Topical Workshop on Top Differential Distributions
Cannes, Sept 28, 2014

New Physics in tt+X resonances

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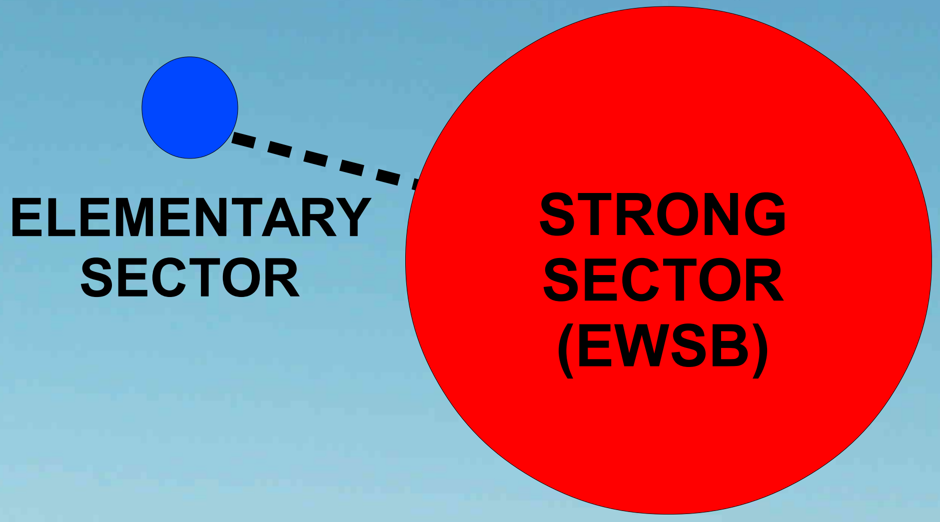
Based on work in collaboration with: Araque, Carmona, Barcelo, Chala, Juknevich, Masip, Perez, Torre, Salvioni, Serra

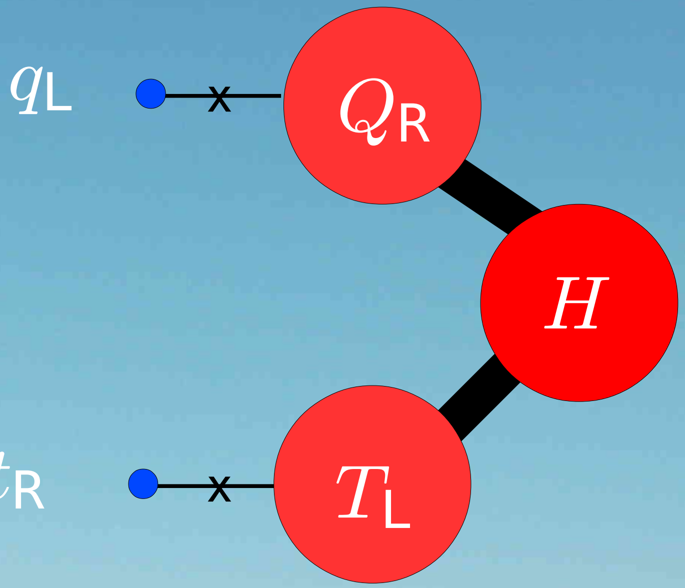
Top … from a BSM perspective

- Why do BSM-ers care about the top?
  - It's a background to almost everything
    - Huge xsec, leptons, jets, ETmiss, ...
  - But also a very useful probe of BSM physics
    - NP is likely to couple predominantly to the top
  - If NP is within LHC reach it might be quite elusive
  - Think top “at large” (not only SM top)
    - Top-like particles (top partners)
    - New production mechanisms
  - I'll use composite Higgs models as an example

Top as a BSM probe

- The top quark has the largest coupling to the EWSB sector. If NP has anything to do with EWSB the top will couple to it in a sizable way.
- Example: Composite Higgs with partial compositeness





Large top coupling to the Higgs implies large coupling to composite resonances

Top as a BSM probe

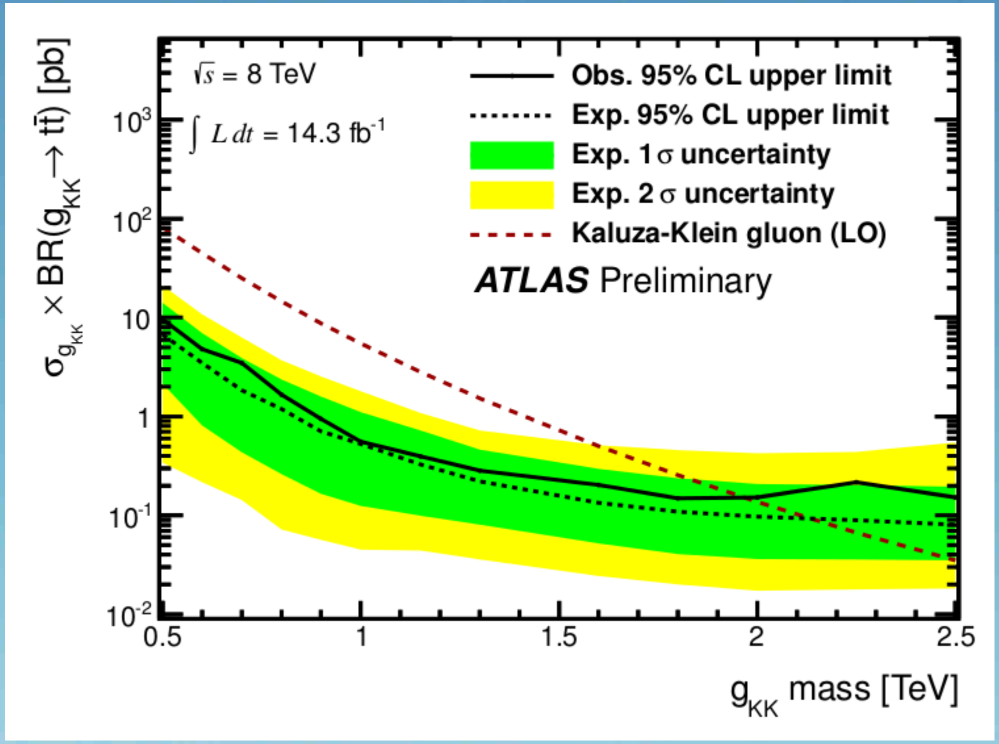
- Which new resonances? Partial compositeness : color is a global symmetry of the strong sector, color octet vector resonances expected (heavy gluons)
- What do these heavy gluons look like?
  - Small couplings to u, d quarks (mostly elementary)
  - Large coupling to top
  - Relatively heavy from EWPT (if mass similar to EW resonances)

