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A search for ttbar resonances in the lepton plus jets channel with ATLAS

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on behalf of the ATLAS Collaboration

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Overview

- Physics models
- Data sample
- Object reconstruction
- Event selection
- Background estimation
- Systematic uncertainties
- Invariant mass reconstruction
- Bayesian limit
- Results
- Prospects of the boosted objects analysis

Physics models

- Several BSM physics models foresee heavy particles decaying into a ttbar resonance at LHC
- To test discovery potential at ATLAS, two benchmark models were studied:
  - Leptophobic topcolor Z' (hep-ph/9911288) to study the analysis performance with narrow resonances and compare results with DØ
  - Kaluza-Klein gluon appearing in Randall-Sundrum models with a warped extra dimension (ATL-PHYS-PUB-2010-008) to study the analysis performance with wide resonances
- Signature: local enhancement (bump) in the invariant mass distribution of the ttbar pair
- As the boost of the top quarks increases, however, decay products of the top pair tend to merge into “monojets”
- Results of the lepton + jets resolved top analysis (ATLAS-CONF-2011-087) and prospects of the boosted objects analysis (ATL-PHYS-PUB-2010-008) will be presented

Resolved analysis

Object reconstruction and selection

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- Electrons:
  - p_T > 25 GeV, |η|<2.47
  - Isolation: (energy deposited in cone of radius ΔR=0.2) < 4 GeV
- Muons:
  - p_T > 20 GeV, |η|<2.5
  - Isolation: (energy deposited in cone of radius ΔR=0.3) < 2.5 GeV
    (sum of track momenta within ΔR=0.3) < 2.5 GeV
- Jets: AntiKt 0.4 algorithm from topological clusters + EM scale calibration
  - p_T > 25, energy scale correction factor from MC (binned in η and p_T)
- B-tagging: Secondary Vertex tagger, select jets with decay length significance >5.85
- Missing transverse energy: Vector sum of calorimeter cells associated to object, with dedicated correction factor.
  - Adding p_T of muons passing selection while subtracting muon deposits in calorimeter cells.
  - Remaining clustered energies included at EM scale

Event selection

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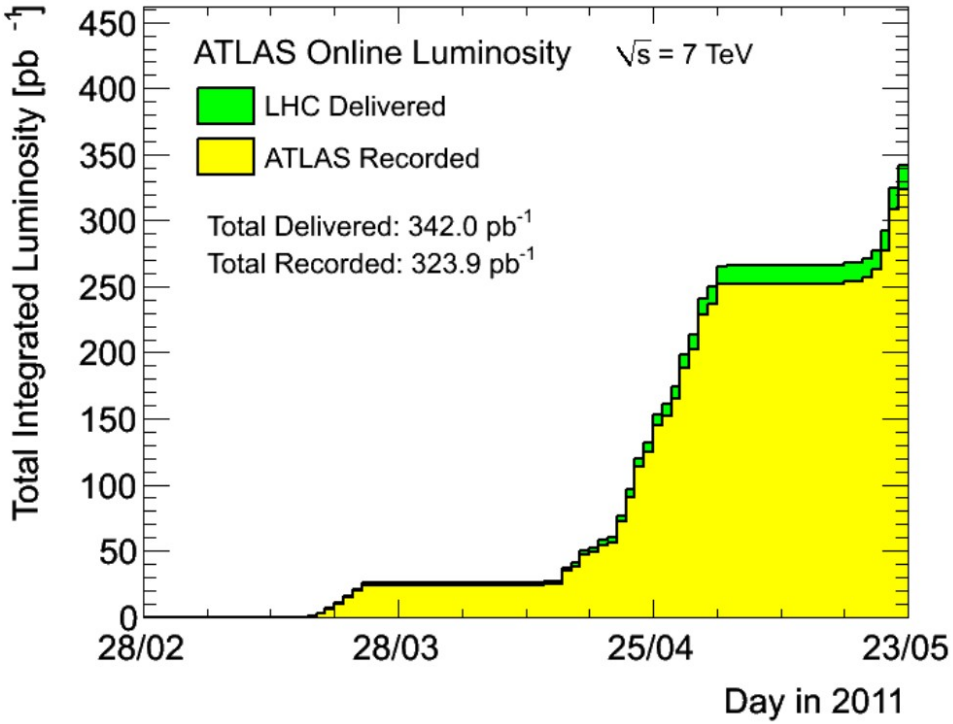
- Event quality:
  - Lepton trigger
  - At least 1 vertex with ≥ 5 reconstructed tracks
  - Event discarded if any jet with p_T > 20 GeV is out-of-time or has calorimeter noise
- Signature cuts:
  - Exactly 1 isolated lepton which must match triggered lepton
  - Veto event if an electron shares an inner detector track with non-isolated muon
  - At least 4 jets with p_T > 25 GeV; at least 1 b-tagged jet
- Background rejection cuts:
  - Electrons: E_T Miss > 35 GeV ; M_T(lepton, E_T Miss) >25 GeV
  - Muons: E_T Miss > 20 GeV ; E_T Miss+M_T(lepton, E_T Miss) >60 GeV

