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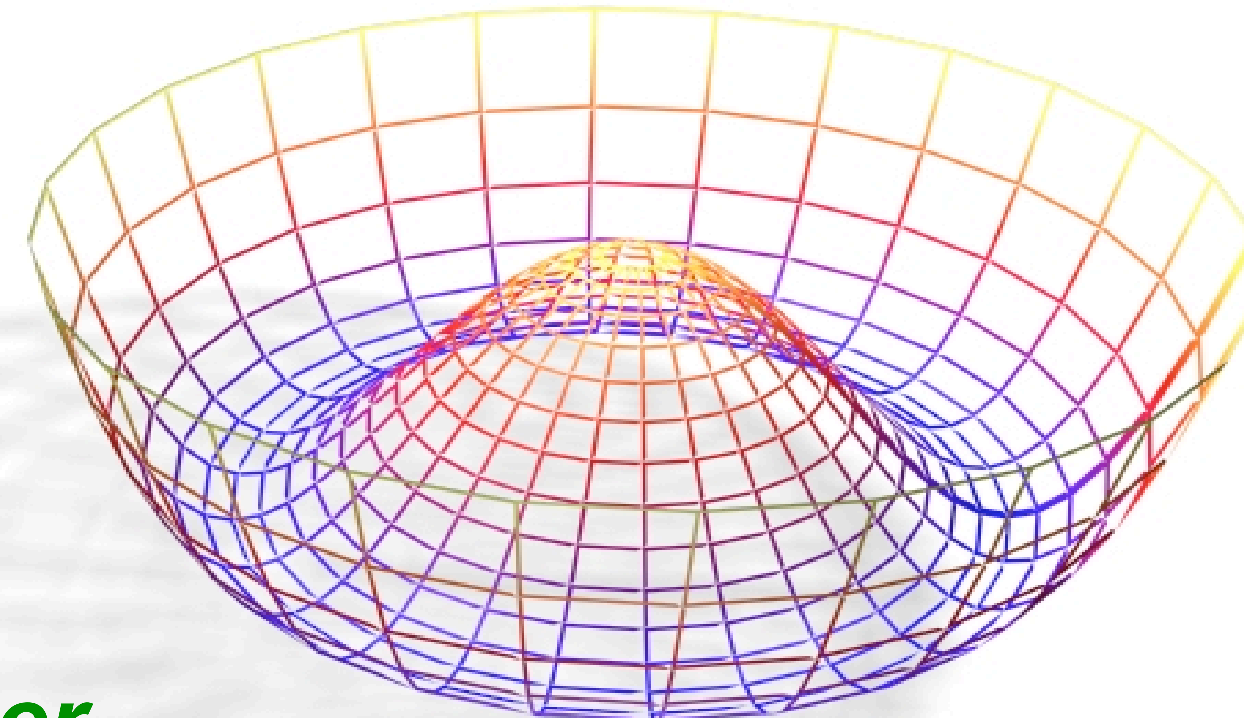
Impact of an Early “Higgs” observation at the LHC on the ILC



Kyle Cranmer
(BNL)

Introduction

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Aim of this talk is to consider the impact on the ILC in the scenario that the LHC observes a Higgs-like object it's early phase (defined as ~$10 fb^{-1}$)

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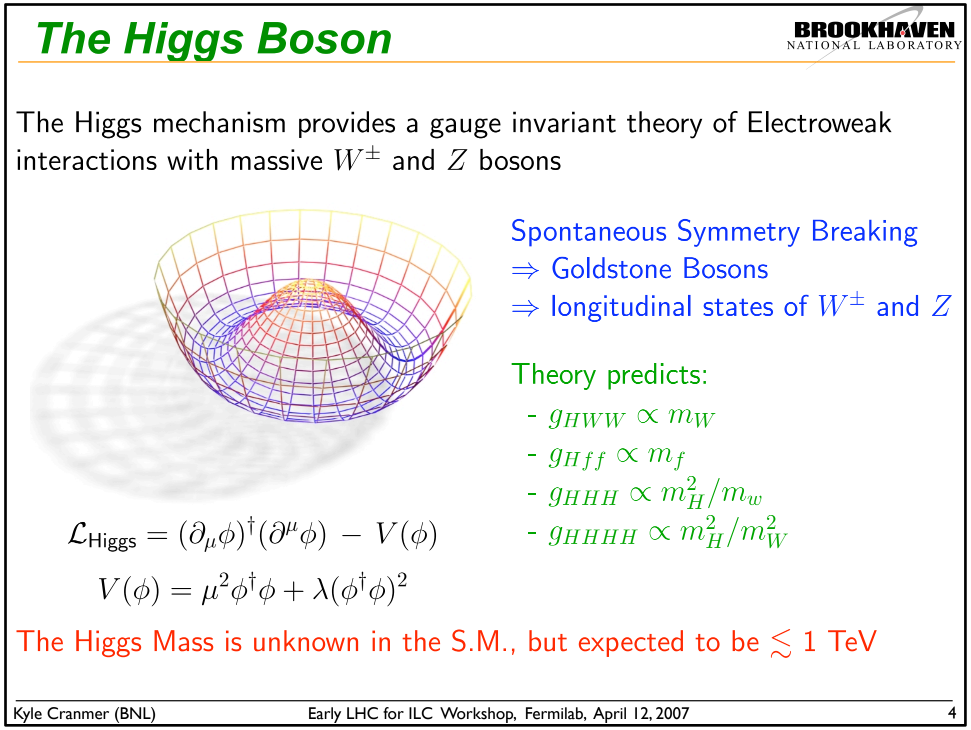
So I will not:

- Try to convince you that the Higgs is interesting



Introduction

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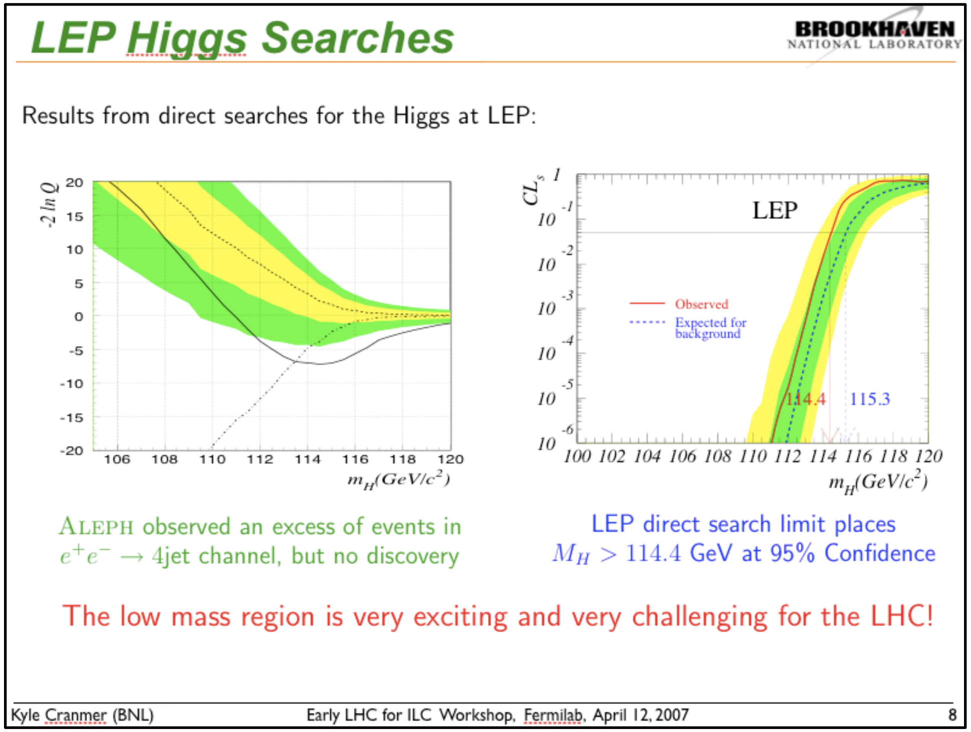
So I will not:

- Tell you about the history of Higgs searches



Introduction

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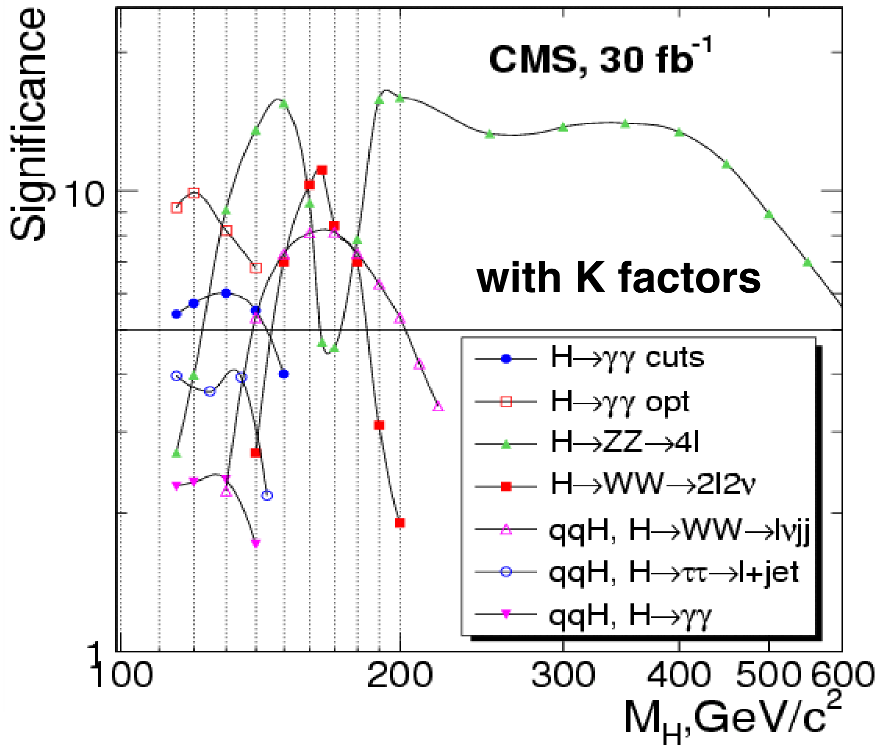
Aim of this talk is to consider the impact on the ILC in the scenario that the LHC observes a Higgs-like object it's early phase (defined as ~10fb^{-1})

So I will not:

- Try to convince you that the LHC can and will discover the Standard Model Higgs



Introduction

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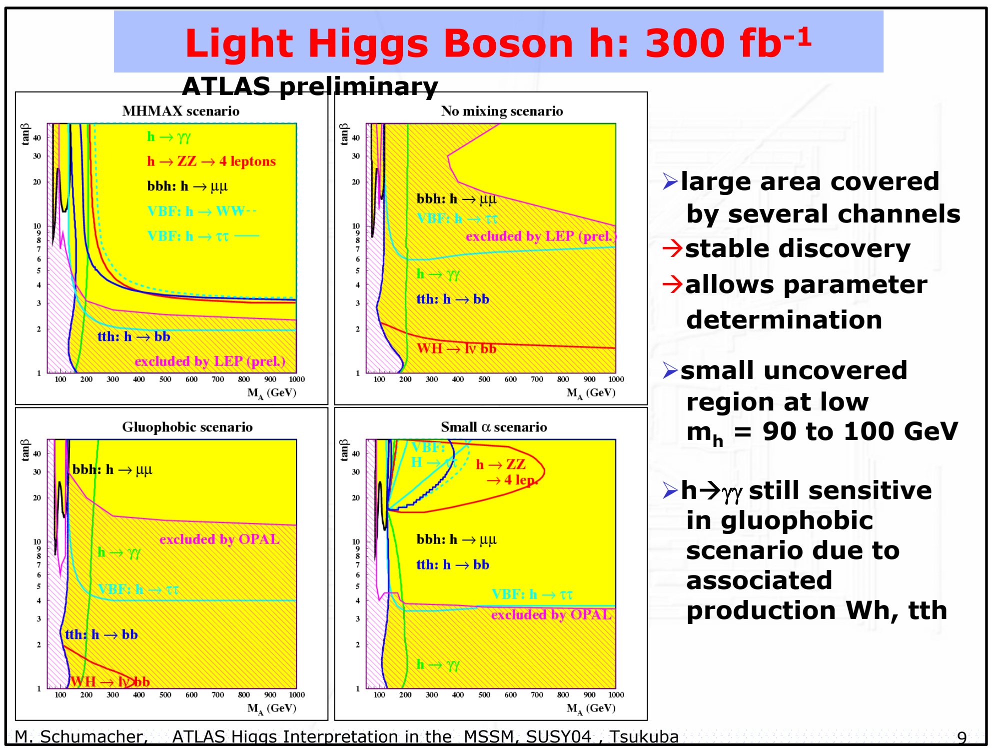
Aim of this talk is to consider the impact on the ILC in the scenario that the LHC observes a Higgs-like object it's early phase (defined as ~10fb^{-1})

So I will not:

- Try to catalog the discovery potential for model X



Introduction

Aim of this talk is to consider the impact on the ILC in the scenario that the LHC observes a Higgs-like object it's early phase (defined as ~10fb^{-1})

However, there are not always results for 10fb^{-1}, so we will have to reinterpret some familiar results and make some rough guesses.

- The recent PTDR from CMS has several results for 10fb^{-1}
- ATLAS is currently producing CSC notes focused on early phase, keep track of studies you would like to request

The first questions we would ask

Quick questions:

- What is the mass roughly? Light or Heavy?
- What kind of decays? Fermions or Bosons)?
  - how many modes are available?
- Does the rate seem roughly consistent with the Standard Model?

Does it look like the Standard Model Higgs?

- More precise answers to the questions above
- Spin, CP, width, coupling measurements, etc.

What is the impact on the ILC?

- Impact in the short term on design / planning
- Impact in the long term in terms of expected physics potential

But first a word from our sponsor...

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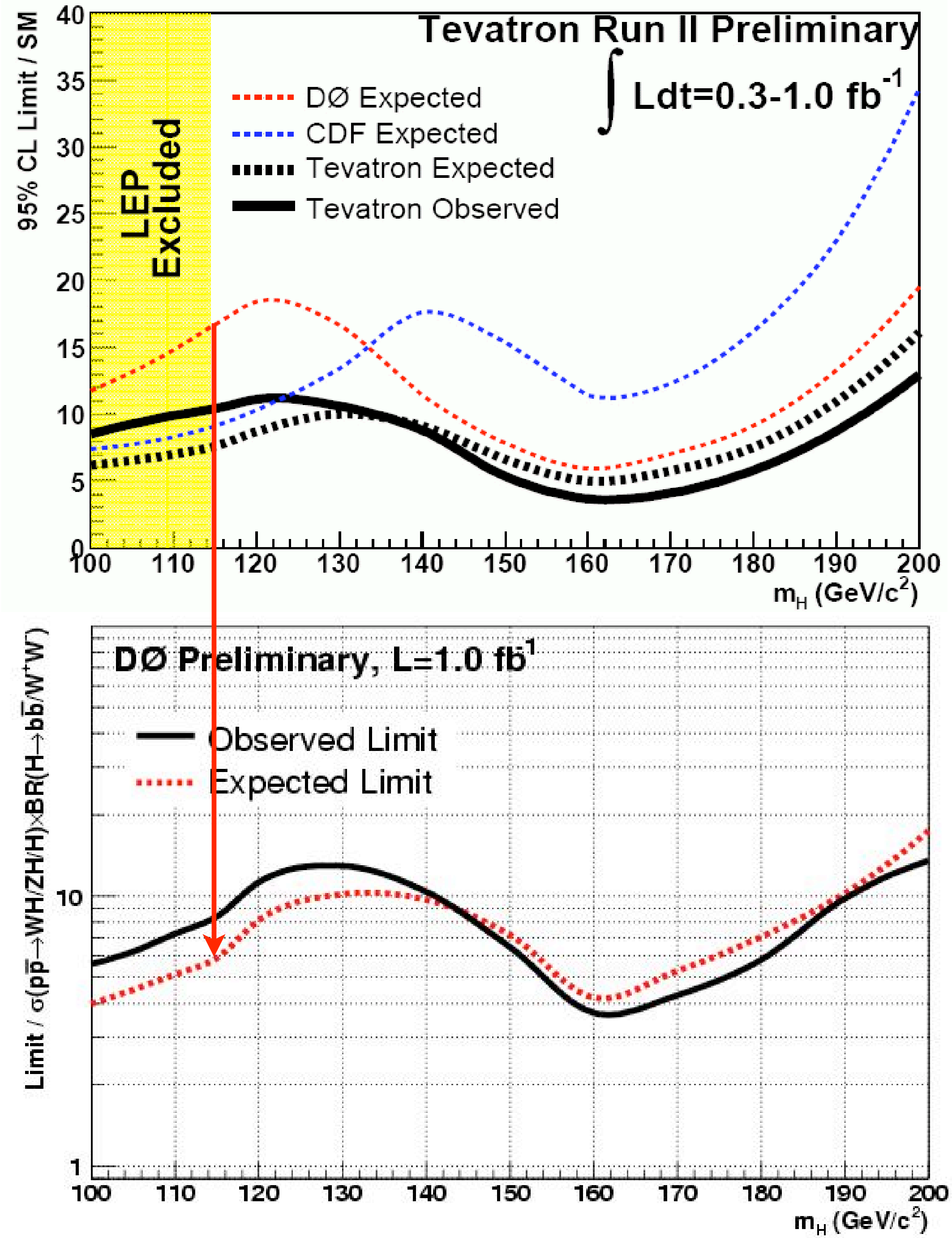
I would like to acknowledge the impressive work being done at the Tevatron Higgs searches

- ✗ Large improvement at low mass: factor of ~3!
  - ✗ Better than luminosity increase alone:

$$\sqrt{L_{New}/L_{old}} = 1.7$$

Wade Fisher's Wine & Cheese

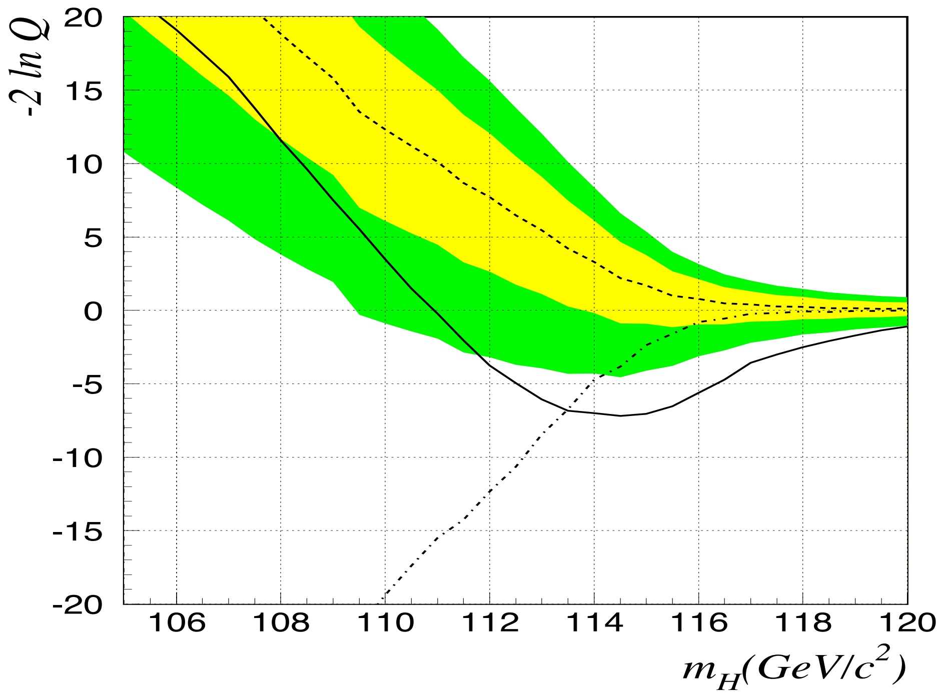
And consider two possible scenarios



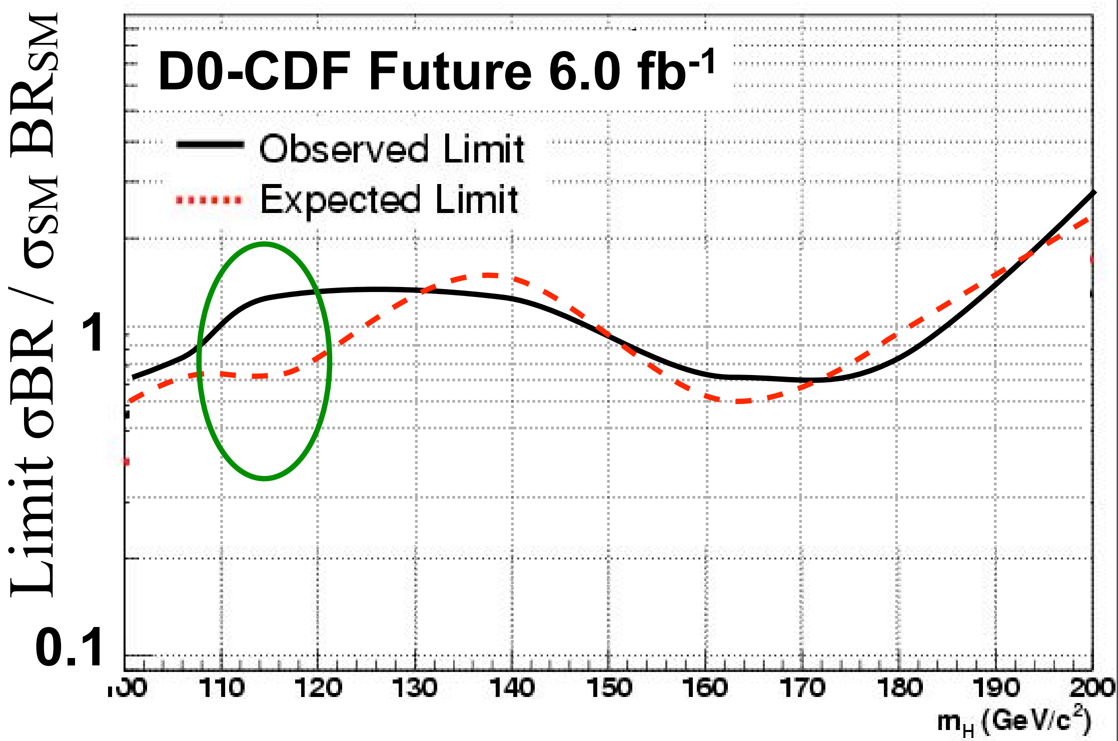
A Possible Scenario

It is possible that the combination will be sensitive to a Standard Model Higgs

- ☑ if the observed limit at ~115 is much higher than the expected, that would be exciting!



ALEPH observed an excess of events in $e^+e^- \to 4$jet channel, but no discovery



A Possible Scenario

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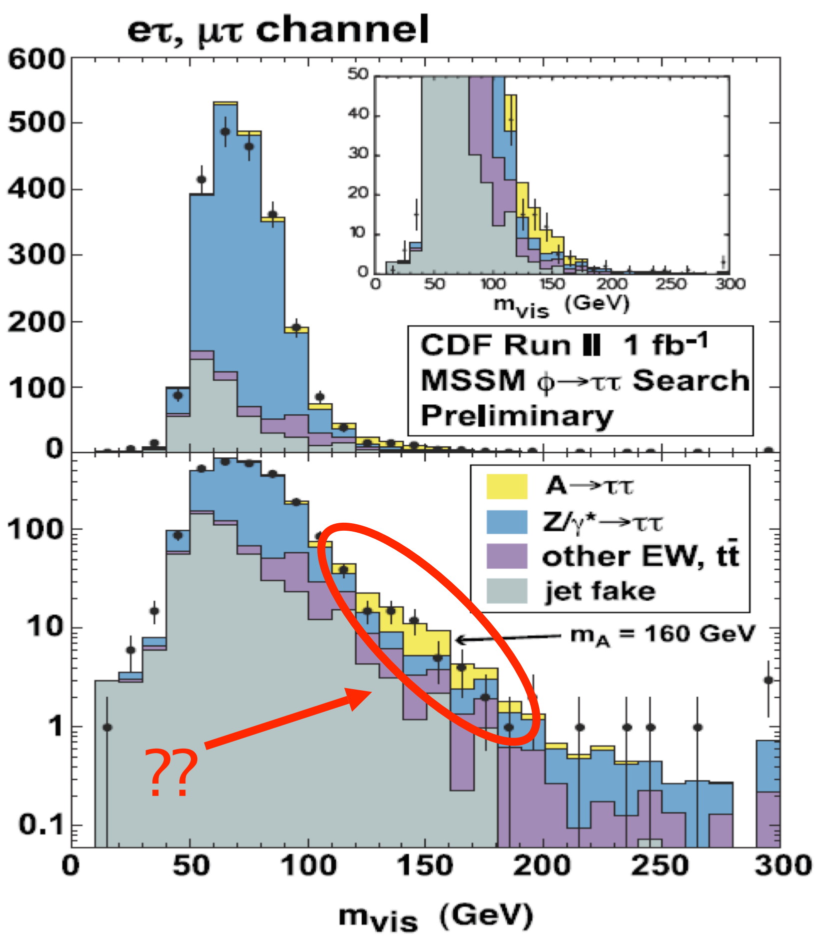
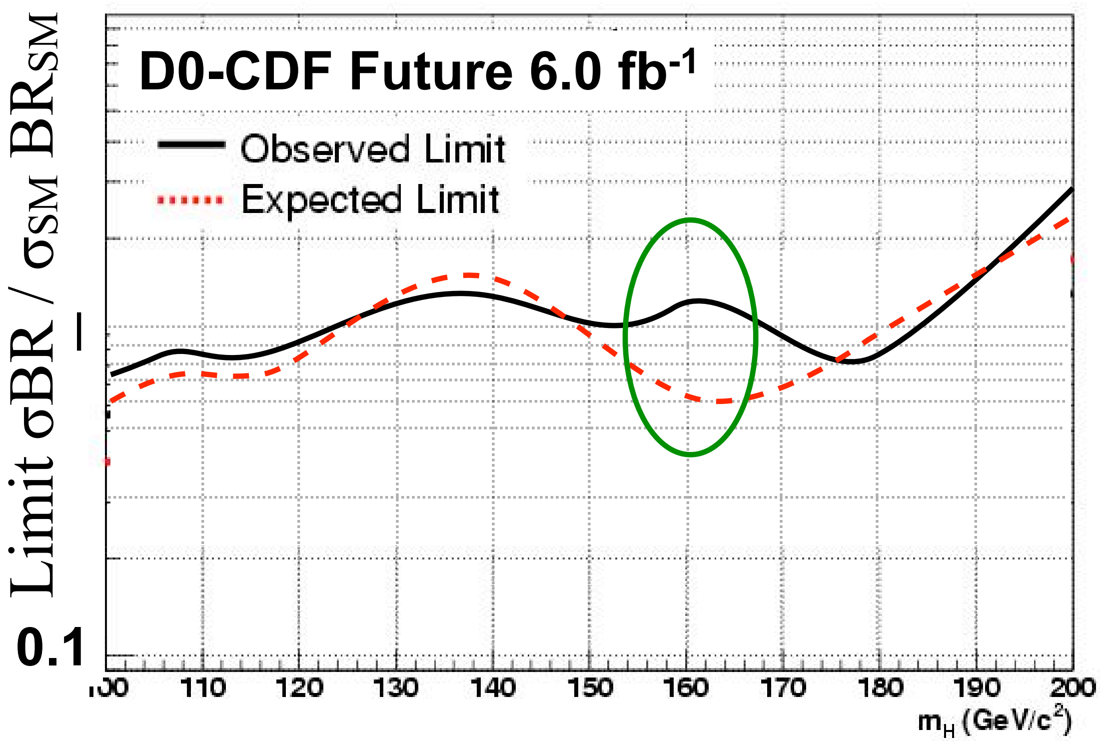
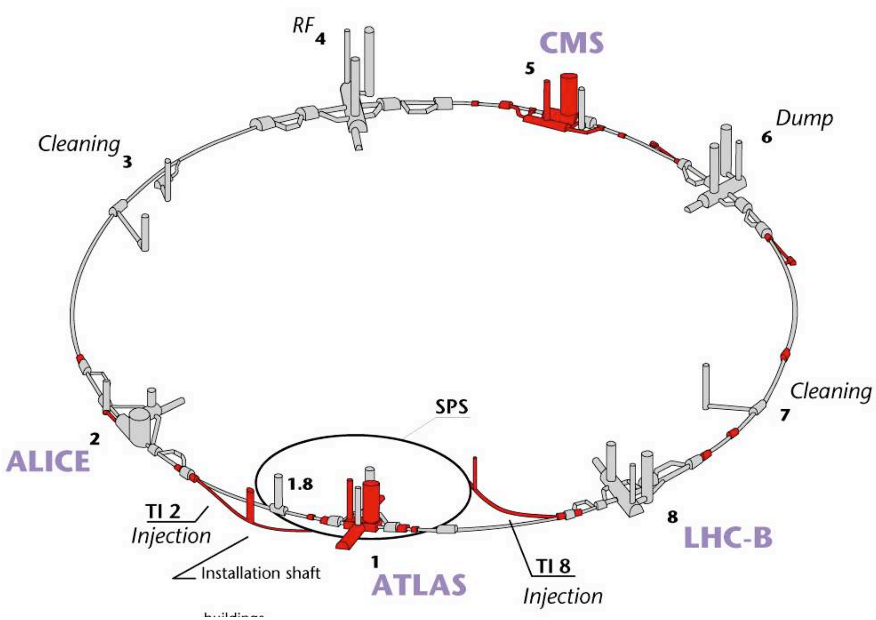
It is possible that the combination will be sensitive to a Standard Model Higgs

- ☑ if the observed limit at ~160 is much higher than the expected, that would also be exciting!

