Precision ew measurements at calibration/Z-pole running

Gudrid Moortgat-Pick (IPPP)

18/11/08

- RDR positron source
- Calibration needs
- Role of polarization
- Physics
- Conclusion and outlook

Thanks a lot to the organizer for providing webex !

RDR Positron Source

- Positron source in RDR:

  - undulator-based source
  - P(e+)~45%
  - Changes needed to do calibration at the Z-pole?
  - How to optimize this option?
  - Could we replace GigaZ via calibration runs?

- Small positron polarization available for physics!

Outcome of polarimetry+energy workshop

- in more detail see executive summary, arXiv:0808.1638 (sent to GDE)
- Since baseline design provides small polarization
  - Flipping of helicity is required or destroy polarization completely (see talk of S. Riemann, source session)
  - This polarization could be enhanced to ~45% (with bunch compressor)
- Spin rotation:
  - 'cheap' and quick kicker system before pre-DR, moved to 400 MeV (see talk of K. Moffet, source session)
- Polarimetry requirements (see talks of J. List, e.g. top session)

Calibration Needs

- How many Z's are needed for calibration?
  - Experience from LEP2
- Calibration needed after annual shutdown
  - After each annual shutdown:
    10 pb/detector + couple of pb's over the year
- No Z-pole calibration needed after push-pull
- For calibration:
  - large emittance, low lumi tolerable (Scope Document 2)
- L_{cal} ? Estimates in the range of $7x10^{31}$ -- $7x10^{32}$
  - Has still to be worked out
  - Therefore requirements based on # of Z-events

Physics: Z-pole data

- **Why do we need such data a.s.a.p.?**
  - **Discrepancy between A_{LR} and A_{FB}**

$$\text{SLD:} \quad \sin^2\theta_{\text{eff}} = 0.23098 \pm 0.00026 \quad (A_{LR}(\ell)),$$
$$\text{LEP:} \quad \sin^2\theta_{\text{eff}} = 0.23221 \pm 0.00029 \quad (A_{FB}(had)).$$

  - **‚most sensitive tests of the Standard Model via measurements of the ew observables as $\sin^2\theta_{\text{eff}}$**

We do need it already now !!!

A_{LR} and $\sin^2\theta_{eff}$

- **Accuracy in $\sin^2\Theta_{eff}$**

$$A_{\rm LR} = \frac{2(1-4\sin^2\theta_W^{\rm eff})}{1+(1-4\sin^2\theta_W^{\rm eff})^2}$$

  - precision in ALR directly transferred to $\sin^2\Theta_{eff}$
  - GigaZ will provide $\Delta \sin^2\Theta_{eff} \sim 1.3 \times 10^{-5}$ (if Blondel scheme)
  - only electron polarization at GigaZ: $\sim 9.5 \times 10^{-5}$
  - current value: 16×10^{-5}
  - What could we gain with a 'fraction' of GigaZ ?

Strategy

- Collect calibration data from several years
  (maybe 5 y, proposal ?)
- Collect data from dedicated Z-pole runs with low lumi
  (25 days / year)
- 'Full' GigaZ would take a few 10^3 low lumi days (on basis of $L_{cal}=7x10^{31}$)
  - Makes no sense to aim for that
  - In case one had higher L_{cal}, one could think about that!
- GigaZ after ILC physic runs is late anyway....2025? (personal comment)
- But already with such a fraction of the GigaZ accuracy we gain a lot in physics!

Physics gain vs. required precision

- **What are the important input quantities?**
  - **Mass of top:**

Heinemeyer, Hollik, Weber, Weiglein '08

current theoretical: intrinsic	$\Delta m_W^{\text{intr,today}} \approx 4$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{intr,today}} \approx 4.7 \times 10^{-5}$
parametric $\delta m_t = 1.2$ GeV	$\Delta m_W^{\text{para},m_t} \approx 11$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},m_t} \approx 3.6 \times 10^{-5}$
$\delta(\Delta\alpha_{\text{had}}) = 35 \times 10^{-5}$	$\Delta m_W^{\text{para},\Delta\alpha_{\text{had}}} \approx 6.3$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},\Delta\alpha_{\text{had}}} \approx 12 \times 10^{-5}$
$\delta m_Z = 2.1$ MeV	$\Delta m_W^{\text{para},m_Z} \approx 2.5$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},m_Z} \approx 1.4 \times 10^{-5}$

