Precision measurements at the LHC

(ATLAS and CMS)

Loops and Legs in Quantum Field Theory

Bastei/Konigstein, 12 April 2000

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LHC luminosity

- $L_{peak} \approx 10^{33}$ cm^{-2} s^{-1} 2005-2008 ("low L")
  $L_{peak} \approx 10^{34}$ cm^{-2} s^{-1} 2009 → (" high L")
  $L_{peak} \approx 2.5 \times 10^{34}$ cm^{-2} s^{-1} ultimate (beam-beam limited)

- $\int L\,dt \approx 10$ fb^{-1} per year at low L
  $\int L\,dt \approx 100$ fb^{-1} per year at high L

- Bunch crossing : **25 ns**

- ~ 20 minimum-bias per crossing high L } **"pile-up"**

→ ~ 700 charged particles $p_T > 150$ MeV per crossing

→ detector speed ($t \leq 50$ ns)
radiation hardness

A few numbers .....

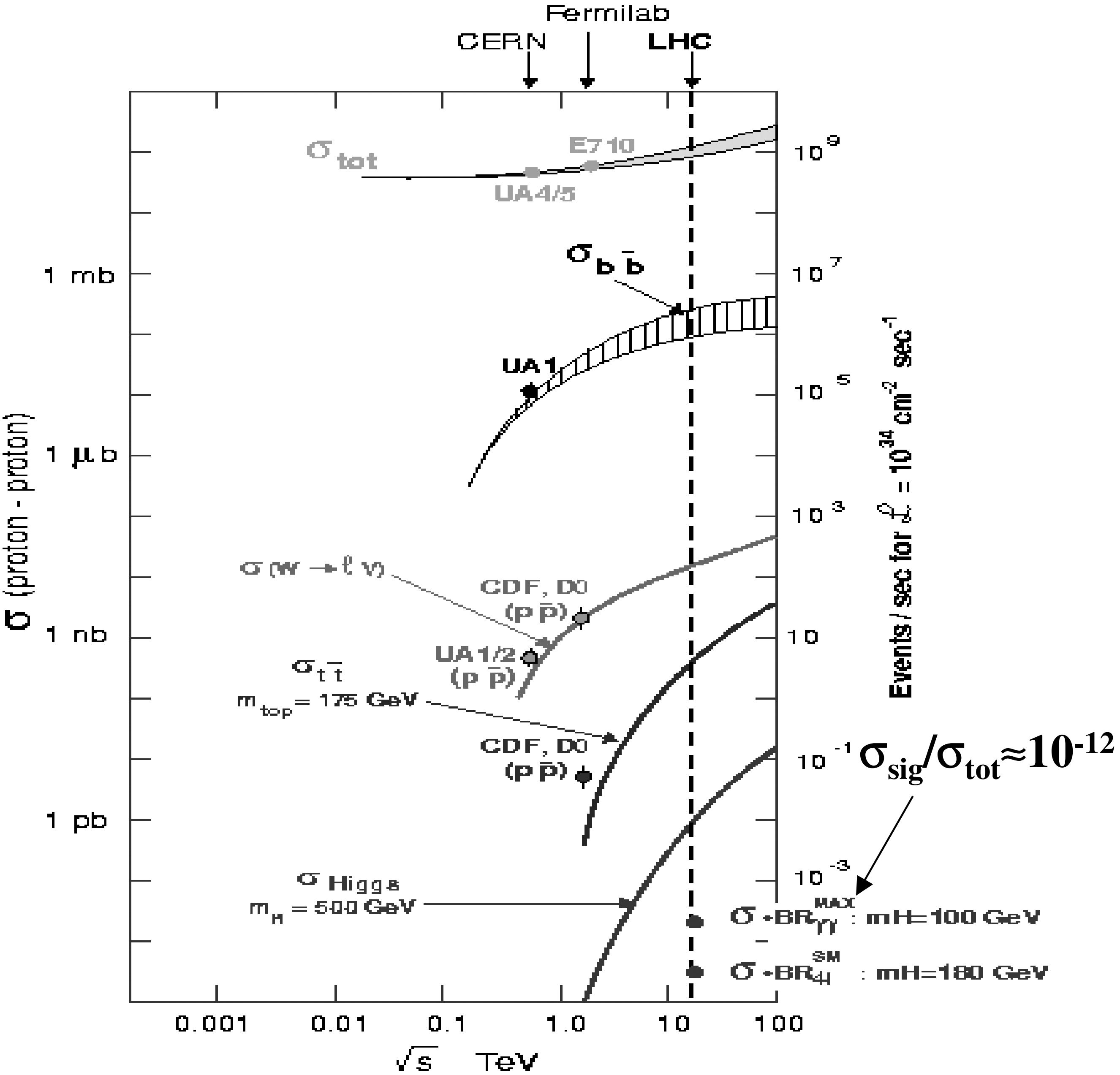
10^{33} cm^{-2} s^{-1}

Process	σ	Events/s	Events/year
$W \to e\nu$	15 nb	15	10^8
$Z \to ee$	1.5 nb	1.5	10^7
$t\bar{t}$	800 pb	0.8	10^7
$b\bar{b}$	500 μb	10^5	10^{12}
$\tilde{g}\tilde{g}$ ($m_{\tilde{g}}$=1 TeV)	1 pb	0.001	10^4
H (m=0.8 TeV)	1 pb	0.001	10^4
QCD jets p_T > 200 GeV	100 nb	10^2	10^9

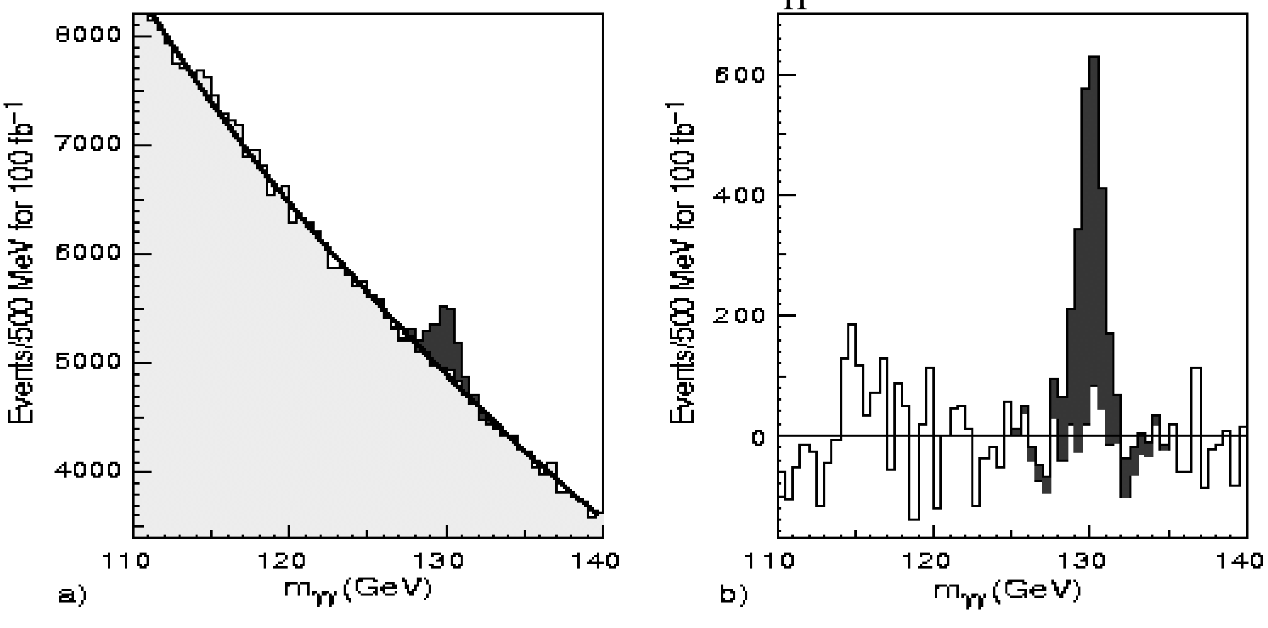
→ LHC is a B-factory, top factory, W/Z factory, Higgs factory, SUSY factory, etc.

Mass reach: up to ≈ TeV
Precision measurements dominated by systematics

Energy dependence of some characteristic cross-sections



CMS 100 fb^{-1} m_H=130 GeV



3 crucial parameters for precision measurements

Uncertainties on :

- **Absolute luminosity** : goal < 5%

Main tools: machine, optical theorem, rate of known processes (W, Z, QED pp $\rightarrow$ pp $\ell\ell$)

- **ℓ energy scale** : goal 1‰ most cases
  0.2‰ W mass

Main tool: $Z \rightarrow \ell\ell$ (1 event/ℓ/s at low L)
close to in mass to m_W, m_h

1‰ achieved by CDF/D0 despite small Z sample

- **Jet energy scale** : goal 1% (m_{top}, SUSY)

limited not only by calorimeter calibration but also by physics (fragmentation, gluon radiation, etc)

Main tools : Z + 1 jet ($Z \rightarrow \ell\ell$)
$W \rightarrow jj$ from top decays (10^{-1} events/s low L)

$\mathbf{t\bar{t} \rightarrow Wb \rightarrow \ell\nu b}$
$\mathbf{\hookrightarrow Wb \rightarrow jjb}$

4% at Tevatron

Requirements: tracker material to 1%, overall alignment to 0.1 μm, overall B-field to 0.1‰, muon E-loss in calorimeters to 0.25%, etc.

Measurements discussed here:

W mass

Drell-Yan production of lepton pairs

Triple Gauge Couplings

Top physics

Higgs

SUSY

W mass

Year 2005 **:** **$\Delta m_W < 30$ MeV** **LEP2+Tevatron**

Motivation to improve:

$$m_W^2\left(1-\frac{m_W^2}{m_Z^2}\right)=\frac{\pi\alpha}{\sqrt{2}G_F}\frac{1}{1-\Delta r}$$

$$\Delta r \downarrow$$

$f(m^2_{top}, \log m_H)$

$\Delta m_W \approx 0.7 \times 10^{-2}\, \Delta m_{top}$ to get similar errors

$\Delta m_{top} \approx 2$ GeV (LHC) requires

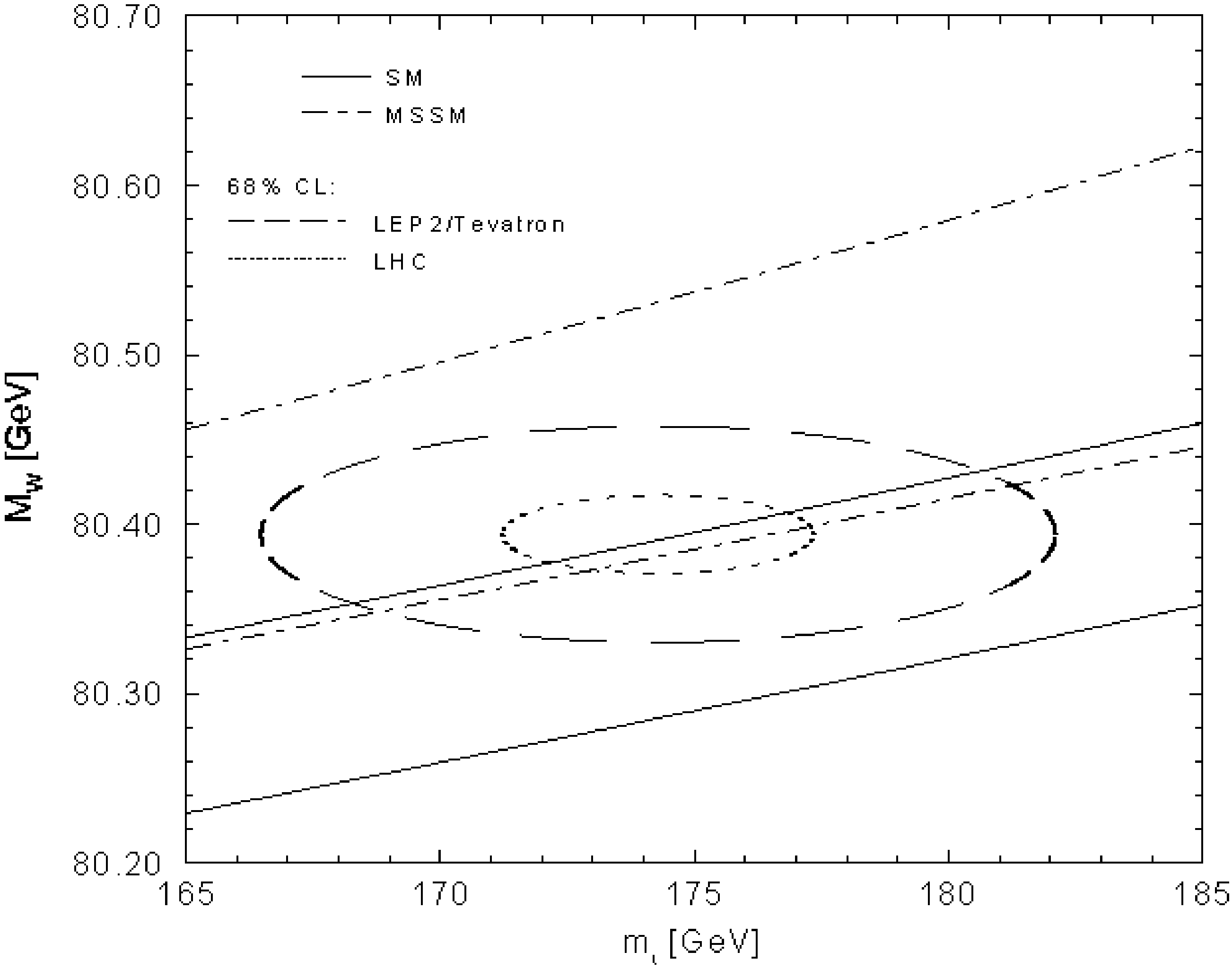
$$\boxed{\Delta m_W \approx 15 \text{ MeV}}$$

