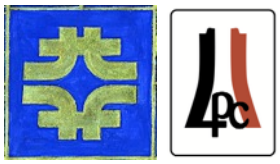


Boosted Higgs and b-tagging and other tools and techniques (part 1)

Nhan Tran, Fermilab

BSM Higgs Workshop, Fermilab
05 November 2014

introduction

This a 2-part talk with Dinko's presentation tomorrow

I will present some "foundations" for important tools for Run II

Part I:

- jet substructure tools
- dealing with pileup

Then Dinko will talk about more Higgs-relevant issues…

Part II:

- b-tagging in boosted/merged topologies
- Higgs-tagging

goal: what is experimentally viable, where are the largest challenges and what should you care about for your analysis (model)?

LHC Run II and beyond

More energy :)

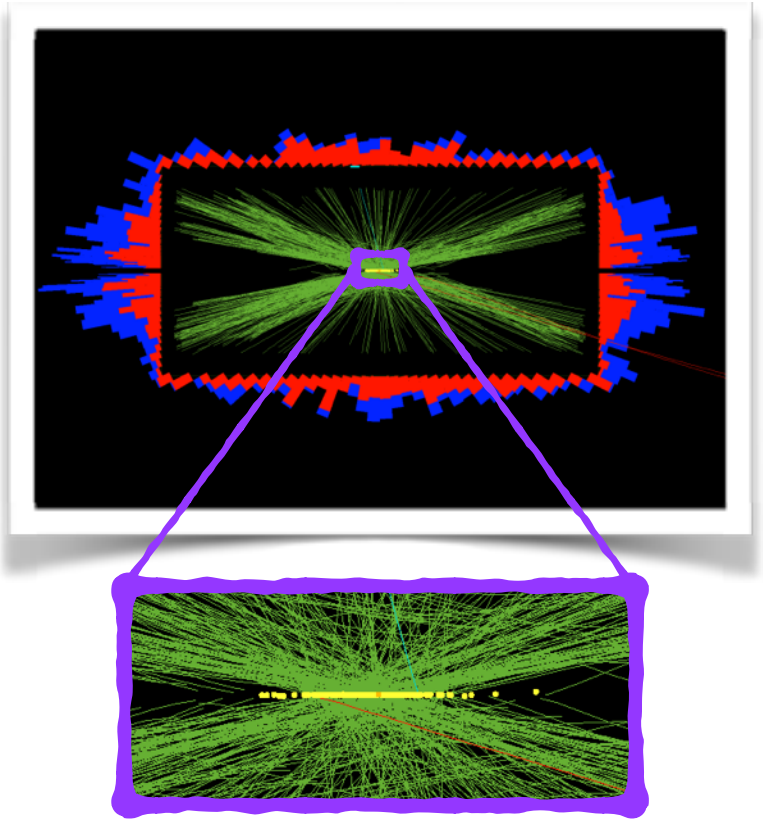
more boost, merged topologies

More pileup :(

jet shapes

jet vetos

VBF jet tagging

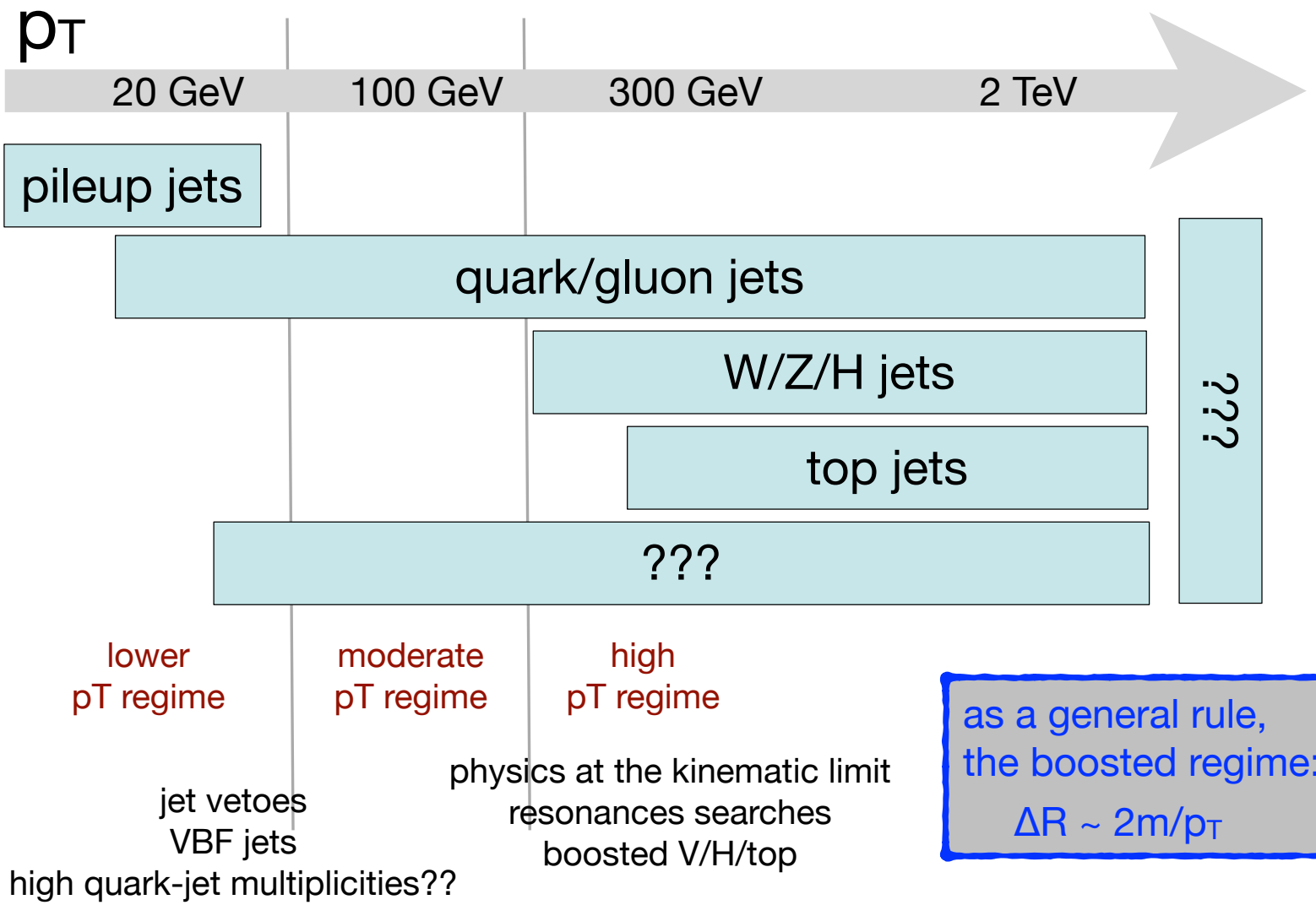


Practically…

jet substructure ↔ pileup mitigation

some observables to consider: jet p_T, mass, tagging; lepton isolation; MET

