High p_T @ EDS

Philip Harris (CERN)
CMS collaboration

Overview

- Review the current results
- Overview of Jet Reconstruction and calibration
- Re-examining of results from another angle
- Look towards the future

LEP Times

Jet at LEP

Jets clustered throughout the whole event (Durham/JADE/Cam...)

Jet at Tevatron

Limited size cone based algorithm(robustness in pp)

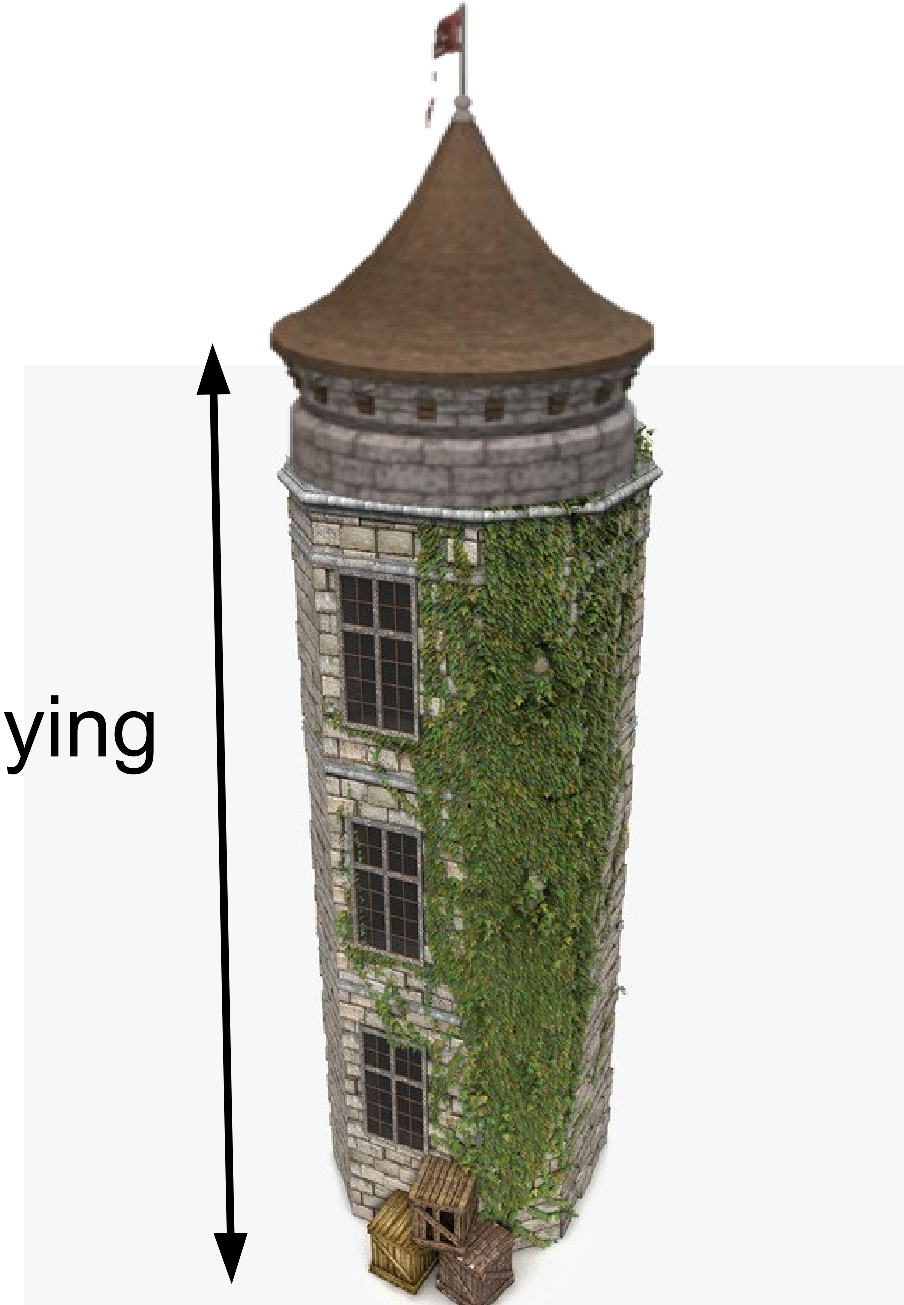
Jet at LHC

Pileup

Anti-k_T algorithm with area based pileup subtraction

LHC Heavy Ion

Jet in HI

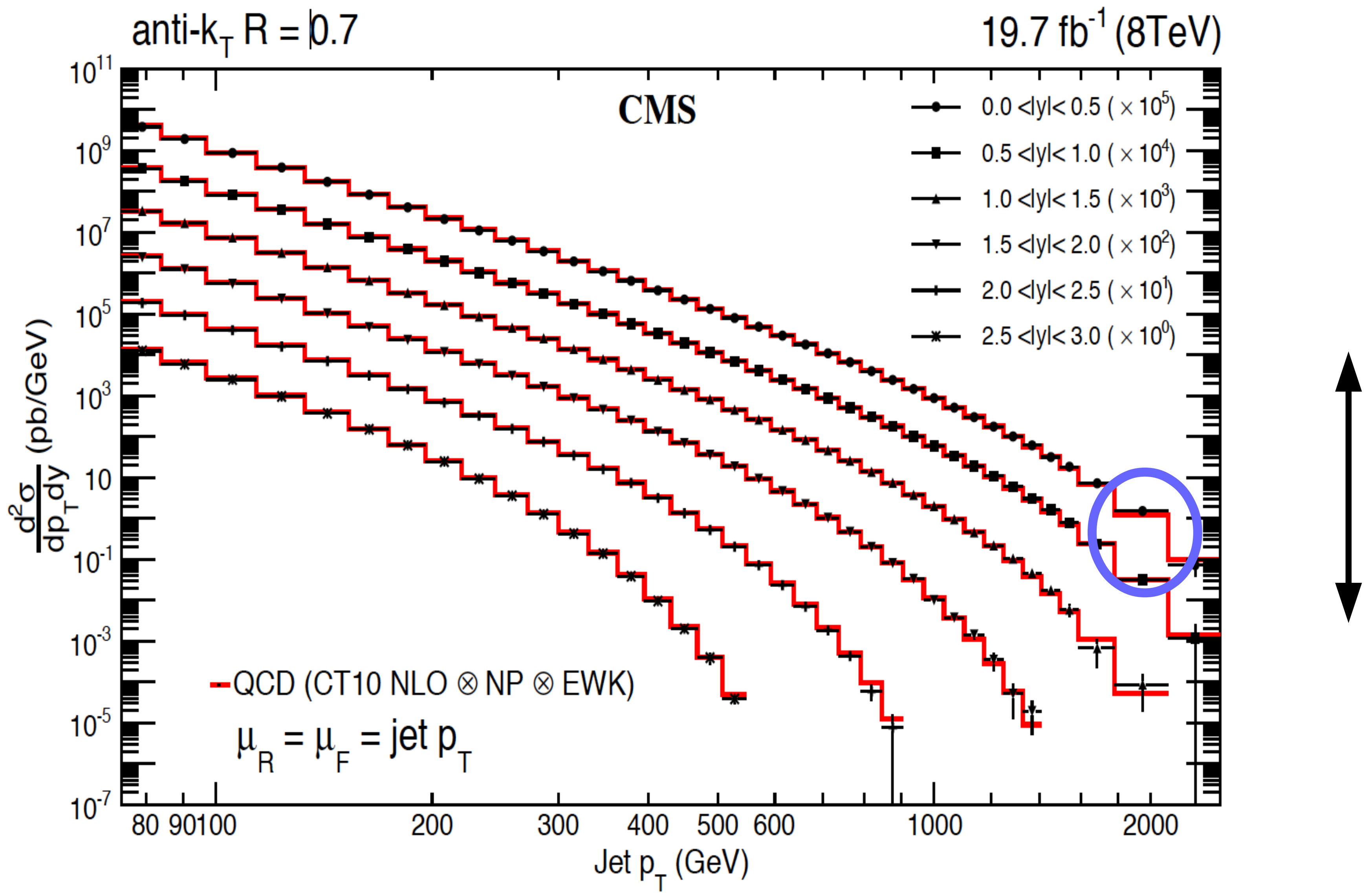


Underlying Event

Anti-k_T algorithm with area based UE and v_2 subtraction

Success of Jets

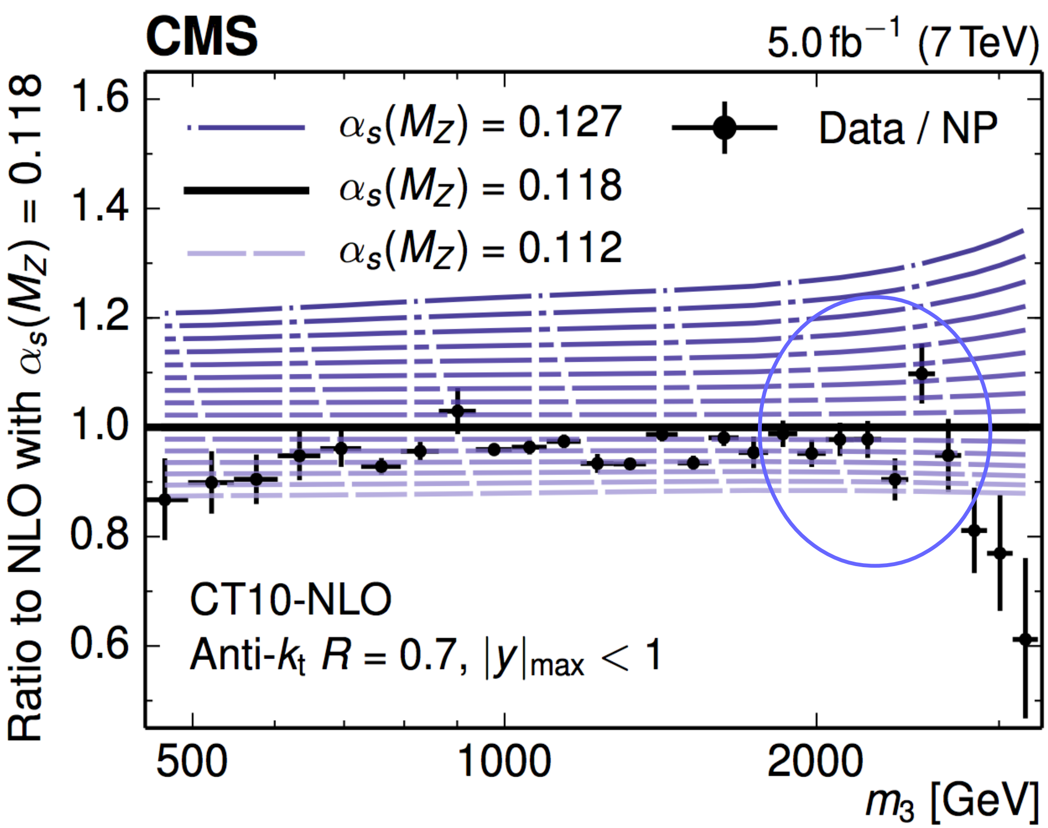
- Jets have brought a tremendous set of results

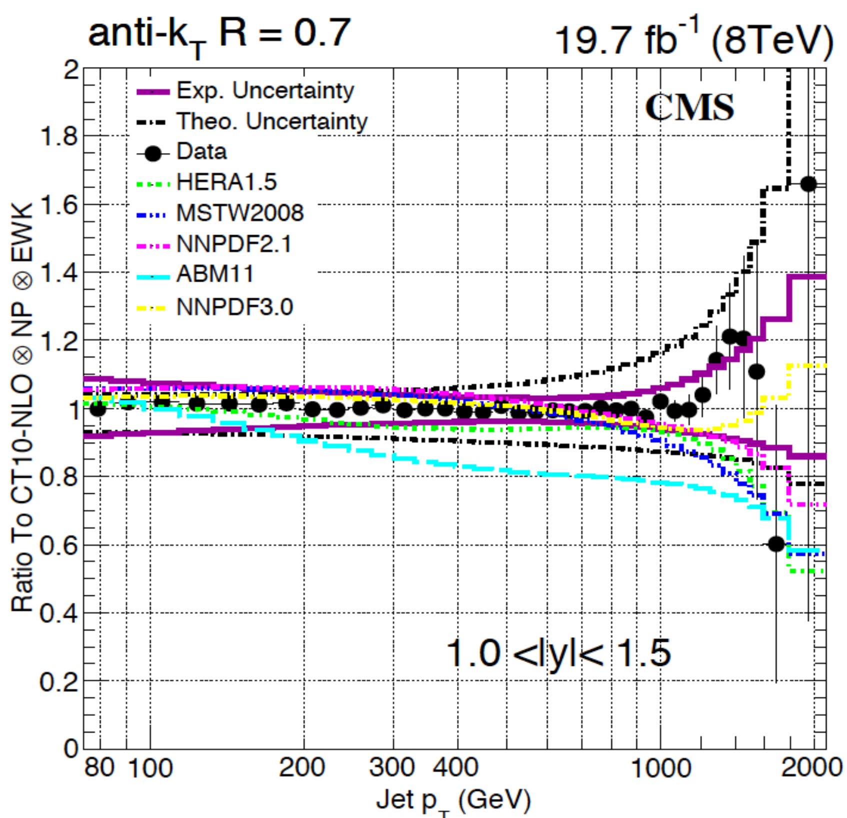


CMS-SMP-12-002

Extracting Core Parameters

- Differential distribution is combination of :
  - Quark Content : PDFs
  - Expanded matrix element in terms of α_s : $\alpha_s(Q^2)$

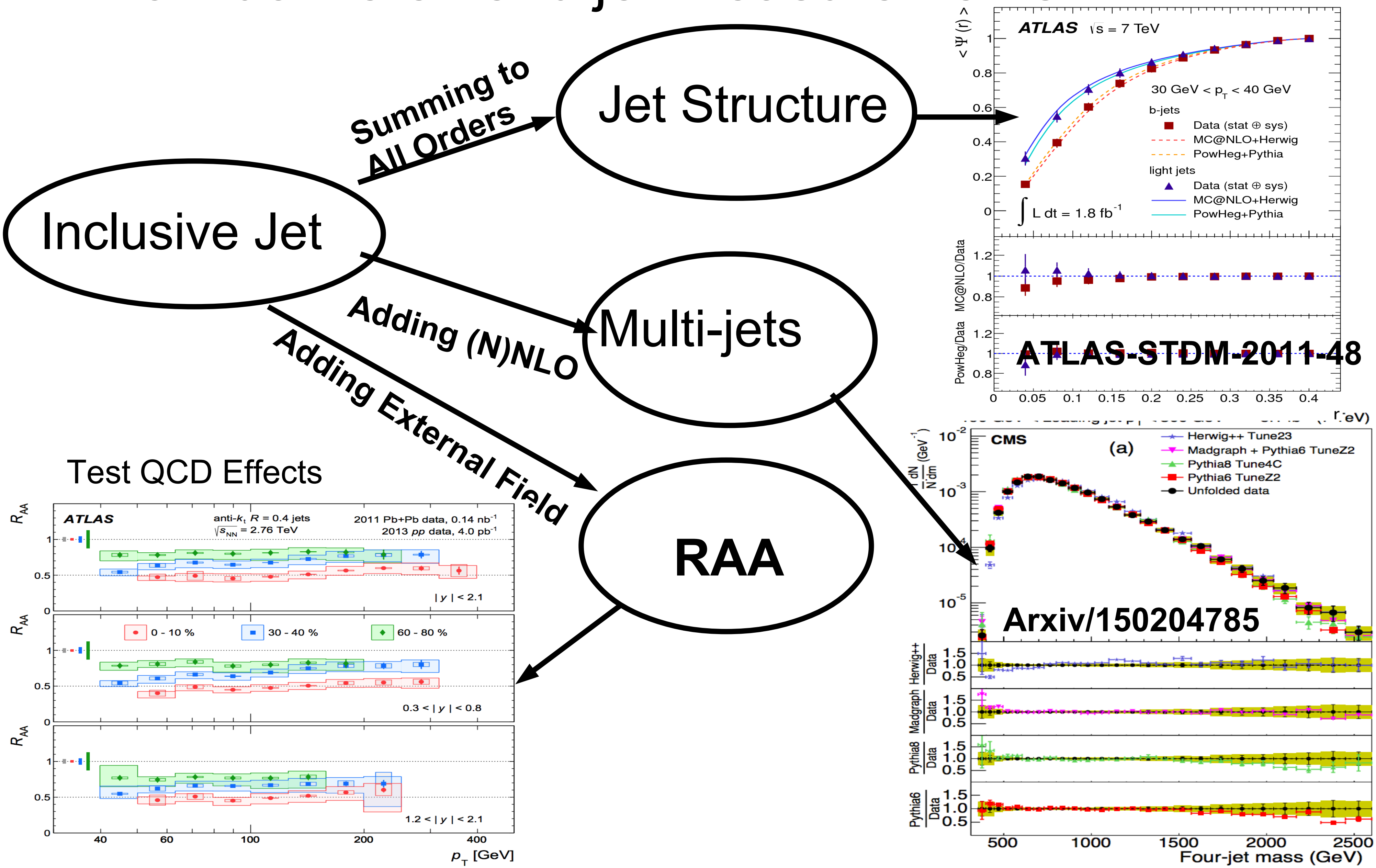




CMS-SMP-12-027 **CMS-SMP-12-002**

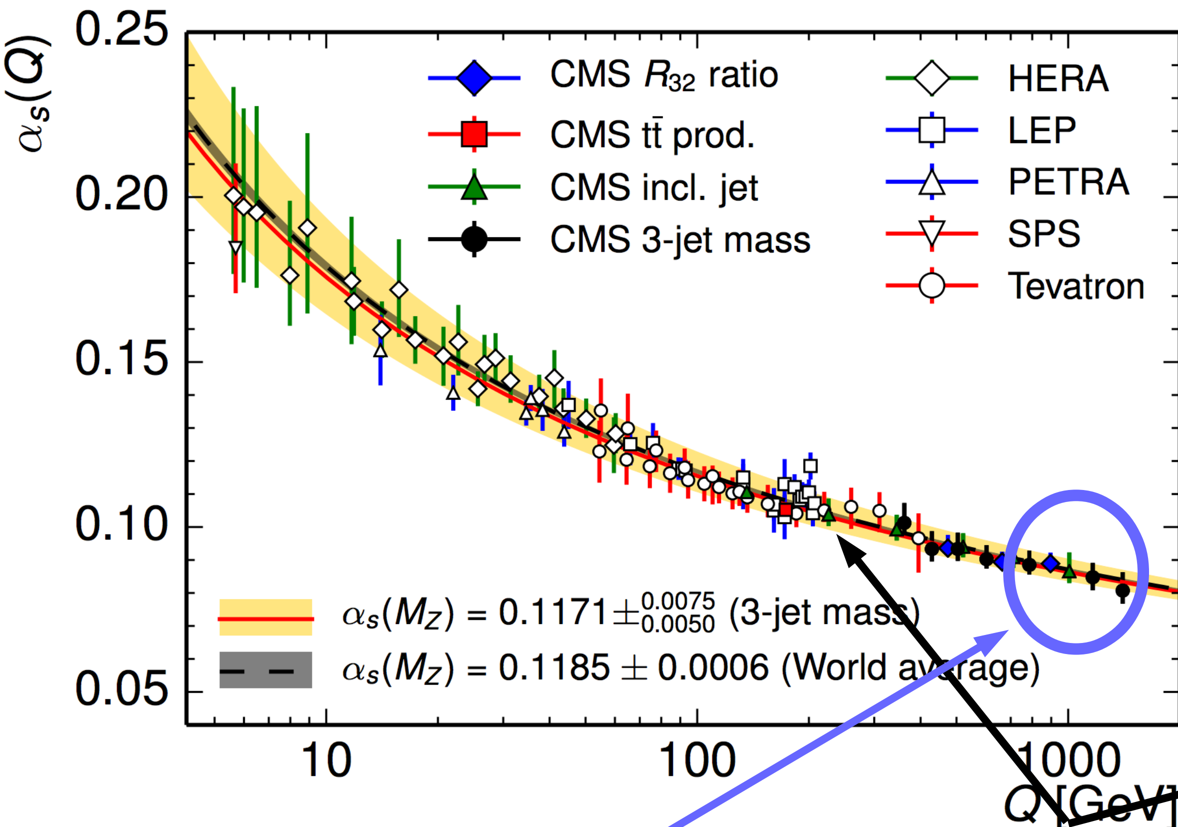
Spin on the same measurement

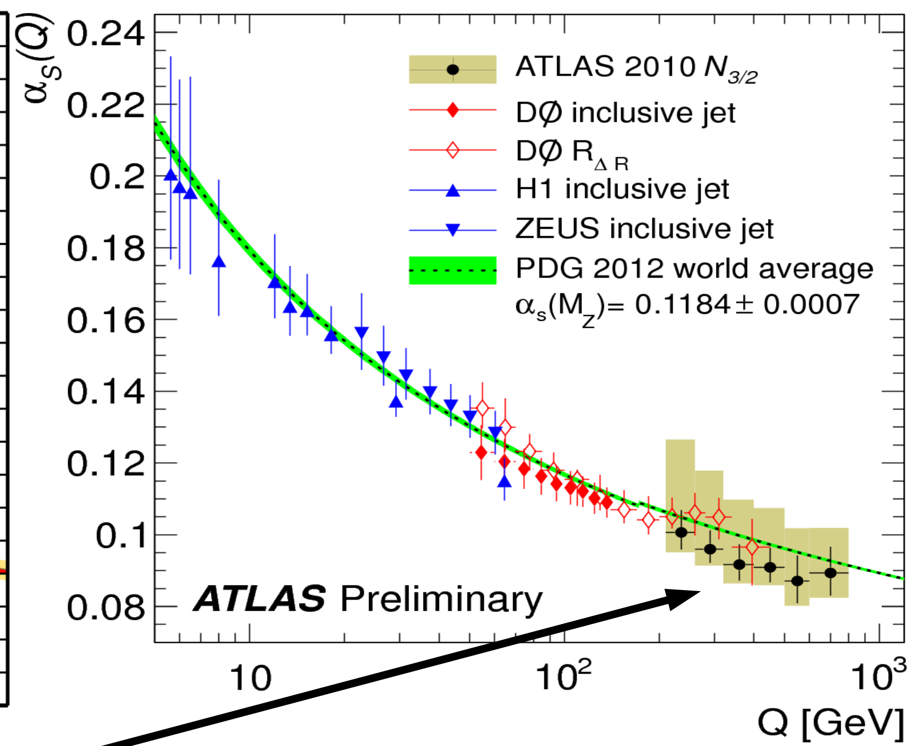
- How do we extend jet measurements?



Allows for the extraction α_s

- Differential cross section of jets or 3jets (mass)
  - Pushes out to the Q^2 limit





3-jet mass

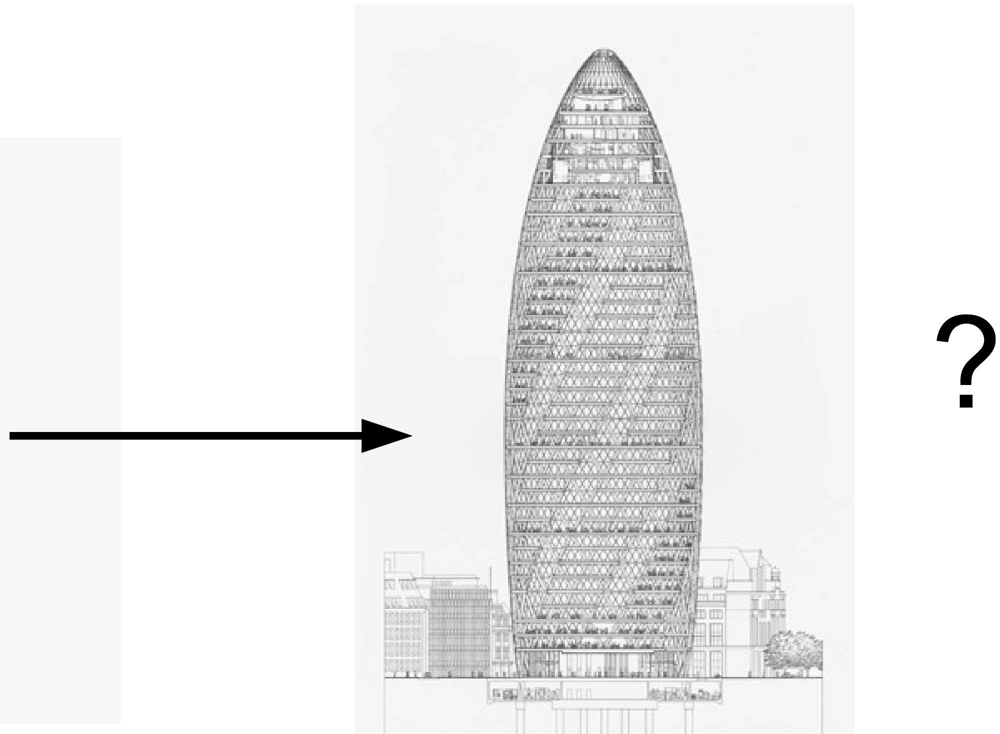
Inclusive jets (7TeV)

See thursday's talk for more

hep-ex/1412.1633

ATLAS-CONF-2013-041

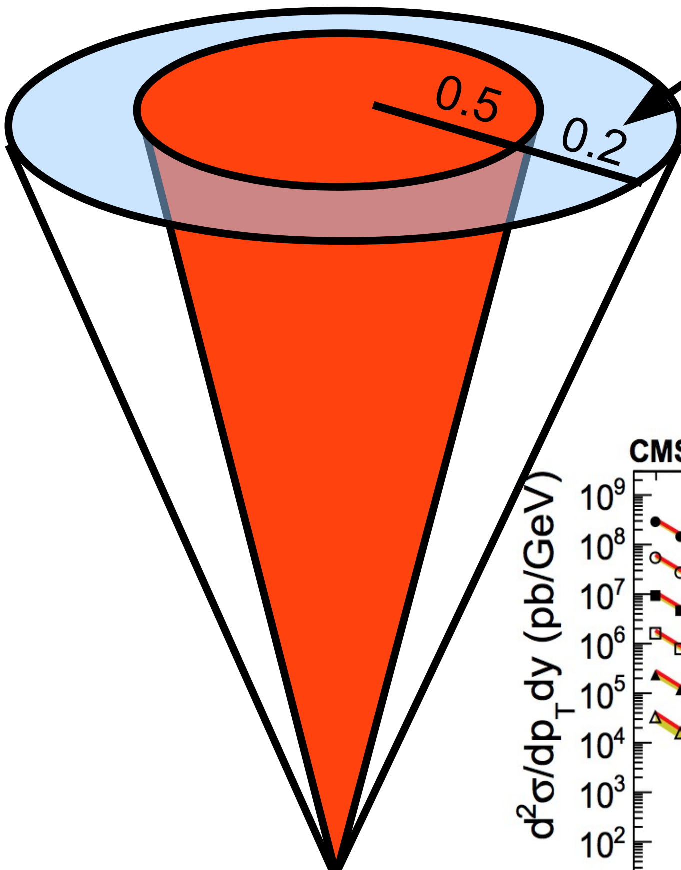
How can we get improve resolution?



- One way of extracting the information is
  - To reshape the jets to extract what you want
  - Modifying/enhancing jet definition we regain info
    - This applies to both experimental and theoretical aspects
    - And those inbetween

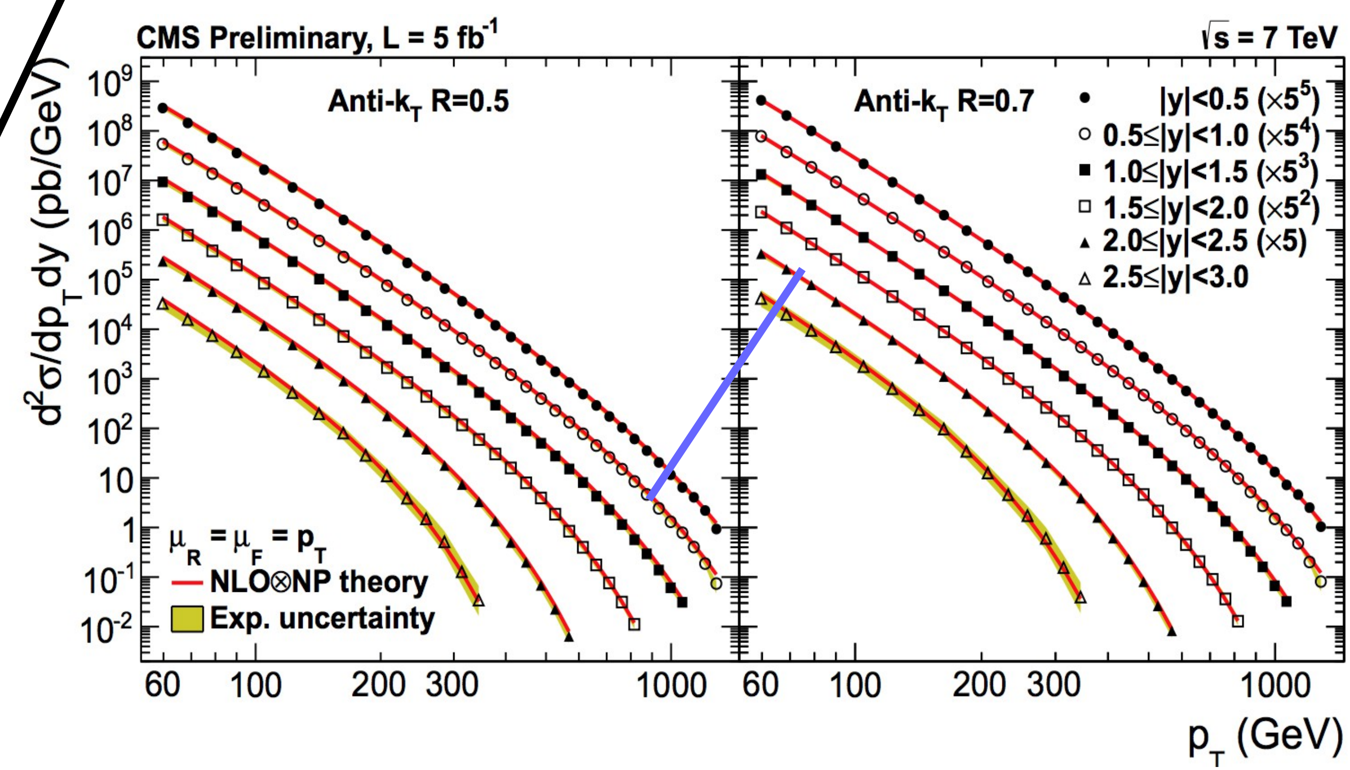
A Simple Example

- Jet Cone Radius

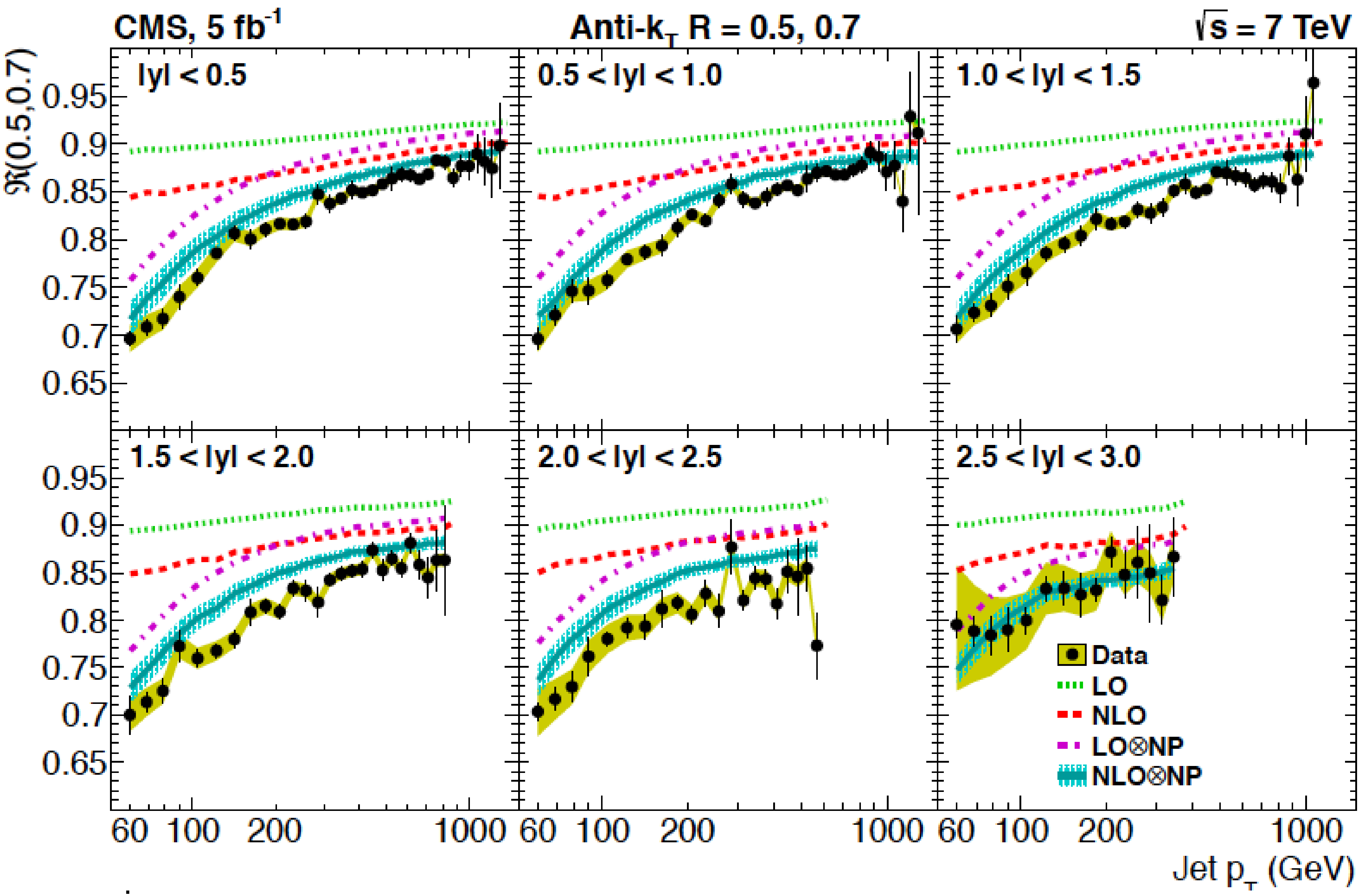


Whats the energy flow in an annulus?

$$\mathcal{R}(p_t; R_1, R_2) = \frac{\frac{d\sigma}{dp_t}(R = R_1)}{\frac{d\sigma}{dp_t}(R = R_2)}.$$

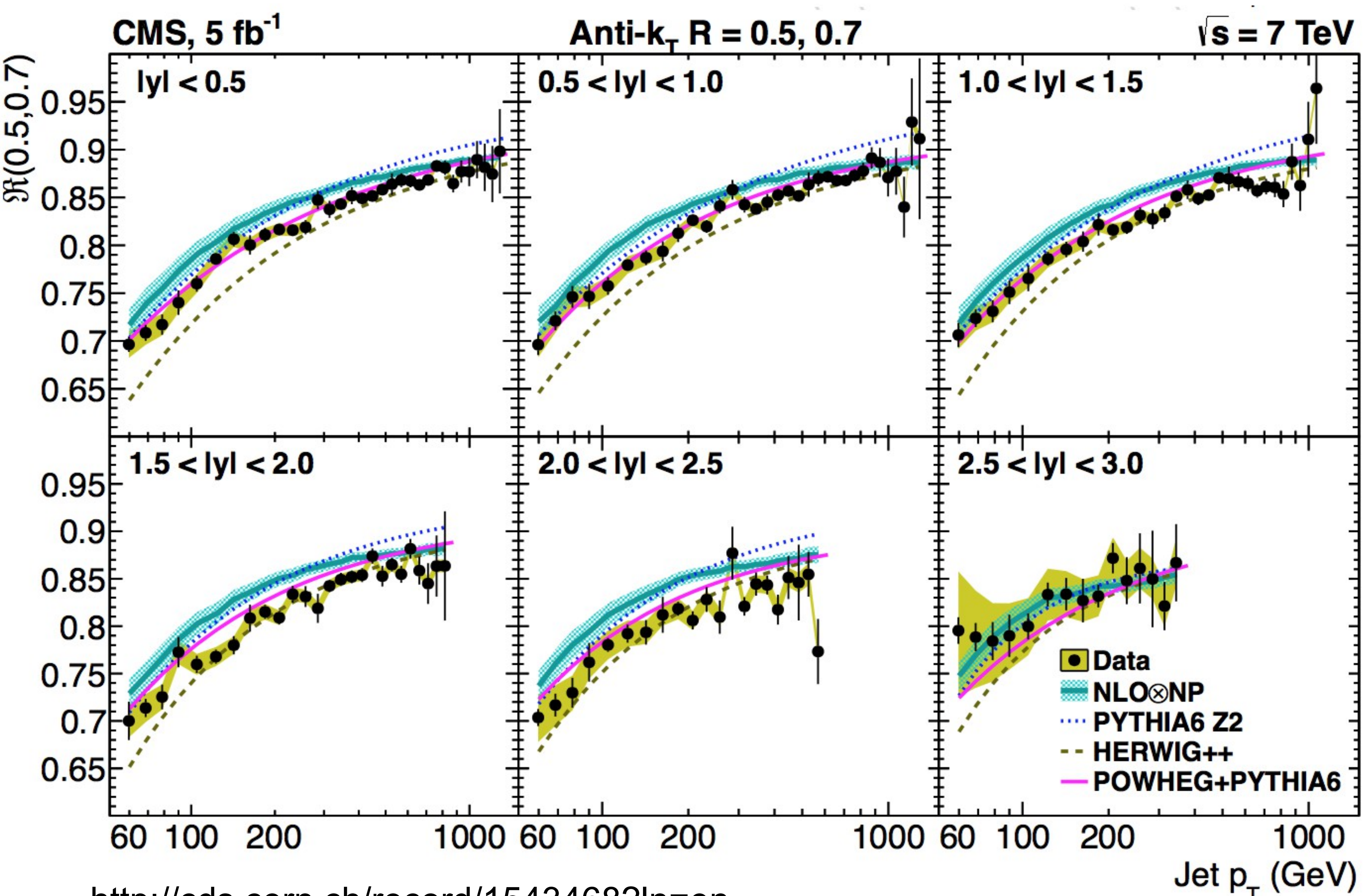


Resolving the Energy Flow



70-90% of jet info is carried in the first 0.5 of the cone

Resolving the Energy Flow

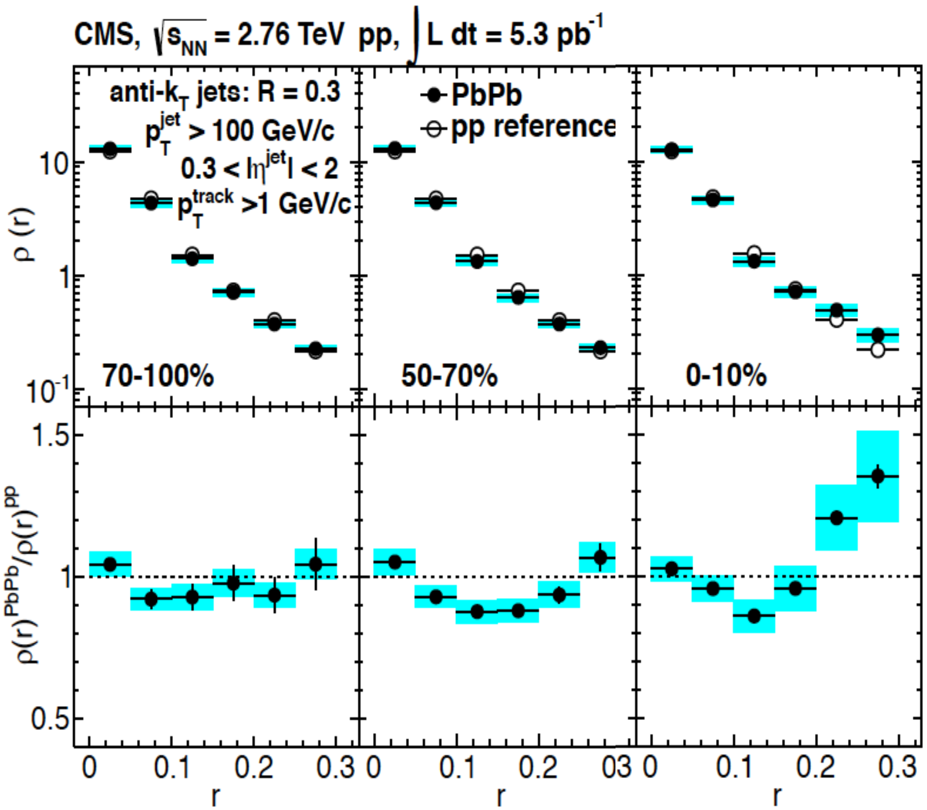


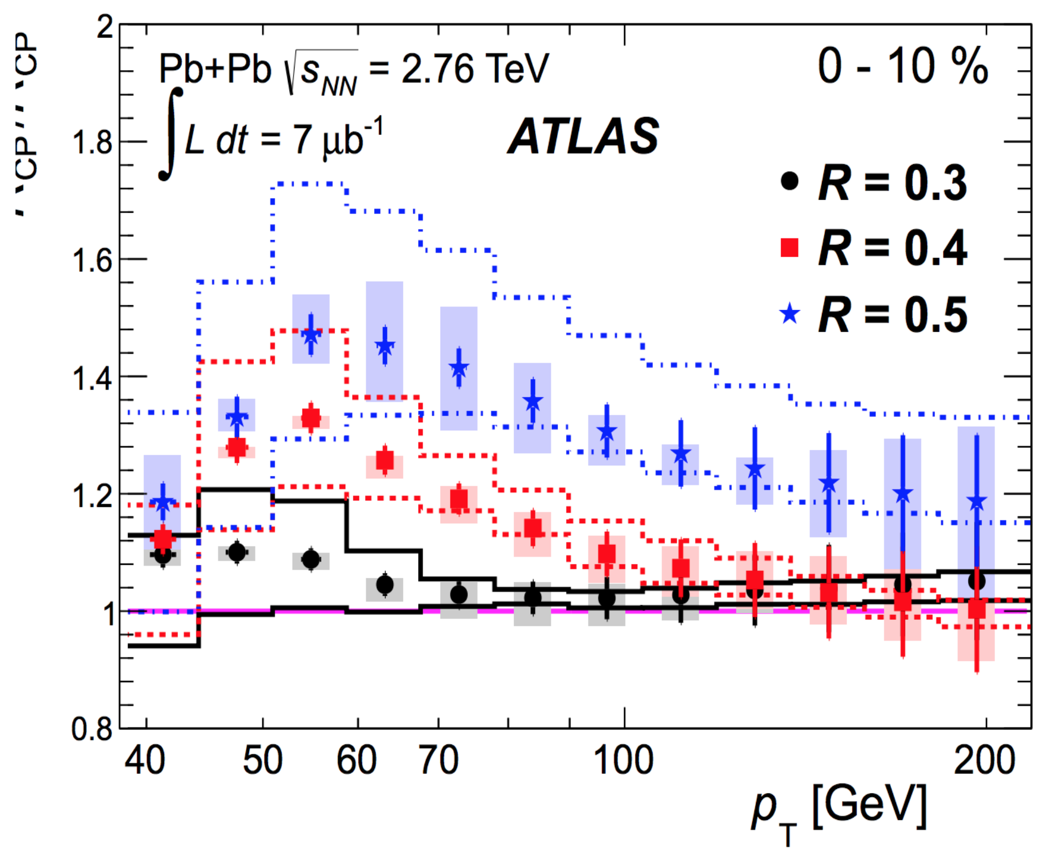
http://cds.cern.ch/record/1543468?ln=en

70-90% of jet info is carried in the first 0.5 of the cone

Resolving the Energy Flow

Extending these jet shape measurements
Yields a very useful tool in Heavy Ion measurements



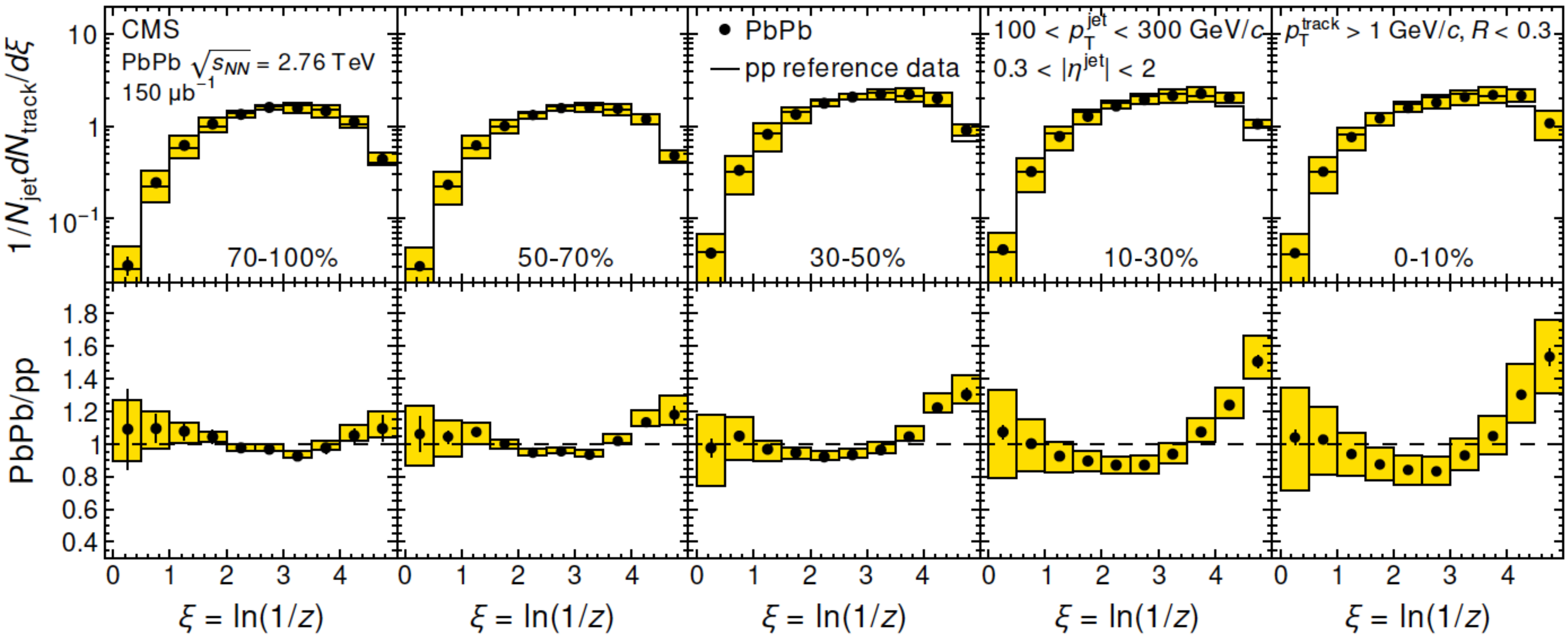


http://arxiv.org/pdf/1208.1967v2.pdf

CMS-HIN-12-002

Resolving the Energy Flow

Leads us to measurement of fragmentation functions
And an understanding of their modifications



How far have we gone to understsand these measuemrents?

CMS-HIN-12-013

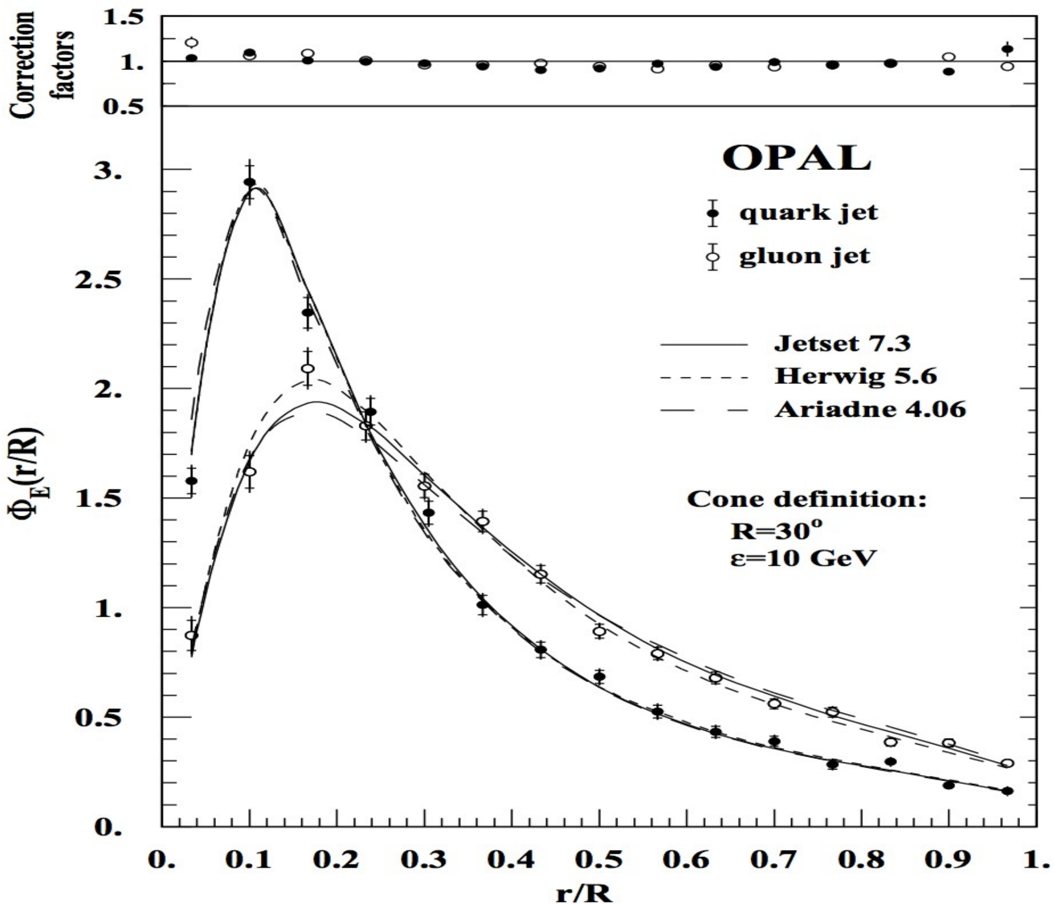
Attempt at Executive Summary

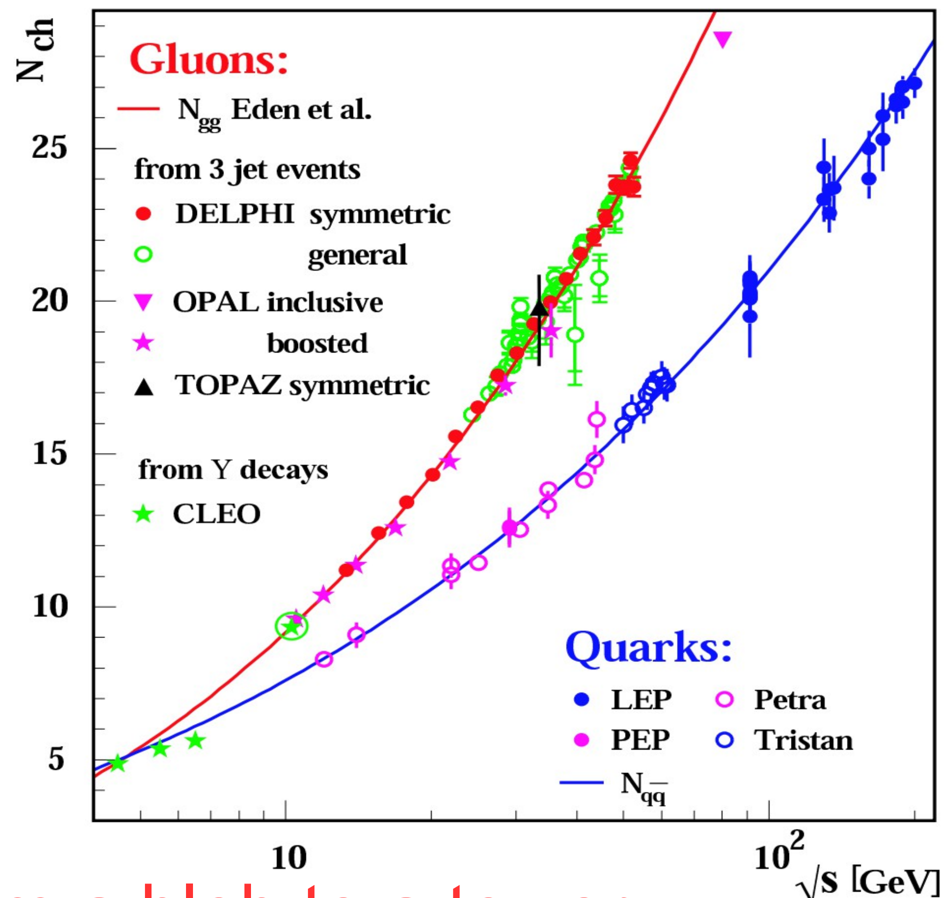
Done/Not Done/**Full Dataset**

Process	7TeV	8TeV	α_S	R_{AA}
Inclusive Jet	**CMS/ATLAS**	**CMS**/ATLAS	**8TeV/7TeV**	2.76/R_{CP}
AKX/AKY ratio	**CMS**/ATLAS	CMS/ATLAS		2.76/2.76
M_{jj} and/or σ_{jj}	**CMS/ATLAS**	CMS/ATLAS		2.76/2.76
azimuthal correlation	**CMS/ATLAS**	CMS/ATLAS		2.76/2.76
Inclusive mulitjet	**CMS**/ATLAS	CMS/ATLAS		
Hadronic Event shapes	**CMS**/ATLAS	CMS/ATLAS		
3 jet mass	**CMS**/ATLAS	CMS/ATLAS	7TeV/ATLAS	
Jet Shapes(radius/ρ)	CMS/ATLAS	CMS/ATLAS		2.76/2.76
R_{32} (3/2 σ)	**CMS/ATLAS**	CMS/ATLAS	7TeV/ATLAS	
Groomed Jet Mass	**CMS/ATLAS**	CMS/ATLAS		
Flavor Composition di-jet	CMS/ATLAS	CMS/ATLAS		
Jet Fragmentation	CMS/ATLAS	CMS/ATLAS		2.76/2.76
B-jet Cross section	**CMS**/ATLAS	CMS/ATLAS		2.76/**-**

Can we do more?

