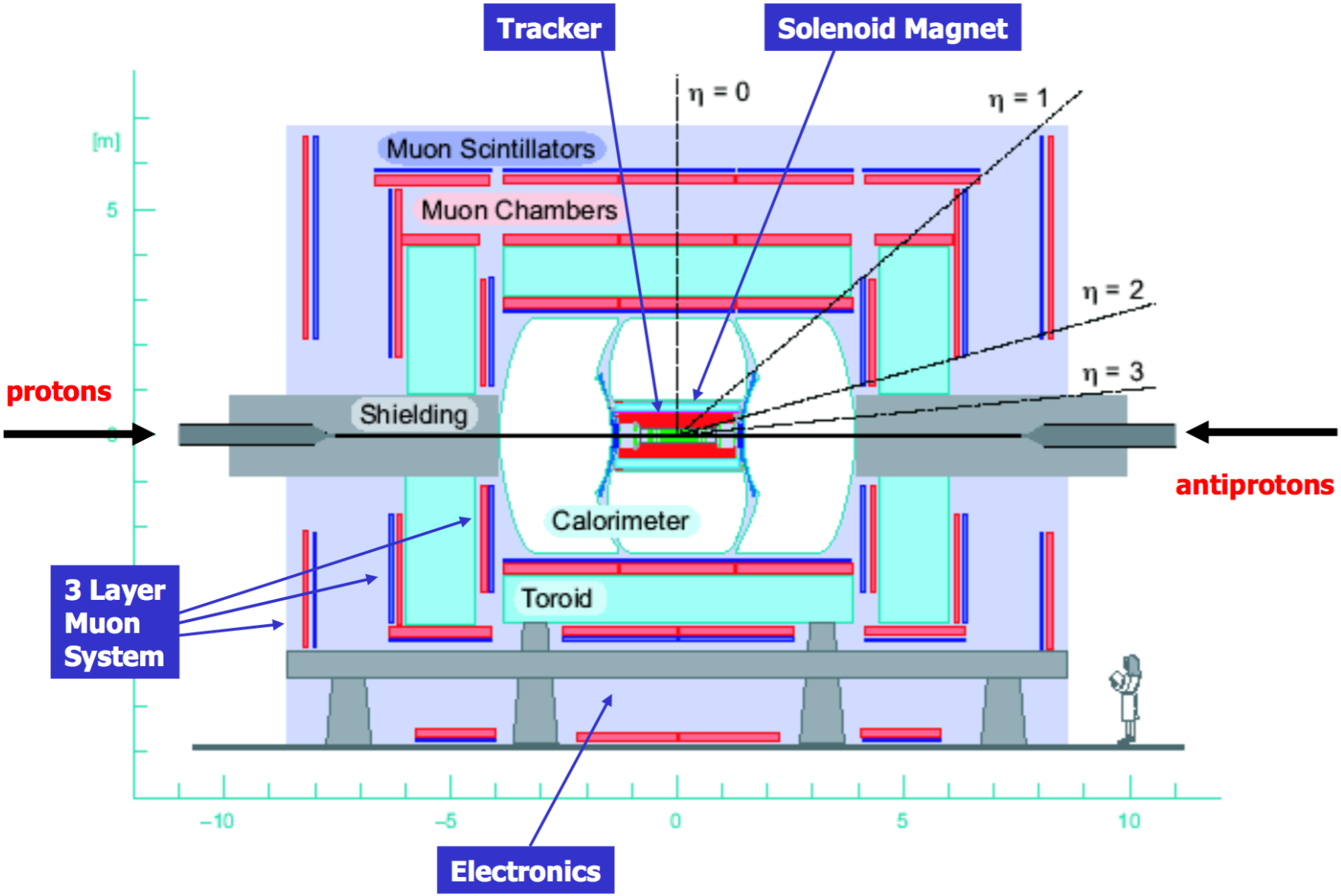
Content

3 Searches for Physics beyond the Standard Model

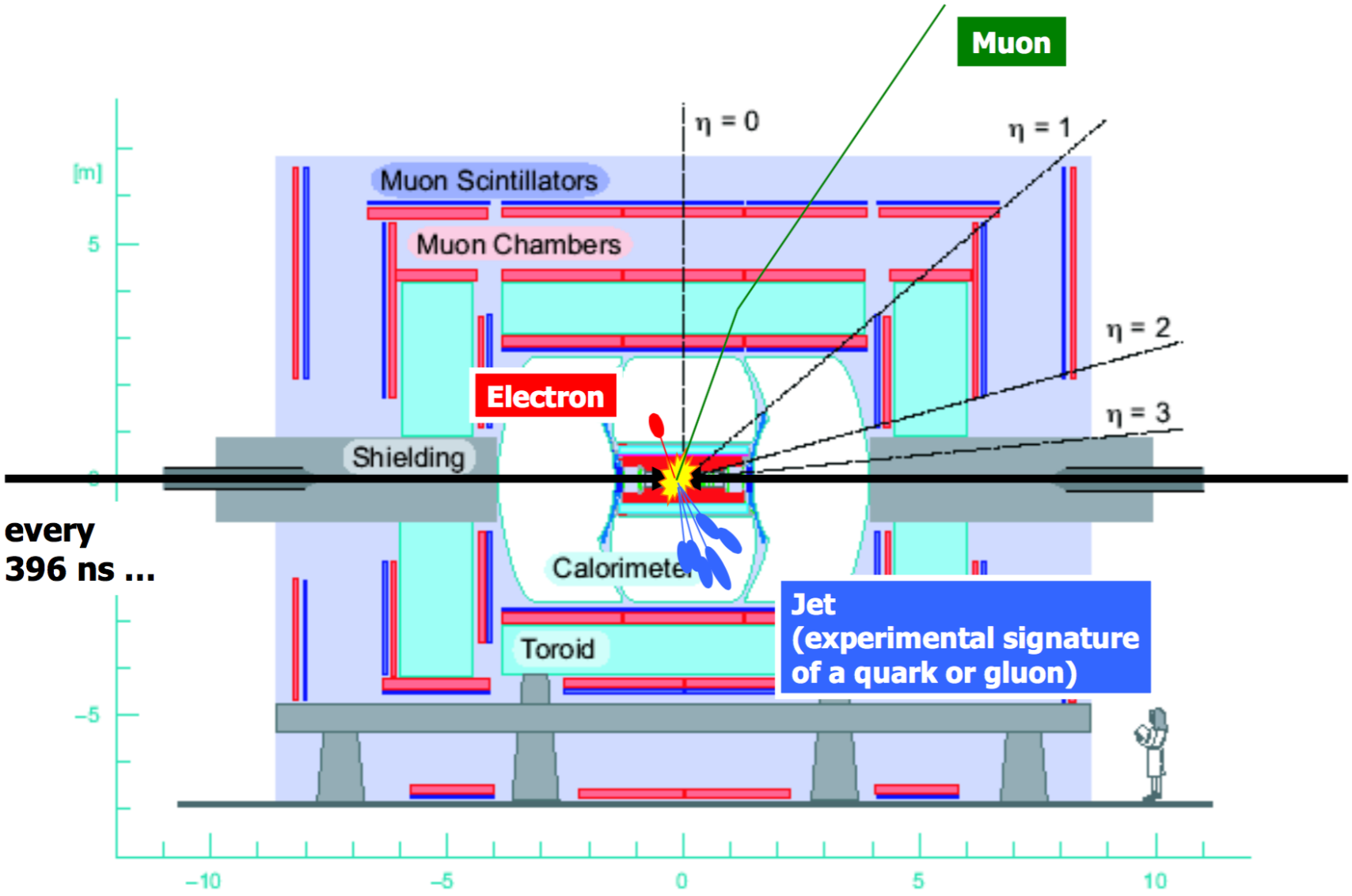
3.1 Experimental Methods

3.2 Theories beyond the Standard Model

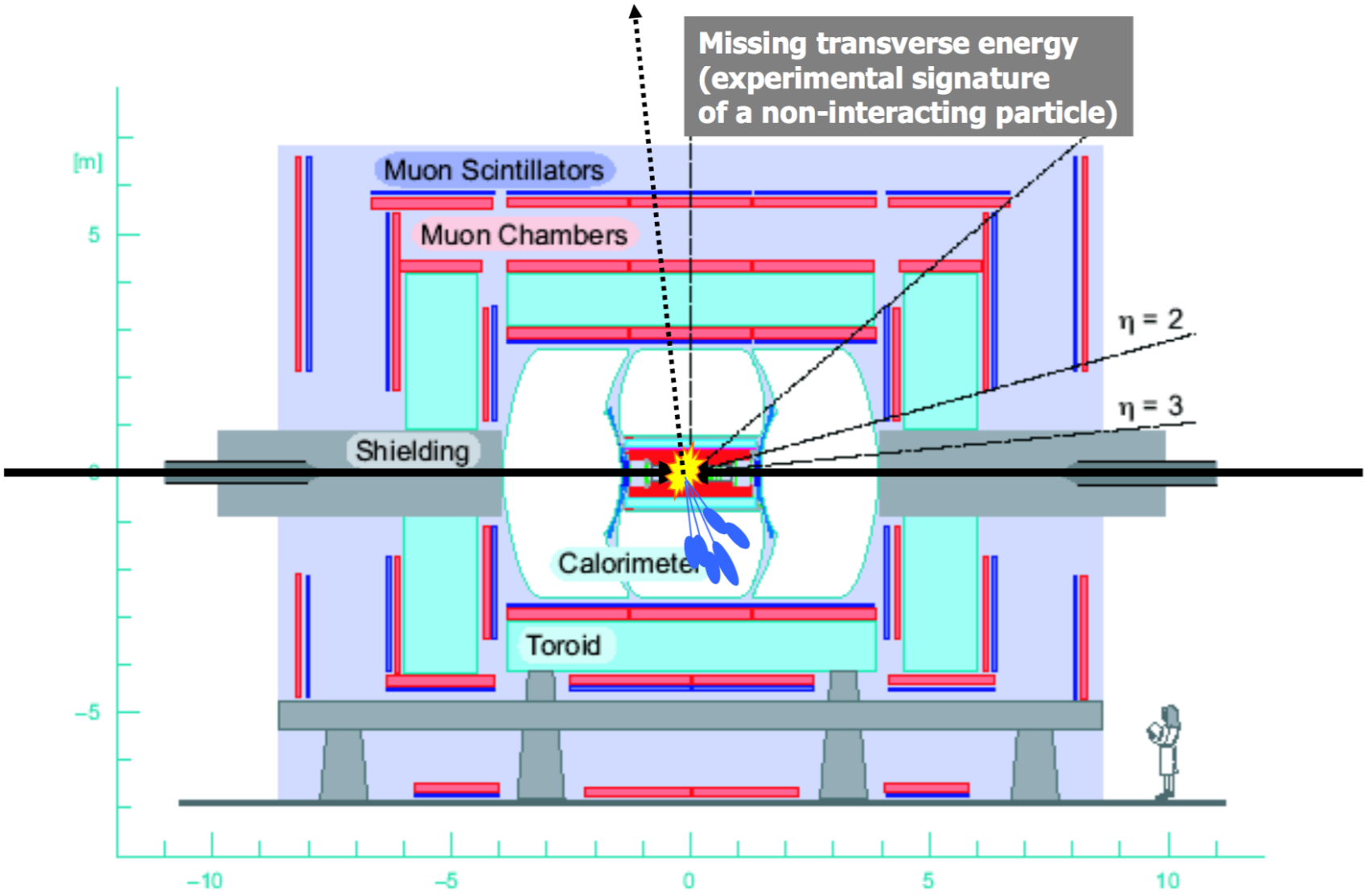
High energy physics experiments: DØ



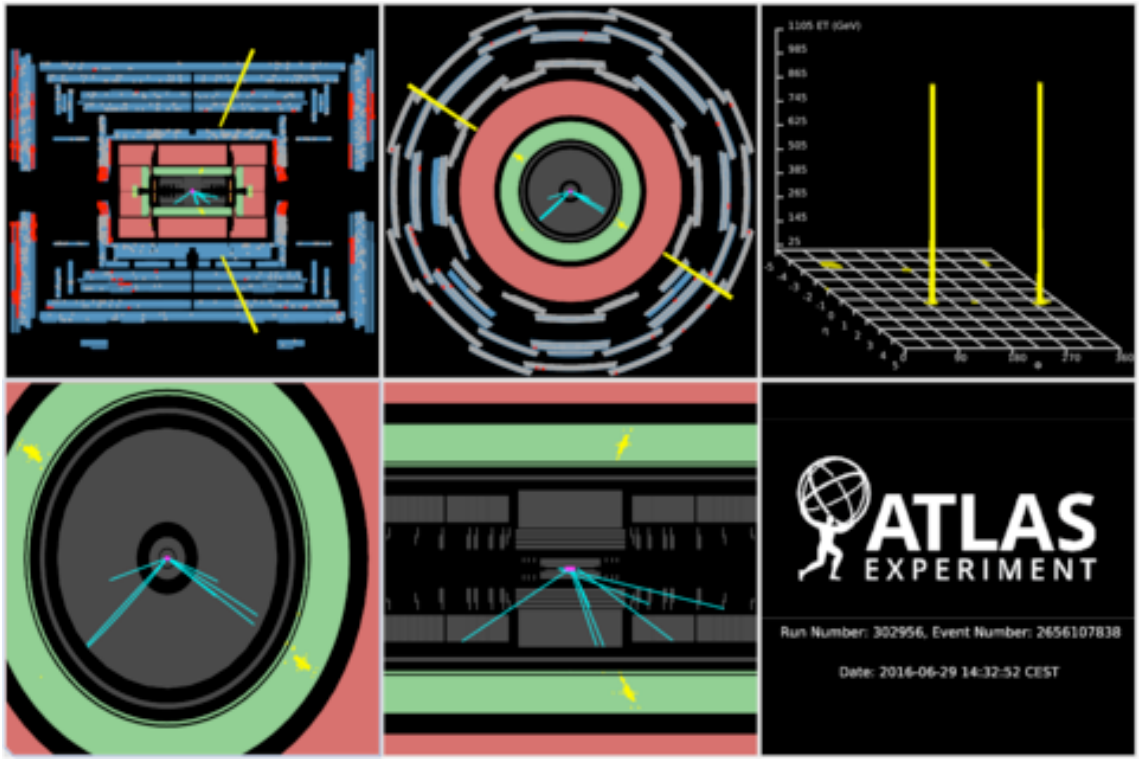
High energy physics experiments: DØ



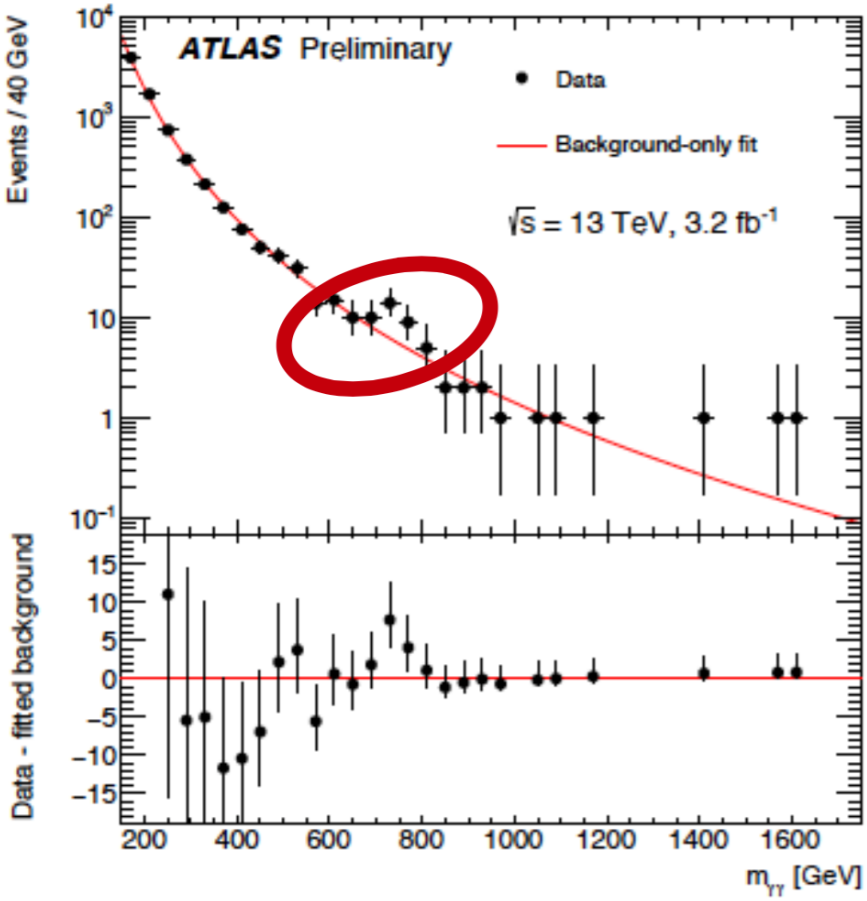
High energy physics experiments: DØ



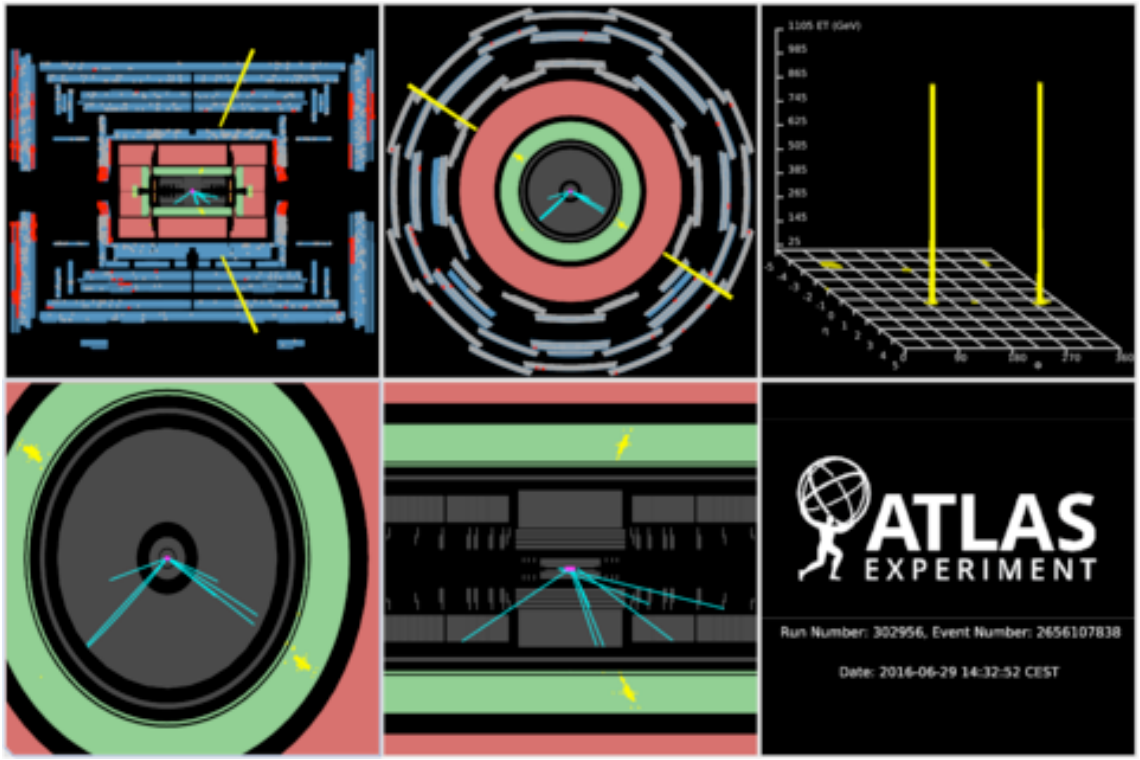
Search for scalar diphoton resonances



$\phi \rightarrow \gamma\gamma$



Search for scalar diphoton resonances



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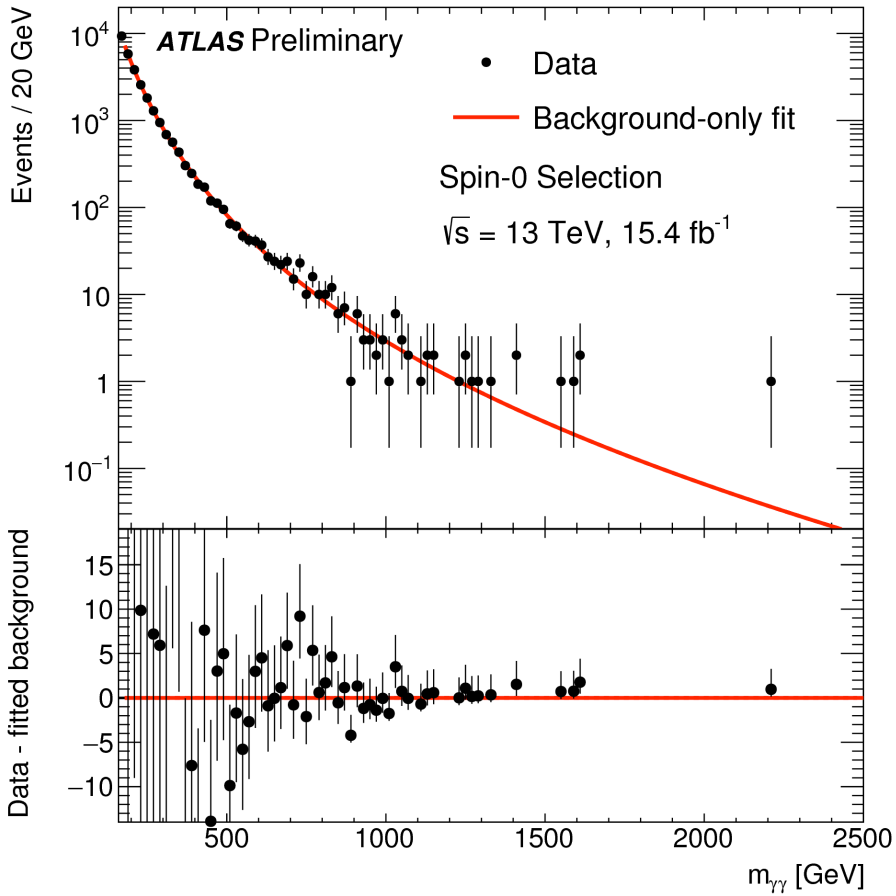
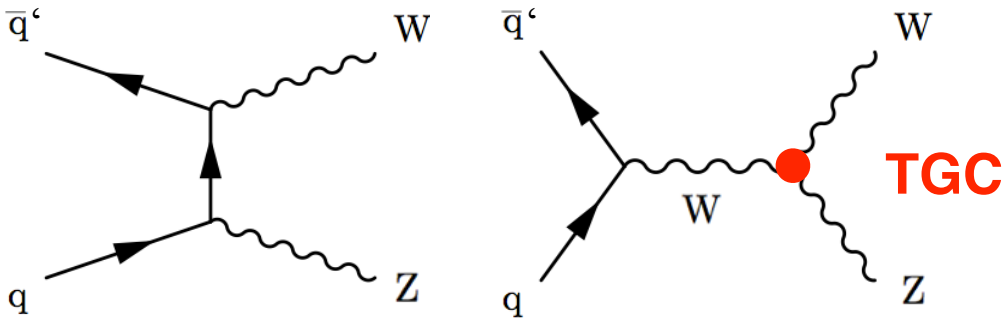
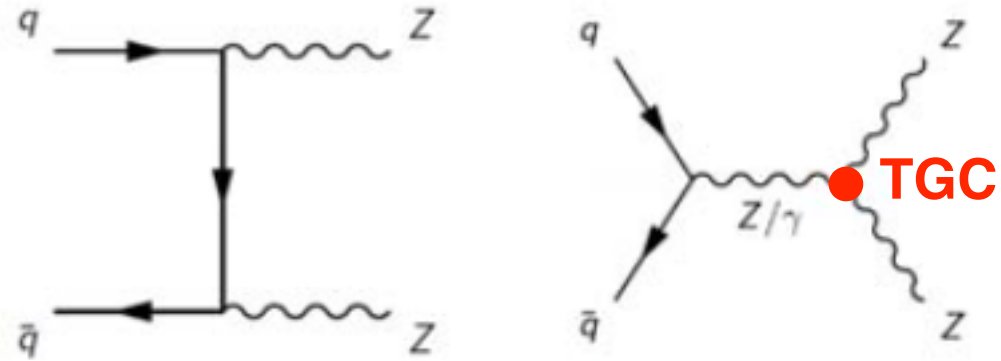
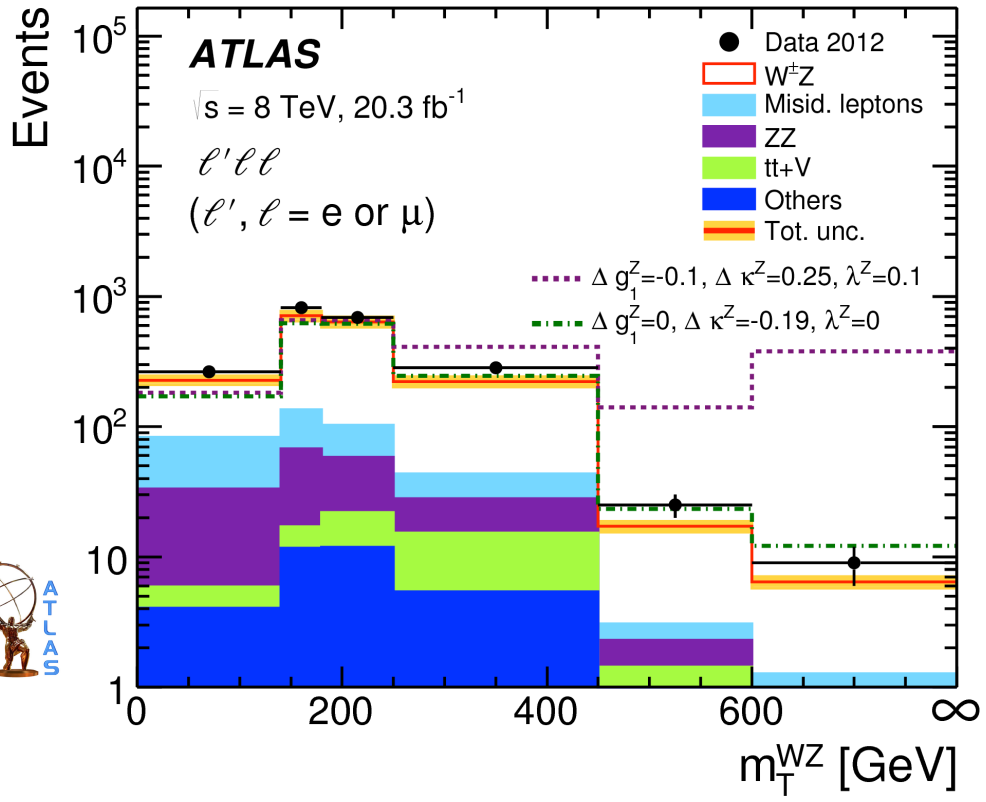
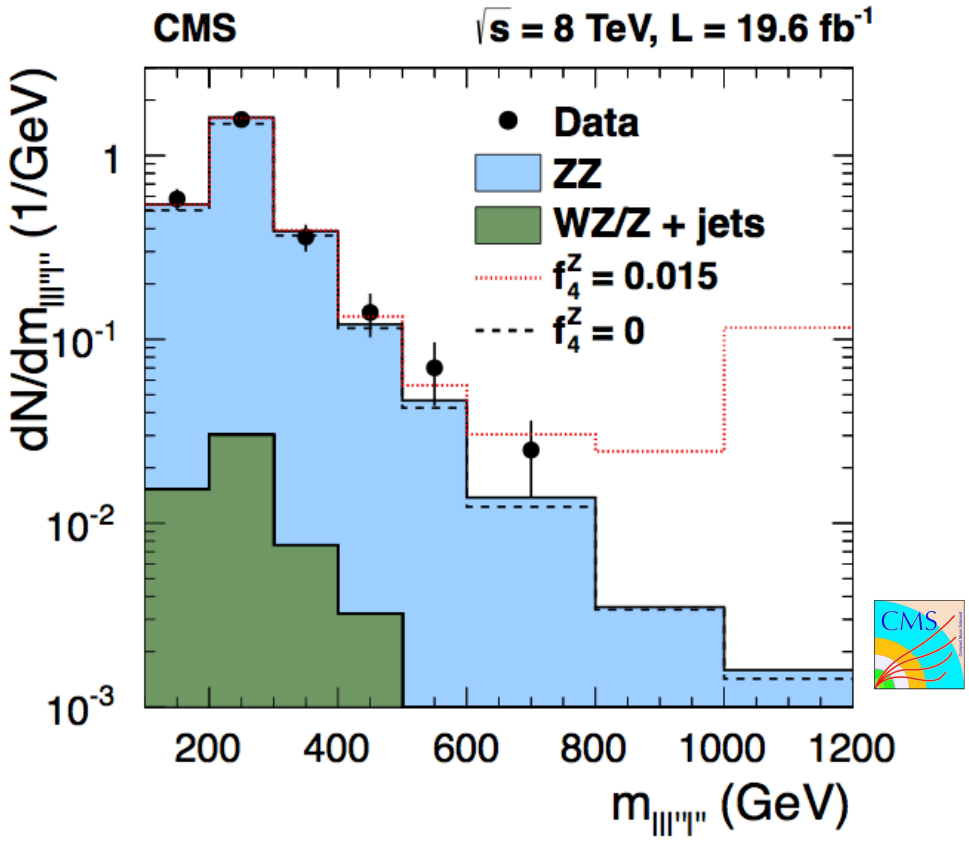


