

# Particle Physics II

## Winter Semester 2011/2012

### Albert-Ludwigs-Universität Freiburg



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<http://terascale.physik.uni-freiburg.de/lehre/>

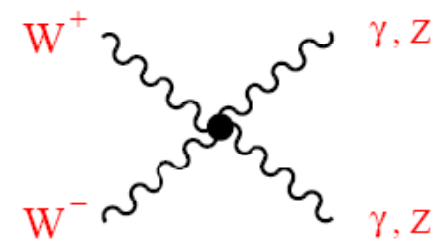
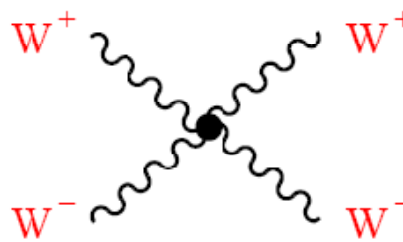
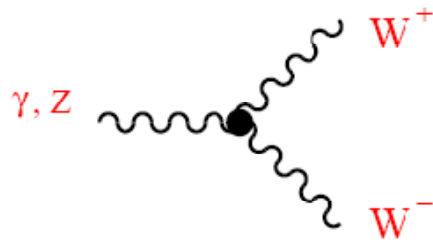
# Kapitel 5

## Die elektroschwache “Vereinigung” im Standardmodell

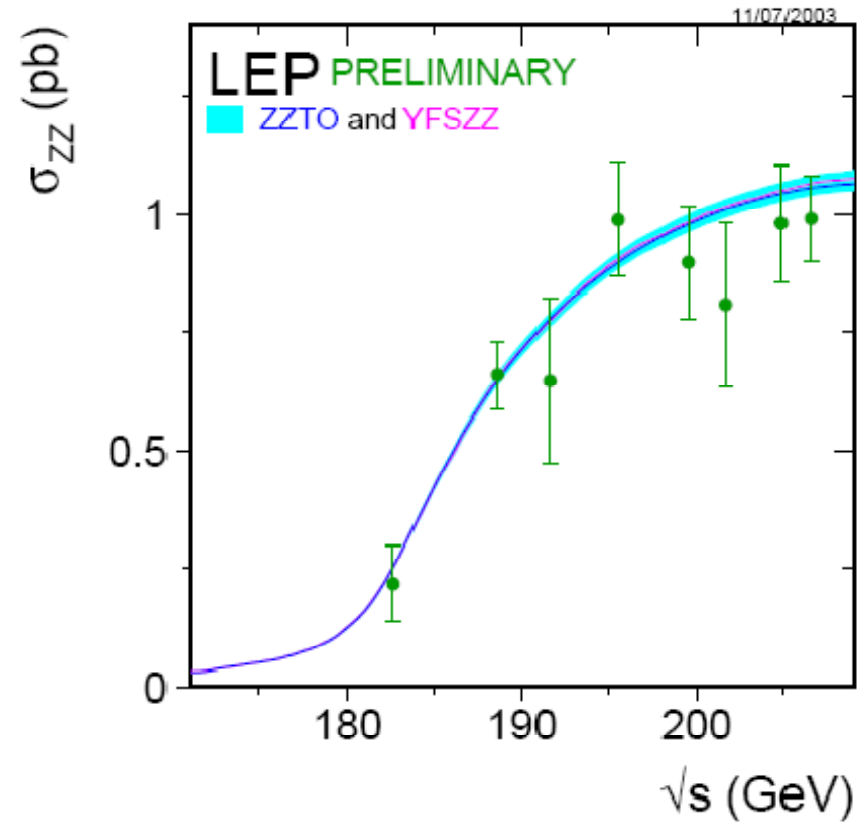
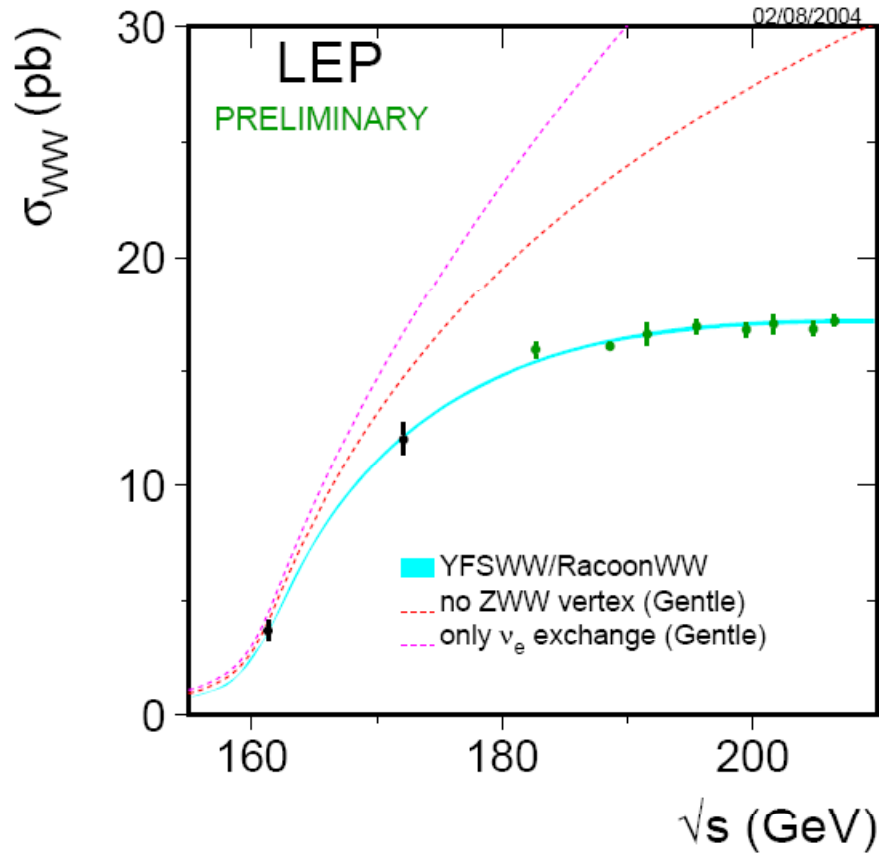
# Selbstwechselwirkung der schwachen Eichbosonen

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

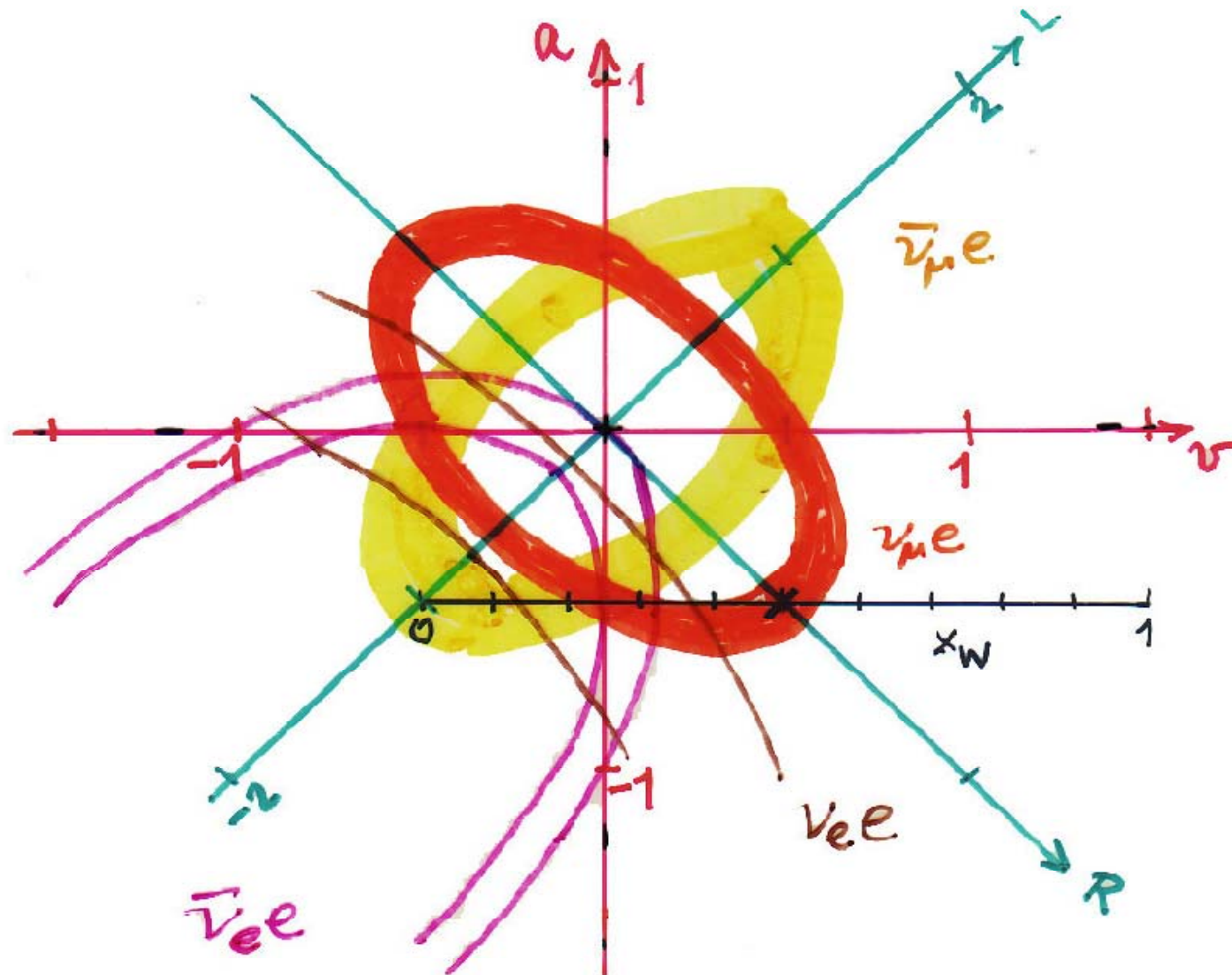
$$\mathcal{L}_4 = -\frac{e^2}{2 \sin^2 \theta_W} \left\{ (W_\mu^\dagger W^\mu)^2 - W_\mu^\dagger W^{\mu\dagger} W_\nu W^\nu \right\} - e^2 \cot^2 \theta_W \left\{ W_\mu^\dagger W^\mu Z_\nu Z^\nu - W_\mu^\dagger Z^\mu W_\nu Z^\nu \right\} \\ - e^2 \cot \theta_W \left\{ 2W_\mu^\dagger W^\mu Z_\nu A^\nu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



