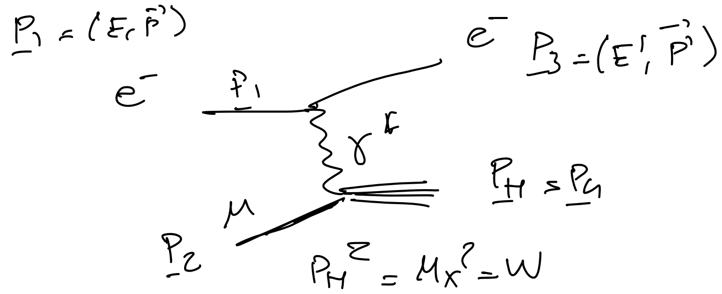
Deep Inelastic Scattering.



$e^- + p \longrightarrow e^- + p$ elastic

$e^- + p \longrightarrow e^- + X$ inelastic.

elastic : $Q^2 = 2M\nu$

inelastic: $W = M^2 - Q^2 + 2M\nu$.

for $W \to M^2 \Rightarrow$ elastic

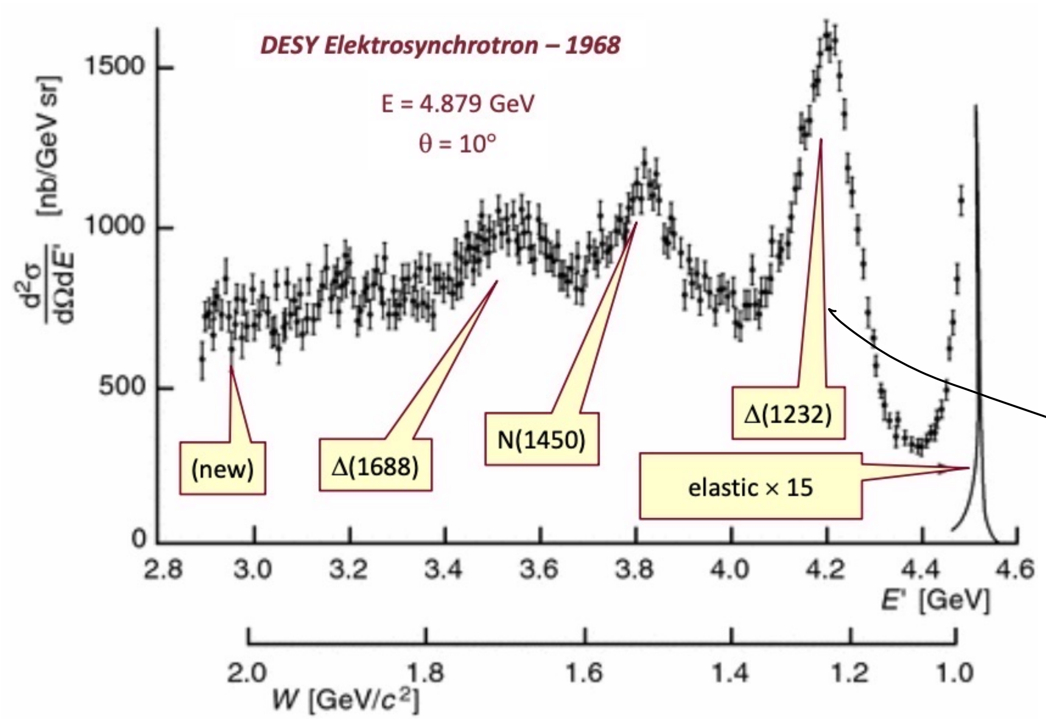
$P_H^2 = M_X^2 = W$

$= M^2 - Q^2 + 2M\nu$.

$\nu = E - E'$

$Q^2 = 2EE'(1-\cos\theta)$.

