LCWS '99 - Sitges

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A simple expression for $f\bar{f}$ production at 500 GeV

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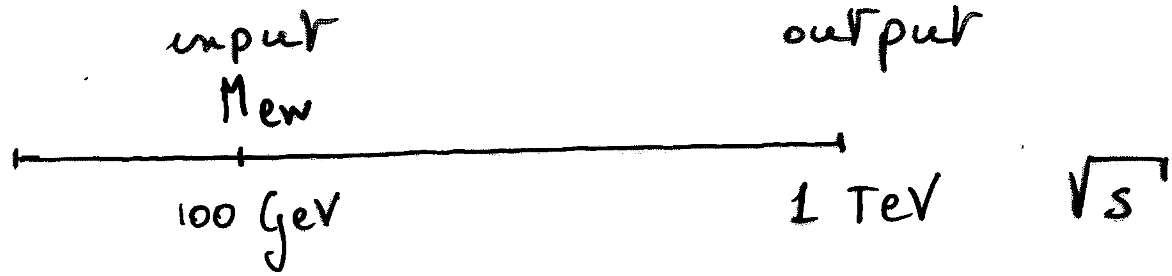
Are SM e.w. corrections to $\sigma(e^+e^- \to \mu^+\mu^-)$ at 1 TeV under control at the 1% level

1 loop "purely ew" effect.



Naïvely $\dfrac{\sigma^{1\,loop} - \sigma^{Born}}{\sigma^{Born}} \sim \underbrace{\dfrac{g^2}{16\pi^2}}_{\sim 2‰} \underbrace{\log\left(\dfrac{1\,TeV}{100\,GeV}\right)^2}_{\sim 5} \sim 1\,\%$

Expect 1% easily (RGE) resum.

Wrong !

$$\sigma^{1\,loop}(\sqrt{s}) \overset{\sqrt{s} \gg M_{ew}^2}{\simeq} \sigma^0 \left[1 + \frac{g^2}{16\pi^2} \left(\underbrace{c_1 L^2 + c_2 L}_{\sqrt{s}\text{ - growing}} + c_3 + \underbrace{\ldots}_{\to 0} \right) \right]$$

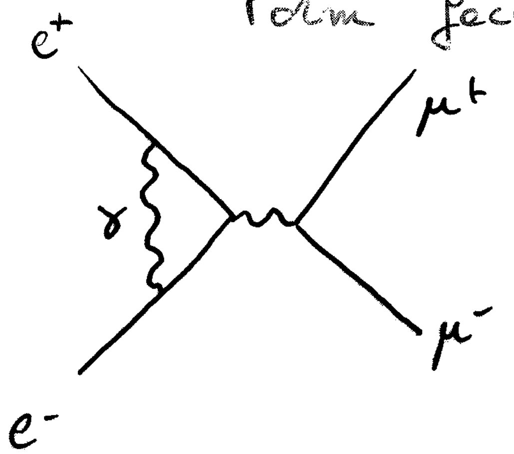
$$L = \log\left(\frac{s}{M_{ew}^2}\right)$$

- calculate c_1 and c_2; calculation is (relatively) easy to perform
- c_1, c_2 are (mainly) determined by IR (not UV) structure
- Typically $\dfrac{\Delta O}{O} \sim (5 \div 10)\%$ at $(0.5 \div 1)$ TeV

QED

V.V. Sudakov,
Sov. Phys JETP, 3 ('56)

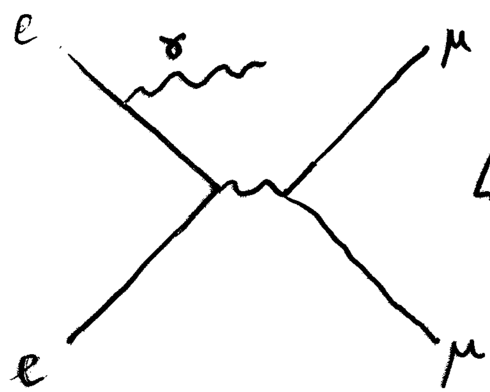
Form factor



$$\Delta\sigma_F \sim \sigma_0\Big(-\alpha\, \overbrace{\log\frac{s}{\lambda^2}}^{\text{IR}}\ \overbrace{\log\frac{s}{m^2}}^{\text{collinear}}\Big)$$

