Opportunities and challenges of TLEP as a precision machine for Electroweak Radiative Corrections

'Will redo te LEP program in a few minutes…. '

TLEP

ZZZZZZZZ

References:

LEP Z peak paper arXiv:hep-ex/0509008 Phys.Rept.427:257-454,2006

LEP2 Electroweak paper arXiv:1302.3415 [hep-ex] Phys. Rep.

Gfitter Group arXiv:1209.2716v2
The Electroweak Fit of the Standard Model after the Discovery of a New Boson at the LHC

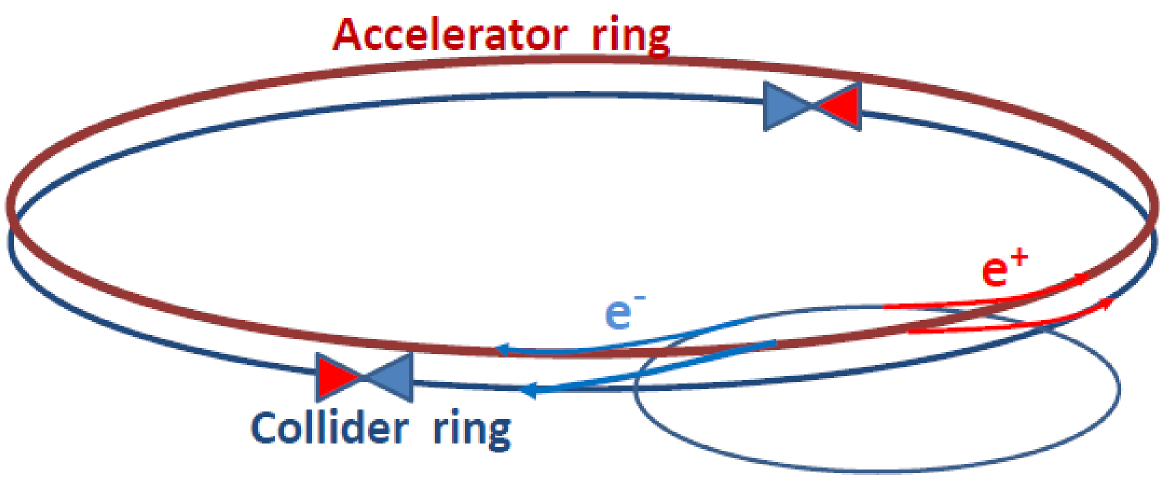
J. Erler and P. Langacker ELECTROWEAK MODEL AND CONSTRAINTS ON NEW PHYSICS PDG dec 20

«and references therein»

Refere also to J. Wenninger’s talk at last TLEP meeting, and a number of LEP polarization
And energy calibration papers.

LEP3 and TLEP

Circular e+e- colliders to study THE BOSON X(126)



But not only…

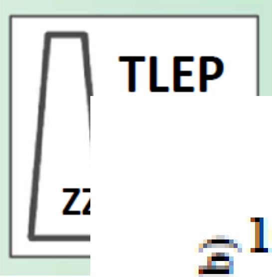
LEP3, TLEP

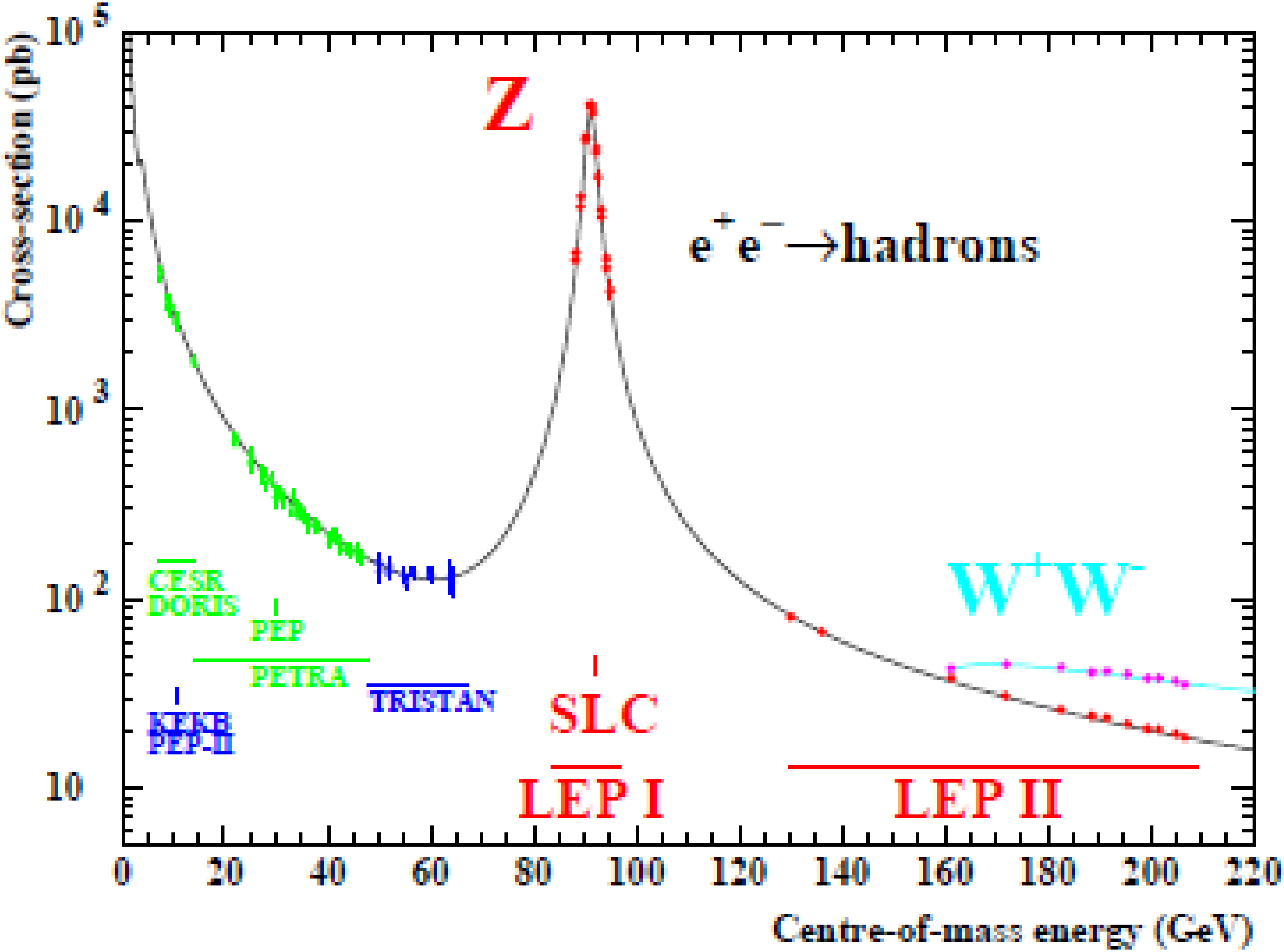
($e^+e^- \to ZH$, $e^+e^- \to W^+W^-$, $e^+e^- \to Z$,[$e^+e^- \to t\bar{t}$])

key parameters

	LEP3	TLEP
circumference	26.7 km	80 km
max beam energy	120 GeV	175 GeV
max no. of IPs	4	4
luminosity at **350 GeV** c.m.	-	**0.7x10^{34} cm^{-2}s^{-1}**
luminosity at 240 GeV c.m.	10^{34} cm^{-2}s^{-1}	5x10^{34} cm^{-2}s^{-1}
luminosity at **160 GeV** c.m.	5x10^{34} cm^{-2}s^{-1}	**2.5x10^{35} cm^{-2}s^{-1}**
luminosity at **90 GeV** c.m.	2x10^{35} cm^{-2}s^{-1}	**10^{36} cm^{-2}s^{-1}**

at the *Z* pole repeating LEP physics programme in a few minutes…


TLEP


Cross-section (pb)
10^5
10^4
10^3
10^2
10
Z
e+e−→hadrons
W+W−
CESR
DORIS
PEP
PETRA
TRISTAN
KEKB
PEP-II
SLC
LEP I
LEP II
0
20
40
60
80
100
120
140
160
180
200
220
Centre-of-mass energy (GeV)

TLEP

ZZZZZZZZ

Once the Higgs boson mass is known, the Standard Model has nowhere to go

$$O_i = f(\alpha_{QED}, \alpha_S, G_F, m_Z, m_{top}, m_H)$$

which are now all known … with some errors

-- Except in the neutrino sector but how? (usually decouples)

