Search for Heavy Resonances in Top Quark Pair Production

Thomas Peiffer

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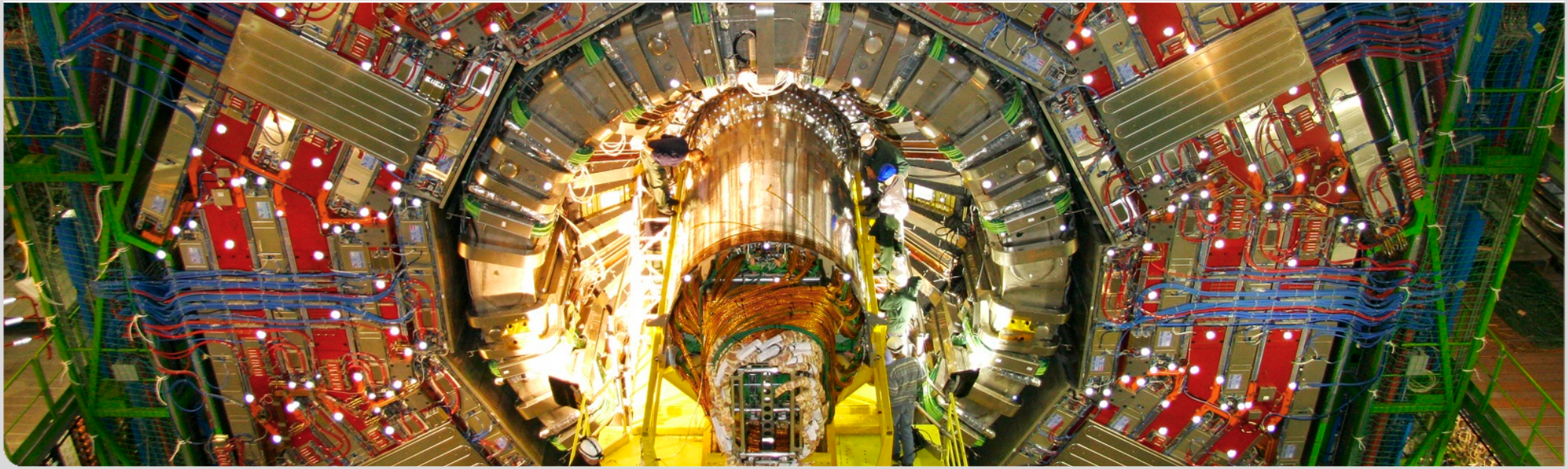
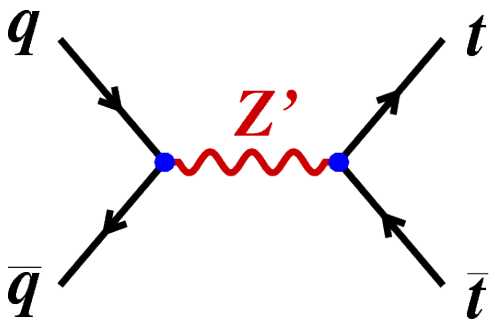
Institut für Experimentelle Kernphysik, Karlsruhe Institute of Technology



Search for Heavy Resonances

- Top quarks play important role in many new physics scenarios.
- New physics might also show up as resonance in the $M_{t\bar{t}}$ spectrum directly.
- Possible candidates for such resonances:
  - Kaluza-Klein gluons
  - Topcolor Z'
  - Exotic heavy Higgs bosons
  - ...

