5. Physik des Z^0-Bosons

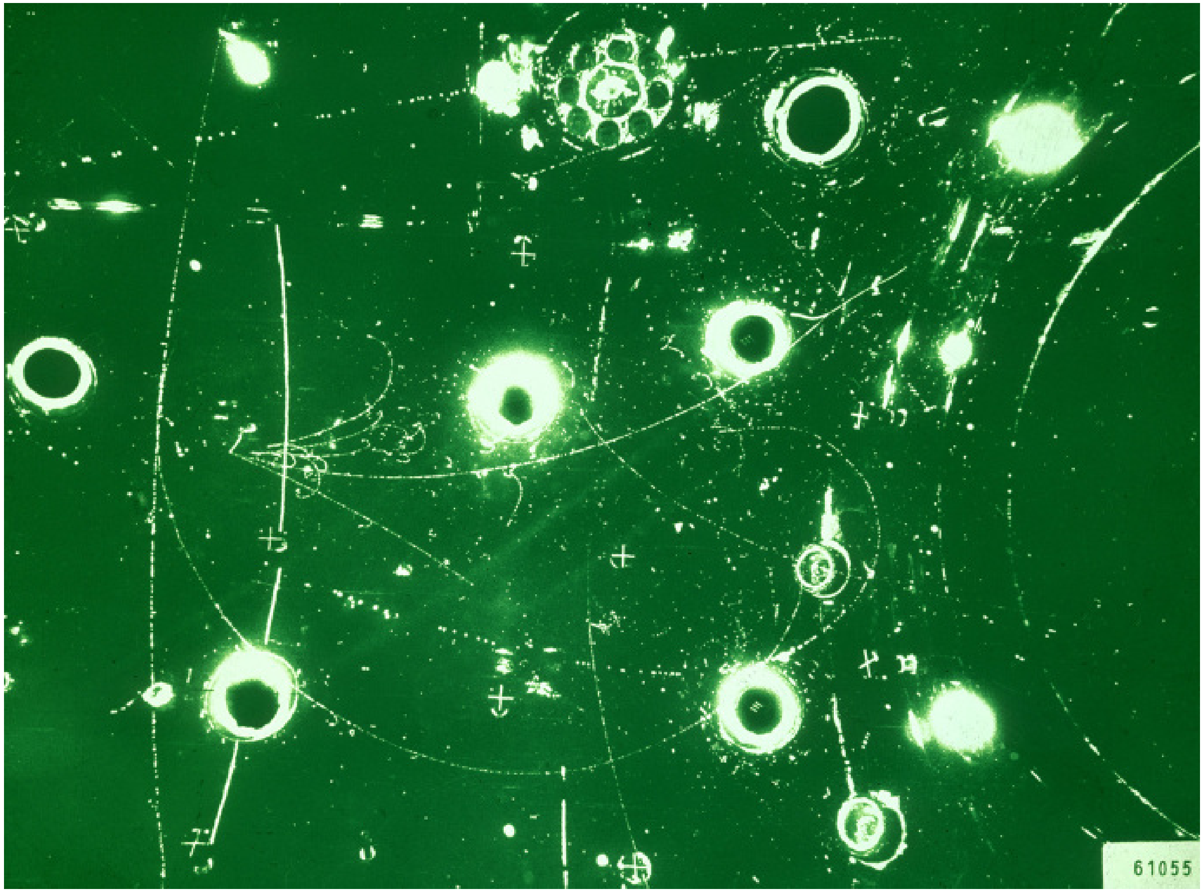
Glashow-Salam-Weinberg-Theorie (GSW)

Gruppe	Kopplung	Felder	Generatoren	physikalische Teilchen
$SU(2)_L$	g	W_μ^1 W_μ^2 W_μ^3	τ_1 τ_2 τ_3	$\left.\right\}$ $\boldsymbol{W}_\mu^\pm = \frac{1}{\sqrt{2}}\left(\boldsymbol{W}_\mu^1 \pm \boldsymbol{W}_\mu^2\right)$ ….. ? …. Z_μ
$U(1)_Y$	g'	B_μ	Y	….. ? …. A_μ

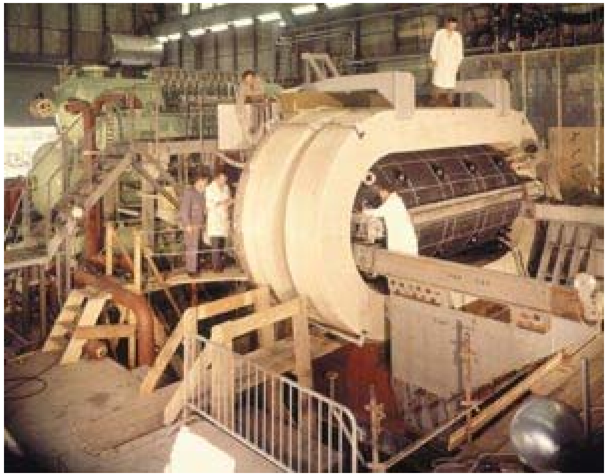
$$
\begin{aligned}
Z^0 &= W^0 \cdot \cos\theta_W - B^0 \cdot \sin\theta_W \\
\gamma &= W^0 \cdot \sin\theta_W + B^0 \cdot \cos\theta_W
\end{aligned}
$$

3 unabhängige Parameter $\quad g,\ g',\ \theta_W \quad$ oder $\quad g,\ M_W,\ \theta_W \quad$ oder $\quad G_F,\ \alpha,\ \theta_W$

5.1 Entdeckung des Neutralen Stroms (NC)



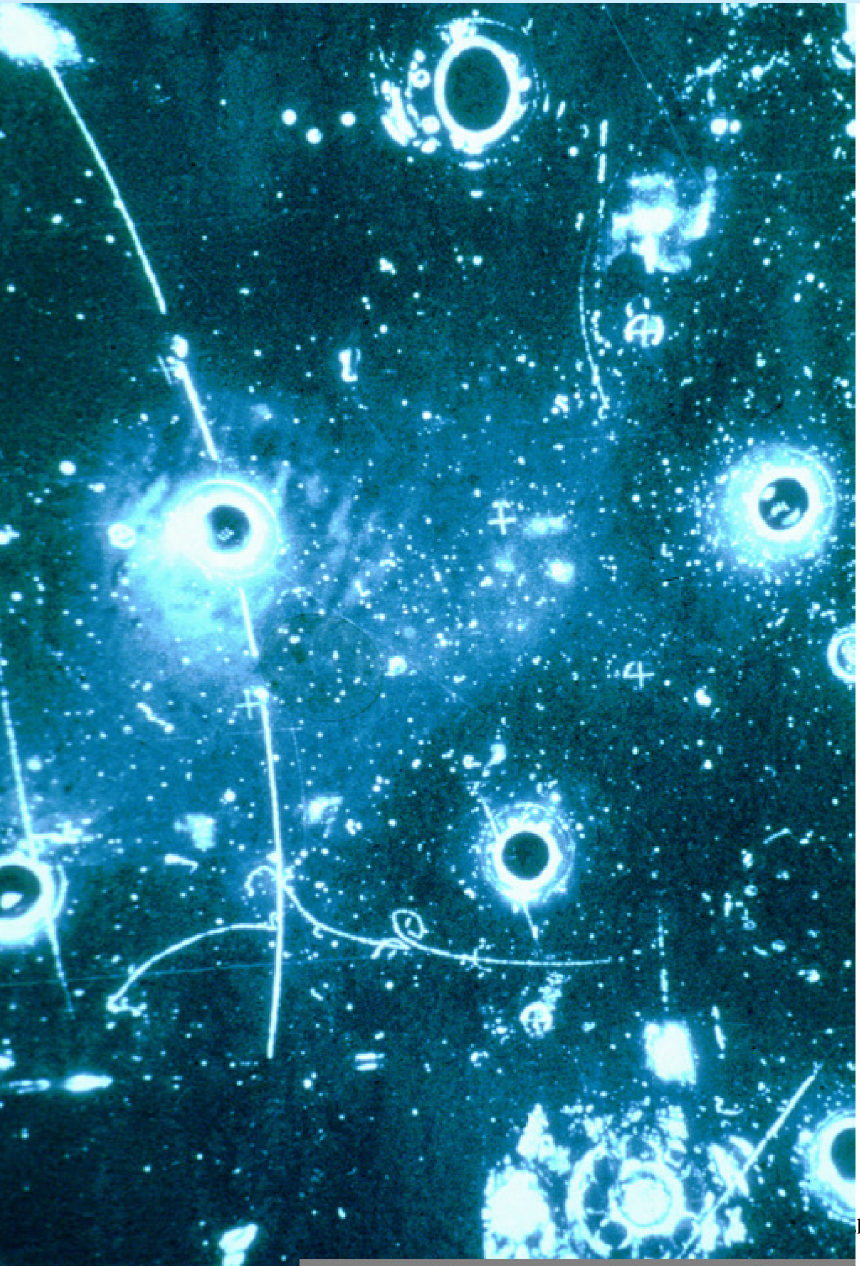
The Gargamelle chamber

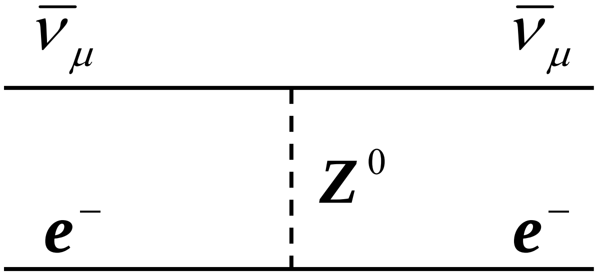


Date: Oct 1973

A hadron event - a neutrino interacting with a nucleon and emerging as a neutrino : first observation of "neutral currents" in the Gargamelle heavy liquid bubble chamber.