pT spectrum


pT
20 GeV
100 GeV
300 GeV
2 TeV
pileup jets
quark/gluon jets
W/Z/H jets
top jets
???
¿¿¿
lower pT regime
moderate pT regime
high pT regime
jet vetoes
VBF jets
high quark-jet multiplicities??
physics at the kinematic limit
resonances searches
boosted V/H/top
as a general rule, the boosted regime:
ΔR ~ 2m/pT

“tools and techniques”

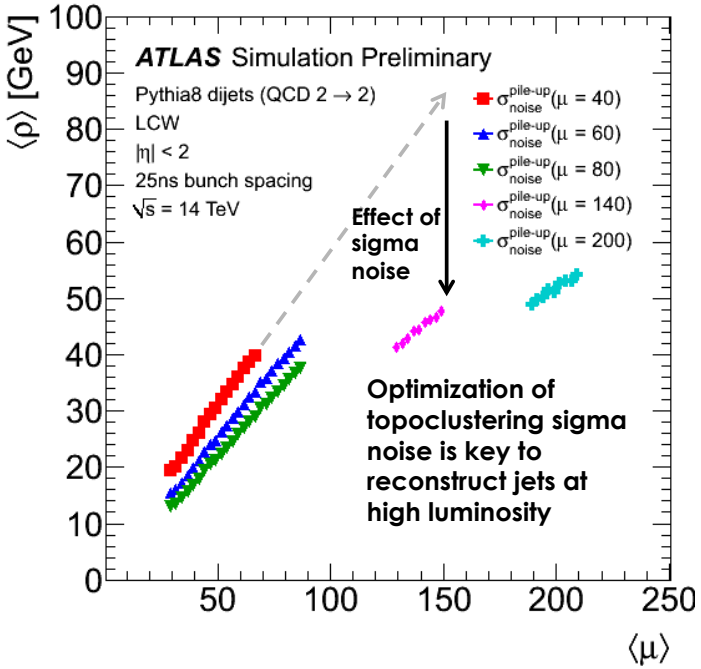
our goal is ***characterizing radiation***

inputs and handles:

local hit reconstruction and event reconstruction

e.g. ATLAS topoclustering and CMS particle flow

tracking plays a key role



jet observables

pT, Y, ϕ

jet shapes and jet taggers

(groomed) jet mass, width, n-subjettiness, CMS/HEP top taggers, …

outline

at low p_T

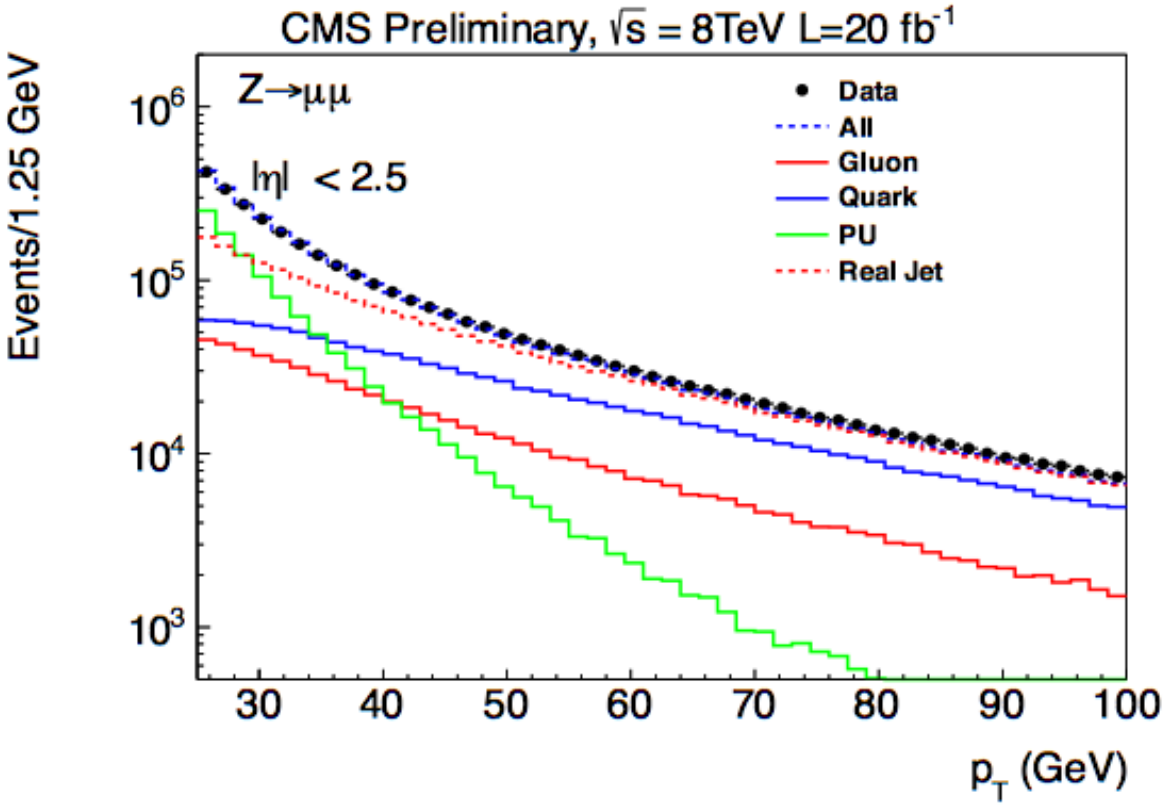
at high p_T

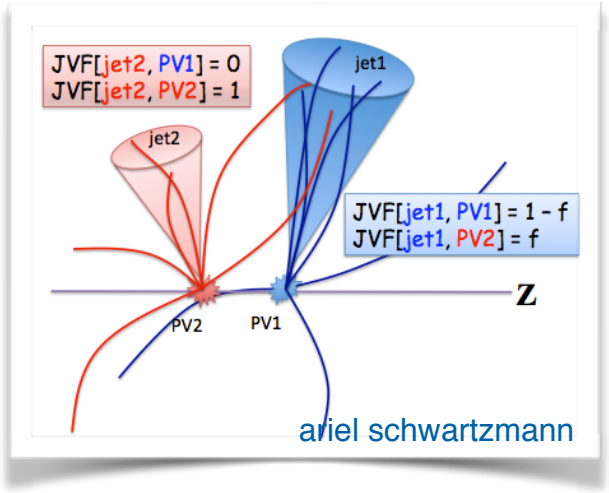
anticipating more pileup

low p_T regime

at low p_T

The low p_T regime is dominated by **quark**, **gluon**, and **pileup jets**.

