Polarization and A_{LR}: analysis summary and final results

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SLD Collaboration Meeting

Kirkwood

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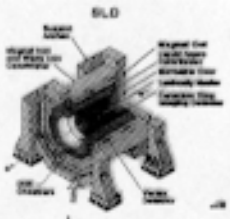
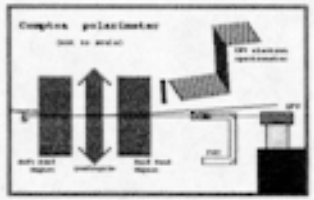


Talk outline



Event selection

$A_m = (N_L - N_R)/(N_L + N_R)$

Instrumental asymmetries: (total < 0.1 %)

- background
- luminosity
- polarization
- energy
- detector acceptance
- positron polarization

A_m corrected

- Laser polarization (0.1 %)
- Detector linearity (0.2 %)
- Electronic noise (0.2 %)
- Analyzing power calibration
- Cross check polarimeters

(0.4 %)

P at Compton IP

- Chromaticity effect (0.16 %)
- Beam-beam, transport depolarization (small)

P at SLD IP

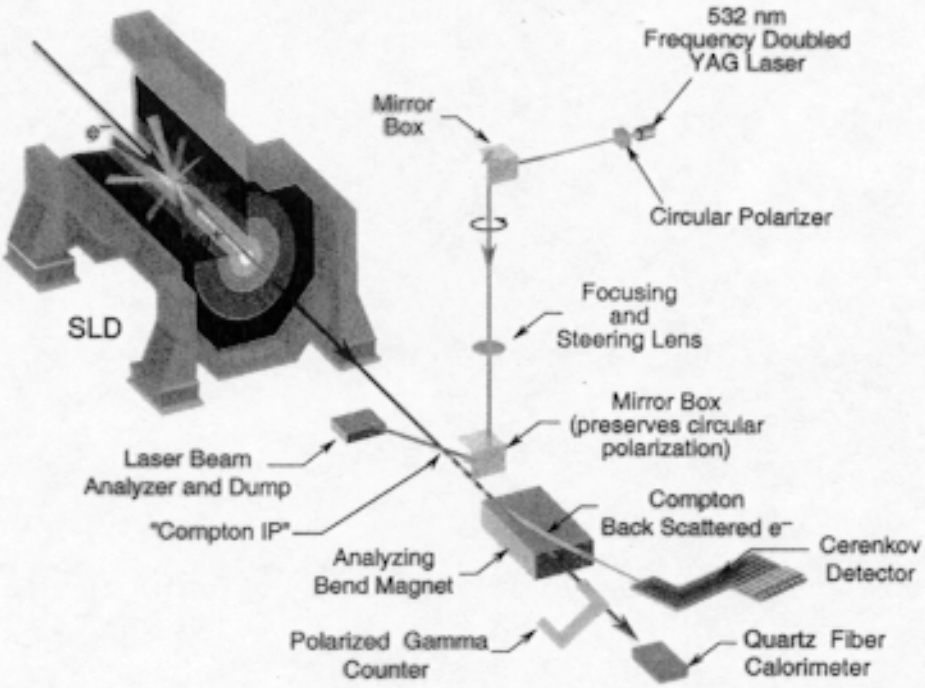
A_{LR}

Energy scale → Initial state corrections, γ-Z interference, γ exchange (2% effect, 0.4% error)

A^0_{LR}

Comparison with LEP and SM

Polarimetry



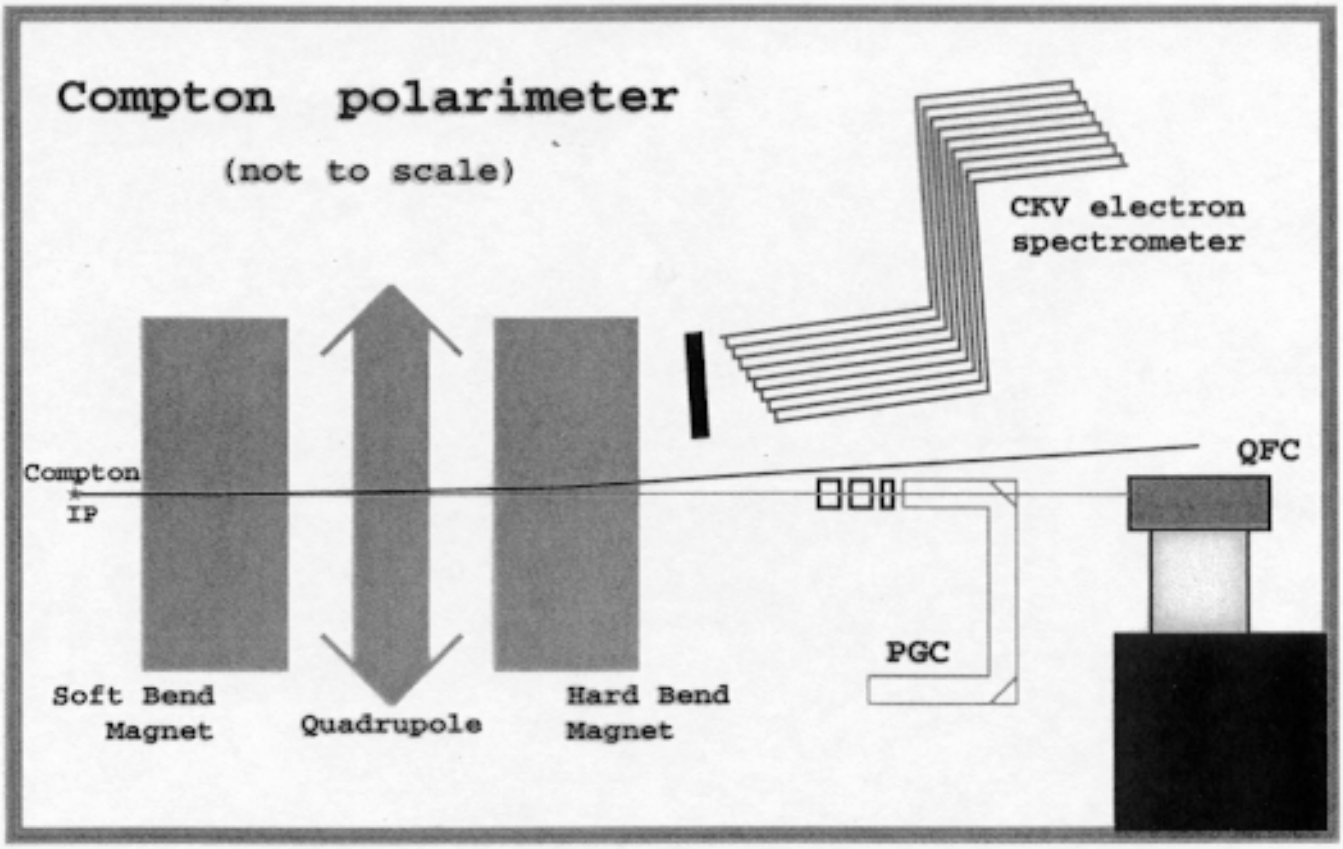
New for the last two runs :

