Physics Potential of Future CMS

Fermilab

Richard Cavanaugh
LHC Physics Center Coordinator

Fermilab Physics Advisory Committee Meeting
Fermilab, 6 June, 2013

Outline

- Introduction
- Physics Landscape after 8 TeV
- Discovery Potential Studies for future CMS
- LHC Physics Center
- Conclusion

With Special Thanks to:

Paolo Giacomelli

Kenichi Hateyakama

Isabell Melzer-Pellmann

Chris Hill

Joe Incandela

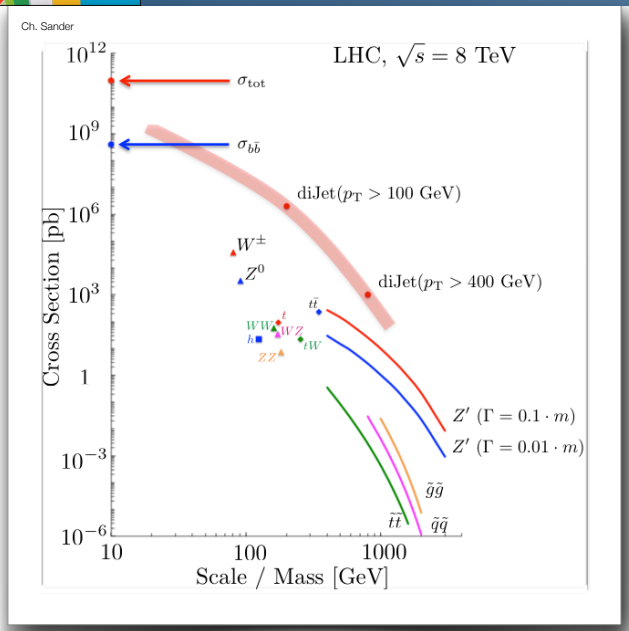
Guenther Dissertori

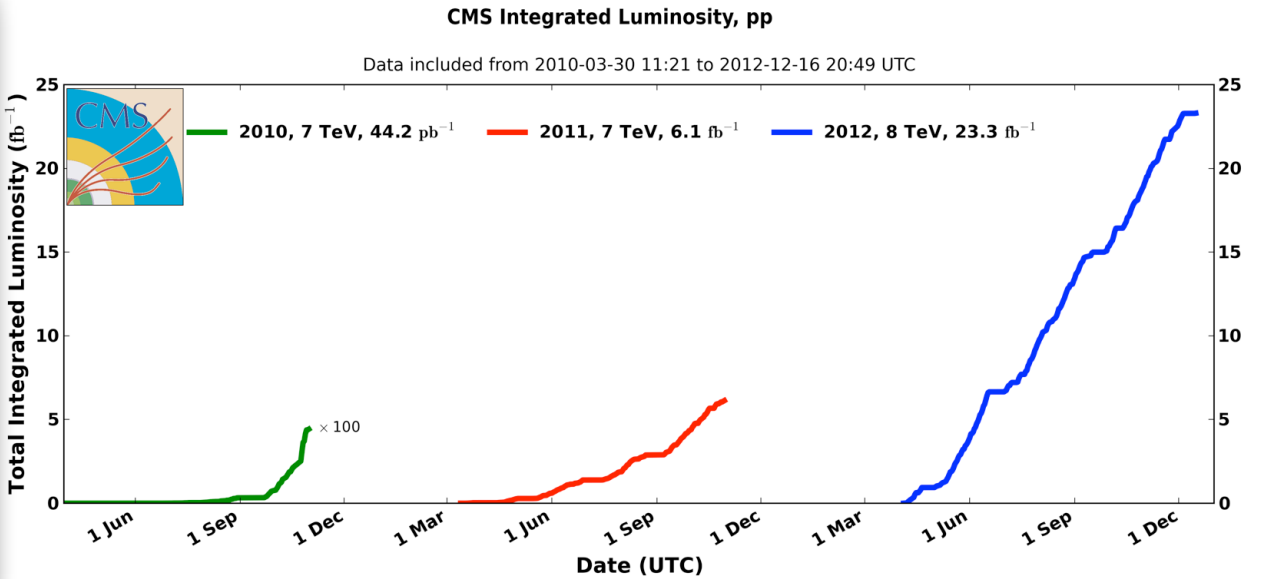
Markus Klute

Boaz Klima

Meenakshi Nairan

The (utterly) Amazing LHC!





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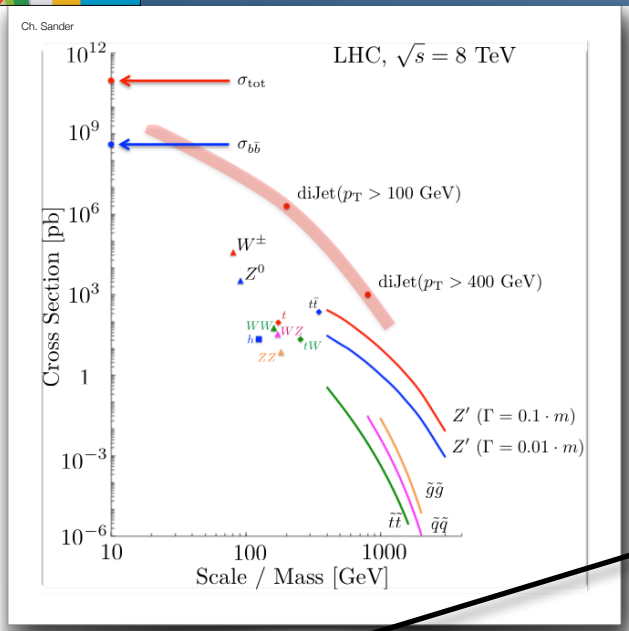

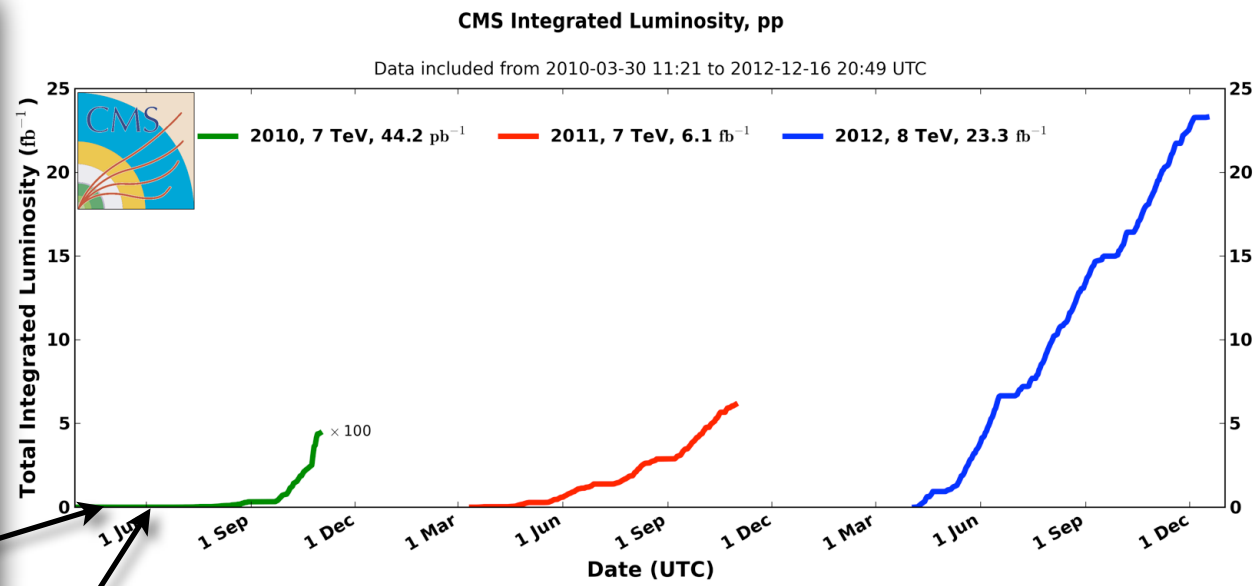

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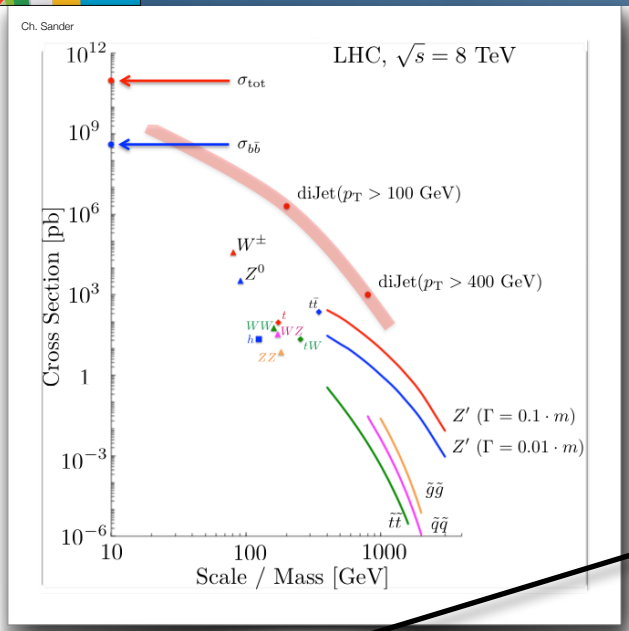

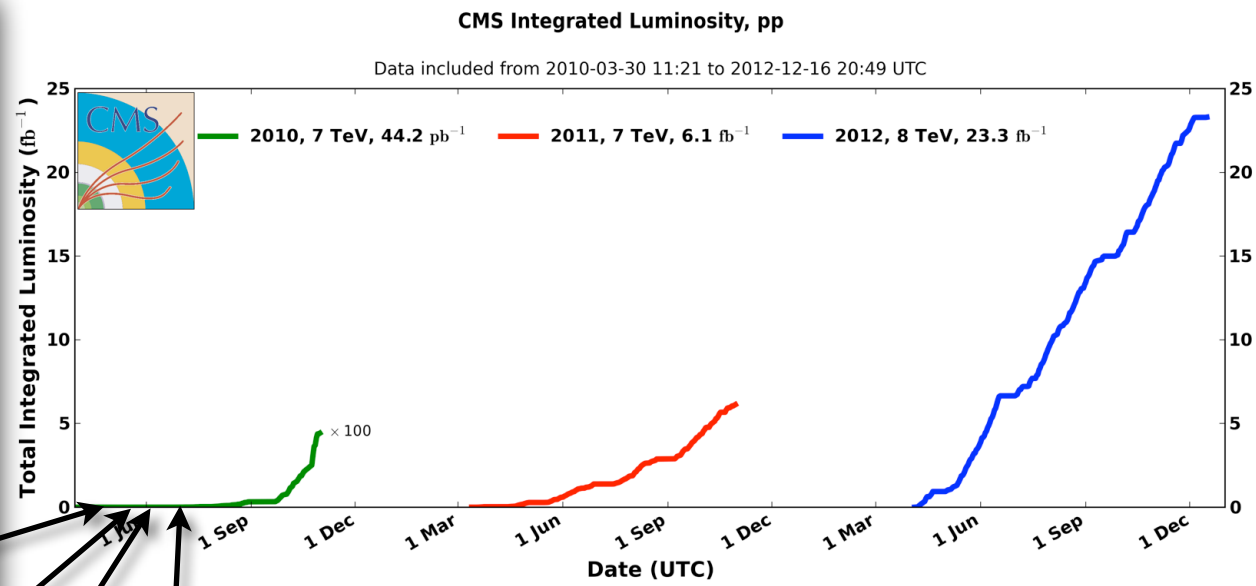

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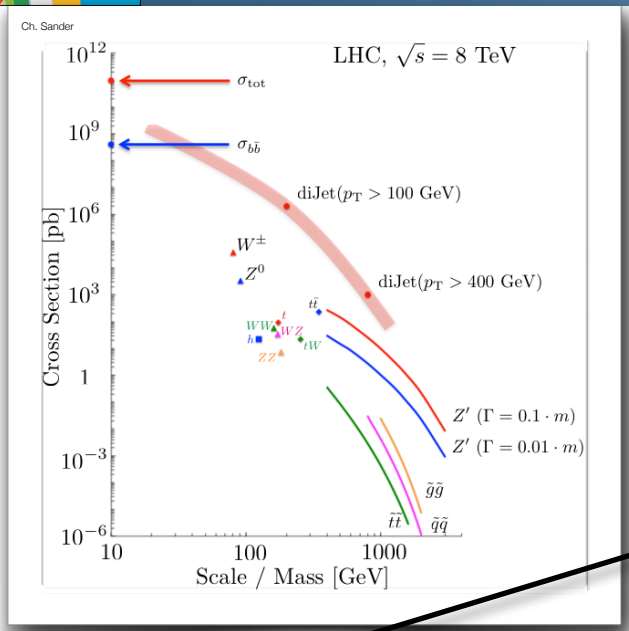

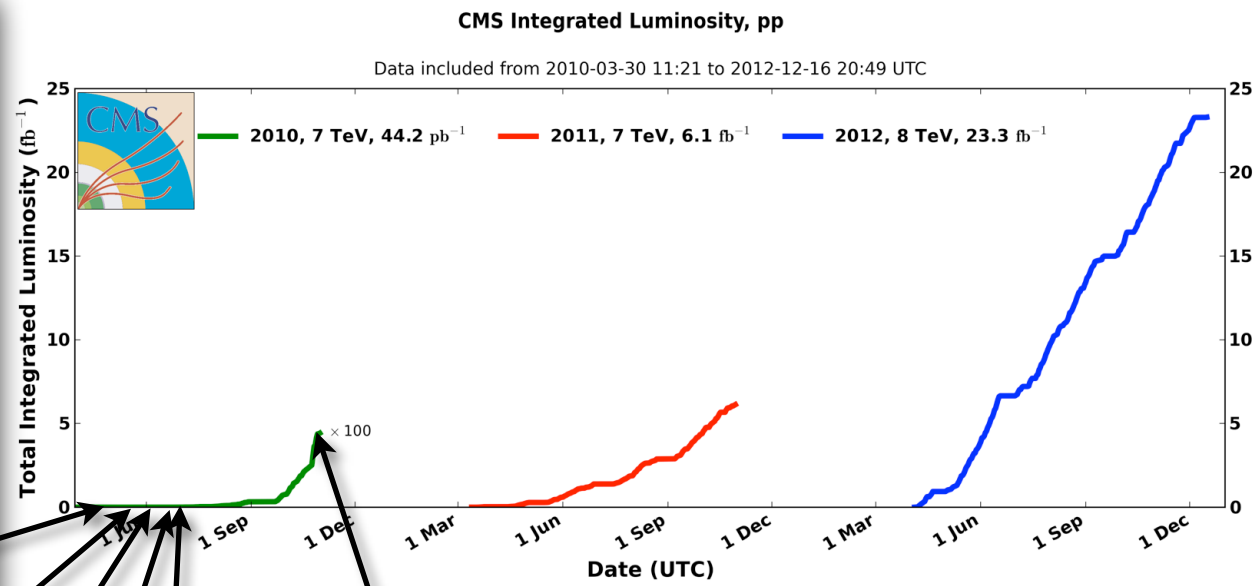

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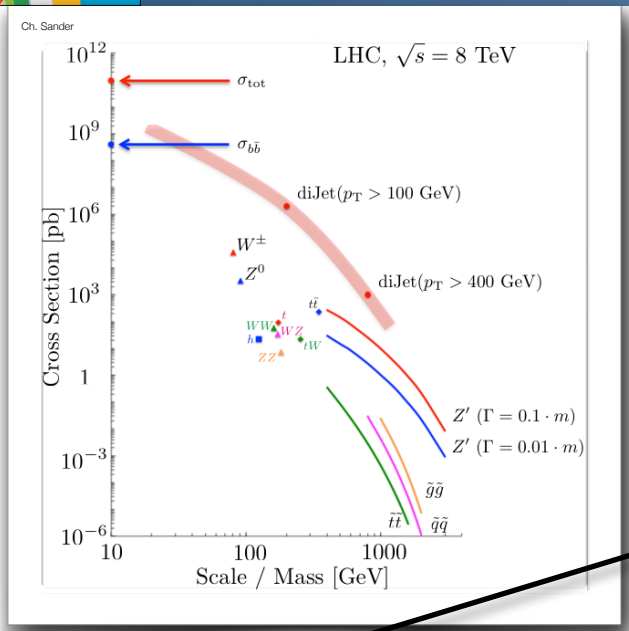

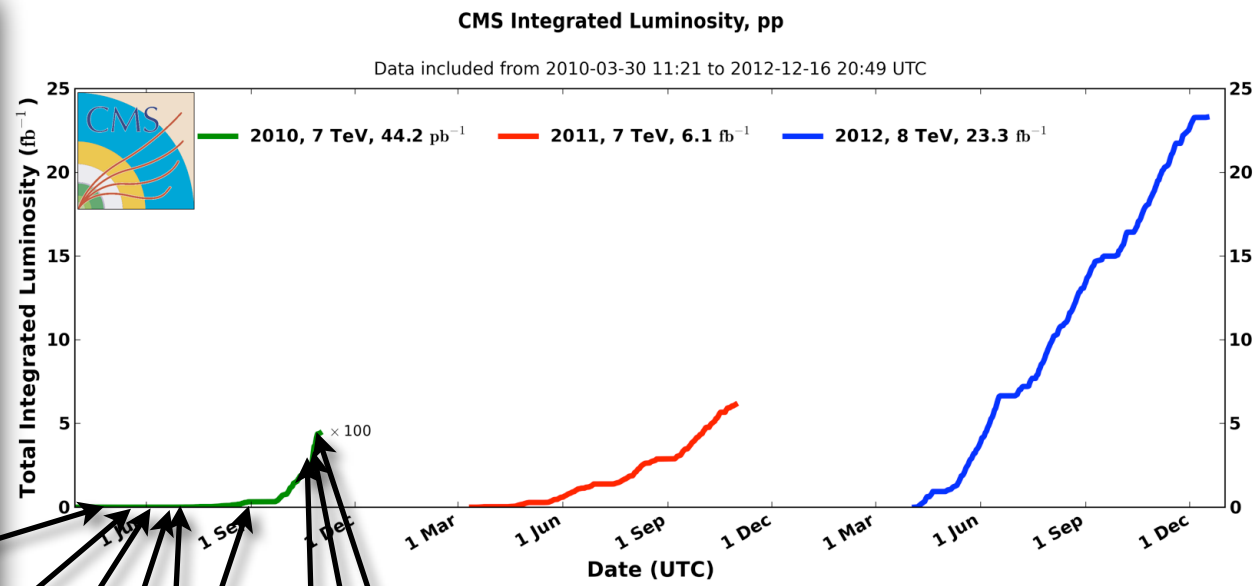

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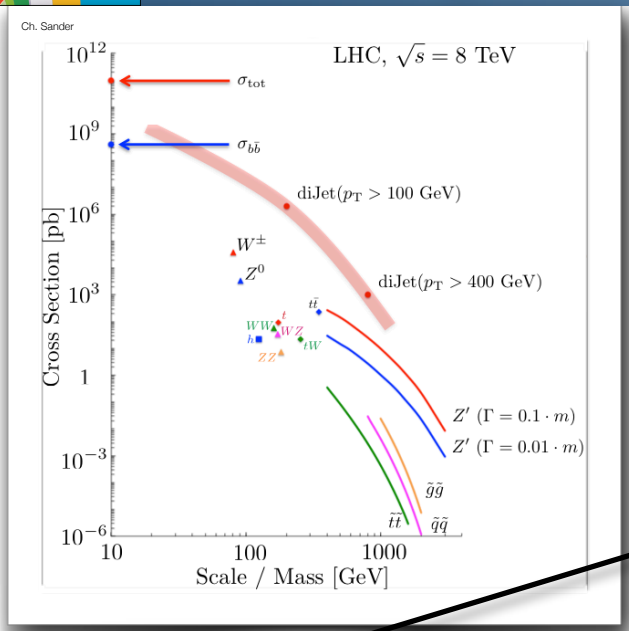

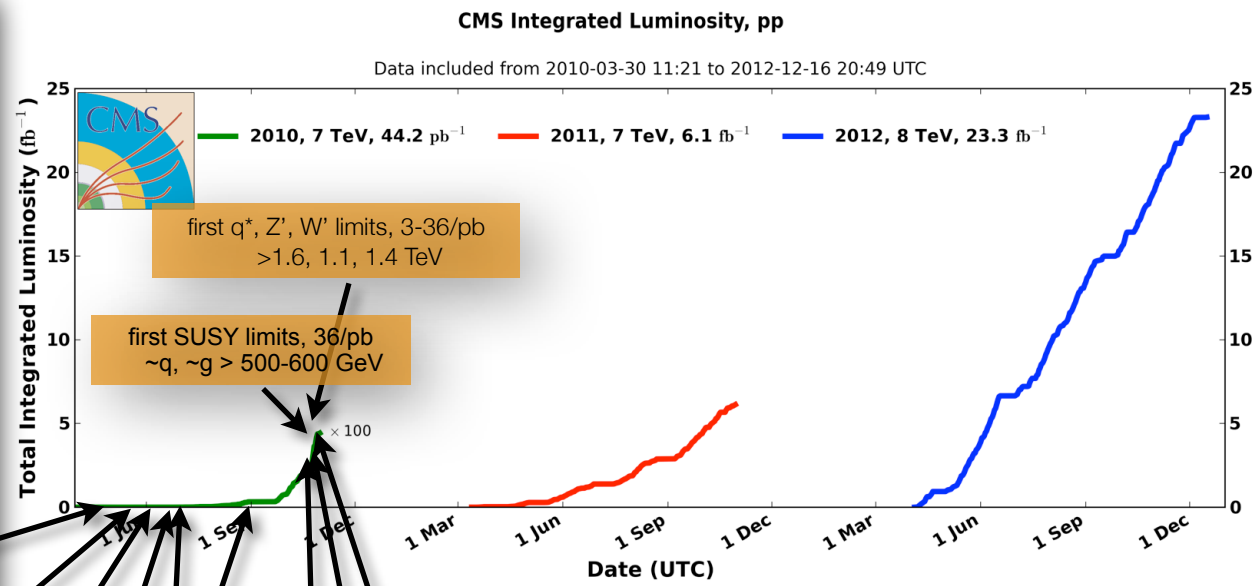

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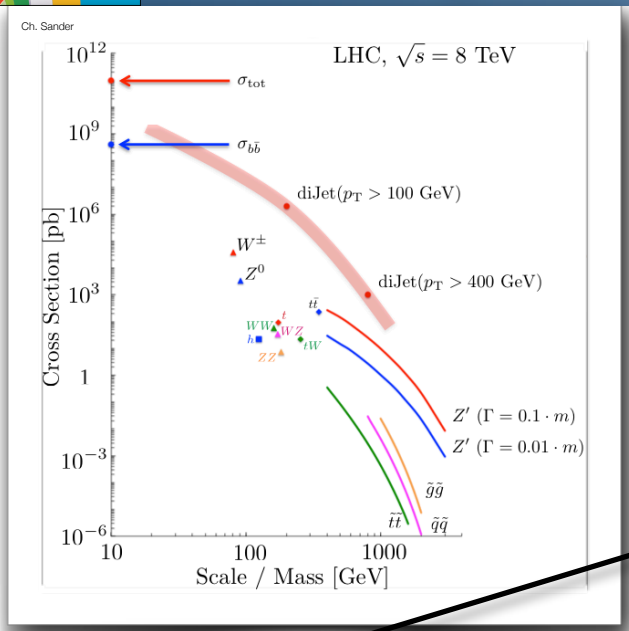

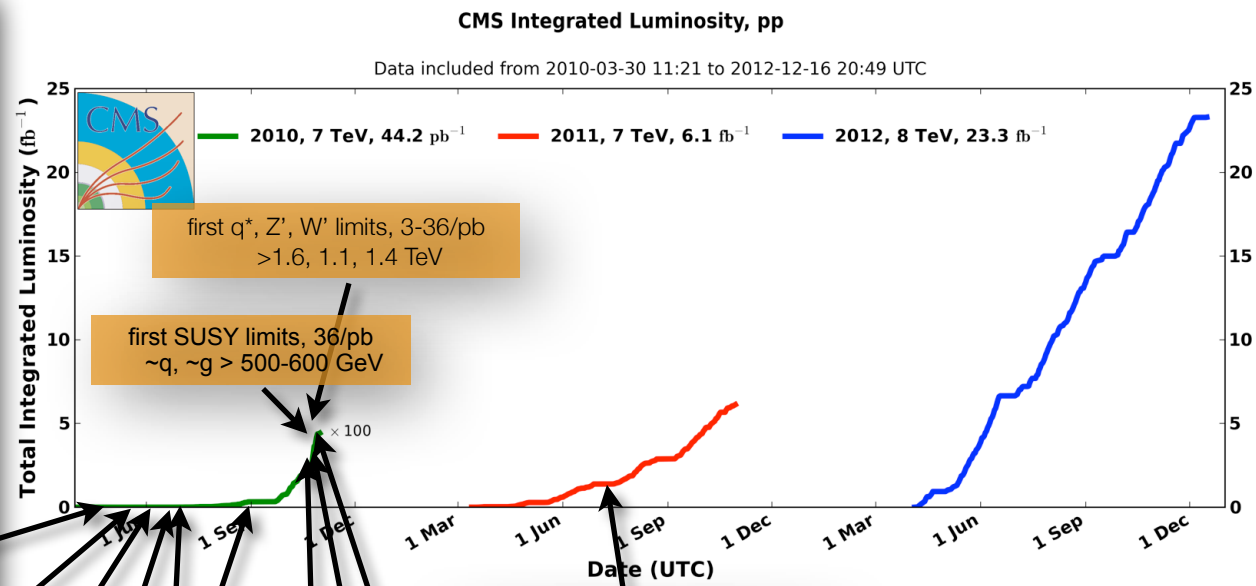

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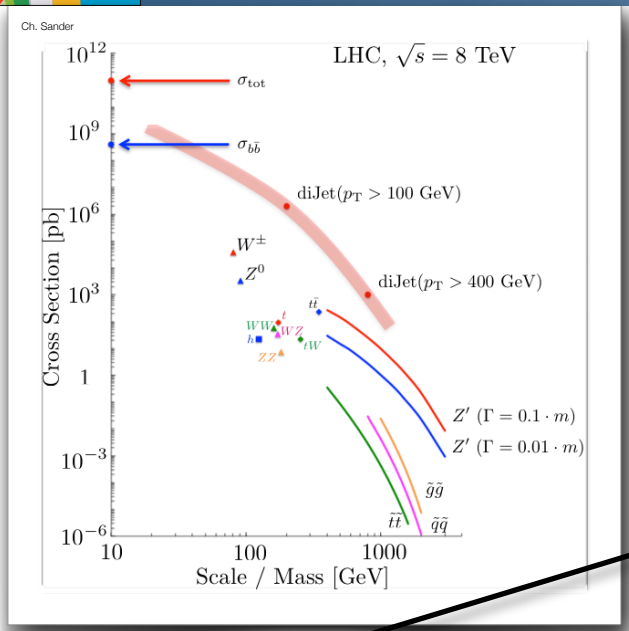

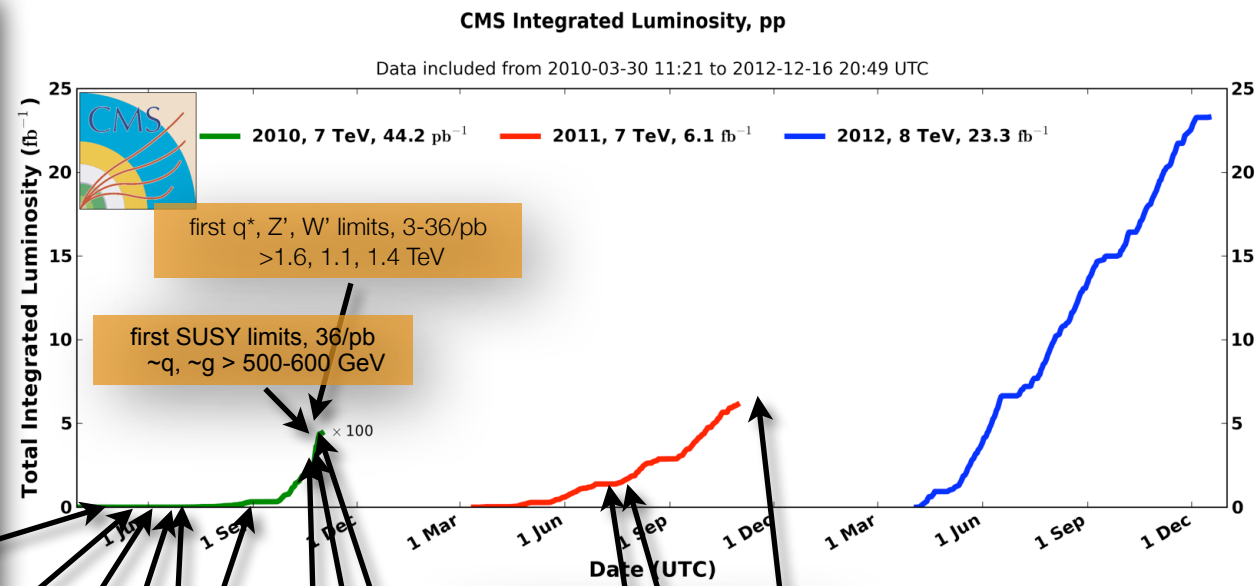

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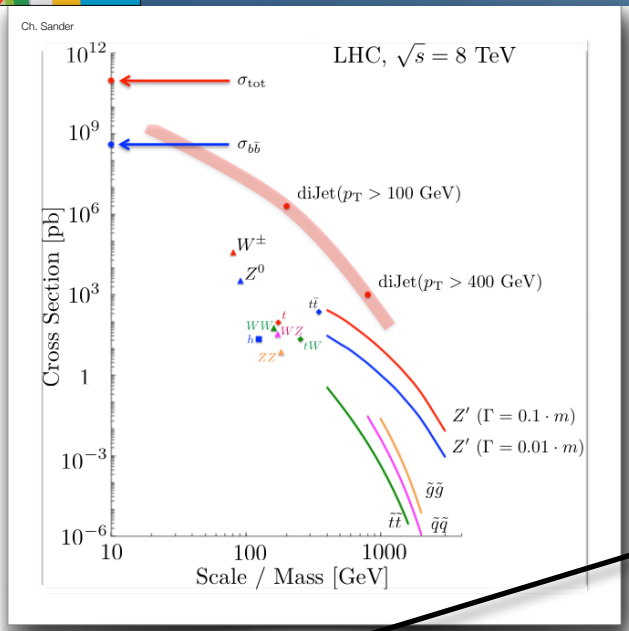

