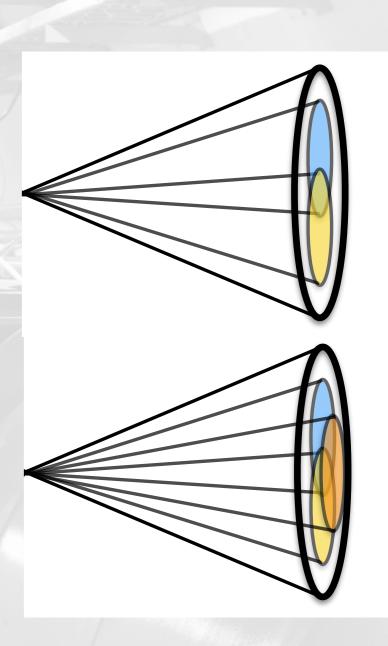


# Goal of this study

- With 100 TeV collisions, many things (boosted W/Z/H/top) will look like a single jet
- We will run a set of jet taggers, based on jet substructure
- The requirement of a good separation vs QCD jets opens new perspective in detector requirements: energy resolution is not the end of the story
- We want to study jet substructure at 100 TeV to set a benchmark for detector specifics
- We took the case of a RS graviton decaying to two Z bosons

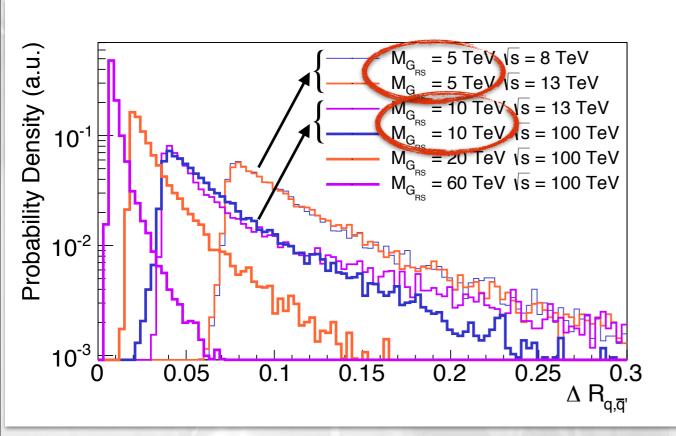
### The Idea

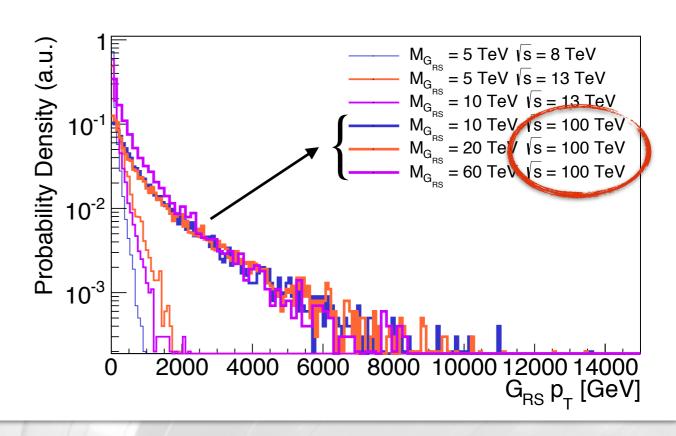
- At large boost, quarks from W/Z/H/top merge into one jet
- The jet has characteristic features to be distinguished from ordinary QCD jets
- An effective discrimination requires the capability of identifying the jet constituents with good momentum/energy and angular resolution
- This could imply a constraint on the detector design (e.g. granularity of the calorimeters)
- In this talk, the case of a RS graviton decaying to ZZ or qq/gg is considered, to set a benchmark for future studies



### ΔR at 100 TeV

(of course) the heavier the mass, the closer the Z daughters





- Small dependence on the resonance pT (i.e. on the beam energy)
- Moderate-mass resonances (10 TeV or so) will be searched as for LHC Run2
- But we want to go higher, hence we need to revolve closer partons (as close as R~0.05)