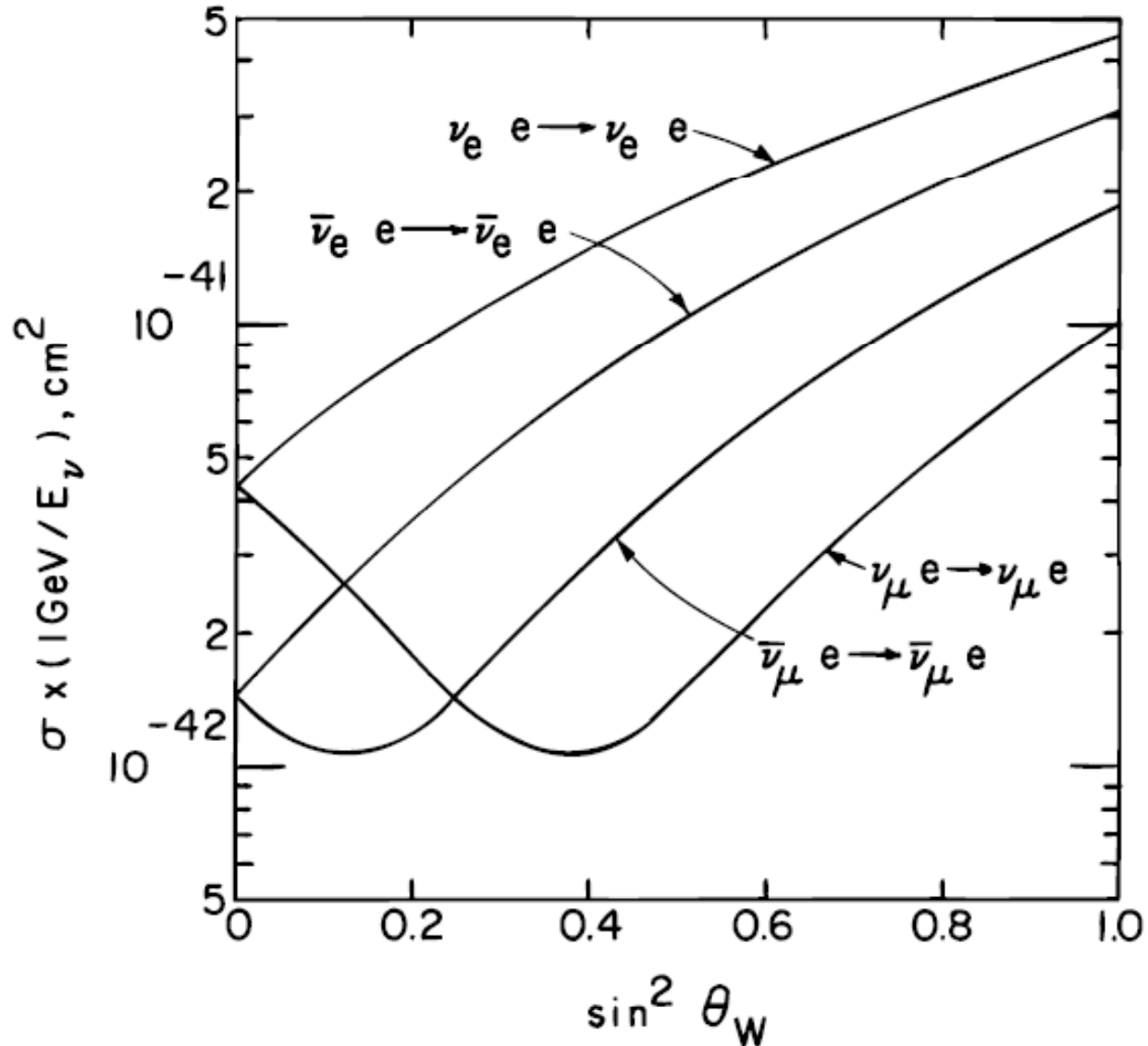
# Test der nicht abelschen Eichstruktur bei LEP2



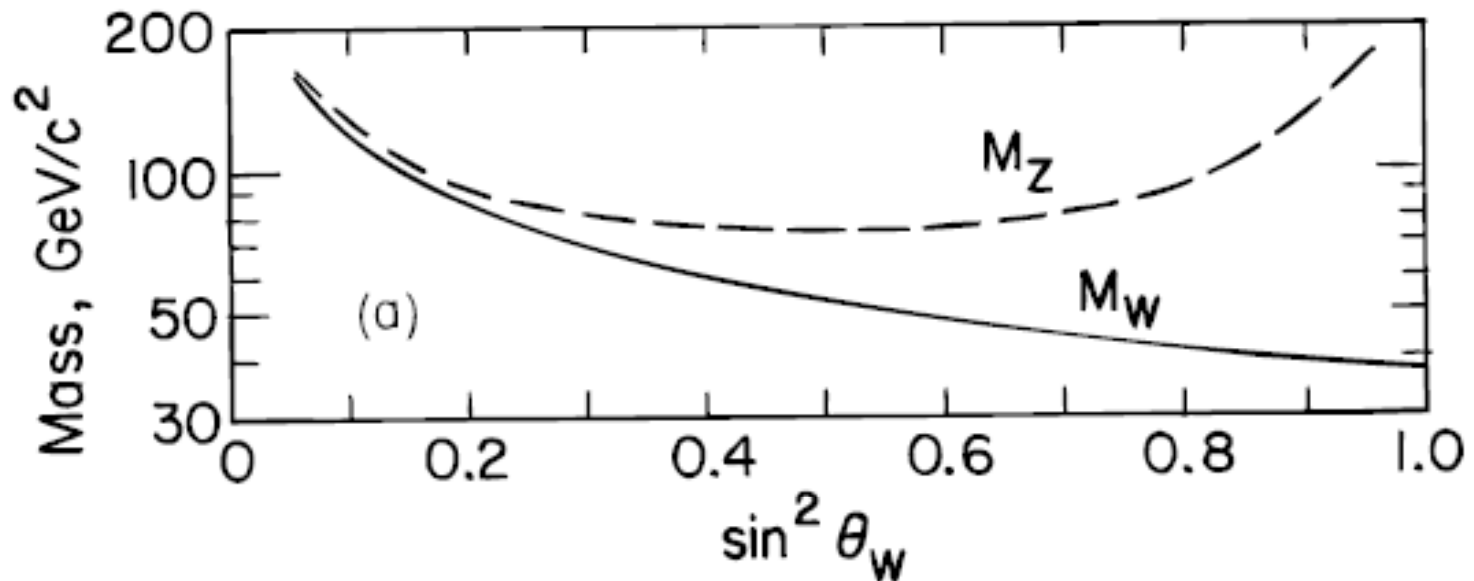
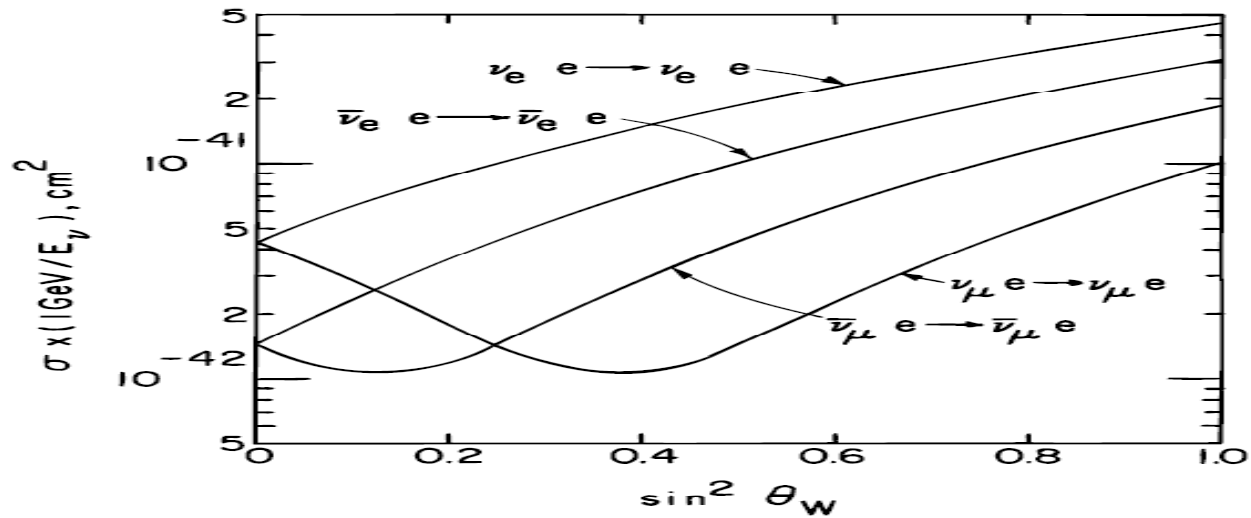
# Bestimmung der Z-Kopplungen in Neutrinostrahlung



