Measuring $\sin^2\theta_W$ While Struggling Against Obscurity

"The SLC ? Are you guys still running ? And by the way, that LEP A_{LR} measurement really nails the Higgs mass, doesn't it ?"

P.C. Rowson

St. Francis Yacht Club
October 5th, 2001

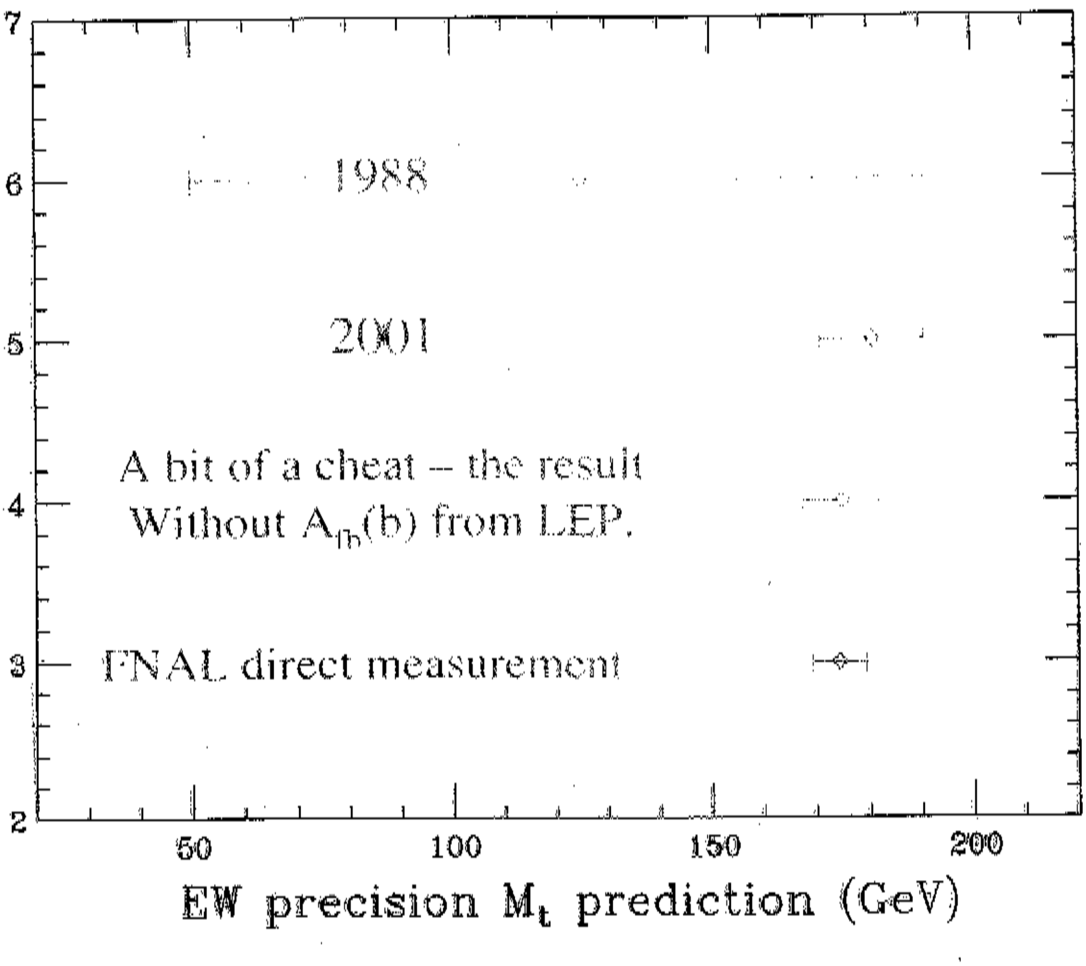
There has certainly been incredible progress in electroweak physics since the start of the Z-pole programs at LEP and SLC.

1988 Munich Intl. Conf. XXIV

- M_Z error of 700 MeV.
- $N_\nu < 6.7$ @ 95% CL
- $\delta \sin^2\theta_W = \pm 0.0048$
- $(m_{top})_{MSM} \approx$ 50-200 GeV
- $(m_{Higgs})_{MSM} <\sim$1 TeV.

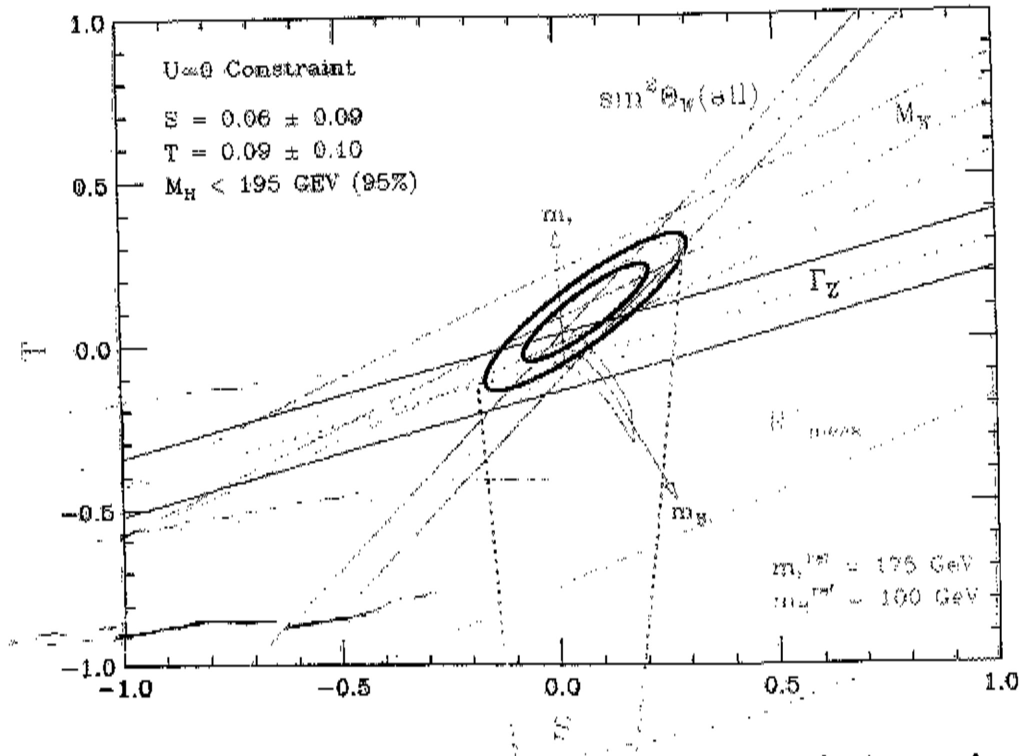
The present

- M_Z error of 2.1 MeV.
- $N_\nu = 2.9841 \pm 0.0083$
- $\delta \sin^2\theta_W = \pm 0.00017$
- $(m_{top})_{MSM} = 181_{-9}^{+11}$ GeV
- $114.1 < (m_{Higgs})_{MSM} < 195$ GeV (@ 95% CL)

