Electroweak Observables at SuperB

Oscar Vives

XVII SuperB meeting.

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SuperB Neutral Current Polarisation Physics: Studies with ZFitter &tc

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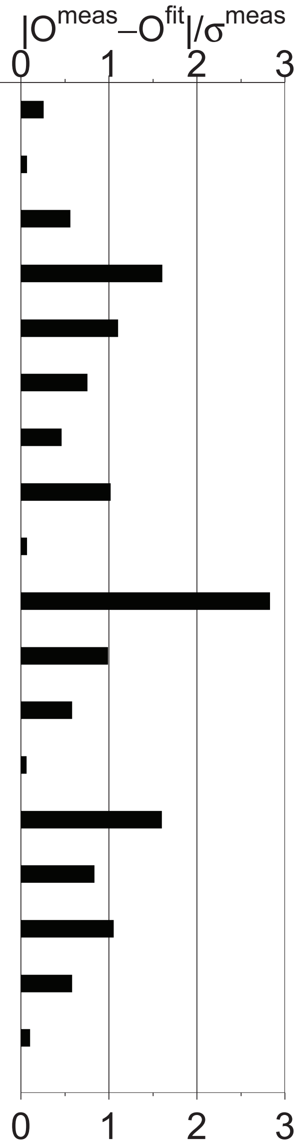
Frascati

Progress and Update . . .

Why Electroweak Measurements at SuperB ??

LEP/SLC SM fit

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21562
R_c	0.1721 ± 0.0030	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.389
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.5



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$$0.0992 \pm 0.0016 \qquad \begin{array}{c} -0.3220 \pm 0.0077 \\ -0.5144 \pm 0.0051 \end{array} \qquad 0.281 \pm 0.016$$

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$$0.01714 \pm 0.00095 \qquad \begin{array}{c} -0.03783 \pm 0.00041 \\ -0.50123 \pm 0.00026 \end{array} \qquad 0.23128 \pm 0.00019$$

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$$\sin^2\theta_{eff}^{b,fit} = 0.23293\pm^{0.00031}_{0.00025},$$

$$\sin^2\theta_{eff}^{l,fit} = 0.23149 \ \pm \ 0.00016.$$

EW AT SUPERB

1.- Inconsistency associated with NC-couplings, g_V^b and g_V^l (in *SM*, $\sin^2 \theta_{eff}^f$).
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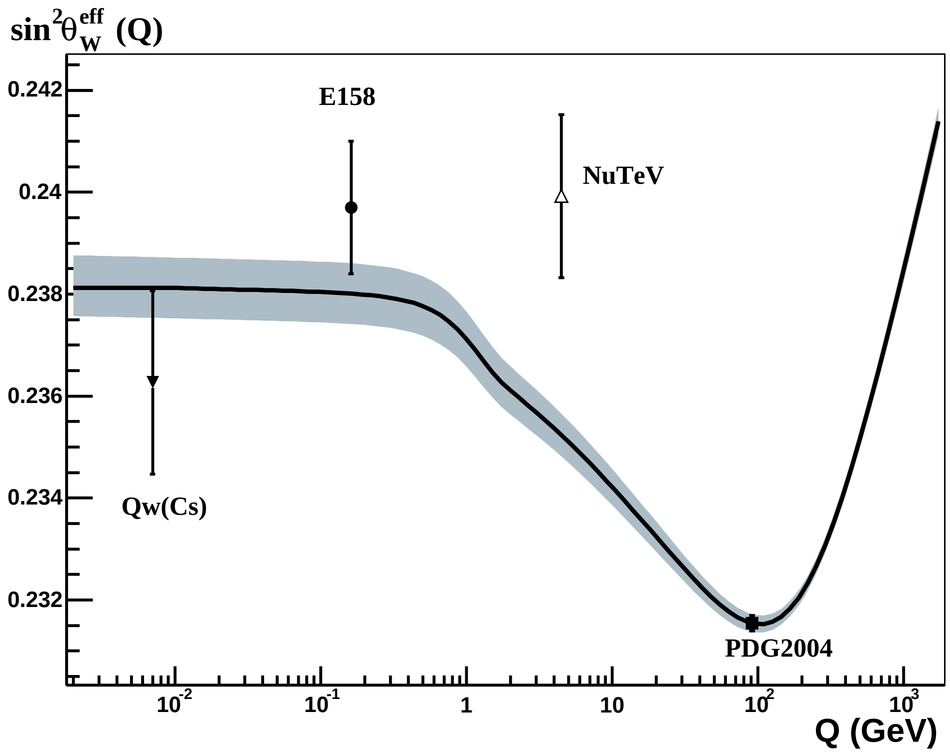

