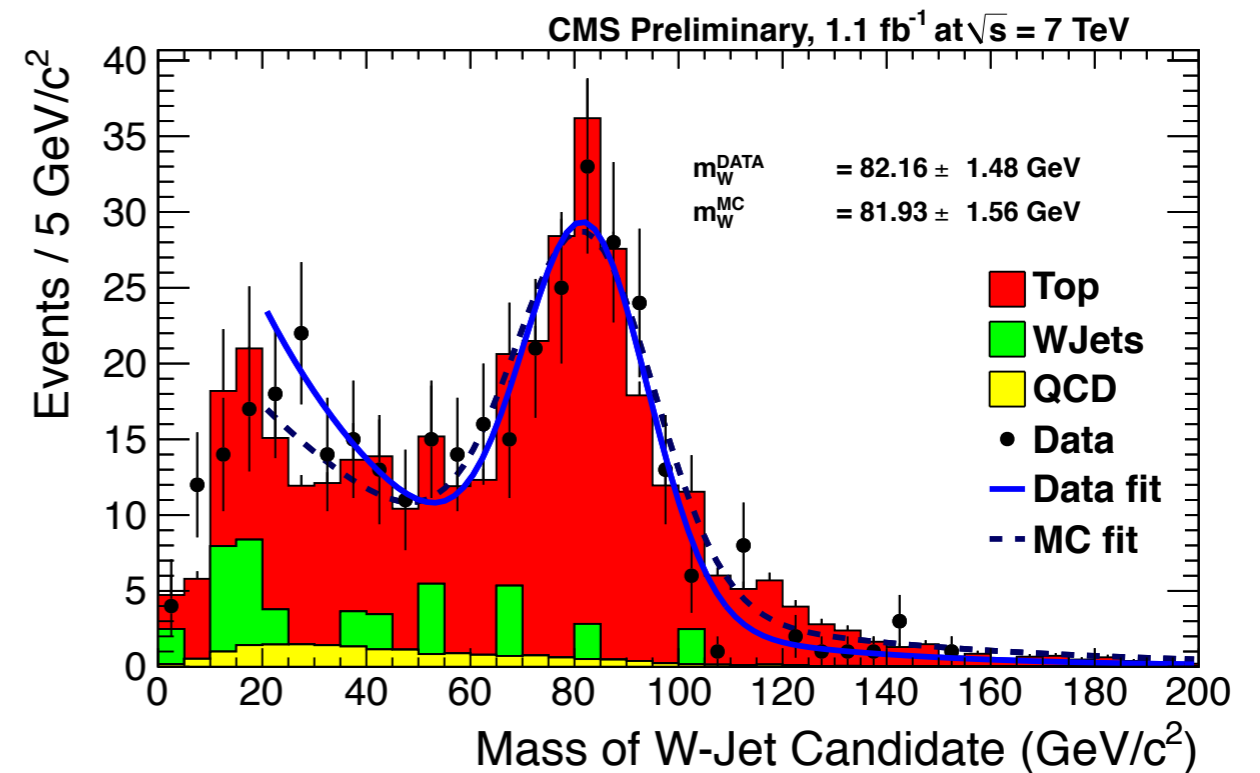
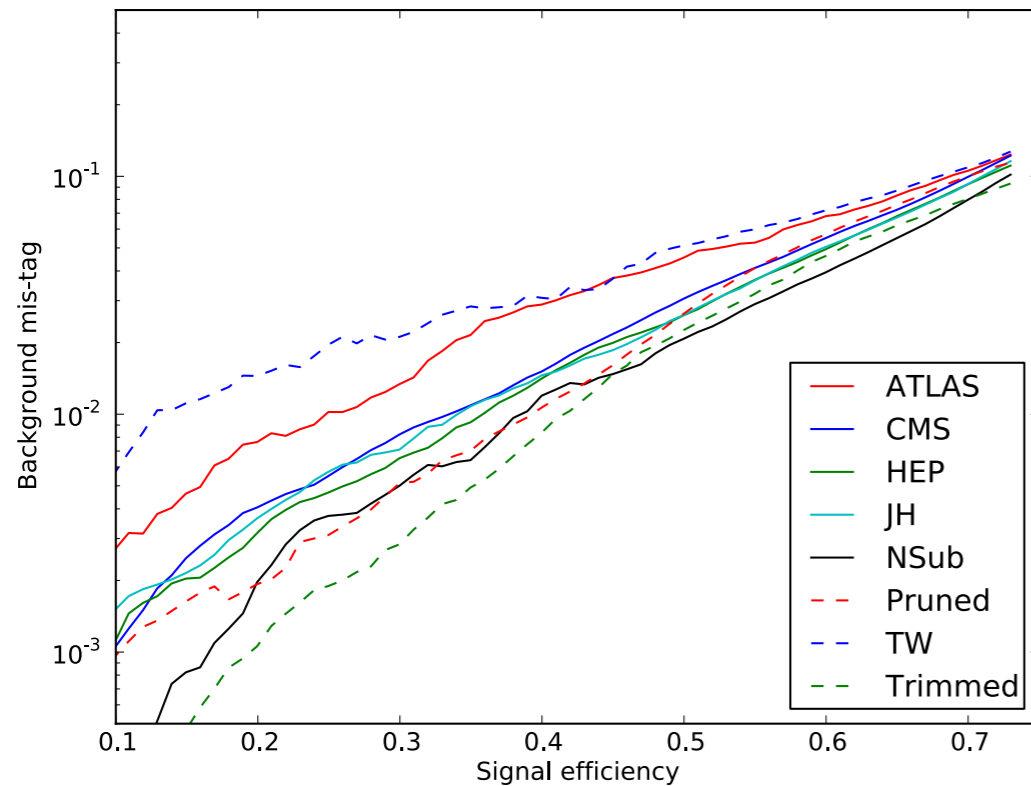


# BOOST 2012: How did we get here?

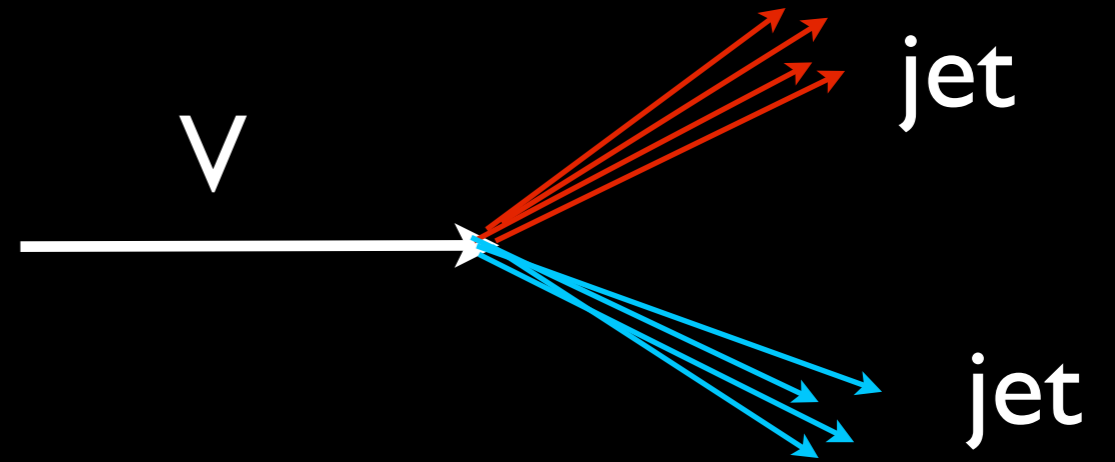
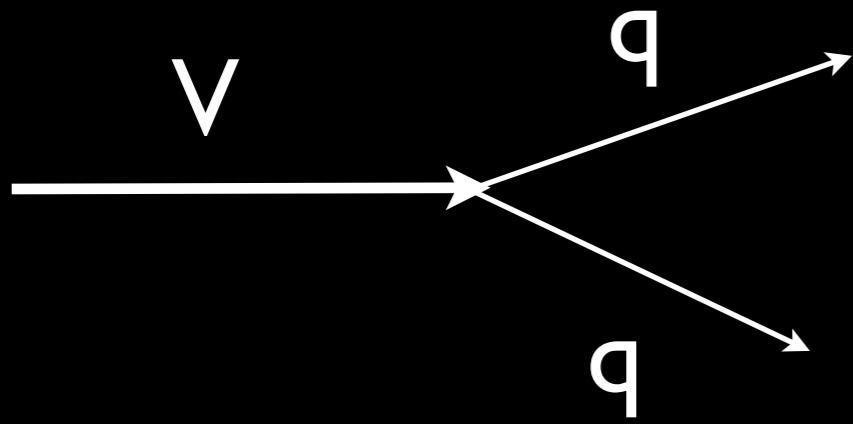


Christopher Vermilion  
IFIC Valencia  
23/7/2012

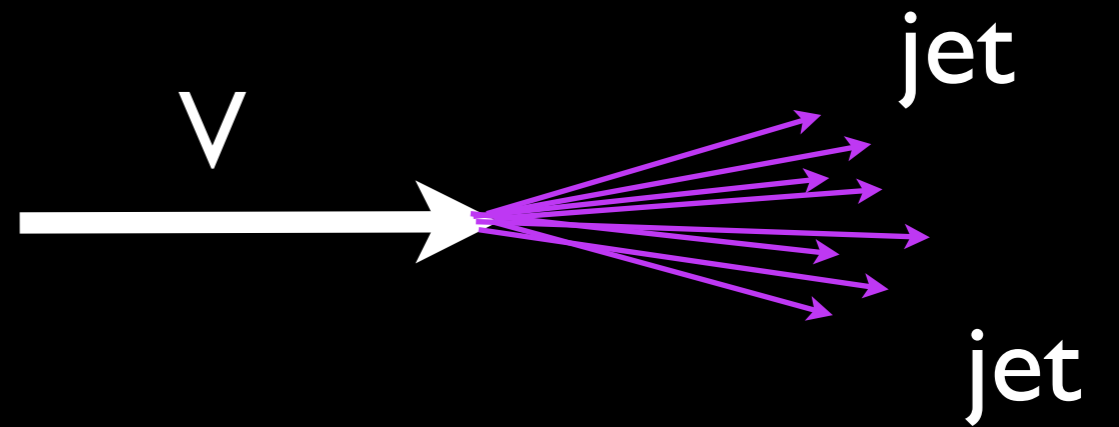
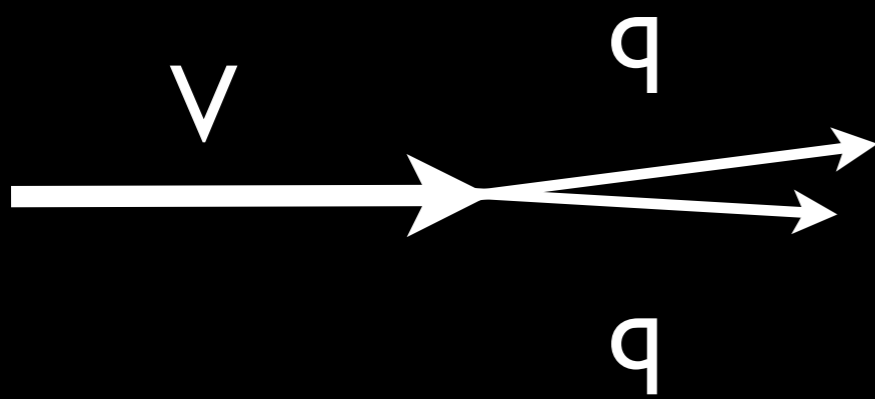