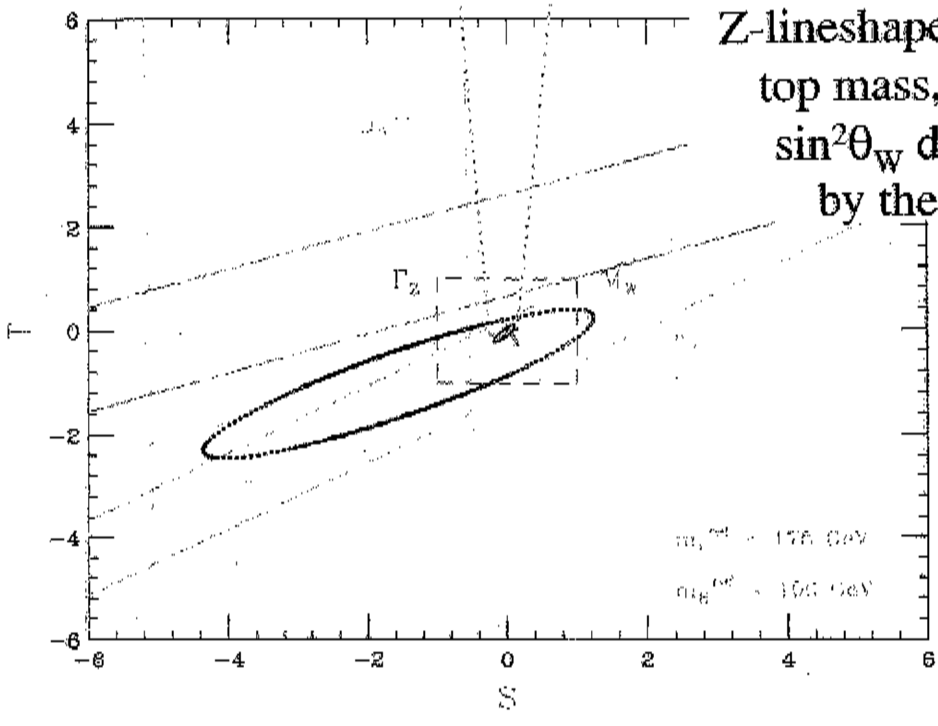


S,T parameters – a useful metric

2001

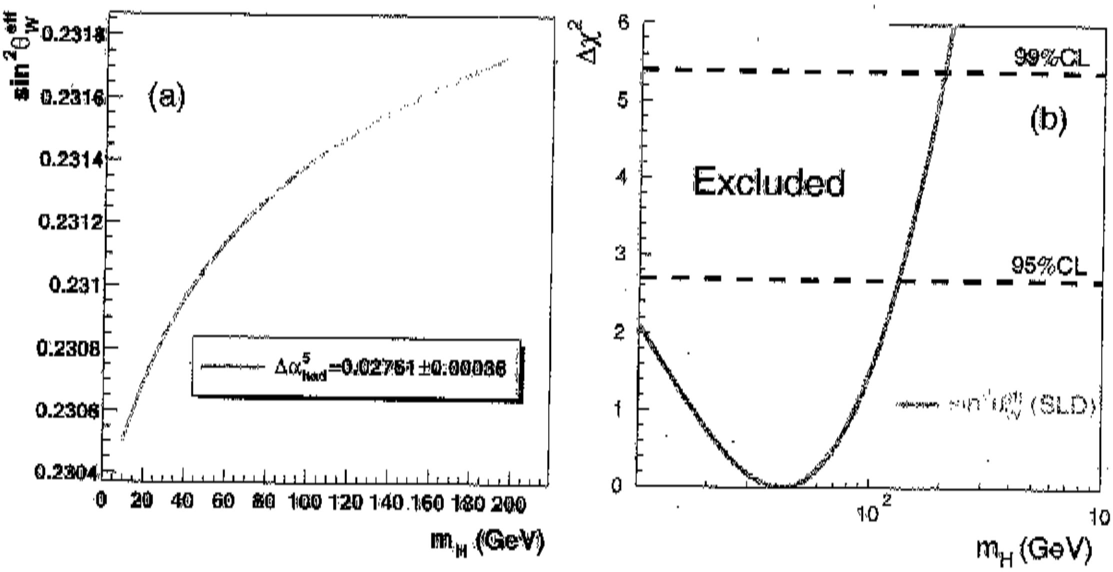


1988



This huge improvement in this MSM test is largely due to LEP's Z-lineshape, FNAL's top mass, and the $\sin^2\theta_W$ data, led by the SLC

How has the MSM been constrained by SLD data ?

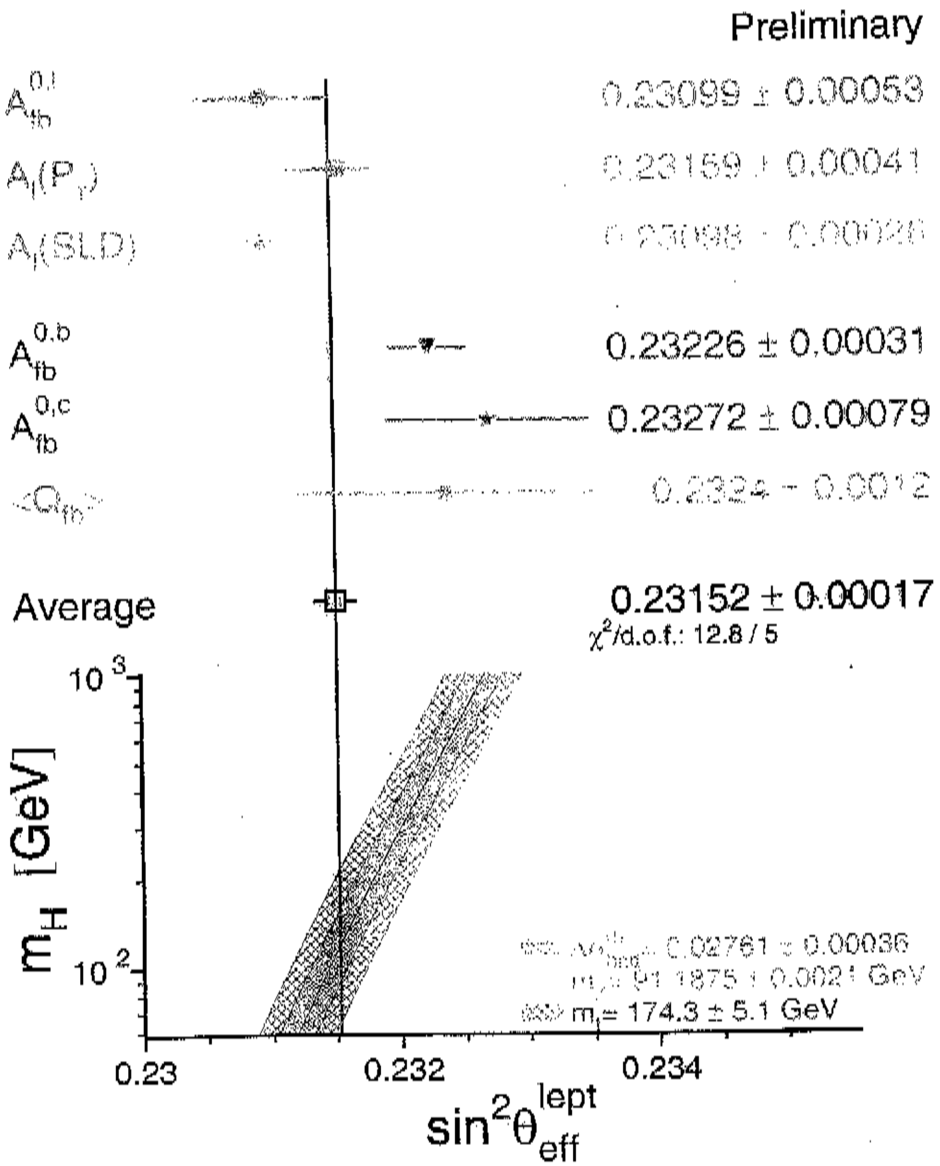


Upper bounds on MSM Higgs mass (GeV)

	95% CL	99% CL	consistency with direct lower bound
SLD	133	205	7%
World	195	260	32%
No $A_{fb}(b)$	133	185	9%

With the exception of the LEP b-asymmetries, the data prefer a significantly low mass, and some might say that the MSM is under a bit of stress if in fact a restricted fit is closer to the truth. The A_l,M_W,Γ_Z,R_l fit is consistent at the <5% CL.