- LEP was able to build clear samples of
  - Quarks and Gluons

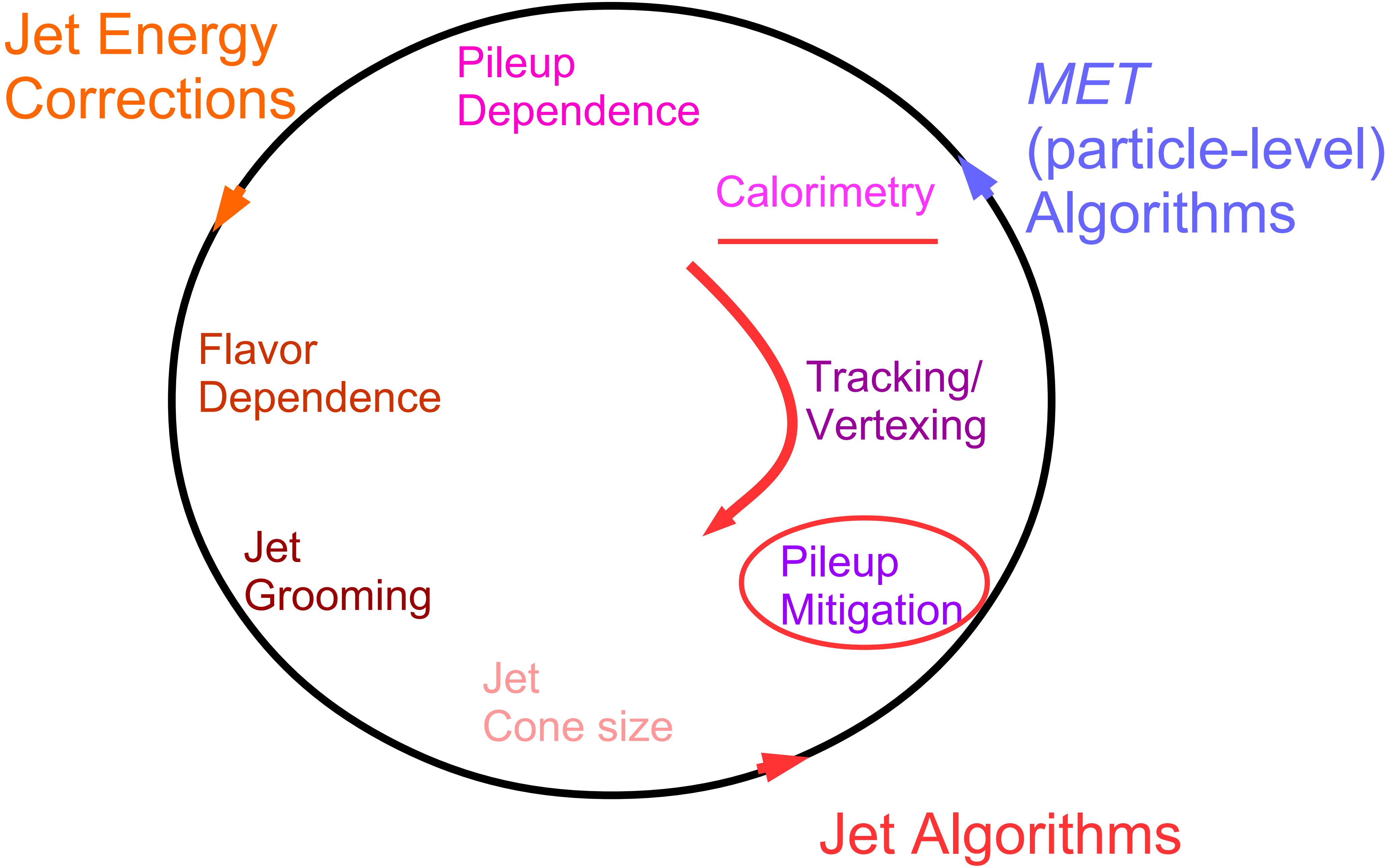


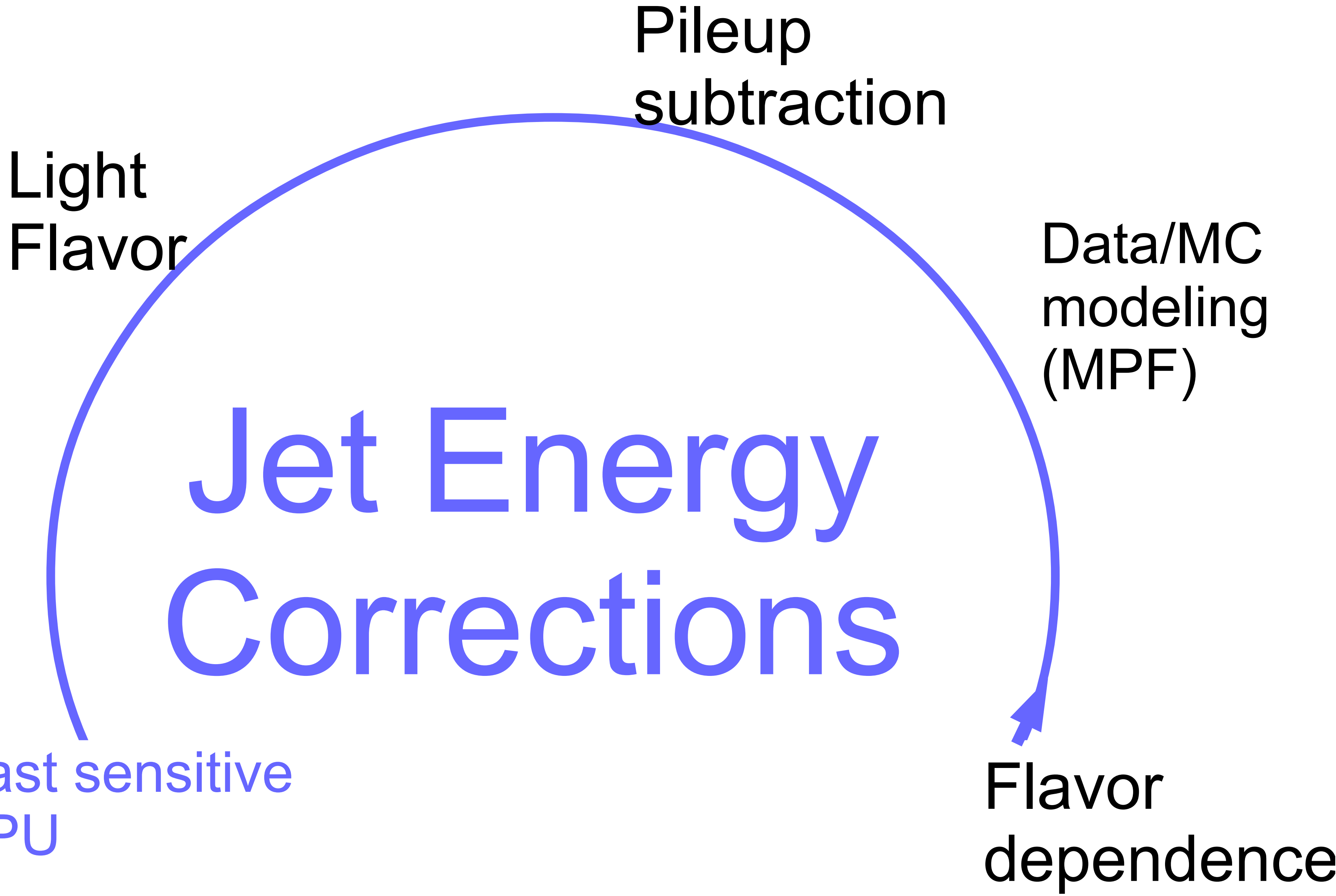


We lost something going form a blob to a tower

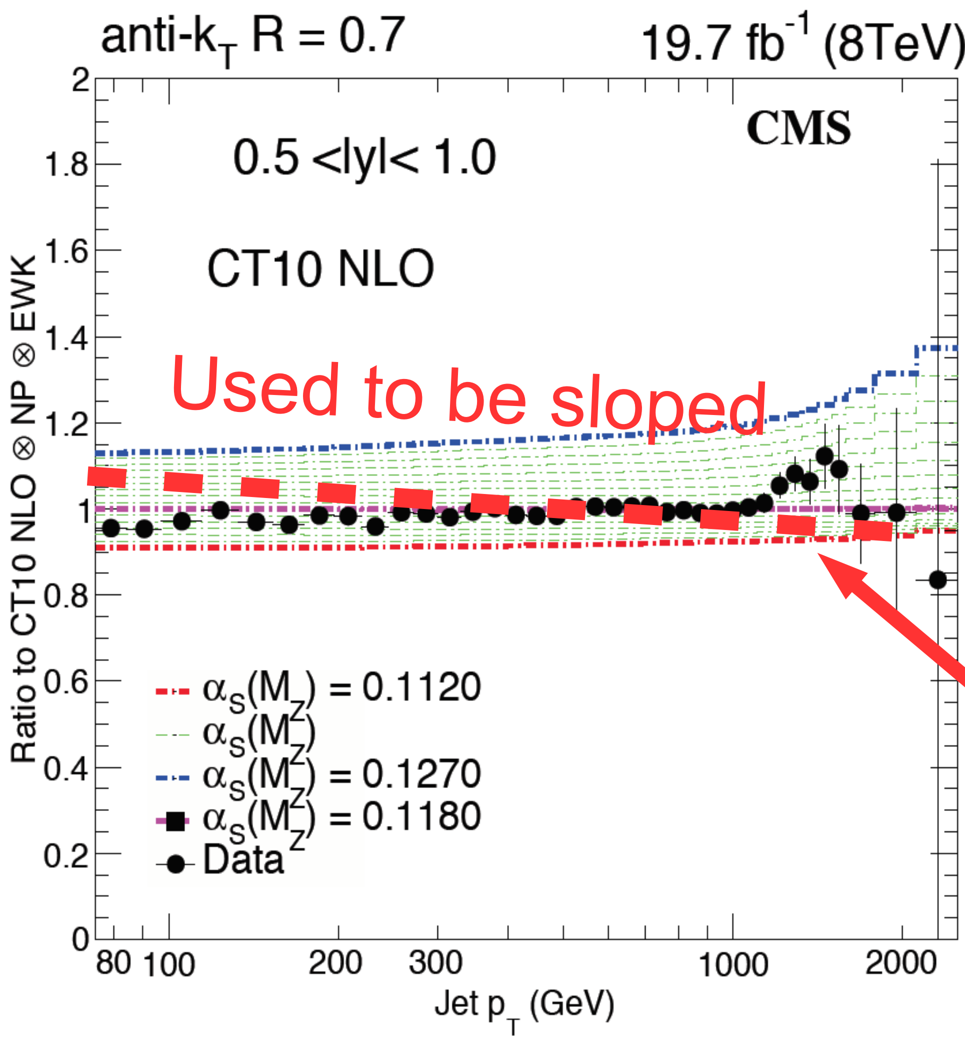
http://arxiv.org/pdf/hep-ex/0110084v1.pdf

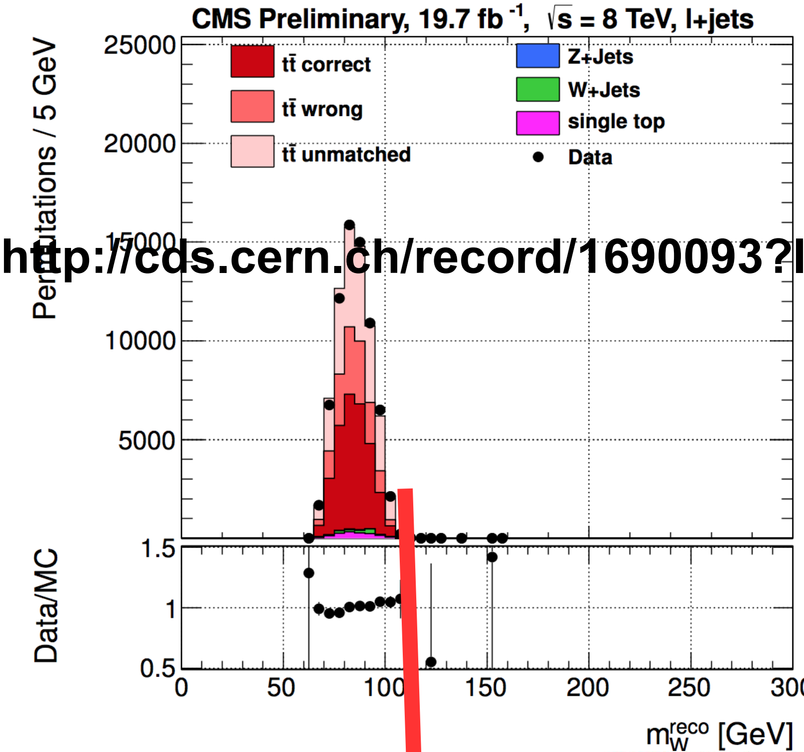
Building a Better Jet



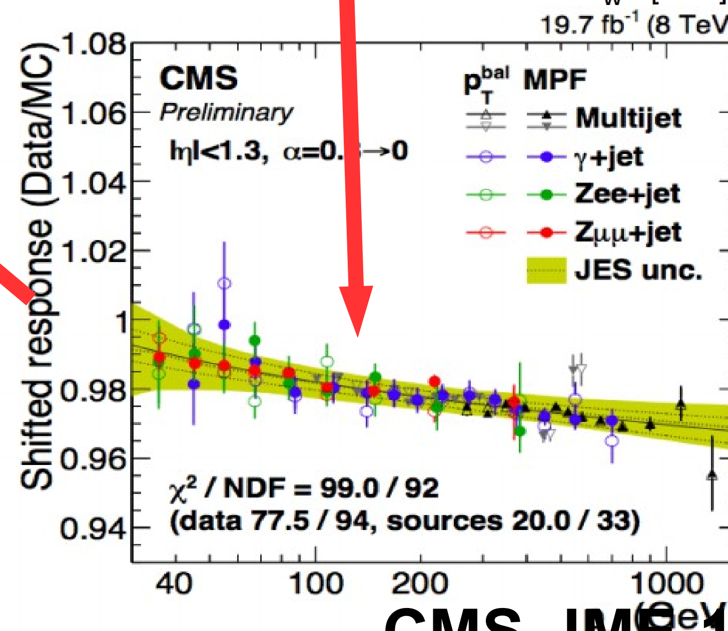

Pileup
subtraction
Light
Flavor
Data/MC
modeling
(MPF)
Jet Energy
Corrections
Least sensitive
to PU
Flavor
dependence

- W mass in top mass measurement
  - Fixed a bias in inclusive jets





http://cds.cern.ch/record/1690093?ln=en

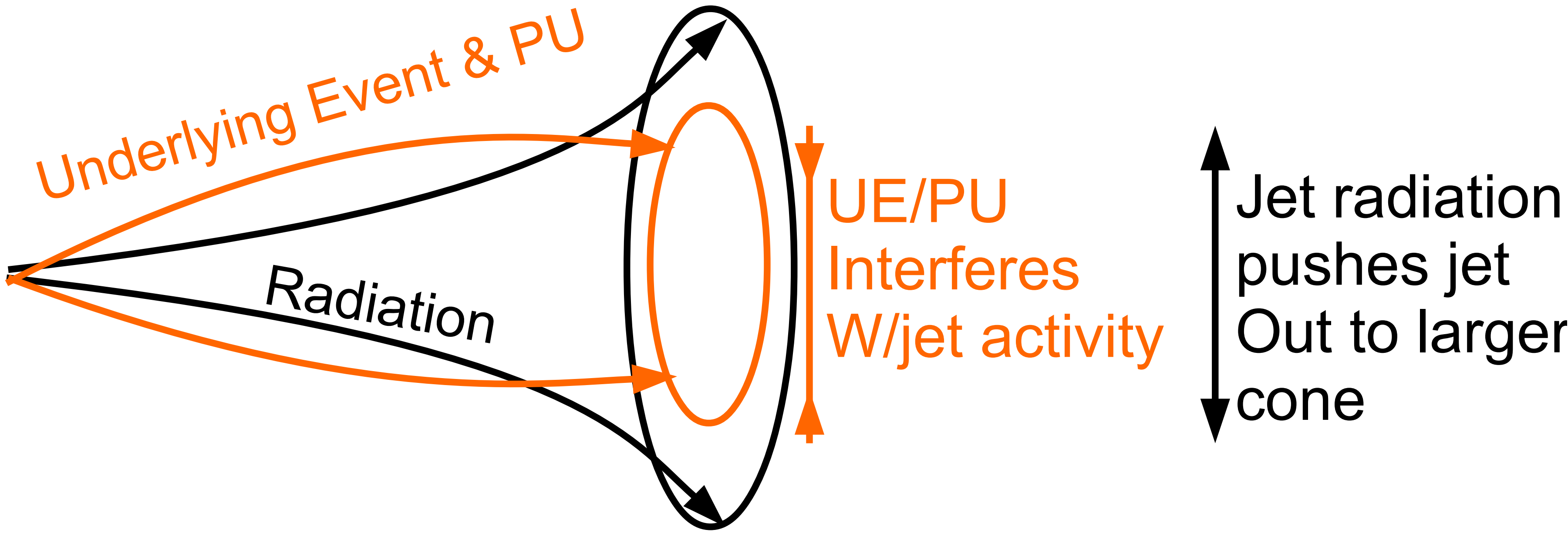


CMS-SMP-12-012

CMS-JME-13-004

Jet Energy Correction

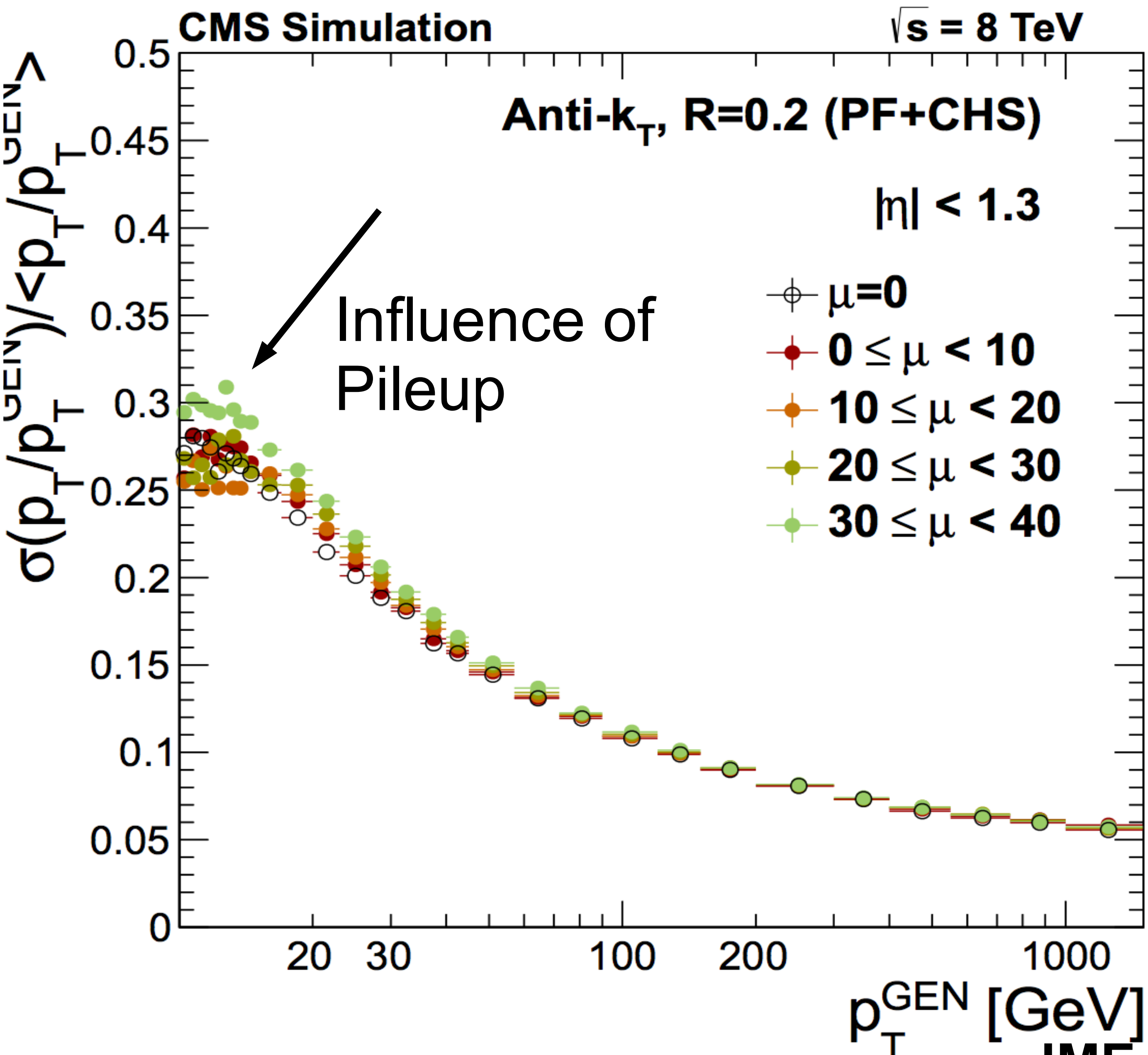
- Correcting to truth



How do we shape our jet against the UE?
Why did CMS switch to AK4?

Jet Energy Correction

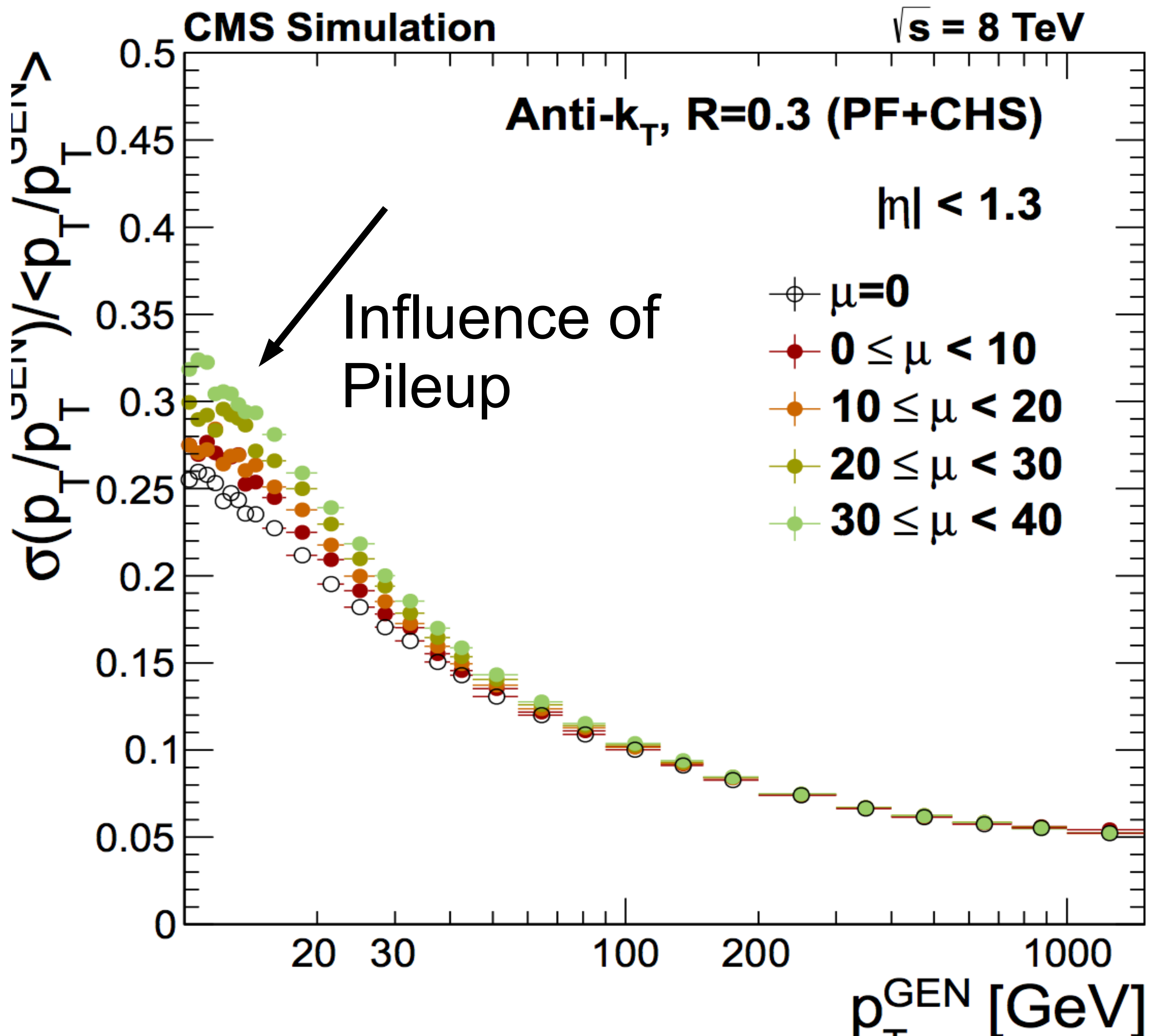
- AK2



JME-DP-14/037

Jet Energy Correction

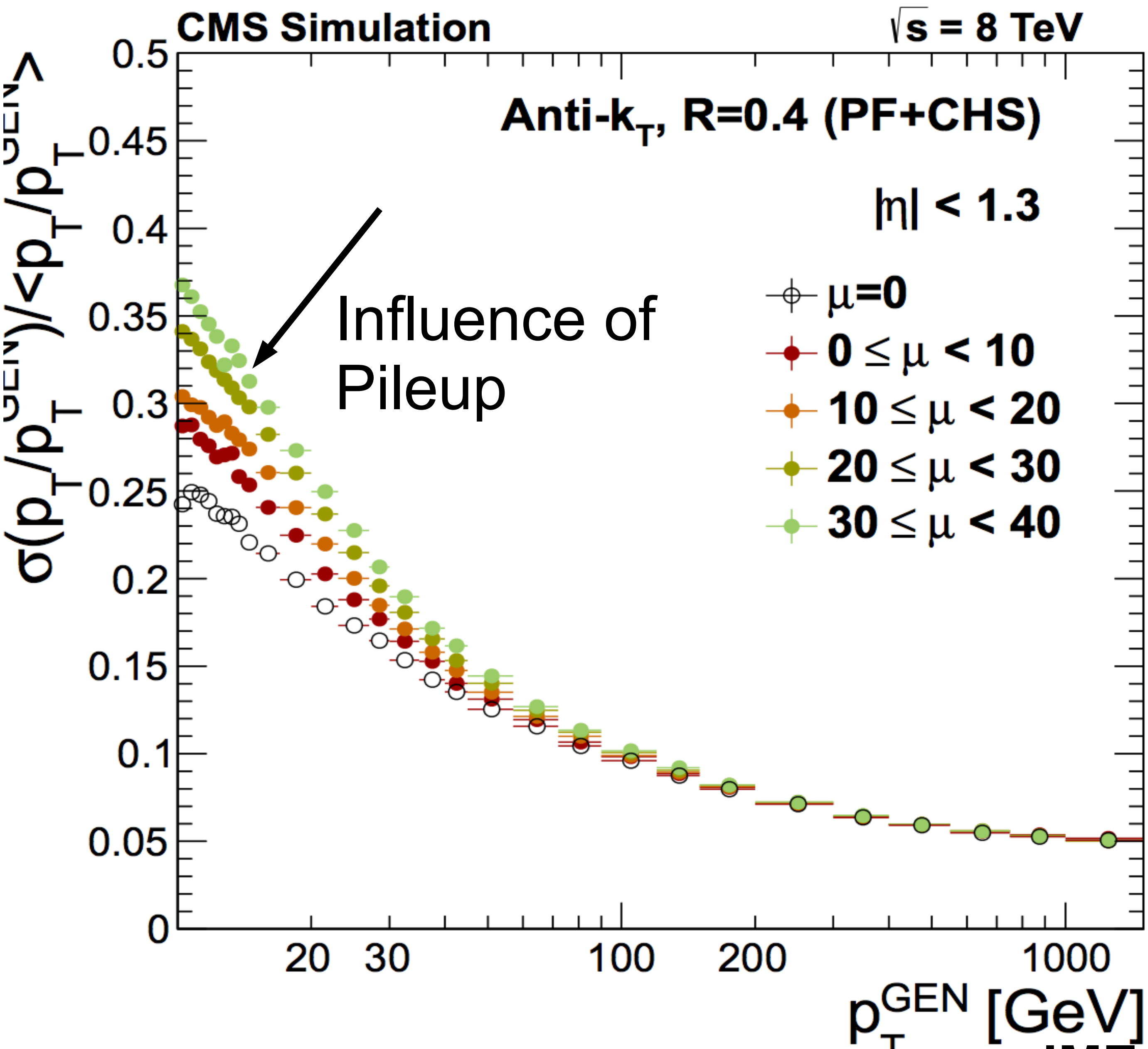
- AK3



JME-DP-14/037

Jet Energy Correction

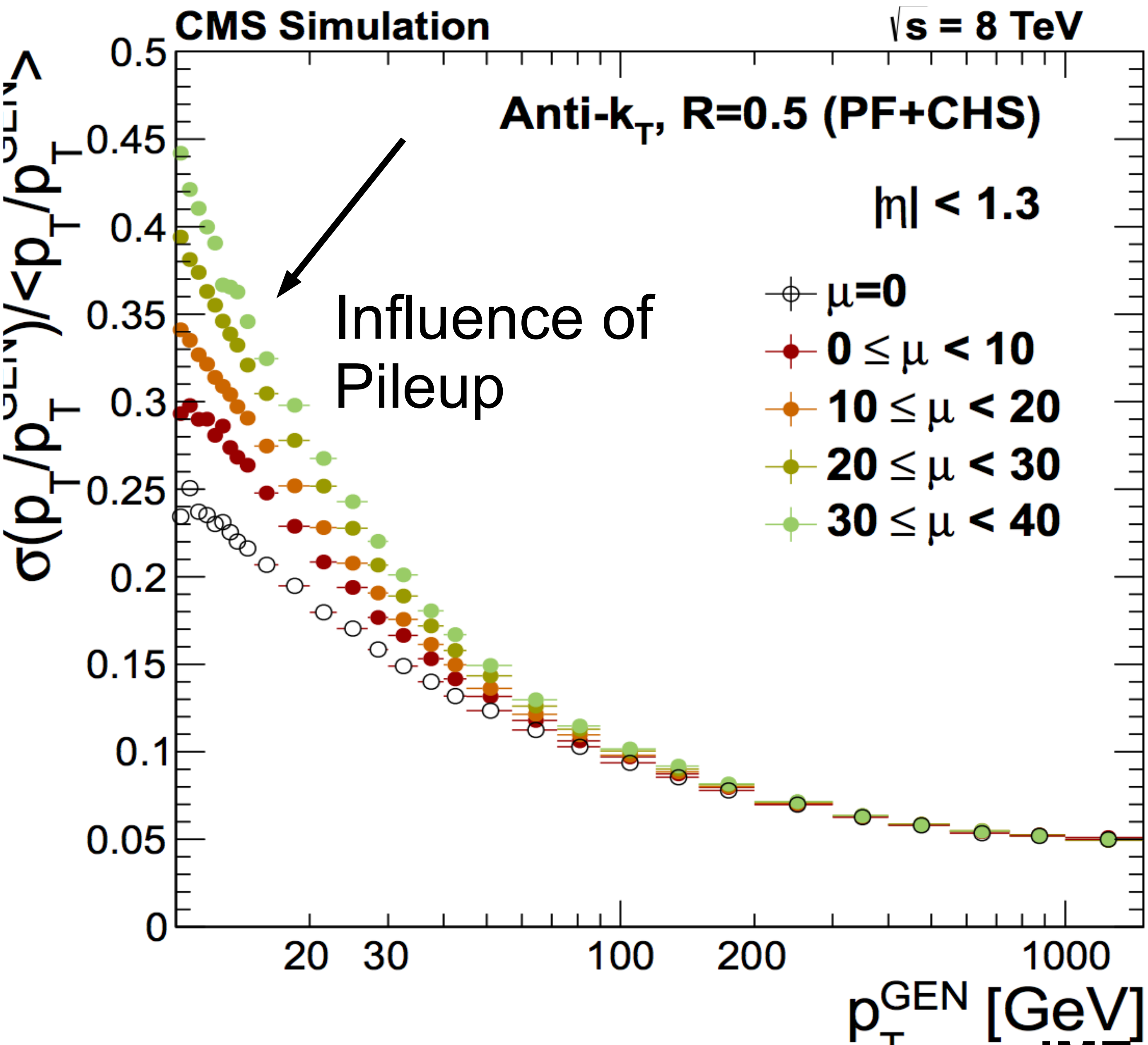
- AK4



JME-DP-14/037

Jet Energy Correction

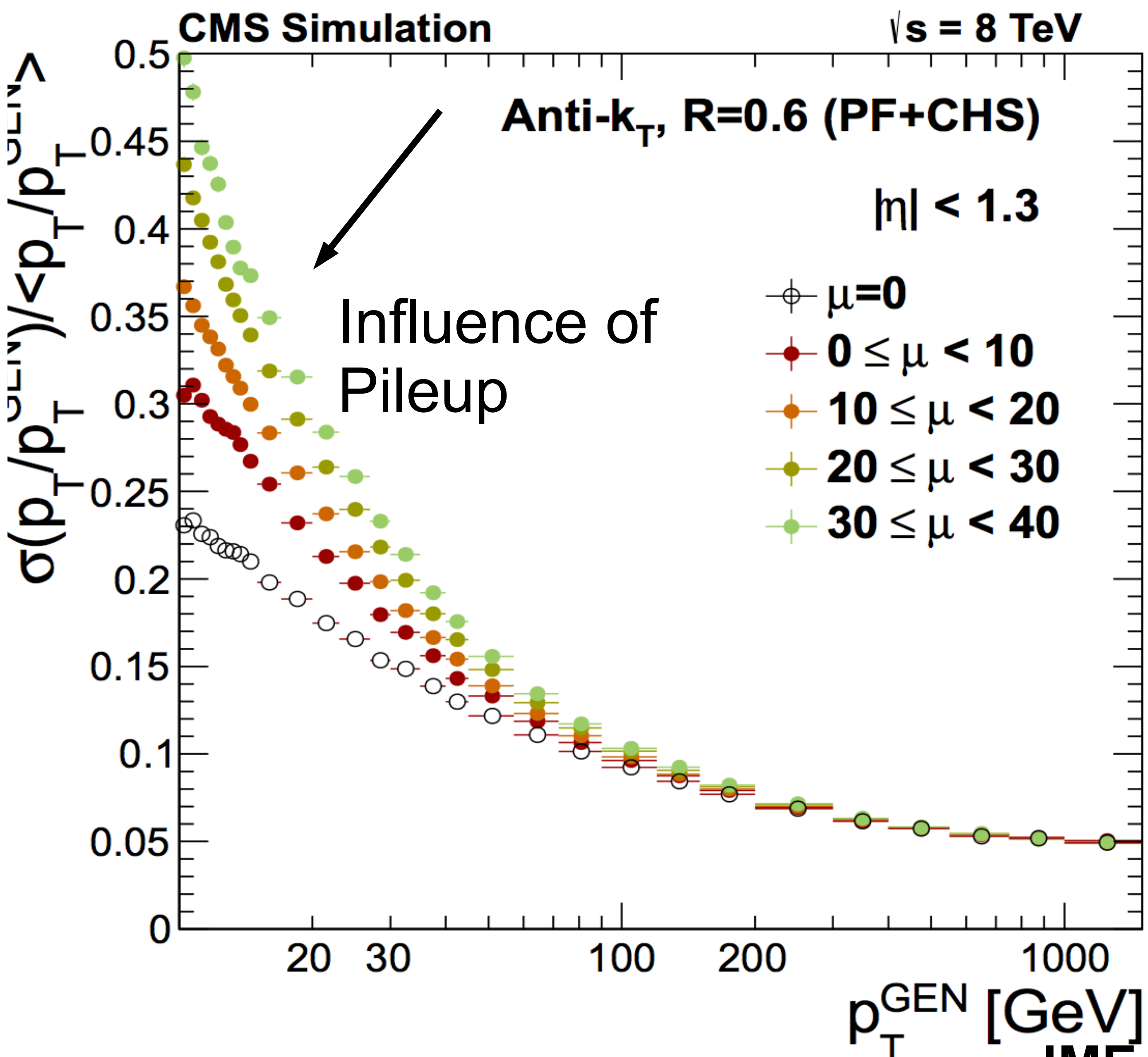
- AK5



JME-DP-14/037

Jet Energy Correction

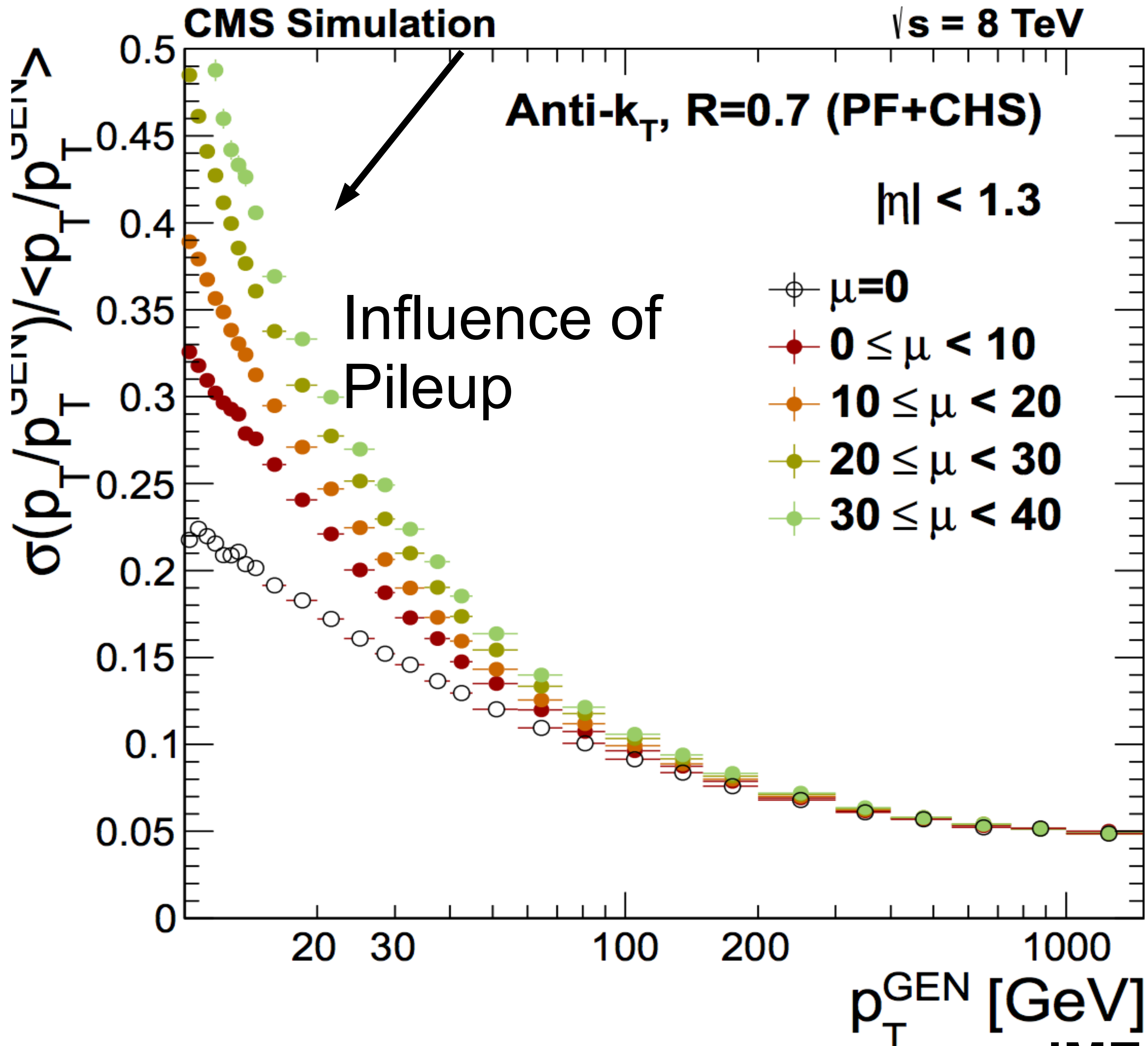
- AK6



JME-DP-14/037

Jet Energy Correction

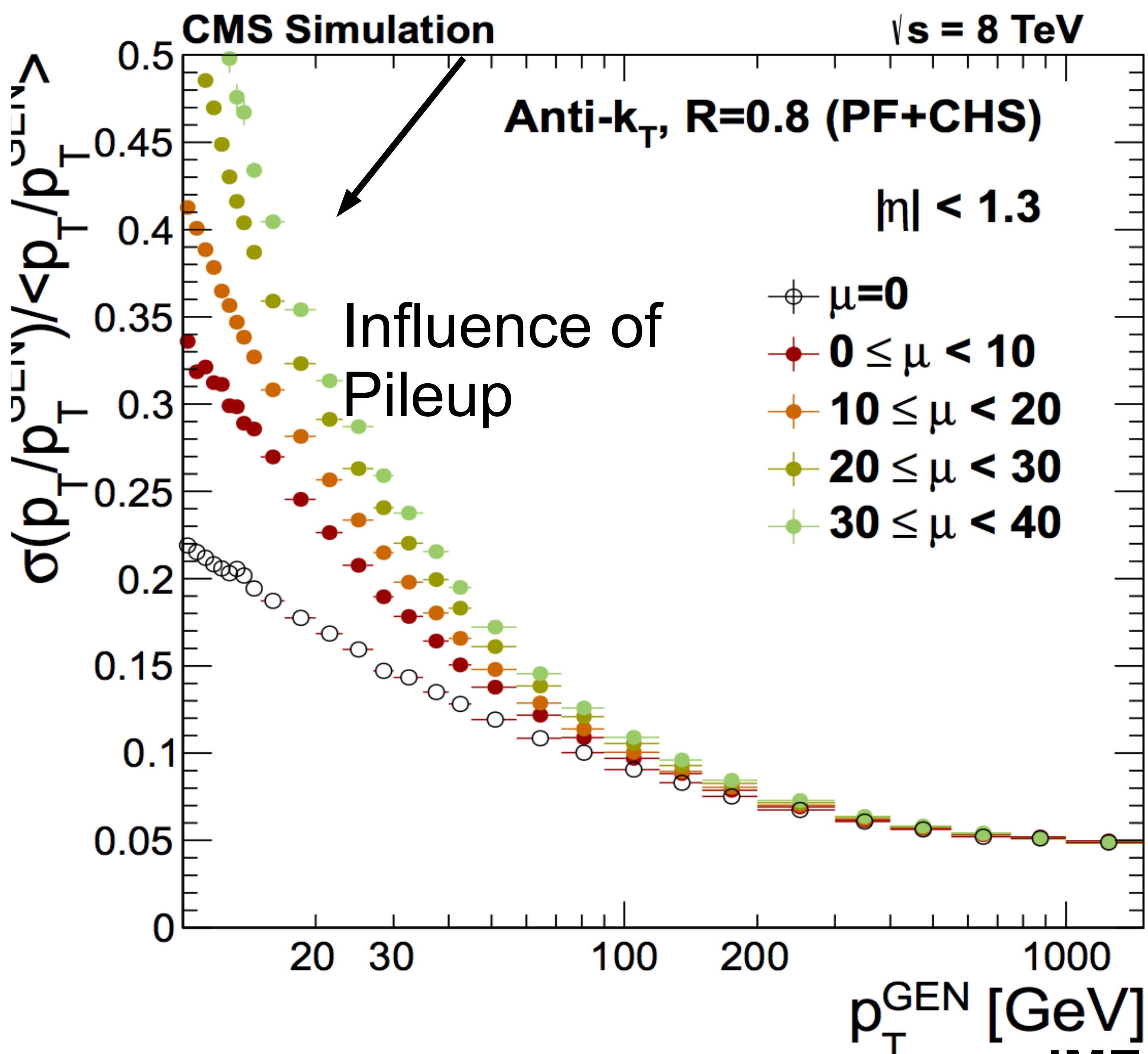
- AK7



JME-DP-14/037

Jet Energy Correction

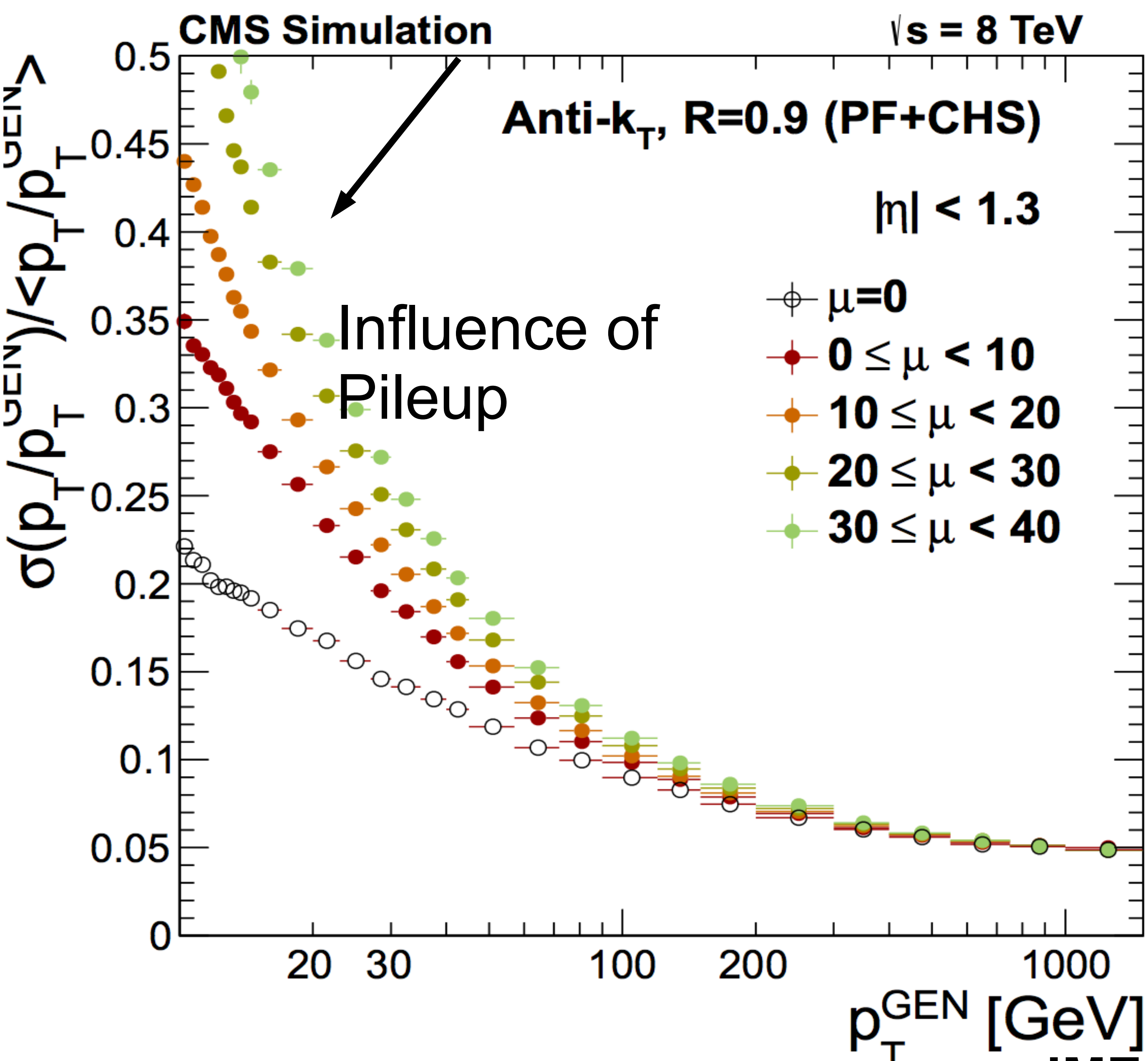
- AK8



JME-DP-14/037

Jet Energy Correction

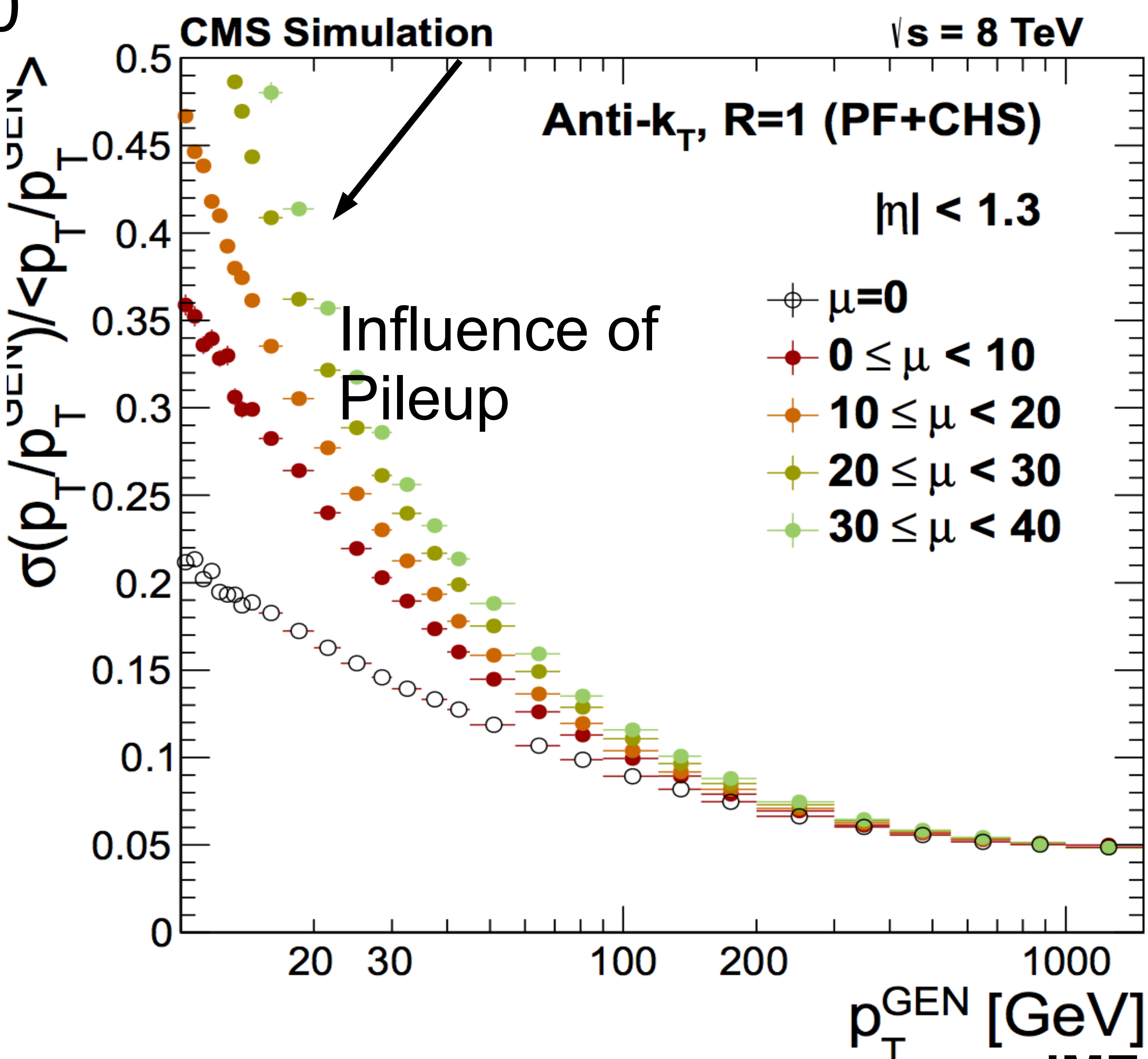
- AK9



JME-DP-14/037

Jet Energy Correction

- AK1.0



JME-DP-14/037

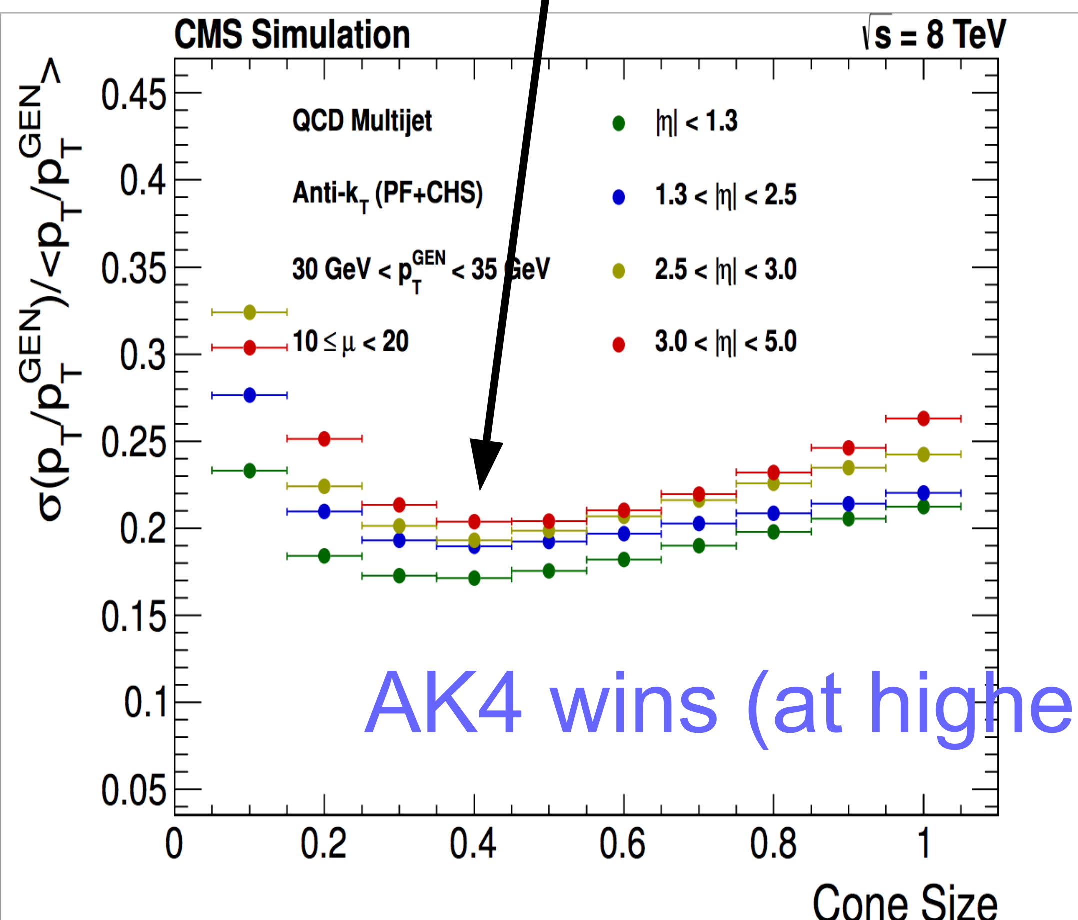
Jet Energy Correction

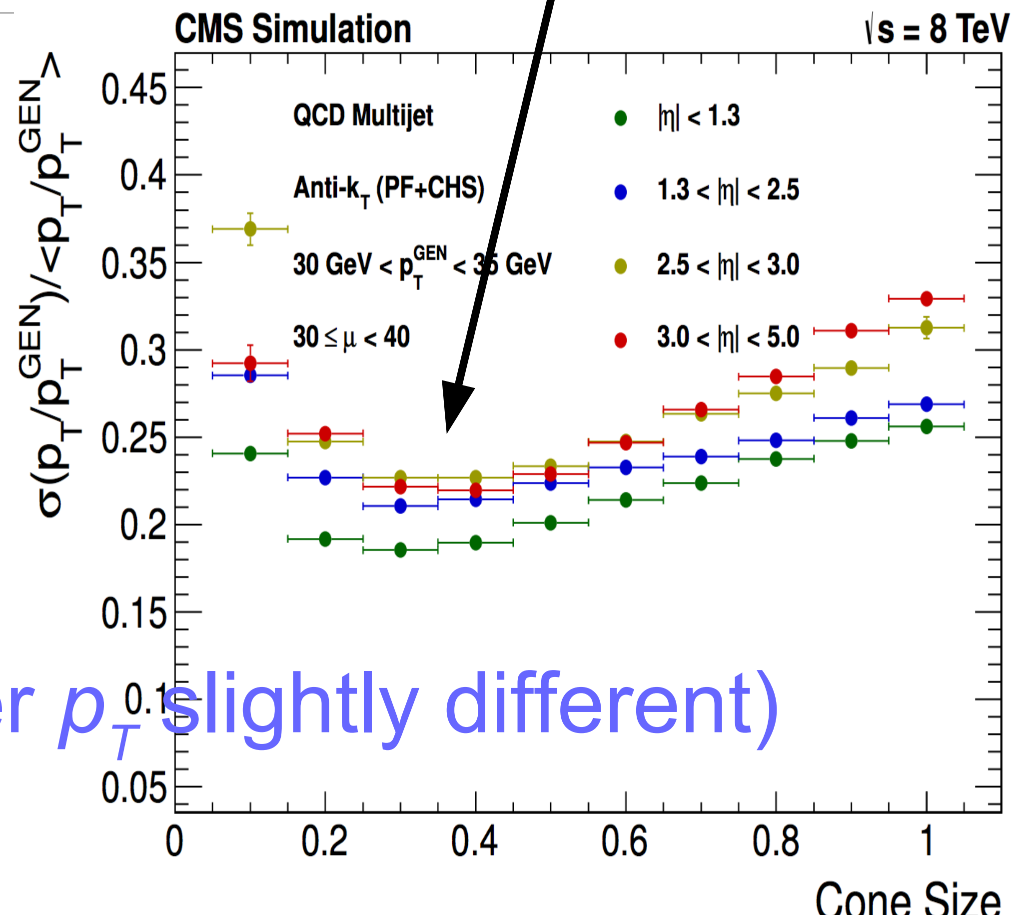
- Executive Summary :

We switch to AK4

Run I PU

Run II PU





AK4 wins (at higher p_T slightly different)

JME-DP-14/037

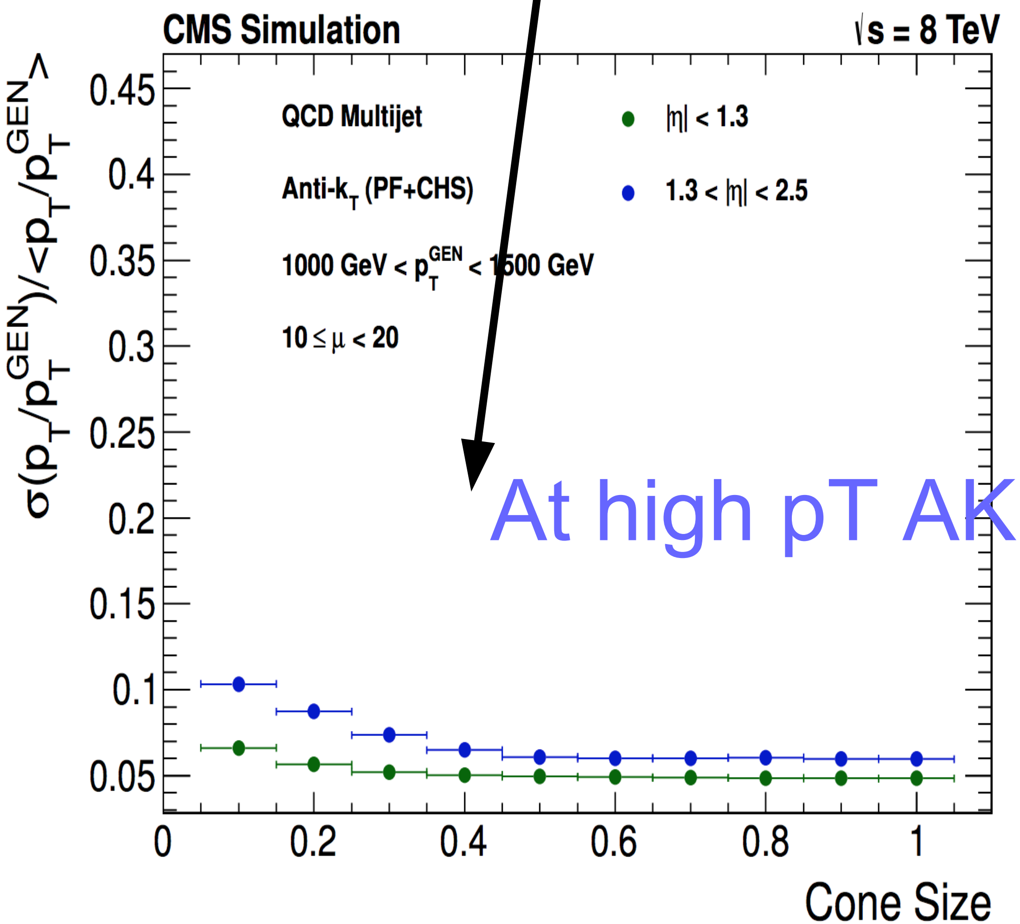
Jet Energy Correction

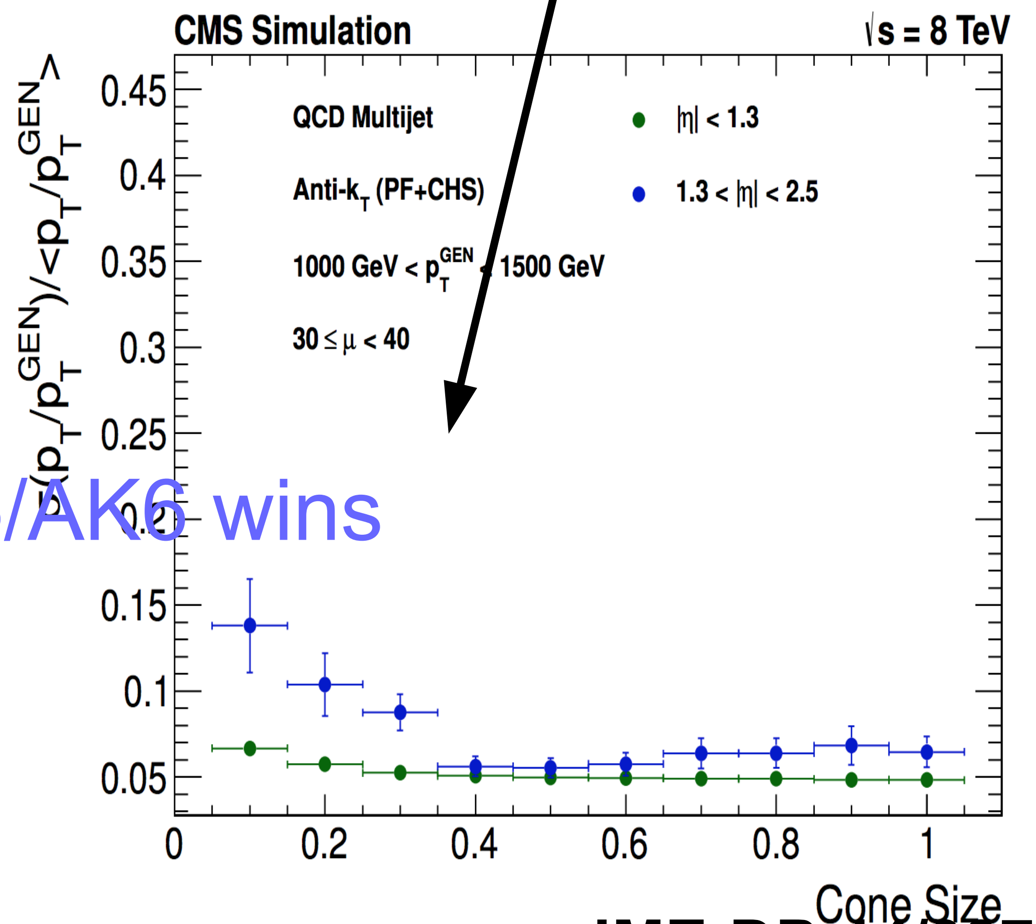
- Executive Summary :

We switch to AK4

Run I PU

Run II PU



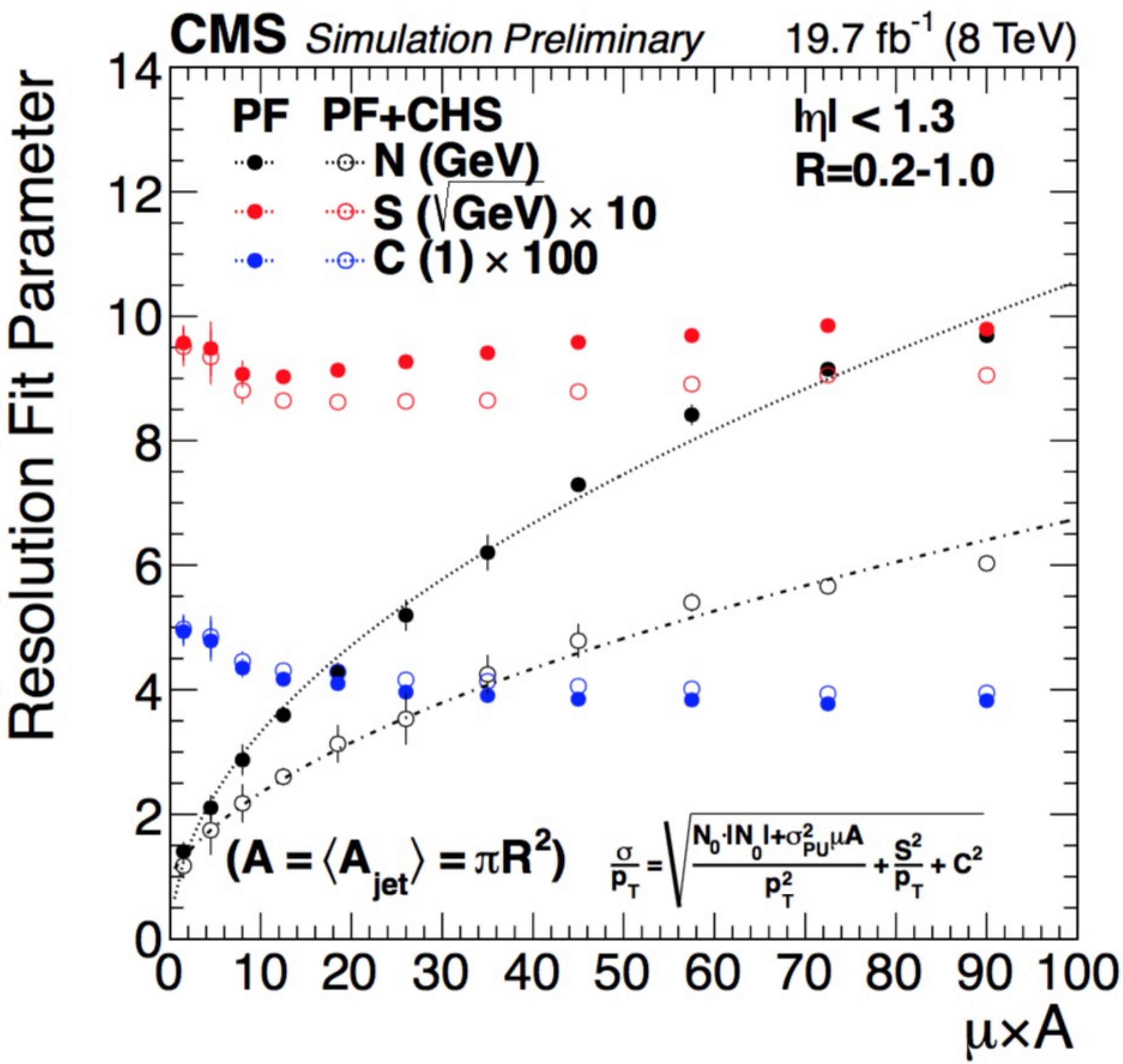


At high pT AK5/AK6 wins

JME-DP-14/037

Stability of our detector

- Using all the jet cones allows plots like this:



JME-DP-14/037

What does it take for E-flow?

