Boost Theory Summary

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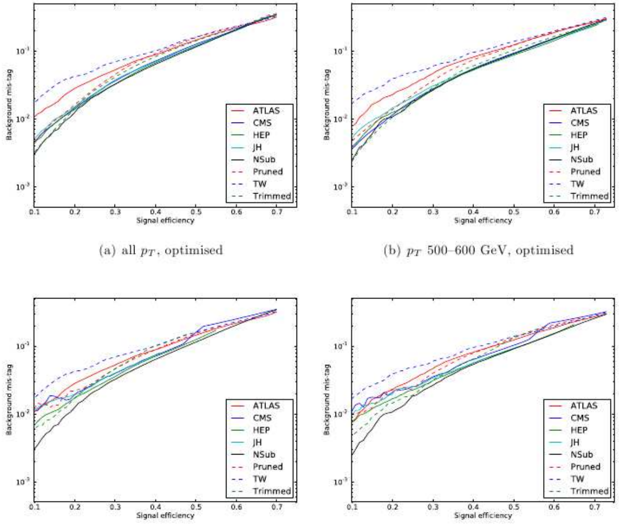
CERN, Princeton University & LPTHE/CNRS (Paris)

Boost 2012
Valencia, Spain, 23–27 July 2012



(a) all p_T, optimised

(b) p_T 500–600 GeV, optimised

(c) all p_T

(d) p_T 500–600 GeV

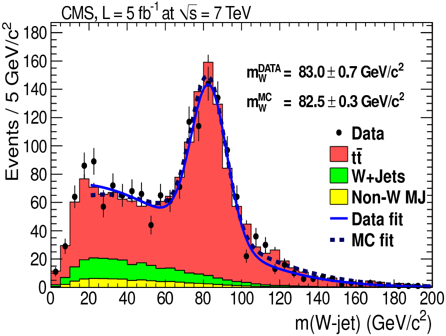
Figure 16. Mis-tag vs. efficiency for several top tagging methods, as tested on SHERPA matched $t\bar{t}+$ jets and multijet samples. For Figures (a) and (b), the input parameters are optimised for each efficiency point. The input parameters for the unoptimised scans are taken from the 35% efficiency point in Figure (b).

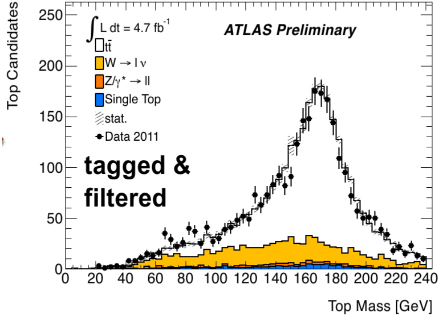
Vermilion

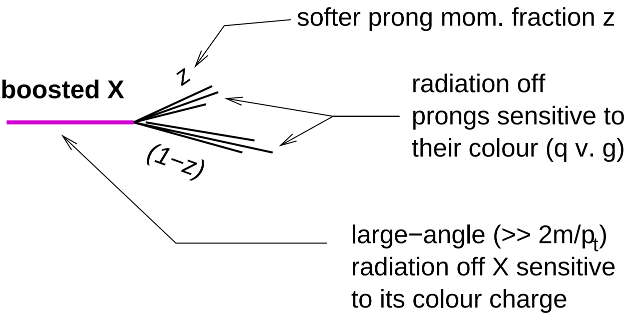
tops vs. QCD, pt. 2

Sherpa

Data: boosted W's and tops!