future parametric		
LHC: $\delta m_t = 1$ GeV	$\Delta m_W^{\text{para},m_t} \approx 6$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},m_t} \approx 3 \times 10^{-5}$
ILC: $\delta m_t = 0.1$ GeV	$\Delta m_W^{\text{para},m_t} \approx 1$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},m_t} \approx 0.3 \times 10^{-5}$
$\delta(\Delta\alpha_{\text{had}}) = 5 \times 10^{-5}$	$\Delta m_W^{\text{para},\Delta\alpha_{\text{had}}} \approx 1$ MeV	$\Delta \sin^2\theta_{\text{eff}}^{\text{para},\Delta\alpha_{\text{had}}} \approx 1.8 \times 10^{-5}$

  - **only progress if $\Delta_{exp} \leq \Delta_{theo}$**

What is achievable with low lumi Z-data?

- **Strategy:**
  - 10 pb^{-1}/ detector after annual shutdown + couple of pb^{-1} / year
  - Collect Z-data for each calibration and dedicated low lumi runs on the Z-pole
  - About 0.6 fb^{-1} needed (~ 100 days) to achieve $\sin^2\theta_{eff}$ ~3x 10^{-5}

    (in collaboration with J. List, K. Moenig, S. Riemann, R. Settles,…)
- **Why is 3 x 10^{-5} useful and best value for now?**
  - only progress if $\Delta_{exp} \leq \Delta_{theo}$
  - Δ_{theo} dominated by Δm_{top}
    - currently about Δm_{top} ~1.2 GeV leading to $\Delta \sin^2\theta_{eff}$ ~ 3.5 x 10^{-5}
    - with exp. LHC Δm_{top} ~1 GeV one ends up $\Delta \sin^2\theta_{eff}$ ~ 3 x 10^{-5}
  - No further gain as long as not Δm_{top} ~0.1 GeV! (ILC precision)

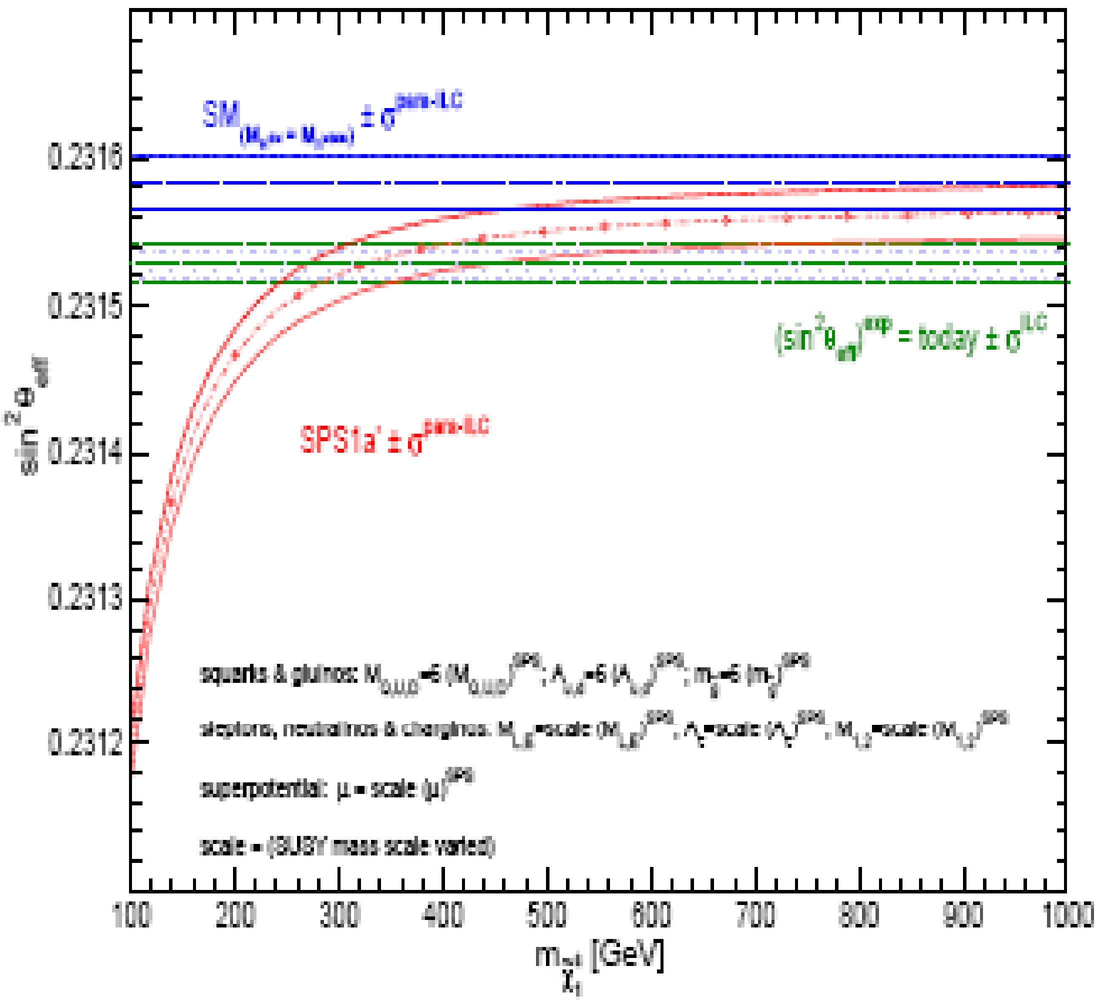
Possible low lumi Z-data: ΔA_{LR}(stat)

