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Recent Results from 7 GeV proton-proton running at CMS

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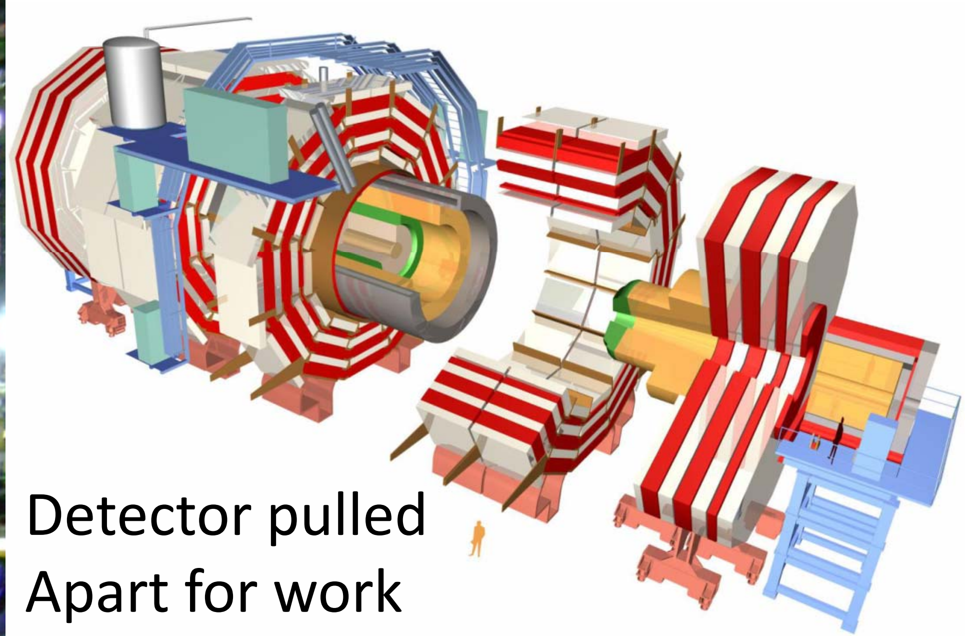
(for the CMS collaboration)

SESAPS 2011

CMS Detector



Detector pulled
Apart for work

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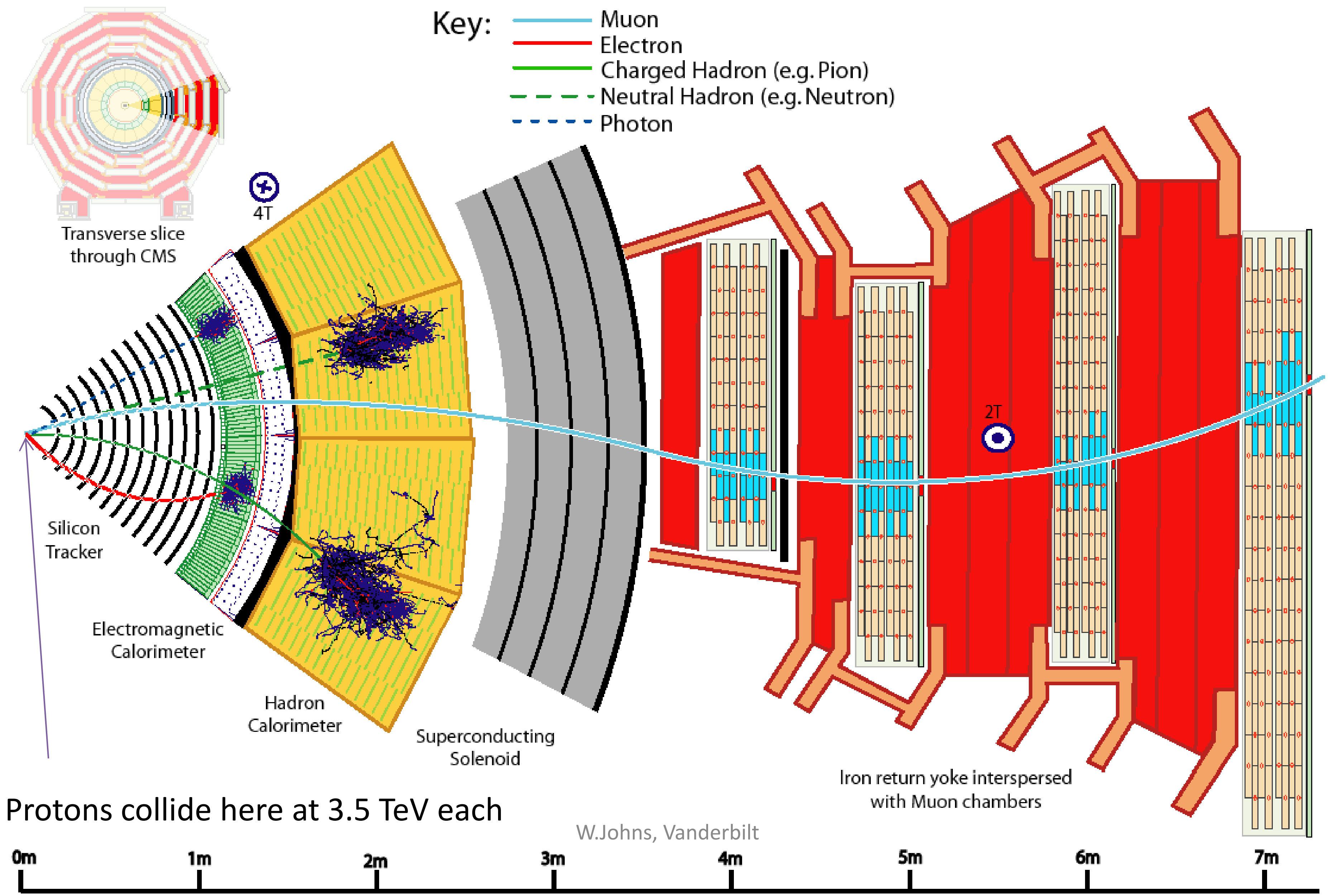
CMS Detector

24 m wide, 12.5 Tons

3.8 Tesla (v_{esc} for ~40kg!)

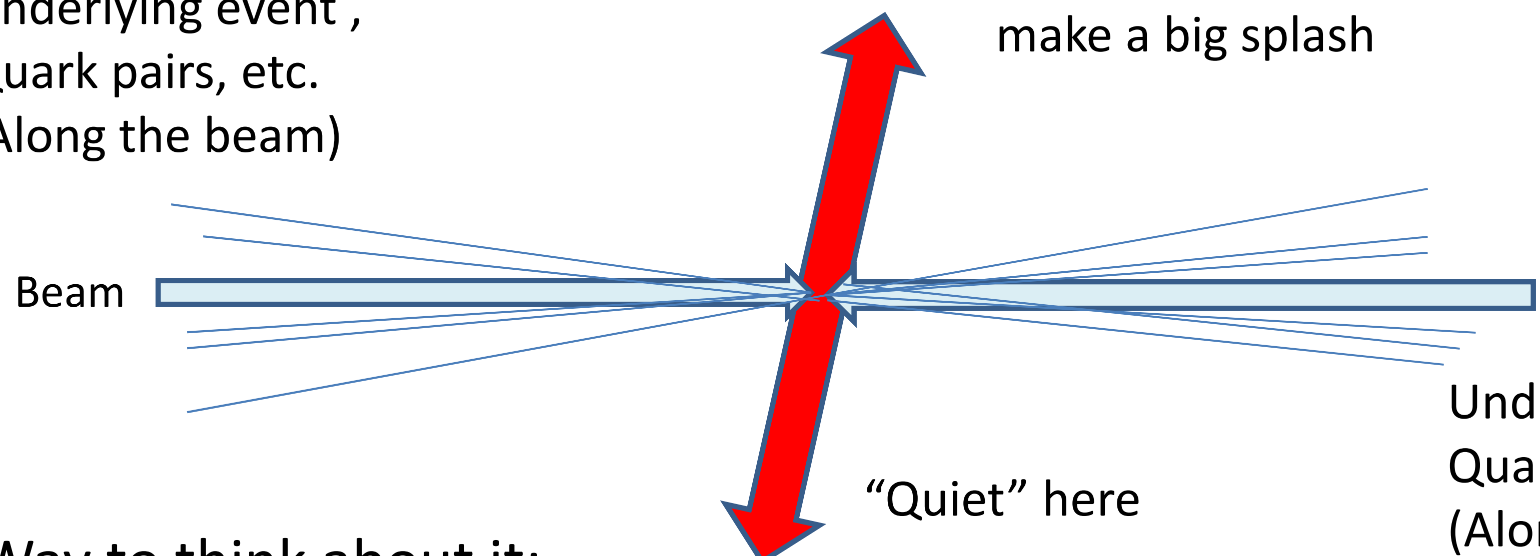
A slice of the CMS experiment



W.Johns, Vanderbilt

Really quite interesting!