IR catastrophe

$\sqrt{s}$ = c.m. energy
m = electron mass
λ = photon mass



$$\Delta\sigma_B \sim \sigma_0\Big(+\alpha \log\frac{\Delta E^2}{\lambda^2}\log\frac{s}{m^2}\Big)$$

ΔE = resolution

$$\sigma_{TOT} \simeq \sigma_0\Big(1-\alpha\log\frac{s}{(\Delta E)^2}\ \log\frac{s}{m^2}\Big)$$

IR finite, double log!

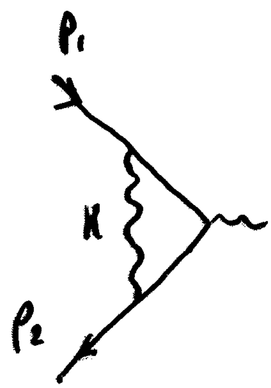
IR ~~divergences~~, factorization, exponentiation

Physical effects

QED : Z lineshape, ...

QCD : Altarelli-Parisi, ---

SM $(m_f = 0)$



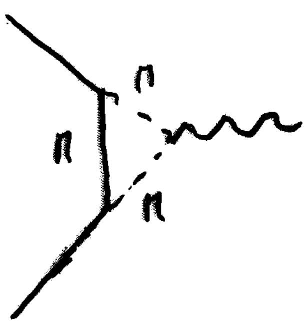
$$\xrightarrow[k\sim 0]{\text{IR}} \quad \underline{\underline{(p_1 \cdot p_2)}} \; V_0 \; \underbrace{\overbrace{\int \frac{d^4k}{(k^2 - M_W^2)(k^2 + 2kp_1)(k^2 + 2kp_2)}}^{C_0(s,\, M_W)}}$$

$$\sim \int \frac{d^4k}{k^2 (kp_1)(kp_2)} \qquad M_W : \text{cutoff}$$

$$C_0(s, M_W) \xrightarrow{s \gg M_W^2} \frac{1}{2s} \log^2 \frac{s}{M_W^2} \quad \Longrightarrow$$

$$\Longrightarrow \; V^{SM} \sim V_0 \, \alpha \, \log^2 \frac{s}{M_W^2}$$

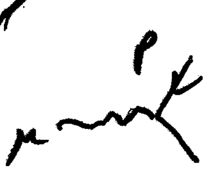
SUSY



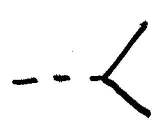
$$\xrightarrow[k\sim 0]{} \quad \underline{\underline{M^2}} \; V_0 \int \frac{d^4k}{(k^2 - M^2)((k+p_1)^2 - M^2)((k+p_2)^2 - M^2)}$$

$$\Longrightarrow V^{SUSY} \sim V_0 \, \alpha \, \boxed{\frac{M^2}{s}} \, \log^2 \frac{s}{M^2}$$

suppressed !

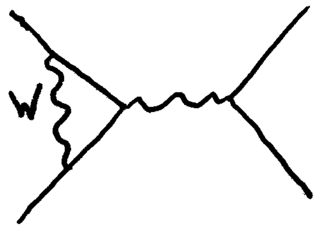
 $\sim p_R^{\mu}$

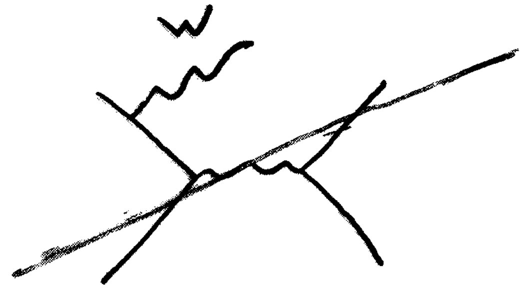
E-growing

 $\sim M$

SM corrections are asymptotically dominant

E. W. corrections





$M_W \neq 0$

W detected

$\Delta\sigma \sim \sigma_0 \, \alpha \, \log^2 \frac{s}{M_W^2}$ (Kurode et al, NPB350, 25)