After all these years ...



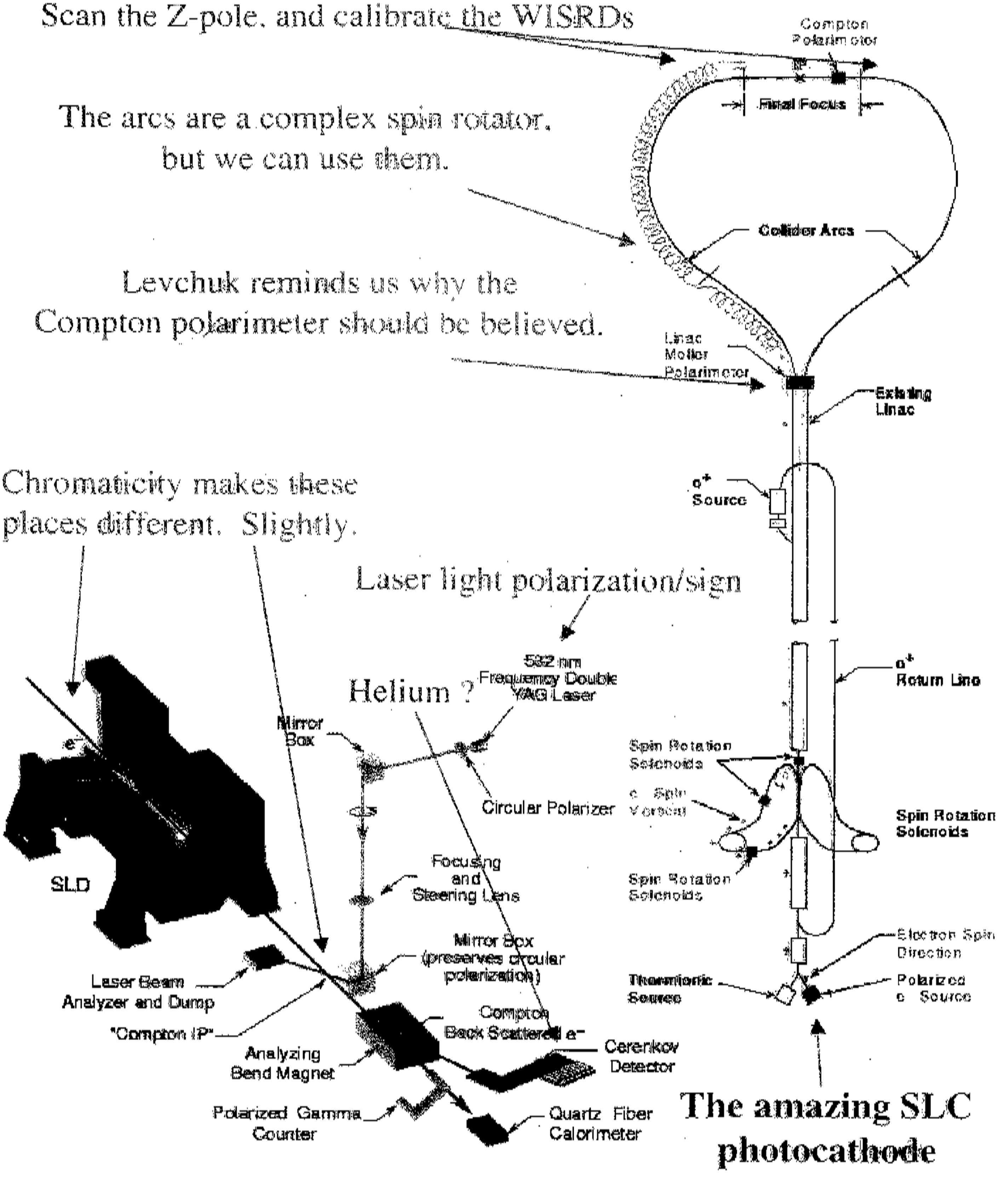
…the LEP lepton asymmetry and tau polarization data and SLD data are in better agreement than ever.

However,

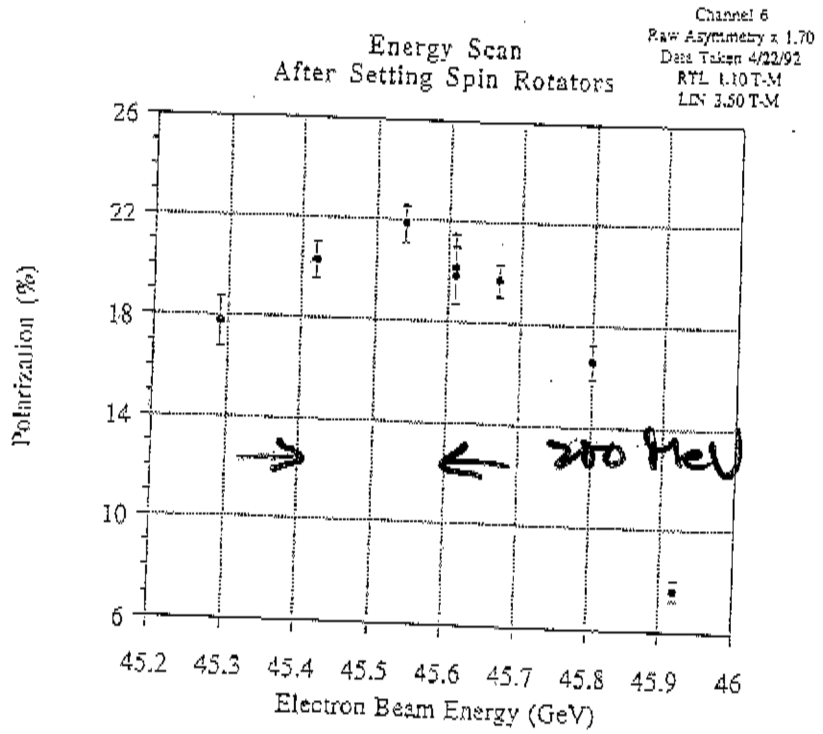
the LEP hadron-based asymmetry mean differs from the global leptons mean by 3.3σ,

