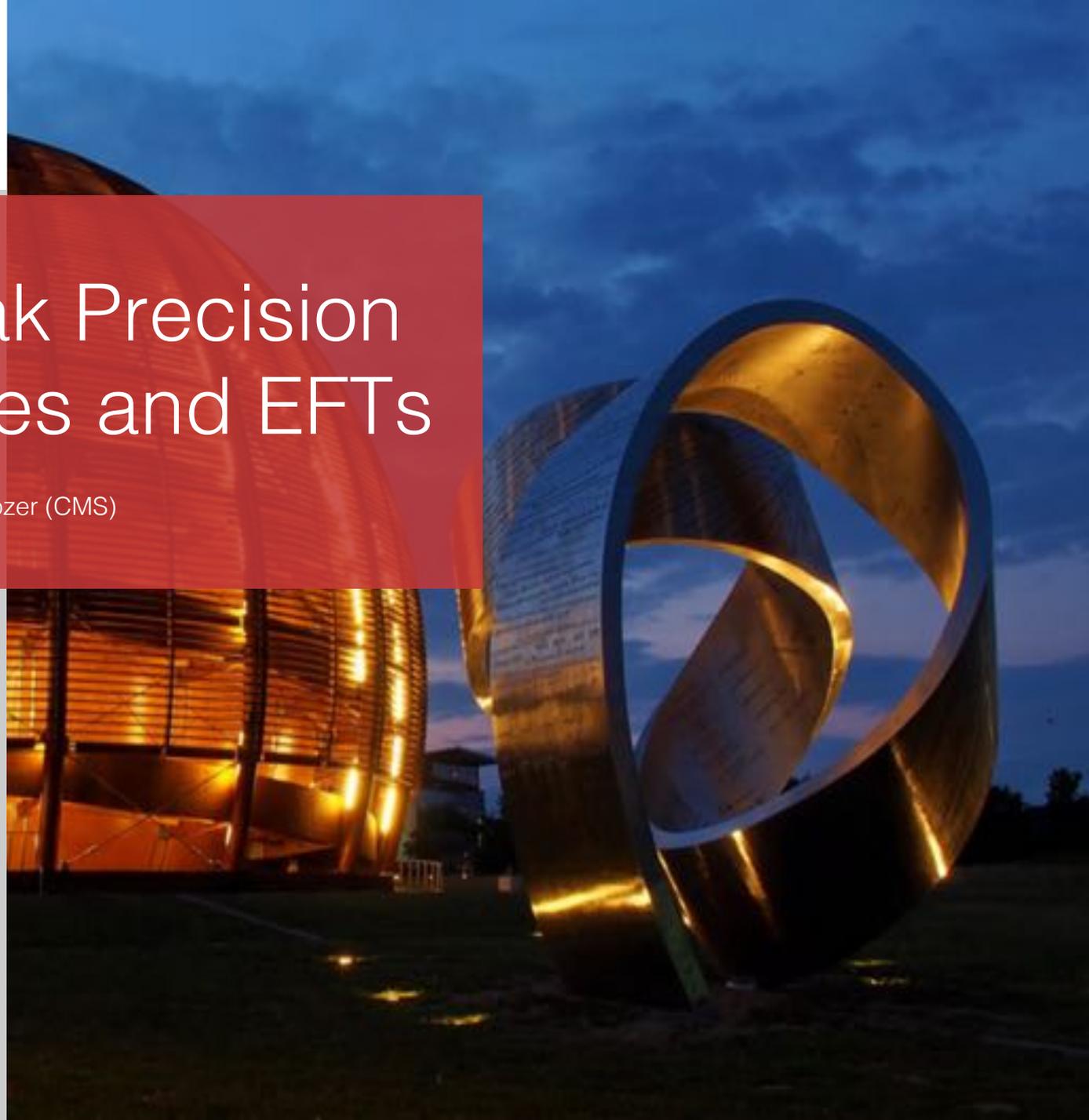




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Electroweak Precision Observables and EFTs

Matthias Schott (ATLAS)
with input and help of Matthias Mozer (CMS)





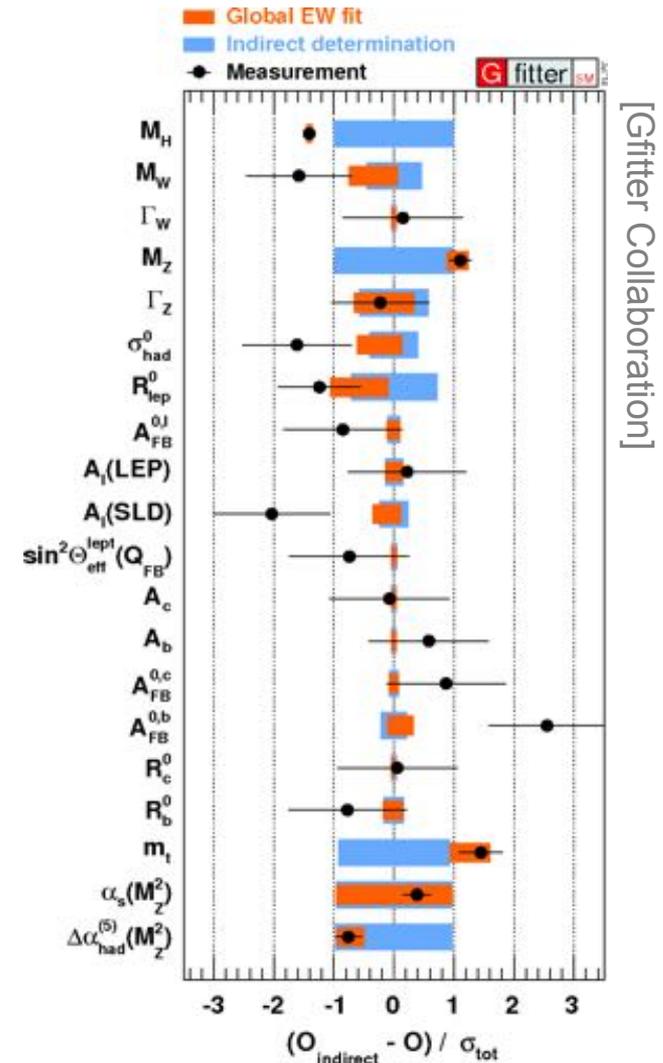
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Global Electroweak Fit

Input to the Global Electroweak Fit

- Input for the global electroweak fit mostly from
 - LEP: Z boson observables
 - Tevatron: W boson, top quark mass
 - LHC: Higgs Boson, top quark mass (see dedicated top-session)
- Note: improvement on m_H precision leaves fit unchanged
- Improvement on m_{top} will be limited by **theoretical uncertainty** on pole-mass definition
- Largest discrepancy between $A_l(\text{SLD})$ and $A_{\text{FB}}^{0,b}$, both sensitive to $\sin^2\theta_W$



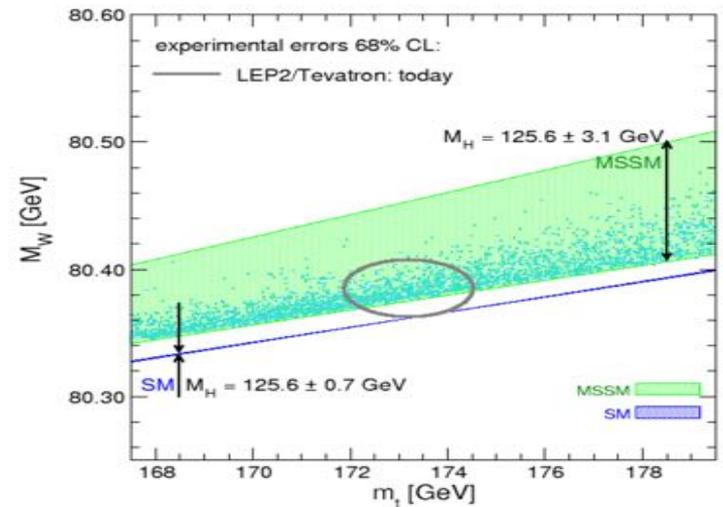
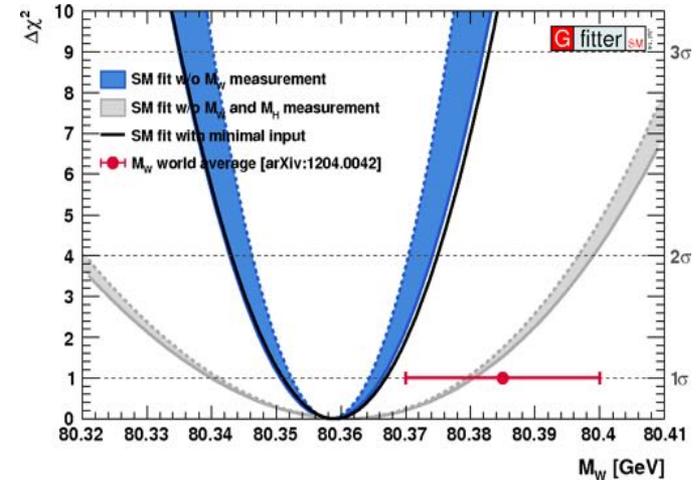
Theory Predictions

- Loop corrections to EW precision observables are known with significantly higher precision than current measurements

	Known corrections	References	Dominant missing orders	Theo. unc. due to missing orders	Exp. unc.
m_W	full loop corrections: $O(\alpha), O(\alpha_s), O(\alpha\alpha_s), O(\alpha^2)$ partial loop corrections: $O(\alpha\alpha_s^2), O(\alpha^2\alpha_s^2m_t^4)$ $O(\alpha^3m_t^6), O(\alpha\alpha_s^3m_t^2)$	[11]	$O(\alpha^2\alpha_s), O(\alpha^3)$	4 MeV	15 MeV
Γ_W	full loop corrections: $O(\alpha_s), O(\alpha), O(\alpha\alpha_s)$	[22, 38–41]	$O(\alpha\alpha_s), O(\alpha^2), O(\alpha_s^2)$		42 MeV
$\Gamma_Z,$ $\Gamma_{lf},$ $\Gamma_{q\bar{q}},$ $R_l,$ $R_c,$ $R_b,$ σ_{had}^0	full loop corrections: $O(\alpha), O(\alpha_s), O(\alpha^2)_{(ferm.loops)},$ $O(\alpha\alpha_s)$ partial corrections: $O(\alpha^2)_{(bos.loops)},$ $O(\alpha\alpha_s^3),$ $O(\alpha^2\alpha_s), O(\alpha\alpha_s^2)$	[42–46]	$O(\alpha_{bos}^2), O(\alpha^3),$ $O(\alpha^2\alpha_s), O(\alpha\alpha_s^3)$	0.5 MeV 0.012-0.014 MeV 0.09-0.21 MeV $5 \cdot 10^{-3}$ $5 \cdot 10^{-5}$ $1.5 \cdot 10^{-4}$	23 MeV $2.5 \cdot 10^{-2}$ $3 \cdot 10^{-3}$ $6.6 \cdot 10^{-4}$
$\sin^2 \theta_{eff}^l,$ $A_l,$ $A_{FB}^{0,f}$	full loops corrections: $O(\alpha), O(\alpha_s), O(\alpha\alpha_s), O(\alpha^2)$ partial loop corrections: $O(\alpha\alpha_s^2), O(\alpha^2\alpha_s^2m_t^4)$ $O(\alpha^3m_t^6), O(\alpha\alpha_s^3m_t^2)$	[13, 28, 47]	$O(\alpha^2\alpha_s), O(\alpha^3), O(\alpha\alpha_s^3)$	$4.4 - 4.7 \times 10^{-5}$ 3×10^{-5} 3×10^{-6}	$3.5 \cdot 10^{-4}$ $1.8 \cdot 10^{-3}$ $1.0 \cdot 10^{-3}$