- **high luminosity running**
- **improved understanding of the detector linearity (error: 0.5 % → 0.2 %)**
- **improved understanding of the SLD IP to Compton IP corrections**

New since the last meeting :

- **cross check polarimeters analysis is complete, the results are used to set a limit on the CKV calibration uncertainty**

Cross check polarimeters



Both QFC and PGC :

- detect Compton scattered photons
- only operated during electron only running
- do not depend on the spectrometer calibration

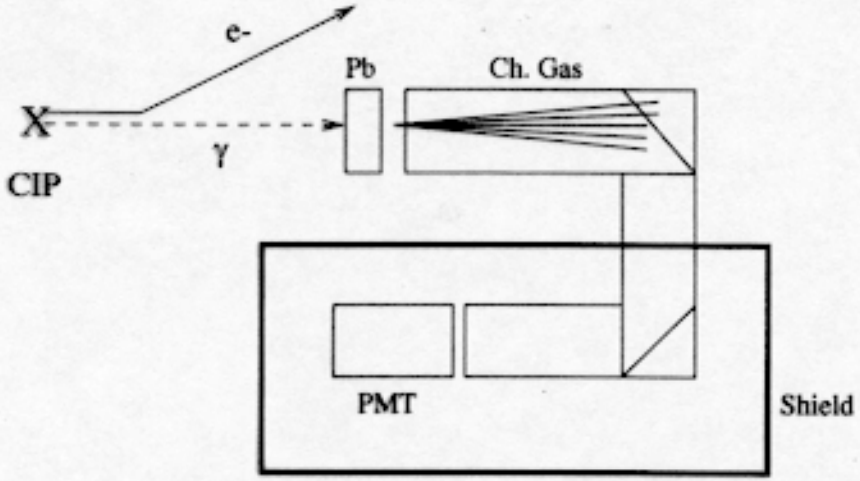
QFC :

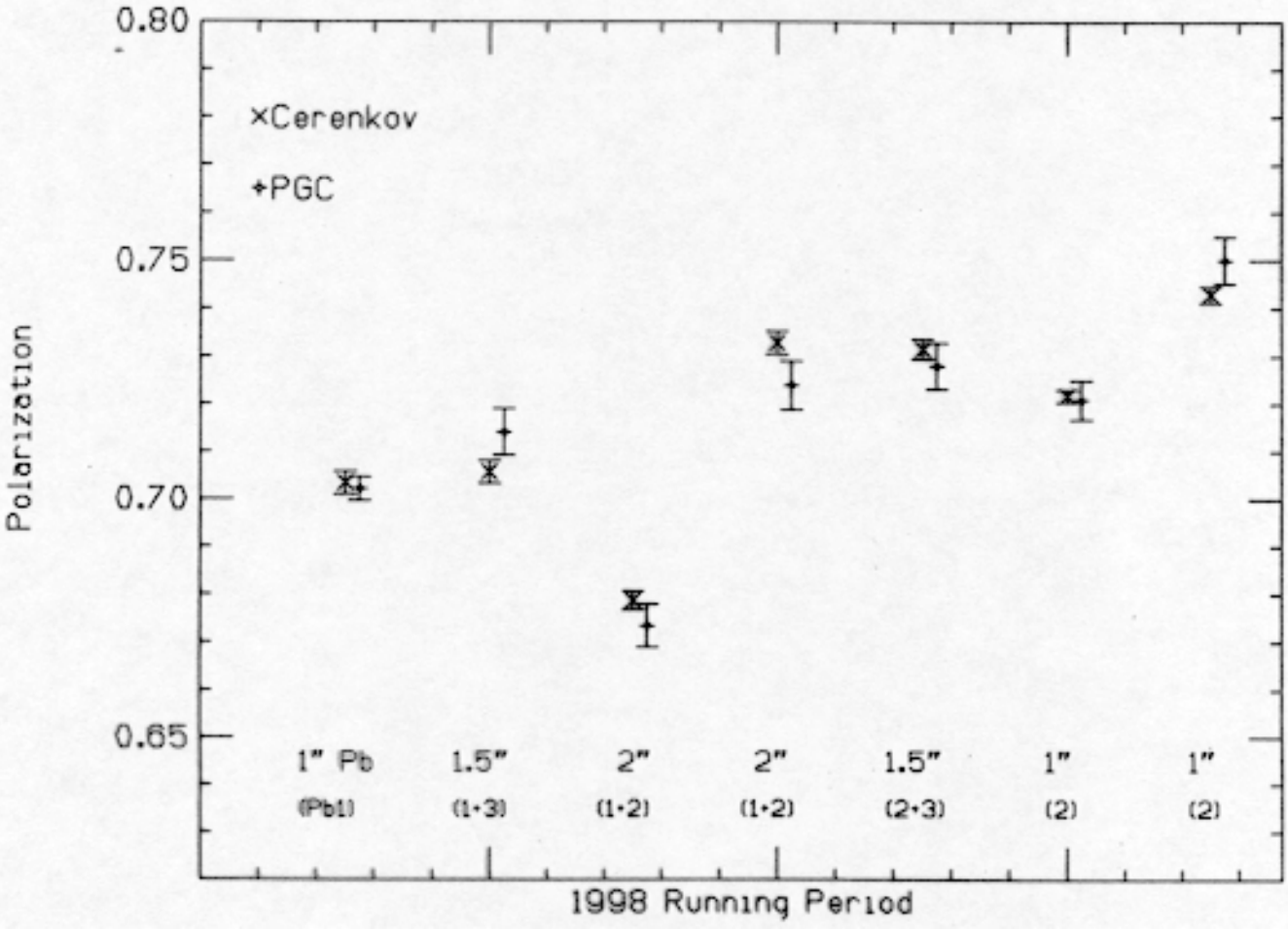
- does not rely heavily on Monte Carlo for calibration
- insensitive to misalignments
- position sensitive

PGC :

