Recent Results from CMS

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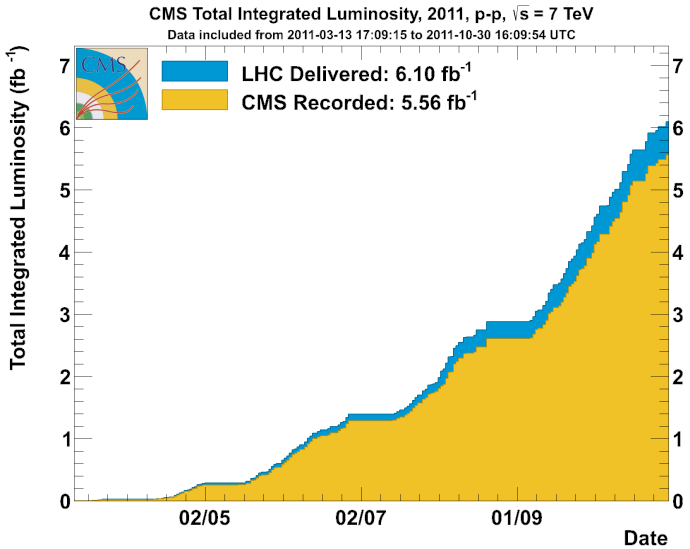
(On behalf of the CMS Collaboration)

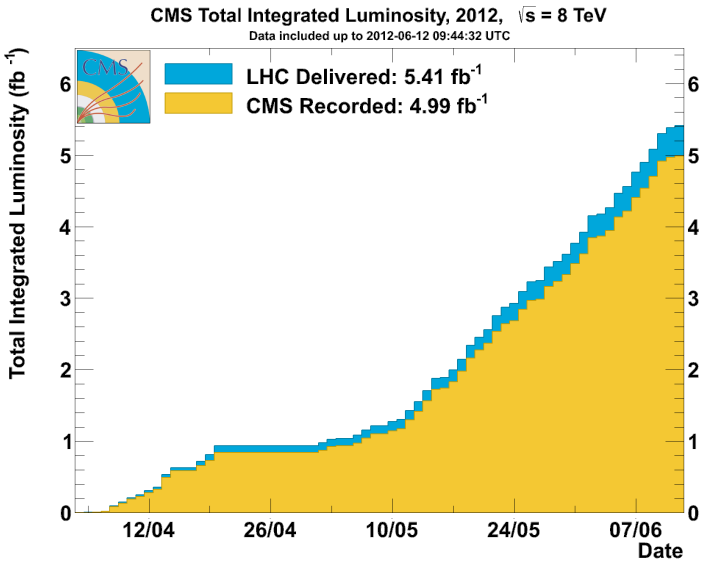
User's Meeting, Fermilab
June 12th, 2012

Overview

- 2011 CMS results
  - B physics
  - Standard Model measurements
  - SUSY searches
  - Non-SUSY Exotic searches
  - Heavy Ions

Higgs results covered by Jake Anderson



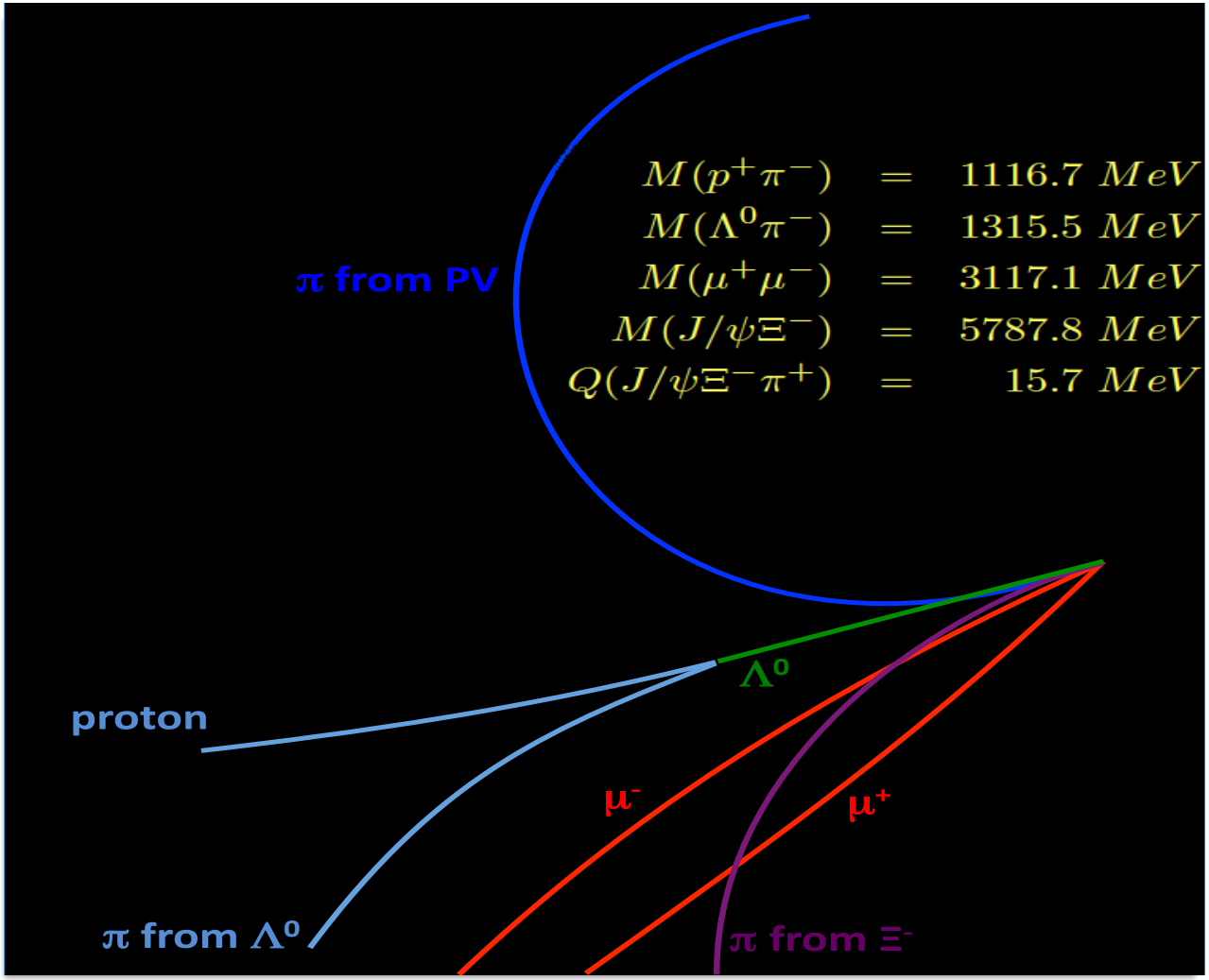


- First 2012 CMS results

All results available at
https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

The beauty of physics…

Observation of Ξ_b^{*0}



Candidate Ξ_b^{*0} event with 3 secondary and ~10 primary vertices

arXiv:1204.5955 (Phys.Rev.Lett.)

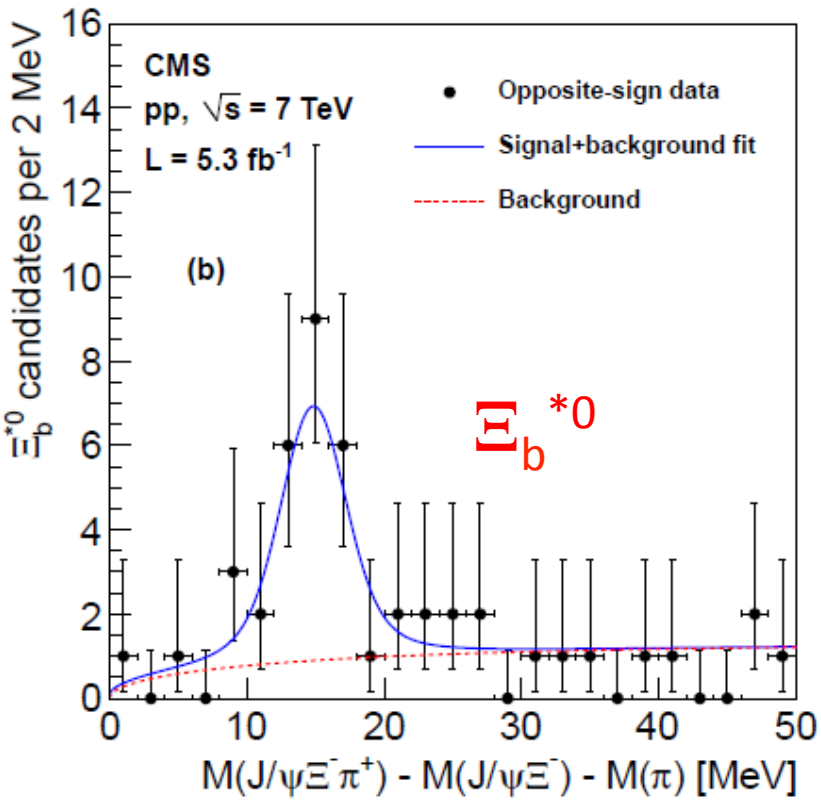
$$\Xi_b^{*0} \to \Xi_b^- \pi^+ \to \Xi^- J/\psi\ \pi^+ \to \Lambda \pi^- \mu^+ \mu^- \pi^+ \to p^+ \pi^- \pi^- \mu^+ \mu^- \pi^+$$

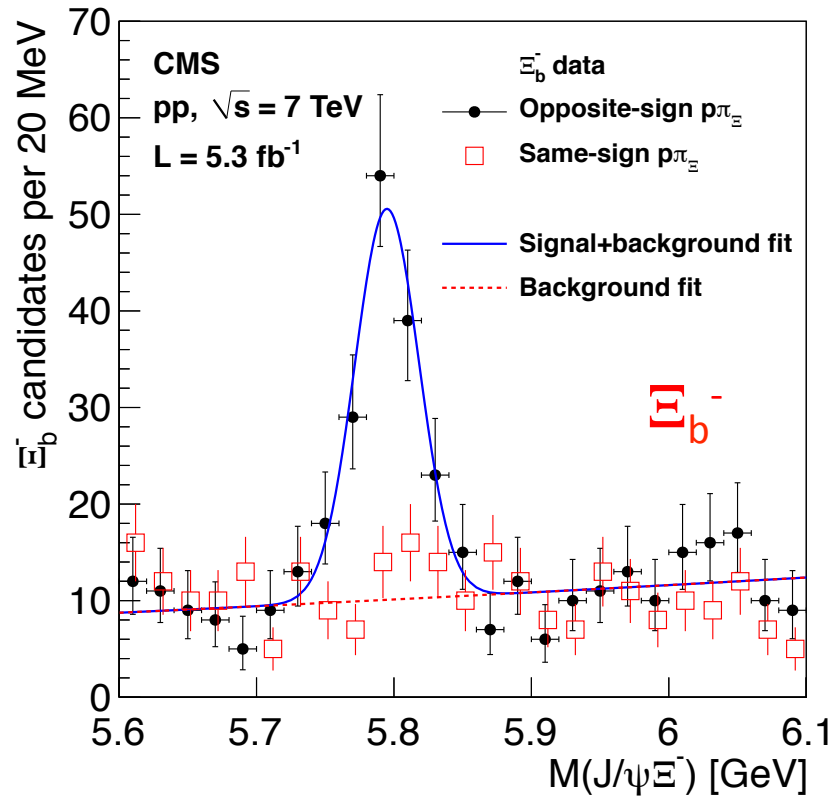
Observation of Ξ_b^{*0}

$M(\Xi_b^{*0}) = (5945.0 \pm 0.7(\text{stat}) \pm 0.3(\text{syst}) \pm 2.7(\Xi_b^-))\ \text{MeV}/c^2$

Theory: 5.94 GeV/c^2 J. G. Korner et al, Prog. Part. Nucl. Phys. 33, 787 (1994)

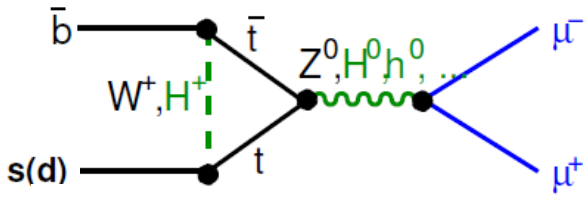
Statisticial significance: 6.9 σ

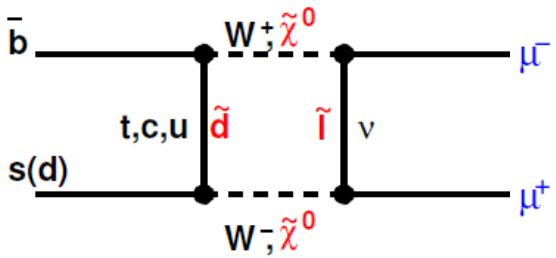




$\Xi_b^{*0} \to \Xi_b^- \pi^+ \to \Xi^- J/\psi\ \pi^+ \to \Lambda \pi^- \mu^+ \mu^- \pi^+ \to p^+ \pi^- \pi^- \mu^+ \mu^- \pi^+$