Data sample

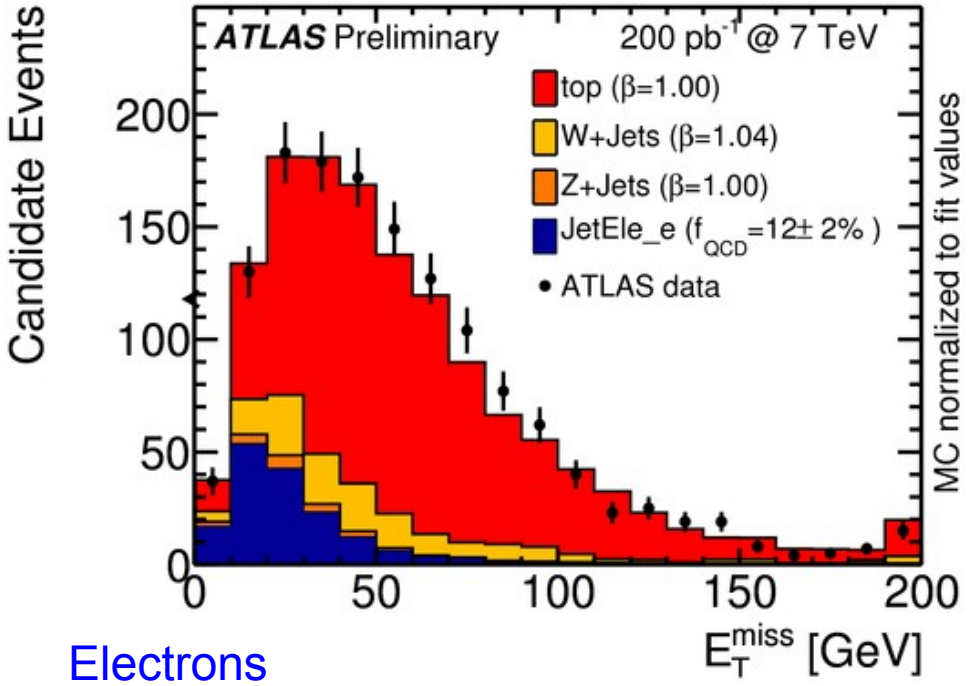


- Data collected in Spring 2011
- Integrated luminosity after Data Quality cuts: **200±9 pb^{-1}**

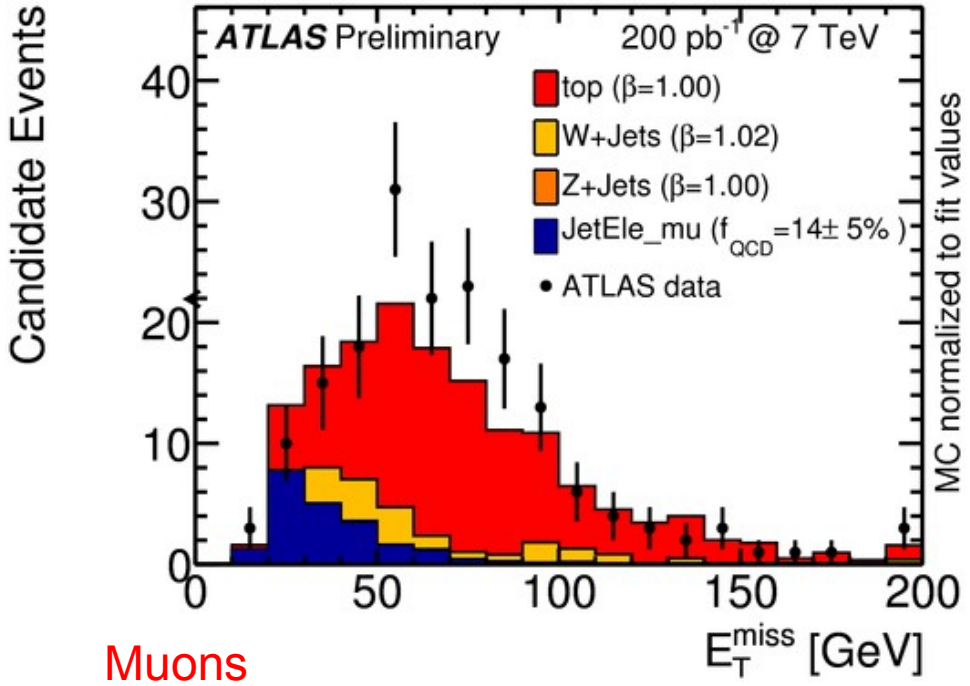
Background estimation

ATLAS-CONF-2011-087

- Data-driven QCD estimation:
  - Substitute lepton with one jet with high EM calorimeter energy fraction (0.80-0.95) with at least four tracks
  - Normalization factor given by fit in E_T Miss spectrum before E_T Miss cut
- QCD fraction: (12±2)% for Electron channel, (14±5)% for Muon channel



Electrons



Muons

Background estimation

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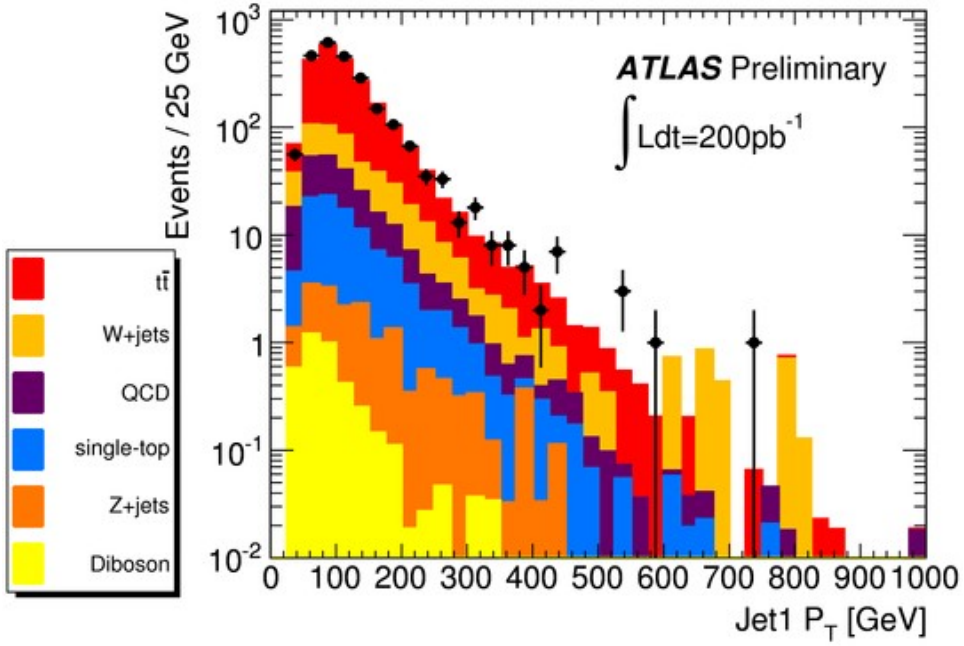
- Comparison of Monte Carlo and QCD spectra after selection shows good agreement with data

