

*Kapitel 4:
Elektromaschwache
Vereinigung im
Standardmodell*

Eichboson-Selbstwechselwirkung

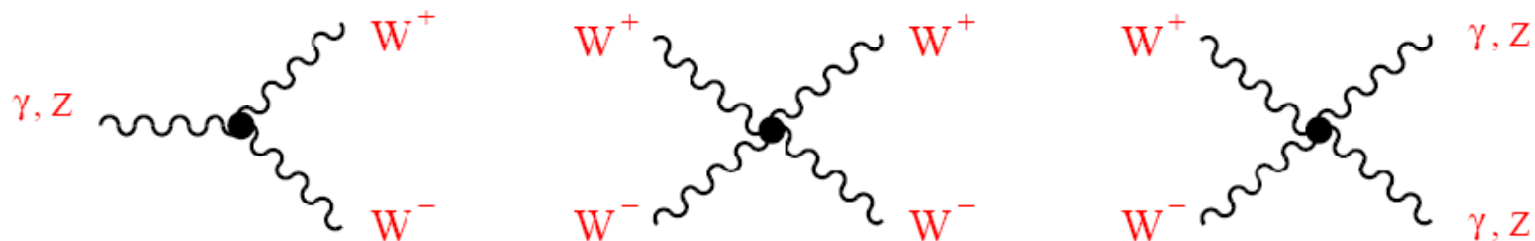
$$\mathcal{L}_3 = -ie \cot \theta_W \left\{ (\partial^\mu W^\nu - \partial^\nu W^\mu) W_\mu^\dagger Z_\nu - (\partial^\mu W^{\nu\dagger} - \partial^\nu W^{\mu\dagger}) W_\mu Z_\nu + W_\mu W_\nu^\dagger (\partial^\mu Z^\nu - \partial^\nu Z^\mu) \right\}$$

$$- ie \left\{ (\partial^\mu W^\nu - \partial^\nu W^\mu) W_\mu^\dagger A_\nu - (\partial^\mu W^{\nu\dagger} - \partial^\nu W^{\mu\dagger}) W_\mu A_\nu + W_\mu W_\nu^\dagger (\partial^\mu A^\nu - \partial^\nu A^\mu) \right\};$$

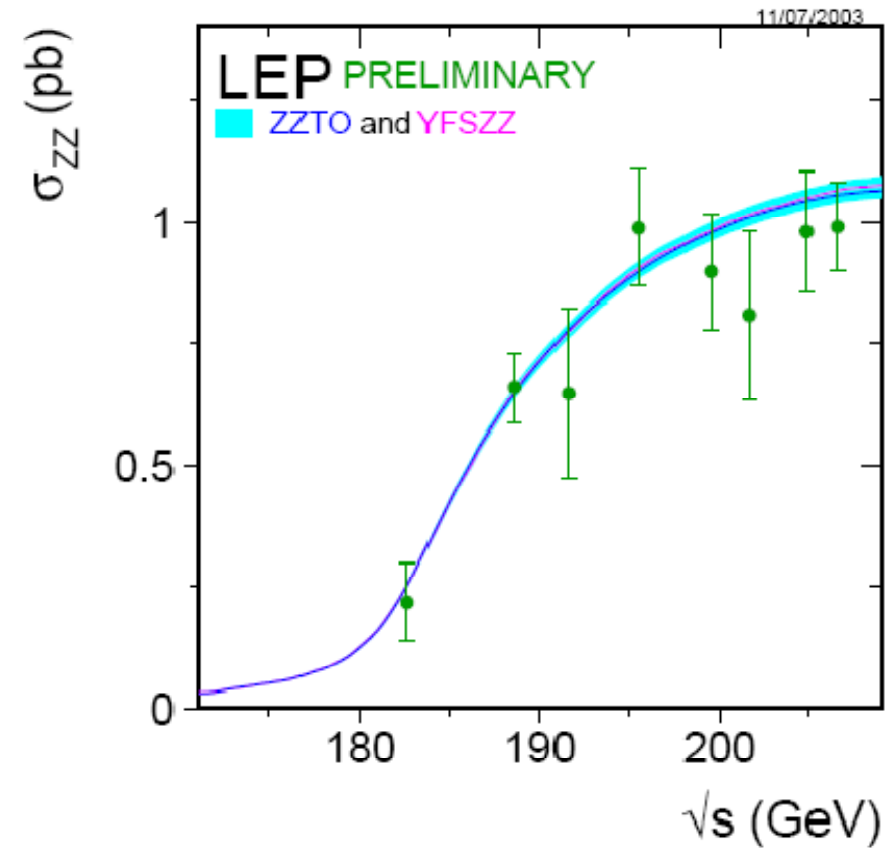
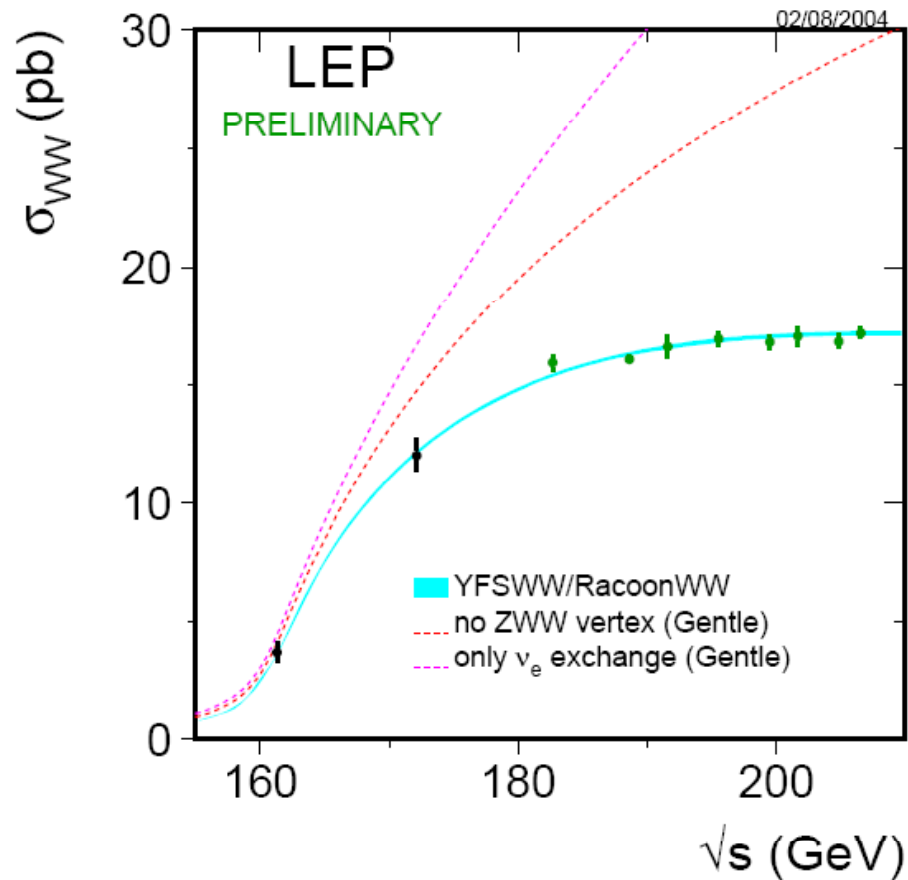
$$\mathcal{L}_4 = -\frac{e^2}{2 \sin^2 \theta_W} \left\{ (W_\mu^\dagger W^\mu)^2 - W_\mu^\dagger W^{\mu\dagger} W_\nu W^\nu \right\} - e^2 \cot^2 \theta_W \left\{ W_\mu^\dagger W^\mu Z_\nu Z^\nu - W_\mu^\dagger Z^\mu W_\nu Z^\nu \right\}$$

$$- e^2 \cot \theta_W \left\{ 2W_\mu^\dagger W^\mu Z_\nu A^\nu - W_\mu^\dagger Z^\mu W_\nu A^\nu - W_\mu^\dagger A^\mu W_\nu Z^\nu \right\}$$

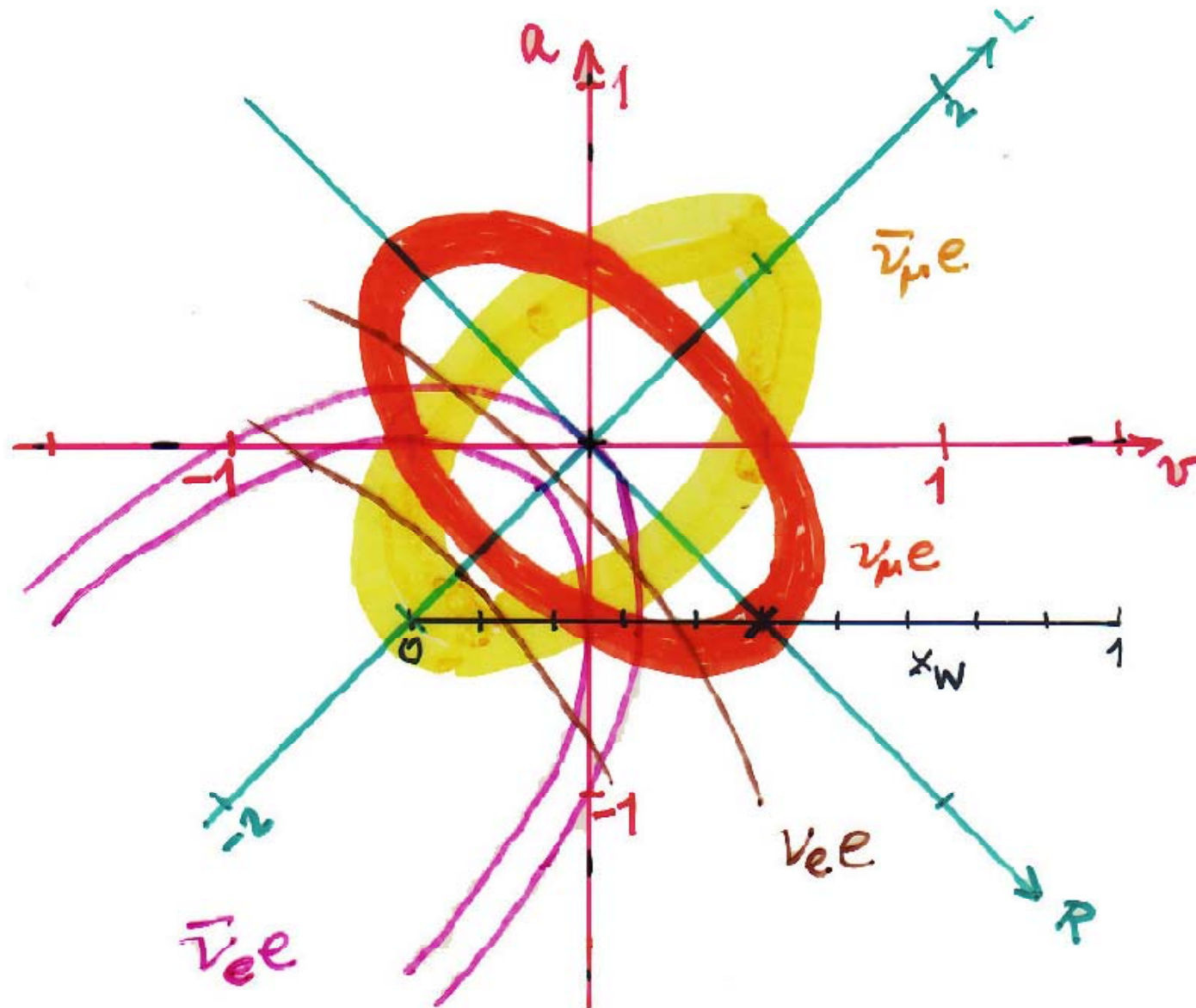
$$- e^2 \left\{ W_\mu^\dagger W^\mu A_\nu A^\nu - W_\mu^\dagger A^\mu W_\nu A^\nu \right\}.$$



