SM HIGGS AT LHC WITH 10 FB^{-1}

David Rainwater

University of Rochester

LHC-ILC Higgs working group

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– What is discovered?

– Improvements and limitations

– Quantum number measurements

Starting assumption:

No new (non-SM) physics at LHC after 10 fb^{-1}.

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10 fb^{-1}, ~ 2 years operation [ignore next 290(2990) fb^{-1}]

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- all calibrations done: e, μ, j, b, τ, $\not{E}_T$ (incl. forward region)

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That is, we can access all SM Higgs channels we expect to see.

Note: interpret the WG charge of "see SM Higgs" to mean at discovery, it's consistent with the SM Higgs hypothesis.

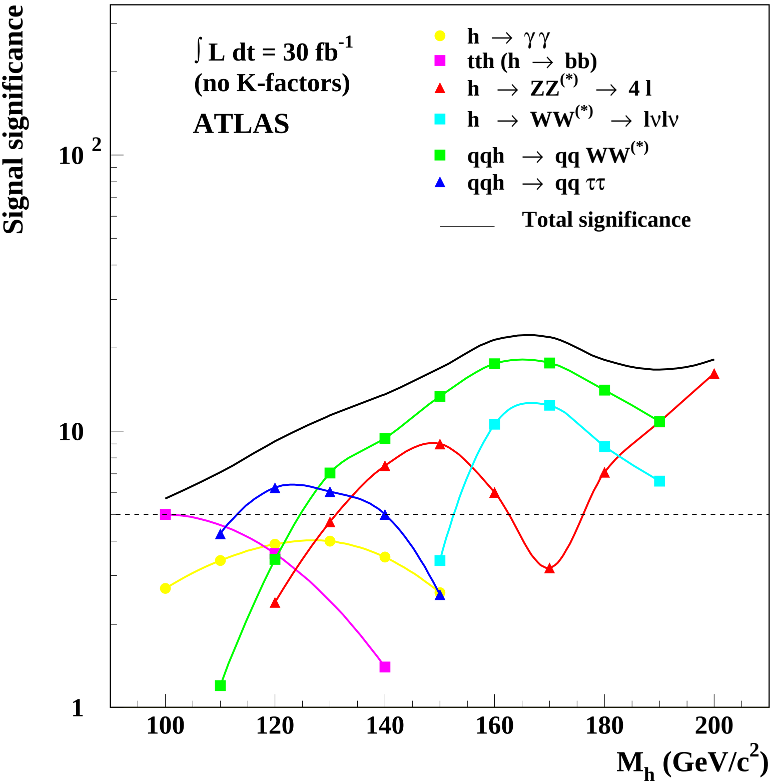
$\longrightarrow$ We must then go looking for deviations!

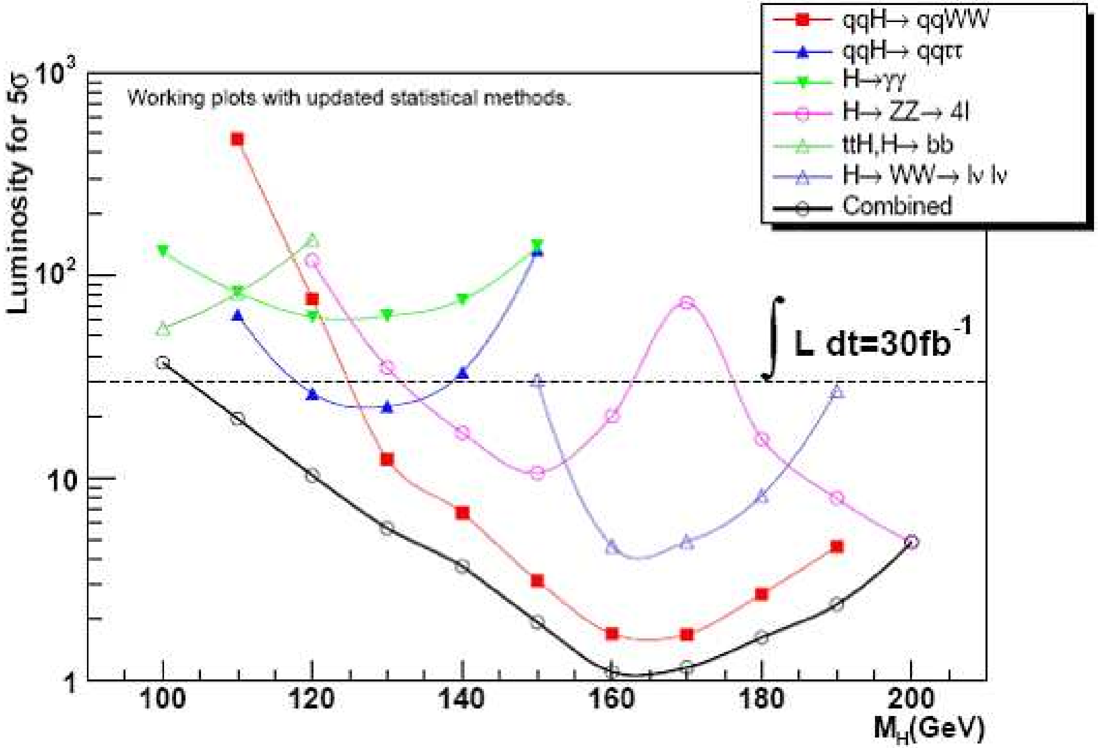
· The true starting point is a SM-like Higgs.