$\frac{s}{M_W^2} \gg 1$

Asymptotic behavior given by IR (no UV) structure

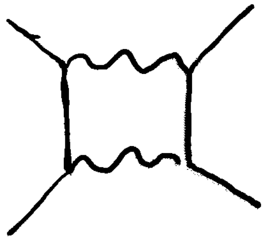
Consider $\sqrt{s} \sim 10\, M_W \sim 800$ GeV ("NLC region")

100

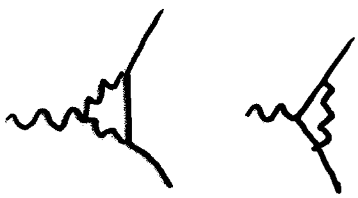
$\frac{\alpha}{4\pi s_W^2} \log^2 \frac{s}{M_W^2} \simeq 5\,\%$

~ 2 ‰ (LEP)

- When (if) do d.ls become dominant
- Is resummation needed @ NLCs (observable dep.)?
- understand asymptotical behavior
- New Physics $\leftrightarrow$ SM ?



$\Rightarrow \left(L^{IR}\right)^2, \; L^{IR}$



$\Rightarrow \left(L^{IR}\right)^2, L^{IR}, L^{UV}$

Asymtotically dominant

$\Rightarrow \; L^{UV}$

$$L^{IR} = L^{UV} = \log\left(s/M_{ew}^2\right)$$

c_1, c_2 calculated for observables. Example:

$$A_{FB}^{\mu} \simeq A_{FB}^{Born}\left[1 + \frac{\alpha_w}{4\pi}\left(-2.1\, L^{UV} + 5.6\, L^{IR} - 0.04\left(L^{IR}\right)^2\right)\right]$$

$$\frac{\alpha_w}{4\pi} = \frac{g^2}{16\pi^2} \simeq 2.5 \quad 10^{-3}$$

When $s \gg M_{ew}^2$ $\quad (L = \log s/M^2)$:

$$\frac{\Delta\sigma^\mu}{\sigma^\mu} \to \frac{\alpha_w}{4\pi}\left[\,0.6 \quad L^{UV} + 9.38 \; L^{IR} - 1.4 \; L^2\,\right]$$

$$\frac{\Delta\sigma^d}{\sigma^d} \to \frac{\alpha_w}{4\pi}\left[-4.8 \; L^{UV} + 20 \; L^{IR} - 2.2 \, L^2\right]$$

