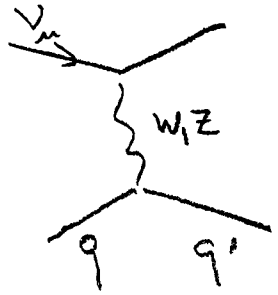
Example: ν deep inelastic scattering



simplify: ignore anti-quarks in target

charged current: $M_{CC}(\nu_{\mu L} d_L \to \mu^-_L u_L) \propto \frac{4G_F}{\sqrt{2}}$

Neutral current: $M_{NC}(\nu_L u_L \to \nu_L u_L) \propto \frac{4G_F}{\sqrt{2}} \cdot 2\left(\frac{1}{2} - \sin^2\theta_W \cdot 0\right)\left(\frac{1}{2} - \frac{2}{3}\sin^2\theta_W\right)$

ν u

$M_{NC}(\nu_L d_L \to \nu_L d_L) \propto \frac{4G_F}{\sqrt{2}} 2\left(\frac{1}{2}\right)\left(-\frac{1}{2} + \frac{1}{3}S_W^2\right)$

$M_{NC}(\nu_L u_R \to \nu_L u_R) \propto$ " $2\left(\frac{1}{2}\right)\left(-\frac{2}{3}S_W^2\right)$

$M_{NC}(\nu_L d_R \to \nu_L d_R) \propto$ " $2\left(\frac{1}{2}\right)\left(\frac{1}{3}S_W^2\right)$

recall $\frac{d\sigma_{QED}}{dx\,dQ^2}(LL \to LL) \sim \frac{4\pi\alpha^2}{Q^4} \cdot 1$

" $(LR \to LR) \sim$ " $(1-y)^2$

$\uparrow \frac{Q^2}{xS}$

choose target with equal number of $p, n \Leftrightarrow u, d$

$\Rightarrow$ pdf's cancel out

$$\Rightarrow \frac{d\sigma^{\nu}_{NC}}{dx\,dQ^2} \Big/ \frac{d\sigma^{\nu}_{CC}}{dx\,dQ^2} = \frac{\left(\frac{1}{2} - \frac{2}{3}S_W^2\right)^2 + \left(\frac{1}{2} - \frac{1}{3}S_W^2\right)^2 + (1-y)^2\,\frac{5}{9}S_W^2}{1}$$

$$= \frac{1}{2} - S_W^2 + \frac{5}{9}S_W^4\left(1 + (1-y)^2\right)$$

anti-neutrinos: $M_{CC}\left(\bar{\nu}_R u_L \to \mu_R^+ d_L\right) \propto \frac{4G_F}{\sqrt{2}}$ $\qquad \frac{d\sigma^{\bar{\nu}}}{dx\,dQ^2} \sim (1-y)^2$

NC similar ...

integrate over detector region $\quad R^{\nu} \equiv \int \frac{d\sigma^{\nu}_{NC}}{dx\,dQ^2} \Big/ \int \frac{d\sigma^{\nu}_{CC}}{dx\,dQ^2}$

$$R^{\bar{\nu}} \equiv \quad " \bar{\nu} \Big/ " \bar{\nu}$$

$$r \equiv \int \frac{d\sigma^{\bar{\nu}}_{CC}}{dx\,dQ^2} \Big/ \int \frac{d\sigma^{\nu}_{CC}}{dx\,dQ^2} \quad \leftarrow \quad \int (1-y)^2 \Big/ \int 1$$

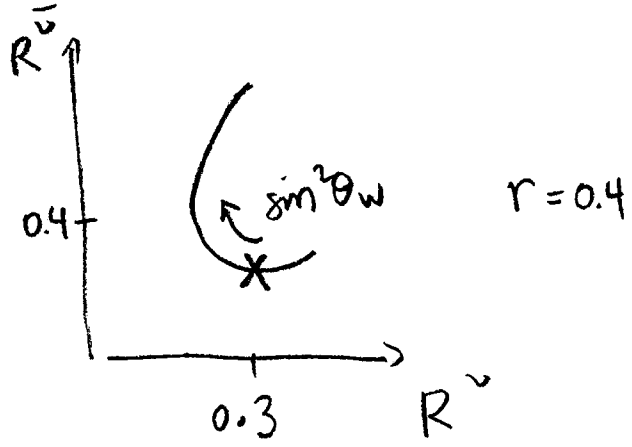
$$\Rightarrow R^{\nu} = \frac{1}{2} - S_W^2 + \frac{5}{9}S_W^4(1+r)$$

$$R^{\bar{\nu}} = \frac{1}{2} - S_W^2 + \frac{5}{9}S_W^4\left(1 + \frac{1}{r}\right)$$

