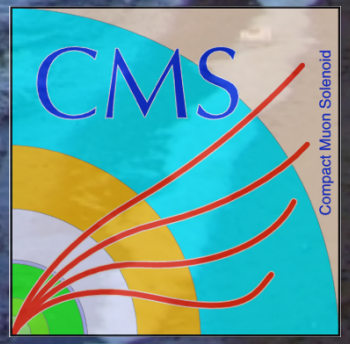
CMS RESULTS ON THE PHYSICS OF TOP QUARKS

James Keaveney

Vrije Universiteit Brussel



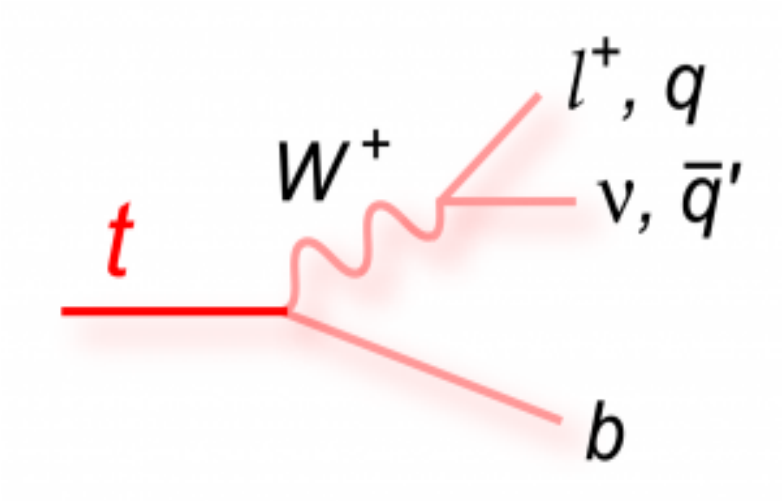
Today's talk

- Introduction and context
- Measurements of Top cross-sections
  - For Single Top measurements, see talk from Natalia Tsirova.
- Measurements of Top mass.
- Measurements of Top properties.
- Conclusions

Introduction and context

- Top physics measurements at 7 and 8 TeV are a central part of the CMS physics program.

Cross sections: provide precise test of perturbative QCD, pQCD, and constrain backgrounds in searches for new physics.



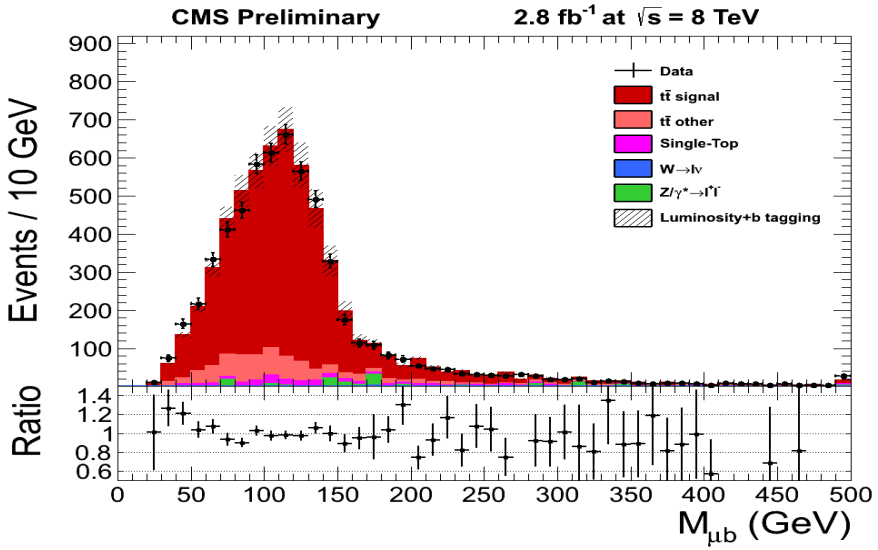
Mass: Top mass M_t, is crucial parameter of Standard Model, SM. Precise measurements provide electroweak constraints on new physics.

