Top Quark Physics II

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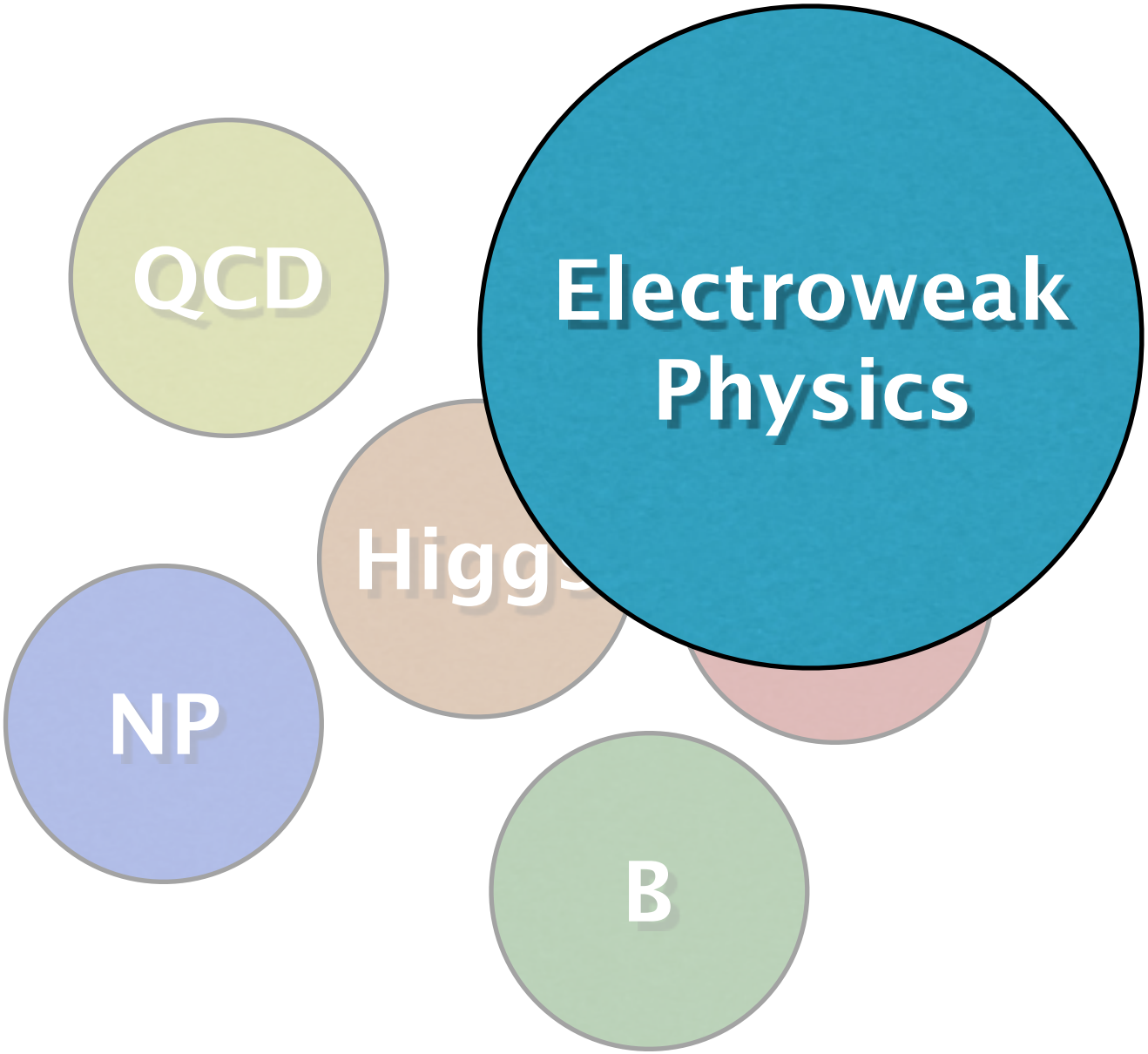
http://www-d0.fnal.gov/~schwanen/top_desy_summer16/Top_lecture2.pdf

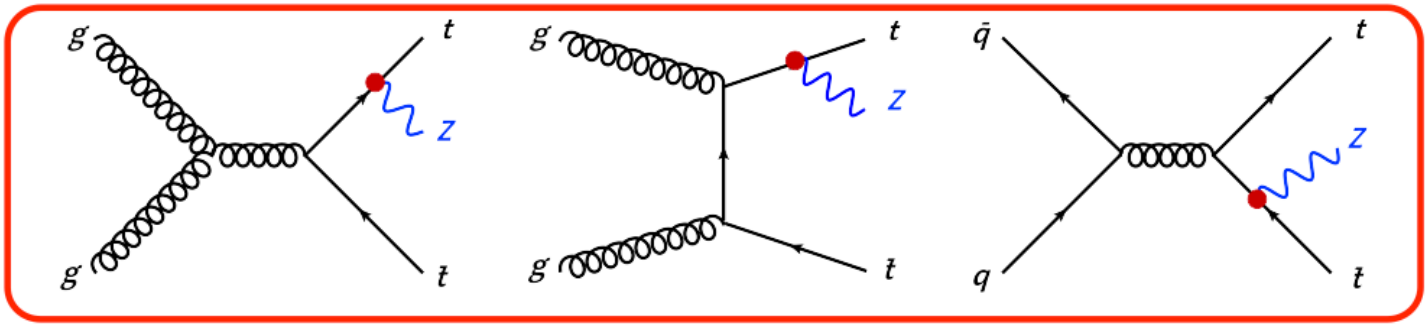
Top Quark Physics Topics



$t\bar{t}Z$ and $t\bar{t}W$ Production

ISR

FSR

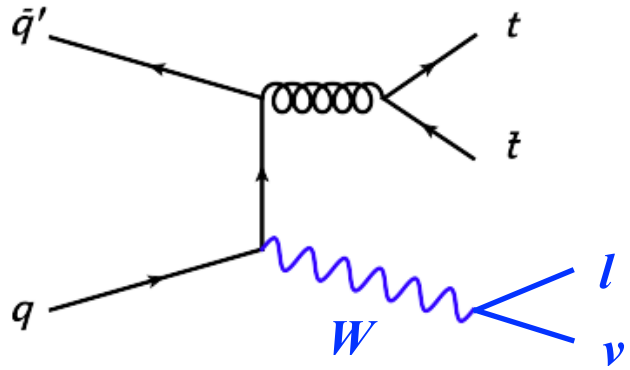


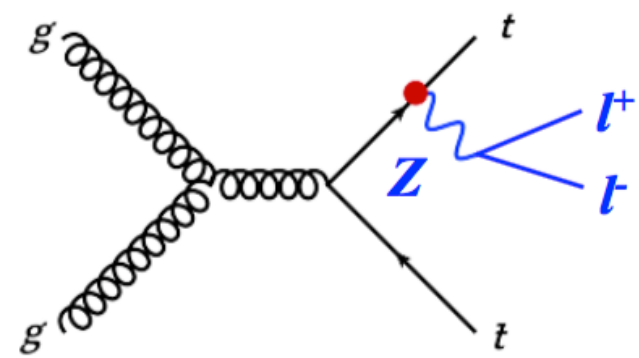
$$-i\,\frac{e}{\sin\vartheta_W \cos\vartheta_W}\,(T_3 - \sin^2\vartheta_W\, Q_t)\gamma^\mu$$

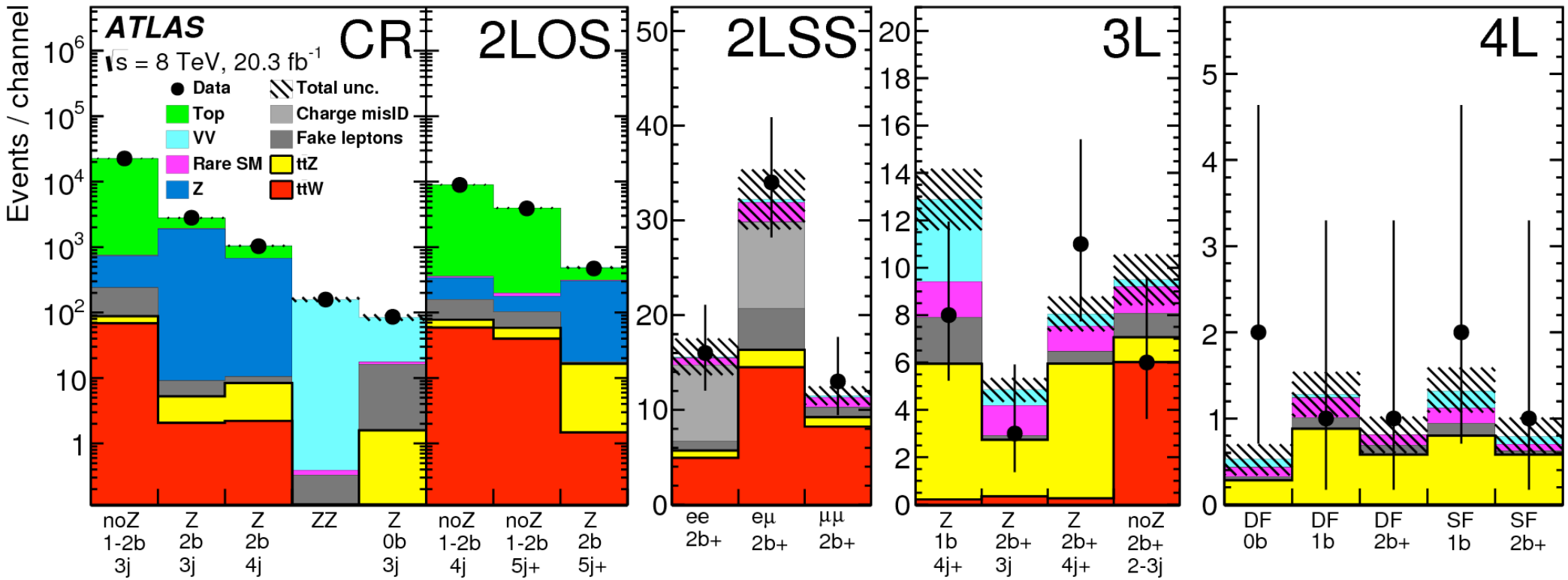
- measure 3rd component of weak isospin
- search for anomalous couplings in $t\bar{t}Z$ vertex

→ it is very interesting to measure rare processes never explored before since new physics could show up!

Search for ttZ and ttW

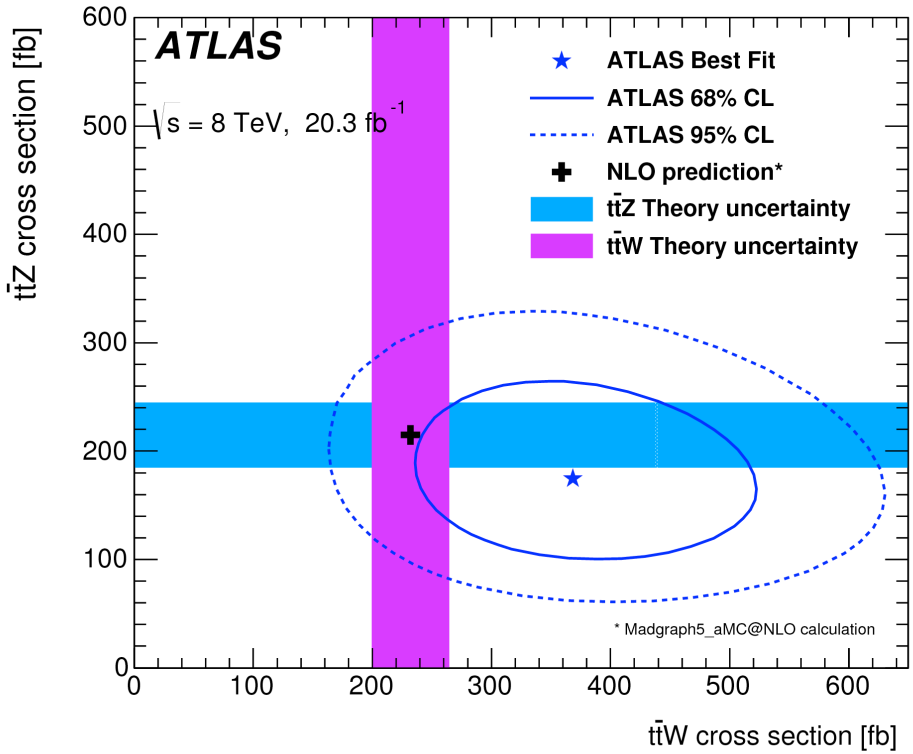


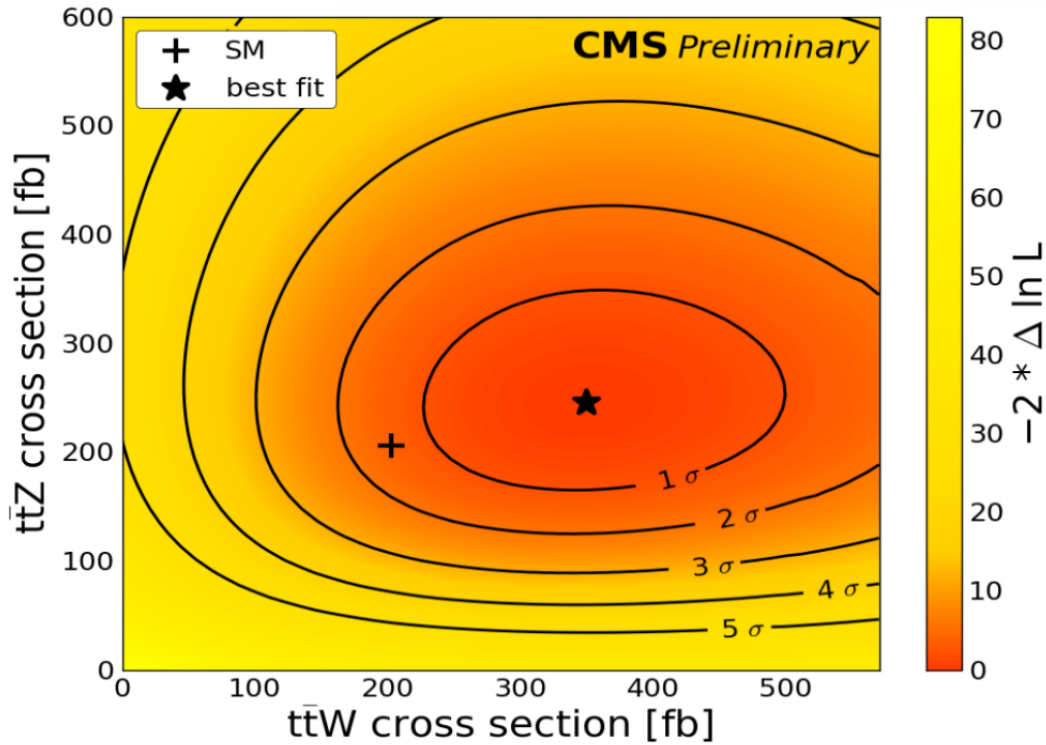




ttW ← → ttZ

Observation of ttV production



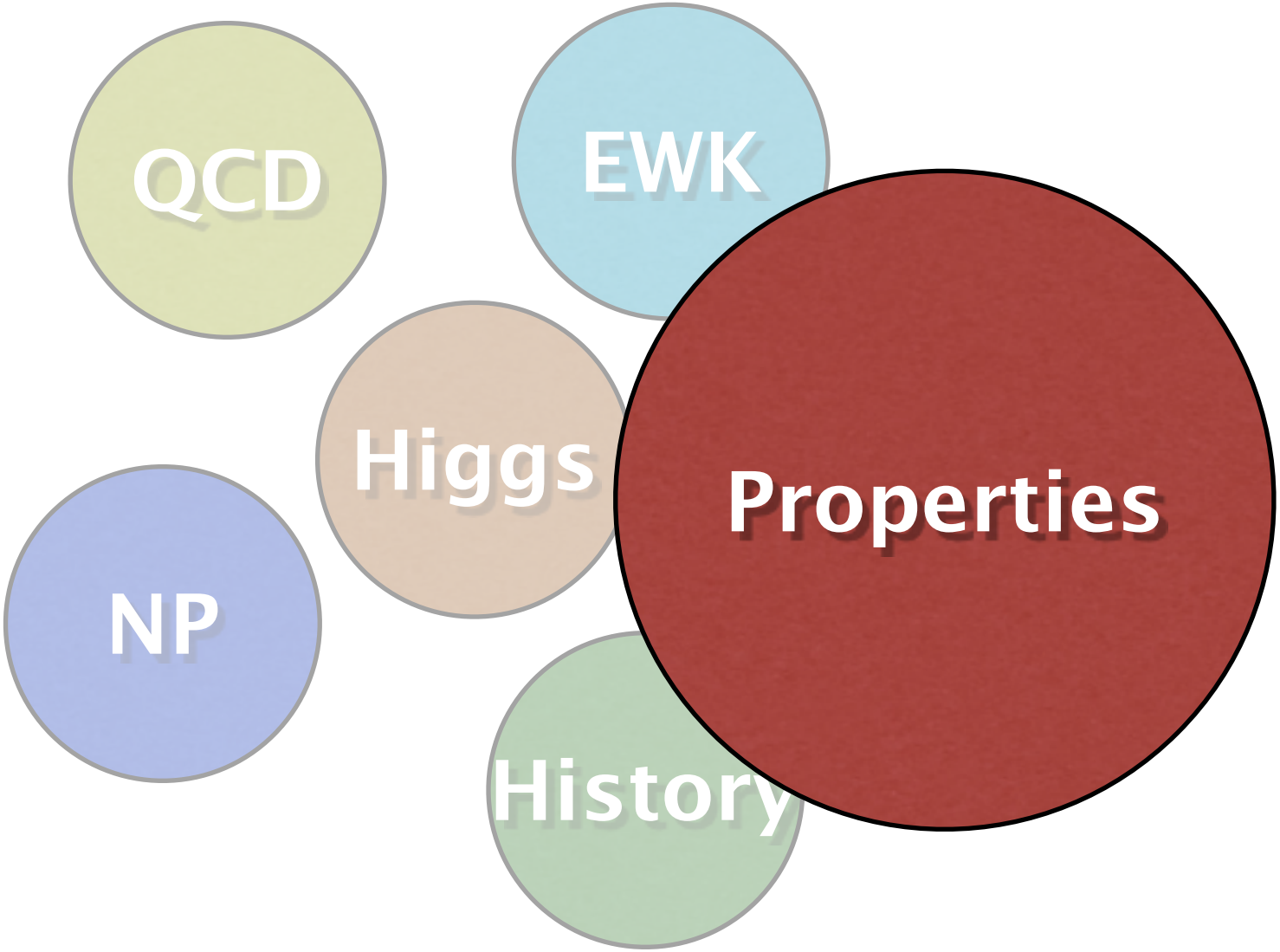


ttW:	3.2 σ (exp)	5.0 σ (obs)
ttZ:	4.5 σ (exp)	4.2 σ (obs)

ttW:	3.8 σ (exp)	4.8 σ (obs)
ttZ:	5.7 σ (exp)	6.4 σ (obs)

