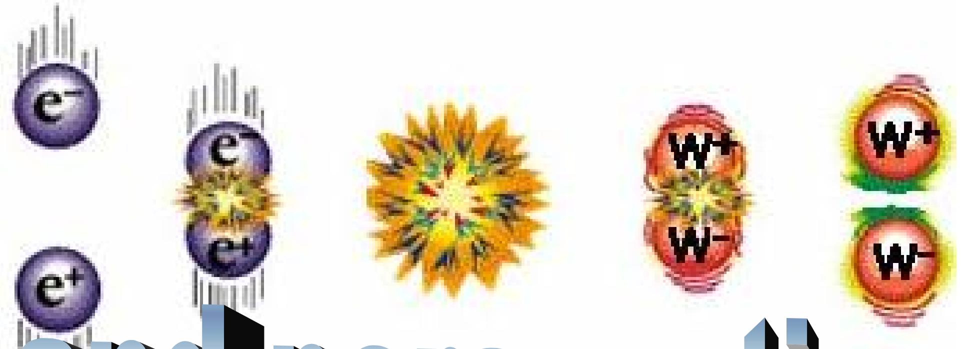
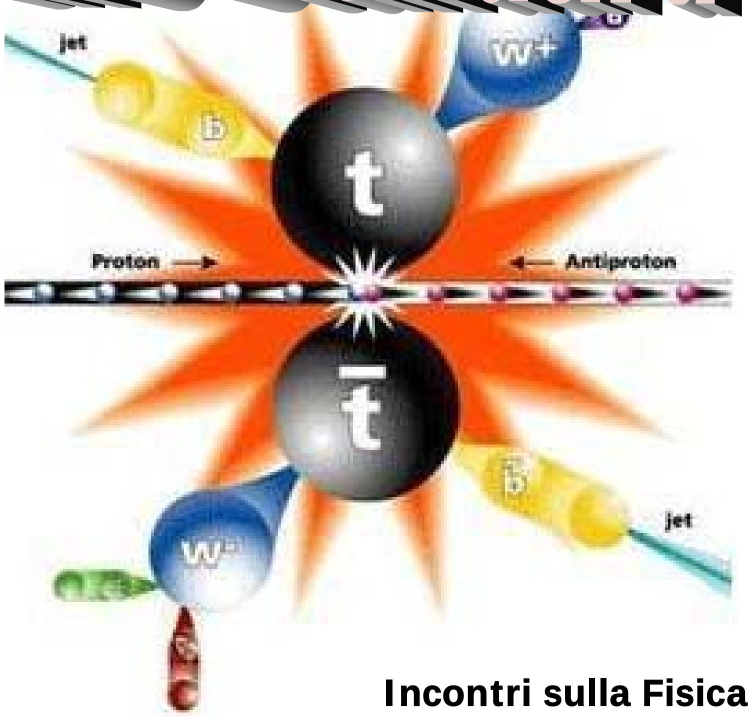
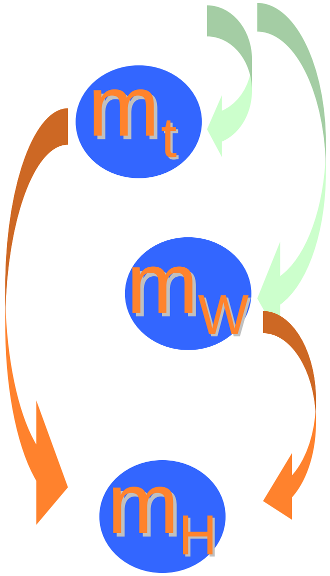


Status and perspectives of the Standard Model fit

- The present
- The near future
- Speculations……




m_t

m_W

m_H

Roberto Chierici
CERN

Torino, Aprile 2004

Incontri sulla Fisica delle Alte Energie

Foreword/disclaimer

Beware! In this talk:

- I will not review the Higgs searches
- I will not go through the list of the observables input to the Standard Model (SM) fit (or EW fit) describing each of them
- I will not go into experimental details of the analyses I will talk about (see this session for further information)
- I will consider the SM hypothesis only
- I will not comment (unless asked to) on theory/parametric uncertainties in the fit (see previous talk)
- I will almost not comment (unless asked to) on the LHC potential (tomorrow session), ending my perspectives at the years 2007-2009

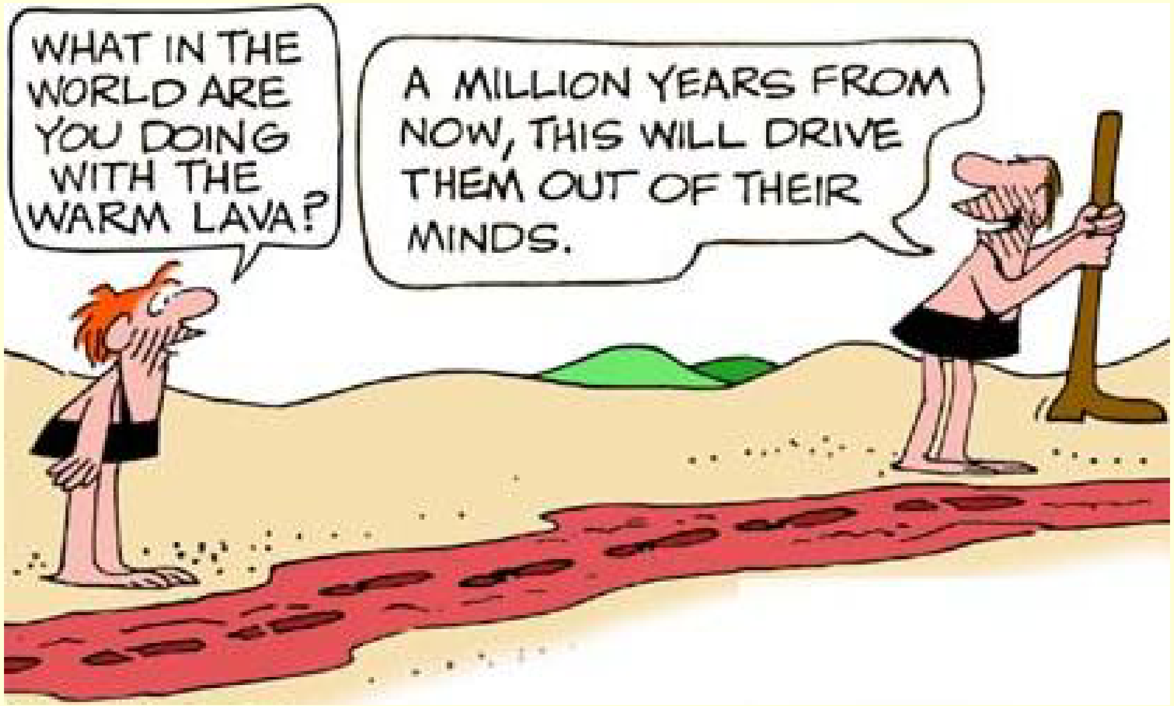
On the other hand:

- ✓ I will try to give space to both the ways in which the SM Higgs is searched for today: directly (LEP, Tevatron) and indirectly (EW fit)
- ✓ I will briefly review the hottest contradictions in the EW fit at present
- ✓ I will focus on the most interesting (and sensitive to the Higgs mass) parameters
- ✓ I will focus on those SM parameters and inputs to the EW fit which are more likely to evolve in the pre-LHC era
- ✓ I will try to give an unbiased picture of what the Higgs constrain (or discovery) can be at the start of the LHC and a bit further ahead

Basically a talk on Tevatron? Maybe...

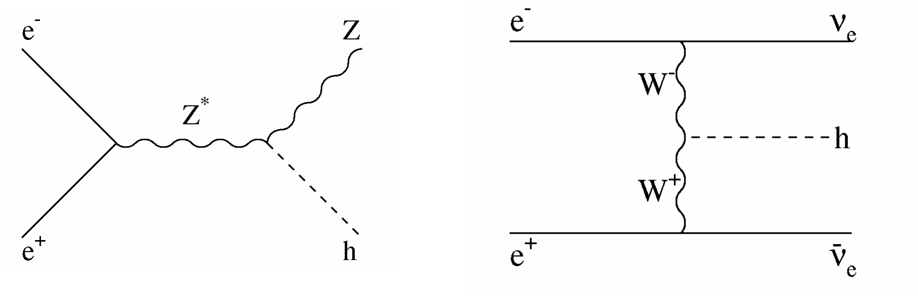
The past

Fast, fast, fast...



SM Higgs direct search at LEP

Search mainly in ZH→ff bb



Final states	bbqq	bbνν	bbll	ττqq
BR(%)	60%	19%	6%	8%

Important ingredients of the analyses:

- High b-tagging efficiency/purity
- Kinematical reconstruction (like W mass)

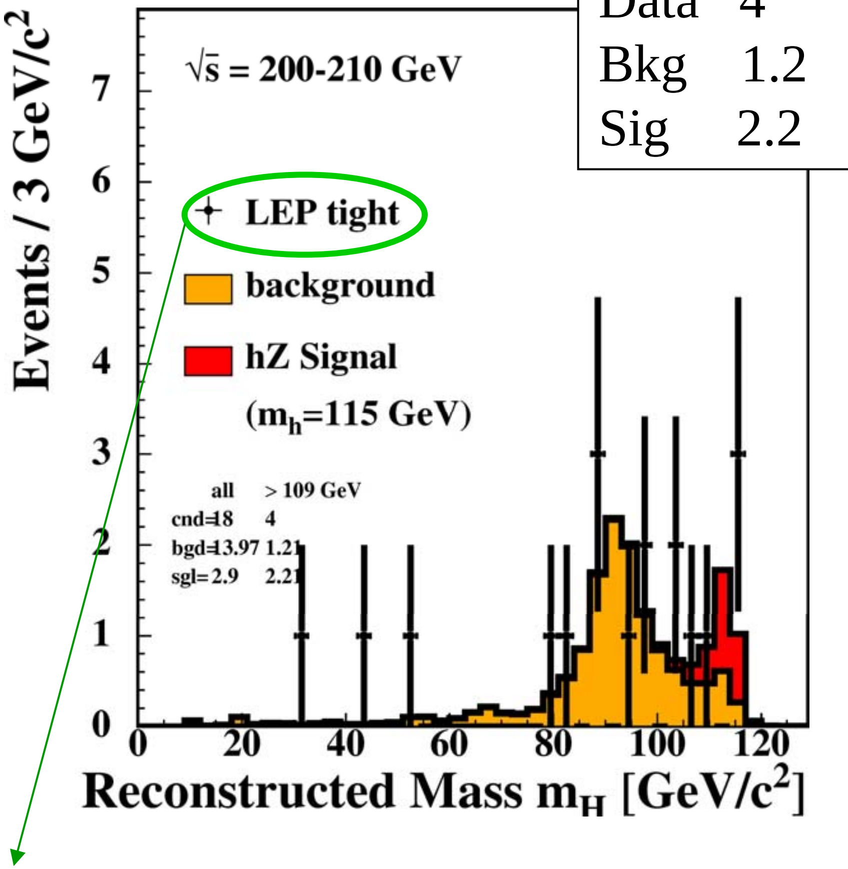
⇒ Good understanding of the detector is essential (tails!)

LEP final combination:

- Combine 2D distributions (m_H(rec.),discriminant variable)
- Use likelihood ratio test hypothesis:

$$Q(m_H)=\mathcal{L}(s+b;\ m_H)\ /\mathcal{L}(b;\ m_H)$$

- The integral of $-2\ln Q$ over ranges of m_H gives the confidence levels

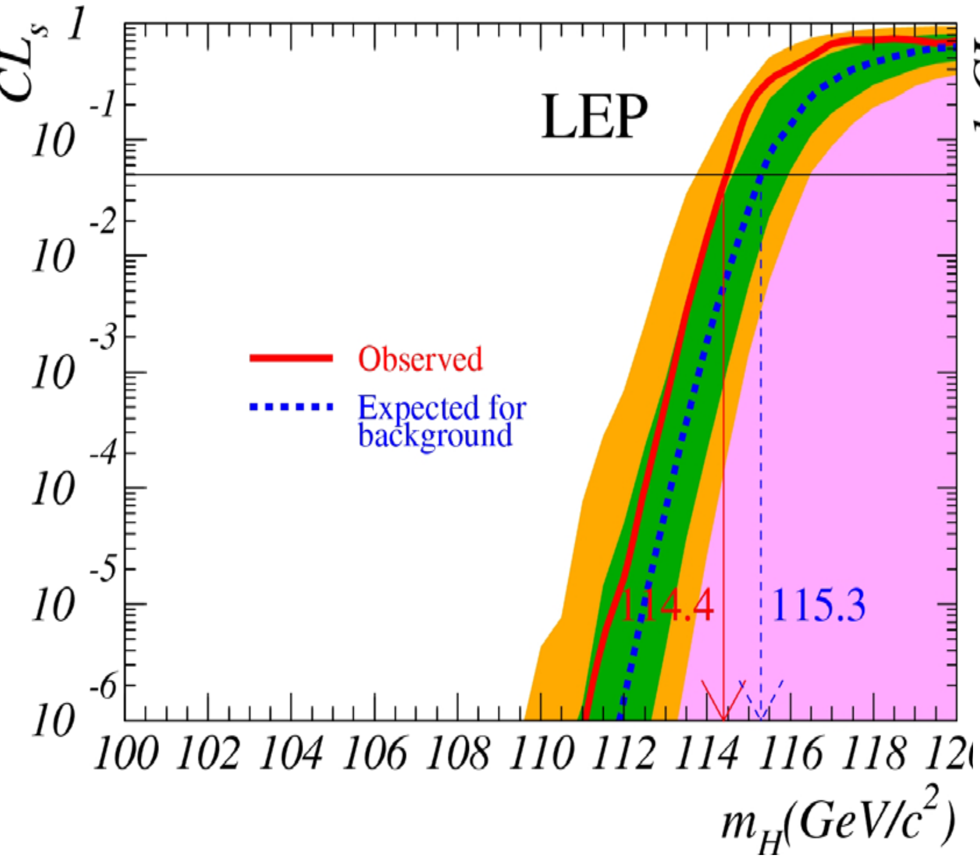


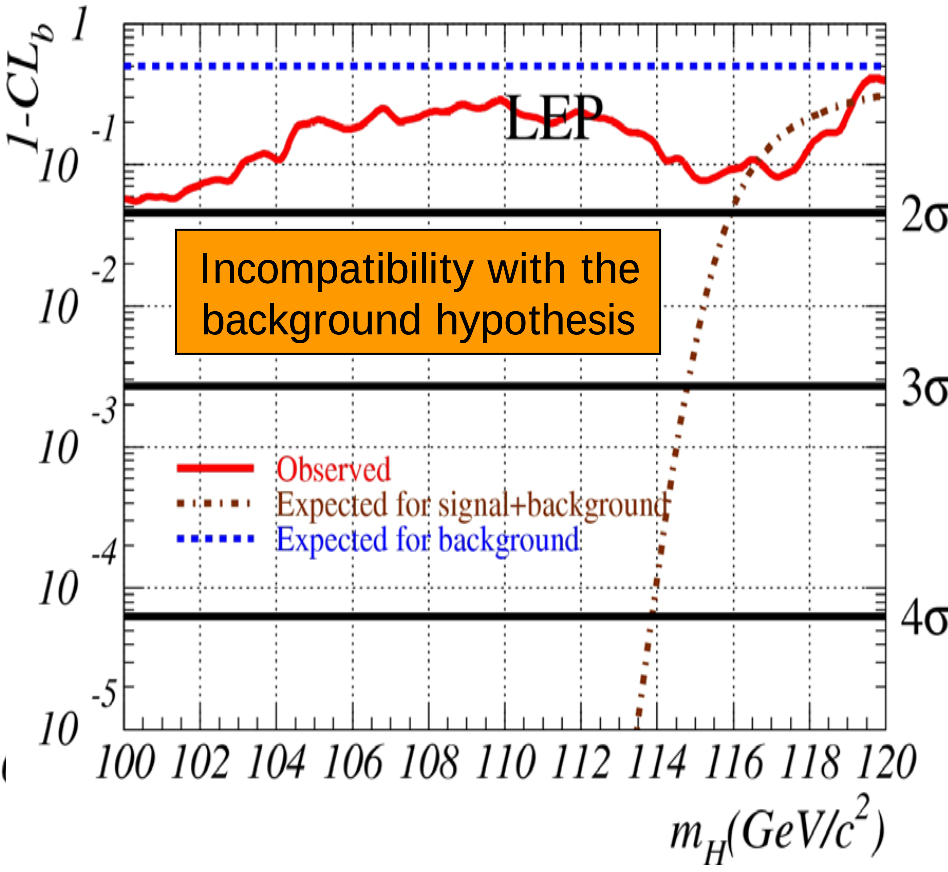
Data	4
Bkg	1.2
Sig	2.2

S/N>2 for reconstructed m_H>109 GeV/c^2

Final LEP Higgs limit

Confidence level for background and signal:



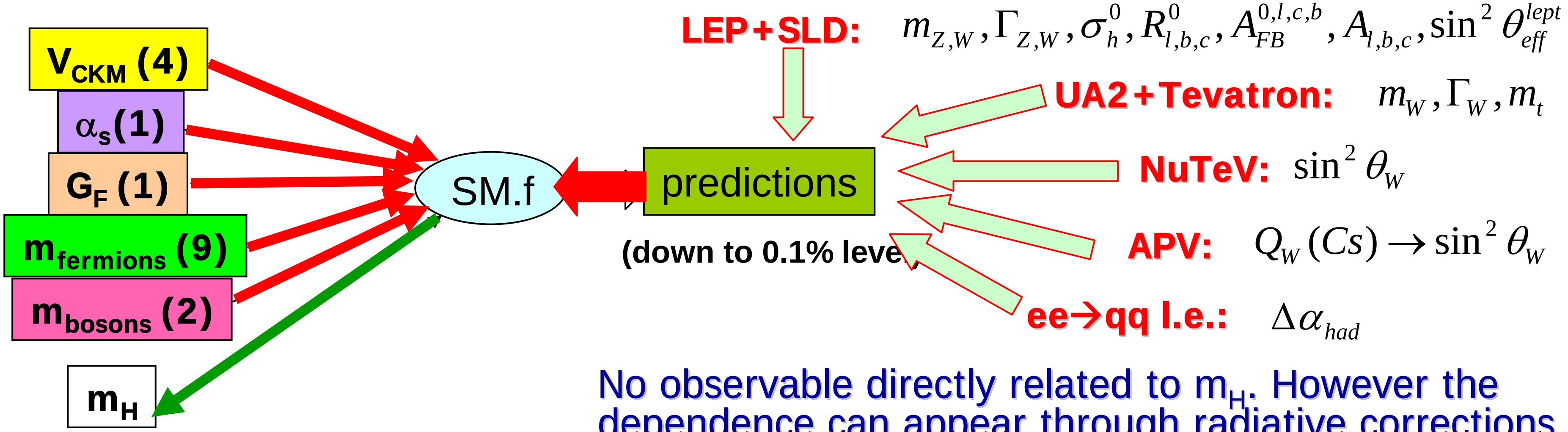


Incompatibility with the background hypothesis

1.7σ excess (8% probability) over the background, concentrated in one channel (qqbb) and one experiment (ALEPH, ~3σ)

⇒ Final LEP2 limit: m_H>114.4 GeV/c^2 @95% CL

What we (think we) know



V_{CKM} (4)

α_s(1)

G_F (1)

$m_{fermions}$ (9)

m_{bosons} (2)

m_H

SM.f

predictions

(down to 0.1% level)

LEP+SLD: $m_{Z,W}, \Gamma_{Z,W}, \sigma_h^0, R^0_{l,b,c}, A_{FB}^{0,l,c,b}, A_{l,b,c}, \sin^2\theta_{eff}^{lept}$

UA2+Tevatron: m_W, Γ_W, m_t

NuTeV: $\sin^2\theta_W$

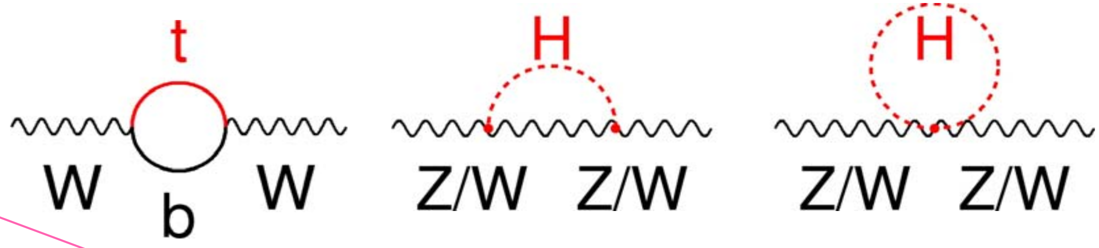
APV: $Q_W(Cs) \rightarrow \sin^2\theta_W$

ee→qq l.e.: $\Delta\alpha_{had}$

No observable directly related to m_H. However the dependence can appear through radiative corrections.
⇒ tree level quantities are changed

$$\frac{m_W^2}{m_Z^2\cos^2\theta_W} = 1 + \boxed{\Delta\rho}$$

$$m_W^2 = \frac{\pi\alpha}{\sqrt{2}\sin^2\theta_W G_F}(1+\boxed{\Delta r})$$



$\Delta\rho$, Δr = f [ln(m_H/m_W), m_t^2]

The uncertainties on m_t, m_W are the dominating ones in the electroweak fit

By making precision measurements (already interesting per se):

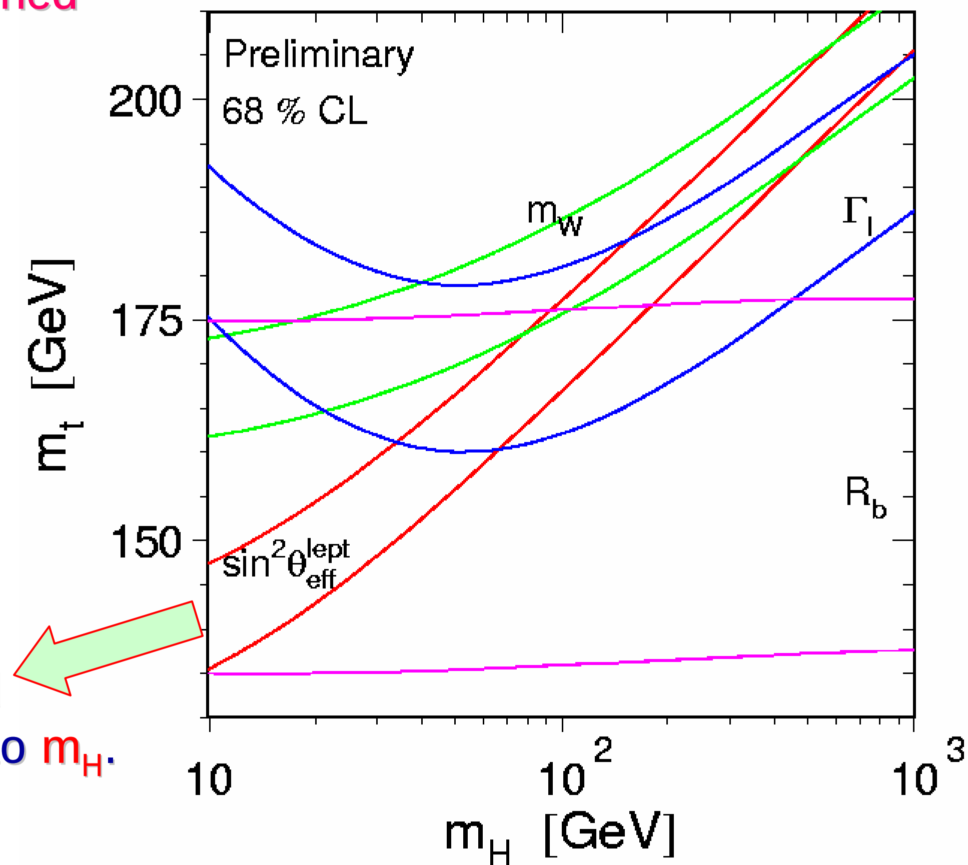
- one can get information on the missing parameter m_H
- one can test the validity of the Standard Model

A global fit?