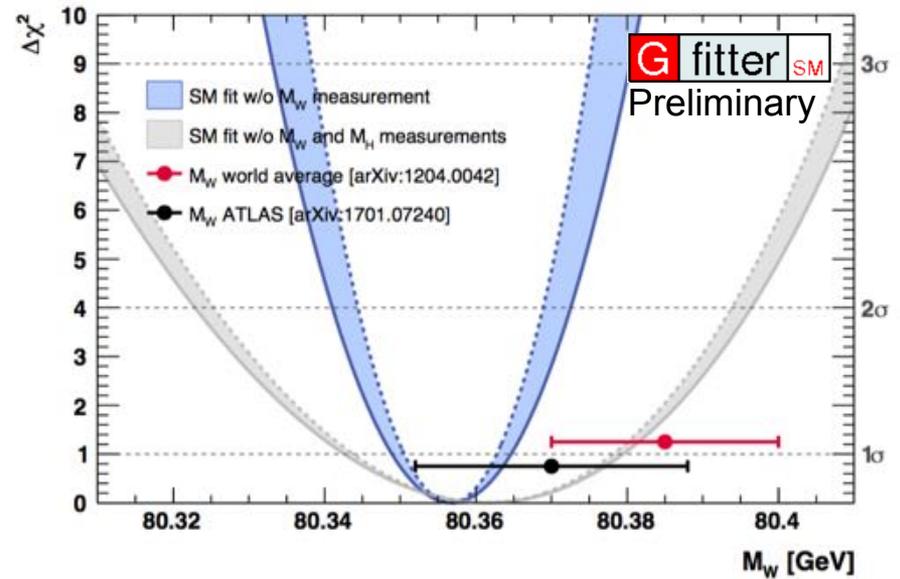
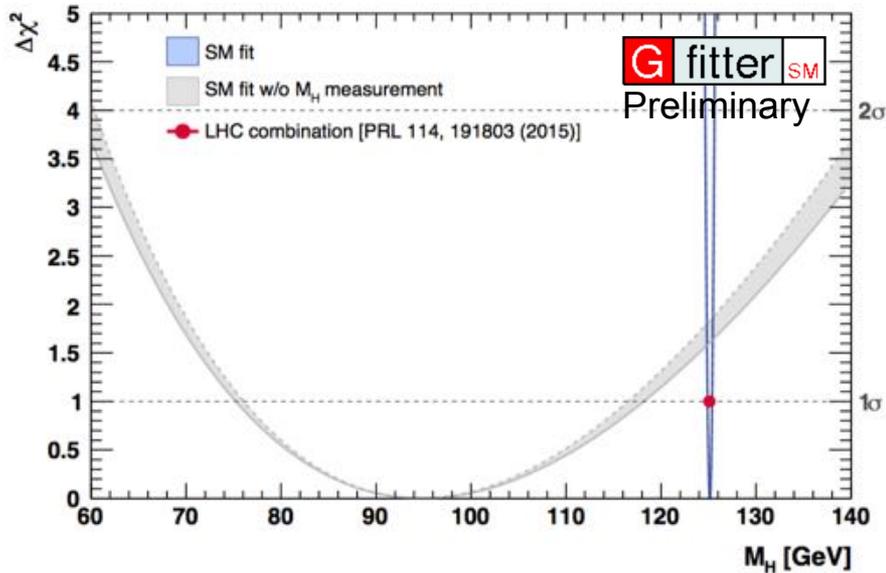
What we need: $m_W, m_{\text{top}}, \sin^2\theta_W$

- “Simple” thing: Test consistency of the Standard Model
 - Before the discovery of the Higgs-Boson: p-value = 0.22
- Electroweak precision measurements are **sensitive to several new physics scenarios**, e.g. SUSY
 - Radiative correction depends on mass splitting (Δm^2) between squarks in SU(2) doublet
 - Precision on m_W could significantly limit the allowed MSSM space



[S. Heinemeyer et. al. arXiv:1311.1663]

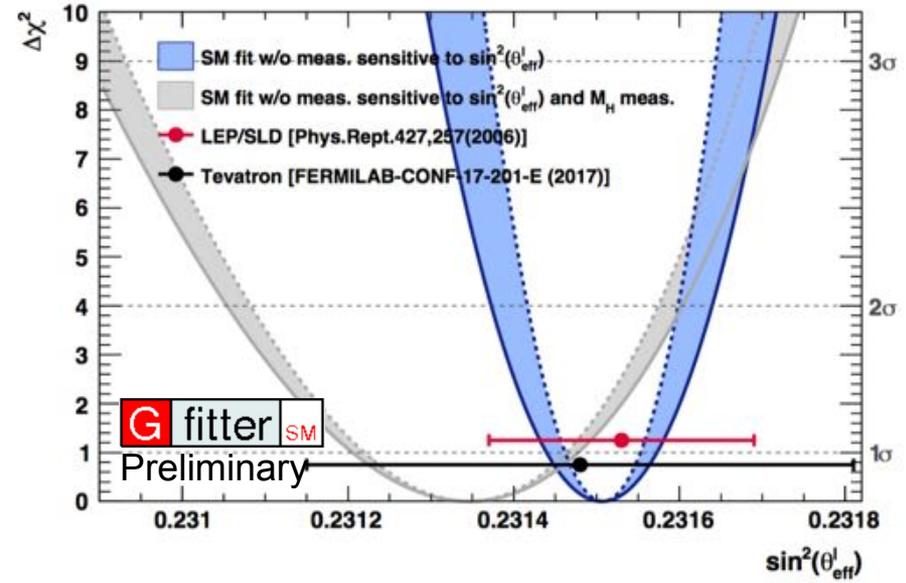
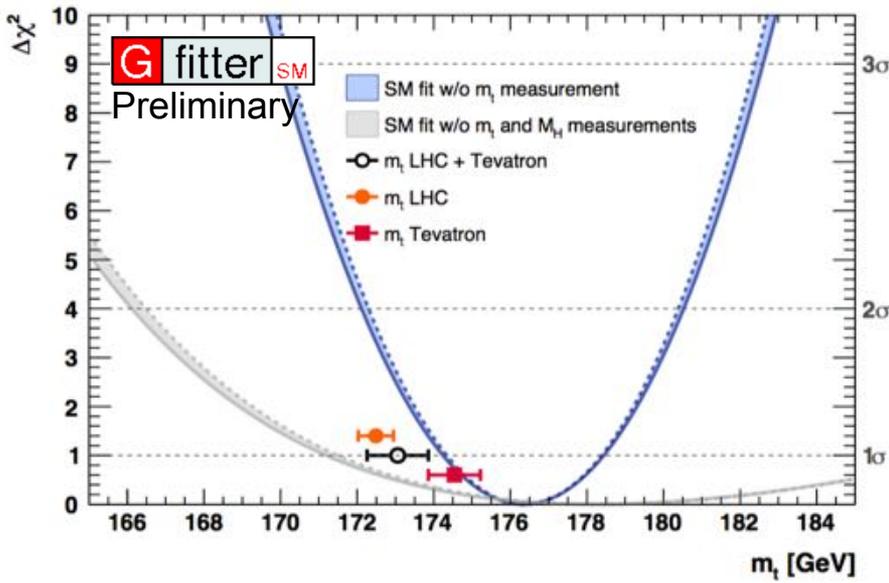
Impact on m_H and m_W Predictions



- The discovery of the Higgs boson fixed the last free SM parameter
 - Note: Precision on m_H is not crucial for the electroweak fit due to logarithmic dependency

- The SM prediction on m_W changed from 80359^{+10}_{-21} MeV to **80357 ± 8 MeV**
 - Dominant uncertainty due to uncertainty of m_{Top} : 5.5 MeV

Impact on m_{top} and $\sin^2\theta_W$ Predictions

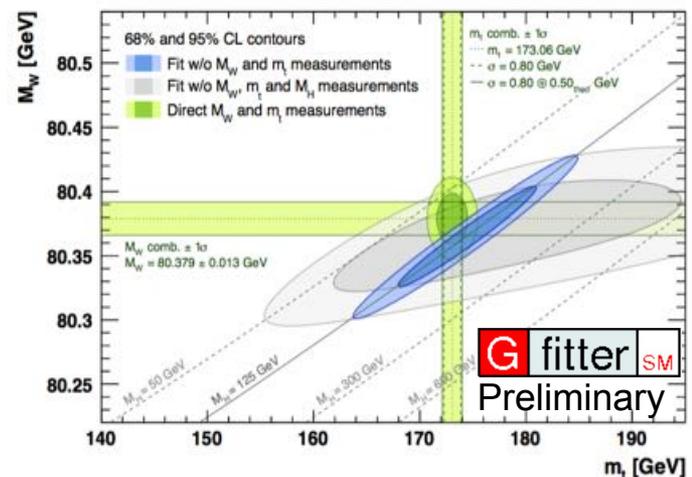
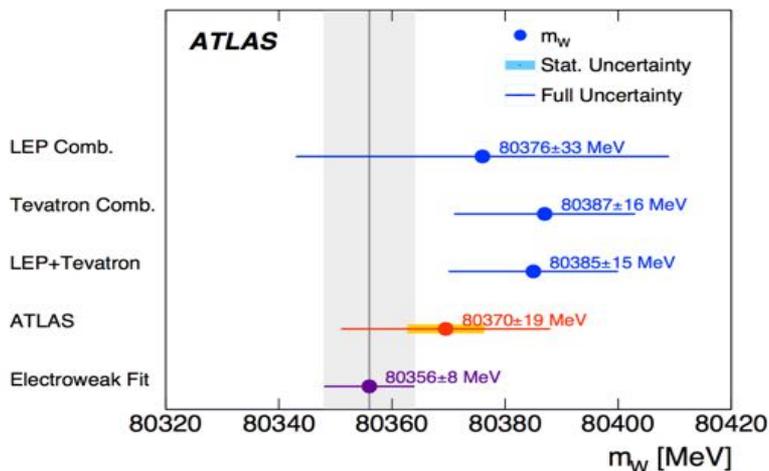
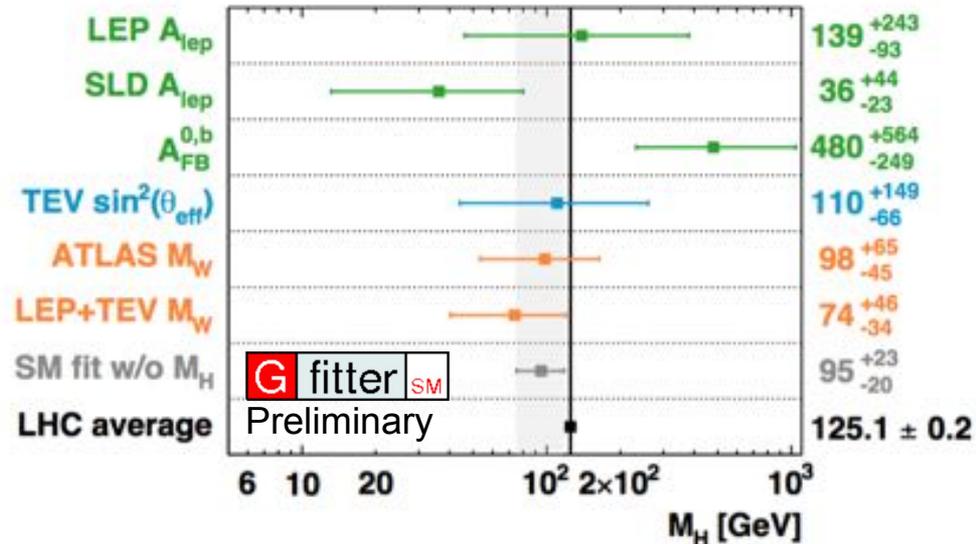


- The SM prediction on m_{Top} changed from $178.2^{+9.8}_{-4.2}$ GeV in 2008 to 176.35 ± 2.1 GeV in 2017

- The SM prediction on $\sin^2\theta_W$ changed from $0.23143 + 0.00010$ in 2008 to $0.23151 + 0.00006$ in 2017
 - Dominant uncertainty due to uncertainty of m_{Top} : 0.00003