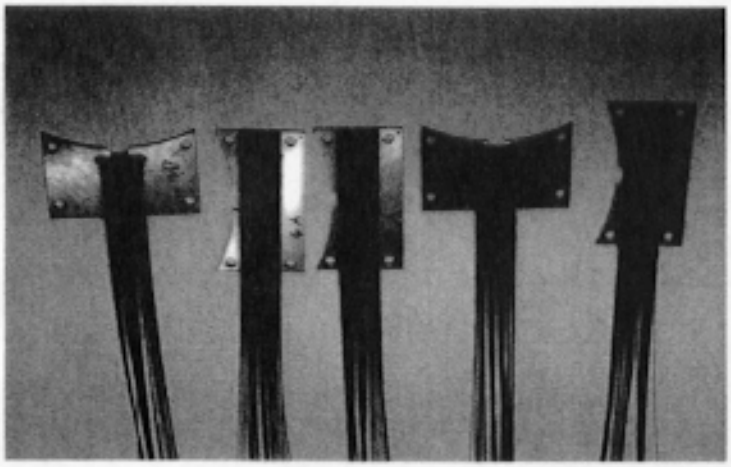
- less sensitive to backgrounds than QFC
- varying preradiator thickness allows for systematics estimate

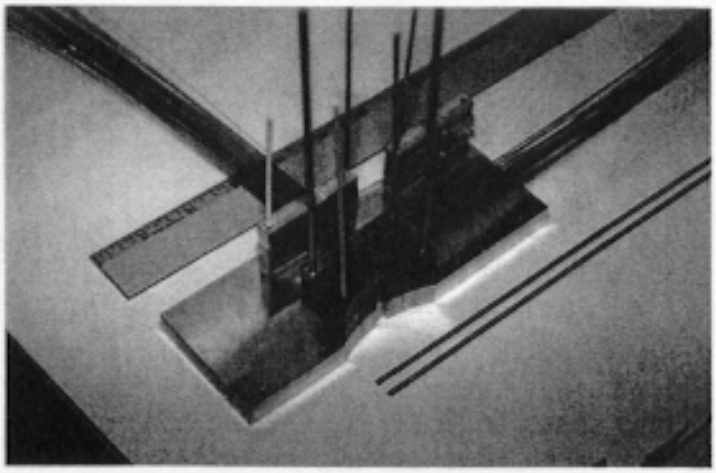
Polarized Gamma Counter (PGC)

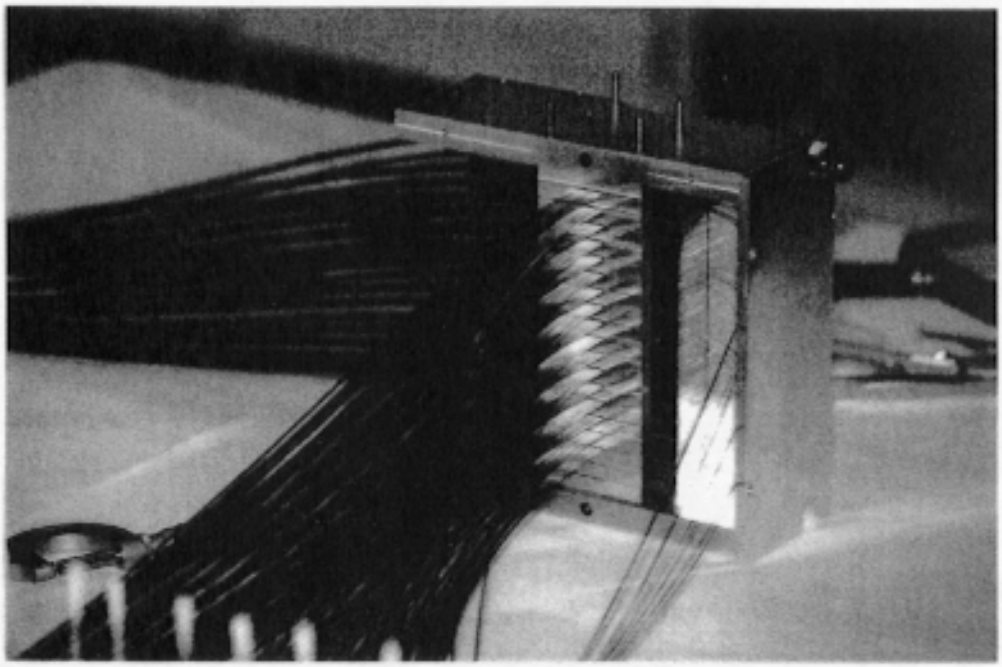


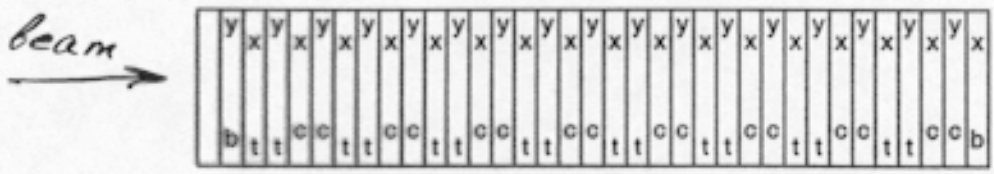


Quartz Fiber Calorimeter (QFC)









x - horizontal fibers
y - vertical fibers

t - layer for total energy measurement
c - layer for position measurement
b - layer read out separately

QFC: summary of systematic errors of the longitudinal polarization measurement. Numbers are given in per cent.

Calorimeter		
Angular acceptance, finite beam size	small	Compton cross section angular dependence, Monte Carlo simulation.
Energy response function linearity	0.2	Monte Carlo simulation, beam test.
Detector misalignment	0.1	Monte Carlo simulation, beam test.
Local non-uniformity	0.3	Monte Carlo simulation, beam test.
Optical cross talk	small	Measurement, Monte Carlo simulation.
Asymmetry contamination by re-scattered electrons	small	Monte Carlo simulation, *in situ* study.
Readout		
Readout linearity	0.5	LED study, beam test.
Electronic cross talk	0.1	*In situ* study.
Laser pickup	0.1	Direct measurement.
Total	0.6	

