To be defined

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Journées de Rencontres Jeunes Chercheurs

26 Nov 2019

Forward Jet Vertex Tagging in ATLAS using the PFlow algorithm

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The ATLAS Detector

- Will not be discussed in detail here
- Already nicely introduced by Reina

Hopefully you were all paying attention!

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Hopefully you were all paying attention!

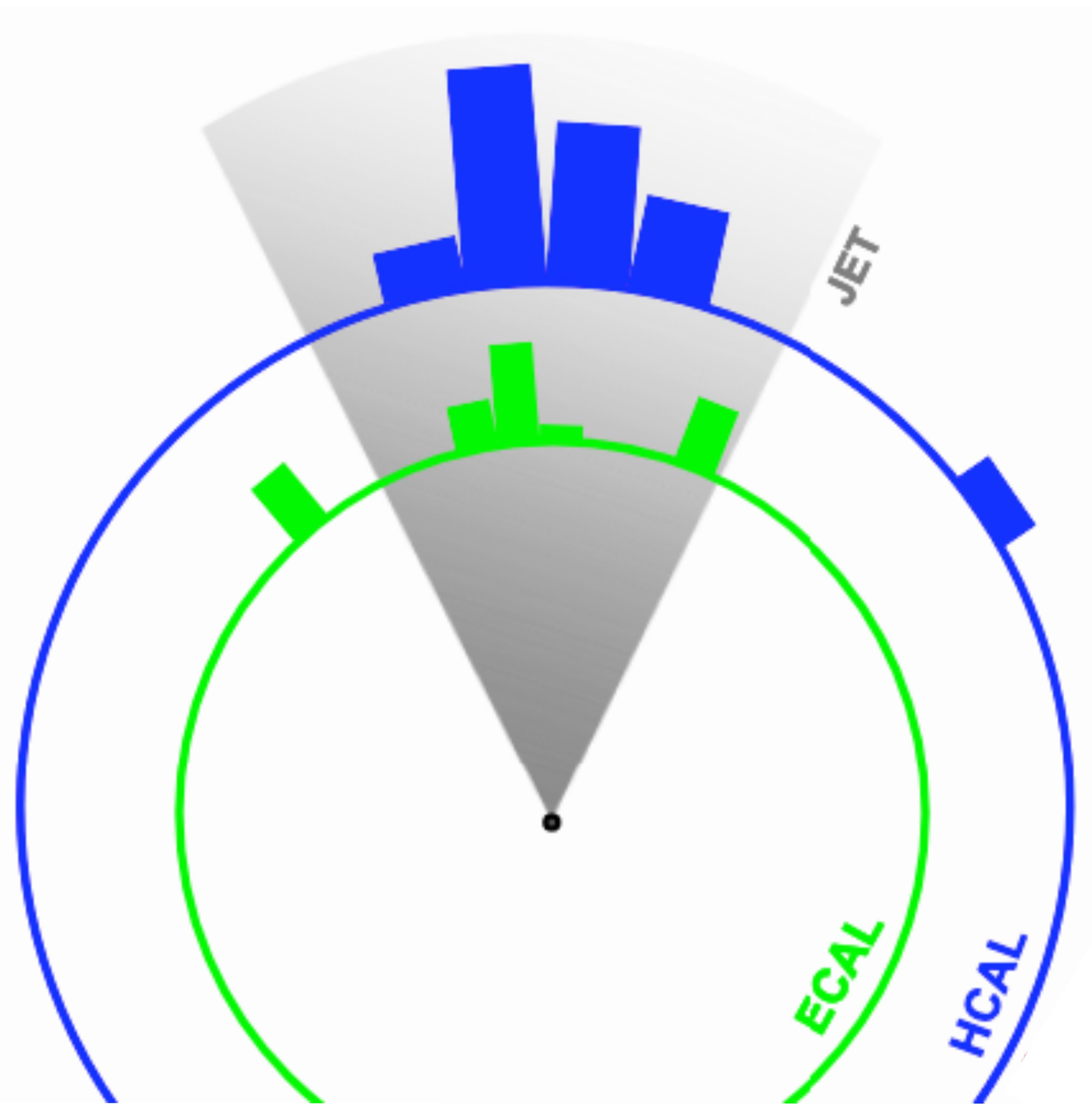
What you need to remember for this talk:

- LHC is primarily a pp collider (or qq collider)
- Jets are produced abundantly
  - a proxy to the initial quark or gluon

Jet Reconstruction

Jet Reconstruction: EMTopo Jets

- Historically, ATLAS has used calorimeter topoclusters as inputs for jet building (EMTopo jets)



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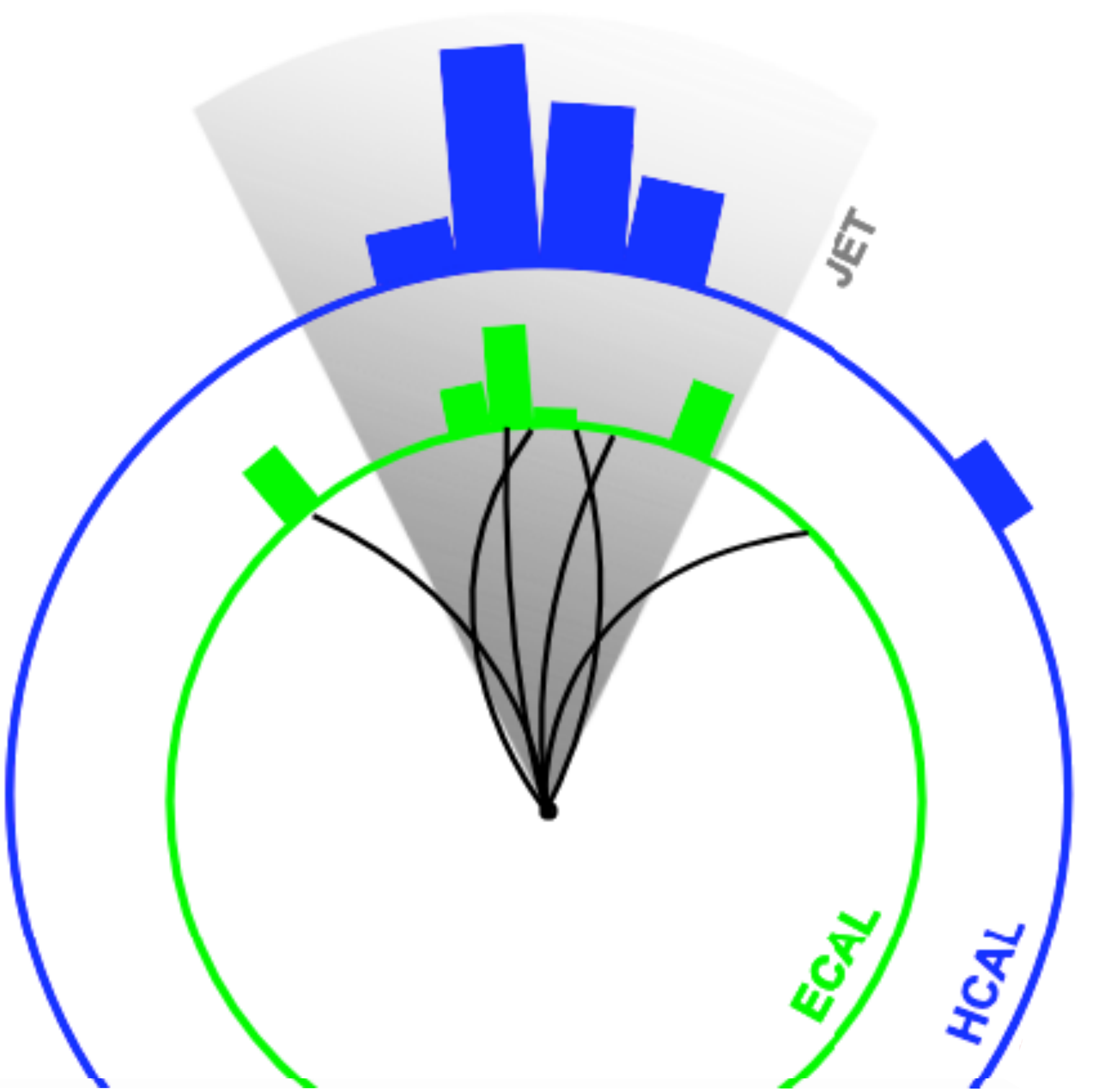

- Add tracking information to jets after jet building

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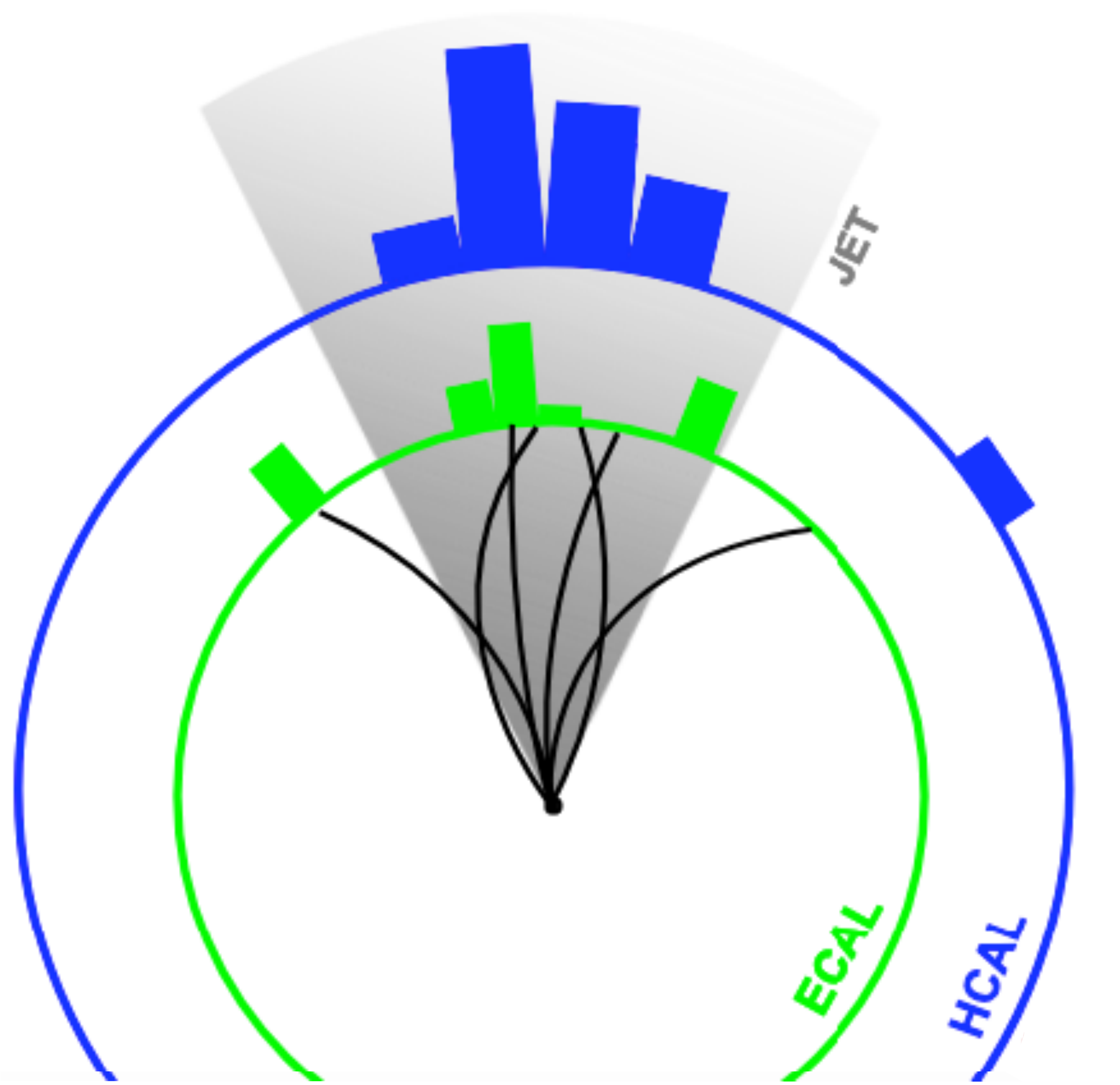
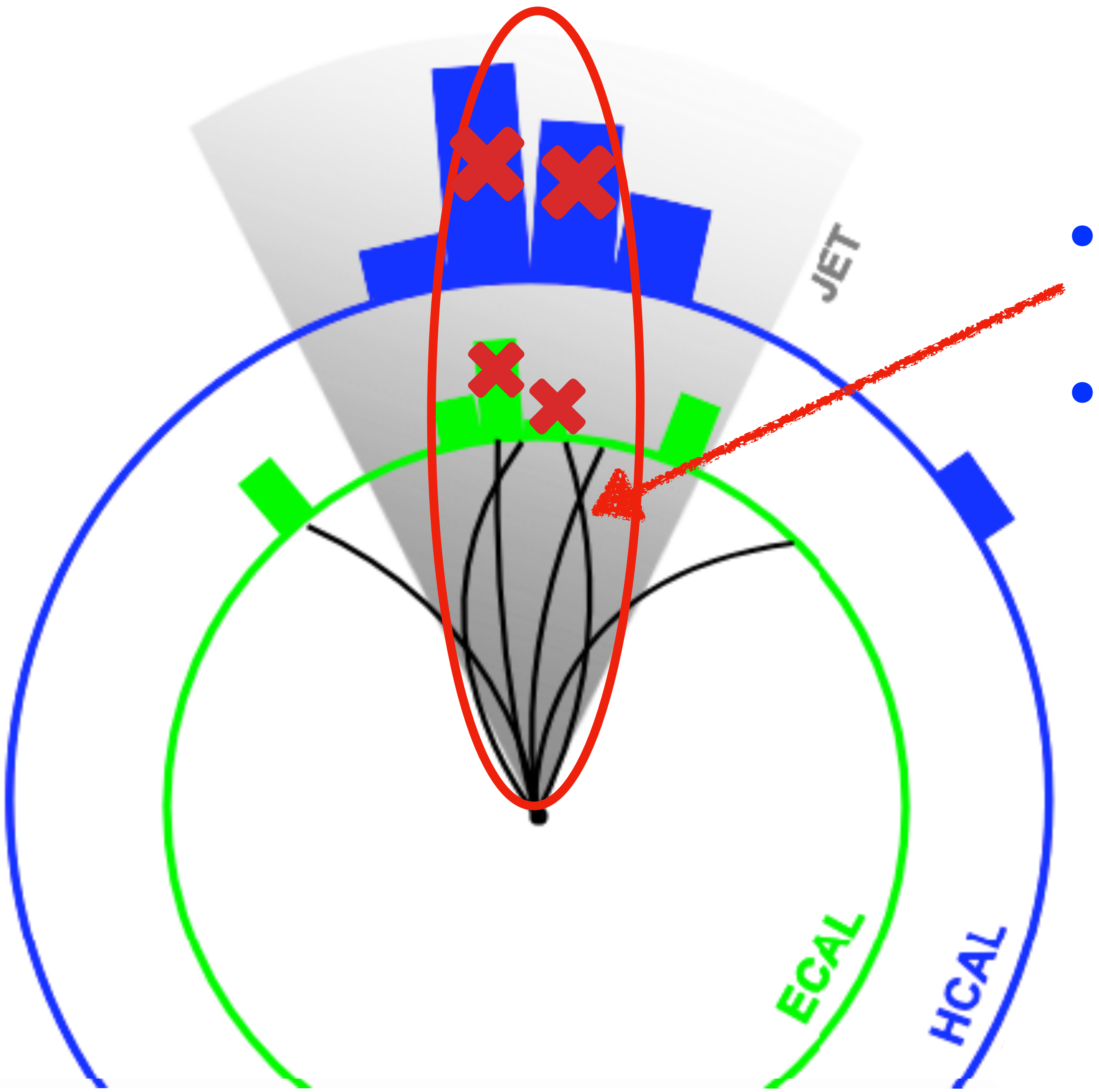