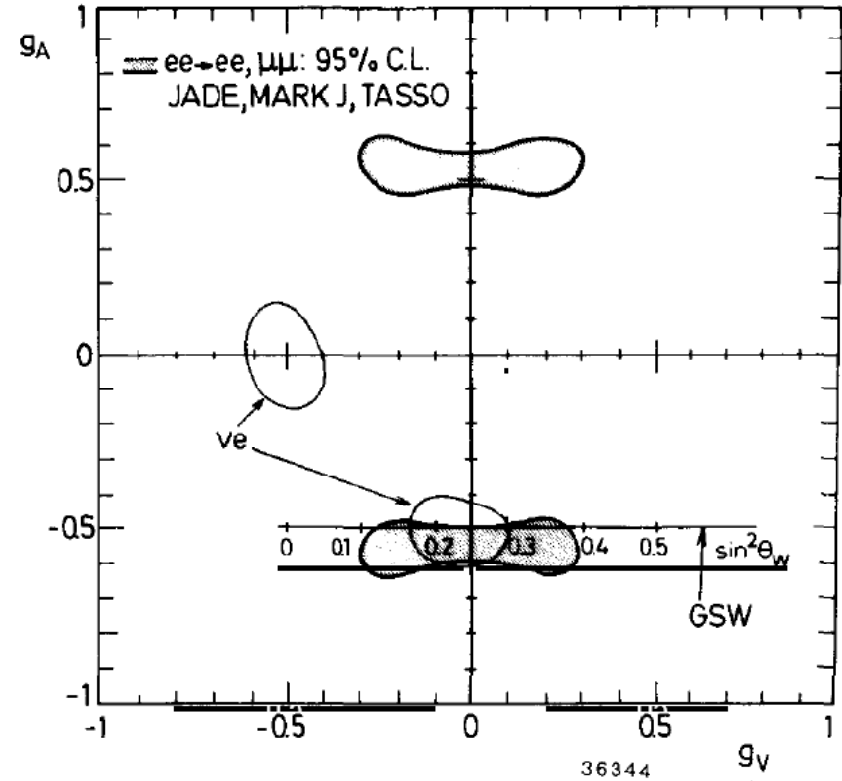
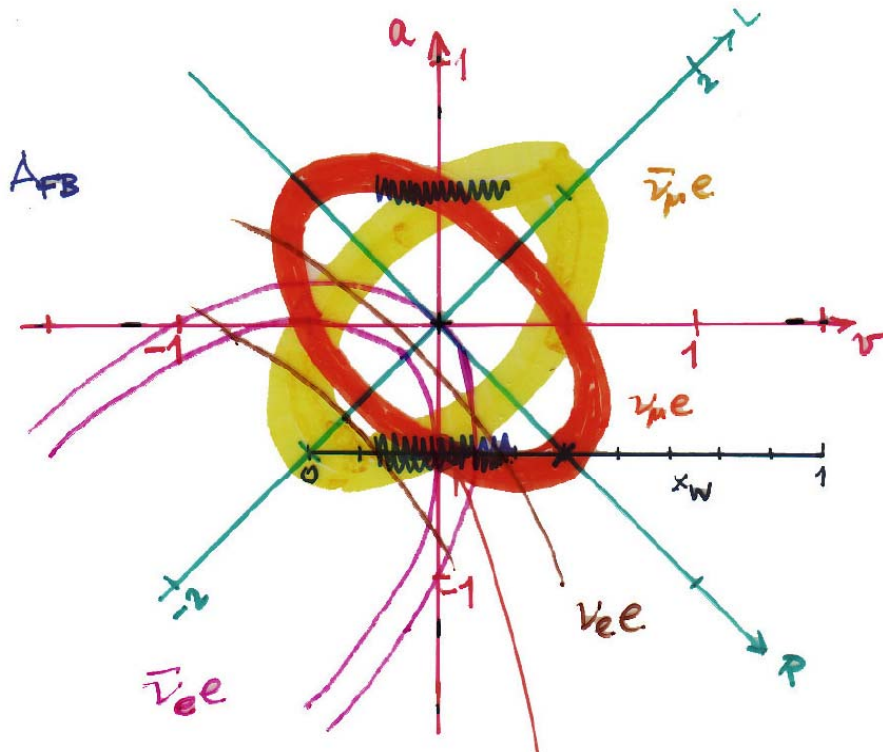
# schwacher Mischungswinkel aus Neutrinostrreuung