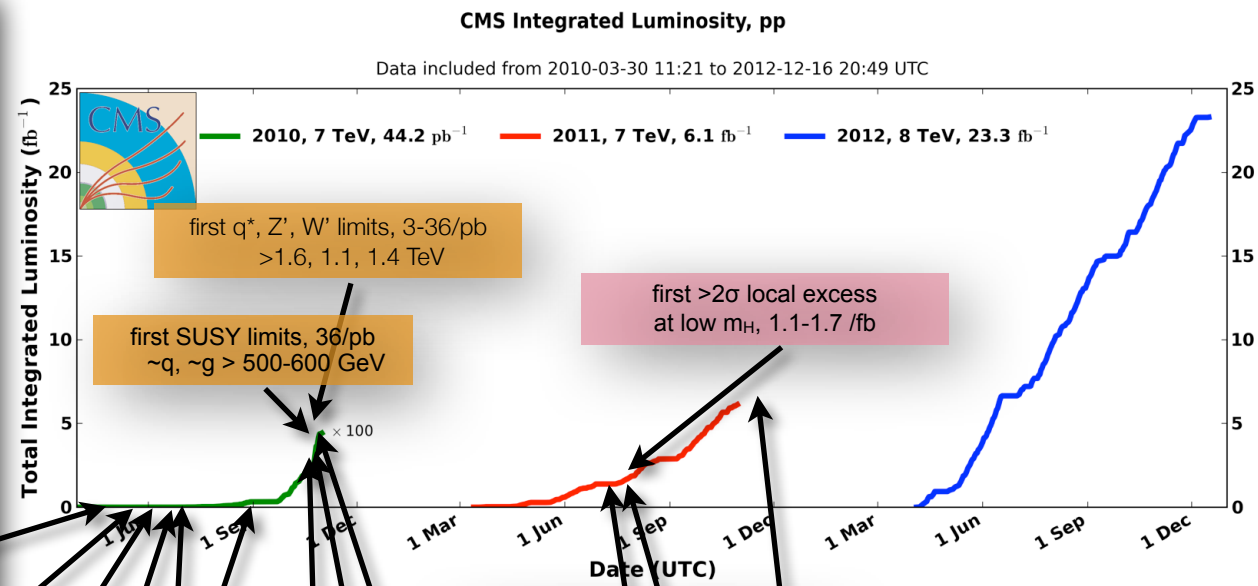

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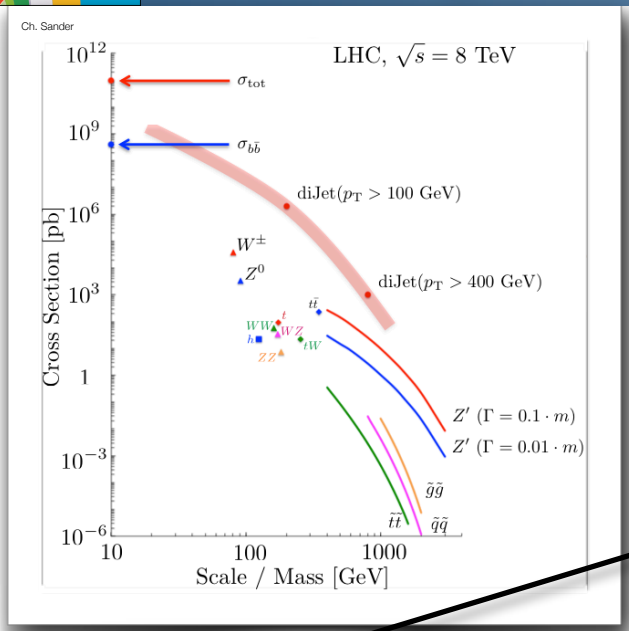

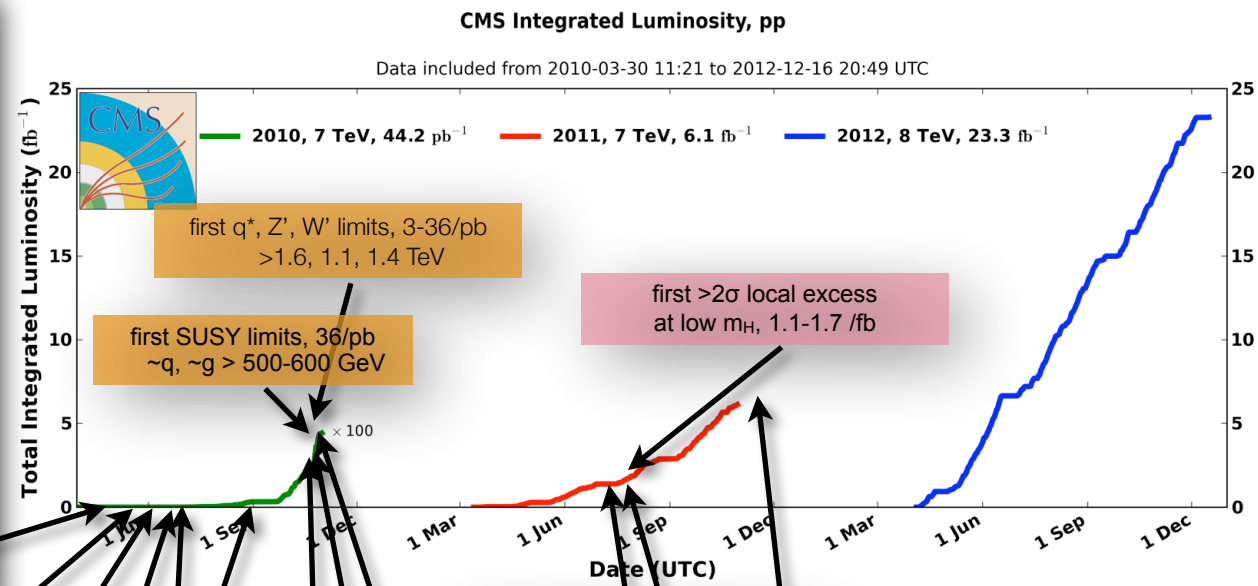

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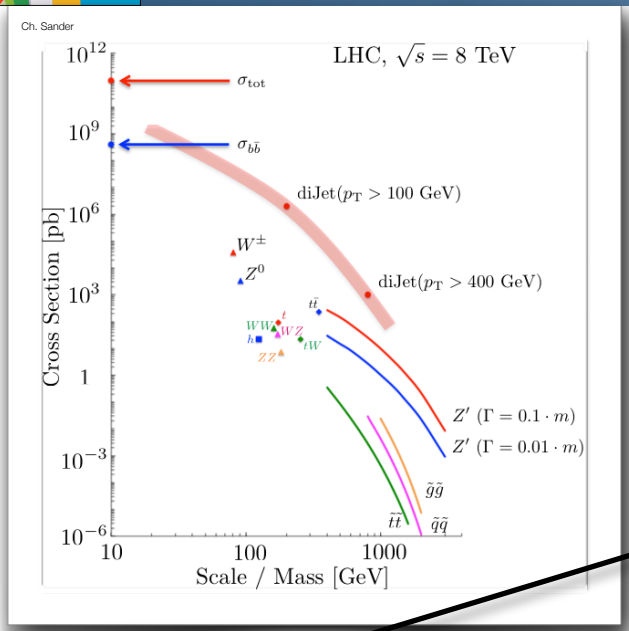

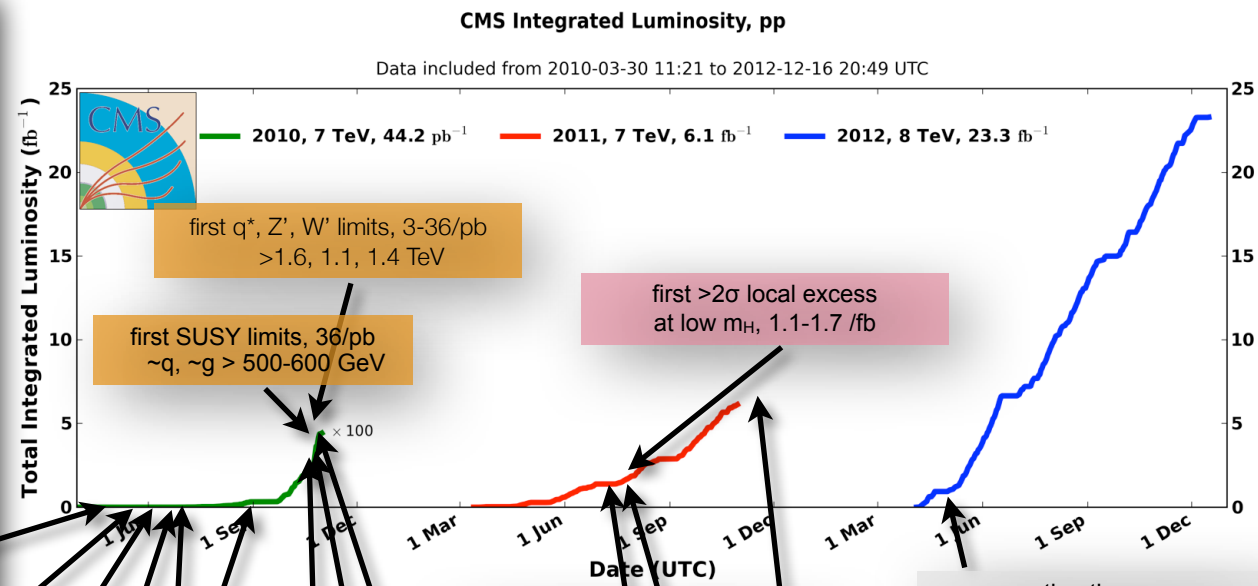

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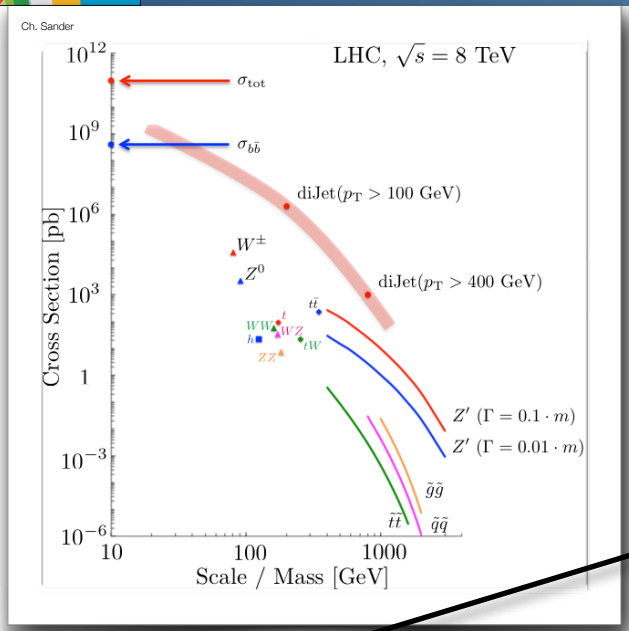

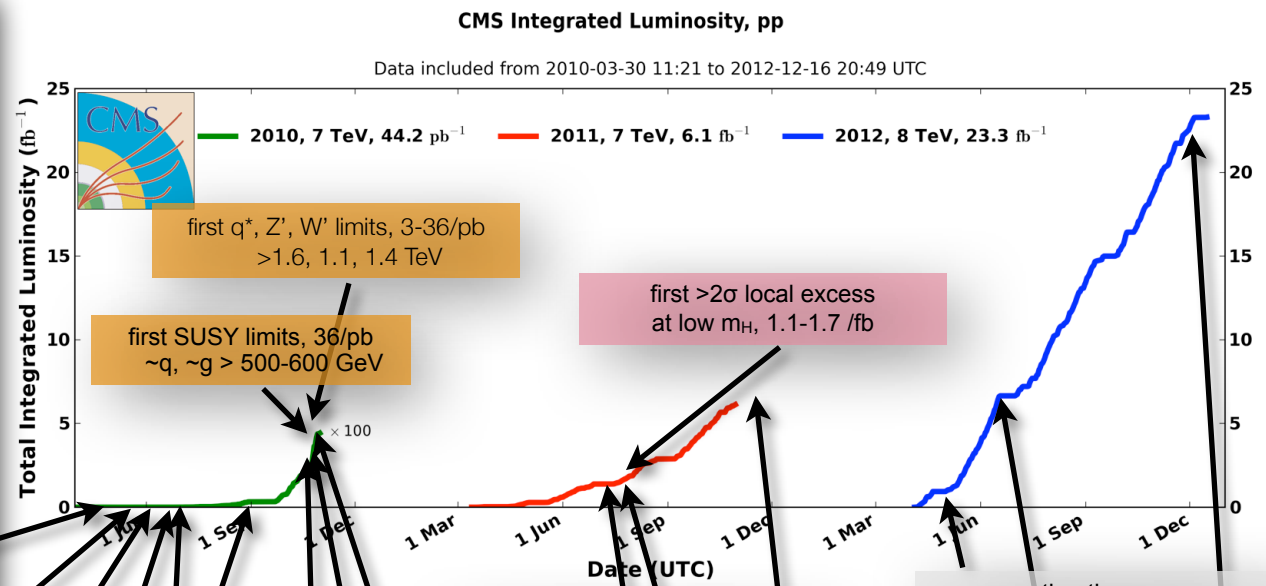

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a new boson is announced, 5 /fb

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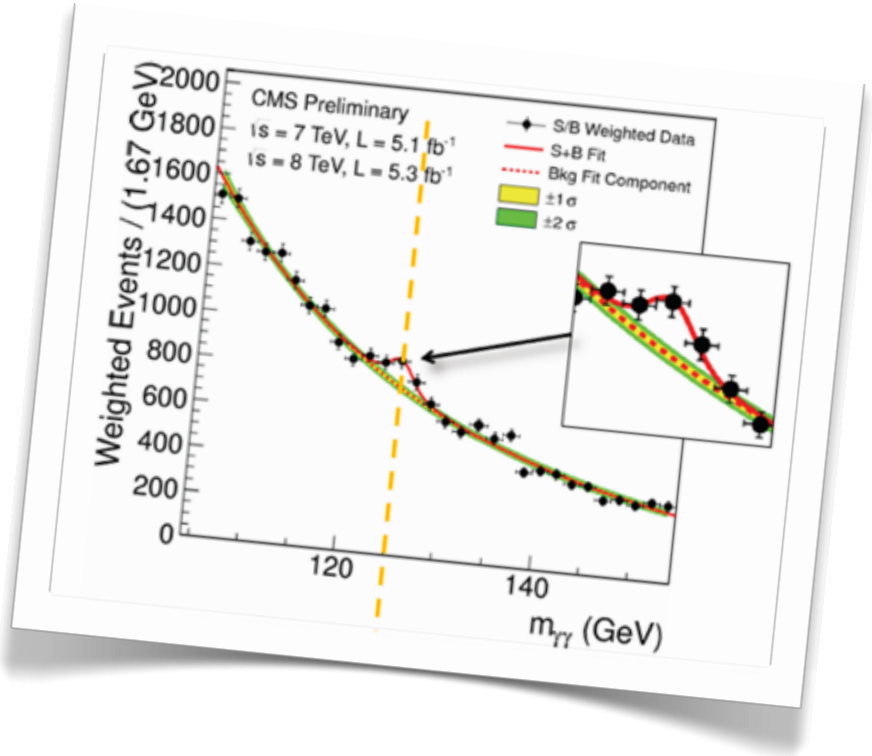

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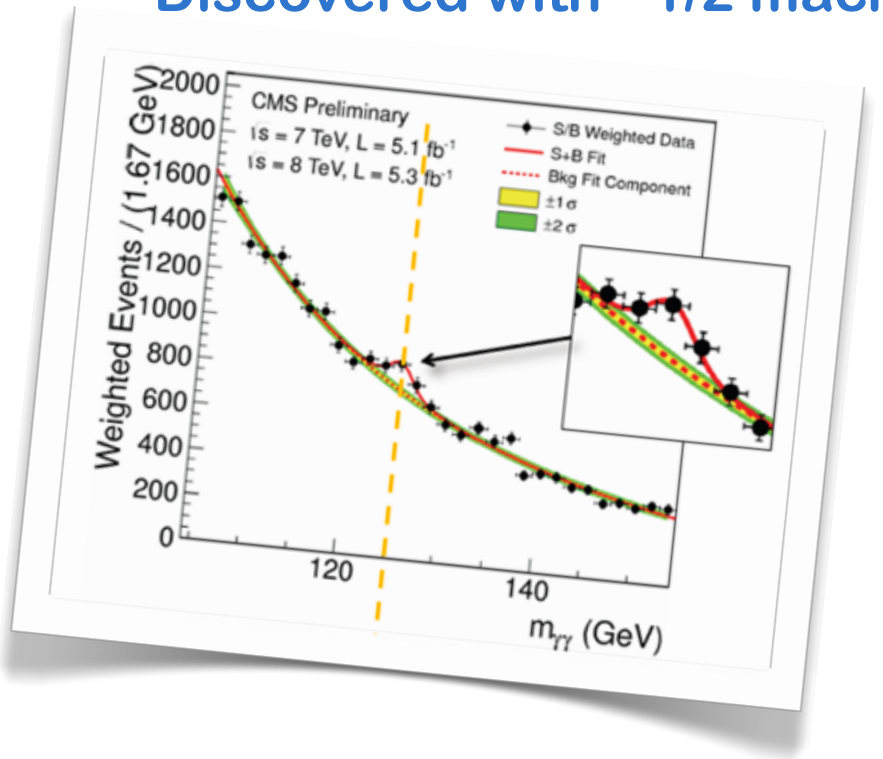

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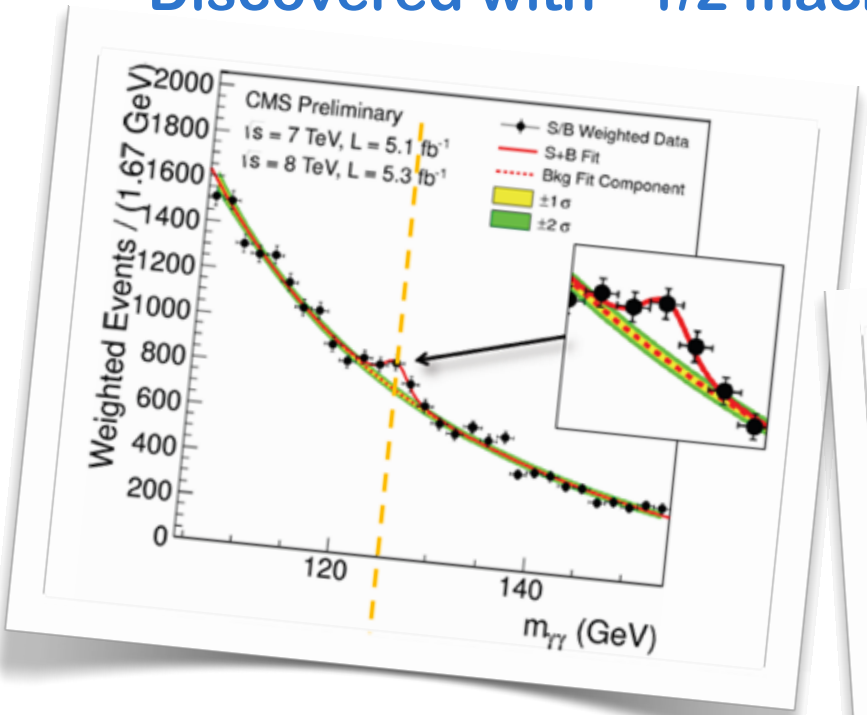

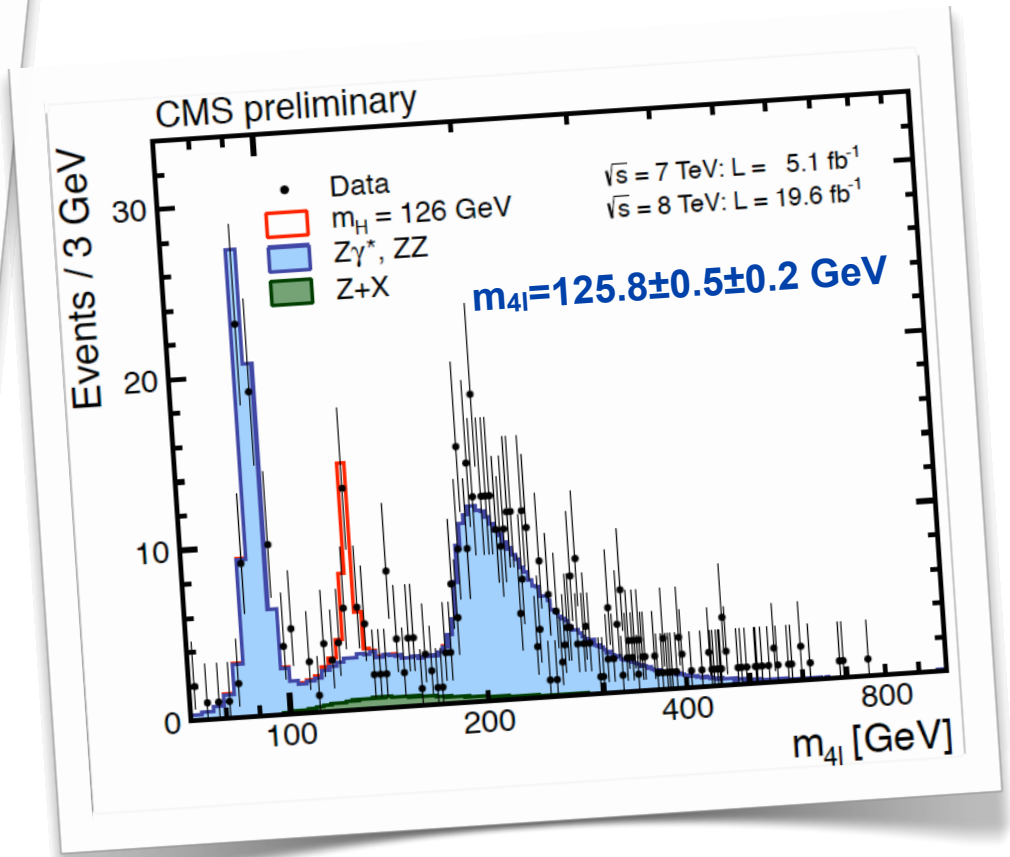

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HENRICUS MARTELLUS WORLD MAP, c1490

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World map 25 yrs after Columbus discovered "India"

Opened up a new era of exploration and discovery

WALDSEEMULLER WORLD MAP, 1507

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  - Only discovery machine at the Energy Frontier for foreseeable future
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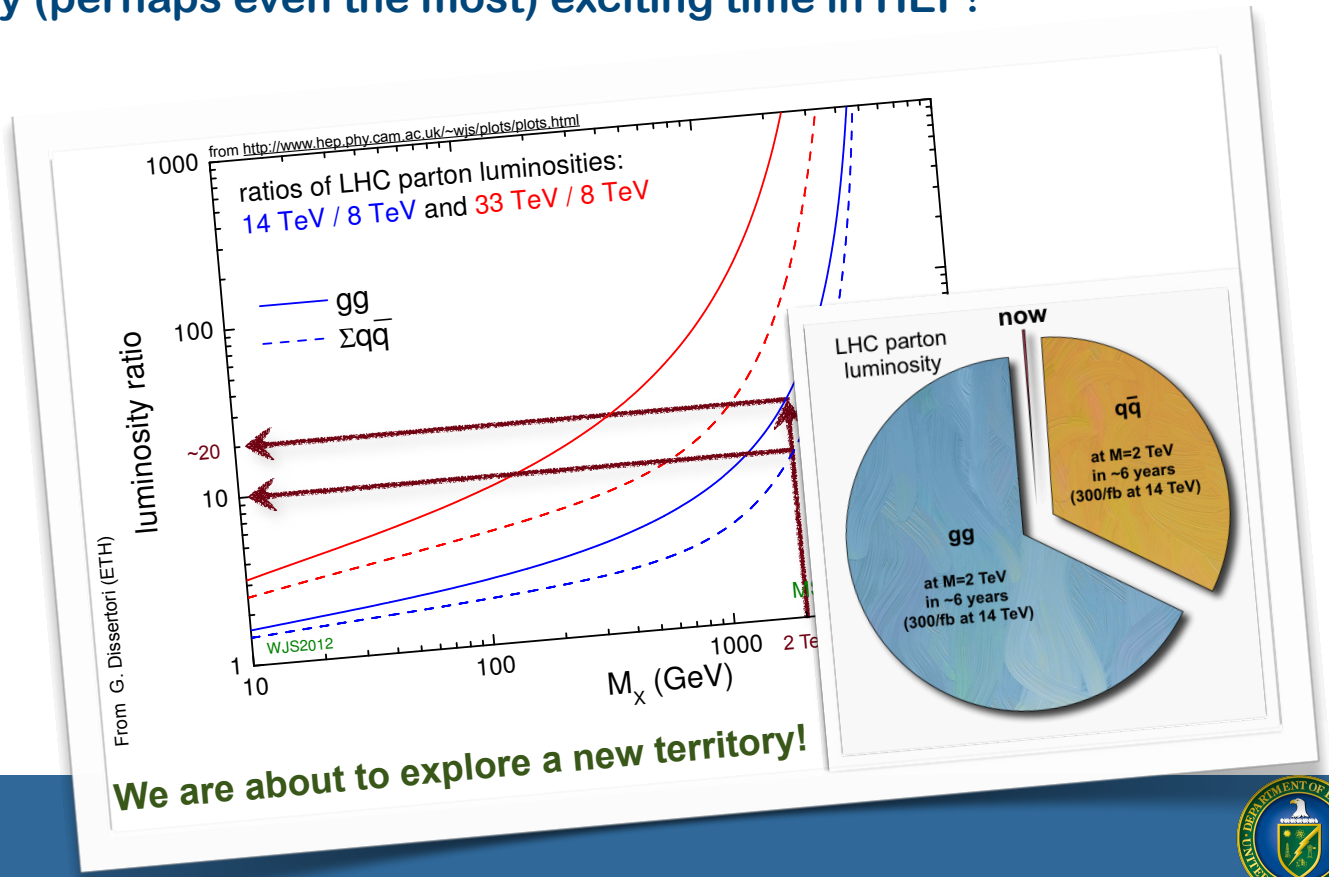

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- With HL-LHC 13/14 TeV data until ~2032 (~3000 fb^{-1})
  - Measure Higgs-like couplings with ultimate precision
  - Study WW scattering
  - Search for new physics in rare processes

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- Phase 2 Upgrade: 5x LHC design luminosity
  - Event pileup reaches ~140 collisions per beam crossing (@ 25 ns)
  - Need solutions to cope with very high rates (10-15 x 2012), radiation and pileup

Pile-up in 2012

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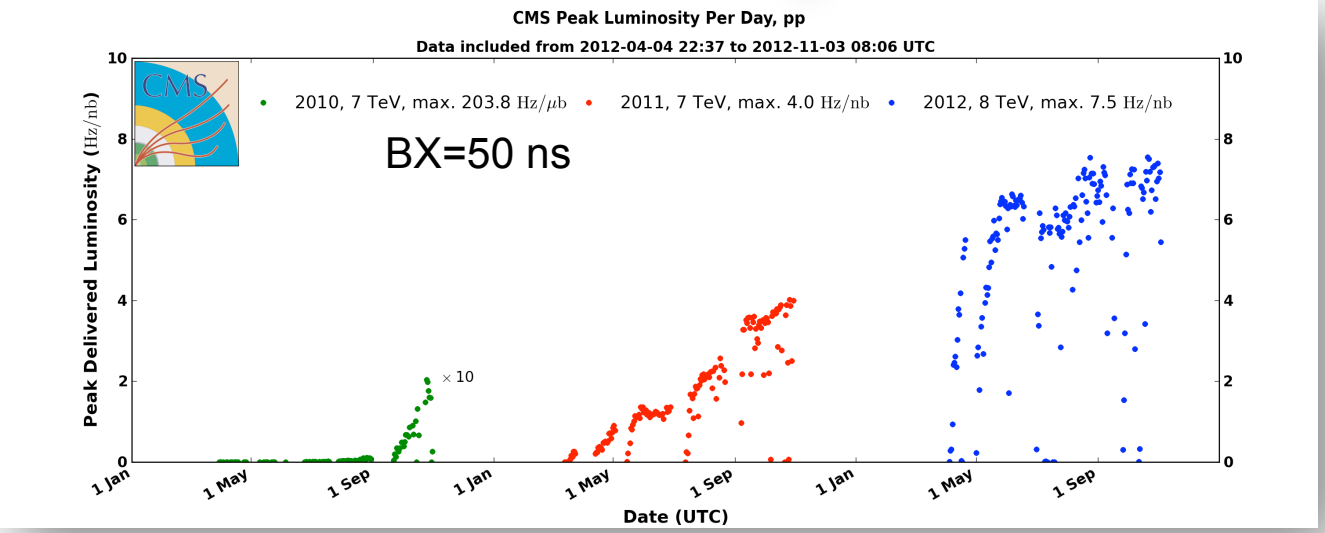

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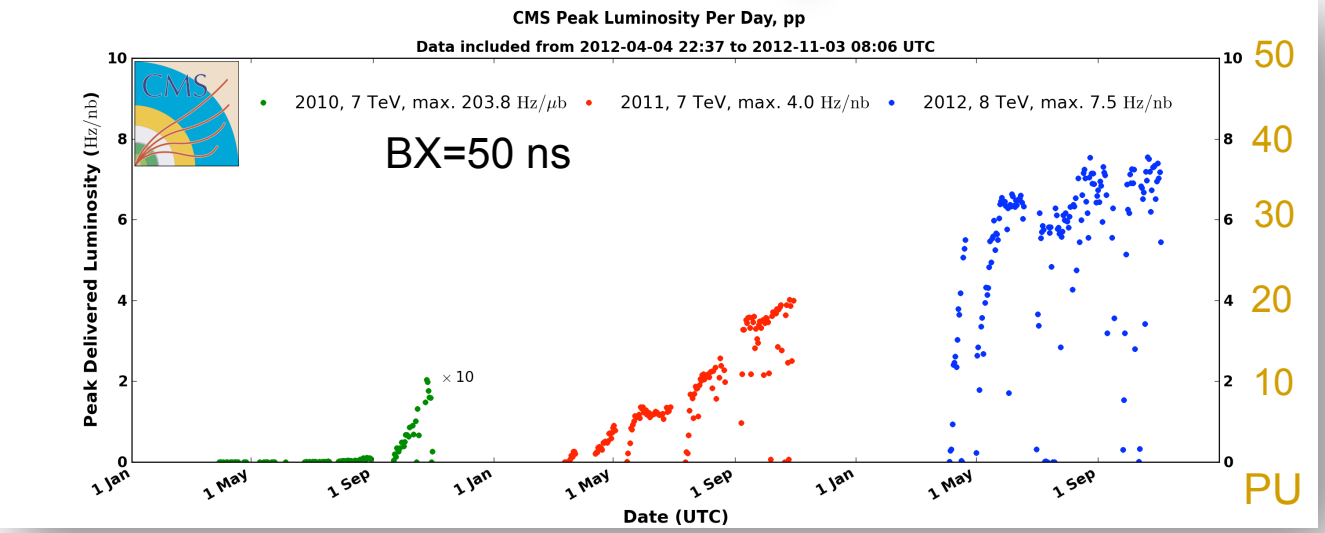

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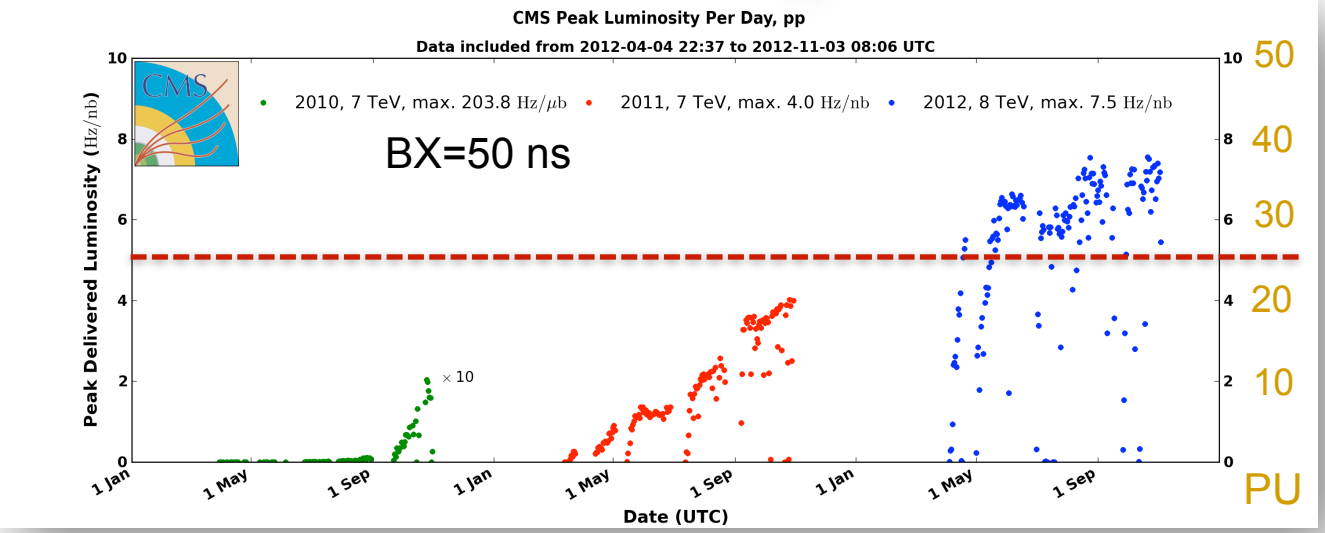

