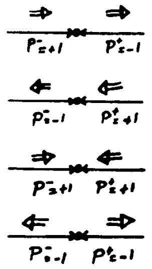
BEAM POLARIZATION ASYMMETRY

$e^+ e^- \to Z$ (at the peak, pure Z)



e^-_R e^+_L $\sigma_R \sim g_r^{e\,2}$

e^-_L e^+_R $\sigma_L \sim g_L^{e\,2}$

e^-_R e^+_R $\sigma = 0$

e^-_L e^+_L $\sigma = 0$

$$A_{LR} = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{g_L^{e\,2} - g_R^{e\,2}}{g_R^{e\,2} + g_R^{e\,2}} = \mathcal{A}_e$$

This is independent on the Decay mode of the Z!

$\Rightarrow$ Just measure σ^{all}_{peak} at the peak for two different beam helicities (if you can)

$10^6 Z's \to \mathcal{O}(10^{-3})$ on $\mathcal{A}_e$

$\mathcal{O}(10^{-4})$ on $\sin^2\theta_W$

This finally looks like what we want!

FORWARD-BACKWARD ASYMMETRY WITH POLARIZED BEAMS

$$A_{FB}^{Pf} = \frac{3}{4} P_Z \cdot \mathcal{A}_f$$

$$\downarrow$$

$$\frac{\mathcal{A}_e + P_{e^+e^-}}{1 + P_{e^+e^-}\mathcal{A}_e}$$

$$P_{e^+e^-} = \frac{P_{e^+} - P_{e^-}}{1 - P_{e^+}P_{e^-}}$$

$\cdot \Leftarrow : P_{e^+}$

$\Rightarrow \cdot : -P_{e^-}$

Form <u>Forward-Backward Polarization asymmetry</u>

$$A_{FB}^{Pol\,f} = \frac{(\sigma_{LF} - \sigma_{RF}) - (\sigma_{LB} - \sigma_{RB})}{+ \quad + \quad +} = \frac{3}{4}\mathcal{A}_f$$

$$= \frac{1}{|P|} \frac{(N_{+P,F} - N_{-P,F}) - (N_{PB} - N_{-P,B})}{+ \quad + \quad +}$$

Purely Parity-Violating quantity

QED effects drop out!

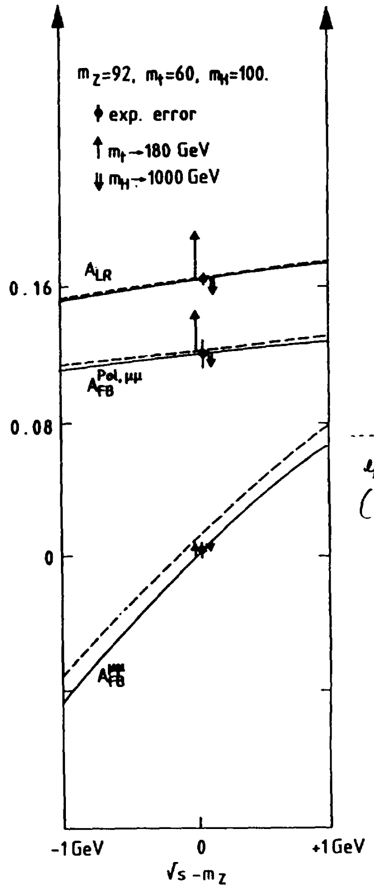
Compare

no Pol $$A_{FB}^{f} = \frac{3}{4} \mathcal{A}_e \mathcal{A}_f$$

with Pol $$A_{LR} = \mathcal{A}_e$$

$$A_{FB}^{Pol\,f} = \frac{3}{4} \mathcal{A}_f$$

- measure directly and independently $\mathcal{A}_f$'s
- no suppression by $\mathcal{A}_e = 0.16$
- no systematic error related to QED effects
- no systematic error related to poor knowledge of $\mathcal{A}_e$
- A_{LR} is f-independent



200 pb^{-1} no Pol
vs 40 pb^{-1}, 50% P.

---- effect of
exp. cuts: 2° Acoll cut
(QED radiation) mostly

+

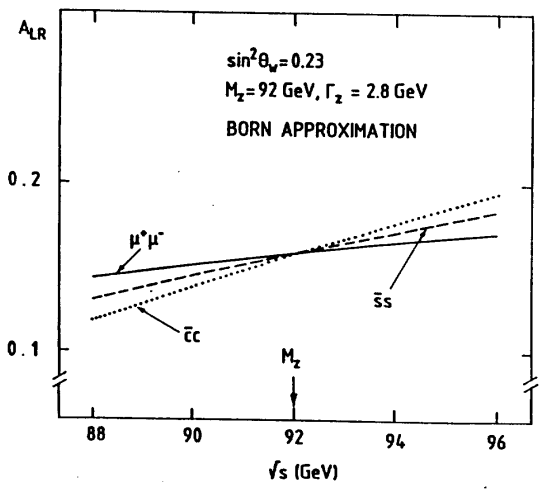


Fig. 3.3 : A_{LR} for different final-state fermions, as a function of $\sqrt{s}$.

no Pol.

A_{LR} A_{FB} A_{FB}^{Pol}

		A_{LR}	$A_{FB}^{(f)}$	$A_{FB}^{pol(f)}$	$\bar{A}_f$
[redacted]	μ,τ	[redacted]	0.02405	0.13431	0.00000
eq.(4),(5),(3),	u,c	0.17908	0.09153	0.51112	0.44665
(12),(13),(14)	d,s,b	0.17908	0.12600	0.70357	0.69163
Including	μ,τ	0.17807	0.02434	0.13355	0.00000
Photon Exchange	u,c	0.17880	0.09157	0.50995	0.44558
	d,s,b	0.17909	0.12604	0.70326	0.69132
Including	μ,τ	0.17245	0.02359	0.13354	0.00420
Photon Exchange	u,c	0.17317	0.08870	0.50994	0.44760
and *Initial Vertex*	d,s,b	0.17345	0.12207	0.70326	0.69169
Including	μ,τ	0.17806	0.02359	0.12934	-0.00420
Photon Exchange	u,c	0.17880	0.09127	0.50825	0.44388
and *Final Vertex*	d,s,b	0.17909	0.12599	0.70297	0.69103
Including	μ,τ	0.17244	0.02286	0.12933	0.00000
Photon Exchange	u,c	0.17316	0.08840	0.50824	0.44590
and *All Vertices*	d,s,b	0.17345	0.12202	0.70297	0.69141
[redacted]	μ,τ	[redacted]	0.00460	0.1274	0.00000
[redacted]	u,c	[redacted]	0.0777	0.5068	0.4465
[redacted]	d,s,b	[redacted]	0.1179	0.7025	0.6912
total	μ,τ	5.5%	83%	5.2%	$< 10^{-3}$
Relative Change	u,c	6.7%	17%	0.8%	2.10^{-4}
from Born value	d,s,b	5.5%	6.3%	0.13%	6.10^{-4}
Born, *changing* m_t	μ,τ	0.19892	0.02968	0.14919	0.00000
to m_t = 180GeV	u,c	0.19892	0.10298	0.51768	0.44635
	d,s,b	0.19892	0.14020	0.70480	0.69154
Relative Change	μ,τ	11%	23%	11%	0.00000
in Born value from	u,c	11%	12.5%	1.3%	6.10^{-4}
Change in m_t	d,s,b	11%	11.2%	0.17%	2.10^{-4}

Table 1: Electroweak effects on A_{LR}, $A_{FB}^{(f)}$, $A_{FB}^{pol(f)}$ and $\bar{A}_f$. Box diagrams have not been included but are very small in the case of polarized asymmetries. Numbers obtained at $\sqrt{s}$ = 92GeV with the computer program EXPOSTAR [12], for m_Z = 92GeV, m_t = 60GeV, m_h = 100GeV (unless otherwise specified).

See. eg. SLC Polarization proposal
or M.L.SWARTZ in Polarization @ LEP 88-06
Vol II p.163

POLARIZATION AT SLC

(noticed already in $\lesssim 1980$ by C. Prescott)

Polarized Source

- Longitudinally Polarized e^- can be produced by Polarized laser on Photo-emissive target (GaAs CsO₂ coated) with $P^- \lesssim \pm 50\%$.
- It can be reversed on a pulse by pulse basis. (SLC Rep. rate is $\lesssim 180$ Hz) by reversing the laser polarization.

Transmission

- can be transmitted to the I.P. with little depolarization (few %) - Solenoid Spin rotators.

$$P^-_{IR} \lesssim \pm 45\%$$

Polarimetry

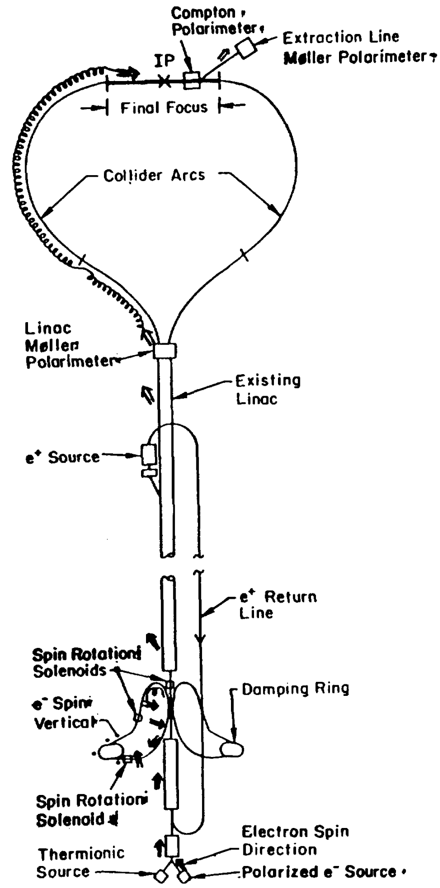
- Measured with compton Polarimetry
  Møller Polarimetry

to $\Delta P/P = (1-5)\%$

Implementation of Polarization-related equipment (which is ordered or ready) awaits good SLC performance.

It can be done at almost no loss in luminosity.

e^+ cannot be polarized.



POLARIZ[illegible] LAYOUT

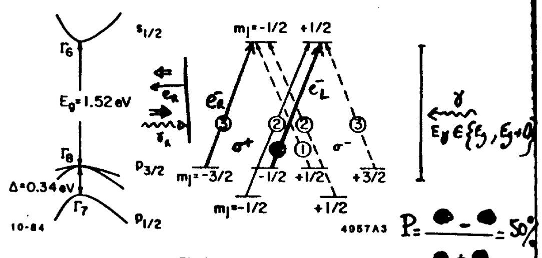


Fig. 3

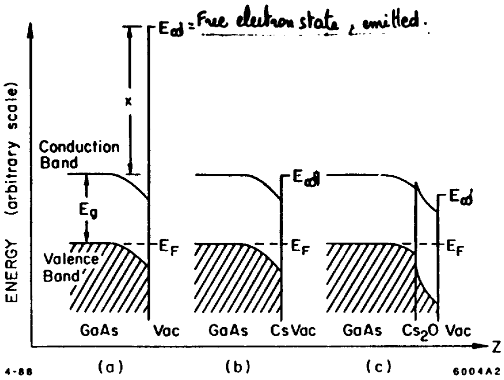
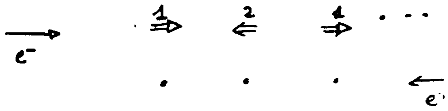


Fig. 4

SLC POLARIZATION RUNNING MODE:



$$\sigma = \sigma_u \cdot (1 - P^+P^- \quad + (P^+ - P^-) A_{LR})$$

measure

$$A_{LR} = \frac{1}{|P|} \frac{\sigma_2 - \sigma_1}{\sigma_2 + \sigma_1}$$

- Data with left and Right handed helicities are taken simultaneously
  - same beam conditions, backgrounds etc.
  - luminosity, trigger & detection efficiencies... cancel out in ratio.
- Limiting error is $\Delta P/P$

$$: \Delta A_{LR} = \frac{1}{P\sqrt{N_1+N_2}} \oplus \underset{0.16}{A_{LR}} \cdot \underset{\substack{0.01\\0.05}}{\Delta P/P} = 8 \, \underset{\substack{0.0002\\ \overline{} \\0.001}}{\Delta \sin^2\theta_W}$$

$\Rightarrow \Delta S_W^2/S_W^2 \sim$ 1-2 10^{-3} Reachable, PROVIDED $\frac{\Delta P}{P} \sim 1\%$

*ABSOLUTE POLARIMETRY: NOT EASY...