Relatively narrow, heavy resonance that decays mostly to tops

Top as a BSM probe

- Such a resonance is being searched for

ATLAS-CONF-2013-052
CMS-B2G-13-001 [PRL]



Bound from CMS slightly more stringent (but K factor of 1.3)

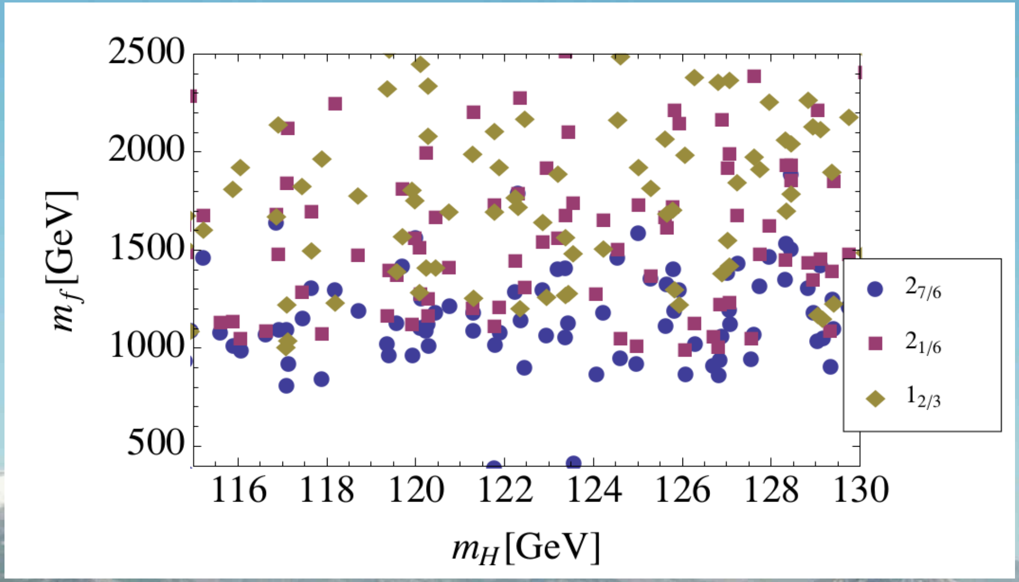
This result includes boosted and resolved analyses

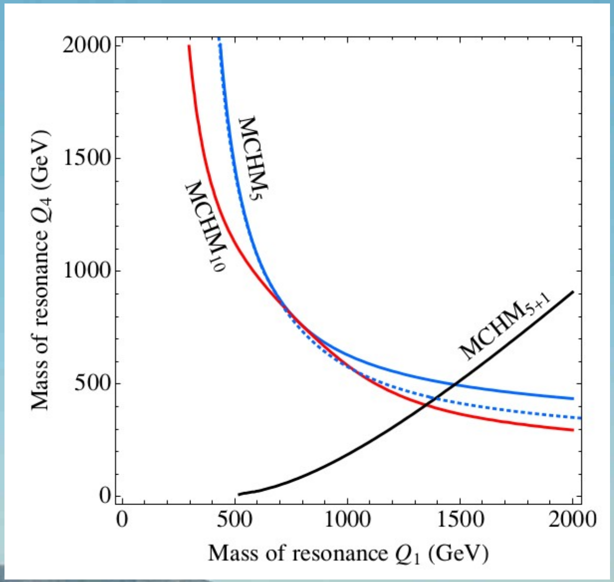
But that's not all we (theorists) expect

Life is not (always) that simple

- Partial compositeness also requires fermion resonances
- The ones the top mixes with to get its mass (top partners) should be light (or Higgs too heavy)

Redi, Tesi JHEP (12); Marzocca, Serone, Shu JHEP (12); Matsedonskyi, Panico, Wulzer JHEP (13); Pomarol, Riva JHEP (12)





Life is not (always) that simple

- Realistic CHM typically require
  - Rich spectrum of light (TeV-ish) top partners
  - Heavy vector resonances (multi-TeV-ish)
- These two features can have an important impact on the collider phenomenology of both:
  - Production of top partners via heavy gluon exchange

    Barcelo, Carmona, Chala, Masip, Santiago NPB (12); Bini, Contino, Vignaroli (12); Carmona, Chala, Santiago JHEP (12); Chala, Santiago PRD (13)
  - tt+X resonances

    Chala, Juknevic, Perez, Santiago (in progress); Torre, Salvioni, Santiago, Serra (in progress)

Life is not (always) that simple

- The heavy gluons we expect are:
  - Have large BR into top partners (tt+X final state)
  - Quite wide
- Benchmark models (MCH45):

De Simone, Matsedonskyi, Rattazzi, Wulzer JHEP (13)

	QQ	tt	Qq	Γ/M
RS-like:	0.0	0.9	0.0	0.1
LTP:	0.8	0.1	0.1	0.7
LTP-narrow:	0.7	0.1	0.1	0.1
LTP-single channel:	0.8	0.0	0.1	0.1
	0.0	0.1	0.9	0.1