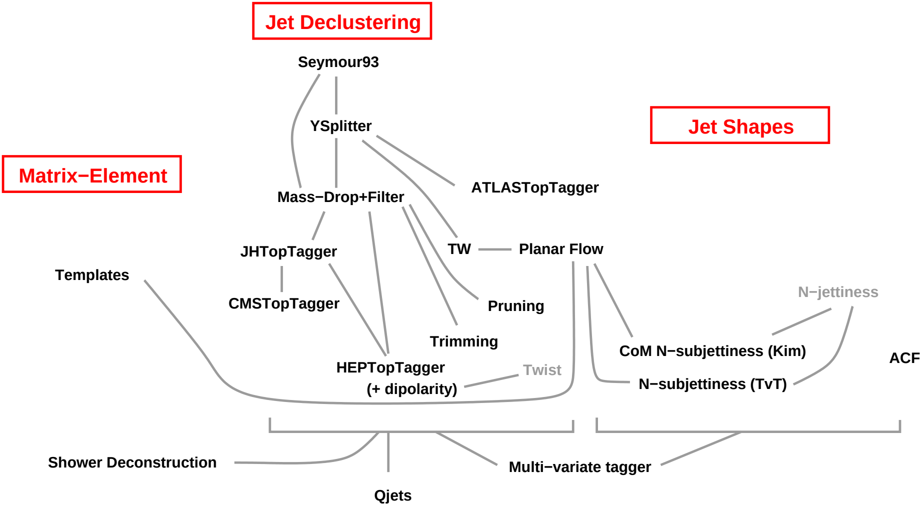




	$g_{\to gg(g)}$	$q_{\to qg(g)}$	$g_{\to b\bar{b}}$	$H_{\to b\bar{b}}$	$t_{\to qq\bar{q}}$
softer prong z	soft	soft	hard	hard	hard
prong colour factors	$2 \times C_A$	$C_F + C_A$	$2 \times C_F$	$2 \times C_F$	$3 \times C_F$
system colour factor	C_A	C_F	C_A	0	C_F

New Methods and Observables

Some taggers and jet-substructure observables



apologies for omitted taggers, arguable links, etc.

Qjets in practice

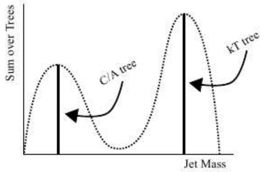
Fastjet Plugin: http://jets.physics.harvard.edu/Qjets

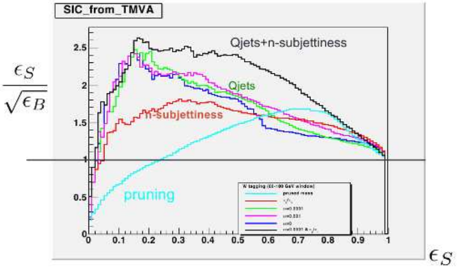
Hornig

- too many trees to consider all
- can sample kT like (or CA like) randomly:
  - at each stage, merge pair w/ prob.

$$\omega_{ij}^{(\alpha)} \equiv \exp\left\{-\alpha \frac{(d_{ij} - d^{\min})}{d^{\min}}\right\}$$

  - this gives a tree,





What is the physics that Qjets is exploiting?
Greater fragmentation in gluonic systems?

Larkoski

- Angular Correlation Function (ACF)

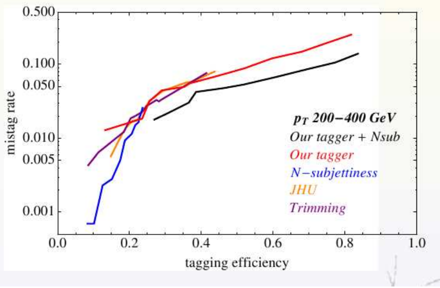
$$\mathcal{G}(R) \equiv \sum_{i \neq j} p_{\perp i} p_{\perp j} \Delta R_{ij}^2 \Theta[R - \Delta R_{ij}]$$

- IRC safe
- If jet is scale invariant, $\mathcal{G}(R) \sim R^D$
  - D = IRC-safe definition of the scaling/ correlation dimension of the jet

ACF (aka energy-energy-correlation moments) is an observable a bit like angularities, but with very special resummation properties — keep an eye on it for the future

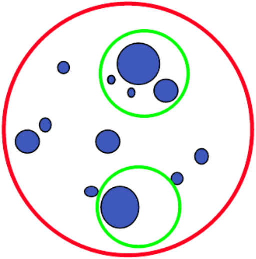
studied for e^+e^- also in Banfi, GPS & Zanderighi '04

Freytsis: Lopsided jets for low-pt tops



Template Overlap Method

Juknevich



Good overlap Ov ~ 1

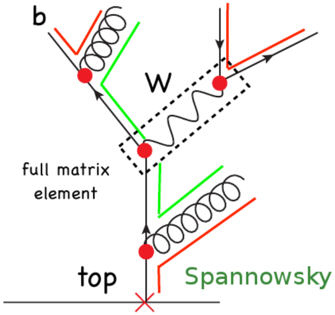
$$Ov \sim \exp\left(-\frac{1}{2E_t^2}\sum_N\left(\sum_{j\in t}E_j - E_t\right)^2\right)$$

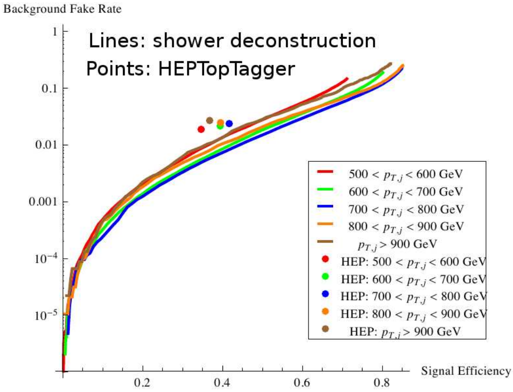
Instead of cutting on subjets, cut on set of templates that you try to match to the jet

