New physics searches with top quarks at ATLAS

Marcel Vos (IFIC, CSIC/UV, Valencia, Spain)

New phenomena discussion session

IMFP2012, Benasque, Spain

Top as a signature for new physics?

Wishful thinking?: Will the top (and bottom) quarks be the messenger by which Beyond The Standard Model physics reveals itself?

See Peter Uwer's talk in yesterday's top quark dicussion session. The top quark is heavy, it's less constrained by (LEP) data, and plays a special role in many BSM proposals

An experimentalist's view: 12 known fermions, 7 experimental signatures: ($\mu^{\pm}$, $e^{\pm}$, $\tau^{\pm}$, E_t^{miss}, uds(g), b/c and top)

Only one that has strong coupling and produces isolated leptons.

top is the new bottom

→ top beats bottom!

(we award a prize for the best graphical illustration of this phrase)

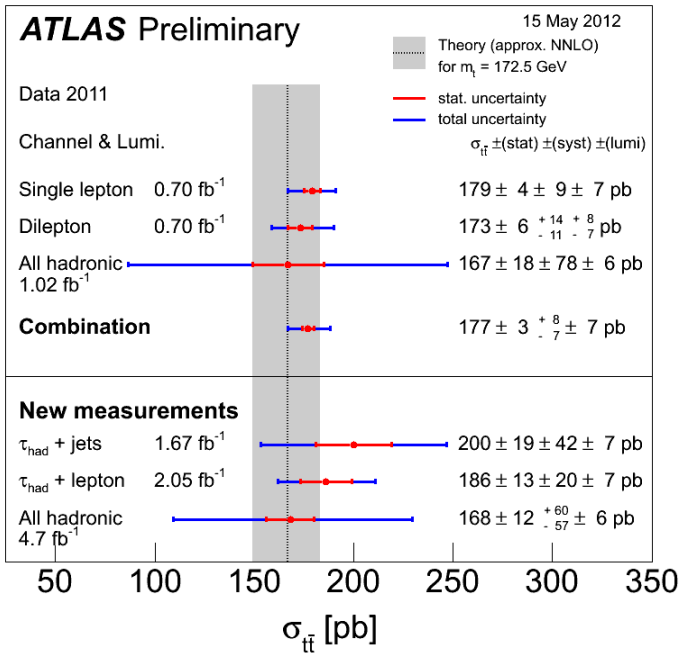
Today: discuss the LHC potential to clarify whether the Tevatron asymmetry measurements are the start of something beautiful

The top quark

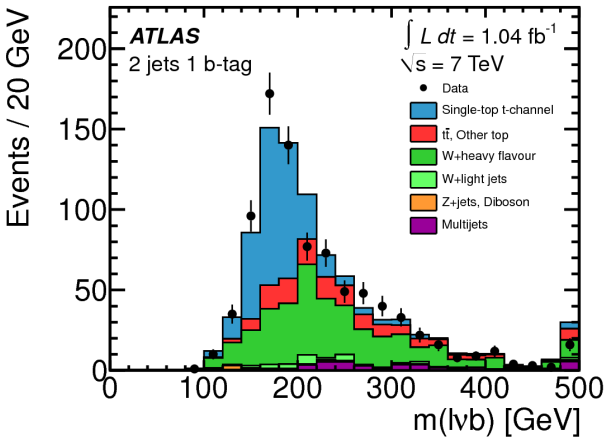
Pair production cross section – no suprises

$m_t = 174.5 \pm 0.6\ (stat) \pm 2.3\ (syst)$ GeV

Spin correlations, W polarization,...



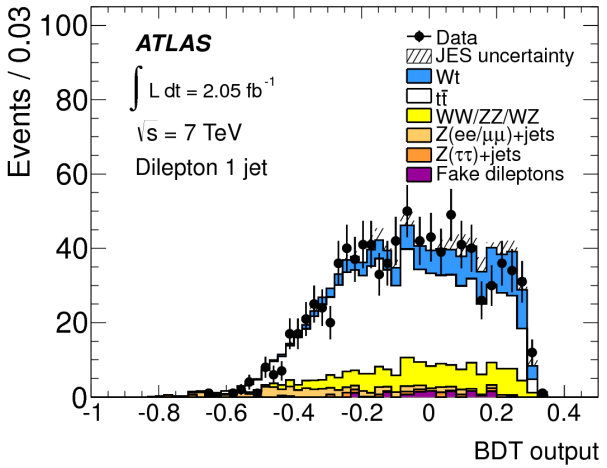
Measurement of the t-channel single top-quark production cross section in pp collisions at √s = 7 T



X-sec = $83 \pm 4\ (stat.)^{+20}_{-19}(syst)$ pb

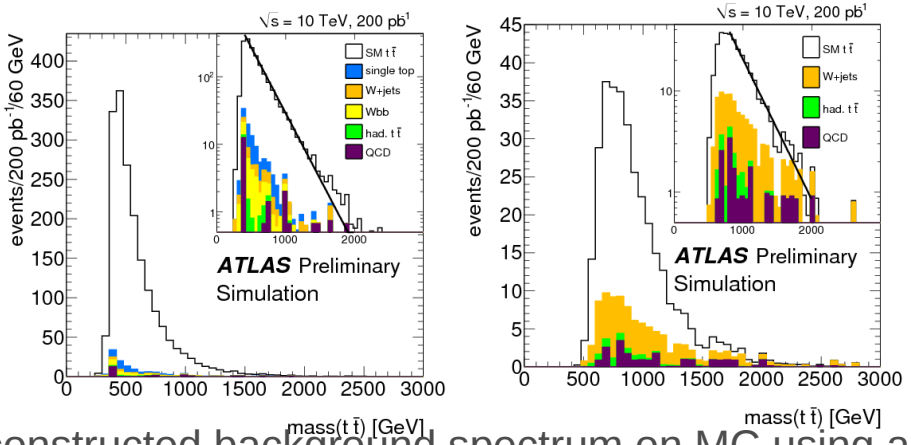
Assuming $|V_{tb}| >> |V_{td}|, |V_{ts}|$

$|V(tb)| = 1.13\ ^{+0.14}_{-0.13}$



Evidence for the associated production of a W boson and a top quark

Top-tagging: Plehn & Spannowsky, BOOST reports



Old plots from our 10 TeV prospects MC note (ATL-PHYS-PUB-2010-008)

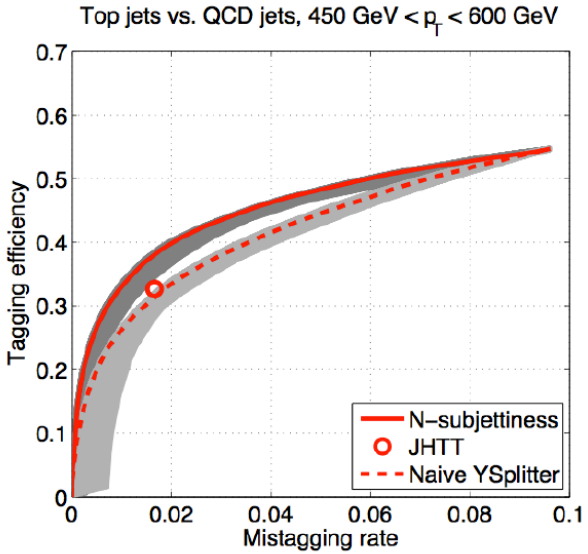
Reconstructed background spectrum on MC using an adapted resolved algorithm (stable at 5 % effieciency up to 2 TeV) and an algorithm developed for boosted top quarks. (15% down to m_{tt} = 700 GeV). Both have comparable mass resolution.