Anomalous Triple Gauge Couplings





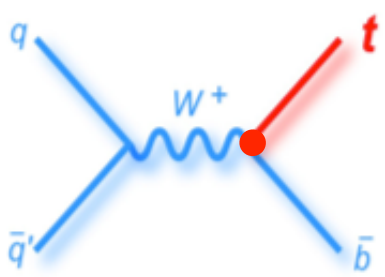


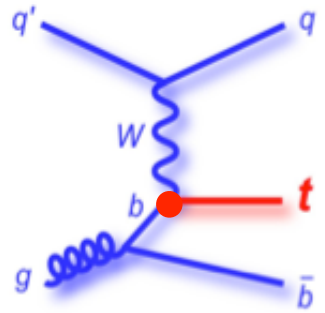


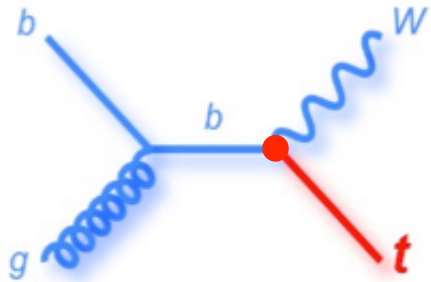
Single Top Quark Production

direct measurement of $|V_{tb}|$

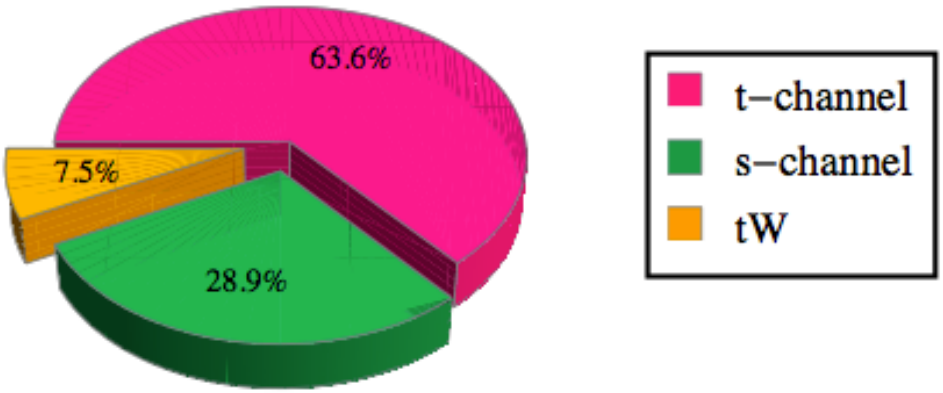
$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



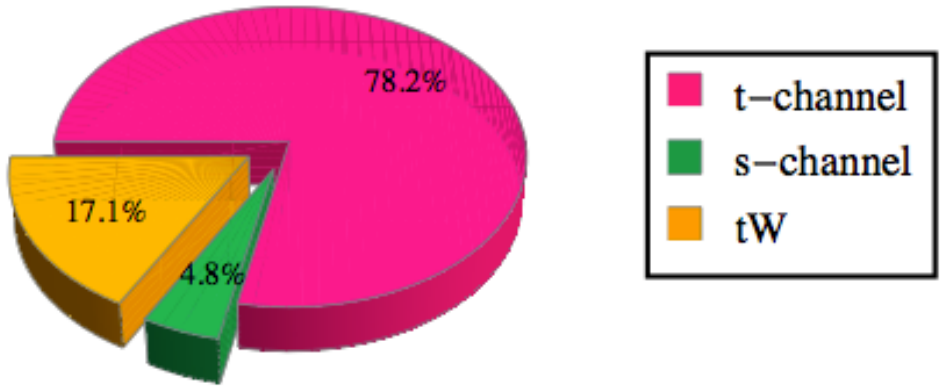




Tevatron



LHC (7 TeV)



⇒ **important to measure all channels separately to search for new physics**

BUT: do not separate Wt in higher orders –an unphysical question!

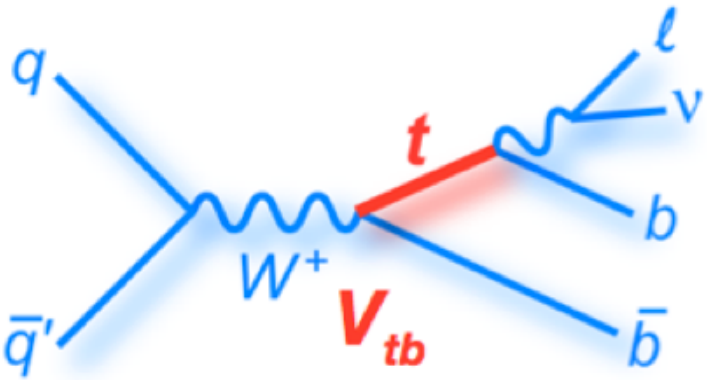
Single Top Quark Selection

s-channel:

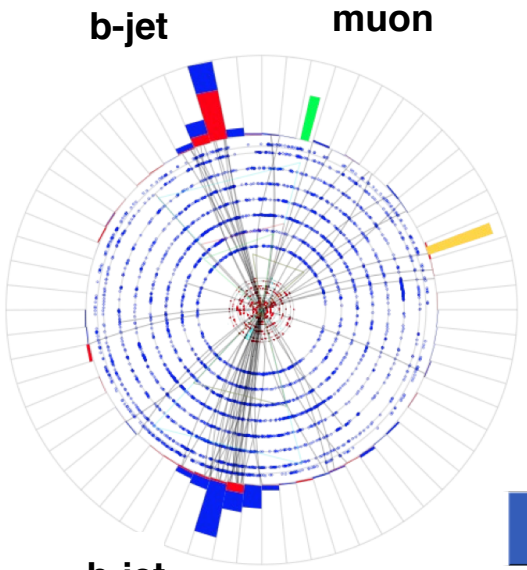
$\sigma_s = 1.05 \pm 0.06$ pb

NLO+NNLL, $m_t = 172.5$ GeV

Kidonakis, PRD 81, 054028 (2010)



- lepton
- missing E_T
- b-jets

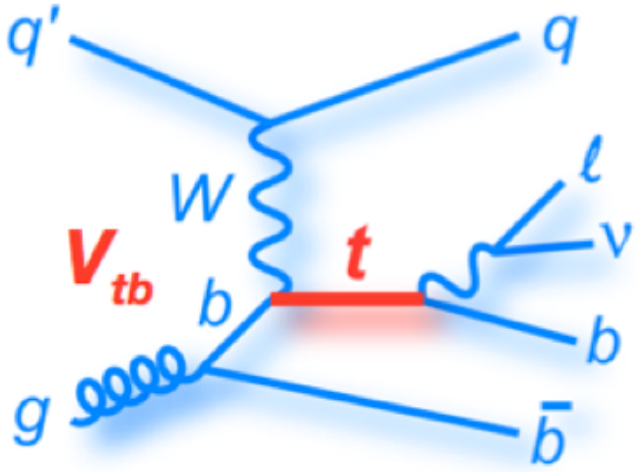


t-channel:

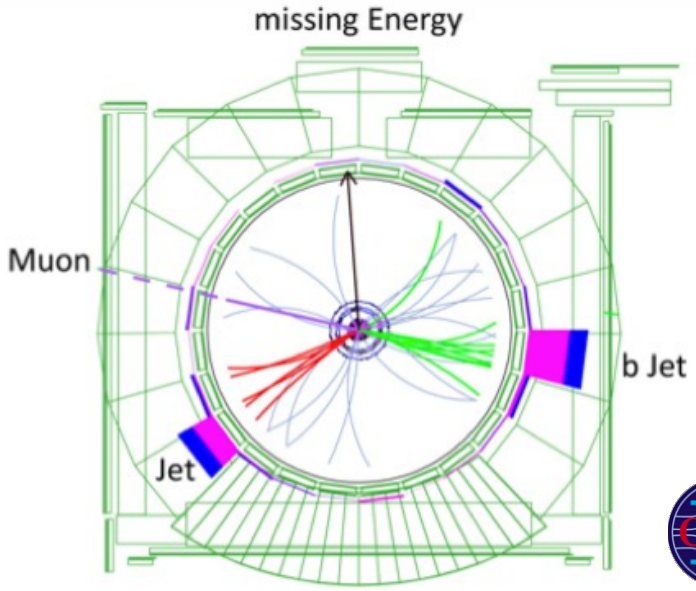
$\sigma_t = 2.12 \pm 0.16$ pb

NLO+NNLL, $m_t = 172.5$ GeV

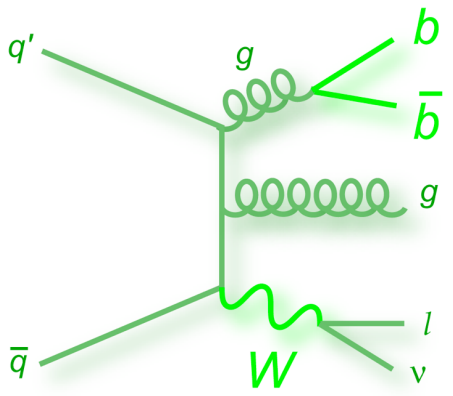
Kidonakis, PRD 83, 091503 (2011)

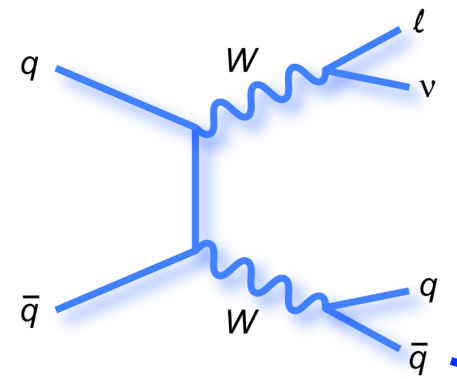


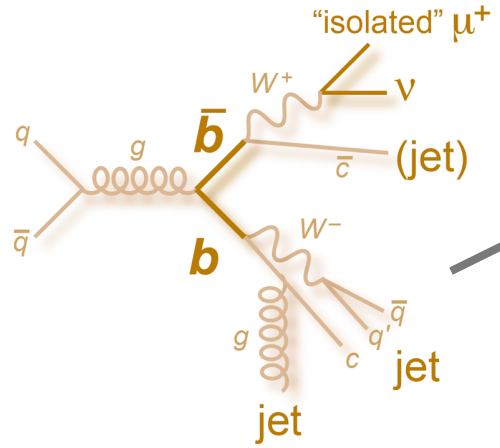
- jets
- lepton
- missing E_T
- b-jets

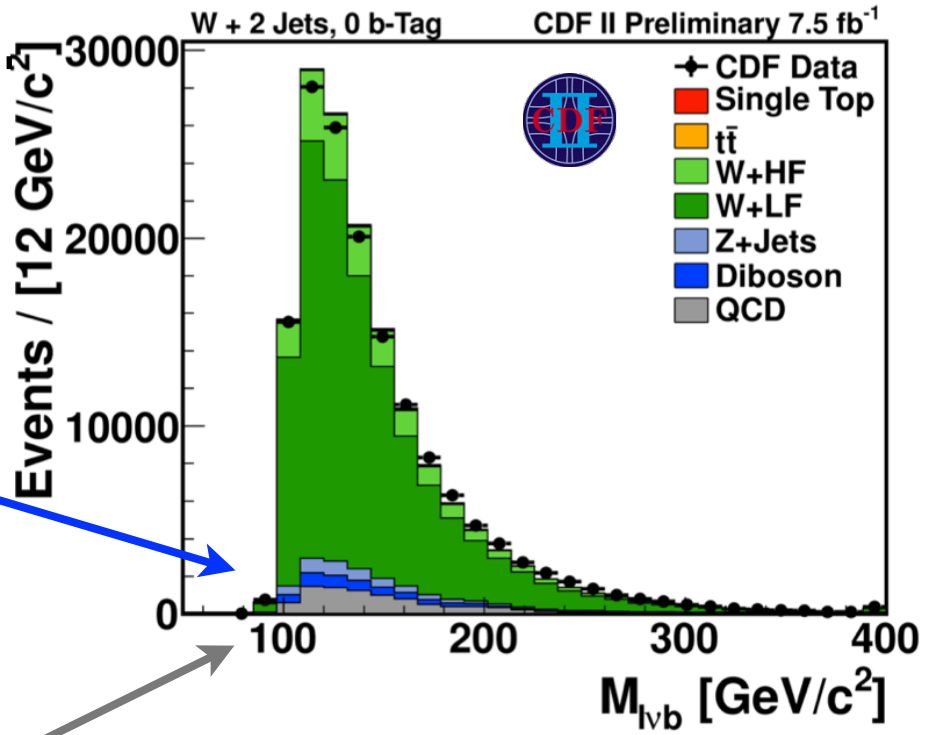


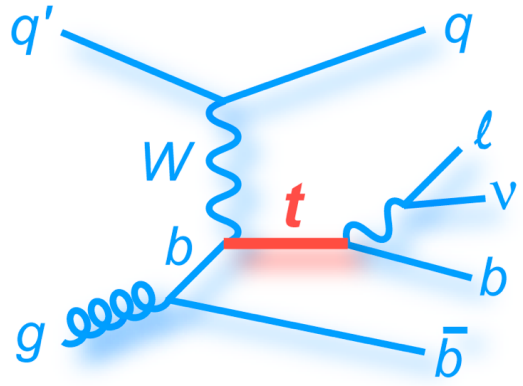
Single Top Quark Yields: pretag

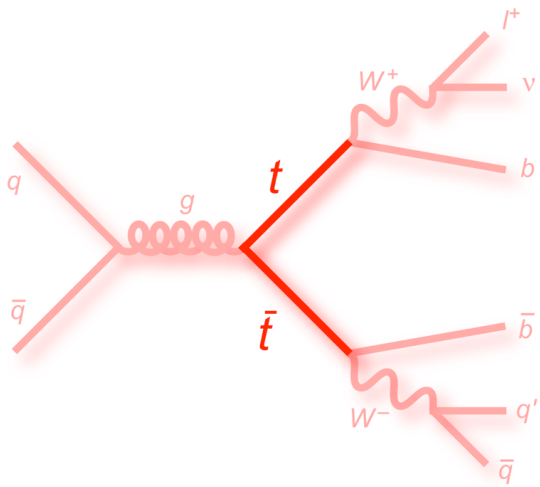






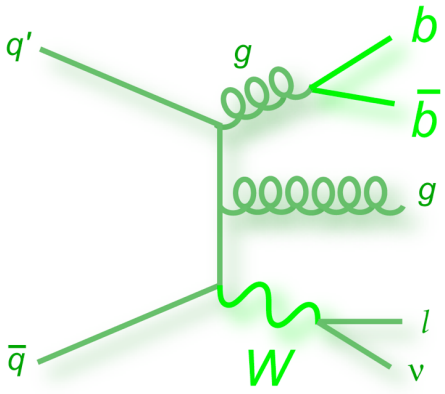


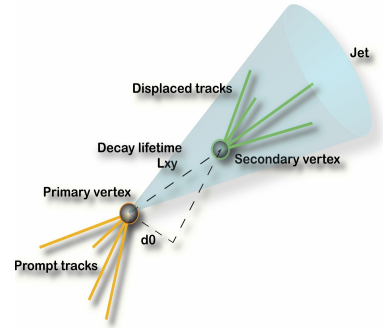


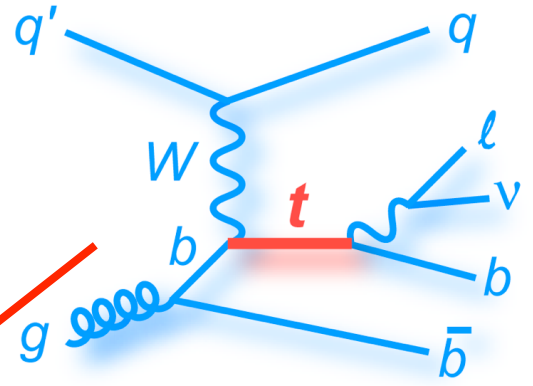


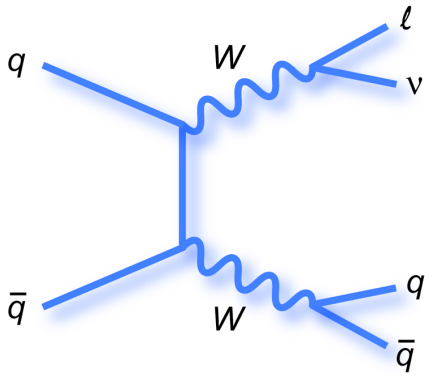
- **best s/b: ~1/200 before b-tagging**

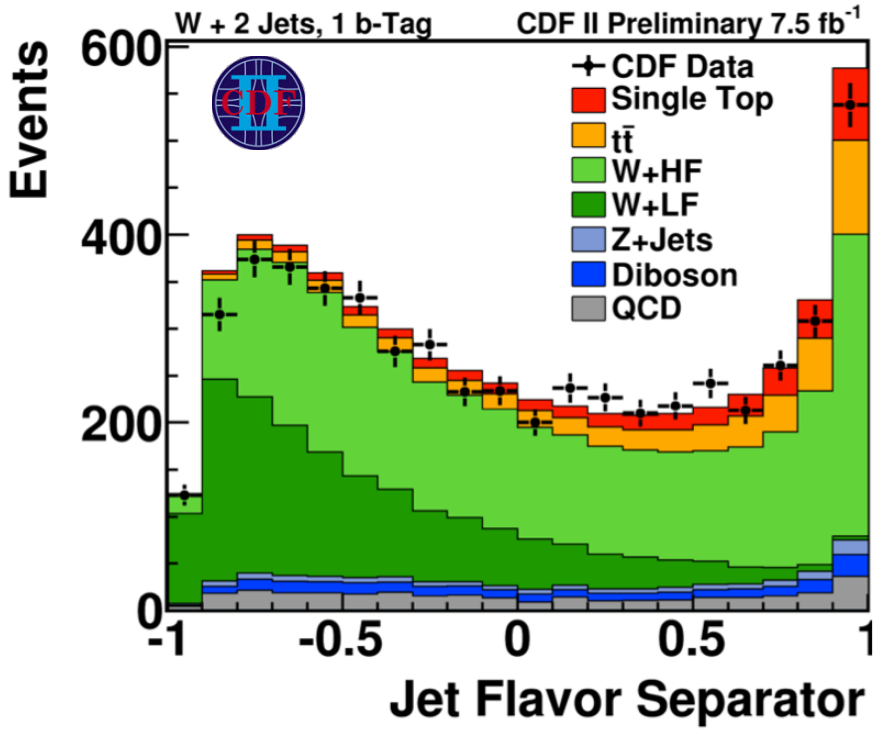
Single Top Quark Yields: b-tagged

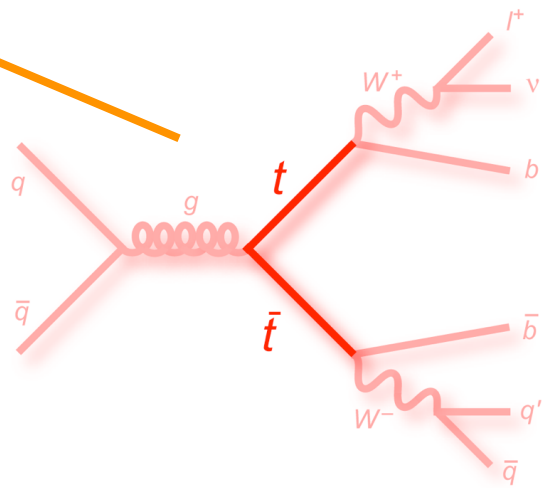


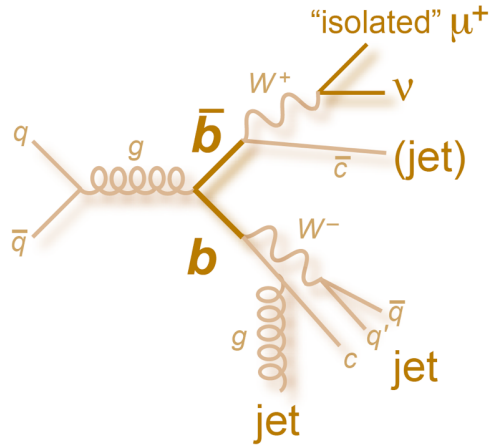






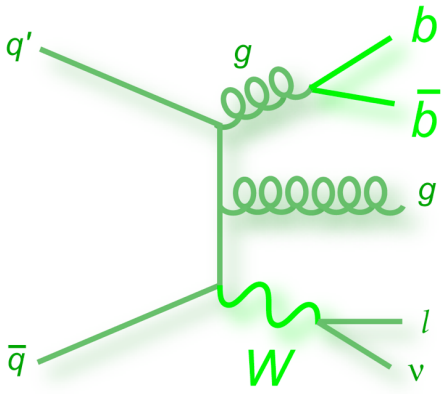


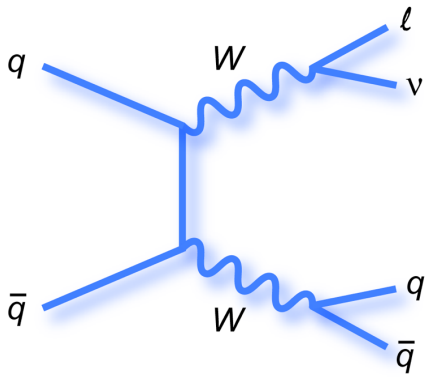


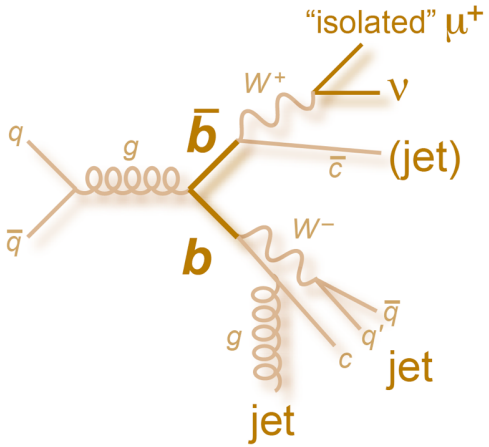


- best s/b: ~1/200 before b-tagging
- best s/b: ~1/10 after b-tagging

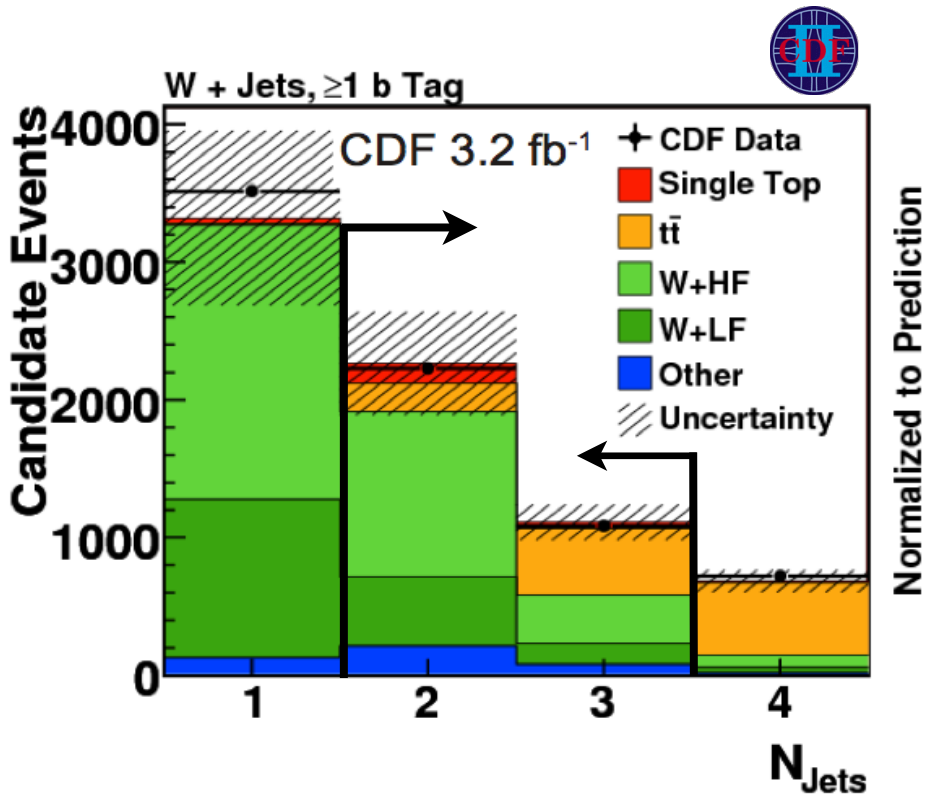
Single Top Quark Yields: b-tagged

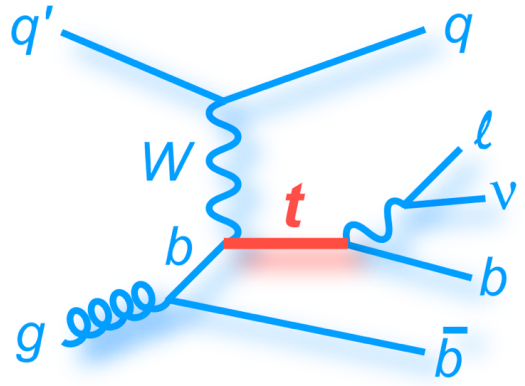


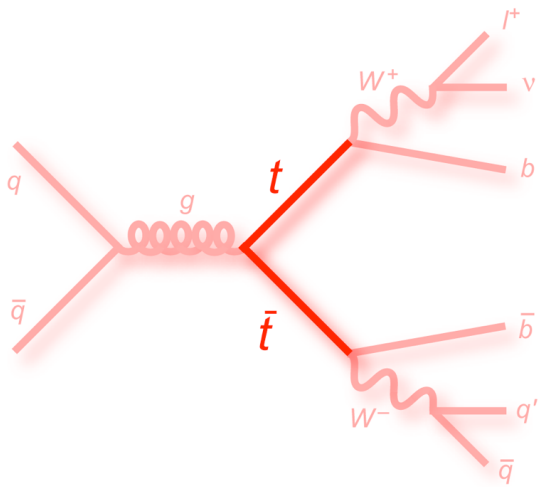




- number of jets and number of b tags to define samples



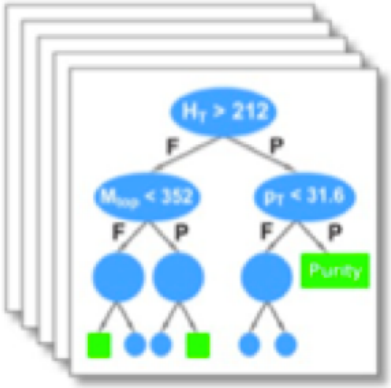




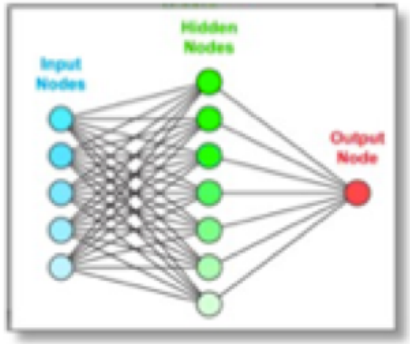
- best s/b: ~1/200 before b-tagging
- best s/b: ~1/10 after b-tagging