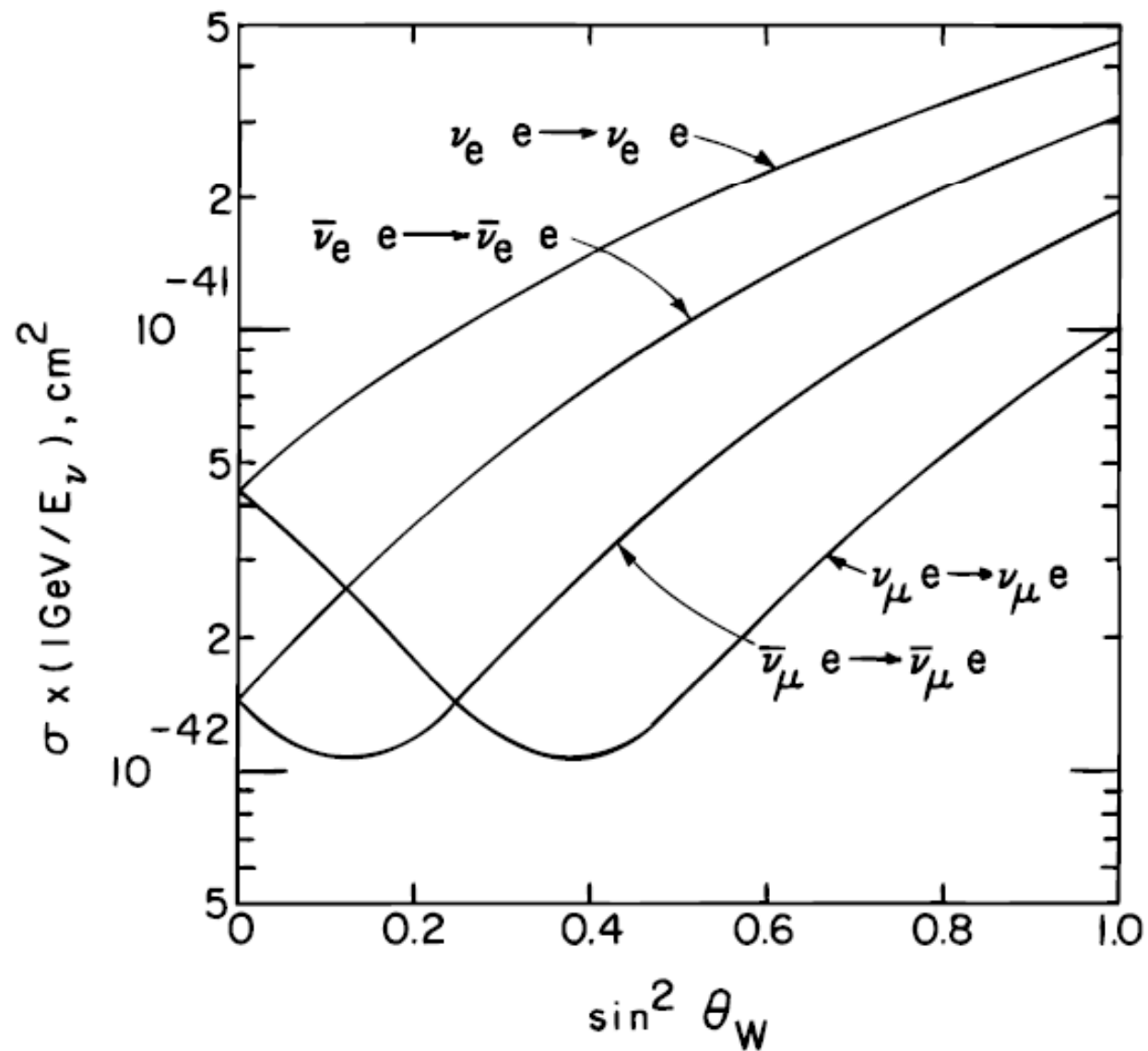
Test der Eichstruktur bei LEP2: $ECM > 160$ GeV



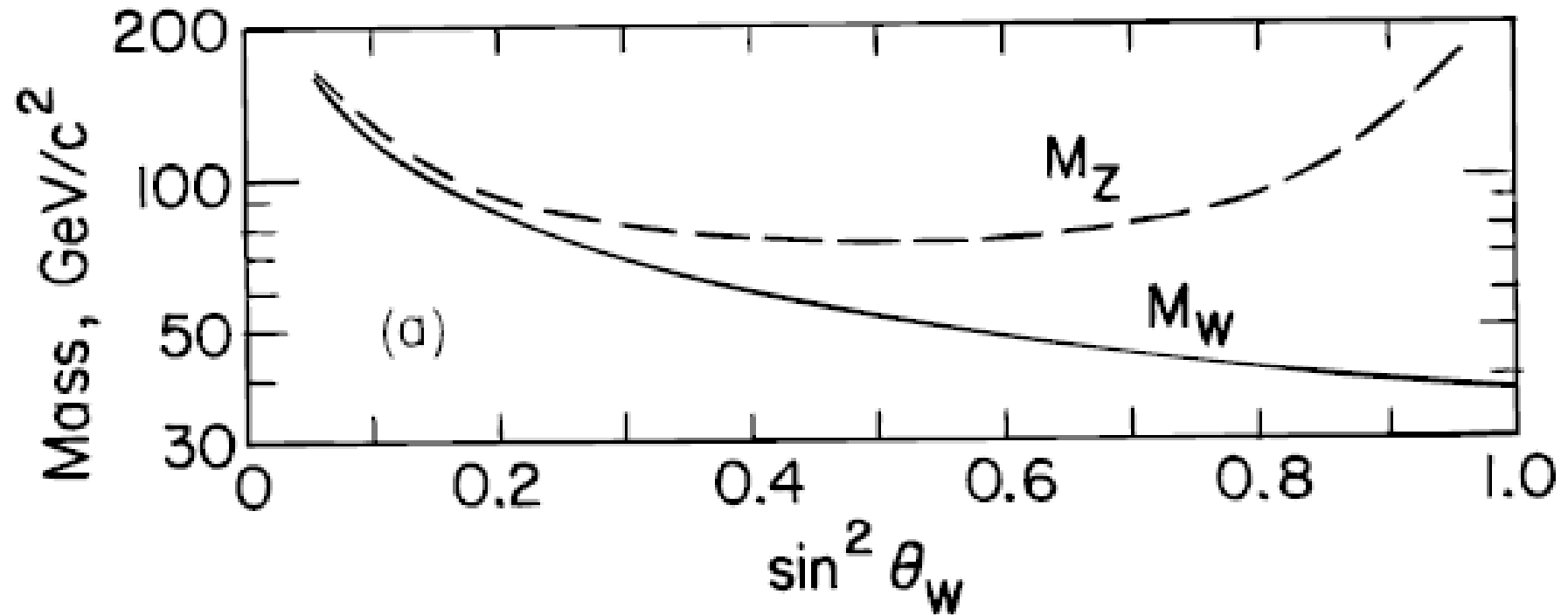
Bestimmung von C_V/C_A aus Neutrino-Lepton-Streuung



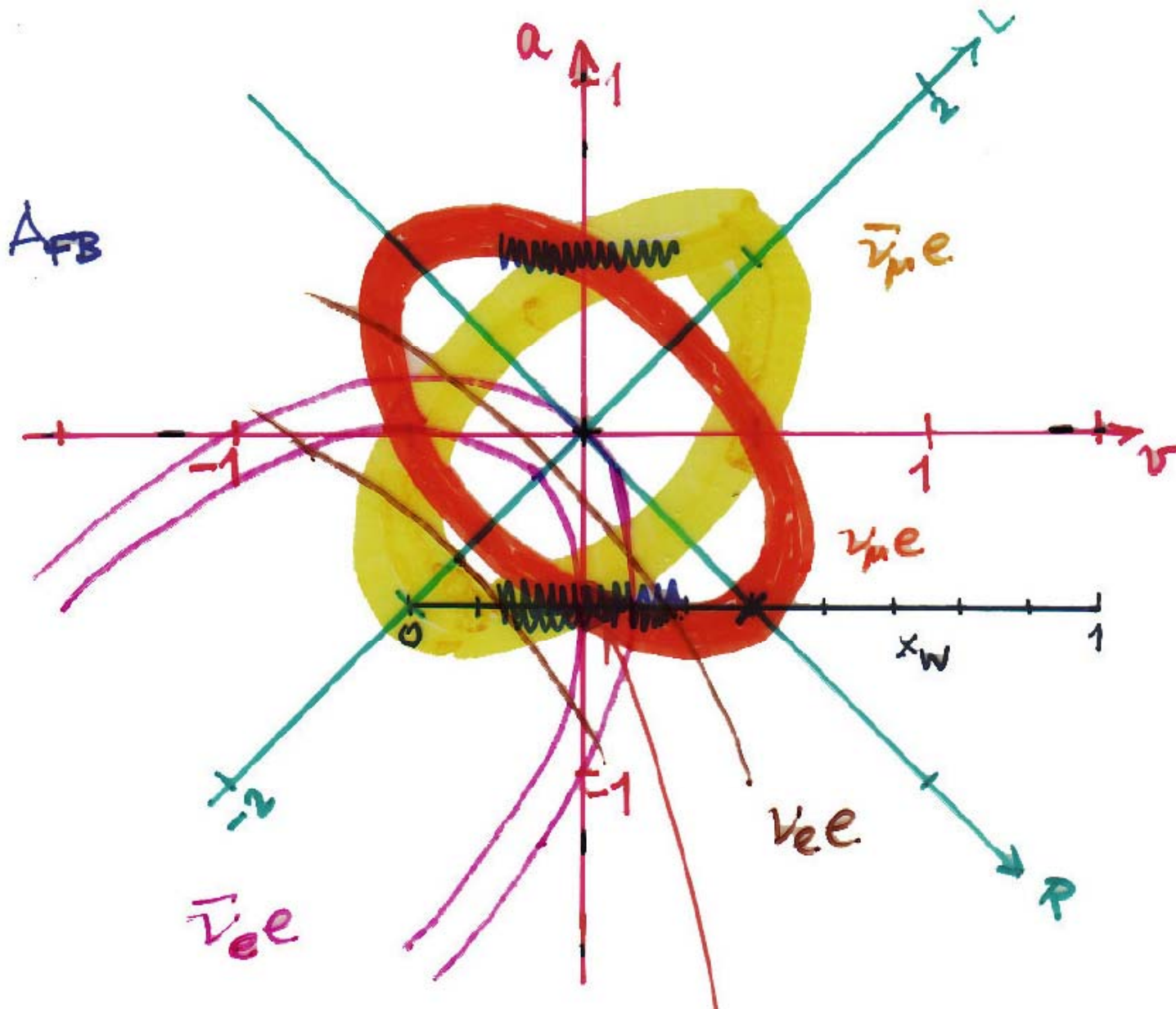
Weinebergwinkel aus Neutrino-Elektron-Streuung