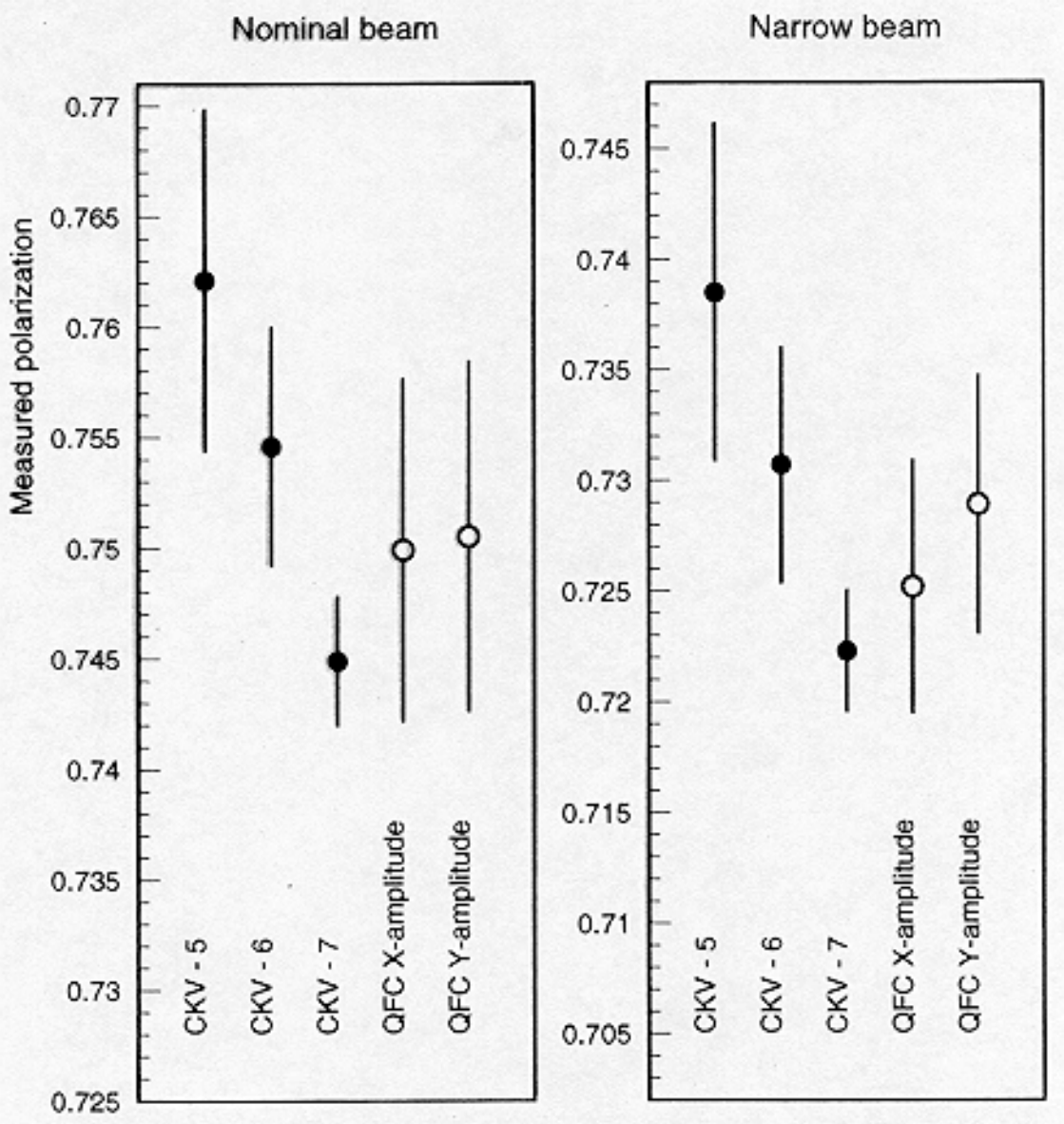


Figure 4.16: Polarization measurements with nominal and "narrow" beams. For the CKV channels, the errors shown on the plot do not include additional contributions due to the observed inter-channel inconsistency. Calibration errors for these channels have been estimated assuming 0.5 mm uncertainty in the position of the Compton edge.

Summary of cross checks

CKV channel 7 is used to calculate polarization

Cross checks - relative deviation from CKV-7 :

QFC : $(+0.65 \pm 0.72)$ %

PGC : (-0.35 ± 0.64) %

CKV-6 : $(+0.68 \pm 0.65)$ %

Combined : $(+0.30 \pm 0.39)$ % ($\chi^2 = 1.9 / 2$ d.o.f.)

Quoted calibration uncertainty for

CKV channel 7

0.4 %

Luminosity weighted average polarization values and associated uncertainties for all SLD runs.

	1992	**1993**	**1994/95**	**1996**	**1997/98**
Relative systematic errors, per cent					
Laser Polarization	2.0	1.0	0.20	0.10	0.10
Detector Linearity	1.5	0.6	0.50	0.20	0.20
Analyzing Power Calibration	1.0	0.6	0.29	0.40	0.40
Electronic noise	0.4	0.2	0.20	0.20	0.20
SLD IP to Compton IP Correction Uncertainty	0.2	1.1	0.17	0.16	0.15
Total	**2.7**	**1.7**	**0.67**	**0.52**	**0.52**
Luminosity weighted average polarization					
	0.224 ± 0.006	**0.630 ± 0.011**	**0.7723 ± 0.0052**	**0.7616 ± 0.0040**	**0.7292 ± 0.0038**

Event selection summary

	1992	1993	1994/95	1996	1997/98
Number of Z^0 bosons produced with left-handed electron beam, N_L	5,226	27,225	52,179	29,016	183,335
Number of Z^0 bosons produced with right-handed electron beam, N_R	4,998	22,167	41,465	22,857	148,259
Measured asymmetry, A_m	0.0223 $\pm$0.0099	0.1024 $\pm$0.0045	0.1144 $\pm$0.0032	0.1187 $\pm$0.0044	0.1058 $\pm$0.0017
Selection efficiency before polarization matching, per cent	90 $\pm$2	93 $\pm$1	89.3 $\pm$0.8	91.9 $\pm$0.9	91.0 $\pm$0.9
Selection efficiency after polarization matching, per cent	88 $\pm$2	91 $\pm$1	86.0 $\pm$0.8	91.4 $\pm$1.0	89.8 $\pm$0.9
Background fraction f_b, per cent	1.4 $\pm$1.4	0.25 $\pm$0.10	0.11 $\pm$0.08	0.029 $\pm$0.021	0.042 $\pm$0.032
Background asymmetry A_b		0.031 $\pm$0.010	0.055 $\pm$0.021	0.033 $\pm$0.026	0.023 $\pm$0.022

