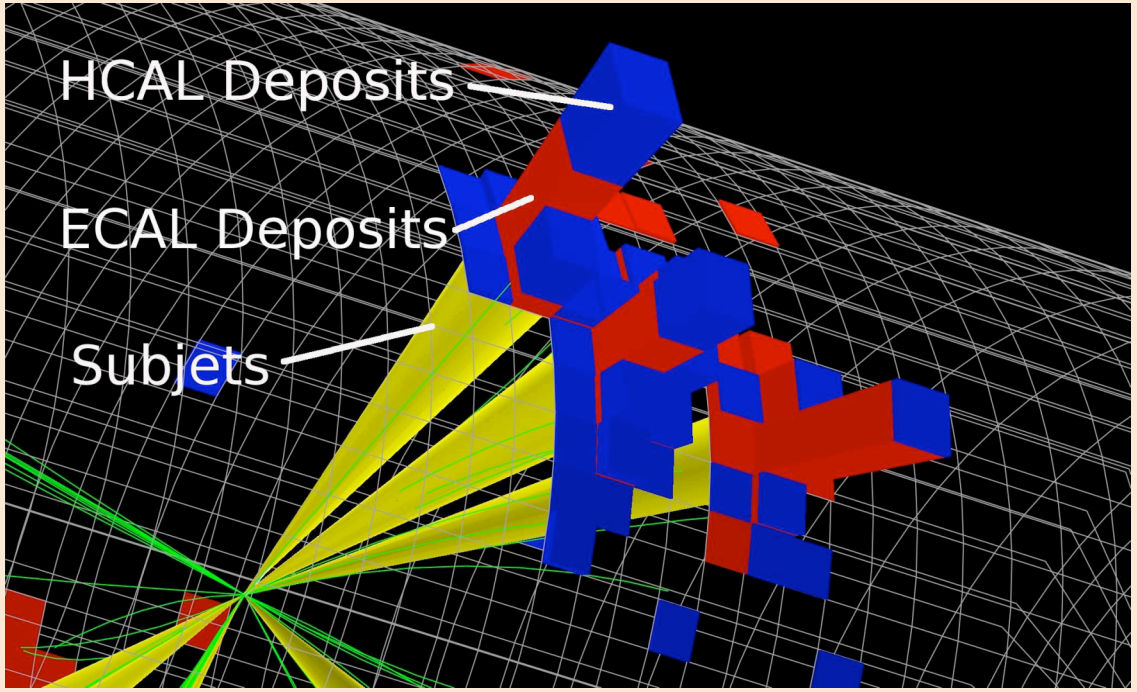


Boosted Top

Salvatore Rappoccio

Johns Hopkins University / CMS / CDF

Fine Print

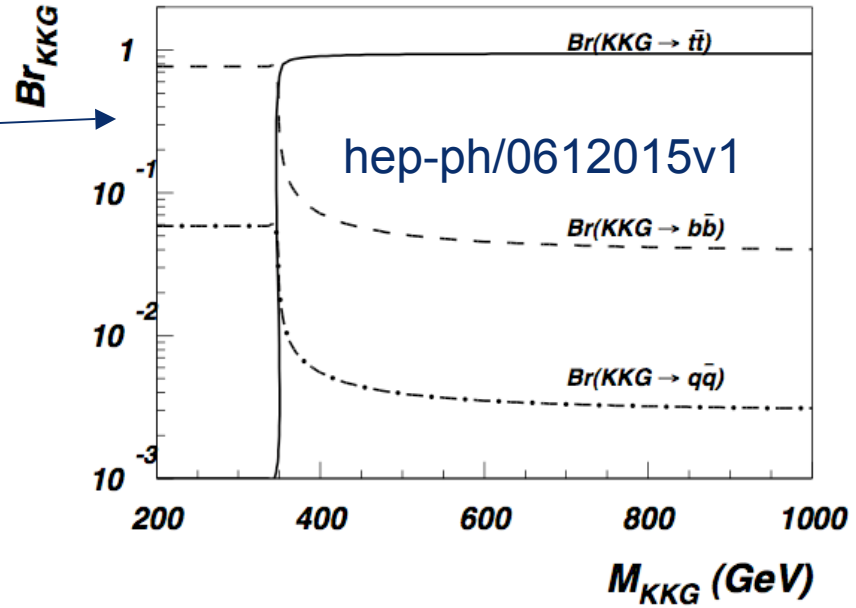
- This talk is meant to stimulate discussion
- Very active area of HEP, many new and exciting developments
  - If I missed something don't be offended!
- Thanks to the many people who have worked on this!

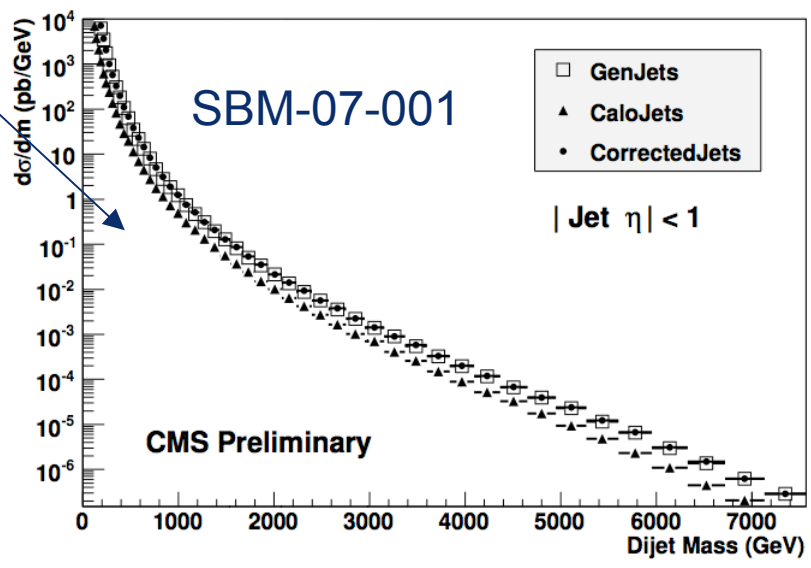
Assorted References

- Theoretical motivations:
  - arXiv:hep-ph/0612015
  - arXiv:0803.1160
- Algorithmic Developments:
  - arXiv:0806.0023
  - arXiv:0802.2470
  - arXiv:hep-ph/0201098
  - arXiv:hep-ph/0702150
  - arXiv:0806.0848v2
  - arXiv:0903.5081
- Tevatron Developments:
  - arXiv:0902.3276
  - arXiv:0709.0705v1
  - arXiv:0804.3664v1
  - arXiv:0803.3256v1
- LHC Developments
  - ATL-COM-PHYS-2008-001
  - ATL-PHYS-PUB-2006-002
  - ATL-PHYS-PUB-2006-033
  - CMS-TOP-2009-009
  - CMS-JME-2009-001
  - CMS-EXO-2009-002
  - CMS-EXO-2009-008

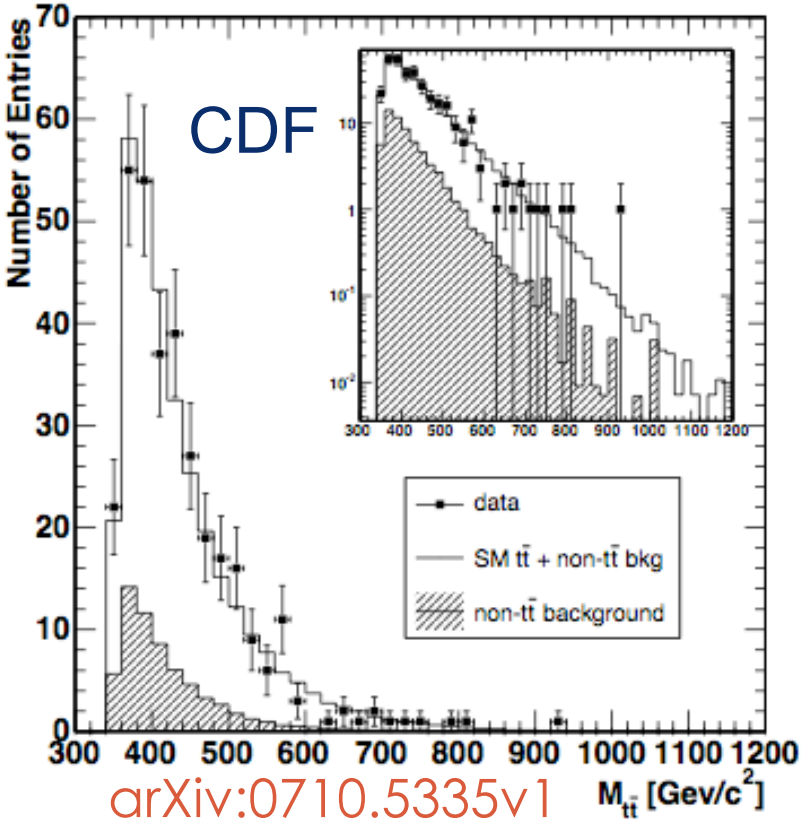
Motivation

- New physics scenarios often involve ttbar resonances
- Are we sensitive to hadronic decays of top?
  - Can we suppress the huge dijet background?
- What about tricks with leptonic decays also?
  - "Traditional" methods are (eventually) ineffective due to crowded environment