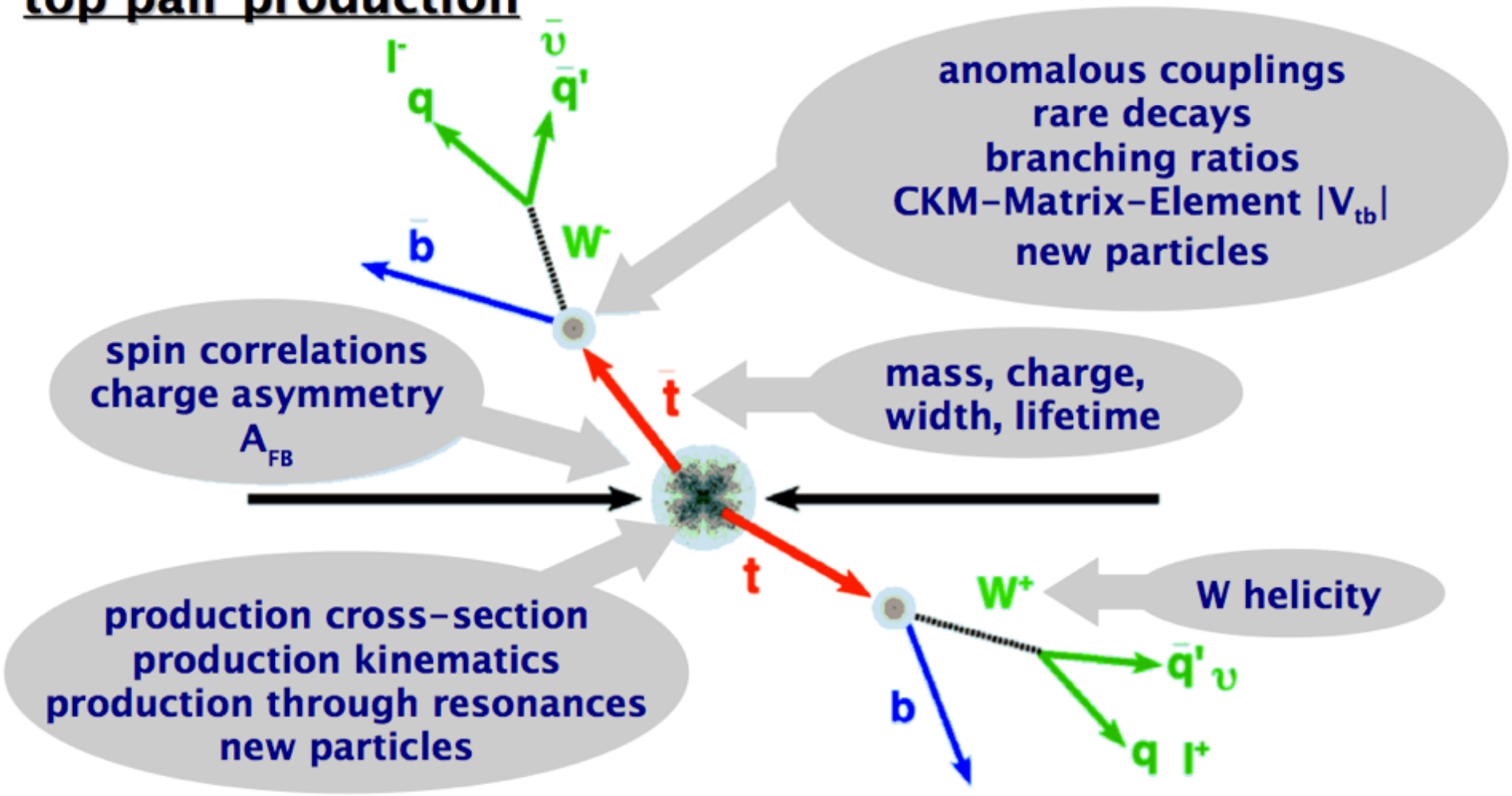
→ **in agreement with the SM prediction**
(ttγ also in agreement with SM prediction)

Top Quark Physics Topics



Top Quark Analyses

top pair production

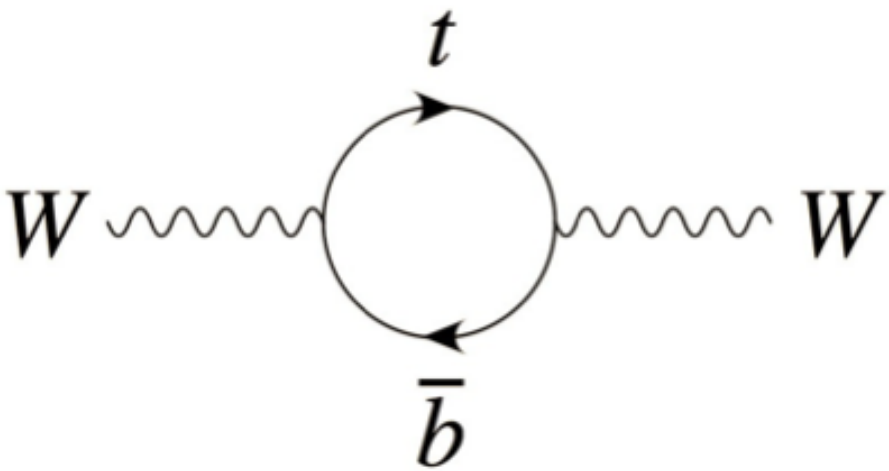


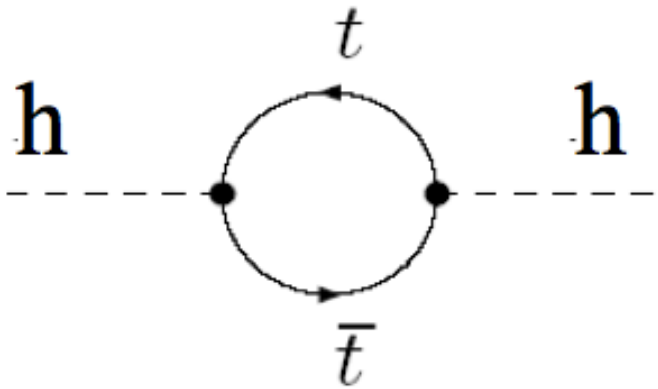
single top production production cross section, CKM-Matrix-Element $|V_{tb}|$, anomalous couplings, searches for new particles

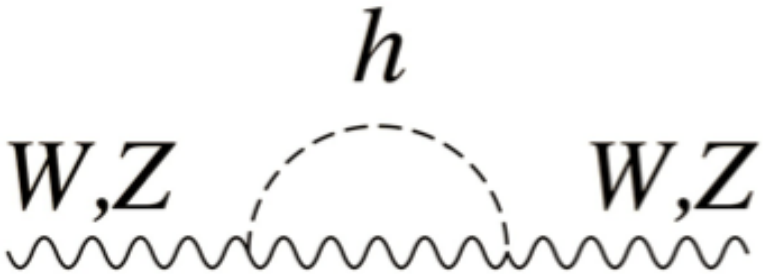
other production modes tt+jets, ttZ, ttW, ttH and their couplings

The Top Quark Mass

- free parameter in the Standard Model
- check the **self-consistency of the Standard Model** in combination with W mass measurement
- prediction on **Higgs mass**

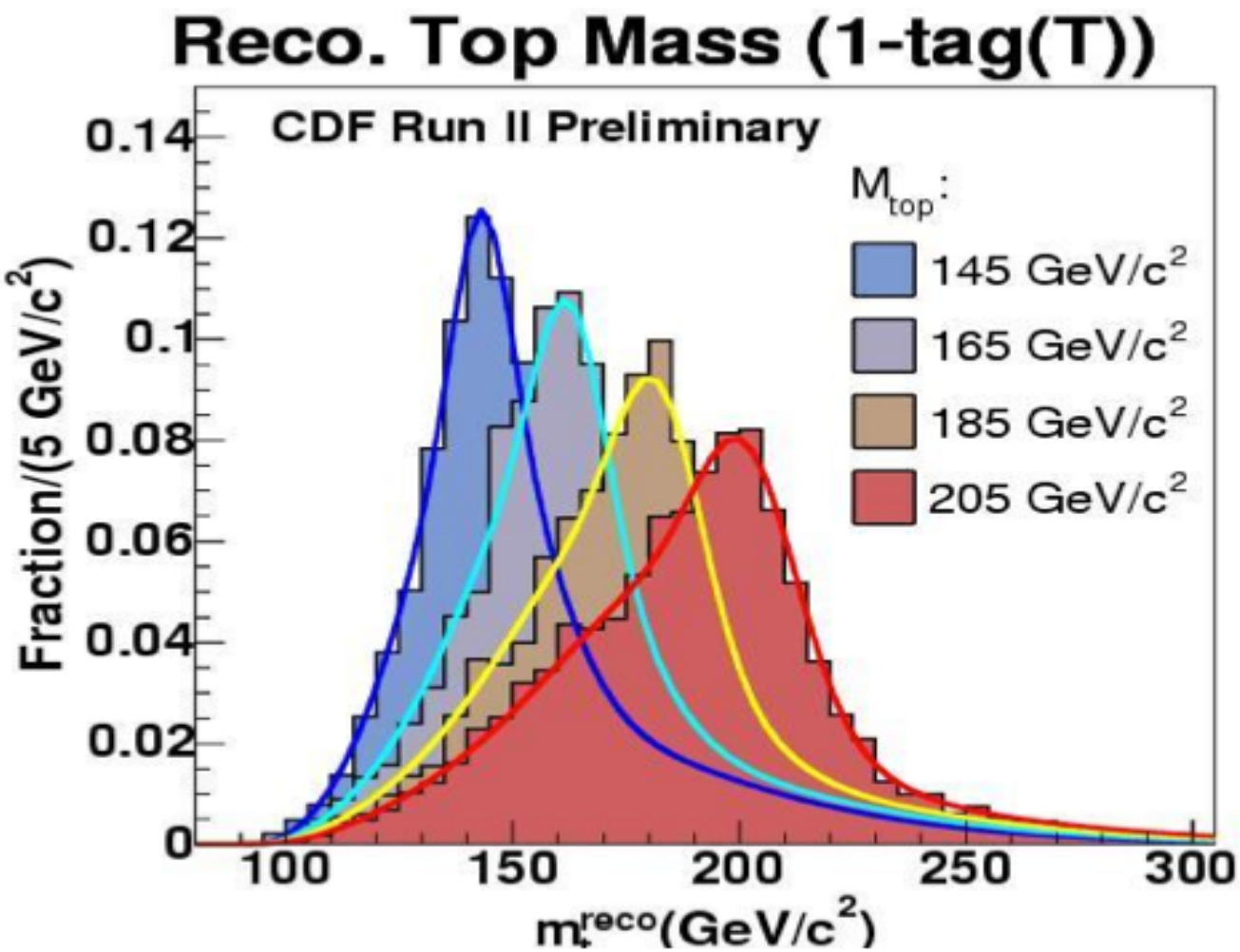






Extraction Techniques: Templates

- use variables strongly correlated with m_{top}
- compare data to MC with different m_{top} hypotheses



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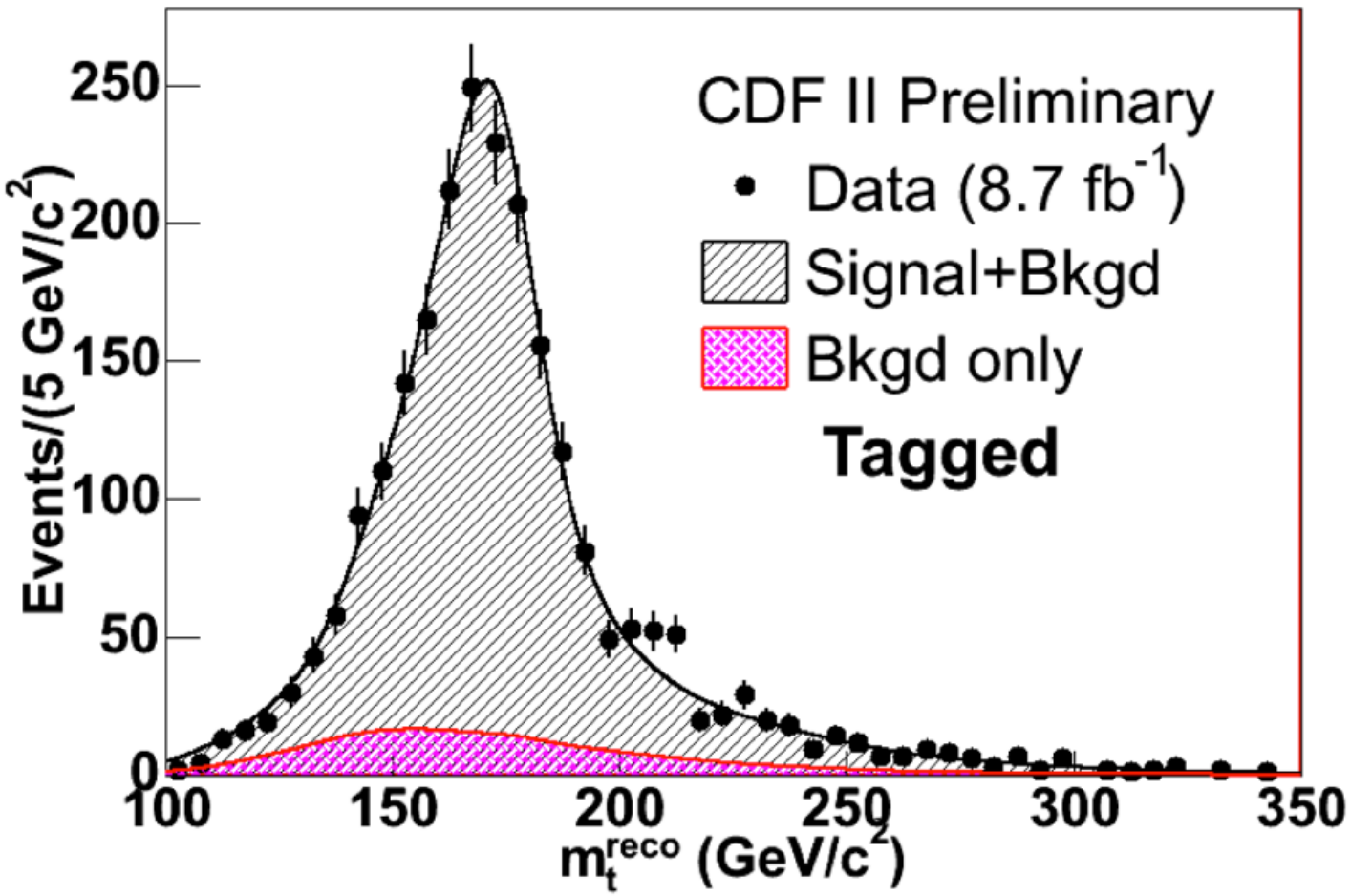

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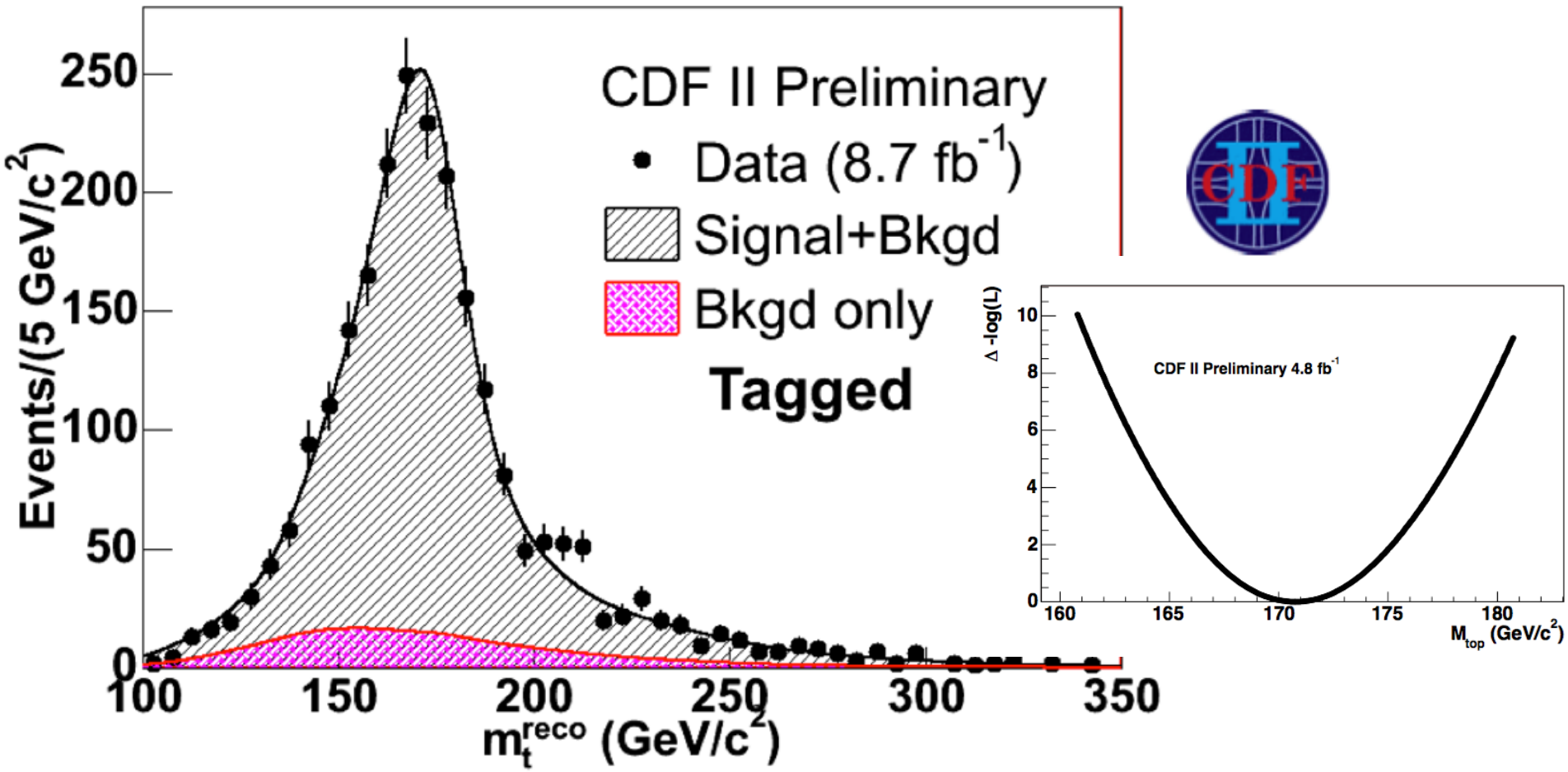
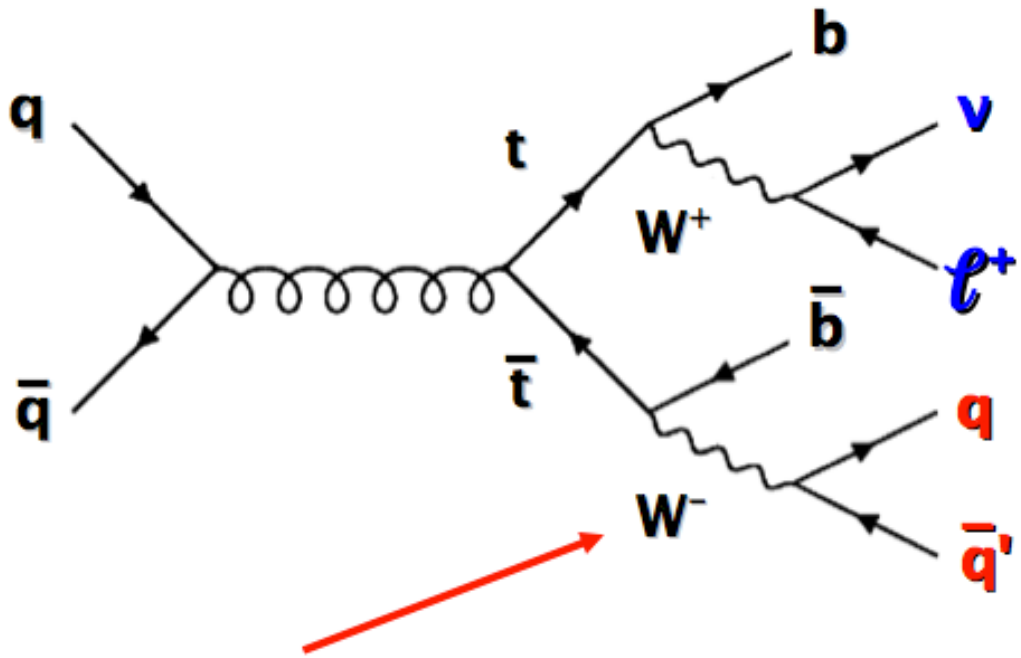