Life is not (always) that simple

- The heavy gluons we expect are:
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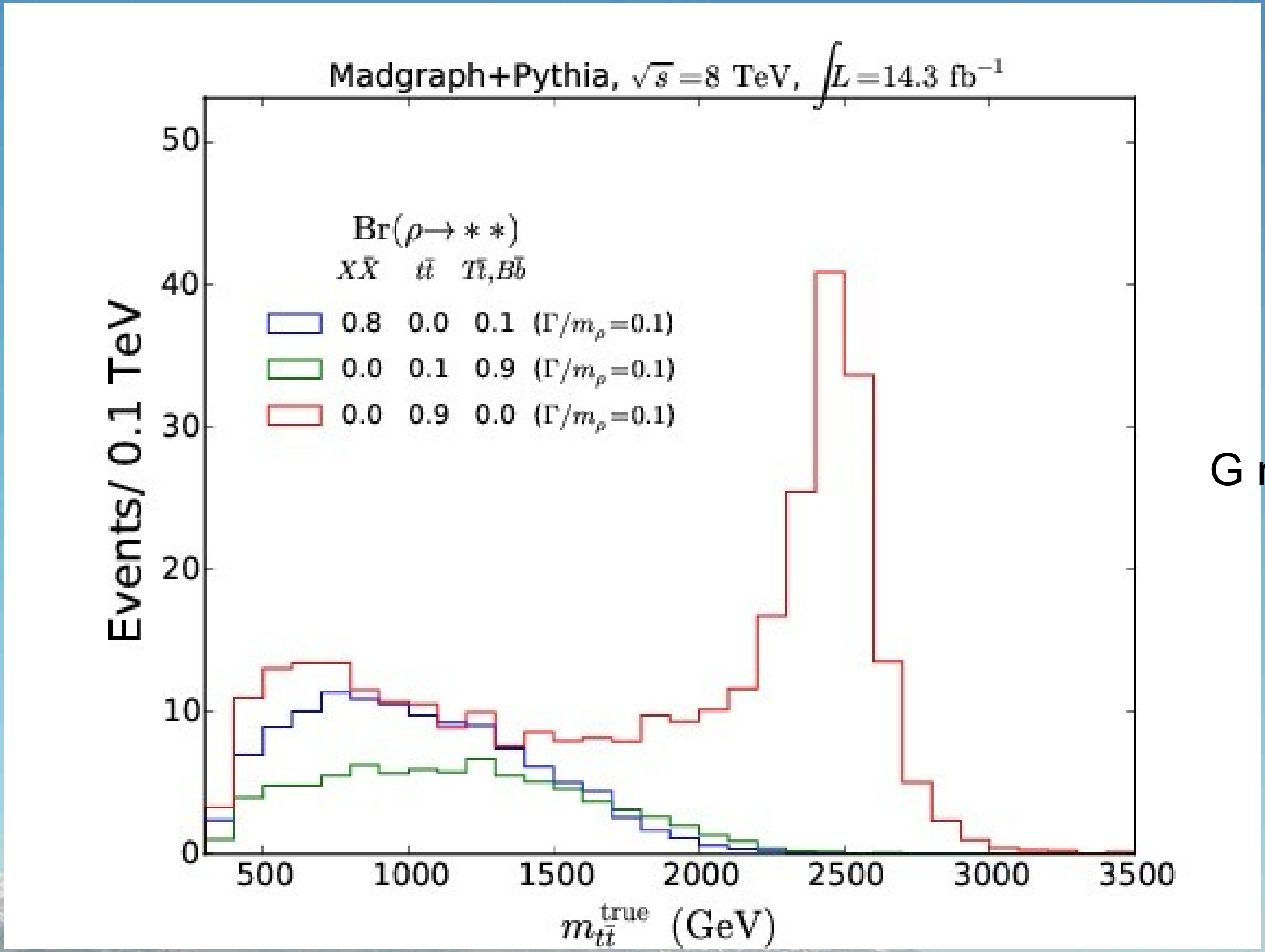
$$pp \to G \to \begin{cases} X_{5/3}\bar{X}_{5/3} \to t\bar{t}W^+W^- \\ X_{2/3}\bar{X}_{2/3} \to t\bar{t} + (ZZ, ZH, HH) \\ T\bar{T} \to (tZ + tH + bW^+)(\bar{t}Z + \bar{t}H + \bar{b}W^-) \\ B\bar{B} \to t\bar{t}W^+W^- \\ t\bar{T} + b\bar{B} + \to t(\bar{t}Z + \bar{t}H + \bar{b}W^-) + b(\bar{t}W^+) \\ t\bar{t} + b\bar{b} + q\bar{q} \end{cases}$$