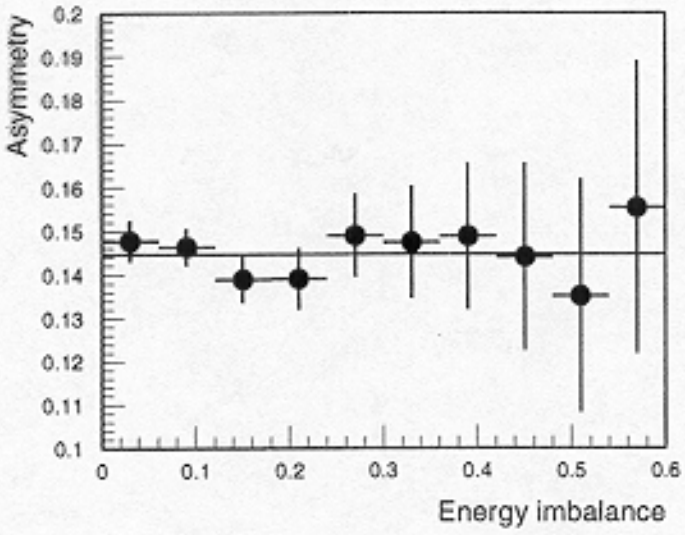


Figure 5.6: Measured asymmetry in Z^0 production binned by the energy imbalance. 1997/98 data sample. Confidence level for a horizontal straight line fit is 63 %.

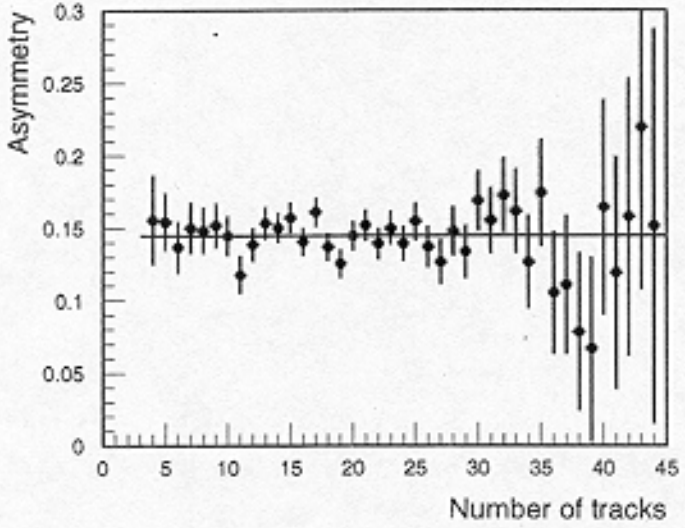


Figure 5.7: Measured asymmetry in Z^0 production binned by the track multiplicity. 1997/98 data sample.

Instrumental asymmetries and corrections

$$A_{LR} = \frac{A_m}{\mathcal{P}_e} + \frac{1}{\mathcal{P}_e}\left[f_b(A_m - A_b) - A_{\mathcal{L}} + A_m^2 A_{\mathcal{P}} - E_{cm}\frac{\sigma'(E_{cm})}{\sigma(E_{cm})}A_E - A_\varepsilon + \mathcal{P}_e\mathcal{P}_p\right]$$

	1992	1993	1994/95	1996	1997/98
Luminosity asymmetry, $A_{\mathcal{L}}$, (10^{-4})	1.8 $\pm$ 4.2	0.38 $\pm$ 0.50	-1.9 $\pm$ 0.3	$+0.03$ $\pm$ 0.50	-1.3 $\pm$ 0.7
Polarization asymmetry, $A_{\mathcal{P}}$, (10^{-4})	-29	-33 $\pm$ 1	$+24$ $\pm$ 10	$+29$ $\pm$ 43	$+28$ $\pm$ 69
Center-of-mass energy asymmetry, A_E, (10^{-4})		0.0044 $\pm$ 0.0001	0.0092 $\pm$ 0.0002	-0.0001 $\pm$ 0.0035	$+0.0028$ $\pm$ 0.0014
$E_{cm}\frac{\sigma'(E_{cm})}{\sigma(E_{cm})}$		-1.9	0.0 $\pm$ 2.5	2.0 $\pm$ 3.0	4.3 $\pm$ 2.9
Detection efficiency asymmetry, A_ε	0	0	0	0	0
Positron beam polarization $\mathcal{P}_p$	< 0.16	< 0.16	< 0.16	< 0.16	-0.0002 $\pm$ 0.0007
Total correction, $\Delta A_{LR}/A_{LR}$, (%)		$+0.10$ $\pm$ 0.08	$+0.2$ $\pm$ 0.06	$+0.02$ $\pm$ 0.05	$+0.16$ $\pm$ 0.07

Beams energies: Z-peak scan

Z mass has been precisely measured by LEP experiments. Z lineshape scan is a natural way to check the SLD energy scale.

With increased luminosity in 1998 this became practical.

Two off-energy points taken : + 880 MeV and - 930 MeV

Complications :

- **WISRD instrumental effects**

  South (electron) WISRD correlates unphysically high energy width measurements with incorrect energy measurements.

  North (positron) WISRD correlates abnormally high collected charge with incorrect energy measurements.

- **Extraction line energy loss**

  Previously used: 45 MeV per beam. New calculation by Mark Woodley : 41.9 MeV in 1997, 36.6 MeV in 1998.