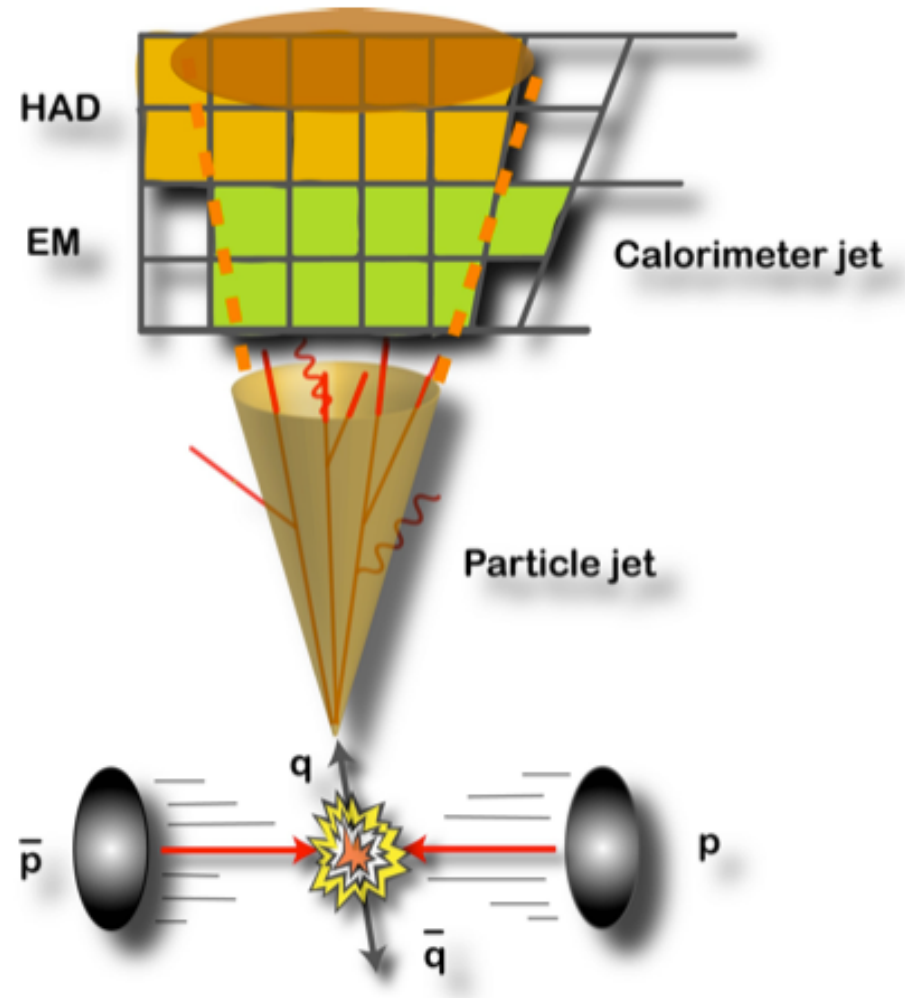
JES calibration



W mass constrains jet energy scale

jet energy scale:

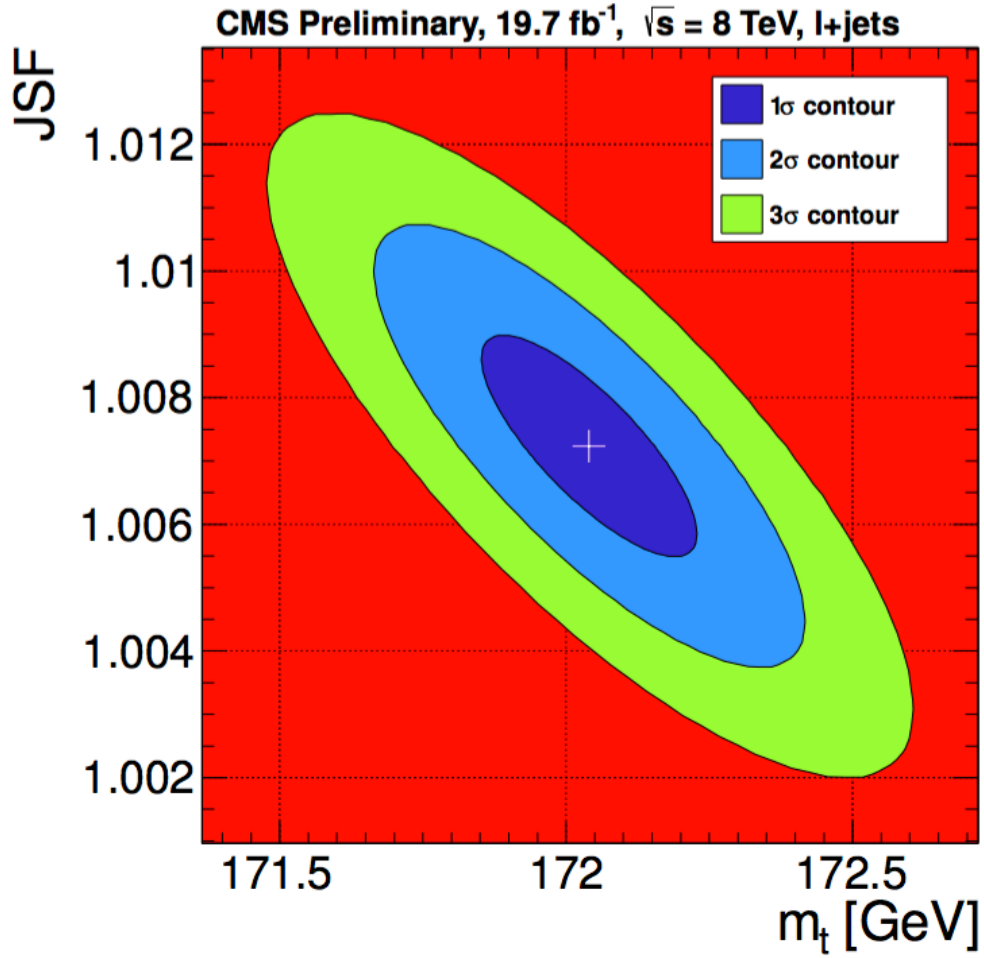
translate jet into parton energy



Result in l+jets Channel

jet energy scale:

translate jet into parton energy



maximum likelihood fit to data

$$m_t = 172.04 \pm 0.19\,(\text{stat.+JSF}) \pm 0.75\,(\text{syst.})\,\text{GeV},$$
$$\text{JSF} = 1.007 \pm 0.002\,(\text{stat.}) \pm 0.012\,(\text{syst.}).$$

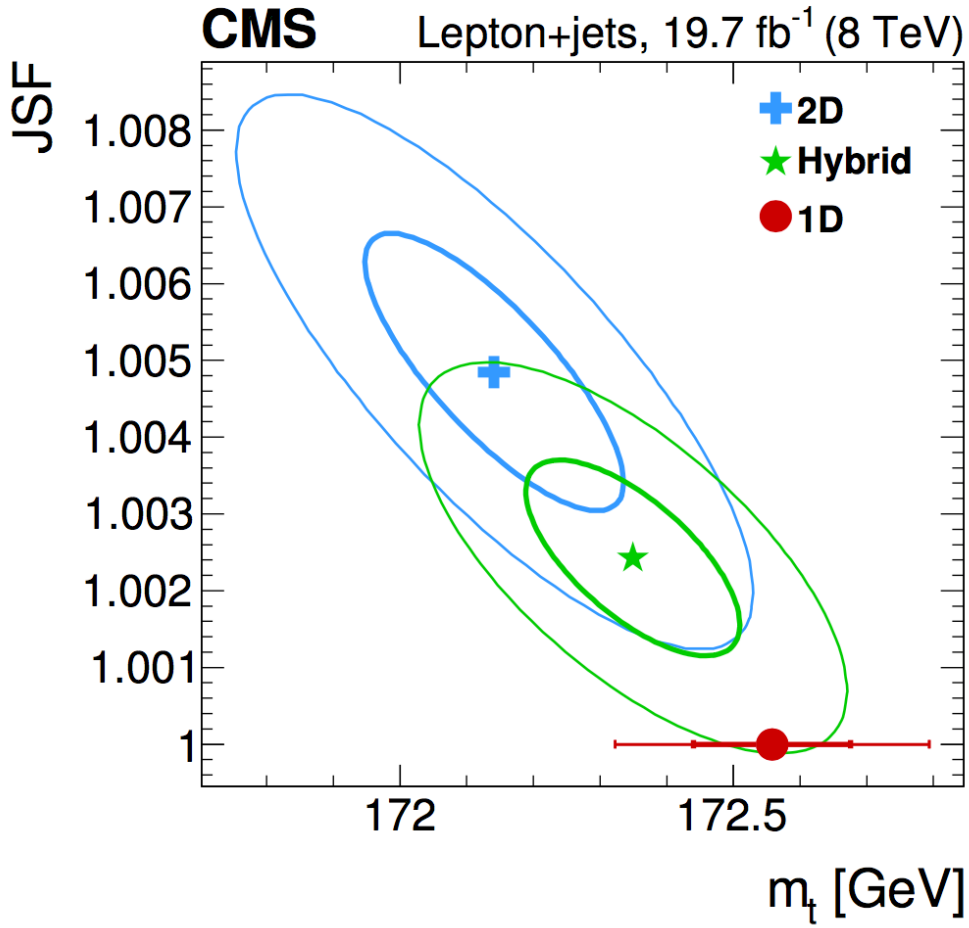
most precise single measurement

±0.45%

Result in l+jets Channel

jet energy scale:

translate jet into parton energy



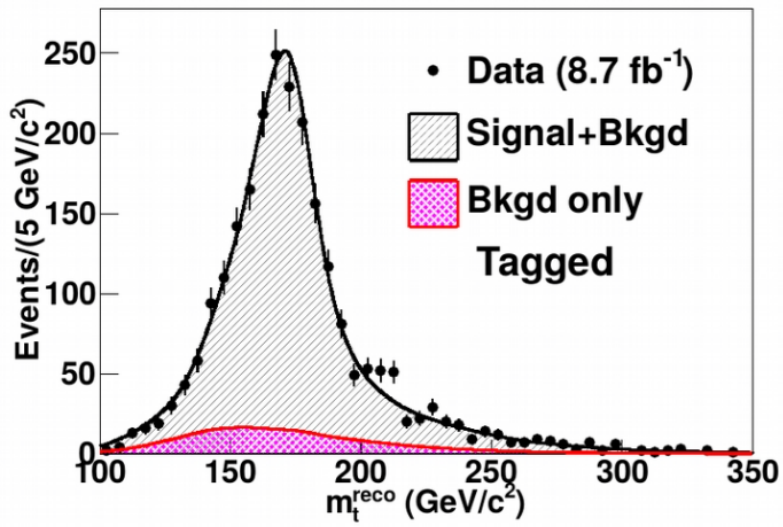
maximum likelihood fit to data

$$m_t^{hyb} = 172.35 \pm 0.16\,(\text{stat+JSF}) \pm 0.48\,(\text{syst})\,\text{GeV}$$

most precise single measurement

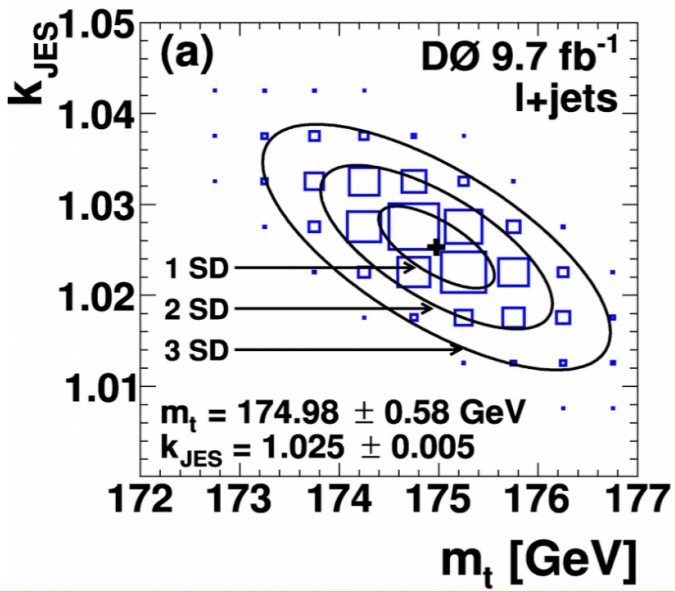
±0.29%

Top mass at the Tevatron



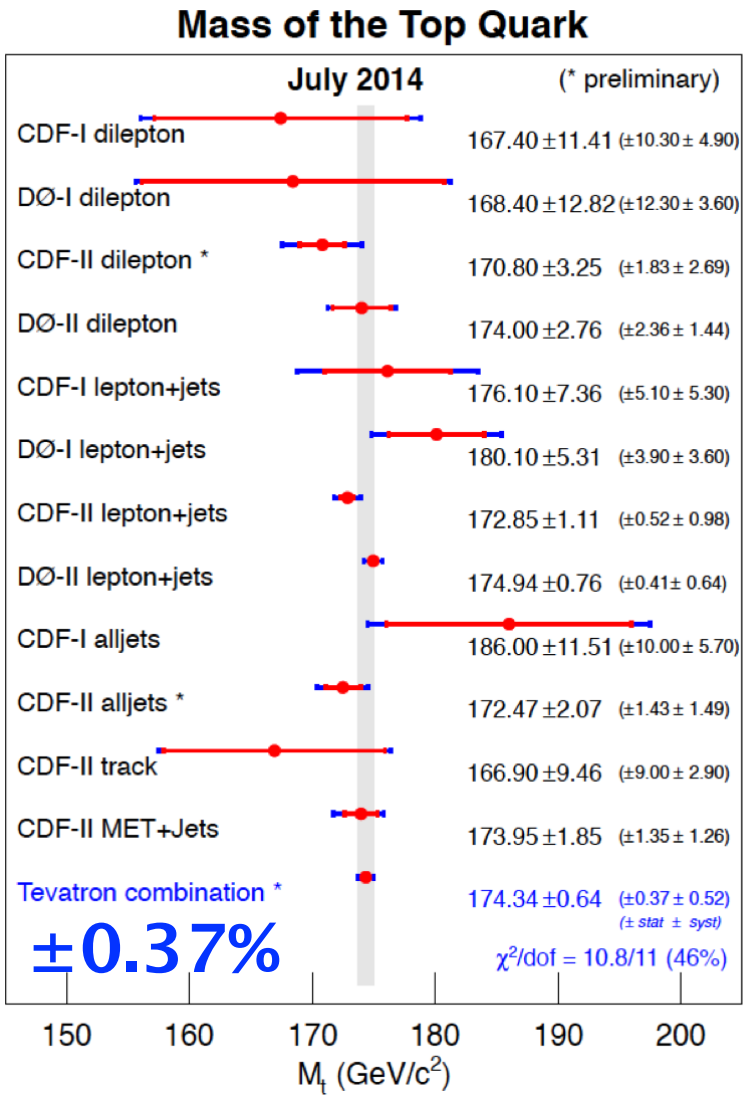
$m_t = 172.85 \pm 0.71$ (stat.) $\pm$ 0.85 (syst) GeV

±0.63%



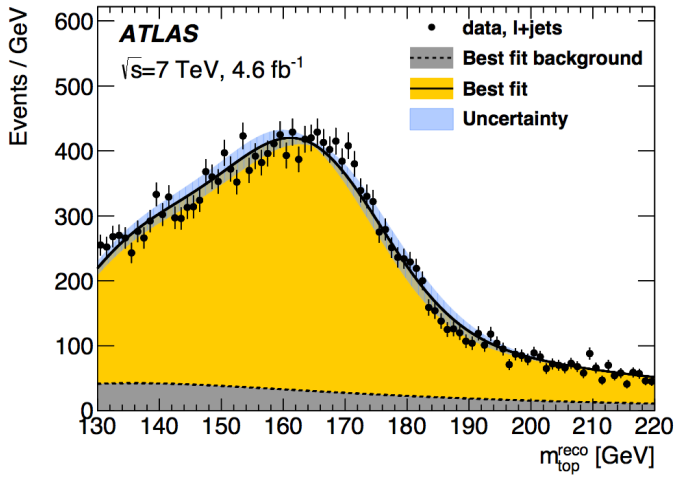
±0.43%

$m_t = 174.98 \pm 0.58$ (stat.) $\pm$ 0.49 (syst) GeV



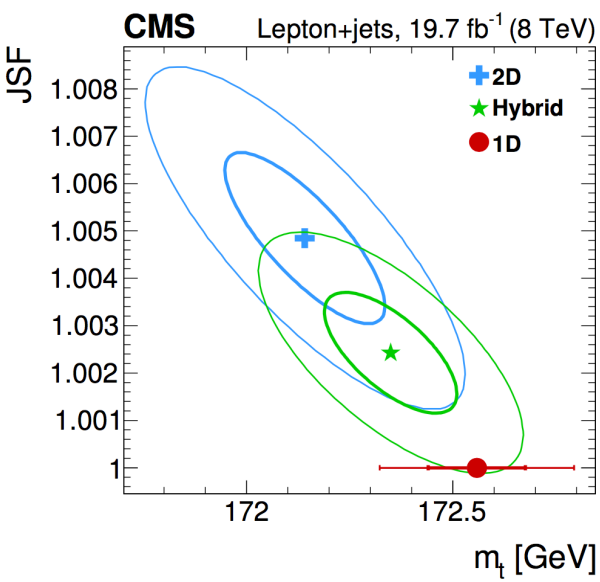
good agreement between all channels...