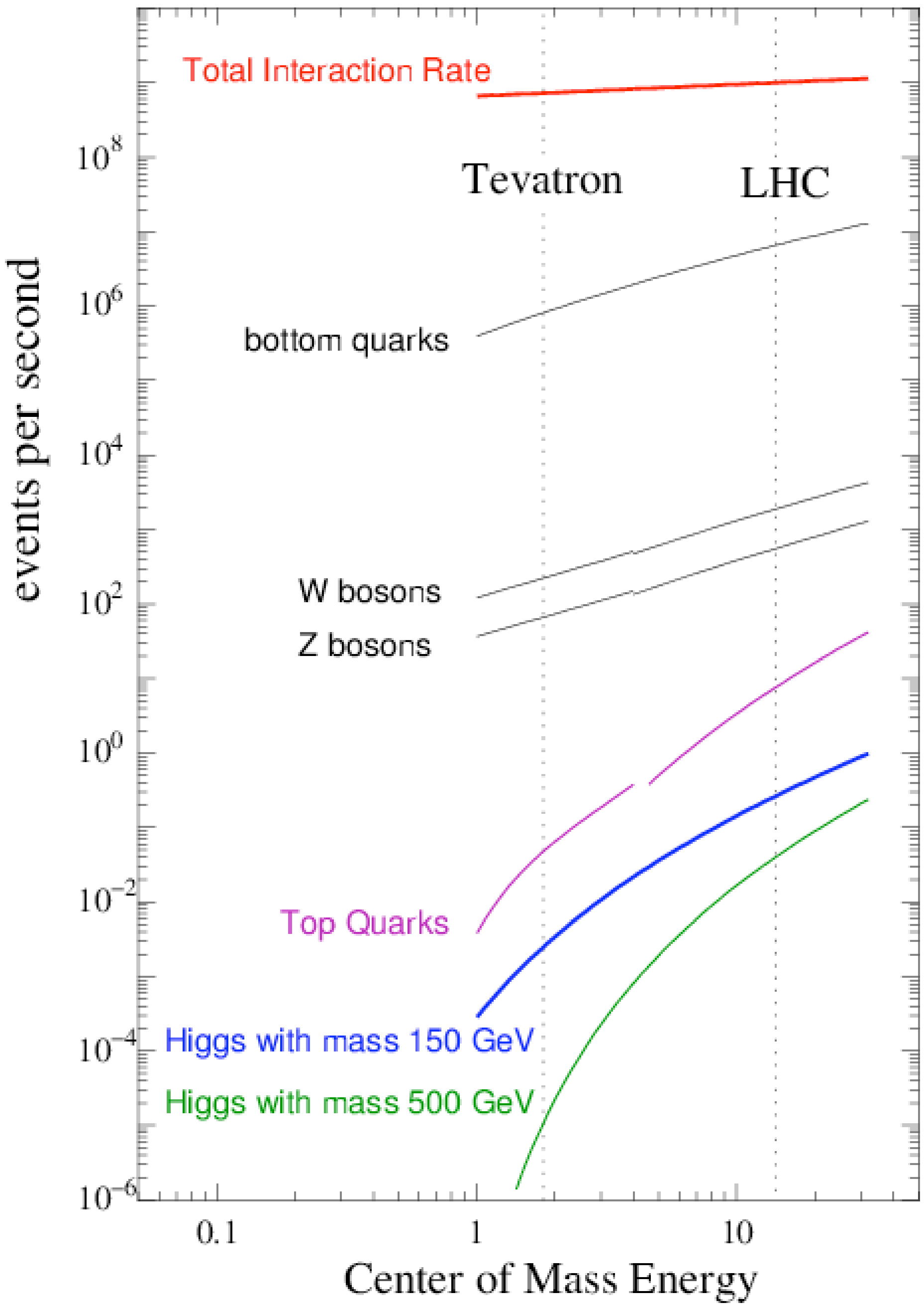




The LHC



- 26 km in circumference
- p-p @ $\sqrt{s} = 14$ TeV
- Instantaneous Luminosity $\approx 10^{33} - 10^{34}$ cm^{-2}s^{-1}
- "pile-up" : 2-20 inelastic collisions per bunch crossing
- 40 MHz bunch crossings

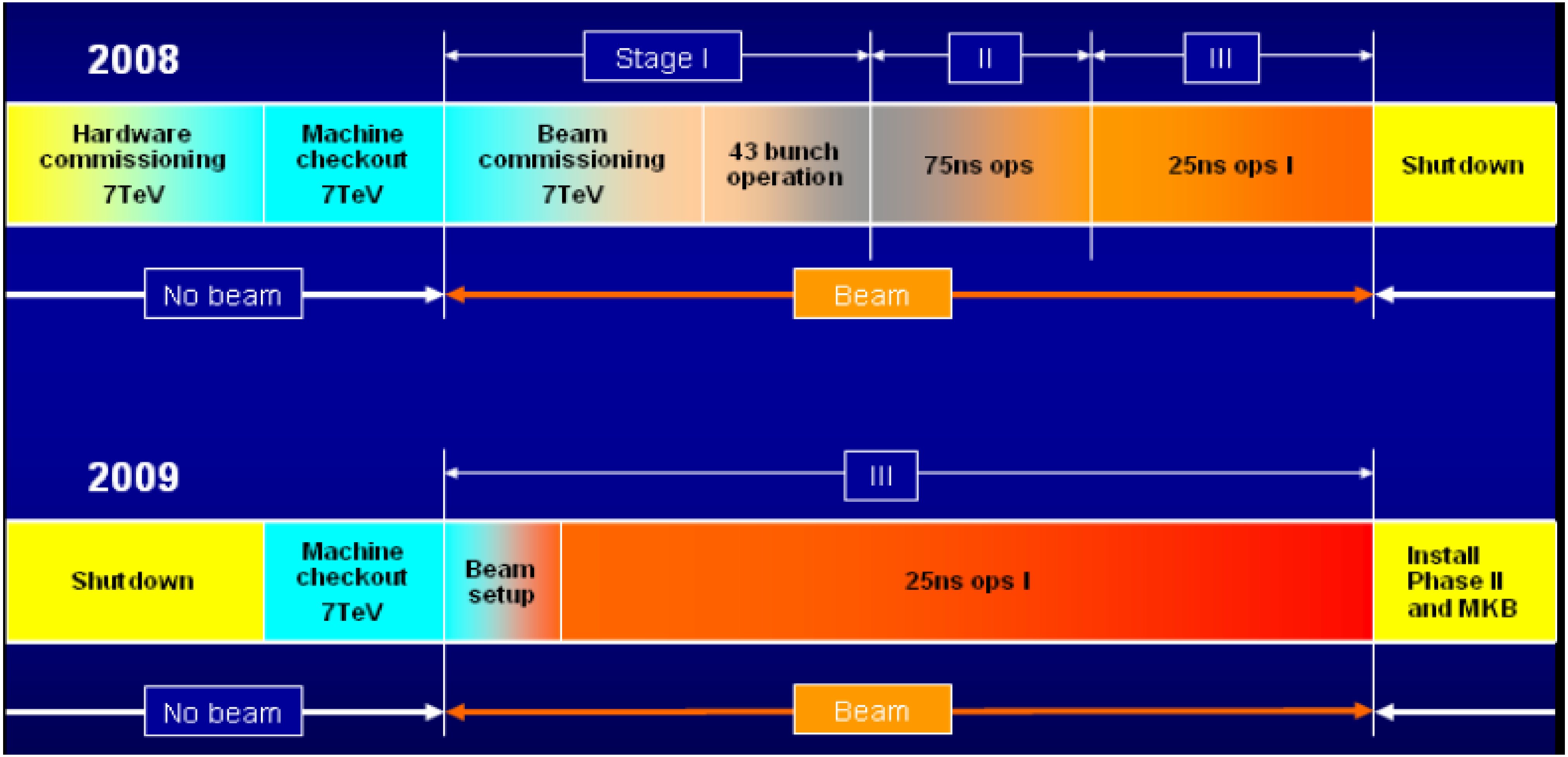


LHC Staged Commissioning

Stage I: "Pilot physics" ~1 month, 43 bunches, no crossing angle, L<10^{32} cm^{-2}s^{-1}

Stage II: 75ns operation, push crossing angle and squeeze, L<10^{33}

Stage III: 25ns operation, nominal crossing angle, L<2*10^{33}



Production and Decay of SM Higgs

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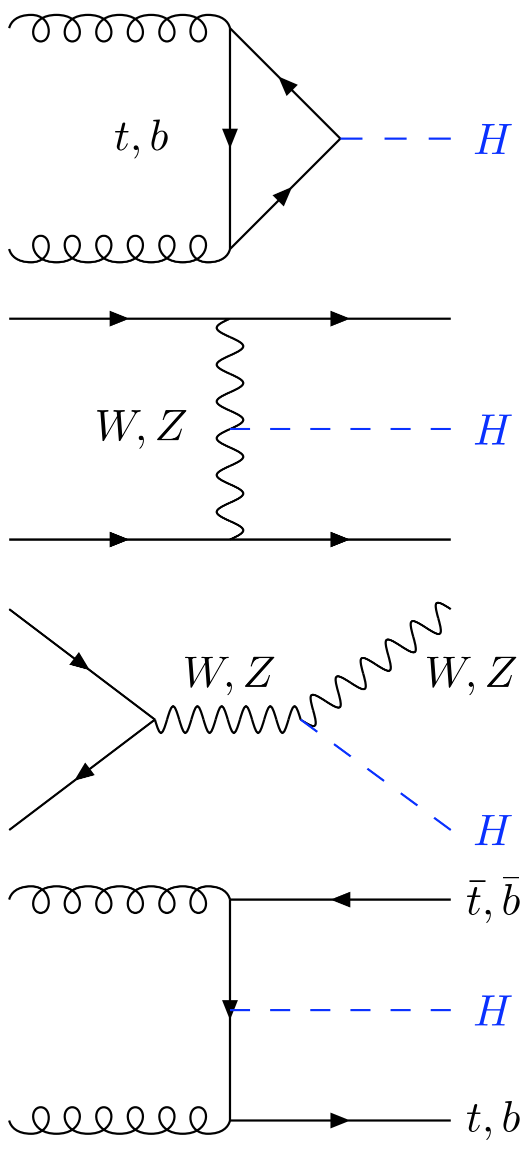

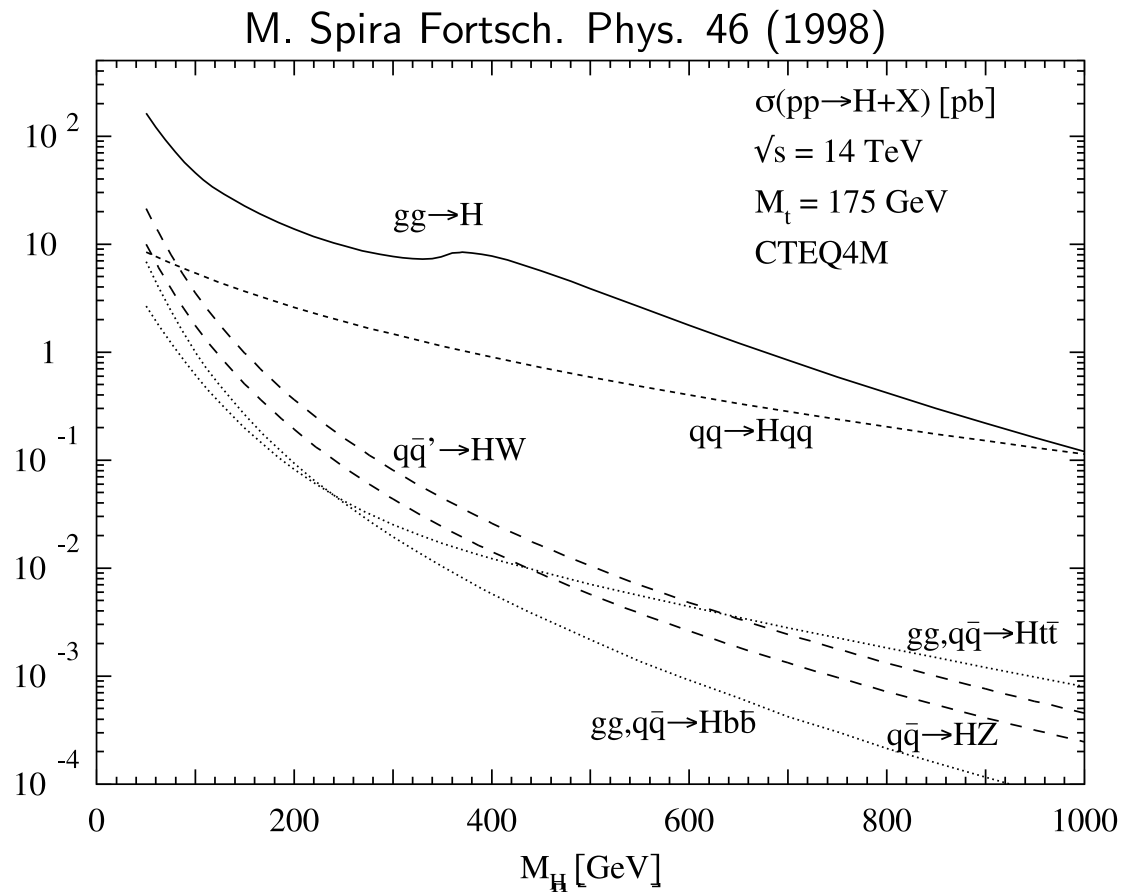

- Gluon-Gluon Fusion dominant production process ($\sim 10pb$).
- Vector Boson Fusion (VBF) $\approx 20\%$ of gg at 120 GeV
- $BR(H \rightarrow b\bar{b})$ dominant at low mass, but need trigger
- Forward Tagging Jets of VBF help S/B

Production and Decay of SM Higgs

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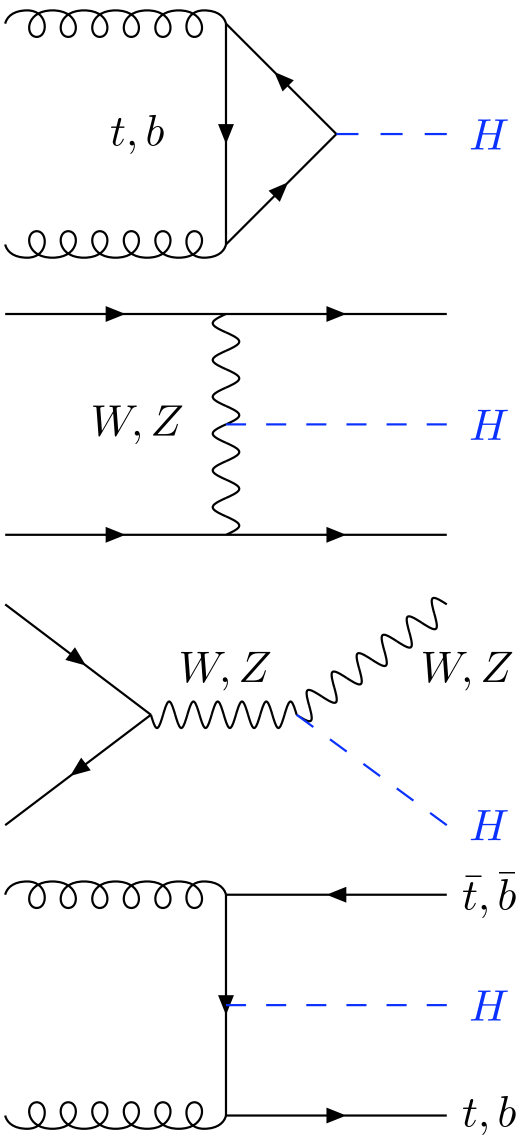
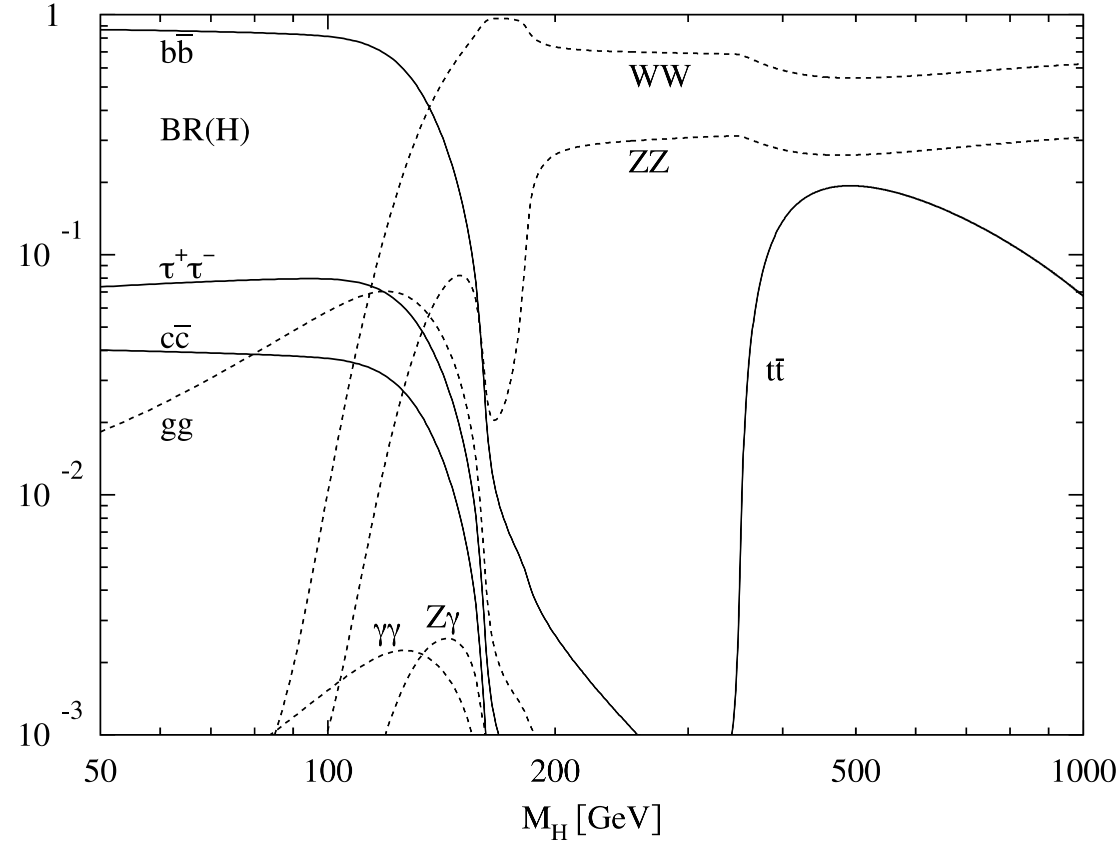


M. Spira Fortsch. Phys. 46 (1998)



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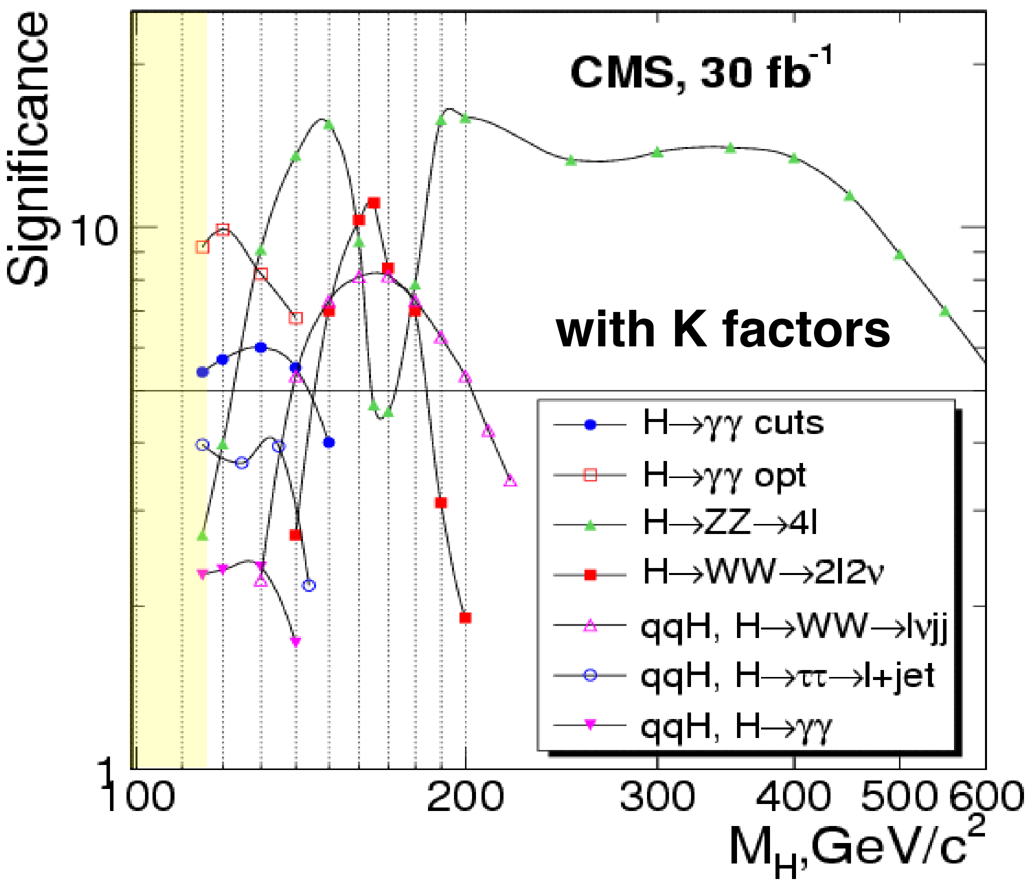
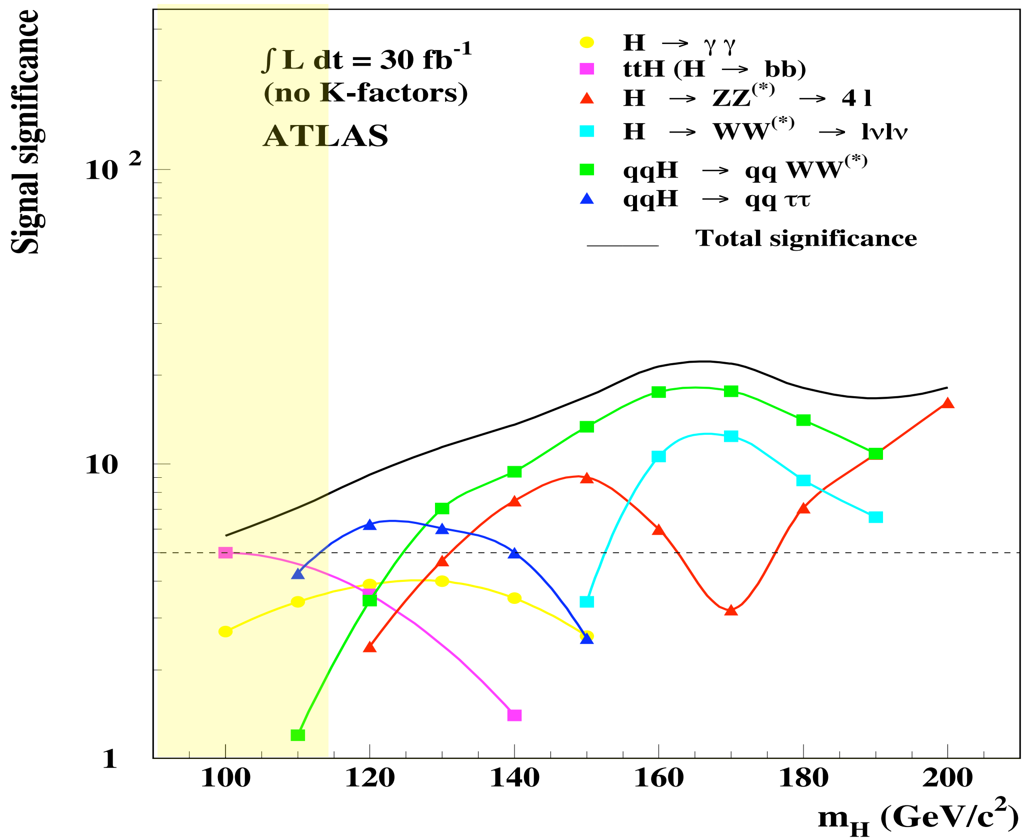
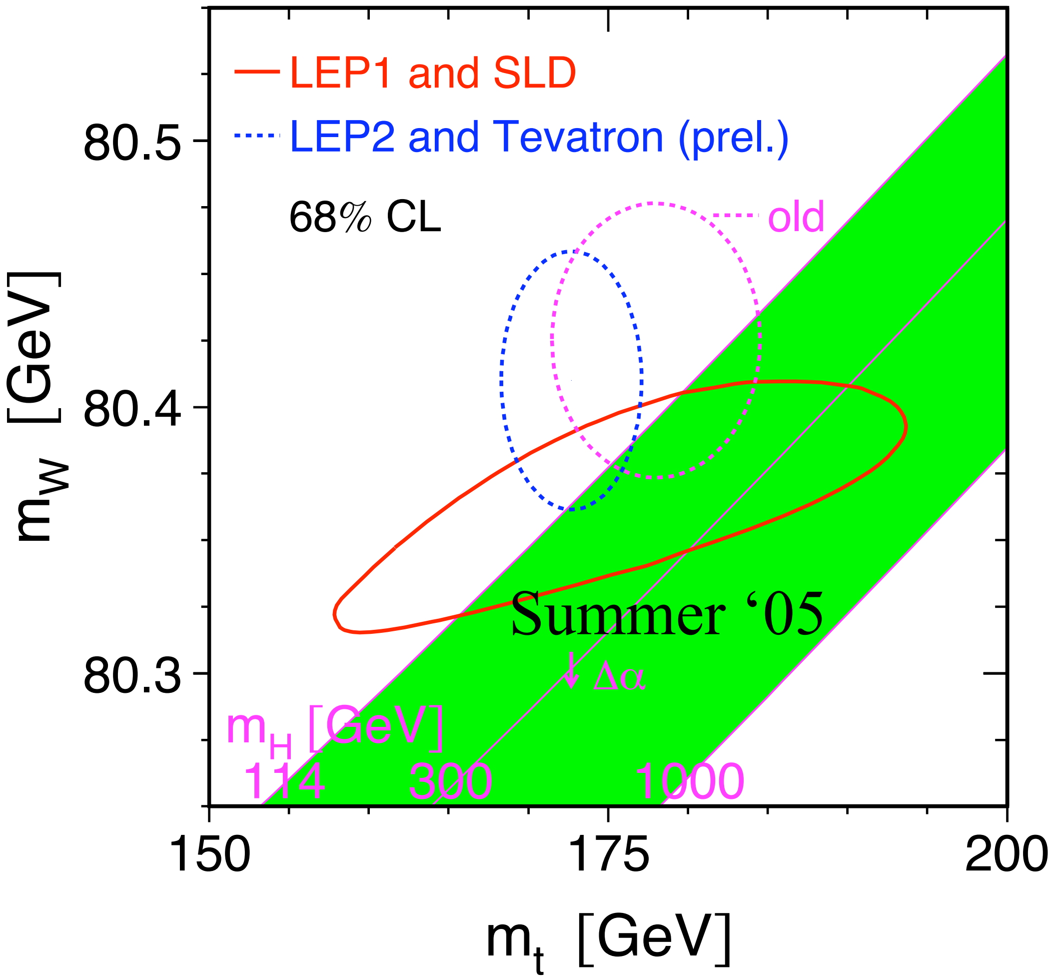
Comparison of ATLAS & CMS Discovery Potential

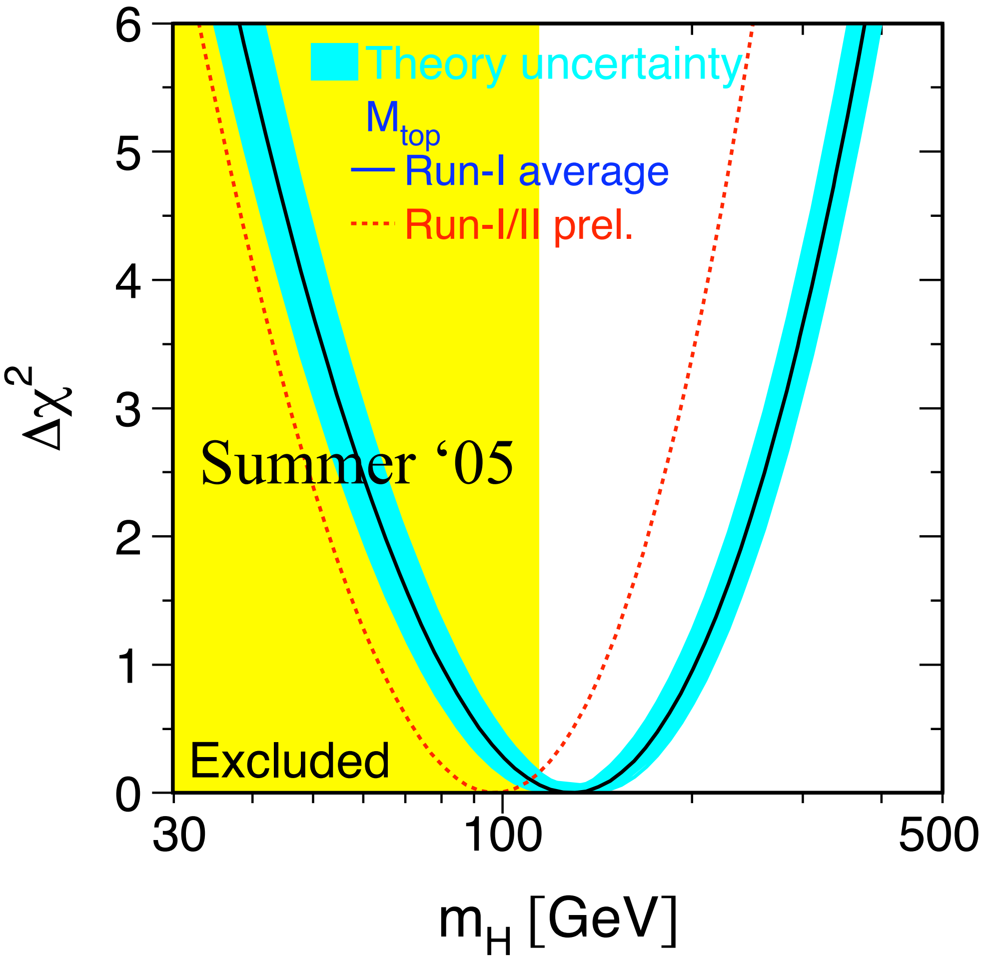




- ATLAS qqH, H$\rightarrow \tau\tau$ include $ee, e\mu, \mu\mu, e\tau_h, \mu\tau_h$ final states
- CMS H$\rightarrow \gamma\gamma$ result looks much more powerful (more later)
- ATLAS qqH, H$\rightarrow$ WW also includes WW $\rightarrow l\nu l\nu$
- CMS results include K factors