$\uparrow$

-- if/when Higgs found: check consistency of theory
-- constrains m_H to 25%

Dependence of M_W on m_t in SM and MSSM

EW precision observables may be useful to distinguish between different models as candidates for the EW theory



Main method : transverse mass

$$m_T^W = \sqrt{p_T^l p_T^\nu (1 - \cos \Delta\varphi_{l\nu})}$$

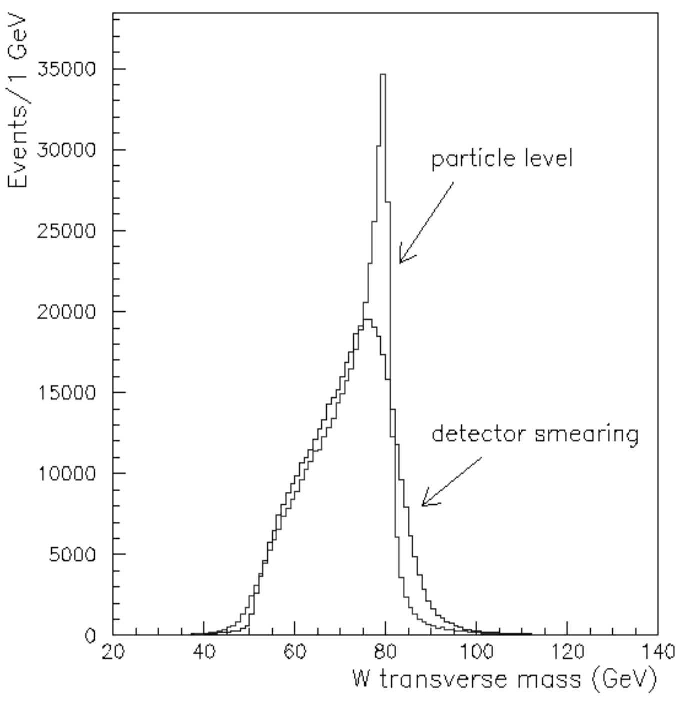
$$\left| \vec{p}_T^{\,l} + \vec{u}_{recoil} \right|$$

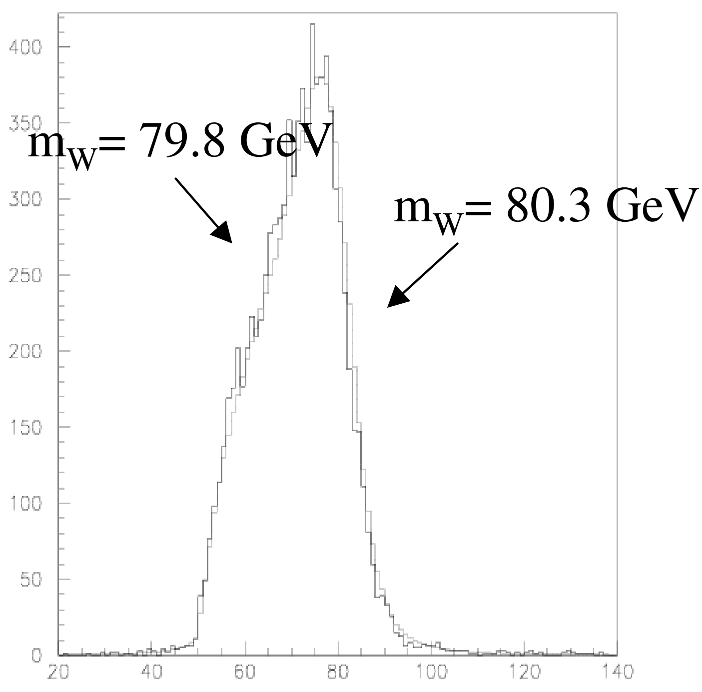
l = e, μ

(from transverse momentum imbalance in calorimeters)

Edge of m_T^W distribution sensitive to m_W

smeared by : W width, detector resolution,
pile-up (technique probably limited to low L)





m_T^W (GeV)

W production and selection

$$\sigma\,(\,pp \to W + X \quad W \to l\nu \;\; l = e, \mu) = 30\,nb$$

⇒ **300×10^6 events produced /exp/year at low L**

Selection cuts :

- isolated charged lepton (e, μ) with P_T>25 GeV, |η|<2.4
- E_t^{miss}> 25 GeV
- No jets with P_T>30 GeV
- Recoil momentum < 20 GeV

Reject Ws at high P_T:
- worse m_T resolution
- higher QCD background

Expected efficiency ~ 20%

60×10^6 well measured $W \to l\nu$ (l =e, μ)
per experiment, per year at low L
(~ 50 times more than Tevatron Run II)

Uncertainties on M_W

- **Statistical error < 2 MeV**
- **Systematic error from Monte Carlo modelling of the data (physics & detector)**

Physics: p_T^W and θ_W
pdfs
W width $\left(R = \frac{\sigma_W}{\sigma_Z} \times \frac{BR(W \to \ell \nu)}{BR(Z \to \ell\ell)} \right)$
Radiative decays $(W \to \ell \nu \gamma)$
Background $(Z \to \mu\mu \text{ for } W \to \mu\nu)$

Detector: Lepton E, p scale
Lepton E, p resolution
Recoil modelling
Lepton ID cuts

- **Most uncertainties (lepton scale, detector resolution, p_T^W, etc.) controlled *in situ* with $Z \to \ell\ell$ sample.**
- **High statistics control sample : ~ 6×10^6 $Z \to \ell\ell$ decays in one year of low L after all selection cuts**
(factor ≈ 50 larger than event samples from Tevatron Run II)
- **Z close in mass to W → small extrapolation**

Preliminary estimation of Δm_W

10 fb^{-1}

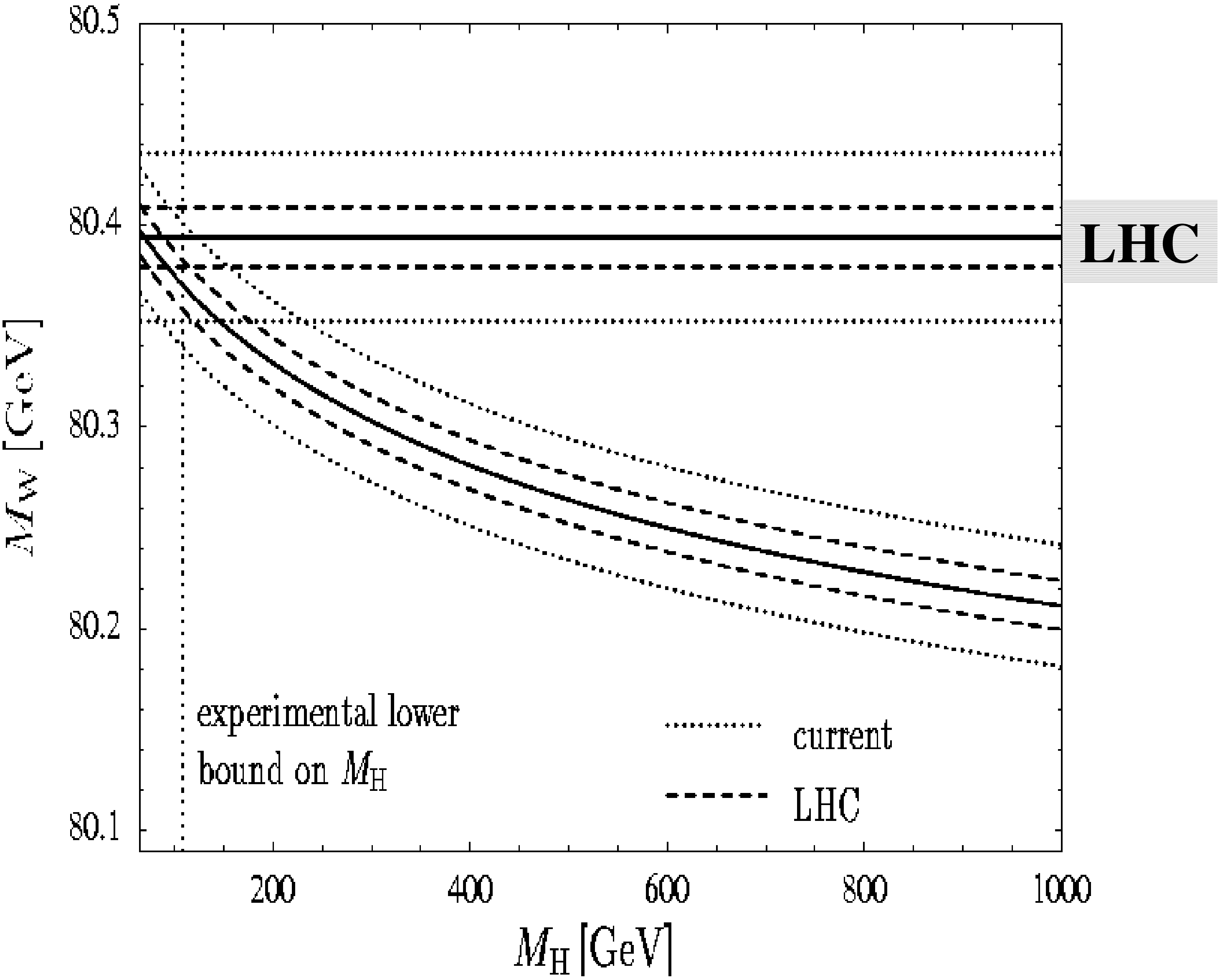
SOURCE	Δm_W CDF Run 1A $W \to e\nu$	Δm_W ATLAS $W \to e\nu$	COMMENTS
Statistics	145 MeV	< 2 MeV	
E/p scale	120 MeV	15 MeV (*)	Run II goal: < 40 MeV
E/p resolution	80 MeV	5 MeV	known to ± 1.5% from Z peak
Recoil model	60 MeV	5 MeV	scales with Z statistics ?
W width	20 MeV	7 MeV	$\Delta\Gamma_W \sim 30$ MeV (Run II)
PDF	50 MeV	10 MeV	constrain also with LHC data
Radiative decays	20 MeV	< 10 MeV	better theoretical calculations
p_T^W	45 MeV	5 MeV	p_T^Z from data, p_T^Z/p_T^W from theory
Background	10 MeV	5 MeV	$Z \to \mu\mu$ known to < 7%
Total	230 MeV	< 25 MeV	per lepton species, per experiment

Recoil from Z evts with $p_T^Z \approx p_T^W$

(*) most serious challenge !!

hope to achieve $\Delta m_W \approx 15$ MeV
by combining both expts and both channels