tt+X resonances

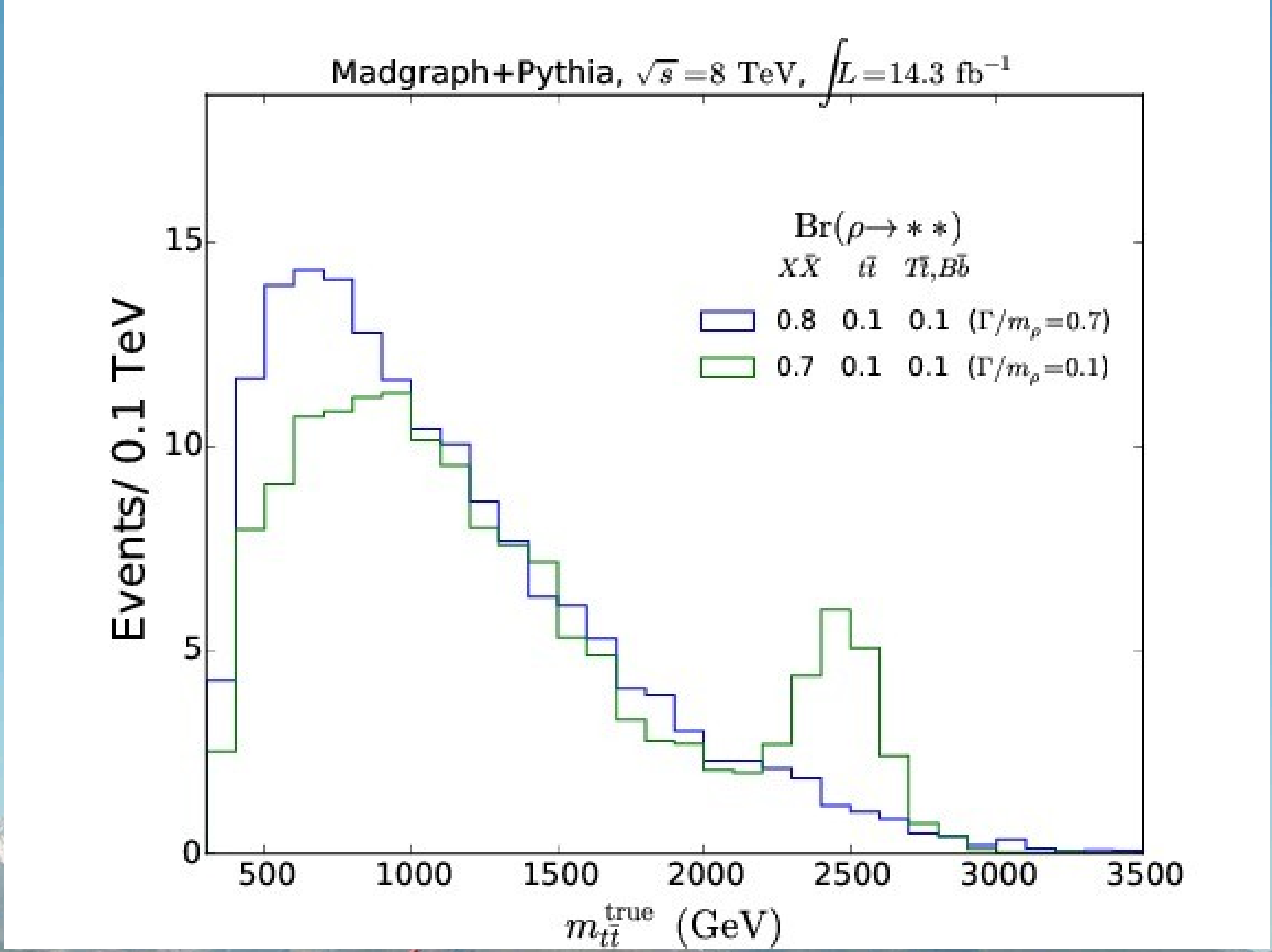
- X is important!



G not reconstructed by tt

tt+X resonances

- X is important!
- Width is important



tt+X resonances

- X is important!
- Width is important
- It gets (almost always) worse at the reconstruction level
  - Larger number of particles makes reconstruction less efficient
  - Smearing/detector effects lead to further misreconstruction

tt+X resonances

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- Width is important
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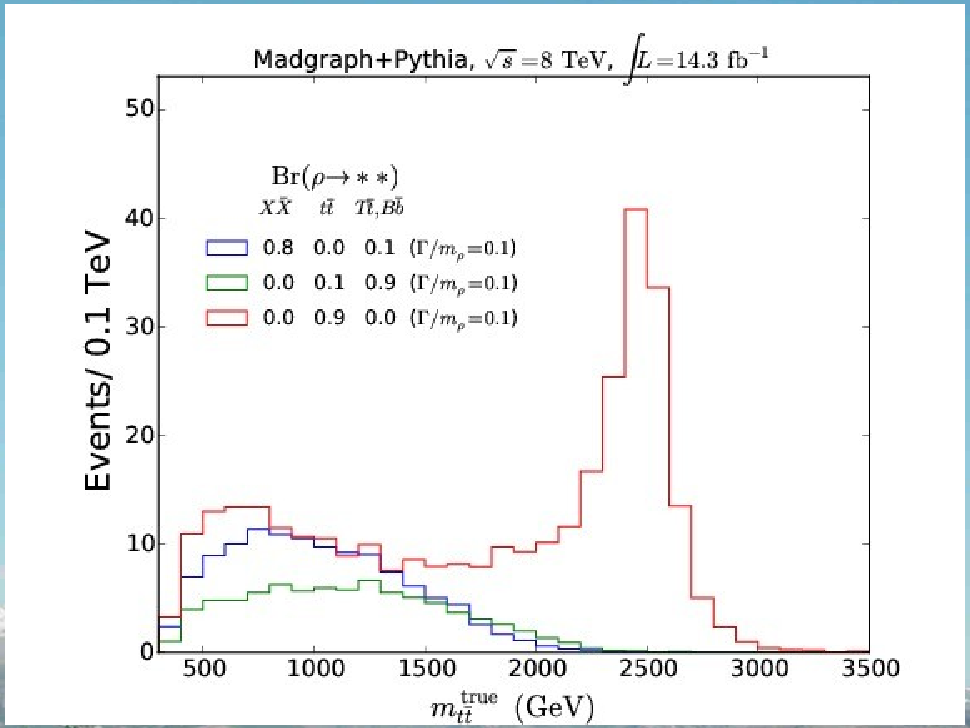