Top mass at the LHC



dilepton
±0.49%

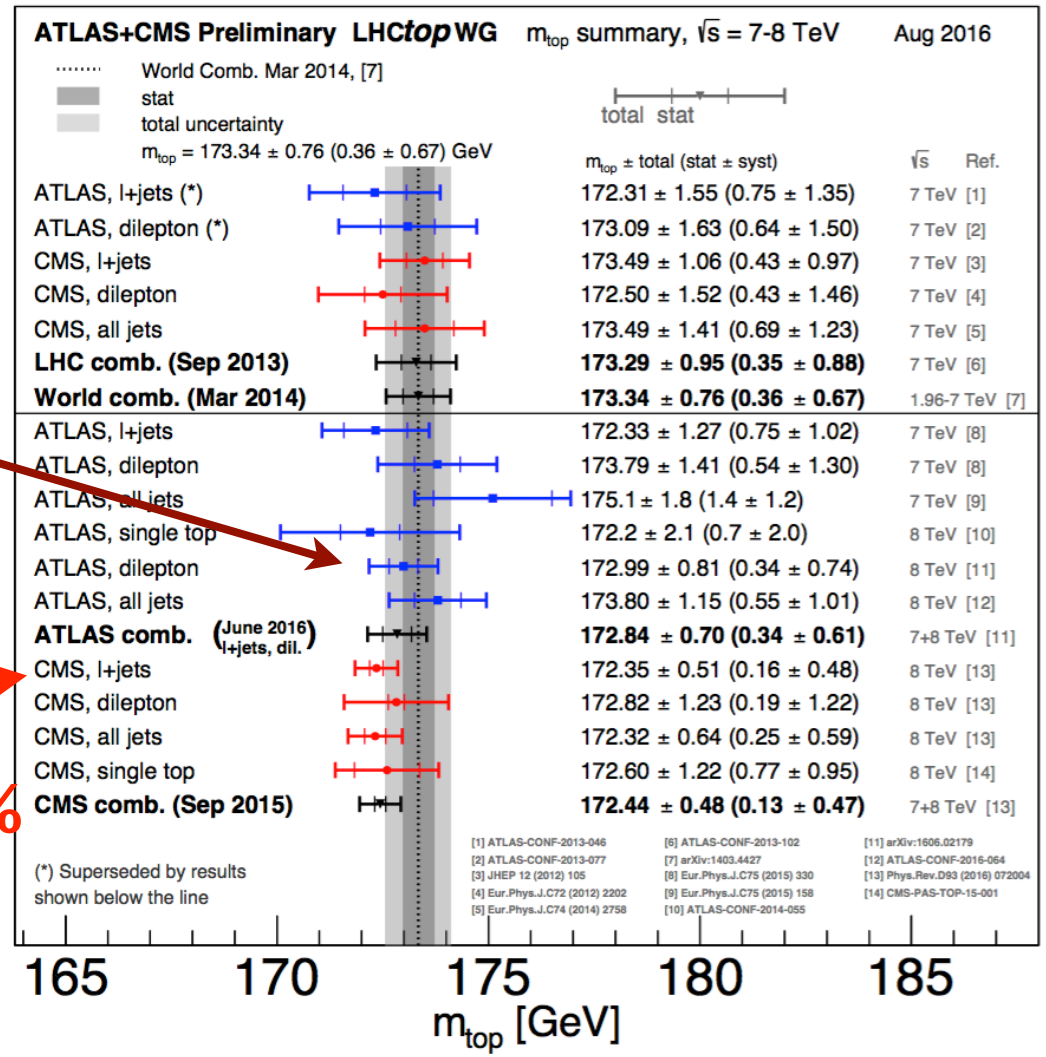
$$m_{top} = 172.99 \pm 0.41\ (\text{stat}) \pm 0.74\ (\text{syst})\ \text{GeV}$$



±0.28%

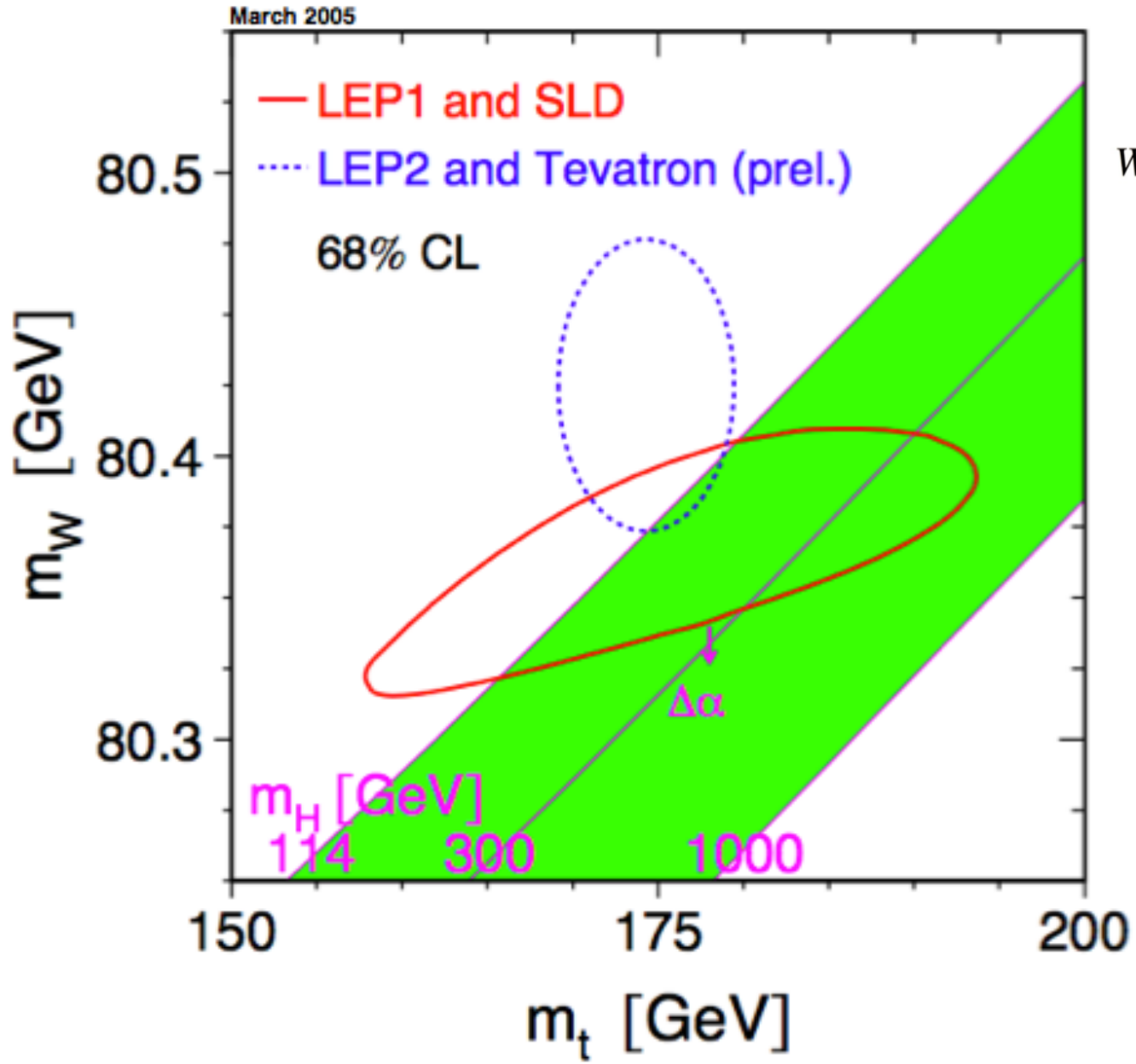
l+jets
±0.29%

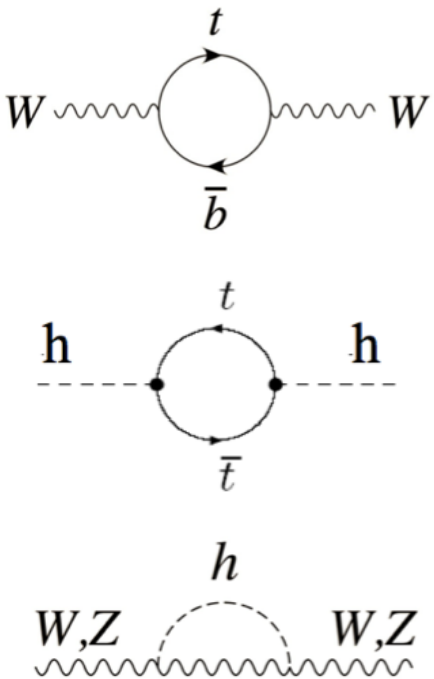
$$m_t^{hyb} = 172.35 \pm 0.16\,(\text{stat+JSF}) \pm 0.48\,(\text{syst})\,\text{GeV}$$



→ **jet energy scale is crucial**

History m_{top} vs. M_W





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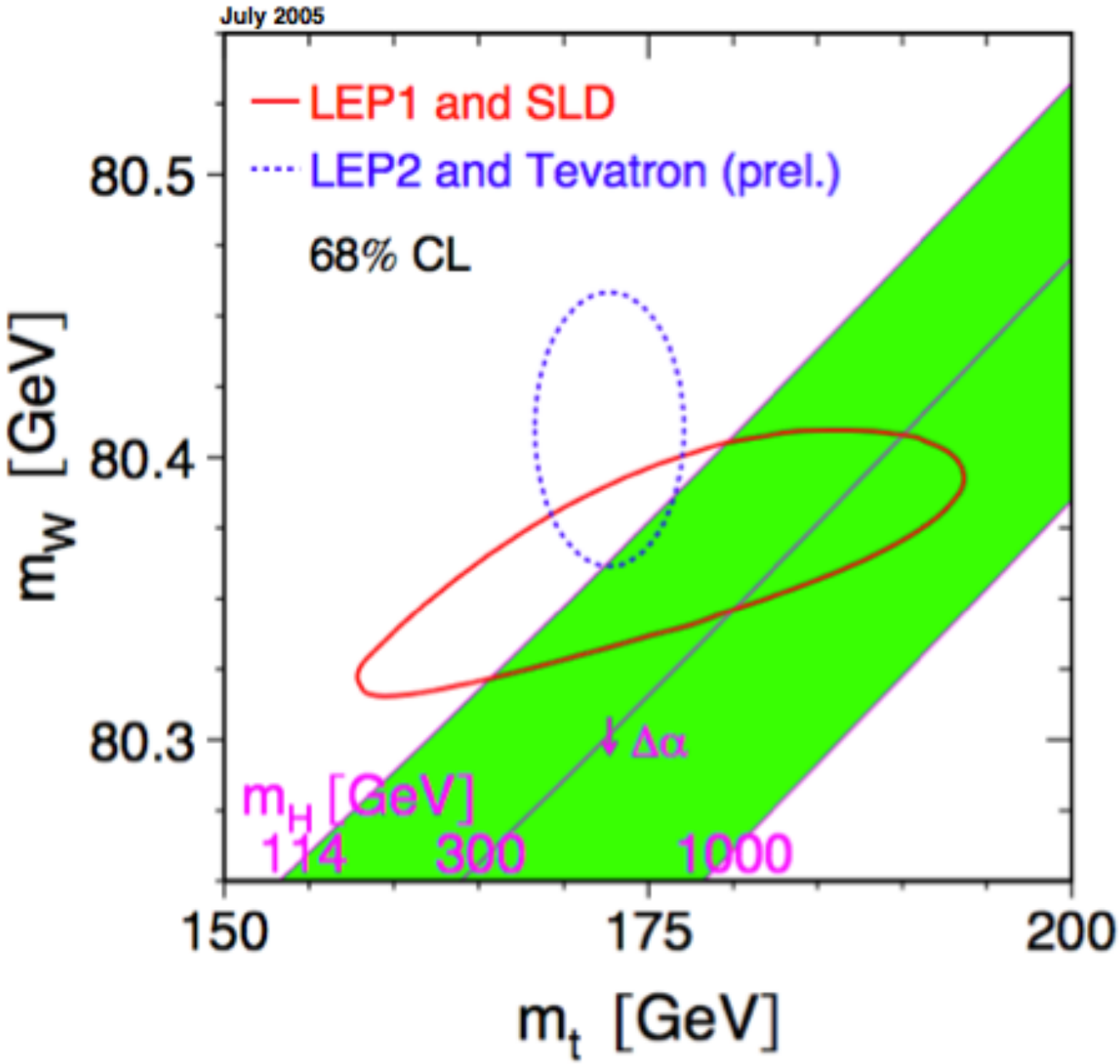

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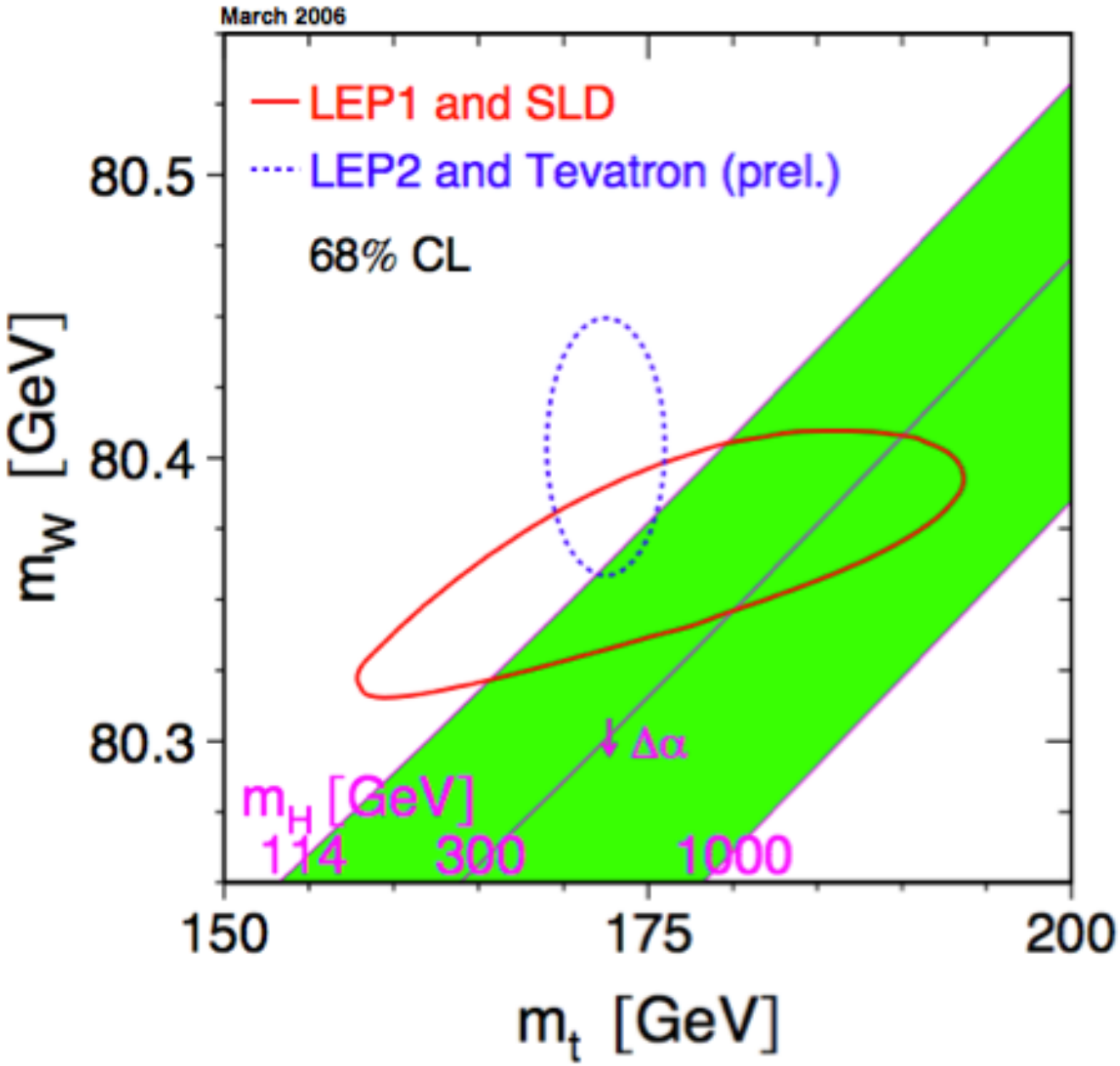

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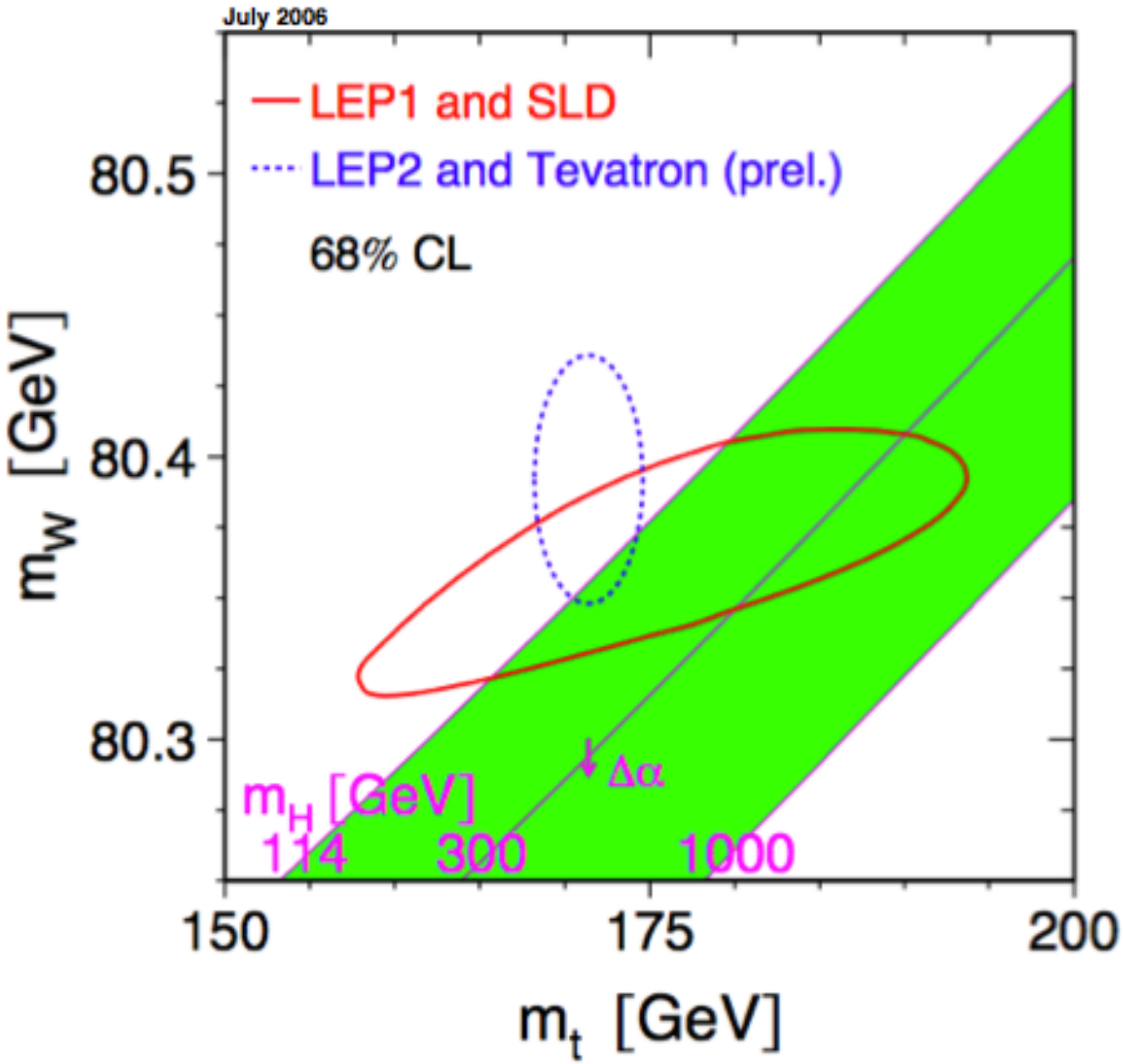

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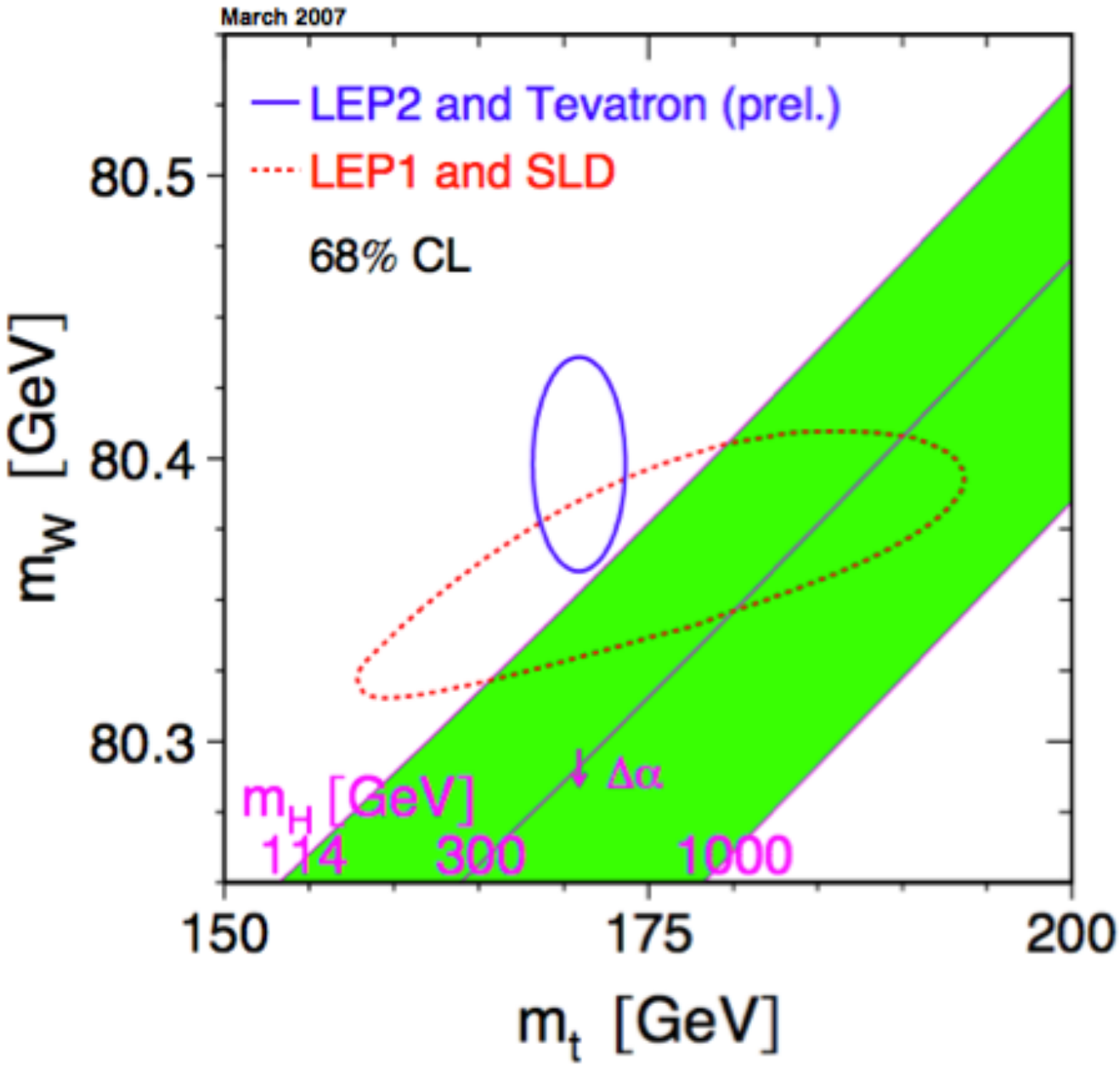