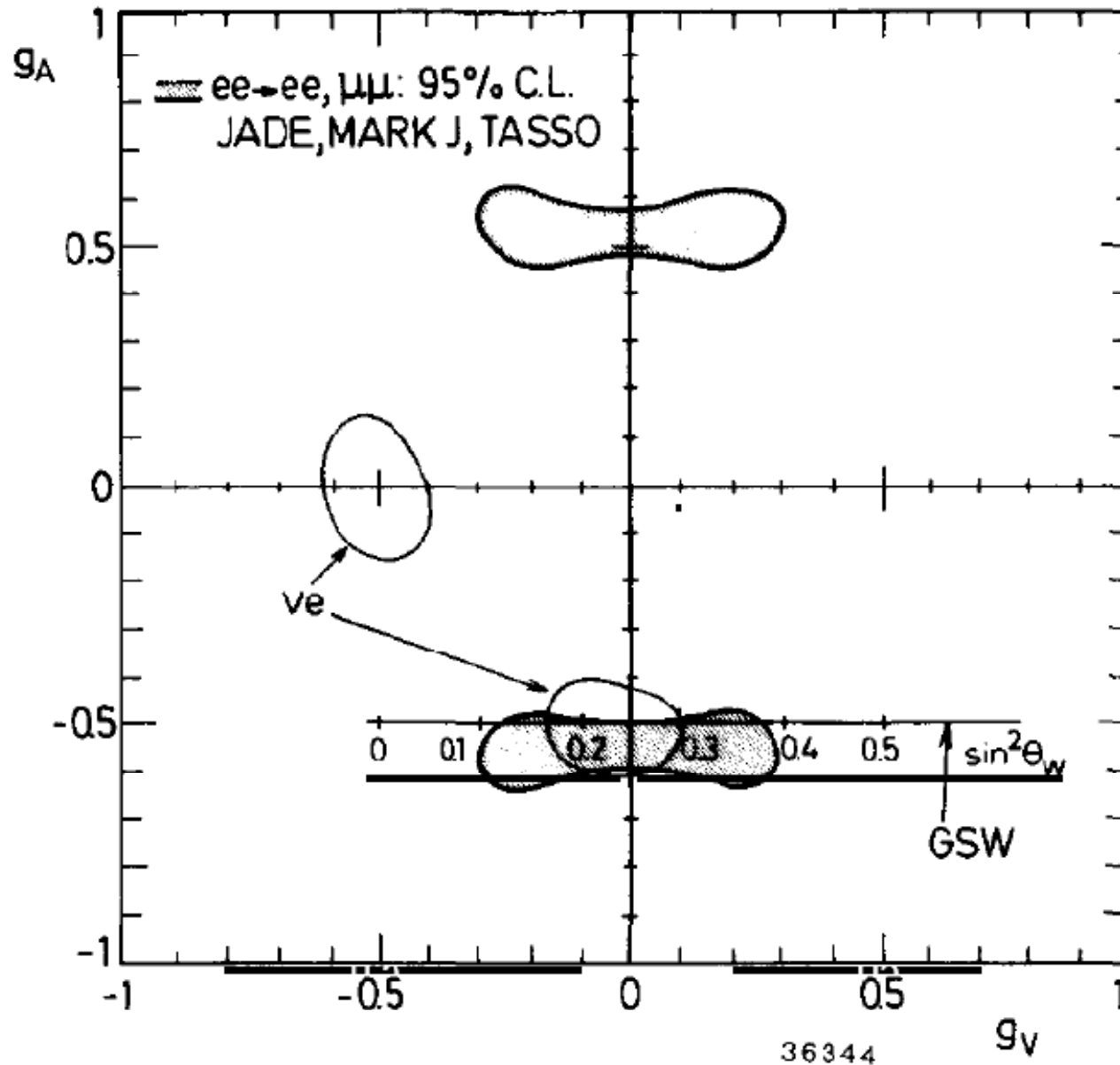
Messung von Weinbergwinkel \rightarrow Vorhersage von $M_{W/Z}$



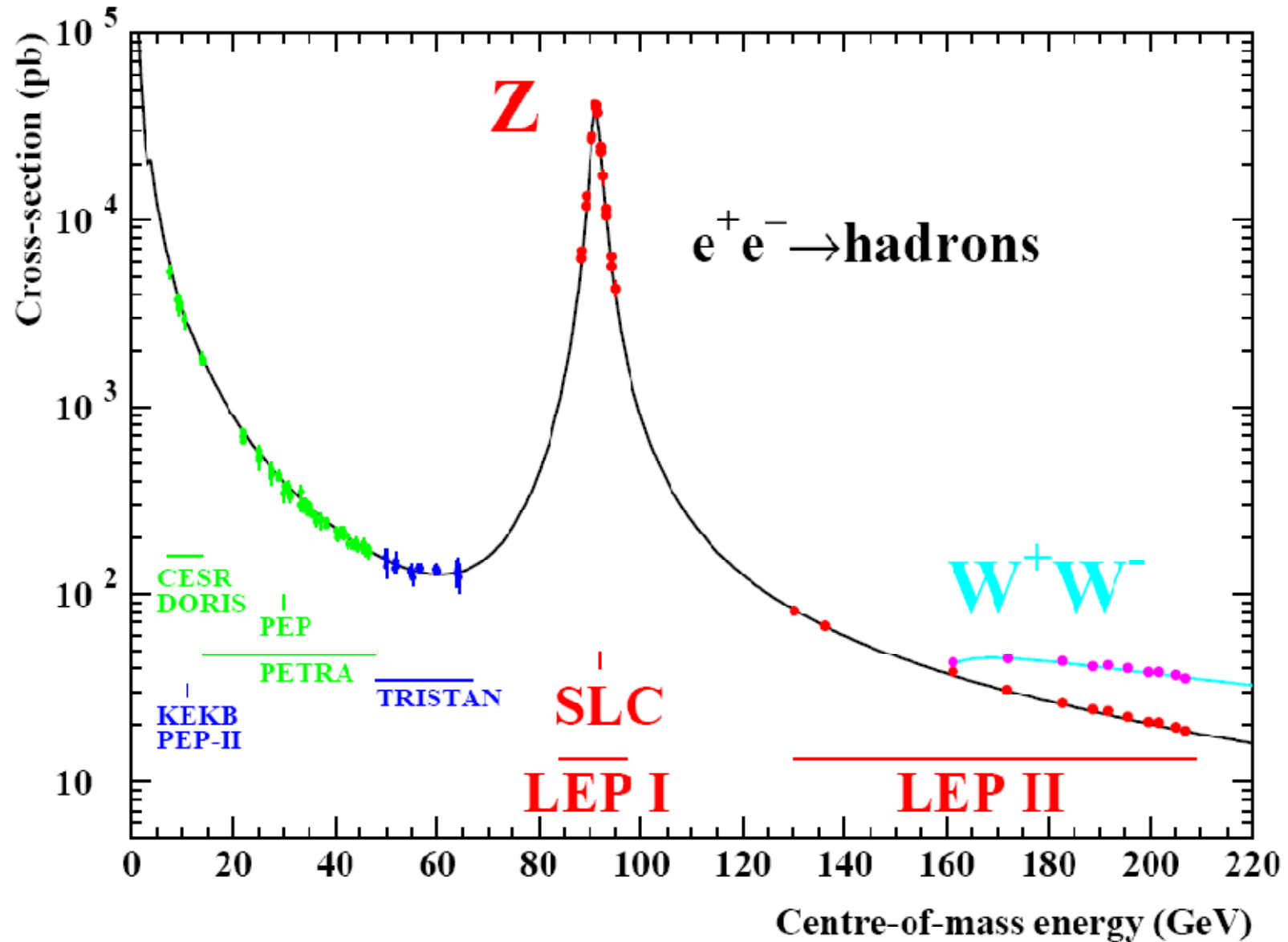
Eindeutige Bestimmung des Weinbergwinkels mit PETRA



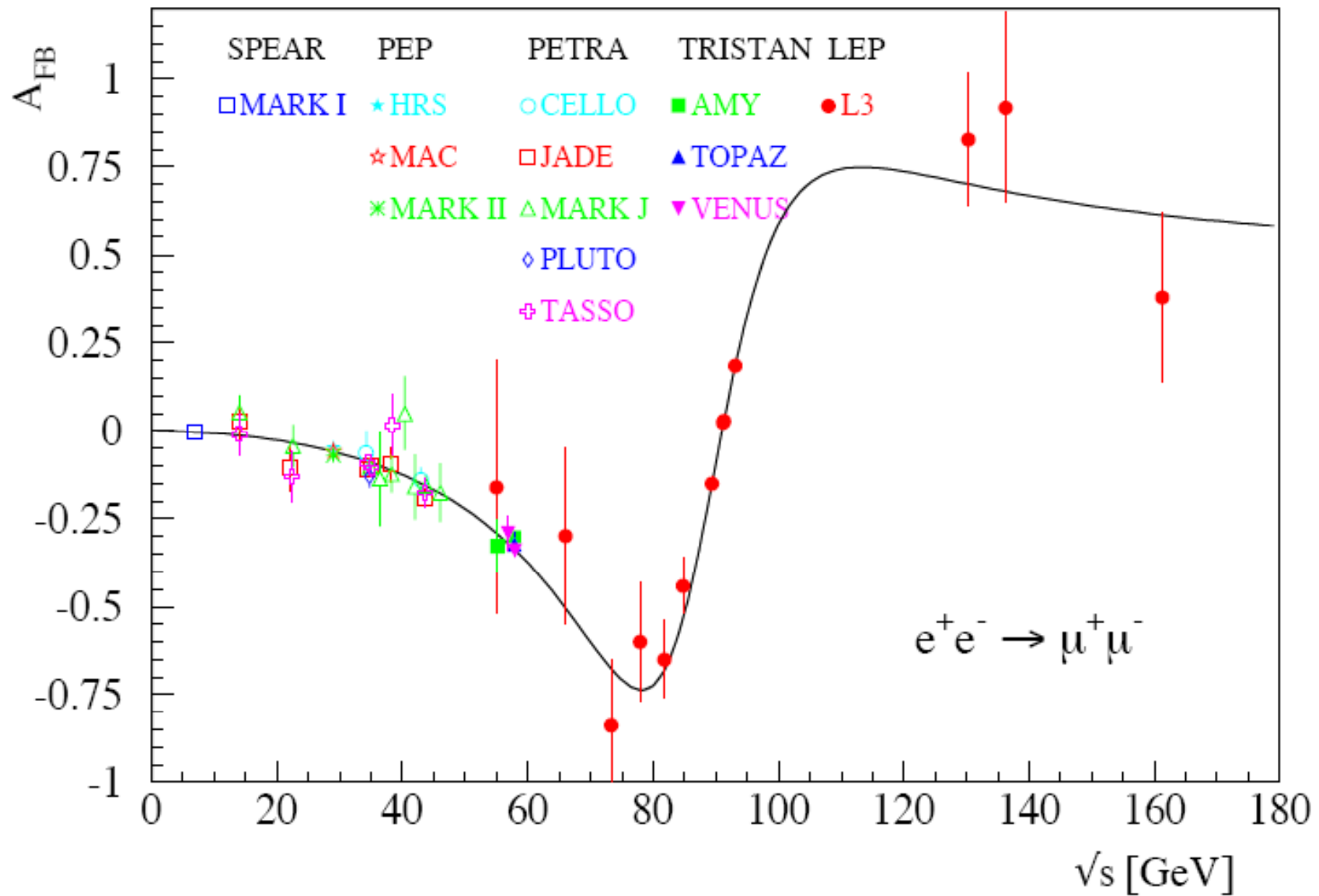
Eindeutige Bestimmung des Weinbergwinkels mit PETRA