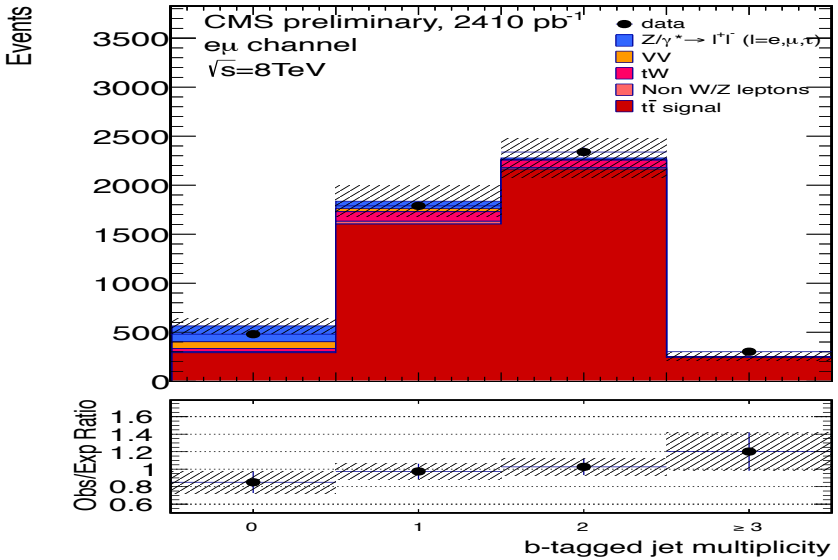
Properties: W polarisation tests V-A structure of Wtb vertex, new physics contributions can modify helicity fractions.
Searches for FCNCs in top decays sensitive to new physics.

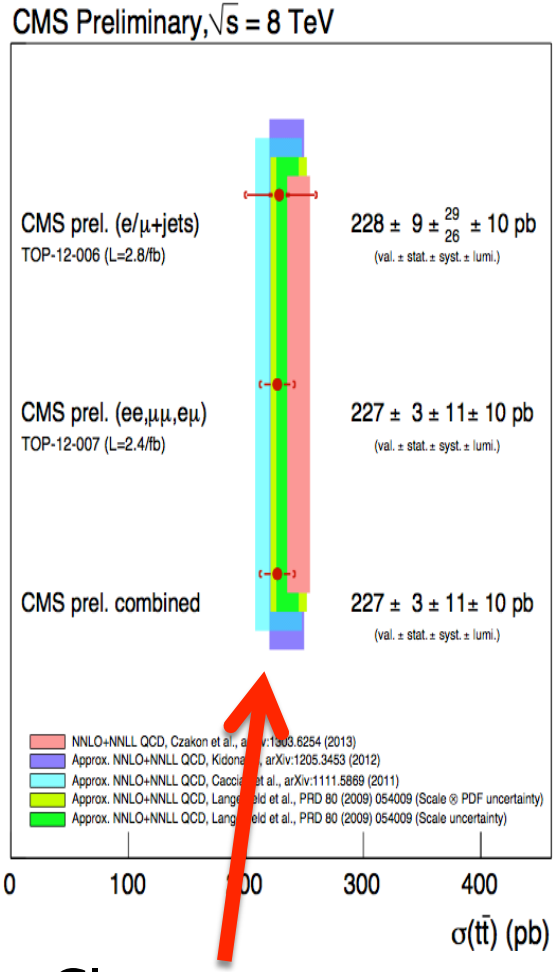
Inclusive cross sections: top pairs (8TeV) (CMS-PAS-TOP-12-007, CMS-PAS-TOP-006)

e/μ + jets:
Template fit to distribution of lepton + b-jet invariant mass.
Systematics:
b-tagging, JES.

ee/μμ/μe -
cut based, high purity
Systematics:
Lepton ID, JES.



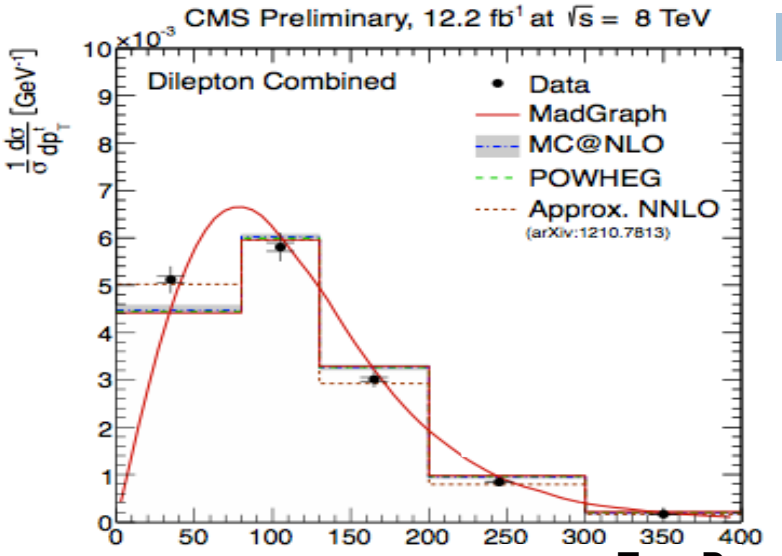




Close agreement with predictions.