-- then any deviation from predictions is a sign of new physics

TLEP

Experimental Input

Observables:

- Z-pole observables: LEP/SLD results [ADLO+SLD, Phys. Rept. 427, 257 (2006)]
- M_W and Γ_W: LEP/Tevatron [arXiv:1204:0042]
- m_t : Tevatron [arXiv:1207:1069]
- $\Delta\alpha_{had}^{(5)}(M_Z)$ [M. Davier et al., EPJC 71, 1515 (2011)]
- $\overline{m}_c$, $\overline{m}_b$: world averages [PDG, J. Phys. G33, 1 (2006)]
- M_H : LHC [arXiv:1207.7214 , arXiv:1207.7235]

Free fit parameters:

- M_Z, M_H, $\Delta\alpha_{had}^{(5)}(M_Z)$, $\alpha_s(M_Z)$, $\overline{m}_c$, $\overline{m}_b$, m_t
- Scale parameters for theoretical uncertainties δM_W (4 MeV), $\delta \sin^2\theta^l_{eff}$ ($4.7 \cdot 10^{-5}$)

M_H [GeV]$^{(\circ)}$	125.7 ± 0.4	LHC
M_W [GeV]	80.385 ± 0.015	Tevatron
Γ_W [GeV]	2.085 ± 0.042	Tevatron
M_Z [GeV]	91.1875 ± 0.0021	LEP
Γ_Z [GeV]	2.4952 ± 0.0023	LEP
$\sigma^0_{\rm had}$ [nb]	41.540 ± 0.037	LEP
R^0_ℓ	20.767 ± 0.025	LEP
$A^{0,\ell}_{\rm FB}$	0.0171 ± 0.0010	LEP
A_ℓ $^{(\star)}$	0.1499 ± 0.0018	LEP / SLC
$\sin^2\theta^\ell_{\rm eff}(Q_{\rm FB})$	0.2324 ± 0.0012	LEP
A_c	0.670 ± 0.027	SLC
A_b	0.923 ± 0.020	SLC
$A^{0,c}_{\rm FB}$	0.0707 ± 0.0035	LEP
$A^{0,b}_{\rm FB}$	0.0992 ± 0.0016	LEP
R^0_c	0.1721 ± 0.0030	LEP / SLC
R^0_b	0.21629 ± 0.00066	LEP / SLC
$\overline{m}_c$ [GeV]	$1.27^{+0.07}_{-0.11}$	
$\overline{m}_b$ [GeV]	$4.20^{+0.17}_{-0.07}$	
m_t [GeV]	173.18 ± 0.94	Tevatron
$\Delta\alpha^{(5)}_{\rm had}(M^2_Z)$ $^{(\triangle\triangledown)}$	2757 ± 10	

$\Delta\rho$: $\equiv \varepsilon_1$

$$\Gamma_\ell = (1+\Delta\rho)\,\frac{G_F\, m_Z^3}{24\pi\sqrt{2}}\left(1+\left(\frac{g_{V\ell}}{g_{A\ell}}\right)^2\right)\left(1+\frac{3}{4}\frac{\alpha}{\pi}\right)$$

ε_3

$$\sin^2\theta_W^{eff}\cos^2\theta_W^{eff} = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}\,G_F\,m_Z^2}\,\frac{1}{1+\Delta\rho}\,\frac{1}{1-\frac{\varepsilon_3}{\cos^2\theta_W}}$$

δ_{vb}

$$\Gamma_b = (1+\delta_{vb})\,\Gamma_d\,\left(1-\text{mass corrections }\alpha\, m_b^2/M_Z^2\right)$$

ε_2

$$M_W^2 = \frac{\pi\alpha(M_Z^2)}{\sqrt{2}\,G_F\,\sin^2\theta_W^{eff}}\cdot\frac{1}{(1-\varepsilon_3+\varepsilon_2)}$$

$\sin^2\theta_W^{eff}$ is defined from

$$\sin^2\theta_W^{eff} = \frac{1}{4}\left(1-\frac{g_{V\ell}}{g_{A\ell}}\right) = \sin^2\theta_W^{eff}{}_{lept}$$

obtained from asymmetries at the Z.

also

Δr

$$m_W^2 = \frac{\pi\alpha}{\sqrt{2}\,G_F}\cdot\frac{1}{\left(1-\frac{M_W^2}{M_Z^2}\right)}\,\frac{1}{(1-\Delta r)}$$

$$\Delta r = \Delta\alpha - \frac{\cos^2\theta_W}{\sin^2\theta_W}\Delta\rho + 2\,\frac{\cos^2\theta_W}{\sin^2\theta_W}\varepsilon_3 + \frac{c^2-s^2}{s^2}\varepsilon_2$$

EWRCs

relations to the well measured

G_F m_Z α_{QED}

at first order:

$\Delta\rho = \alpha/\pi\ (m_{top}/m_Z)^2$

$-\ \alpha/4\pi\ \log\ (m_h/m_Z)^2$

$\varepsilon_3 = \cos^2\theta_w\ \alpha/9\pi\ \log\ (m_h/m_Z)^2$

$\delta_{vb} = 20/13\ \alpha/\pi\ (m_{top}/m_Z)^2$

complete formulae at 2d order
including strong corrections
are available in fitting codes

e.g. ZFITTER , GFITTER

Example (from Langacker, Erler PDG 2011)

$\Delta\rho = \varepsilon_1 = \alpha(M_Z) \,.\, T$

$\varepsilon_3 = 4 \sin^2\theta_W \;\alpha(M_Z) \,.\, S$

From the EW fit

$\Delta\rho$ = 0. 0004+0.0003−0.0004

-- is consistent with 0 at 1σ

-- is sensitive to non conventional Higgs bosons (e.g. in SU(2) triplet with 'funny v.e.v.s)

-- is sensitive to Isospin violation such as $m_t \neq m_b$

$$\rho_0 = 1 + \frac{3\,G_F}{8\sqrt{2}\pi^2} \sum_i \frac{C_i}{3}\,\Delta m_i^2 \;, \qquad (10.63)$$

where the sum includes fourth-family quark or lepton doublets, $\binom{t'}{b'}$ or $\binom{E^0}{E^-}$, right-handed (mirror) doublets, non-degenerate vector-like fermion doublets (with an extra factor of 2), and scalar doublets such as $\binom{\tilde{t}}{\tilde{b}}$ in Supersymmetry (in the absence of L–R mixing).

Measurement implies $$\sum_i \frac{C_i}{3}\,\Delta m_i^2 \leq (52\ \text{GeV})^2.$$

Similarly

$$S = \frac{C}{3\pi} \sum_i \Big(t_{3L}(i) - t_{3R}(i) \Big)^2 ,$$

Would be sensitive to a doublet of new fermions where Left and Right have different masses etc…

Note that often EW radiative corrections do not decouple with mass => a very powerful tool of investigation

TLEP ZZZZZZZZ

Electroweak precision observables at e+e- collider

comments :

-- most powerful relationships : m_Z vs O_i

-- limitation from uncertainty in $\alpha_{QED}(m_Z)$

will affect maximally m_Z vs $\sin^2\theta^{eff}_W$ (all Z peak asymmetries)

will affect m_Z vs m_W interpretation

will *not* affect such quantities as m_Z vs Γ_{lept}

and m_Z vs R_b= Γ_b / Γ_{had}

-- great premium on m_Z and Γ_Z from the line-shape scan

-- Γ_b / Γ_{had} will be obtained from high luminosity at the Z peak.

Number of Events										
	$Z \to q\overline{q}$					$Z \to \ell^+\ell^-$				
Year	A	D	L	O	LEP	A	D	L	O	LEP
1990/91	433	357	416	454	1660	53	36	39	58	186
1992	633	697	678	733	2741	77	70	59	88	294
1993	630	682	646	649	2607	78	75	64	79	296
1994	1640	1310	1359	1601	5910	202	137	127	191	657
1995	735	659	526	659	2579	90	66	54	81	291
Total	4071	3705	3625	4096	15497	500	384	343	497	1724

Table 1.2: The $q\overline{q}$ and $\ell^+\ell^-$ event statistics, in units of 10^3, used for Z analyses by the experiments ALEPH (A), DELPHI (D), L3 (L) and OPAL (O).