Design value
25 pileup events
(L=10^{34}, BX=25 ns)

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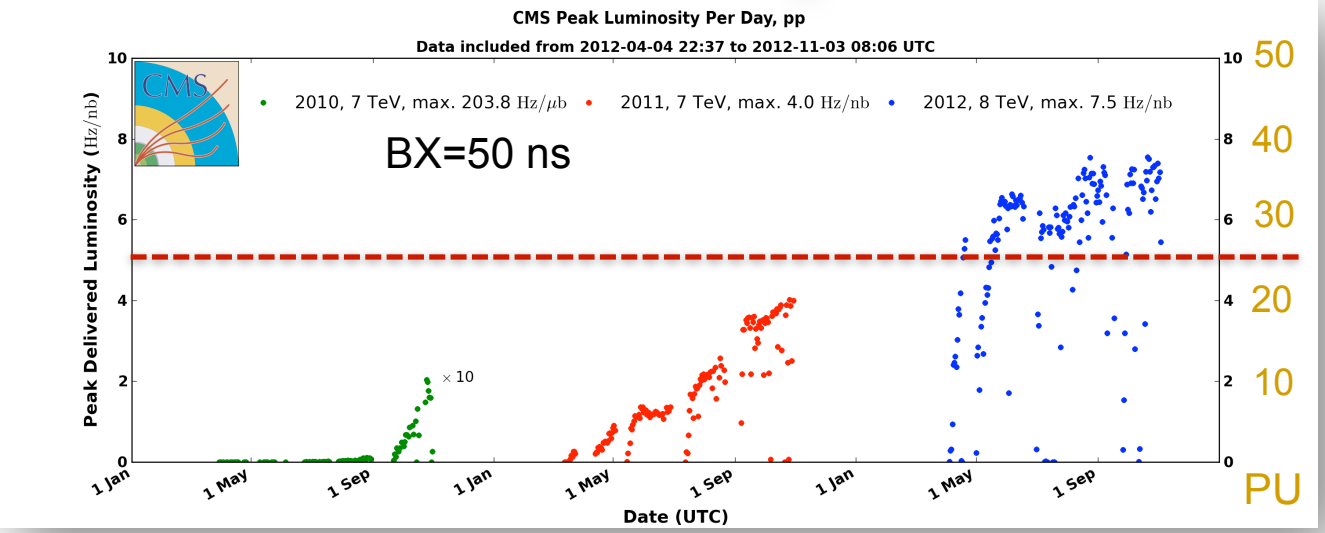

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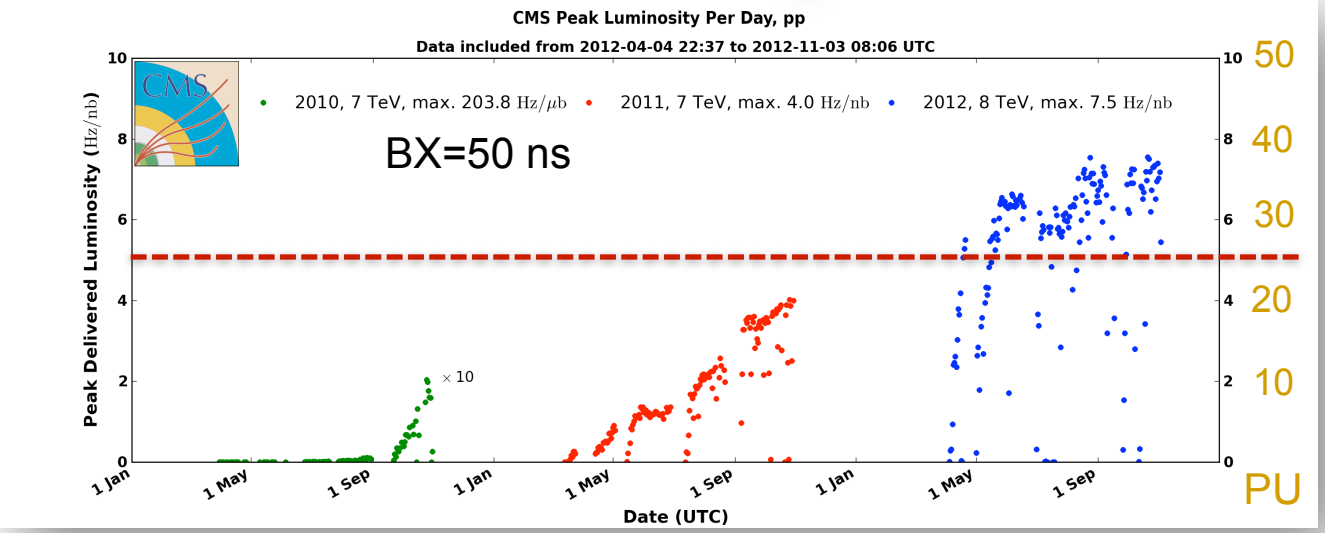

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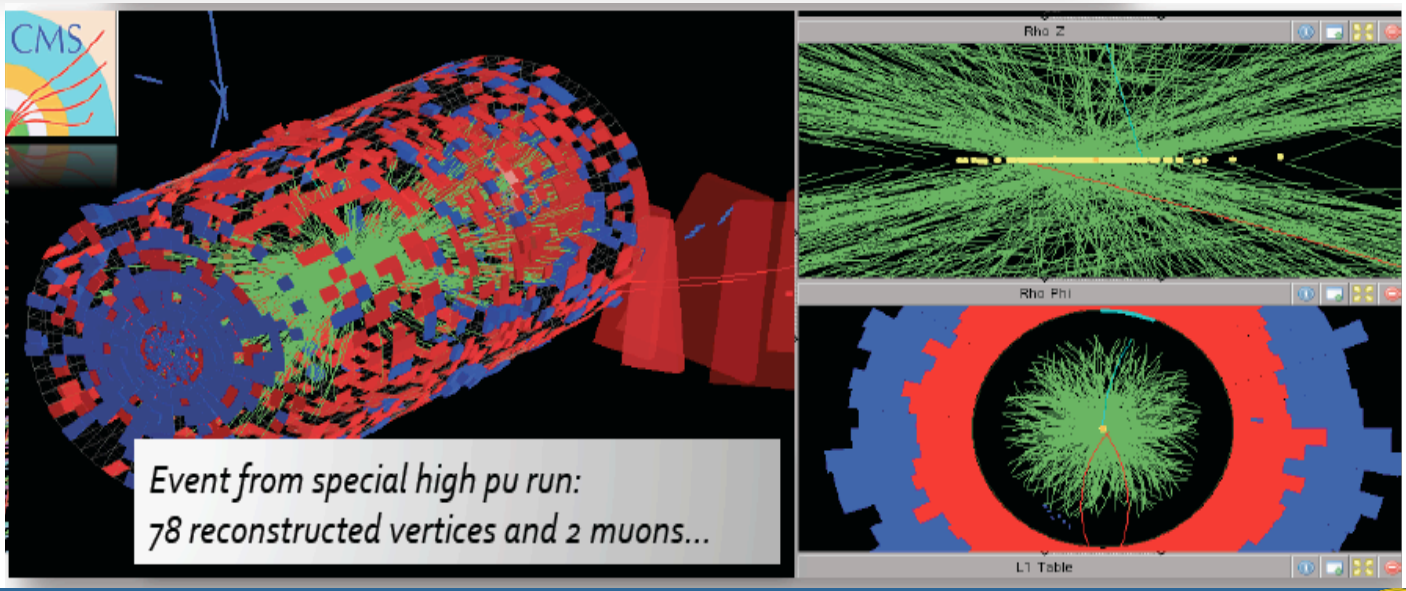
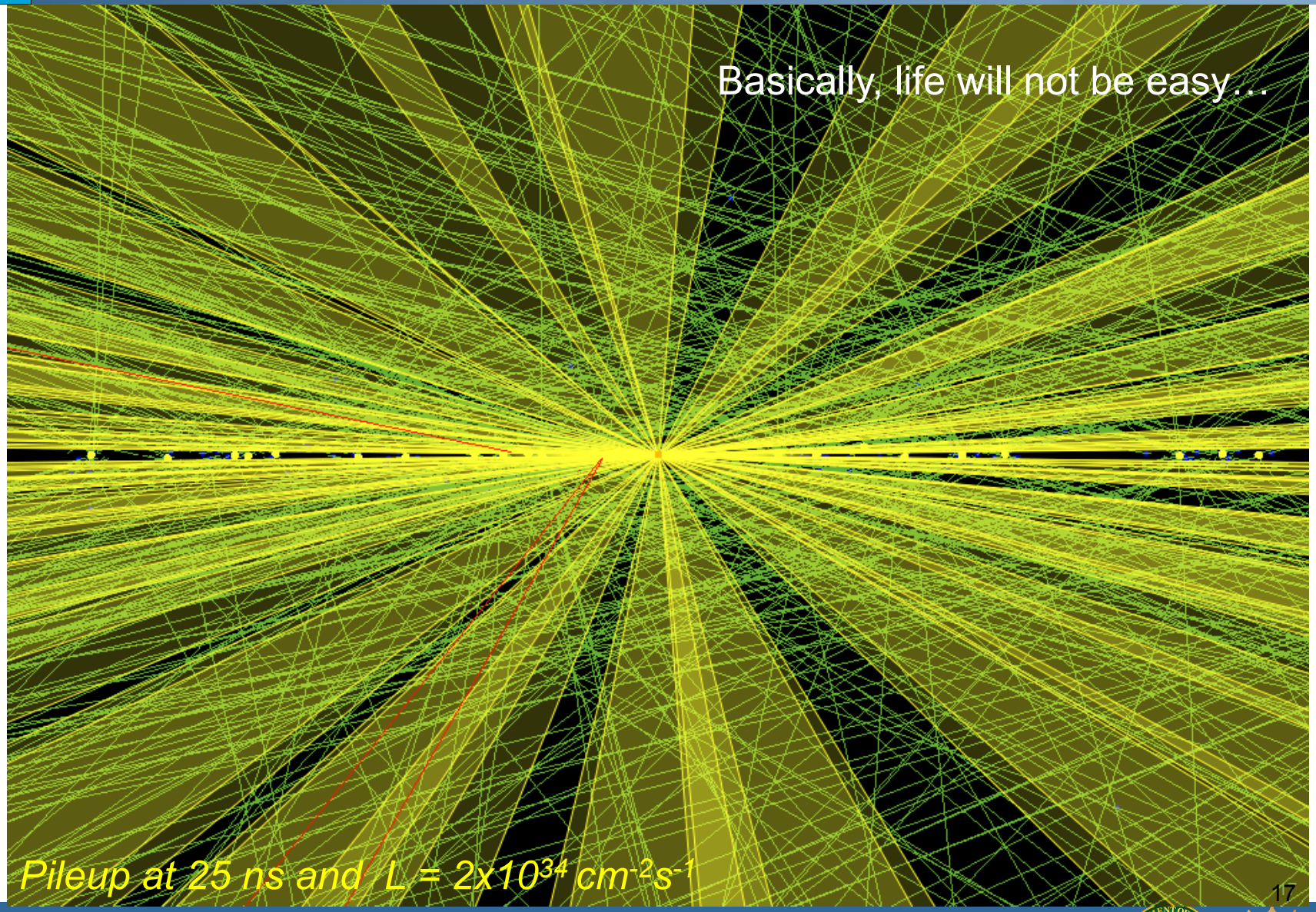
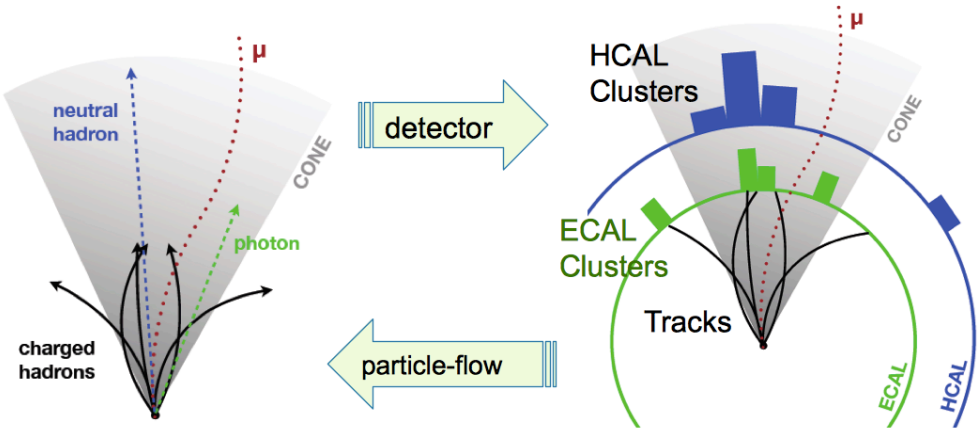
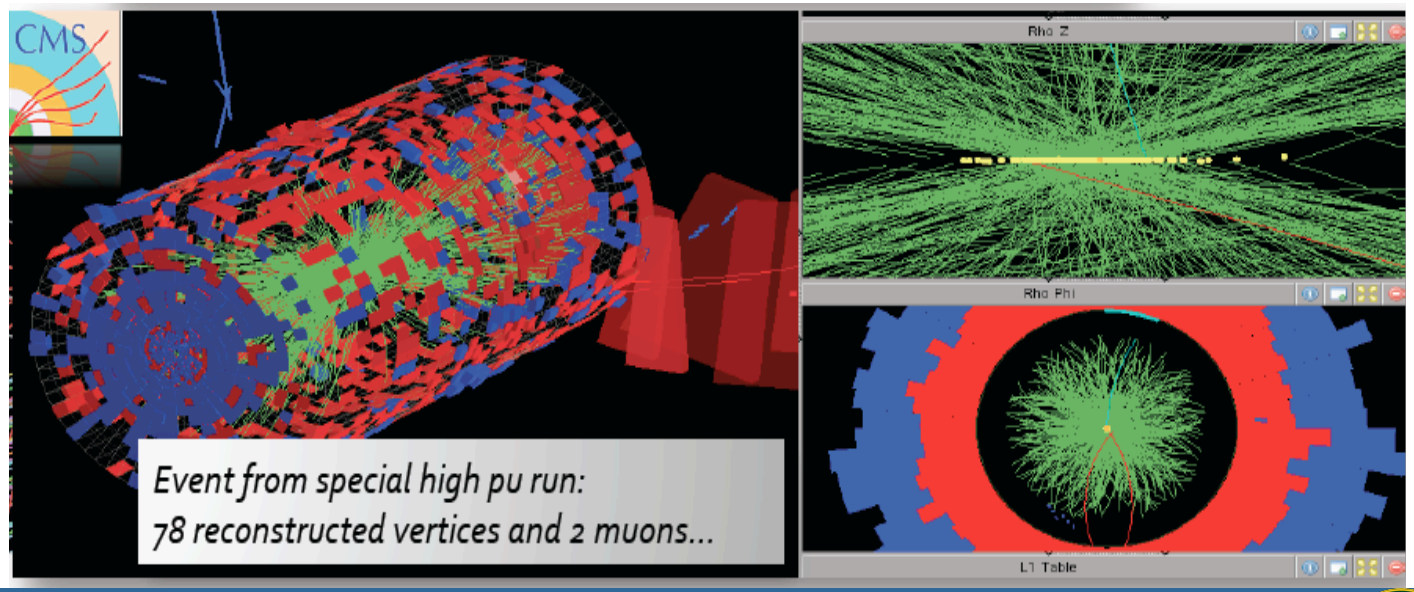


Pile-up at Design Luminosity



Pile-up Experience in 2012





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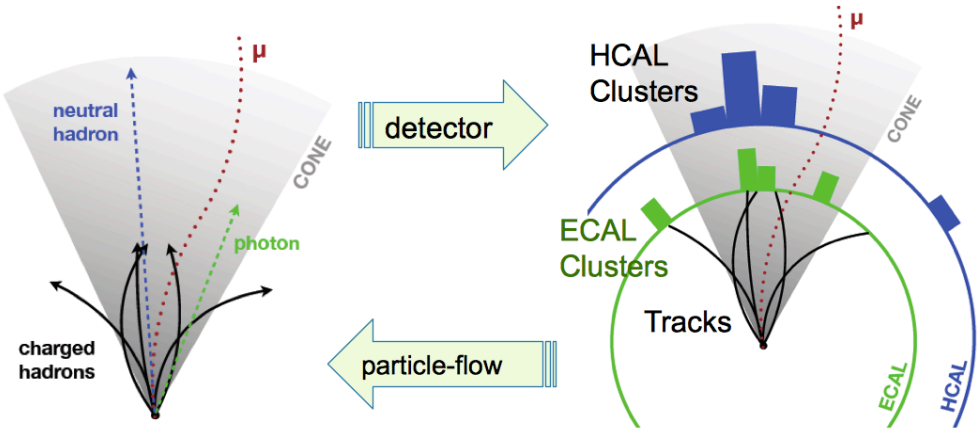

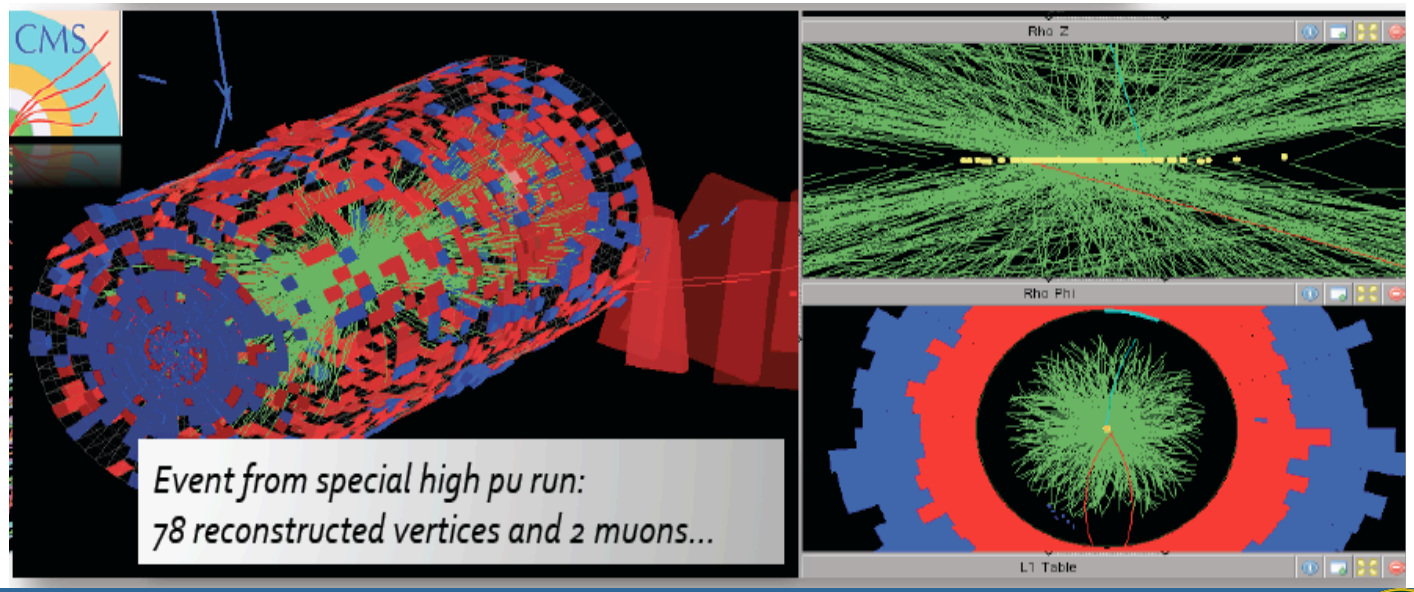

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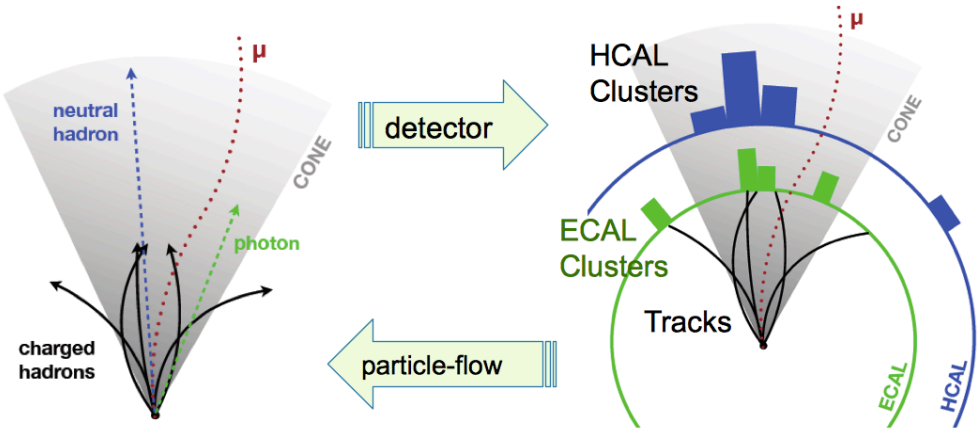

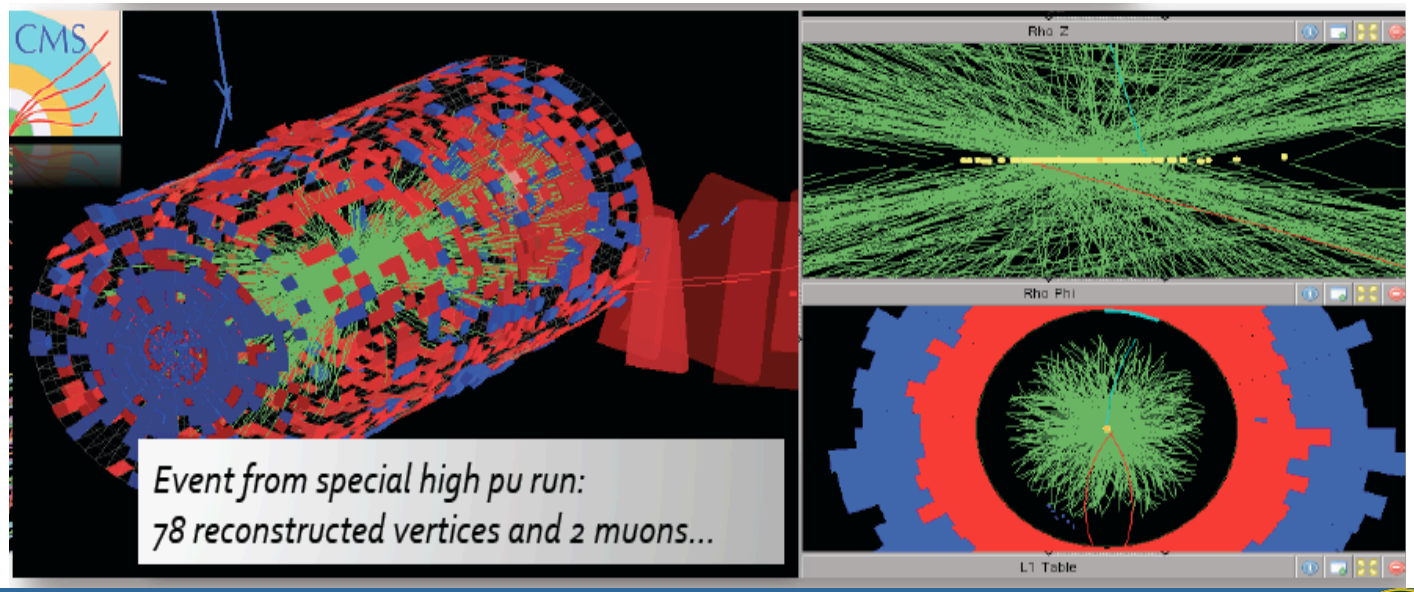

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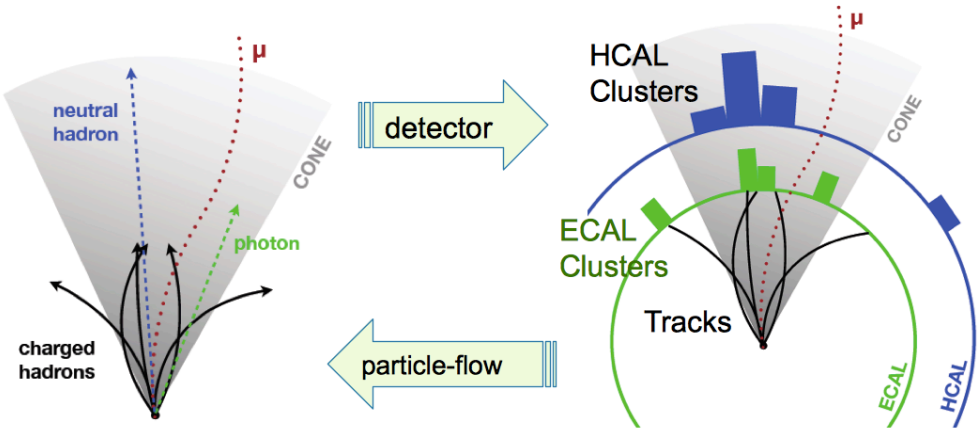

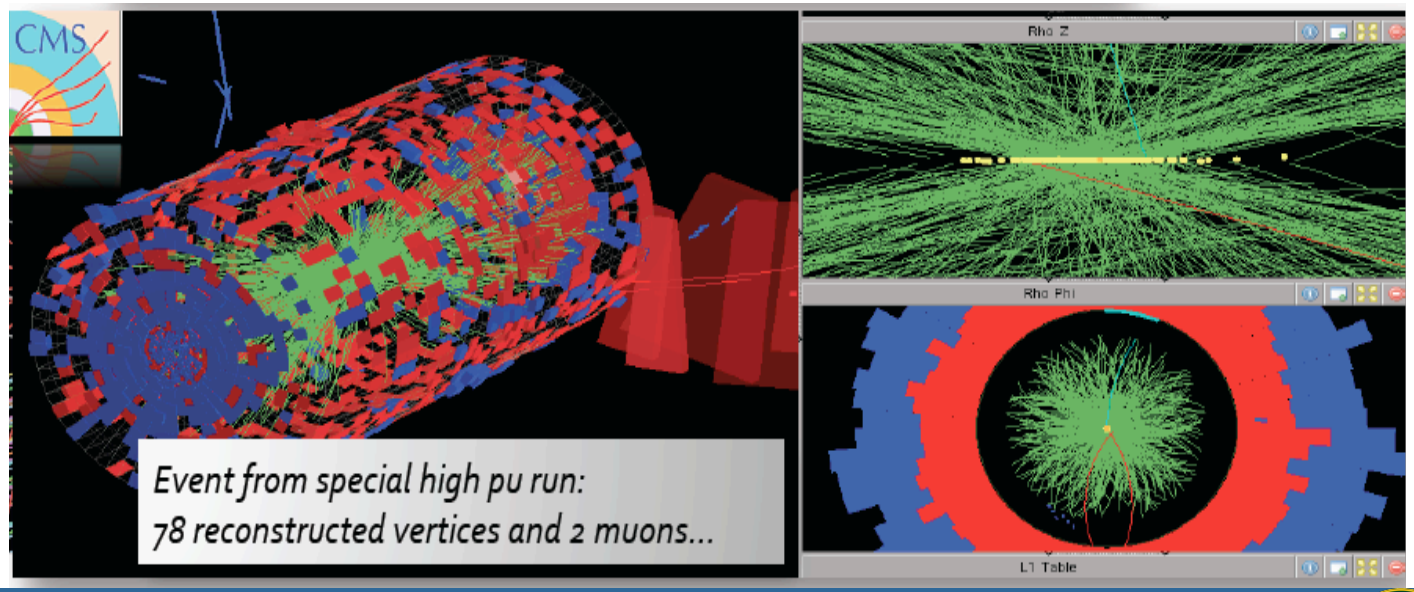

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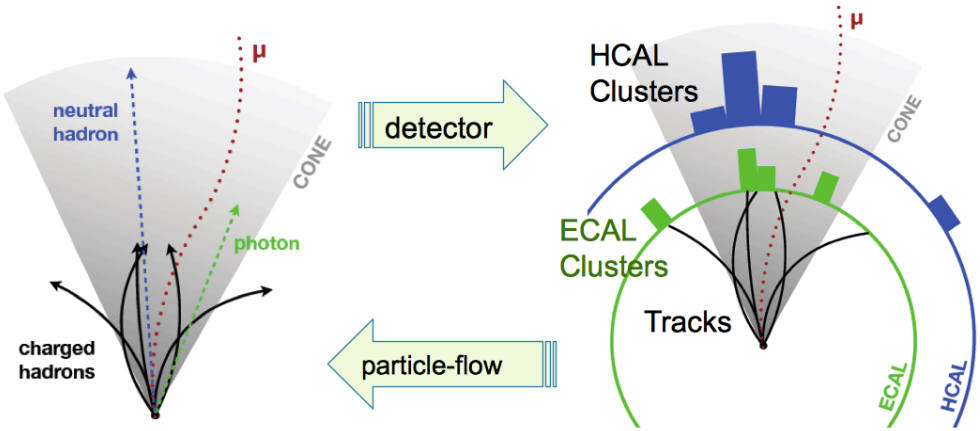

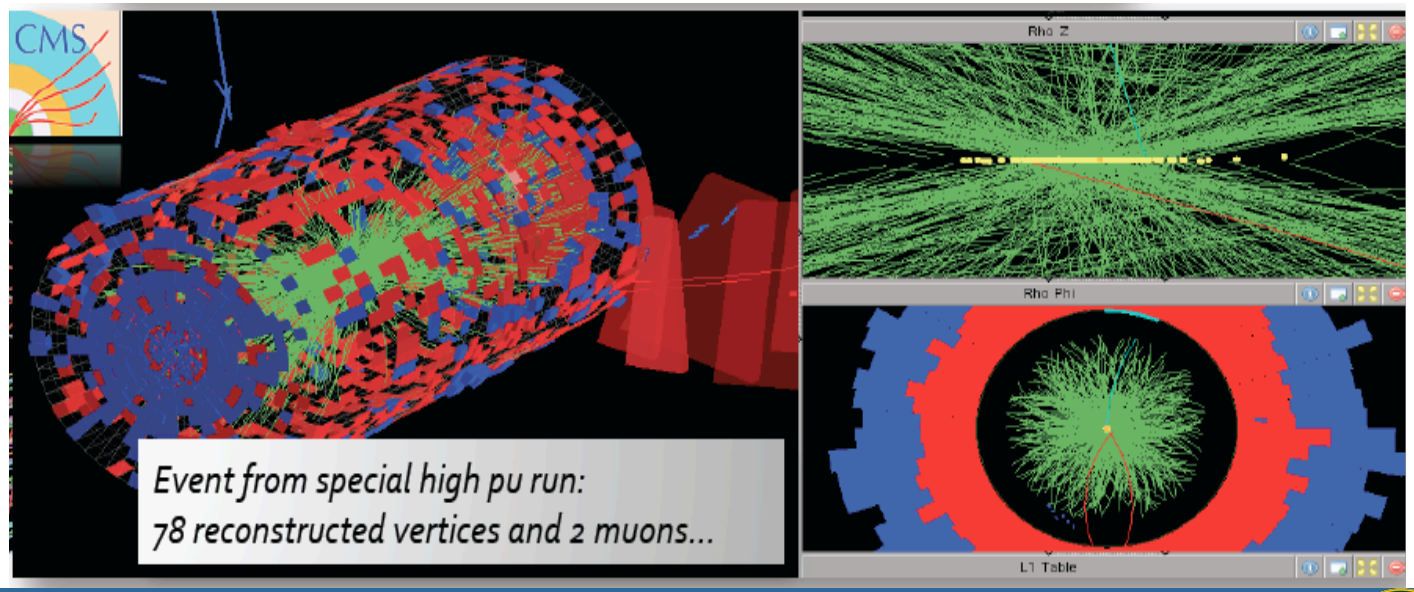

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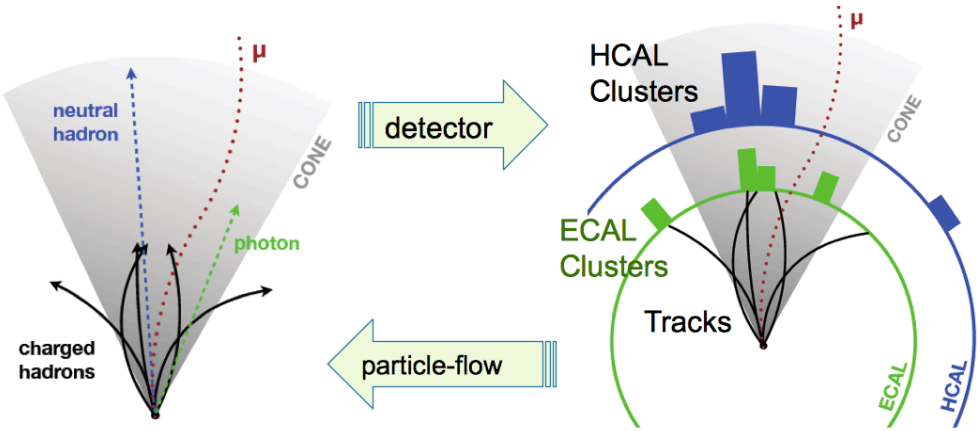

