Beyond MSSM Higgs @ CMS

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(On behalf of the CMS Collaboration)

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SM Higgs Search: Summer 2012

You have seen the CMS + ATLAS seminar on July 4

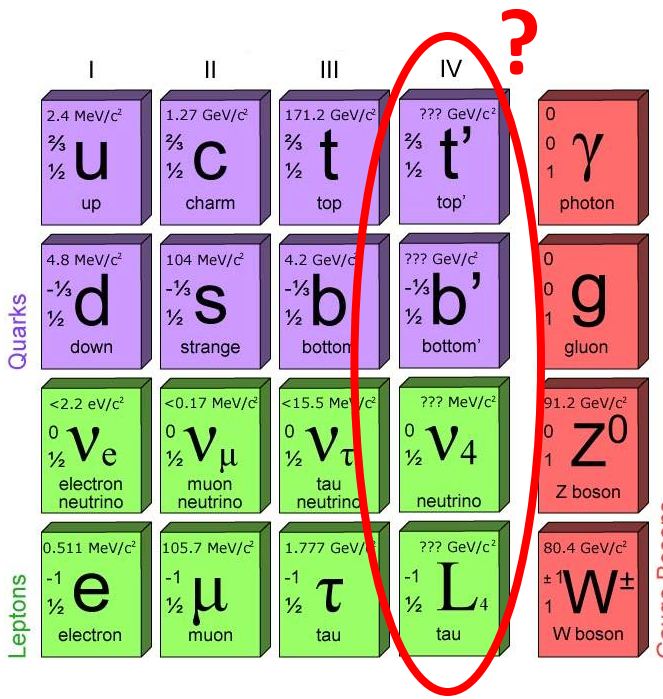
CMS will present detailed results on the SM Higgs search tomorrow:

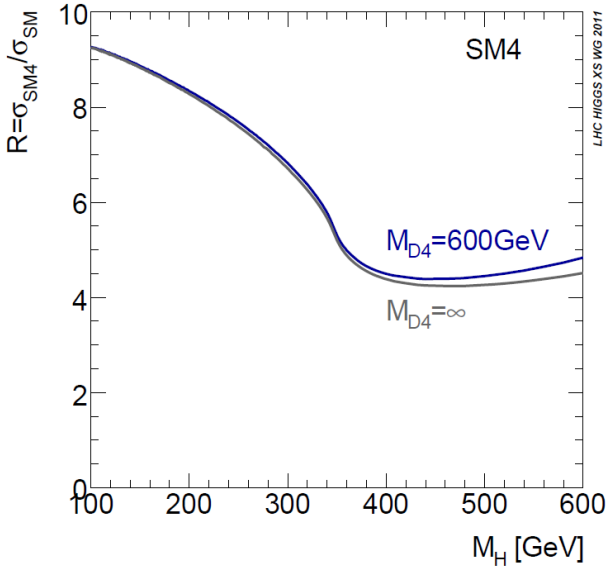
09:00 – SM Higgs decaying to taus – Josh Swanson
10:15 – SM Higgs decaying to ZZ (2l2ν, 2l2q) – Francesco Pandolfi
11:00 – SM Higgs decaying to ZZ (4l) – Markus Klute
11:45 – SM Higgs decaying to WW (2l2ν, 2l2q) – Emanuele di Marco
14:00 – SM Higgs decaying to b quarks – David Lopes Pegna
15:15 – SM Higgs decaying to photons – Sergei Ganjour
16:30 – Higgs combination and properties – Sara Bolognesi

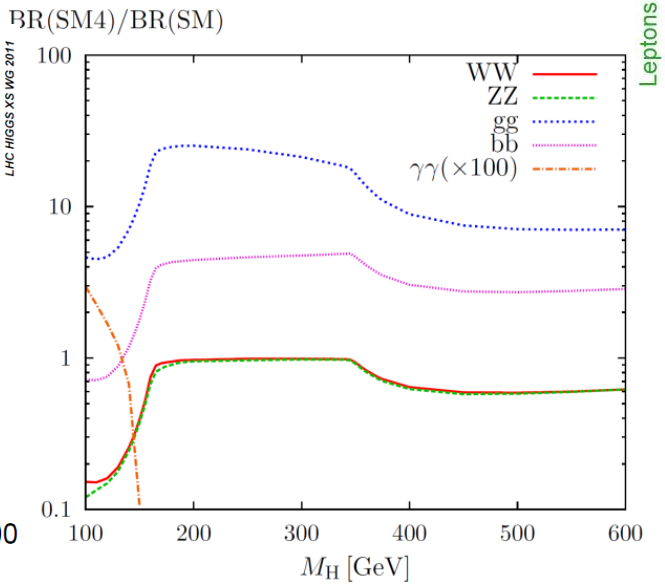
There is now strong evidence for a Higgs-like sector, in this talk I will present CMS searches for potential Higgs bosons beyond the MSSM

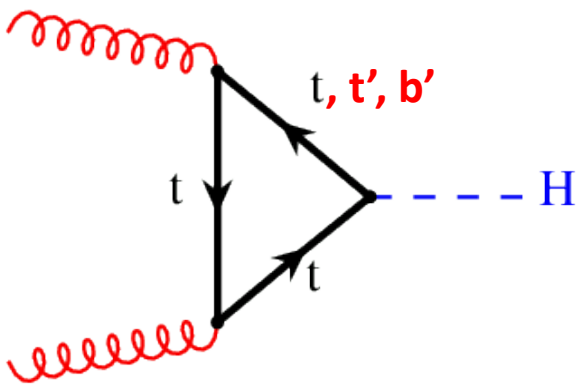
Higgs in a SM with 4 Generations

- **Reinterpret SM Higgs search in the context of 4th generation**
- **Large impact on production and decay rates**
  - Gluon fusion enhanced up to ~ x 10
  - BFs modified significantly