- **Beam-beam disruption corrections**

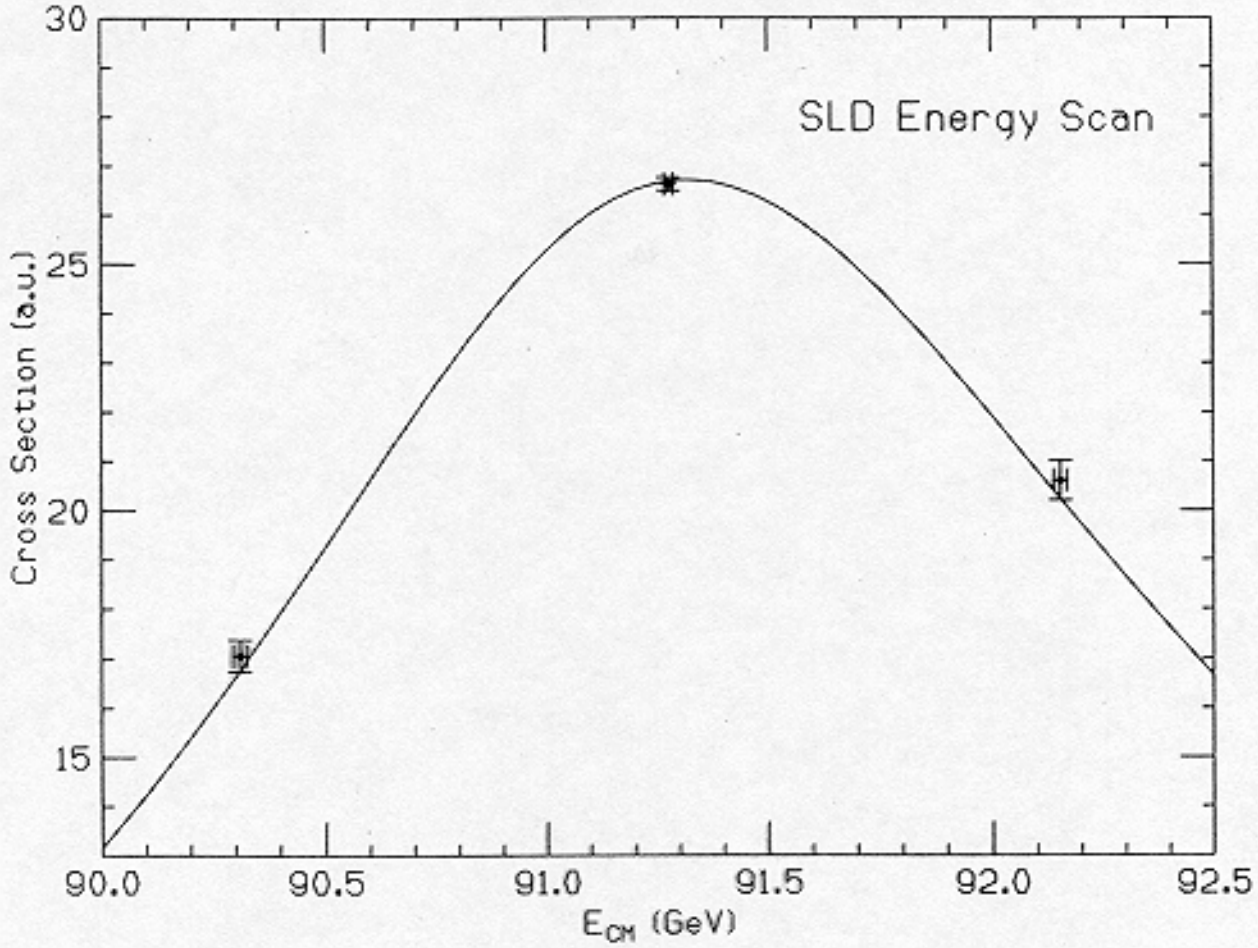
  Measured by looking at the difference between energies measured during normal and single beam running.

  GINEA-PIG simulation (Mike Woods) confirms the size of the effect and an assumption that pre-collision losses are 50 % of the total loss..

Z-peak scan data summary

	Low energy point	Peak	High energy point
Intended energy setpoint	90.352 GeV	91.284 GeV	92.167 GeV
Uncorrected energy measured by WISRD	90.236 GeV	91.176 GeV	92.048 GeV
Positron WISRD correction	-13.4 ± 6.7 MeV	-0.3 ± 0.2 MeV	0
Electron WISRD correction	-20.9 ± 10.5 MeV	-4.9 ± 2.5 MeV	$+3.0 \pm 1.5$ MeV
SLD IP to WISRD energy loss	$+36.9 \pm 1.0$ MeV per beam	$+36.9 \pm 1.0$ MeV per beam	$+36.9 \pm 1.0$ MeV per beam
Beam-beam disruption correction	$+33.4 \pm 10.0$ MeV	$+32.5 \pm 10.0$ MeV	$+28.1 \pm 15.0$ MeV
Corrected energy measured by WISRD	90.309 ± 0.016 GeV	91.277 ± 0.010 GeV	92.153 ± 0.015 GeV
Z events	3,312	52,123	3,724
Bhabha events	12,621	122,850	11,174
Trigger inefficiency	0.030	0.023	0.033

Z-peak scan fit



ZFITTER (Morris) : 91.230 ± 0.025 GeV (χ^2 = 1.2 / 1 d.o.f)

BHK + KF fit (Ray) : 91.226 ± 0.025 GeV (χ^2 = 1.5 / 1 d.o.f)

Average: 91.228 ± 0.025 GeV $\Rightarrow$

-41 ± 25 MeV offset compared to LEP result

BPM-based analysis (Pantaleo) :

-50 ± 22 MeV offset compared to LEP result

Correction applied to the data: -46 ± 25 MeV

Luminosity weighted corrections and average center-of-mass energies for the SLD 1997 and 1998 Z data samples.

	1997	1998
WISRD instrumental correction	1 ± 1 MeV	4 ± 2 MeV
SLD IP to WISRD energy loss correction	$+41.9 \pm 1.0$ MeV per beam	$+36.9 \pm 1.0$ MeV per beam
Beam-beam disruption correction	$+22.3 \pm 10.0$ MeV	$+30.4 \pm 10.0$ MeV
Average energy after instrumental corrections	91.277 ± 0.010 GeV	91.286 ± 0.010 GeV
WISRD scale correction (based on Z-peak scan results)	-46 ± 25 MeV	-46 ± 25 MeV
Final average energy	91.231 ± 0.029 GeV	91.240 ± 0.029 GeV

Luminosity-weighted average center-of-mass energies for all SLD runs.

1992	91.55 ± 0.04 GeV
1993	91.26 ± 0.02 GeV
1994/95	91.28 ± 0.03 GeV
1996	91.26 ± 0.03 GeV
1997/98	91.237 ± 0.029 GeV

Summary of A_{LR}^0 systematics

(per cent)

