3!}+\frac{<r^2>^2q^2}{5!}\right\}$$

Measurements at higher beam energies !

Rosenbluth Separation

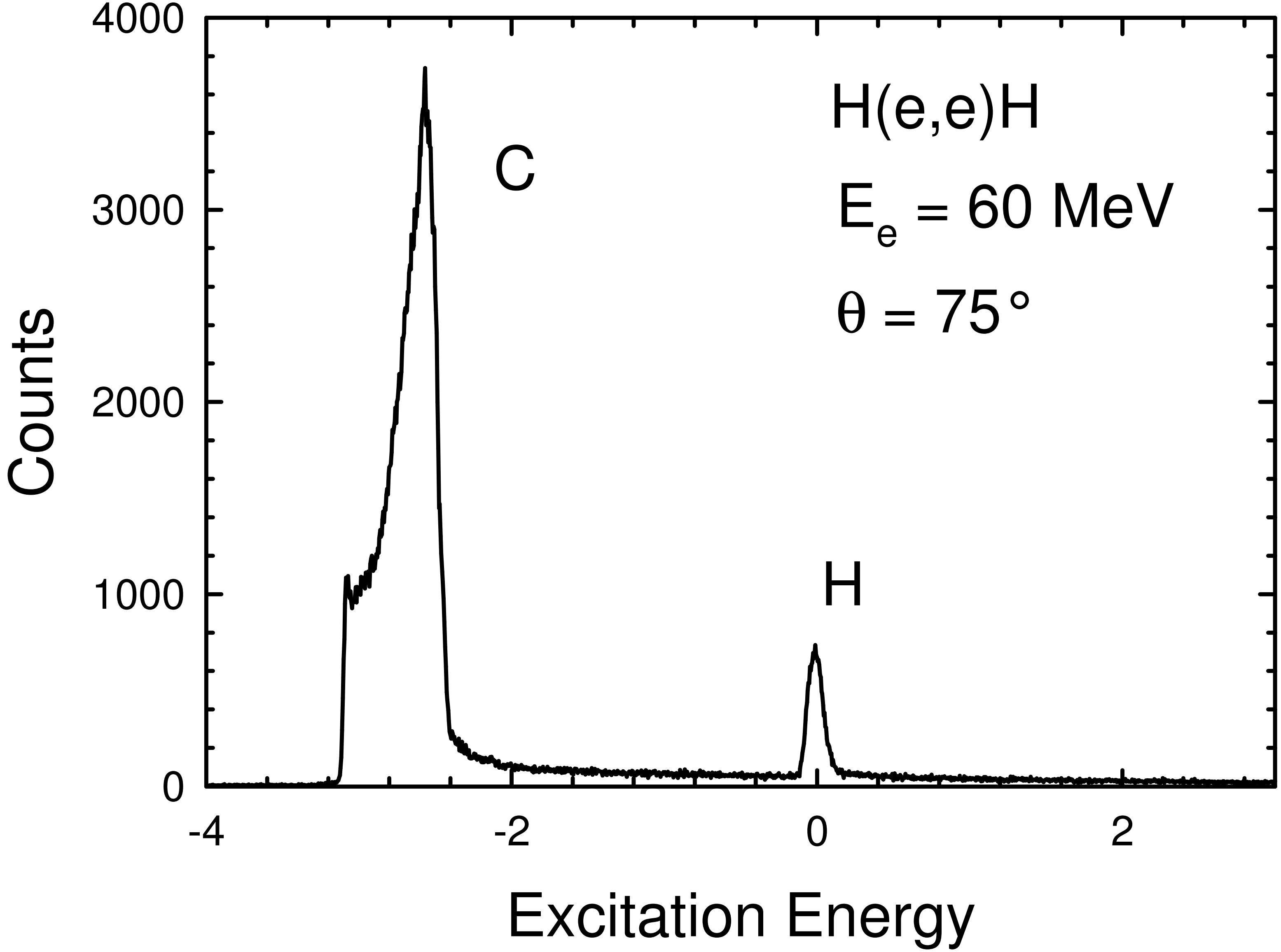
$$\frac{\dfrac{d\sigma}{d\Omega}}{\left(\dfrac{d\sigma}{d\Omega}\right)_{Mott}} = \left\{ A(Q^2) + B(Q^2)\tan^2\frac{\theta}{2} \right\}$$