10 FB^{-1}: IS A SM HIGGS DISCOVERED?

(also see talks by A. DeRoeck and B. Mellado)

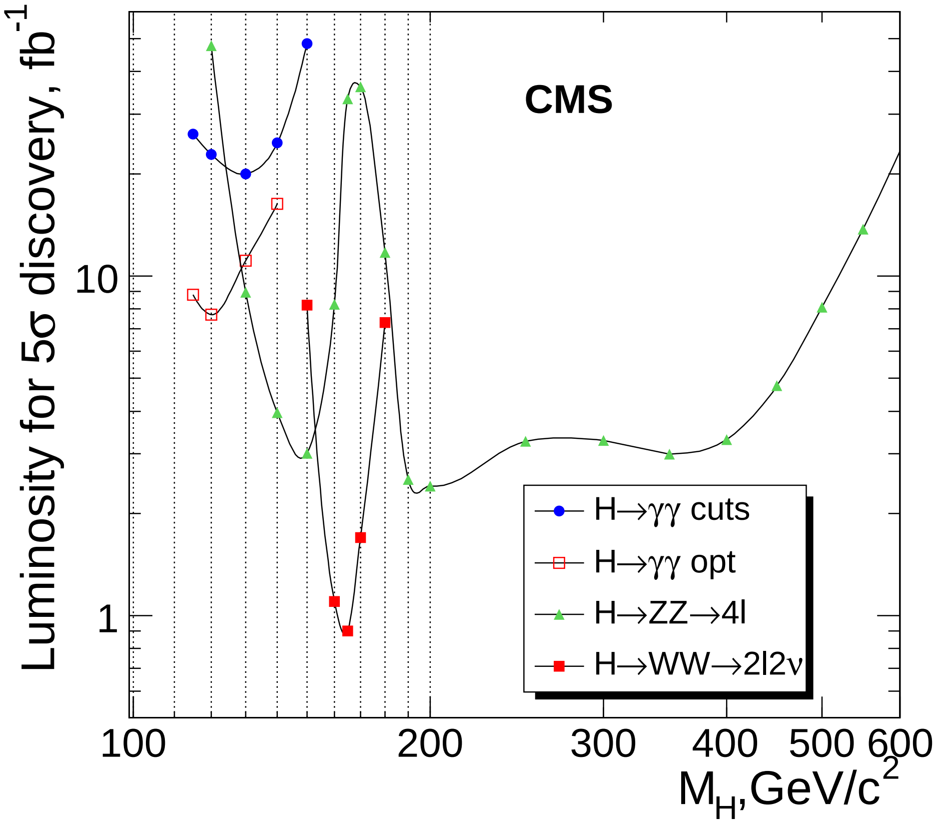
ATLAS says...





- annoying gap between LEP exclusion and 120 GeV
- WBF channels most important for discovery
- entire mass range covered by multiple channels
- for most range, data have Higgs before detectors understood

CMS says...



- WBF studies not even quoted – not so developed (pessimistic compared to ATLAS)
- However, entire M_H range covered, from LEP limit up! (no discovery gap)

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Things to keep in mind:

1. Some “good” channels impossible,
   e.g. $t\bar{t}H, H \rightarrow b\bar{b}$ — bad for Y_b measurement.

2. WBF-everything will keep getting better.

3. Many channels statistically limited, not systematics.
   ($S \ll B$ in $gg \rightarrow H$, but large rate; $S \gg B$ in WBF, but rate smaller)

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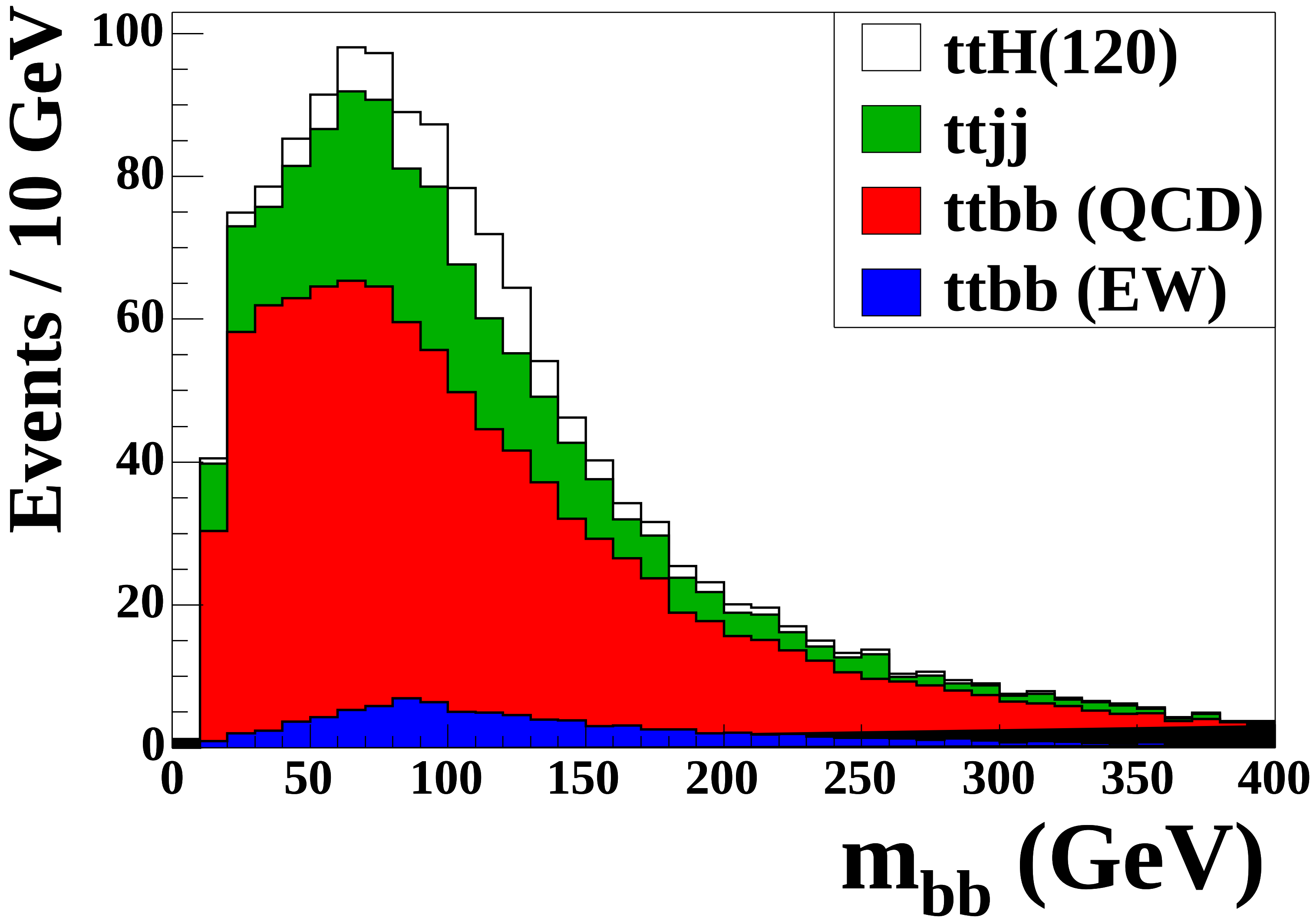
   $\longrightarrow$ situation would improve dramatically with few$\times$10 fb^{-1}