- Add tracking information to jets after jet building
    - Or do PFlow!

Jet Reconstruction: PFlow Jets

Particle Flow:

- In PFlow a cell-based energy subtraction algorithm is applied
- Removes overlaps between momentum and energy measurements made in tracker and calorimeters



- Match tracks to calorimeter clusters
- Remove matched clusters

Jet Reconstruction: PFlow Jets

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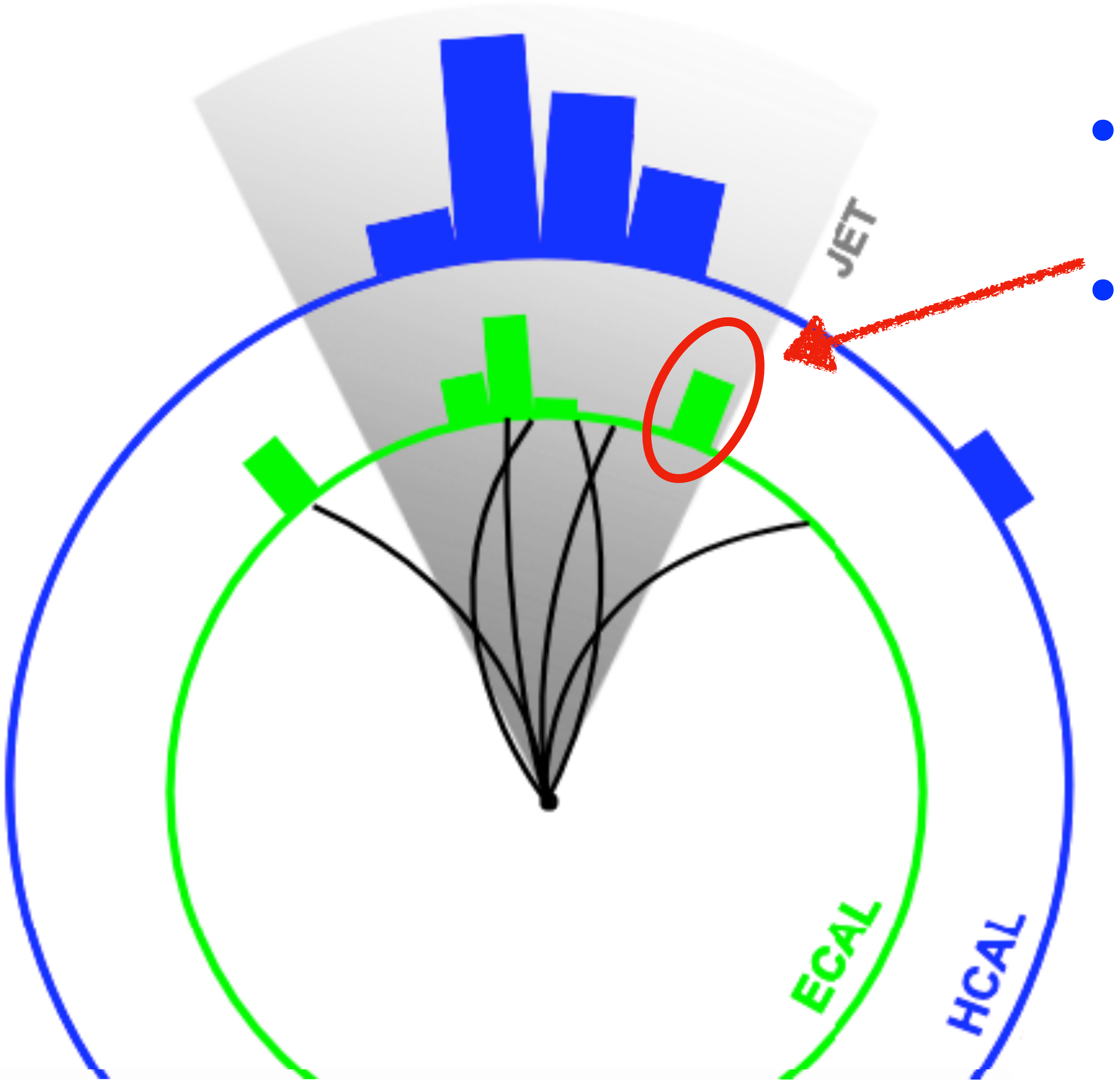

- Keep clusters that are not matched to any track
- These clusters are neutral particles that don't interact with the tracker

Jet Reconstruction: PFlow Jets

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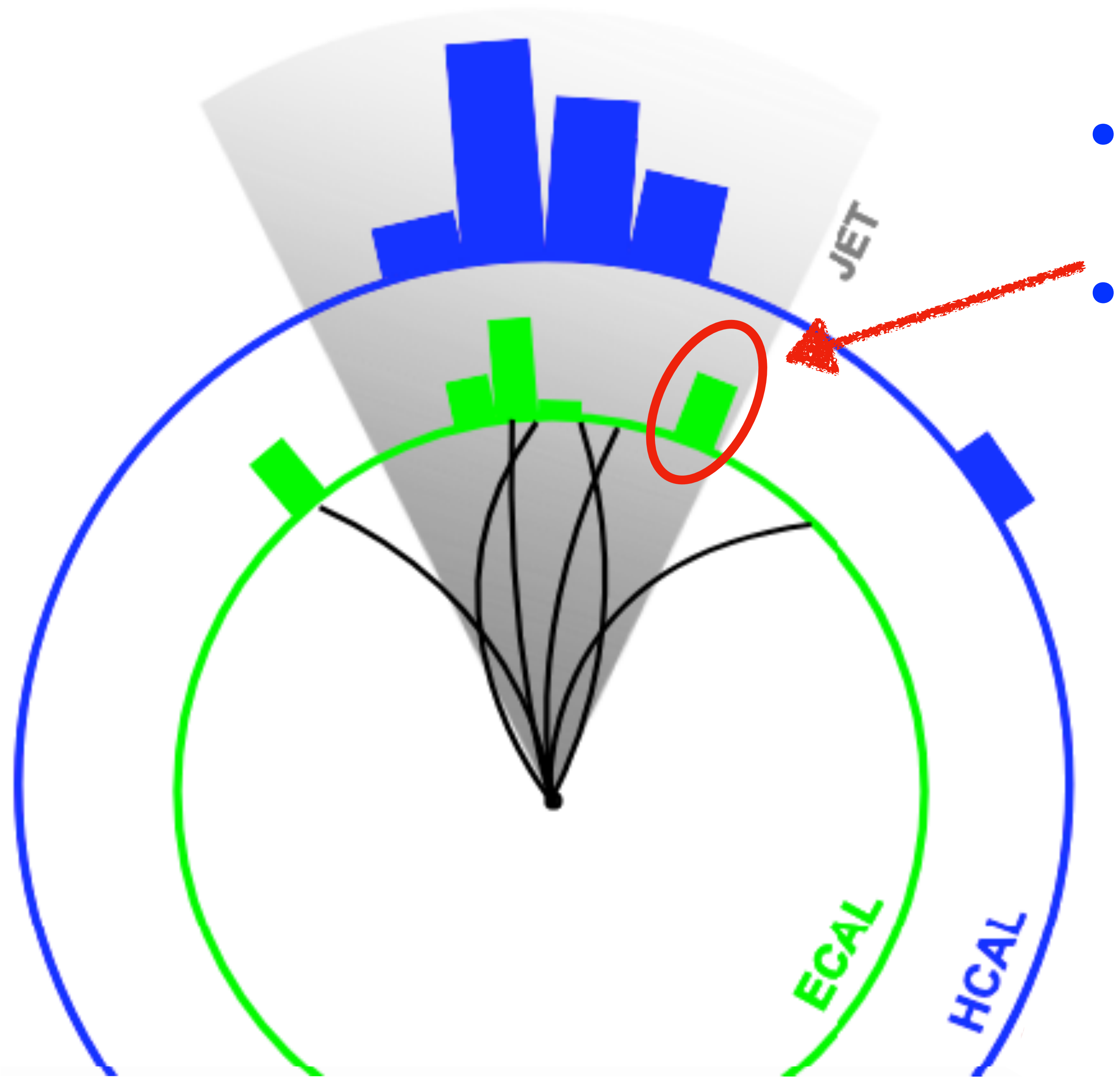

- Keep clusters that are not matched to any track
- These clusters are neutral particles that don't interact with the tracker

New inputs to Jet Building:

- Selected tracks coming from the hard-scatter vertex
- Clusters that survived the energy subtraction step

Jet Reconstruction: PFlow Jets

Particle Flow:

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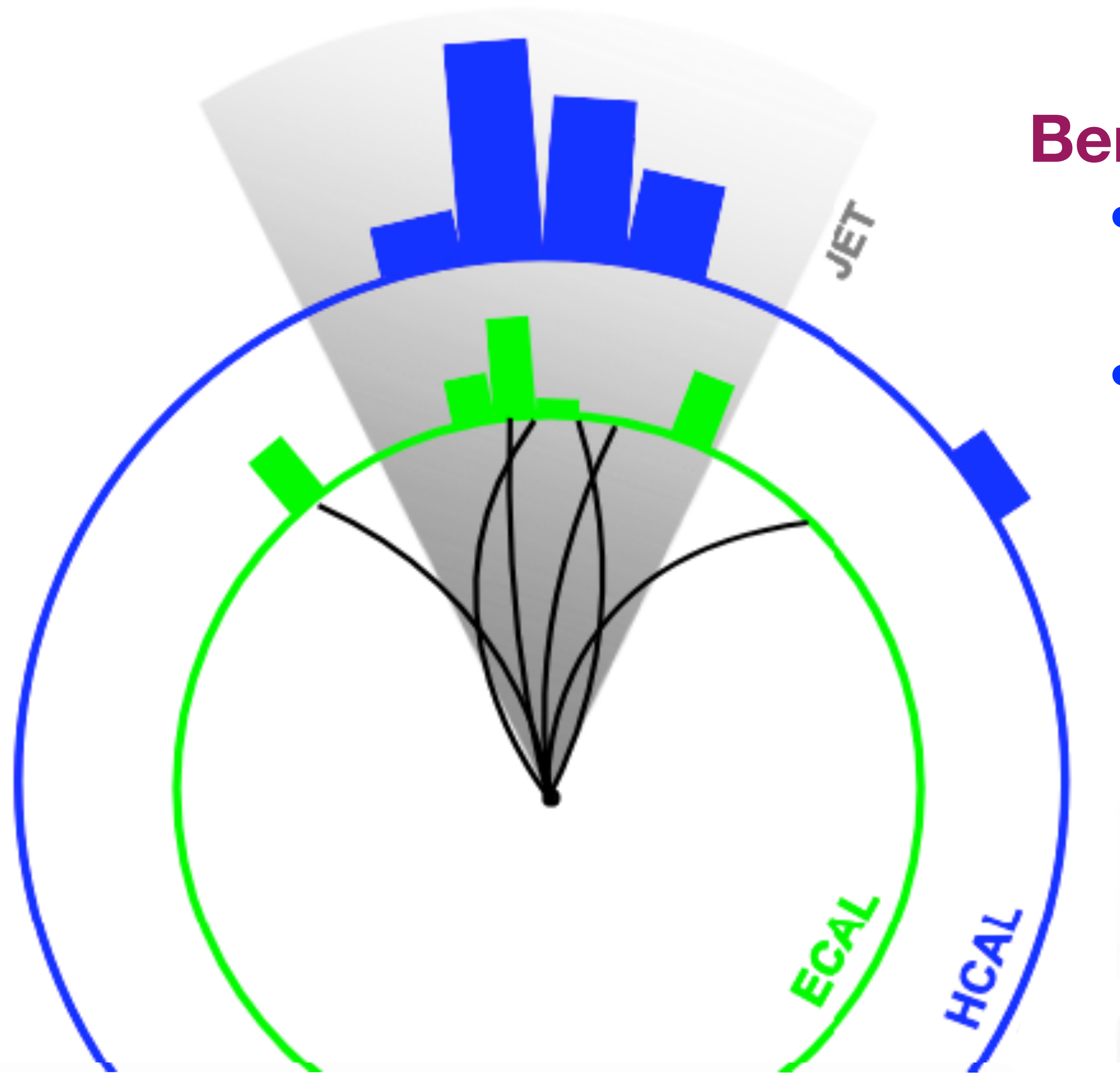
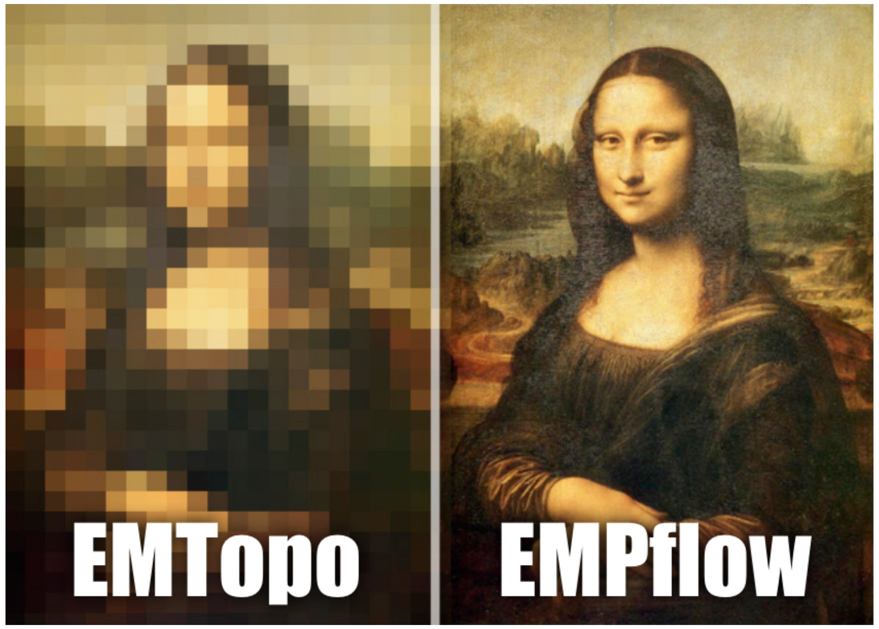


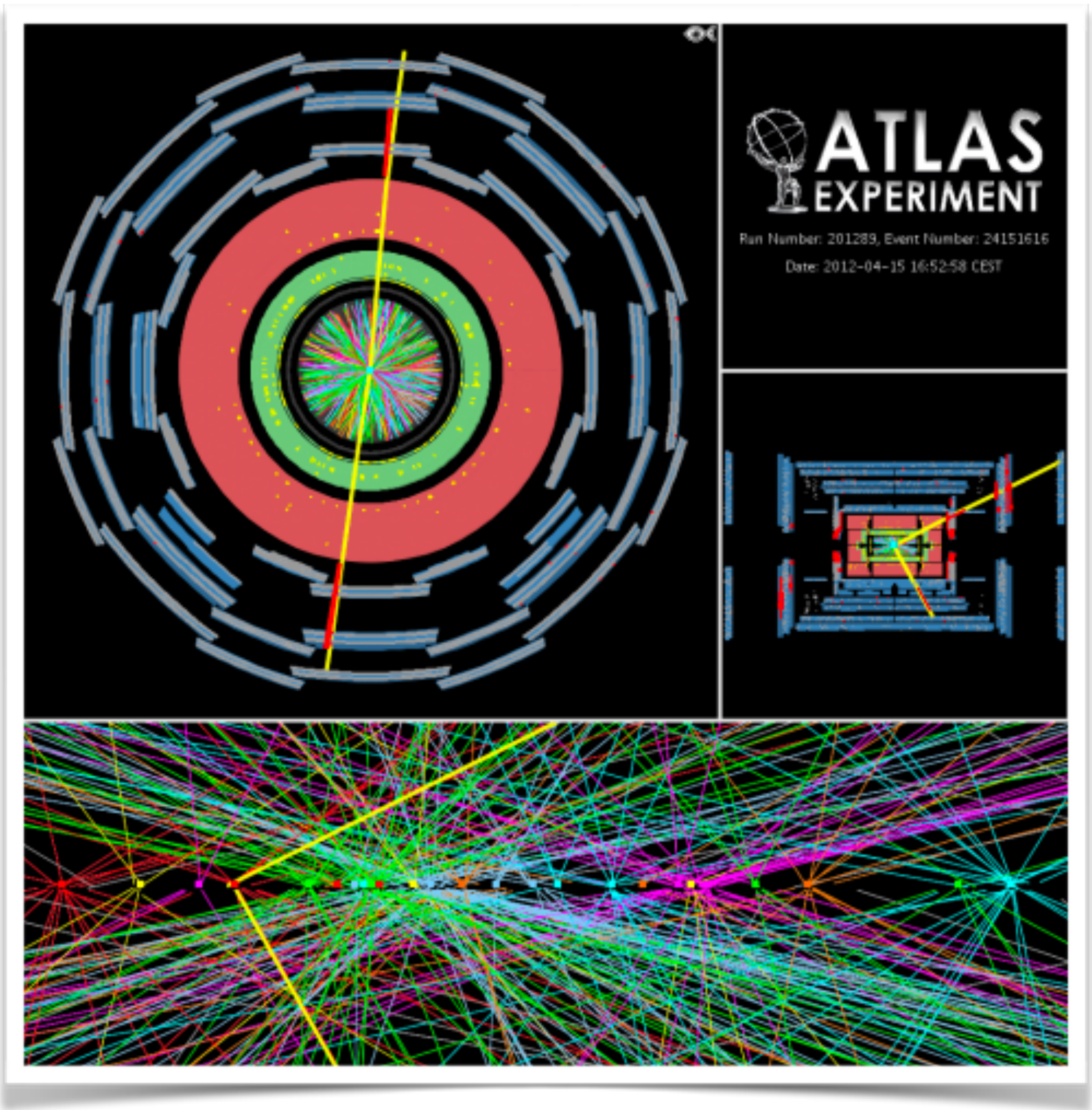
Benefit:

- Benefit from much better low-energy resolution in tracker
- Direct association to primary vertex



Pile-Up

The price of Luminosity in LHC



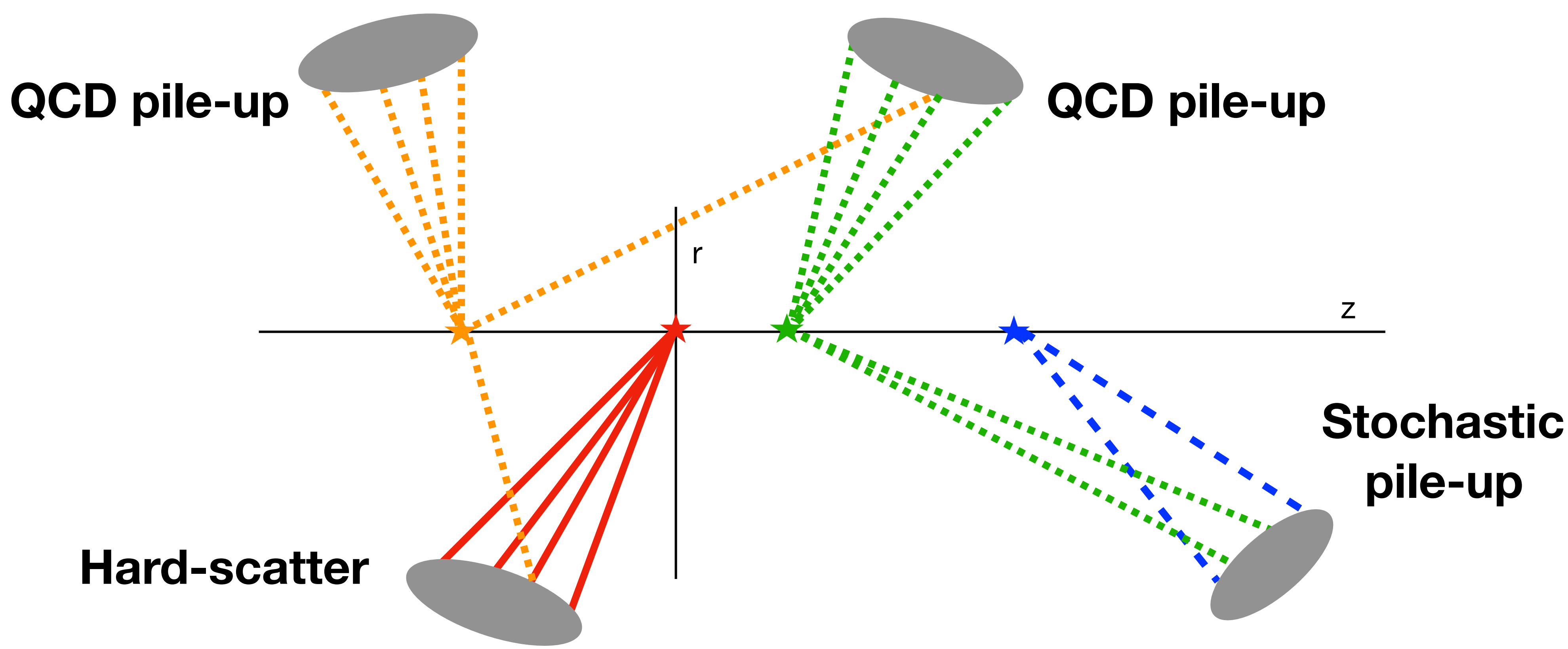
Z→μμ event with 25 reconstructed vertices