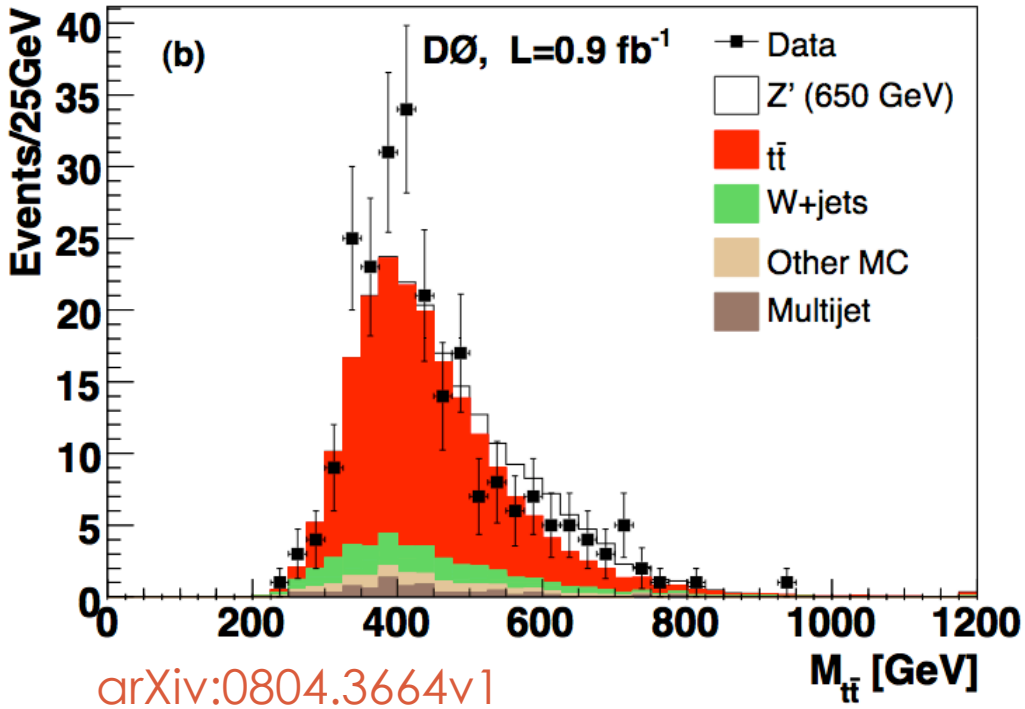




Experimental Status



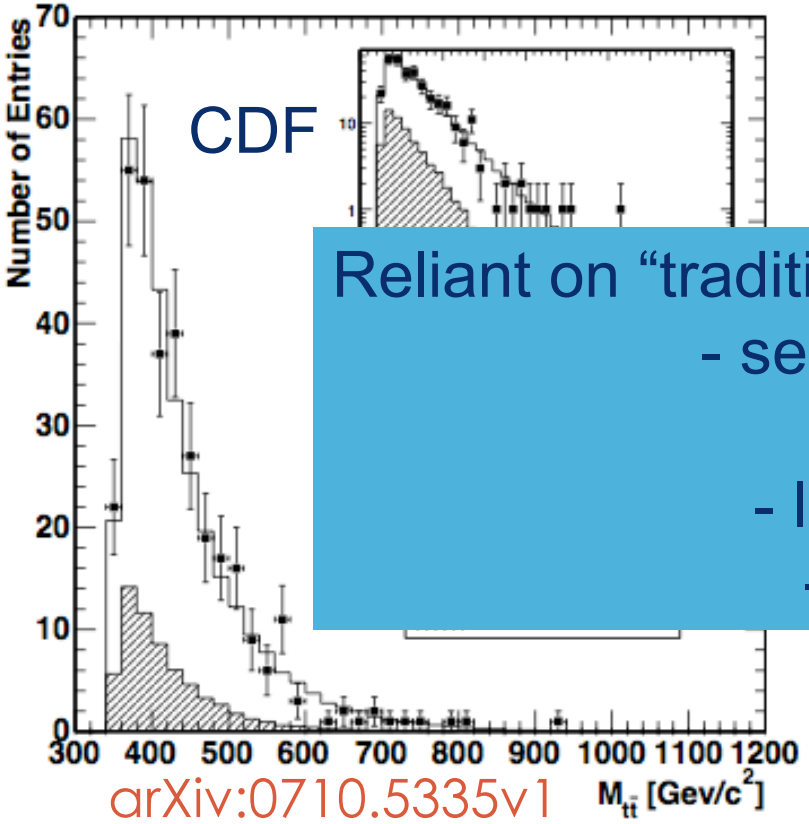
arXiv:0710.5335v1



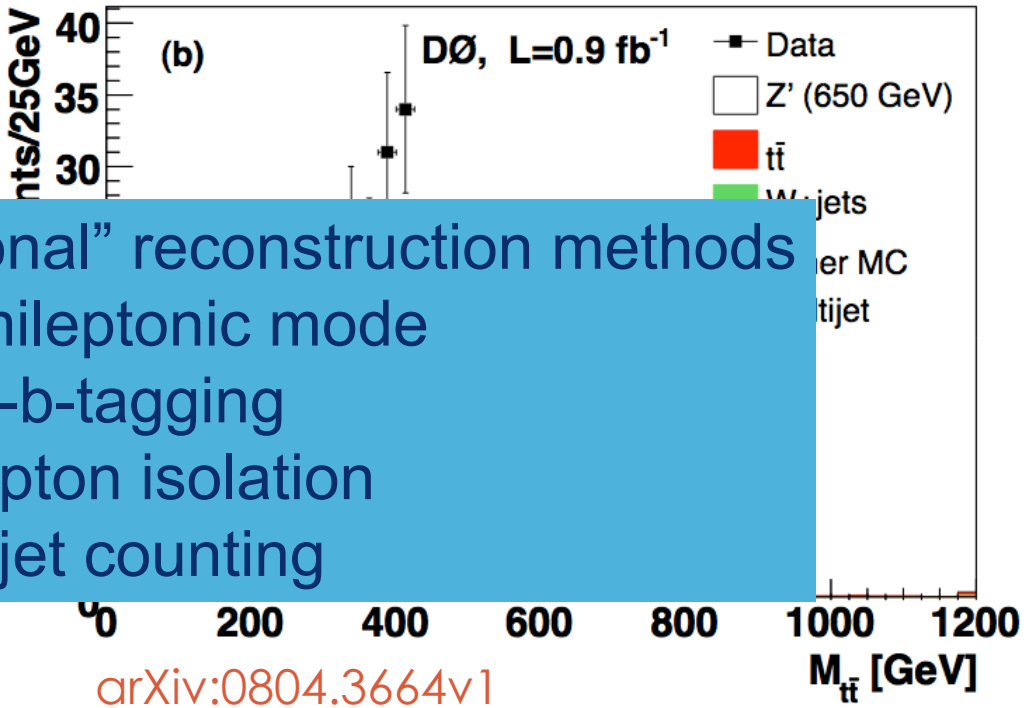
arXiv:0804.3664v1

$M_{Z'} > 700\ GeV/c^2$

Experimental Status



arXiv:0710.5335v1

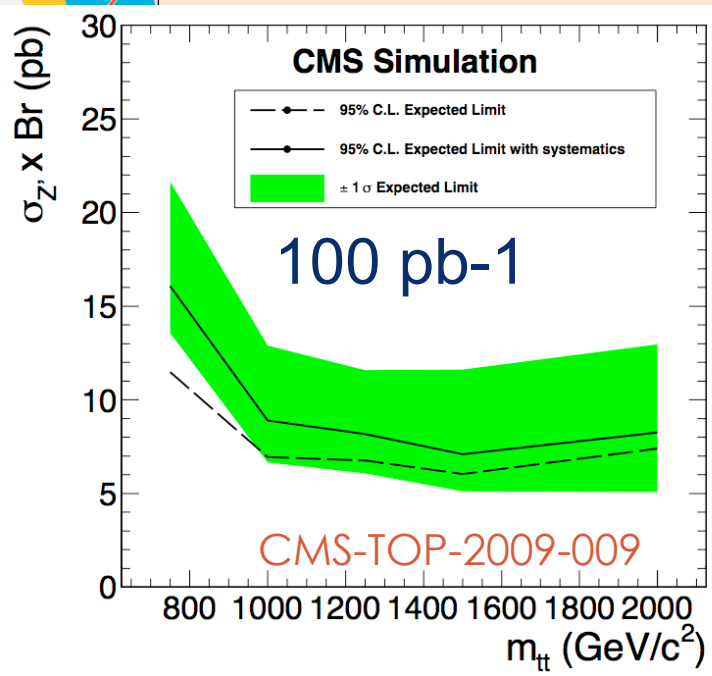


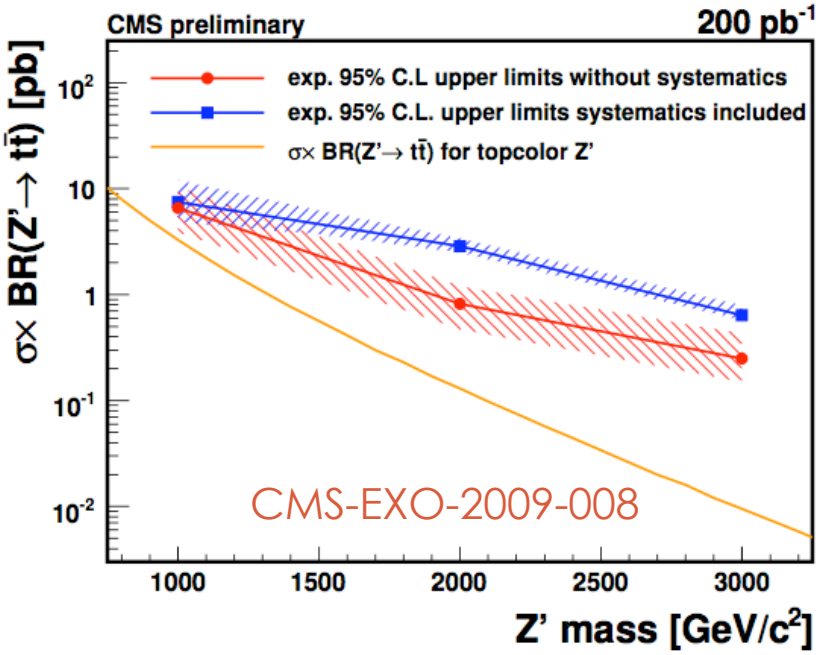
arXiv:0804.3664v1

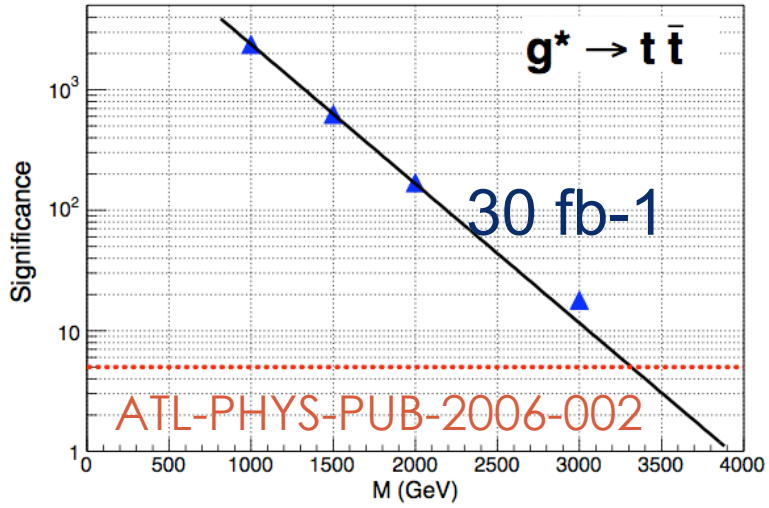
Reliant on "traditional" reconstruction methods
- semileptonic mode
-b-tagging
- lepton isolation
- jet counting