Multivariate Analyses

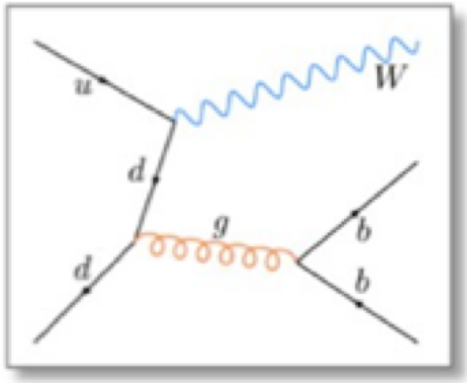
Boosted Decision Trees



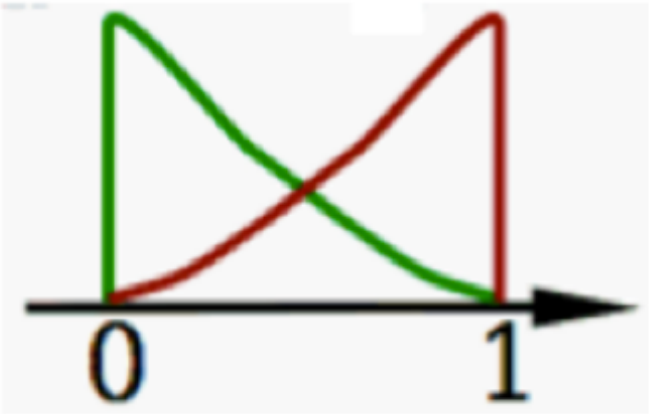
Neural Networks



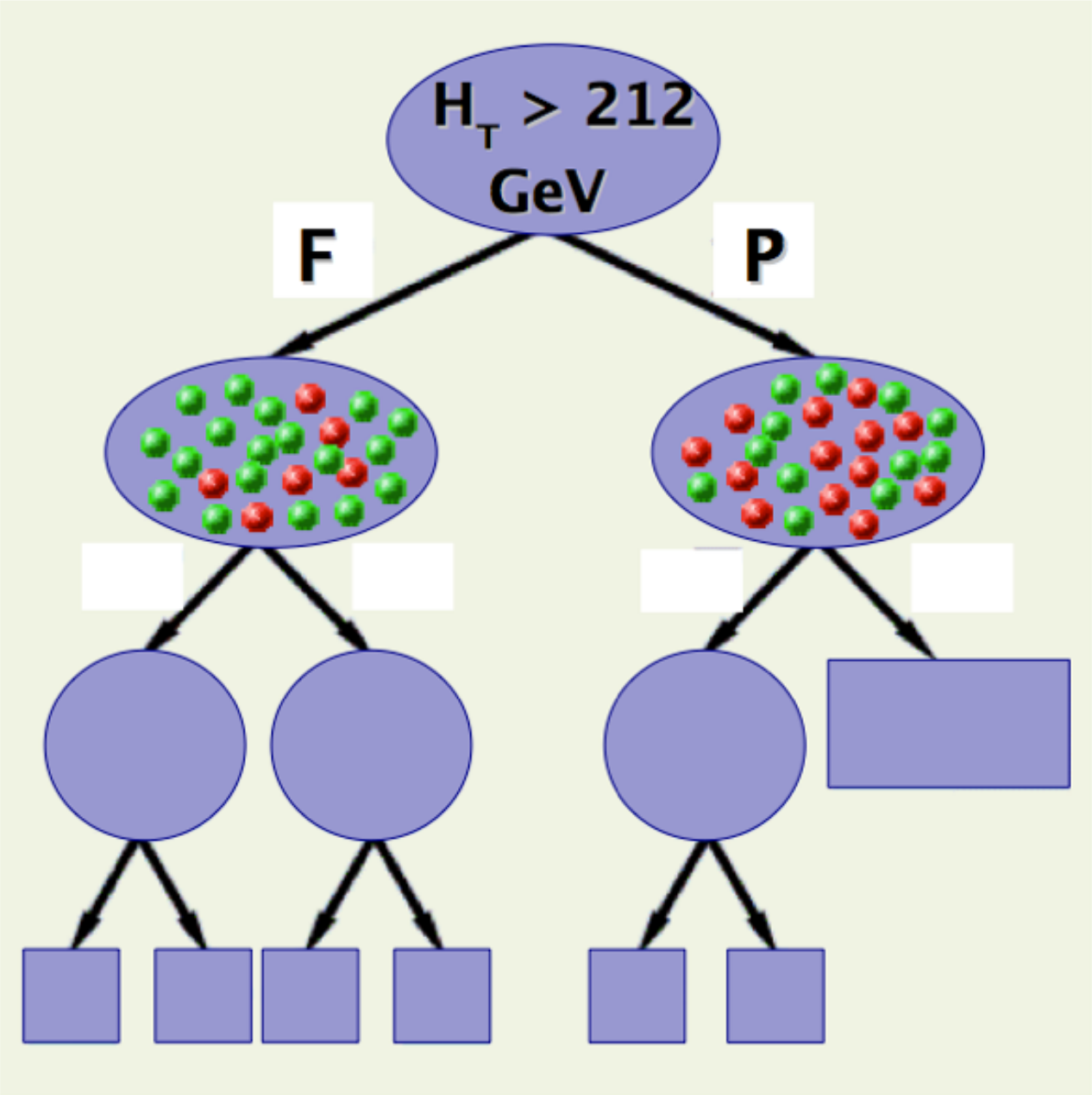
Matrix Elements



background **signal**

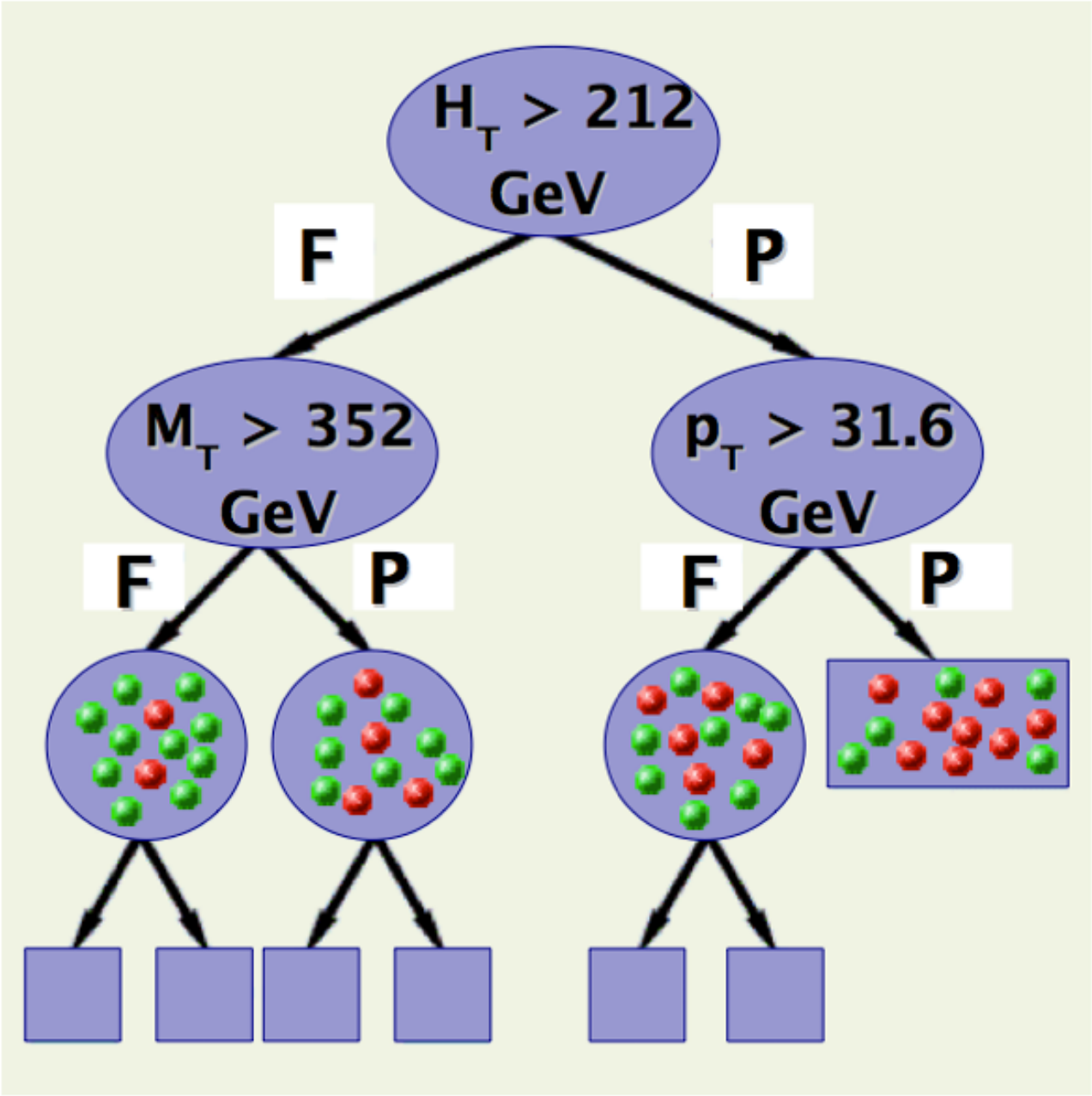


Boosted Decision Trees



- **IDEA: recover events that fail criteria in cut-based analyses**

Boosted Decision Trees



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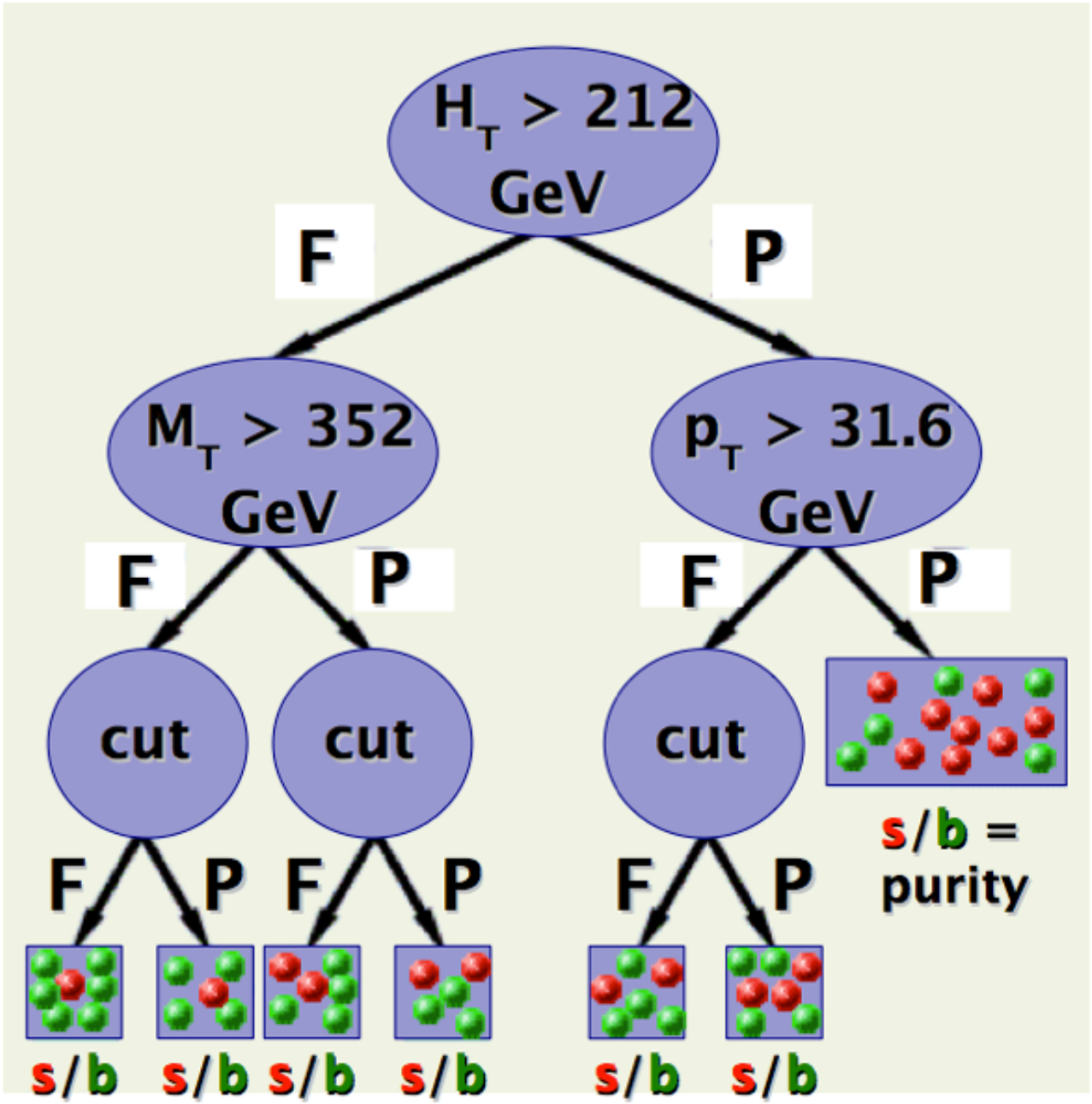
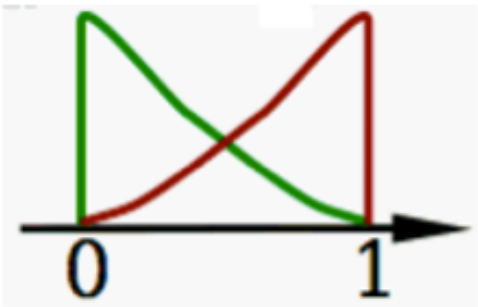
Boosted Decision Trees

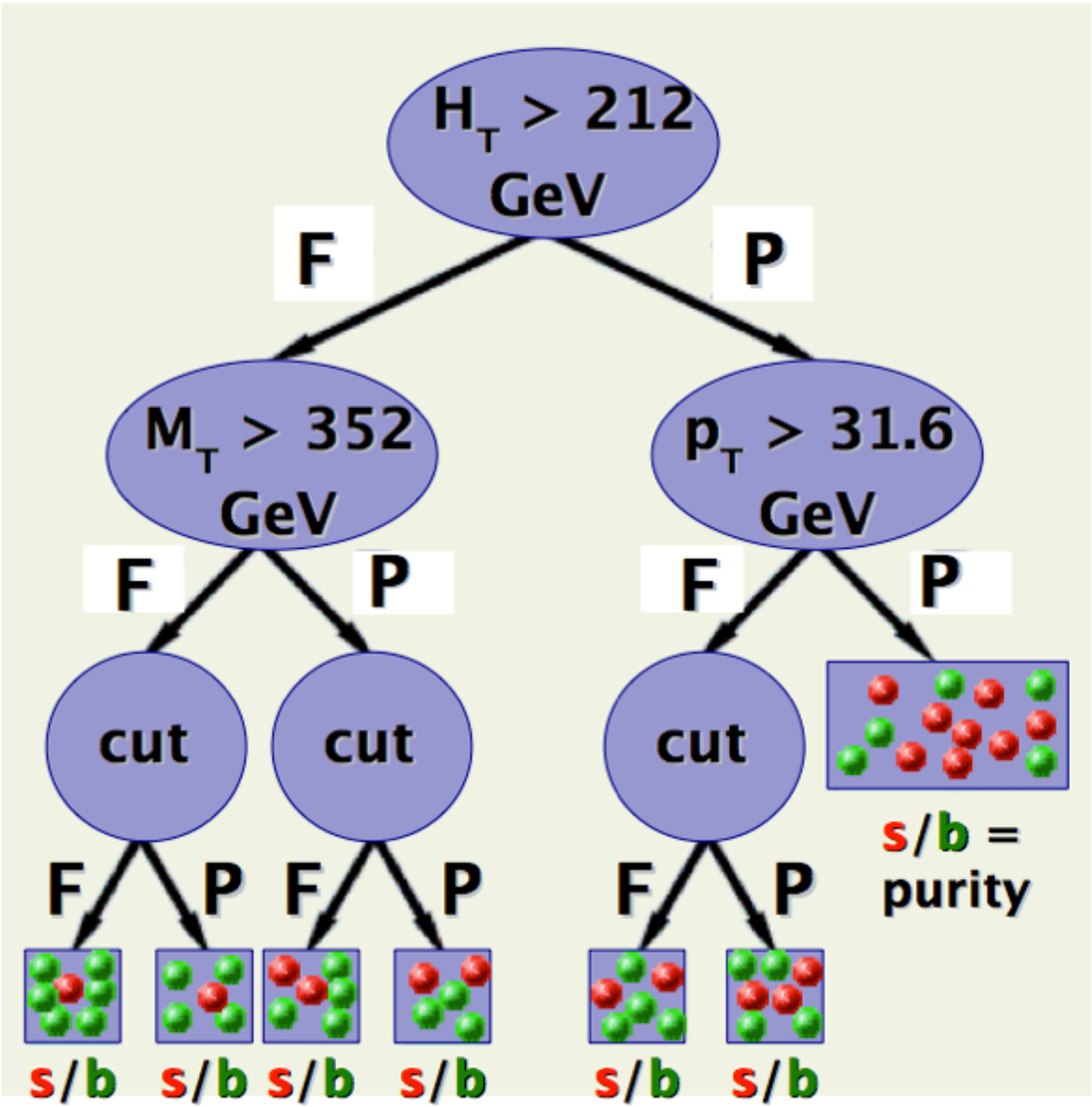


- **IDEA: recover events that fail criteria in cut-based analyses**

- **result: weight for every event**



Boosted Decision Trees

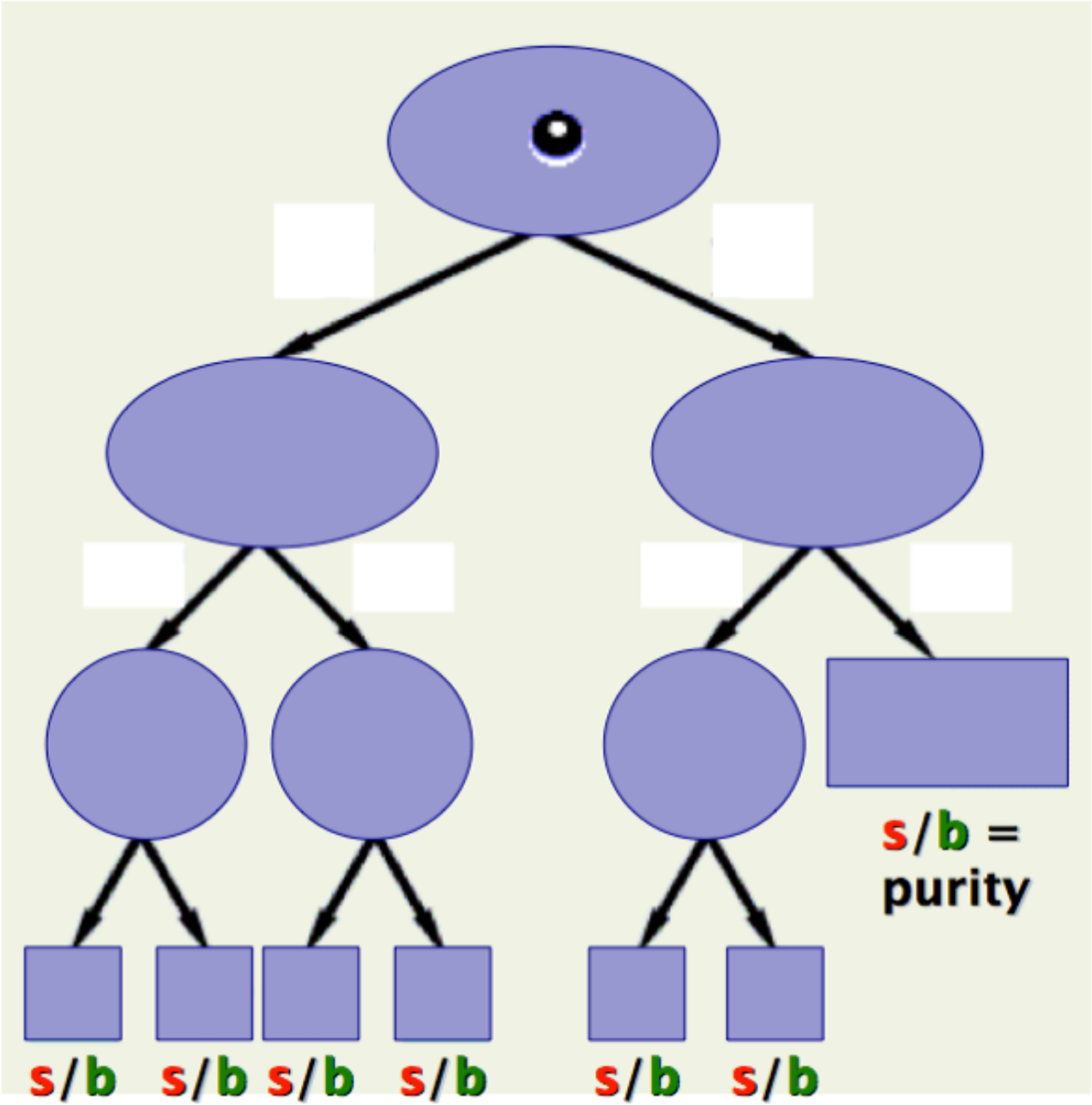


- **IDEA: recover events that fail criteria in cut-based analyses**

boosting:

- train tree: T_k
- derive weight: α_k
- retrain tree: T_{k+1} to minimize error
- average: $T = \Sigma\, \alpha_i\, T_i$

Boosted Decision Trees



- **IDEA: recover events that fail criteria in cut-based analyses**

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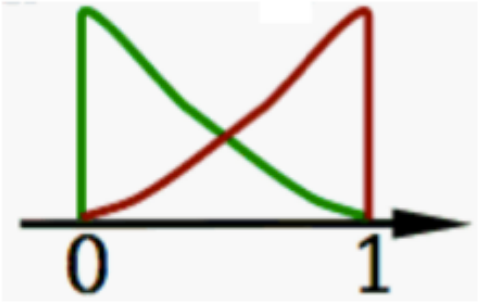
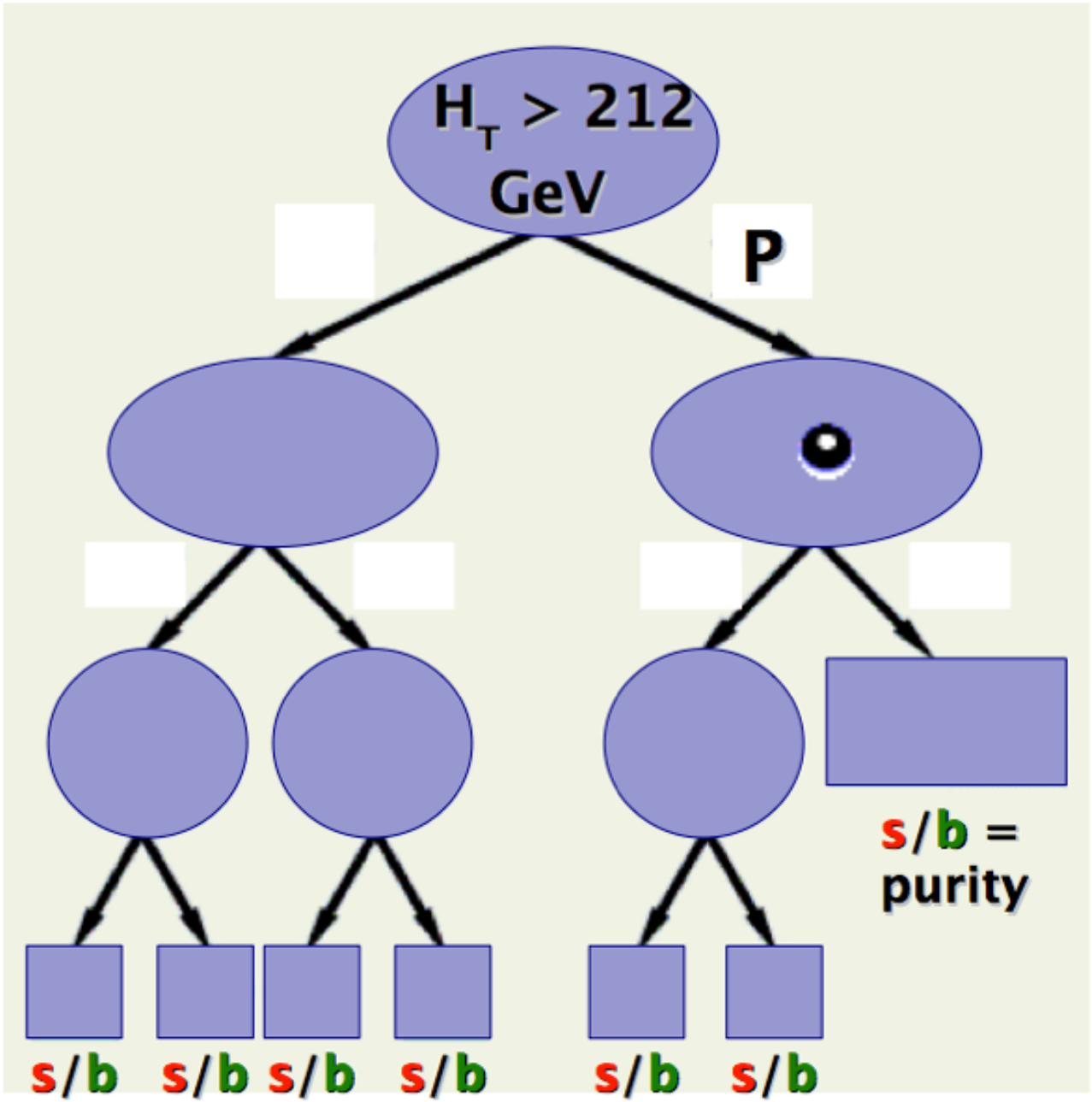
background signal



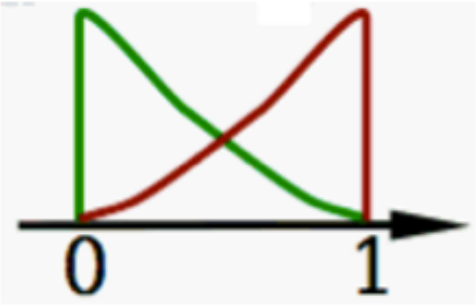
Boosted Decision Trees



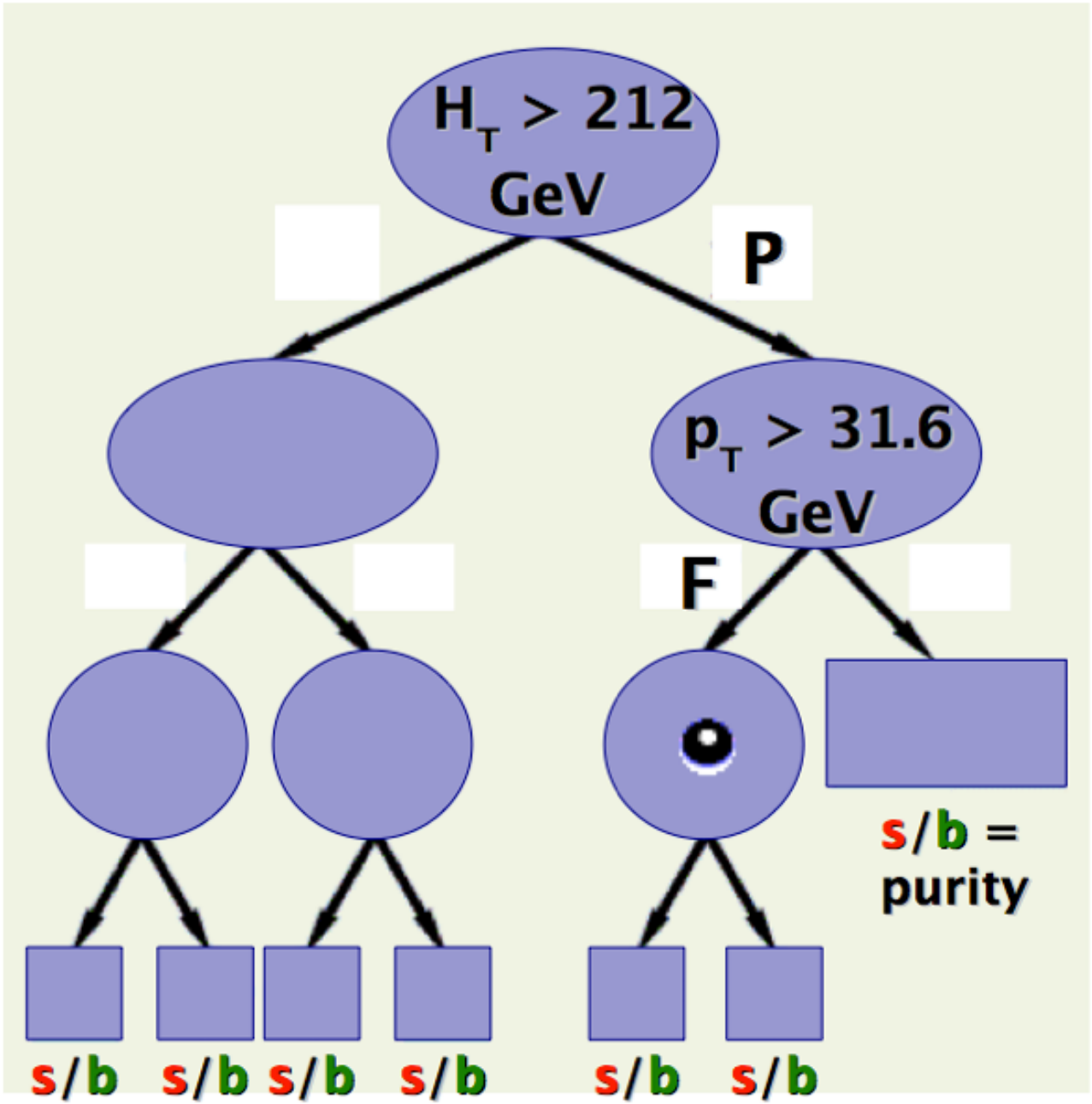
- **IDEA: recover events that fail criteria in cut-based analyses**