Pile-up Effects:

- In-time pile-up occurs when multiple collisions per bunch crossing happen
- Out-of-time pile-up happens due to slow or uncorrected detector response with energy leftovers in the calorimeters from previous bunch crossings

Pile-up effects are background for physics processes
→ Need to be tagged and removed

Origin and Structure of Pile-Up Jets



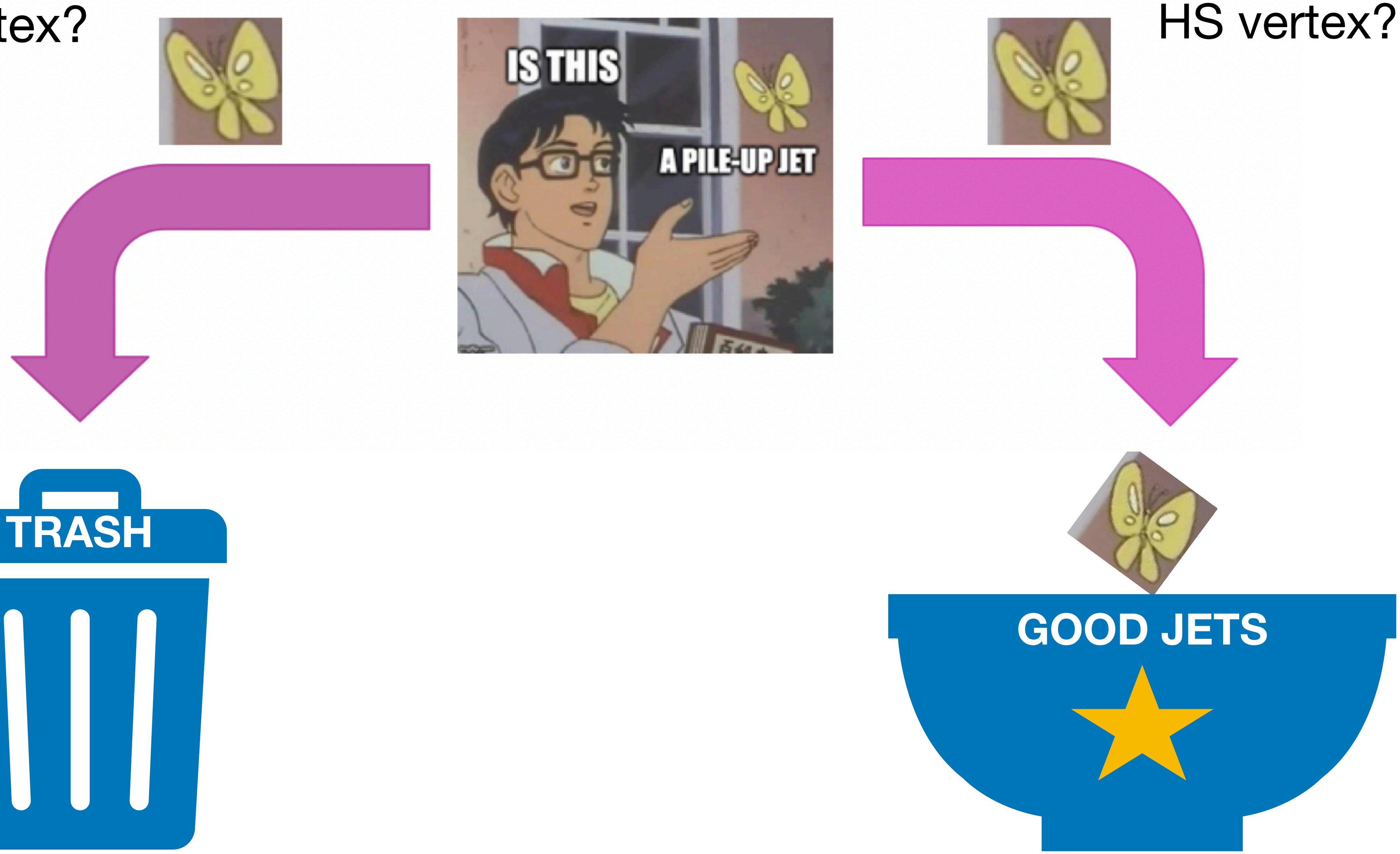
- **QCD pile-up jets:** contain particles from a single QCD process in a single pile-up interaction vertex
- **Stochastic pile-up jets:** combine particles from different interactions

Pile-Up Cleaning

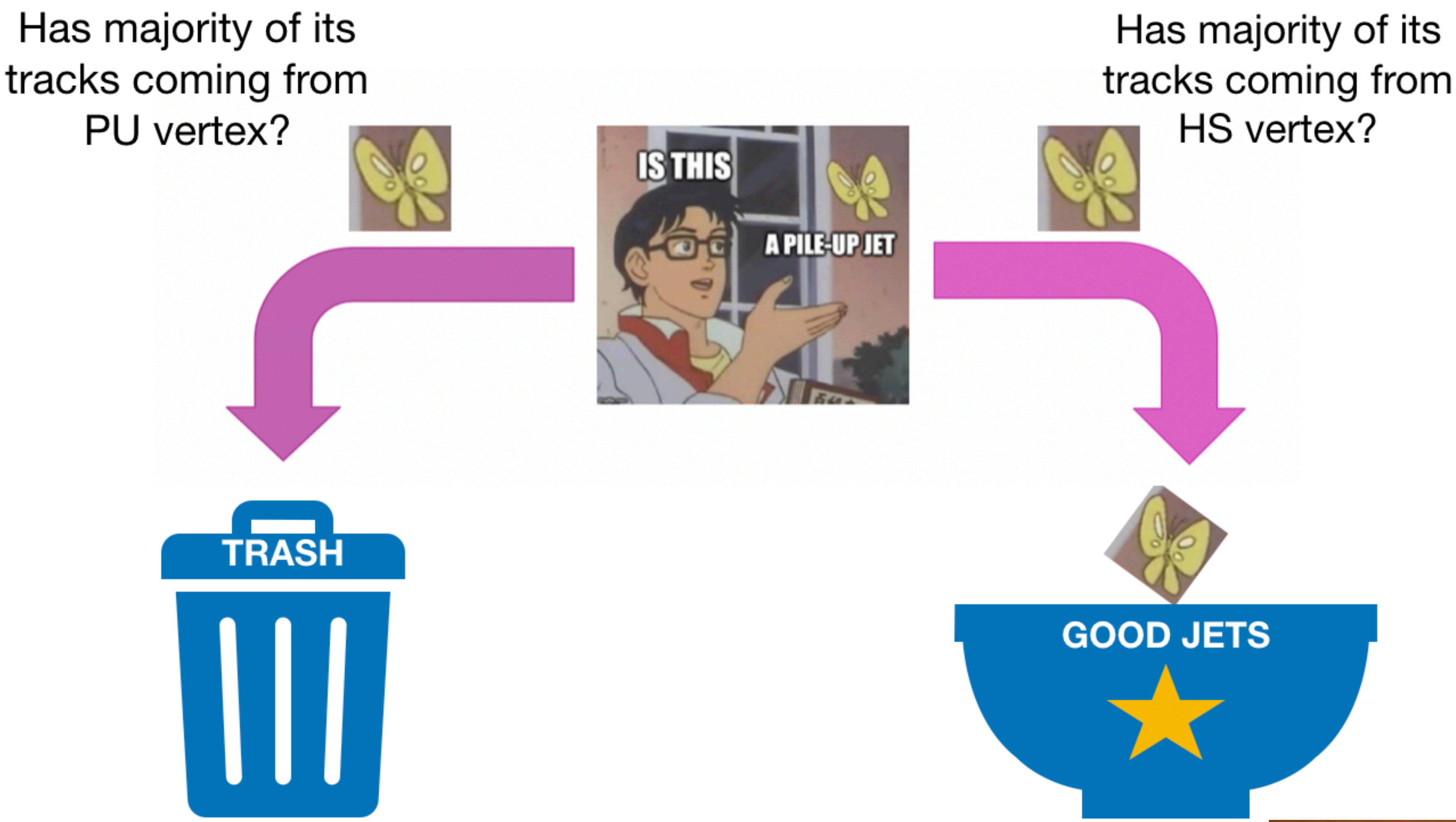
Pile-Up Jet Tagging

Has majority of its tracks coming from PU vertex?

Has majority of its tracks coming from HS vertex?