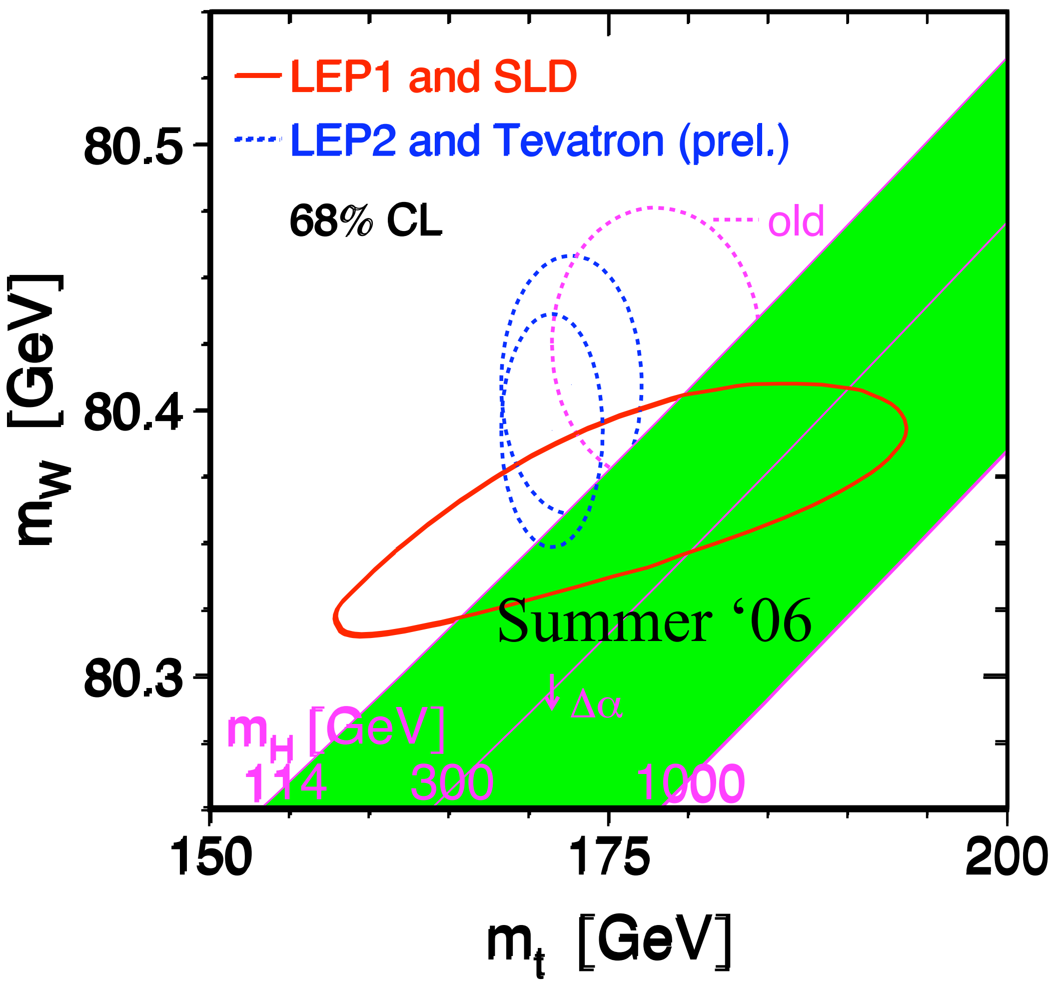
Motivation for a Light Higgs

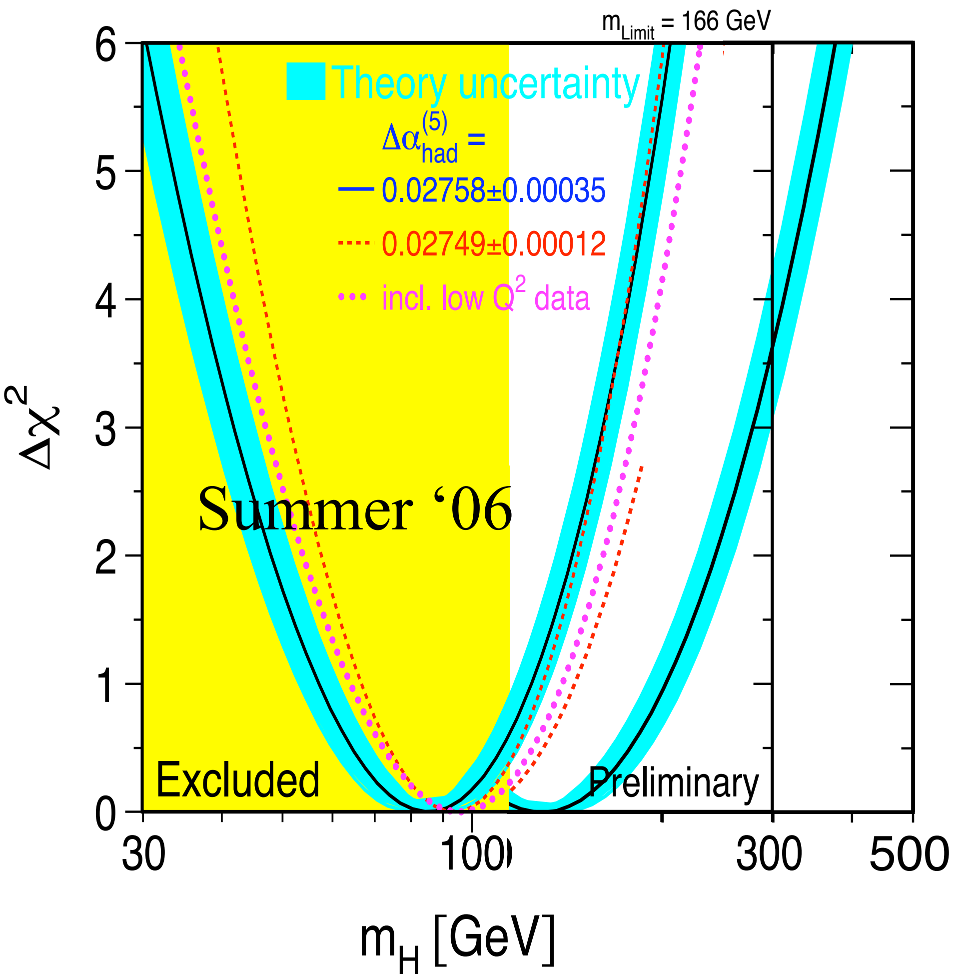




- Electroweak precision measurements sensitive to M_H
- Direct search limits, exclude M_H < 114 GeV
- If Standard Model, expect M_H < 237 GeV at 95% Confidence Level

Motivation for a Light Higgs





- Electroweak precision measurements sensitive to M_H
- Direct search limits, exclude $M_H < 114$ GeV
- If Standard Model, expect $M_H < 166$ GeV at 95% Confidence Level

Motivation for a Light Higgs

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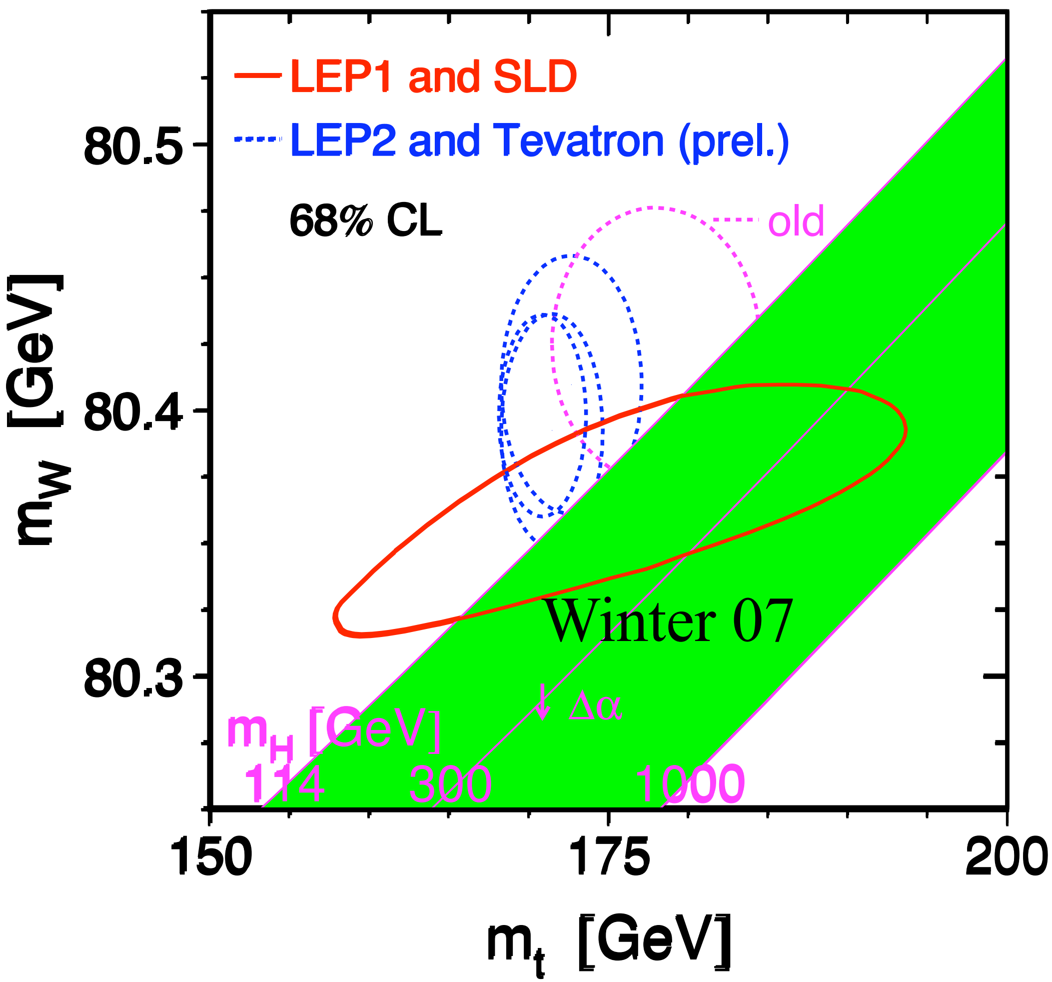

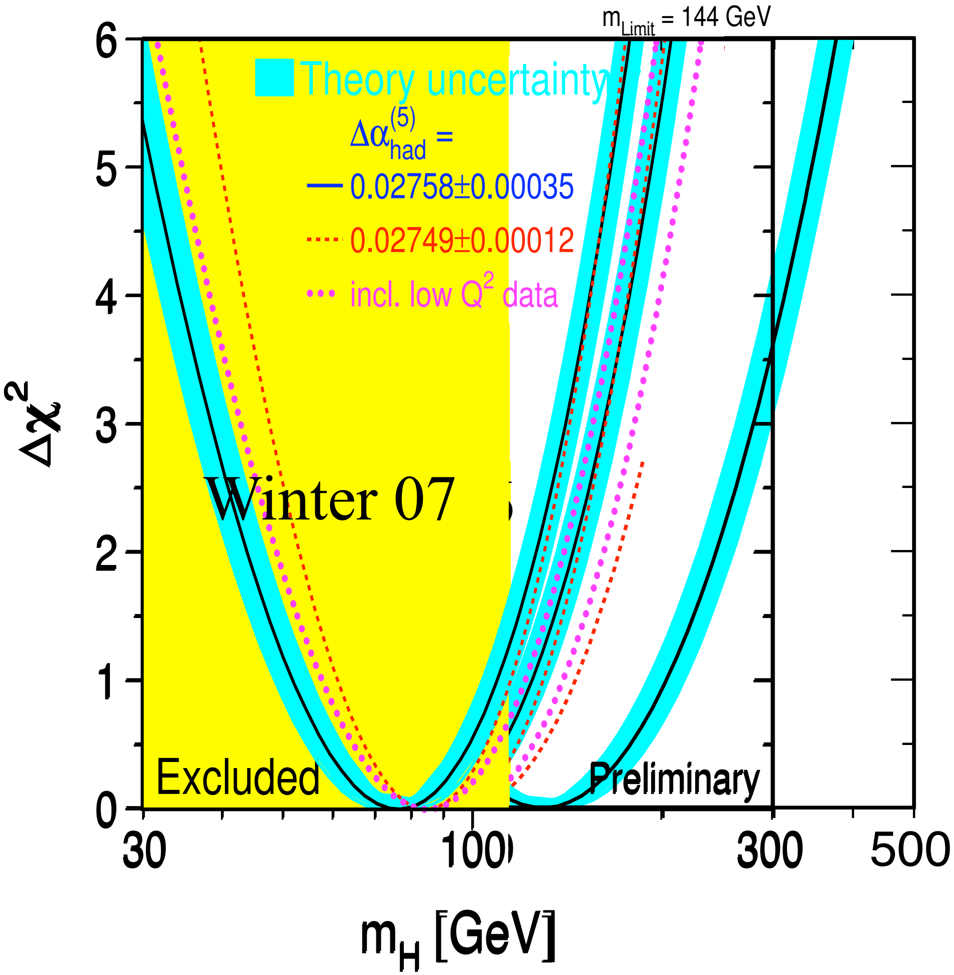

- Electroweak precision measurements sensitive to M_H
- Direct search limits, exclude M_H < 114 GeV
- If Standard Model, expect M_H < 144 GeV at 95% Confidence Level

What If We Find a Heavy Higgs?

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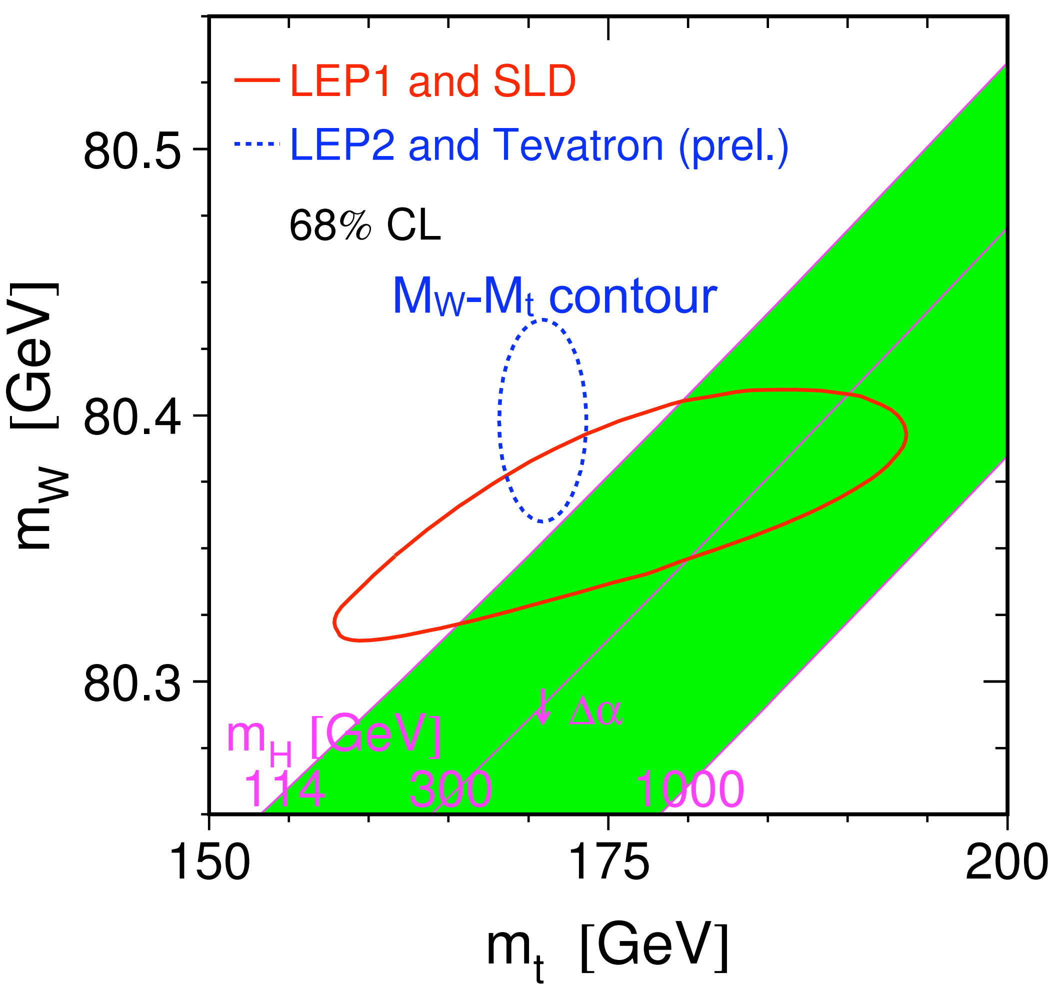

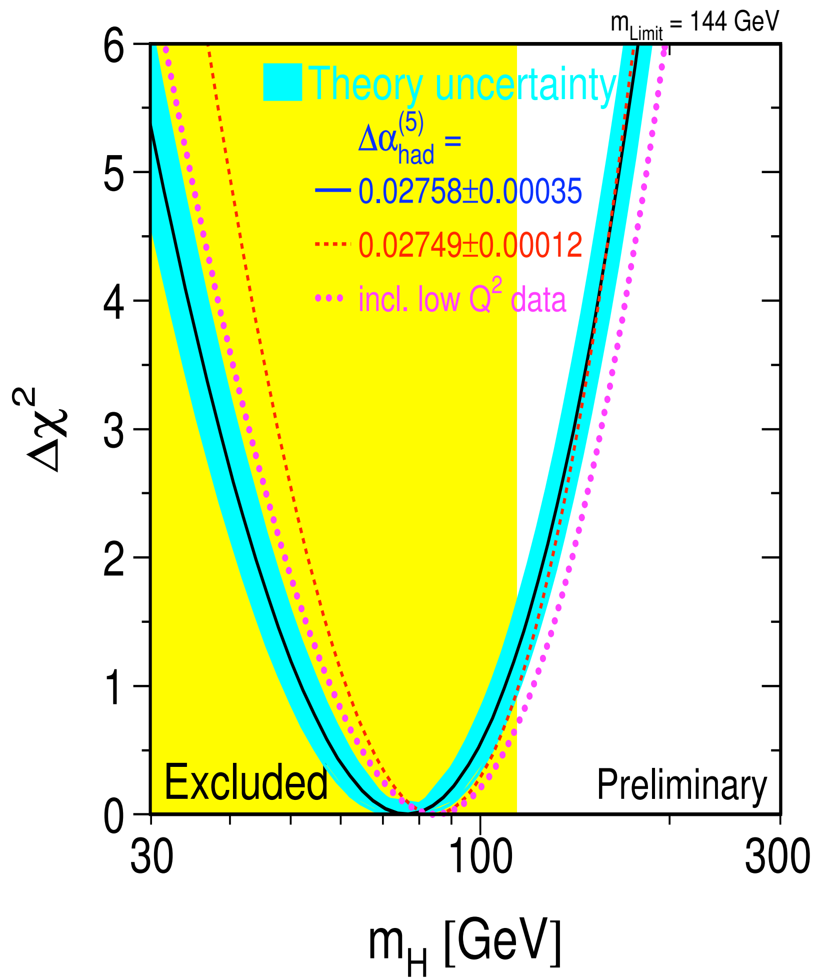

- What if we find a Higgs with M_H>400 GeV? And LHC M_t ~ Tevatron
- Contours of $\Delta\chi^2$ are not a goodness-of-fit measure
- Incompatibility of M_W, M_t, M_H a sign of physics beyond the SM
- Obvious impact on ILC design if M_H>250, 400 GeV

What If We Find a Heavy Higgs?

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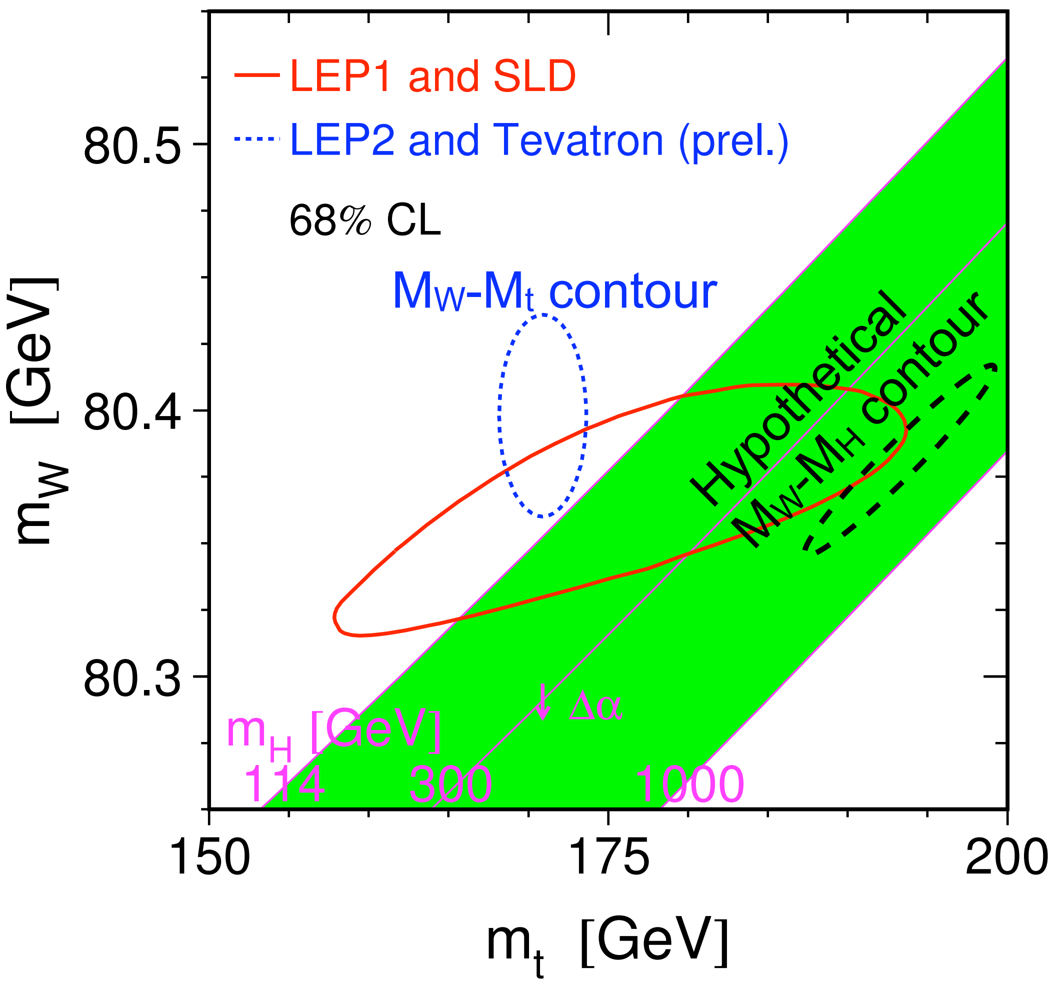

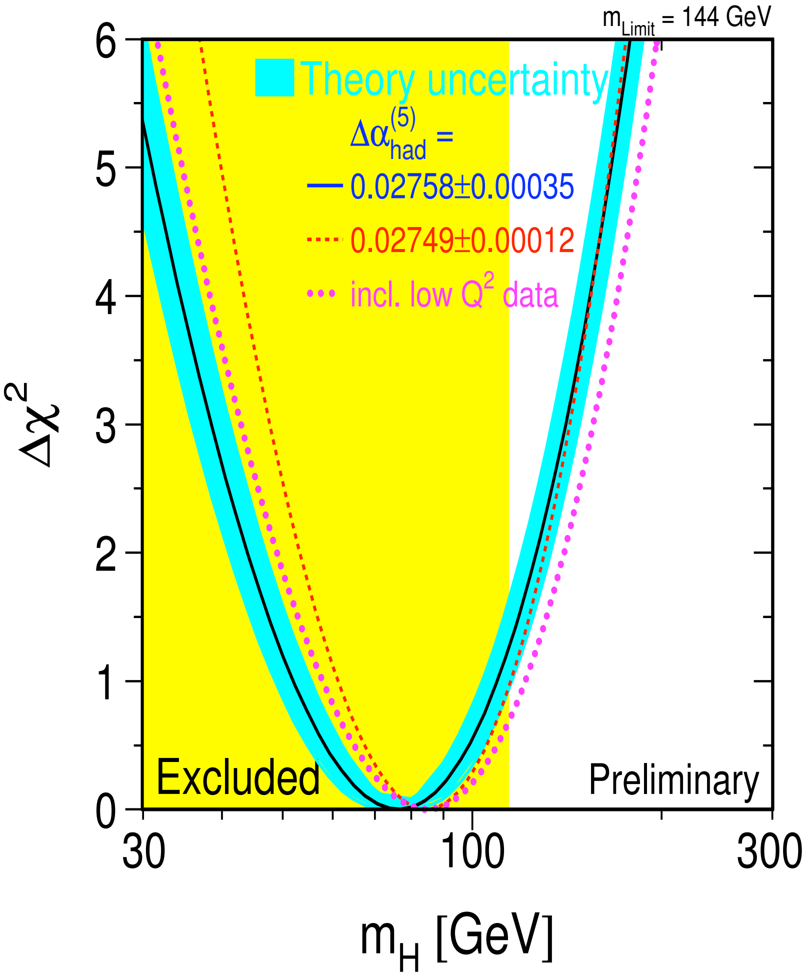

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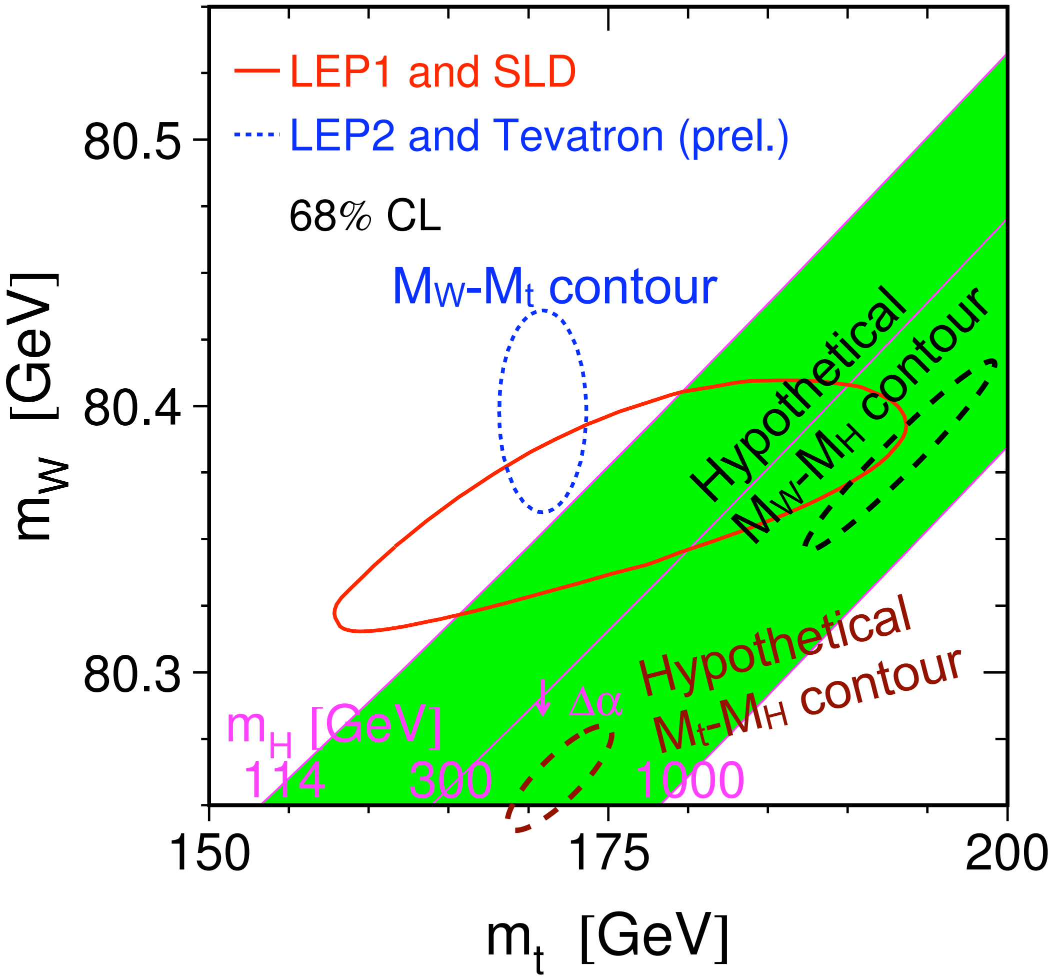

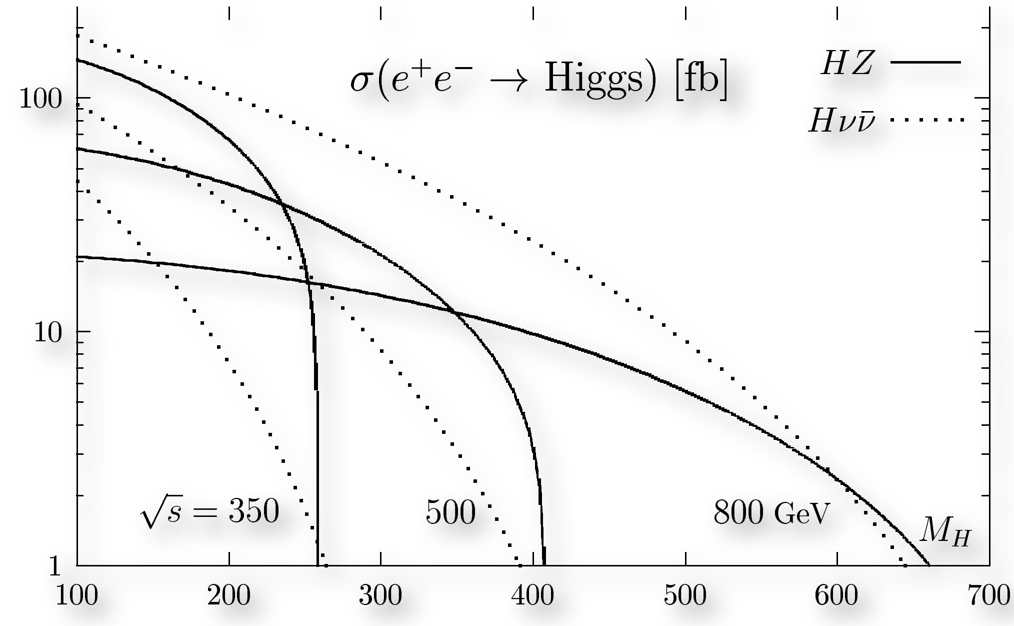

Tesla TDR

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In an Ideal World....

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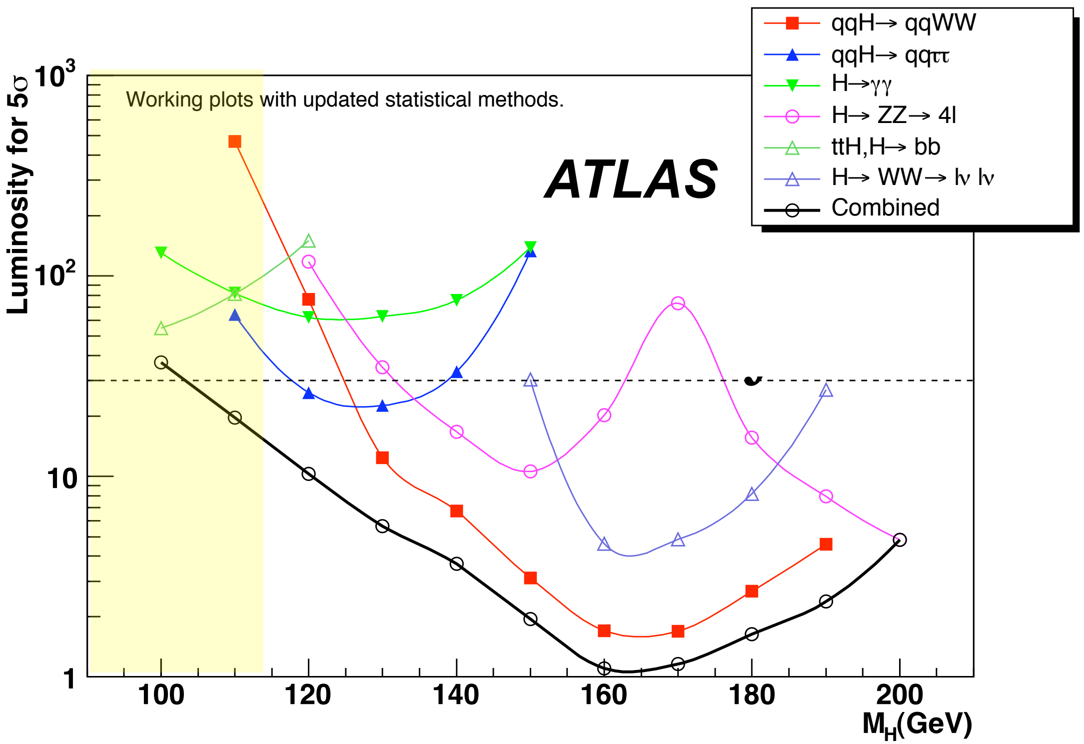
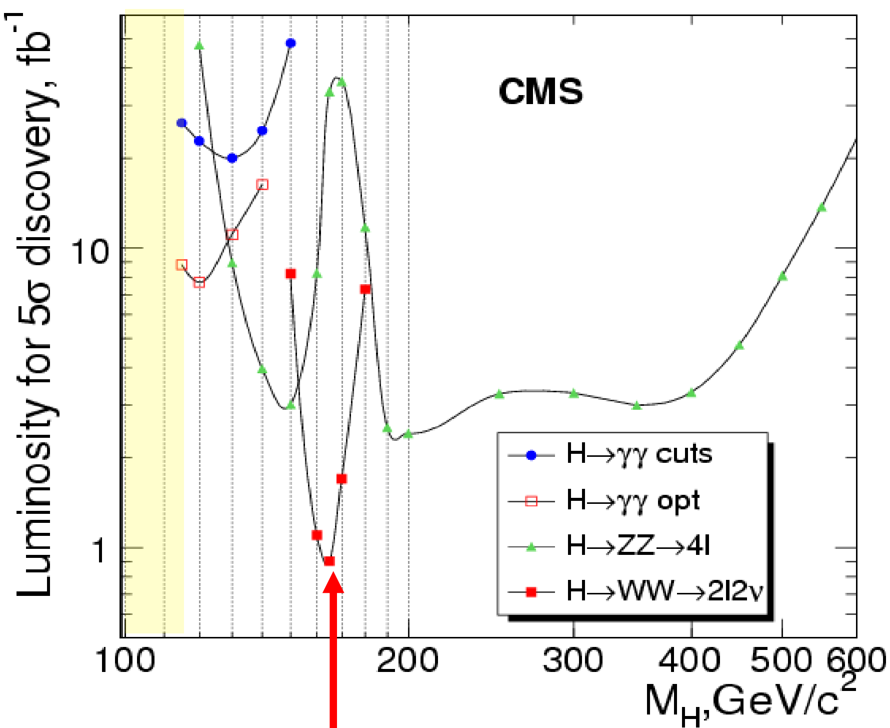
Even including our (naive?) estimates of systematics, the standard model Higgs can be discovered with 1–15 fb^{-1} of data





Discovery with ~1 fb^{-1}

Of course, that's well understood data.