$\int \mathcal{L}$	No. of Z's	$\int_{\text{days}} \mathcal{L}_{\text{cal}}$	$P(e^-)$	$P(e^+)$	ΔA_{LR}	$\sin^2\theta_{\text{eff}}$
6 pb^{-1}	1.8×10^5	1	90%	0	2.7×10^{-3}	3.4×10^{-4}
			90%	40%	3.3×10^{-3}	4.2×10^{-4}
			90%	60%	2.2×10^{-3}	2.8×10^{-4}
24 pb^{-1}	7.3×10^5	4	90%	0	1.5×10^{-3}	1.9×10^{-4}
			90%	40%	1.6×10^{-3}	2.1×10^{-4}
			90%	60%	1.1×10^{-3}	1.4×10^{-4}
60 pb^{-1}	1.8×10^6	10	90%	0	1.1×10^{-3}	1.4×10^{-4}
			90%	40%	1.0×10^{-3}	1.3×10^{-4}
			90%	60%	7.0×10^{-4}	8.9×10^{-5}
0.6 fb^{-1}	18×10^6	100	90%	0	8.1×10^{-4}	1.0×10^{-4}
			90%	40%	3.3×10^{-4}	4.2×10^{-5}
			90%	60%	2.2×10^{-4}	2.8×10^{-5}
0.9 fb^{-1}	27×10^6	150	90%	0	7.9×10^{-4}	1.0×10^{-4}
			90%	40%	2.7×10^{-4}	3.4×10^{-5}
			90%	60%	1.8×10^{-4}	2.3×10^{-5}
1.2 fb^{-1}	36×10^6	200	90%	0	7.9×10^{-4}	1.0×10^{-4}
			90%	40%	2.3×10^{-4}	3.0×10^{-5}
			90%	60%	1.6×10^{-4}	2.0×10^{-5}

Physics gain with $\sin^2\theta_{eff}$=3 x 10^{-5}

- **Hints for new physics in worst case scenarios:**
  - Only Higgs @LHC
  - No hints for SUSY
- **Deviations at Z-pole**
  - Hints for SUSY
- **Powerful test!**
  - We should not miss this option

Heinemeyer, Hollik, Weber, Weiglein '07 + Power report



What's the role of polarization?

- Derive the statistical uncertainty of A_{LR}

  If only polarized electrons:

  ΔA_{LR} determined by polarimeter uncertainty

  $A_{LR} = 1 / P(e-) \times [\sigma_L - \sigma_R] / [\sigma_L + \sigma_R]$

  – Pure error propagation:

    uncertainty depends on $\Delta\sigma_L$, $\Delta\sigma_R$, $\Delta P/P$

  – For large statistics, σ (ee -> Z -> had) ~ 40 nb:

    main uncertainty from ΔP/P~ 0.5 % up to 0. 25%

  – Since 'only' calibration and begin of ILC, we assume

    ΔP/P = 0.5 %

  – Higher $P(e^-)$ better, we assumed 90%

Blondel Scheme

- Two polarized beams available
  - Express A_{LR} only by cross sections

$$\sigma = \sigma_{\rm unpol}[1 - P_{e^-}P_{e^+} + A_{\rm LR}(P_{e^+} - P_{e^-})],$$

$$A_{\rm LR} = \sqrt{\frac{(\sigma_{++} + \sigma_{+-} - \sigma_{-+} - \sigma_{--})(-\sigma_{++} + \sigma_{+-} - \sigma_{-+} + \sigma_{--})}{(\sigma_{++} + \sigma_{+-} + \sigma_{-+} + \sigma_{--})(-\sigma_{++} + \sigma_{+-} + \sigma_{-+} - \sigma_{--})}}$$