$= 4EE' \sin^2\frac{\theta}{2}$



Elastic

$$E' = \frac{E}{1 + \frac{2E}{M}(1-\cos\theta)}$$

$e^- + p \longrightarrow e^- + p^*$

$$\left.\frac{d\sigma}{d\Omega}\right|_{DIS} = \frac{\alpha^2}{Q^4} E'^2 \cos^2\frac{\theta}{2} \left[W_2(Q^2,\nu) + 2W_1(Q^2,\nu)\tan^2\frac{\theta}{2} \right].$$

phase space relativistic

spin of electron

W_1, W_2 structure functions.

elastic scattering : $F_1(Q^2)$, $F_2(Q^2)$.

Coulomb-like interaction

magnetic moment

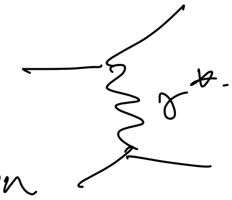
(E', θ) (Q^2, ν) (x, y) $x = \frac{Q^2}{2M\nu}$, $y = \frac{\nu}{E} = \frac{E - E'}{E}$

$[\sigma] = L^2 = E^{-2}$

$$2M W_1(Q^2,\nu) = F_1(x,Y).$$

$$\nu W_2(Q^2,\nu) = F_2(x,Y)$$

From theory : $\dfrac{W_2}{W_1} = \left(\dfrac{Q^2}{\nu^2+Q^2}\right)(1+R).$

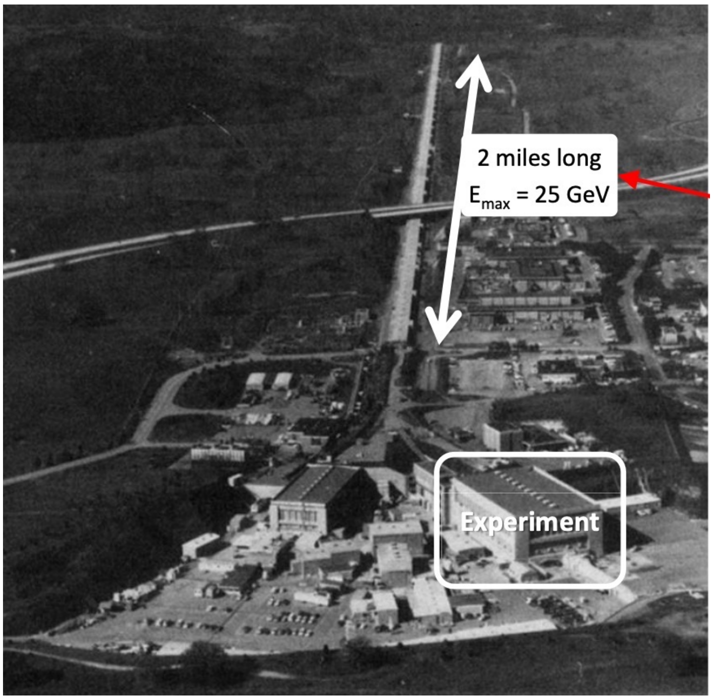


$R = \dfrac{\sigma_S}{\sigma_T}$ $\sigma_S \longrightarrow$ cross section of longitudinal pol. photon

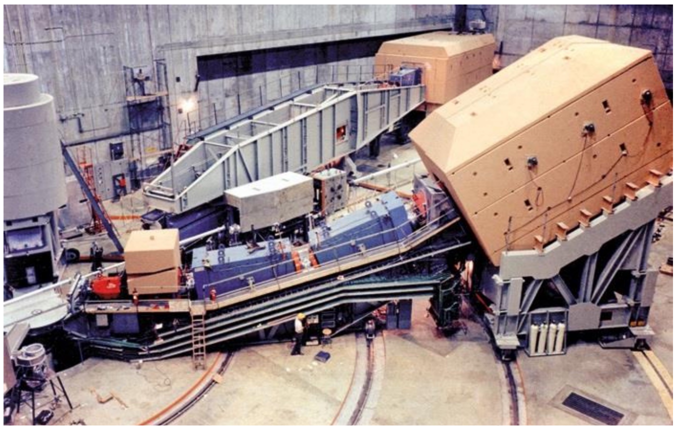
$\sigma_T \longrightarrow$ cross section for transv. pol. photon.