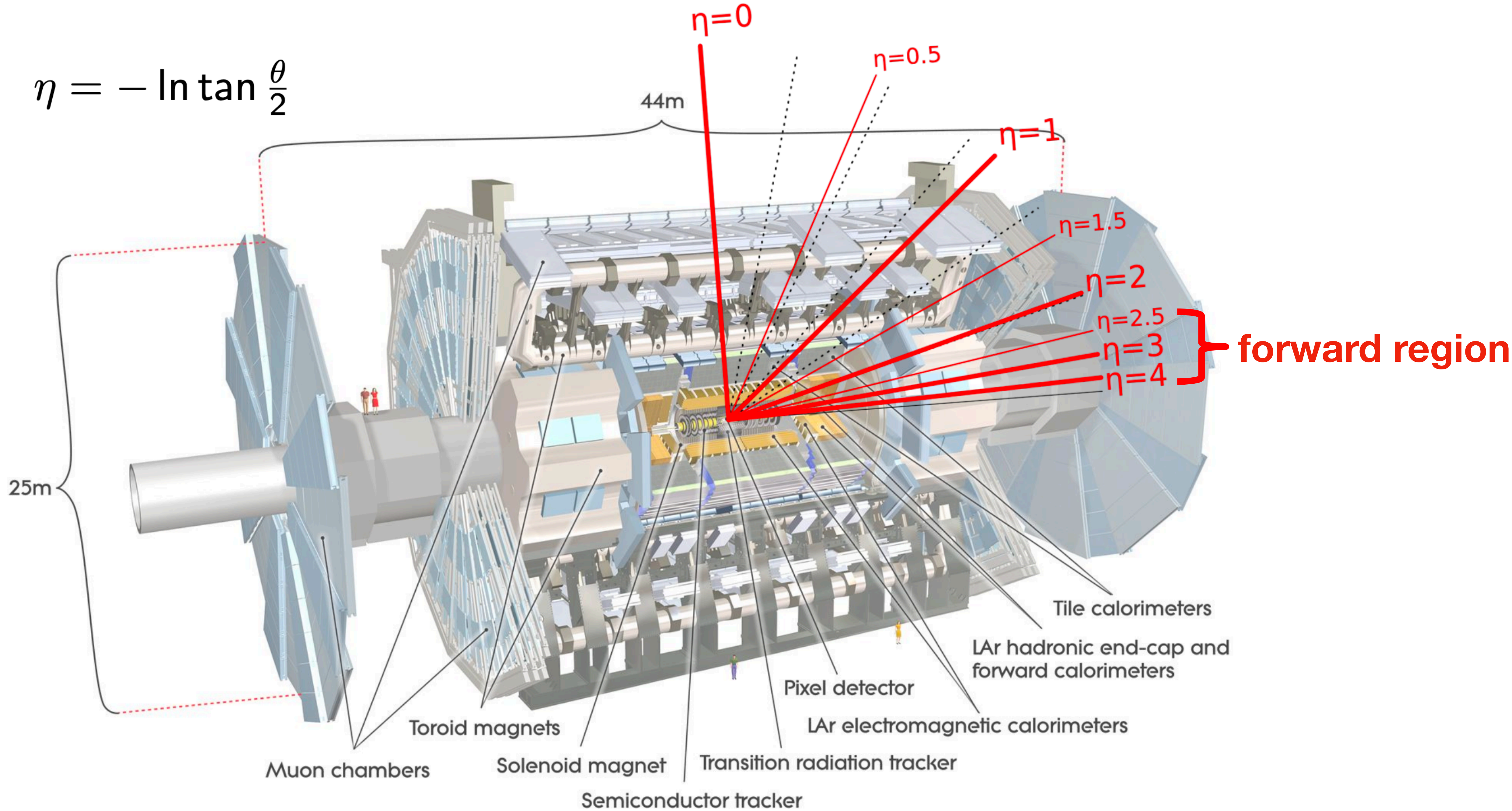
Pile-Up Jet Tagging



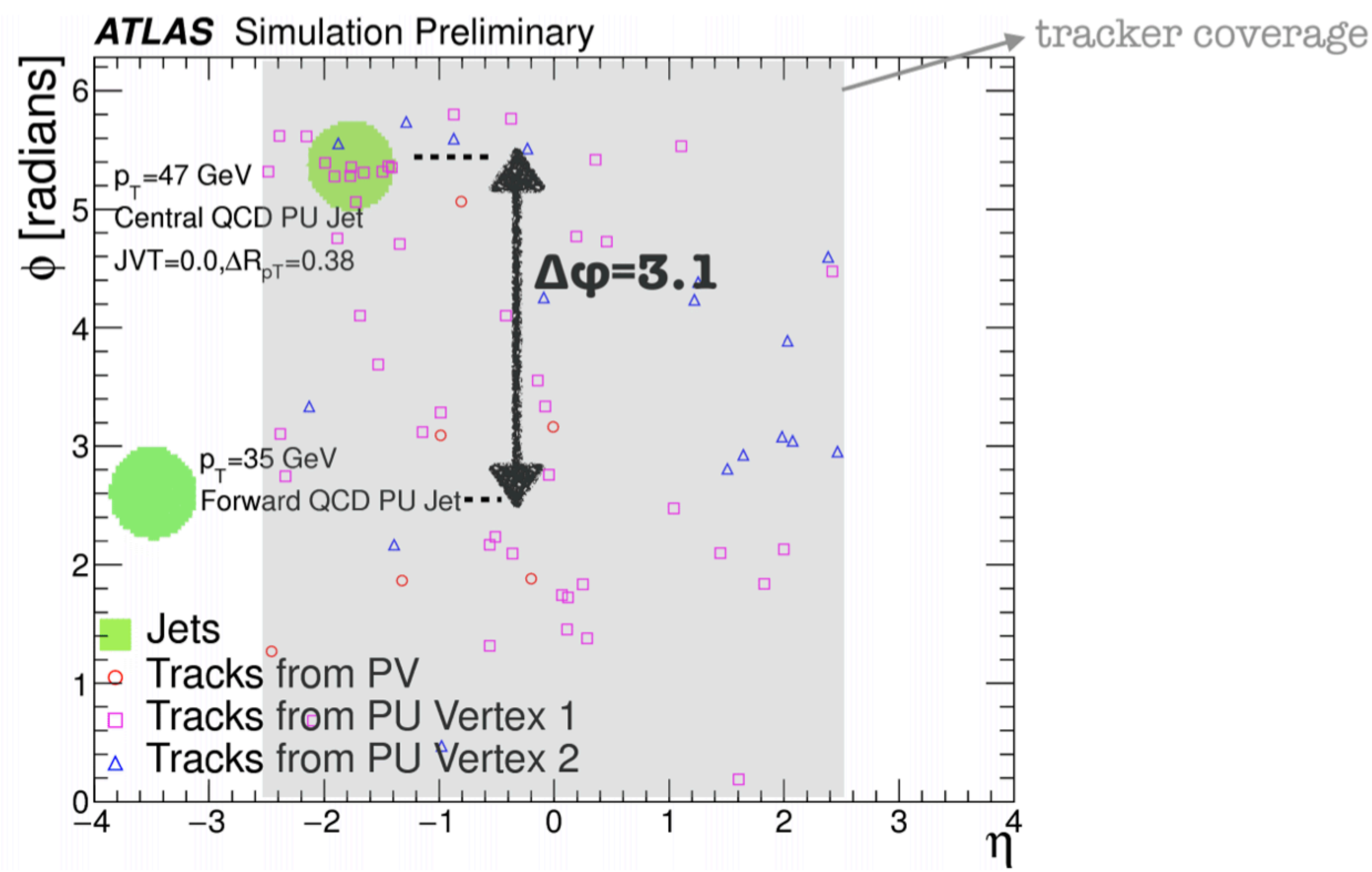
- Vertex information suppress pile up in $|\eta|<2.5$
- Forward jets outside the tracking coverage → No tracking information for these jets

Pseudorapidity

$$\eta = -\ln \tan \frac{\theta}{2}$$



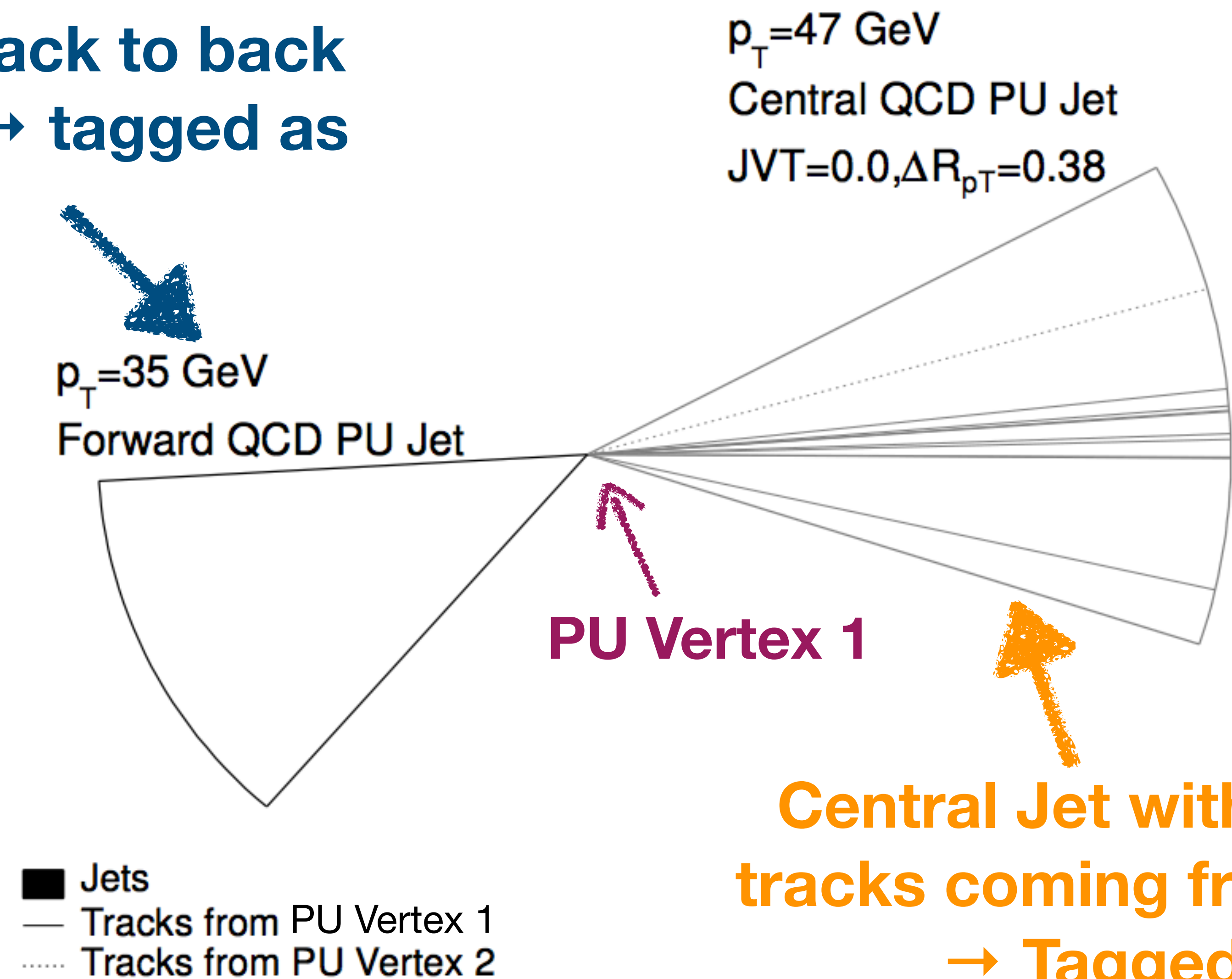
Forward Pile-Up Jet Tagging



- **What do we know?**
  - ✦ QCD pileup jets are mostly produced in pairs
  - ✦ Due to transverse momentum conservation, the two jets in the pair will have opposite directions in the transverse plane
  - ✦ Take advantage of this correlation to tag QCD pileup jets in the forward region