# Low- $p_T$ boson decay



# High- $p_T$ boson decay



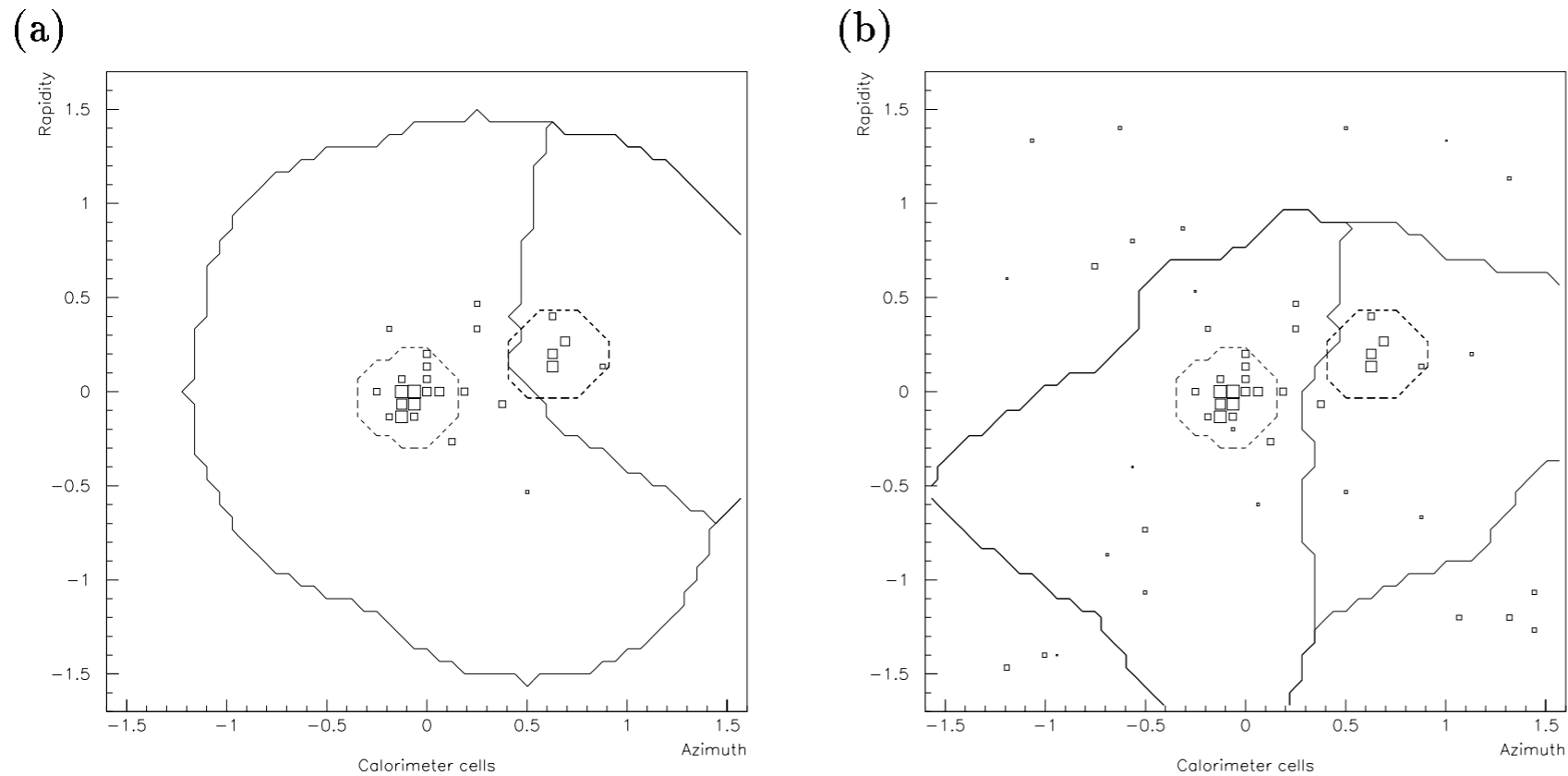


Figure 2: A hadronic W decay, as seen at calorimeter level, (a) without, and (b) with, particles from the underlying event. Box sizes are logarithmic in the cell energy, lines show the borders of the sub-jets for infinitely soft emission according to the cluster (solid) and cone (dashed) algorithms.

LU TP 93-8

## Searches for New Particles Using Cone and Cluster Jet Algorithms: A Comparative Study

Michael H. Seymour  
 Department of Theoretical Physics, University of Lund,  
 Sölvegatan 14A, S-22362 Lund, Sweden

Mike Seymour

Z. Phys. C62 (1994) 127

Google  christopher.vermilion... 0 + Share

Get directions My places

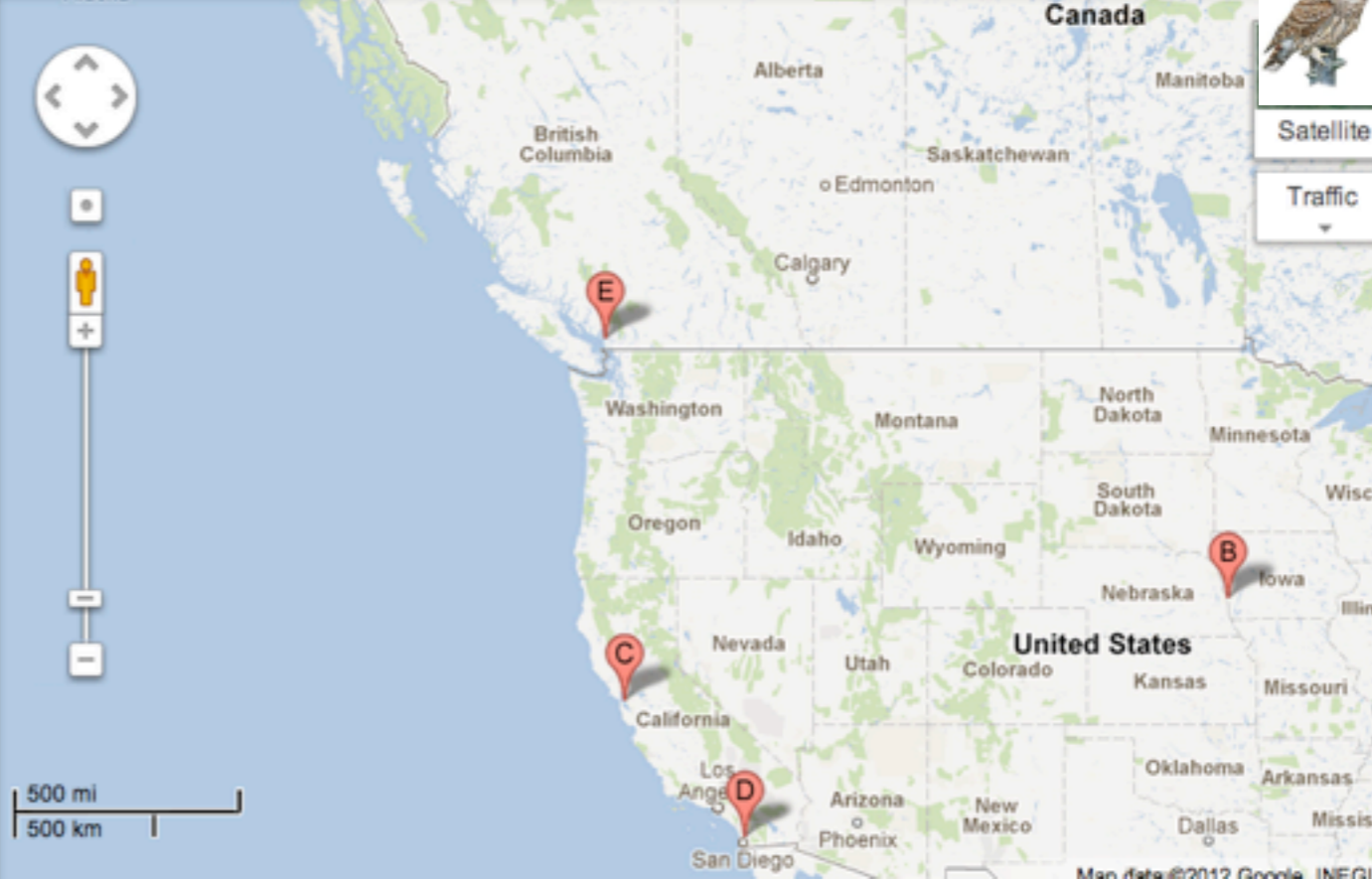
### superconducting super collider

Search the web for **superconducting super collider** Top web result shown

**Superconducting Super Collider - Wikipedia, the free encyclopedia**  
The **Superconducting Super Collider (SSC)** (also nicknamed the Desertron) was a particle accelerator complex under construction in the vicinity of Waxahachie, ...  
[en.wikipedia.org](http://en.wikipedia.org)

**A Ice Cave Technology**  
5600 Lake Otis Parkway, Anchorage, AK  
(907) 771-0543 · [icecavetechnology.com](http://icecavetechnology.com)  
"Super Conducting Super Collider. PowerPoint presentation. Television commercial. Computer kiosk. Data visualization and animation. Web sites and marketing" - icecavetechnology.com

**B Cryo Nebraska Inc**

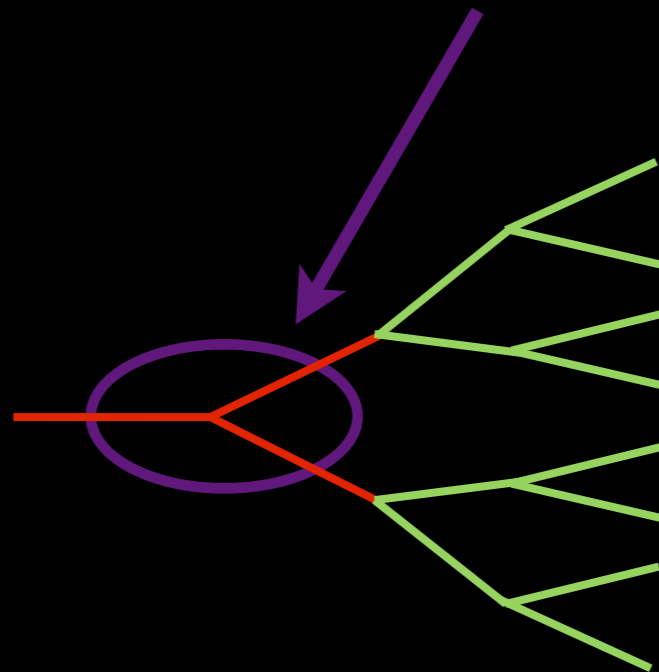


# Several further papers on boosted W's in the run-up to the LHC

hep-ph/0201098, hep-ph/0702150

ATLAS Y-Splitter (ATL-PHYS-CONF-2008-008): Same variable, applied to tops

Look at kT merging scale here



$$d_{ij} = \min(p_{Ti}^2, p_{Tj}^2) R_{ij}^2$$

# “Breakthrough” paper: Butterworth, Davison, Rubin, Salam (0802.2470)

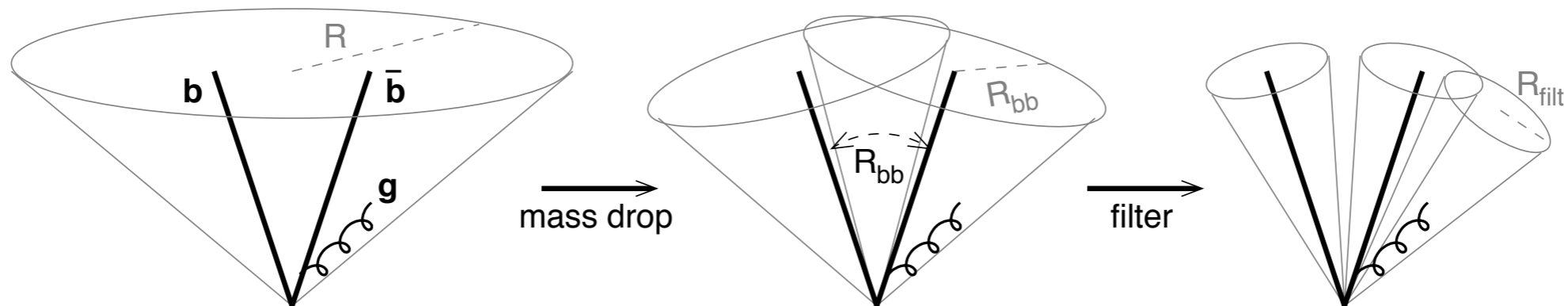


FIG. 1: The three stages of our jet analysis: starting from a hard massive jet on angular scale  $R$ , one identifies the Higgs neighbourhood within it by undoing the clustering (effectively shrinking the jet radius) until the jet splits into two subjects each with a significantly lower mass; within this region one then further reduces the radius to  $R_{filt}$  and takes the three hardest subjects, so as to filter away UE contamination while retaining hard perturbative radiation from the Higgs decay products.