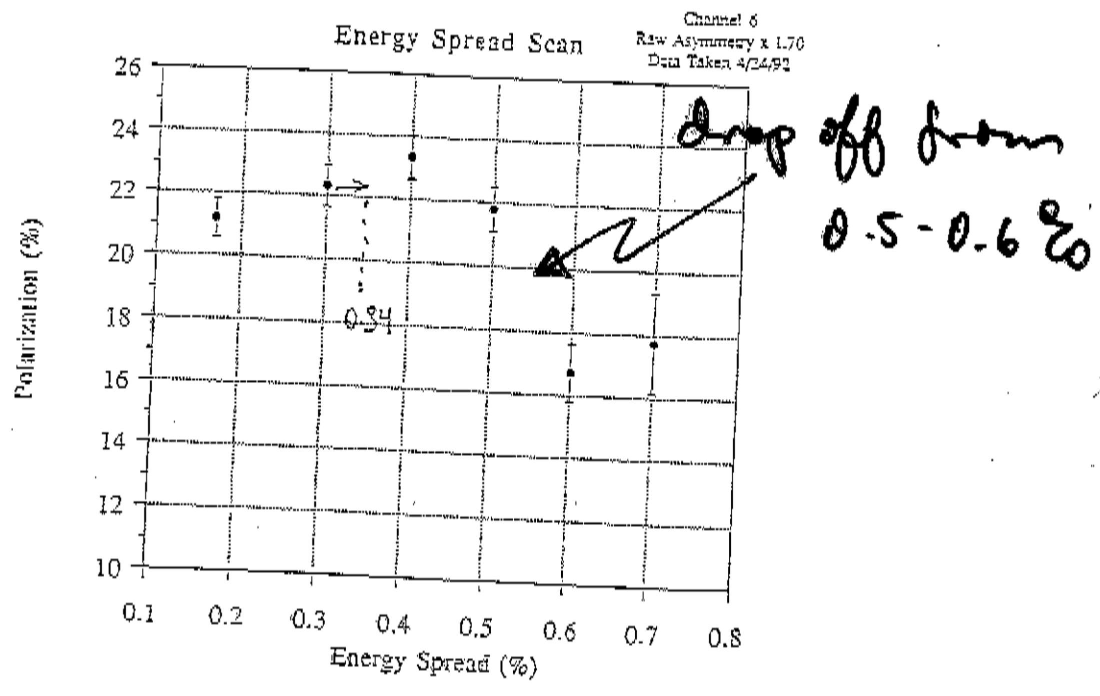
while the SLD $A_{b,c}$ data are consistent with the MSM.

The SLD/SLC polarization 'episodes'



Recall the old E, δE vs P data...





Polarized Compton Scattering: theory

Compton Scattering References

correct — 1. H.A. Olsen, *Applications of QED*, Springer Tracts in Modern Physics, Vol. 44, p.83, 1968.

correct — 2. S.B. Gunst, L.A. Page, Phys.Rev., Vol. 92, number 4, 1953. Modern Physics, Vol. 44, p.83, 1968.

ambig. — 3. F.W. Lipps, H.A. Tolhoek, Physica XX, p. 395, 1954. Modern Physics, Vol. 44, p.83, 1968.

wrong — 4. C. Prescott, SLAC-TN-73-1 (Revised), 1973.

ambig. — 5. S. Gasiorowicz, *Elementary Particle Physics*, John Wiley & Sons, 1966.

wrong — 6. L.W. Fagg, S.S. Hanna, *Polarization Measurements on Nuclear γ Rays*, Rev.Mod.Phys., Vol. 31, no.3, 1959.

... as checked by S. Drell | M. Peskin

NOTE: All refs. agree on the magnitudes

1. Total Internal Reflection Technique

This method, due to M. Zolotorev (and Fresnel), relies on the fact after a total internal reflection, the components of linear polarization parallel to and perpendicular to the plane of reflection undergo different phase shifts $\delta_{\|}$ and $\delta_{\perp}$ respectively, so that the two components are relatively phase shifted. It can be shown (see texts such as Smythe, Jackson or Landau/Lifschitz) that the relative phase defined as

$$\delta = \delta_{\perp} - \delta_{\|},$$

is a ~~positive~~ *negative* quantity. This means that in general linear light will, after a total internal reflection, become elliptical with a known handedness. For a material of refractive index n, and for an incident angle θ, the relative phase lag δ is given by :

$$tan(\frac{\delta}{2}) = \frac{cos\theta}{sin^2\theta}\sqrt{sin^2\theta - \frac{1}{n^2}}.$$

For glass $n \approx 1.5$, $i \cong 37°$

Analysis says that the prism here is equivalent to a λ/4 plate with a slow axis ⊥ to the plane of reflection.

(M. [illegible] memo due soon)

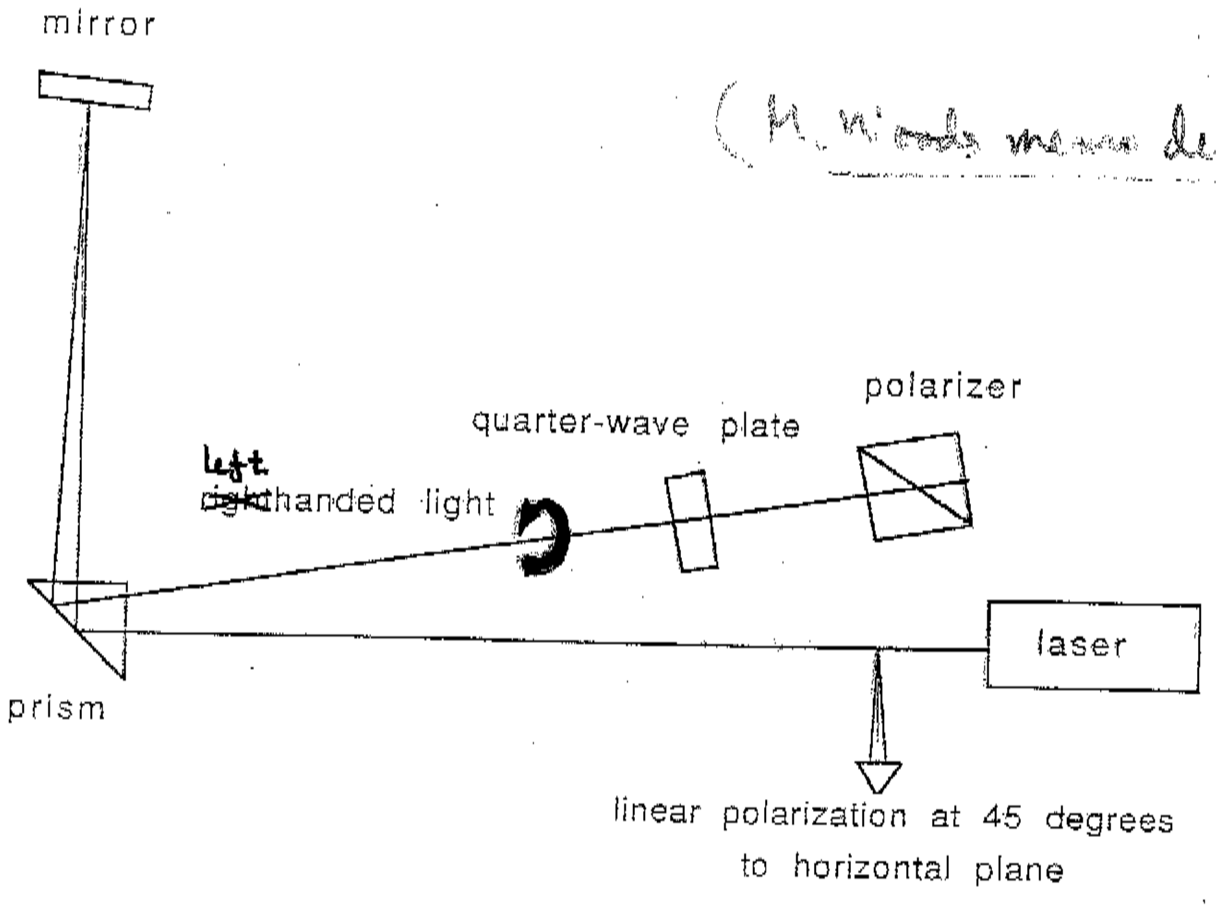
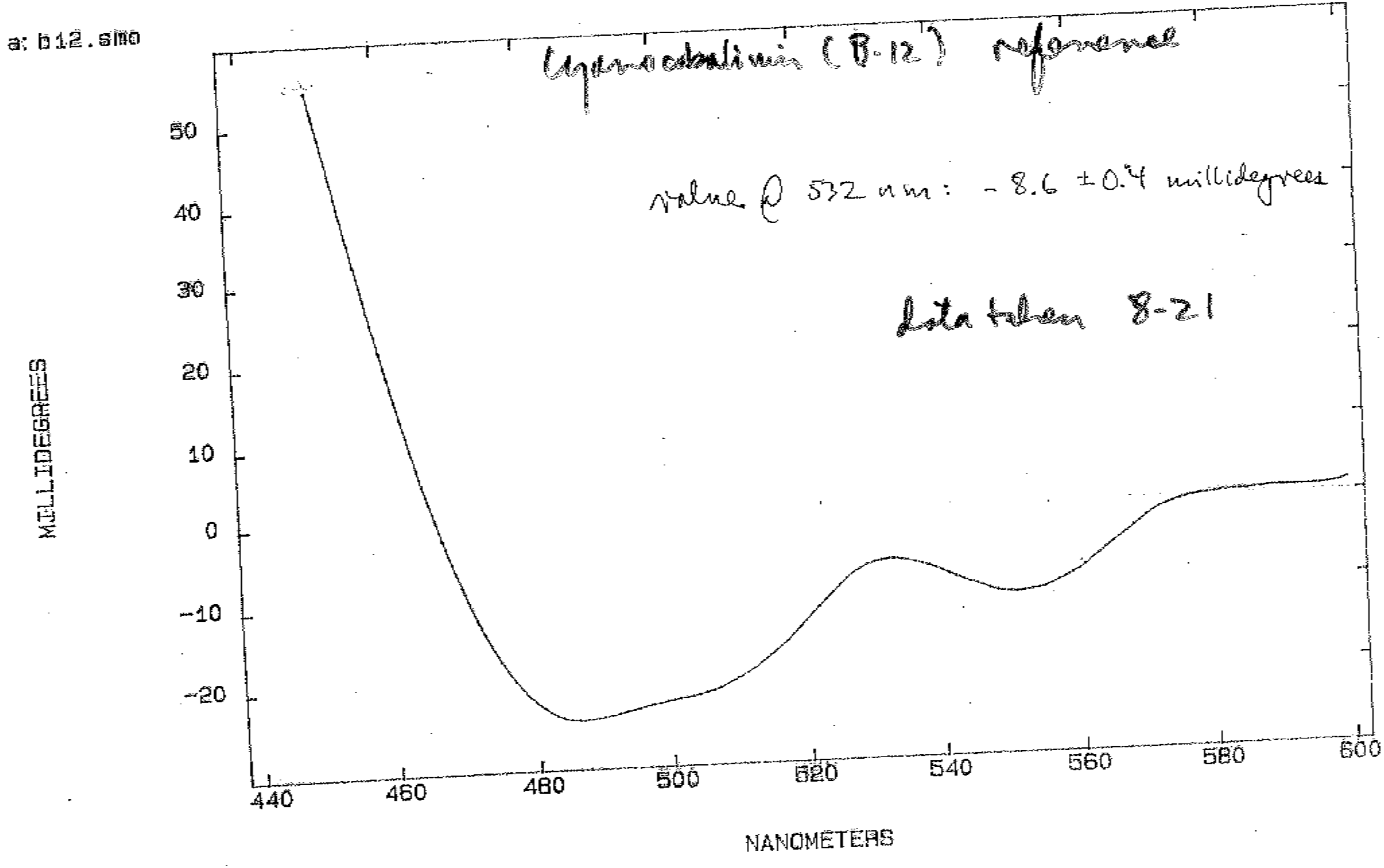