All precision “observables” in the SM fit are calculated in terms of a small set of input parameters: m_Z, G_μ, $\alpha(m_Z)$, m_l, m_q, m_t, m_H, α_s. They constitute the fit parameters.
Both observables and input parameters are constraints in the fit and are subject to their experimental uncertainties.
Theory errors in the expressions of the “observables” introduce further uncertainties
m_Z, G_μ, $\alpha(0)$, m_l are the most precisely measured input parameters –can be seen as fixed in the fit-, $\alpha_s(m_Z)$ is very well constrained

⇒ the dominant uncertainties come at present from:
- The top mass m_t
- The hadronic contribution to the fine structure constant $\Delta\alpha_{had}$
- The Higgs mass itself m_H

⇒ the dominant theory errors involve:
- $\sin^2\theta_{eff}$
- The W mass m_W



Amongst the experimental measurements leading to precision “observables”, m_W and $\sin^2\theta_{eff}$ are the most sensitive parameters to m_H.

What we measured

Not a very healthy fit (P less than 5%)

- **Anomaly #1**

$\sin^2\theta_{eff}$ from quark asymmetries agree each other and point towards a heavy Higgs

$\sin^2\theta_{eff}$ from lepton asymmetries agree each other and prefer a light Higgs

Separately they (dis)agree at the 3σ level

- **Anomaly #2**

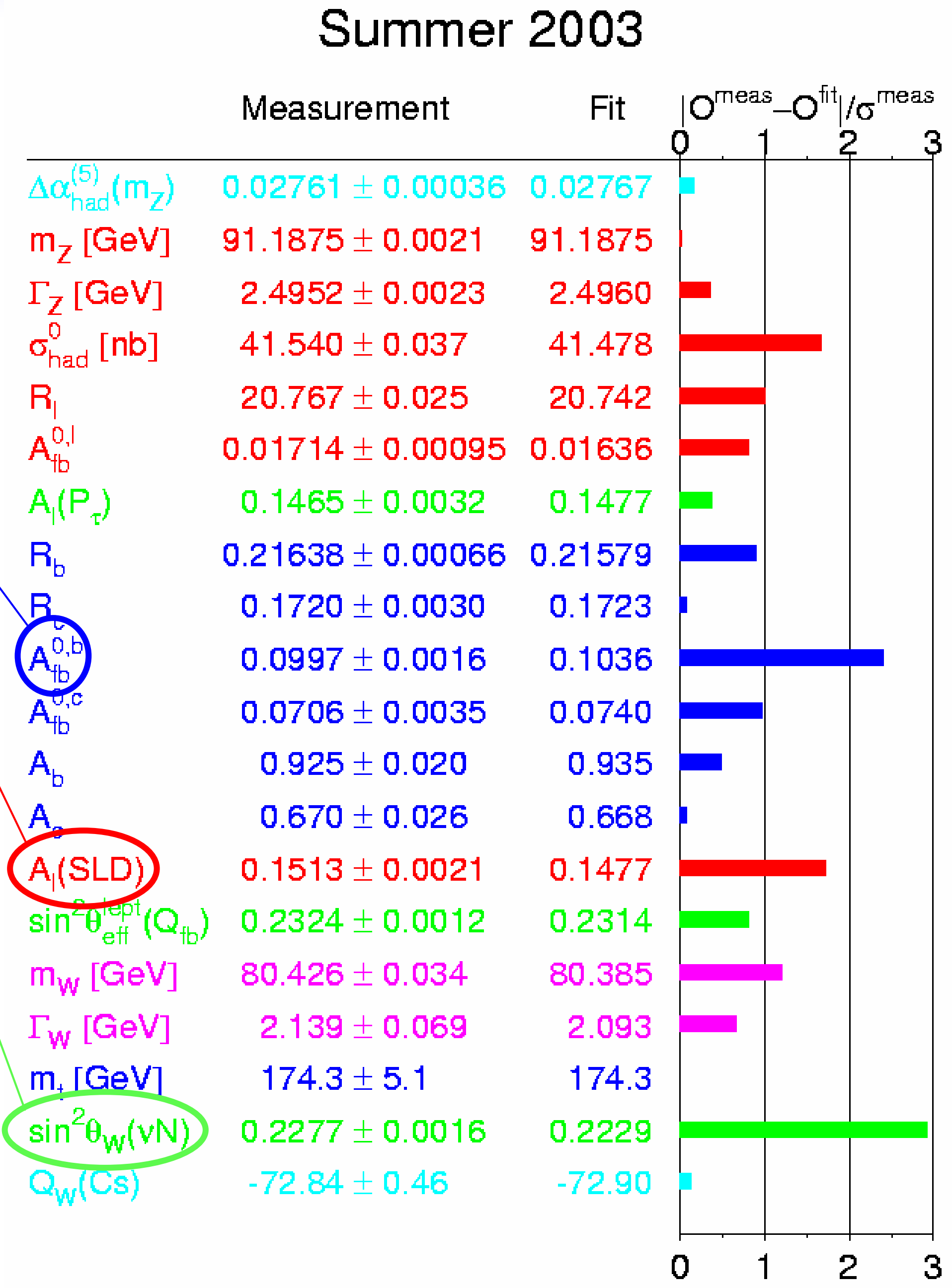
NuTeV measures $\sin^2\theta_W$ from NC/CC νN DIS cross sections, and its measure is 3σ away from the predictions

(feeling is that the TU are largely underestimated)

- **Anomaly #3**

The Higgs boson is not found yet

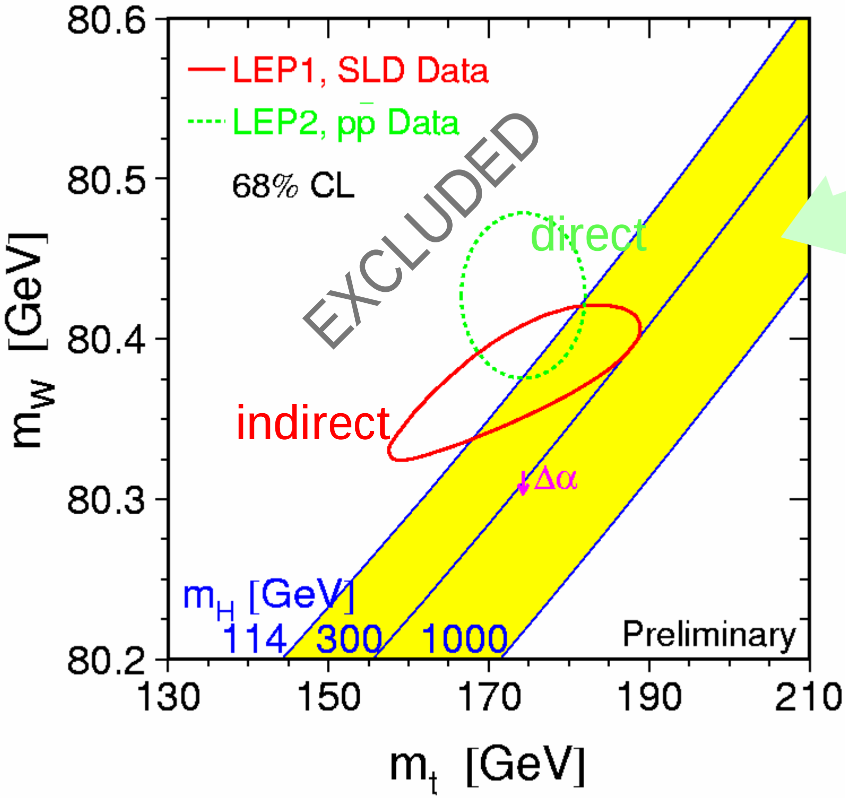
All “anomalies” concern very m_H sensitive variables !



Summer 2003

	Measurement	Fit
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02761 ± 0.00036	0.02767
m_Z [GeV]	91.1875 ± 0.0021	91.1875
Γ_Z [GeV]	2.4952 ± 0.0023	2.4960
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	0.01636
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1477
R_b	0.21638 ± 0.00066	0.21579
R_c	0.1720 ± 0.0030	0.1723
$A_{fb}^{0,b}$	0.0997 ± 0.0016	0.1036
$A_{fb}^{0,c}$	0.0706 ± 0.0035	0.0740
A_b	0.925 ± 0.020	0.935
A_c	0.670 ± 0.026	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1477
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.426 ± 0.034	80.385
Γ_W [GeV]	2.139 ± 0.069	2.093
m_t [GeV]	174.3 ± 5.1	174.3
$\sin^2\theta_W(\nu N)$	0.2277 ± 0.0016	0.2229
$Q_W(Cs)$	-72.84 ± 0.46	-72.90

Where we were



Status of inputs WC2004:

m_t=174.3 ±5.1(exp) GeV/c^2

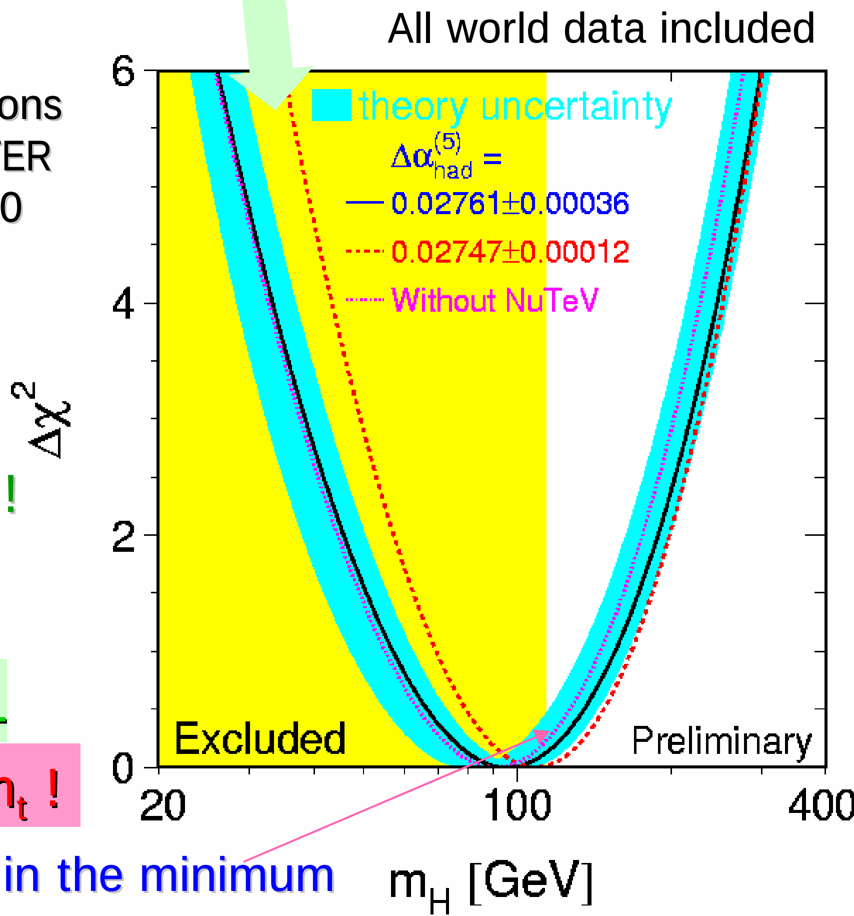
m_W=80.426 ±0.034(exp) GeV/c^2

m_Z=91.1875 ±0.0021(exp) GeV/c^2

Γ_Z=2.4952 ±0.0023(exp) GeV

SM predictions from ZFITTER and TOPAZ0 programs

All world data included



Direct and indirect data favour a light Higgs !

$$\Rightarrow m_H = 96^{+60}_{-38}\, GeV\ / c^2$$ ($\delta m_H/m_H \approx$ 51%)

m_H<219 GeV/c^2 @95% CL

35% shift in m_H for 5 GeV/c^2 (1σ) shift in m_t !

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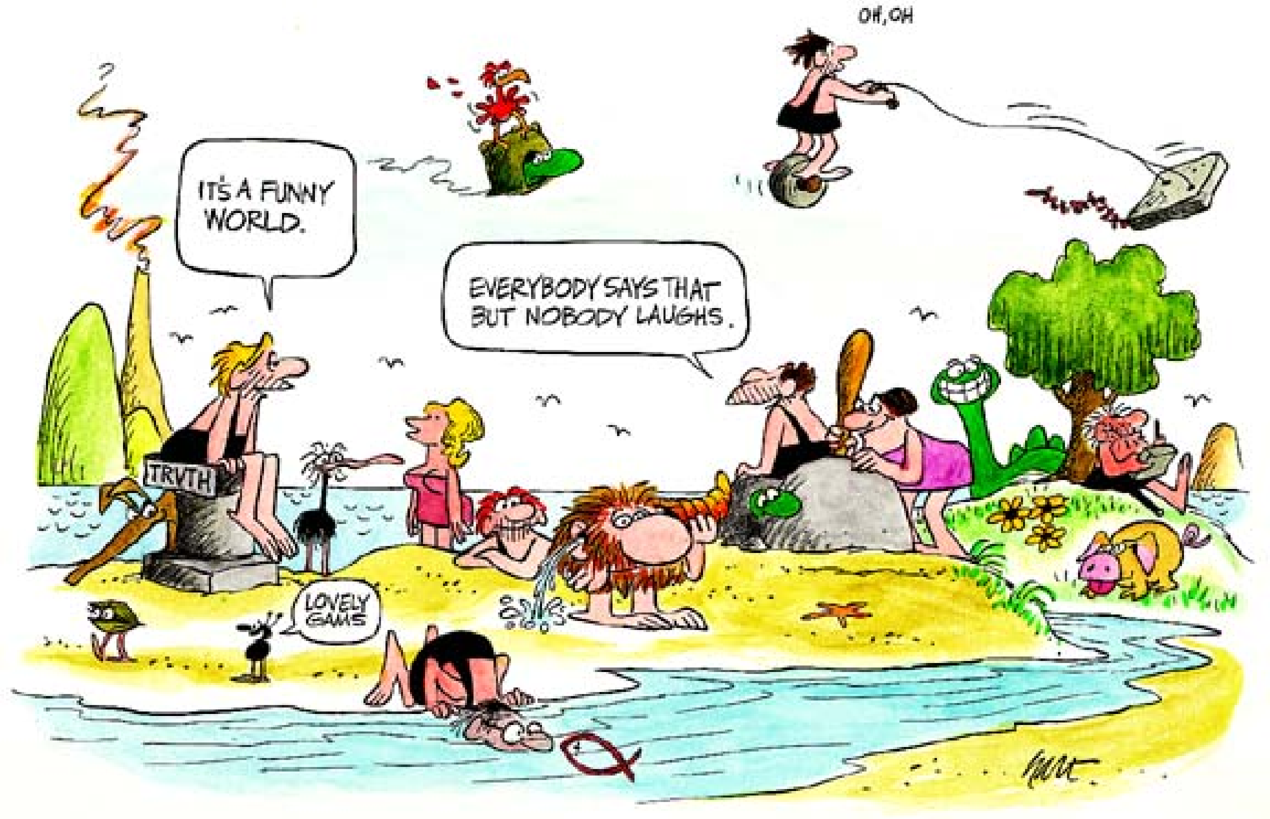
Small impact of NuteV in the minimum

The present

Not the ideal one...



Are we satisfied?

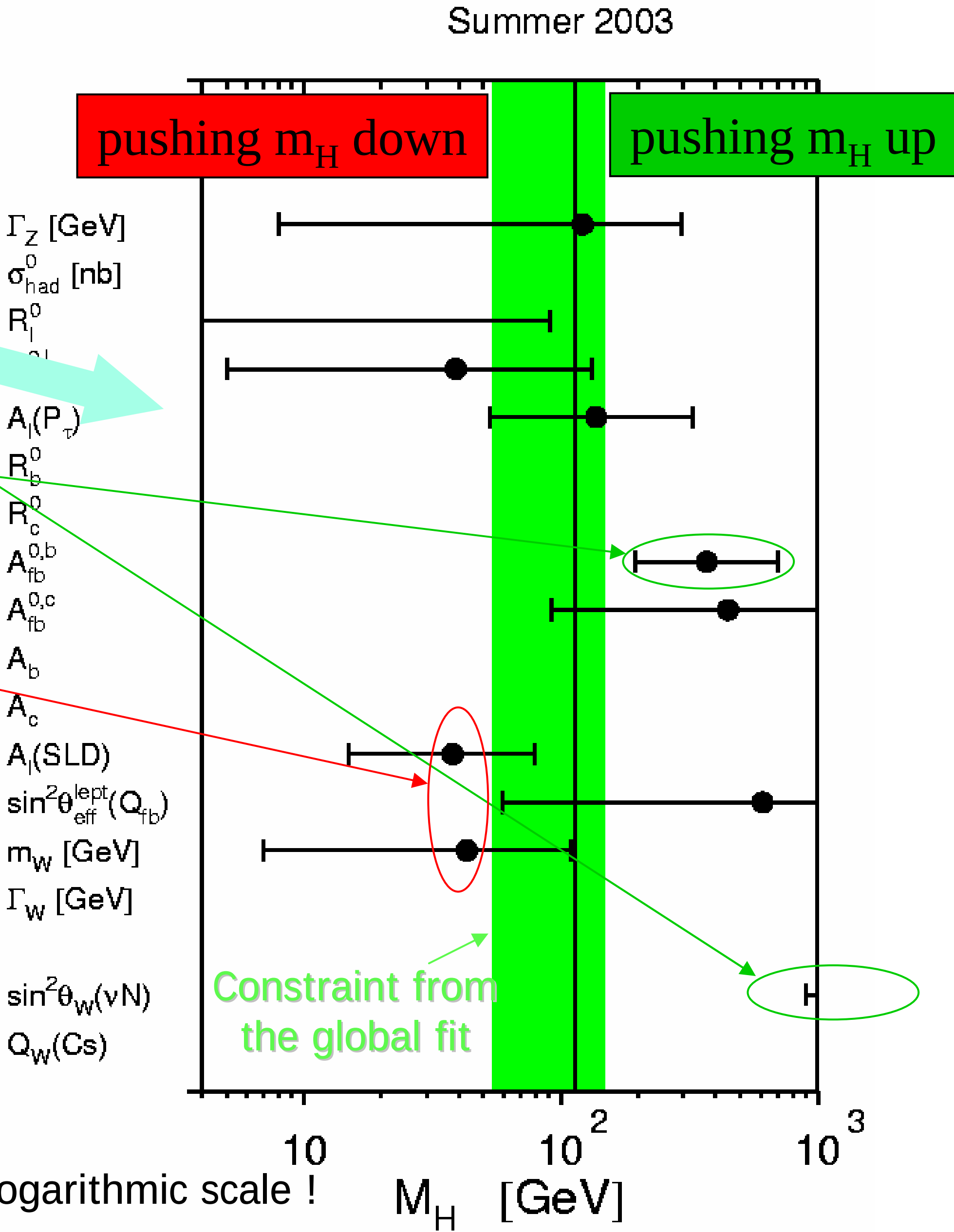
A global fit can sometimes hide striking discrepancies…

Constraint on m_H from each pseudo-observable from a 5 parameter fit where $\Delta\alpha_{had}$, $\alpha_s(m_Z)$, m_Z, m_t are fixed

There are only the hadronic asymmetries and the NuTeV result that are pushing for a high Higgs mass

They seem to contradict the result from other measurements like A_l or m_W.

Beware: this is an old plot already !

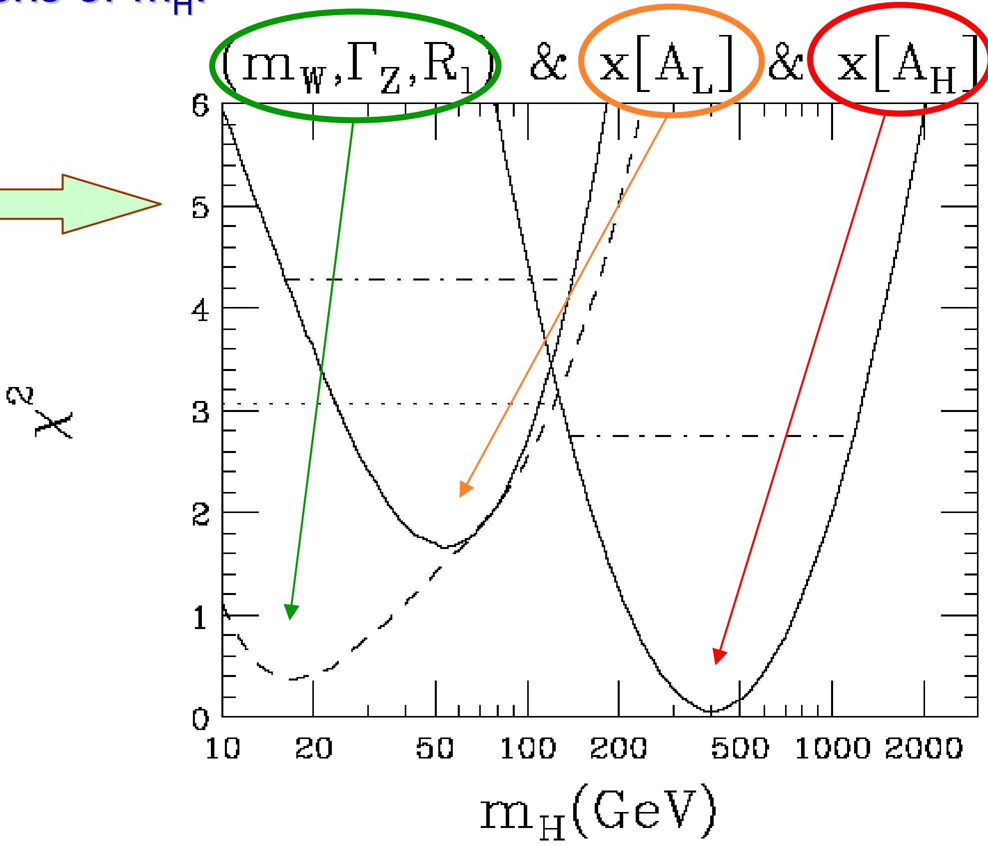


beware: logarithmic scale !