IMPROVEMENTS AND LIMITATIONS

(just a couple examples)

Current $t\bar{t}H, H \to b\bar{b}$ outlook: (30 fb^{-1}) [Cammin et al., ATLAS, 2006]



- ▷ S/B now about 1/6 for $M_H = 120$ GeV
- ▶ shape change now very marginal

And in the (lack of) shape lies the sleeping dragon...

Two types of analysis error in measuring backgrounds:

1. statistical error on sideband measurement
2. systematic error on shape extrapolation to signal region

Significance formula changes: $\frac{S}{\sqrt{B}} \rightarrow \frac{S}{\sqrt{B(1+B\triangle^2)}}$

where $\triangle$ is the shape uncertainty (a kind of normalization uncer.)

If S/B fixed as lumi $\uparrow$, signif. saturates [Cranmer, 2005]:

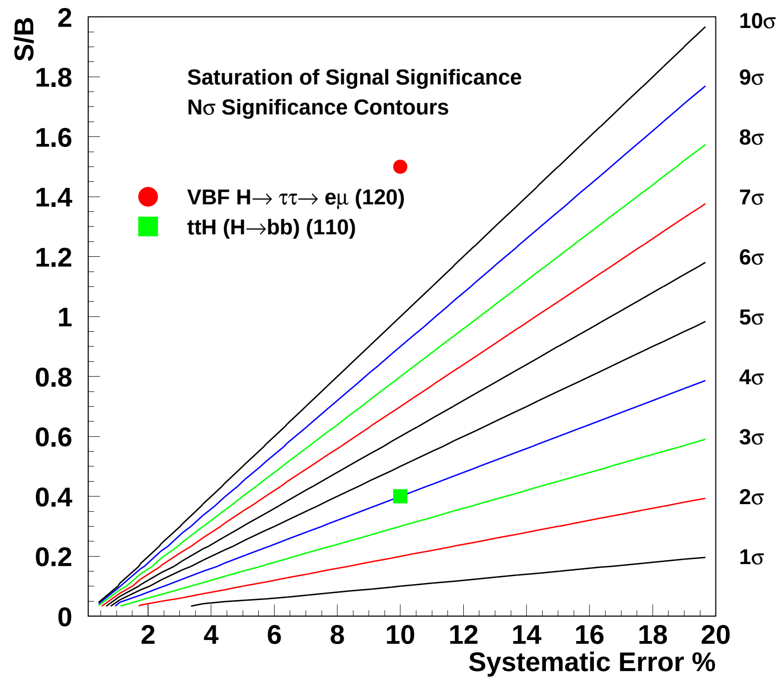
$$\sigma_\infty = \frac{S/B}{\triangle_{\rm shape}}$$

$\triangle = 10\%$ for $t\bar{t}H, H \rightarrow b\bar{b}$,

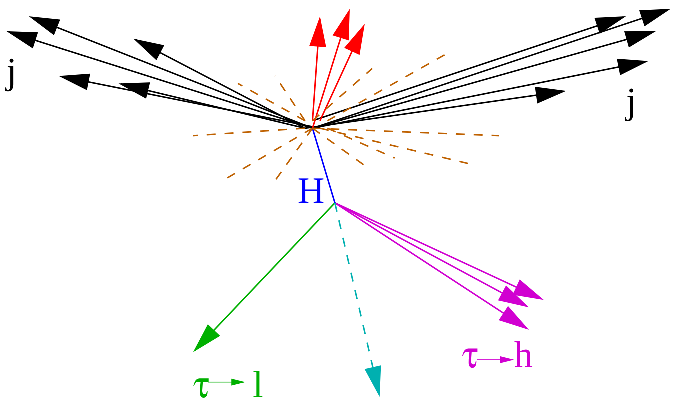
so can *never* get to 5σ as $L \rightarrow \infty$

$\Rightarrow$ limits not just discovery,
but use as measurment

(see also CERN-CMS-NOTE-2006-119)



New work on WBF $H \to \tau^+\tau^-$ [K. Cranmer, BNL]