- Lots of particle action along the beam direction
- Not as much transverse to the beam
- Use beam energy to make a Heavy Particle

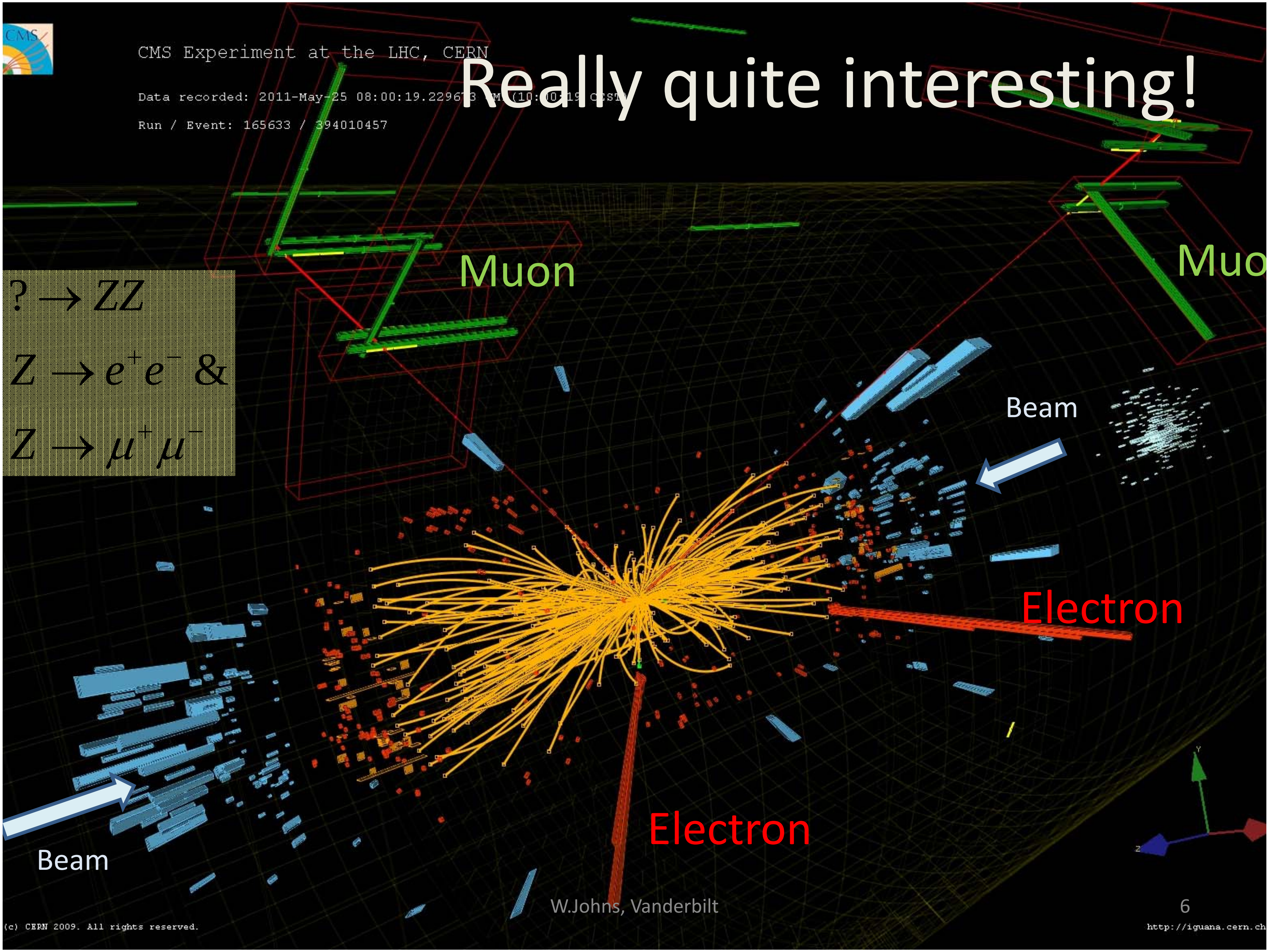


Way to think about it:

Beam energy -> Making a big mass ($E=mc^2$)

Big mass decays into 2 particles - Come at any angle, back to back

Really quite interesting!



$? \to ZZ$

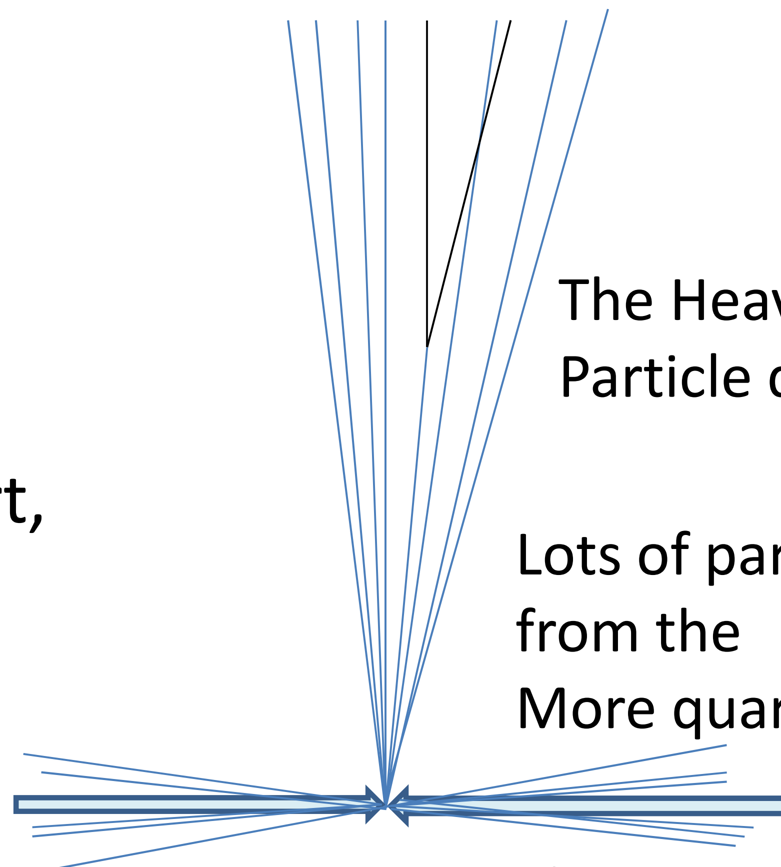
$Z \to e^+e^-$ &

$Z \to \mu^+\mu^-$

Not all events are as clean…

- Particles can interact violently in the detector
  - It's a question of probabilities – more likely in a Cal
- Some processes are messy by their nature
  - Try to pull quarks apart, get more quarks
- Need the *whole* detector to do a good job of separating

And you get a mess when you were hoping for one big thing



A high B field (+other stuff) helps

- Consider that a 1 TeV charged particle will only bend by about ~1 mm in the tracker
  - Precision tracking helps a lot
  - Can use a Tau particle to get at higher mass
    - A reconstructed mass peak will spread out more
    - But the Tau decay can be clean to a muon, and separable from other processes
      - Think about that heavy quark without the "quark pairs"
  - Can use a calorimeter to measure "momentum"
  - It's also a win-some lose-some since it is easier to trigger on a very stiff (straight) transverse muon
    - So it can help to measure muon momentum again

Language of colliders

- The machine delivers a particle Luminosity
  - Proportional to collision frequency, number of particles in each beam bunch, and inversely proportional to the overlap in the beams

$$\mathrm{L} \propto f\, N_1 N_2 / (\Delta x \Delta y)$$

  - And the creation rate for a particular process is given by $\mathrm{R} = \mathrm{L}\sigma$
  - Where the sigma represents the cross-section for the process in question
    - Proportional to the number of "scattered" particles per incident flux (has units of area)
    - One can increase L in a number of ways

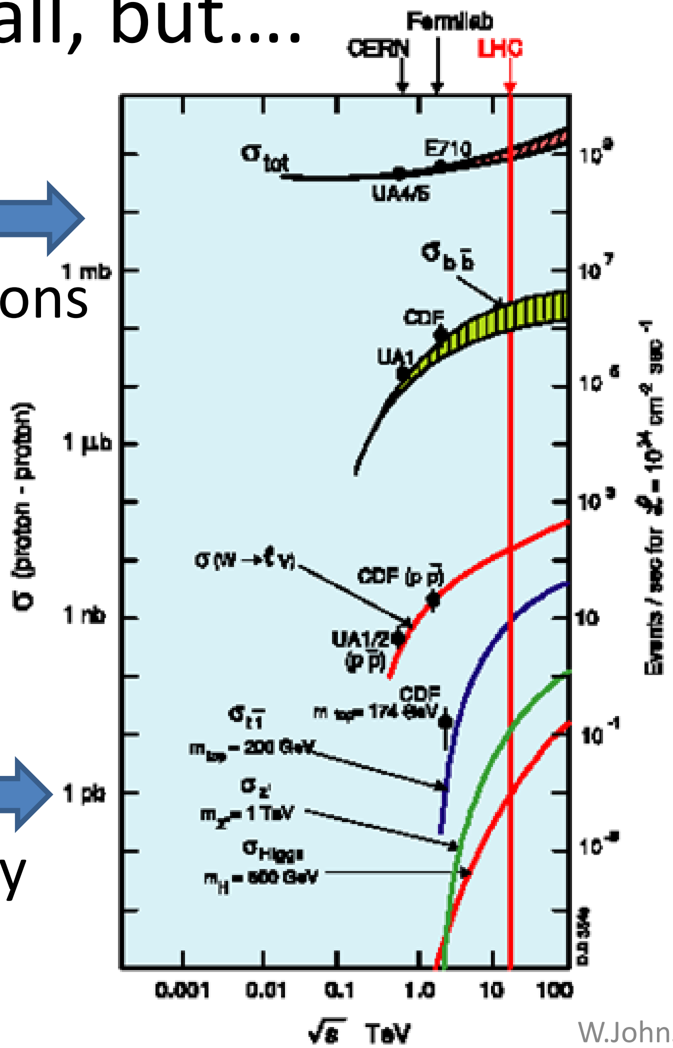
Couple of reasons this is interesting

- Higgs rate will be small, but….