New: 3-body templates for 2-body decays
+ results for Higgs searches
Soon: publicly available implementation

Shower deconstruction: matrix element method "on steroids"

Need to convert the shower history into analytic expression





What's new: it has now been applied to tops

What I like about it: it uses "maximal" physics info, so there are good reasons why it should work better than other methods

Schwartz

Work in progress with
David Krohn, Tongyan Lin
and Wouter Waalewijn

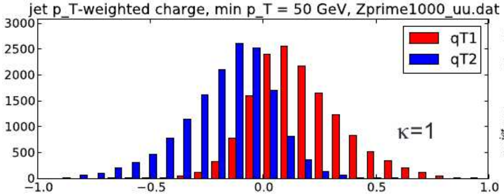
JET CHARGE

Measured the energy-weighted **jet charge**:

$$\mathcal{Q}^i_\kappa = \frac{1}{E_{\text{jet}}} \sum_{j \in \text{jet}} Q_j (E_j)^\kappa$$

- Consider jets from

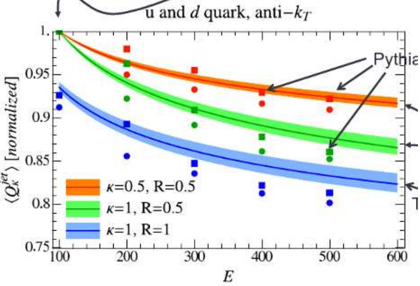
$$Z' \to \bar{u}u$$



Compare to Pythia

$$\langle \mathcal{Q}^i_\kappa \rangle = \frac{1}{16\pi^3} \frac{\widetilde{\mathcal{J}}_{ij}(E,R,\kappa,\mu)}{\mathcal{J}_i(E,R,\mu)} \sum_h Q_h \widetilde{D}^h_j(\kappa,\mu)$$

Me
at e



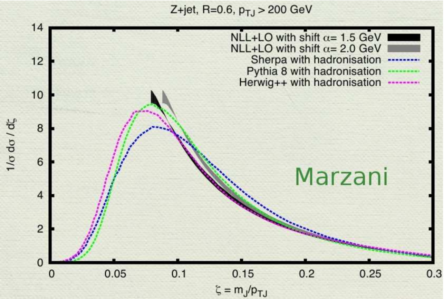
Jet Masses and other calculations

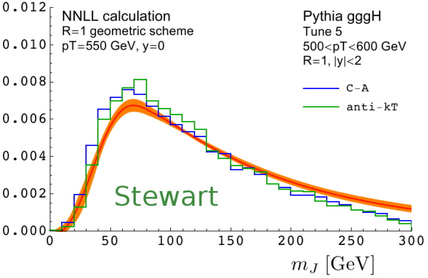
$$m^2 \simeq p_{t1} p_{t2} \Delta R_{12}^2$$

for parton with $p_t = 300$ GeV, jet $R = 0.7$,
30 GeV of jet mass comes from 7 GeV emission

for parton with $p_t = 2$ TeV, jet $R = 0.7$,
30 GeV of jet mass comes from 1 GeV emission

This sensitivity to low momentum scales is what makes masses difficult





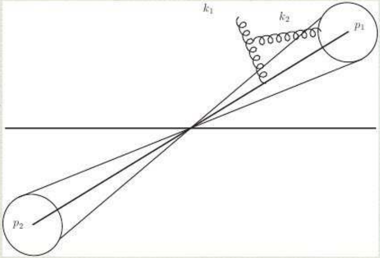
Resummed jet masses compared to Monte Carlo showers

These results are a significant theory development of the workshop

but, be aware of the fine print

Non-global logarithms

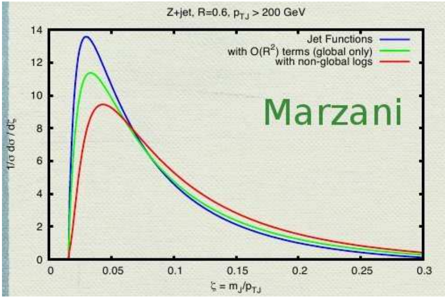
- BUT, even if we use anti-k_t, exponentiation of the independent emission is not the whole story
- The jet-mass is a non-global observable: it receives single log corrections from correlated emission
- This is a $C_F C_A$ term and it's missed by single gluon exponentiation
- In principle we need to consider any number of gluons outside the jet
- Colour structure becomes intractable, so the resummation is performed in the large N_c limit