Comparison between Theory & Experiment

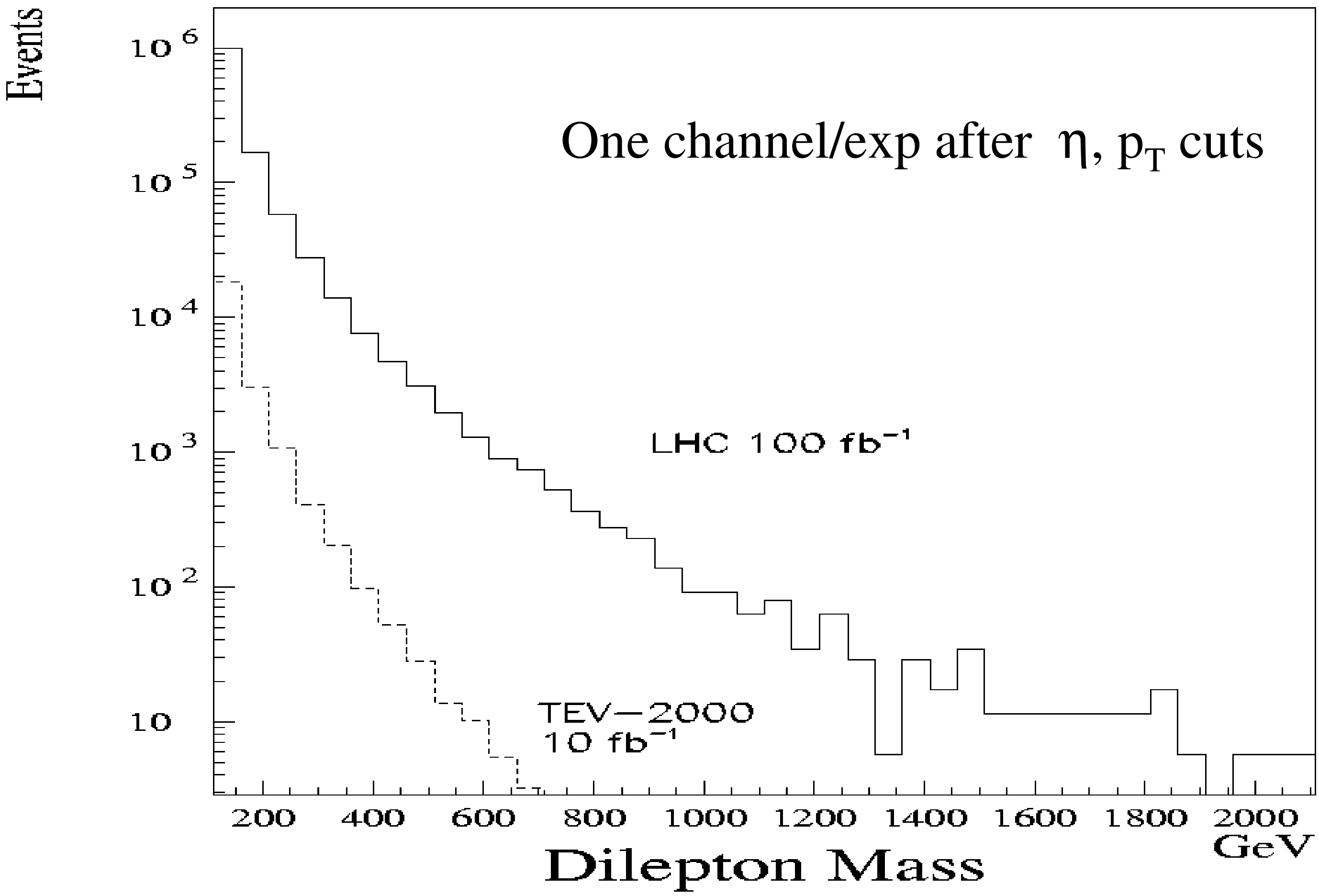


Stringent bound on M_H to be confronted (hopefully!) with directly measured value

Drell-Yan production of lepton pairs

Distinctive experimental signature:
pair of isolated leptons with opposite charge

Experimental backgrounds low (W^+W^-,t^+t^-,cc,bb,tt, fakes,etc.)



Measure:

Total cross section $\sigma(y,M)$

Forward-Backward Asymmetry $A_{FB}(y,M)$

y: rapidity of lepton pair

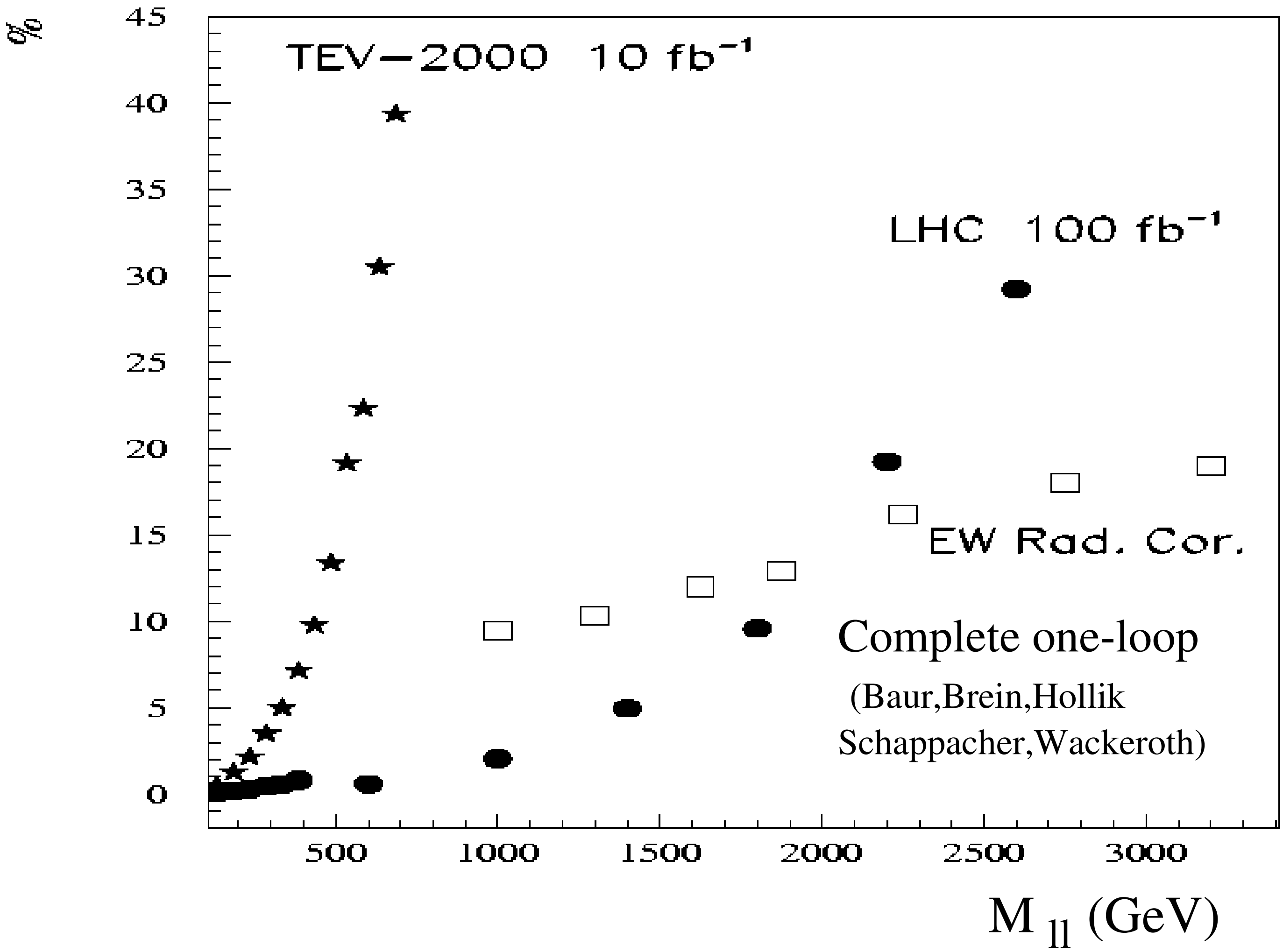
M : invariant mass of lepton pair

- **Main exp. systematics on σ from L**
  (known at few % level)
- **pdfs constrained experimentally by η distributions of leptons from W, Z decays**

$$\frac{d^2\sigma}{dM_{ll}dy}(pp \to l_1 l_2) \approx \sum_{i,j} (f_{i/p}(x_1) + f_{j/p}(x_2) + (i \leftrightarrow j))\,\hat{\sigma}$$

- **Precise measurement of σ and A_{FB} requires good knowledge of EW radiative corrections**:

Rel. exp. error on σ_{ll}



Corrections can be probed up to ≈ 2 TeV

From FB asymmetry A_{FB} in di-lepton production near the Z pole $\Longrightarrow$ $\sin^2\theta_{eff}^{lept}(M^2_Z)$

$\sin^2\theta_{eff}^{lept}(M^2_Z) = 0.23148 \pm 0.00017$ LEP+SLD

Measurement of A_{FB} requires tag of q, $\bar{q}$ directions

$q\bar{q} \to l^+ l^-$ Only q can be valence quark $\Rightarrow$ on average higher momentum wrt sea $\bar{q}$

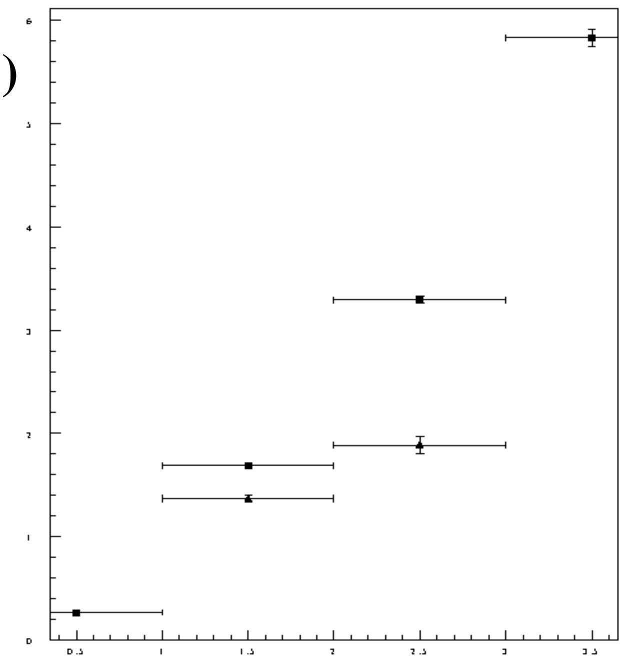
A_{FB} signed according to sign of y_{ll}

- $p^e_T > 20$ GeV
- $85.2 < M_{ee} < 97.2$ GeV^2
- one $e^\pm$ within $|\eta| < 2.5$

If very forward $e^\pm$ tagged

- other $e^\pm$ identified in forward calorimeters $2.5 < |\eta| < 4.9$

significance of measurement increased



For moderate jet rejection ($\sim 10^2$) in fwd calo.

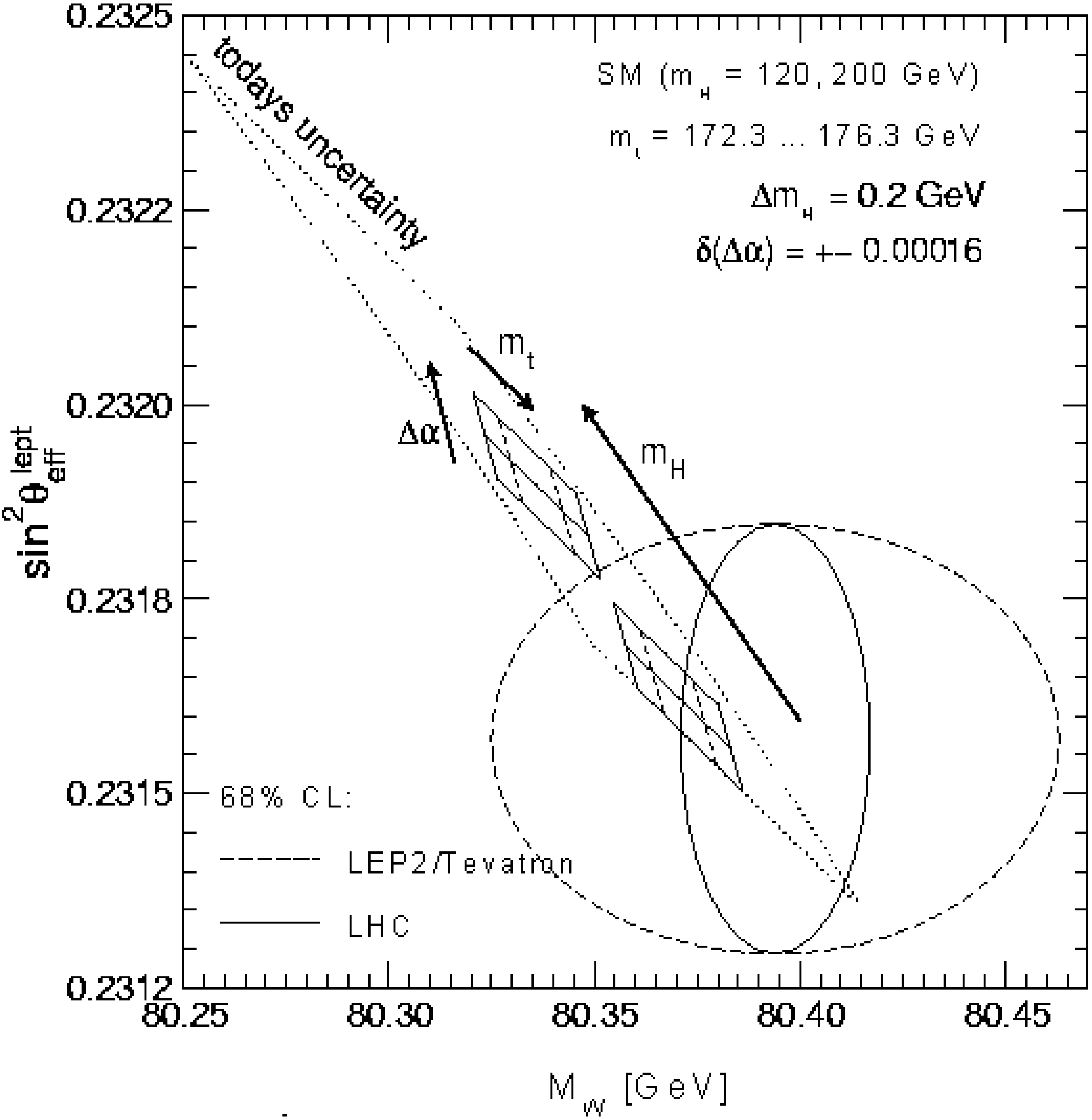
$$\delta_{stat}\sin^2\theta_{eff}^{lept}(M^2_Z) \approx 1.4\ 10^{-4}$$