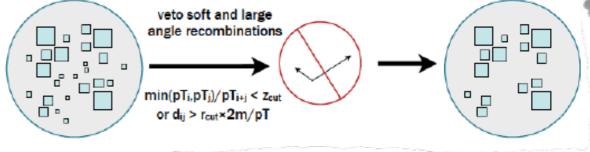
# Pruning

- Start from a large-radius jet( CA with R=0.8 for CMS)
- Recluster the jet constituents and evaluate the hardness and angular separation of the last recombination

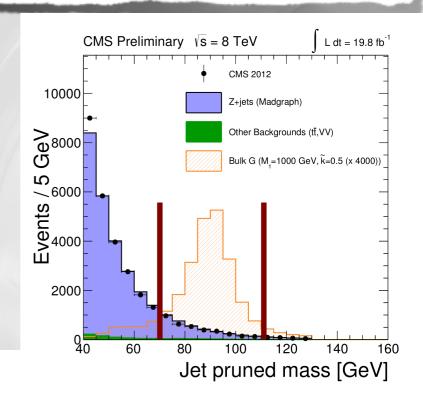
arXiv:0903.5081 arXiv:0912.0033

angular separation

$$z = \frac{\min(p_{T, i}, p_{T, j})}{p_{T, JET}} > 0.1 \left| \Delta R < 0.5 \frac{M_{JET}}{p_{T, JET}} \right|$$



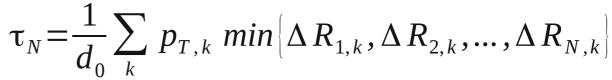
- Remove the softest subject if conditions not satisfied
- Procedure removes soft and large-angle radiation from QCD. Improves the mass resolution
- Also mitigates the pile-up contamination