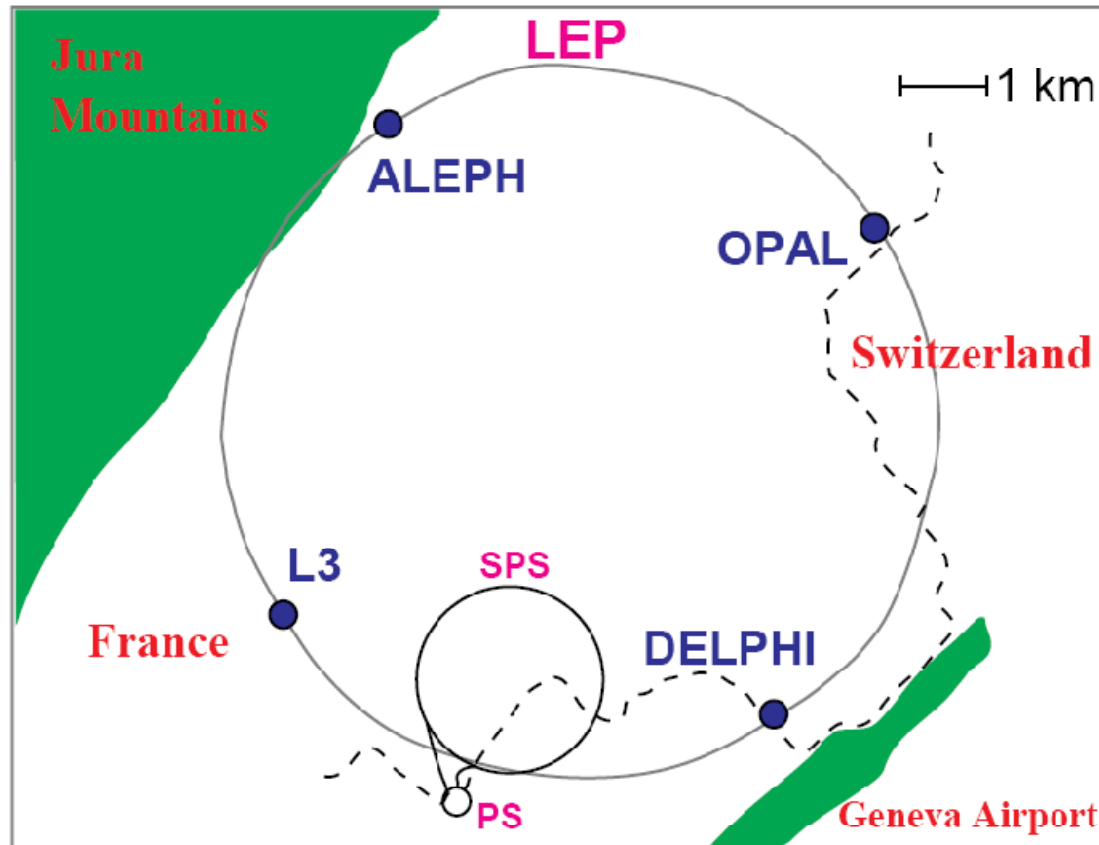
Energieabhängigkeit des totalen WG $e^+e^- \rightarrow \text{Hadronen}$



Vorwärts-Rückwärts-Asymmetrie



Datennahme bei LEP: $E \sim M_Z$

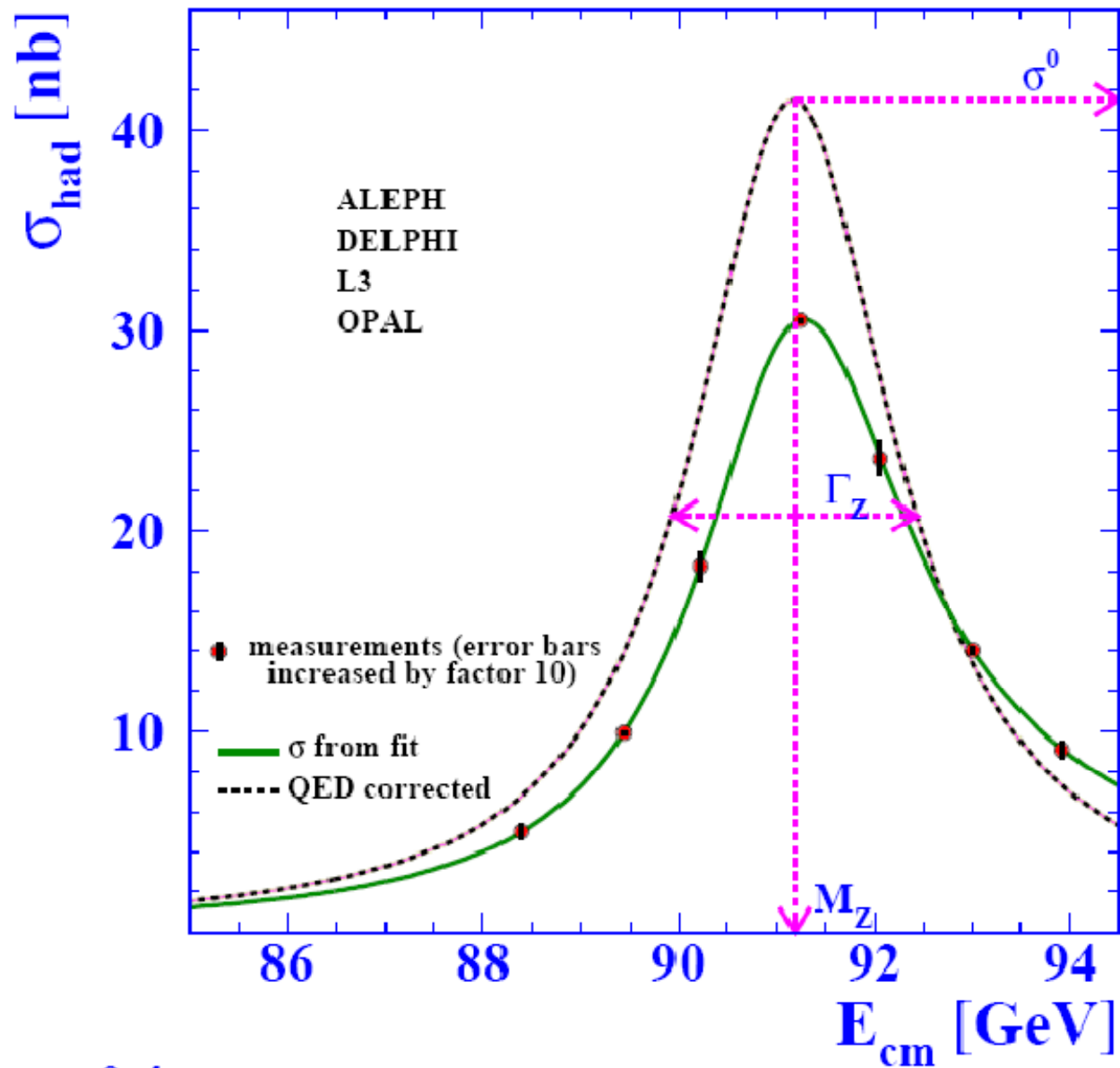


Year	Centre-of-mass energy range [GeV]	Integrated luminosity [pb^{-1}]
1989	88.2 – 94.2	1.7
1990	88.2 – 94.2	8.6
1991	88.5 – 93.7	18.9
1992	91.3	28.6
1993	89.4, 91.2, 93.0	40.0
1994	91.2	64.5
1995	89.4, 91.3, 93.0	39.8

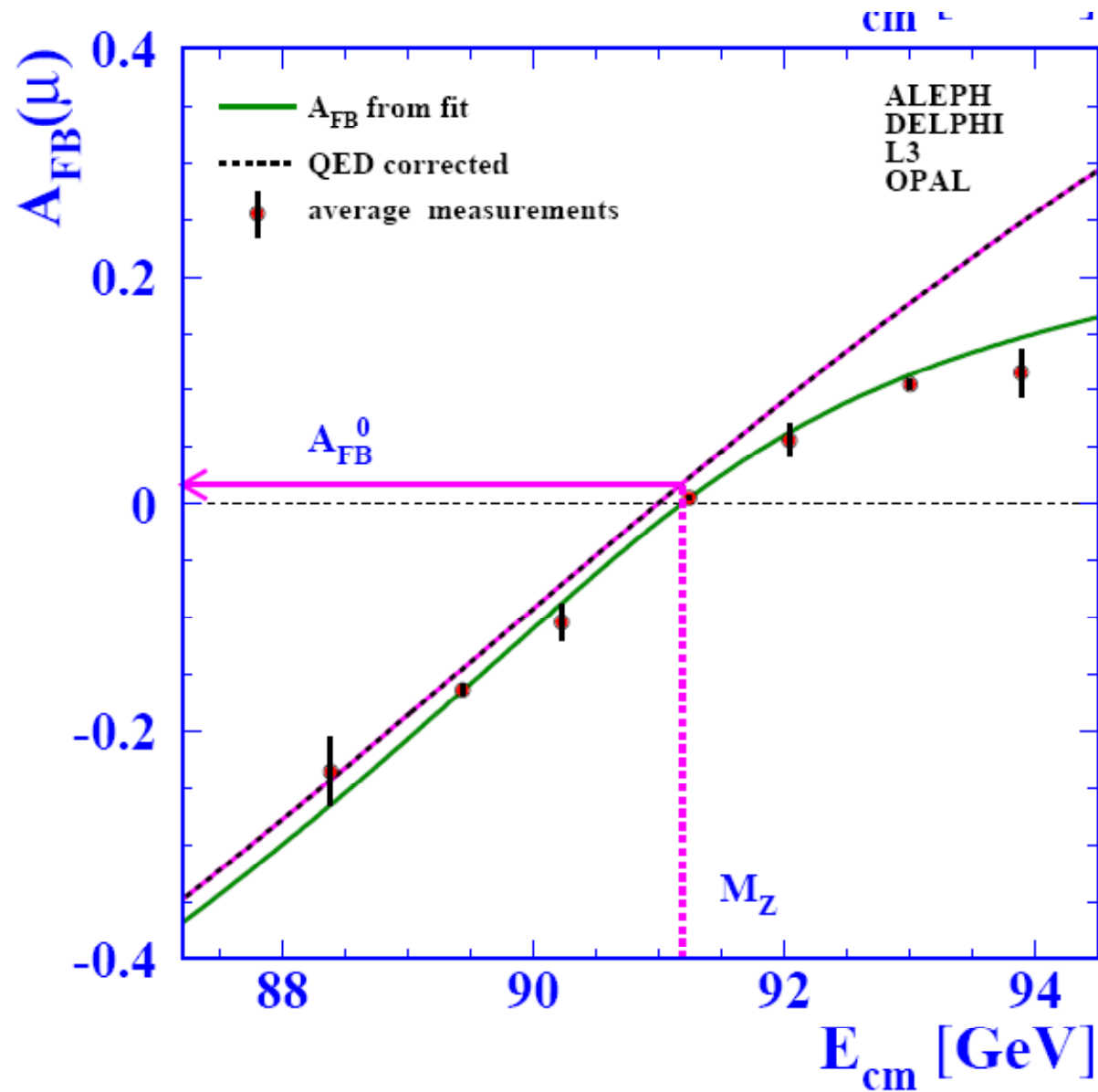
Unit=
1000 Events

Year	Number of Events									
	$Z \rightarrow q\bar{q}$					$Z \rightarrow \ell^+\ell^-$				
	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