$0 < R < \infty$

Bjorken $W_2 = \dfrac{1}{\nu} F_2(Q^2,\nu) = \dfrac{1}{\nu} F_2(\omega)$ $\omega = \dfrac{2M\nu}{Q^2} = \dfrac{1}{x}$



new machine @ SLAC 1968



$e^- + T \longrightarrow e^- + X.$
↳ liquid H, He

3 spectrometers: 1.6 GeV $\theta \simeq 34^\circ$
8 GeV. $\theta \geq 12^\circ$
20 GeV.
} mainly for e^-.

$e^- + p \to e^- + p$ elastic scattering.
monitor uniformity of liquid target.
measure P.

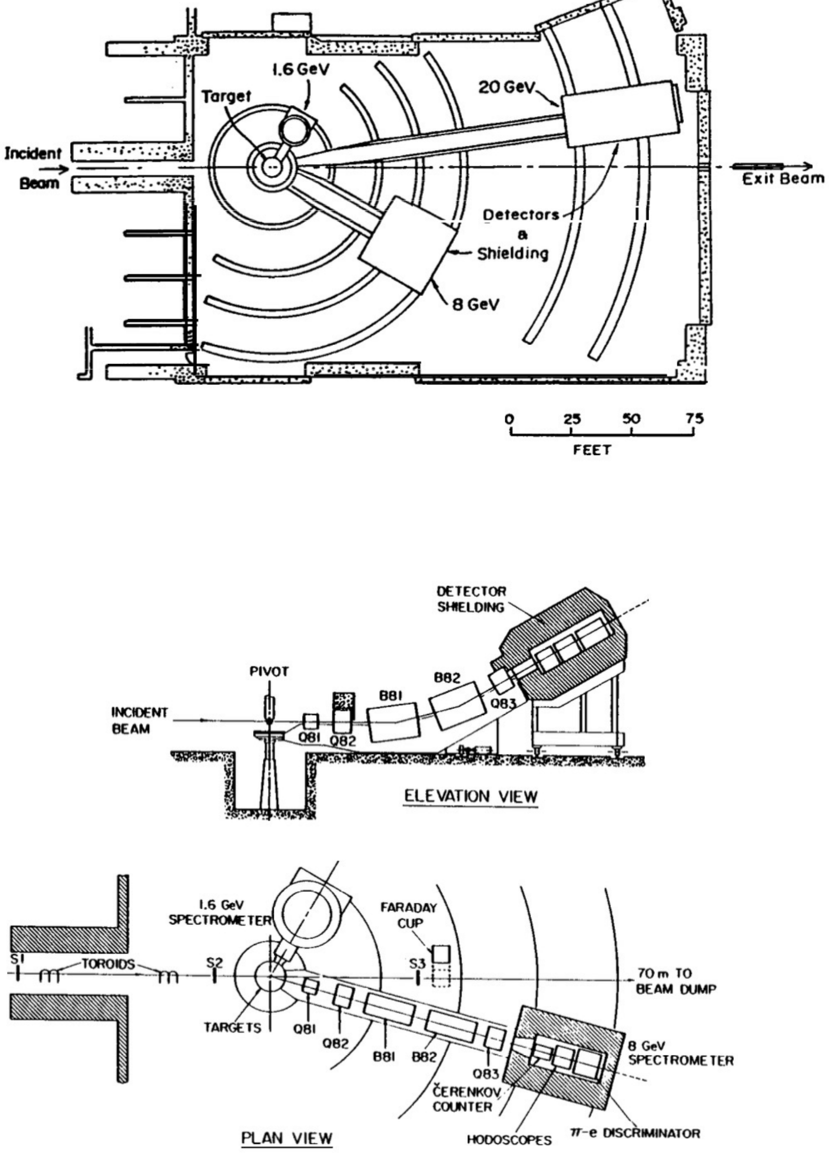


Fig. 2. (a) Plan view of End Station A and the two principal magnetic spectrometers employed for analysis of scattered electrons. (b) Configuration of the 8 GeV spectrometer, employed at scattering angles greater than 12°.