Differential cross sections: top pairs (8TeV) CMS-PAS-TOP-12-028, CMS-PAS-TOP-12-041

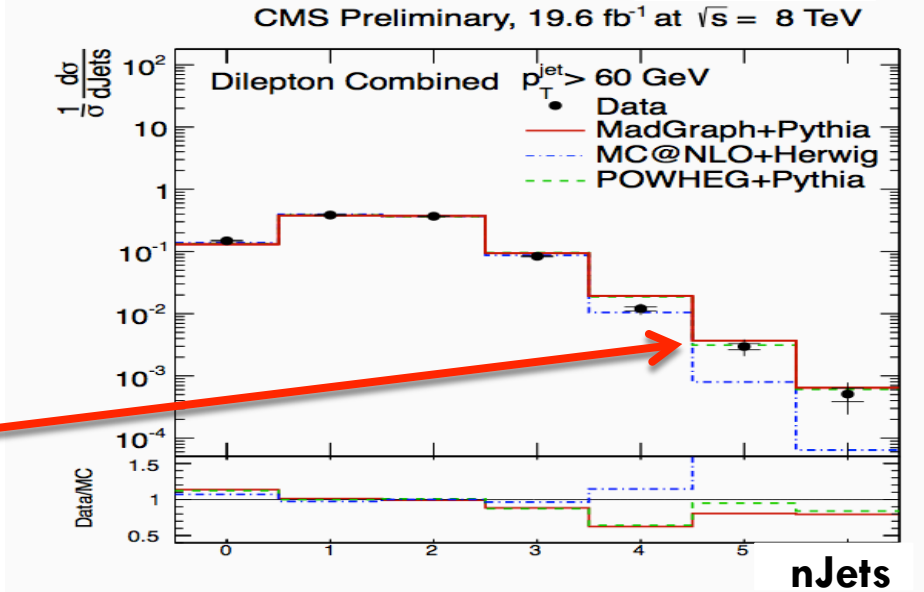
Differential cross section – top pair production as a function of the kinematics of leptons, jets, top quark and ttbar system. Compares well with approx. NNLO pQCD predictions.



Top Pt

Measurement of jet multiplicity in top pair events- differential cross-section as a function of jet multiplicity. Data compared with MADGRAPH +Pythia, MC@NLO+Herwig and POWHEG+Pythia.