Rare Decays: $B_{d,s} \rightarrow \mu^+\mu^-$



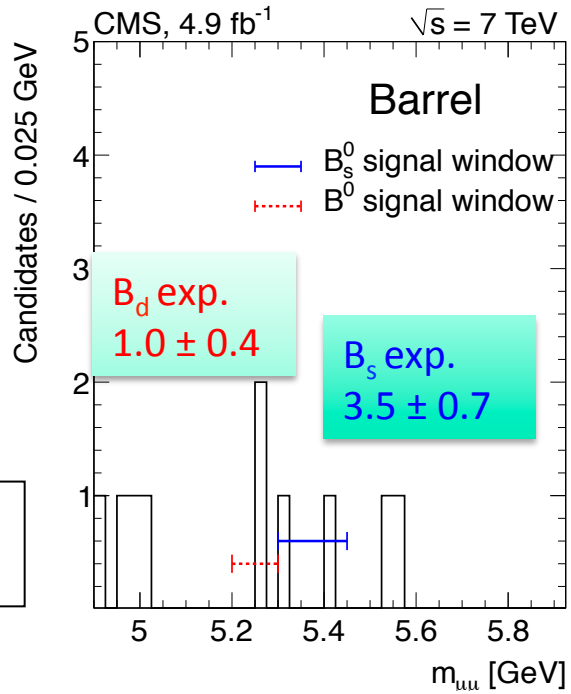


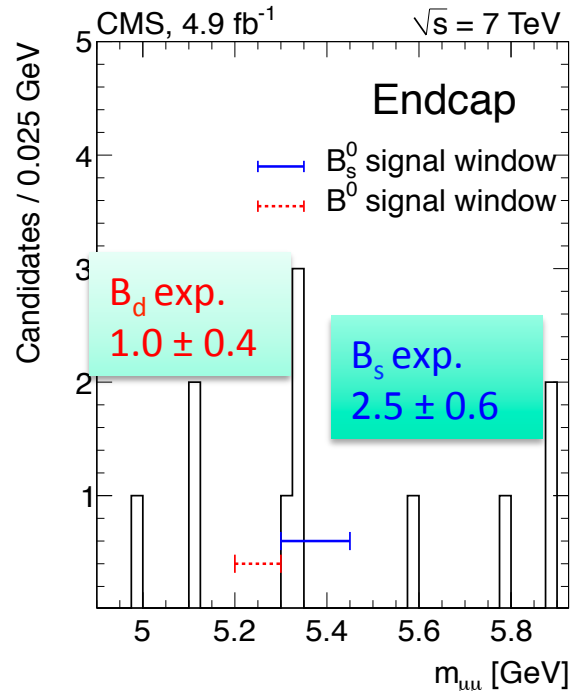
- Decays highly suppressed in SM
  - Effective FCNC decay

$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) = (3.2 \pm 0.2) \times 10^{-9}$$
$$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-) = (1.0 \pm 0.1) \times 10^{-10}$$

Buras, Isidori & Paradisi Phys.Lett. B694 402 (2010)

- Large increases in $B(B_{d,s} \rightarrow \mu^+\mu^-)$ for new physics scenarios



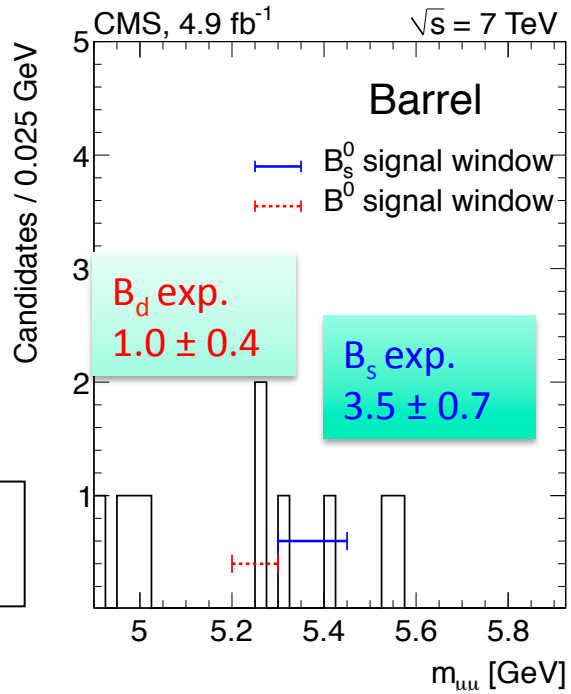


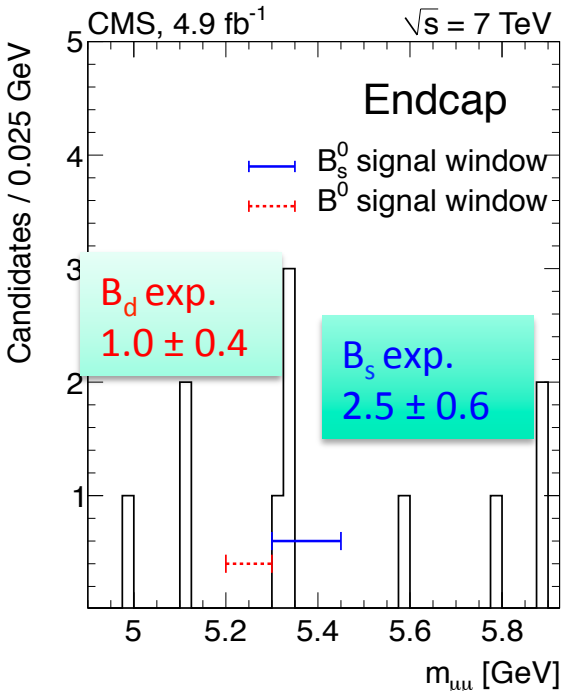
arXiv:1203.3976 (JHEP)

Rare Decays: $B_{d,s} \rightarrow \mu^+\mu^-$

upper limit (95%CL)	observed	expected
$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$	7.7×10^{-9}	8.4×10^{-9}
$\mathcal{B}(B^0 \rightarrow \mu^+\mu^-)$	1.8×10^{-9}	1.6×10^{-9}

MVA in the works:
20-30% improvement

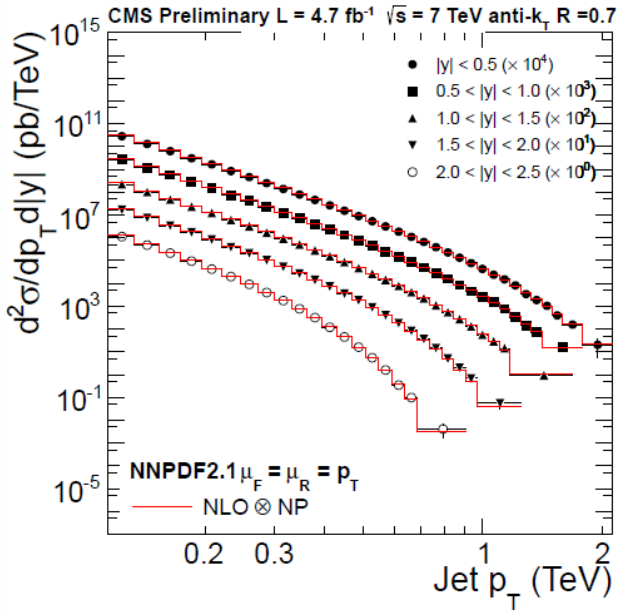




arXiv:1203.3976
to appear in JHEP

Standard Model Measurements

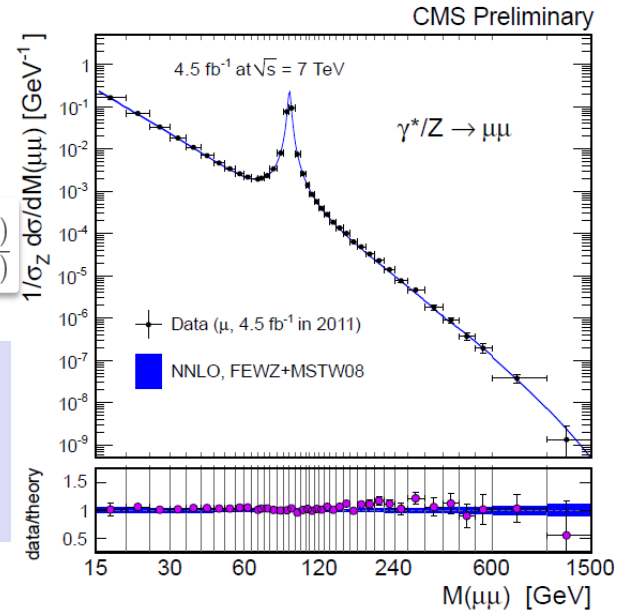
Jets, W, and γ*/Z



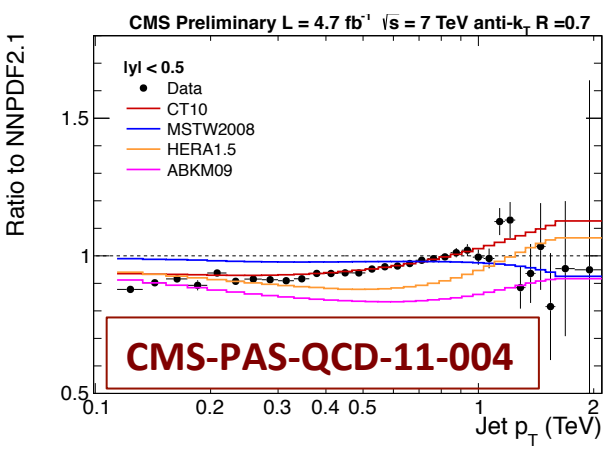
CMS-PAS-SMP-12-001

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}$$

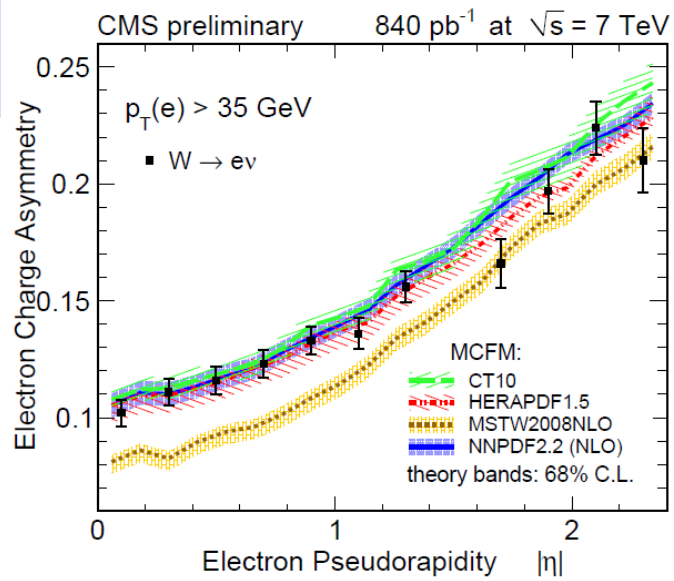
W electron charge asymmetry measured to 0.5-1% per bin of 0.1 in Δη. Constrains u/d PDF ratio



Inclusive jet and dijets. 2-4% JES. Constrains gluon PDF up to x=0.6



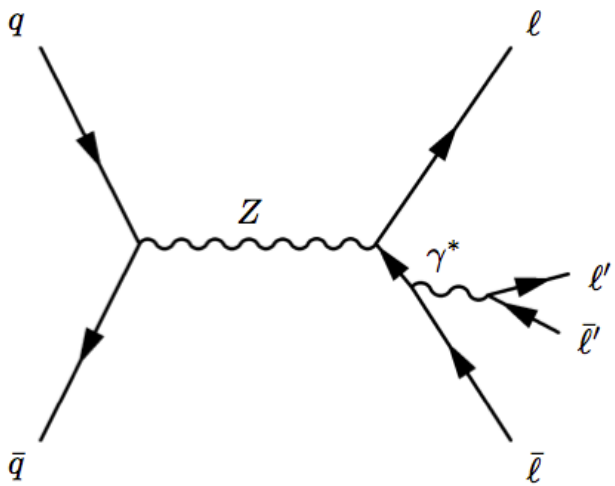
CMS-PAS-QCD-11-004

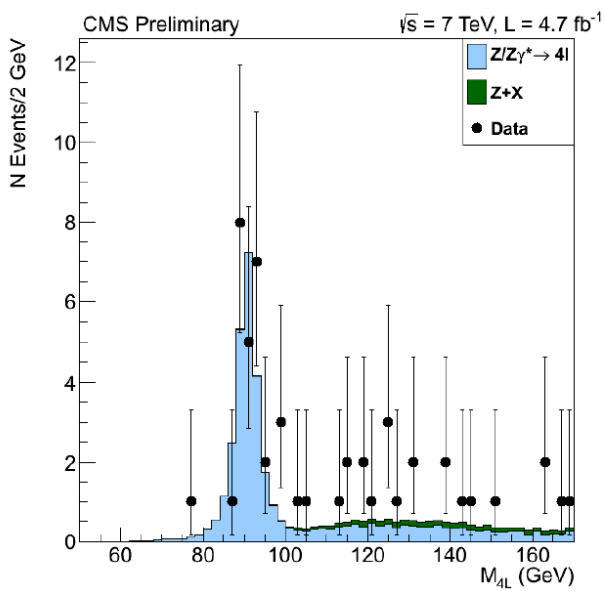


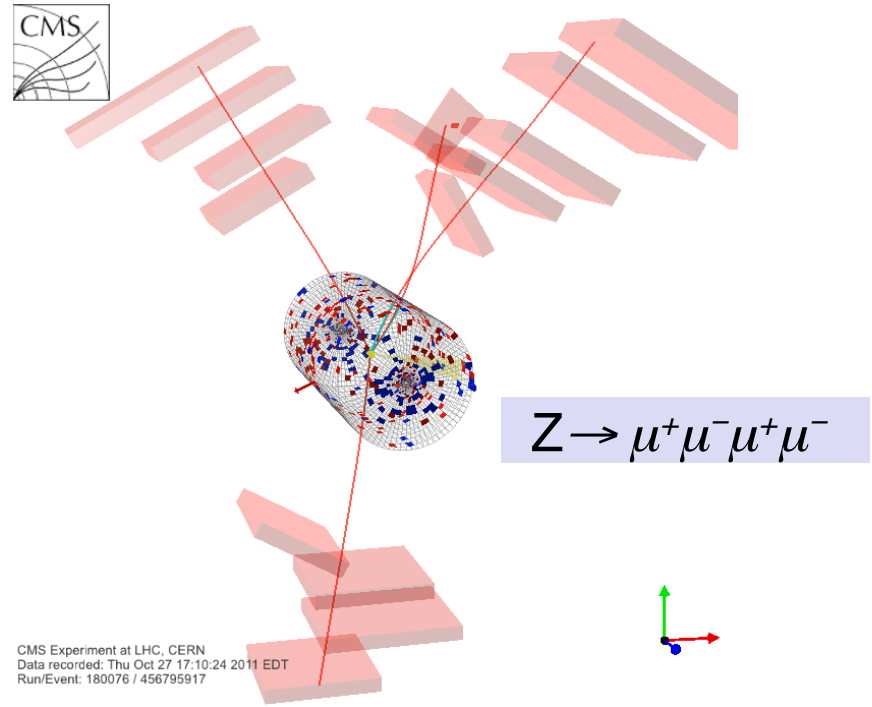
Differential Drell-Yan cross section: 2.5M μμ pairs tests NNLO cross sections and PDFs