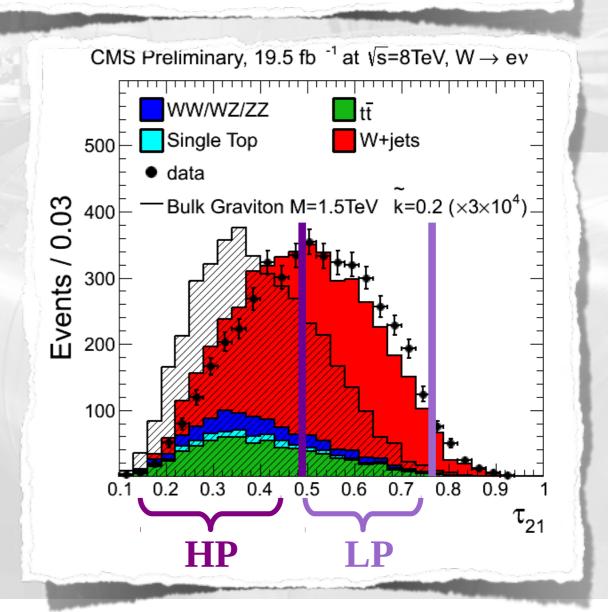


# N-subjettiness

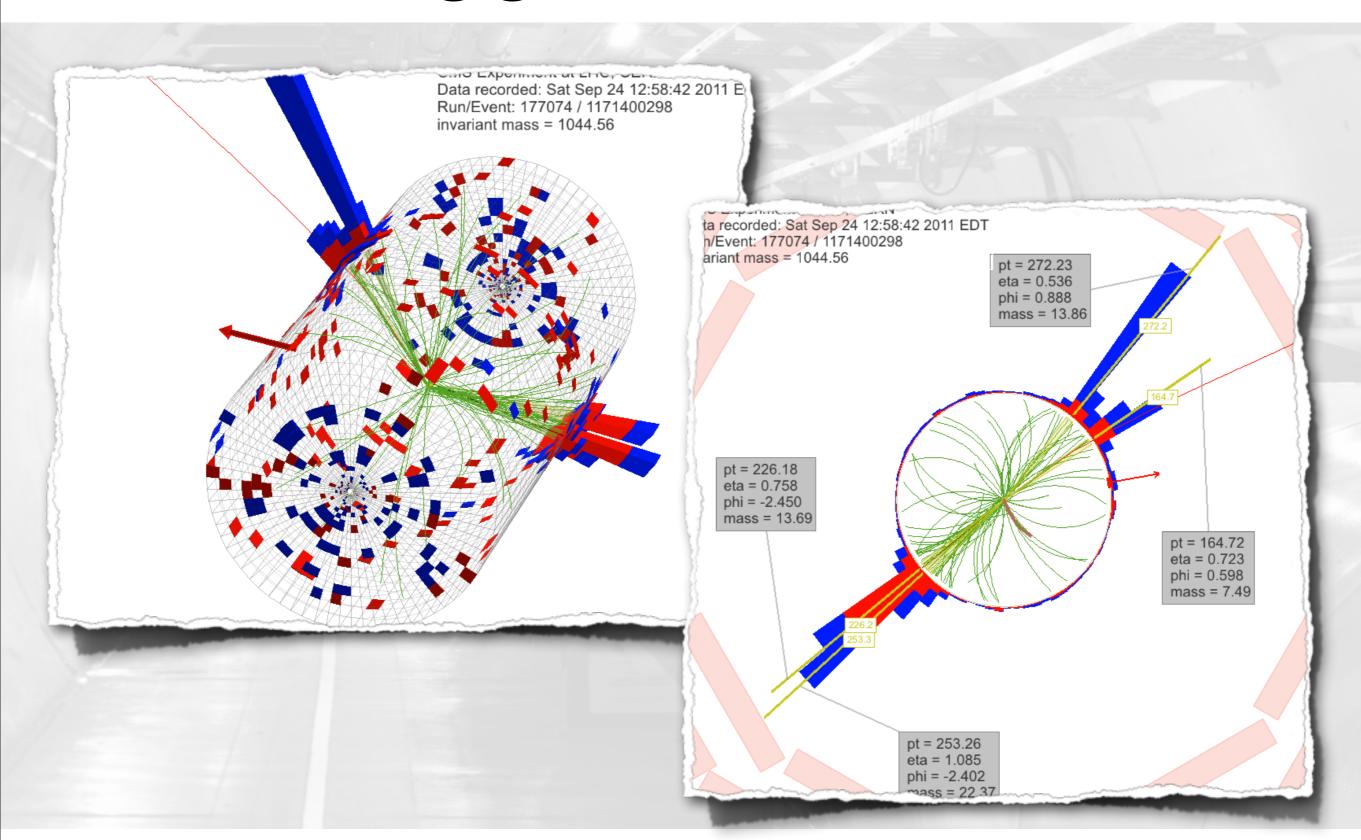
- Check the topological compatibility between the jet and the hypothesis of N subjets
- Start from unpruned jets
- Compute tN as
- Use the ratio t2/t1 to discriminate signal from bkg
- Reject events with t2/t1>0.75
- Classify the other events in highpurity and low-purity