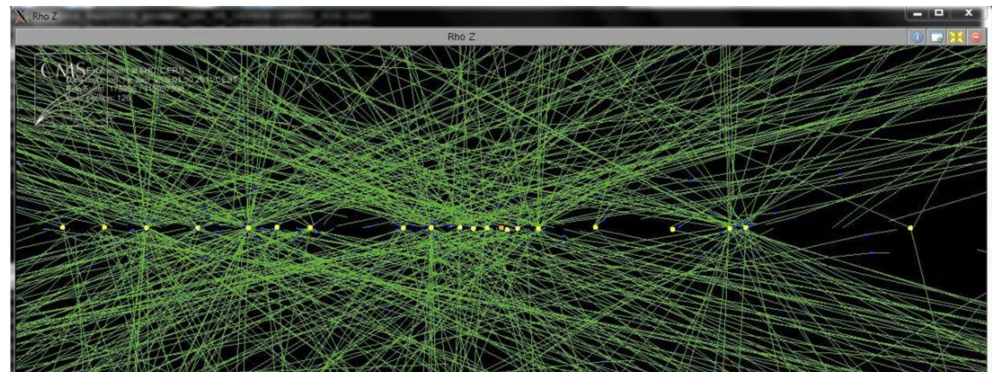
Multiple Interactions

x1000

Higgs Territory



- Increasing N gives more multiple p-p interactions:



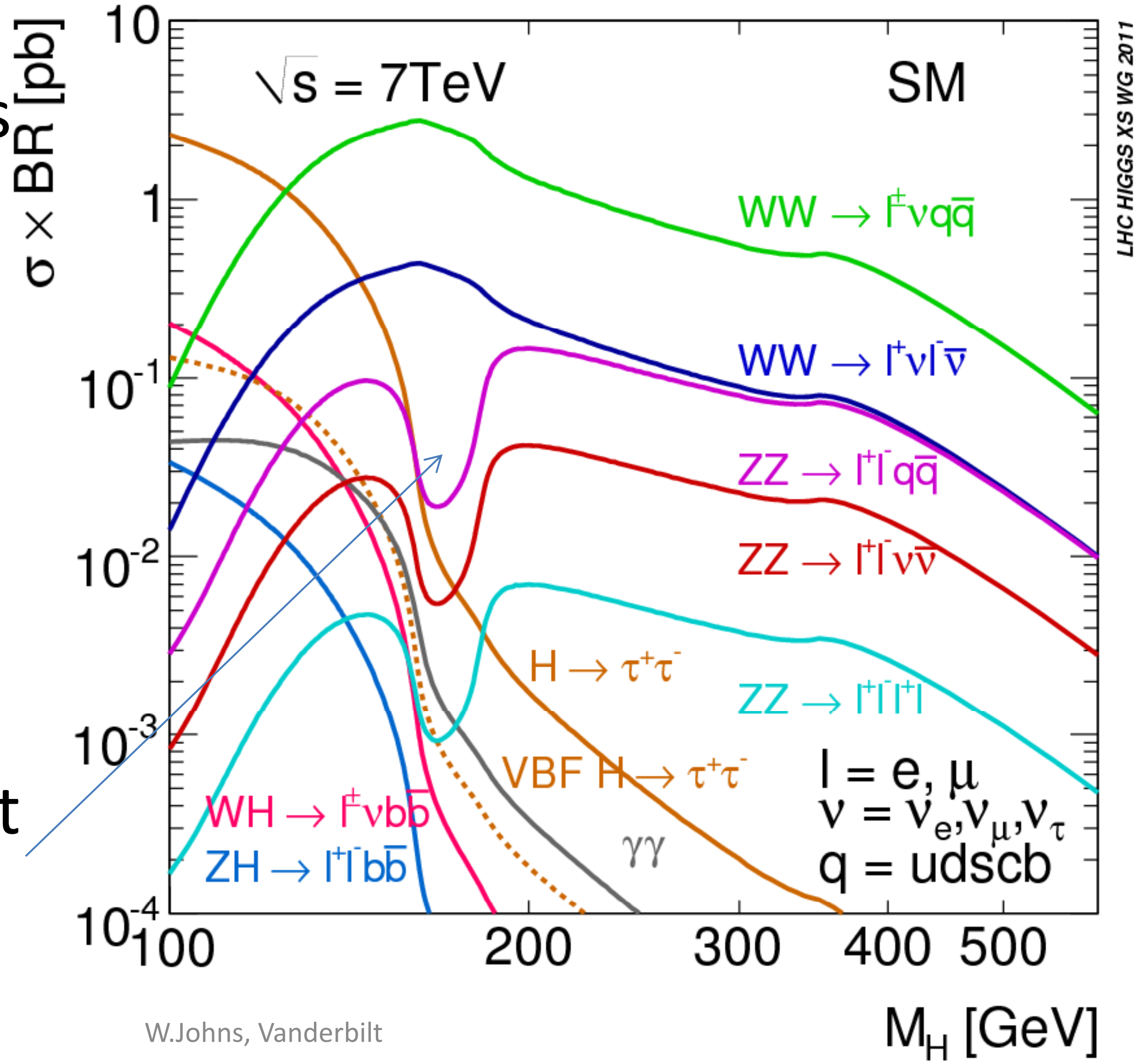
Multiple interactions at CMS (~10 cm wide)

– “pileup” is challenging for the detector and event reconstruction

> The LHC is trying to increase *f* now for more L

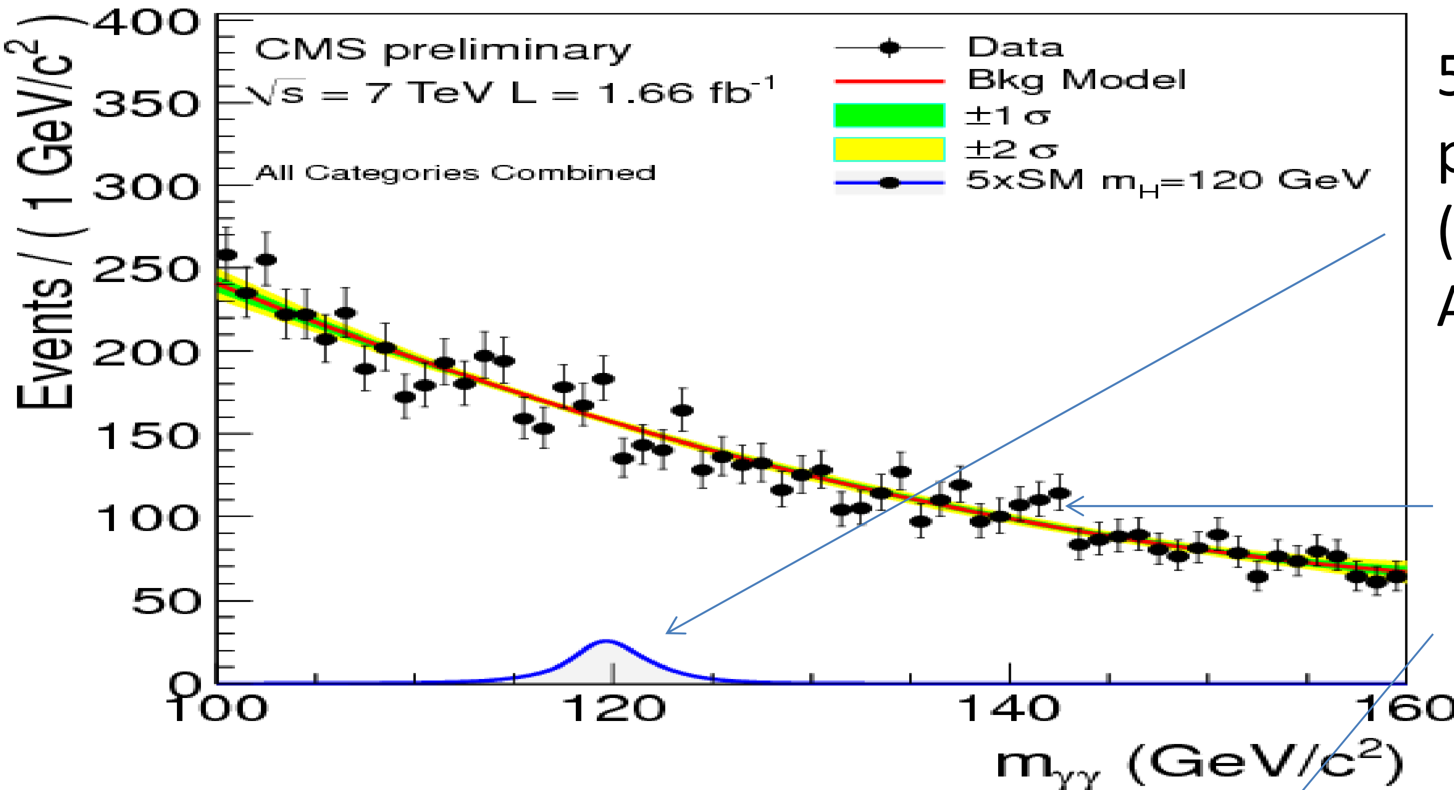
Looking for Higgs

- Notice the leptons
- Notice the mode into 2 photons
- Notice for the "q"'s we used particles with a b quark (the separation)
- Also, we'll see that "dip" later on…



