Physics backgrounds in the FCAL detectors at CLIC

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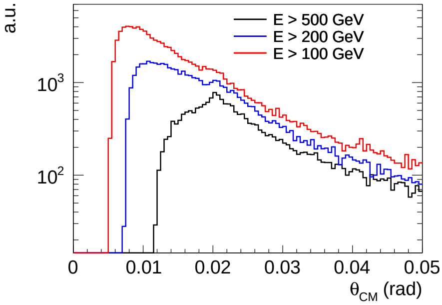
Introduction

Questions to be answered by this analysis

- Influence of single particles from coincident Bhabha events (and other processes) on the luminosity measurement
- 4f backgrounds in the luminosity measurement
- Rate of coincident Bhabha particles in the FCAL detectors and the electron tagging
- How important is the distinction of hadrons in the very forward region?
  - Is particle-type distinction in the FCAL detectors necessary for the luminosity measurement and electron tagging.

Most important processes emitting high-energy particles in the FCAL angular range

- Bhabha scattering
  - High cross section
  - Cross-section scales with 1/s and with θ^{-3}
    $\rightarrow$ Beamstrahlung **increases the total cross-section** for the Bhabha scattering and **boosts particle angles** of low-angle Bhabha events into the detector
- Four-fermion scattering
  - Main source of hadronic background
  - Can give a Bhabha-event-like signature



CM scattering angle of Bhabha particles detected above 20 mrad in the lab frame

Two ways in which these backgrounds affect measurements

- **Mimicking** the signal signature
  - Systematic uncertainty defined by the **ratio** σ_B/σ_S after event selection
- **Pile-up** with the signal or background
  - Events that occur very often may "add particles" to the analysed events and thus **change the apparent signature**
  - Systematic uncertainty defined by the **probability of occurence of a background event** in 1 timestamp (note: no dependence on the signal xs)

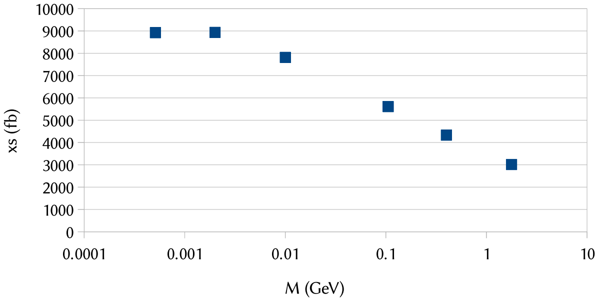
Analyses affected by high-energy particles at low angles

- Luminosity measurement
  - High precision required
  - Sensitive to both mimicking and pile-up backgrounds
- Electron tagging
  - Important for analyses with missing energy in the signal signature and backgrounds with spectator electrons
  - Sensitive to pile-up backgrounds
- Precise analyses with forward electrons in the signal final state

Cross-section calculations

Cross-section calculation of relevant processes

- WHIZARD 2.2 using luminosity files from Guinea-Pig and ISR in the collinear approximation. (No FSR)
- Bhabha xs uncertainties several % (comparison with BHWIDE)
- Four-fermion production:
  - Nontrivial effect of particle masses on the cross sections
  - Difficult convergence for $e^+e^-u\bar{u}$, $e^+e^-d\bar{d}$ and $e^+e^-e^+e^-$– Cross-check by scanning the mass-dependence of the xs
  - Uncertainties up to (at least) 20 % for individual 4f processes



Results

Luminosity measurement – 1.4 TeV CLIC

Process	cross-section (nb)	Rel. syst. unc. (uncorrected)
Signal	0.147	–
4f mimicking Bhabha – total	0.00122	8.3×10^{-3}
4f mimicking Bhabha – hadrons	2.0×10^{-5}	1.4×10^{-4}
Pile-up Bhabha evts / one side	0.35	0.019
Pile-up 4f	0.017	9.0×10^{-4}
Pile-up 4f (hadron detected)	0.0025	1.3×10^{-4}