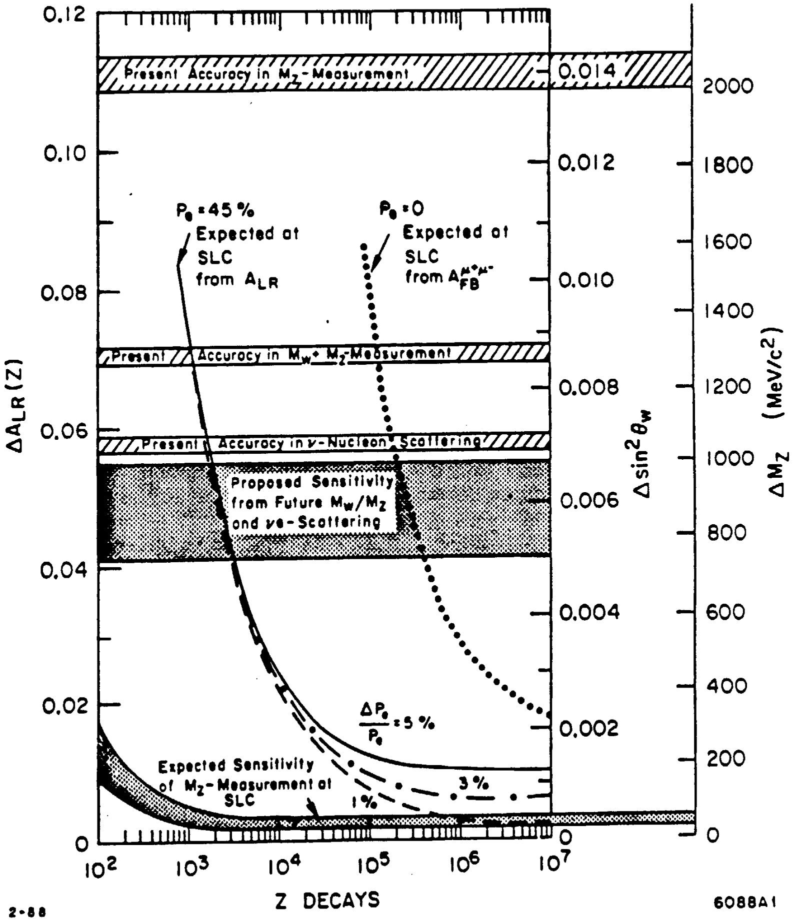

0.12
0.10
0.08
0.06
0.04
0.02
0
$\Delta A_{LR}(Z)$
Present Accuracy in M_Z-Measurement
Present Accuracy in M_W+ M_Z-Measurement
Present Accuracy in ν-Nucleon Scattering
Proposed Sensitivity from Future M_W/M_Z and νe-Scattering
P_e=45 % Expected at SLC from A_{LR}
P_e=0 Expected at SLC from $A_{FB}^{\mu^+\mu^-}$
$\frac{\Delta P_e}{P_e}$=5 %
3 %
1 %
Expected Sensitivity of M_Z-Measurement at SLC
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0
$\Delta \sin^2\theta_W$
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ΔM_Z (MeV/c^2)
10^2
10^3
10^4
10^5
10^6
10^7
Z DECAYS
2-88
6088A1

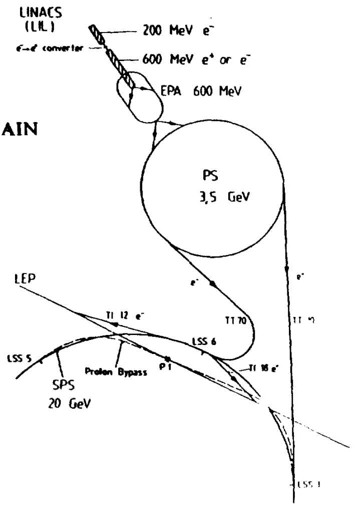
Fig. 1

Due to the complexity of the injection System ⇒
[including 3×ramping-up in circular machines]
It is UNREALISTIC to INJECT Polarized e±

⇒ obtain TRANSVERSE POLARIZATION
at nominal energy VIA
SOKOLOV-TERNOV effect

Need SPIN-ROTATORS to obtain
LONGITUDINAL POLARIZATION in experiment

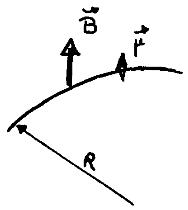
THE LEP INJECTOR CHAIN



GENEVA
1983

Ref. B.W. MONTAGUE
Phys. Rep. 113 #1 (1984)

TRANSVERSE POLARIZATION via SOKOLOV TERNOV



synchrotron radiation has SMALL spinflip probability

$$W^{\uparrow\downarrow\pm} \sim W^{\uparrow\uparrow} \cdot \xi^2 \; (1 \pm 0.94)$$

$$\xi \sim O(10^{-6}) \propto \frac{E^2}{R}$$

+ for e^- spin aligned with $\vec{B}$. ($\vec{\mu}$ opposite!)

Large asymmetry $\frac{W^{\uparrow\downarrow+} - W^{\uparrow\downarrow-}}{W^{\uparrow\downarrow}} \sim 0.94$

tends to align $\vec{B}$ and $\vec{\mu}$

<u>RESULT</u> THEORETICALLY <u>LARGE</u> TRANSV. POL.

BUILDS UP SLOWLY.

$$\tau_p(\text{sec}) = 98.66 \quad R^3(\text{m}) \,/\, E^5(\text{GeV})$$

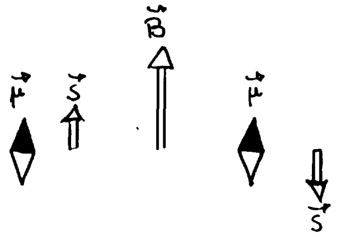
<u>SEEN</u> in any storage ring where it was searched for! ACO, VEPP2, SPEAR, VEPP4 DORIS CESR, PET

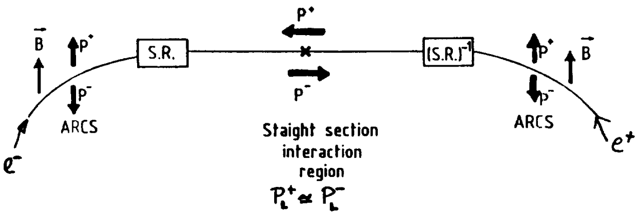
used for physics only seldom

- machine energy calibration
- $A_\perp^{\text{Jet}}$ in SPEAR.

NOTE

$$\vec{P}_{\perp e^+} = -\vec{P}_{\perp e^-}$$





$$\sigma = \sigma_u \left(1 - P^+P^- + (P^+ - P^-) A_{LR}\right)$$

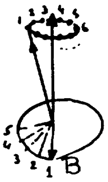
if $P=1$: $\sigma = 0$!

$P^+ \sim P^-$: Sensitivity to A_{LR} is 0.

Need selective depolarization of e^+ or e^- !

DEPOLARIZER

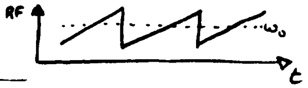
Principle similar to NMR:
observe position of slightly disturbed spin at each passage in one place of the ring : (11 kHz)
(it has turned $104 + \varepsilon$ times)



Superposition of RF field will kill the spin if effect piles up
VERY SMALL PERTURBATION IS SUFFICIENT

APPLICATIONS

- ◆ IF $P_\perp$ available ⇒ measure E_b to 10^{-5}
  ⇒ $\Delta M_Z \lesssim$ MeV from E_b . [overall ~10-20 MeV
- ◆ By CROSSING THE RESONNANCE CONTINUOUSLY , MAINTAIN BEAM DEPOLARIZED.



$$P = P_0 \frac{1}{1 + \frac{\tau_P}{\tau_D}}$$

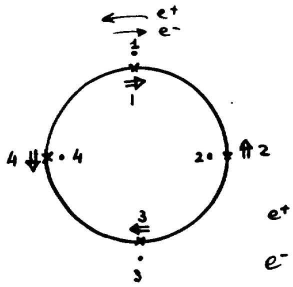
$\tau_D \ll 1$ sec (horiz. component destroyed in ~ 20 msec due to quantum fluctuations)

⇒ $P < 10^{-3} P_0$ (Buon, Jowett)

- ◆ SMALL FIELD SUFFICIENT ⇒ GATING OK

ANY BUNCH IN THE MACHINE CAN B EPT AT $P=0$

LEP HAS 4 e^+ and 4 e^- BUNCHES.



original suggestion
(Rossmanith-Placidi)
lep note 545

depolarize every other bunch

in each I.R:

	1	2	3	4
e^+	•	⇐	•	⇐
	1	4	3	2
e^-	⇒	•	⇒	•
σ:	σ_2	σ_1	σ_2	σ_1

$$\sigma_1 = \sigma_U\left[1 + P^+ A_{LR}\right]$$

$$\sigma_2 = \sigma_U\left[1 - P^- A_{LR}\right]$$

$$\sigma_{1,2} = \frac{\#\text{ events } (Z^0) \text{ in bunch } 1,2}{\text{normalization (bhabhas)}}$$

SIMILAR TO SLC: σ_1 and σ_2 are measured SIMULTANEOUSLY, WITH BEAMS CIRCULATING IN THE SAME MACHINE, IN THE SAME DETECTOR

SYSTEMATICS LIMITED BY POLARIMETRY

(10^6 Z^0's ($40 pb^{-1}$) is matched by $\Delta P/P = 1\%$ absolute)

One WAY TO GET AROUND $\frac{\Delta P}{P} = 1\%$ Absolute IN LEP

INSTEAD OF:

e^-	⇒ •	•	⇒ •	•
e^+	•	⇐ •	•	⇐ •
	σ_1	σ_2	σ_1	σ_2

Do This:
"4-bunch scheme"

e^-	⇒ •	•	•	⇒ •
e^+	•	⇐ •	•	⇐ •
	σ_1	σ_2	σ_3	σ_4

A.B. 1986
(Aleph note 168)

Solve for P^+, P^-, A_{LR}!

$$\begin{cases} \sigma_1 = \sigma_U(1 - P^- A_{LR}) \\ \sigma_2 = \sigma_U(1 + P^+ A_{LR}) \\ \sigma_3 = \sigma_U \\ \sigma_4 = \sigma_U(1 - P^- P^+ + (P^+ - P^-) A_{LR}) \end{cases}$$

- all cross-sections are measured simultaneously

Luminosity and POLARIMETRY are ONLY RELATIVE MEASUREMENTS

Result: 10^6 events ⇒ $\Delta \sin^2\vartheta_W = 0.00035$

Measuring A_{LR}

$$A_{LR} = \frac{1}{P} \frac{\sigma_2 - \sigma_1}{\sigma_2 + \sigma_1}$$

$$\sigma_i = \frac{\text{"\# Z events"}_i}{\text{"normalization"}}$$

- event selection
- normalization
- Polarimetry

(See Aleph note 87-(7))

Z° Selection

- Keep Z°'s and reject $\gamma\gamma$, cosmics, B.G. Bhabhas.

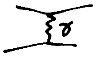
  DUE TO Z° Abundance this is $O(10^{-2})$ less of a problem than in eg PEP/PETRA
  NO PROBLEM.

- Effective E_{CM} shifts
  - QED vs cuts
  - IF Z° IS ON SPIN RESONNANCE..... MUST RUN UP TO ~440 Mev off The pole

$\frac{\partial A_{LR}}{\partial E_{CM}}$ is SMALL ⇒ no problem

OK.

NORMALIZATION

use $e^+e^- \to e^+e^-$  (P_L indept.)

RATES: ($Z^0_{nb} = 25nb$)

- Standard Lumi counters ($\theta_{e^+,e^-} > 50mrad$)
  - ~ 25nb (Aleph,Delphi,Opal) lose $\sqrt{2}$ in precision
  - ~ 100nb (L3) lose $\lesssim 10\%$
- VSALM ($\theta_{e^+e^-} \in [5-7 \text{ mrad}]$)
  - ~ 600 nb OK.

SYSTEMATICS

- small difference between bunches can occur
  - depolarizer - OK.
  - Intensity ⇒ background level.
  - beam-beam blow-up from opposite bunches. with various intensities.

⇒ { beam width and divergence
background

can be different from one bunch to the next.
Intensities will be tuned to ±1% at fill then evolve.....

BUNCH-TO-BUNCH SYSTEMATICS

OTHER THAN SLC, BEAMS ARE STORED FOR ~ 5hrs

Each bunch evolves - potentially differently - on its own. Bunches are differentiated by

- the depolarizer
- Its own intensity
- The intensity of the bunches it crosses.

SLC → $1/\sqrt{N_{pulses}}$ 4.10^9 LEP → $1/\sqrt{N_{Fills}}$ 400

LEP division statements

- Position of interaction points will be identical
- Beam divergences will be identical up to beam-beam blow up
- Bunch intensities will be made equal to ±1%
- Polarization levels since e^+ and e^- orbits are not the same Their polarization need not be the same : $P^+ \neq P^-$
- Beam position and Beam divergence will be CONTINUOUSLY MONITORED For each bunch.

REQUIREMENT ON NORMALIZATION
SYSTEMATICS :

$\Delta A_{LR} < 0.001$ ($\frac{1}{3}$ of goal error)

$\Rightarrow \Delta\left(\frac{L^+ - L^-}{L^+}\right) < 0.002 \cdot P \quad \sim \underline{\underline{10^{-3}}}$

[Large P is beneficial]

CAN ONE KEEP SYSTEMATICS UNDER CONTROL AT THIS LEVEL ?

WHAT CAN VARY ? EVERYTHING.

$x, x', y, y', z,$
$\sigma_x, \sigma_x' \; \underline{\sigma_y \, \sigma_y'} \; \sigma_z$ I.

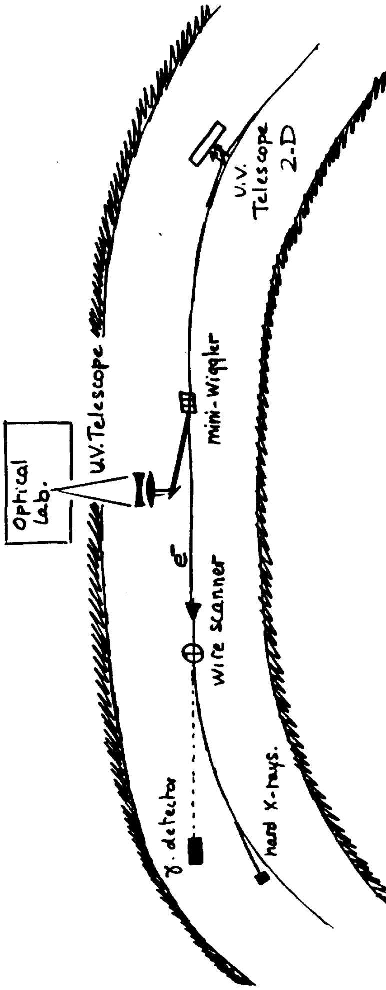
mostly these two!

⇒ These quantities are monitored in LEP with some precision

[what matters is difference between bunches circulating at the same time in the same lattice → relative accuracy]

(C Bovet)

LEP EMITTANCE MONITORS



⇒ beam position & emittance
will be monitored to good enough precision [$\Delta E \sim O(10^{-3}$
CORRECTION PROCEDURE (IF NEEDED) STILL UNCLEAR.