reachable (one exp, $e^\pm$ channel, 100 fb^{-1})

WHAT ABOUT SYSTEMATICS?

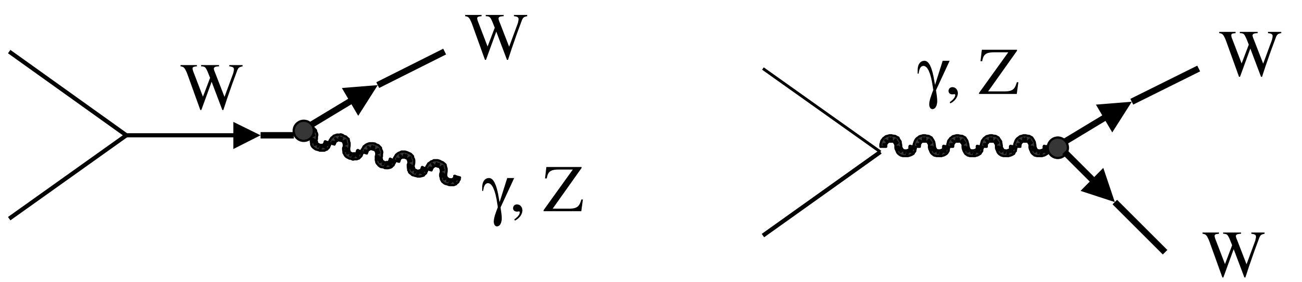
Main effect: uncertainty on pdfs

Agreement among different pdfs tested at 1% level (statistical power of the study). Needs another factor of 10. New measurements from HERA/Tevatron/LHC will improve understanding of pdfs



SM (m_H = 120, 200 GeV)
m_t = 172.3 ... 176.3 GeV
Δm_H = 0.2 GeV
$\delta(\Delta\alpha)$ = +- 0.00016
todays uncertainty
m_t
m_H
$\Delta\alpha$
68% CL:
LEP2/Tevatron
LHC
$\sin^2\theta_{eff}^{lept}$
M_W [GeV]
0.2325
0.2322
0.2320
0.2318
0.2315
0.2312
80.25
80.30
80.35
80.40
80.45

Triple Gauge couplings



•Probe non-Abelian structure of SU(2) x U(1)
and sensitive to New Physics

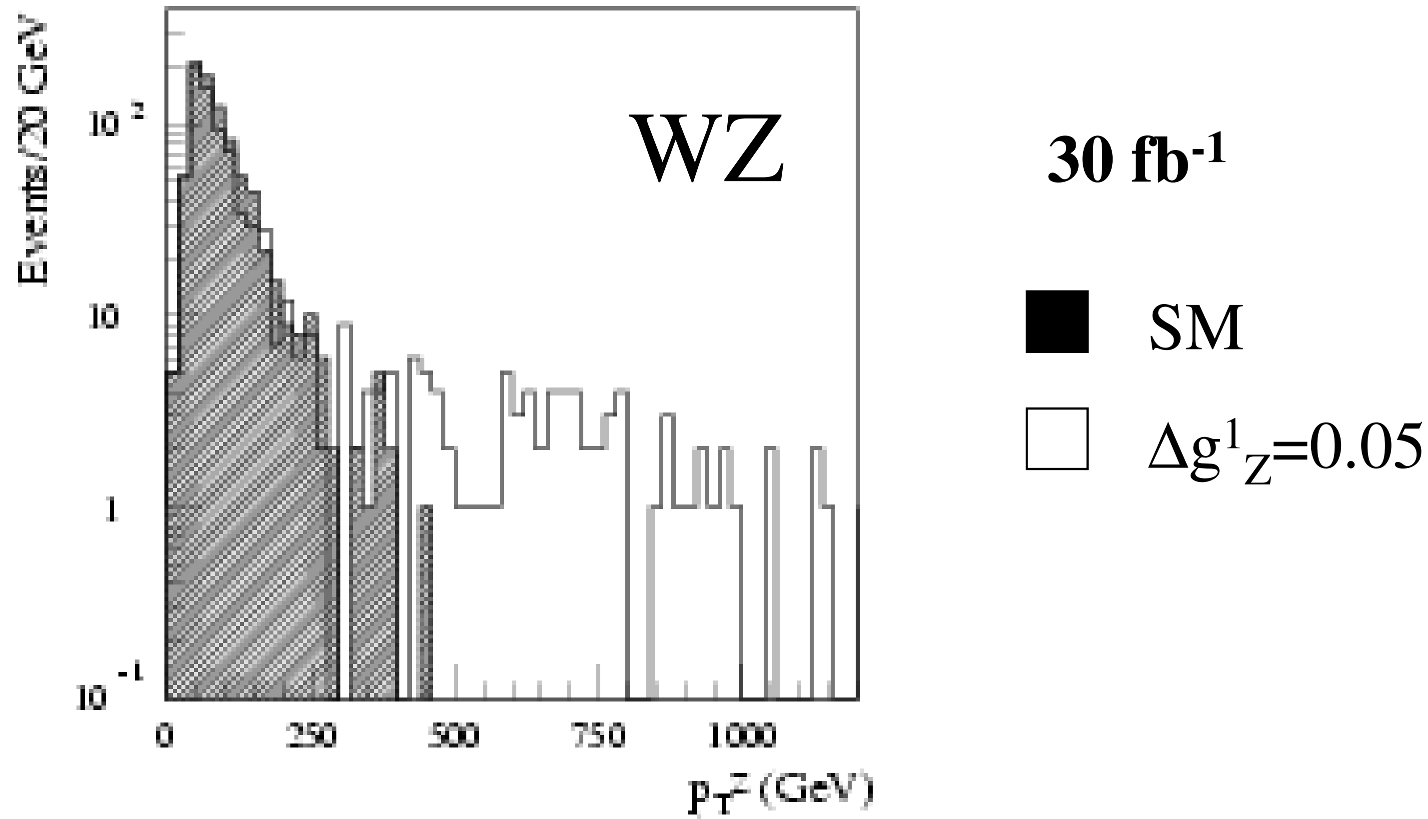
- Year 2005 : $\mathbf{g^1_Z, \lambda_\gamma, k_\gamma, \lambda_Z, k_Z}$ known to better than 10^{-2} from LEP2+Tevatron

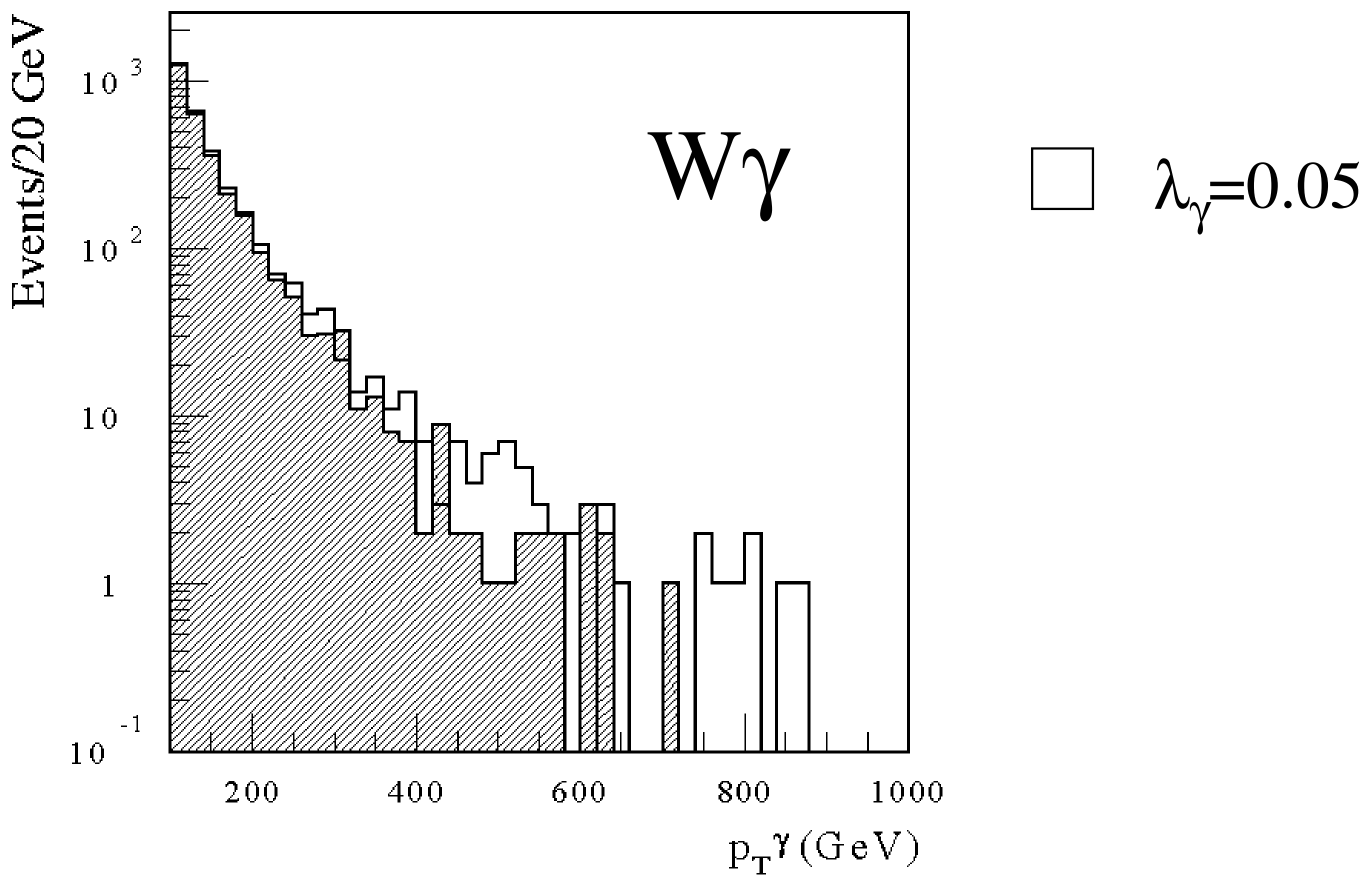
- Some anomalous contributions increase with s
  $\rightarrow$ high sensitivity at LHC

- $W\gamma \rightarrow l\nu\ \gamma$
  $WZ \rightarrow l\nu\ ll$
  $WW \rightarrow l\nu\ l\nu$ large tt background

• Sensitivity from :
  -- cross-section measurements: λ-type increase with s
  -- p_T, θ distributions: sensitive to different TGC's, constrain k-type

Need to know precisely Wγ, WZ production from theory





Systematics (background, NLO, pdf) under study (should be small, concentrated at low p_T)