- **result: weight for every event**

background signal

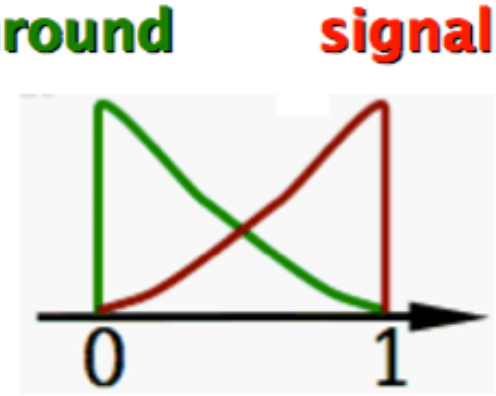


Boosted Decision Trees

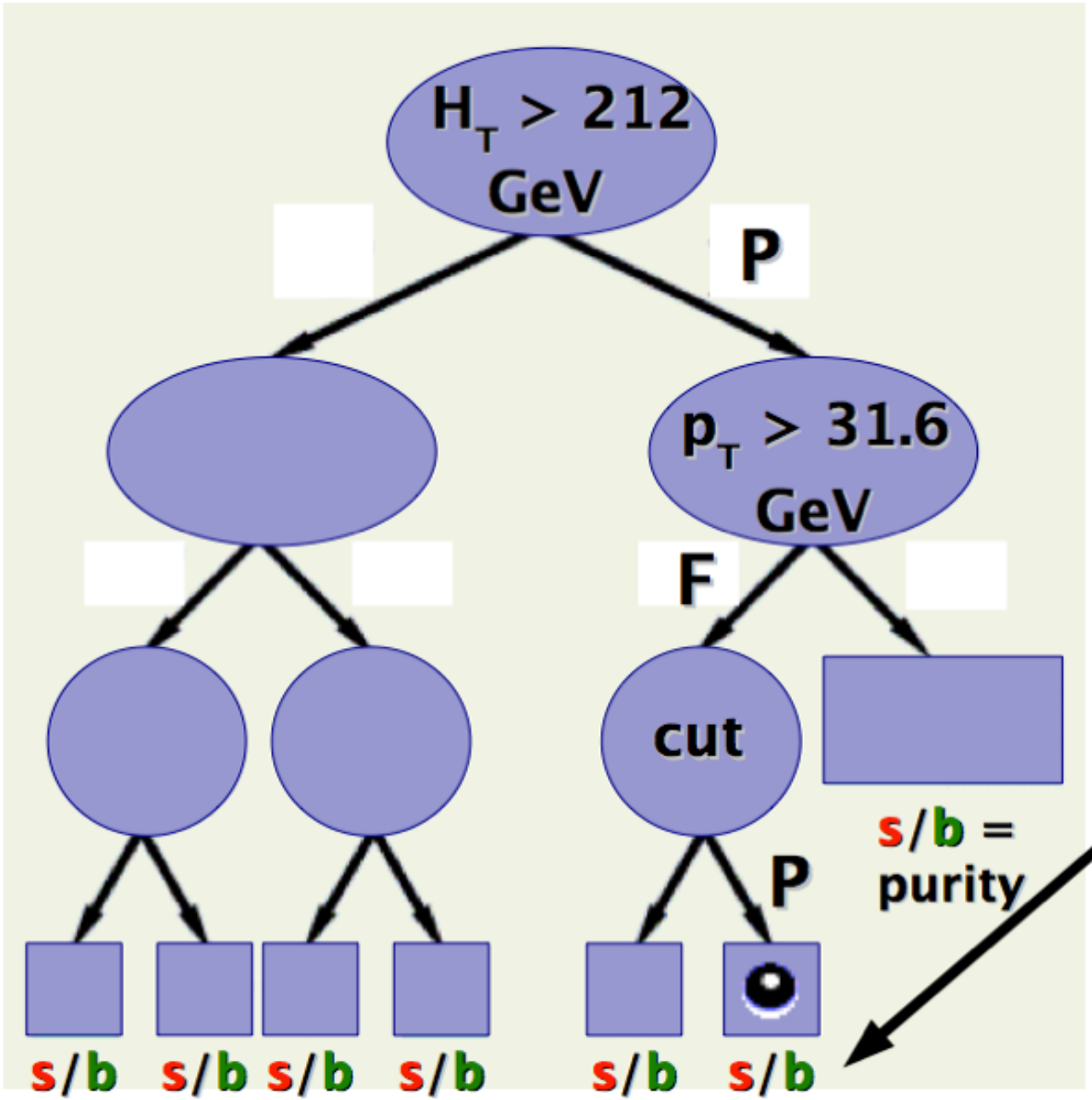


- **IDEA: recover events that fail criteria in cut-based analyses**

- **result: weight for every event**



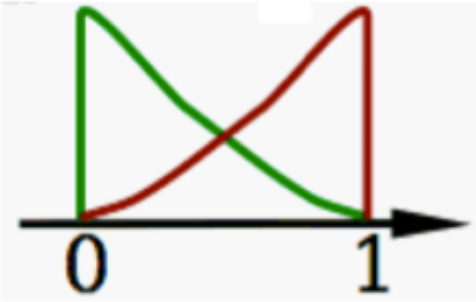
Boosted Decision Trees



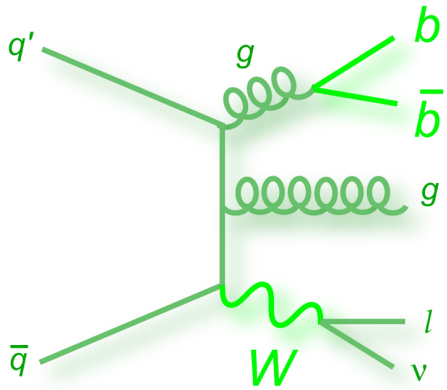
- **IDEA: recover events that fail criteria in cut-based analyses**

- **result: weight for every event**

background signal



Output Discriminant for s+t channel



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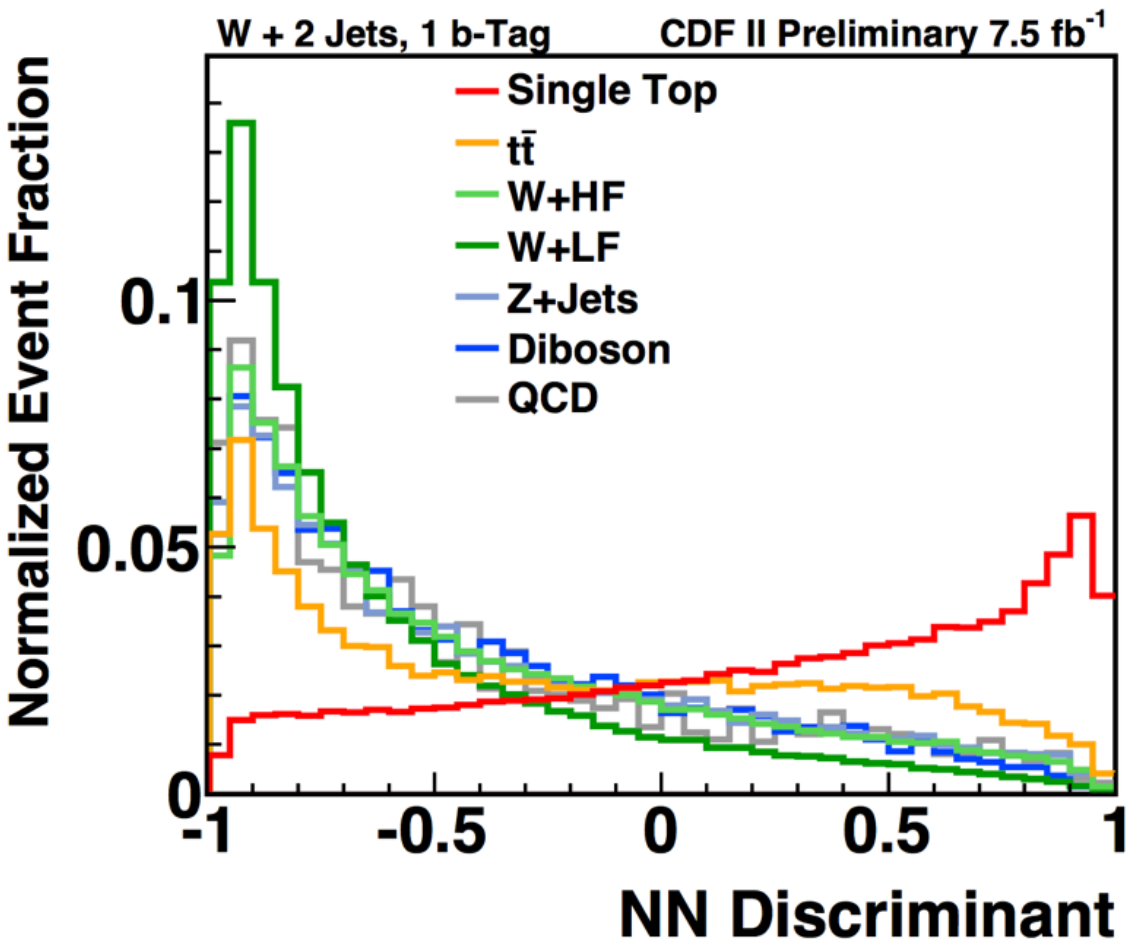
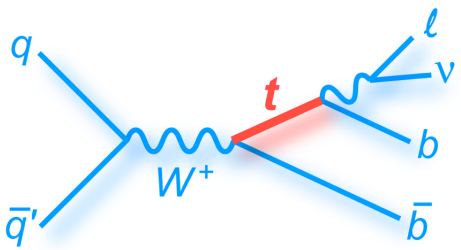
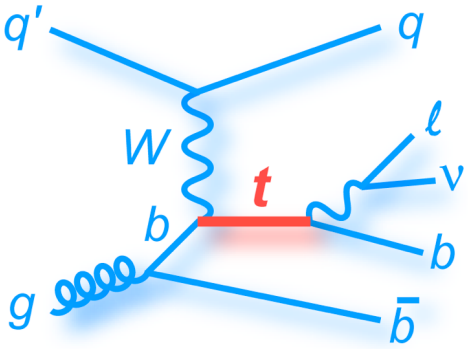
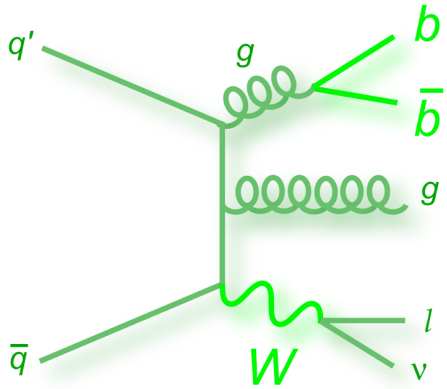


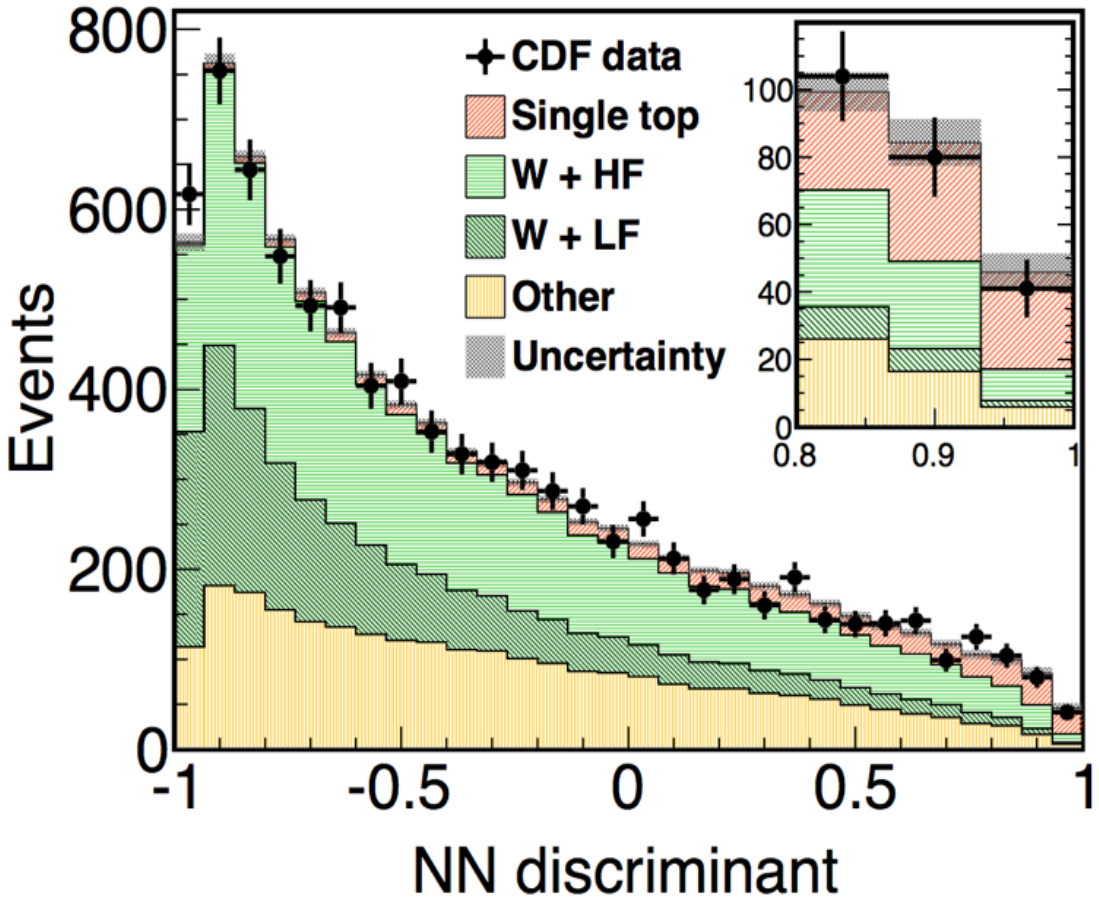


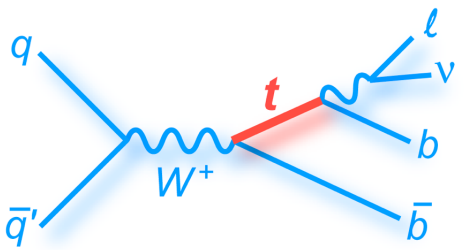


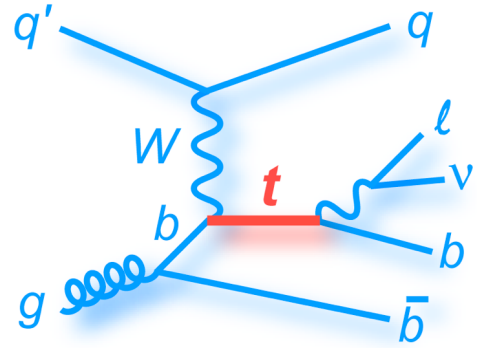
Output Discriminant for s+t channel



Phys. Rev. Lett. 113, 261804 (2014)



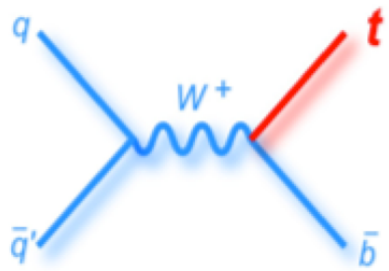


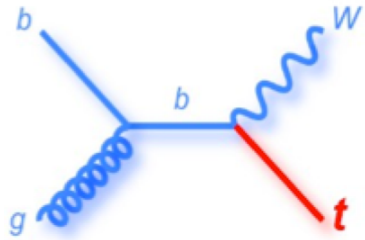


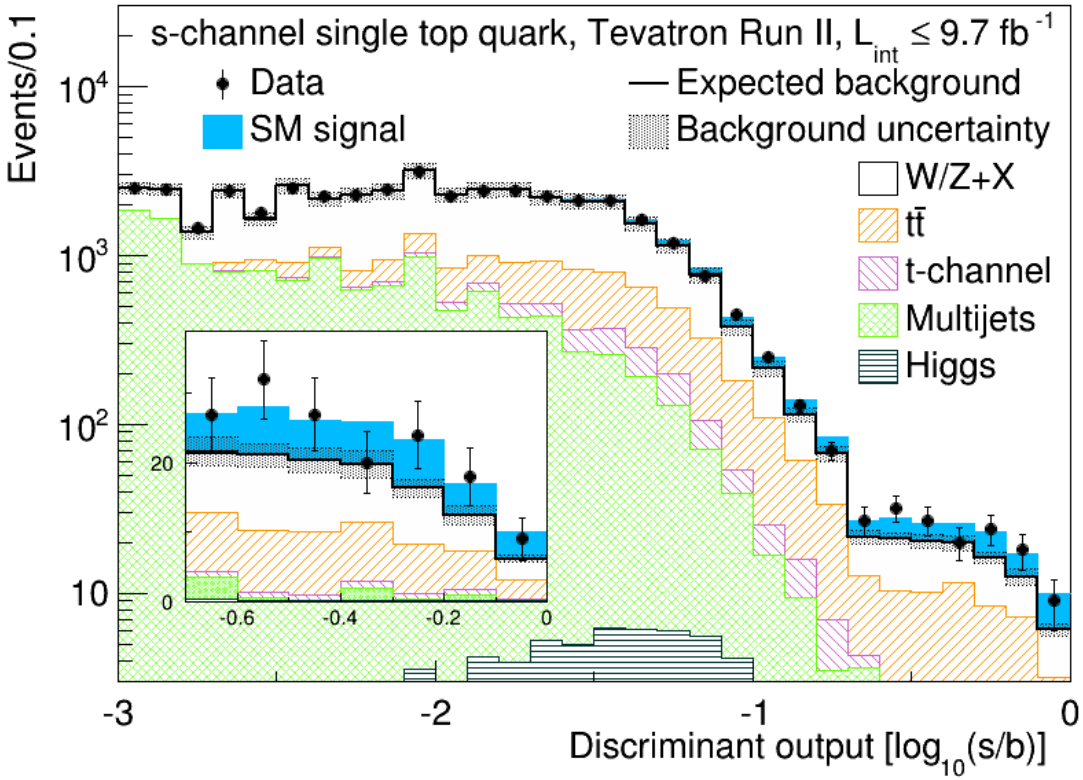
→ **s+t channel observed by CDF and D0 in 2009**

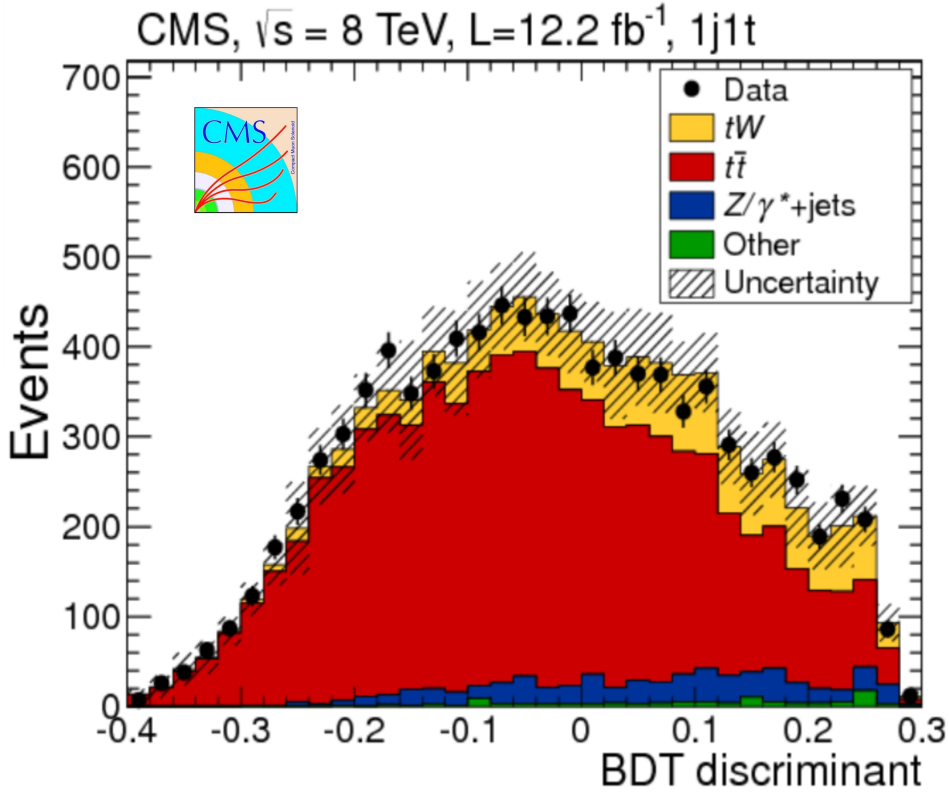
Single Top Quark Observation

s- and Wt-channel Production





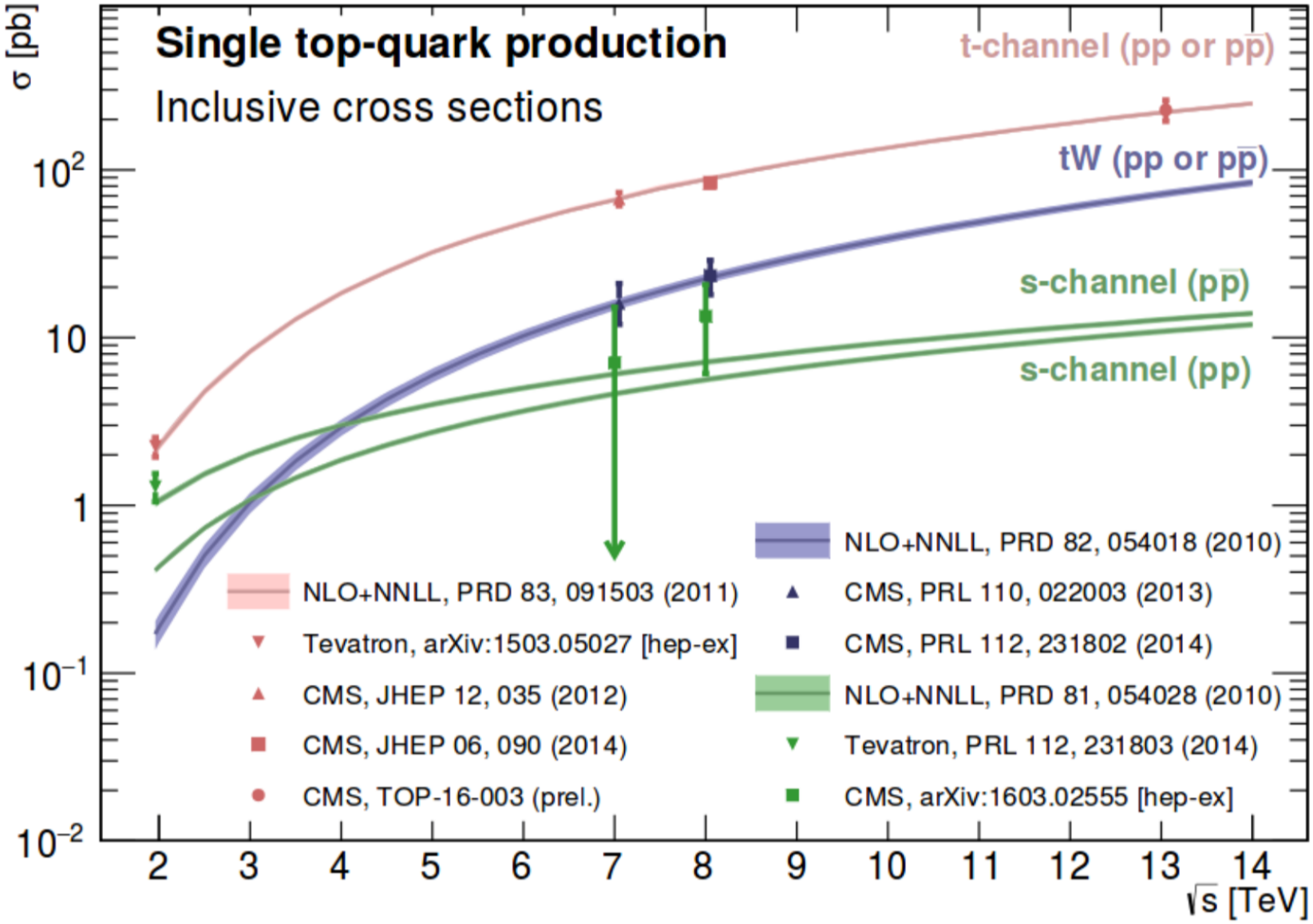


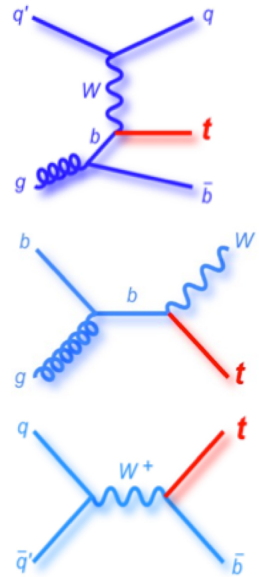


→ observation: 6.3 s.d.

→ observation: 6.1 s.d.