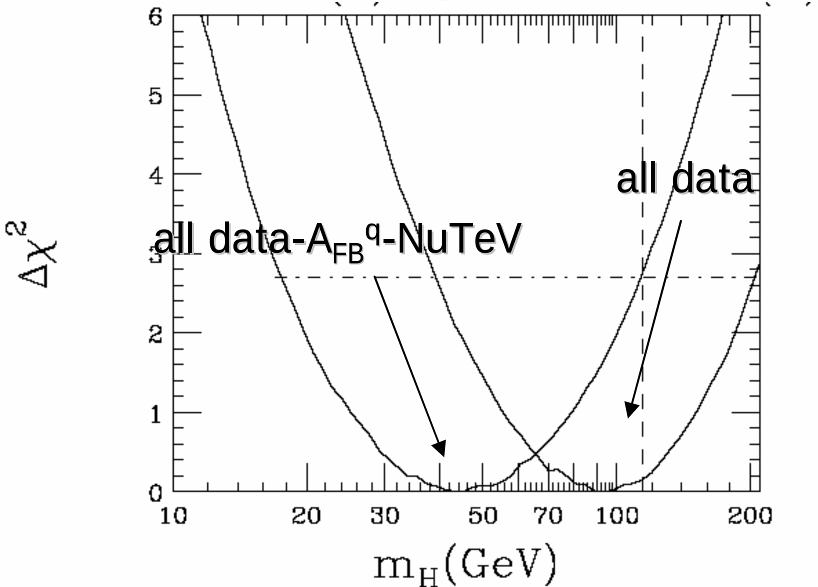
The Chanowitz point of view

The poor consistency of the m_H sensitive sector (m_W,A_{LR},A_{FB}^b) is cause for concern in assessing the reliability of the SM predictions of m_H.

	90% CL m_H (GeV/c^2)
m_W	$10<m_H<161$
A_{LR}	$10<m_H<122$
A_{FB}^b	$130<m_H<1200$



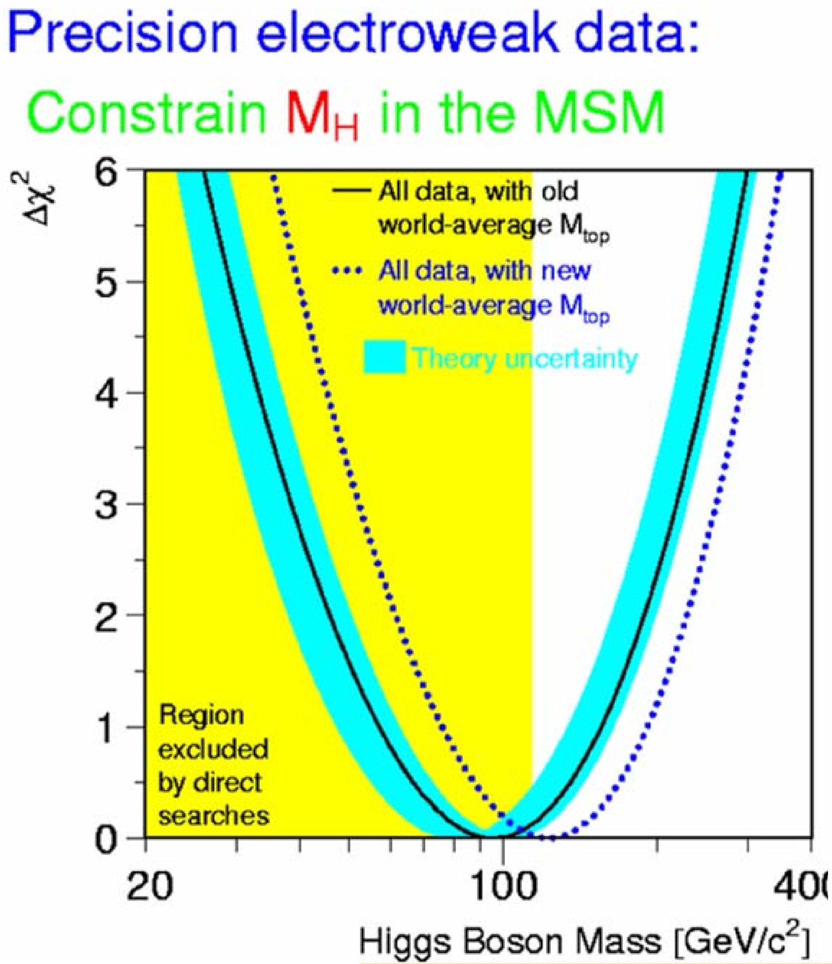
- × statistical fluctuation?
- × new physics?
- × underestimated correlated systematic?
  why not in the A_{FB}^q ?

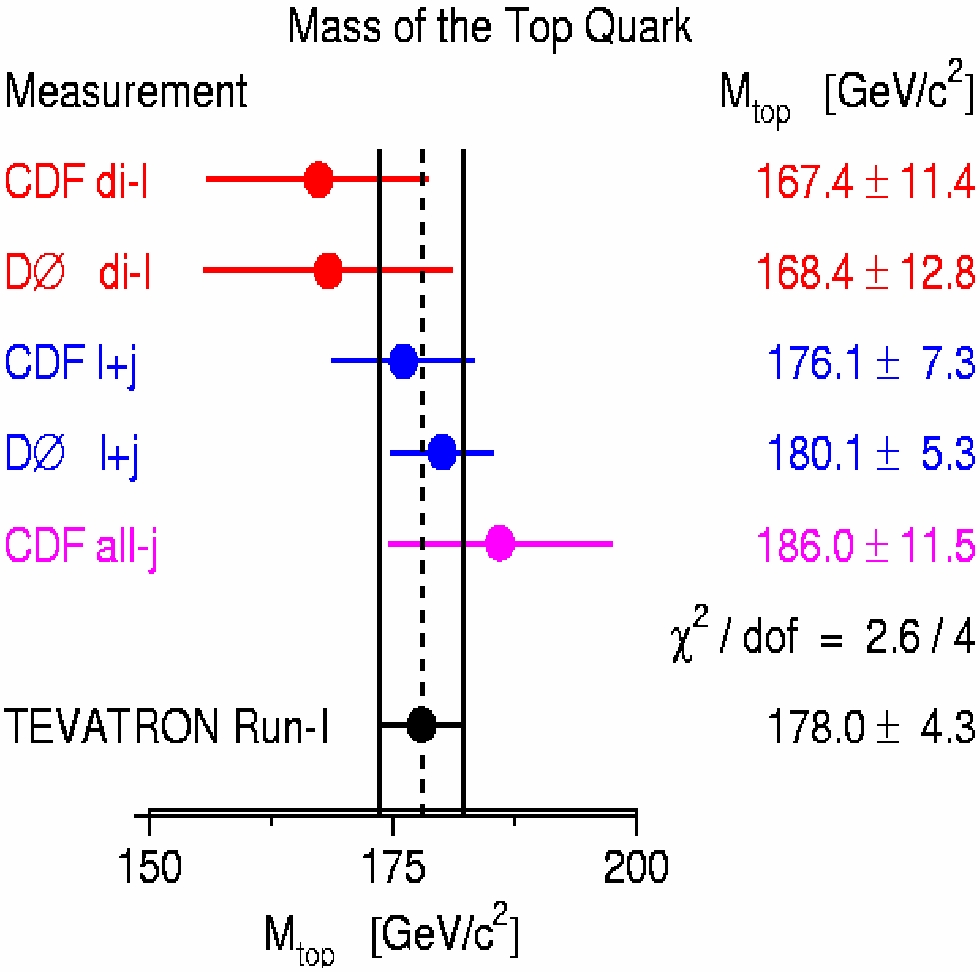


Removing the hadronic asymmetries from the fit (i.e. one assumes there is an unknown large systematic error) makes the fit very good, but inconsistent with direct search data !

Did I tell the whole truth?

Not really! On the (suspicious) date of the 1st April a new Tevatron combined top mass was produced with consequent effect on the "blue-band" plot...



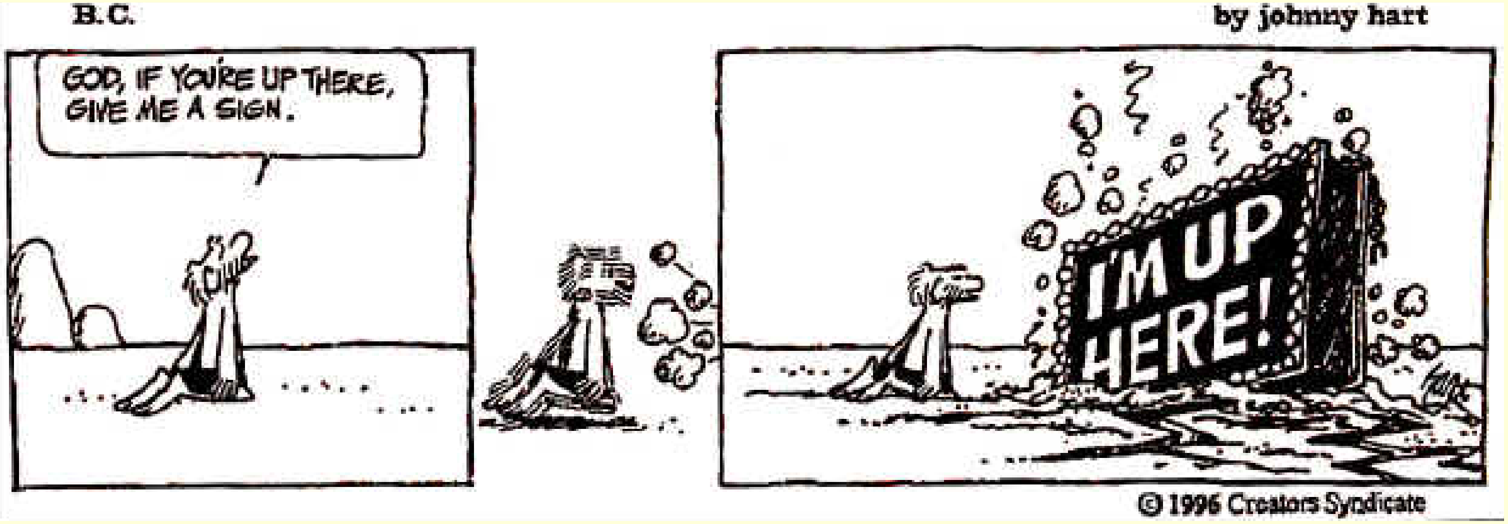


Ready for a dancing blue band in the next years !!!

m_W m_t $\sin^2\theta_{eff}$

The future

Yes, ok...



Tevatron now and in the future

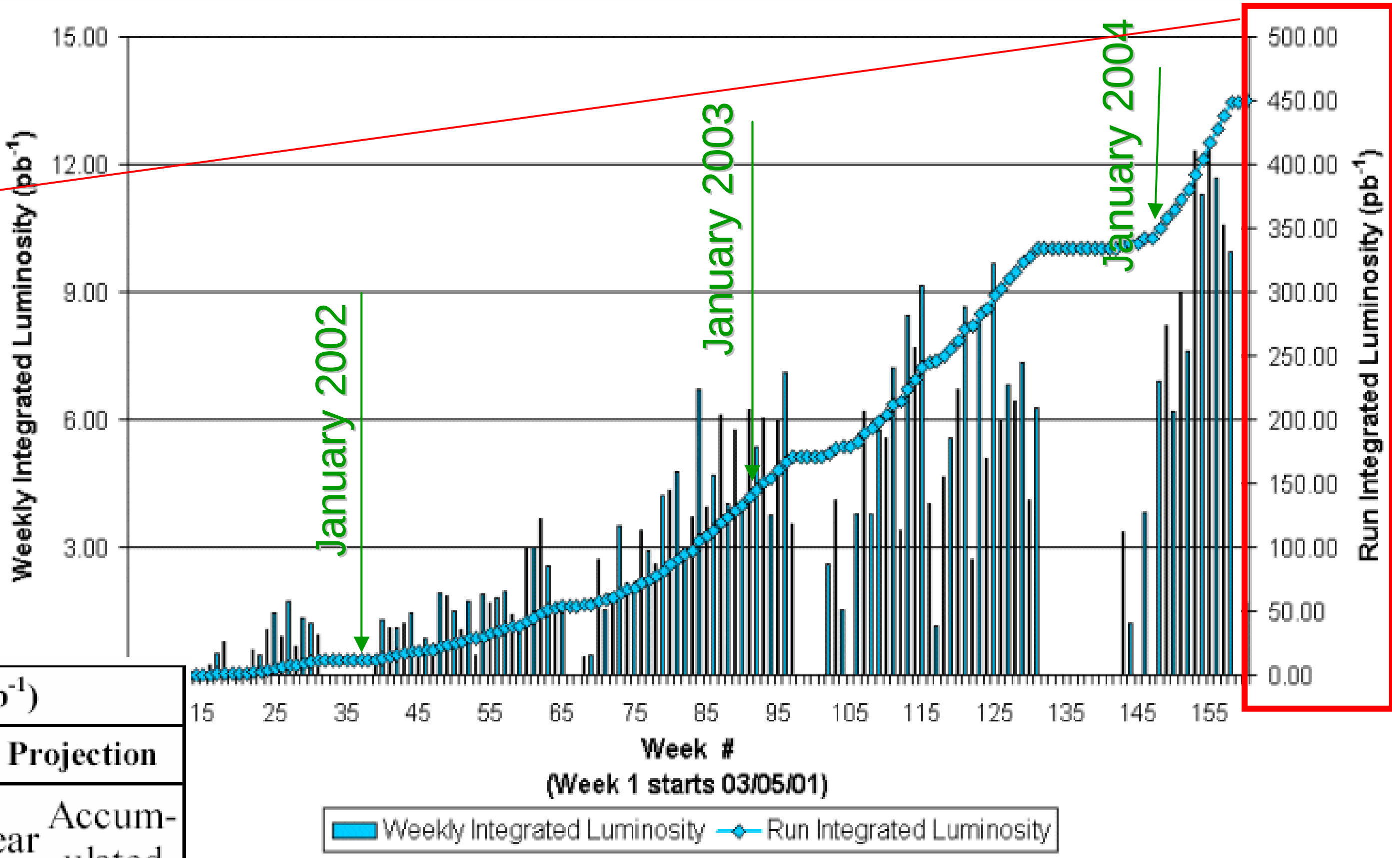
Sounds fine...

>450/pb delivered

>350/pb on tape

Data taking efficiency routinely about 85%

ΔLumi~6%



Integrated Luminosity (fb^{-1})				
	Design Projection		Base Projection	
	per year	Accum-ulated	per year	Accum-ulated
FY03	0.22	0.30	0.20	0.28
FY04	0.38	0.68	0.31	0.59
FY05	0.67	1.36	0.39	0.98
FY06	0.89	2.24	0.50	1.48
FY07	1.53	3.78	0.63	2.11
FY08	2.37	6.15	1.14	3.25
FY09	2.42	8.57	1.16	4.41

Tevatron project plan

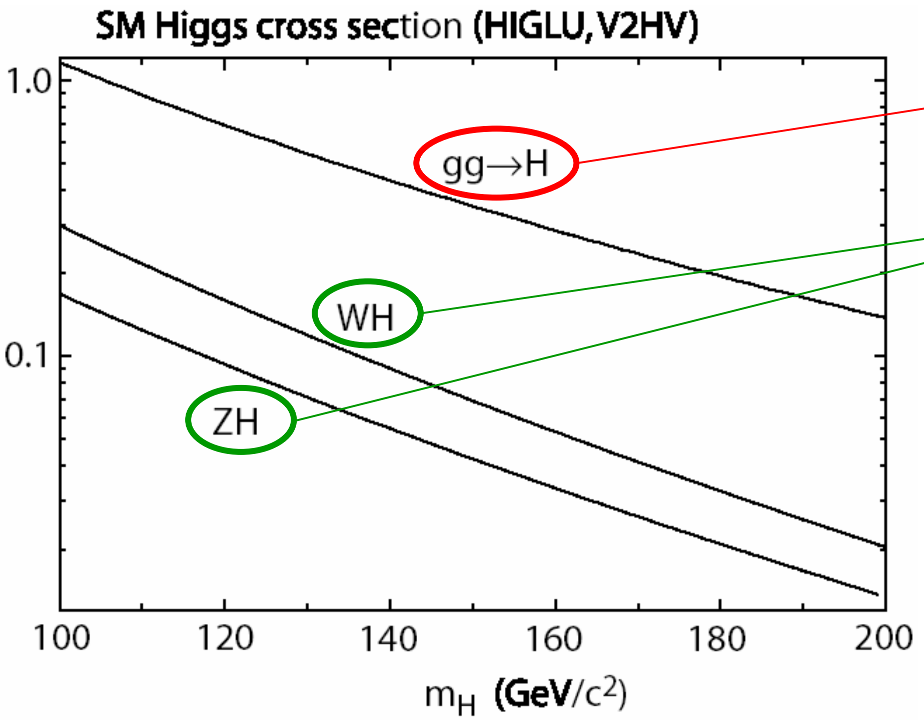
(http://www.fnal.gov/pub/now/upgradeplan/)

Run I	1992-1995	80/pb (E_{CM}=1.8 TeV)
Run IIa	in progress	300/pb FY2003 (E_{CM}=2 TeV)
Run IIb		4.4/fb to 8.6/fb by FY2009

“realistic” pre-LHC region

Direct search at the Tevatron

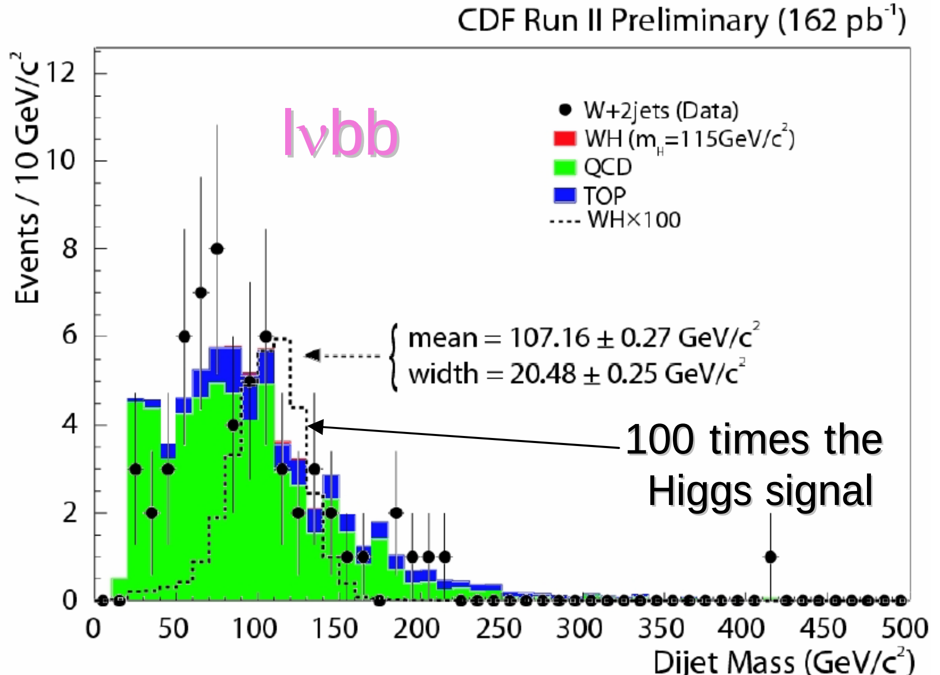
The direct SM Higgs search at the Tevatron is based on W/Z+H production


SM Higgs cross section (HIGLU,V2HV)

Overwhelmed by large QCD background

Leptonic decay channels of W and Z provide excellent signature

$m_H<2m_W$	$m_H>2m_W$
b-tagging	lepton id.
di-jet mass resolution	missing E_T

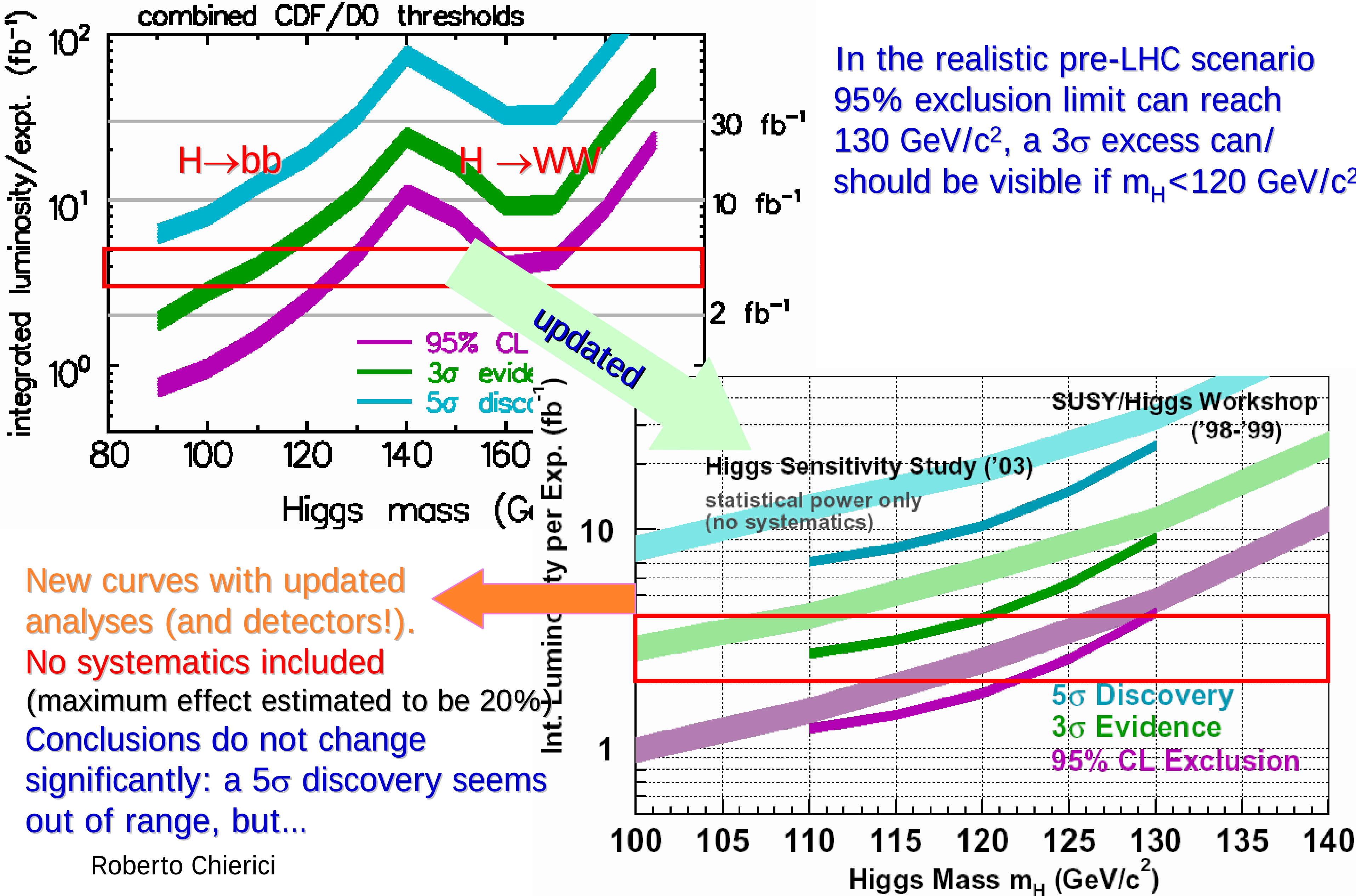

CDF Run II Preliminary (162 pb^{-1})

100 times the Higgs signal

Channels: llbb, $\nu\nu$bb,lνbb

No evidence for Higgs production will be possible in a single production channel, combination is needed

Discovery potential at the Tevatron



In the realistic pre-LHC scenario 95% exclusion limit can reach 130 GeV/c^2, a 3σ excess can/ should be visible if m_H<120 GeV/c

New curves with updated analyses (and detectors!).