Table 1: *Uncertainties in the bunch to bunch normalization from systematic changes in the bunch geometry*

Parameter at I.R.	typical value	known to	absolute loss in ‰ for typ. val.	systematic uncert. in ‰, $\Delta L_i/L_i$
<x>	100 μm	15 μm	0.9	0.14
σ_x	300 μm	10 μm	2.4	0.08
<y>	100 μm	5 μm	0.9	0.05
σ_y	12 μm	1 μm	0.1	0.01
<z>	1 mm	0.7 mm	0.8	0.59
σ_z	33 mm	0.5 mm	28.0	0.38
<x'>	0	2 μrad	0	0.05
$\sigma_{x'}$	175 μrad	5 μrad	2.6	0.08
<y'>	0	10 μrad	0	0.24
$\sigma_{y'}$	175 μrad	5 μrad	2.6	0.08
total			O (3%)	0.8 ‰

ALEPH

>49 mrad

L3

>29 mrad

Systematic Uncertainties in relative luminosity measurement

Parameter at I.P.	Typical Value	Known to	Absolute Change in °/oo for Typical Value	Systematic* Uncert. °/oo
<x>	100 μm	15 μm	0.1	0.10
σ_x	300 μm	10 μm	1.5	0.05
<y>	100 μm	5 μm	0.1	0.03
σ_y	12 μm	1 μm	0.06	0.01
<z>	1 mm	0.7 mm	0.1	0.11
σ_z	33 mm	0.5 mm	1.5	0.08
<x'>	0	2 μrad	0	0.01
$\sigma_{x'}$	175 μrad	5 μrad	0.05	0.01
<y'>	0	10 μrad	0	0.04
$\sigma_{y'}$	175 μrad	5 μrad	0.05	0.01
Total				0.45

* these errors $\Delta(L)/L$ are obtained under the assumption that all distributions are gaussian.

POLARIMETRY

e^-	•	→	•	→
	1	2	3	4
e^+	←	•	•	←
	1	2	3	4

$$\sigma_1 = \sigma_u \left[1 + P_1^+ A_{LR} \right]$$
$$\sigma_2 = \sigma_u \left[1 - P_2^- A_{LR} \right]$$
$$\sigma_3 = \sigma_u$$
$$\sigma_4 = \sigma_u \left[1 - P_4^+ P_4^- + (P_4^+ - P_4^-) A_{LR} \right]$$

4 equations → σ_u P^+ P^- A_{LR} *if*

- $\mathbf{P}_{aepd} \equiv 0$ (OK) must be verified.
- $P_1^+ = P_4^+$, $P_2^- = P_4^-$ Not Necessarily true
- No time evolution WRONG.

HOWEVER , CAN BE USED TO EXTRACT ABSOLUTE CALIBRATION OF e^+ and e^- POLARIMETERS

$$P^{\pm}_{true} = \alpha^{\pm} P^{\pm}_{meas} \quad \left[\text{luminosity-weighted integrals} \right]$$

PROVIDED

- POLARIZATION IS CONSTANTLY MONITORED [reading at <10' intervals ⇒ no 2D order on eq. 4]
- [luminosity weighted integral of] CALIBRATION CONSTANT IS THE SA (within ± 3 10^{-3}) for bunch 1 and ⊕
  2 " 4 ⊖

→ bunch -to- bunch systematics [at a less stringent level than Bhabhas...]

IF THESE CONDITIONS ARE FULLFILLED THE MEASUREMENT OF ALR IS NOT LIMITED BY $\Delta P/P$ SYSTEMATICS.

- ANOTHER IMPORTANT ROLE OF THE POLARIMETER : TUNING OF LEP . THIS REQUIRES VERY FAST MEASUREMENT OF THE POLARIZATION.

Polari metry

Principle : measure Left-Righ Asymmetry of back-scattered Polarized laser beam on $e^{\pm}$ beam

transverse electron polarization → up-down asymmetry
longitudinal " → energy "

With reasonably standard laser (300 mJ/pulse, 10 Hz)
Yag Nd doubled 530 nm

get ~ $10^{4\pm 1}$ recoils / pulse

$\Delta P \sim 2\%$ per minute

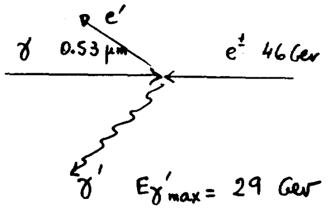
Systematic errors are very small on relative polarization measurements $\Delta P/p \sim 0.2\%$

Absolute measurement no better than ~2%

THUS
LEP no Pol
SLC, Pol (need absolute $\Delta P/p$)
LEP, Pol
precision ↑

N.B. Can also use (with cristals) $\vec{e}^+\vec{e}^- \to e^+e^-\vec{\gamma}$ ↳ when hard, Polarized.
(G. Bologna, G. Diambrini)

compton scattering :



$E_{\gamma'max} = 29$ Gev

$P_{\perp e,\gamma} \sim 1$ Mev $\theta \sim 20\,\mu$rad
6 mm @ 300 m

FORESEEN $P_\perp$ - meter

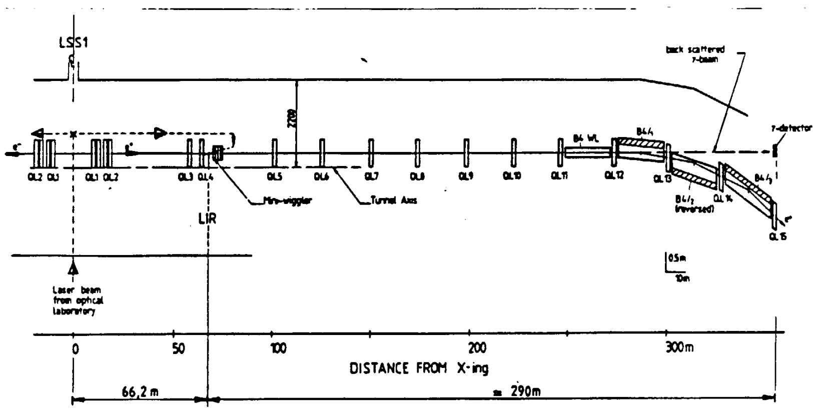
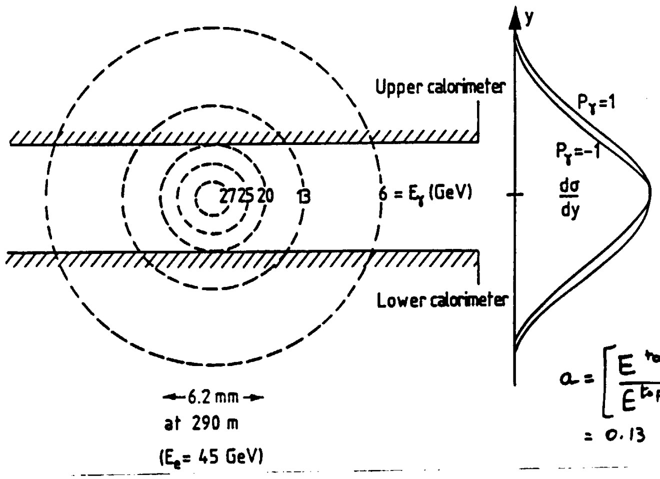


Fig. 3.4 : Layout of the LEP division proposal for transverse polarization measurement.

intersection point chosen to minimize effect of Beamdivergence

H. PLACIDI, R. ROSSMANITH, LEP-BI/86-25



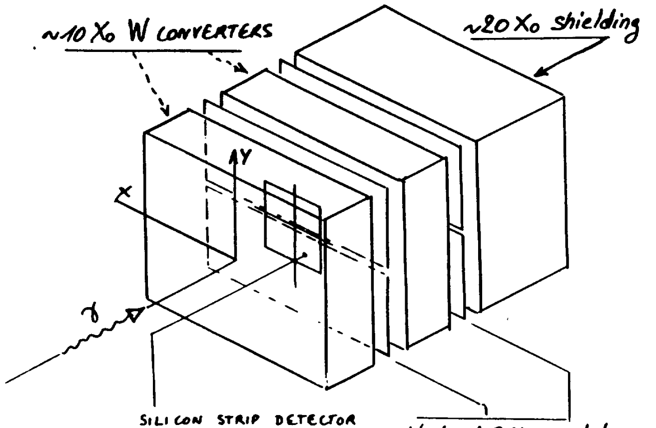
$$a = \left[\frac{E^{top} - E^{low}}{E^{top} + E^{low}}\right]^{P=1} = 0.13$$

Fig. 3.5 : Situation at the gamma detector 290 m downstream of the e-γ interaction point. (In addition there is a smearing of ±1.1 mm vertically and ±12 mm horizontally).

EXPECTED PERFORMANCE : > $10^{4\pm1}$ Backscatters/shot at 10 Hz ⇒ $\Delta P = 2\%$ in 2′

$P_\perp$-METER : γ DETECTOR

(M.PLACIDI in WORKSHP ON Pol^n at LEP)
(NOV 89)



SILICON STRIP DETECTOR

(VERTICAL PROFILE)

16 ch / 32 mm / $\pm 6\sigma_{\gamma V}$

[measurement of Barycenter displacement more reliable than up down asymmetry]

Vertical Silicon plates
~ 50 x 80 mm^2
± 2 mm dead area
in midplane

ESTIMATE $\frac{\Delta P}{P}$ (absolute) $\lesssim \pm 5\%$; but VERY GOOD $\frac{\Delta P}{P}$(relative)

Initial state radiation from $e^+e^- \to e^+e^-\gamma$

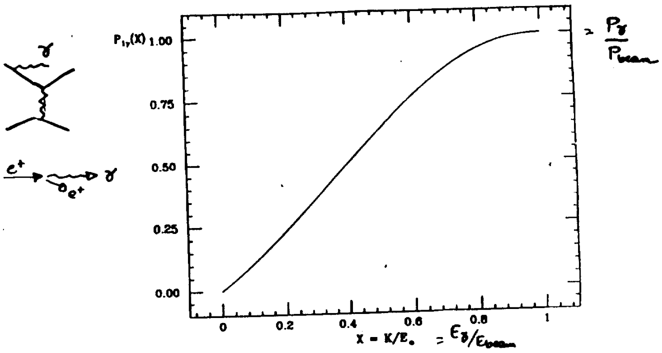


Fig.1

Very abundant (~20 γ/crossing with E/1 ~ 0.2)

Measure Photon polarization using property of cristals to have {Polarization dependend radiation length / axis orientation ϕ.

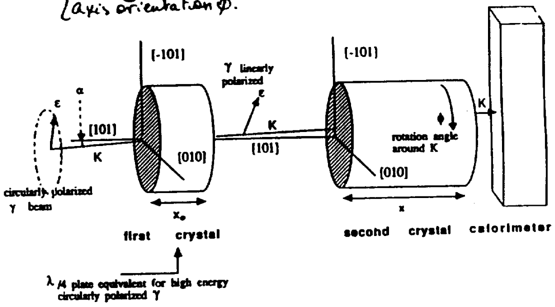


Fig.8

P_L meter:

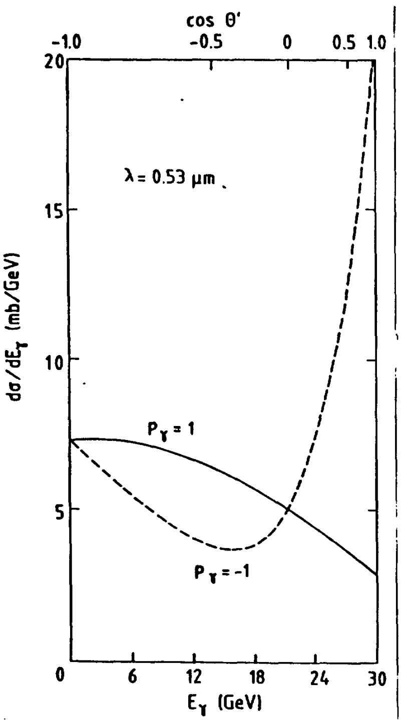


Fig. 3.6 : Energy spectrum of Compton scattered laser photons: the electrons are 100% longitudinally polarized. Right ($P_\gamma = 1$) and left ($P_\gamma = -1$) circular light polarization. The Compton scattering angle θ' in the electron rest frame is also indicated

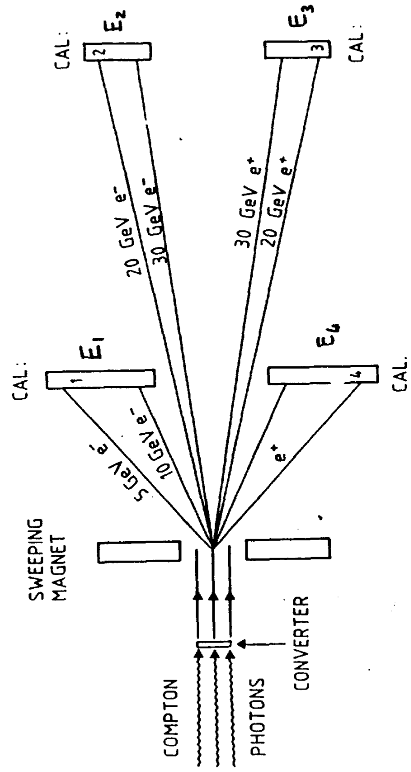


FIG. 19

$$a = \underbrace{\frac{\left\{\frac{E_2+E_3}{E_1+E_4}\right\}_L - \left\{\frac{E_2+E_3}{E_1+E_4}\right\}_R}{+}}_{0.47} . P_e . P_\gamma$$

Measurement of A_{LR} via 4 bunch scheme

$$\Delta_{A_{LR}} = \sqrt{\frac{(1+1/\gamma)(1+\rho)^2}{P^2 N} + \frac{(1+\rho^2)}{4P^2}\left(\frac{\Delta L}{L}\right)^2_{syst} + \left(A_{LR}\cdot\frac{\Delta P}{P}\right)^2_{syst}}$$

relative bunch to bunc

γ = bhabha rate / Z rate

ρ = fraction of running time for $\cdot\cdot$ + $\Rightarrow\Leftarrow$ configuratio
optimized. (need ~ 20% for P = 50%)

$\Rightarrow$ for P = 50%

2 pb^{-1} will match precision of 200 pb^{-1} unpol

40 pb^{-1} will get $\Delta A_{LR} \lesssim 0.003$!

