Impact of minimal machine on physics and calibration

Gudrid Moortgat-Pick (IPPP)

29/10/08

- RDR positron source
- Calibration needs
- Physics
- Schemes

RDR Positron Source

- Positron source in RDR:
  - K=0.92
  - λ_U=11.5 mm
  - L=147 m (200 m)
  - E_{1st}= 10 MeV
  - E_b= 150 GeV
  - B_{max}=0.86 T
  - $P(e^+)$~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

Polarimetry+energy workshop@Zeuthen 4/08

- executive summary sent to the GDE, please see arXiv:0808.1638

- since baseline design provides small polarization
  - flipping of helicity is required or destroy polarization completely (see talk of S. Riemann at LCWS07 and polarimetry workshop)
  - if even bunch compressor used: capture efficiency increased by factor 2, polarization raises up to 45%!........

- Recommendation:

5. Implement parallel spin rotator beamlines with a kicker system before the damping ring to provide rapid helicity flipping of the positron spin.

6. Move the pre-DR positron spin rotator system from 5 GeV to 400 MeV. This eliminates expensive superconducting magnets and reduces costs.

7. Move the pre-DR electron spin rotator system to the source area. This eliminates expensive superconducting magnets and reduces costs.

Calibration Needs

- How many Z's are needed for calibration?
  - Experience from LEP2
  - After each annual shutdown:

    10 pb/detector + couple of pb's over the year
- Calibration needed after annual shutdown
- No Z-pole calibration needed after push-pull
- For calibration: large emittance, low lumi tolerable (Scope 2)
- L_{cal} ? About 7×10^{31} (Nick@Tesla) vs. 7×10^{32} (Andrei S)
  - Has still to be worked out
- But stable energy, since $\Delta A_{LR} / \Delta\sqrt{s} \sim 0.2\% / \mathrm{GeV}$

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 $\sin^2\theta_{eff}$**

We do need it already now !!!

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

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

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

- 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 ?

Possible low lumi Z-data

$\int \mathcal{L}$	No. of Z's	$\int_{\rm days} \mathcal{L}_{\rm cal}$	$P(e^-)$	$P(e^+)$	$\Delta A^0_{\rm LR}$	$\Delta A_{\rm LR}$	$\sin^2\theta_{\rm eff}$
6 $\rm pb^{-1}$	1.8×10^5	1	90%	0	–	2.7×10^{-3}	3.4×10^{-4}
			90%	40%	3.3×10^{-3}	4.4×10^{-3}	5.6×10^{-4}
			90%	60%	2.2×10^{-3}	3.0×10^{-3}	3.8×10^{-4}
24 $\rm pb^{-1}$	7.3×10^5	4	90%	0	–	1.5×10^{-3}	1.9×10^{-4}
			90%	40%	1.6×10^{-3}	2.2×10^{-3}	2.8×10^{-4}
			90%	60%	1.1×10^{-3}	1.5×10^{-3}	1.9×10^{-4}
60 $\rm pb^{-1}$	1.8×10^6	10	90%	0	–	1.1×10^{-3}	1.4×10^{-4}
			90%	40%	1.0×10^{-3}	1.4×10^{-3}	1.8×10^{-4}
			90%	60%	7.0×10^{-4}	9.4×10^{-4}	1.2×10^{-4}
0.6 $\rm fb^{-1}$	18×10^6	100	90%	0	–	8.1×10^{-4}	1.0×10^{-4}
			90%	40%	3.3×10^{-4}	4.4×10^{-4}	5.6×10^{-5}
			90%	60%	2.2×10^{-4}	3.0×10^{-4}	3.8×10^{-5}
0.9 $\rm fb^{-1}$	27×10^6	150	90%	0	–	7.9×10^{-4}	1.0×10^{-4}
			90%	40%	2.7×10^{-4}	3.6×10^{-4}	4.6×10^{-5}
			90%	60%	1.8×10^{-4}	2.4×10^{-4}	3.1×10^{-5}
1.2 $\rm fb^{-1}$	36×10^6	200	90%	0	–	7.9×10^{-4}	1.0×10^{-4}
			90%	40%	2.3×10^{-4}	3.1×10^{-4}	4.0×10^{-5}
			90%	60%	1.6×10^{-4}	2.1×10^{-4}	2.7×10^{-5}
1.8 $\rm fb^{-1}$	54×10^6	300	90%	0	–	7.8×10^{-4}	1.0×10^{-4}
			90%	40%	1.9×10^{-4}	2.6×10^{-4}	3.2×10^{-5}
			90%	60%	1.3×10^{-4}	1.7×10^{-4}	2.2×10^{-5}