NC: leptonisches Ereignis

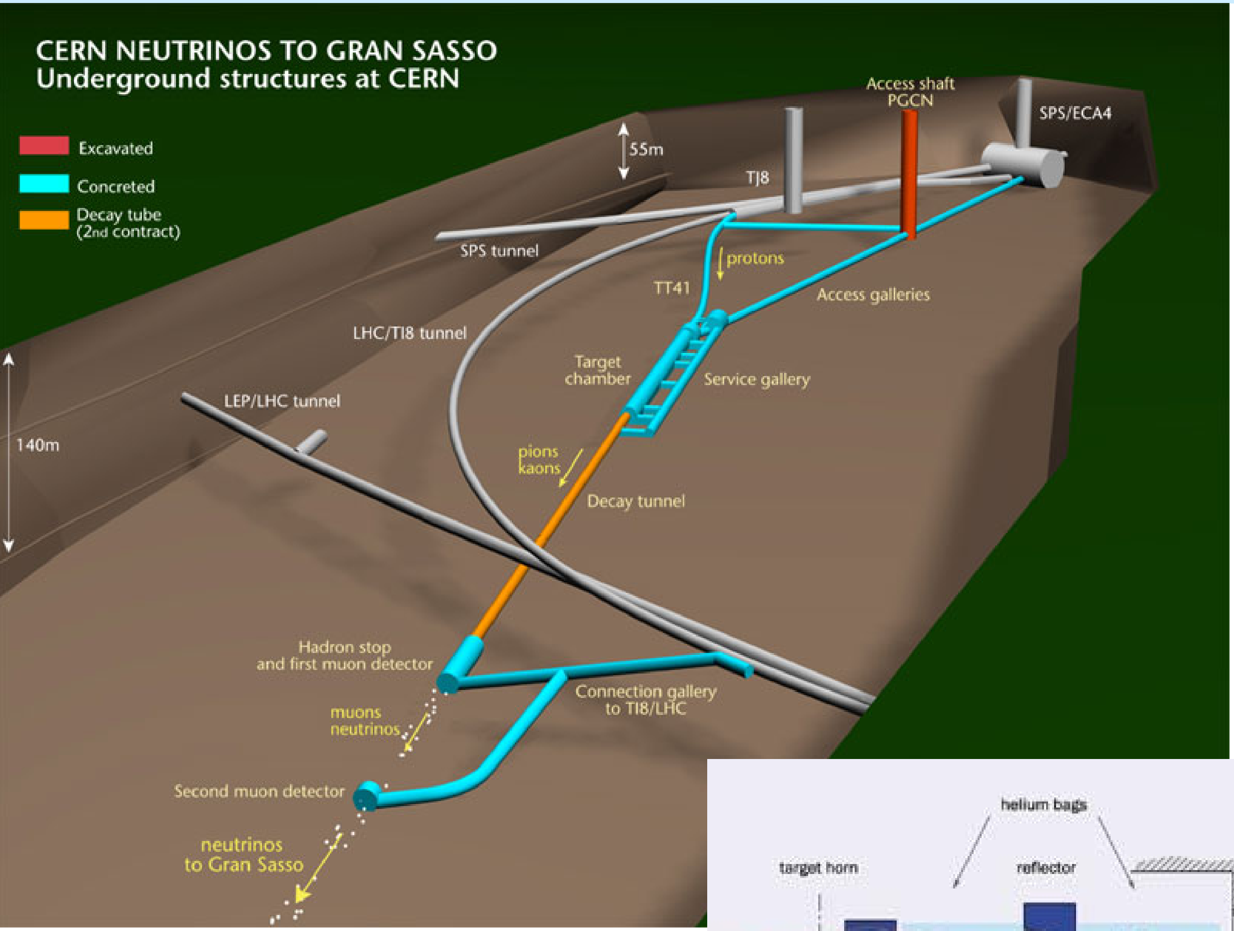


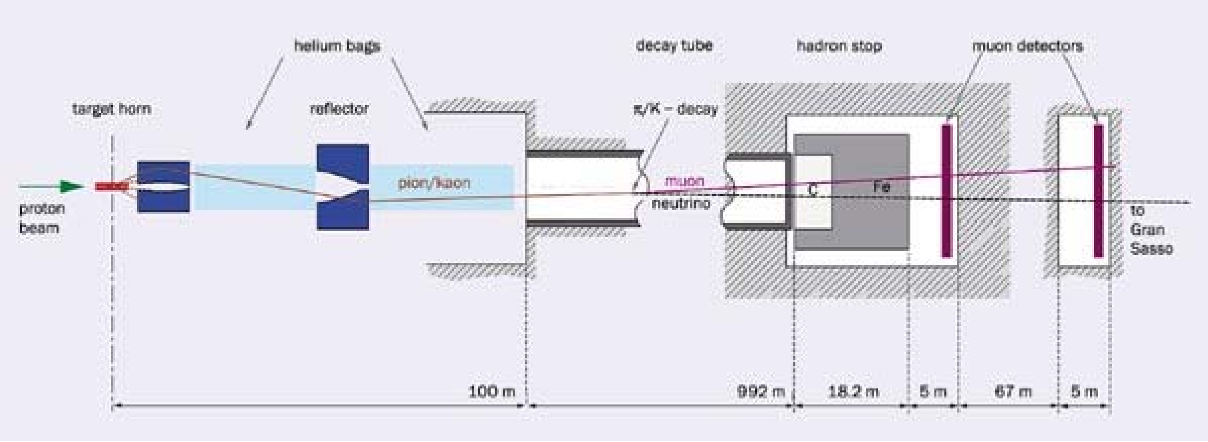


Date: 1973

A lepton event - a neutrino interacting with a electron and emerging as a neutrino : first observation of "neutral currents" in the Gargamelle heavy liquid bubble chamber. In the photograph, an unseen neutrino interacts with an electron and emerges as a neutrino instead of changing into a muon - what is seen (horizontally) is the track of the electron. This lepton event offers proof of the existence of neutral currents.

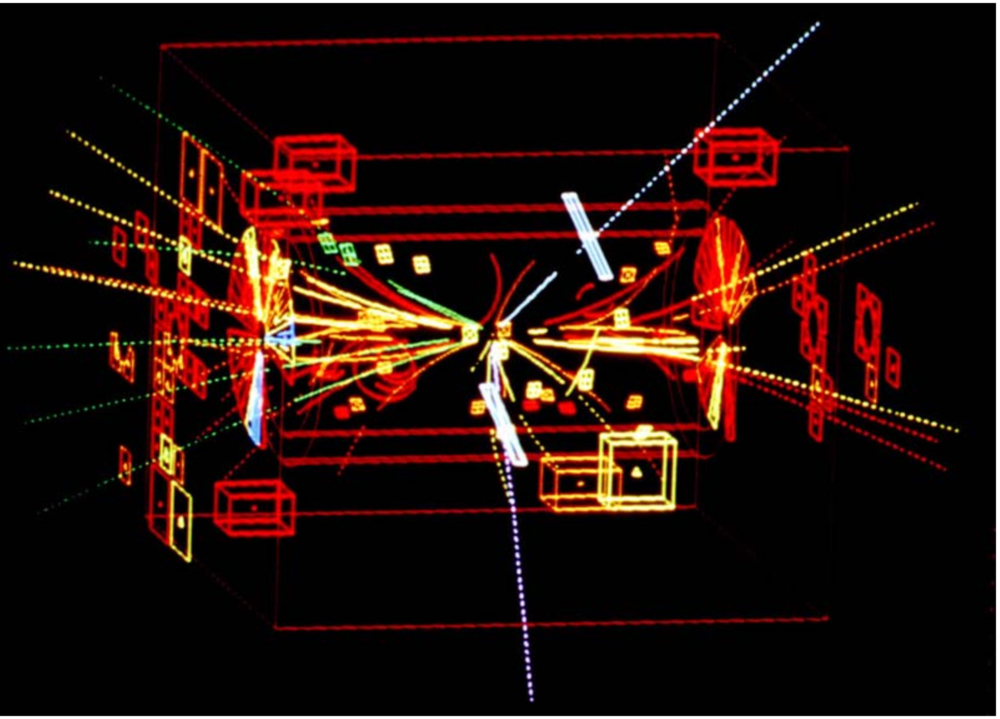
Neutrino-Strahlen (Beispiel CNGS)

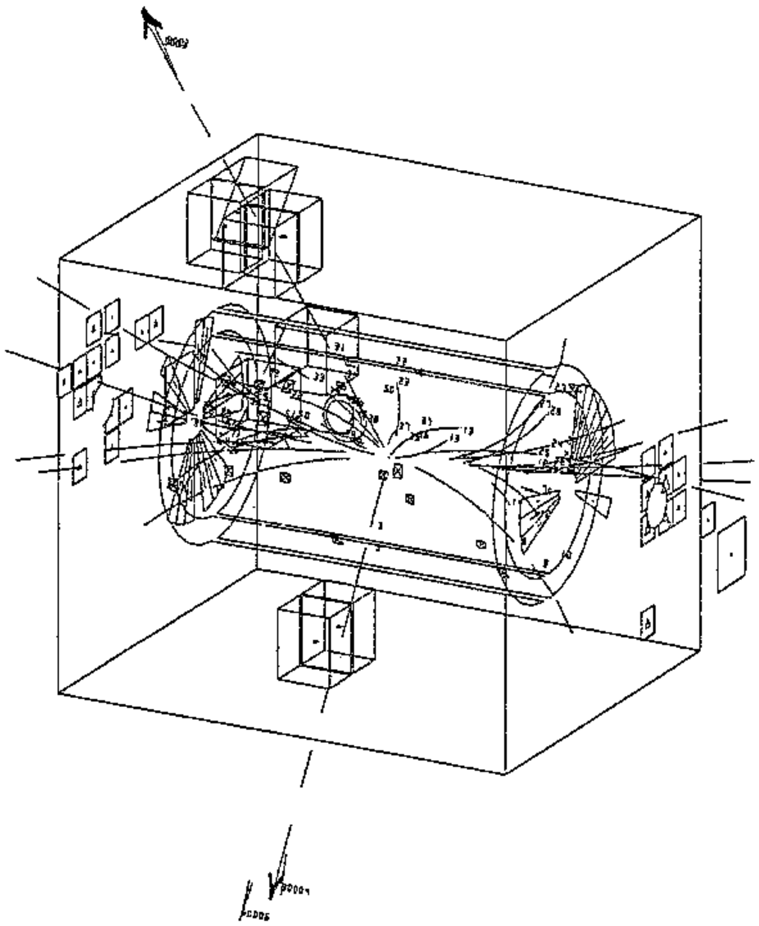


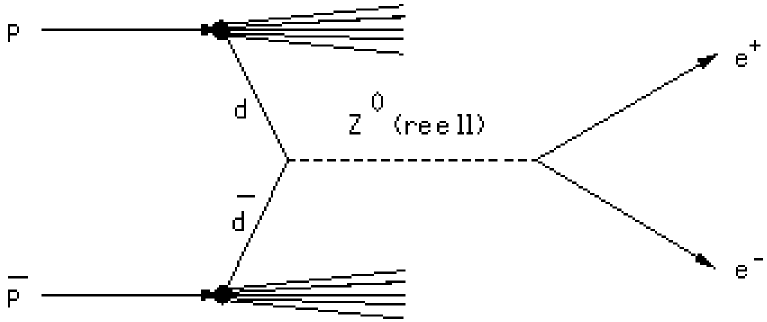


Direkte Erzeugung des Z^0-Bosons

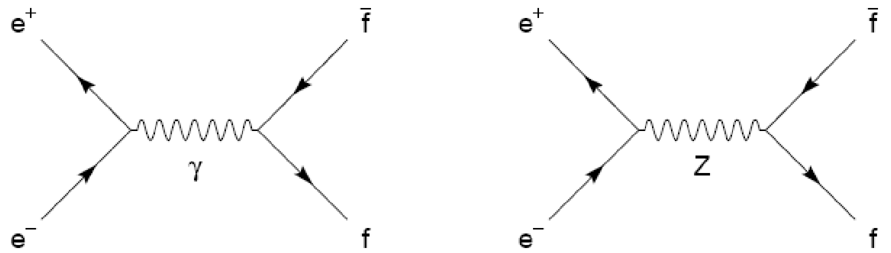
First candidate Z event at UA1, 1983.