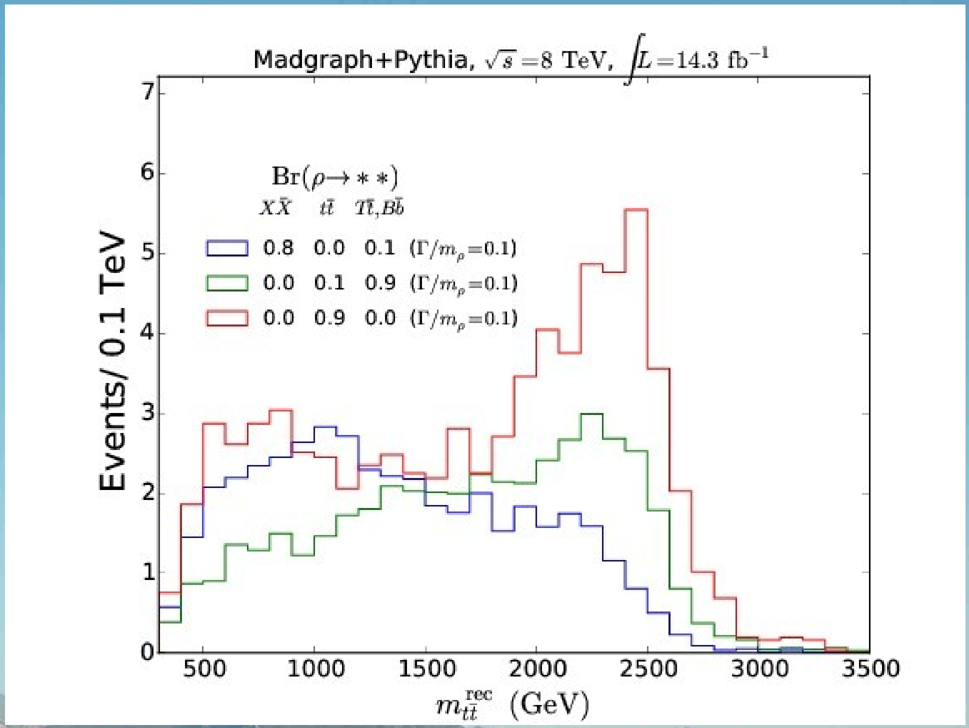

tt+X resonances

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