No systematics included

(maximum effect estimated to be 20%)

Conclusions do not change significantly: a 5σ discovery seems out of range, but...

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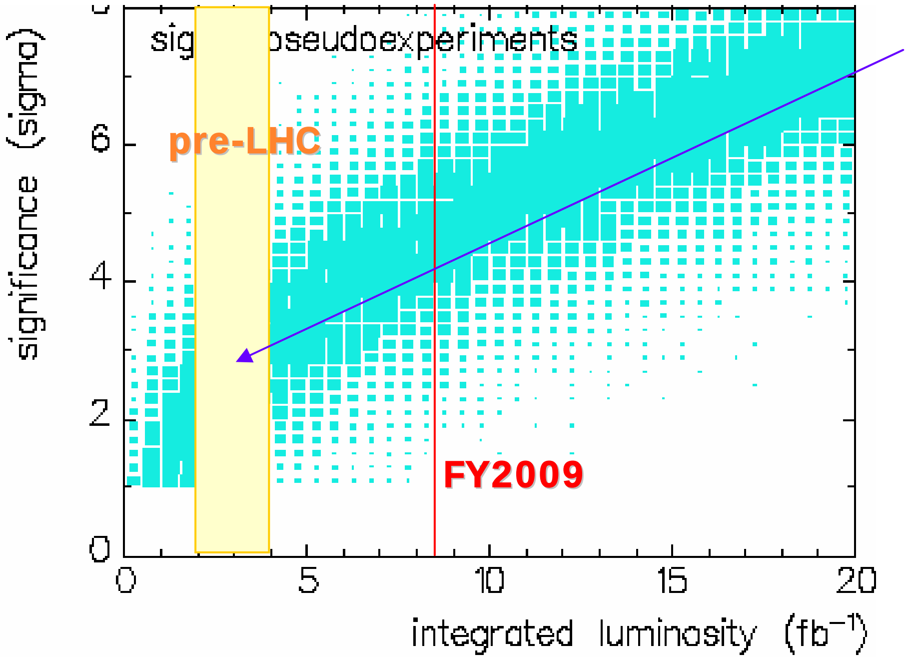
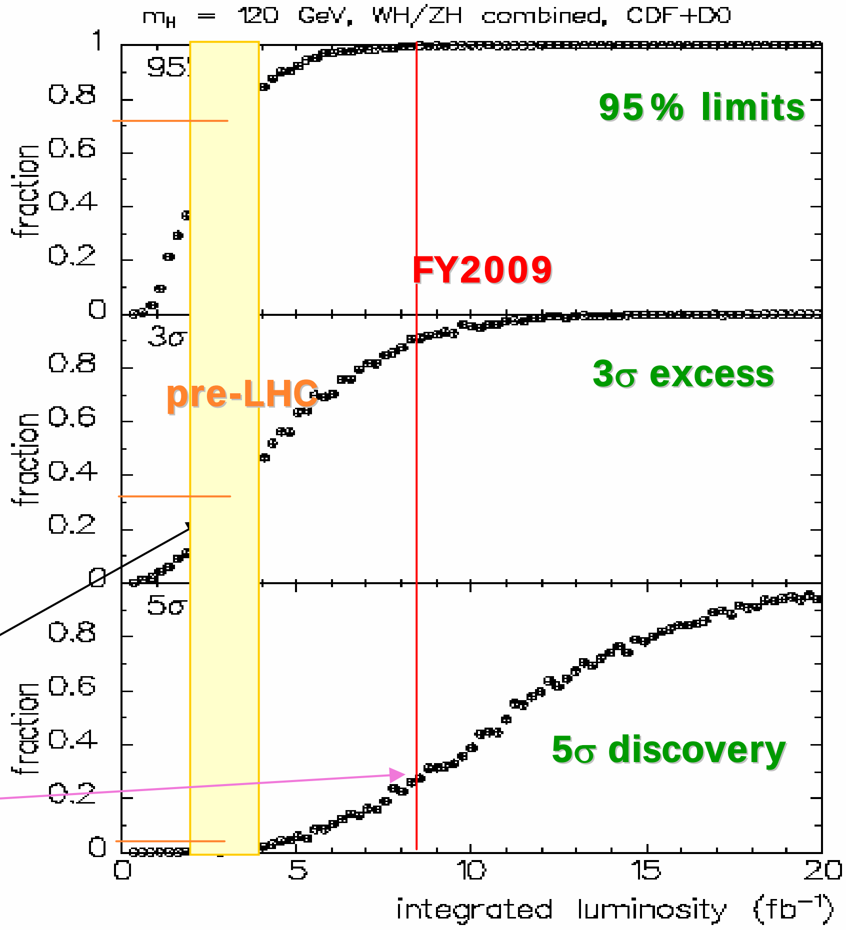
Around-the-corner SM Higgs

WH+ZH, 115 GeV/c^2, no systematics



If the Higgs is very close to 115 GeV/c^2,
A 3σ excess can be seen with only 3/fb.
8/fb or more needed for a 5σ discovery.

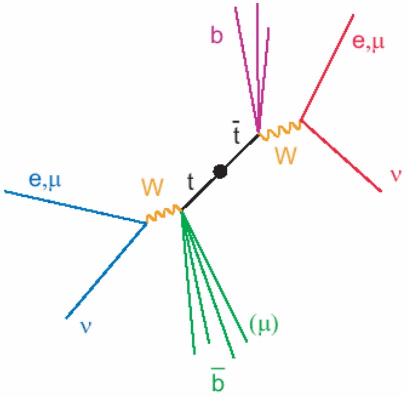


Fraction of pseudo-experiments satisfying a certain criteron for m_H=120 GeV/c^2.

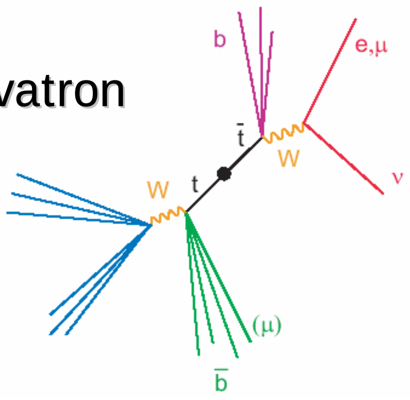
Example: there is a probability between 20 and 50% that Tevatron will have at least a 3σ excess before LHC if the Higgs mass is 120 GeV/c^2.

Example 2: there is a probability of 30% that Tevatron will have discovered the Higgs in 2009 if the Higgs mass is 120 GeV/c^2.

Near future of m_t



Tevatron



Tevatron only, through the analyses of di-lepton events or lepton+jet from the decay of the Ws

Status of inputs (preliminary):

$m_t=(178.0 \pm 2.7$ (stat) ± 3.3 (syst)) GeV/c^2

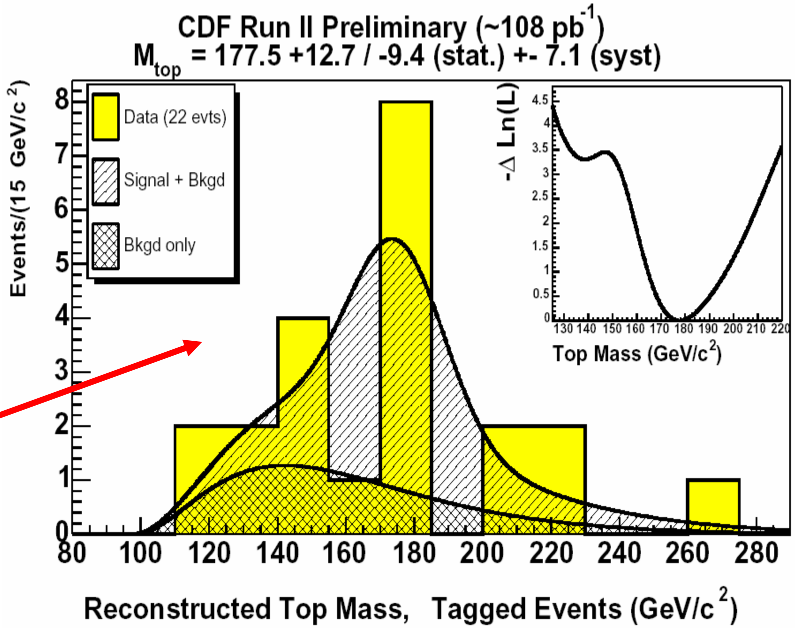
(latest Tevatron updated combination – RunI data)

$m_t=(175 \pm 17$ (stat) ± 8 (syst)) GeV/c^2

(CDF di-leptons – RunII data)

$m_t=(178^{+13}_{-9}$ (stat) ± 7 (syst)) GeV/c^2

(CDF lepton+jets – RunII data)



Perspectives: just a matter of statistics (also for the main systematics) and optimized use of the available information

One Tevatron experiment alone expects 500 b-tagged tt l+jets events/fb:

⇒ 2-3 GeV/c^2 can be expected for the Tevatron combined value per 2-4/fb

In 2009, if the upgrade plan is respected, an error on m_t of 1.5 GeV/c^2 from Tevatron alone is expected

Near future of m_W

	$q\bar{q}\ell\nu$	$q\bar{q}q\bar{q}$	Both
ISR/FSR	8	8	8
Hadronisation	19	18	18
Detector	14	10	14
LEP Beam Energy	17	17	17
Colour Reconnection	–	90	9
Bose-Einstein	–	35	3
Total Systematic	31	101	31
Statistical	32	35	29

!!

LEP is completing its W mass analyses+ combination

Bottleneck in the systematic part of the fully hadronic channel: FSI !

Not easy to say what will be the final error, hereafter I will assume it will stick to 40 MeV/c² (not unrealistic, anyway...)

$$m_W^T = \sqrt{2 p_l^T p_\nu^T (1 - \cos\Delta\phi)}$$

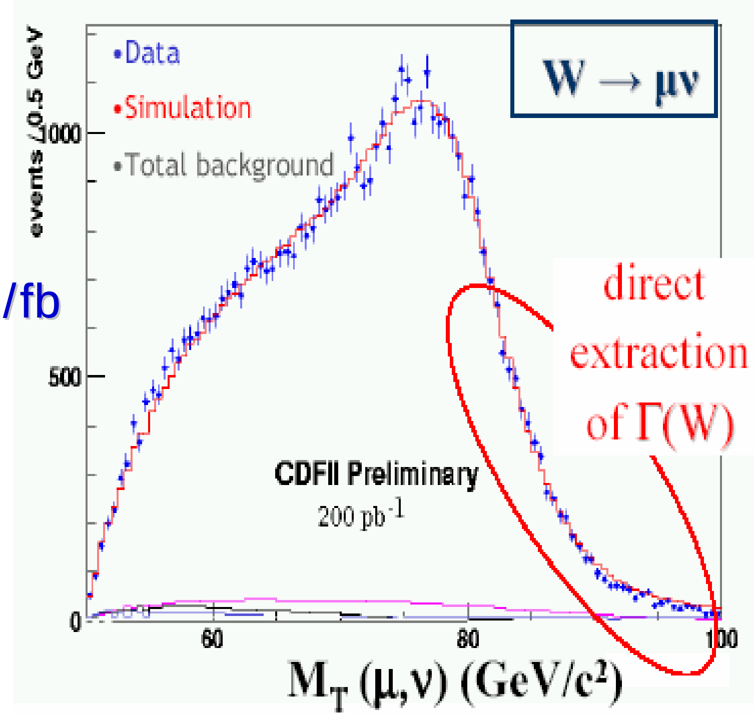
One Tevatron experiment alone expects:

δm_W=55 (stat) ± 80 (syst) MeV/c² per 100/pb

Statistics and systematics approximately scale with $N^{-1/2}$

⇒ 40 MeV/c² (exp) per experiment are expected per 2/fb (that makes about 30 MeV/c² CDF+D0 combined)

⇒20 MeV/c² combined can be in the reack for 4/fb

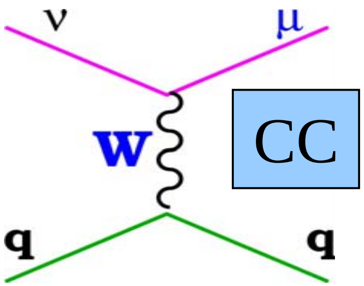


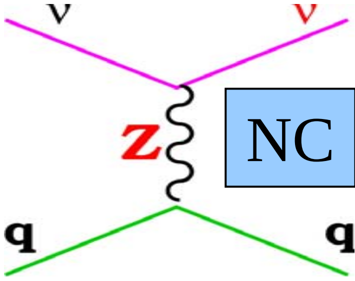
direct extraction of Γ(W)

In 2009, if the upgrade plan is respected, an error on m_W of 15 MeV/c² from Tevatron alone is expected

Near future of $\sin\theta_W$:NuTeV

$$R = \frac{\sigma(\nu N \to \nu X) - \sigma(\bar{\nu} N \to \bar{\nu} X)}{\sigma(\nu N \to \mu^- X) - \sigma(\bar{\nu} N \to \mu^+ X)} = g_L^2 - g_R^2 = \frac{1}{2} - \sin^2\theta_W$$





$\Rightarrow \sin\theta_W = 0.2277 \pm 0.0013(\text{stat}) \pm 0.009(\text{syst})$

Global SM fit: 0.2227 ± 0.00037

$\sin^2\theta_W \equiv 1 - m^2_W/m^2_Z \Rightarrow m^2_W = 80.14 \pm 0.08\ \text{GeV}/c^2$

- PDFs at ~LO, should be updated (work ongoing...)
- Asymmetries: s^-~0.002 agrees with theory and with the re-analysis of old DIS νN data, could explain 1/3 of the discrepancy
- Isospin violations ($u_p(x) \neq d_n(x)$) within the experimental reach could also explain 1/3 of the discrepancy
- Nuclear shadowing and other nuclear effect under study, though less convincing
- New physics/supersimmetry cannot easily account for this (f.i. Gambino hep-ph/0211009)
- EW corrections should be small (small sensitivity)

$$R = \frac{1}{2} - \sin^2\theta_W + K(\overset{\neq 0?}{\boxed{u^- - d^-}} + c^- - \overset{\neq 0?}{\boxed{s^-}})$$

$$q^- = \int_0^1 x[q(x) - \bar{q}(x)]dx$$

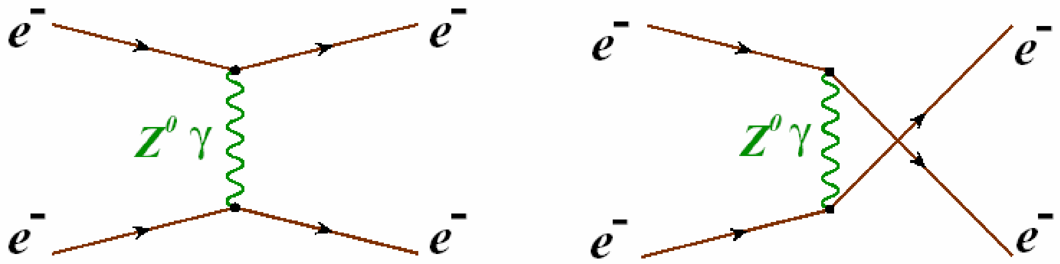
“MRST has performed a global analysis including possibility of isospin violation [...] this could potentially reduce NuTeV discrepancy by 1-1.5σ, although range of allowed isospin violation could also remove discrepancy altogether or make it worse [...] conclusion is that existing data allows level of isospin violation which could either solve NuTeV discrepancy or make it worse”

⇒If the theory error associated to the measurement does not account for this, it is underestimated

⇒Stay tuned for an update

http://home.fnal.gov/~gzeller/nutev.html#NLOQCDCorrections, linked from the main NuTeV page

Near future of sinθ$_W$: SLAC E158



$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

$$A_{PV} \propto (1 - 4\sin^2\theta_W)$$

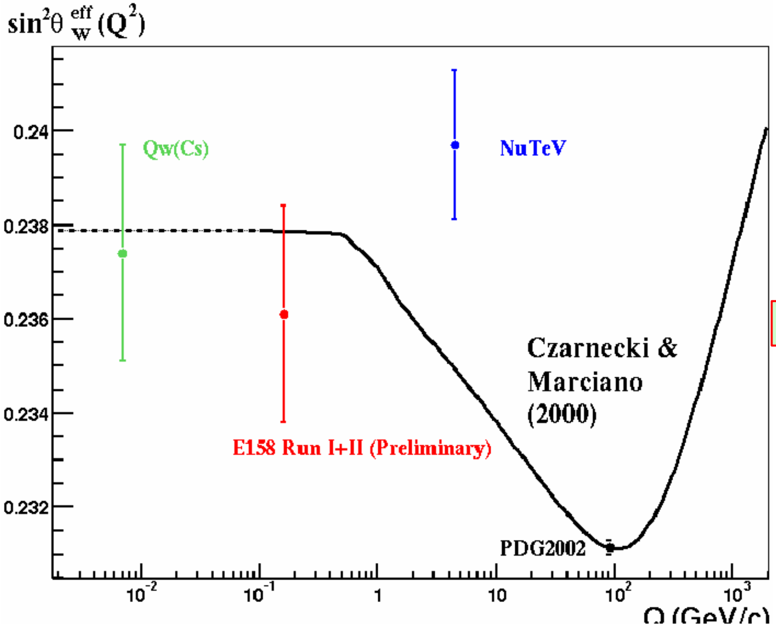
$$A_{PV}^{meas} = P_e \cdot A_{PV}$$

Parity violation in Moller scattering: at tree level A_{PV}=-3 10^{-7}

E158 goal: δsin^{2}θ$_W$~0.001

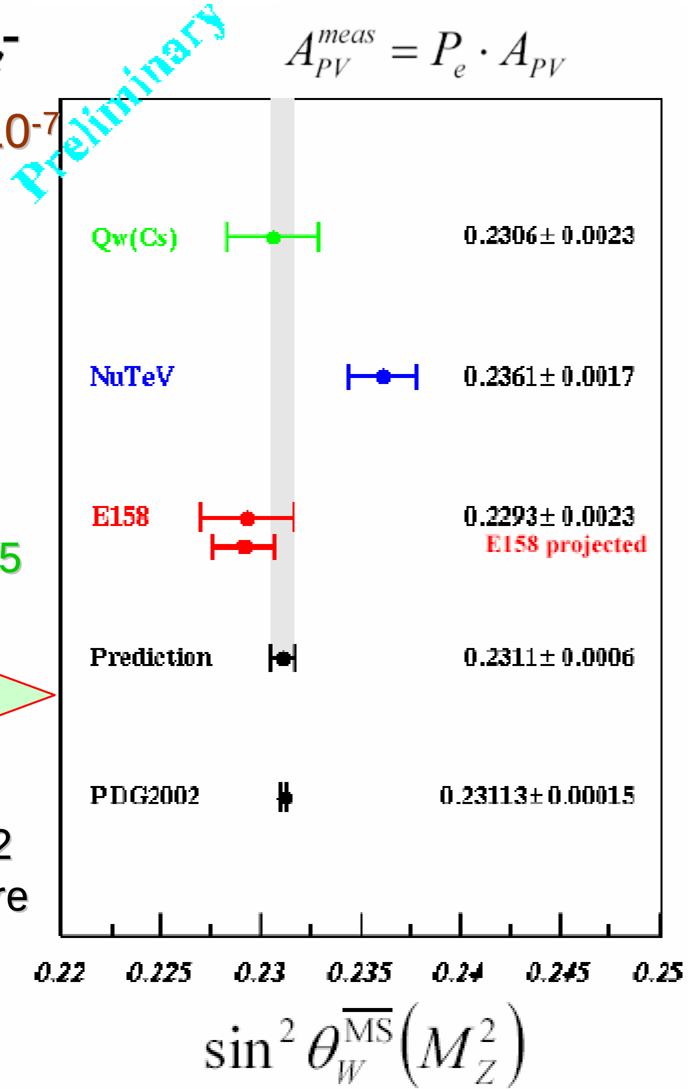
Best measurement of θ$_W$ away from the Z pole

(E=48 GeV; Q^2=0.03 GeV^2, beam polarisation ~ 85%)



Run III data being analysed: expect δsin^{2}θ$_W$(m$_Z$^{2})~0.0015 by Summer 2004