## Two steps:

Mass drop identifies hard splitting within clustering history

Filtering “zooms” in and only keeps three hardest subjects

# The dam breaks

[Johns Hopkins] Top Tagging (Kaplan, Rehermann, Schwartz, Tweedie; 0806.0848)

3-body kinematic variables (Thaler, Wang; 0806.0023)

New jet shapes (Almeida, et al.; 0807.0234, 0810.0934)

Pruning (Ellis, Vermilion, Walsh; 0903.5081)

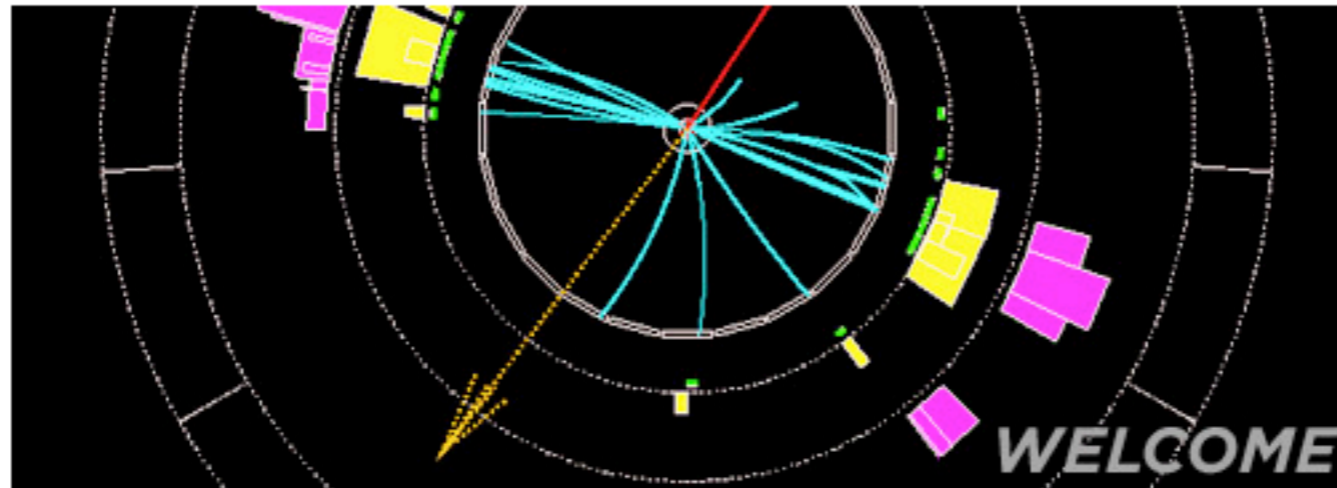


# BOOST 2009

GIVING NEW PHYSICS A BOOST

SLAC NATIONAL

- Home
- Registration
- Participant List
- Agenda
- Accommodations
- General Information
- Travel and Directions
- Visa Information
- Social Event
- Contact



## Giving New Physics a Boost

Thursday and Friday, July 9-10, 2009 from 8:00 am to 5:00 pm.

Kavli Auditorium

SLAC National Accelerator Laboratory

Menlo Park, California

<http://www-conf.slac.stanford.edu/Boost2009/default.asp>

Check out the indico page for a fascinating look at boosted physics in 2009...

# Another year of boosted physics

Jet Trimming (Krohn, Thaler, Wang; 1912.1342)

CMS Top Tagging (0909.4894)

More jet shapes (Chekanov, Proudfoot, Levy, Yoshida; 1002.3982, 1009.2749)

Template overlap (Almeida et al.; 1006.2035)

Jet Pull (Gallicchio, Schwartz; 1001.5027)

HEP Top Tagger (Plehn, Salam, Spannowsky; 0910.5472)

Quite a few more!

# BOOST 2010

<http://www.physics.ox.ac.uk/boost2010/index.asp>



arXiv:1012.5412

Really great idea:  
follow-up report!

**Boosted objects: a probe of  
beyond the standard model  
physics** \*

A. Abdesselam<sup>1</sup>, A. Belyaev<sup>2,3</sup>, E. Bergeaas Kuutmann<sup>4</sup>,  
U. Bitenc<sup>5</sup>, G. Brooijmans<sup>6</sup>, J. Butterworth<sup>7</sup>, P.  
Bruckman de Renstrom<sup>8</sup>, D. Buarque Franzosi<sup>9</sup>, R.  
Buckingham<sup>1</sup>, B. Chapleau<sup>10</sup>, M. Dasgupta<sup>11</sup>, A.  
Davison<sup>7</sup>, J. Dolen<sup>12</sup>, S. Ellis<sup>13</sup>, F. Fassi<sup>14</sup>, J. Ferrando<sup>1</sup>,  
M.T. Frandsen<sup>15</sup>, J. Frost<sup>16</sup>, T. Gadfort<sup>17</sup>, N. Glover<sup>18</sup>,  
A. Haas<sup>19</sup>, E. Halkiadakis<sup>20</sup>, K. Hamilton<sup>21</sup>, C. Hays<sup>1</sup>, C.  
Hill<sup>22</sup>, J. Jackson<sup>3</sup>, C. Issever<sup>1</sup>, M. Karagoz<sup>1</sup>, A. Katz<sup>23</sup>,  
L. Kreczko<sup>24</sup>, D. Krohn<sup>25</sup>, A. Lewis<sup>1</sup>, S. Livermore<sup>1</sup>,  
P. Loch<sup>26</sup>, P. Maksimovic<sup>27</sup>, J. March-Russell<sup>15</sup>, A.  
Martin<sup>28</sup>, N. McCubbin<sup>3</sup>, D. Newbold<sup>24</sup>, J. Ott<sup>29</sup>,  
G. Perez<sup>30</sup>, A. Policchio<sup>13</sup>, S. Rappoccio<sup>27</sup>, A.R.  
Raklev<sup>31</sup>, P. Richardson<sup>18</sup>, G.P. Salam<sup>25,32,33</sup>, F.  
Sannino<sup>34</sup>, J. Santiago<sup>35</sup>, A. Schwartzman<sup>19</sup>, C.  
Shepherd-Themistocleous<sup>3</sup>, P. Sinervo<sup>36</sup>, J. Sjoelin<sup>37,38</sup>,  
M. Son<sup>39</sup>, M. Spannowsky<sup>40</sup>, E. Strauss<sup>19</sup>, M. Takeuchi<sup>41</sup>,  
J. Tseng<sup>1</sup>, B. Tweedie<sup>27,42</sup>, C. Vermilion<sup>43</sup>, J. Voigt<sup>29</sup>,  
M. Vos<sup>44</sup>, J. Wacker<sup>19</sup>, J. Wagner-Kuhr<sup>29</sup>, and M.G.  
Wilson<sup>19</sup>

M. Karagoz, G. P. Salam, M. Spannowsky, M. Vos (editors)



## Outcome I: Survey of motivation

What signals involve boosted heavy particles?

Which techniques have been suggested for each of these signals?

## Outcome II: Survey of techniques

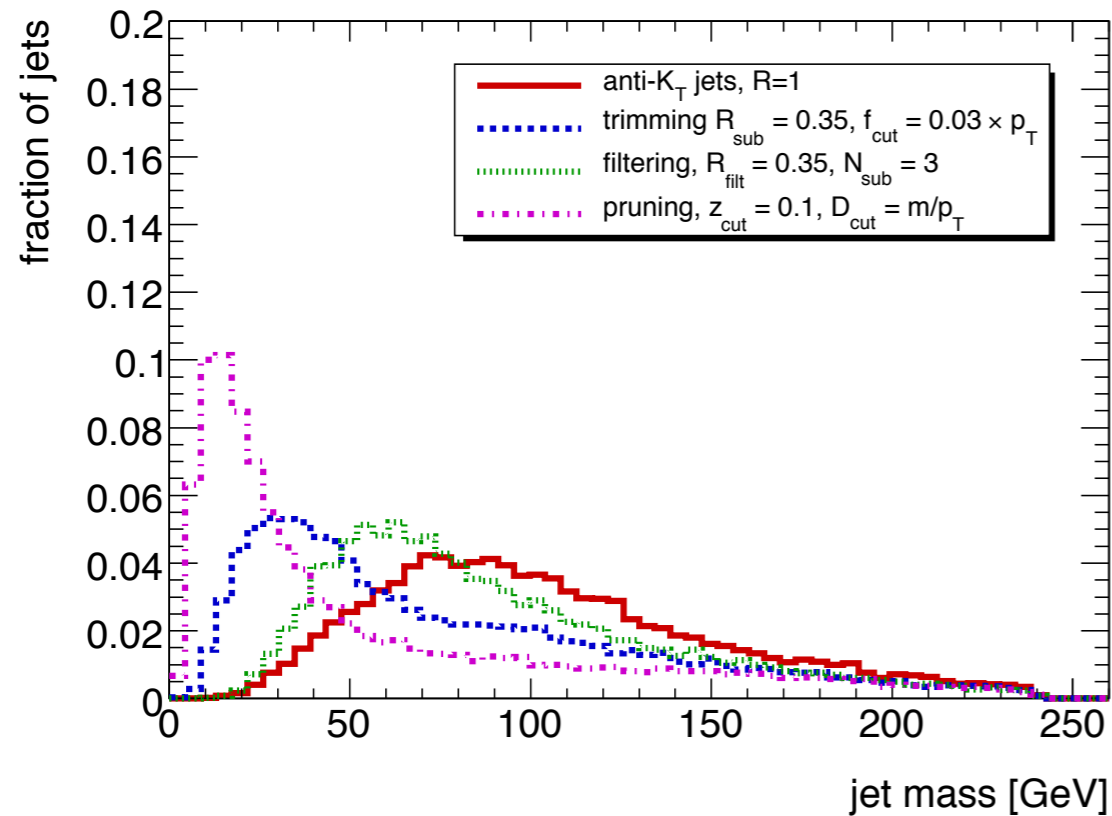
This time organized by strategy, not target

Allowed some degree of comparison between techniques.

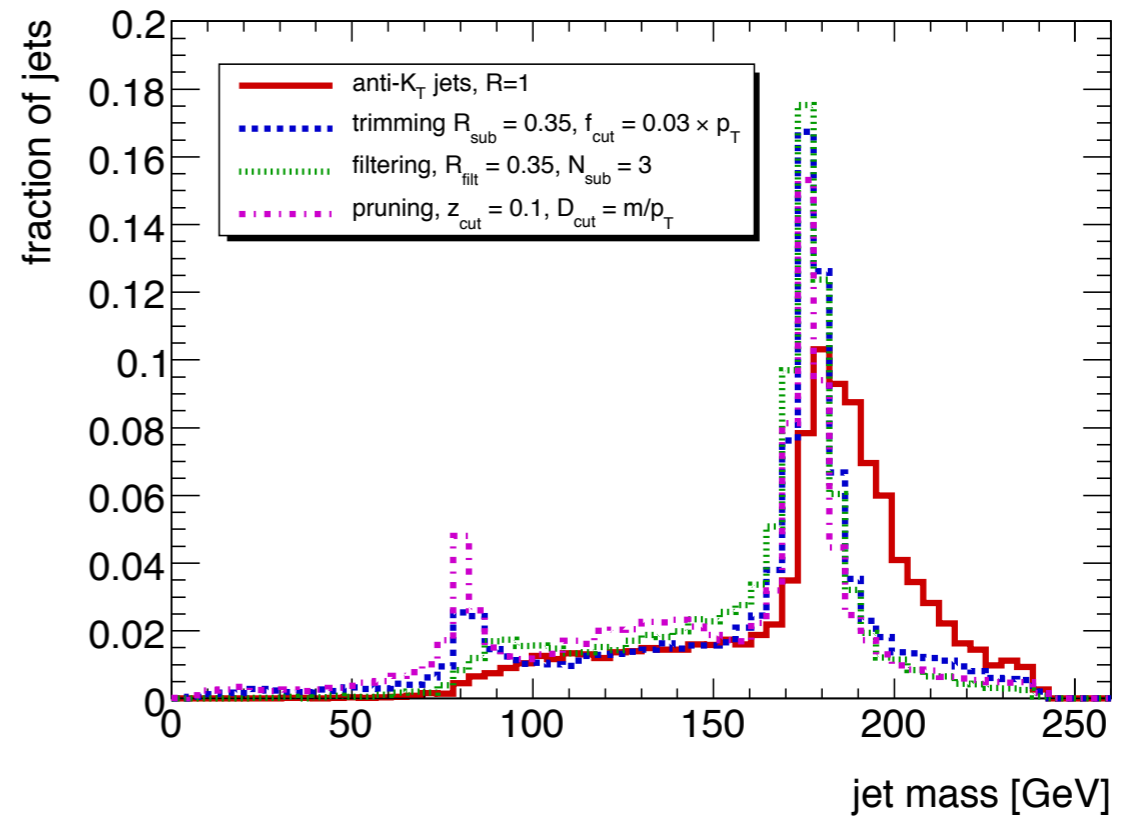
## Outcome III: Survey of experimental results

First survey of its kind -- starts from the beginning!

