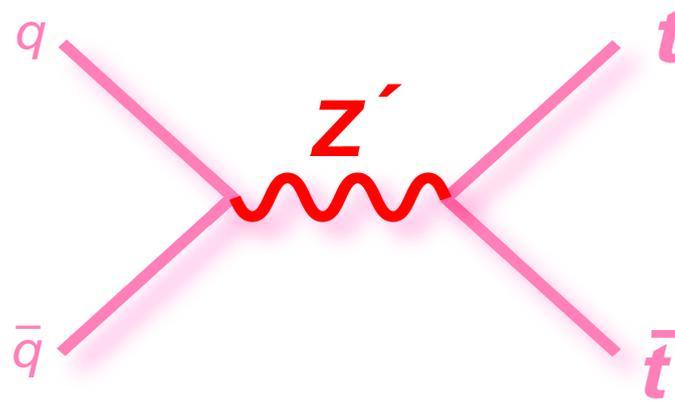




ATLAS



Search for $t\bar{t}$ resonances in ATLAS and CMS at $\sqrt{s}=7$ TeV

GDR Terascale @Clermont

Outline:

- Motivations
- Theoretical models
- ATLAS results
- CMS results
- Summary

Reina Camacho Toro
LPC-Clermont Ferrand

GDR @Terascale
LPC-Clermont Ferrand, France
April 23-25th 2012

Why do we search for top resonances?

Top quark



- Discovered in 1995 at TEVATRON
- Electric charge: $2/3 e$
- Spin: $1/2$
- **Mass: $172.0 \pm 0.9 \pm 1.3 \text{ GeV}/c^2$**
- **LHC is a top factory**

→ $\sigma = 165 \text{ pb}$ (7 TeV) : 20 time larger than TEVATRON
→ 10 $t\bar{t}$ pairs per minute
@ $10^{33} \text{ cm}^{-2}\text{s}^{-1}$



■ **Heavy top mass could hint an intimately connection between the top and beyond the Standard Model (BSM) physics**

■ Many models (e.g. Technicolor, extra dimensions models as Randall Sundrum or ADD, little Higgs...) predict the existence of new particles that couples preferentially to the top quark

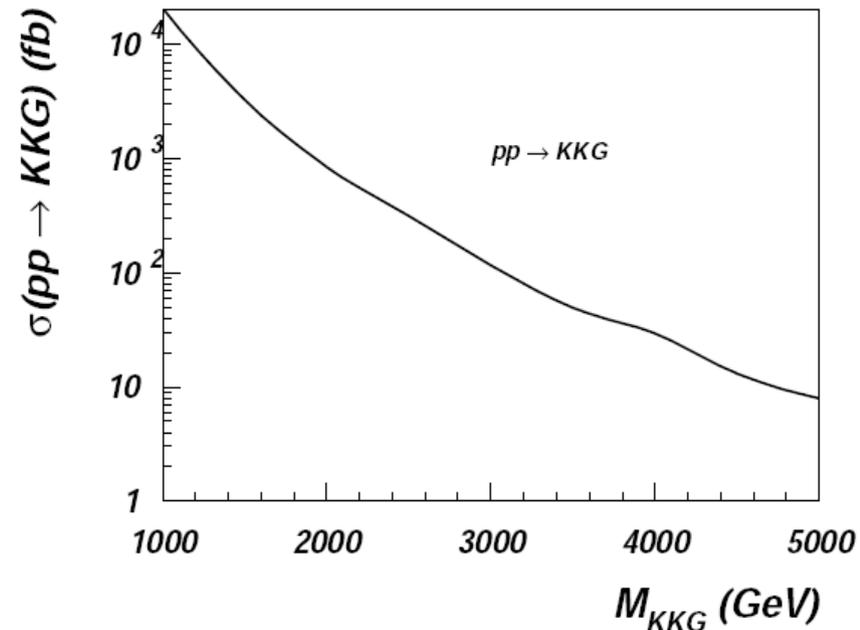
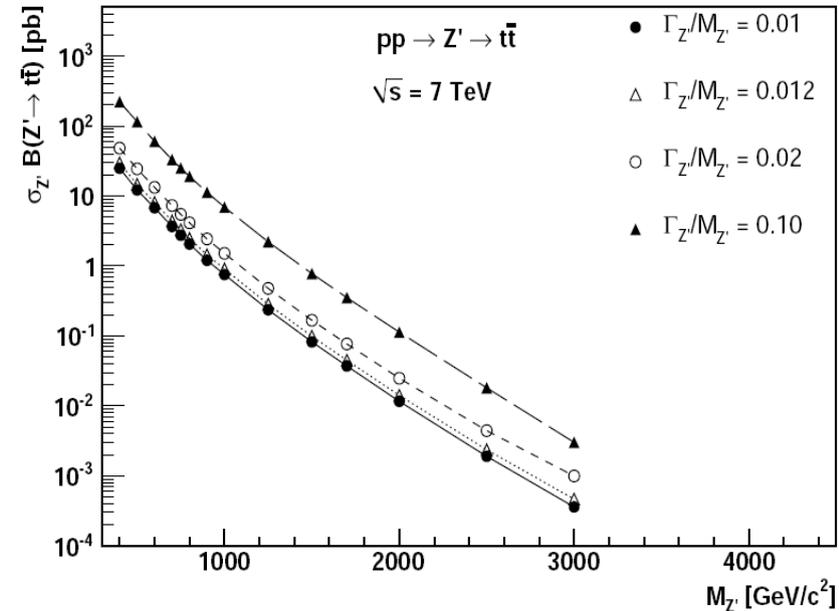
■ **$t\bar{t}$ production seems to be a good and natural place to look**

■ Others possibilities to keep in mind: forward-backward asymmetry, top polarisation...

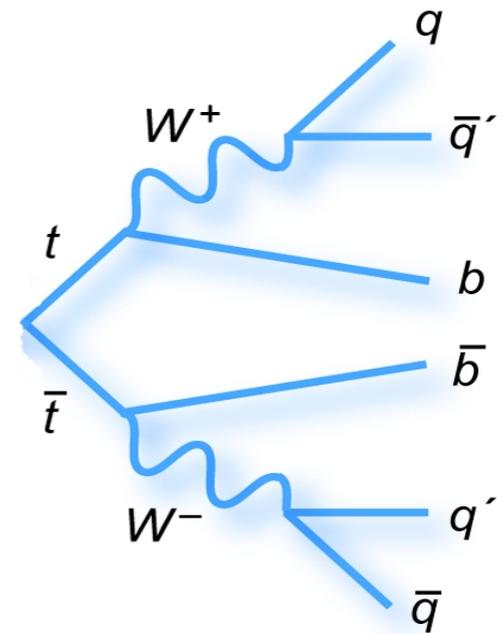
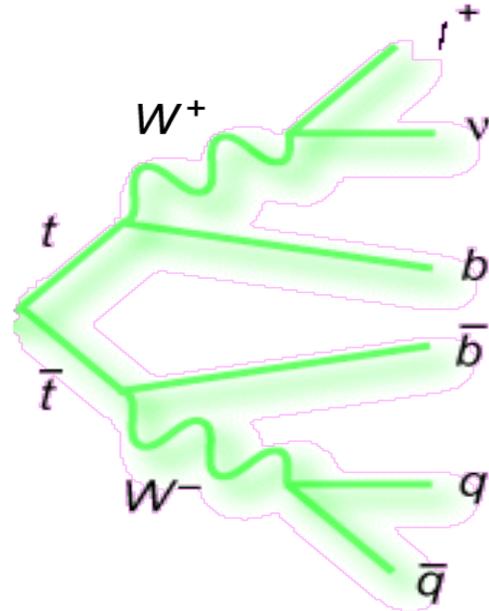
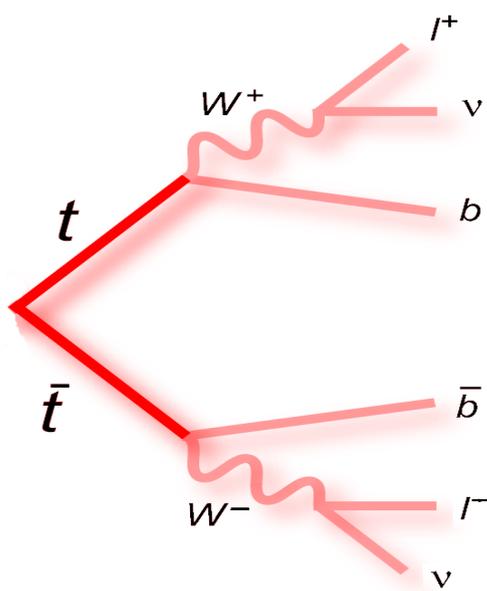
Benchmarks

Two different benchmark scenarios are considered:

- Topcolor-assisted technicolor (Z') [1][2]
 - Spin-1
 - Color singlet
 - Leptophobic and topophylic
 - Narrow resonance: width 1.2% (ATLAS), 1.2%, 3% and 10% (CMS)
- RS Kaluza-Klein gluon (g_{KK}) [3][4]
 - Spin-1
 - Color octet
 - Chosen RS KK gluon models couple more strongly to the top than other SM particles
 - Broad resonance: with $\sim 15\%$ (ATLAS) and $\sim 20\%$ (CMS)