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γ-Z interference effects

Subdominant corrections to electromagnetic contributions.

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C-odd

Forward-Backward asymmetry, A_{FB}, is P-even and C-odd.
On the Z-pole:

$$A_{FB}(M_Z) = \frac{g_V^e g_A^e g_V^f g_A^f}{((g_V^e)^2 + (g_A^e)^2)\left((g_V^f)^2 + (g_A^f)^2\right)}$$

C-odd

But, at 10 GeV:

$$A_{FB}(M_Z) = \frac{3\, G_F\, s}{4\sqrt{2}\pi\alpha}\, \frac{g_A^e g_A^f}{Q_f}$$

$\Rightarrow$ **At SuperB, vector couplings dominated by γ**
only axial couplings . . . , no information on $\sin^2\theta_W$

P-odd

Product $g^e_{A,V}\; g^f_{V,A}$. Two options:

Unpolarized beams	Polarized electron beam
Only τ-polarization	Left-Right asymmetry
	both for leptons and B-mesons

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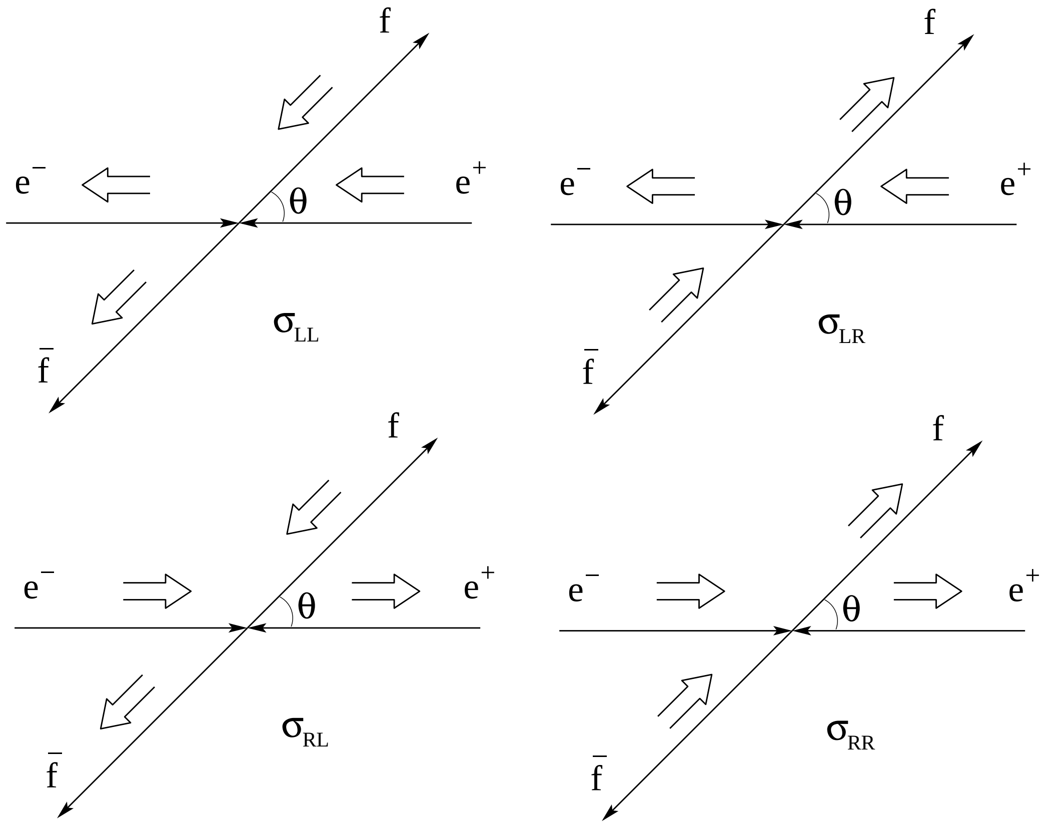