ATLAS supports fat jets and substructure!
n-subjettiness (arXiv:1011.2268 [hep-ph], arXiv:1108.2701 [hep-ph])

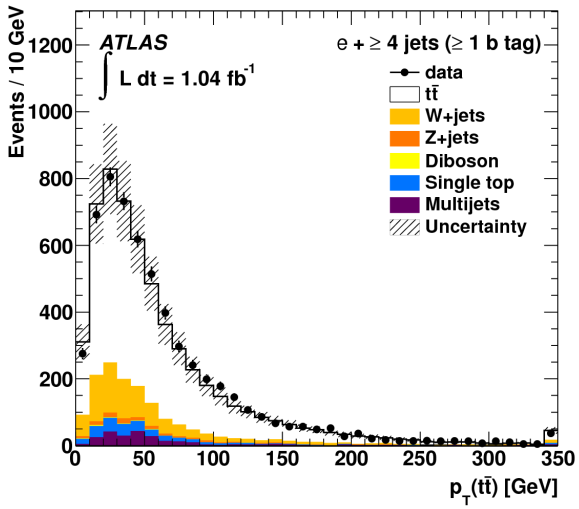
HepTopTagger [arXiv:1006.2833] for fully hadronic final states

Template top-tagging

For the CMS vision see Luca Scodellaro's slides



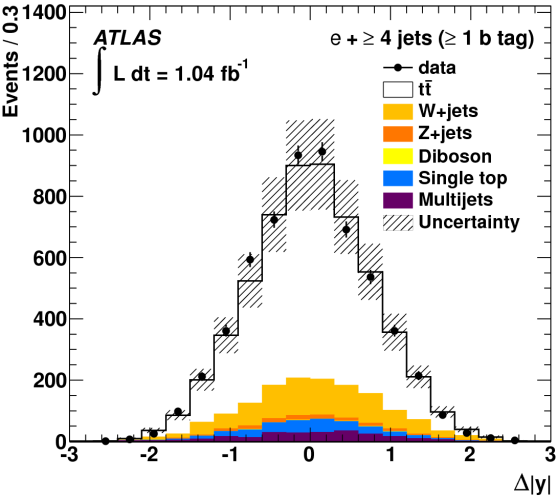
Charge asymmetry

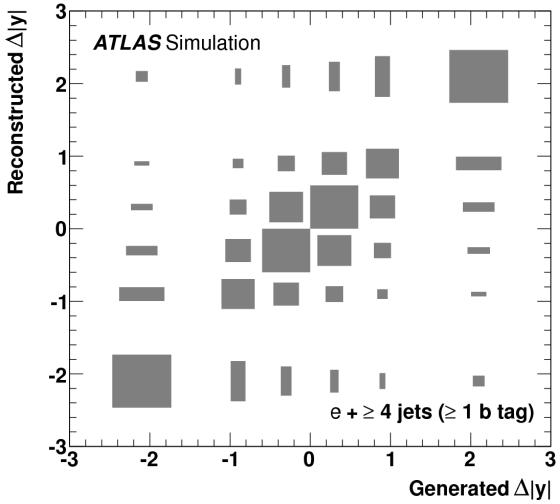


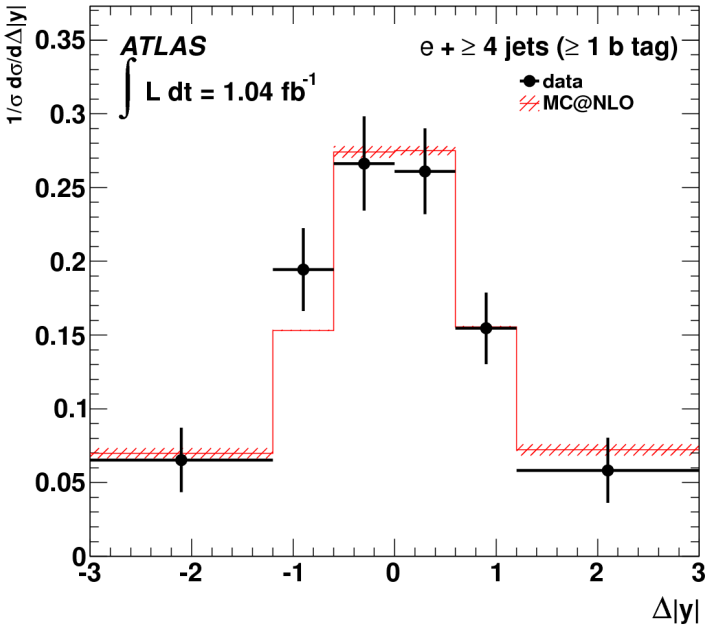
Clean tt selection, mostly close to threshold

No attempt to enrich qq initiated production beyond binning in m_{tt}

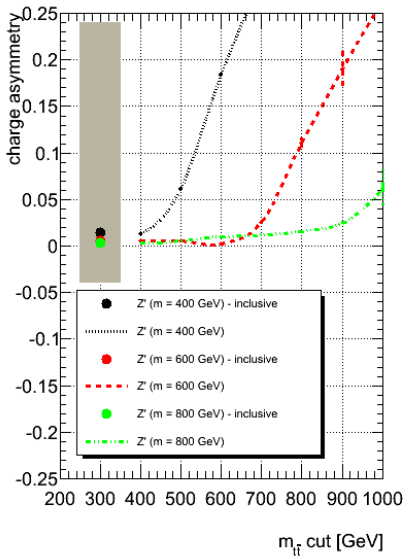
Unfolding





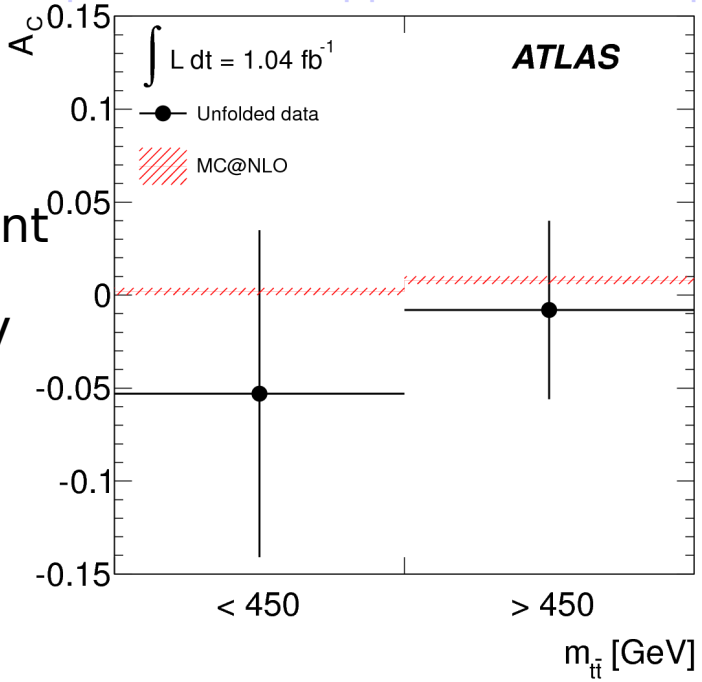


Charge asymmetry

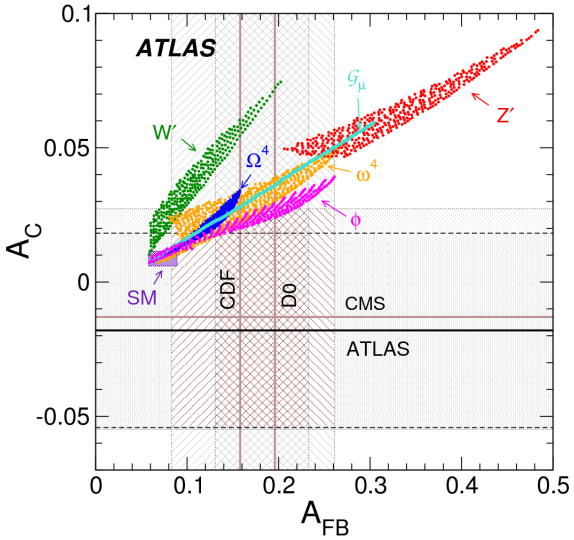


Inclusive measurement and two mass bins <450 GeV, >450 GeV

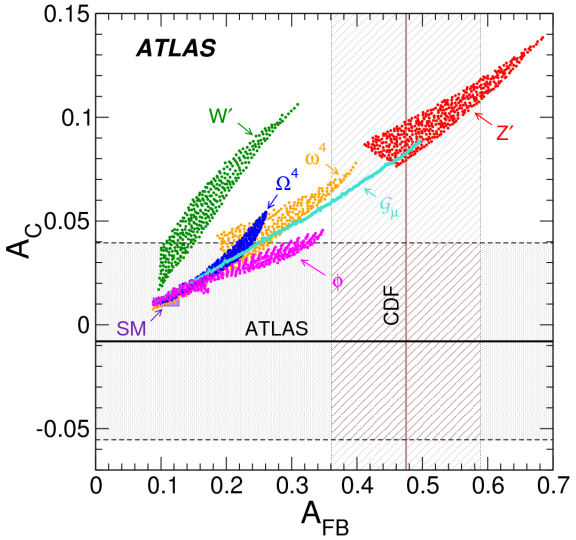
A_C vs. mass for Z' model (V. Sanchez, A. Hyaya)