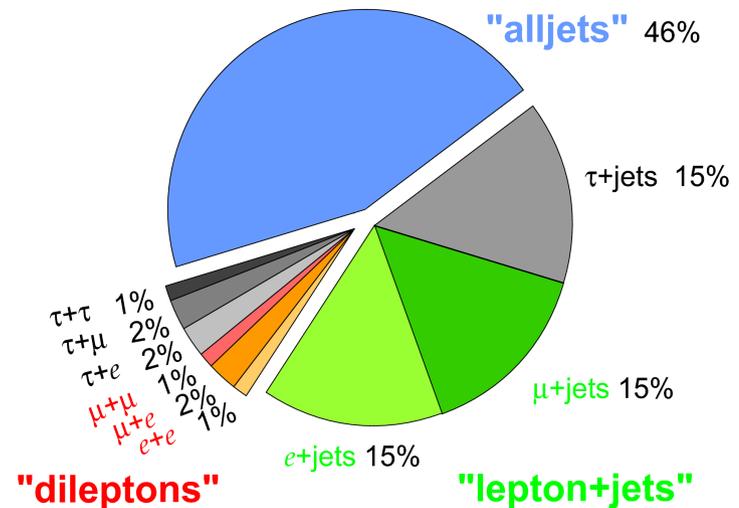


Top pair signatures



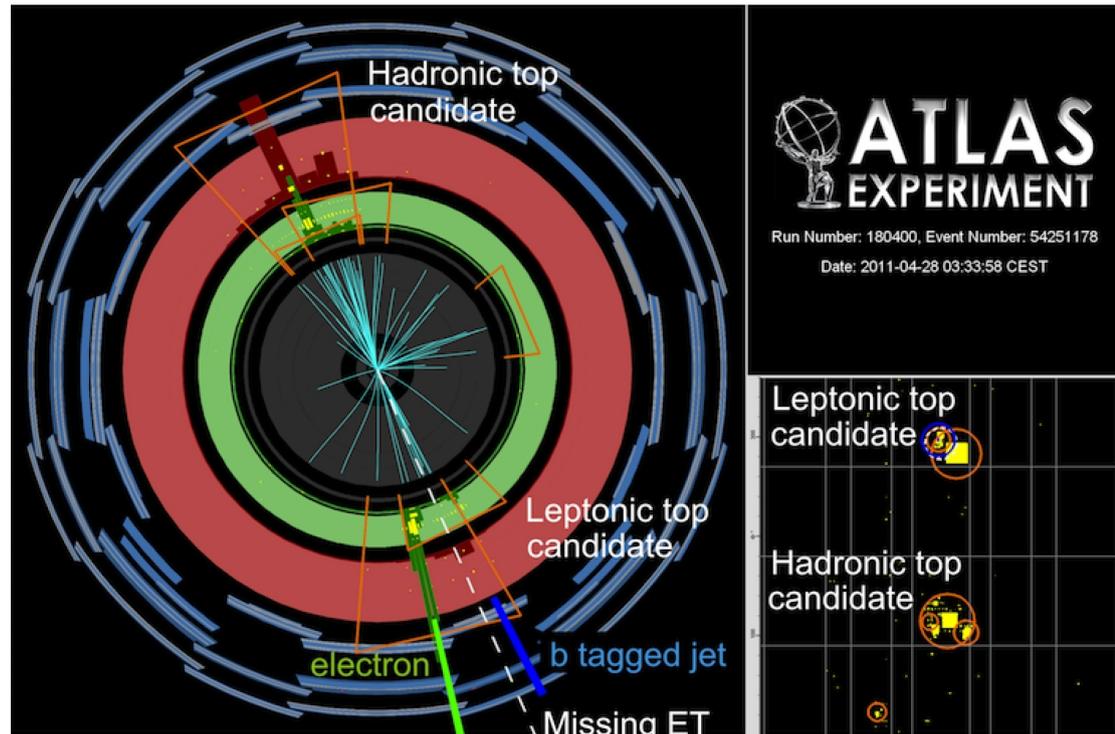
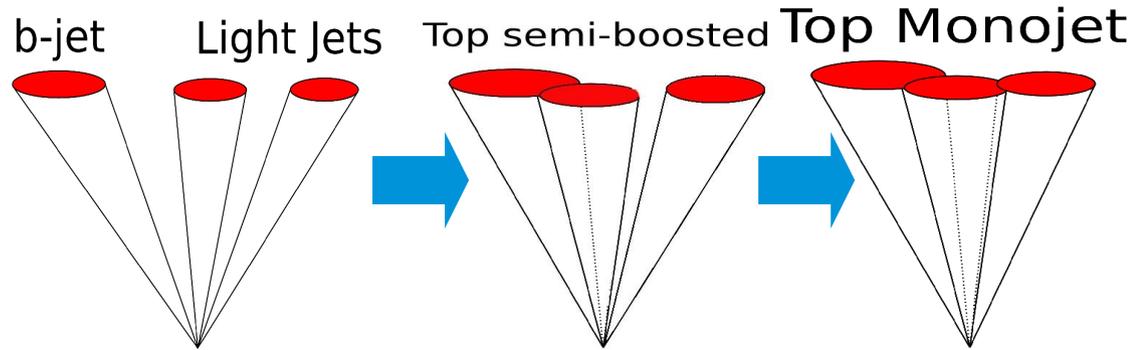
- **"Dileptons" $l=e,\mu$:**
 - Very clear signature
 - Low branching fraction: 4.9%
 - Ambiguities in reconstruction
- **"Lepton+jets" $l=e,\mu$:**
 - Clear signature
 - Branching fraction: 29.6%
 - Reduced background (W+jets, QCD, single top, Z+jets, dibosons)
- **"All jets":**
 - Large branching fraction: 46%
 - QCD background difficult to control
 - Ambiguities in reconstruction

Top Pair Branching Fractions



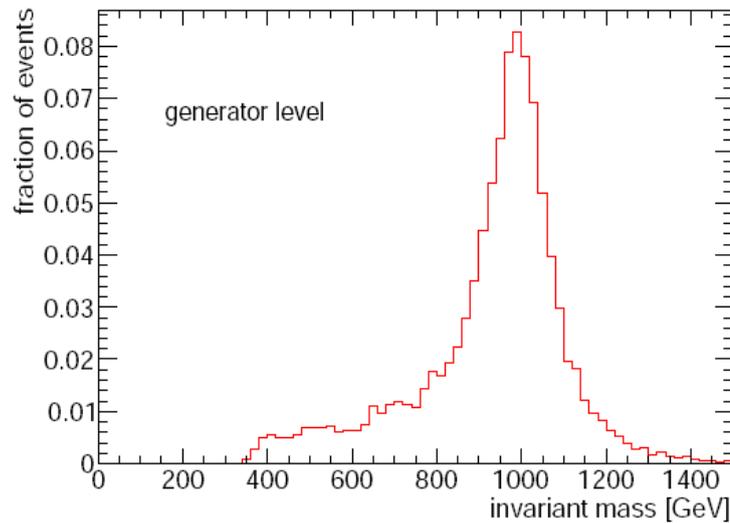
Top pair signatures

- At high $t\bar{t}$ mass:
 - Top gets more and more boosted
 - Objects (leptons and jets) merge into monojets
- Jet substructure needs to be studied
- Different algorithms used depending on event topology



tt resonance @parton level

Width resonance effect

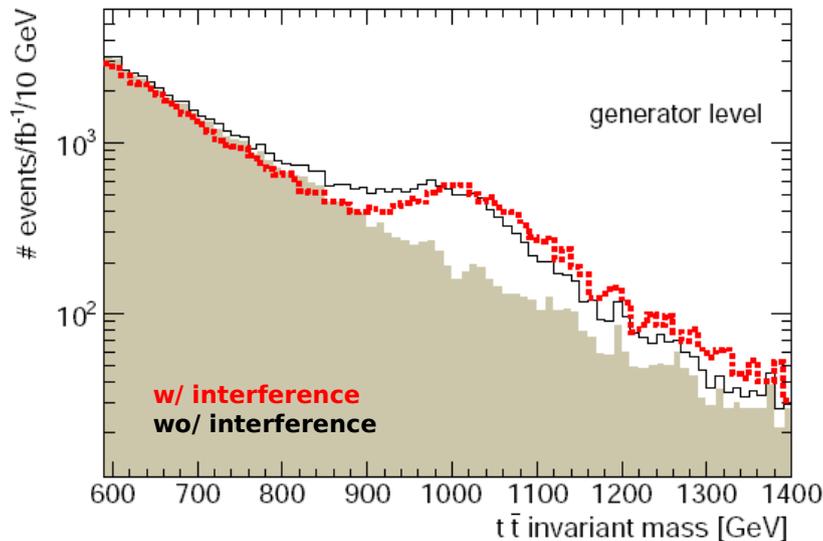


$g_{KK} (m = 1 \text{ TeV})$

ATL-COM-PHYS-2010-153

- Tail toward lower mass
- Due to the convolution of the quark PDF and the g_{KK} Breit-Wigner distribution
- Effect is more evident for higher masses
- This effect is combined with the detector resolution

Interference effect



- Destructive interference between SM processes and strongly coupled resonances leads to a reduction of the low mass tail
- Interference is not simulated in present studies since the SM bkg and signals are generated separately



ATLAS results

Two channels:

■ Dilepton channel:

ATLAS-CONF-2011-123 (1.04 fb^{-1})

- ◆ Exactly 2 isolated leptons, opposite sign
- ◆ ≥ 2 jets anti- k_T $R=0.4$
- ◆ No b-tagging
- ◆ ee and $\mu\mu$ channels:
 - Z mass veto ($|m_{ll} - m_Z| > 10 \text{ GeV}$)
 - MET > 40 GeV
- ◆ $e\mu$ channel: (to reject diboson bkg)
 - $H_T (= \sum p_T^{\text{jets}} + \sum p_T^{\text{lept}}) > 130 \text{ GeV}$

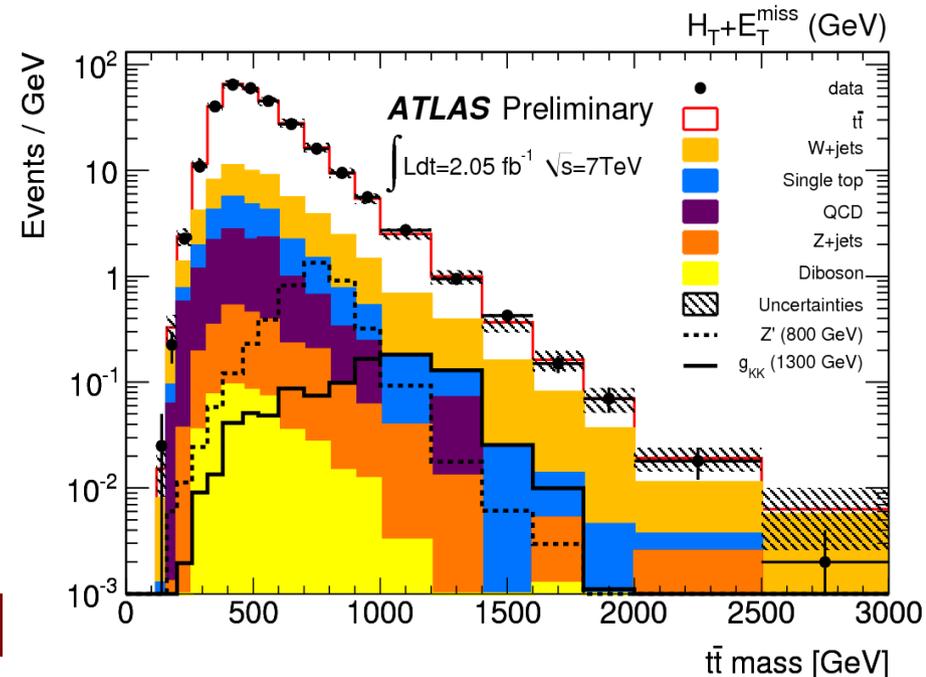
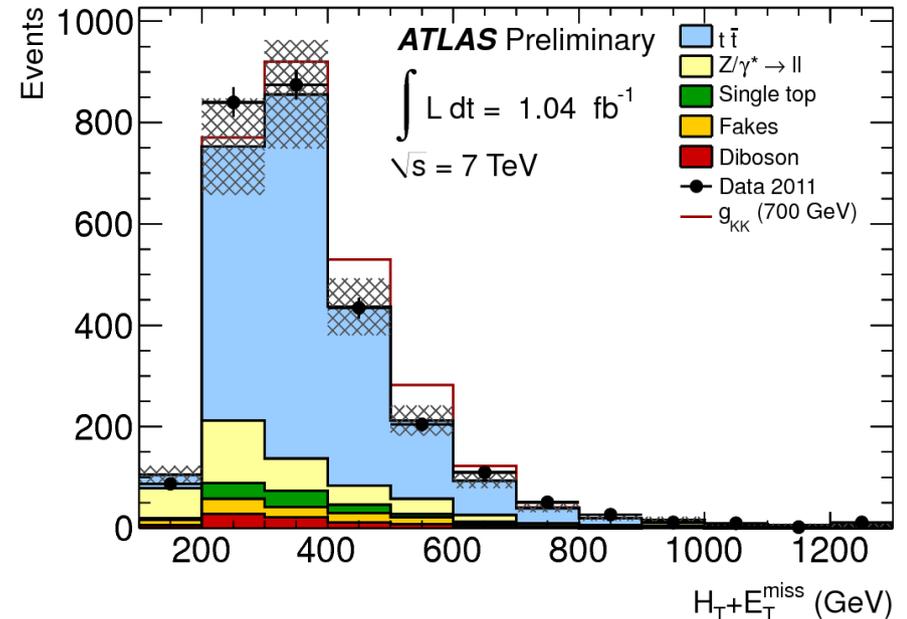
■ Lepton+jets channel:

ATLAS-CONF-2012-029 ($e/\mu + \text{jets } 2.05 \text{ fb}^{-1}$)

- ◆ Exactly 1 isolated lepton. Veto on 2nd lepton
- ◆ ≥ 4 jets or ≥ 3 jets (if one of the jets has a mass > 60 GeV) anti- k_T $R=0.4$
- ◆ Leading jet $p_{T,j} > 60 \text{ GeV}$
- ◆ e channel: MET > 25 GeV and $m_T^W > 25 \text{ GeV}$
- ◆ μ channel: MET > 20 GeV and MET + $m_T^W > 60 \text{ GeV}$
- ◆ ≥ 1 b-tagged jet

Multijet background estimated from data

Final discriminant variable

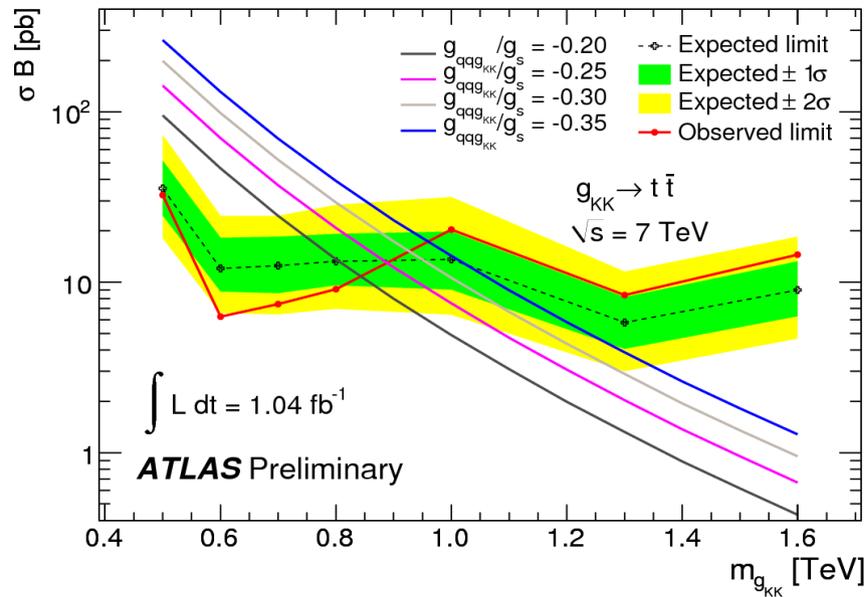


ATLAS results

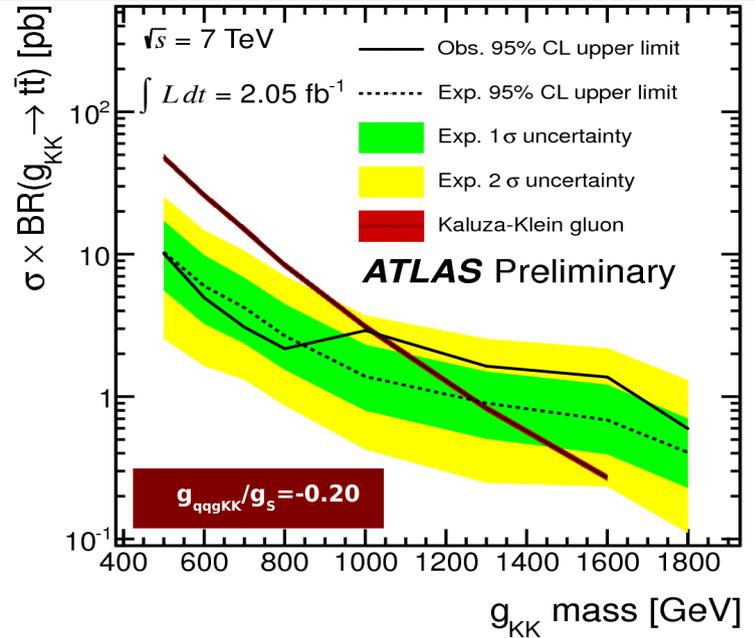
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Dilepton channel

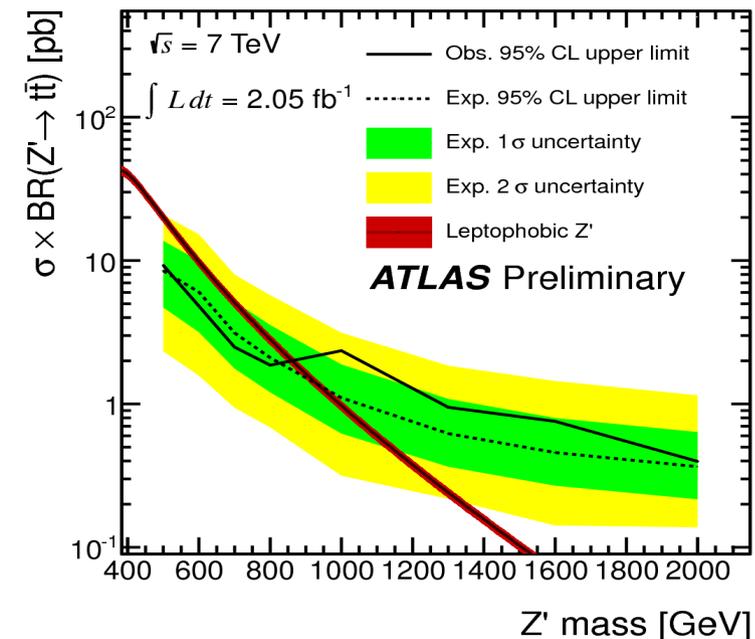


Lepton+jets channel



Channel	Z' (GeV) 1.2%	g_{KK} (GeV)
Dilepton		$m_{g_{KK}} < 840$
Lepton+jets	$500 < m_{Z'} < 860$	$500 < m_{g_{KK}} < 1025$

- Bayesian approach used
- Biggest shape systematic uncertainties:
 - Jet energy scale and resolution
 - B-tagging efficiency (lepton+jets)
 - ISR/FSR and MC generator
 - W+HF sample normalization (lepton+jets)

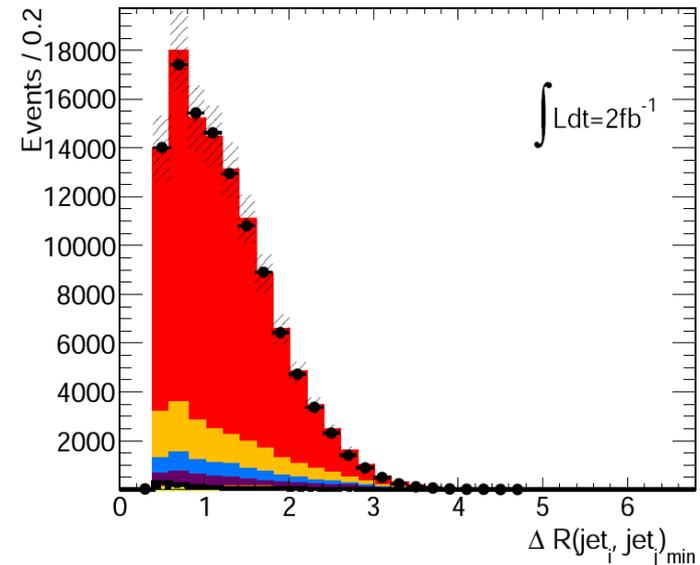
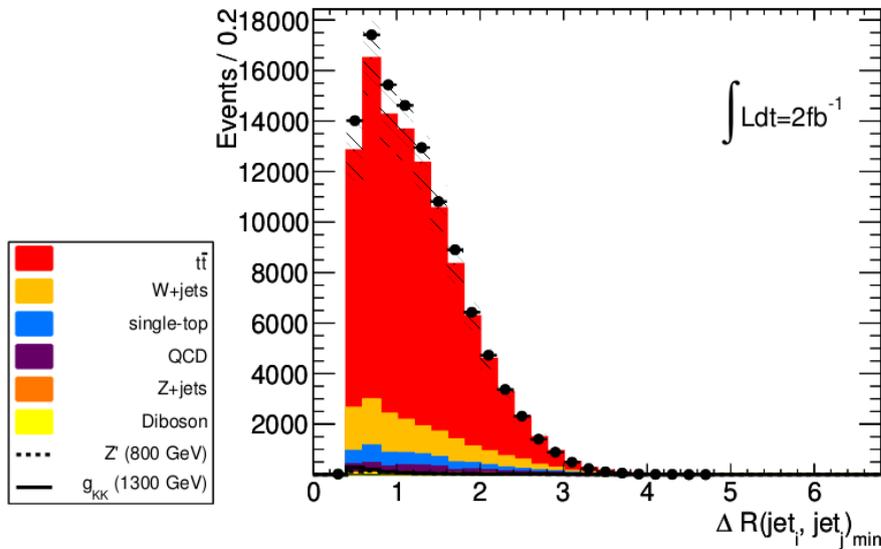
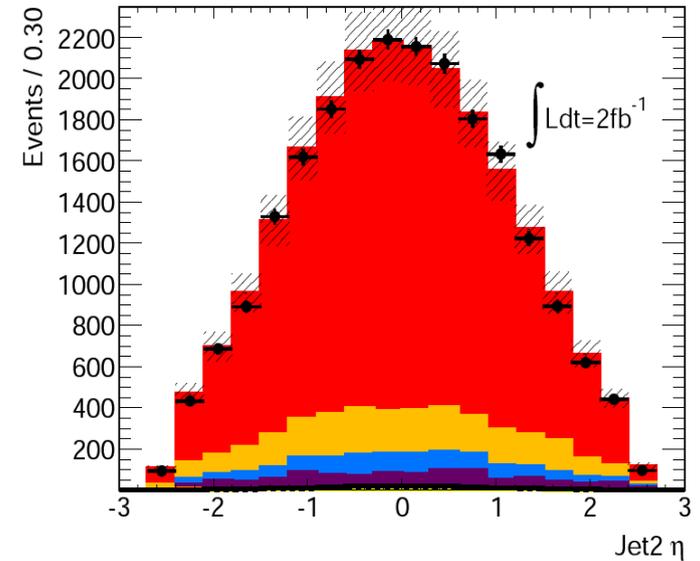
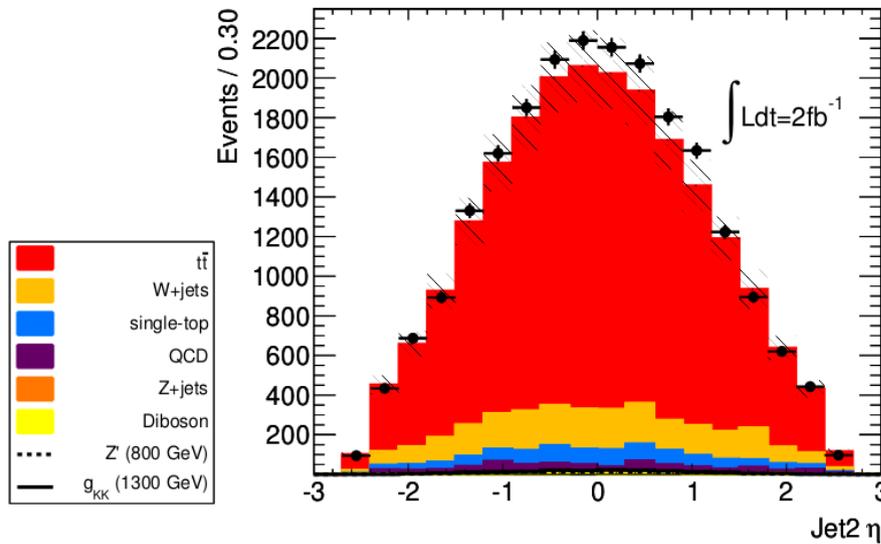