with,

$$\sigma_{LL} \propto (g_L^e)^2 (g_L^f)^2,$$

$$\sigma_{RL} \propto (g_L^e)^2 (g_R^f)^2,$$

$$\sigma_{RL} \propto (g_R^e)^2 (g_L^f)^2,$$

$$\sigma_{RR} \propto (g_R^e)^2 (g_R^f)^2$$

Conservation of angular momentum

- Initial state: $|1,\pm1\rangle_{\hat{z}} = (0,0,\pm1)$.
- Final estate: eigenvalues of $s_\theta = s_x \sin\theta + s_z\cos\theta$

$$|1,-1\rangle_\theta = (\cos^2\tfrac{\theta}{2}, \tfrac{\sin\theta}{\sqrt{2}}, \sin^2\tfrac{\theta}{2}) \qquad |1,+1\rangle_\theta = (\sin^2\tfrac{\theta}{2}, -\tfrac{\sin\theta}{\sqrt{2}}, \cos^2\tfrac{\theta}{2})$$

$$\begin{aligned}
\frac{d\sigma_{LL}}{d\cos\theta} &\propto \left| g_L^e g_L^f \; {}_{\hat{z}}\langle 1,-1|1,-1\rangle_\theta \right|^2 \propto (g_L^e)^2 (g_L^f)^2 \;\; (1+\cos\theta)^2 \\
\frac{d\sigma_{LR}}{d\cos\theta} &\propto \left| g_L^e g_R^f \; {}_{\hat{z}}\langle 1,-1|1,\;\;1\rangle_\theta \right|^2 \propto (g_L^e)^2 (g_R^f)^2 \;\; (1-\cos\theta)^2 \\
\frac{d\sigma_{RR}}{d\cos\theta} &\propto \left| g_R^e g_R^f \; {}_{\hat{z}}\langle 1,\;\;1|1,\;\;1\rangle_\theta \right|^2 \propto (g_R^e)^2 (g_R^f)^2 \;\; (1+\cos\theta)^2 \\
\frac{d\sigma_{RL}}{d\cos\theta} &\propto \left| g_R^e g_L^f \; {}_{\hat{z}}\langle 1,\;\;1|1,-1\rangle_\theta \right|^2 \propto (g_R^e)^2 (g_L^f)^2 \;\; (1-\cos\theta)^2
\end{aligned}$$

therefore, the total cross section

$$\frac{d\sigma}{d\cos\theta} \propto (1+\cos^2\theta)\left((g_V^e)^2 + (g_A^e)^2\right)\left((g_V^f)^2 + (g_A^f)^2\right) + 4\;\cos\theta\left(g_V^e g_A^e g_V^f g_A^f\right)$$

Forward-Backward asymmetry

Only possible in leptonic pair production. Not present in $B\overline{B}$:

$$A^0_{FB} = \frac{\sigma(\cos\theta > 0) - \sigma(\cos\theta < 0)}{\sigma(\cos\theta > 0) + \sigma(\cos\theta < 0)}$$
$$= -\frac{6}{\sqrt{2}}\,(\frac{G_F s}{4\pi\alpha})\,(\frac{|\vec{p}|p^0}{2(p^0)^2 + m_l^2})\; g_A^e g_A^l\; \frac{\mathrm{Re}\{1 + Q_b^2\Upsilon(s)\}}{|1 + Q_b^2\Upsilon(s)|^2}\,.$$

Pure photonic loop corrections also contribute to A_{FB}, (no γ-Z interference).