Figure 1


a: b12.smo
Cyanocobalamin (B-12) reference
value @ 532 nm: -8.6 ± 0.4 millidegrees
data taken 8-21
MILLIDEGREES
50
40
30
20
10
0
-10
-20
440
460
480
500
520
540
560
580
600
NANOMETERS

High Precision A_{LR} : Specialized Experiments and Crosschecks

Early Years (1992-95)

- e^- bunch helicity transmission verification

Strong current/helicity correlation setup in SLC verified synchronization of Z & pol data that is automatically provided by hardware –``Extinction test".

- Linac Moller polarimeter/Spin transport tests.

Moller polarimeter, and spin rotation solenoids used to verify the integrity of spin transport : precision Compton polarimeter (and the photocathode Mott polarimeter measurements) are confirmed to ~3%.

- Spin rotation via SLC arc trajectory perturbations

Spin manipulation w/o spin rotation solenoids allows for adjustable arc spin precession sensitivity *dP/dE* - This is minimized, as is the beam energy spread, and chromatic corrections to the polarimeter measurement, in `93 at >1%, are reduced to <0.2%.

SLD BEAM EXTINCTION TEST

M. Woods
07-31-92

R: normal
L: "extinct"

1. PLS SETUP (30 minutes)
   - Put CPS controller in manual advance
   - Add quarter-wave plate and polarizer after CPS Pockels Cell
   - Align quarter-wave plate
   - Put CPS controller in auto advance

2. BEAM SETUP (30 minutes)
   - Adjust BIC and Focus_Z and Lens Box to achieve nominal beam intensity and noise conditions at IP
   - All SLD subsystems should be up
   - Dumper positrons in South Arc

3. SLD SETUP (10 minutes)
   - Setup ~~2~~ 3 random triggers; ~~one at 1 Hz and one at 0.2 Hz~~ 0.5 Hz ("LAC"), 0.1 Hz ("4LC"), 0.05 Hz + CDC calibration pulse (1 / minute)

4. SLD Datataking (1 hour)
   - SLD takes data for 1 hour.

5. Restore PLS (15 minutes)
   - Remove quarter wave plate and polarizer

6. Restore Beams
   - Restore BIC and Focus_Z and Lens Box
   - Recover Collisions at IP

7. Restore SLD Trigger (10 minutes)

TOTAL TIME REQUIRED:
- 1 hour setup
- 1 hour data taking
- 15 minute PLS recovery
- Time to recover collisions?

Preferred Time: Saturday, Aug. 1 0830 to start

High Precision A_{LR} : Specialized Experiments and Crosschecks

Later Years (1995-98)

- Two additional polarimeter detectors operated.

Two detectors of the Compton scattered photons (the Compton e^- are used in the primary device), with divergent systematics, calibrate the primary device to 0.4%.

- Z peak scan for energy spectrometer calibration.

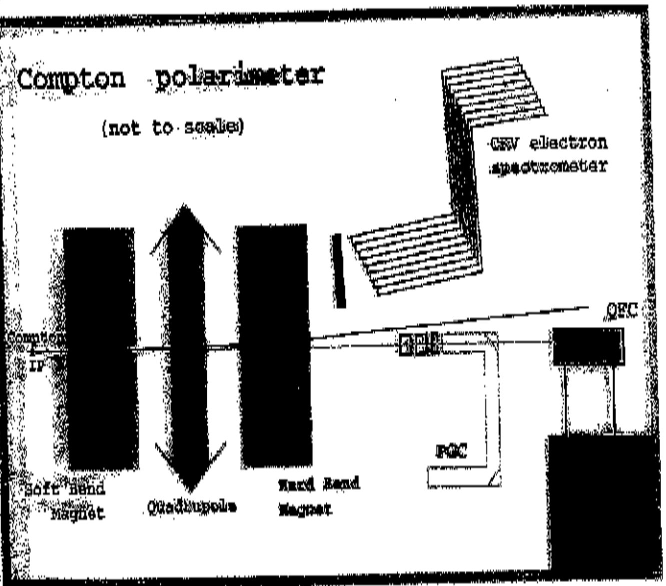
During the '98 run, a short three-point peak scan (~10K Z equivalents) was used to calibrate the Espec system against the LEP Mz. Results increase sys.error due to δE_{cm} to 0.4% (prior estimate was 0.3%) and indicate a small offset.