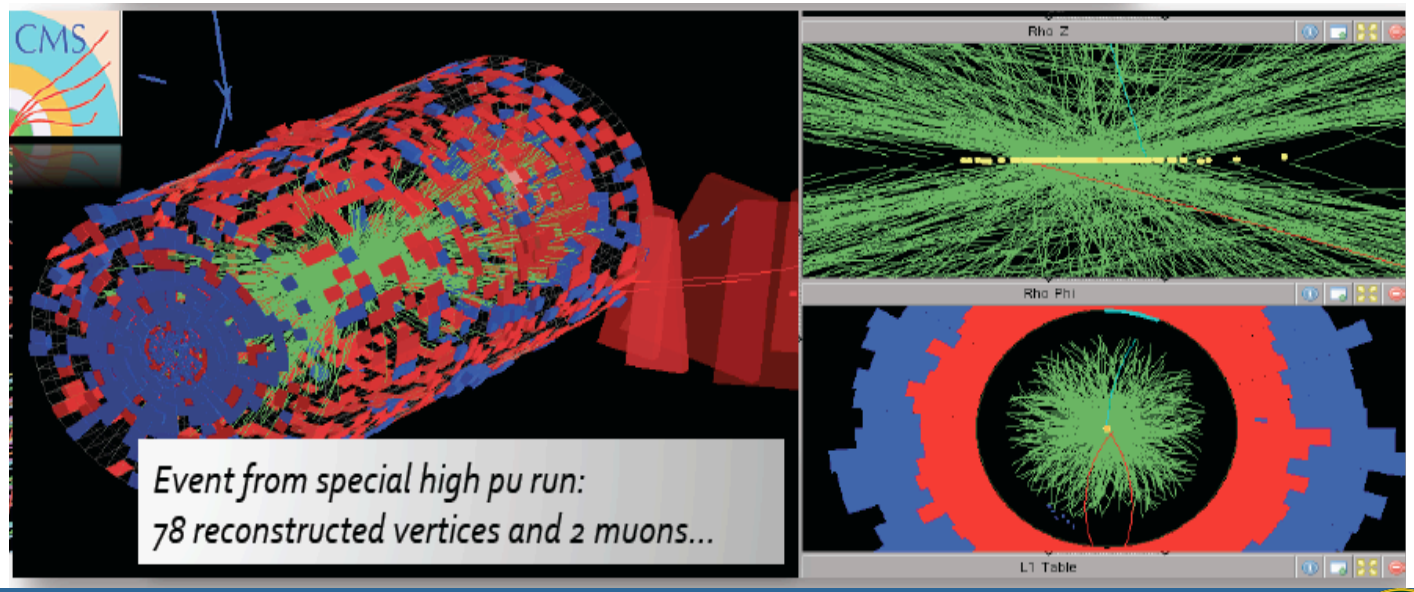

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Fermilab

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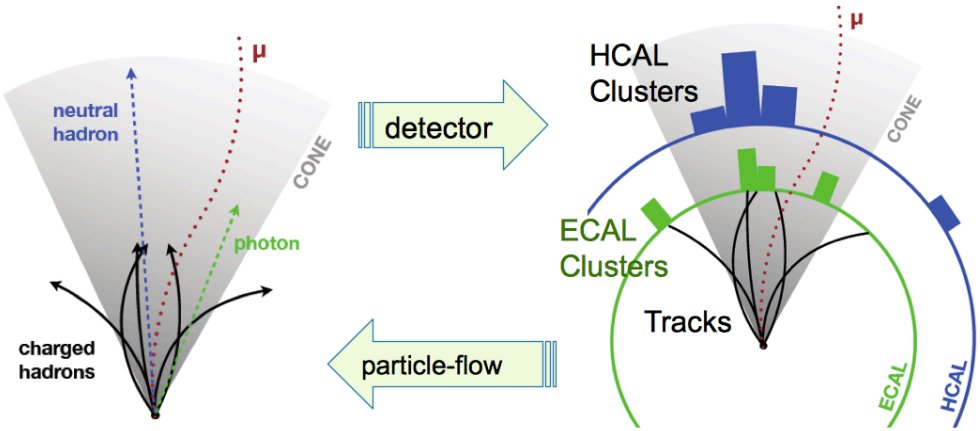

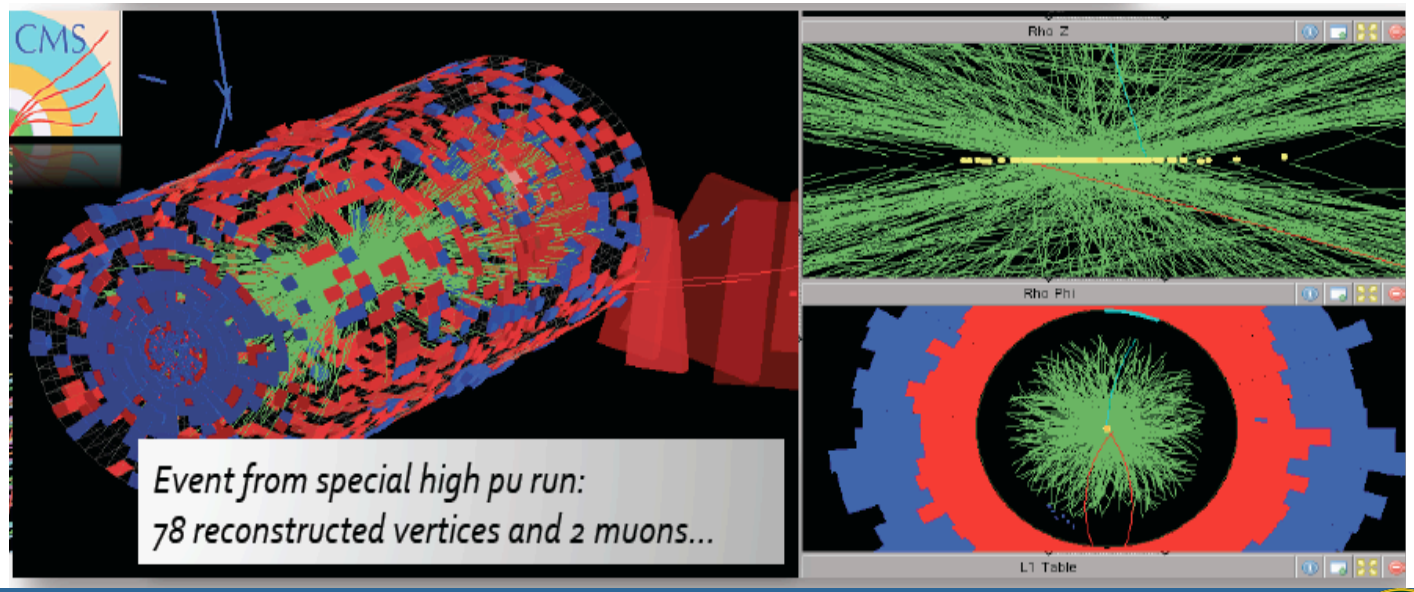

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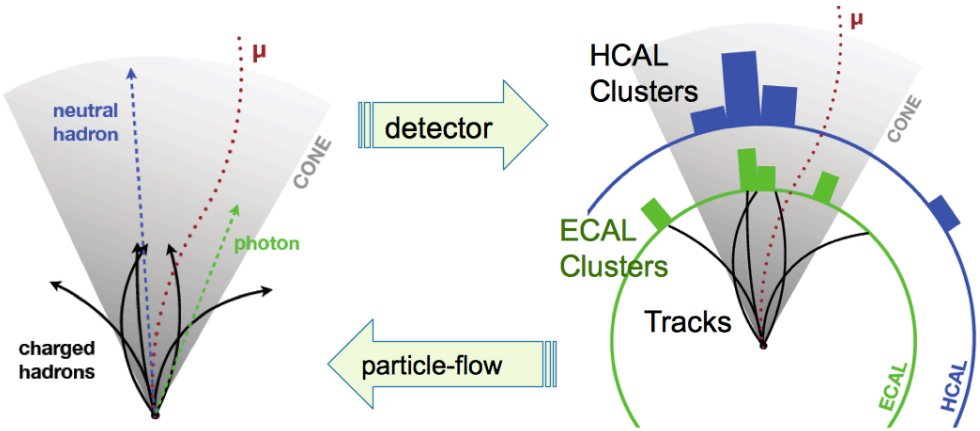

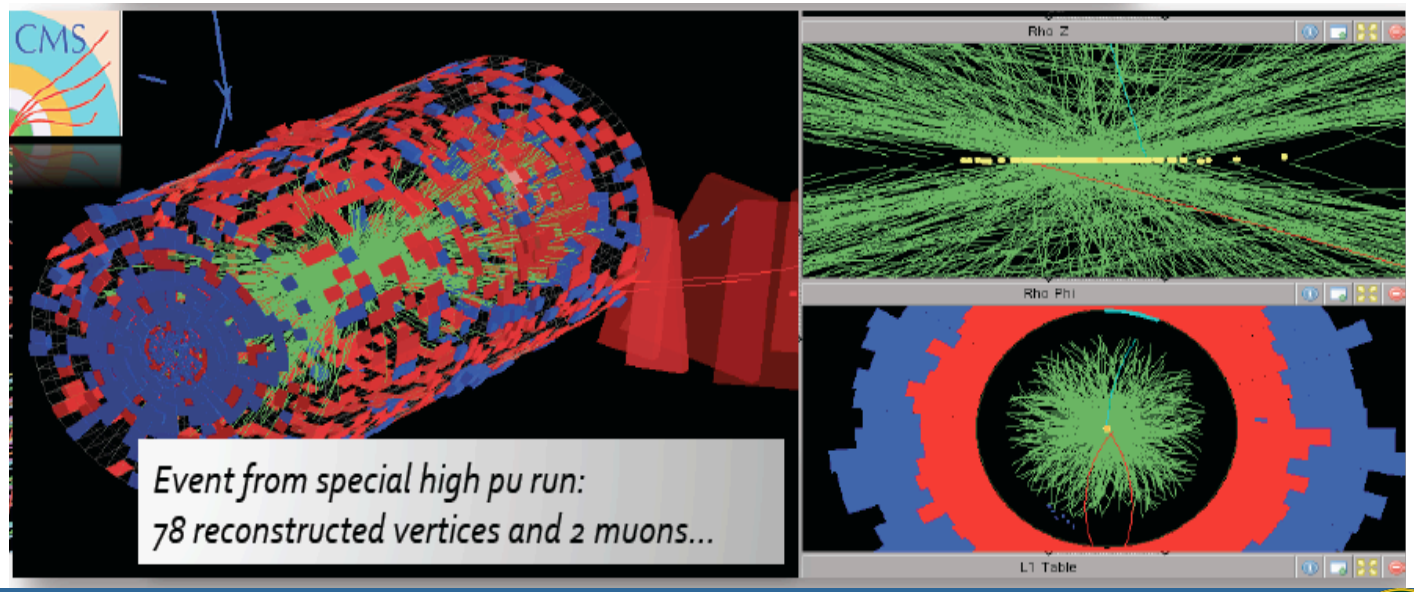

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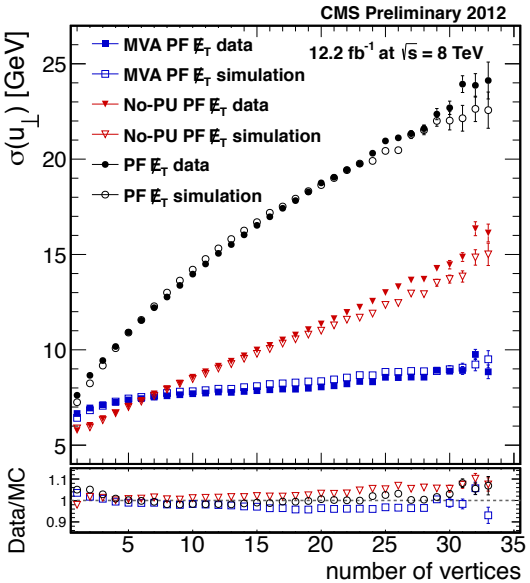

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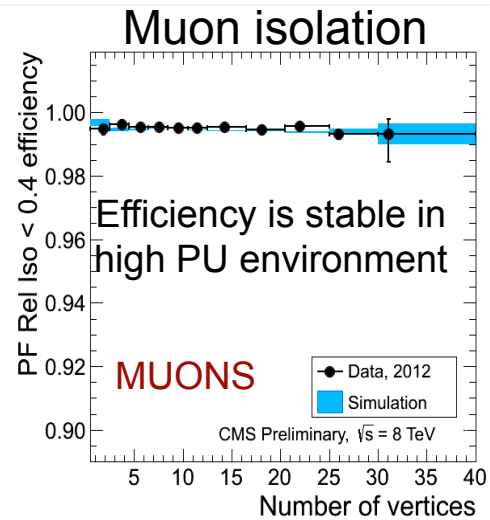

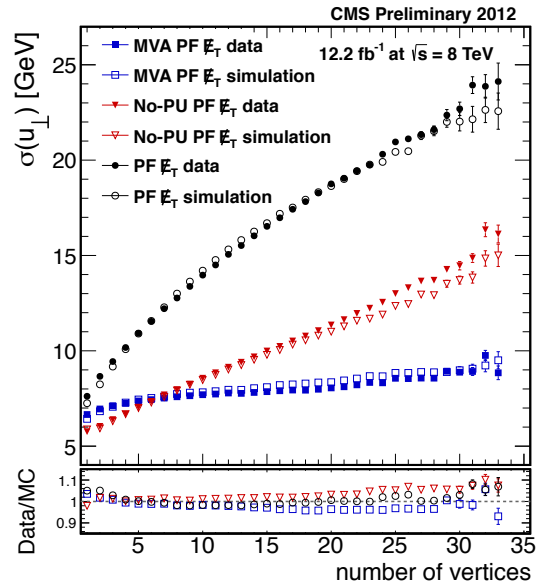

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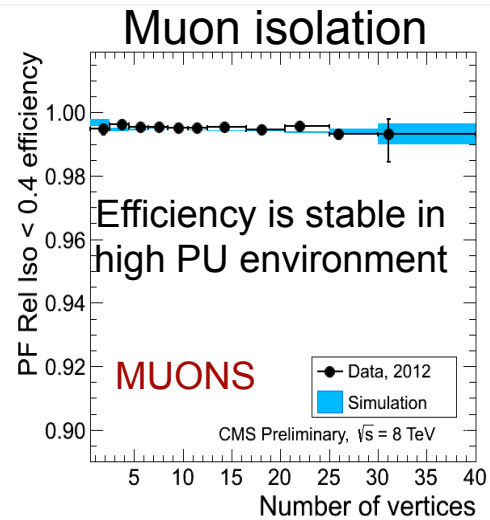
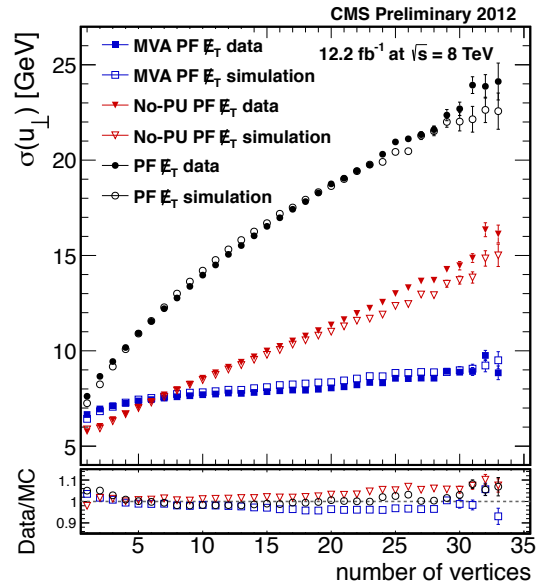
Very efficient reconstruction code is needed to stay within computing budget





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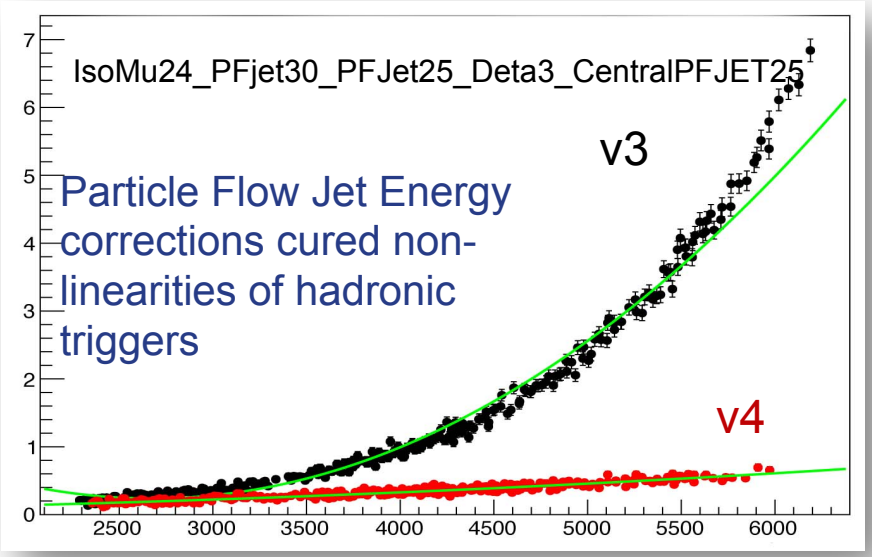

Luminosity $\mu b^{-1}s^{-1}$

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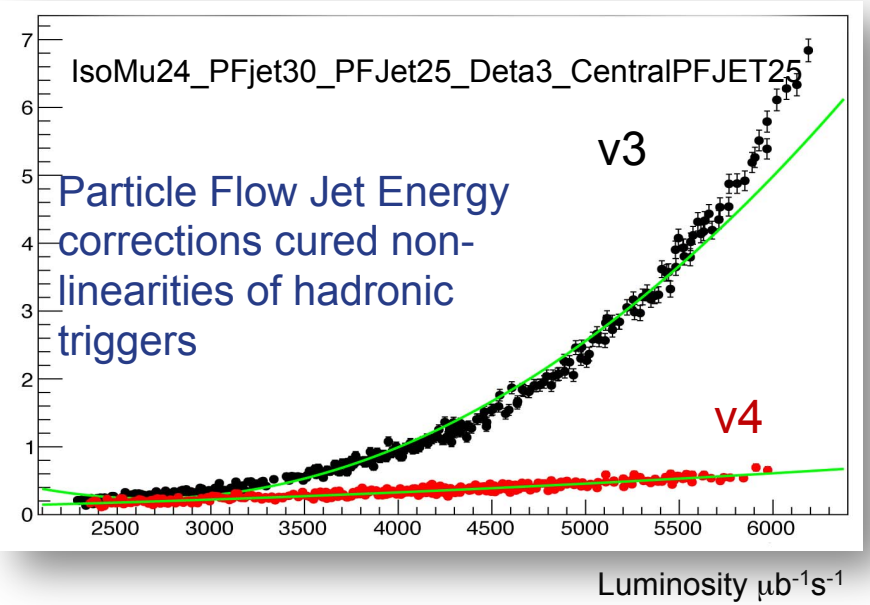

HLT CPU time:

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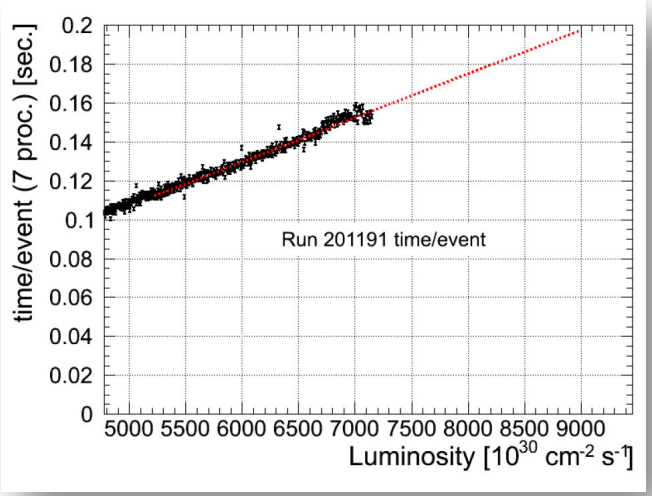

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The experience obtained in 2012 with peak pileup of ~35 events gives confidence for high-luminosity running post Long Shutdown 1

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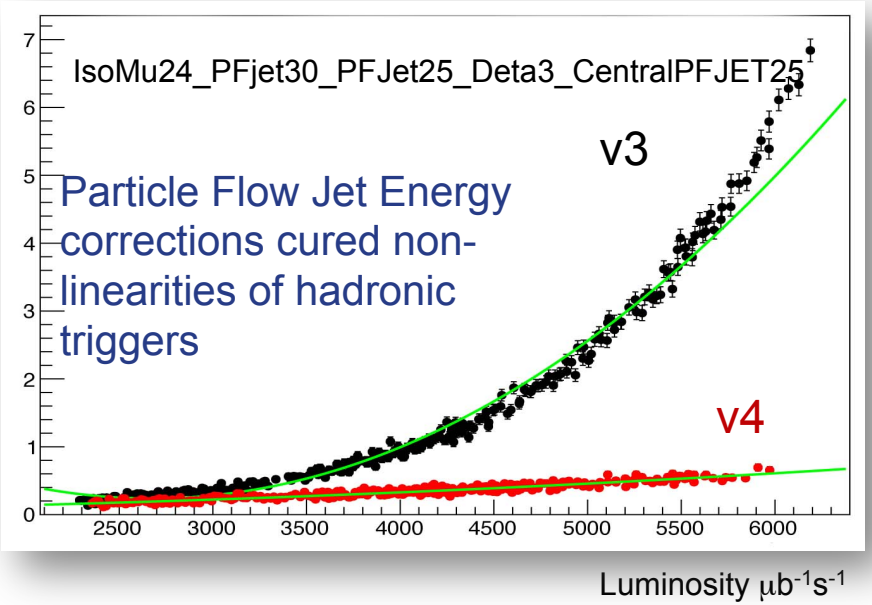

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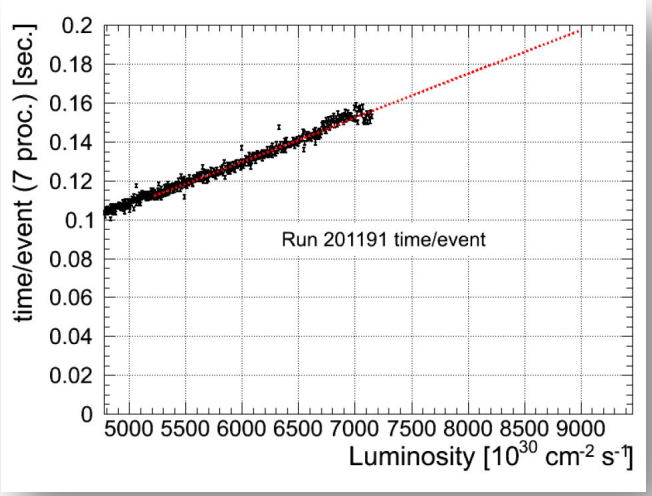

Physics Landscape after 8 TeV

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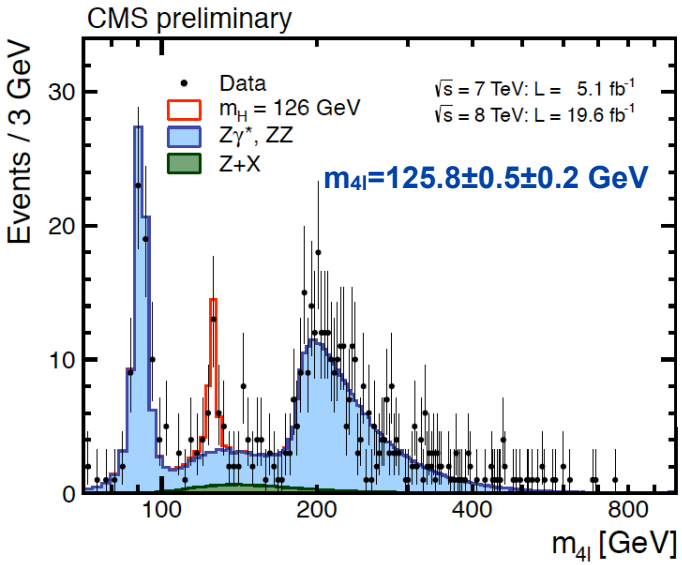

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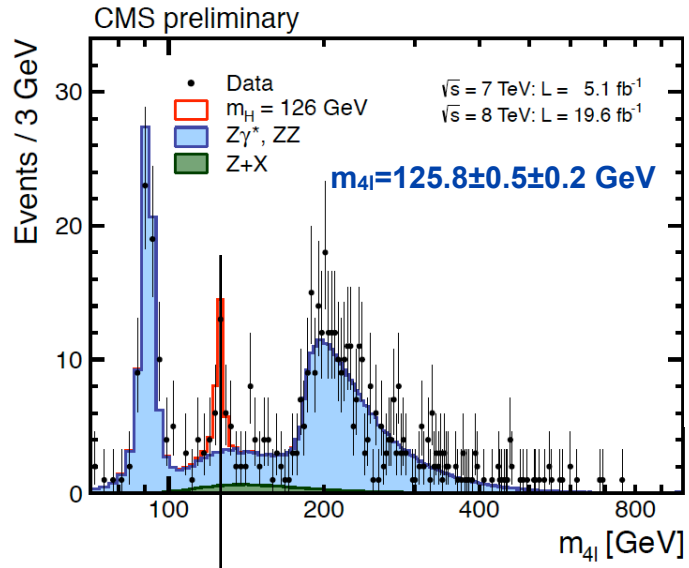
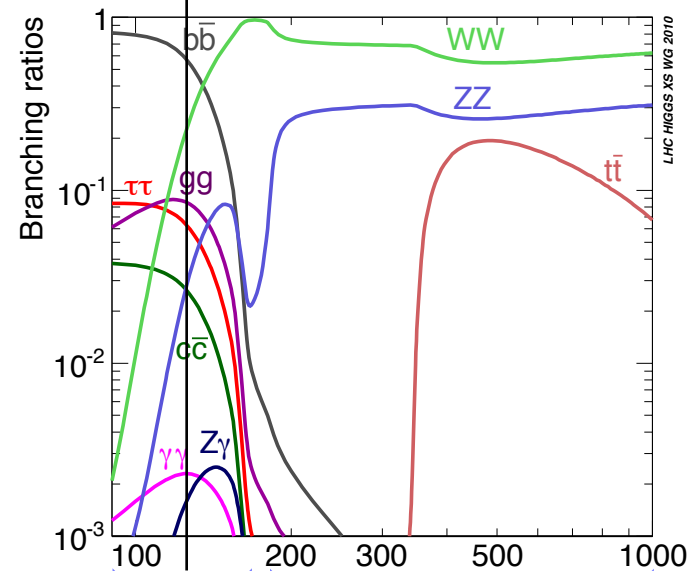
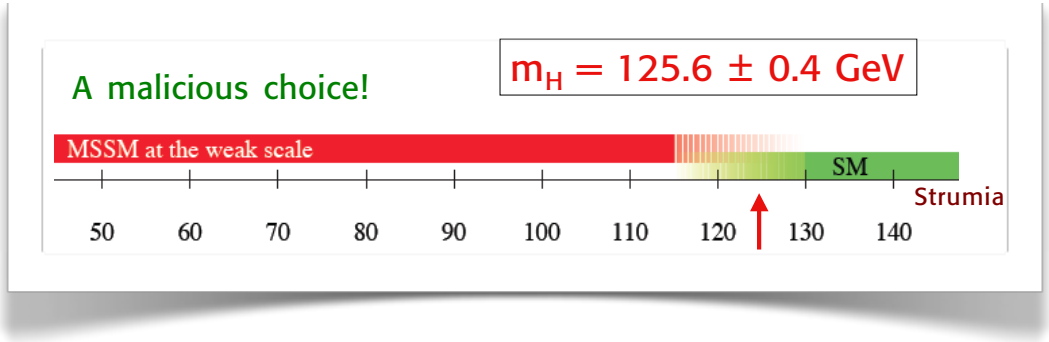
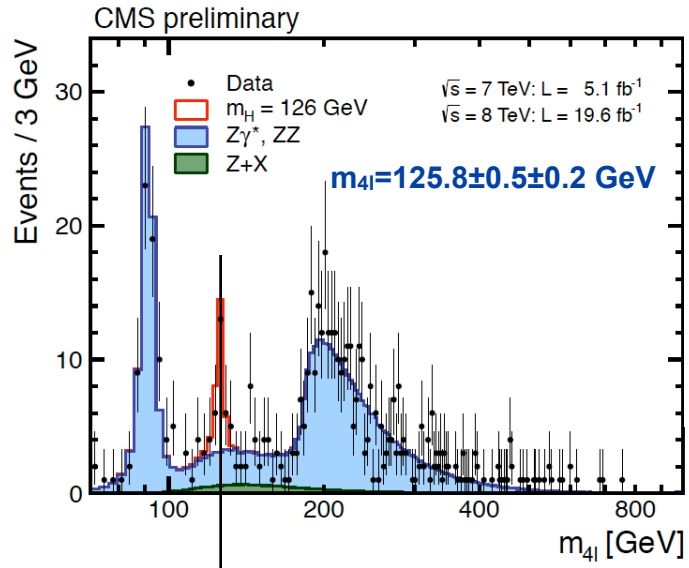