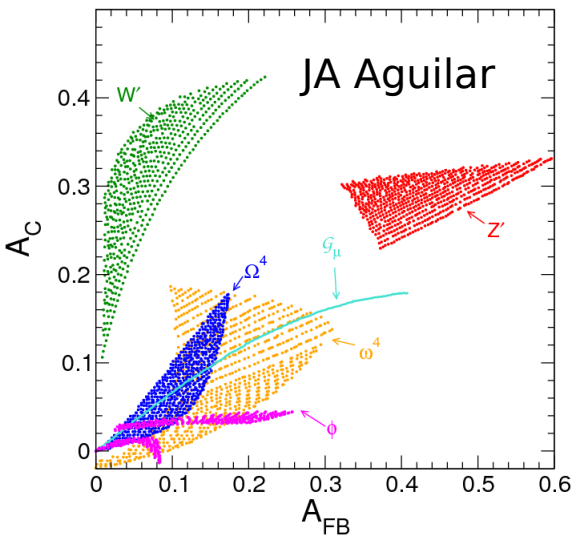
Impact on model zoo inclusive



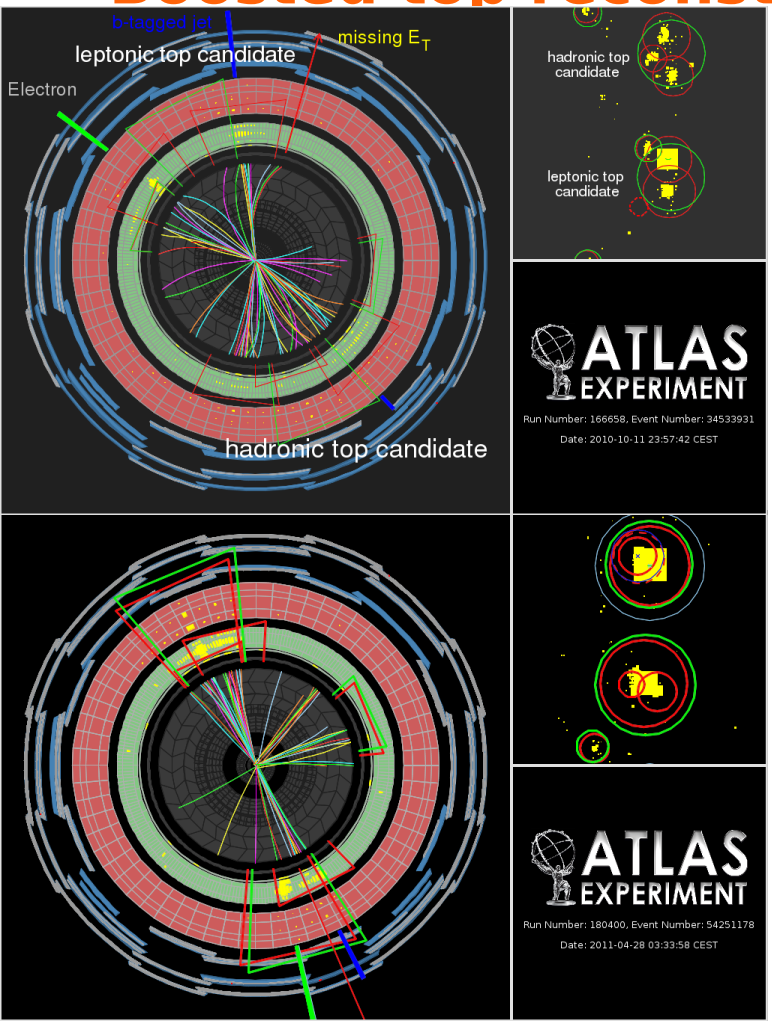
m_{tt} > 450 GeV (Tevatron and LHC)



M_{tt} > 800 GeV (LHC only)



Boosted top reconstruction

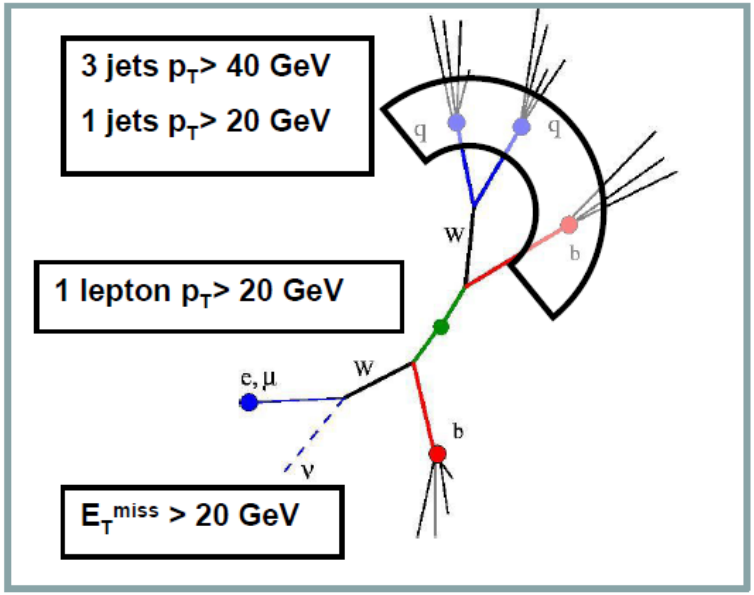


ATLAS-CONF-2011-087

ATLAS-CONF-2011-073

Can use the clear correlation between directions when assigning jets to top quark candidates

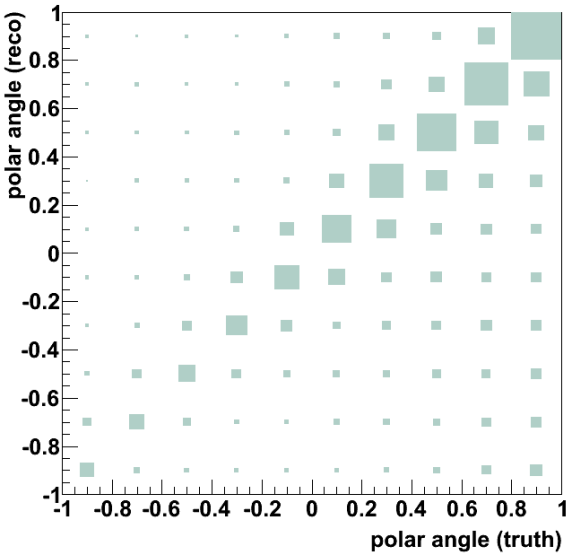
anti-k_t with R=0.4 yields only 3 jets



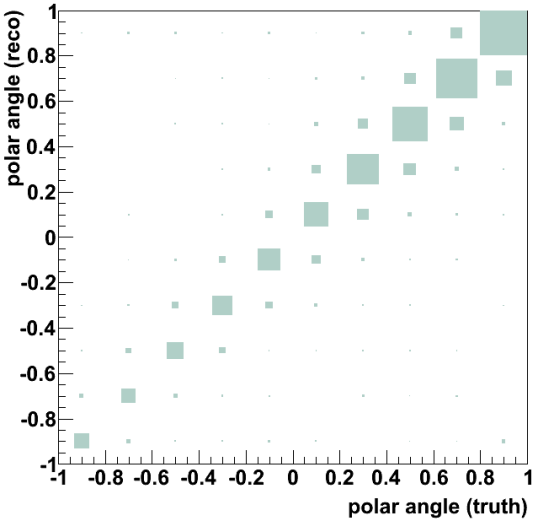
Charge asymmetry

If we select high mass and reconstruct them with adequate tools, we moreover get rid of the strong migration in the reconstructed top direction