$\Delta s^2 / s^2 = 1.6\ 10^{-3}$

Theoretical limit presently set by uncertainty
in $e^2_*(M_Z^2)$. (low energy e^+e^- data)
to $\Delta A_{LR} = 0.002$ (remeasure?)
$\Delta s^2/s^2 = 10^{-3}$

IV obtaining Longitudinal POLARIZATION in LEP

It looks as if,
were polarized beams available,
one could make very good use of them ....

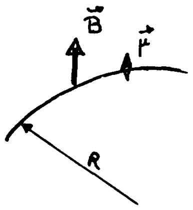
How can one get Polarization in LEP?

[illegible] Bad -

- transverse polarization build-up in the Arcs (Sokolov Ternov
  τ_p = 310 min. @ LEP, 46 GeV. Too slow! $\tau_L = 200'$
- depolarizing effects (defects) increase $\propto E$.
- Energy spread of same order as distance between depolarizing resonances.
- Polarization not expected → not foreseen
  (how and where to build spin Rotators?)
- Polarization vs Luminosity - ?

It is also fair to say that polarization has not been sought after very hard in low energy machines. (no incent for φ!)
But it been seen everywhere (80% at PETRA)

TRANSVERSE POLARIZATION via SOKOLOV TERNOV



synchrotron radiation has SMALL spin flip probability

$$W^{\uparrow\downarrow\pm} \sim W^{\uparrow\uparrow} \cdot \xi^2 \; (1 \pm 0.94)$$

$$\xi \sim O(10^{-6}) \propto \frac{E^2}{R}$$

\+ for e^- spin aligned with $\vec{B}$. ($\vec{\mu}$ opposite!)

Large asymmetry $\frac{W^{\uparrow\downarrow +} - W^{\uparrow\downarrow -}}{W^{\uparrow\downarrow}} \sim 0.94$

tends to align $\vec{B}$ and $\vec{\mu}$

<u>RESULT</u> THEORETICALLY <u>LARGE</u> TRANSV. POL.

BUILDS UP SLOWLY.

$$\tau_p(\text{sec}) = 98.66 \quad R^3(\text{m}) \,/\, E^5(\text{GeV})$$

<u>SEEN</u> in any storage ring where it was searched for! ACO, VEPP2, SPEAR, VEPP4 DORIS CESR, PETRA

used for physics only seldom

- machine energy calibration
- $A_\perp^{\text{Jet}}$ in SPEAR.

---

in LEP 46 GeV, $R \sim 3$ km $\Rightarrow \tau_p \sim 5$ hrs!

need $\boxed{\text{WIGGLERS}}$, foreseen in straight section

<u>Exist</u> →

$B^+ \sim 1$T

$B^- \sim 0.4$T

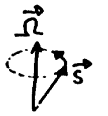
$$\tau_p^W = \frac{\tau_p}{1 + \frac{B^{+3}\ell^+ + 2B^{-3}\ell^-}{(2\pi R \cdot B^3)_{\text{RING}}}} \quad \searrow$$

$$P_\infty^W = P_\infty \cdot \frac{B^{+2} - B^{-2}}{B^{+2} + B^{-2}} \quad \searrow$$

$$\Delta E_W = \Delta E \cdot \sqrt{\frac{1 + \frac{\int_W B^3 d\ell}{\int_{\text{RING}} B^3 d\ell}}{1 + \frac{\int_W B^2 d\ell}{\int_{\text{RING}} B^2 d\ell}}} \quad \uparrow$$

- Polarization time decreases to ~ 80'
- Asymptotic pol reduced by ~ 0.75 with Existing Wigglers. could be almost 100% P_∞ with dedicated wigglers.
- Increase in beam energy spread <u>UNAVOIDABLE</u> ⇒ LIMITING FACTOR due to DEPOLARIZING RESONNANCES!

SPIN PRECESSION



Thomas, Bargman Michel Telegdi equation: $\frac{d\vec{S}}{dt} = \vec{\Omega}_{BMT} \times \vec{S}$

$$\vec{\Omega}_{BMT} = -\frac{e}{m\gamma}\left[\vec{B} + \underleftrightarrow{\gamma a \vec{B}_\perp + a \vec{B}_\parallel}\right]$$

relevant part in particle's rest frame

$$a = \frac{g-2}{2} = 1.1596\ 10^{-3}$$

- $\gamma a \approx 104$ for $E_b = 46$ GeV

SPIN RESPONDS 104 TIMES MORE TO TRANSV. PARASITIC MAG. FIELDS THAN THE PARTICLE

- IF ANY IMPERFECTION "PILES-UP" TURN AFTER TURN

$\Rightarrow$ STRONG DEPOLARIZATION (SPIN RESONNANCE)

Integer resonnances $\gamma a = k_0$

Vertical & Horizontal Betatron " " $\pm Q_x$ $\pm Q_y$

Synchrotron " " " " $\pm Q_s$

SPACING BETWEEN RESONNANCES IS CONSTANT

[$\Delta E = 440$ MeV for Integer resonnances]

BUT ENERGY SPREAD ↗ WITH ENERGY $\Delta E \approx 50$ MeV at 50 GeV

$\ast \longrightarrow$

$\Rightarrow$ IT IS HARDER AT LEP !

SIMULATIONS GOING ON (KOUTCHOUK)

$\ast \longrightarrow$

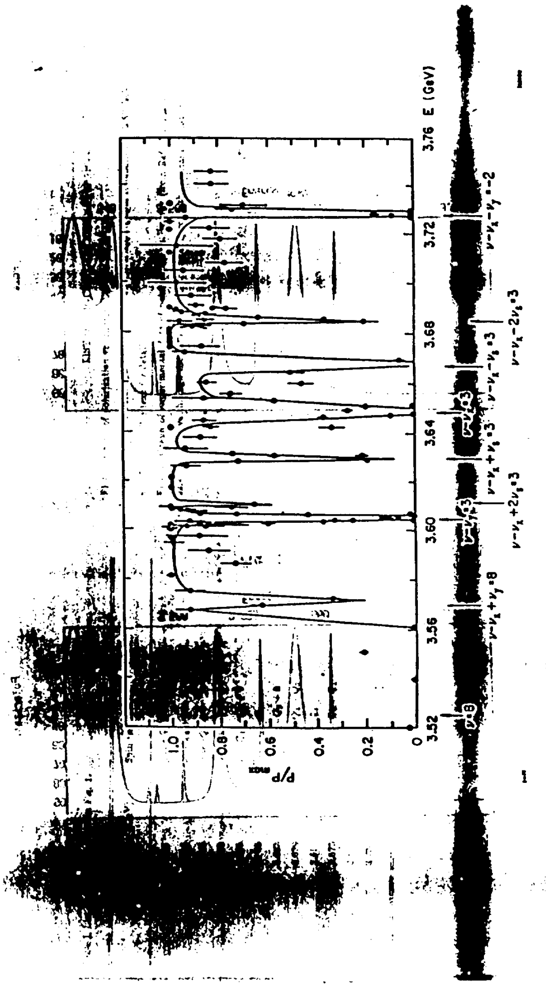


FIG 3

POLARIZATION FIGURE OF MERIT

$$\Delta A_{LR} = \sqrt{\frac{1}{P^2 N}} \Rightarrow F = \int_{run} P^2(t)\,\mathcal{L}(t)\,dt.$$

50% polarization, 40 pb^{-1} ⇐ F = 10 pb^{-1}

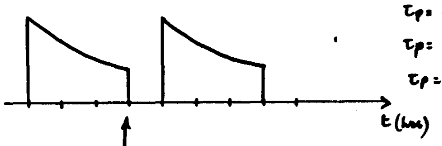
EFFECTIVE POLARIZATION:

$$\langle\!\langle P \rangle\!\rangle = \sqrt{\frac{\int_{run} P^2(t)\,\mathcal{L}(t)\,dt}{\int_{run} \mathcal{L}(t)\,dt}} = \sqrt{\frac{F}{L}}$$

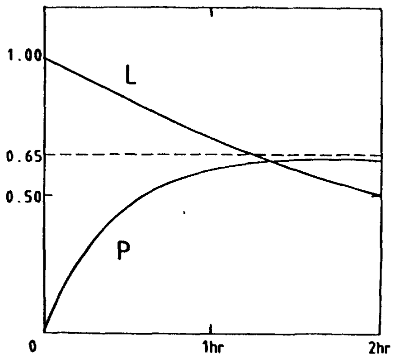
- optimization of F in running conditions:

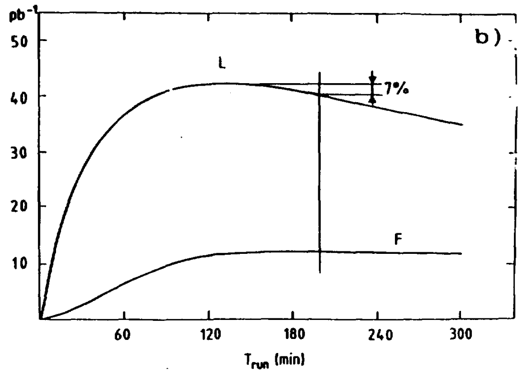
Loss in L:

τ_p = 300'	33%
τ_p = 90'	17%
τ_p = 36'	7'



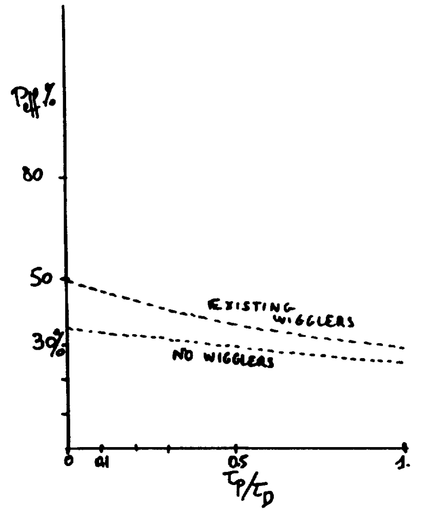
when shall I dump the beam to fill again





EFFECTIVE POLARIZATION

$$P_{eff} = \sqrt{\frac{\int P^2 L(t)\,dt}{\int L(t)\,dt}}$$



(Reaching 50% effective polarization with existing wigglers is a LOSING PROPOSITION)

65

damping (4)
& emittance (4) wigglers
Foreseen Asymmetric

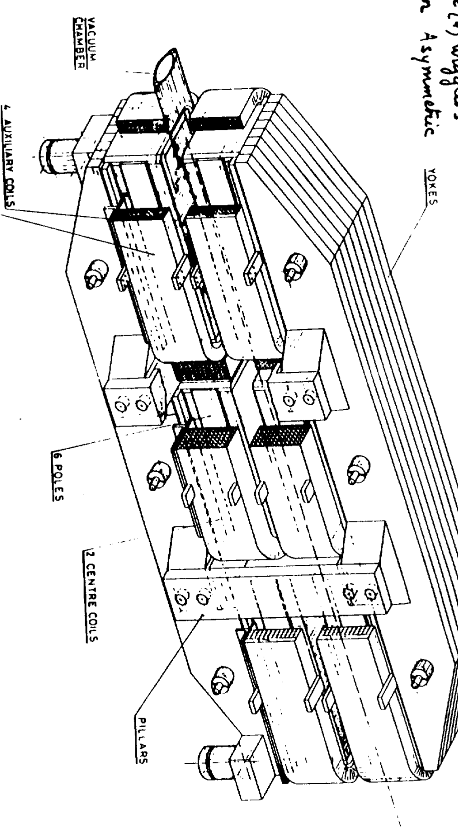


Fig. 6.11 Wiggler magnet (preliminary design)

Progress # 1: (A.B, John Jowett)

DEDICATED POLARIZATION WIGGLERS.

It is obvious that even 90′ is too long considering

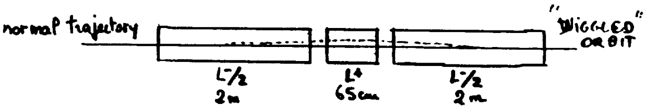
i) τ_p vs $\tau_L \sim 180'$

ii) imagine trimming 8 [correlated] knobs that take 1h 30′ to respond, to find an optimum!

$$W_p = 1/\tau_p \propto \left(\frac{1}{\gamma^5}\right) \int_{ring} |B|^3 d\ell$$

LEP : 18 km . B = 0.05 T $B^3\ell = 2.4$

add wigglers:



B	- 0.2T	+ 1.3T	- 0.2T	$\underline{\Sigma B.L = 0}$
$B^3\ell$	0.016	1.42	0.016	
12 such units ⇒ $\Sigma B^3\ell$:	0.19	$\boxed{17.14}$	0.19	

LIMITATION : INCREASE IN $\Delta E/E$ → INCREASE OF LATERAL BEAM SIZE IN THE ARCS ⇒ HITS THE PIPE

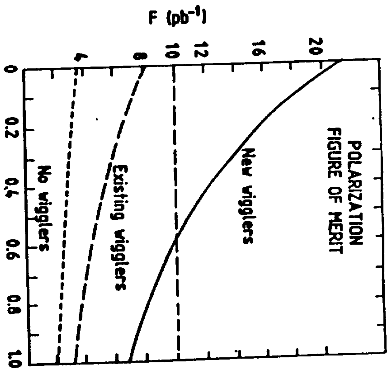


Figure 7: Polarization figure of merit, F, and effective polarization as a function of the relative strength of depolarizing effects τ_p/τ_d for different wiggler configurations.

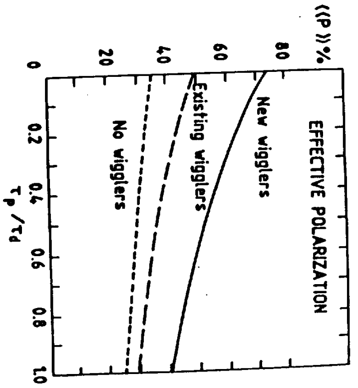


Figure 8: Effective polarization as a function of the relative strength of depolarizing effects τ_p/τ_d for different wiggler configurations.