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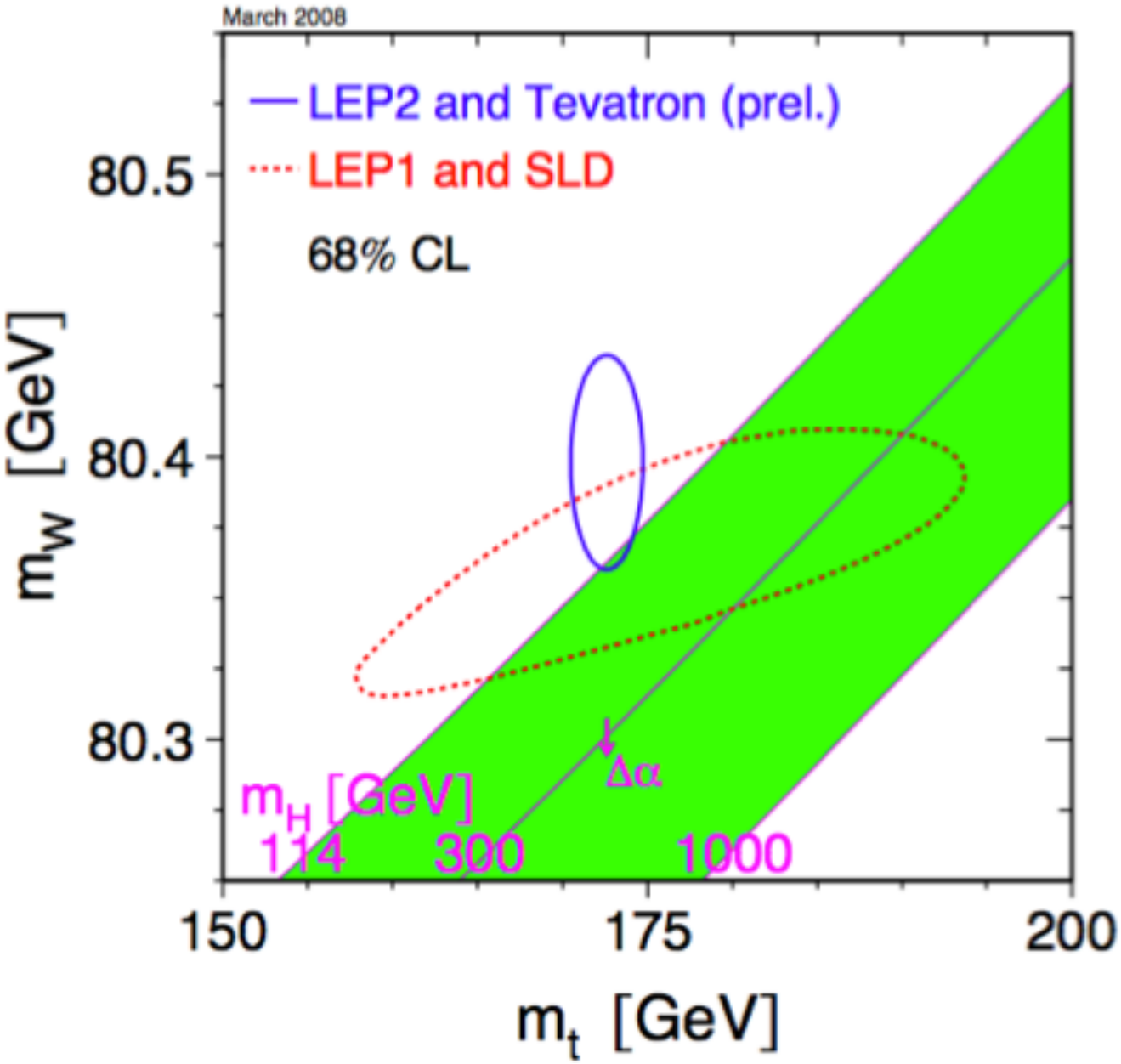

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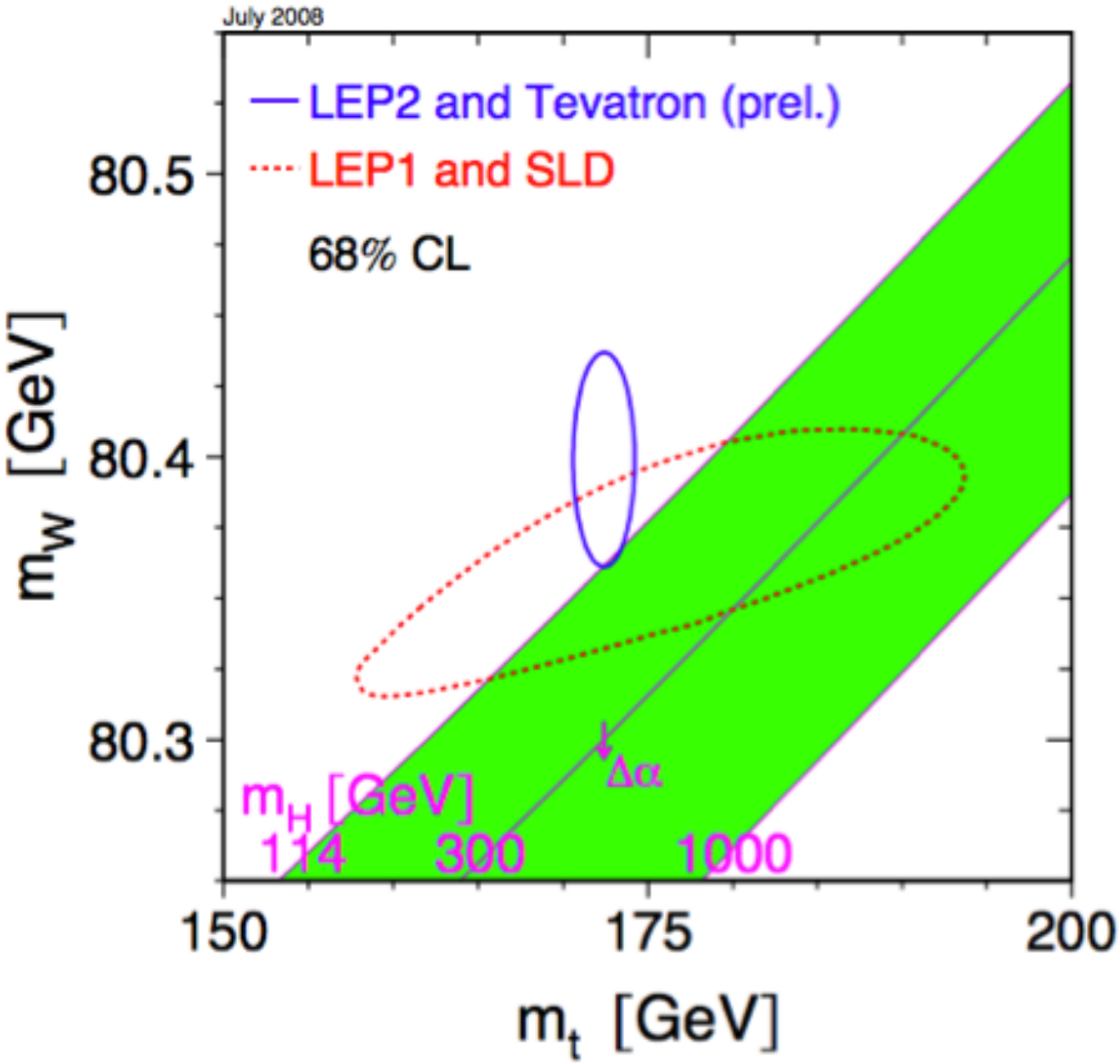

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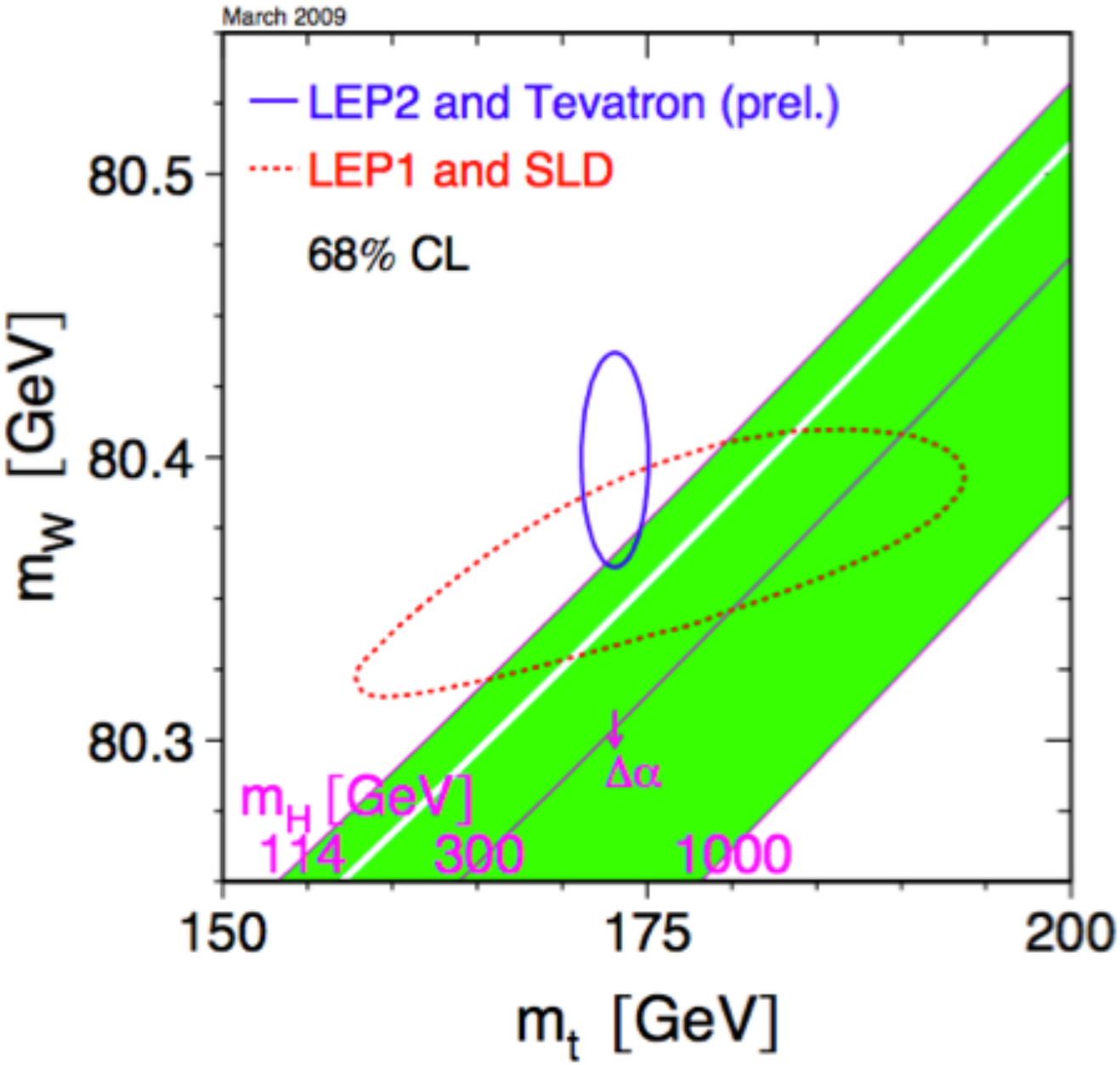

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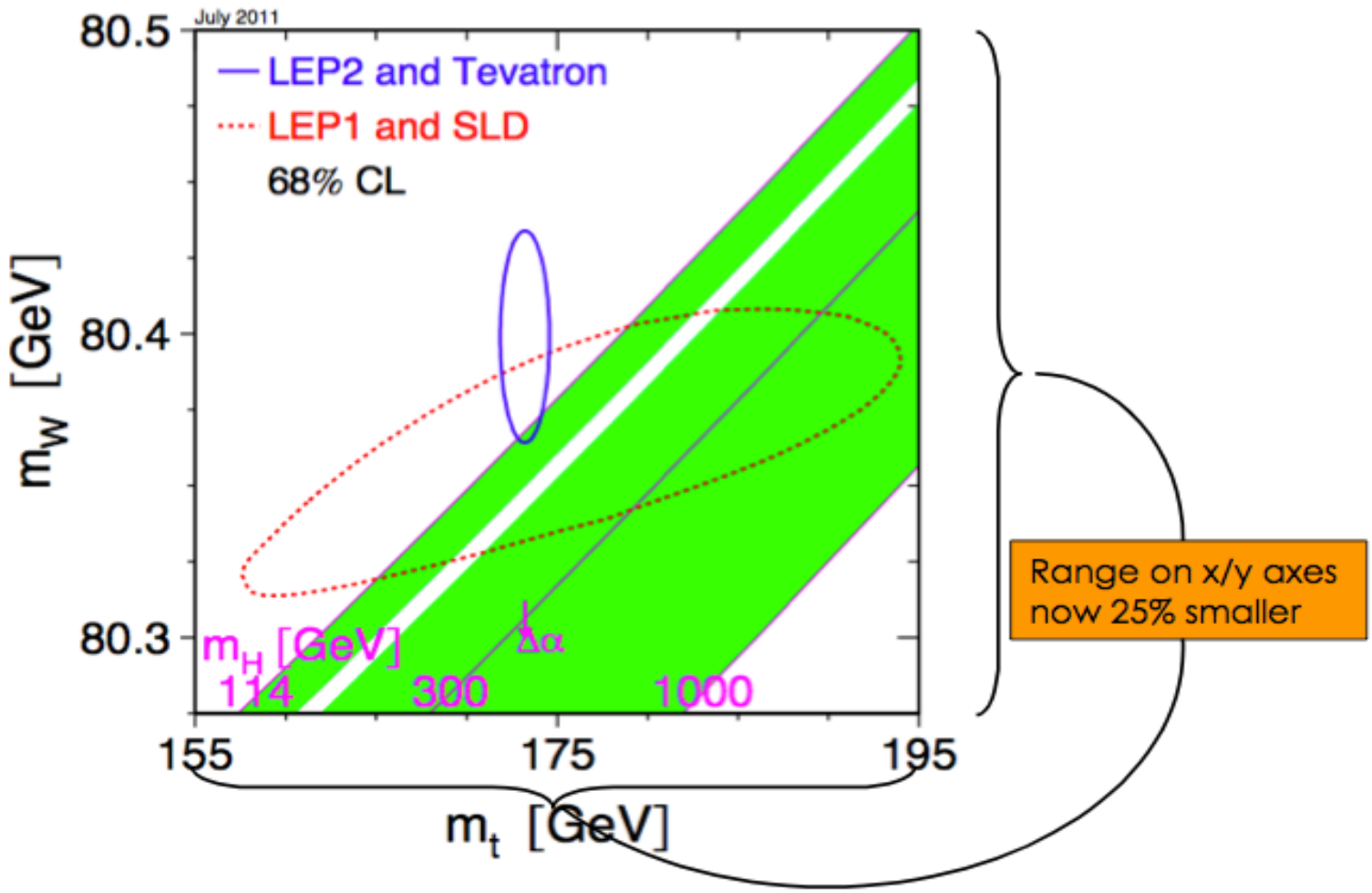

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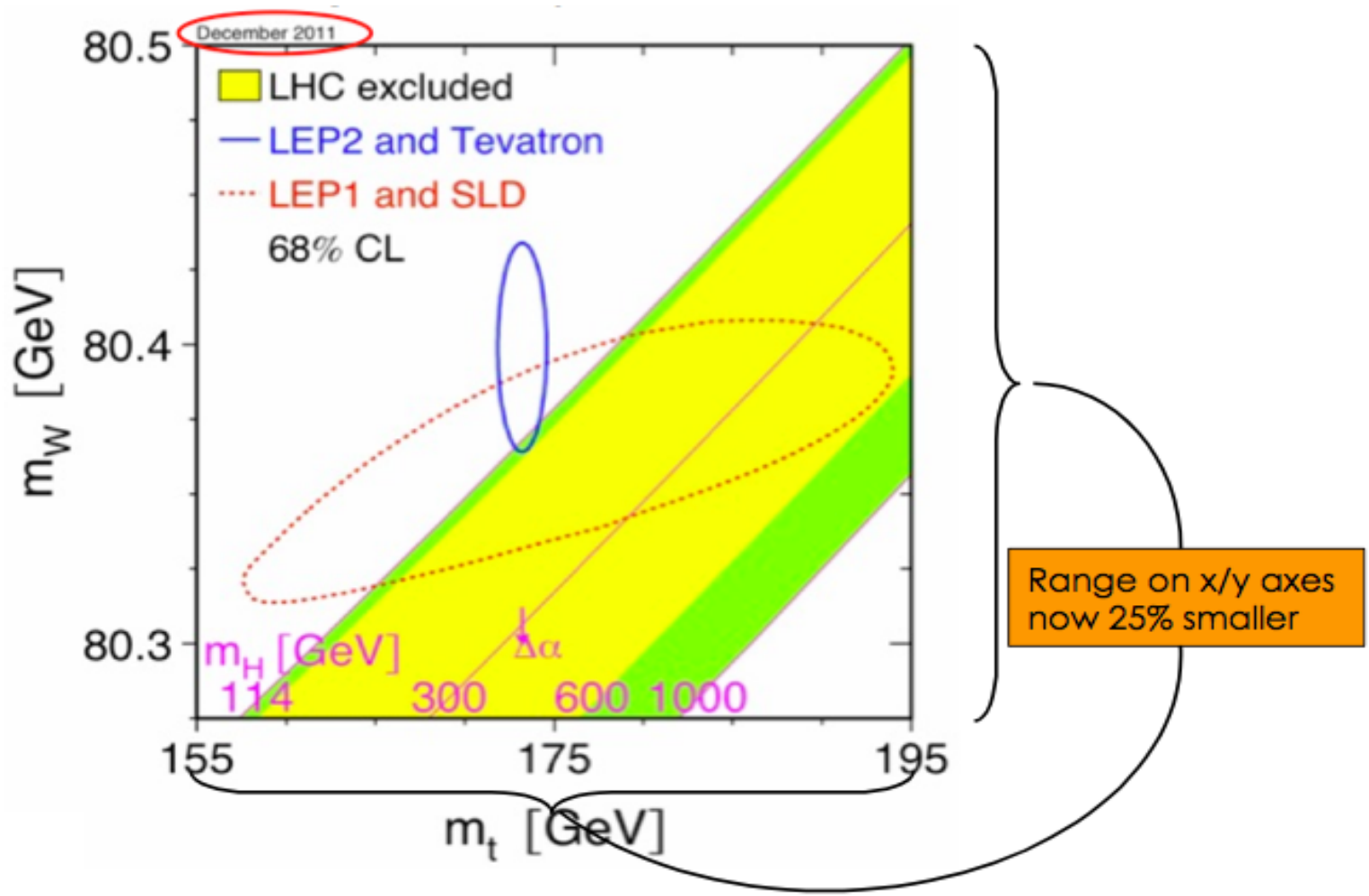