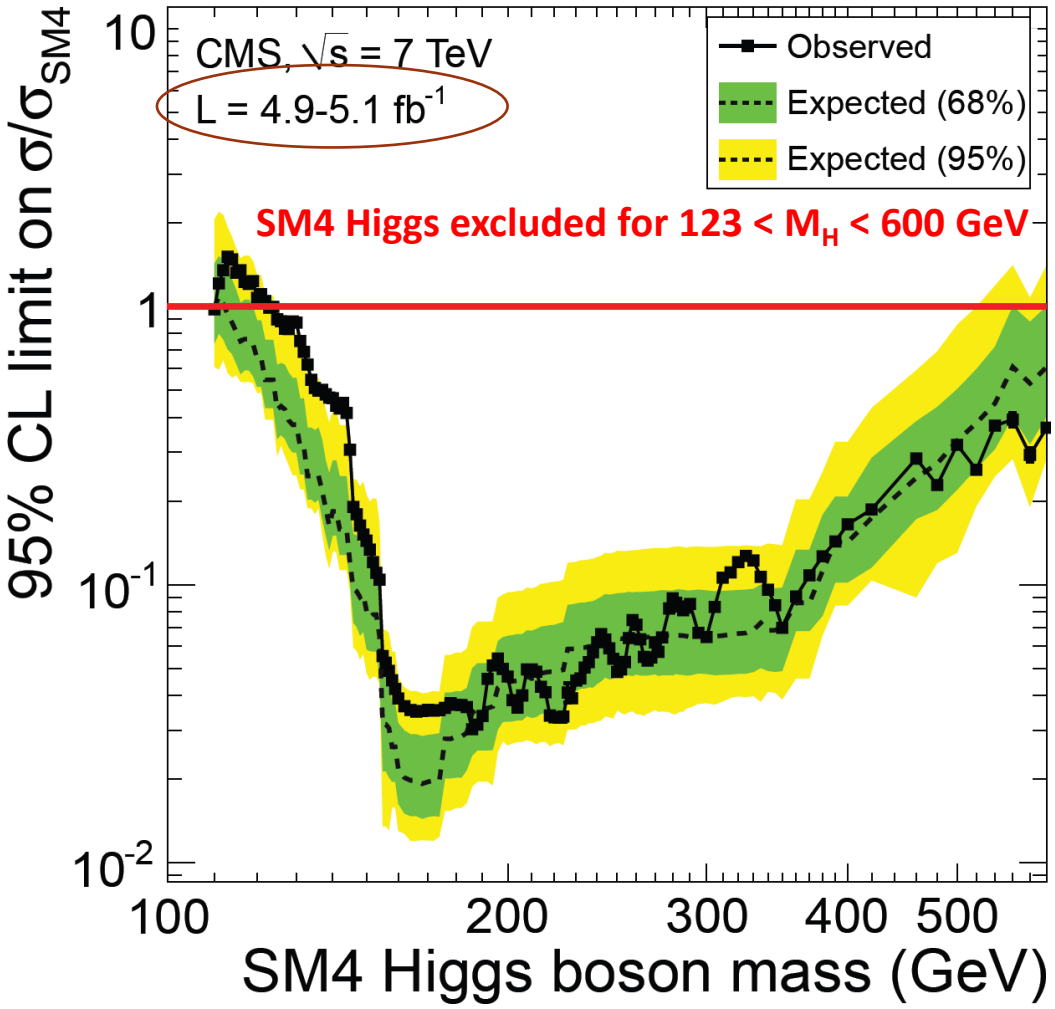
Limits on SM4 Higgs

- **Model parameters**
  - LHC XS WG benchmark:

$$m_{d4} = m_{L4} = m_{\nu} = 600 \text{ GeV}$$

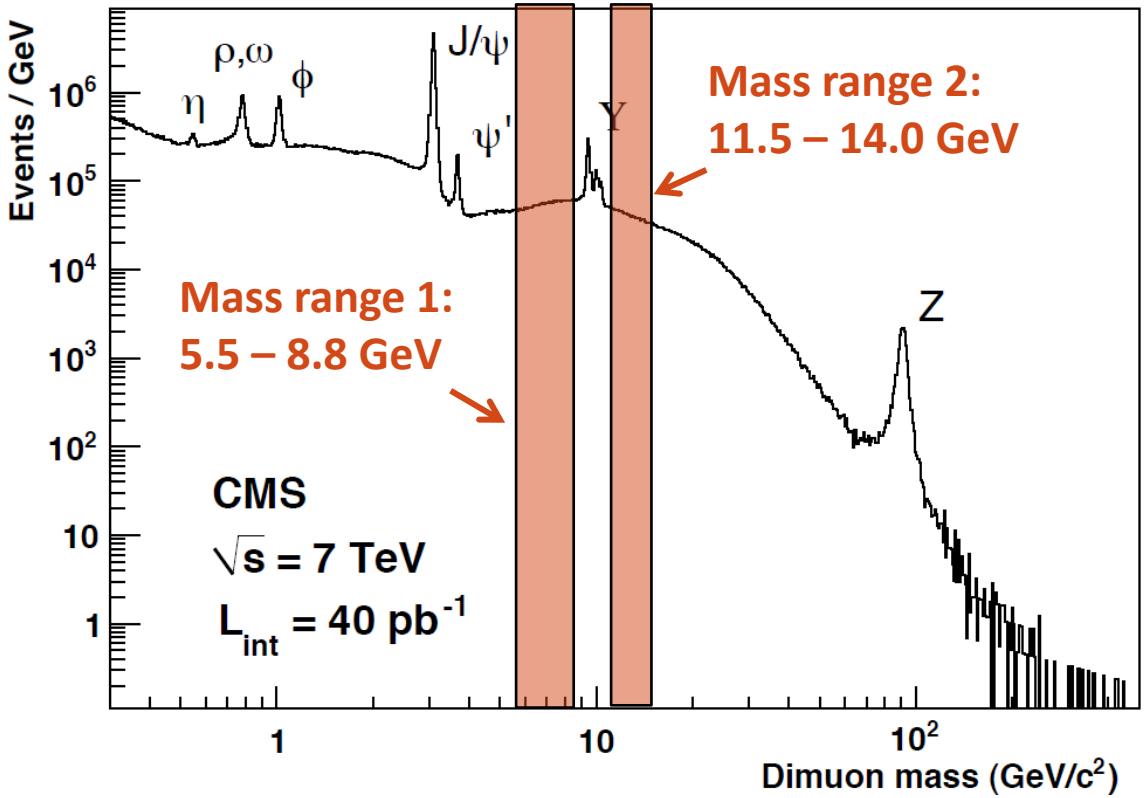
$$m_{u4} - m_{d4} = \left[1 + \frac{1}{5}\ln\left(\frac{m_H}{115}\right)\right] \cdot 50 \text{ GeV}$$

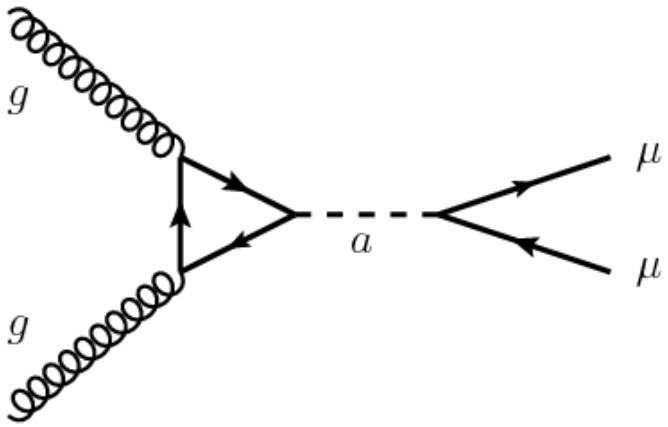
- **Use existing SM search results @ 7 TeV**
  - gg fusion dominates, neglect VBF and VH production
  - Channels contributing:
    - $H \rightarrow \gamma\gamma$
    - $H \rightarrow \tau\tau$
    - $H \rightarrow WW(2l2\nu)$
    - $H \rightarrow ZZ(4l, 2l2\nu, 2l2q, 2l2\tau)$