  - Pure error propagation:

    uncertainty depends on $\Delta\sigma_{LL}$, $\Delta\sigma_{LR}$, $\Delta\sigma_{RL}$, $\Delta\sigma_{RR}$ not on $\Delta P/P$
  - Only relative measurements wrt flipping polarization needed

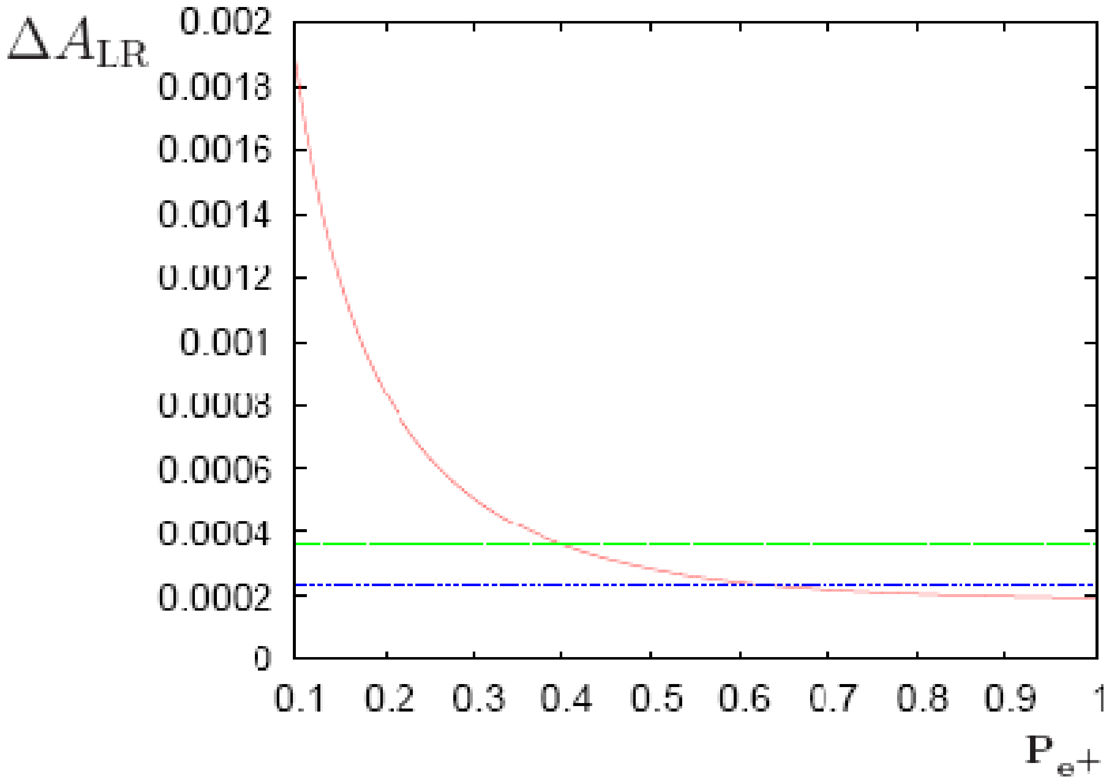
    $\Delta P / P = 0.5$ % should be sufficient
  - Some calibration time in LL and RR required

    assumed 10%, but that's not the optimum (see later)