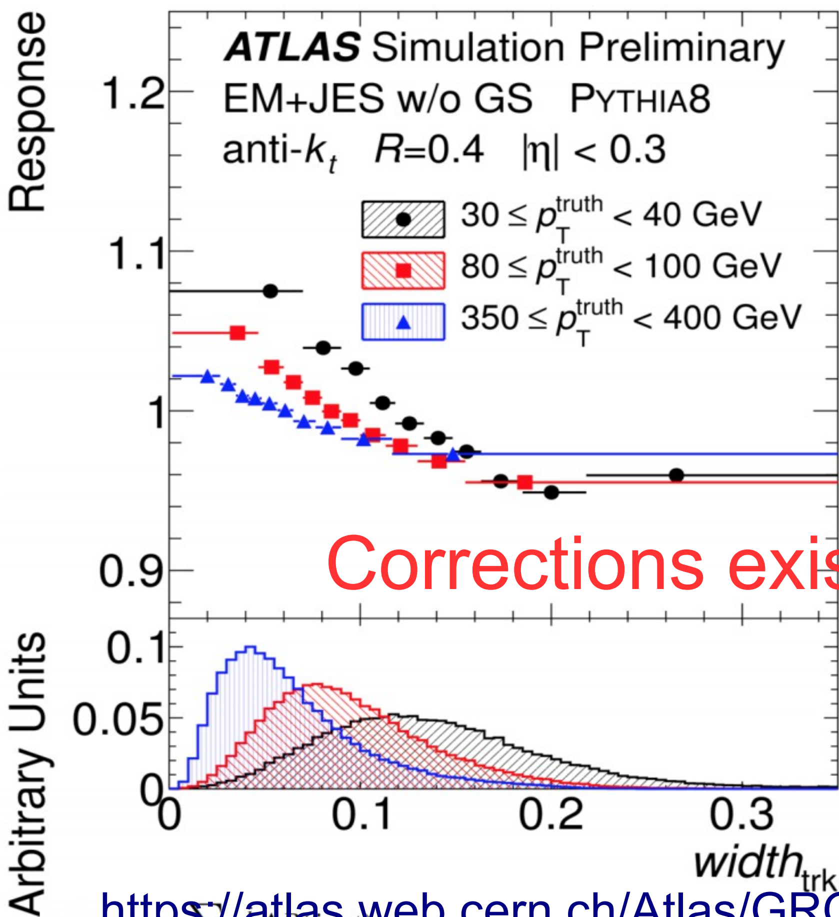
- Need to reconstruct a jet and correct it

ATLAS	Cluster+correct Calorimeter Cells (Topoclusters)	Cluster Topoclusters To jets	(ρ) PU Correction +Global Correction Of Jet (p_T+η)	Residual Correction of Jet (using width/tracks) GSC
CMS	Cluster Calorimeter Cells (pf clustesr)	Link Tracks to Pfclusters (pf particles)	Correction Of PF Candidate (p_T+η)	(ρ) PU Correction + Global Correction of Jet (p_T+η)

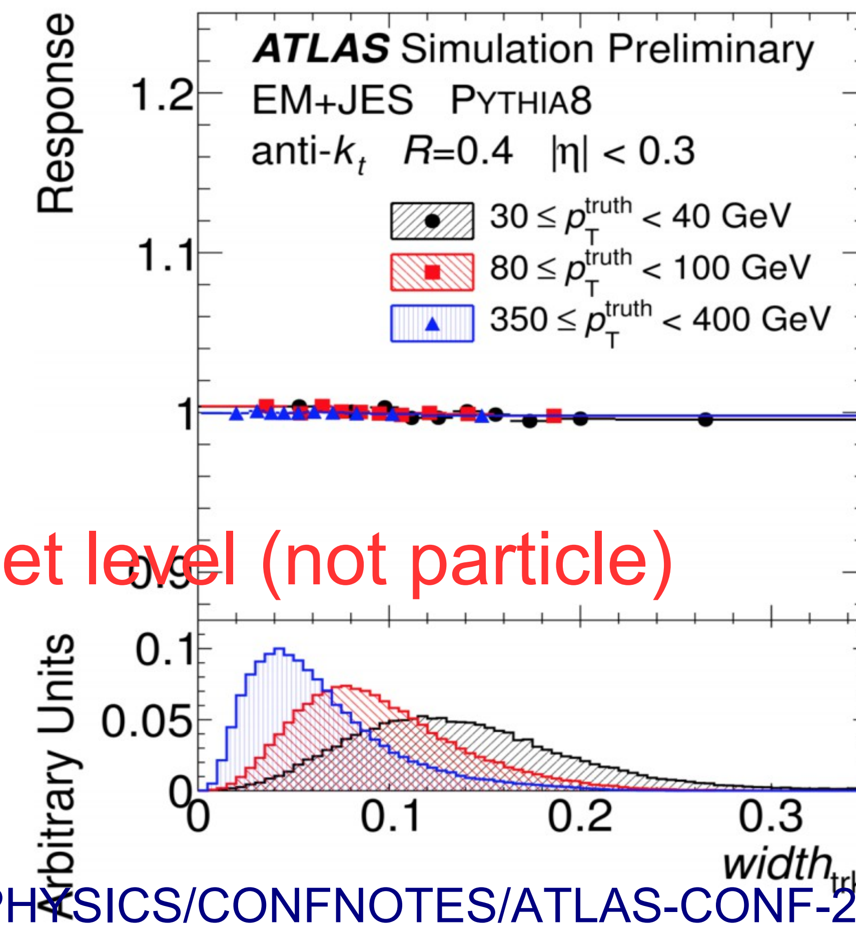
Jet-Level in ATLAS

- While ATLAS does not use pflow
  - Yields resol. loss(Charged parts)+worse granularity
  - Compensates w/improved granularity through GSC

Before GSC



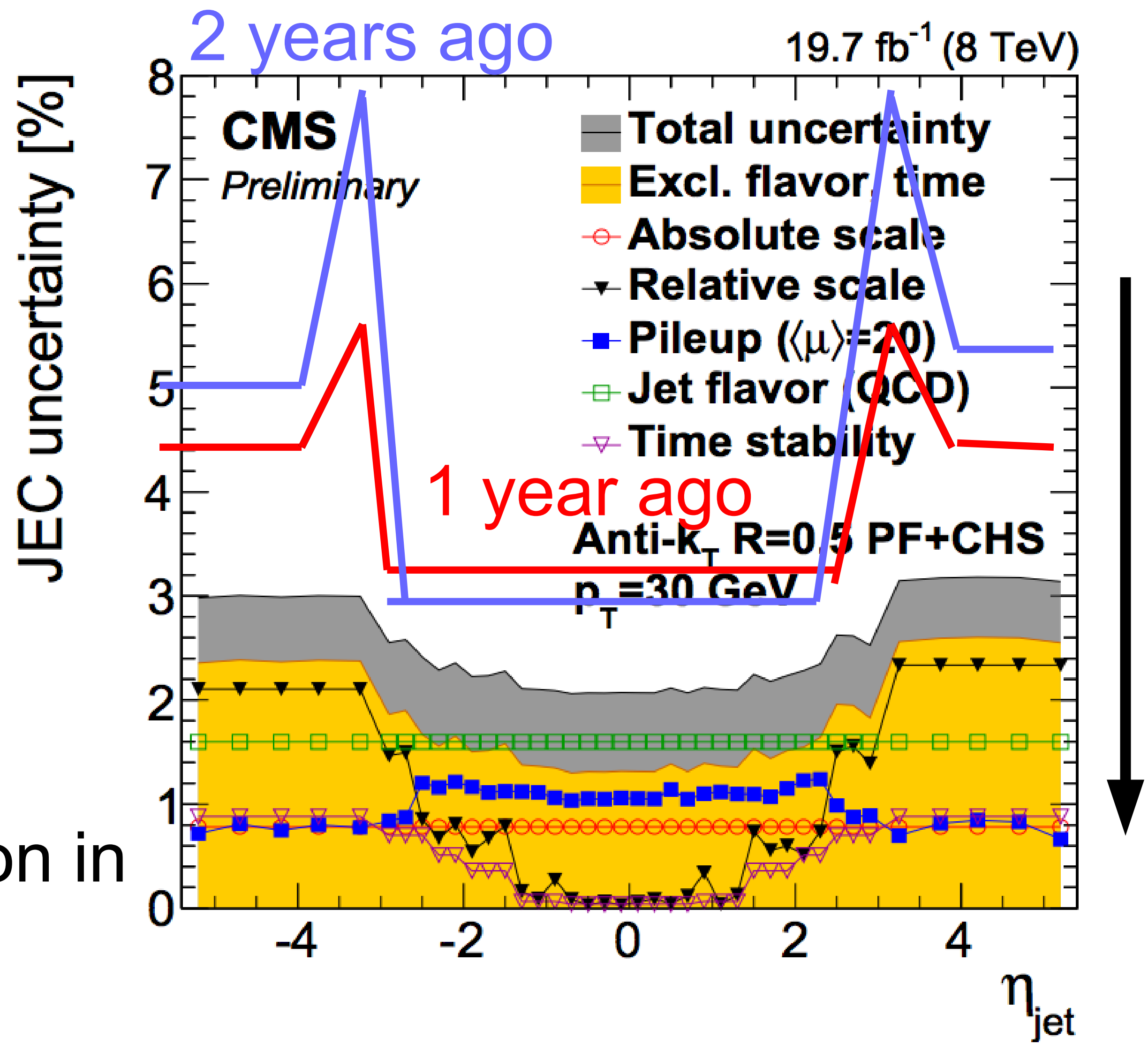
After GSC



Corrections exist at jet level (not particle)

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2015-00

Jet Energy Scale



Understanding of JEC Steadily improved

As we dealt with detector effects

Similar progression in ATLAS

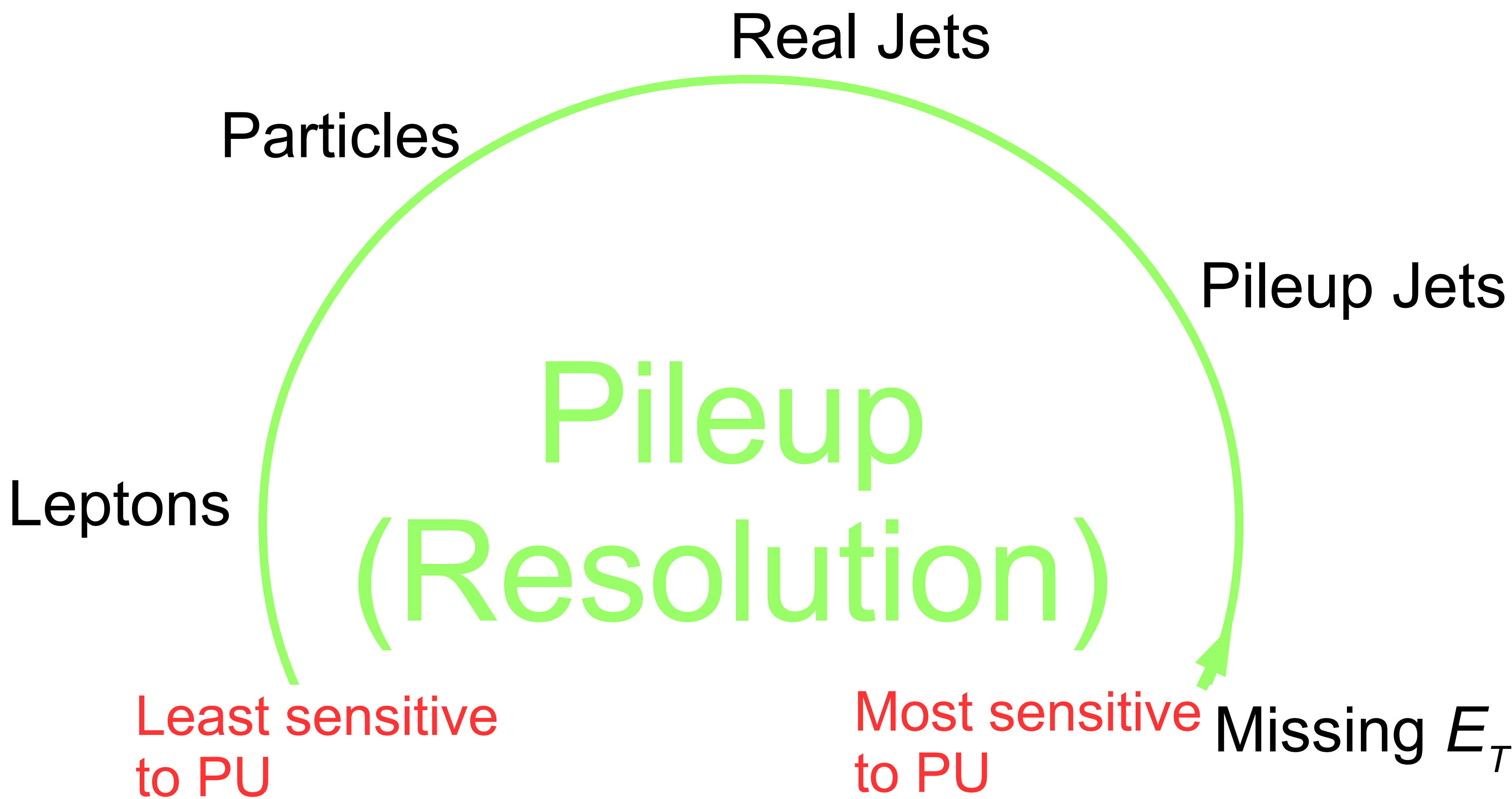
- Run II: expect same trend with a faster timescale
- We are now down to 3% uncertainty a 30 GeV!

JME-13-004

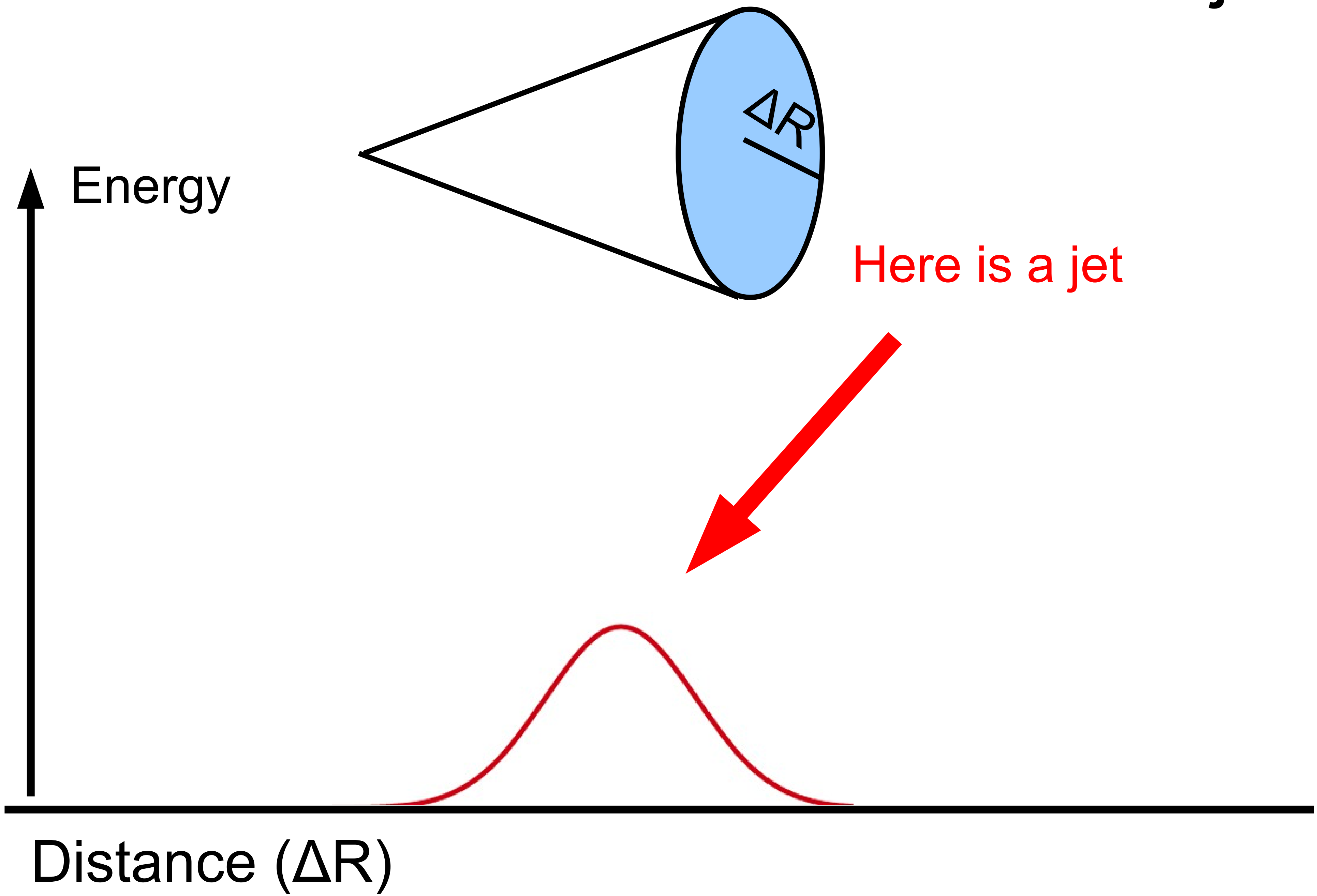
Dealing w/PU or UE :

Key questions :

What happens to a jet in pileup?
What is the composition of pileup?


Real Jets
Particles
Pileup Jets
Leptons
Pileup
(Resolution)
Least sensitive to PU
Most sensitive to PU
Missing E_T

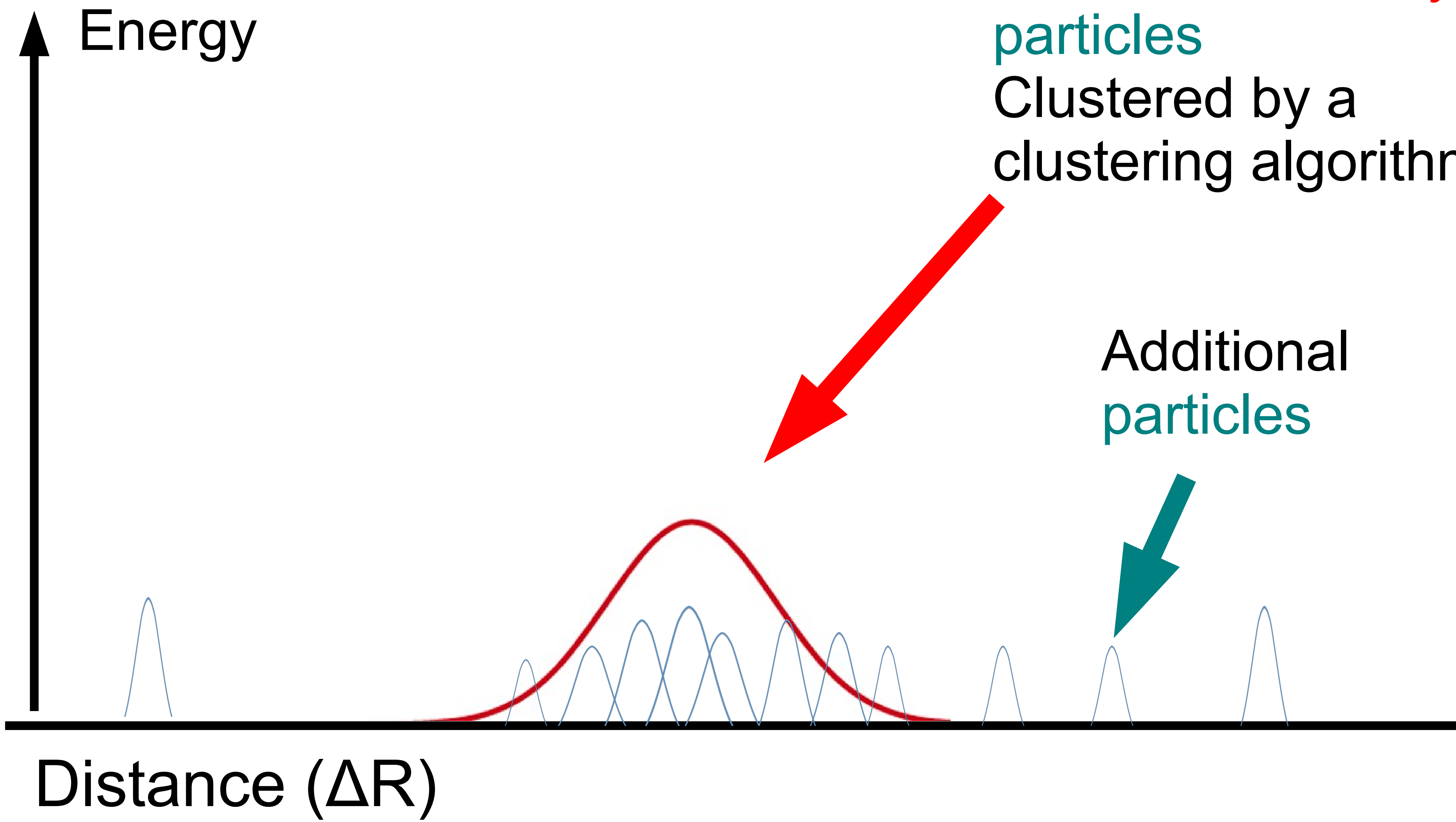
Consider a jet



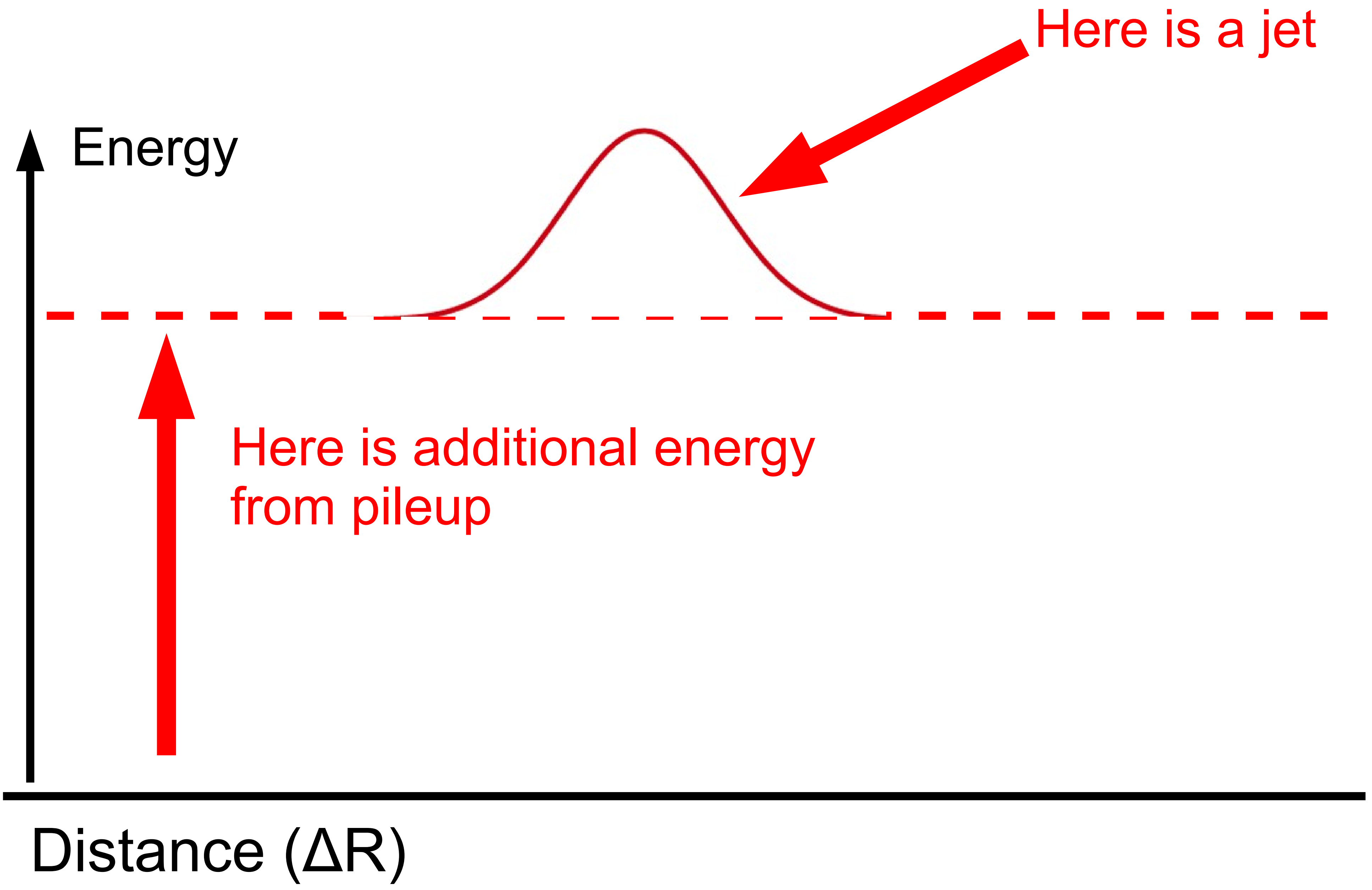
Consider a jet

It is made of many particles
Clustered by a clustering algorithm

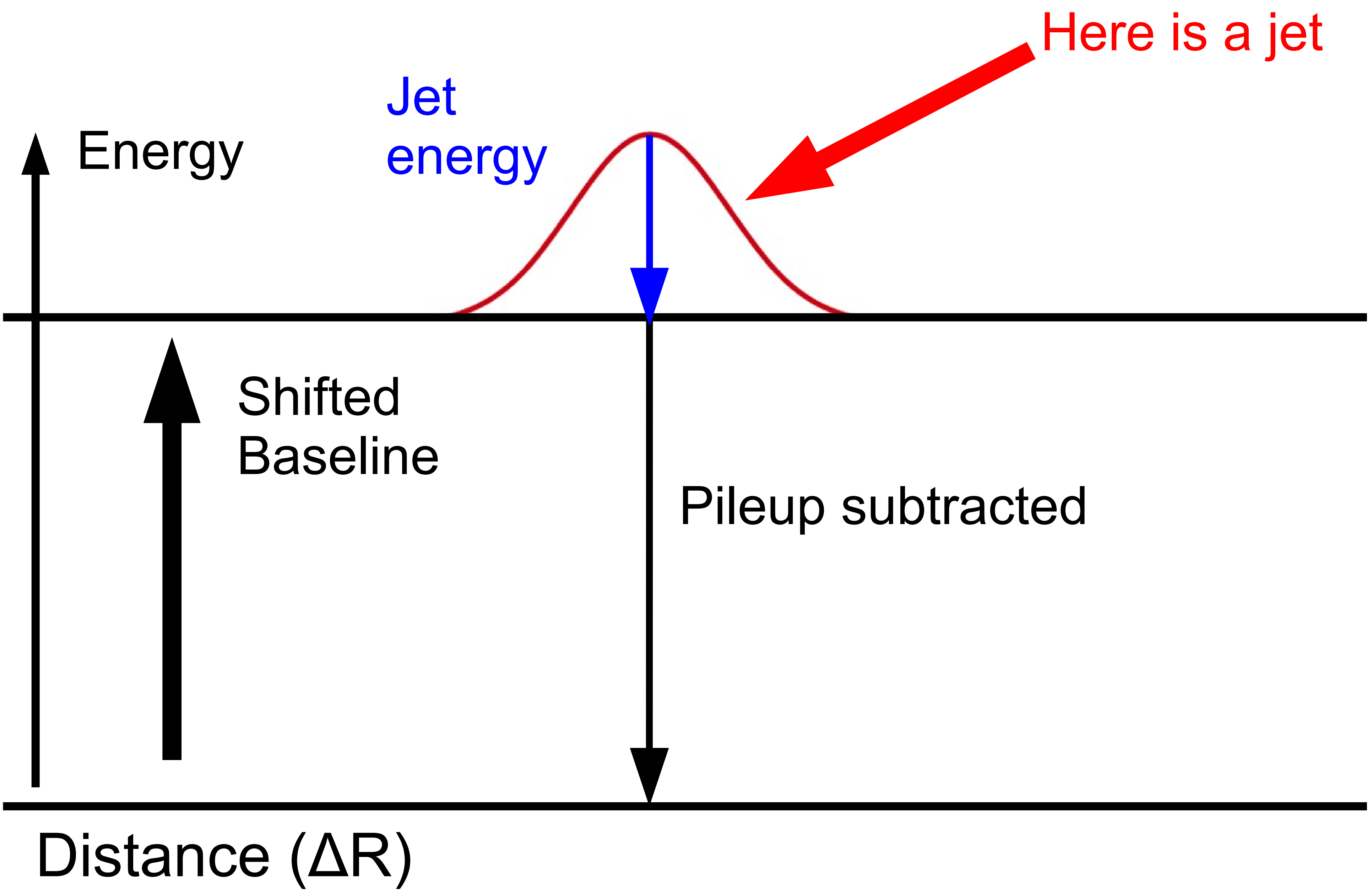
Additional particles



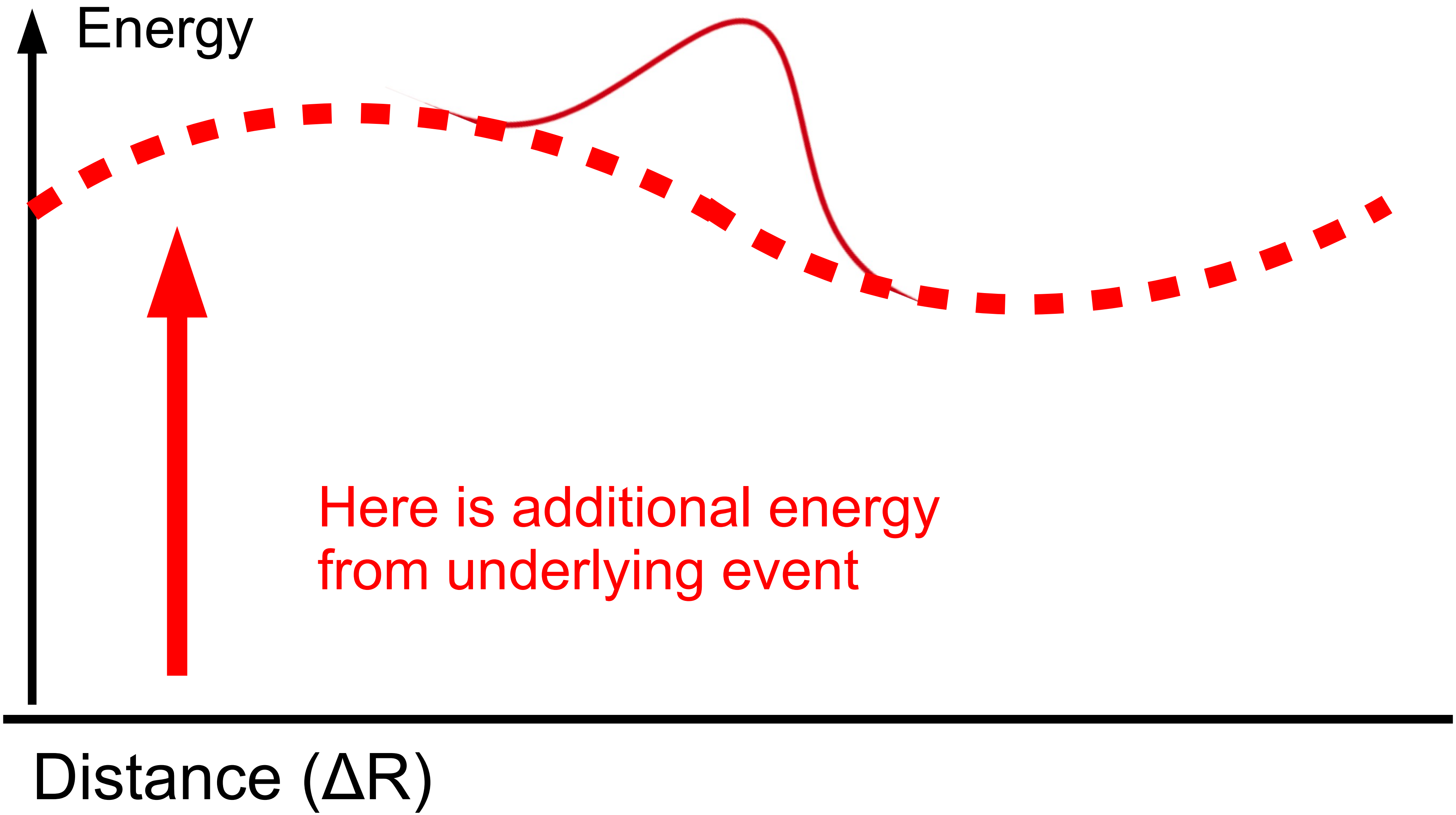
Consider a jet in high pileup



Consider a jet in high pileup

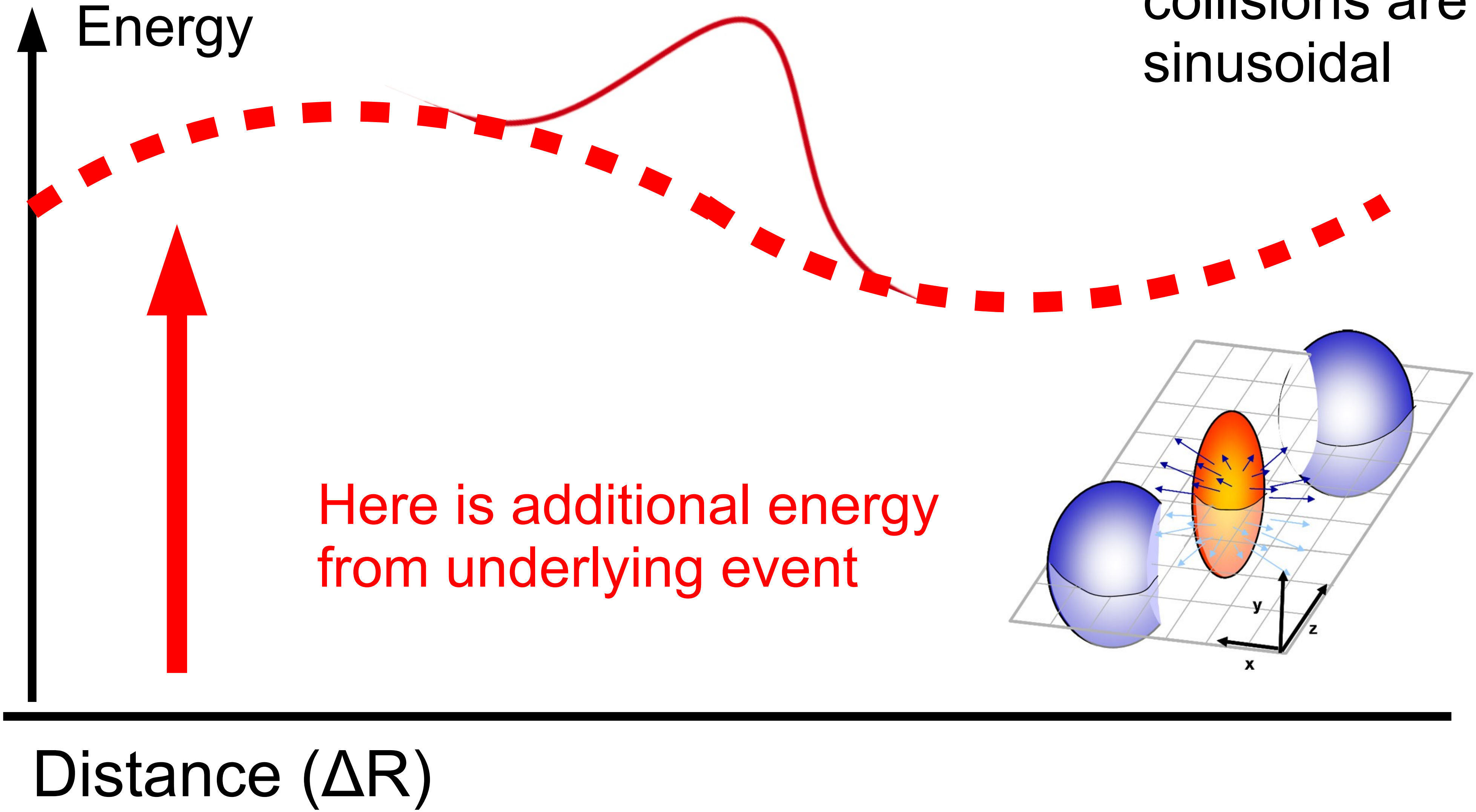


Consider a jet in Heavy Ions

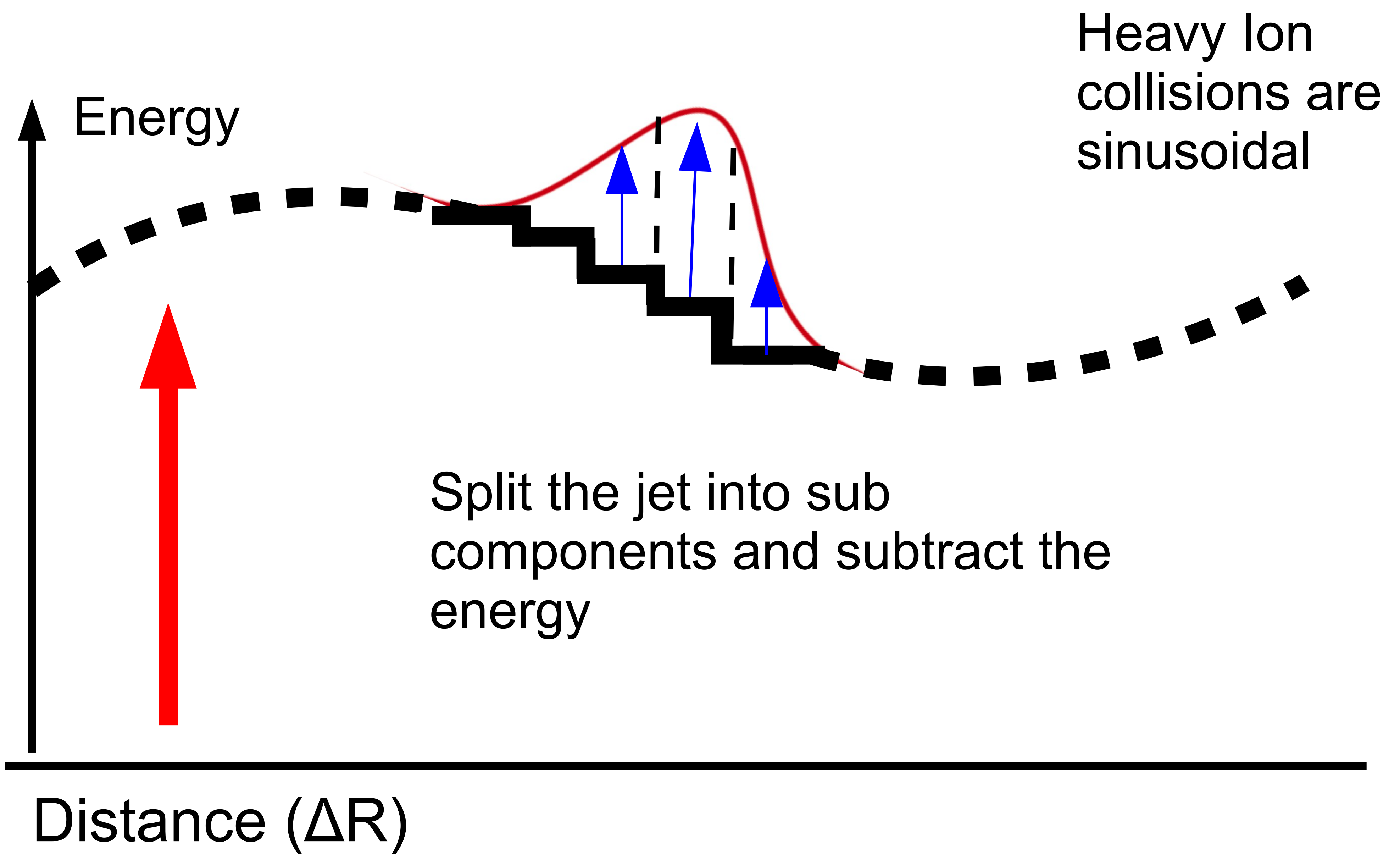


Consider a jet in Heavy Ions

Heavy Ion collisions are sinusoidal

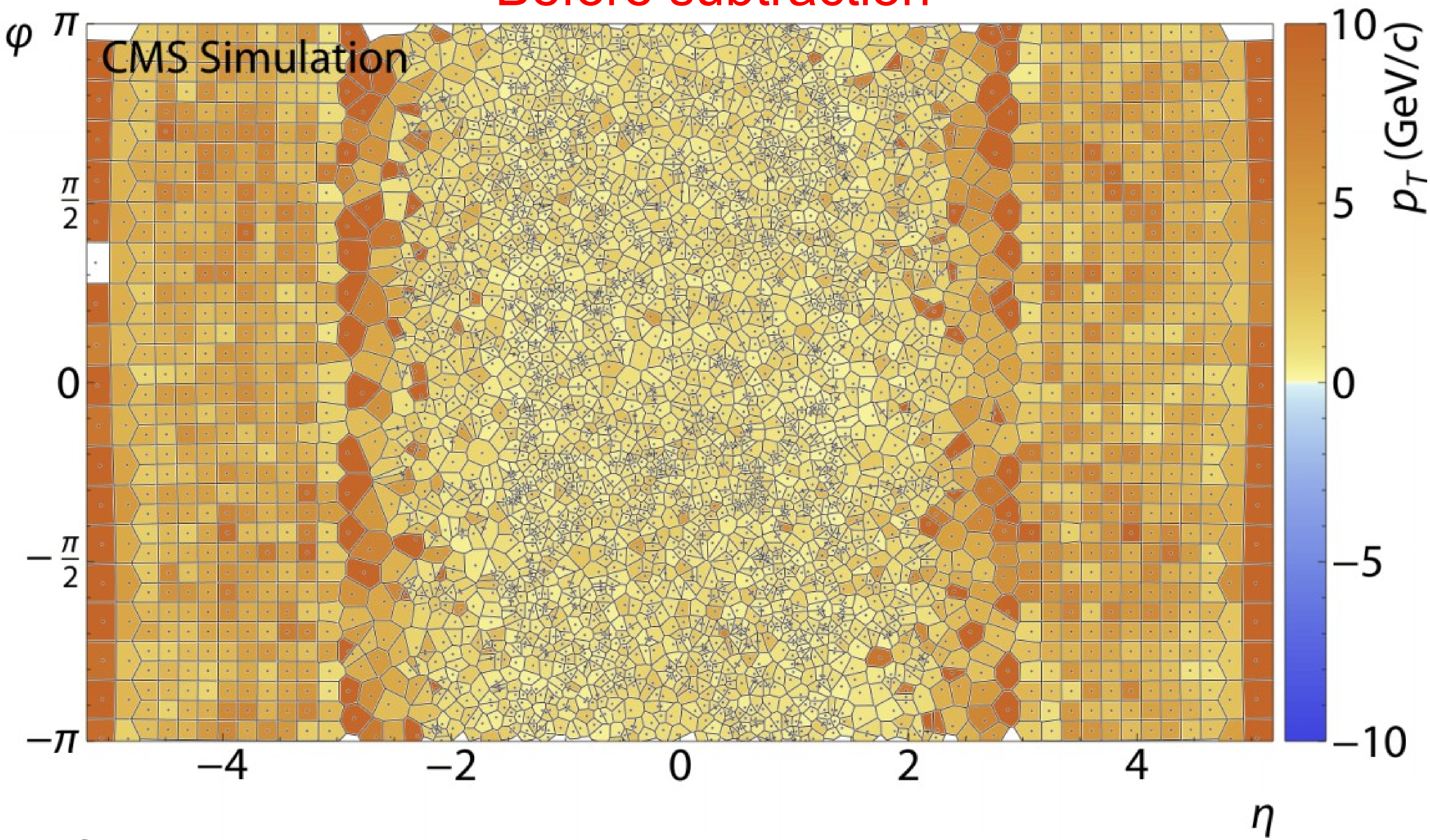


Consider a jet in Heavy Ions



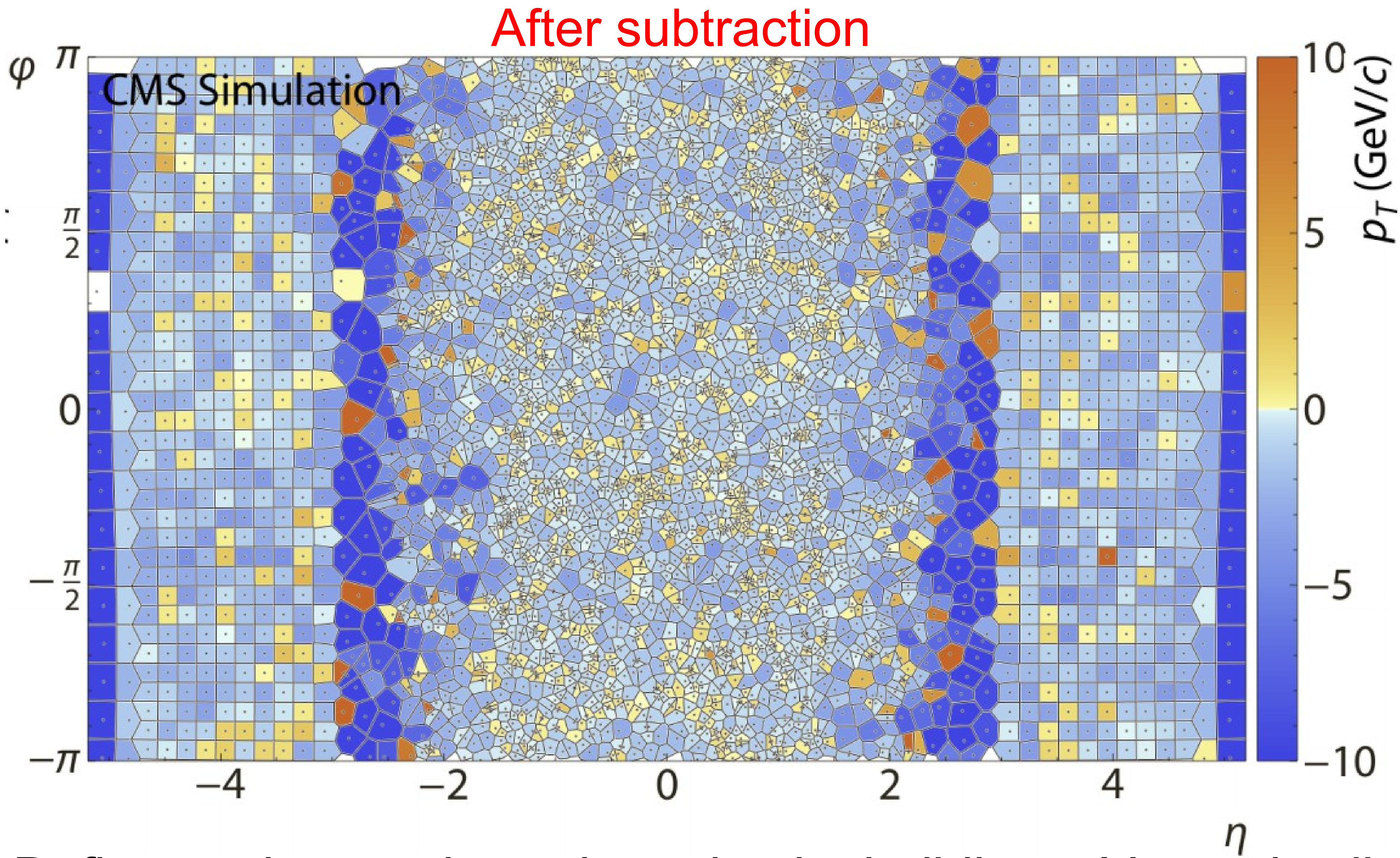
Led to HF/Voronoi Method

Before subtraction



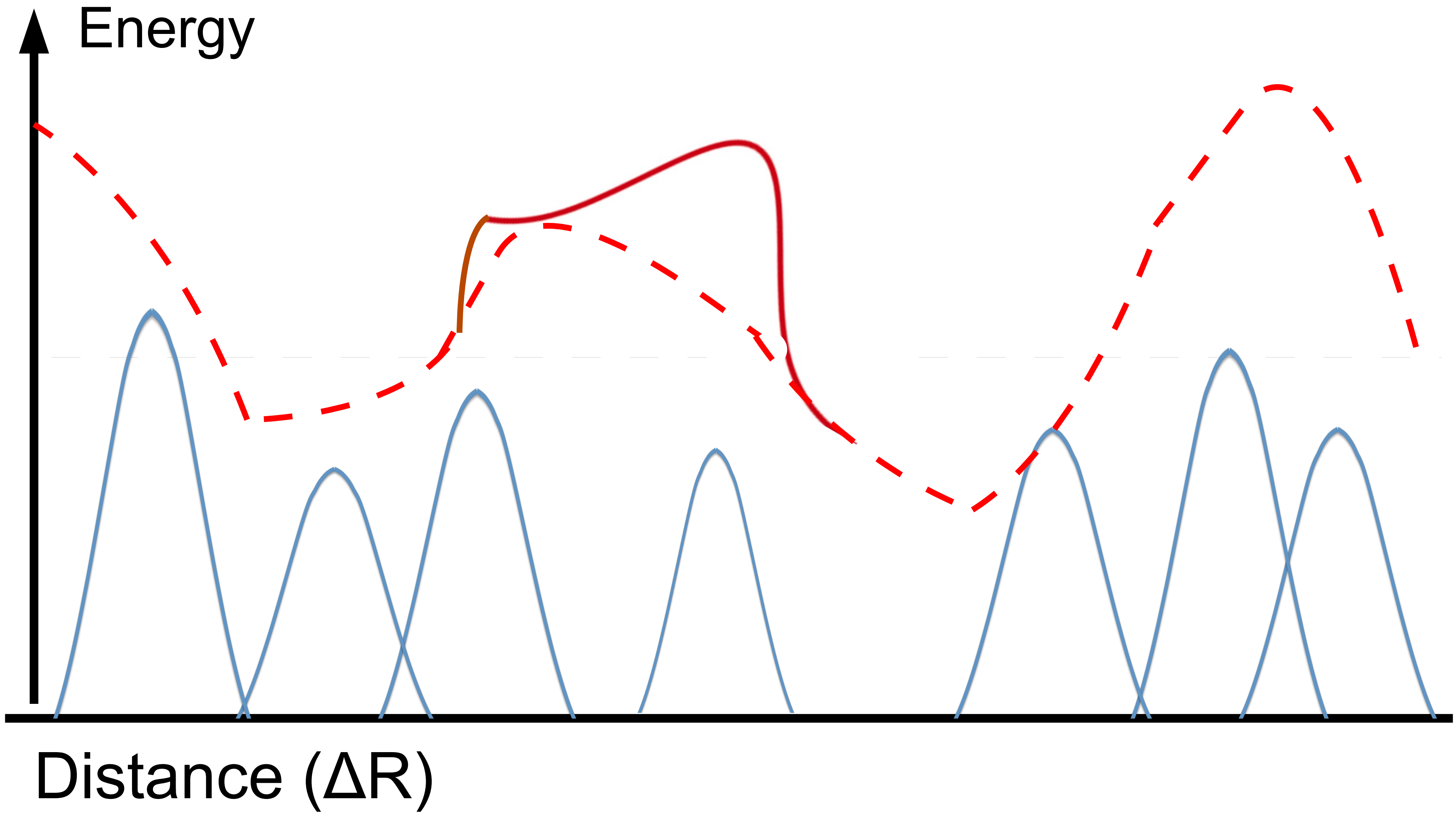
Define each stepwise subtraction by building a Voronoi cell

Led to HF/Voronoi Method

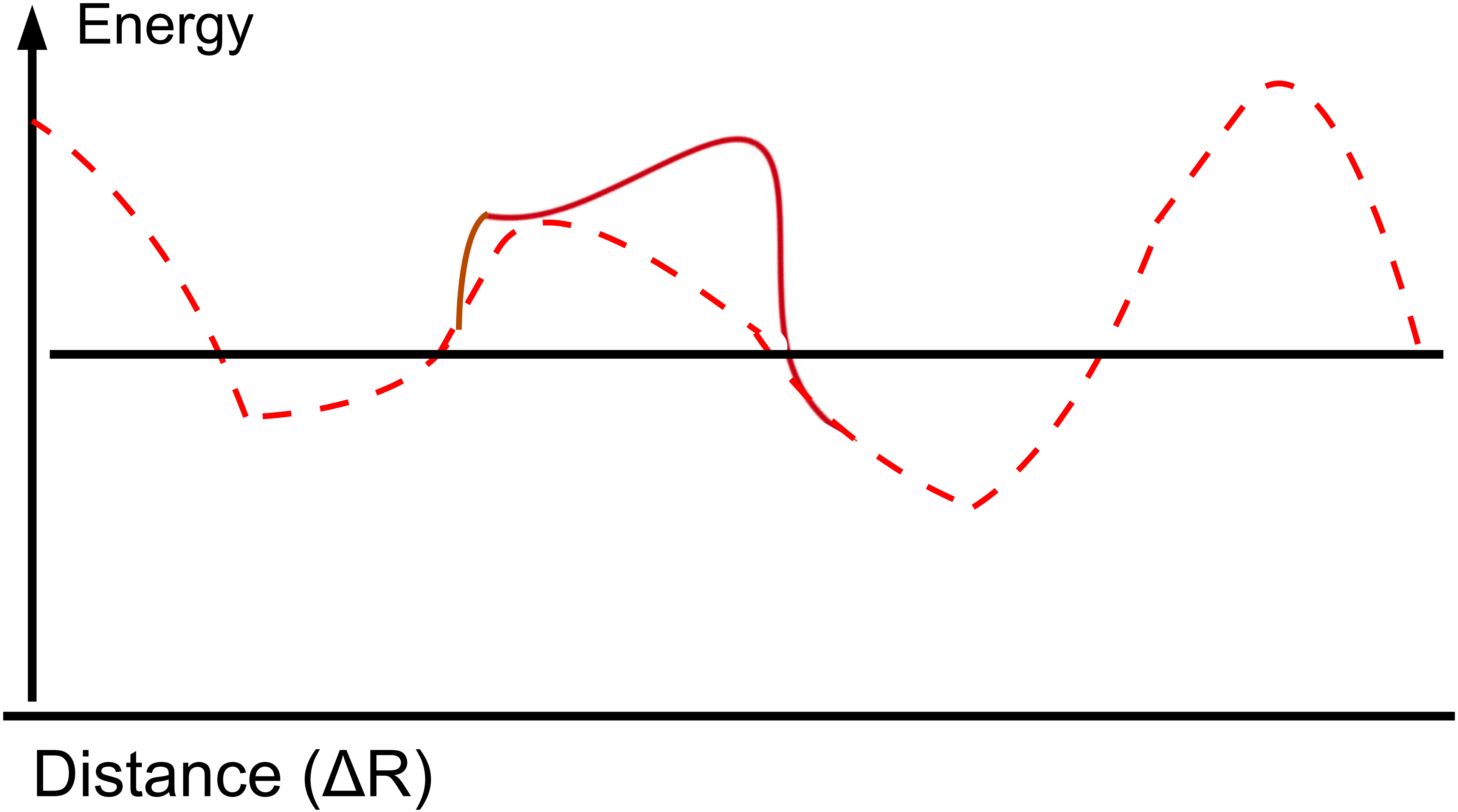


Define each stepwise subtraction by building a Voronoi cell

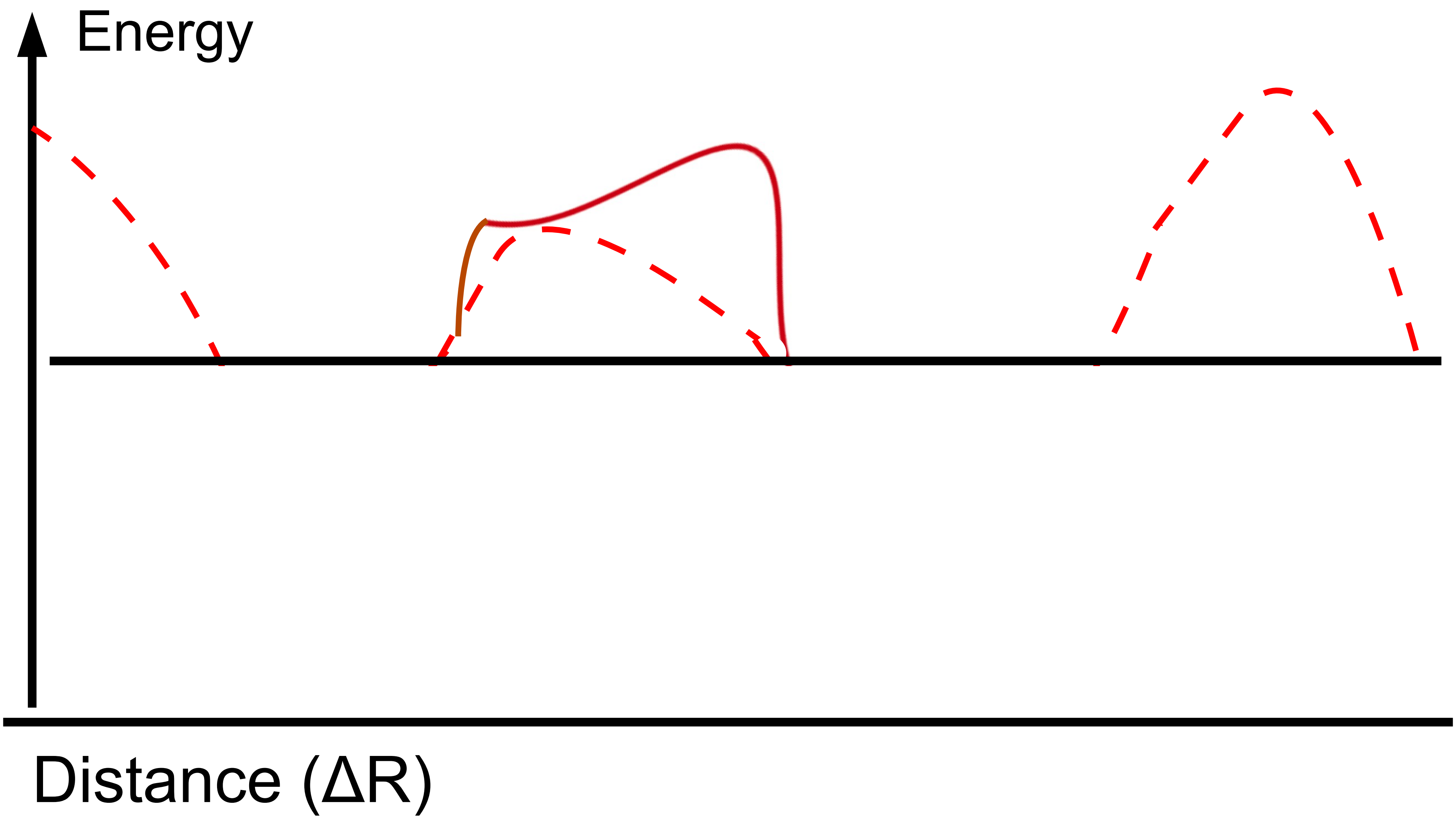
A jet in realistic pileup



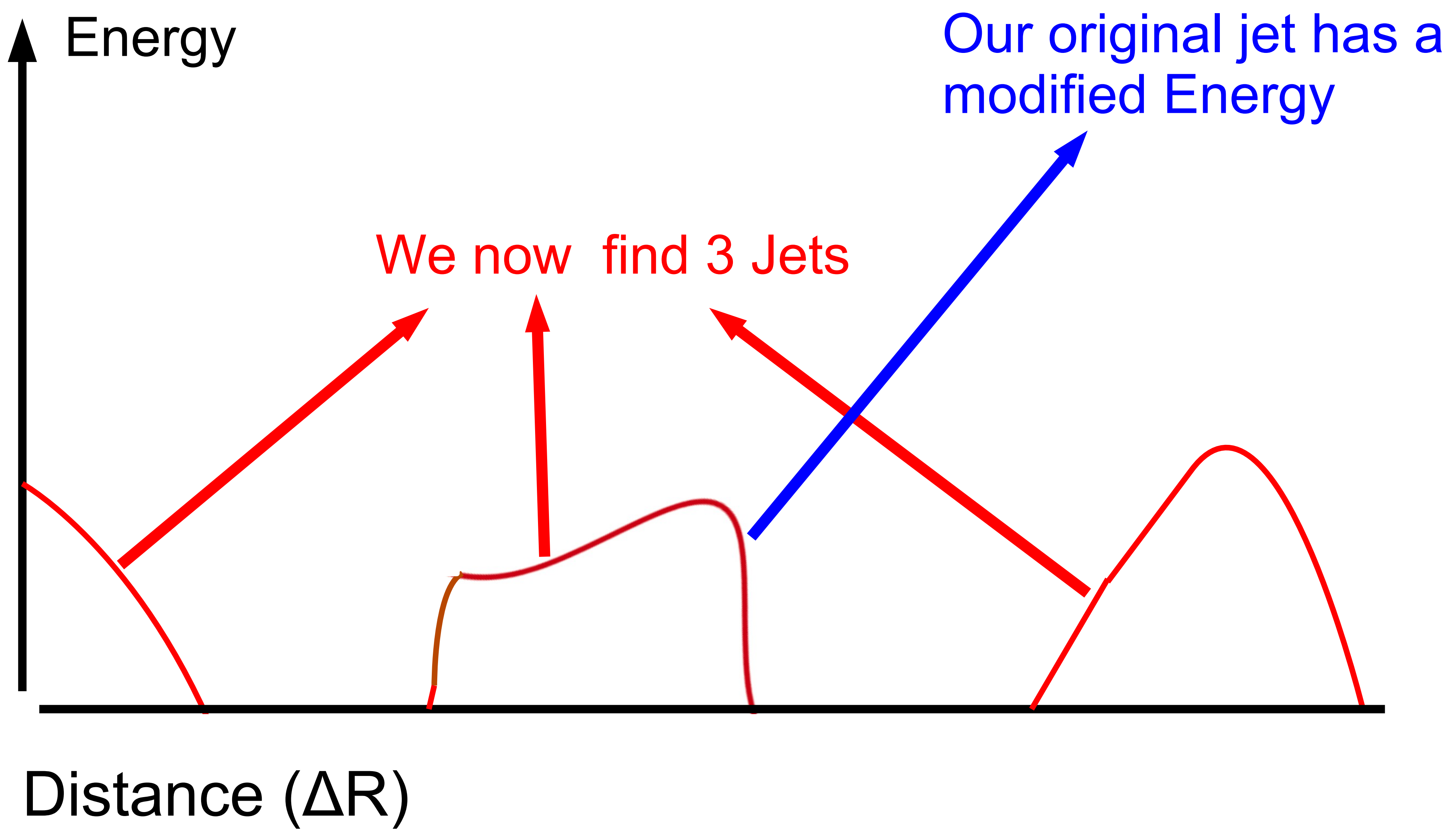
Conventional subtraction



Conventional subtraction



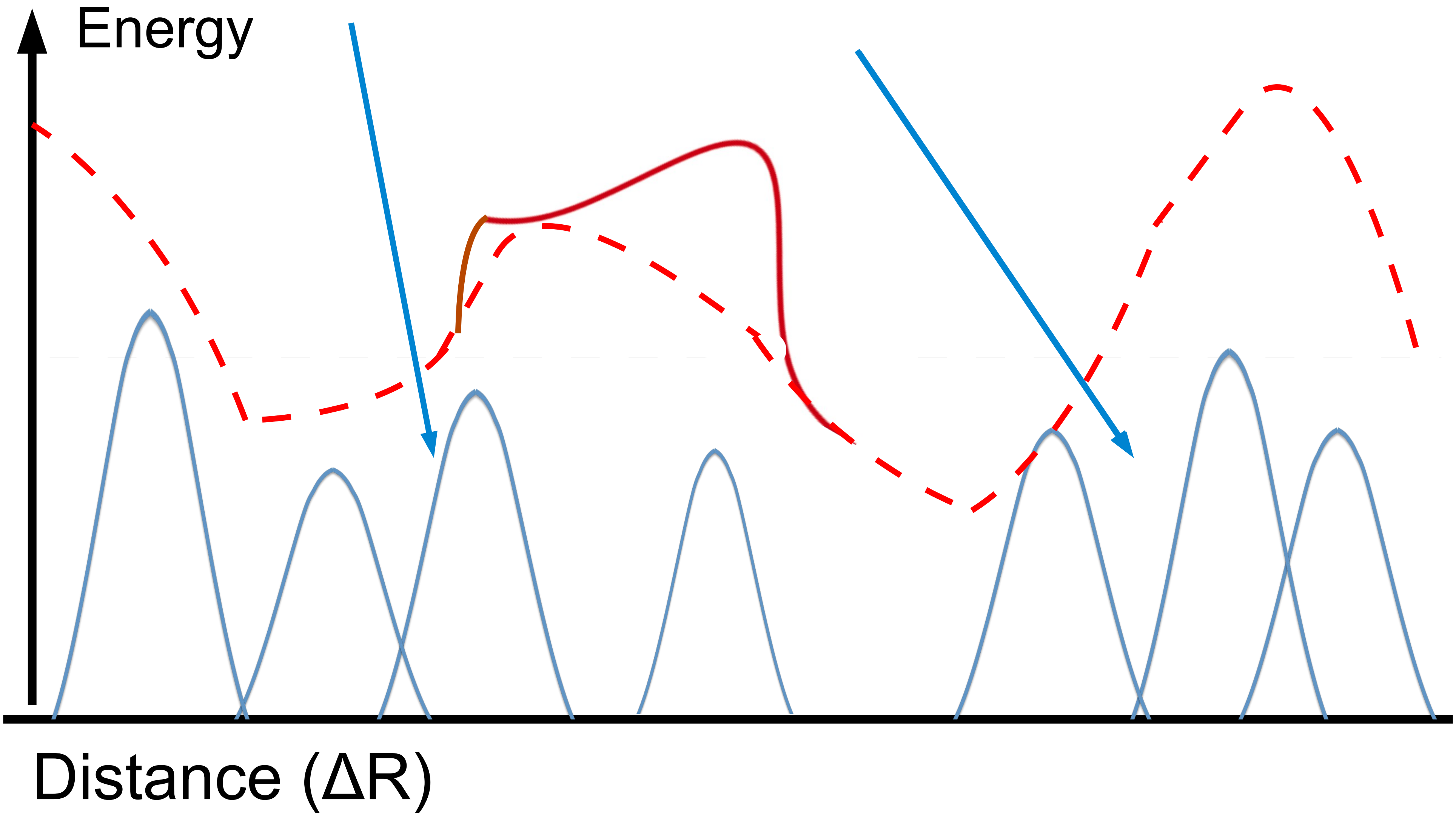
Conventional subtraction



Conventional subtraction

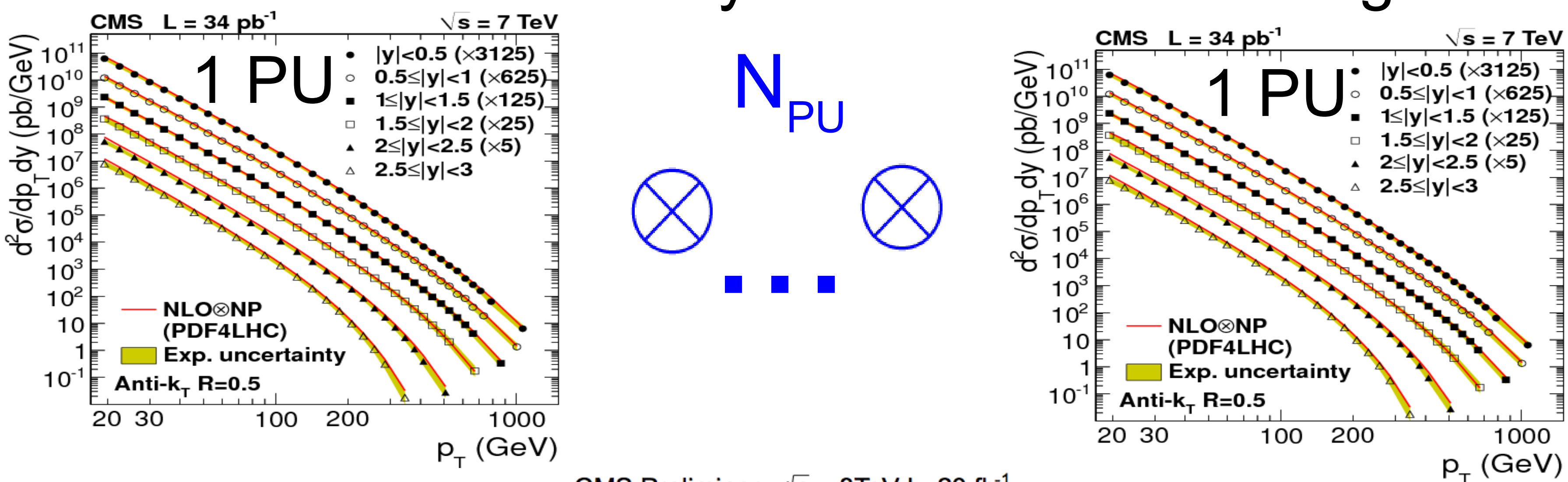
Lets back track

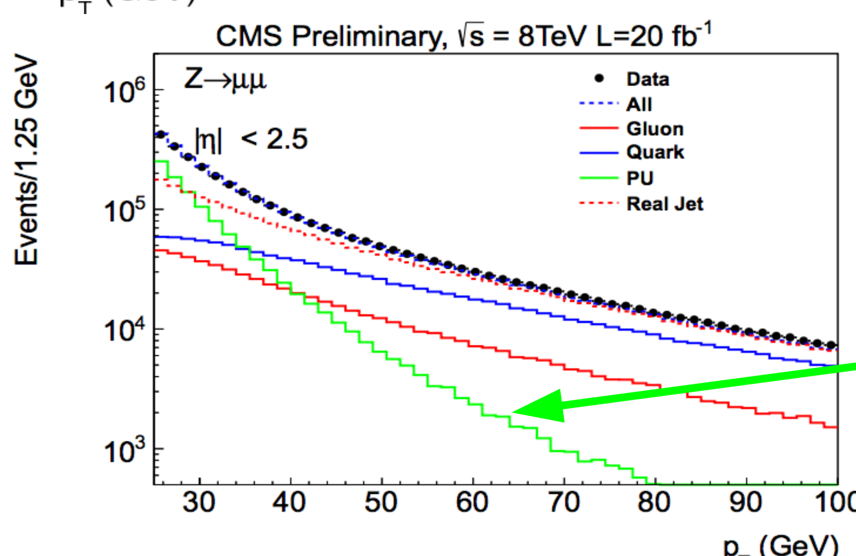
What is the composition of the pileup?