ATLAS: lepton+jets MC@NLO & PDFs

Work in progress

CTEQ6.6

MSTW2008nlo

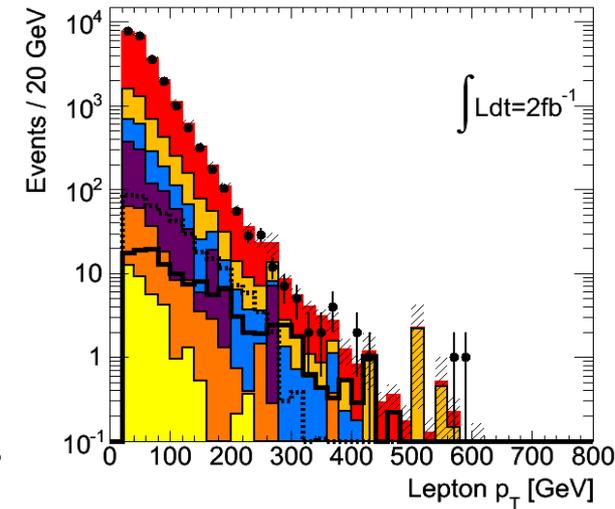
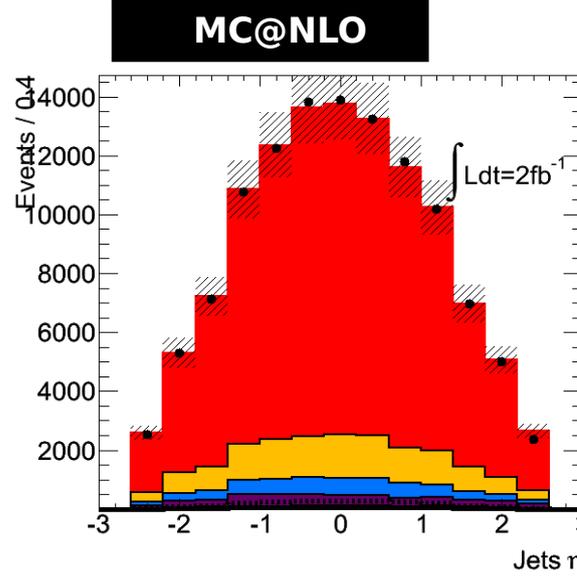
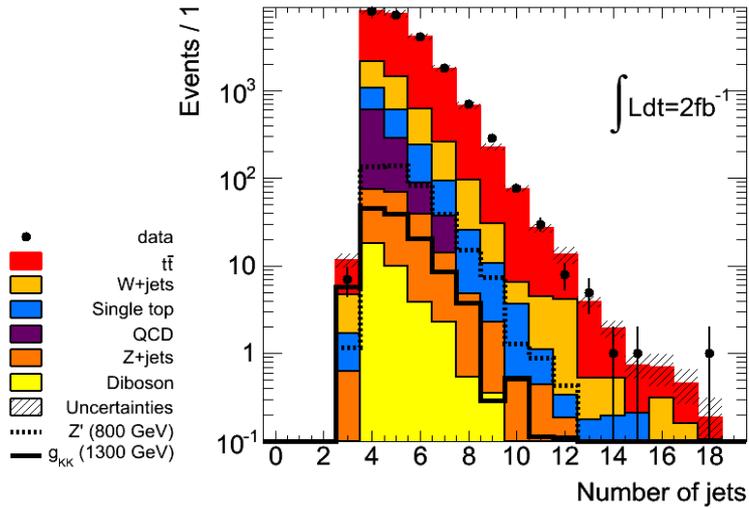


- MSTW2008nlo leads to a better agreement in the angular variables
- SM tt and single top samples are reweighted to these PDF

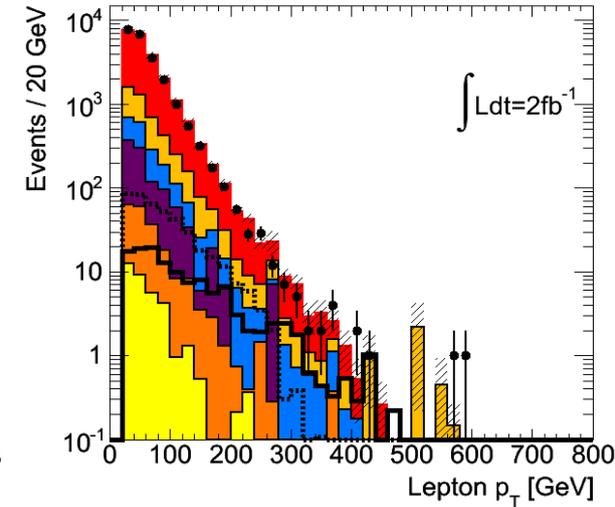
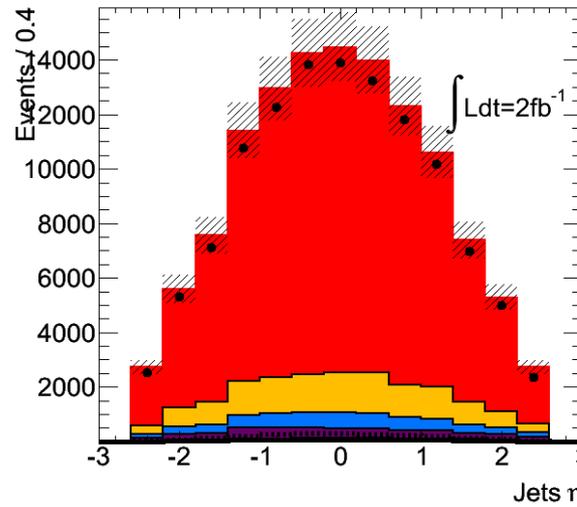
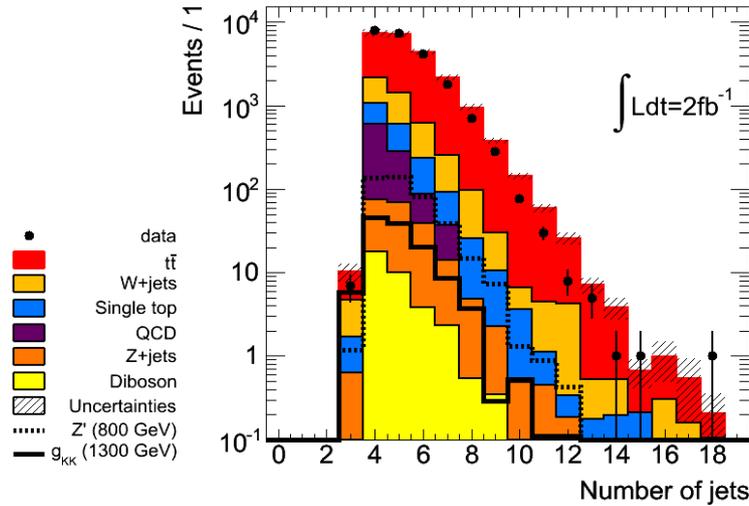
ATLAS: lepton+jets generator dependence

Work in progress

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Powheg+Herwig



■ Jet multiplicity ($p_T > 20$ GeV) and kinematic distributions better described by samples generated with MC@NLO

CMS results

Four channels:

- Dilepton channel:
CMS PAS TOP-11-010 (5.0 fb^{-1})
- Lepton+jets resolved channel:
CMS-PAS-TOP-11-009 (e/μ +jets 4.7 fb^{-1})
- Lepton+jets boosted channel:
CMS PAS EXO-11-092 (e +jets 4.3 fb^{-1})
CMS PAS EXO-11-055 (μ +jets 1.1 fb^{-1})
- All hadronic boosted channel 4.6 fb^{-1} :
CMS-EXO-11-006 (4.6 fb^{-1})

CMS results

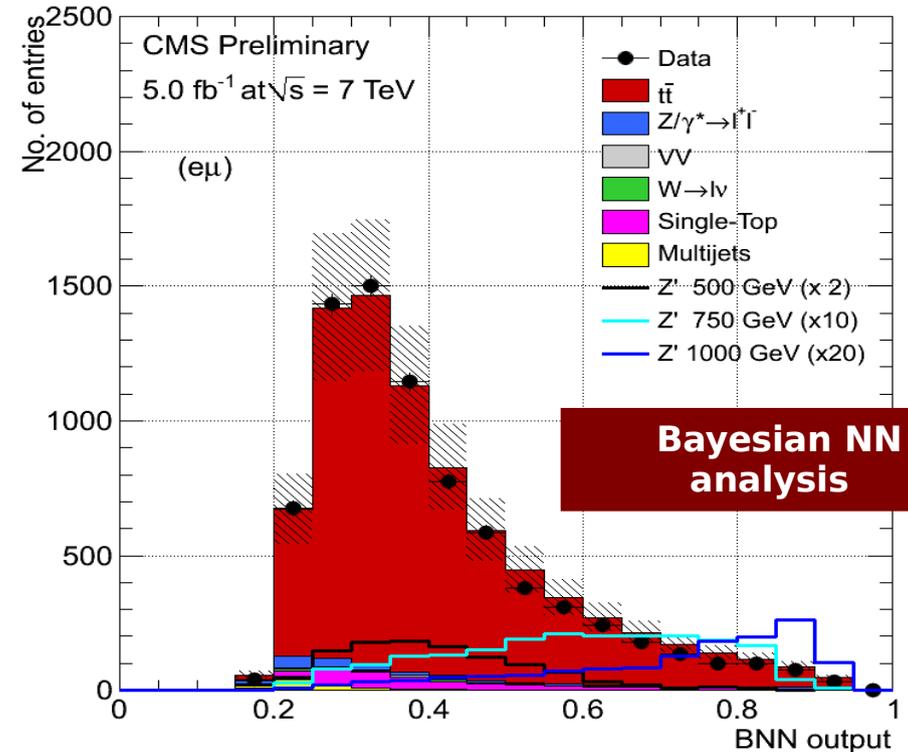
Final discriminant variable

Four channels:

■ Dilepton channel:

CMS PAS TOP-11-010 (5.0 fb^{-1})

- ◆ Exactly 2 isolated leptons
- ◆ ≥ 2 jets $\text{anti-}k_T, R=0.5$
- ◆ ≥ 1 b-tagged jet
- ◆ ee and $\mu\mu$ channels:
 - Z mass veto ($76 < m_{ll} < 106 \text{ GeV}$)
 - $\text{MET} > 30 \text{ GeV}$
- ◆ No extra condition in $e\mu$ channel