# schwacher Mischungswinkel u. $M_{W/Z}$ aus $\nu$ -Streuung

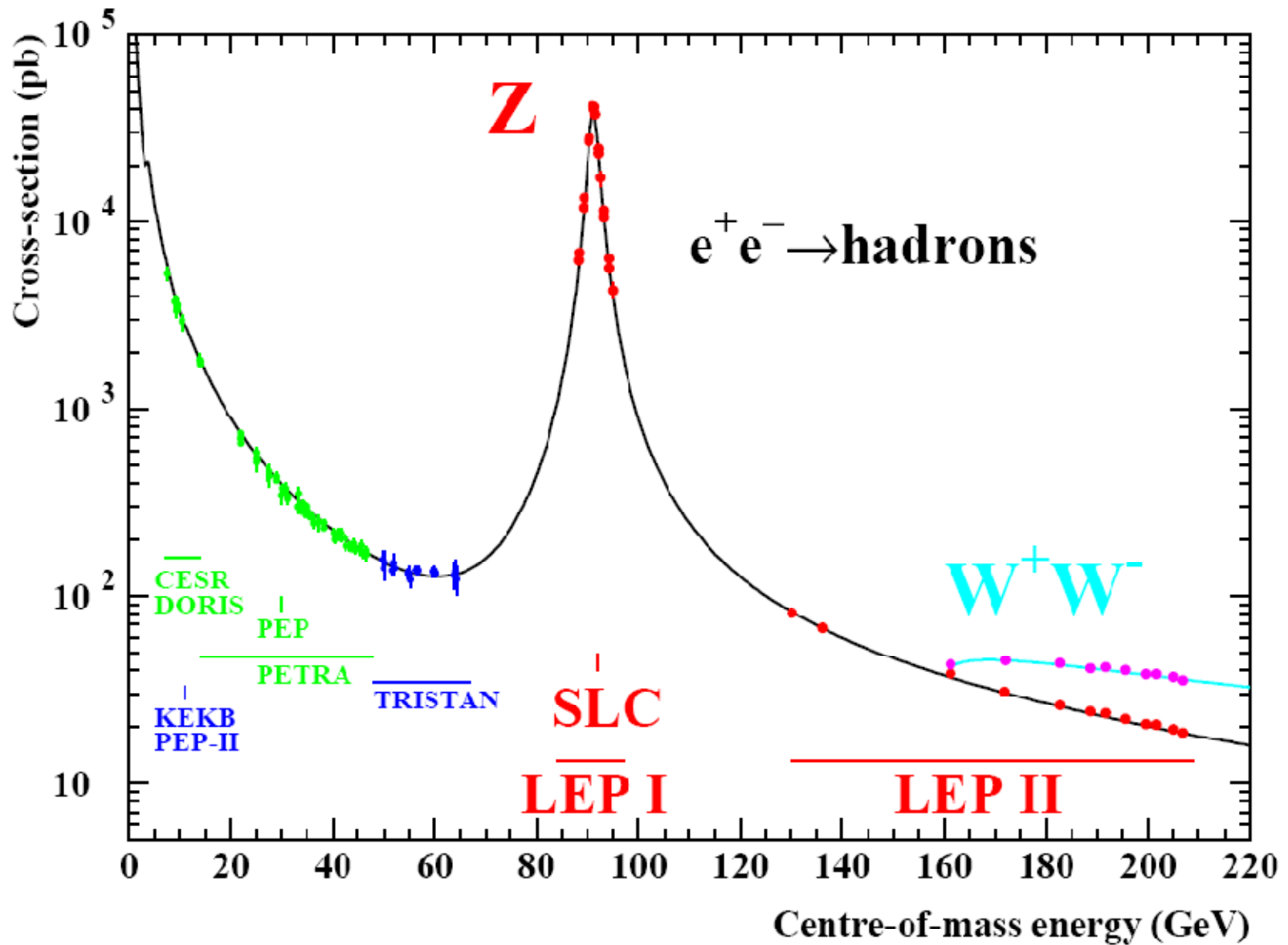


# Z-Kopplungen bei PETRA

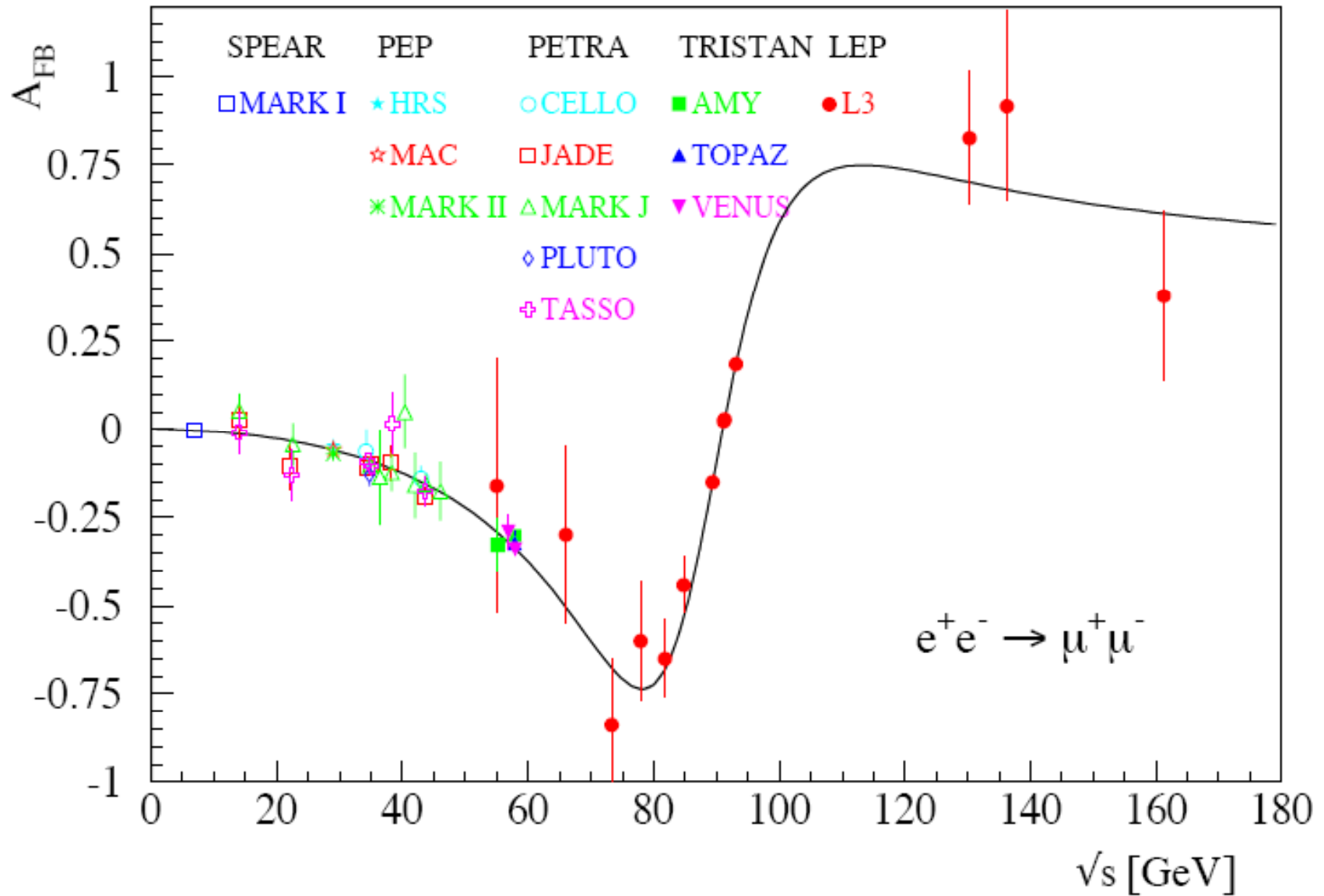




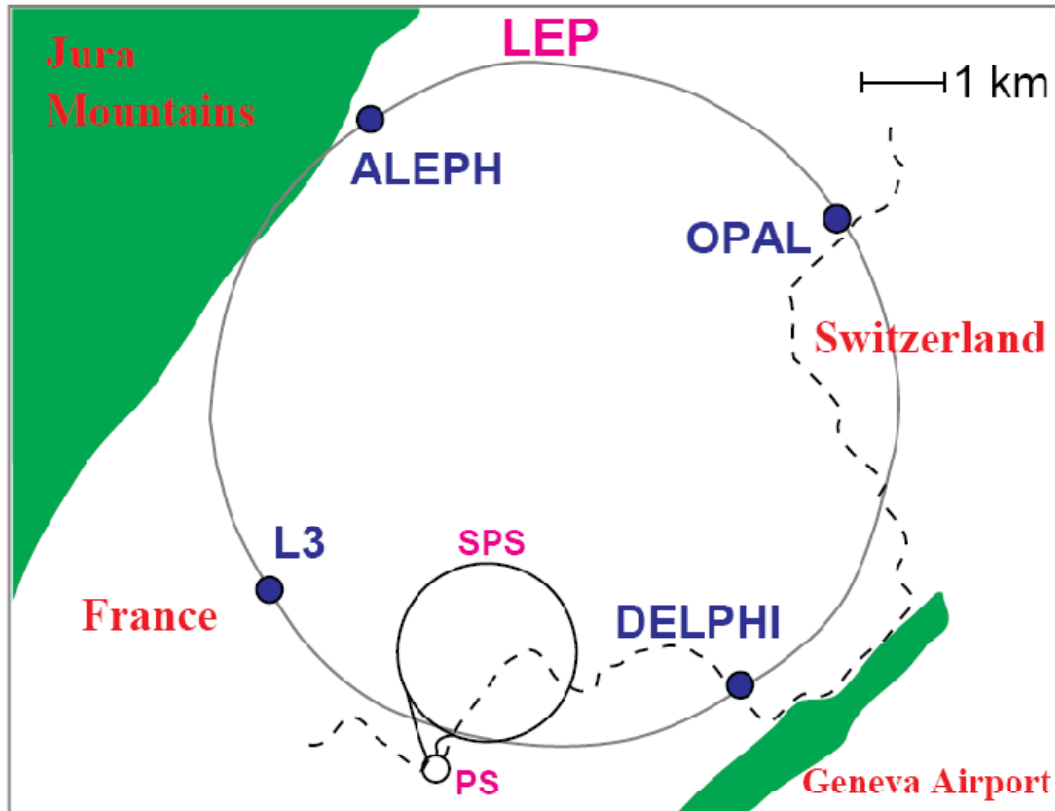
# Energieabhängigkeit von $e^+e^- \rightarrow \text{Hadronen}$



# Vorwärts-Rückwärtsasymmetrie



# Datennahme bei LEP1

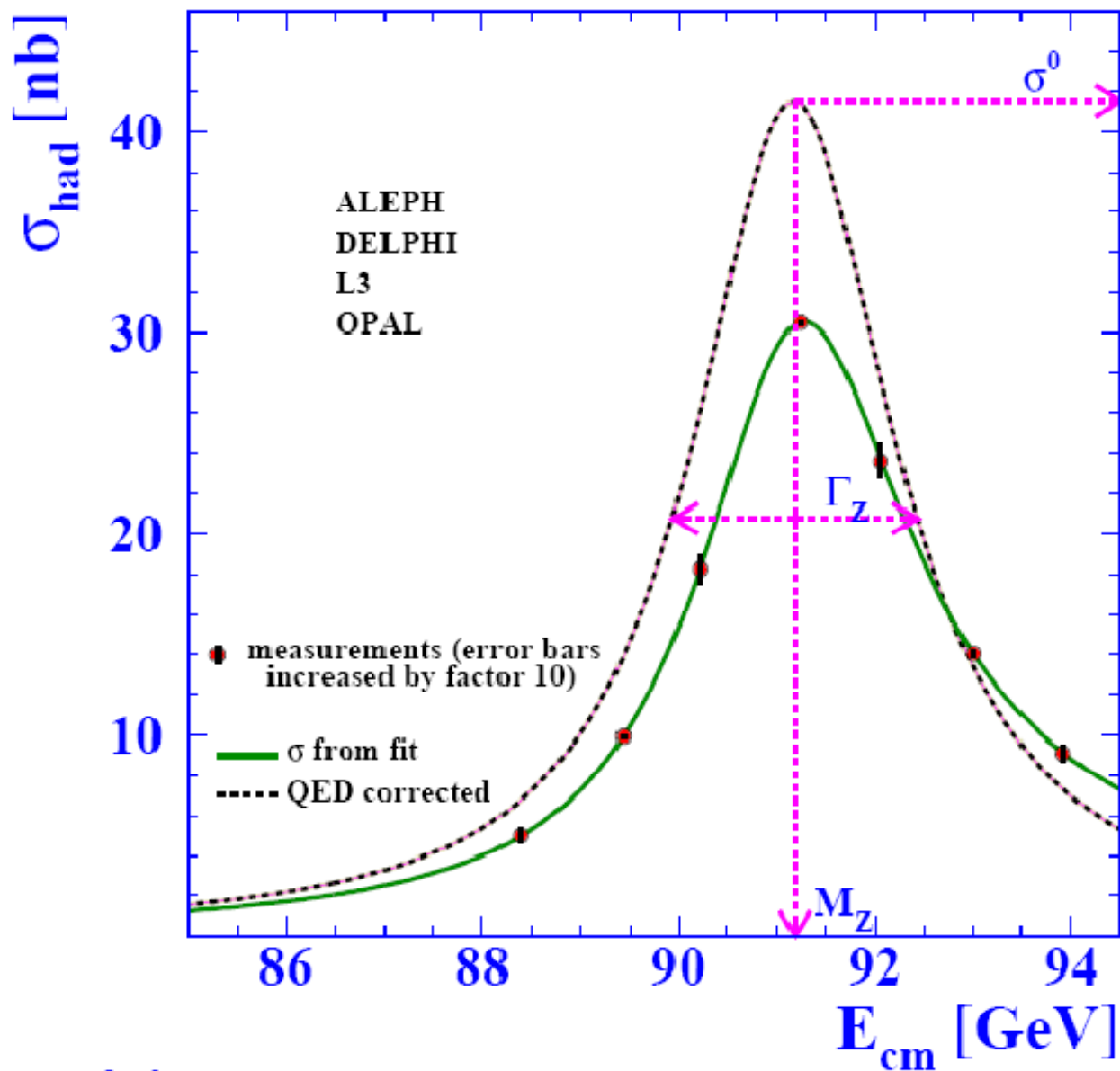


Year	Centre-of-mass energy range [GeV]	Integrated luminosity [ $\text{pb}^{-1}$ ]
1989	88.2 – 94.2	1.7
1990	88.2 – 94.2	8.6
1991	88.5 – 93.7	18.9
1992	91.3	28.6
1993	89.4, 91.2, 93.0	40.0
1994	91.2	64.5
1995	89.4, 91.3, 93.0	39.8

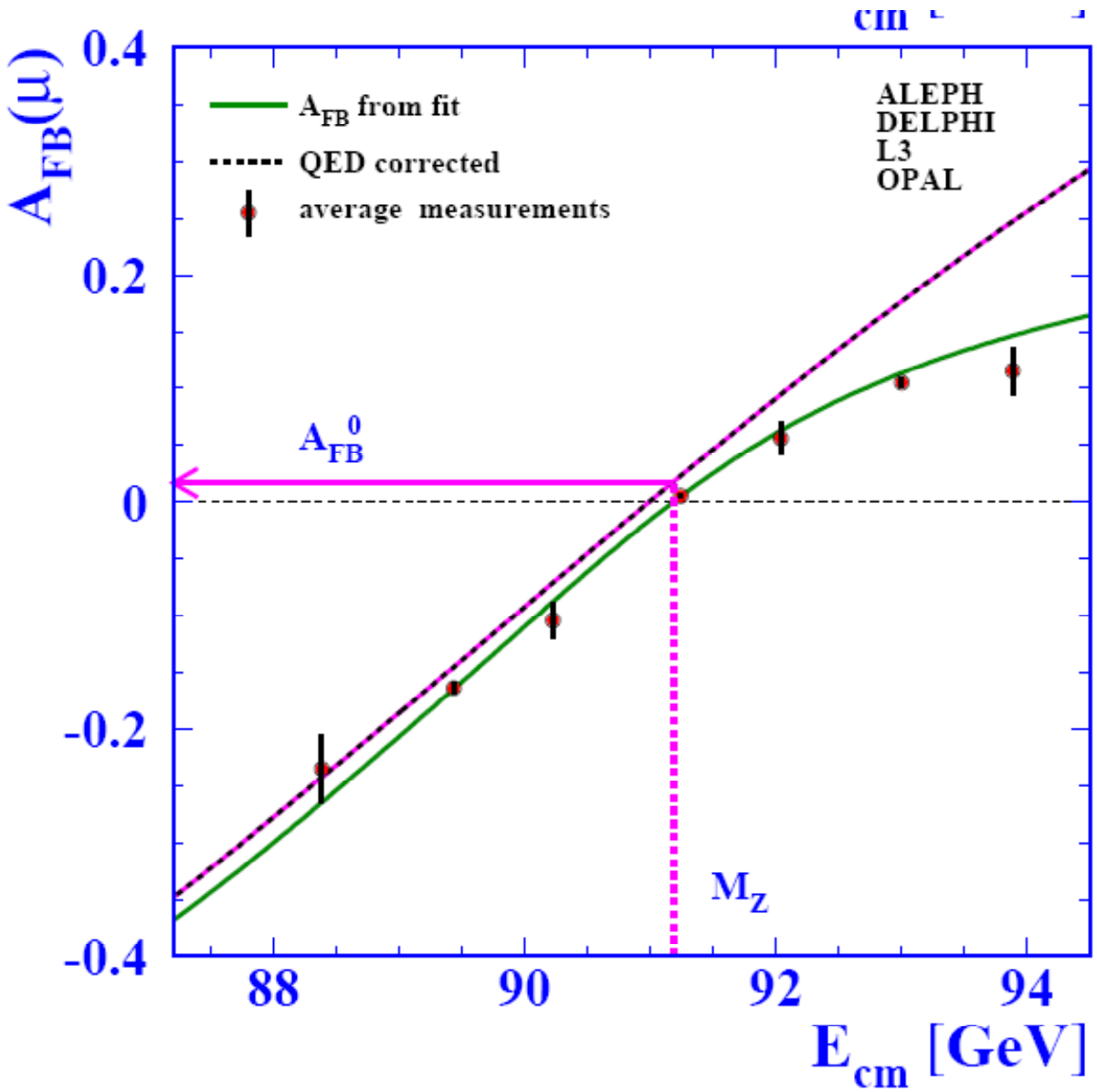
Year	Number of Events									
	$Z \rightarrow q\bar{q}$					$Z \rightarrow \ell^+\ell^-$				
	A	D	L	O	LEP	A	D	L	O	LEP
1990/91	433	357	416	454	1660	53	36	39	58	186
1992	633	697	678	733	2741	77	70	59	88	294
1993	630	682	646	649	2607	78	75	64	79	296
1994	1640	1310	1359	1601	5910	202	137	127	191	657
1995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