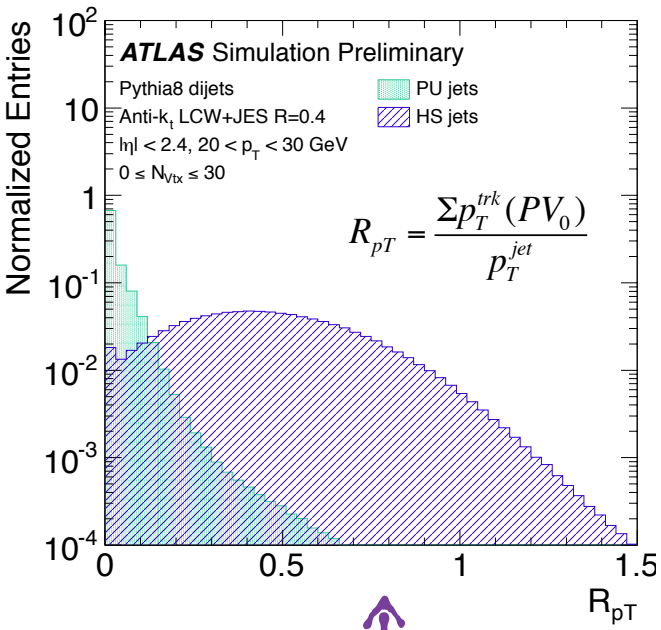


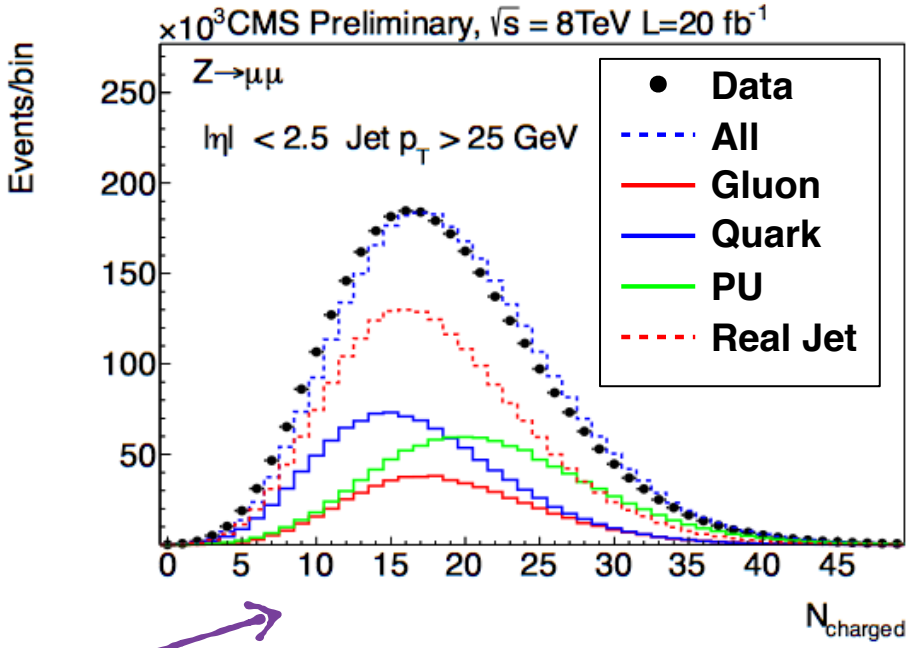


Using all information, can do a better removing them:
track-based observables and jet shapes