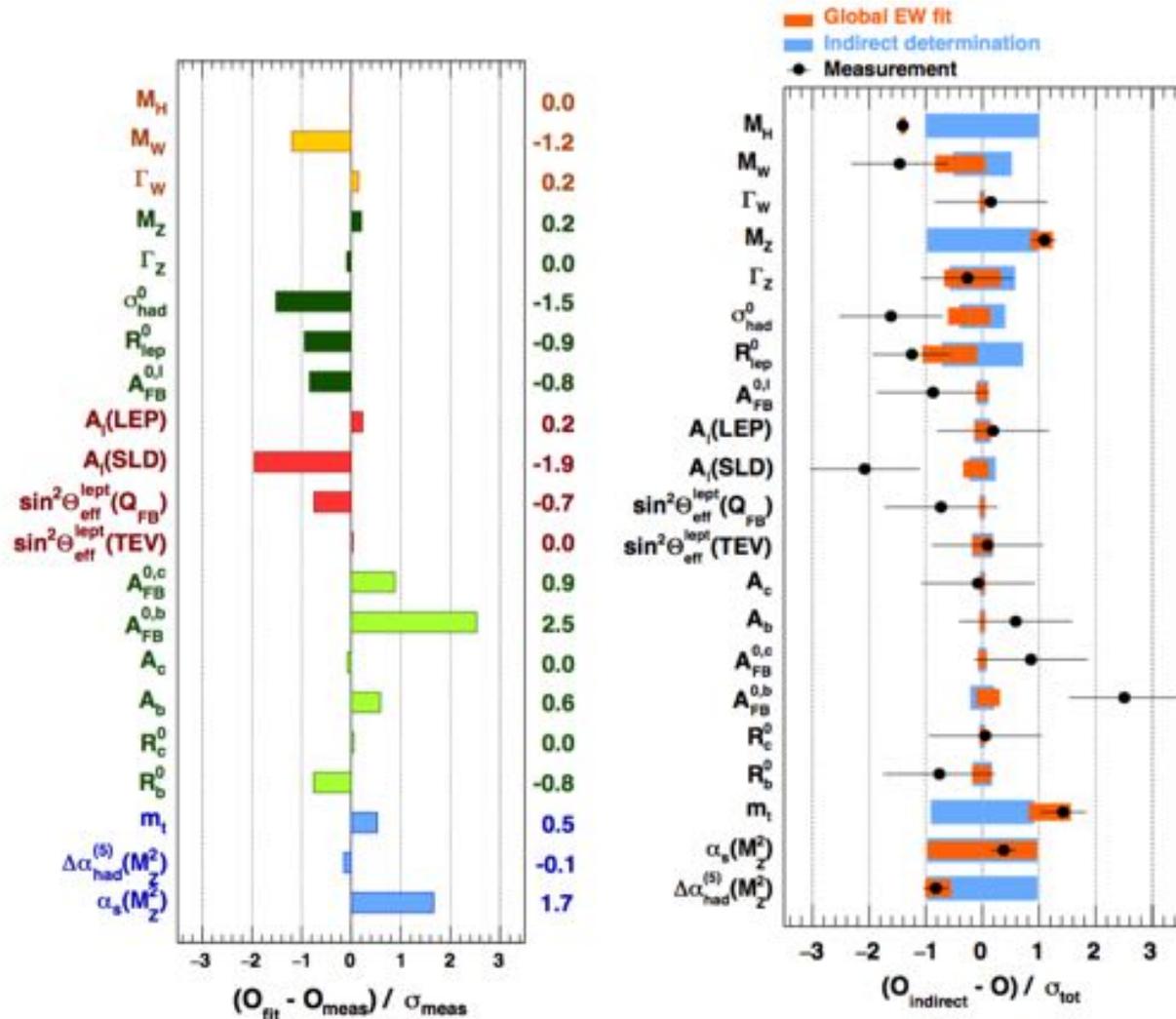
Impact of new measurements from the LHC

- New round of precision measurements moves everything more to the Standard Model
 - m_W (ATLAS) in perfect agreement with SM
 - $\sin^2\theta_W$ from Tevatron also in perfect agreement
 - Maybe LEP/SLD discrepancy just a statistical effect



Summary on the Consistency Tests of the Standard Model

- Before the discovery of the Higgs, we had an overall “consistency” of the SM of $p=0.22$
- As of 2017: χ^2 value of 17.6 for 15 degrees of freedom, corresponding to a p-value of 0.28
 - Mainly due to new m_W and m_{top} measurements

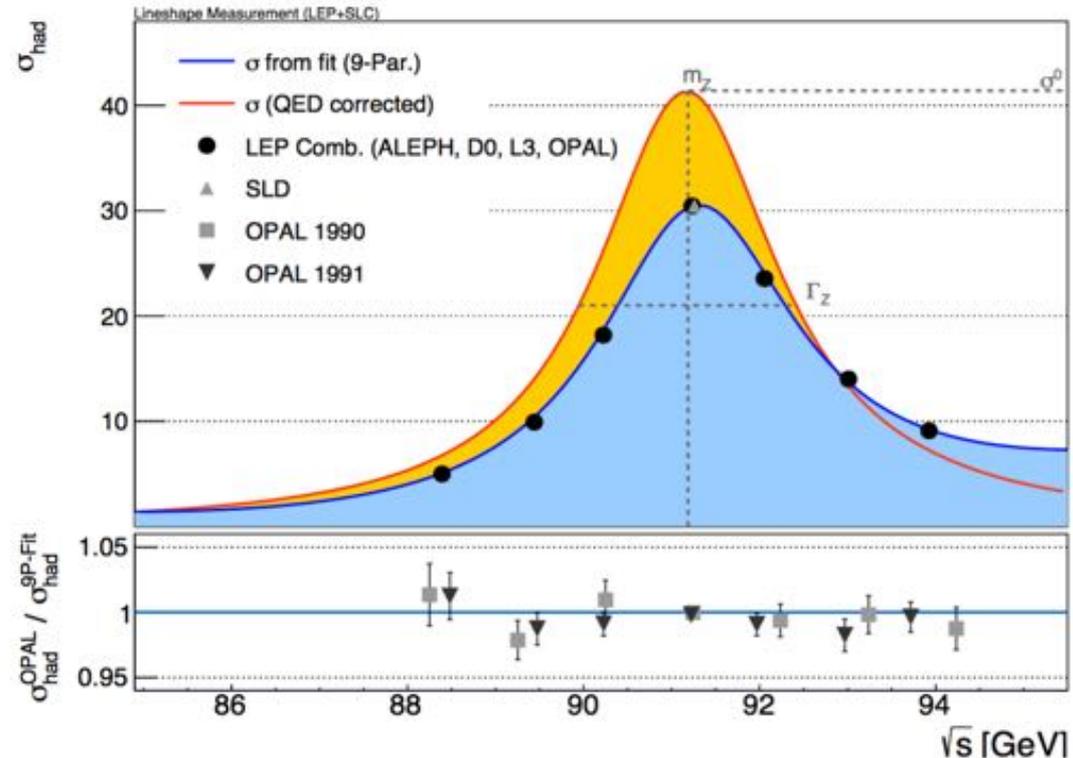




Historical Precision Measurements

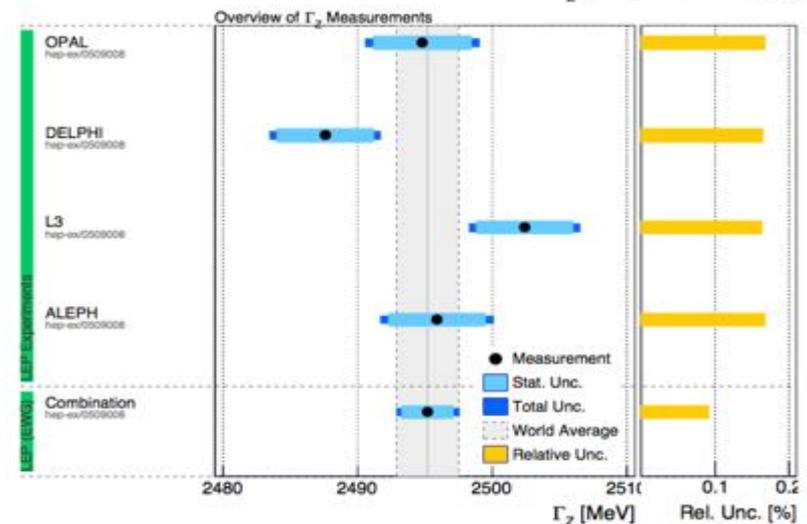
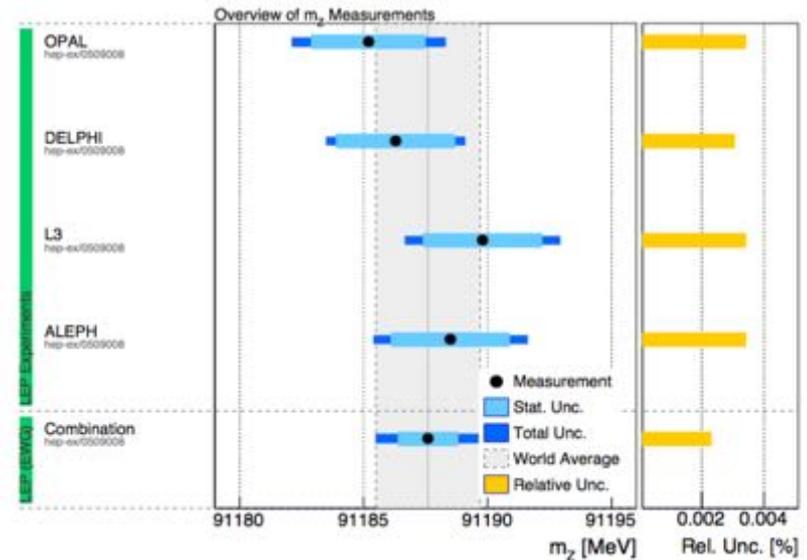
Measurements at LEP and SLD (1/3)

- All measurements related to the Z boson already more than 20 years old
- Based on a 9-parameter fit of a Breit-Wigner to the combined measurement of $\sigma(ee \rightarrow ff)$ for different \sqrt{s}
 - m_Z, Γ_Z, σ_0
 - R_e, R_μ, R_τ
 - $A_{FB}(e), A_{FB}(\mu), A_{FB}(\tau)$
- Observables that enter the electroweak fit typically assume lepton universality



Measurements at LEP and SLD (2/3)

- Individual measurements of m_Z and Γ_Z are statistically limited and compatible to each other
- Combined values have significant systematic uncertainties due to beam energy calibration and inter-calibration
- No serious measurements of the lineshape performed at SLAC



Measurements at LEP and SLD (3/3)

- Leptonic ratios measured at LEP to high precision

$$R_l^0 = \frac{\sigma_{had}^0}{\sigma_{l+l-}^0} = \frac{\Gamma_{had}}{\Gamma_{l+l-}}$$

- statistically limited (sys. cancel)
- Competative measurement of R_b and R_c at SLD
- Good compatibility to SM pred.
- Used to derive $\alpha_S(m_Z)$ in the global electroweak fit