NMSSM: $a_1 \rightarrow \mu^+\mu^-$

- **Add a scalar singlet to MSSM Higgs family**
  - 3 CP even (h_1, h_2, h_3) , 2 CP odd (a_1, a_2), and $H^{\pm}$
  - Out pops a potentially light boson
    - $a_1 = a_{\mathrm{mssm}} \cdot \cos\theta_A + a_S \cdot \sin\theta_A$



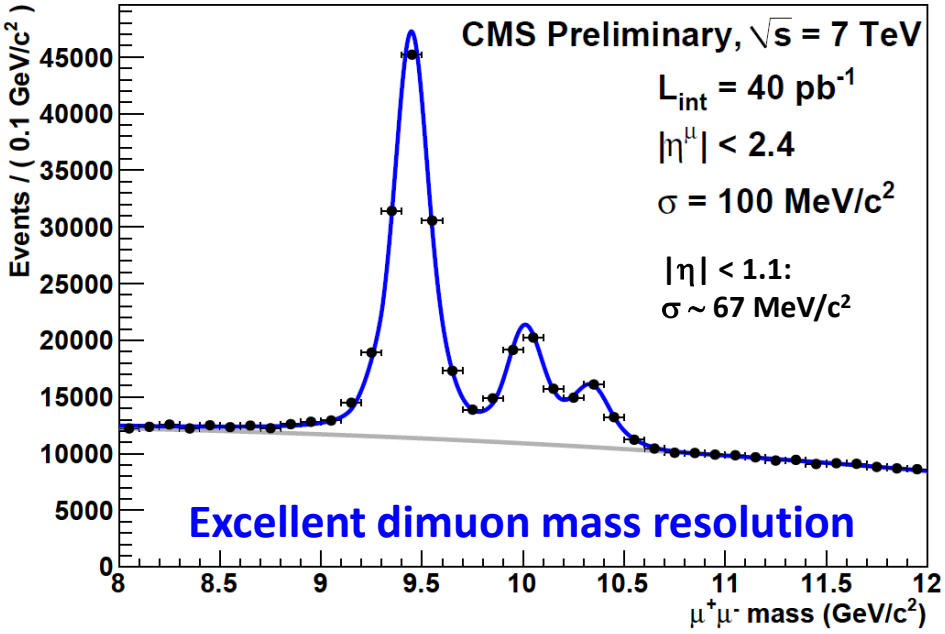


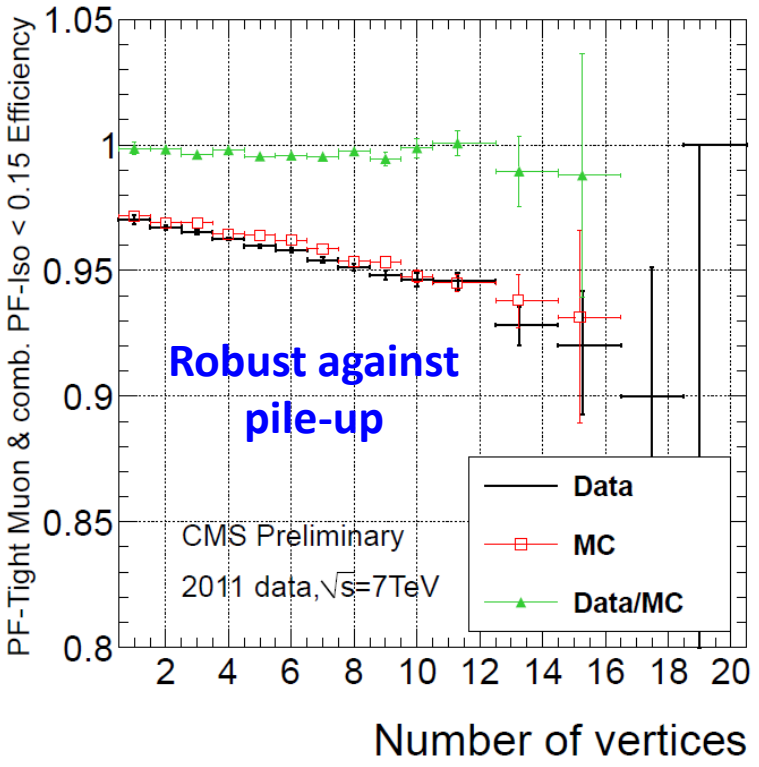
At CMS: search above and below the Upsilon family

- Larger production rate relative to Tevatron
- Extended search relative to BaBar ($m_a > m_{\Upsilon(3S)}$)

Muon Trigger and Selection

- **Trigger (prescaled)**
  - OS dimuon, $p_T^{\mu} > 3.5$ GeV
  - $p_T^{\mu\mu} > 6.0$ GeV
  - $5.5 < m_{\mu\mu} < 14$ GeV
  - Prompt impact parameter