# Outcome IV: Monte Carlo studies (with public samples)



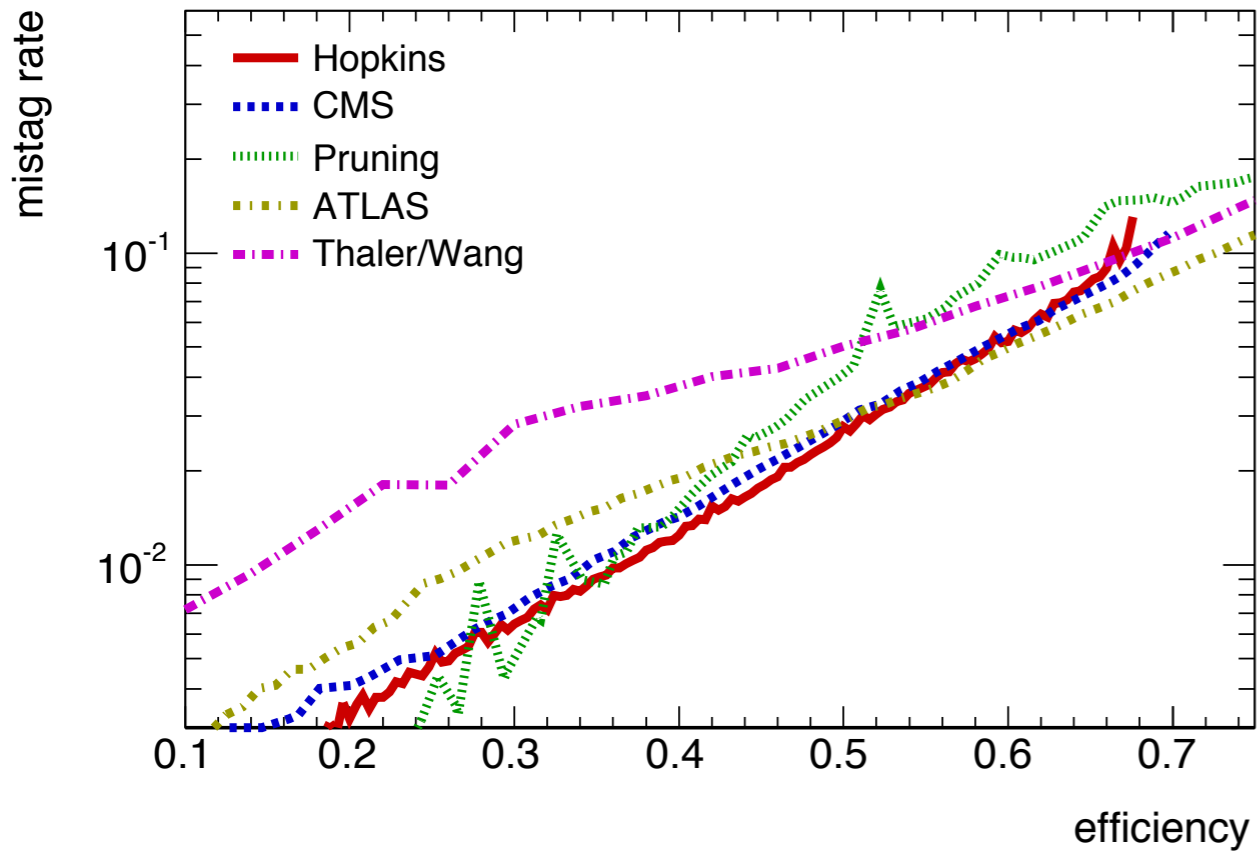
(a) dijets, 500–600 GeV



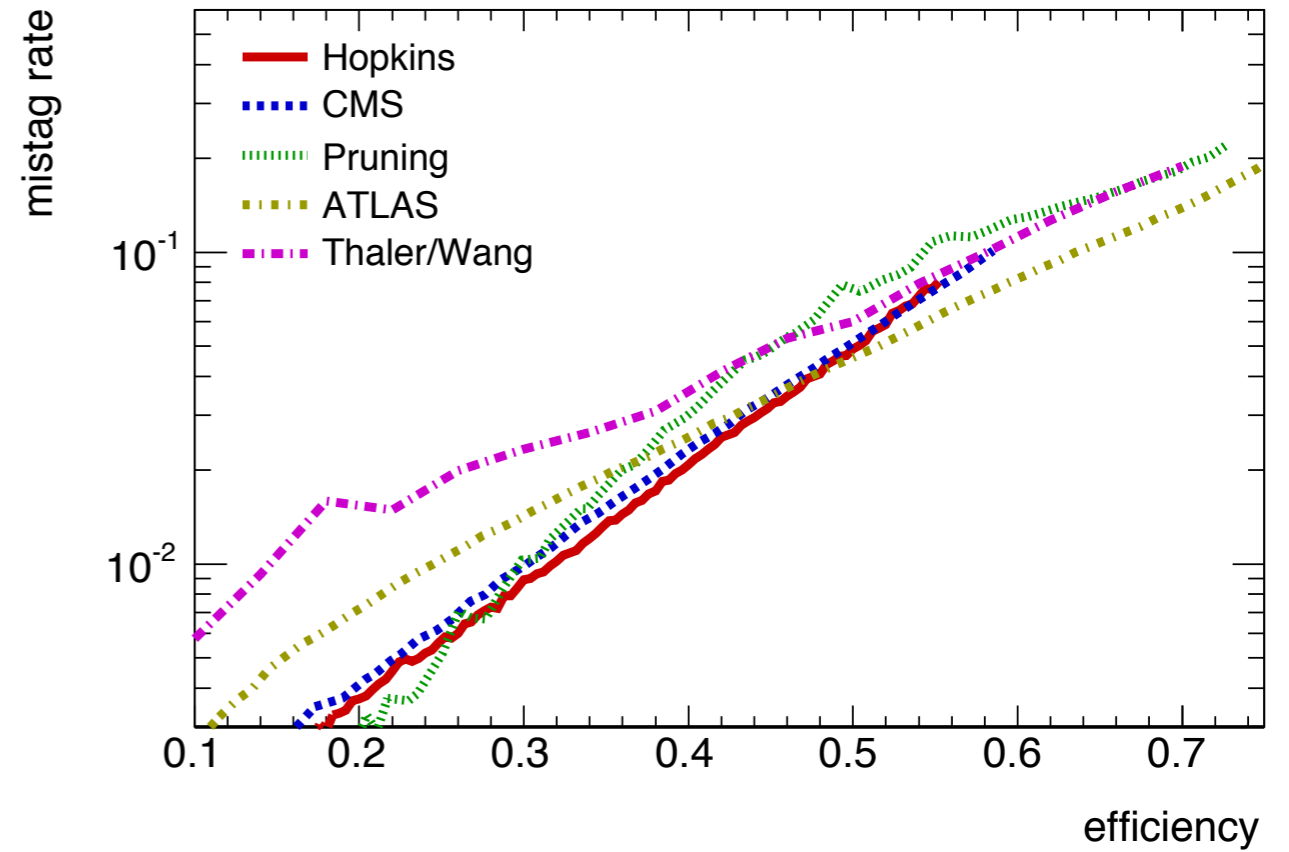
(b)  $t\bar{t}$ , 500–600 GeV

## Jet masses after grooming

See the report for a nice discussion of the different behaviors at low mass!