LEP = 16 Million hadronic Z decays, 1.7 Million leptonic decays,

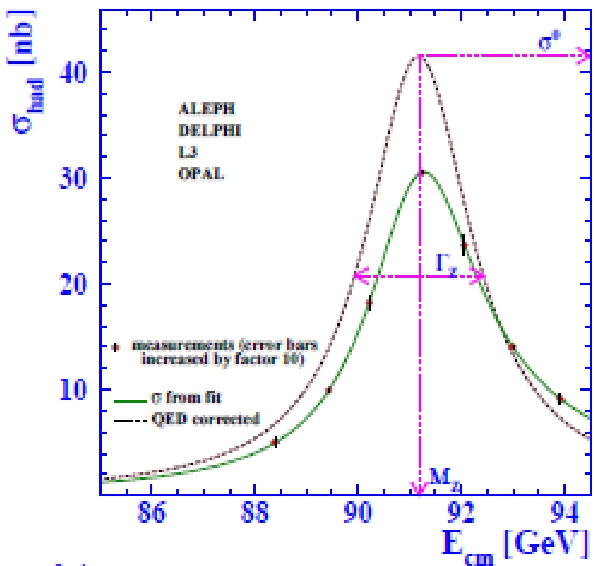
10^{31} /cm^2/s → 0.3 Z events per second + 4 times that rate in Bhabhas = 1.5 events per second.

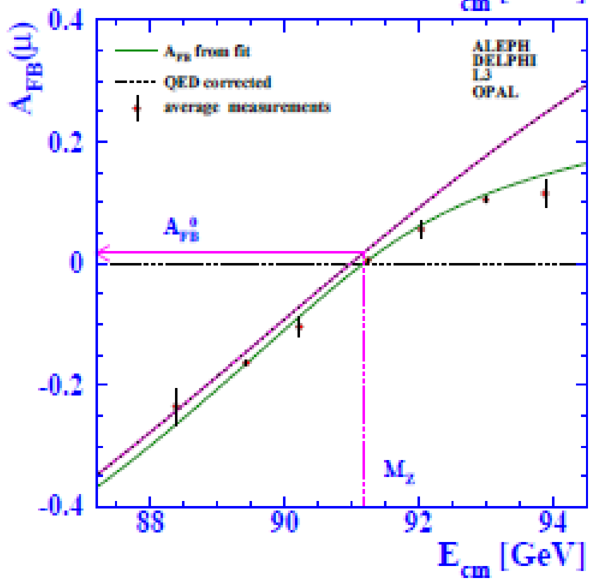
10^{36} /cm^2/s → 30’000 events per second **30KHz** …. 120 KHz with the Bhabhas
10^7 seconds → 3 10^{11} Z decays. TeraZ

CHALLENGE I design of detector and DAQ system to keep high precision in cross-section measurement

Small angle e+e- is necessary for luminosity determination as large angle e+e- is dominated by Z decays themselves

Re-measuring the Z line shape

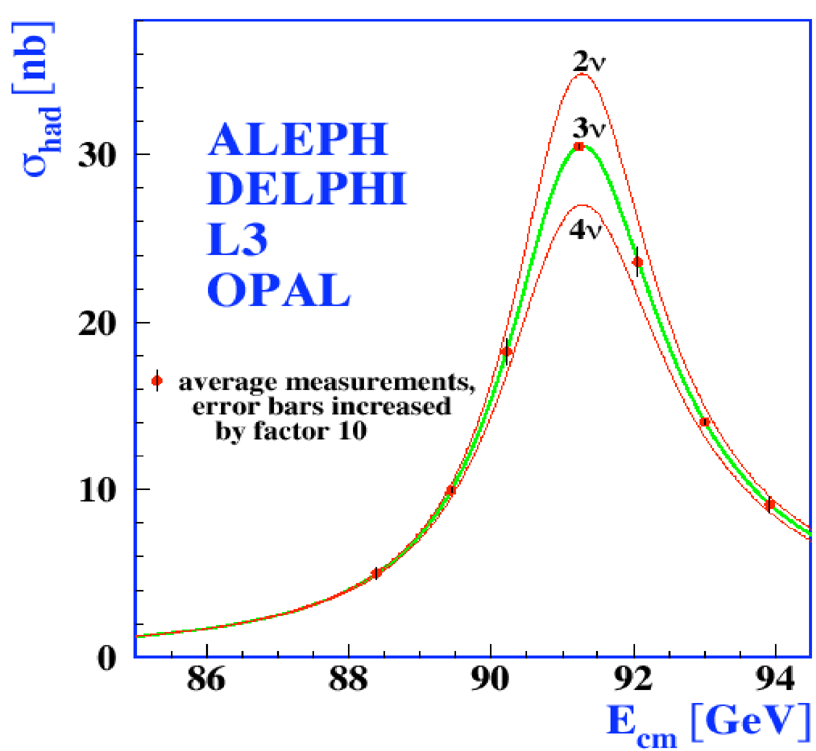


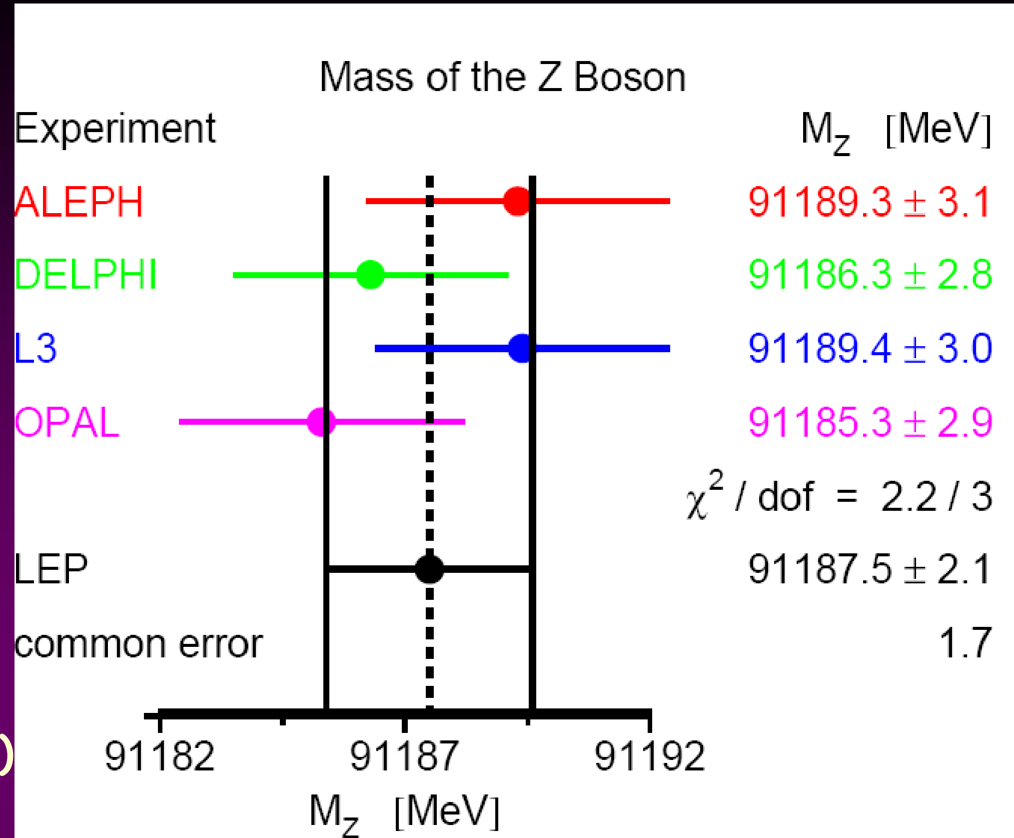


Statistical errors will reduce nicely
can we reduce systematics also?