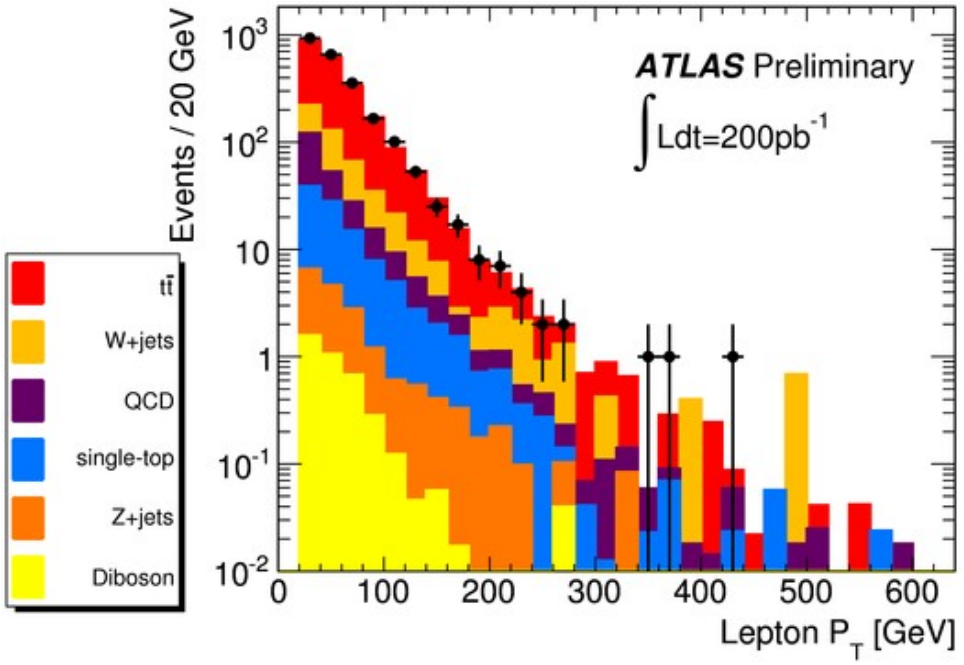
Leading Jet p_T distrubtion

Electron and muon channels combined



Lepton p_T distrubtion

Electron and muon channels combined



Yields after selection

ATLAS-CONF-2011-087

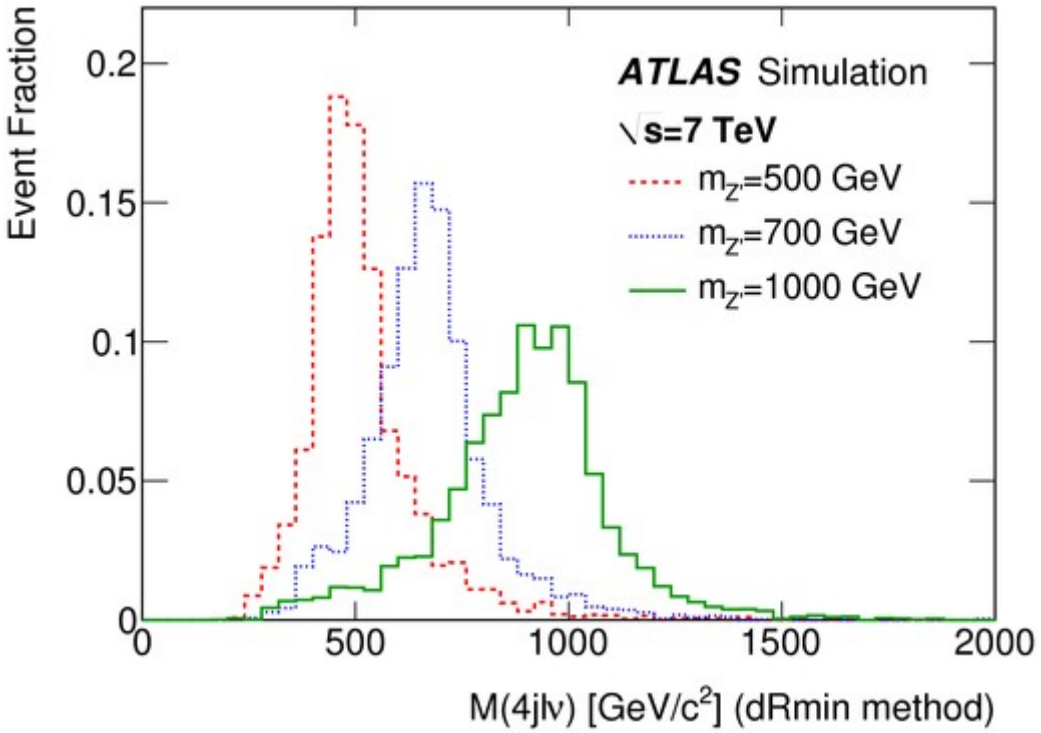
Expected and observed yields after event selection for 200 fb^{-1}