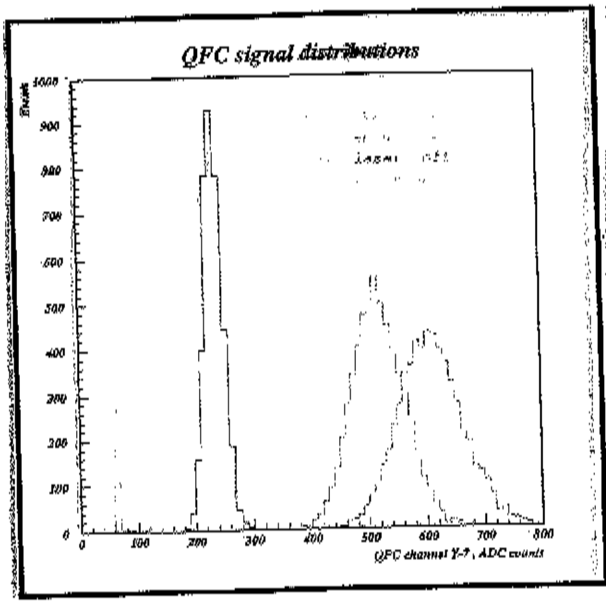
- Dedicated experiment verifies e^+ is unpolarized

At the end of the '98 run, an experiment using the Moller polarimeter in End Station A confirmed that $\mathbf{P}_{e+}$ is consistent with zero (-0.02±0.07%), settling a long standing question.

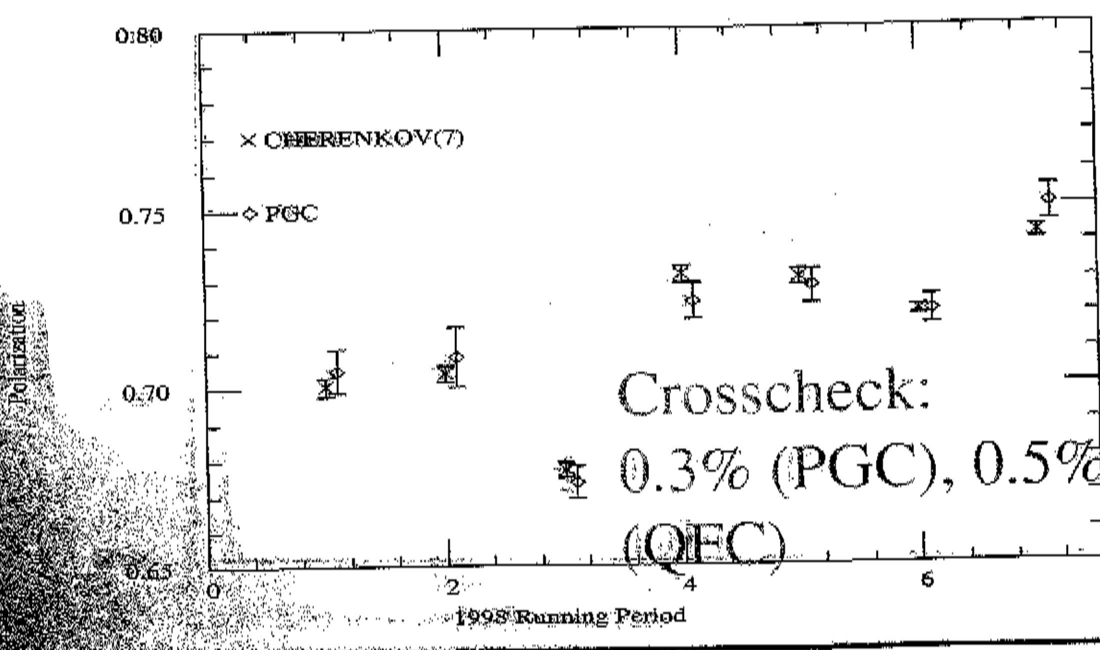
Gamma Polarimeter Crosschecks

Two detectors sensitive to Compton photons, the Polarized Gamma Counter (PGC), and the Quartz Fiber Calorimeter (QFC) - are used to measure an energy asymmetry, independently of the spectrometer used for the precision Cherenkov detector.