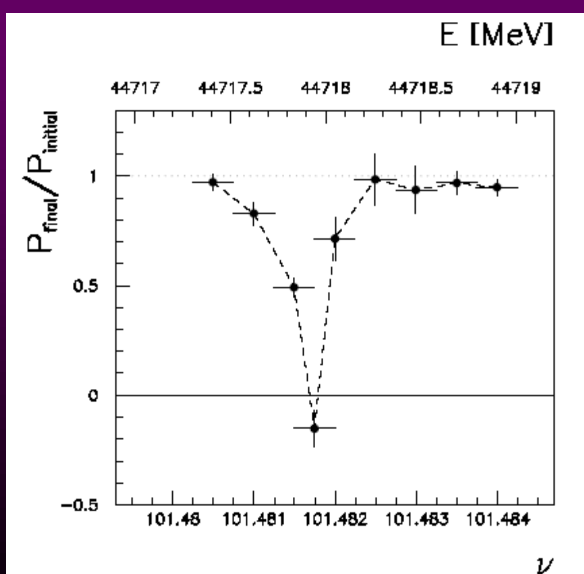
$$\Delta m_Z \approx \frac{1}{2} \cdot \Delta(E_{+2} + E_{-2}) \text{ and}$$
$$\Delta\Gamma_Z \approx \frac{\Gamma_Z}{E_{+2} - E_{-2}} \Delta(E_{+2} - E_{-2}) \,.$$

-- Energy calibration
-- Luminosity measurements
-- Cross-section measurements





energy resolution (resonant depolarization) +-200 keV! variations due to tides, trains, rain, etc..



m_Z= 91187.5 +-2.1 MeV

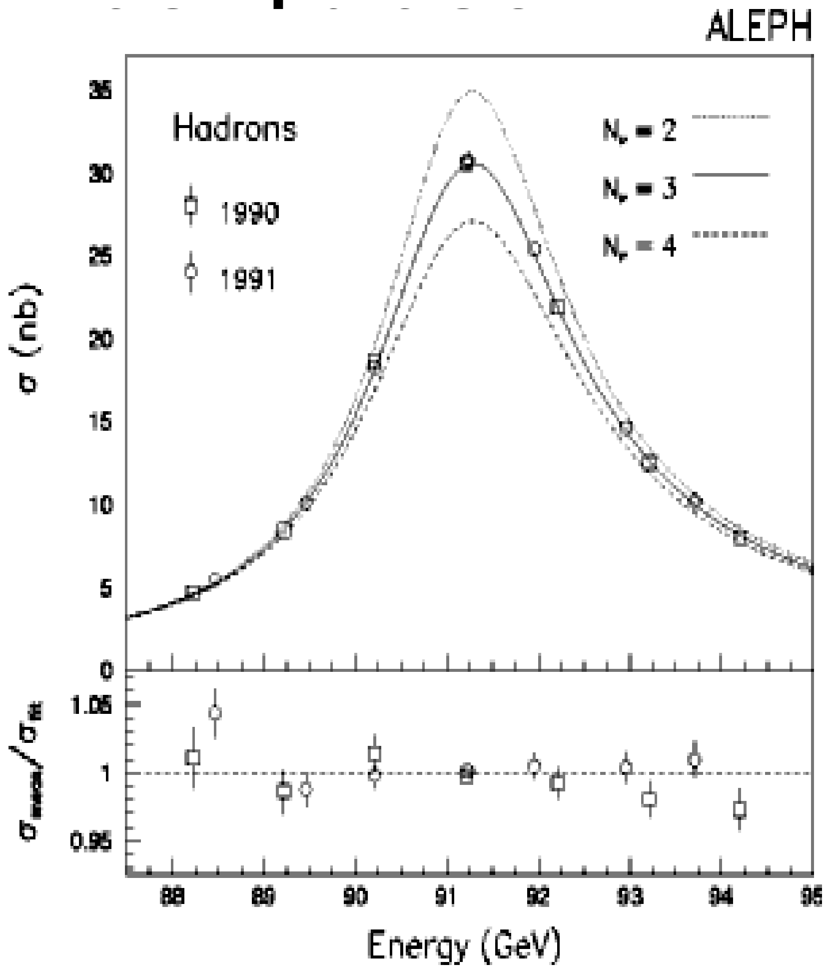
Energy calibration systematics was 10 times that the measurement itself because .. measurement was not performed continuously.

End of fills – systematically shifted

55% transverse polarization was achieved

1989 The Number of light neutrinos

$e^+e^- \rightarrow Z \rightarrow q\bar{q}$, vs $e^+e^- \rightarrow Z \rightarrow \nu\bar{\nu}$



is this 2σ effect
an indication of
massive sterile neutrinos?

ALEPH+DELPHI+L3+OPAL in 2001 N_ν = 2.984 ±0.008

Error dominated by systematics on luminosity.

Beam Polarization at TLEP-Z

injecting polarized electrons and positrons? A discouraging parameter against this is the spin tune $\nu_s = E_{beam}$ [GeV]/0.4406486
=103.5 at the Z peak. Crossing all these resonances in the acceleration will kill polarization for sure.

➔ Build up polarization by Sokolov Ternov effect at high energy.

$$\tau = A\frac{\hbar^2}{mce^2}\left(\frac{mc^2}{E}\right)^2\left(\frac{H_0}{H}\right)^3$$

where A is the limiting degree of polarization (92.4%) and τ is the polarization time.

The polarization time at the Z peak was **300 minutes in LEPI**
It will be $300x(80/27)^3$ ~ 9'000 minutes or **150 hours at TLEP-Z – ouch.**

we can use wigglers and we must be patient.

Polarization Wigglers as they were designed for LEP I
(A.B and John Jowett, in Polarization at LEP, CERN Yellow report 88-06)

Asymmetric B- B+ B- 12 magnets in straight sections → 65 m total

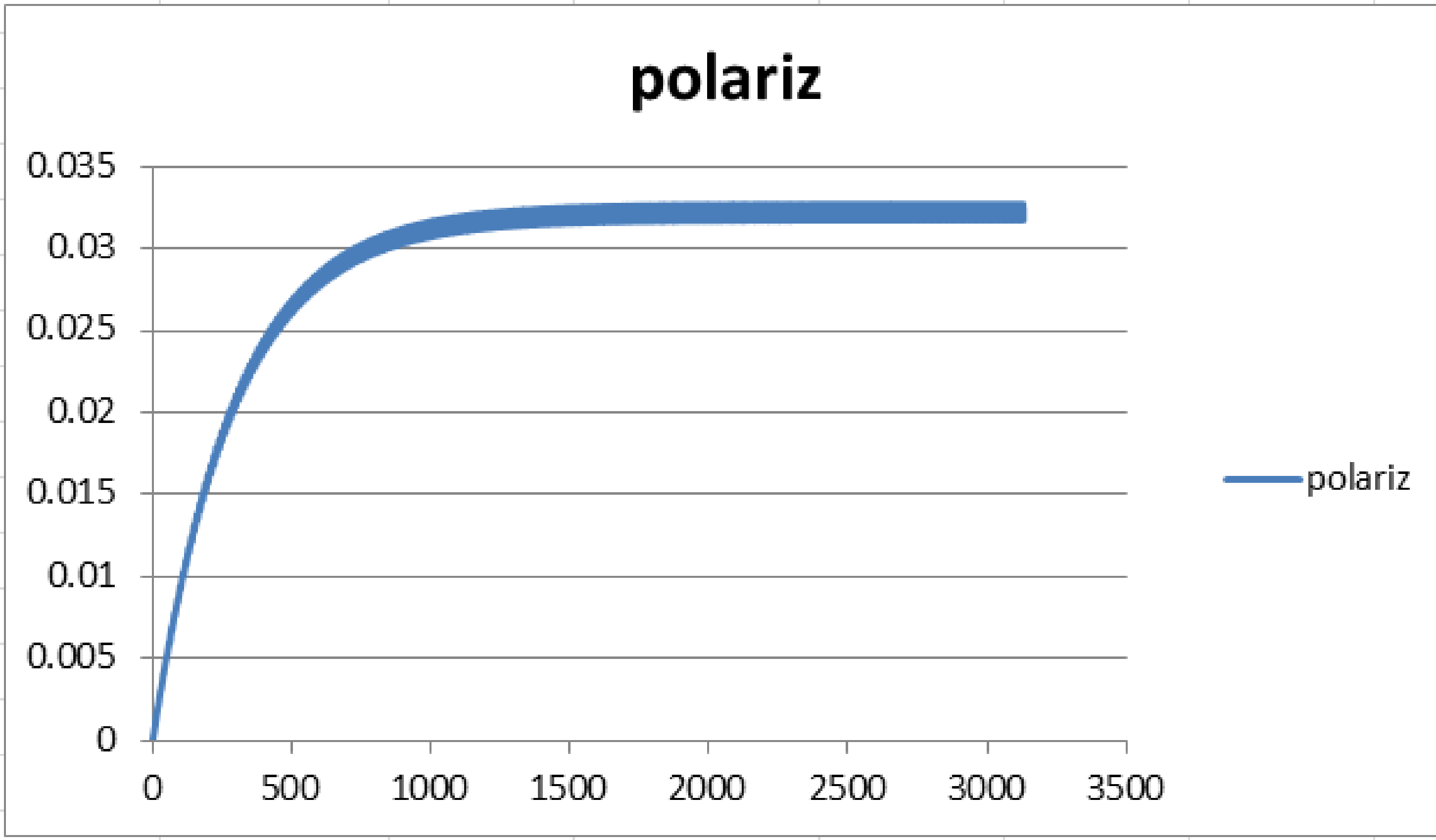
$$\max B_+ \simeq 1.3\,\mathrm{T}, \qquad L_+ = 0.65\,\mathrm{m}, \qquad L_- = 4.0\,\mathrm{m}, \qquad L_g = 0.25\,\mathrm{m}.$$

3 kW of SR locally per mA → 4 MW extra power at the Z.