- How long will that take?

Detectors at Startup

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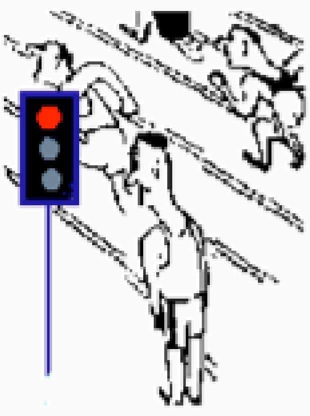
❷ Which detectors the first year ?

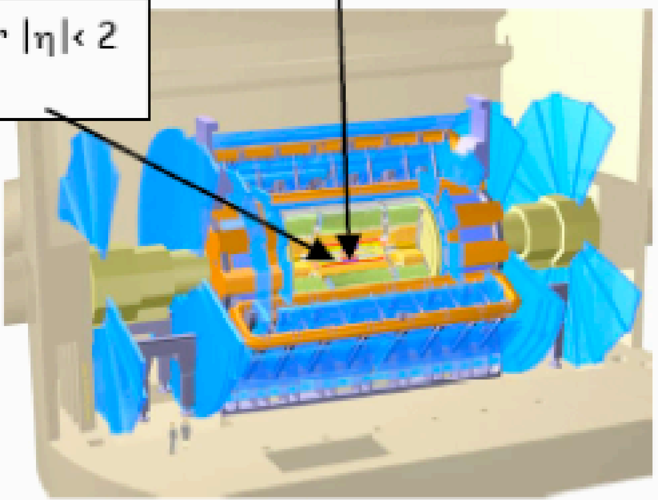
RPC over $|\eta|<1.6$ (instead of $|\eta|<2.1$)
4^{th} layer of end-cap chambers missing

Pixels and end-cap ECAL
installed during first shut-down



Detectors progressing well and will be fairly complete at start-up

TRT acceptance over $|\eta|<2$
(instead of $|\eta|<2.4$)



Both experiments:
deferrals of high-level Trigger/DAQ processors
→ LVL1 output rate limited to
~ 50 kHz CMS (instead of 100 kHz)
~ 40 kHz ATLAS (instead of 75 kHz)

Impact on physics visible but acceptable
Main loss : B-physics programme strongly reduced (single μ threshold p_T> 14-20 GeV)

De Roeck, Wine & Cheese

Early Detector Performance

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	Expected Day 0	Goals for Physics
ECAL uniformity	~ 1% ATLAS ~ 4% CMS	< 1%
Lepton energy scale	0.5—2%	0.1%
HCAL uniformity	2—3%	< 1%
Jet energy scale	<10%	1%
Tracker alignment	20—200 μm in Rϕ	$\mathcal{O}$(10 μm)

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The 2008 Physics Run

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With the first physics run in 2008 ($\sqrt{s}$ = 14 TeV) ....

$0.1\text{-}1\ fb^{-1}$

1 fb^{-1} (100 pb^{-1}) ≡ 6 months (few days) at L= $10^{32}\ cm^{-2}s^{-1}$ with 50% data-taking efficiency
→

Channels (examples ...)	Events to tape for 100 pb^{-1} (per expt: ATLAS, CMS)	Total statistics from some of previous Colliders
$W \to \mu\nu$	~ 10^6	~ 10^4 LEP, ~ 10^6 Tevatron
$Z \to \mu\mu$	~ 10^5	~ 10^6 LEP, ~ 10^5 Tevatron
$tt \to W b W b \to \mu\nu + X$	~ 10^4	~ 10^4 Tevatron
QCD jets p_T > 1 TeV	> 10^3	---
$\tilde{g}\tilde{g}$ m = 1 TeV	~ 50	---

With these data:

- Understand and calibrate detectors in situ using well-known physics samples
  e.g. - $Z \to ee, \mu\mu$ tracker, ECAL, Muon chambers calibration and alignment, etc.
  - $tt \to bl\nu\ bjj$ jet scale from $W \to jj$, b-tag performance, etc.
- Measure SM physics at $\sqrt{s}$ = 14 TeV : W, Z, tt, QCD jets ...
  (also because omnipresent backgrounds to New Physics)

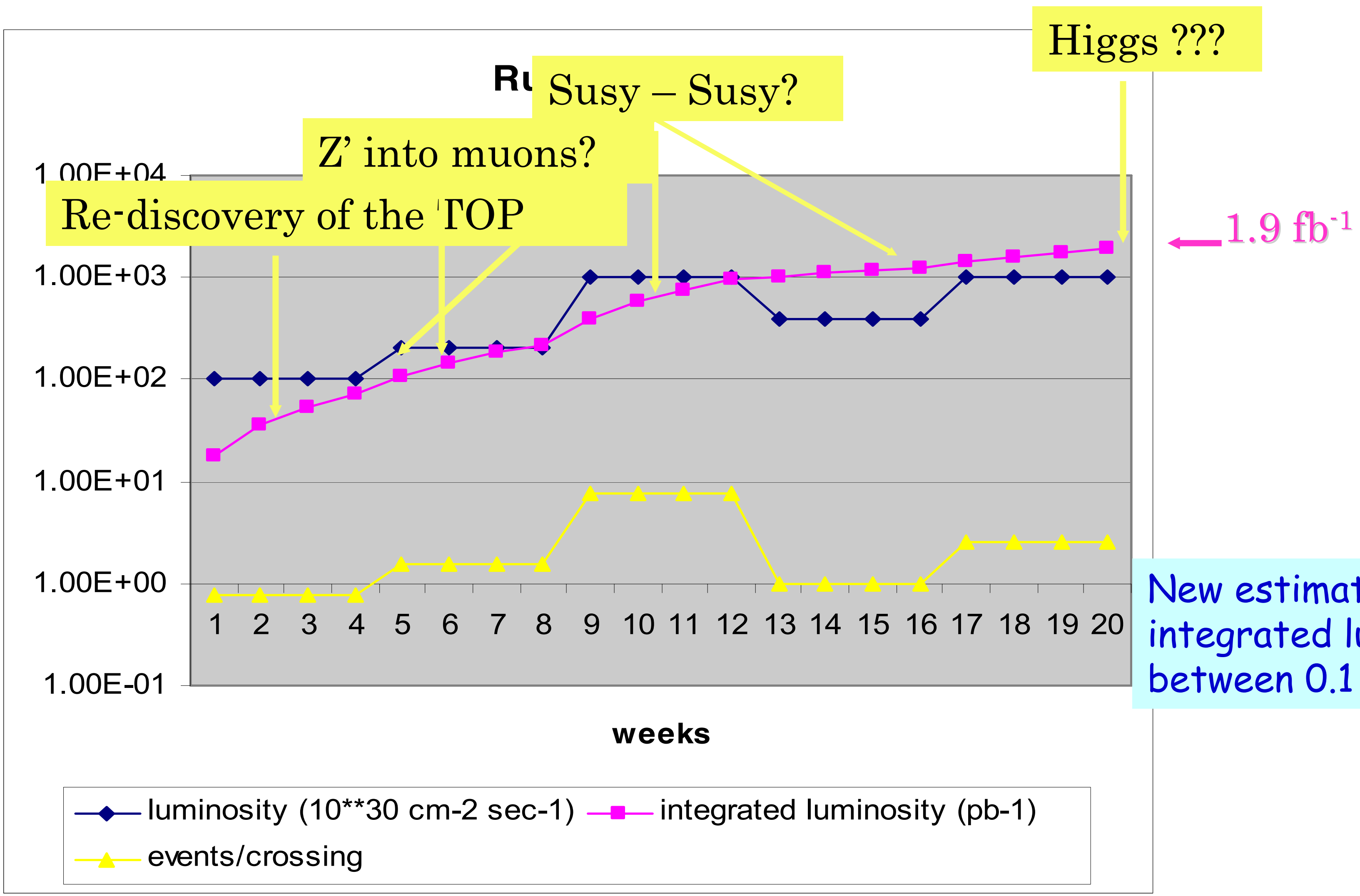
[F. Gianotti, ICHEP 06]

A rough timeline

Efficiency = 30%

2008

G. Rolandi
(Before schedule change)



New estimate integrated lumi between 0.1 and 1 fb-1

Vector Boson Fusion Higgs

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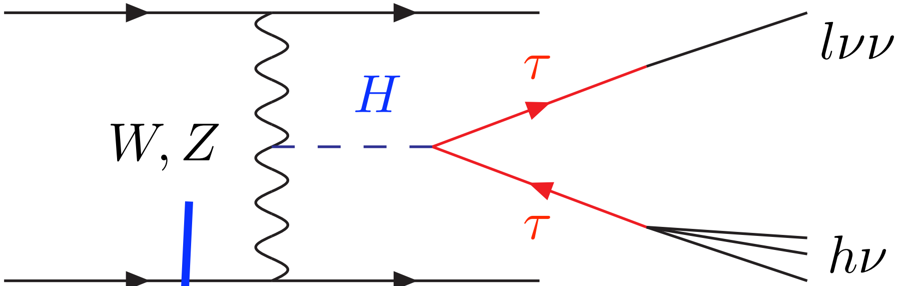
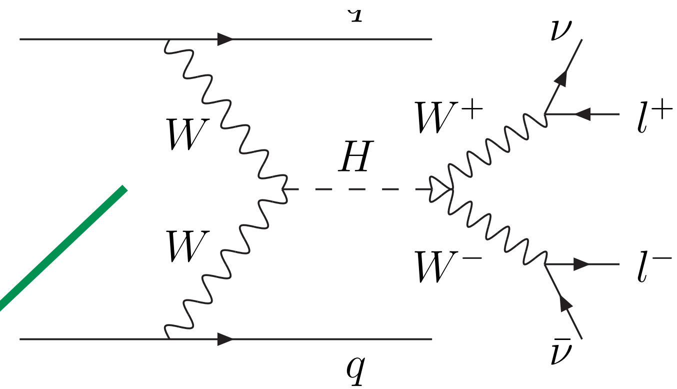
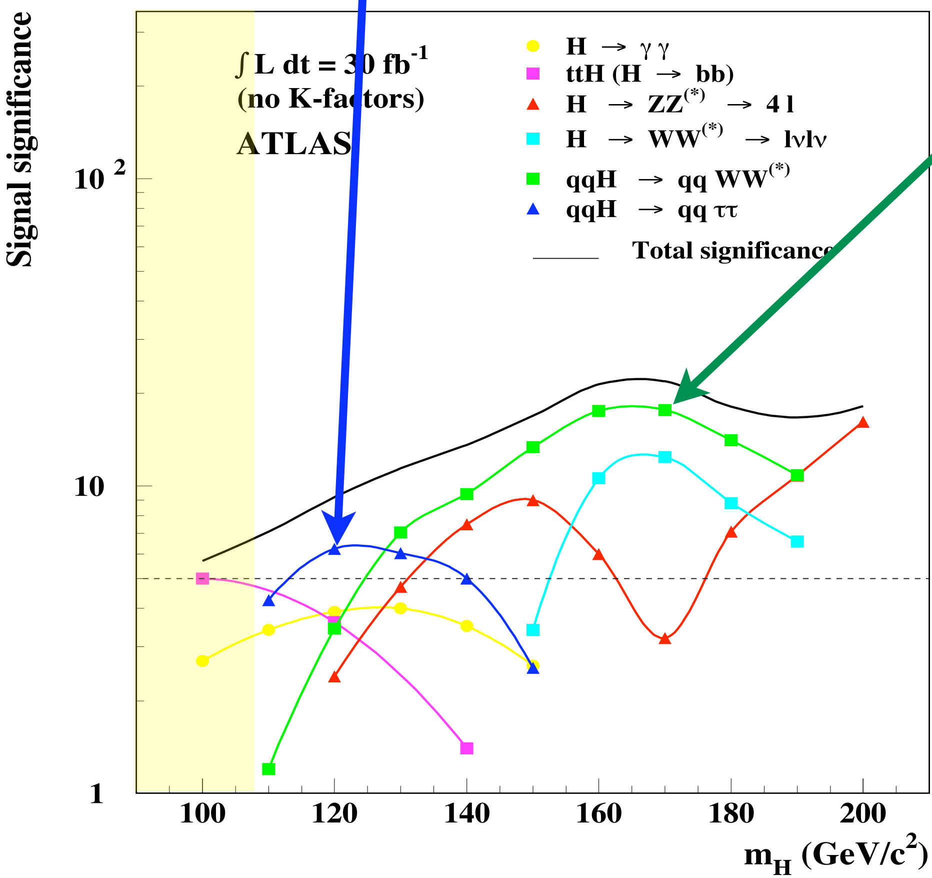






VBF channels were not included at the time of the ATLAS Physics TDR in 1999

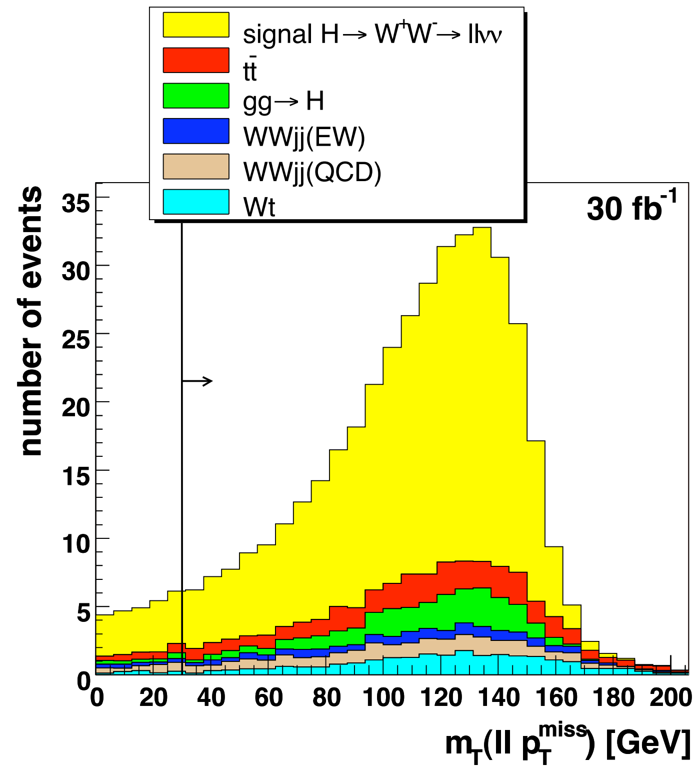
In 2003 new results from ATLAS on low-mass Higgs released

- VBF channels dominant
- ttH(bb) drops in significance

VBF also very important for coupling measurements

VBF $H \to WW \to ll\nu\nu$

	signal (fb)		background (fb)					
	VV	gg	$t\bar{t}$ + Wt	$WW+jets$		$\gamma^*/Z+jets$		total
				EW	QCD	EW	QCD	
Lepton acceptance	5.20	17.30	8456	17.1	617.2	7.09	4980	14077
+ Forward Tagging	1.85	0.27	82.6	10.7	1.83	2.10	45.2	142.4
+ Lepton angular cuts	1.36	0.18	13.5	0.89	0.27	0.81	7.47	22.9
+ τ rejection	1.27	0.18	12.9	0.83	0.27	0.15	1.64	15.8
+ Jet mass	0.88	0.08	6.39	0.43	0.08	0.11	0.83	7.84
+ P_T^{tot}	0.68	0.05	1.40	0.32	0.04	0.10	0.46	2.32
+ Jet veto	0.59	0.05	0.61	0.28	0.04	0.10	0.32	1.35
+ $m_T(\ell\ell\nu)$-cut	0.52	0.05	0.58	0.27	0.03	0.02	0.05	0.95
$H \to WW^{(*)} \to e\mu + X$	0.52	0.05	0.58	0.27	0.03	0.02	0.05	0.95
$H \to WW^{(*)} \to ee/\mu\mu + X$	0.50	0.04	0.58	0.30	0.03	0.03	0.39	1.33



- ✦ Based on work of Rainwater, Zeppenfeld in 1999-2000 (hep-ph/9906218)
- ✦ Initial study with fast simulation, now studied with full simulation
- ✦ Can't reconstruct m_H, only "transverse mass" m_T
- ✦ Dominated by irreducible $t\bar{t}$+jets and WW+jets background
- ✦ Possible discovery channel for $M_H > 125$ GeV with 30 fb^{-1}

Vector Boson Fusion $H\to\tau\tau$

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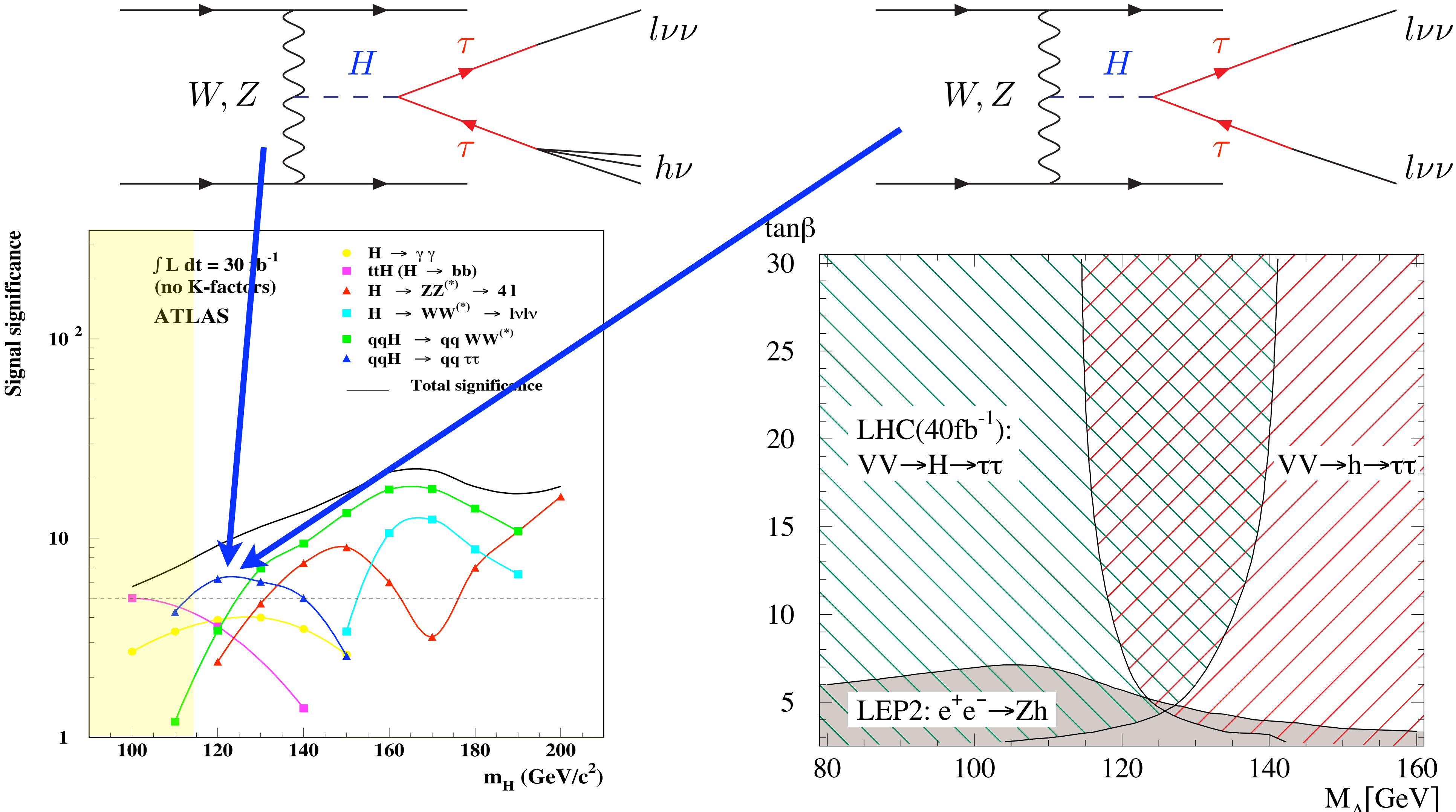

Standard Model (Atlas Scientific Note)

Plehn, Rainwater, Zeppenfeld hep-ph/9911385

Most powerful channel near LEP limit and very important for MSSM.

The Collinear Approximation

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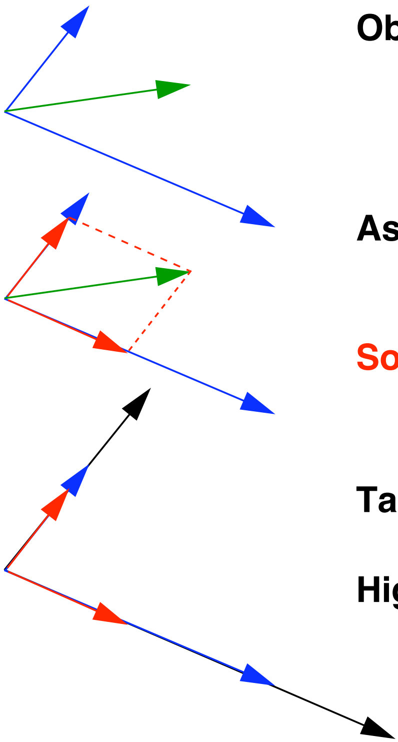
Mass Reconstruction:



Observe

missing transverse momentum
and visible Tau–decay products

Assume Tau decay products
collinear with original Tau

Solve 2 linear equations
for the neutrinos

Taus can be reconstructed

Higgs can be reconstructed

$$x_{\tau h} = \frac{h_x l_y - h_y l_x}{h_x l_y + \not{p}_x l_y - h_y l_x - \not{p}_y l_x}$$

$$x_{\tau l} = \frac{h_x l_y - h_y l_x}{h_x l_y - \not{p}_x h_y - h_y l_x + \not{p}_y h_x}$$

Some Comments:

After jet cuts, $M_{\tau\tau}$ is the only discrimination we use between $Z \to \tau\tau$ and $H \to \tau\tau$

Collinear approximation doesn't take into account MissingET resolution

Define x_τ: fraction of τ's momentum in visible decay product

$$M_{\tau\tau} = \sqrt{2(E_h + E_{\nu h})(E_l + E_{\nu l})(1 - \cos\theta_{\tau\tau})}$$

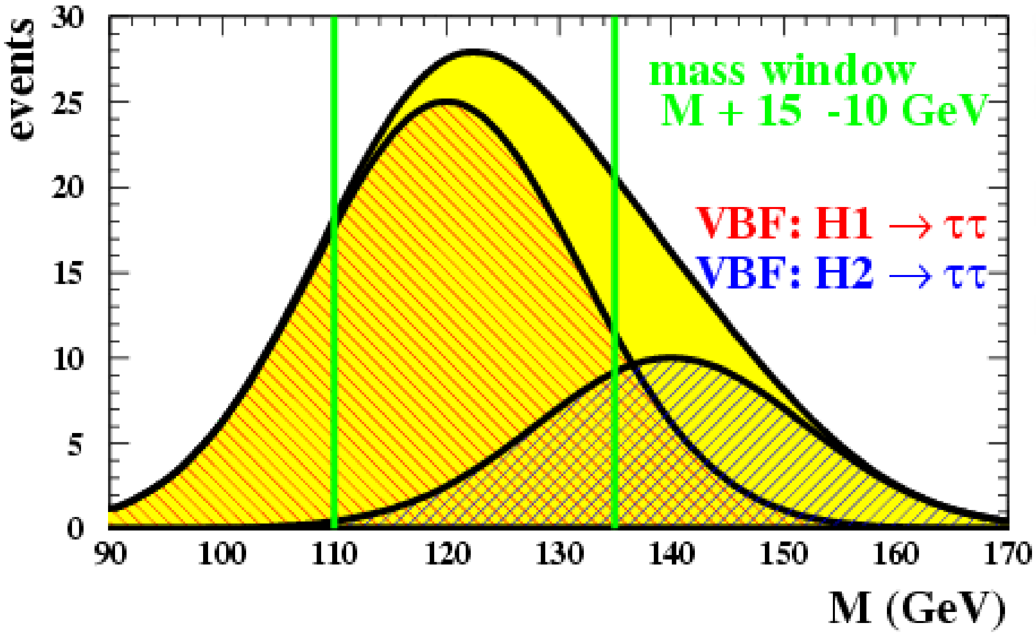
is equivalent to $M_{\tau\tau} = \frac{M_{ll}}{\sqrt{x_{\tau l} x_{\tau h}}}$

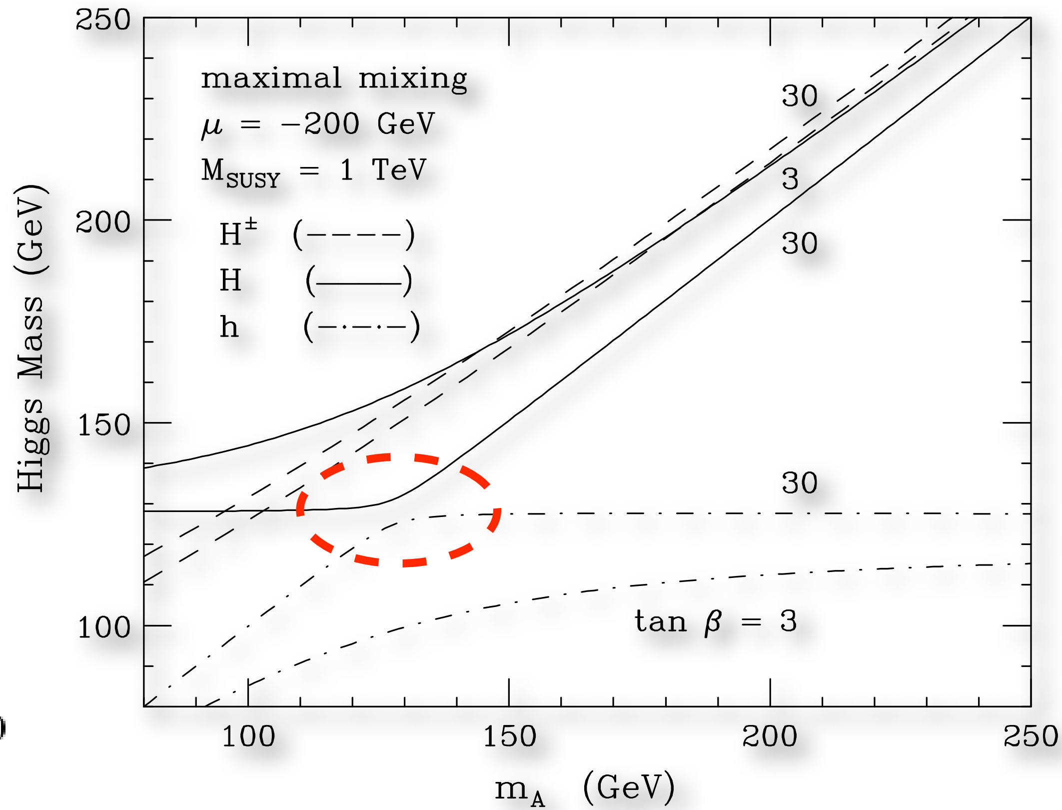
only when $0 < x_\tau < 1$

More than one Higgs?