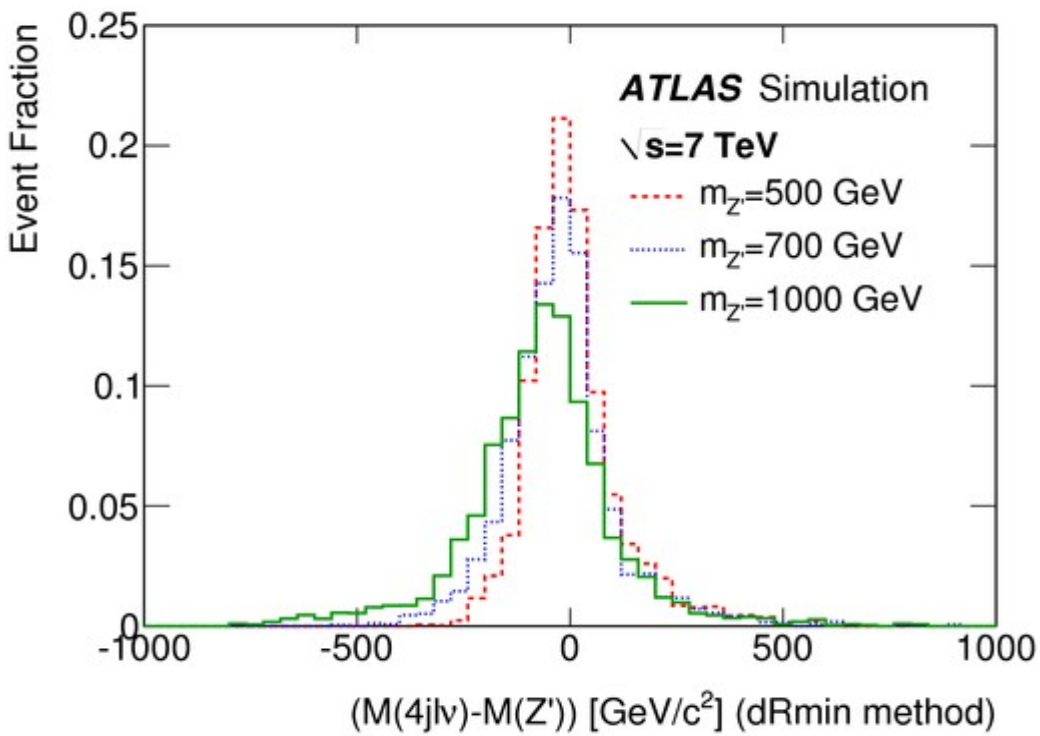
	Electron channel	Muon channel
$t\bar{t}$	724	988
Single top	36	50
W+jets	93	172
Z+jets	6	8
Diboson	2	2
Total MC Background	861	1220
QCD Background	35	105
Total Expected	896	1325
Data observed	935	1396
Z', $m = 500$ GeV	15	21
g_{KK}, $m = 700$ GeV	68	93

Invariant mass reconstruction

ATLAS-CONF-2011-087

- Neutrino p_z reconstructed by imposing W mass constraint
- Crucial to keep tails in the invariant mass distribution under control
- Influence of ISR and FSR jet reduced by applying ΔR constraint: remove jets if $\Delta R > 2.5 - 0.015 \times m_j$, where m_j is the jet mass and ΔR is w.r.t. the lepton or the nearest jet
- Method tested on Z' Monte Carlo, good resolution achieved





Bayesian limit

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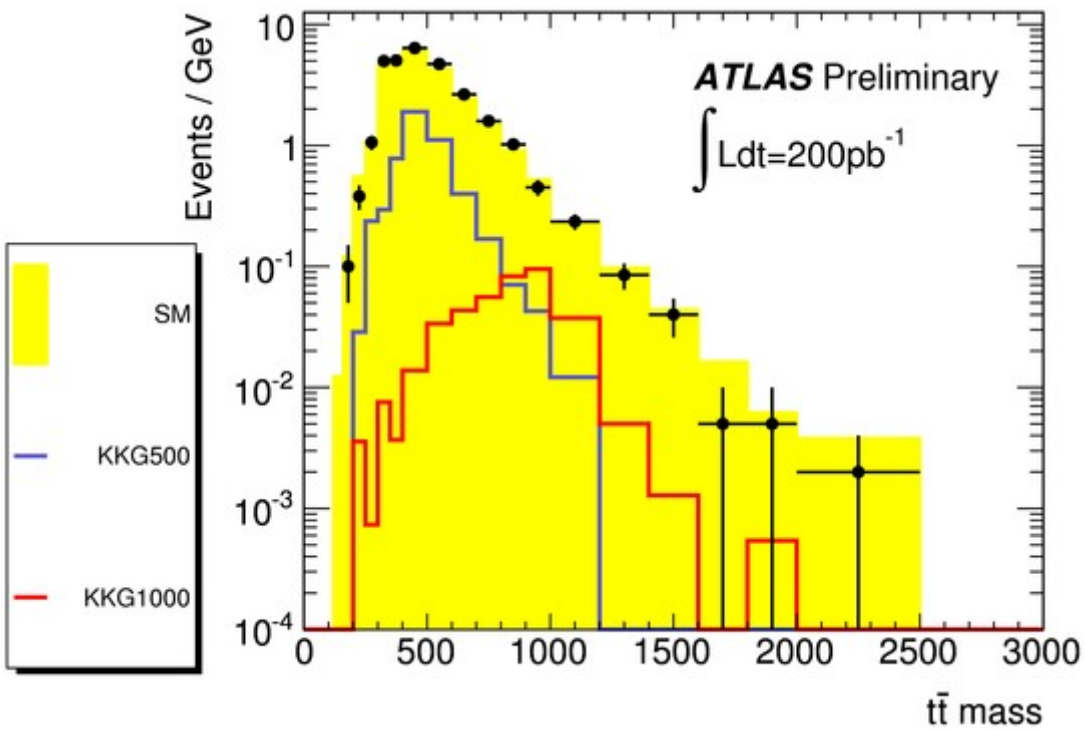
- Search of excess data with BumpHunter finds no evidence of resonance in invariant mass spectrum
- Bayesian approach to estimate limits for cross-section of BSM models:
  - Assume bins distributed by Poisson distribution
  - Include systematic uncertainties by smearing the Poissonian
  - Multiply for each mass bin the likelihood of data being from SM processes only
  - Prior probability distribution of signal: uniform distribution
  - Evaluate 95% C.L. from posterior distribution to extract limits



Invariant mass spectrum on logarithmic scale, Electron and Muon channels combined

Systematic uncertainties

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		Systematic uncertainties
Luminosity		4.5%
Background normalization	SM $t\bar{t}$	(+7.0 -9.6)%
	Single top	10%
	W+jets	35%
	Dibosons	5%
	QCD	e : 30% μ : 50%
Lepton trigger and reconstruction efficiencies		≤ 1.5%

- The dominant shape uncertainties arise from b-tagging efficiency (11%), jet energy scale (9%), modeling of ISR/FSR (7%).
- Other uncertainties on MC modeling have substantially smaller impact.