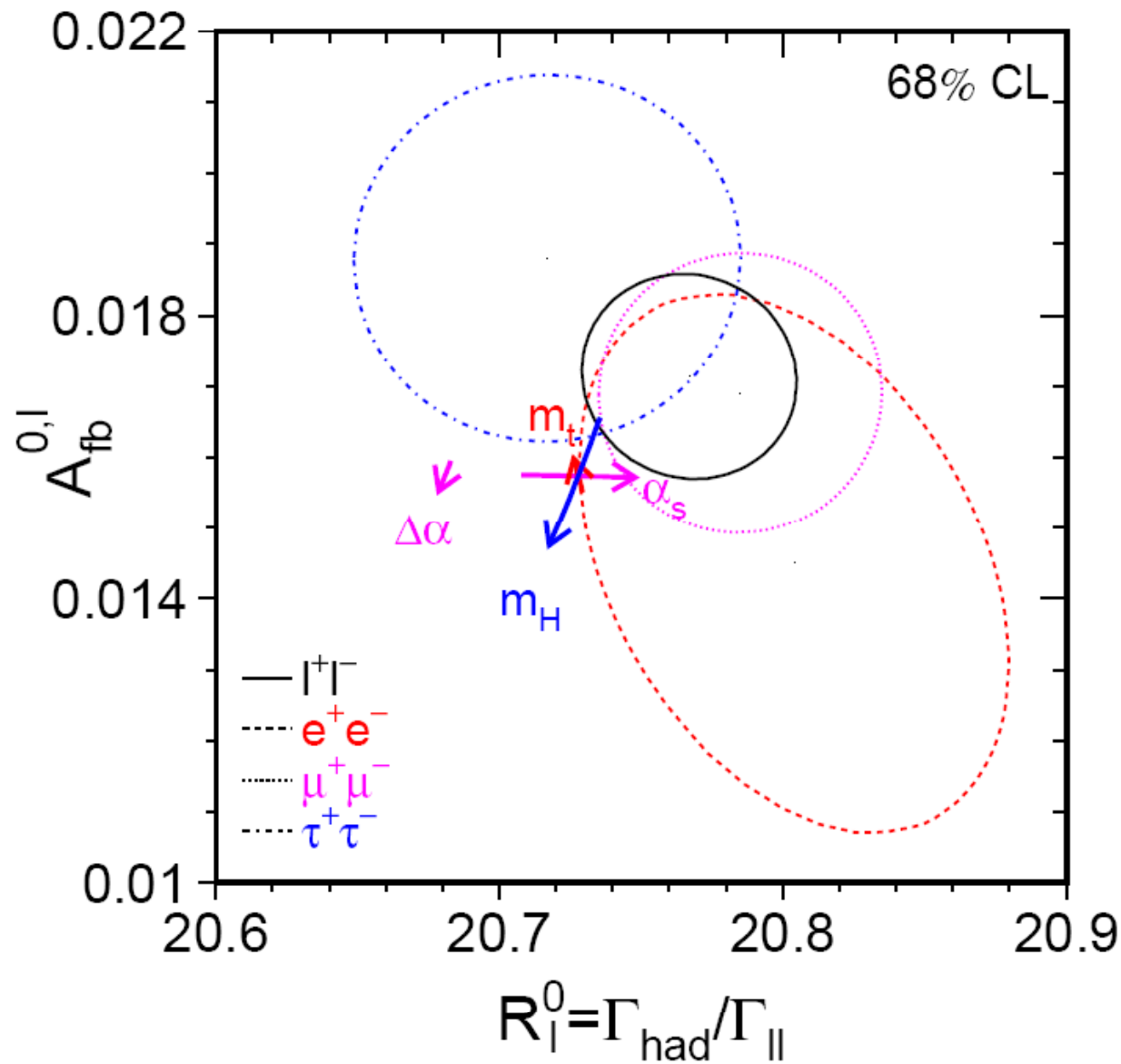
Die Z-Lineshape



Vorwärts-Rückwärts-Asymmetrie der Myonen



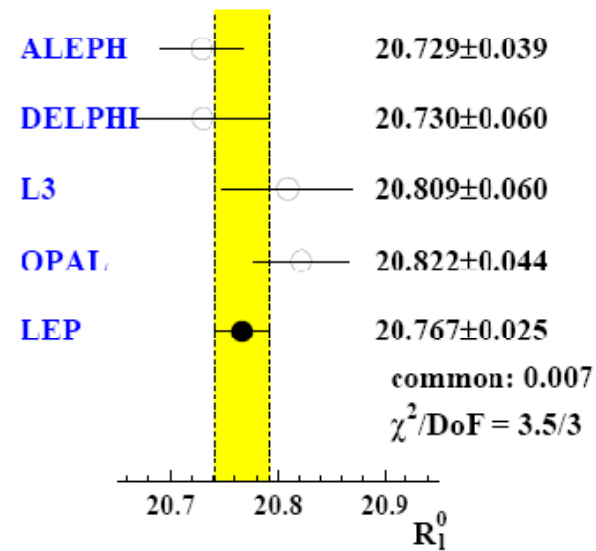
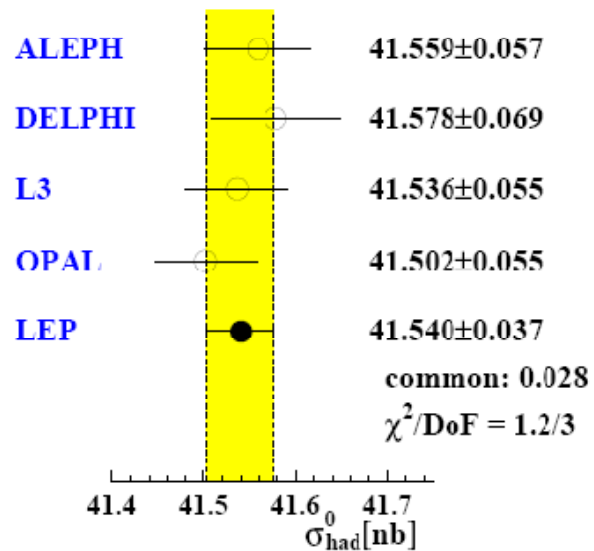
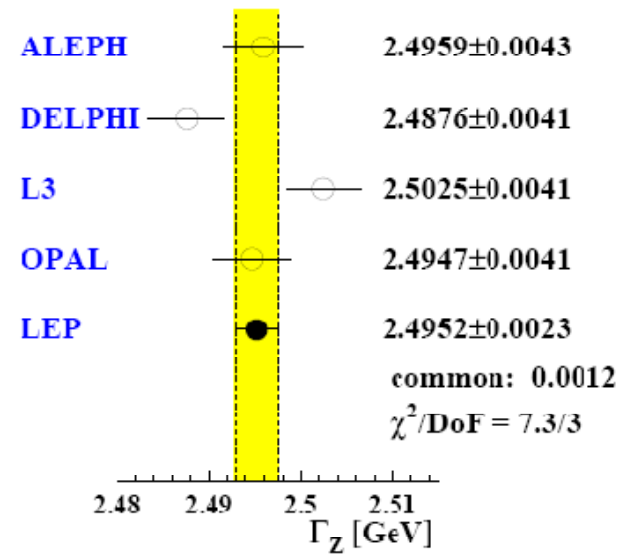
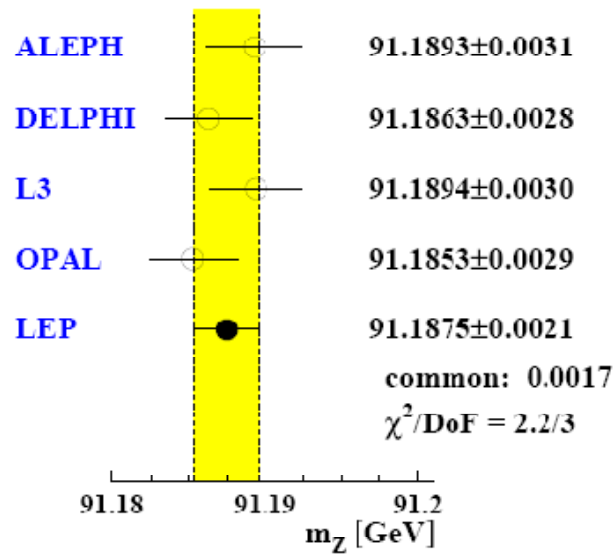
Test der Lepton-Universalität



Lineshape-Parameter bei LEP

With lepton universality		Correlations				
$\chi^2/\text{dof} = 36.5/31$		m_Z	Γ_Z	σ_{had}^0	R_ℓ^0	$A_{\text{FB}}^{0,\ell}$
m_Z [GeV]	91.1875 ± 0.0021	1.000				
Γ_Z [GeV]	2.4952 ± 0.0023	-0.023	1.000			
σ_{had}^0 [nb]	41.540 ± 0.037	-0.045	-0.297	1.000		
R_ℓ^0	20.767 ± 0.025	0.033	0.004	0.183	1.000	
$A_{\text{FB}}^{0,\ell}$	0.0171 ± 0.0010	0.055	0.003	0.006	-0.056	1.000