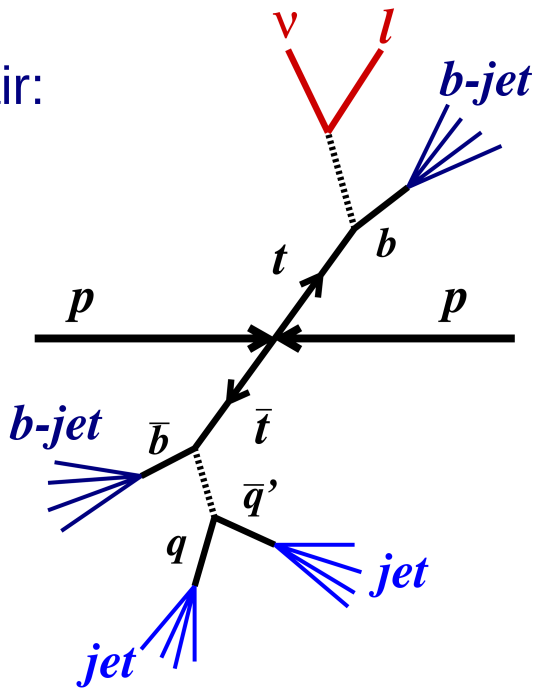


- Presented measurement: model independent search for narrow resonances in the muon+jets decay channel.

Event Kinematics

Top quarks originating from a heavy resonance decay are produced with large boost

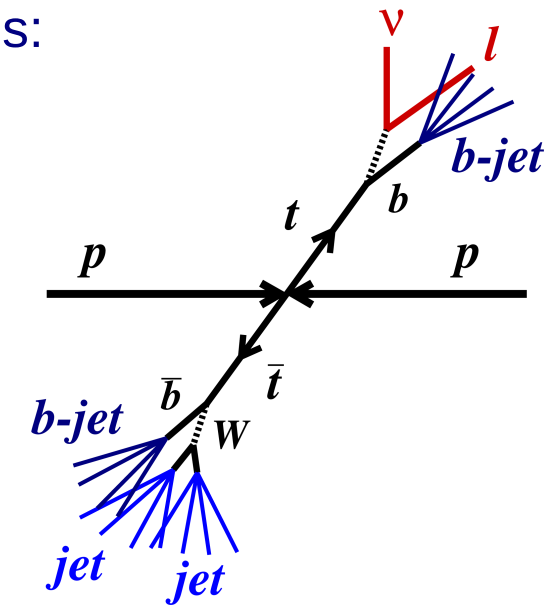
SM top pair:



Signature:

- one charged lepton
- missing transverse energy (neutrino)
- 4 jets

Boosted tops:

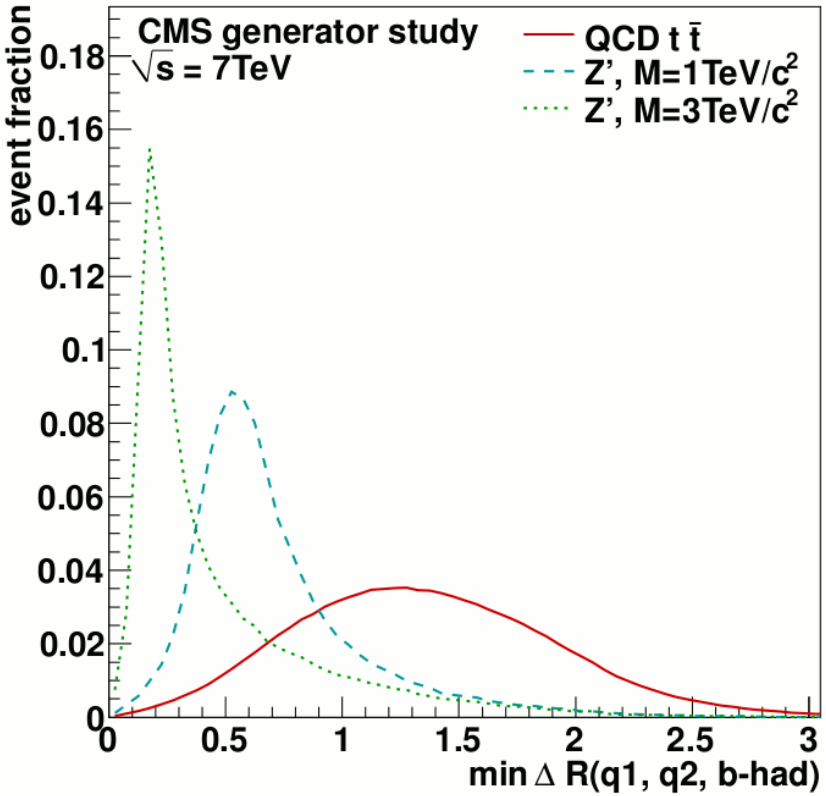


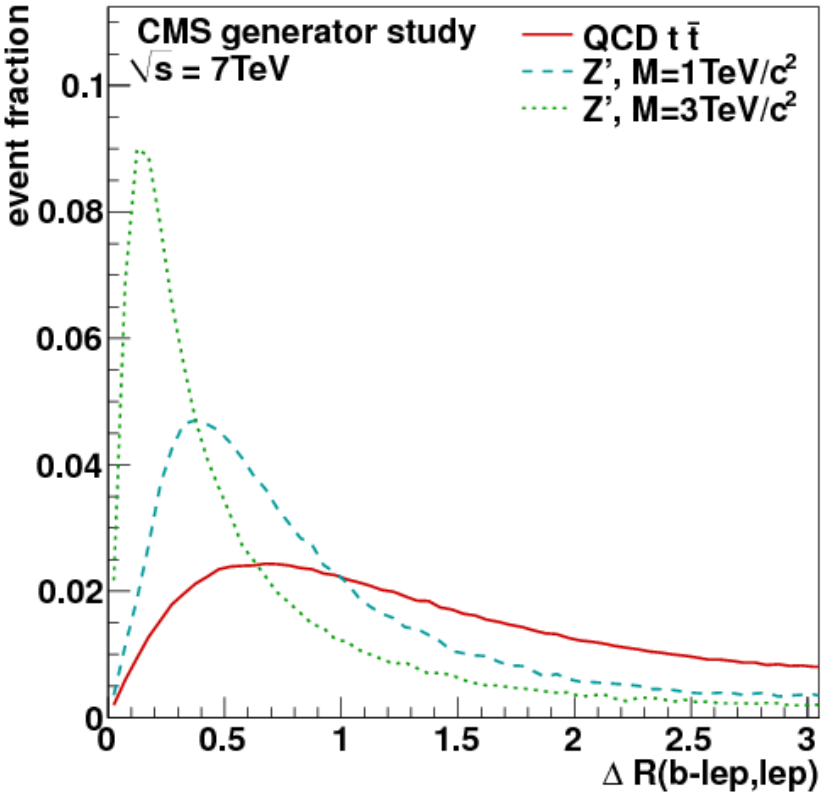
Signature:

- one (often non-isolated) charged lepton
- missing transverse energy
- 2 or more high-energetic jets

Event Kinematics

Distances between the decay products of the top quarks:





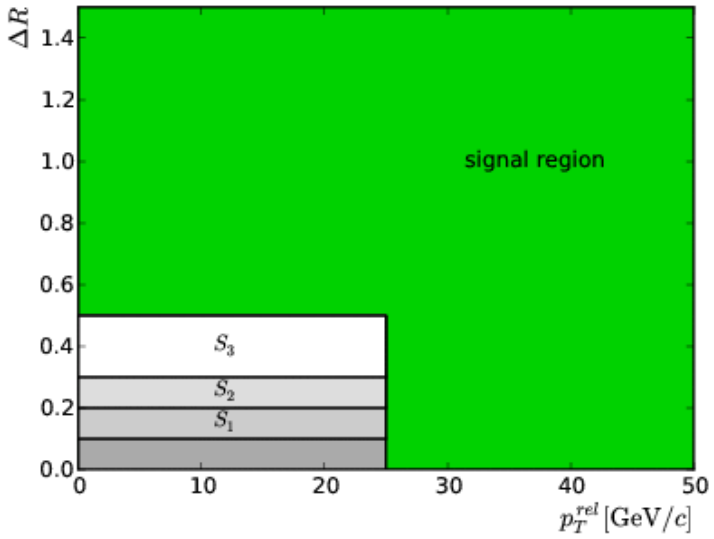
Generator study with MadGraph for l+jets decay channel