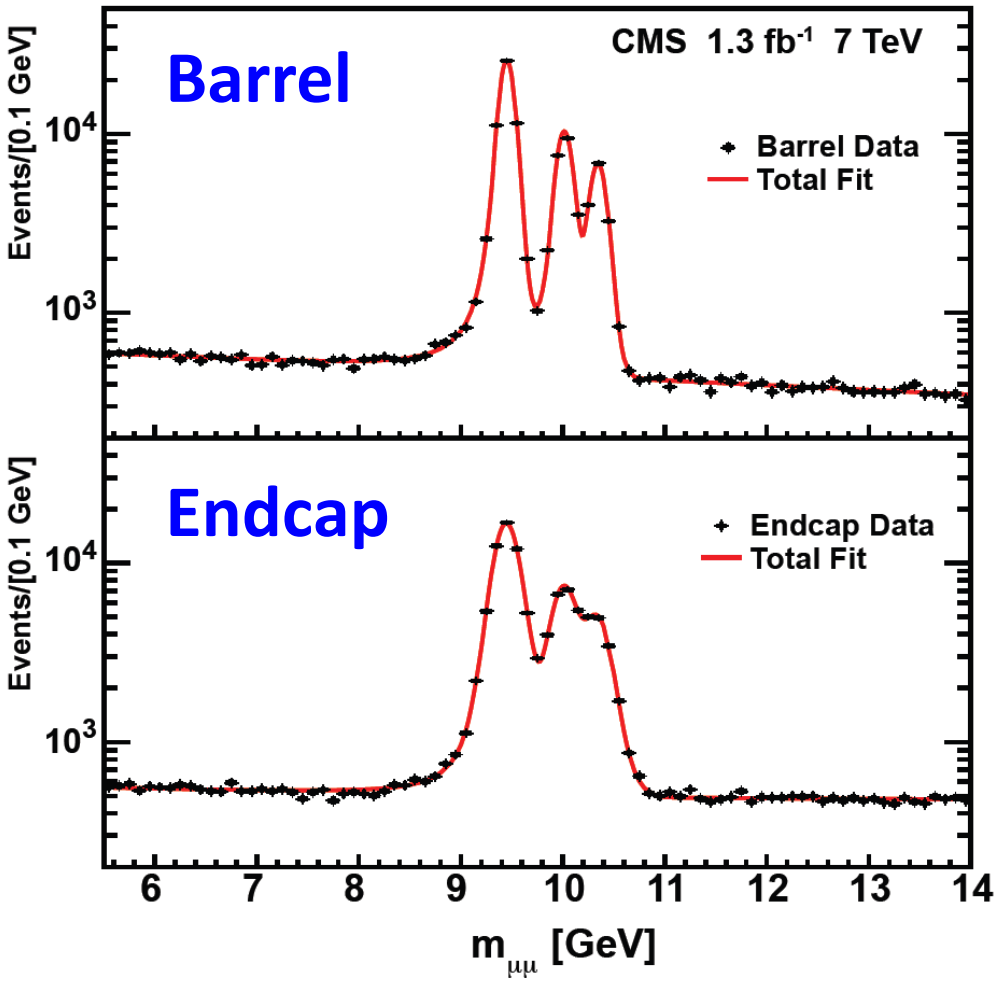




- **Muon selection**
  - $p_T^{\mu} > 5.5$ GeV; $|\eta| < 2.4$
  - > 10 hits (> 0 pixel); χ^2/ndof < 1.8
  - Isolation in a cone of $\Delta R = 0.3$:
    - $\frac{p_T(\mathrm{chg})+E_T(\mathrm{ntrl})}{p_T^{\mu}} < 0.2$

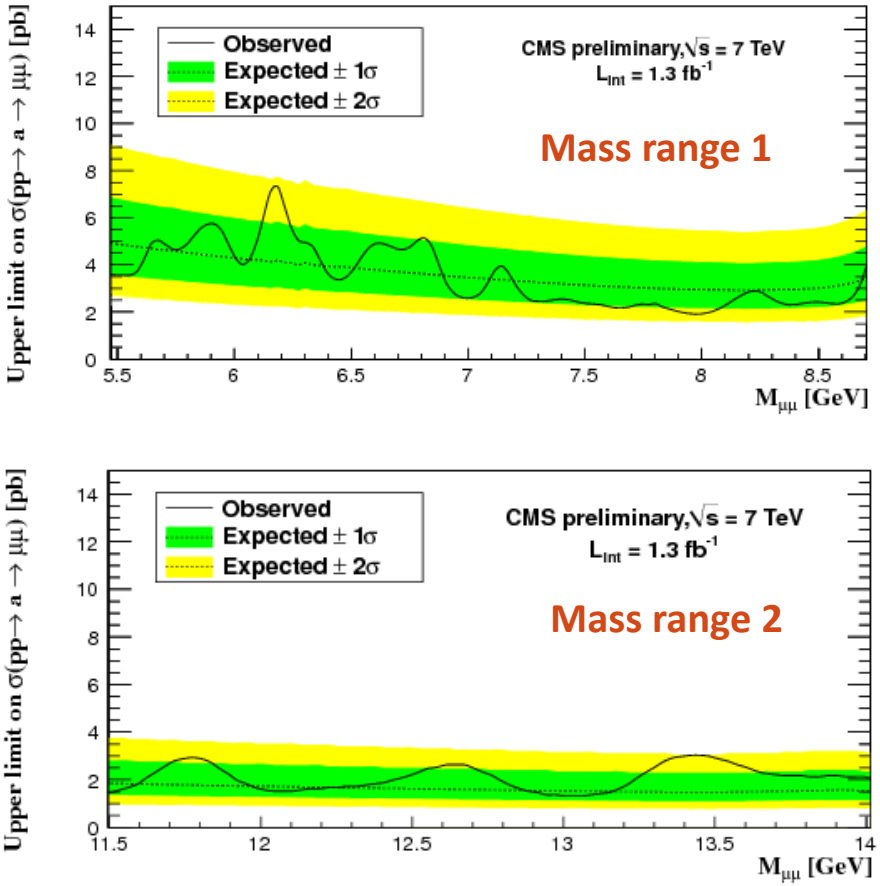
Search for $a_1 \rightarrow \mu^+\mu^-$

- **Signal extraction**
  - Binned ML fit over 5.5 – 14 GeV
  - Mass scan in 30 MeV steps
- **Background model**
  - QCD: 1st-order polynomial
  - Y(NS): double crystal ball
    - 1S floating; 2S & 3S tied to 1S
- **Signal model**
  - Single Gaussian
  - Mean fixed to center of step
  - Width fixed to detector resolution
    - Range 1: 50 – 120 MeV
    - Range 2: 90 – 190 MeV