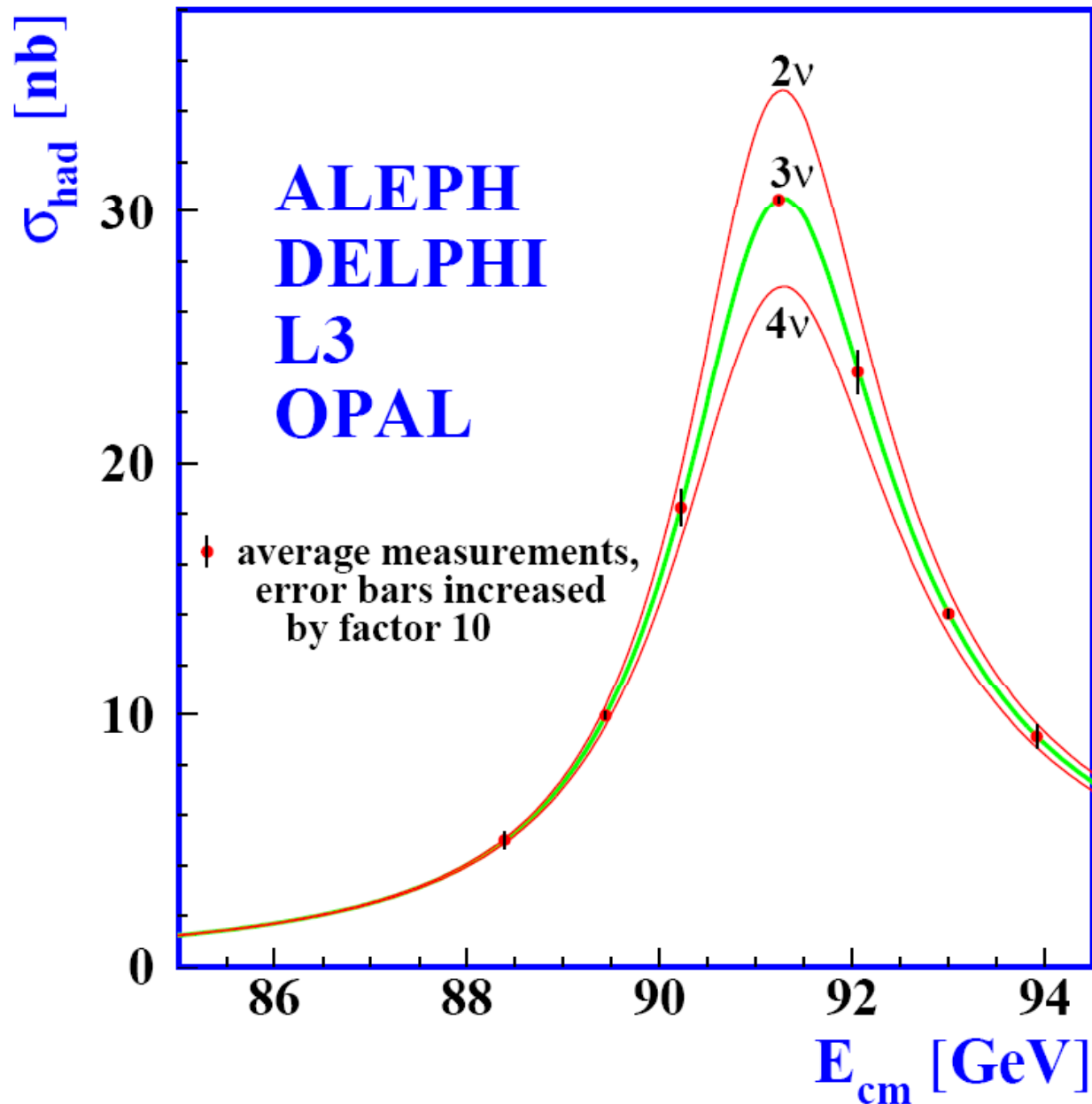
Lineshape-Parameter bei LEP



Lineshape-Parameter bei LEP

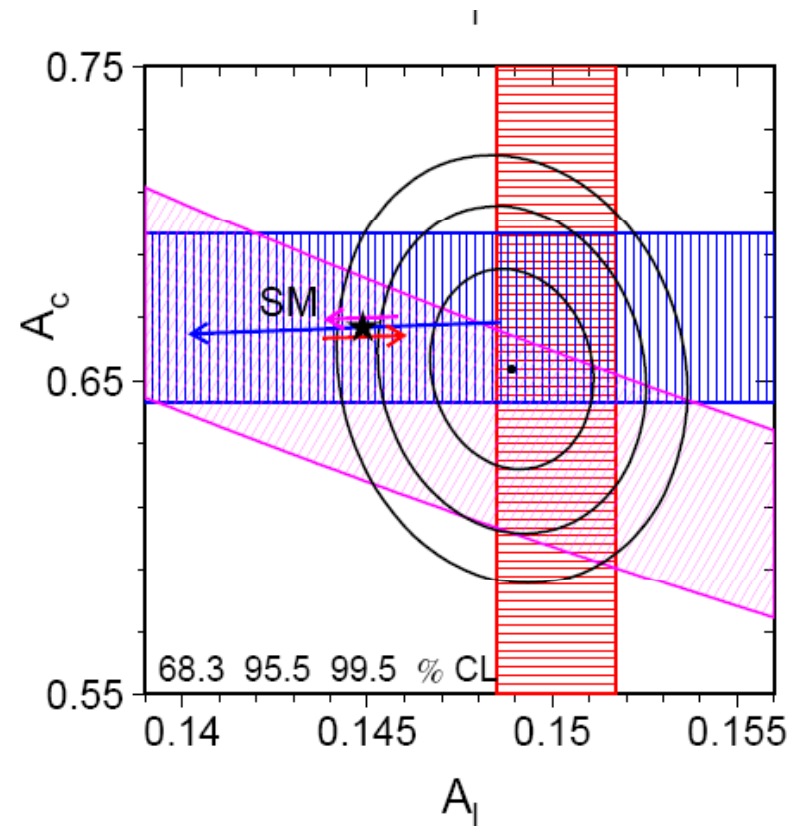
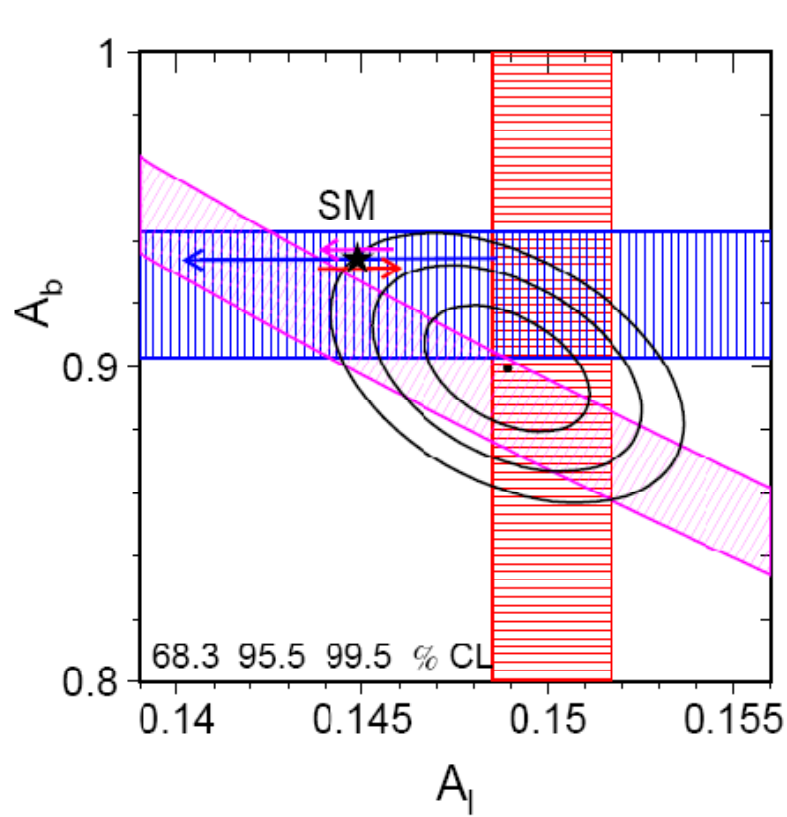
Parameter	Average		Correlations						
Γ_{ff}	[MeV]								
Without Lepton Universality									
			Γ_{had}	Γ_{ee}	$\Gamma_{\mu\mu}$	$\Gamma_{\tau\tau}$	$\Gamma_{b\bar{b}}$	$\Gamma_{c\bar{c}}$	Γ_{inv}
Γ_{had}	1745.8	± 2.7	1.00						
Γ_{ee}	83.92	± 0.12	-0.29	1.00					
$\Gamma_{\mu\mu}$	83.99	± 0.18	0.66	-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		

Anzahl der Neutrino-Generationen



Bestimmung von A_f

Parameter	Average	Correlations		
		\mathcal{A}_ℓ	\mathcal{A}_b	\mathcal{A}_c
\mathcal{A}_ℓ	0.1489 ± 0.0015	1.00		
\mathcal{A}_b	0.899 ± 0.013	-0.42	1.00	
\mathcal{A}_c	0.654 ± 0.021	-0.10	0.15	1.00

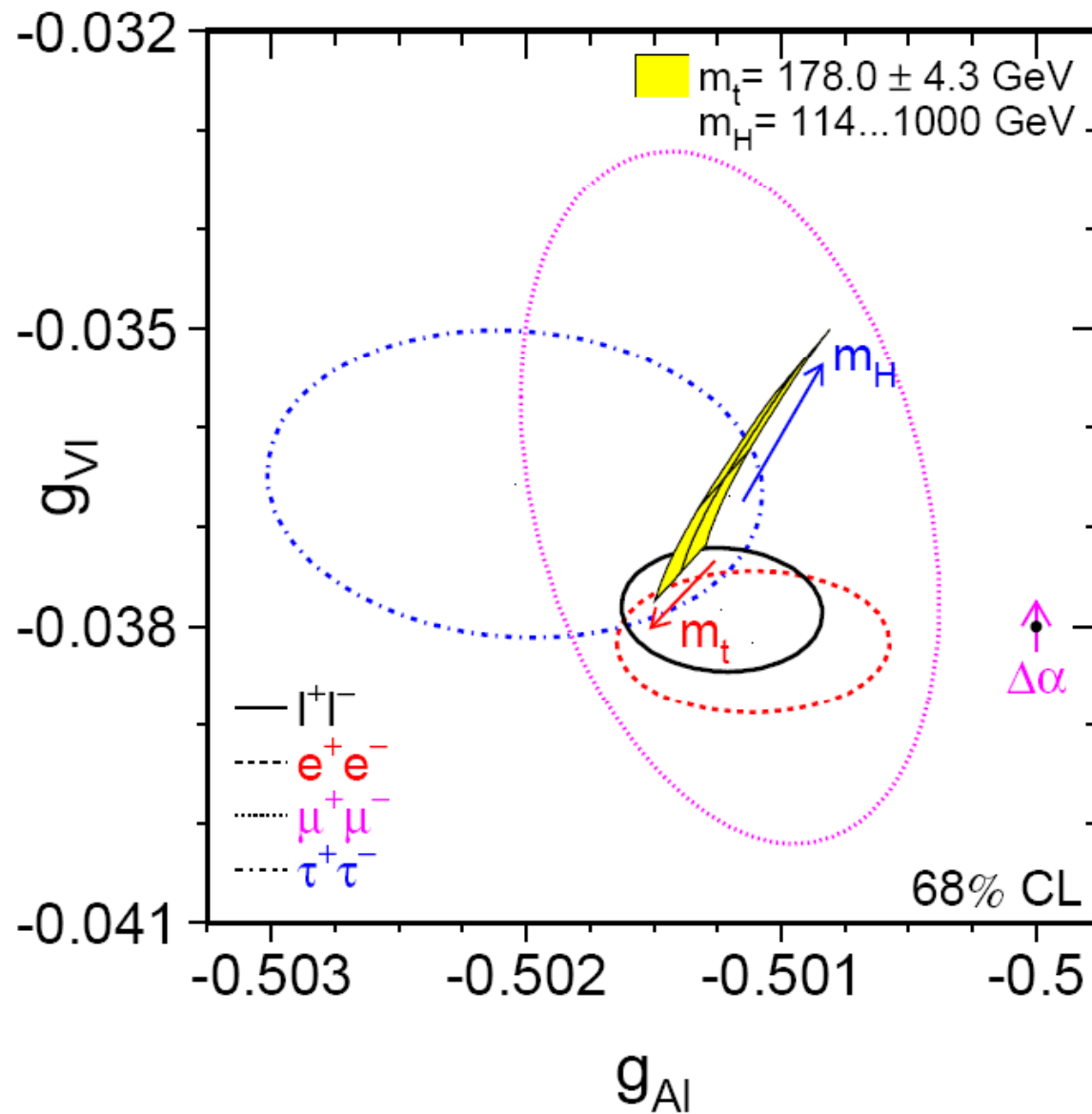


Bestimmung der Kopplungen

Parameter	Average	Correlations						
		$g_{A\nu}$	g_{Ae}	$g_{A\mu}$	$g_{A\tau}$	g_{Ve}	$g_{V\mu}$	$g_{V\tau}$
$g_{A\nu} \equiv g_{V\nu}$	$+0.5003 \pm 0.0012$	1.00						
g_{Ae}	-0.50111 ± 0.00035	-0.75	1.00					
$g_{A\mu}$	-0.50120 ± 0.00054	0.39	-0.13	1.00				
$g_{A\tau}$	-0.50204 ± 0.00064	0.37	-0.12	0.35	1.00			
g_{Ve}	-0.03816 ± 0.00047	-0.10	0.01	-0.01	-0.03	1.00		
$g_{V\mu}$	-0.0367 ± 0.0023	0.02	0.00	-0.30	0.01	-0.10	1.00	
$g_{V\tau}$	-0.0366 ± 0.0010	0.02	-0.01	0.01	-0.07	-0.02	0.01	1.00

Parameter	Average	Correlations						
		$g_{L\nu}$	g_{Le}	$g_{L\mu}$	$g_{L\tau}$	g_{Re}	$g_{R\mu}$	$g_{R\tau}$
$g_{L\nu}$	$+0.5003 \pm 0.0012$	1.00						
g_{Le}	-0.26963 ± 0.00030	-0.52	1.00					
$g_{L\mu}$	-0.2689 ± 0.0011	0.12	-0.11	1.00				
$g_{L\tau}$	-0.26930 ± 0.00058	0.22	-0.07	0.07	1.00			
g_{Re}	$+0.23148 \pm 0.00029$	0.37	0.29	-0.07	0.01	1.00		
$g_{R\mu}$	$+0.2323 \pm 0.0013$	-0.06	-0.06	0.90	-0.03	-0.09	1.00	
$g_{R\tau}$	$+0.23274 \pm 0.00062$	-0.17	0.04	-0.04	0.44	-0.03	0.04	1.00