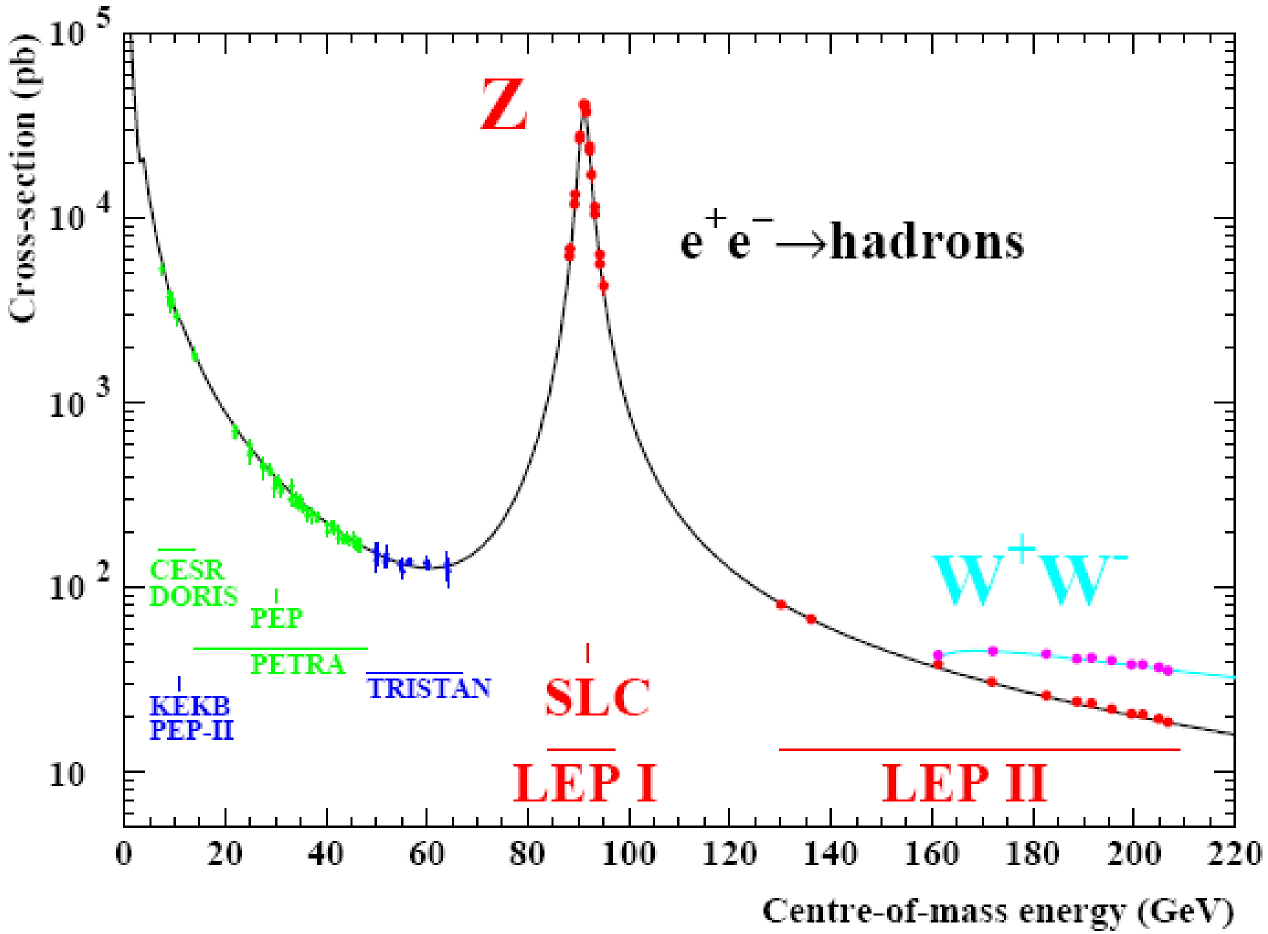




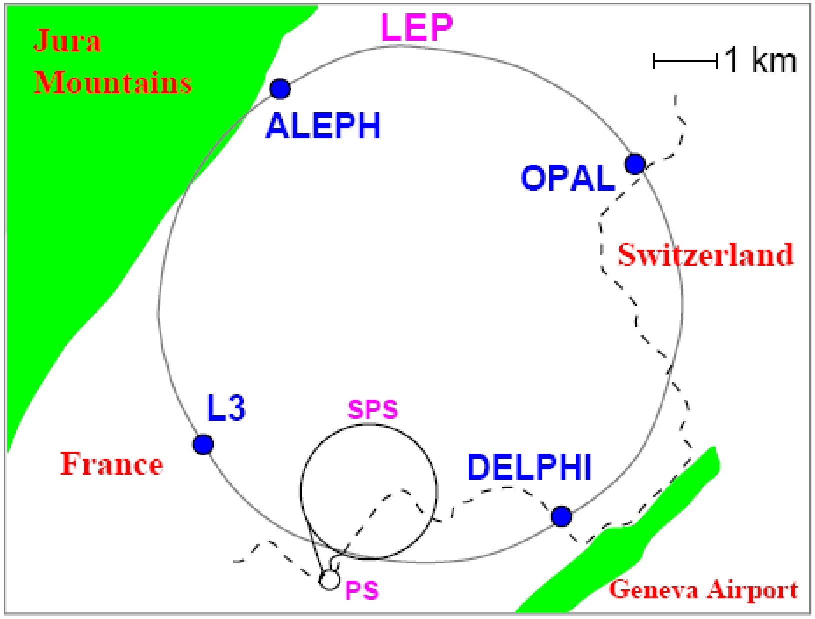


5.2 Resonante Erzeugung des Z^0-Bosons in e^+e^-

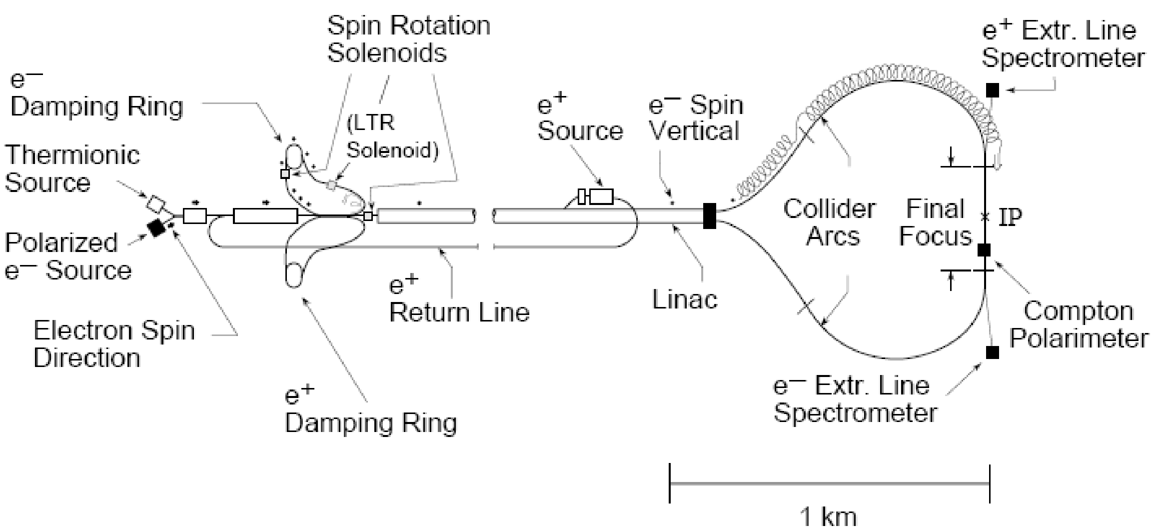




LEP/SLC-Ergebnisse



$$
\begin{aligned}
m_Z &= 91.1875 \pm 0.0021 \text{ GeV} \\
\Gamma_Z &= 2.4952 \pm 0.0023 \text{ GeV} \\
\rho_\ell &= 1.0050 \pm 0.0010 \\
\sin^2 \theta_{\text{eff}}^{\text{lept}} &= 0.23153 \pm 0.00016 \,.
\end{aligned}
$$



Schwacher Isospin und NC-Kopplungen

Family			T	T_3	Q
$\begin{pmatrix} \nu_e \\ e \end{pmatrix}_L$	$\begin{pmatrix} \nu_\mu \\ \mu \end{pmatrix}_L$	$\begin{pmatrix} \nu_\tau \\ \tau \end{pmatrix}_L$	1/2	+1/2 −1/2	0 −1
ν_{eR}	$\nu_{\mu R}$	$\nu_{\tau R}$	0	0	0
e_R	μ_R	τ_R	0	0	−1
$\begin{pmatrix} u \\ d \end{pmatrix}_L$	$\begin{pmatrix} c \\ s \end{pmatrix}_L$	$\begin{pmatrix} t \\ b \end{pmatrix}_L$	1/2	+1/2 −1/2	+2/3 −1/3
u_R	c_R	t_R	0	0	+2/3
d_R	s_R	b_R	0	0	−1/3

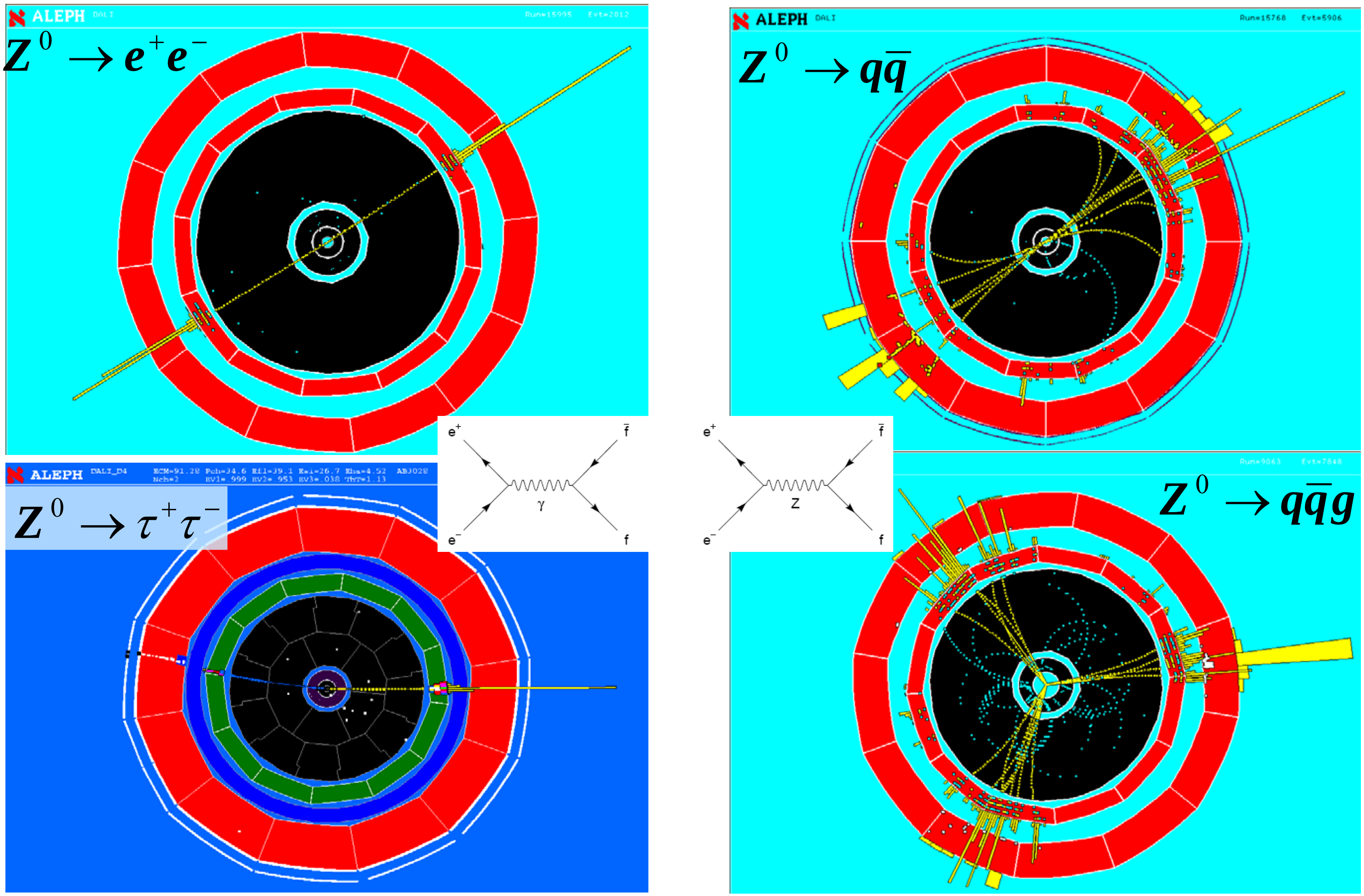
$$g_V = 2I_3 - 4Q\sin^2\theta_W$$

$$g_A = 2I_3$$

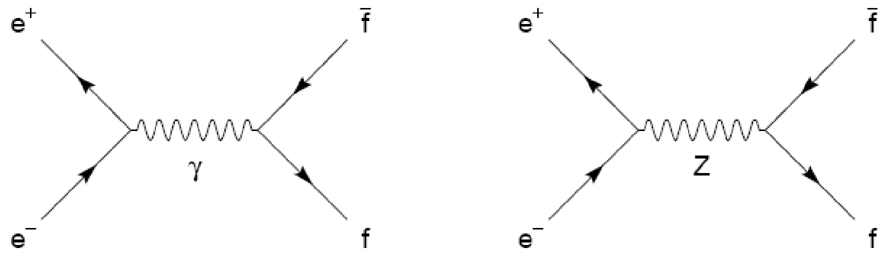
.on $\sin^2\theta_W \approx 1/4$ sind die Vorhersagen

	Q	I_3	g_V	g_A
ν	0	+1/2	+1	+1
e	−1	−1/2	0	−1
u,c,t	2/3	+1/2	+1/3	+1
d,s,b	−1/3	−1/2	−2/3	−1