Data prefers MadGraph, POWHEG to MC@NLO

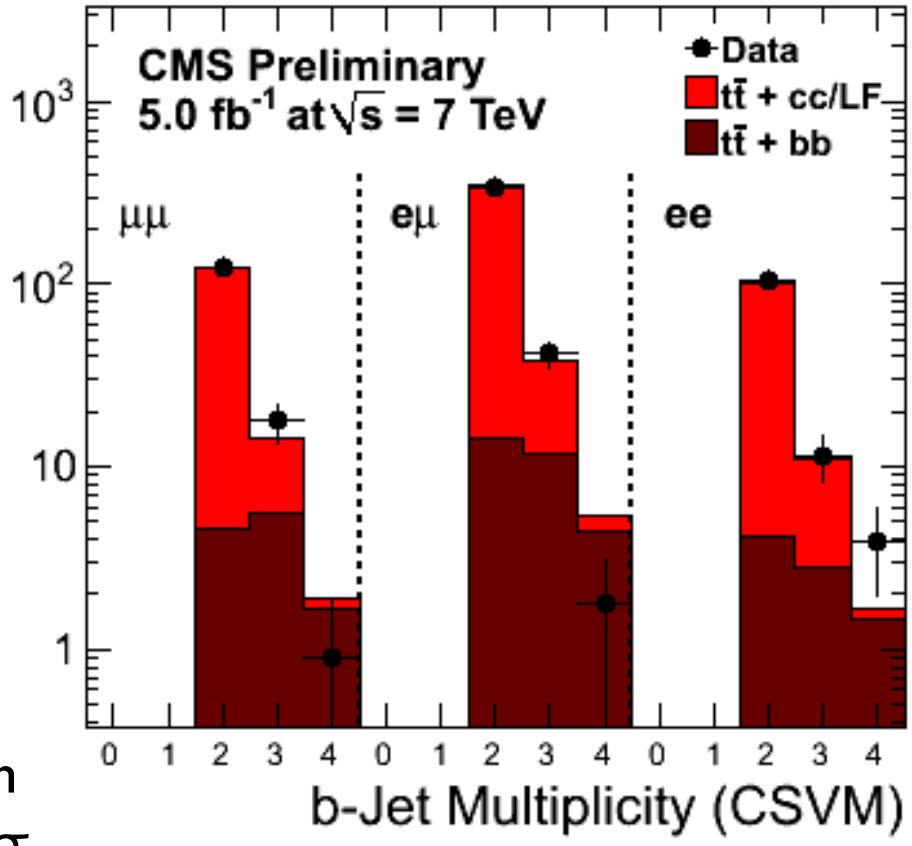


nJets

Cross sections: top pair + bottom pair (7TeV) CMS PAS TOP-12-024

First measurement of the cross section ratio: $\sigma_{ttbb}/\sigma_{ttjj}$

- The ttbb process is an irreducible background to the ttH (H->bb) process.
- ttH measurements potentially allow direct measurement of Yukawa coupling to H.
- Fit to b-jet multiplicity distribution in dilepton channel to extract $\sigma_{ttbb}/\sigma_{ttjj}$



$\sigma_{ttbb}/\sigma_{ttjj}$ = 3.6 ± 1.1(stat) ± 0.9(syst)% (MADGRAPH 1.2% POWHEG 1.3%)

Cross sections: top pair + vector boson (7 TeV)

Phys. Rev. Lett. 110 (2013) 172002

- Tri-lepton analysis:
  searches for process -

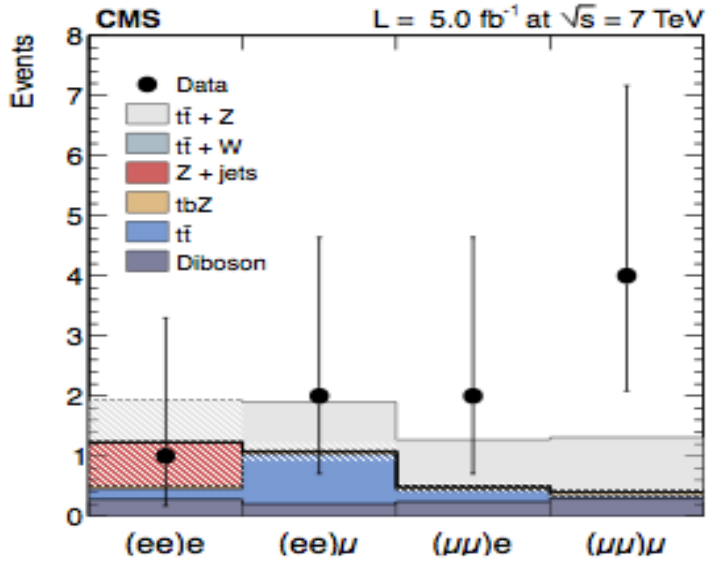
$$pp \to t\bar{t}Z \to (t \to b\ell^{\pm}\nu)(t \to bjj)(Z \to \ell^{\pm}\ell^{\mp}) \qquad (\text{with } \ell = e \text{ or } \mu)$$

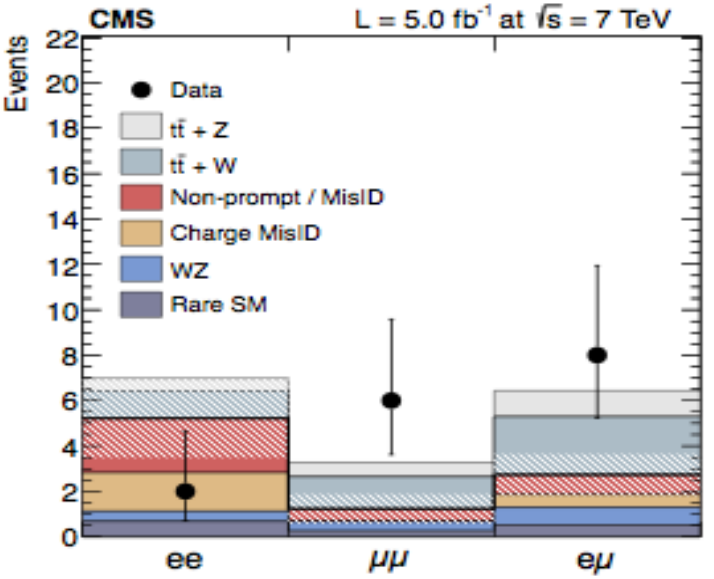
- Same-sign dilepton analysis:
  searches for processes -