CMS-PAS-EWK-11-007

‘Rare’ processes





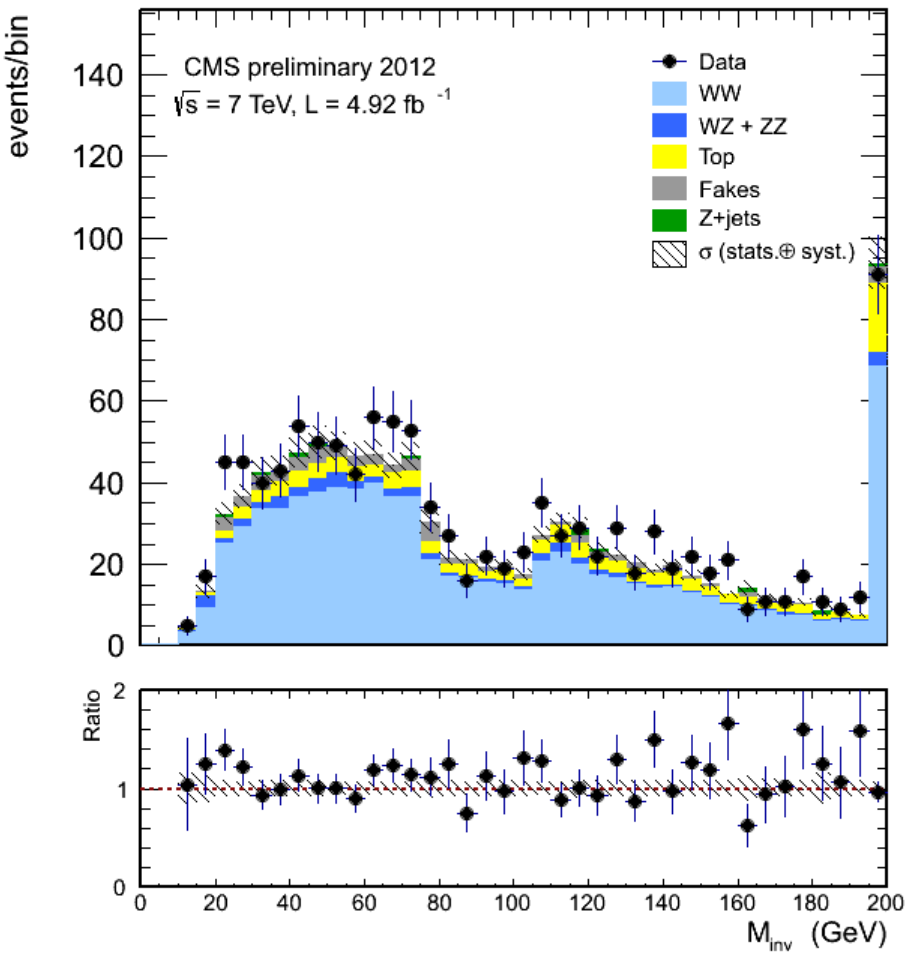


$Z \rightarrow \mu^+\mu^-\mu^+\mu^-$

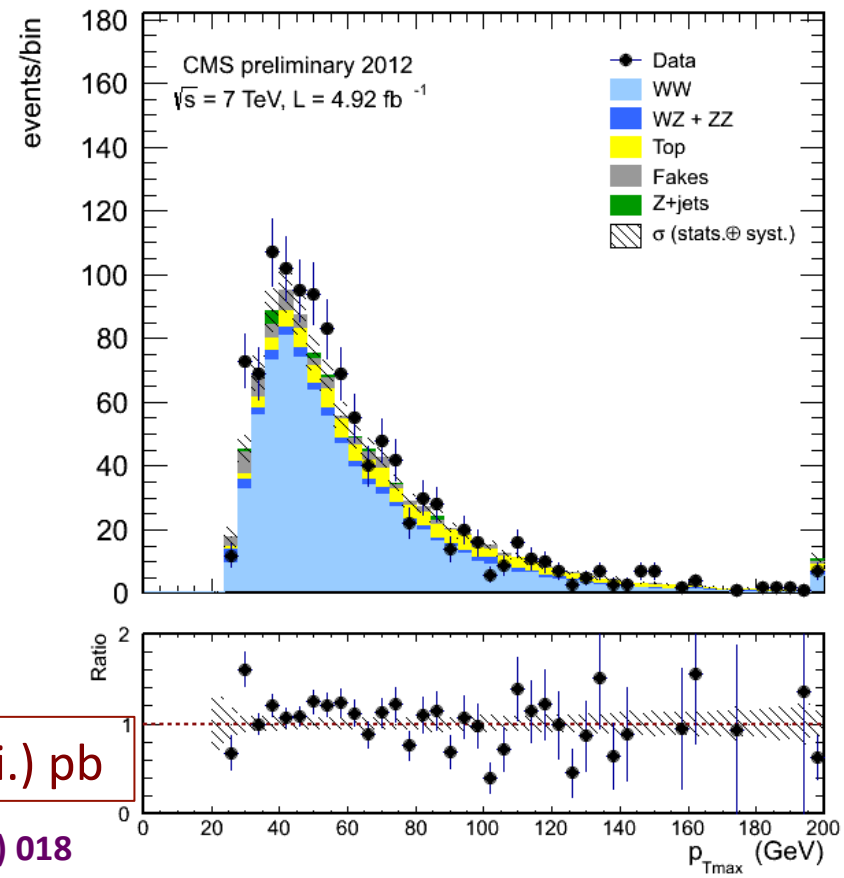
CMS-PAS-SMP-12-009

First 4-fermion Z→llll decays observed at a hadron collider! Statistical significance: 8.9 σ (BR = 4.4·10^{-6}), σ ≈ 125±26 fb

Dibosons



800 *WW→ lνlν* events observed in 2011, ±10% xsec precision. Constrains Higgs backgrounds and anomalous trilinear electroweak couplings



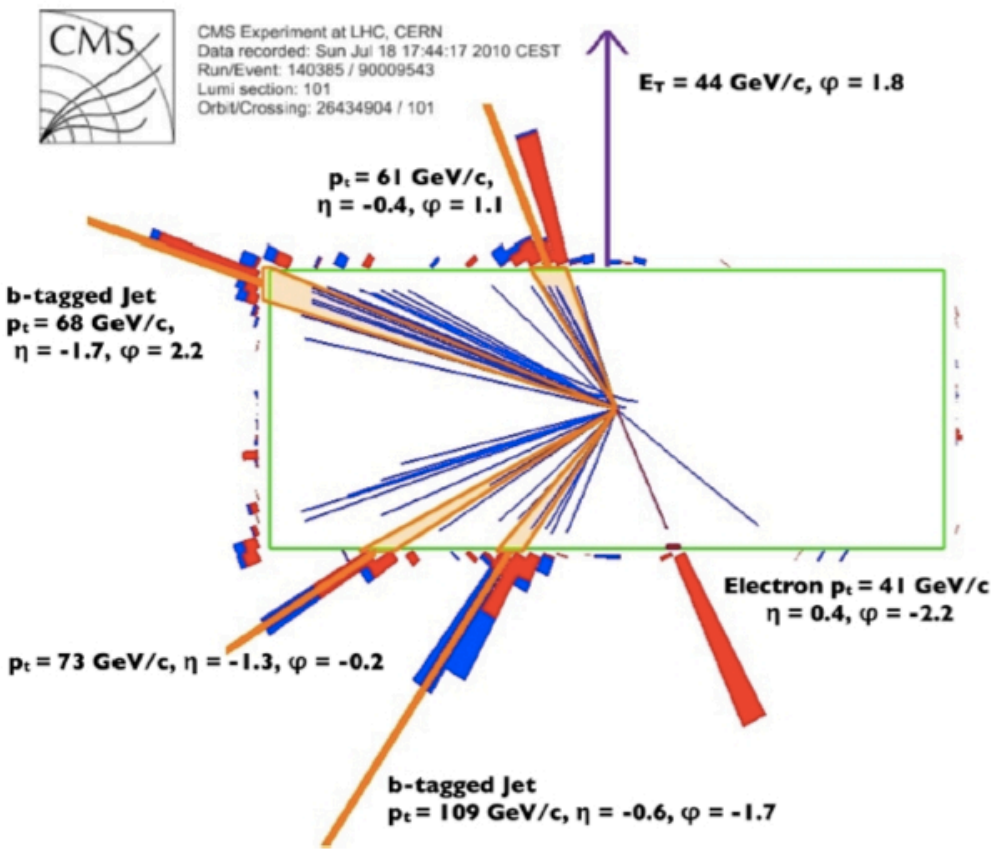
CMS-PAS-SMP-12-005

σ(WW): 52.4 ± 2.0 (stat.) ± 4.5 (syst.) ± 1.2 (lumi.) pb

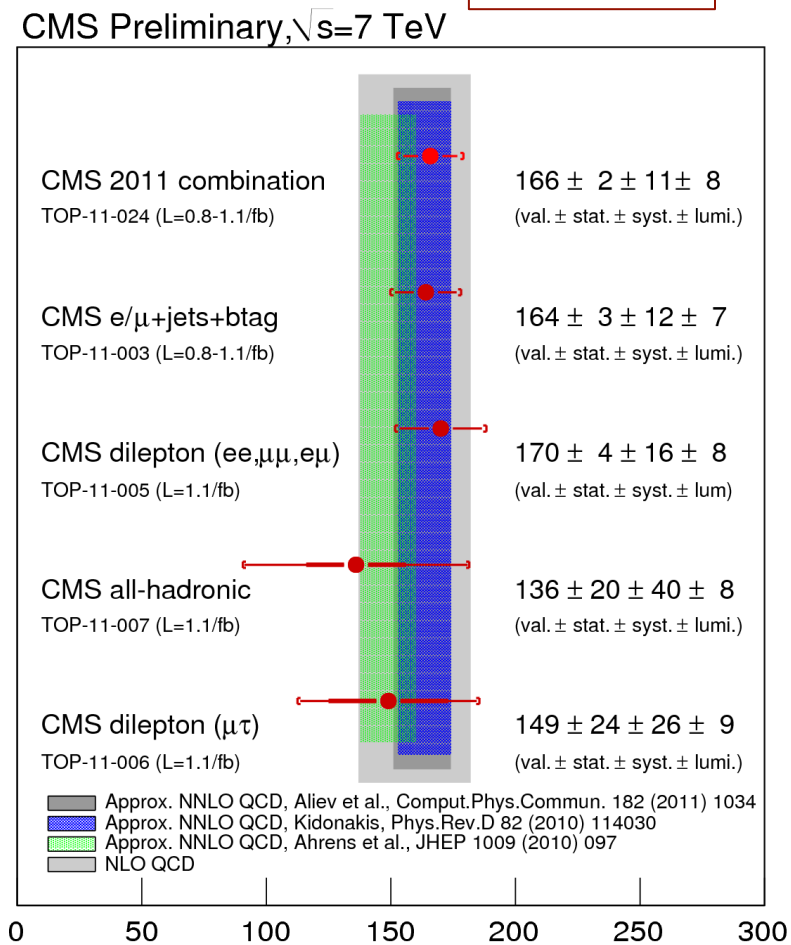
Theory: 47 ± 2.0 pb **Campbell et al, JHEP 1107 (2011) 018**

Top Factory

- Top pair cross section
  - lepton(e,μ, tau)+jets, di-lepton and fully hadronic final states

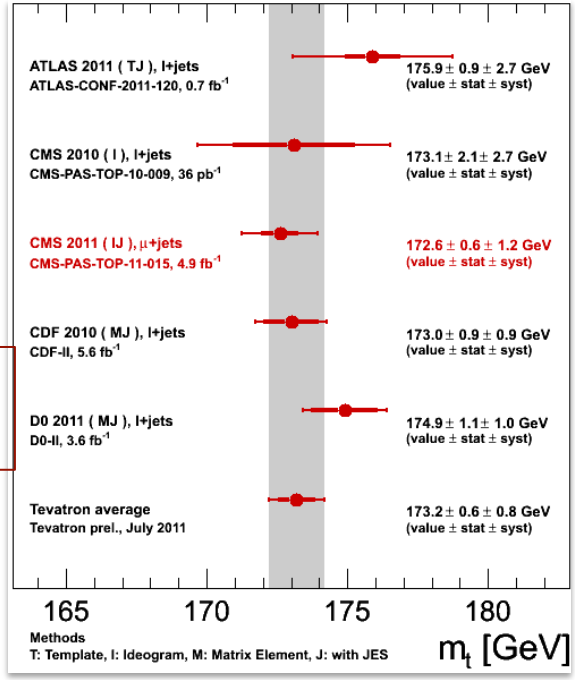


TOP-11-024

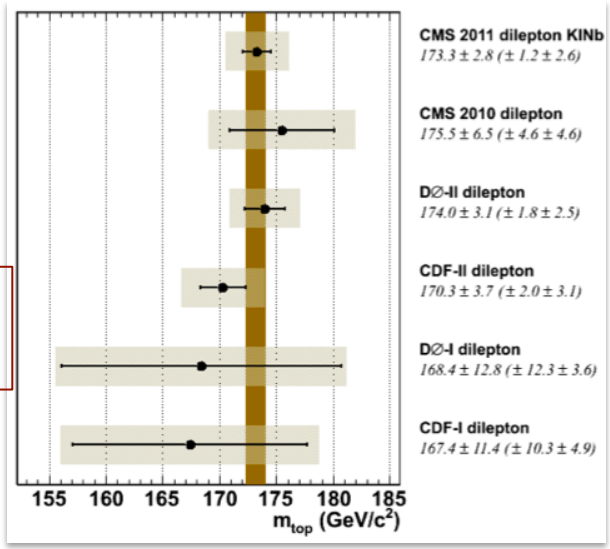


hadronic tau + jets final state not yet included in the combination

Top mass



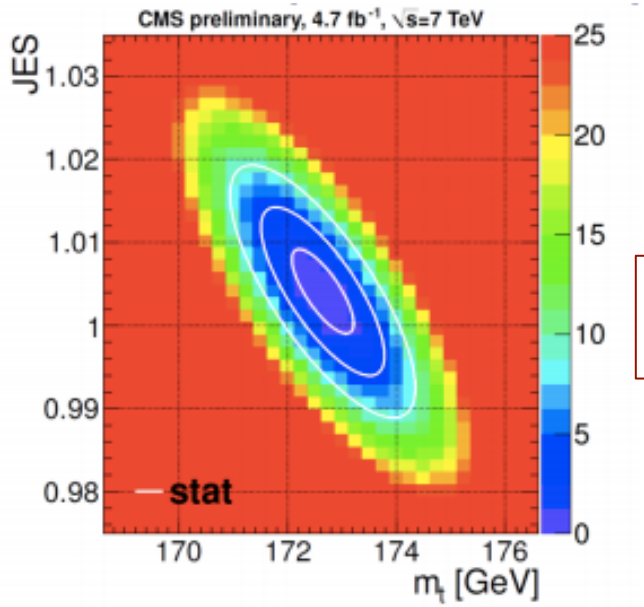
Lepton+jets: TOP-11-015



Dilepton: TOP-11-016

CMS average: 172.6 ± 0.4 ± 1.2 GeV

Lepton+jets channel: W-mass constraint is used to simultaneously determine the Jet Energy Scale (JES)