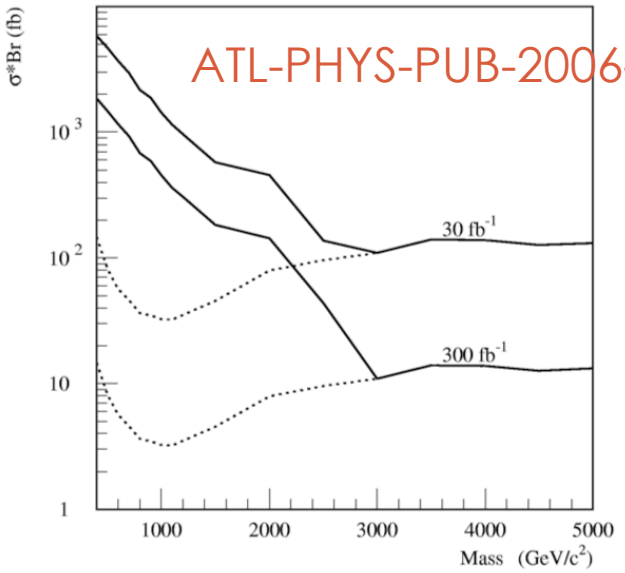
$M_{Z'} > 700$ GeV/c^2

Semileptonic Sensitivities at LHC

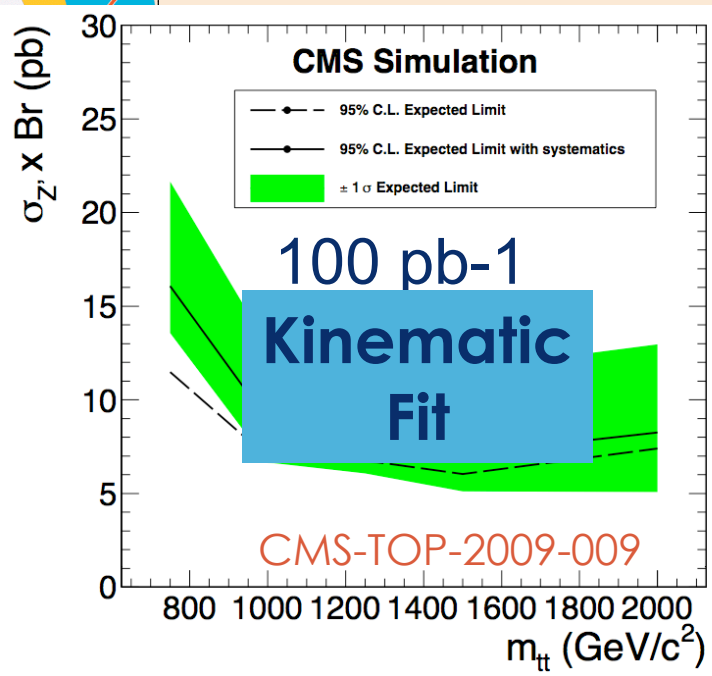


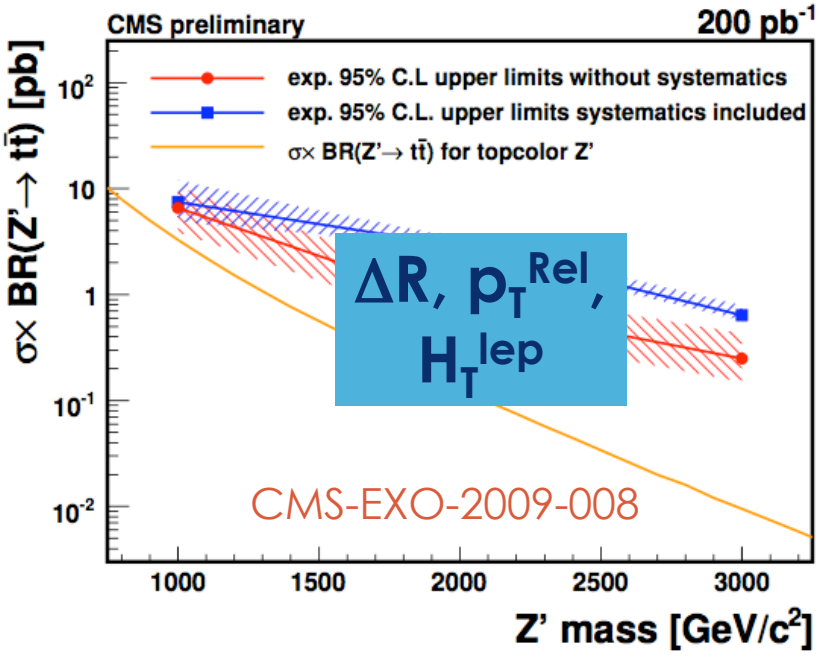


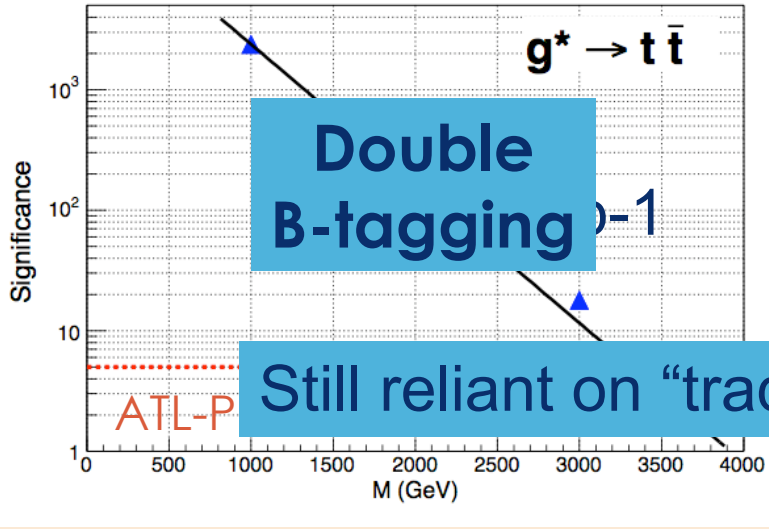


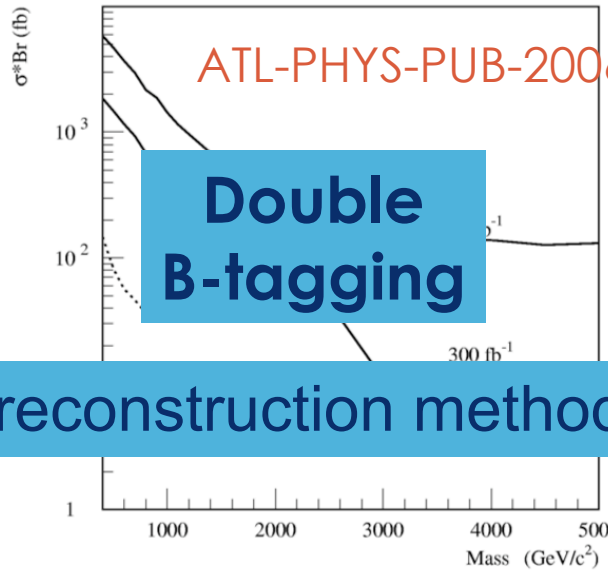


Semileptonic Sensitivities at LHC



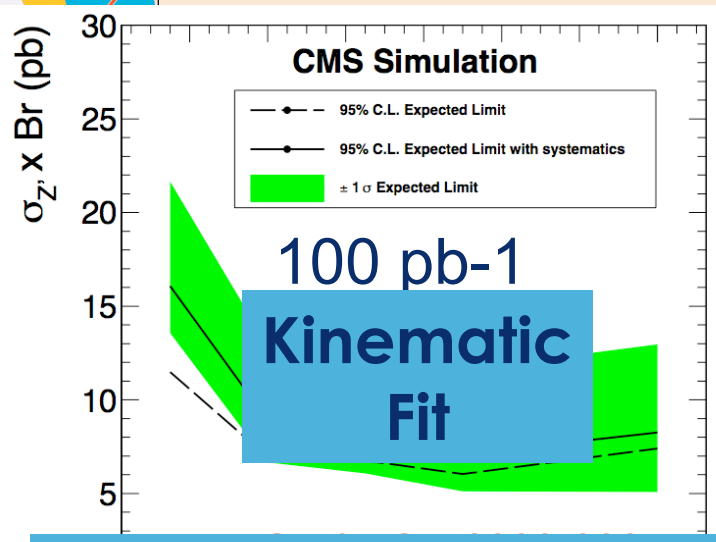




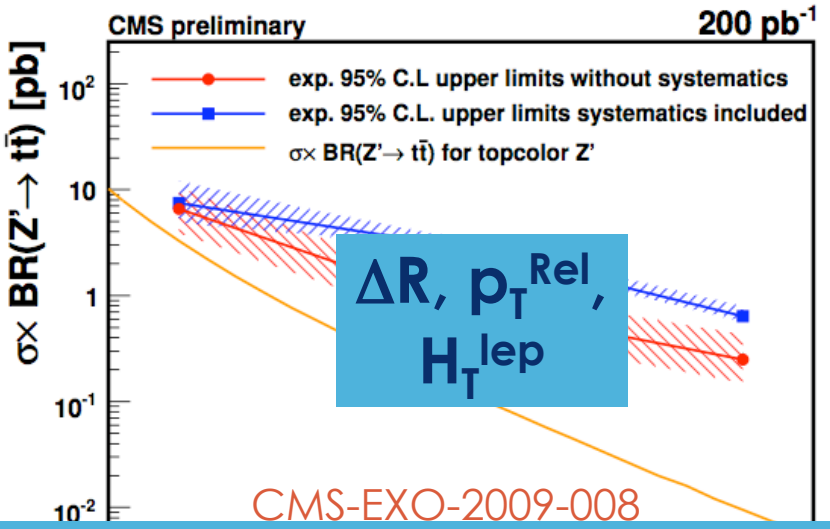


Still reliant on "traditional" reconstruction methods…

Semileptonic Sensitivities at LHC



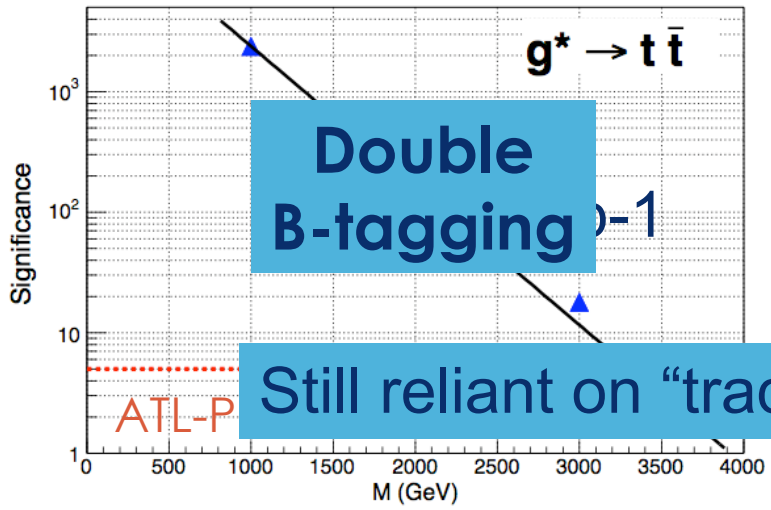
Kinematic Fit



ΔR, p_T^{Rel}, H_T^{lep}

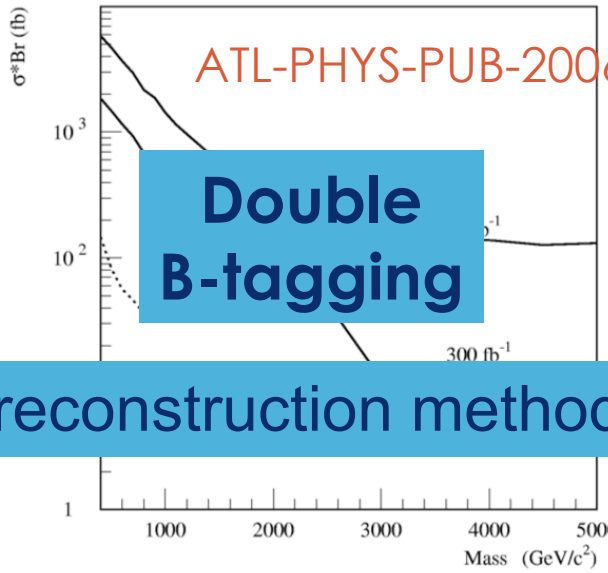
CMS-EXO-2009-008

Is there anything else we can think of?



Double B-tagging