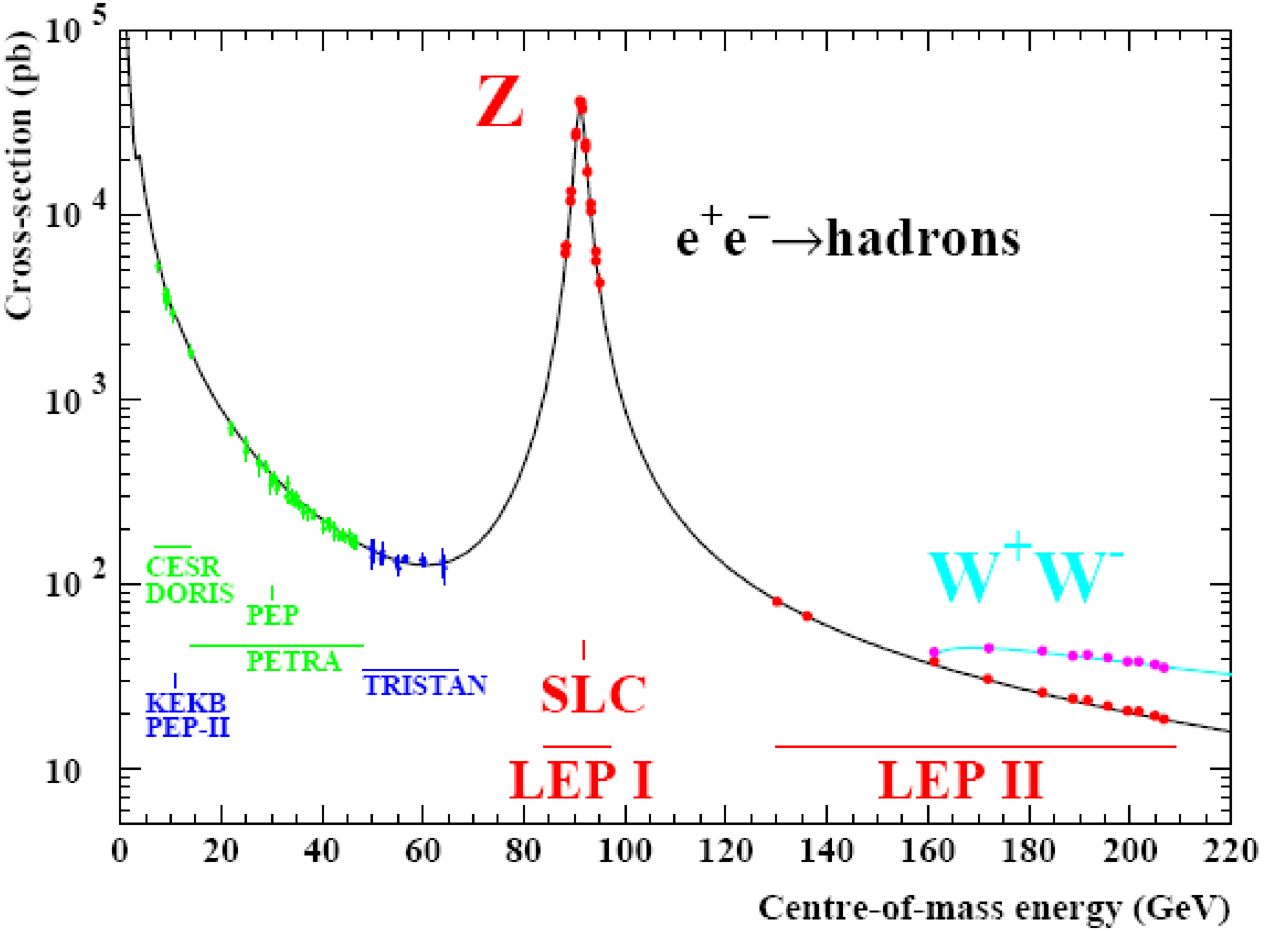
Z^0-Zerfälle bei LEP



Z^0-Resonanz

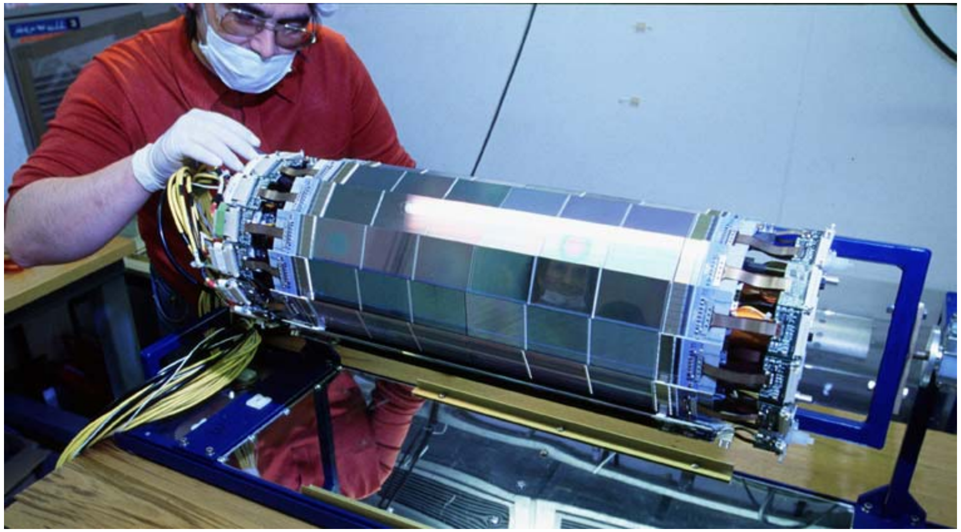


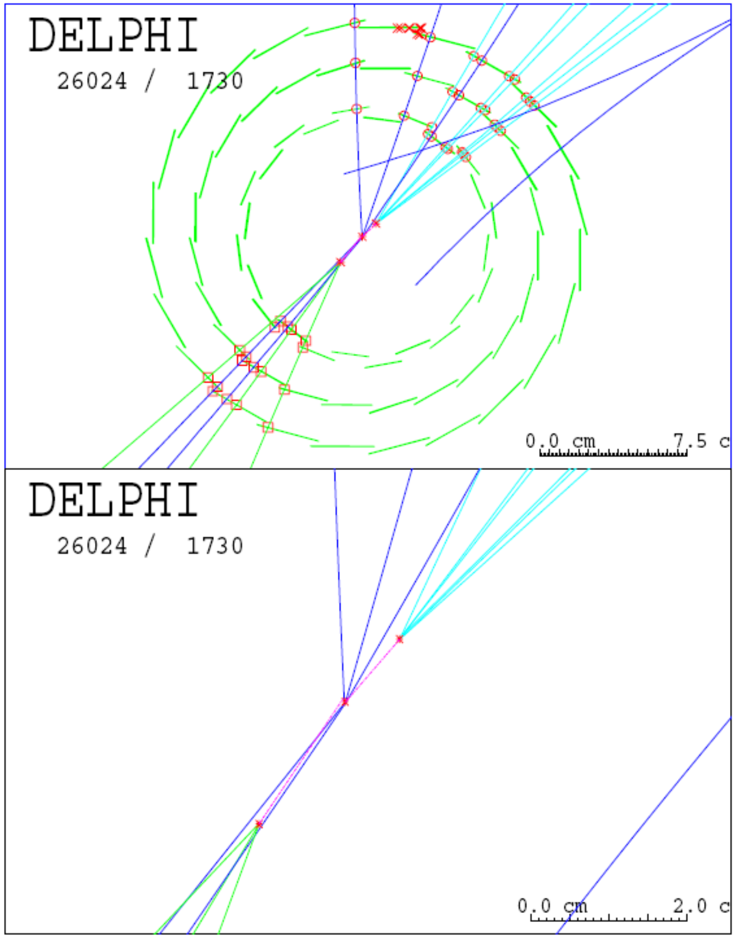
e+
f̄
e−
f
γ
e+
f̄
e−
f
Z

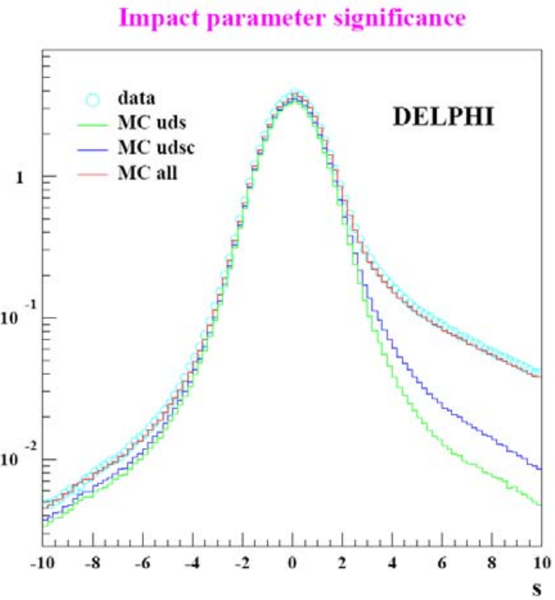


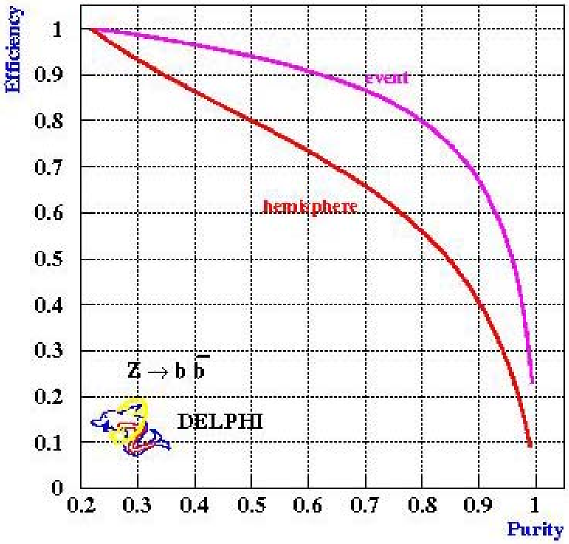
Cross-section (pb)
10 5
10 4
10 3
10 2
10
Z
e+e−→hadrons
W+W-
CESR
DORIS
PEP
PETRA
TRISTAN
KEKB
PEP-II
SLC
LEP I
LEP II
0
20
40
60
80
100
120
140
160
180
200
220
Centre-of-mass energy (GeV)

Flavour-Tagging

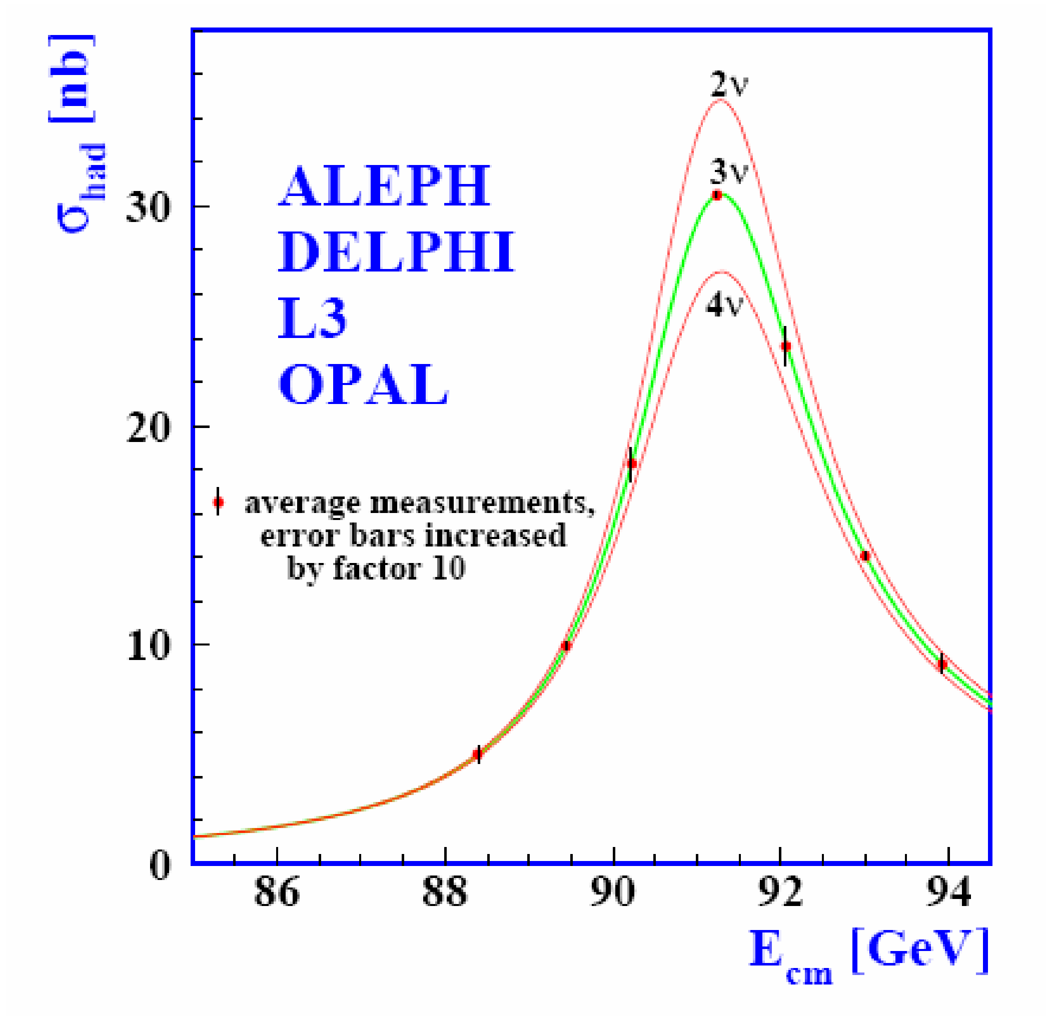








Anzahl der Neutrinoarten



Partielle Breiten

Parameter $\Gamma_{f\bar{f}}$	Average [MeV]	Correlations						
Without Lepton Universality								
		Γ_{had}	Γ_{ee}	$\Gamma_{\mu\mu}$	$\Gamma_{\tau\tau}$	$\Gamma_{b\bar{b}}$	$\Gamma_{c\bar{c}}$	Γ_{inv}
Γ_{had}	1745.8 ± 2.7	1.00						
Γ_{ee}	83.92 ± 0.12	−0.29	1.00					
$\Gamma_{\mu\mu}$	83.99 ± 0.18	0.66	−0.20	1.00				
$\Gamma_{\tau\tau}$	84.08 ± 0.22	0.54	−0.17	0.39	1.00			
$\Gamma_{b\bar{b}}$	377.6 ± 1.3	0.45	−0.13	0.29	0.24	1.00		
$\Gamma_{c\bar{c}}$	300.5 ± 5.3	0.09	−0.02	0.06	0.05	−0.12	1.00	
Γ_{inv}	497.4 ± 2.5	−0.67	0.78	−0.45	−0.40	−0.30	−0.06	1.00
With Lepton Universality								
		Γ_{had}	$\Gamma_{\ell\ell}$	$\Gamma_{b\bar{b}}$	$\Gamma_{c\bar{c}}$	Γ_{inv}		
Γ_{had}	1744.4 ± 2.0	1.00						
$\Gamma_{\ell\ell}$	83.985 ± 0.086	0.39	1.00					
$\Gamma_{b\bar{b}}$	377.3 ± 1.2	0.35	0.13	1.00				
$\Gamma_{c\bar{c}}$	300.2 ± 5.2	0.06	0.03	−0.15	1.00			
Γ_{inv}	499.0 ± 1.5	−0.29	0.49	−0.10	−0.02	1.00		

5.4 Lorentz-Struktur der Z^0-Kopplung

cosθ-Verteilung

$$\frac{2s}{\pi}\frac{1}{N_c^{\mathrm{f}}}\frac{d\sigma_{\mathrm{ew}}}{d\cos\theta}(\mathrm{e^+e^-}\to\mathrm{f\bar{f}}) \;=$$

$$\underbrace{|\alpha(s)Q_{\mathrm{f}}|^2\,(1+\cos^2\theta)}_{\sigma^\gamma}$$

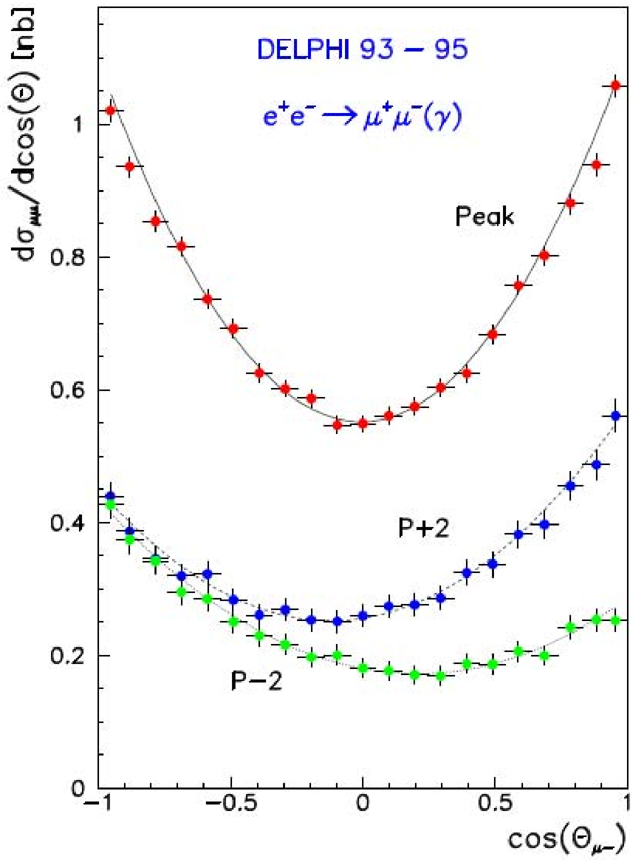
$$\underbrace{-8\Re\left\{\alpha^*(s)Q_{\mathrm{f}}\chi(s)\left[\mathcal{G}_{\mathrm{Ve}}\mathcal{G}_{\mathrm{Vf}}(1+\cos^2\theta)+2\mathcal{G}_{\mathrm{Ae}}\mathcal{G}_{\mathrm{Af}}\cos\theta\right]\right\}}_{\gamma\text{–Z interference}}$$