quarks, gluons, and pileup jets

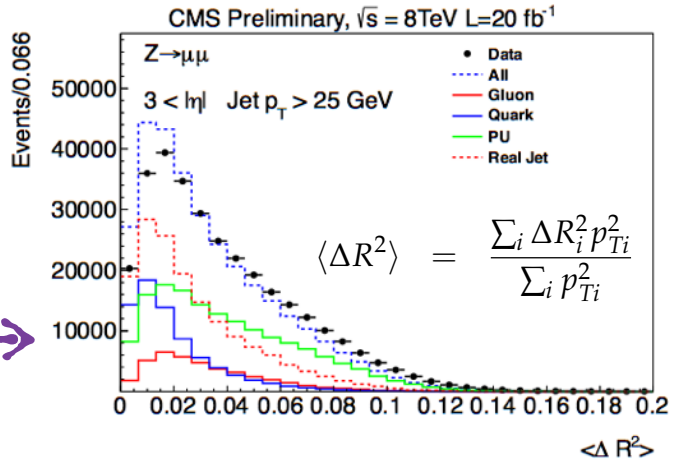
CMS PAS JME-13-005
ATLAS-CONF-2014-018





Various track-based and shape/mutiplicity observables

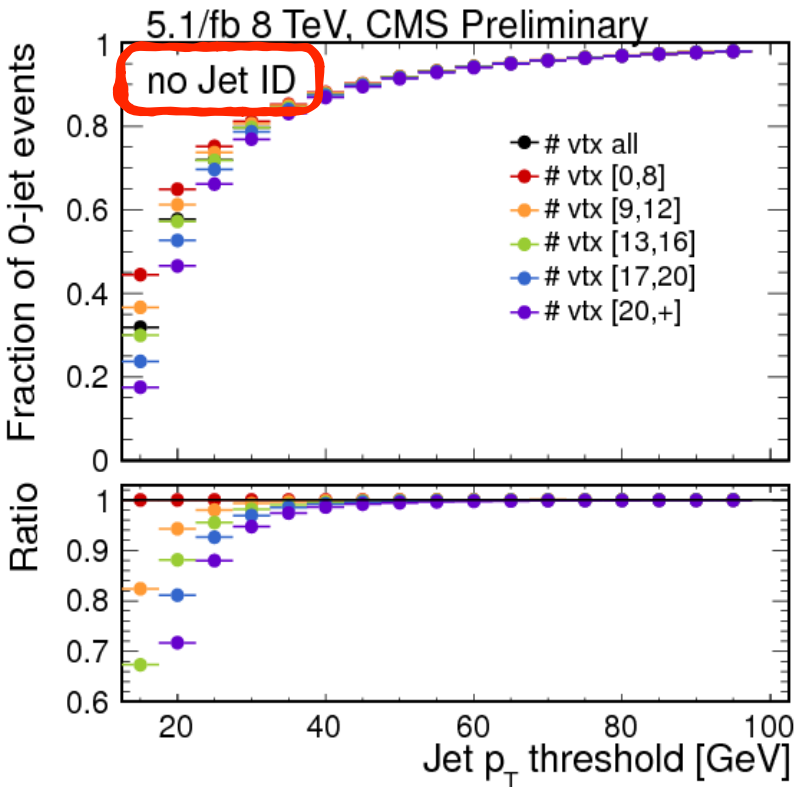
Using shape-based observables is possible even when no tracker is available!

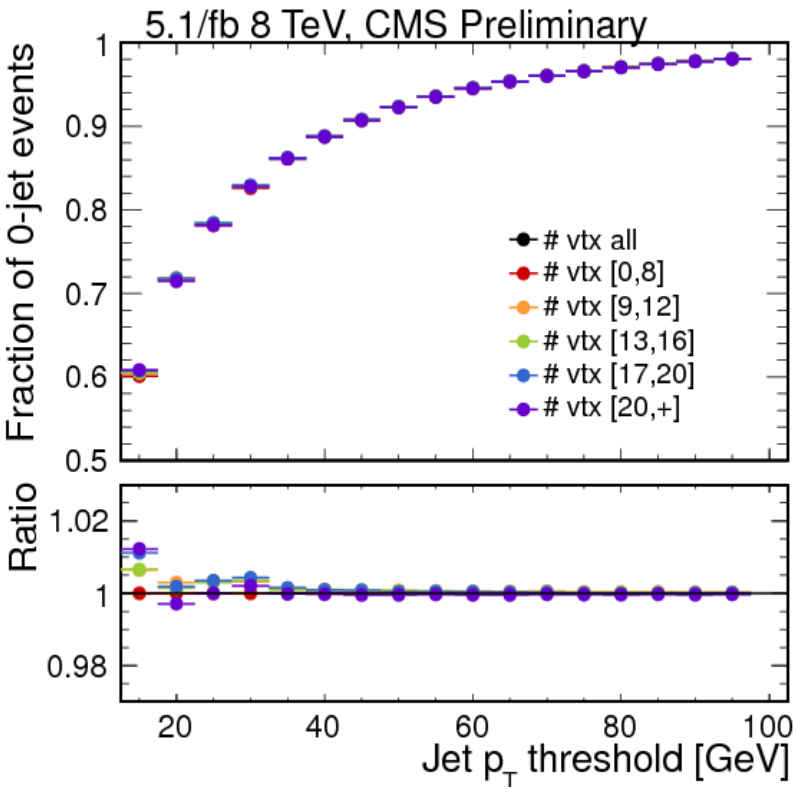


example: h→ττ

CMS PAS JME-13-005

jet counting stabilizes with pileup jet ID applied





even when there are no jets in your final state, there are jets in your final state

high p_T regime

at high pT

CMS: 1410.4227

separating a W/Z/H/t jet from a high p_T quark or gluon★ jet

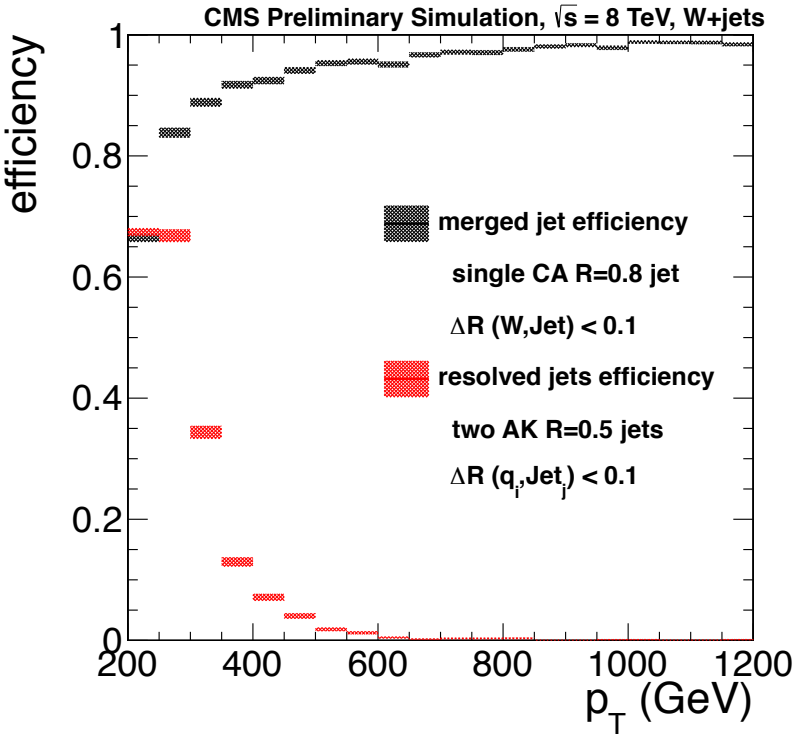
1. jet mass: four-vector sum of particles in a jet

2◎. W/Z/H/t/? have non-trivial [n-prong] structure

3. b-tagging (see Dinko's talk)

★ high p_T quark or gluon* jet discrimination too!