Unit=  
1000 Events

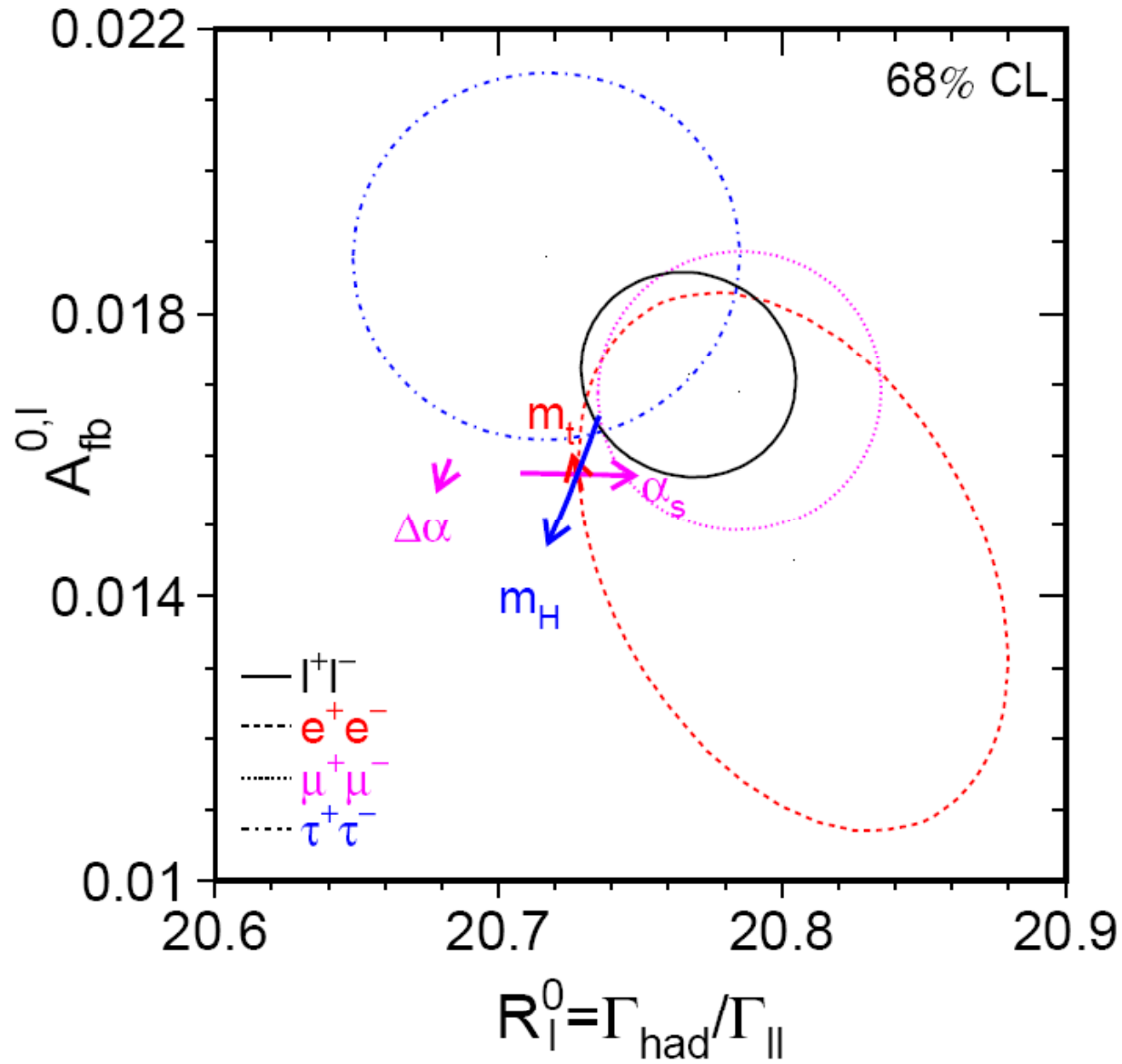
# Die Z-„Lineshape“



# Die Vorwärt-Rückwärtsasymmetrie bei Myonen

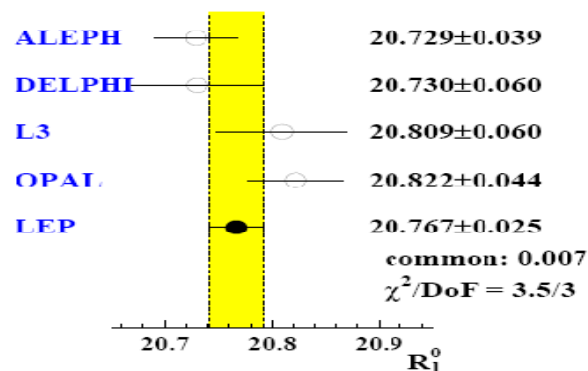
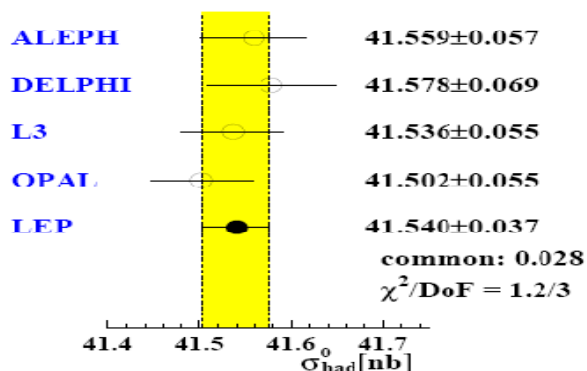
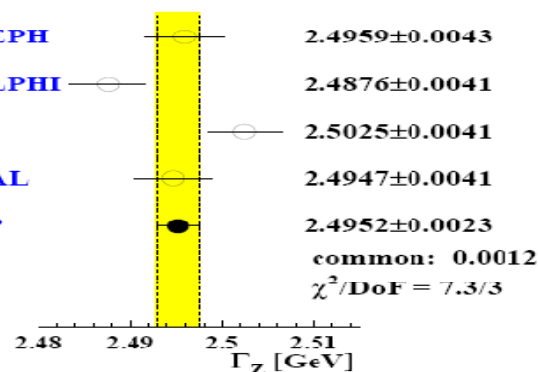
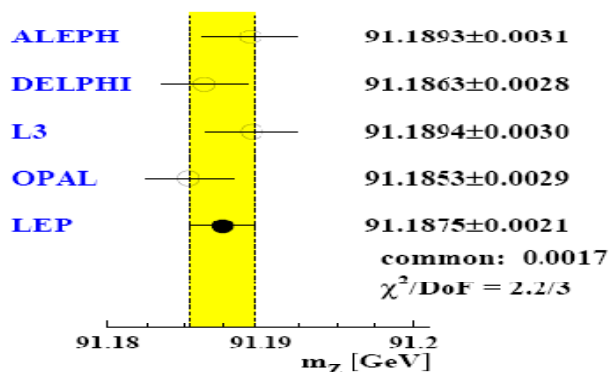


