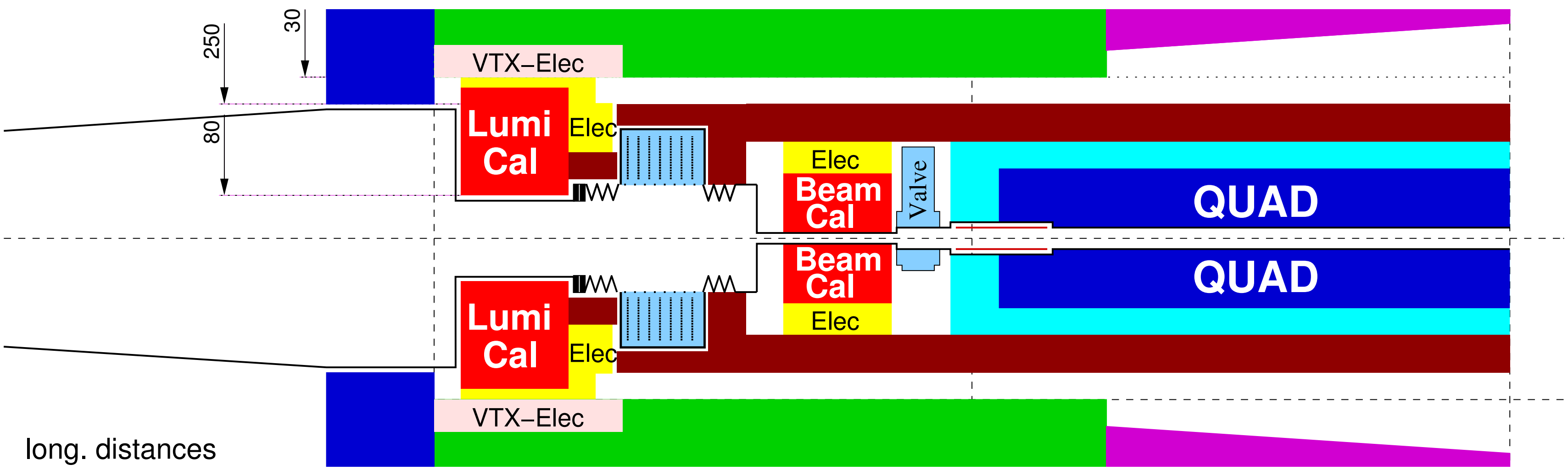
What Precision do we need on the Luminosity Measurement?

Klaus Mönig

Introduction

Forward region detectors serve two purposes:

- Hermeticity: Increase acceptance down to lowest possible angles. Mainly relevant for vetoing $\gamma\gamma$ induced $\mathrm{e}^+\mathrm{e}^- \rightarrow \mathrm{e}^+\mathrm{e}^- X$ events. Beamcal and Lumical are important $\rightarrow$ Philip Bambade's talk
- Precision luminosity measurement: Bhabha scattering in the forward region. Extremely good control of systematics required. Only Lumical is relevant.