$$pp \to t\bar{t}W \to (t \to b\ell^{\pm}\nu)(t \to bjj)(W \to \ell^{\pm}\nu);$$
$$pp \to t\bar{t}Z \to (t \to b\ell^{\pm}\nu)(t \to bjj)(Z \to \ell^{\pm}\ell^{\mp}) \qquad (\text{with } \ell = e \text{ or } \mu).$$

Final result:

$$\sigma_{t\bar{t}V} = 0.43^{+0.17}_{-0.15}\,(\text{stat.})\,^{+0.09}_{-0.07}\,(\text{syst.})\,\text{pb}.$$





Top mass (7TeV): JHEP 12(2012) 105 [arXiv:1209.2319]

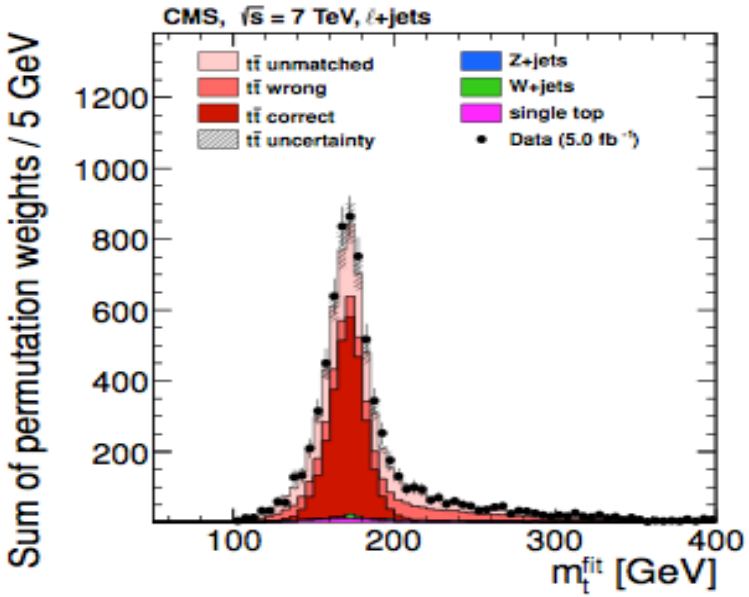
Event Selection: 1 lepton, 4 jets, 2 b-tagged jets.

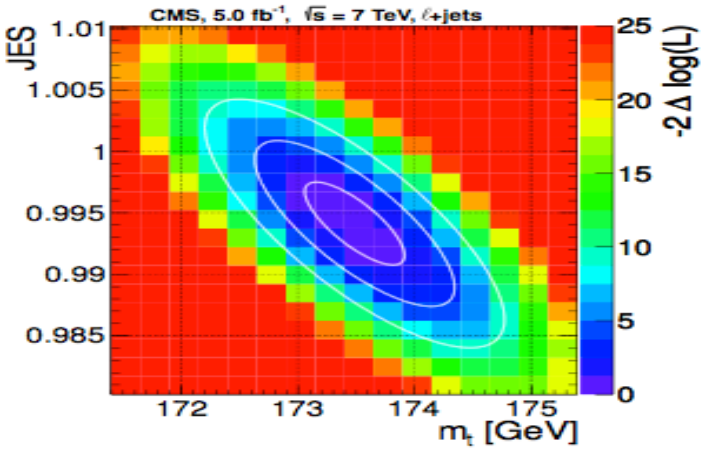
Kinematic fit to jet combinations to extract top mass.

Fit solutions weighted by fit probability to suppress effect of wrong combinations.