In some regions of MSSM Higgs sector, M_H & M_h are quite close in mass... closer than $H \to \tau\tau$ mass resolution

- are we seeing two Higgs or one Higgs with $\sigma BR \gg \sigma_{SM} BR_{SM}$
- in that case we need $H \to \gamma\gamma$ to resolve the ambiguity
- observation of just the lightest Higgs doesn't shed much light on MSSM Higgs sector

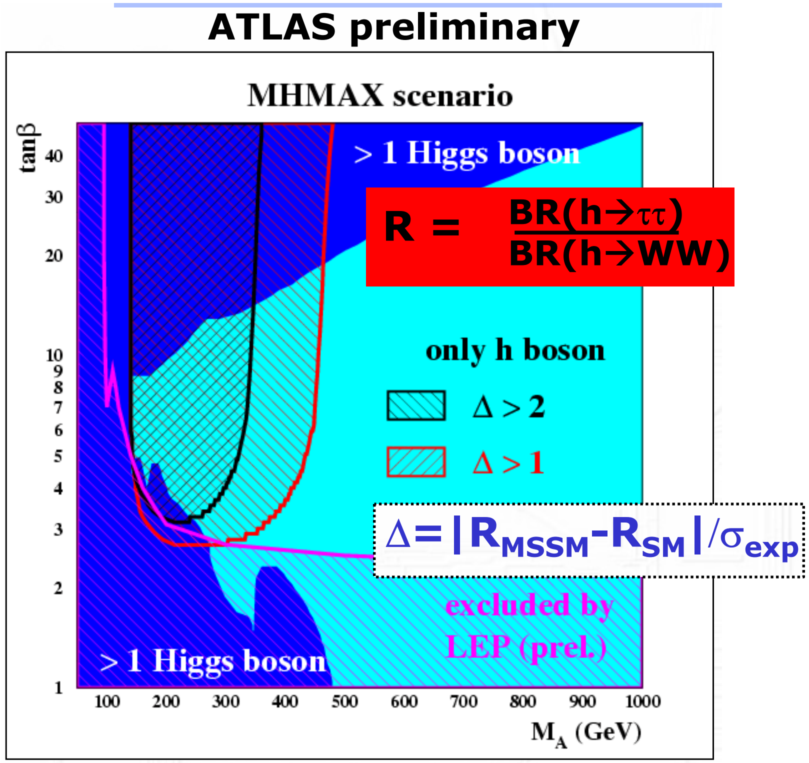




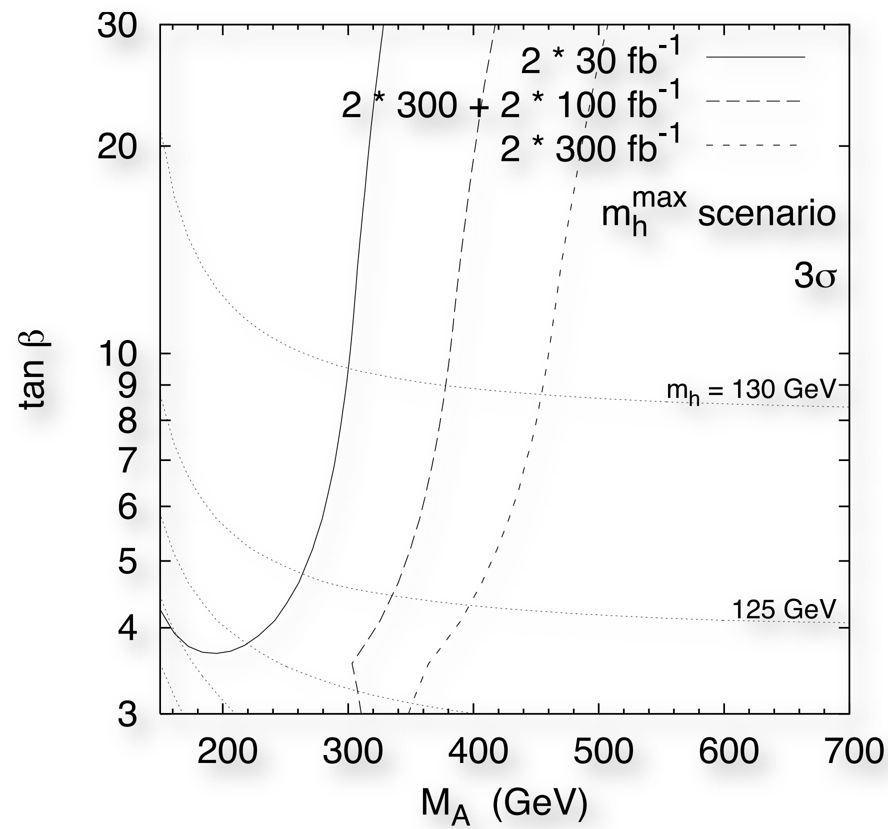
SM vs. MSSM with one Higgs

Some studies of the ability to distinguish the h of the MSSSM from the H of the Standard Model

- use rate measurements to distinguish models
  - rates can change rapidly with M_H, so a good mass measurement needed



- only statistical errors considered
- assume Higgs mass exactly known



Phys.Rev.D70:113009,2004 (hep-ph/0406323)

ATLAS Developments for $H \to \gamma\gamma$

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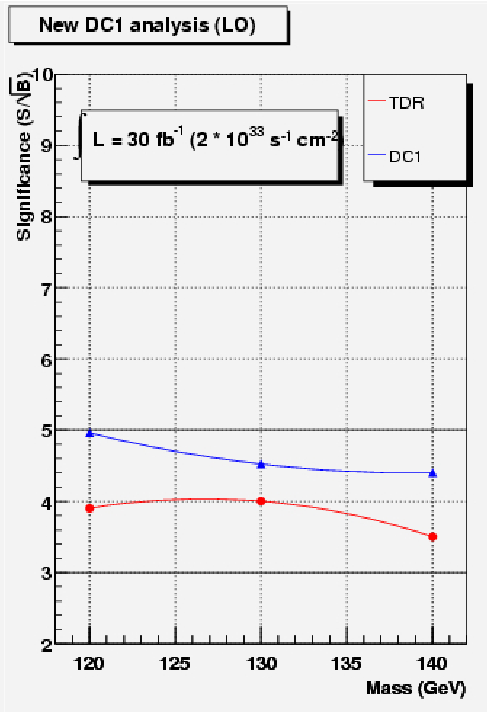
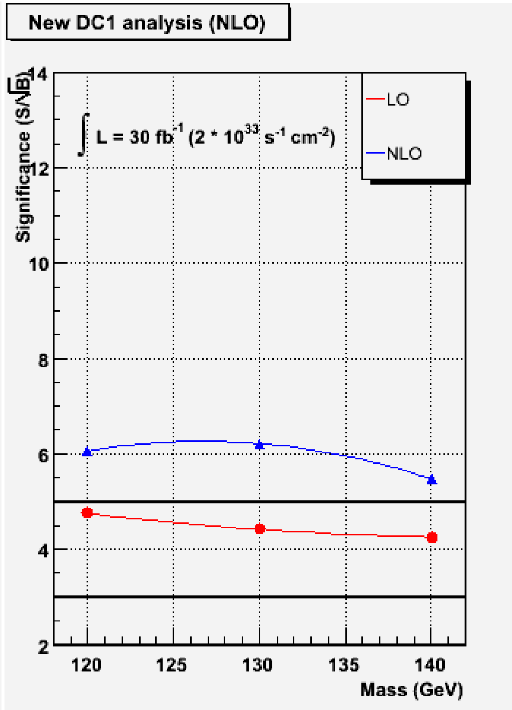
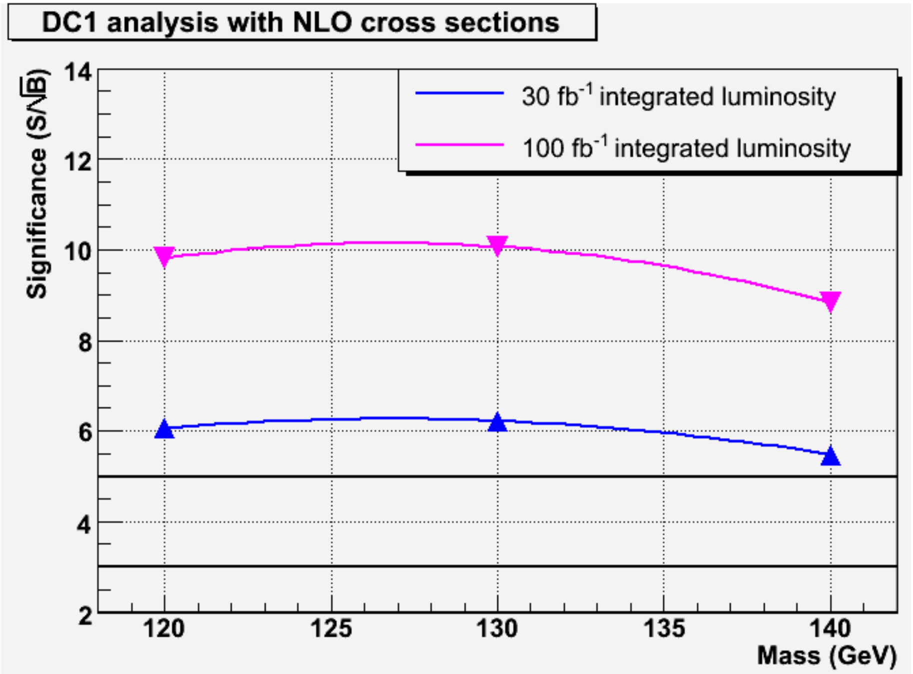
Since the 2003 low-mass Higgs, several studies for this channel.

- both theoretical and experimental developments
- ATLAS result is now comparable to CMS "cuts" result







Updated LO Results X NLO K factors = Big improvement! >5σ with 10fb^{-1}

With 10 fb^{-1} one can expect $6\sigma/\sqrt{3} \approx 3.4\sigma$ excess for a Standard Model Higgs with mass <140 GeV

Acta Phys. Pol. B: 38 (2007)

ATLAS Improved $H \rightarrow \gamma\gamma$ Analysis

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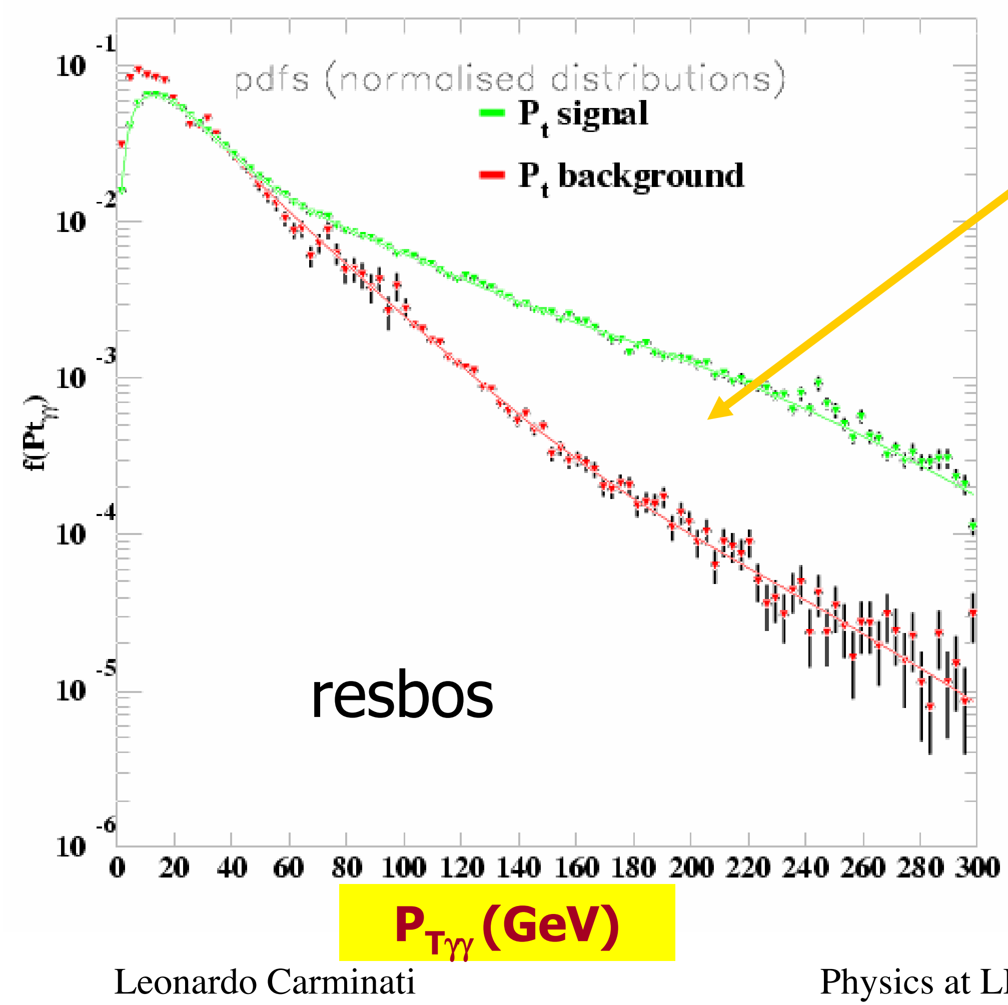
(III) Improvements to the standard inclusive analysis

- Improve the discovery potential using the shape of kinematical variables
  - One has to assume some theoretical knowledge



- Likelihood ratio method based on P_T and $\cos\theta^*$ (well predicted in NLO calculations) of signal and background
- Each event is weighted by the likelihood ration
- With a likelihood analysis a further 30-40% improvement in the discovery potential has been reported.

Acta Phys. Pol. B: 38 (2007)

The Rise and Fall of ttH, H→ bb

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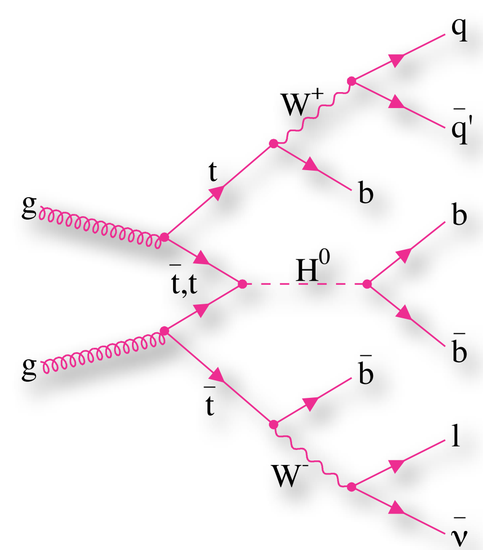
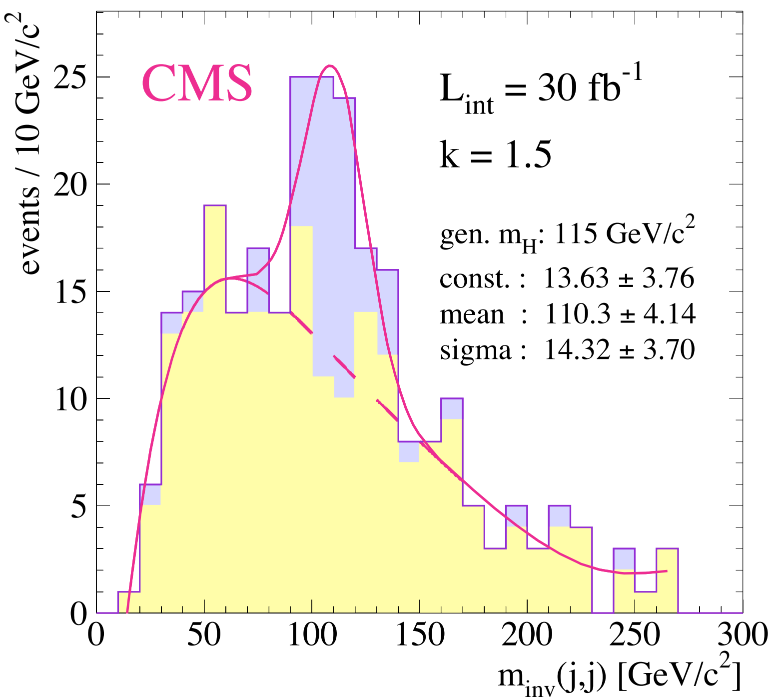
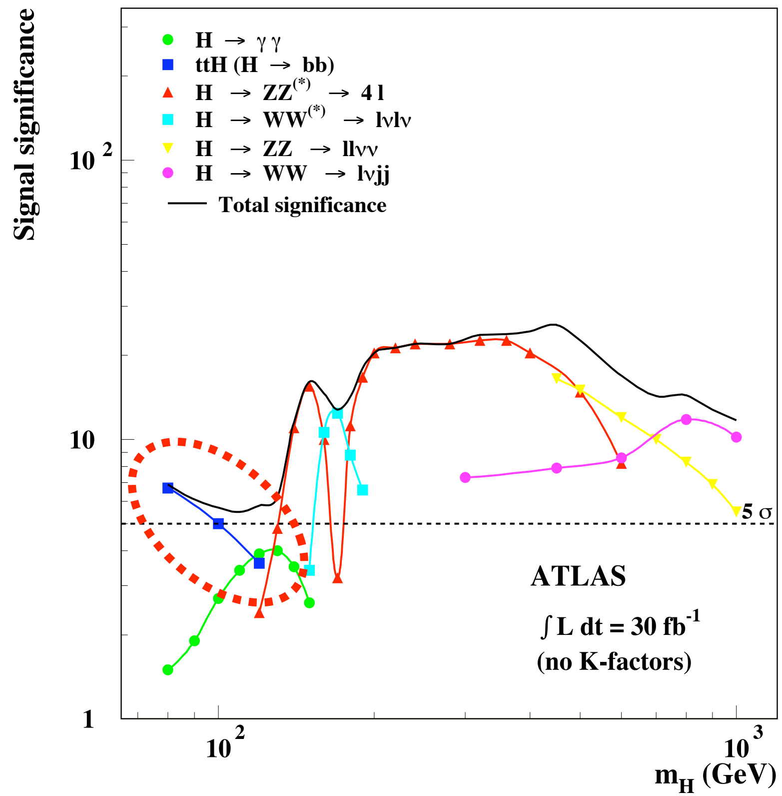
Initially, both ATLAS and CMS indicated ttH with H bb would be a powerful discovery channel near the LEP limit.



Improved Monte Carlo tools and treatment of systematics now show only marginal sensitivity





ttH (H→bb)

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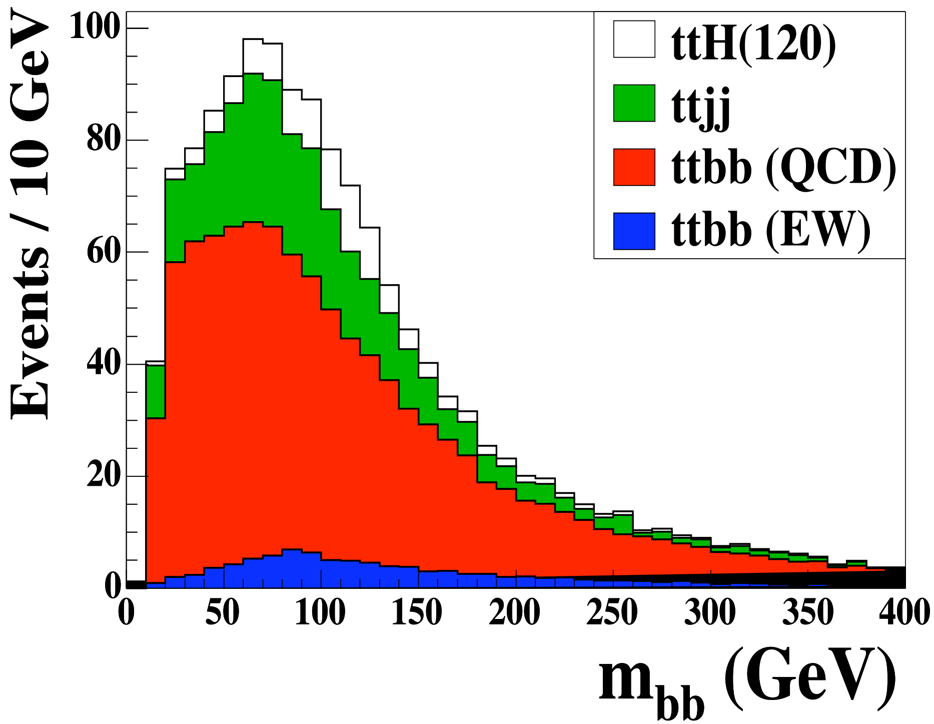
J. Cammin & M. Schumacher, ATL-PHYS-2003-024 (nice thesis by J. Cammin)



Combinatorial background is challenging with 4b-jets and ≥ 6 jets total

Signal efficiency goes like ϵ_b^4

Signal & bkgnd. have similar shape

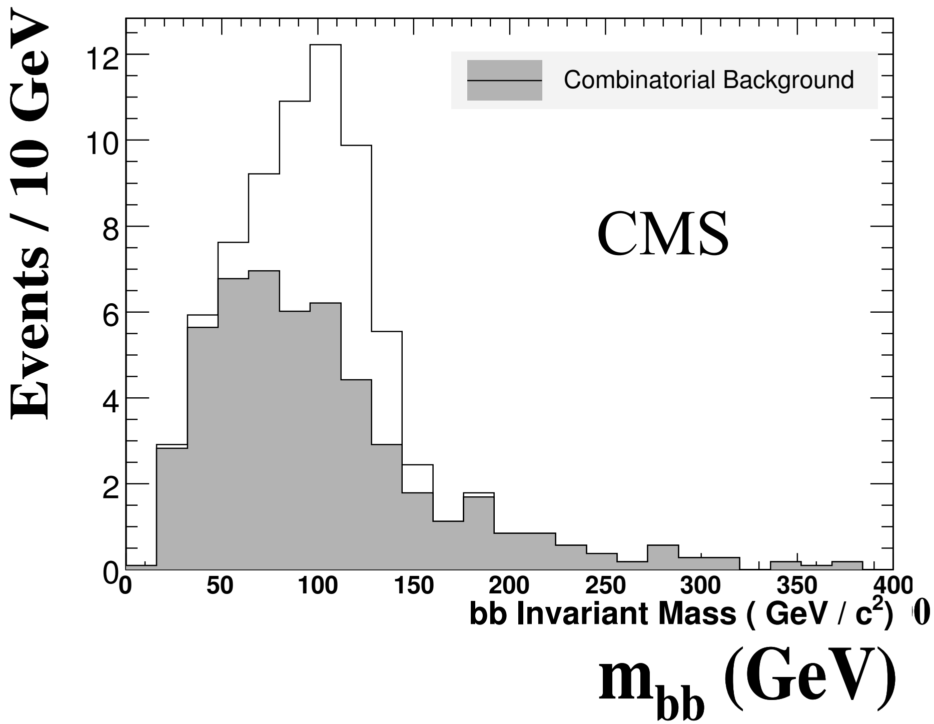
Estimating $ttjj$ and $ttbb$ background from data difficult, large systematics

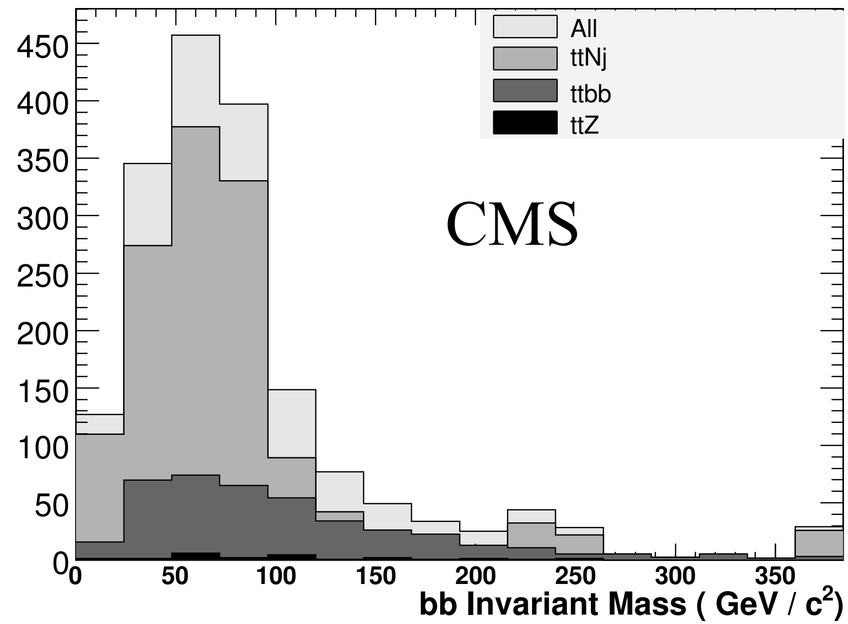
- This is (was) one of the few powerful channels near the LEP limit

It's not clear if this channel will ever reach 5σ

ttH (H→bb)

J. Cammin & M. Schumacher, ATL-PHYS-2003-024 (nice thesis by J. Cammin)





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Estimating $ttjj$ and $ttbb$ background from data difficult, large systematics

- This is (was) one of the few powerful channels near the LEP limit

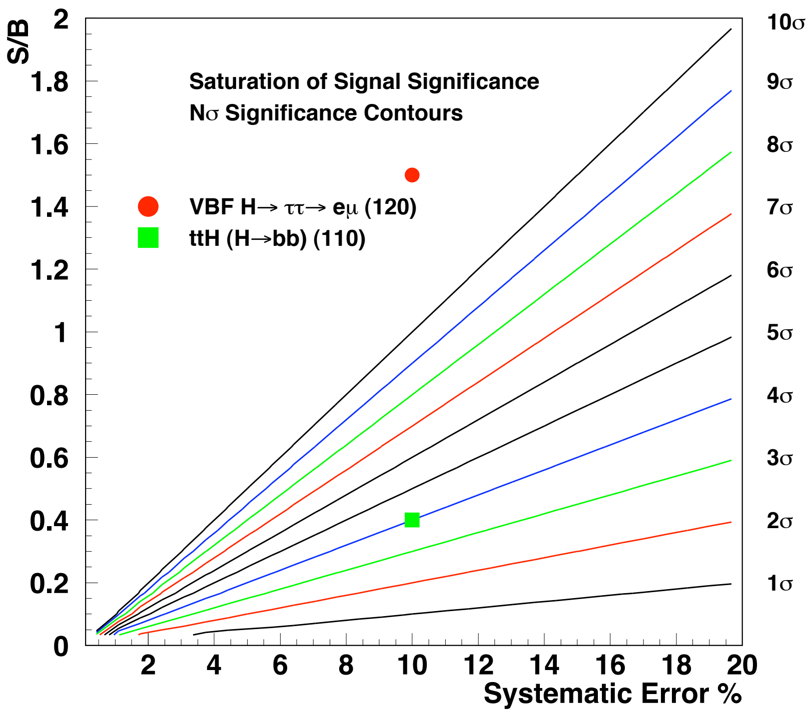
It's not clear if this channel will ever reach 5σ

A Note on Systematic Errors

Background determination from sidebands carries two sources of error:

- statistical error from sideband measurement
- systematic on extrapolation from sideband to signal-like area (shape systematic)

The shape systematic does not (necessarily) reduce with increased luminosity



Normal significance measure $s/\sqrt{b}$
is replaced by $s/\sqrt{b(1+b\Delta^2)}$

If s/b is fixed as we increase luminosity, the expected significance saturates:

$$\sigma_\infty = \frac{s/b}{\Delta_{shape}}$$

With its low S/B and 10% shape systematic, $ttH(\to bb)$ can't get to 5σ even with $L \to \infty$

Mass, Spin, CP, & Coupling Measurements

Early Results
&
Ultimate Limits

Precise Mass Measurments

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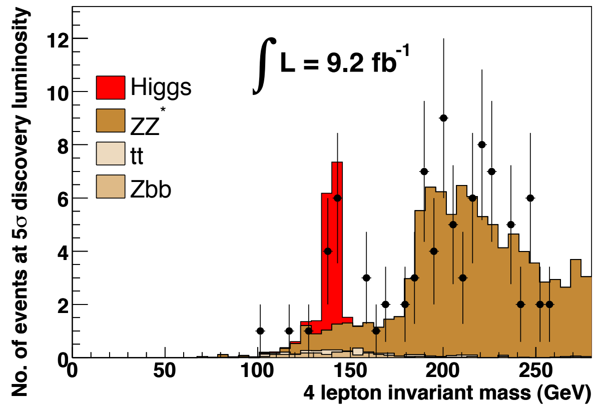
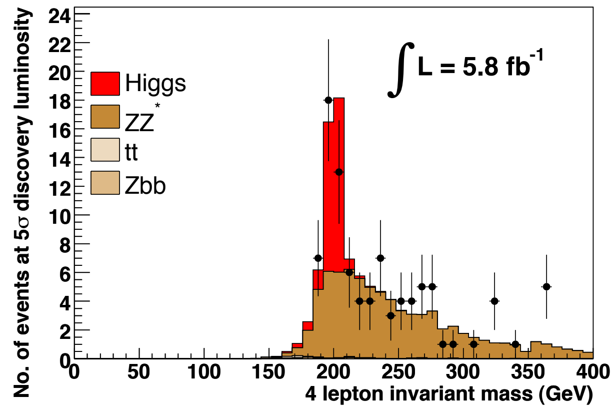
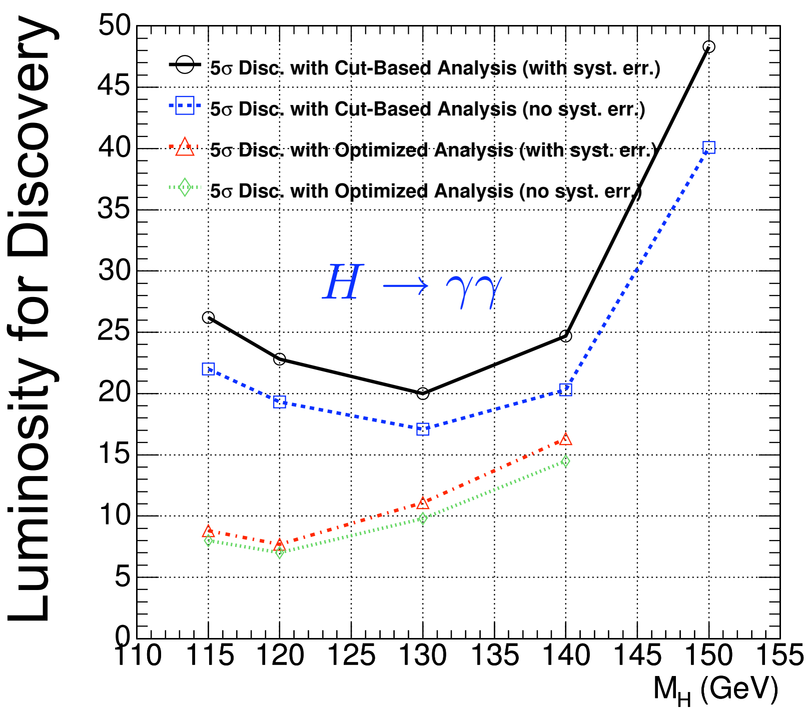
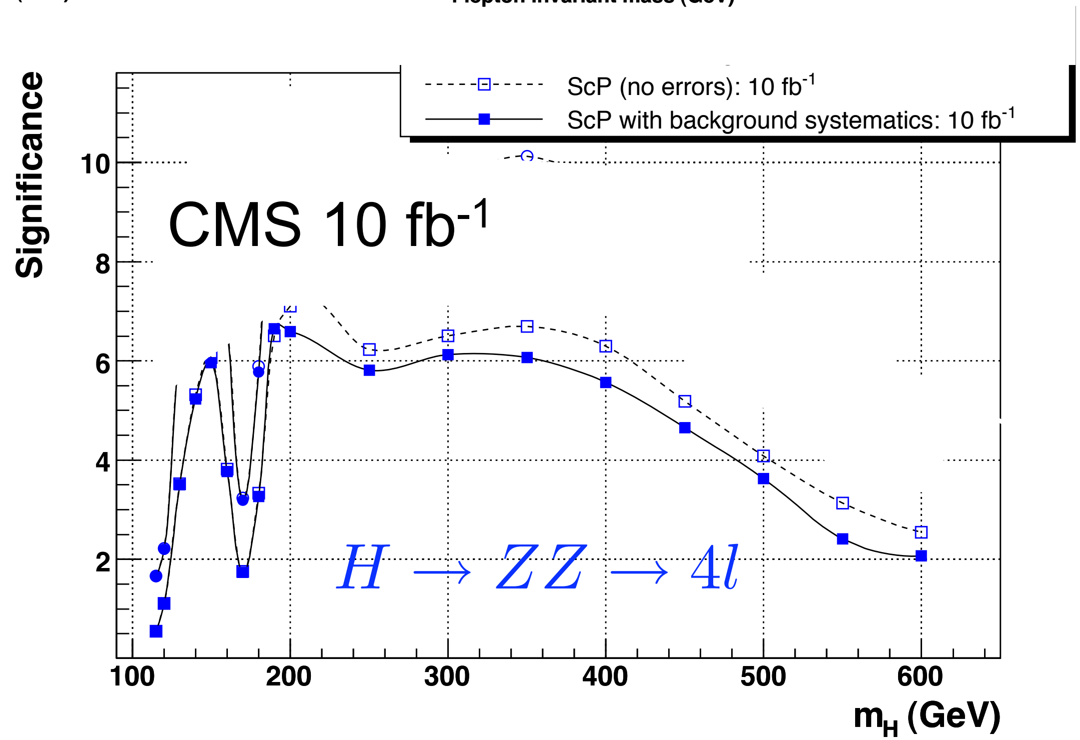
Both $H \to ZZ \to 4l$ and $H \to \gamma\gamma$ should be accessible in the early phase, and provide precise mass measurements