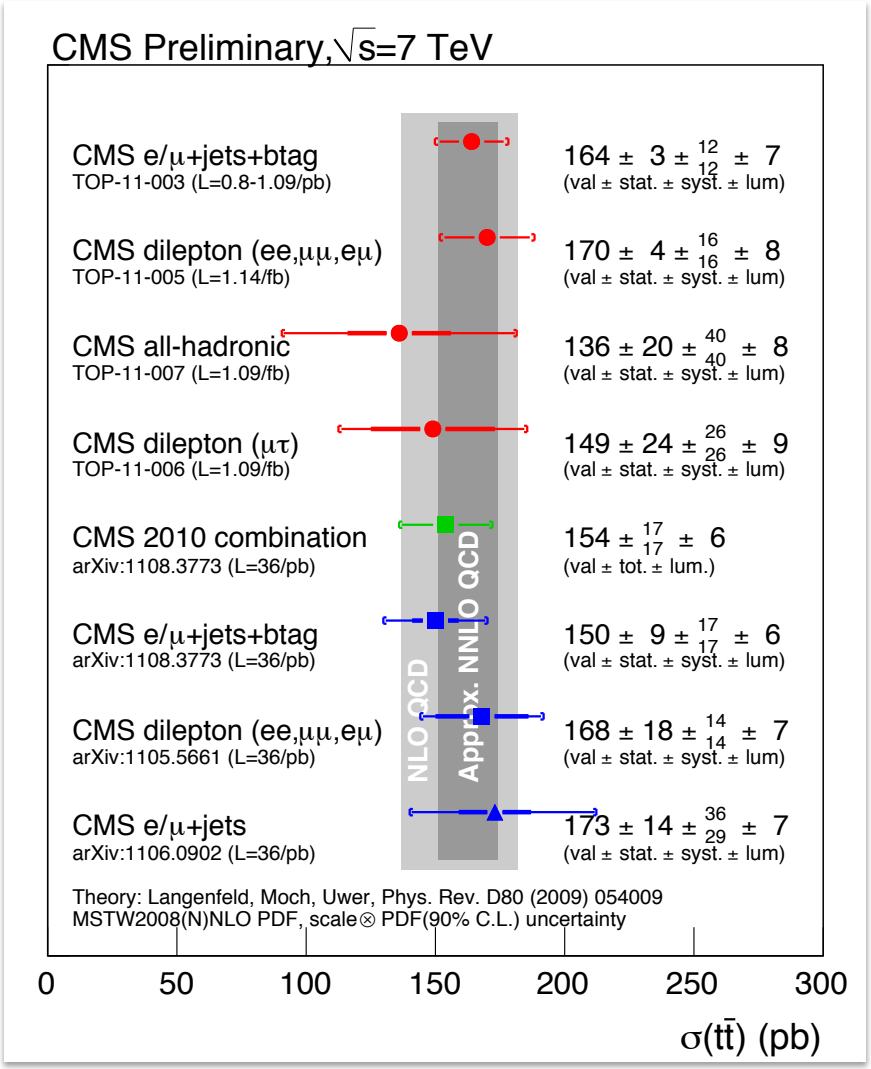
Lepton+jets: TOP-11-015

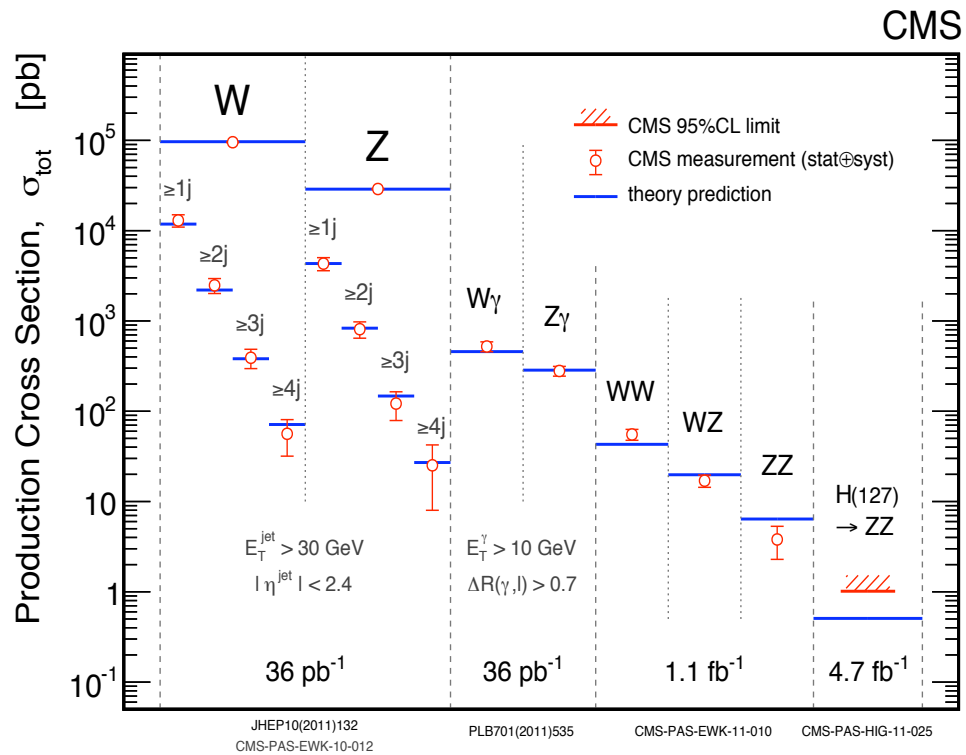
$$m_t = 172.64 \pm 0.57\,(\text{stat+JES}) \pm 1.18\,(\text{syst})\ \text{GeV}$$
$$\text{JES} = 1.004 \pm 0.005\,(\text{stat}) \pm 0.012\,(\text{syst})$$

~1.3 (syst) GeV including color reconnection;
Underlying event expected to be small

Cross-check: after applying the calibration obtain using 44660 events m_t = 172.6 ± 0.2 ± 1.8 GeV which confirms the main result

Standard Model @ 7 TeV 2010-2011

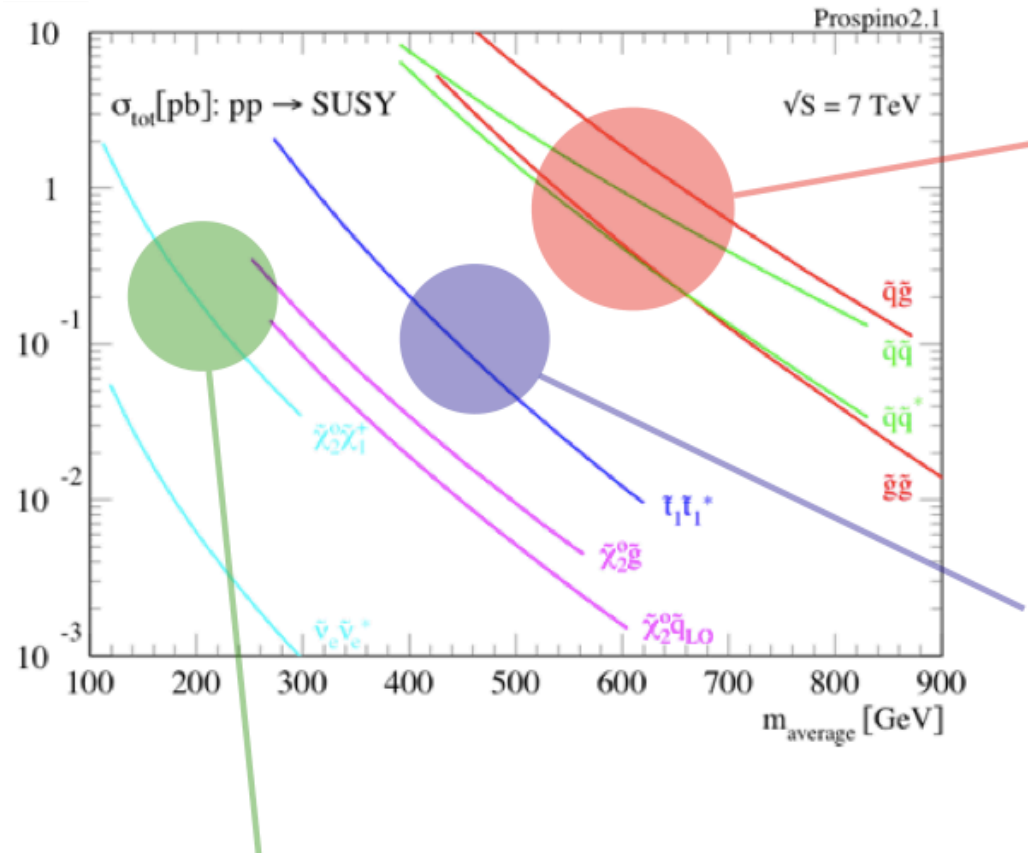




Excellent agreement between SM predictions and data

SUSY

SUSY @ CMS



Strong Production
(jets, MET, HT)

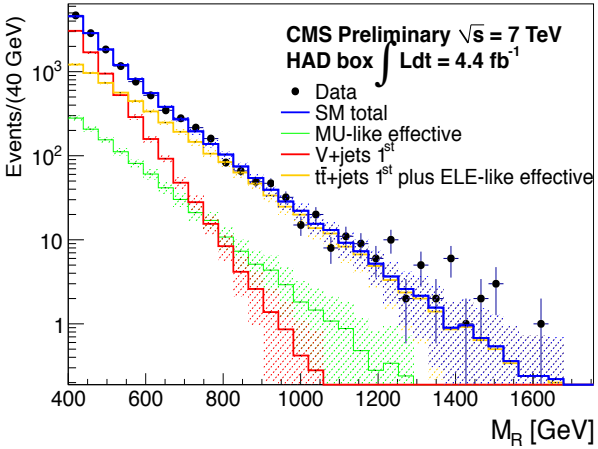
3rd Generation Production
(b jets, same-sign leptons)

EWK Production
(low MET, multiple soft leptons)

Hadronic SUSY searches

All-hadronic searches:

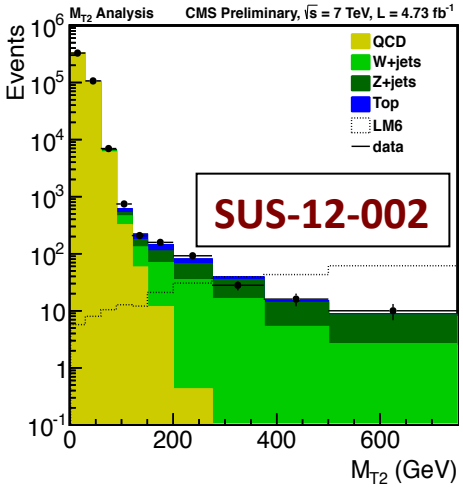
- Razor variables M_R
- H_T and missing H_T
- M_{T2}



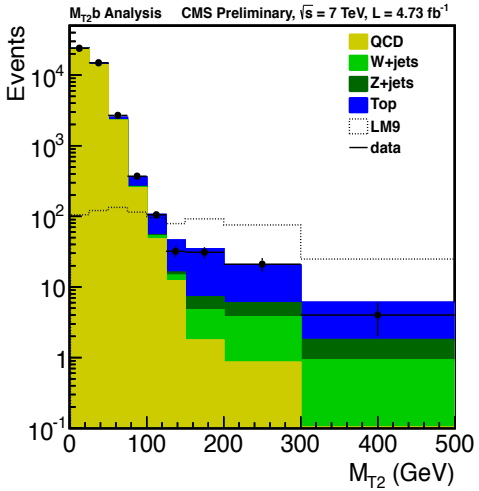
SUS-12-005

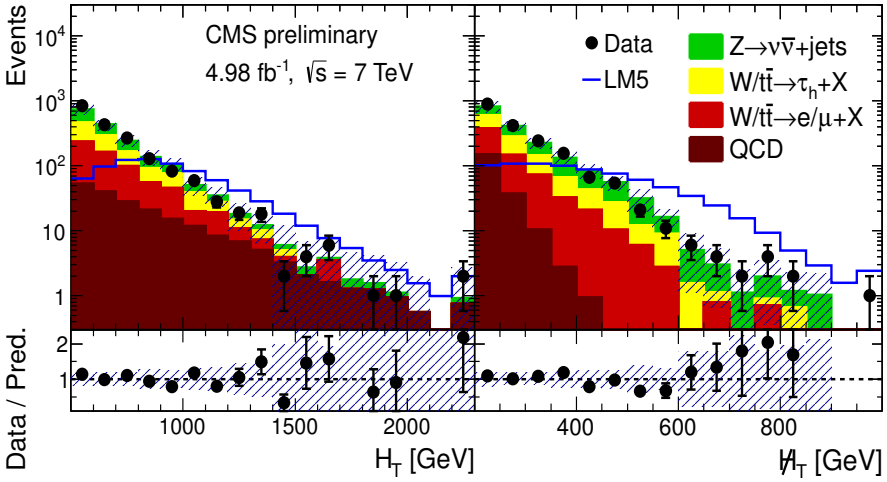
$$M_{T2}(m_\chi) = \min_{p_T^{\chi(1)}+p_T^{\chi(2)}=p_T^{miss}} \left[\max\left(m_T^{(1)}, m_T^{(2)}\right)\right]$$

$$(m_T^{(i)})^2 = (m^{vis(i)})^2 + m_\chi^2 + 2\left(E_T^{vis(i)} E_T^{\chi(i)} - \vec{p}_T^{\,vis(i)} \cdot \vec{p}_T^{\,\chi(i)}\right)$$