Measure $R^{\nu}, R^{\bar{\nu}}, r \Rightarrow$ 2 relations

$\Rightarrow$ test theory and determine S_W^2

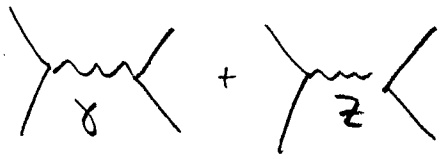
PLOT 48



$e^+e^- \to \mu^+\mu^-$ including the Z (problem set 4)

w/o Z: $\frac{d\sigma}{d\cos\theta} \sim (1+\cos^2\theta)$

w. Z: asymmetric in $\cos\theta$ $\Rightarrow$ forward-backward asymmetry.

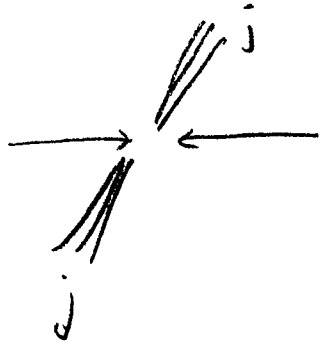
linear in $\cos\theta$ term:  interference

$e^+e^- \to q\bar{q}$: same diagrams

best for d, s, b

- $J_{EM} \sim 1/3$
- $J_Z^L \sim \boxed{-\frac{1}{2}} - \sin^2\theta_W(-1/3)$ ← "big" LR asymmetry
- $J_Z^R \sim -1/3 \sin^2\theta_W$

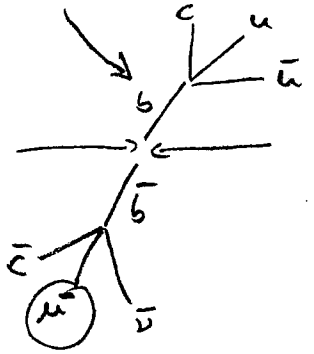
but it's $e^+e^- \to j\bar{j}$



jet charge not good observable.

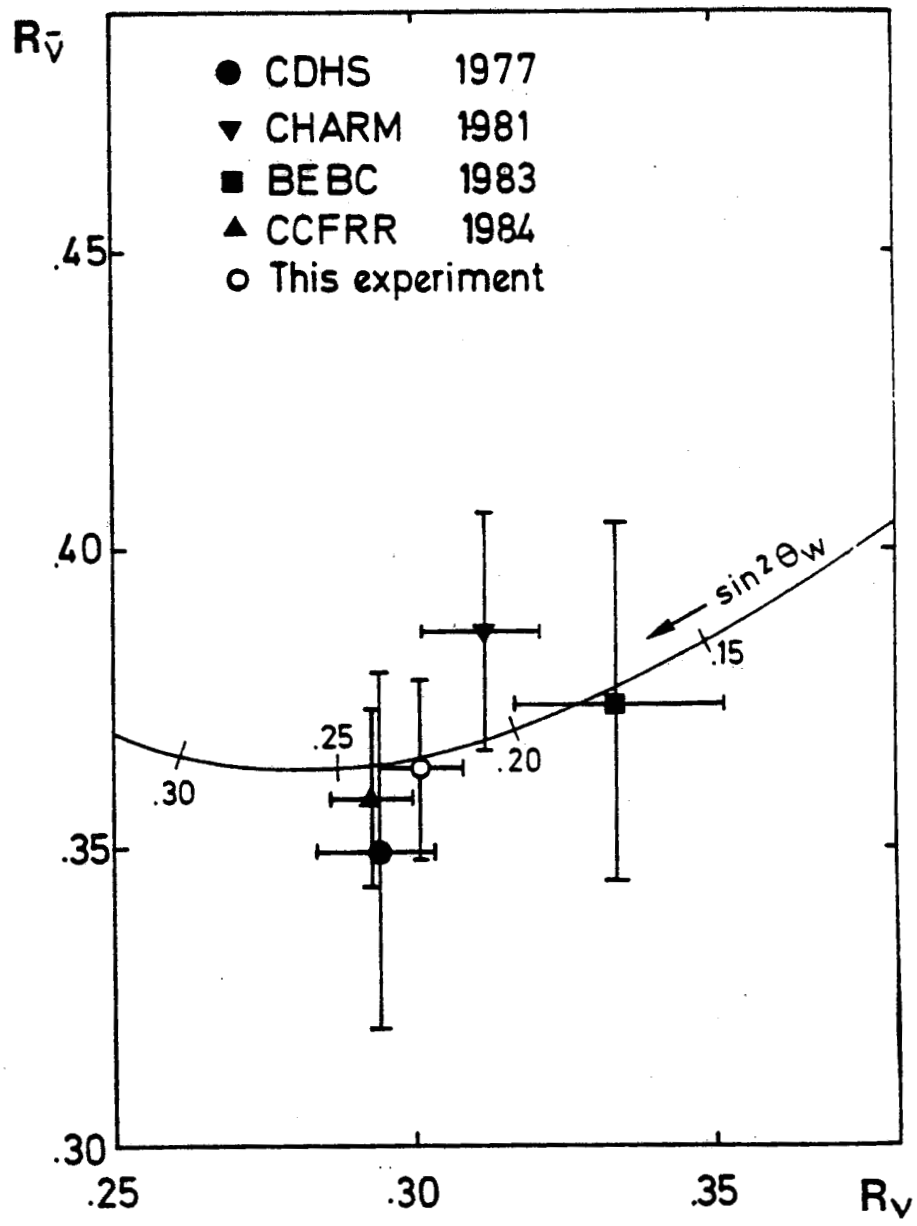
for b quarks: b-tagging via <u>displaced vertex</u>