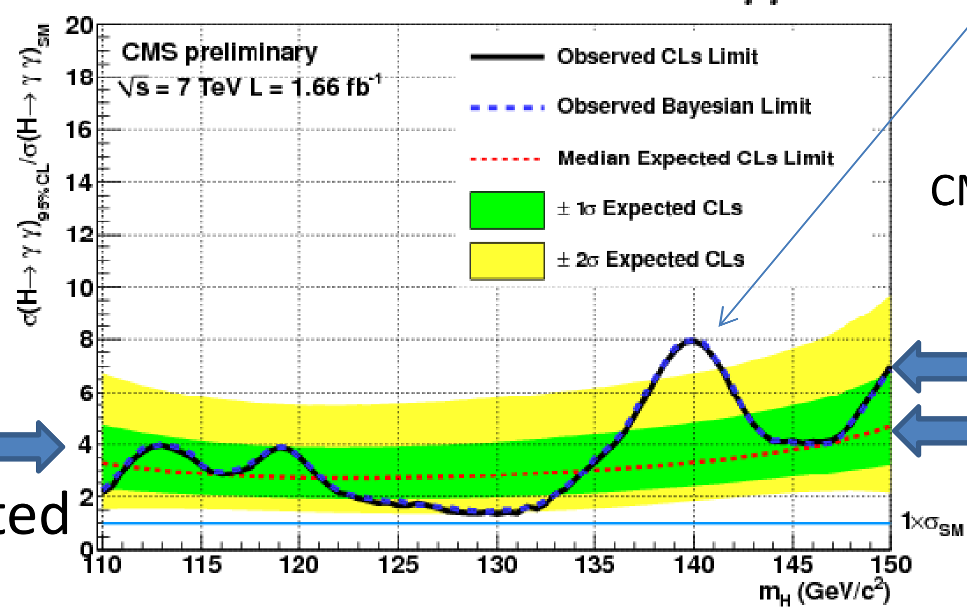
Higgs -> $\gamma\gamma$

- Need to separate this from the “q” background
  - Quarks can decay into neutral mesons and baryons
    - Contribution from π^0->$\gamma\gamma$ can be hard to remove!
    - At high momentum, can look like a single photon
  - Look at depositions and tracks around the photon candidate to try and isolate (make a clean) photon
- Not all photons are resolved the same way
  - Some interact before the calorimeter
    - And the calorimeter has a barrel part and an endcap part
  - Separate the analysis: categories based on where the photon is detected, and if it interacted before the Cal



5x the theory prediction (all classes ~ Avg resolution)

More interesting if We knew to look here before the fit



CMS-PAS-HIG-11-021

Ratio to theory (SM) expected

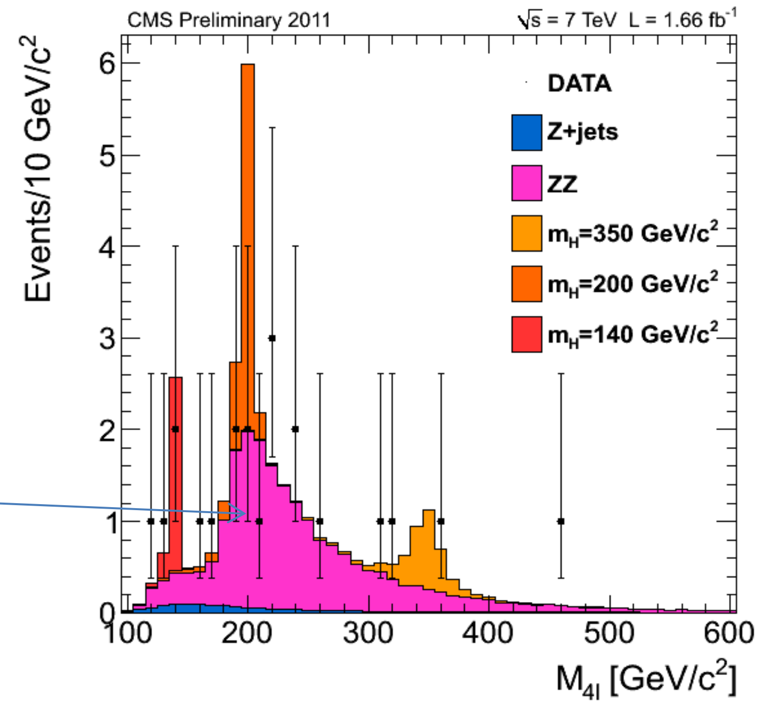
What we saw

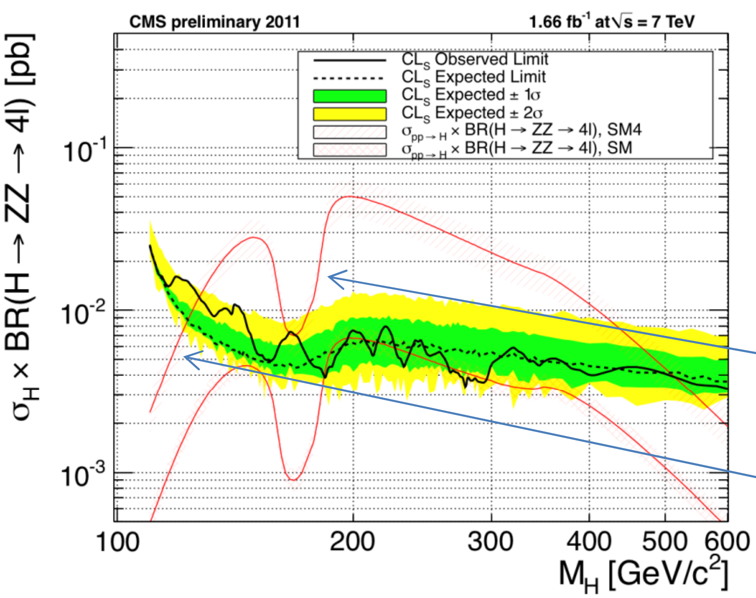
What we expected with background

Higgs -> ZZ

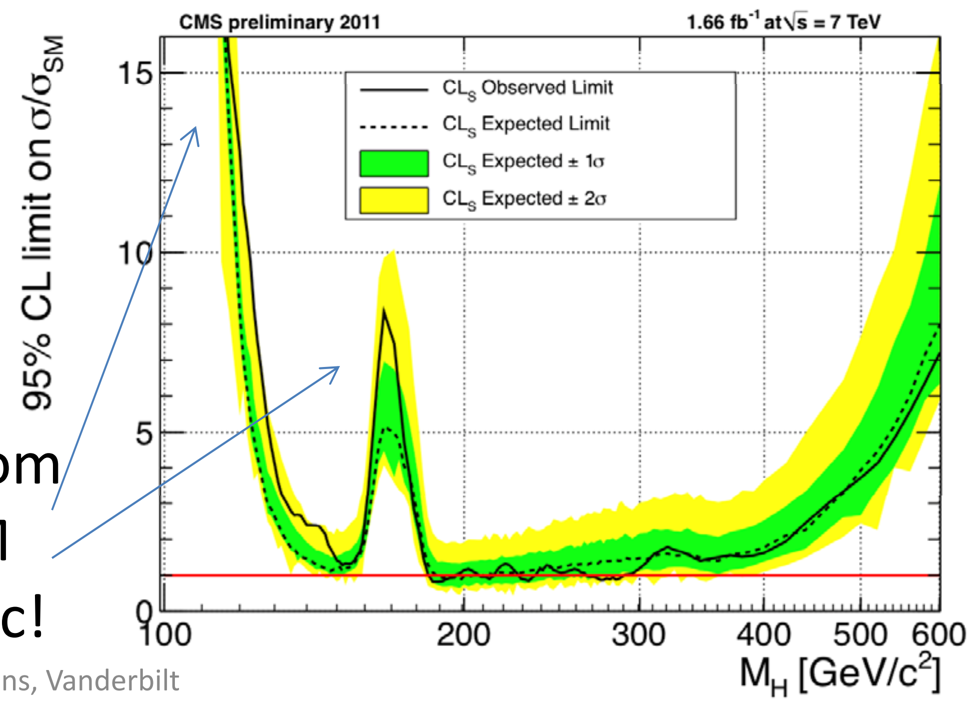
CMS-PAS-HIG-11-015

- Like our event display!
  - Can be very clean
  - Expect p-p collisions to produce ZZ “background”
  - $(e^+e^-)(\mu^+\mu^-)$, $2(e^+e^-)$, $2(\mu^+\mu^-)$
    - Isolate these from “q” too
    - Come from same point





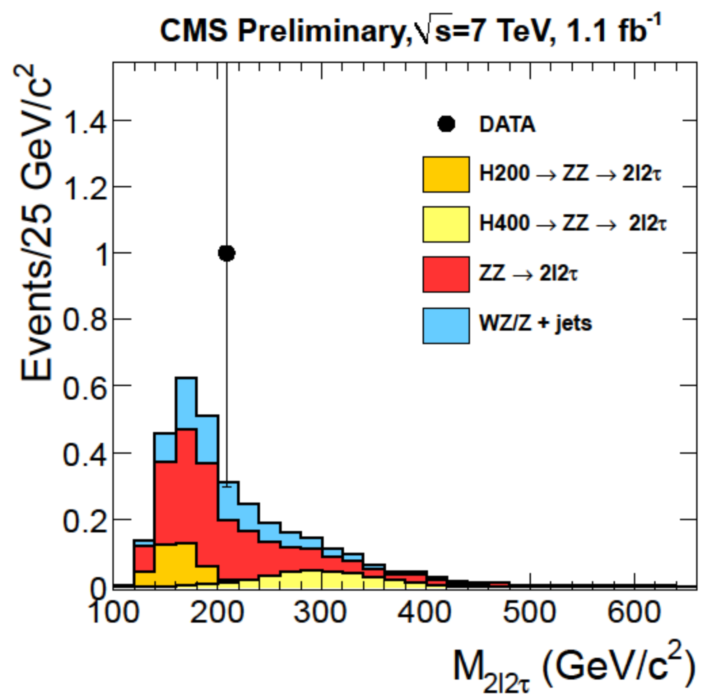
From SM calc!

