Issues on Z-pole calibration

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Introduction

- The detectors need calibration data on the Z
- In the push-pull solution it is discussed to have Z calibration data after each detector swap
- The envisaged luminosity is $\mathcal{L} \sim 7 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$

➠ This corresponds to $1.8 \cdot 10^6$ hadronic Z-decays per day (3 times SLD statistics!)

- If beam polarisation and polarimetry are available this can nicely be used for an A_{LR} measurement.

  Reminder

$$\sin^2\theta^l_{eff}(\mathrm{SLD}) = 0.23098 \pm 0.00026$$
$$\sin^2\theta^l_{eff}(\mathrm{LEP+SLD}) = 0.23153 \pm 0.00016$$

Possible precision

$\sigma = \sigma_0(1 - \mathcal{P}_{e^+}\mathcal{P}_{e^-} + (\mathcal{P}_{e^+} - \mathcal{P}_{e^-})A_{\rm LR})$

$$A_{\rm LR} = \frac{A_{\rm LR}(meas)}{\mathcal{P}} \Rightarrow \Delta A_{\rm LR}(stat) = \frac{1}{\sqrt{N}\mathcal{P}}, \; \frac{\Delta A_{\rm LR}}{A_{\rm LR}} = \frac{\Delta \mathcal{P}}{\mathcal{P}}$$

Electron polarisation only ($\mathcal{P}_{e^-} = 80\%$):

- $\Delta \mathcal{P}_{e^-}/\mathcal{P}_{e^-} = 0.25\% \Rightarrow \Delta A_{\rm LR} = 0.000375 \longrightarrow \Delta \sin^2 \theta^l_{eff} = 0.000047$
  Factor 5 to SLD, factor 3 to LEP+SLD
- needs 11MZ to match (6 days)

Also positron polarisation ($\mathcal{P}_{e^+} = 30\%$):

- $\mathcal{P}_{\rm eff} = 0.89$, $\Delta \mathcal{P}_{\rm eff}/\mathcal{P}_{\rm eff} = 0.54 \Delta \mathcal{P}_{e^\pm}$, 24% cross section increase for J=1 (count "effective" Z)
- $\Rightarrow \Delta A_{\rm LR} = 0.00020 \longrightarrow \Delta \sin^2 \theta^l_{eff} = 0.000025$
  Factor 10 to SLD, factor 6 to LEP+SLD
- needs 25M "effective" Z to match (14 days)

Blondel scheme for calibration data?

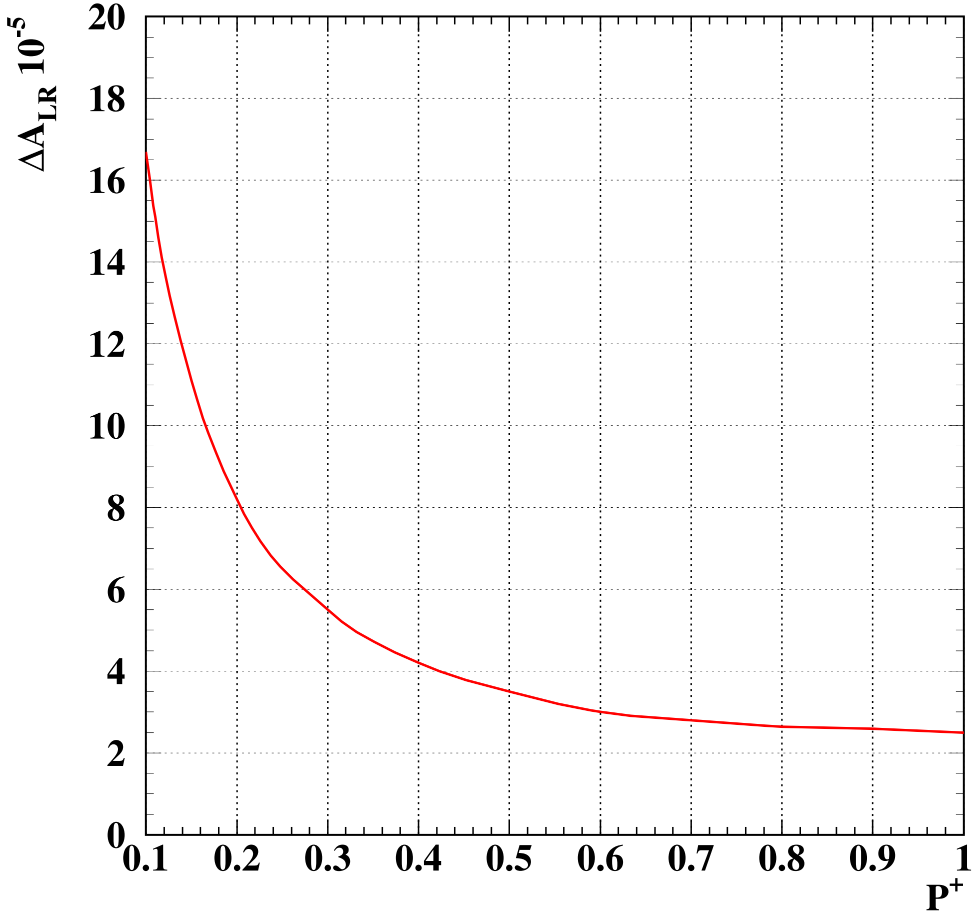
- Previous calculations have been done for $\mathcal{P}_{e^+} = 60\%$,
  $\mathcal{P}_{e^+} = 30\%$ considerably worse