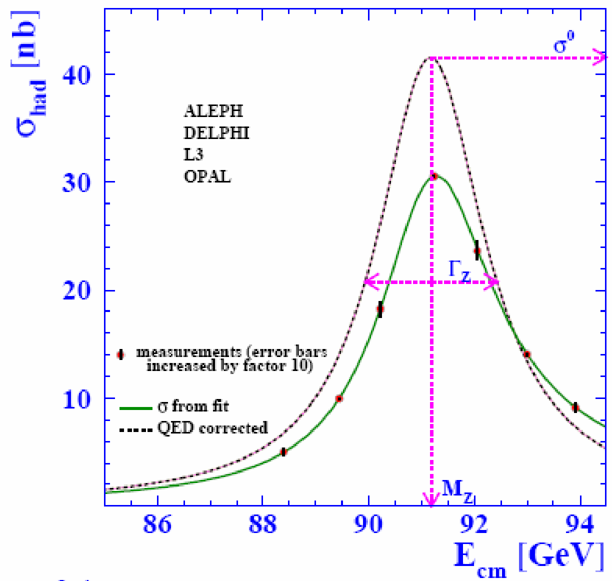
$$\underbrace{\begin{array}{c}+16|\chi(s)|^2\left[(|\mathcal{G}_{\mathrm{Ve}}|^2+|\mathcal{G}_{\mathrm{Ae}}|^2)(|\mathcal{G}_{\mathrm{Vf}}|^2+|\mathcal{G}_{\mathrm{Af}}|^2)(1+\cos^2\theta)\right.\\ \left.+8\Re\left\{\mathcal{G}_{\mathrm{Ve}}\mathcal{G}_{\mathrm{Ae}}{}^*\right\}\Re\left\{\mathcal{G}_{\mathrm{Vf}}\mathcal{G}_{\mathrm{Af}}{}^*\right\}\cos\theta\right]\end{array}}_{\sigma^{\mathrm{Z}}}$$

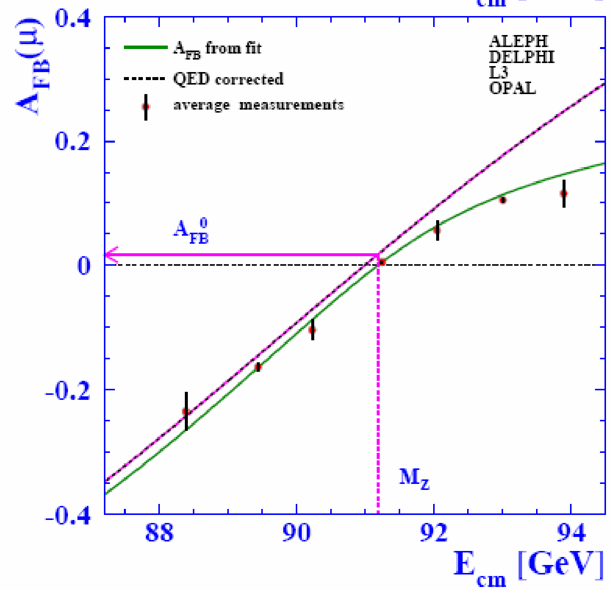
with:

$$\chi(s) \;=\; \frac{G_{\mathrm{F}}m_{\mathrm{Z}}^2}{8\pi\sqrt{2}}\frac{s}{s-m_{\mathrm{Z}}^2+is\Gamma_{\mathrm{Z}}/m_{\mathrm{Z}}},$$