Selection

- CMS data with L_{int}=1.1 fb^{-1}
- single muon trigger
- at least 2 jets with p_T>50 GeV/c and |η|<2.4
- leading jet with p_T>250 GeV/c
- one muon with p_T>35 GeV/c and |η|<2.1
  - instead of isolation cut: combined 2D cut on $p_{T,rel}$ and ΔR(l,jet)
- $H_{T,lep}$>150 GeV ($H_{T,lep}=p_{T,lep}+E_T^{miss}$)

Inverted 2D cut is utilized to model QCD background from data.

Process	N_{exp}			ϵ [%]
	Jet cut	Lepton cut	$H_{T,lep}$ cut	
W+jets	2780.7	2157.4	1385.9 ± 93	3.9×10^{-3}
Z+jets	452.3	393.4	204.3 ± 13	5.9×10^{-3}
QCD $t\bar{t}$	1090.8	613.9	385.3 ± 60	0.21
Single-Top	73.7	40.0	26.0 ± 1.8	0.058
QCD multijet	—	—	57.2 ± 9	—
Total background	—	—	2058.7 ± 130	—
Data	—	—	1817	—
Z' ($M = 1$ TeV/c^2)	125.7	58.7	46.5	4.1
Z' ($M = 2$ TeV/c^2)	306.6	130.2	121.8	10.7
Z' ($M = 3$ TeV/c^2)	294.6	119.7	113.6	9.9



Reconstruction

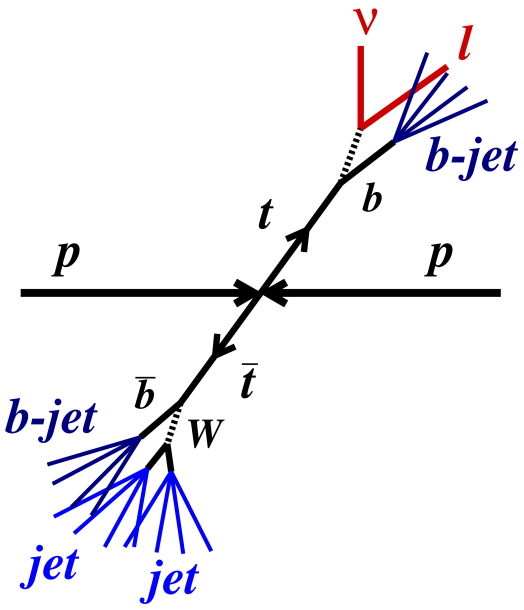
A new reconstruction technique of the top 4-momenta has to be developed in the high mass selection (only 2 jets required, decay products not well separated).

- Assign each jet to either the leptonically or hadronically decaying top quark or to none of them.
- One or two solutions for neutrino momentum from W mass constraint
- Choice of hypothesis:
  - 1st: reconstruct leptonic top:
    Take hypotheses with smallest:

$$\Sigma \Delta R = \Delta R(b_{lep}, t_{lep}) + \Delta R(\nu, t_{lep}) + \Delta R(lep, t_{lep})$$