ILC500



ILC1000



Nacho Garcia, Eduardo Ros, MV, DESY ILC Forum 2012

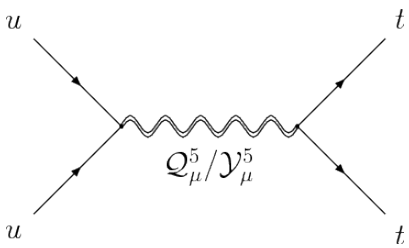
For another way of avoiding dilution of the asymmetry (boost along z), see:
Boosting the t tbar charge asymmetry., JA Aguilar, A Juste, F Rubbo, PLB707 (2012)

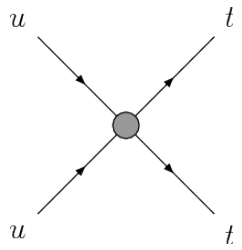
Direct searches

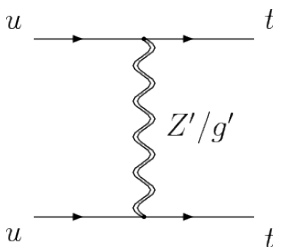
Direct searches!

Same sign tops

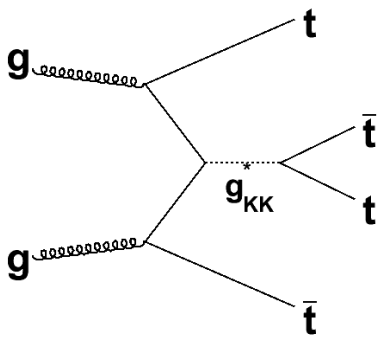
E. Berger et al, Search for Color Sextet Scalars in Early LHC Experiments, arXiv:1005.2622 [hep-ph]





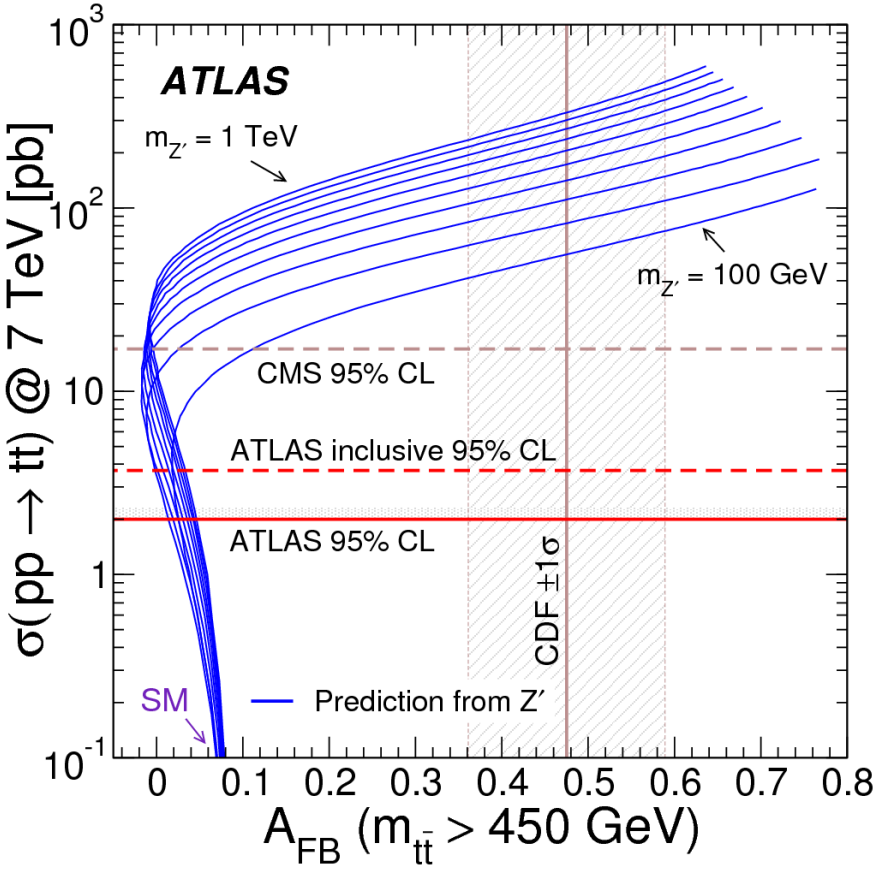


Four-top production (SM, compositeness, resonances)

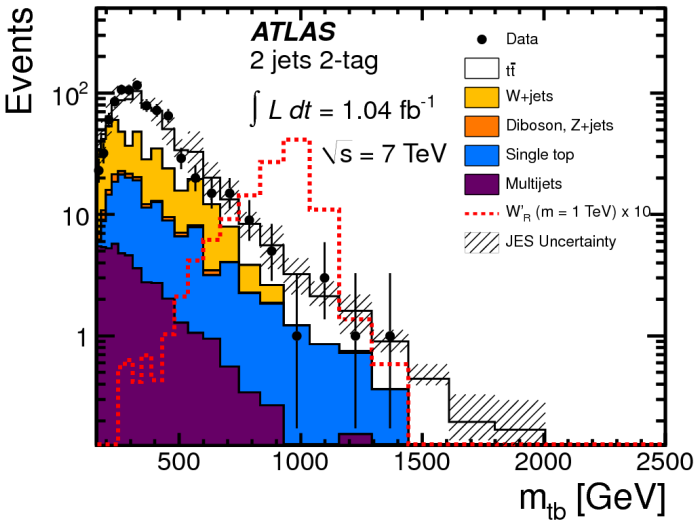


Pomarol/Serra

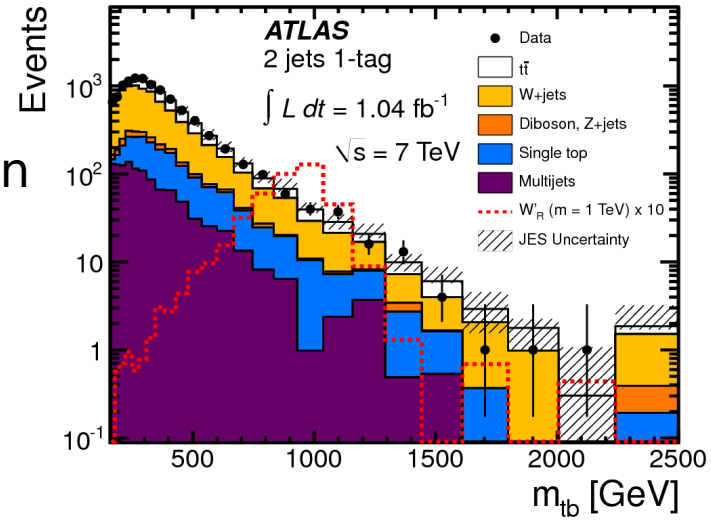
G. Servant, M.V. Et al , arXiv:1005.1229 [hep-ph]