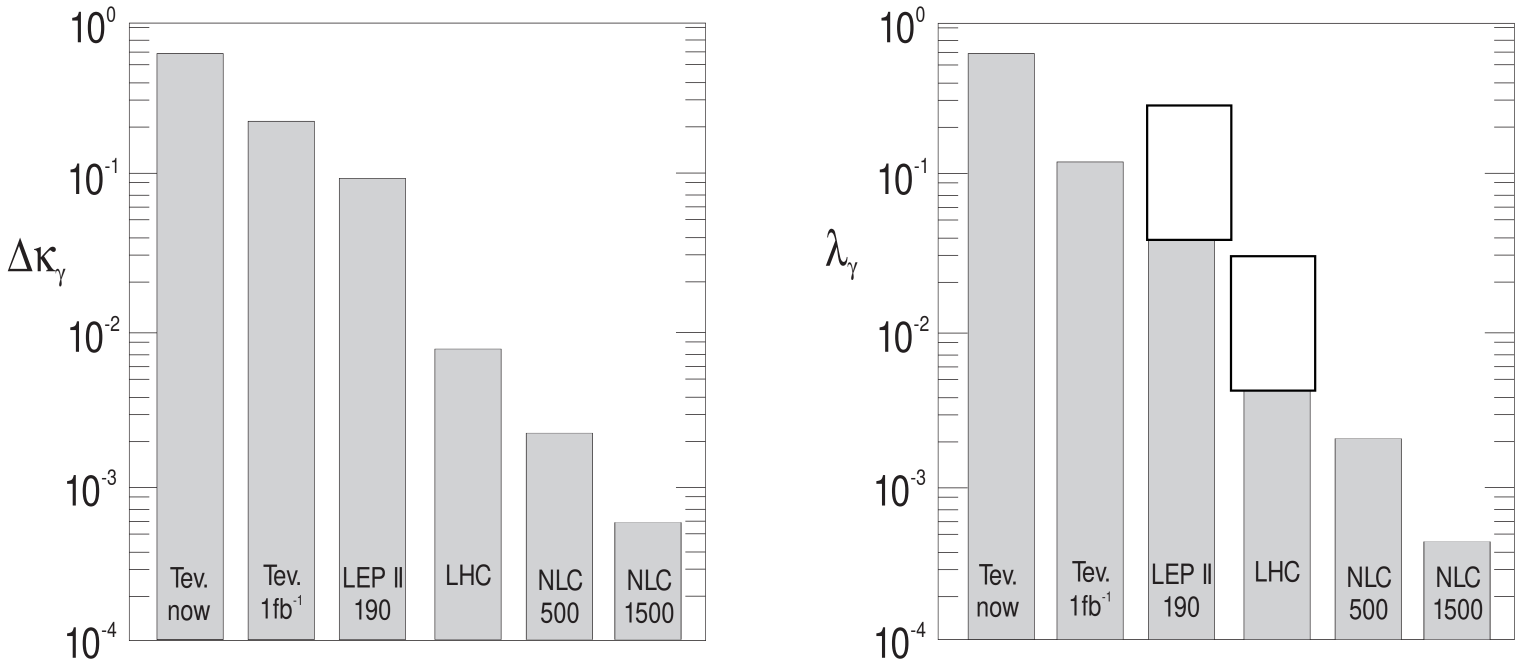
Λ=10 TeV

Coupling	**95% CL**
Δg^1_Z	**0.008**
λ_γ	**0.0025**
λ_Z	**0.006**
Δk_γ	**0.035**
Δk_Z	**0.07**

ATLAS
30 fb^{-1}

One coupling varied at a time

LEP present precision: ≈ 0.05 to 0.10



Comparison of representative 95% C.L. upper limits on $\Delta \mathbf{k}_\gamma$ and λ_γ for present and future accelerators

Top physics

Most intriguing fermion (large mass, large width, radiative corrections, etc.)

→ precision measurements needed (limited by statistics at Tevatron)

LHC:

- $\sigma(t\bar{t}) \approx$ **830 pb** $\approx$ **10^7 $t\bar{t}$ pairs per year at low L**

  ↑ **7 pb at $\sqrt{s}$ = 1.8 TeV**

→ measure $\mathbf{m_t}$ **,** $\boldsymbol{\sigma_{tt}}$**,** $\mathbf{V_{tb}}$**, rare decays, polarisation, single top**, etc.

Measurements and their interpretation dominated by exp. and th. systematic uncertainties

- $t\bar{t}$ production is main background to New Physics (Higgs, SUSY, …)
- $W \rightarrow jj$ in $t\bar{t}$ events: *in situ* calibration of jet scale

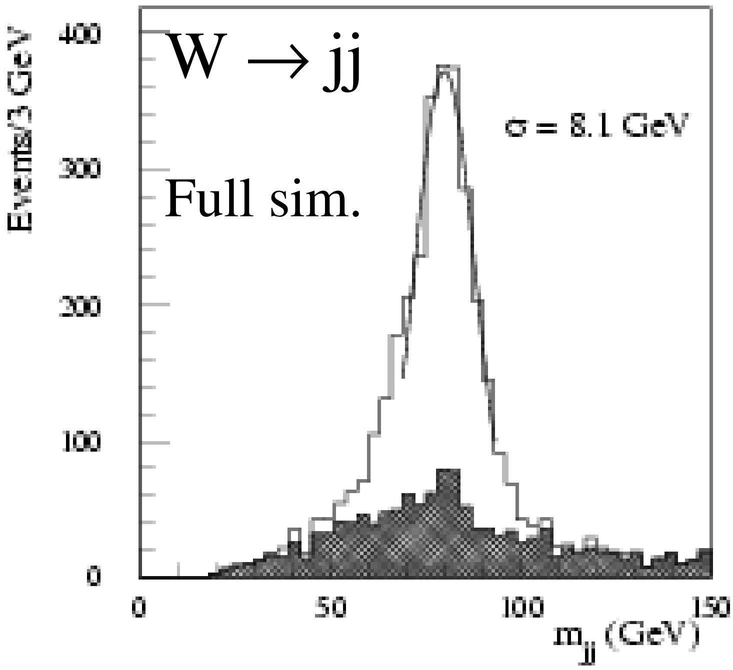
Measurement of m_{top}

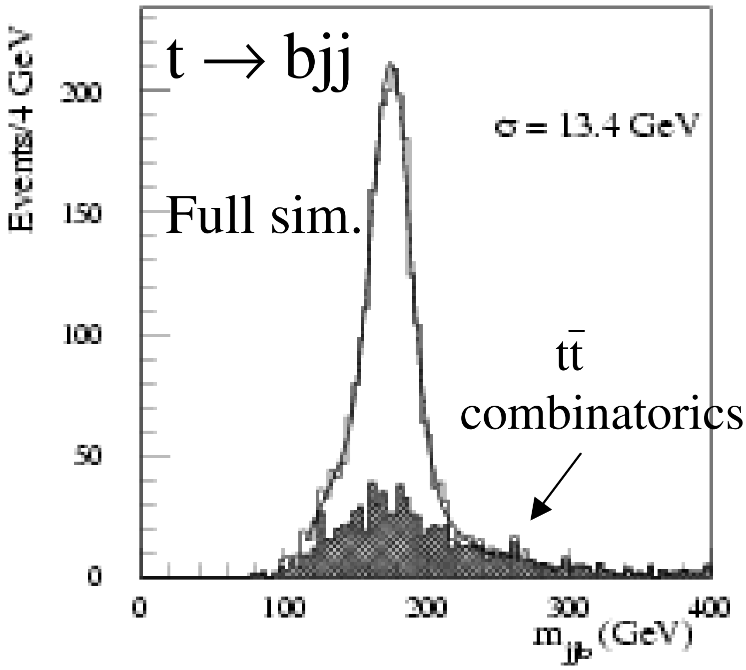
- Year 2005 : $\Delta m_{top} \approx 3$ GeV (Tevatron)

- Best channel: $t\bar{t} \rightarrow Wb \rightarrow l\nu b$ $\approx 29.6\%$ of all tt evts
  $\quad\quad\quad\quad\quad\quad\quad\;\; \hookrightarrow Wb \rightarrow jjb$

top mass determined from hadronic part of decay $m_t = m_{jjb}$
leptonic top used to tag event: hight p_T lepton
large E_T^{miss}

- After all cuts : 130 000 $t\bar{t}$ events 10 fb^{-1}, S/B ~ 65





Contribution	Δm_{top} (GeV)
statistics	< 0.07
light-jet scale	0.3
b-jet scale	0.7
b-fragmentation	0.3
ISR	0.3
FSR	1.2
background	0.2
Total	≈1.5 GeV

10 fb^{-1}
1 experiment

dominated by
knowledge
of physics

m_t in leptons plus jets channel

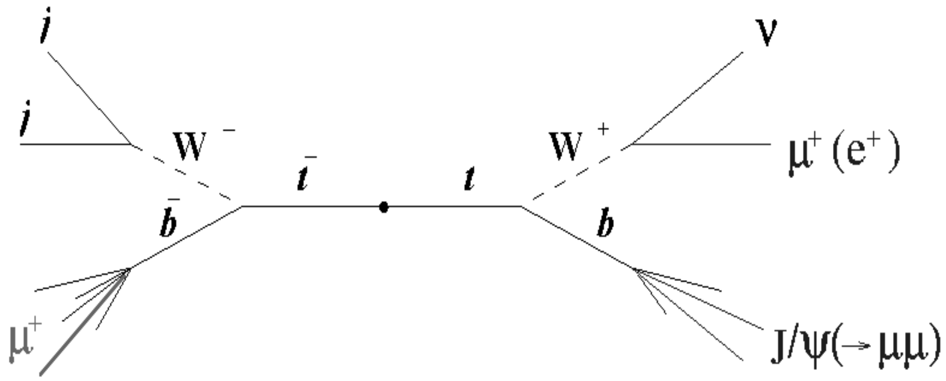
•Special sub-sample where t and $\bar{t}$ have high p_T.
•Cleaner topology → lower combinatorics and background
•Jets from top decay are close → FSR sensitivity reduced by summing up calorimetric energy in cone around top direction

m_t in di-lepton channel

•Complementary to single lepton + jets
•Indirect: relies on relation between kinematic distribution of top decay products and m_t

m_t from $t \to J/\Psi + X$ decays

pioneered by CMS



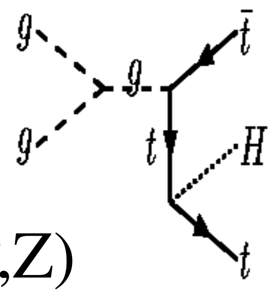
•Correlation between m_t and inv.mass of J/Ψ + lepton system (heavy object (J/Ψ) → larger fraction of b momentum → stronger correlation with m_t)
•BR ≈ 10^{-5} but signal very clean
• Completely indep. systematics (b fragmentation)
Very promising

Different samples → Important cross-checks

Other measurements

- $\sigma(t\bar{t})$ to < 10 % (L uncertainty)
- find $X \rightarrow t\bar{t}$ up to ≈ 3 TeV (σ x BR > 10 fb)
- $t\bar{t}$ spin correlations (top decays fast ⟶ no hadronic bound states ⟶ information on top spin not diluted)

- **Couplings**



ttH to ≈ 10 % (stat. only)

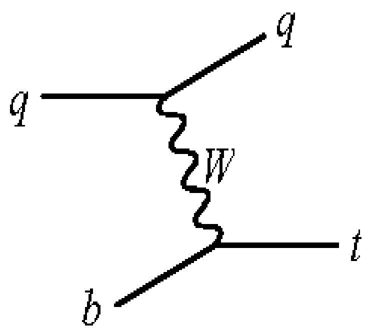
FCNC couplings tVc, tVu (V=g,γ,Z)

BR ($t \rightarrow Zq$) ≈ 10^{-4}
BR ($t \rightarrow \gamma q$) ≈ 10^{-5}
BR ($t \rightarrow gq$) ≈ 10^{-5}

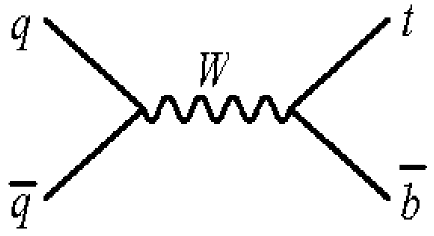
In general at least factor 10 better than Tevatron

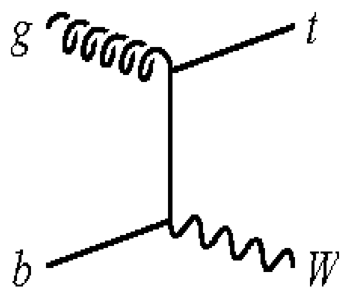
- **Single top:** σ ≈ 300 pb (40% of $t\bar{t}$)

Never observed so far!!