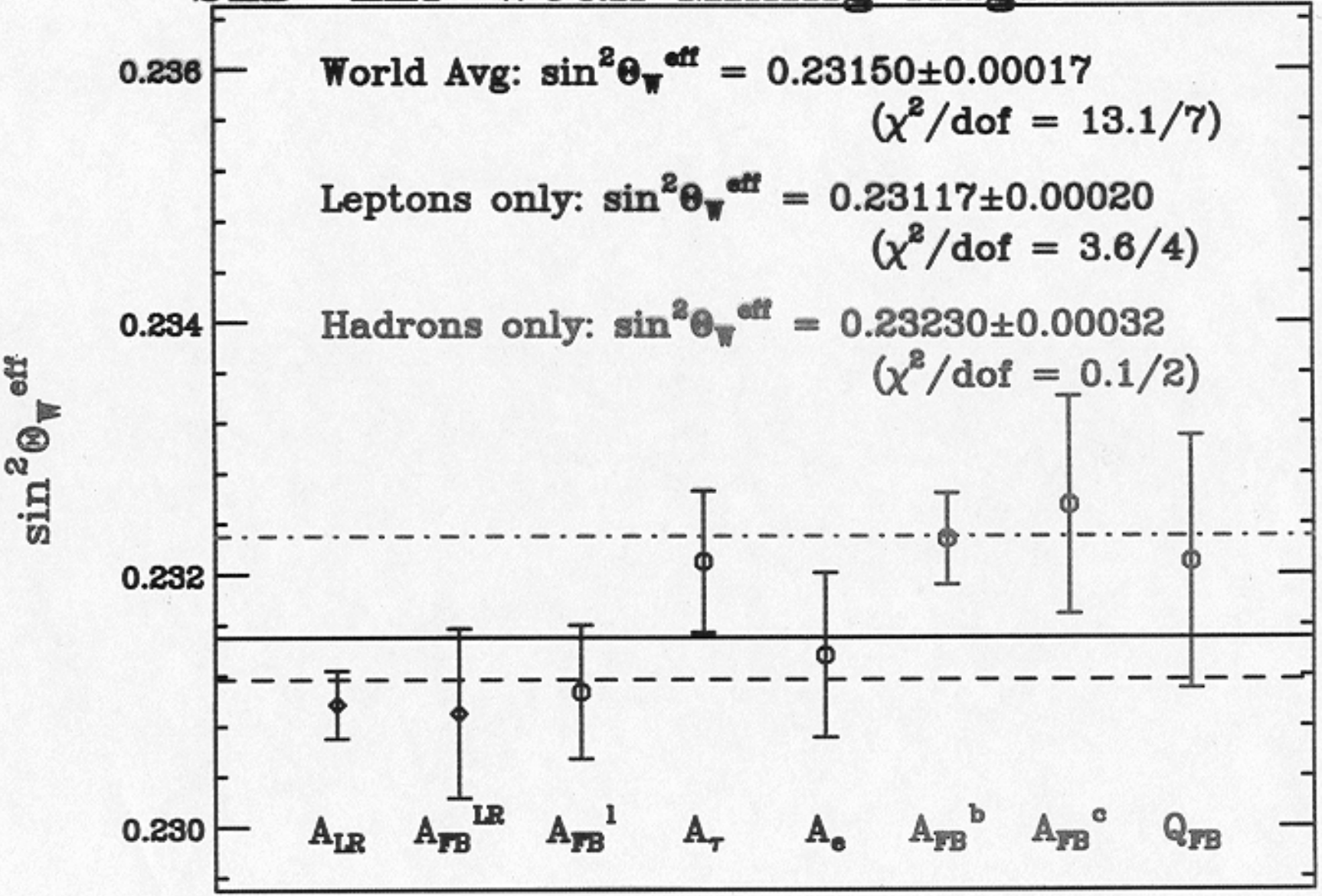
	1992	1993	1994/95	1996	1997/98
Polarimeter	**2.7**	**1.3**	**0.64**	**0.50**	**0.50**
SLD IP to Compton IP	**-**	**1.1**	**0.17**	**0.16**	**0.15**
Instrumental corrections to ALR	**2.4**	**0.1**	**0.06**	**0.05**	**0.07**
EW Int. corrections	**-**	**-**	**0.33**	**0.37**	**0.39**
Total	**3.6**	**1.7**	**0.75**	**0.63**	**0.64**