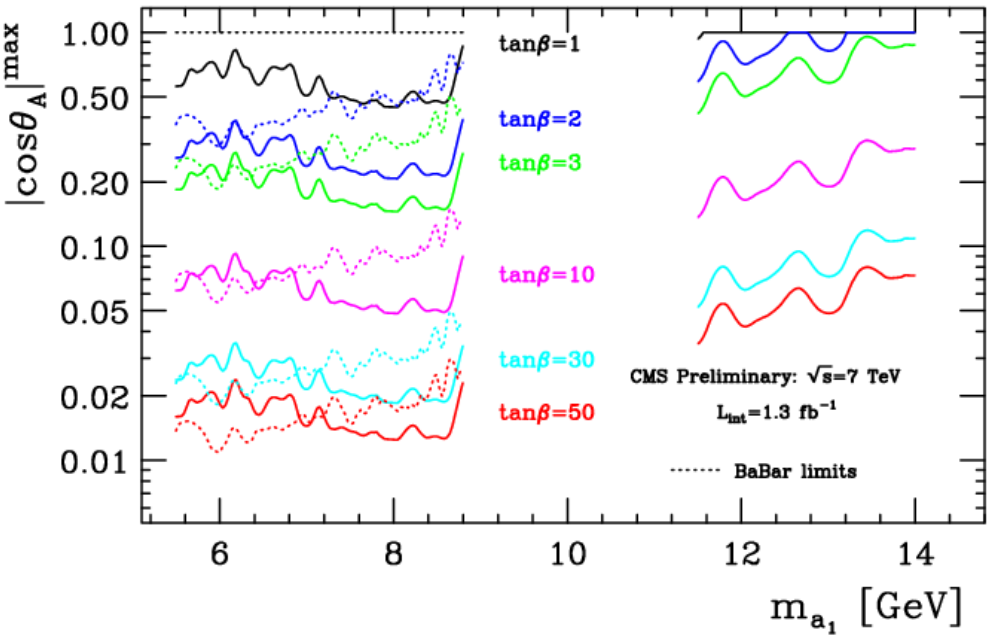


Exclusion Limits: $a_1 \rightarrow \mu^+\mu^-$

Cross Section x BF Upper Limits



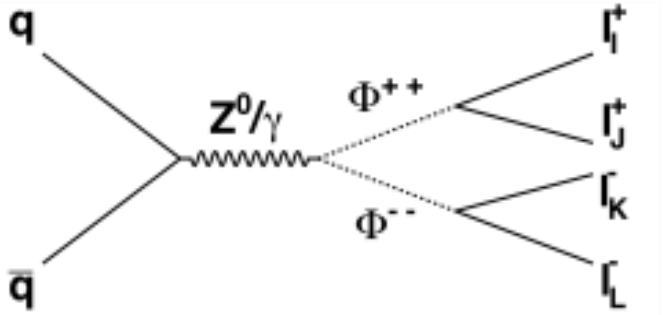
No significant signal observed in 1.3fb^{-1} @ 7 TeV, exclusion limits set at the level of 2 – 6 pb for σ x B

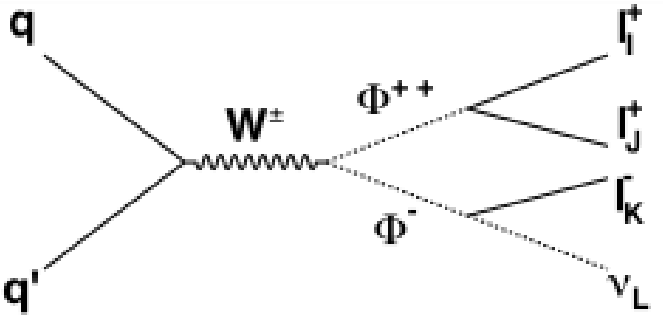


BaBar searches in Υ(3s) decays
(See talk by Y. Kolomensky later in this session)

Doubly Charged Higgs Φ^{++}

- **Minimal Type II See-Saw Models**
  - Prediction of additional scalar field that is a triplet under $SU(2)_L$
  - New Higgs-like particles: Φ^{++}, Φ^{+}, Φ^{0}
  - If observed, would open a new window on neutrino physics accessible at the LHC
- **CMS search for Φ++ and Φ+**
  - Produced in pairs, or in association with singly charged Higgs (first time)
  - Unique experimental signature
  - Search in 7 TeV data using same-sign lepton combinations of all flavors