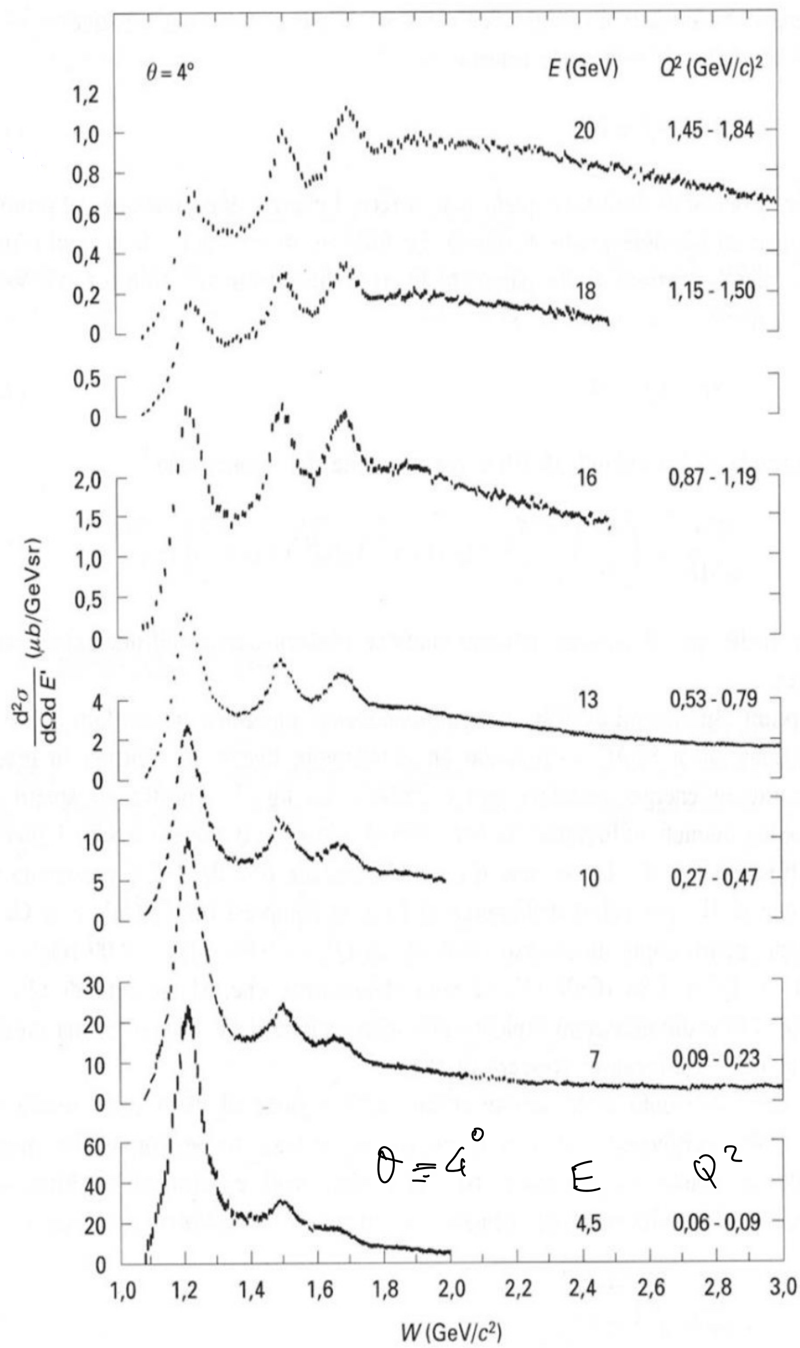
$Q^2 = 2EE'(1-\cos\theta)$.

Q: Quadrupoles.

B: bending.
dipoles.

Cerenkov.
for e^-/π
discrim

e^-/π
shower
properties.



1) Fixed E, θ

$\Rightarrow$ Interval of Q^2, W

$W = M^2 - Q^2 + 2M\nu$.