Forward Pile-Up Jet Tagging

Forward Jet back to back with a PU jet → tagged as PU



Central Jet with majority of tracks coming from PU Vertex → Tagged as PU

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Forward Pile-Up Jet Tagging

Forward Jet back to back with a PU jet → tagged as PU

p_T=47 GeV
Central QCD PU Jet

Central Jet with majority of tracks coming from PU Vertex → Tagged as PU

Jets
Tracks from PU Vertex 1
Tracks from PU Vertex 2

- **What do we know?**
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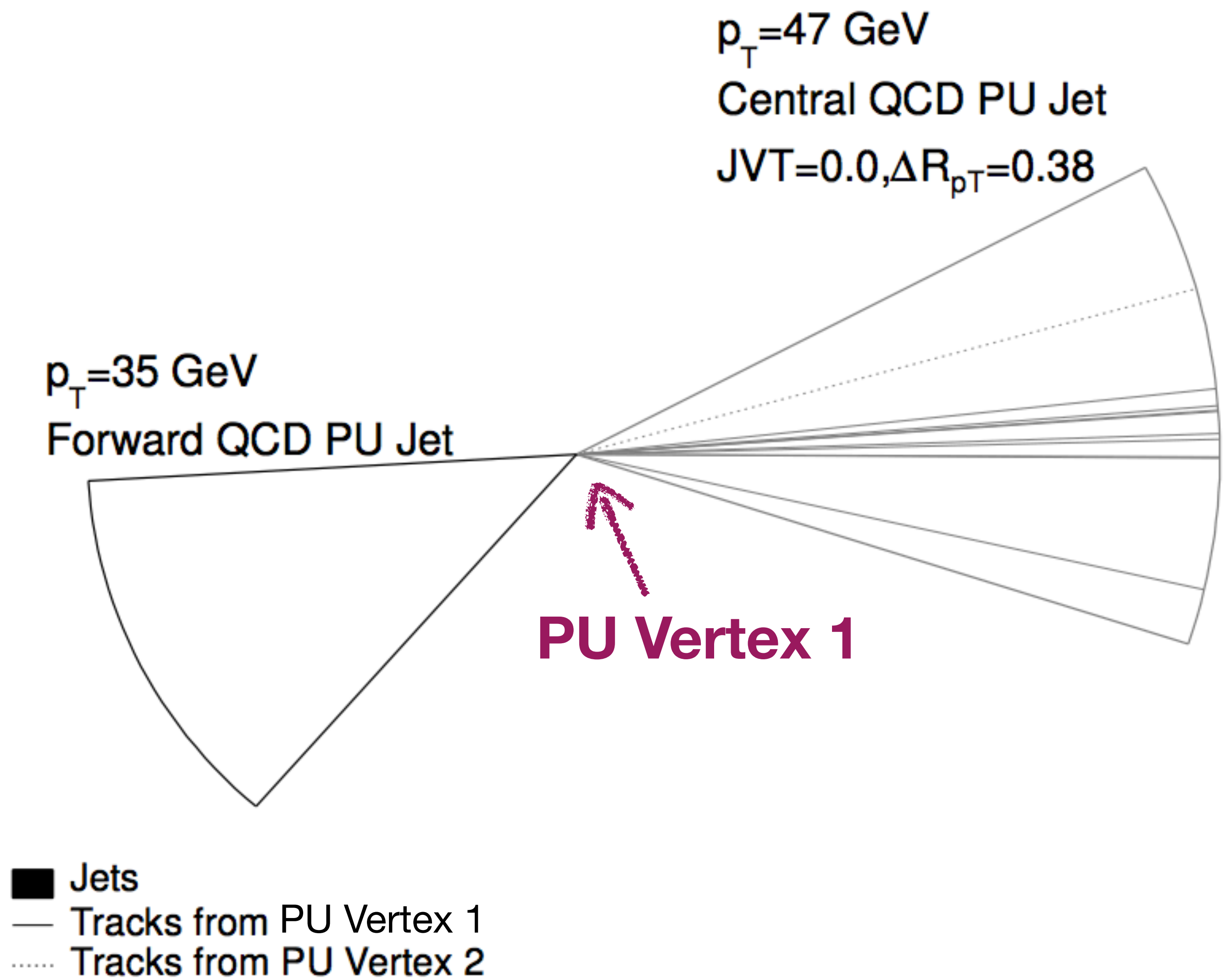
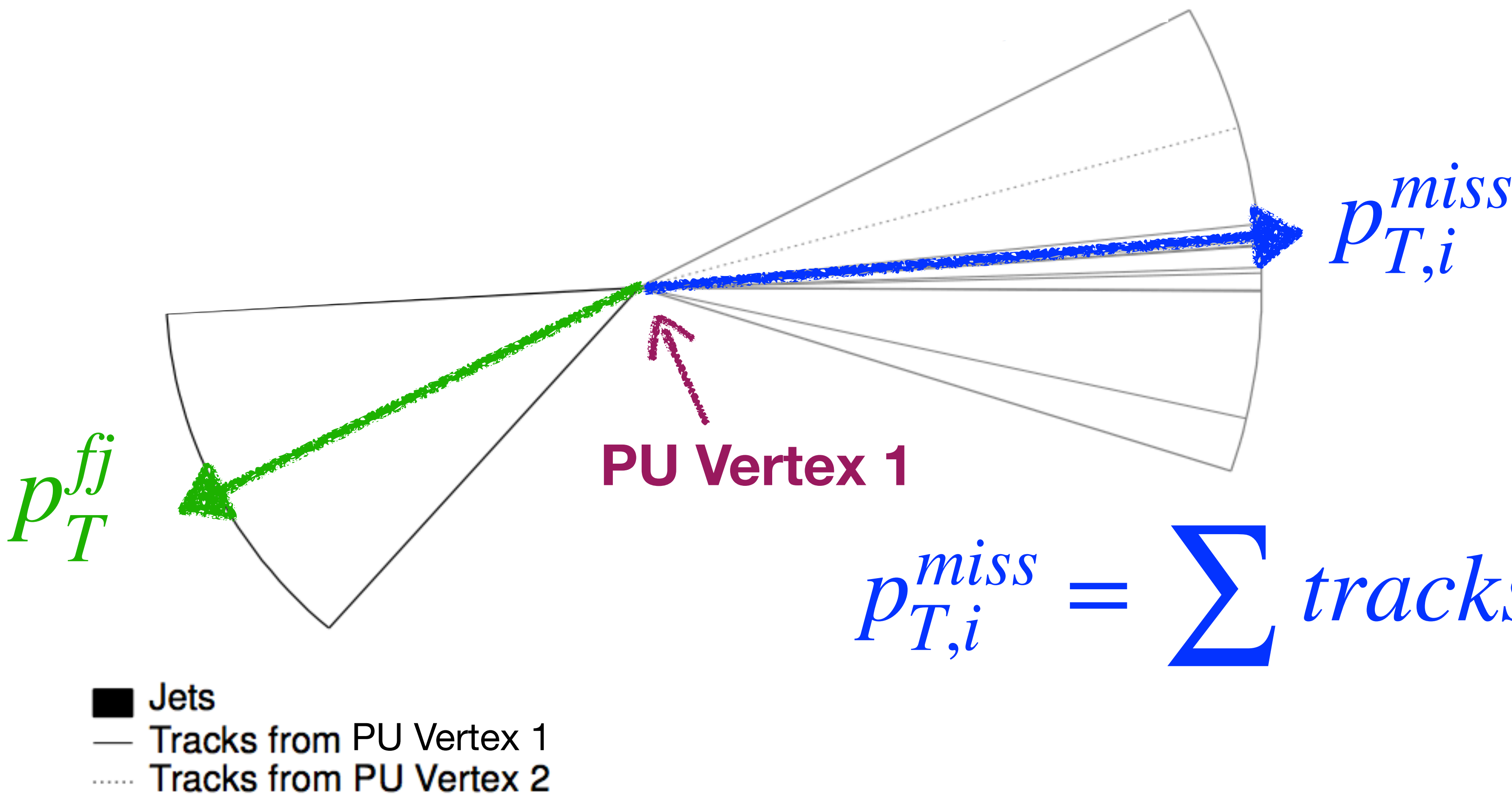
Main Disadvantage



- **Based on the assumption that both jets are reconstructed**
- **Not always the case!**

Instead

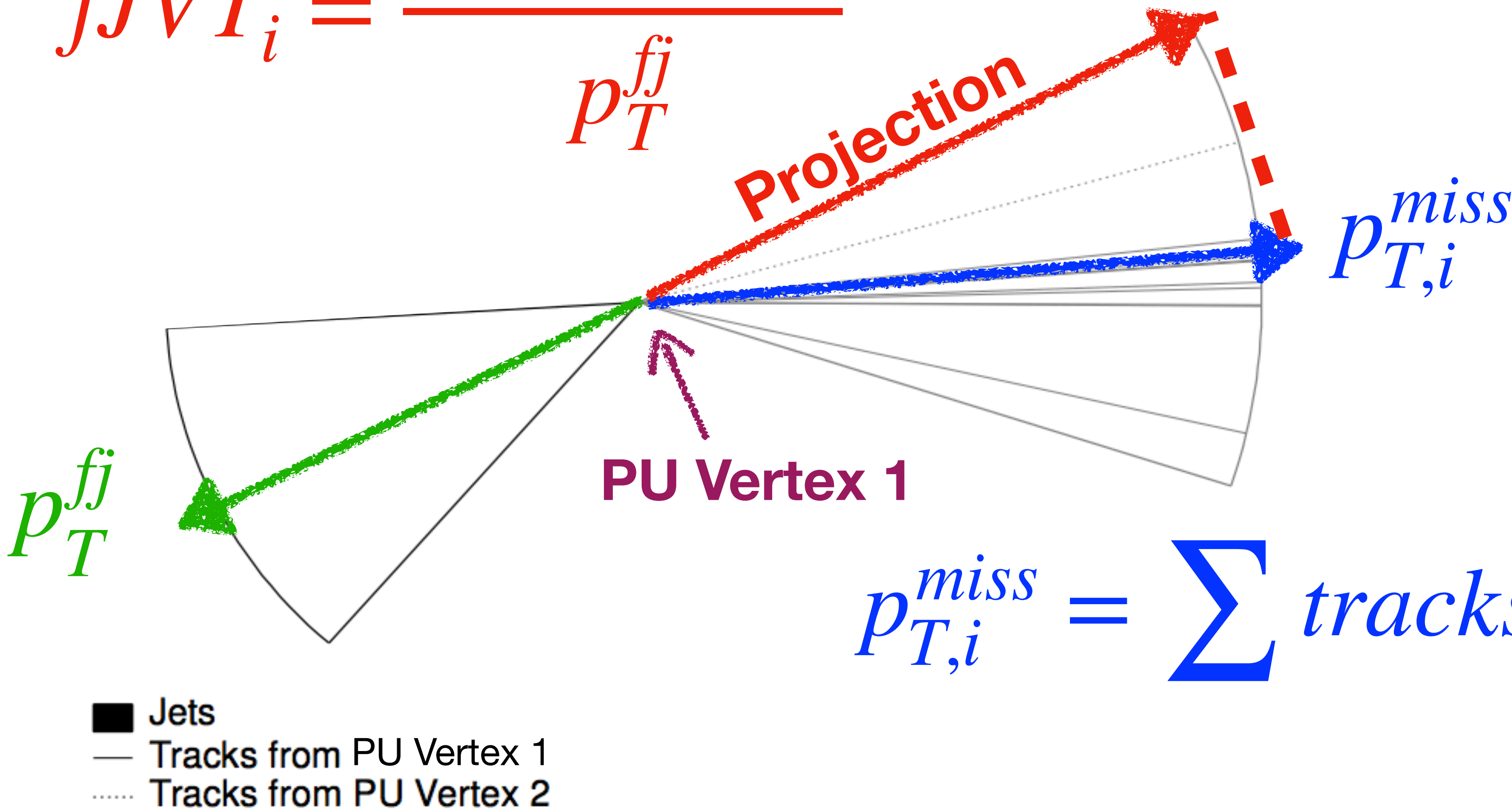


$$p_{T,i}^{miss} = \sum tracks || jets$$

- Calculate the missing transverse momentum, using tracks or jets, for the PU vertex and take projection on forward jet

Instead

$$fJVT_i = \frac{Projection}{p_T^{fj}}$$



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- Calculate the missing transverse momentum, using tracks or jets, for the PU vertex and take projection on forward jet
- Look if projection is proportional to the forward jet momentum