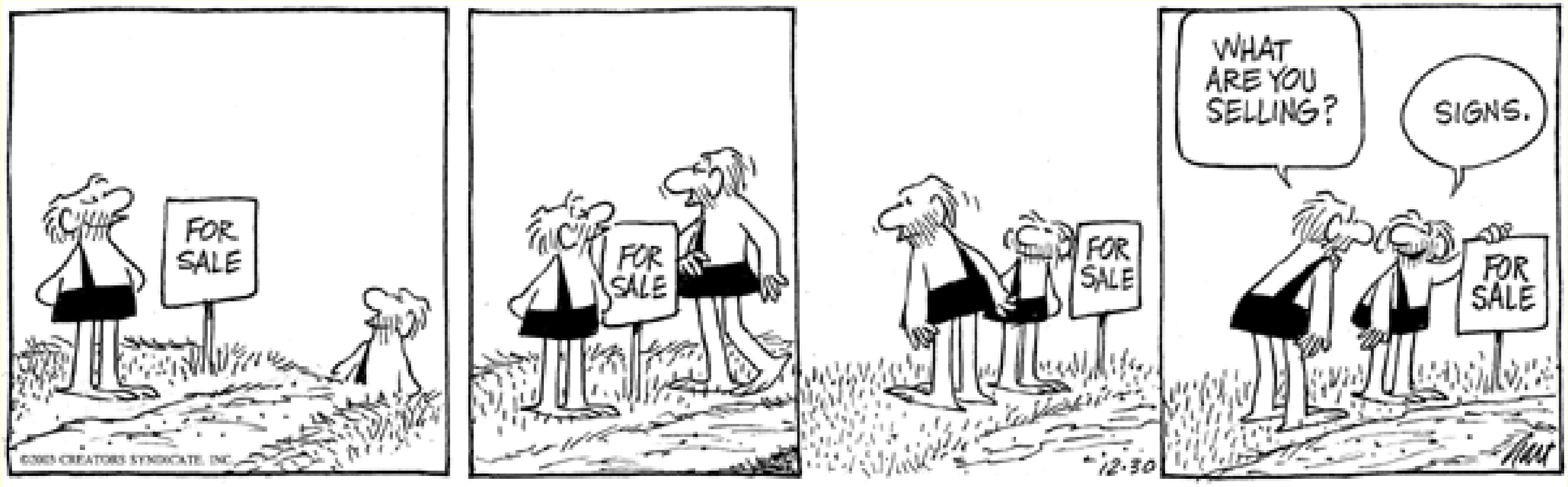
Other ideas for δsin^{2}θ$_W$(Q^2~0)~0.002 at nuclear reactors are around...



sin^{2}θ$_W$(Q^2=0.026GeV^2)=(0.2367±0.0017(stat) ±0.0014(syst))

Speculations

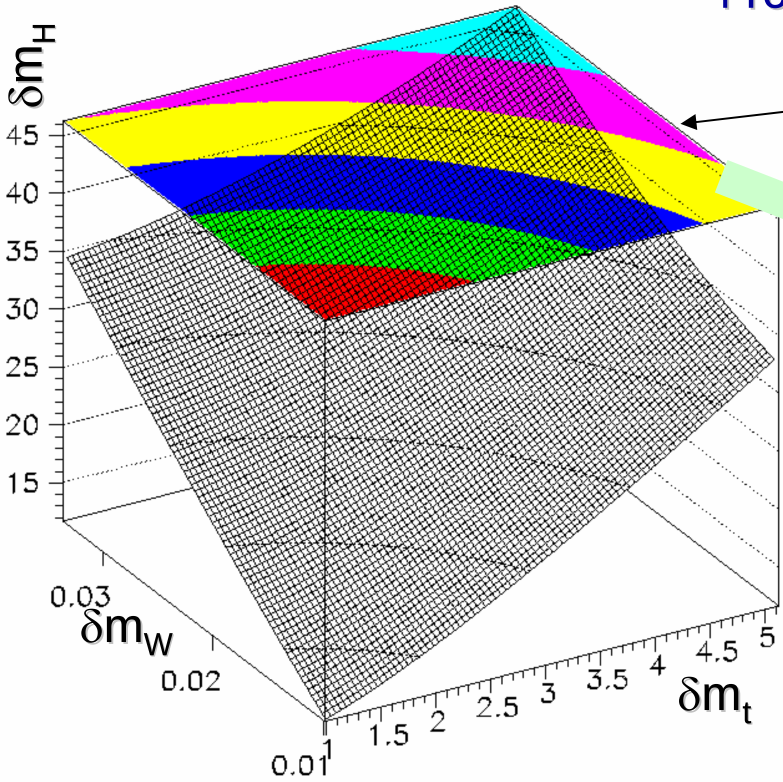
That’s what I am good at…

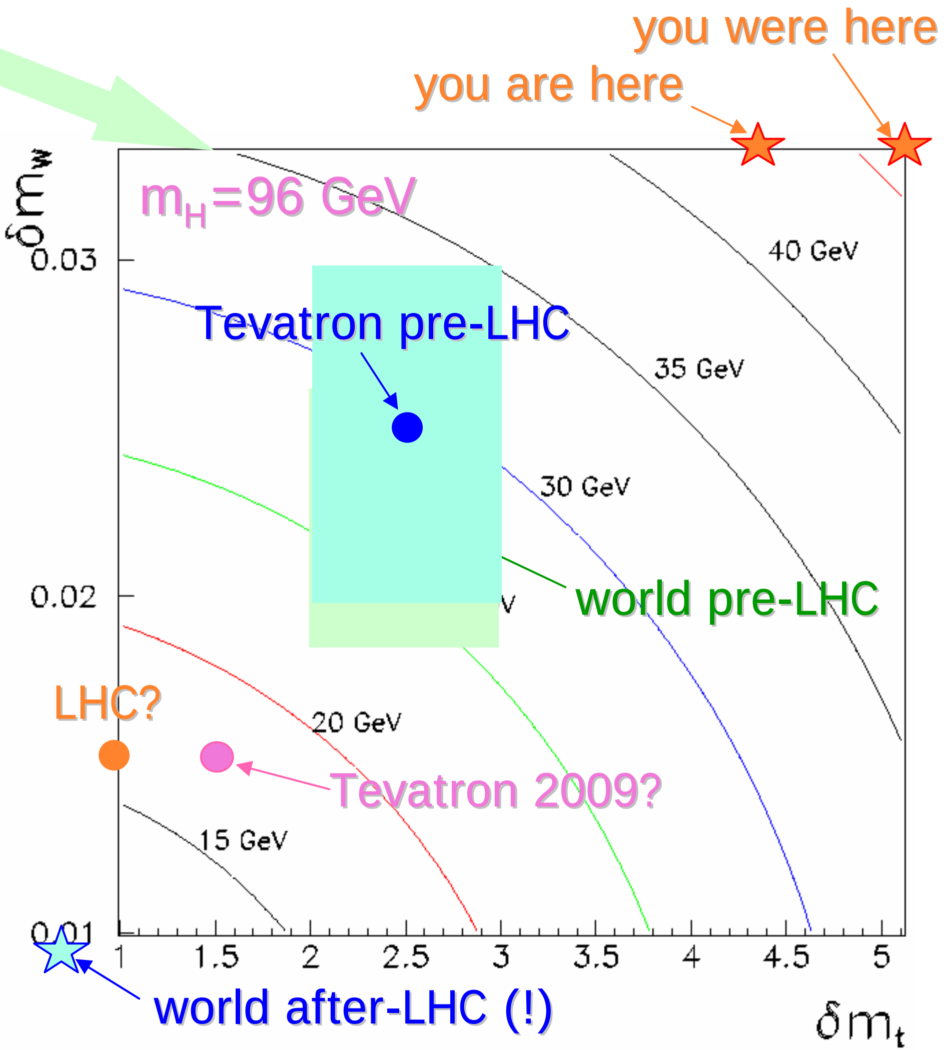


Indirect error on m_H

From the improved expected errors on m_W and m_t

Awramik, Czakon, Freitas, Weiglein, hep-ph/0311148
(analytical expression of m_W as a function of m_t and m_H
with two-loop corrections. Valid at the 0.5 MeV/c^2 scale)





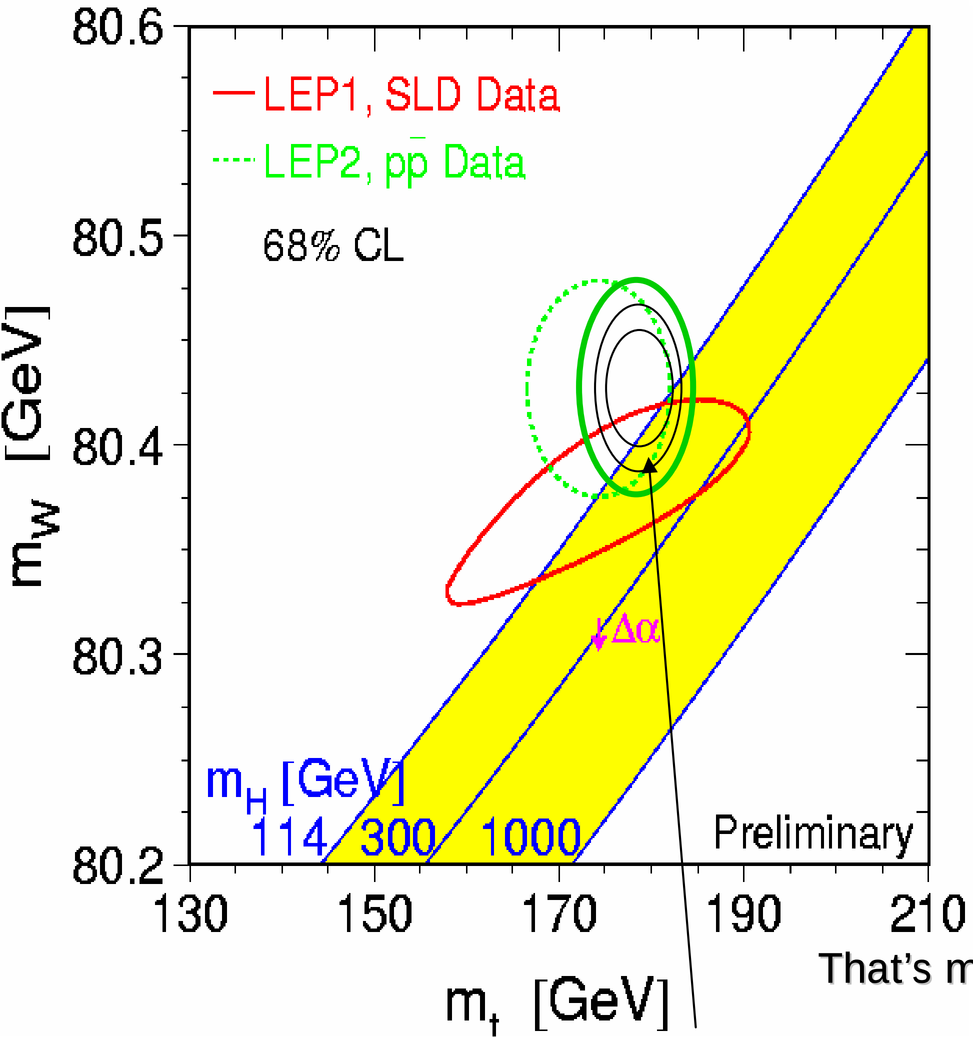
Thumb-rule for similar impact on m_H:

$$\delta m_W \approx 0.7 \times 10^{-2}\, \delta m_t$$

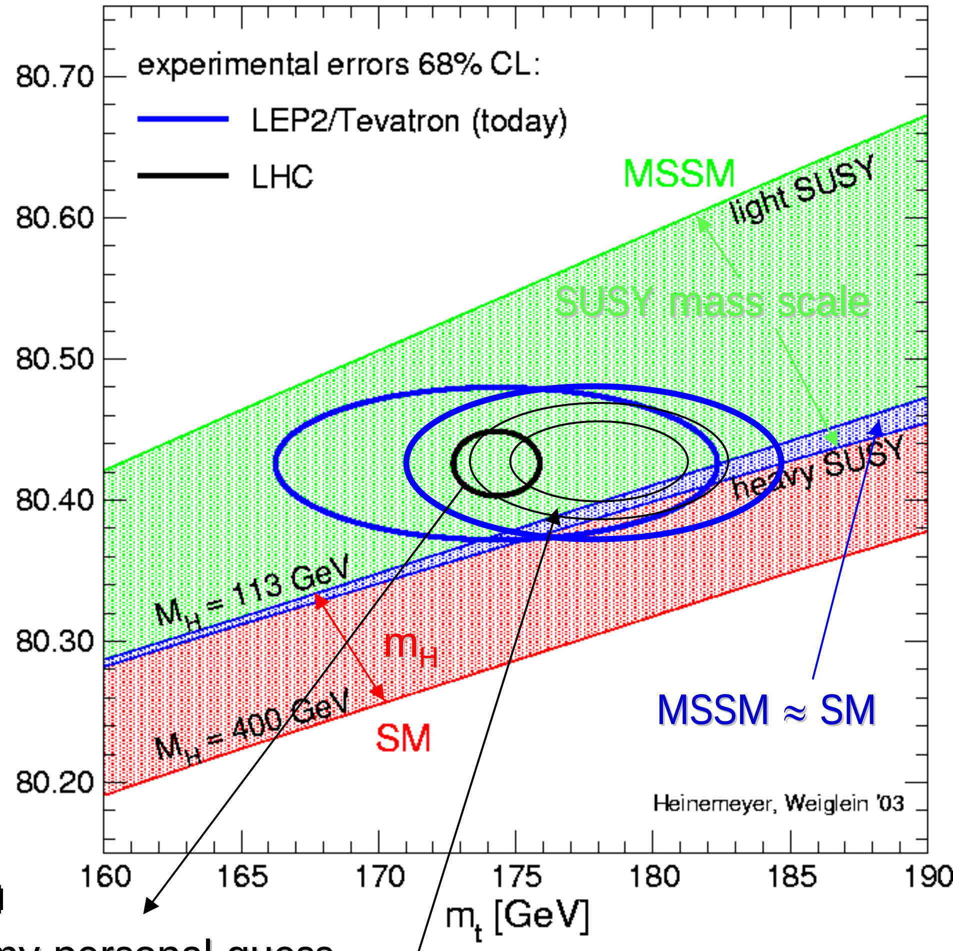
$\delta m_H / m_H \approx$ 51% 45% 28% 18% 10%

Roberto Chierici

Constraining in the pre-LHC era



Weiglein, Heinemeyer



That's my personal guess...

Reasonable range before LHC starts

Surprises in the indirect fit before LHC can come only if <m_t> and <m_W> will change

Conclusions

- LEP approaching the end of its inputs: m_W at the 40 MeV/c^2 level, no significant excess compatible with the SM Higgs boson.
- Tevatron is going well. There are different plausible perfomance pictures before LHC: here we have chosen a range of luminosities between 2 and 4/fb

- New Tevatron combination partly reconcile the SM fit with the unsuccessful Higgs direct searches
- In the pre-LHC era Tevatron is the key: dancing EW fit in the next years (m_t,m_W)

Anomalies here and there still present in the EW fit.

- The most controversial one (that will remain such for a long time) concerns the lepton vs quark asymmetries and their effect on m_H
- $\sin^2\theta_W$: changes expected from updated NuTeV and E158 inputs…

- In the Higgs-around-the-corner hypothesis chances are Tevatron closes the game
- In the mass regime of about 120 GeV/c^2 the Higgs will probably be a LHC+Tevatron discovery
- For higher masses only LHC can tell, but indications still can come from Tevatron
- In the absence of signal, the Higgs can be constrained in the SM up to 25% before the start of the LHC

Backup

Parametric and theory uncertainties

In the SM fit all “observables” are expressed in terms of a few input parameters
⇒ two sources of errors come into play in the fit

- Errors on the input parameters themselves (from data) propagate in the fit and give origin to the parametric uncertainties.
  - ⚐ dominated by the error on m_t
- Unknown higher orders in the predictions (truncation errors) also add uncertainties which are genuine theory uncertainties.
  - ⚐ dominated by errors on m_W and $\sin\theta_{eff}$.

	$\delta\sin\theta_{eff}(10^{-4})$	$\delta m_W(\mathrm{MeV}/c^2)$
PU m_t	3	30
PU $\Delta\alpha_{had}$	1	6
TU	0.6	4

The blue band in the m_H χ^2 curve includes the effect of all theory uncertainties

There is a general consensus that it can be determined by comparing codes with different, but equivalent, factorisation schemes or resummation techniques...a reasonable shortcut

The inclusion of higher order corrections in the codes improves the theory error:

- ✘ $\Delta\alpha_{had}$ –largest uncertainty to $\alpha(m_Z)$- is used in two different estimations, data driven (0.02761±0.00036 ⇒ $\delta m_W \sim 7$ MeV/c^2) or theory driven (0.02747±0.00012)
- ✘ m_W with fermionic and bosonic two loops correction ⇒ $\delta m_W \sim 4$ MeV/c^2

Perspectives pre-LHC:

$\sin^2\theta_{eff}=(1+\Delta k)\,\sin^2\theta_W$ at the two-loops (fermions and bosons) is close (Awramik et al)

Asymmetries

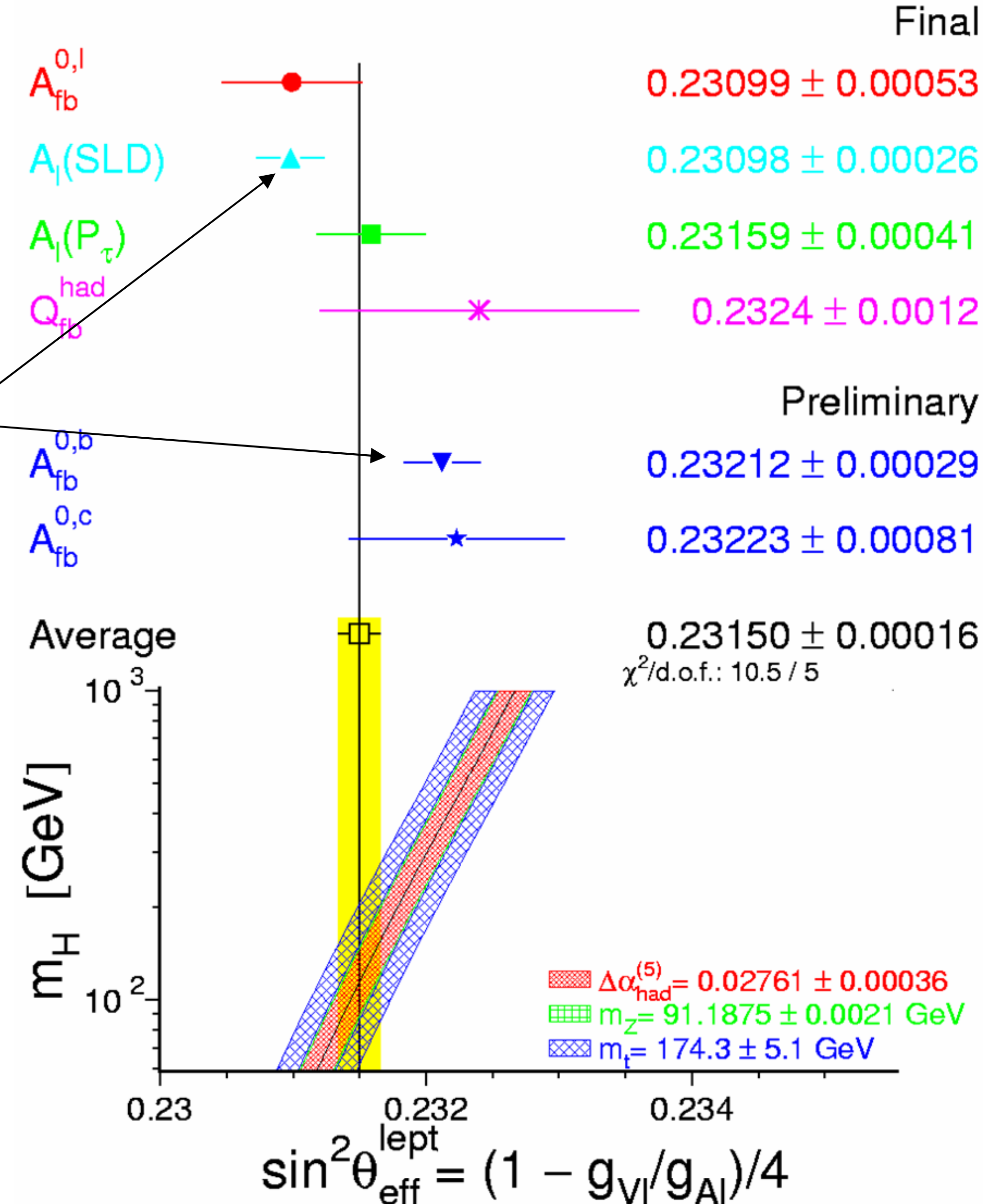
Assuming lepton universality:

$$\chi^2/\text{dof(lept.)} = 1.6/2 \ (P = 44.0\%)$$
$$\chi^2/\text{dof(hadr.)} = 0.06/2 \ (P = 96.8\%)$$
$$\chi^2/\text{dof(tot.)} = 10.5/5 \ (P = 6.2\%)$$

hadrons *vs* leptons 3σ

2.9σ between 2 most precise quantities

($\mathcal{A}_\ell$ and $A_{FB}^{0,b}$)



The precision observables

Are the ones that at tree level depend only on α_{em} ,G_F, M_Z, and $\sin\theta_W$

At tree level:

$G_F = \pi\alpha / \sqrt{2}\, m_W^2 \sin^2\theta_W$ relation between EM and Weak constants

$\rho \equiv m_W^2 / m_Z^2 \cos^2\theta_W = 1$ relation between neutral and charged weak coupling

The interaction of the Z with fermions is given by the left- and right- handed couplings g_L and g_R:

$g_L = \sqrt{\rho}\,(I_3 - Q \sin^2\theta_W)$ left fermions couple with Z and γ

$g_R = \sqrt{\rho}\,(Q \sin^2\theta_W)$ right fermions couples with γ

or alternatively Vector and Axial couplings:

$g_V = g_L - g_R$, $g_A = g_L + g_R$

$$\begin{cases} g_v = \sqrt{\rho}\,(I_3 - 2\,Q \sin^2\theta_W) \\ g_A = \sqrt{\rho}\, I_3 \end{cases}$$

$$A_{LR} = \sigma_{LR} / \sigma_{TOT} = A_e$$
$$= 2\, g_{Ae}\, g_{Ve} / (g^2_{Ae} + g^2_{Ve})$$
$$A_{pol} = \sigma_{pol} / \sigma_{TOT} = A_f$$
$$= 2\, g_{Af}\, g_{Vf} / (g^2_{Af} + g^2_{Vf})$$
$$A_{FB} = ¾\, \sigma_{FB} / \sigma_{TOT} = ¾\, A_e\, A_f$$