◎ beware of correlations with #1

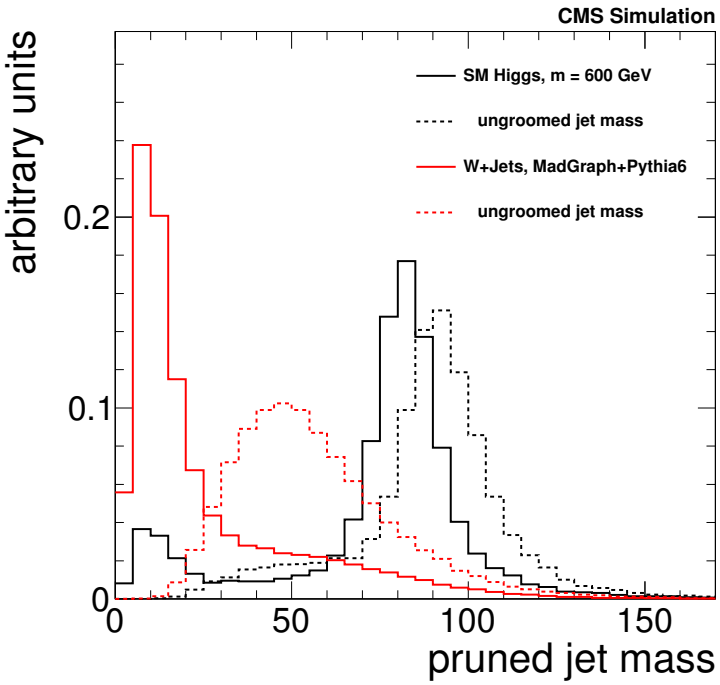


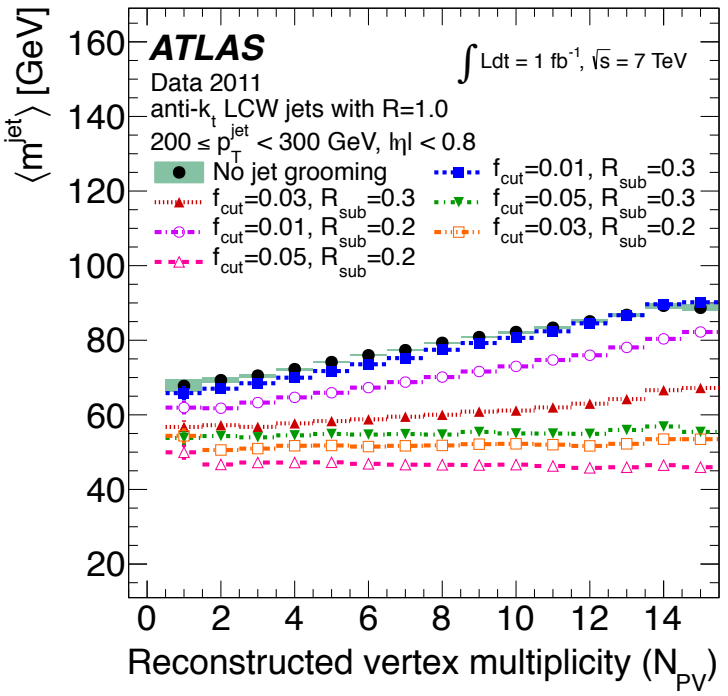
groomed jet mass

ATLAS: 1306.4945
CMS PAS HIG-13-008

Grooming tends to push the jet mass scale of the **background to lower values** while **preserving the hard scale of the heavy resonance**

Grooming techniques are also vital in **reducing the pileup dependence** of the jet mass





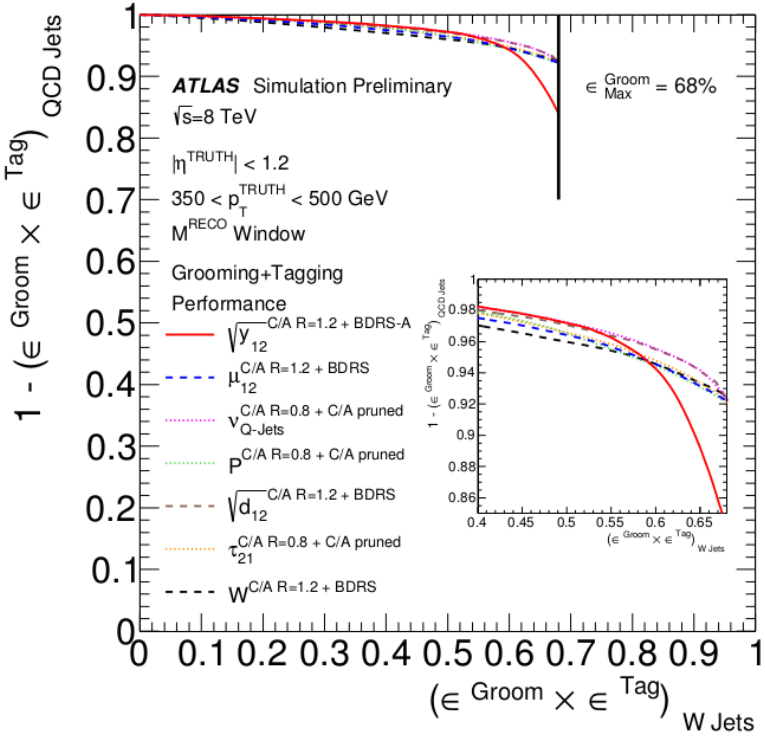
ATLAS and CMS have scanned many different groomers and grooming parameters

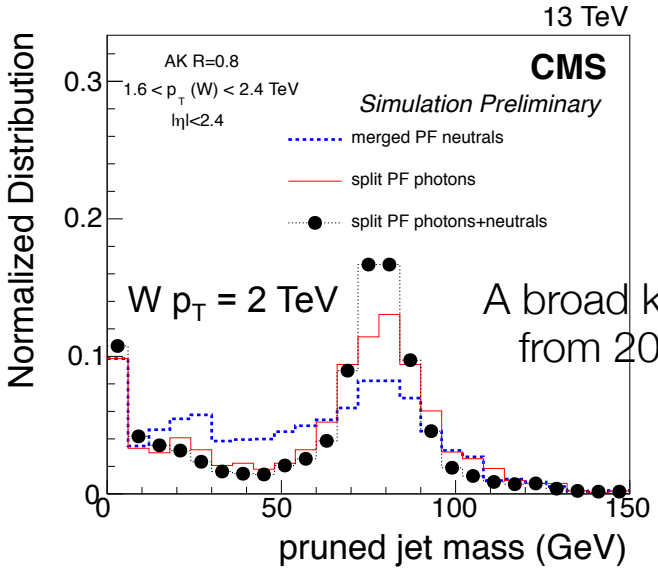
two-prong tagging (W's)