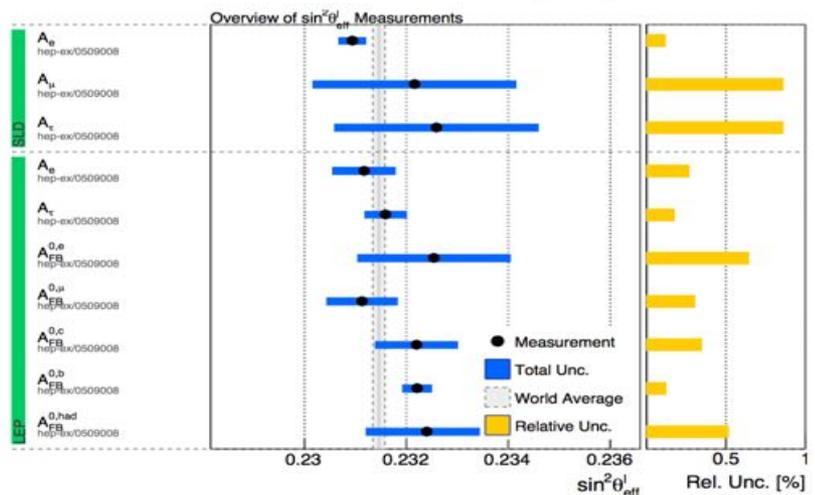
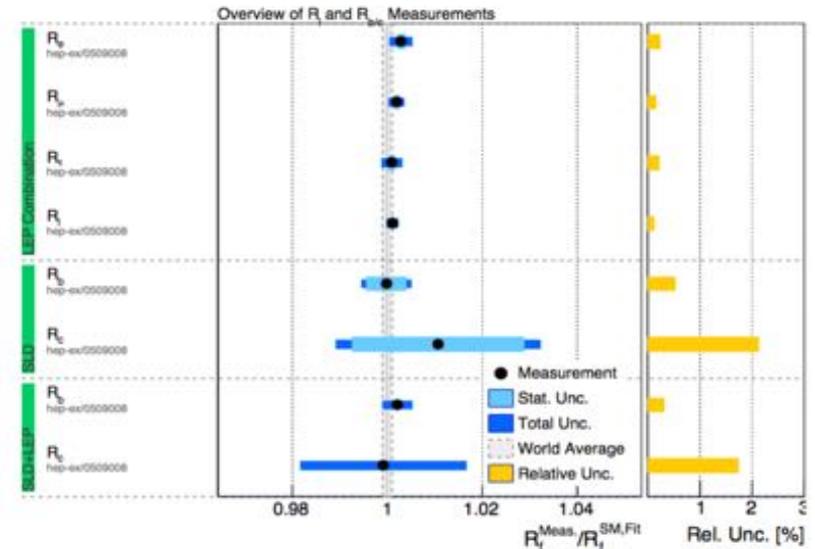
- Asymmetry (SLD) and Forward-Backward Asymmetry (LEP)

$$A_{FB} = \frac{\sigma_F - \sigma_B}{\sigma_F + \sigma_B}$$

$$A_{FB}^0 = \frac{3}{4} A_f A_{f'}$$

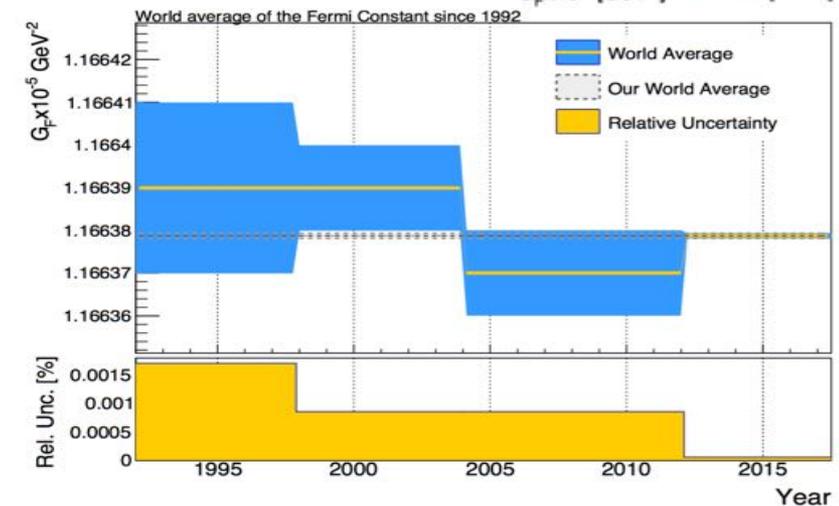
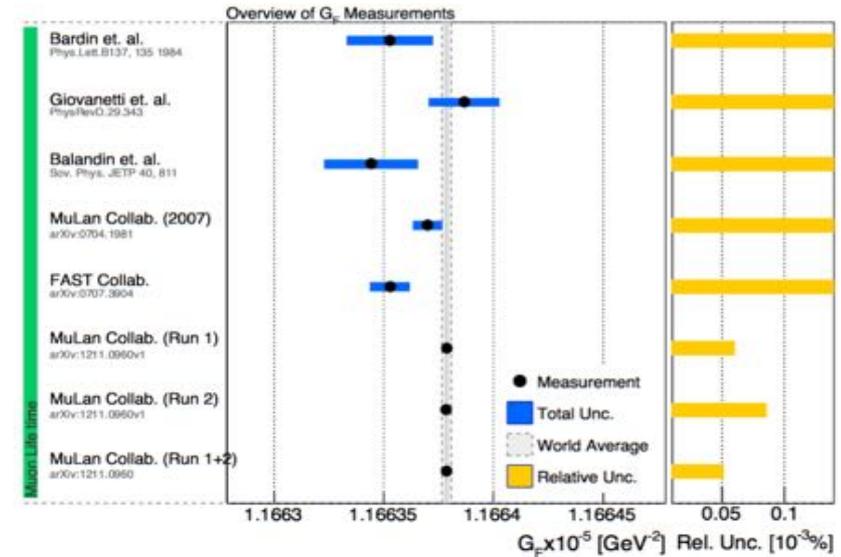
$$A_f = 2 \cdot \frac{g_v^{f'}/g_a^{f'}}{1 + (g_v^{f'}/g_a^{f'})^2} = \frac{1 - 4|Q_f| \sin^2 \theta_{eff}^f}{1 - 4|Q_f| \sin^2 \theta_{eff}^f + 8|Q_f|^2 \sin^4 \theta_{eff}^f}$$

- statistically limited (similar to R_l)



Fermi and Fine-Structure Constants

- Fine-Structure constant precisely measured via quantum Hall effect and anomalous magnetic moment of electron
 - $1/137.035999139(31)$
- Fermi-Constant
 - $G_F = 1.1663787(6) \times 10^{-5} \text{GeV}^{-2}$
 - Measurement of muon-lifetime
 - limited for long by the missing knowledge on the 2-loop QED corrections to the muon decay rate
 - Once corrections were known, experiments started to catch up
 - Basic idea for ultimate precision: dedicated pulsed beam
 - 2.7σ to result from FAST collaboration





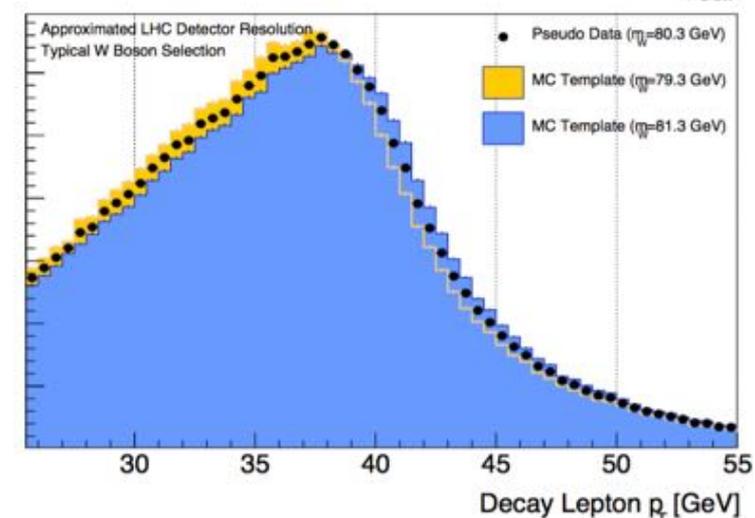
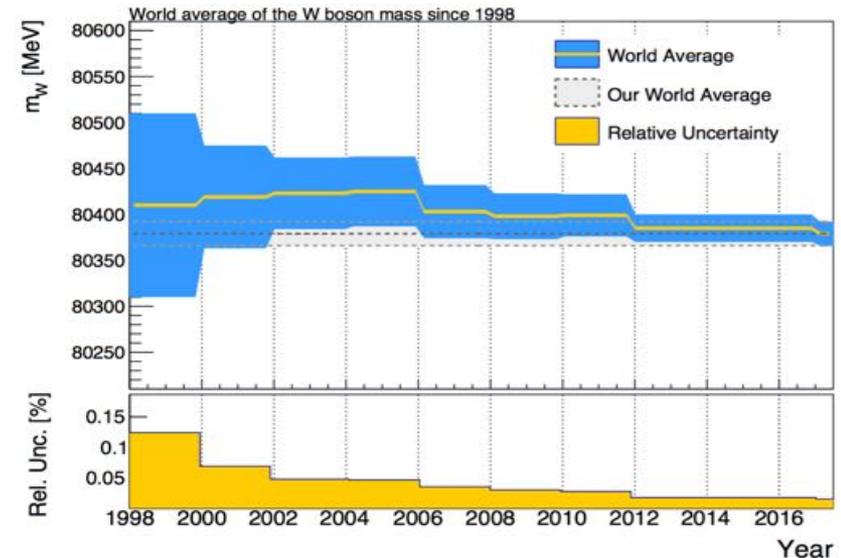
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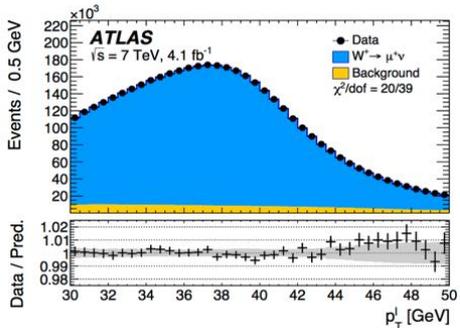
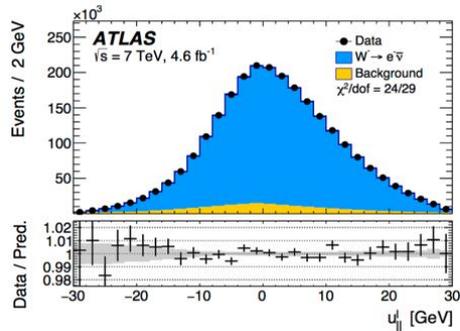
Newer Precision
Measurements

Measurement of the W Boson Mass (1/4)

- Last round of measurements of m_W already published in 2012
 - CDF+D0: $\Delta m_W = 15$ MeV
 - Latest update by ATLAS in 2016: $\Delta m_W = 19$ MeV
- Basic measurement approach: Template fit method
 - $p_T(W)$
 - Angular coefficients
 - EWK corrections
 - PDFs



Measurement of the W Boson Mass (2/4)

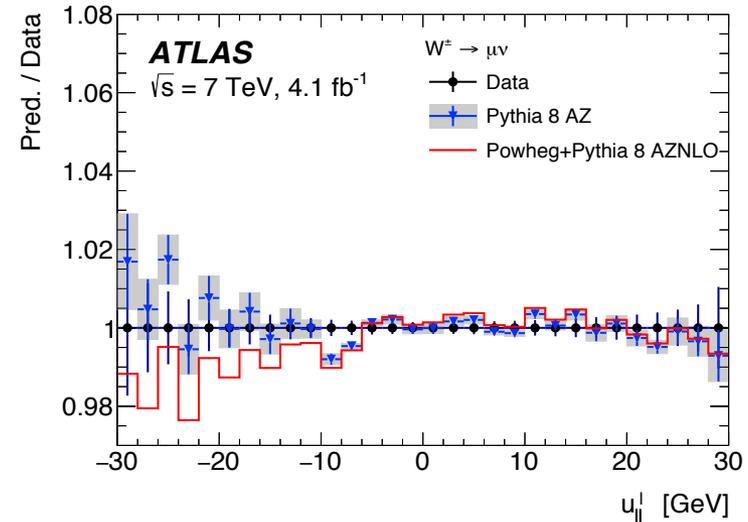
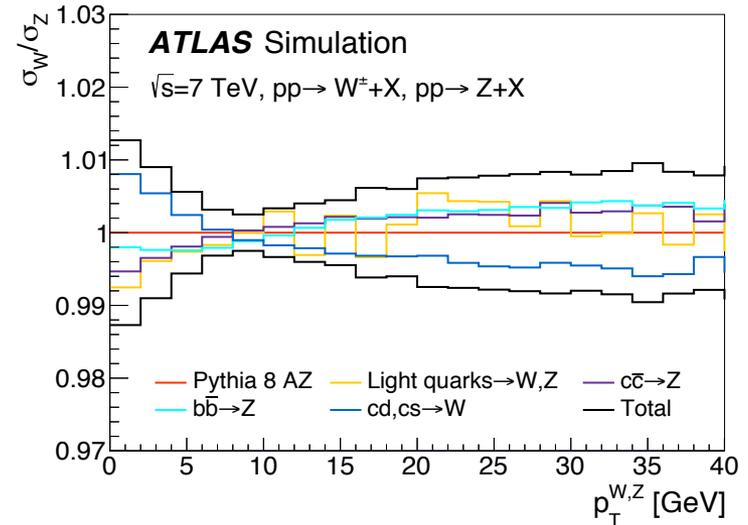