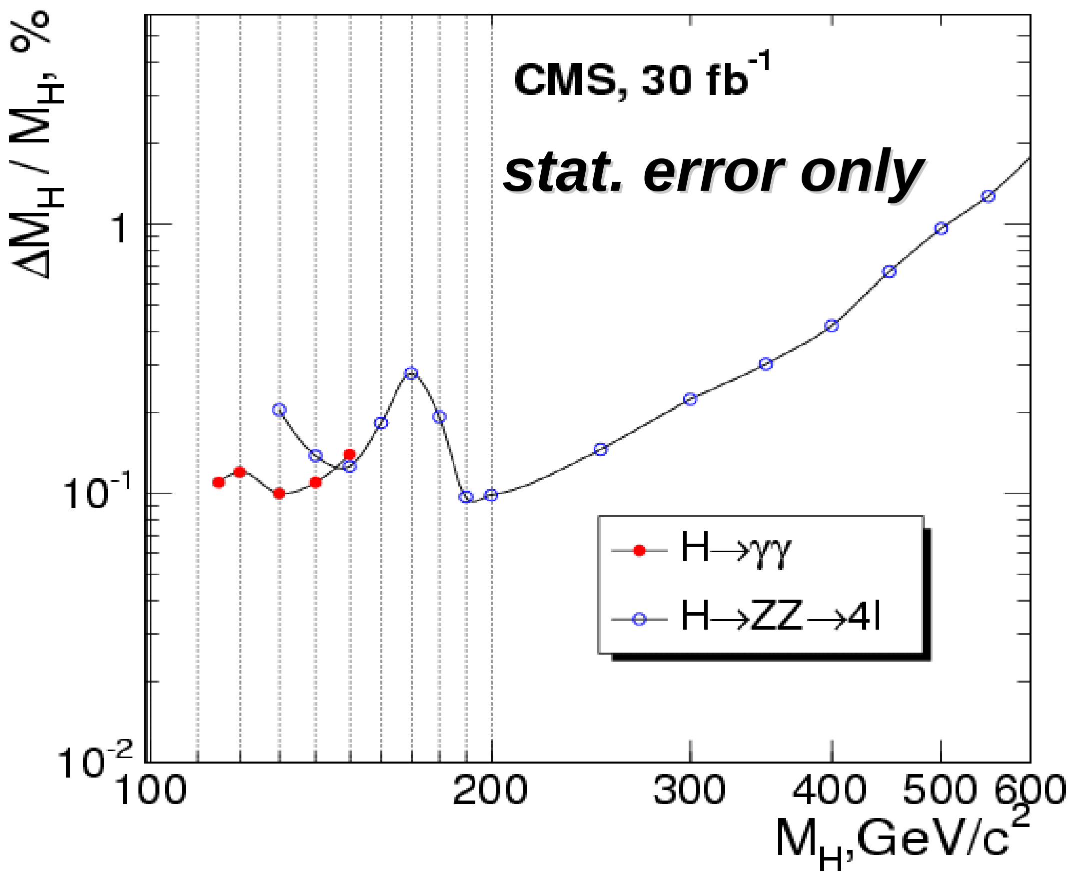


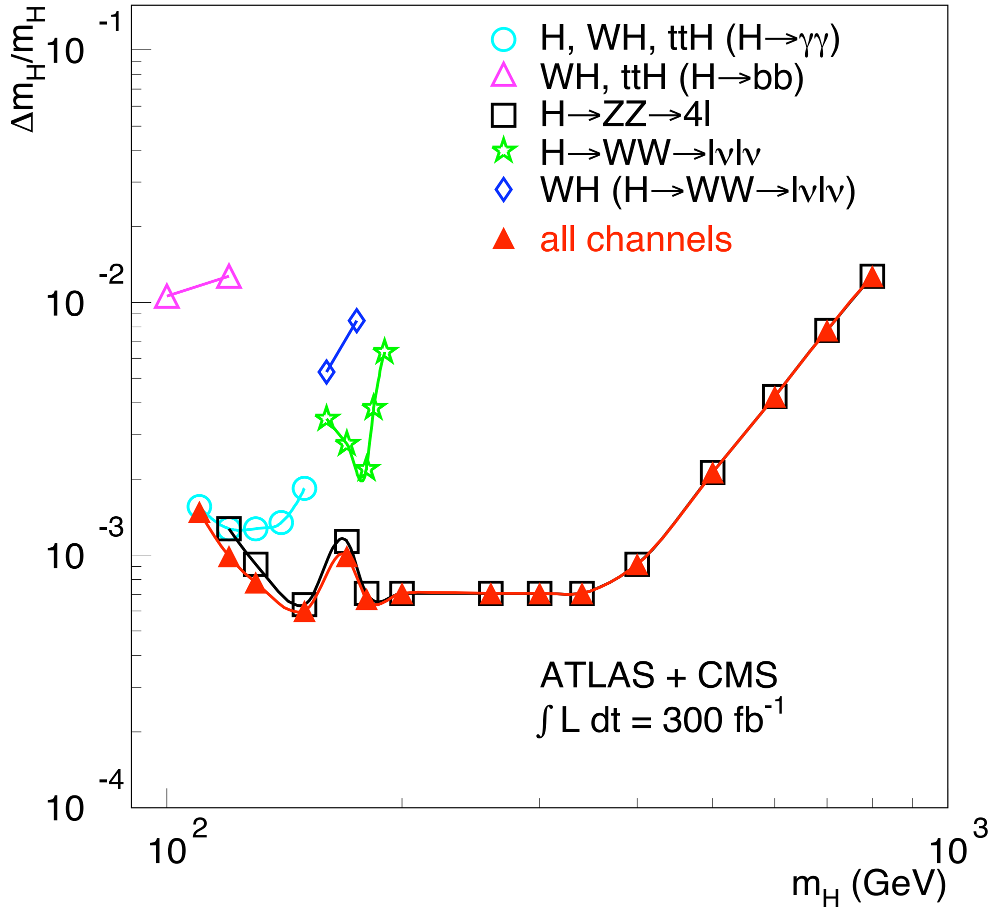






Mass Measurements





Even in early phase, we should be able to measure the mass to < 1%

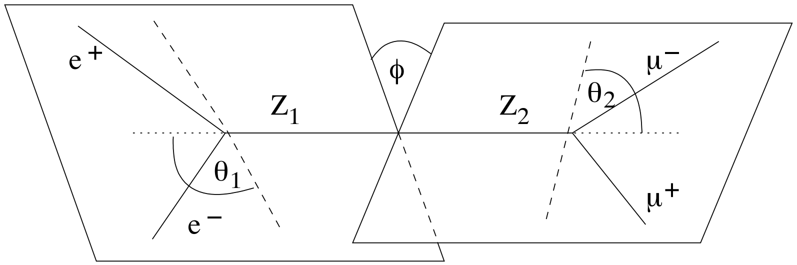
- ultimately <0.1%, unless Higgs is heavy & width dominates

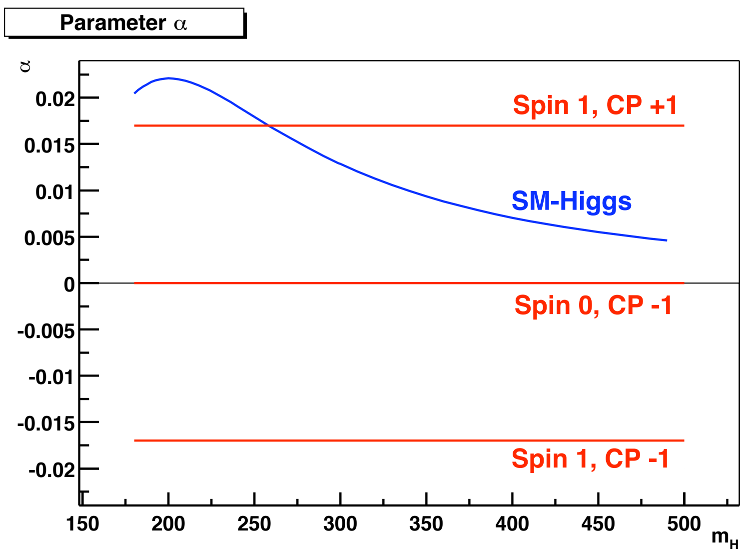
Spin & CP Measurements

We can naively scale results from ATLAS study for $100 fb^{-1}$

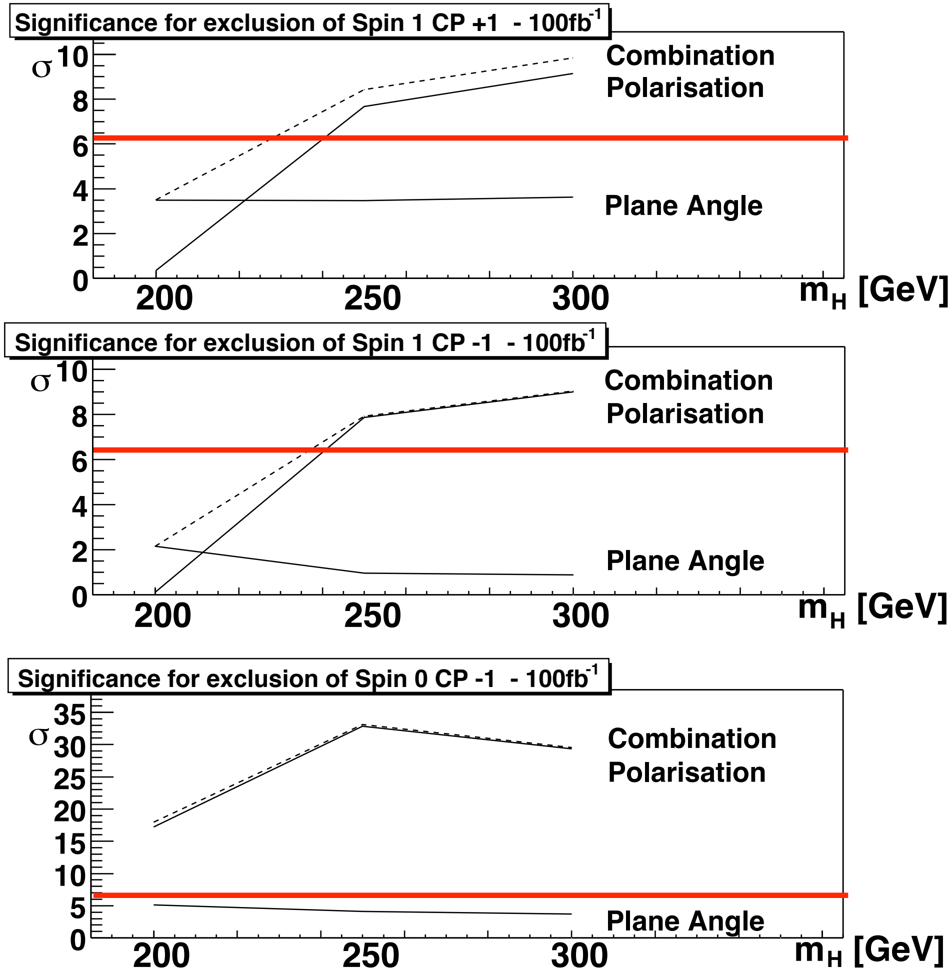
2σ at $10\ fb^{-1}$ ~ 6.3σ at $100\ fb^{-1}$

Exclusions look possible for $M_H > 250 GeV$





Eur. Phys. J. C 32, 209 (2004)



CMS Spin & CP Results

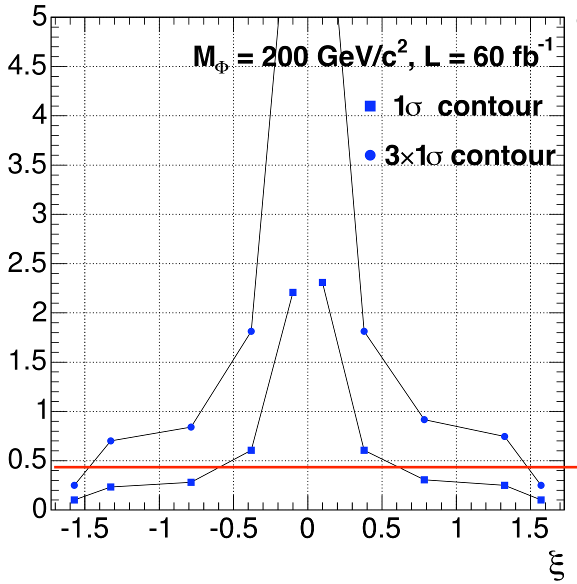
Similar study by CMS. Results presented with $60 fb^{-1}$

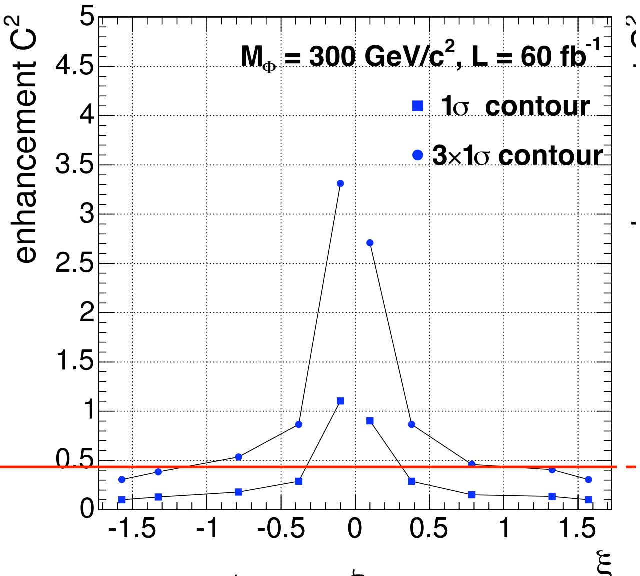
- What values ξ can one exclude with $10 fb^{-1}$ assuming Standard Model B.R. & xsection (ie. C=1)?

$$\mathcal{C}^{J=0}_{\Phi VV} = \kappa \cdot g^{\mu\nu} + \frac{\zeta}{m_V^2} \cdot p^\mu p^\nu + \frac{\eta}{m_V^2} \cdot \epsilon^{\mu\nu\rho\sigma} k_{1\rho} k_{2\sigma},$$

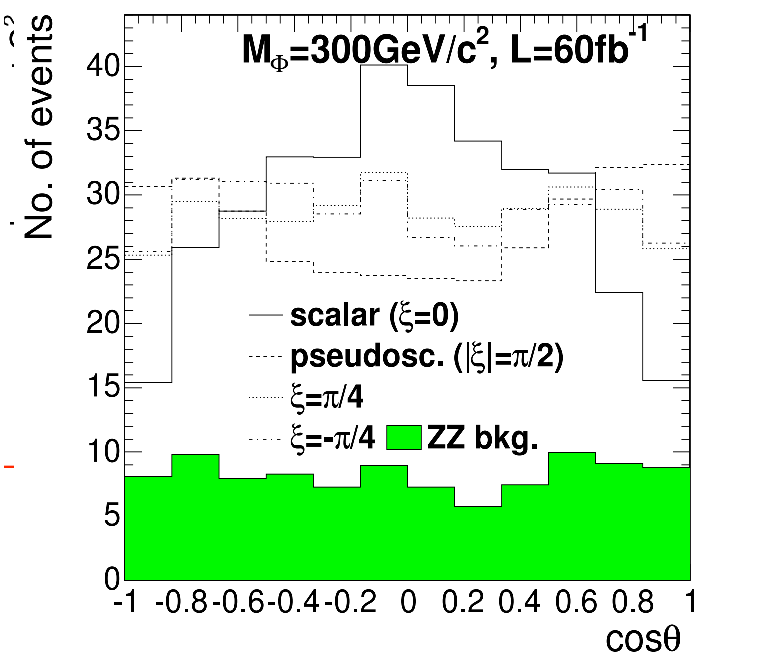
$$d\Gamma(\eta) \sim H + \eta\, I + \eta^2 A.$$

$$C^2 = (\sigma \times Br)/(\sigma_{SM} \times Br_{SM})$$





$$\tan\xi \equiv \eta,$$

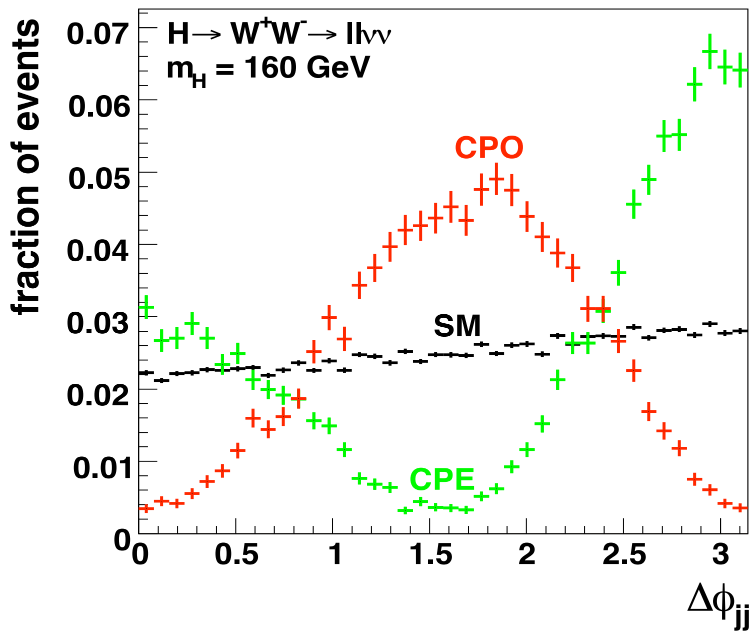


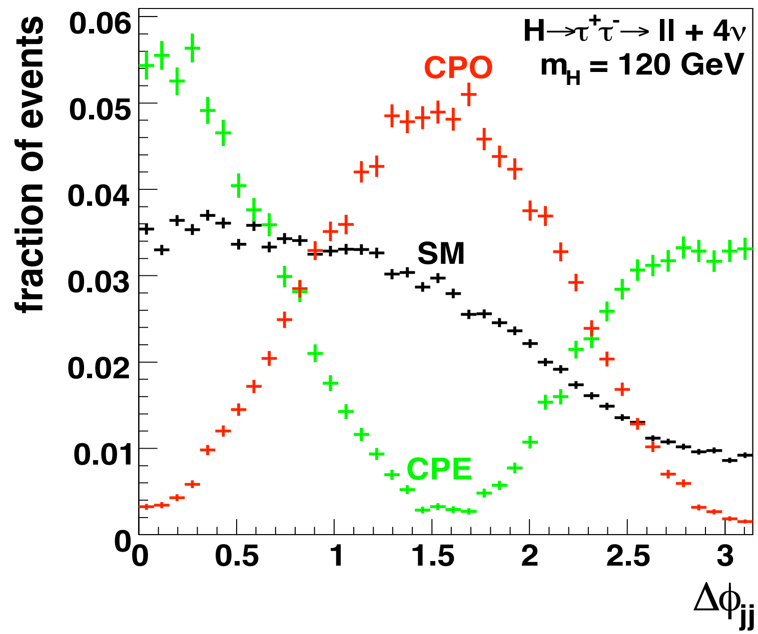
Recent ATLAS note on using $\Delta\phi_{jj}$ in VBF events to measure tensor structure of HVV vertex based on:

- Plehn, Rainwater, Zeppenfeld, Phys. Rev. Lett. 88, (2002), hep-ph/0105325
- Figy, Zeppenfeld, Phys. Lett. B591 (2004) 297, hep-ph/0403297

$$T^{\mu\nu}(q_1,q_2) = a_1(q_1,q_2)\,g^{\mu\nu} + a_2(q_1,q_2)\left[q_1\cdot q_2 g^{\mu\nu} - q_2^{\mu} q_1^{\nu}\right] + a_3(q_1,q_2)\,\epsilon^{\mu\nu\rho\sigma} q_{1\rho} q_{2\sigma}$$

$$g_{5e/o}^{HWW} = g_{5e/o}^{HZZ}\cos^2\theta_w \qquad a_2(q_1,q_2) = -\frac{2}{\Lambda_{5e}} g_{5e}^{HZZ}, \qquad a_3(q_1,q_2) = \frac{2}{\Lambda_{5o}} g_{5o}^{HZZ}$$





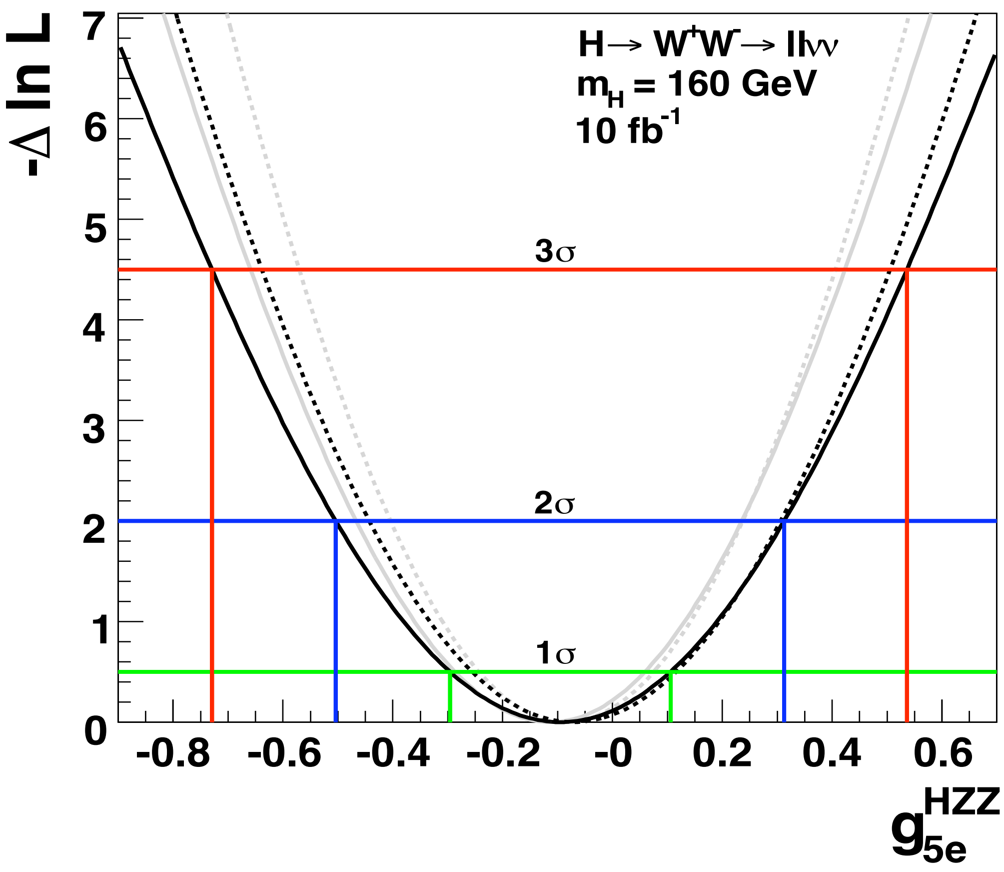
Ruwiedel, Schumacher, Wermes
SN-ATLAS-2007-060

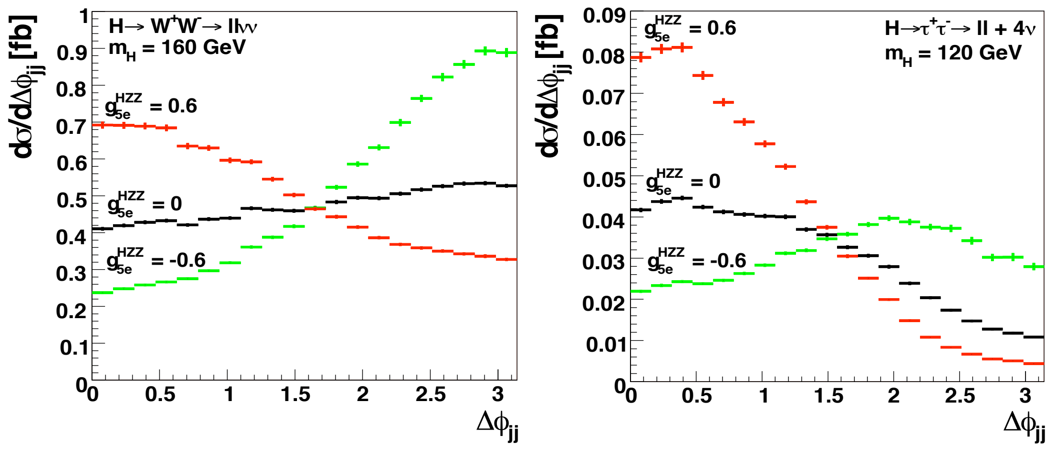
CP Measurements from Jets in VBF

BROOKHAVEN NATIONAL LABORATORY

The analysis considers measurements in early phase

- For M_H=160 GeV, anomalous CP even coupling measured with $10 fb^{-1}$
- For M_H=120 GeV, anomalous CP even coupling measured with $30 fb^{-1}$





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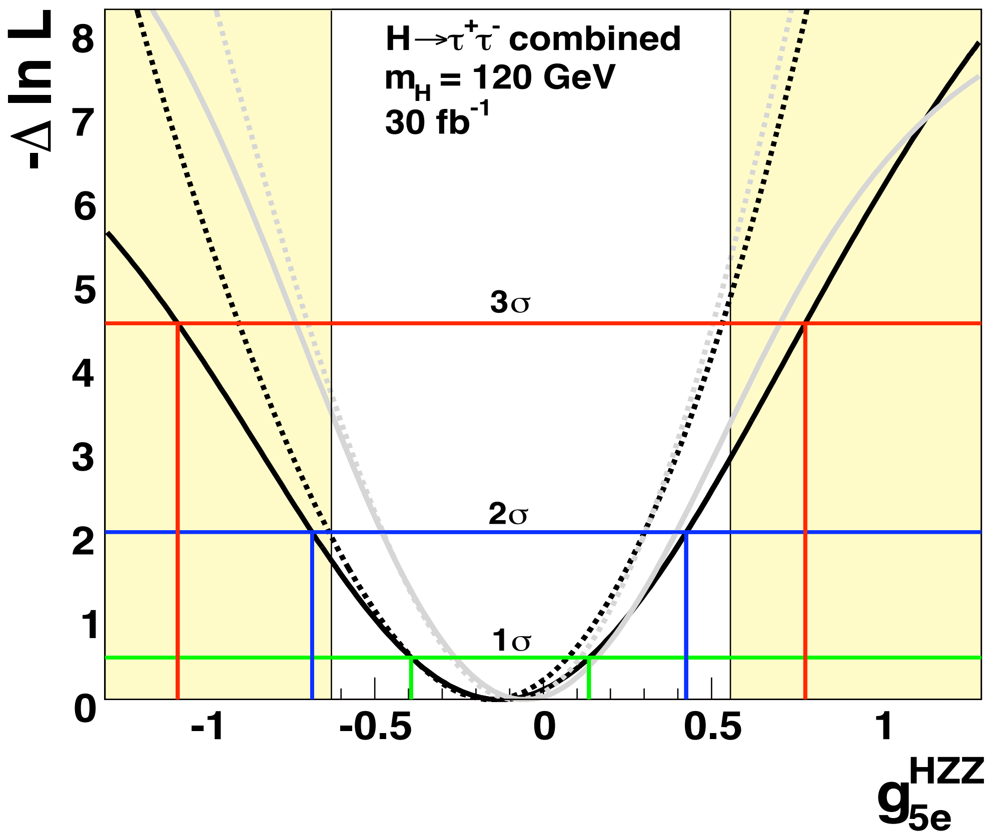

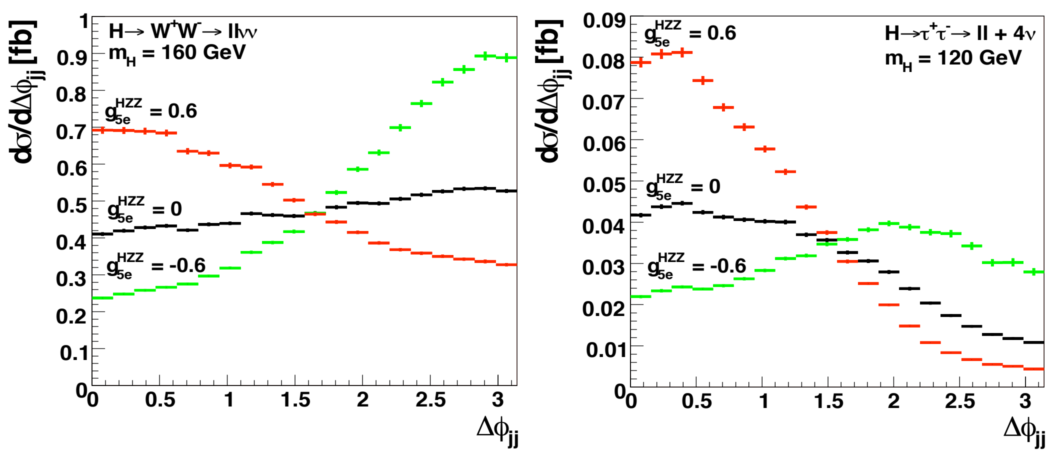

Ruwiedel, Schumacher, Wermes
SN-ATLAS-2007-060

Coupling Measurements

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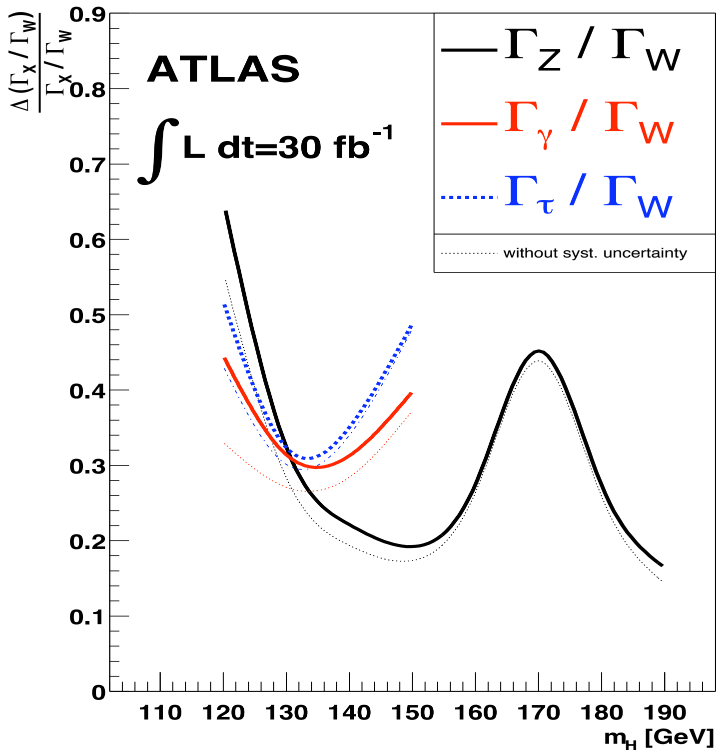
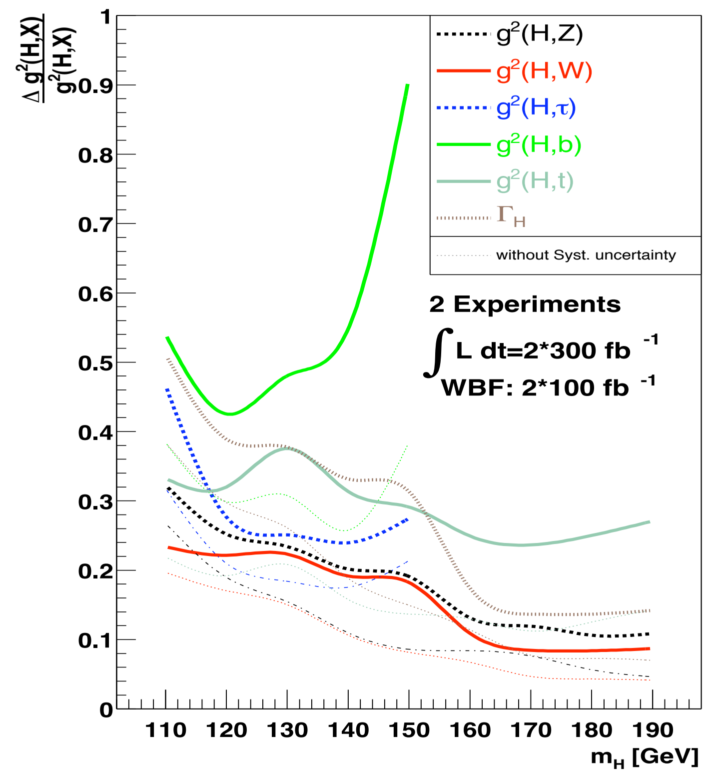
M. Dührssen, et. al. ATL-PHYS-2003-030 & Phys.Rev.D70:113009,2004 (hep-ph/0406323)





Assume CP-even, spin-0, only one Higgs

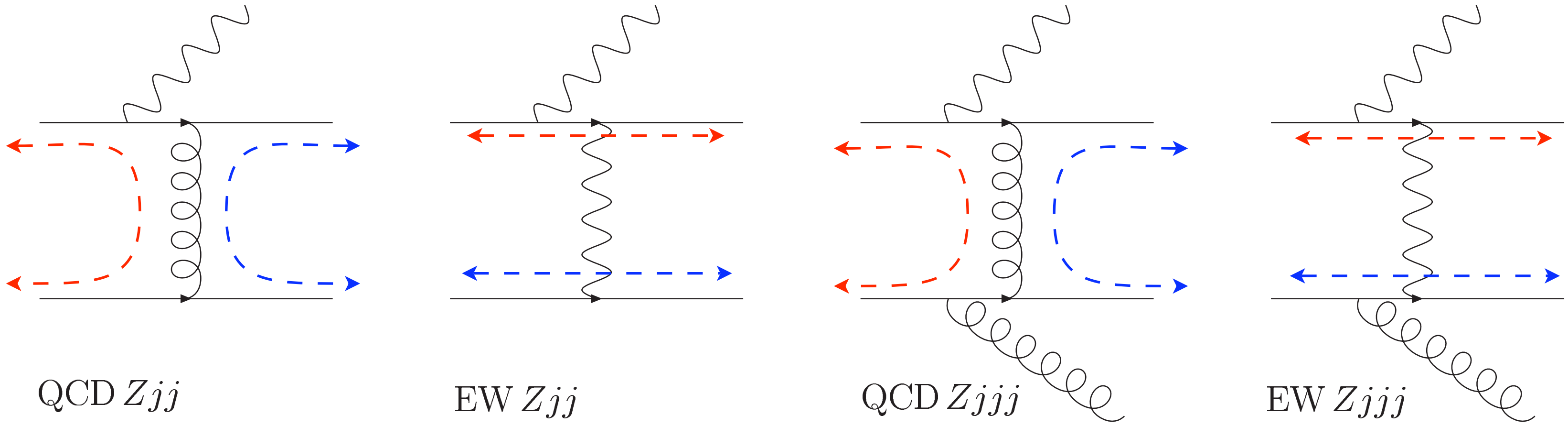
Ratios of partial widths
to within 20% with 30 fb^{-1}