CMSPASJME13006





## A VV-tagged event @ 8TeV



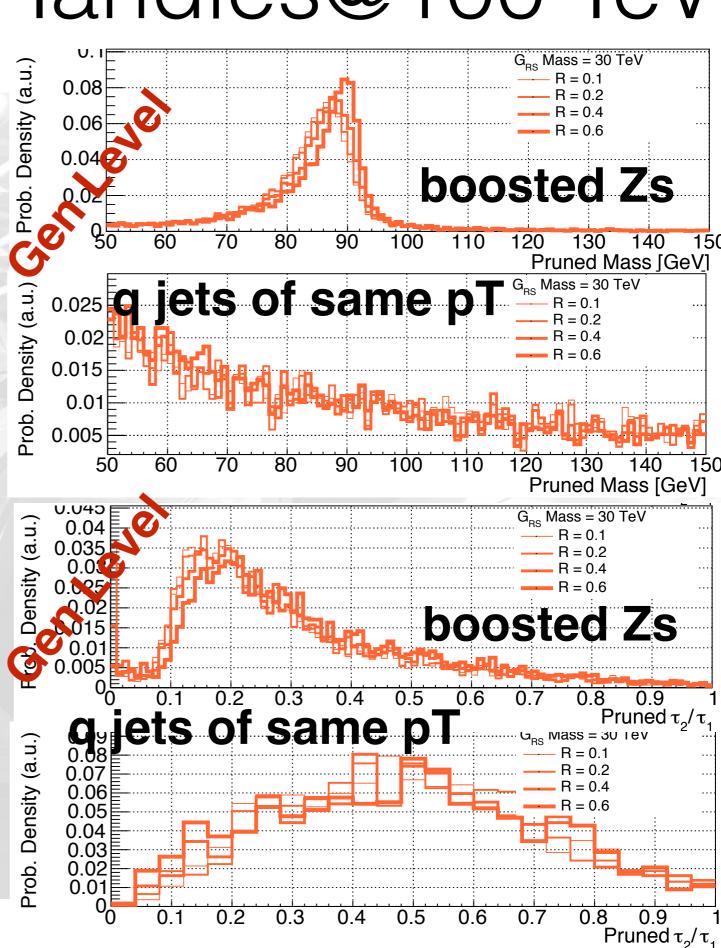
#### Discrimination Handles@100 TeV

#### The (pruned) Jet Mass

- jet mass computed after removing soft radiation (jet grooming)
- Works better than ordinary mass (which does not peak at 0 for bkg)

#### The jet substructure

- Discriminate jets according to the distribution of its constituents around jet axis
- Several variables proposed. Here N-subjettiness used (as in CMS)





### Three Reconstruction Scenarios

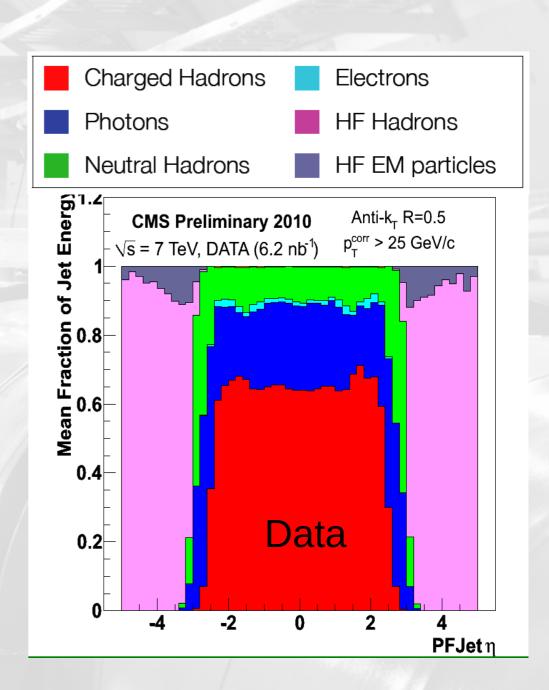
 The best case scenario: We can identify each constituent (eg using a PF reconstruction)



 the worst case scenario: the calorimeter granularity is not good enough to distinguish constituents (eg neutral hadrons)

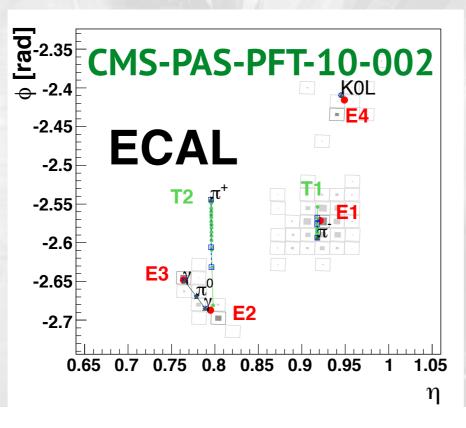
 The intermediate case: (super) granular ECAL + good tracker, while HCAL not segmented enough