ATL-P



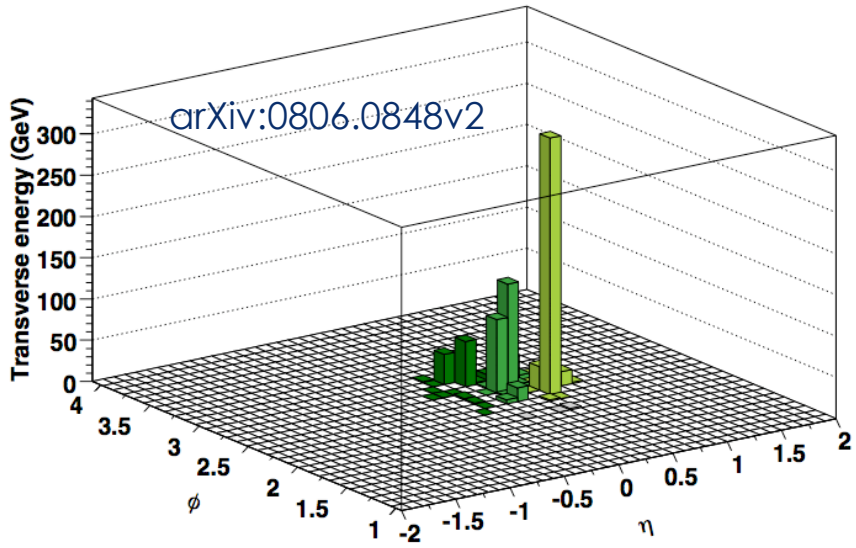
ATL-PHYS-PUB-2006-002

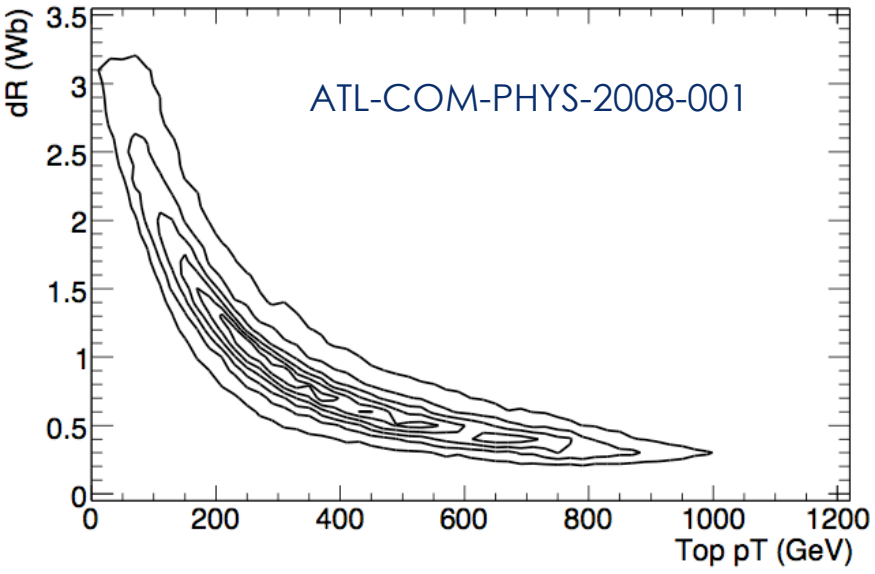
Double B-tagging

Still reliant on "traditional" reconstruction methods…

New Idea: Top Jets

- Even moderate parent masses will result in collimated top "jets"
- Substructure can still be resolved
  - **Subjets**
- Two mass scales involved:
  - Top mass
  - W mass
    - **Affects angular distribution of subjets**
- For QCD, only gluon emission scales
  - Tend toward "zero" mass, smaller anglular separation





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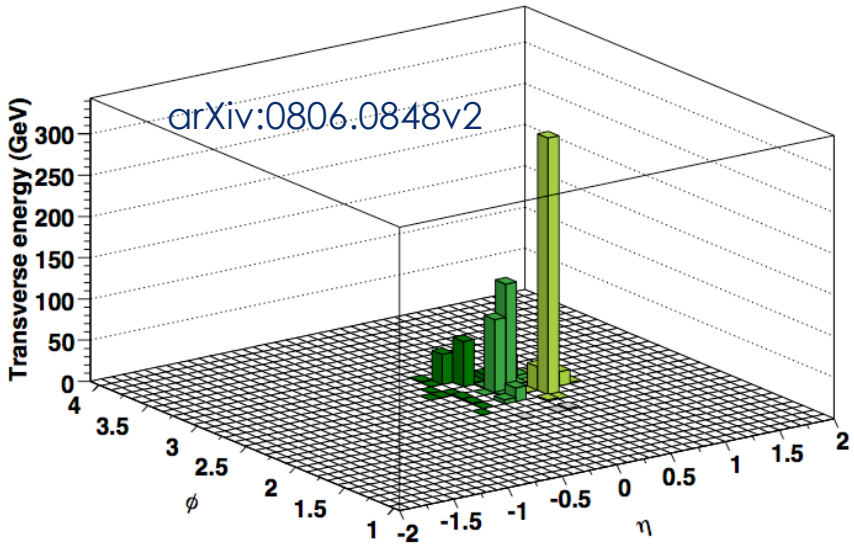
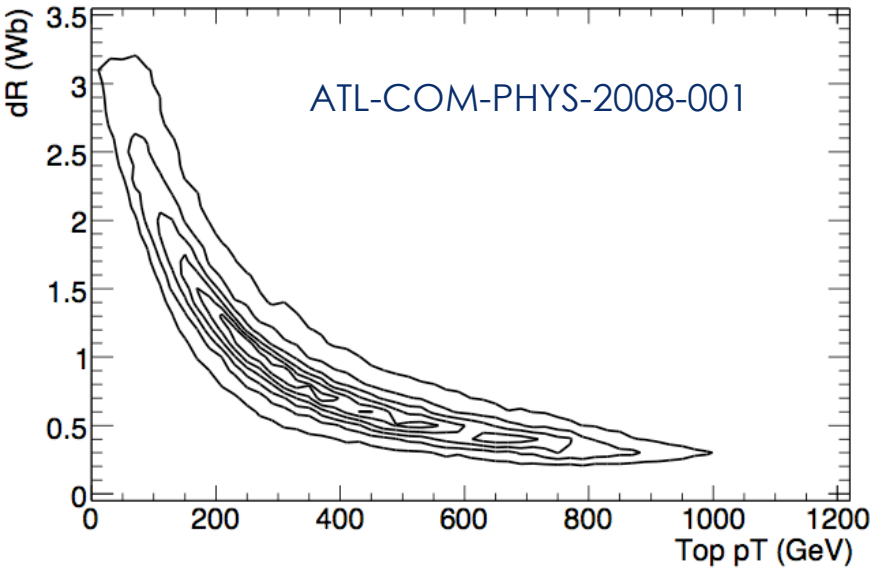
Much Work in the Area of Subjets!