Table 4: Lumi at Z-pole $\mathcal{L}_{\rm cal} = 7 \times 10^{31}\ {\rm cm^{-2}s^{-1}}$, $\sigma(e^+e^- \to Z \to had) \sim 30$ nb, $A_{\rm LR} = 0.154$, $\Delta P/P = 0.5\%$, $\mathcal{L}_{++,--}/\mathcal{L} = 0.1$

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

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

current theoretical: intrinsic	$\Delta m_W^{\rm intr,today} \approx 4$ MeV	$\Delta \sin^2\theta_{\rm eff}^{\rm intr,today} \approx 4.7 \times 10^{-5}$
parametric δm_t=1.8 GeV $\delta(\Delta\alpha_{\rm had}) = 35 \times 10^{-5}$	 $\Delta m_W^{\rm para,m_t} \approx 11$ MeV $\Delta m_W^{\rm para,\Delta\alpha_{had}} \approx 6.3$ MeV	 $\Delta \sin^2\theta_{\rm eff}^{\rm para,m_t} \approx 5.4 \times 10^{-5}$ $\Delta \sin^2\theta_{\rm eff}^{\rm para,\Delta\alpha_{had}} \approx 12 \times 10^{-5}$
δm_Z=2.1 MeV	$\Delta m_W^{\rm para,m_Z} \approx 2.5$ MeV	$\Delta \sin^2\theta_{\rm eff}^{\rm para,m_Z} \approx 1.4 \times 10^{-5}$

LHC

future parametric δm_t=2 GeV δm_t=1 GeV δm_t=0.1 GeV	 $\Delta m_W^{\rm para,m_t} \approx 12$ MeV $\Delta m_W^{\rm para,m_t} \approx 6$ MeV $\Delta m_W^{\rm para,m_t} \approx 1$ MeV	 $\Delta \sin^2\theta_{\rm eff}^{\rm para,m_t} \approx 6 \times 10^{-5}$ $\Delta \sin^2\theta_{\rm eff}^{\rm para,m_t} \approx 3 \times 10^{-5}$ $\Delta \sin^2\theta_{\rm eff}^{\rm para,m_t} \approx 0.3 \times 10^{-5}$