BY PLACING

POLARIZATION - DEDICATED WIGGLERS

IN STAIGHT SECTION, ONE CAN REDUCE

THE POLARIZATION TIME TO 36′ (10%)

GOODIES:

$$P_\infty^{MAX} = \frac{\Sigma B^3 \rho}{\Sigma |B^3 \rho|} = 89\% \quad (\text{max no wiggs} = 92.4\%)$$

Depolarizing effects:

$$\text{rate} \quad w_D = 1/\tau_D \;\alpha\; \sum_{\text{magnets}} B^3 \rho \left\{ \underbrace{\left| \gamma \cdot \frac{\partial \hat{n}}{\partial \gamma} \right|^2}_{} \right\}$$

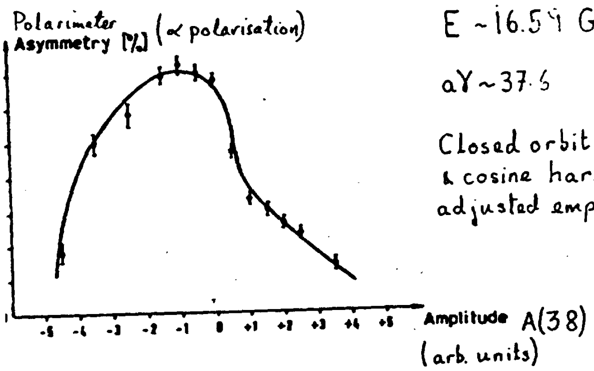
This is the change of the direction (unit vector $\hat{n}$) of the equilibrium spin axis when losing $\frac{\partial \gamma}{\gamma}$ energy by radiation in this magnet.

$\frac{\partial n}{\partial \gamma} = 0$ in perfect machine, $\neq 0$ in presence of real defects.

once again wigglers dominate!

It is much easier to make $\frac{\partial \hat{n}}{\partial \gamma} = 0$ in a few magnets (wigglers) {$\boxed{2}$ stations of 6 wigglers each} Than in every magnet in the machine

Closed orbit correction-scheme

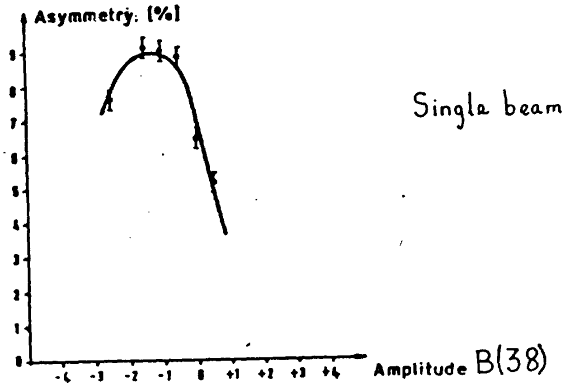


PETRA

E ~ 16.59 GeV

aγ ~ 37.6

Closed orbit sine & cosine harmonics adjusted empirically

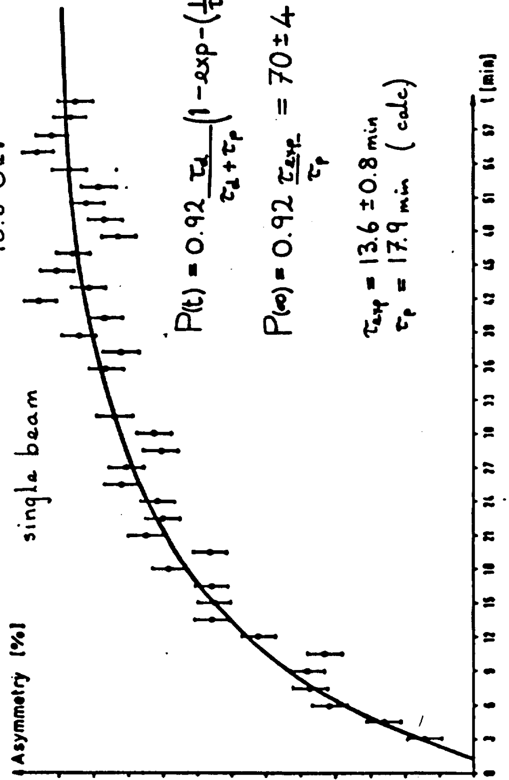


Single beam.

⑦

PETRA
single beam

16.5 GeV



$$P(t) = 0.92\,\frac{\tau_d}{\tau_d+\tau_p}\left(1-\exp-\left(\frac{1}{\tau_p}+\frac{1}{\tau_d}\right)t\right)$$

$$P(\infty) = 0.92\,\frac{\tau_{exp}}{\tau_p} = 70\pm4\,\%$$

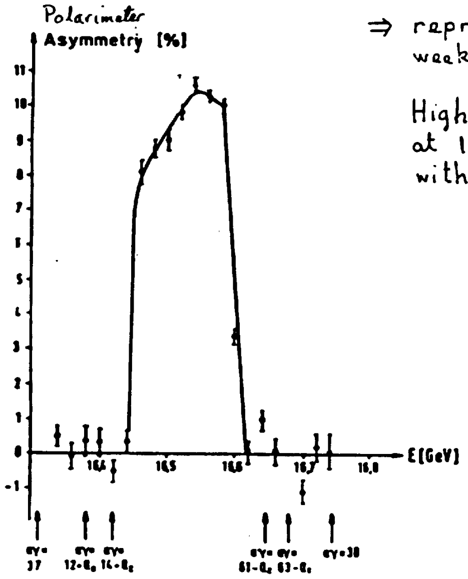
$\tau_{exp} = 13.6 \pm 0.8$ min

$\tau_p = 17.9$ min (calc)

---

⑫

PETRA



Single beam

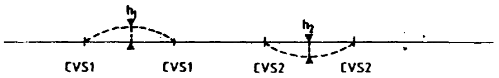
Optimize 38th harmonics.

⇒ reproducible over weeks

Highest $\overset{\text{polarisation}}{\wedge}$ ~ 70-80% at 16.52 GeV. with 37+38

SPIN CORRECTORS FOR LEP

LITTLE ROTOSPINS : DO NOT MODIFY ORBIT OTHER WISE -



Vertical betatron phase:

Φ_y:	0	π	2π	3π

Spin phase (at aγ=104.2)

χ :	0	2π+π/4	4π+π/2	6π+3π/4

Fig. 2 Situation of the two vertical bumps situated at 90° phase advance on one side of the machine.

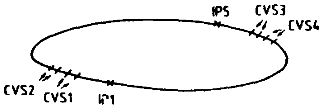


Fig. 3 The four bumps used to optimize the polarization.

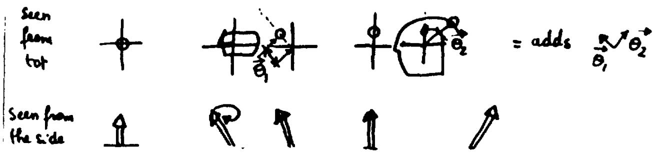


Table 2

Same as Table 1, but in the machine without wigglers

Corrector settings (μrad)				P% (%)	τ_p/τ_D All magnets				$\langle\delta\bar{n}\rangle$ (mrad)
CVS1	CVS2	CVS3	CVS4		All	s	x	y	
0	0	0	0	$\boxed{7.74}$	9.97	9.74	0.13	0.09	15.82
10	0	0	0	7.81	9.87	9.62	0.125	0.079	14.59
0	-10	0	0	8.69	8.77	8.59	0.153	0.103	14.85
0	0	-10	0	8.48	9.00	8.78	0.151	0.102	14.92
0	0	0	-10	7.96	9.67	9.42	0.146	0.103	14.37
0	-30	0	0	10.81	6.85	6.78	0.19	0.137	13.47
0	-60	0	0	13.65	5.22	5.28	0.29	0.208	13.13
0	-80	0	0	14.25	4.95	5.108	0.37	0.26	14.13
0	-100	0	0	13.36	5.35	5.58	0.46	0.34	15.94
0	-78	-30	0	23.72	2.58	2.67	0.466	0.355	16.99
0	-78	-60	0	32.97	1.57	1.59	0.59	0.47	21.01
0	-78	-80	0	30.78	1.67	1.62	0.69	0.56	24.01
0	-78	-68	0	33.44	1.54	1.52	0.63	0.506	22.19
0	-78	-68	-10	40.117	1.11	1.06	0.67	0.55	21.13
0	-78	-68	-30	49.06	0.73	0.58	0.78	0.65	19.30
0	-78	-68	-40	48.05	0.76	0.57	0.84	0.70	18.69
0	-78	-68	-35	49.08	0.73	0.55	0.82	0.67	19.01
10	-78	-68	-35	50.27	0.68	0.51	0.76	0.62	18.48
20	-78	-68	-35	46.86	0.81	0.63	0.72	0.57	18.10
Optimum:									
8	-78	-68	-33	50.53	0.68	0.51	0.76	0.62	18.69
Ref. wiggler settings:									
21	-82	-61	-35	45.23	0.88	0.72	0.70	0.55	17.52

	Corrector settings (μrad)				P% (%)	τ_p/τ_D All magnets				τ_p/τ_D Wigglers				$\langle\delta\bar{n}\rangle$ (mrad)
	CVS1	CVS2	CVS3	CVS4		All	s	x	y	All	s	x	y	
	0	0	0	0	$\boxed{10.56}$	7.53	7.47	0.016	0.017	6.33	6.29	0.00007	0.0068	15.82
1	-10	0	0	0	10.11	7.91	7.85	0.019	0.022	6.67	6.64	Negl.	0.0079	17.13
2	0	+10	0	0	9.36	8.62	8.55	0.016	0.014	7.26	7.21	"	0.0045	16.93
3	0	0	+10	0	9.62	8.37	8.31	0.017	0.014	7.03	7.00	"	0.0047	16.87
4	0	0	0	+10	10.13	7.89	7.83	0.014	0.014	6.64	6.60	"	0.0042	17.34
5	0	-30	0	0	14.93	5.03	5.01	0.024	0.035	4.19	4.18	"	0.018	13.46
6	0	-60	0	0	19.38	3.65	3.70	0.035	0.062	3.02	3.07	"	0.037	13.04
7	0	-80	0	0	20.63	3.37	3.48	0.045	0.085	2.77	2.86	"	0.053	14.13
8	0	-100	0	0	19.63	3.59	3.77	0.056	0.113	2.94	3.10	"	0.073	15.94
9	0	-80	-30	0	33.62	1.68	1.81	0.057	0.126	1.36	1.49	"	0.081	17.235
10	0	-80	-60	0	42.78	1.10	1.26	0.073	0.175	0.91	1.07	"	0.117	21.29
11	0	-80	-80	0	38.47	1.34	1.51	0.085	0.210	1.14	1.32	"	0.144	24.31
12	0	-80	-50	0	41.45	1.17	1.32	0.067	0.157	0.96	1.11	"	0.104	19.86
13	10	-80	-60	0	47.04	0.91	1.03	0.068	0.156	0.72	0.84	"	0.104	20.34
14	20	-80	-60	0	48.71	0.85	0.92	0.063	0.140	0.64	0.72	"	0.092	19.49
15	30	-80	-60	0	47.19	0.91	0.95	0.058	0.120	0.67	0.71	"	0.080	18.77
16	20	-80	-60	-10	60.72	0.48	0.57	0.068	0.156	0.332	0.42	"	0.104	18.60
17	20	-80	-60	-20	72.54	0.24	0.34	0.074	0.174	0.120	0.23	"	0.116	18.84
18	20	-80	-60	-30	80.08	0.126	0.248	0.082	0.192	0.021	0.16	"	0.130	17.25
19	20	-80	-60	-40	79.55	0.133	0.272	0.087	0.210	0.025	0.18	"	0.144	16.84
*	20	-80	-60	-35	80.94	0.110	0.240	0.085	0.201	0.010	0.156	"	0.137	17.02
	Refined optimum (another six steps):					$\Sigma\lvert\Gamma\rvert^2$	$\Sigma\Gamma_s^2$	$\Sigma\Gamma_x^2$	$\Sigma\Gamma_y^2$	$\Gamma^2_{(w)}$	$\Gamma^2_{s(w)}$	$\Gamma^2_{x(w)}$	$\Gamma^2_{y(w)}$	
	21	-82	-61	-35	$\boxed{81.25}$	0.109	0.242	0.085	0.208	$\boxed{0.004}$	0.157	0.0005	0.140	17.52

RESULT :

- A high degree of polarization (85% in 1st order
  65% with tracking
  seems obtainable.

Correction procedure takes ~

τ_p × 4 × 5 ~ 10 hrs
correctors needed points/corrector (multiply by π !)

Feasible if good machine stability.

- Polarization figure of meritt greatly improved
  ($\int P^2(t)\, L(t)\, dt$)

  $P_{eff} \gtrsim 50\%$.

This is a VERY important step !

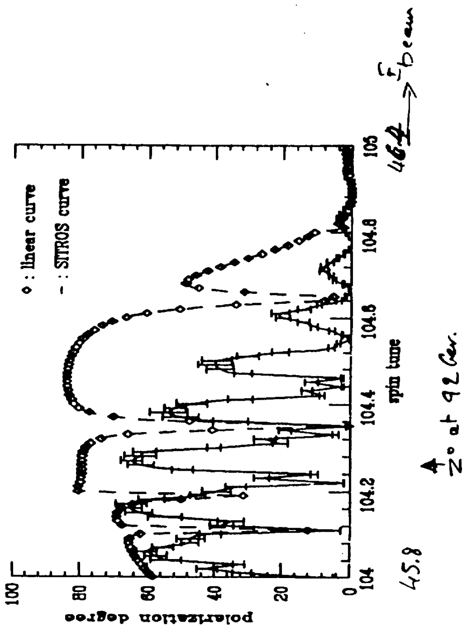
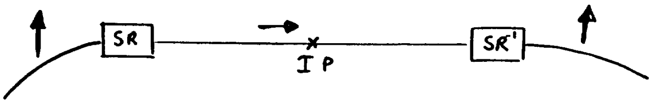


Figure 7: Effect of a partial harmonic correction of D_y (nh=104/sine)

analysis of the final [illegible] bit and dispersion shows that the empirical harmonic spin matching resulted in [illegible] kening of the sine component of the closed orbit harmonic 104, demonstrating [illegible] play between the dispersion and closed orbit harmonics.