- Optimal A_{LR} for J=0 fraction of 30% (was 10%)
  cross section enhancement only 10%

- $\Delta A_{\mathrm{LR}} = 1.8/\sqrt{N}$
  (was $\Delta A_{\mathrm{LR}} = 1.1/\sqrt{N}$)

- Useful beyond 75 M "effective" Z (40 days)

ΔA_{LR} as a function of $\mathcal{P}_{e^+}$ (for 10^9 Z)



Beam issues

How is the positron beam produced?

- Undulator at 150 GeV then beam is decelerated with full field
  $\Rightarrow E_b = 50\,\mathrm{GeV} \Rightarrow$ too much

➟ lower E_b in undulator ➟ lower e^+ yield ➟ less polarisation?

- 0.23% beam energy spread at 250 GeV ➟ 1.3% or 580 MeV at 45.5 GeV for electron beam
  This is certainly too much for physics, is this ok for calibration?
- Can we install a special source for the undulator and inject the beam from the damping ring behind the undulator? (Can use XFEL source for positron creation?)

Polarisation flipping

- If polarisation can be flipped fast (e.g. per train) many systematics cancel out
- If polarisation is flipped slower must normalise with Lumi monitors
- This means one gets sensitive to time variations in luminosity measurement and Z selection
- Electron polarisation only: flipping no problem
- Also positron polarisation:
  - e^+, e^- polarisation are correlated (J=0,1), no use flipping only one polarisation
  - Possibility for fast e^+ flipping cheap with two parallel spin rotators close to source (K. Moffeit)
  - If nominally no positron polarisation must make sure that polarisation is really 0 ($< 0.01\%$)

Beam energy issues

$\frac{dA_{\mathrm{LR}}}{d\sqrt{s}} = 2 \cdot 10^{-2}/\mathrm{GeV}$

$\Delta A_{\mathrm{LR}} = 0.0001 \Rightarrow \Delta\sqrt{s} = 5\,\mathrm{MeV}$

Needed running time for 5 MeV precision: 1 h each at $m_{\mathrm{Z}} \pm 1\,\mathrm{GeV}$

How long is the setup time needed for the miniscan?

What precision is needed for calibration?

Can the E_b spectrometers ensure the beam energy within $\frac{\Delta E_B}{E_B} \leq 8 \cdot 10^{-5}$ from calibration run to calibration run?

Conclusions

- Z-calibration data offer the world's best measurement of $\sin^2\theta^l_{eff}$
- Positron polarisation may improve this by a factor 2 (or more)
- For this polarimetry at the Z is a must
- The generation of the positron beam should be looked at seriously
- A $\sqrt{s}$ precision of 5 MeV has to be ensured with scans and/or beam spectrometers