SUS-12-002

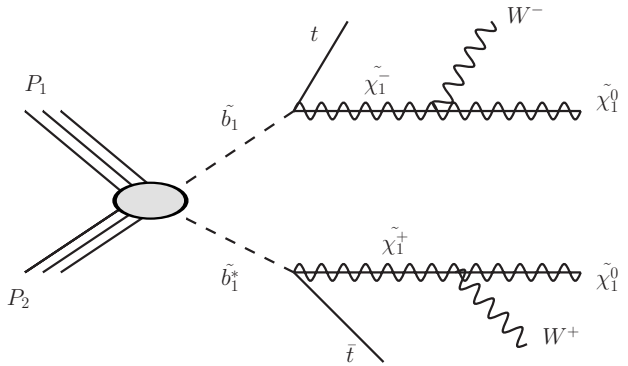


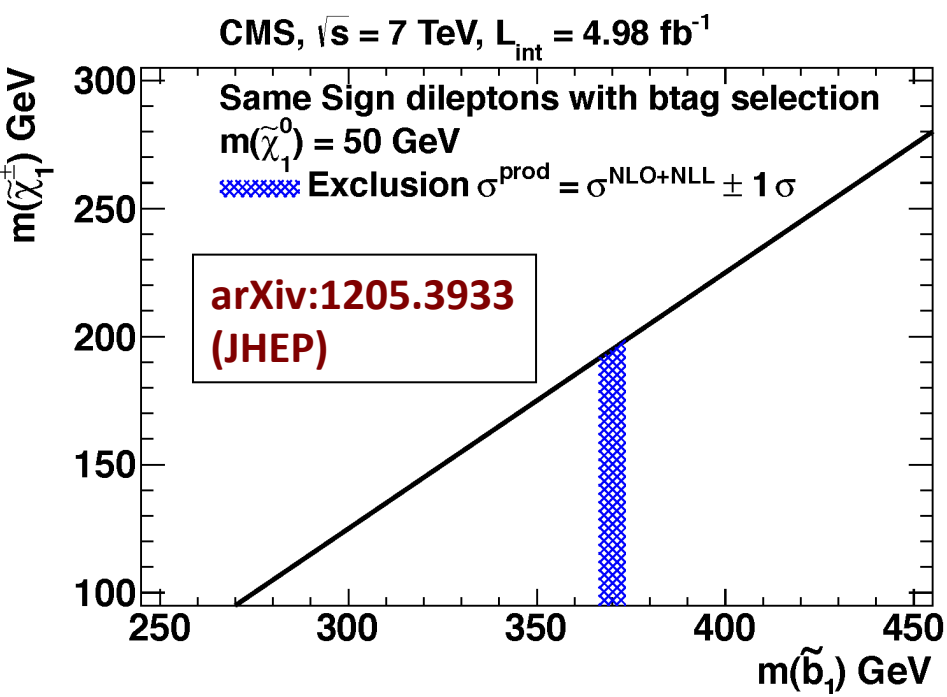


SUS-12-011

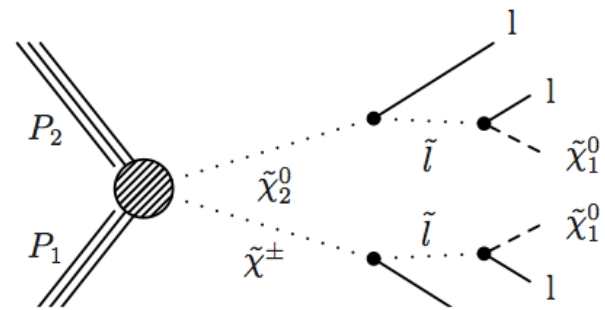
Leptonic SUSY searches

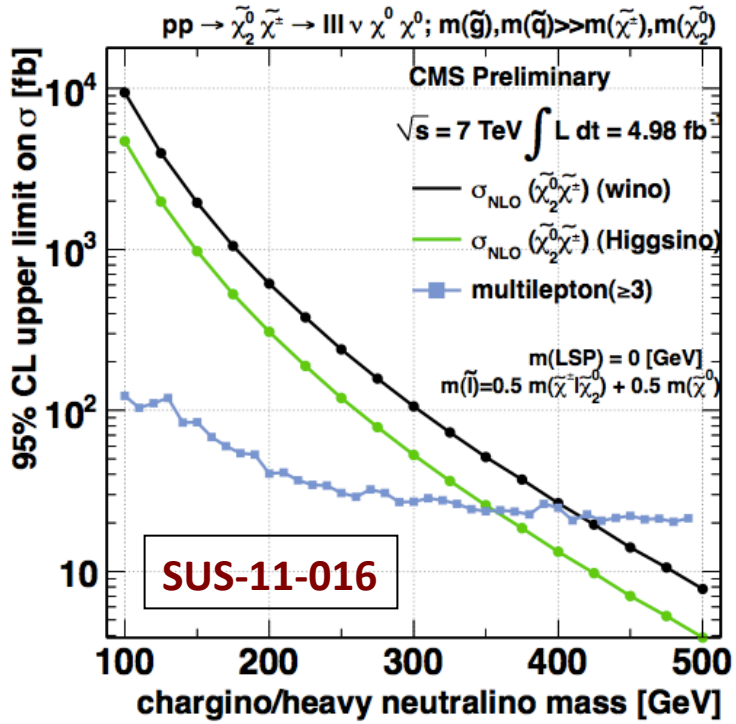
3rd generation searches
Same-sign dileptons + bjets





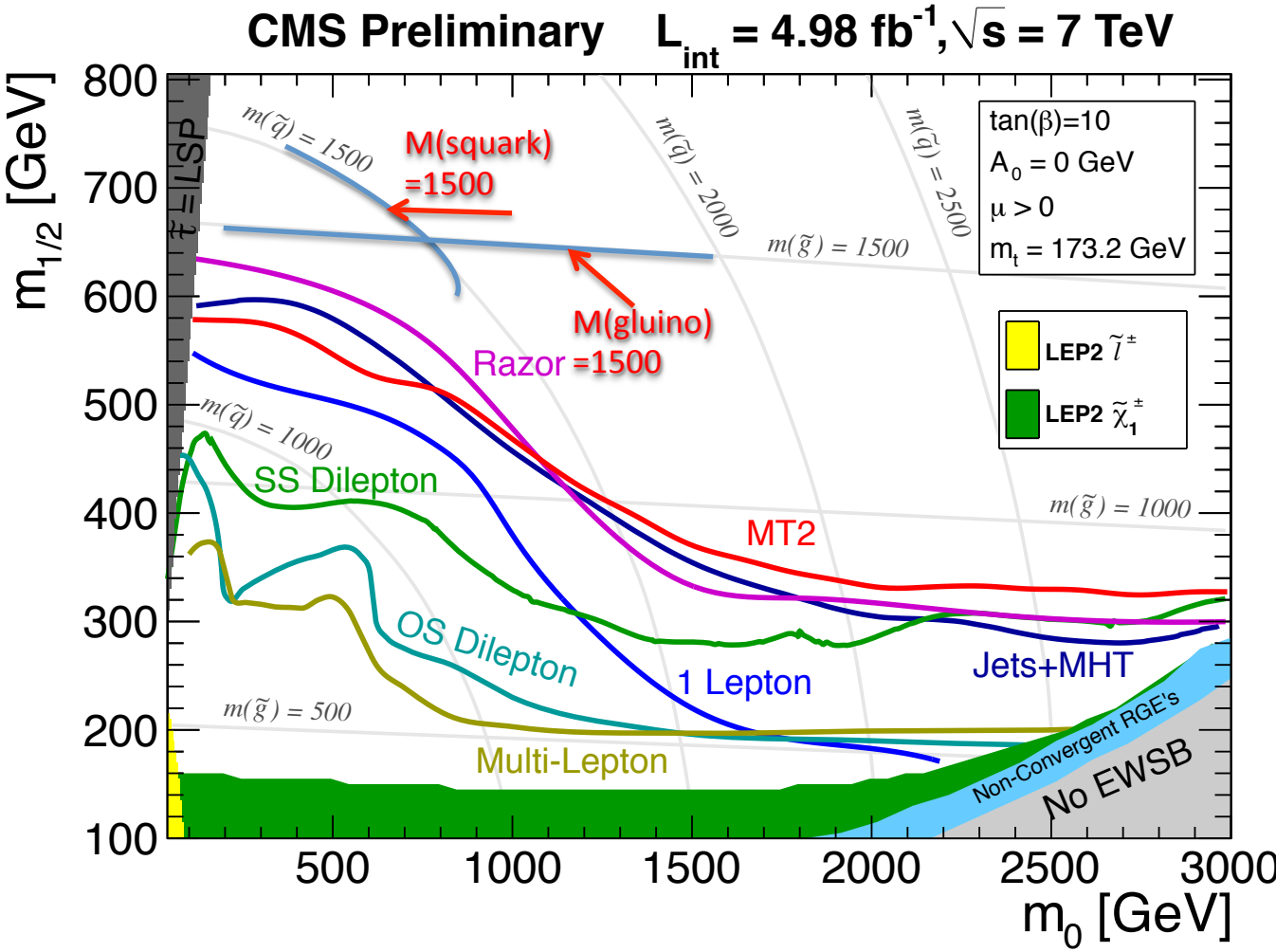
EWK production
≥ 3 leptons search (e,μ,τ)



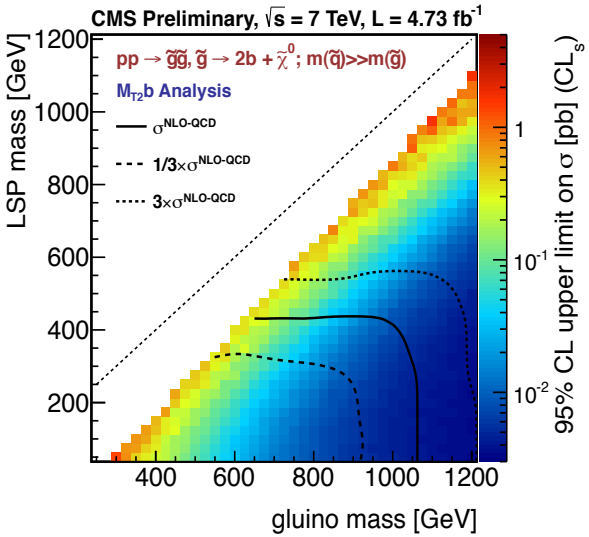


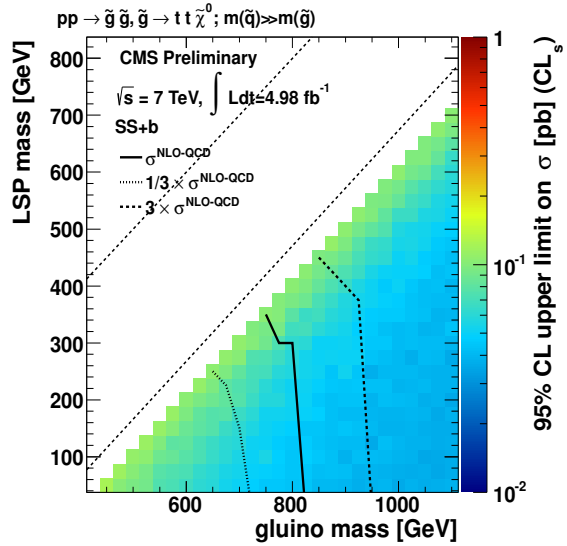
SUSY Perspective

- Simple SUSY models are under pressure
  - Limits > 1000 GeV squarks and gluinos
- SUSY is not dead yet
  - 115-130 GeV Higgs tailor made for SUSY
  - More complicated (and interesting) "natural" SUSY models still plentiful

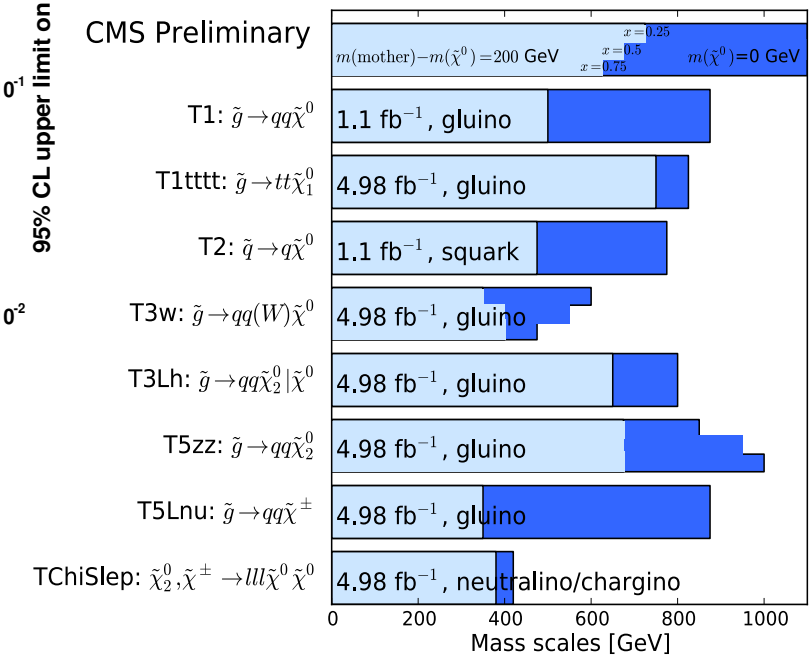


Simplified Model Spectra (SMS)