Luminosity determination

Luminosity precision is determined by statistics of interesting processes

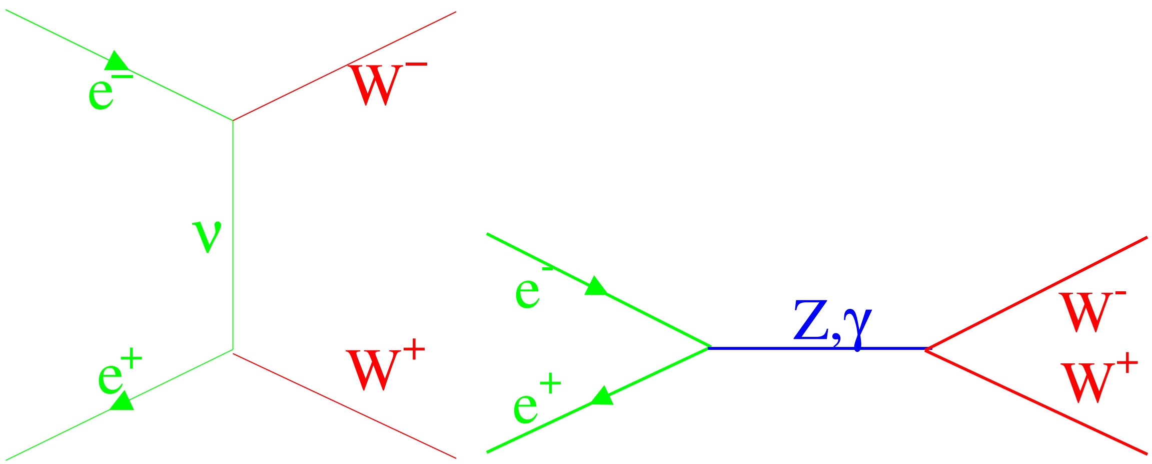
- $e^+e^- \to W^+W^-$: $\sim 10\,\mathrm{pb}$ at $\sqrt{s} = 340\,\mathrm{GeV}$ scaling with 1/s
  ➟ $\mathcal{O}(10^6)$ events ➟need 10^{-3} precision
- $e^+e^- \to f\bar{f}$: $\sim 5\,\mathrm{pb}$ at $\sqrt{s} = 340\,\mathrm{GeV}$ scaling with 1/s
  ➟ $\mathcal{O}(10^6)$ events ➟need 10^{-3} precision
- GigaZ: aim for 10^9 hadronic Z decays. Relevant physics quantities (except N_ν) need also leptonic decays (10% of hadronic decays)
  ➟ need 10^{-4} precision

Reached at LEP:

- cross section of lumi-monitor $> 60\,\mathrm{nb}$
  ($25\mathrm{mrad} < \theta < 60\mathrm{mrad}$) ($\to$ cross section also at ILC no problem)
- experimental error on $\mathcal{L}$: $\Delta\mathcal{L} = 0.03\%$
- theoretical error on $\mathcal{L}$: $\Delta\mathcal{L} = 0.05\%$ $\to$ being worked on

$e^+e^- \to W^+W^-$

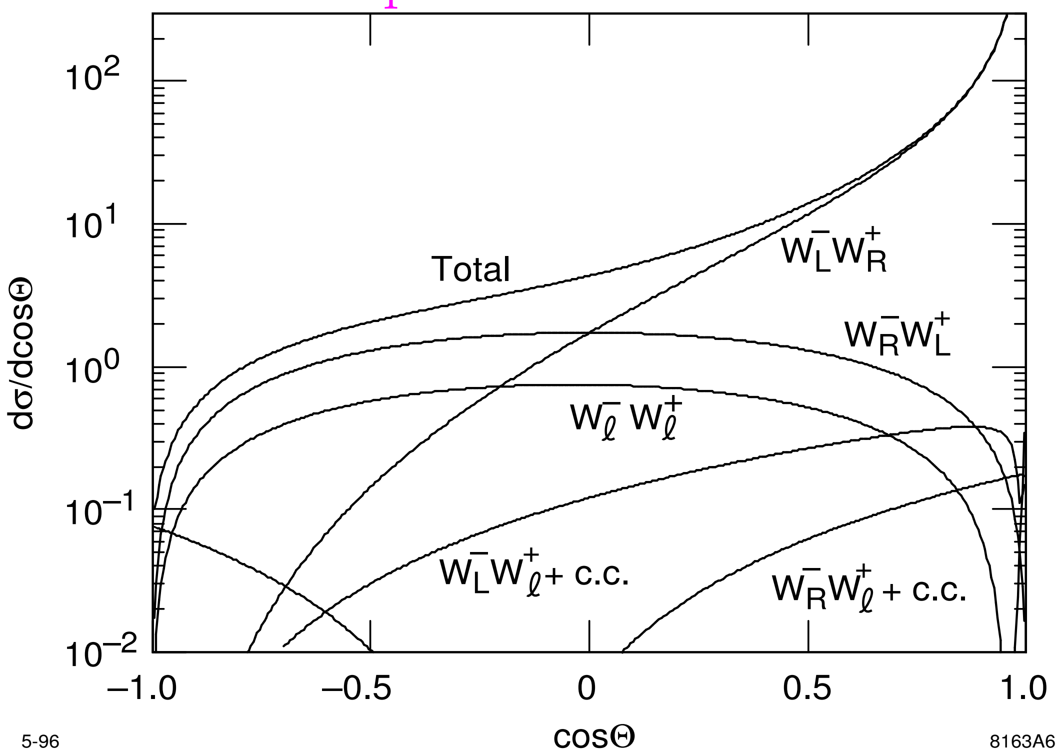
W-pair production from ν t-channel and Z,γ s-channel exchange