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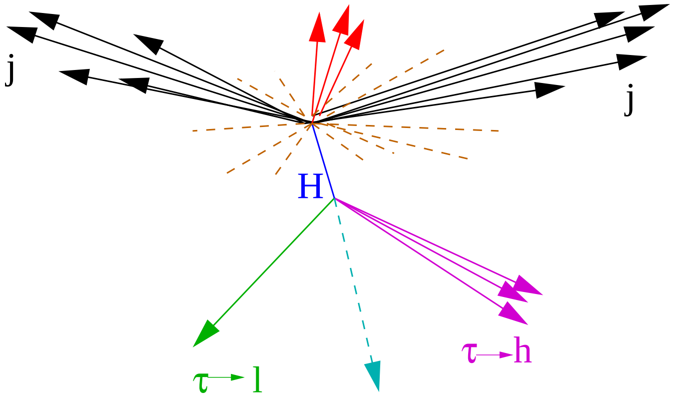

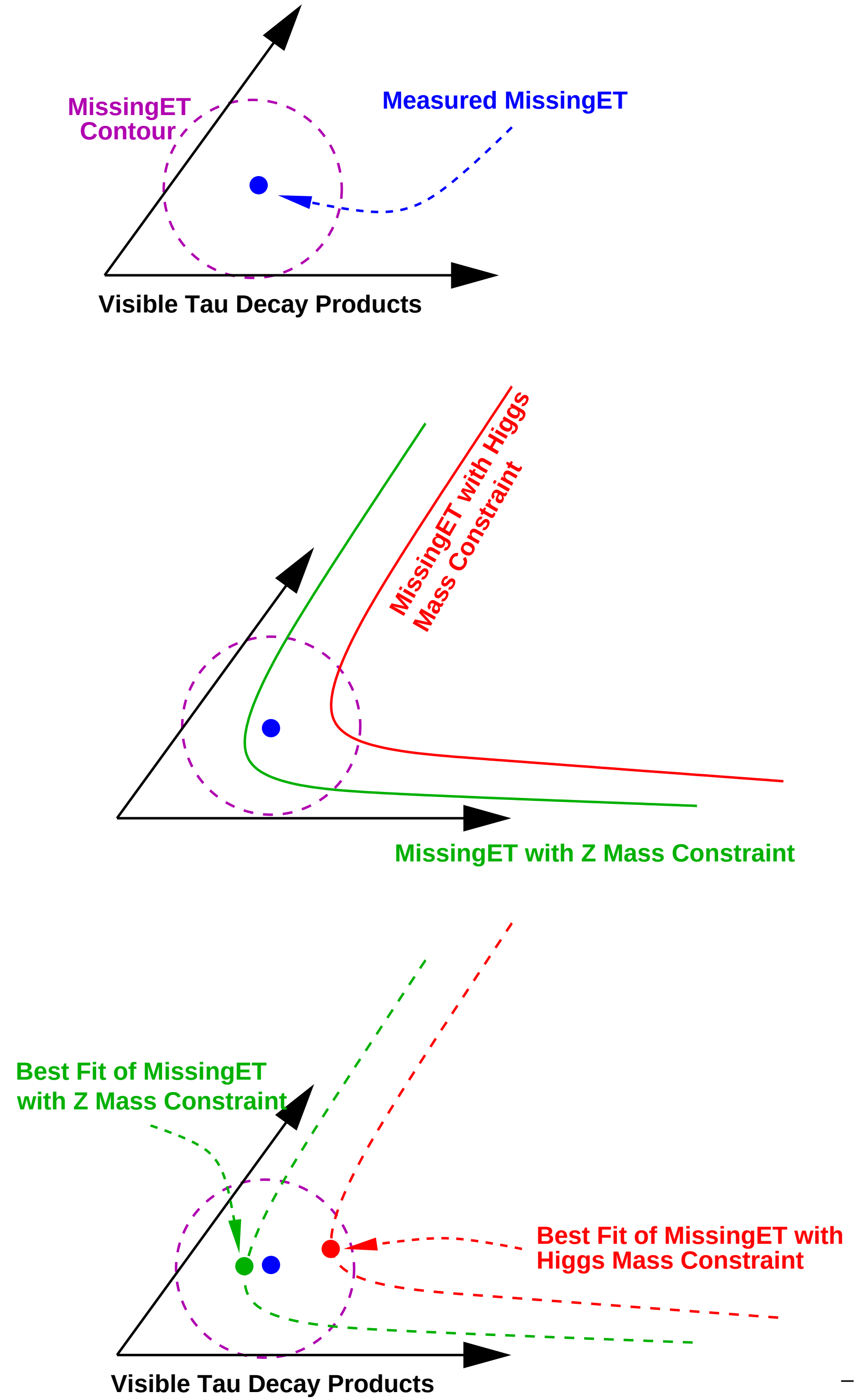

Major issue: $\not{p}_T$ resolution

Perform constrained fit to *both* M_Z and M_H, calculate $\triangle\chi^2$ to determine better consistency with

$H \to \tau^+\tau^-$ v. $Z \to \tau^+\tau^-$

$\longrightarrow$ recovers a lot of lost signal
$\longrightarrow$ enhances S/B by factor 4

+ neural net attack on dist'bns, etc.

Plenty more work to do on taus!