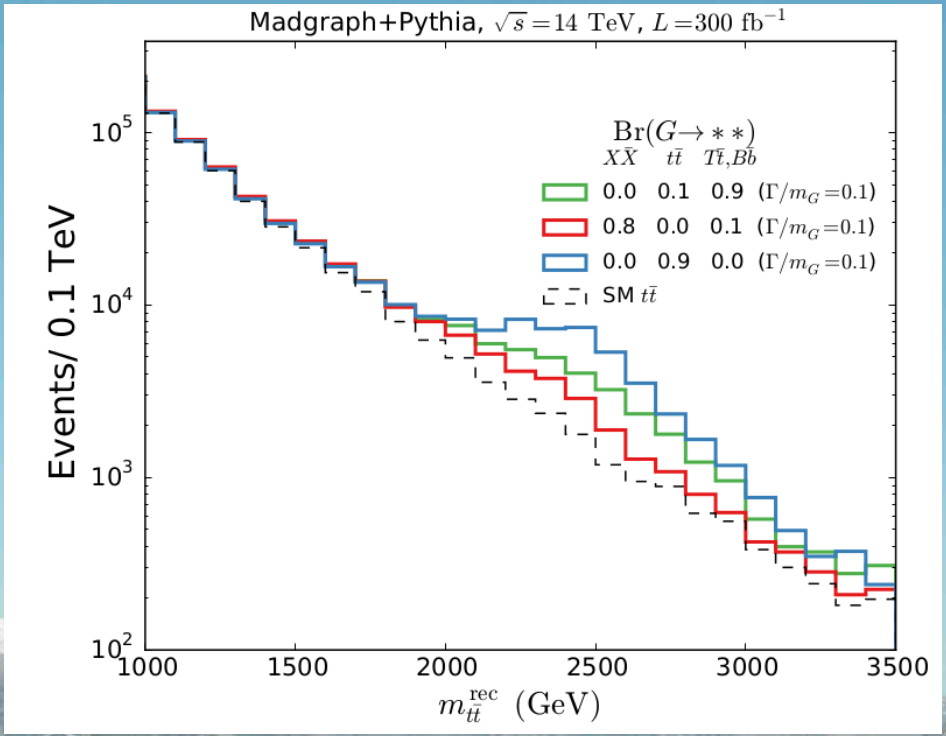
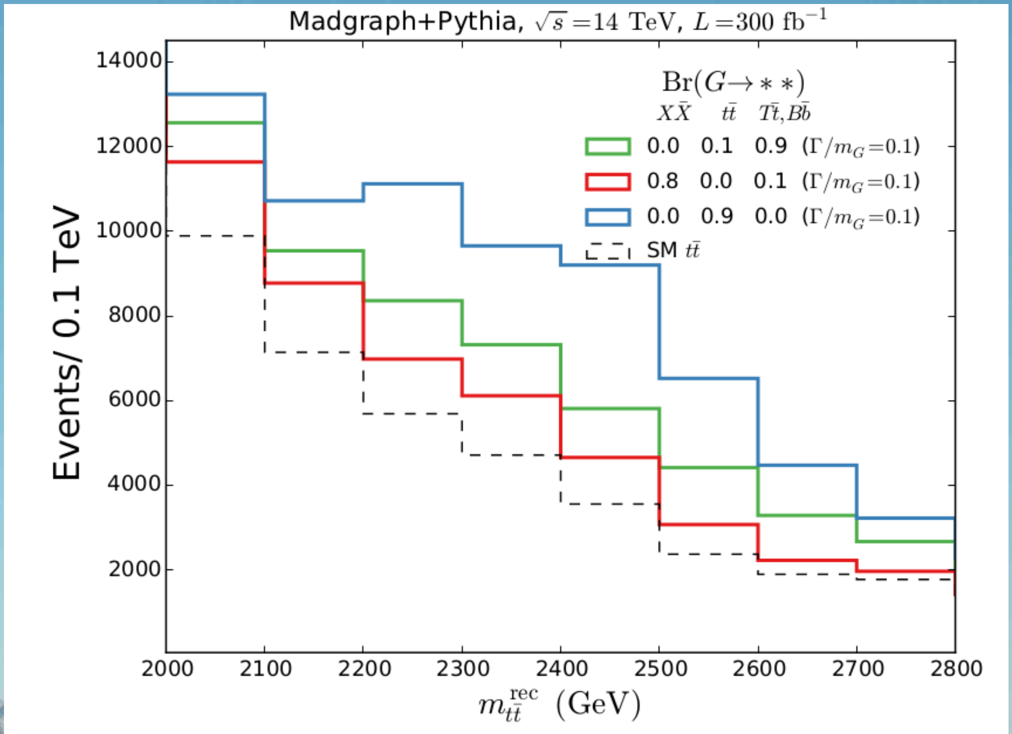
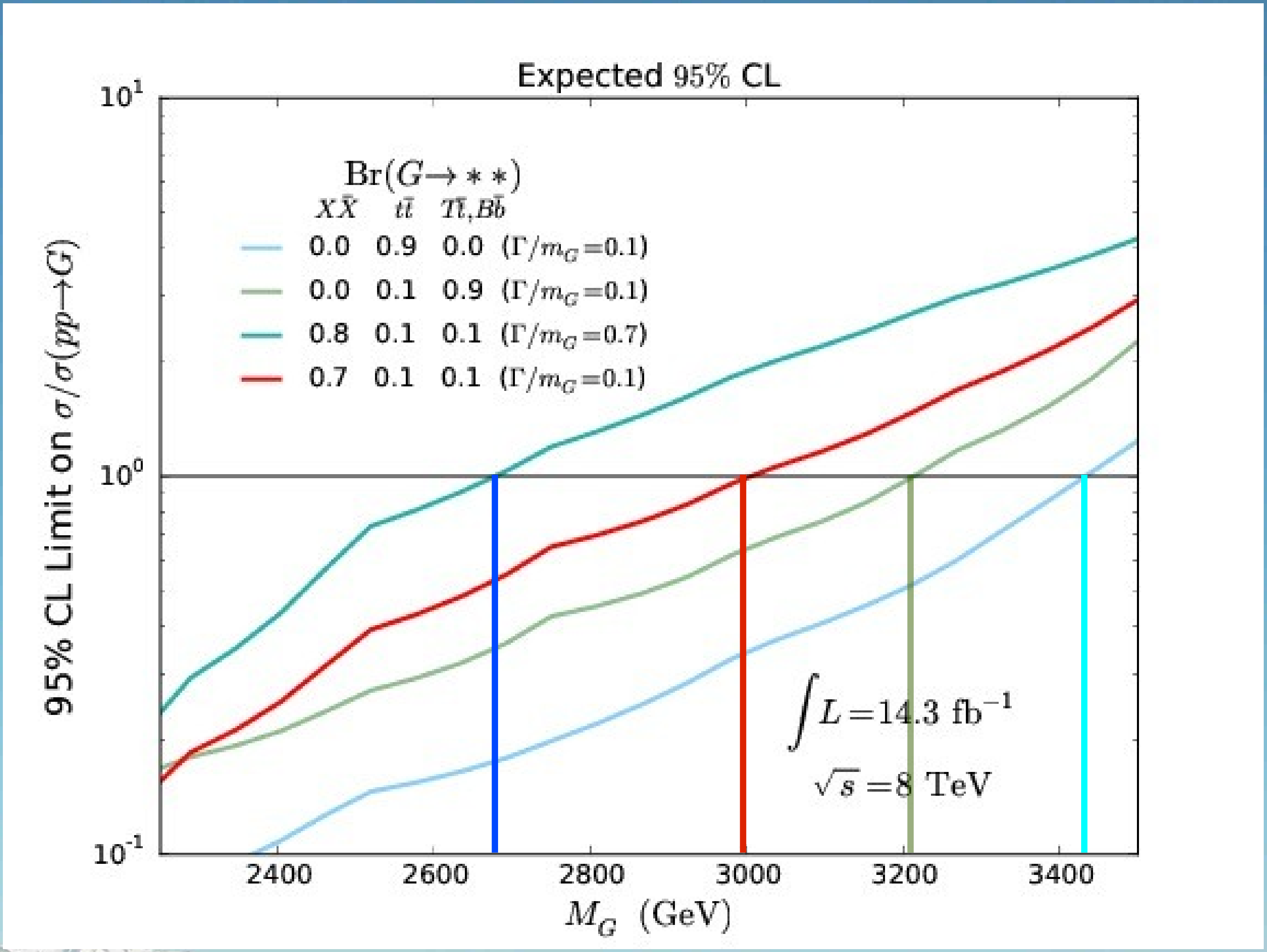