1/3 of tt





- probe Wtb vertex ⟶ sensitive to new physics
- V_{tb} to ≈ 10% (stat. error < 1%)
- top polarisation

Standard Model Higgs

- σ (pp $\rightarrow$ H + X) $\approx$ 30 pb $\quad m_H = 100$ GeV
  $\approx$ 100 fb $\quad m_H = 1$ TeV

- Large QCD backgrounds $\rightarrow$ look for final states with leptons and photons

- **Main channels**:

l = e, μ

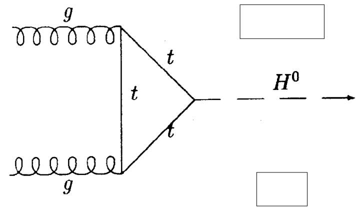
m_H < 180 GeV: $WH \rightarrow l\nu b\bar{b}$, $t\bar{t}H \rightarrow t\bar{t}\, b\bar{b}$, $H \rightarrow \gamma\gamma$,
$H \rightarrow ZZ^* \rightarrow 4l$, $H \rightarrow WW(^*) \rightarrow l\nu l\nu$

m_H > 180 GeV: $H \rightarrow ZZ \rightarrow 4l$,
$H \rightarrow ZZ \rightarrow ll\,\nu\nu$ $(400 < m_H < 900$ GeV$)$
$H \rightarrow WW \rightarrow l\nu jj$ $(m_H > 400$ GeV$)$

- Detector performance critical (often S/B << 1):
  b-tagging, EM energy resolution, muon momentum resolution, multi-jet mass resolution, γ/j separation, forward jet tag, electron reconstruction, E_T^{miss} measurement, …..)

$H \to \gamma\gamma$

$80 \leq m_H \leq 150$ GeV



σ x BR ≈ 50 fb (BR ≈ 10^{-3})

Backgrounds (challenging for EM calorimeter):

Theory knowledge should be as accurate as possible

$\gamma\gamma$ (irreducible) : $\sigma_{\gamma\gamma}$~ 3 pb → need σ_m≈1%

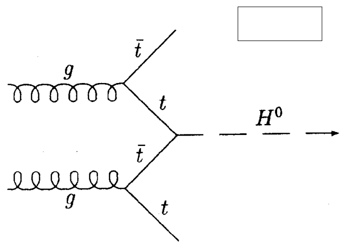
γj+jj : $\sigma_{\gamma j}$ ~ 10^3 $\sigma_{\gamma\gamma}$ → need R_j ≈ 10^4

Excellent photon/jet discrimination required

γ-jet o γ-jet backround over $\gamma\gamma$ at 20% level after full γ-ID

$t\bar{t}H \to t\bar{t}b\bar{b}$

$80 \leq m_H \leq 130$ GeV



σ x BR ≈ 300 fb

Complex final state: H → bb, t → bjj, t → blν

(l=e , μ for trigger)

Combinatorial background from signal

reduced by reconstructing both top quarks (ε ≈ 1%)

→ b-tagging is crucial

Backgrounds : continuum ttbb, ttjj (dominant but measurable), Wjjjjjj, etc.

$H \to ZZ \to 4\,l$

$180 \leq m_H < 700$ GeV

ME calculations for W/Z+n jets should be as complete as possible

Gold-plated channel

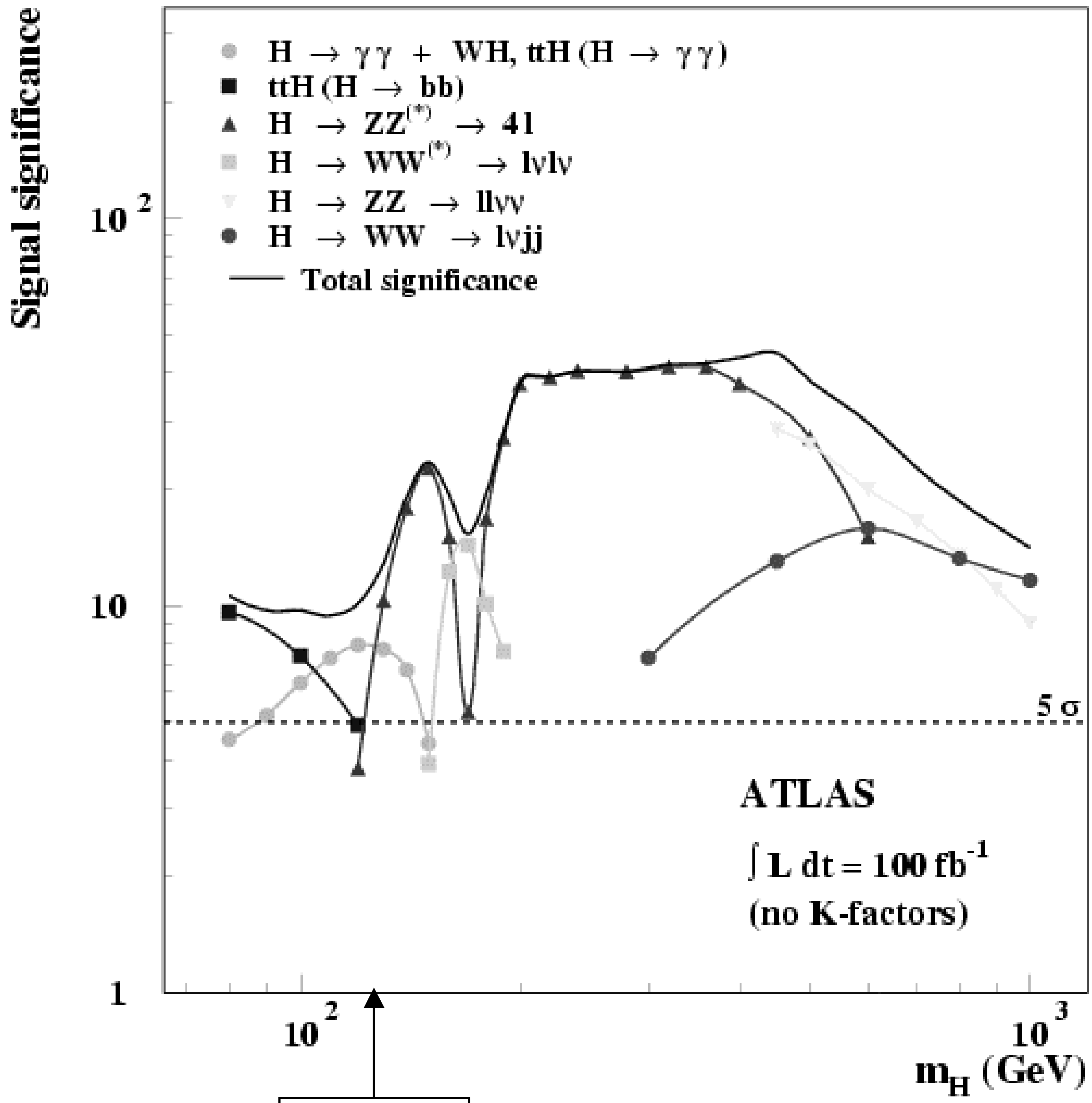
σ x BR ≈ 1-10 fb

Background: ZZ continuum (S/B > 2)

Γ_H >> 1 GeV (dominates exp mass resolution for m_H>300 GeV)

→ detector performance not crucial

SM Higgs discovery potential

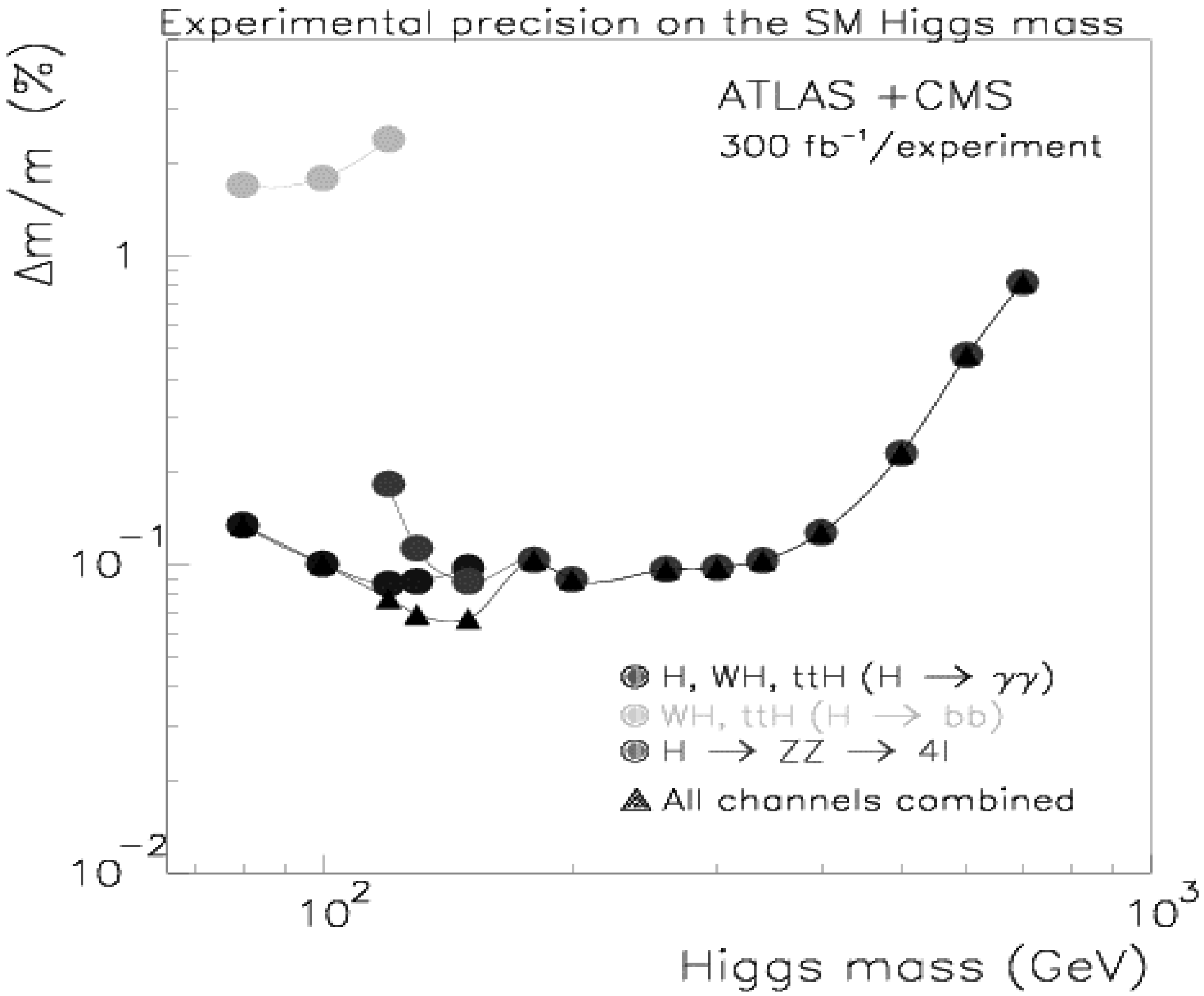


LEP2 limit

- Higgs can be discovered (signal > 5σ) over full mass range after 1 year of operation
- In most cases > 1 channel available
- No k-factors used. k~1.3 for signal $\rightarrow$ results optimistic only if k $\geq$ 2 for backgrounds

Measurement of the Higgs parameters

Higgs mass



- precision dominated by 4l and 2γ channels
- ≈ 0.1% precision up to m_H ≈ 500 GeV
- still at 1% level for m_H ≈ 700 GeV
- dominant syst. uncertainty from l/jet scale
- no theory errors included (e.g. mass shift for large Γ_H due to interference resonant/non-resonant production)

Higgs mass in MSSM

LEP lower limit: ≈ 90 GeV
upper theoretical limit: ≈115−130 GeV

MSSM Higgs	$\Delta m/m$ (%)
h, A, H $\rightarrow \gamma\gamma$	0.2–0.4
H $\rightarrow$ 4 l	0.2–0.4
H/A $\rightarrow \mu\mu$	0.2–1.5
h $\rightarrow$ bb	1–2
H $\rightarrow$ hh $\rightarrow$ bb $\gamma\gamma$	1–2
A $\rightarrow$ Zh $\rightarrow$ bbll	1–2
H/A $\rightarrow \tau\tau$	1–10