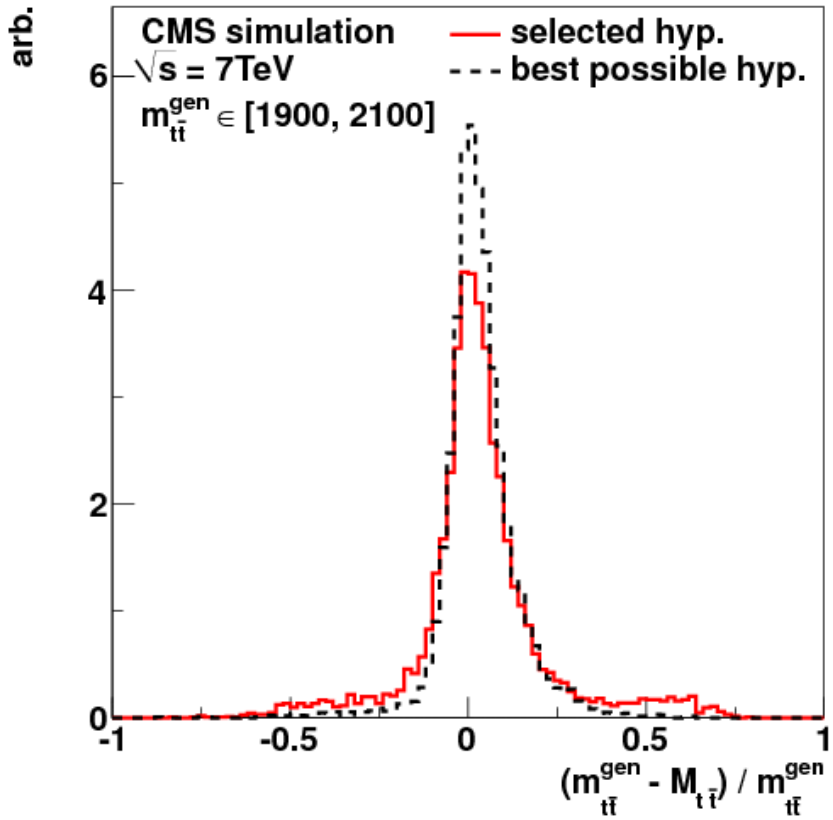
  - 2nd: reconstruct hadronic top:
    From all remaining hypotheses choose hypothesis with largest:

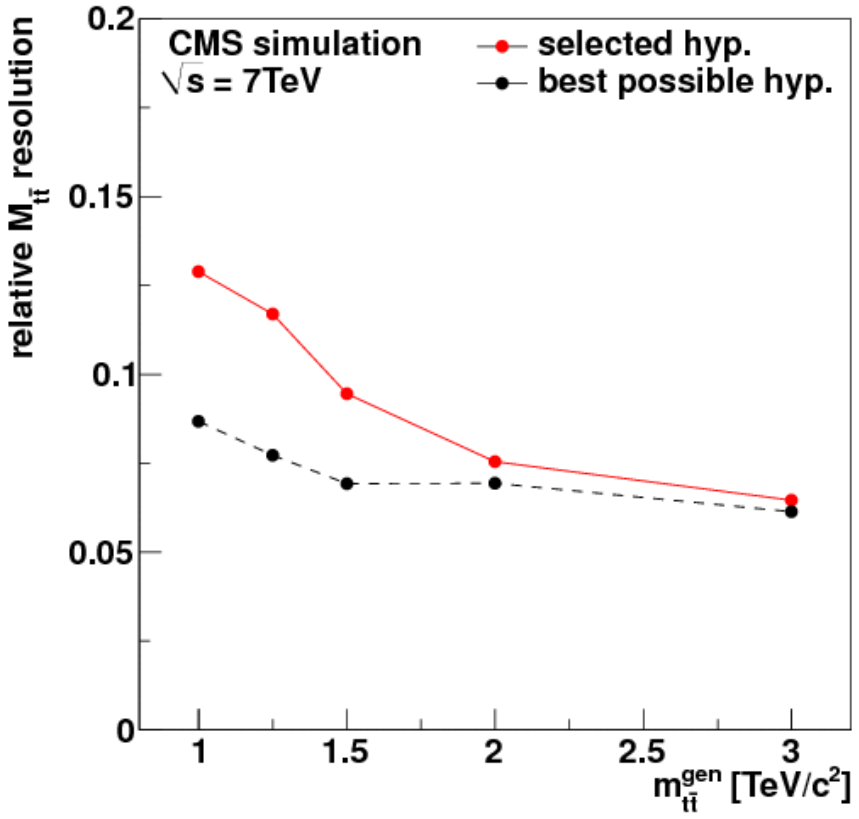
$$\Delta R(t_{had}, t_{lep})$$



Reconstruction Performance

- Relative mass resolution for selected reconstruction hypothesis compared to best possible one in simulation:

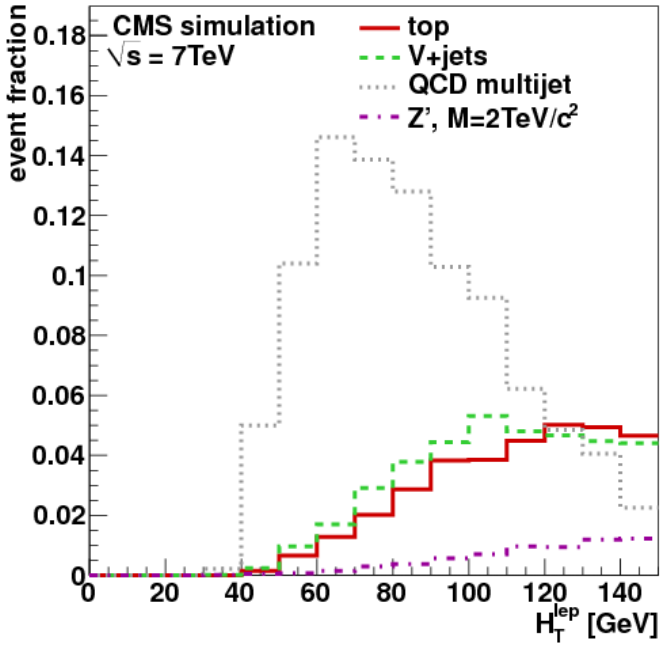


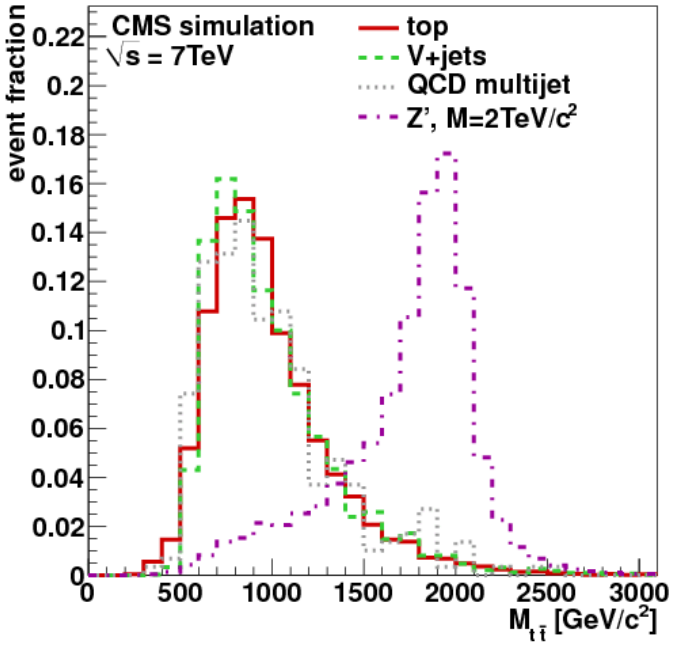


- Best resolution reached for resonance masses of several TeV.