Composition of pileup

- Every collision starts with quarks
  - This leads to jets in the final state
  - Now combine many different collisions together



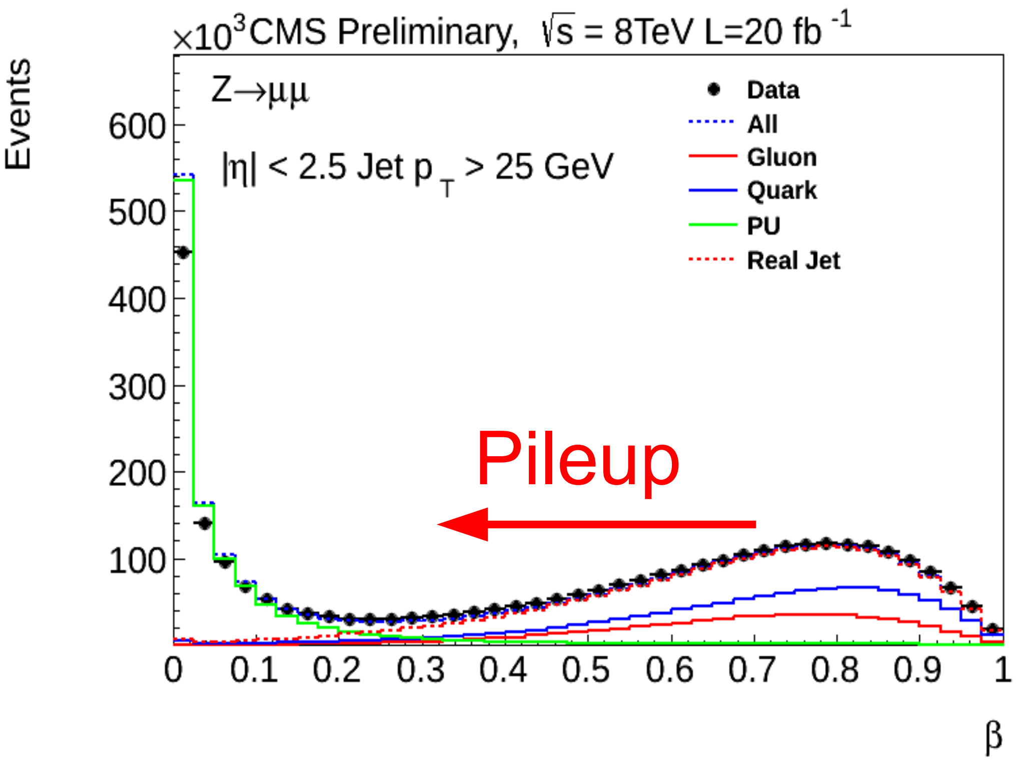


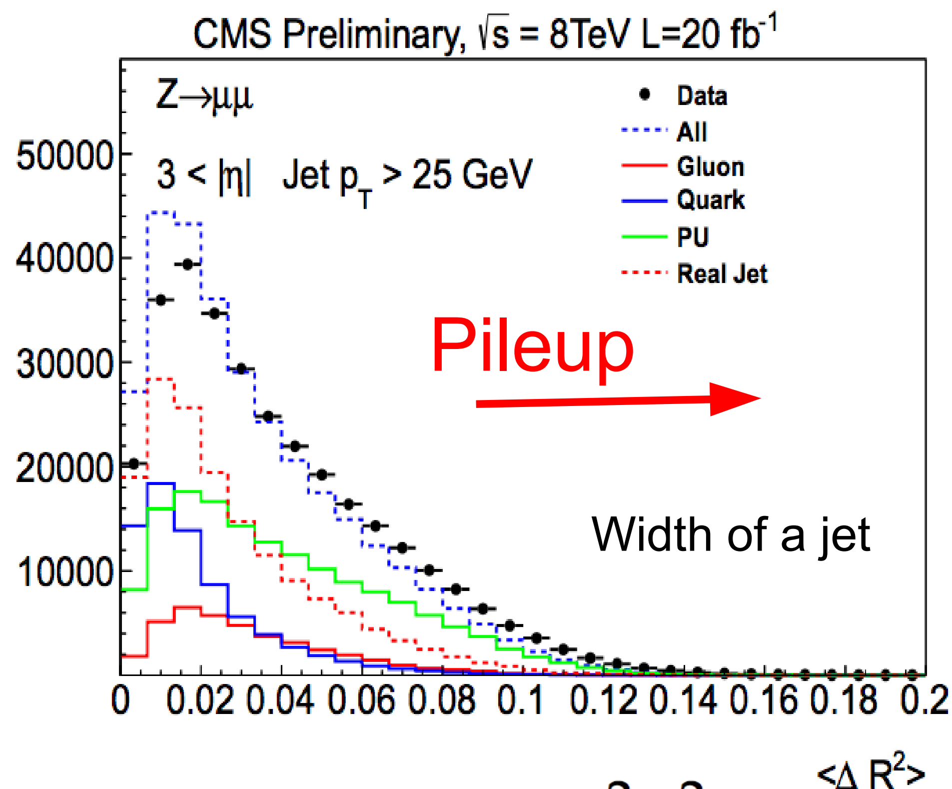
Jets overlapping
Gives pileup jets

CMS-JME-13-005

Identifying pileup jets

- Can identify pileup jets by :
  - Jets that are associated to the primary vertex
  - Looking for objects that are wide(overlapping)

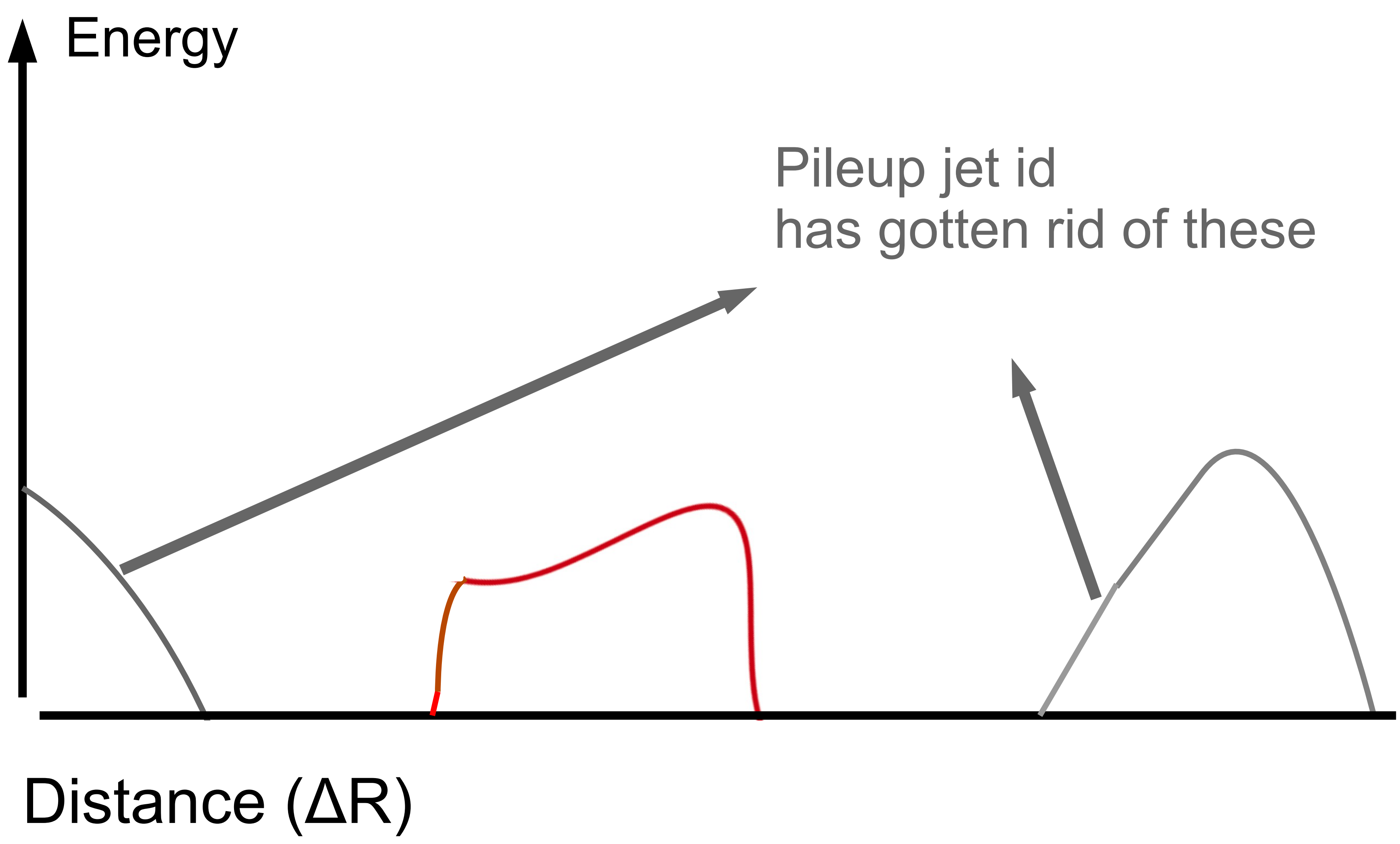




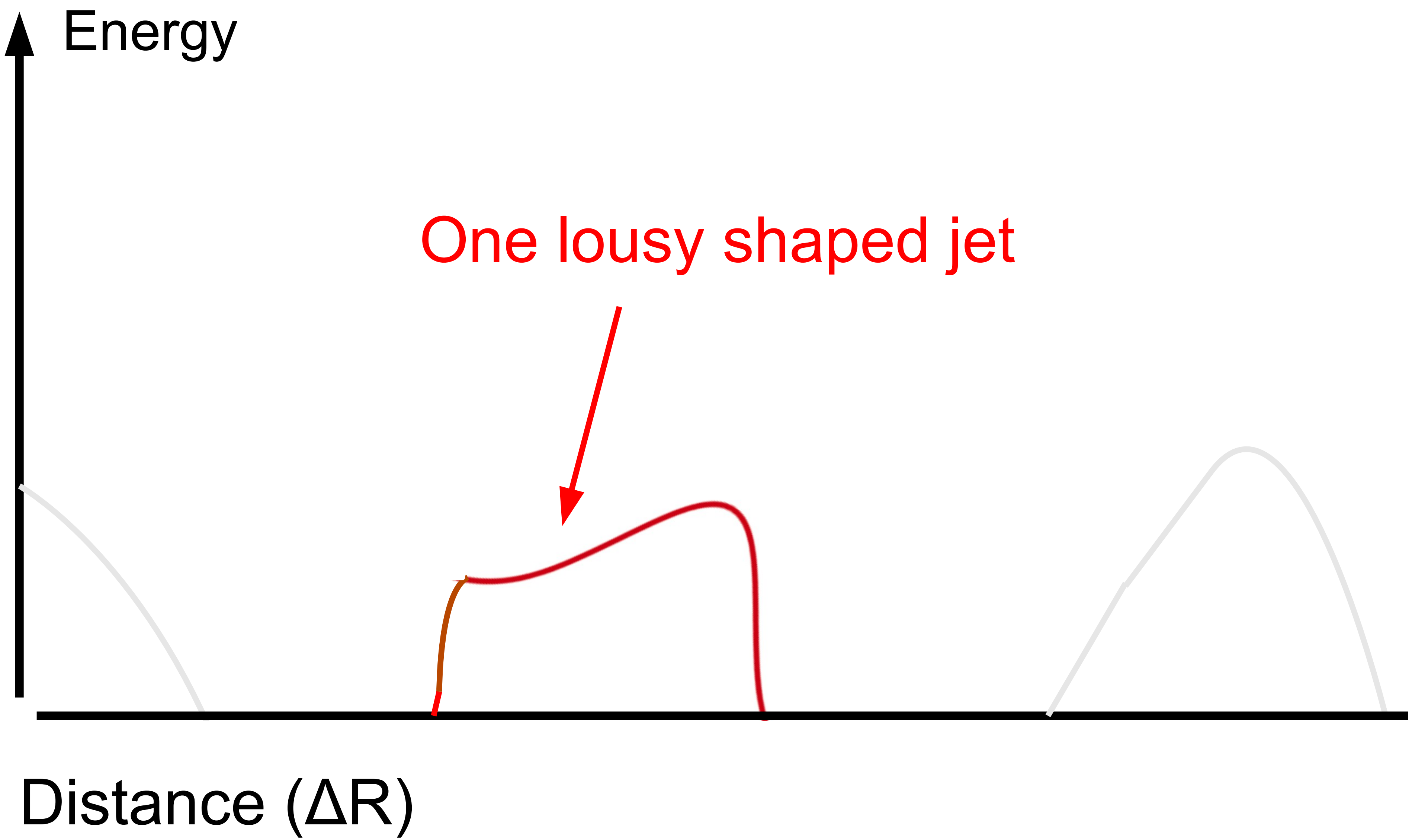
$$\beta = \frac{\sum_{i \in PV} p_{Ti}}{\sum_i p_{Ti}} \qquad \langle \Delta R^2 \rangle = \frac{\sum_i \Delta R_i^2 p_{Ti}^2}{\sum_i p_{Ti}^2}$$

CMS-JME-13-005

Pileup Jet Id Effect



State of the art one year ago



What if we could fix this?

- Consider merging two concepts together

HF/Voronoi
(Particle level subtraction)

Pileup Jet Id
(Discriminating against Pileup)

PileUp Per Particle Id
(Pileup discrimination per particle)

What if we could fix this?

- Consider merging two concepts together

HF/Voronoi
(Particle level subtraction)

Pileup Jet Id
(Discriminating against Pileup)

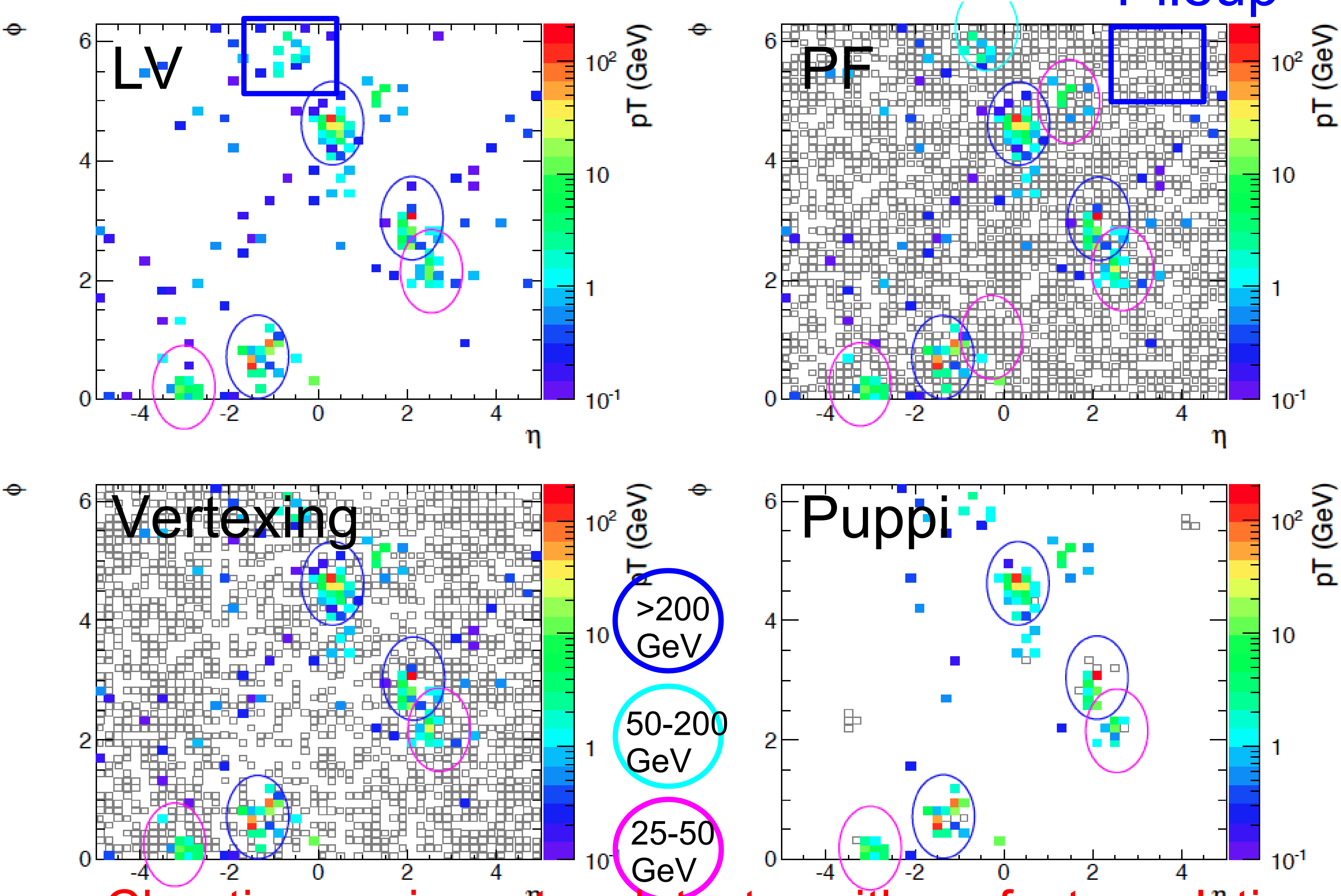
PileUp Per Particle Id
(Pileup discrimination per particle)

JHEP 1410 (2014) 59
http://arxiv.org/pdf/1407.6013.pdf

An example event

Real event

Pileup

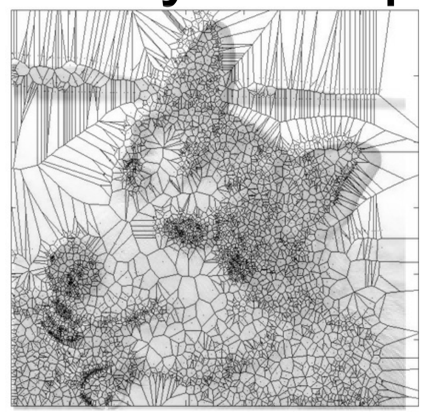


Cheating : using a toy detector with perfect resolution

Evolution of PU Subtraction

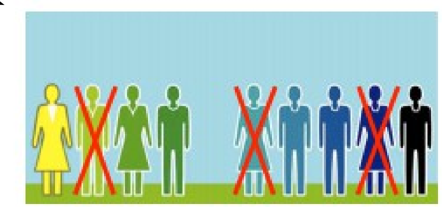
Aim is to remove pileup at particle level

Heavy Ion approach



HF Voronoi
Per-particle subtraction
Using voronoi cells

PUPPI
PU Jet id @particle level

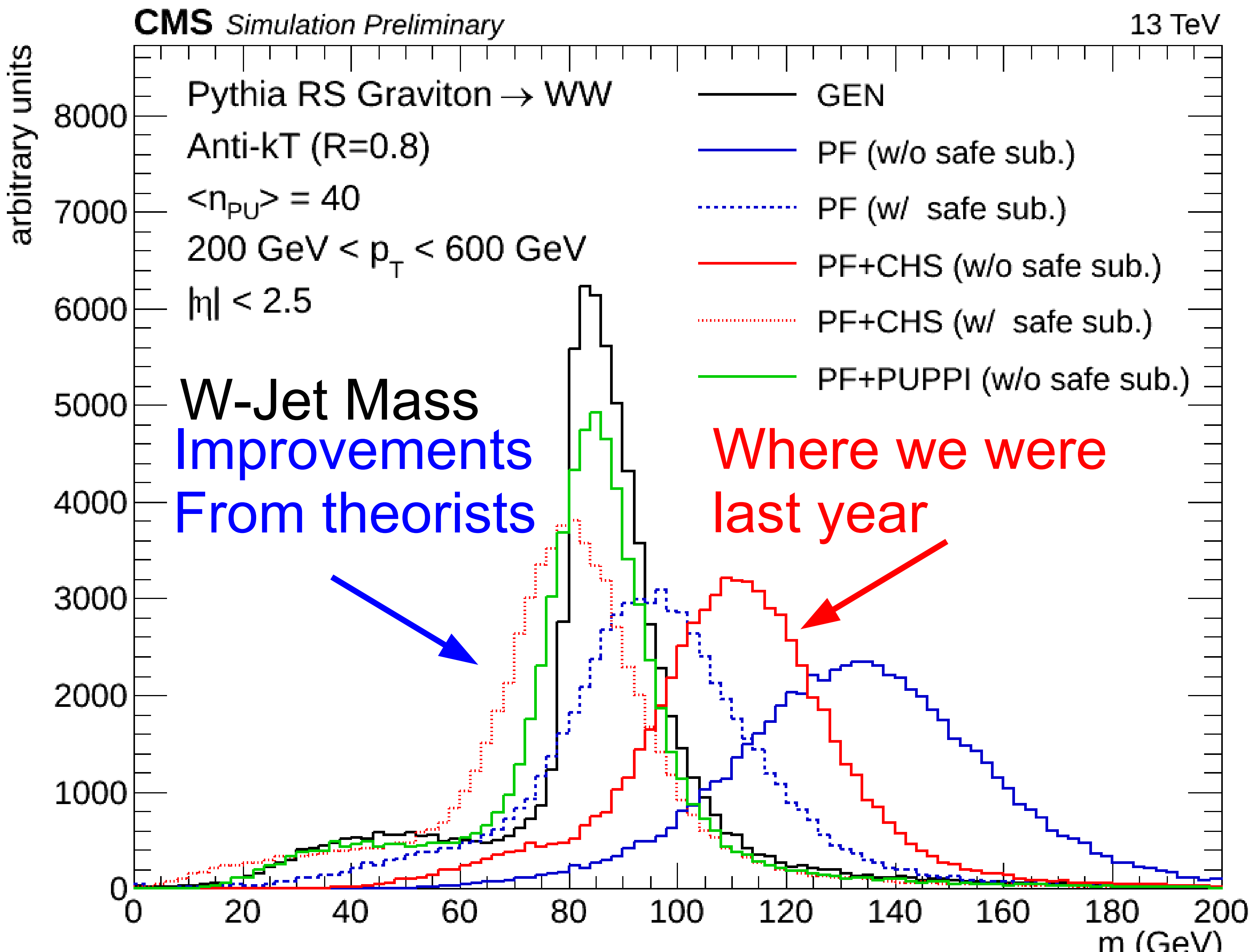


Constituent Subtraction
ρA correction per particle

Soft Killer
Median ρ removal
Per particle

JME-DP-13-018
JME-14-001

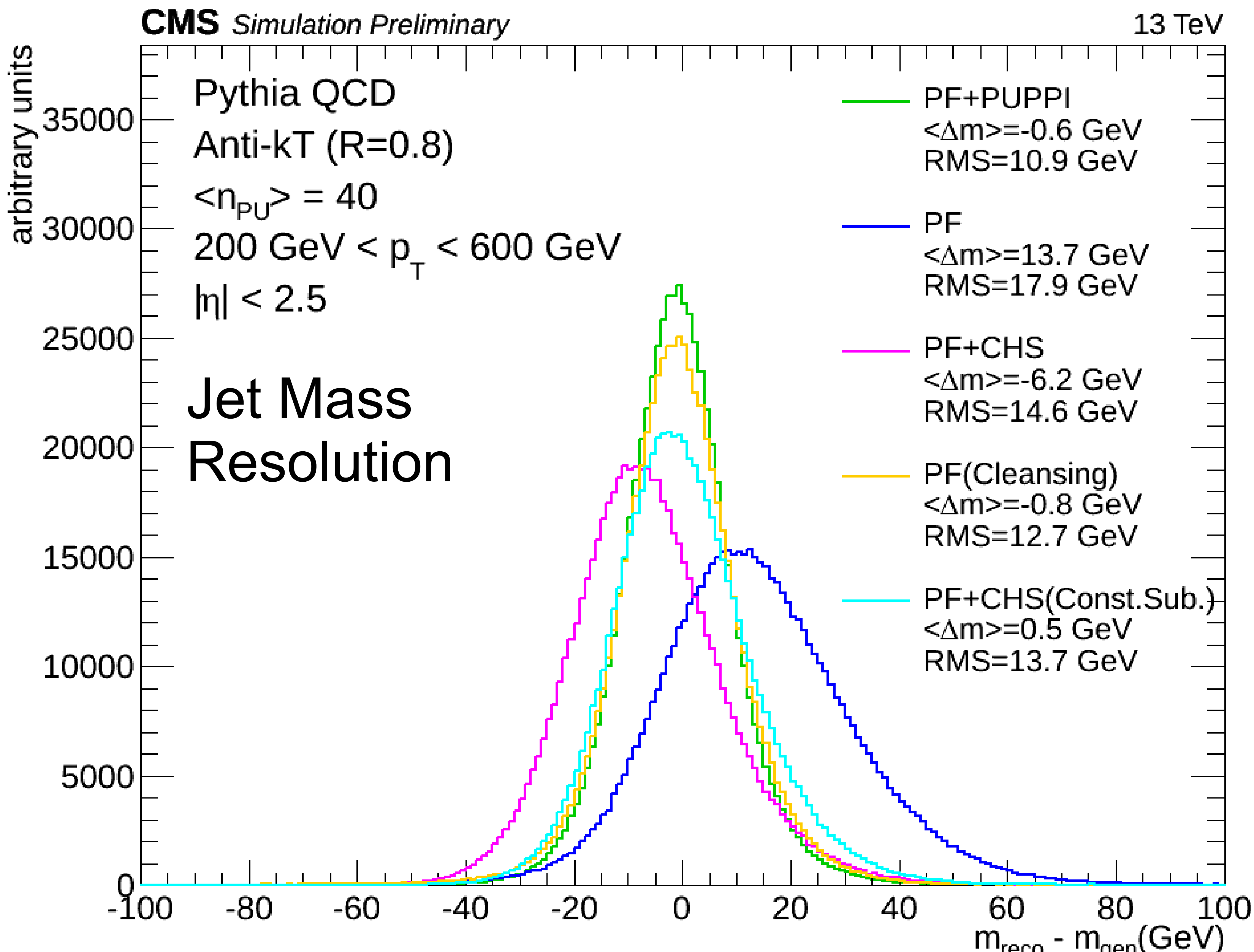
Jets in CMS



Baseline comparison is state of the art ρ subtraction

CMS-JME-14-001

Jets in CMS

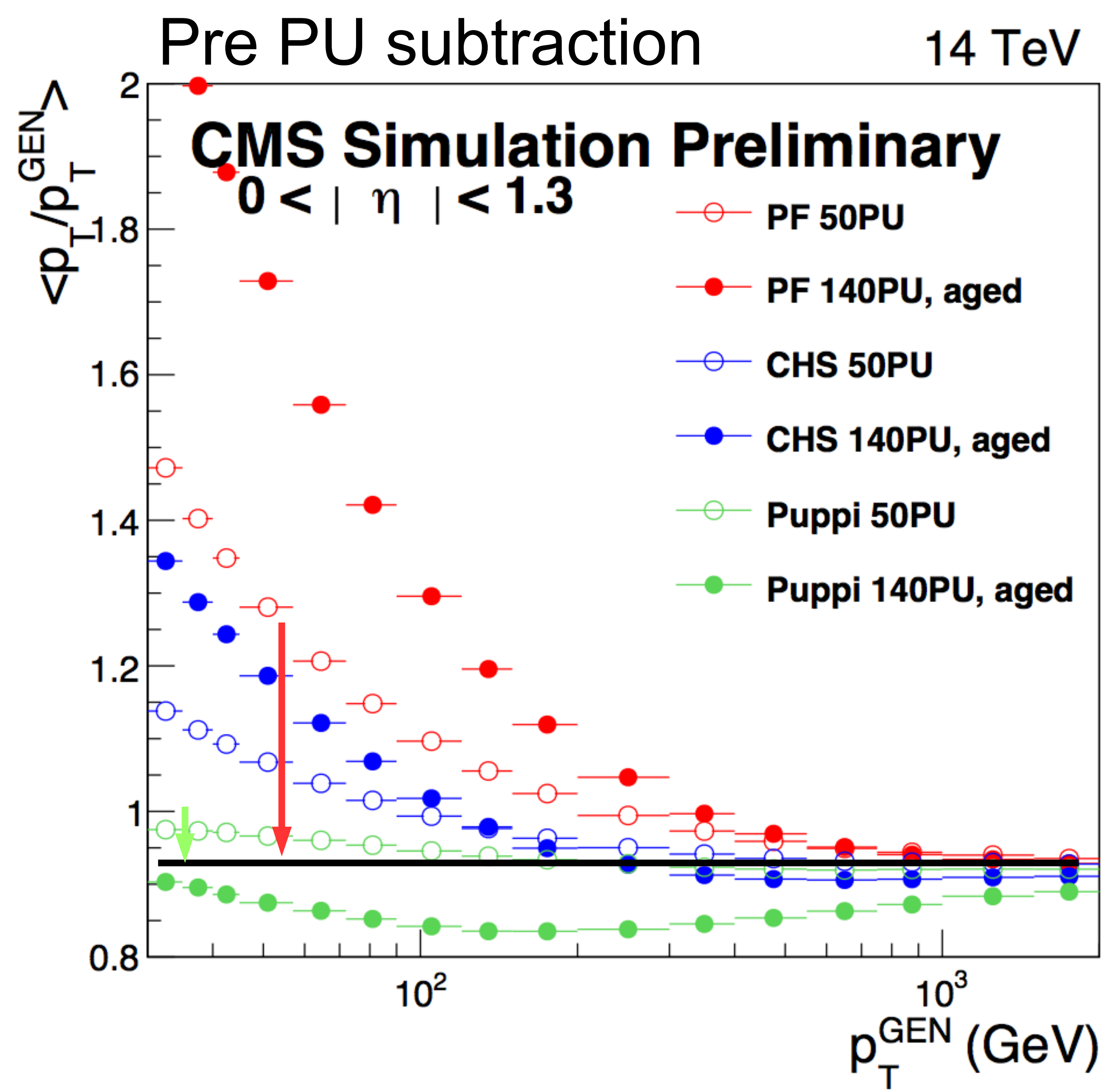


Mass resolution shows clear improvement (40 PU)

CMS-JME-14-001

Evolution of PU Subtraction

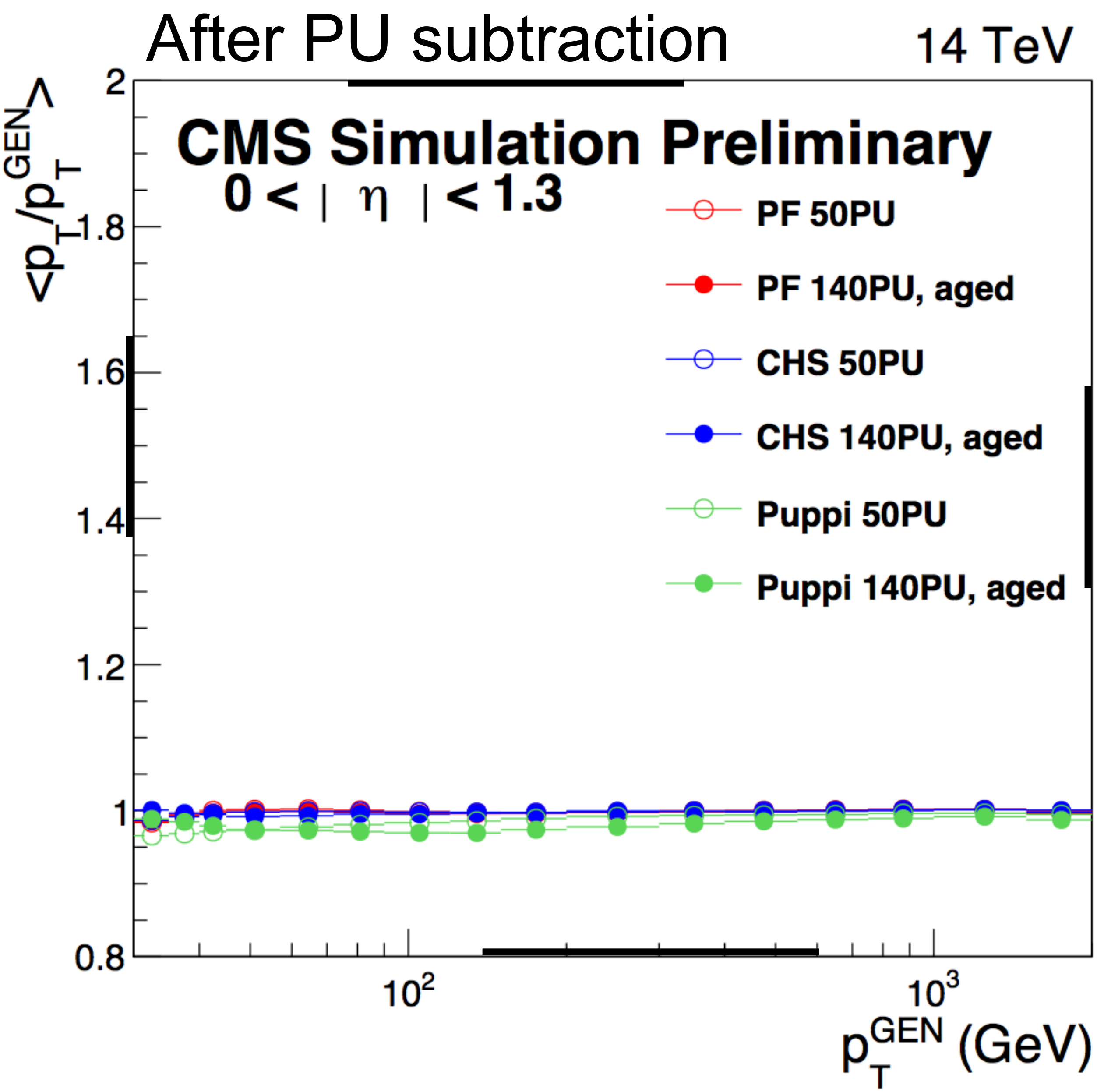
Aim is to remove pileup at particle level



FTR-ECFA

Evolution of PU Subtraction

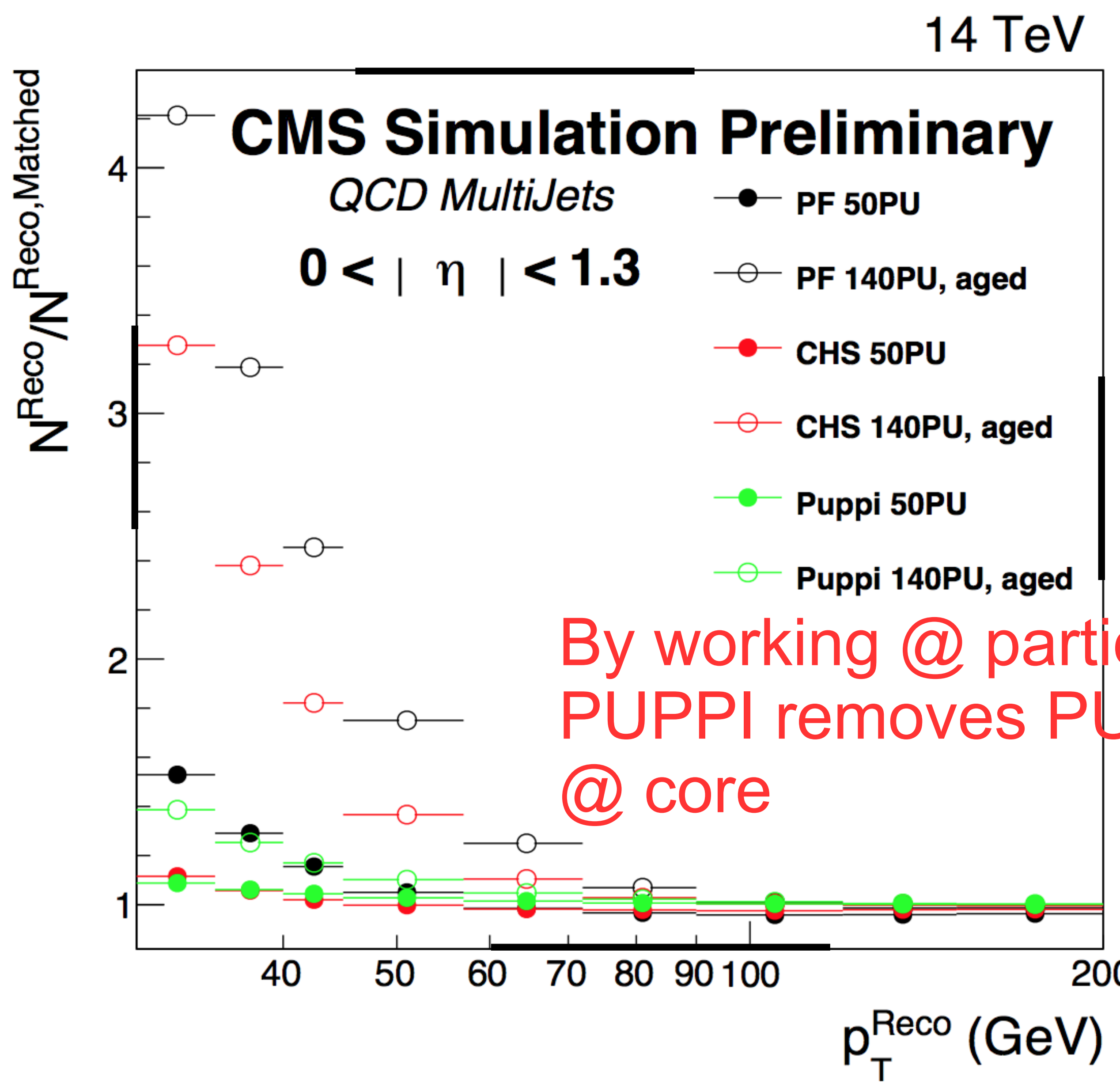
Aim is to remove pileup at particle level



FTR-ECFA

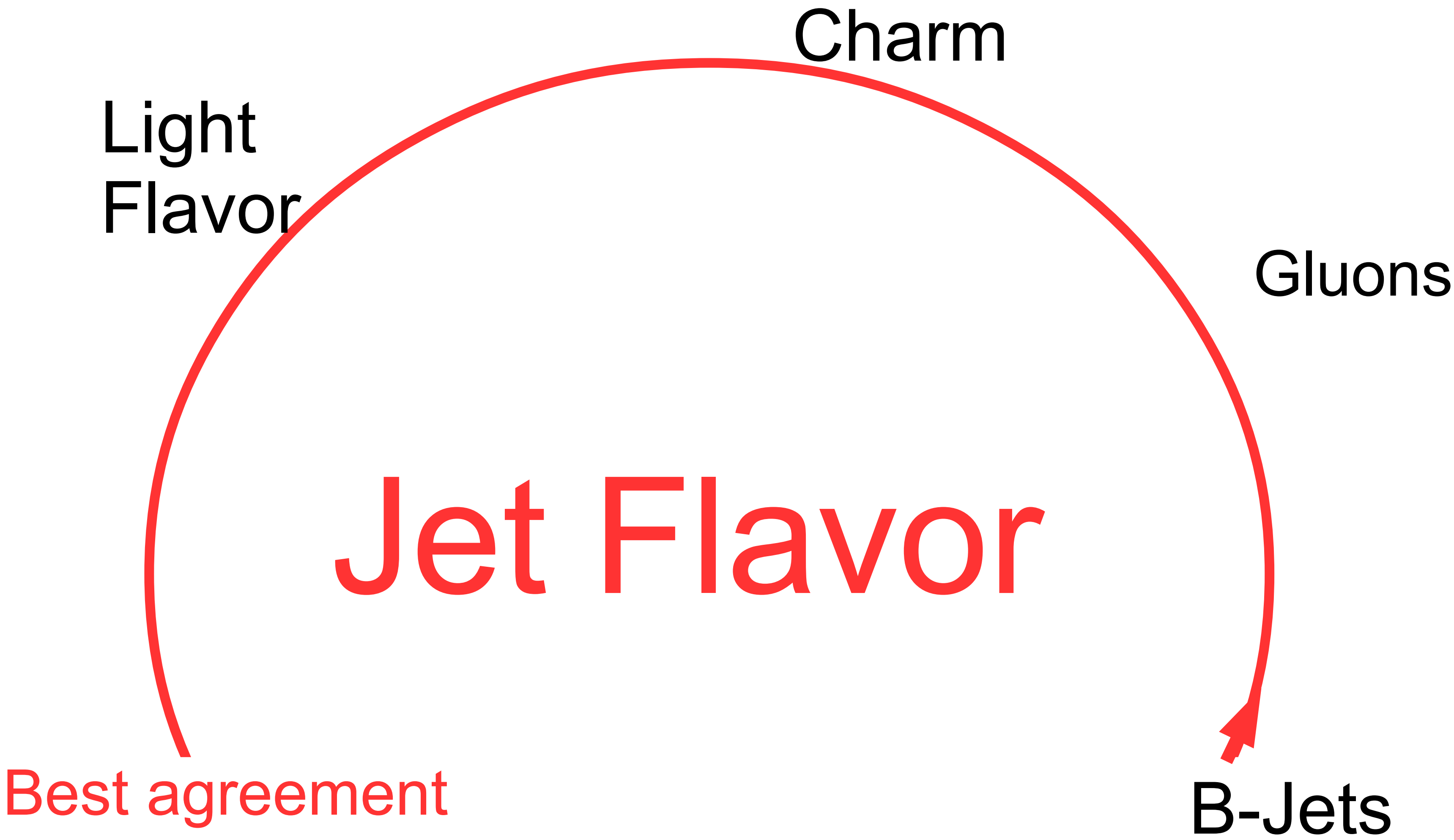
Evolution of PU Subtraction

Aim is to remove pileup at particle level



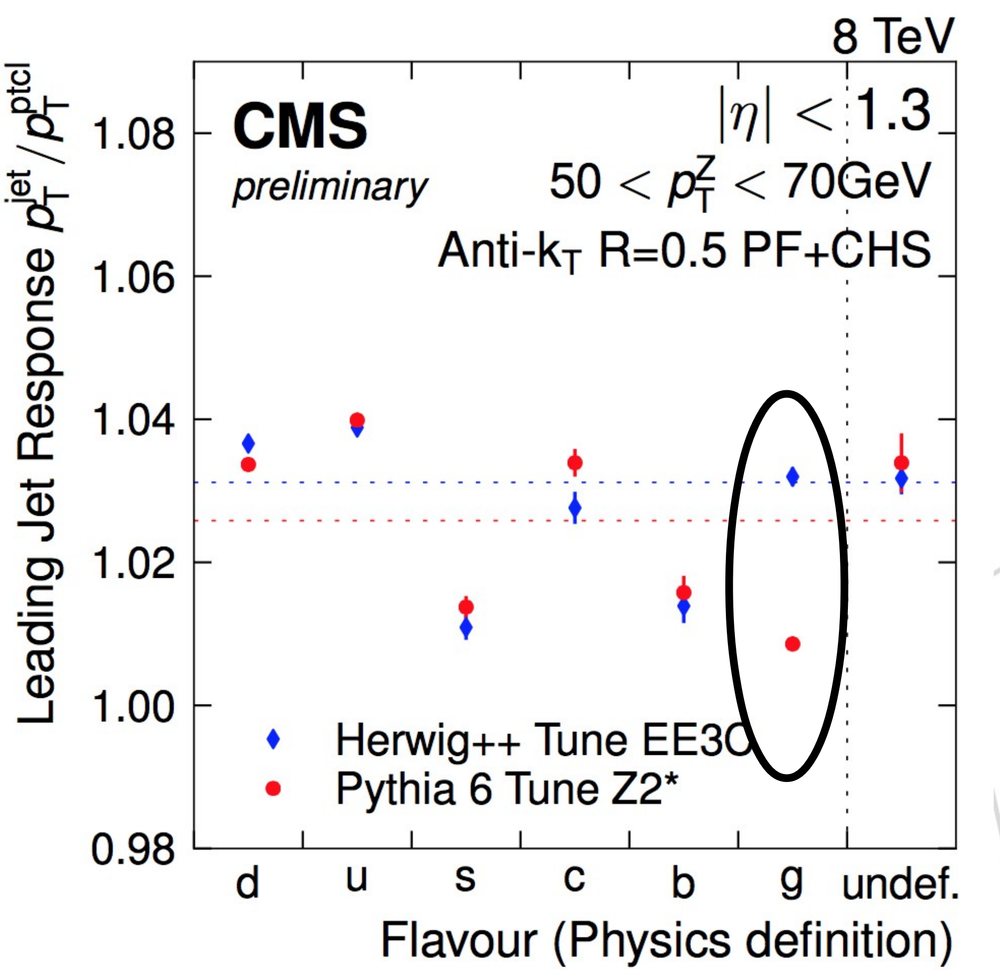
By working @ particle level PUPPI removes PU Jets @ core

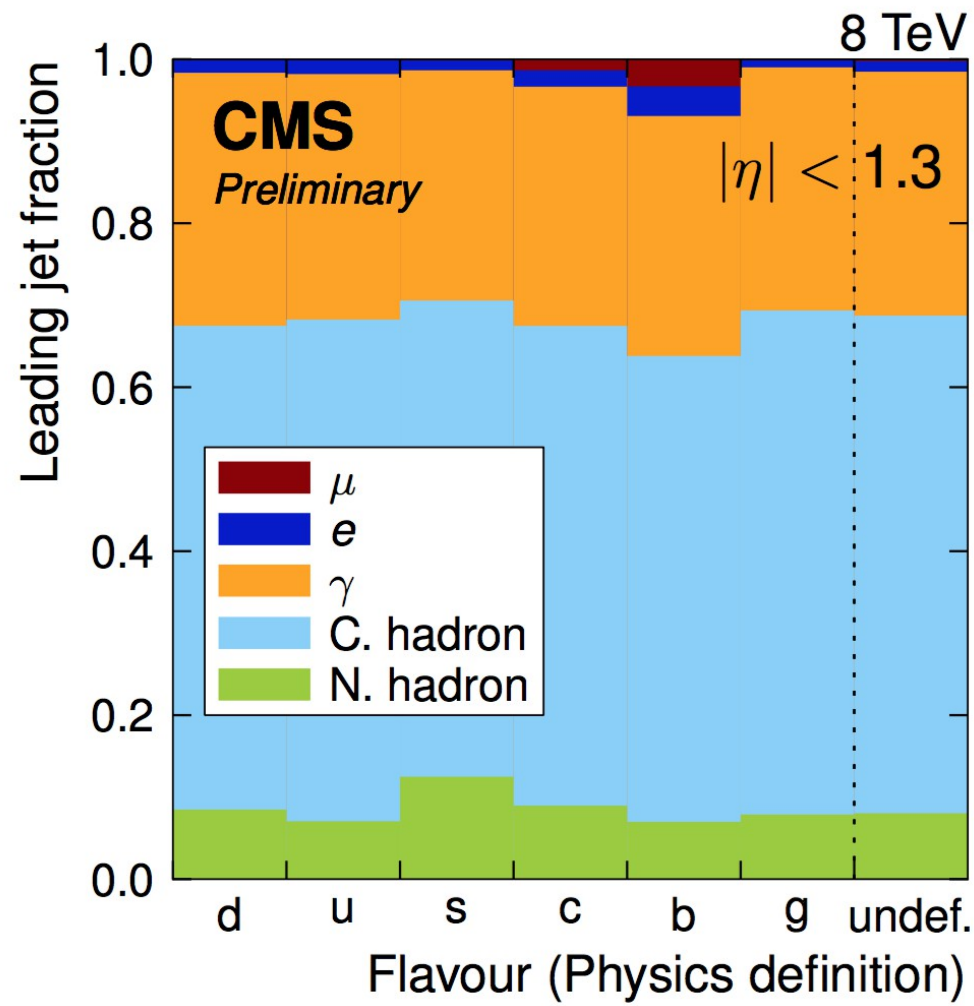
FTR-ECFA


Charm
Light
Flavor
Gluons
Jet Flavor
Best agreement
B-Jets

Splitting by Flavor

- Flavor is known to vary in response





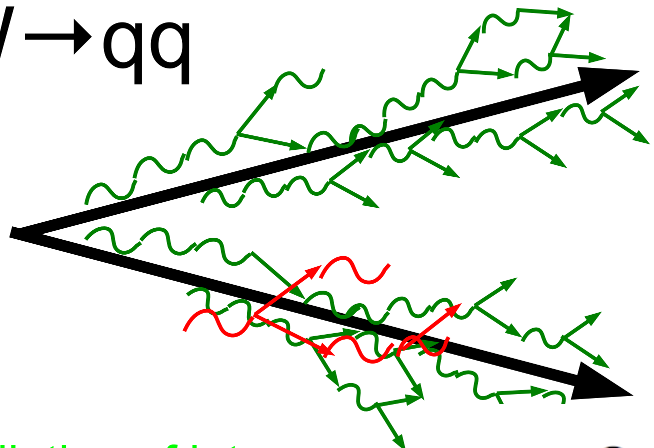
Isolating flavor based jet variations are key to beating down jet scale

CMS-JME-13-004

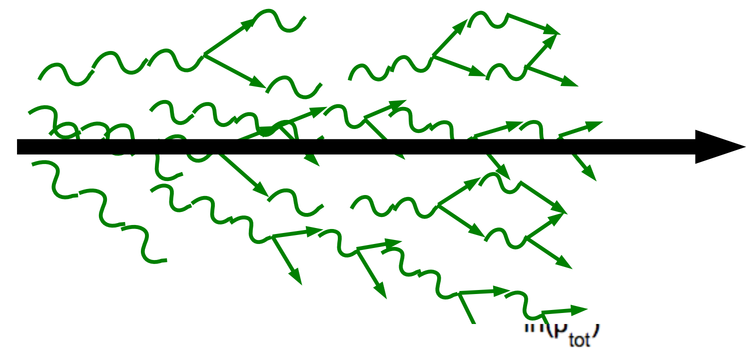
Jet Shape Polpuri

- Large amount of work to find two pronged jets

W→qq



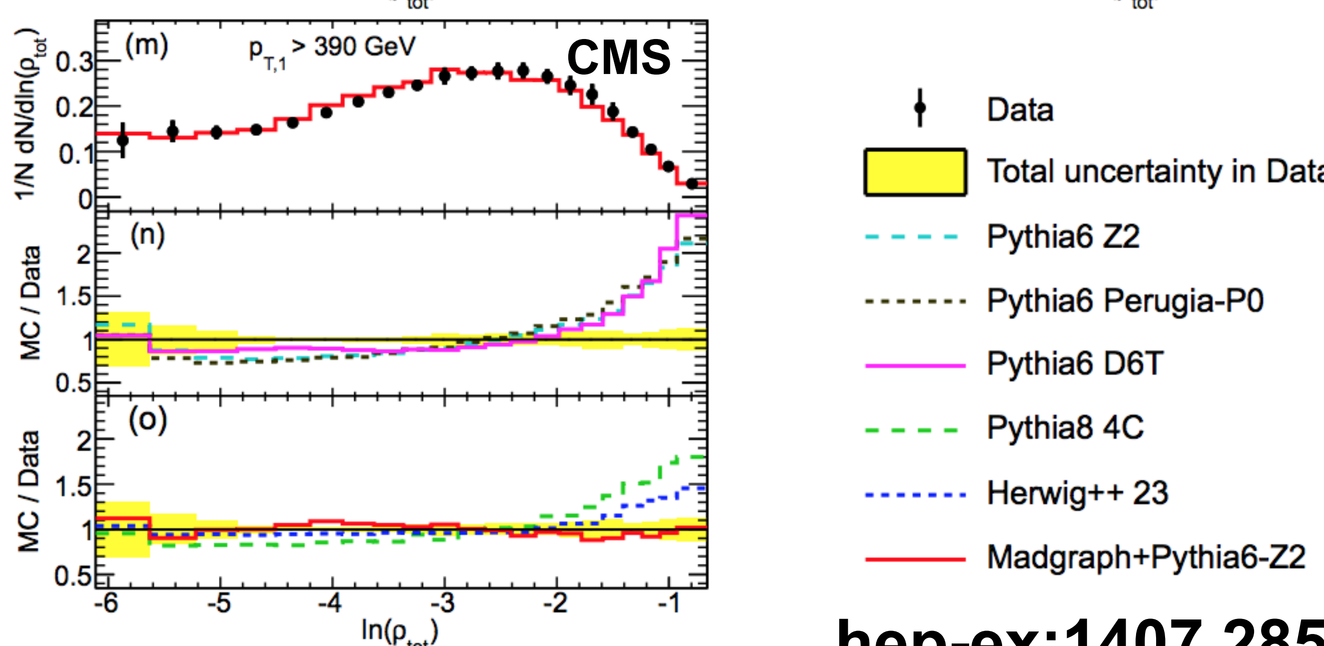
vs.