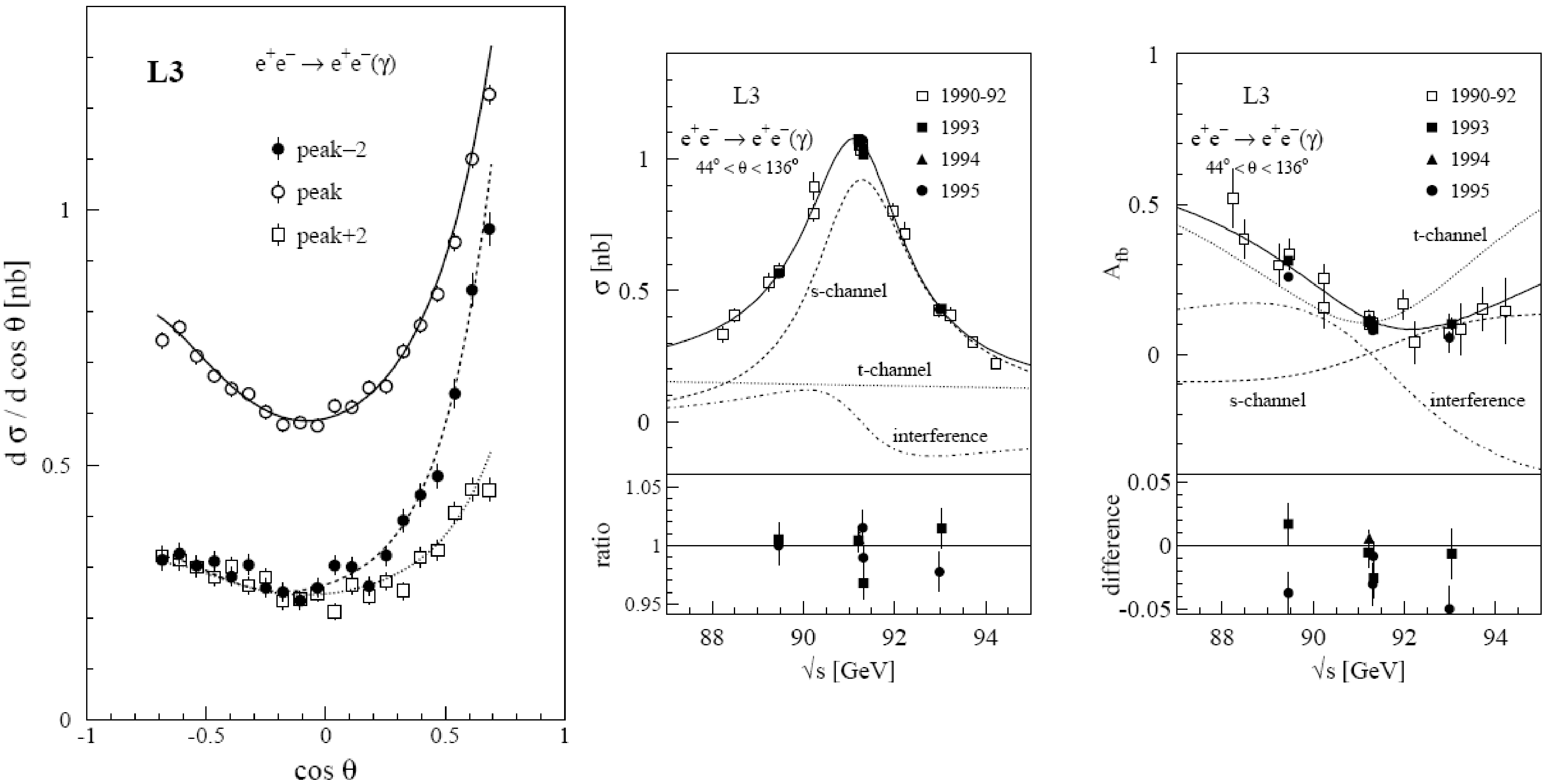
FB-Asymmetrien





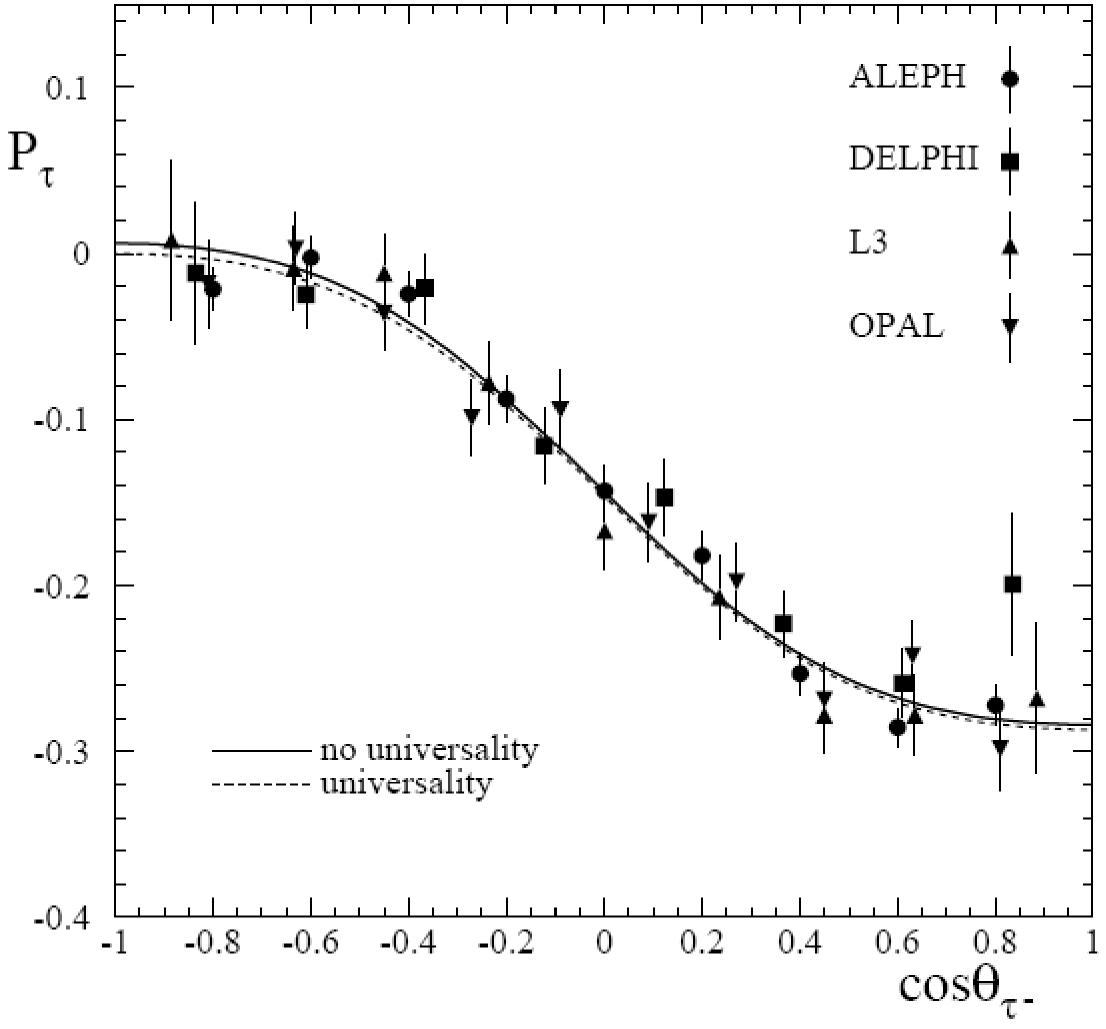


FB-Asymmetrien

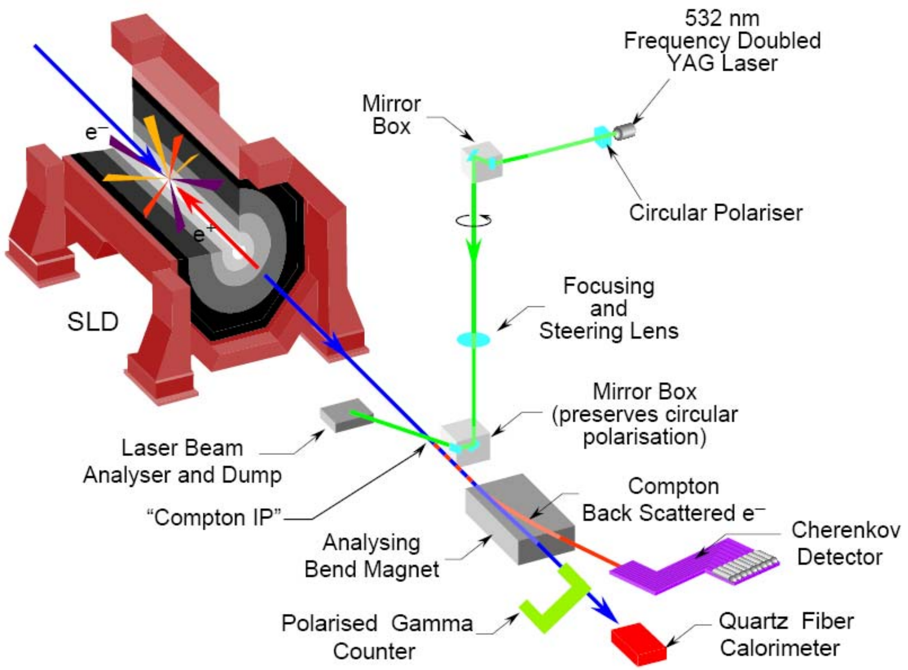


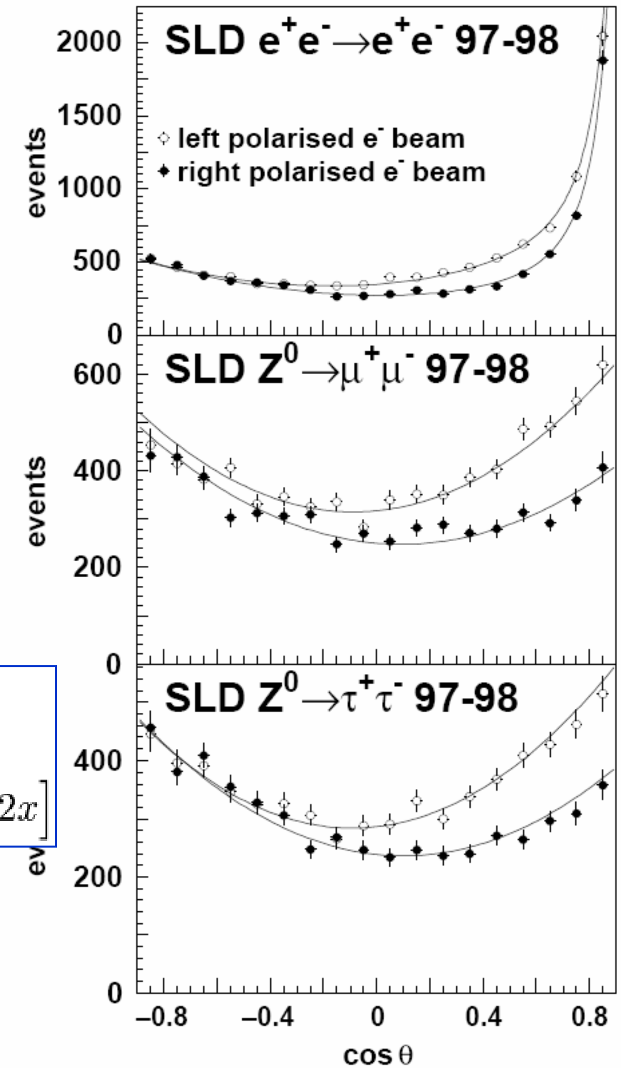
τ-Polarisation

$$\mathcal{P}_\mathrm{f}(\cos\theta) \;=\; -\frac{\mathcal{A}_\mathrm{f}(1+\cos^2\theta)+2\mathcal{A}_\mathrm{e}\cos\theta}{(1+\cos^2\theta)+2\mathcal{A}_\mathrm{f}\mathcal{A}_\mathrm{e}\cos\theta}$$



LR-Asymmetrien (SLC)





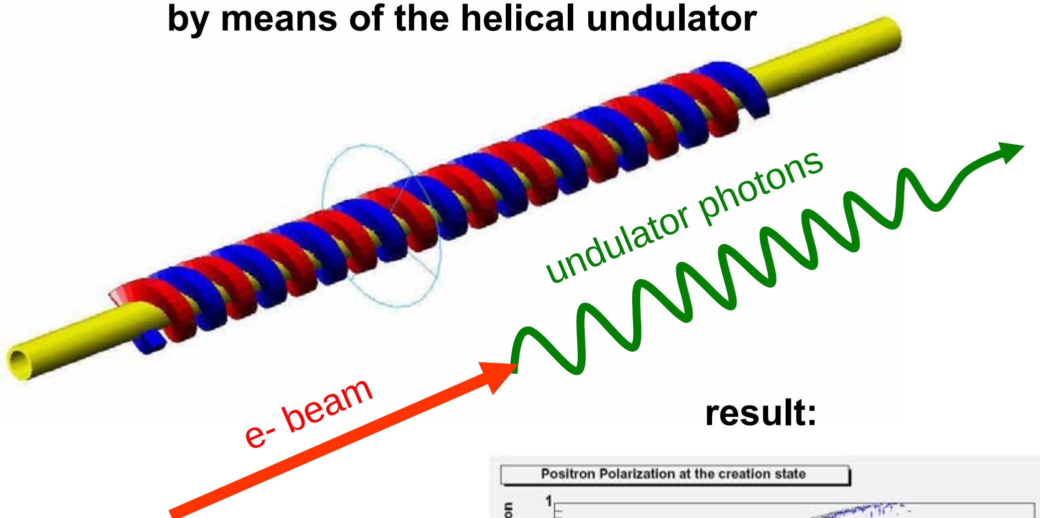
$$\frac{d}{dx}\sigma_Z(x,s,\mathcal{P}_e;\mathcal{A}_e,\mathcal{A}_\ell) \equiv f_Z(s)\Omega_Z(x,\mathcal{P}_e;\mathcal{A}_e,\mathcal{A}_\ell)$$
$$= f_Z(s)\left[(1-\mathcal{P}_e\mathcal{A}_e)(1+x^2)+(\mathcal{A}_e-\mathcal{P}_e)\mathcal{A}_\ell 2x\right]$$

Parameter	Average	Correlations		
		$\mathcal{A}_e$	$\mathcal{A}_\mu$	$\mathcal{A}_\tau$
$\mathcal{A}_e$	0.1516 ± 0.0021	1.000		
$\mathcal{A}_\mu$	0.142 ± 0.015	0.038	1.000	
$\mathcal{A}_\tau$	0.136 ± 0.015	0.033	0.007	1.000

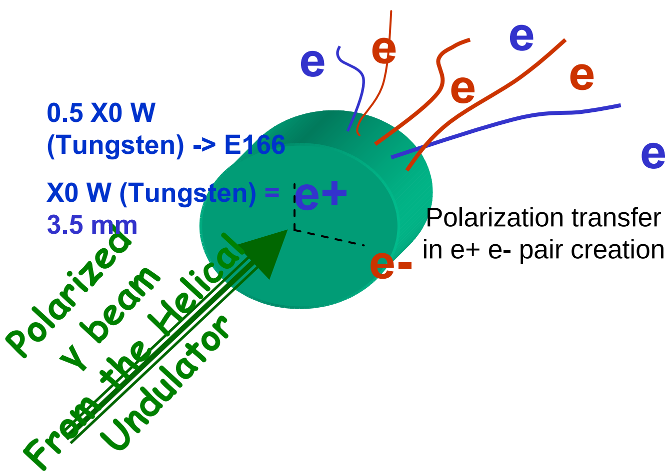
polarized positrons

- ***polarized positrons:*** production and measurement of polarization before the main linac, i.e. at low energies

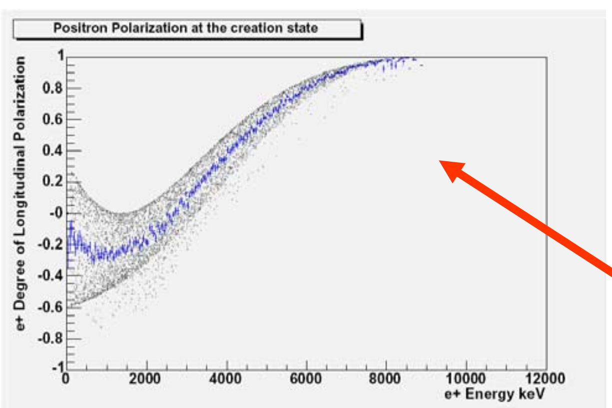
A: production of polarized photons by means of the helical undulator



B: production of polarized positrons by polarized photons



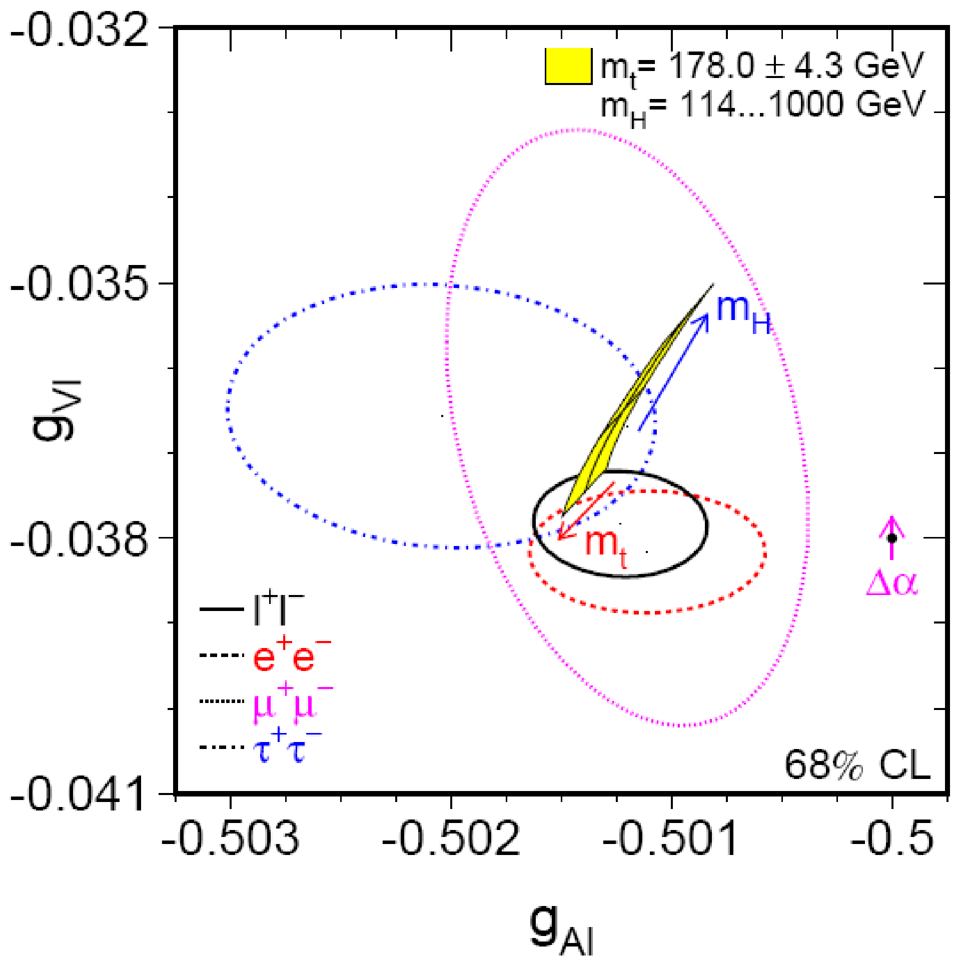
result:



Positron Polarization profile created by the undulator photons

C: measure the polarization degree at different energies

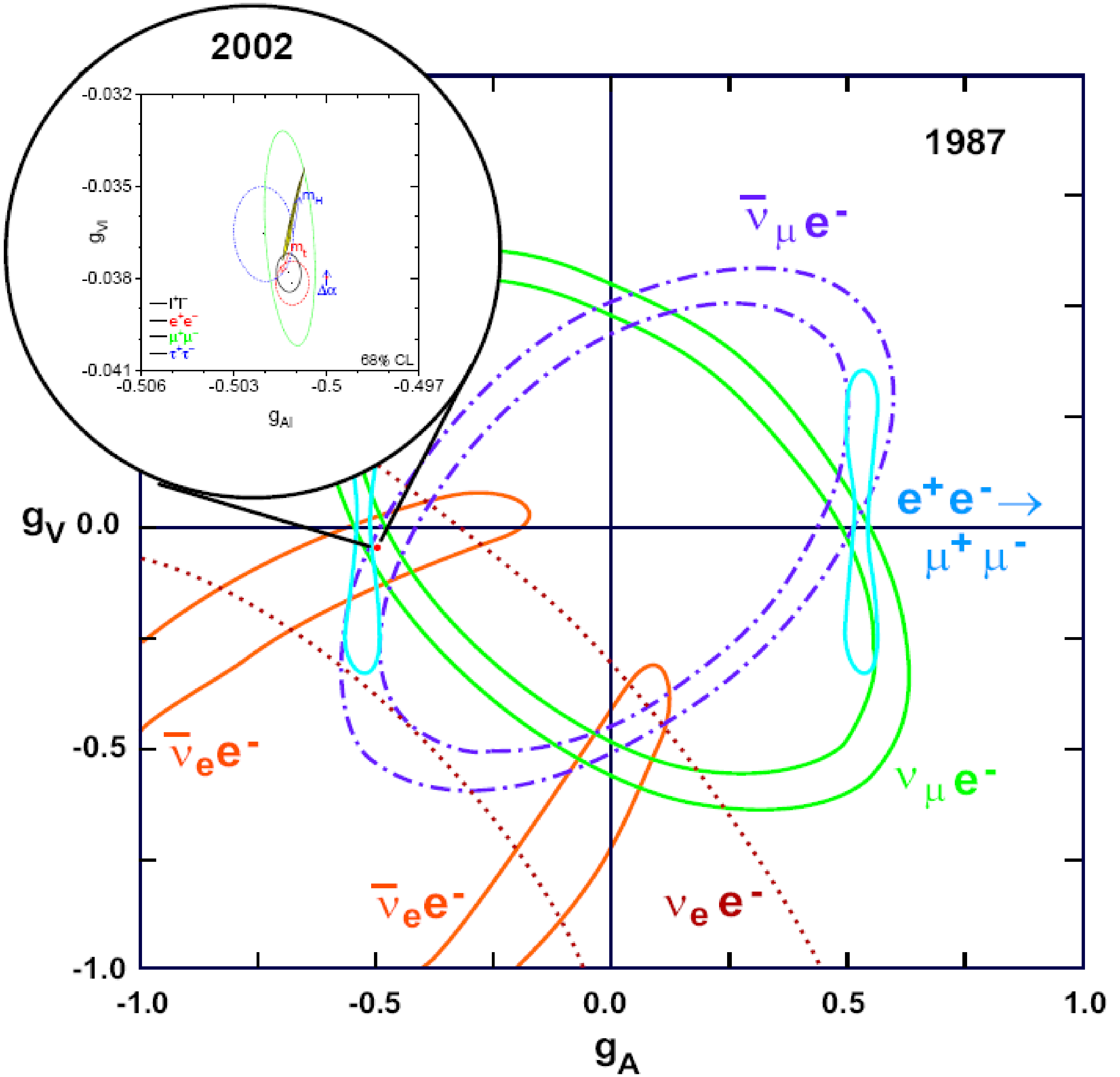
g_V, g_A Messungen



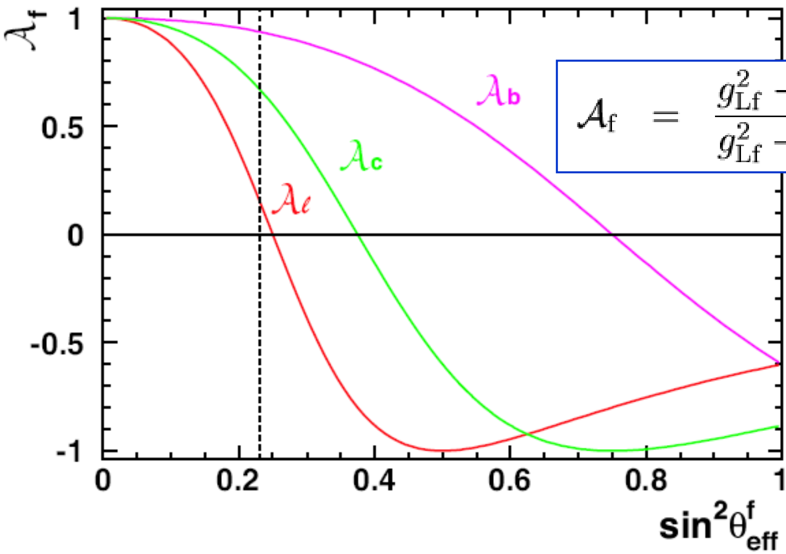
Parameter	Average	Correlations		
		g_ν	$g_{A\ell}$	$g_{V\ell}$
$g_{A\nu} \equiv g_{V\nu}$	$+0.50076 \pm 0.00076$	1.00		
$g_{A\ell}$	-0.50123 ± 0.00026	-0.48	1.00	
$g_{V\ell}$	-0.03783 ± 0.00041	-0.03	-0.06	1.00

Parameter	Average	Correlations		
		$g_{L\nu}$	$g_{L\ell}$	$g_{R\ell}$
$g_{L\nu}$	$+0.50076 \pm 0.00076$	1.00		
$g_{L\ell}$	-0.26953 ± 0.00024	-0.29	1.00	
$g_{R\ell}$	$+0.23170 \pm 0.00025$	0.22	0.43	1.00

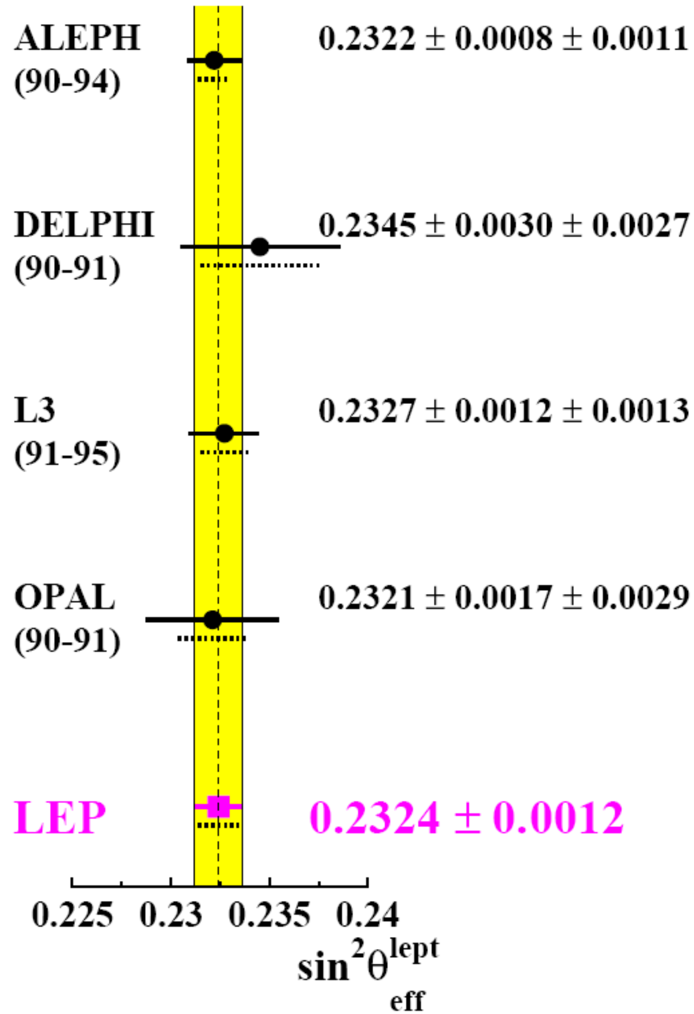
g_V, g_A Messungen vor und nach LEP



Sensitivität der Asymmetrien auf $\sin^2\theta_W$



$$\mathcal{A}_\mathrm{f} = \frac{g^2_\mathrm{Lf} - g^2_\mathrm{Rf}}{g^2_\mathrm{Lf} + g^2_\mathrm{Rf}} = \frac{2 g_\mathrm{Vf} g_\mathrm{Af}}{g^2_\mathrm{Vf} + g^2_\mathrm{Af}}$$

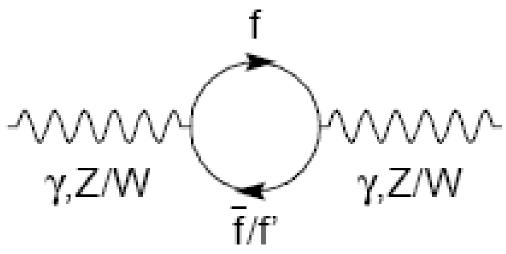


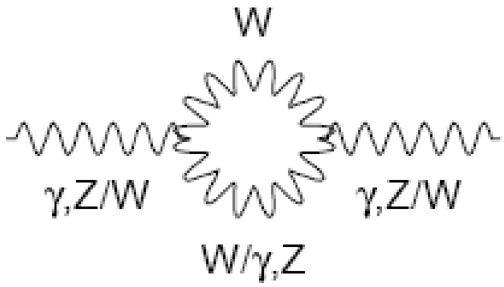
$$g_V = 2\,I_3 - 4\,Q\,\sin^2\theta_W$$
$$g_A = 2\,I_3$$

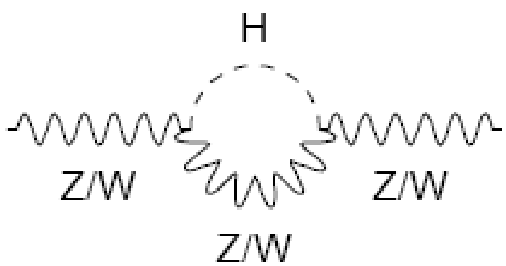
$\sin^2\theta_W \approx 1/4$ sind die Vorhersagen

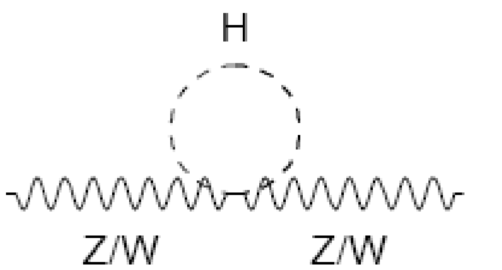
	Q	I_3	g_V	g_A
ν	0	+1/2	+1	+1
e	−1	−1/2	0	−1
u,c,t	2/3	+1/2	+1/3	+1
d,s,b	−1/3	−1/2	−2/3	−1

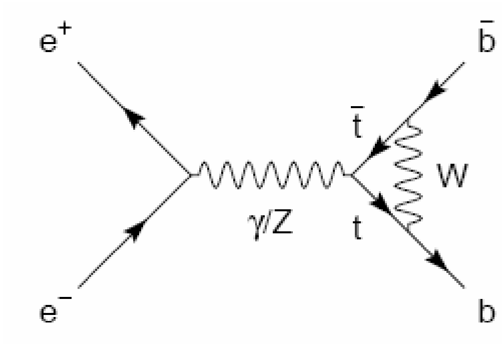
Strahlungskorrekturen: Präzisionstests

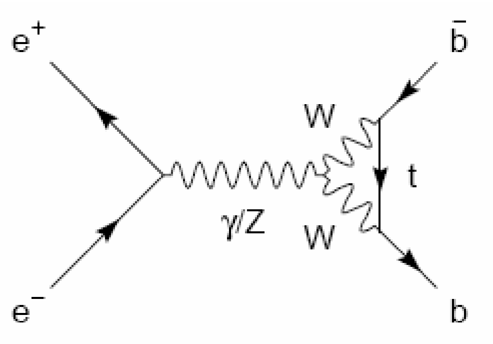












The Standard Model is a non-trivial structure with a few constants showing up in many places: Many opportunities to check !

In perturbation theory all these parameters tend to get connected and influenced by the mass scale they are considered at

$\mathcal{L}_{\rm SM} =$

$$-\frac{1}{2}\partial_\nu g^a_\mu \partial_\nu g^a_\mu - g_s f^{abc}\partial_\mu g^a_\nu g^b_\mu g^c_\nu - \frac{1}{4} g_s^2 f^{abc} f^{ade} g^b_\mu g^c_\nu g^d_\mu g^e_\nu + \frac{1}{2} i g_s^2 (\bar q^\sigma_i \gamma^\mu q^\sigma_j) g^a_\mu + \bar G^a \partial^2 G^a + g_s f^{abc}\partial_\mu \bar G^a G^b g^c_\mu$$

$$-\partial_\nu W^+_\mu \partial_\nu W^-_\mu - M^2 W^+_\mu W^-_\mu - \frac{1}{2} \partial_\nu Z^0_\mu \partial_\nu Z^0_\mu - \frac{1}{2c_w^2} M^2 Z^0_\mu Z^0_\mu - \frac{1}{2} \partial_\mu A_\nu \partial_\mu A_\nu - \frac{1}{2} \partial_\mu H \partial_\mu H - \frac{1}{2} m_h^2 H^2 - \partial_\mu \phi^+ \partial_\mu \phi^-$$

$$-M^2\phi^+\phi^- - \frac{1}{2} \partial_\mu\phi^0\partial_\mu\phi^0 - \frac{1}{2c_w^2} M\phi^0\phi^0 - \beta_h \left[\frac{2M^2}{g^2} + \frac{2M}{g}H + \frac{1}{2}(H^2+\phi^0\phi^0+2\phi^+\phi^-)\right] + \frac{2M^4}{g^2}\alpha_h$$

$$-igc_w \left[\partial_\nu Z^0_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - Z^0_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + Z^0_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)\right]$$

$$-igs_w \left[\partial_\nu A_\mu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - A_\nu (W^+_\mu \partial_\nu W^-_\mu - W^-_\mu \partial_\nu W^+_\mu) + A_\mu (W^+_\nu \partial_\nu W^-_\mu - W^-_\nu \partial_\nu W^+_\mu)\right]$$

$$-\frac{1}{2} g^2 W^+_\mu W^-_\mu W^+_\nu W^-_\nu + \frac{1}{2} g^2 W^+_\mu W^-_\nu W^+_\mu W^-_\nu + g^2 c_w^2 \left(Z^0_\mu W^+_\mu Z^0_\nu W^-_\nu - Z^0_\mu Z^0_\mu W^+_\nu W^-_\nu\right) + g^2 s_w^2 \left(A_\mu W^+_\mu A_\nu W^-_\nu - A_\mu A_\mu W^+_\nu W^-_\nu\right)$$