σ_{LR} difference between σ for Left and Right handed incoming fermions

σ_{pol} difference between σ for Left and Right handed outgoing fermions

σ_{FB} difference between σ for outgoing fermions going Forward or Backward

Radiative corrections

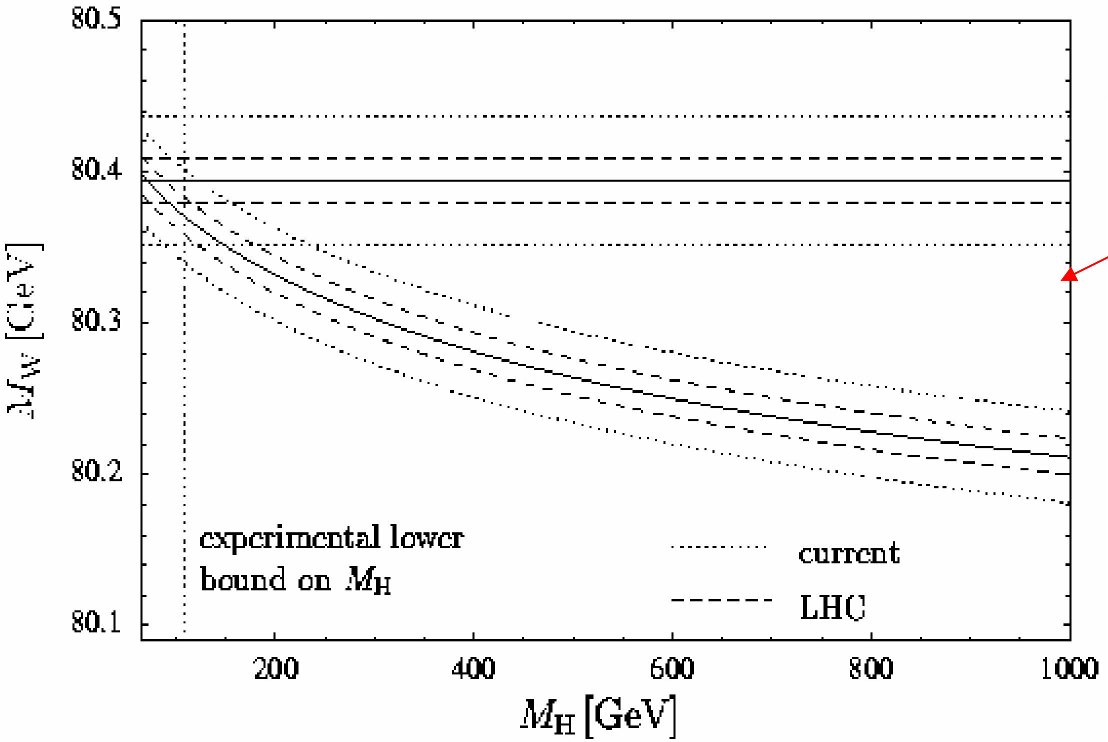
$$\rho = \frac{m_W^2}{m_Z^2 \cos^2\theta_W} = 1 \quad\Longrightarrow\quad \bar{\rho} = 1 + \Delta\rho$$

$$\sin^2\theta_W = 1 - \frac{m_W^2}{m_Z^2} \quad\Longrightarrow\quad \sin^2\theta_{eff} = (1 + \Delta\kappa)\sin^2\theta_W$$

$$m_W^2 = \frac{\pi\alpha}{\sqrt{2}\sin^2\theta_W G_F} \quad\Longrightarrow\quad m_W^2 = \frac{\pi\alpha}{\sqrt{2}\sin^2\theta_W G_F}(1 + \Delta r)$$

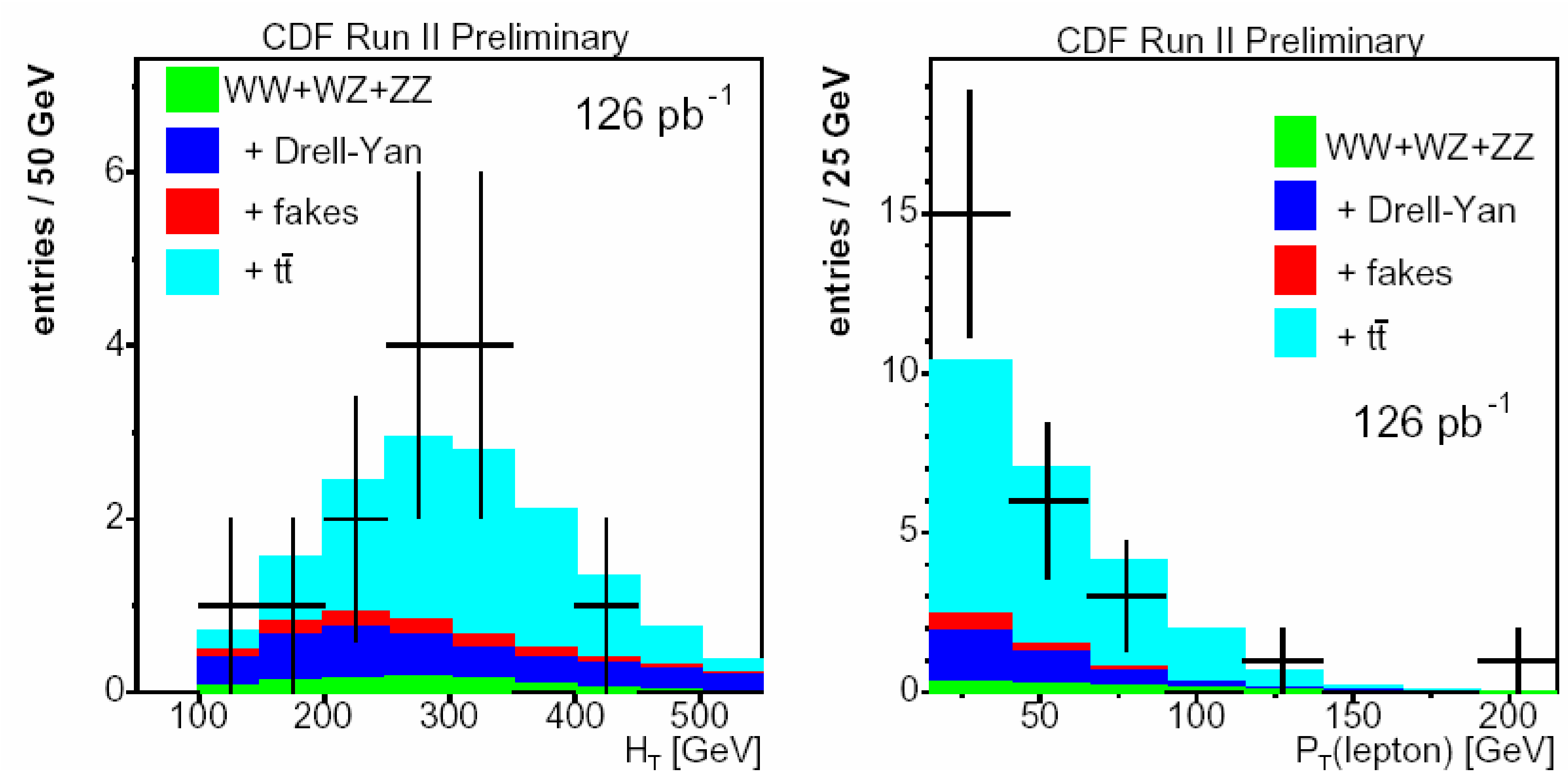
$$\alpha(0) \quad\Longrightarrow\quad \alpha(m_Z^2) = \frac{\alpha(0)}{1 - \Delta\alpha}$$

with : $\Delta\alpha = \Delta\alpha_{lept} + \Delta\alpha_{top} + \Delta\alpha_{had}^{(5)}$

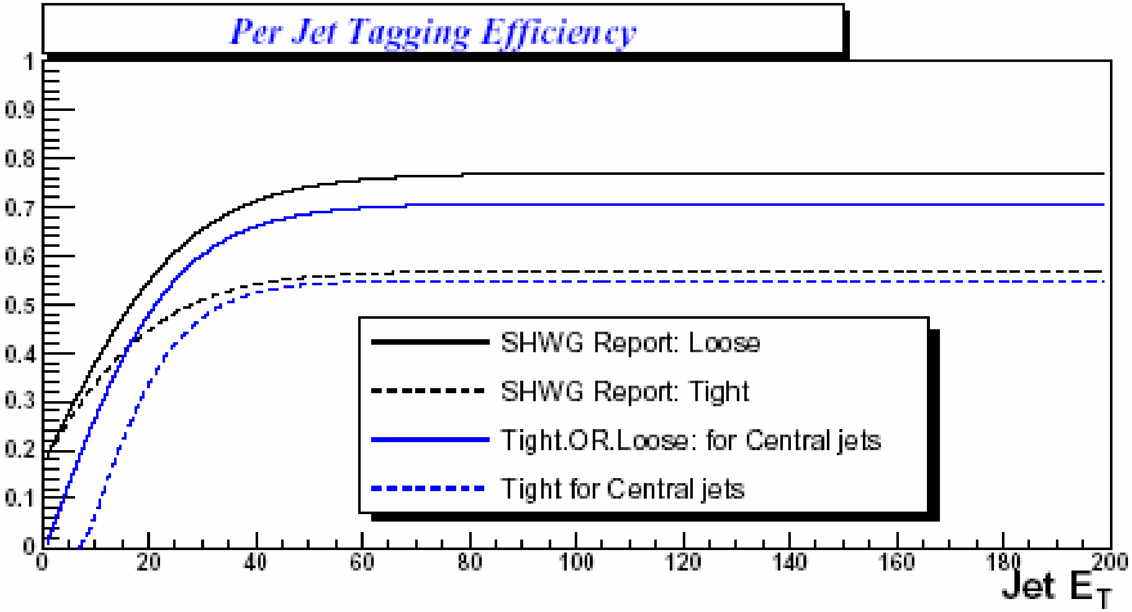


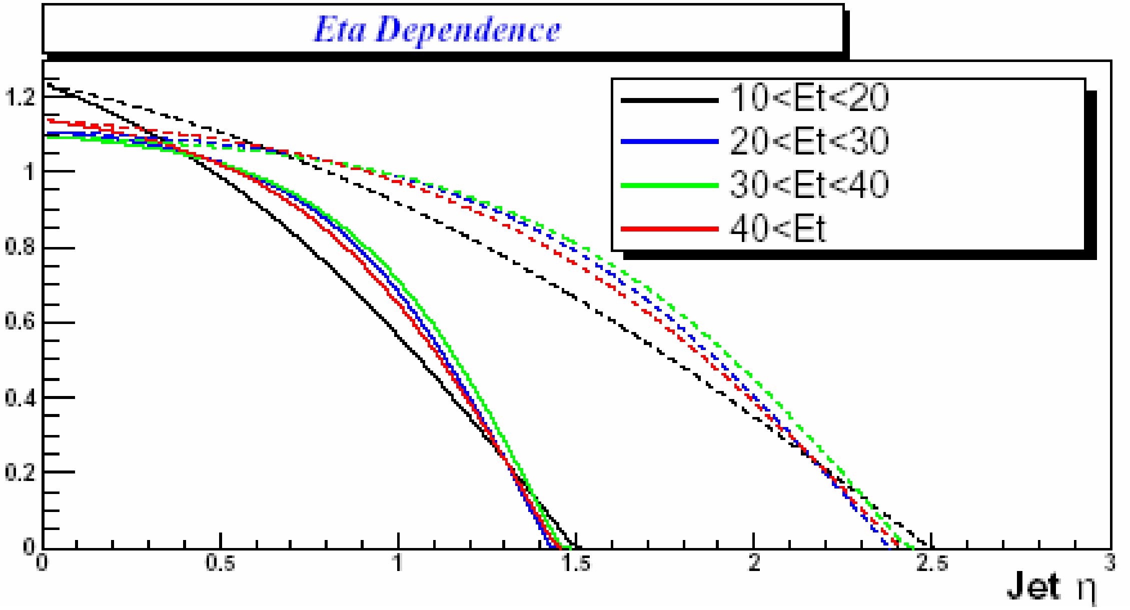
$$\Delta\rho, \Delta\kappa, \Delta r = f\left(m_t^2, \log(m_H), \ldots\right)$$

Top evidence at RunII

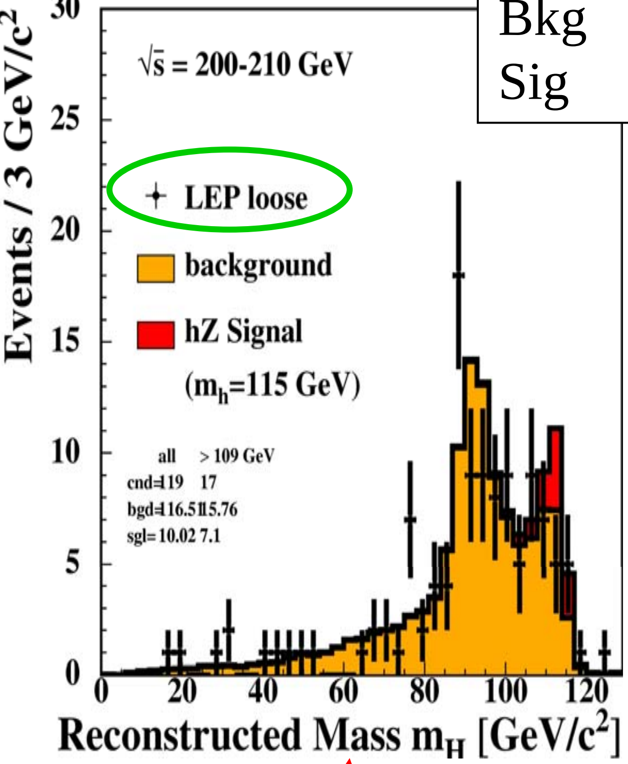


Tevatron b-tagging

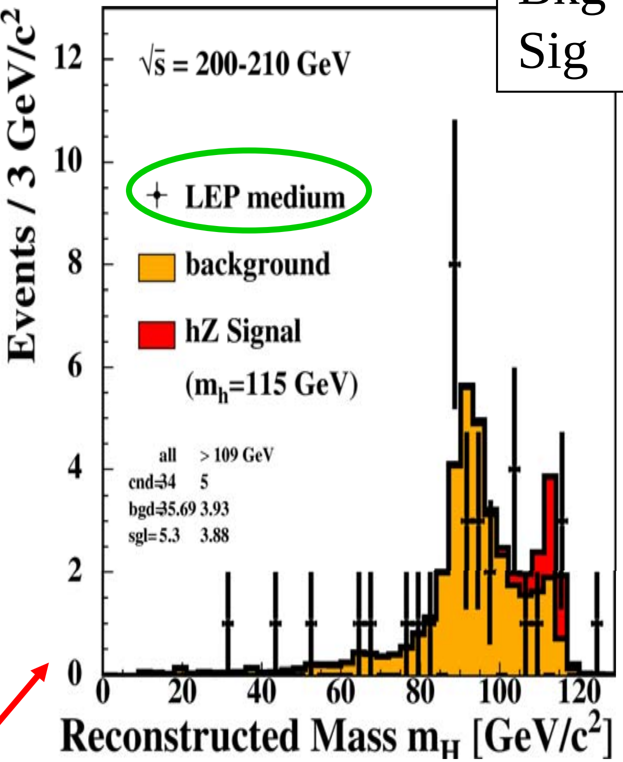




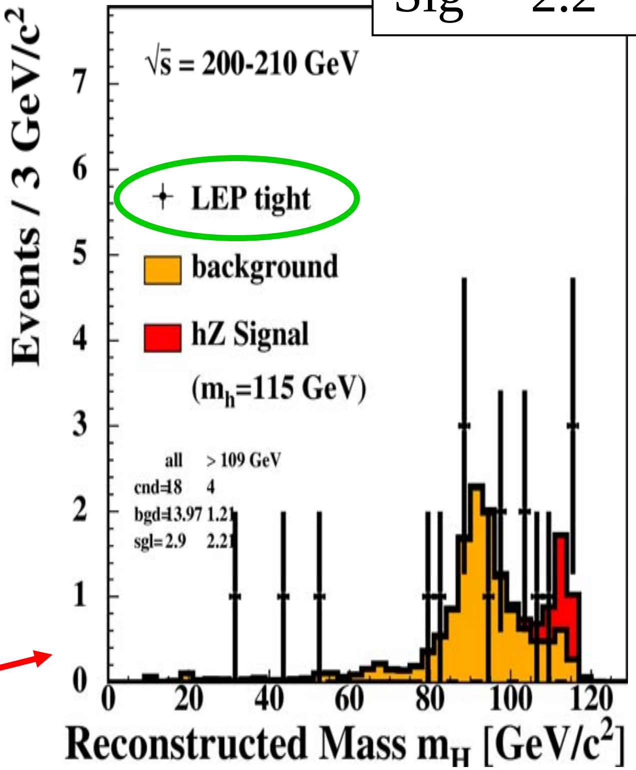
Mass distributions



Data 17
Bkg 15.8
Sig 7.1



Data 5
Bkg 3.9
Sig 3.8



Data 4
Bkg 1.2
Sig 2.2

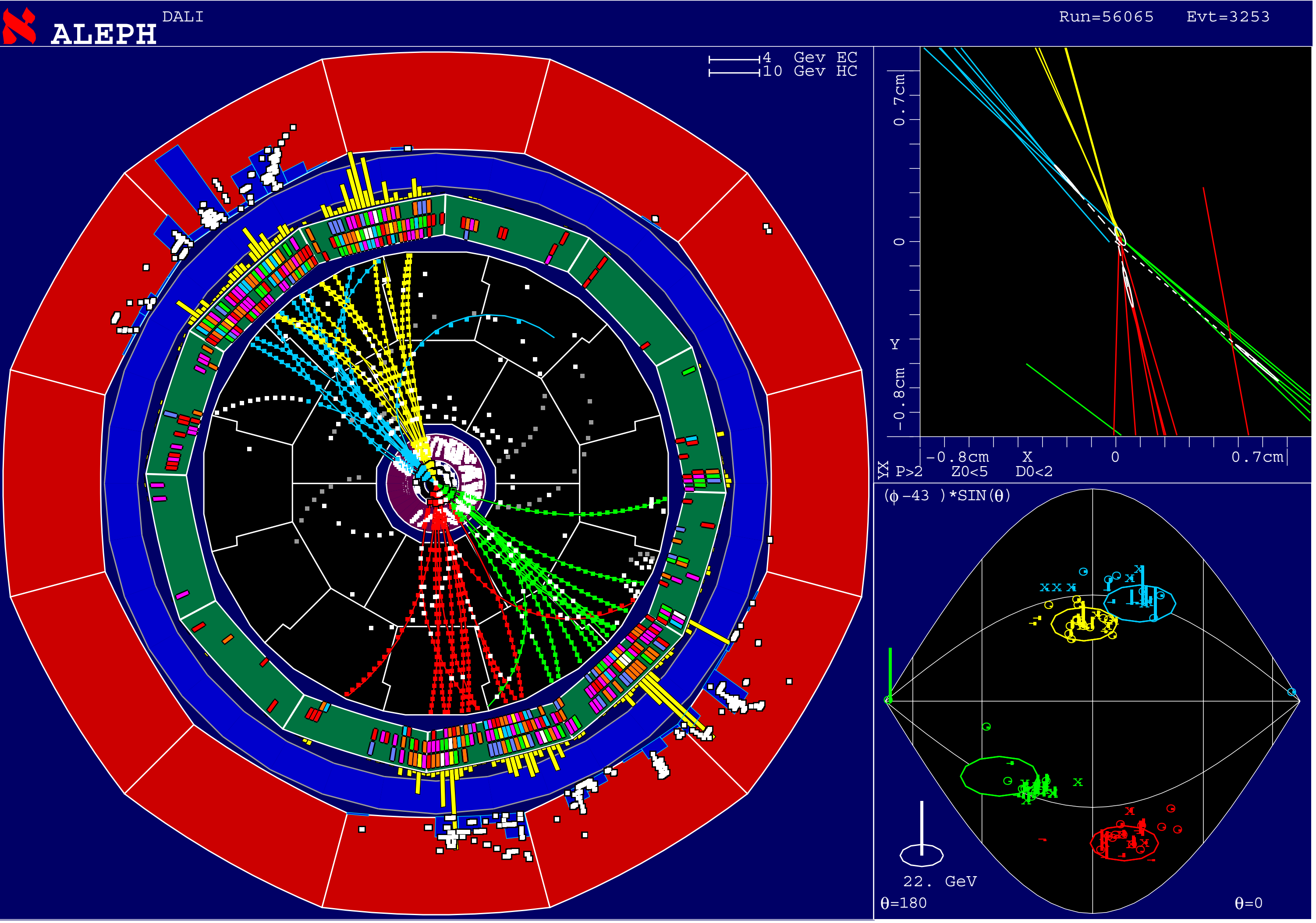
>0.5

>1

>2

S/N for reconstructed m_H>109 GeV/c^2

The candidate



4 b cand.