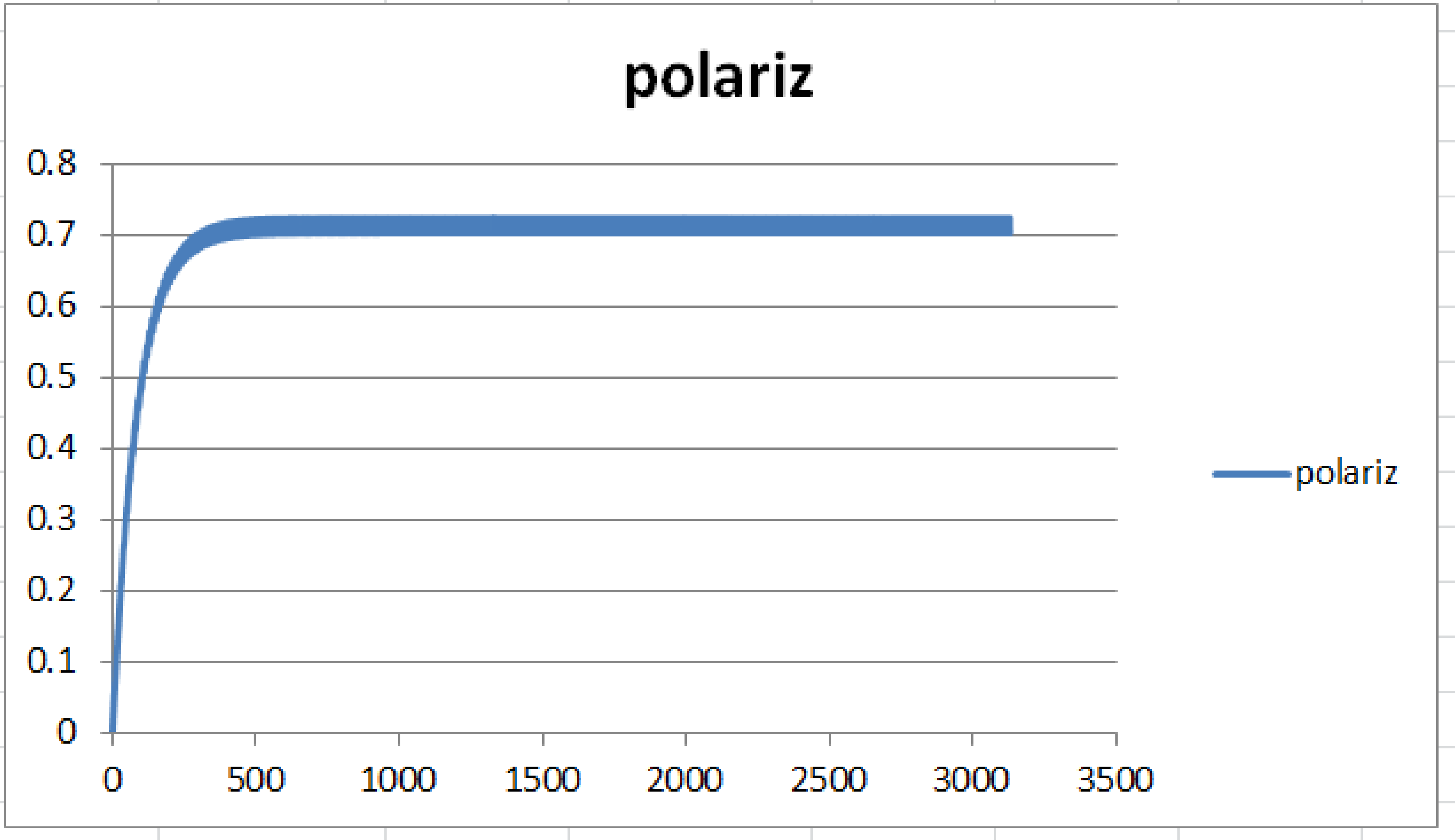
~100 minutes polarization time.

→ Will also increase the energy spread, so practical compromise has to be found

G	H	I	J	K	L	M	N	O
		beam lifetime	300	polarization lifetime	9000	refill every	10	
			mins		mins		mins	



beam lifetime	300	polarization lifetime	120	refill every	10
	mins		mins		mins



THIS ASSUMES ASYMPTOTIC POLARIZATION OF 90%

KORATZ

LEP3/TLEP parameters -1

soon at SuperKEKB:
β_x^*=0.03 m, β_Y^*=0.03 cm

	LEP2	LHeC	LEP3	TLEP-Z	TLEP-H	TLEP-t
beam energy E_b [GeV]	104.5	60	120	45.5	120	175
circumference [km]	26.7	26.7	26.7	80	80	80
beam current [mA]	4	100	7.2	1180	24.3	5.4
#bunches/beam	4	2808	4	2625	80	12
#e−/beam [10^{12}]	2.3	56	4.0	2000	40.5	9.0
horizontal emittance [nm]	48	5	25	30.8	9.4	20
vertical emittance [nm]	0.25	2.5	0.10	0.15	0.05	0.1
bending radius [km]	3.1	2.6	2.6	9.0	9.0	9.0
partition number J_ε	1.1	1.5	1.5	1.0	1.0	1.0
momentum comp. α_c [10^{-5}]	18.5	8.1	8.1	9.0	1.0	1.0
SR power/beam [MW]	11	44	50	50	50	50
β^*_x [m]	1.5	0.18	0.2	0.2	0.2	0.2
β^*_y [cm]	5	10	0.1	0.1	0.1	0.1
σ^*_x [μm]	270	30	71	78	43	63
σ^*_y [μm]	3.5	16	0.32	0.39	0.22	0.32
hourglass F_{hg}	0.98	0.99	0.59	0.71	0.75	0.65
ΔE^{SR}_{loss}/turn [GeV]	3.41	0.44	6.99	0.04	2.1	9.3

SuperKEKB: $\varepsilon_y/\varepsilon_x$=0.25%

LEP3/TLEP parameters -2

LEP2 was not beam-beam limited

	LEP2	LHeC	LEP3	TLEP-Z	TLEP-H	TLEP-t
$V_{RF,tot}$ [GV]	3.64	0.5	12.0	2.0	6.0	12.0
$\delta_{max,RF}$ [%]	0.77	0.66	5.7	4.0	9.4	4.9
ξ_x/IP	0.025	N/A	0.09	0.12	0.10	0.05
ξ_y/IP	0.065	N/A	0.08	0.12	0.10	0.05
f_s [kHz]	1.6	0.65	2.19	1.29	0.44	0.43
E_{acc} [MV/m]	7.5	11.9	20	20	20	20
eff. RF length [m]	485	42	600	100	300	600
f_{RF} [MHz]	352	721	700	700	700	700
δ^{SR}_{rms} [%]	0.22	0.12	0.23	0.06	0.15	0.22
$\sigma^{SR}_{z,rms}$ [cm]	1.61	0.69	0.31	0.19	0.17	0.25
L/IP[10^{32}cm^{-2}s^{-1}]	1.25	N/A	94	10335	490	65
number of IPs	4	1	2	2	2	2
Rad.Bhabha b.lifetime [min]	360	N/A	18	74	32	54
Υ_{BS} [10^{-4}]	0.2	0.05	9	4	15	15
n_γ/collision	0.08	0.16	0.60	0.41	0.50	0.51
$\Delta\delta^{BS}$/collision [MeV]	0.1	0.02	31	3.6	42	61
$\Delta\delta^{BS}_{rms}$/collision [MeV]	0.3	0.07	44	6.2	65	95

LEP data for 94.5 - 101 GeV consistently suggest a beam-beam limit of ~0.115 (R.Assmann, K. C.)