Results

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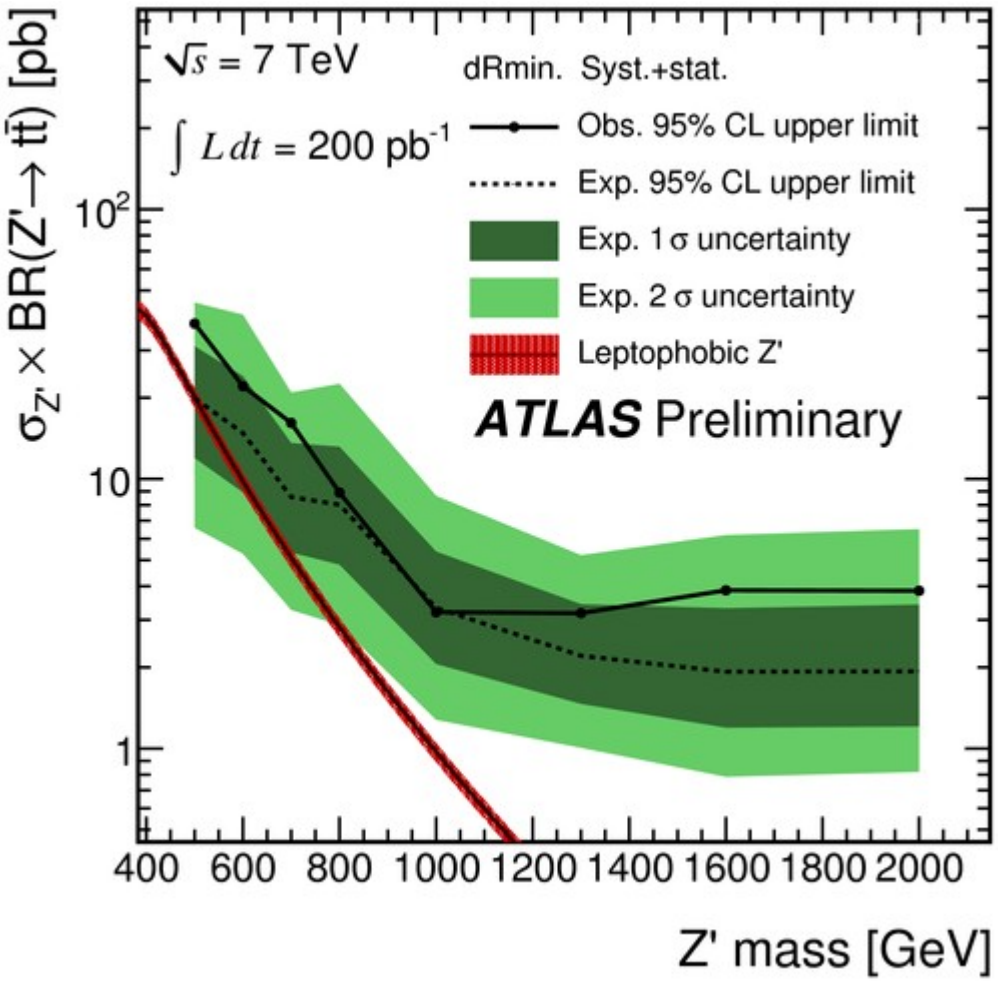
- For Topcolor Z' resonances the observed 95% C.L. limits range from:
  - 38 pb at m = 500 GeV to
  - 3.2 pb at m = 1300 GeV



Results

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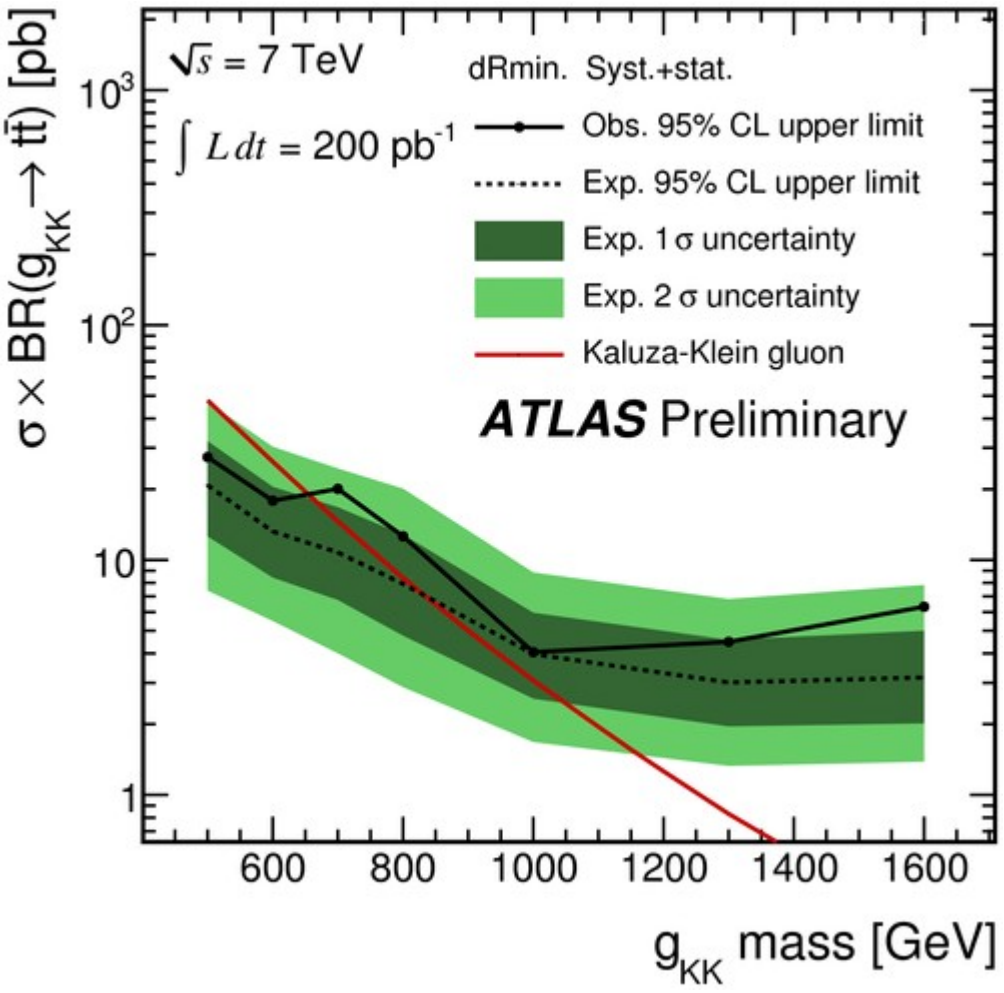
- Kaluza-Klein gluons with masses below 650 GeV are excluded at 95% C.L.