The next step that will be performed is a complete and simultaneous compensation of the harmonics 104 and 105 of the vertical orbit and dispersion.

SPIN ROTATORS.



- must restore the spin perfectly for any particle in beam phase space
  [Spin-Matching , Spin-transparency]

- 2 possibilities
  - straight-section rotators – fully antisymmetric
  - arc rotators – not antisymmetric.

Unless they are made with Solenoids
(but 90° (spin) → 480 T.m !)

involve vertical bumps. → problems with R.F floor etc....

- The Simplest Straight-Section Spin Rotator
  [RICHTER-SCHWITTERS]

can be spin-matched perfectly-

×→

requires
- 15 mrad tilt of ALEPH.
- synchrotron-radiation shielding. ×→

CHEAP (< 2MSF) , no depolarization problems with RF in OPAL, RF + magnet in L3.

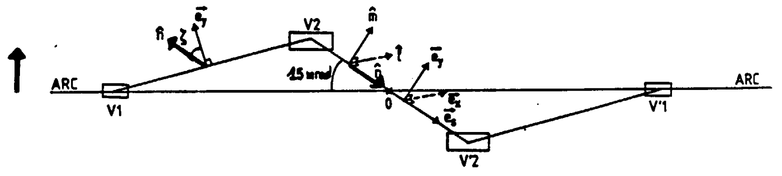
- Spin-matching of arc rotators is difficult and not obviously feasible. (may be impossible,

involve 200 m of arcs to be removed and re[illegible] on each side of each experiment.

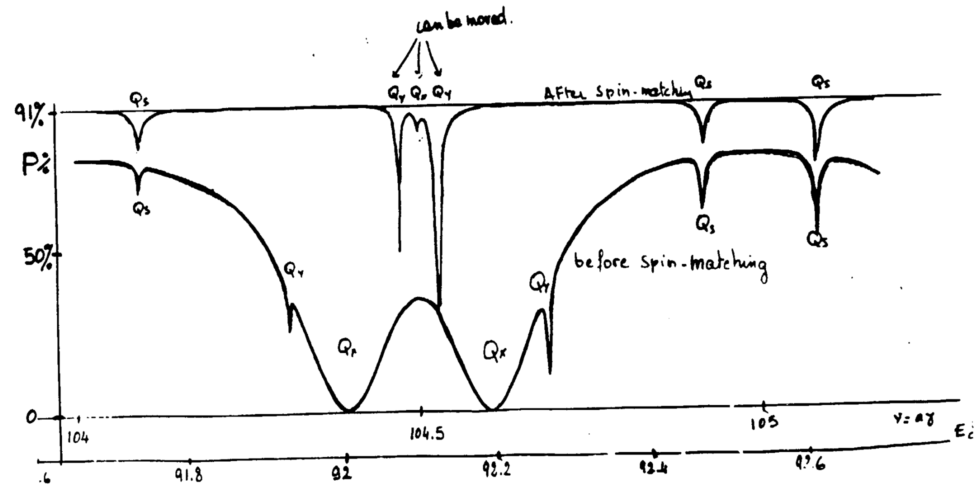
not-so-cheap ~ 6MSF (?)

A solution has been found that would fit SS4 and SS8 – as long as they are not equipped with RF.

No solution exists yet that would fit all 4 experiment
It is the next foreseen step to be studied



1 Richter-Schwitters Spin Rotator in a perfect machine.



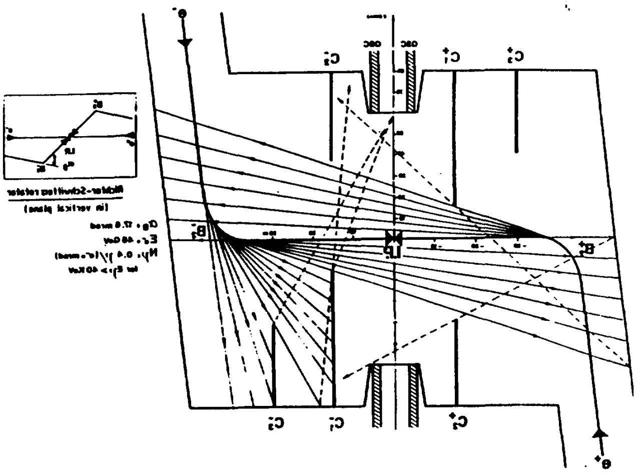
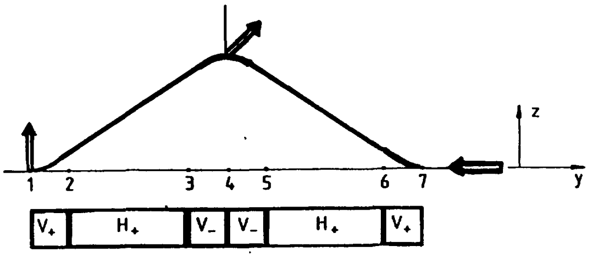
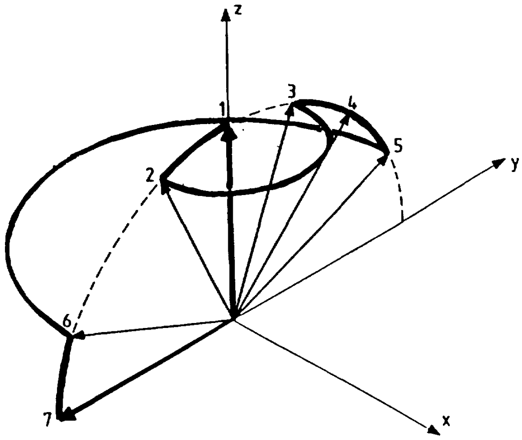


Figure 1

Photon Background from Richter-Schwitters Spin Rotators



Separated-bend rotator; vertical orbit



Separated-bend rotator; motion of spin vector

Quite a few problems remain to be solved by the machine theory group:

- × Spin matching of experimental solenoids (should exist)
- × - - - - - - interaction point (should exist)
- × Arc rotators (may not exist)
- × stability of correction procedures

LUMINOSITY VS POLARIZATION ?

Difficulty comes from the strong depolarization occuring when nearing beam-beam limit.

- * spin-matching IP possible (in principle)
  .nb. almost ok at E = 46 Gev!
- * wigglers reduce the relative importance of all sources of depolarization including beam-beam
- * increasing the number of bunches does not a-priori modify the polarizability of the beams.
- * beam-beam limit is only attained at beg. of fil.

See what we can do in real life.... A loss of up to a factor of 2 or 3 is not to be excluded.
more would probably kill the project ?

PETRA (D. P. BARBER
(Workshop on Polarization at LEP)

BEAM-BEAM EFFECTS

Beam-beam forces : Non-linear focussing forces ⇒

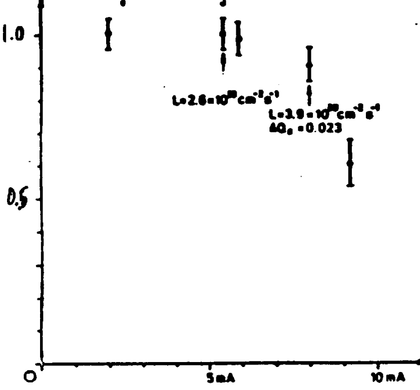
Beam blow up ⇒

$\mathcal{L}$ limited

Expect depolarization: Tracking simulation ?

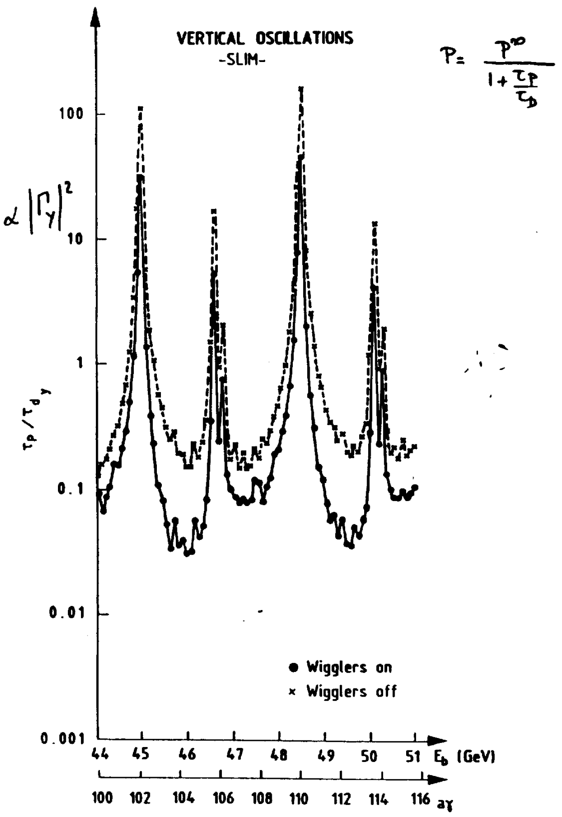
?

$$R = \frac{\text{Asymm. beam-beam}}{\text{Asymm. single}}$$



Conditions :
1) 16.52 GeV
2) Optimised (P~70%)

Checks
1) Fill to fill stability
2) σ_y ⇔ Polarimetry
3) Tune shift



$$P = \frac{P^\infty}{1 + \frac{\tau_P}{\tau_D}}$$

SCENARIOS

- Longitudinal polarization will not be possible unless an active attitude is taken towards it.

START:

NOW * Strong transverse polarization programme
(order wigglers, get polarimeter running etc...)
order et polarimeter

NOW * finalize theoretical studies
Finalize design of spin rotators to reserve the space

T° * order spin rotators

T° * begin construction of longitudinal polarimeter
upgrade of experiments

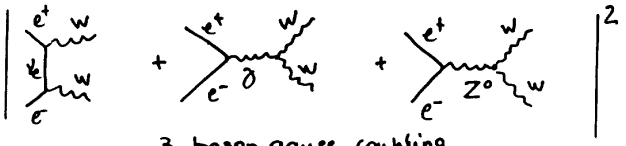
T° is either • overwhelming success of theoretical study
(end 1989?) or • successfull operation of Polarized Hera
(- 1992) or • Successfull operation of Polarized LEP.

T° + 18 months = T_1 (1991 - 1992)
* Commission LEP with Polarized beams, check it works.

T_1 + X * schedule Polarized beam experiments
earliest 1992. X can be very different from 0 if physics
1993-1994?. says so ; (new threshold found etc...)
* It is important that polarized beam set.up be reversible to planar set up quickly.

KOST

V $e^+e^- \to WW$



3 boson gauge coupling.

Interference between these diagrams garantees finite cross section

S.M cross section is minimal.

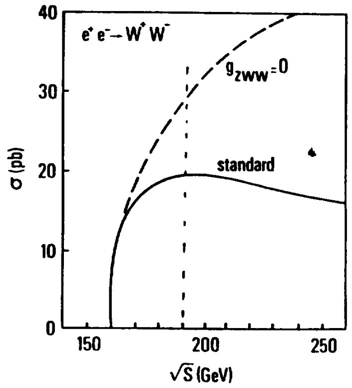
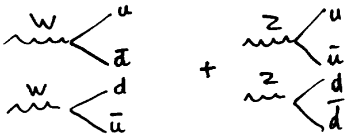


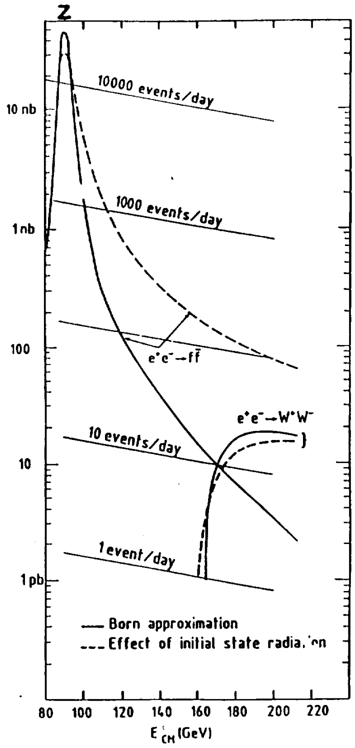
Figure 3

+ little subtlety with $e^+e^- \to WW$ and ZZ production

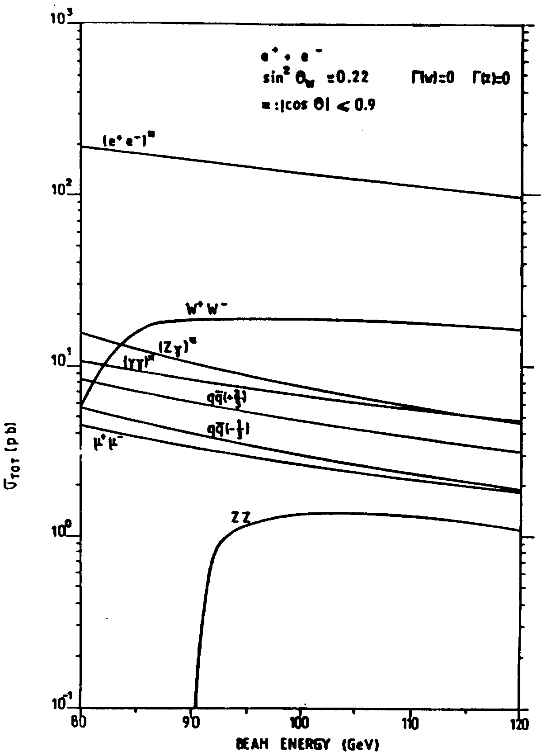


interfere

Small effect.