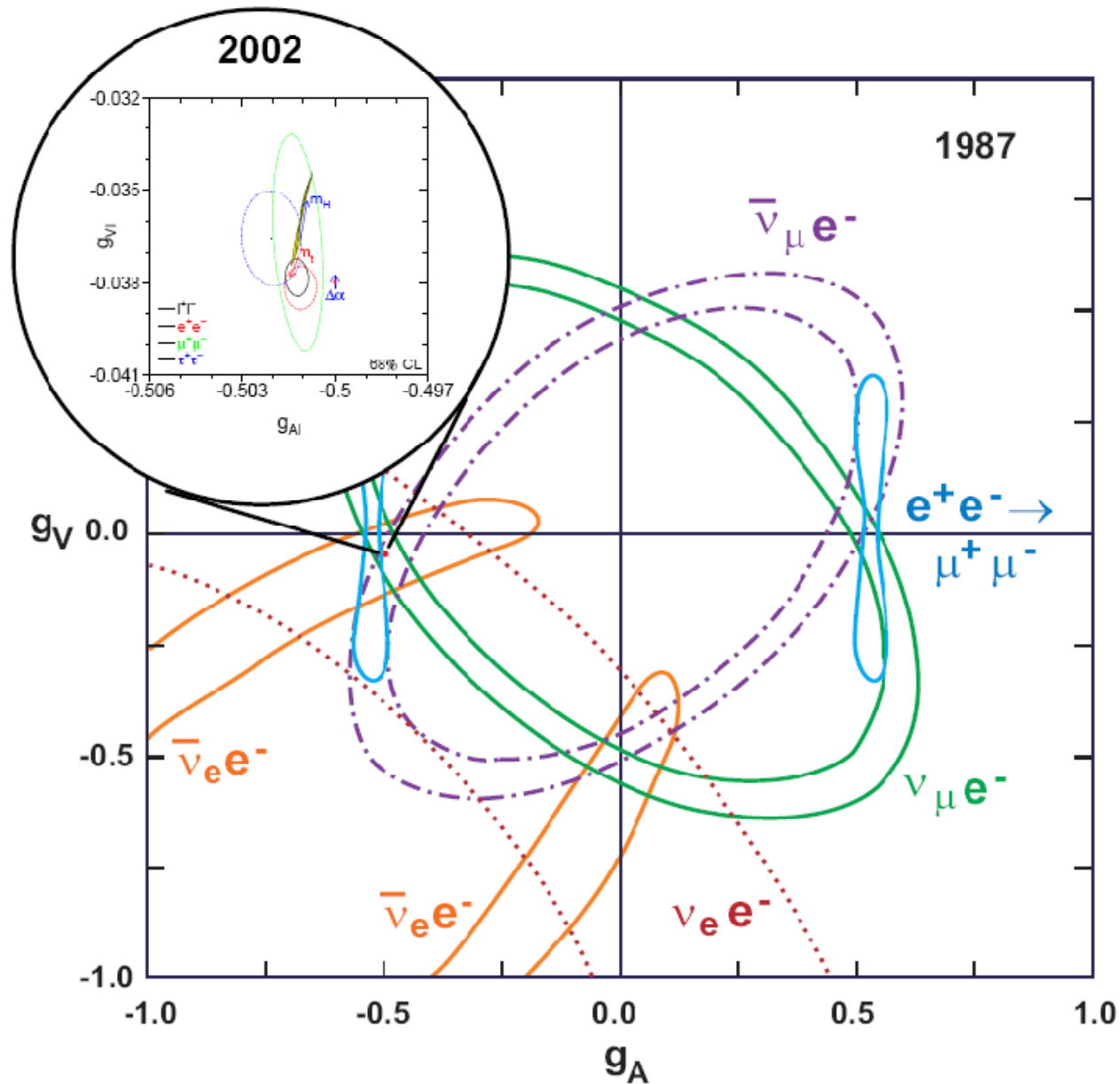
Test der Leptom-Universalität: Kopplungen



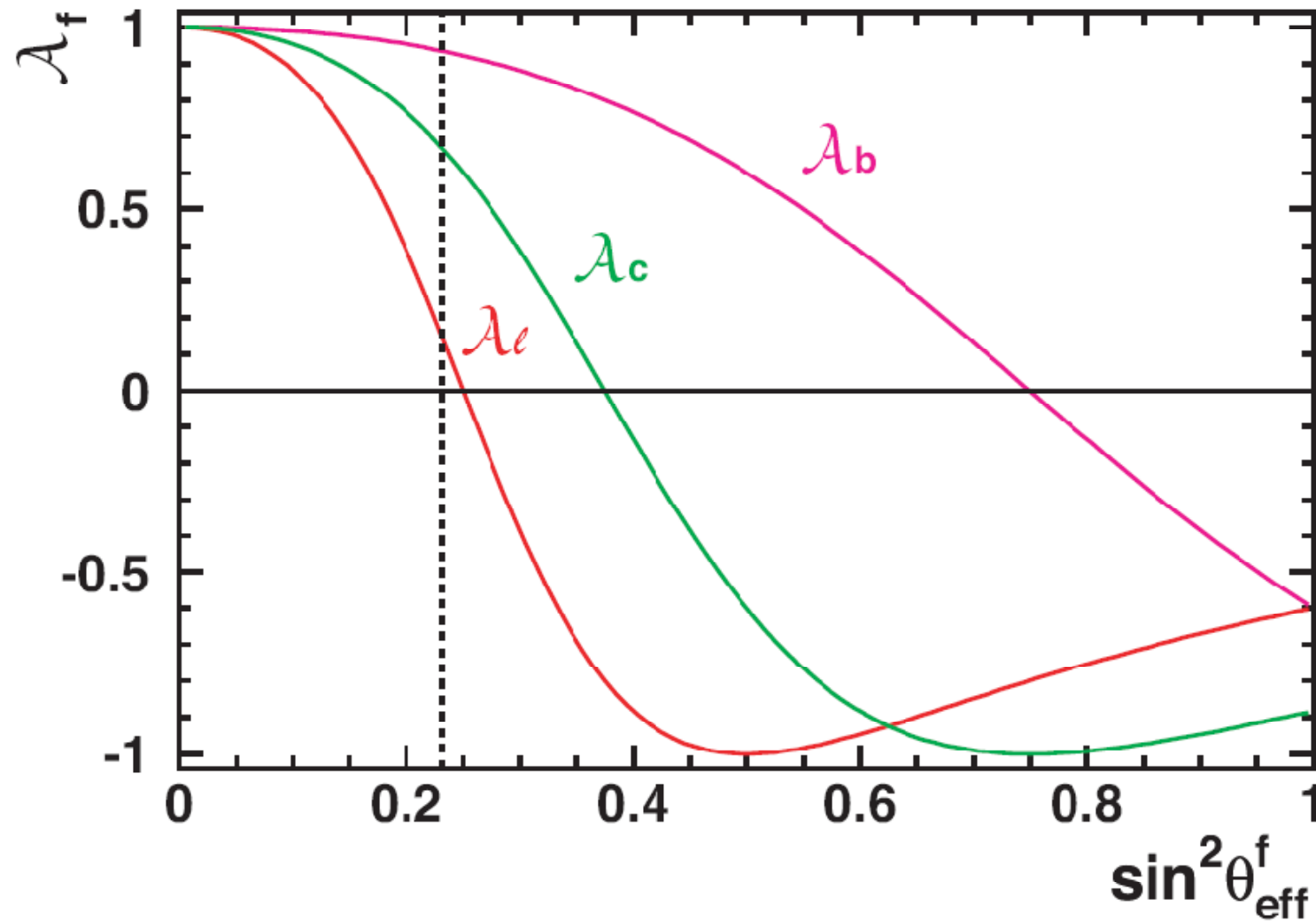
Parameter	Average	Correlations		
		g_ν	$g_{A\ell}$	$g_{V\ell}$
$g_{A\nu} \equiv g_{V\nu}$	$+0.50076 \pm 0.00076$	1.00		
$g_{A\ell}$	-0.50123 ± 0.00026	-0.48	1.00	
$g_{V\ell}$	-0.03783 ± 0.00041	-0.03	-0.06	1.00

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

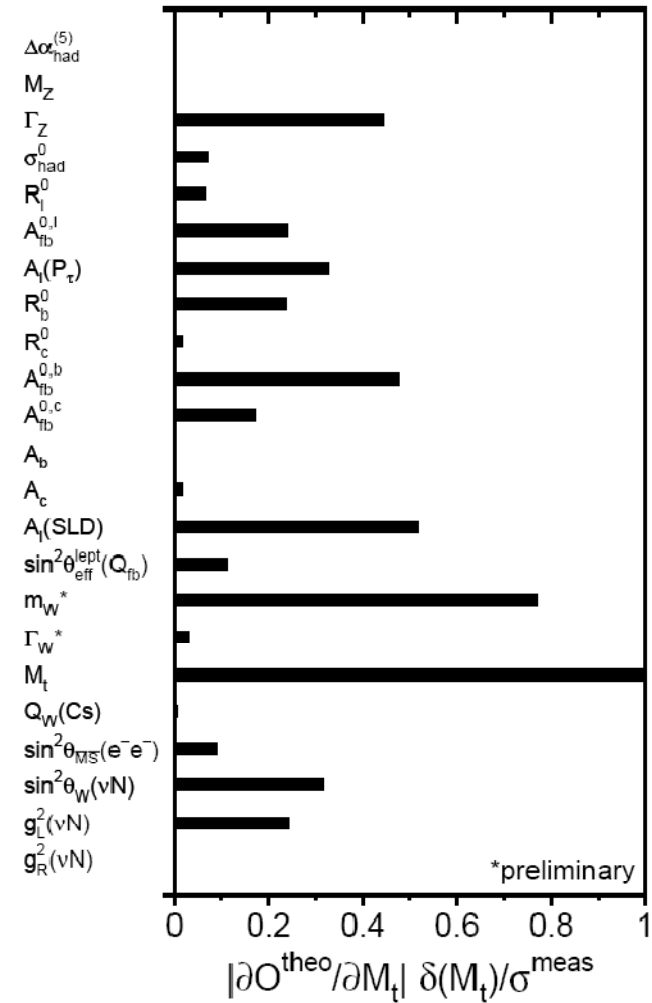
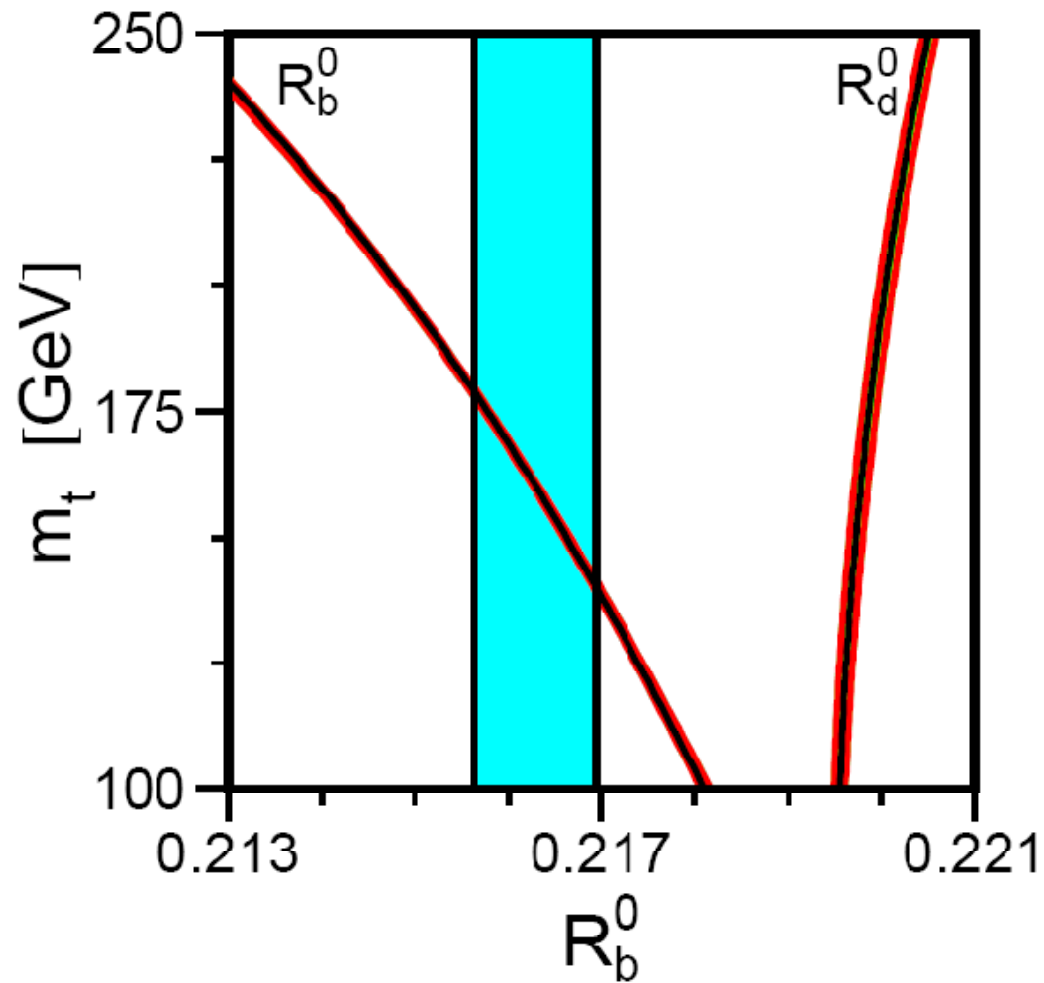
Präzision in Kopplungen: vor und nach LEP