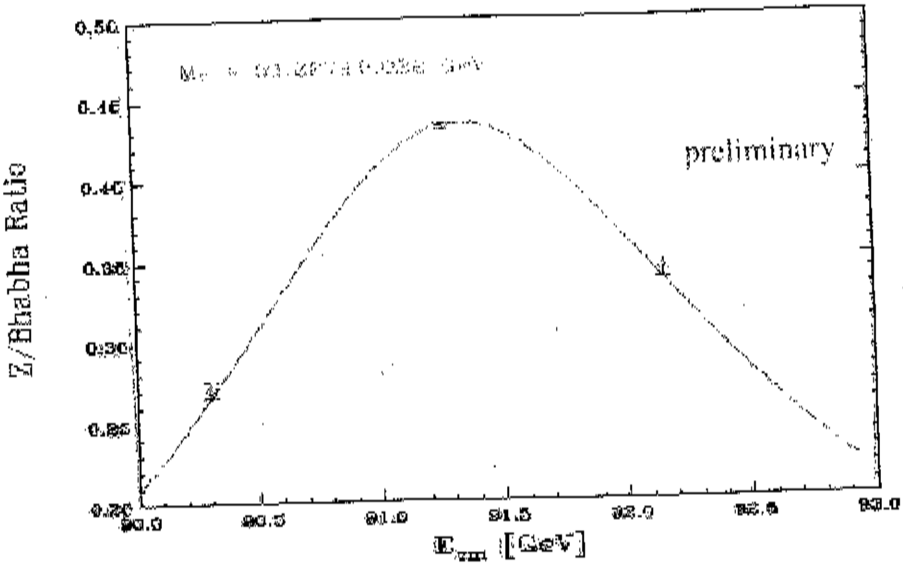


PGC vs. Cherenkov

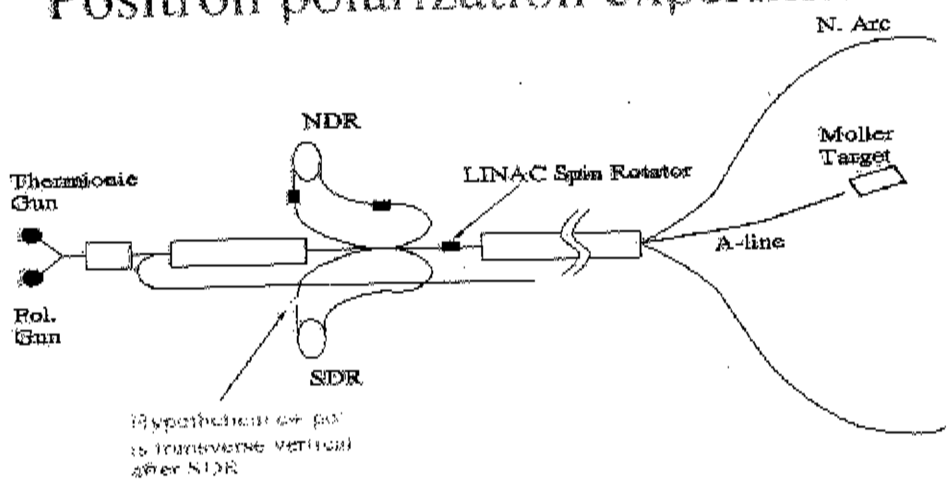


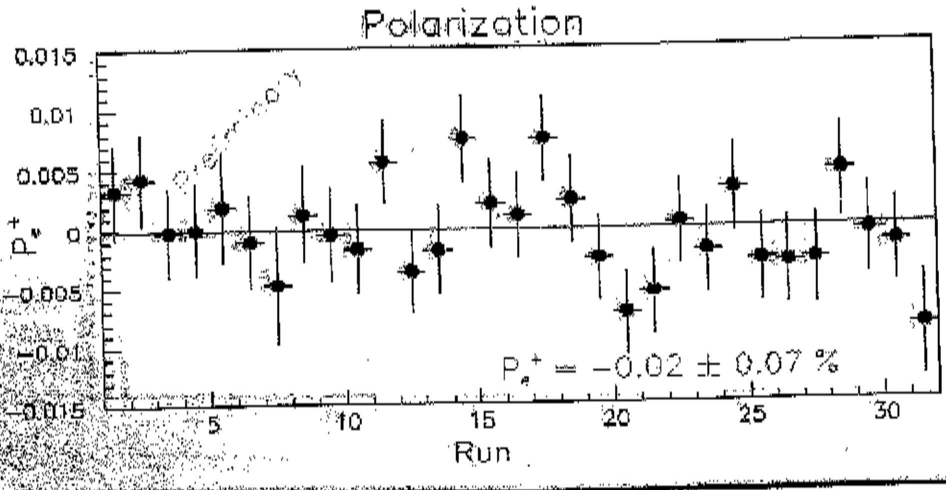
Crosscheck:
0.3% (PGC), 0.5% (QFC)

The Z-Peak scan

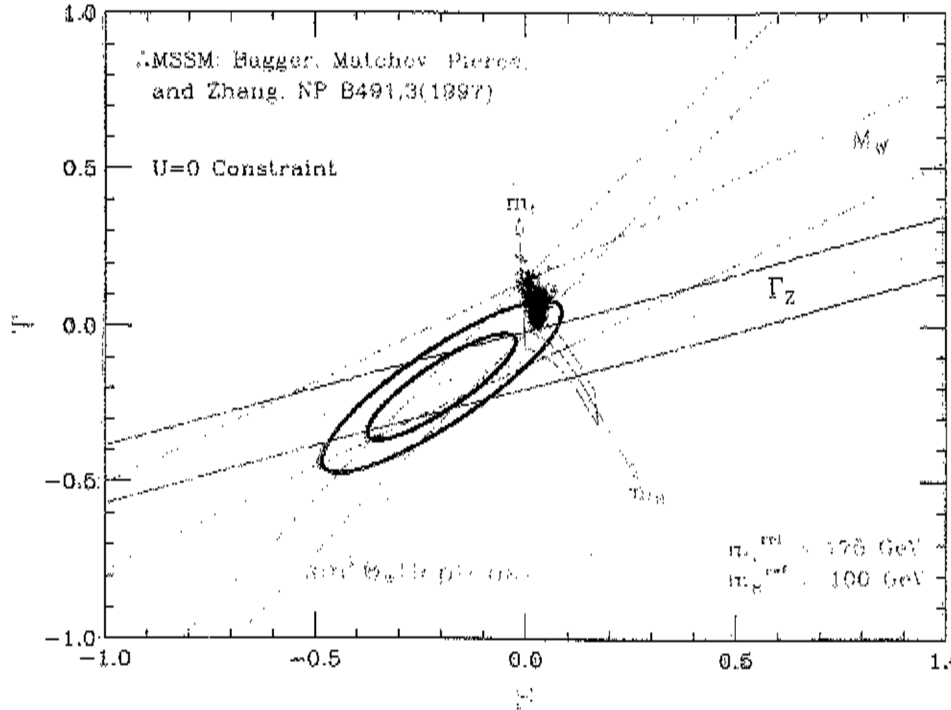


Positron polarization experiment





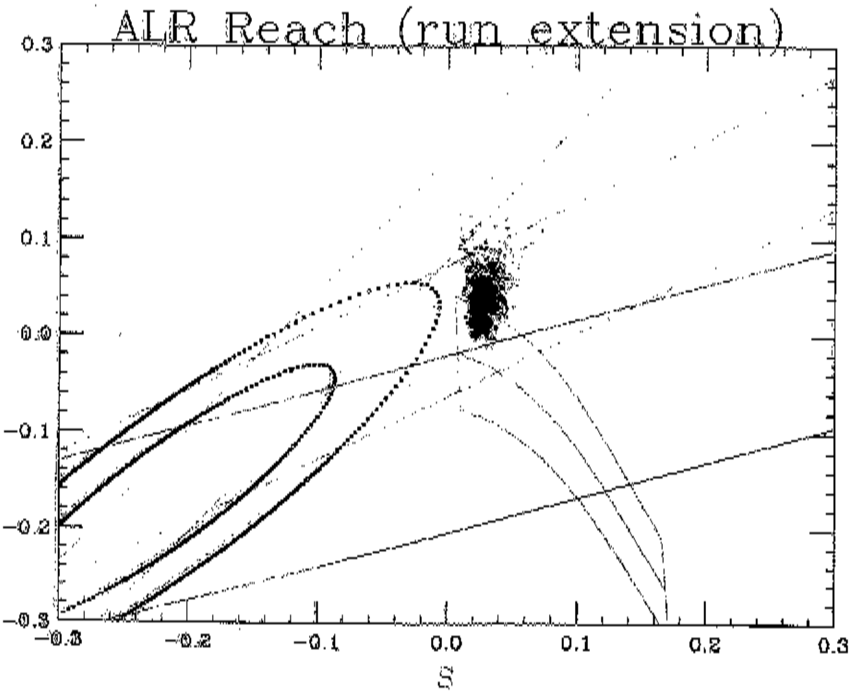
Beyond MSM tests : The STU parameters



The global EW fit compared with the MSM and MSSM. The red points are sampled from the allowed ranges of the 5 MSSM parameters.

In the event of a confrontation with the MSM :
Can the precision data help guide the way ?

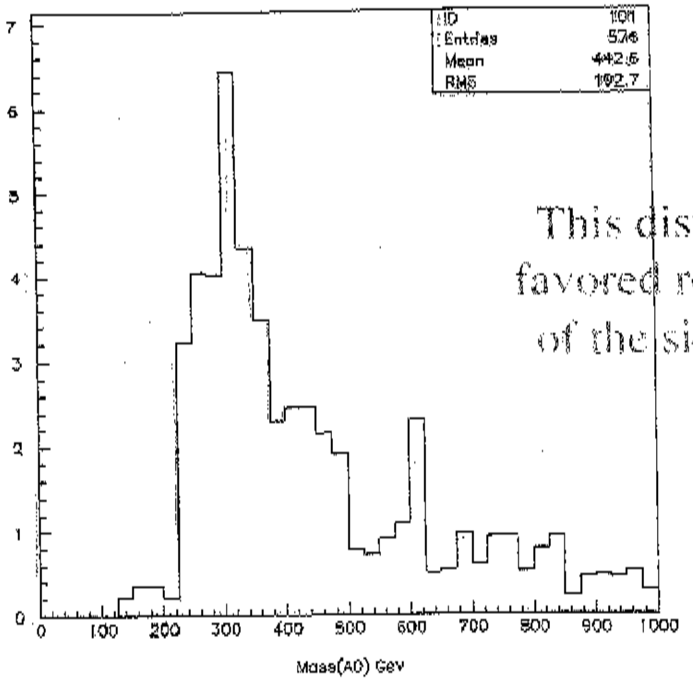
Assuming the above A_{LR} value, the MSSM could be significantly Constrained (modest factor 2 improvement, A_{LR} / M_W shown).