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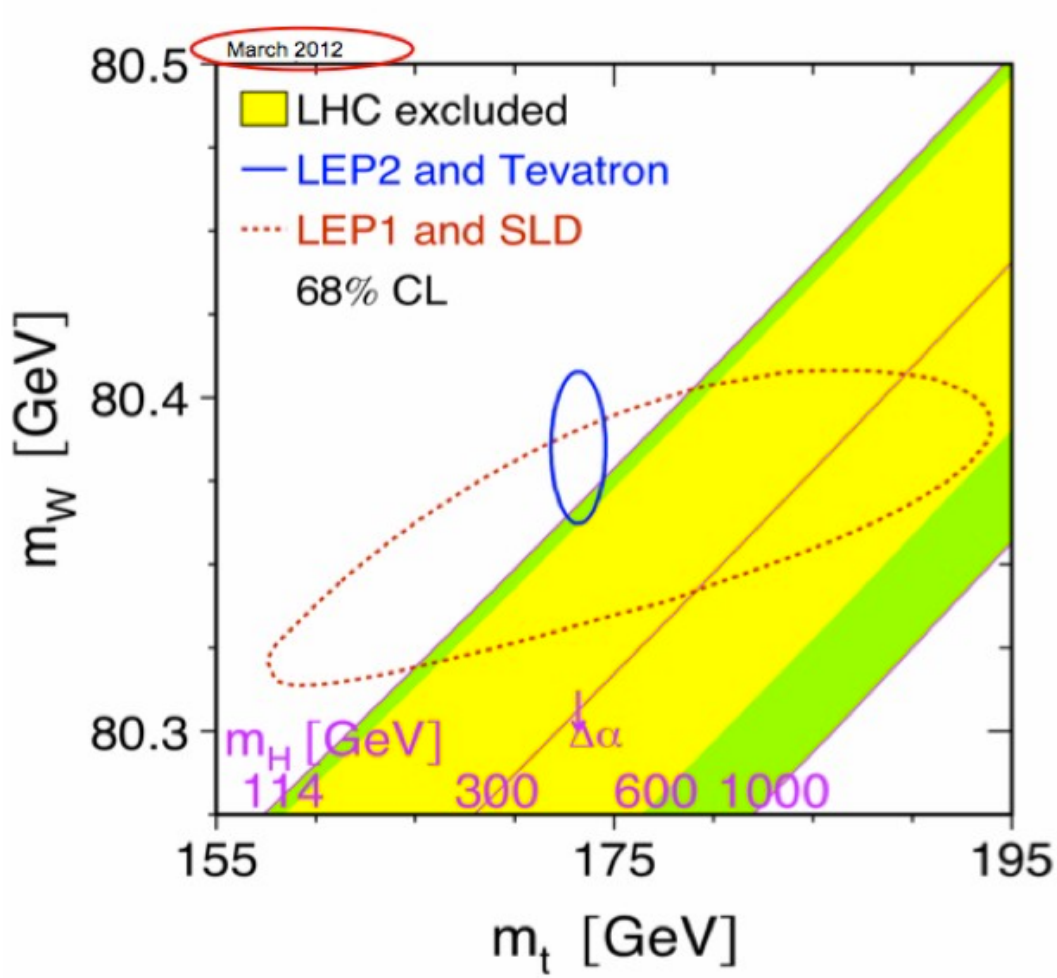

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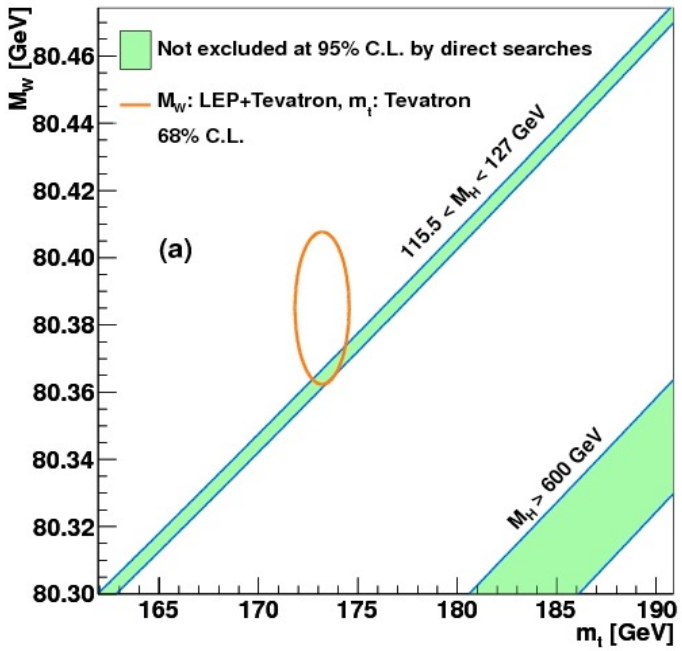
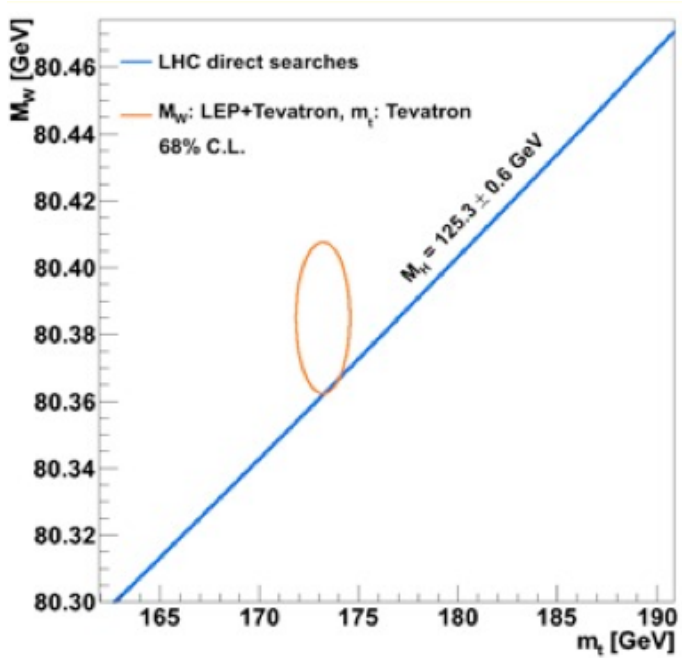


History m_{top} vs. M_W

July 2012

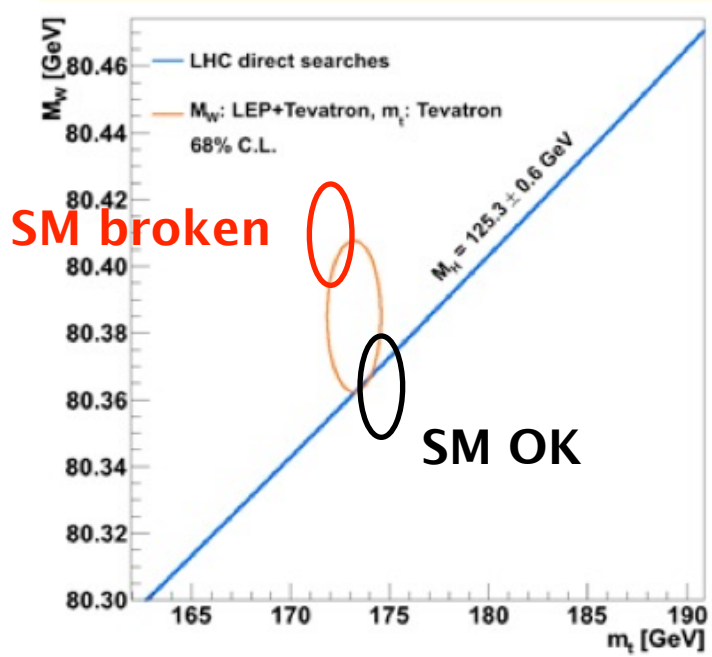


→ Standard Model is self-consistent

History m_{top} vs. M_W

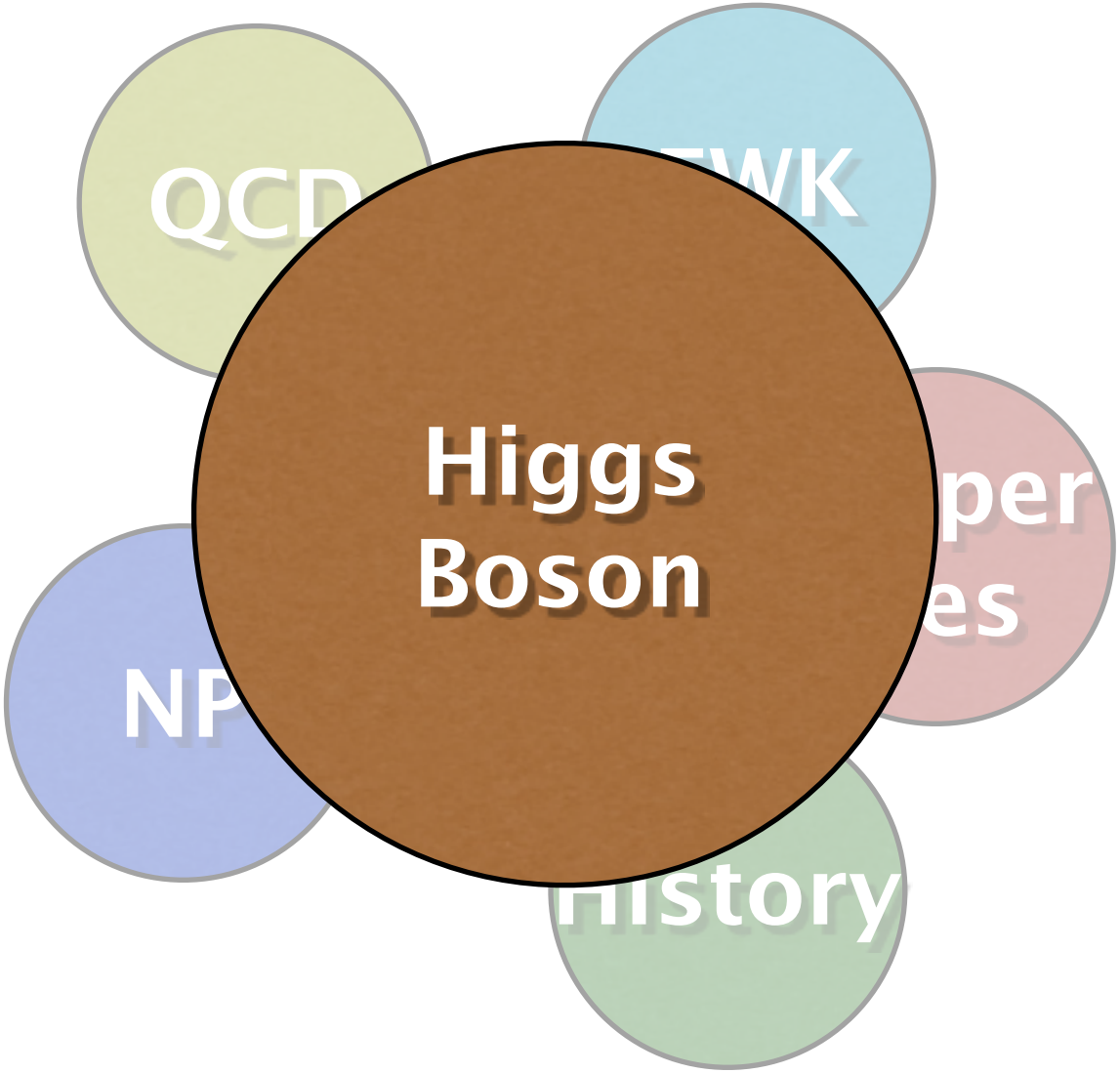
July 2012

future:
$\Delta(m_W)$=6 MeV

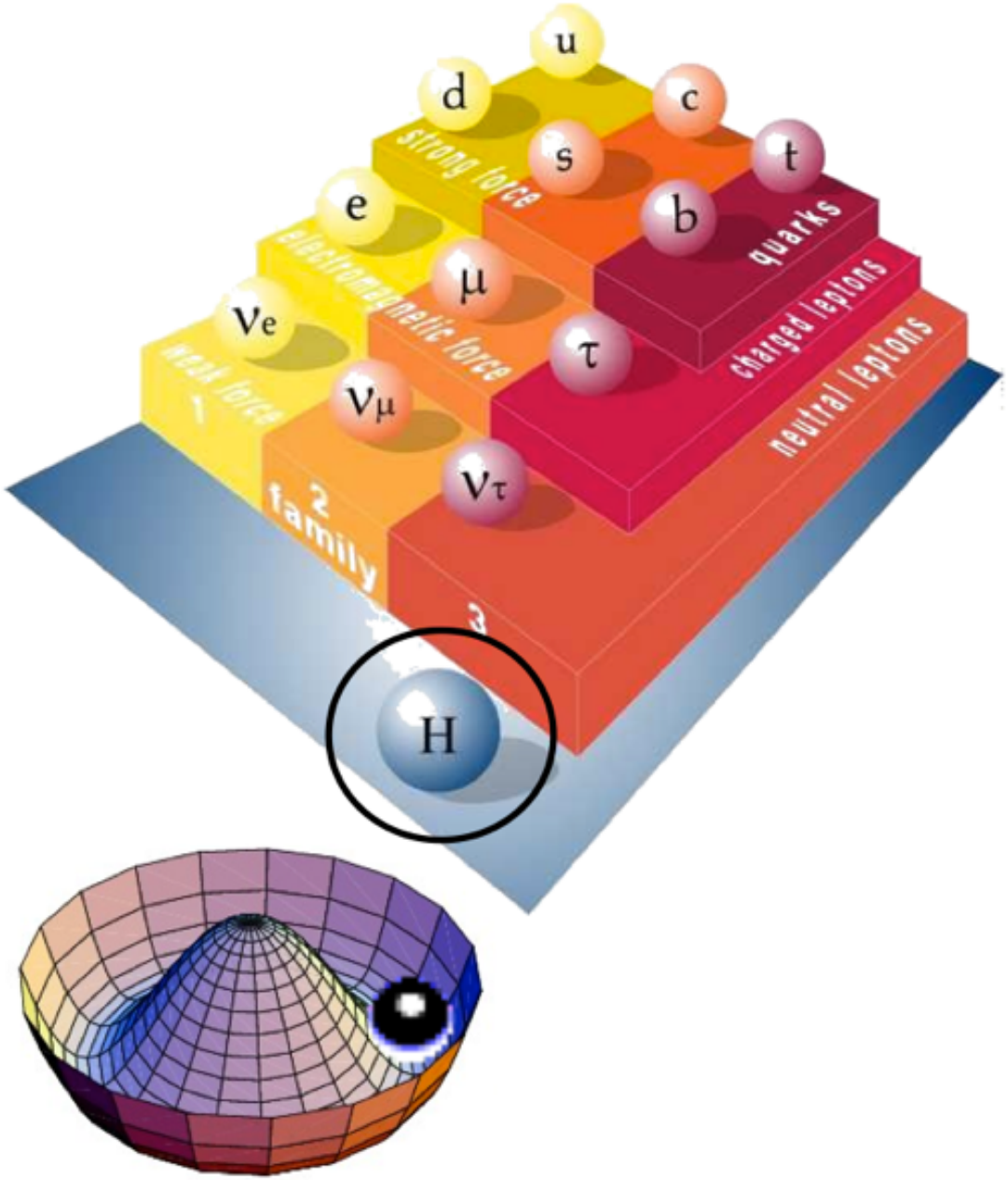


improved W mass measurement is critical

Top Quark Physics Topics



Open Questions in the SM



- is it the Higgs as predicted in the SM?
- why is the top quark so heavy?
- what is the role of the top quark itself in electroweak symmetry breaking?

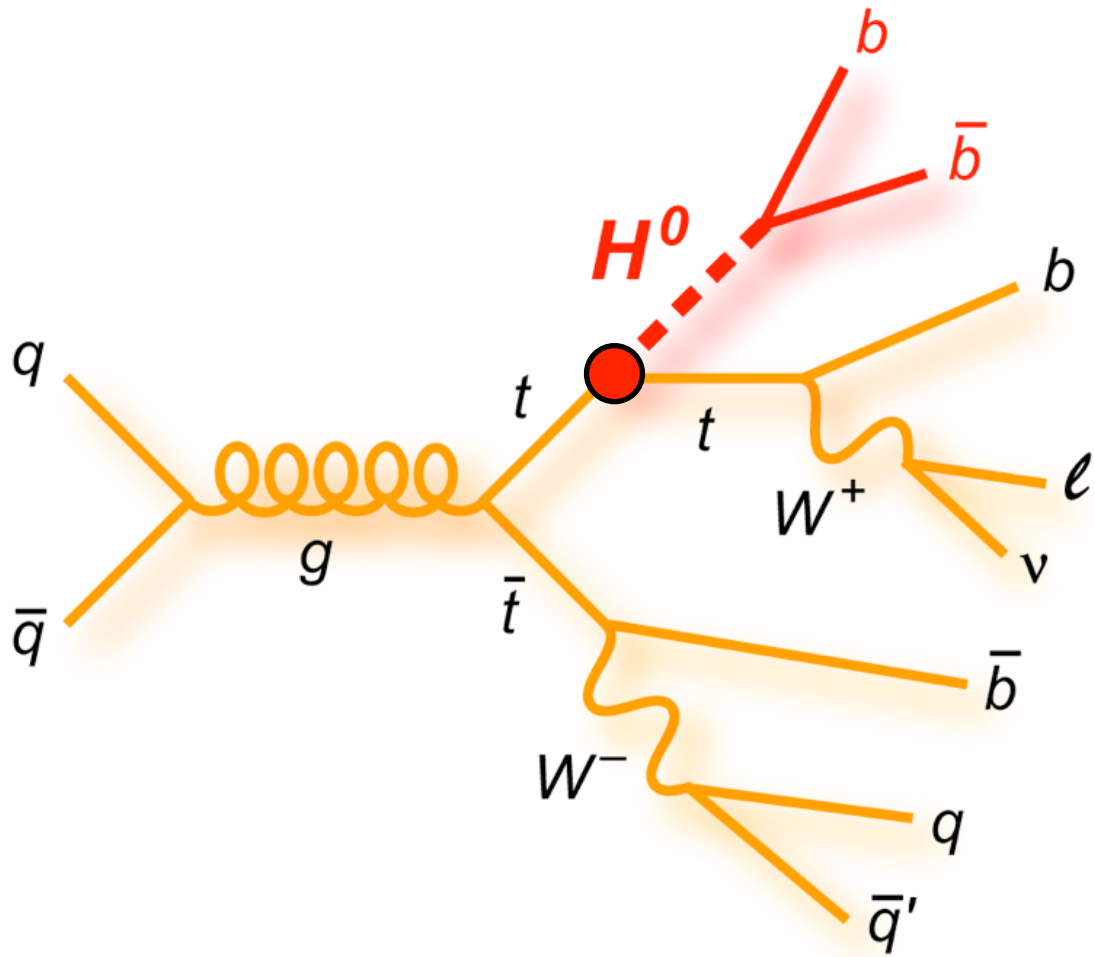
→ analyse the interplay between top quark and Higgs boson