QUANTUM NUMBER MEASUREMENTS

or, “After the champagne”

Confirm that candidate resonance is SM Higgs

$\longrightarrow$ SM has very specific predictions for its quantum numbers

- colorless – trivial
- neutral – trivial
- mass – measure as accurately as poss. (cf. DeRoeck & Mellado)
- spin 0
  - · easy to confi rm as boson by decay products
  - · if $H \to \gamma\gamma$ seen, not $S = 1$
  - · $S \geq 2$ is exotic – ignore for now
- CP even
- gauge couplings: g_W w/ tensor structure $g^{\mu\nu}$
- Yukawa couplings: $|Y_f| = \frac{m_f}{\mathrm{v}}$
- spontaneous symmetry breaking potential (λ_{3H})

► these things get increasingly difficult

$\longrightarrow$ many look like SM, but we want precision to distinguish BSM

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  $\longrightarrow$ becomes far less interesting for a SM-like Higgs candidate
  - large $Y_{u,d}$ would stand out – huge rate and altered y_H dist'bn
  - small Y_t would stand out – no $gg \longrightarrow H$ production
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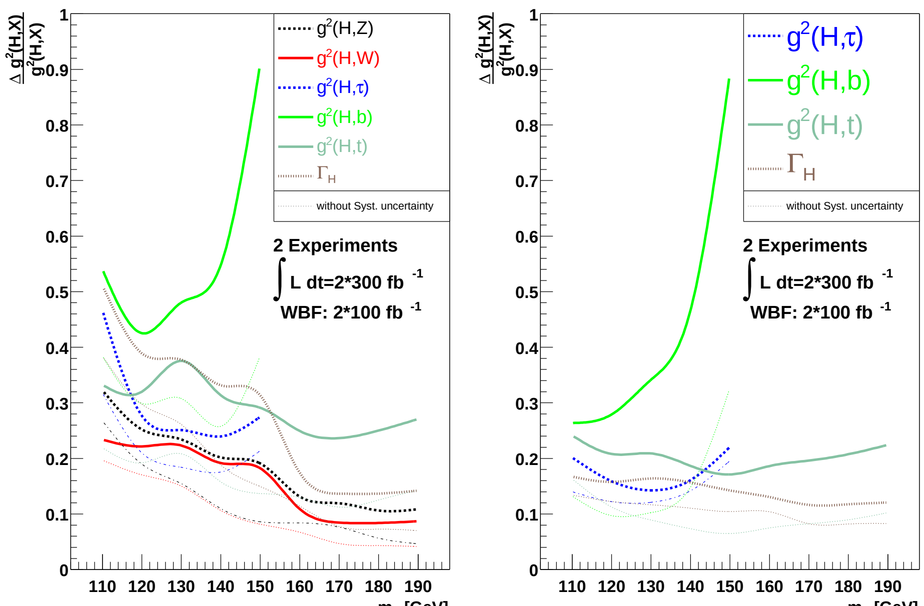
Note: Dührssen-type analysis impossible with only 10 fb^{-1}

(absolute H couplings with 300 fb^{-1})

[hep-ph/0406323]

At 10 fb^{-1}: "consistent w/ SM"

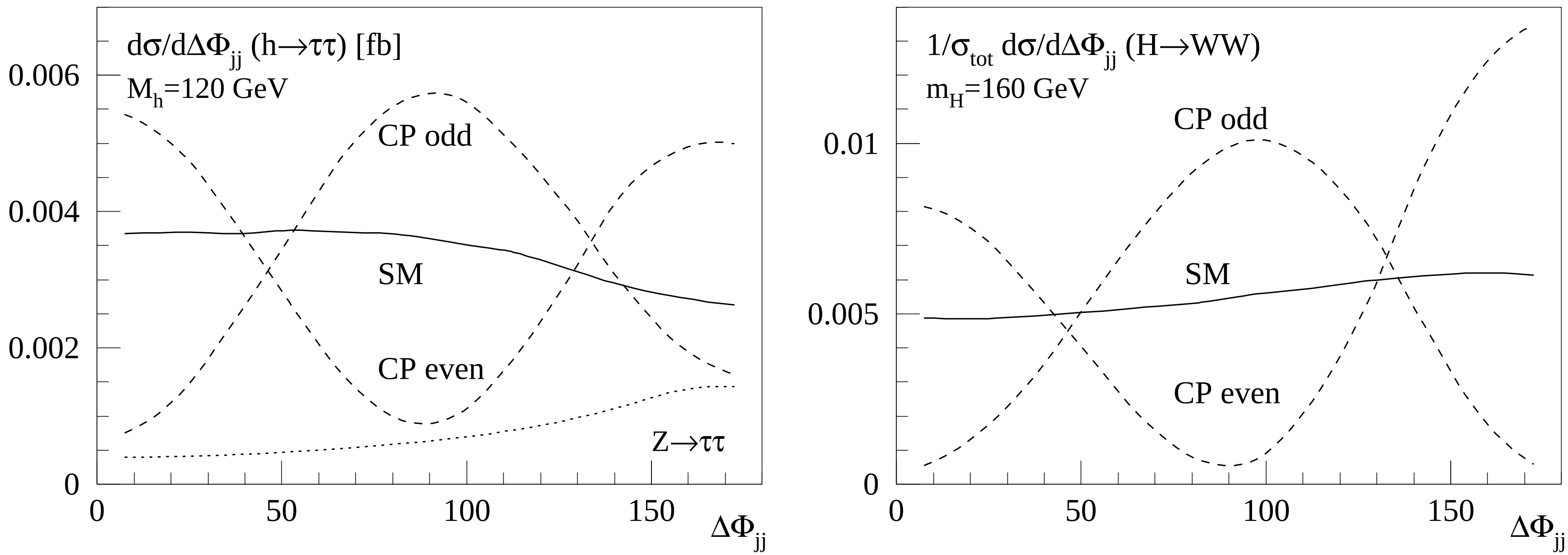


So what can we do at LHC?