Separation of el. and mag. contributions: Same q, different kinematics (E_e,θ)

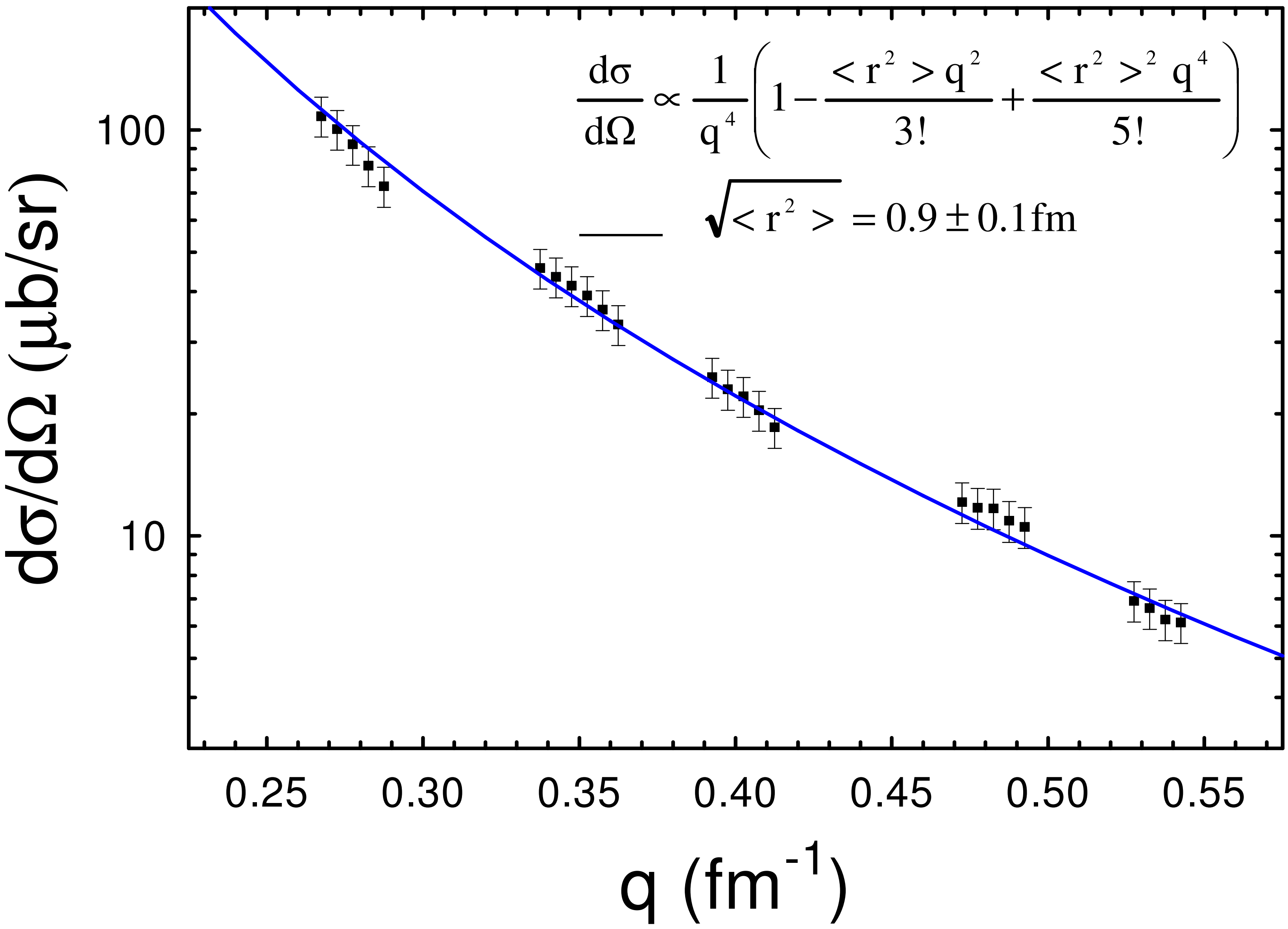


e-p Scattering

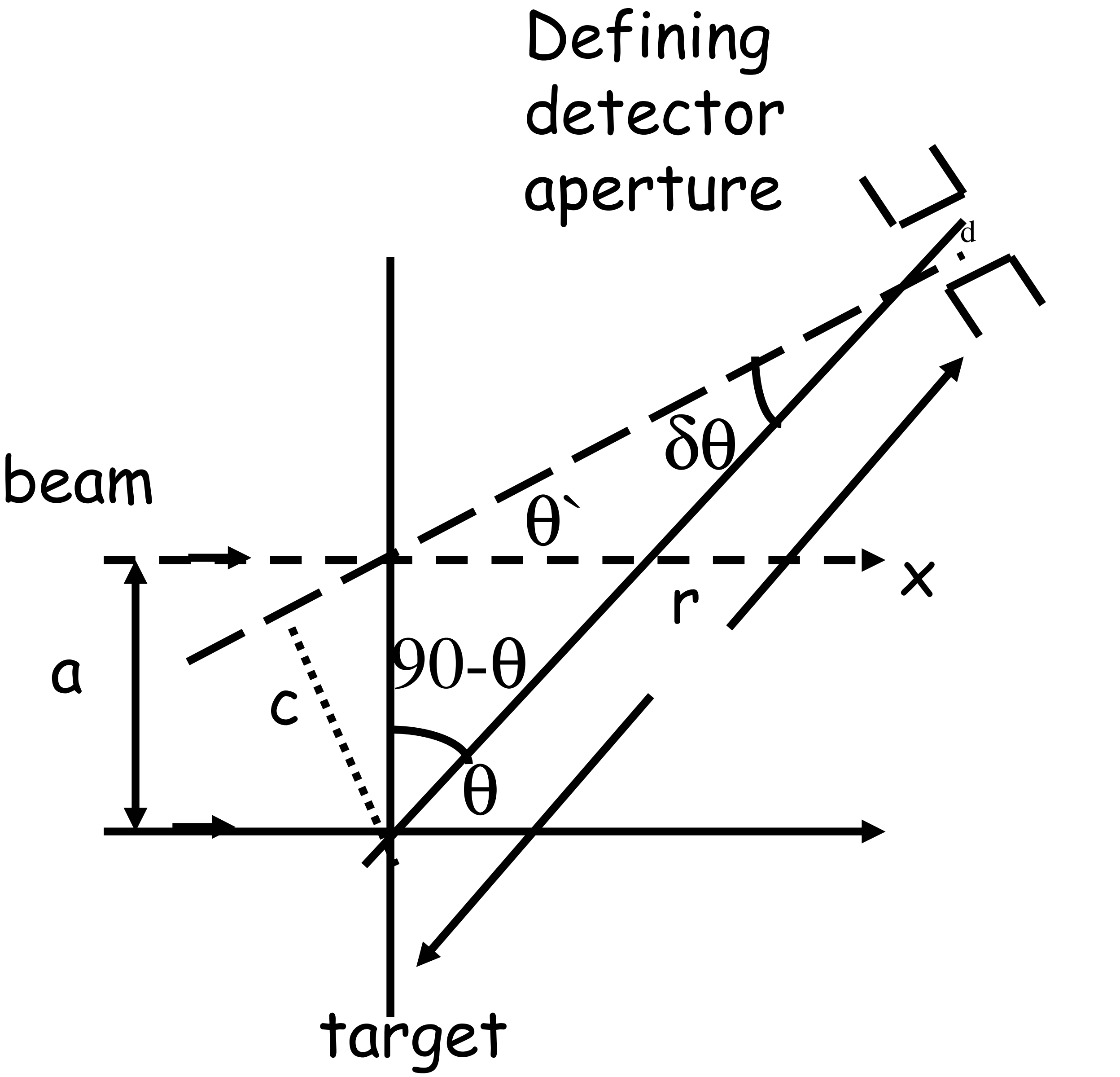
Spectrometer spectra



Test Experiment



Effect of beam spot on the angle defination of the detector:



Beam dia. =
a = 2mm
Detector
Distance=
r = 20cm

$$\tan \delta\theta = c/\,r$$

$$= a*\cos(\theta)/r$$

Si Detectors

Si – Detectors 2.5 x 2.5 cm^2

θ_p °	E_p(MeV)	Reichweite (µm)	Dicke (µm)
20°	8.90	570	800
30°	7.57	440	600
40°	5.92	290	380
50°	4.16	160	250
60°	2.52	70	100
70°	1.18	22	50
80°	0.3	3	12