Experiment	DZero		CDF		ATLAS	
	p_T^{lep} [MeV]	m_T [MeV]	p_T^{lep} [MeV]	m_T [MeV]	p_T^{lep} [MeV]	m_T [MeV]
m_W	80367		80390	80366	80376	80370
Stat. Unc.	13	14	12	14	10	7
Sys. Unc.	18	20	12	11	20	11
Model Unc.	13	14	11	13	14	13
Total Unc.	26	28	20	22	25	19
Lepton Calib. Unc.	17	18	7	7	10	9
Had. Calib. Unc.	5	6	9	8	15	3
Other Exp. Unc.	1	2	3	3	8	5
PDF	11	11	10	9	10	8
QED Effects	7	7	4	4	3	6
$p_T(W)$ modelling	2	5	3	9	10	9
Reference	[41]		[40]		[42]	
Final Result of Collaboration	80375 ± 23		80387 ± 19		80370 ± 19	
(Stat., Exp. Sys., Model Unc.)	80375 ± 11 ± 15 ± 13		80387 ± 12 ± 10 ± 12		80370 ± 7 ± 11 ± 14	

- Most sensitive measurement from the m_T distributions at Tevatron, but from the p_T distribution at ATLAS (pile-up!)
 - Much larger dependence on $p_T(W)$ modelling for ATLAS
- Largest uncertainties due to PDFs but different origin
 - acceptance effects for Tevatron, but polarization effects at LHC

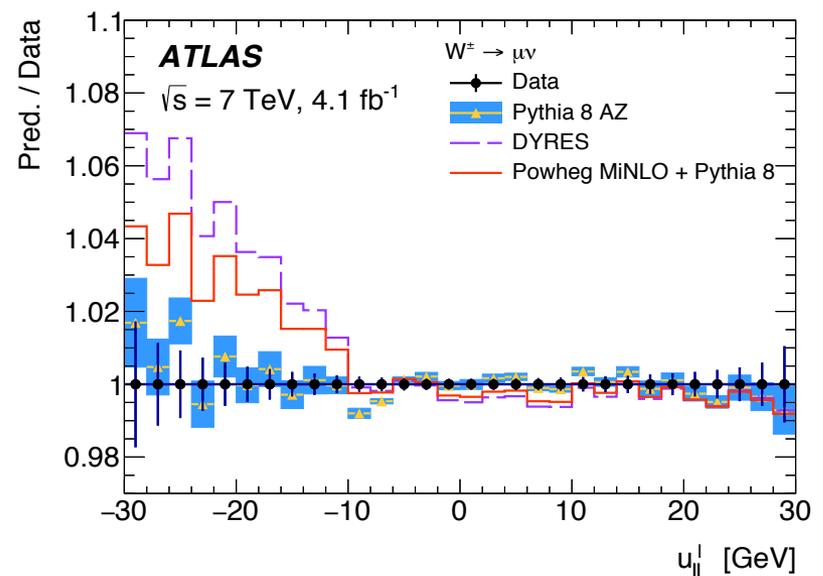
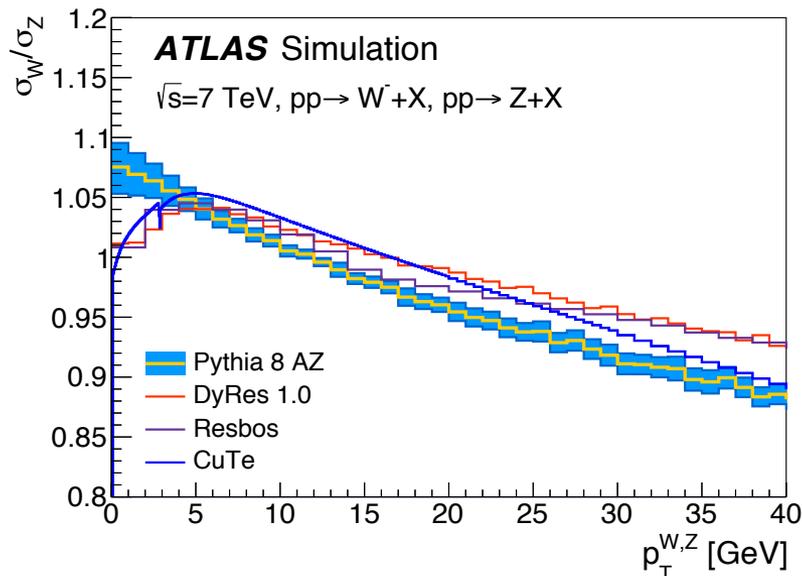
Measurement of the W Boson Mass (3/4) – $p_T(W)$

- Uncertainties from exp. $p_T(Z)$ unc. and theory unc. on the W/Z p_T ratio
- Heavy-flavour-initiated (HFI) production introduce decorrelation
 - $bb/cc \rightarrow Z$ accounts for 3-6%
 - $cs \rightarrow W$ is $\sim 20\%$ of W production
 - HFI addressed with
 - charm mass variations
 - decorrelating the PS between light and HFI processes
- Central prediction and uncertainty validated with the recoil distribution
 - end up with compatible central value and similar uncertainties compared to “model approach”



Measurement of the W Boson Mass (4/4) – $p_T(W)$

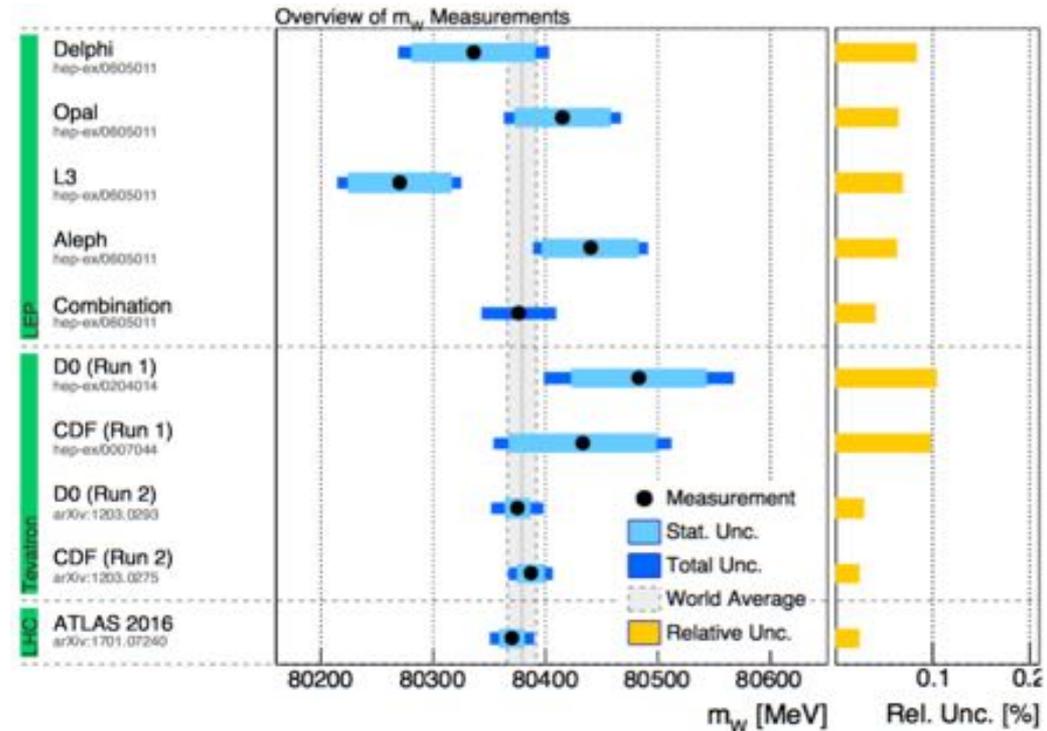
- Theoretically more advanced calculations were also attempted
 - DYRES (and other resummation codes : ResBos, CuTe)
 - Powheg MiNLO + Pythia8
- All predict a **harder $p_T(W)$ spectrum for given $p_T(Z)$ distribution**
 - Behaviour is **disfavoured by data** (comparison of $u_{||}$ distribution)



Overview of W Boson Mass Measurements

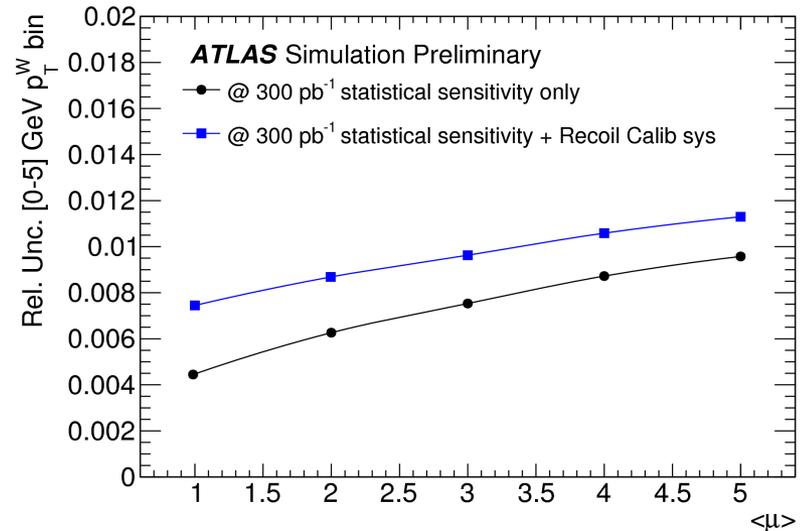
- No official combination of ATLAS and Tevatron results
- Preliminary (and unofficial) combination
 - Assuming that experimental uncertainties are fully uncorrelated
 - Assuming that model uncertainties (8 MeV for Tevatron, 14 MeV for ATLAS) are 50% correlated ($p_T(W)$ small correlation, PDFs some correlation)
 - “New World Average” as input for the fits:

$$m_W = 80379 \pm 13 \text{ MeV}$$



Future W Boson Mass Measurements at the LHC

- Low pile-up run at 5/13 TeV allows for precise $p_T(W)$ measurement
 - Low pile-up leads to improves resolution of ETMiss, i.e. one might even get m_W measurement based on the transverse mass
- Advertise the LPPC Working Group Meetings as a joint effort of theorists and all LHC experiments
 - Dedicated subgroup on EW Precision observables
 - Dedicated subgroups on SMEFT



Electroweak precision measurements at the LHC WG

To subscribe to the WG mailing list, go to [this page](#).
WG public [twiki page](#).

Tasks:

- gauge boson production cross sections and distributions
- associated production of gauge bosons and jets
- TGC's
- MW
- AFB and extraction of $\sin^2\theta_W$
- ...

The WG will address:

- the study of the systematics, experimental and theoretical, relative to the above measurements
- the definition of measurements and tools (MC generators, theory calculations, detector simulation, special running conditions, ...) required to address the above systematics and carry out the programme

The WG will also discuss the issues related to the comparison and combination of the results from the various experiments and, when relevant, the combination with LEP and Tevatron results.