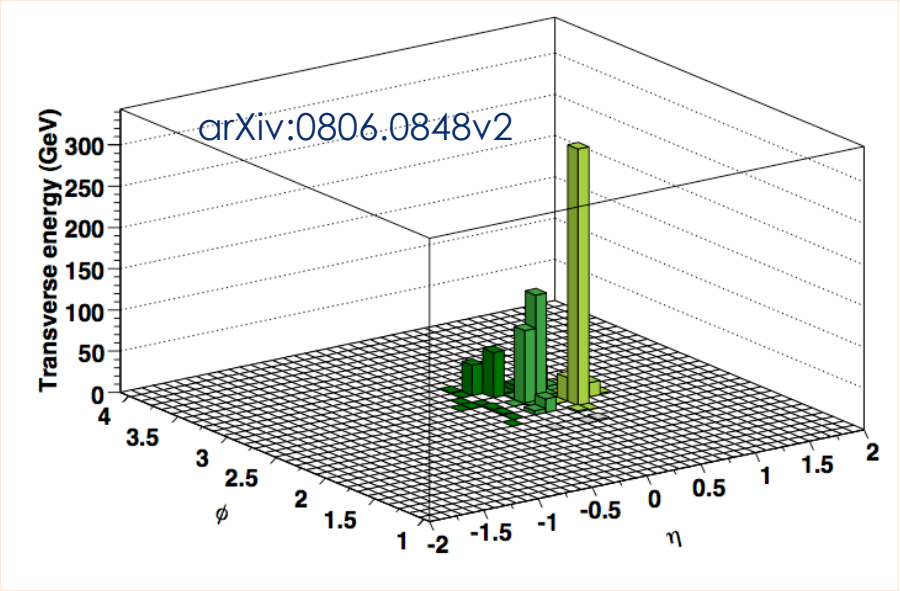
Examine this in detail





New Idea: Top Jets

- How to get at substructure?
- Cone-like algorithms are not very good
  - Start with "large pt" and then incorporate "small pt"
  - This is going to wash out substructure



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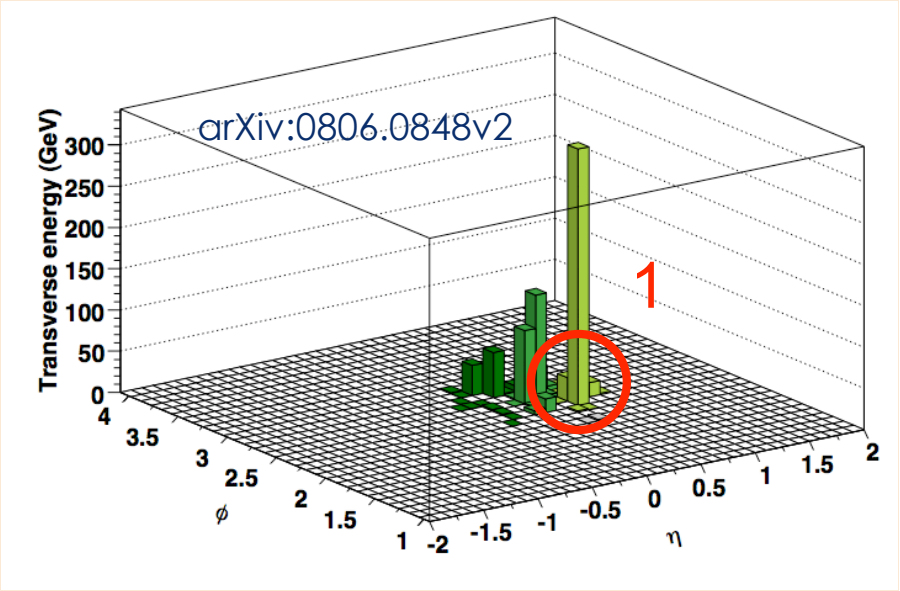

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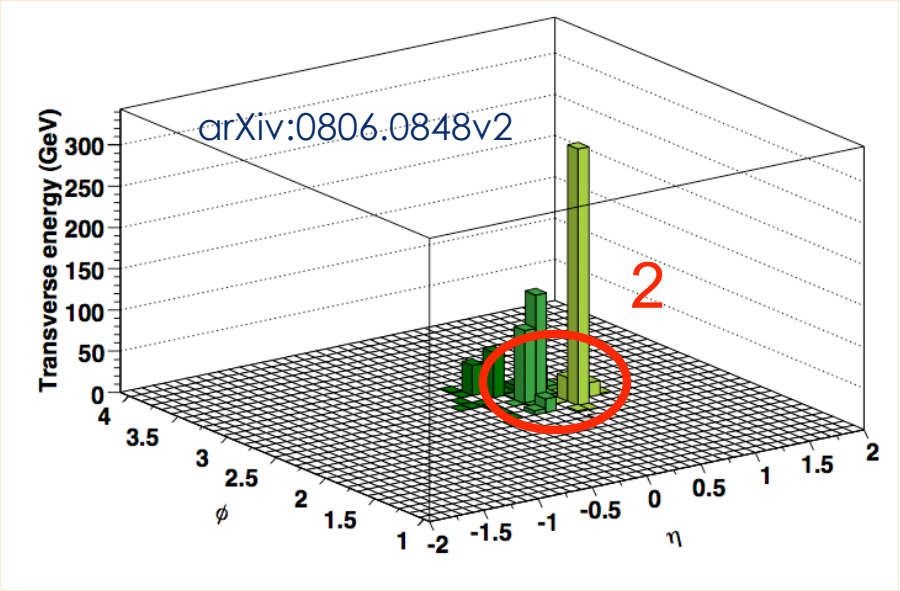

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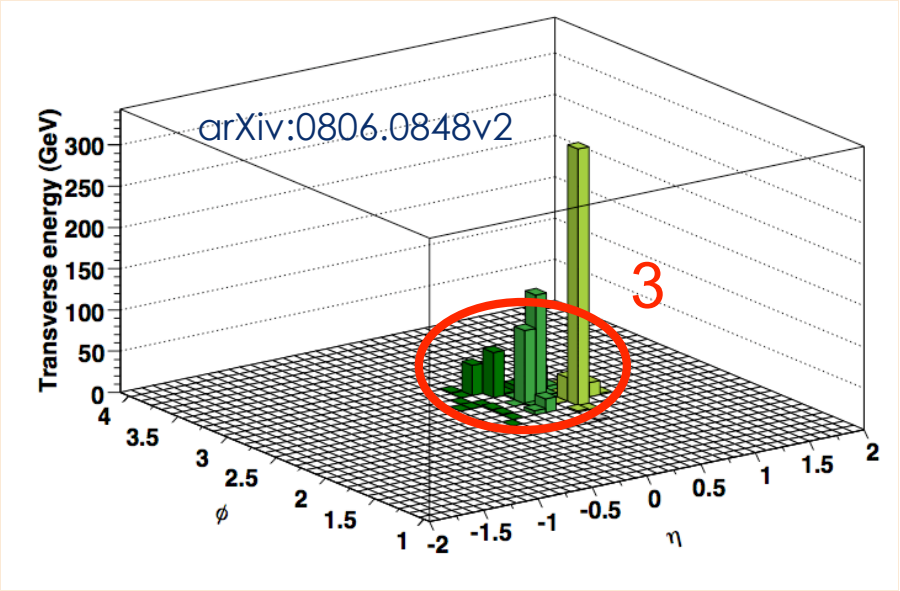
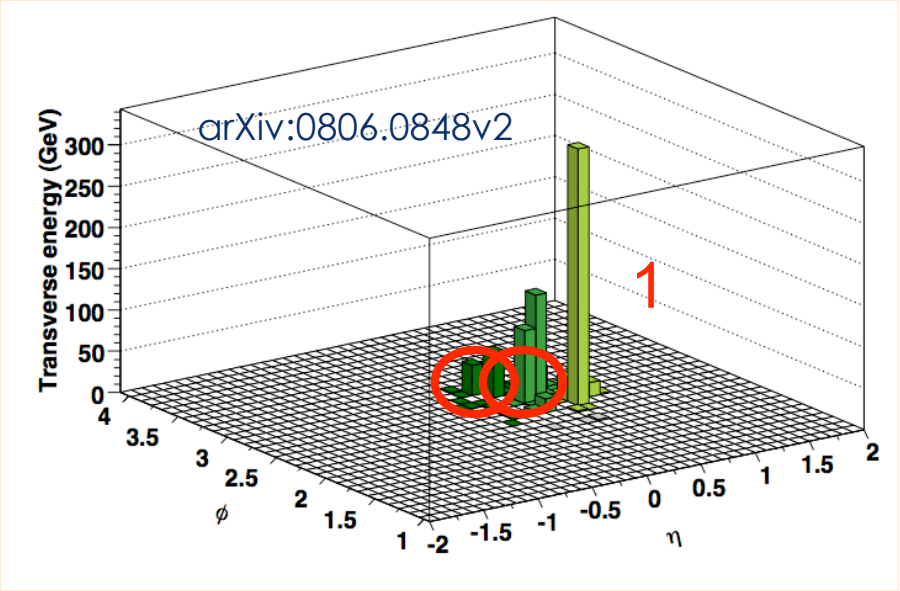