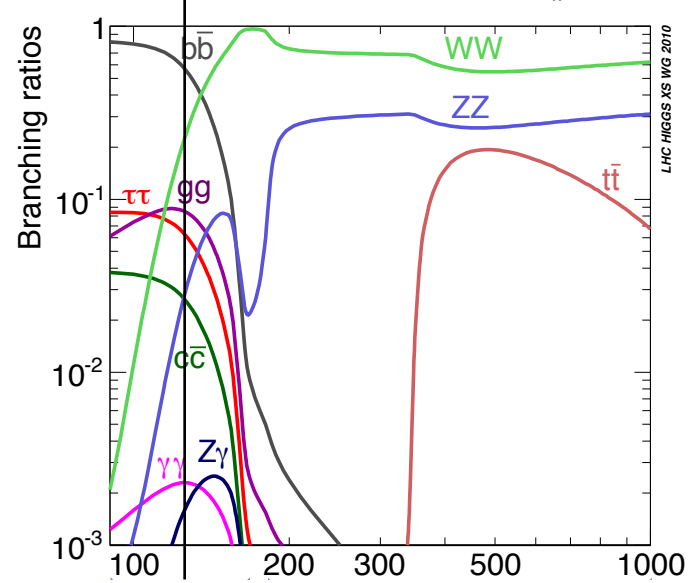


Physics Landscape after 8 TeV

- Higgs sits at intriguing mass!
- On the one hand: light…
  - all decay modes accessible
  - important to maintain performance of all objects at high luminosity running
- On the other hand: heavy…
  - uncomfortable for Minimal Supersymmetry







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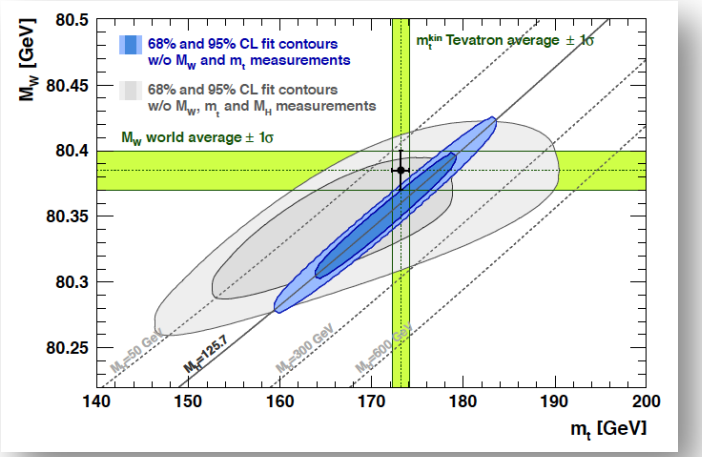

arXiv:1209.2716

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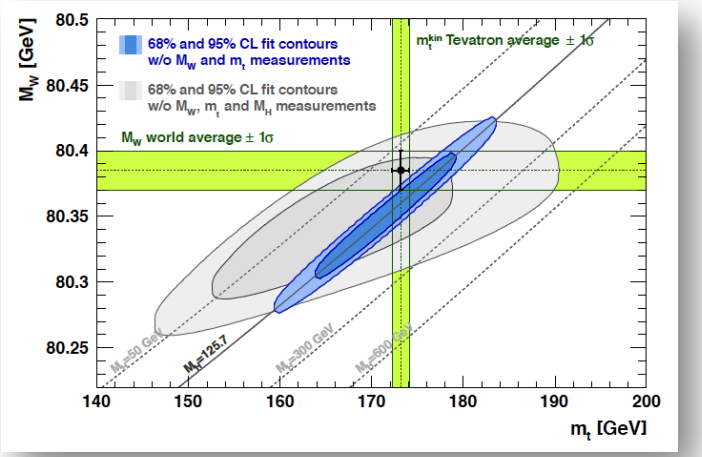

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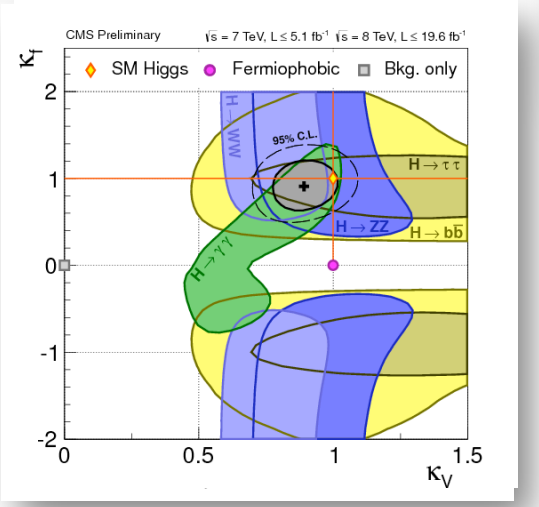
Fit to C_V and C_F (couplings to bosons and to fermions)



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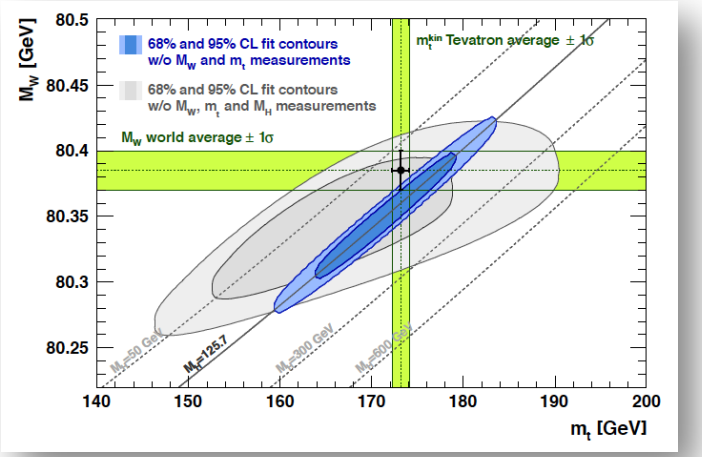

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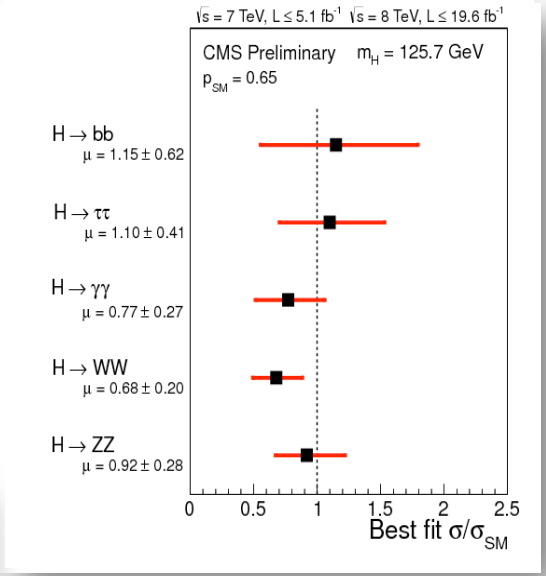

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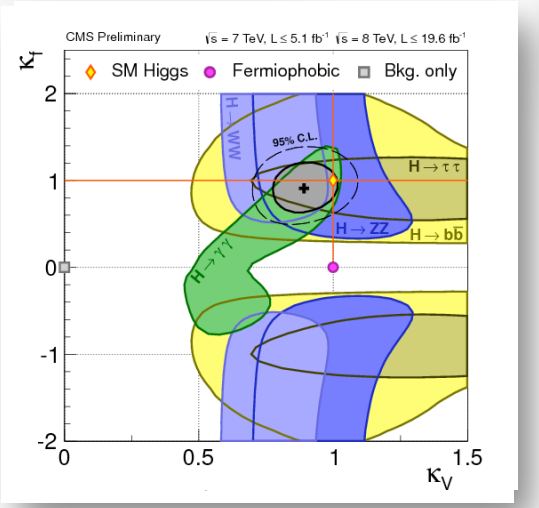
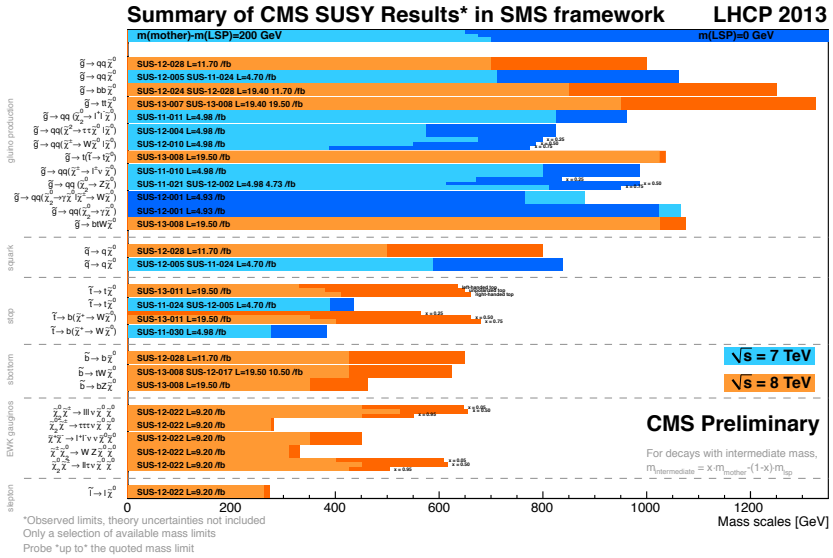


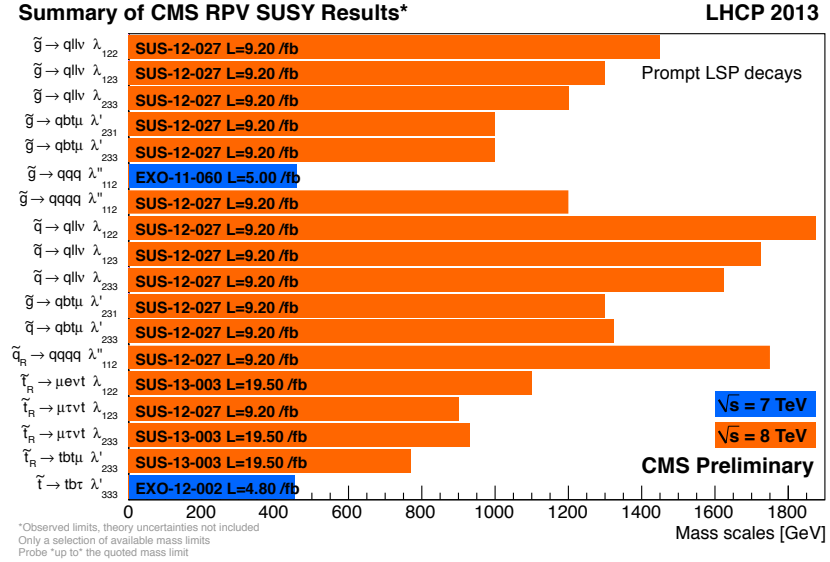
Overall best-fit signal strength in the combination:

$\sigma/\sigma_{SM} = 0.80 \pm 0.14$

Physics Landscape after 8 TeV

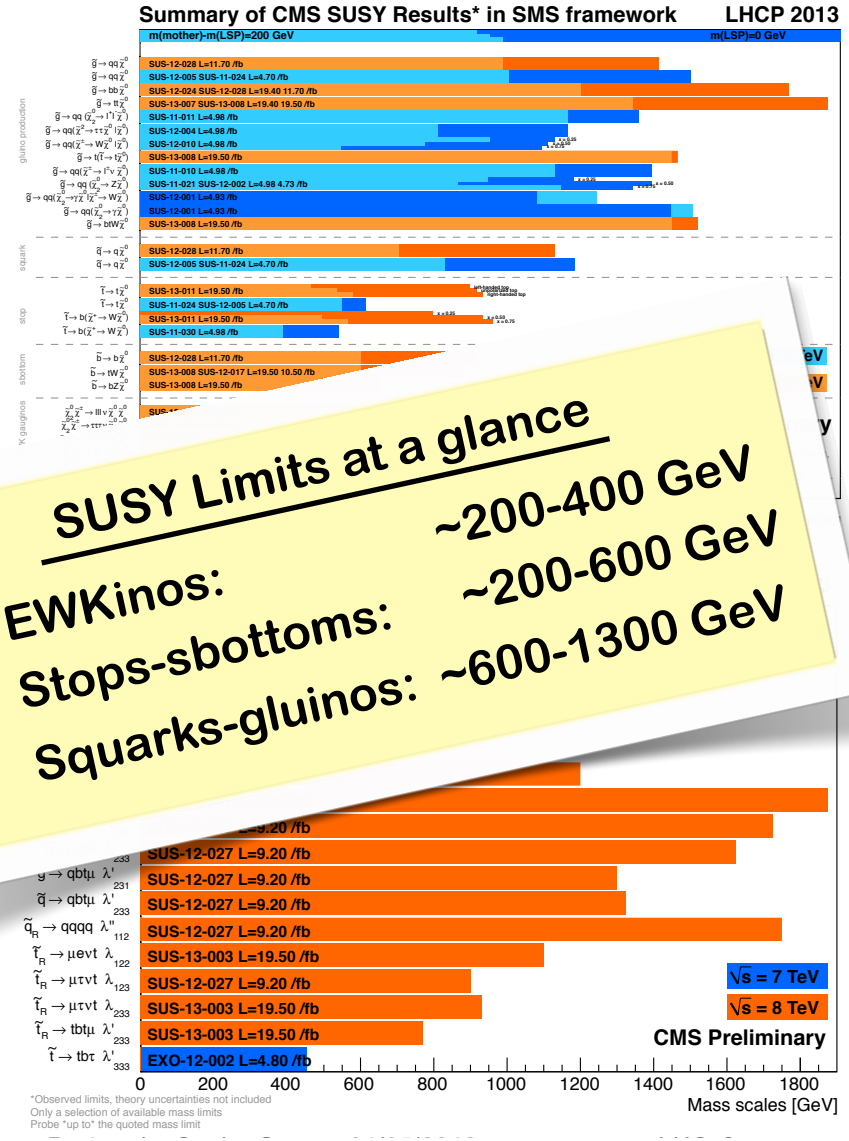
Fermilab





Physics Landscape after 8 TeV

Fermilab



SUSY Limits at a glance

EWKinos: ~200-400 GeV

Stops-sbottoms: ~200-600 GeV

Squarks-gluinos: ~600-1300 GeV

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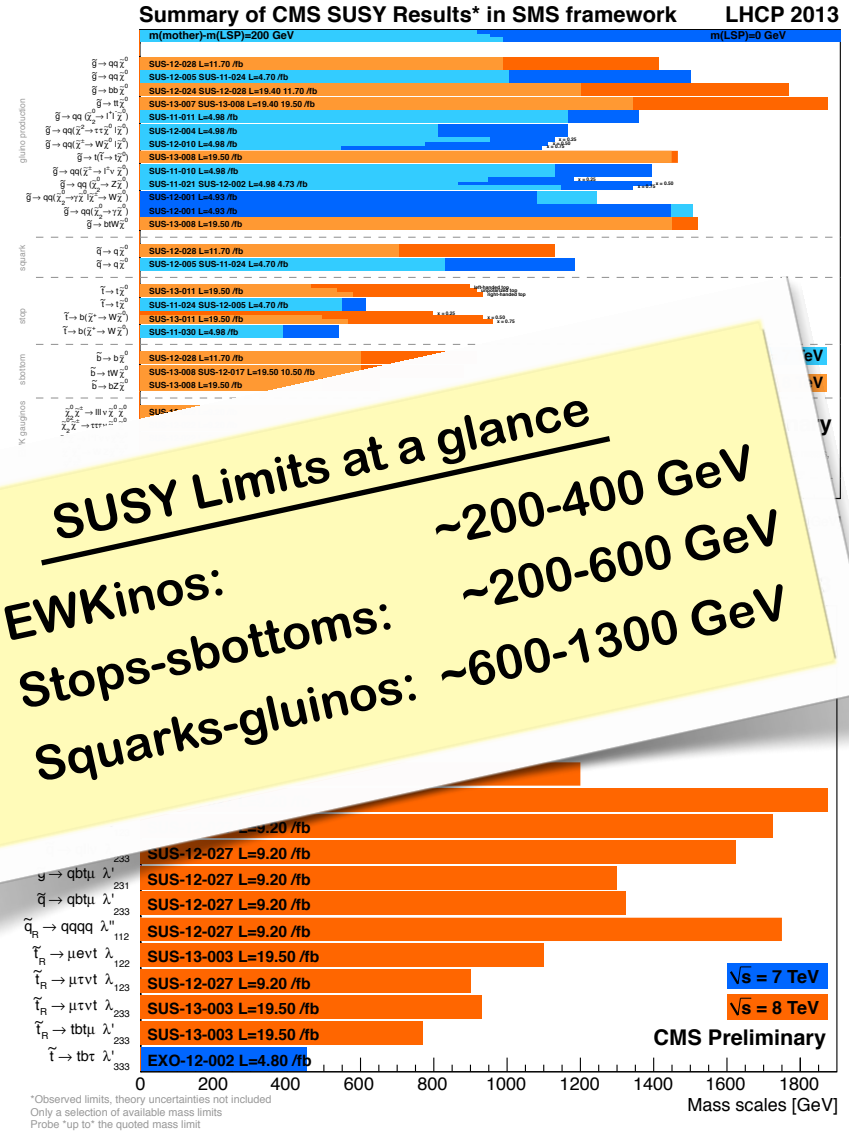

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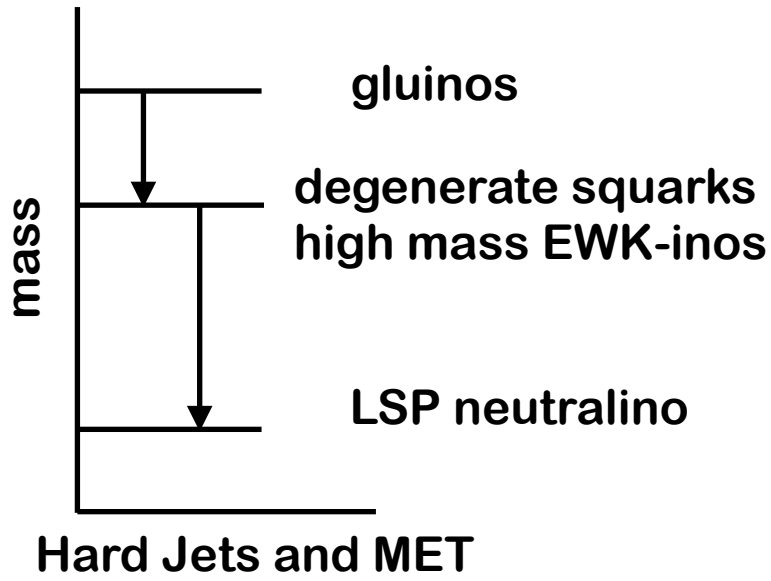

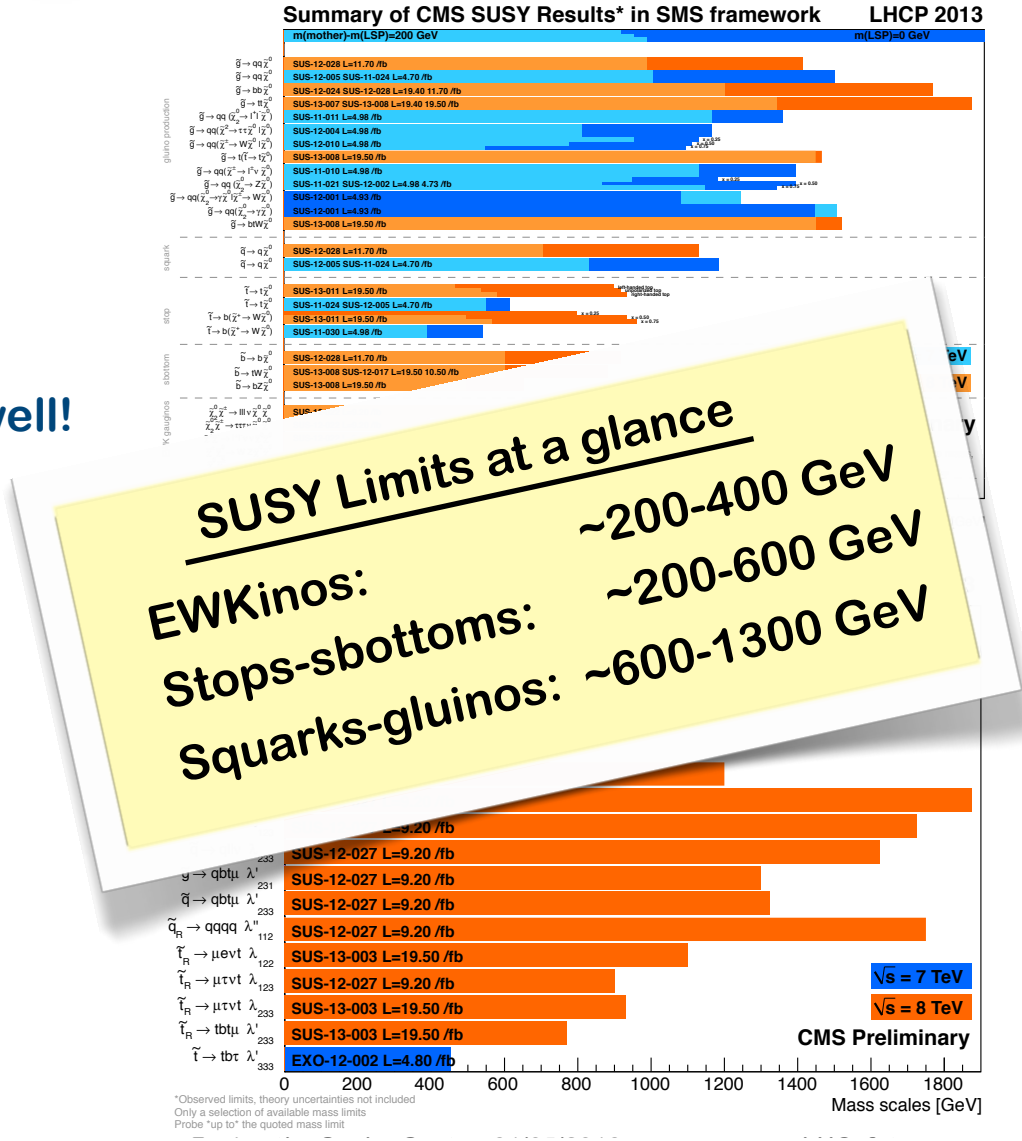

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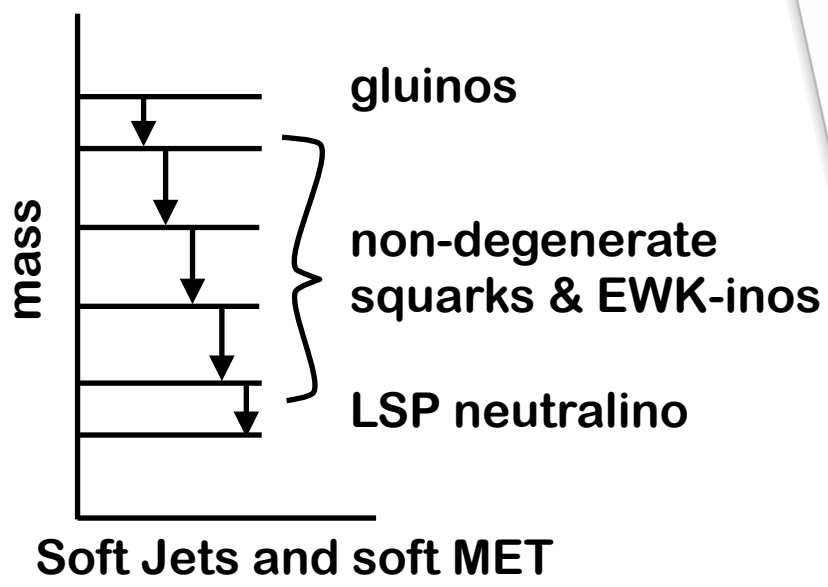

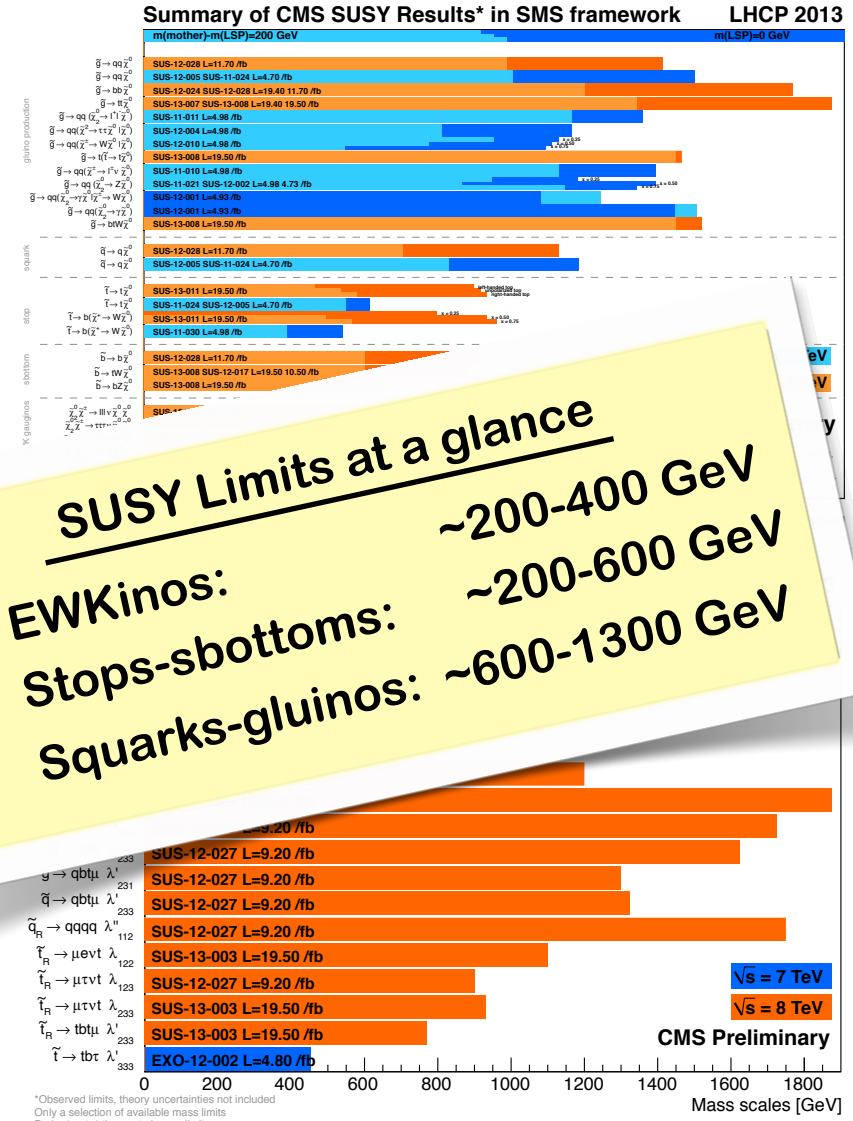

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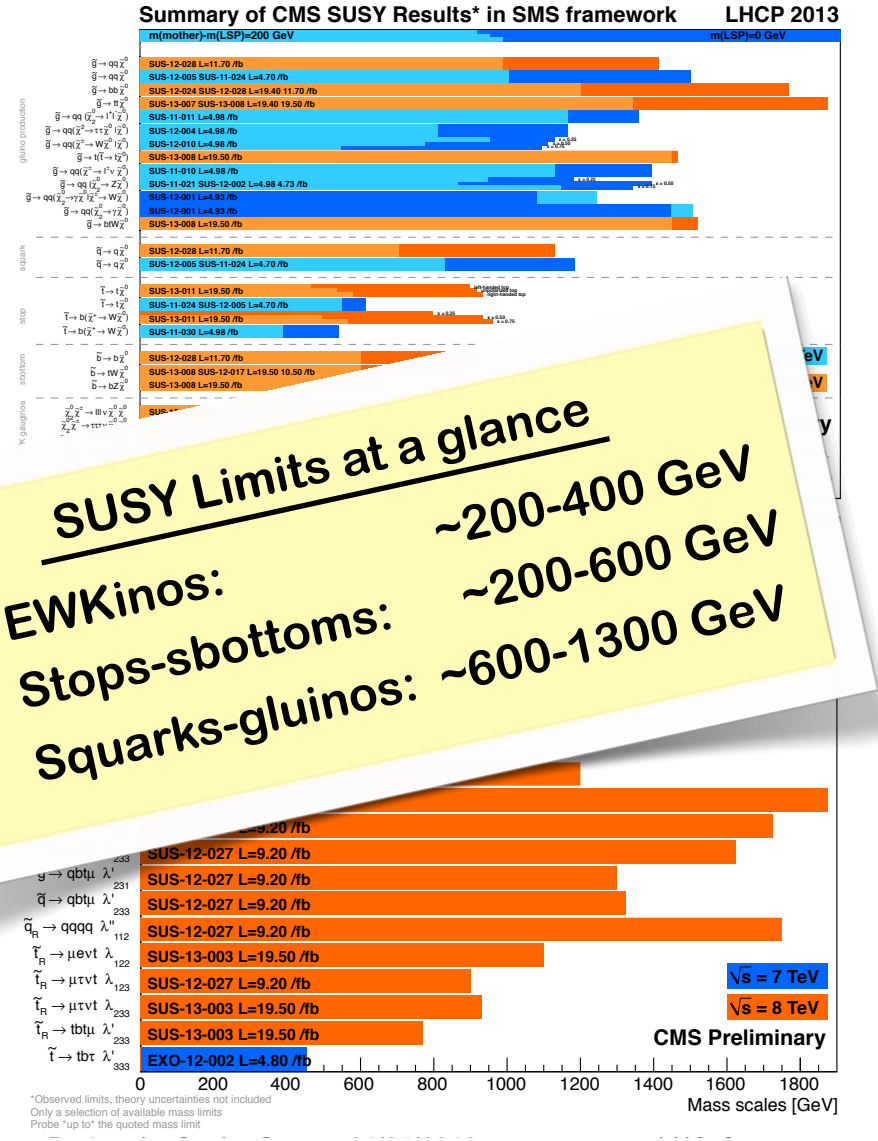

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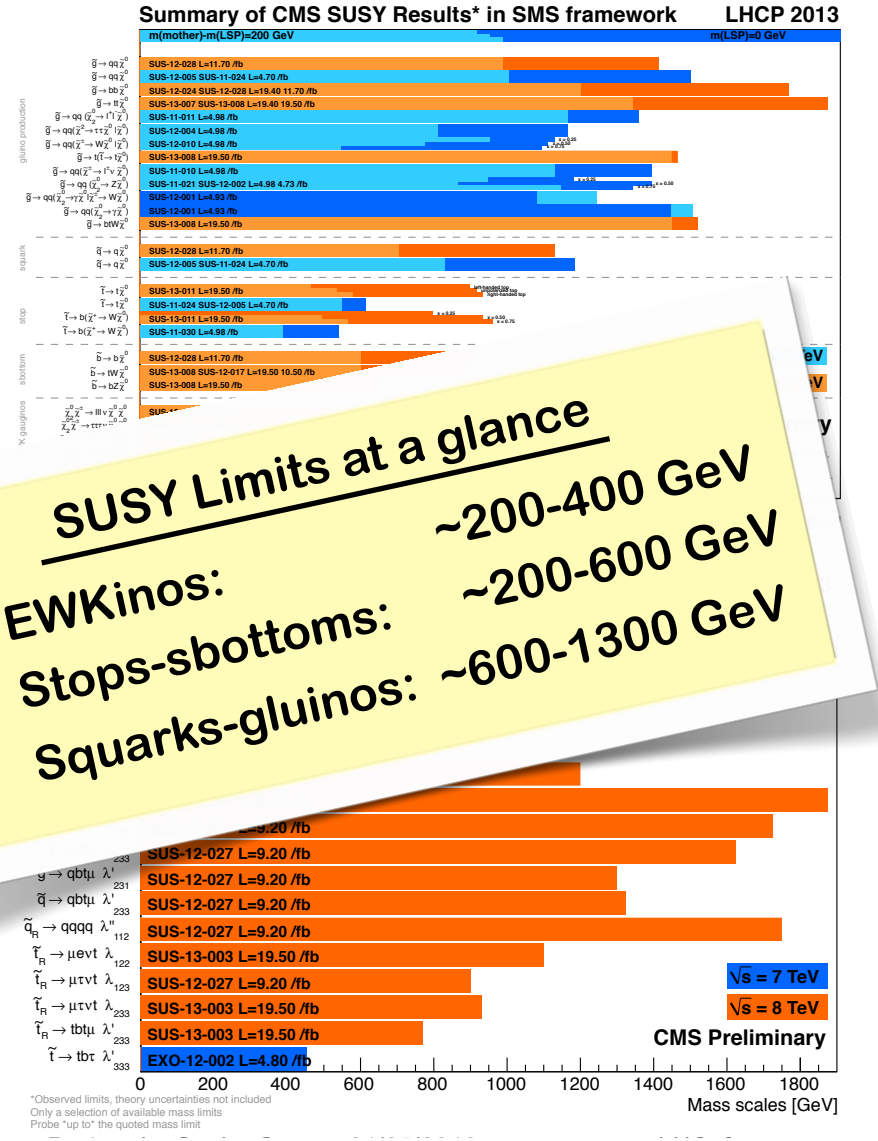
- SUSY as a principle remains both alive & well!
  - To it's credit, LHC has successfully killed several toy SUSY models!