<https://lpcc.web.cern.ch>

LHC WORKING GROUPS

Dark Matter WG
WG Meetings
WG documents

Electroweak WG
WG Documents
WG Meetings

Forward Physics WG
WG TWIKI PAGE
WG documents
WG meetings

Heavy Flavour WG
WG Documents
WG Meetings

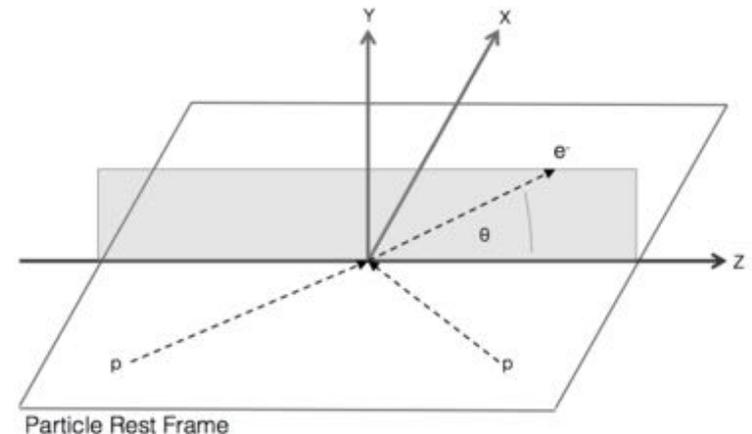
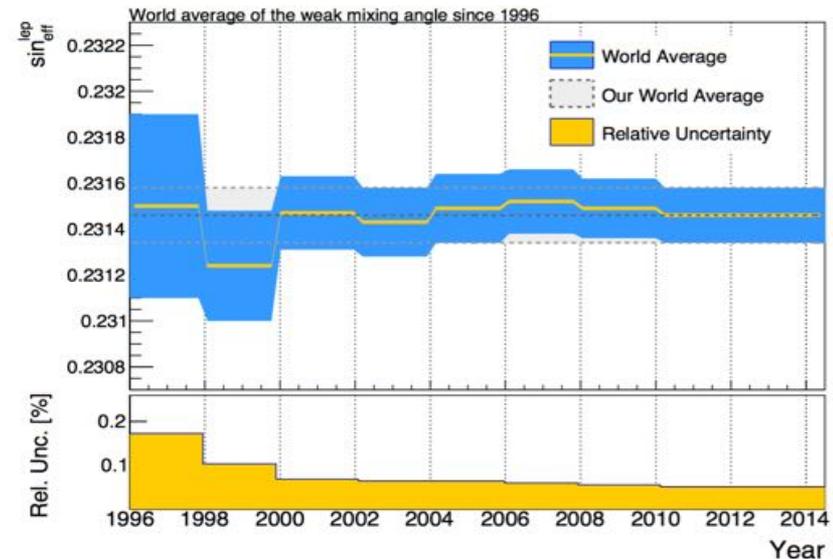
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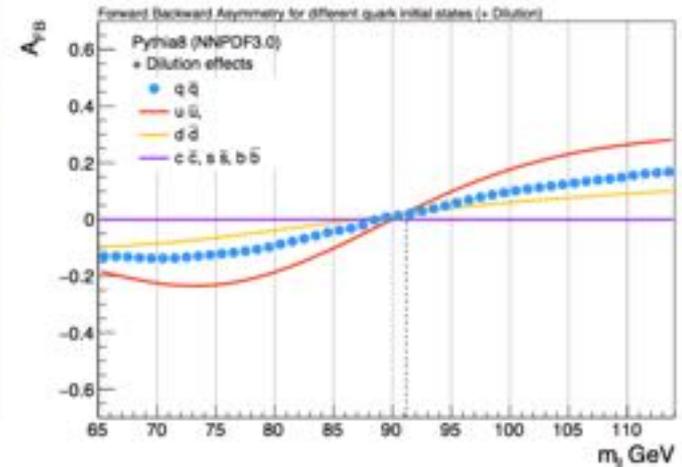
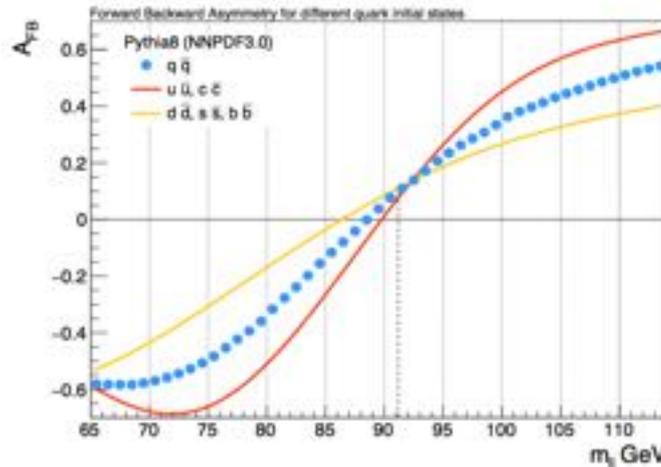
Measurement of the Electroweak Mixing Angle (1/5)

- Discrepancy of LEP and SLD measurement on $\sin^2\theta_W$ triggered quite some interest in recent years
- Problem at Hadron colliders: Do not know incoming fermion direction on an event-by-event basis
 - Problem reduced at Tevatron, very prominent at LHC
 - Significant $p_T(Z)$ due to ISR
 - Need reference frame to define forward- and background angle θ
 - Collins Soper frame
- Use (variation) of template fit approach to extract $\sin^2\theta_W$



Measurement of the Electroweak Mixing Angle (2/5)

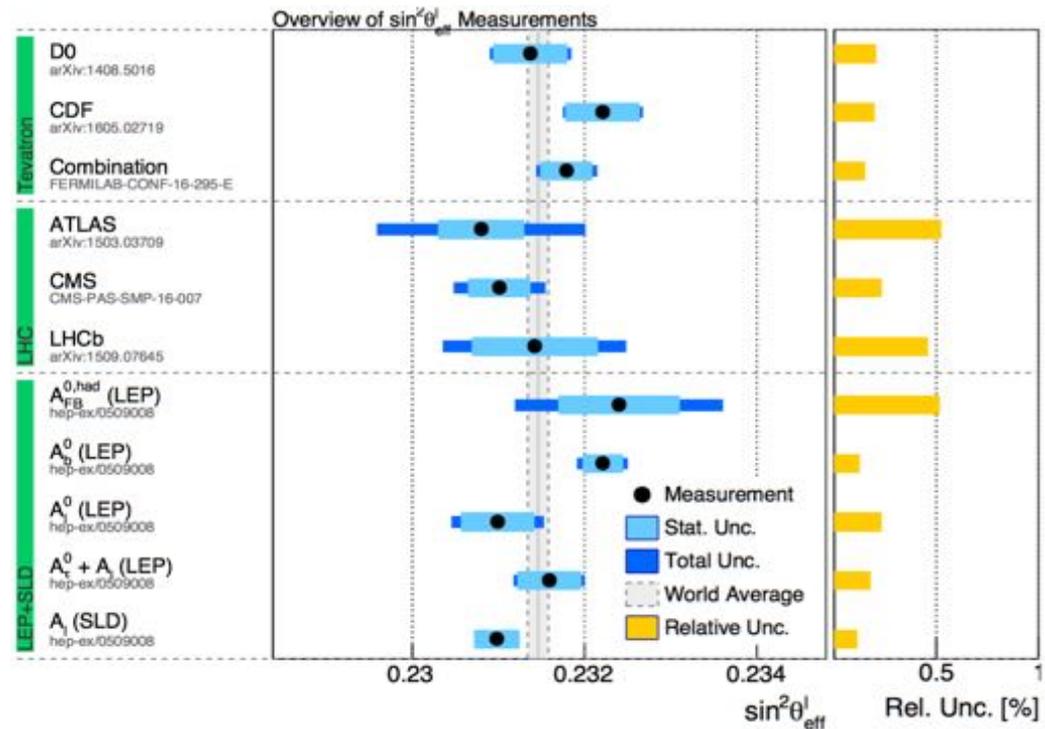
- Forward backward asymmetry also induced by Z/ γ interference
- Need to integrate over all initial state quarks
- Knowledge on PDFs is essential!
- Tevatron stat. limited
- LHC limited by PDFs



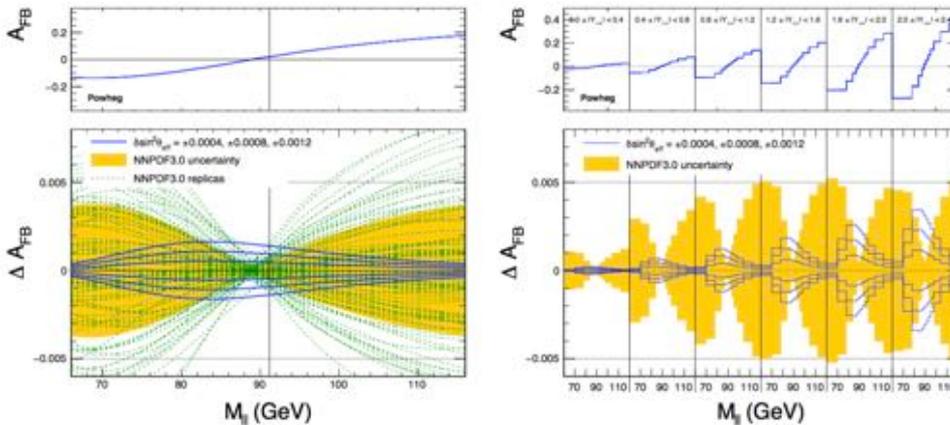
$\sin^2 \theta_{eff}^{lep}$	Value	Stat. Unc.	Exp. Unc.	PDF Unc.	Model Unc.	Total Unc.
D0	0.23137	0.00043	0.00004	0.00017	0.00008	0.00047
CDF	0.23221	0.00043	0.00003	0.00016	0.00006	0.00046
Tevatron (Comb.)	0.23179	0.00030	0.00003	0.00017	0.00006	0.00035
ATLAS	0.23080	0.00050	0.00060	0.00090	0.00020	0.00121
CMS	0.23101	0.00036	0.00018	0.00030	0.00016	0.00053
LHCb	0.23142	0.00073	0.00052	0.00043*	0.00036*	0.00106
$A_{FB}^{0,had}$ (LEP)	0.23240	0.00070	0.00100	-	-	0.00120
A_t^0 (LEP)	0.23099	0.00042*	0.00032*	-	-	0.00053
$A_\tau + A_e$ (LEP)	0.23159	0.00037*	0.00018*	-	-	0.00041
$A_{FB}^{0,b}$ (LEP)	0.23221	0.00023*	0.00017*	-	-	0.00029
A_t (SLD)	0.23098	0.00026*	0.00000*	-	-	0.00026

Measurement of the Electroweak Mixing Angle (3/5)

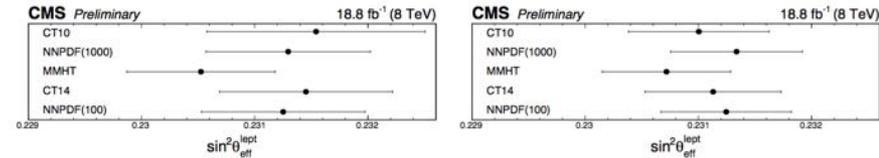
- Latest (and last) Tevatron results [1605.02719, 1408.5016] already close to individual LEP measurements
 - between SLD and A_{FB}^{0b}
- Can LHC improve?
 - Most recent CMS measurement CMS-PAS-SMP-16-007 reaches a precision of 0.00030 for PDF systematics



Measurement of the Electroweak Mixing Angle (4/5)



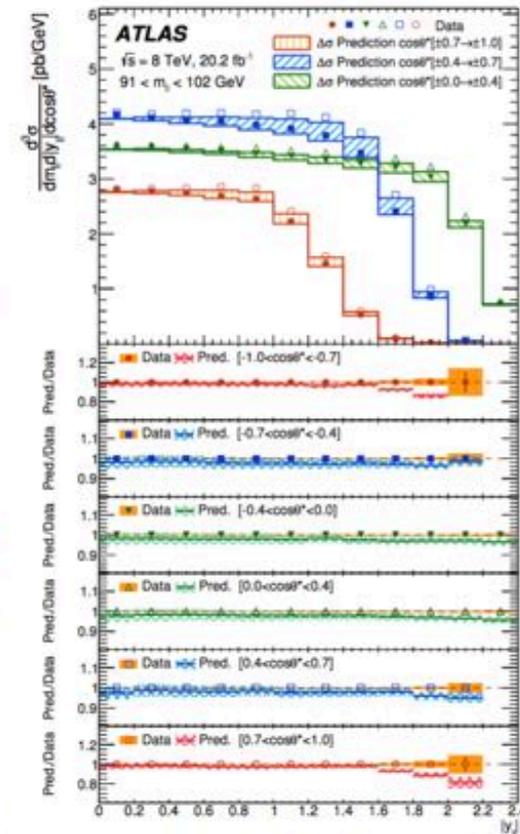
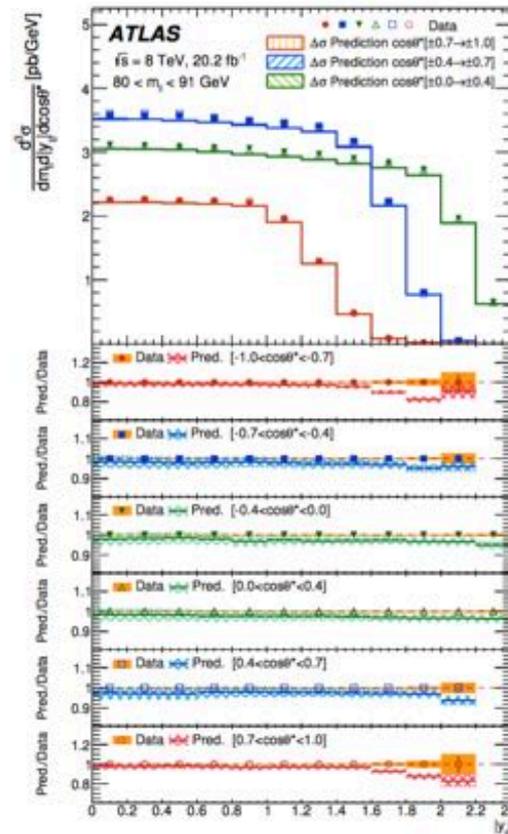
Channel	without constraining PDFs	with constraining PDFs
Muon	0.23125 ± 0.00054	0.23125 ± 0.00032
Electron	0.23054 ± 0.00064	0.23056 ± 0.00045
Combined	0.23102 ± 0.00057	0.23101 ± 0.00030