HZ hyp.
m_H=114.4 GeV/c^2

NN = 0.997

jet	**b-tag:**
	Z
1	**0.994**
2	**0.78**
	H
3	**0.993**
4	**0.999**

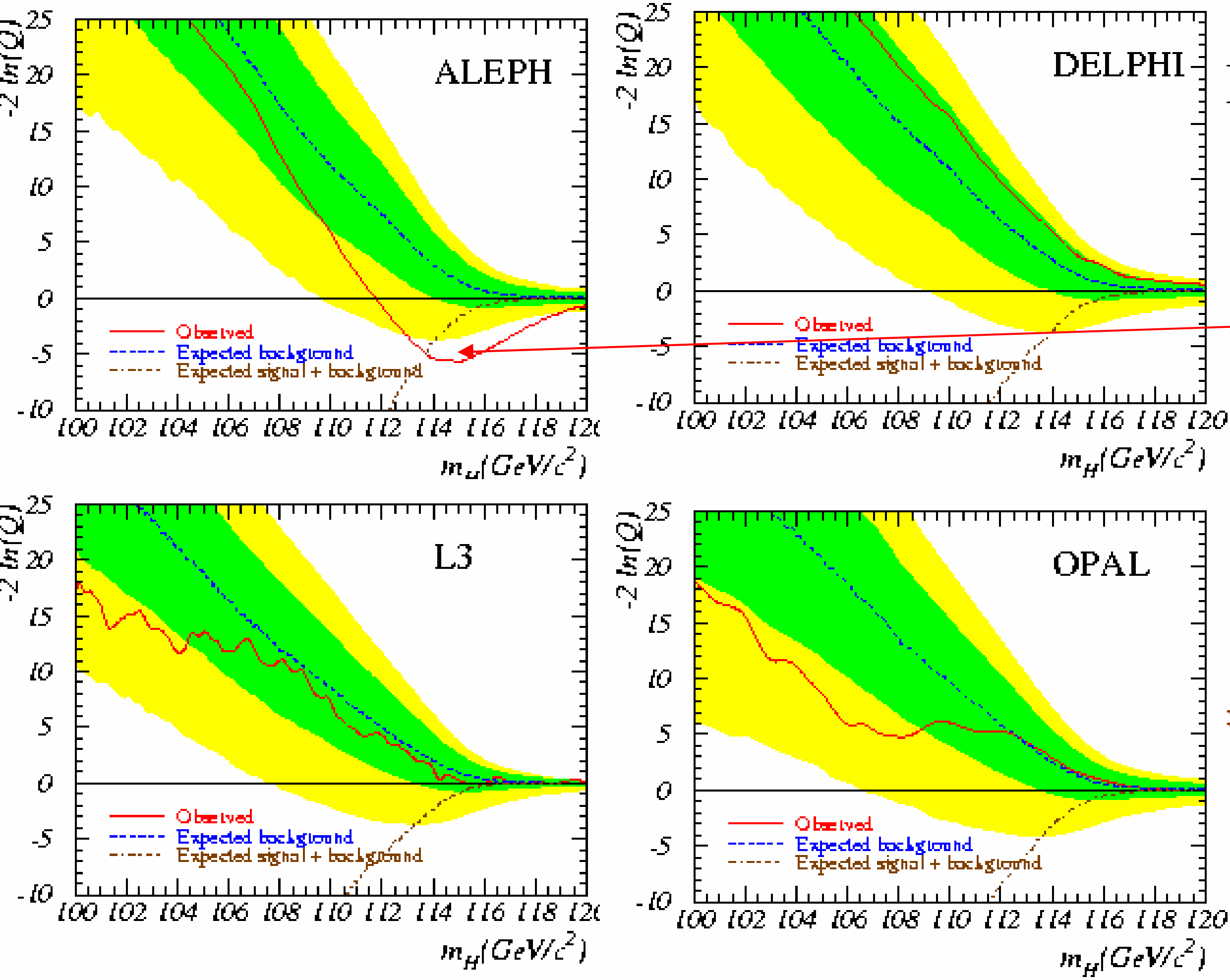
ZZ hyp.
m_Z=97 GeV
m_Z=94 GeV

A 22 GeV shower in SICAL that was giving Evis = 252 GeV is rejected by a better algorithm : m_H= 112.8 –> m_H=114.4

The Higgs per experiment

Observed and expected behaviour of the test statistics per experiment

$$-2\ln Q = -2\ln\frac{L_{s+b}}{L_b} = -2\ln\frac{\prod_i P_{s_i+b_i}}{\prod_i P_{b_i}} = -2\sum_i\left\{\ln P_{s_i+b_i} - \ln P_{b_i}\right\} = 2s_{tot} - 2\sum_i n_i \ln\left\{1+\frac{s_i}{b_i}\right\}$$



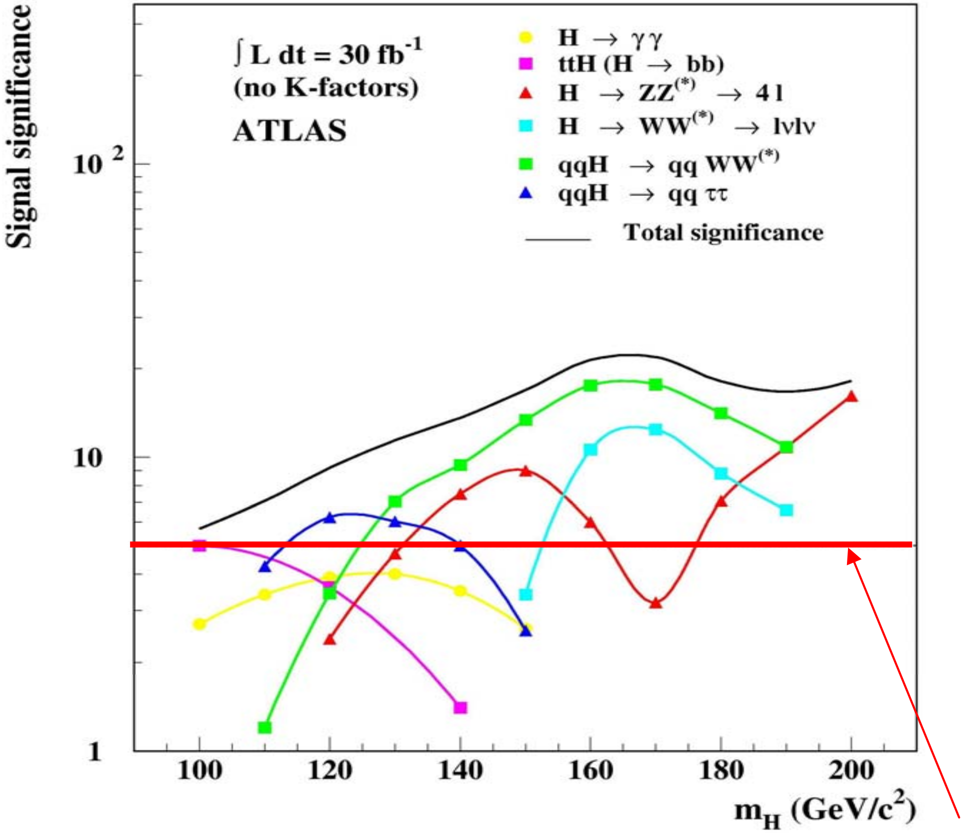
$$\ln P = \ln\frac{e^{-\mu}\mu^n}{n!} = -\mu + n\ln\mu - \ln n!$$

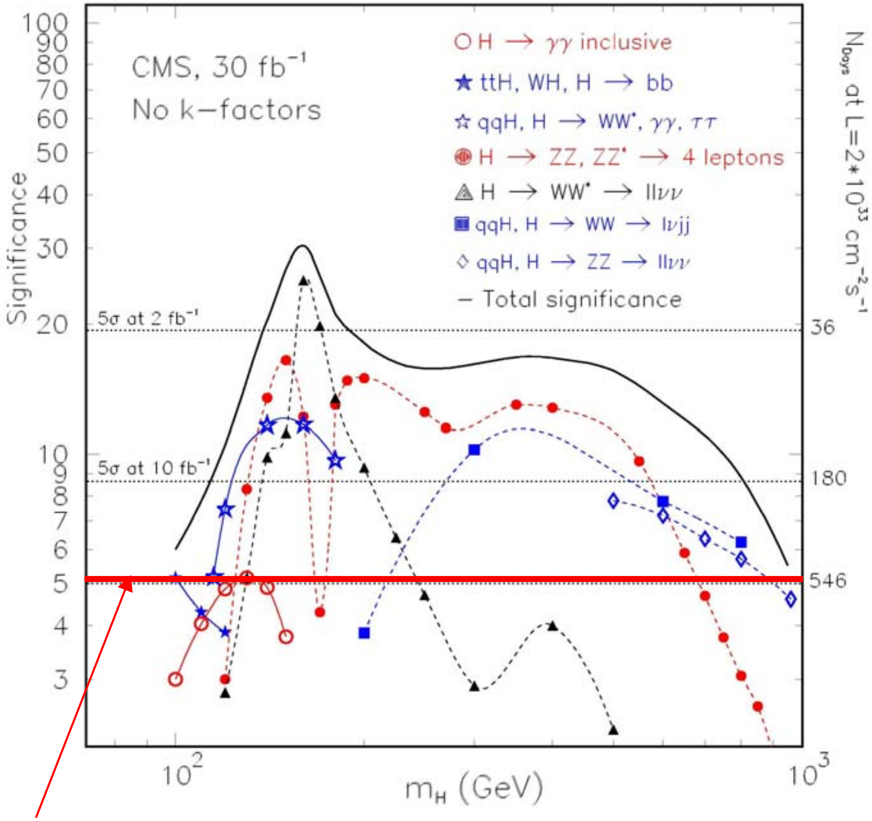
~ 3σ effect

None of the experiment can claim a discovery !

⇒ worth running another year?

SM Higgs search at the LHC





5σ

No holes in m_H coverage !

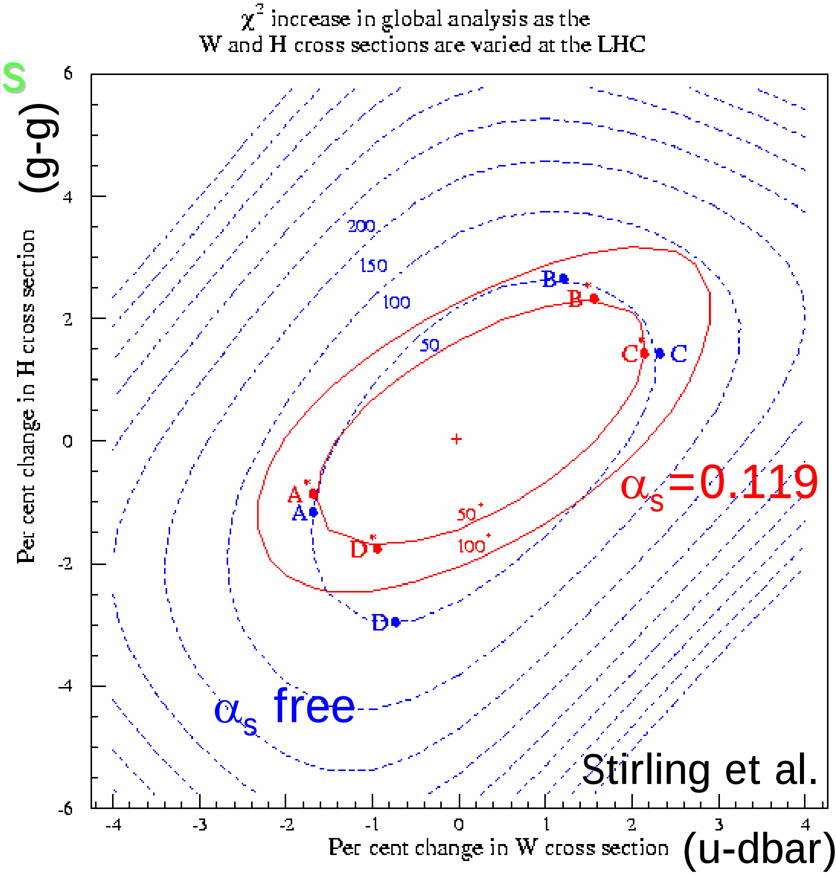
Discovery happens early in the game (the plots are for 30/fb)

Constraining pdfs at the LHC

How? For an s-channel process (W, Z, W/ZW/Z, tt) $m^2=sx_1x_2$ and $y=1/2\ln(x_1/x_2)$

$$\frac{dN_X}{dy} = \frac{d\sigma_{qq,gg\to X}}{dy} \bullet L \bullet pdf_{qq,gg}(x_1,x_2;Q^2)$$

$\Rightarrow x_{1/2} = e^{\pm y}\, m/\sqrt{s}$



From the shape of y differential cross-sections we can constraint different pdfs

(one can measure L•pdf)

$\Rightarrow$ Single W, Z, W/ZW/Z can bring info on regions of x close to tt production
(q-antiq x range between 3 10^{-4} and 0.1)

$\Rightarrow$ γ or Z+jet can help in the q-g case
(g x range between 5 10^{-4} and 0.2)
($x_{b,c}$ range between 10^{-3} and 0.1)

$\Rightarrow$ W+jet can help for x_s

$\Rightarrow$ $d\sigma/dy(W^-)/d\sigma/dy(W^+) \approx d(x_1)/u(x_1)$ at large y

$\Rightarrow$ All the high Q^2 region is covered !
A few % on g and light quarks -syst. » stat.
And 5-10% on s, c, b might be reached

To which extent can we extrapolate from q-q ↔ g-g?

b fragmentation

CDF and D0 b-quark production data show an excess over NLO theory predictions by about a factor two or more

experiment

$$\frac{d\sigma^B}{dp_T} = \frac{d\sigma^b}{dp_T} \otimes D^{b\longrightarrow B}(z)$$

pQCD

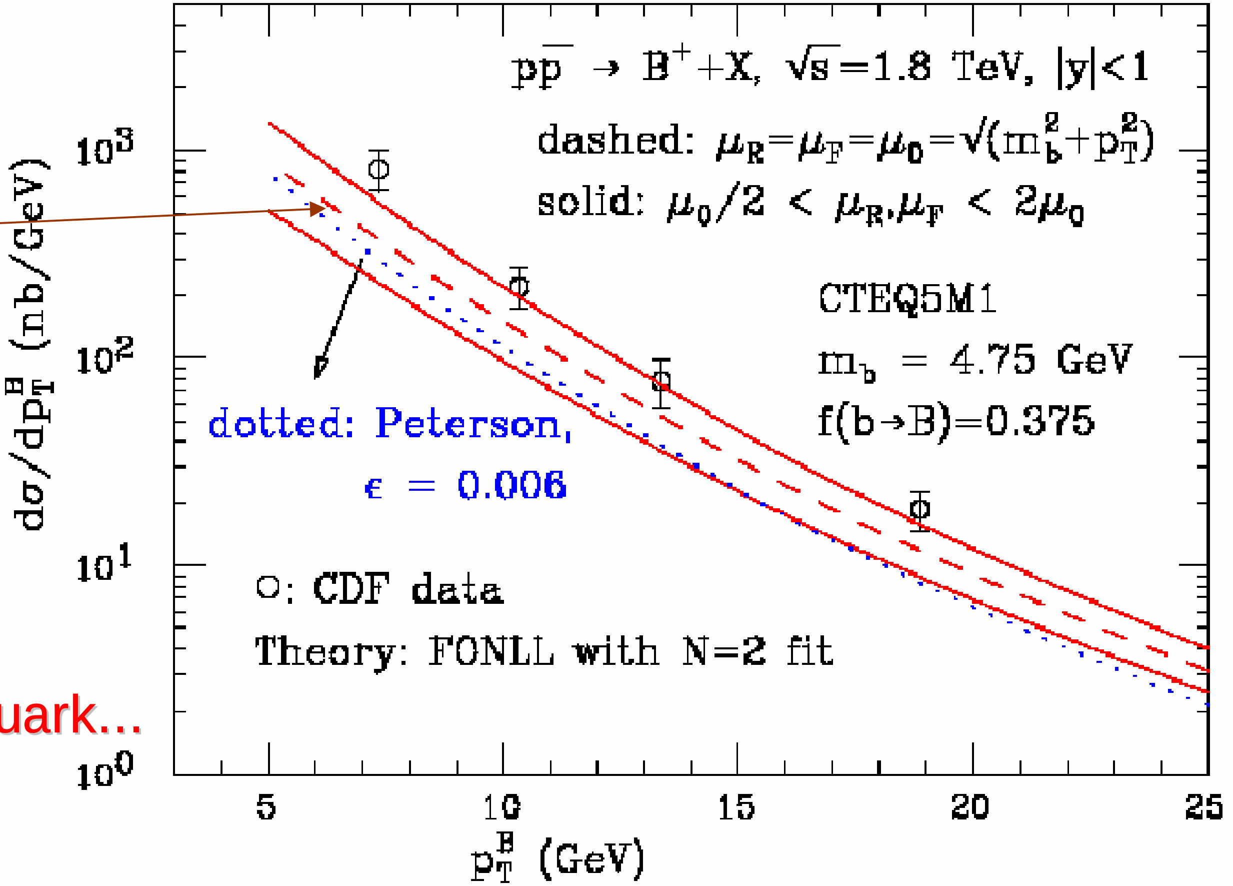
bridge: f.i. Peterson fragmentation function

Replace Peterson with non-perturbative fragmentation function determined from e^+e^- data with N=2 fit in moments space

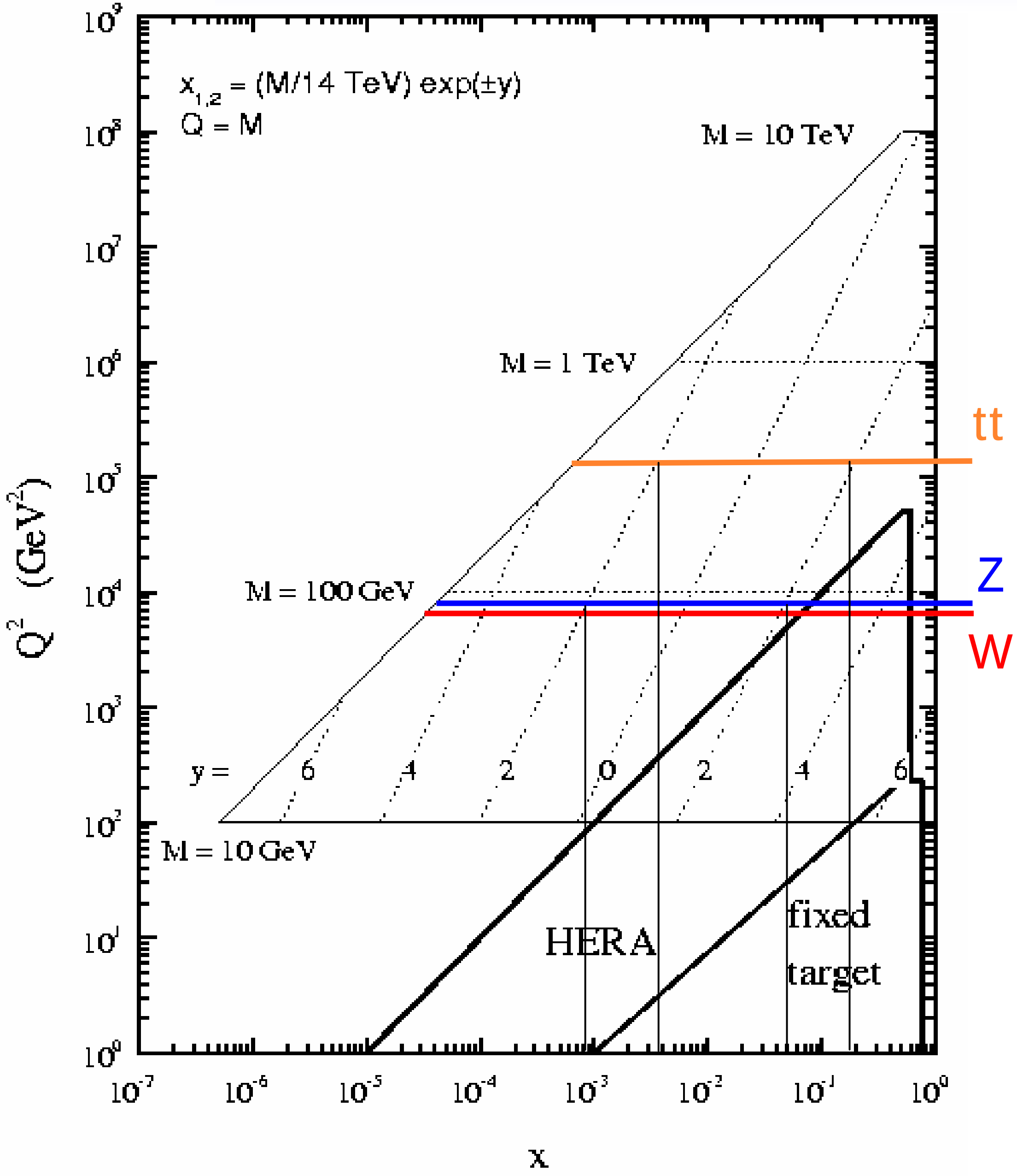
⇒ agreement with data drastically improved…

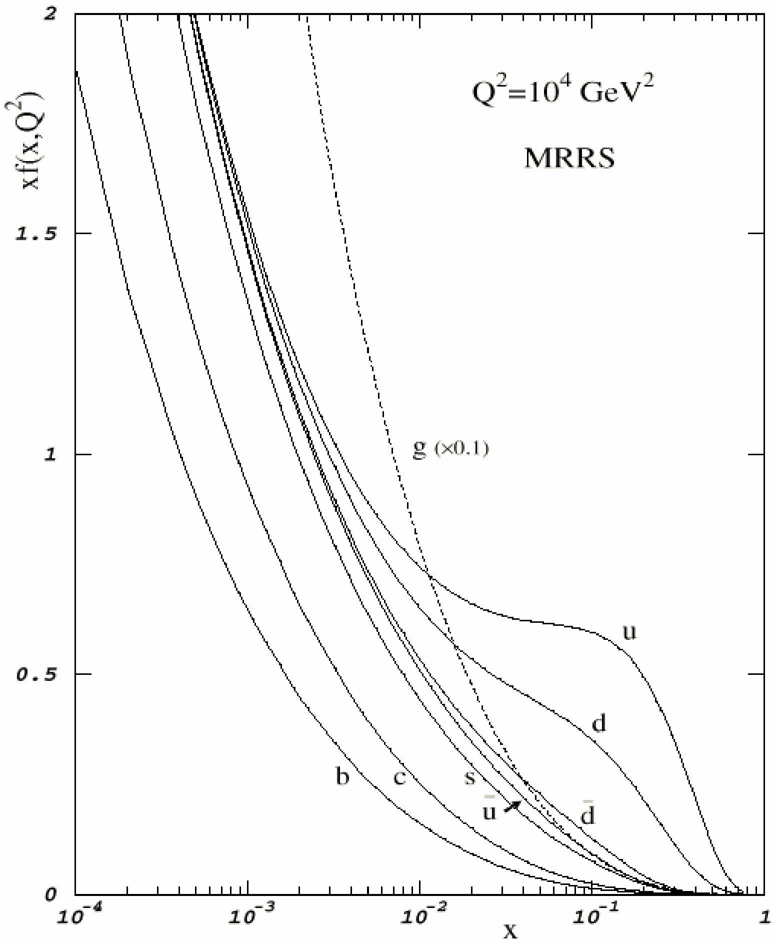
⇒ still unclear how to realistically determine a systematic due to the fragmentation of the b-quark…