Radiation of jets

Pileup/Other radiation

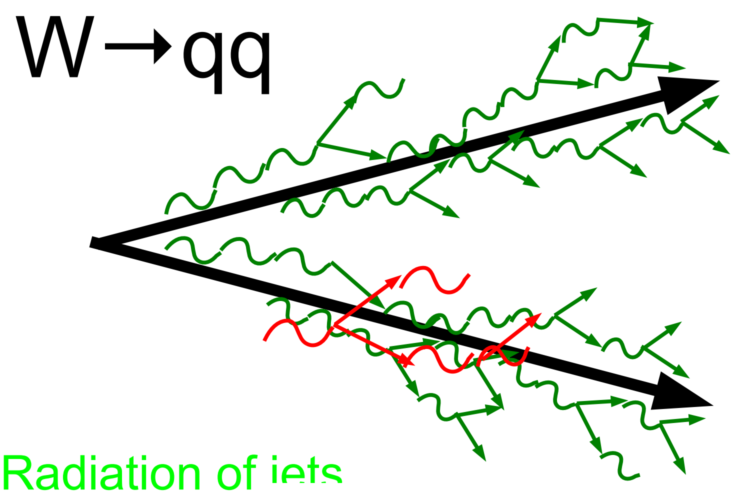
Pick an example
Mass



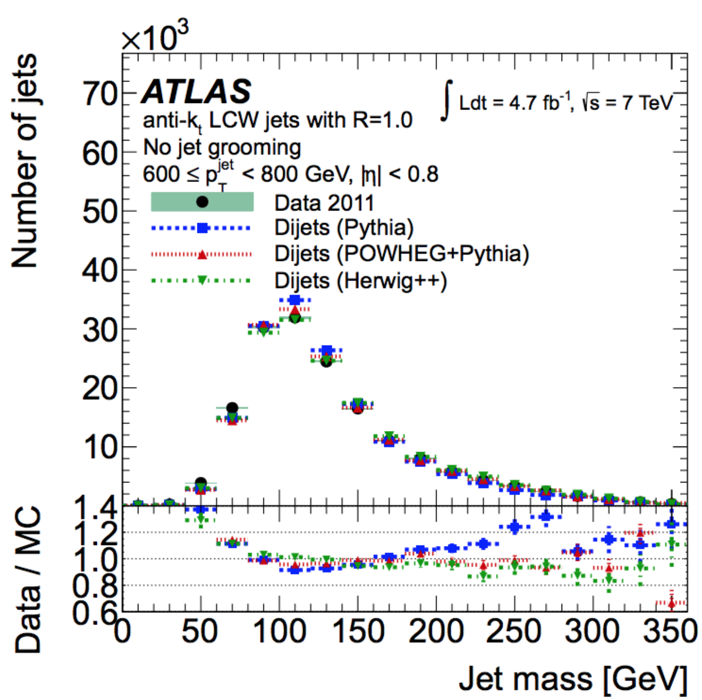
hep-ex:1407.2856

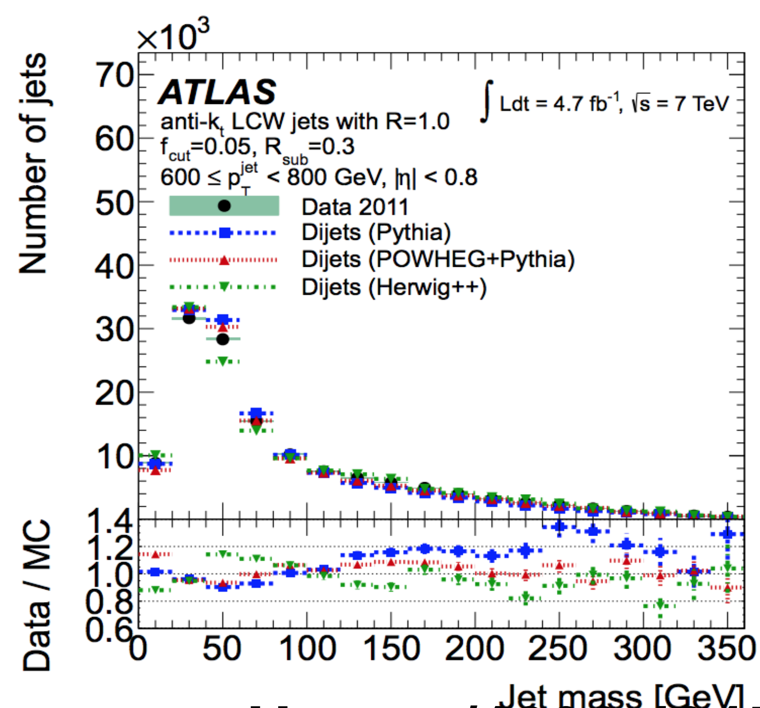
Jet Shape Polpuri

- Large amount of work to find two pronged jets



Radiation of jets
Pileup/Other

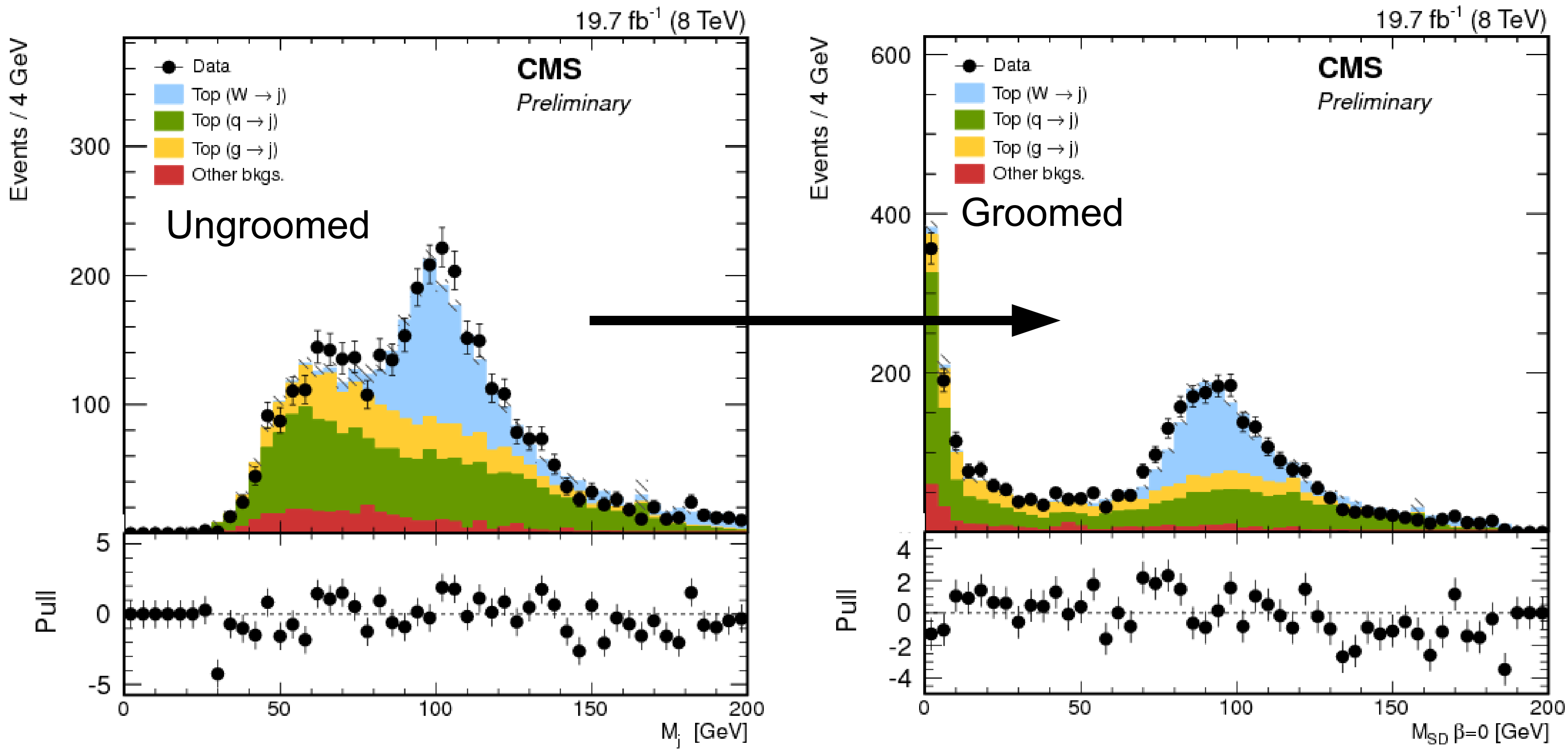




Hep-ex/1306.4945v1

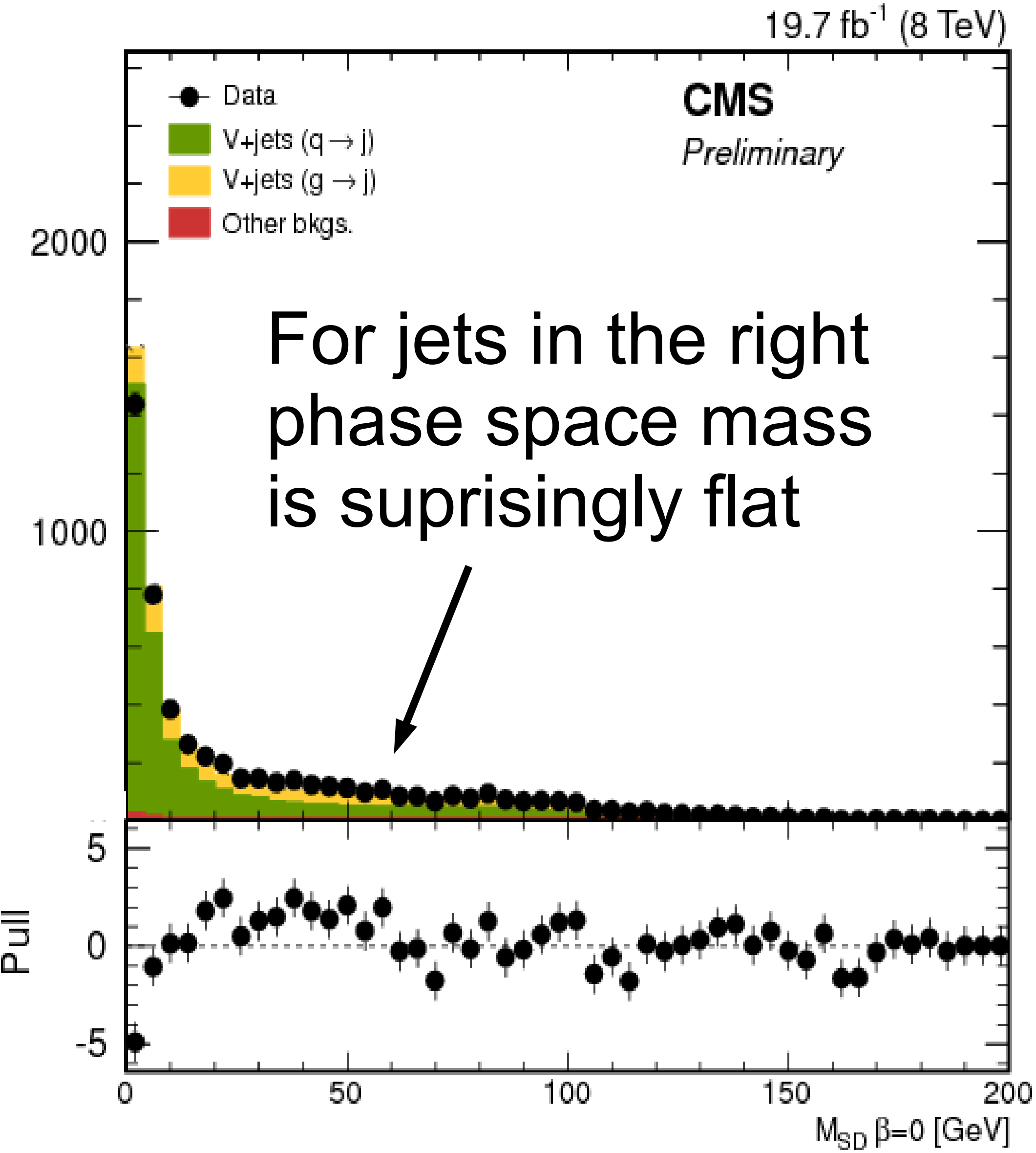
Going to High p_T

- Bringing tops to higher p_Ts
  - W bosons start to merge
  - Time for some jet grooming

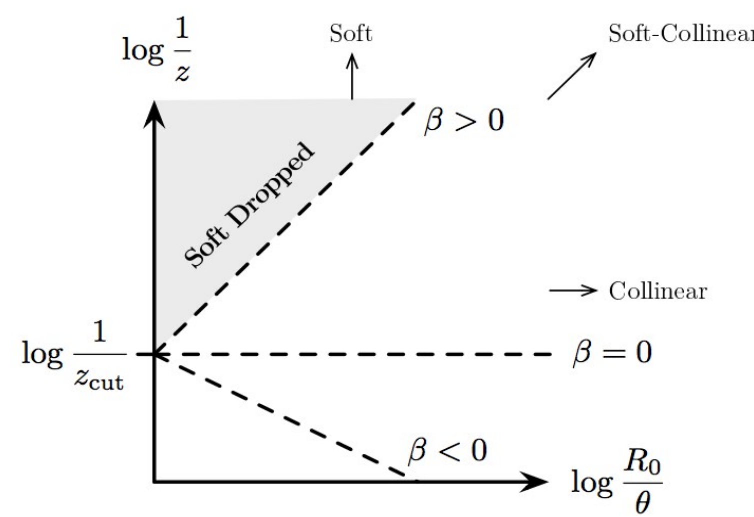


JME-14-002

Soft Drop

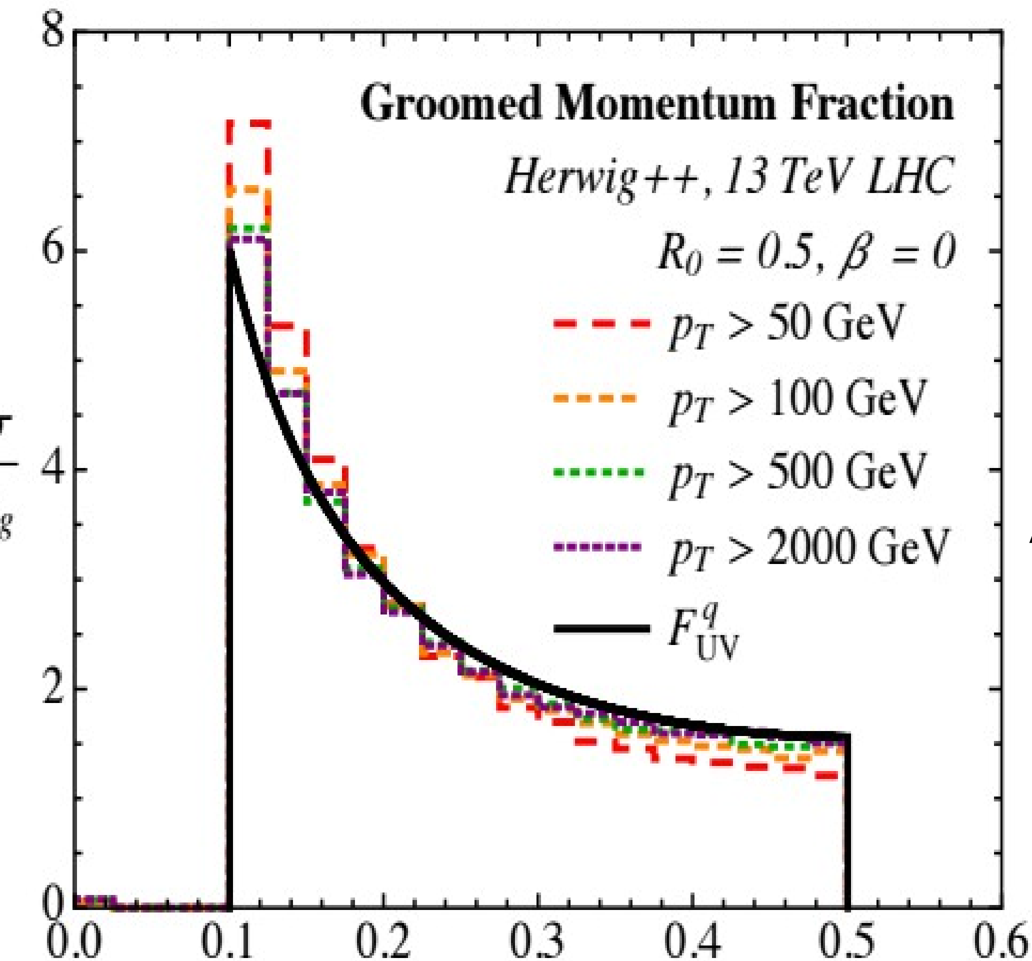


0. Decluster jet to jet_1, jet_2
1. Stop if
$$\frac{\min(p_T^1, p_T^2)}{p_T^1 + p_T^2} > z_{cut} R_{12}^{\beta}$$
2. If not stopped : drop lowest p_T subjet
3. Goto 0



CMS-JME-14-002

Advantages of Soft Drop



$$\overbrace{\frac{\min(p_T^1, p_T^2)}{p_T^1 + p_T^2}}^{z_g} > z_{cut} R_{12}^{\beta}$$

Soft Drop special properties

Nearly invariant over Large phase space

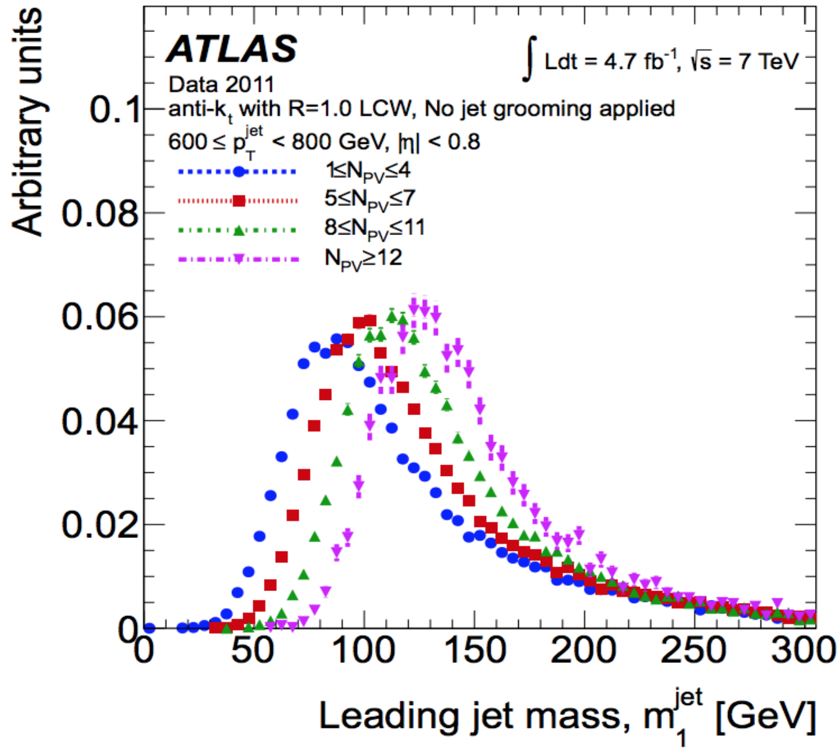
Allows for benchmarks

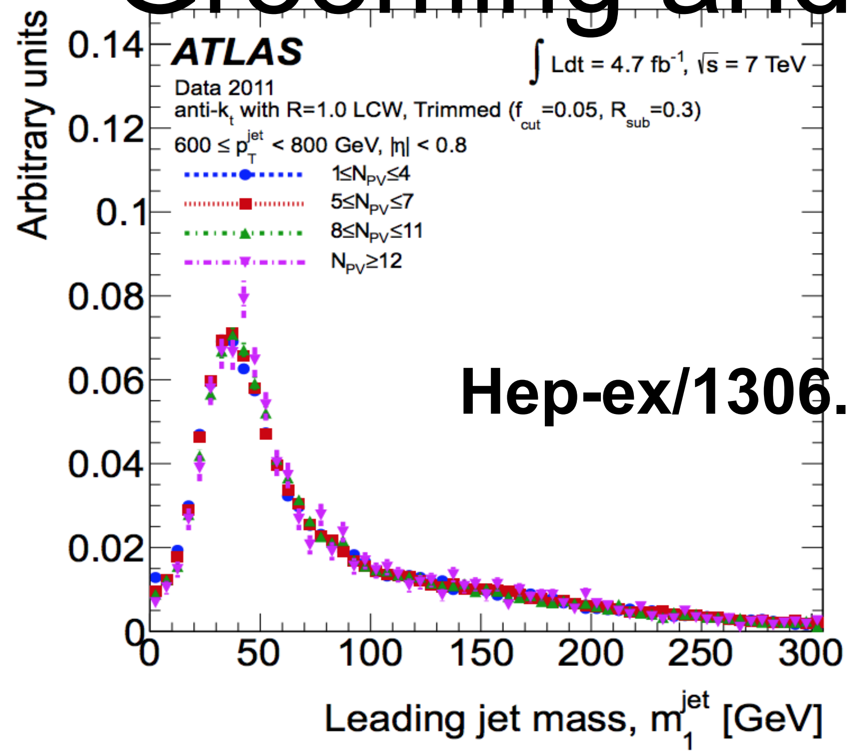
Is this variable robust in QGP?

Further work needed

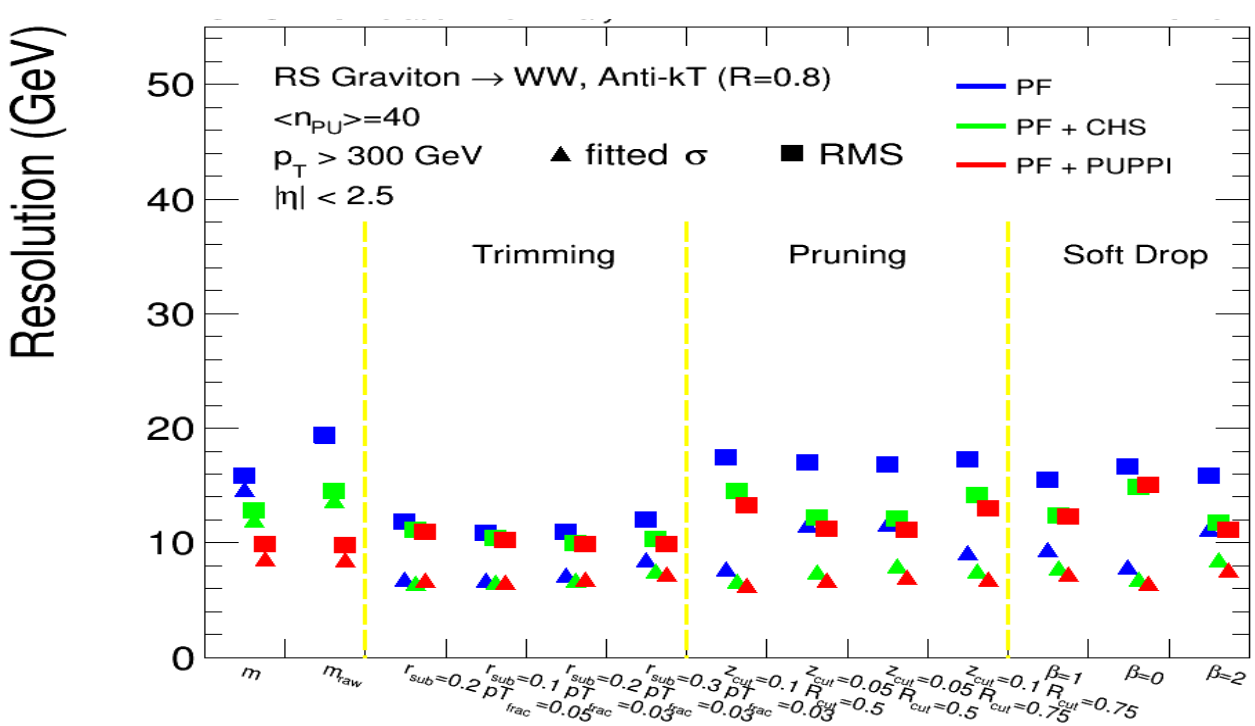
Hep-ph/1502.0179v2

Grooming and PU





Hep-ex/1306.4945v1



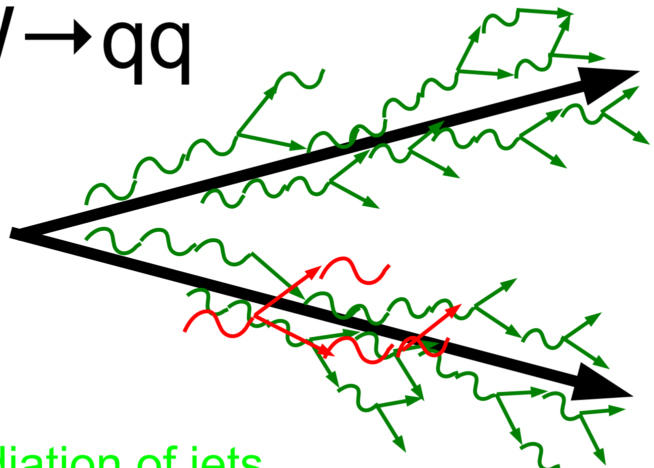
Per particle approaches
Work well against pileup/UE

CMS-JME-14-001

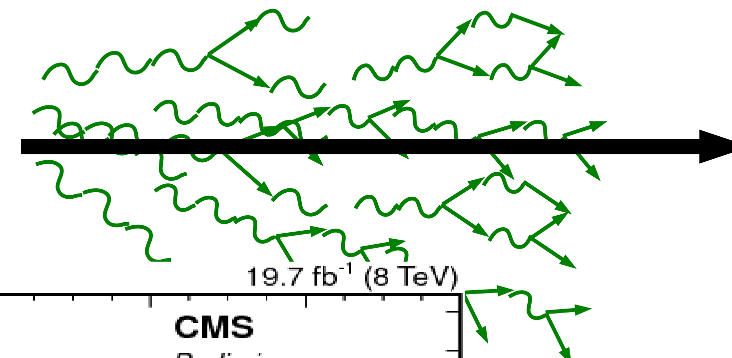
Jet Shape Polpuri

- Large amount of work to find two pronged jets

W→qq



vs.



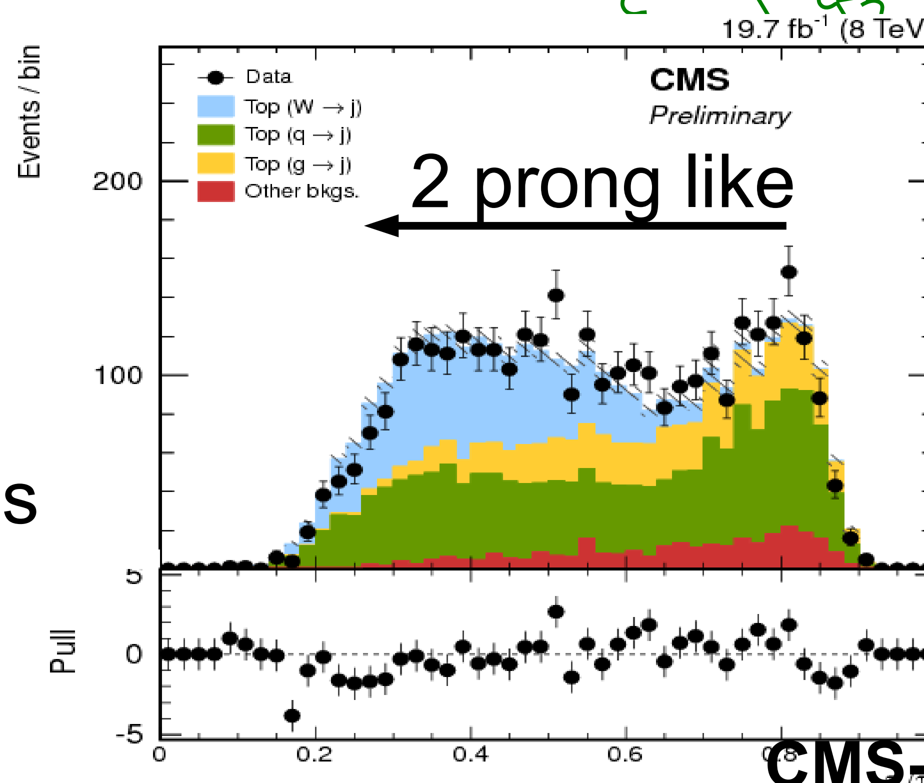
Radiation of jets

Pileup/Other radiation

Pick another example

τ_2/τ_1

Likelihood of two prongs

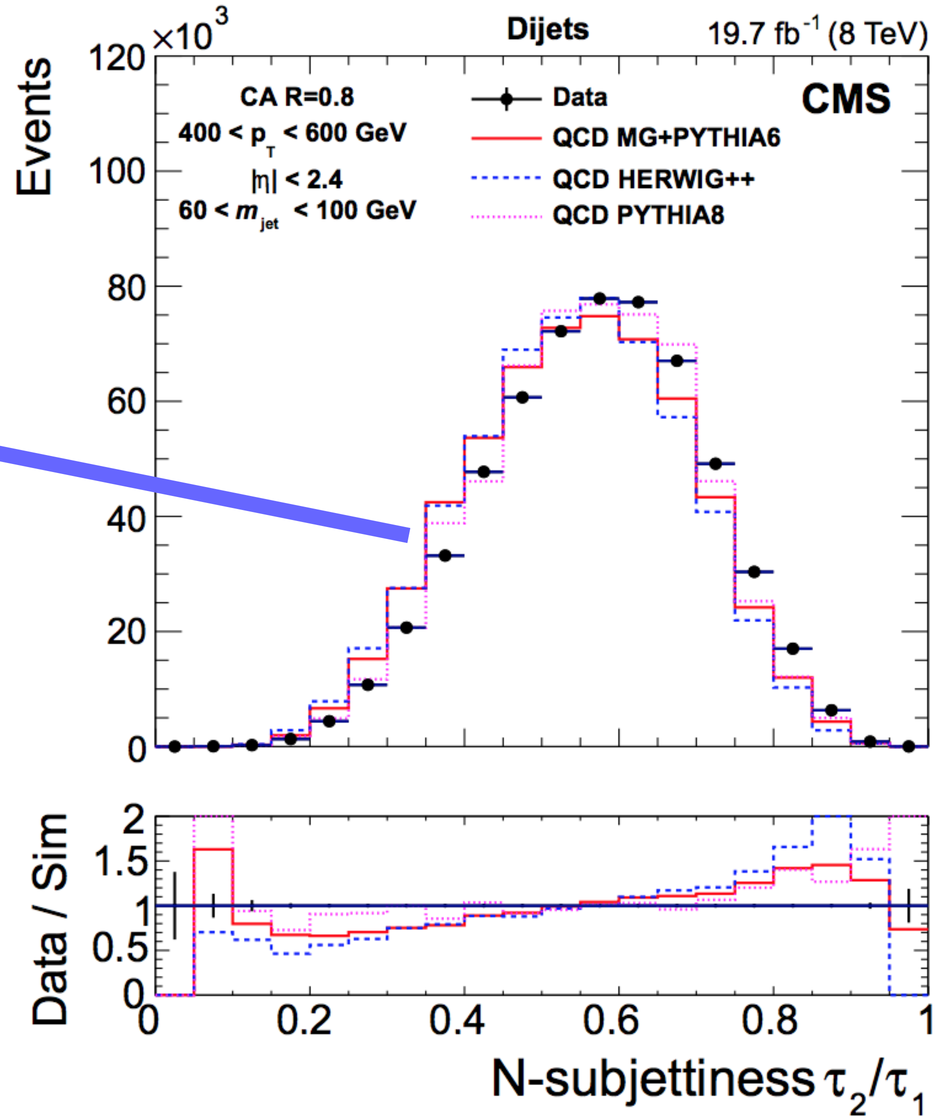


CMS-JME-13-006

Large number of features in τ_2/τ_1

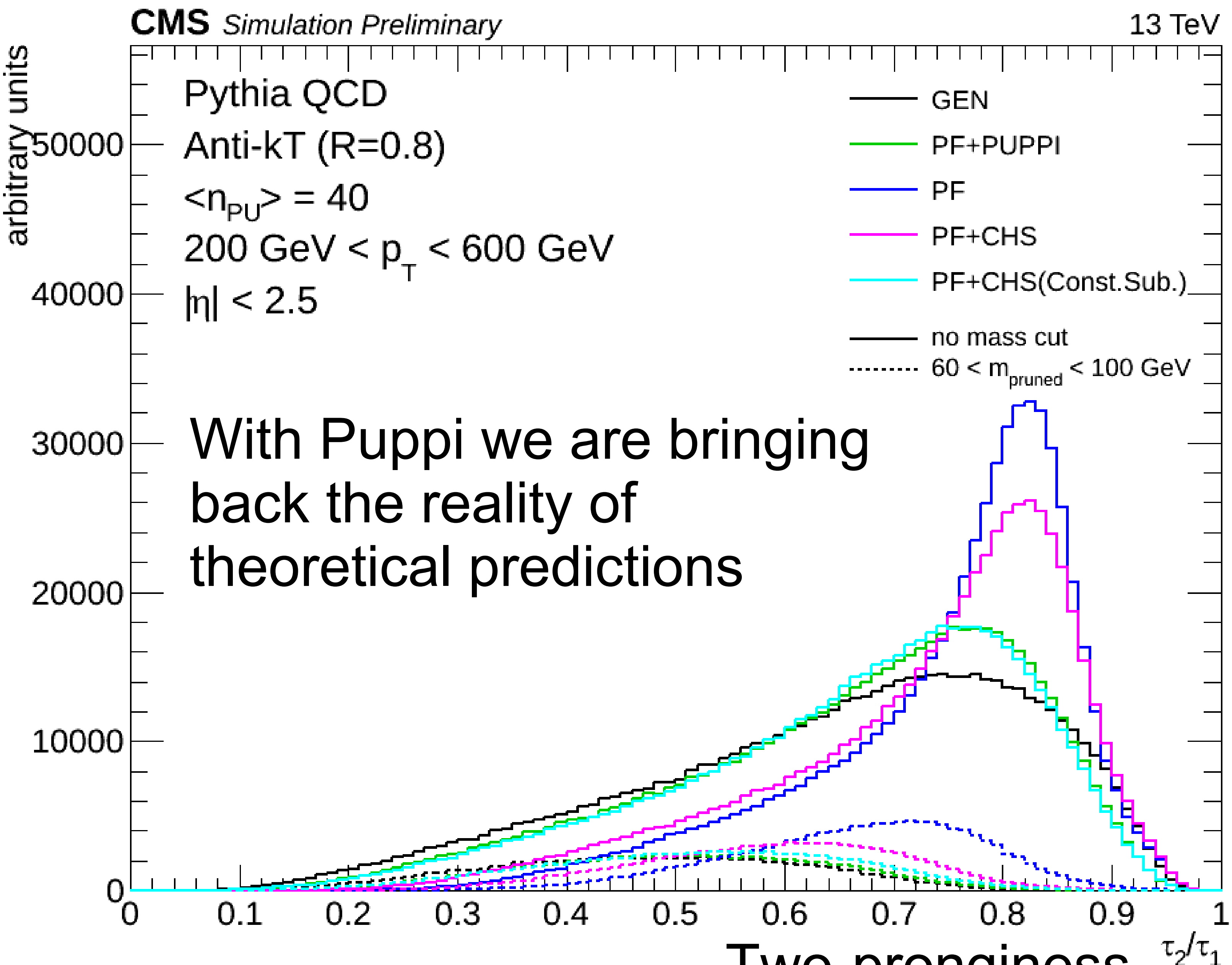
- Sensitive to different shower structures

Was strong motivation to switch to Pythia 8 inside CMS



CMS-JME-13-006

Large number of features in τ_2/τ_1



With Puppi we are bringing back the reality of theoretical predictions

Two-pronginess

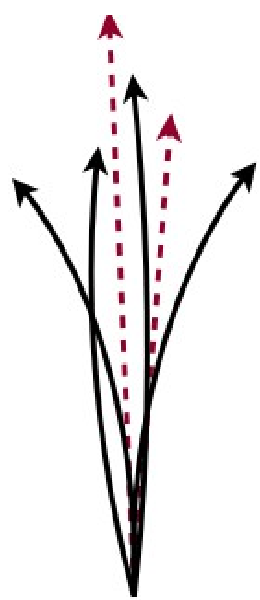
CMS-JME-14-001

Quark Gluon Discrimination

- Goal : Separate quarks and gluons
  - New technique for modeling of discriminant in data
  - Application : AK5 Jets
  - Potential application to many other approaches

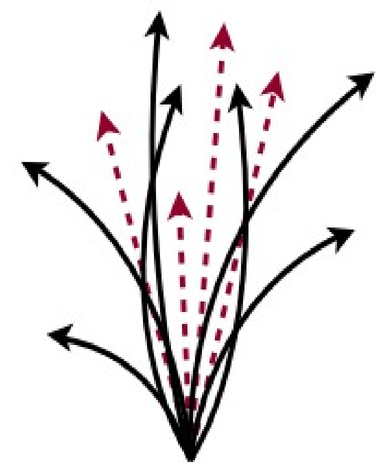
Quark jets:

Narrow
Have less particles
High p_T core
Enhanced in Z/γ+jets



Gluon jets:

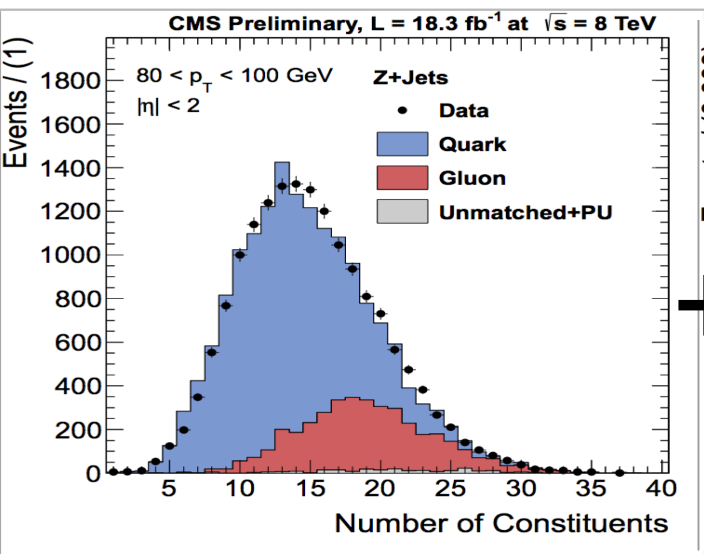
Wide
More particles
Lower p_T
Enhanced in dijet



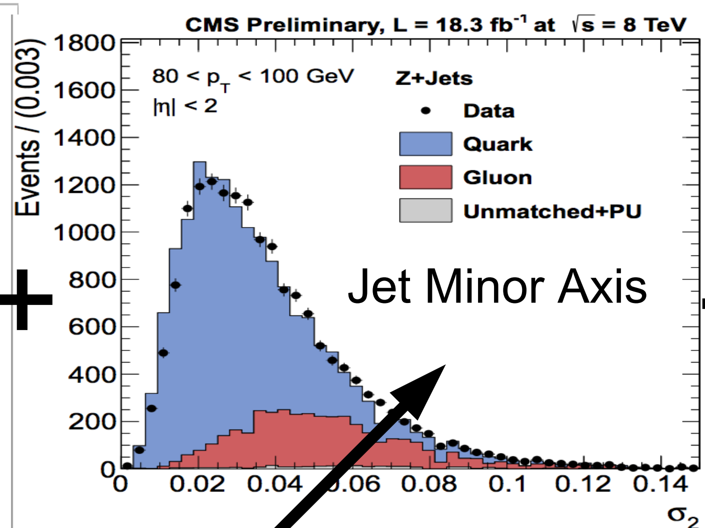
CMS-JME-13-002

Quark Gluon Discrimination

- Discriminating Variables Combined into a likelihood



+



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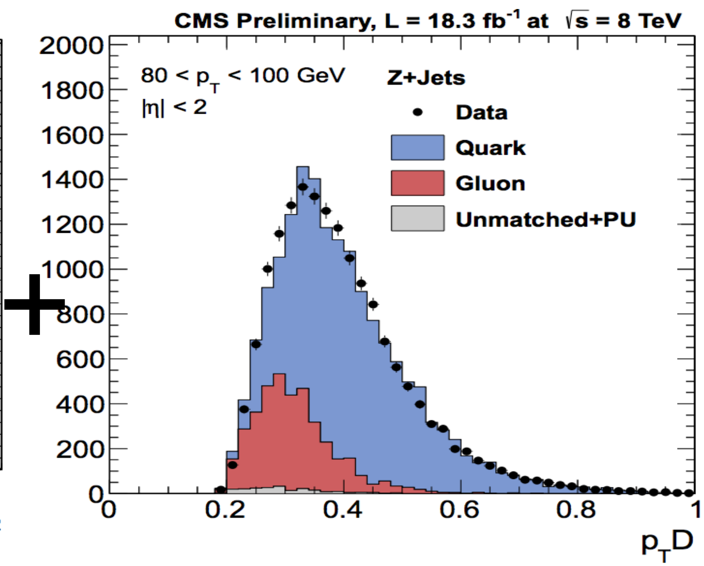


$$\begin{pmatrix} \sum_i p_{\mathrm{T},i}^2 \Delta\eta_i^2 & -\sum_i p_{\mathrm{T},i}^2 \Delta\eta_i \Delta\phi_i \\ -\sum_i p_{\mathrm{T},i}^2 \Delta\eta_i \Delta\phi_i & \sum_i p_{\mathrm{T},i}^2 \Delta\phi_i^2 \end{pmatrix}$$

$\lambda_{1,2}$ are the eigenvalues of this matrix

$$\sigma_1 = (\lambda_1 / \sum_i p_{\mathrm{T},i}^2)^{1/2}$$
$$\sigma_2 = (\lambda_2 / \sum_i p_{\mathrm{T},i}^2)^{1/2}$$

$$\sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$$

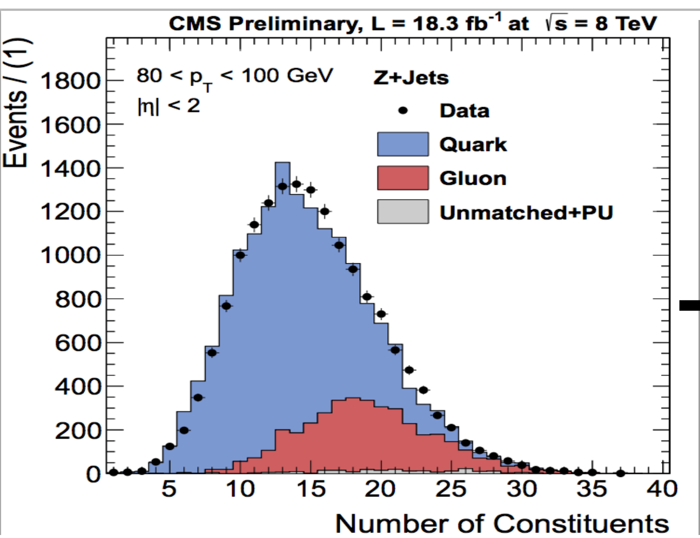
$$p_T D = \frac{\sqrt{\sum_i p_{\mathrm{T},i}^2}}{\sum_i p_{\mathrm{T},i}}$$

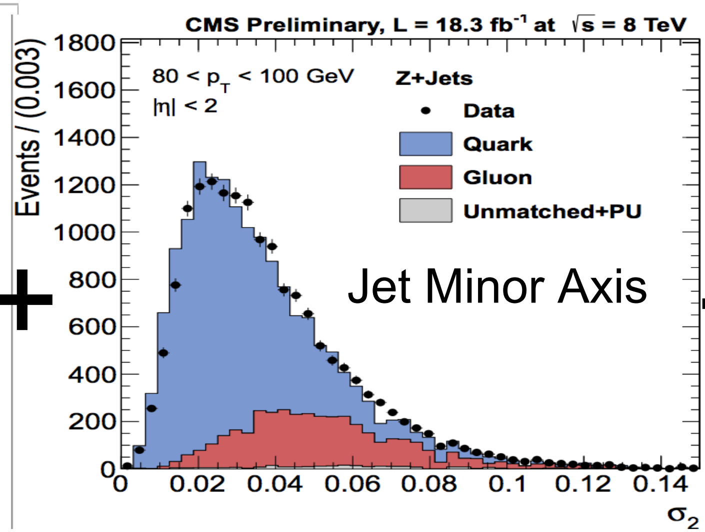
Most Discriminating Variable

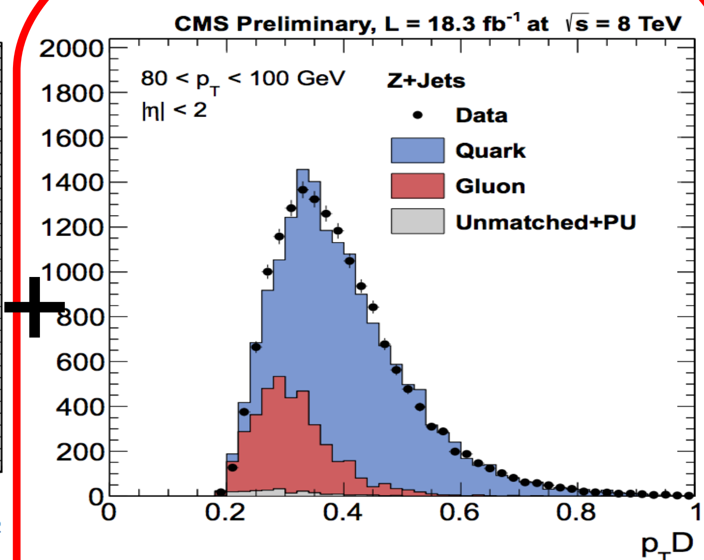
CMS-JME-13-002

Quark Gluon Discrimination

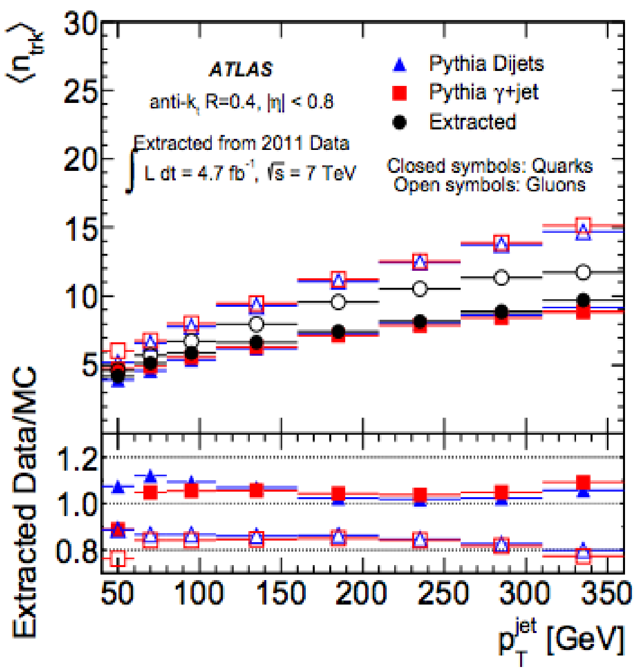
- Discriminating Variables Combined into a likelihood

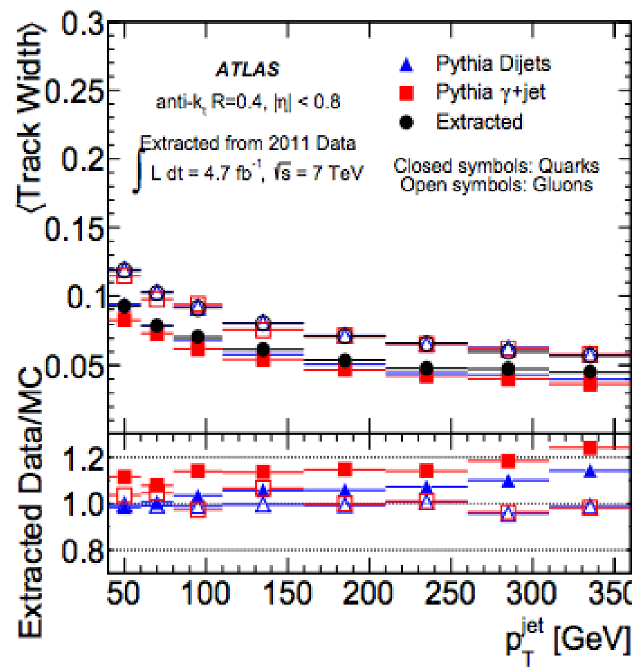






$$p_T D = \frac{\sqrt{\sum_i p_{T,i}^2}}{\sum_i p_{T,i}}$$



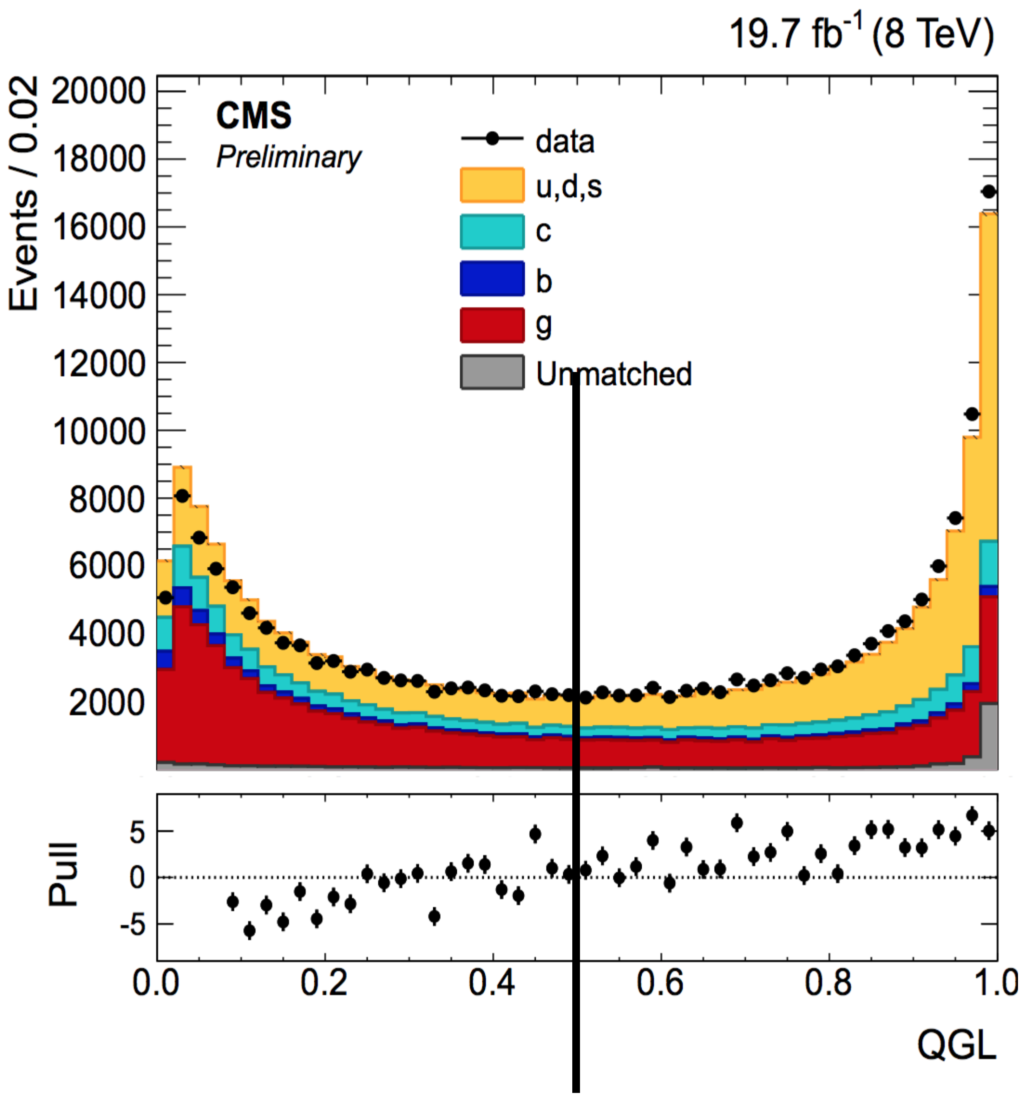


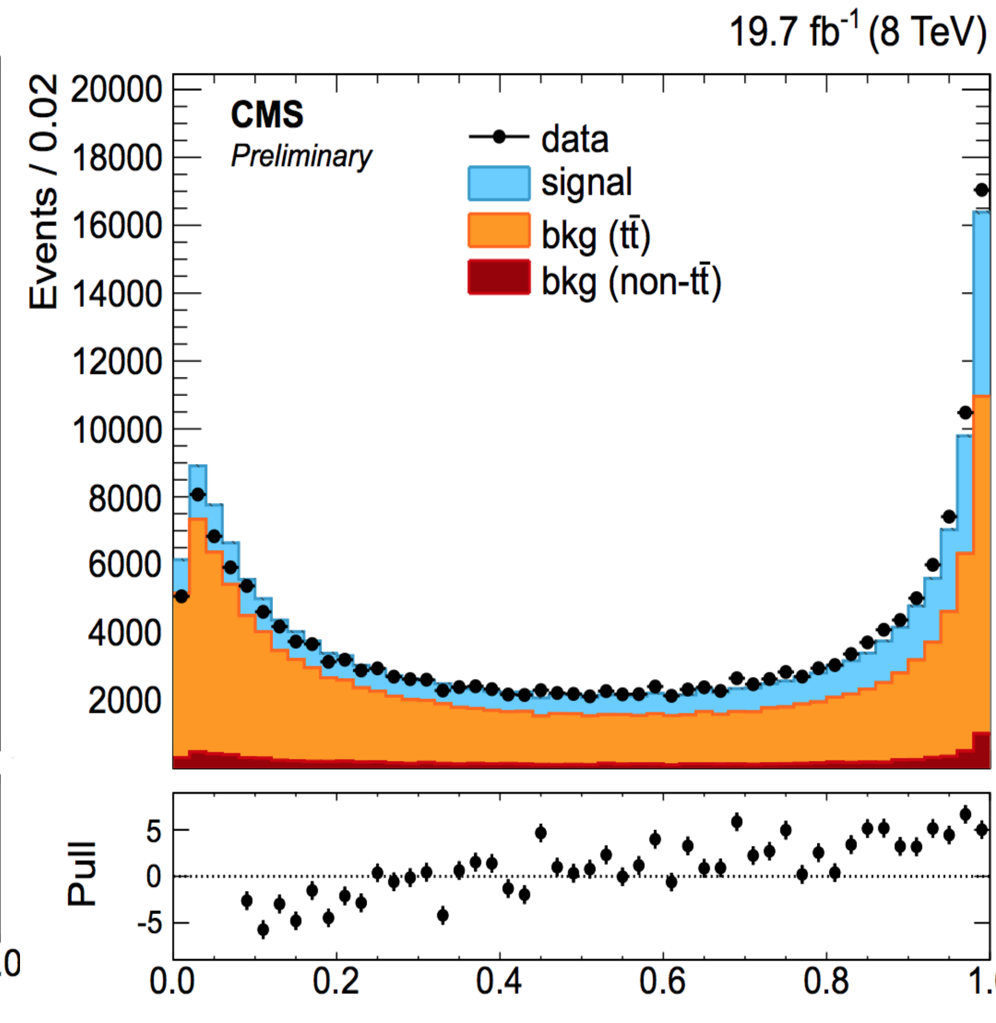
Most Discriminating Variable

CMS-JME-13-002

Isolating Gluons

- Quarks and gluons can be separated
  - One of our benchmark channels are tops



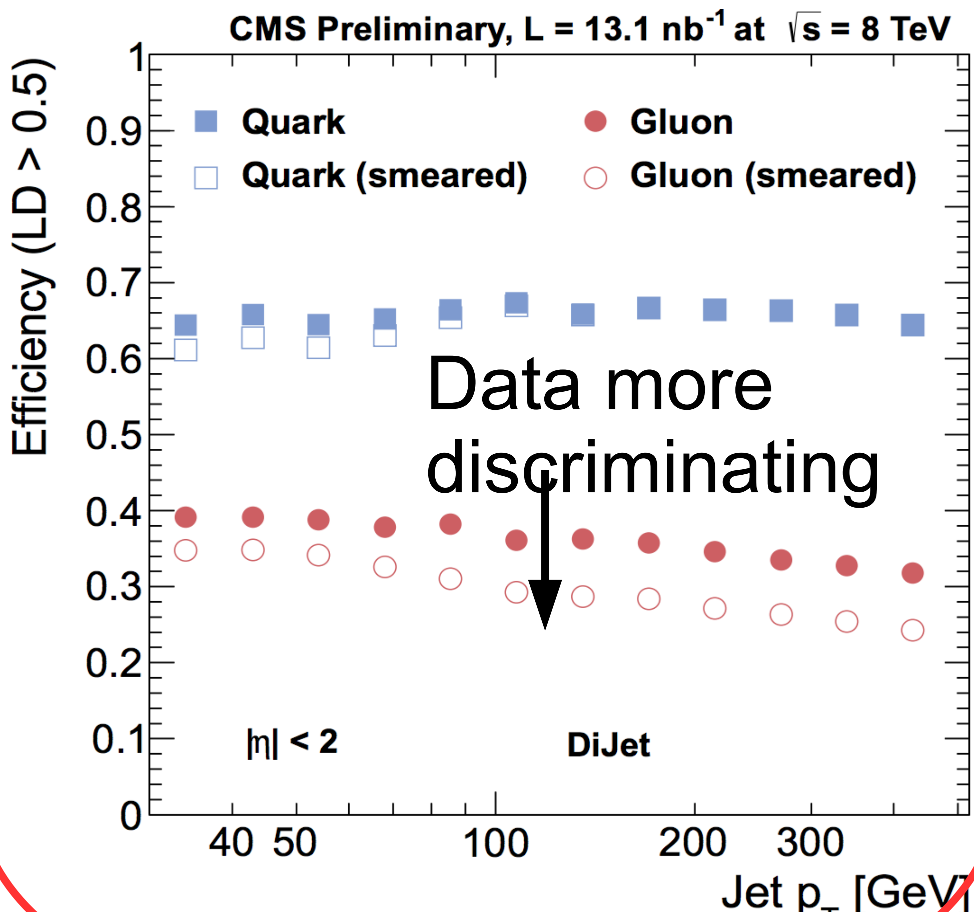


JME-14-002

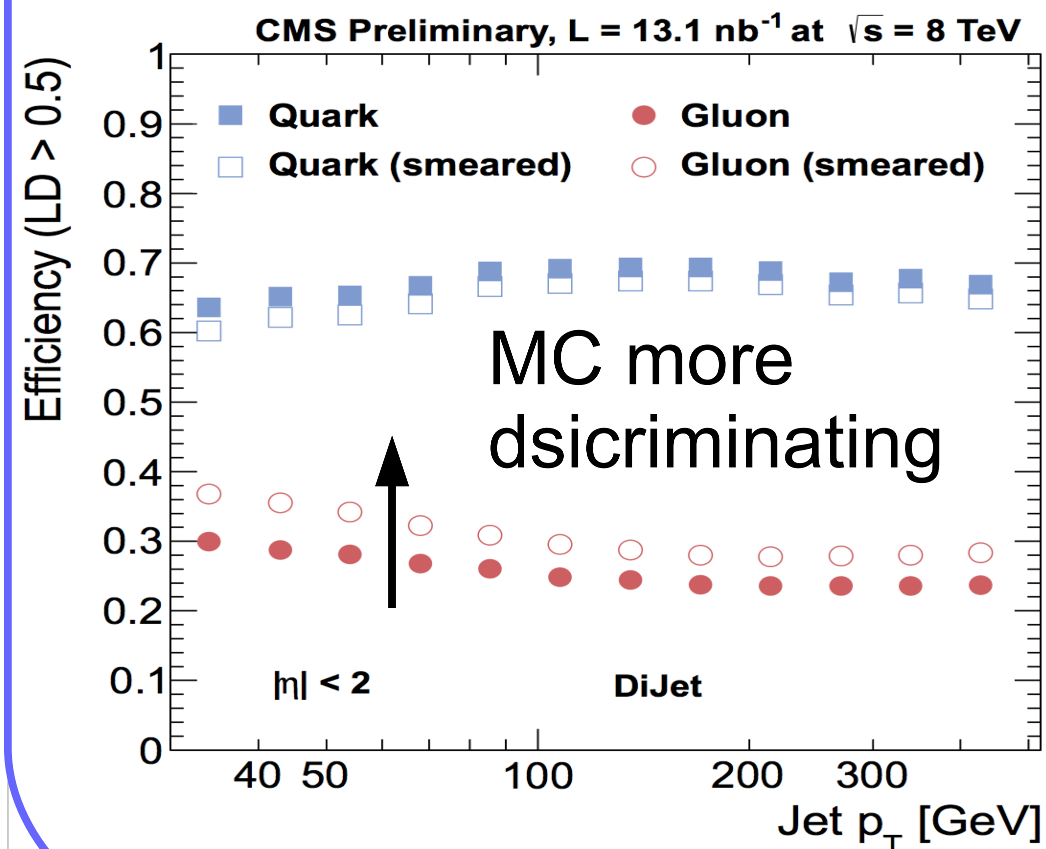
Isolating Gluons

- Differences between data,Pythia and Herwig
  - Can be understood with the help of QGL

Herwig



Pythia



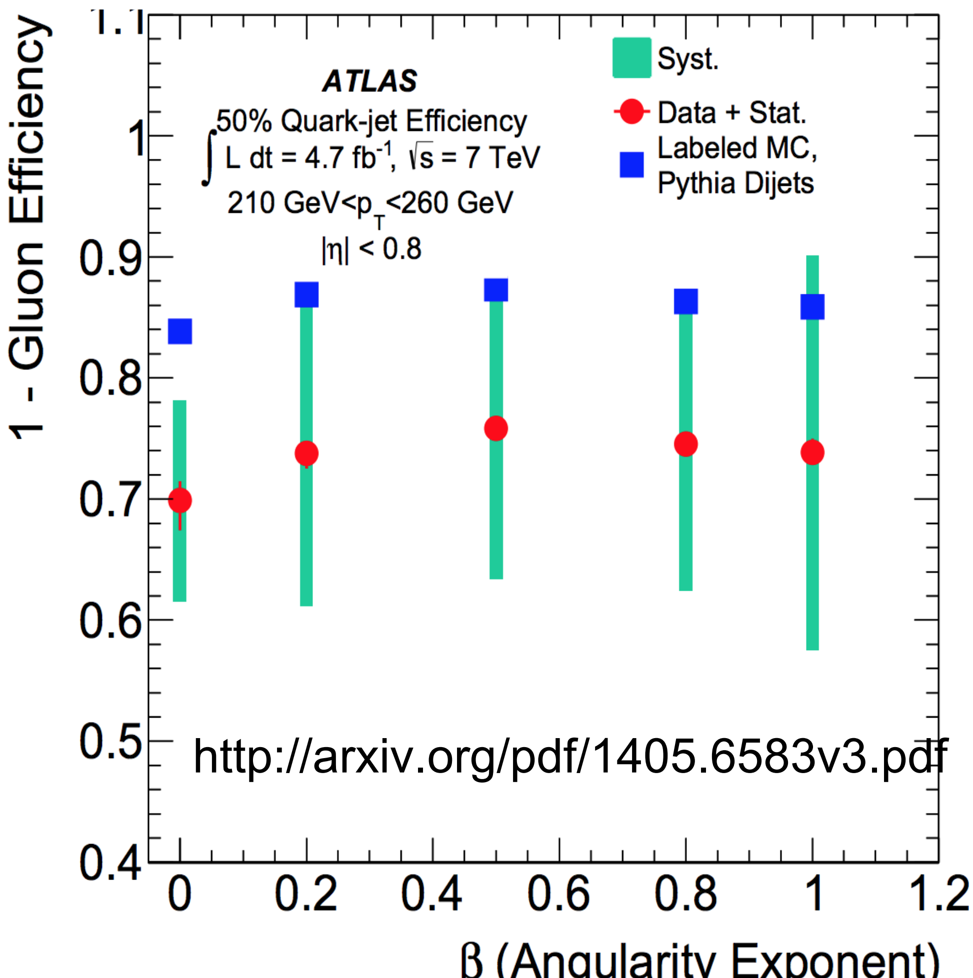
JME-13-002

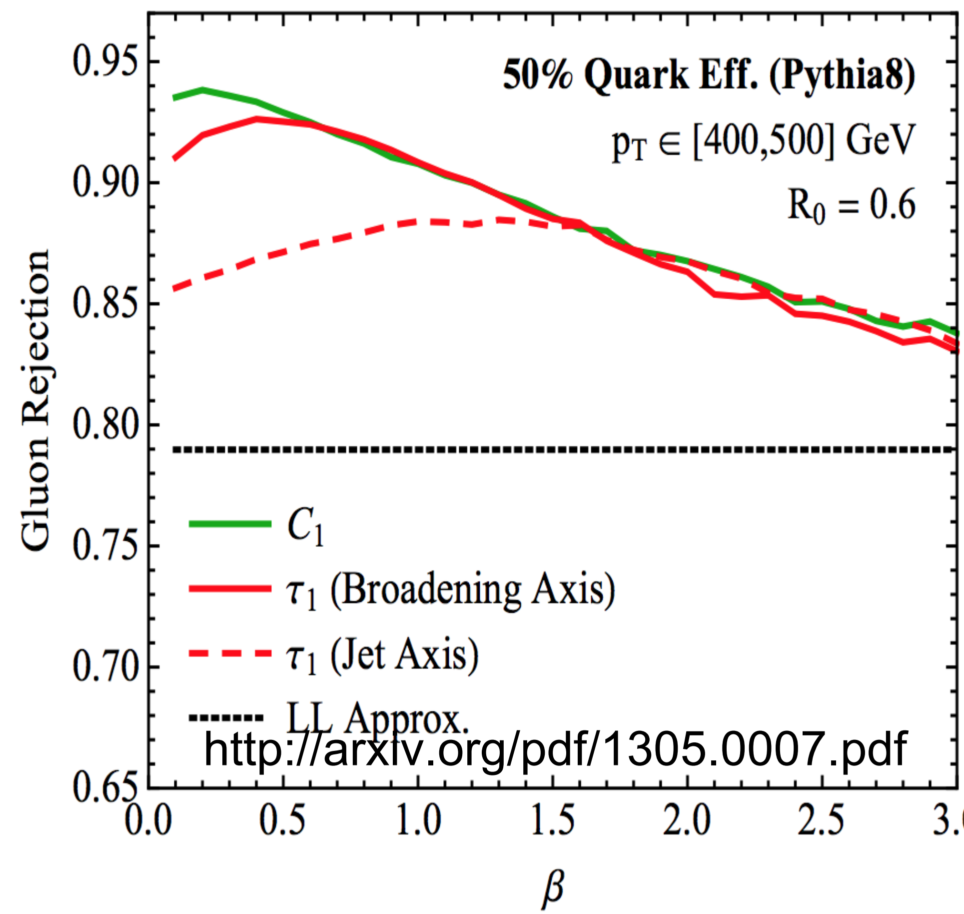
Building a Measurement

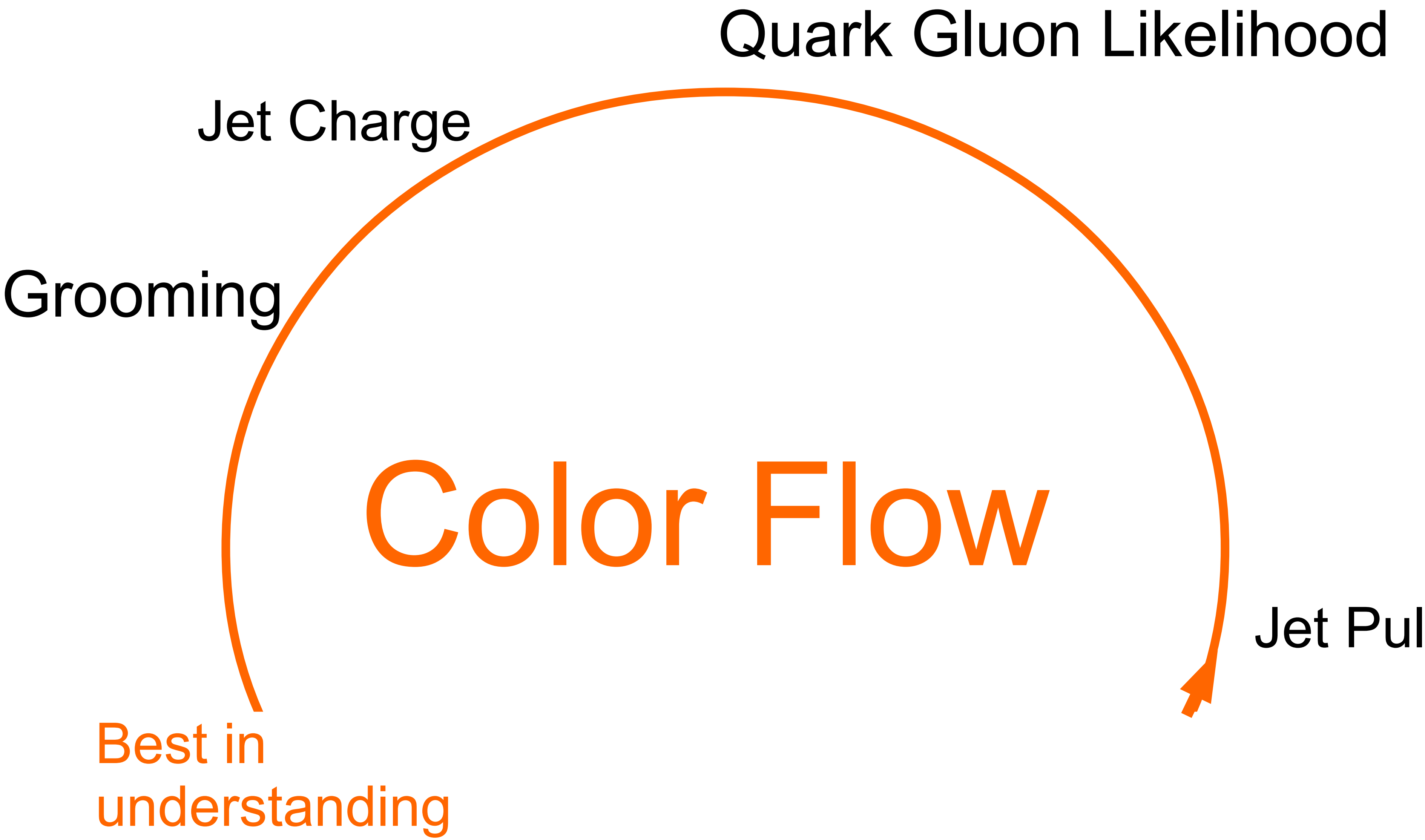
$$C_N^{(\beta)} \equiv \frac{r_N^{(\beta)}}{r_{N-1}^{(\beta)}} = \frac{\mathrm{ECF}(N+1,\beta)\,\mathrm{ECF}(N-1,\beta)}{\mathrm{ECF}(N,\beta)^2}$$