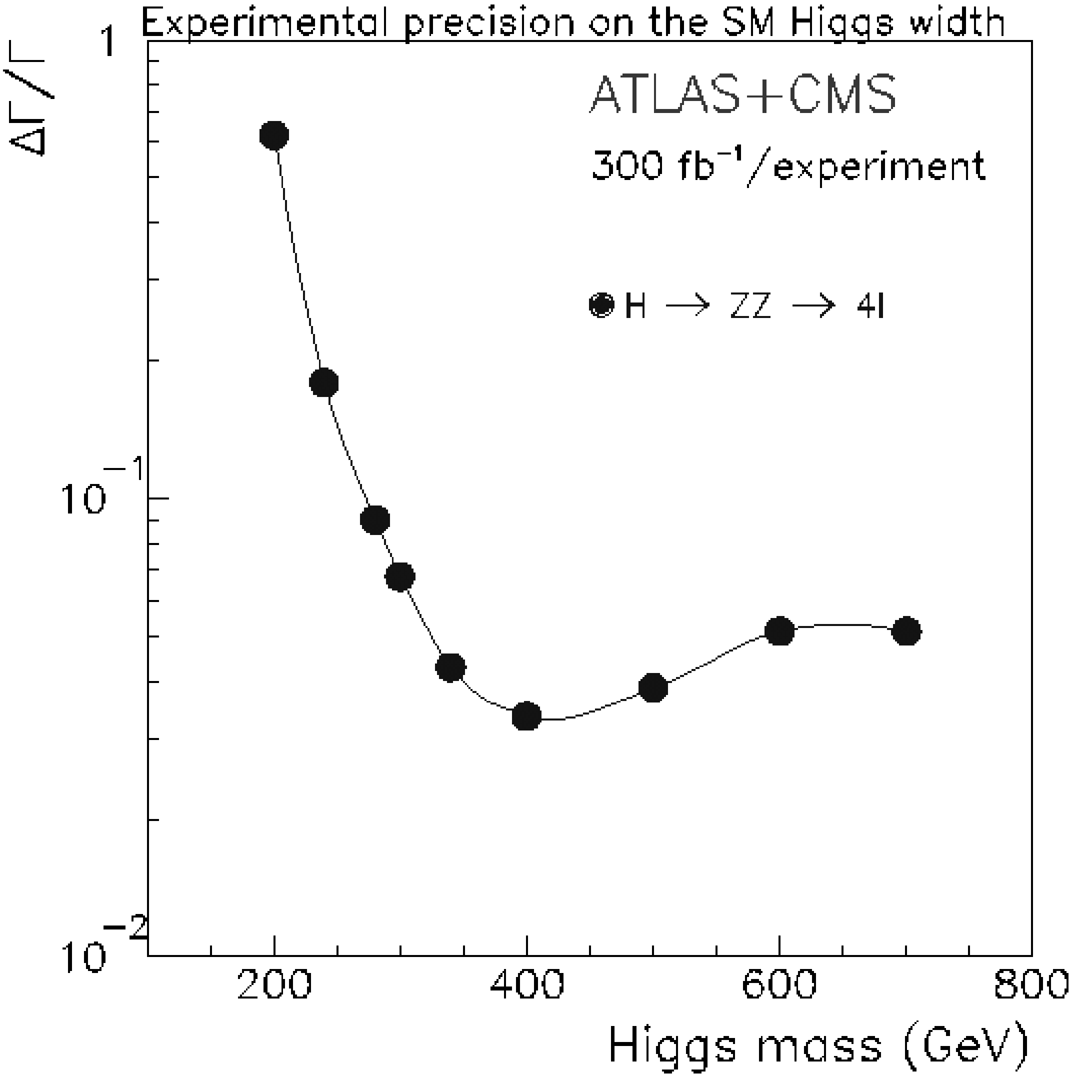
300 fb^{-1}

Systematic error on abs. energy scale:
≈ 0.1% for l/γ
≈ 1% for jets

Important to have a matching between the experimental error and the theoretical precision of the relation between m_h and the MSSM parameters

Higgs width

•Measured directly from width of reconstructed peak
•Only possible for m_H <200 GeV ($\Gamma_H \approx$ detector resolution)



≈ 5% precision for 300 < MH <700 GeV
(region where best discovery channel H→ZZ →4l)
Detector resolution measured to 1.5% from Γ_Z

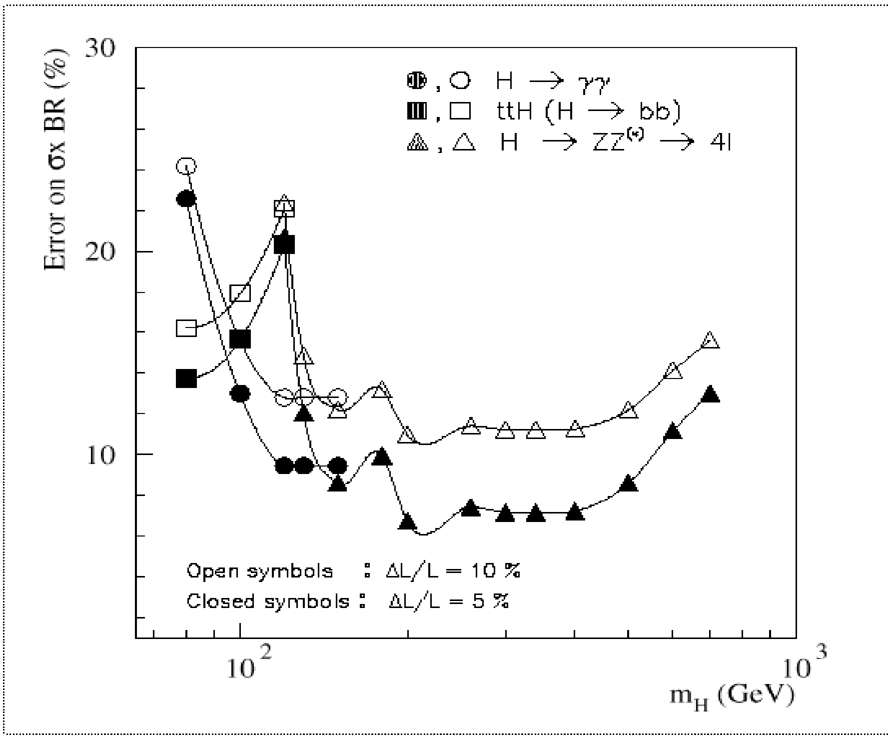
Uncertainty from Z radiative decays

Higgs production rates: σ x BR

•typical precisions:

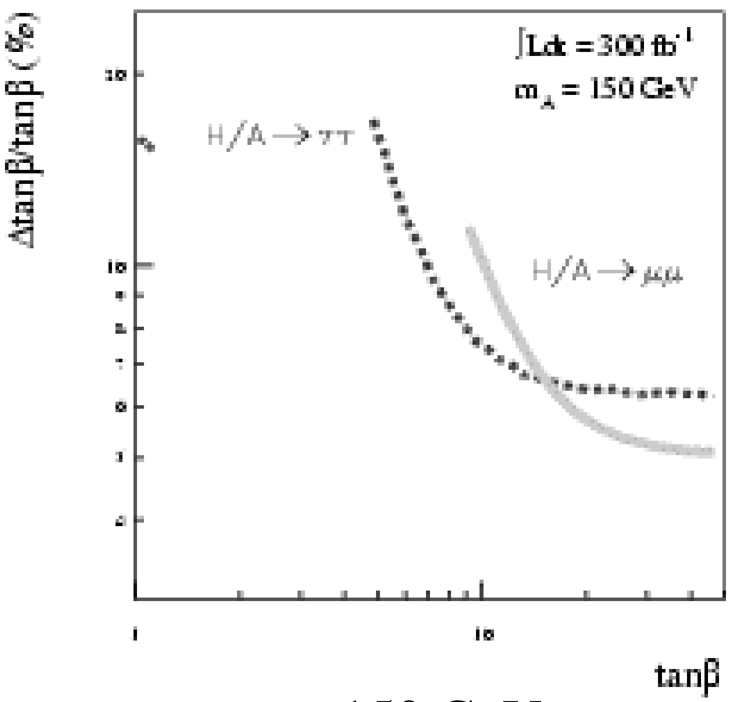
7% -20%
(depending on m_H)

• dominant syst.:
luminosity (5-10%)



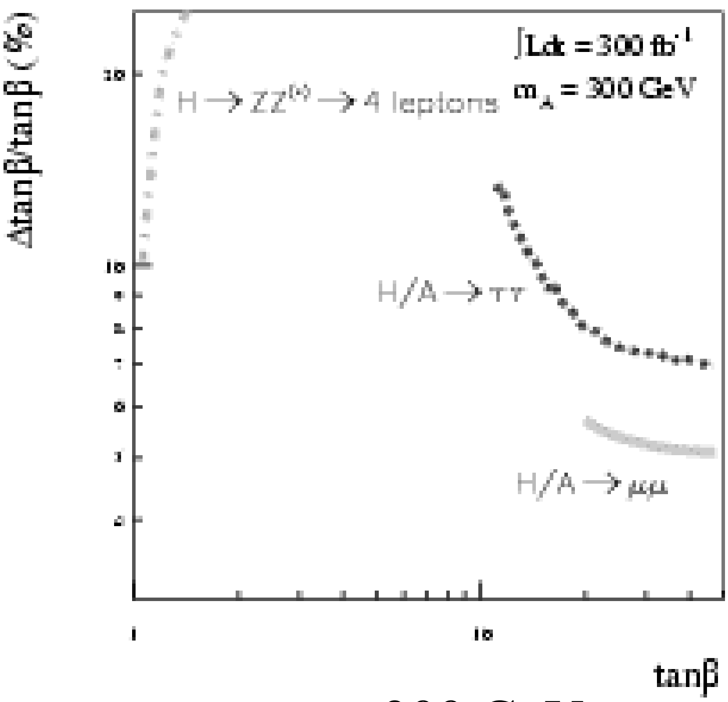
- rate of $H \rightarrow ZZ^{(*)} \rightarrow 4l$ allows disentangling SM/MSSM (~10 times smaller in MSSM)
- rate of $A/H \rightarrow \tau\tau, \mu\mu$ allows measurement of tgβ

ATLAS



m_A=150 GeV

ATLAS



m_A=300 GeV

Couplings and branching ratios:

- Can be obtained from rate measurements if σ (pp H+X) known from theory
- Otherwise: measure ratios of rates for different channels $\rightarrow$ ratios of couplings $\rightarrow$ many constraints of theory
- A few examples here

300 fb^{-1}

From	One measures	Error
$\frac{(t\bar{t}H + WH) \rightarrow \gamma\gamma + X}{(t\bar{t}H + WH) \rightarrow b\bar{b} + X}$	$\frac{BR\ (H \rightarrow \gamma\gamma)}{BR\ (H \rightarrow b\bar{b})}$	≈ 15 % (*) 80-120 GeV
$\frac{H \rightarrow \gamma\gamma}{H \rightarrow 4l}$	$\frac{BR\ (H \rightarrow \gamma\gamma)}{BR\ (H \rightarrow ZZ^*)}$	≈ 7 % 120-150 GeV
$\frac{t\bar{t}H \rightarrow \gamma\gamma, b\bar{b}}{WH \rightarrow \gamma\gamma, b\bar{b}}$	$\left(\frac{t\bar{t}H}{WWH}\right)^2$	≈ 15 % (*) 80-120 GeV