(d) 500–600 GeV



(b) all  $p_T$  samples

Comparative efficiencies for distinguishing tops, QCD



## Several results I'm skipping over

Dependence on MC, UE, calorimeter clustering

Other pT ranges

## Limitations of 2010 comparisons

Only tops vs. QCD

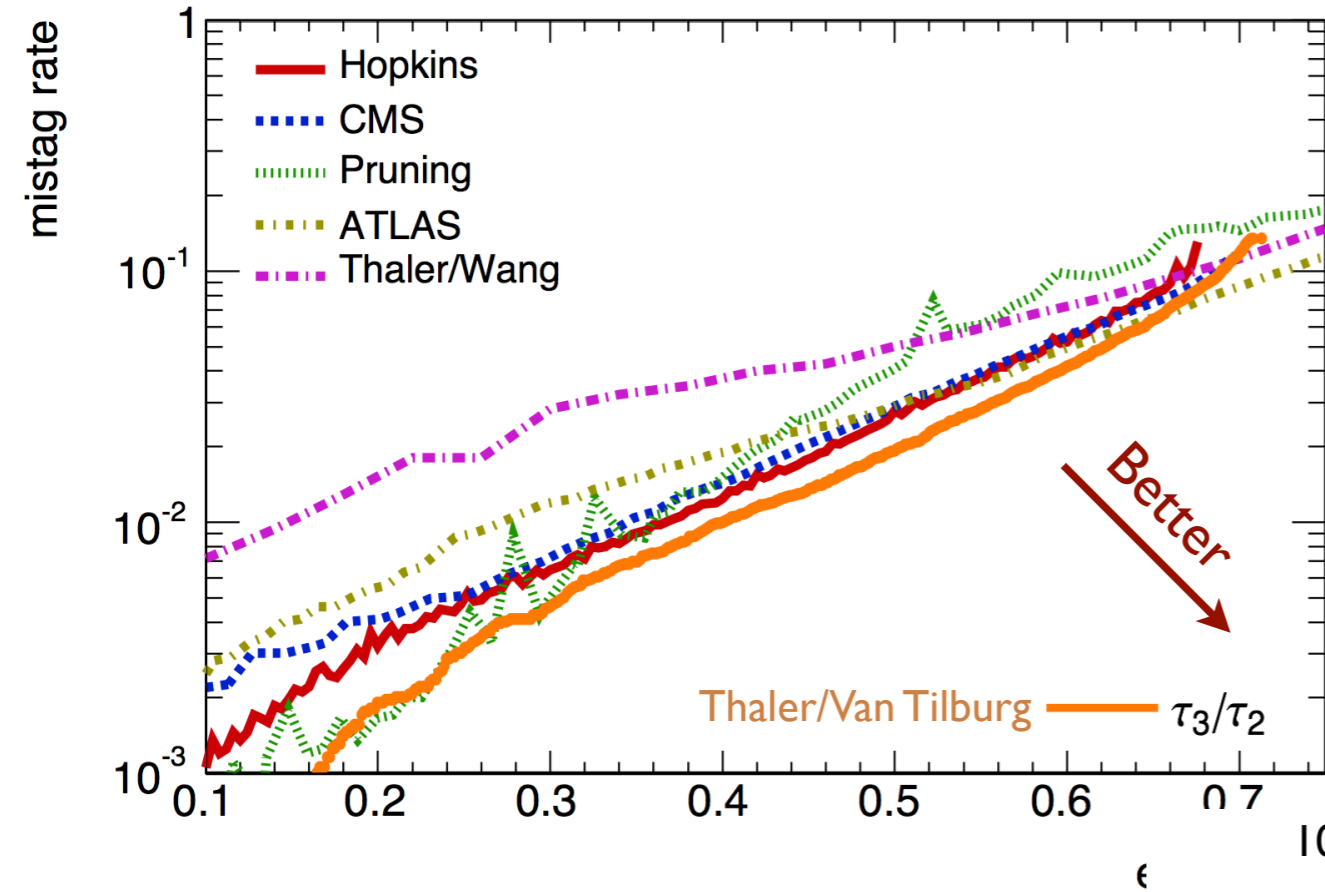
No pile-up dependence

Only “available” techniques

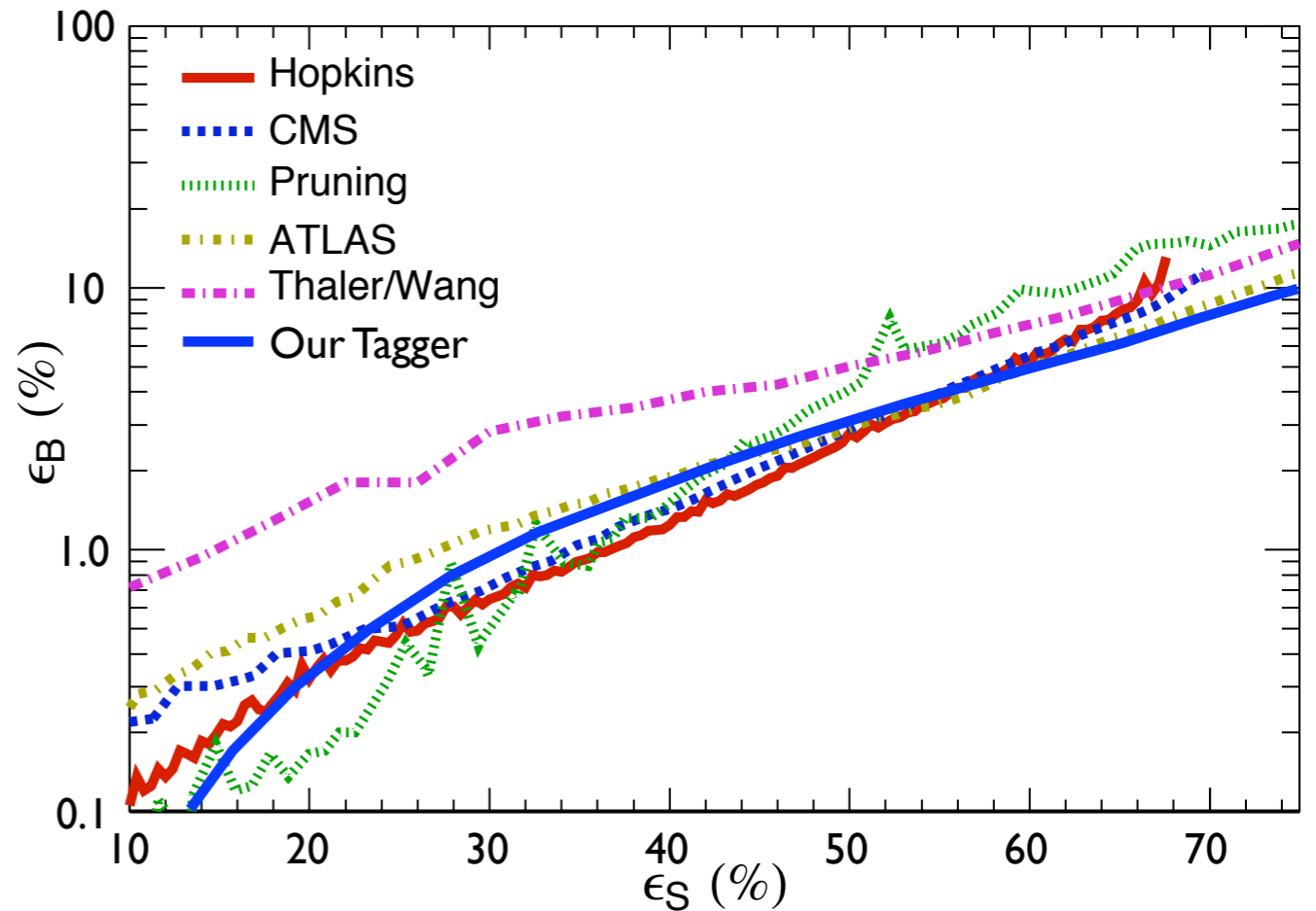
**Each analysis implemented independently!**

Some of these were remedied in 2011 report,  
some are still on the to-do list!

500 GeV < p<sub>T</sub> < 600 GeV



# NSubjettiness



“Substructure without trees” / angular correlation functions

anti-kT, R=1.0, 500 GeV < p<sub>T</sub> < 600 GeV

Meanwhile...



Search

About 249,000,000 results (0.43 seconds)



SafeSearch



Web

Related searches: [meanwhile book](#)

Images

Videos

News

Shopping

More

Any time

Past 24 hours

Past week

Custom range...

All results

By subject

Personal

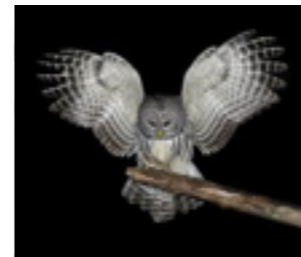
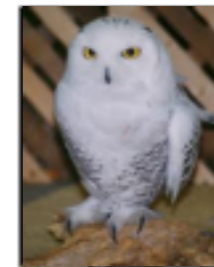
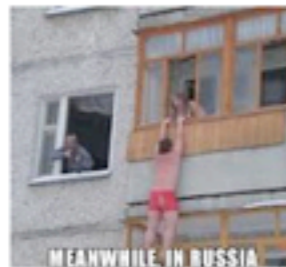
Any size

Large

Medium

Icon

Larger than





**MEANWHILE, IN RUSSIA**



**MEANWHILE, IN FINLAND**

**MEANWHILE IN**



**ALABAMA**

MEANWHILEIN.ORG





**Meanwhile in Spain...**

N-Subjettiness (Thaler, Van Tilburg 1011.2268; Kim 1011.1493)

Dipolarity (Hook, Jankowiak, Wacker; 1102.1012)

“Jet substructure without trees” (Jankowiak, Larkoski; 1104.1646)

Shower deconstruction (Spannowsky, Soper 1102.3480)

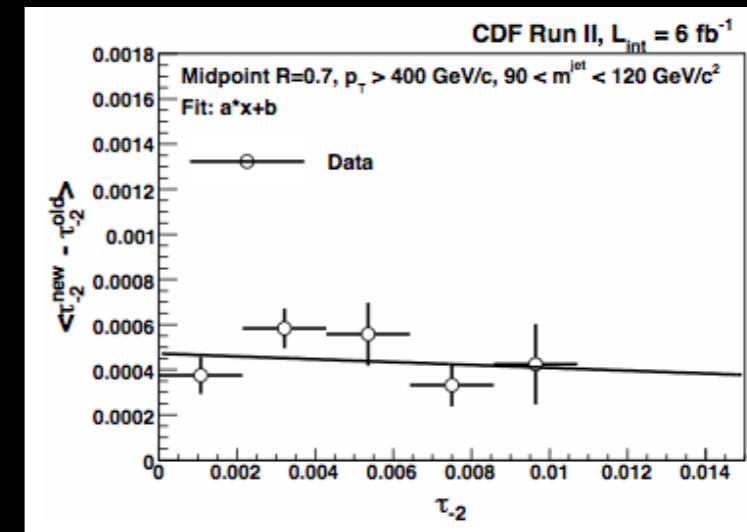
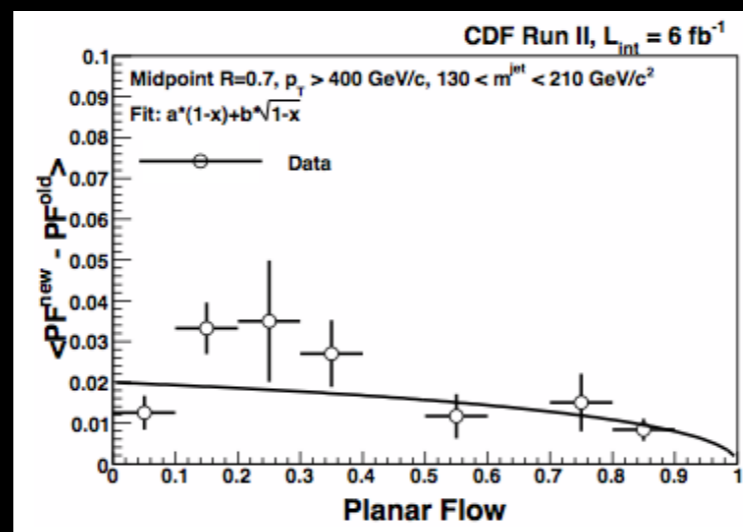
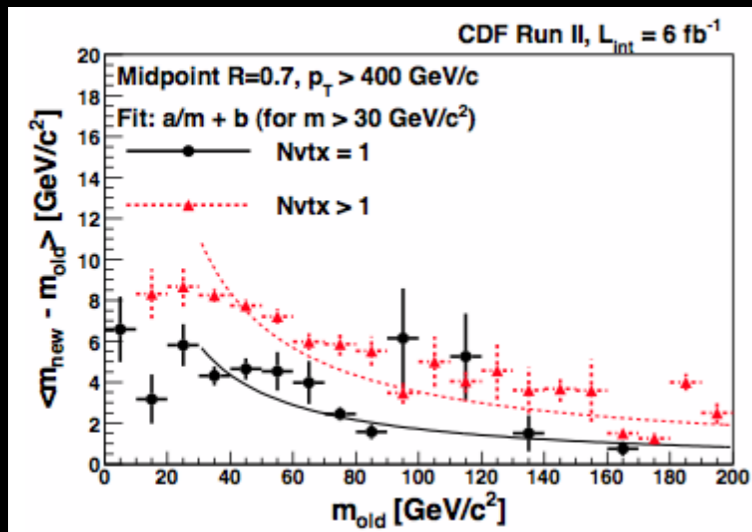
HEP Top Tagger++ (Plehn, Spannowsky, Takeuchi, Zerwas; 1006.2833...)

Multivariate quark/gluon discrimination (Gallicchio, Schwartz; 1106.3076)

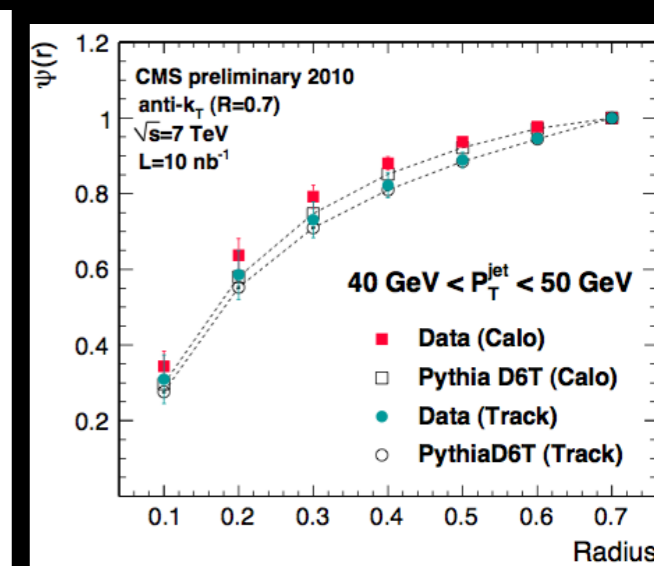
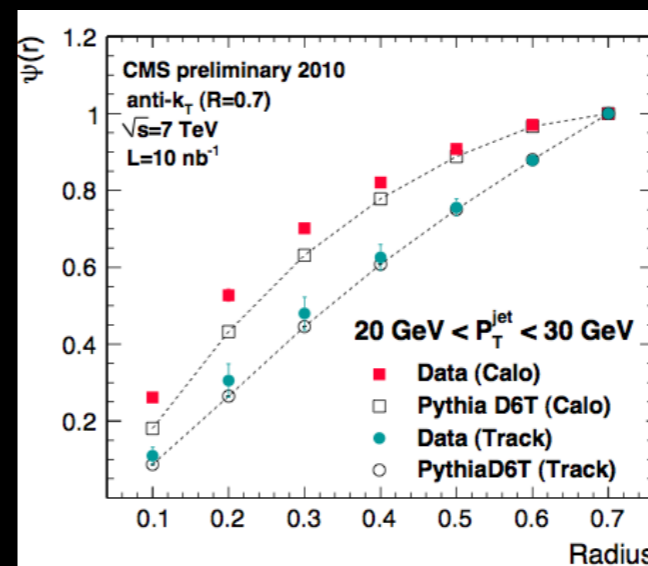
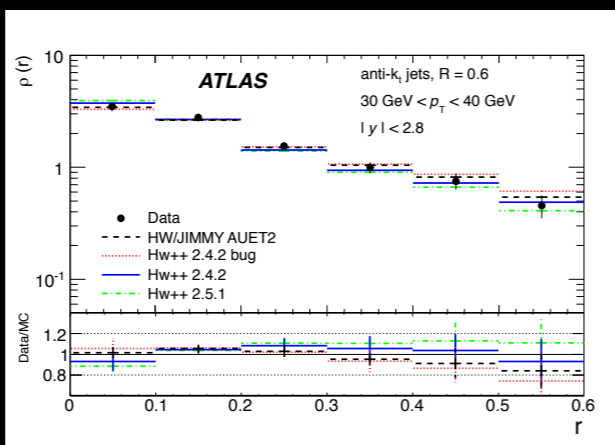
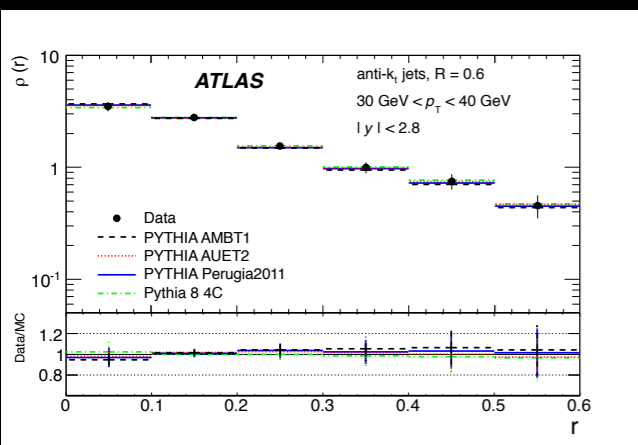
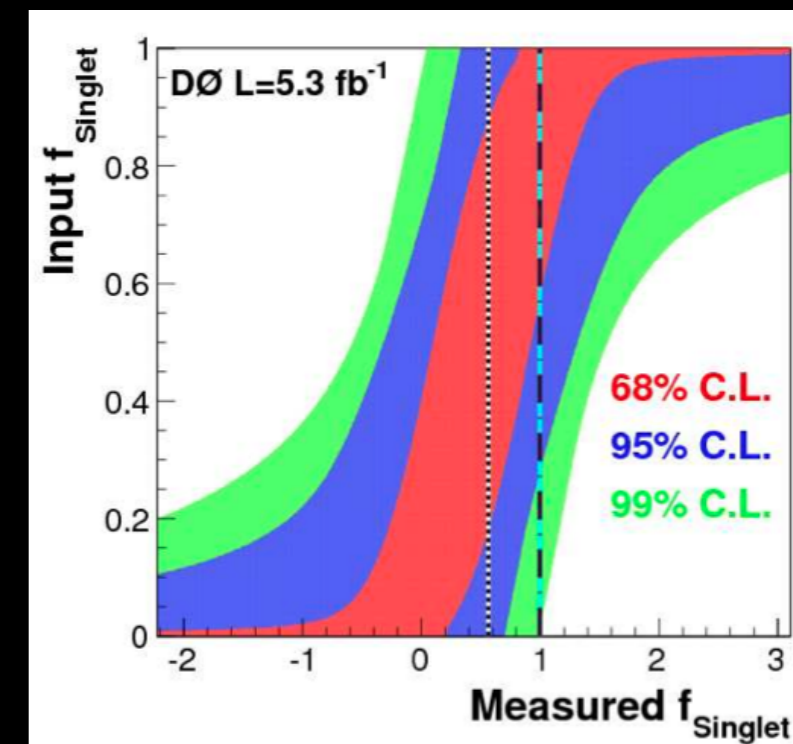
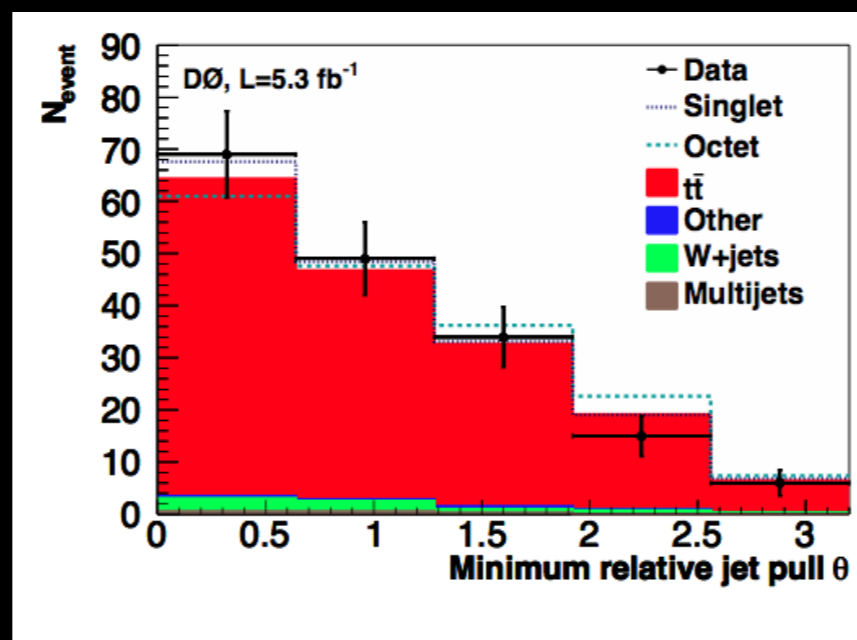
ISR tagging (Krohn, Randall, Wang 1101.0810)