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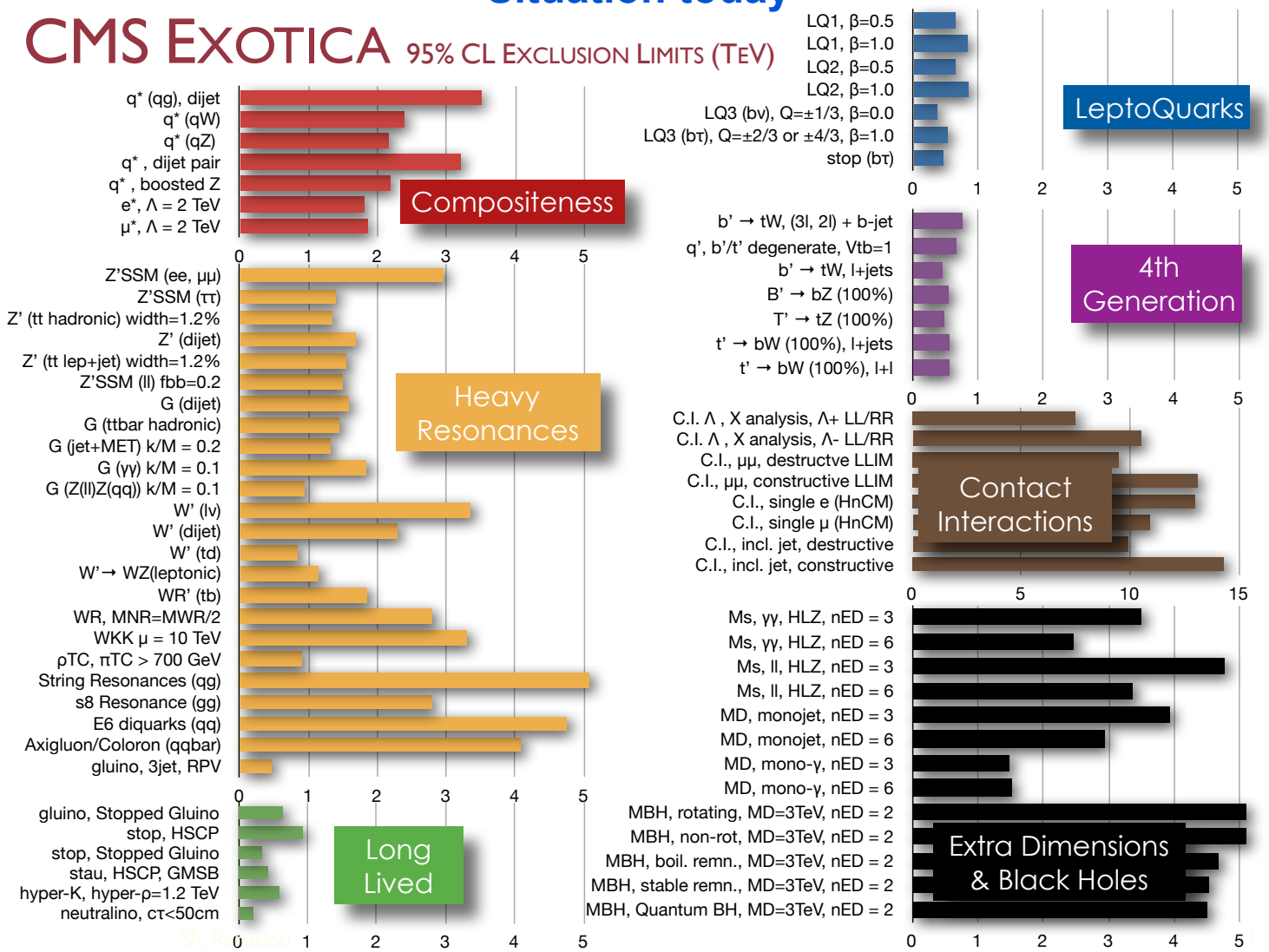

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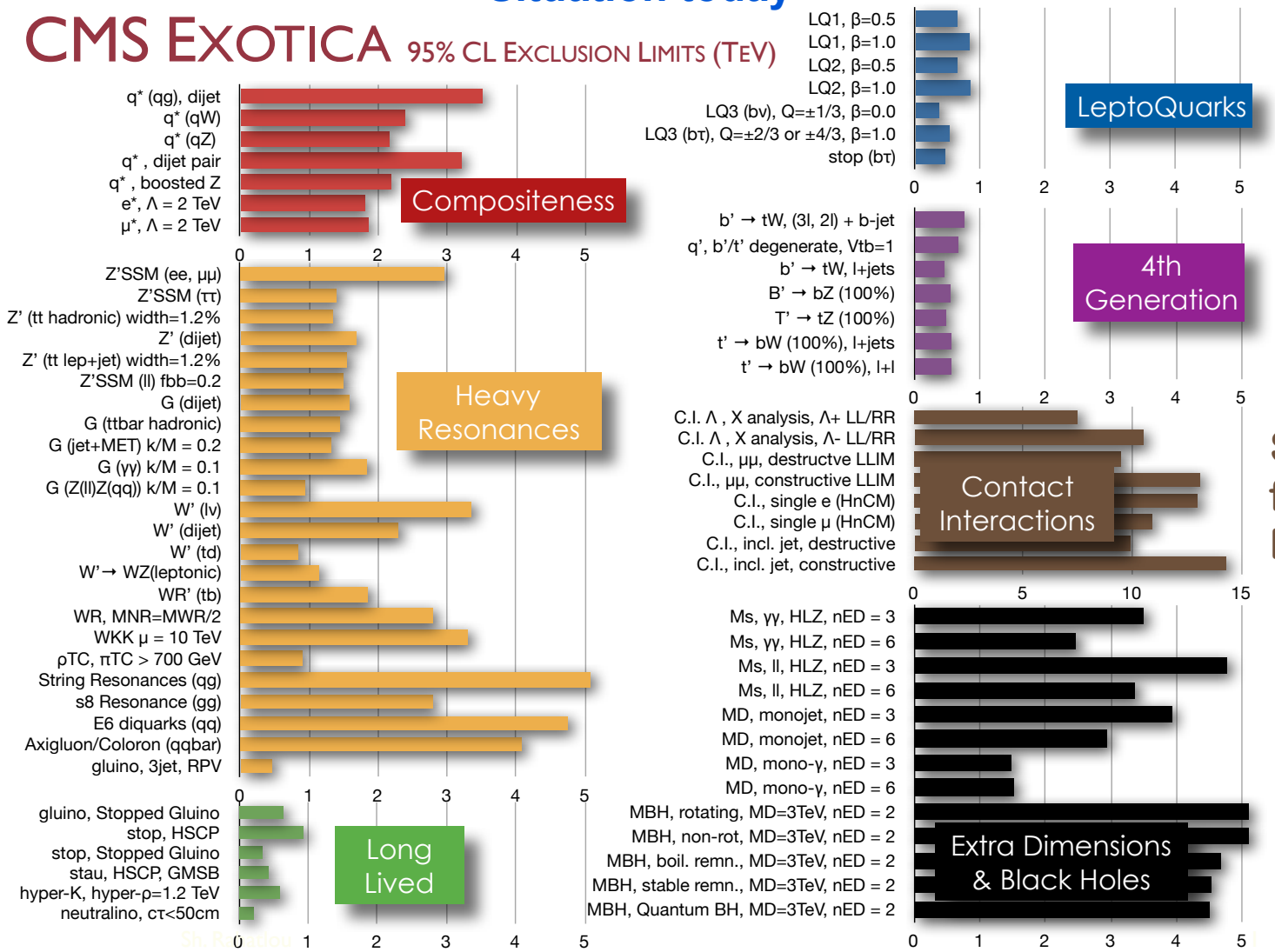

Sensitivity far beyond LHC k-limit!

Physics Program Priorities

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The discovery of a Higgs boson at m_H~125 GeV defines the physics priorities

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  - Characterise any New Physics discovered during Phase 1 at 14 TeV
  - Search for new physics in very rare processes

Examples of Expected Phase 1 Improvements

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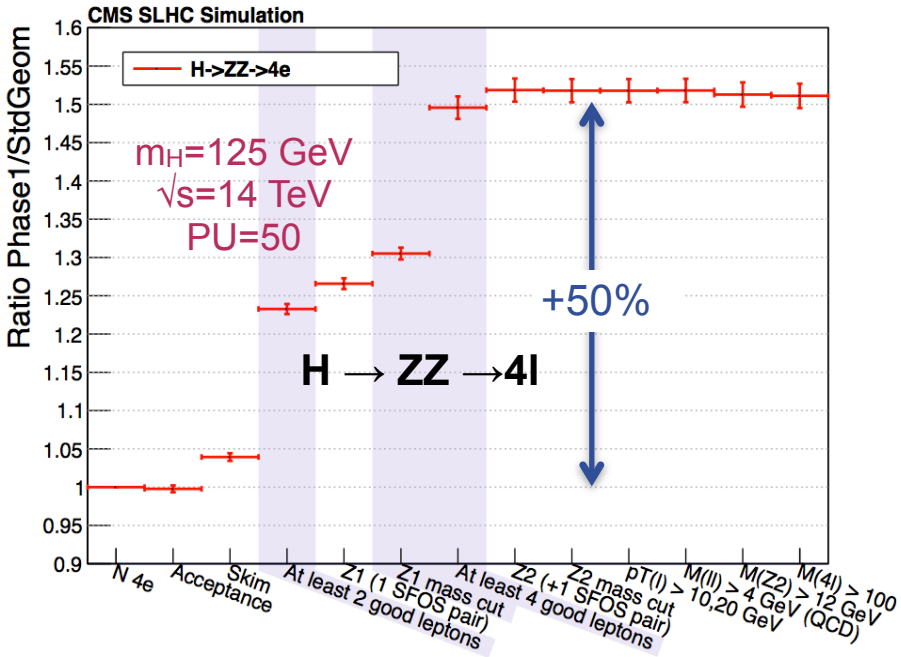

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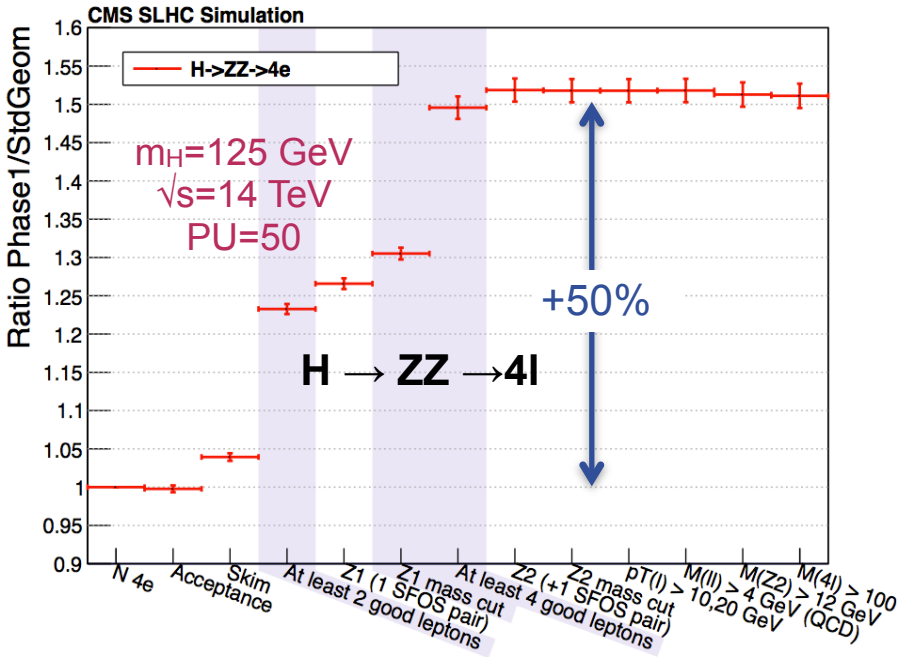

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H→ 4μ	+41%
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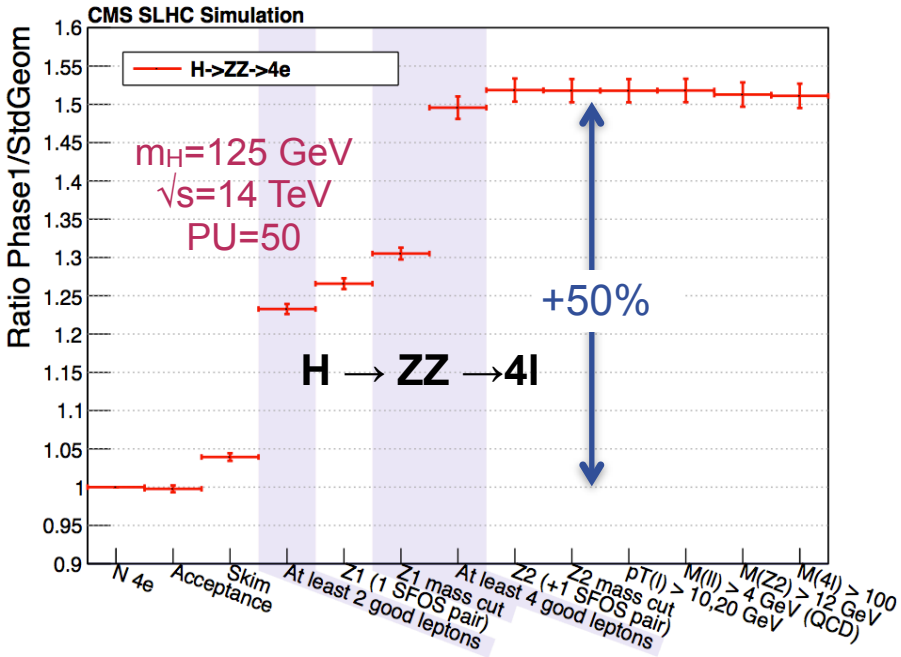

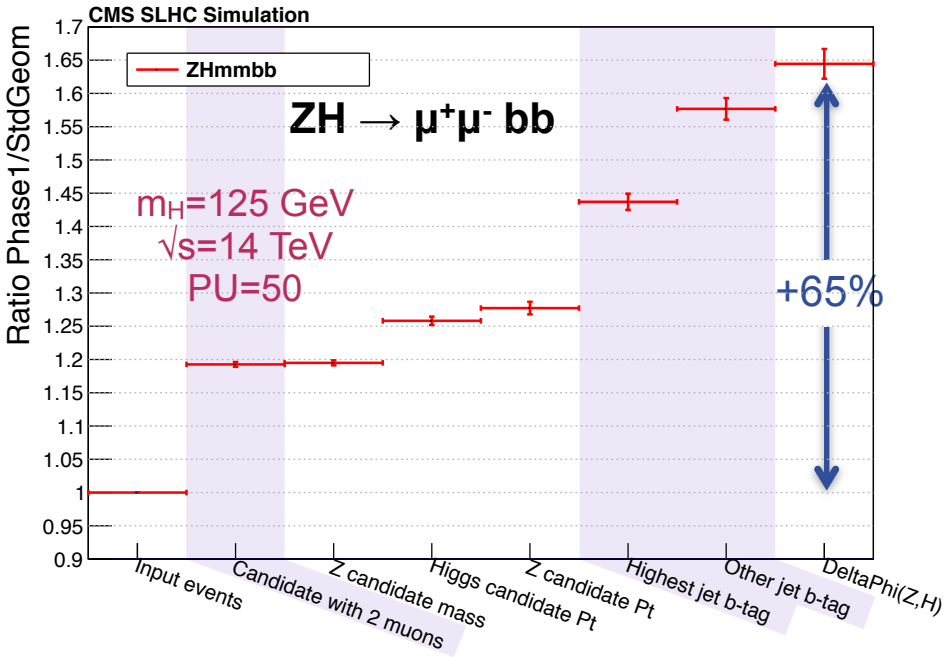

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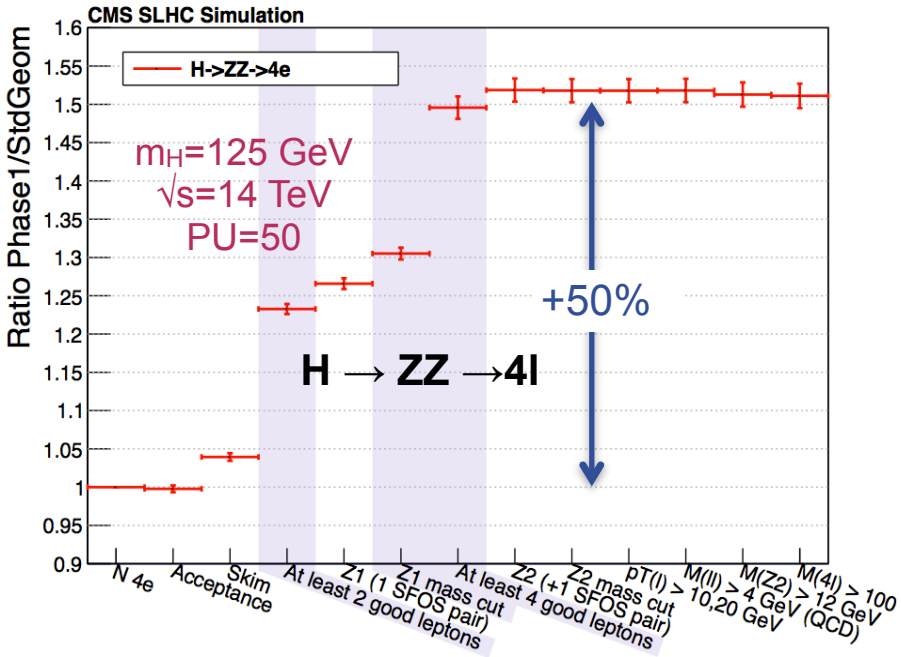

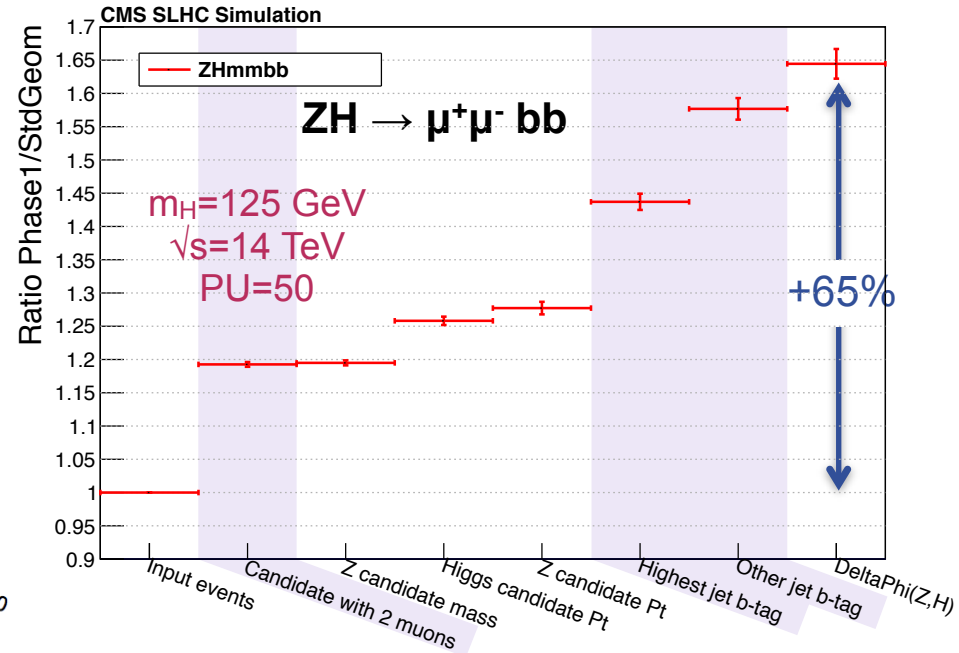

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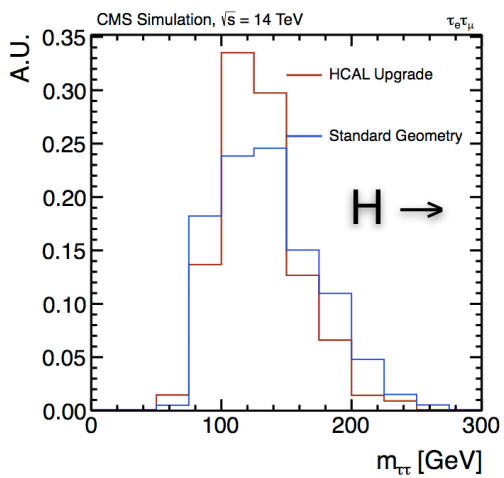

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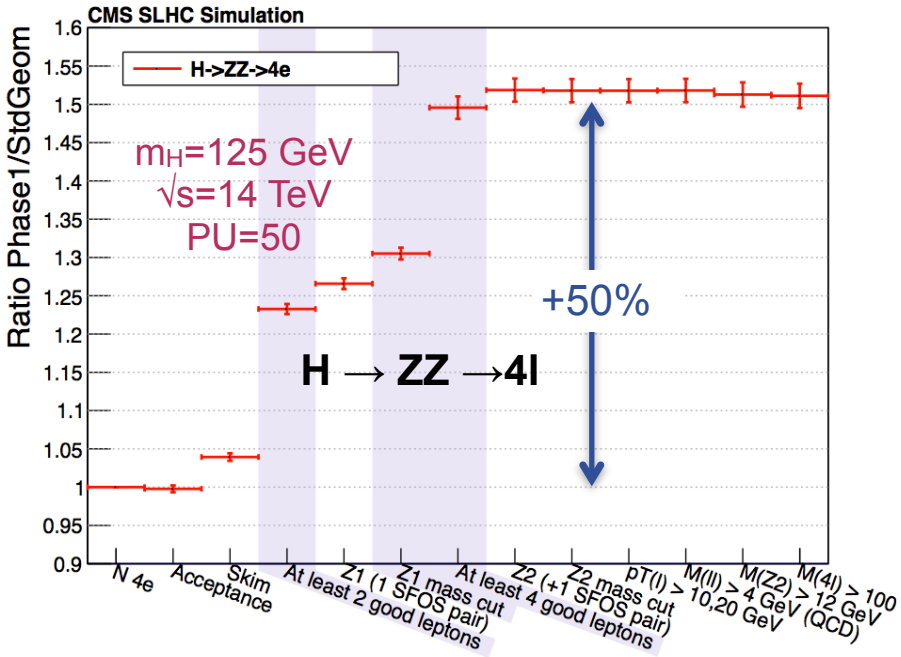

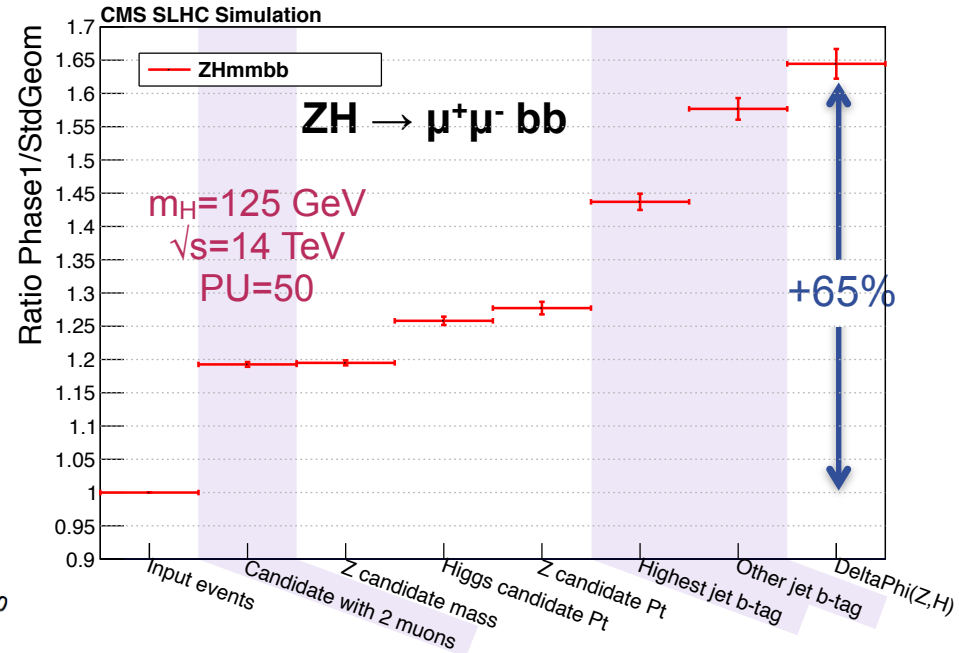

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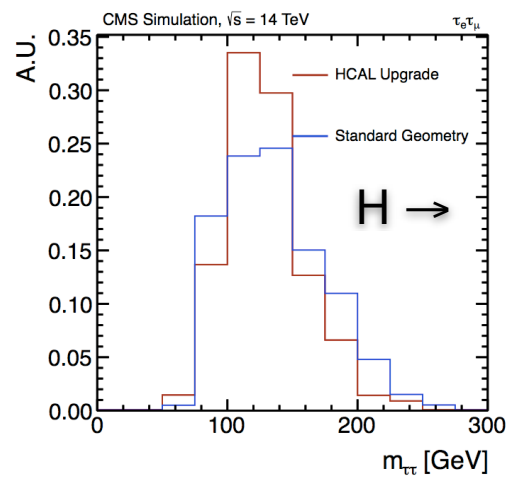

Total efficiency improvement: factor of 2.5 (4.5% → 11%)

Improved jet and MET → 25% improvement in $m_{\tau\tau}$ resolution

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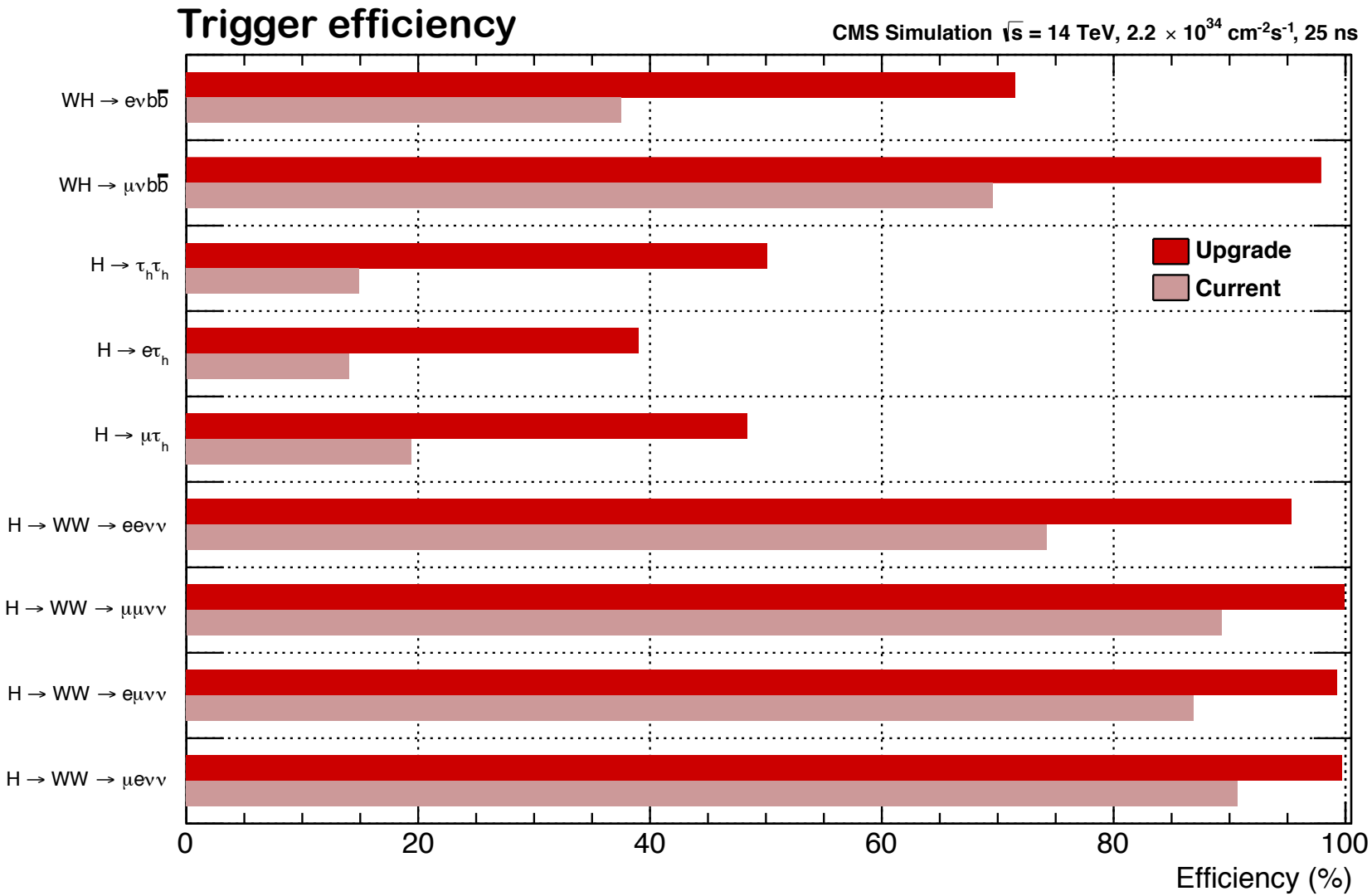

Higgs Projections after LS1

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Fermilab

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  - Scenario 3: set theoretical uncertainties to zero, leave other syst. uncertainties the same as in 2012

Higgs BR with 300 1/fb

- Upgraded detector performances assumed the same as 2012 detector
- Three scenarios:
  - Scenario 1: same systematics as in 2012
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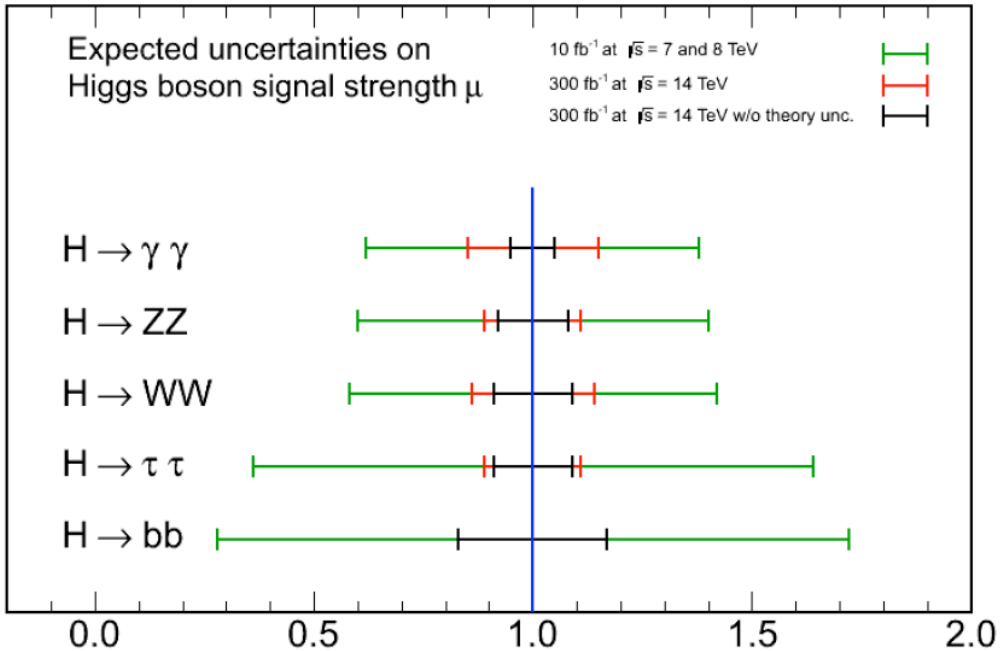
CMS Projection