→ Generalized version of ptD

$$\ln \Sigma_g \simeq \frac{C_A}{C_F}\left(1 + \frac{n_F - C_A}{3C_A}\sqrt{\frac{\alpha_s C_F}{\pi \beta \ln 1/\Sigma_q}} + \frac{n_F - C_A}{C_A}\frac{\alpha_s}{36\pi}\frac{b_0}{\beta}(2-\beta) + \frac{\alpha_s \pi}{3}\frac{C_A - C_F}{\beta} - \frac{17}{36}\frac{\alpha_s}{\pi}\frac{C_F}{C_A}\frac{n_f - C_A}{\beta \ln 1/\Sigma_q} + \ldots\right)\ln \Sigma_q\,.$$



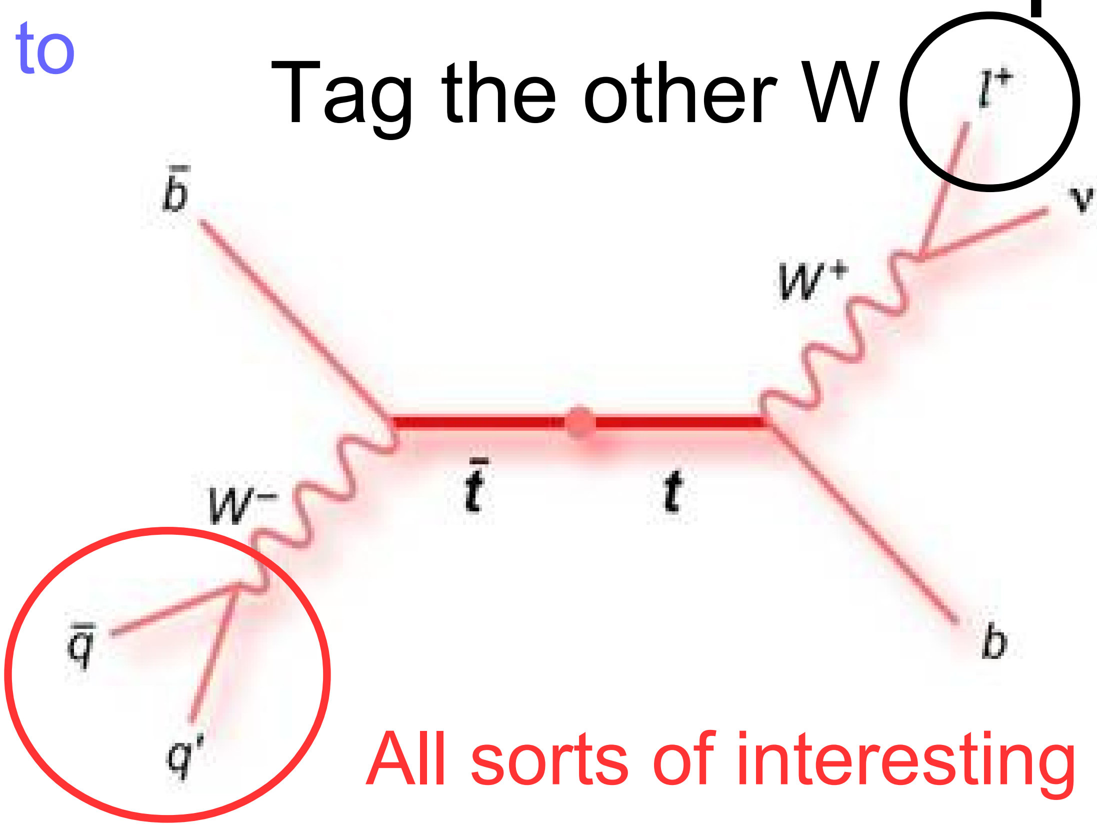



Quark Gluon Likelihood
Jet Charge
Grooming
Color Flow
Jet Pull
Best in
understanding

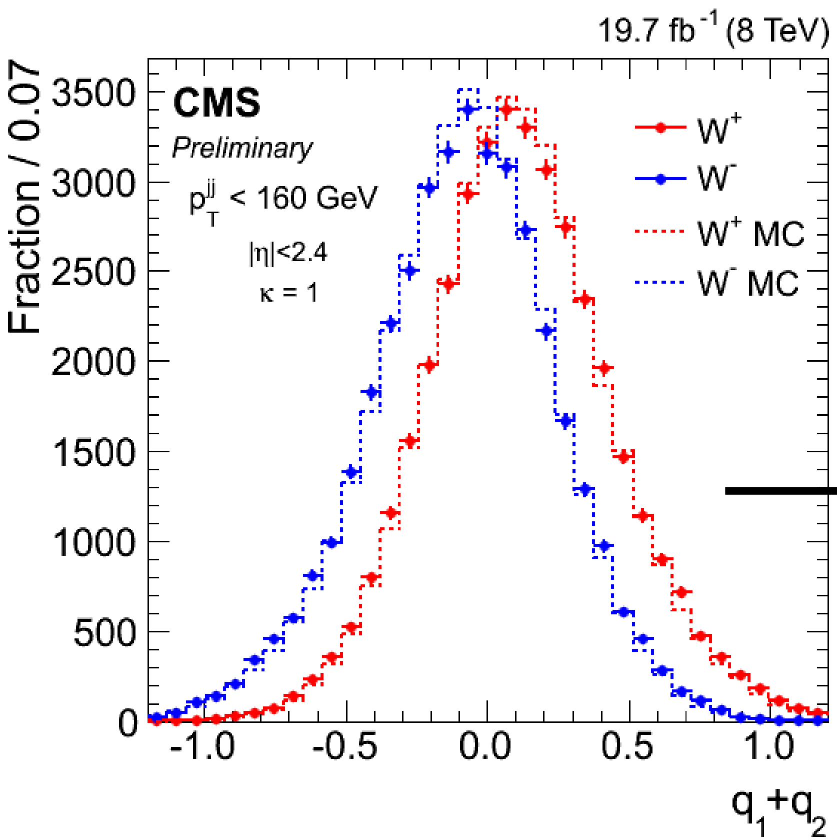
Fun with Tops

Tops have become a tool to understand the profound details of QCD

Tag the other W



All sorts of interesting stuff



Di-jet charge

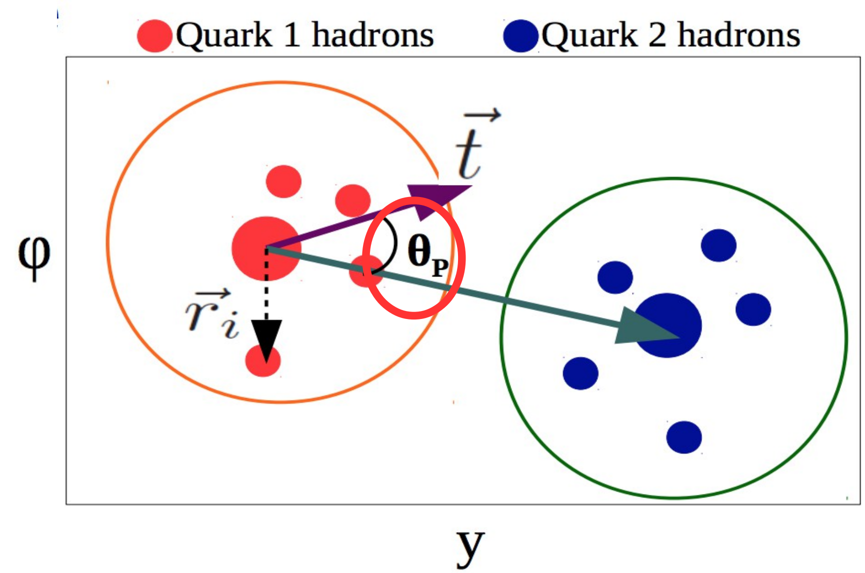
JME-13-006
JME-14-002

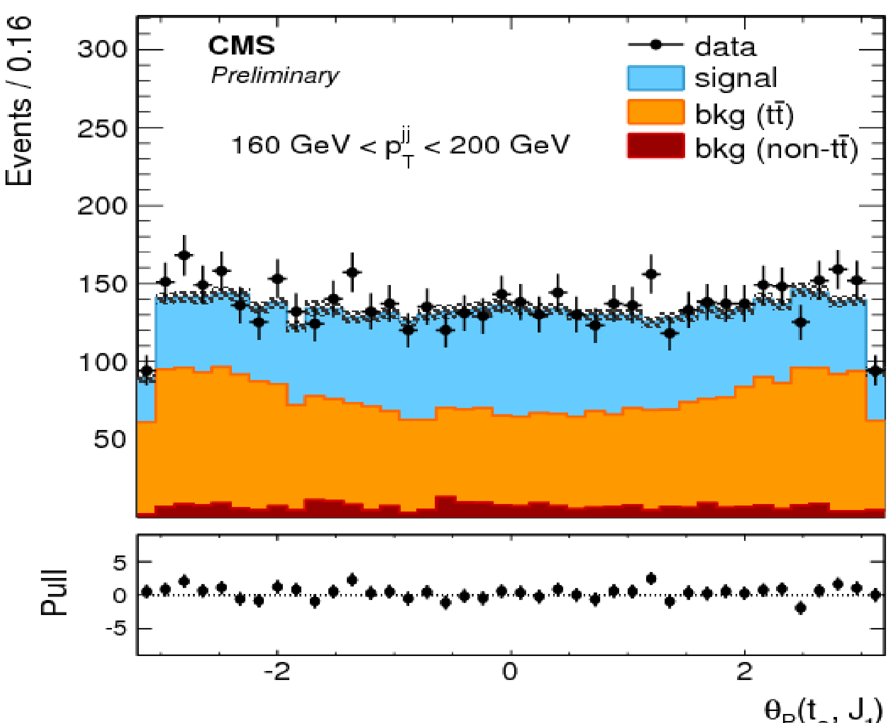
Color Flow in Tops

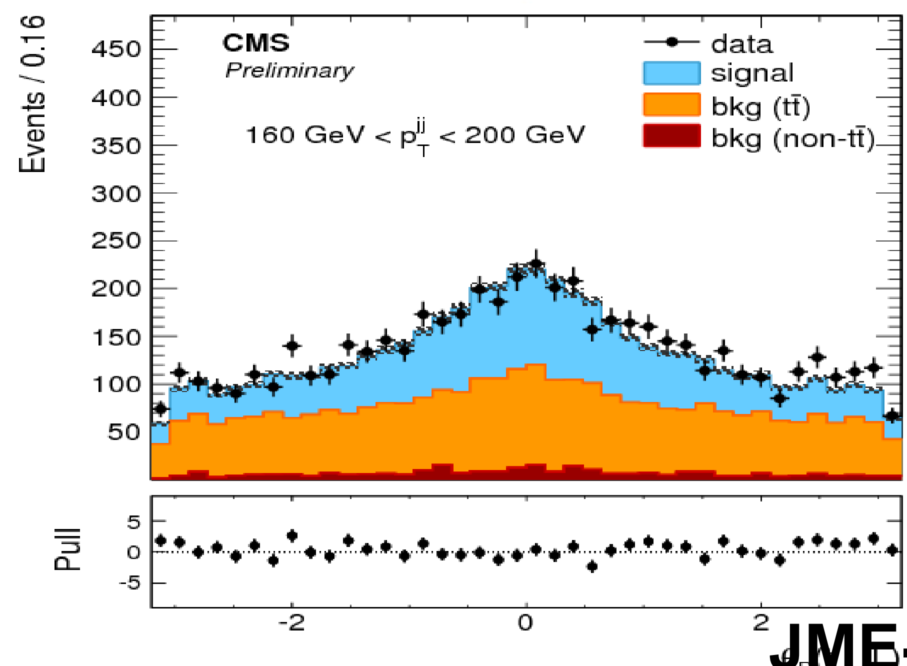
- Start to measure color flow between W bosons

$$\vec{t} = \sum_i \frac{(p_T)_i \, |r_i|}{(p_T)_{\text{jet}}} \vec{r}_i$$

$$\vec{r}_i = (\Delta y_i, \Delta \phi_i)$$







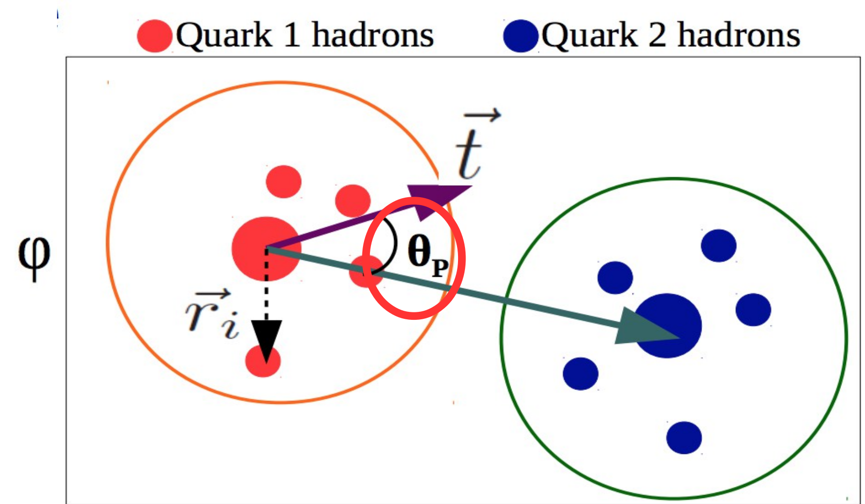
JME-14-002

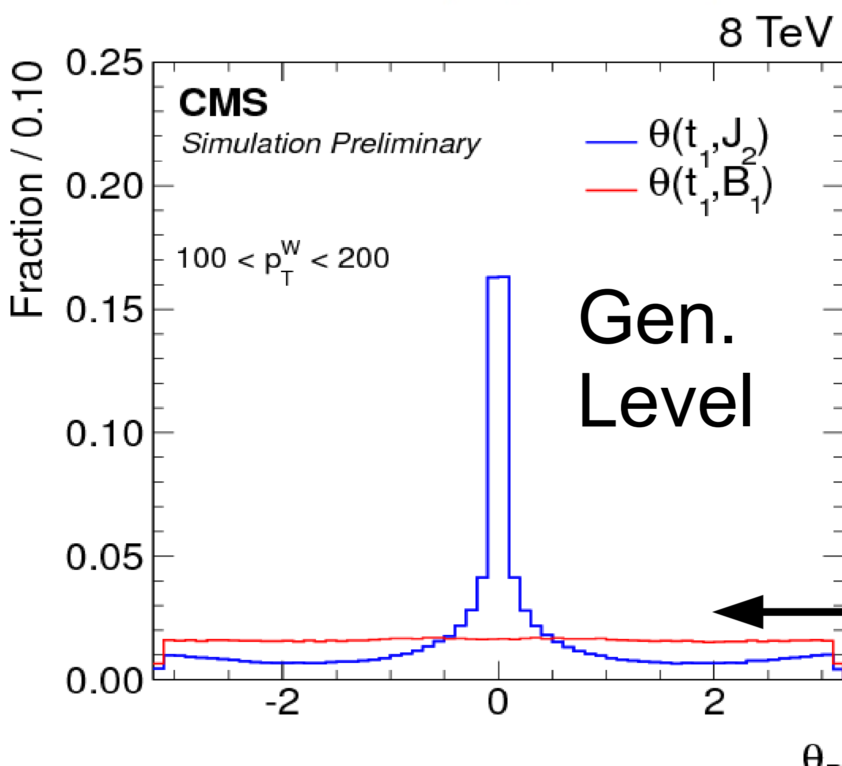
Color Flow in Tops

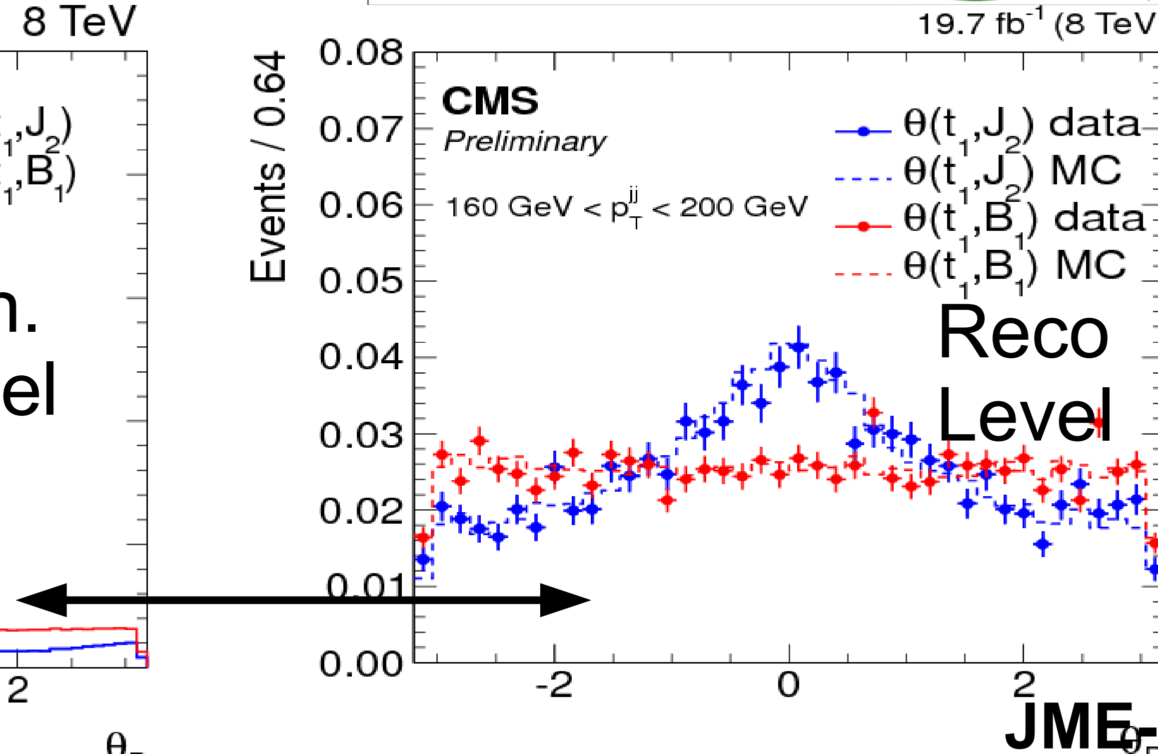
- Background subtracting

$$\vec{t} = \sum_i \frac{(p_\mathrm{T})_i \, |r_i|}{(p_\mathrm{T})_\mathrm{jet}} \vec{r}_i$$

$$\vec{r}_i = (\Delta y_i, \Delta \phi_i)$$

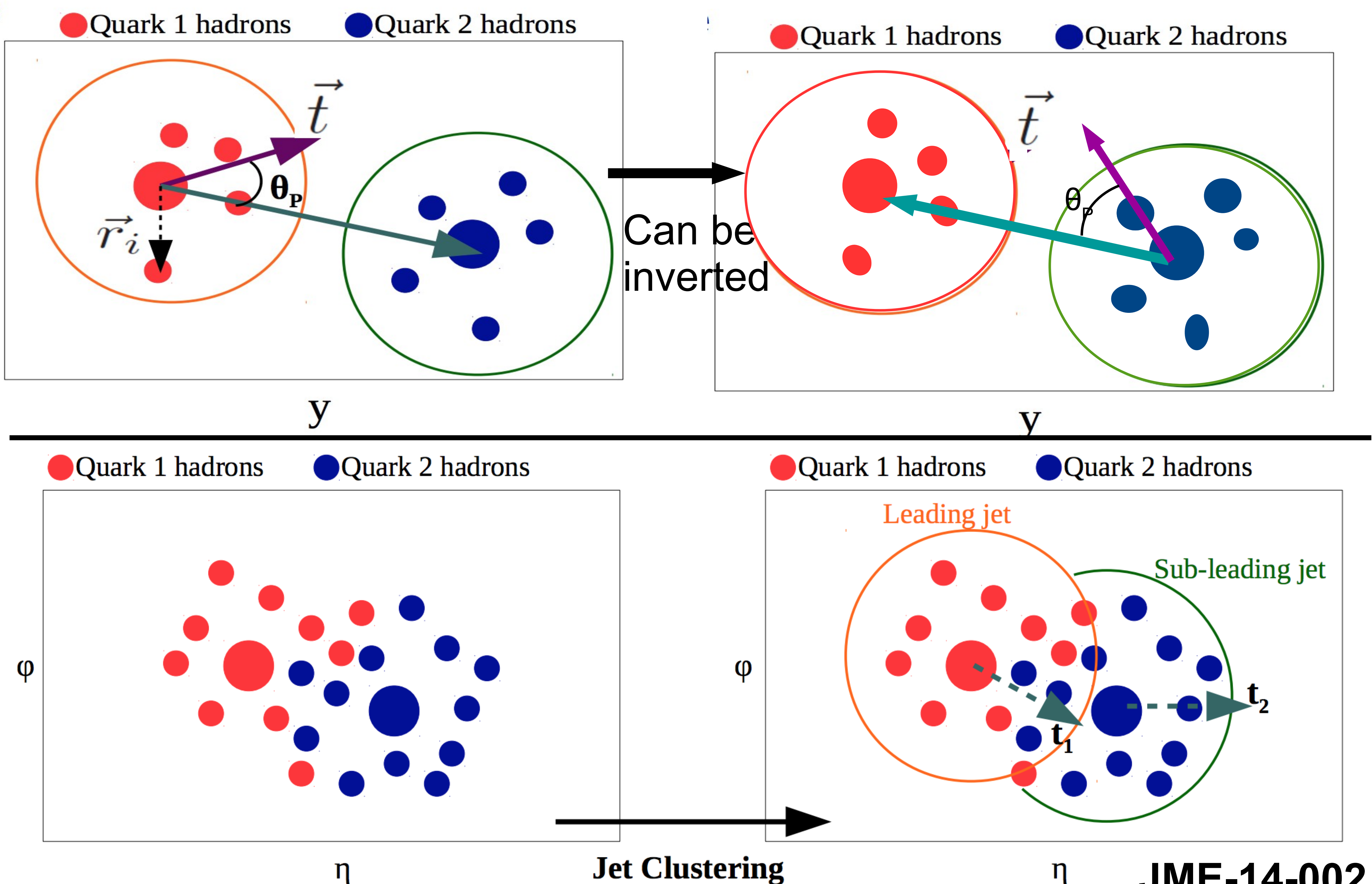






JME-14-002

Color Flow in Tops



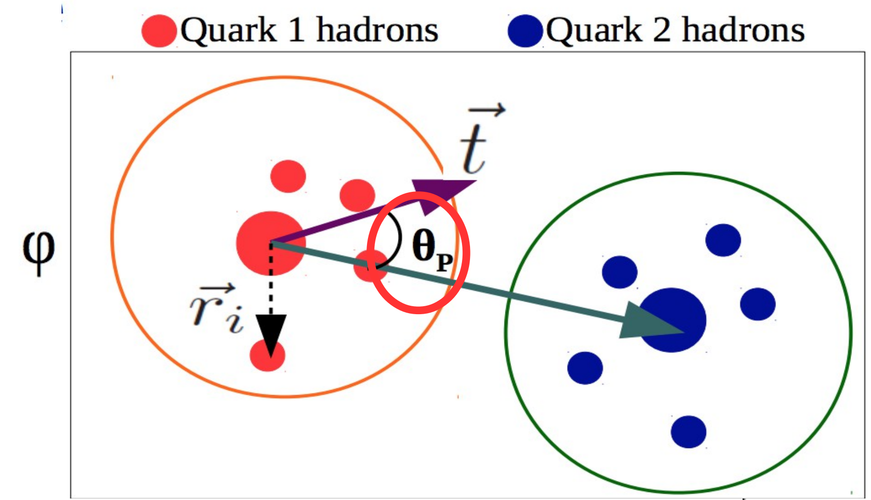
JME-14-002

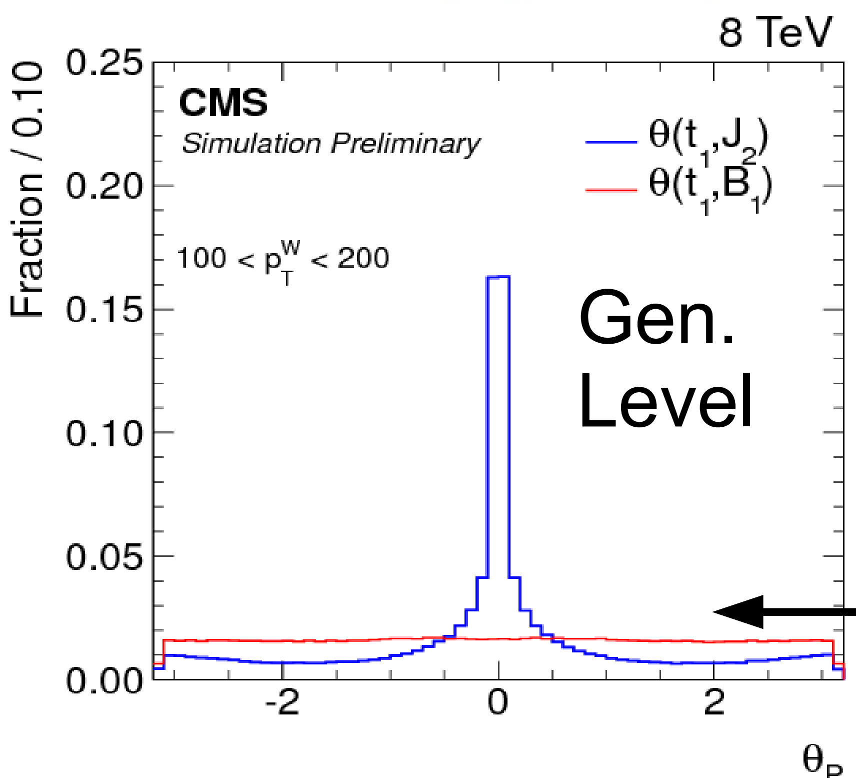
Color Flow in Tops

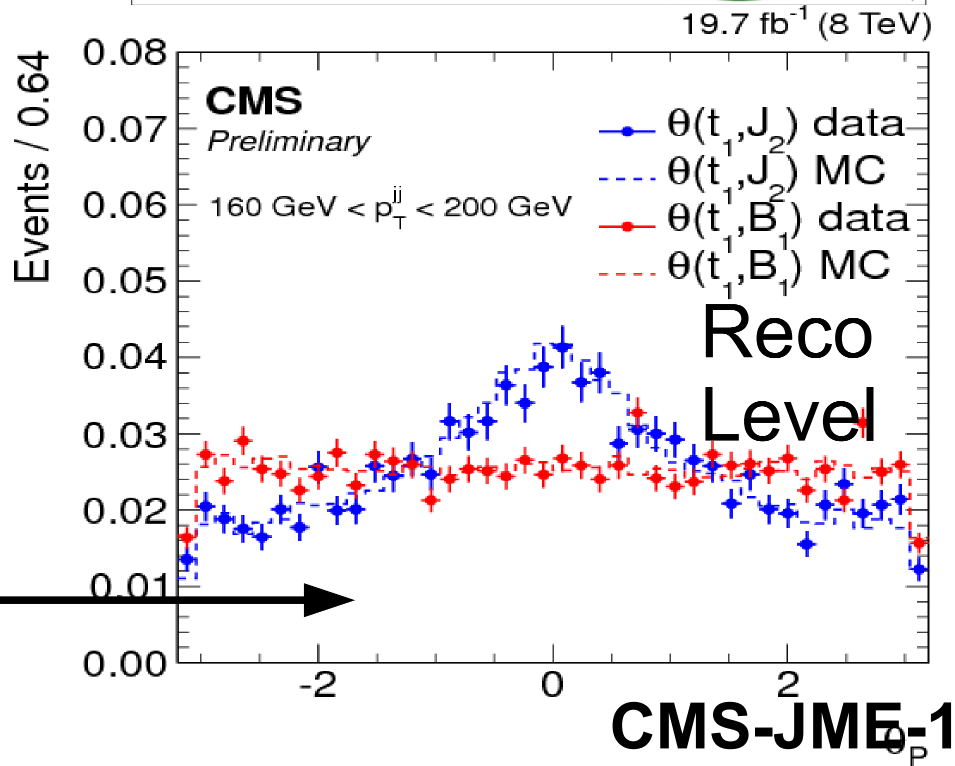
- Background subtracting

$$\vec{t} = \sum_i \frac{(p_T)_i \, |r_i|}{(p_T)_{\text{jet}}} \vec{r}_i$$

$$\vec{r}_i = (\Delta y_i, \Delta \phi_i)$$

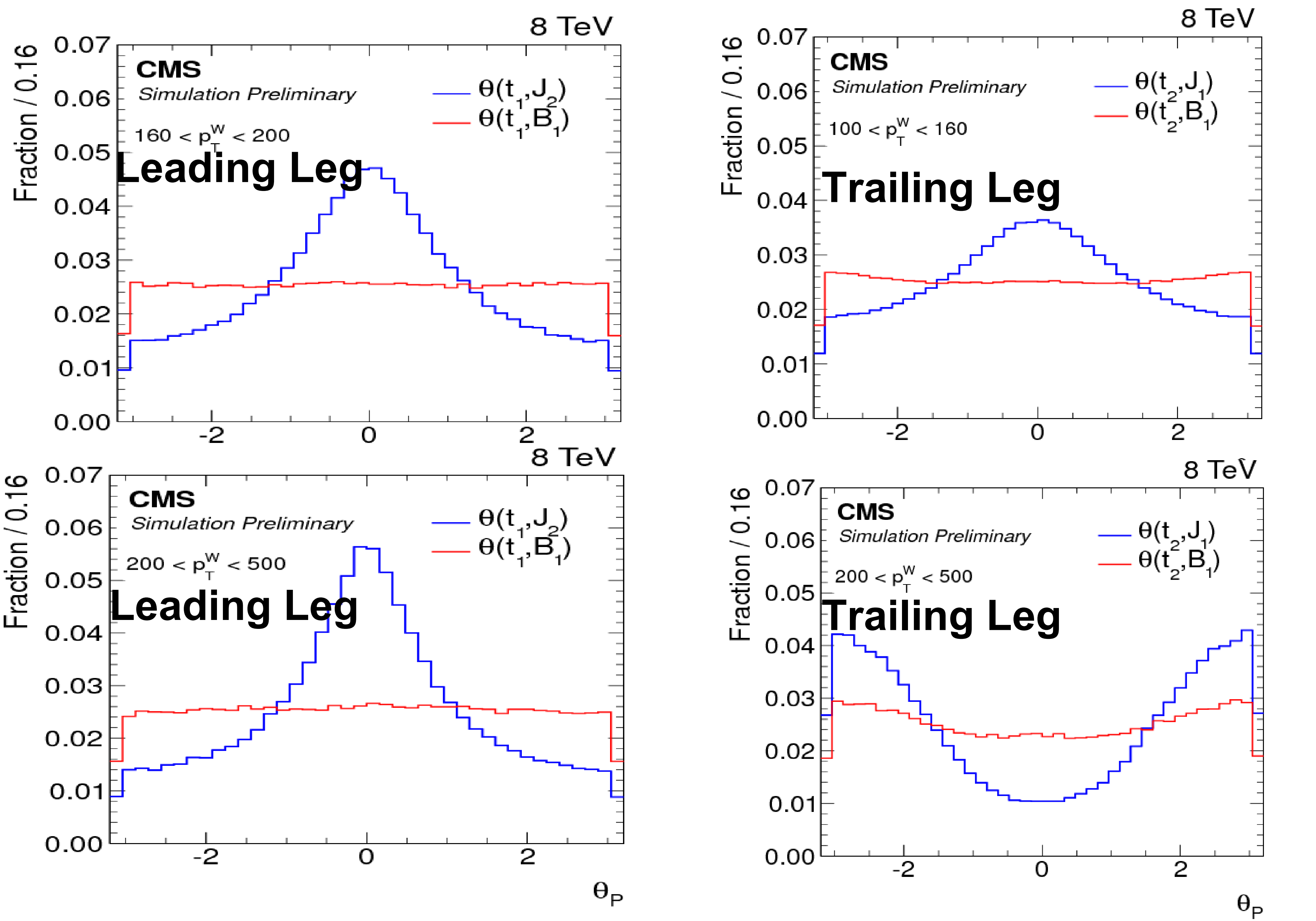




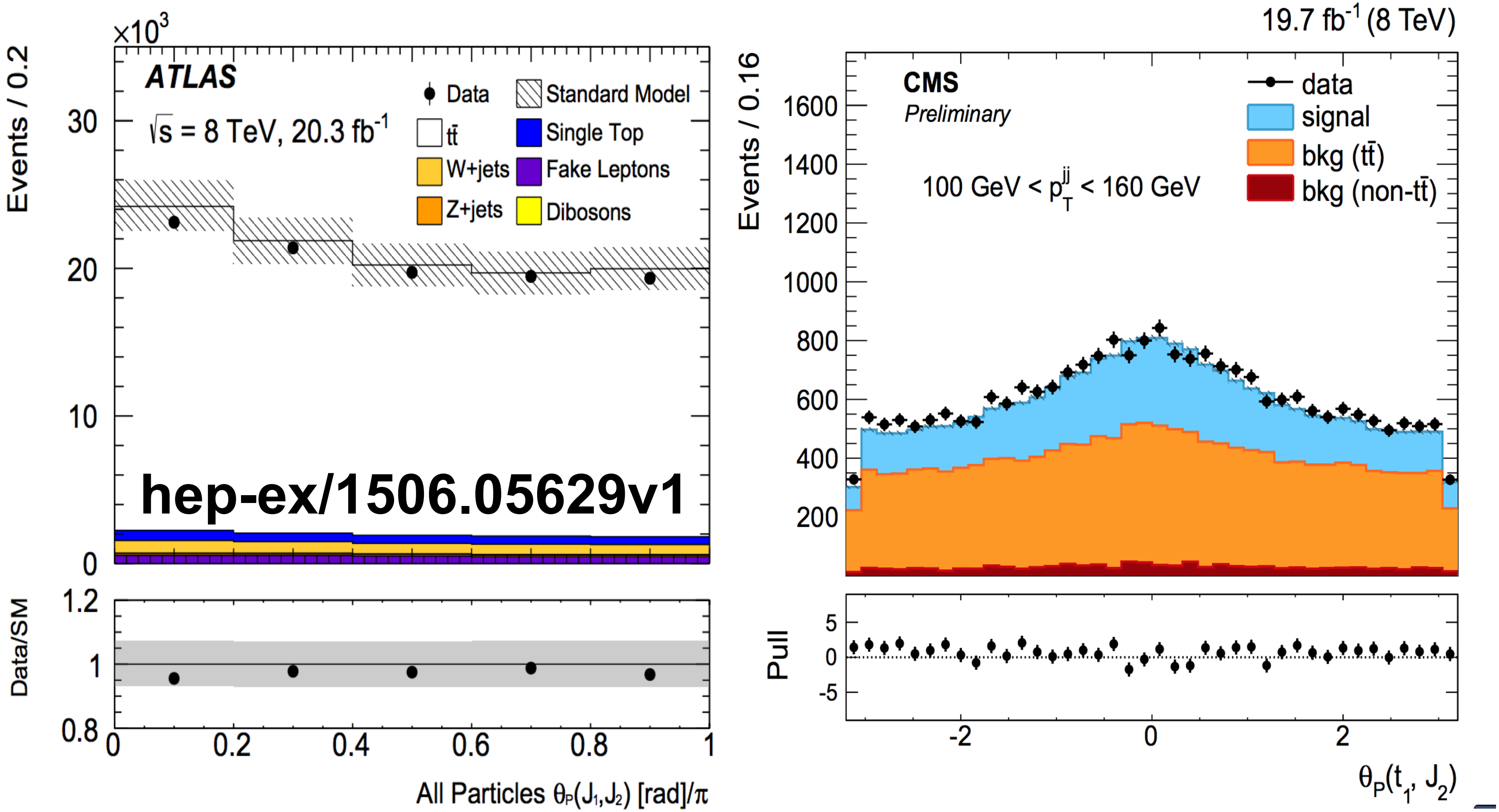


CMS-JME-14-002

Interesting Features of Color Flow

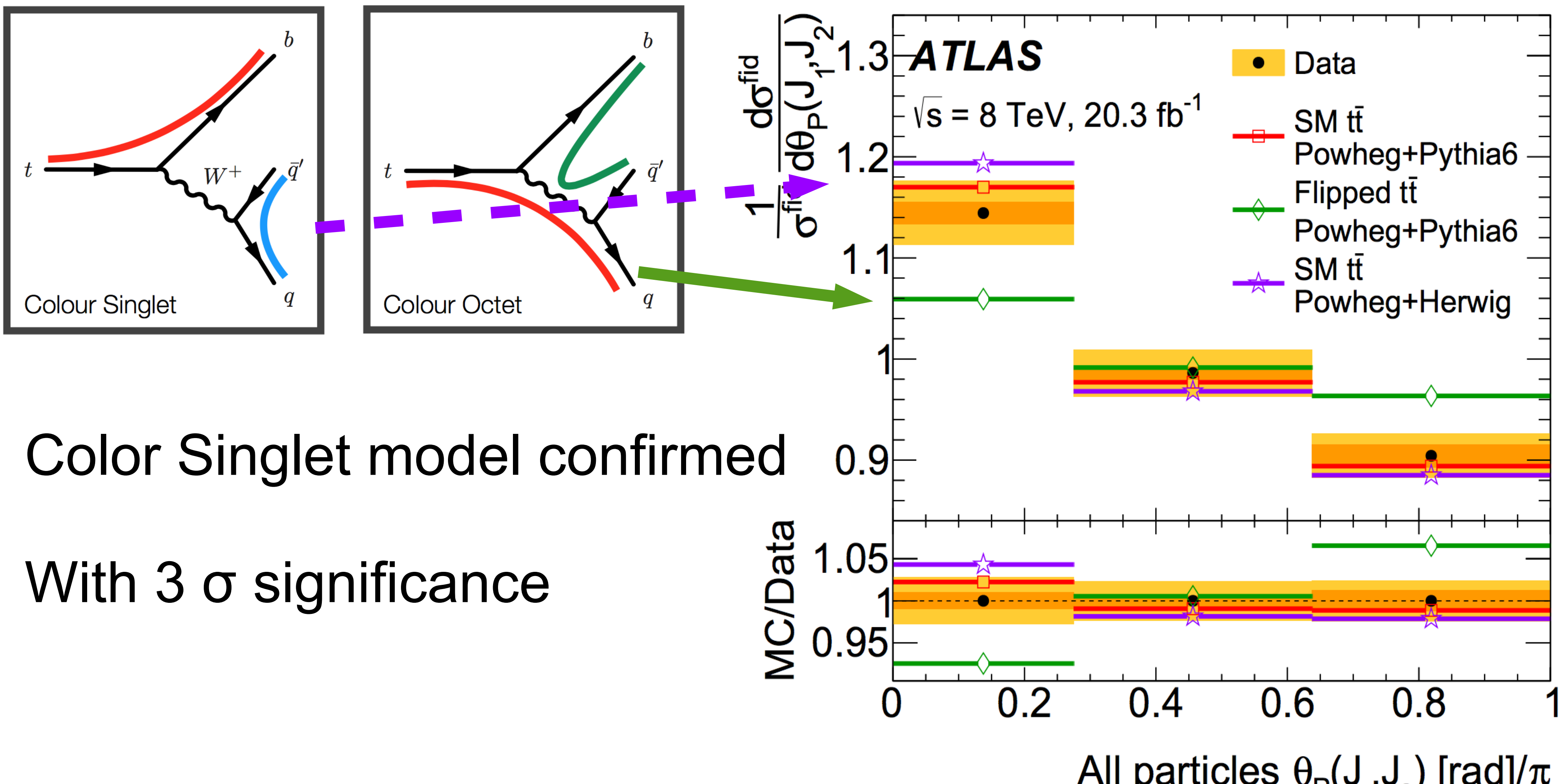


Both experiements actively looking



Similar performances : indicative of robustness

Can confirm ColorFlow in tops



Color Singlet model confirmed

With 3 σ significance

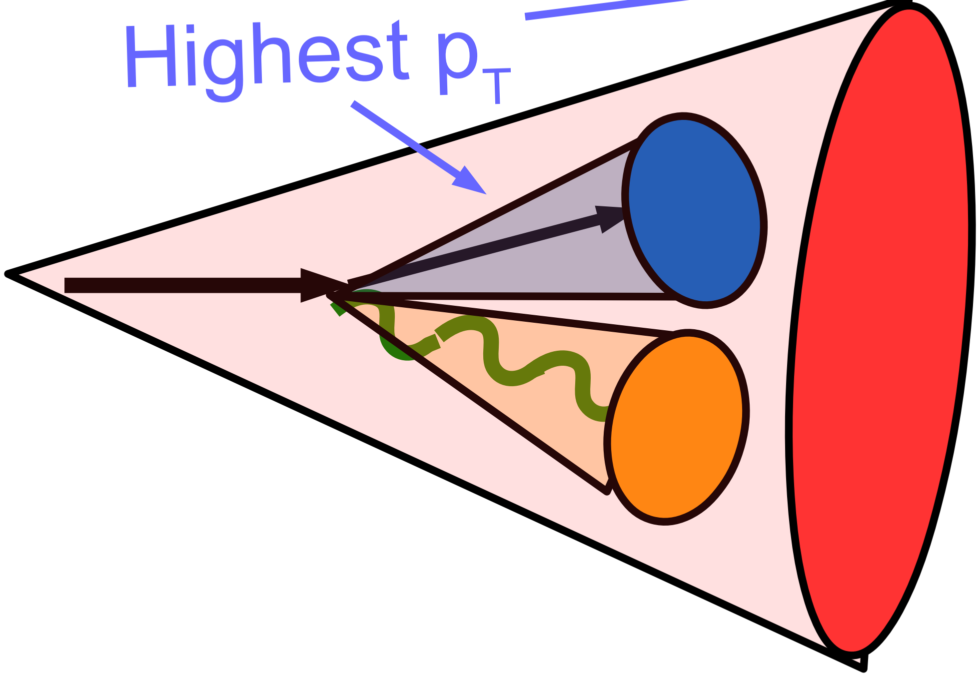
There is still more to be understood with these variables

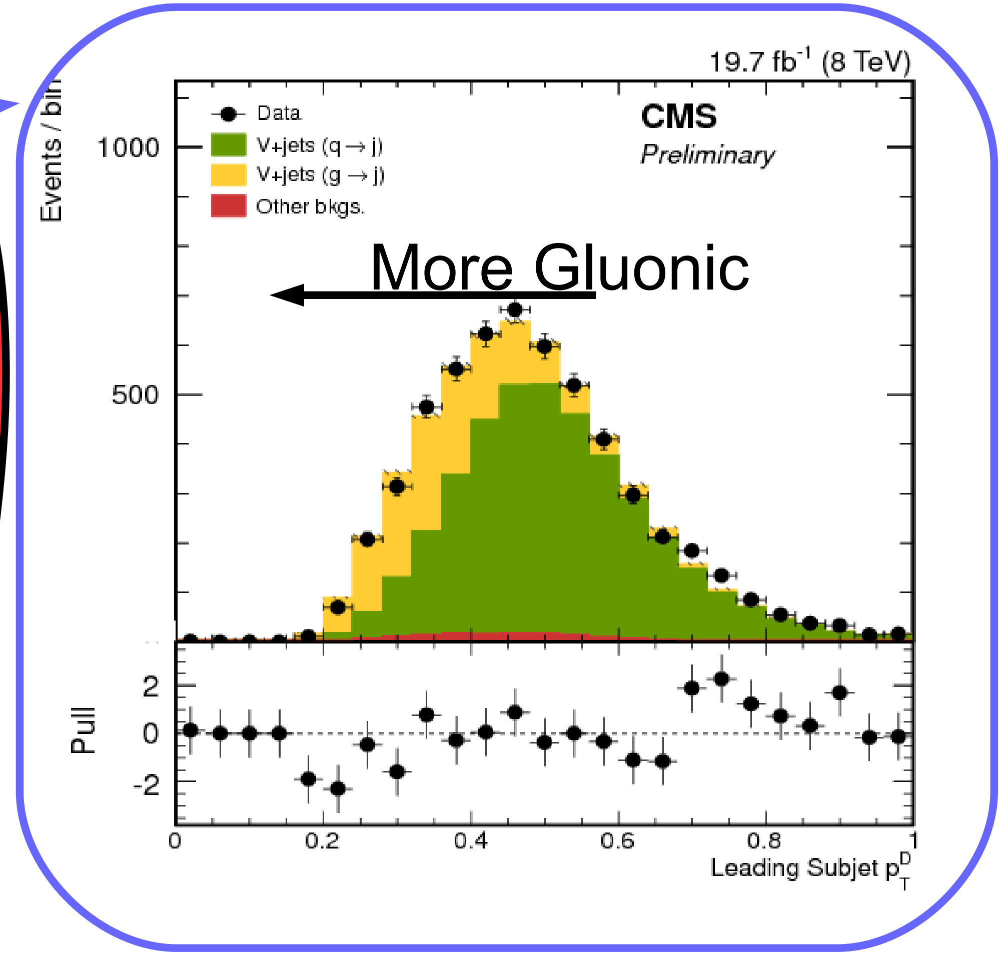
hep-ex/1506.05629v1

Resolving the Splitting themselves

- Now at the stage where we have a box of tools
  - We can try to combine them

Subjet reconstruction
w/ Quark Gluon discrimination





JME-14-002

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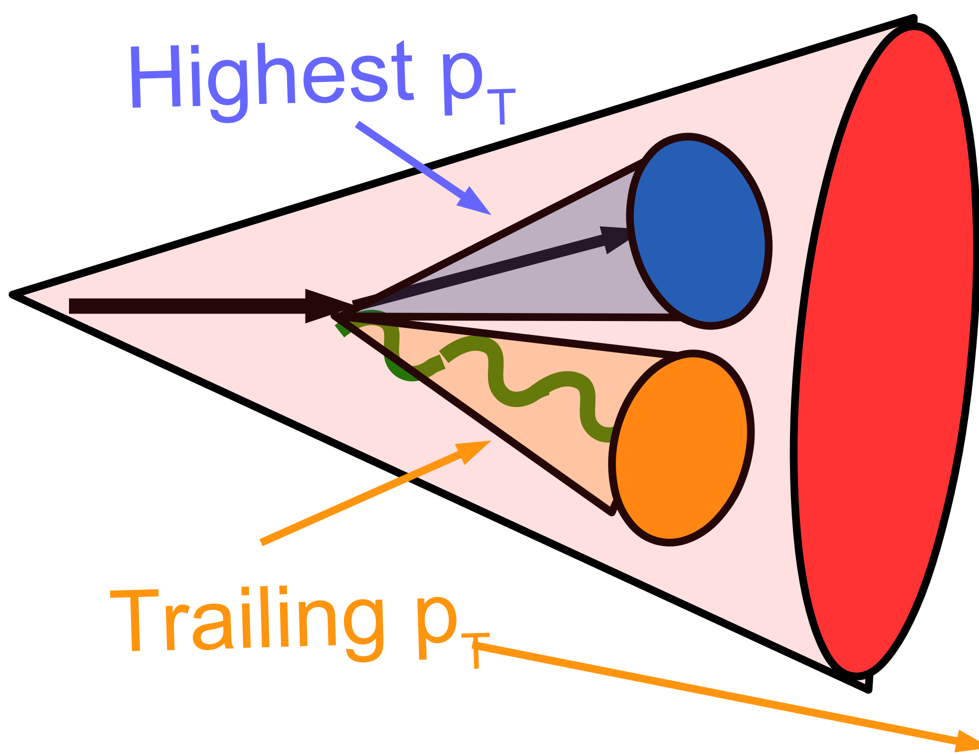
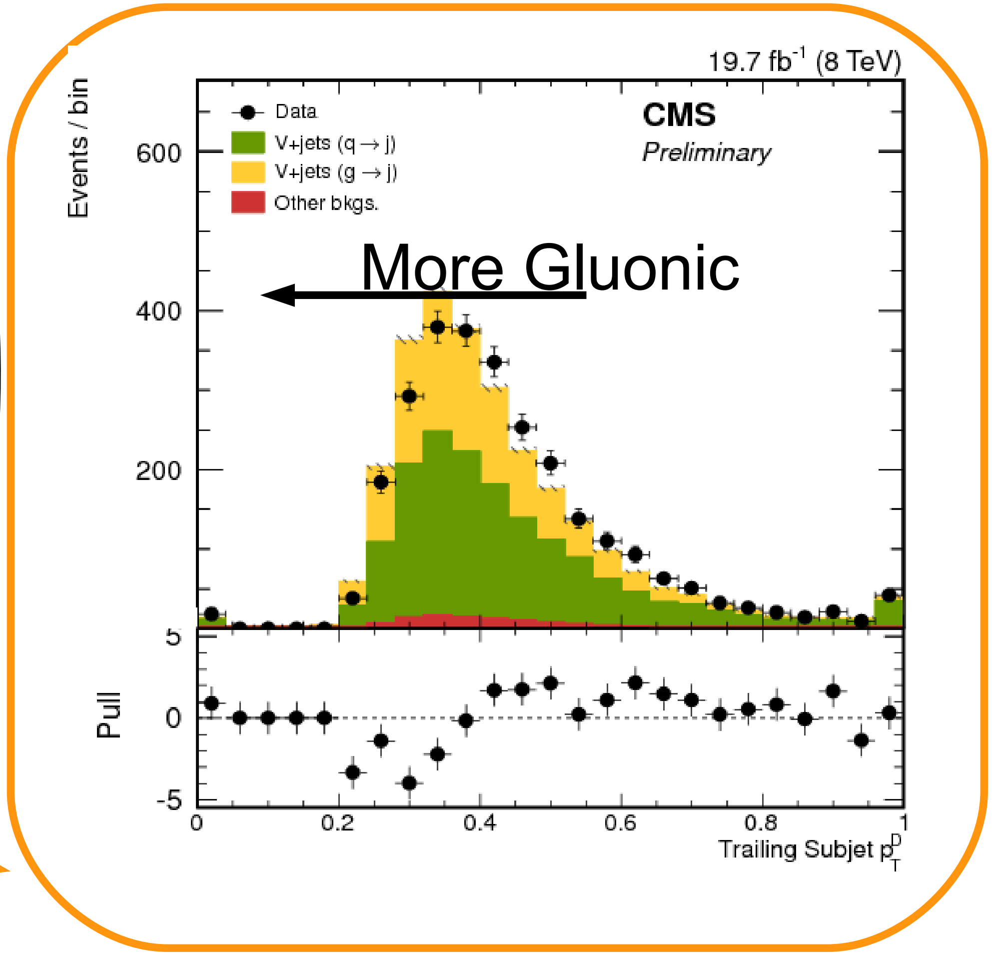
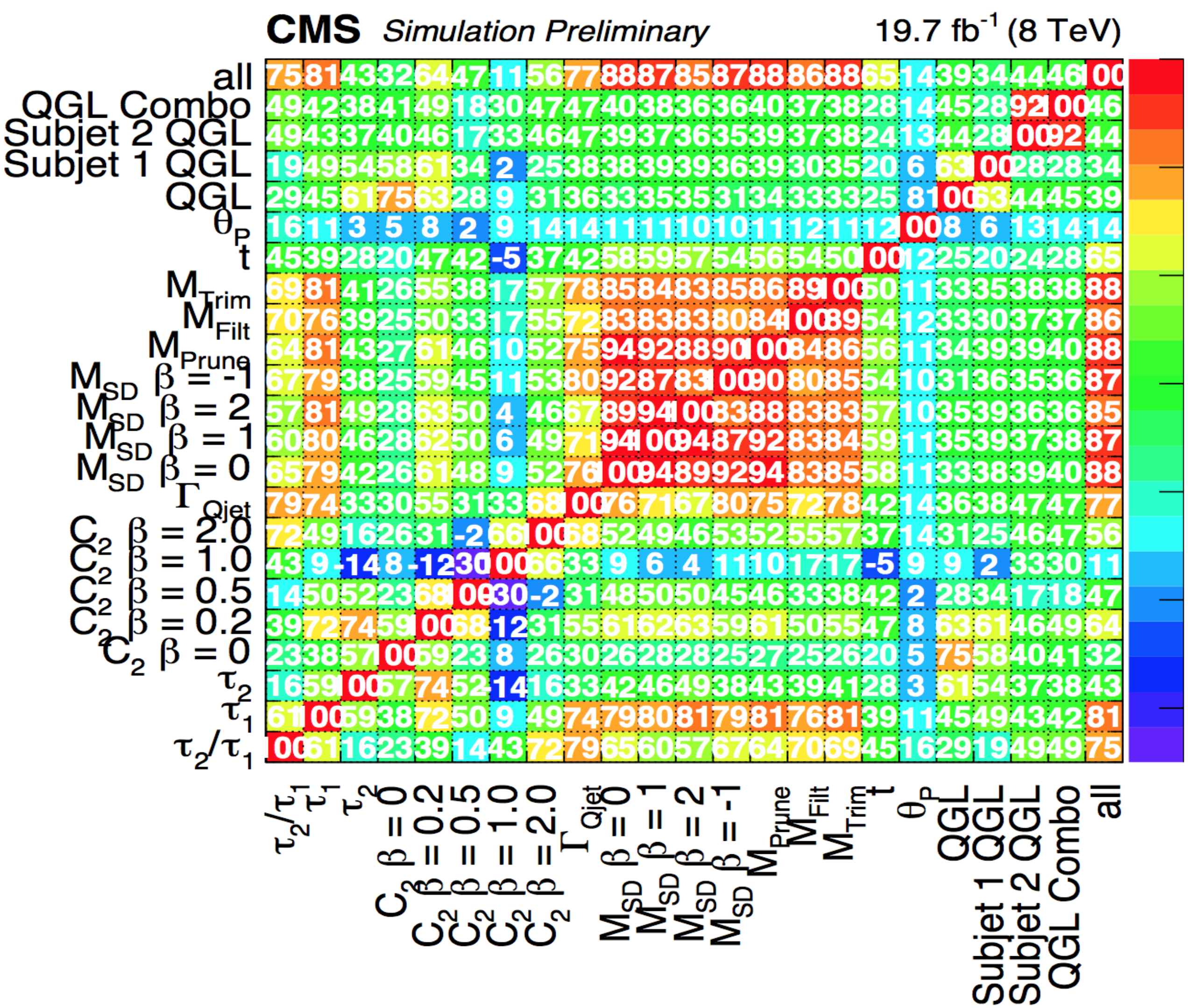




JME-14-002

Too Many Variables

- Now at the stage where we have a box of tools
  - Understanding the full picture can bring even more



JME-14-002

Too Many Variables

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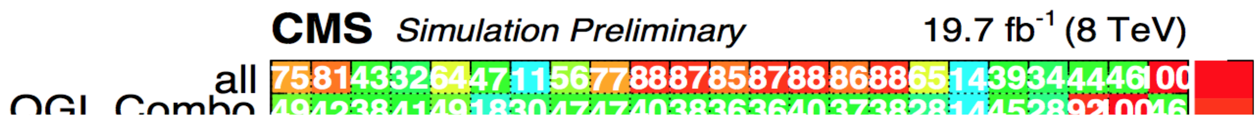
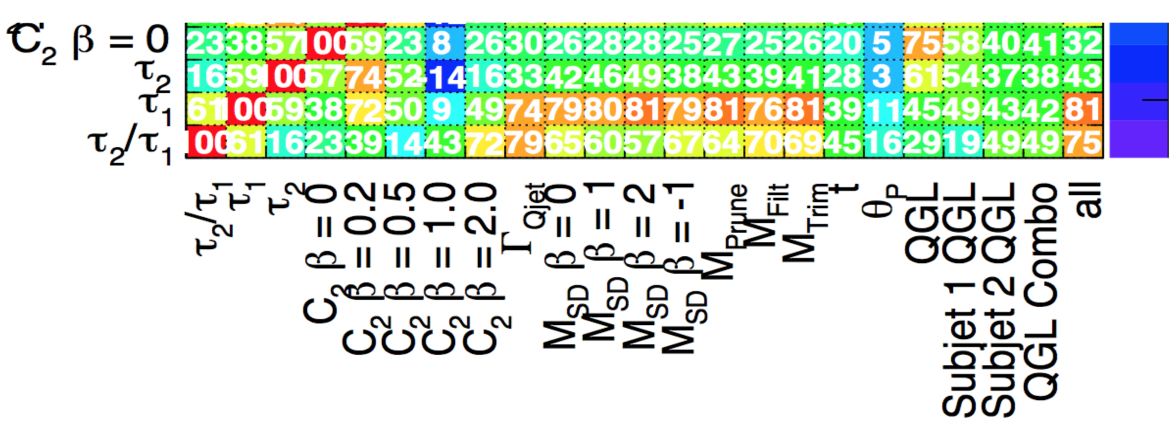


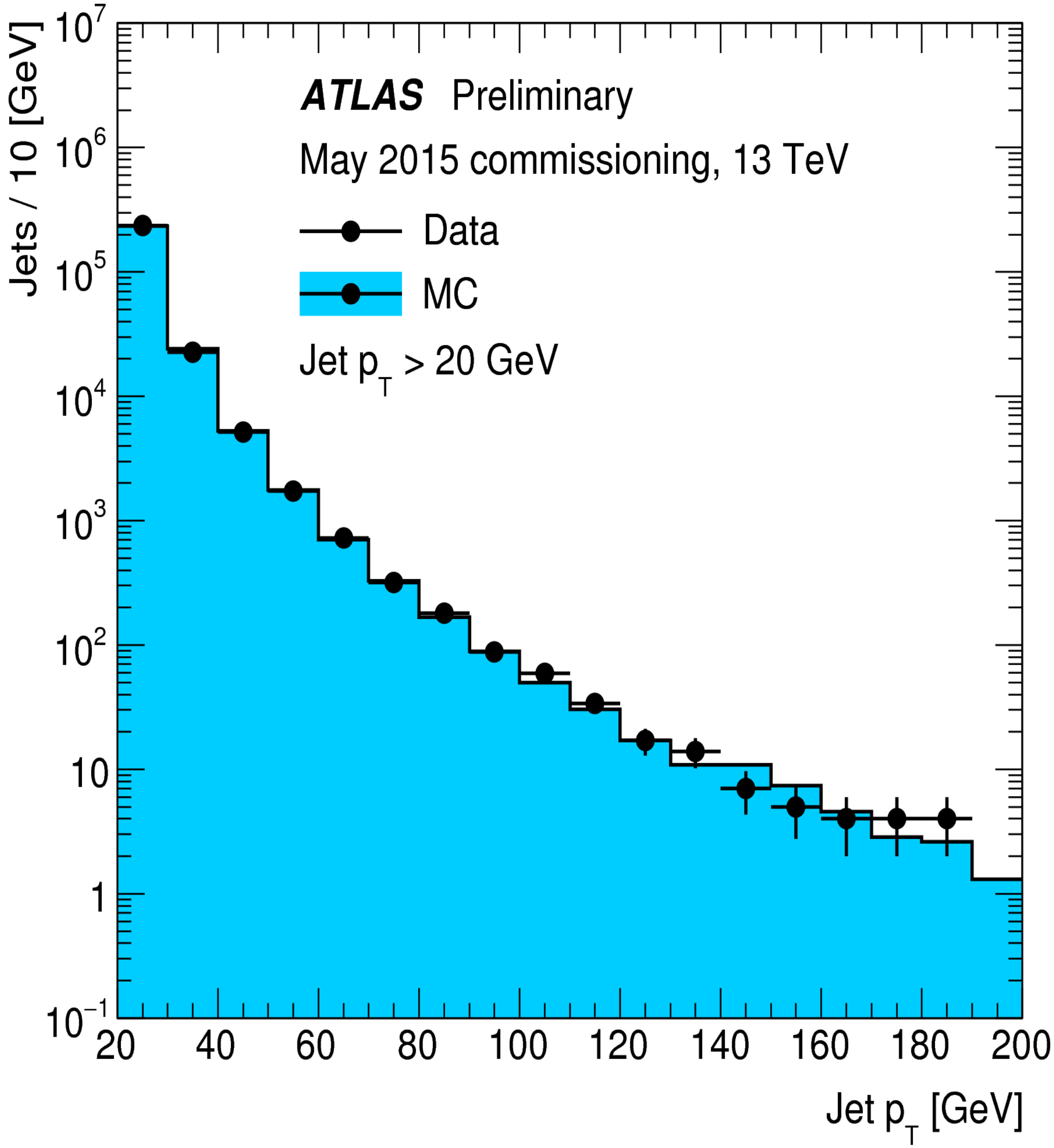
Do we have enough tools to start measurements in the QGP?