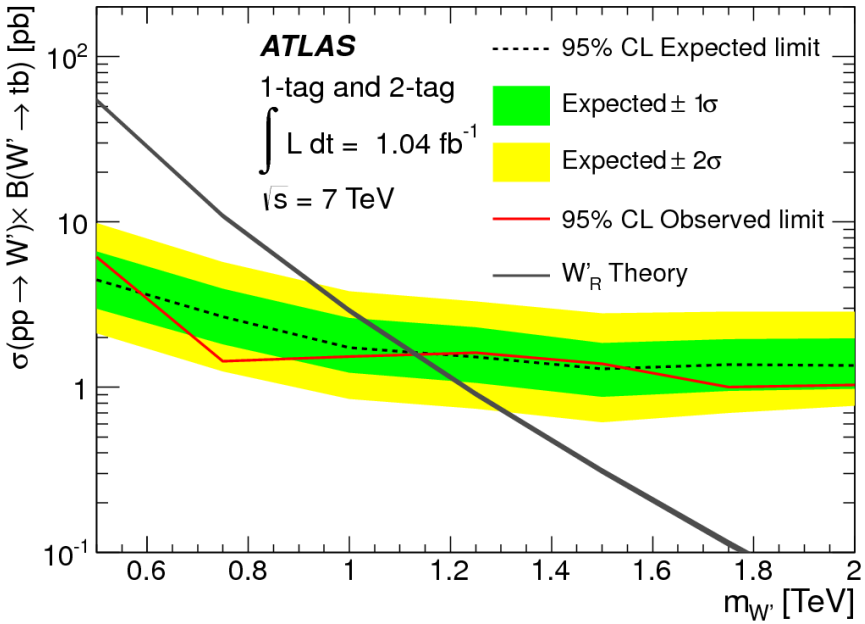
W' → tb



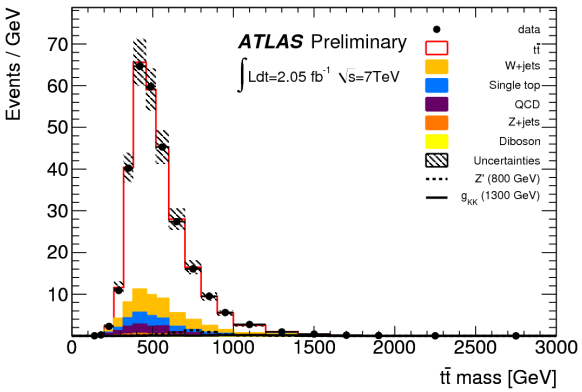
Single and double tagged signal region



Selection similar to single top (but less stringent)



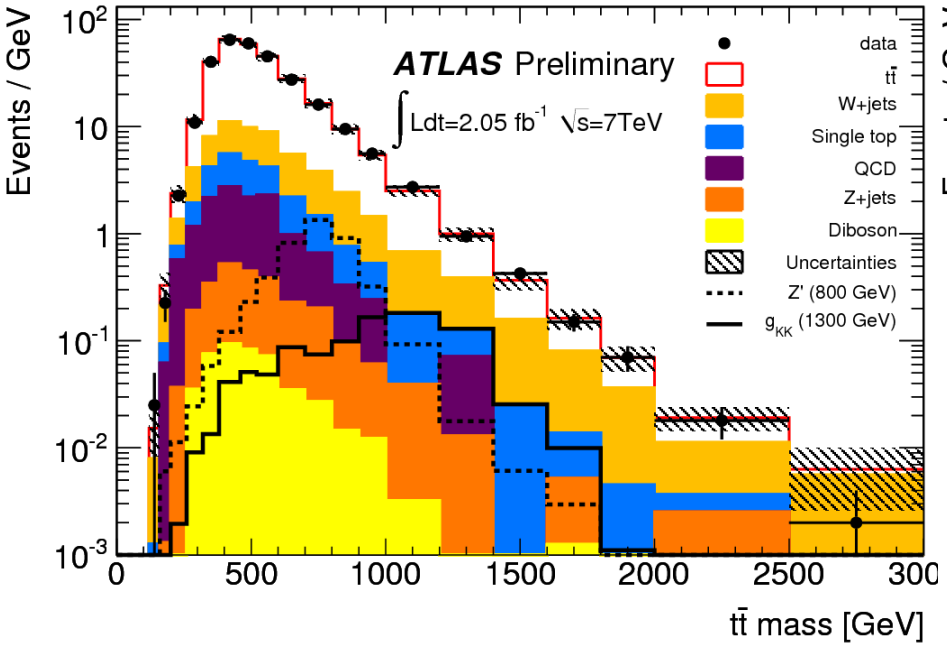
$t\bar{t}$ resonances



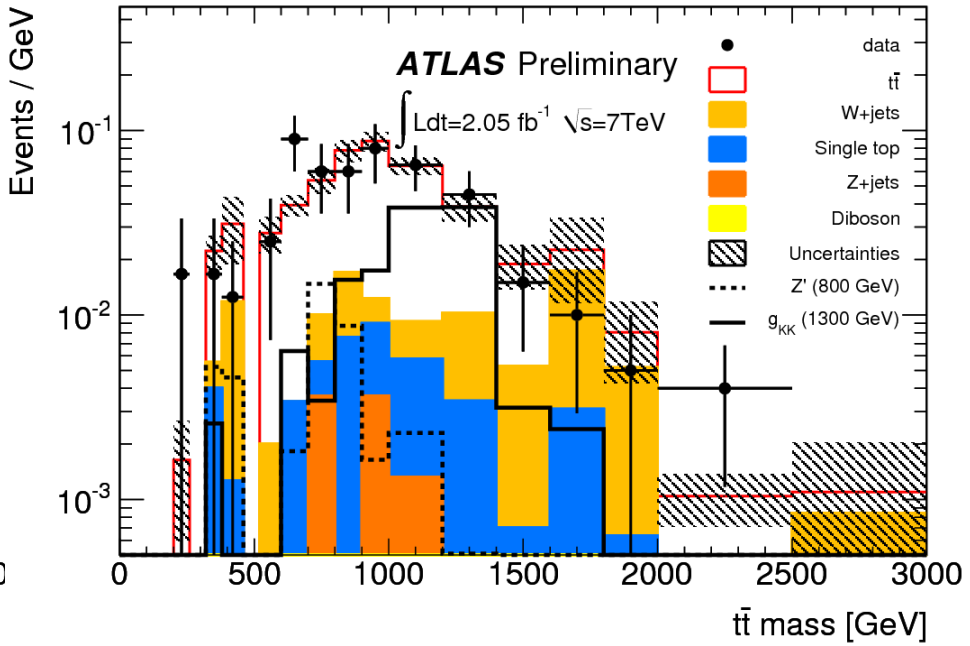
Nearly 80% of expected SM population of the Signal Region is due to tt pair production

Rejection for W+jets degraded for high mass, but still adequate. The “fat” jet region selects some of the most interesting events

Full Signal Region



“fat” jet region



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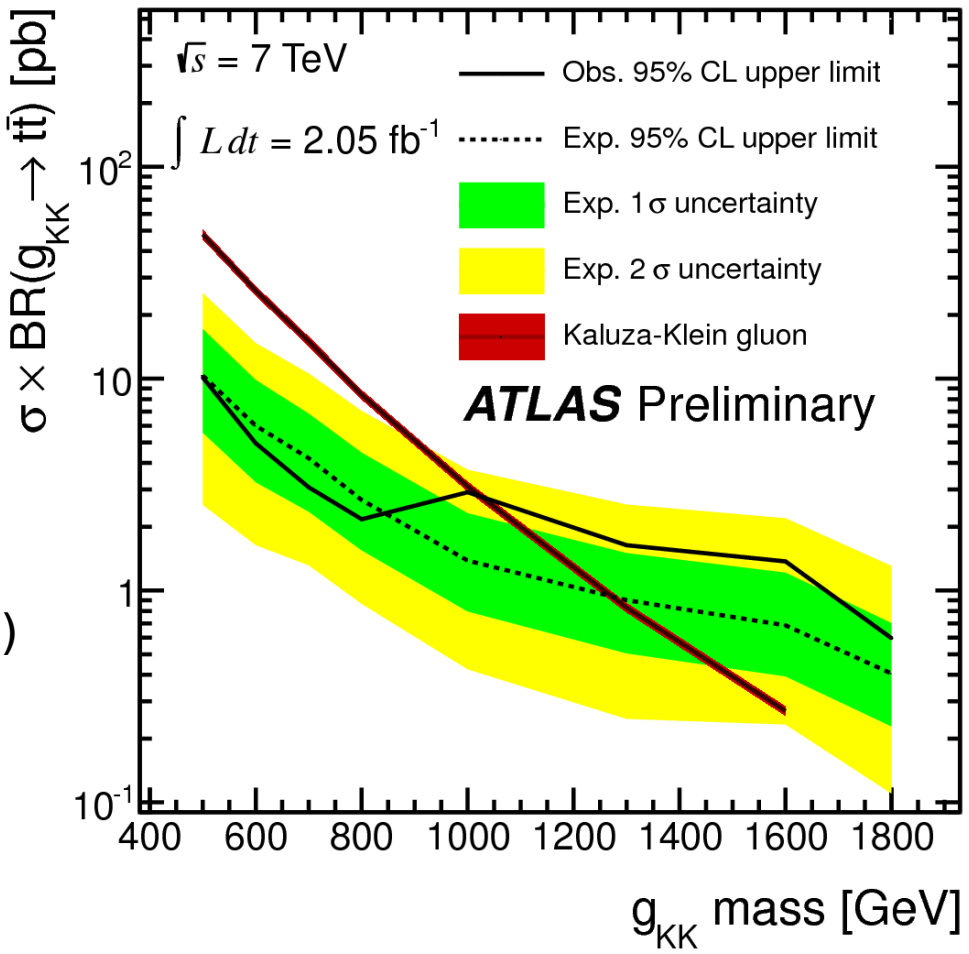
Searches with boosted top quarks: $t\bar{t}$ resonances