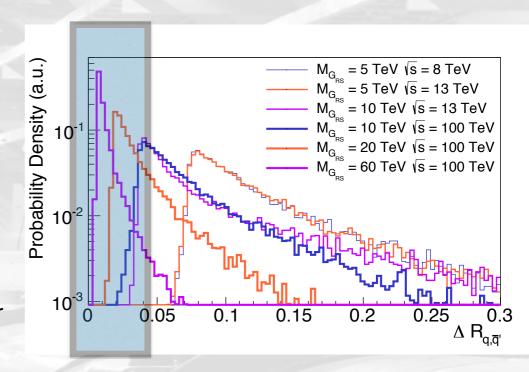


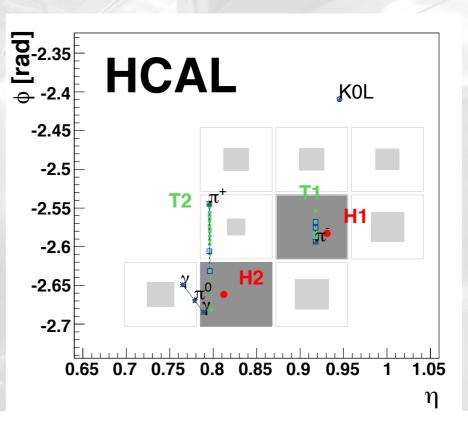


## Calorimeter Granularity Today

- CMS taken as an example
- In ECAL cell size in (h,f) is ~(0.02,0.02)
- In ECAL cell size in (h,f) is ~(0.1,0.1)
- ECAL already in the right ballpark
- Assuming no granularity improvement but a bigger inner tracker, the same cell size in cm implies a sensitivity to smaller  $\Delta R$



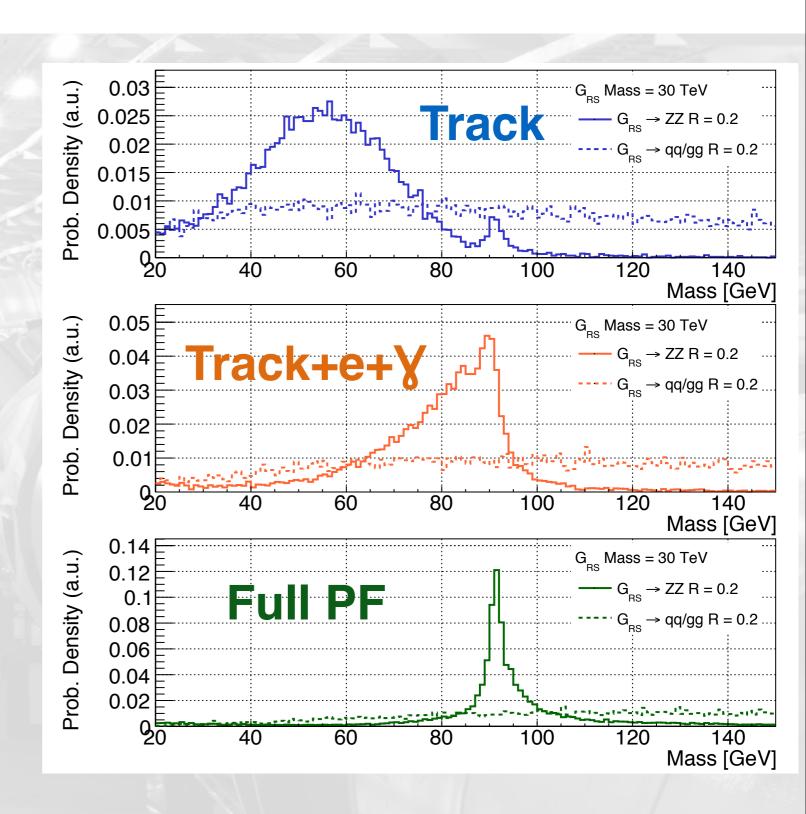




### "Reconstructed" Jet Mass

- Still assuming perfect resolution
- Different jet constituents used in the three scenarios: full PF, Tracksonly, tracks+Ele+Photons (EGTracks)
- Jet size R=0.2 for M<sub>RS</sub>=30 TeV