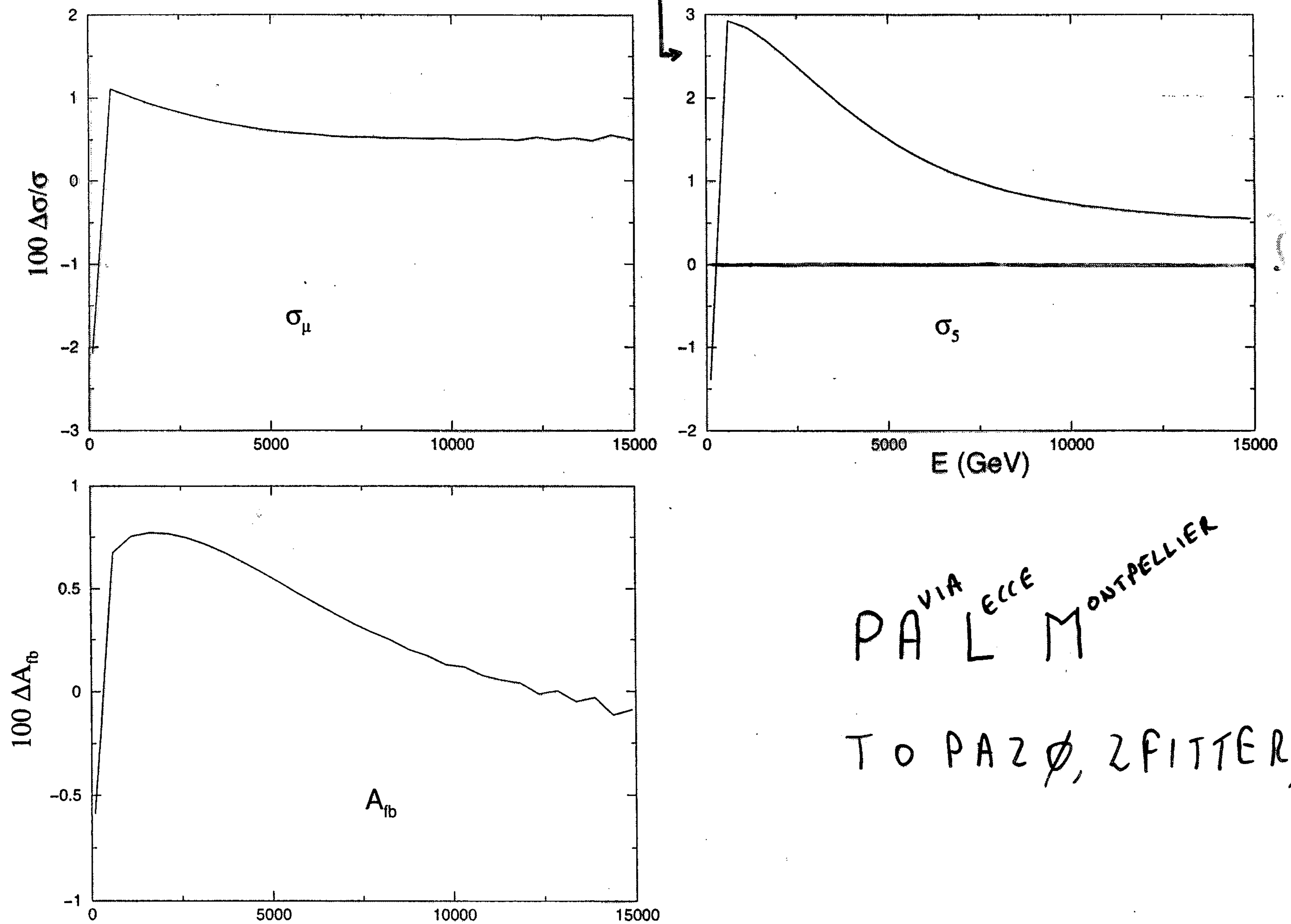
$$\frac{\Delta\sigma^u}{\sigma^u} \to \frac{\alpha_w}{4\pi}\left[-1.5 \; L^{UV} + 6.1 \; L^{IR} - 1.7 \, L^2\right]$$

$$\frac{\Delta\sigma^\mu}{\sigma^\mu}(200\,\text{GeV}) \sim 3.3\,\% \;\Big(\underset{IR}{0.9} + \underset{UV}{0.1}\Big)$$

$$\frac{\Delta\sigma_\mu}{\sigma_\mu}(600\,\text{GeV}) \sim 4.5\,\% \;\Big(\underset{IR}{0.9} + \underset{UV}{0.1}\Big)$$

$$\frac{\Delta O}{O}\,(0.5 \div 1 \;\text{TeV}) \sim (5 \div 10)\,\% \;\Big(\underset{IR}{0.6 \div 0.9} + \underset{UV}{0.1 \div 0.4}\Big)$$

$100\ (\sigma^{num} - \sigma^{en}) / \sigma^{BORN}$



~ 0.6

PA^VIA L^ECCE M^ONTPELLIER

TO PAZØ, ZFITTER, ...

Conclusions

- "pure ew" corrections are asymptotically described by simple formulas; coefficients of leading terms are calculated
- corrections are "big" in the TeV range and dominated by IR structure

Future / Problems

- numerical $\leftrightarrow$ analytical
- other processes
- Higher orders? Resummation? (at 1%)