ILC

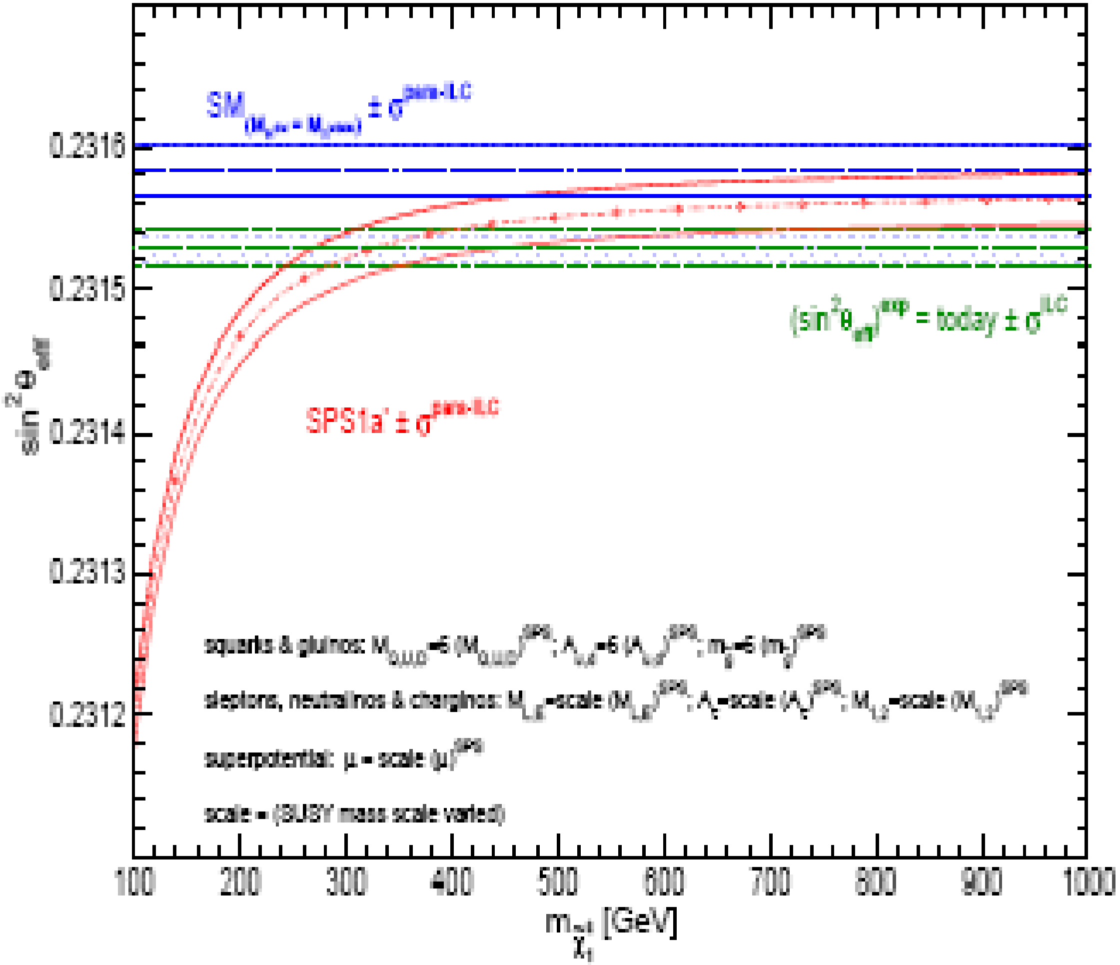
  - only progress if $\Delta_{exp} \leq \Delta_{theo}$

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 about 5000 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 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

Schemes for e^+ production

- **How to achieve the Z-pole energy with e^- beam?**
- **Several possibilities:**
  - **Deceleration of e- beam after 150 GeV point**

    Problem:

    - **still to high for Z-pole: slight fine tuning with E_b needed**
    - **some emittance dilution (probably ok)**
    - **but large energy spread……. (probably not ok for calibration)**

Undulator at 50 GeV

- Running of undulator at lower energy, Eb=50GeV
  - $E_{1st} \sim \gamma^2 /(1+K^2) / \lambda_U \sim 1$ MeV (too low for pair production, >2 MeV)
  - Several solutions:

  a) Take only higher harmonics, e.g. from n=2,..,8

  b) Use other K for calibration (assuming λ_U fixed)

  K-> 0.3: $E_{1st} \sim 2$ MeV
  - Probably 7 x 10^{31} ok
- Higher emittance (beam sees full linac impedance) but for calibration probably ok
  - If problems: bypass solution
- What is about energy spread in this case?
  - 1.5% for 150 GeV -> at 50 GeV ?

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's with the 250 GeV option?

- If we use E_b=250 GeV, maybe choose E_{1st}~25 MeV
  - Running at 50 GeV leads to same problems at before
  - E_{1st} < 2 MeV, but taking either higher harmonics or changing K factor should work
  - By-pass solution in case emittance problems occur
- Option discussed at TESLA times
  - 2^{nd} e+ source in remaining e- linac and 2^{nd} undulator to get higher lumi
- Believe for calibration first option should be fine
  - Probably 7 x 10^{31} ok

Conclusion + Open issues

- **Different schemes possible for e+@Z-pole**
  - **Different options how to reach the Z-pole including by-pass, 2nd source etc. should be studied**
- **Promising physics case for using low lumi Z-pole data**
  - **Powerful tests now and…… GigaZ would be very late**
- **Would it be possible to cost and build ILC piece-wise? (but layout for 500, of course)**
  - **Detectors at 500 position, but only drift lines after RF's? Steps, e.g., 90 GeV, 350 GeV, 500 GeV?**