⇒ we are bound to wait…



LHC parton kinematics

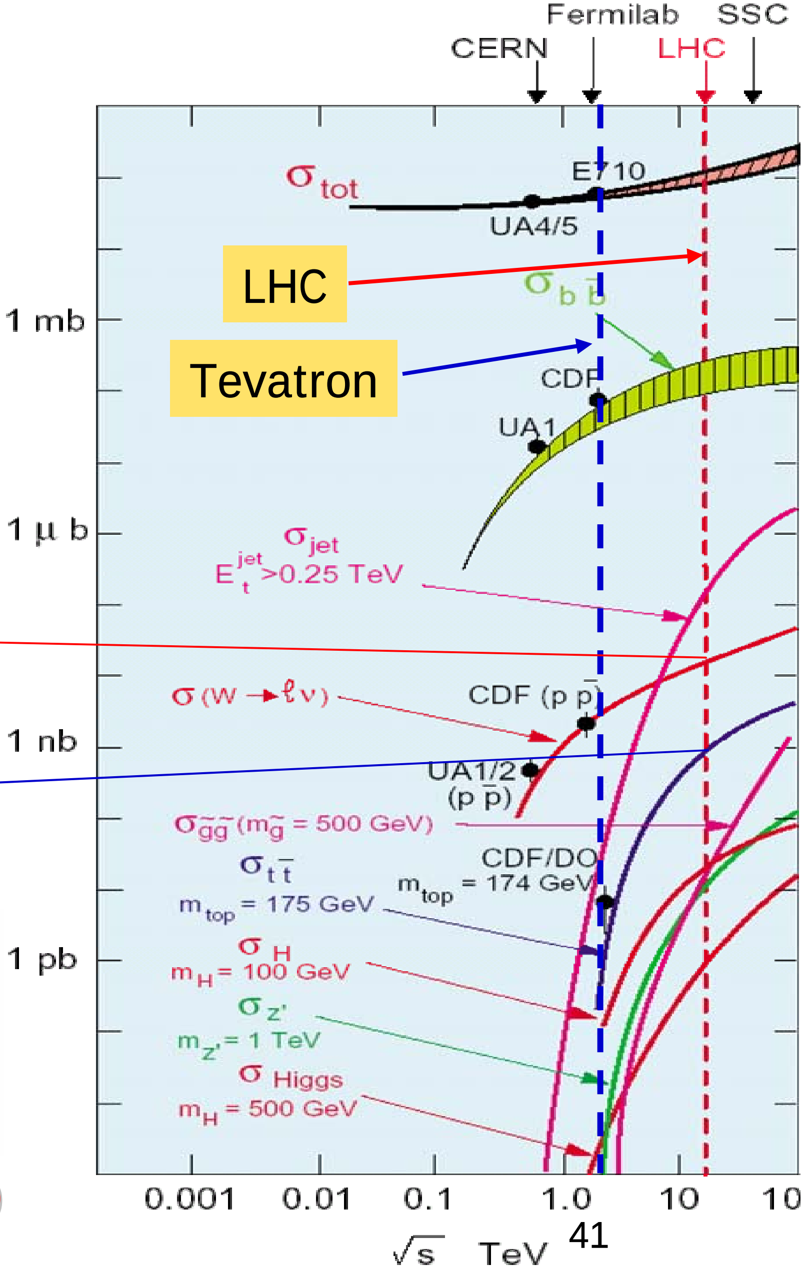


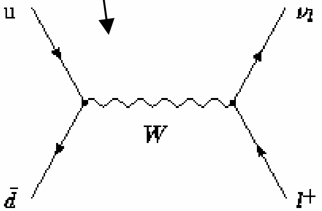


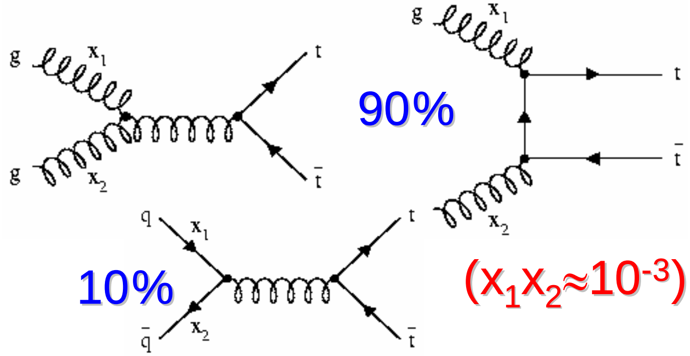
Expected statistics

	E_{CM} TeV	Lumi $cm^{-2}s^{-1}$	Int. Lumi/y fb^{-1}
TeVatron	2	$<10^{32}$	0.3
LHC(low lumi)	14	2×10^{33}	10
LHC(high lumi)	14	10^{34}	100

process	σ(pb)	Events/s	Events/y
bb	5×10^{8}	10^{6}	10^{12}
Z→ee	1.5×10^{3}	~3	10^{7}
W→eν	1.5×10^{4}	~30	10^{8}
WW→eνX	6	10^{-2}	6×10^{3}
tt	830	~2	10^{7}
H(700 GeV)	1	2×10^{-3}	10^{4}







90%

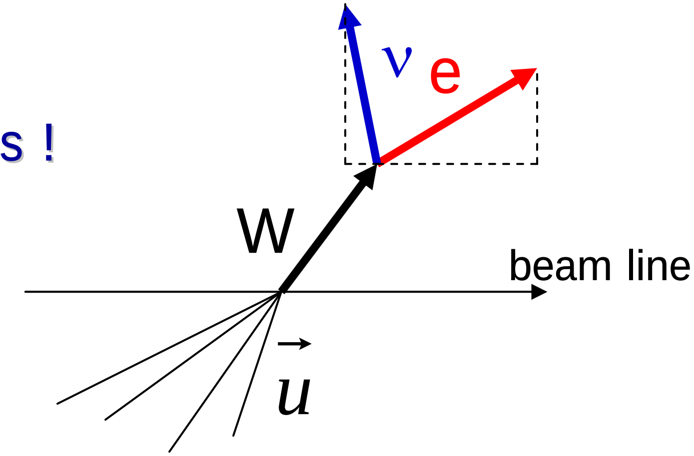
10%

$(x_1 x_2 \approx 10^{-3})$

The W mass

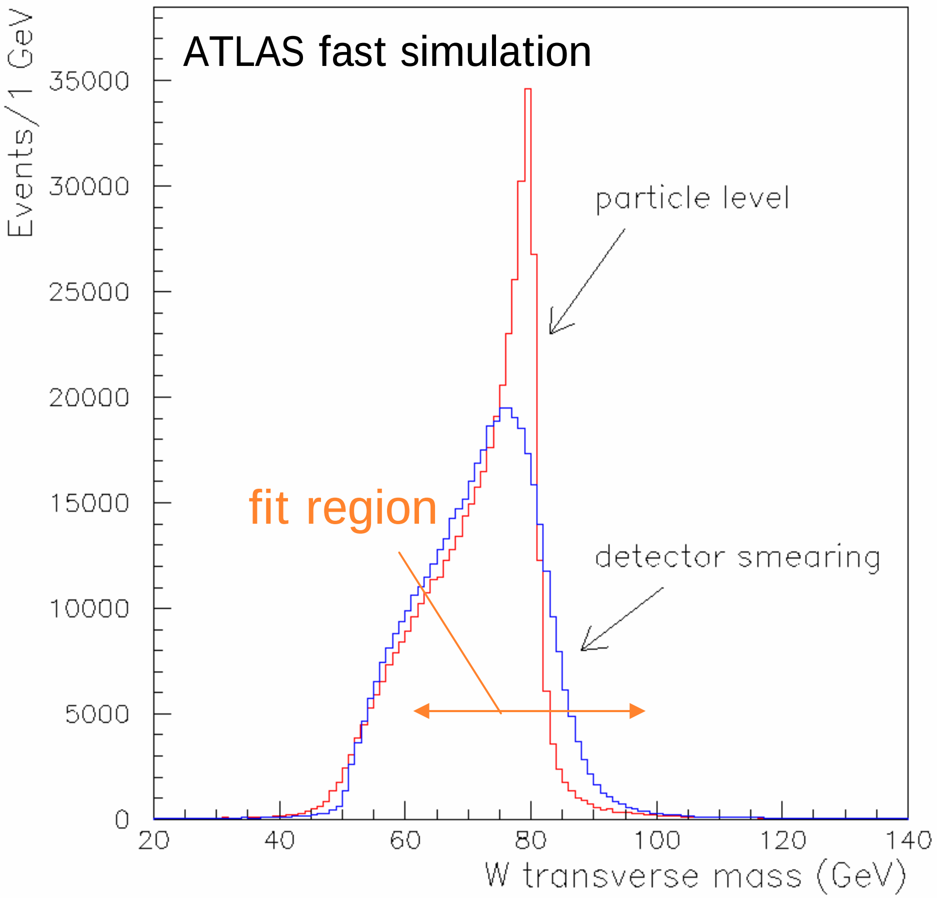
W-pair cross-section is too low
Single W: no direct determination of m_W possible
because of the missing neutrino, but huge statistics !

$$m_W^T = \sqrt{2\, p_l^T\, p_\nu^T \left(1 - \cos\Delta\phi\right)}$$



$$\vec{p}_\nu^{\,T} = -\left(\vec{p}_l^{\,T} + \vec{u}\right)$$

(missing p^T)

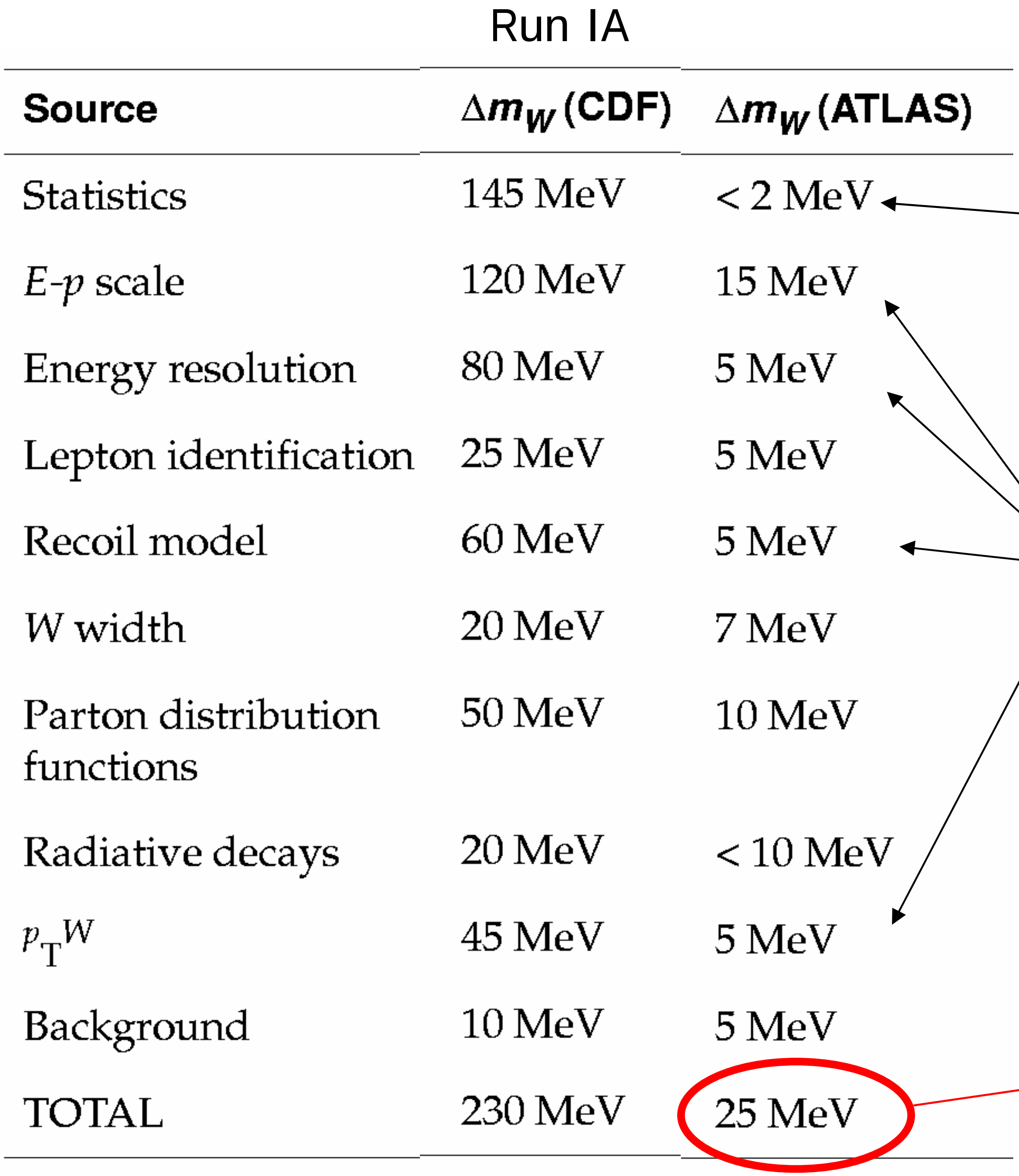


Selection efficiency: ~25% with
- $p_T > 25$ GeV
- $E_T^{miss} > 30$ GeV
- No jets with $p_T > 30$ GeV
- Recoil $|u| < 20$ GeV

still 60 millions W/y-e after selection !
(50 times Tevatron)

⇒ <2MeV/y as a statistical uncertainty

After one year of LHC



	Run IA	
Source	**Δm_W (CDF)**	**Δm_W (ATLAS)**
Statistics	145 MeV	< 2 MeV
E-*p* scale	120 MeV	15 MeV
Energy resolution	80 MeV	5 MeV
Lepton identification	25 MeV	5 MeV
Recoil model	60 MeV	5 MeV
W width	20 MeV	7 MeV
Parton distribution functions	50 MeV	10 MeV
Radiative decays	20 MeV	< 10 MeV
p_T^W	45 MeV	5 MeV
Background	10 MeV	5 MeV
TOTAL	230 MeV	25 MeV

Uncertainties per experiment per year and per lepton

The real improvement

Internal calibration from Z data mainly. Need excellent control of energy flow+ momentum scale

15 MeV LHC combined will then be reached... still all is very challenging !!!

The top mass at LHC

LHC will be a top factory:

O(10^7) t-pair/y, con σ_{NLO}(tt)~830 pb !!

Golden channel: qqbblν

(10^5 events/y accounting for efficiencies already)

The reconstruction starts with the W mass:

- different ways to pair the right jets to form the W
- jet energies calibrated using m_W

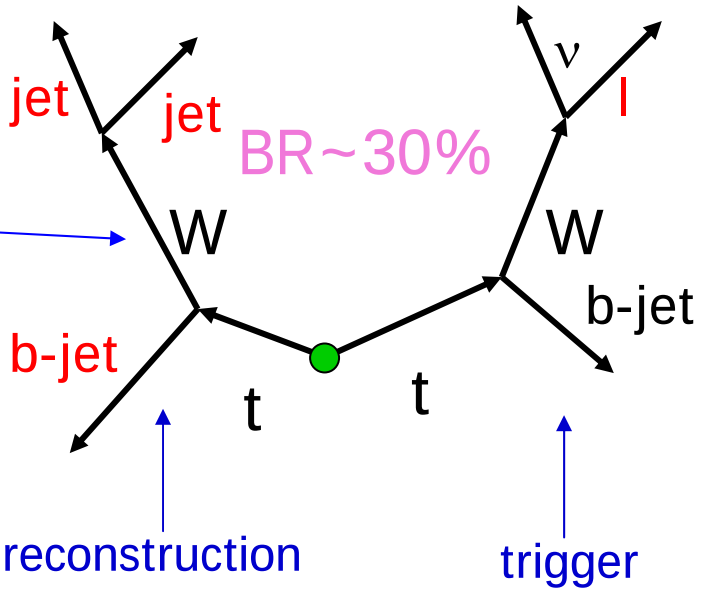
Important to tag the b-jets:

- enormously reduces background (physics and combinatorial)
- clean up the reconstruction
- present offline estimates

$\varepsilon_b \approx 40\%$ for rejections $r_{u,d} \approx 10^{-3}$, $r_c \approx 10^{-2}$

Constrained fitting, statistical methods for reconstructing the t will be used

but it is not the statistical power that worries...



Selection efficiency: ~5-10% with:

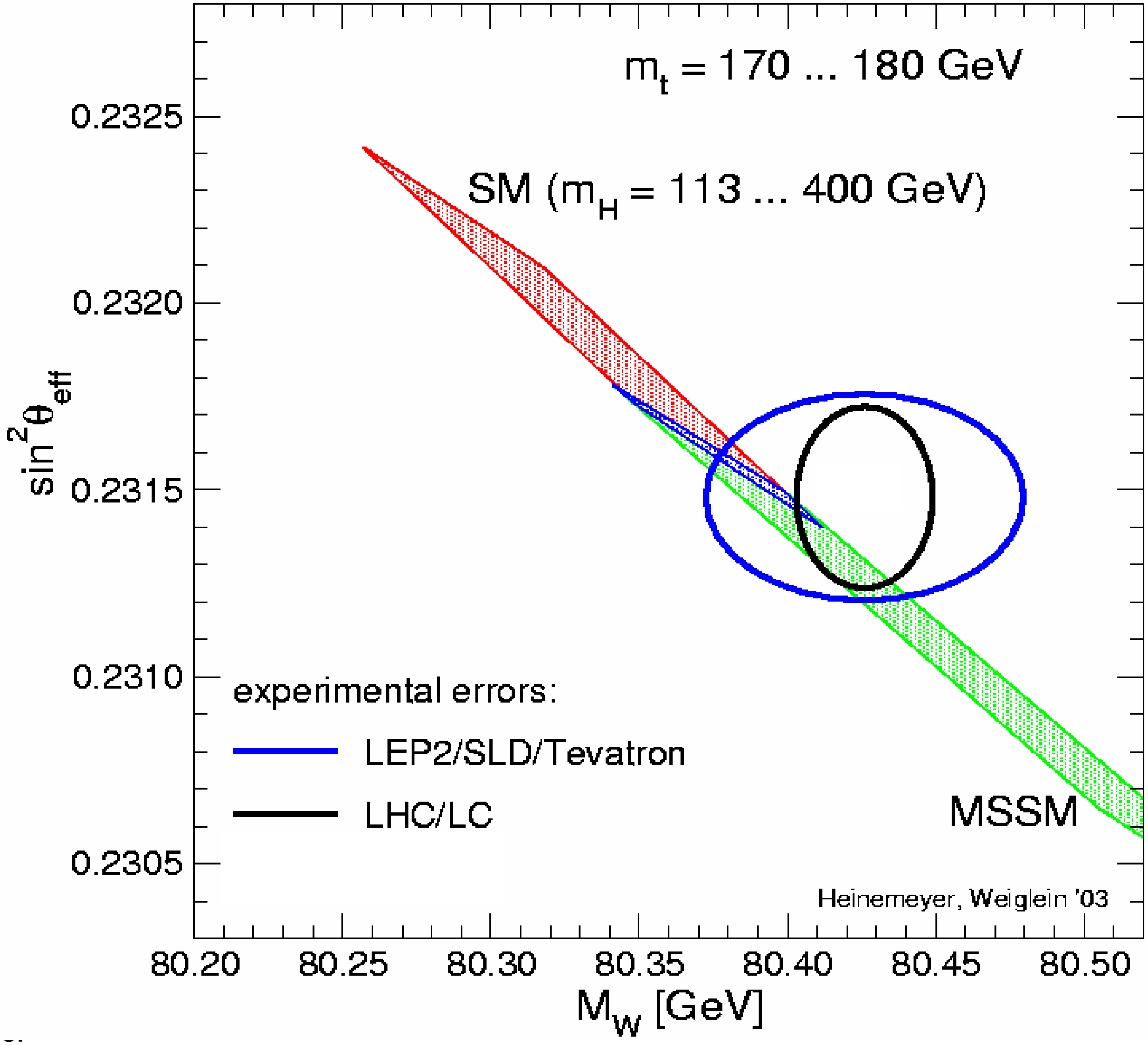
- p_T>20 GeV
- E_T^{miss}>20 GeV
- 4 jets with p_T>40 GeV
- >1 b-tagged jet

Background: <2%

W/Z+jets, WW/ZZ/WZ

Constraining the SM at the LHC

Not really much with $\sin^2\theta_{eff}$ at the LHC, it seems...



Perspective at the LHC

Let us repeat the EW fit only changing the errors on the top and the W masses:

δm_W=15 MeV; δm_t=1 GeV

(world combined will look better than these ! – Tevatron run II, LEP2)

(current central values assumed)

SM constraints on m_H:

With experiment driven $\Delta\alpha_{had}$:

$$\Rightarrow m_H = 63^{+22}_{-18}$$

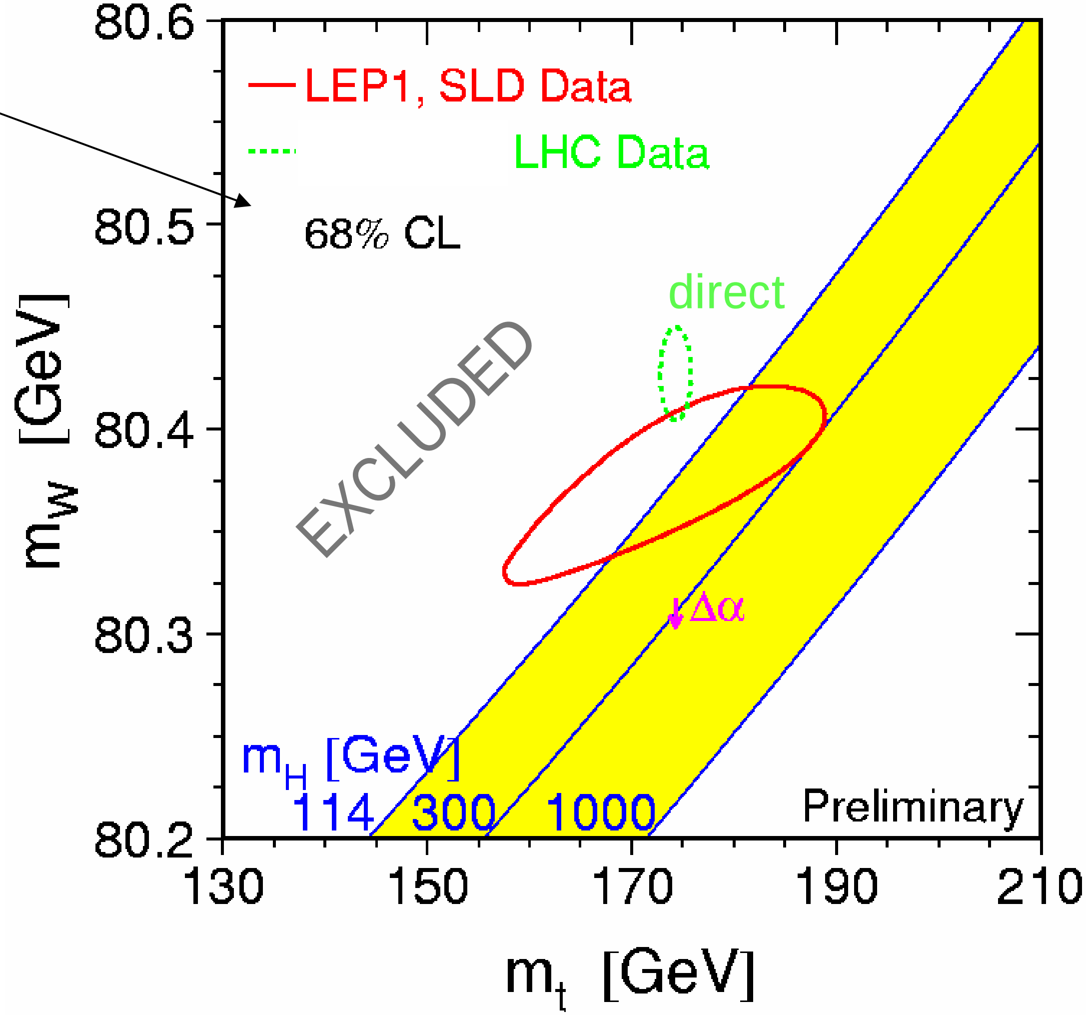
($\delta m_H/m_H \approx$ 32%)

Using also $\Delta\alpha_{had}$=0.00012

$$\Rightarrow m_H = 73^{+20}_{-16}$$

($\delta m_H/m_H \approx$ 25%)

Thanks to M.Grunewald



Chances of ruling out the SM !