Rule out (at 95% C.L.) the existence of a narrow (leptophobic) Z' (in topcolor models) or a heavy broad KK excited state of the gluon

σ x BR < 9.3 pb at m = 500 GeV
σ x BR < 0.95 pb at m = 1300 GeV
Excluded mass range:
500 GeV < m(Z') < 860 GeV
500 GeV < m(g_{KK}) < 1025 GeV

Diversify benchmarks (broader)
Spin-off search for boosted T quark (R. Barcelo, Granada)

Comparison to a truly boosted analysis of lepton+jets $t\bar{t}$ events (Arizona, DESY, Oxford, IFIC, DESY)
→ proof of principle for the "boosted paradigm"



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Conclusions

Several angles to attack the Tevatron FB asymmetry result at the LHC

Charge asymmetry (cf. German's talk)
Push the charge asymmetry to corners of phase space:
- $t\bar{t}$ invariant mass, IFIC team
- boost along z, Aguilar, Juste, Rubbo

Direct searches:
- same sign top quarks
- W' → tb
- g* → $t\bar{t}$

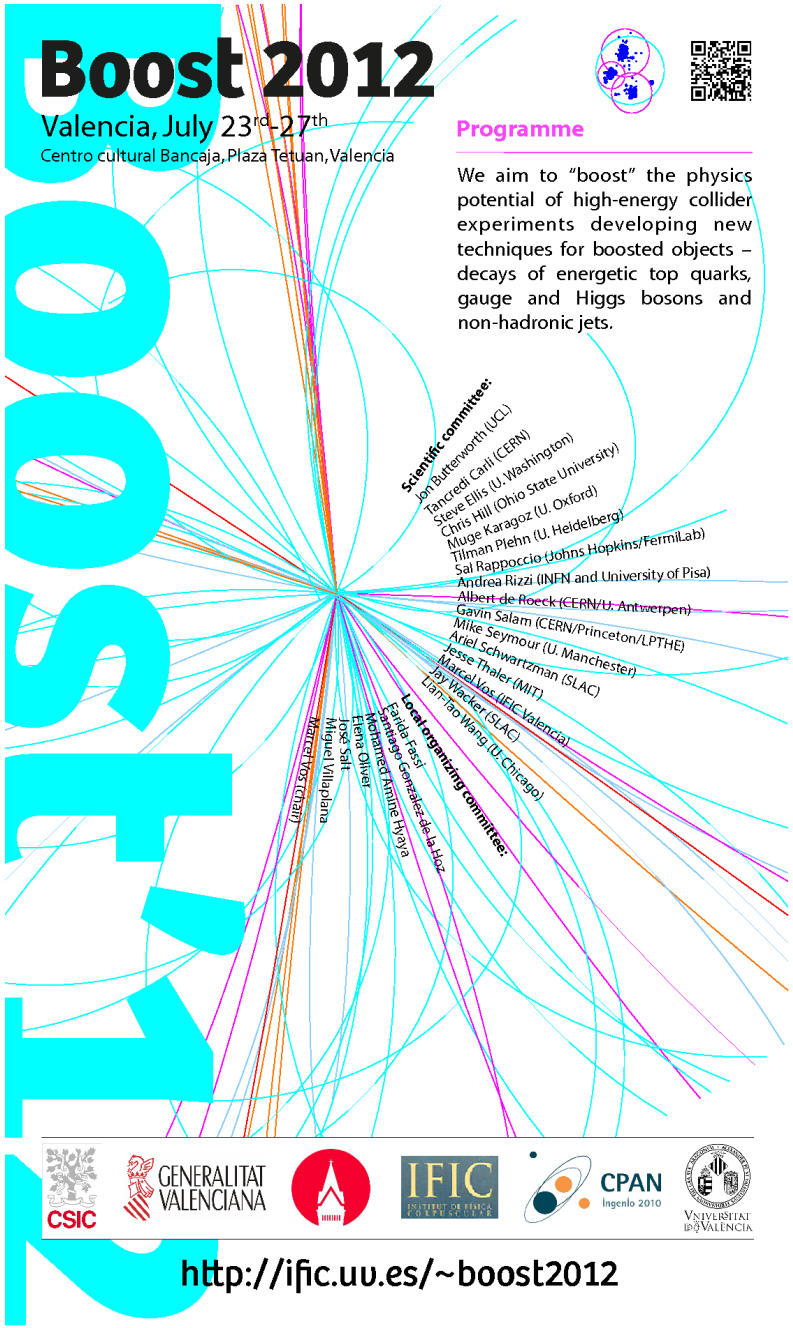
Stay tuned

Summer in Valencia!

The hottest event of the year: the scientific program, the ambient temperature, Bankia...

Registration already exceeds the envisaged limit.

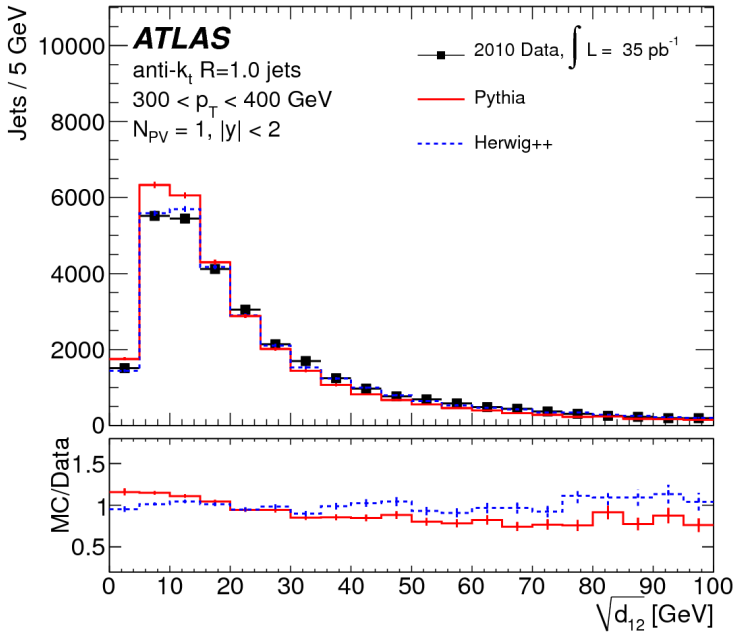
Program being defined... one Spanish contribution proposed so far (M. Chala)