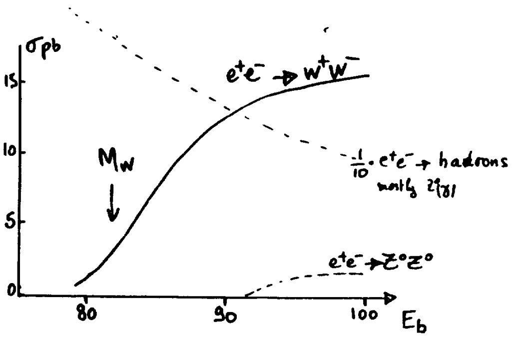
LEP is a machine for Electro Weak physics —



].4 : Integrated cross sections (without radiative corrections)

MEASUREMENT OF M_W [LEP 200]

W mass group LAL 87-07
Jan 87



2 methods:

- SCAN THRESHOLD

<u>500 pb^{-1}</u> over 5 points : <u>75</u> , $M_W - 1$, <u>M_W</u>, $M_W + 1$, <u>95</u>

$\Delta M_W^{stat} \approx \pm 80$ Mev

Syst:
- Background ± 80 Mev.
- luminosity $\overset{1\%}{(p.t.p)}$ ± 25 Mev
- radiative effects ?

SCAN → ΔM_W ~ ± 120 Mev

W mass. The scan of ww threshold is very lengthy and does not provide the maximum possible number of events. Try analysing events produced at the cross section maximum

500 pb^{-1} at $E_b = 95$ Gev. ⇒ ~7500 W pairs

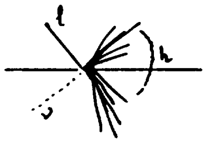
good events

3 types of events ⓪ $e^+e^- \to W\ W\ (\gamma)$ –
$\hookrightarrow \ell\nu\ \ell\bar\nu$

① $e^+e^- \to W\ W\ (\gamma)$ 1500
$\hookrightarrow \ell\nu\ q\bar q(g)$

② $e^+e^- \to W\ W$ 3000
$\hookrightarrow q\bar q q\bar q\ (g,g)$

Events of class ① turn out to be the most useful (problem with class ② : large gluon emission results in jet confusion (50% of events have at least 1 substantial extra jet))



measure E_ℓ (well)
$(\vec P, E)_h$ (less well : missing ν, K_L, cracks, resolution)
no need for jet reconstruction

Constraints typical of e^+e^- annihilation

$$M_{W_1} \sim M_{W_2} \Rightarrow E_{beam} = E_{W_1} = E_{W_2}$$

modulo – $\Gamma_W \neq 0$, Initial state radiation – (final was not studied)

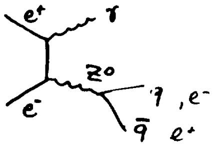
sets $\vec P_h = \vec P_h^{\,meas} \cdot E_{beam}/E_h$, $\vec P_\nu = -\vec P_\ell - \vec P_h$

Obtain $\Delta M_W^{stat} \sim 60$ Mev.

<u>Study of systematic shifts reveals</u>

- Sensitivity to relative h to e calibration
  (1% → ± 100 Mev)

  idea : calibrate on
  statistics limited
  → ± 70 Mev.

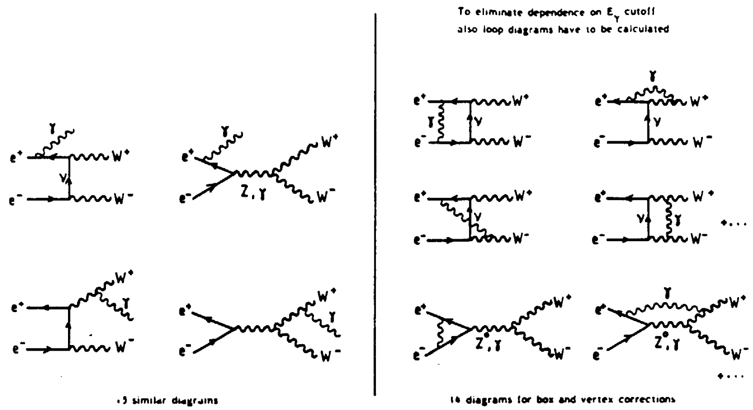


- ⇒ $\Delta M_W \simeq 100$ Mev

NB. This is very much statistics limited...

500 pb^{-1} has never been obtained in a year in e^+e^-
[best year of PEP – PETRA ~ 100 pb^{-1}]

<u>Luminosity is crucial point here.</u>



To eliminate dependence on E_γ cutoff also loop diagrams have to be calculated

+3 similar diagrams

14 diagrams for box and vertex corrections

Fig.2 : Diagrams contributing to radiative corrections

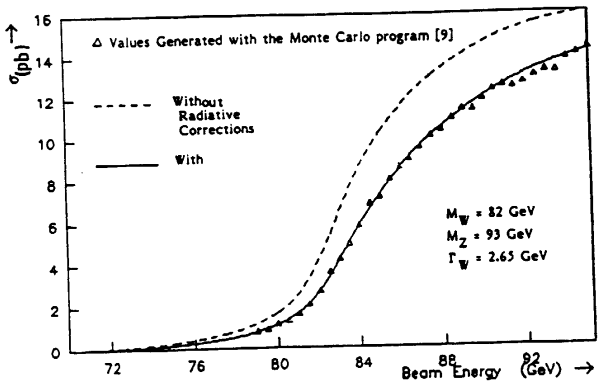
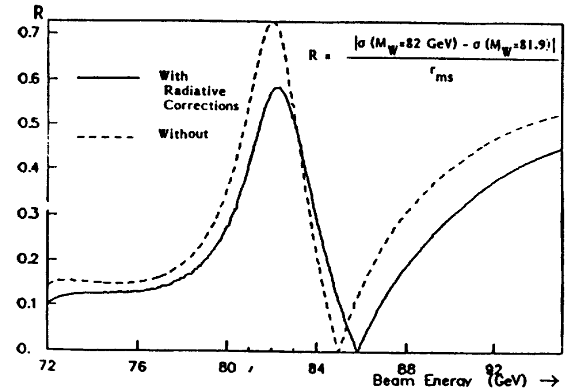
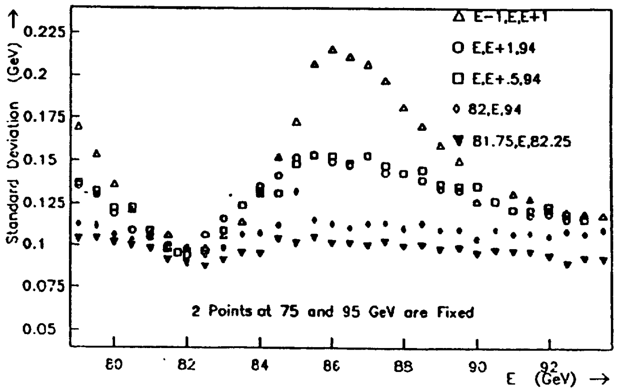


Fig.8 : Comparison of cross sections with and without radiative corrections





$e^+e^- \to W$
$\hookrightarrow \ell\nu \hookrightarrow q\bar{q}$
$(+ g,\gamma)$'s

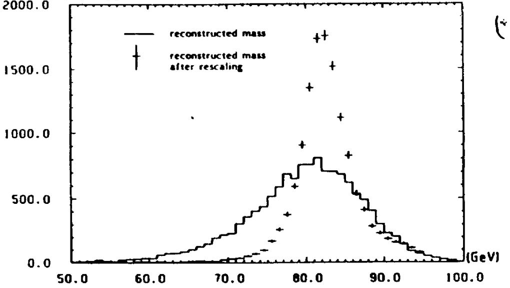


Fig. 13 : Reconstructed mass distributions for class I events (calorimetric approach)

$e^+e^- \to W W$
$\hookrightarrow q\bar{q}q\bar{q}$
$(+ gg,\gamma)$'s

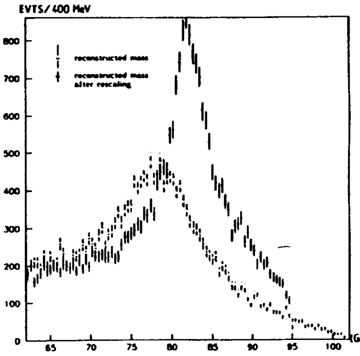


Fig. 14 : Reconstructed mass distributions for class 2 events (granular detector approach)

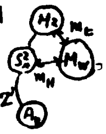
PRECISION MEASUREMENTS
AT LEP

CONCLUSIONS.

- BECAUSE OF NON-DECOUPLING, ELECTROWEAK RENORMALIZATION EFFECTS 

ARE SENSITIVE TO PHYSICS BEYOND LEP ENERGY SCALE.

- IT IS NOT EQUIVALENT TO MEASURE M_W and $\sin^2\theta_W (M_Z^2)$, obtained from MEASUREMENT OF COUPLING CONSTANTS

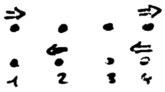


- PRECISION REQUIRED FOR SENSITIVITY TO HIGGS MASS IS $\Delta \sin^2\theta_W^* / \sin^2\theta_W^* \leq 2\,10^{-3}$

- IT IS NOT POSSIBLE TO REACH THIS SENSITIVITY FROM MEASUREMENTS WITHOUT POLARIZED BEAMS, WHICH ARE SYSTEMATICS LIMITED AT THE LEVEL OF $\Delta \sin^2\theta_W / \sin^2\theta_W \simeq 5\,10^{-3}$ EVEN WHEN AVERAGING ALL OF THEM.

- A_{LR} WITH LONGITUDINALLY POLARIZED BEAMS PROVIDES A POWERFUL AND SYSTEMATICS-SAFE MEASUREMENT $\Delta \sin^2\theta_W / \sin^2\theta_W \sim 1.5\,10^{-3}$ FOR $40\,pb^{-1}$ and 50% LONGITUDINAL POLARIZATION

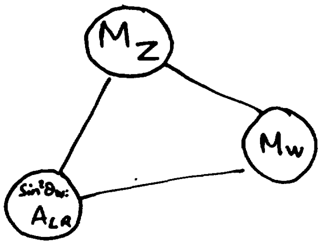
- MEASUREMENTS IN LEP ARE POTENTIALLY BETTER THAN SLC DUE TO THE AVAILABILITY OF e^- and e^+ POLARIZATION

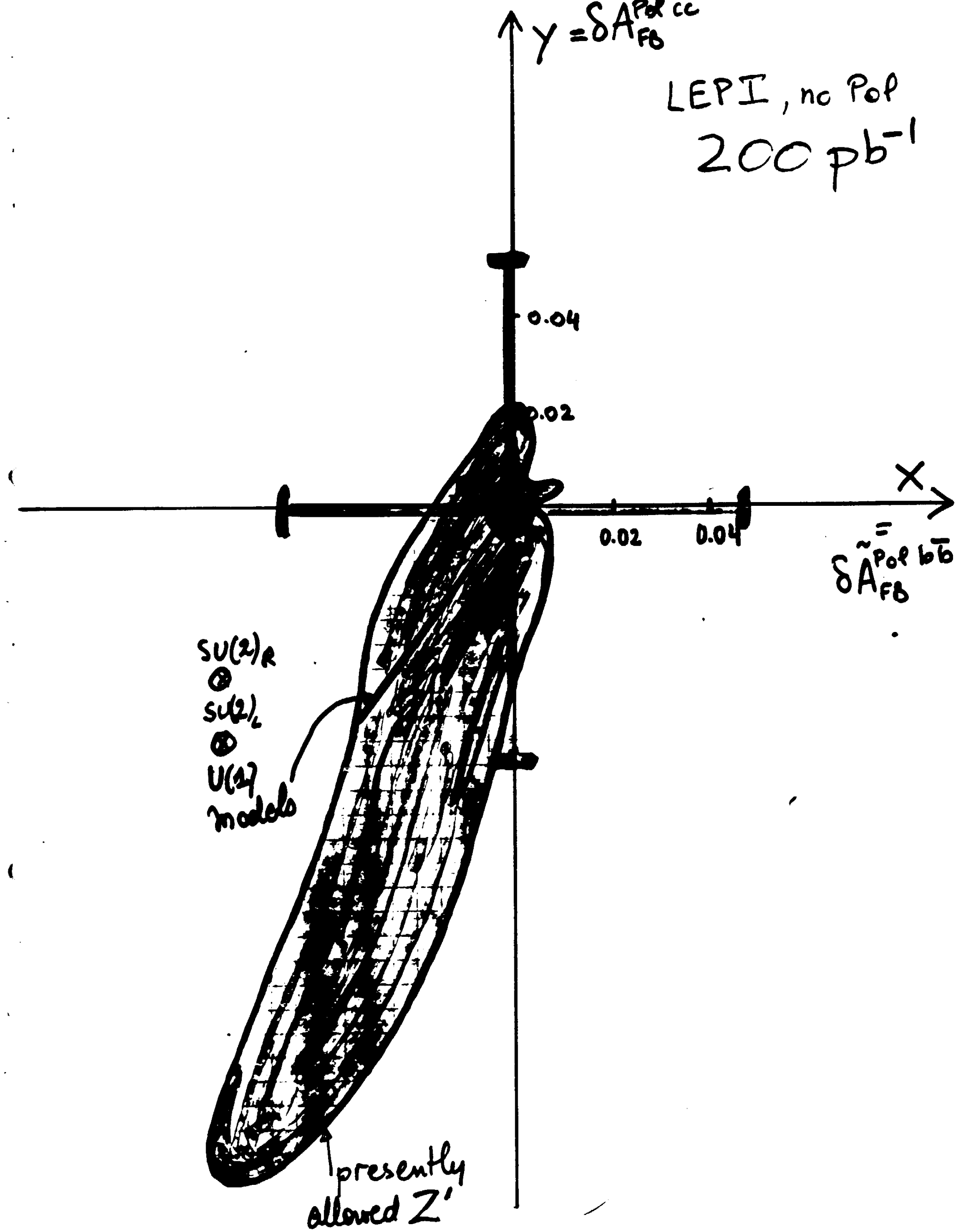


- OBTAINING LONGITUDINAL POLARIZATION IN LEP REQUIRES AN ACTIVE ATTITUDE.
  - DEDICATED WIGGLERS FOR TRANSVERSE POLARIZATION PROGRAMME
  - SPIN ROTATOR STUDIES TO RESERVE THE SPACE.