New Idea: Top Jets

- How to get at substructure?
- Sequential combination algorithms produce "subjets" naturally in the course of the algorithm!
  - Exploit the clustering sequence



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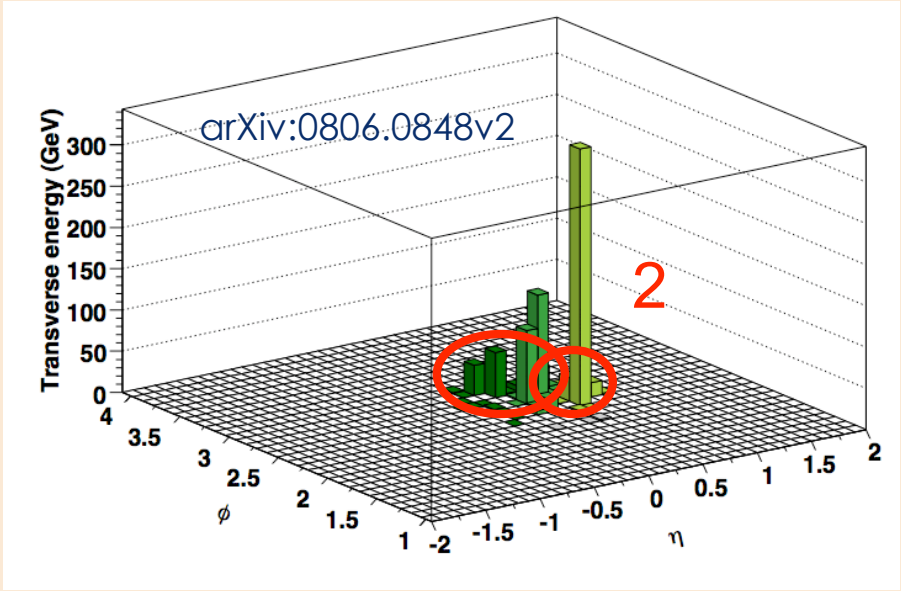

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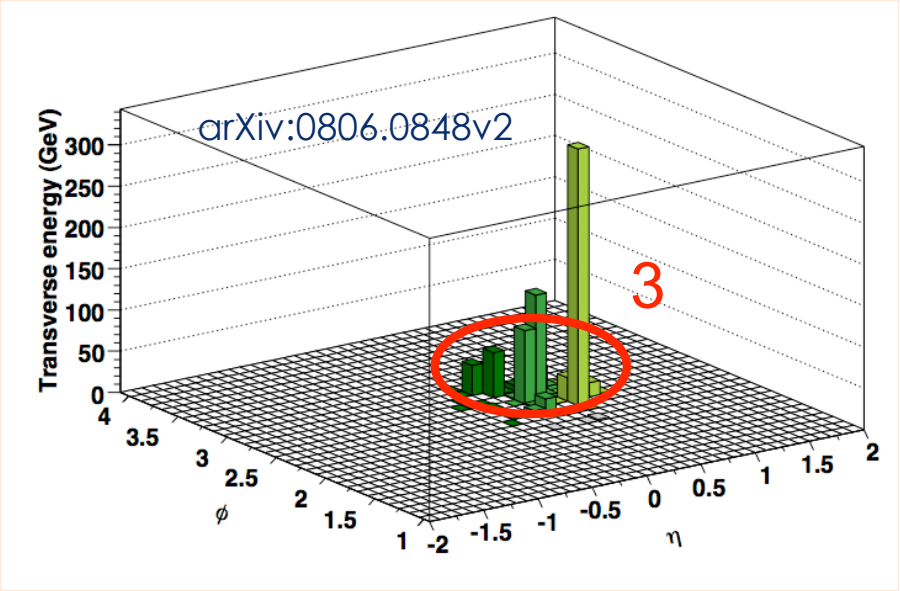


Look at sequential combination in more detail

Sequential Combination

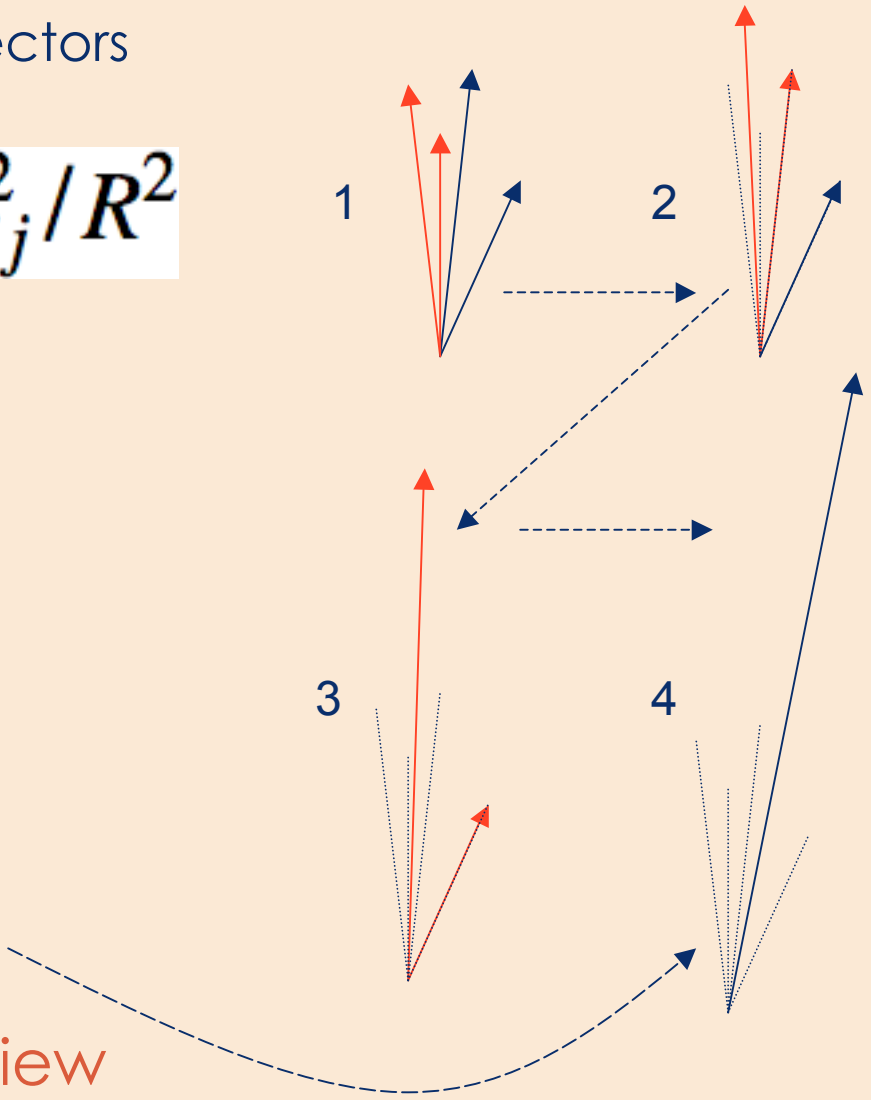
- Pairwise examination of input 4-vectors
- Calculate d_{ij}

$$d_{ij} = min(k_{ti}^n, k_{tj}^n)\Delta R_{ij}^2 / R^2$$

  - N = 2: k_T
  - N = 0: Cambridge Aachen
  - N = -2: anti-k_T
- Also find the "beam distance"

$$d_{iB} = k_{T,i}^n$$

- Find min of all d_{ij} and d_{iB}
- If min is a d_{ij}, merge and iterate
- If min is a d_{iB}, classify as a final jet
- Continue until list is exhausted



fastjet manual has good overview

Substructure Finding

Top-down

- "Peel off" layers of jet clustering sequence
- Throw away soft and colinear clusters

4 -> 3 -> 2 ->1

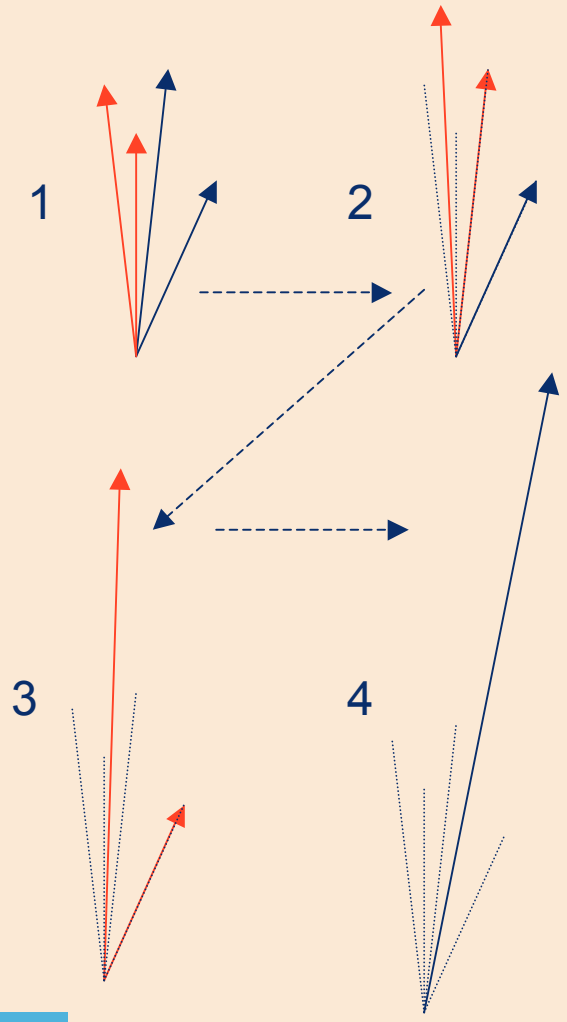
- arXiv:hep-ph/0201098
- arXiv:hep-ph/0702150
- arXiv:0806.0848v2