2D Max. Likelihood fit to extract M_t and JES

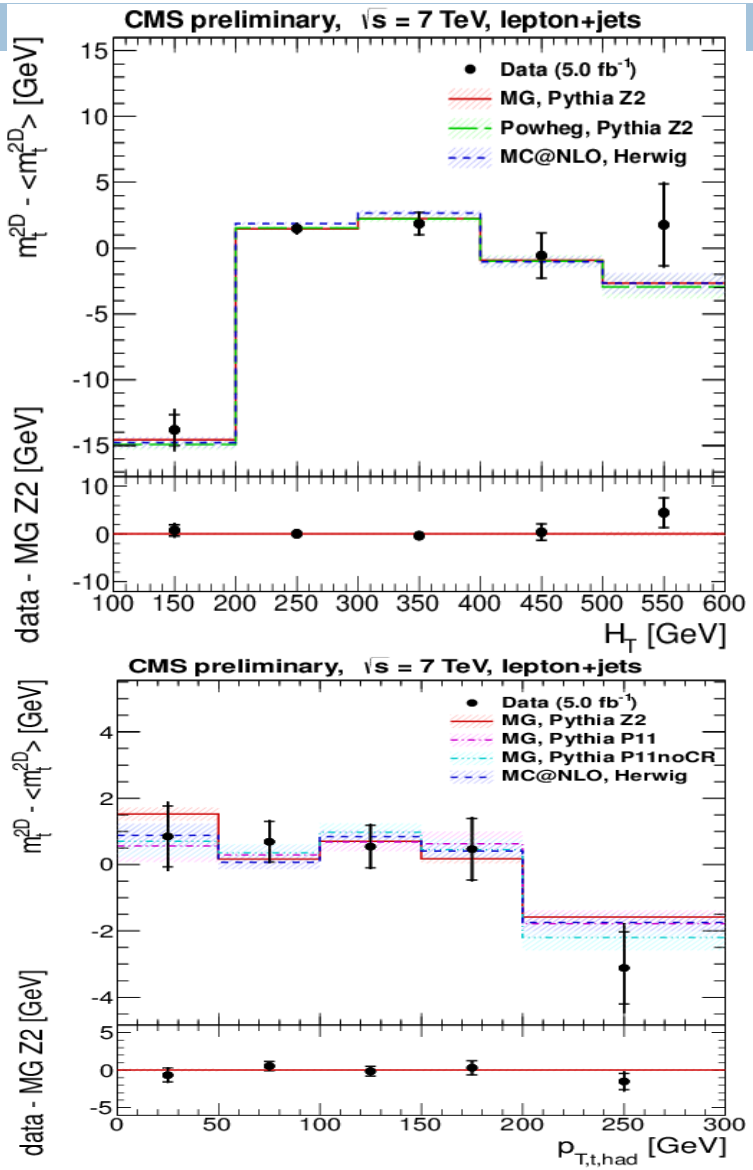
m_t = 173.49 ± 0.43(stat. + JES) ± 0.98 (sys.) GeV





Study of the dependence of the top-quark mass measurement on event kinematics (7TeV): CMS-PAS-TOP-12-027

- First data study of possible kinematic biases in the measurement of M_t
- M_t is determined in bins of numerous kinematic observables.
- Effects on M_t well reproduced by MADGRAPH, POWHEG and MC@NLO.