2) peaks of baryons

3) $\sigma \searrow$ for $E \nearrow$ at same W.

4) at Fixed E, θ resonances decrease for $W \nearrow$.

$$\frac{d^2\sigma}{d\Omega\, dE'} = \frac{\#\text{events}}{\underbrace{(\Delta\Omega)}_{\text{solid angle of detector}}\ \underbrace{(\Delta E')}_{\text{bins of } E'}}$$

$W = M^2 - Q^2 + 2M\nu$.

$Q^2 = 2EE'(1 - \cos\theta)$.

E fixed by beam.

$\theta = 4^\circ$ $\quad$ E' from E.

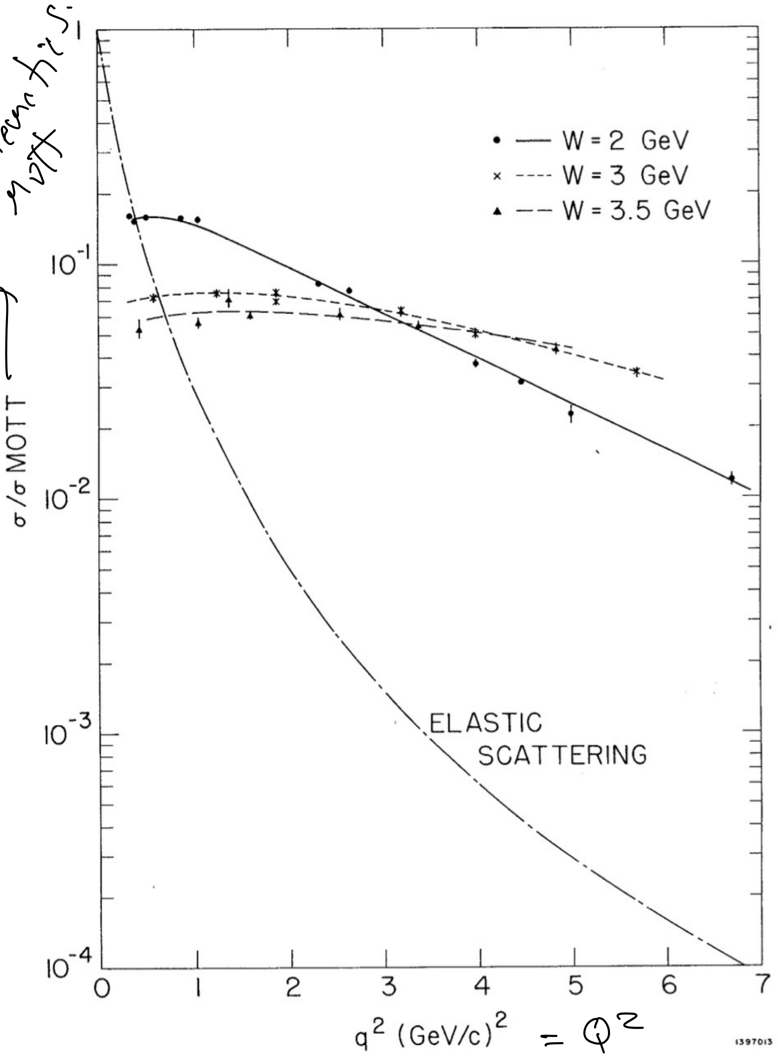
5) For very large W.

$$\frac{d\sigma}{d\Omega}\frac{1}{dE'} \simeq 1\text{-}2\ \frac{\mu b}{GeV}\frac{1}{sr}$$

$$\frac{\left.\frac{d\sigma}{d\Omega}\right|_{DIS}}{\left.\frac{d\sigma}{d\Omega}\right|_{Mott}} = W_2(Q^2,\nu) + 2W_1(Q^2,\nu)\tan^2\frac{\theta}{2} = R(Q^2)$$

at fixed θ.

all increments in Mott



$= Q^2$

Elastic scattering.