- $\sin^2\theta_{\text{eff}}$ via χ^2 -minimizing between data and MC A_{FB} distributions
 - templates by POWHEG (NLO in α_s , NNPDF3.0); Pythia8 for additional PS
- Reweighting technique, where PDF variations that describe distributions of A_{FB} better receive a larger weight
 - reduction of PDF unc. by 50%.
- Carefully handle EWK corrections to $\sin^2\theta_{\text{eff}}$ definition used in generators
 - Enhanced Born Approximation

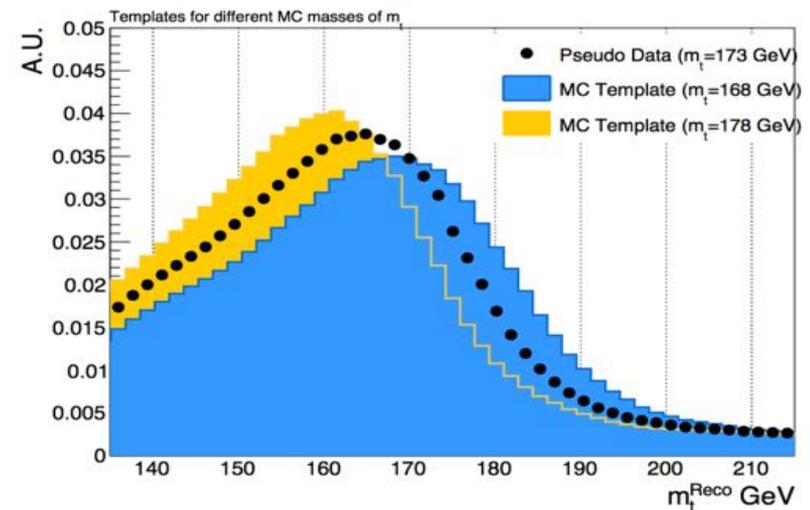
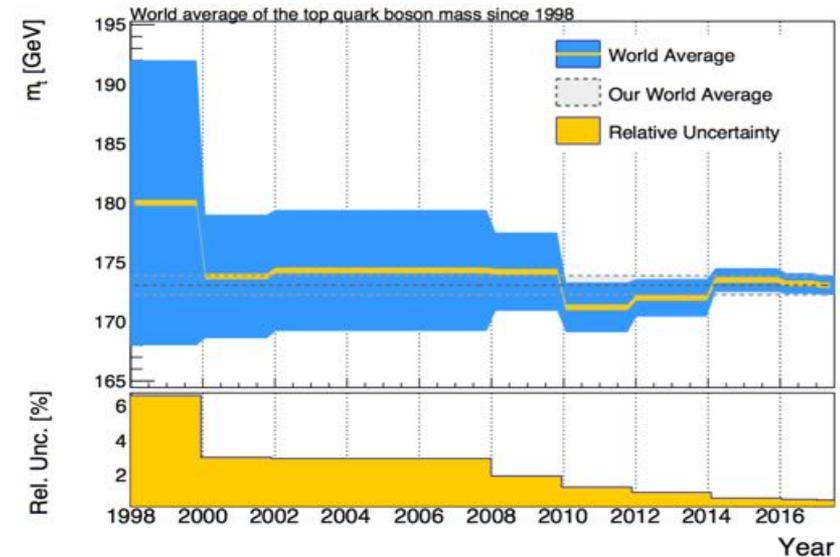
Measurement of the Electroweak Mixing Angle (5/5)

- PDF Uncertainties have been thought for long to be the limiting factor to be dominating at the LHC
 - CMS has proven that they can be drastically improved
 - ATLAS has the potential to use forward electrons, i.e. reduce the dilution effect
- New triple-differential measurement of Z/γ^*
 - $m_{||}$, $|y_{||}|$, $\cos\theta^*$ in the Collins–Soper frame
 - Can be used to simultaneously fit PDFs and the electroweak mixing angle
 - LEP precision in reach!

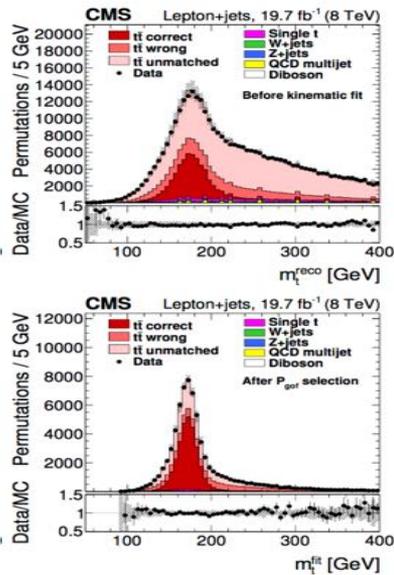


Measurement of the Top Quark Mass (1/3)

- Several approaches to measure the kinematic top-quark mass (template-method, matrix-element method, ideogram method, ...)
- World average dominated until 2011 by Tevatron, then LHC started to play crucial role
- Important: EW-fit needs pole mass of top-quark as input, but measured m_{top} at Tevatron and LHC is a MC parameter
 - Assume additional uncertainty of 500 MeV (not known if this is conservative)



Measurement of the Top Quark Mass (2/3)

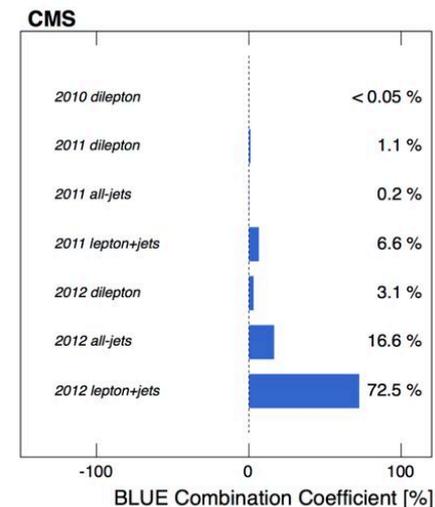
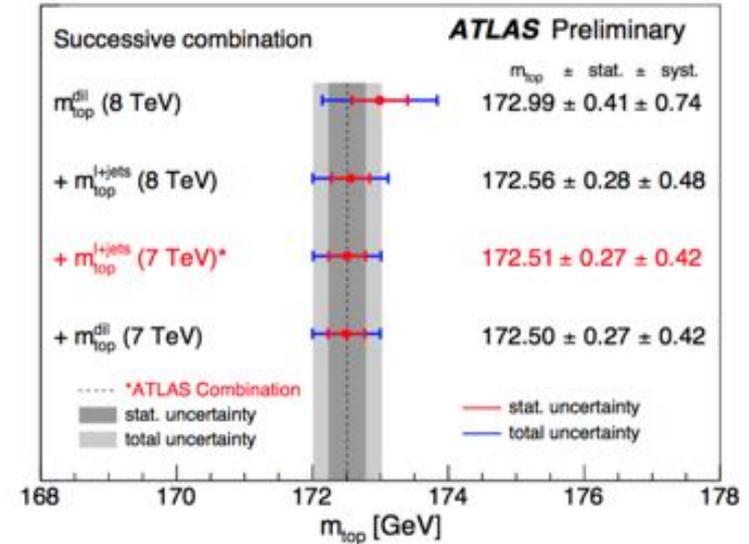


Experiment	Channel	Method	Value [GeV]	Stat. Unc. [GeV]	Sys. Unc. [GeV]	Total Unc. [GeV]	Jet Unc. [GeV]	Exp. Unc. [GeV]	Model Unc. [GeV]	UE + Color [GeV]	Had. Unc. [GeV]
CDF	l+jets	Template	172.85	0.71	0.85	1.11	0.55	0.60	0.1	0.22	0.57
CDF	ν +jets	Template	173.93	1.64	0.87	1.86	0.48	0.56	0.32	0.33	0.36
Dzero	l+jets	M.E.	174.98	0.58	0.49	0.76	0.29	0.32	0.19	0.12	0.26
CMS	l+jets	AMWM	172.82	0.19	1.22	1.23	0.34	0.81	0.84	0.11	0.79
CMS	l+jets	Ideogram	172.35	0.16	0.48	0.51	0.12	0.43	0.15	0.08	0.33
ATLAS	l+jets	Template	172.33	0.75	1.03	1.27	0.64	0.62	0.48	0.19	0.18
Dzero	semi-lep.	Matrix	173.93	1.61	0.88	1.83	0.67	0.42	0.36	0.15	0.31
ATLAS	semi-lep.	Template	172.99	0.41	0.74	0.85	0.62	0.30	0.25	0.11	0.22
CDF	full.had.	Template	175.07	1.19	1.55	1.95	1.12	0.98	0.28	0.32	0.29
ATLAS	full.had.	Template	173.72	0.55	1.01	1.15	0.69	0.68	0.2	0.2	0.64
CMS	full.had.	Ideogram	172.32	0.25	0.59	0.64	0.28	0.41	0.24	0.21	0.3

- Most precise measurements performed in the lepton+jets channel
 - Significant differences in assigned model uncertainties of different experiments; maybe some space for unification

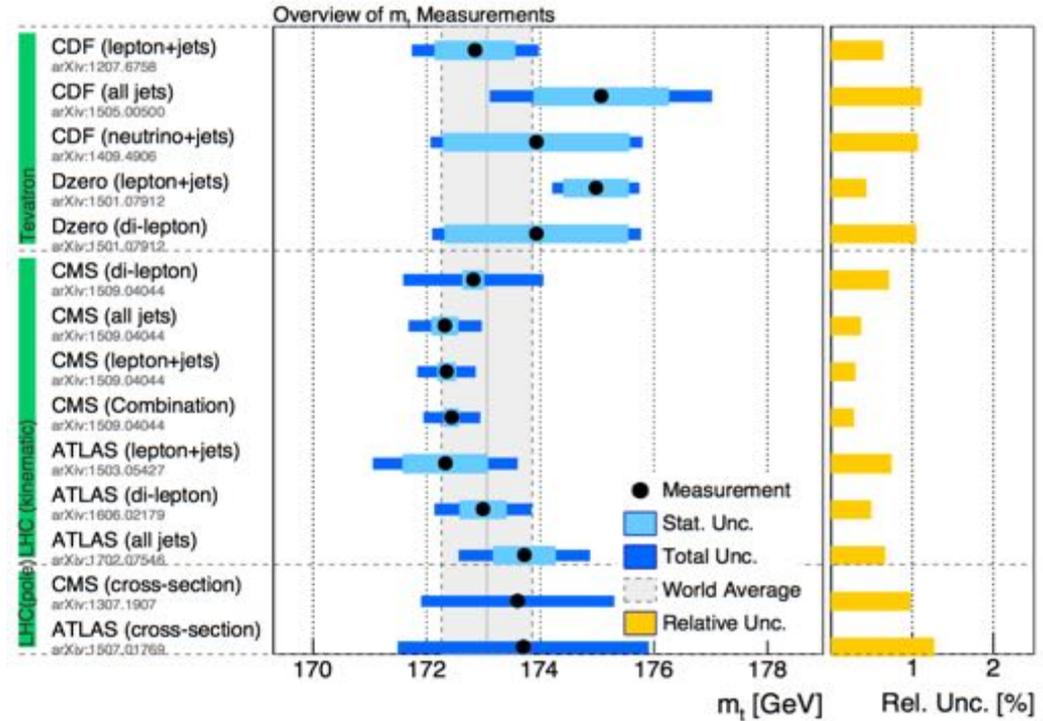
Measurement of the Top Quark Mass (3/3)