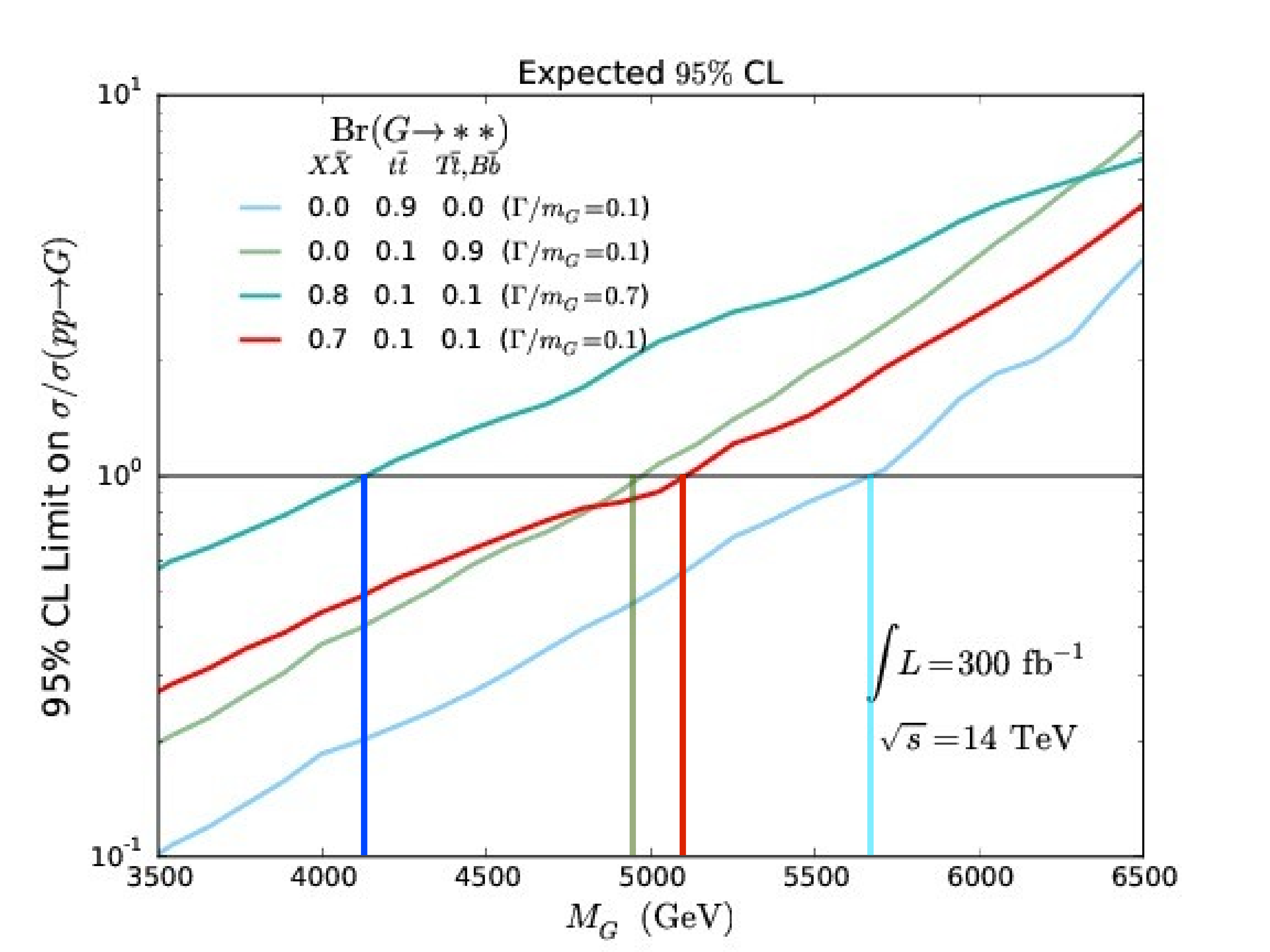


tt+X resonances



700-800 GeV difference at the LHC8!!

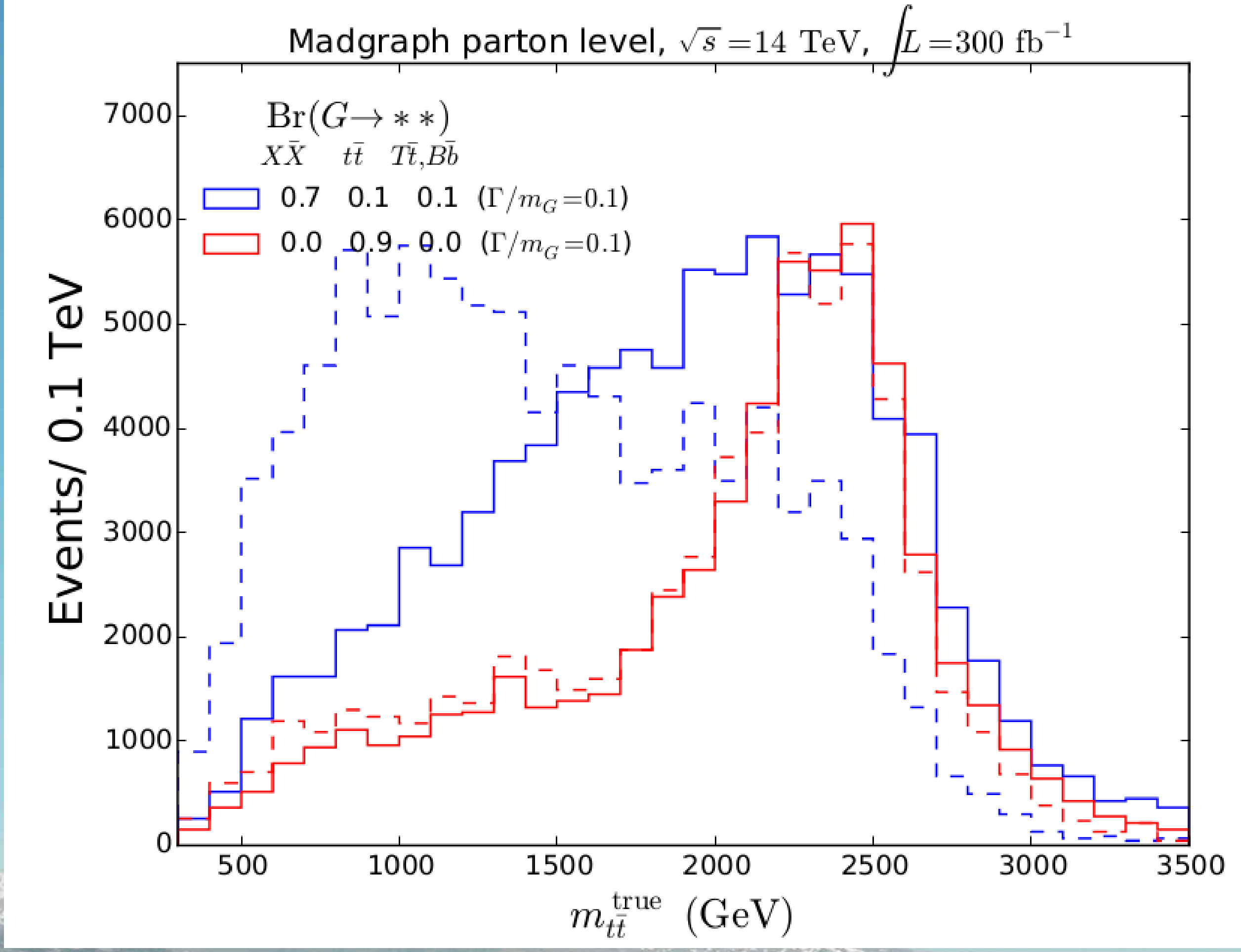
tt+X resonances



1.5 TeV difference at the LHC14!!

tt+X resonances

- Can we do better? Yes! Try to add the X



- Top partners are heavy: V, H likely boosted
- Add fat (ΔR=1), hard (pT>200 GeV) jets to the invariant mass