WBF production measures vertex structure (indep. of decay)

CP & spin determination: [hep-ph/0105325,0609075]

$g^{\mu\nu}$ of $SU(2)$ v. $\Phi W^{\mu\nu} W_{\mu\nu}$ D-5 operators (CP-even/odd)

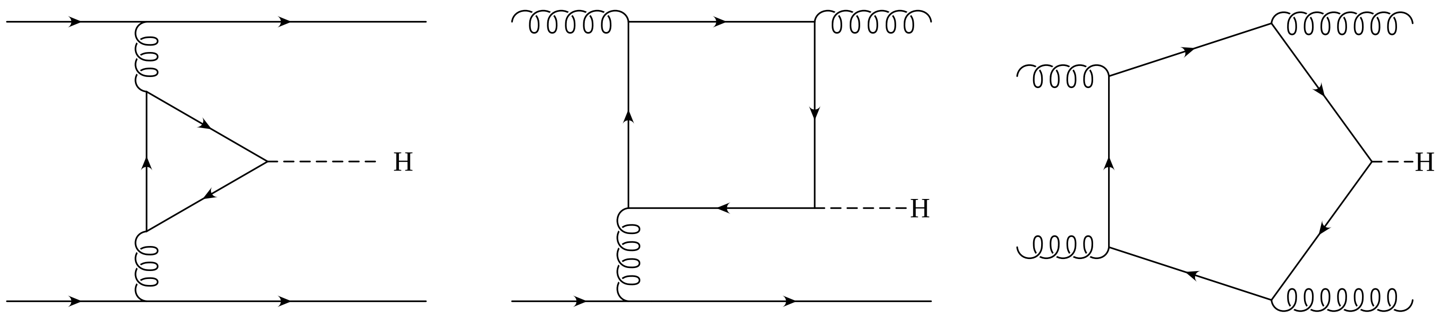


- need about 10x lumi past discovery to bin ϕ_{jj}

$\longrightarrow$ distributions not vulnerable to NLO QCD [hep-ph/0608158]

$\longrightarrow$ contamination from $gg \to Hgg$ is an issue

$gg \to Hgg$ “contamination” to WBF Hjj signal [hep-ph/0108030]



(a) (b) (c)

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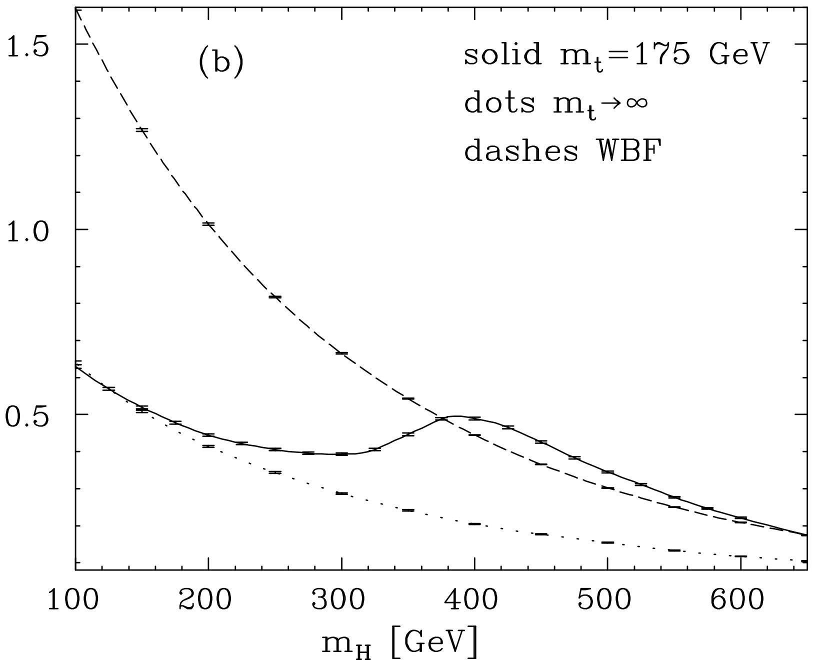

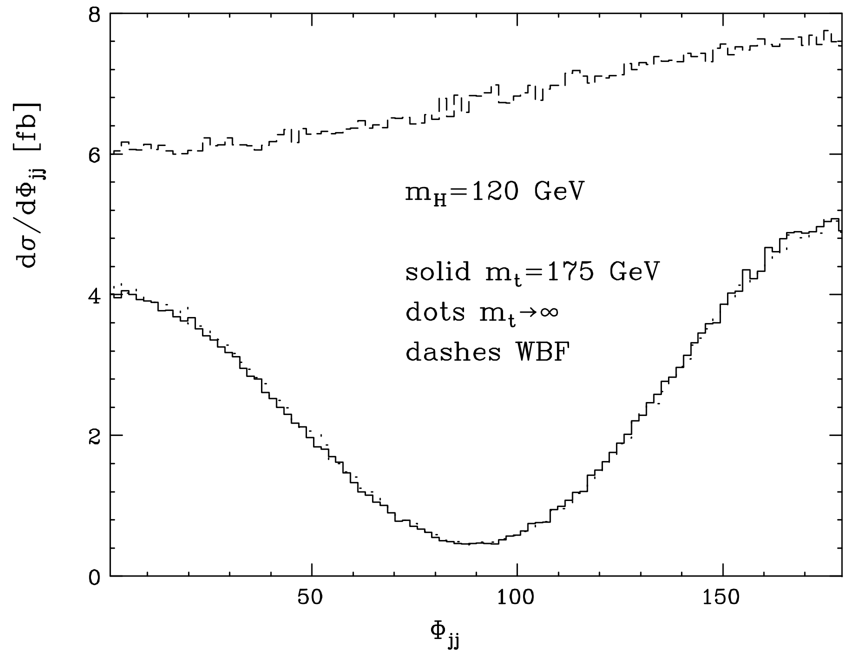

▷ +1/3 rate ↑ w/ WBF cuts @ low M_H! (no MJV) but different ϕ_{jj}

▶ rate uncertain to more than a factor 2

$\longrightarrow$ can ultimately sort out, but not likely by 10 fb^{-1}

Note: SM + D5-even oper. interfere, but QCD does not...