- ATLAS (ATLAS-CONF-2017-071)
 - $m_t^{\text{MC}} = 172.08 \pm 0.39$ (stat) ± 0.82 (syst) GeV
 - Significant gain by using „cleverly“ correlation during the combination to previous ATLAS measurements
 - $m_t^{\text{MC}} = 172.51 \pm 0.27$ (stat) ± 0.42 (syst) GeV
- Most precise value from CMS (arXiv: 1509.04044)
 - $m_t^{\text{MC}} = 172.35 \pm 0.51$ GeV
 - The top quark mass is measured using the lepton + jets, all-jets and dilepton decay channels at 8 TeV
 - Already on assumed 500 MeV theory uncertainty level



Overview of Top-Quark Mass Measurements

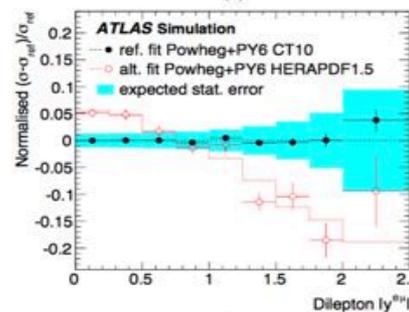
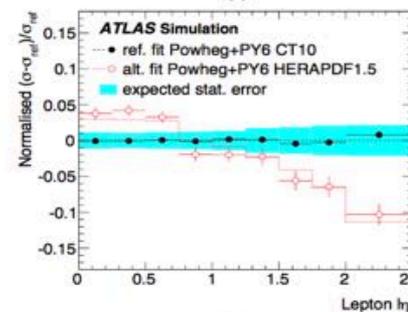
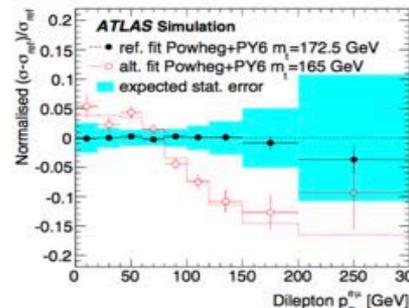
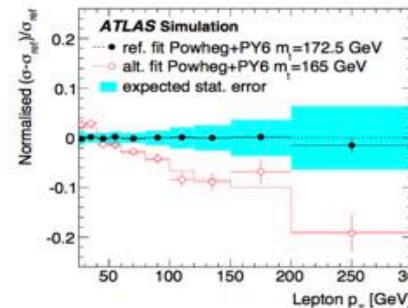
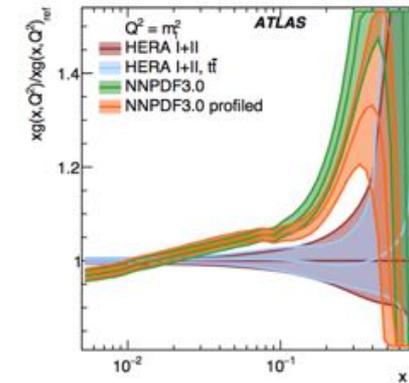
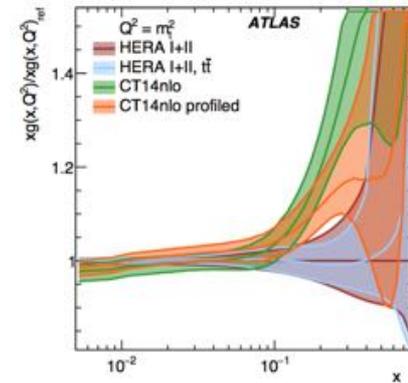
- No official combination of latest ATLAS and Tevatron results
- Preliminary combination
 - Correlations are taken from experiments
 - for unpublished correlations, assume correlations of last published results
 - Observe tension between TeV and LHC by 2.5σ
 - driven by D0 lepton + jets measurement
 - naive combination of 4 experiments yields to p-value of 0.02.



- Employ PDG prescription to force χ^2/N_{dof} in combination to one
 - Leads to increased systematics
 - $m_t^{\text{average}} = 173.06 \pm 0.80 \text{ GeV}$

Pole-Mass Measurements

- Absolute and normalised differential cross-section measurements, in the di-leptonic $e\mu$ pair channel with one or two b-tagged jets at 8 TeV
 - Constrain gluon PDFs
 - normalised lepton p_l and dilepton $p_{e\mu}$, $m_{e\mu}$, p_e+p_μ and E_e+E_μ distributions are sensitive to pole-mass of the top-quark
- Compare with fixed order prediction at NLO (MCFM) and extract
 - $m_{\text{top}} = 173.2 \pm 0.9$ (stat) ± 0.8 (sys) ± 1.2 (model) GeV
 - much higher statistics for full run-2 and comparison to NNLO predictions might lead to uncertainty below 1 GeV



1709.09407



Constraints of new physics

Gfitter Group (R. Kogler, J. Haller, T. Pfeiffer,
A. Hoecker, K. Mönig, J. Stelzer, M.S.)

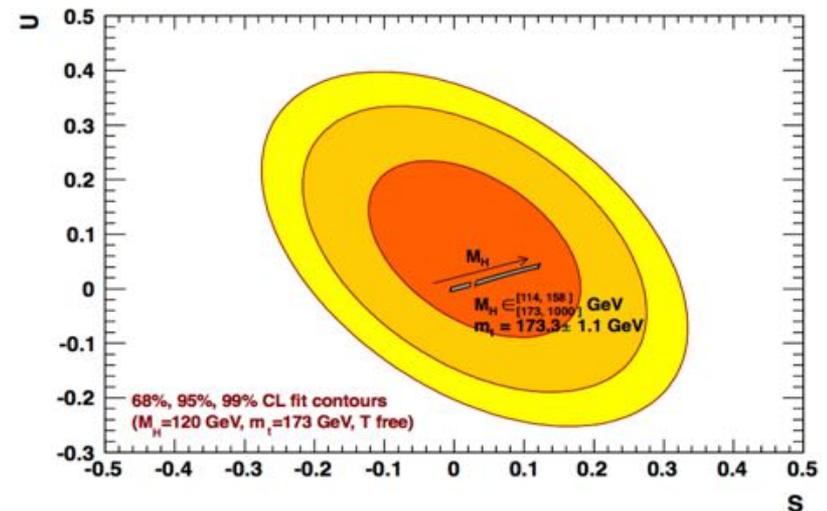
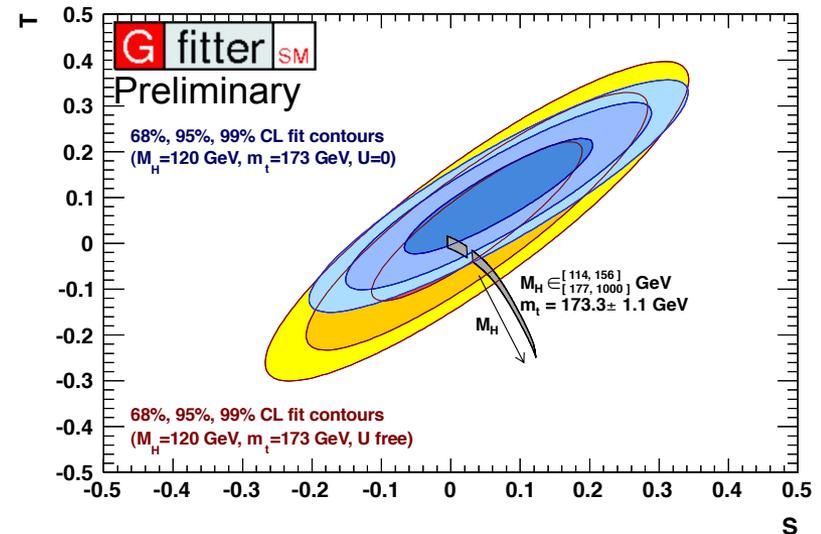
Oblique Corrections

- Oblique corrections from New Physics described through STU parameters [Phys. Rev. D46, 1 (1991)]

- Oblique corrections reabsorbed into electroweak parameters

$$O_{\text{meas}} = O_{\text{SM}(m_H, m_t)} + c_S S + c_T T + c_U U$$

- S-Parameter: New Physics contributions to neutral currents
- T-Parameter: Difference between neutral and charged current processes
- U-Parameter: (+S) New Physics contributions to charged currents
- Higgs discovery fixed reference point of SM



Constraining EFT Parameters with EWK Precision Measurements

- STU is ill-defined in an EFT approach
 - How can electroweak precision measurements be used in a global EFT fit?
 - Following a private discussion with Mike Trott

- Electroweak form-factors that modify the relations between the EWK parameters, will also be affected by EFT
 - One has to check for measurement bias first before interpreting a measurement in terms of SMEFT. E.g.
 - LEP II TGC analyses should not be used
 - m_W measurement at hadron colliders can be used, but e.g. not the LEP measurements (<https://arxiv.org/pdf/1606.06502.pdf>)
 - Further details can be found in
 - <https://arxiv.org/pdf/1701.06424.pdf>
 - <https://arxiv.org/pdf/1705.05652.pdf>

$$\frac{\delta m_W^2}{\hat{m}_W^2} = \hat{\Delta} \left[4C_{HWB} + \frac{c_{\hat{\theta}}}{s_{\hat{\theta}}} C_{HD} + 4\frac{s_{\hat{\theta}}}{c_{\hat{\theta}}} C_{H\ell}^{(3)} - 2\frac{s_{\hat{\theta}}}{c_{\hat{\theta}}} C_{\ell\ell} \right]$$

$$\frac{\delta \Gamma_W}{\hat{\Gamma}_W} = \frac{\sqrt{2}}{3\hat{G}_F} \left[C_{H\ell}^{(3)} + 2C_{Hq}^{(3)} \right] - \sqrt{2}\delta\hat{G}_F - \frac{3}{2} \frac{\delta m_W^2}{\hat{m}_W^2}$$

$$\delta G_F = -\frac{64\pi^2}{2\hat{G}_F^2} \frac{r_2^\ell - r_5^\ell}{\Lambda^2},$$

$$\frac{\delta m_Z^2}{\hat{m}_Z^2} = -c_T - 2\frac{\hat{m}_W}{\hat{m}_Z} \sqrt{1 - \frac{\hat{m}_W^2}{\hat{m}_Z^2}} c_1,$$

$$\frac{\delta m_W^2}{\hat{m}_W^2} = -2c_{12},$$

Summary

- Measurements of Electroweak precision observables at the LHC made huge progress in recent years
 - Precision of several Tevatron and LEP measurements surpassed
 - Expect large reduction of measurement uncertainties in coming years
 - Theory/Model uncertainties have to be reduced with new approaches and ideas
- Re-Interpretation of EWK observables in terms of EFT will be the future direction
 - Personal Question: Does it make sense to look also at other LEP observables at the LHC?

Oblique Corrections (2/2)

- The following is from a private discussion with **Mike Trott**
- STU approach as theoretical assumptions attached:
 - no gauge field coupling to fermion vertex corrections due to new physics, or at least such effects are negligible compared to 2 point effects
 - This assumptions are ill defined in an EFT sense as a field redefinition can move a correction from the gauge field 2 point function to the corresponding vertex and back.
- One Model in which the STU approach makes sense
 - SM with an undiscovered Higgs, since direct vertex corrections are indeed small at tree and loop level for a gauge field coupling to 2 light fermions due to corrections from an undiscovered Higgs (The higgs-yukawa couplings to light fermions are small)
 - however, now the Higgs is discovered: Assuming there are no vertex corrections in the EFT is ill defined as it means that the results for an STU fit are basis dependent and unphysical, results depend on the coordinate choice in wilson coefficient space in other words.