$\tau_b \sim 1\,ps \cdot 3 \cdot 10^8 \frac{m}{s} \approx 0.3\,mm$ measurable!

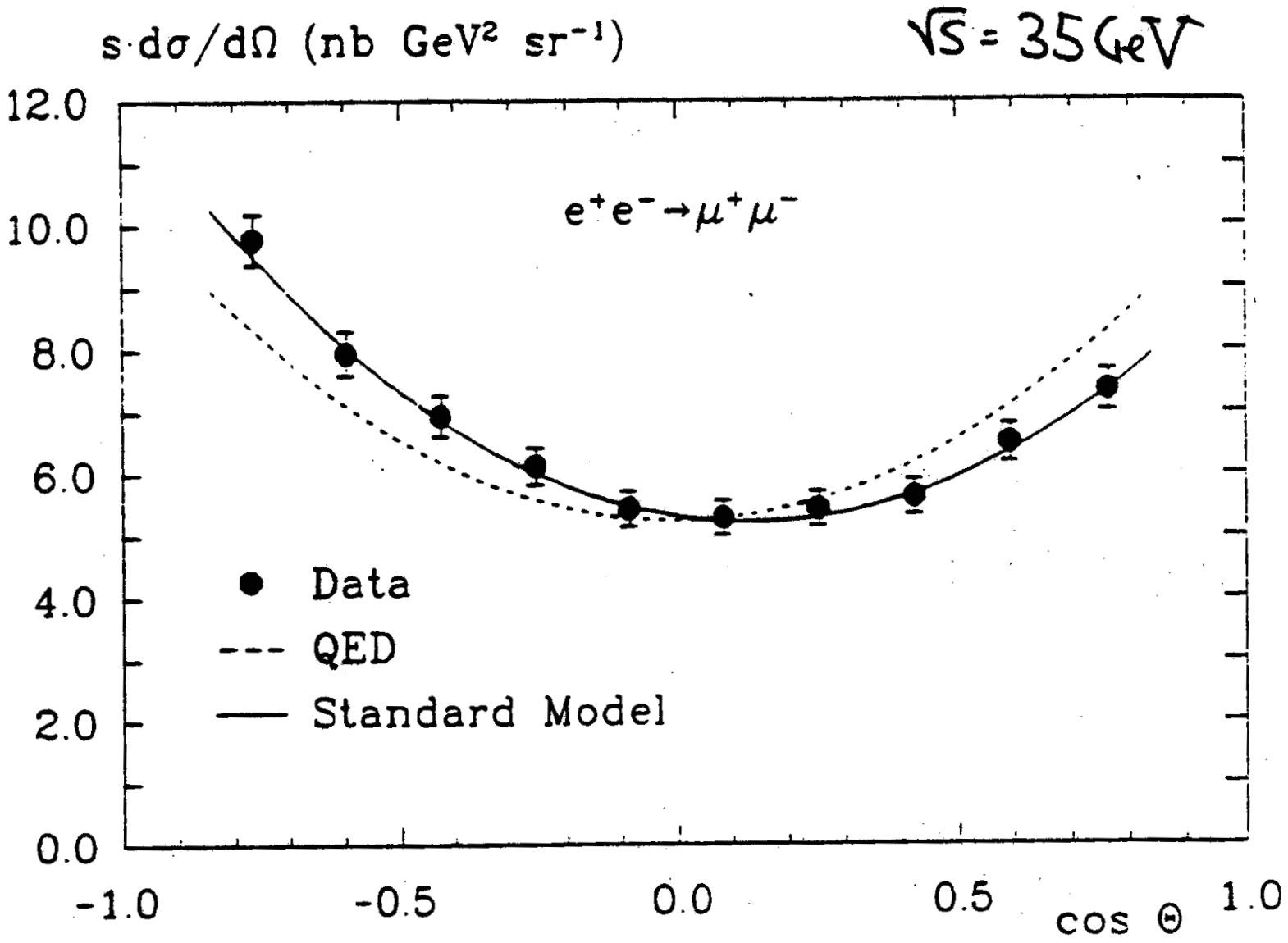


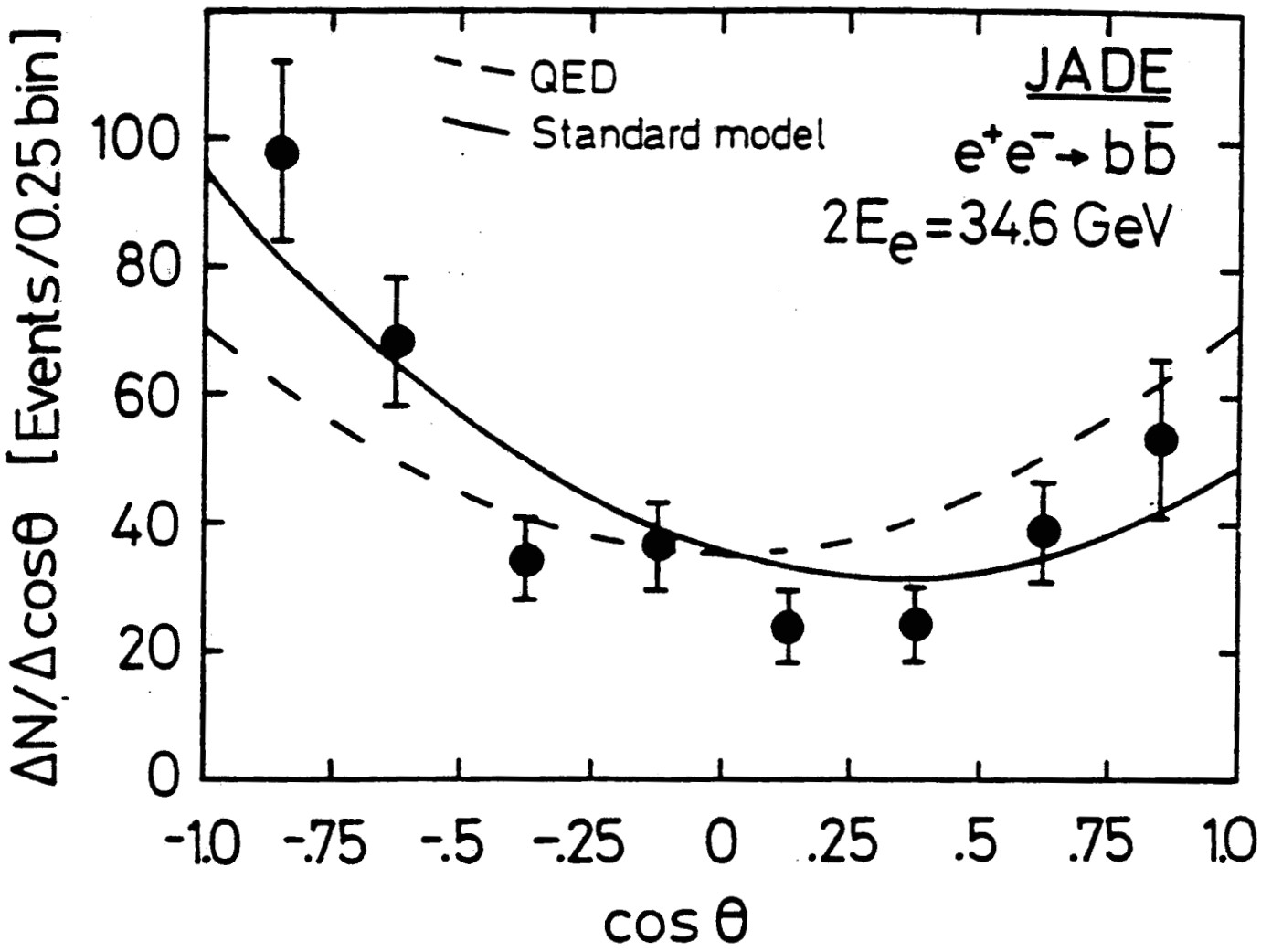