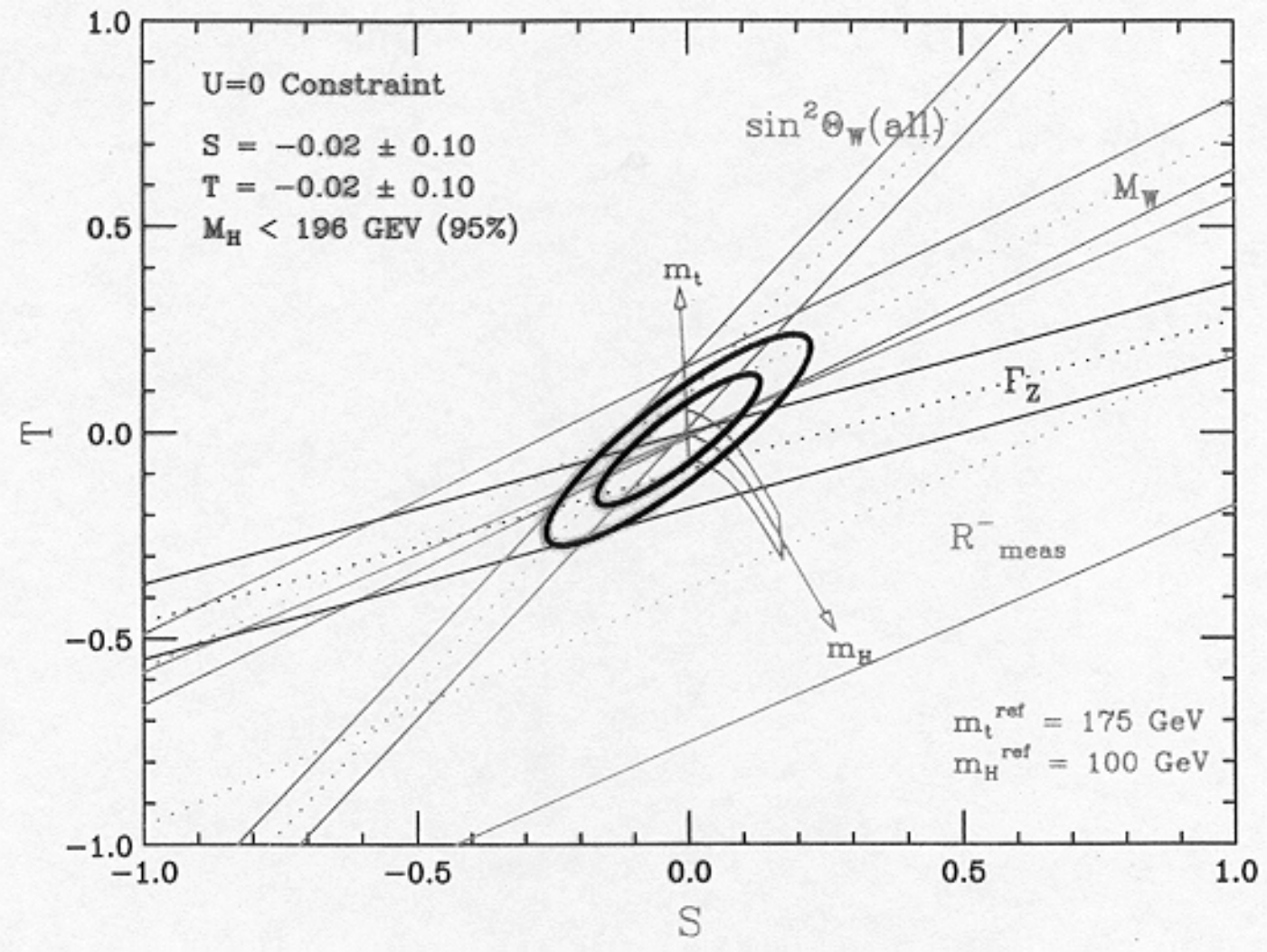
SLD A_{LR}^0 summary

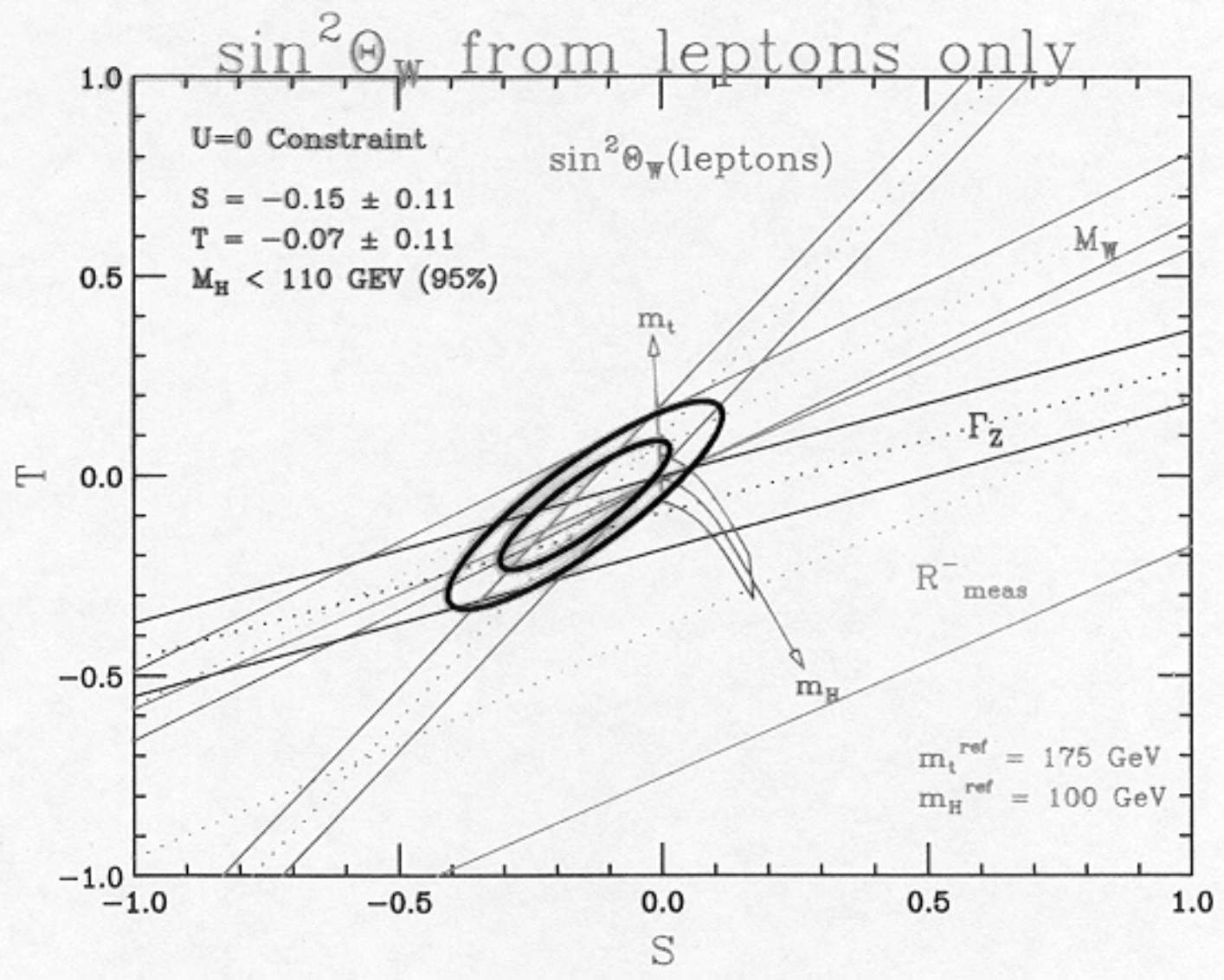
	A_{LR}	A_{LR}^0	$sin^2\theta_W^{eff}$
1992	0.100 $\pm 0.044 \pm 0.004$	0.097 $\pm 0.044 \pm 0.004$	0.2378 $\pm 0.0056 \pm 0.0005$
1993	0.1628 $\pm 0.0071 \pm 0.0028$	0.1656 $\pm 0.0071 \pm 0.0028$	0.2292 $\pm 0.0009 \pm 0.0004$
1994/95	0.1485 $\pm 0.0042 \pm 0.0010$	0.1512 $\pm 0.0042 \pm 0.0011$	0.23100 $\pm 0.00054 \pm 0.00014$
1996	0.1559 $\pm 0.00572 \pm 0.00084$	0.15929 $\pm 0.00573 \pm 0.00101$	0.23100 $\pm 0.00073 \pm 0.00013$
1997/98	0.1454 $\pm 0.00237 \pm 0.00077$	0.14906 $\pm 0.00237 \pm 0.00096$	0.23126 $\pm 0.00030 \pm 0.00012$
All combined		0.15138 ± 0.00216	0.23097 ± 0.00027

Combined with A_lepton (talk by Toshi) :

SLD–LEP Weak Mixing Angle Results




U=0 Constraint
S = −0.02 ± 0.10
T = −0.02 ± 0.10
M_H < 196 GEV (95%)
sin²Θ_W(all)
M_W
Γ_Z
R⁻ meas
m_t
m_H
m_t^ref = 175 GeV
m_H^ref = 100 GeV
1.0
0.5
0.0
−0.5
−1.0
T
S


sin²Θ_W from leptons only
U=0 Constraint
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T = −0.07 ± 0.11
M_H < 110 GEV (95%)
sin²Θ_W(leptons)
M_W
m_t
Γ_Z
R⁻ meas
m_H
m_t^ref = 175 GeV
m_H^ref = 100 GeV
T
S
1.0
0.5
0.0
−0.5
−1.0
−1.0
−0.5
0.0
0.5
1.0