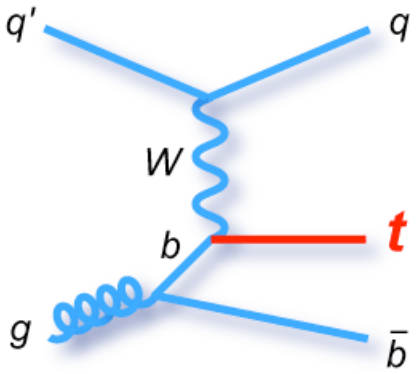
Single channel cross sections



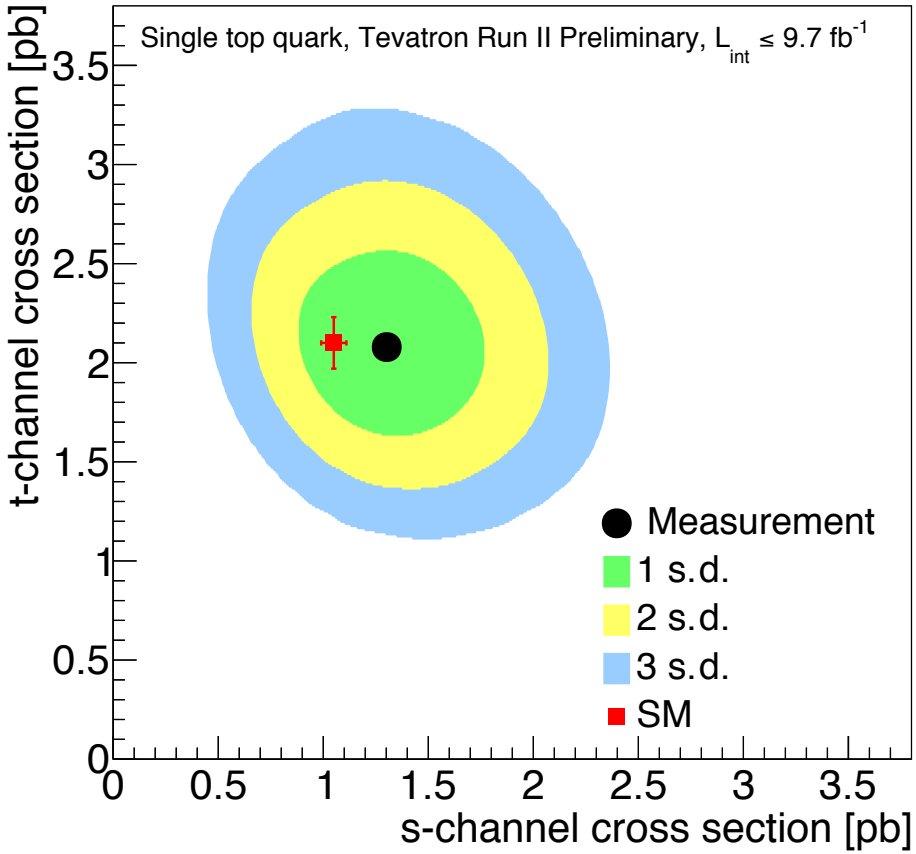


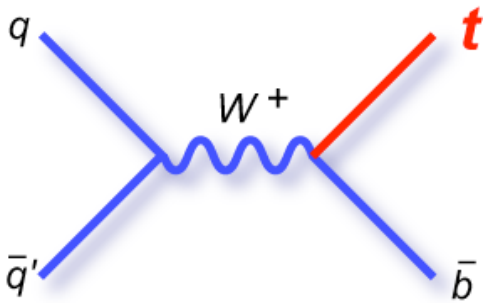
→ **all production modes observed!**

Single Top s- vs. t-channel

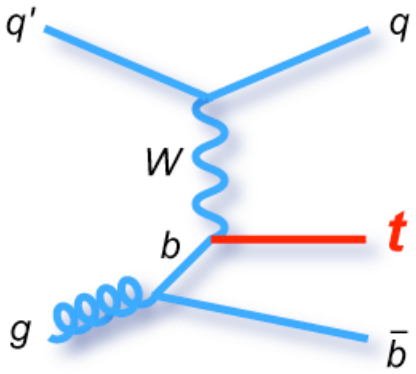


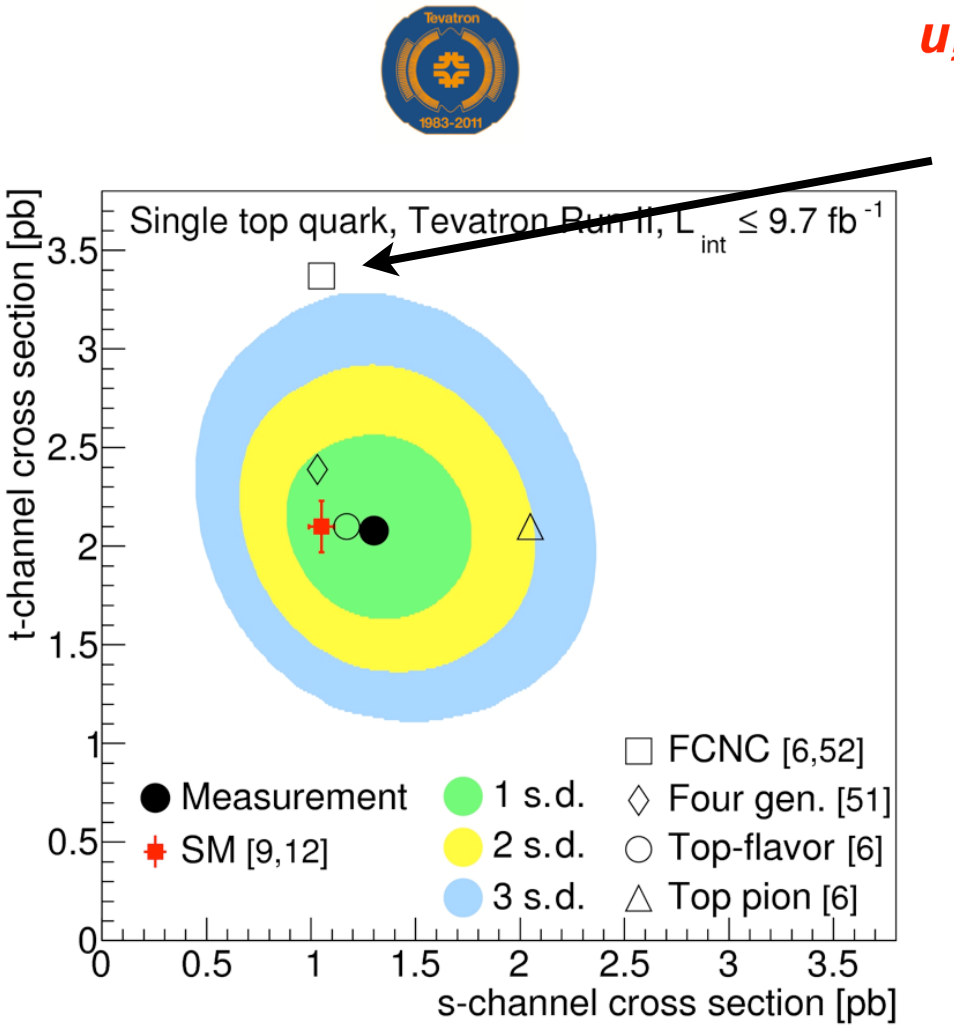
PRL 115, 152003 (2015)

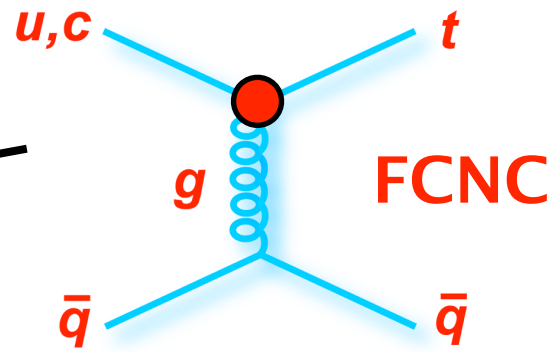


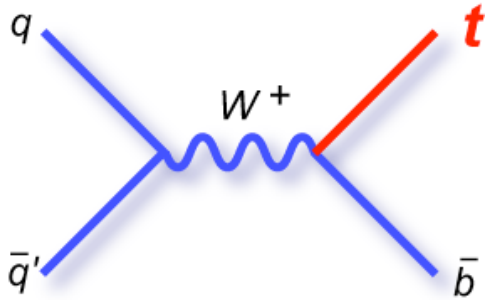


Single Top s- vs. t-channel

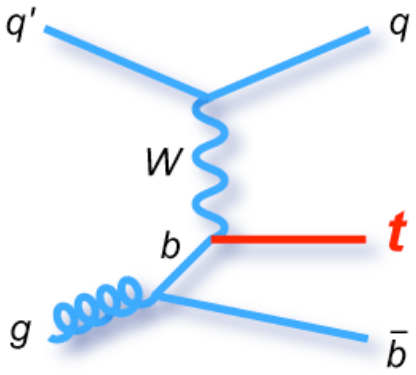


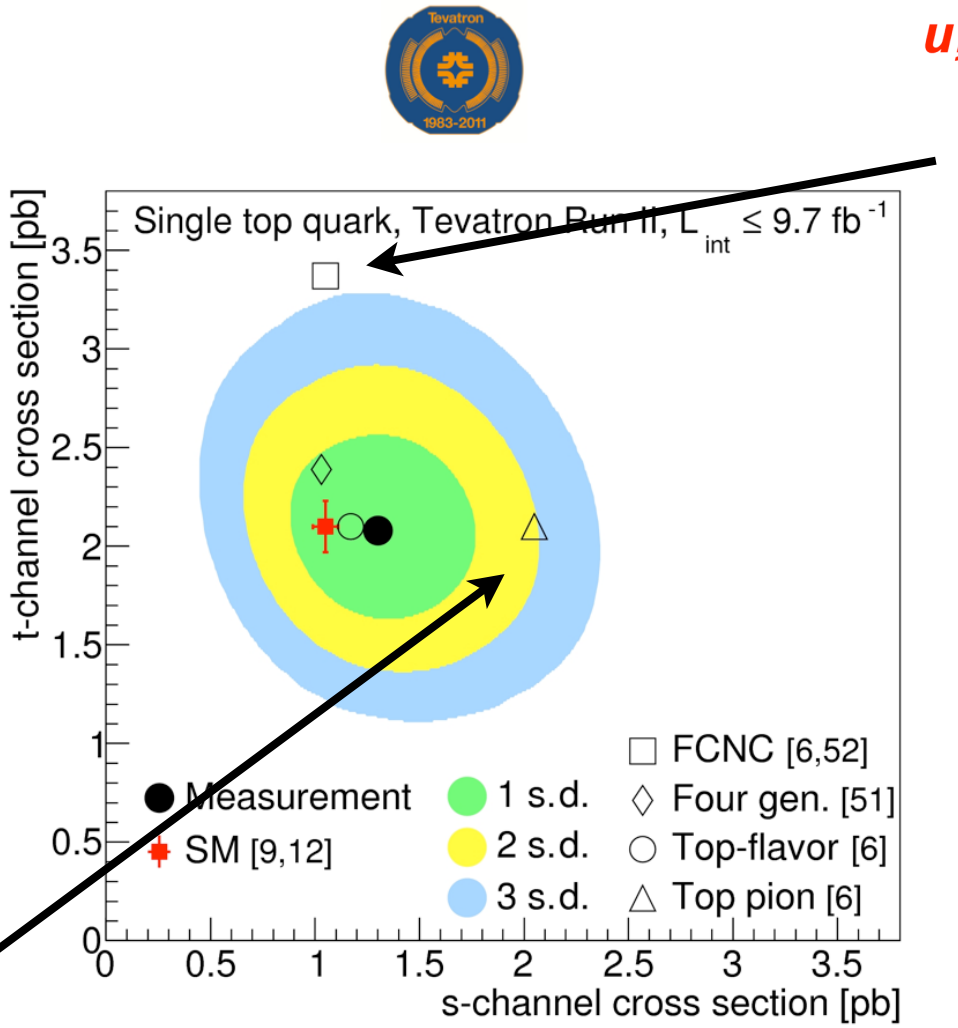


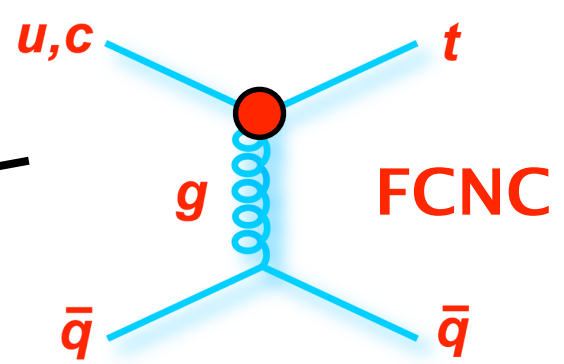


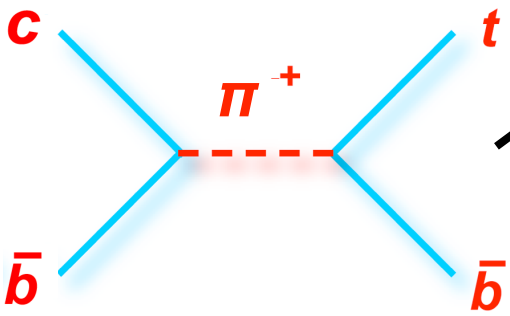


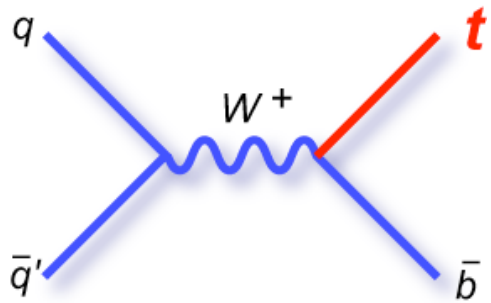
Single Top s- vs. t-channel





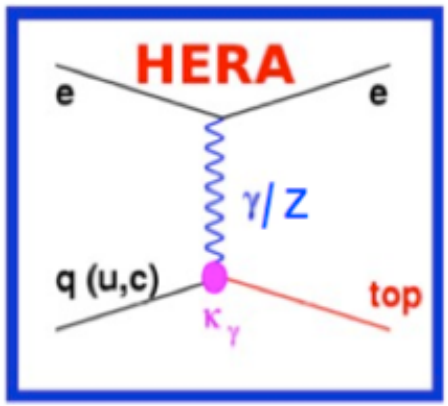


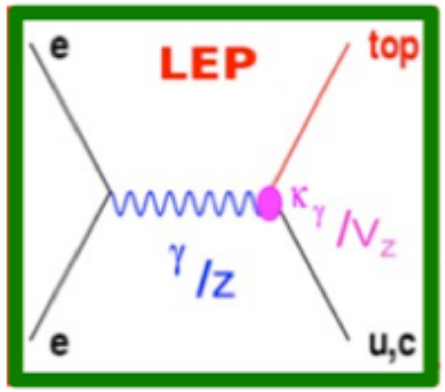


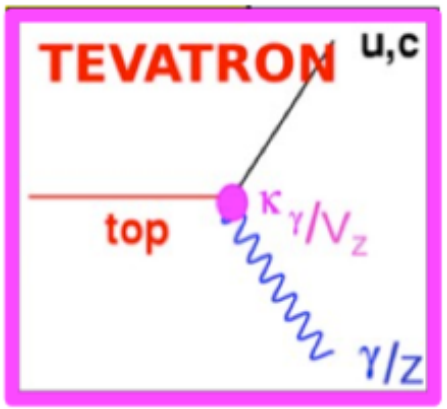


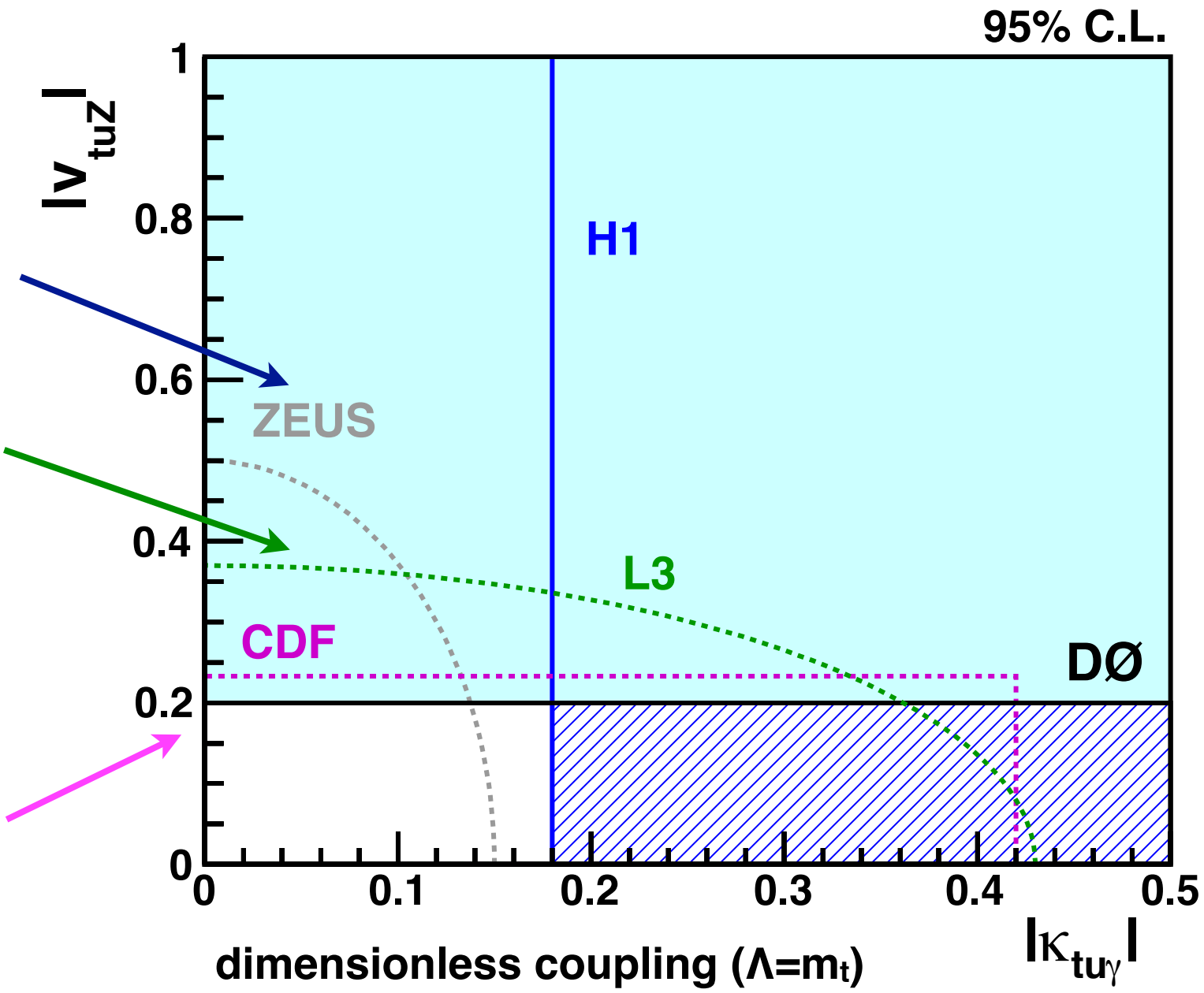
⇒ important to study production channels separately

FCNC Top Couplings at Colliders



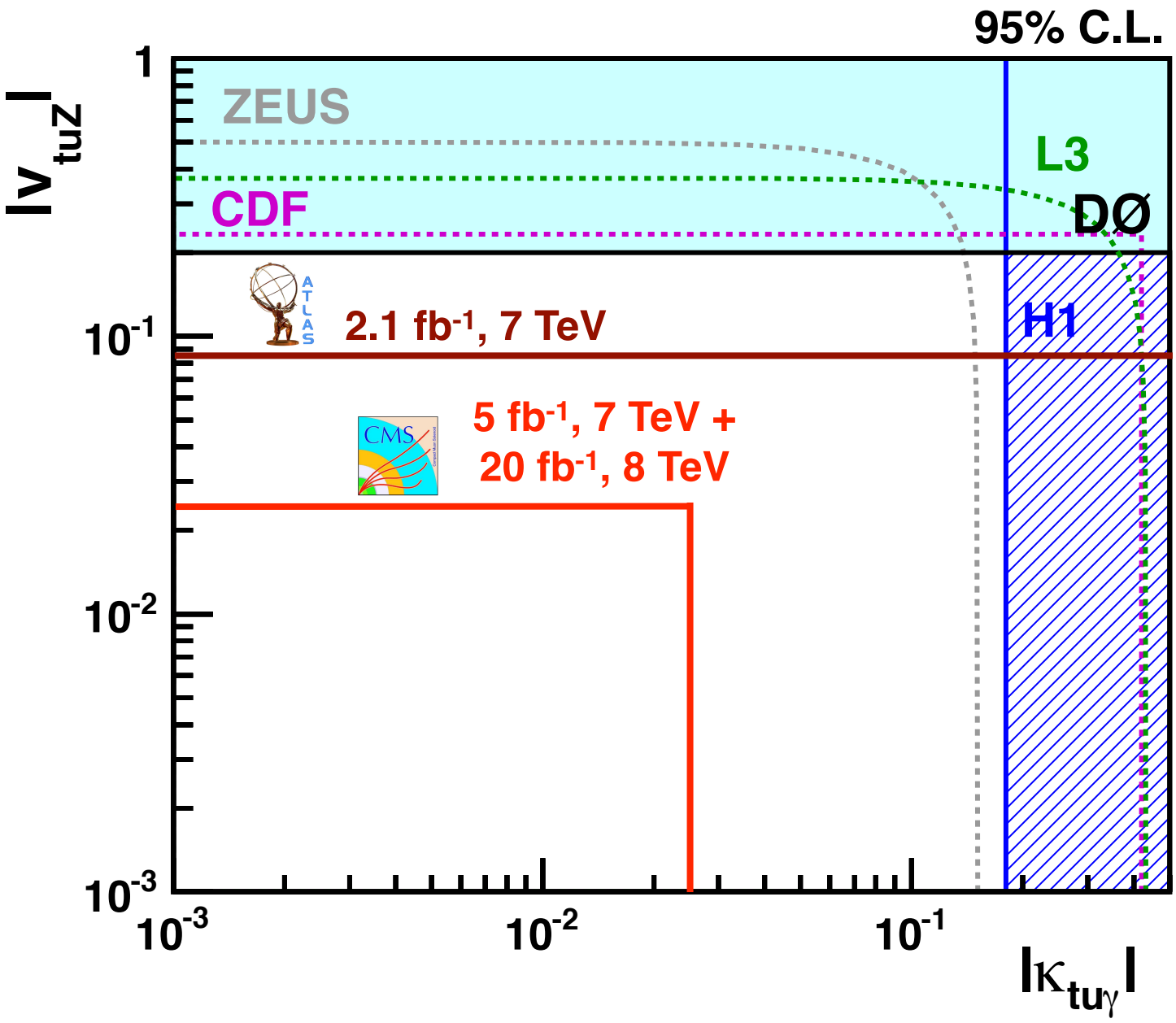


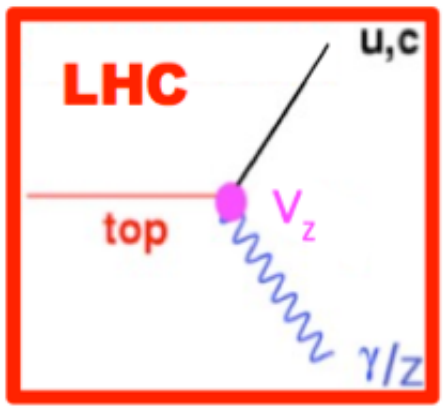




FCNC Top Couplings at Colliders

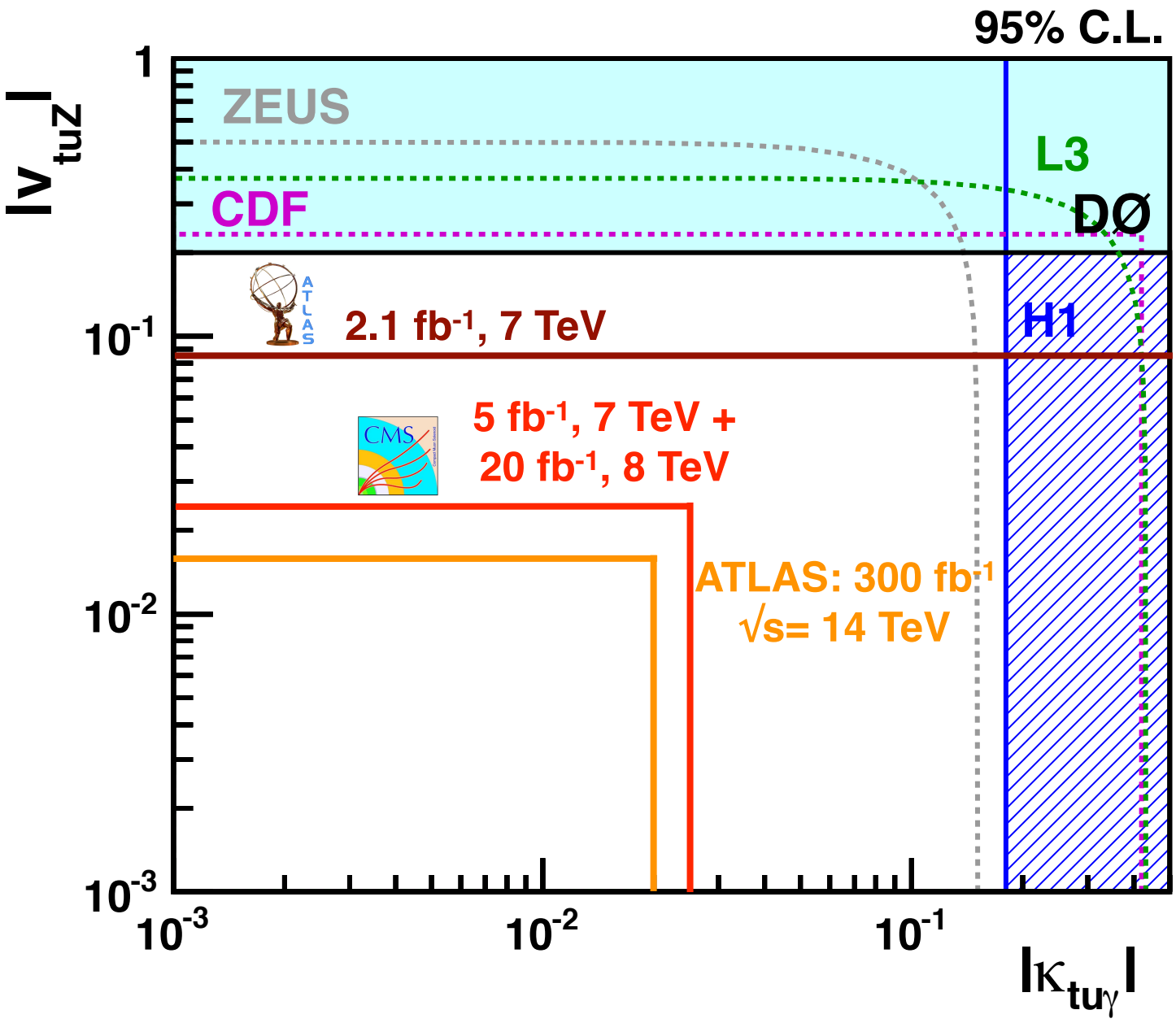
Top Quark Working Group Collaboration, arXiv:1311.2028 [hep-ph]

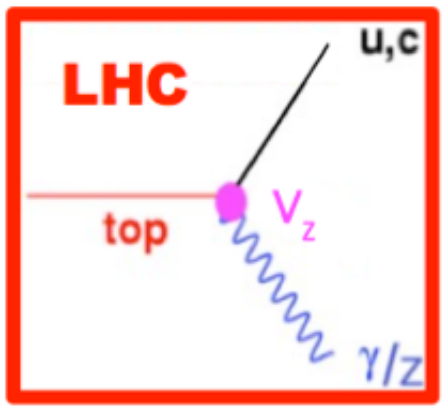




FCNC Top Couplings at Colliders

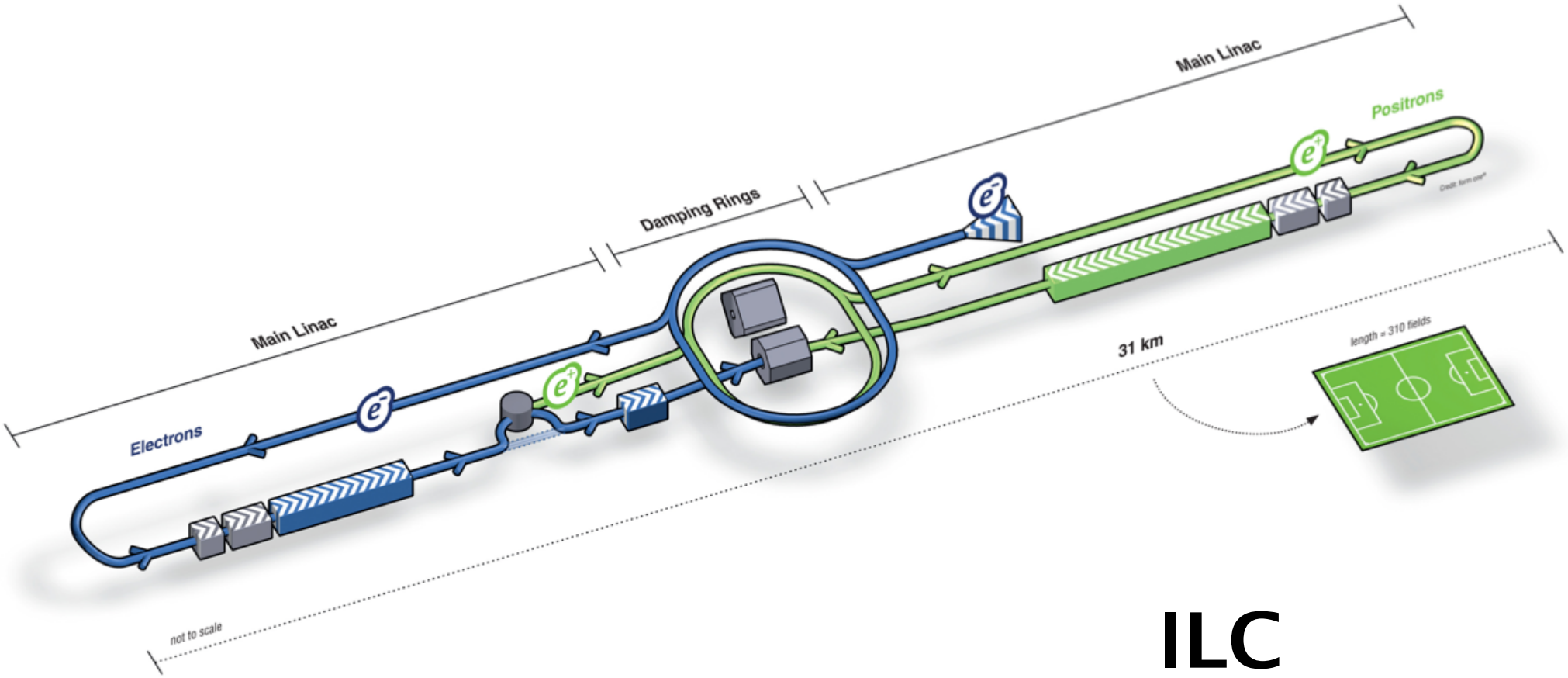
Top Quark Working Group Collaboration, arXiv:1311.2028 [hep-ph]