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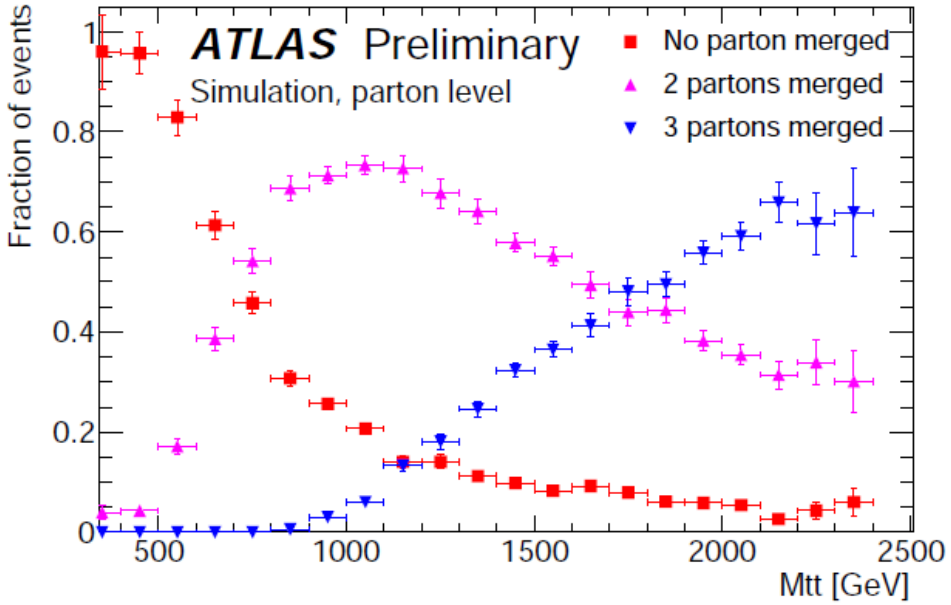
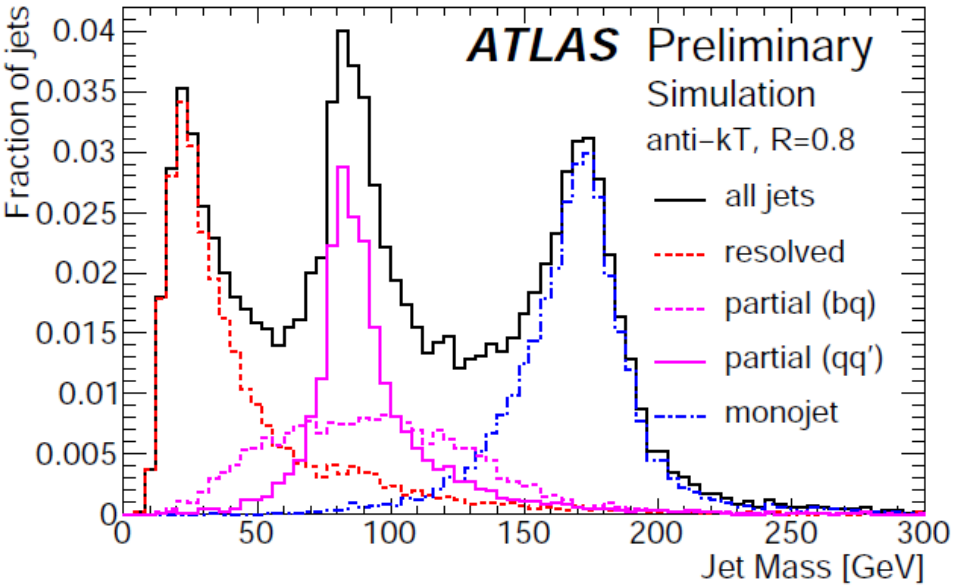
Boosted Analysis