$\theta = 10^\circ$

$R(Q^2=0) = 1.$

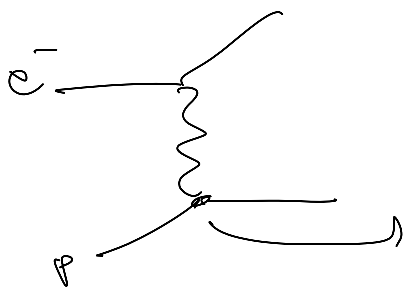
$$\frac{d\sigma}{d\Omega}\Big|_{Mott} = \underbrace{\frac{\alpha^2}{Q^4} E'^2}_{\text{Ruth.}} \underbrace{\cos^2\frac{\theta}{2}}_{\text{Spin-1/2 } e^-} \underbrace{\frac{E'}{E}}_{\text{recoils}}$$

$$\frac{d\sigma}{d\Omega}\Big|_{Rosenbluth} =$$

$$\frac{d\sigma}{d\Omega}\Big|_{Mott} \times \left[(F_1^2 + F_2^2) + (F_1^2 + F_2^2) \tan^2\frac{\theta}{2} \right]$$

F_1: Coulomb interaction

F_2: mag. moment interaction



$$\left(F_1(Q^2)\gamma^\mu + i\sigma_{\mu\nu} q_\nu F_2(Q^2)\right)$$

1) Elastic scattering $\sigma \searrow$ for $Q^2 \nearrow$ expected.

point like scattering.

2) inelastic scattering. $\frac{d\sigma}{d\Omega}$ almost flat vs. Q^2

Remember Rutherford:
$$\frac{d\sigma}{d\Omega}\Big|_{non-pointlike} = \frac{\alpha^2}{Q^2} E^2 \, |F(Q^2)|^2$$

$F(0) = 1.$

Form factor:

if proton point like $\Rightarrow |F(Q^2)| \simeq 1$.

if proton has structure $\Rightarrow |F(Q^2)|^2 \simeq 1 - \frac{1}{6} q^2 \langle r \rangle^2$ at $Q^2 \simeq 0$.

Since $\frac{\sigma}{\sigma_{Mott}} \simeq$ flat vs. $Q^2 \Rightarrow$ point-like spin 1/2 scattering.

3) $\frac{\sigma}{\sigma_{Mott}} \ll 1$.

$$\alpha = \frac{Z_T Z_{p} e^2}{4\pi} \quad \text{for } e^- + X.$$

$$\alpha = \frac{Z_X e^2}{4\pi} = Z_X \alpha$$

$$\Rightarrow \frac{\sigma_{tot}}{\sigma_{Mott}} \simeq Z_X^2 \Rightarrow Z_X < 1$$

DIS $e^- + p \to e^- + X$.

behaves like $e^- + T$. where T: pointlike spin 1/2. $Z_T < 1$.

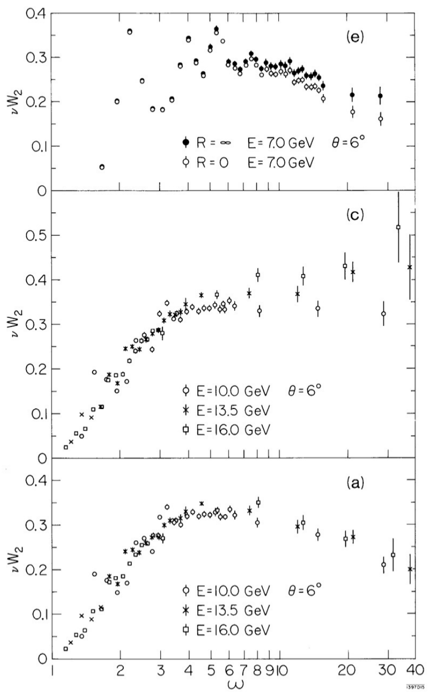


Fig. 2a, 2c, 2e

$$F_2(Q^2, \nu) = \nu W_2(Q^2, \nu).$$

$$\omega = \frac{2M\nu}{Q^2} = \frac{1}{x}$$