# Test der Leptonuniversalität



# Lineshape-Parameter bei LEP

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

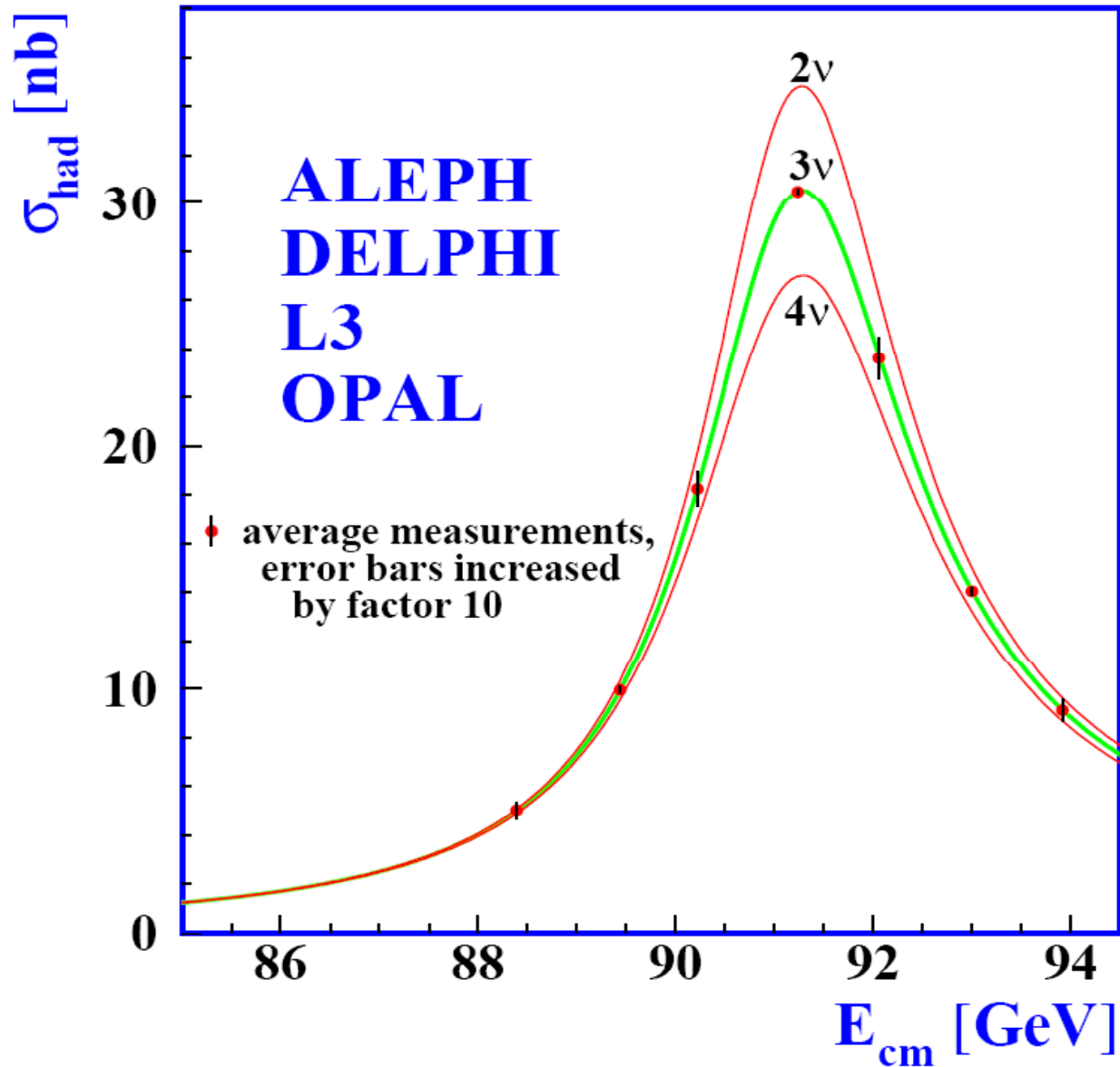


# Partialbreiten bei LEP

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

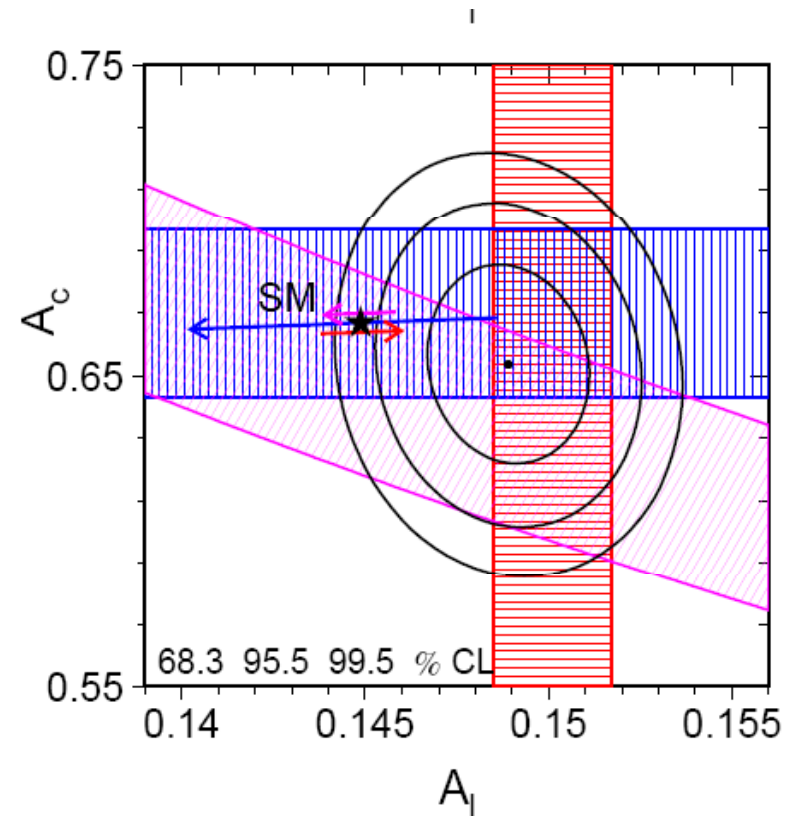
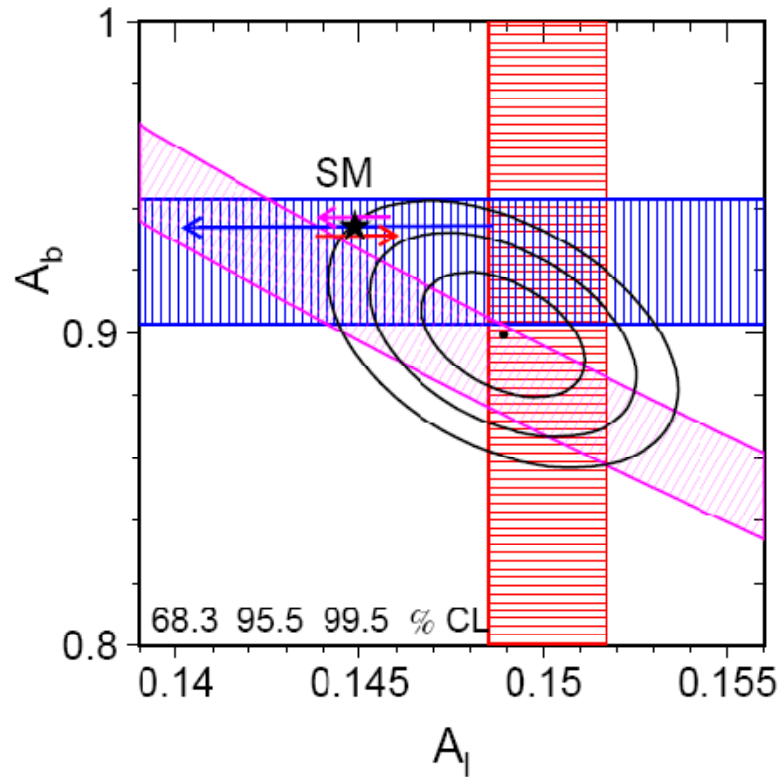


# Anzahl der leichten Neutrino-Generationen



# Bestimmung der Asymmetrieparameter $A_f$

Parameter	Average	Correlations		
		$A_\ell$	$A_b$	$A_c$
$A_\ell$	$0.1489 \pm 0.0015$	1.00		
$A_b$	$0.899 \pm 0.013$	-0.42	1.00	
$A_c$	$0.654 \pm 0.021$	-0.10	0.15	1.00



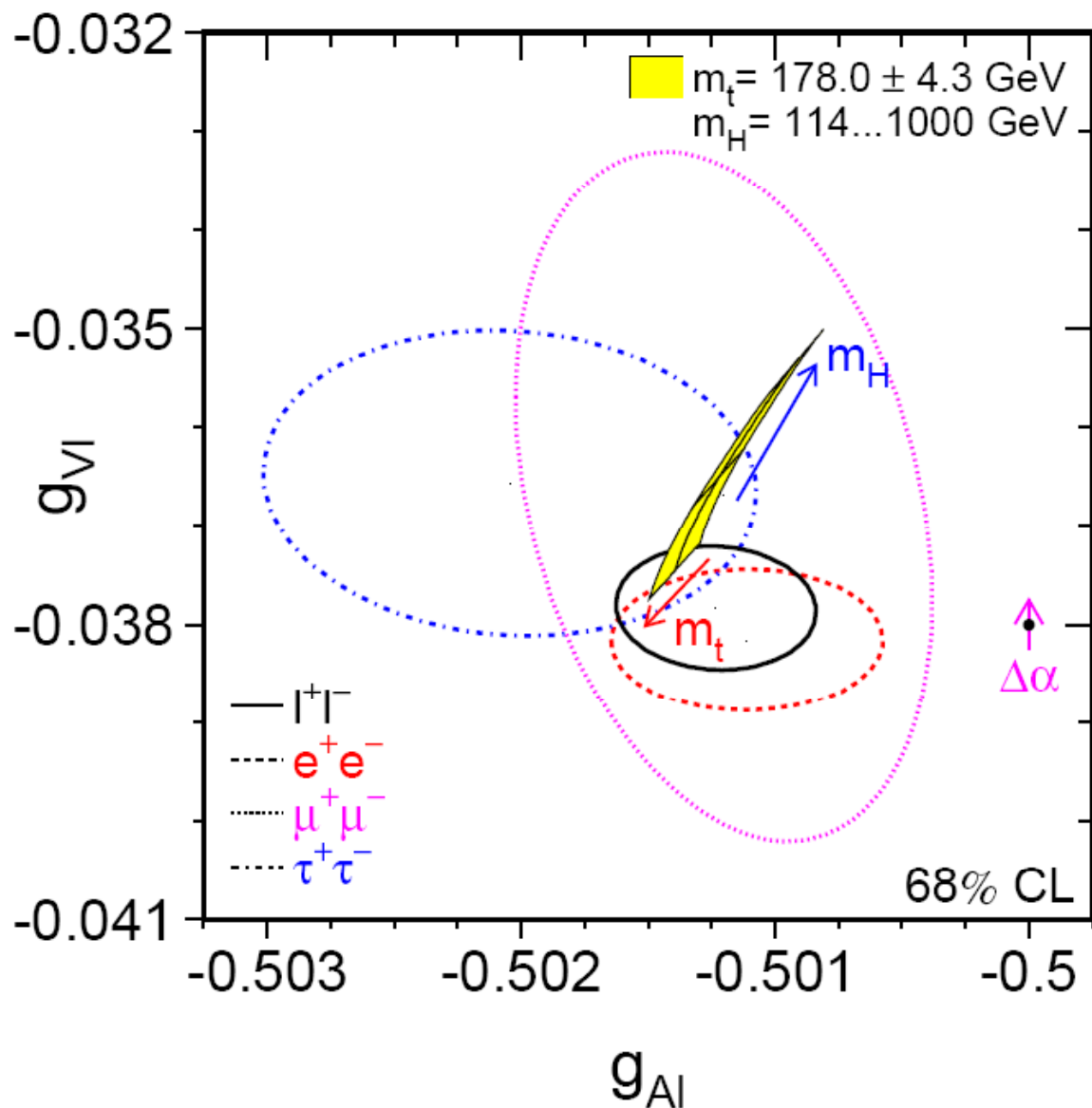
# Bestimmung der Kopplungen

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						
$g_{Ae}$	$-0.50111 \pm 0.00035$	-0.75	1.00					
$g_{A\mu}$	$-0.50120 \pm 0.00054$	0.39	-0.13	<b>1.00</b>				
$g_{A\tau}$	$-0.50204 \pm 0.00064$	0.37	-0.12	0.35	1.00			
$g_{Ve}$	$-0.03816 \pm 0.00047$	-0.10	0.01	-0.01	-0.03	1.00		
$g_{V\mu}$	$-0.0367 \pm 0.0023$	0.02	0.00	-0.30	0.01	-0.10	1.00	
$g_{V\tau}$	$-0.0366 \pm 0.0010$	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						
$g_{Le}$	$-0.26963 \pm 0.00030$	-0.52	1.00					
$g_{L\mu}$	$-0.2689 \pm 0.0011$	0.12	-0.11	<b>1.00</b>				
$g_{L\tau}$	$-0.26930 \pm 0.00058$	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	<b>0.90</b>	-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 Leptonuniversalität: Kopplungen