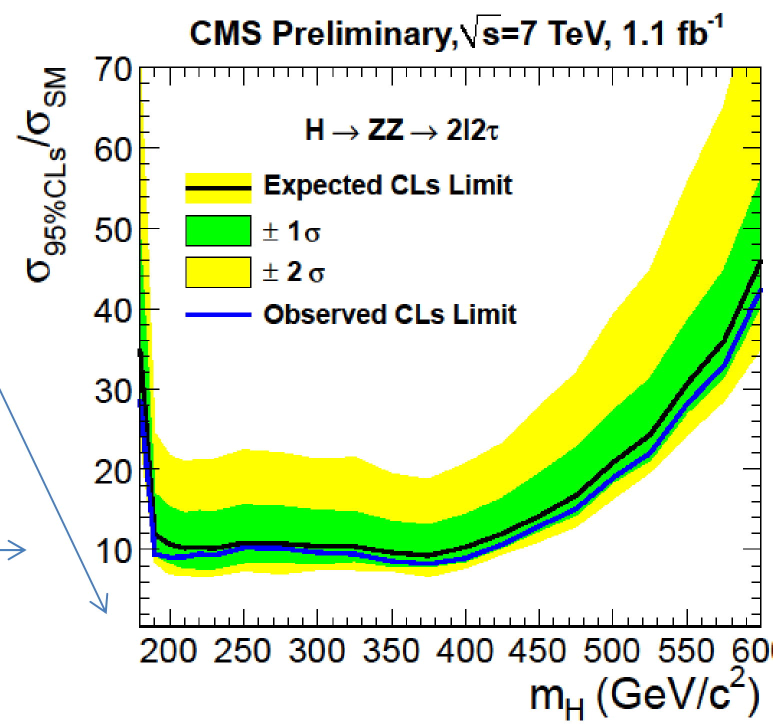


Higgs -> ZZ

CMS-PAS-HIG-11-013

- As before, but one Z decays to 2 taus: $e\tau_h$, $\mu\tau_h$, $\tau_h\tau_h$
- Care taken to avoid double counting from previous ZZ
- Hadronic tau decays can be fairly clean as well
  - The tau doesn't have the "q" pairs at creation
  - The particles from the tau can be well collimated (less spray)
- Notice this limit starts at a higher mass than the previous
- Also notice that it's hard to stray beyond your predicted with no events!

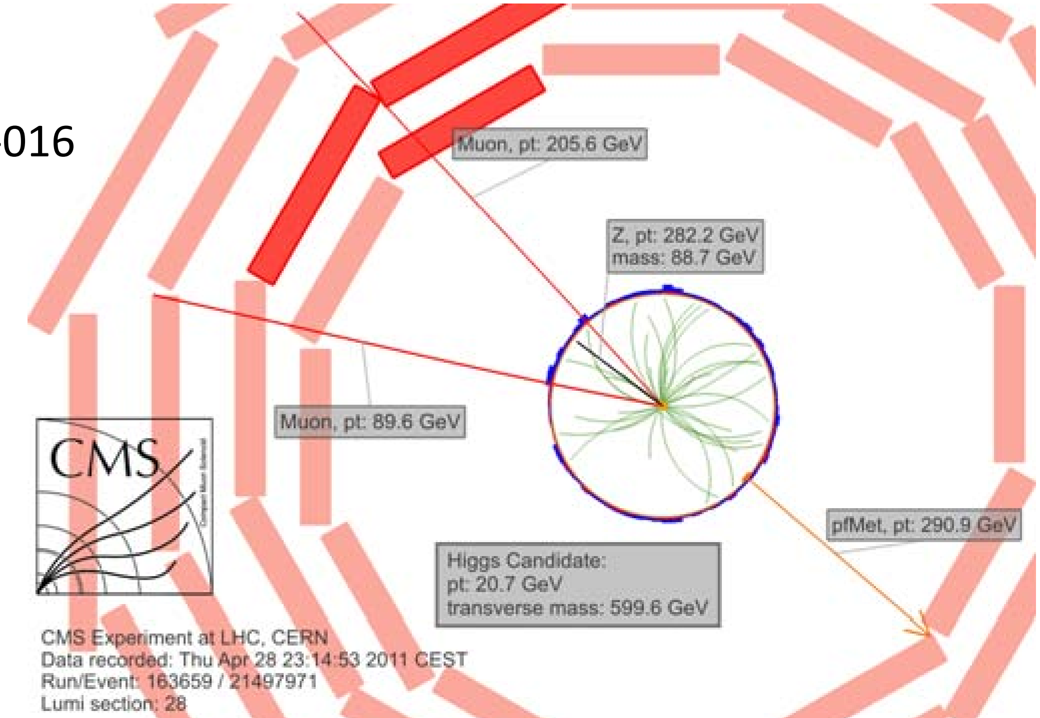


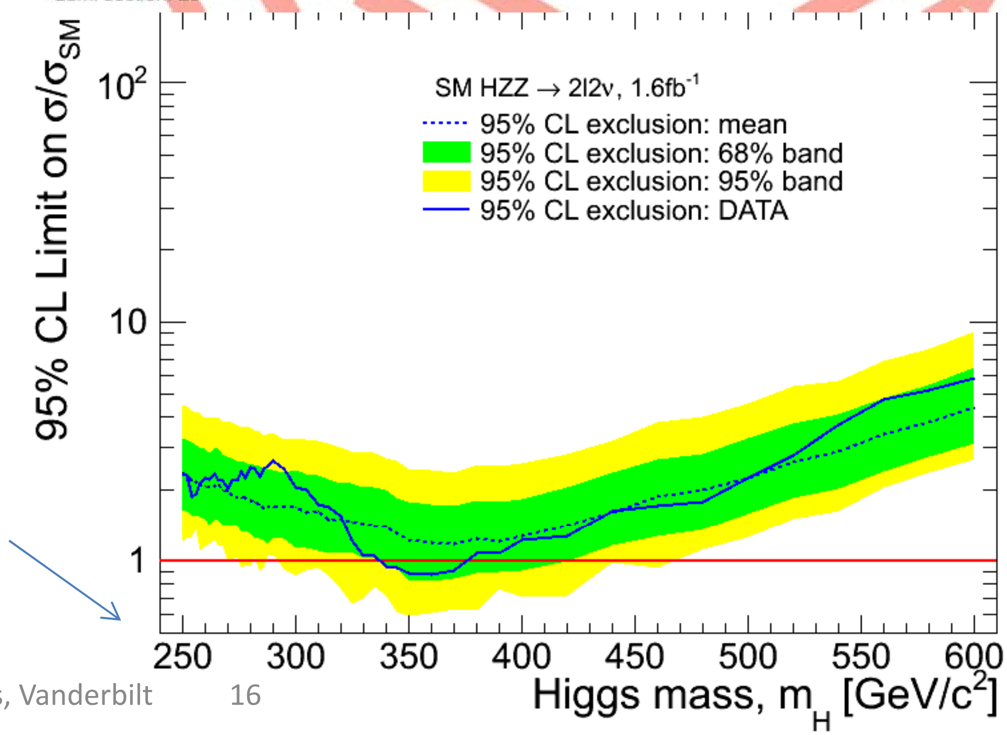


Higgs -> ZZ

CMS-PAS-HIG-11-016

- Remember transverse momentum balance?
- We can use the balance as a signature
- Use the balance, form Higgs Mass
- As before (e^+e^-) or ($\mu^+\mu^-$), but other Z decays to 2 neutrinos!
- Higher mass here too