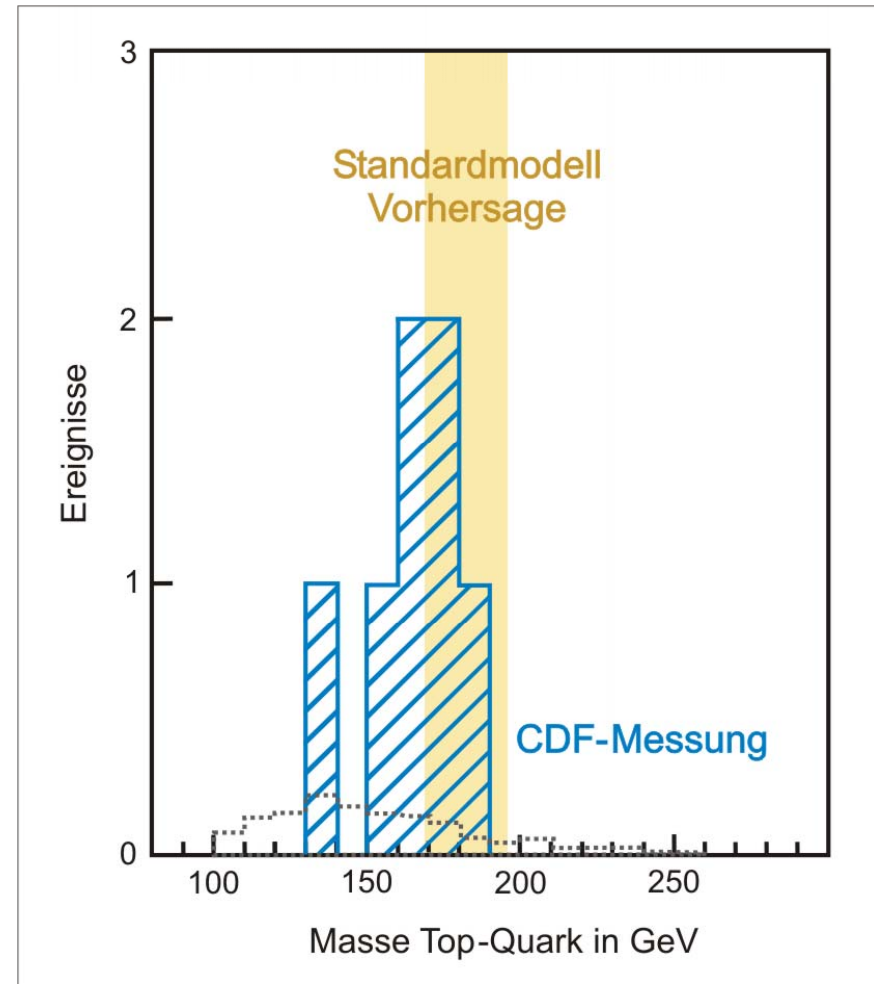
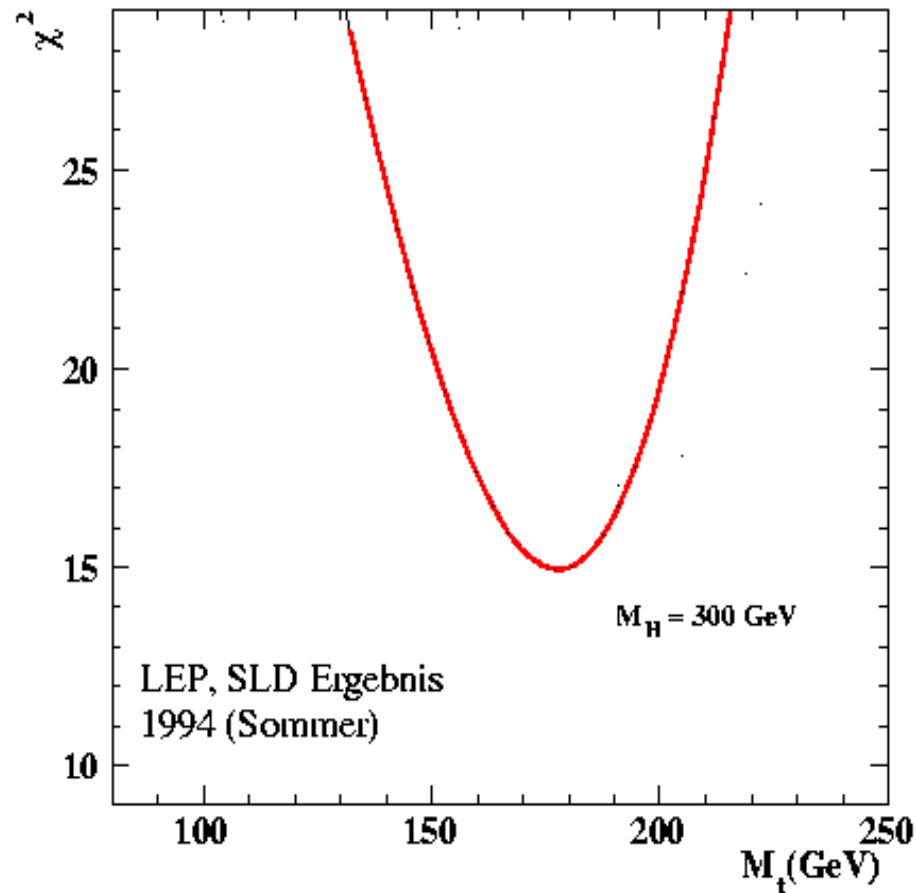
Abhängigkeit A_f von Weinbergwinkel



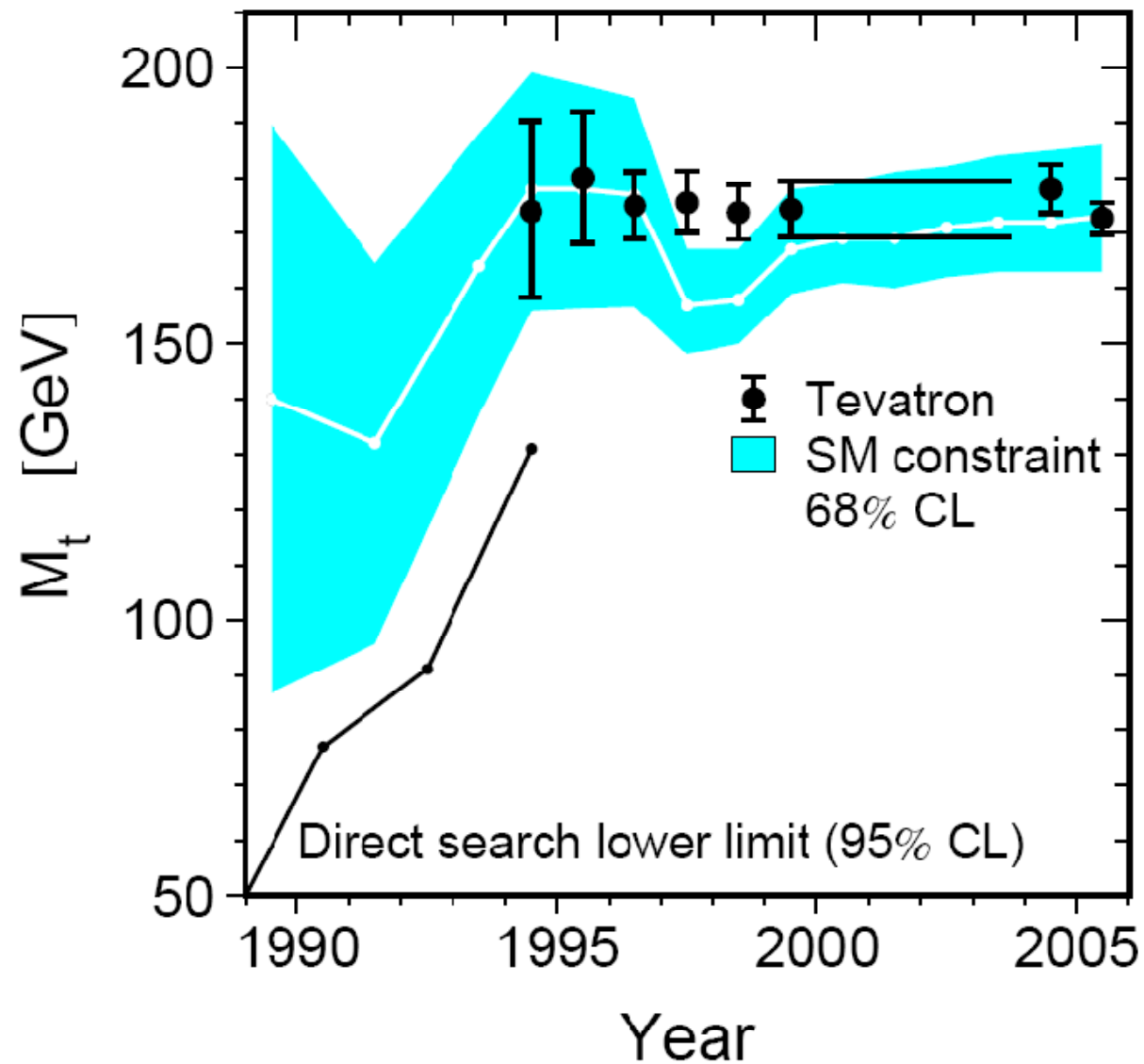
Sensitivität auf M_{top}



Vorhersage und Entdeckung des Top-Quarks (94)



Vorhersage und Messung von M_{top}



Vorhersage von Masse des top-Quark und des W-Bosons