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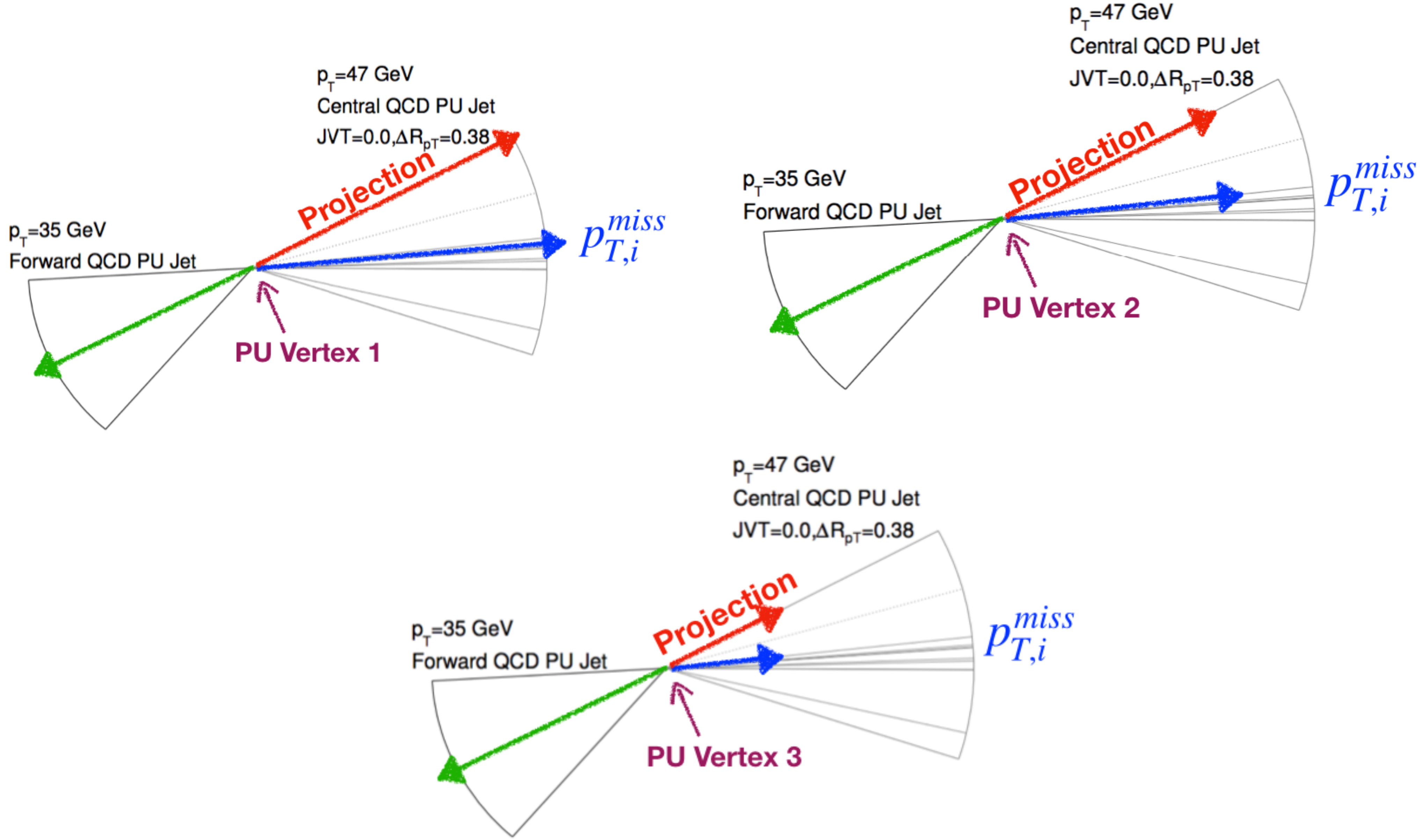
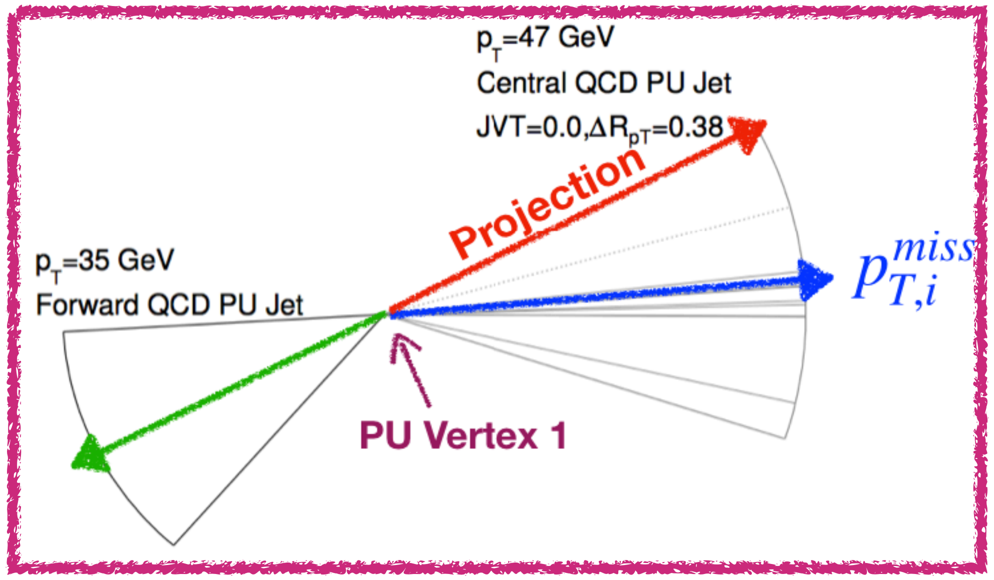
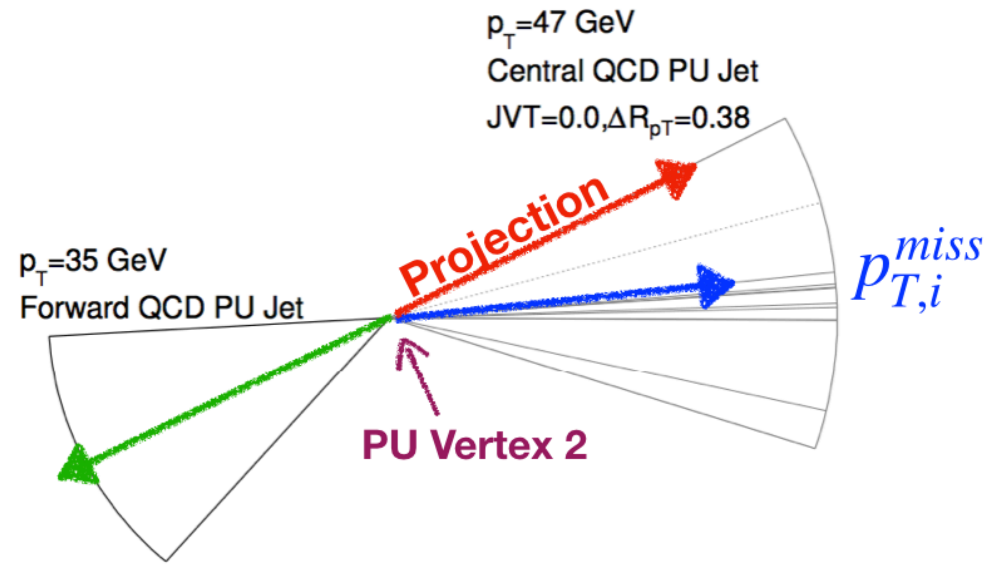


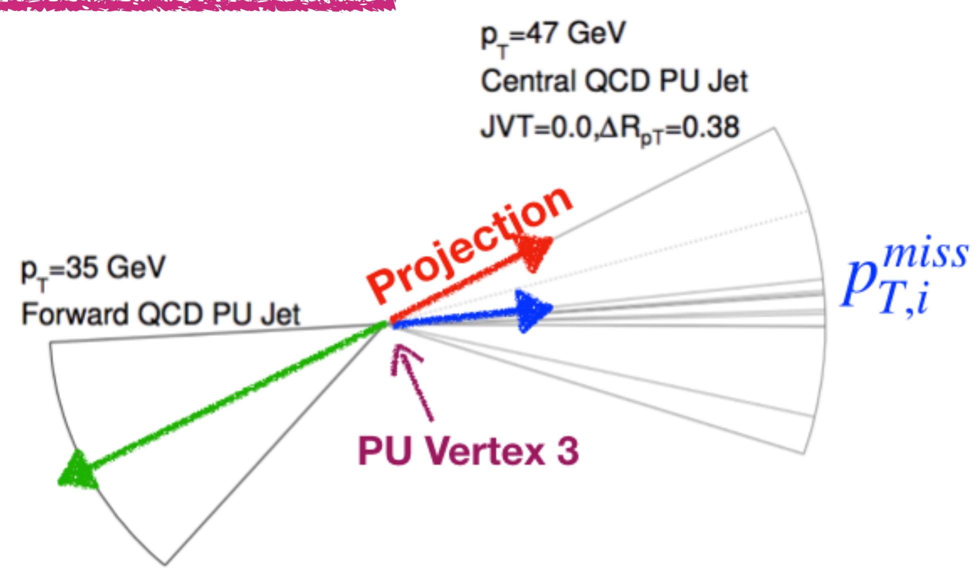
- Calculate the missing transverse momentum, using tracks or jets, for the PU vertex and take projection on forward jet
- Look if projection is proportional to the forward jet momentum
- Repeat process for every pile-up vertex of the event

Instead



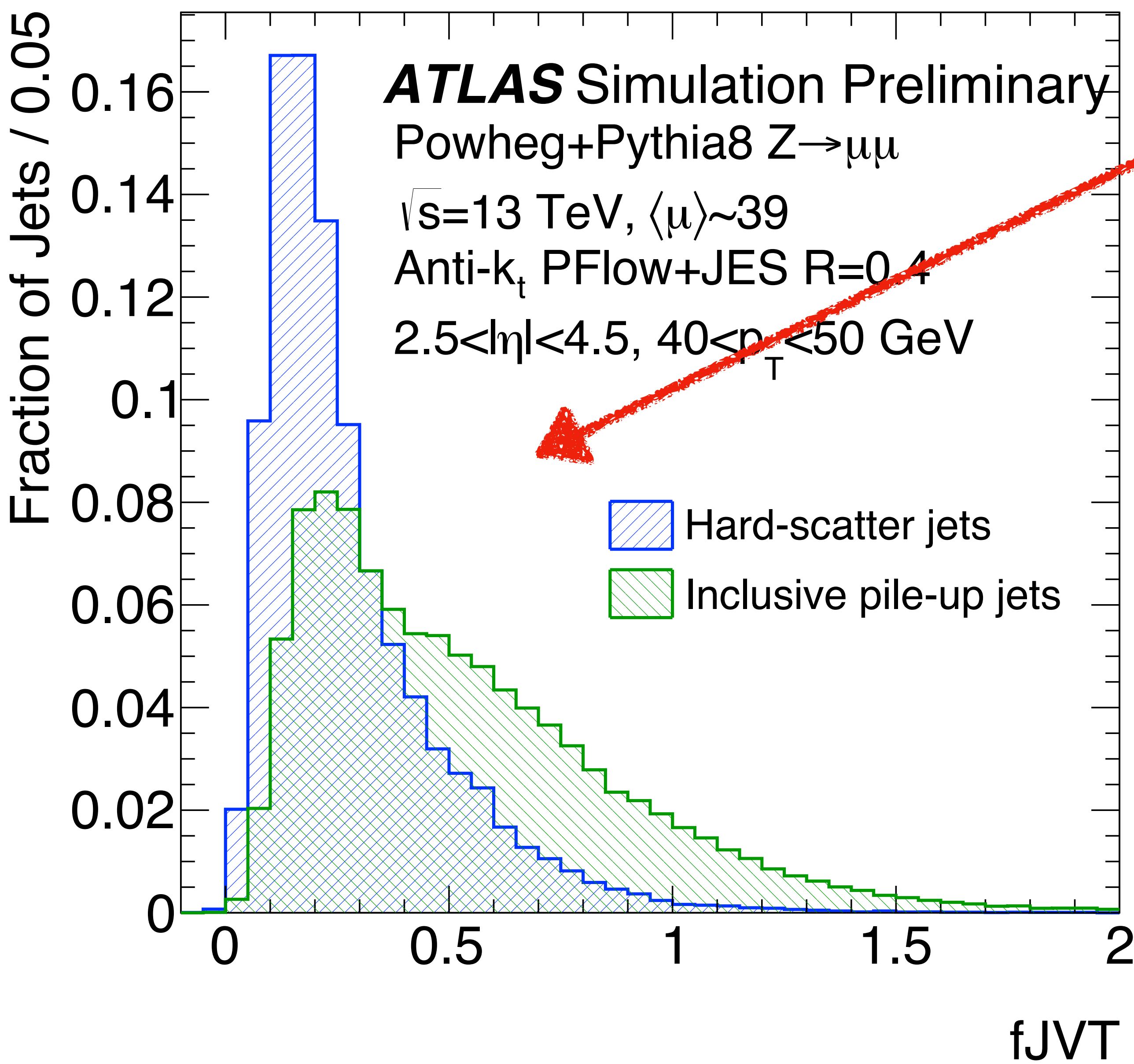


$$fJVT_1 = \frac{Projection}{p_T^{fj}}$$



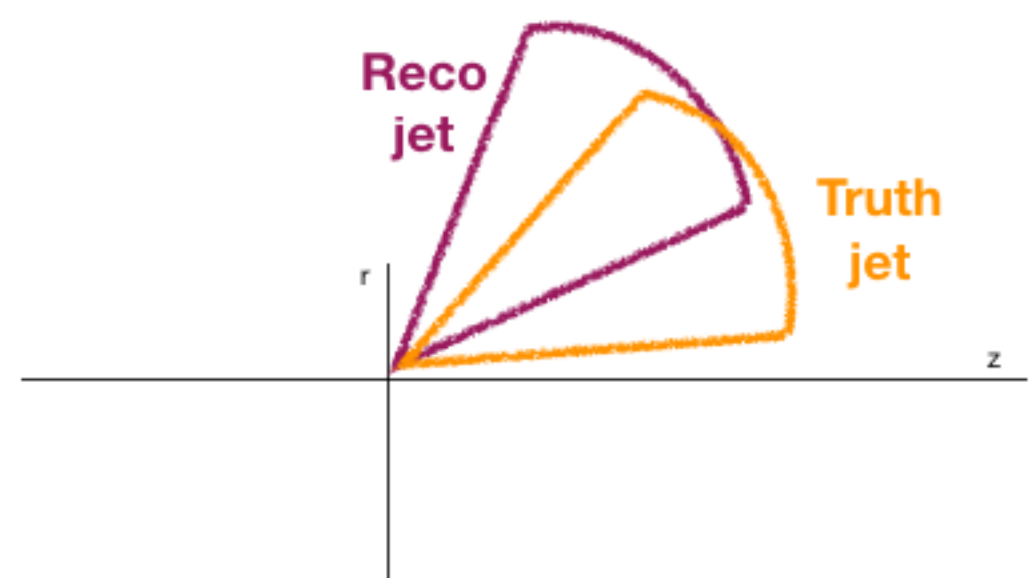
- Calculate the missing transverse momentum, using tracks or jets, for the PU vertex and take projection on forward jet
- Look if projection is proportional to the forward jet momentum
- Repeat process for every pile-up vertex of the event
- Choose vertex with largest fJVT value