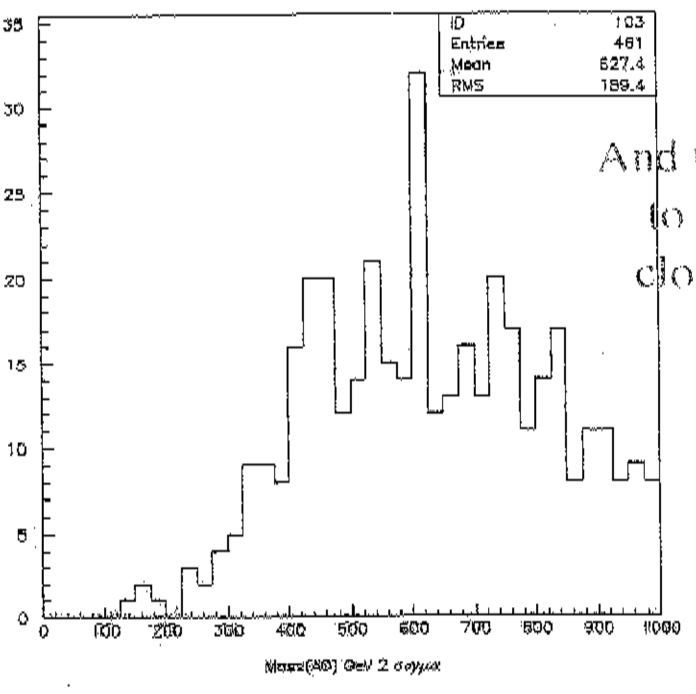
... an illustration of how MSSM can be bounded by future high precision A_{LR} data.

(see Erler and Pierce, Nuc. Phys. B 256, 1998 for a complete treatement of the EW data)

... Look at a MSSM parameter - say, M_A



This distribution corresponds to the favored region, weighted by the error, of the $\sin^2\theta_W^{eff}$ band in the ST plot.



And this distribution corresponds to the complementary region closer to the Standard Model.

This sort of analysis might someday be done at a future LC, with far better resolution.

In some sense, our collaboration was lucky in rather perverse ways

Early Years of the SLC

- SLC startup was incredibly painful ...

But as a result, the SLD was able to move onto the beamline promptly when the Mark II moved off.

- Polarized beam – the centerpiece of the SLC program - also came late ...

But the SLD was able to put this tool to use for the first time, leading to several 'first' measurements.

In addition, the source worked beyond expectations.

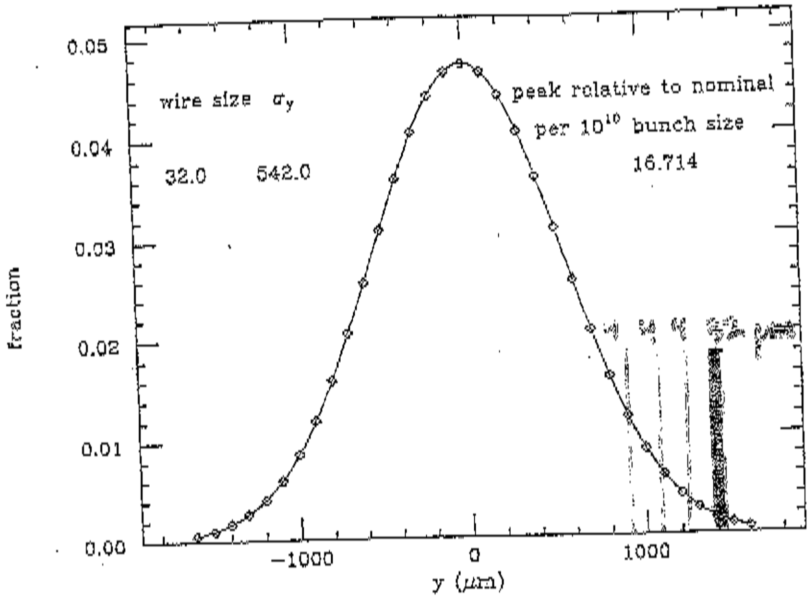
In the Later Years

- The low SLC rep.rate eventually paid off ...

The powerful VXD ended up working far more effectively than I (for one) ever imagined it would.

[illegible]
A Bazarko
8-91

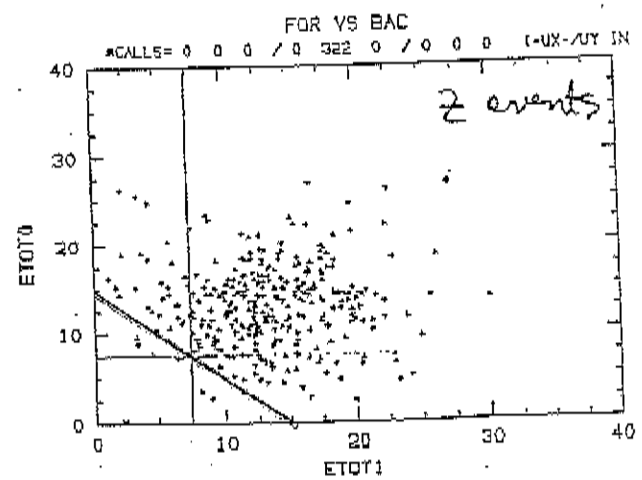
Effective Overlap Function

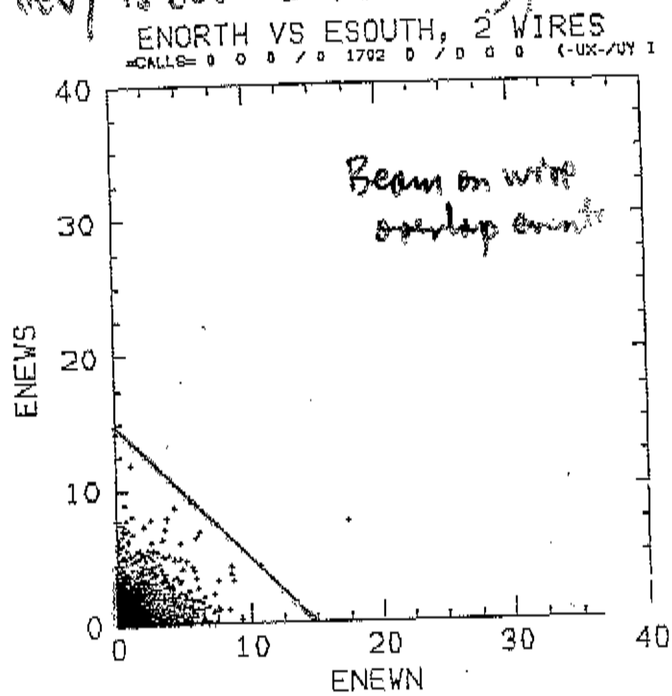


Calculate effective $\int \mathcal{L}$ for ep scattering due to the wires and compare this to a nominal hydrogen plasma (3×10^{18} cc^{-1}, 0.4 cm long)..

... then overlap single beam on wire events to simulate e^+e^- running.

Consider a forward | backward 15 GeV / 15 GeV LAC trigger.





... Conclude that nominal plasma at I.P. would lead to F/B LAC trigger rate of ~0.04 Hz

Last but not least …

- We never had to try the Plasma Lens !