Operation mode for lineshape measurement

operation mode probably different for the Z line shape measurement,
for high intensity peak measurements and for
longitudinal polarization measurements

Proposed for line shape measurement :
it is important to keep a number of bunches transversally polarized to perform the calibration continuously. ***These bunches need not be colliding.***
➔ **Keep some fraction of the 2625 bunches not colliding and measure continuously.**

Thanks to synchrotron oscillations the average energy of colliding beams cannot be different to that of circulating beams (this can be checked by beam position in dispersion zones)

Spin matching techniques of LEP can be used (low beta, solenoids, imperfections, etc..)
hopefully easier **if we careful thought ahead of time.**

This should allow the systematic error to be reduced below the 100 keV/beam level per measurement , with improvement expected as 1/sqrt(N_{meas})

Other line shape uncertainties and systematic errors

-- **statistics**
LEP1 → $\Delta\Gamma_Z$= 3 MeV with one year of data
TLEP → $\Delta\Gamma_Z$= O(10 keV)…! (probably does not need one full year!)
Clearly systematics will be the issue.

-- **absolute cross-section** has an impact on $\Gamma_{inv} / \Gamma_{\ell} = N_\nu \Gamma_\nu / \Gamma_{\ell}$
This is dominated by calculations of Bhabha scattering
Improvement requires new calculations of higher order QED corrections

-- **dependence of acceptance on E_{CM}** (small if efficiency is high)

-- **understanding of non-resonant background**
→ was statistical analysis
→ probably requires scanning the resonance over a broader range of E_{CM} to idenify this component more precisely.

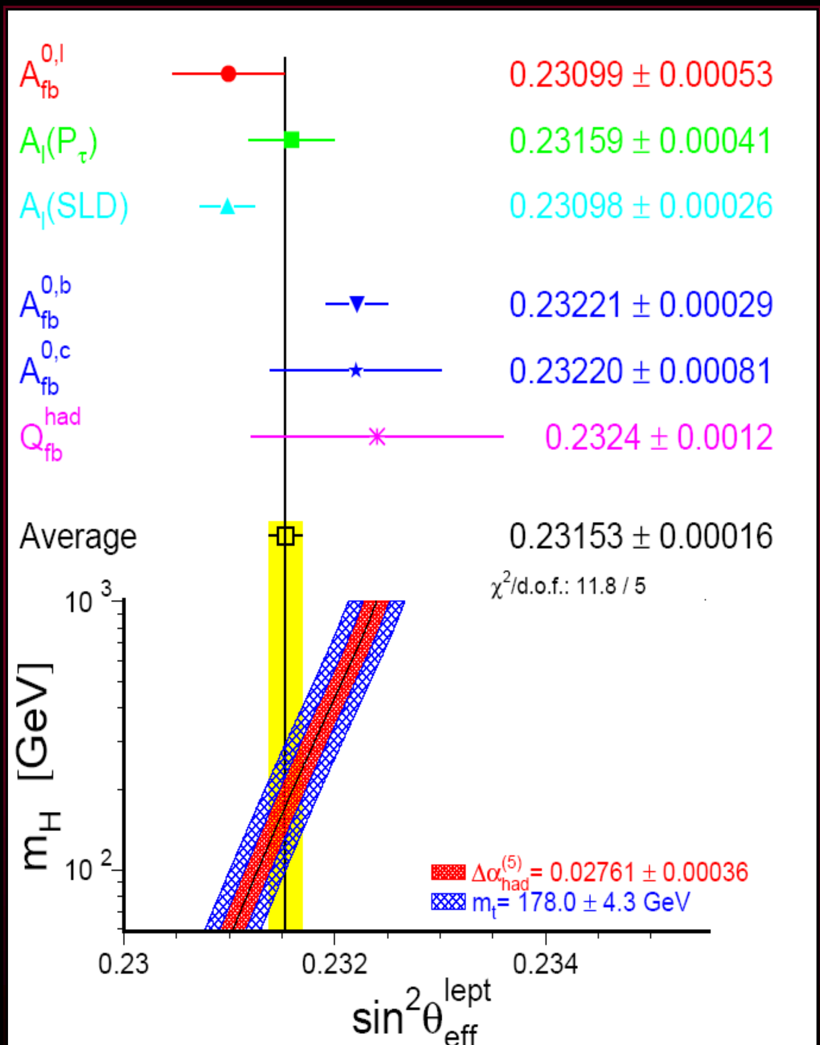
Easy to improve $\Delta\Gamma_Z$, much less easy to improve N_ν

Measuring $\sin^2\theta_W^{eff}(m_Z)$

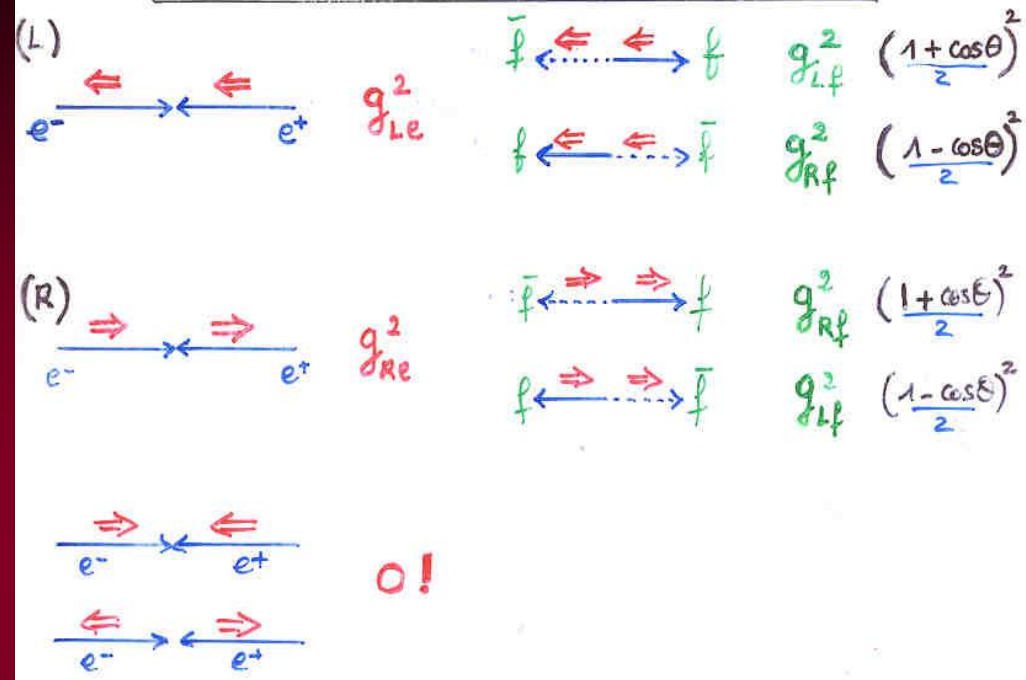
$$\sin^2\theta_W^{eff} \equiv \frac{1}{4}(1 - g_V/g_A)$$

$$g_V = g_L + g_R$$

$$g_A = g_L - g_R$$



Helicity effects in $e^+e^- \to f\bar{f}$



Pol'd BEAM ⇒

$$A_{LR} = \frac{\sigma_L^{tot} - \sigma_R^{tot}}{\sigma_L^{tot} + \sigma_R^{tot}} = \frac{g_{Le}^2 - g_{Re}^2}{g_{Le}^2 + g_{Re}^2} \equiv \mathcal{A}_e = \frac{2 g_{Ve} g_{Ae}}{g_{Ve}^2 + g_{Ae}^2}$$

$$A_{FB}^{Pol\,f} = \frac{\sigma_L^{Ff} - \sigma_L^{Bf} - (\sigma_R^{Ff} - \sigma_R^{Bf})}{\sigma_L^{Ff} + \sigma_L^{Bf} + \sigma_R^{Ff} + \sigma_R^{Bf}} = \frac{3}{4}\mathcal{A}_f$$

no Pol available:

$$A_{FB} = \frac{\sigma_u^{Ff} - \sigma_u^{Bf}}{\sigma_u^{Ff} + \sigma_u^{Bf}} = \frac{3}{4}\mathcal{A}_e \mathcal{A}_f$$

Pol^n analyses τ

$$\langle P_f \rangle = \frac{\sigma_u^R - \sigma_u^L}{\sigma_u^R + \sigma_u^L} = -\mathcal{A}_f$$

$$A_{FB}^{Pol} = \frac{\sigma_u^{RF} - \sigma_u^{LF} - (\sigma_u^{RB} - \sigma_u^{LB})}{\sigma_u^{RF} + \sigma_u^{LF} + \sigma_u^{RB} + \sigma_u^{LB}} = -\frac{3}{4}\mathcal{A}_e$$