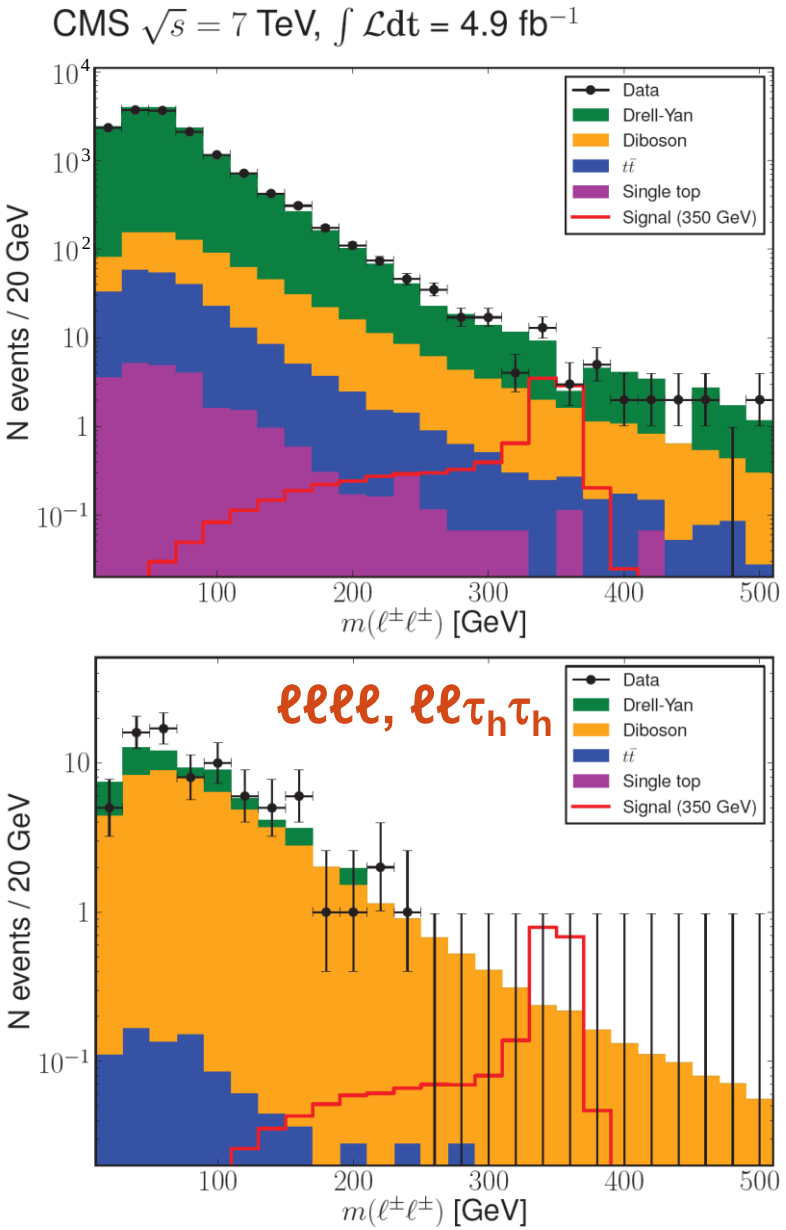




Φ^{++} and Φ^{+} are assumed to be degenerate in mass

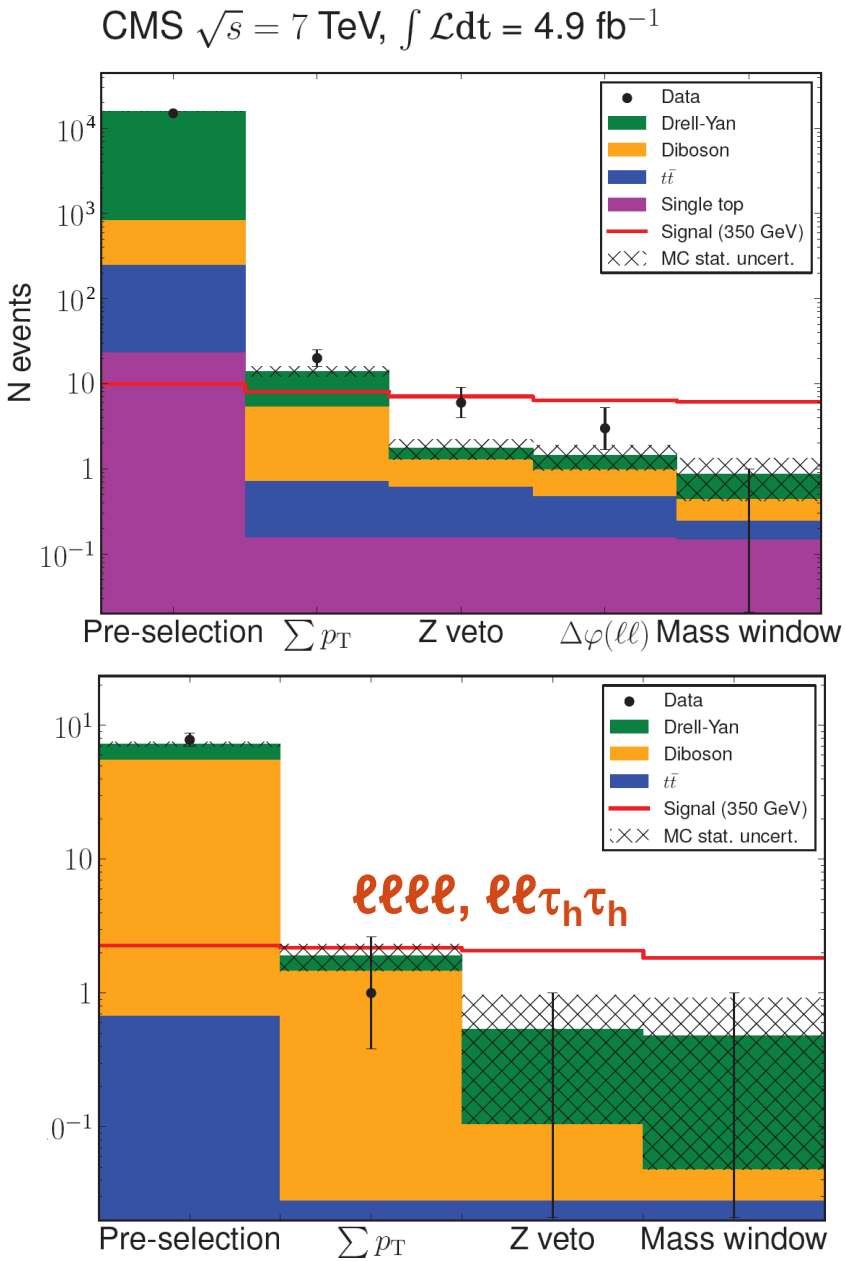
Φ^{++} Search Strategy (I)

- **Search for 3 or 4 charged leptons**
  - All flavor combinations (1 or 2 τ_h)
  - SM bkgs mostly from fake leptons
  - $\Phi^{++} \rightarrow W^+W^+$ assumed to be negligible
- **Lepton selection**
  - Double lepton trigger (ε = 99.5%)
    - 17/8 GeV for ee, eμ; varying for $\mu\mu$
  - $p_T^e > 15$ GeV, $p_T^\mu > 5$ GeV
  - Hadronic tau reconstruction
    - Particle flow based algorithm
    - "hadrons plus strips" to combine $\pi^\pm$, π^0
    - $p_T^\tau > 15$ GeV
  - **All leptons required to be isolated**

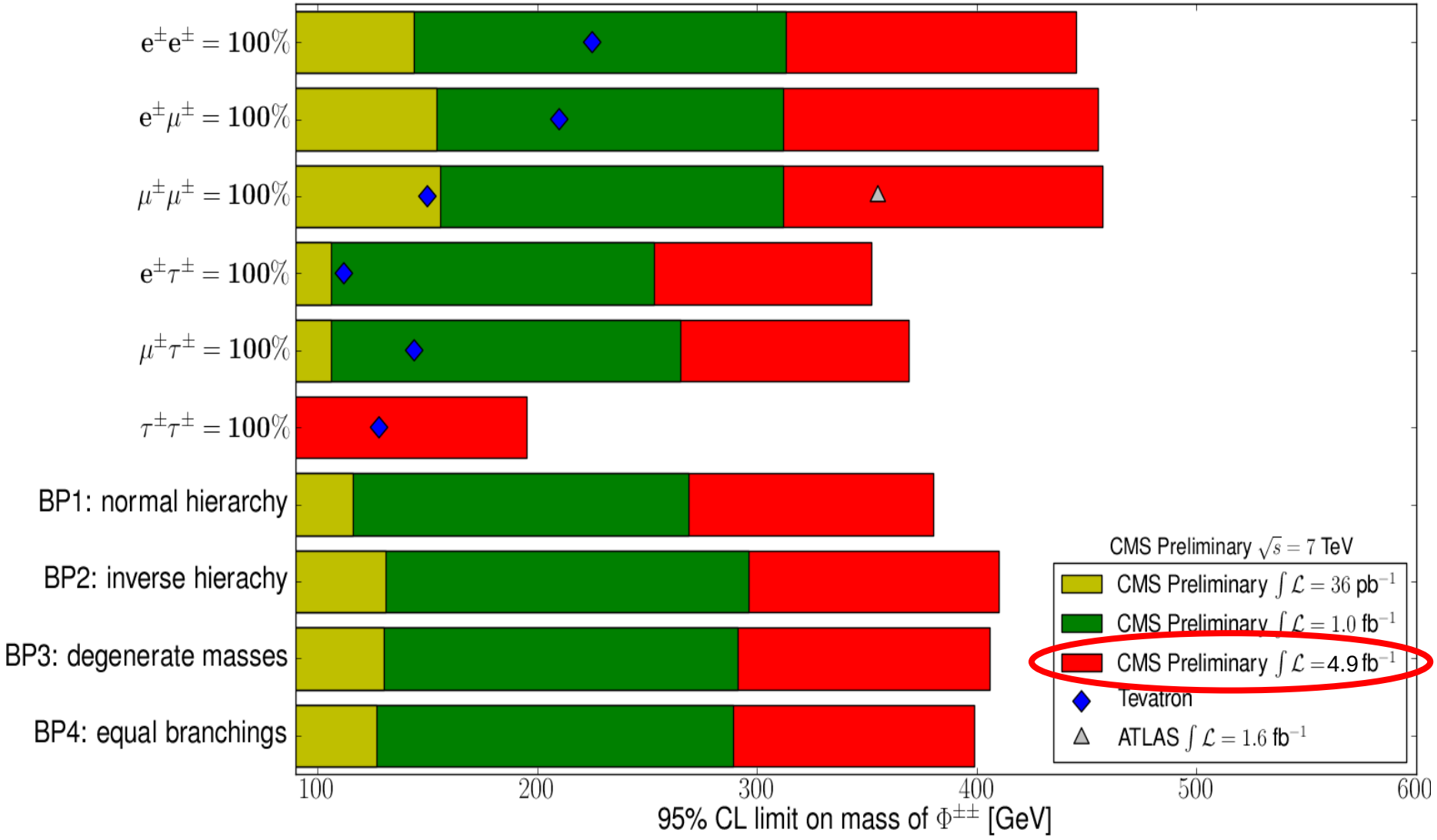


Φ^{++} Search Strategy (II)