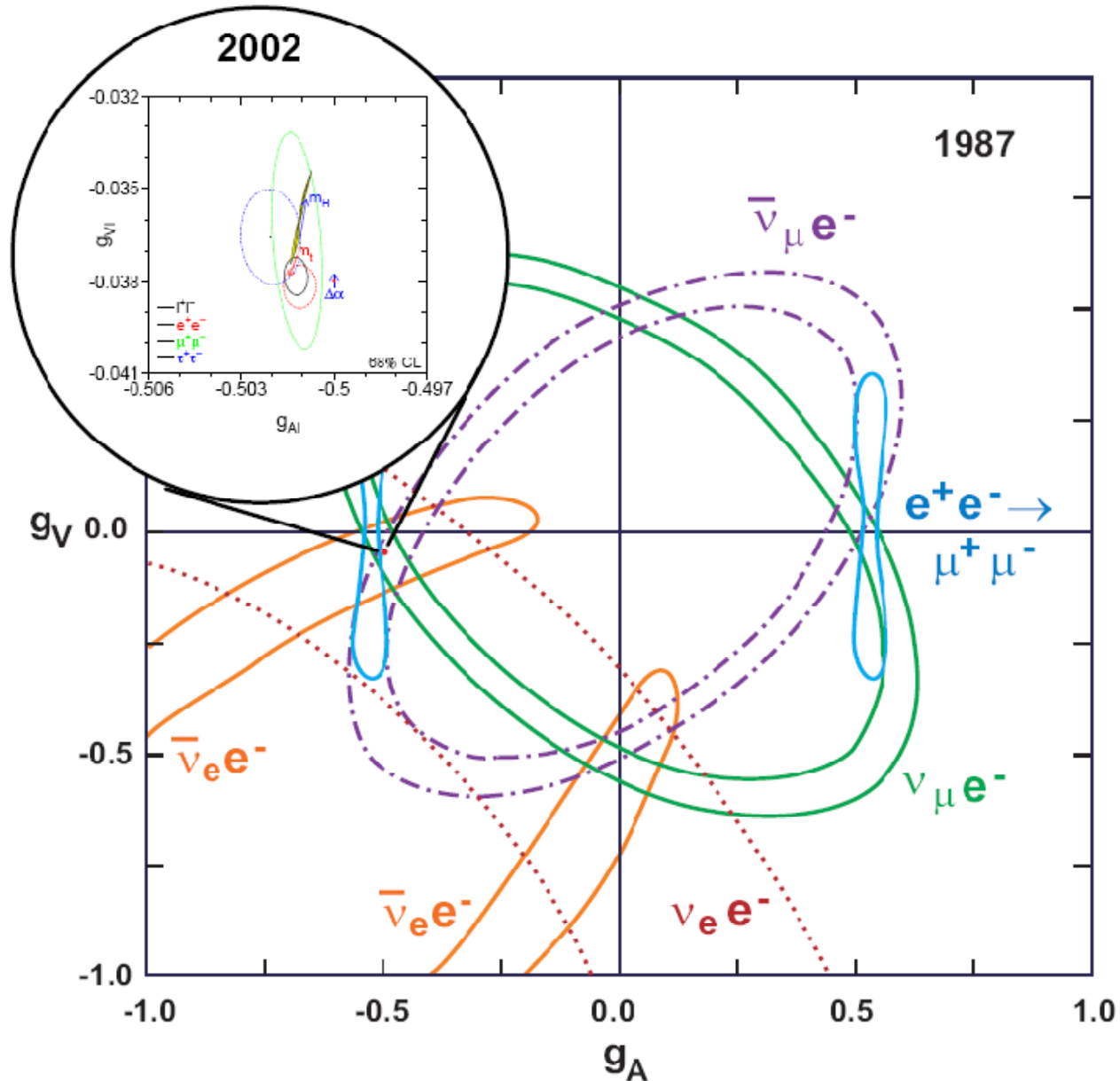


Parameter	Average	Correlations		
		$g_\nu$	$g_{A\ell}$	$g_{V\ell}$
$g_{A\nu} \equiv g_{V\nu}$	$+0.50076 \pm 0.00076$	1.00		
$g_{A\ell}$	$-0.50123 \pm 0.00026$	-0.48	1.00	
$g_{V\ell}$	$-0.03783 \pm 0.00041$	-0.03	-0.06	1.00

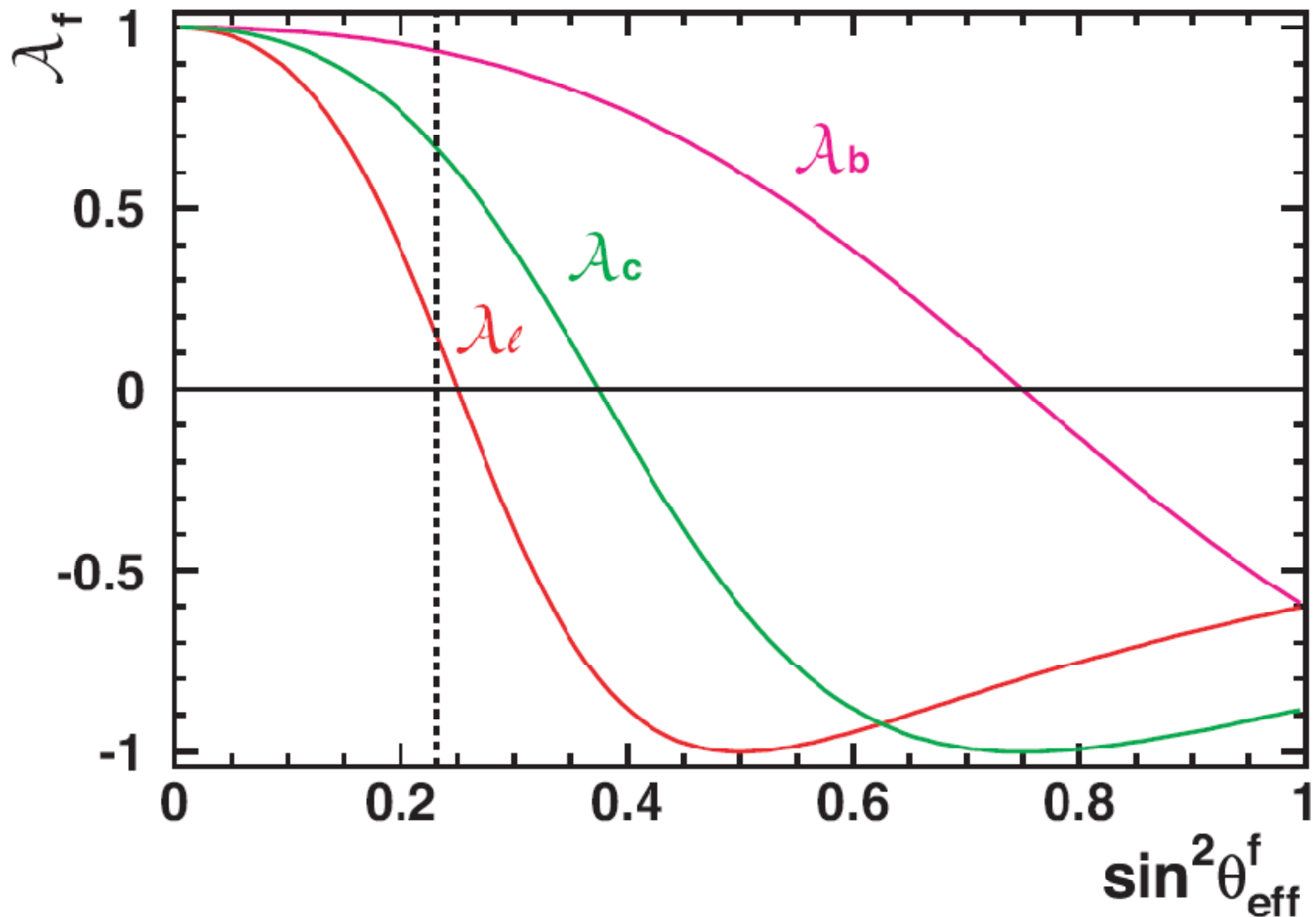
  

Parameter	Average	Correlations		
		$g_{L\nu}$	$g_{L\ell}$	$g_{R\ell}$
$g_{L\nu}$	$+0.50076 \pm 0.00076$	1.00		
$g_{L\ell}$	$-0.26953 \pm 0.00024$	-0.29	1.00	
$g_{R\ell}$	$+0.23170 \pm 0.00025$	0.22	0.43	1.00