Longitudinal polarization

Once polarization is transverse it needs to be rotated in the direction of the beam to become longitudinal in the IP region and again the same transverse in the next arcs

➔ **the art of spin rotators** (there have been many proposals, probably best are the Hera rotators)

For longitudinal polarization experiments we need to keep the beam **polarized while in collisions. Experiments at LEP showed that this was possible -- >**

Top up mode should provide stable operation which is essential for the orbit corrections, but will dilute the beam polarization as $P = (1/\tau_P) / (1/\tau_P + 1/\tau_{lumi})$

10^{11} Z @ P=40%

➔ towards $\Delta \sin^2\theta_W^{eff} = 10^{-6}$ this is two order manitude better than the present 0.00016

Unlike the Z line shape re-measurement which could be a few weeks of running this is more likely to be **a one year affair.**

EXPERIMENTS ON BEAM-BEAM DEPOLARIZATION AT LEP

R. Assmann*, A. Blondel*, B. Dehning, A. Drees°, P. Grosse-Wiesmann, H. Grote, M. Placidi, R. Schmidt,
F. Tecker†, J. Wenninger

PAC 1995

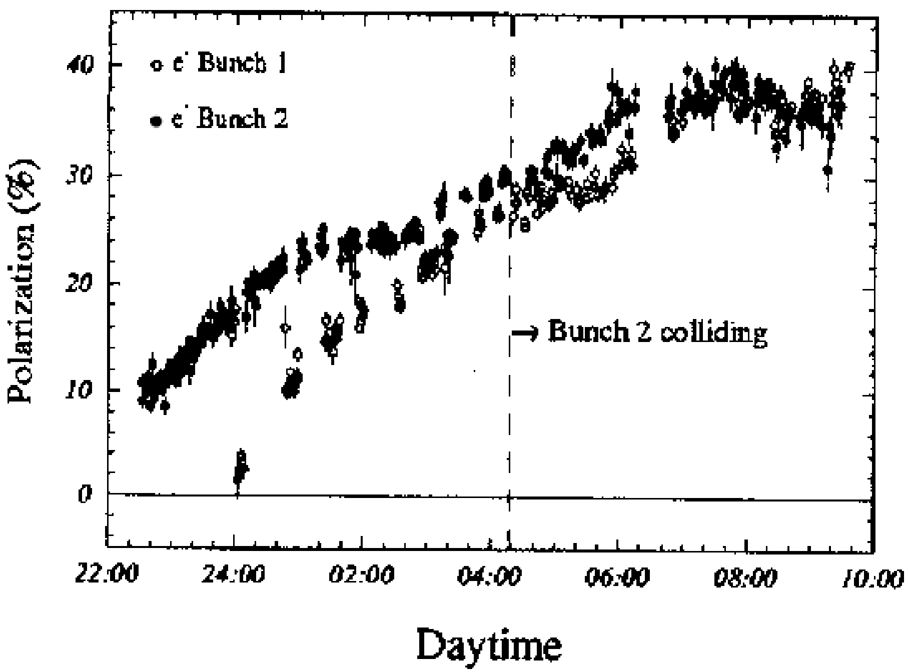


Figure. 3. Polarization level during third experiment

- With the beam colliding at one point, a polarization level of 40 % was achieved. The polarization level was about the same for one colliding and one non colliding bunch.
- It was observed that the polarization level depends critically on the synchrotron tune : when Q_s was changed by 0.005, the polarization strongly decreased.

experiment performed at an energy of 44.71 GeV the polarization level was 40 % with a linear beam-beam tune shift of about 0.04/IP. This indicates, that the beam-beam depolarization does not scale with the linear beam-beam tune shift at one crossing point. Other parameters as spin tune and synchrotron tune are also of importance.

This was only ever tried 3 times!
Best result: P = 40% , ξ^*_y= 0.04 , one IP
Assuming 4 IP and ξ^*_y= 0.01 ➔

reduce luminositiy x 10 still, 10^{11} Z @ P=40%

Measurement of A_{LR}

electron bunches	1⇐	2	3	4⇐
positron bunches	1	2⇒	3	4⇒
cross sections	σ_1	σ_2	σ_3	σ_4
event numbers	N_1	N_2	N_3	N_4

$$\sigma_1 = \sigma_u (1 - P^-_e A_{LR})$$

$$\sigma_2 = \sigma_u (1 + P^+_e A_{LR})$$

$$\sigma_3 = \sigma_u$$

$$\sigma_4 = \sigma_u [1 - P^+_e P^-_e + (P^+_e - P^-_e) A_{LR}]$$

Verifies polarimeter with experimentally measured cross-section ratios

statistics

ΔA_{LR} = 0.0025 with about 10^6 Z^0 events,

ΔA_{LR} = 0.000015 with 10^{11} Z and 40% polarization in collisions.

$\Delta \sin^2\theta_W^{eff}$ (stat) = O(2.10^{-6})

M_W

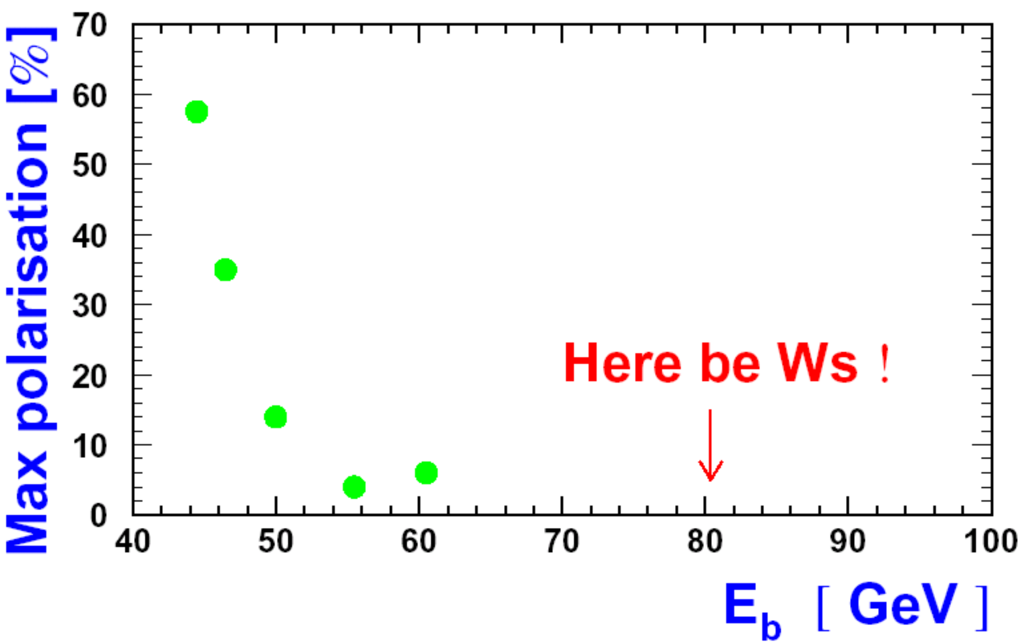
Experimentally main irrecucible systematic is due to beam energy
(others are extracted statistically)

LEP2 4 10^4 W pair events ➔ Δm_W= 23 MeV (of which 20 is stat, 10 is E_beam)

TLEP 4 10^7 W pairs ➔ Δm_W < 1 MeV   (quid of energy calbration?)

Polarization at LEP2

- Under optimal machine conditions, a polarization $P_{\perp}$ of 57% was measured at LEP around the Z resonance.
- In practice most E calibrations were performed with $P_{\perp}$ ~5-15%.
- Above the Z the maximum polarization dropped quickly as the energy spread (and therefore ν_s spread) became large(r).
  - *No $P_{\perp}$ was ever measured above 60 GeV.*



The theoretical predictions were much more optimistic !

Beam Polarization at TLEP-W

It is generally agreed that the main limitation to obtain polarization at LEP2 was beam energy spread

$$\nu_s = \frac{E}{440.6486(1)\,[\mathrm{MeV}]}$$

Energy spread should remain small so that $\Delta\nu_s << 1$

At TLEP the larger radius of the machine should help.

$$\Delta E \propto E^2 / \sqrt{\rho}$$

The spin tune spread of LEP2 at 61 GeV is equal to that of TLEP at 81 GeV ☺

➔ If the machine is as well aligned etc... as LEP2
(and we should aim to do much better!)

Polarization for energy calibration at W threshold should be straightforward.

Table 1: Sample of TLEP Physics performance goals.