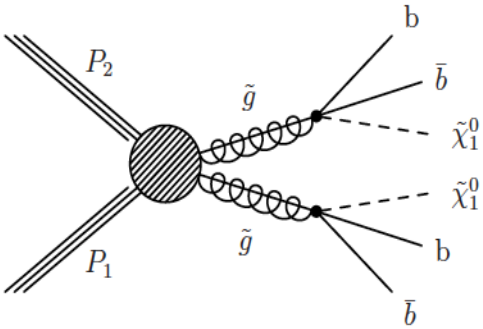




SUS-11-016

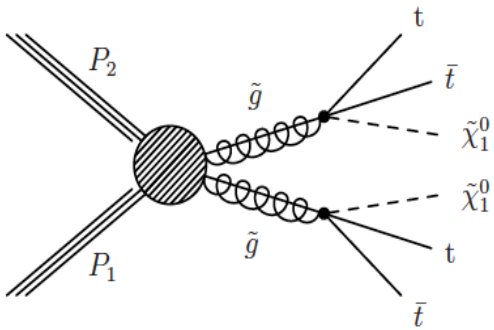


All hadronic w/ b-tags



SUS-12-002

SS leptons + b-tags



SUS-11-020

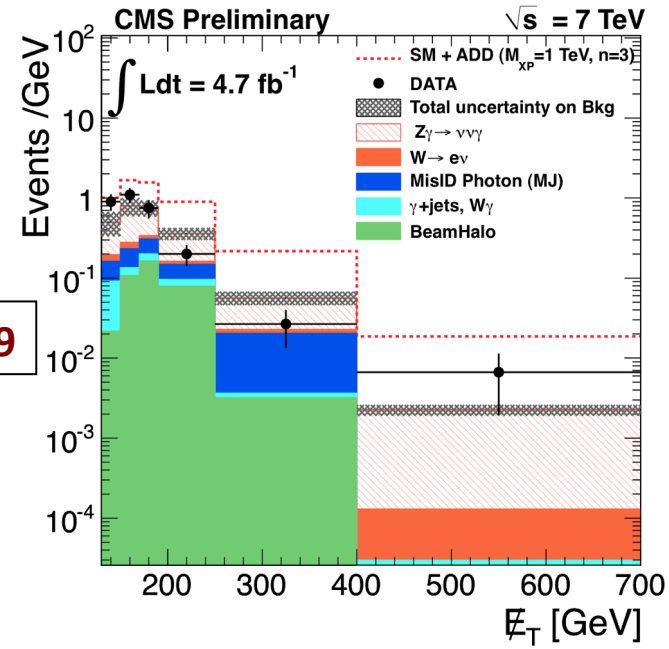
Provide a broader view of results: e.g. Limits for a massless Neutralino (dark blue) are significantly reduced (light blue) when requiring it to be 200 GeV less than the heavy gluino mass.

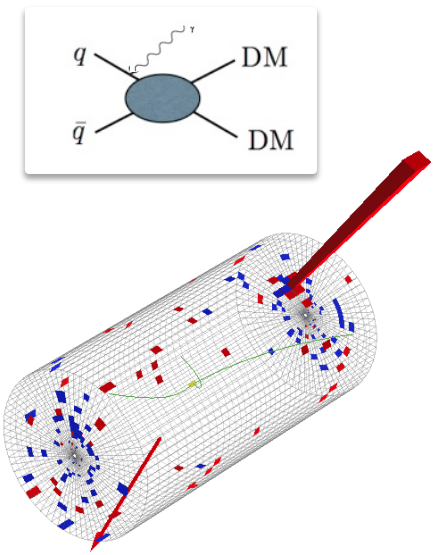
Exotica

Search for Dark Matter

- Pair-produced DM particles via monojets & monophotons (ISR)
  - Look for "nothing" plus a single radiated photon or jet
  - Probing the same effective operators as in direct detection
  - High sensitivity to **spin-dependent couplings**
  - Extends direct detection below 5 GeV
    - *Interpret also in ADD LED, set limits on Planck Scale vs. EDs*

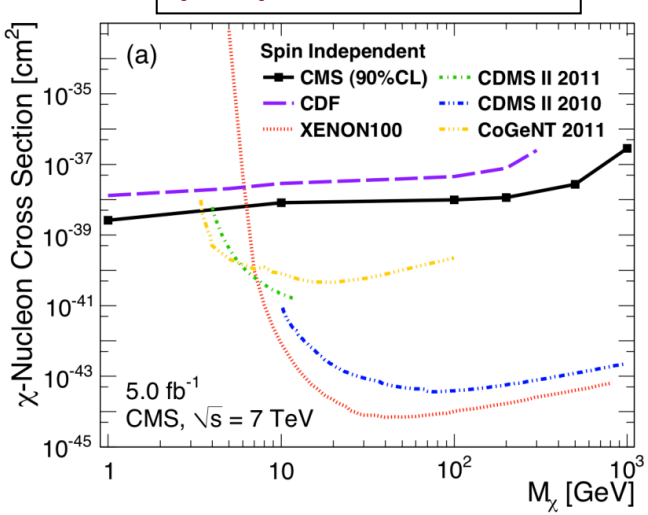
EXO-11-059

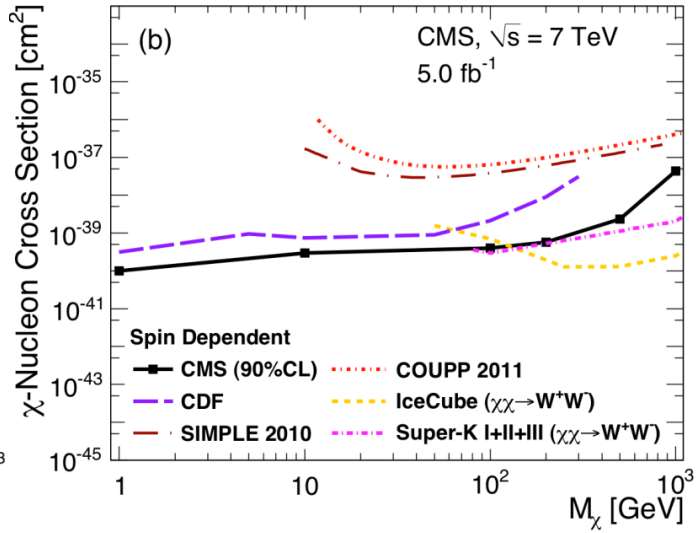




CMS Experiment at LHC, CERN
Data recorded: Sun Apr 24 22:57:52 2011 CDT
Run/Event: 163374 / 314736281
Lumi section: 604

arXiv:1204.0821 (PRL)

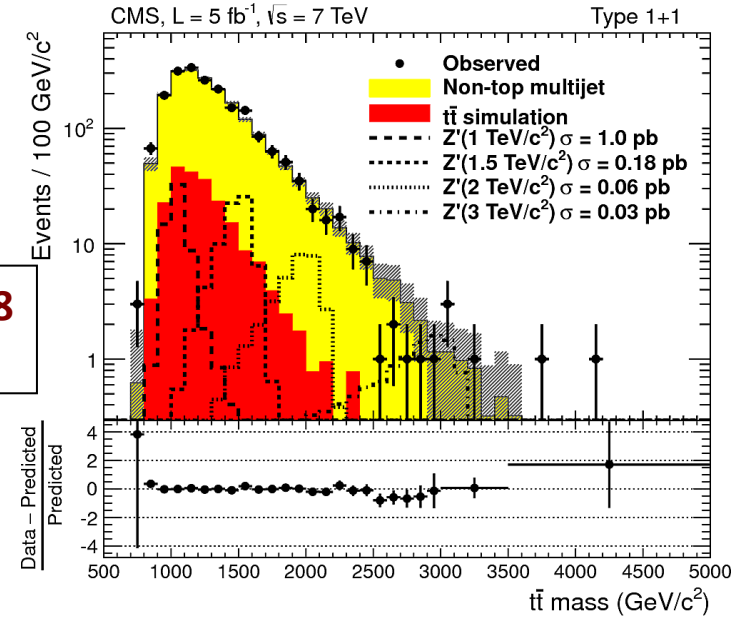




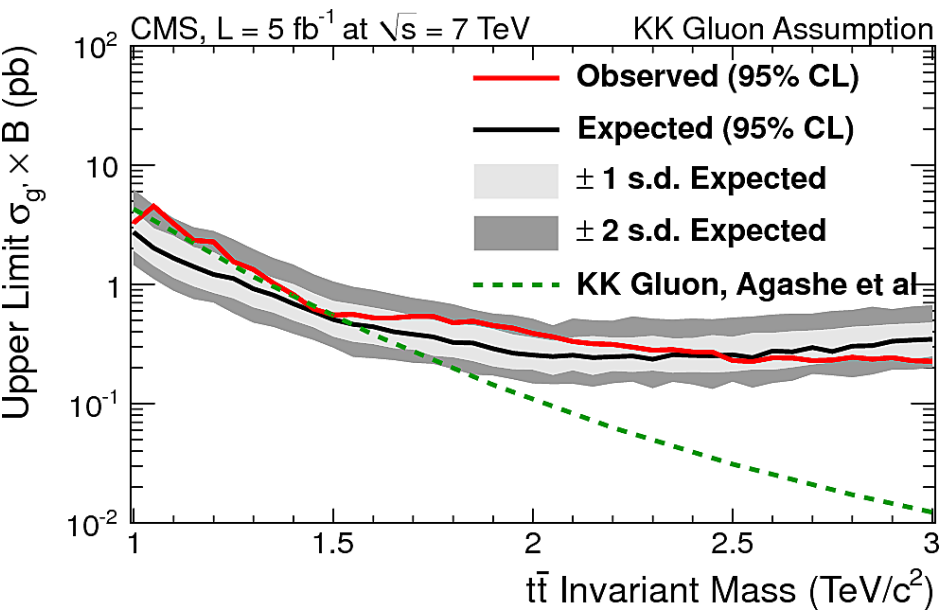
Z'(tt)

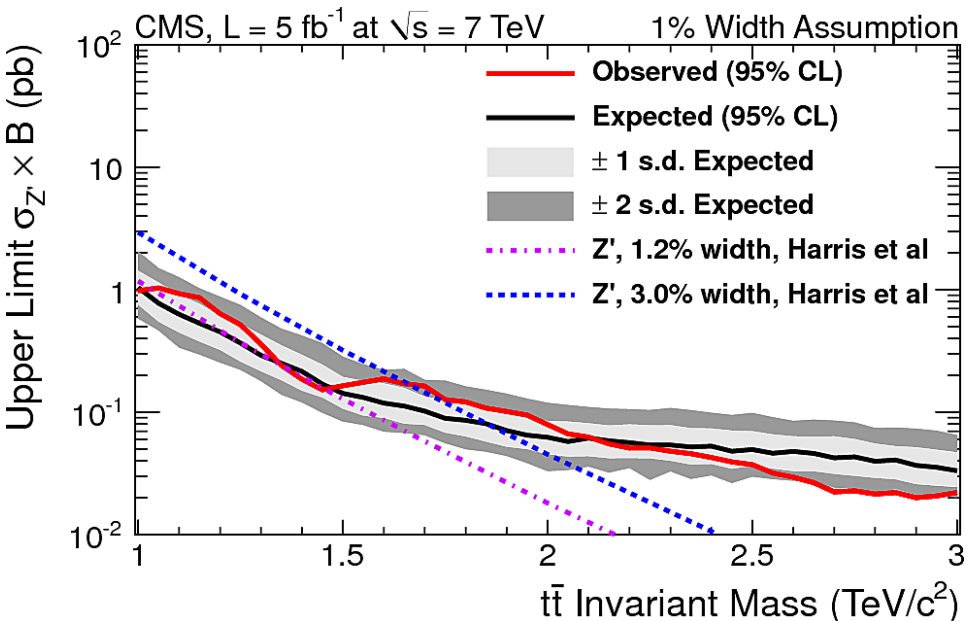
- New gauge interaction
  - Large couplings to 3rd generation
- Search for boosted top pairs
  - Sensitive to large Z' masses
  - Based on jet sub-structure
- Limits on σ x BR for varying Z' widths

arXiv:1204.2488 (JHEP)



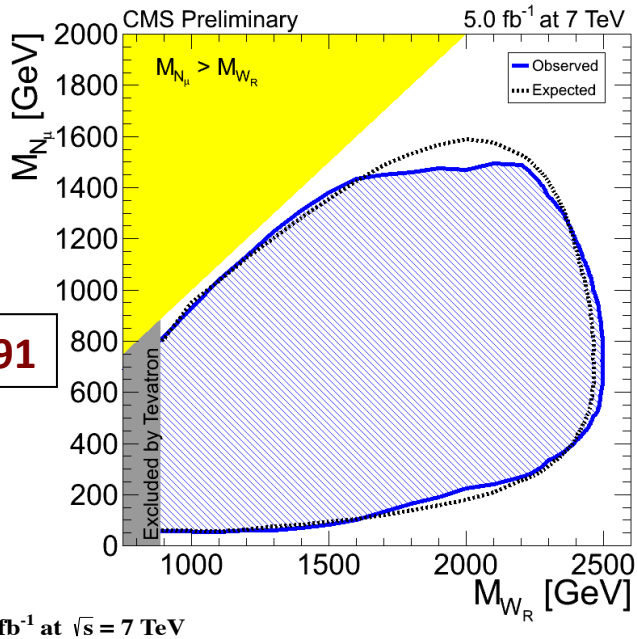
Strong limits on RS-KK gluons, other resonances decaying to $t\bar{t}$