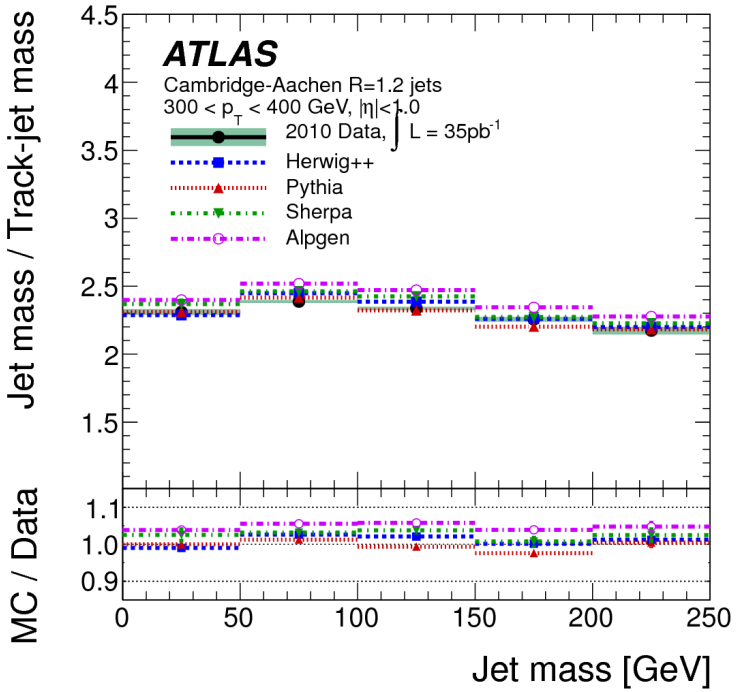


Commissioning jet substructure

The energy and mass calibration and scale uncertainties for the anti-k_t jets with R=1 are based on the work in arXiv:1203.4606 [hep-ex] (Adam Davison's talk in this workshop)
Use locally calibrated topological clusters so that jet-level corrections are small. Determine jet-level corrections on MC to correct reconstructed energy or mass to the scale of matched particle jets

Check the detector-level distribution



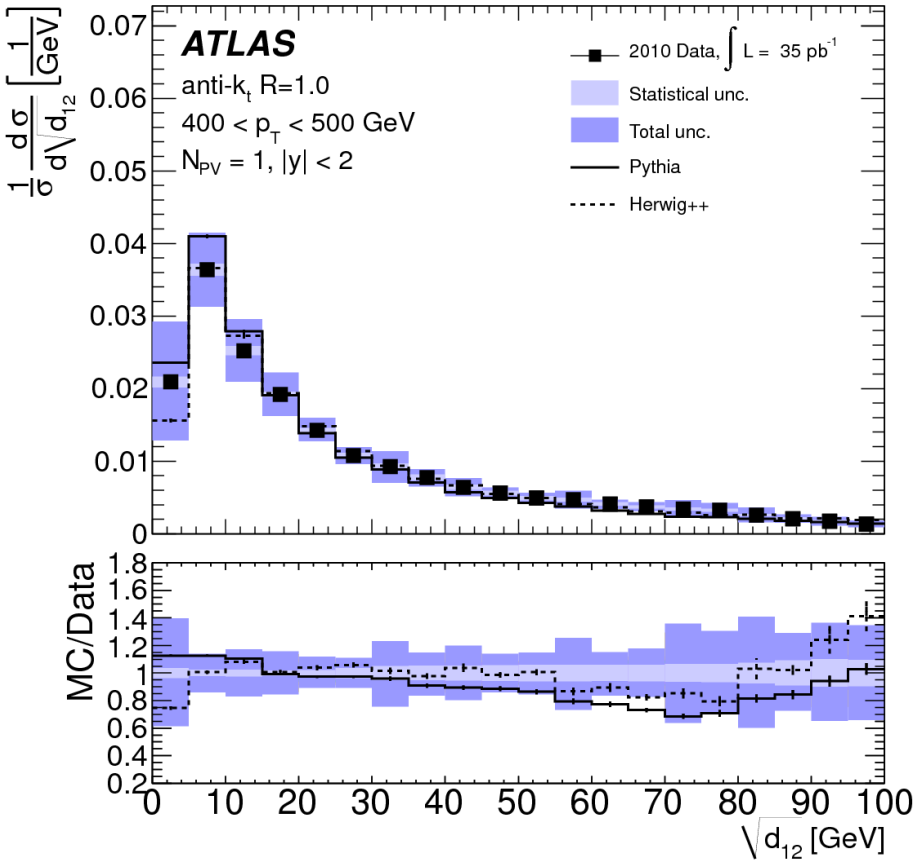


Determine scale uncertainty for E, m and $\sqrt{d_{12}}$ in situ by comparing track and calo jets

Commissioning jet substructure

arXiv:1203.4606 [hep-ex] and Adam's talk

Distribution at “particle-level”, after correcting for all detector effects show reasonable agreement between data and most MC within not-too-large systematic uncertainties:
- Parton Shower model is adequate
- Detector response is under control
- Underlying event OK



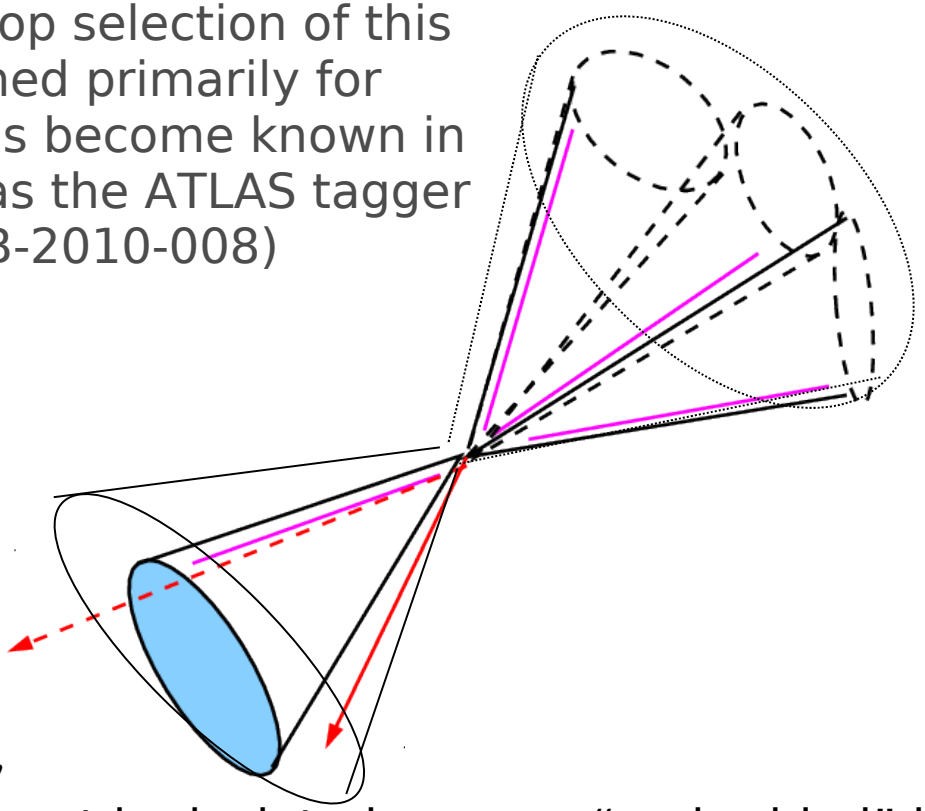
What about pile-up?

Pile-up has been shown to have a big impact on some substructure observables (most notoriously, jet mass)
We can mitigate the impact on analysis by grooming or smart choice of observables, by correcting using smart techniques, and by modeling pile-up correctly in MC

boosted top quark reconstruction

$t \rightarrow bW \rightarrow bjj$
reconstruct a single “fat” jet (R=1-1.5)
measurable substructure (jet mass, splitting scales, ...)