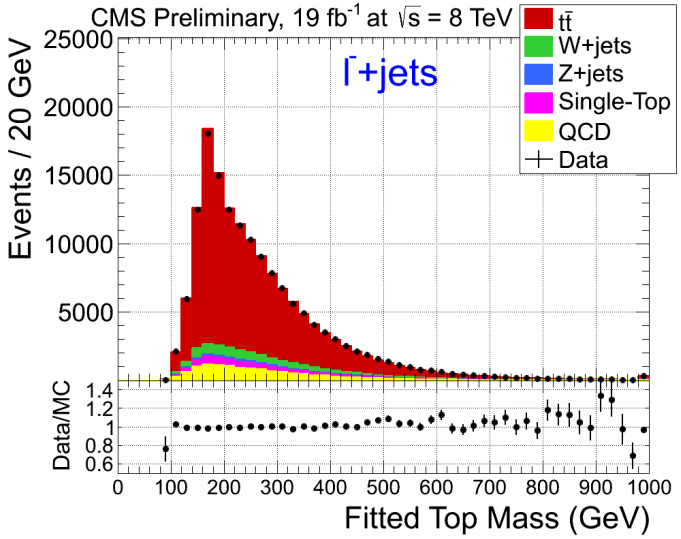


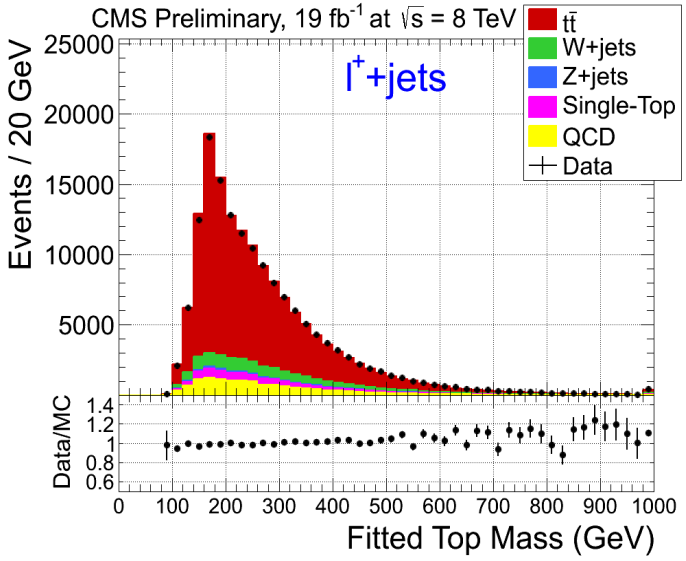
Top mass difference (8TeV) CMS-PAS-TOP-12-031

Tests CPT invariance -> involved in extensions of the Standard Model.

Kinematic fit in lepton (anti-lepton) + jets events to extract anti-top (top) masses and

$\Delta M_t = M_t - M_{anti\text{-}t}$





Final result:

$$\Delta m_t = -272 \pm 196 \text{ (stat.)} \pm 122 \text{ (syst.) MeV}$$

Significantly more precise than previous measurements.

Consistent with CPT invariance.

Top properties: Search for FCNC in top decay (8 TeV)
CMS PAS TOP-12-037

Search for decay chain

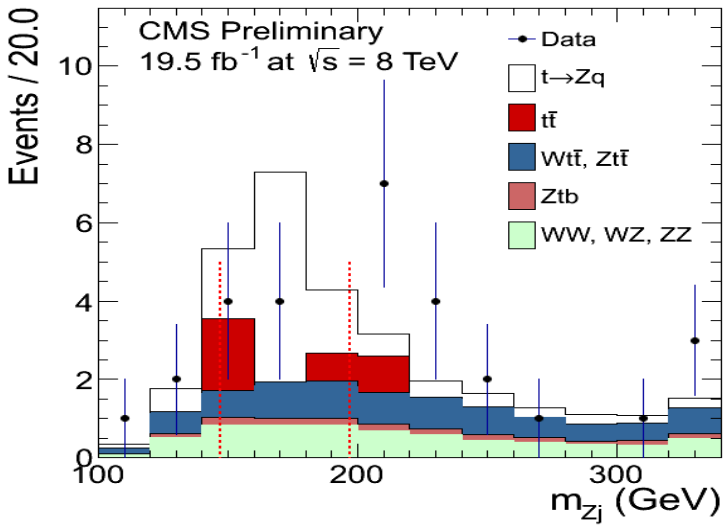
$t\bar{t} \rightarrow Wb+Zq \rightarrow l\ \nu\ b + l\,l\,q$

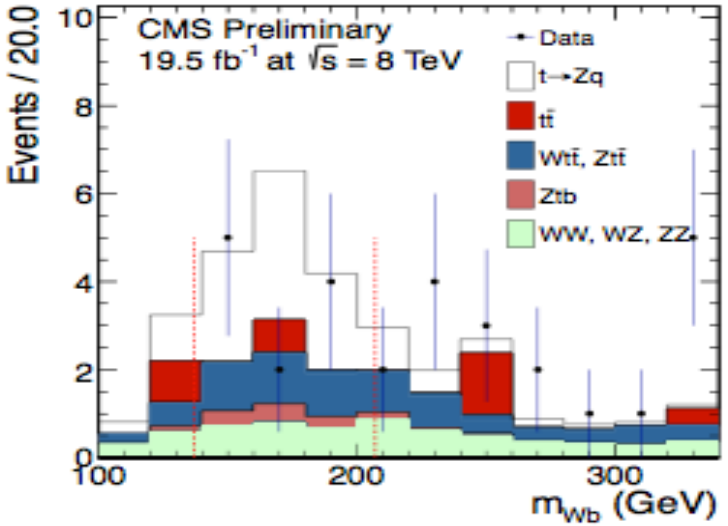
- Highly suppressed in SM, but enhanced in new physics models.