→ measure the top-Higgs Yukawa coupling

Associated top-Higgs Production

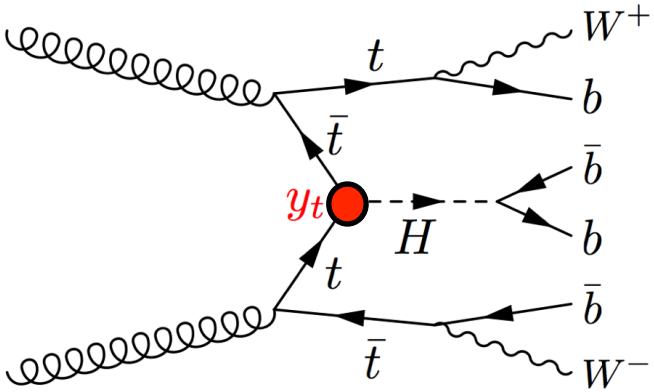
- only process to measure top-Higgs-Yukawa coupling directly

→ will provide important information about role of top quark in process of mass generation

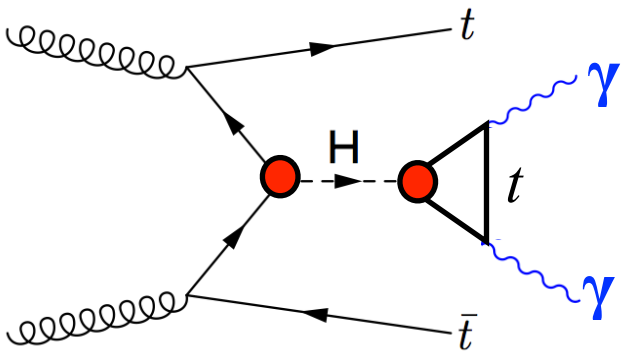


Search for ttH production

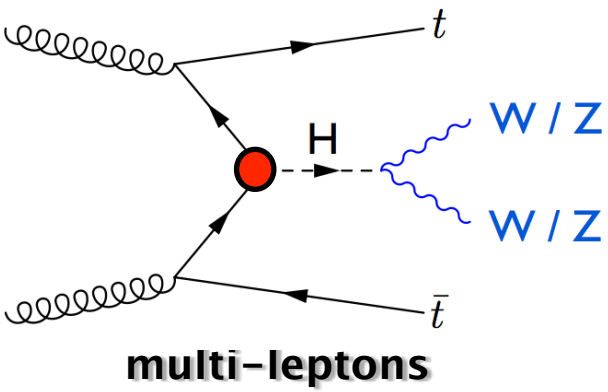
H→bb



H→γγ

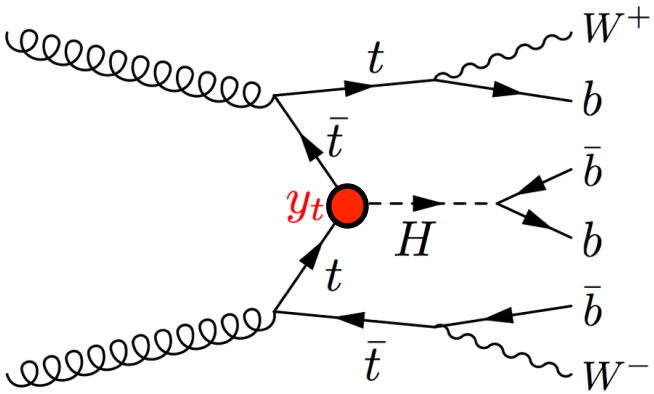


H→WW, ZZ

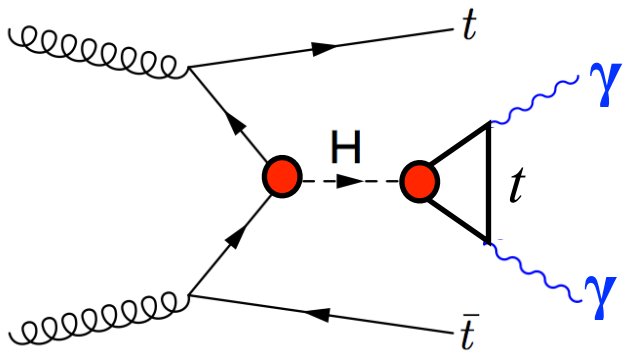


Search for ttH production

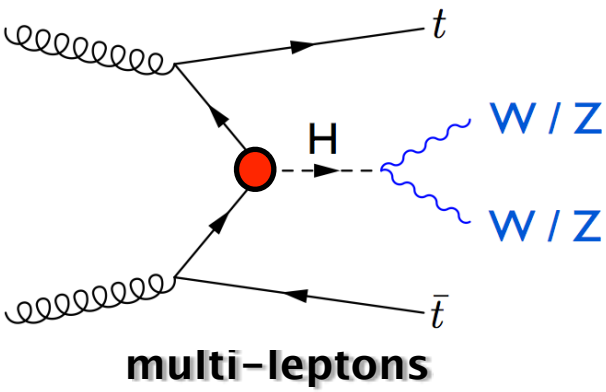
H→bb

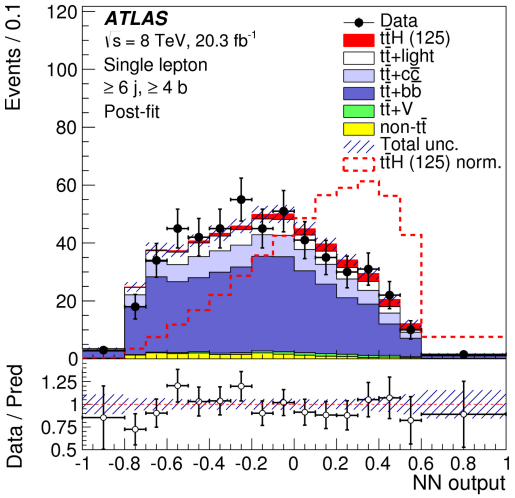


H→γγ



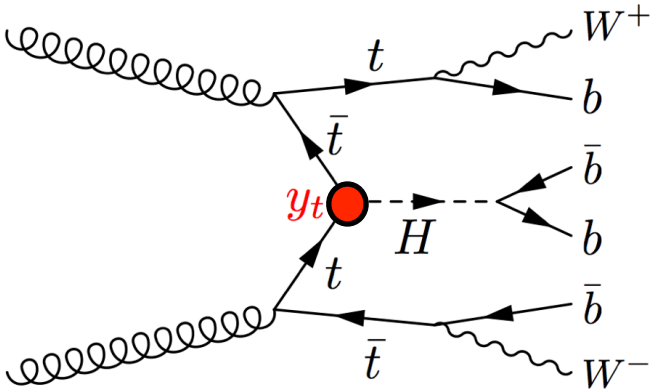
H→WW, ZZ



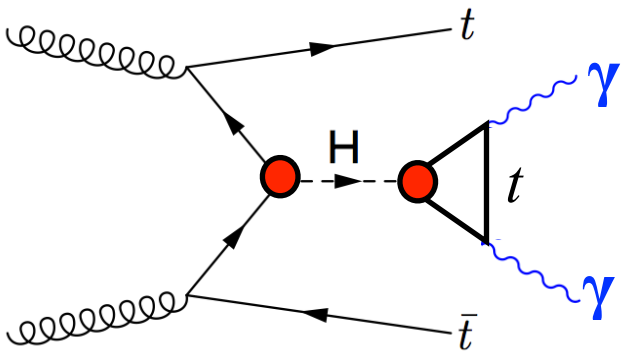


Search for ttH production

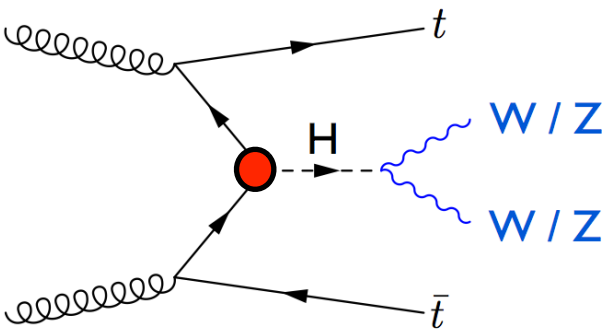
H→bb



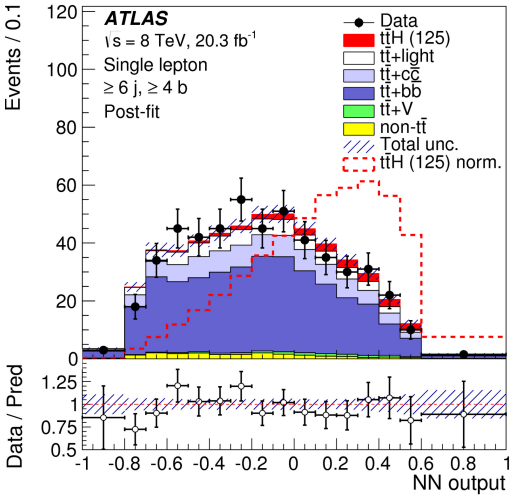
H→γγ

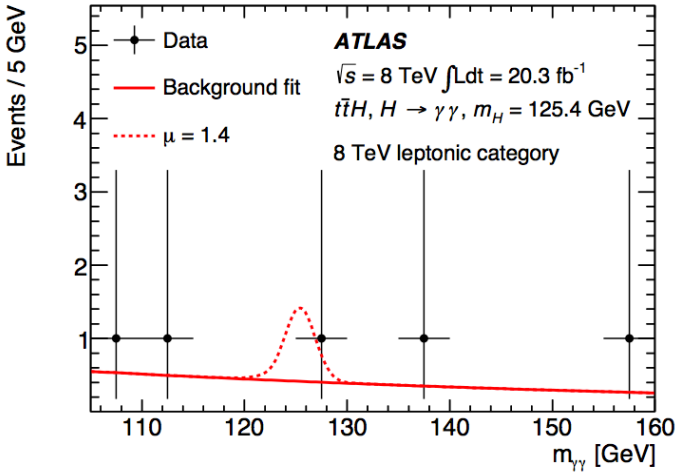


H→WW, ZZ



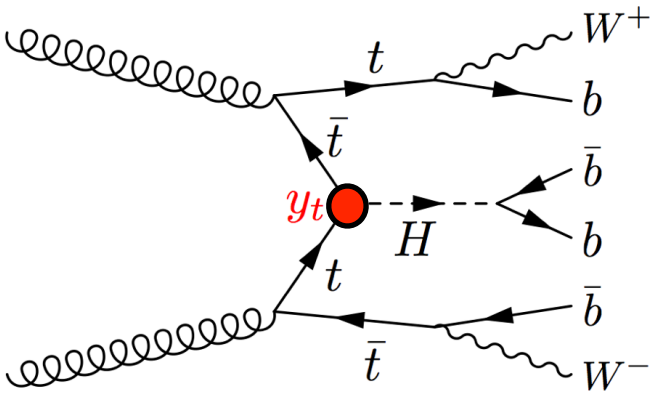
multi-leptons



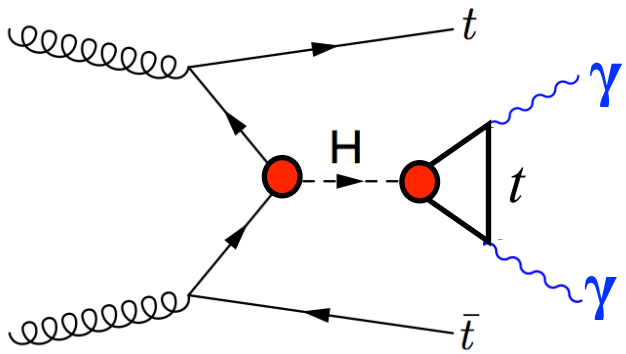


Search for ttH production

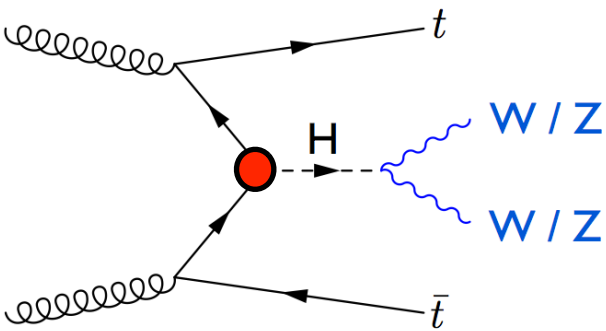
H→bb



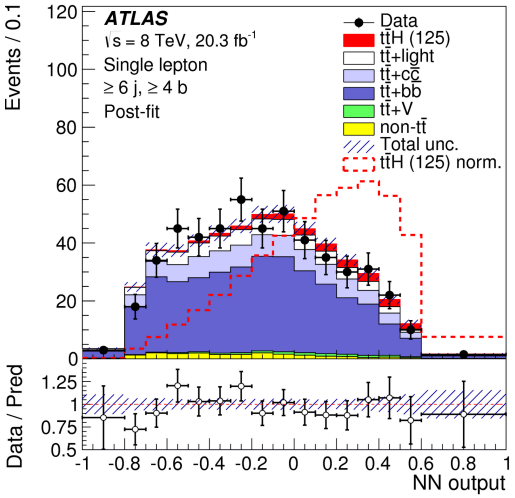
H→γγ

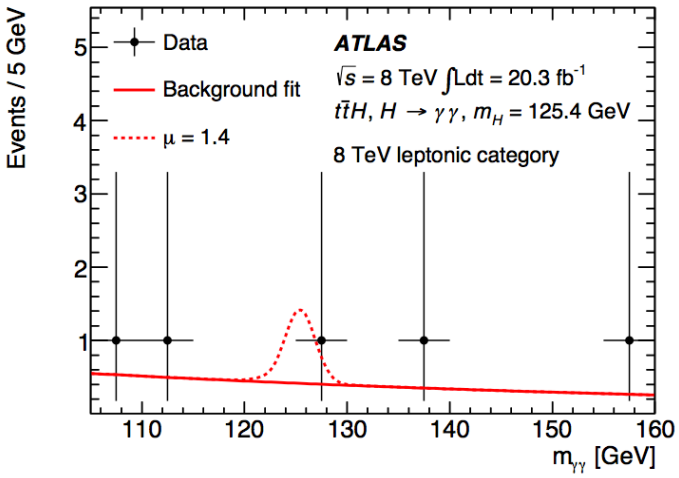


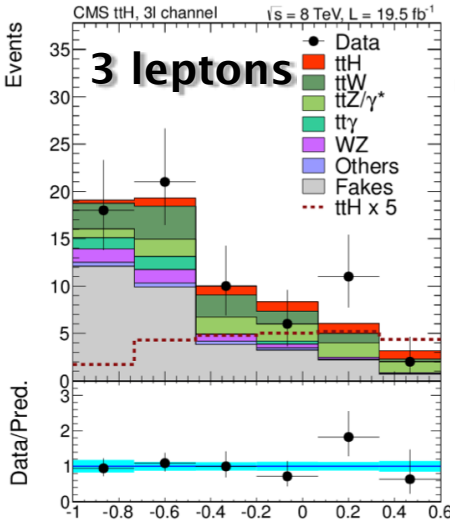
H→WW, ZZ

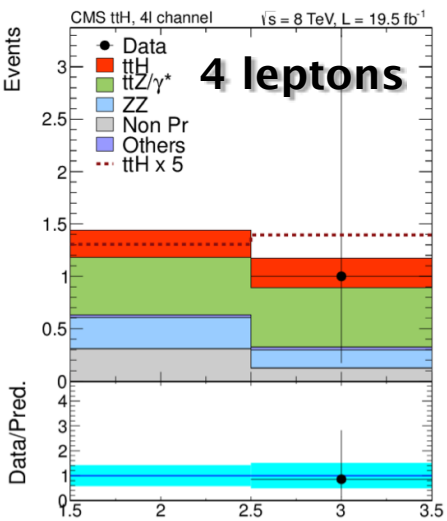


multi-leptons



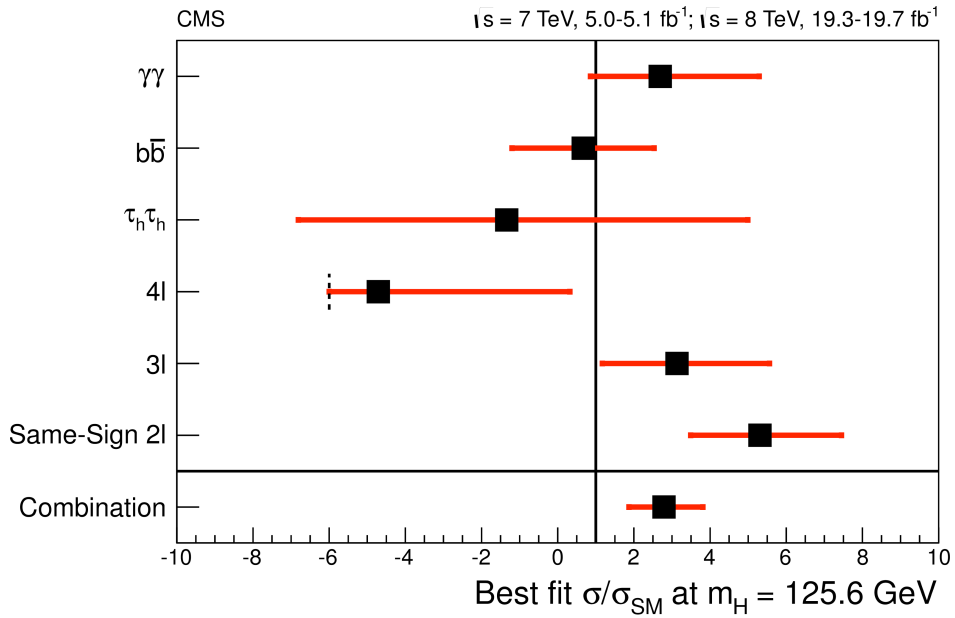






Results in ttH

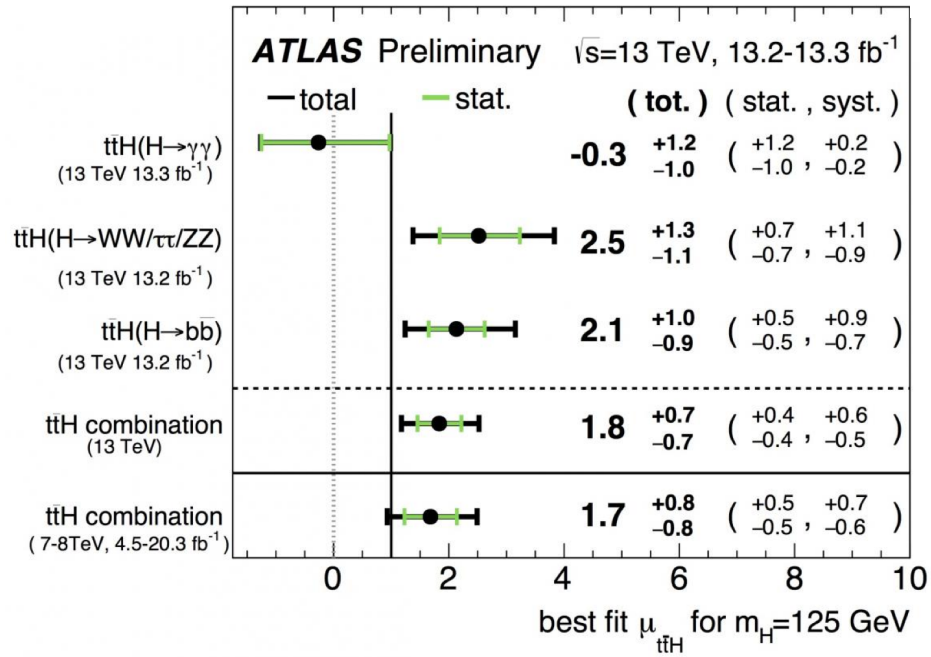
7 and 8 TeV



σ/σ_{SM}

4.5σ (1.7σ exp)