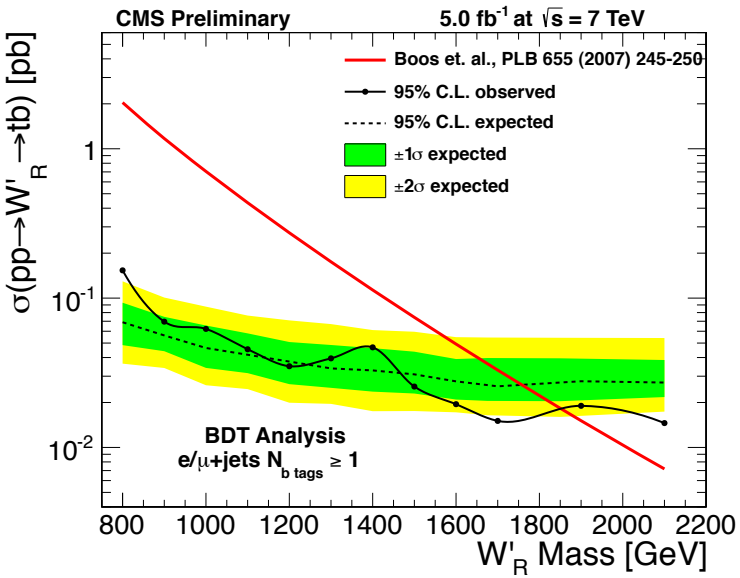


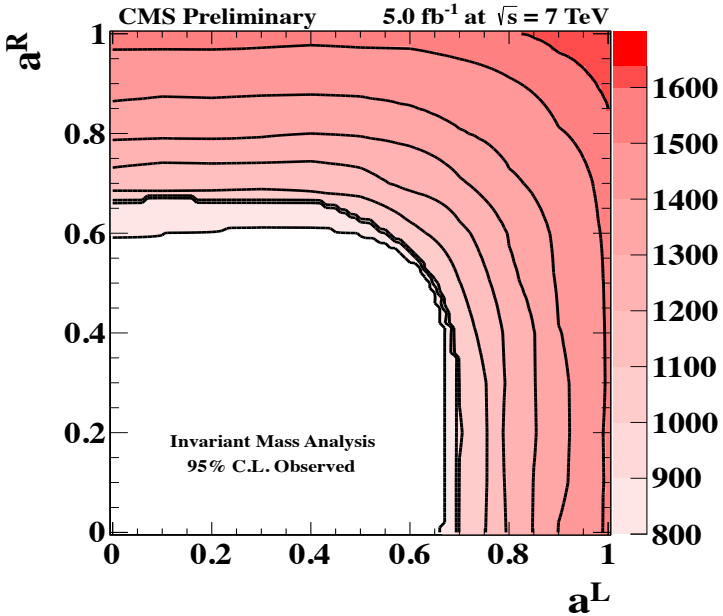
W' Bosons

- Right-handed W_R' with SM-like couplings as a benchmark model
- W'_R
  - consider decays to a muon and a heavy muon neutrino
- W'(tb)
  - Also considered arbitrary combination of left and right-handed couplings to fermions



EXO-11-091



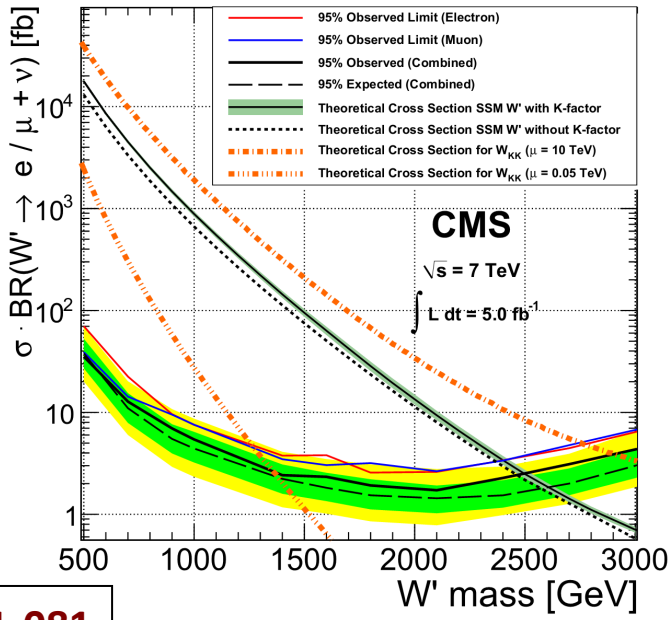


EXO-12-001

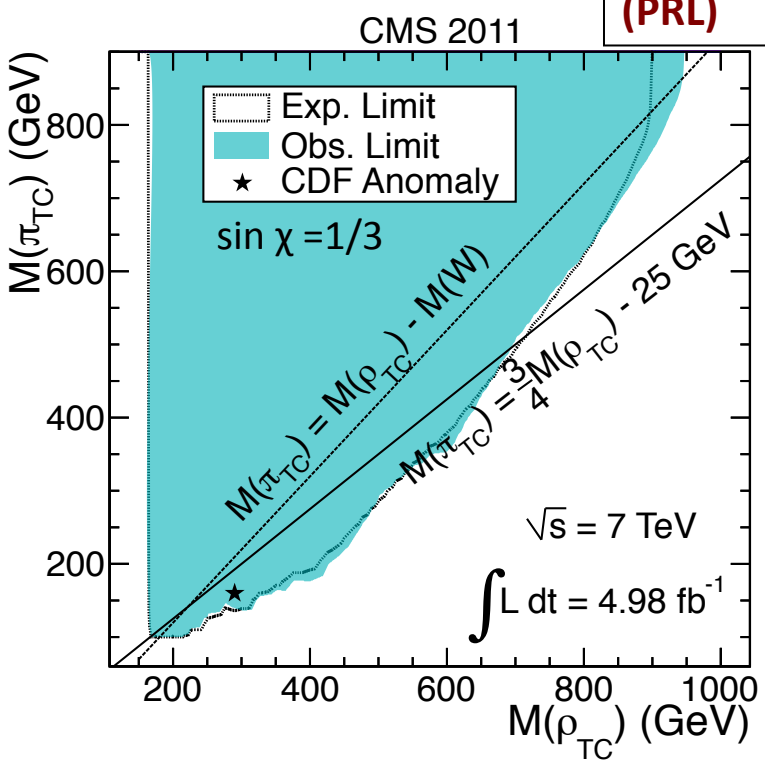
W' Bosons

- Extensive set of decay channels
  - W' (lν), W'(WZ), W'(VZ)
- Interpret results for different models and under varying assumptions
  - Kaluza-Klein W'(KK), SSM, Technicolor…

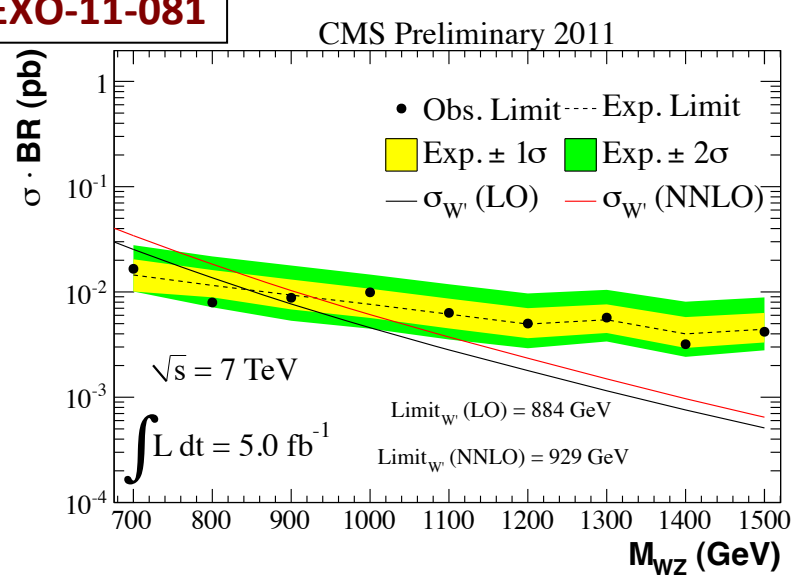
arXiv:1204.4764 (JHEP)



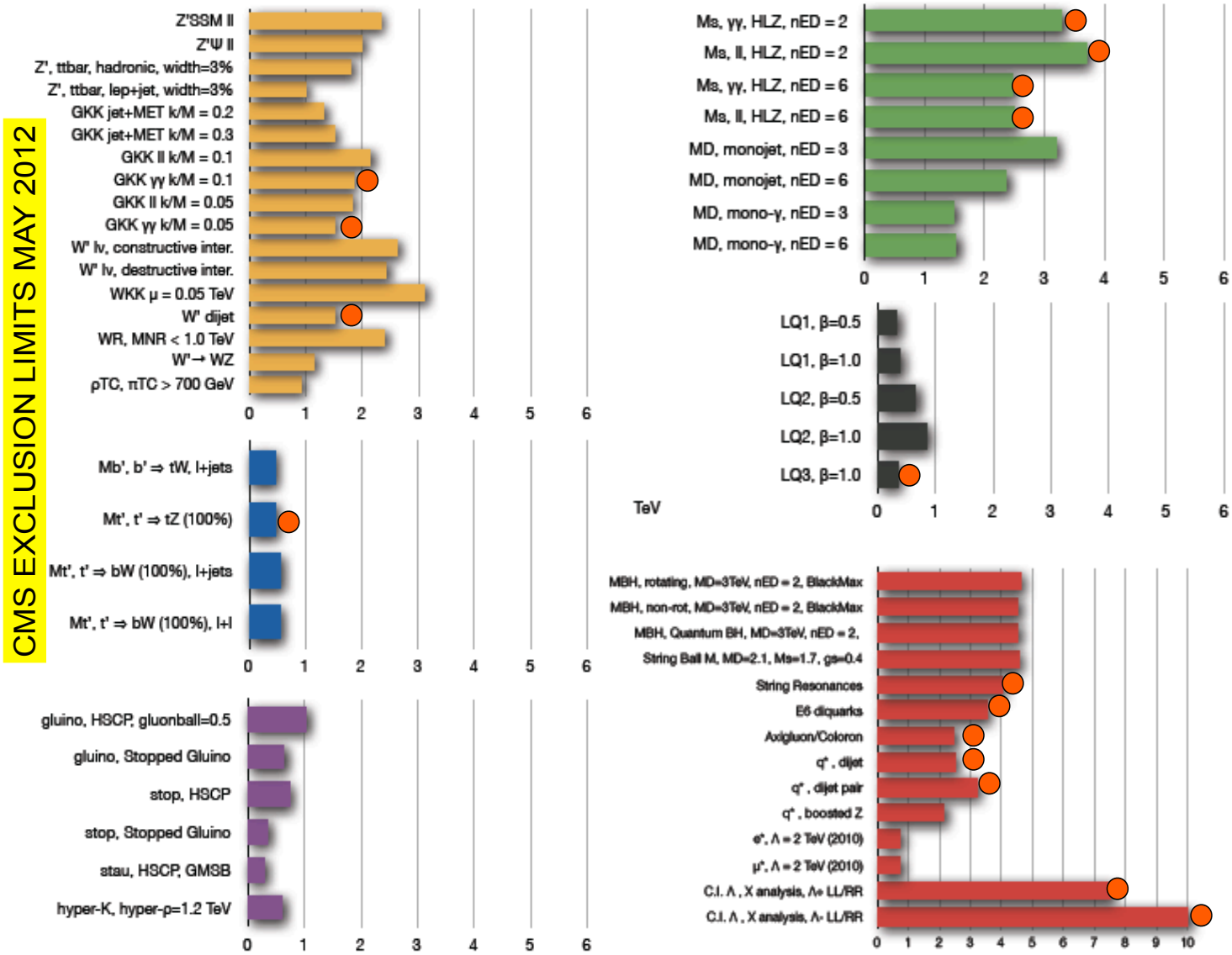
arXiv:1206.0433 (PRL)