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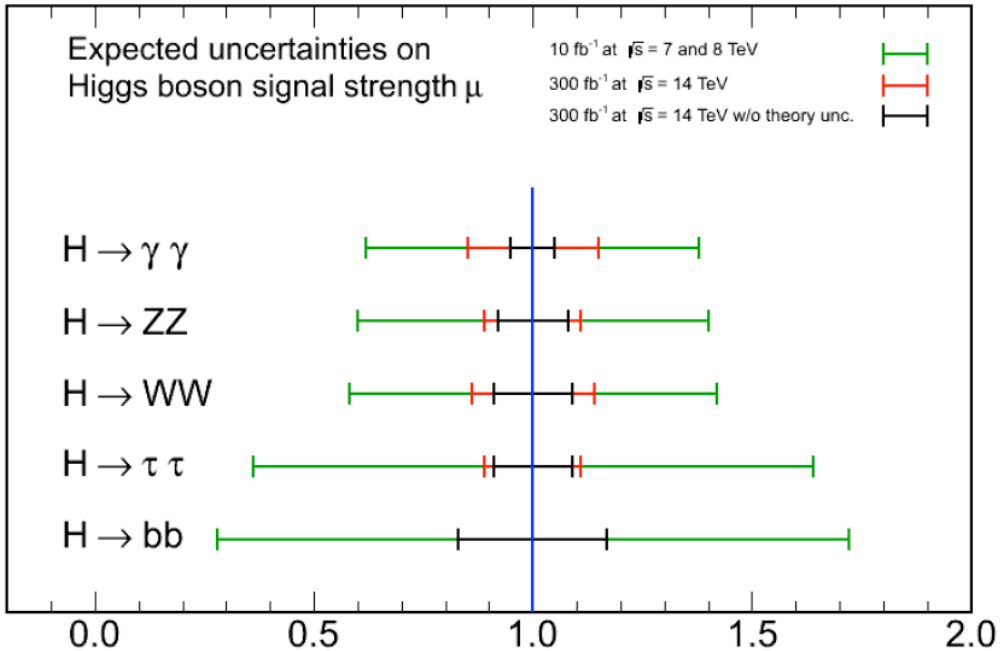

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With 300 fb^{-1} the precision on the signal strength is expected to be 10-15% per channel

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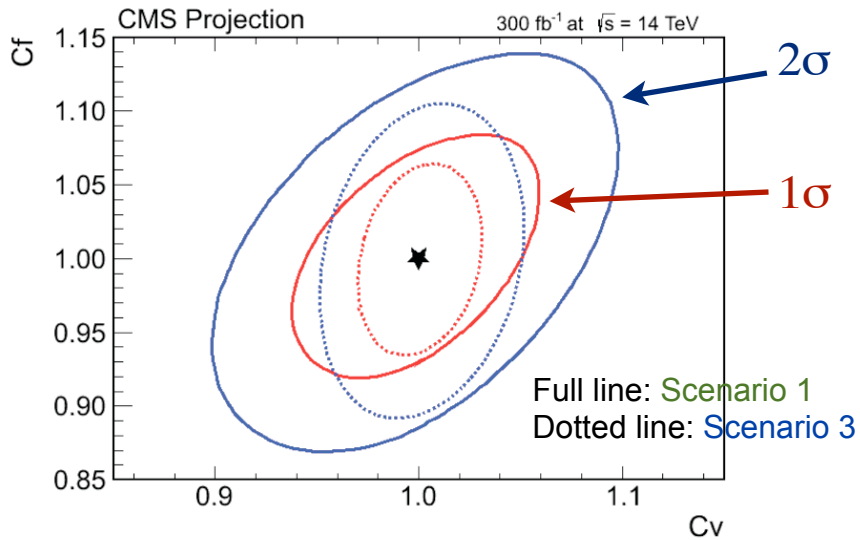

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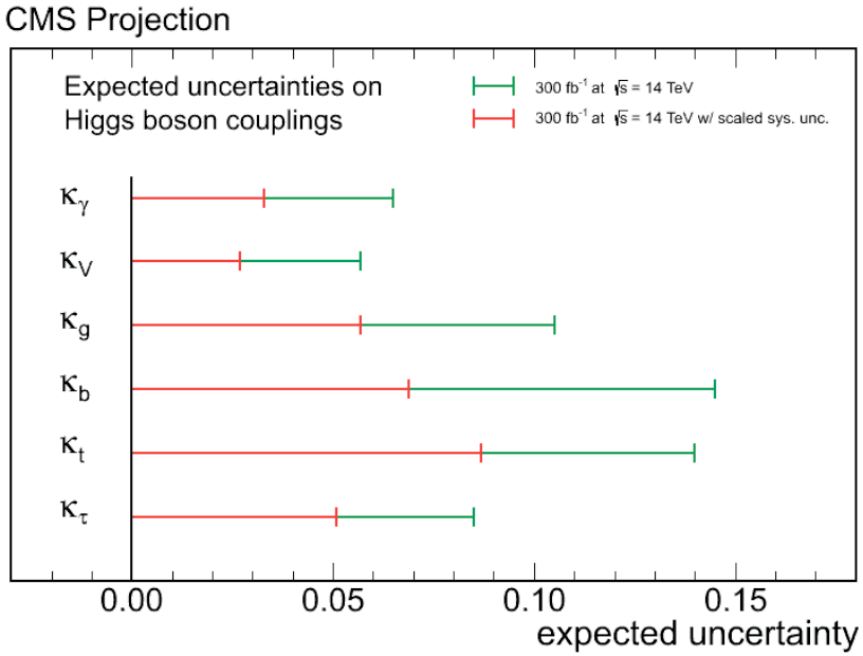

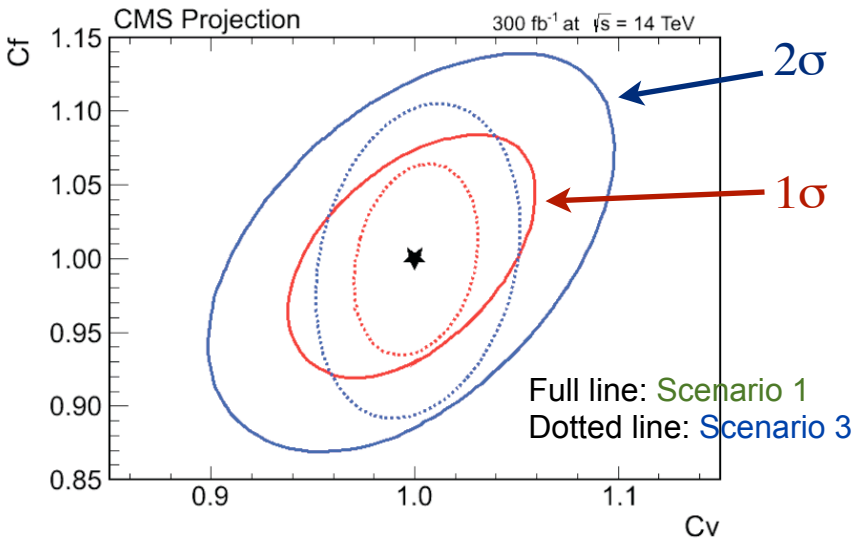

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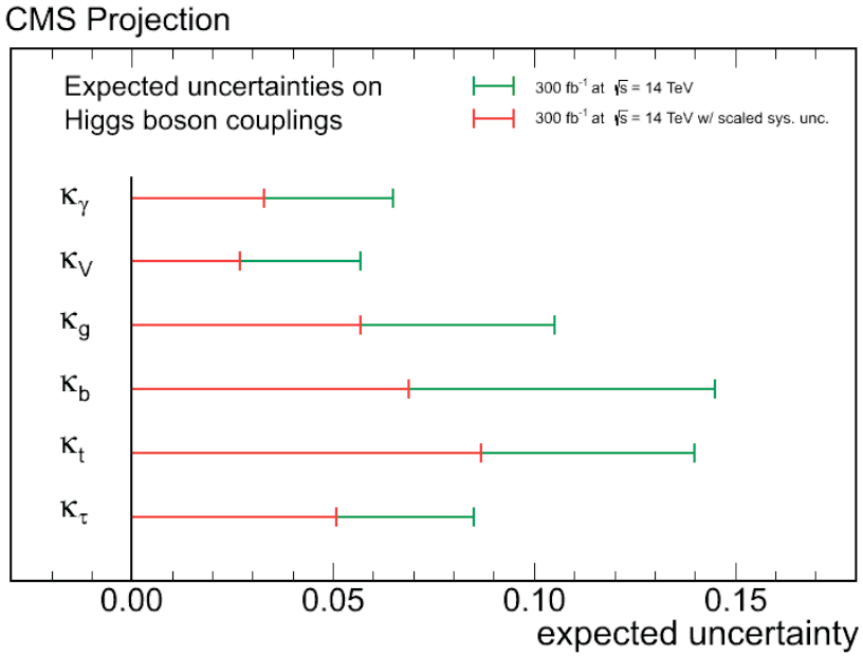

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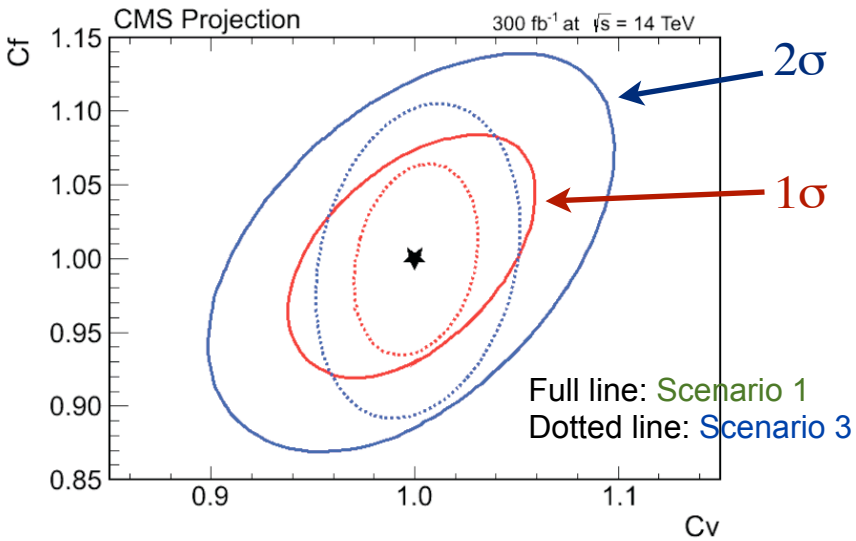

With 300 fb^{-1} the uncertainties on the Higgs couplings are expected in the range $\sigma(\kappa_V) \sim 3\text{-}6\%$

$\sigma(\kappa_f) \sim 5\text{-}15\%$

Higgs Couplings @ 3000 1/fb

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κ_V	4.5	1.0
κ_g	7.5	2.7
κ_b	11	2.7
κ_t	8.0	3.9
κ_τ	5.4	2.0

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- With 3000 fb^{-1} the Higgs couplings can be determined with high precision (1-4%)

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Moving beyond the SM: Searching for NP

- Nature has not easily revealed her secrets
  - many possible roads beyond the SM
  - the potential for unexpected new discoveries is very rich
  - cannot cover all the different models or possibilities in this talk
- I will focus on one, well known, well studied example
  - Supersymmetry
  - can (and does) act as a proxy for many other types of BSM
  - arguably well motivated (will not review here)
- In any event
  - we publish our search results in terms of Simplified models
  - allows theory community to "re-interpret" our results in terms of their favourite BSM model

SUSY reach at high energy & luminosity

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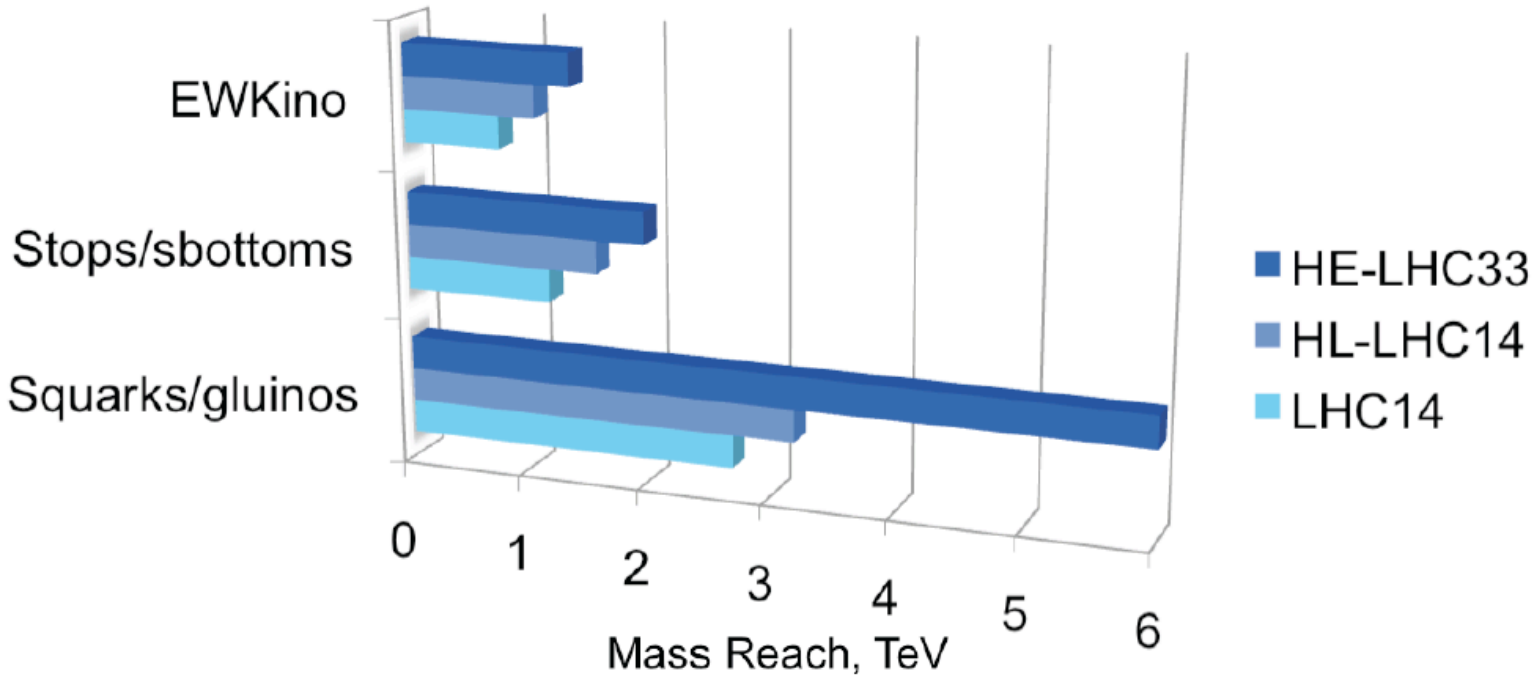

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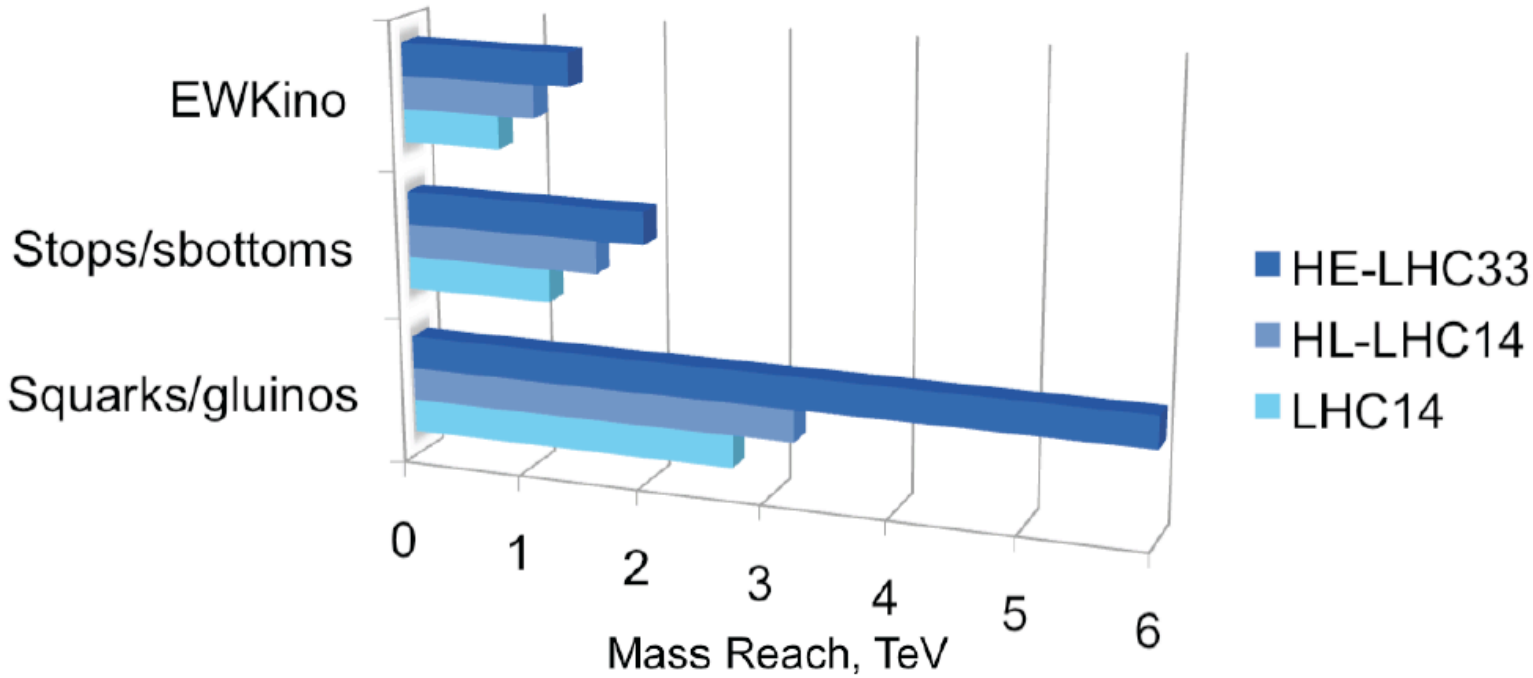

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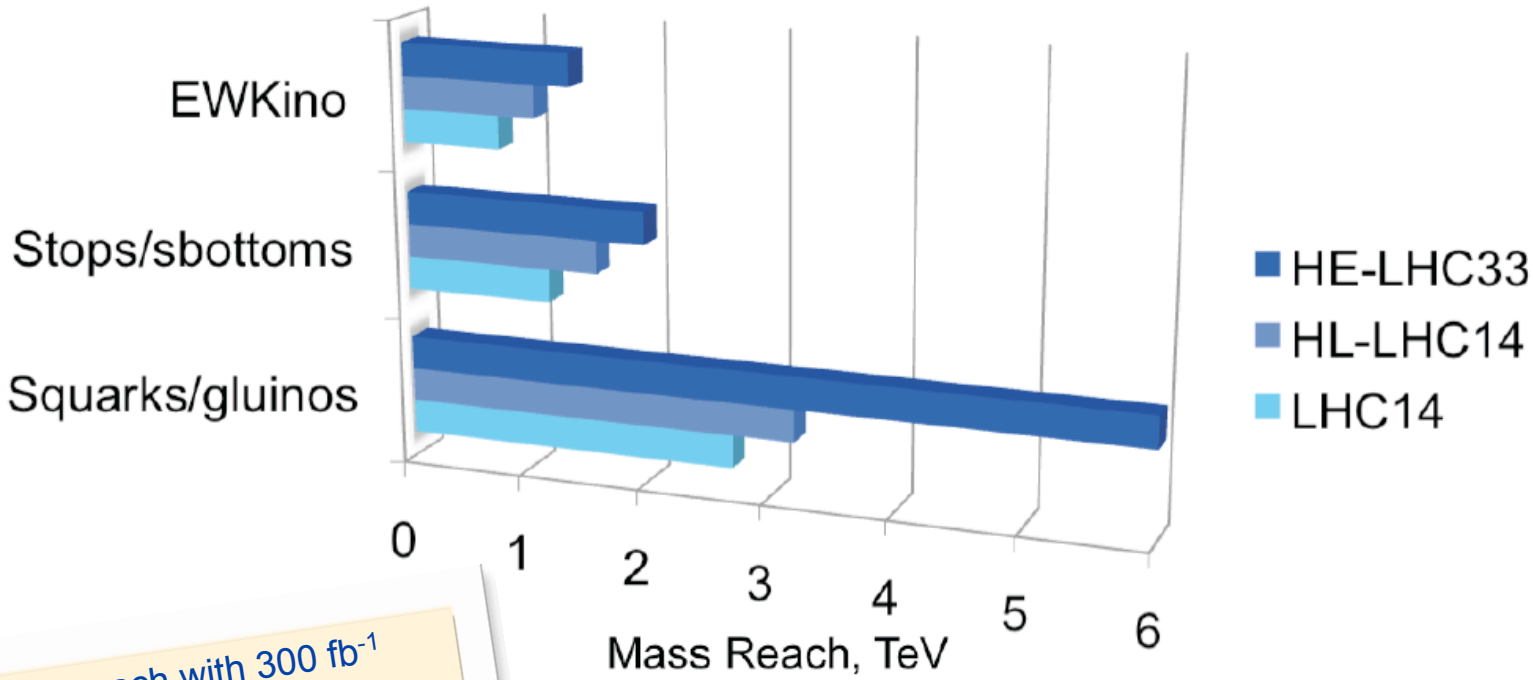

SUSY reach with 300 fb^{-1}
EWKinos up to ~ 800 GeV
Stops,sbottoms up to ~ 1TeV
squarks,gluinos up to ~2.5 TeV

Priorities for SUSY Searches

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"Difficult"

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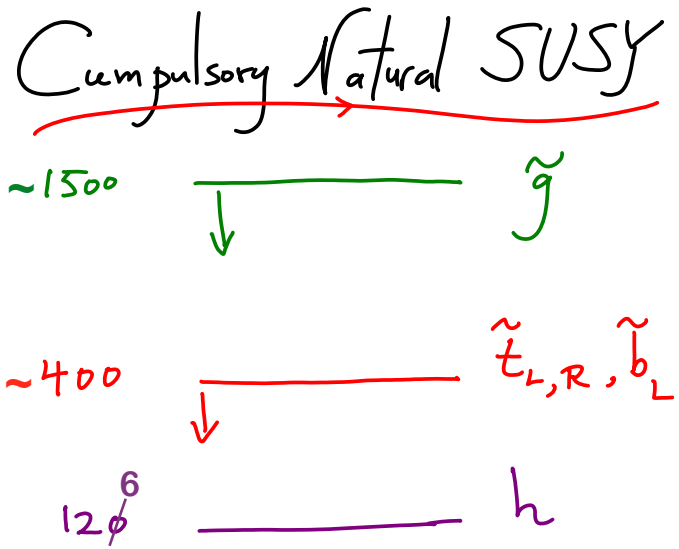

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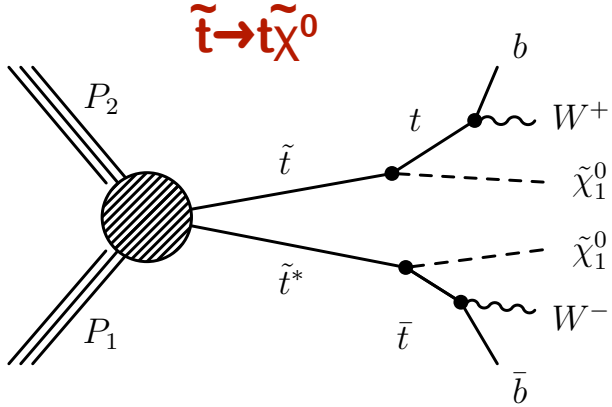

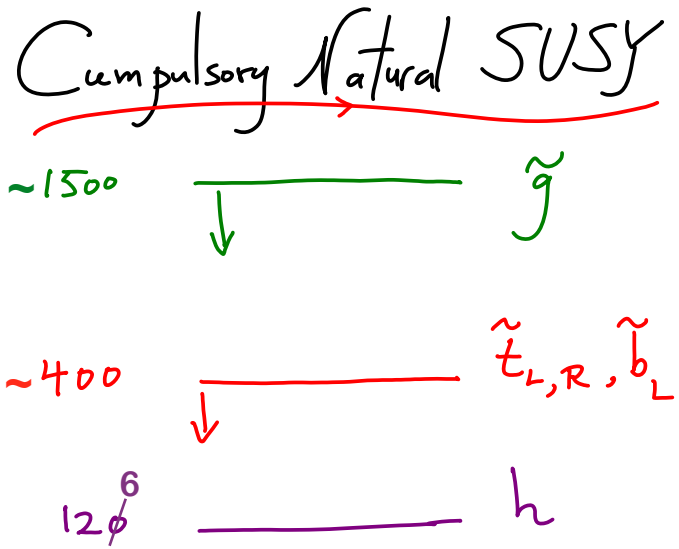

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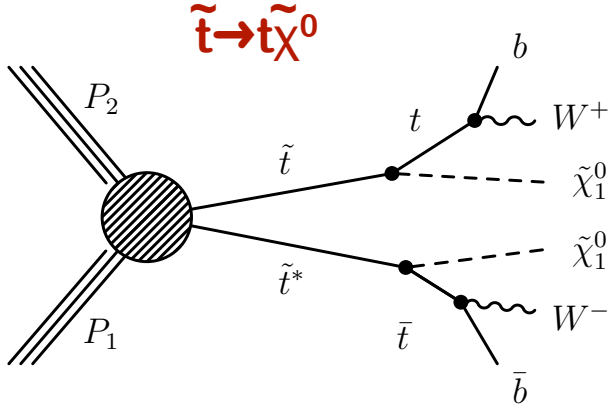

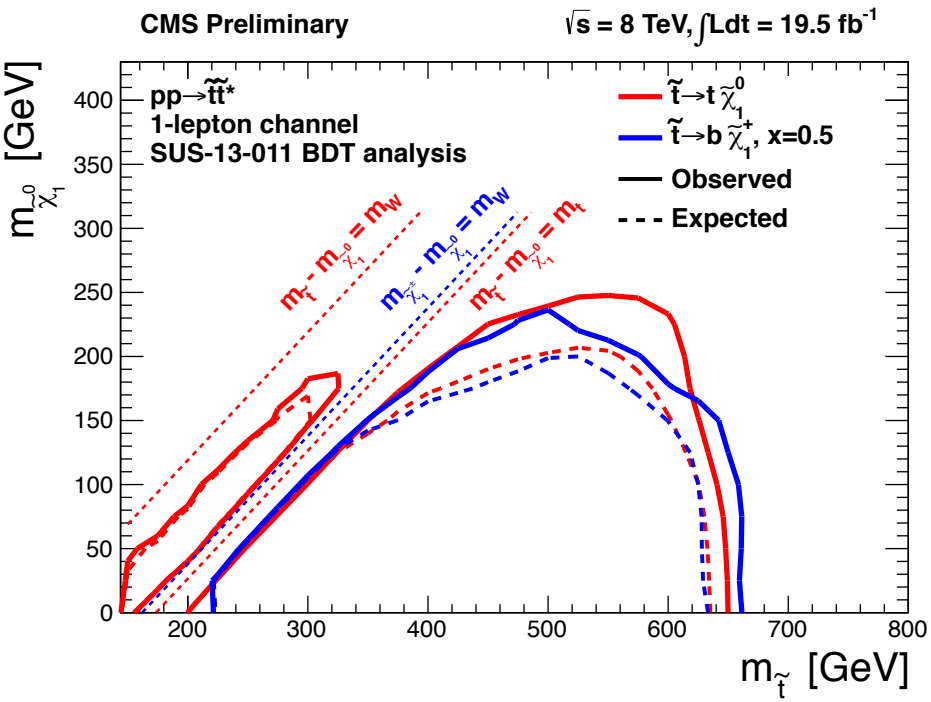

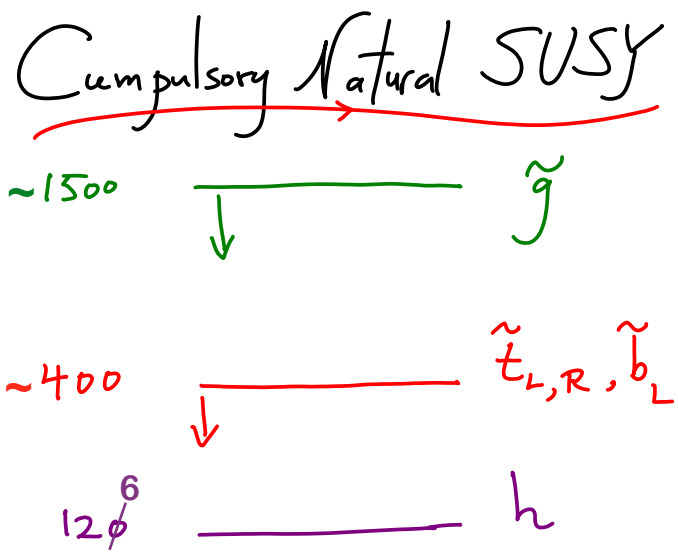

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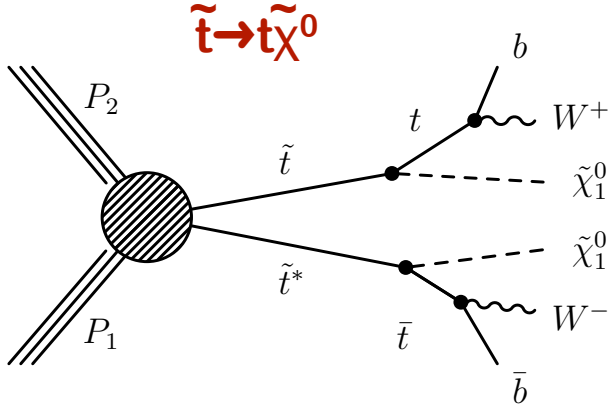