Likelihood Fit

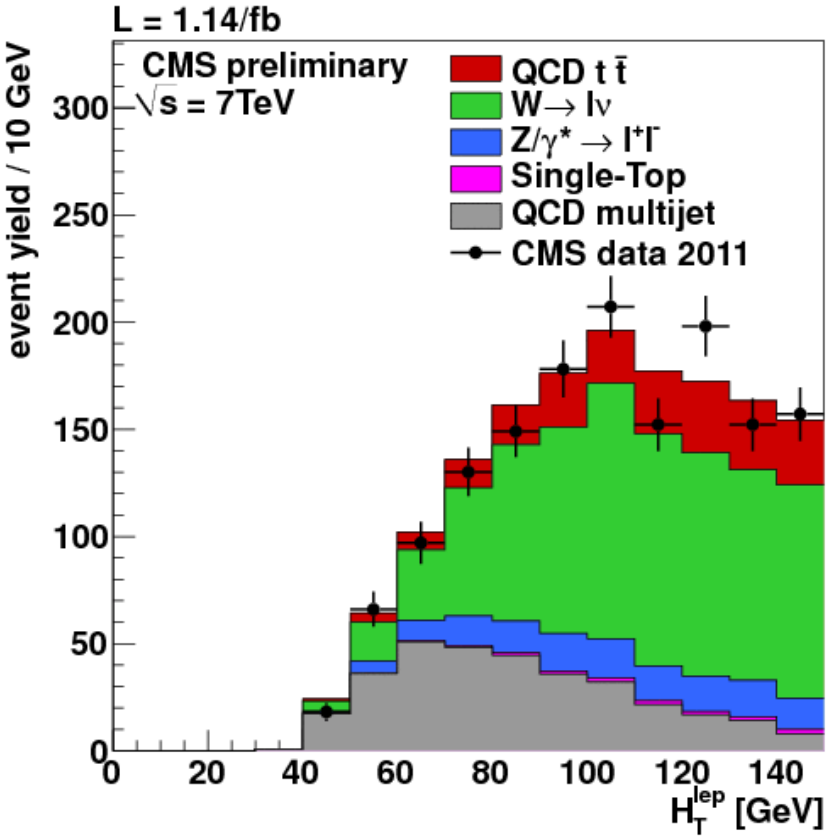
- Binned likelihood fit is performed to estimate signal fraction or upper limits on resonance cross section.
- Fit is performed simultaneously for $M_{t\bar{t}}$ distribution and $H_{T,lep}$ in sideband to constraint the background contributions.
- Systematic uncertainties are included as additional nuisance parameters.
- Considered systematics: jet energy scale, jet energy resolution, Q2 scale, matching threshold, ISR/FSR, QCD model, luminosity, PDF