$$+g^2 s_w c_w \left[A_\mu Z^0_\nu (W^+_\mu W^-_\nu - W^+_\nu W^-_\mu) - 2A_\mu Z^0_\mu W^+_\nu W^-_\nu\right] - g\alpha \left[H^3 + H\phi^0\phi^0 + 2H\phi^+\phi^-\right]$$

$$-\frac{1}{8} g^2 \alpha_h \left[H^4 + (\phi^0)^4 + 4(\phi^+\phi^-)^2 + 4(\phi^0)^2\phi^+\phi^- + 4H^2\phi^+\phi^- + 2(\phi^0)^2H^2\right] - gMW^+_\mu W^-_\mu H - \frac{1}{2} g \frac{M}{c_w^2} Z^0_\mu Z^0_\mu H$$

$$-\frac{1}{2} ig \left[W^+_\mu(\phi^0\partial_\mu\phi^- - \phi^-\partial_\mu\phi^0) - W^-_\mu(\phi^0\partial_\mu\phi^+ - \phi^+\partial_\mu\phi^0)\right] + \frac{1}{2} g \left[W^+_\mu(H\partial_\mu\phi^- - \phi^-\partial_\mu H) - W^-_\mu(H\partial_\mu\phi^+ - \phi^+\partial_\mu H)\right]$$

$$+\frac{1}{2} g \frac{1}{c_w} Z^0_\mu(H\partial_\mu\phi^0 - \phi^0\partial_\mu H) - ig\frac{s_w^2}{c_w} MZ^0_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) + igs_wMA_\mu(W^+_\mu\phi^- - W^-_\mu\phi^+) - ig\frac{1-2c_w^2}{2c_w} Z^0_\mu(\phi^+\partial_\mu\phi^-$$

$$-\phi^-\partial_\mu\phi^+) + igs_wA_\mu(\phi^+\partial_\mu\phi^- - \phi^-\partial_\mu\phi^+) - \frac{1}{4} g^2 W^+_\mu W^-_\mu \left[H^2 + (\phi^0)^2 + 2\phi^+\phi^-\right] - \frac{1}{4} g^2 \frac{1}{c_w^2} Z^0_\mu Z^0_\mu [H^2 + (\phi^0)^2$$

$$+2(2s_w^2-1)^2\phi^+\phi^-] - \frac{1}{2} g^2 \frac{s_w^2}{c_w} Z^0_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+) - \frac{1}{2} ig^2 \frac{s_w^2}{c_w} Z^0_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) + \frac{1}{2} g^2 s_w A_\mu\phi^0(W^+_\mu\phi^- + W^-_\mu\phi^+)$$

$$+\frac{1}{2} ig^2 s_w A_\mu H(W^+_\mu\phi^- - W^-_\mu\phi^+) - g^2\frac{s_w}{c_w}(2c_w^2-1)Z^0_\mu A_\mu\phi^+\phi^- - g^1 s_w^2 A_\mu A_\mu \phi^+\phi^- - \bar e^\lambda(\gamma\partial + m_e^\lambda)e^\lambda - \bar\nu^\lambda\gamma\partial\nu^\lambda$$

$$-\bar u^\lambda_j(\gamma\partial + m_u^\lambda)u^\lambda_j - \bar d^\lambda_j(\gamma\partial + m_d^\lambda)d^\lambda_j + igs_wA_\mu[-(\bar e^\lambda\gamma^\mu e^\lambda) + \frac{2}{3}(\bar u^\lambda_j\gamma^\mu u^\lambda_j) - \frac{1}{3}(\bar d^\lambda_j\gamma^\mu d^\lambda_j)]$$

$$+\frac{ig}{4c_w}Z^0_\mu \left[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar e^\lambda\gamma^\mu(4s_w^2 - 1 - \gamma^5)e^\lambda) + (\bar u^\lambda_j\gamma^\mu(\frac{4}{3} s_w^2 - 1 - \gamma^5)u^\lambda_j) + (\bar d^\lambda_j\gamma^\mu(1 - \frac{8}{3} s_w^2 - \gamma^5)d^\lambda_j)\right]$$

$$+\frac{ig}{2\sqrt{2}}W^+_\mu \left[(\bar\nu^\lambda\gamma^\mu(1+\gamma^5)e^\lambda) + (\bar u^\lambda_j\gamma^\mu(1+\gamma^5)C_{\lambda\kappa}d^\kappa_j)\right] + \frac{ig}{2\sqrt{2}}W^-_\mu \left[(\bar e^\lambda\gamma^\mu(1+\gamma^5)\nu^\lambda) + (\bar d^\kappa_j C^\dagger_{\lambda\kappa}\gamma^\mu(1+\gamma^5)u^\lambda_j)\right]$$

$$+\frac{ig}{2\sqrt{2}}\frac{m_e^\lambda}{M}\left[-\phi^+(\bar\nu^\lambda(1-\gamma^5)e^\lambda) + \phi^-(\bar e^\lambda(1+\gamma^5)\nu^\lambda)\right] - \frac{g}{2}\frac{m_e^\lambda}{M}\left[H(\bar e^\lambda e^\lambda) + i\phi^0(\bar e^\lambda\gamma^5 e^\lambda)\right]$$

$$+\frac{ig}{2M\sqrt{2}}\phi^+ \left[-m_d^\kappa(\bar u^\lambda_j C_{\lambda\kappa}(1-\gamma^5)d^\kappa_j) + m_u^\lambda(\bar u^\lambda_j C_{\lambda\kappa}(1+\gamma^5)d^\kappa_j)\right] + \frac{ig}{2M\sqrt{2}}\phi^- \left[m_d^\lambda(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1+\gamma^5)u^\kappa_j) - m_u^\kappa(\bar d^\lambda_j C^\dagger_{\lambda\kappa}(1-\gamma^5)u^\kappa_j\right]$$

$$-\frac{g}{2}\frac{m_u^\lambda}{M}H(\bar u^\lambda_j u^\lambda_j) - \frac{g}{2}\frac{m_d^\lambda}{M}H(\bar d^\lambda_j d^\lambda_j) + \frac{ig}{2}\frac{m_u^\lambda}{M}\phi^0(\bar u^\lambda_j\gamma^5 u^\lambda_j) - \frac{ig}{2}\frac{m_d^\lambda}{M}\phi^0(\bar d^\lambda_j\gamma^5 d^\lambda_j) + \bar X^+(\partial^2 - M^2)X^+ + \bar X^-(\partial^2 - M^2)X^-$$

$$+\bar X^0\left(\partial^2 - \frac{M^2}{c_w^2}\right)X^0 + \bar Y\partial^2 Y + igc_wW^+_\mu(\partial_\mu\bar X^0 X^- - \partial_\mu\bar X^+ X^0) + igs_wW^+_\mu(\partial_\mu\bar Y X^- - \partial_\mu\bar X^+ Y) + igc_wW^-_\mu(\partial_\mu\bar X^- X^0 - \partial_\mu\bar X^0 X^+)$$

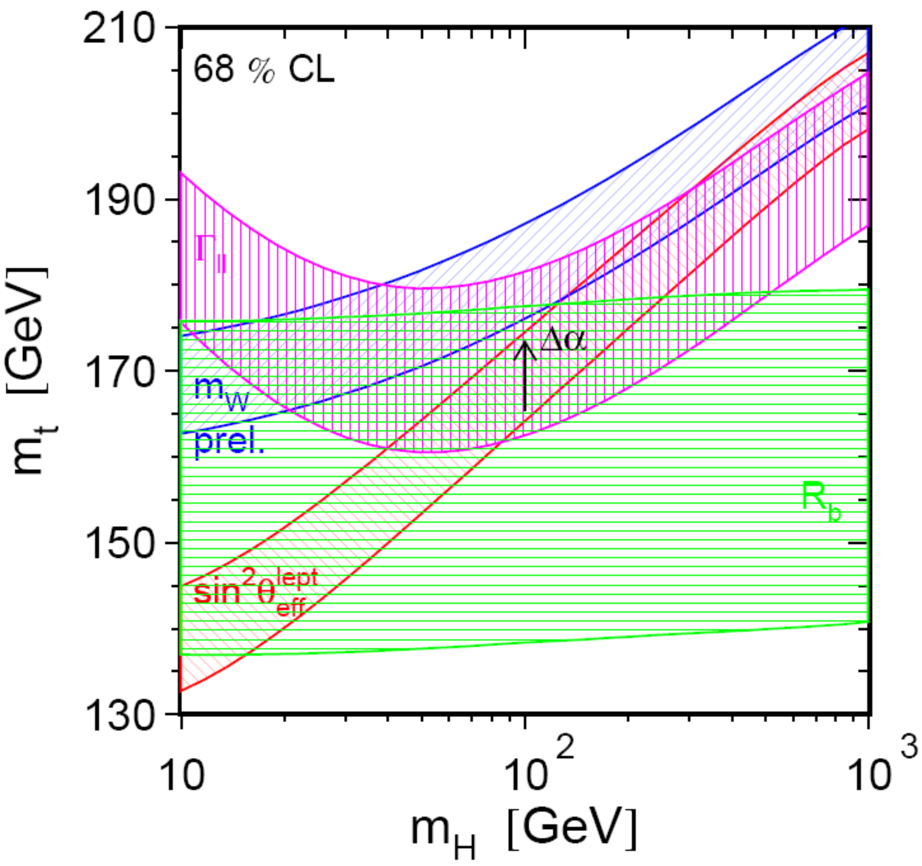
$$+igs_wW^-_\mu(\partial_\mu\bar X^- Y - \partial_\mu\bar Y X^+) + igc_wZ^0_\mu(\partial_\mu\bar X^+X^+ - \partial_\mu\bar X^-X^-) + igs_wA_\mu(\partial_\mu\bar X^+X^+ - \partial_\mu\bar X^-X^-) - \frac{1}{2} gM[\bar X^+X^+H + \bar X^-X^-H$$

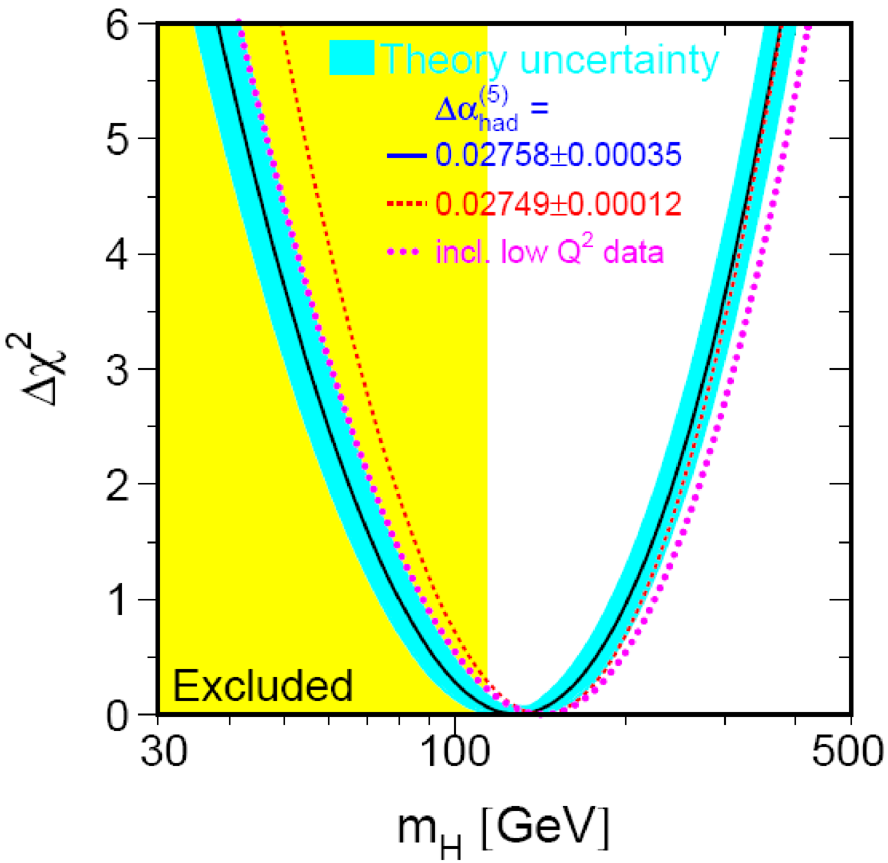
$$+\frac{1}{c_w^2}\bar X^0X^0H] + \frac{1-2c_w^2}{2c_w}igM[\bar X^+X^0\phi^+ - \bar X^-X^0\phi^-] + \frac{1}{2c_w}igM[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-] + igMs_w[\bar X^0X^-\phi^+ - \bar X^0X^+\phi^-]$$

$$+\frac{1}{2} igM[\bar X^+X^+\phi^0 - \bar X^-X^-\phi^0]$$

From Diagrammatica by M. Veltman (typo's=my problem)

Einschränkungen für die Higgs-Masse





Übereinstimmung mit dem SM

	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02758 ± 0.00035	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4959
σ_{had}^0 [nb]	41.540 ± 0.037	41.478
R_l	20.767 ± 0.025	20.742
$A_{fb}^{0,l}$	0.01714 ± 0.00095	0.01643
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21629 ± 0.00066	0.21579
R_c	0.1721 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0992 ± 0.0016	0.1038
$A_{fb}^{0,c}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.410 ± 0.032	80.377
Γ_W [GeV]	2.123 ± 0.067	2.092
m_t [GeV]	172.7 ± 2.9	173.3