- **Final analysis optimization**
  - Scalar sum of lepton p_T
  - Z mass veto
  - Φ^{++} signal mass window
  - Selections are optimized as a function of m_Φ separately for $\ell\ell$, $\ell\tau_h$, and $\tau_h\tau_h$ events, where ℓ = e, μ
- **Background estimation**
  - From data sidebands in m_Φ
  - Obtained from pre-selection sample
  - Extrapolate to signal region with MC
- **Dominant systematics**
  - Theory uncertainty
  - Background extrapolation (stat)



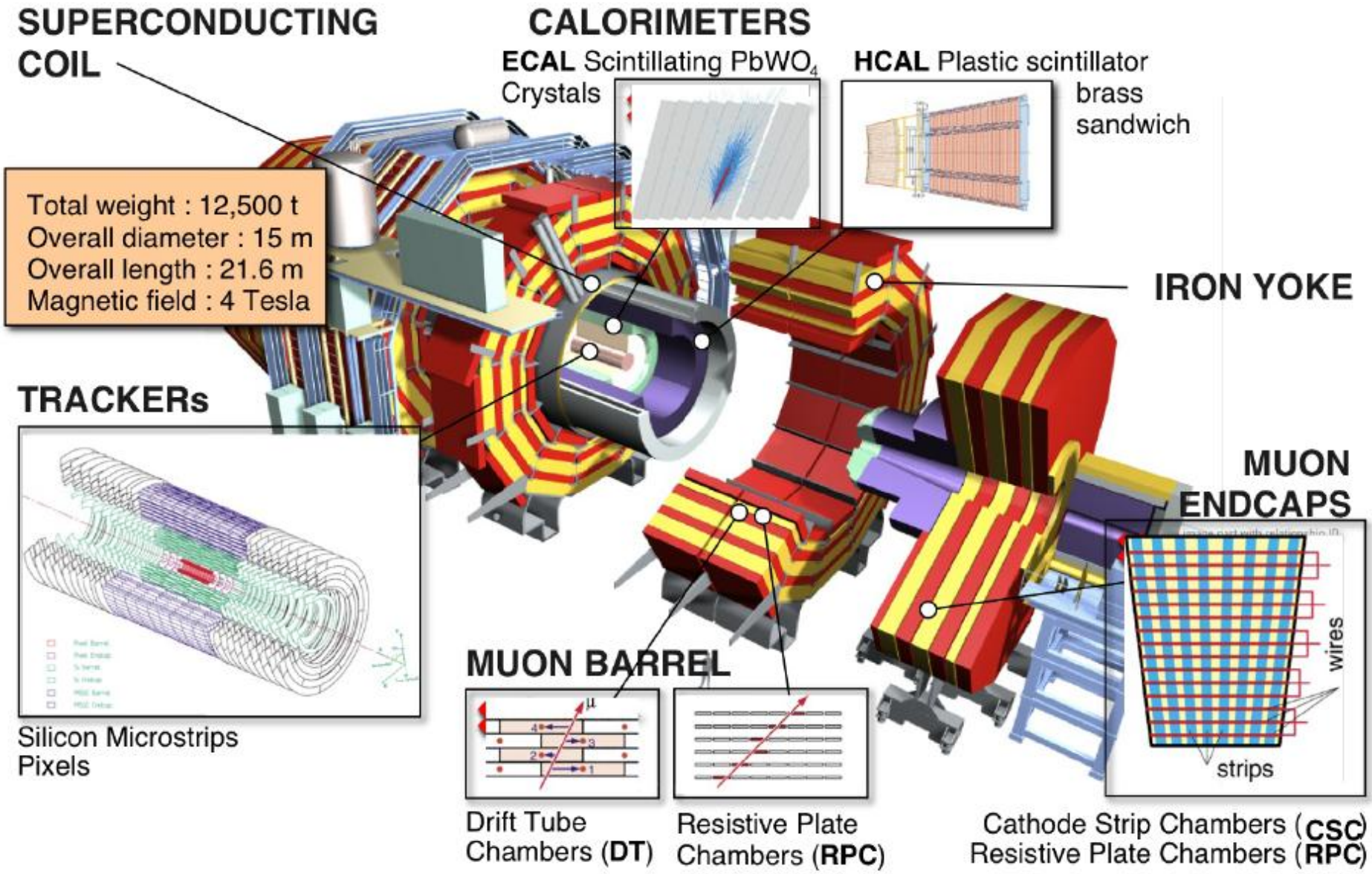
Limits on Φ^{++} Production



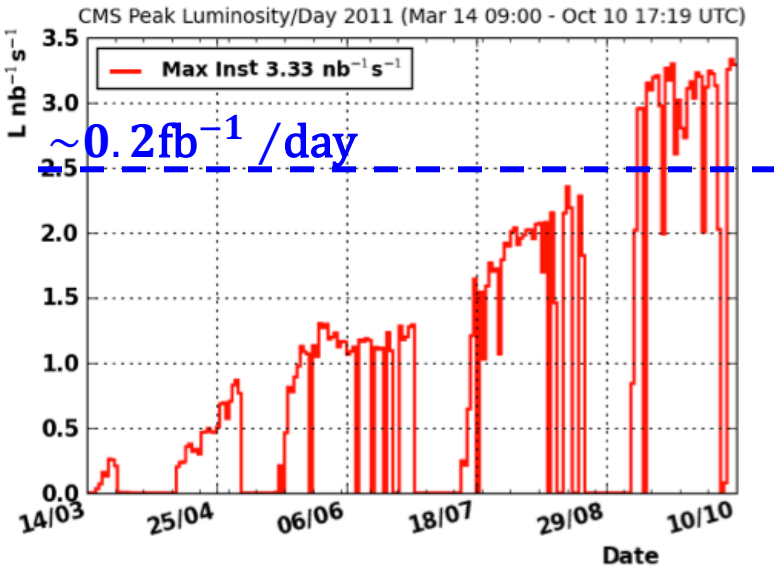
Summary

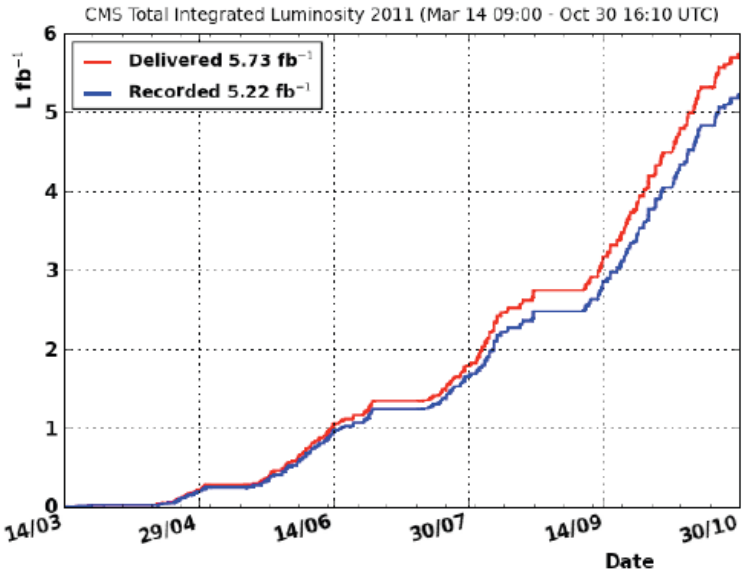
- **LHC continues its outstanding performance**
  - On track to deliver > promised samples in 2012
  - Run has been extended to February 2013
- **Evidence for an excess near 125 GeV in the context of the search for the SM Higgs**
  - See July 7 sessions for details
- **Active CMS searches for beyond MSSM Higgs**