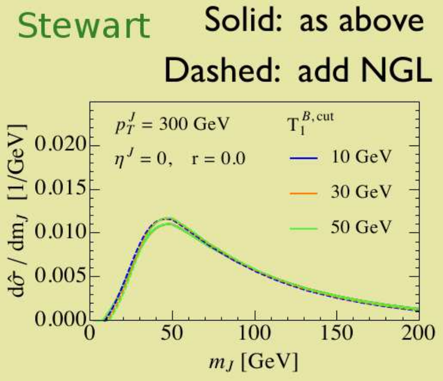


Dasgupta and Salam (2001)
Banfi, Marchesini and Smye (2002)

Marzani

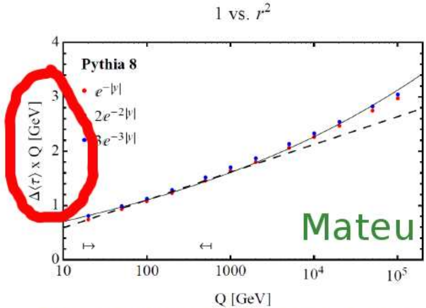
Do (NLL!) non-global logs matter when you do NNLL?





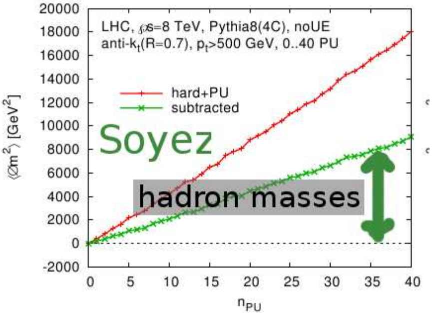
opposing conclusions
[see backup slides for my detailed opinion]

Hadron masses matter for jet masses



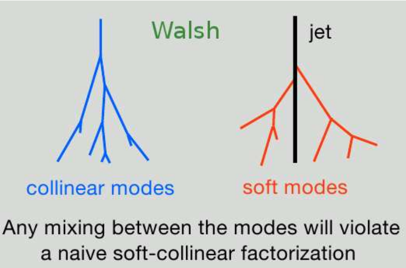
For this exercise we use first moment

$$\Omega_1^c(\mu) = \boxed{\Omega_1^c(\mu_0)} - \frac{\alpha_s(\mu_0)C_A}{\pi}\log\left(\frac{\mu}{\mu_0}\right)\boxed{\Omega_{\log}^c(\mu_0)}$$



What about calculating masses with grooming?

Schwartz



arXiv.org > hep-ph > arXiv:1002.4557

Non-Global Logarithms in Filtered Jet Algorithms

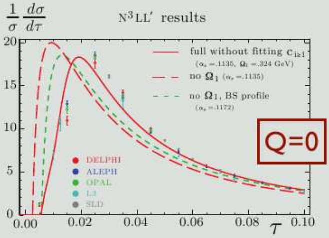
Mathieu Rubin

(Submitted on 24 Feb 2010 (v1), last revised 10 May 2010 (this version, v2))

We analytically and numerically study the effect of perturbative gluons emission on the "Filtering analysis", which is part of a subjet analysis procedure proposed two years ago to possibly identify a low-mass Higgs boson decaying into b\bar{b} at the LHC. This leads us to examine the non-global structure of the resulting perturbative series in the leading single-log large-N_c approximation, including all-orders numerical results, simple analytical approximations to them and comments on the structure of their series expansion. We then use these results to semi-analytically optimize the parameters of the Filtering analysis so as to suppress as much as possible the effect of underlying event and pile-up on the Higgs mass peak reconstruction while keeping the major part of the perturbative radiation from the b\bar{b} dipole.

My opinion: with all techniques we have at hand, I see no reason why we can't obtain reasonably precise predictions for groomed techniques

Thaler: **Recycling Thrust Results**



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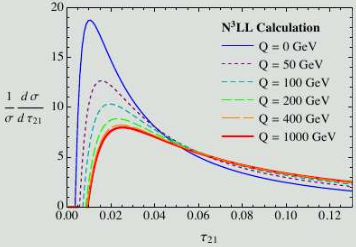


[Abbate, Fickinger, Hoang, Mateu, Stewart; see also Becher, Schwartz]

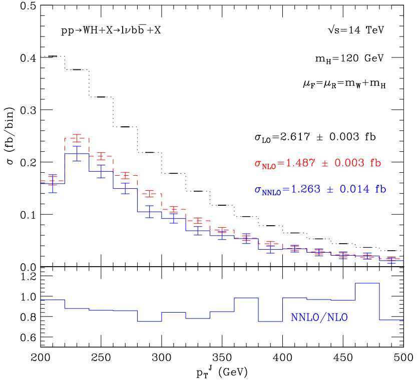
Hard, Jet, and Soft Functions to $O(\alpha_s^2)$