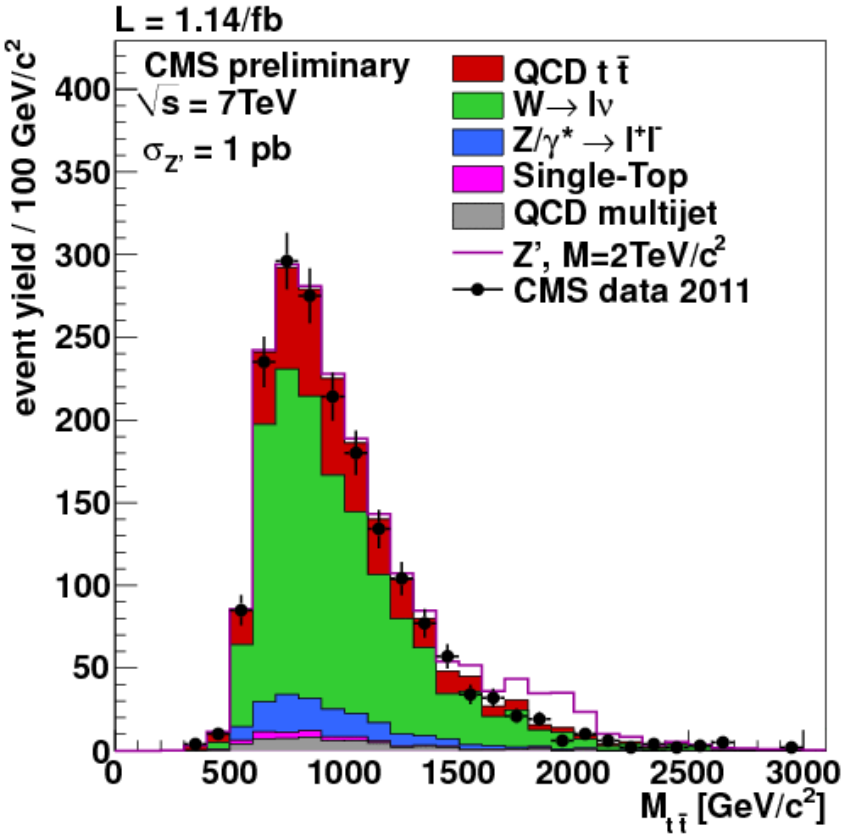




Results

- Background templates scaled to most probably value given by the likelihood fit:



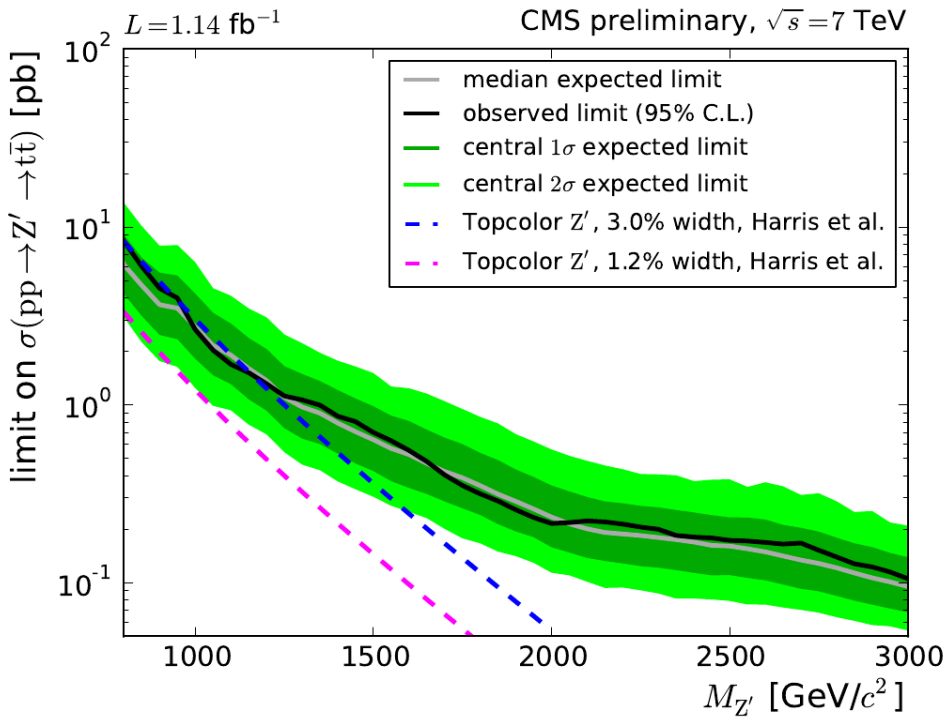


- Good agreement between data and background models.

Results

- Upper limits on resonance cross section obtained from Bayesian inference of the likelihood function.
- Expected limits from pseudo experiments with background only are in good agreement with observed limits.

- Obtained limits are below 1 pb for resonance masses above 1.3 TeV/c^2.
- Can exclude topcolor Z' reference model with a width of 3% for masses around 1 TeV/c^2.



Conclusion

- New physics could be visible as resonance in $M_{t\bar{t}}$.
- Developed strategy to search for such resonances in the multi-TeV range using the muon+jets decay channel.
- Obtained limits are of the order of 1 pb or smaller with 1.1 fb^{-1} of CMS data.
- No hint for new physics yet.

Reference:

CMS-PAS EXO-11-055