International Linear Collider

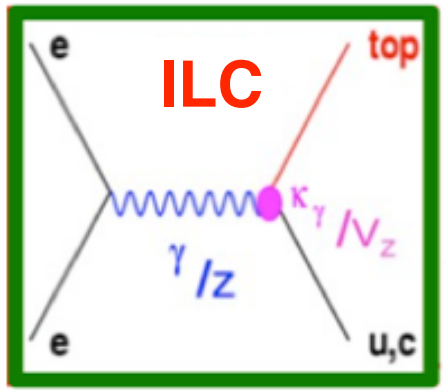
- **next generation of e^+e^- precision physics: Linear Collider**

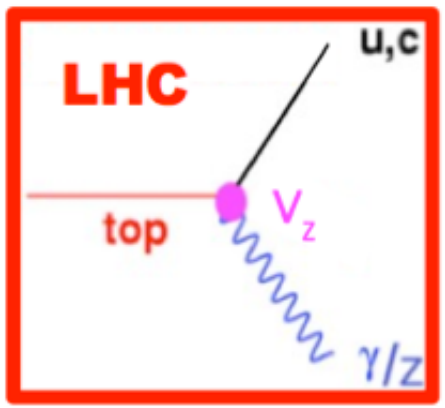


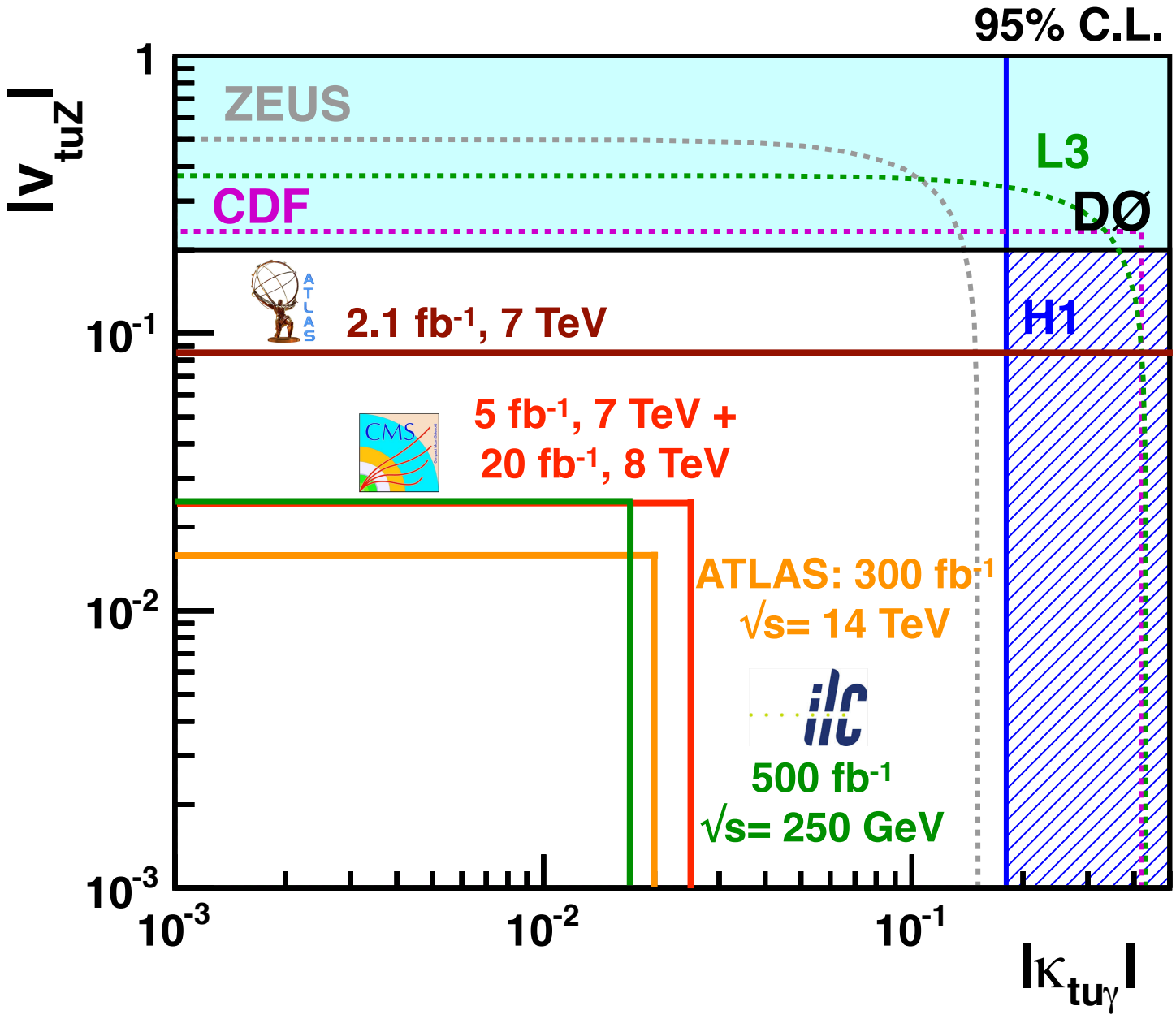
ILC

FCNC Top Couplings at Colliders

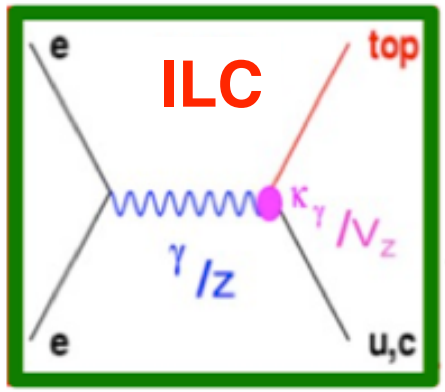
Top Quark Working Group Collaboration, arXiv:1311.2028 [hep-ph]

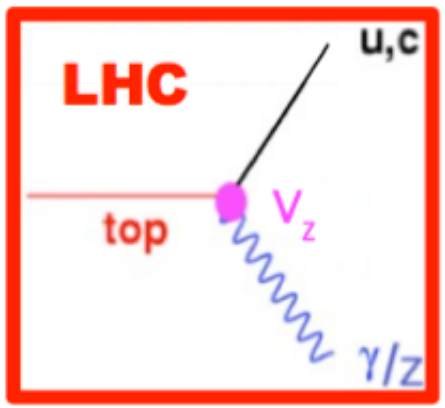


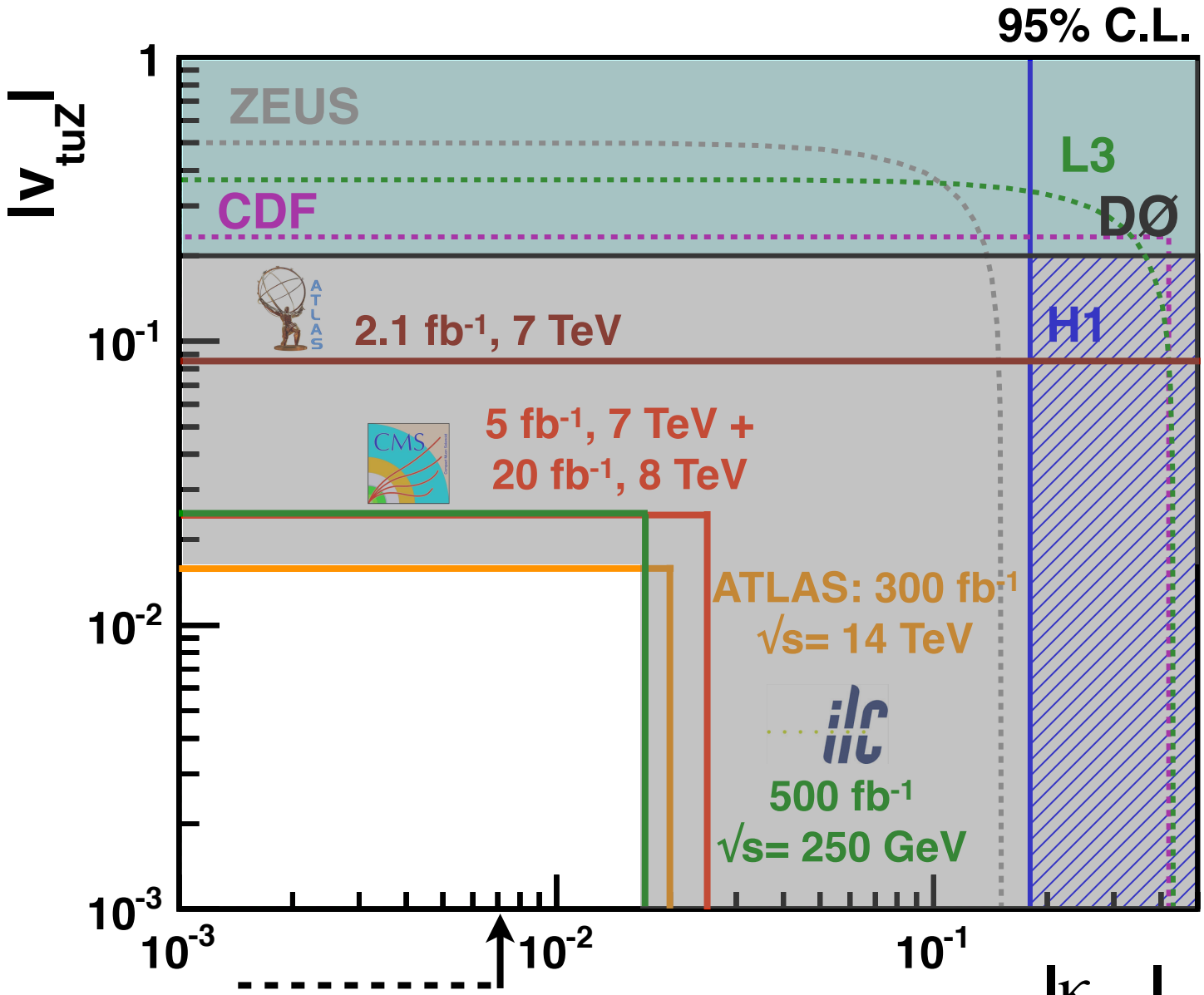




FCNC Top Couplings at Colliders





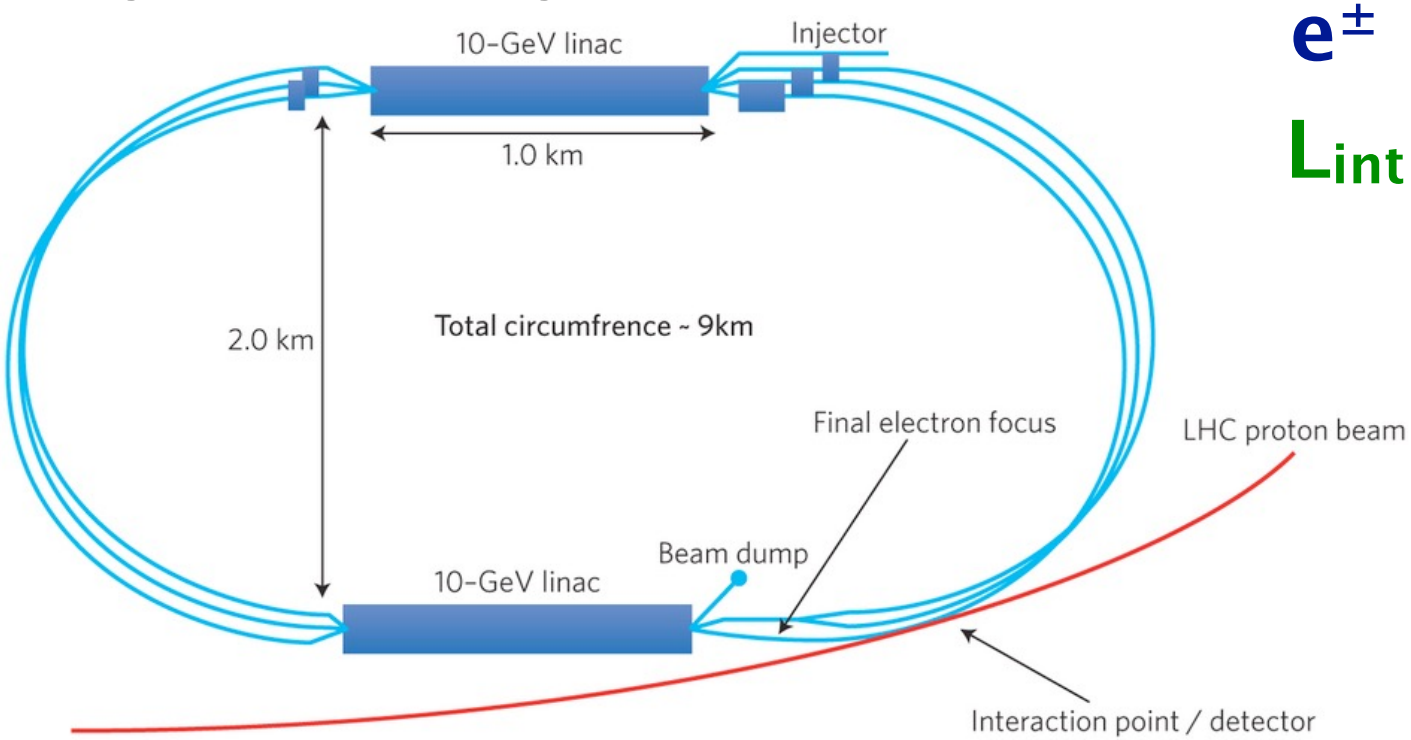


→ test SUSY, little Higgs, technicolor...

Linac-Ring Collider LHeC

- **next generation of ep physics**: Large Hadron Electron Collider

Energy Recovering Linac



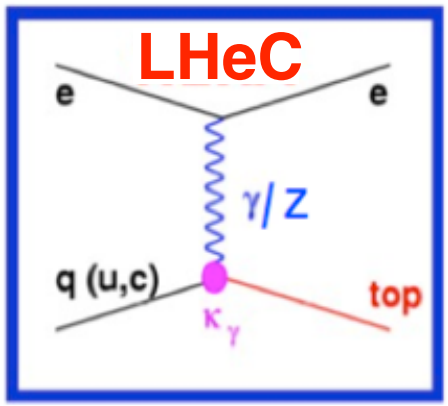
$e^{\pm}$ beam: 60 GeV

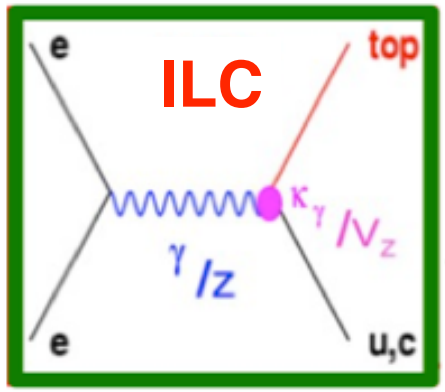
L_{int}=1 fb^{-1}-1 ab^{-1}

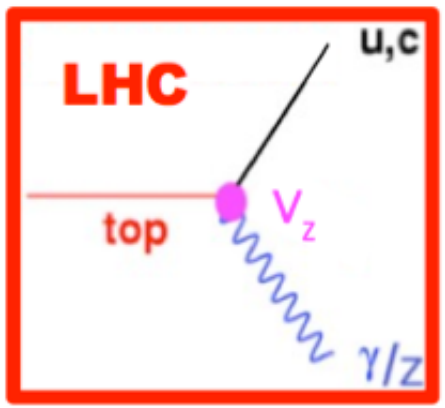
operated synchronously

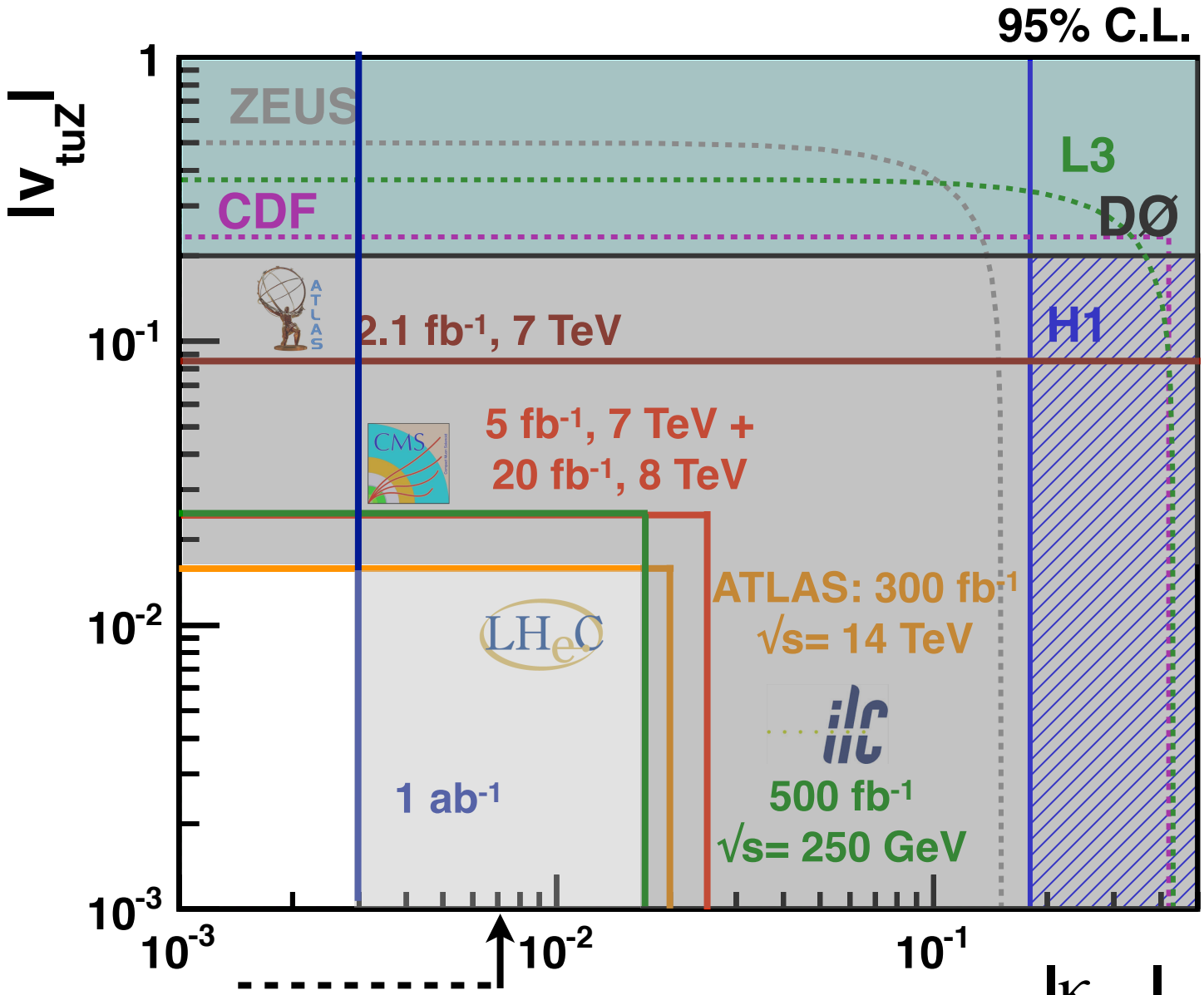
- with HL-LHC:
  p beam: 7 TeV, $\sqrt{s}$=1.3 TeV

Search for FCNC in Top Quark Decays



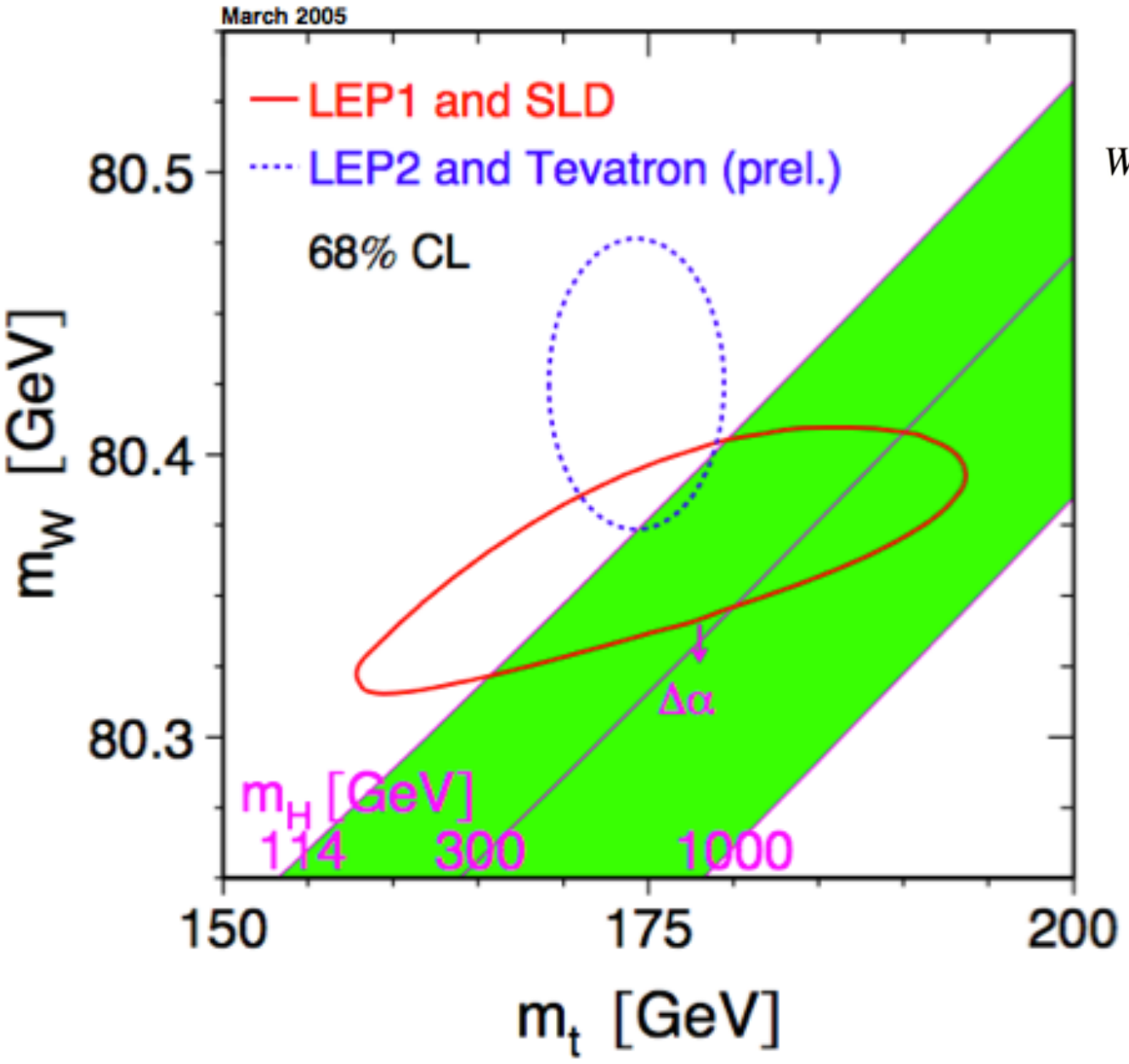


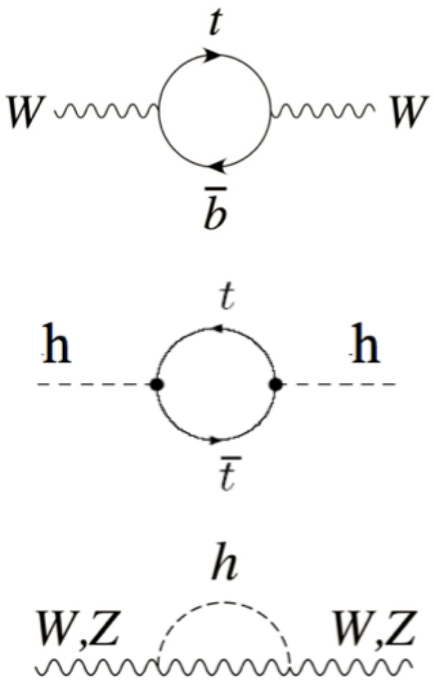




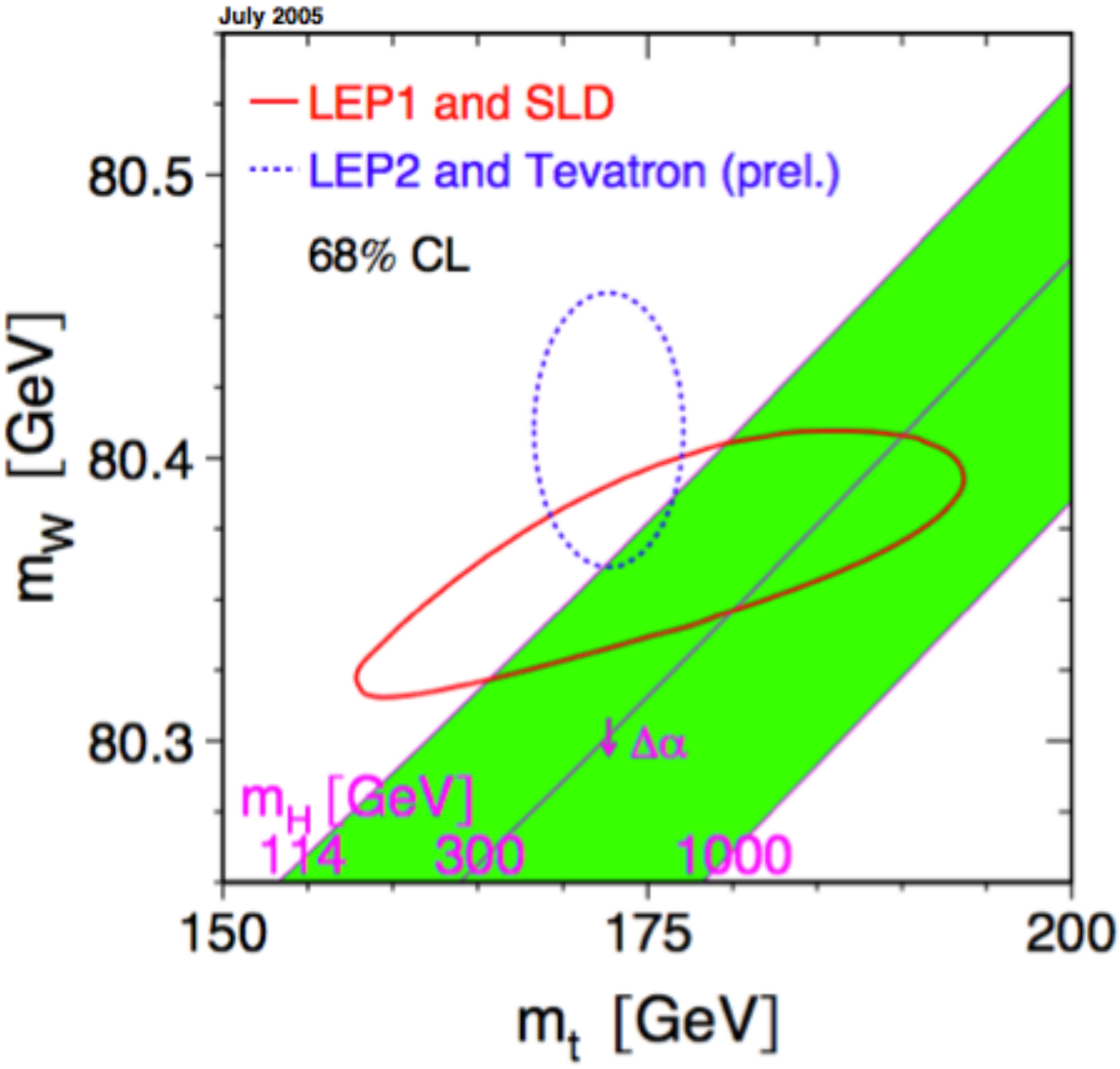
→ test SUSY, little Higgs, technicolor...