Resummation to N^{3}LL

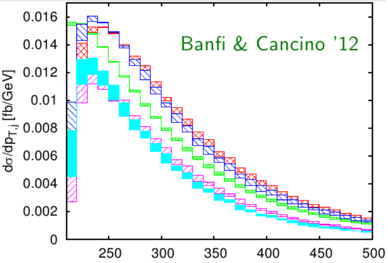
Leading Shift from Non-Perturbative Power Correction
[See Vicent Mateu's Talk]

NB: one still needs to select the jet mass (which has NLL ISR distortion)

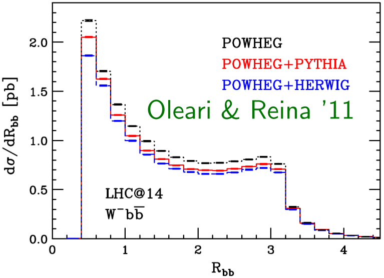
Ferrera, Grazzini & Tramontano '11
WH production (differential) @NNLO



WH prod^n & decay @NLO

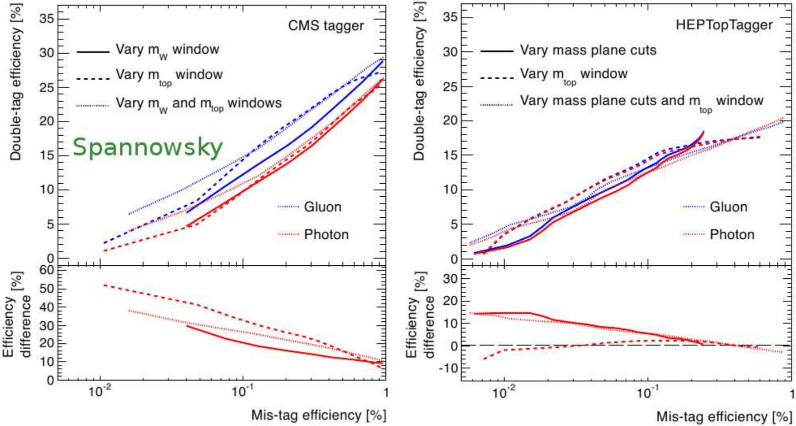


$Wb\bar{b}$ background in POWHEG



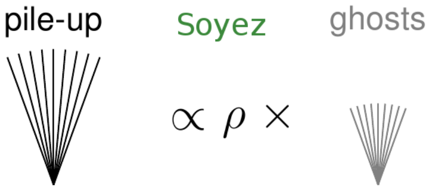
Robustness

Robustness to colour-flow? (Octet v. singlet resonances)

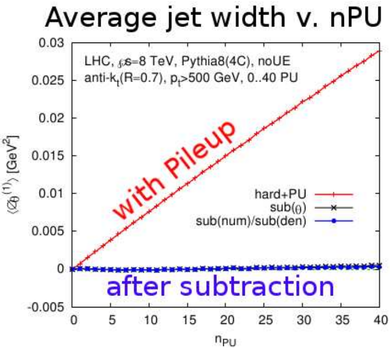


Conclusion: top-tagger with in-built grooming $\ll$ affected

NB: sensitivity appears for aggressive working points (very low mistag), while experiments work with higher mistag rates



$$f_{\rm sub}(\text{jet}) = f_{\rm full}(\text{jet}) - \rho\, a_{\rm ghost}\, \partial_{\rm ghostscale} f_{\rm full}(\text{jet}) + \frac{1}{2}(\rho\, a_{\rm ghost})^2\, \partial^2_{\rm ghostscale} f_{\rm full}(\text{jet}) + \ldots$$



Application to τ_3/τ_2 based top tagging:

without pileup:	35% v. 2%
with 30 pileup:	20% v. 0.5%
after subtraction:	35% v. 2%

Software tools

SpartyJet tools: Moments

Vermilion

- `HullMomentTool`
- `EtaPhiMomentTool`
- `PtDensityTool`
- `JetAreaCorrectionTool`
- `YSplitterTool`
- `JetMomentTool:`
  - `HeavierSubjetMass`
  - `FinalDij`
  - `z`
  - `DeltaR`
  - `zcell`
  - `zcut[N]`