Multijet background estimated from data

CMS results

Four channels:

Lepton+jets resolved channel:

CMS-PAS-TOP-11-009 (e/μ +jets 4.7 fb^{-1})

- ◆ One isolated lepton
- ◆ Tight veto on 2nd lepton
- ◆ ≥ 3 jets anti- k_T $R=0.5$
- ◆ Leading jet $p_T > 70 \text{ GeV}$
- ◆ $MET > 20 \text{ GeV}$
- ◆ Events classified according to jet multiplicity and number of b-jets

Lepton+jets boosted channel:

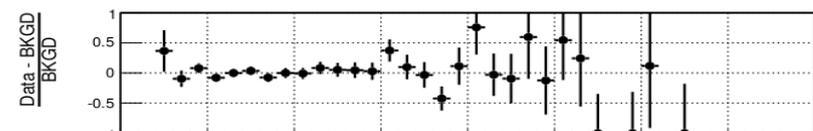
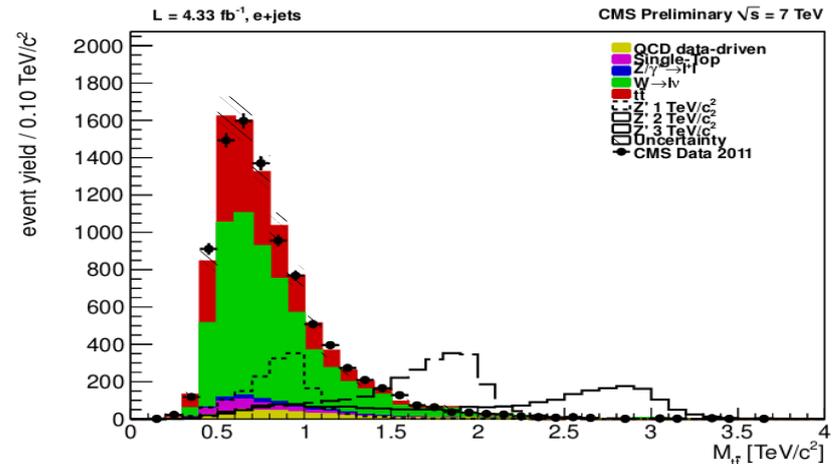
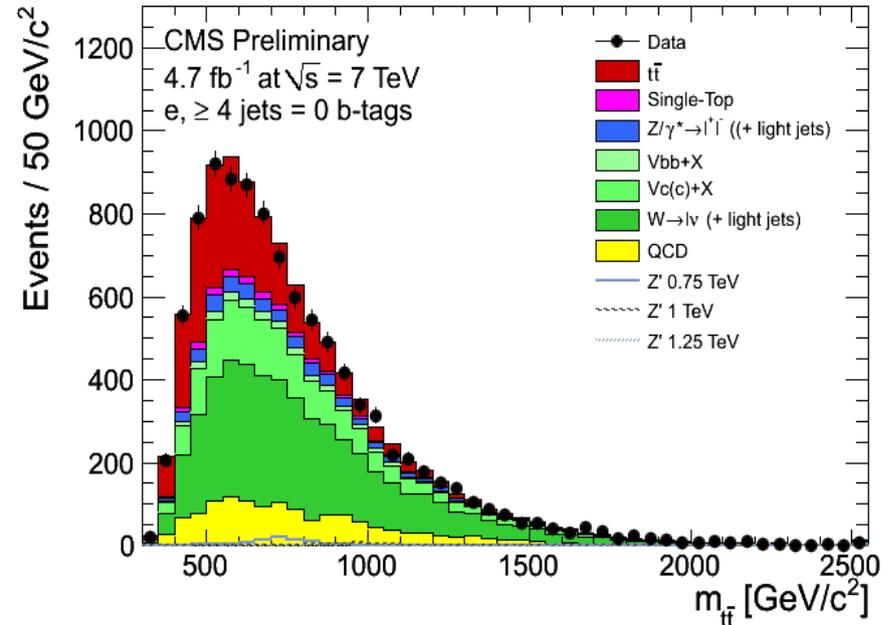
CMS PAS EXO-11-092 (e +jets 4.3 fb^{-1})

CMS PAS EXO-11-055 (μ +jets 1.1 fb^{-1})

- ◆ Both analyses have a similar event selection
- ◆ One high p_T lepton, not isolated
- ◆ ≥ 2 jets anti- k_T $R=0.5$
- ◆ Leading jet $p_T > 150 \text{ GeV}$
- ◆ Triangular cut applied in the $\Delta\phi(l, MET)$ or $\Delta\phi(\text{jet}_1, MET)$ vs MET planes to reduce multijet bkg
- ◆ No b-tagging applied

Multijet and W+jets background estimated from data

Final discriminant variable



CMS results

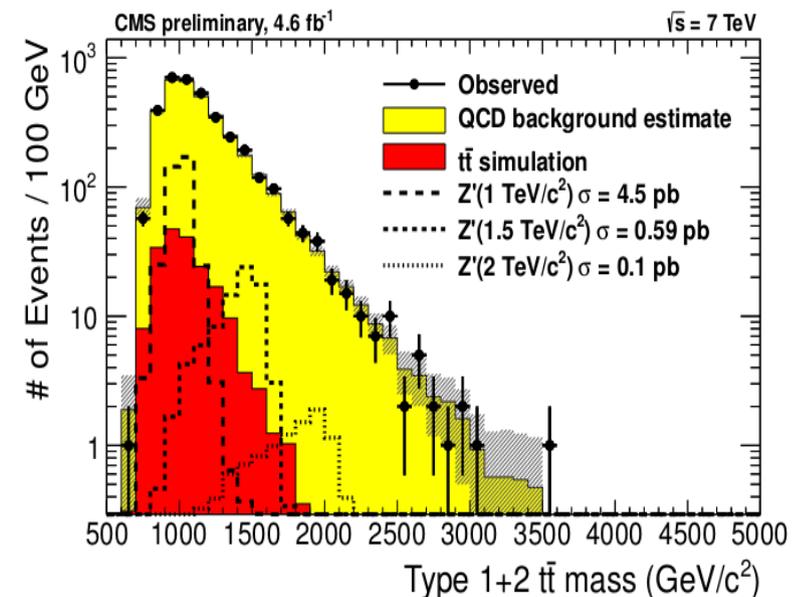
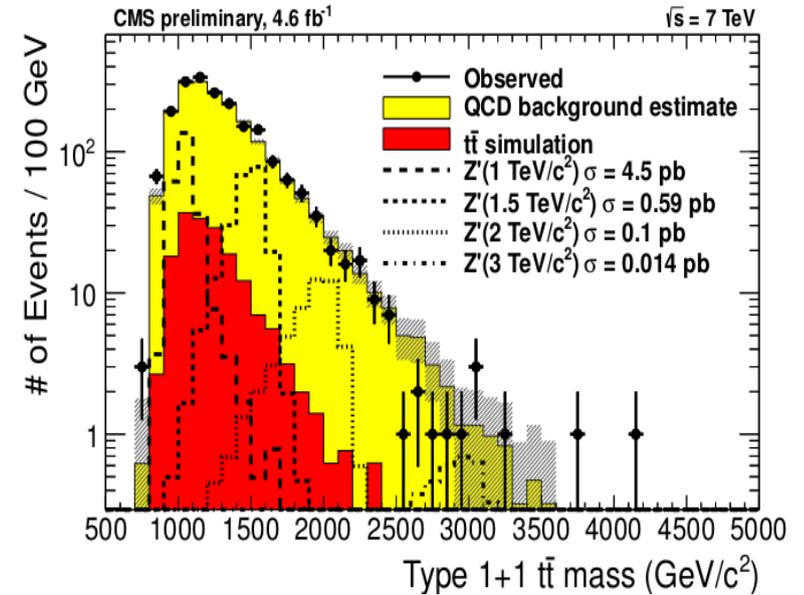
Final discriminant variable

Four channels:

All hadronic boosted channel:

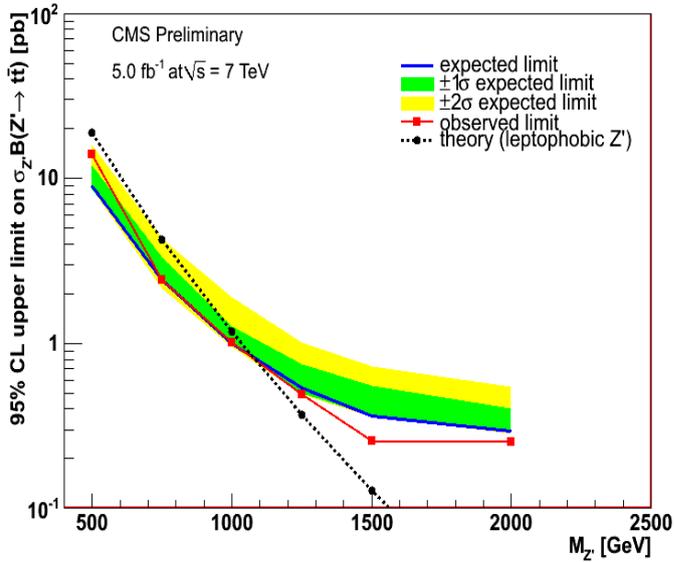
CMS-EXO-11-006 (4.6 fb^{-1})

- ◆ ≥ 1 jet CA $R=0.8$ with $p_{\text{T}} > 350 \text{ GeV}$
- ◆ No b-tagging
- ◆ Two channels defined:
 - **1+1**: two fat jets required to be **top tagged**[5]. Highly boosted. All 3 jets merged into one in both sides
 - **1+2**: one fat jet and two other jets in the other side (only 2 jets merged in). One of them **W-tagged**[6]. Moderate boost
- ◆ Non-top multijet bkg (NTMJ) estimated using the probability for non-top jets to pass the top jet selection