$$A_{FB} = \frac{A^0_{FB} - 4.5\,\alpha/\pi}{1 - 8\,g_V^e\,\chi\,\mathrm{Re}\{\frac{g_V^l + g_V^b\,Q_b\Upsilon(s)}{1 + Q_b^2\Upsilon(s)}\}} \quad \text{with} \quad \chi = \frac{G_F}{\sqrt{2}}\,\frac{M_Z^2}{8\pi\alpha}\,\frac{s}{s - M_Z^2}\,,$$

LEFT-RIGHT ASYMMETRY

– With **polarized** electron beam of polarization P, the total cross section to fermion pairs,

$$\sigma(P) \quad = \quad \sigma(P=0)[1 \ + \ \frac{4}{\sqrt{2}} \, (\frac{G_F q^2}{4\pi\alpha}) \, (\frac{g_A^e g_V^f}{Q_f}) \ P] \, .$$

– Therefore, the integrated Left-Right asymmetry A_{LR}, for $B\overline{B}$ final states,

$$A_{LR}^b = \frac{\sigma(P) - \sigma(-P)}{\sigma(P) + \sigma(-P)} = \frac{4}{\sqrt{2}} \, (\frac{G_F q^2}{4\pi\alpha}) \, (\frac{g_A^e g_V^b}{Q_b}) \ P$$

$\Longrightarrow$ Sensitive to g_V^b (or g_V^l for A_{LR}^l) therefore to $\sin^2\theta_W$ in *SM*.

τ POLARIZATION

– $P_{z,x}$ is P-violating, thus sensitive to $g_V \cdot g_A$. In the presence of initial beam polarization, P_e, we have:

$$P_{z'}^{(-)}(\theta, P_e) = -\frac{8G_F\ s}{4\sqrt{2}\pi\alpha}\,\mathrm{Re}\{\frac{g_V^l - Q_b g_V^b \Upsilon(s)}{1+Q_b^2\Upsilon(s)}\} \times$$
$$\left(g_A^\tau \frac{|\vec{p}|}{p^0} + 2\ g_A^e \frac{\cos\theta}{1+\cos^2\theta}\right) + P_e \frac{\cos\theta}{1+\cos^2\theta}\ .$$

– Measurable through the angular distribution of decay products. In the $\tau \to \pi\nu_\tau$ channel, with $\hat{k}$ the pion direction:

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\Omega} = \frac{1}{4\pi}[1 + \vec{P}\cdot\hat{k}(\Omega)]$$

$\Rightarrow$

- Proportional to $g_V \cdot g_A$, if $P_e = 0$
- $P_e \neq 0$, additional handle on beam polarization.

Numerical analysis

– With 75 ab^{-1}, $\sim 10^{11}$ lepton and $\sim 10^{9}$ B–$\overline{B}$ pairs at SuperB

$$\Downarrow$$

$\boxed{\text{Only statistical error} \propto \frac{1}{\sqrt{N}}:}$

– Statistical errors in the different asymmetries:

$$\begin{aligned}
A^b_{LR} &= (0.03\ P\ g^b_V) \pm 3\times 10^{-5} &\Rightarrow&\quad \sim g^b_V\ (10.58\ \mathrm{GeV}) \pm 10^{-3}\\
A^l_{LR} &= (0.02\ P\ g^l_V)\ \pm 3\times 10^{-6} &\Rightarrow&\quad \sim g^l_V\ (10.58\ \mathrm{GeV}) \pm 10^{-4}\\
A_{FB} &= (0.015\ g^e_A g^l_A)\ \pm 3\times 10^{-6} &\Rightarrow&\quad \sim g^l_A\ (10.58\ \mathrm{GeV}) \pm 10^{-4}
\end{aligned}$$

$\Rightarrow$ In principle, competitive with **LEP** measurements at M_Z.

Conclusions

Electroweak measurements possible at **SuperB** with polarized beams.

$\Downarrow$

- In the absence of **beam polarization**, A_{FB} measures only axial couplings, g_A^f
- In the absence of **beam polarization**, only τ polarization can measure, g_V^l and g_V^b.
- With **polarized electron beam**, A_{LR} can measure g_V^l and g_V^b with high precision, at the level of **LEP** measurements.