SpartyJet tools: Substructure

- `TopDownPruneTool`
  - `MassDropToop`
  - `JHPruneTool`
- `SubjetCutTool`
- `SubjetMergeTool`
- `FilterTool`
  - `BDRSFilterTool`
- `N(Sub)Jettiness`
- `WTaggerTool`
- `TopTaggerTool`
  - `JHTopTagger`
  - `CMTopTagger`
  - `CMSTopTagger`
  - `HEPTopTagger`

SpartyJet tools: Selectors

- `JetPtSelectorTool(ptmin, nmax)`
- `JetPtOrESelectorTool(ptmin, emin)`
- `JetEtaCentralSelectorTool(eta)`
- `JetEtaForwardSelectorTool(eta)`
- `JetMassSelectorTool(mass)`
- `JetInputPdgIdSelectorTool(vector<int> ids)`
- `JetMomentSelectorTool<Momen>(name, min_val, max_val)`


fastjet.hepforge.org/contrib/

FastJet is hosted by Hepforge, IPPP Durh

- fastjet.fr
- fastjet-contrib
- contrib svn
- Tracker
- Wiki

FastJet Contrib

The fastjet-contrib space is intended to provide a common location for access to 3rd party extensions of FastJet.

As of late May 2012, the contrib space is not quite up yet, but we hope it will be soon. If you are interested in contributing, contact one of the FastJet authors.

Soyez

Currently working on the guidelines

- files required (COPYING, AUTHORS, README, an example)
- build system (Makefile with little requirements)
- ...

FJ contrib is still in a seedling stage.
Its success will rely on community input

ATLAS_2010_S8591806	Charged particles at 900 GeV in ATLAS
ATLAS_2010_S8817804	Inclusive jet cross section and di-jet mass and chi spectra at 7 TeV in ATLAS
ATLAS_2010_S8894728	Track-based underlying event at 900 GeV and 7 TeV in ATLAS
ATLAS_2010_S8914702	Inclusive isolated prompt photon analysis
ATLAS_2010_S8918562	Track-based minimum bias at 900 GeV and 2.36 and 7 TeV in ATLAS
ATLAS_2010_S8919674	W+jets jet multiplicities and pT
ATLAS_2011_CONF_2011_090	Single lepton search for supersymmetry
ATLAS_2011_CONF_2011_098	B-jets search for supersymmetry with 0-leptons
ATLAS_2011_I919017	Measurement of ATLAS track jet properties at 7 TeV
ATLAS_2011_I925932	Measurement of the W pT with electrons and muons at 7 TeV
ATLAS_2011_I926145	Measurement of electron and muon differential cross-section from heavy-flavour decays
ATLAS_2011_I944826	KS0 and Lambda production at 0.9 and 7 TeV with ATLAS
ATLAS_2011_I945498	Z+jets in pp at 7TeV
ATLAS_2011_S8924791	Jet shapes at 7 TeV in ATLAS
ATLAS_2011_S8971293	Dijet azimuthal decorrelations
ATLAS_2011_S8983313	0-lepton squark and gluino search
ATLAS_2011_S8994773	Calo-based underlying event at 900 GeV and 7 TeV in ATLAS
ATLAS_2011_S9002537	Muon charge asymmetry in W events at 7 TeV in ATLAS
ATLAS_2011_S9019561	Two lepton supersymmetry search
ATLAS_2011_S9041966	1-lepton and 2-lepton search for first or second generation leptoquarks
ATLAS_2011_S9108483	Long-lived heavy charged particle search
ATLAS_2011_S9120807	Inclusive isolated diphoton analysis
ATLAS_2011_S9126244	Measurement of dijet production with a veto on additional central jet activity
ATLAS_2011_S9128077	Measurement of multi-jet cross sections
ATLAS_2011_S9131140	Measurement of the Z pT with electrons and muons at 7 TeV
ATLAS_2011_S9212183	0-lepton squark and gluino search
ATLAS_2011_S9212353	Single lepton search for supersymmetry
ATLAS_2011_S9225137	High jet multiplicity squark and gluino search
ATLAS_2012_CONF_2012_001	4 or more lepton plus missing transverse energy SUSY search
ATLAS_2012_CONF_2012_033	0-lepton squark and gluino search
ATLAS_2012_CONF_2012_037	High jet multiplicity squark and gluino search
ATLAS_2012_CONF_2012_041	Single lepton search for supersymmetry
ATLAS_2012_I1082009	$D^{*\pm}$ production in jets
ATLAS_2012_I1082936	Inclusive jet and dijet cross sections at 7 TeV
ATLAS_2012_I1083318	W+jets production at 7 TeV
ATLAS_2012_I1084540	Rapidity gap cross sections measured with the ATLAS detector in pp collisions at sqrt(s) = 7 TeV.
ATLAS_2012_I1091481	Azimuthal ordering of charged hadrons
ATLAS_2012_I1093738	Isolated prompt photon + jet xsection
ATLAS_2012_I1094568	Measurement of ttbar production with a veto on additional central jet activity
ATLAS_2012_I1095236	b-jets search for supersymmetry with 0- and 1-leptons
ATLAS_2012_I1112263	3 lepton plus missing transverse energy SUSY search
ATLAS_2012_I943401	Search for supersymmetry with 2 leptons and missing transverse energy
ATLAS_2012_I946427	Search for supersymmetry with diphotons and mising Transverse Momentum
CMS_2010_S8547297	Charged particle transverse momentum and pseudorapidity spectra from proton-proton collisions at 900 and 2360 GeV.
CMS_2010_S8656010	Charged particle transverse momentum and pseudorapidity spectra from proton-proton collisions at 7000 GeV.
CMS_2011_S8884919	Measurement of the NSD charged particle multiplicity at sqrt(s) = 0.9, 2.36, and 7 TeV with the CMS detector.
CMS_2011_S8941262	Production cross-sections of muons from b hadron decays in pp collisions
CMS_2011_S8950903	Dijet azimuthal decorrelations in pp collisions at $\sqrt{s} = 7$ TeV
CMS_2011_S8957746	Event shapes
CMS_2011_S8968497	Measurement of dijet angular distributions and search for quark compositeness in pp collisions at $\sqrt{s} = 7$ TeV
CMS_2011_S8973270	B/anti-B angular correlations based on secondary vertex reconstruction in pp collisions
CMS_2011_S8978280	Kshort, Lambda, and Cascade- transverse momentum and rapidity spectra from proton-proton collisions at 900 and 7000 GeV.
CMS_2011_S9086218	Measurement of the inclusive jet cross-section in pp collisions at $\sqrt{s} = 7$ TeV
CMS_2011_S9088458	Measurement of ratio of the 3-jet over 2-jet cross section in pp collisions at sqrt(s) = 7 TeV
CMS_2011_S9120041	Traditional leading jet UE measurement at $\sqrt(s)=0.9$ and 7 TeV
CMS_2011_S9215166	Forward energy flow in MB and dijet events at 0.9 and 7 TeV
CMS_QCD_10_024	Pseudorapidity distributions of charged particles at sqrt(s)=0.9 and 7 TeV