CMS: 1410.4227
ATL-PHYS-PUB-2014-004

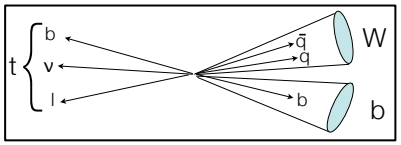
Understanding the plethora of various observables

Pushing the performance of taggers to its bounds

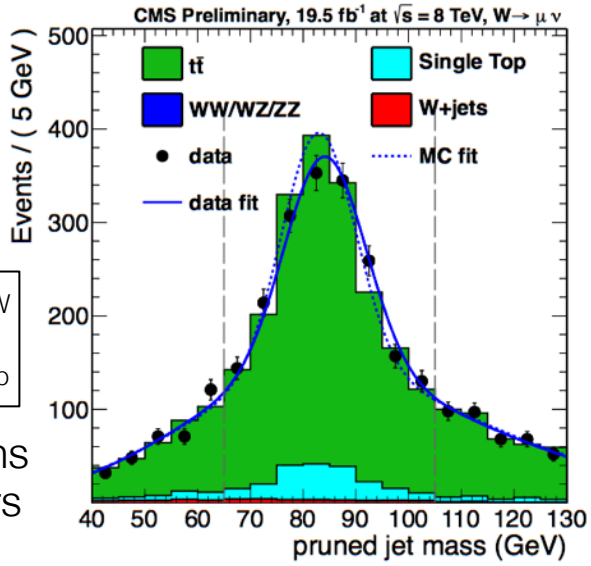




A broad kinematic regime from 200 GeV - 2 TeV



data-driven validations of the various taggers



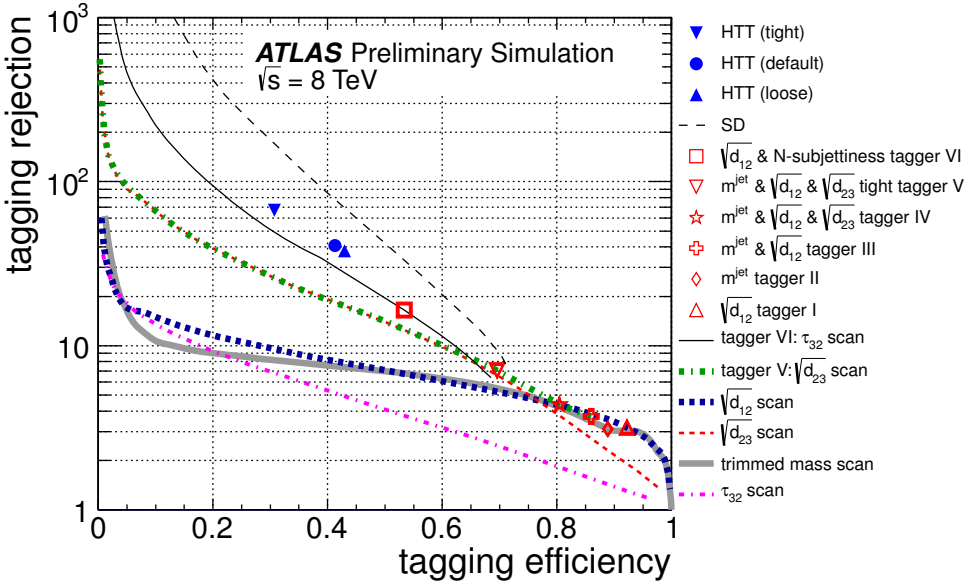
3-prong taggers (tops)

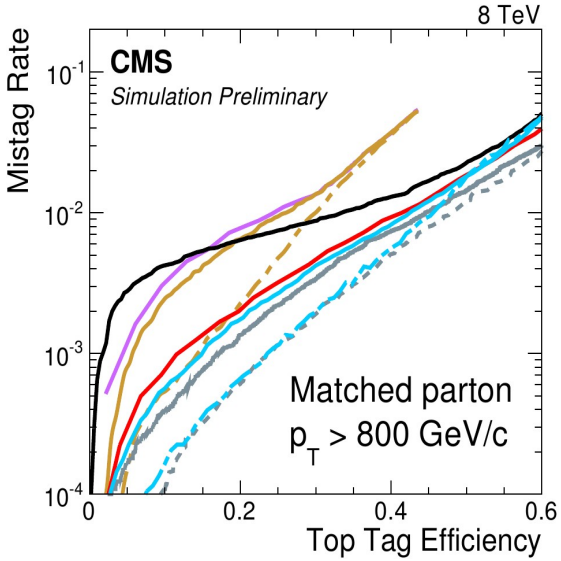
CMS PAS JME-13-007
ATLAS-CONF-2013-084

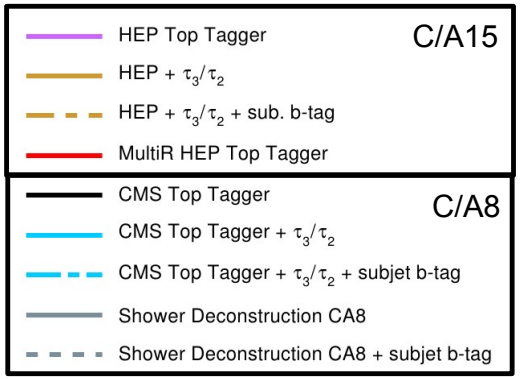
As in the case of W's:

Understanding the plethora of various observables

Pushing the performance of taggers to its bounds







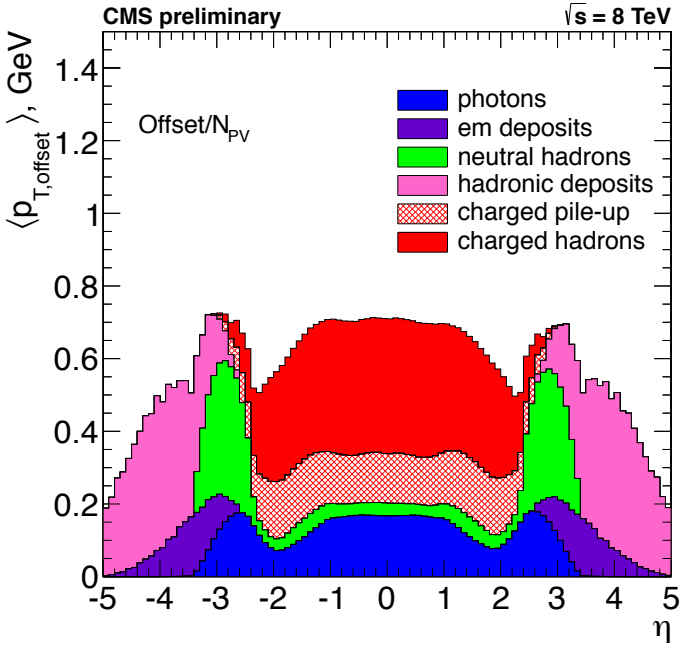
for top-tagging, b-tagging in boosted topologies becomes very important

(More in Dinko's talk)

anticipating more pileup

pileup affects all jet observables

jet shape observables are particularly susceptible to such effects



The scale of the problem:

pileup scenarios for 2015

40 PU, 50 ns BX

20 PU, 25 ns BX

@40 PU, R=1.0,

this is ~90 GeV of energy per jet!

approaches to pileup

Run I

$\rho^{\mu} \times A^{\mu}$

removing charged PU

tagging pileup jets

grooming (for masses)

[no unified way to do jet shape corrections]

for Run II

Can we simplify, compactify, or improve on these methods?

approaches to pileup

berta,leitner,miller,spousta:1403.3108
cacciari,salam,soyez:1407.0408
bertolini,harris,low,NT:1407.6013

Run I

$\rho^{\mu} \times A^{\mu}$

removing charged PU

tagging pileup jets

grooming (for masses)

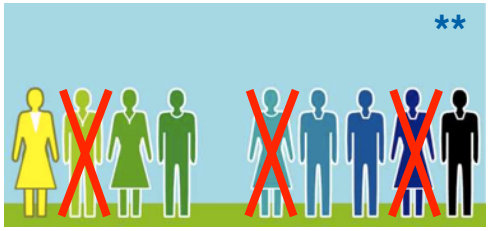
[no unified way to do jet shape corrections]

for Run II

Can we simplify, compactify, or improve on these methods?

Next generation PU algorithms, intuitively try to correct at the "particle" level

Some ideas (and a gross oversimplification for the uninitiated)…



constituent subtraction
extension of area formalism
to the particle level

soft killer
an extension of median ρ
formalism to particle level

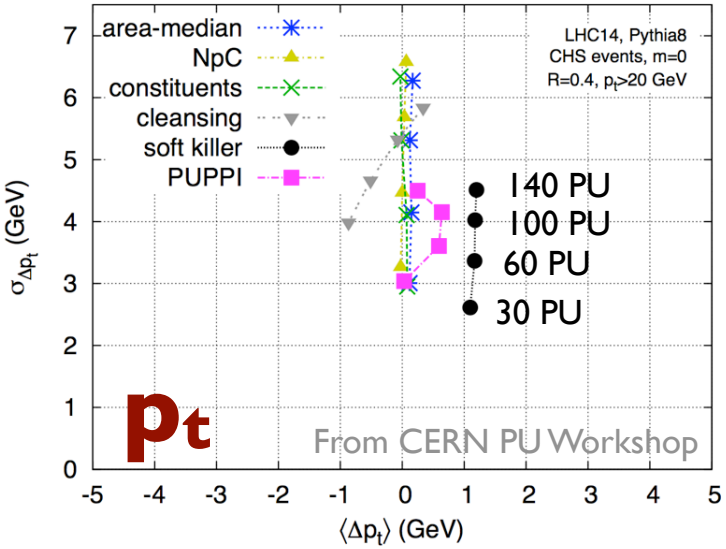
PUPPI
an extension of pileup
jet ID to particle level

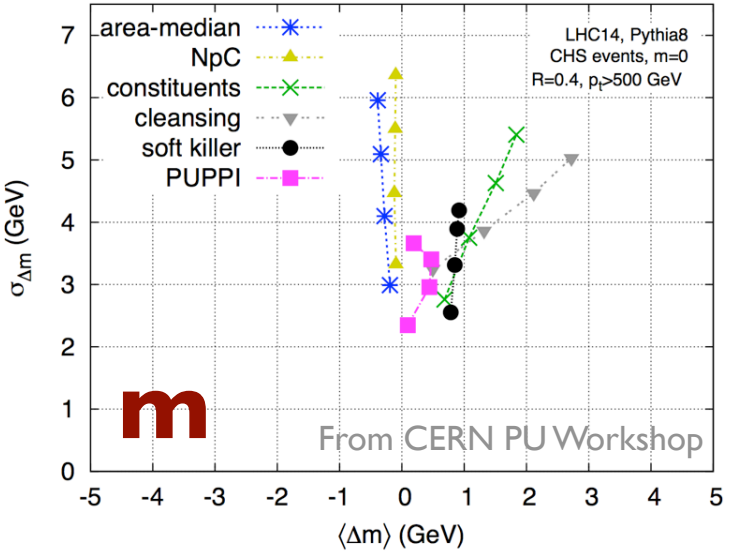
**Logo unsanctioned by the authors

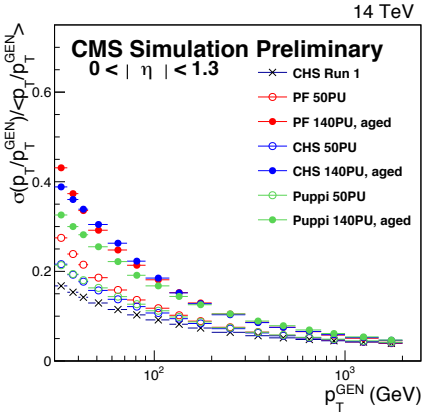
at particle level…

https://indico.cern.ch/event/306155/

A workshop dedicated to putting many methods on equal footing
[at particle level, usual caveats apply]