  - No evidence for any excess above backgrounds
  - Strong constraints on SM4, light pseudoscalar (a_1), and doubly charged Higgs boson hypotheses

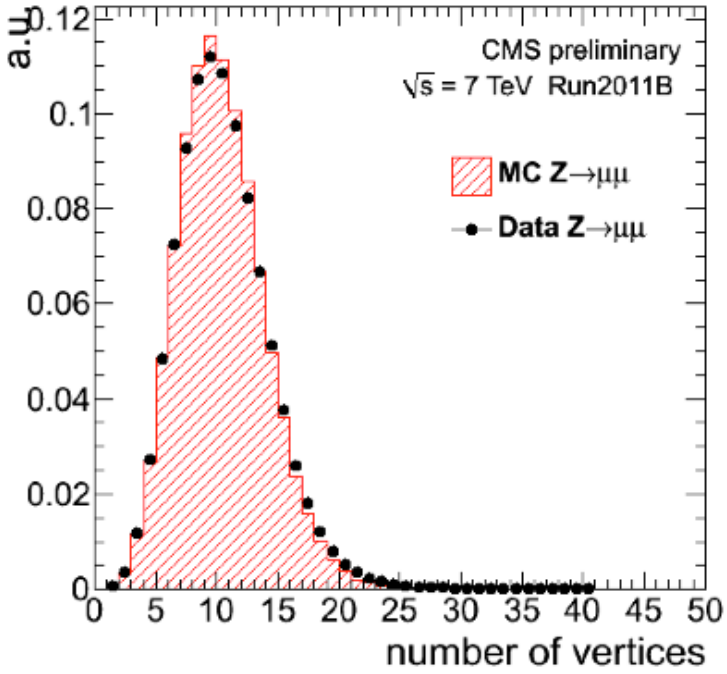
CMS Apparatus



LHC and CMS Performance (2011)



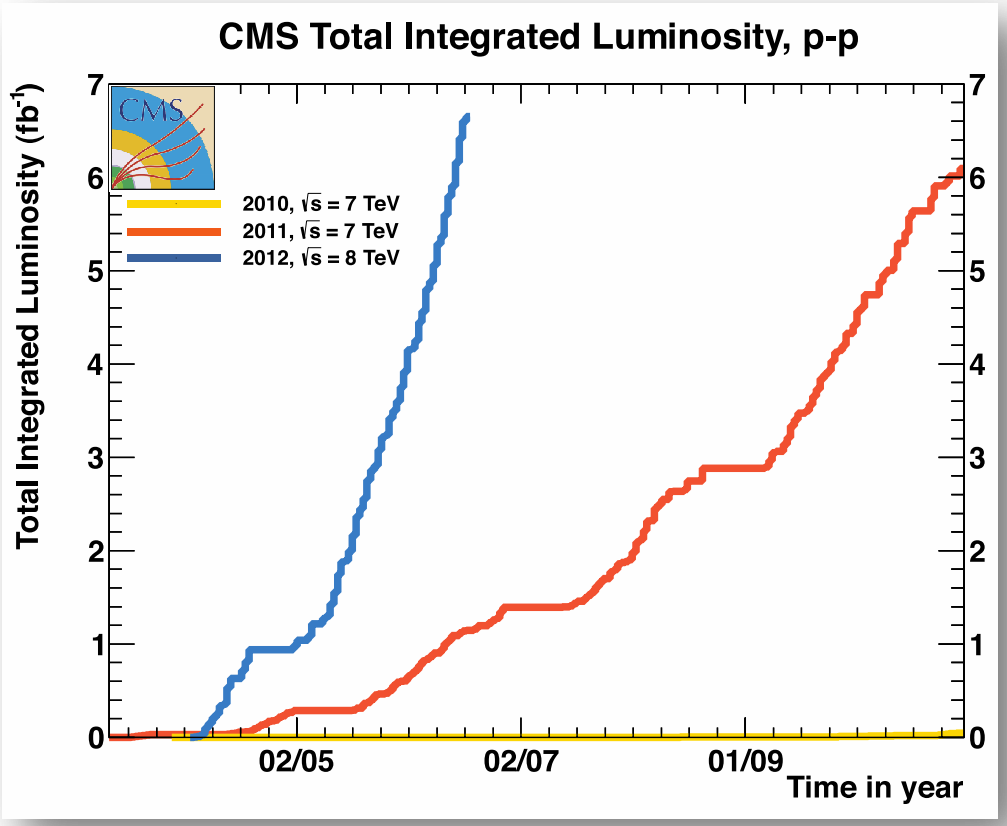




- peak lumi ~ $3.5 \times 10^{-33} cm^{-2} s^{-1}$
- > 5/fb recorded @ > 90% eff
- mean pile-up ~10, not a problem

LHC in 2012

Higher energy (4 TeV per beam) and higher luminosity (> 7e33)



- **Phenomenal performance**
  - Record luminosity (> 5e33) achieved shortly after startup
  - 1fb^{-1} delivered in a few weeks
  - Sustained rate of > 1.5fb^{-1} /wk
  - Total delivered exceeds 6 fb^{-1}
- **Challenging conditions**
  - Average pile-up 10-30
  - Triggers are working!
    - Extensive development over the break
    - In many cases, rates are less than we expected (or feared)
  - CMS is in great shape
    - > 90% data-taking efficiency, as usual