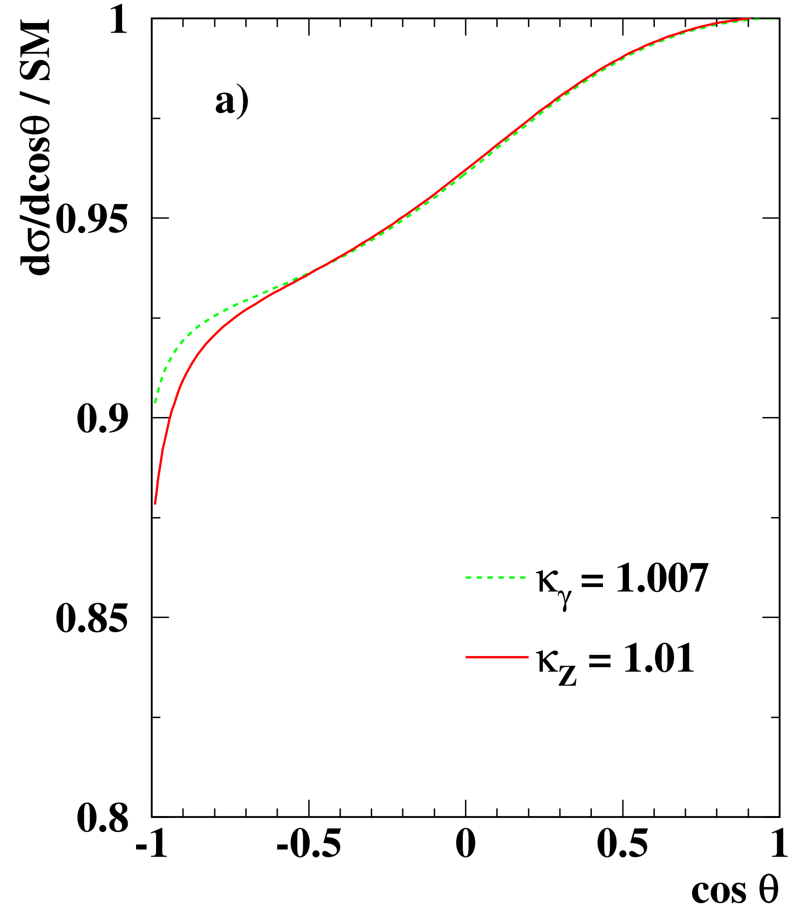
Cross section strongly forward peaked

However forward peak independent on anomalous couplings

Differential cross section for W-pair production



Ratio of anomalous TGC cross section to the SM



Normalisation in TGC fits can be obtained internally

Luminosity measurement only interesting for anomalous $e\nu W$ couplings

$\mathbf{e^+e^- \to f\bar{f}}$

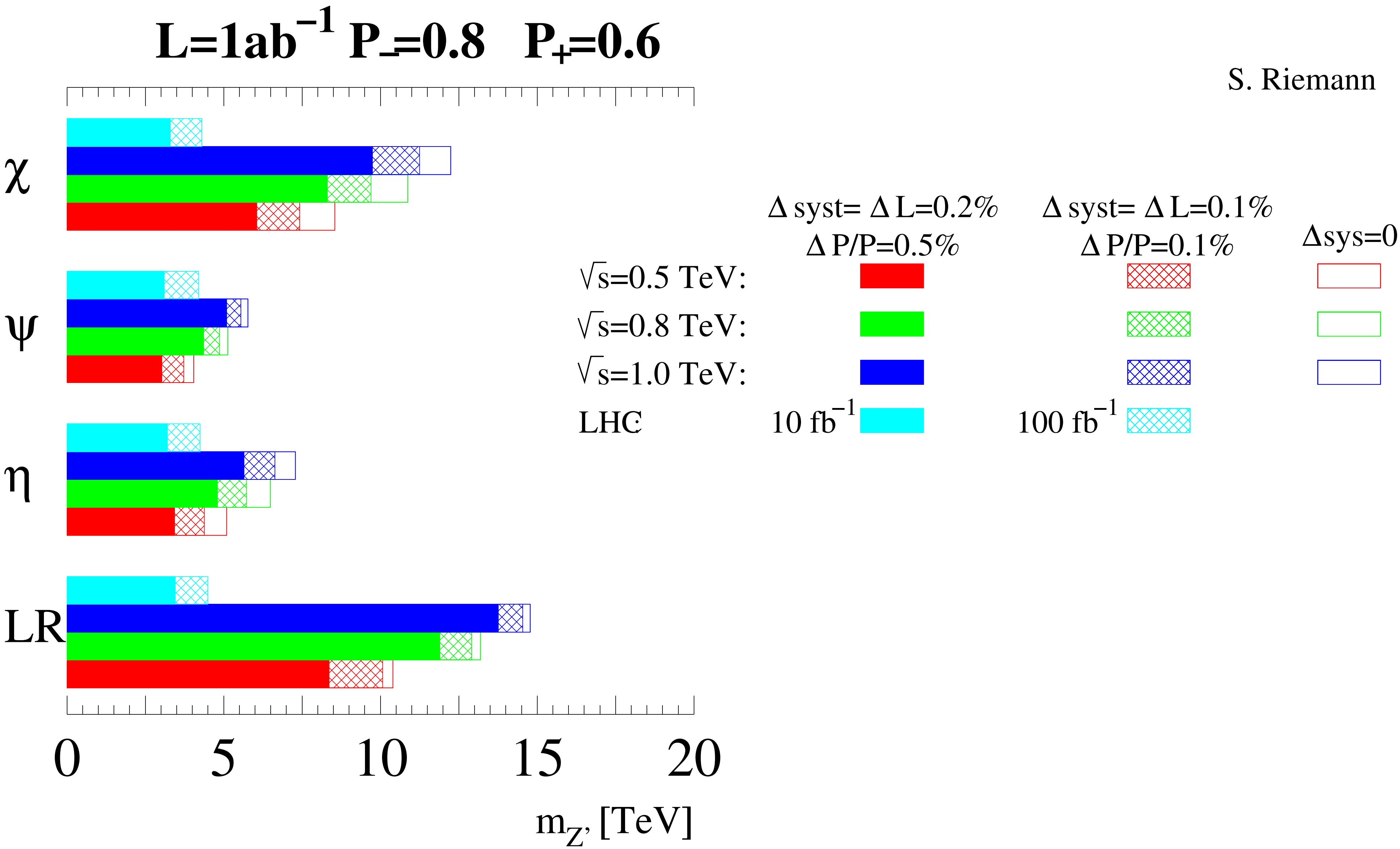
$e^+e^- \to f\bar{f}$ is sensitive to physics at very high scales (compositness, Z', extra space dimensions)

Sensitivity is mainly via interference with Standard Model amplitude
➠ $\propto 1/M^2$

All observables (cross section, left-right asymmetry, forward-backward asymmetry) are important

Systematic errors (e.g. luminosity) effect results significantly

Z' limits in different models



GigaZ

GigaZ = 10^9 Z at $\sqrt{s} \approx m_{\rm Z}$

Main aim: $\sin^2\theta^l_{eff}$ determination ➠ no $\mathcal{L}$ dependence

Important additional information from “lineshape” parameters $\Gamma_{\rm Z}$, $\sigma_0^{\rm had}$, R_l

Interesting information is obtained from combination of these parameters:

$$\sigma_0^{\rm had} = \frac{12\pi}{m_Z}\frac{\Gamma_e\Gamma_{\rm had}}{\Gamma_Z^2}$$