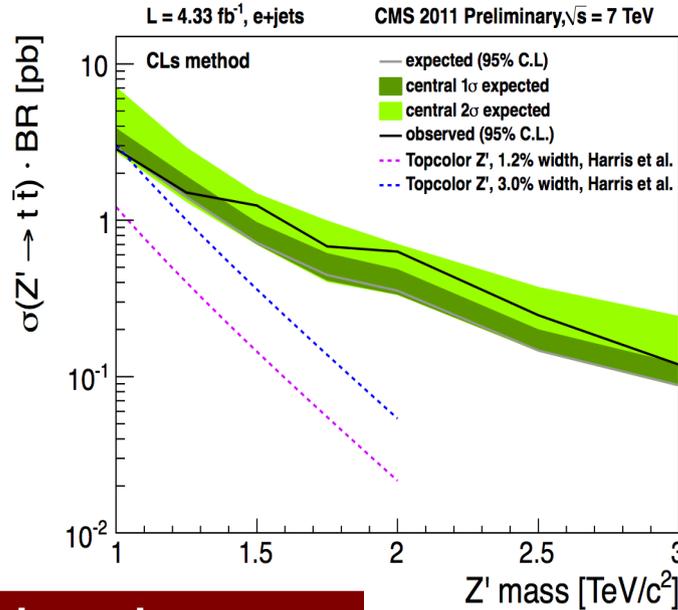


CMS results

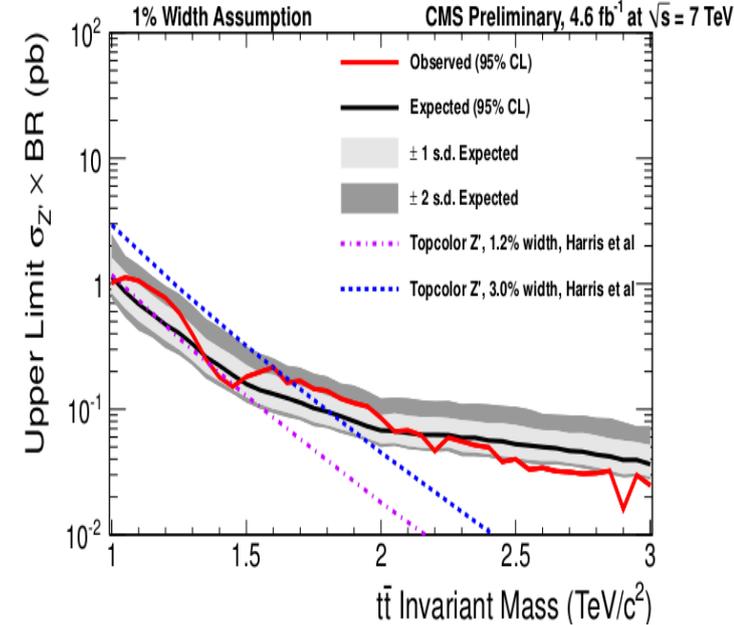
Dilepton channel



Lepton+ jets channel semi-boosted



All hadronic boosted



CL approach used

Channel	Z' (GeV) 1.2%	Z' (GeV) 3%	Z' (GeV) 10%	g_{KK} (GeV)
Dilepton	500 < $m_{Z'}$ < 1100			
e+jets semi-boosted	2.51(0.62) pb for Z' 1(2) TeV @95%	-		
μ +jets semi-boosted	-	805 < $M_{Z'}$ < 935, 960 < $m_{Z'}$ < 1060		
Lepton+jets	500 < $m_{Z'}$ < 1300		500 < $m_{Z'}$ < 1700	1000 < $m_{Z'}$ < 1400
All hadronic	1300 < $m_{Z'}$ < 1500	1000 < $m_{Z'}$ < 1600	1000 < $m_{Z'}$ < 2000	1400 < $m_{g_{KK}}$ < 1500

See backup for the rest of the limit plots

Summary and Outlook

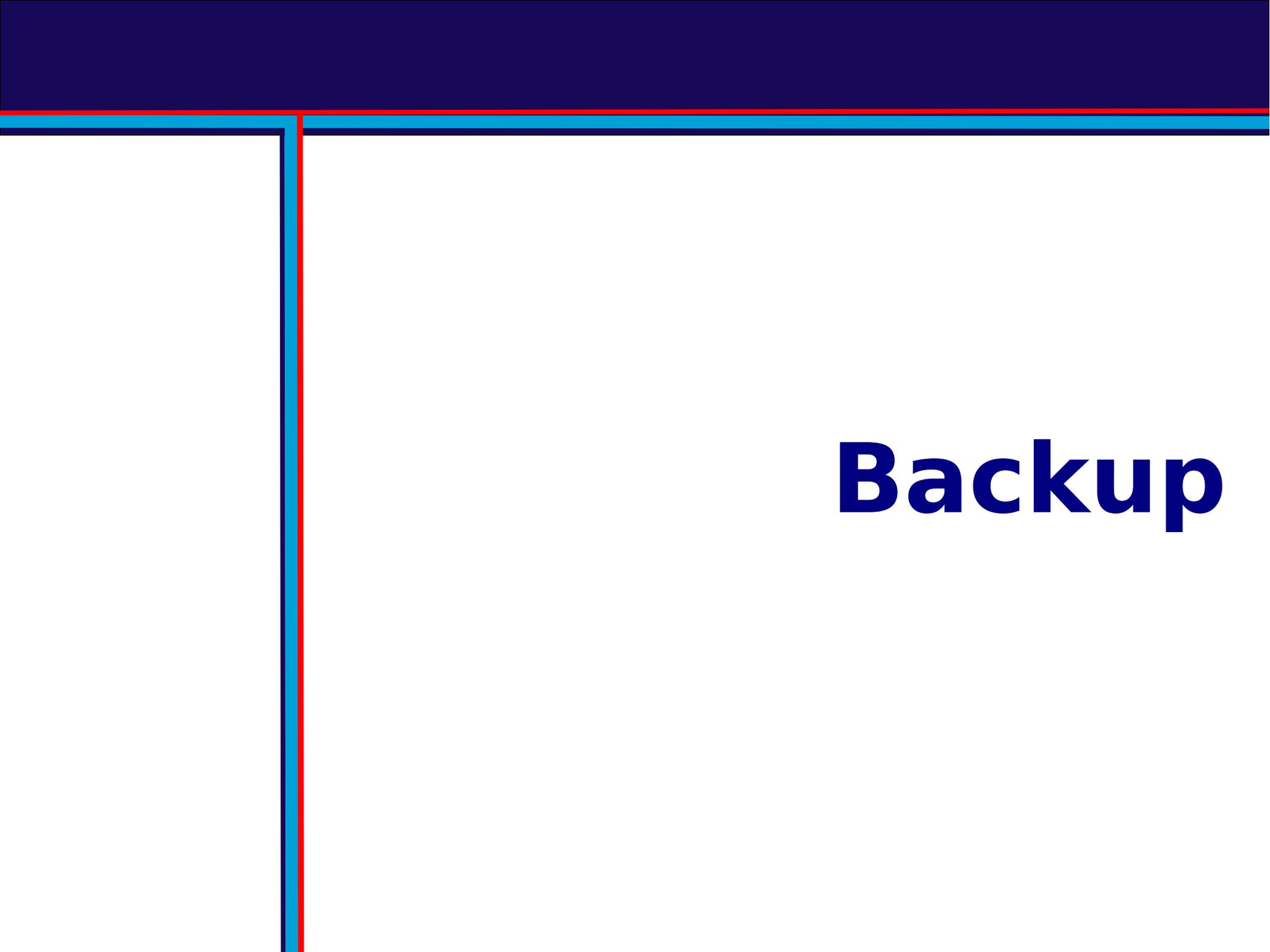
- So far, the search for a $t\bar{t}$ resonance done in ATLAS and CMS does not show any evidence of a signal
- Limits on the mass for the leptophobic topcolor Z' model and KK gluon were set
- Efforts between groups to develop orthogonal analyses, that can be easily combined. In particular between resolved and boosted topologies
- New BSM signals to be tested
- Need to reduce systematic uncertainties
- Waiting forward for 2012 data!



References

- [1] C. Hill. Topcolor Assisted Technicolor. arXiv:hep-ph/9411426v2
- [2] R. Harris et al. Cross Section for Topcolor Z' decaying to top-antitop. arXiv:hep-ph/9911288v1
- [3] B. Lillie et al. The Bulk RS KK-gluon at the LHC. arXiv:hep-ph/0701166v1
- [4] K. Agashe. LHC Signals from Warped Extra Dimensions. arXiv:hep-ph/0612015v1
- [5] CMS. A Cambridge-Aachen (C-A) based Jet Algorithm for boosted top-jet tagging. CMS-PAS-JME-09-001
- [6] S. Ellis. Recombination Algorithms and Jet Substructure: Pruning as a Tool for Heavy Particle Searches. arXiv:0912.0033v1

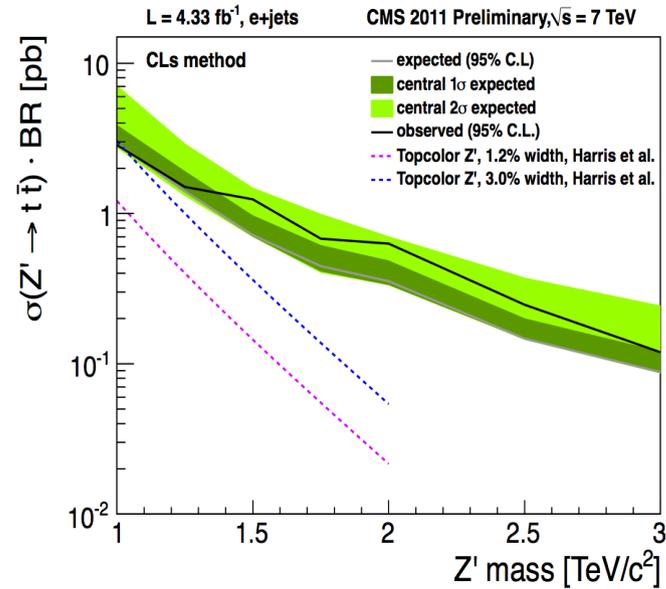
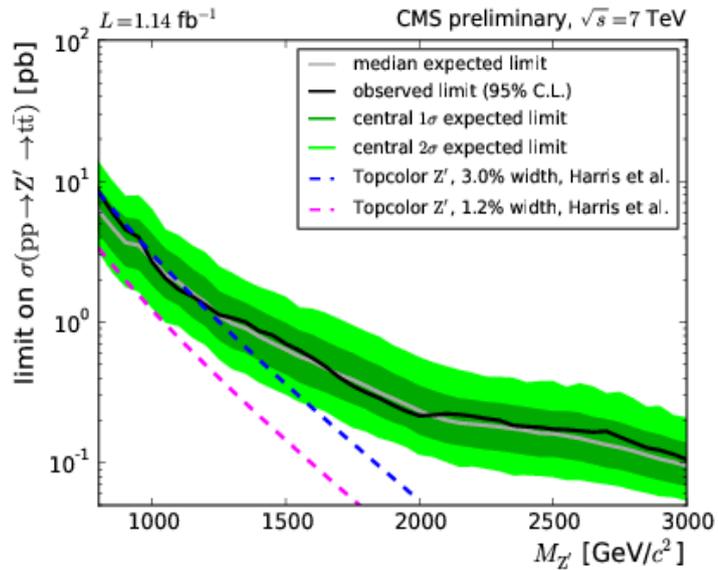