New physics multi-tagging (Kribs, Martin, Roy, Spannowsky; 0912.4731, 1006.1656)

And more...!



# BOOST 2011 Datastravaganza!



# Goals for 2011 report

Summarize progress

Establish theory/experiment goals

Extend comparisons

**Publish tools**

# Theory wish list

Jet mass (in  $V+j$ ,  $jj$ , multijet; multi-differential useful)

Jet shapes:  $N$ -subjettiness ( $N=1,2,3$ ;  $\beta=1,2$ ), planar flow,  
subjettiness multiplicities

Groomed observables (all of the above)

Event shapes: 0/1-jettiness,  $Y_{23}$

# Comparisons

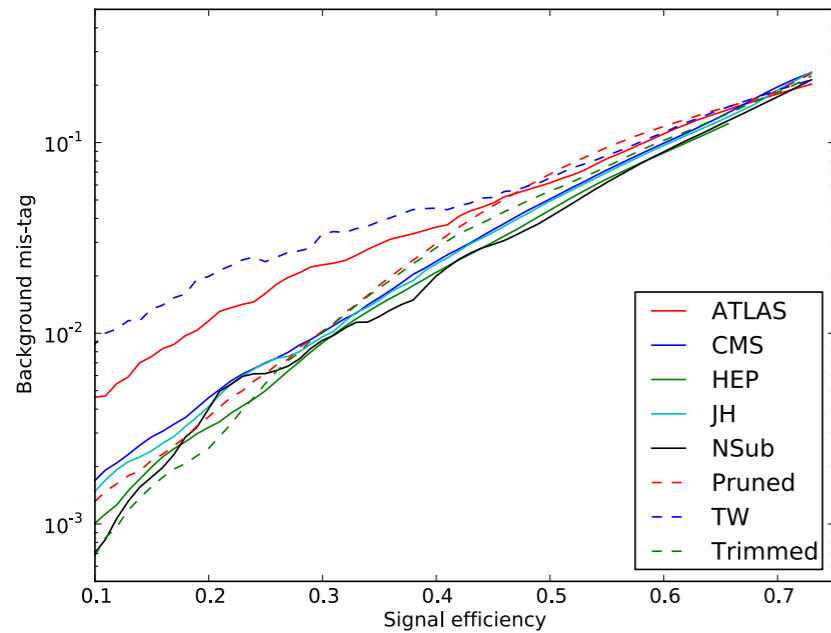
Extend last yet with:

more methods

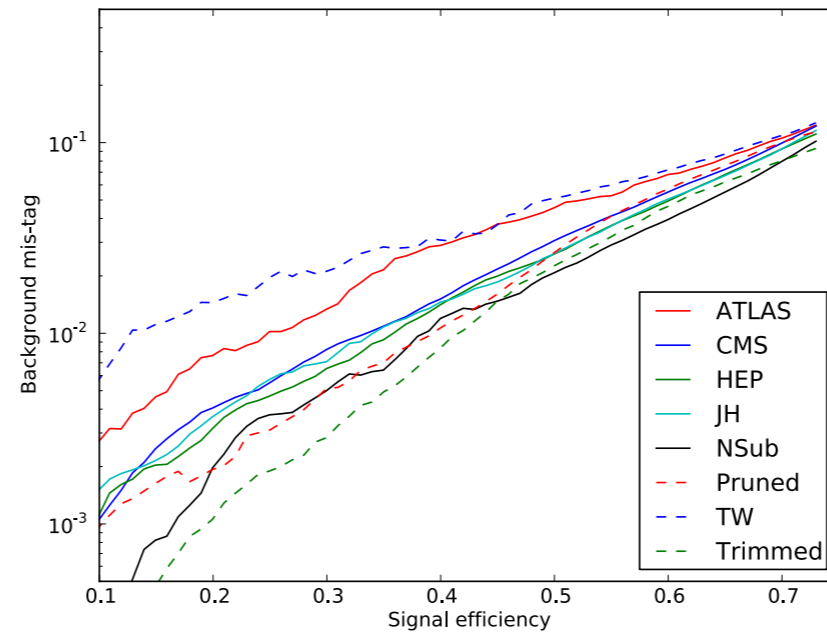
more MCs

standardized, published tools

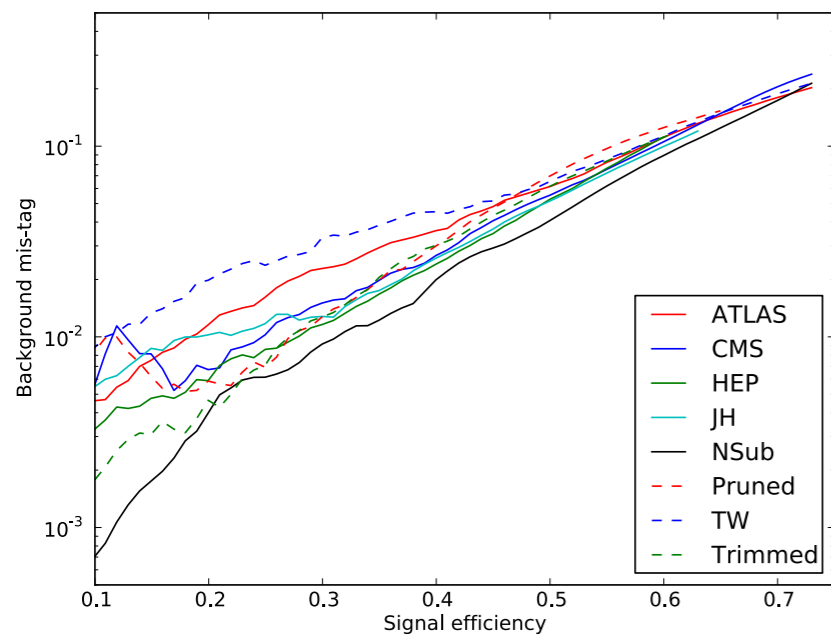
tops  
vs.  
QCD,  
pt. 2



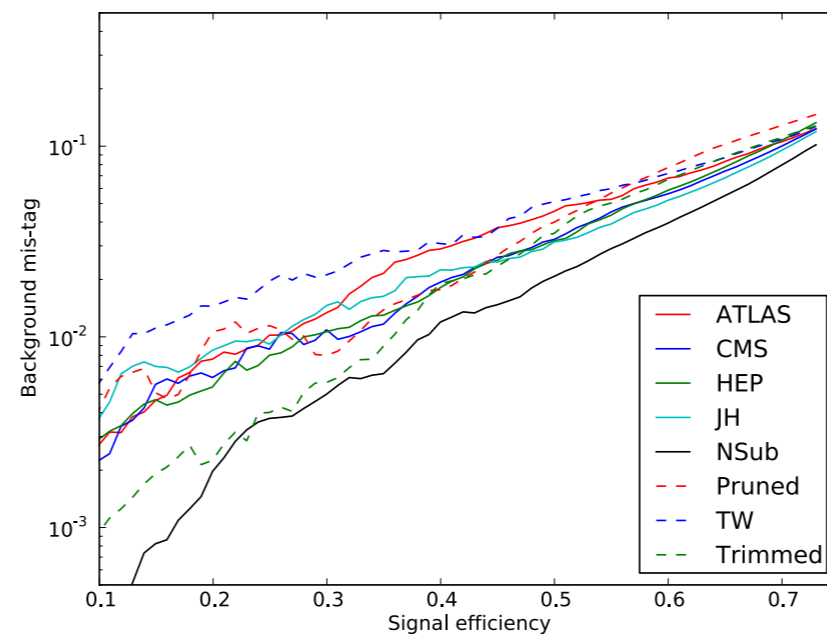
(a) all  $p_T$ , optimised



(b)  $p_T$  500–600 GeV, optimised



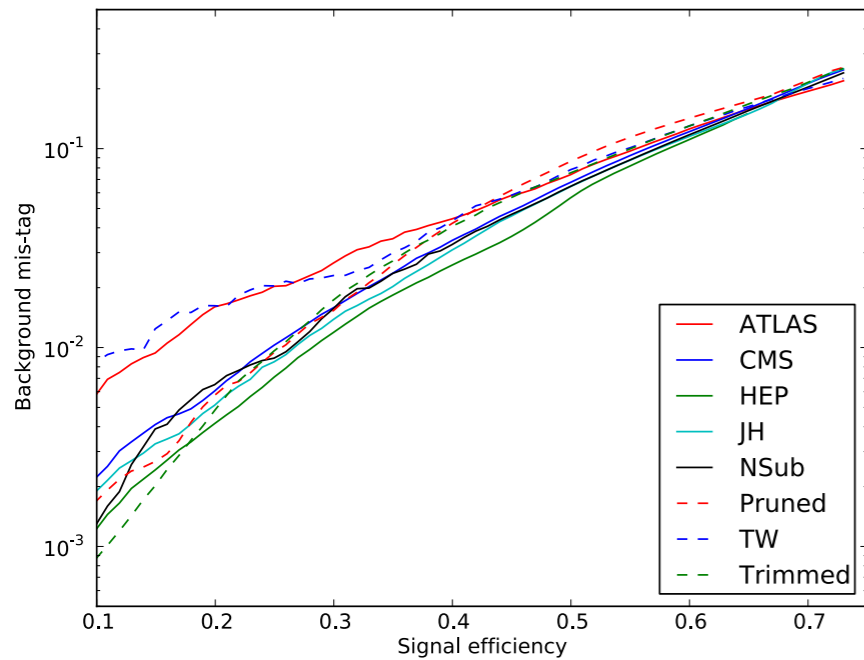
(c) all  $p_T$



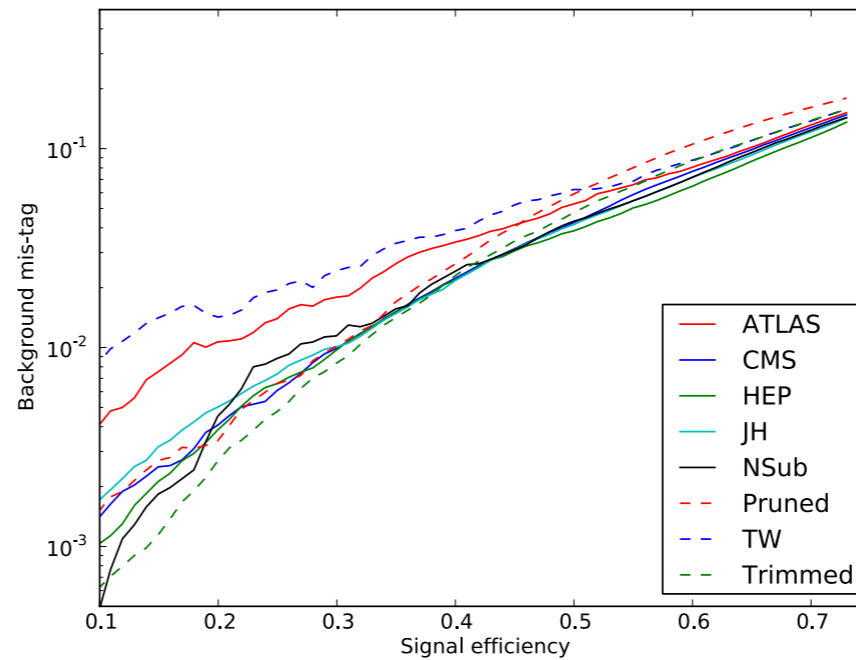
(d)  $p_T$  500–600 GeV

**Figure 14.** Mis-tag vs. efficiency for several top tagging methods, as tested on HERWIG 6.5  $t\bar{t}$  and dijet 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).

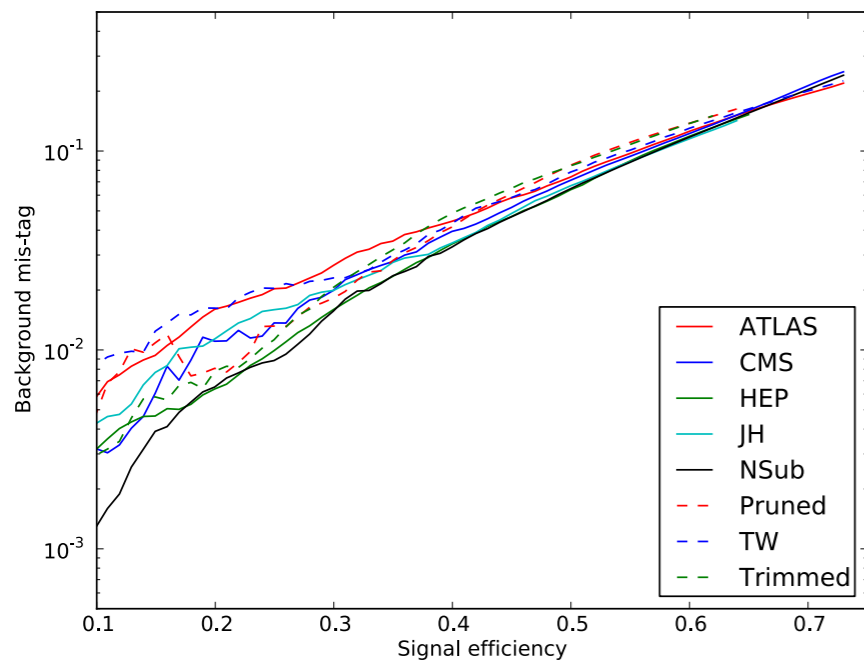
Herwig 6.5



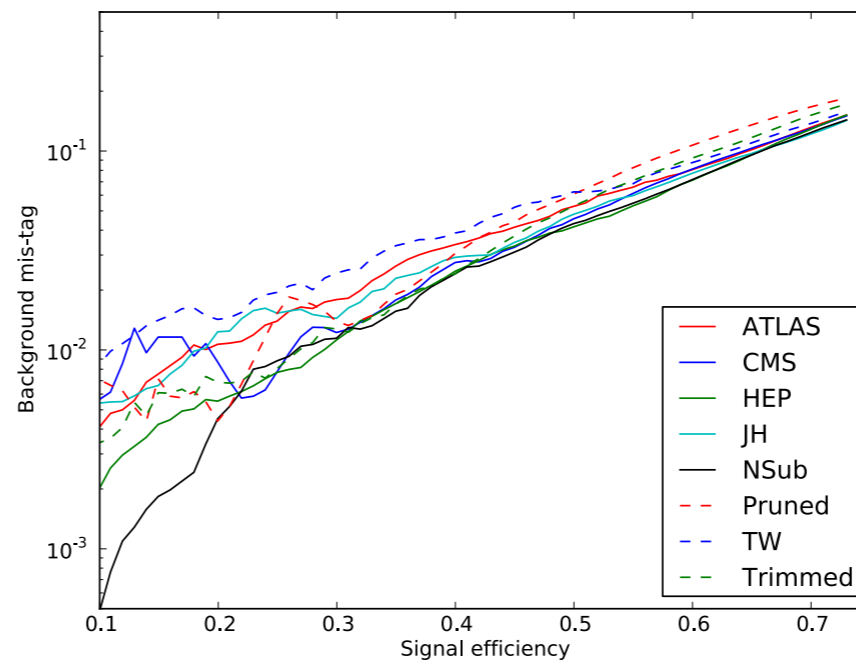
(a) all  $p_T$ , optimised



(b)  $p_T$  500–600 GeV, optimised



(c) all  $p_T$



(d)  $p_T$  500–600 GeV

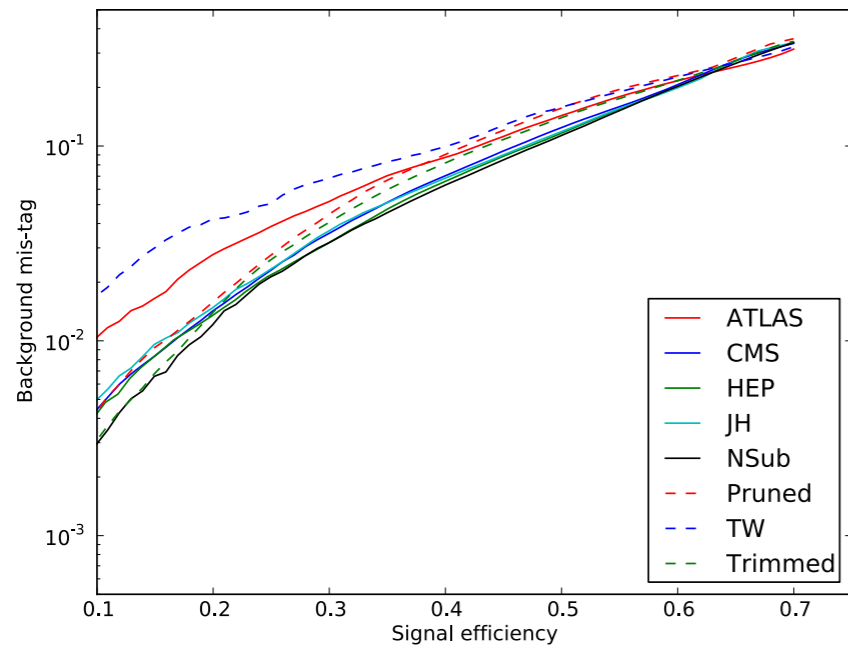
**Figure 15.** Mis-tag vs. efficiency for several top tagging methods, as tested on HERWIG++  $t\bar{t}$  and dijet samples. For Figures (a) and (b), the input parameters are optimised for each efficiency point. The input parameters for the unoptimised scans are taken from the 35% efficiency point in Figure (b).