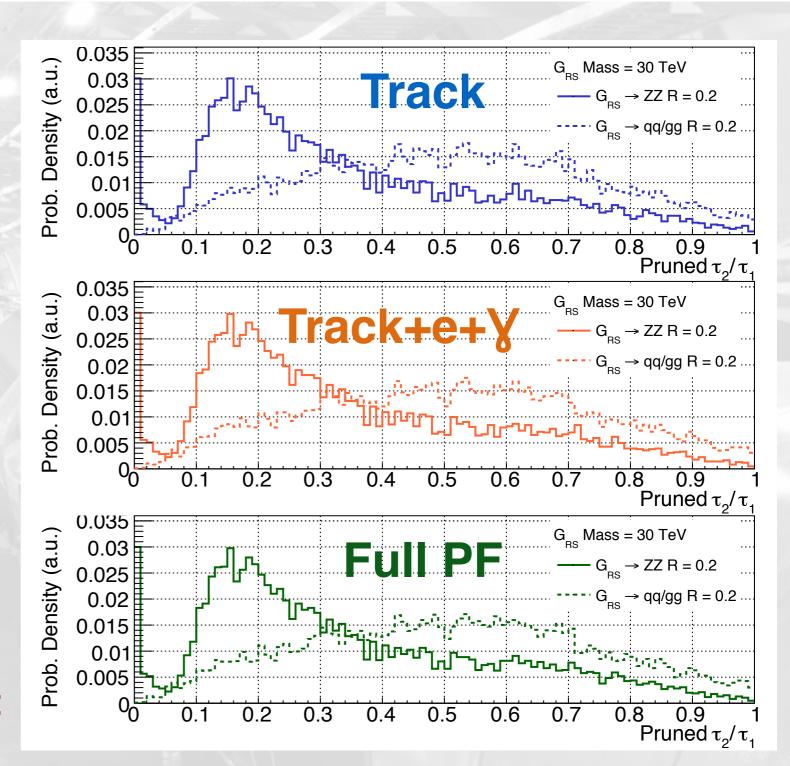
Fluctuations in hadronization give worse resolution
This will be compensated by worse angular resolution on neutral hadrons



### "Reconstructed" Jet Substructure

- Still assuming perfect resolution
- Different jet constituents used in the three scenarios: full PF, Tracksonly, tracks+Ele+Photons (EGTracks)
- Jet size R=0.2 for M<sub>RS</sub>=30 TeV

Difference is marginal
But a track-only
reconstruction is more robust
against pileup



### Conclusions

- Boosted W/Z/H reconstruction with jet substructure provides a good physics case to study the performances of a detector design
- This is a new topic, which comes with new needs (and new implications on the detector)
- A good jet energy resolution is still fundamental
- In addition, a good subject reconstruction points to the need of good angular resolution (particularly in the tracker) for a good jet mass resolution (main ingredient in commonly used taggers)
- Substructure information with only tracks shows good performances (so far), which makes life easier
- NEXT: evaluate the added value of high granularity in ECAL, and eventually in HCAL
- NEXT: evaluate the impact of the PU on the discrimination



### Assumptions/Simplifications

- I consider the case of a RS Graviton decaying to two Z
- Since jets are the interesting topic here, I concentrated on hadronic decays (of course a real analysis would consider also the leptonic decays)
- (For the moment) I only consider yen-level particles to cluster jets (removing neutrinos) and I am ignoring to a large extent the detector limitations
- I considered the CMS V-tag ingredients since I am familiar with those. No claim of optimal/better/whatever here
- I am not claiming that what I will show you is real, I am showing you the best-case scenario
- No rocket science: you can imagine what you will see with a simple kinematic argument

### Event Generation

- Use Pythia8 (with default PDF setting) for 100 TeV GRS production and decay
- k/M=0.1, corresponding to the (simple) narrow-width case
- Only ZZ final states generated
- Not enough time to run QCD high-stat MC on my laptop.
   Used a sample of GRS->qq for QCD jets
- No PU generated at this level (no idea of what the PU would be)

# Event Processing

- Homemade package (BSM@LHC), already developed for some LHC pheno study
- Parametric simulation of the detector response
- Interfaced to Pythia or to LHEfiles
- Need some work, but it could be shared to interested people