Boosted objects analysis

ATL-PHYS-PUB-2010-008

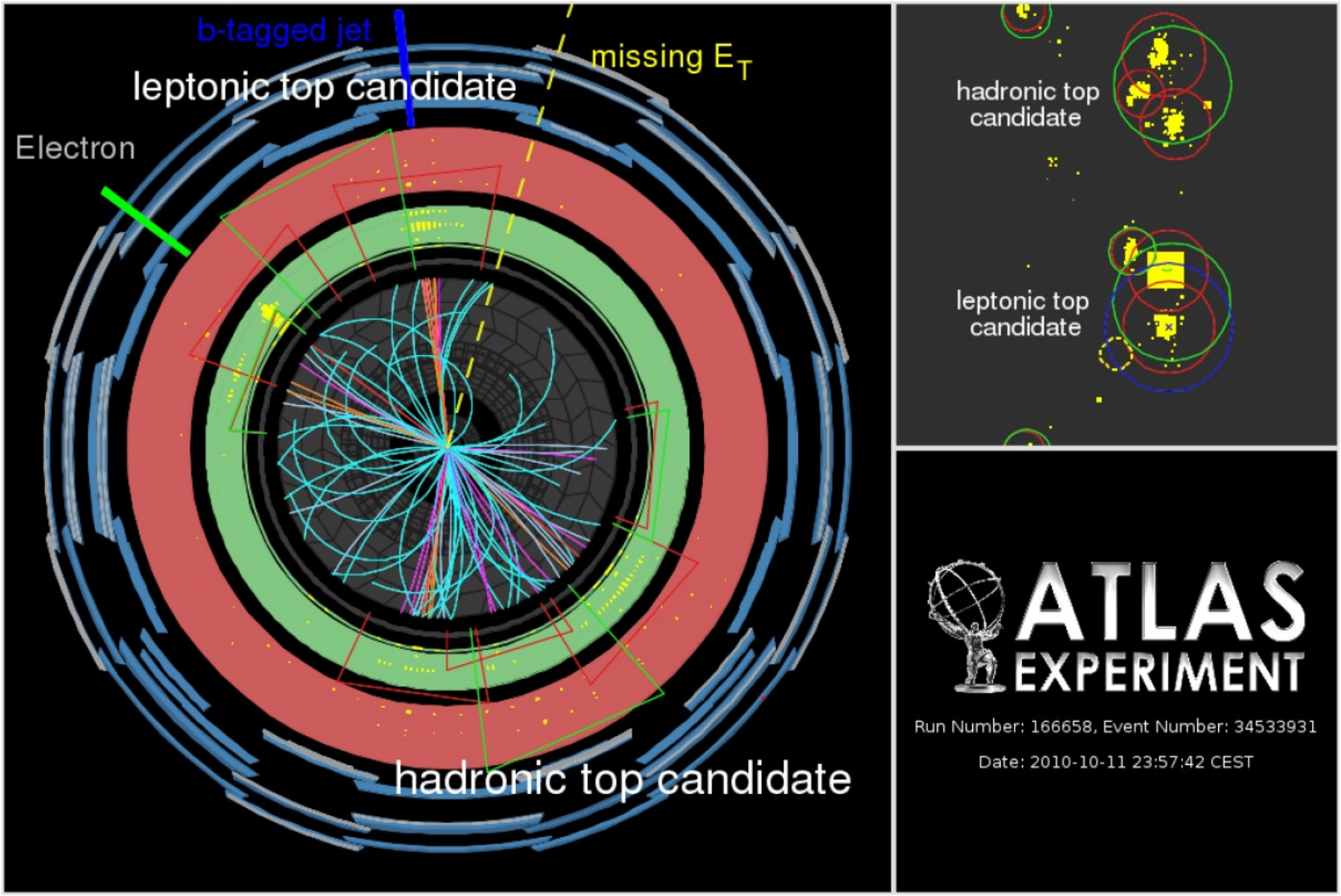
- Topology of ttbar events changes as total invariant mass increases
- At low end of the spectrum, decay products of top pair fully resolved
- As invariant mass increases, angular separation between decay products narrows, jets merge
- At very high m_{tt}, top pair decay products collimated into back-to-back “monojets”
- Monojets have typically a large mass; study of monojet substructure was performed