tags the b charge

PLOT 52



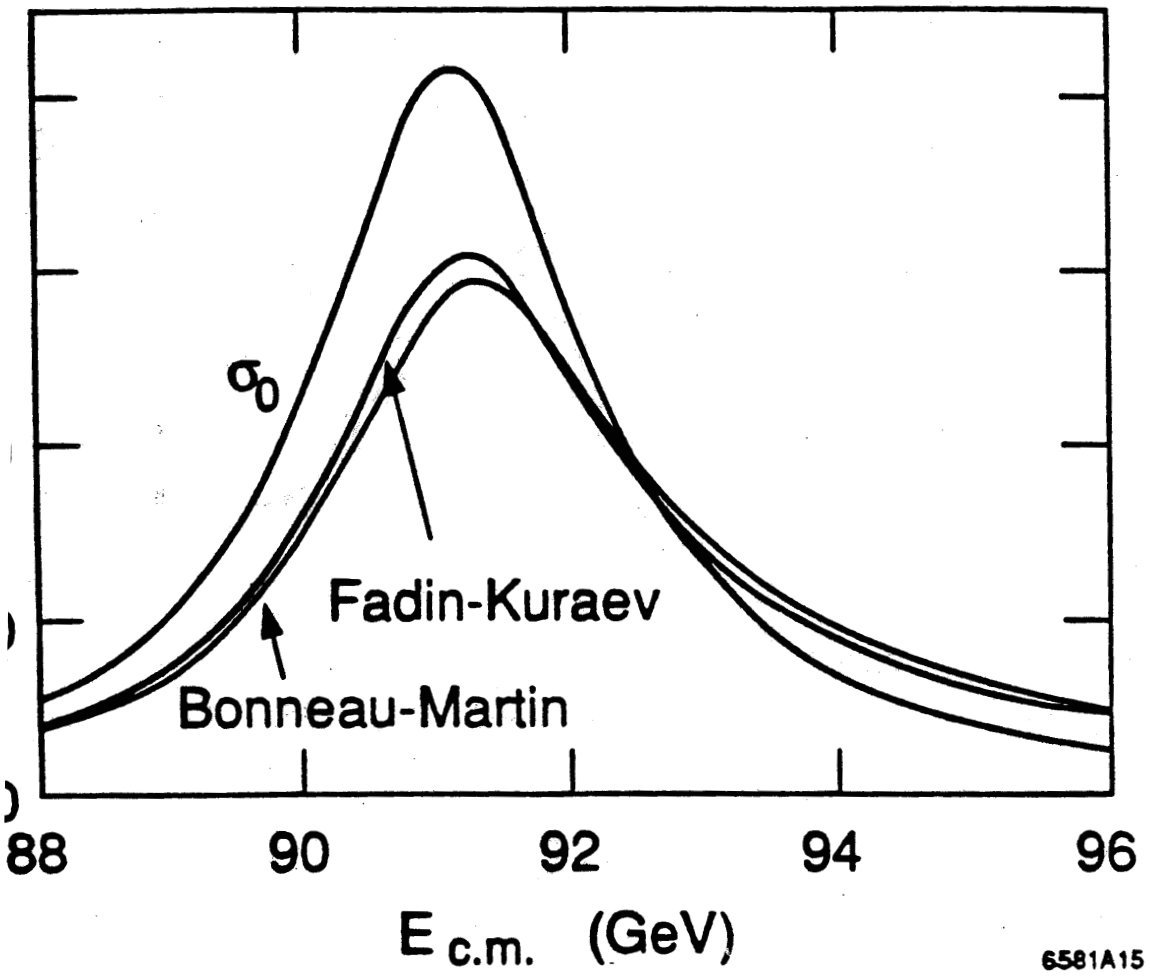
H. Abramowicz et al (CDHS)
Z Phys. C 28 51 (1985)


s·dσ/dΩ (nb GeV² sr⁻¹)
√s = 35 GeV
e⁺e⁻→μ⁺μ⁻
Data
QED
Standard Model
12.0
10.0
8.0
6.0
4.0
2.0
0.0
-1.0
-0.5
0.0
0.5
1.0
cos Θ



W. Bartel et al. (JADE)
Phys. Lett. 146B, 437 (1984)

Radiative Return



Z width, number of neutrinos