tops  
vs.  
QCD,  
pt. 2

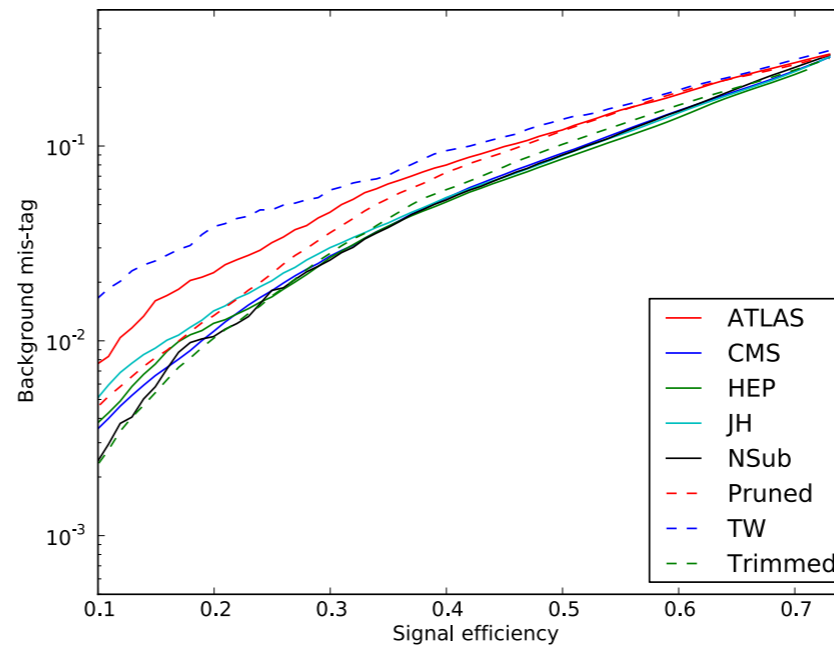
Herwig++



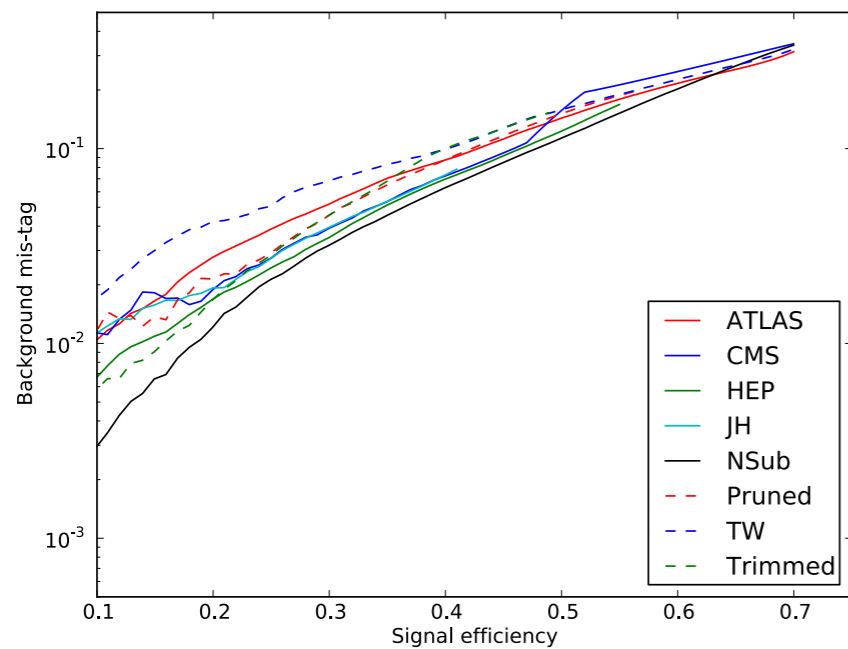
# tops vs. QCD, pt. 2



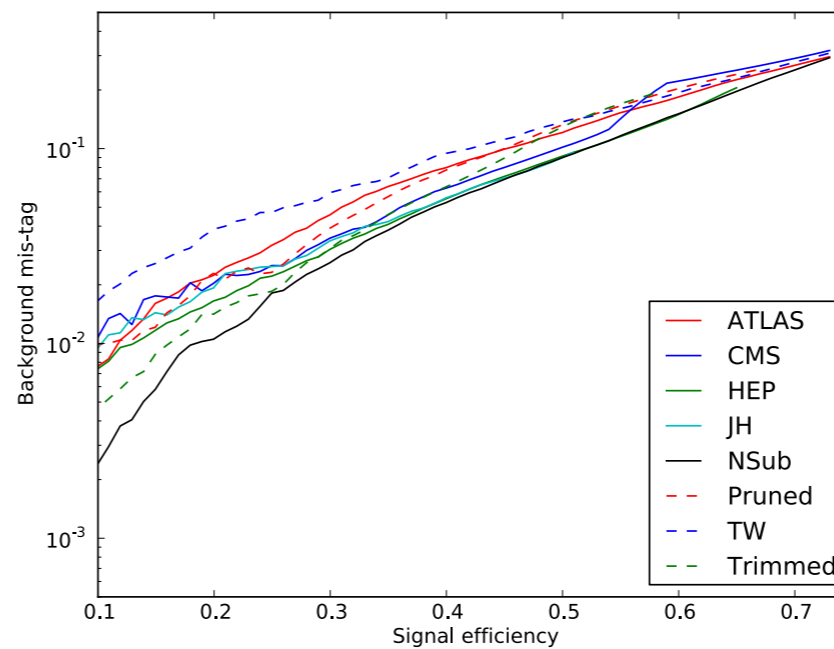
(a) all  $p_T$ , optimised



(b)  $p_T$  500–600 GeV, optimised



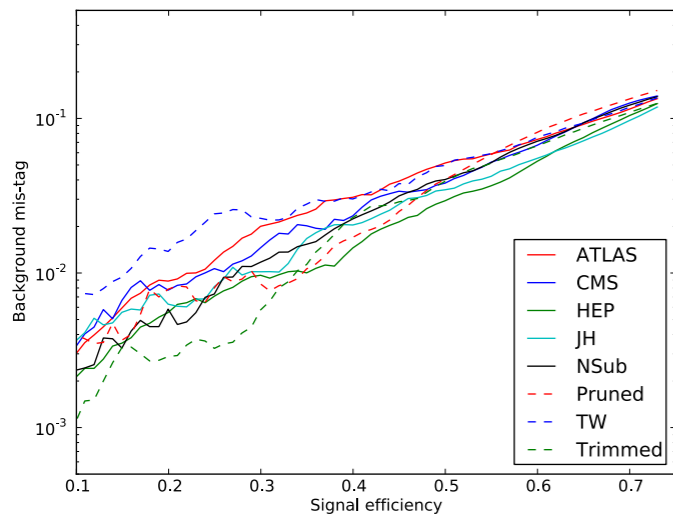
(c) all  $p_T$



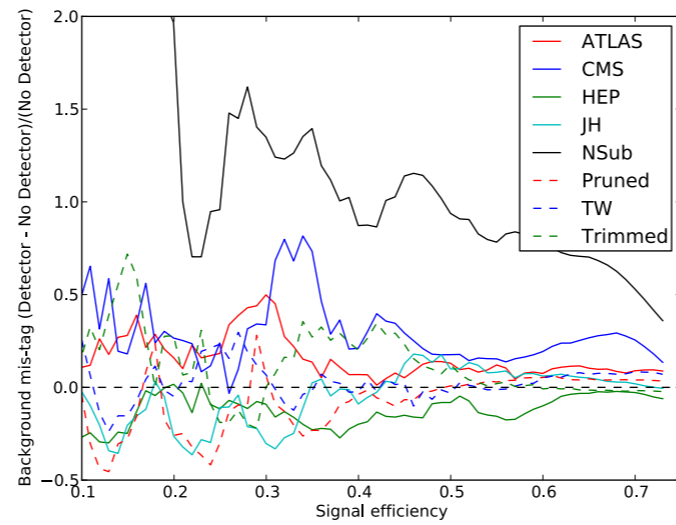
(d)  $p_T$  500–600 GeV

**Figure 16.** Mis-tag vs. efficiency for several top tagging methods, as tested on SHERPA matched  $t\bar{t} + \text{jets}$  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).

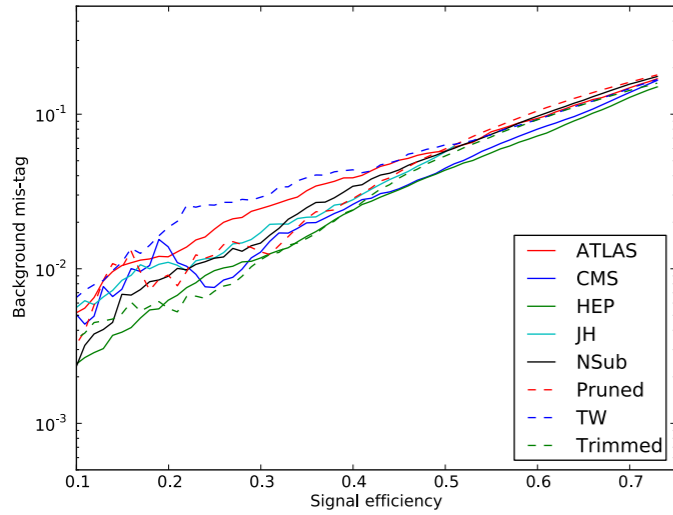
# Sherpa



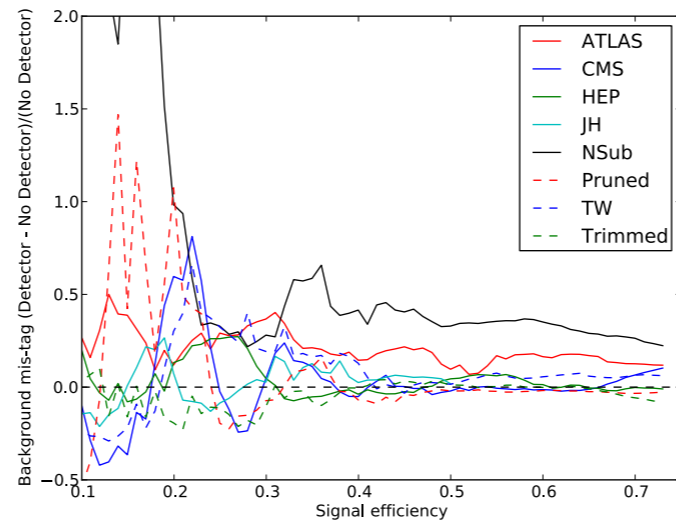
(a) HERWIG



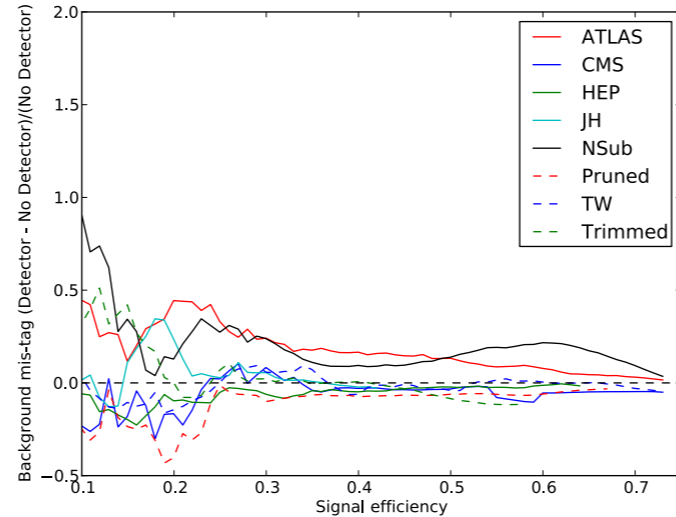
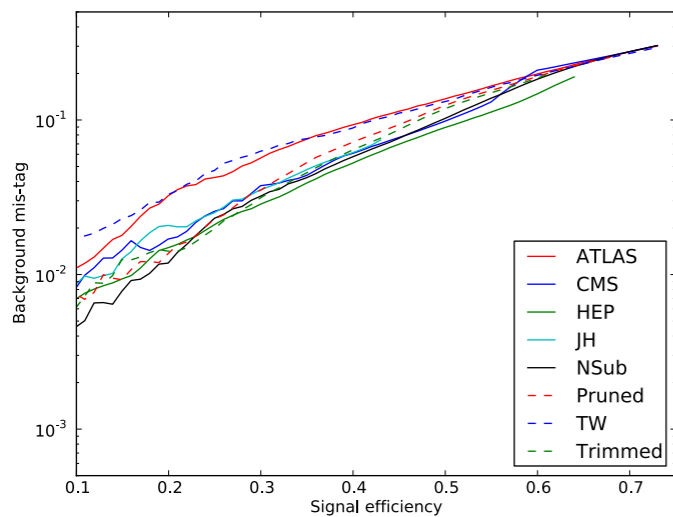
(b) HERWIG, fractional difference



(c) HERWIG++



(d) HERWIG++, fractional difference



tops  
vs.  
QCD,  
pt. 2

Detector  
effects

Big picture: These comparisons are a *baseline!*

<http://boost2011.org>

All tools implemented in SpartyJet: see Wed. tutorial!!

Long term: “fastjet/contrib”

# BOOST: The home game

This is the whole point!



# Lots of questions left unanswered!

Other signals?

Pile up?

Theory synthesis?

Complicated topologies?

More interesting  $p_T$  ranges?

**Assignment: Answer these questions!**

## More tasks for this week:

What are our priorities/goals for next year?

What haven't we done?

Should we write another report??

How? What should it contain?

Thank you!





dipolarity



Search

About 71,200 results (0.29 seconds)

Web

### [Dipolarity and God](https://researchspace.auckland.ac.nz/handle/2292/567)

<https://researchspace.auckland.ac.nz/handle/2292/567>

by MD Brimblecombe - 2000 - [Cited by 1](#) - [Related articles](#)

The Christian doctrine of the Trinity is about one God in three divine persons, with one of these three becoming human (without ceasing to be divine) in Jesus of ...

Images

Maps

Videos

News

### [Jet Dipolarity: Top Tagging with Color Flow](#)

[arxiv.org](#) › [hep-ph](#)

by A Hook - 2011 - [Cited by 5](#) - [Related articles](#)

4 Feb 2011 – Abstract: A new jet observable, **dipolarity**, is introduced that can distinguish whether a pair of subjects arises from a color singlet source.

Shopping

More

### [The dipolarity/polarisability of 1-alkyl-3-methylimidazolium ionic ...](#)

[xlink.rsc.org](#) › [Journals](#) › [New Journal of Chemistry](#)

by R Lungwitz - 2010 - [Cited by 25](#) - [Related articles](#)

Based on the developed tool to measure Kamlet–Taft polarity parameters  $\alpha$  (hydrogen bond donating ability),  $\beta$  (hydrogen bond accepting ability), and  $\pi^*$  ...

Show search tools





dipolarity

Search

About 71,200 results (0.29 seconds)

Web

### [Dipolarity and God](https://researchspace.auckland.ac.nz/handle/2292/567)

<https://researchspace.auckland.ac.nz/handle/2292/567>

by MD Brimblecombe - 2000 - [Cited by 1](#) - [Related articles](#)

The Christian doctrine of the Trinity is about one God in three divine persons, with one of these three becoming human (without ceasing to be divine) in Jesus of ...

Images

Maps

Videos

News

### [Jet Dipolarity: Top Tagging with Color Flow](https://arxiv.org/abs/1102.0001)

[arxiv.org](https://arxiv.org/abs/1102.0001) › [hep-ph](#)

by A Hook - 2011 - [Cited by 5](#) - [Related articles](#)

4 Feb 2011 – Abstract: A new jet observable, **dipolarity**, is introduced that can distinguish whether a pair of subjects arises from a color singlet source.

Shopping

More

### [The dipolarity/polarisability of 1-alkyl-3-methylimidazolium ionic ...](https://xlink.rsc.org/Journals/New%20Journal%20of%20Chemistry)

[xlink.rsc.org](https://xlink.rsc.org/Journals/New%20Journal%20of%20Chemistry) › [Journals](#) › [New Journal of Chemistry](#)

by R Lungwitz - 2010 - [Cited by 25](#) - [Related articles](#)

Based on the developed tool to measure Kamlet–Taft polarity parameters  $\alpha$  (hydrogen bond donating ability),  $\beta$  (hydrogen bond accepting ability), and  $\pi^*$  ...

Show search tools

“...From a trinitarian foundation, a theology of God can be developed which expresses both the being-becoming and one-many dipolarities....”