13 TeV

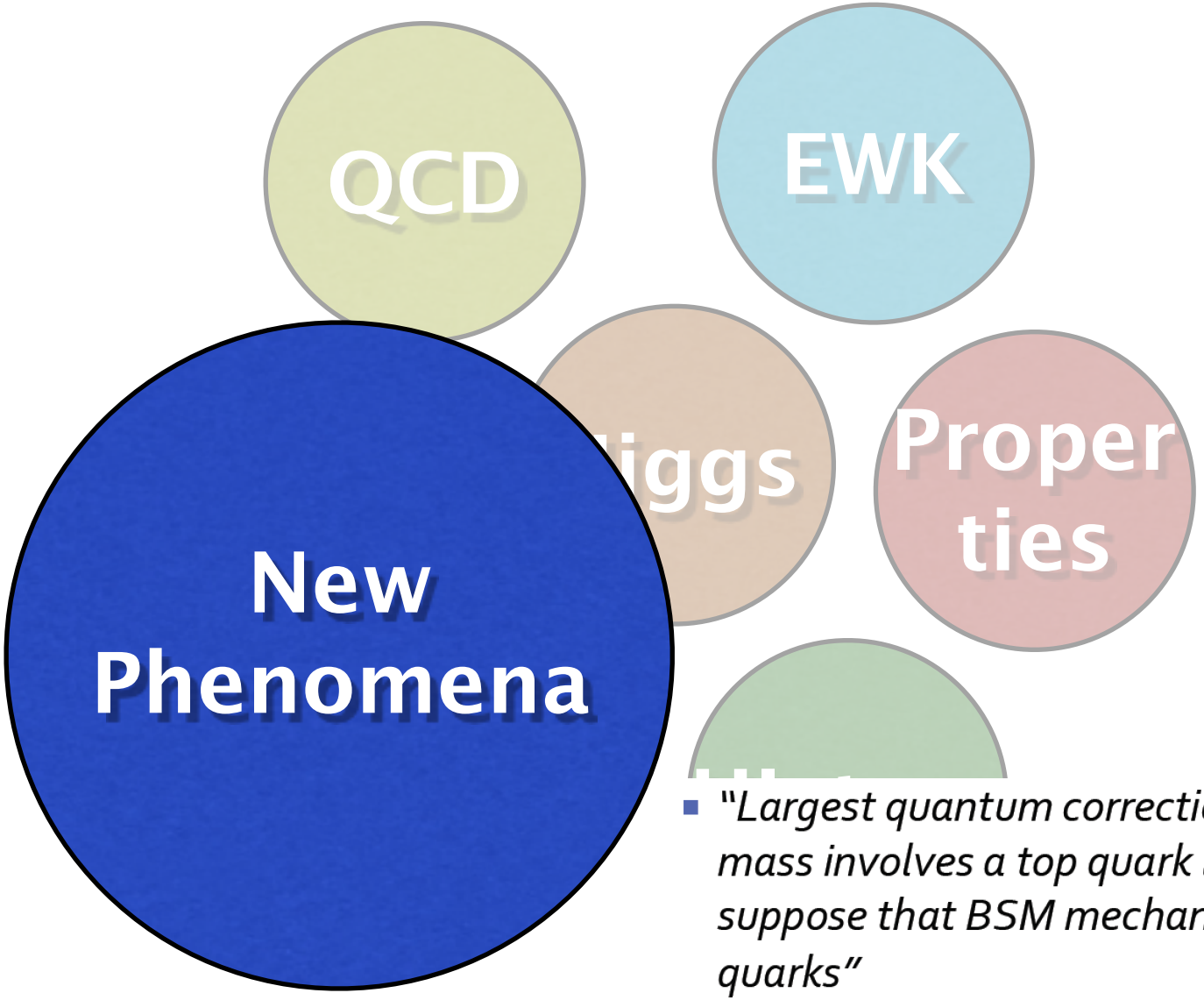


σ/σ_{SM}

2.8σ (1.8σ exp)

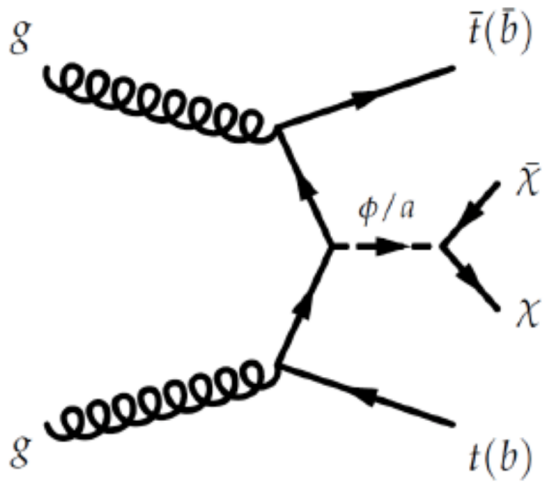
→ observation in Run-II
→ measurement of top-Yukawa coupling

Top Quark Physics Topics



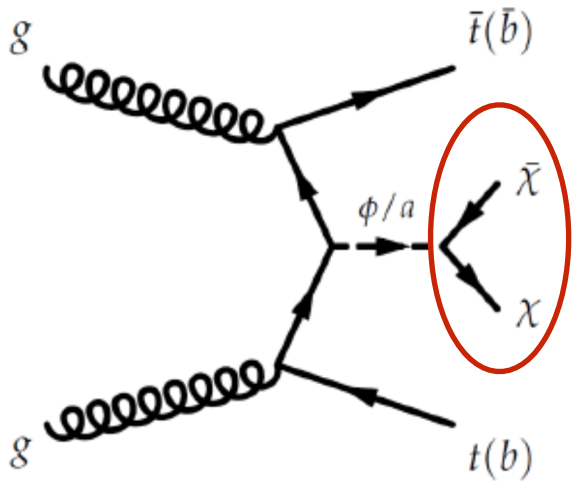
- *"Largest quantum correction to the Higgs boson mass involves a top quark loop, it is natural to suppose that BSM mechanisms involve top quarks"*

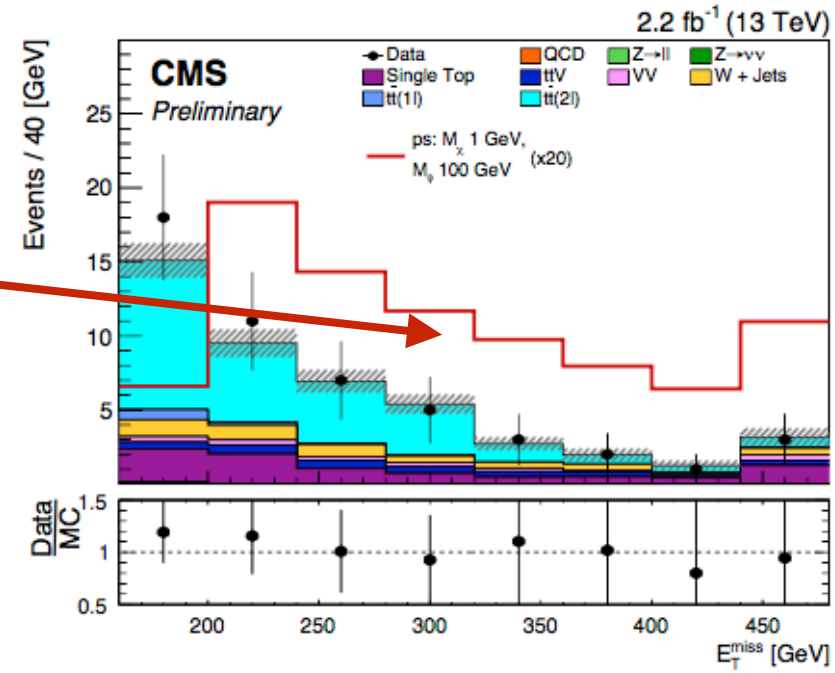
Direct Searches for New Physics



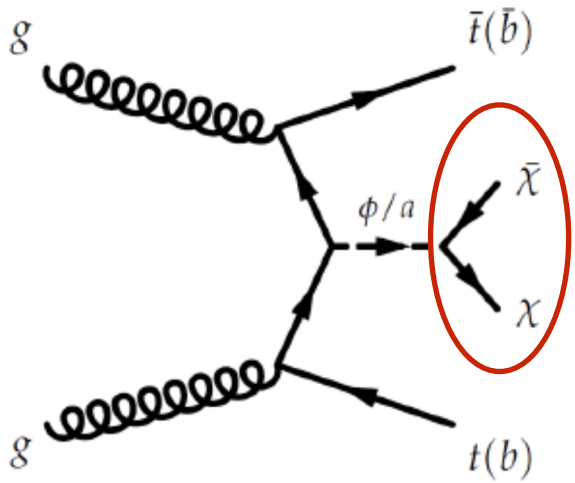
darth matter

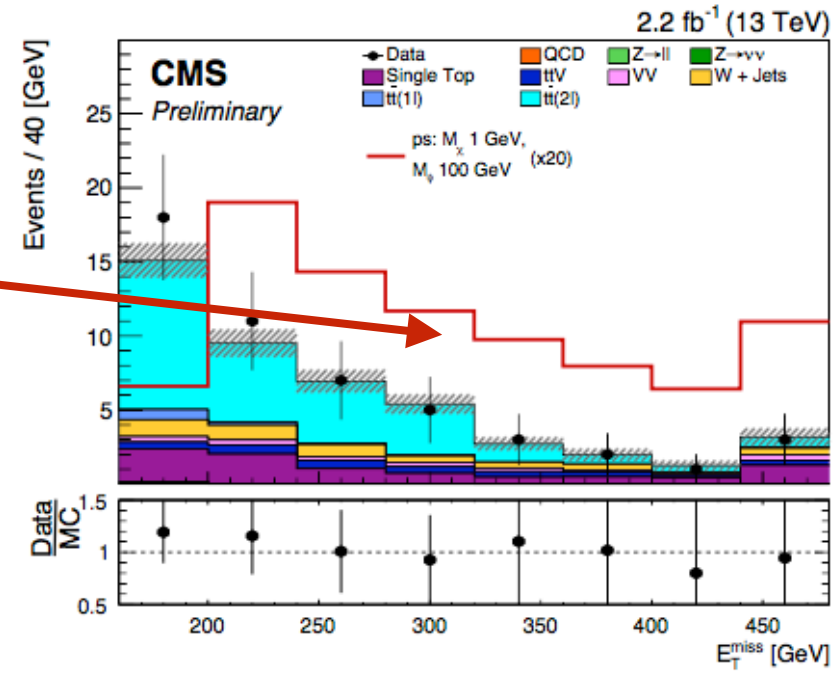
Search for Dark Matter in top pairs

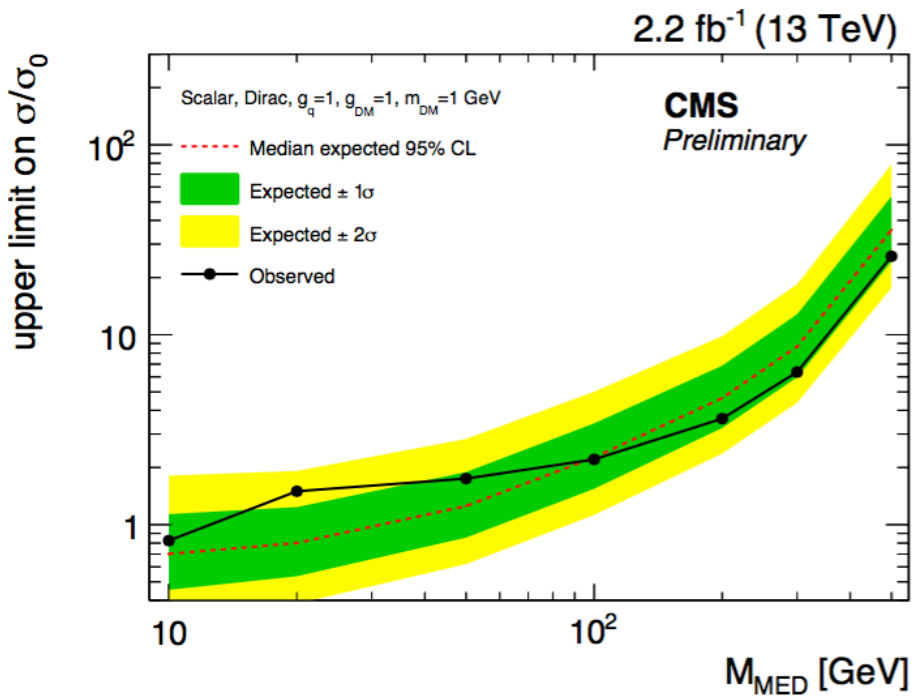




Search for Dark Matter in top pairs

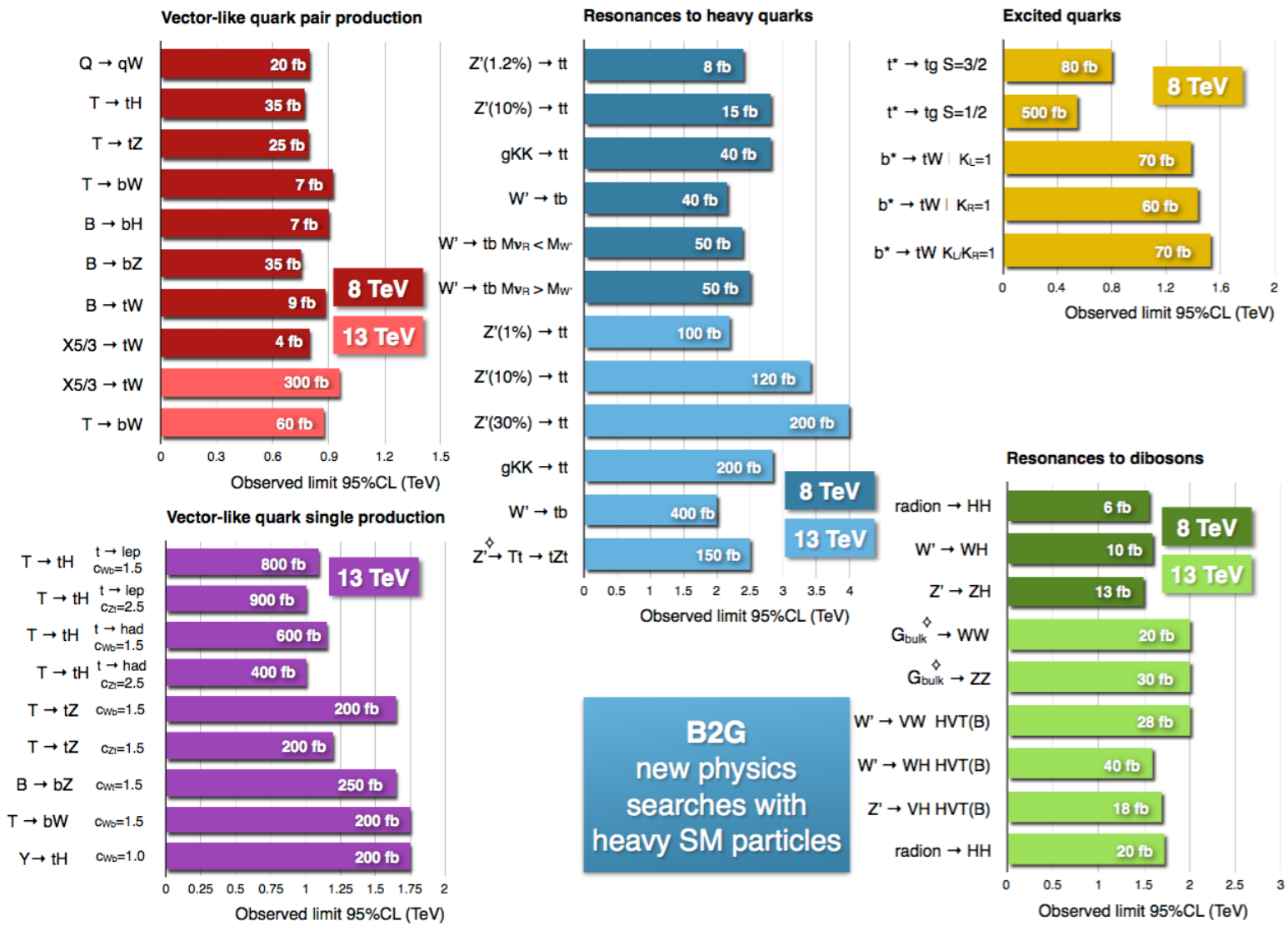






→ no hint for new physics so far…

Pushing the TeV scale

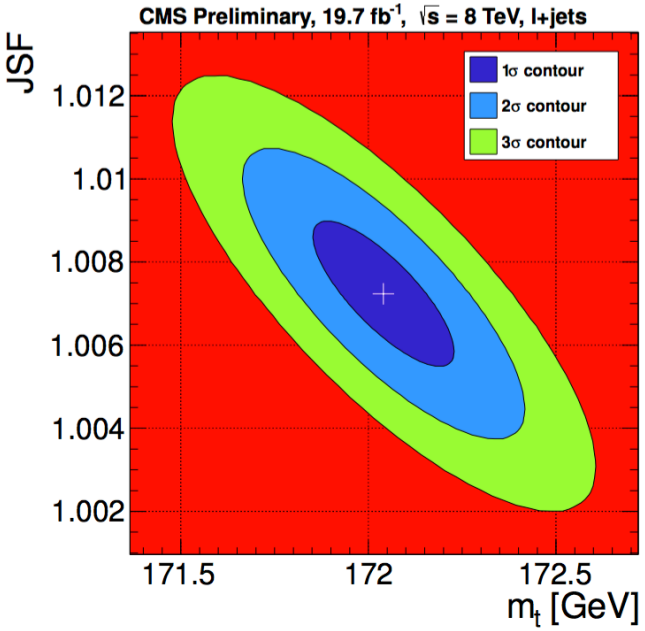


→ lots of opportunities for discovery in Run-II

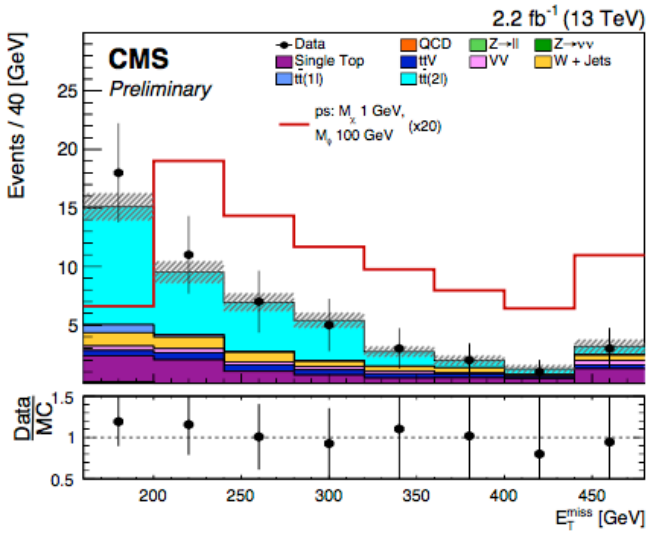
Summary

- the top quark is a very rich field of research
- very interesting candidate for new physics!
- measure properties with highest possible precision to find new physics:

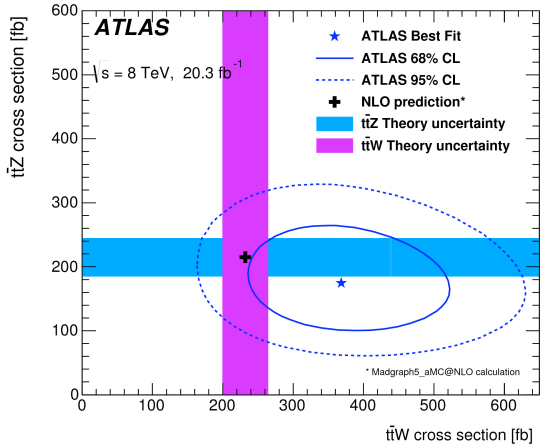
– high precision cross sections and properties



– high precision searches



– rare processes



→ observe more SM processes in Run-II, many high precision property/cross section measurements to come, discover new physics (in)directly???

Summary

let's smash the SM in Run-2!