QCD HIGHLIGHTS IN THE TESLA TDR

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On behalf of

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3.4 Quantum Chromodynamics

3.4.1 Introduction

Strong-interaction measurements at TESLA will form an important component of the physics programme. The collider offers the possibility of testing QCD at high energy scales in the experimentally clean, theoretically tractable e^+e^- environment. In addition, $\gamma\gamma$ interactions will be delivered free by Nature, and a dedicated $\gamma\gamma$ collider is an additional option, allowing detailed measurements of the relatively poorly understood photon structure. The benchmark physics main topics are:

- Precise determination of the strong coupling α_s.
- Measurement of the Q^2 evolution of α_s and constraints on the GUT scale.
- Measurement of the total $\gamma\gamma$ cross section and the photon structure function.

3.4.2 Precise determination of α_s

3.4.2.1 Event Shape Observables

3.4.2.2 The $t\bar{t}$ System

3.4.2.3 A High-luminosity Run at the Z^0 Resonance

3.4.2.1 Event Shape Observables

Introduction

Detector systematic errors

Event selection and backgrounds

Hadronisation uncertainties

Theoretical uncertainties

LINEAR COLLIDER $\alpha_s(M_Z^2)$ MEASUREMENT

EVENT SHAPE OBSERVABLES

- **Studied at Snowmass 96 (Burrows *et al.*, SLAC-PUB-7371)**

- **ECFA/DESY Workshop: O. Biebel**

  N. America: B. Schumm *et al.*

- **Statistics:**

  $\geq$ 50k $q\bar{q}$ events $\Rightarrow$ $\Delta\alpha_s \leq 0.001$

- **Detector systematics:**

  currently $\Delta\alpha_s \sim 0.002$

  Excellent tracking + calorimetry $\Rightarrow$ $\Delta\alpha_s \sim 0.001$

- **Hadronisation uncertainties $\sim 1/Q$**

  At $Q = 500$ GeV $\Rightarrow$ $\Delta\alpha_s < 0.001$

- **Limiting precision:**

  Higher-order pQCD contributions: $\Delta\alpha_s \sim 0.006$

  $\Rightarrow$ NNLO calculation needed - IN PROGRESS

3.4.2.2 The $t\bar{t}$ System

Introduction

$\sigma_{t\bar{t}}$ near threshold

$\sigma_{t\bar{t}}$ above threshold

$t\bar{t}g$ events

LINEAR COLLIDER α_s MEASUREMENT

TOP QUARK OBSERVABLES

- $\sigma_{t\bar{t}}$ **near threshold (Peralta** *et al.***)**

  new NNLO calculations $\Rightarrow$

  reduced correlation $\alpha_s \leftrightarrow M_t$ $\Delta\alpha_s = 0.002$ (?)

  THEORY UNCERTAINTY ± 0.012

- $\sigma_{t\bar{t}}$ **above threshold (Bernreuther)**

  PRELIMINARY study of NLO calculations

  $\sqrt{s} = 400$ **GeV:** $\Delta\alpha_s = 0.005$

  (theory limiting)

  $\sqrt{s} \geq 500$ **GeV:** $\Delta\alpha_s = 0.012$

  (exp. syst. limiting)

- $e^+e^- \rightarrow t\bar{t}g$ **(Brandenburg)**

3.4.2.3 A High-luminosity Run at the Z^0 Resonance

Introduction

$\Gamma_Z^{had}/\Gamma_Z^{lept}$

$\Gamma_\tau^{had}/\Gamma_\tau^{lept}$

En passant:

Running b mass

QCD colour factor measurement

Rich programme of 'all the rest'

LINEAR COLLIDER $\alpha_s(M_Z^2)$ MEASUREMENT

HIGH-STATISTICS RUN AT THE Z^0 RESONANCE

- **Z^0 decay widths: $\Gamma_Z^{had}/\Gamma_Z^{lept}$**

  calculated at NNLO

  current precision, 16M Z^0 at LEP: $\Delta\alpha_s = 0.003$

  1GZ^0 $\Rightarrow$ $\Delta\alpha_s = 0.0009$ (M. Winter)