tt+X resonances

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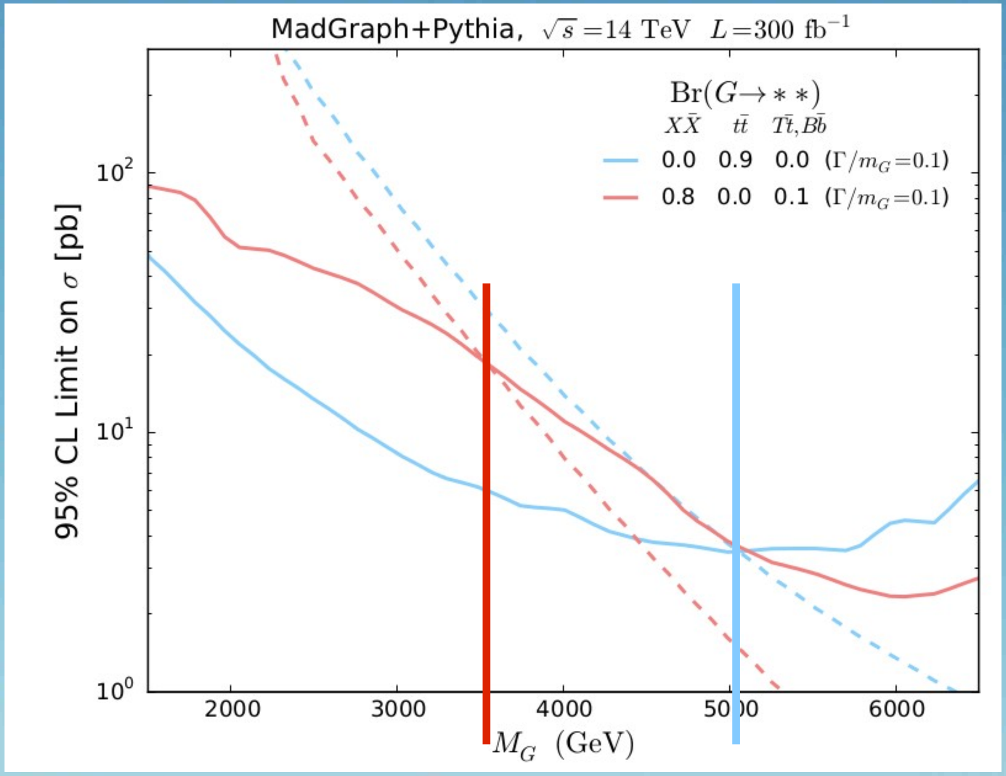
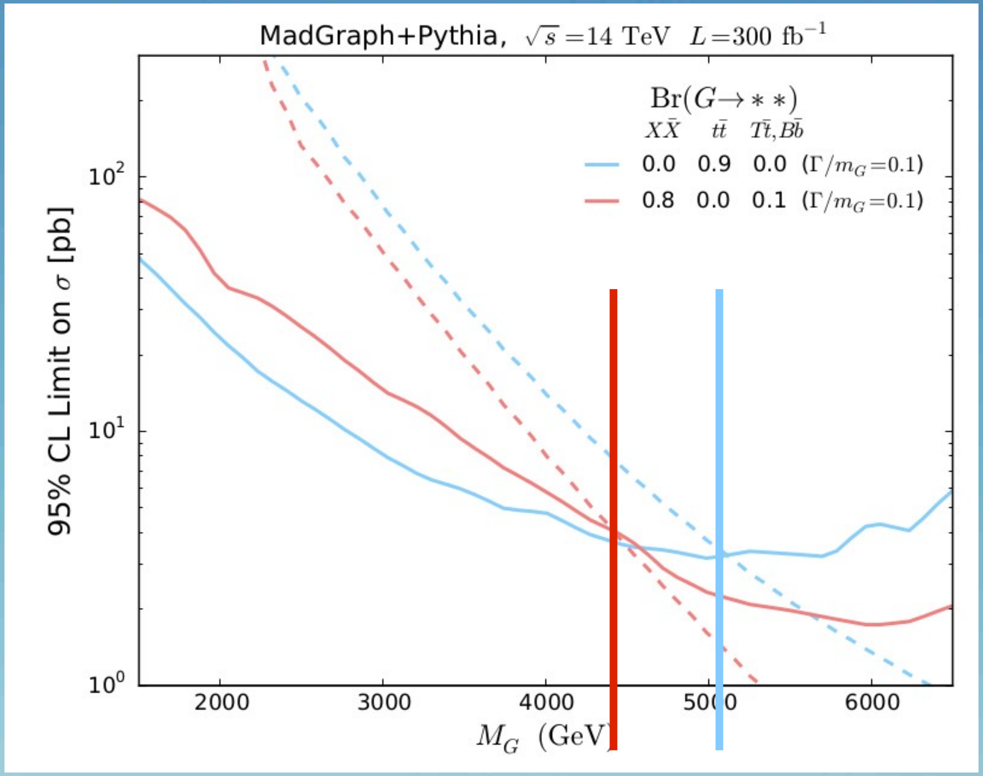


Current analysis



Improved analysis

tt+X resonances

- Of course is is also important to know with the best possible precision:
  - The ttbar tail
  - The production of the top (partners) via the heavy gluon (wide resonance)
- EW vector resonances also present (in progress)
  - Width is not an issue but smaller cross sections
  - Other final states (VV, l+l-) might also be relevant
- There is also an interesting interplay between tt+X resonance searches and top partner searches (under investigation)

Summary

- Time-line for presentation of experimental results: NP searches come first, SM measurements much later
- Based on the notion that "If there is new physics, sooner or later it will clearly stick out and we won't miss it"
- This notion is not necessarily true: current direct and indirect constraints seem to point in the opposite direction. NP within the LHC reach is likely to be elusive.
- Precision top physics might be crucial to discover NP
- By top I mean more than SM top
  - New production mechanisms
  - Top-like objects