(will help discriminate EW v. QCD Hjj)

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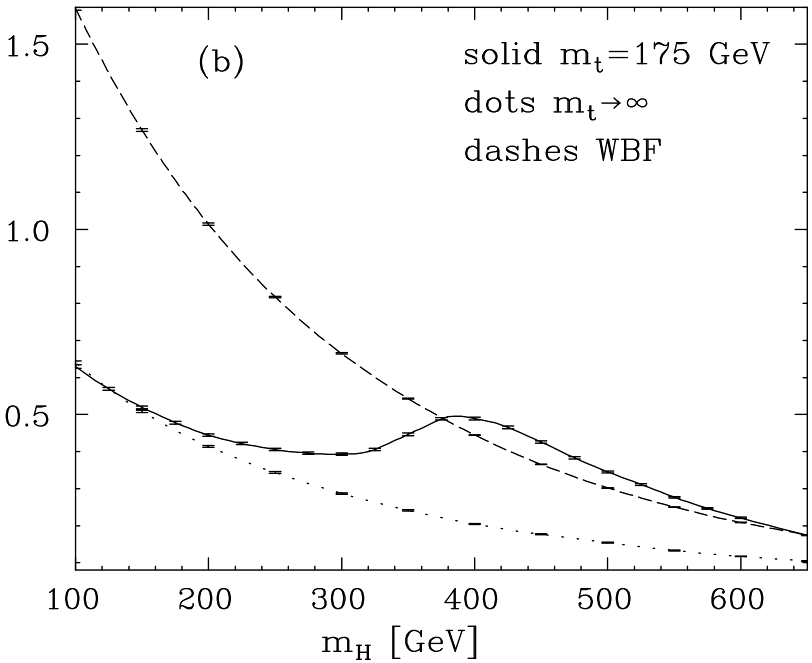

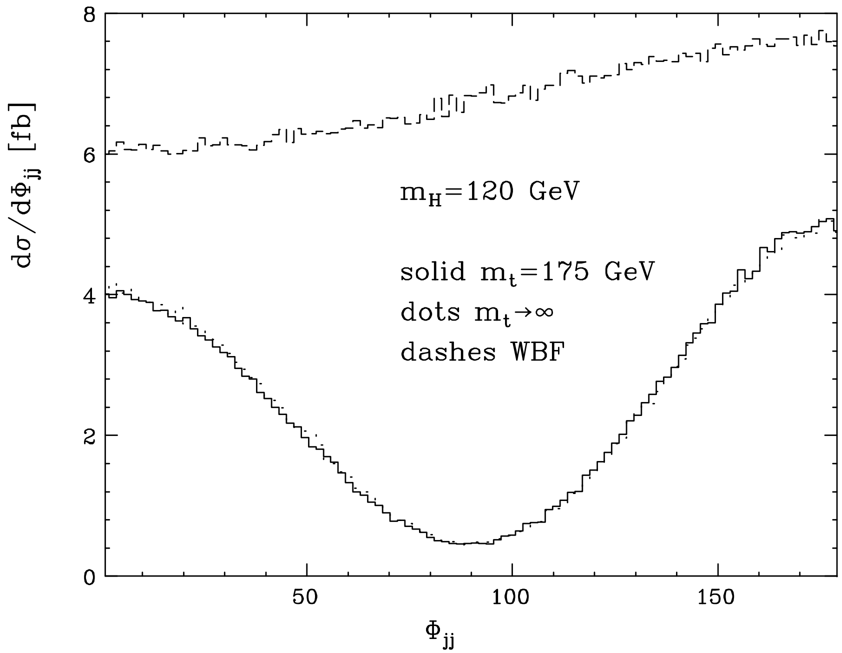

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At 10 fb^{-1}: “consistent w/ SM”

WBF turns out to be cricical. How well do we understand it?

Open issues:

1. MJV (minijet veto – QCD radiation pattern from color flow)

   at primitive stage, but measure in data (EW v. QCD Zjj)

   $\longrightarrow$ not yet used by ATLAS/CMS; WBF improves a lot with it

   · probably under control by 10 fb^{-1}

2. Better understanding of $t\bar{t}$+jets:

   off-shell effects, normalization and shape changes @ NLO

   · better theory control now [hep-ph/0703120] but need data

3. Contamination from GF signal + jets: $gg \to Hgg$.

   Only partially understood.

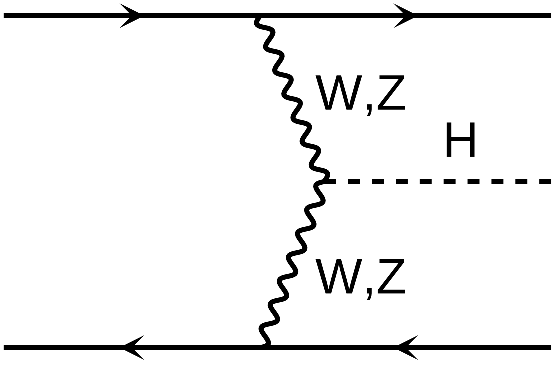
   Probably take > 10 fb^{-1} to get under control.