RIVET
[Buckley]

The standard for making (unfolded) analyses reproducible

Analyses

Technicolor/Composite Higgs Theories

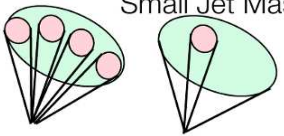
$$pp \to \rho_T \rho_T \to (\pi_T \pi_T)(\pi_T \pi_T) \to ((t\bar{t})(t\bar{t}))((t\bar{t})(t\bar{t}))$$

Wacker

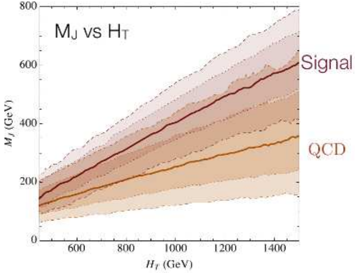
takes jet substructure beyond boosted topologies: neat!

Large Jet Mass

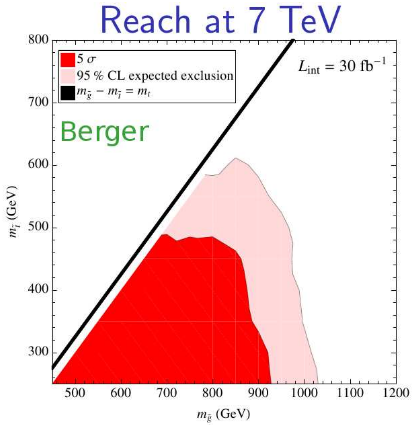
Small Jet Mass



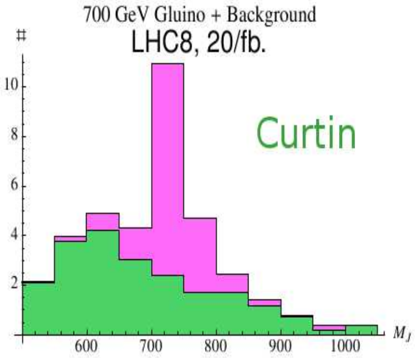
$\frac{m_j}{p_T} \sim 1$ $\frac{m_j}{p_T} \sim 0.3$