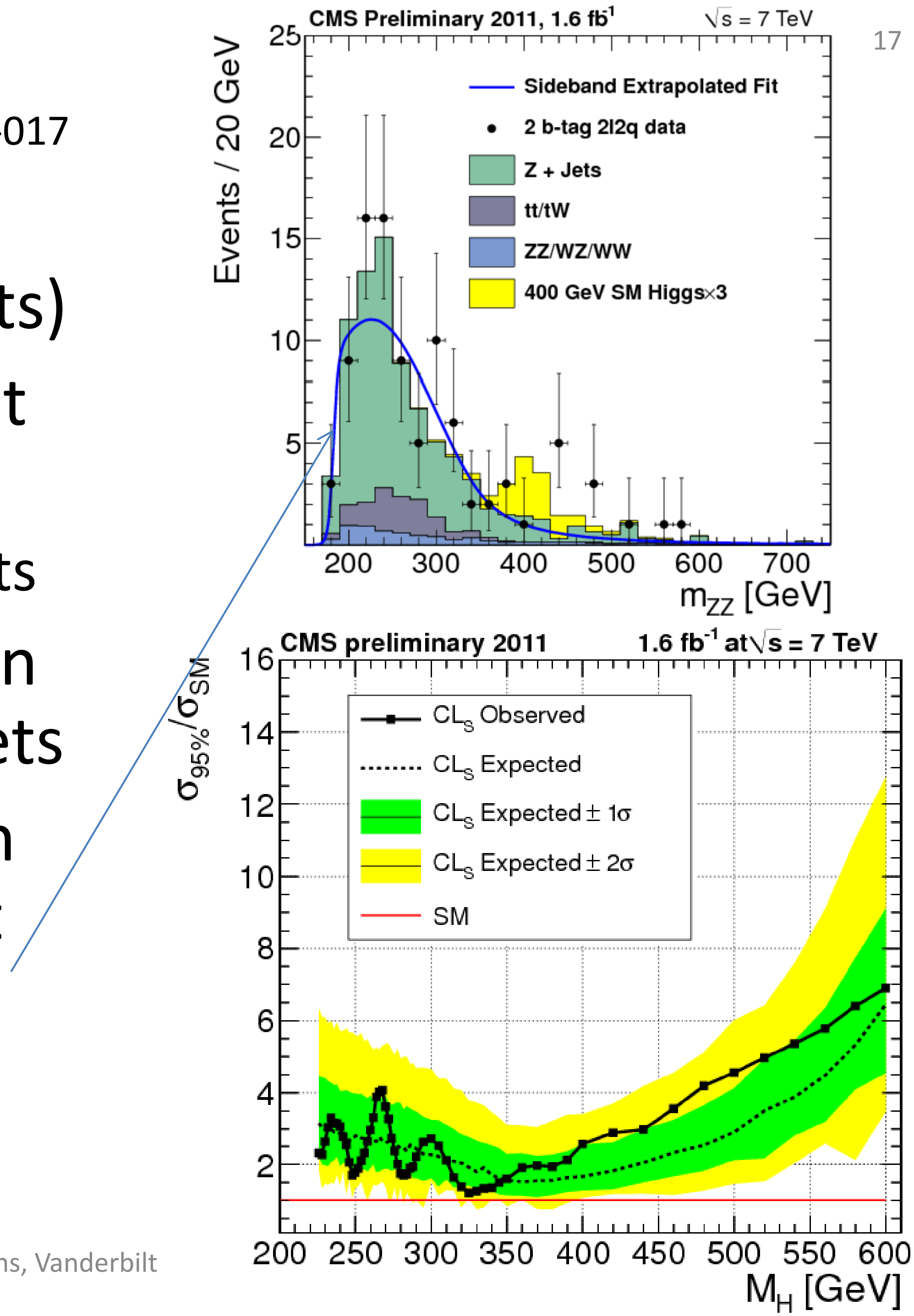




Higgs -> ZZ

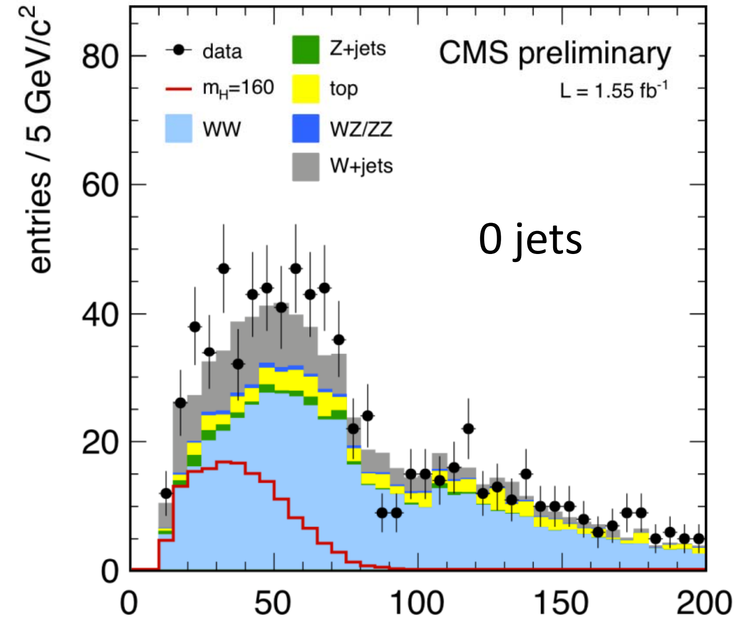
CMS-PAS-HIG-11-017

- As before (e^+e^-) or ($\mu^+\mu^-$), but use "q" as signal (2 jets)
- Separate Heavy from Light quark jets
  - Categorize on # b quark jets
- Separate quark from gluon (wider & more particle) jets
- Use kinematic variables in clean up, off Z mass di-jet sideband to estimate background

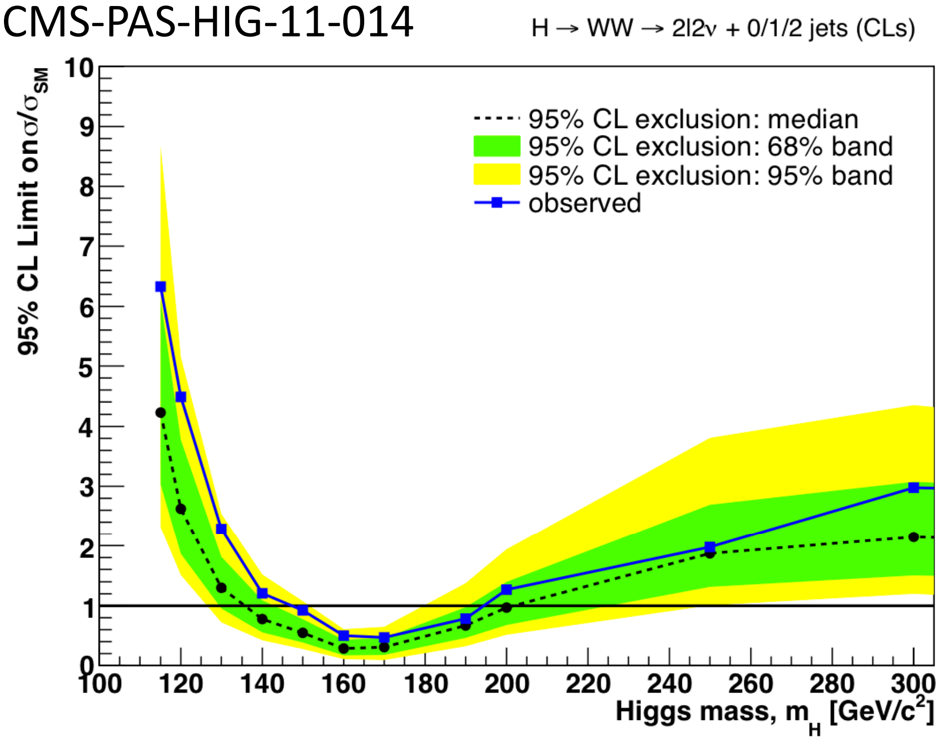


Higgs -> W^+W^-

- Powerful Mode
- Bkgnds from p-p -> WW, top, W+jets
- WW -> $e^+\nu e^-\nu$, $\mu^+\nu\mu^-\nu$, $e^{+/-}\nu\mu^{-/+}\nu$: Missing E_T
- Leptons go ~same dir
- Can also have 0, 1 or 2 jets made with H
  - Split in categories to optimize analysis

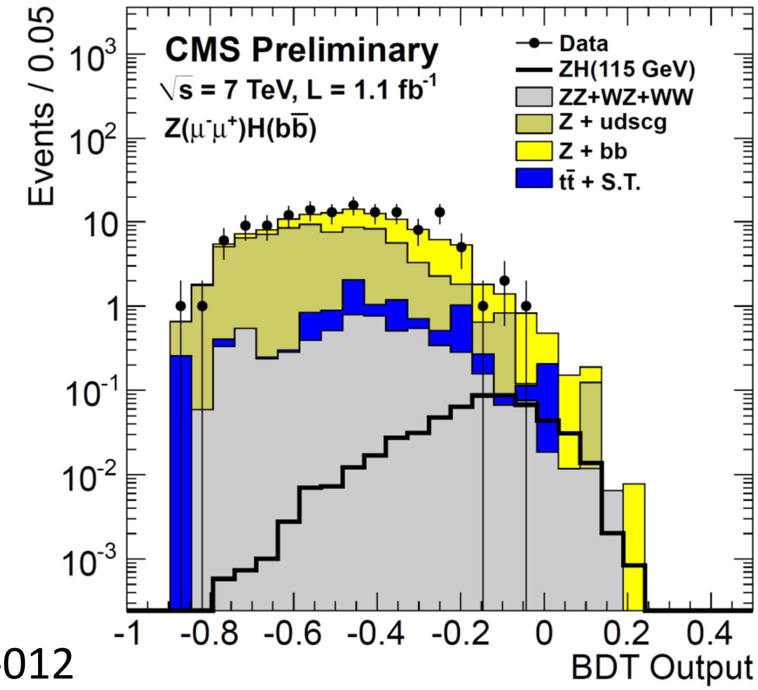


CMS-PAS-HIG-11-014

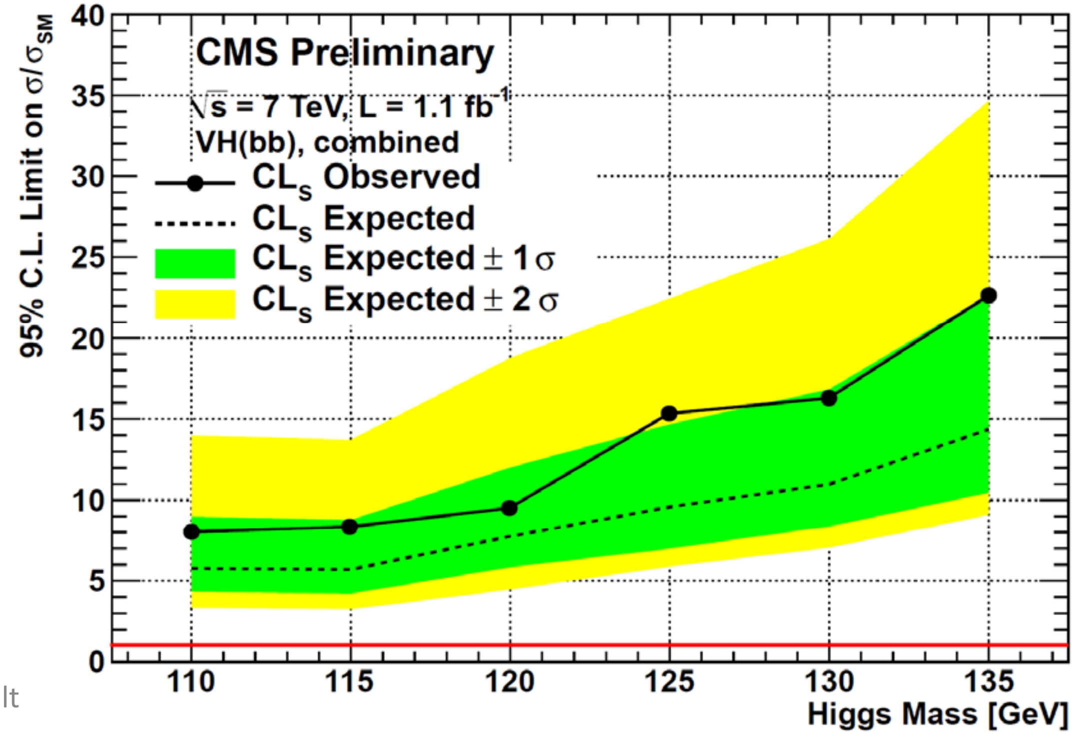


Z,W & (Higgs -> $b\bar{b}$)