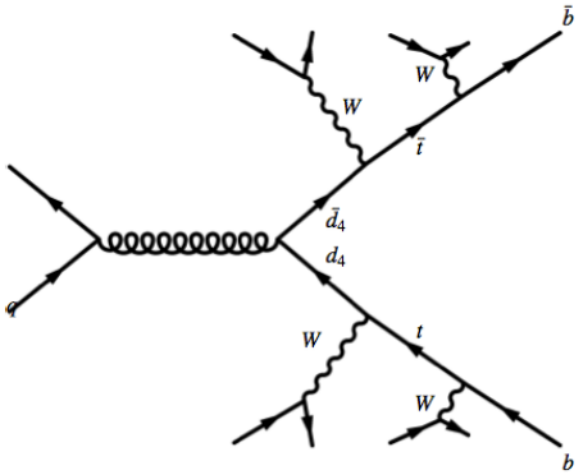
The hadronic top selection of this scheme designed primarily for lepton+jets has become known in the literature as the ATLAS tagger (ATL-PHYS-PUB-2010-008)



Jet mass = invariant mass obtained when 4-vectors of all jet constituents are added
k_t splitting scale
$\sqrt{d_{n\,n+1}}$ = run k_t inside jet, undo last steps, and record k_t distance (scale) of the split from n to n+1 pseudo-jets

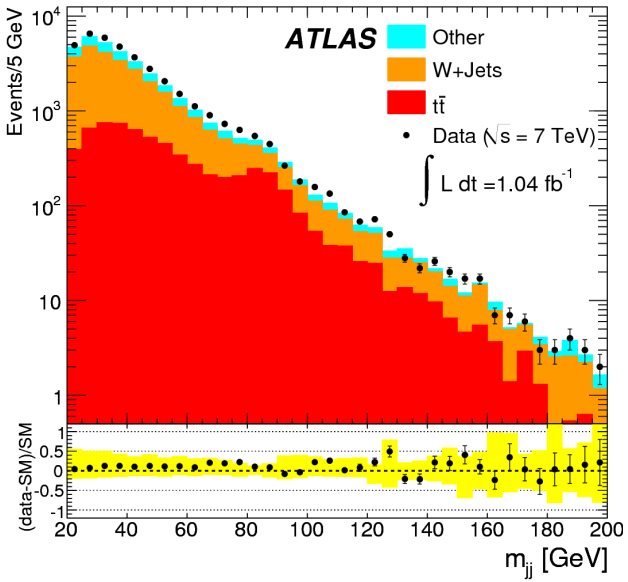
$t \rightarrow bW \rightarrow bl\nu$
lepton might not be isolated or even “embedded” in the jet
Alternative isolation variables (Thaler & Wang), mini-isolation (Tweedie)

b' → Wt

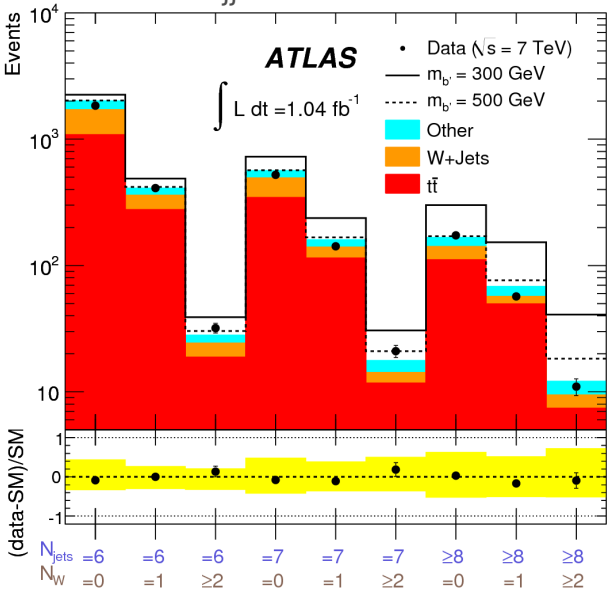


"Boosted objects without substructure"
(ATLAS b' search in arXiv:1202.6540)
Signal: tt pair + 2 boosted W bosons

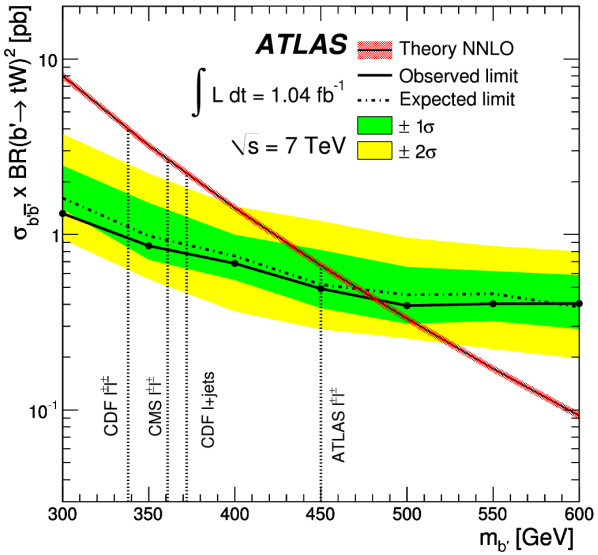
Combine two R=0.4 jets in a $\Delta R < 1$ cone



Count the Ws (pairs with $70 < m_{jj} < 100$ GeV



Exclusion at 95 % CL m(b') < 480 GeV



Searches with boosted top quarks: tt resonances

Fully hadronic & boosted lepton + jets in progress

Di-lepton not discussed today (1.04/fb ATLAS-CONF-2011-123)

ATLAS lepton + jets (2.04/fb ATLAS-CONF-2012-029)

Signal Region =
Standard "lepton + jets" selection

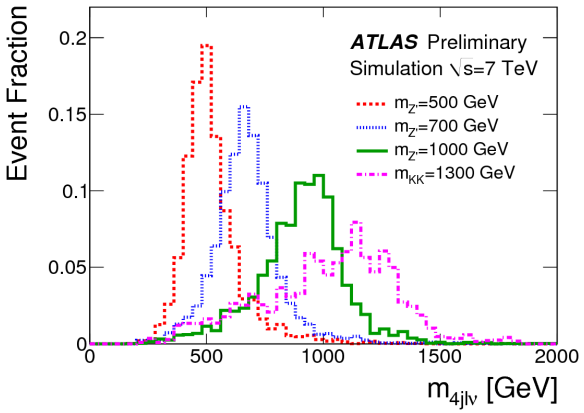
- isolated lepton
- missing transverse momentum
- 4 jets, one b-tagged

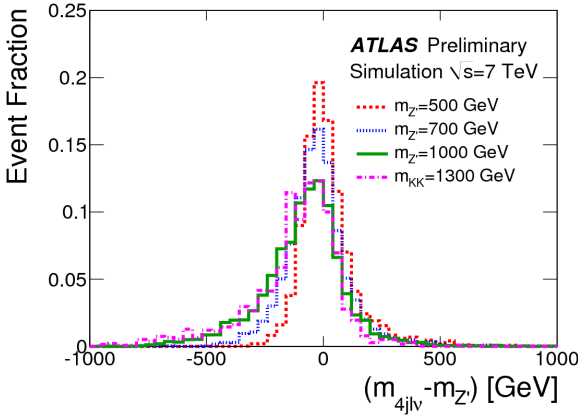
+ "fat" jet region

m_j > 60 GeV; only 3 jets are required (1% of SR)

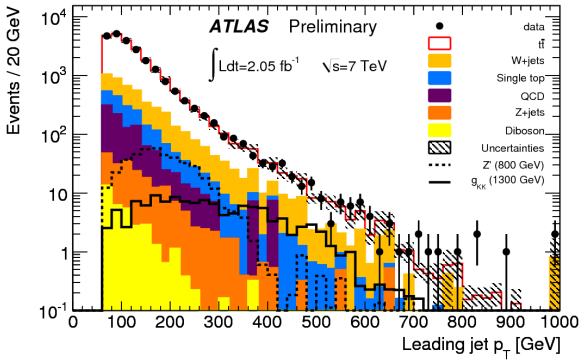
Reconstruct m_{tt} by **combining l, ν, and 4 leading** jets with $|\eta|<2.5$ (ISR/FSR mitigation based on ΔR)

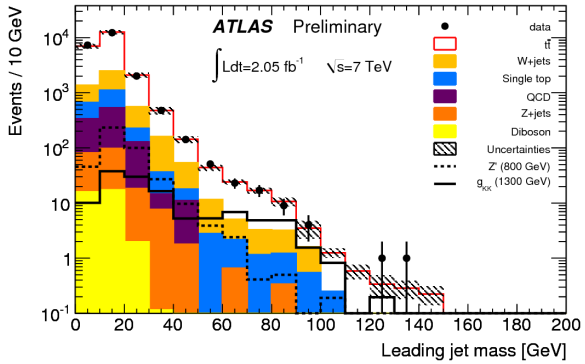
For high jet mass events **combine fat jet + nearest jet, l + nearest jet, ν**





tt mass resolution





anti-k_t jets with R=0.4 well modeled, including internal structure

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