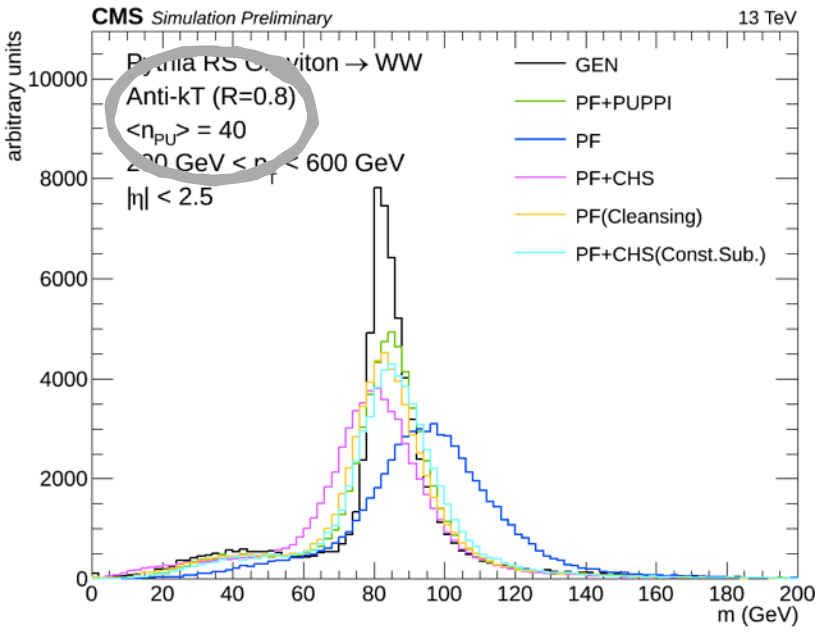
Gives a feeling for the various methods performance vs. pileup

Important to see these algorithms within the experiments

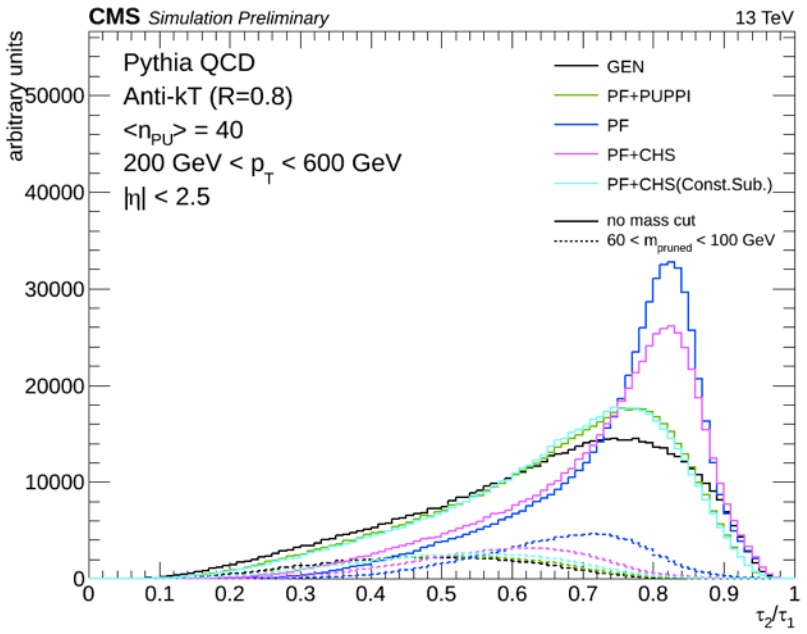
CMS ECFA studies, HL-LHC

jet shapes

First studies within the experiments give promising results!



Boosted W mass



n-subjettiness τ_2/τ_1

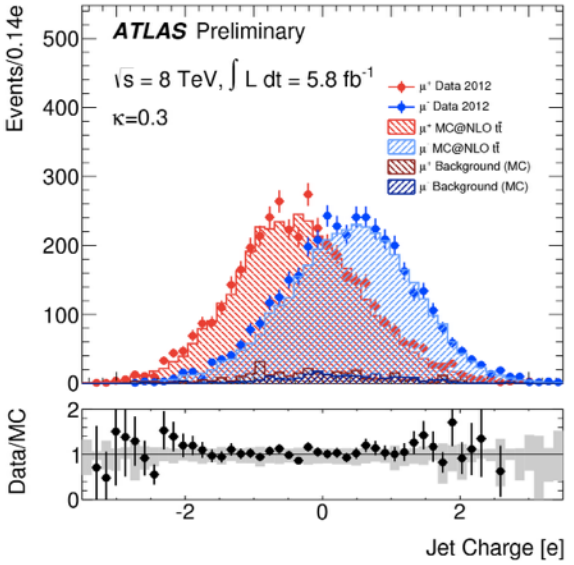
summary

other things I like but don't have time to talk about

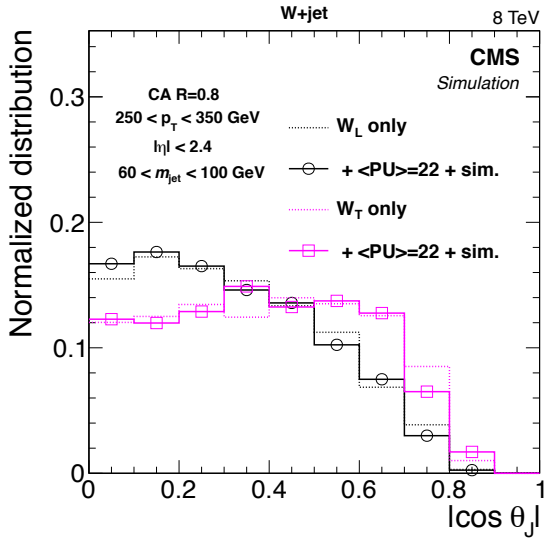
CMS PAS JME-13-006

Jet charge can be used to discriminate between W^+ and W^-

- comparison to data (in semi-leptonic ttbar) shows nice agreement!



Helicity angle can be measured using subjet kinematics



Missing transverse energy and lepton isolation can be improved by tagging jets (or particles) as pileup

summary

at low p_T

jet vetoes and VBF jet tagging are going to be a challenge as pileup increases; tag jets as “pileup”, “quark”, or “gluon”

at high p_T

understanding 2-prong and 3-prong boosted objects is maturing using studies with boosted W’s and tops

can use this as proxies for “SM” Higgs and other new possible particles

anticipating more pileup

as pileup grows, we will need more sophisticated methods to mitigate its effects

new ideas are available and being explored by the experiments

Stay tuned for Dinko’s talk more specifically about Higgs-tagging!