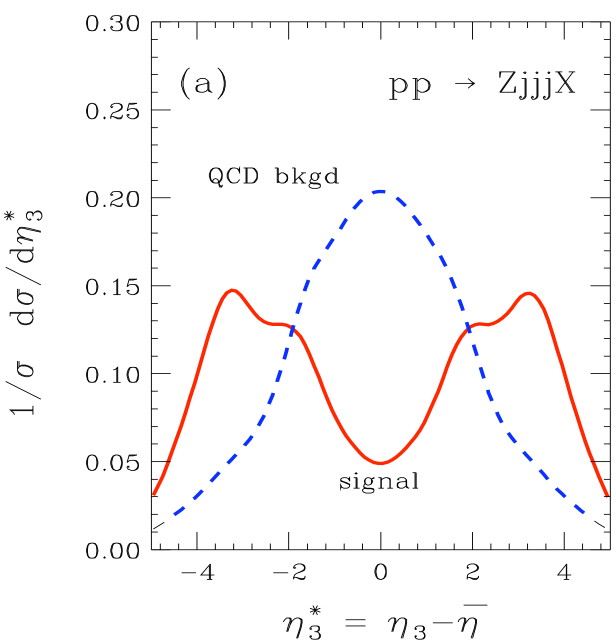
Weak assumptions:
$g(H,V) < 105\% g(H,V,SM)$
allow for unobserved decays & new loops

Absolute couplings measured
to within 10% with 2×300 fb^{-1}

The Central Jet Veto

The dominant background for $H \rightarrow \tau\tau$ is the irreducible Z+jets





Flow of color-charge leads to different distributions for additional QCD radiation for Electroweak and QCD Zjj background

A Central Jet Veto is a major tool for the VBF analyses

Limits existing analyses to "low" luminosity

Assumed Uncertanties

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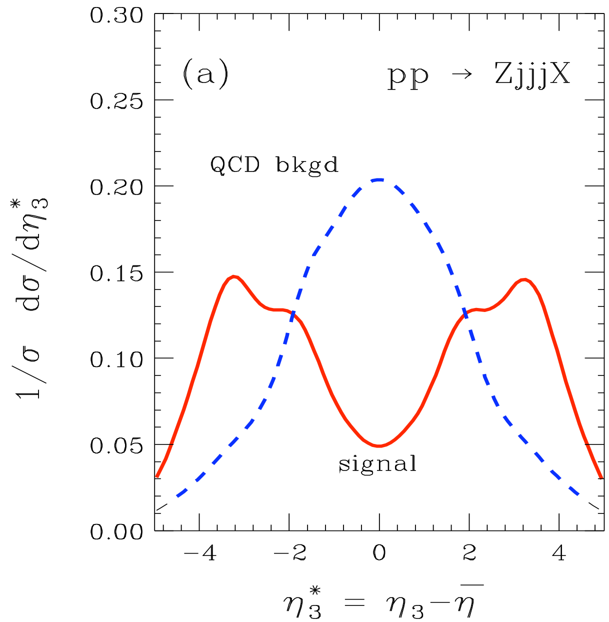
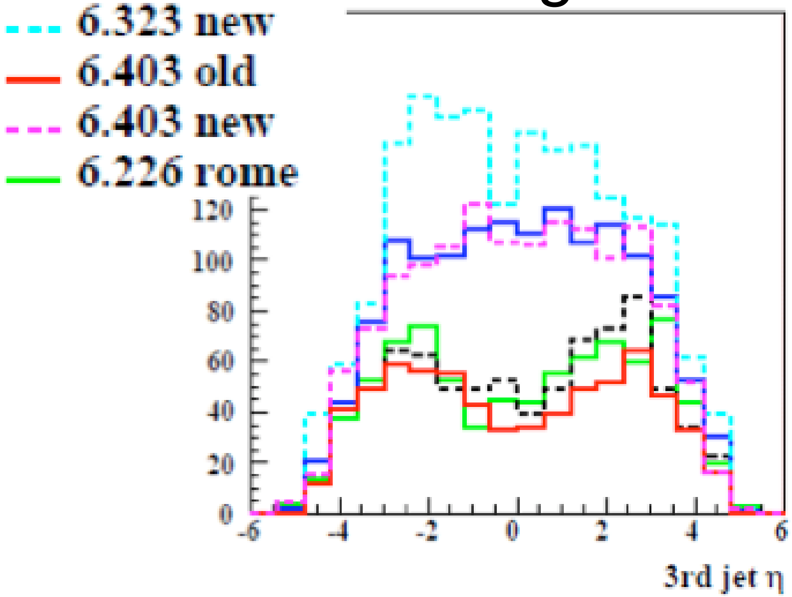
Assumed systematic uncertainties in the coupling measuements

L	5%	Measurement of luminosity
ϵ_D	2%	Detector efficiency
ϵ_L	2%	Lepton reconstruction efficiency
ϵ_γ	2%	Photon reconstruction efficiency
ϵ_b	3%	b-tagging efficiency
ϵ_τ	3%	hadronic τ-tagging efficiency
ϵ_{Tag}	5%	WBF tag-jets / jet-veto efficiency
ϵ_{Iso}	3%	Lepton isolation ($H \to ZZ \to 4\ell$)

Theorist's Dream



Experimentalist's Nightmare



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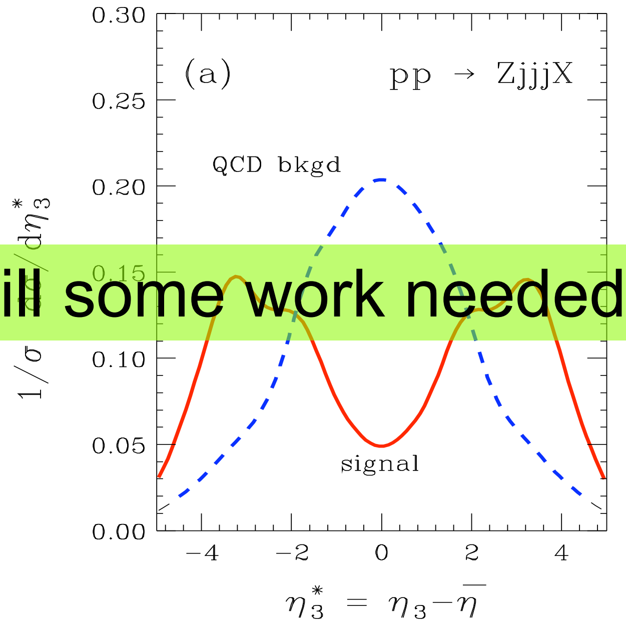

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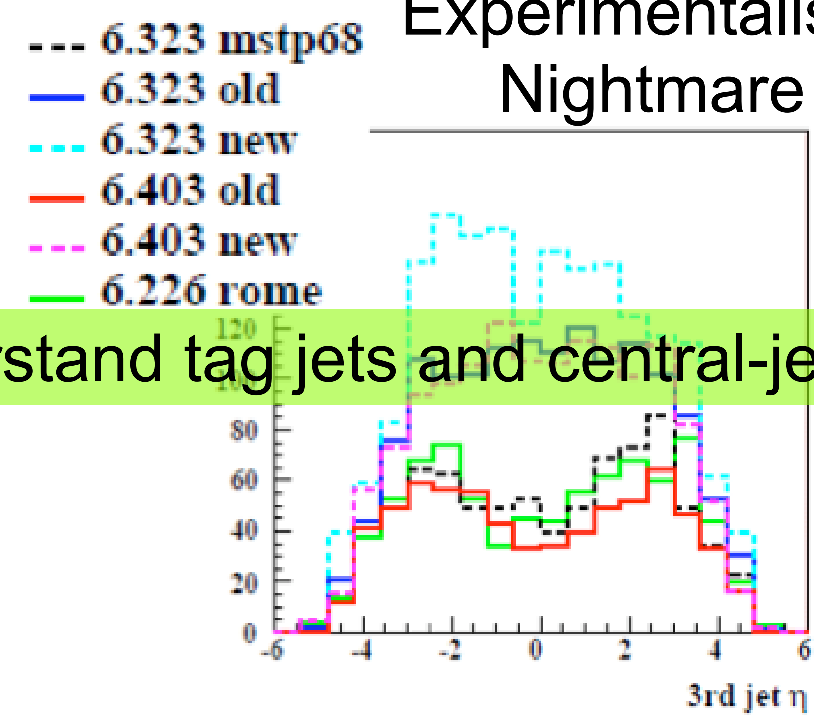
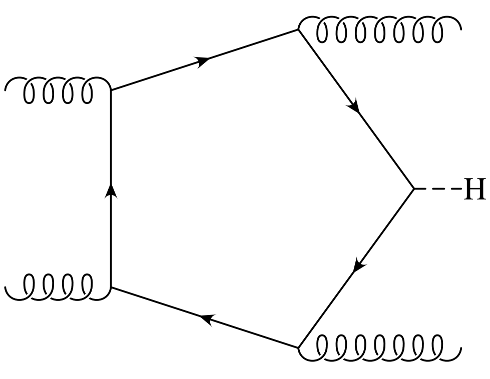


Still some work needed to understand tag jets and central-jet veto

Progress on Systematic Errors

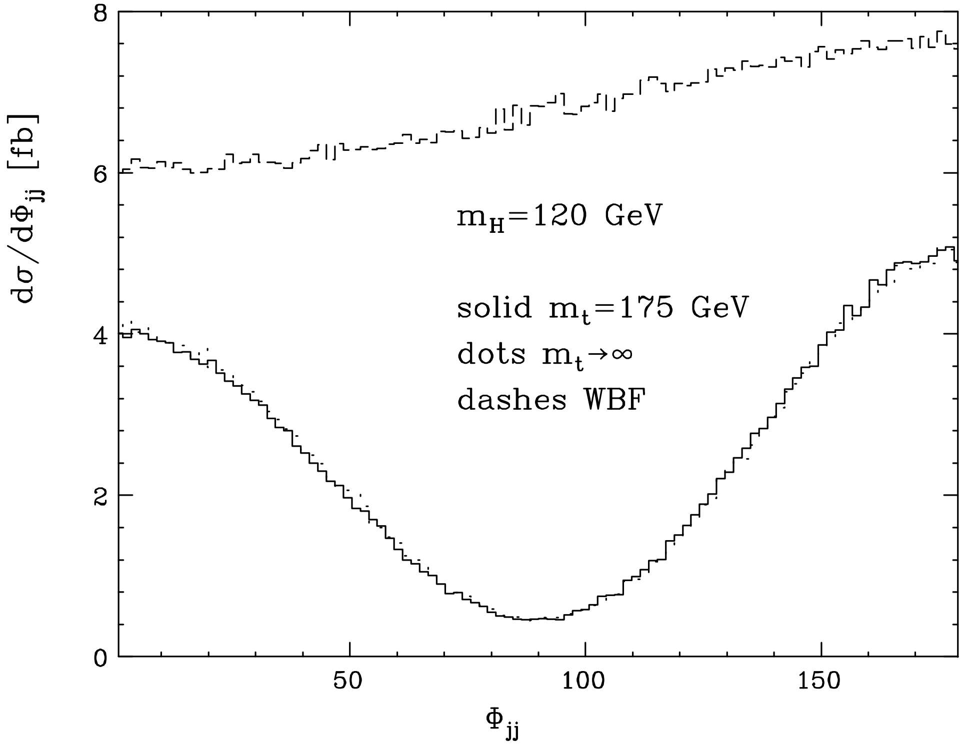
GF	20%
$t\bar{t}H$	15%
WH	7%
ZH	7%
WBF	4%
$gg \to Hgg$	100%

Table 3: Theoretical QCD and PDF uncertainties on the various Higgs boson production channels. The channel $gg \to Hgg$ was added to all WBF analyses at 10% of the WBF rate with an uncertainty of a factor 2.



(c)

V. Del Duca, C. Oleari, D. Zeppenfeld, et. al. hep-ph/0108030



$\Delta\phi_{jj}$ can be used to fit relative contribution from $gg \to Hgg$

Should reduce systematic error considerably.

$H \to \mu\mu$ at the LHC?

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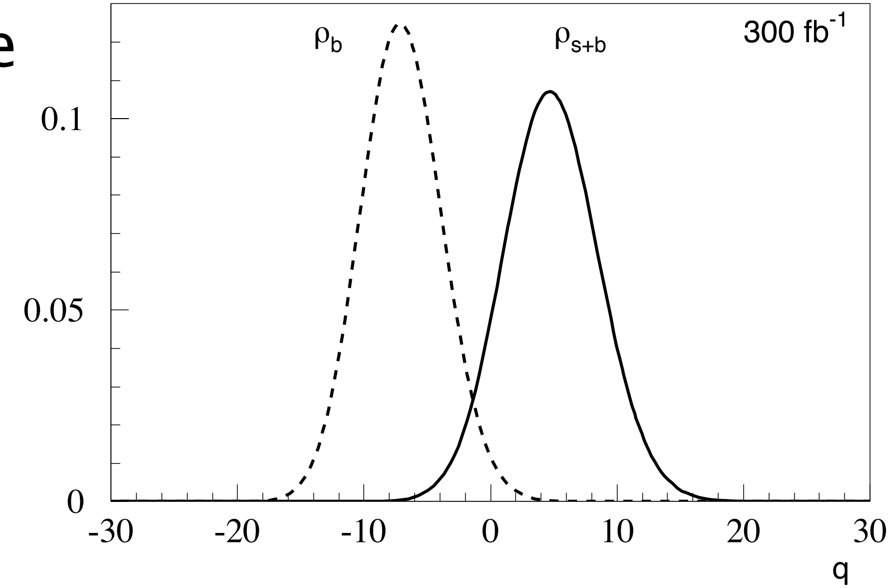
Original cuts in hep-ph/0107180 give 1.8σ / experiment for 300 fb^{-1}

Tilman Plehn and I showed that using theory equivalent of "Matrix Element technique" we can achieve

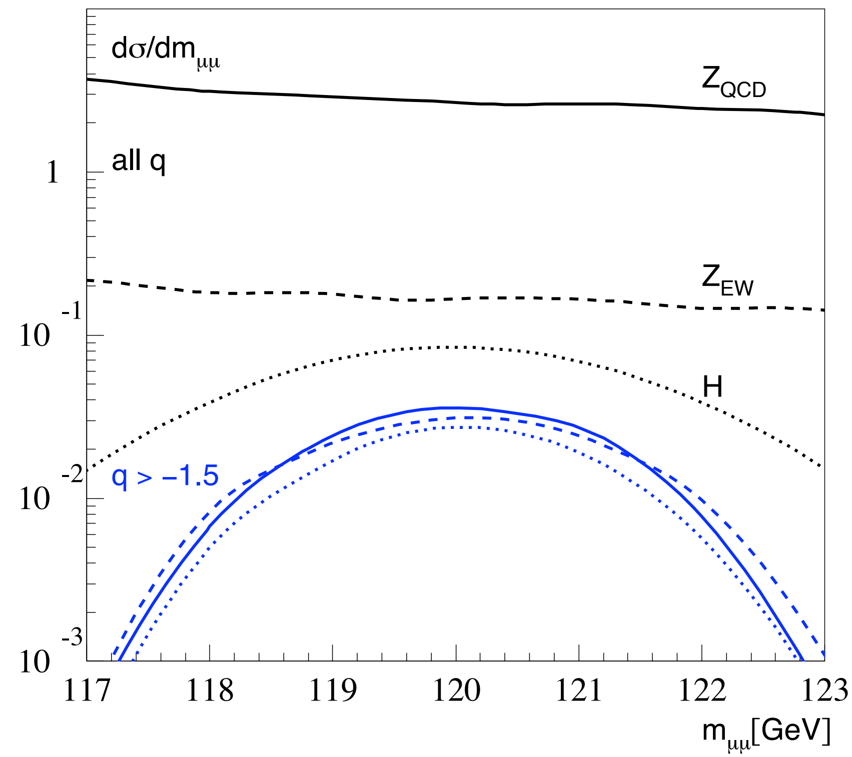
3.2σ / experiment with 300 fb^{-1}



Including Central Jet Veto efficiencies from hep-ph/0107180, we expect

- 4.4σ / experiment with 300 fb^{-1}

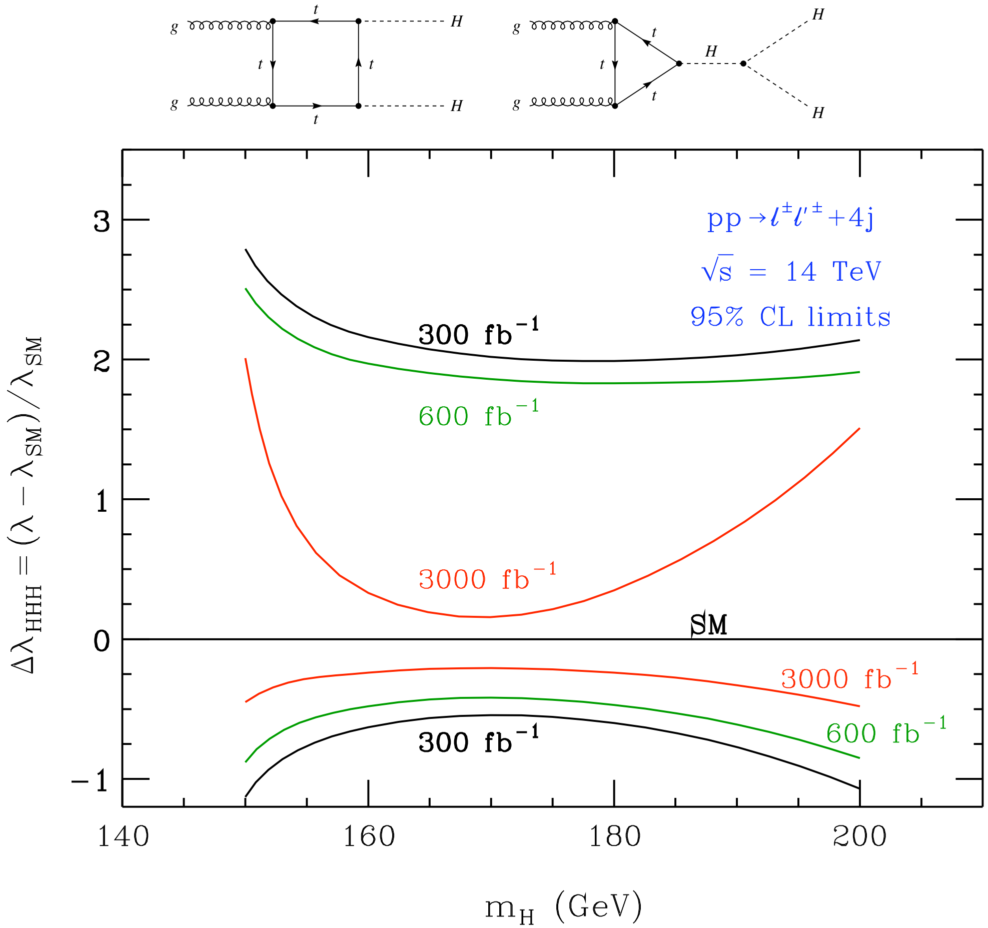
Conclusion: the use of multivariate techniques & event weighting may make it possible to observe $H \to \mu\mu$ at the LHC!



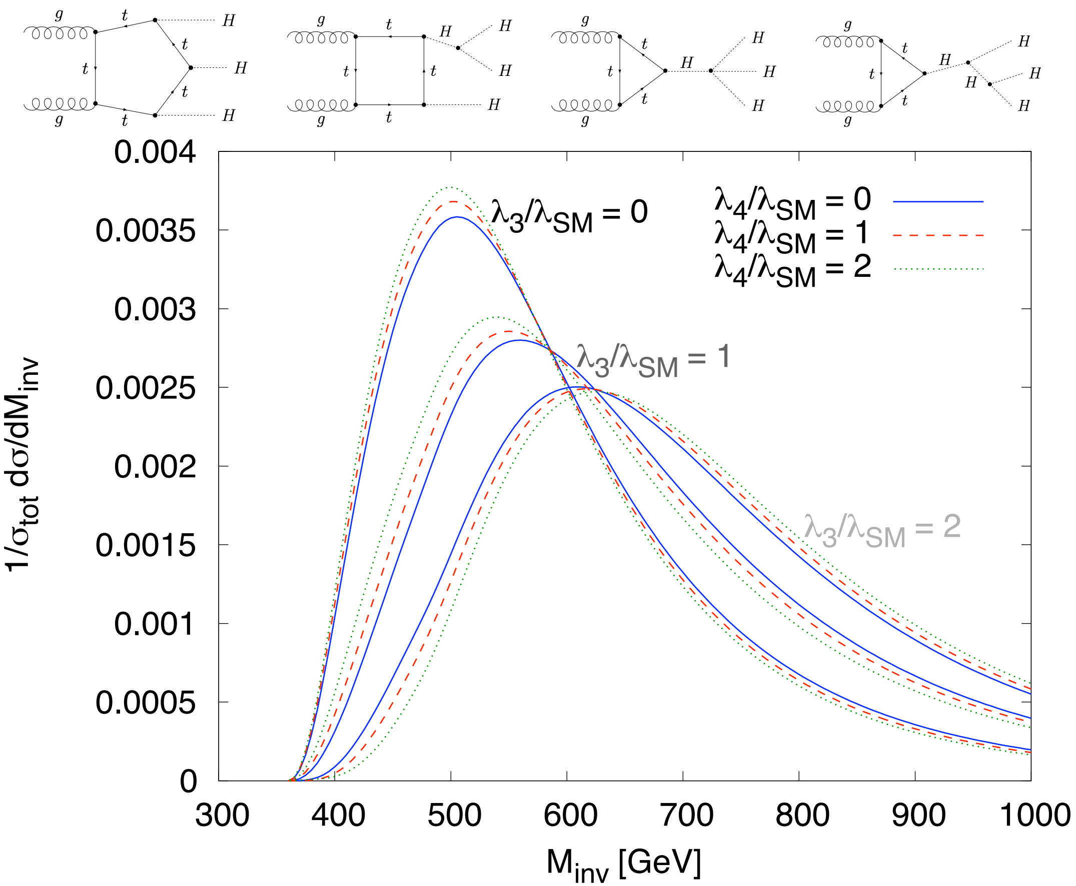
hep-ph/0605268

Higgs Self Coupling

hep-ph/0211224



hep-ph/0507321



Parton-level:

- $\lambda_{HHH} = 0$ can be excluded at 95% CL
- λ_{HHH} determined at 20-30%

ATLAS and CMS studies still preliminary

Interference between diagrams important

Variation in trilinear self-coupling dominates

No hope of measuring quartic self-coupling at SLHC or VLHC

Other Developments

Growing Interest in $pp \rightarrow pHp$

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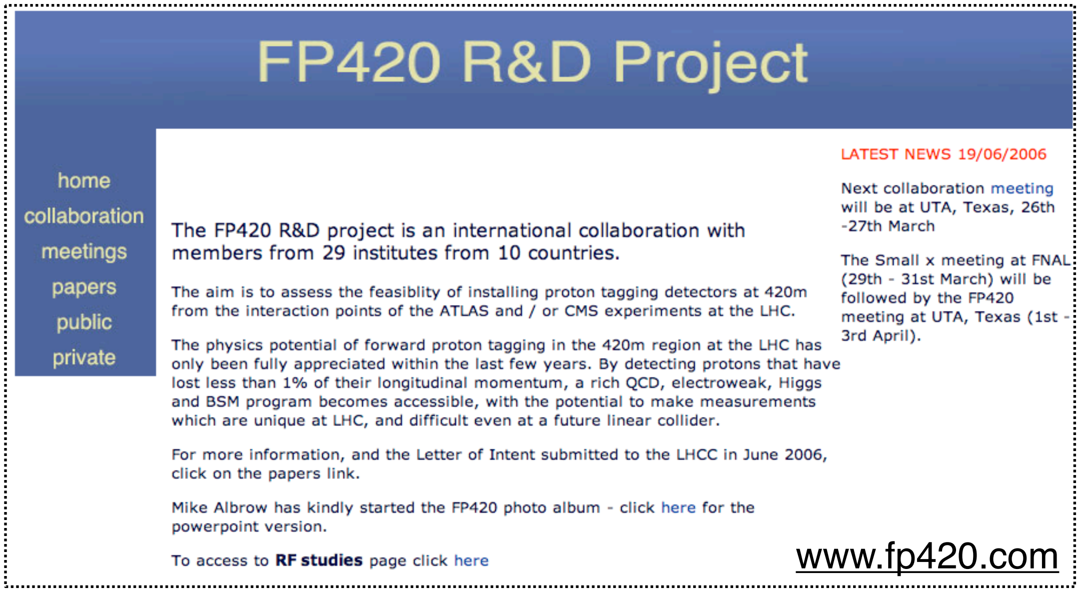
Growing interest in central exclusive Higgs production

- starting to see some studies in the collaborations



FP420 R&D Project

home
collaboration
meetings
papers
public
private

The FP420 R&D project is an international collaboration with members from 29 institutes from 10 countries.

The aim is to assess the feasiblity of installing proton tagging detectors at 420m from the interaction points of the ATLAS and / or CMS experiments at the LHC.

The physics potential of forward proton tagging in the 420m region at the LHC has only been fully appreciated within the last few years. By detecting protons that have lost less than 1% of their longitudinal momentum, a rich QCD, electroweak, Higgs and BSM program becomes accessible, with the potential to make measurements which are unique at LHC, and difficult even at a future linear collider.

For more information, and the Letter of Intent submitted to the LHCC in June 2006, click on the papers link.

Mike Albrow has kindly started the FP420 photo album - click here for the powerpoint version.

To access to **RF studies** page click here

LATEST NEWS 19/06/2006

Next collaboration meeting will be at UTA, Texas, 26th -27th March

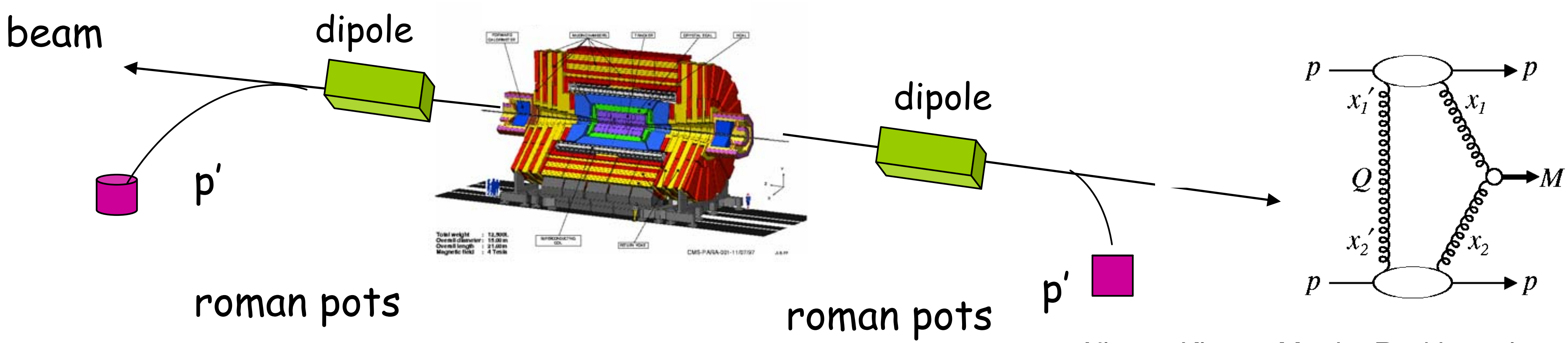
The Small x meeting at FNAL (29th - 31st March) will be followed by the FP420 meeting at UTA, Texas (1st - 3rd April).

www.fp420.com

First Look at pp→pHp with H→WW→ll

B.Mellado, W.Quayle and Sau Lan Wu
(University of Wisconsin)

Special thanks to M.Albrow, V.Khoze, T.Sjöstrand
Higgs WG meeting 10/04/07



Albrow, Khoze, Martin, Ryskin+ others

Higgs Dalitz Decays

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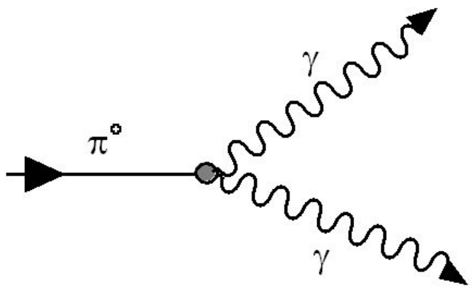
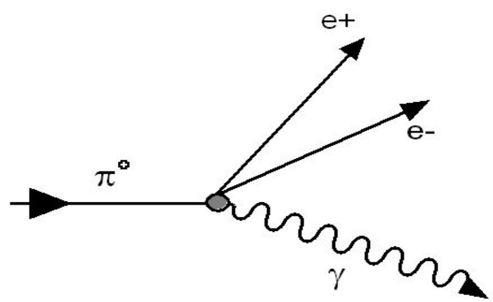
The Higgs may have decays analogous to pion Dalitz decays

- initial BR estimates are 10% of $H \to \gamma\gamma$



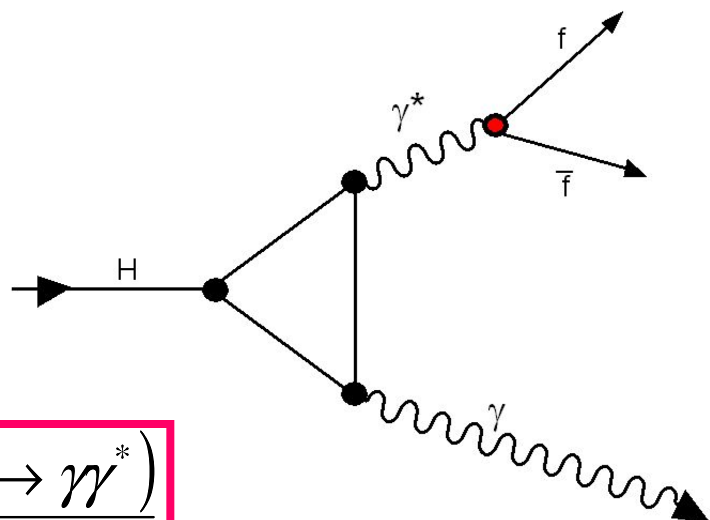
99.8%



1.18%

[Stroynowski, Firan]

Chanel	m_H=100GeV	m_H=150GeV	m_H=200GeV
	ρ	ρ	ρ
$H \to e^+ e^- \gamma$	0.0326	0.0339	0.0348
$H \to \mu^+ \mu^- \gamma$	0.0161	0.0174	0.0183
$H \to \tau^+ \tau^- \gamma$	0.0073	0.0085	0.0095
$H \to u \bar{u} \gamma$	0.0203	0.0220	0.0232
$H \to d \bar{d} \gamma$	0.0051	0.0055	0.0058
$H \to s \bar{s} \gamma$	0.0037	0.0042	0.0045
$H \to c \bar{c} \gamma$	0.0115	0.0132	0.144
$H \to b \bar{b} \gamma$	0.0016	0.0020	0.0023
	0.1003	0.1067	0.1128



$$\rho = \frac{\sigma(H \to \gamma\gamma^*)}{\sigma(H \to \gamma\gamma)}$$

- **Process analogous to π^0 Dalitz decay**
- **No more low mass constraint, that means that all kinematicaly allowed fermions can be observed**:

e, μ, τ, u, d, s, c, b, (t)

- **The triangular loop may have any charged fermions or bosons**

- Still to assess: Interference with Z γ γ

Conclusions

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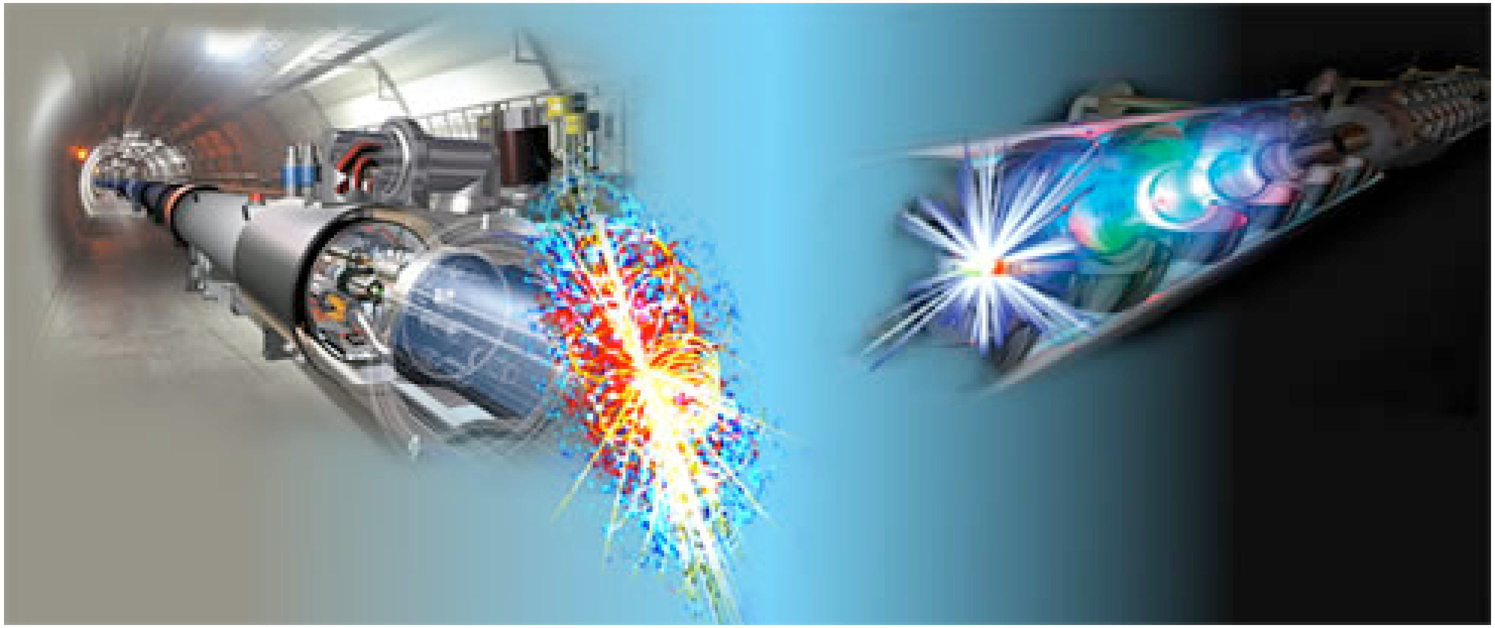
The early phase of the LHC can have a significant impact on the ILC both in terms of short-term decision making and long-term physics potential

Many scenarios to consider and discuss during the remainder of he workshop!