Bottom-up

- Start from "ground up" of clustering sequence
- Throw away soft and colinear clusters

1 -> 2 -> 3 -> 4

- arXiv:0810.0934



Comparable results for both

Substructure Finding

Top-down

- "Peel off" layers of jet clustering sequence
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4 -> 3 -> 2 ->1

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In the interest of time, discuss top-down only

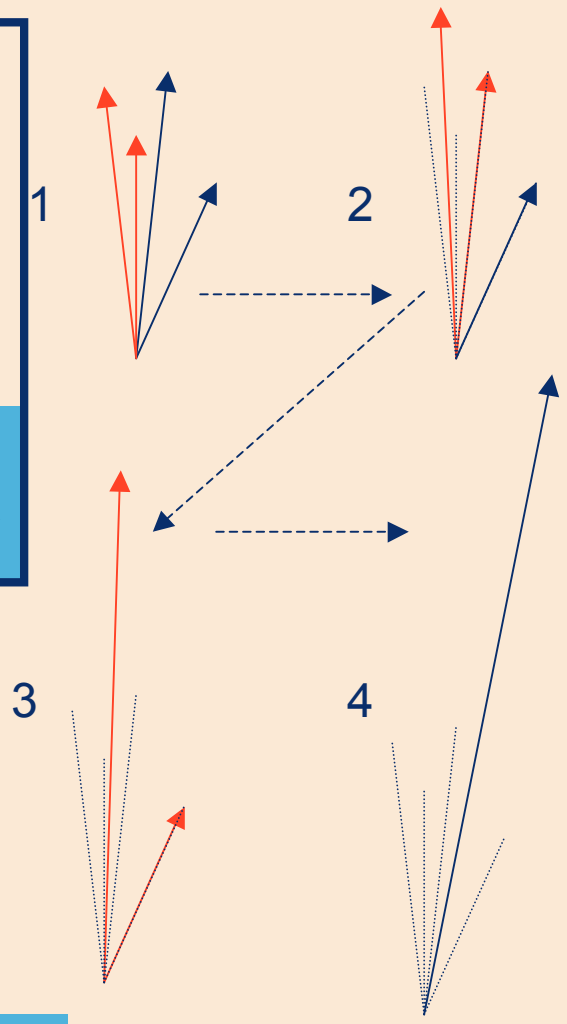
Bottom-up

- Start from "ground up" of clustering sequence
- Throw away soft and colinear clusters

1 -> 2 -> 3 -> 4

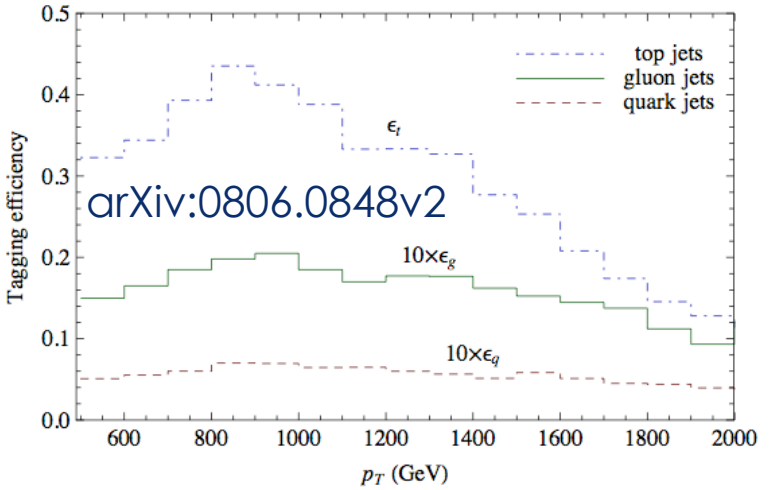
- arXiv:0903.5081

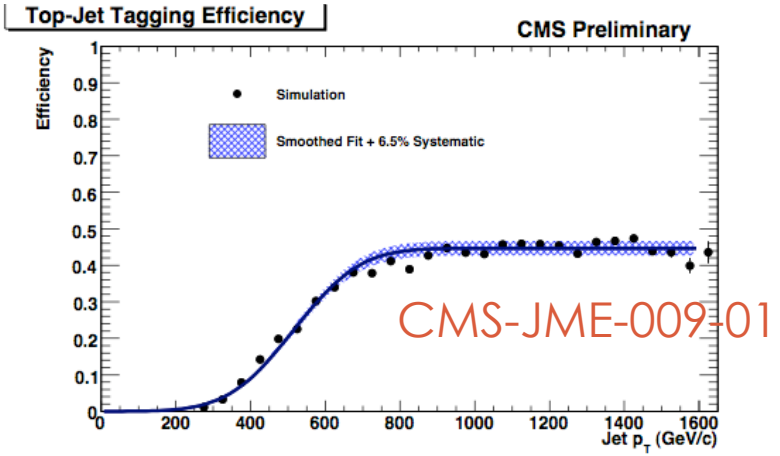
Comparable results for both

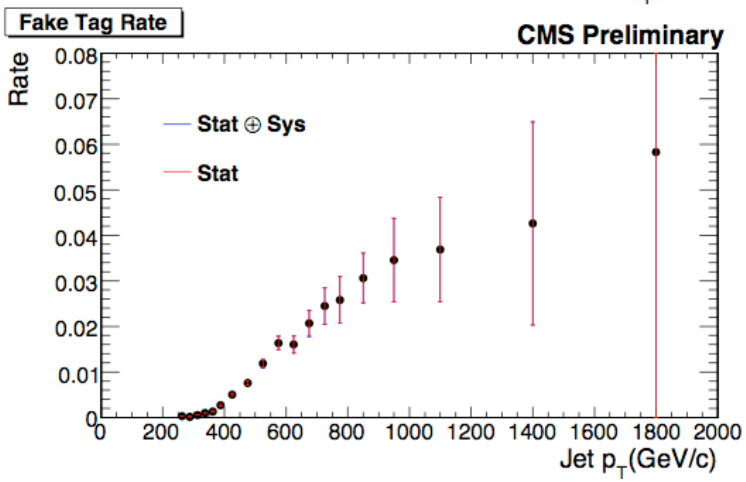


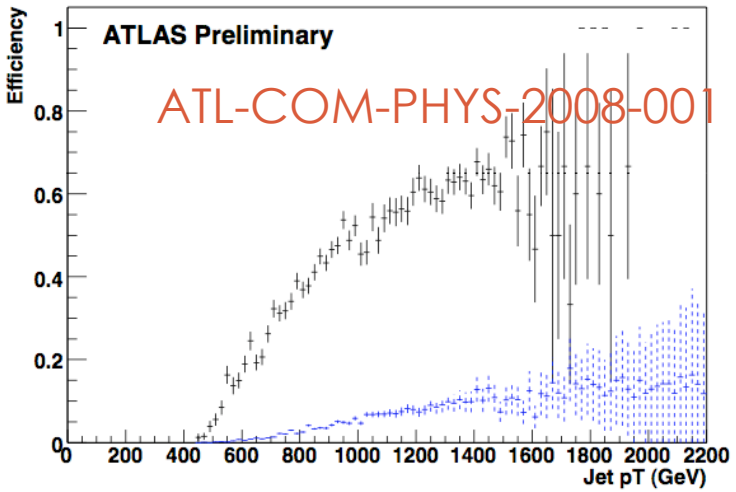
Substructure Finding

- Exploit kinematics!
  - Angular information
  - Mass of top, W
  - Mass "drop" from full jet
  - Energy scale at which decomposition occurs
  - …
  - All provide **very powerful** discrimination against generic QCD





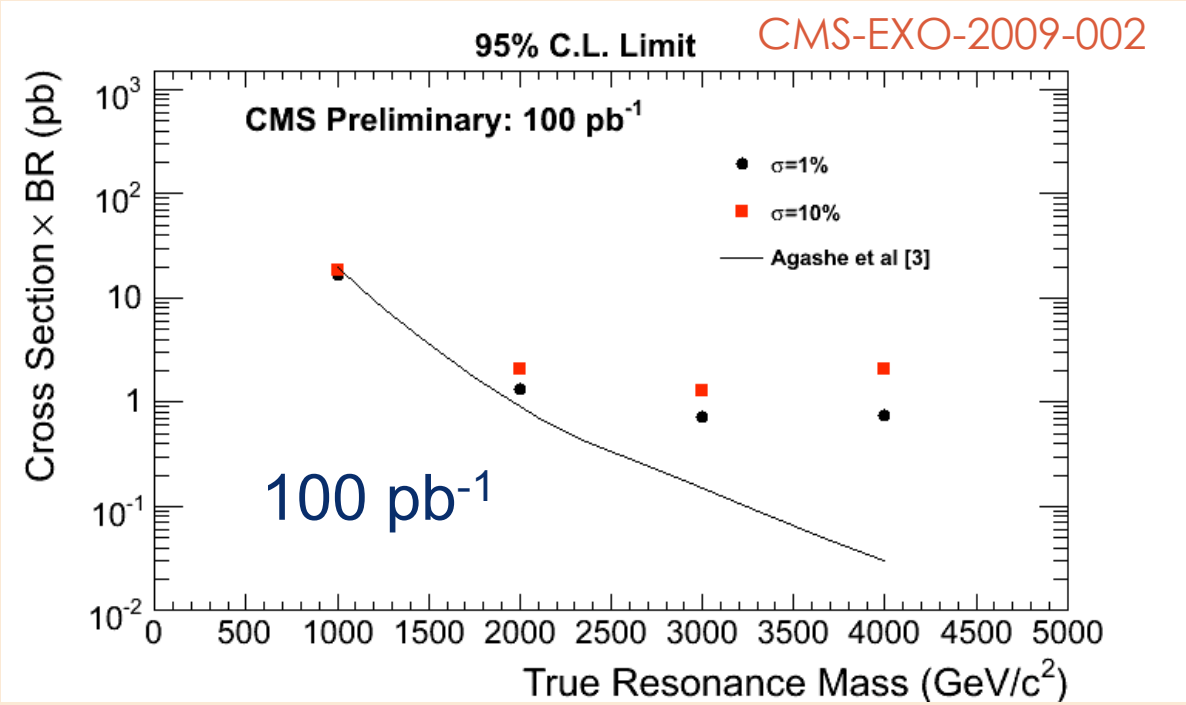




@Tevatron4LHC

All-Hadronic Sensitivities at LHC

CMS-EXO-2009-002



Comparable sensitivities to semileptonic mode for low mass, Better sensitivity at high mass