(*) also in MSSM for $m_A > 200$ GeV

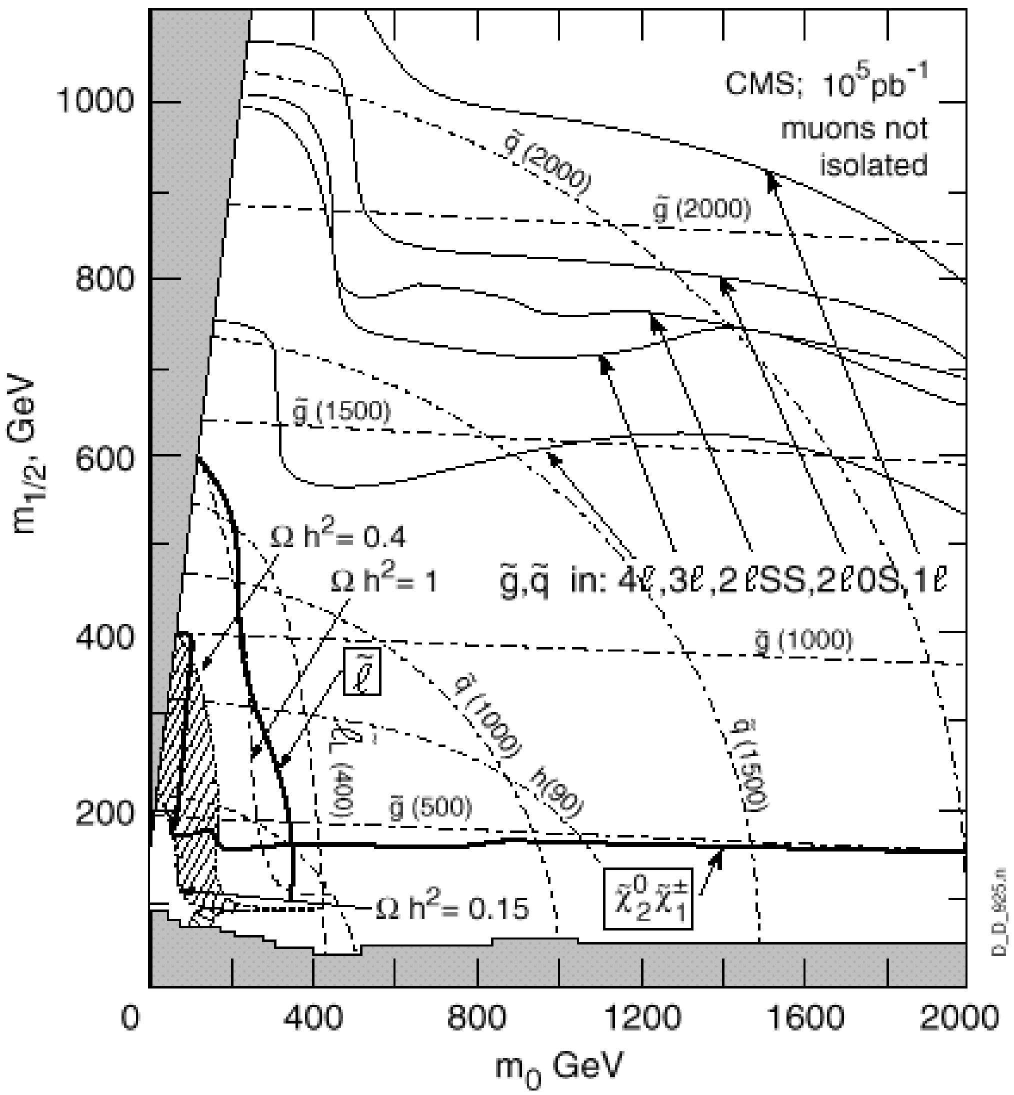
Error dominated by statistics
Many other possibilities under study in SM (e.g. ratio of WW to gg fusion) and MSSM (e.g. ratio of A/H to $\mu\mu$ and to $\tau\tau$)

SUPERSYMMETRY

Can be discovered up to $m_{\tilde{q},\tilde{g}}$ ~ 2 TeV
(~ independent of model parameters)
using inclusive signatures

$\sigma(\tilde{q}\tilde{q}, \tilde{g}\tilde{g}, \tilde{q}\tilde{g}) \approx \text{pb}$ $\quad m_{\tilde{q},\tilde{g}} \sim 1$ TeV

$\tilde{q}, \tilde{g}$ undergo cascade decays →
many **jets, leptons, missing E_T** in final state



CMS,
100 fb^{-1}
mSUGRA

5 σ contours
for various
signatures
with high p_T l

Can ATLAS and CMS perform **precise measurements** (masses, couplings, etc.) $\rightarrow$ **extract fundamental parameters of theory** ?

Not obvious (two LSPs, not enough constraints to reconstruct mass peaks)

5 points of mSUGRA studied

Point	m_0 (GeV)	$m_{1/2}$ (GeV)	A_0 (GeV)	tgβ	sgn μ
1	400	400	0	2.0	+
2	400	400	0	10.0	+
3	200	100	0	2.0	–
4	800	200	0	10.0	+
5	100	300	300	2.1	+

Point	$\tilde{g}$ mass (GeV)	$\tilde{u}_R$ mass (GeV)	$\chi^\pm$ mass (GeV)	$\tilde{e}_R$ mass (GeV)	h mass (GeV)
1	1004	925	325	430	95
2	1008	933	321	431	115
3	298	313	96	207	68
4	582	910	147	805	112
5	767	664	232	157	93

-- Reconstruct exclusive decay chains $\rightarrow$ determine masses from kinematic distributions (often model-independent)

-- Global fit of the model to all measurements $\rightarrow$ determine parameters (à la LEP)

Example : $pp \to \tilde{q}_L \tilde{q}_R$

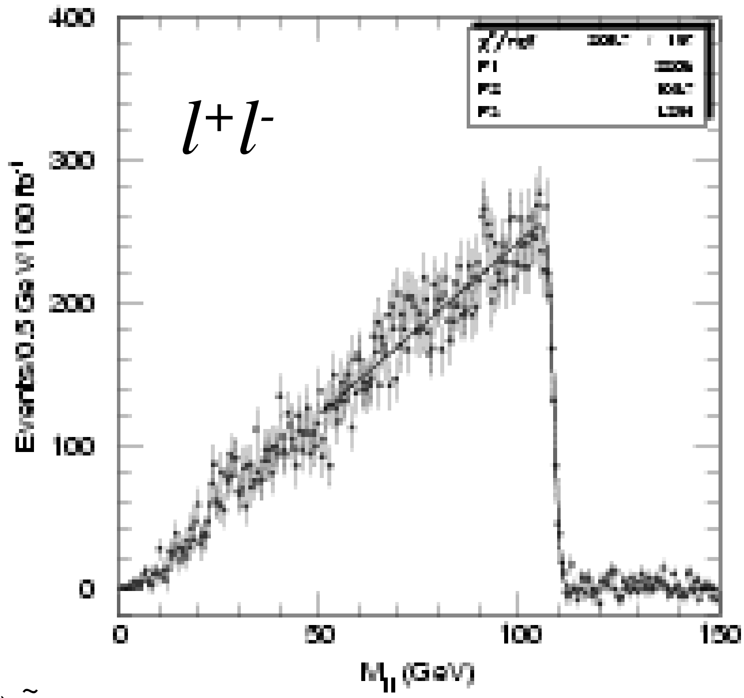
Point 5

$\tilde{q}_L \to q\, \chi^0{}_2$

$\hookrightarrow \tilde{l}_R \ l$

$\hookrightarrow l\, \chi^0{}_1$

$m_{\tilde{q}_L} = 690$ GeV

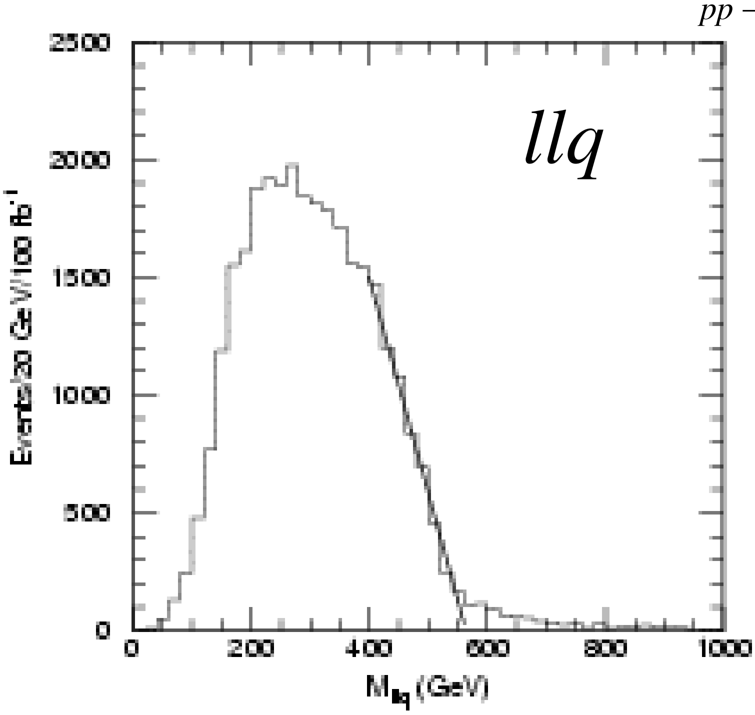


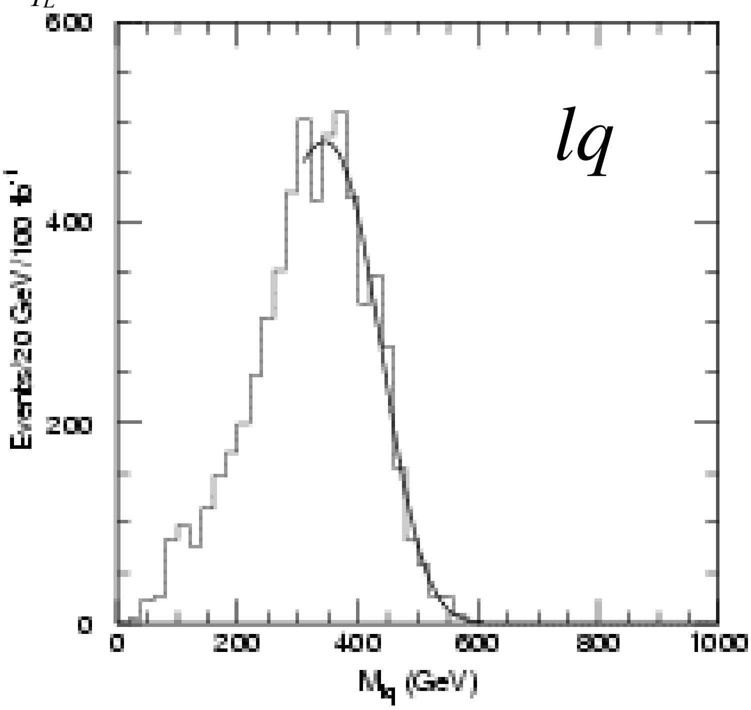
ll constrains $\chi^0{}_{1,2}$ $\tilde{l}_R$

llq constrains $\chi^0{}_{1,2}$ $\tilde{q}_L$

lq constrains $\chi^0{}_2$ $\tilde{l}_R$ $\tilde{q}_L$

$pp \to \tilde{q}_L$





End-points can be measured with precision of 1‰ to 1% for 100 fb^{-1}

Summary of measurements for Point 5

ATLAS

Measured mass	Value (GeV)	Error (%) 30 fb^{-1}	Error (%) 300 fb^{-1}
h	92.9	1	0.2
l^+l^- edge	108.7	0.4	0.2
$\tilde{l}_R$	157.2	1.2	0.3
$\tilde{l}_L$	239	4	1
$\tilde{q}_L$	688	1.7	1
$\tilde{q}_R$	662	3	1.5
$\tilde{g}$	767	2.6	1.5
$\tilde{t}_1$	493	--	10

Particles directly observable:

$$\tilde{q}_L, \tilde{q}_R, \tilde{g}, \tilde{t}_1, \tilde{b}_R, \tilde{l}_R, \tilde{l}_L, h, \chi^0_2$$

These experimental measurements used to constrain the model and its parameters:

$m_0(GeV)$	$m_{1/2}(GeV)$	$tg\beta$	ATLAS 300 fb^{-1}
100 ± 1.4	300 ± 1.7	2 ± 0.09	

Precision of order 1%

Conclusions

- LHC has <u>huge discovery potential</u> for New Physics:
  - -- SM Higgs : full mass range
  - -- MSSM Higgs : cover m_A , tgβ plane fully
  - -- SUSY : $\tilde{q}, \tilde{g}$ up to m ~ 2 TeV
  - -- Beyond SUSY (LQ, W', Z', etc.) : up to m ~ 5 TeV

- <u>Great potential</u> also for <u>precise measurements</u>:
  - -- m_W to ≈ 15 MeV, TGC to 10^{-3}
  - -- many measurements in top sector (precision ~ %)
  - -- Higgs mass : 1 ‰ (SM, h) to 1% (A/H)
  - -- many SUSY measurements
    → fundamental parameters to ≈ %

- Excellent multi-purpose detectors needed (b-tagging, l/j energy resolution, dynamic range, particle identification) → under construction

Many thanks to Fabiola Gianotti for her help
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