EXO-11-081



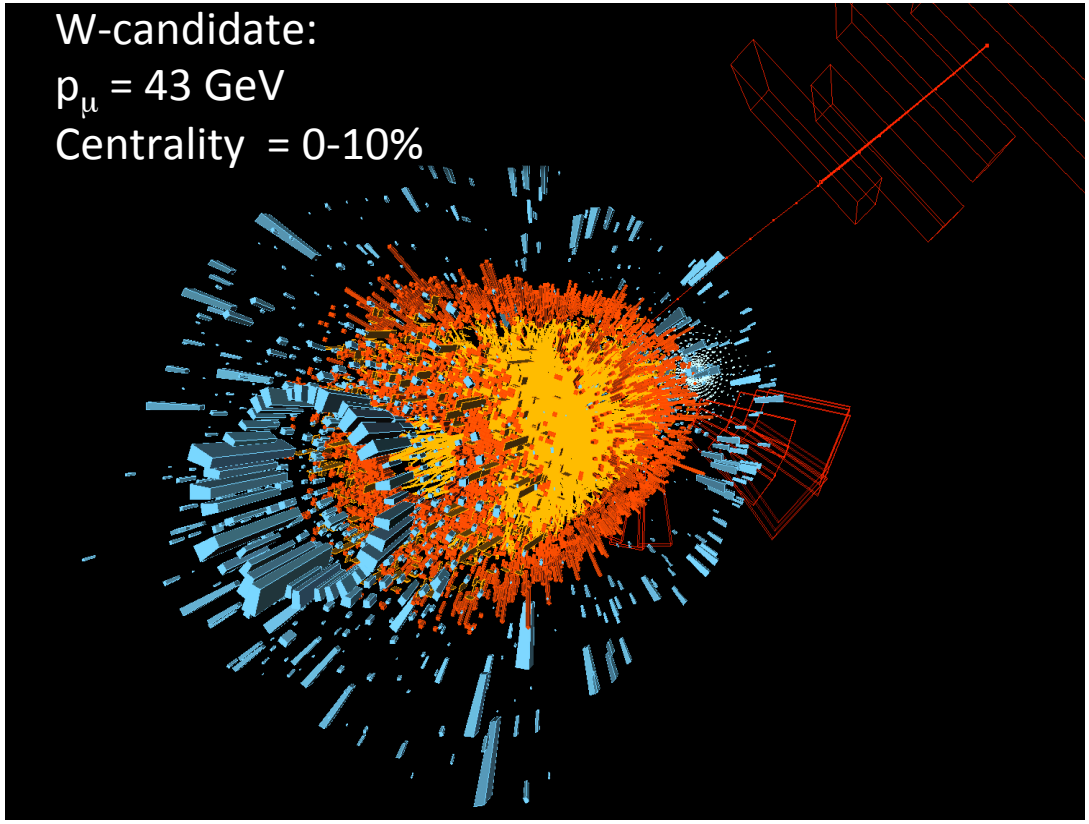
Exotica Summary



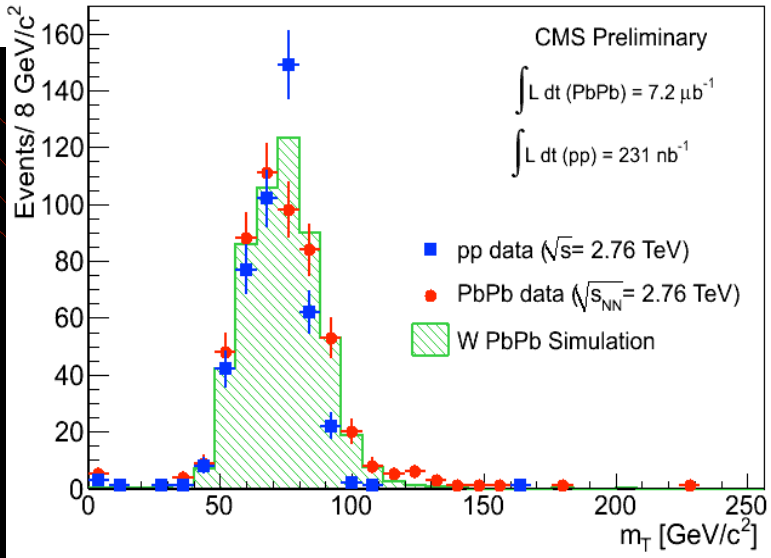
Not yet updated for full 5 fb^{-1}

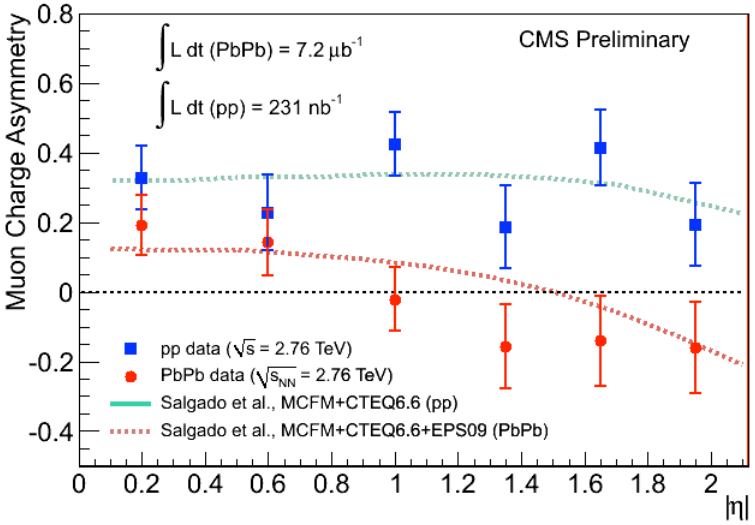
Heavy Ions

Heavy-Ion Physics: W Production



HIN-11-008



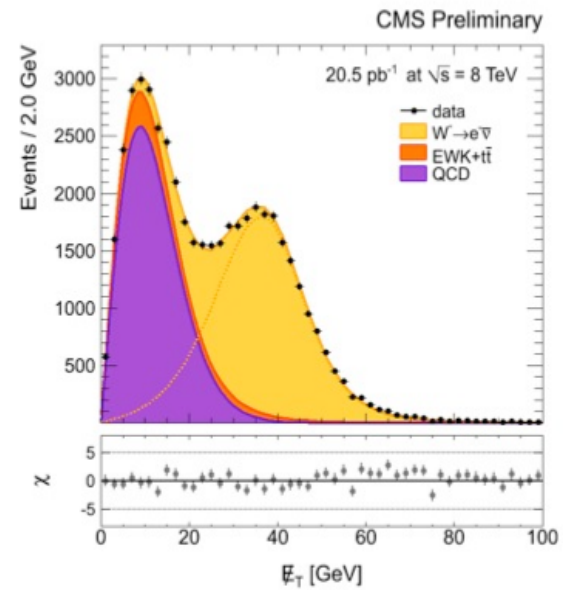


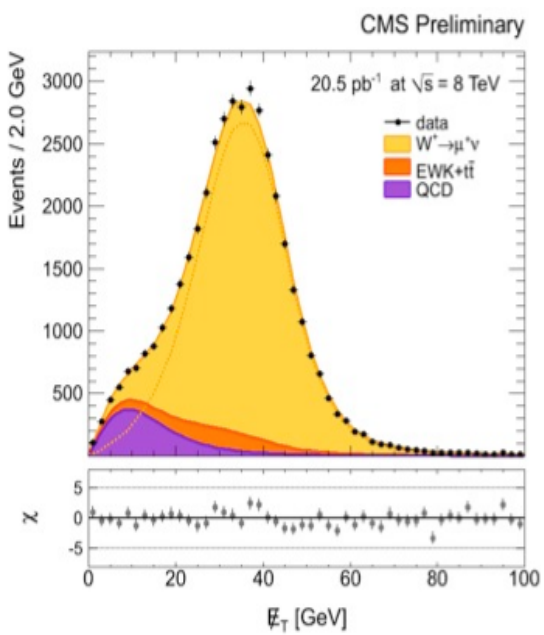
- Consistent with the pp
  - Taking into account nucleon content of colliding Ions

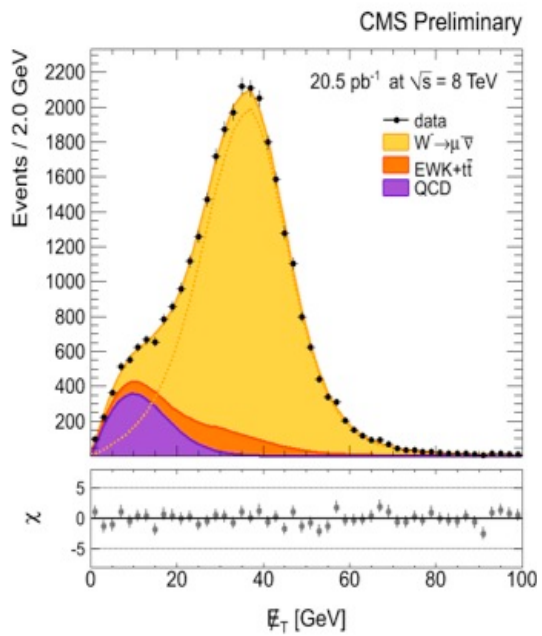
8 TeV Results

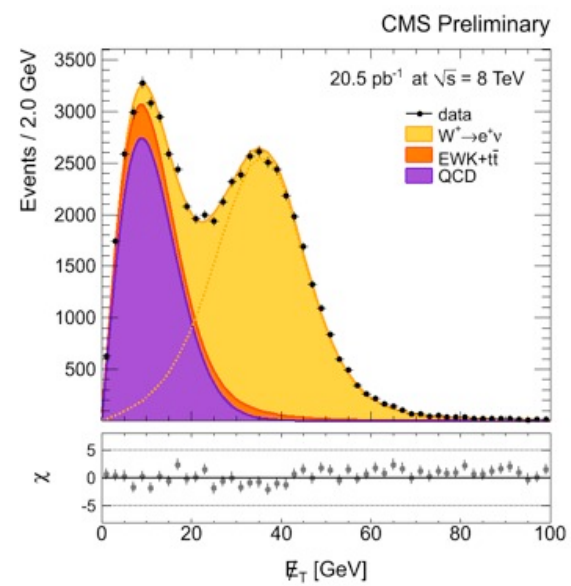
W→ eν, μν @ √s=8 TeV

- Data are special low-PU (<N>~5) runs only
  - Muon p_T > 20 GeV, |η| < 2.1, Electron E_T > 25 GeV , |η| < 2.5
  - Lepton selection identical to 2010 cross section analysis
- W signal recoil model tuned to Z data
- QCD shape tuned to non-isolated lepton data
  - Normalization of W, EWK, QCD histograms fit to the data
  - i.e. only the shapes are being tested against our modeling



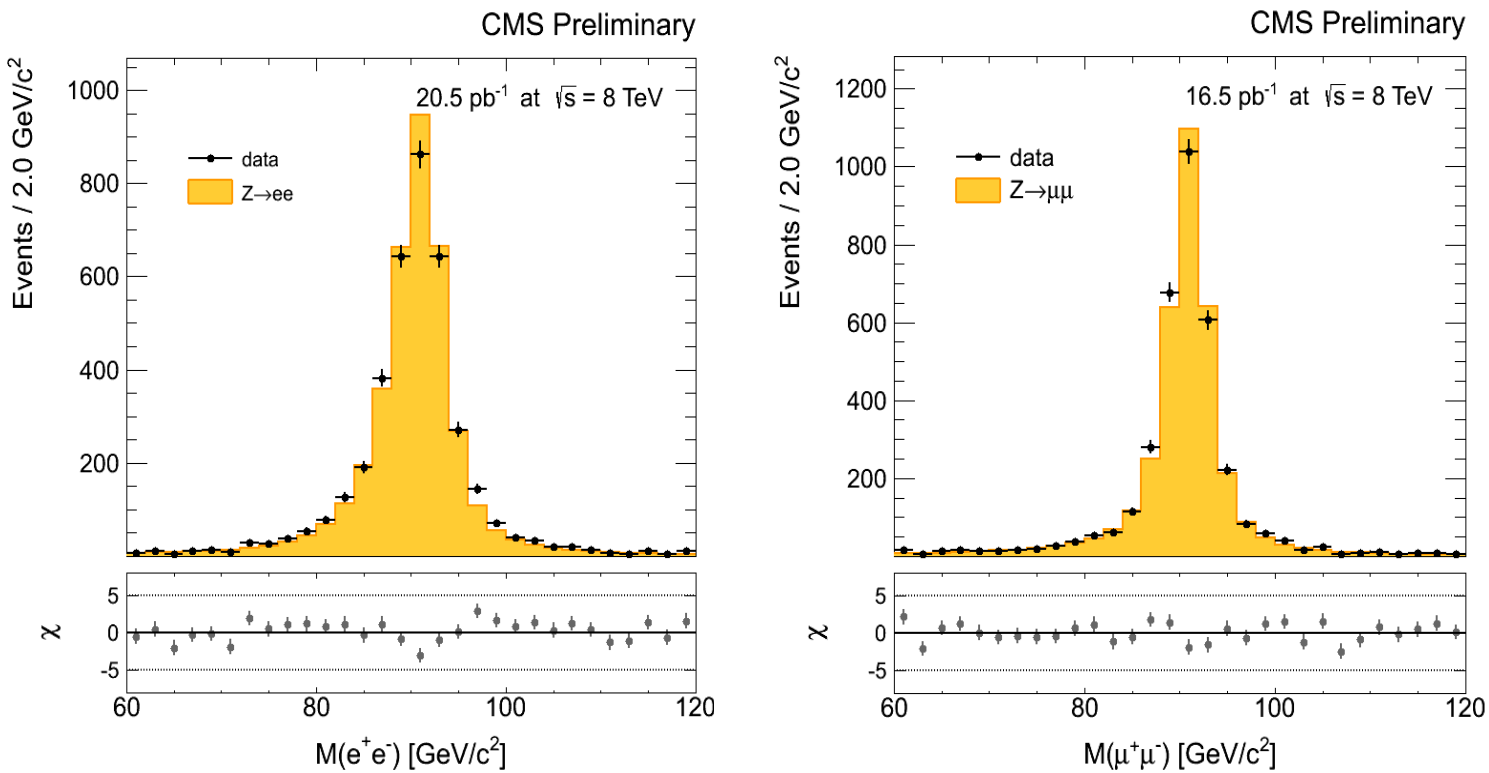






$Z \rightarrow e^+e^-$, $\mu^+\mu^-$ @ $\sqrt{s}$=8 TeV

- Data are special low-PU (<N>~5) runs only
  - Muon p_T > 20 GeV, $|\eta|$ < 2.1, Electron E_T > 25 GeV , $|\eta|$ < 2.5
  - Lepton selection identical to 2010 cross section analysis
- No lepton E_T or p_T corrections
- $Z \rightarrow e^+e^-$,$\mu^+\mu^-$ histogram is special low-PU DY MC normalized to the data



Summary

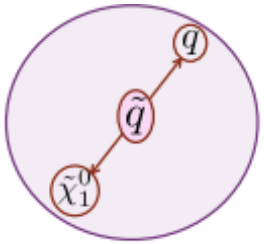
- The excellent LHC performance and smooth operation of the CMS detector allowed for a rich physics program in 2011
  - Extensive set of 2011 full dataset results and publications
- No discovery yet but vast and new territory explored
- First major results at $\sqrt{s}$ = 8 TeV in 2012 are coming soon
  - We are expanding our searches for new physics into more difficult areas
- Stay tuned…

Additional Material

Razor Variables

- Search for pair production heavy particles
  - squarks and gluinos
- Objects grouped into two "megajets"
  - perform event-by-event test that they represent visible portion of decays
- Use two kinematic variables: M_R and R
  - Evaluated in *razor* frame:

    M_R is invariant under this longitudinal boost



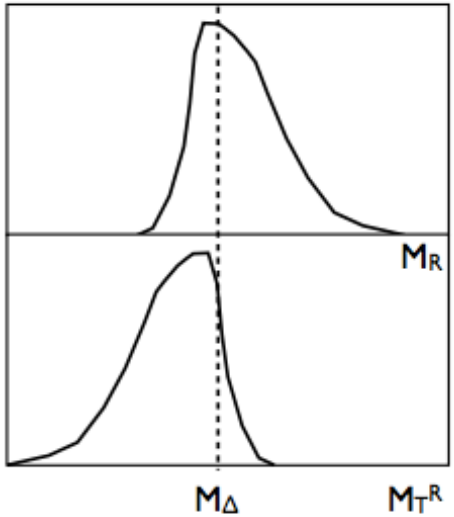
$$M_\Delta \equiv \frac{M_{\tilde{q}}^2 - M_{\tilde{\chi}}^2}{M_{\tilde{q}}}$$

$$M_R \equiv \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}\,.$$

← M_R peaks at M_Δ

$$M_T^R \equiv \sqrt{\frac{\not{E}_T(p_T^{j1} + p_T^{j2}) - \vec{\not{E}}_T \cdot (\vec{p}_T^{\,j1} + \vec{p}_T^{\,j2})}{2}}$$

← M_Δ edge in M_T^R



$$R \equiv \frac{M_T^R}{M_R}$$

← R is ratio of the two and related to MET