$pp \to \tilde{g}\tilde{g}, \tilde{g} \to t\bar{t}\chi^0$
JH Top Tagger



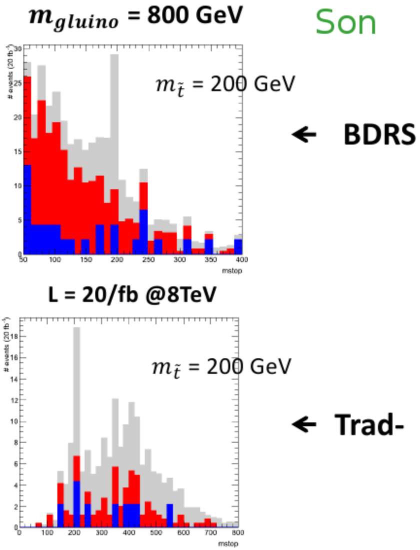
RPV $\tilde{g} \to qqq$
τ_{32} etc. + subjets



RPV SUSY search with

$$m_{\tilde{t}} < \frac{1}{4} m_{\tilde{g}}$$

Either pure substructure
(HEPTopTagger + BDRS)
or partial substructure
(HEPTopTagger + standard)

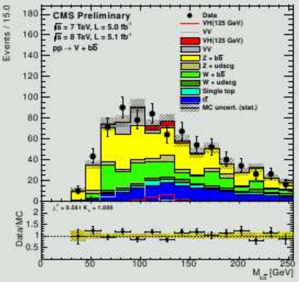


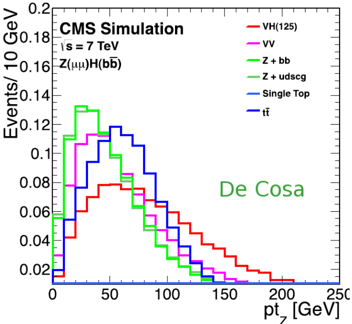
VH with $H \to b\bar{b}$: jet substructure or not?

Best channel $q\bar{q} \to VH, H \to b\bar{b}$

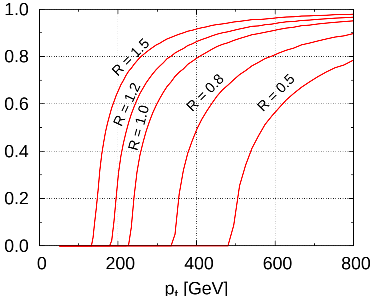
Plehn

- CMS analysis available after ICHEP
- focus on boosted regime $p_{T,V} \gtrsim 120$ GeV
  b-tagging e.g. with $50\%, 6\%, 0.15\%$
  $\Delta m_{bb}/m_{bb} \sim 10\%$
  fudge factor Data/MC=$1.91 \pm 0.14_{\text{shape}}$ for $Wb\bar{b}$
  data-estimated background $\Delta\sigma/\sigma \sim 10\%$
  12 observables in BDT [most of them understood]
  no side bands with any S/B





fraction of 125 GeV Higgses in fat jet v. p_t



Outlook

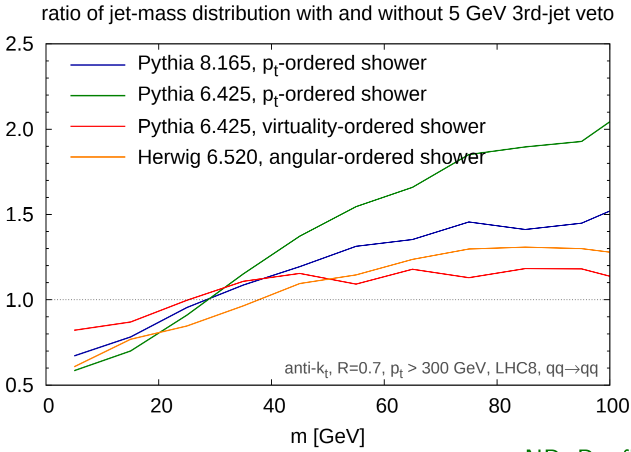
Progress we've made, theoretical and experimental, was not imaginable a few years ago, when the discussion about jets used to be confined to "cone" v. "k_t"

Today we have basic subjet tools + many advances (shapes, Qjets, deconstruction, BDT taggers, . . .)

Successful adoption by the experiments!

Job for theorists now:
Really understand the taggers?
Understand intermediate p_t regions?
More searches?

EXTRAS



Impact on jet mass distribution of 5 GeV veto on jets outside the main two jets.

Effects at 20 – 50%.

NB: Banfi, Corcella & Dasgupta '06 found Herwig 6 models NG logs well

My opinion: calculating something that's not quite jet mass in order to limit NG logs is not the best avenue for high accuracy comparisons with data

Banfi, Dasgupta, Khelifa-Kerfa & Marzani '10