- Large dijet bkgnd
- But mode has lower H mass sensitivity
- Boosted Decision Tree (BDT) for fits
- Z+jets and di-boson states big background
- 5 channels:
  - Z->e^+e^-, $\mu^+\mu^-$, or $\nu\nu$
  - W-> $e\nu$, $\mu\nu$

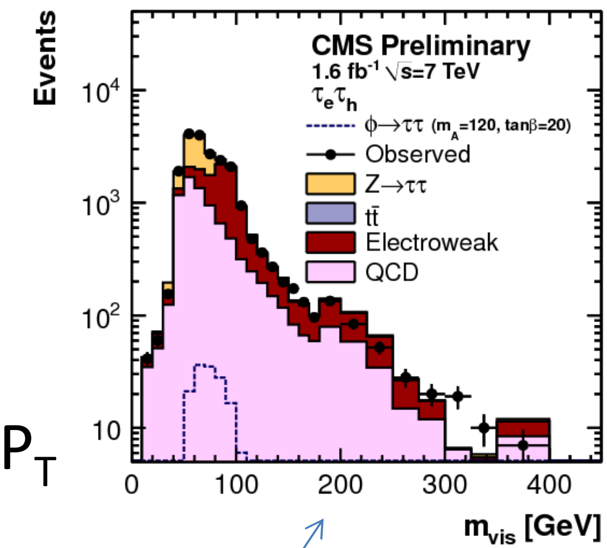


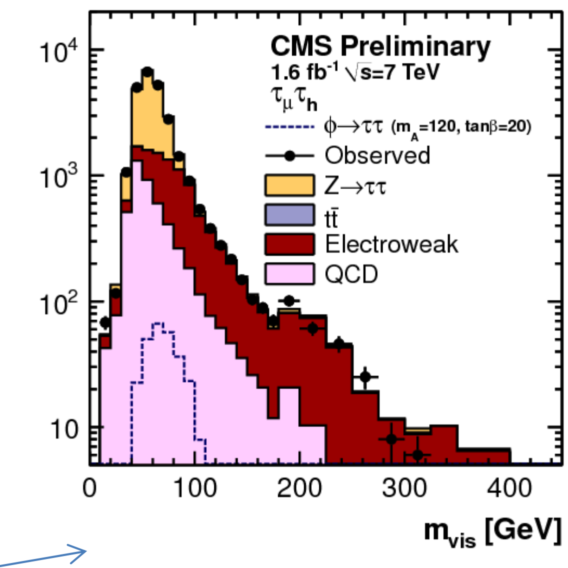
CMS-PAS-HIG-11-012



Higgs -> $\tau^+\tau^-$

- Use $e\tau_h$, $\mu\tau_h$,$e\mu$
- SM : 2 jets adtl
  - Helps cut bkgnd
  - Big dijet mass and P_T