Looking Forward



- LHC is an established precision device
  - Strong PDF/α_s measurements exist
  - Precision jet measurements
  - Extending measurements beyond
- A new set of tools have emerged
  - Approach PU/UE with more rigor
  - Deep understanding of jets in hadronic collisions
    - Starting to feel like the LEP precision results
- Questions for the community?
  - **How can we best use new tools for measurements?**
  - **What ~~can~~should be brought over to Heavy Ions?**

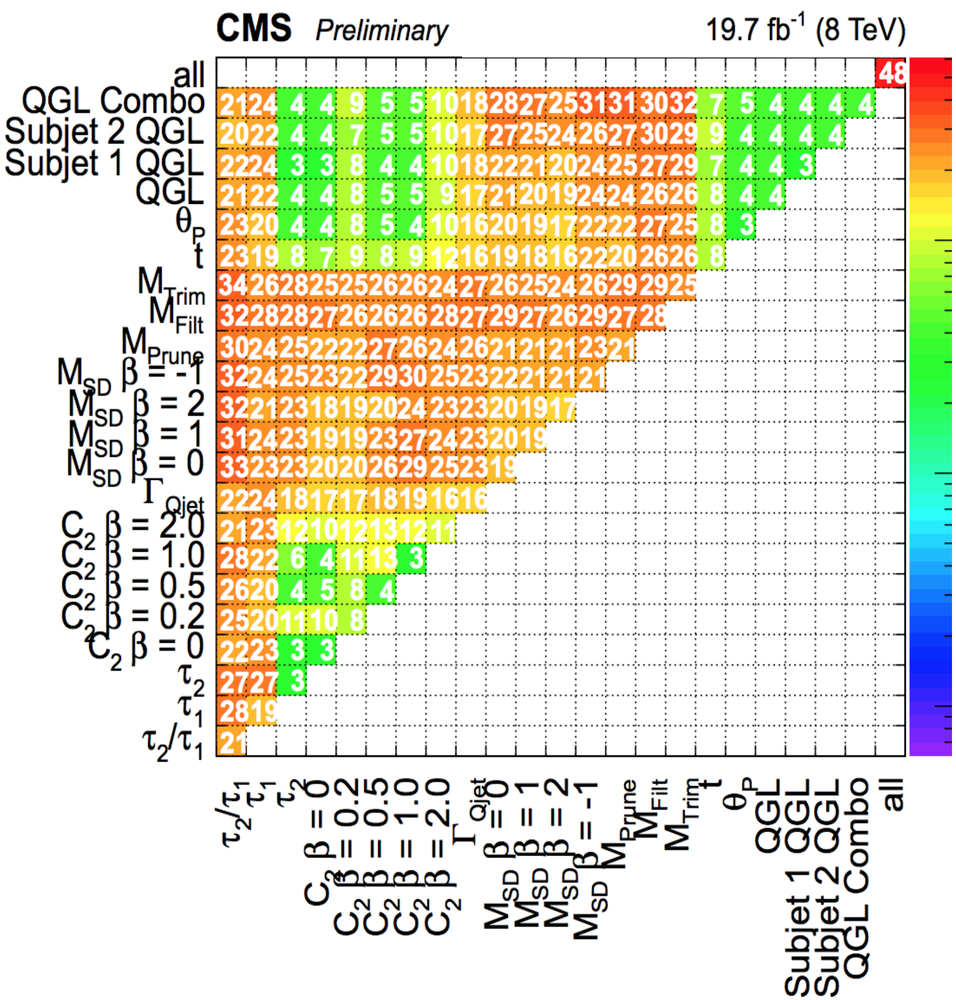


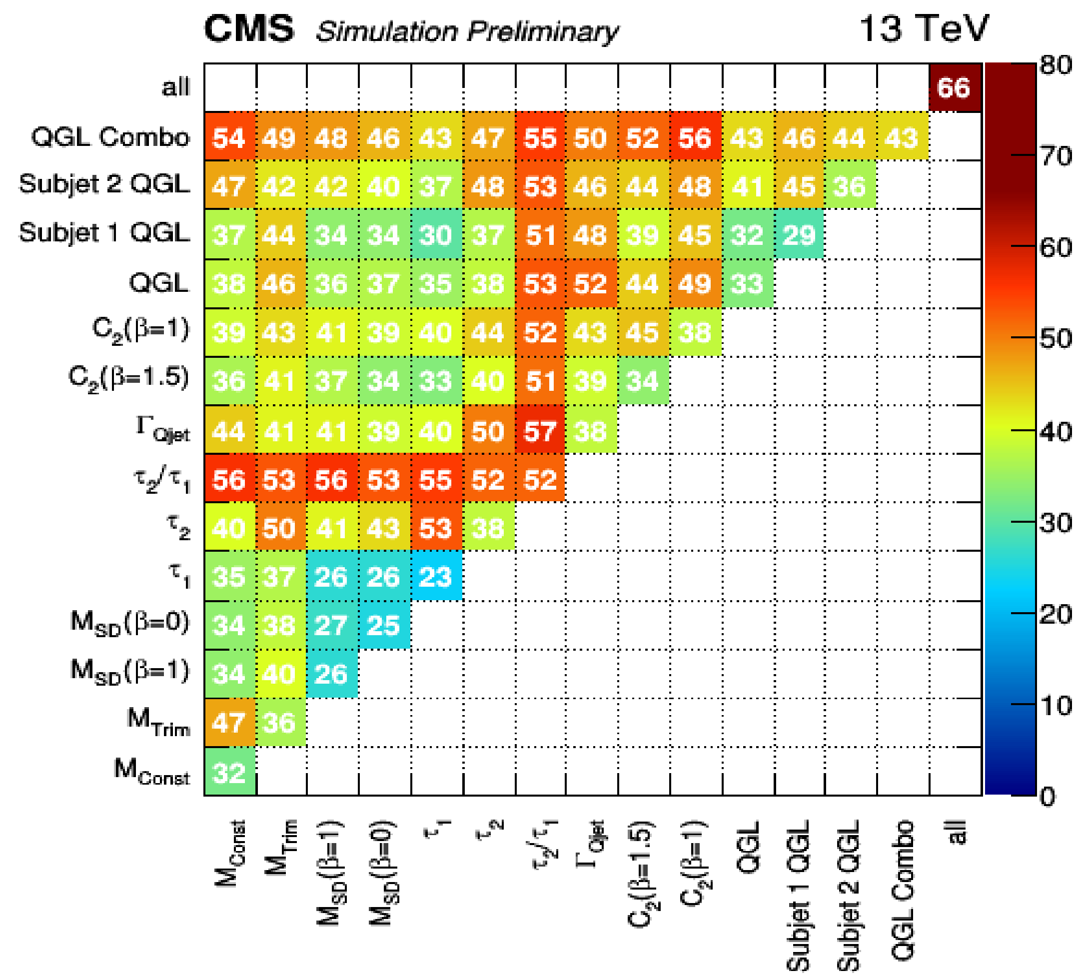
Fin

ATLAS-JETM-2015-001

Understanding Observables

- There are many more observables



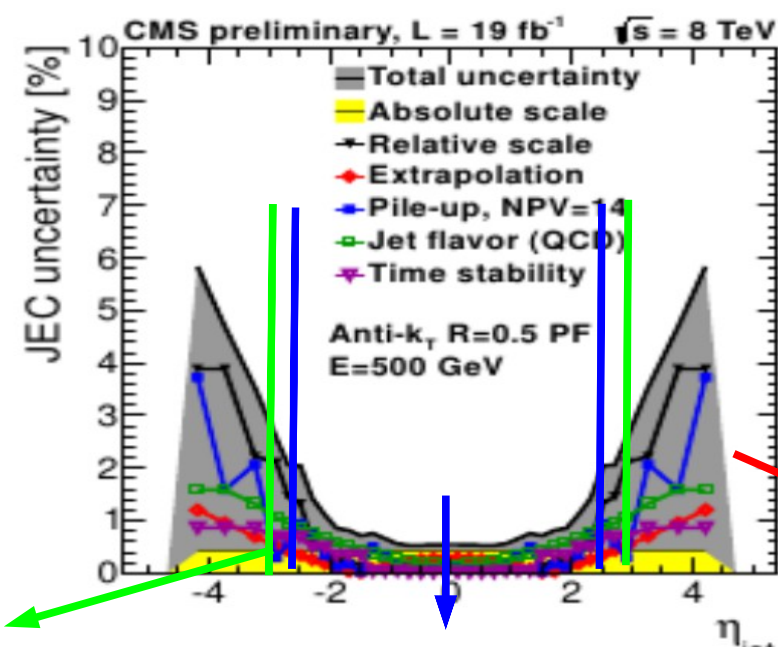


Doing our best to document them all

JME-14-002

JERC

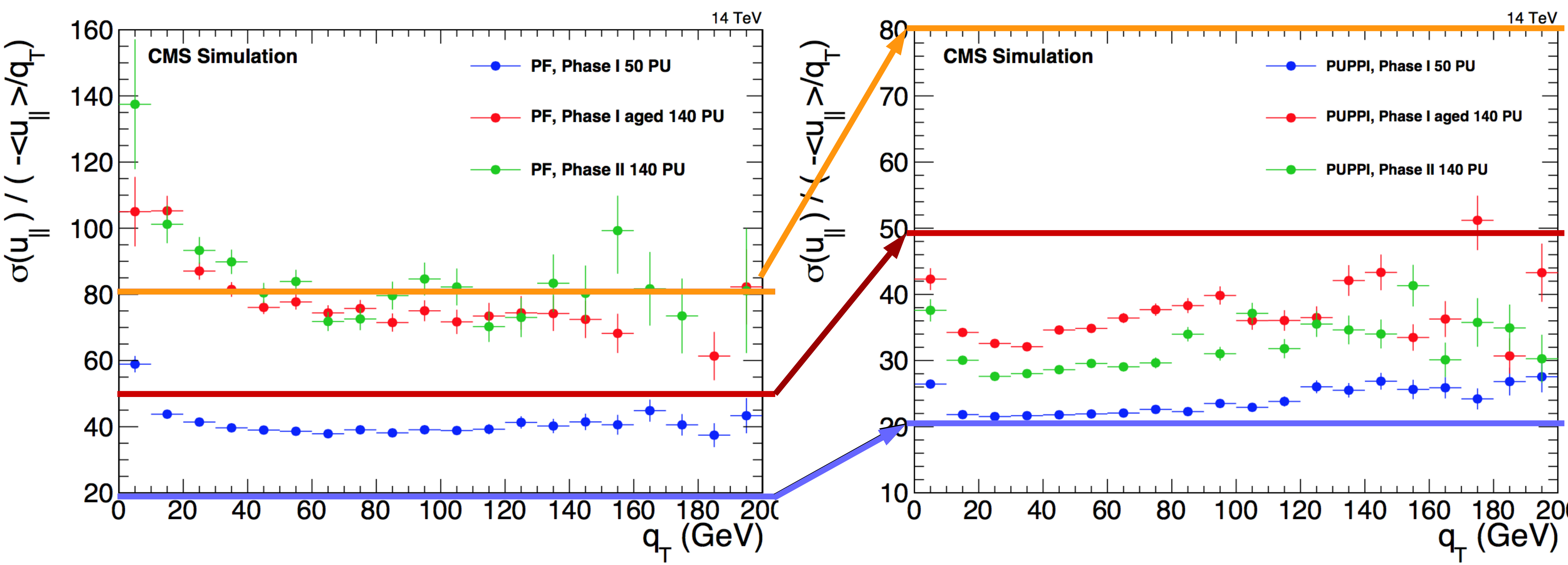
- JERC : Jet Energy Resolutions and Corrections
  - Previous simple steps are quite involved
    - Corrections still peformed on Calo/J+Track/Partciel Flow Jets
  - Jets are different creatures at different η
  - Consistency with trigger (L1 and HLT): a necessity
    - Note that the L1 Trigger is not particle flow based



2.5<|η|< 3.0: Calo+some tracks |η| < 2.5: Calo+tracks 3.0<|η| < 5.0: Fwd Calo

Bringing it bak to LEP

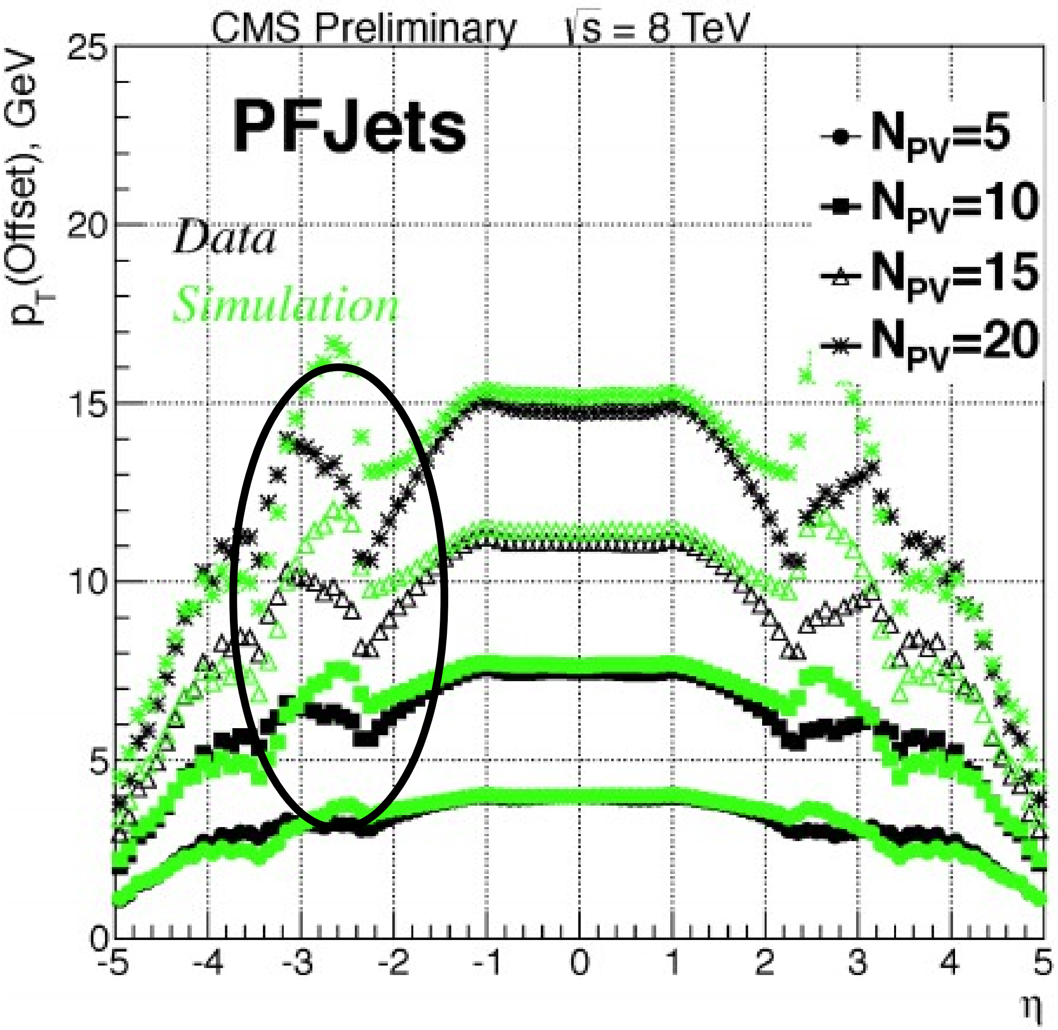
- The final α_s measurement used event shapes
  - In approaches like PUPPI we minimize UE effects
  - Allow's us to preserve much of the hard scatter



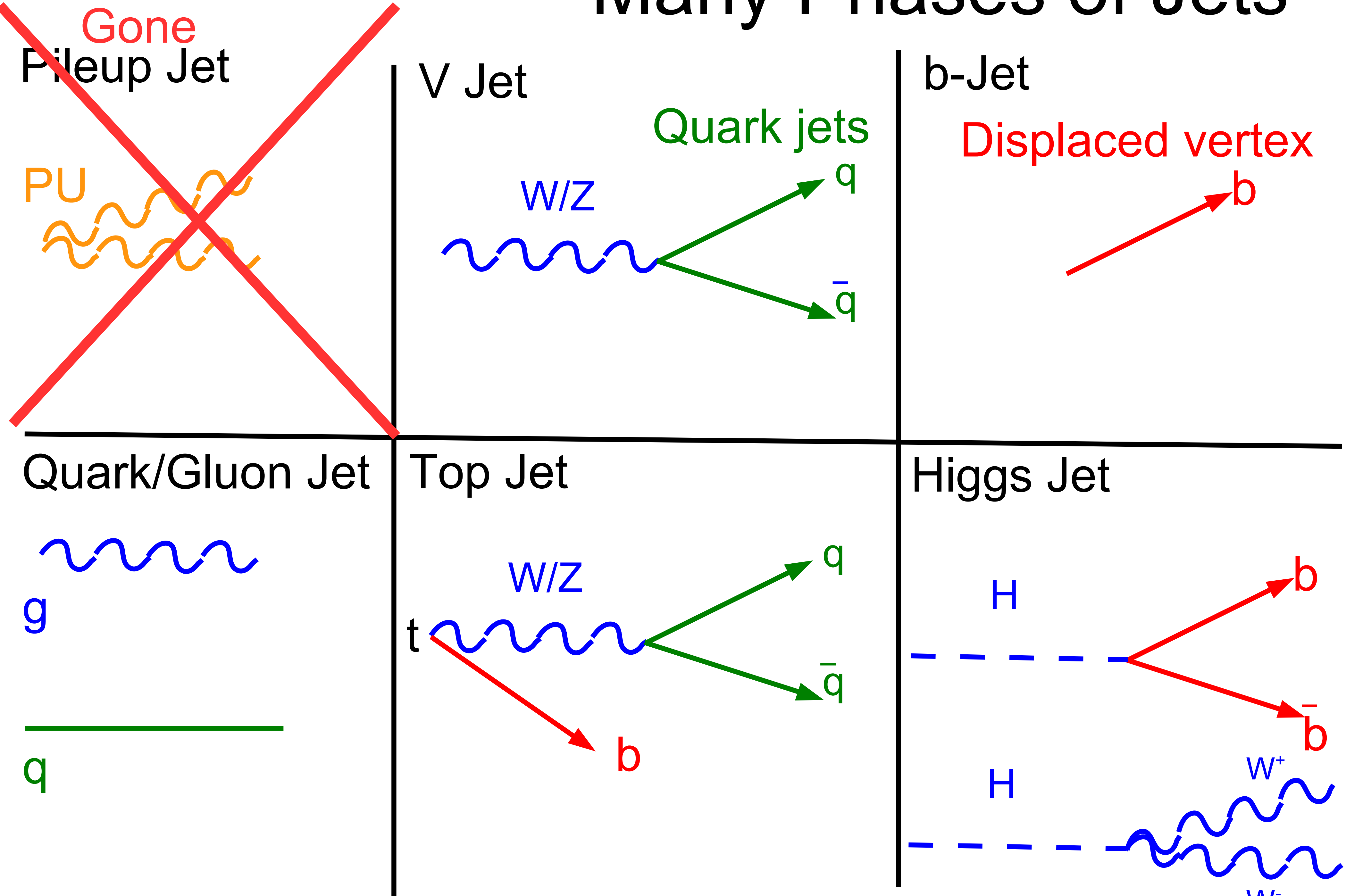
8TeV Precision

- Pileup Subtraction
  Pileup measured in zero bias events : effectively is 1 2D Plot

How do we deal with the systemaitcs?

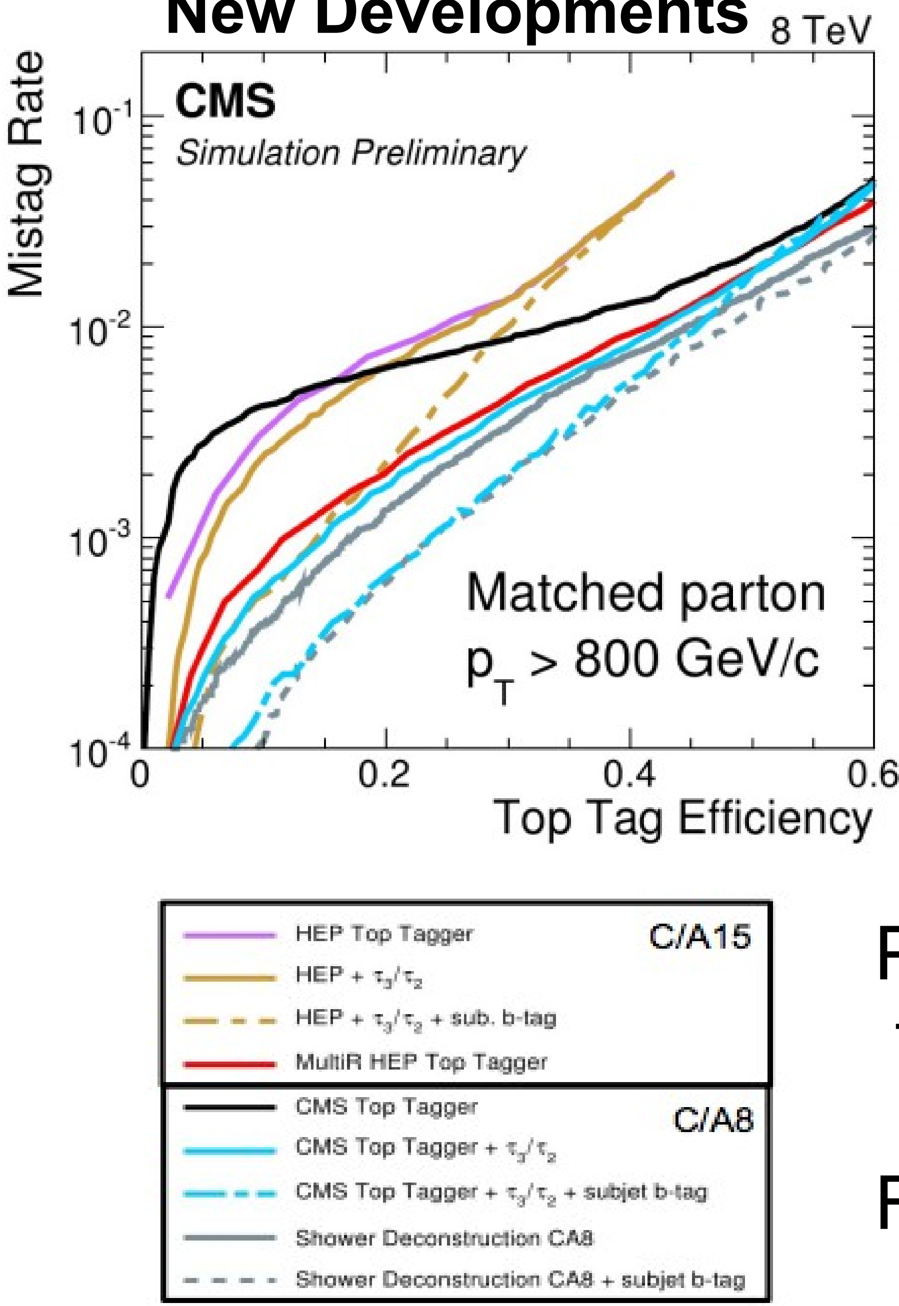


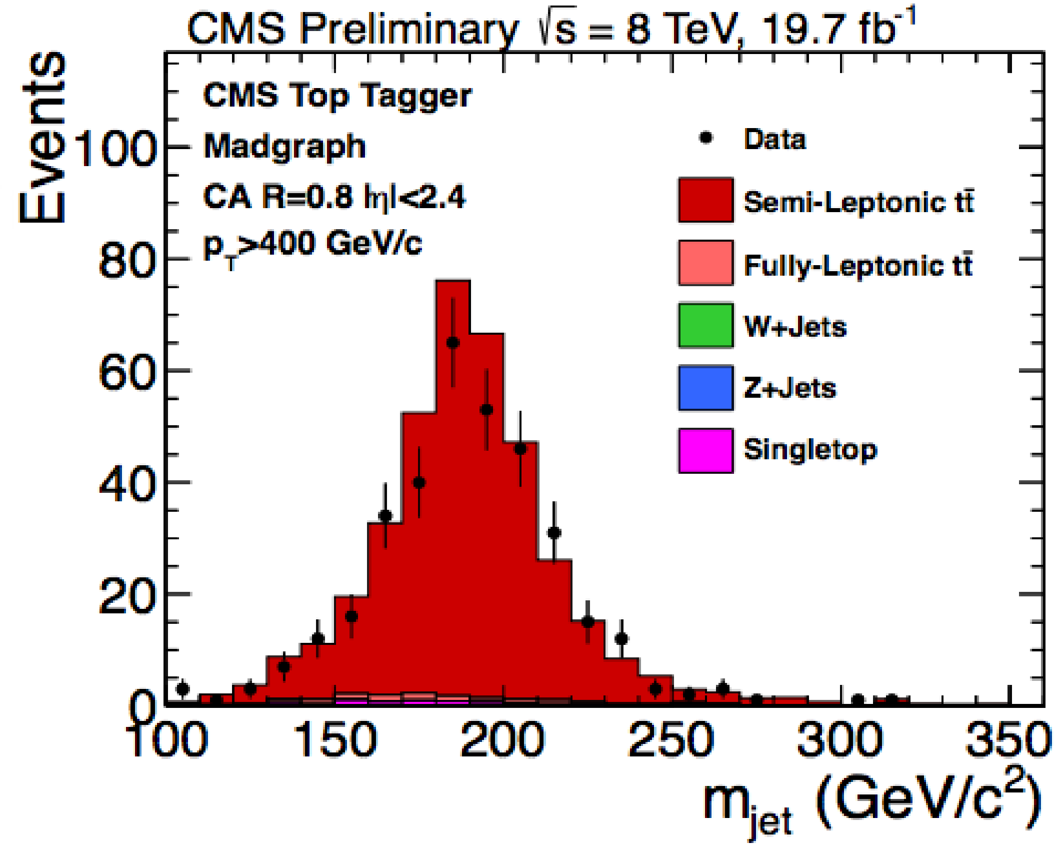
Many Phases of Jets



Tagging Hadronic Tops

Top Tagging
New Developments





Plethora of techniques exist
for boosted top tagging

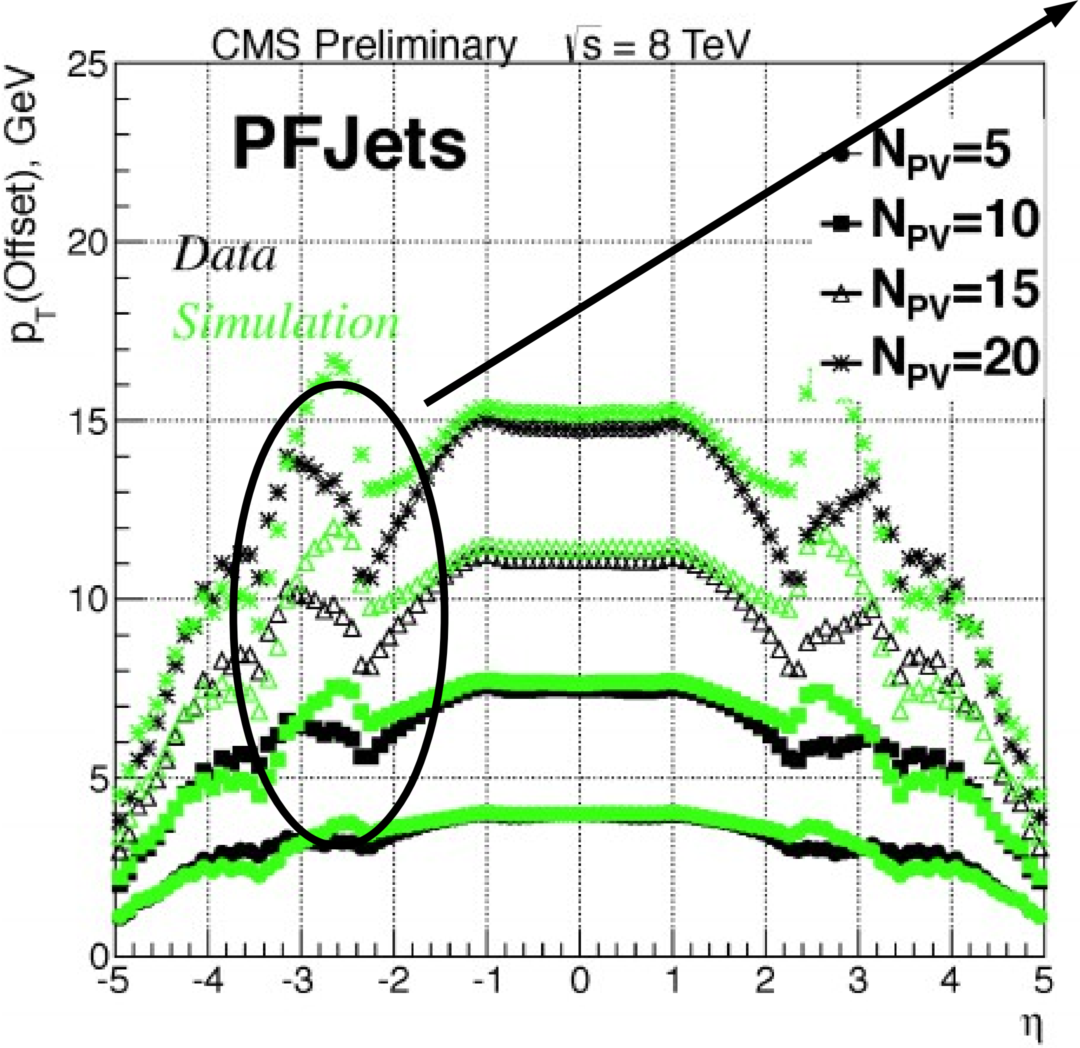
Fake rates comparable to leptons

JME-13-007
JME-DP-14/038

8TeV Precision

- Pileup Subtraction

  Pileup measured in zero bias events : effectively is 1 2D Plot



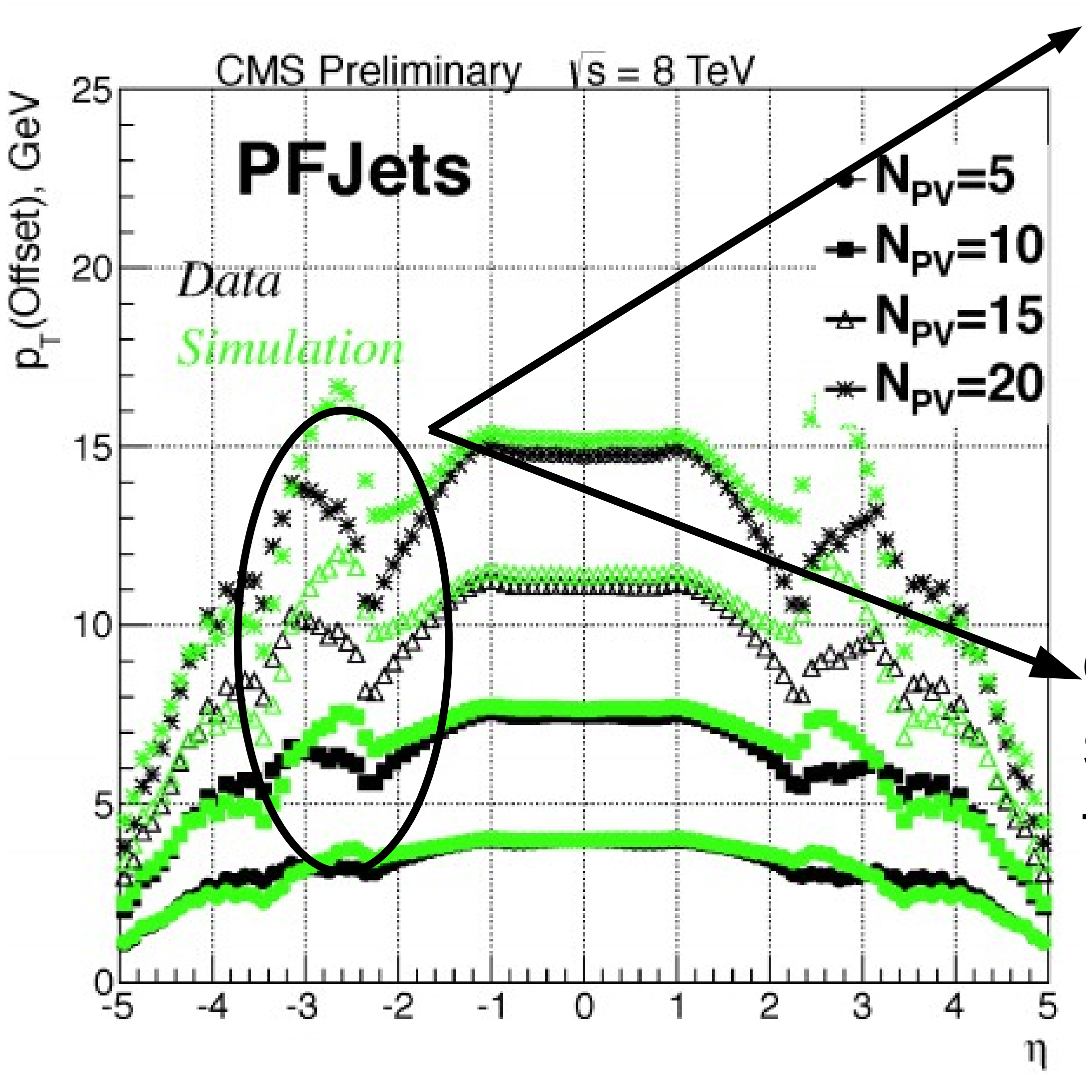
Originally had systematic unc. Based on full data/MC difference

How do we deal with the systemaitcs?

8TeV Precision

- Pileup Subtraction

  Pileup measured in zero bias events : effectively is 1 2D Plot



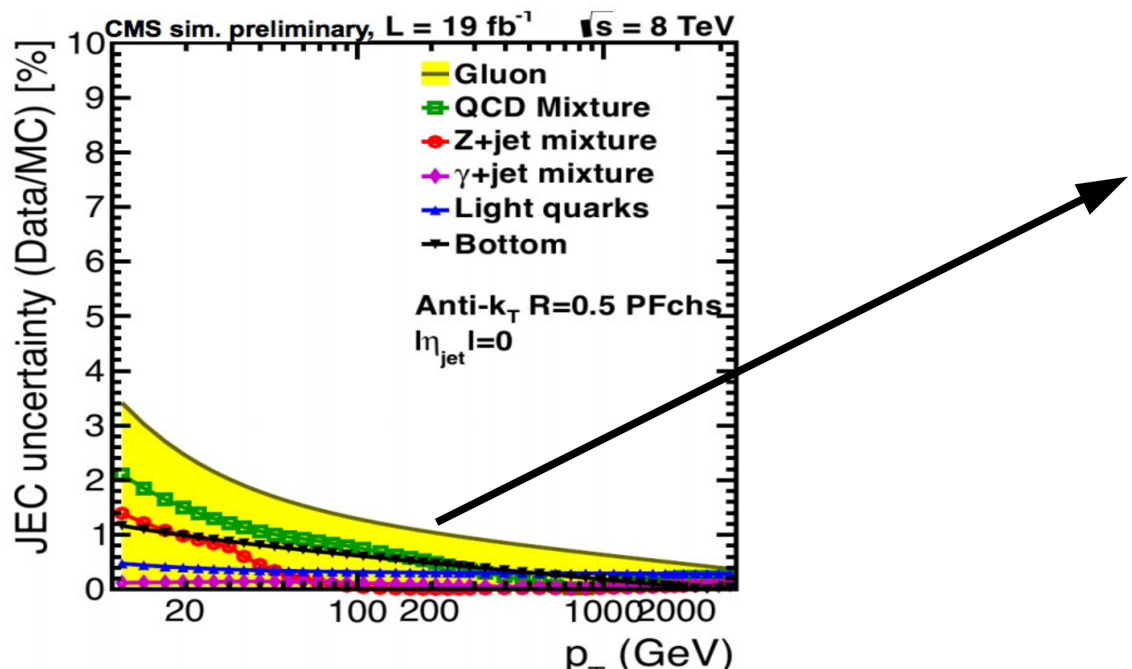
Migrated to residual bias Using same jets w/o pileup

How do we deal with the systemaitcs?

Data/MC disagreement subsequently fixed (out of time PU)

Flavor Dependence

- Understanding flavor dependence
  - A general theme in jet energy corrections 2013
  - New technology was exploited
- Old times : Physics can be pure gluons/quarks
- Update : All physics have both quark and gluons
  - Thus quote systematic by quark gluon composition

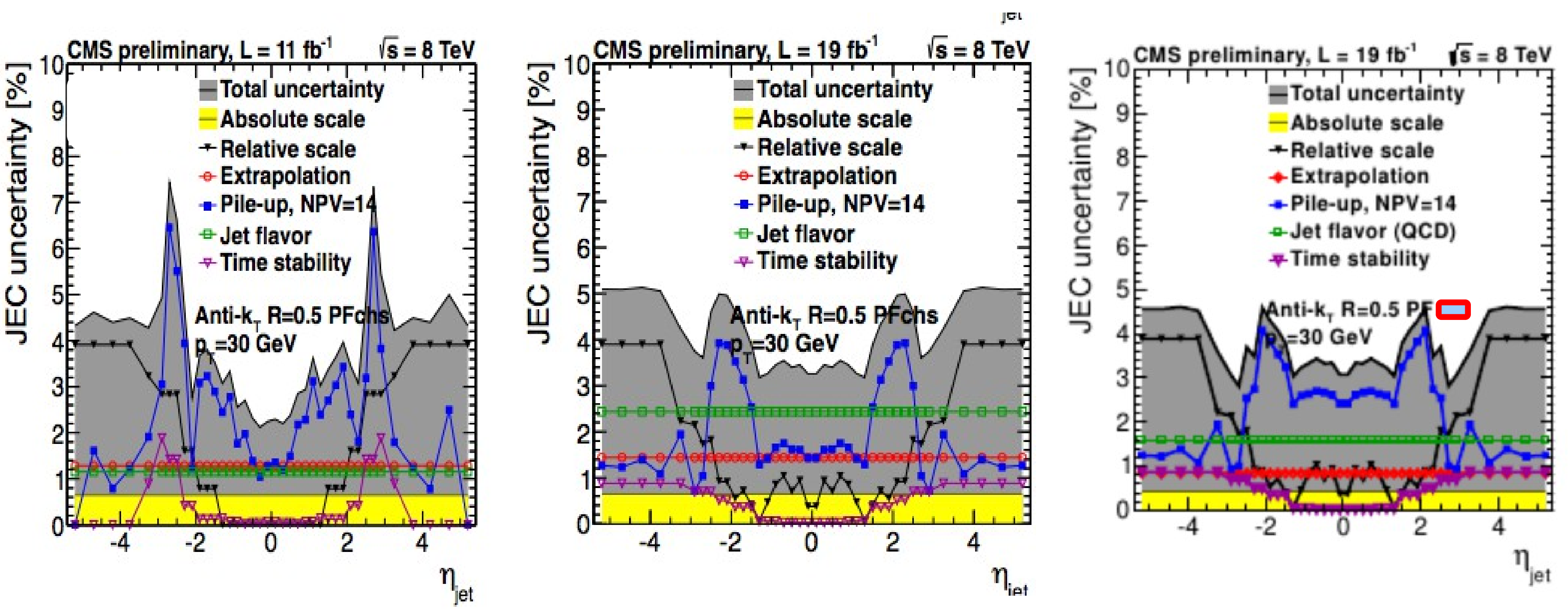


Different unc. For different componsition

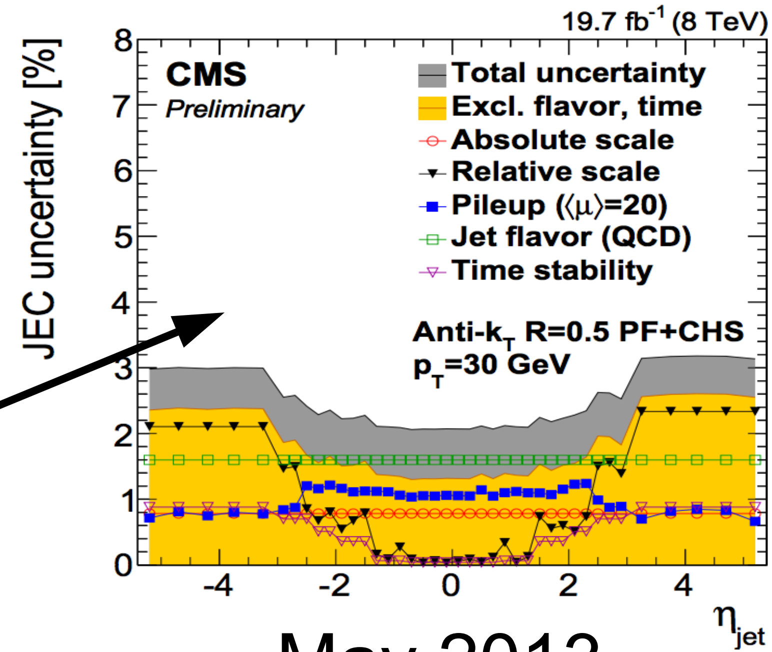
Evolution

- Where are we being limited :
  - Relative scale in the forward region
    - Result is the statiscal uncertainty of the method
  - Pileup (at low pT)

2012 May 2013 July 2013

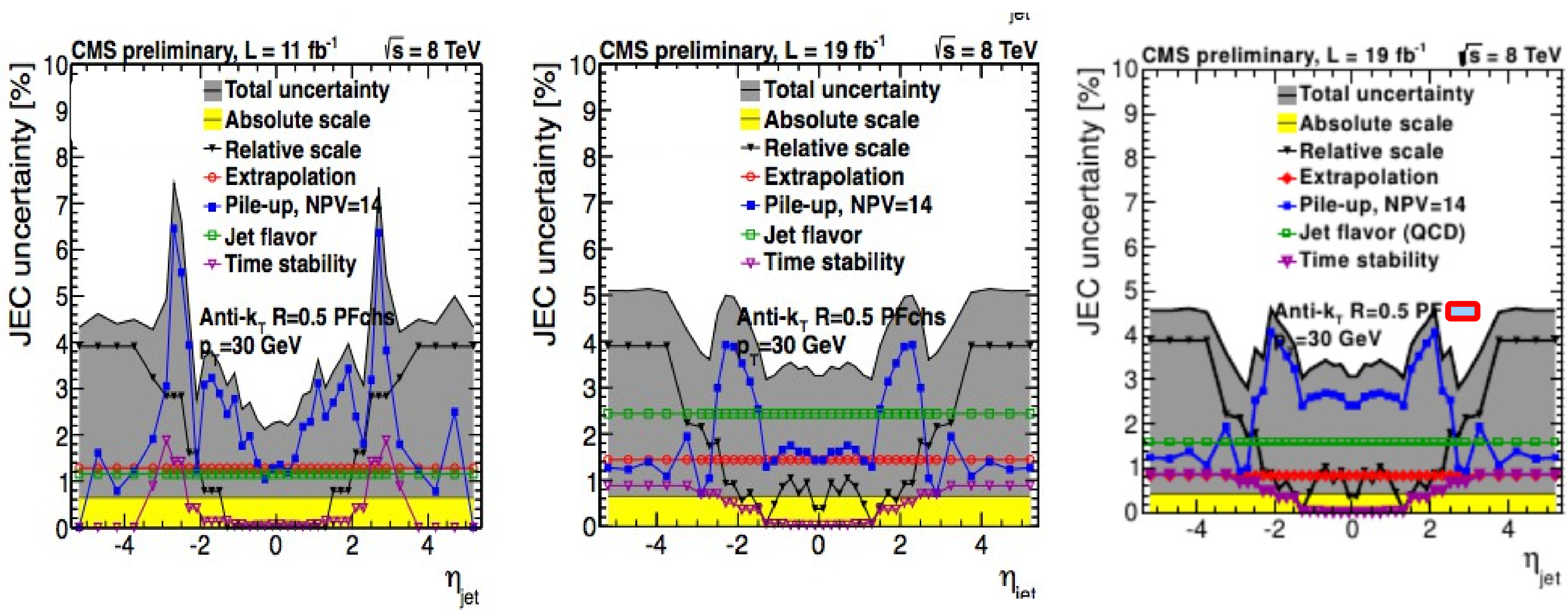


Evolution



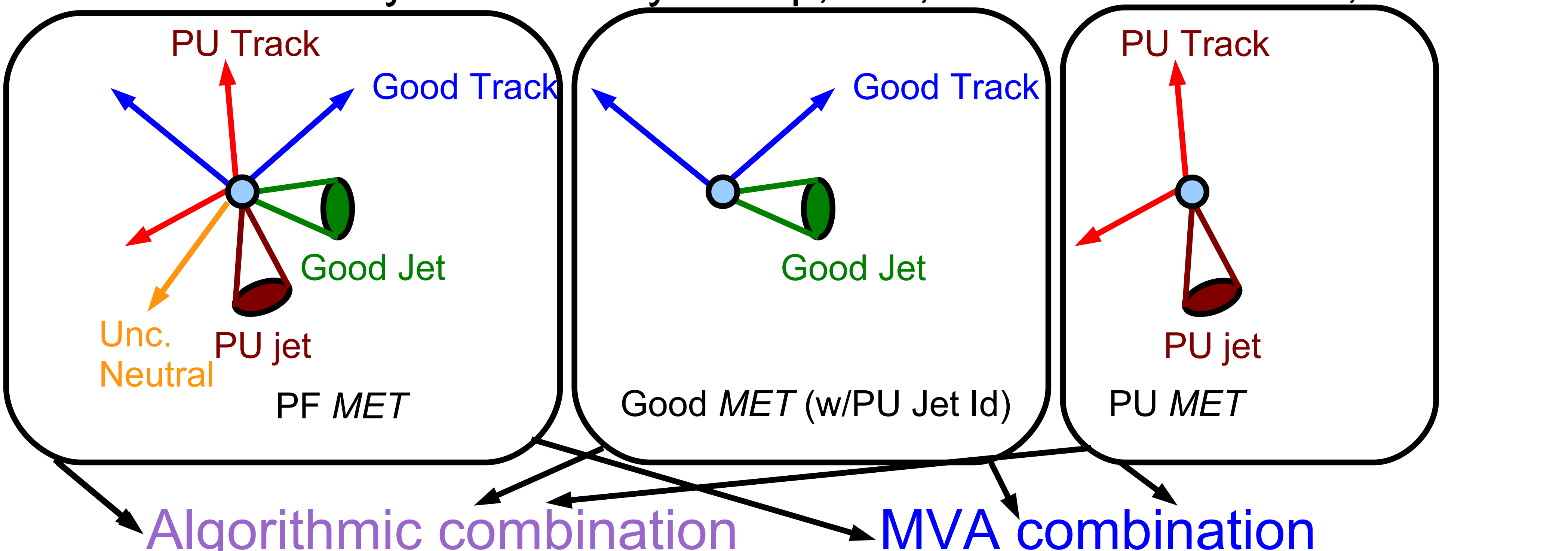
Now

2012 May 2013 July 2013



Garbage Collection: PU Reduced *METs*

- *MET* is effectively summing up all the trash
  - PU Reduced *METs* Equivalent to Recycling
    - Sorting your garbage by Metals/Plastics/Paper
    - Sort your event by Pileup,Jets,unclustered Neutral, tracks



Combine all of the estimates into one best estimate

There is no perfect way to remove objects from the *MET*

Garbage Collection: PU Reduced *METs*

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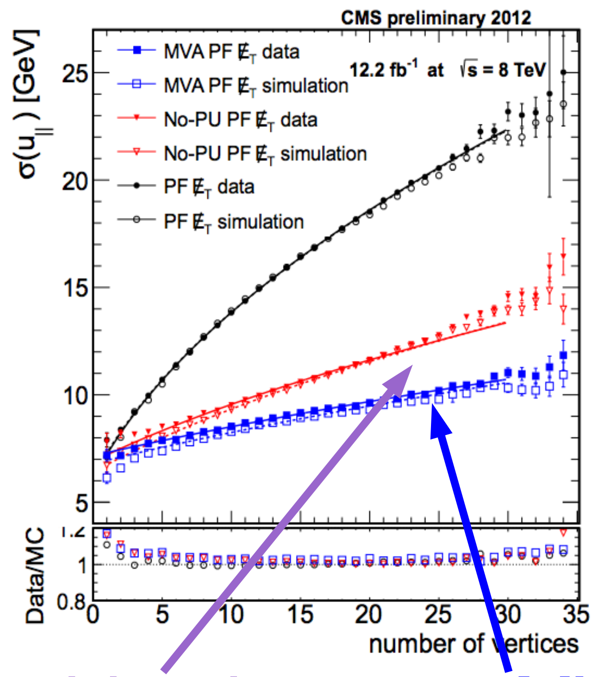


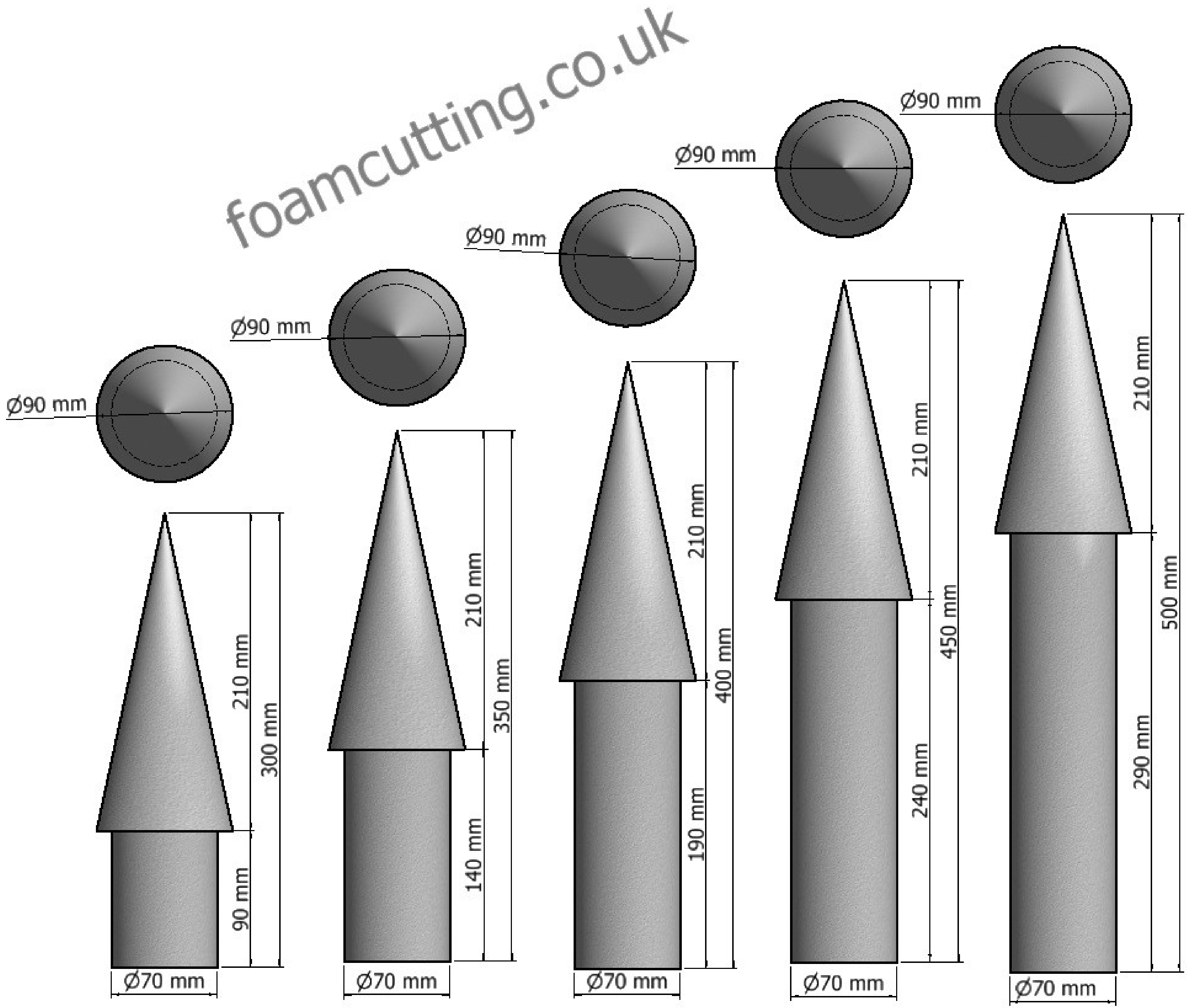
Algorithmic combination

MVA combination

Combine all of the estimates into one best estimate

There is no perfect way to remove objects from the *MET*

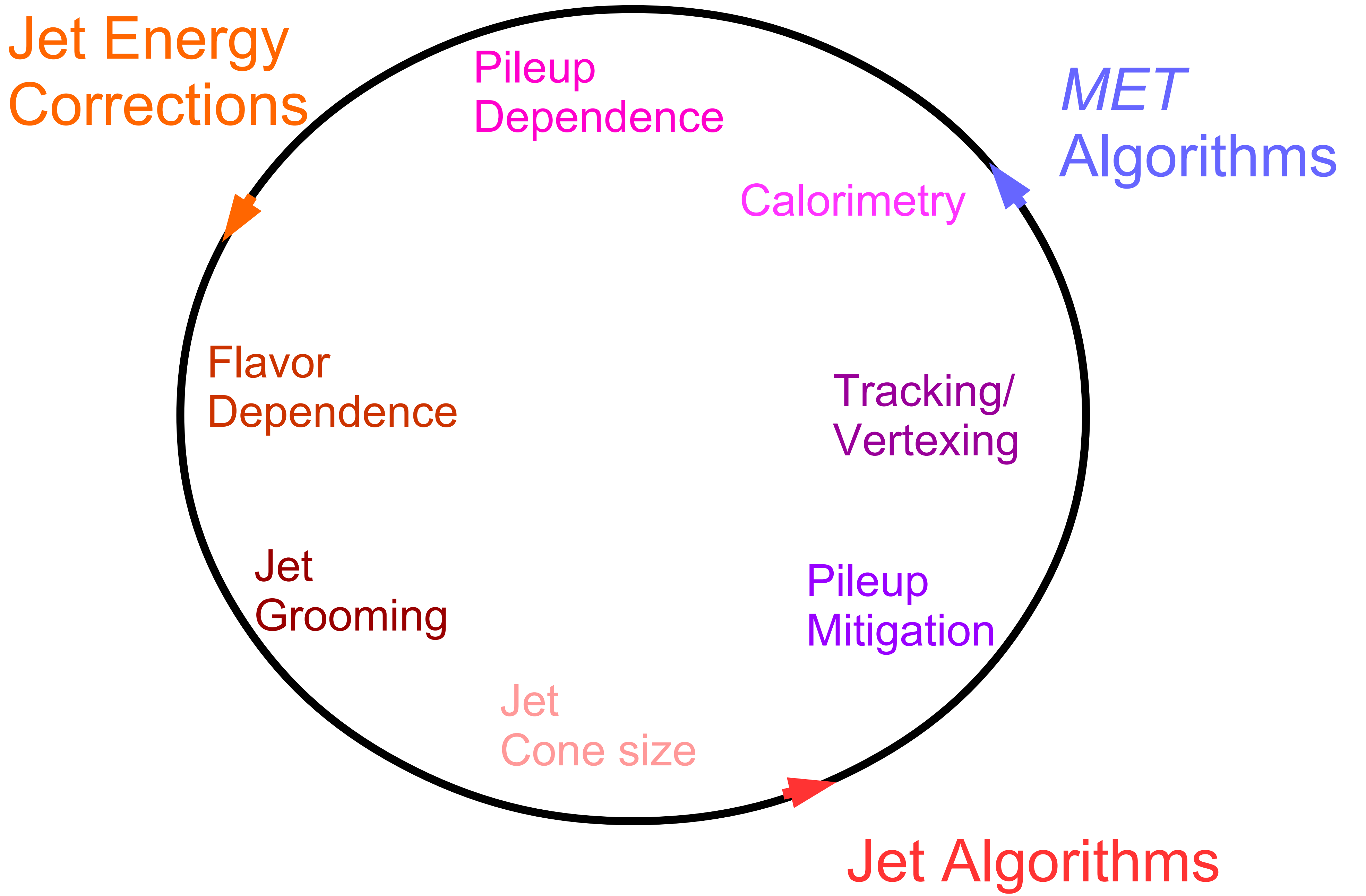
I HC



foamcutting.co.uk
Ø90 mm
Ø90 mm
Ø90 mm
Ø90 mm
Ø90 mm
210 mm
300 mm
90 mm
Ø70 mm
210 mm
350 mm
140 mm
Ø70 mm
210 mm
400 mm
190 mm
Ø70 mm
210 mm
450 mm
240 mm
Ø70 mm
210 mm
500 mm
290 mm
Ø70 mm

LHC Heavy Ion

Cycle of Development



Documenting Run I

JEC

- JME-13-001 : b-jet energy scale
- JME-13-004 : Run I JEC Performance
- JME-14-003 : ATLAS/CMS JEC Combo

JME-14-005 : JPT performance

JME-DP-14/037 : Jet Cones

JME-DP-13/018 : HI UE sub.

MET

- JME-13-003 : Run I *MET* Performance

Almost public

Jet Algorithms

- JME-13-002 : Quark/Gluon Discrimination
- JME-13-005 : Pileup Jet Id
- JME-13-006 : Boosted W-tagging performance
- JME-13-007 : Top Tagging performance
- JME-14-001 : Pileup subtraction in jets
- JME-14-002 : V-tagging Observables and correlations

JME-DP-14/038 : Top Tagging

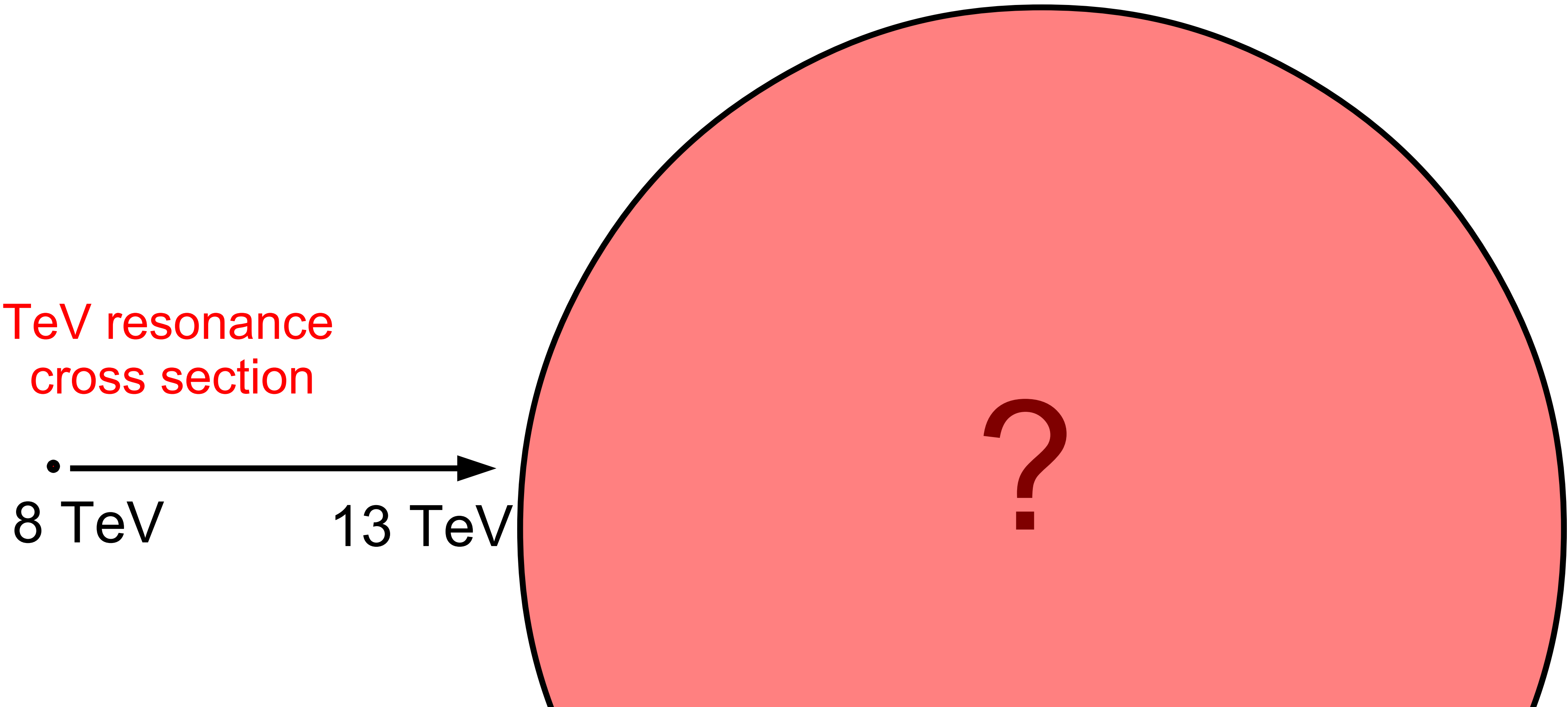
What happens next?

- LHC goes up in energy : 8 TeV to 13 TeV

Higgs Cross Section

A new opportunity to search for new physics

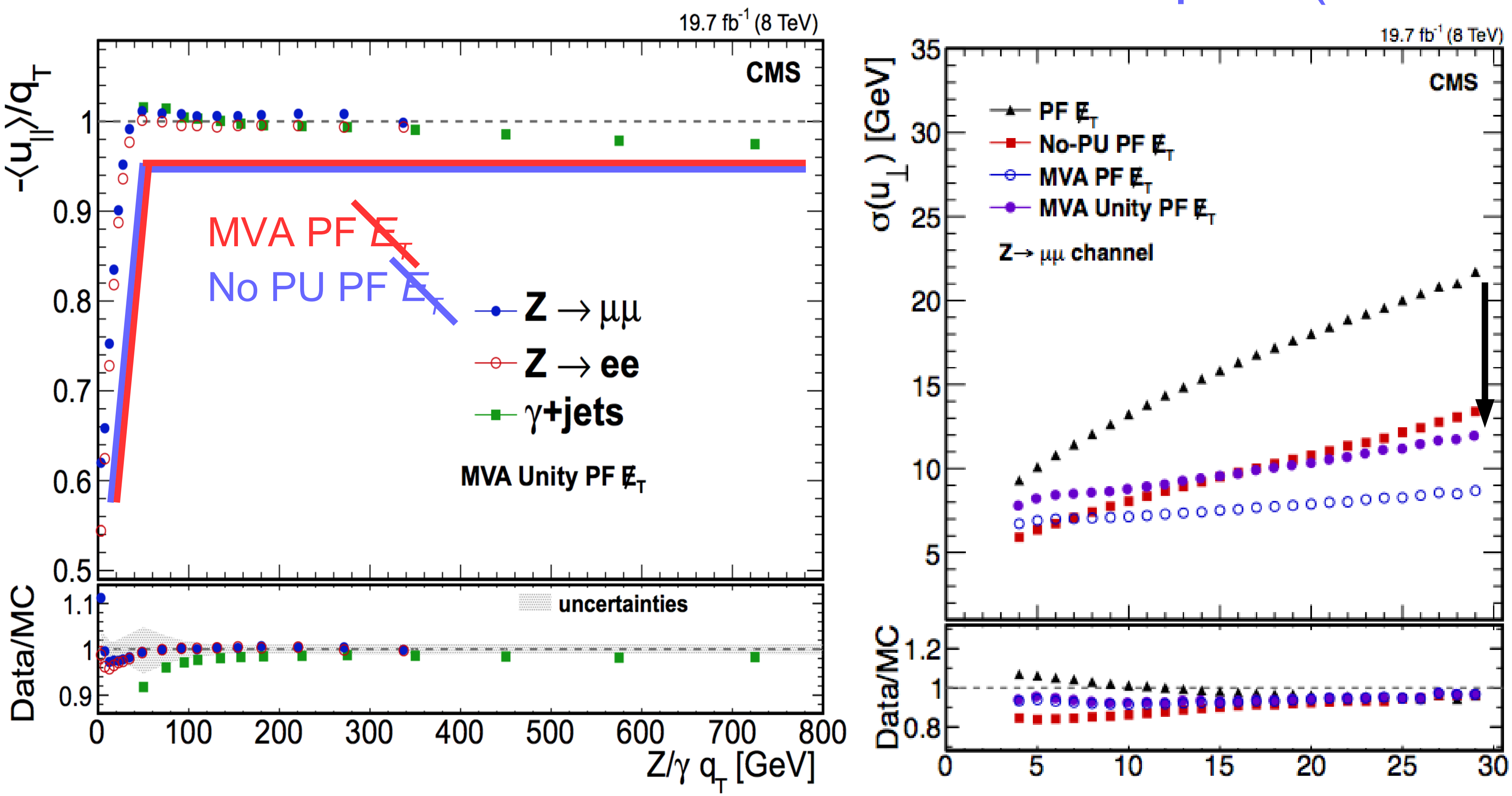
2 TeV resonance cross section



Impact of Pileup on *MET*

- *MET* has a large effect on pileup

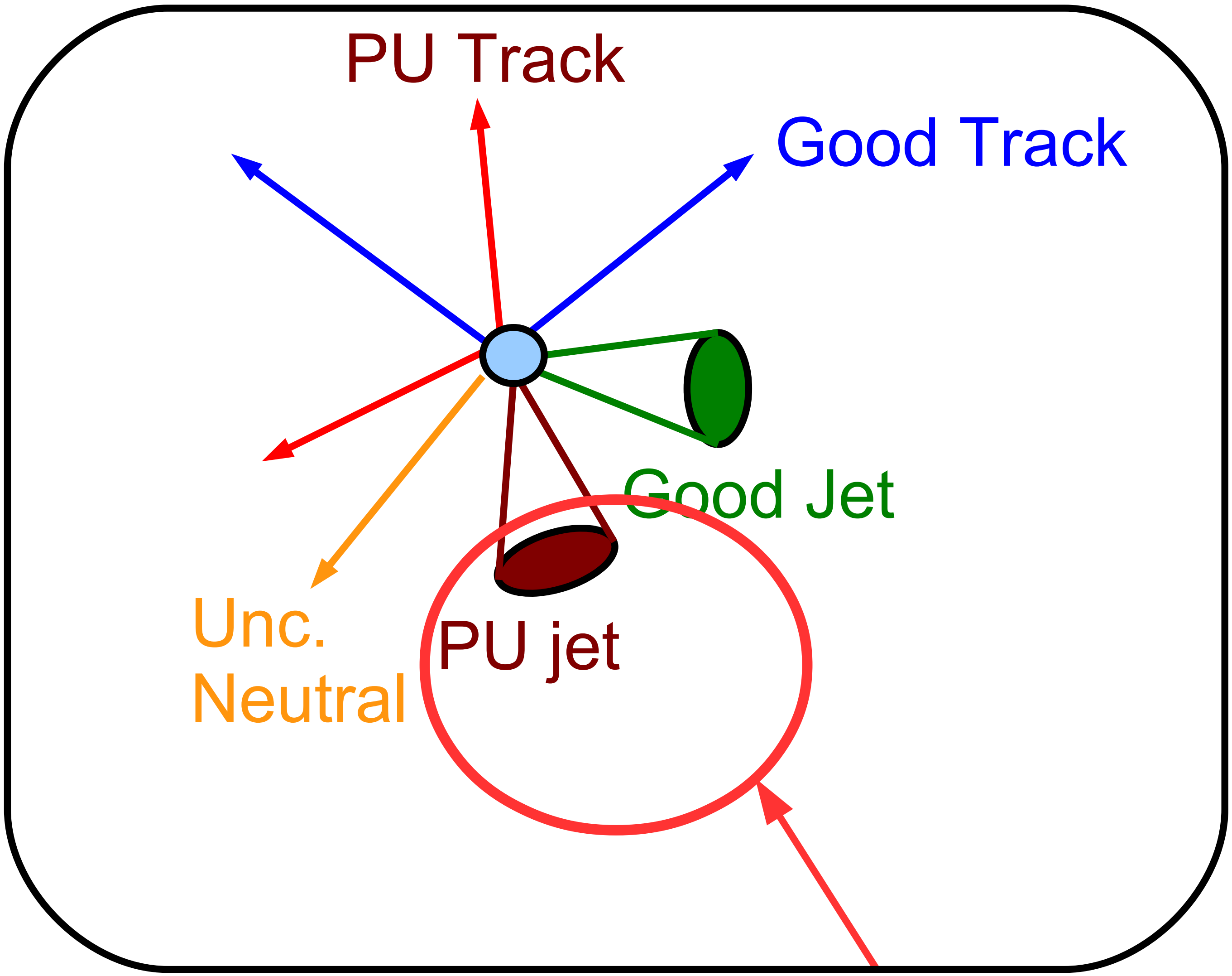
We can reduce with advanced techniques (MVA *MET*)



Final *MET* (MVA Unity) keeps response at unity

JME-13-003

Whats causing the PU dependence?