NB: Y-splitter ATLAS analysis didn't post sensitivites but the analysis is active

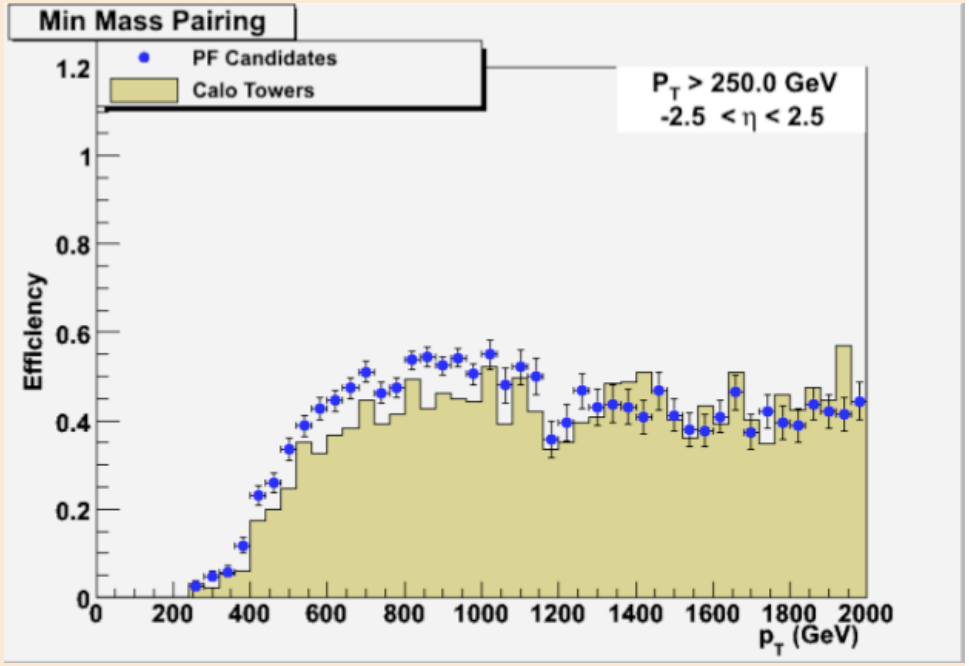
The Devil is in the Cliche

JOHNS HOPKINS UNIVERSITY

- Improvements in reconstruction
- How to characterize top-taggers in data
- Combining information and channels
- Wide resonances

Improvements in Reconstruction

- Use of finer-grain angular resolution
  - "Particle flow"
  - Unclustered track hit information
- Subjet energy corrections

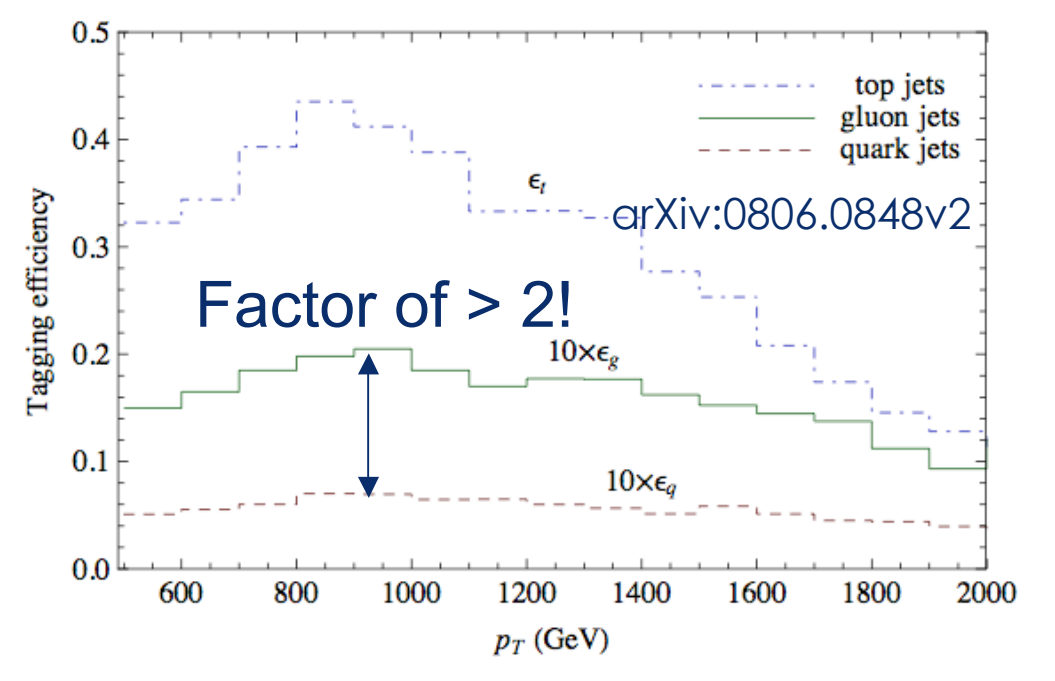


Top "Tag" Characterization

- Efficiency
  - Find a sample of top jets
  - Find a data-to-MC "scale factor"
  - Apply to other samples
- Candidate sample:
  - Ttbar continuum in semileptonic sample
    - "Tag" leptonic top (with lepton)
    - "Probe" hadronic top
- Fake rate
  - Find an unbiased signal-depleted sample of jets
  - Characterize fake rate as a function of jet characteristics
- Candidate sample:
  - QCD Dijets
    - "Anti-tag" one side
    - "Probe" away side

Combination Issues

- Data-driven **efficiency** in hadronic sample
  - From semileptonic signal region
- Data-driven **background** in semileptonic sample
  - From a sample with different gluon fraction
  - Needs a correction
- How to resolve these two issues in a data-driven way?



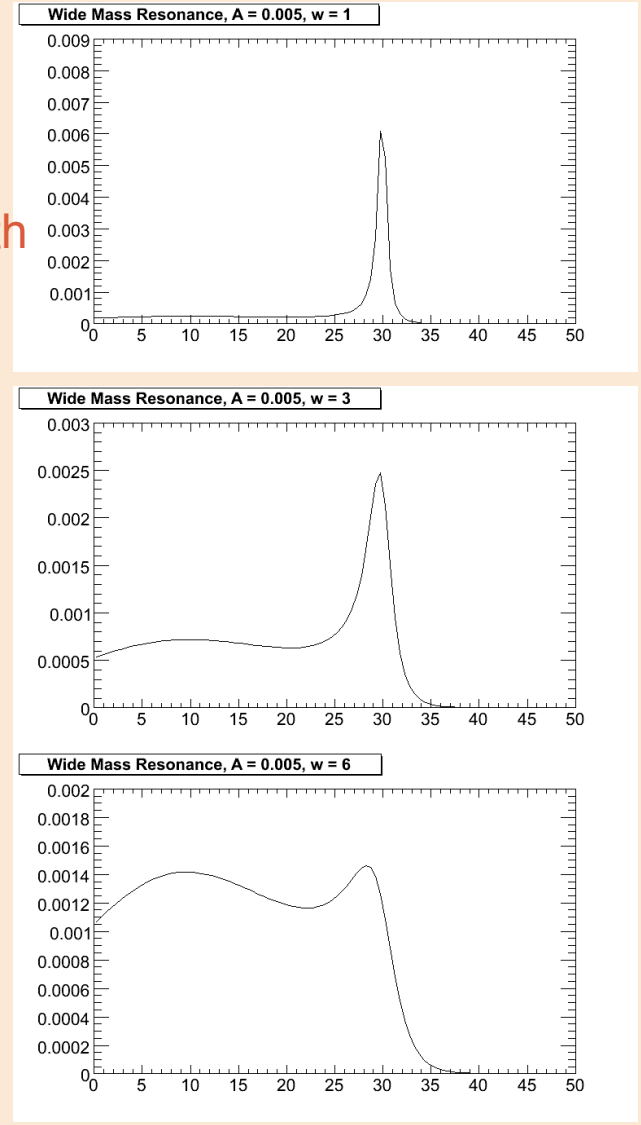
Wide Resonances

- Interplay can happen between PDF's and falling tail of wide resonances
- Manifests in a "dual hump" structure
- A "bump hunt" can rapidly turn into a "global excess" hunt

- Analyses need to be prepared to deal with this!

- Makes an accurate background model **absolutely critical**
  - **Data-driven approaches are probably the only viable option for these cases**

Increasing width



Discussion

- This was meant to stimulate discussion
- The results were arranged pedagogically instead of historically
  - May have left out some pieces, if so, please bring them up so we can discuss them!
- Now the conversation is supposed to organically grow