Event selection: eee, eeμ μμe or μμμ, 2 jets, 1 b-jet and missing transverse energy > 30 GeV

Reconstruct top candidates from Wb and Zj systems

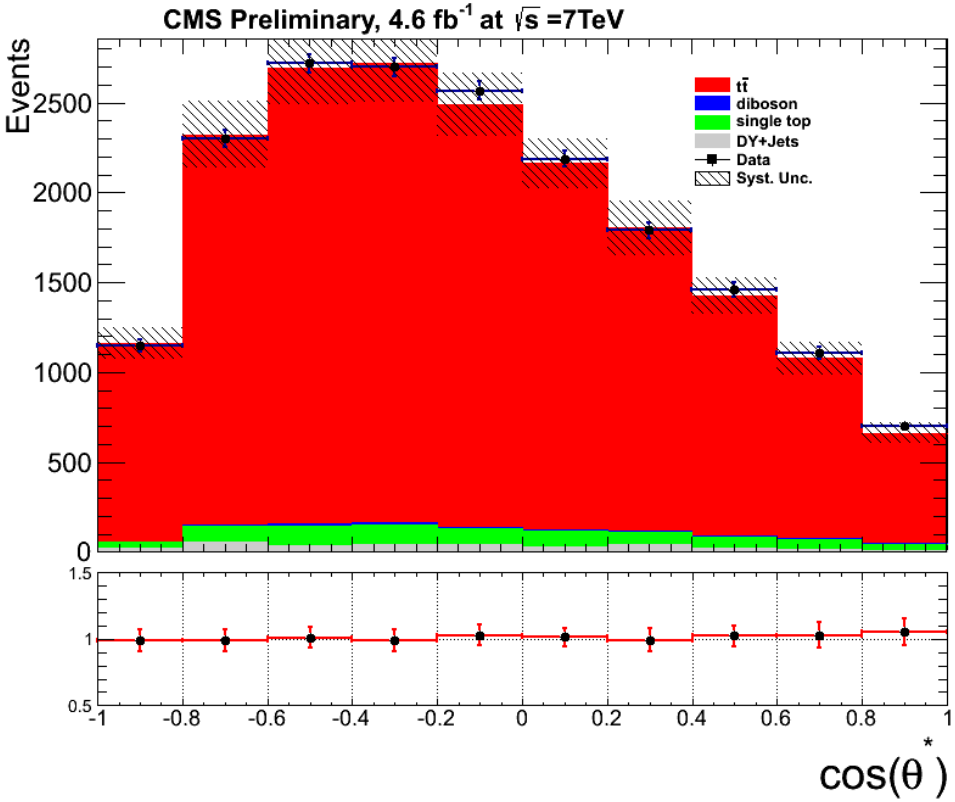
Br.(t → Zq) greater than 0.07 % excluded @ 95 % C.L.





Top properties: W polarisation (7TeV) CMS-PAS-TOP-12-015

- Test V-A structure of Wtb vertex
- W helicity fractions (FL, F0, FR) sensitive to new physics. In limit of massless leptons, FR=0.
- Extract fractions from fit to θ^* distribution.
- θ^* = angle between the charged lepton in the W rest frame and the W boson in the top rest frame



FL = 0.288 ± 0.035(stat) ± 0.040(sys)
F0 = 0.698 ± 0.057(stat) ±0.063(sys)
FR = 0.014 ± 0.027(stat) ± 0.042(sys)
Consistent with SM.

Conclusions

- Large and varied Top quark physics program ongoing at CMS.
- Measurements of cross sections (tt, ttbb, ttV) provide tests of pQCD and contraints on background to new physics searches.
- Measurements of top mass (m_t, $\Delta m_{t\text{-}tbar}$) provide tests of SM consistency and CPT invariance and constrain new physics models.
- Measurements of top properties (W polarisation, FCNCs) are sensitive to the presence of new physics.

Top sector tested to higher precision than ever before…

No sign of deviations from SM observed.