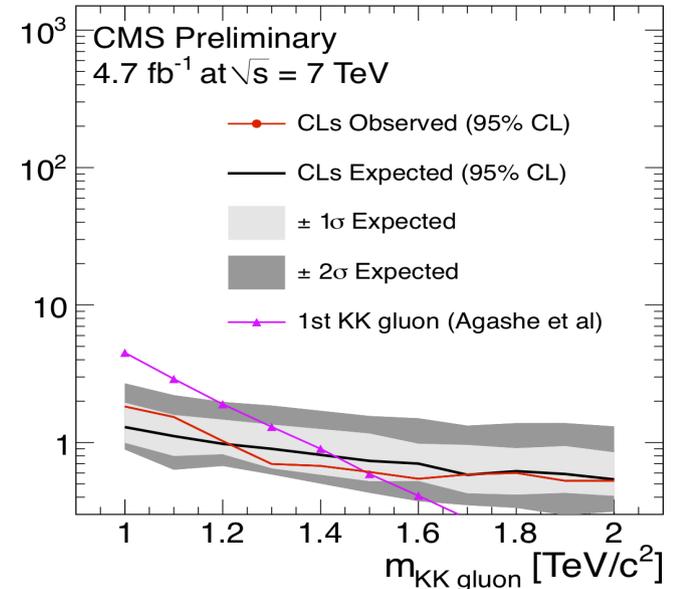
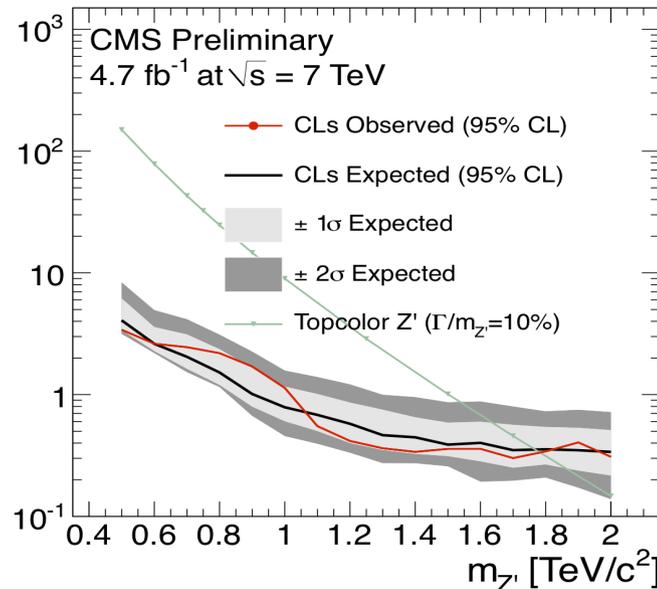
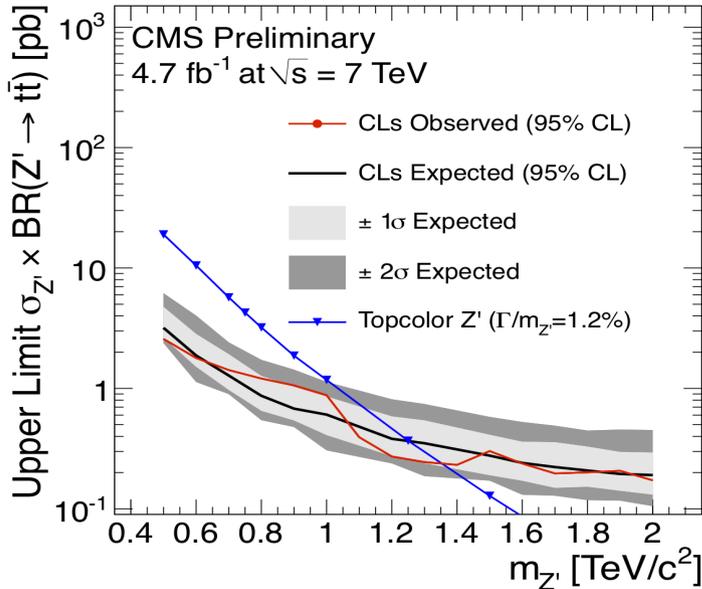
Backup

CMS results

Lepton+ jets channel semi-boosted

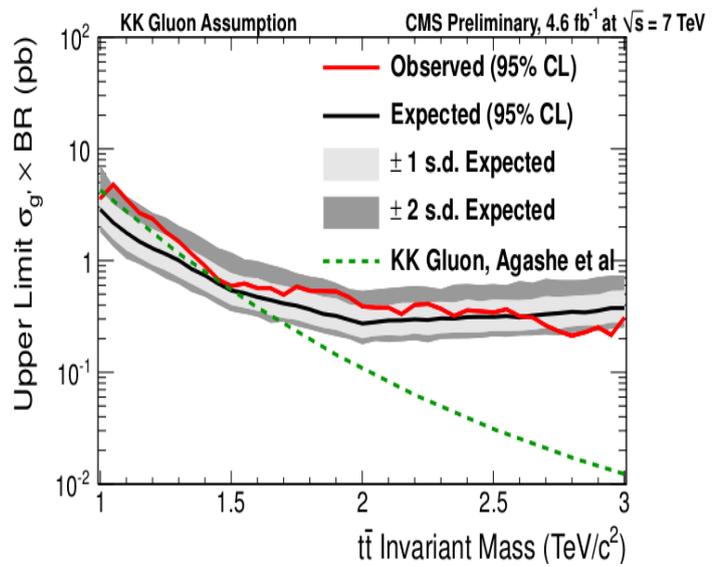
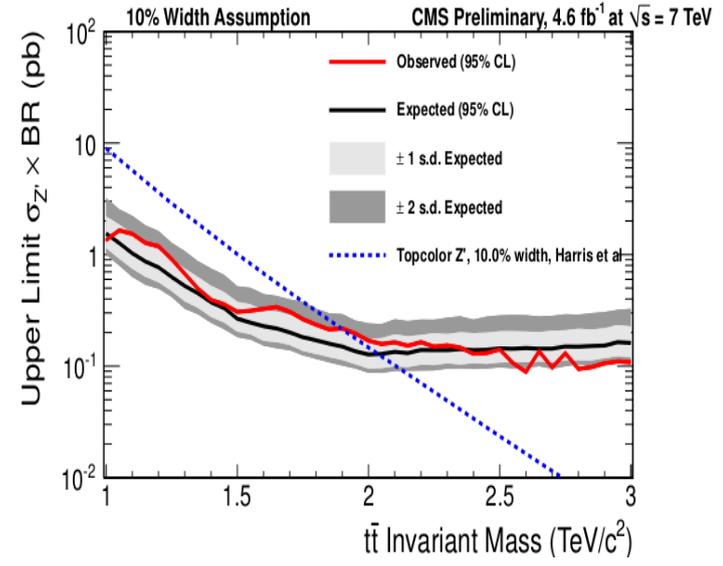
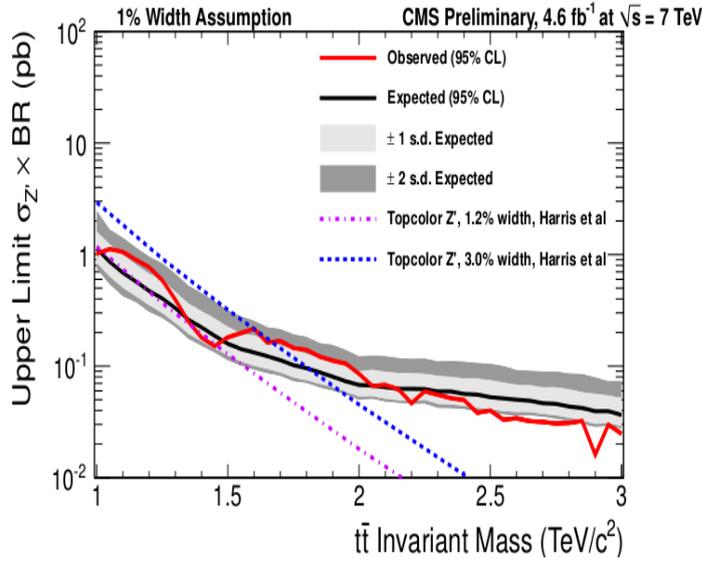


Lepton+ jets channel resolved



CMS results

All hadronic boosted

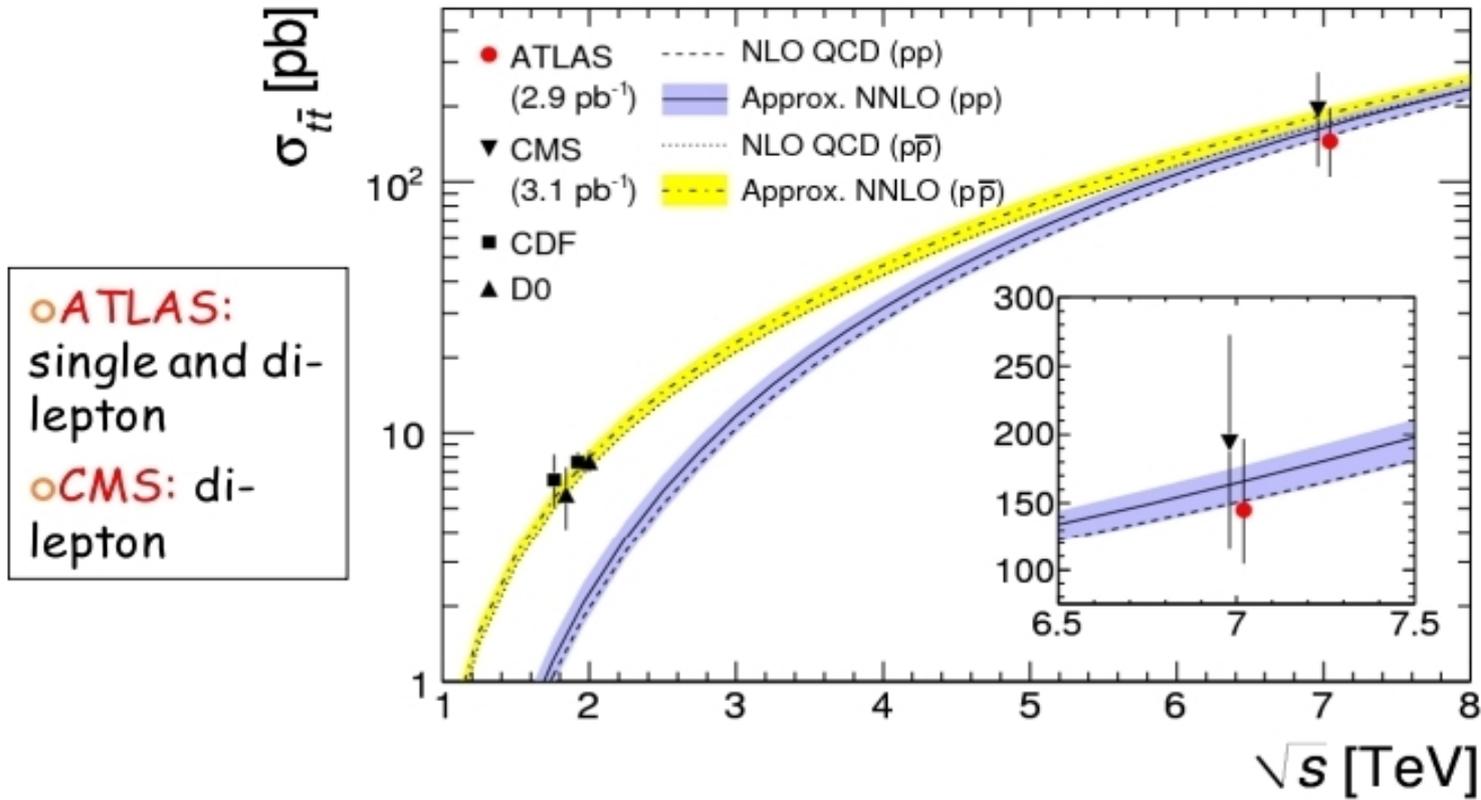


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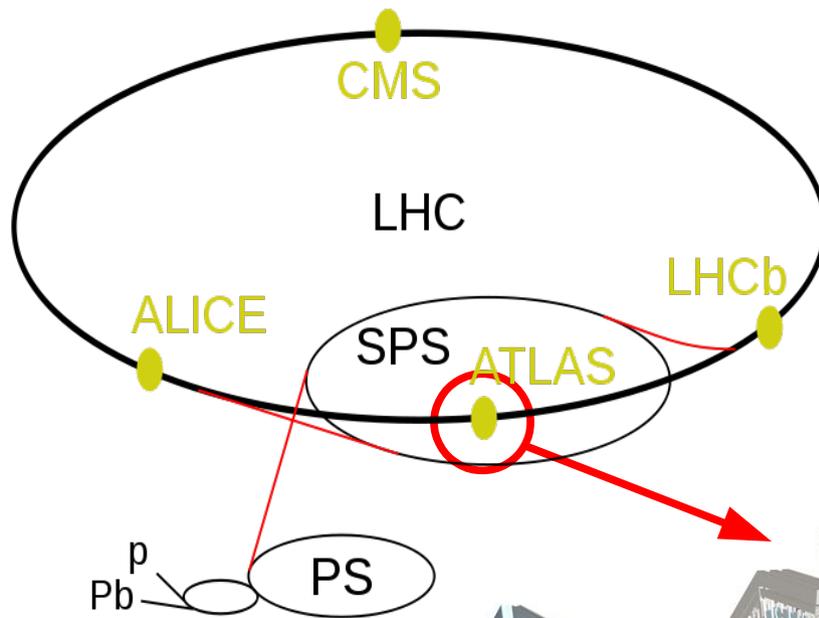
FIRST TOP PAIR CROSS SECTION MEASUREMENT IN ATLAS WITH 3pb⁻¹