Physics region	E_{beam} (GeV)	E_{CM} (GeV)	Luminosity in each of 4 experiments $cm^{-2}s^{-1}$	Beam Polarization	Physics goals
Z peak	44-47	88-94	10^{36}	Transverse for energy calibration >5%	One year of data taking: $>3\times10^{11}$ Z decays per experiment $>6\times10^{10}$ $\bar{b}b$ pairs per experiment Z mass and width to 0.1 MeV/c^2 $\Delta\rho_\ell$ to $\leq 5\,10^{-5}$; Improvements in R_{had} R_b Γ_{inv}, etc
Z peak	45.6	91.2	$>10^{35}$	Longitudinal: 50%	A_{LR} A_{FB}^{Pol} ; $\sin^2\theta_\ell^{eff}$ to $\leq 3\,10^{-6}$
W pair threshold and maximum	80-90	160-180	2.10^{35}	Transverse for calibration >5% (useful, but not compulsory)	One year of data taking: W mass to <1 MeV/c^2
ZH threshold and cross-section maximum	110-125	220-250	5.10^{34}	Not required	5 years of data taking at ZH maximum (combined with 5 years at the $t\bar{t}$ threshold). W mass to ≤1 MeV/c^2 5×10^5 ZH events/expt m_H (MeV) 7 $\Delta\Gamma_H / \Gamma_H$ 1.3% $\Delta\Gamma_{inv} / \Gamma_H$ 0.15% $\Delta g_{H\gamma\gamma} / g_{H\gamma\gamma}$ 1.4% $\Delta g_{Hgg} / g_{Hgg}$ 0.7% $\Delta g_{Hww} / g_{Hww}$ 0.25% $\Delta g_{HZZ} / g_{HZZ}$ 0.2% $\Delta g_{H\mu\mu} / g_{H\mu\mu}$ 7% $\Delta g_{H\tau\tau} / g_{H\tau\tau}$ 0.4% $\Delta g_{Hcc} / g_{Hcc}$ 0.65% $\Delta g_{Hbb} / g_{Hbb}$ 0.22%
$t\bar{t}$ threshold and High Energy (E_{CM} > 340 GeV)	170-180	340-360	7.10^{33}	Not required	5 years of data taking: Top quark mass to 100 MeV/c^2 3.5 10^4 Hvv events

Theoretical limitations

TLEP

R. Kogler, Moriond EW 2013

SM predictions (using other input)

$$M_W = 80.3593 \pm 0.0005_{m_t} \pm 0.0001_{M_Z} \pm 0.0005?_{\Delta\alpha_{had}}$$

$$\pm 0.0005?_{S} \pm 0.0000_{M_H} \pm 0.0040_{theo}$$

0.0005
- 0.001

$$= 80.359 \pm 0.011_{tot}$$

$$\sin^2\theta^{\ell}_{eff} = 0.231496 \pm 0.000003_{m_t} \pm 0.000001_{M_Z} \pm 0.000003?_{\Delta\alpha_{had}}$$

$$\pm 0.000001?_{S} \pm 0.000000_{M_H} \pm 0.000047_{theo}$$

0.000002

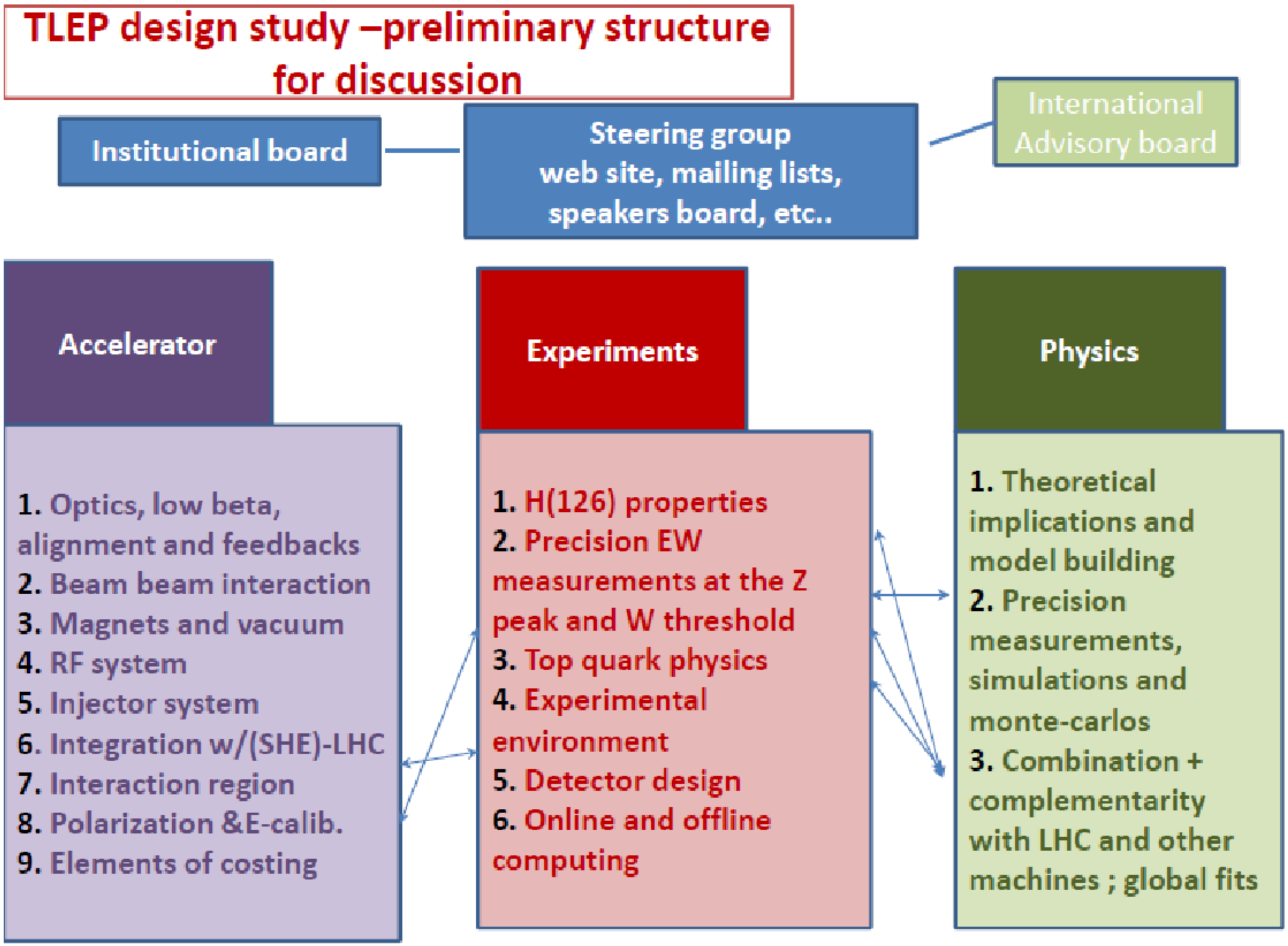
$$= 0.23150 \pm 0.00010_{tot}$$

Experimental errors at TLEP will be 20-100 times smaller than the present errors.

BUT can be typically 10 -30 times smaller than present level of theory errors

Would love similar error breakdown for Γ_Z, Γ_{ee}, R_b etc…

Table 2 Preliminary TLEP design study structure for discussion



TLEP

Outlook

We can improve EWRC sensitive observables at TLEP around the Z resonance and Mw by factors between 20 and 100. **This provide a very powerful probe to new physics**

-- Z peak observables can be measured with fantastic statistics.
b and hadron width, tau polarization, forward backward asymmetries

-- Beam polarization is critical for line shape and polarized asymmetry.
At TLEP, polarization time is 150 hours. Polarization wigglers are necessary,
also, polarimeters and spin rotators, etc…

-- new measurements of the Z mass and widths (electron and neutrino) require line shape precision scan – unique to a circular machine. **aim: <<0.1 MeV on m_Z, Γ_Z** ~~ILC~~

-- Longitudinal polarization should be feasible at ~40% level or more with reduced luminosity
Top-up injection should help a lot. **aim $\Delta\sin^2\theta_W^{eff}$ = 2 10^{-6} .**

-- there are many other systematic errors related to luminosity measurement and detection uncertainties which need to be addressed as well. **B tagging!**

-- beam polarization at WW feasible thanks to larger radius of TLEP **aim Δm_W < 1 MeV** ~~ILC~~

-- suggest a workshop/working groups dedicated for this.