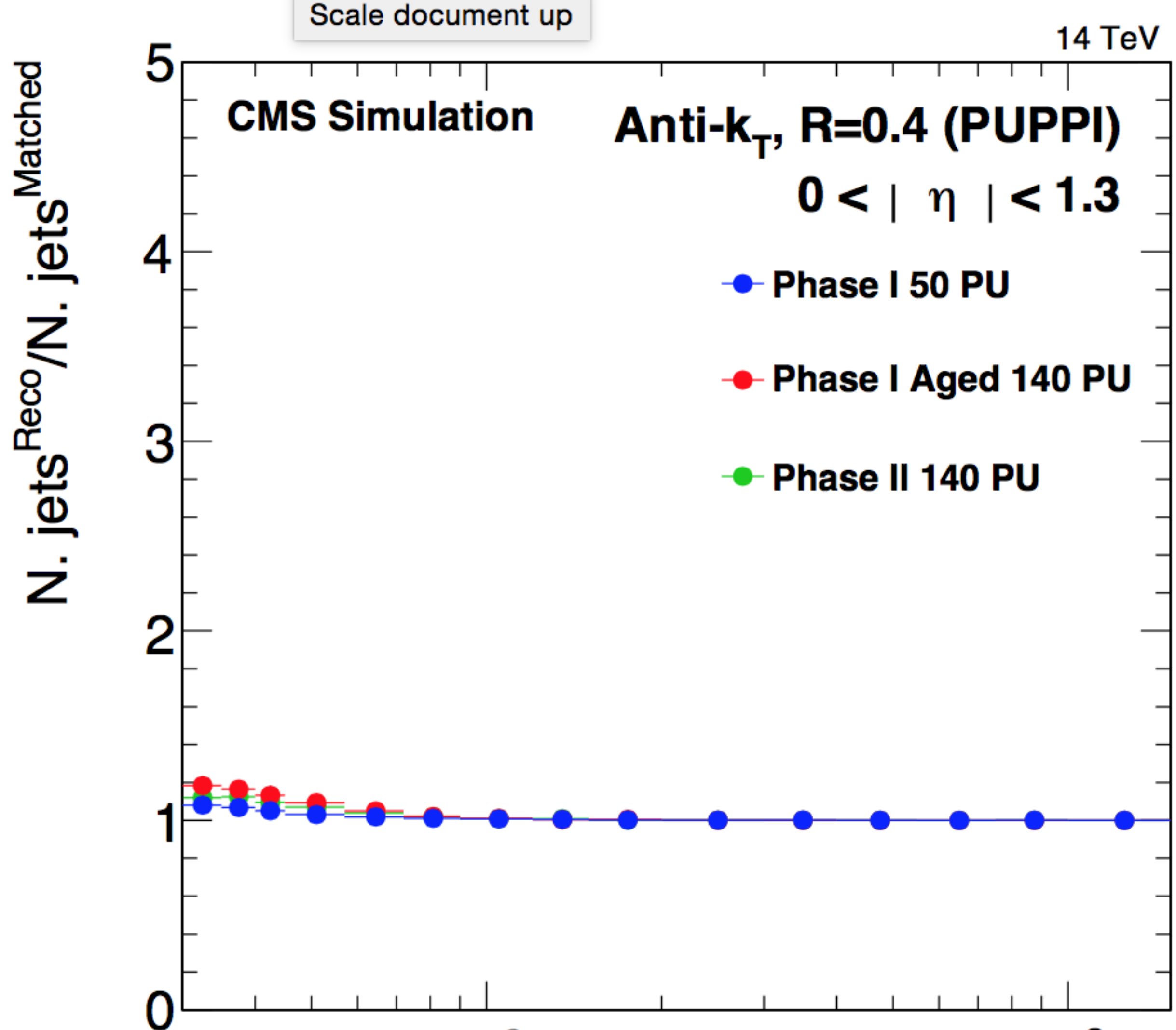


Dominant component of *MET* are PU Jets

JME-13-005

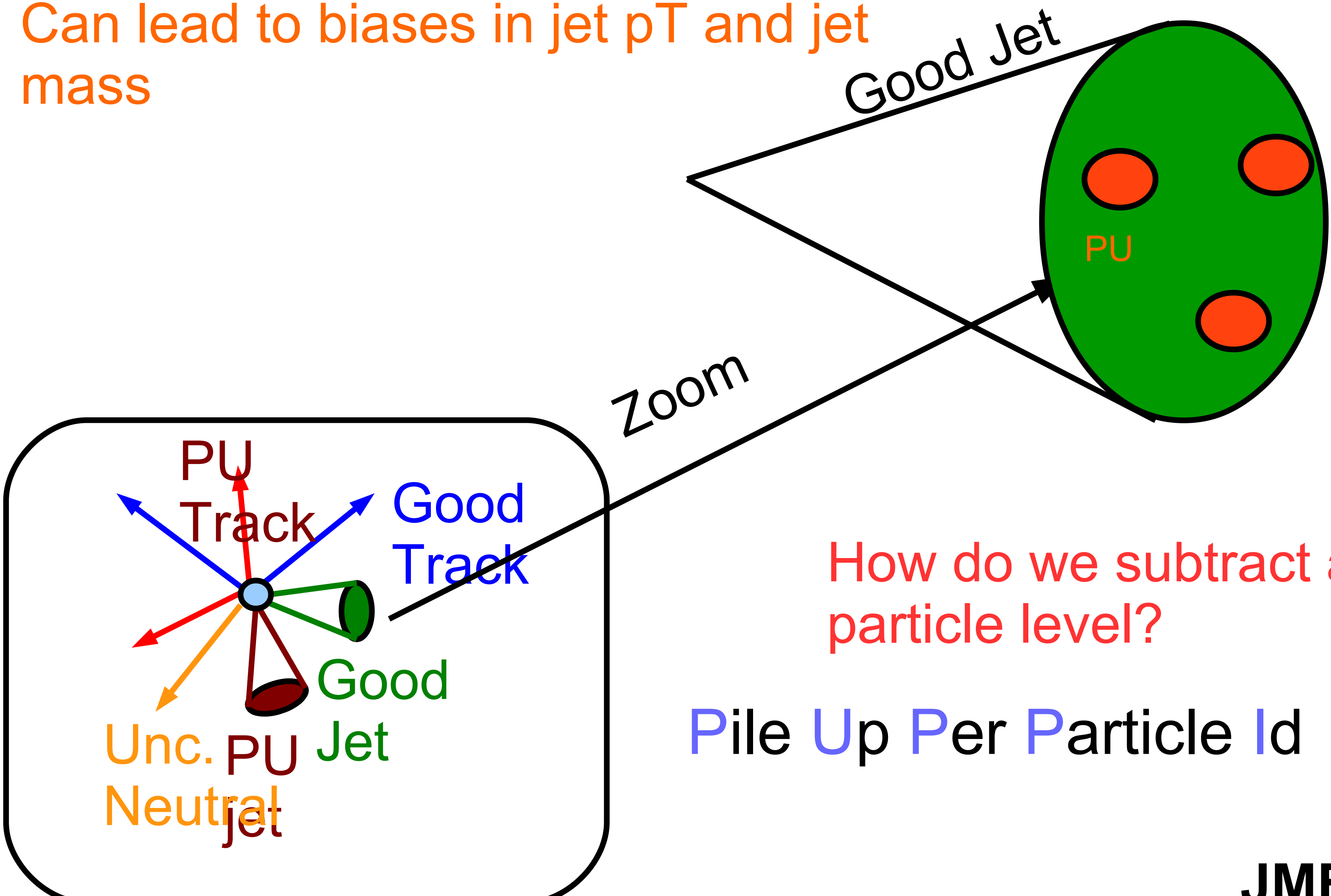
Upgrade Final Performance

Scale document up



Evolution of PU Subtraction

Pileup effects jets at the particle level
Can lead to biases in jet pT and jet mass



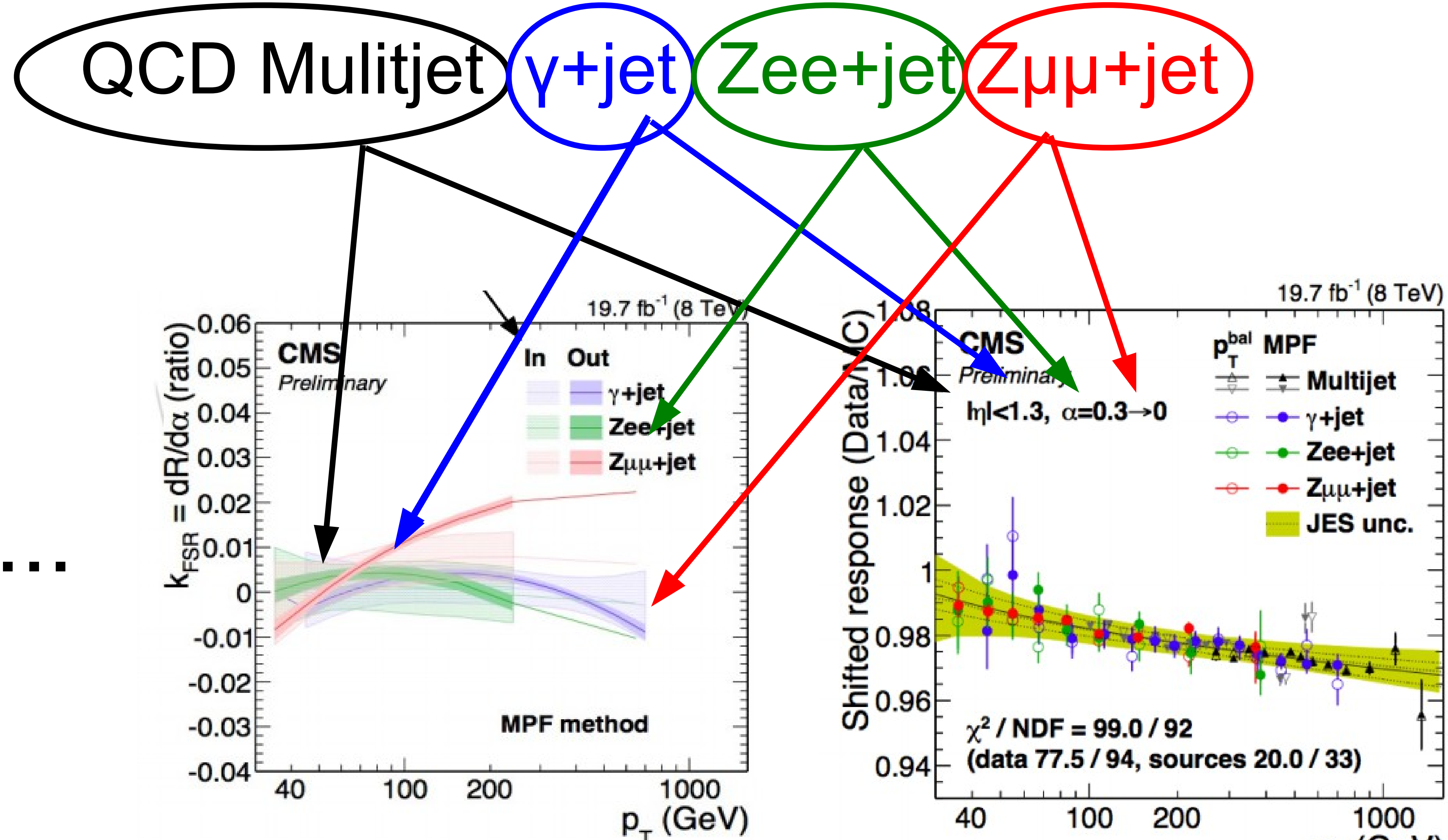
How do we subtract at the particle level?

Pile Up Per Particle Id

JME-14-001

Global Fit

- Data/MC understood by a global fit



...

Profile all unc. : Lep. scale/Response/...

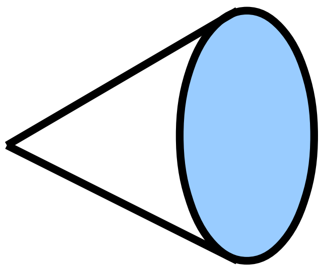
JME-13-004

Isolation of Quarks

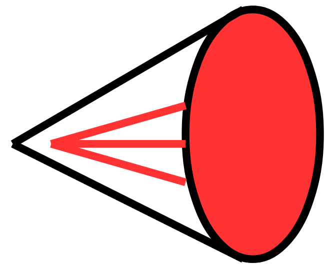
Quark Jets

b(displaced) Jets

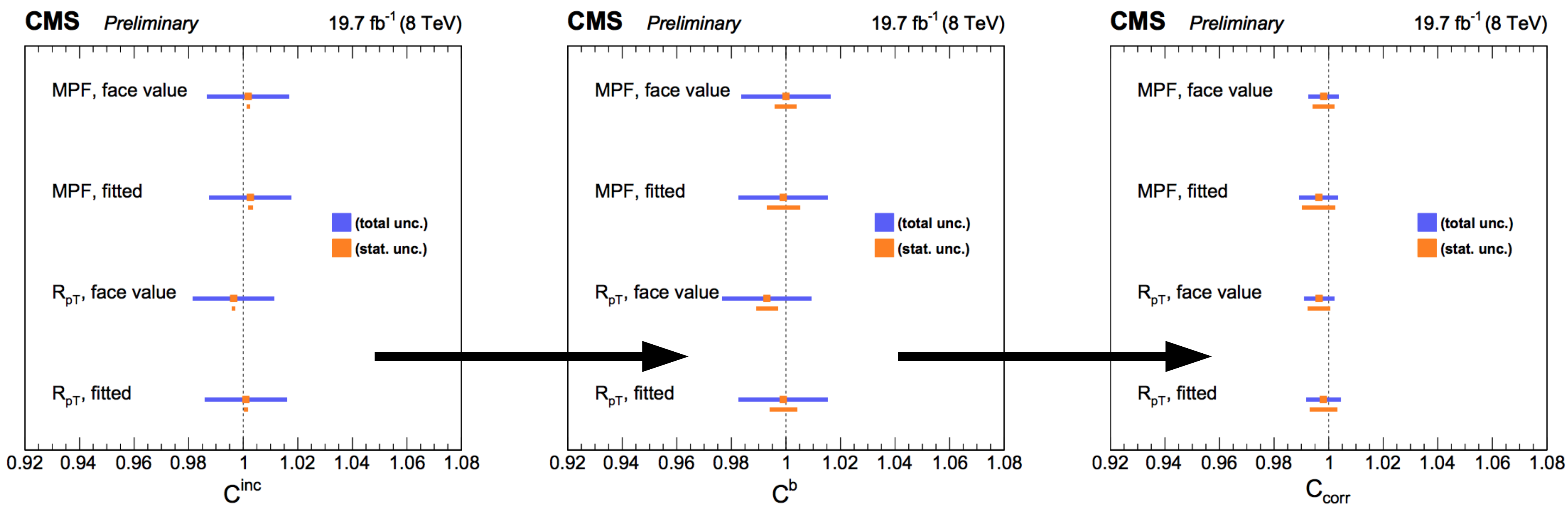
1



X



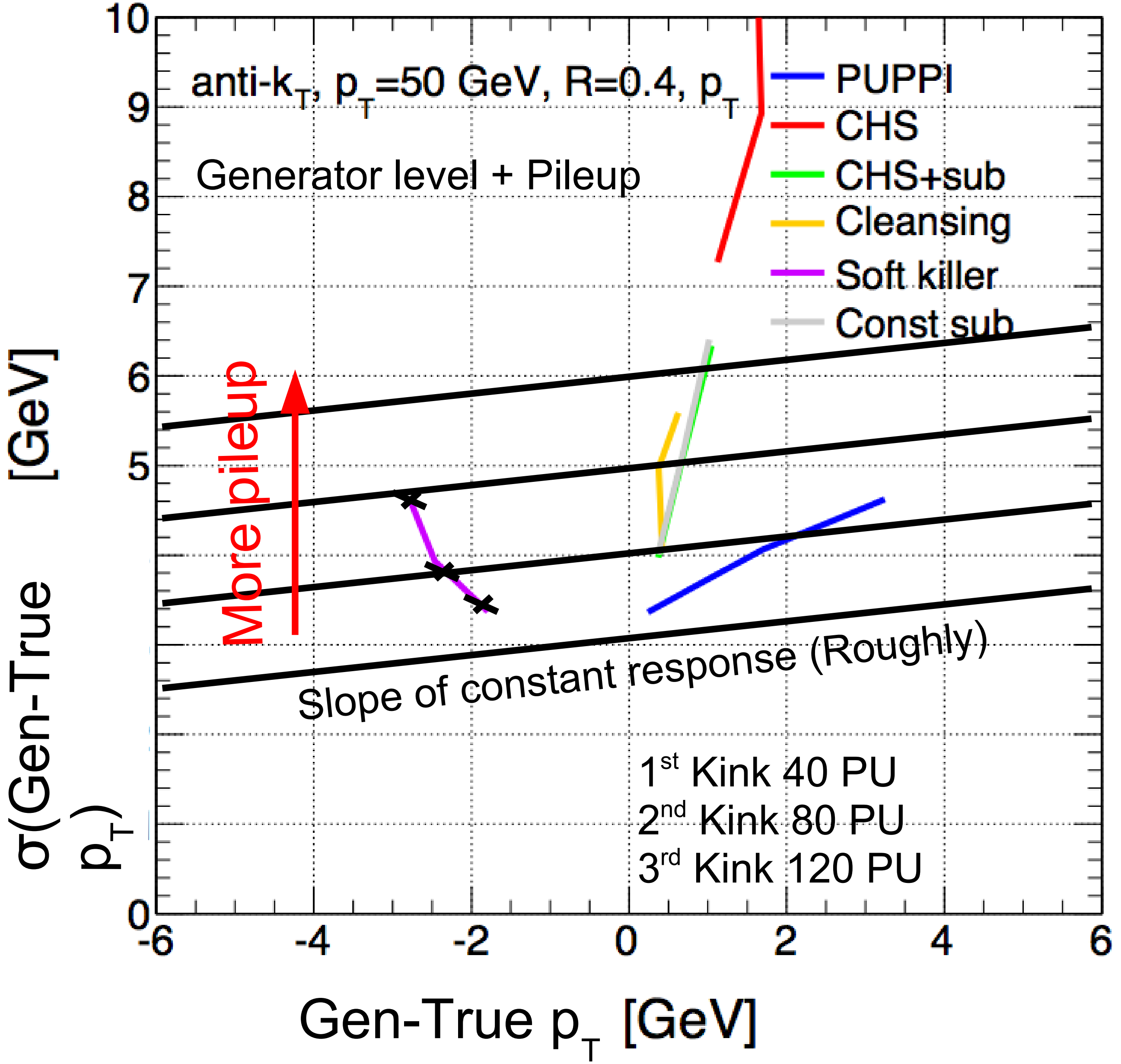
= Sub percentage precision



Correction confirms no significant deviation in b vs light flavor response

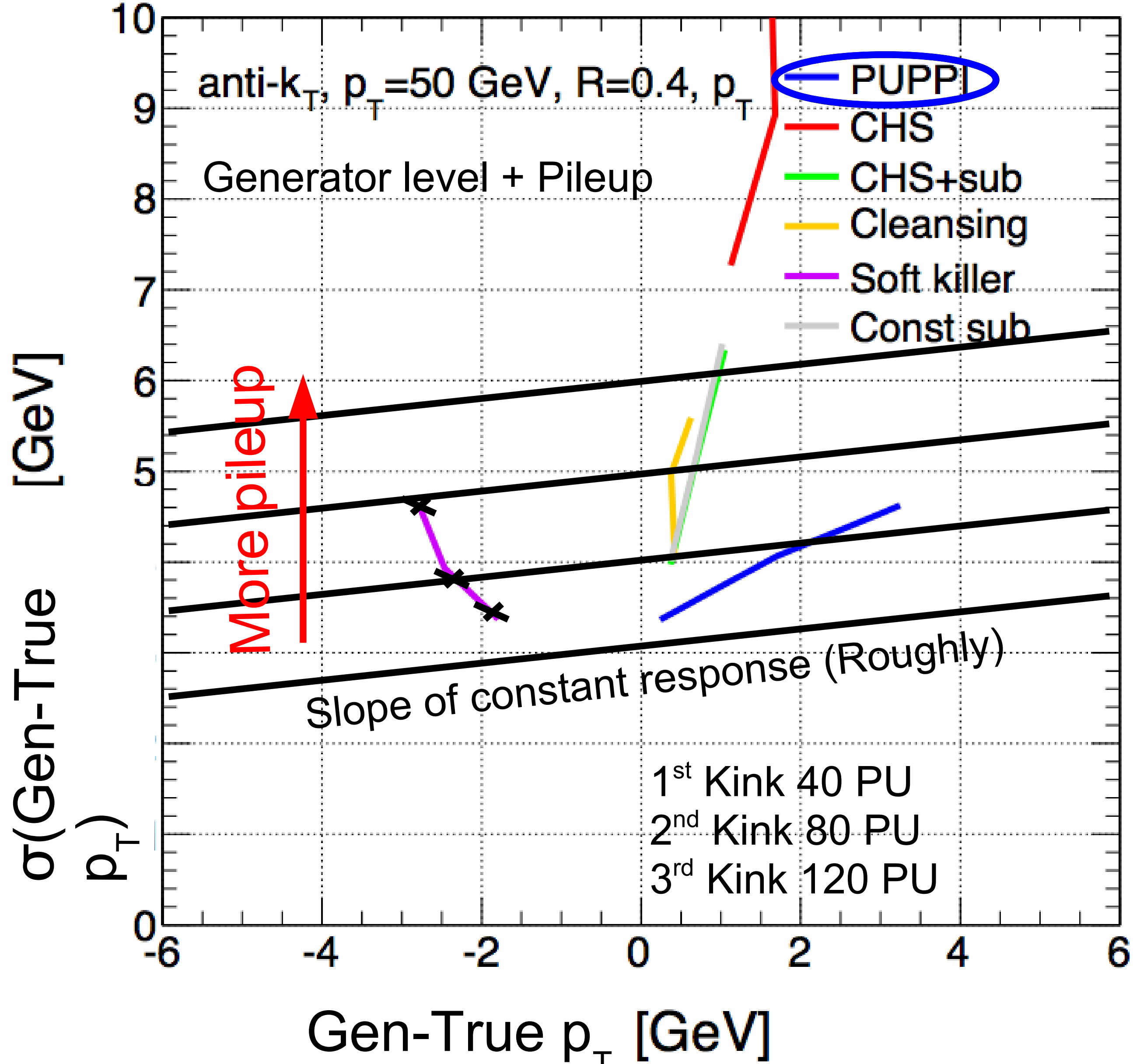
JME-13-001

Pileup Subtraction : Whats new?



Plot from the the Pileup workshop (made by PUPPI team)

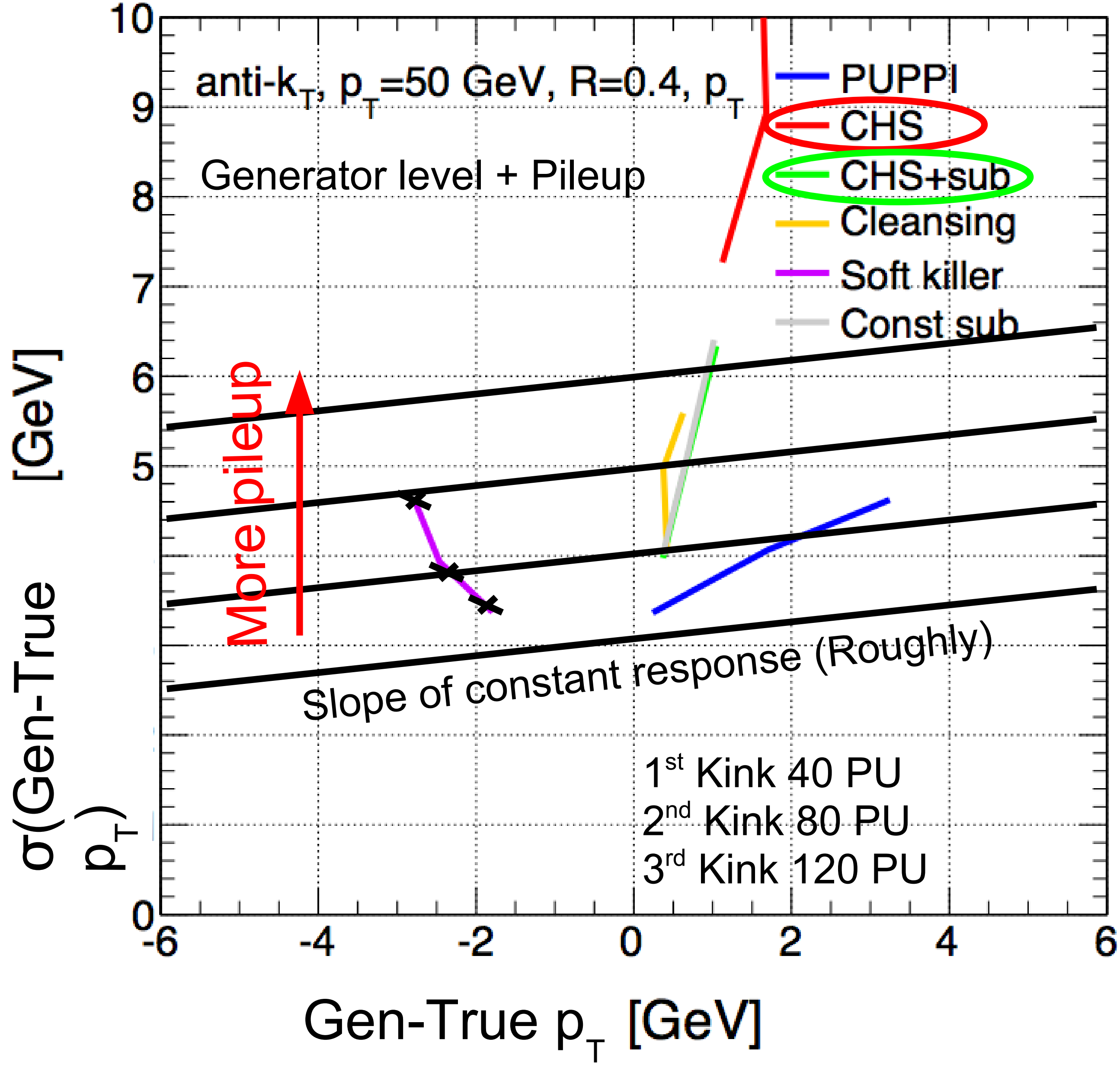
Pileup Subtraction : Whats new?



New Approach
More @ end
Originated from HF/Vorinoi

PUPPI = Pile Up Per Particle Id (Per particle sub.)

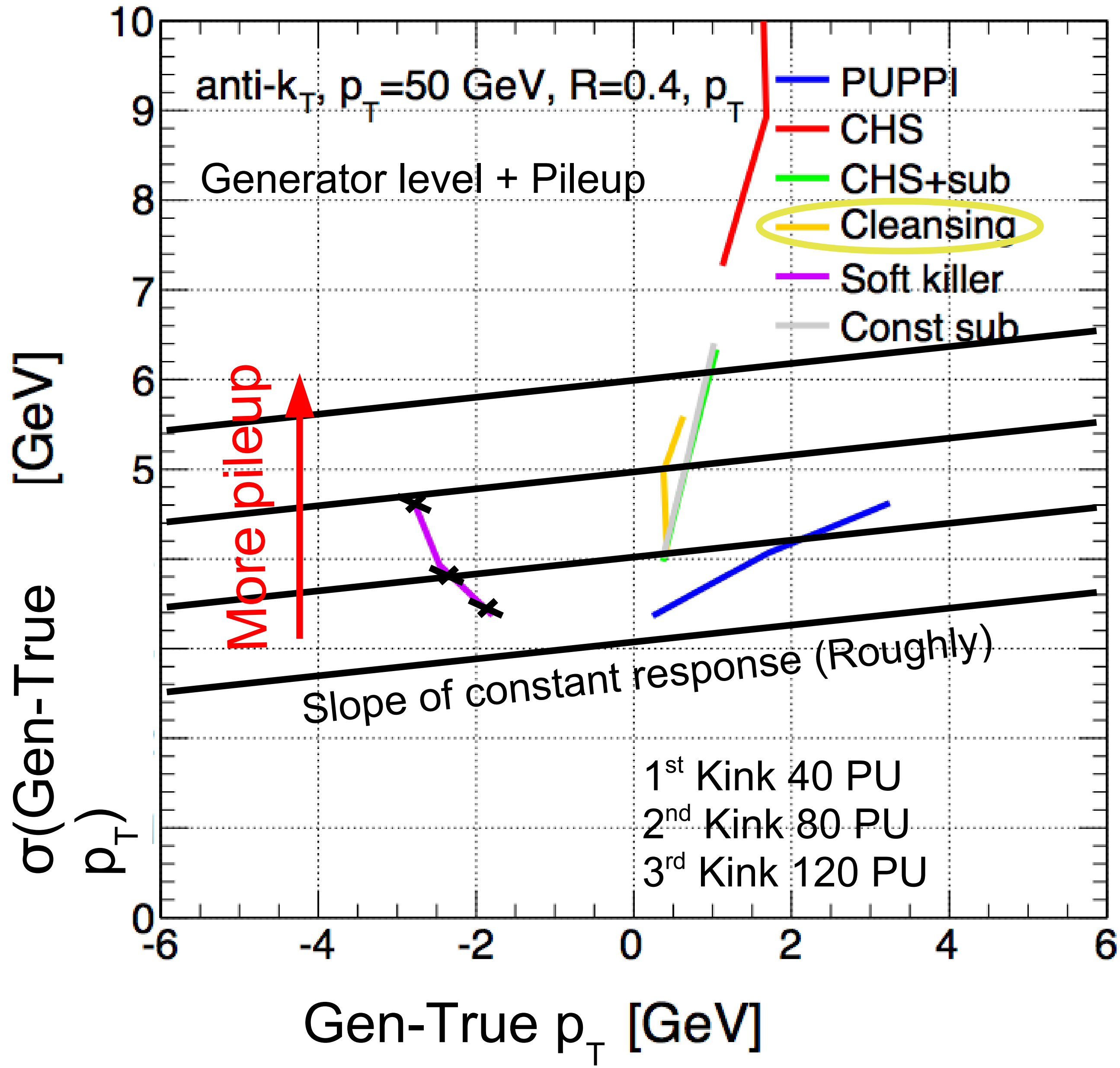
Pileup Subtraction : Whats new?



New Approach
More @ end
Originated from
HF/Vorinoi

Use vertexing
to remove
tracks + ρ

Pileup Subtraction : Whats new?



New Approach
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Use vertexing
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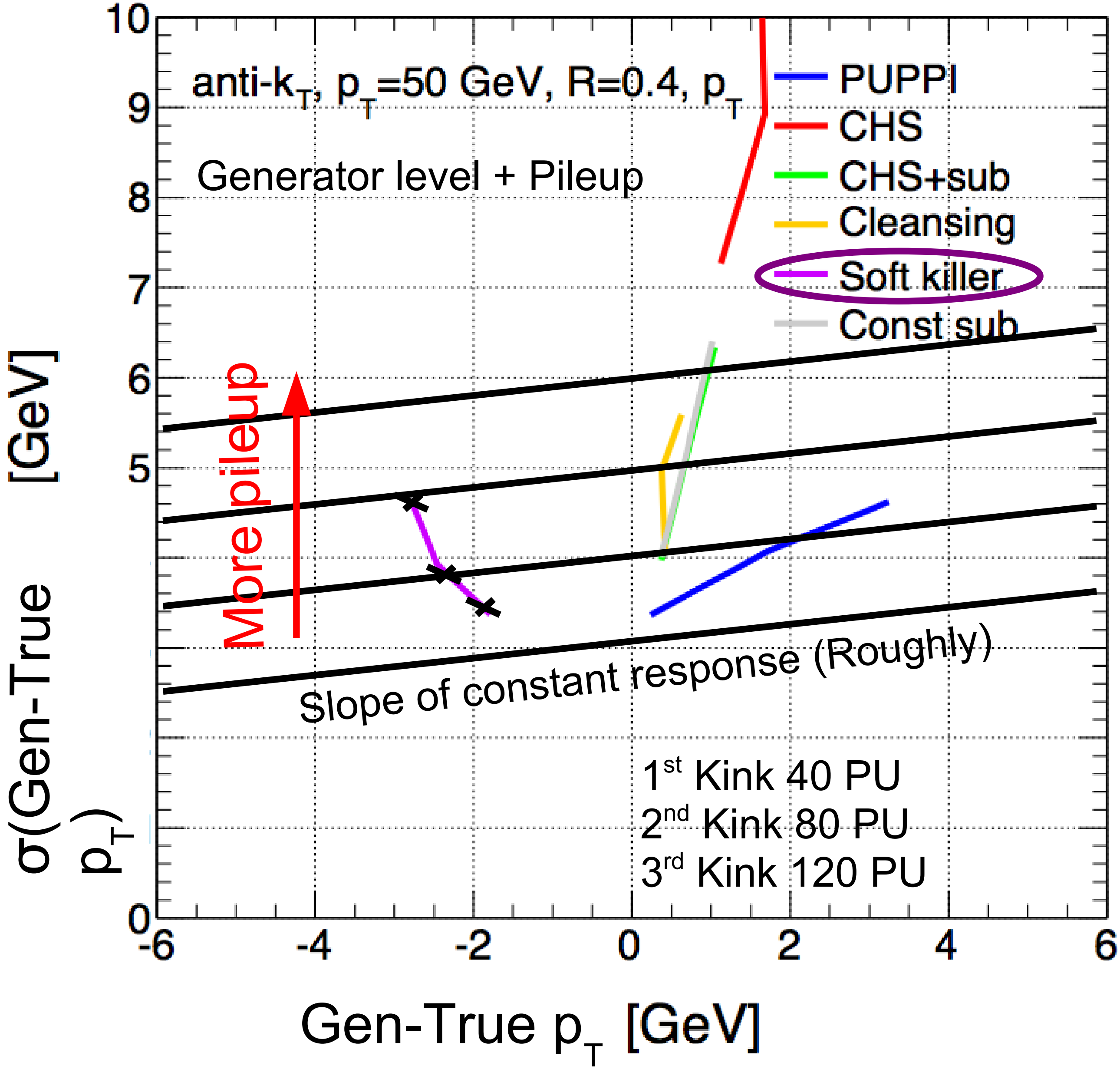
Substructure &
vertexing

Pileup Subtraction : Whats new?



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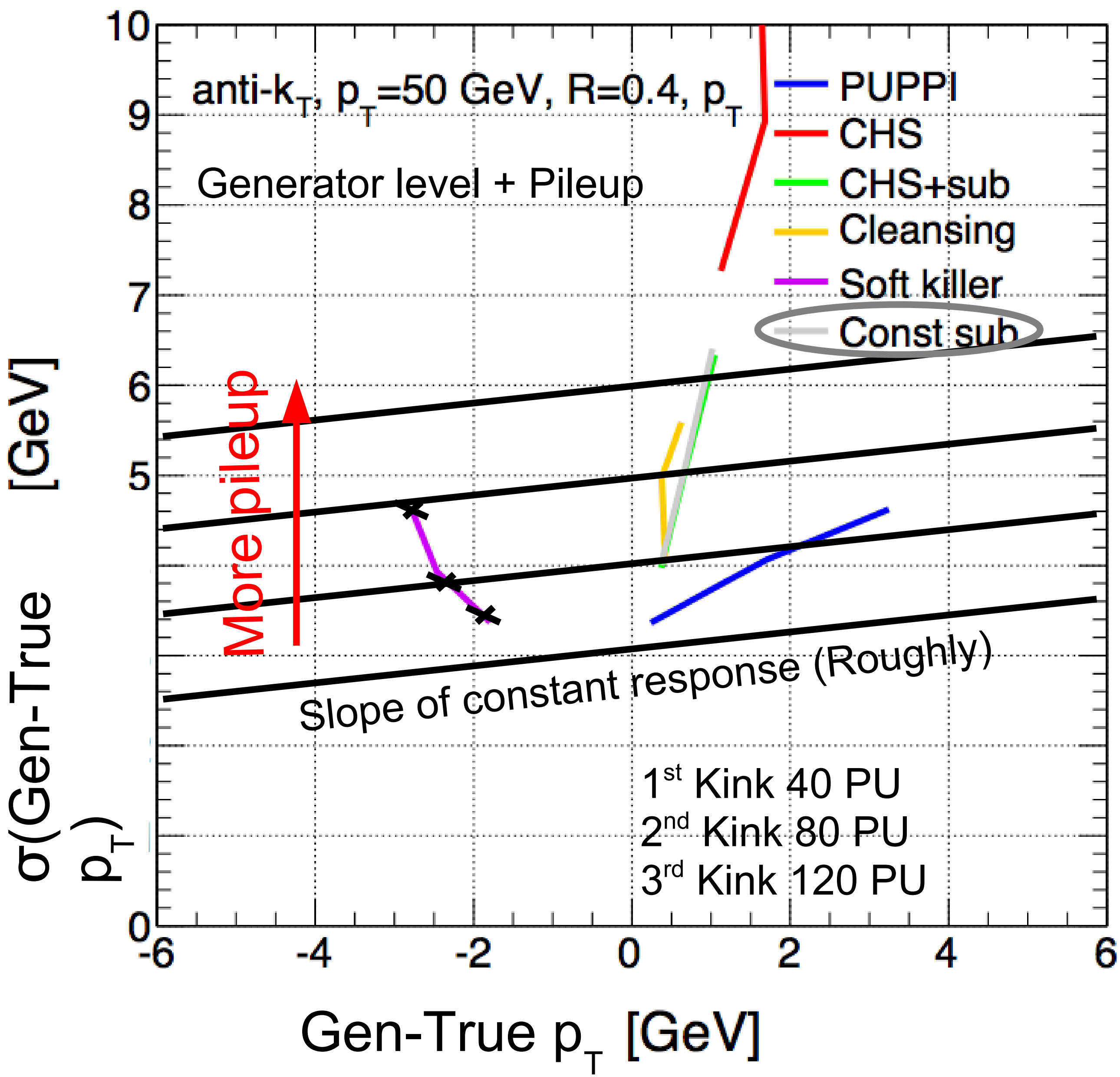
Next talk

Pileup Subtraction : Whats new?



New Approach
More @ end
Originated from HF/Vorinoi

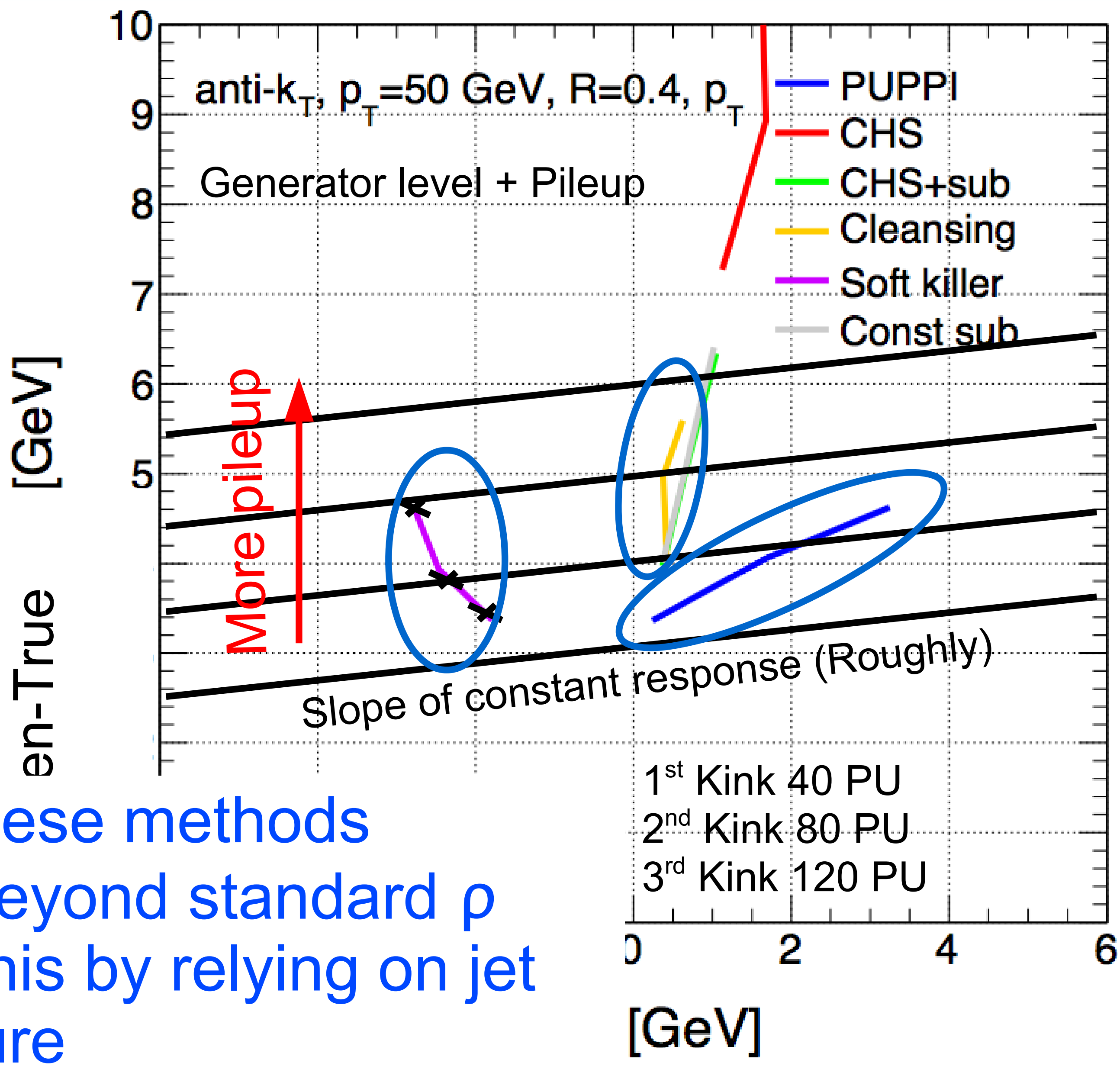
Use vertexing to remove tracks + ρ

Substructure & vertexing

Next talk

ρ per particle (using area) as oppose to jet

Pileup Subtraction : Whats new?



New Approach More @ end Originated from HF/Vorinoi

Use vertexing to remove tracks + ρ

Substructure & vertexing

Next talk

ρ per particle (using area) as oppose to jet

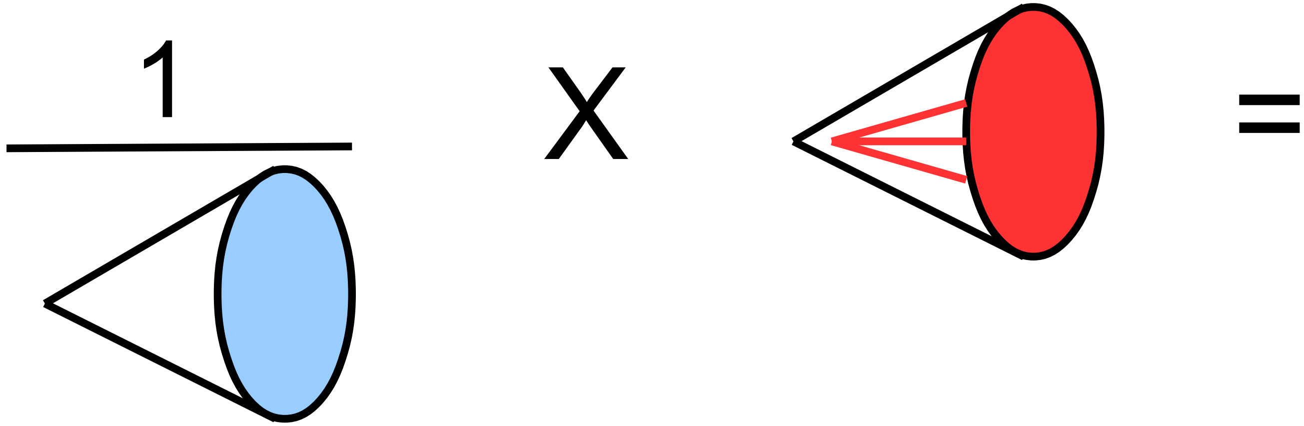
Each of these methods improve beyond standard ρ

Each do this by relying on jet substructure

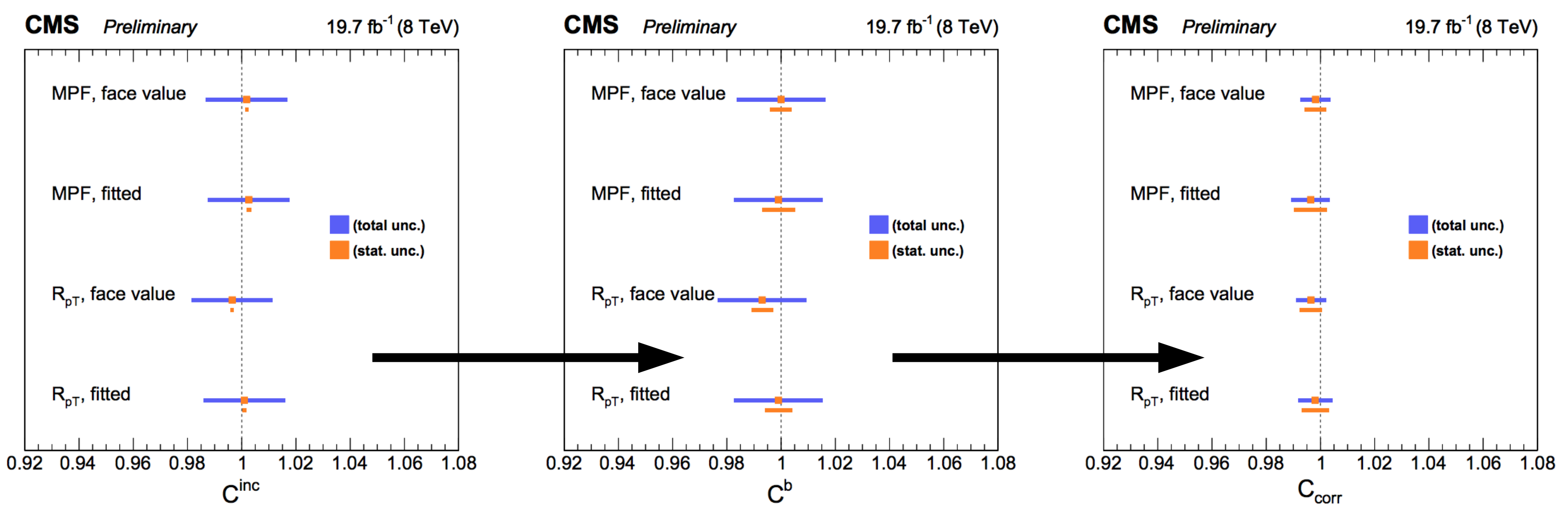
Isolation of Quarks

Quark Jets

b(displaced) Jets



Sub percentage precision



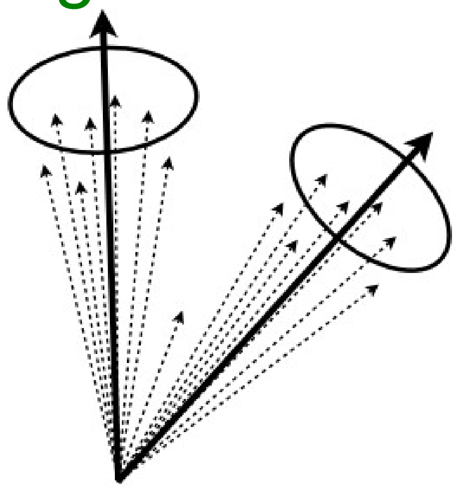
Correction confirms no significant deviation in b vs light flavor response

JME-13-001

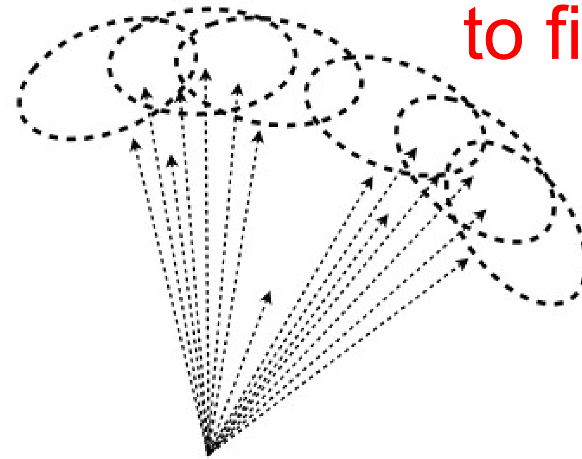
hep-ph/1310.7584

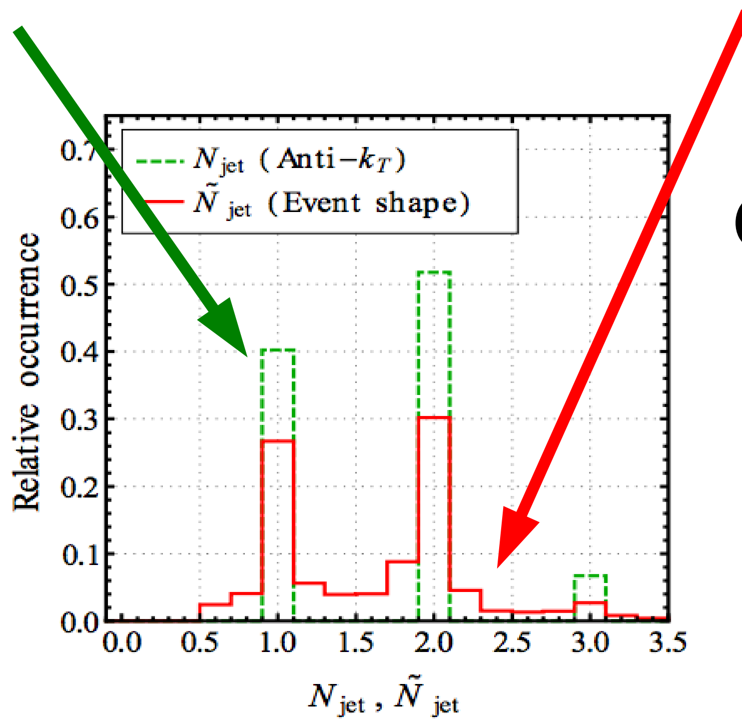
Jets Without Jets

Conventional :
Circle a region of activity



Jets without Jets :
Look around each particle
to find activity

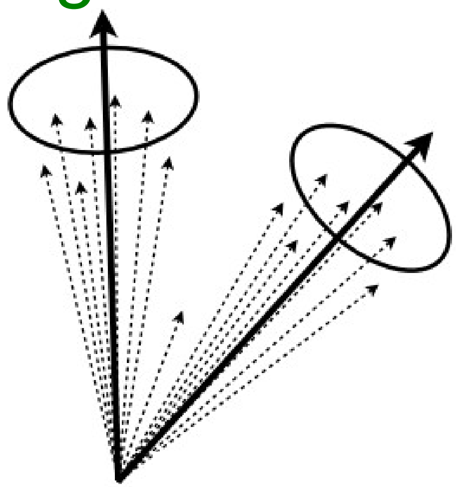




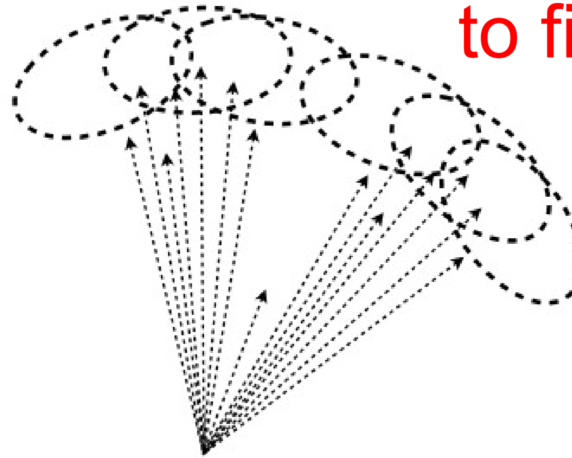
Global properties
can be inferred from
local particle information

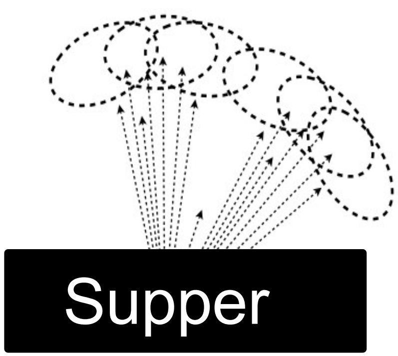
Jets Without Jets

Conventional :
Circle a region of activity



Jets without Jets :
Look around each particle
to find activity

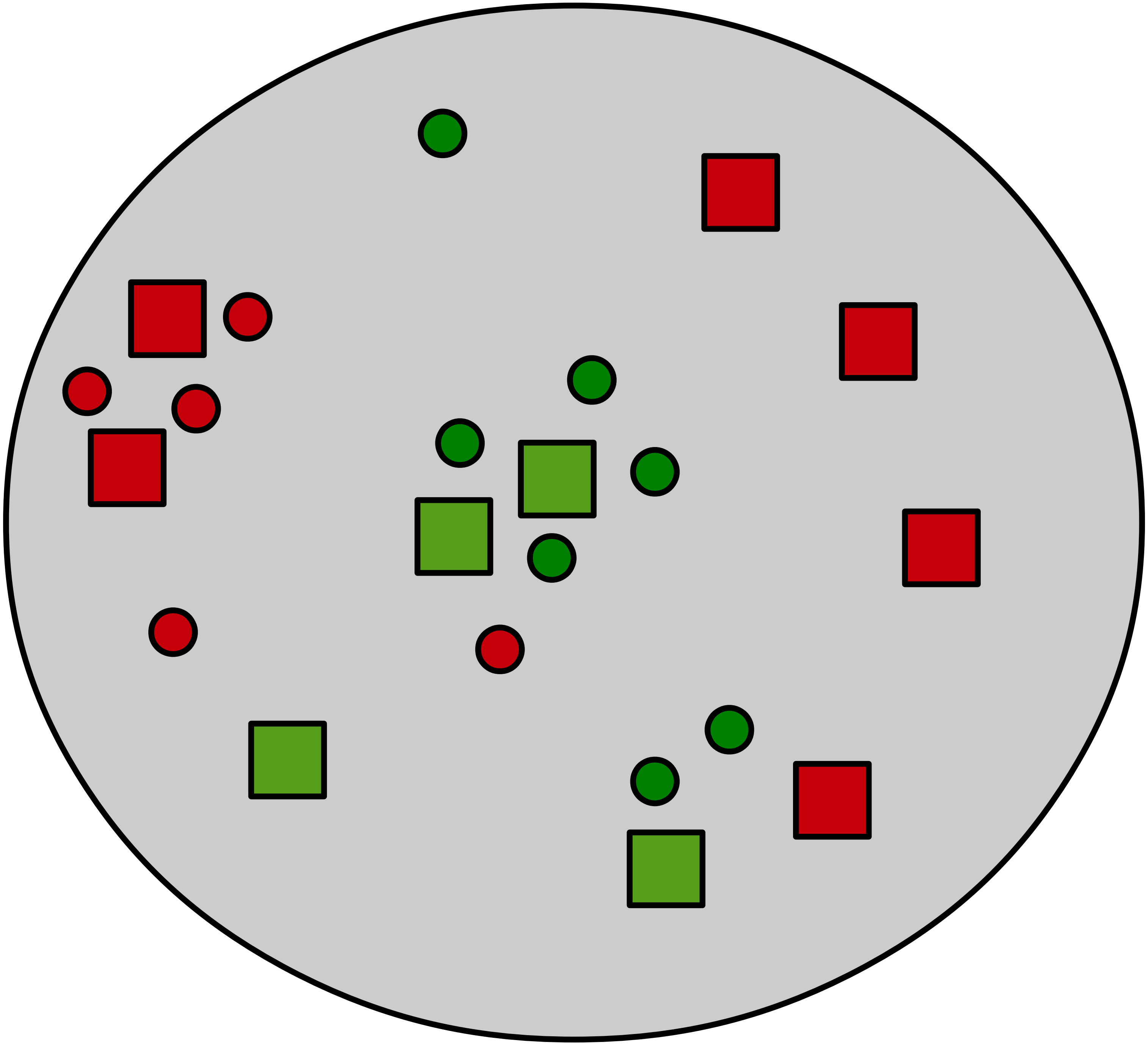




Puppi builds
on top of the jets without
jets paradigm

Puppi algorithm

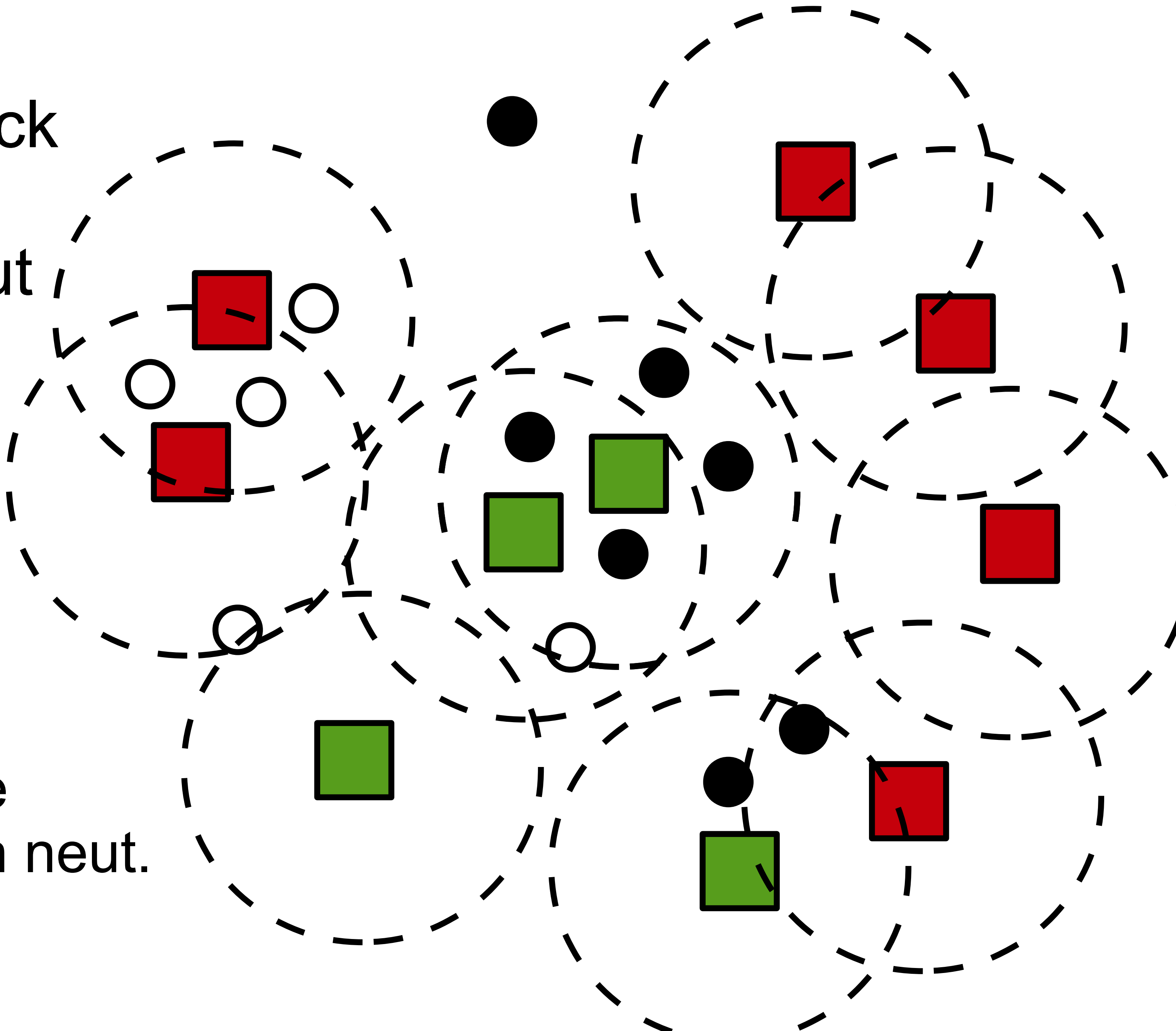
Key
- Good Track
- PU Track
- Good Neut
- PU Neut
- Chosen
- Removed



Puppi algorithm

Key
- Good Track
- PU Track
- Good Neut
- PU Neut
- Chosen
- Removed

Step 1
Vertexing
Step 2
Draw a cone
About each neut.



After Puppi

Key
- Good Track
- PU Track
- Good Neut
- PU Neut
- Chosen
- Removed

Step 5
Re-interpret evt
(Re-cluster)