Backup Slides

$H \rightarrow \mu\mu$ at the LHC?

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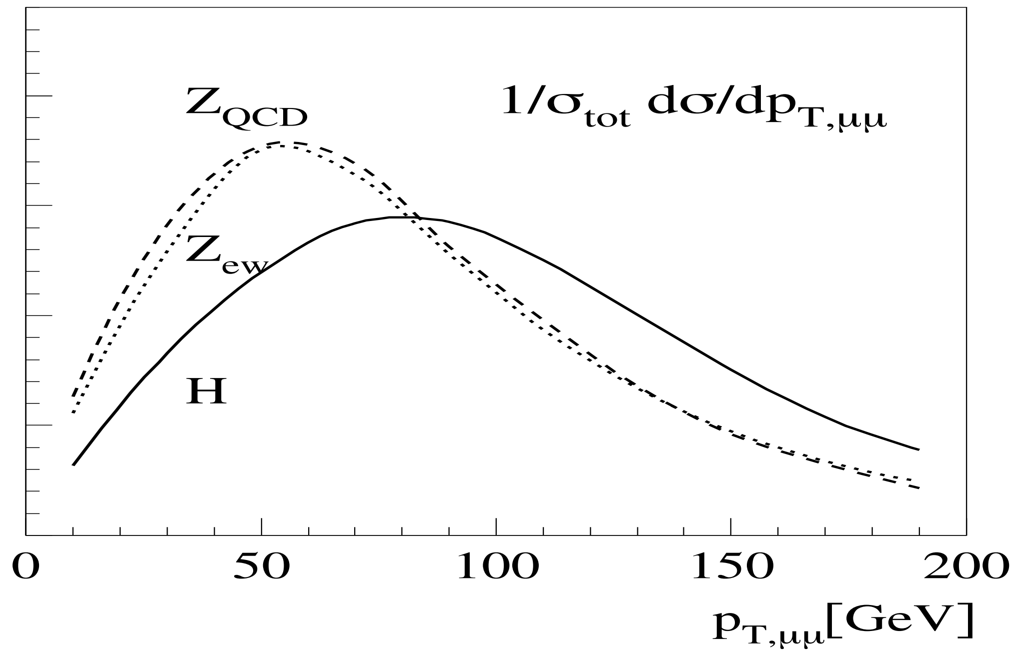
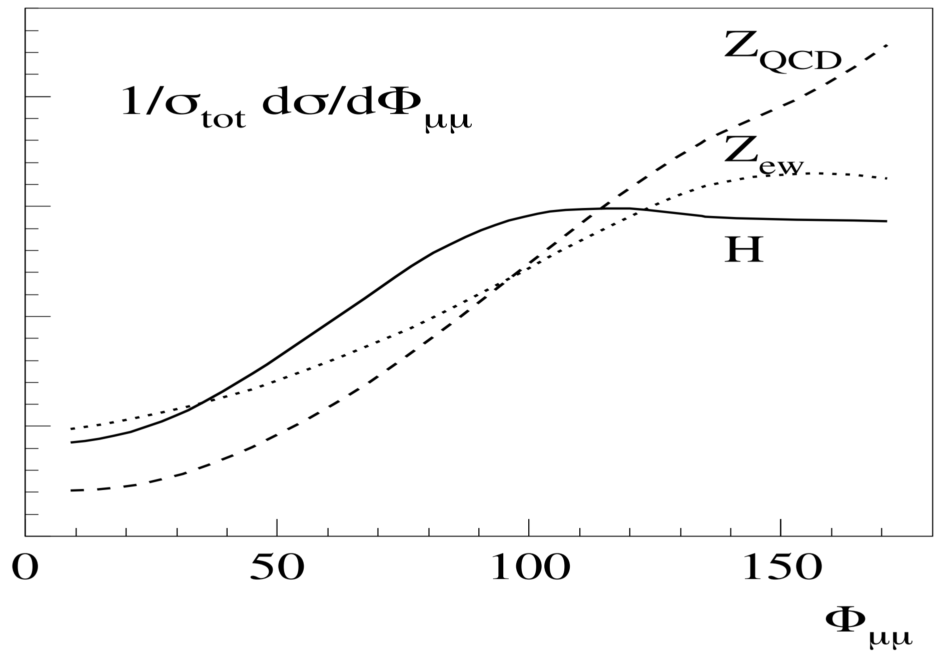
In hep-ph/0107180, Tilman Plehn and David Rainwater investigated the potential of VBF $H \rightarrow \mu\mu$ to measure Yukawa coupling to second-generation fermions at LHC.

Even with 300 fb^{-1}, best cuts only achieve 1.8σ significance for $M_H = 120$ GeV.

However, they note several other variables with discriminating power:





They suggested the use of Neural Networks or some multivariate algorithm

Tao Han & Bob McElrath (hep-ph/0201023) included gluon fusion, still no discovery.

ATLAS Higgs Discovery Potential 1999 → 2003

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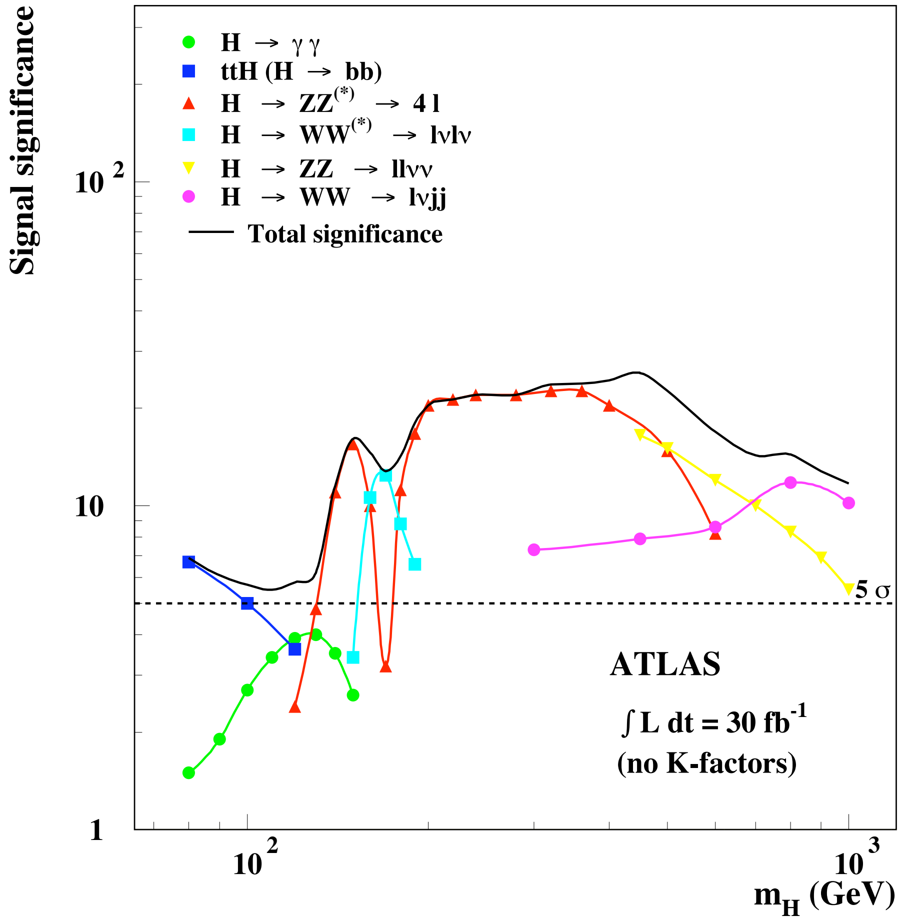
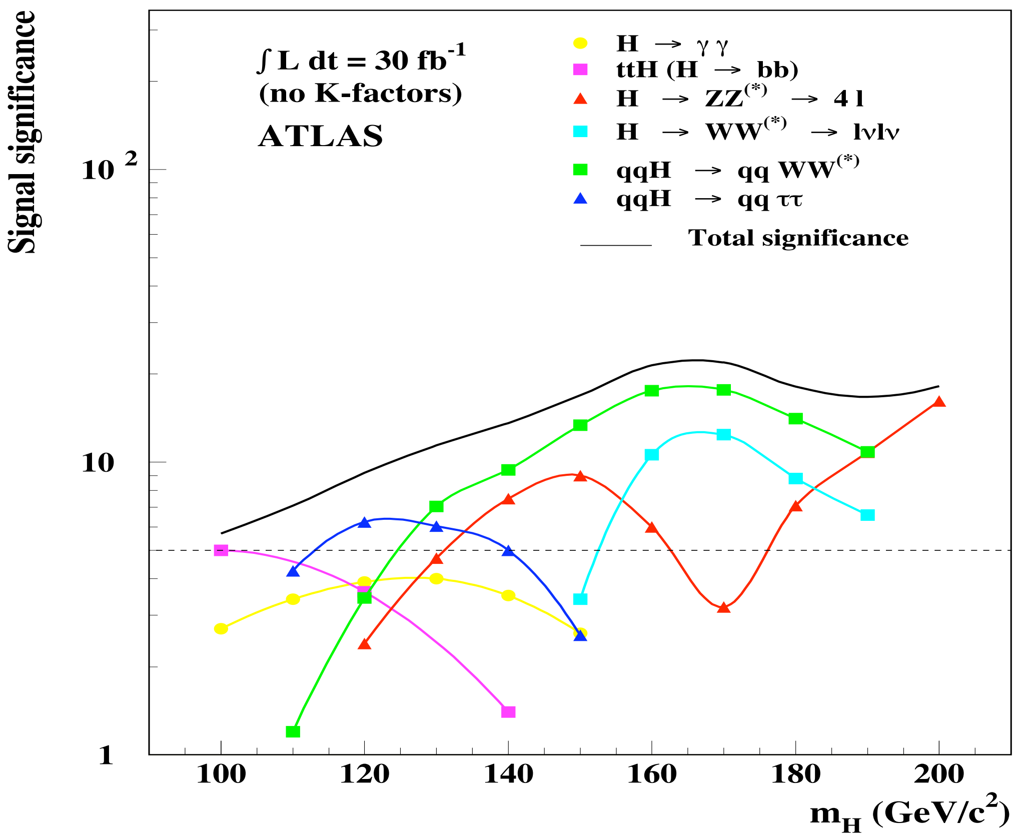


Higgs Potential in ATLAS TDR (1999)



Addition of Vector Boson Fusion Channels at Low mass SN-ATLAS-2003-024

Both ATLAS and CMS cover entire SM Higgs mass range early in LHC running

(III) NLO cross sections

Signal

- Gluon-gluon fusion events generated from ResBos (K factor ~ 1.8)
- VBF from PYTHIA 6.224 (LO)+ 1.04 K factor (from ResBos and HiGlu)
- Associated production from PYTHIA (LO)
- $H \to \gamma\gamma$ branching ratio of PYTHIA corrected with HDecay

Irreducible background

- DIPHOX and ResBos : treatment of the background at NLO
- Increase of 47 % due to the LO -> NLO transition
- @NLO ~125 fb/GeV for M_H=120 GeV (after cuts and photon efficiency)

Reducible background

- jet/jet events dominated by gluon initiated jets (easier to reject) while γ/jet events dominated by quark initiated jets
- the total contribution @LO is close to TDR although dominated by γ/jet : ~ 20 fb/GeV
- K factor ~ 1.7: at NLO ~30 % of irreducible back.

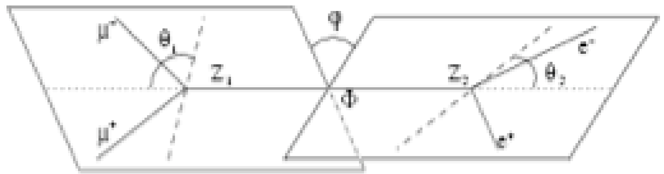
Leonardo Carminati Physics at LHC 2006 13

CP properties of Higgs

Higgs boson CP properties from $\phi \to ZZ \to e^+e^-\mu^+\mu^-$

Two observables:

- Angle between decay planes in Higgs rest-frame
- Angle between leptons and Z-momentum the Z rest-frame (Gottfried-Jackson angle).

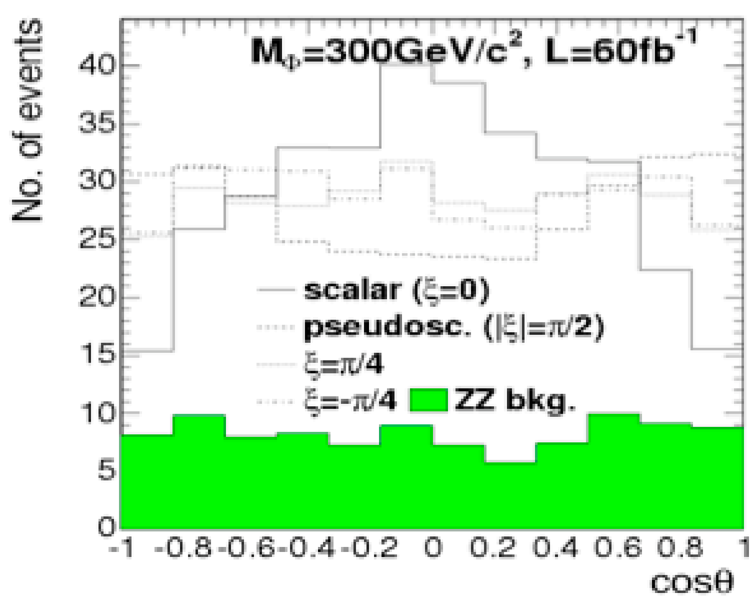


Decay width for $\phi \to ZZ \to e^+e^-\mu^+\mu^-$ can be written as

$d\,\Gamma(\eta) \sim H + \eta\, I + \eta^2 A$,

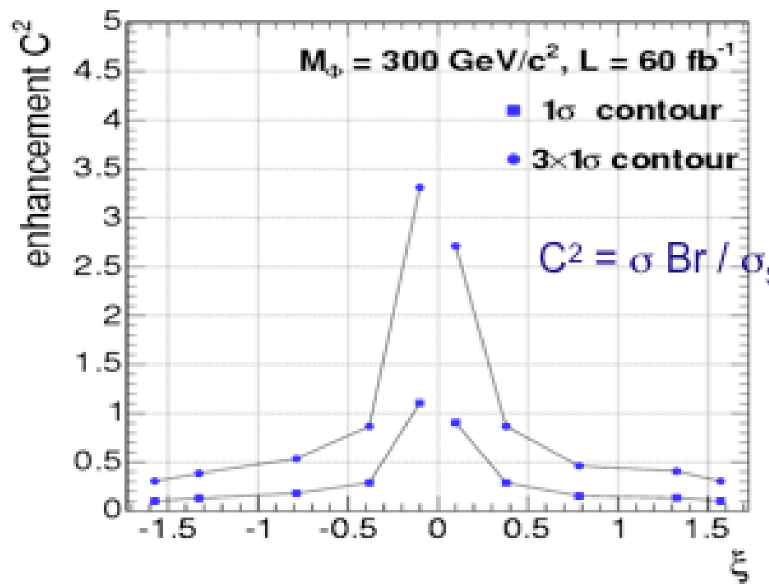
H = scalar, A = pseudoscalar, I = interference (CP-violating)

$\eta = \tan(\xi)$, $-\pi/2 < \xi < +\pi/2$



R. Kinnunen
CMS Physics TDR Results

C^2 needed to exclude H_{SM}



$C^2 = \sigma\, Br / \sigma_{SM}\, Br_{SM}$

13th Nordic Physics Workshop
Physicum, Helsinki

Vector Boson Fusion $H \rightarrow \tau\tau$

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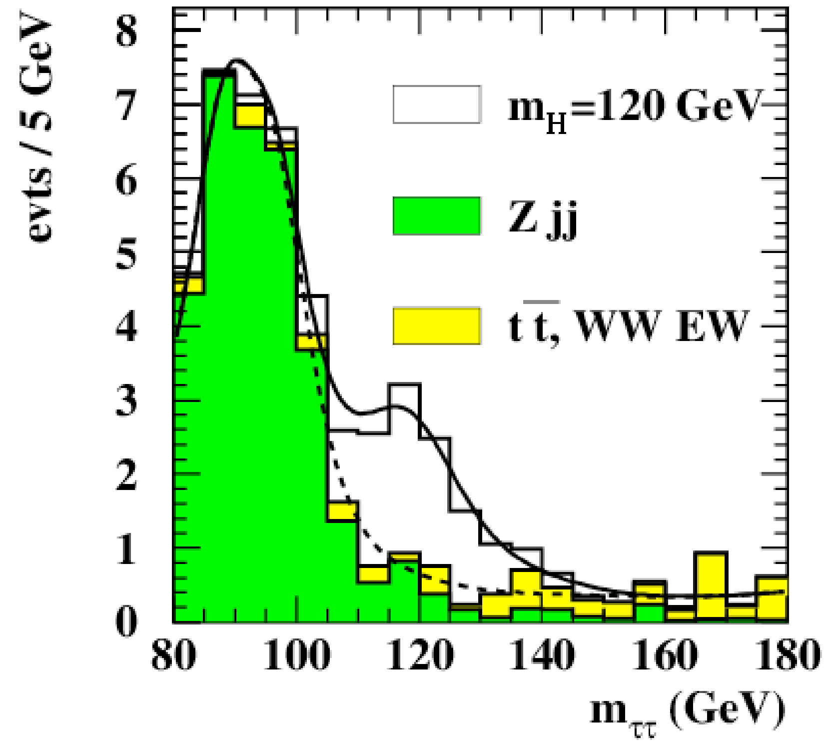
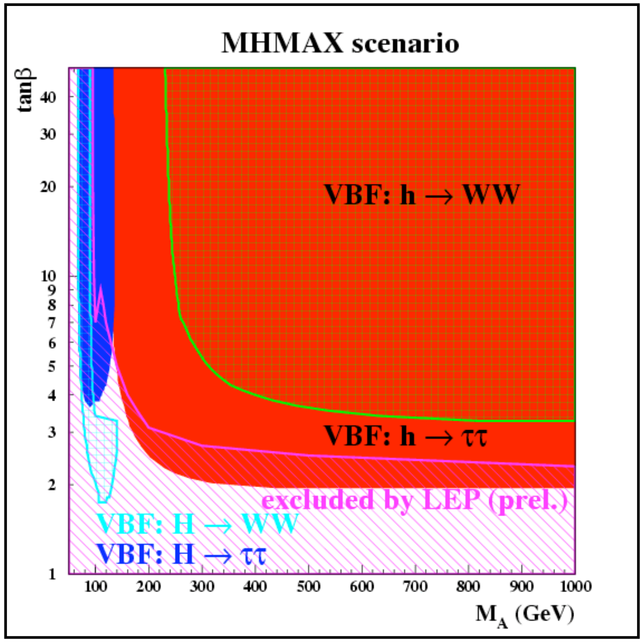
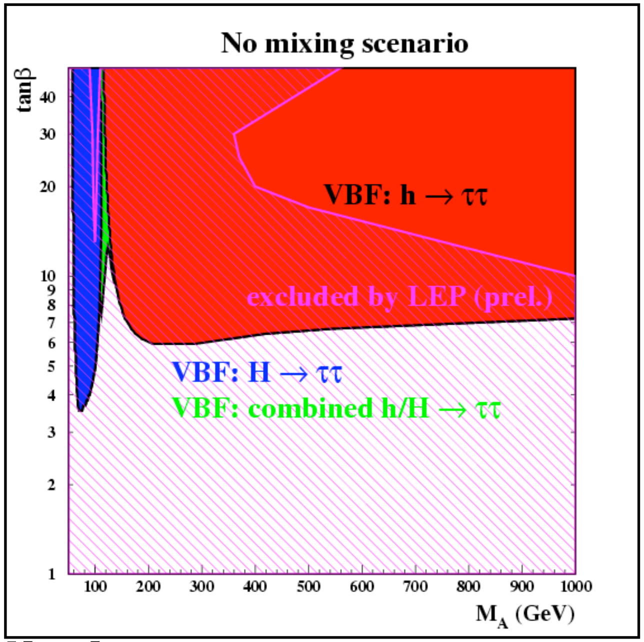
	signal (fb)		background (fb)					
	VV	gg	$t\bar{t} + jets$	$WW + jets$ EW	$WW + jets$ QCD	$\gamma^*/Z + jets$ EW	$\gamma^*/Z + jets$ QCD	Total
Lepton acceptance	5.55		2014.	18.2	669.8	11.6	2150.	4864.
+ Forward Tagging	1.31		42.0	9.50	0.38	2.20	27.5	81.6
+ P_T^{miss}	0.85		29.2	7.38	0.21	1.21	12.4	50.4
+ Jet mass	0.76		20.9	7.36	0.11	1.17	9.38	38.9
+ Jet veto	0.55		2.70	5.74	0.05	1.11	4.56	14.2
+ Angular cuts	0.40		0.74	1.20	0.04	0.57	3.39	5.94
+ Tau reconstruction	0.37		0.12	0.28	0.001	0.49	2.84	3.73
+ Mass window	0.27	0.01	0.03	0.02	0.0	0.04	0.15	0.24
$H \rightarrow \tau\tau \rightarrow e\mu$	0.27	0.01	0.03	0.02	0.0	0.04	0.15	0.24
$H \rightarrow \tau\tau \rightarrow ee$	0.13	0.01	0.01	0.01	0.0	0.02	0.07	0.11
$H \rightarrow \tau\tau \rightarrow \mu\mu$	0.14	0.01	0.01	0.01	0.0	0.02	0.07	0.11

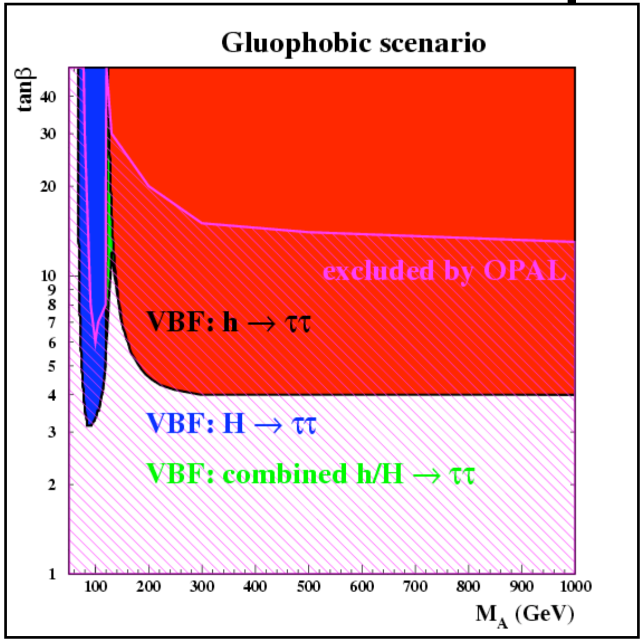


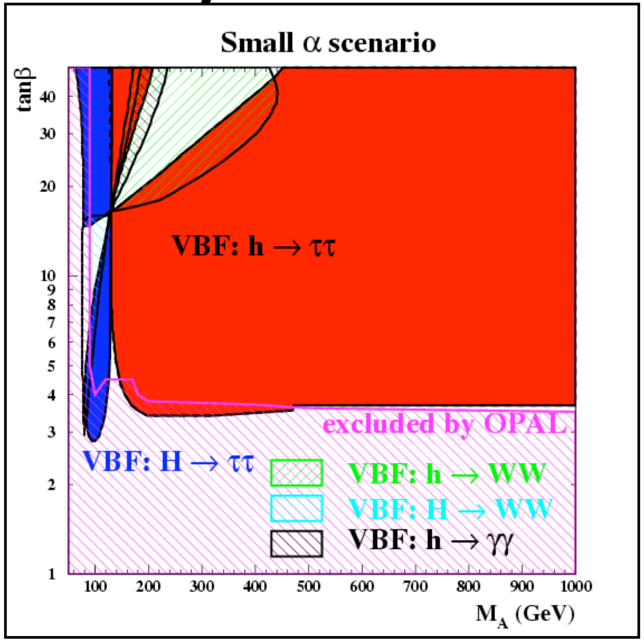
- ✦ Based on work of Rainwater, Zeppenfeld, Hagiwara, Plehn in 1999-2000
- ✦ Used fast simulation: 90% lepton efficiency, parametrized τ-id, etc.
- ✦ Possible discovery channel for $M_H = $ 115-140 GeV with 30 fb^{-1}
- ✦ Dominated by irreducible $Z \rightarrow \tau\tau$ background
- ✦ Published in: Eur. Phys. J., C 32 (2004) 19-54 & SN-ATLAS-2003-024



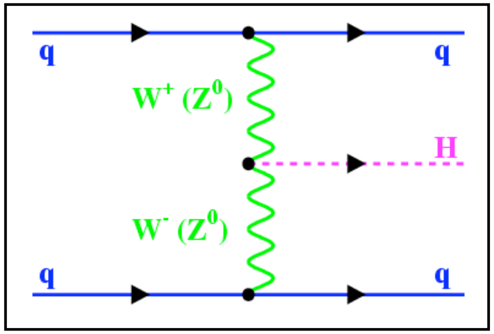


ATLAS preliminary





VBF:qq→qqH



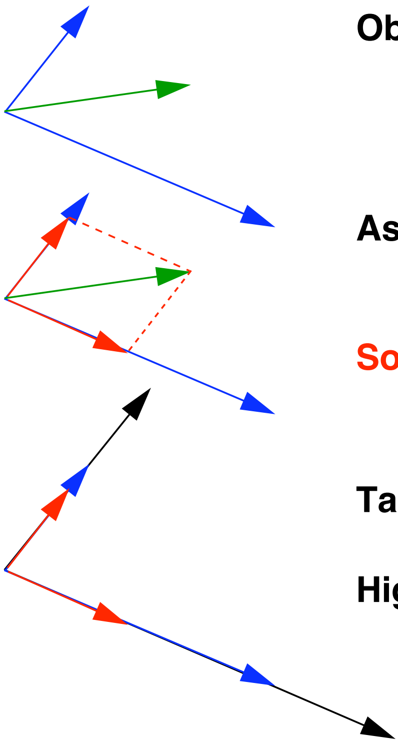
studied for M_H>110GeV at low lumi running

almost gurantees discovery of at least one h or H with 30 fb^{-1}

Following work by Plehn, Rainwater, Zeppenfeld

The Collinear Approximation

Mass Reconstruction:



Observe

missing transverse momentum
and visible Tau–decay products

Assume Tau decay products
collinear with original Tau

Solve 2 linear equations
for the neutrinos

Taus can be reconstructed

Higgs can be reconstructed

$$x_{\tau h} = \frac{h_x l_y - h_y l_x}{h_x l_y + \not{p}_x l_y - h_y l_x - \not{p}_y l_x}$$

$$x_{\tau l} = \frac{h_x l_y - h_y l_x}{h_x l_y - \not{p}_x h_y - h_y l_x + \not{p}_y h_x}$$

Some Comments:

After jet cuts, $M_{\tau\tau}$ is the only discrimination we use between $Z \to \tau\tau$ and $H \to \tau\tau$

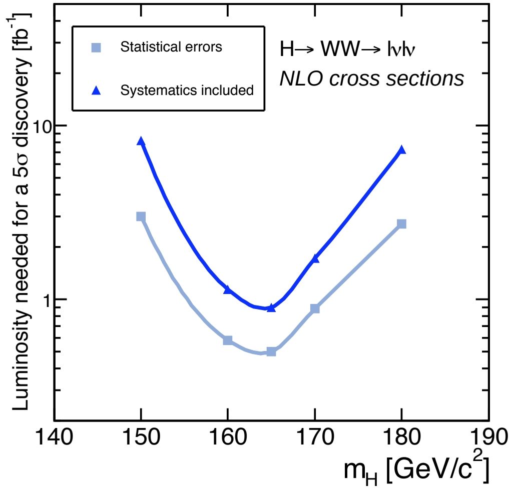
Collinear approximation doesn't take into account MissingET resolution

Define x_τ: fraction of τ's momentum in visible decay product

$$M_{\tau\tau} = \sqrt{2(E_h + E_{\nu h})(E_l + E_{\nu l})(1 - \cos\theta_{\tau\tau})}$$

is equivalent to $M_{\tau\tau} = \frac{M_{ll}}{\sqrt{x_{\tau l} x_{\tau h}}}$

only when $0 < x_\tau < 1$


Statistical errors
Systematics included
H→ WW→ lνlν
NLO cross sections
Luminosity needed for a 5σ discovery [fb⁻¹]
10
1
140
150
160
170
180
190
m_H [GeV/c²]