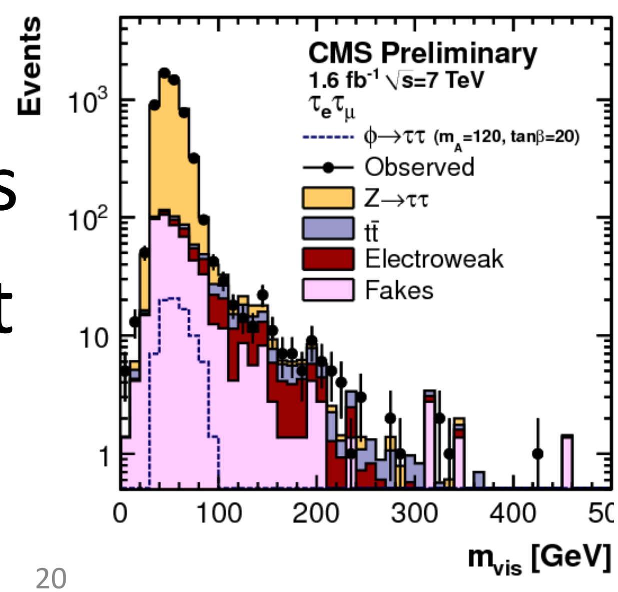


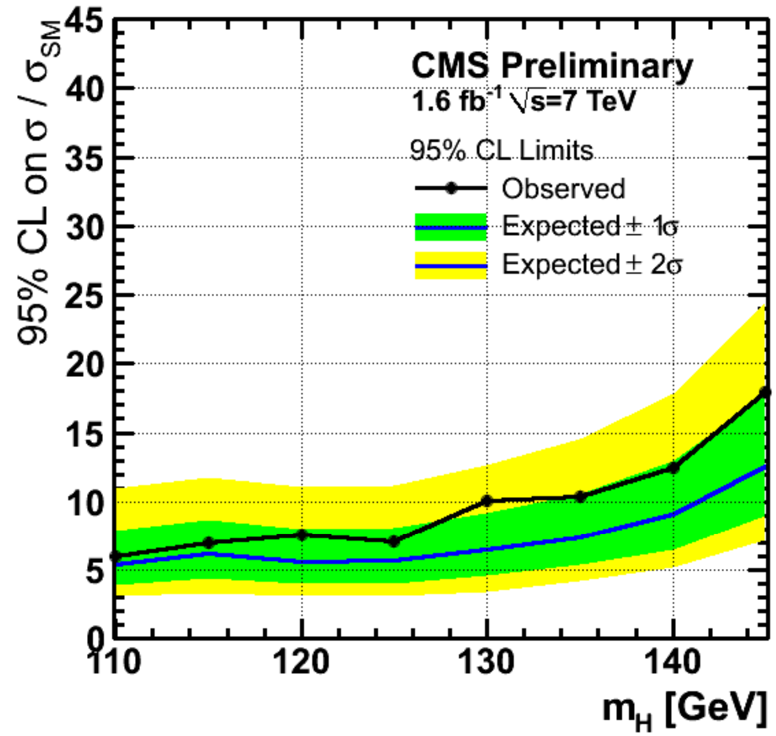


- SM : 0 or 1 jet additional

  -- Separate category

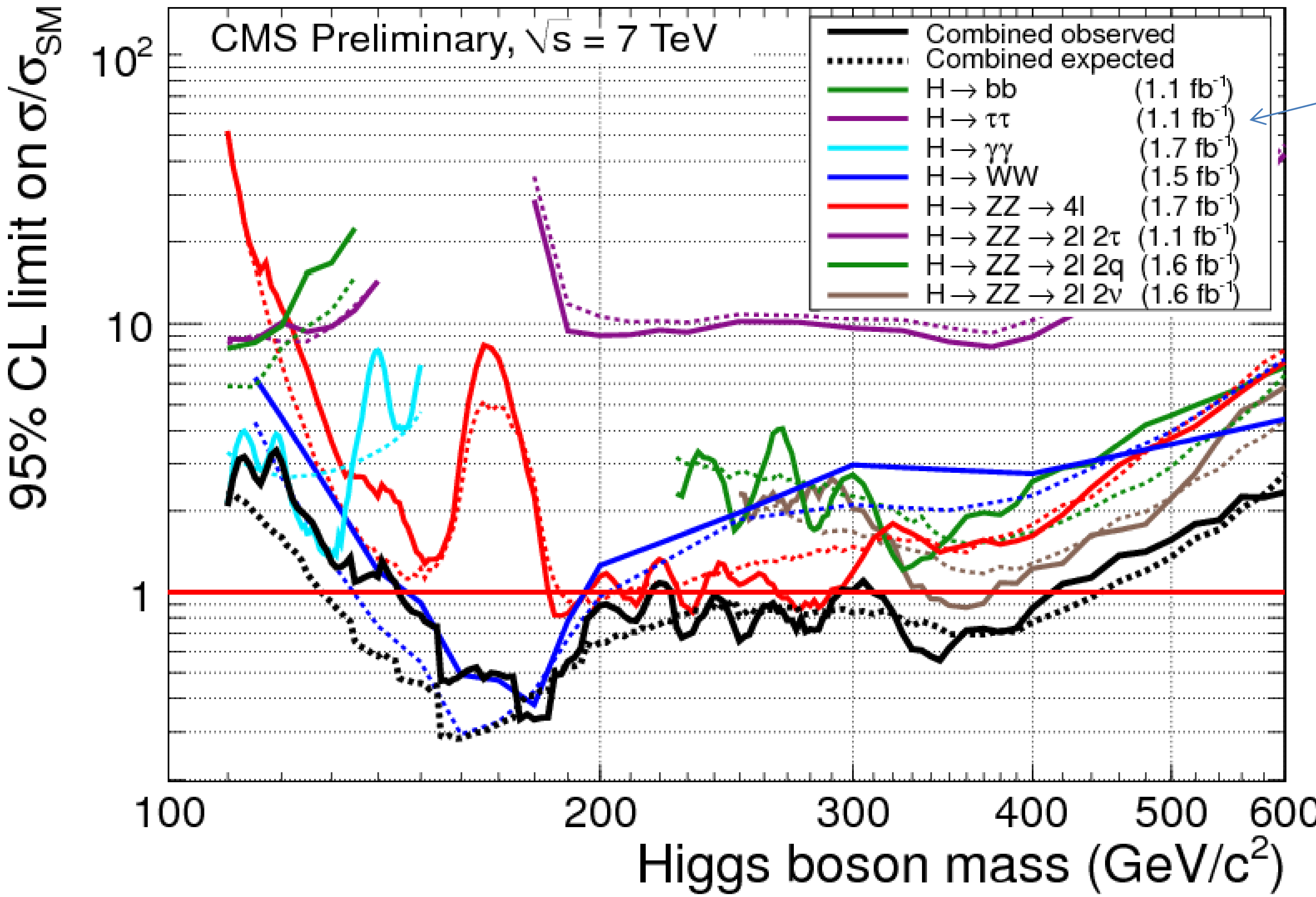
  Combine categories for limit





CMS-PAS-HIG-11-020

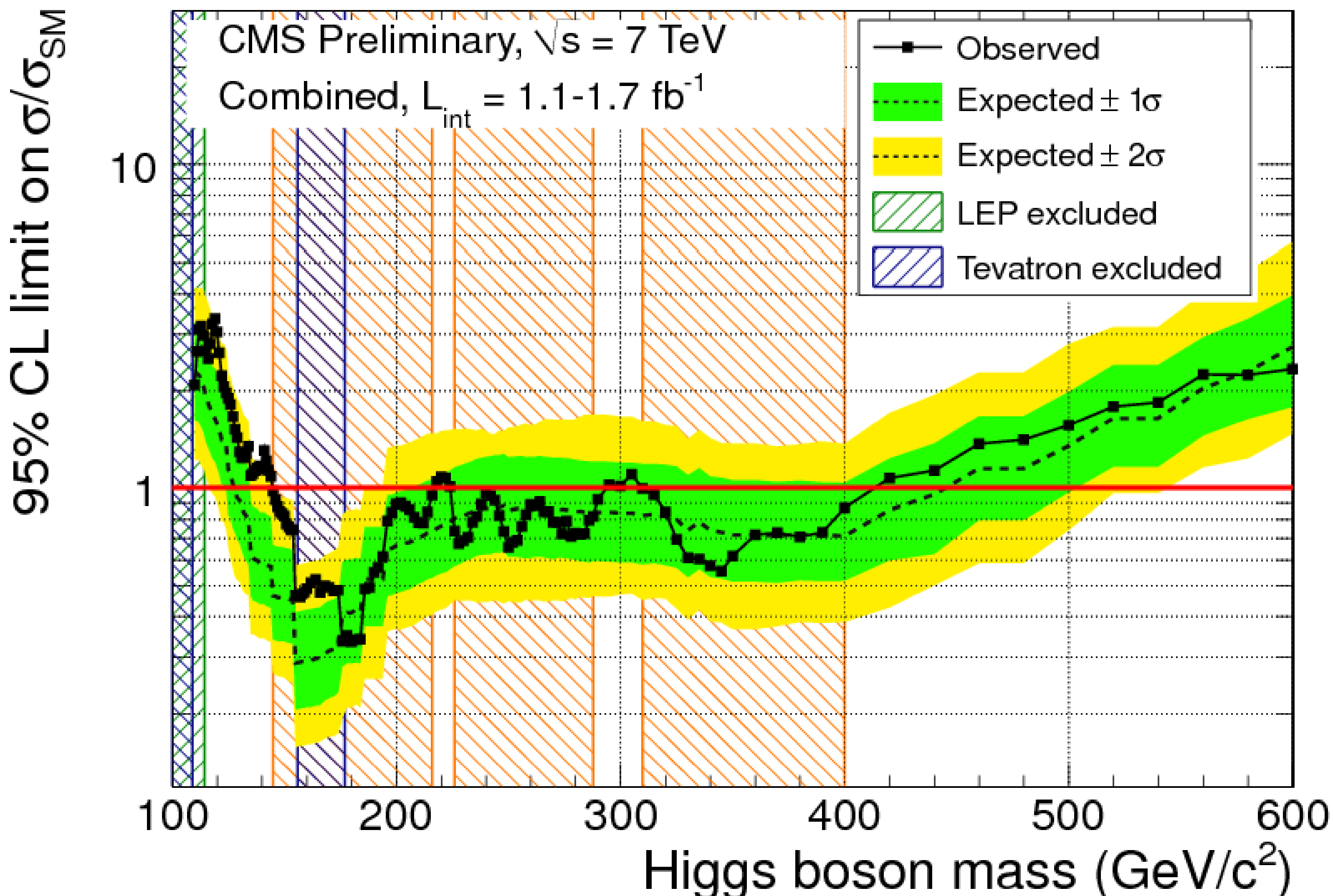
Higgs Limit Summary



Older result

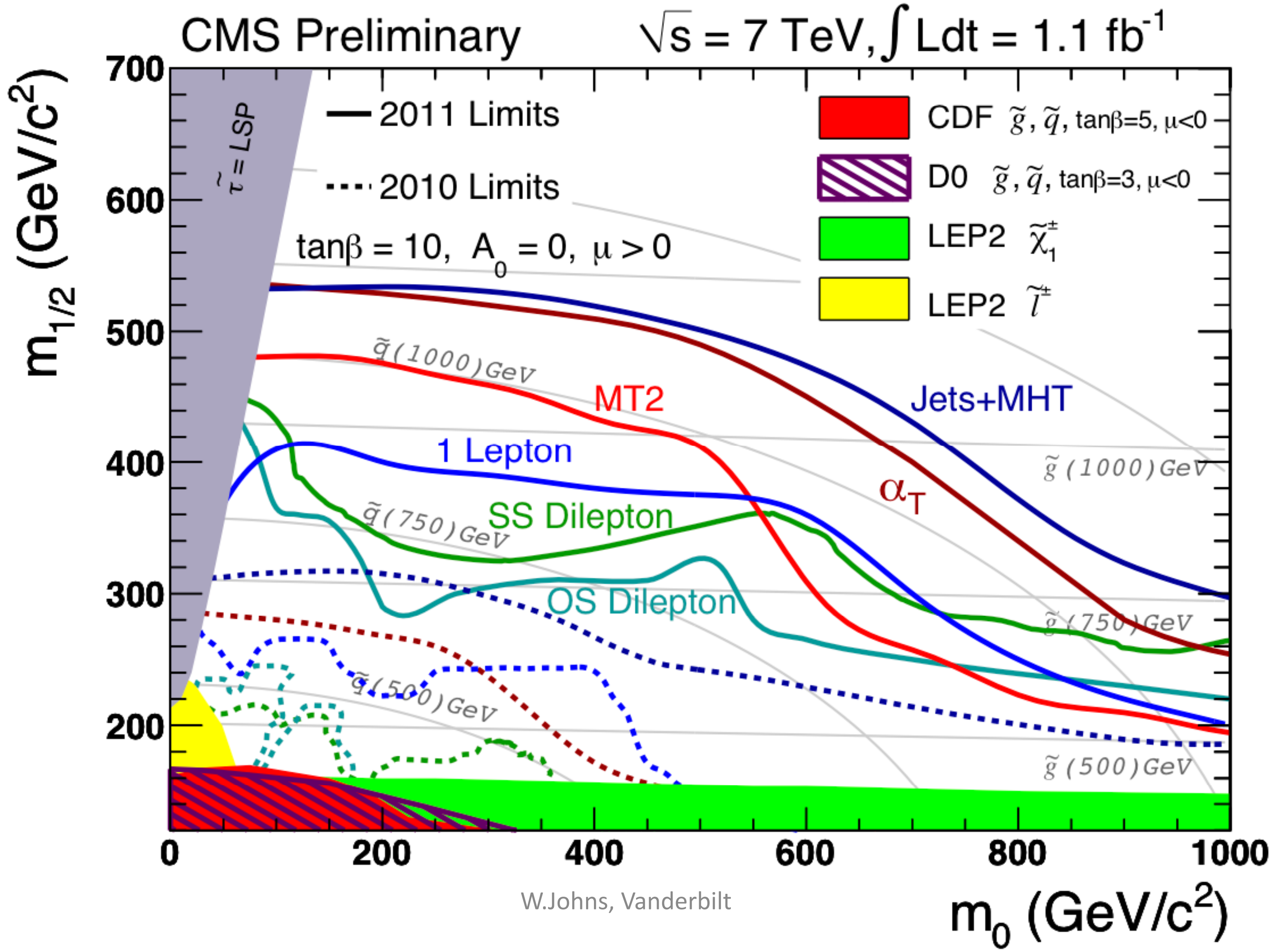
CMS-PAS-HIG-11-009

Combined Higgs Limit is pushing on the "SM" prediction space



Supersymmetry results

I will just show a summary slide here



Expect more CMS (LHC) Results soon

- Have more than 3 times the data used for most of the analyses shown here
  - Could get pretty exciting in the next few months
- If we can go to 25 ns bunches, perhaps we can get double next year w/o too much trouble
- Many analysis challenging the Standard Model
  - (also MSSM, but I won't mention that)
- The results shown indicate the detector and analyses techniques are working well to provide a broad and interesting physic program!