History m_{top} vs. M_W

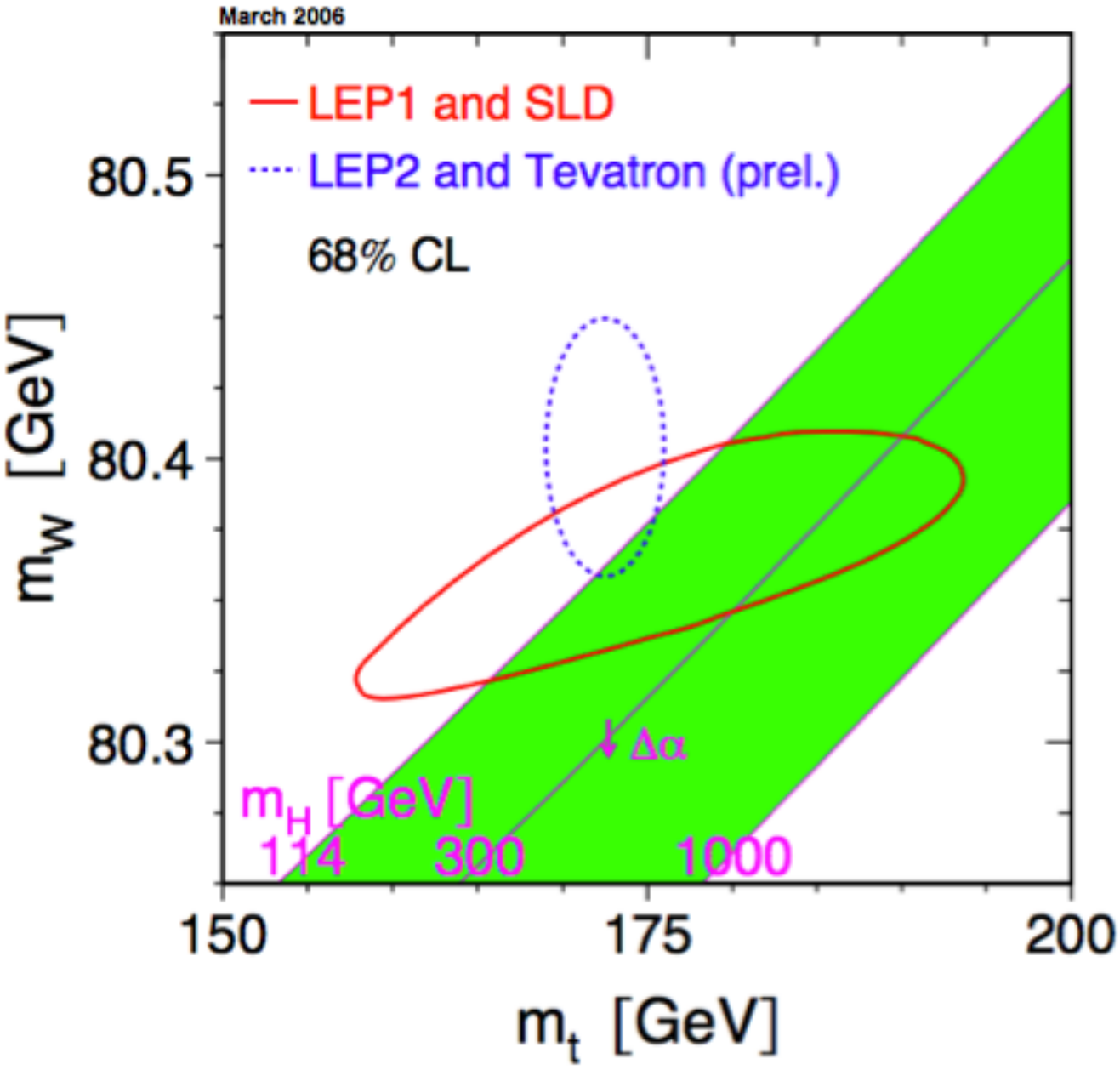




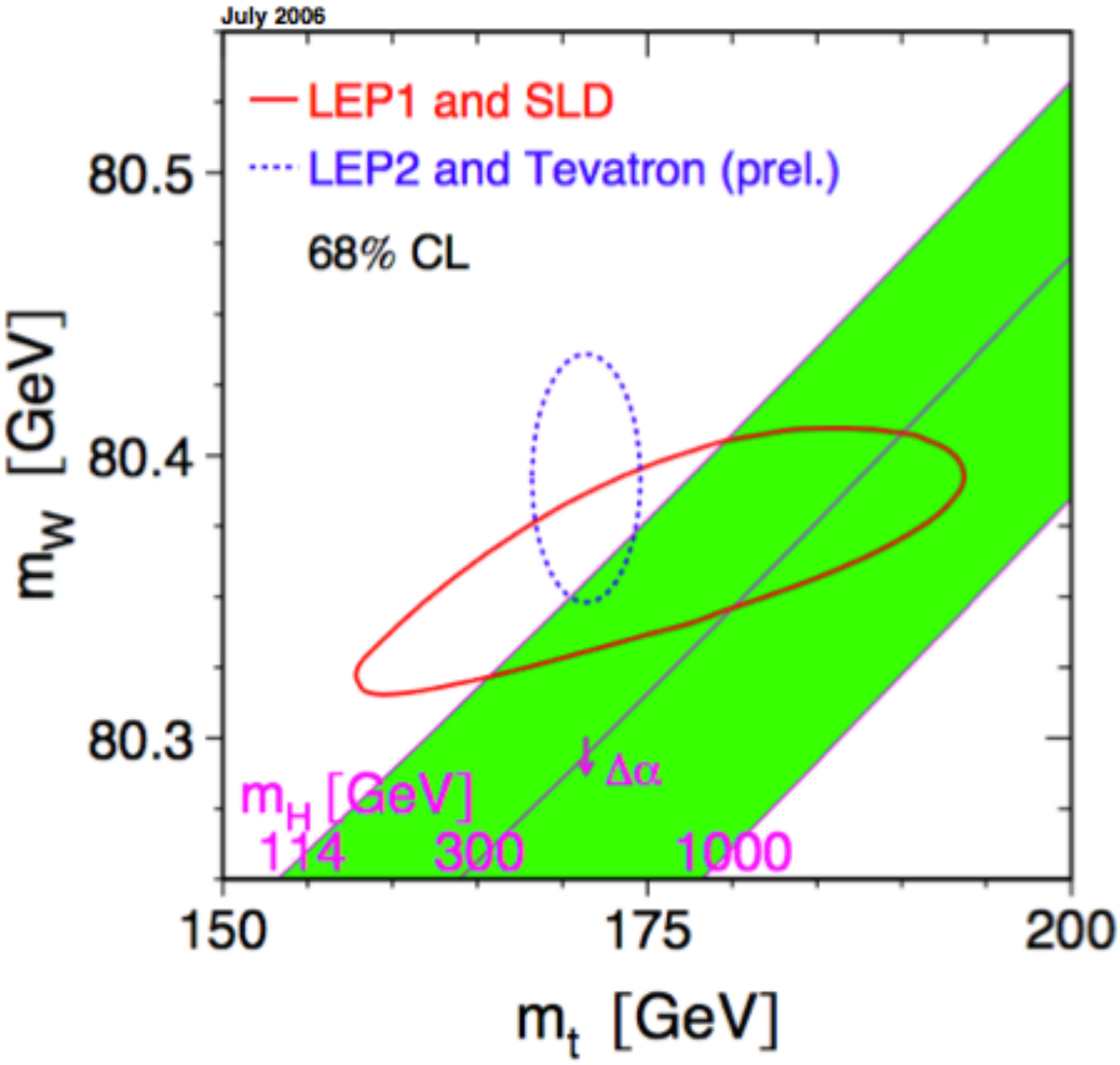
History m_{top} vs. M_W



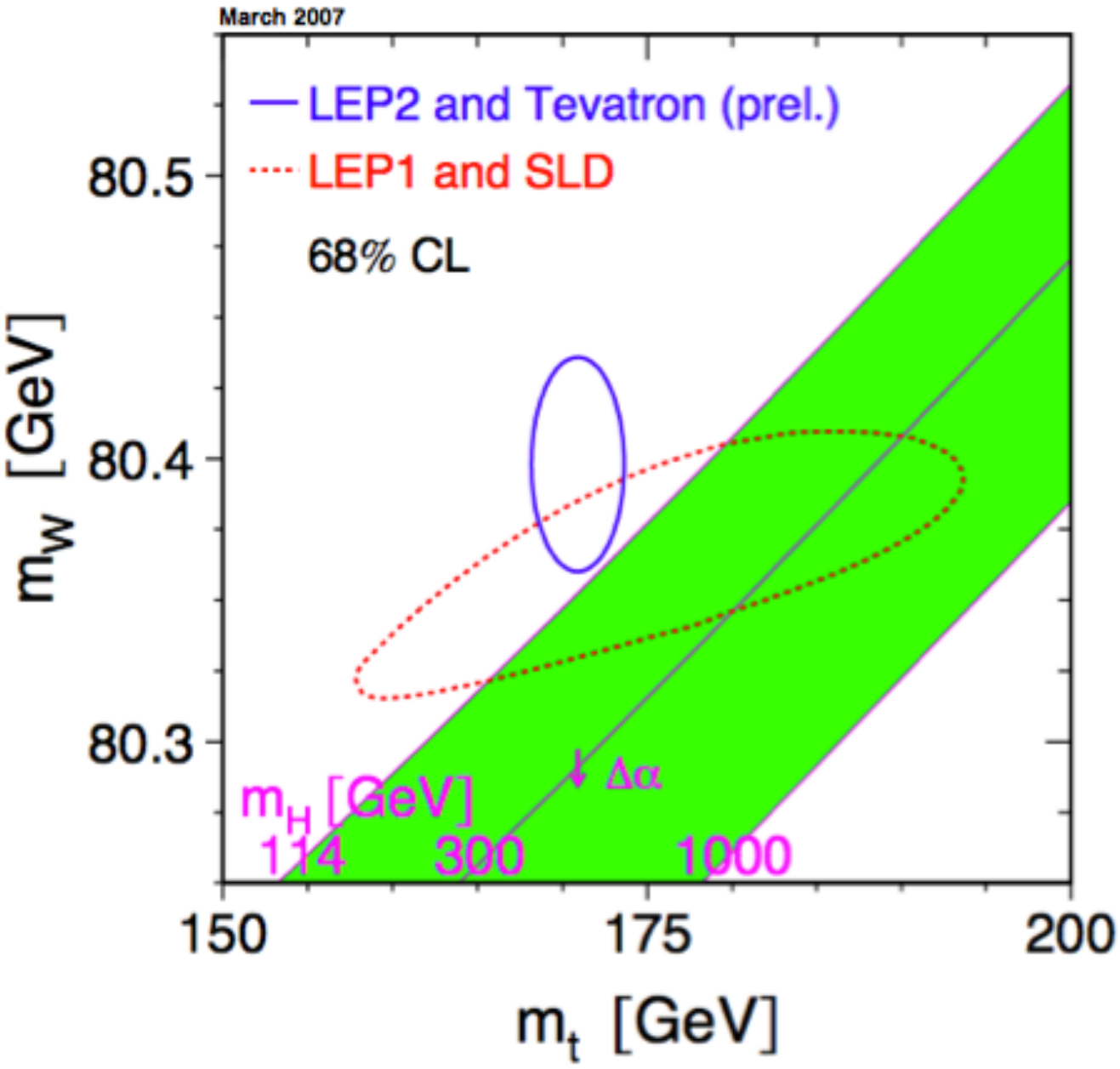
History m_{top} vs. M_W



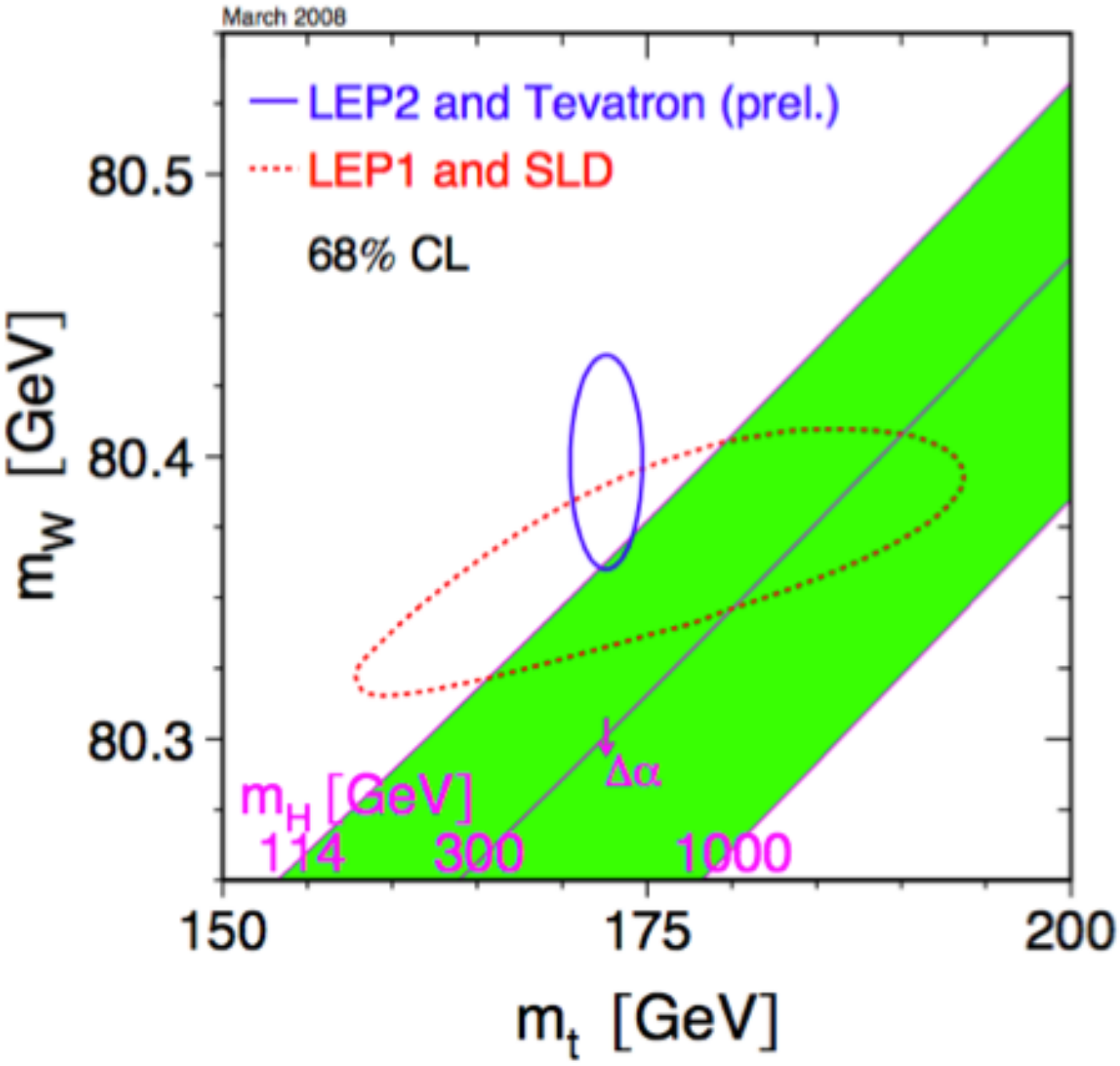
History m_{top} vs. M_W



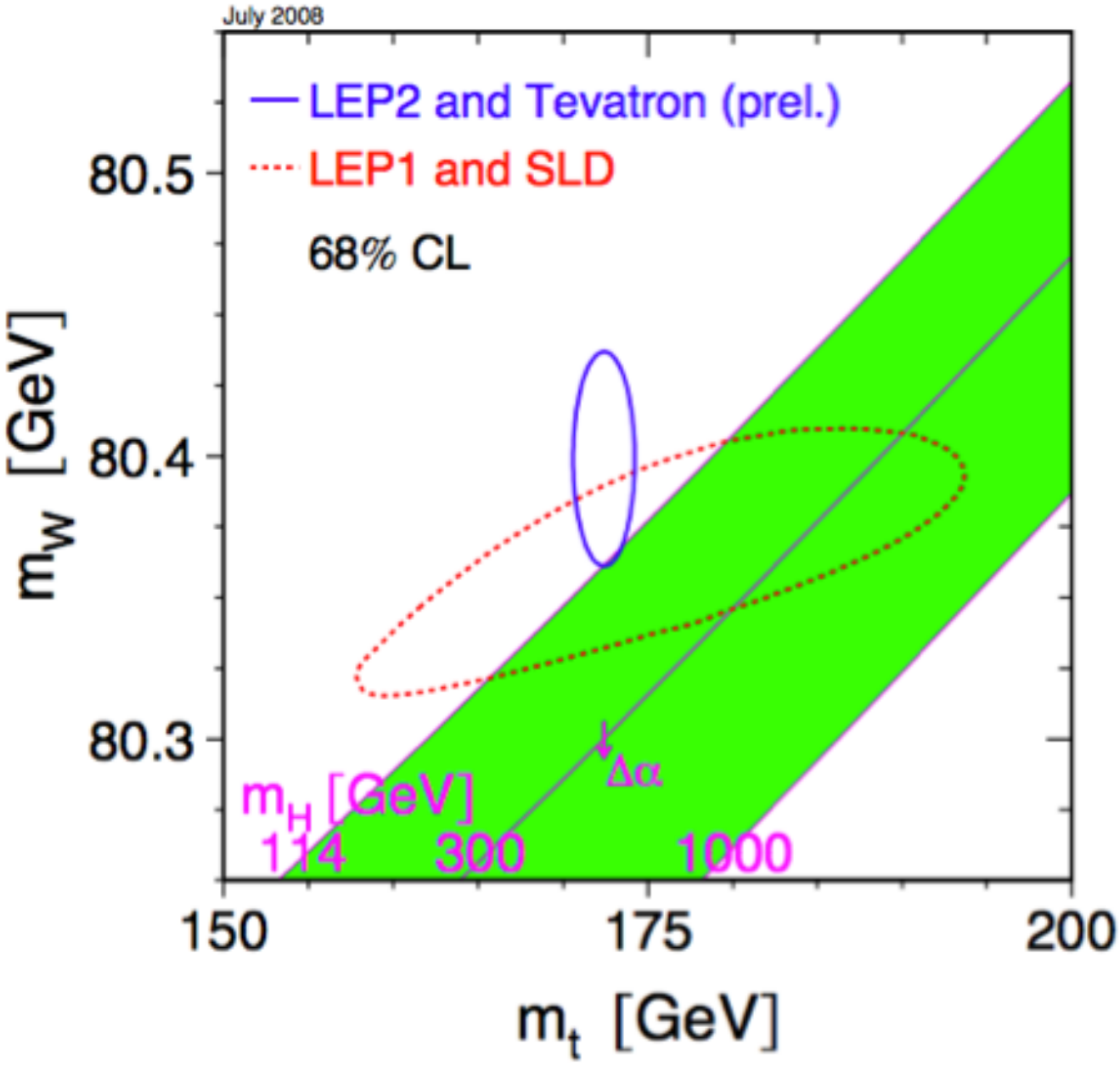
History m_{top} vs. M_W



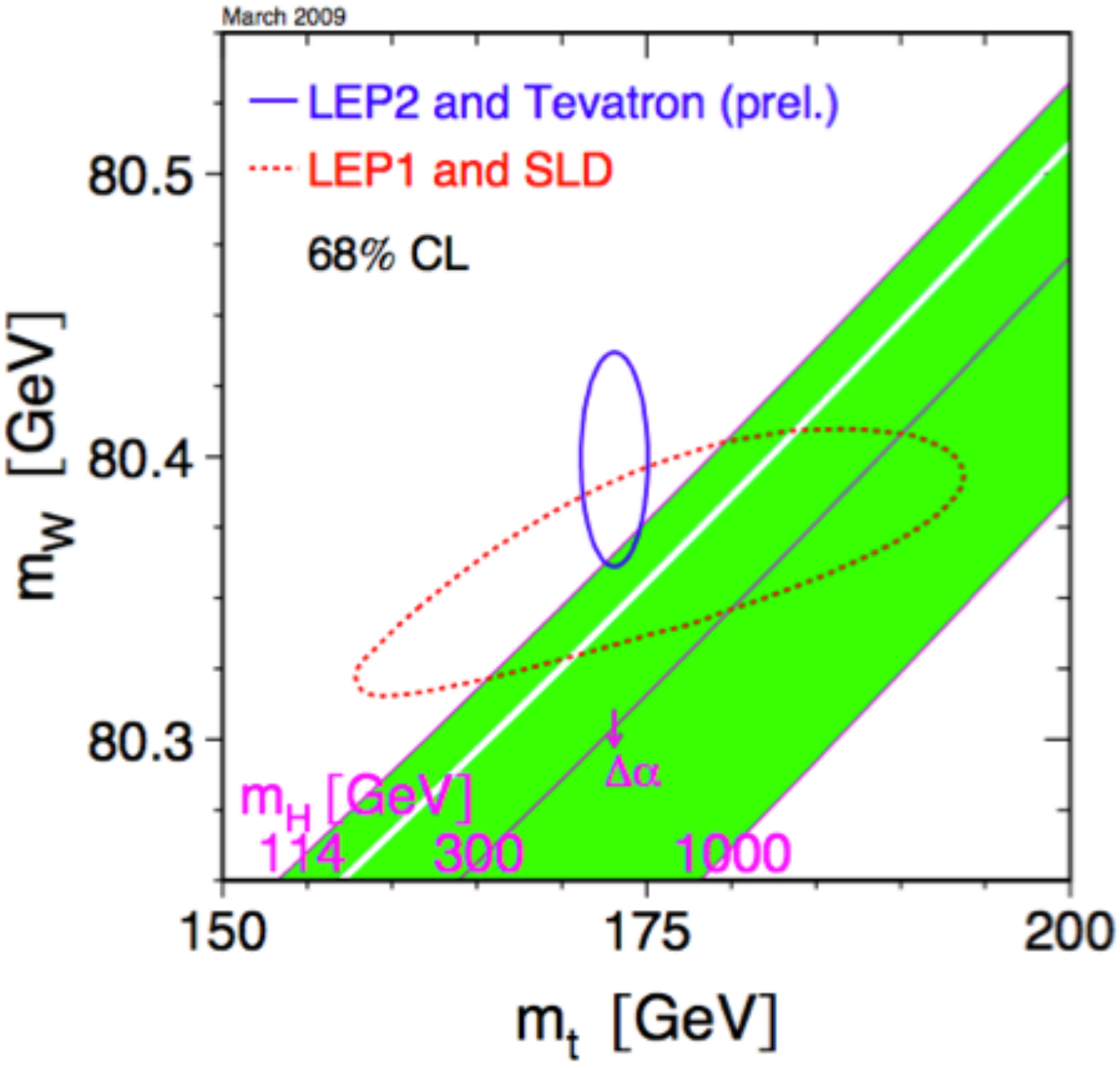
History m_{top} vs. M_W



History m_{top} vs. M_W



History m_{top} vs. M_W



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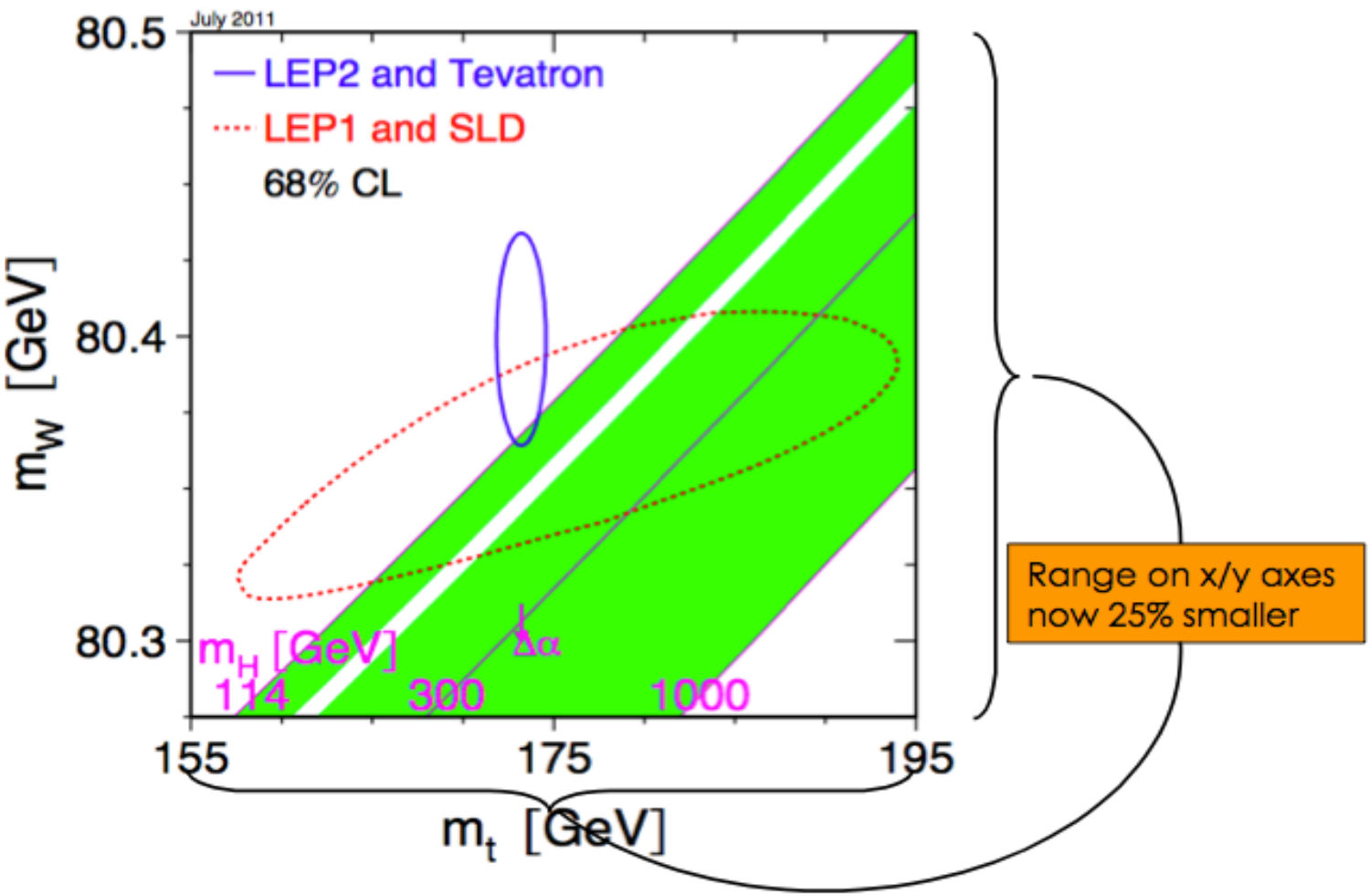
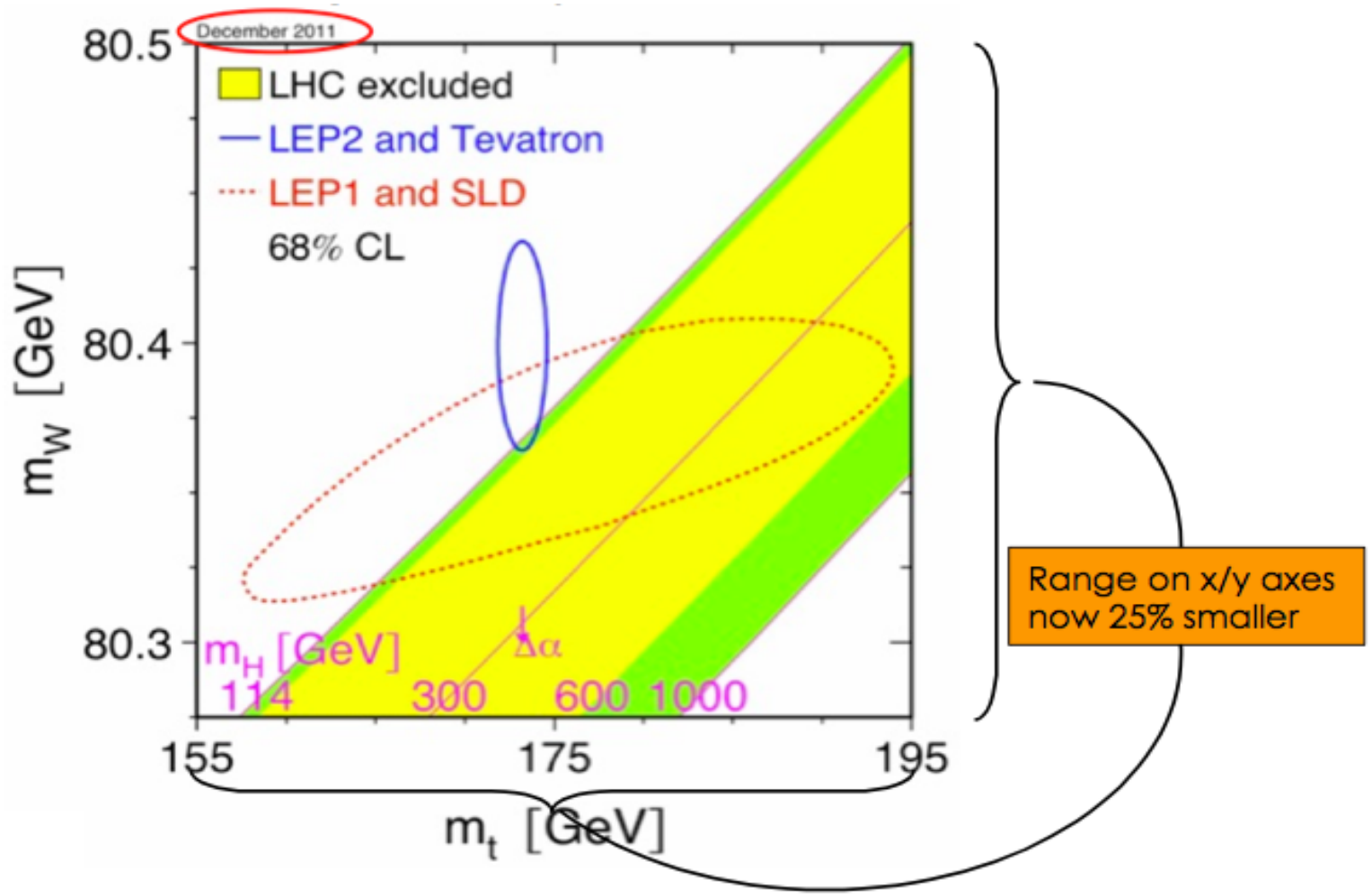
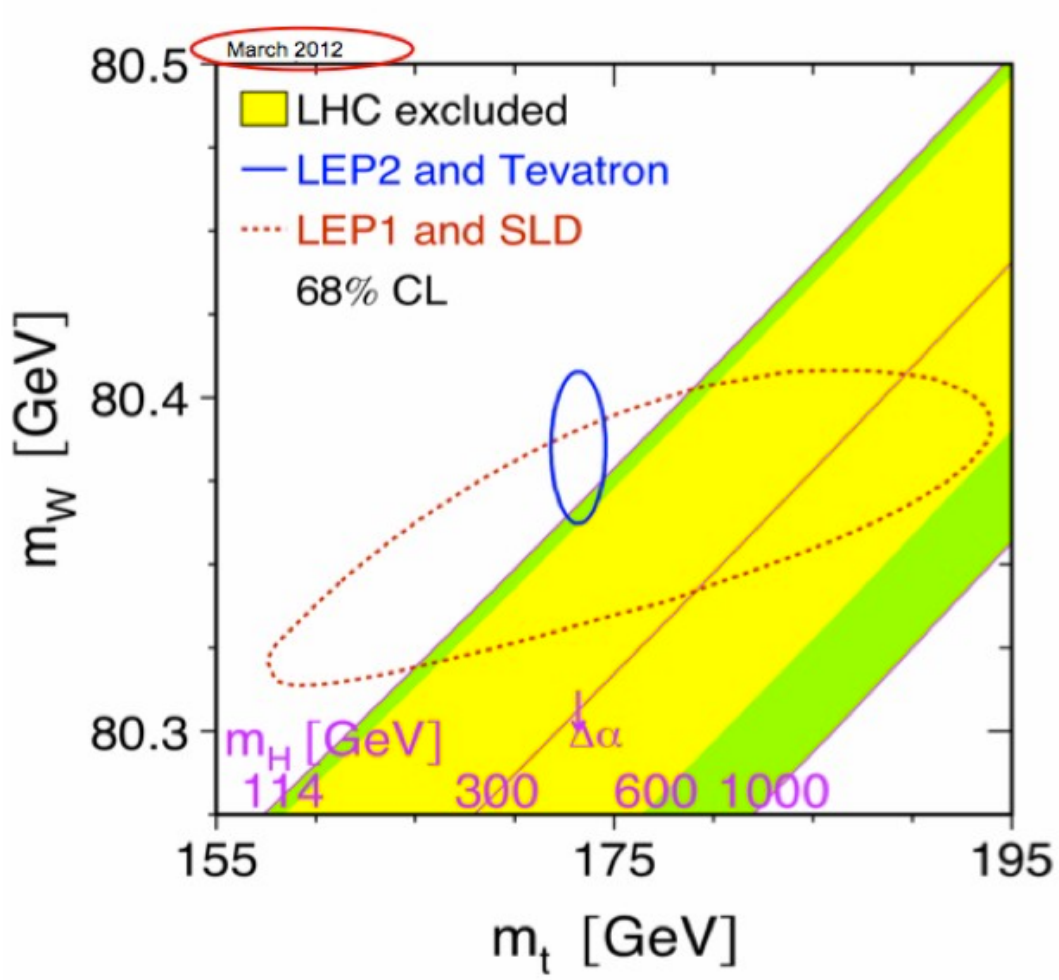