- LEP WILL IMPROVE OUR UNDERSTANDING OF BASIC RELATIONS IN $SU(2)_L \times U(1)$

By ~ 1 order of magnitude in 3 dimensions





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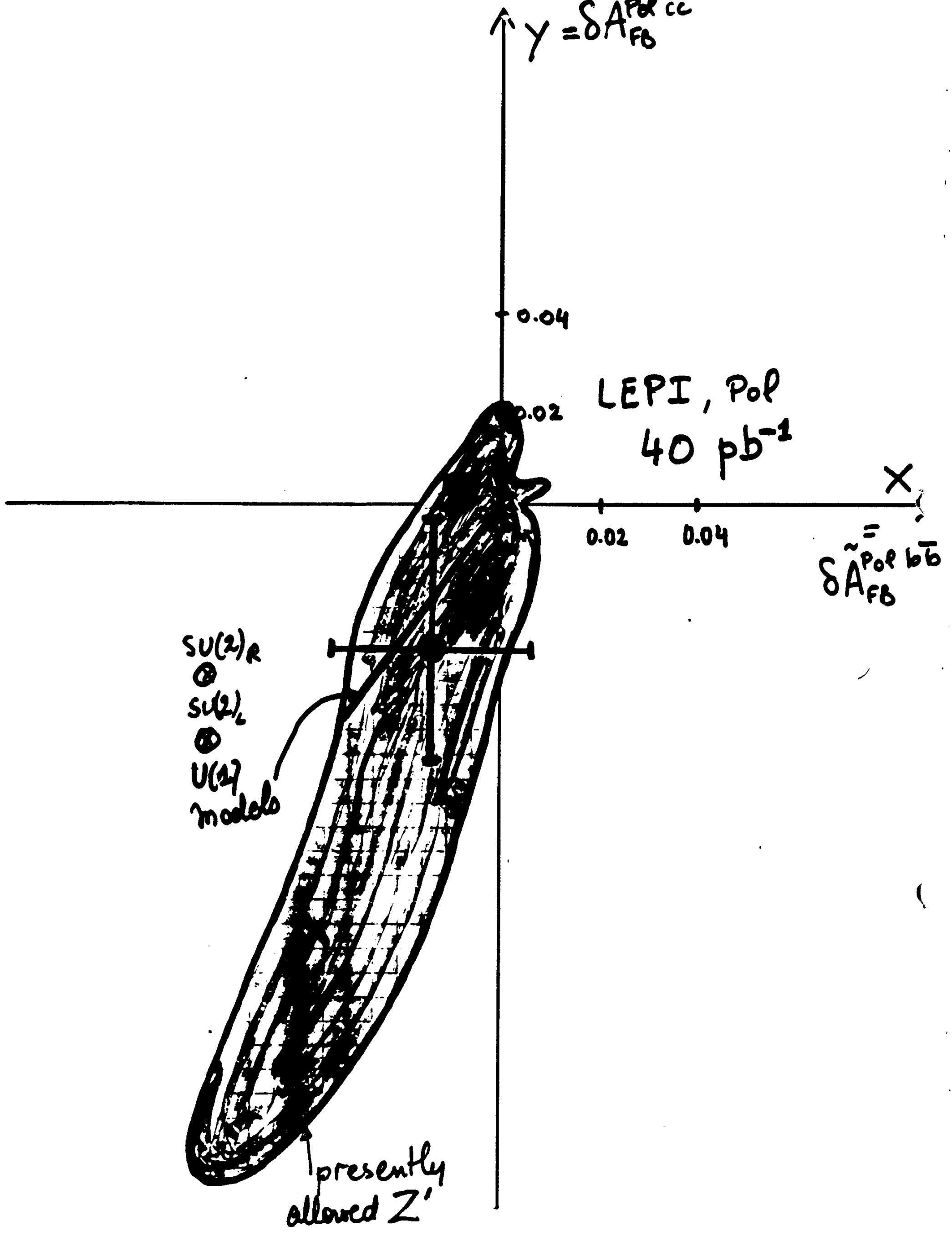
C. VERZEGNASSI



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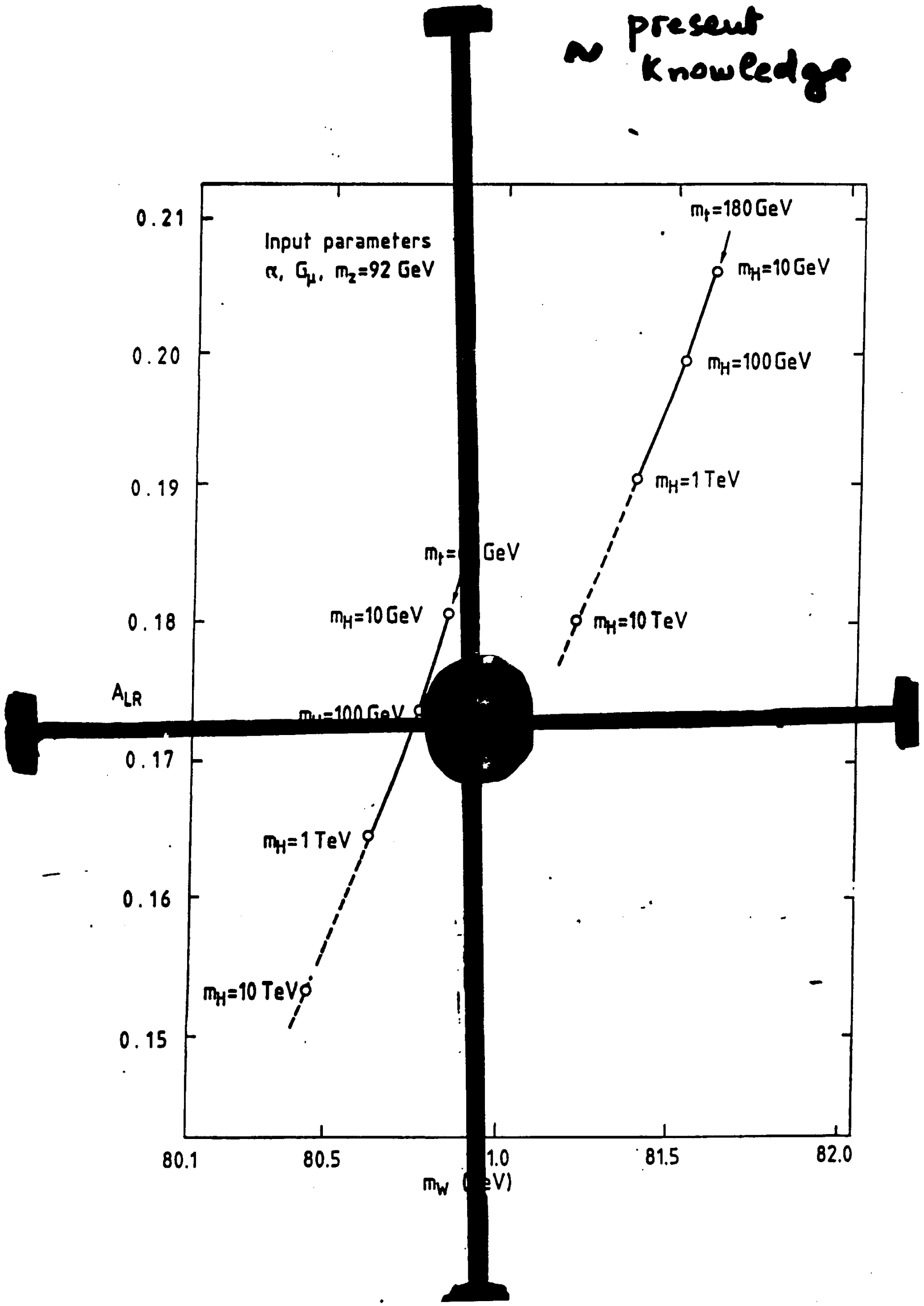
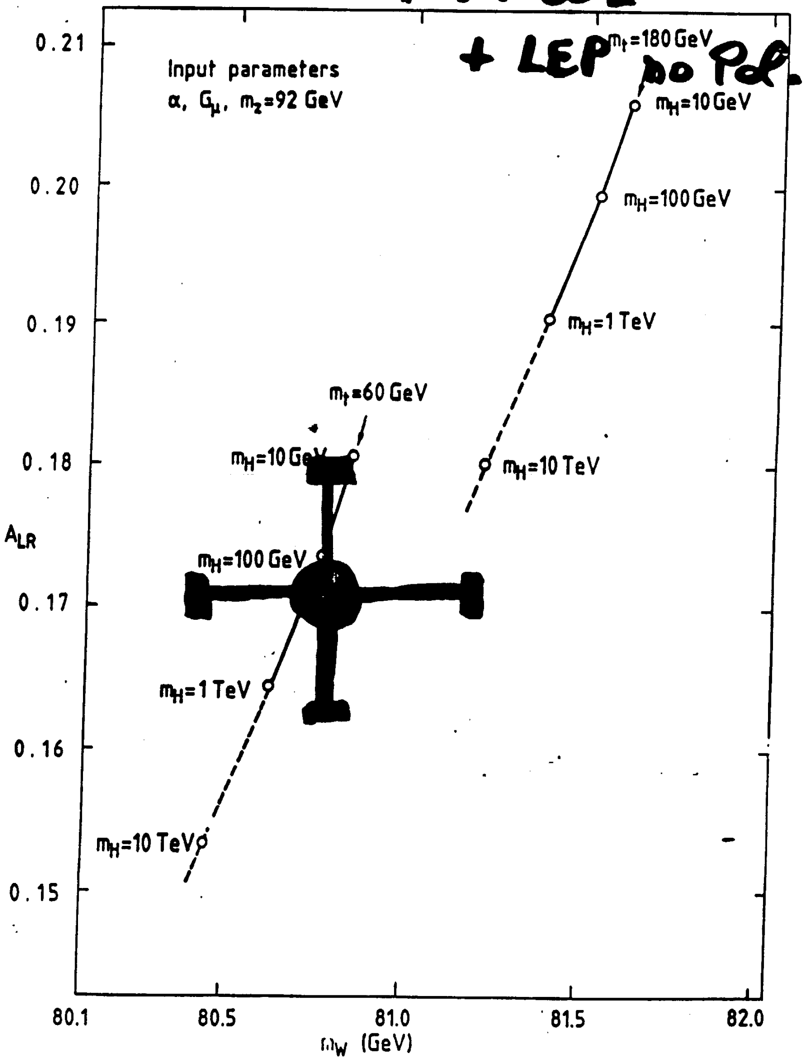
LEP, 50% Polarization
$40 pb^{-1}$

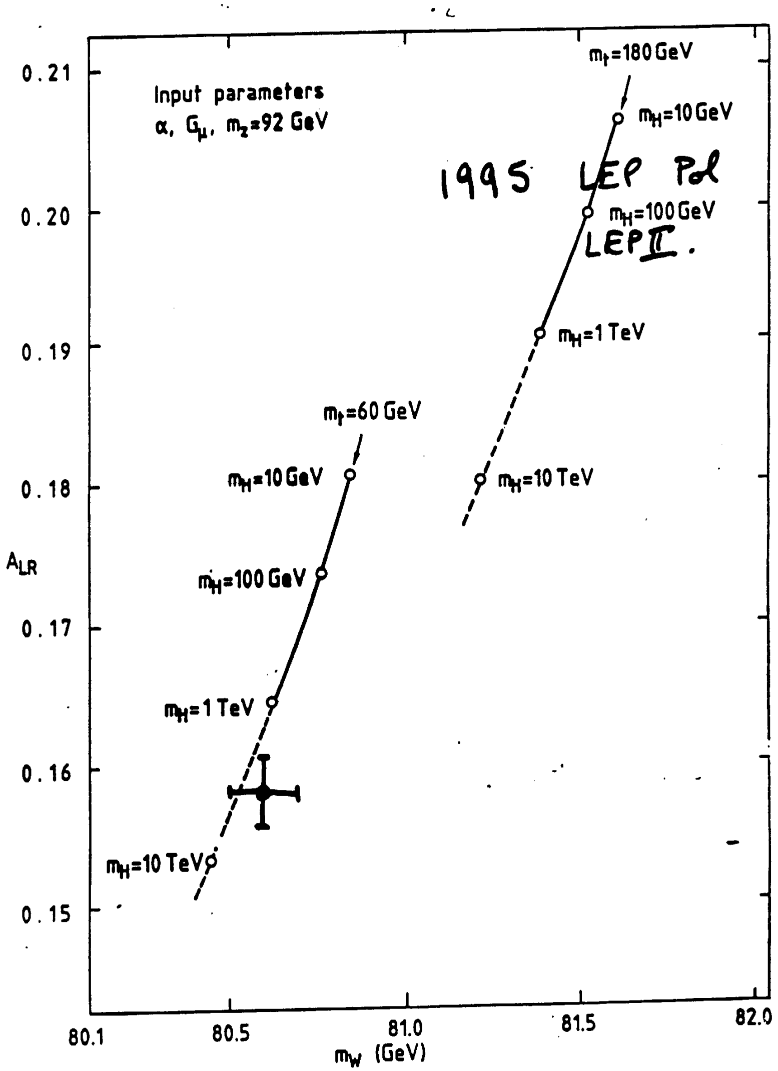


~ present knowledge

1991: ACOL

+ LEP no Pol.





Input parameters
α, G_μ, m_z=92 GeV
m_t=180 GeV
m_H=10 GeV
1995 LEP Pol
m_H=100 GeV
LEPII.
m_H=1 TeV
m_H=10 TeV
m_t=60 GeV
m_H=10 GeV
m_H=100 GeV
m_H=1 TeV
m_H=10 TeV
A_{LR}
0.21
0.20
0.19
0.18
0.17
0.16
0.15
80.1
80.5
81.0
81.5
82.0
m_W (GeV)