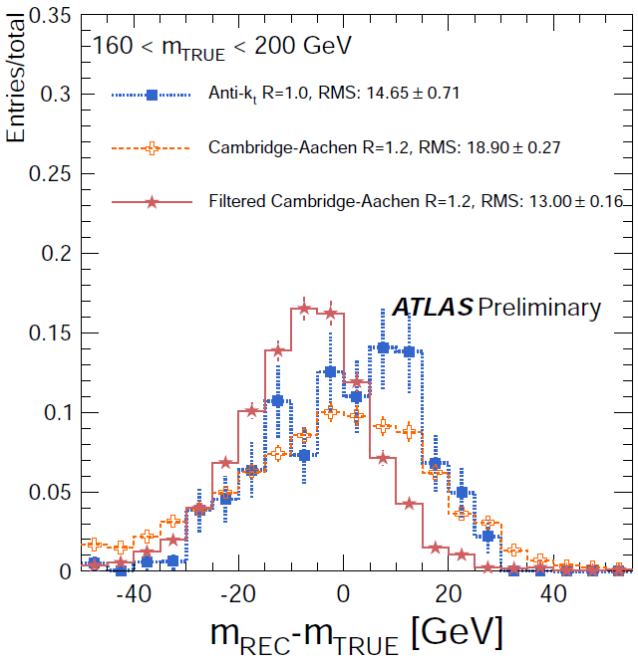
Boosted top pair candidate

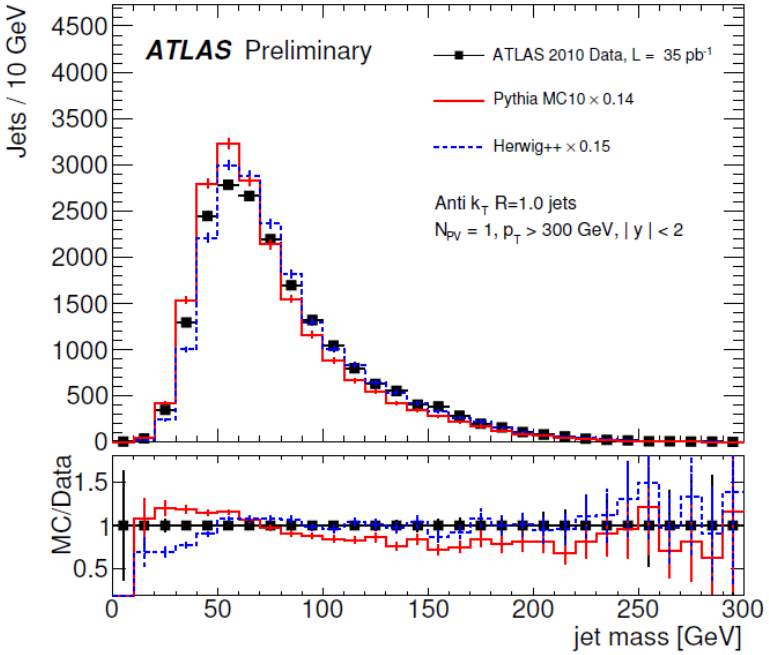
ATLAS-CONF-2011-073



Substructure of boosted jets

ATLAS-CONF-2011-073

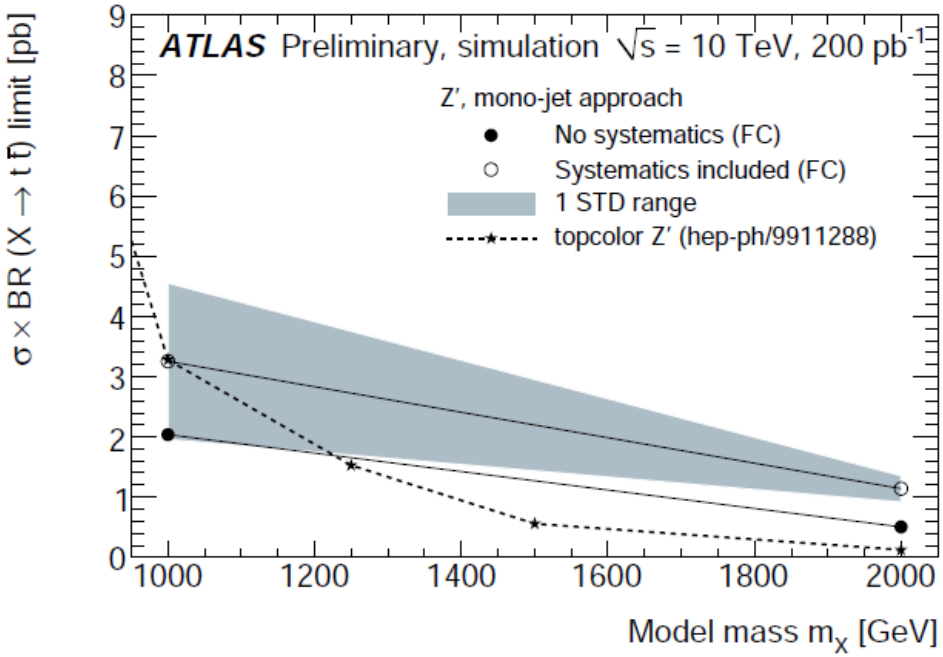




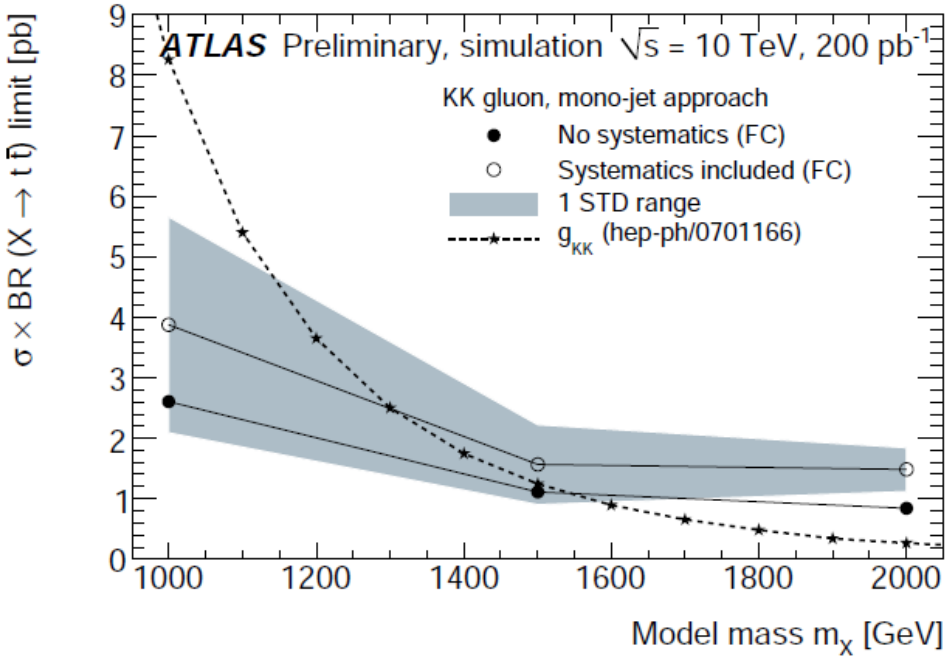
- In simulation, final states with $m_{jet} \sim m_{top}$ have a good jet-mass resolution
- Pile up is biggest problem:
  - influences anti-kt 1.0; needs calibration
  - Cambridge-Aachen jets seem less affected
- Jet mass in data described reasonably by Pythia and Herwig

Prospects

ATL-PHYS-PUB-2010-008



mono-jet, Z'



mono-jet, broad resonance

- Boosted top analysis will improve chances to find high-mass resonances if any exist. Otherwise, stringent limits can be set
- With 200 pb^{-1} at 10 TeV, exclusion limits can be set for processes with cross-section ~3 pb and a resonance mass of 1 TeV; more stringent limits at higher masses

Conclusions

- A search for top quark pair resonances in the lepton plus jets final states has been performed with the ATLAS experiment at the LHC, with fully resolved top decay products
- No evidence for resonances was found, limits were set to BSM physics
- For narrow (Topcolor Z') resonances the observed 95% C.L. limits range from:
  - 38 pb at m = 500 GeV to
  - 3.2 pb at m = 1300 GeV
- Wide resonances (Kaluza-Klein gluons) with masses below 650 GeV are excluded at 95% C.L.
- The search for resonances is expected to improve significantly with the combination of the resolved analysis with the boosted top analysis