- Lumi cut (one particle): E > 350 GeV, $43\,\text{mrad} < \theta < 80\,\text{mrad}$
- Lumi signature: Lumi cut + $E_{CM} > 1000\,\text{GeV}$ + 2-sides coincidence
- Pile up can be reduced by imposing an acoplanarity cut $\Delta\phi_{max}$. Reduction ratio approx. $2\Delta\phi_{max}/2\pi$

Luminosity measurement – 3 TeV CLIC

Process	cross-section (nb)	Rel. syst. unc. (uncorrected)
Signal	0.049	–
4f mimicking Bhabha – total	3.0×10^{-4}	6.1×10^{-3}
4f mimicking Bhabha – hadrons	6.4×10^{-6}	1.3×10^{-4}
Pile-up Bhabha evts / one side	0.072	5.4×10^{-3}
Pile-up 4f	0.0042	3.2×10^{-4}
Pile-up 4f (hadron detected)	9.5×10^{-4}	4.0×10^{-5}

- Lumi cut (one particle): E $>$ 800 GeV, $43\,\text{mrad} < \theta < 80\,\text{mrad}$
- Lumi signature: Lumi cut + $E_{CM} > 2200\,\text{GeV}$ + 2-sides coincidence
- Pile up can be reduced by imposing an acoplanarity cut $\Delta\phi_{max}$. Reduction ratio approx. $2\Delta\phi_{max}/2\pi$

Electron tagging – 1.4 TeV CLIC

Process	cross-section (nb)	Rel. syst. unc. (uncorrected)
Bhabha – tagging cut	1.30	0.068
4f – tagging cut	0.079	4.3×10^{-3}
4f – tagging cut hadrons only	0.015	7.9×10^{-4}

- Tagging cut (at least one particle):
  - $E > 200$ GeV,
  - $30\,\text{mrad} < \theta < 140\,\text{mrad}$

Electron tagging – 3 TeV CLIC

Process	cross-section (nb)	Rel. syst. unc. (uncorrected)
Bhabha – tagging cut	0.60	0.045
4f – tagging cut	0.037	2.8×10^{-3}
4f – tagging cut hadrons only	7.4×10^{-3}	5.6×10^{-4}

- Tagging cut (at least one particle):
  - $E > 500$ GeV,
  - $20\,\text{mrad} < \theta < 140\,\text{mrad}$

Electrons from piled-up Bhabha scattering in the MAIN detector

p_T cut (GeV)	xs 1.4 TeV (nb)	P_{hit} (1.4 TeV) %	xs 3 TeV (nb)	P_{hit} (3 TeV) %
5	0.212	1.14	0.144	1.09
10	0.152	0.82	0.102	0.78
20	0.103	0.56	0.063	0.48
50	0.055	0.30	0.028	0.22

- Cut (at least one particle):
  - $140\,\mathrm{mrad} < \theta < \pi - 140\,\mathrm{mrad}$,
  - $p_T > p_{T,cut}$

Conclusions and outlook

Conclusions

- Bhabha particles as background in electron tagging: Reduction of the statistics by several %.
- Bhabha particles as background in luminosity measurement:
  - 1.4 TeV CLIC: $\Delta N/N = -1.9$ %
  - 3.0 TeV CLIC: $\Delta N/N = -0.5$ %
  - Can be reduced one order of magnitude by the coplanarity criterion
- Four-fermion backgrounds in the luminosity measurement taking into account luminosity spectrum and the longitudinal event boost.
  - 1.4 TeV CLIC: $\sigma_{4f}/\sigma_{Bhabha} = 8.3 \times 10^{-3}$
  - 3.0 TeV CLIC: $\sigma_{4f}/\sigma_{Bhabha} = 6.1 \times 10^{-3}$
- Distinction of hadrons at low angles (in the FCAL or LHCAL detectors) is of little importance for the Luminosity measurement and electron tagging
- Precise measurements ($\delta\sigma/\sigma < 1\%$) should take into account electrons from piled-up Bhabha events in the main detector.

To be done

- Include FSR and tau decays – small increase in 4f cross sections expected due to muons and taus emitting FSR
- Detector simulation
- Apply selections to coincident backgrounds in luminosity measurement (coplanarity; pick the most energetic electron on each side)
- Review the status of the uncertainty of the luminosity measurement