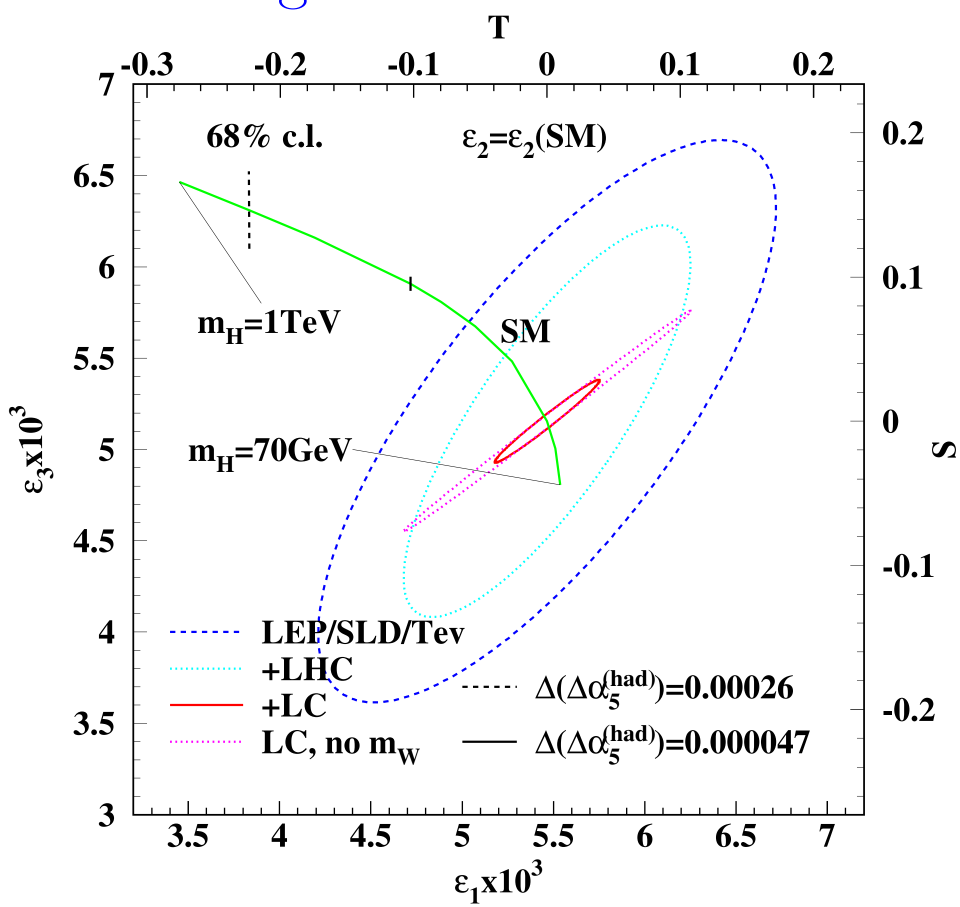
$$R_l = \frac{\Gamma_{\rm had}}{\Gamma_l}$$

$\Rightarrow$ need all parameters with about the same accuracy

- Γ_Z: difficult to estimate (beam energy, beamstrahlung, beamspread) but $\Delta\Gamma_Z = 1\,\text{MeV}$ ($\Delta\Gamma_Z/\Gamma_Z = 4\cdot 10^{-4}$) seems realistic
- R_l: $\Delta R_l/R_l = 10^{-4}$ from lepton statistics

➡ need lumi error (exp+theo) $\Delta\mathcal{L}/\mathcal{L} \sim 2\cdot 10^{-4}$

Gain of GigaZ:



- small axis: $\sin^2\theta^l_{eff}$
  $\Rightarrow$ no luminosity dependence
- large axis: m_W if $\varepsilon_2 = U = SM$, otherwise Γ_l
  $\Rightarrow$ luminosity precision essential

Important in interpretations outside SM!

Conclusions

At ILC a precise luminosity determination is needed

- $\sim 0.1\%$ at the high energy

- 10^{-4} should be aimed for at GigaZ