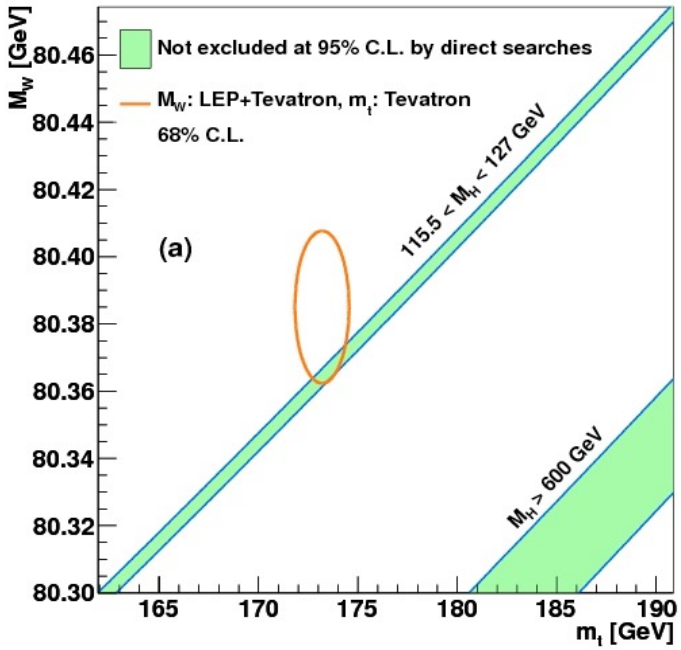
History m_{top} vs. M_W



History m_{top} vs. M_W

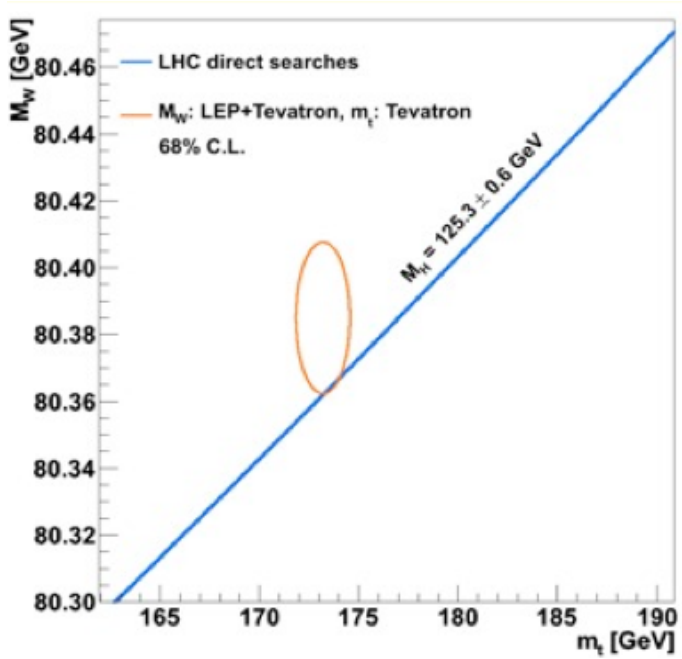


History m_{top} vs. M_W



History m_{top} vs. M_W

July 2012

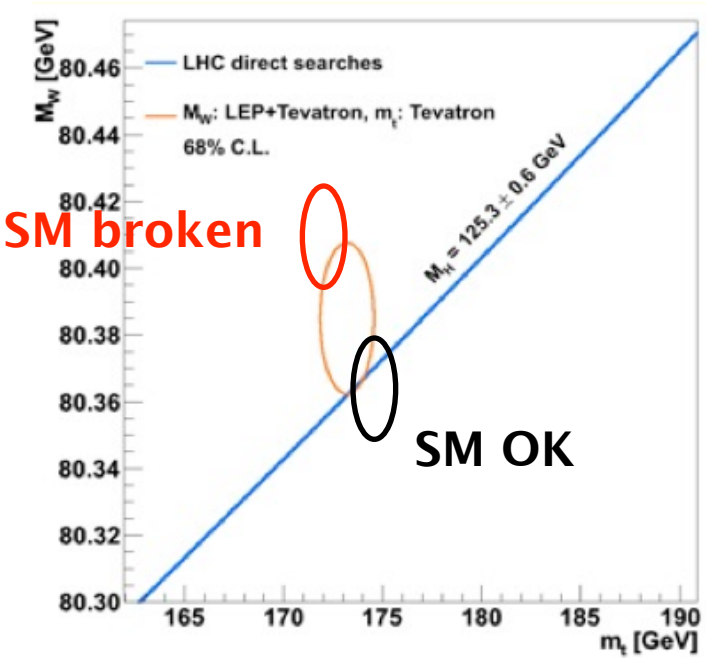


→ Standard Model is self-consistent

History m_{top} vs. M_W

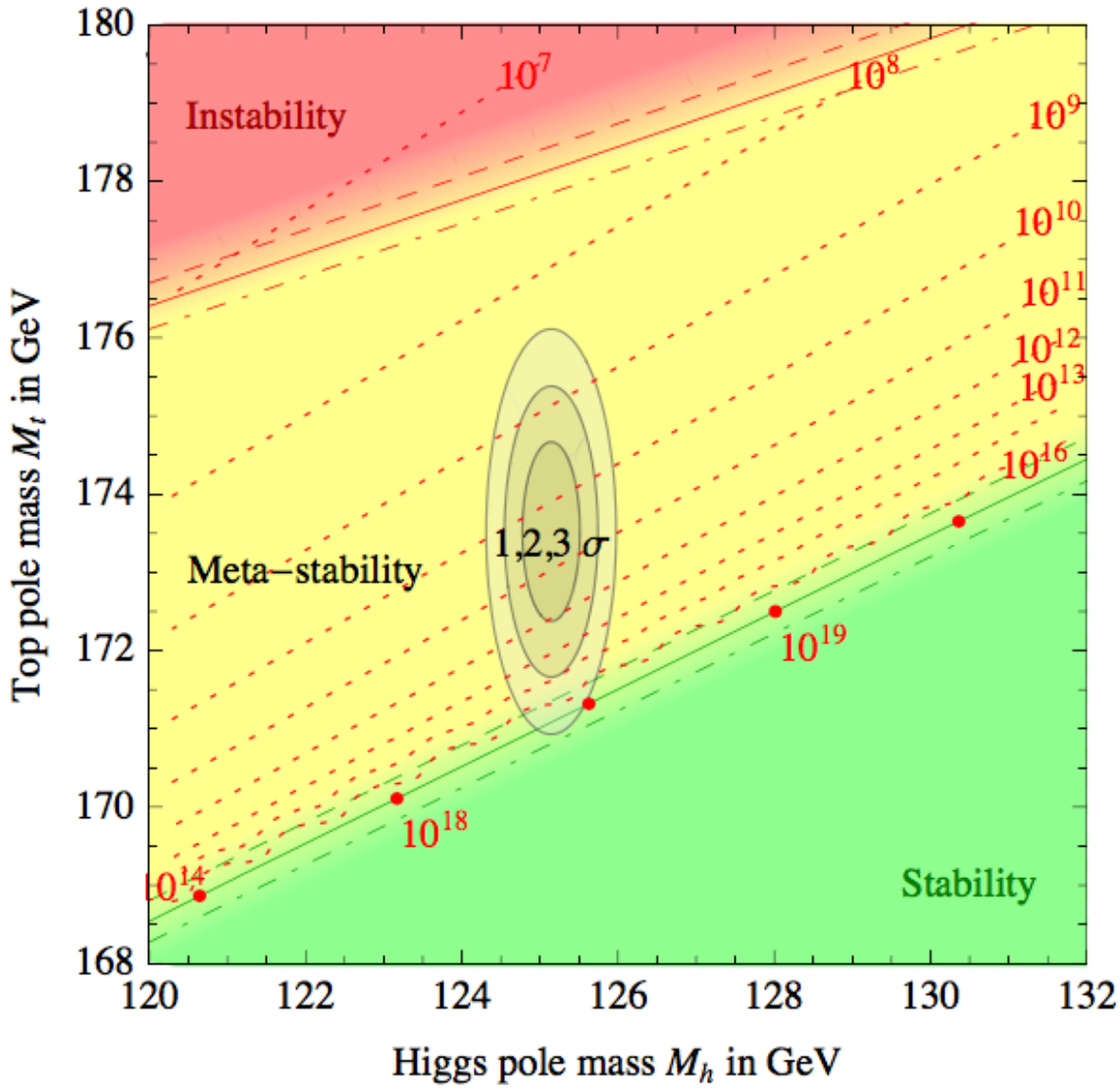
future:
$\Delta(m_W)$=6 MeV

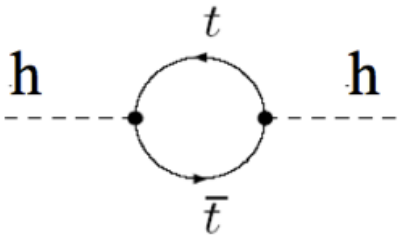
July 2012



improved W mass measurement is critical

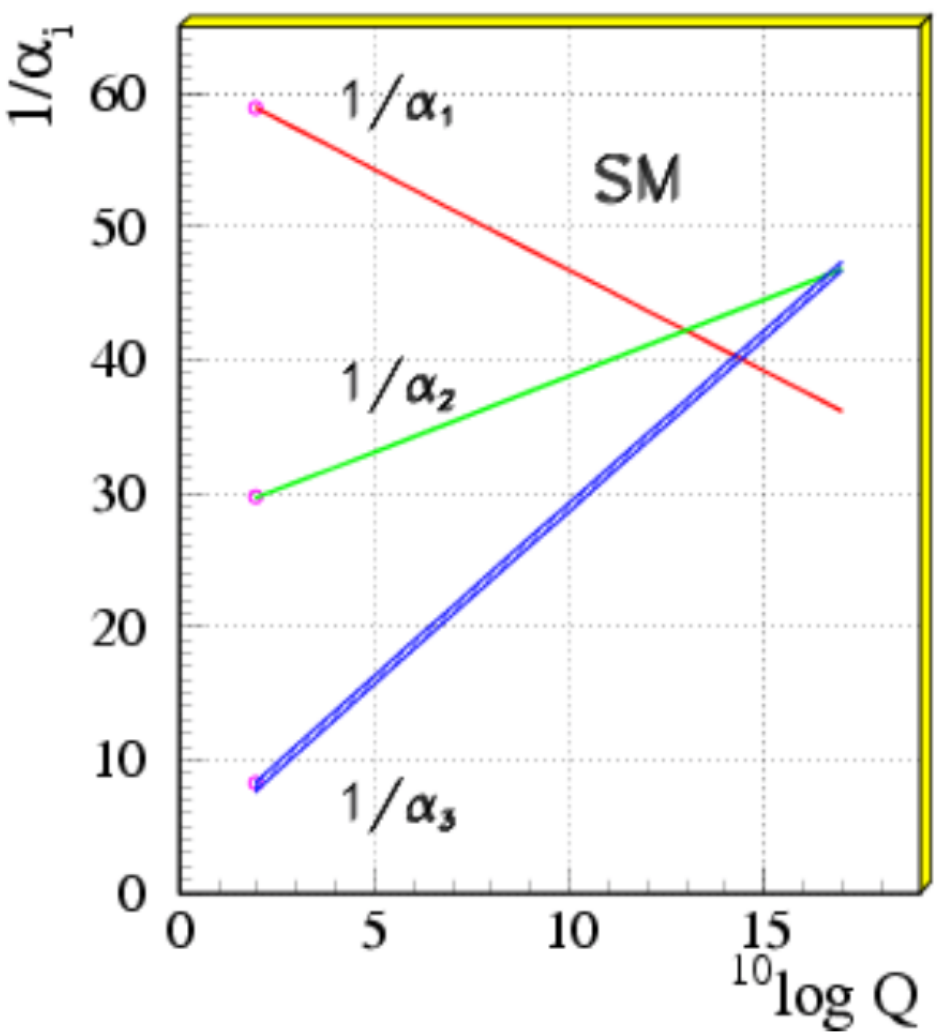
m_{top} vs. M_H

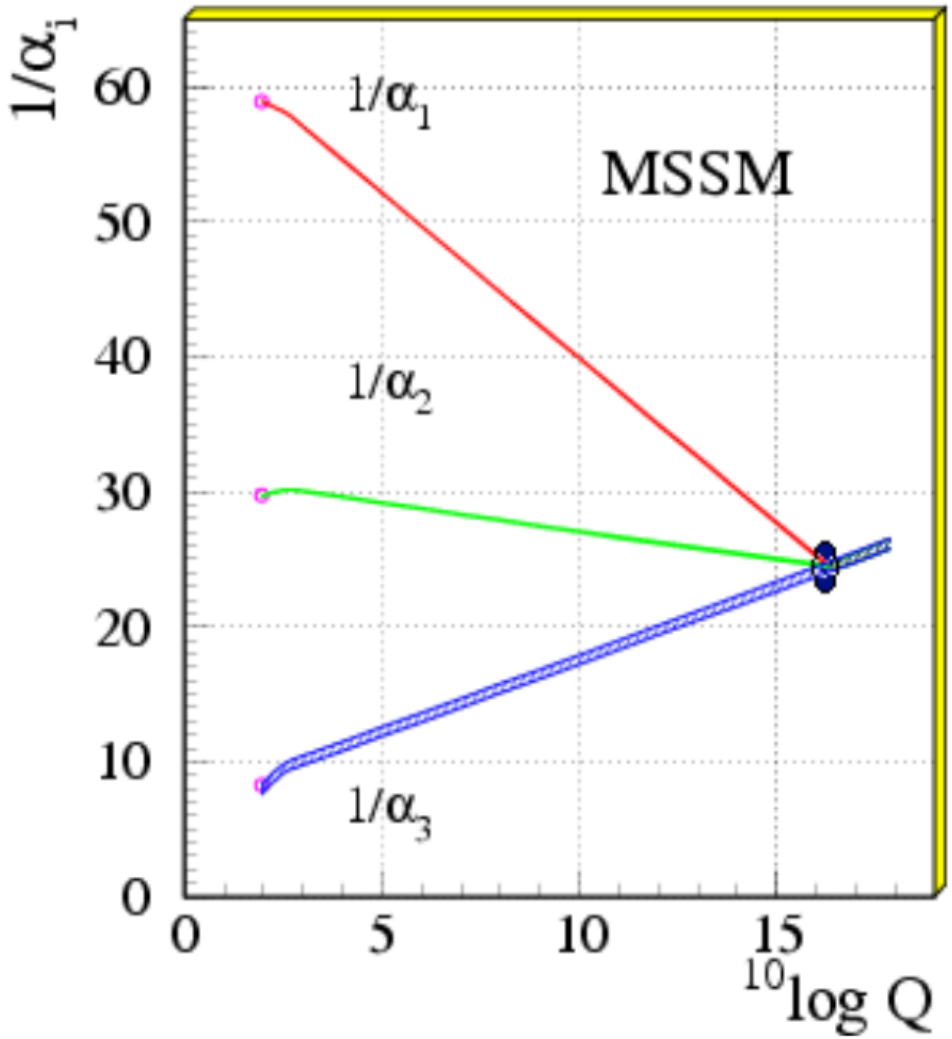




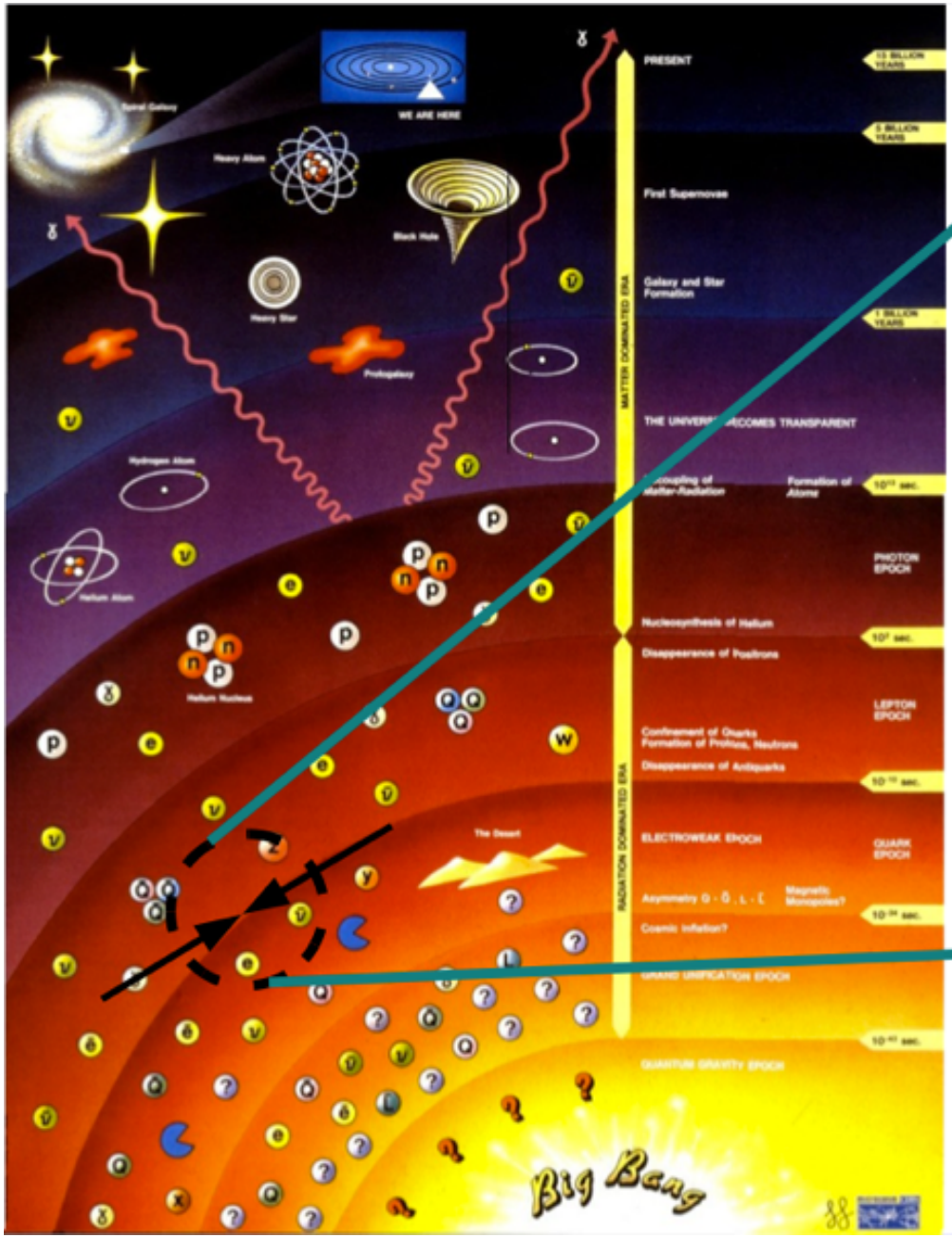
check the "fate of the Universe"

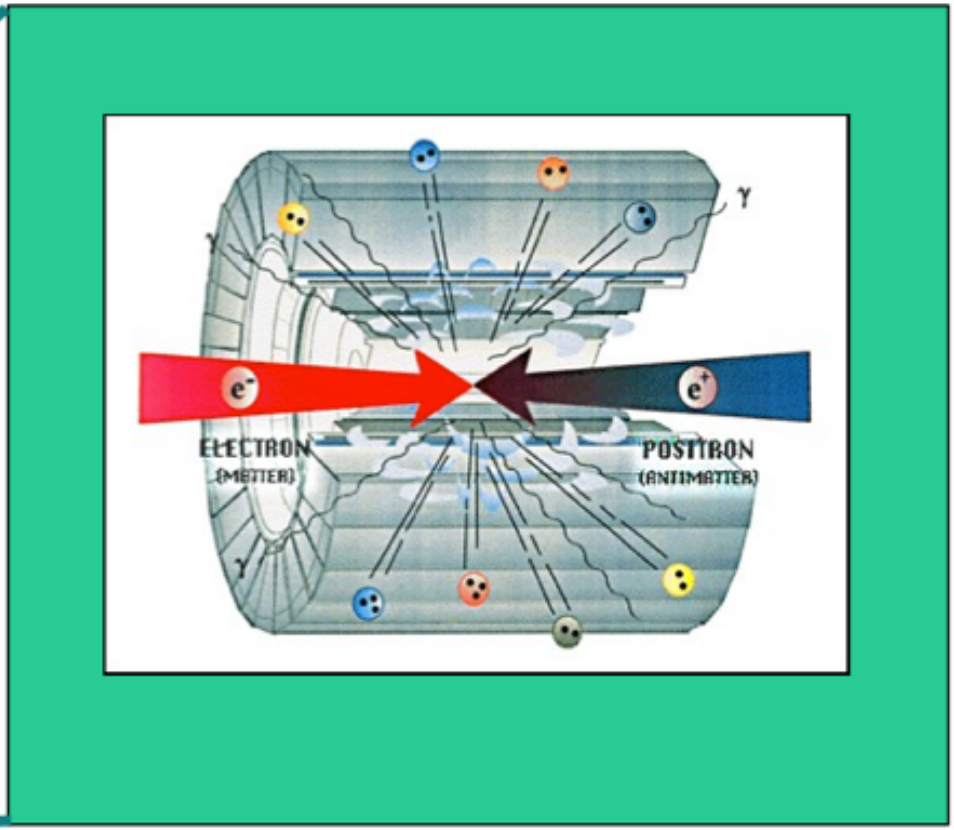
Grand Unified Theories (GUT)



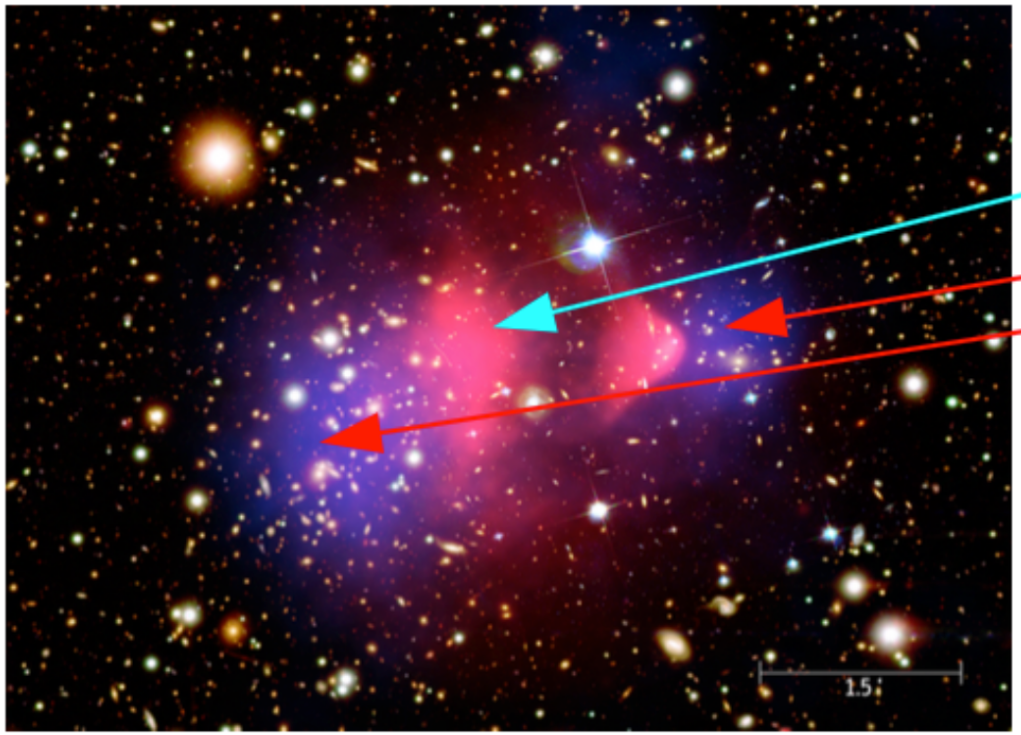


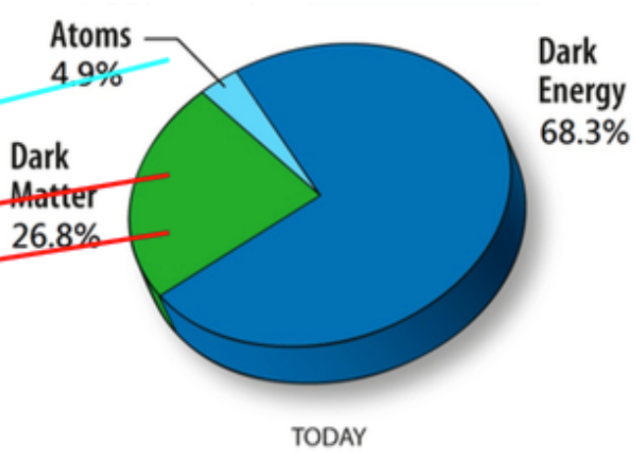
Big Bang in the Lab?





Dark Matter





Dark matter inferred from star motion and gravitational lensing