Dependence of ΔA_{LR}(stat) on $P(e^+)$

- **On basis of 10^6 Z's**
- **$P(e^+)$ important**
- **Strictly speaking:**

  $P(e^+)$=60% desirable

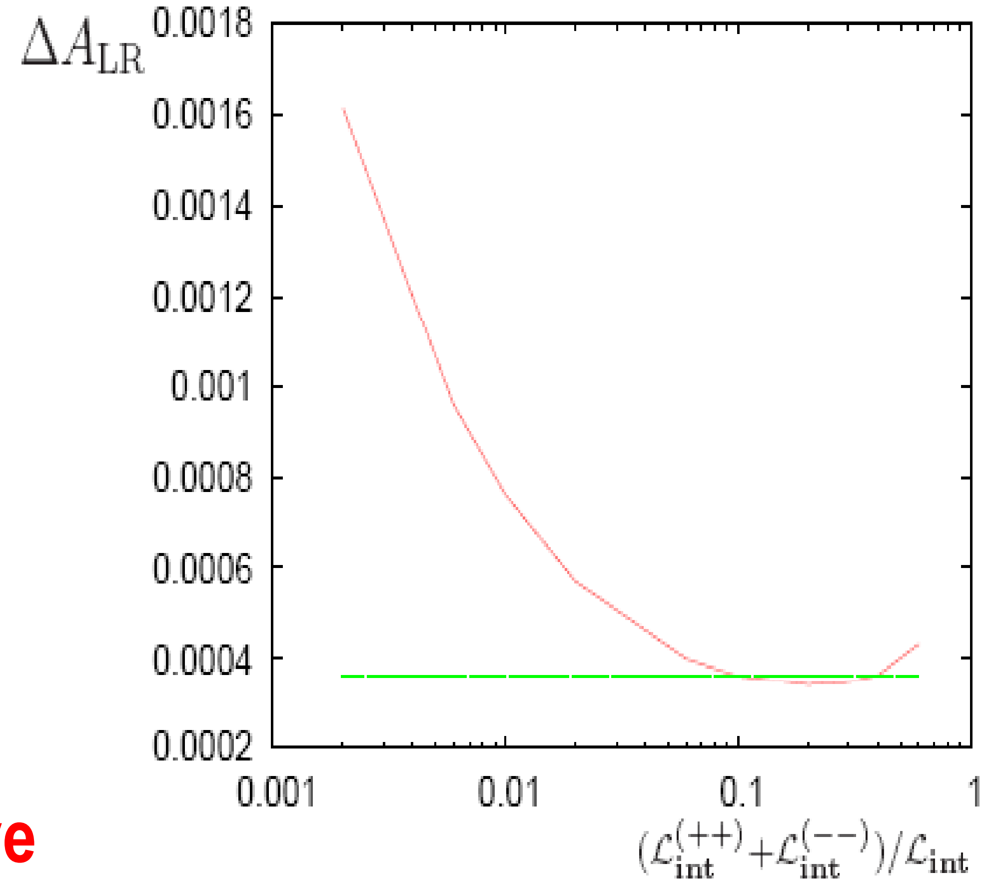


cf also Hawkings, Moenig, 1999 on basis of 10^9 Z-events, GigaZ studies

Dependence of $\Delta A_{LR(stat)}$ on L_{++} and L_{--}

- What is the optimum time running in (++) and (--) mode?
- Assume $P(e^+)=40\%$
- Best value at about

  $(L_{++} - L_{--})/L_{int}=25\%$
- But does not significantly reduce the uncertainty!
- Higher P(e+) more effective



Schemes for e^+ production

- **Several possibilities to achieve the Z-pole:**
  - **Deceleration of e- beam after 150 GeV point**
    - **still to high for Z-pole: slight fine tuning with E_b needed**
    - **some emittance dilution but larger energy spread (probably ok)**
  - **Running of undulator at lower energy, E_b=50GeV**
    - **dependence on higher harmonics, K value tuning useful**
    - **lower lumi but ok for calibration (estimated $7x10^{31}$ ok)**
    - **Larger emittance (but ok for calibration)**
    - **Iff problems: bypass solution**

How to reach the Z-pole?

- **Other possibility:**
  - use other e- source for undulator, but inject e- beam for calibration from DR after undulator ?
  - probably too much effort, but should be studied ……
- **What about undulator at 250 GeV option?** ('minimal machine' approach)
  - Running at 50 GeV and same as before (higher harm, K-value)
  - Bypass solution, etc.

So no showstopper (also for high energy physics run)…

Conclusion

- **Promising physics case for using low lumi Z-pole data**
  - **Large physics gain in ew prec. Physics, A_{LR} vs A_{FB}, worst case scenarios, etc** ***(see forthcoming paper)***
  - **Powerful tests at an early stage and** ***(GigaZ comes late, but could be further motivated by these low lumi data)***
  - **Polarized e- and e+, helicity flipping and polarimeters needed** ***(see other talks of Jenny, Sabine and Ken)***
- **Different schemes possible for e+@Z-pole, optimization needed**
- **We should not miss this opportunity!**