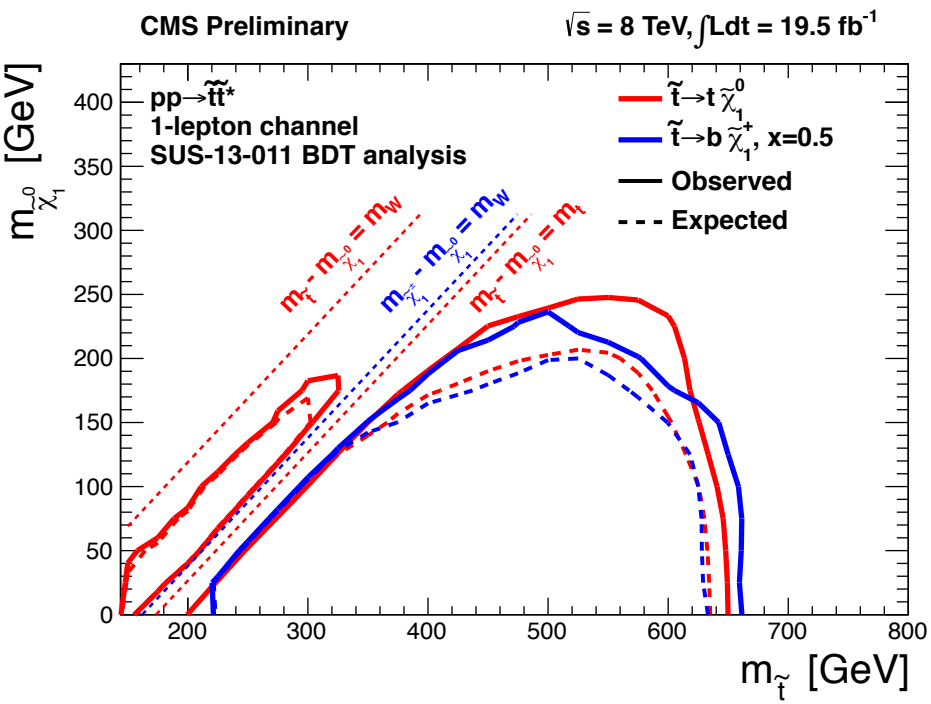

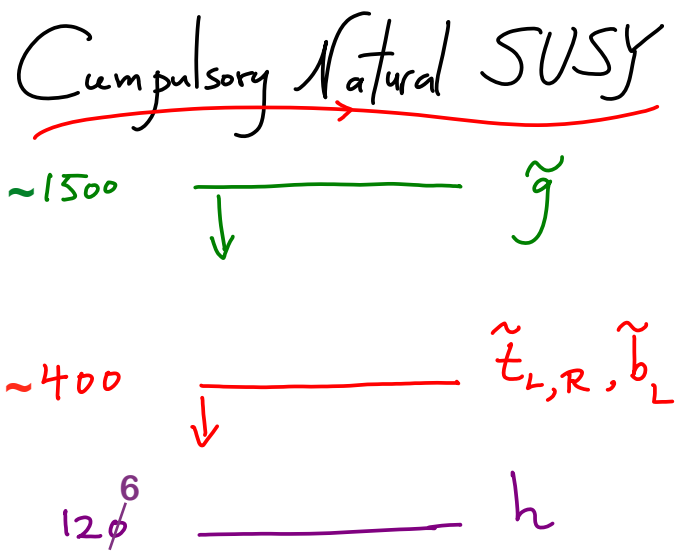

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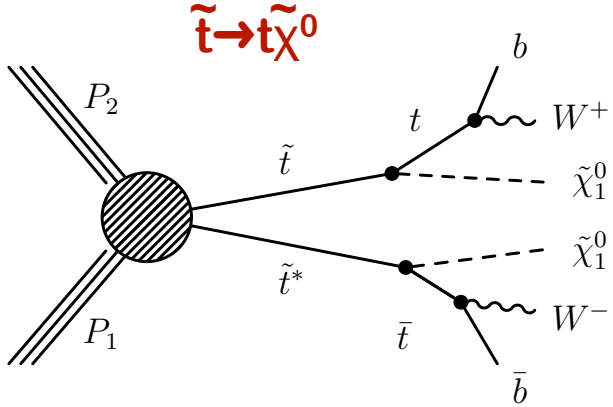

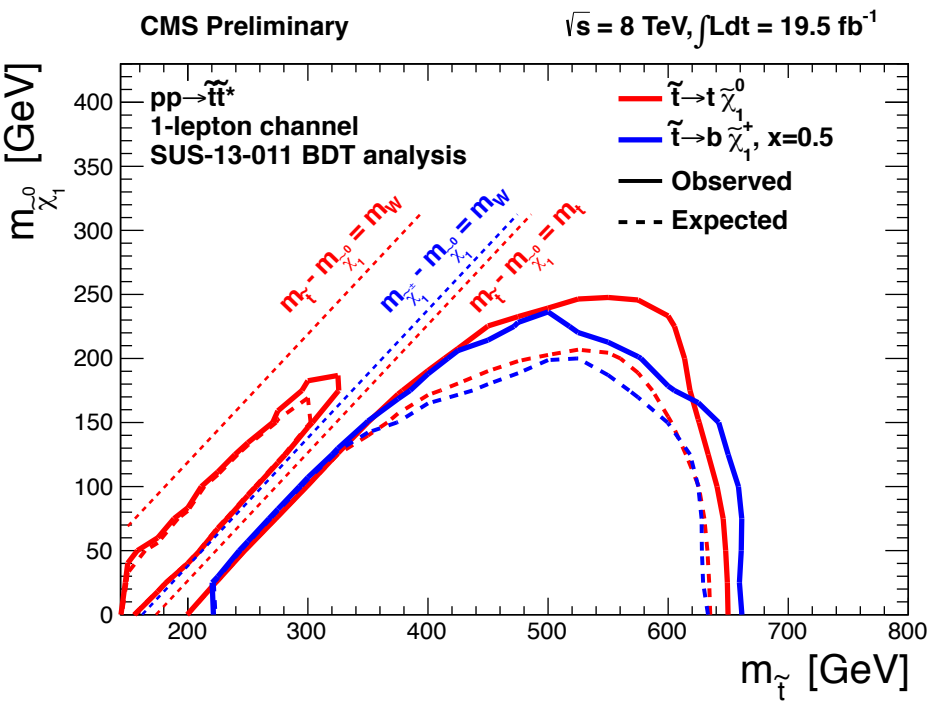

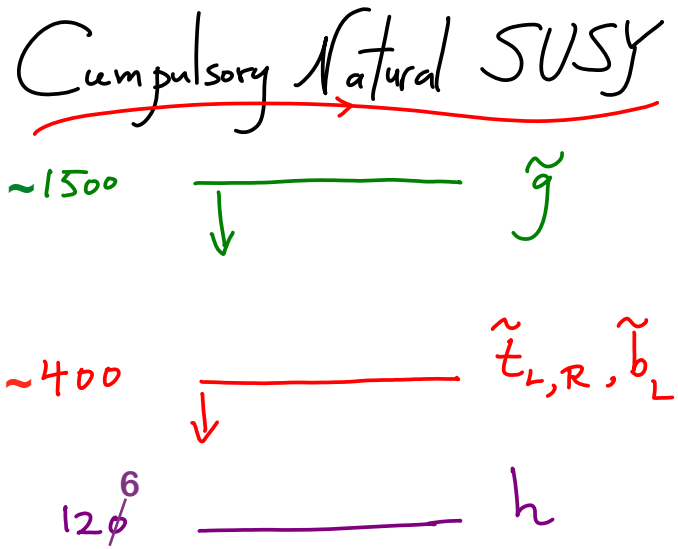

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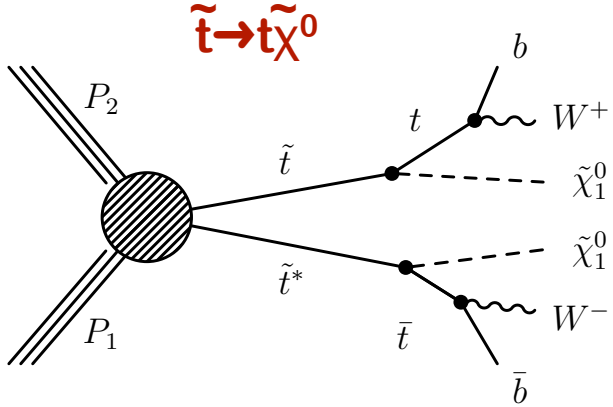

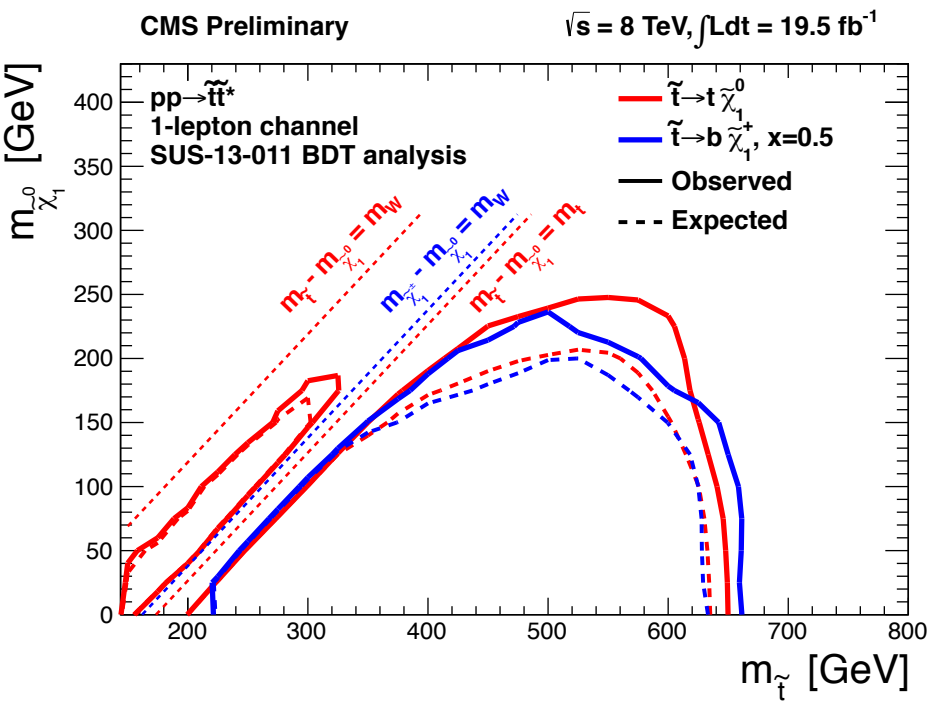

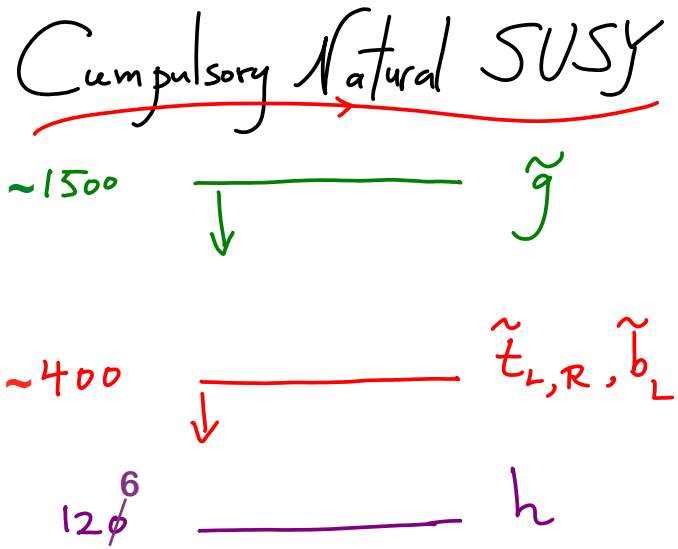

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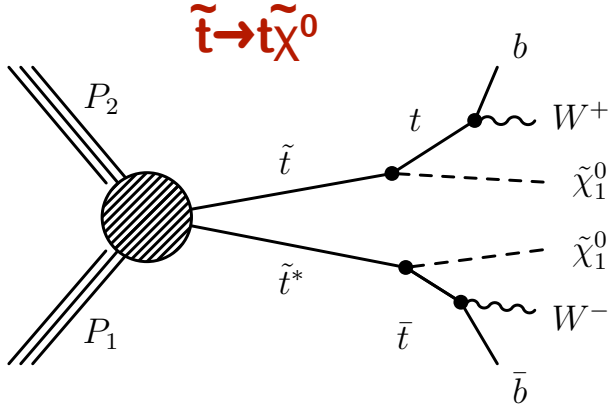

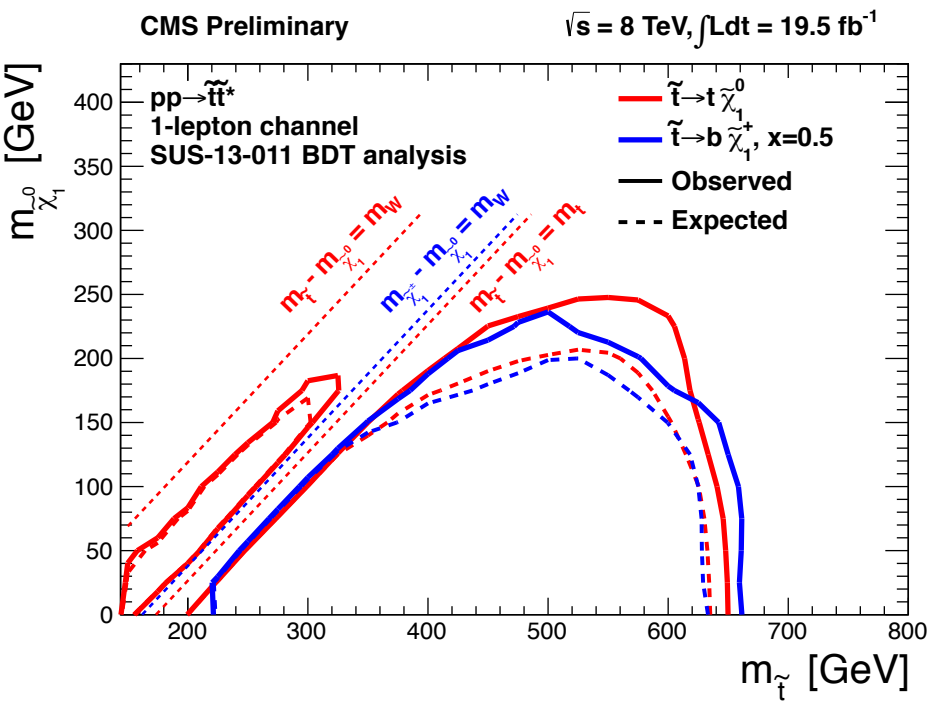

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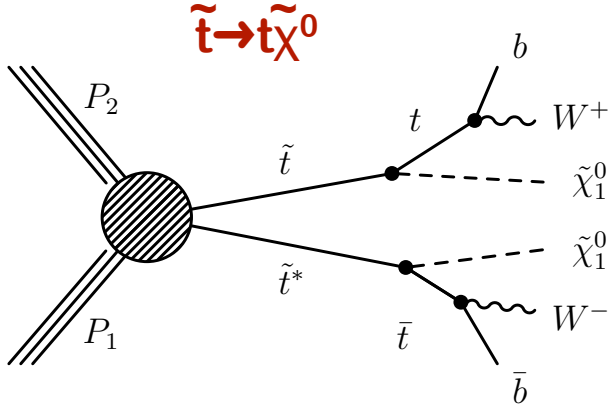

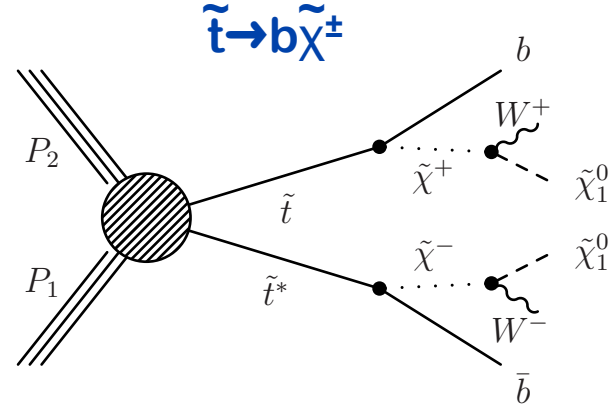

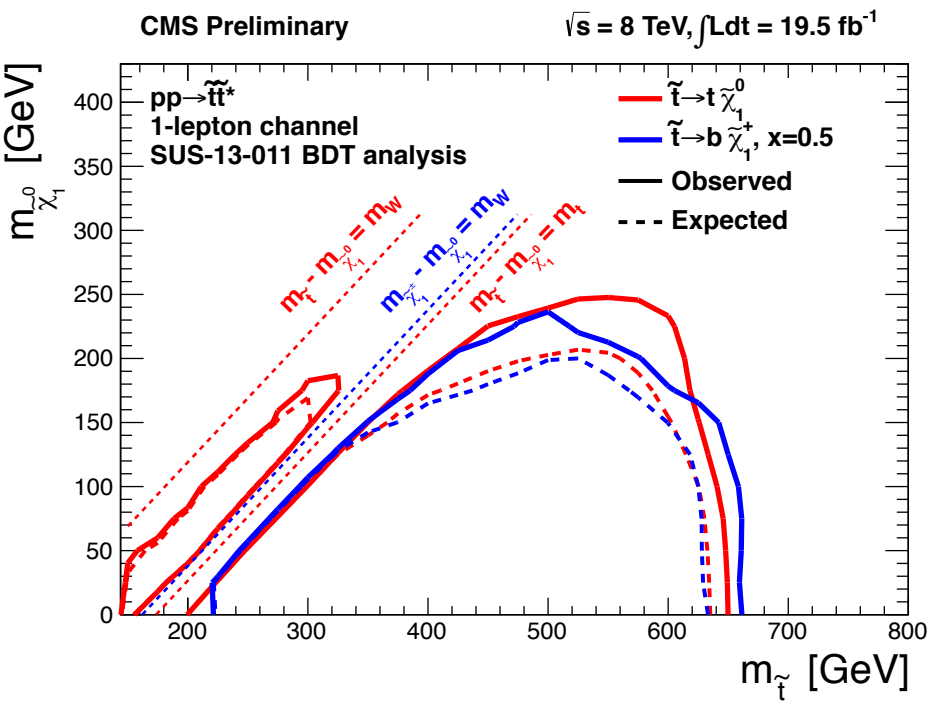

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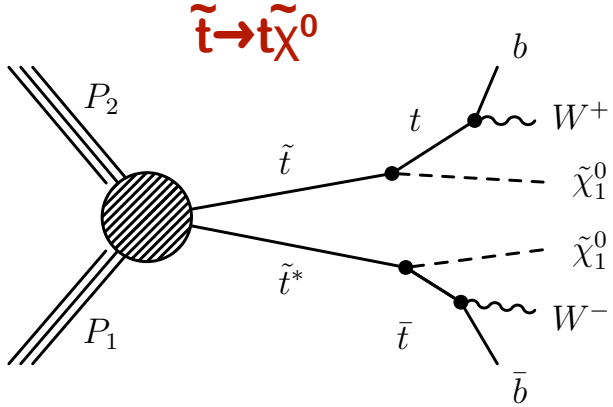

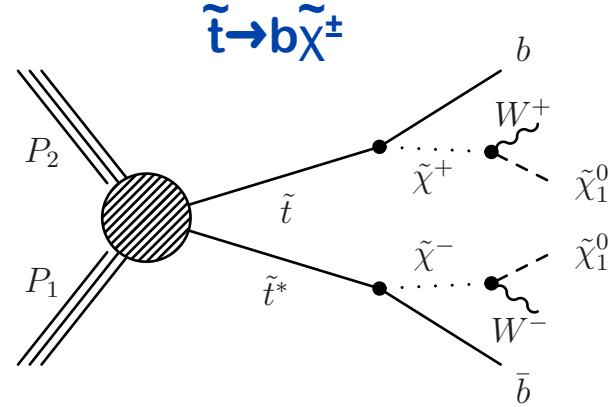

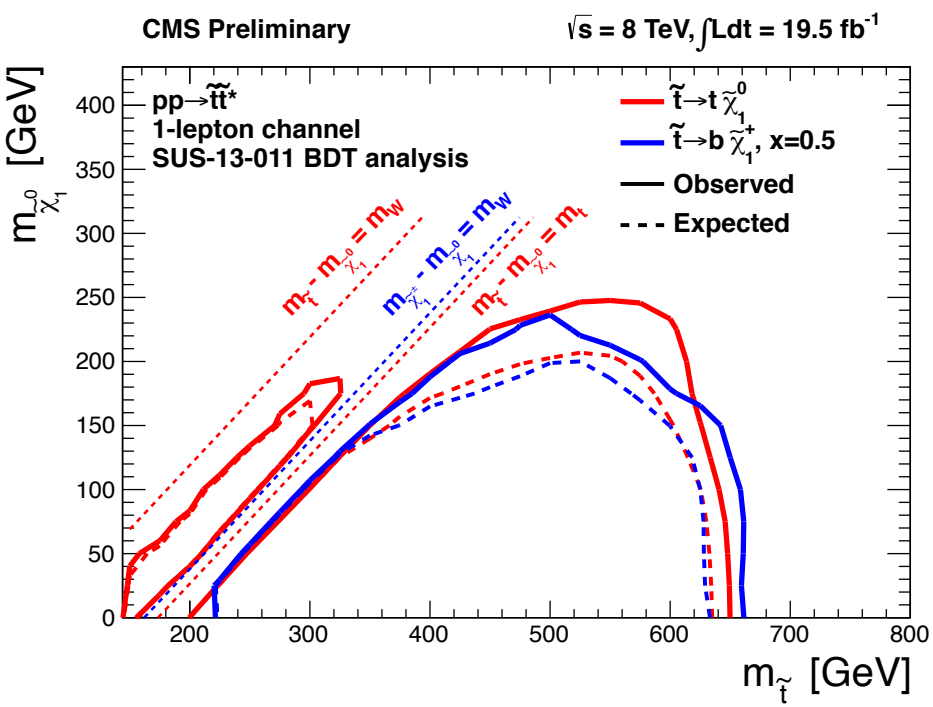

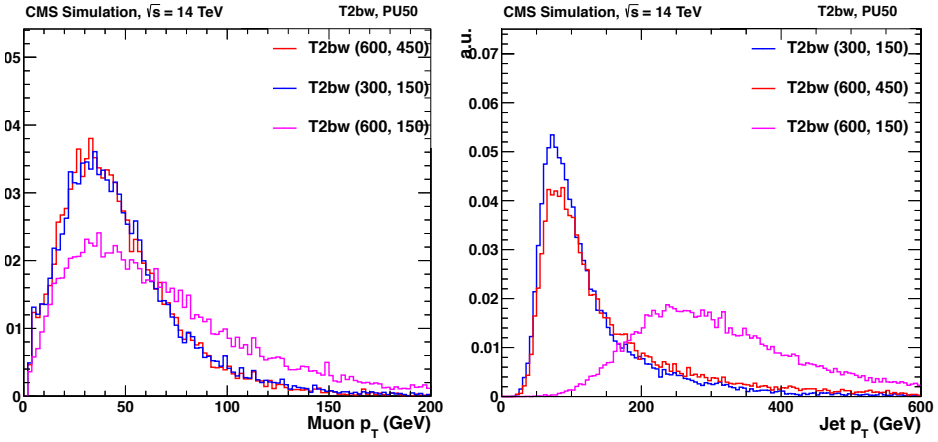

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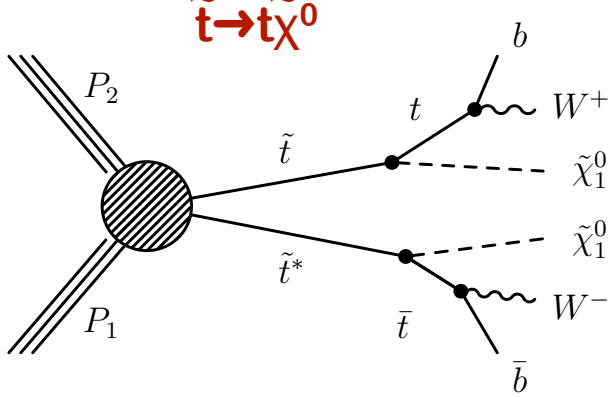

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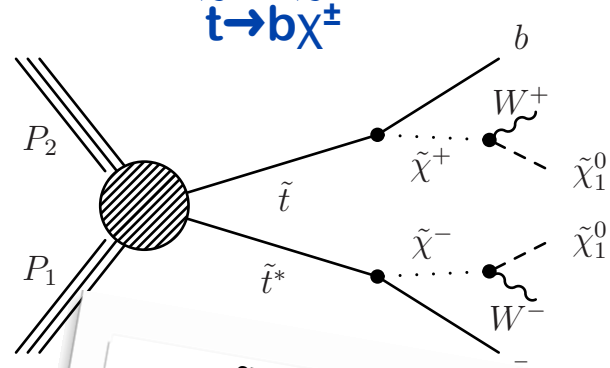

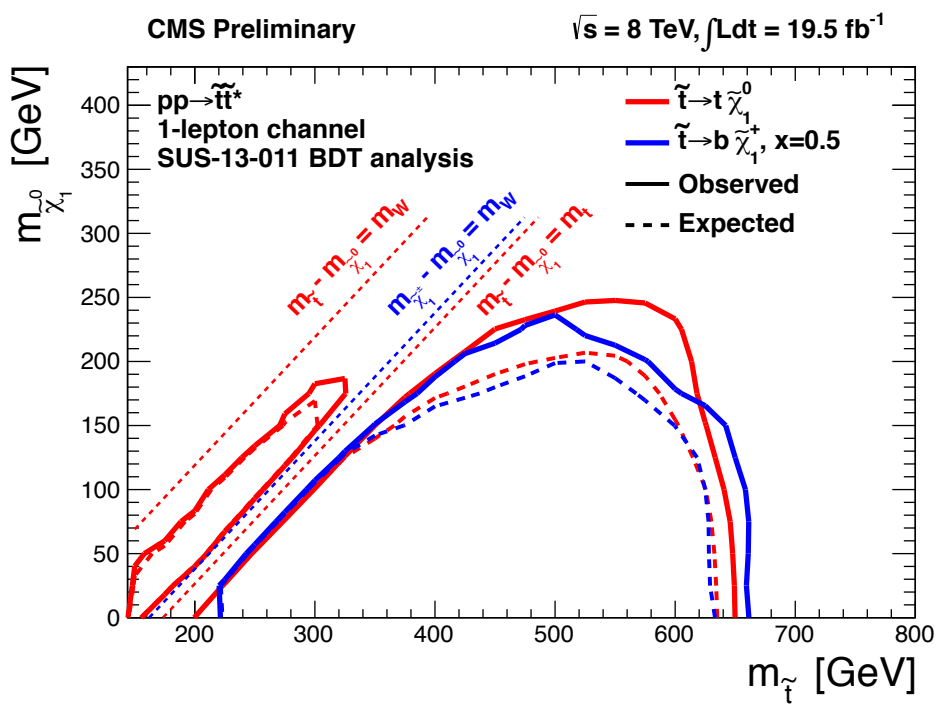

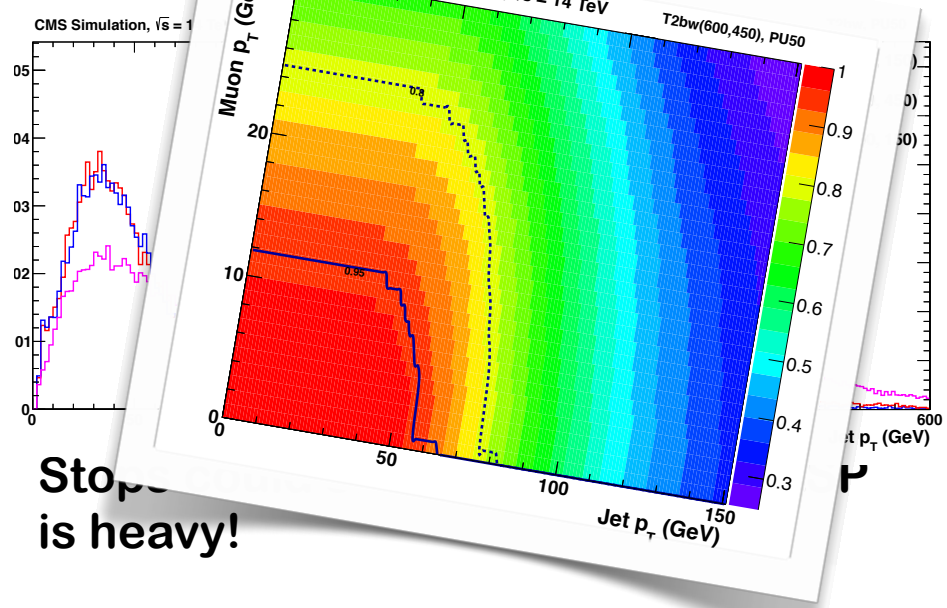

Stop is heavy!

Vital to maintain trigger thresholds as low as possible!

Helping to make it all happen: The LPC

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- Interaction with theory community very fruitful
  - new ideas brought into real experimental analyses
    - stealth susy, jet substructure, etc
  - Visiting scientists & seminars weekly

Shaping our future: The LPC and Snowmass

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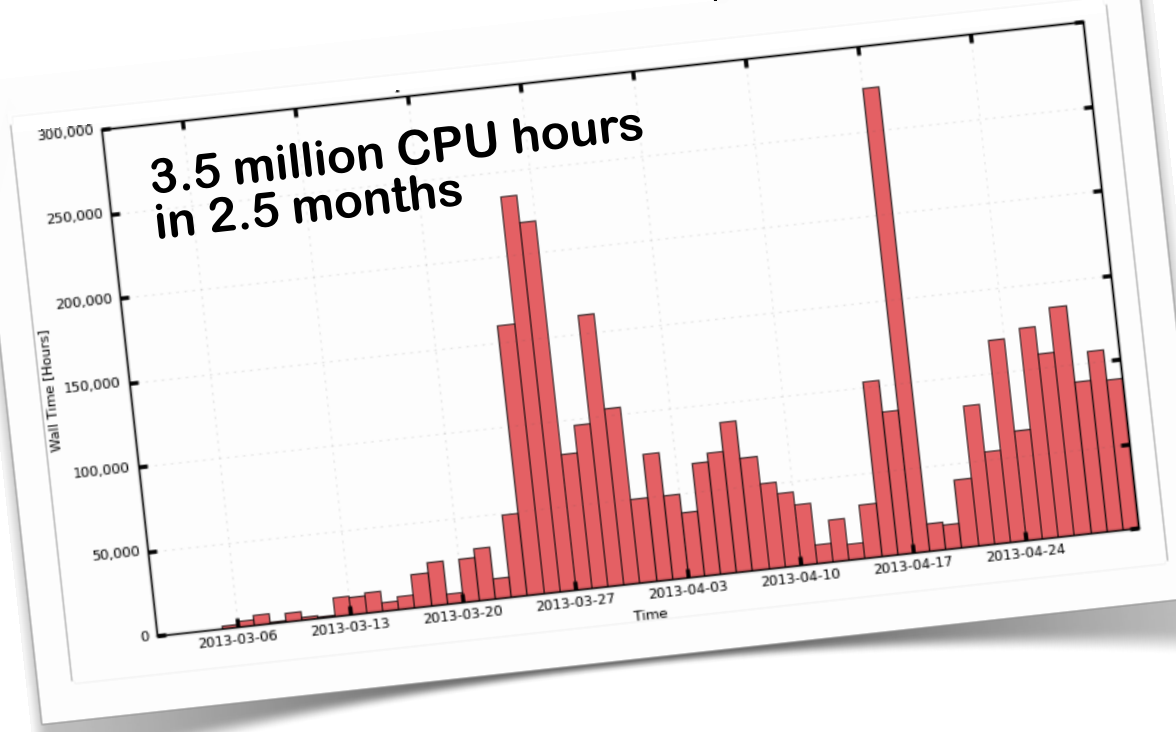

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- Several snowmass studies underway at the LPC
  - Examples: t', T5/3, heavy higgs H and A with H->WW, ZZ, A->Zh, hh

Conclusion

- The LHC is a Discovery Machine
- New era of exploration: 13 TeV LHC Run
  - Only discovery machine at the Energy Frontier for foreseeable future
  - Much (much) more landscape will be revealed in just a few years!
  - Huge impact on the future of our field!
  - Truly exciting time in HEP!
- The Physics Potential at High Energy and at High Luminosity is compelling
  - Precision Higgs Measurements
  - Natural EWSB; Supersymmetry
  - Unexpected New Phenomena
- The LHC Physics Center is playing a central role