$$\sigma_{t\bar{t}} = 145 \pm 31^{+42}_{-27} \text{ pb}$$

EPJC 71 (2011) 1577

ATLAS detector

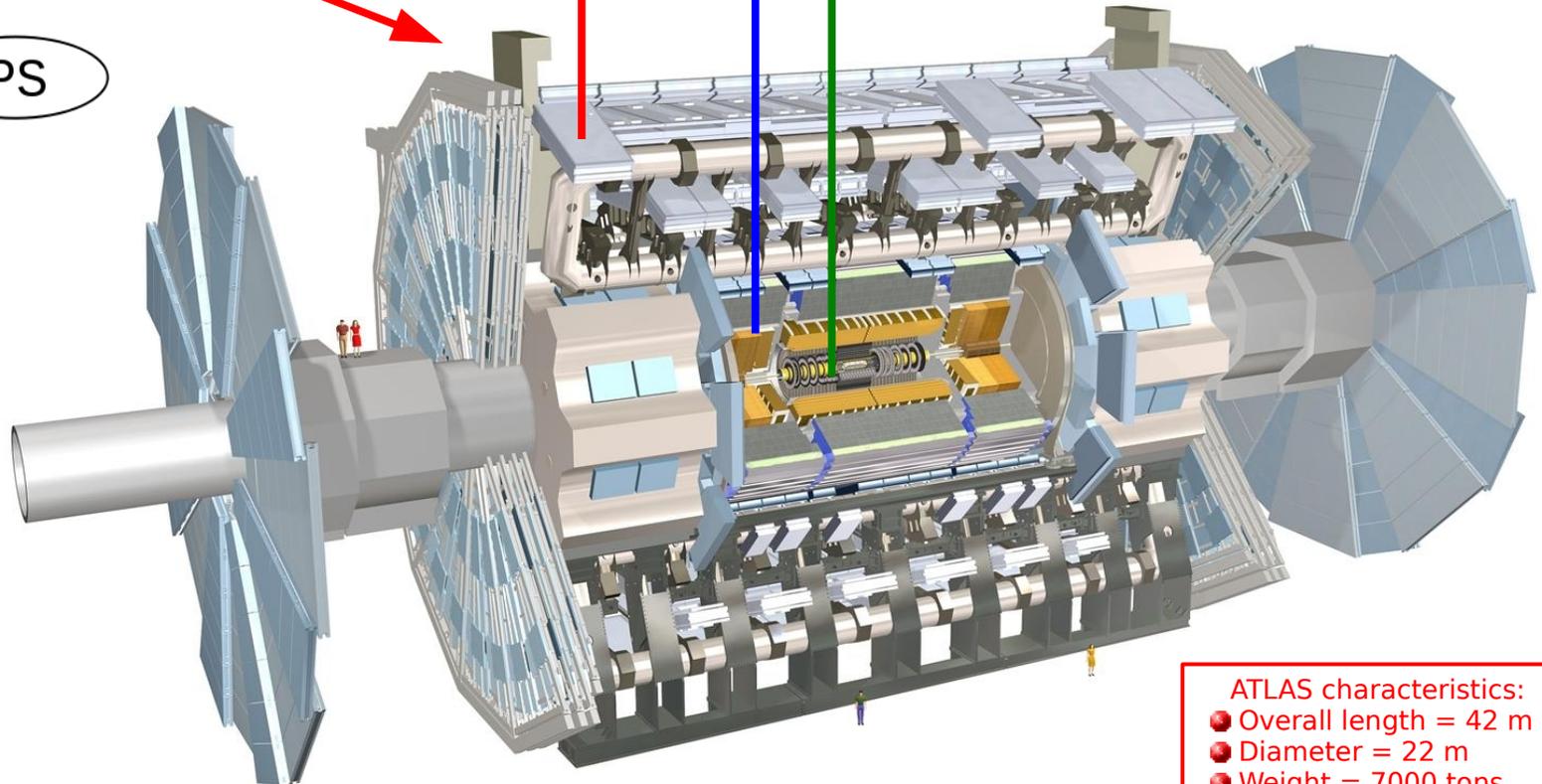


→ Muon chambers: measurement of muons momentum.

→ EM and hadronic calorimeters: particle energy measurement.

→ Inner detector: vertex reconstruction, trajectories and measurement of charged particles momentum.

→ Trigger: record events with a specific signature.



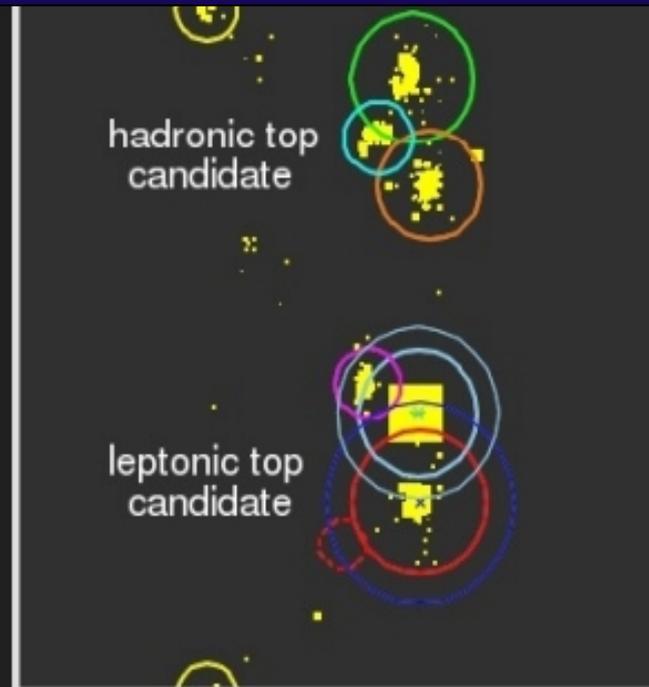
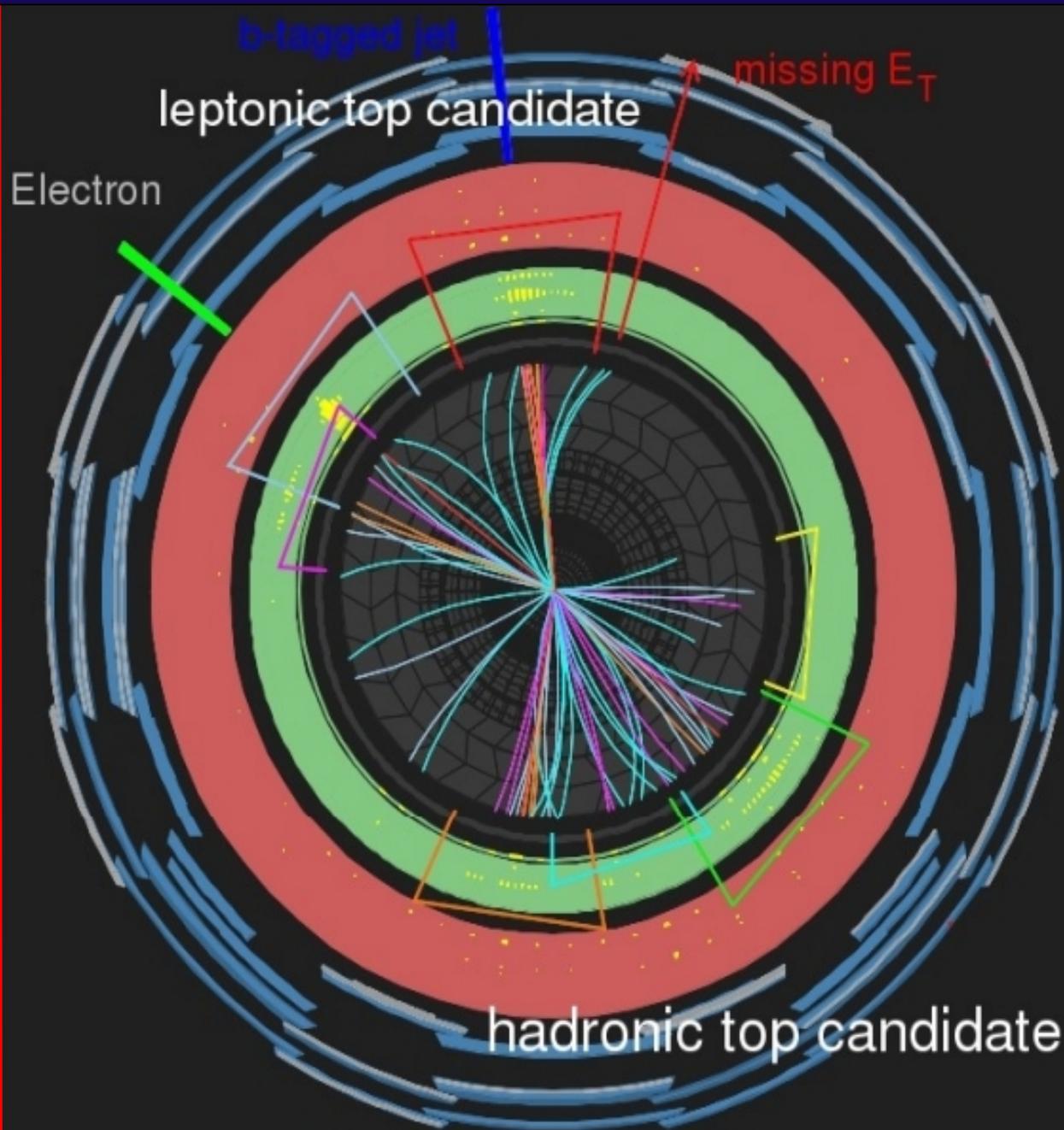
- ATLAS characteristics:
- Overall length = 42 m
 - Diameter = 22 m
 - Weight = 7000 tons

But, how does a $t\bar{t}$ event look in reality?

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ATLAS



ATLAS EXPERIMENT

Run Number: 166658, Event Number: 34533931

Date: 2010-10-11 23:57:42 CEST

$t\bar{t}$ mass distributions: events with a HM jet

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