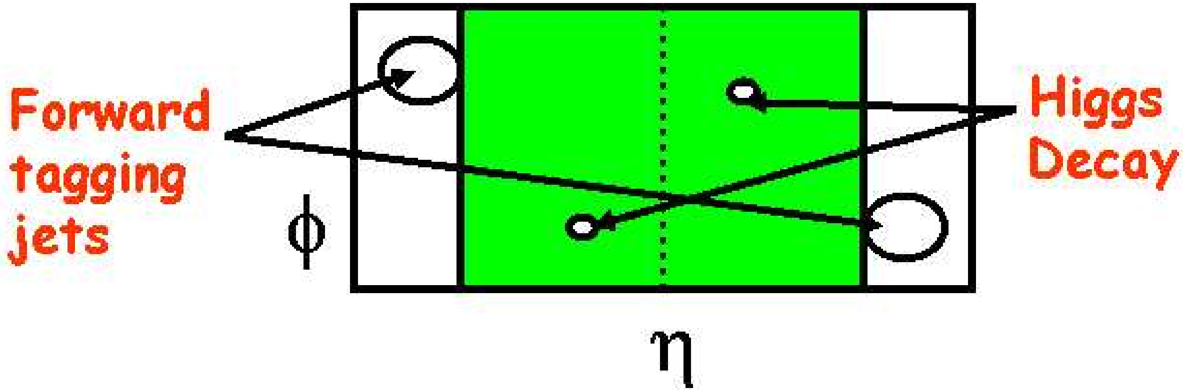
SUMMARY

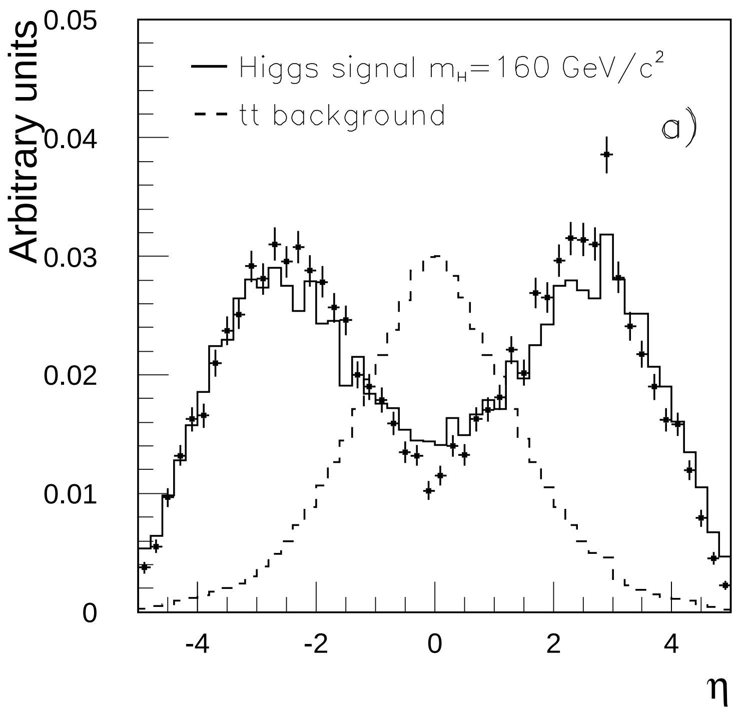
- Current SM Higgs pheno is pessimistic
  – many improvements possible and known or expected
- Detailed couplings analysis not possible with 10 fb^{-1}
- CP/$g^{\mu\nu}$ analyses marignal by 10 fb^{-1}
  (maybe if $M_H > 150$ GeV)
- By 10 fb^{-1} we will be able to say for sure,
  “consistent with Standard Model”, but not much more
- Few$\times 10$ fb^{-1} would dramatically, qualitatively improve all

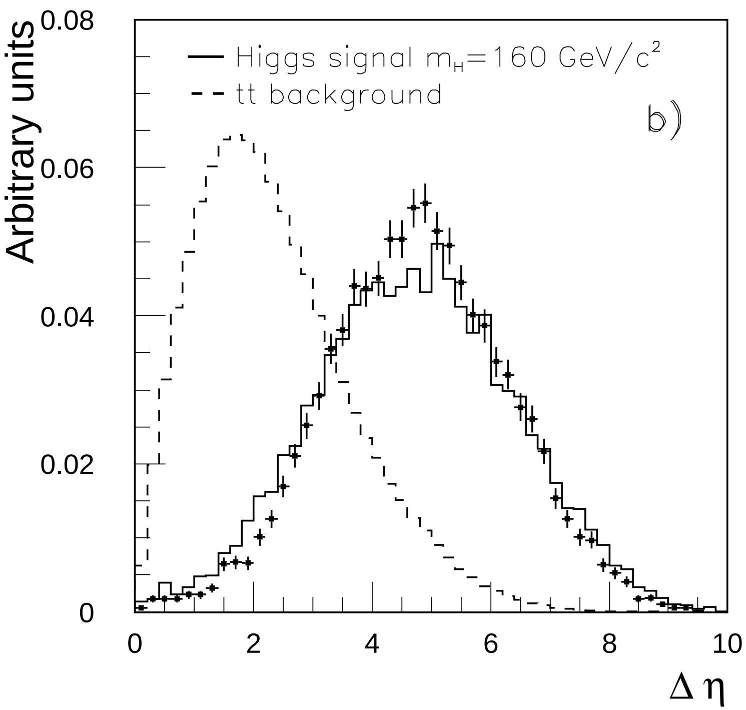
So what is this WBF process anyway?

An incoming quark pair emits a pair of gauge bosons, which fuse; quarks get scattered far-forward/backward into detector as jets









$\longrightarrow$ QCD processes look different