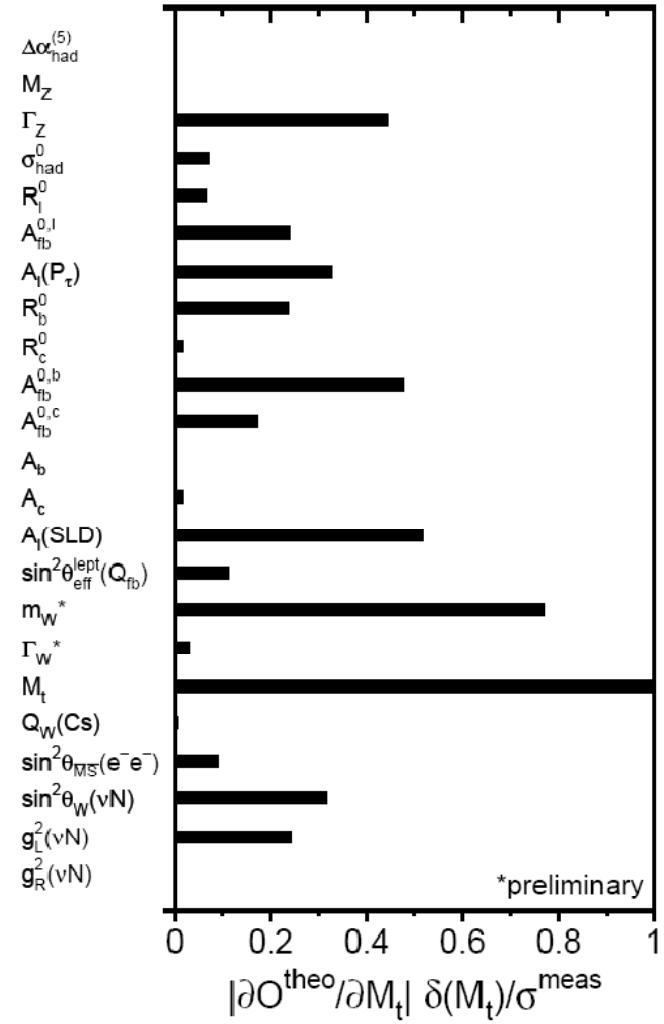
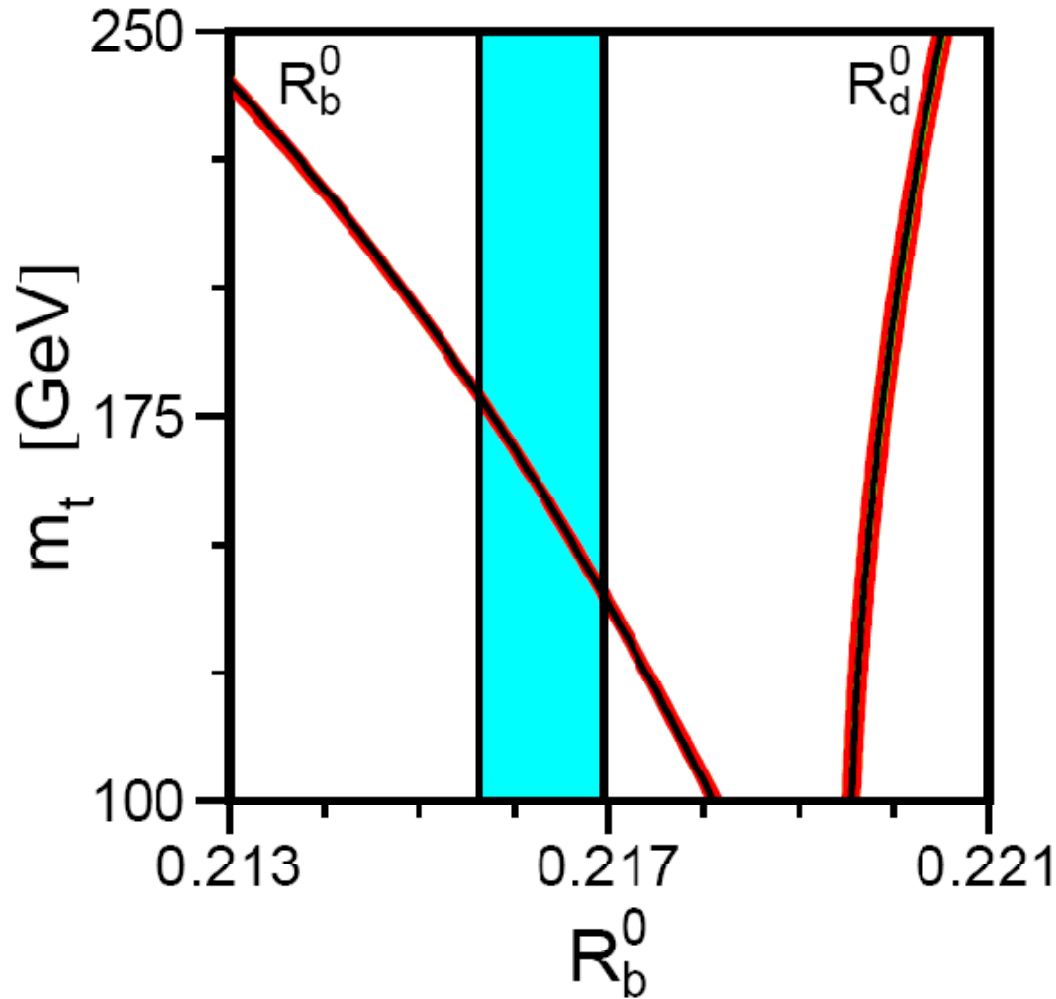
# Kopplungen: Präzision vor und nach LEP/SLD



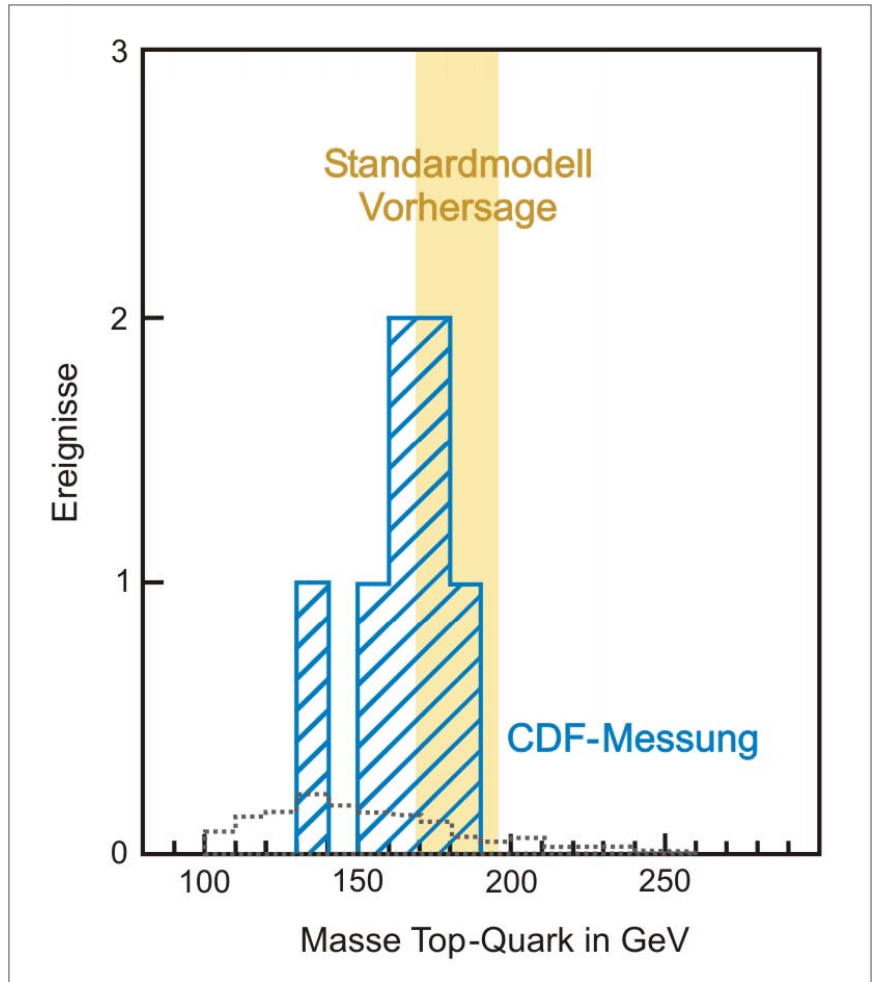
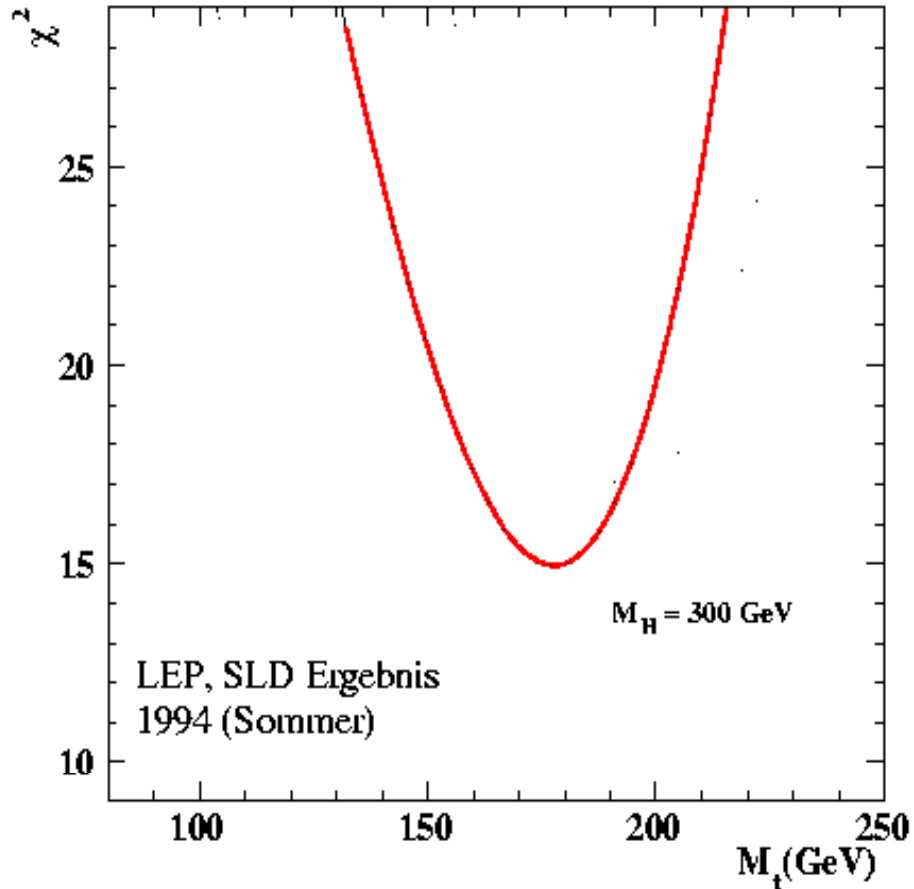
# Sensitivität auf schwachen Mischungswinkel



# Sensitivität auf die Masse des Top-Quarks



# Vorhersage und Entdeckung des Top-Quarks





# Vorhersage und Entdeckung des Top-Quarks