  theoretically very safe

- **τ decay widths: $\Gamma_\tau^{had}/\Gamma_\tau^{lept}$**

  calculated at NNLO

  current exp. precision, LEP+CLEO: $\Delta\alpha_s = 0.001$

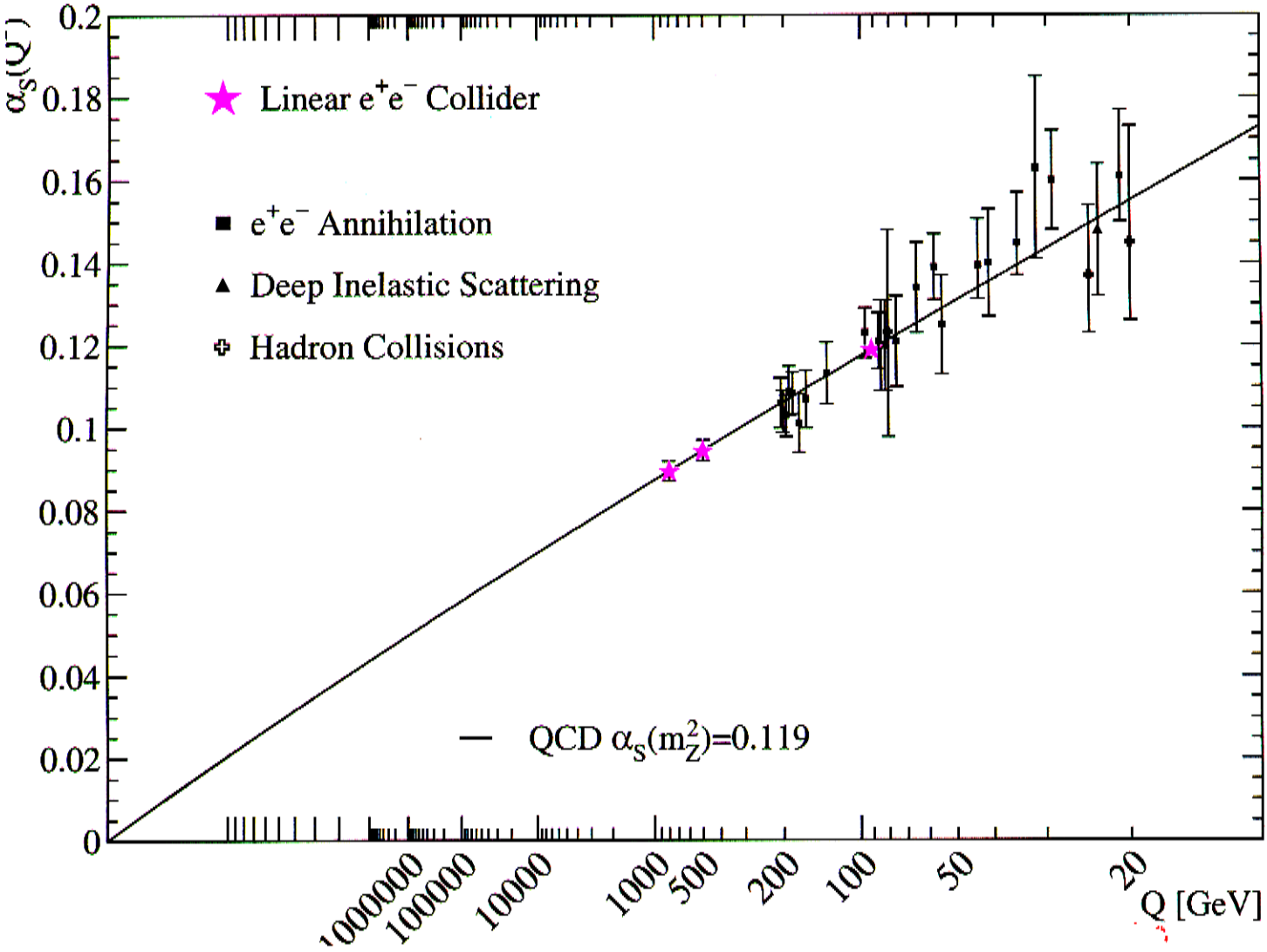
  theoretical uncertainties $\Rightarrow$ $\Delta\alpha_s = 0.001 \rightarrow 0.006$

3.4.2 Q^2 Evolution of α_s

Extrapolation to GUT scale

$\Rightarrow$ Low-energy data points at TESLA would be desirable

(New coloured particles)


$\alpha_s(Q^2)$
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Linear e^+e^- Collider
e^+e^- Annihilation
Deep Inelastic Scattering
Hadron Collisions
QCD $\alpha_s(m_Z^2)$=0.119
1000000
100000
10000
1000
500
200
100
50
20
Q [GeV]

OTHER IMPORTANT e^+e^- QCD TOPICS

- **Hard gluon radiation in $t\bar{t}$ events:**

  $\Rightarrow$ Test of flavour-independence of strong int.

  $\Rightarrow$ Limits on anomalous strong top-quark couplings

  $\Rightarrow$ Determination of running top mass

- **Soft gluon radiation in $t\bar{t}$ events:**

  $\Rightarrow$ Measurement of Γ_t

- **Polarisation-based asymmetries in $q\bar{q}g$ events:**

  $\vec{P}_e \cdot \vec{k_{q1}} \times \vec{k_{q2}}$ (CP+ T−)

  $\vec{P}_e \cdot \vec{k_q} \times \vec{k_{\bar{q}}}$ (CP− T−)

  $\Rightarrow$ Search for anomalous final-state interactions

- **Particle multiplicity in heavy- vs. light-quark jets**

  $\Rightarrow$ add long lever-arm to current tests

- **Colour reconnection and Bose-Einstein correls.**

- **Hadronisation studies and renormalon physics**