fJVT Discriminant

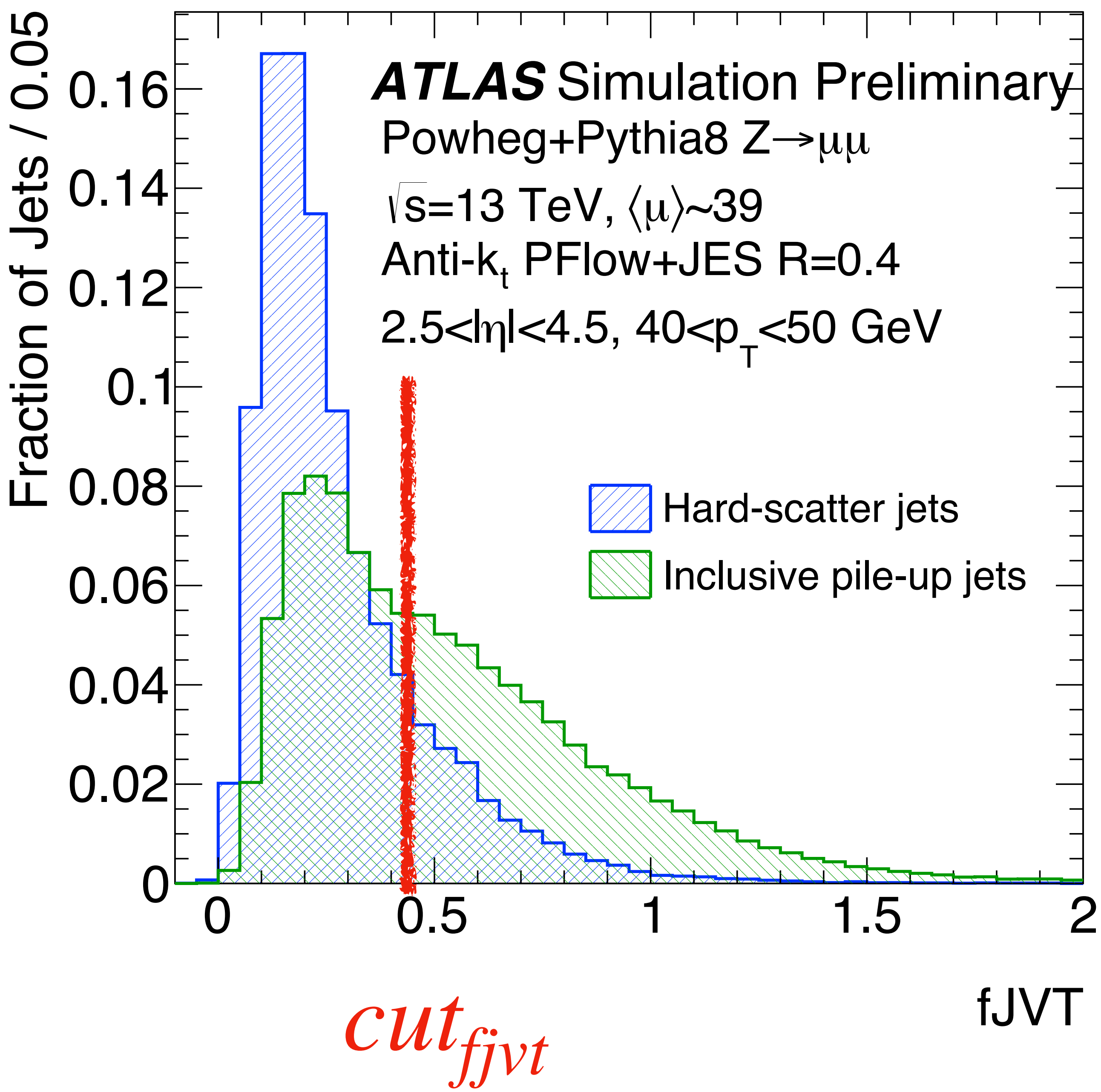


Fill histo with the calculated fjvt value for every forward jet

- To evaluate performance:
  - Reconstruct truth-particle jets
- Tag forward jets as:
  - hard-scatter if a truth-particle hs jet is geometrically matched to the forward jet
  - as pile-up otherwise



fJVT Discriminant

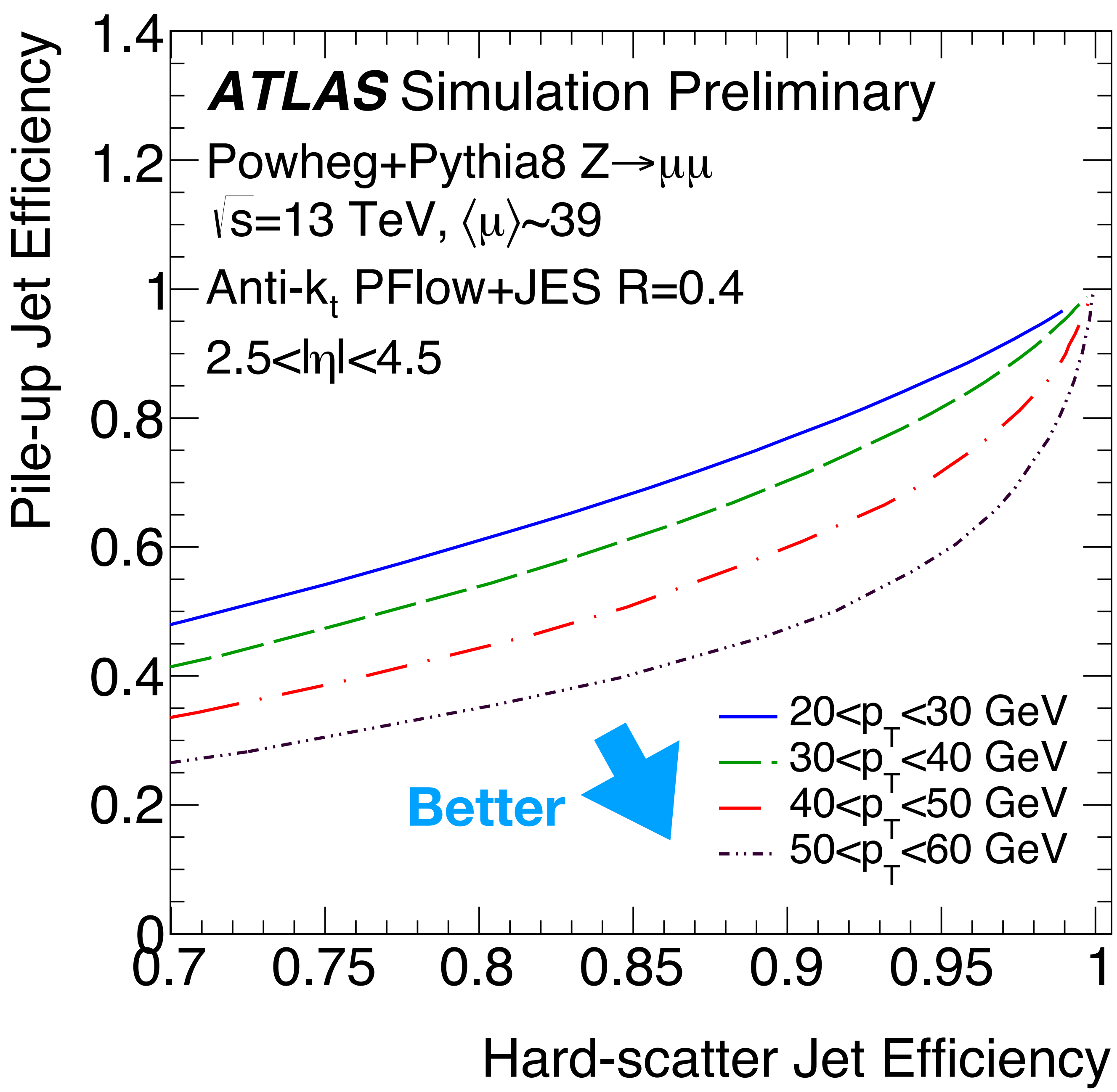


- Define HS and PU efficiencies :

$$\varepsilon_{\mathrm{HS}} = \frac{\mathrm{N}(\mathrm{jets}_{\mathrm{HS}}^{\mathrm{matched}}, \quad \text{with fJVT} < \mathrm{cut}_{\mathrm{fjvt}})}{\mathrm{N}(\mathrm{jets}_{\mathrm{HS}}^{\mathrm{matched}})}$$

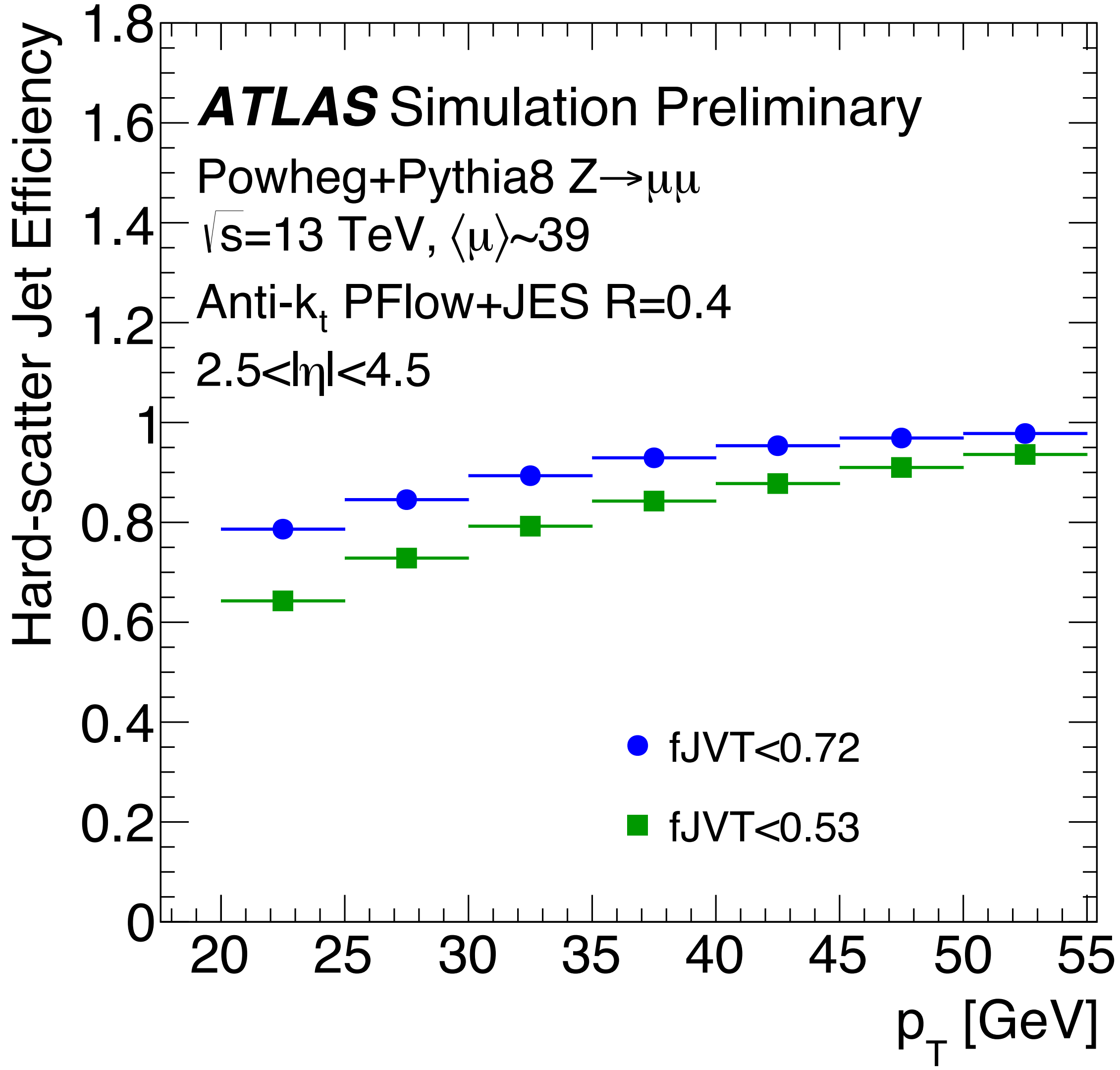
$$\varepsilon_{\mathrm{PU}} = \frac{\mathrm{N}(\mathrm{jets}_{\mathrm{PU}}^{\mathrm{matched}}, \quad \text{with fJVT} < \mathrm{cut}_{\mathrm{fjvt}})}{\mathrm{N}(\mathrm{jets}_{\mathrm{PU}}^{\mathrm{matched}})}$$

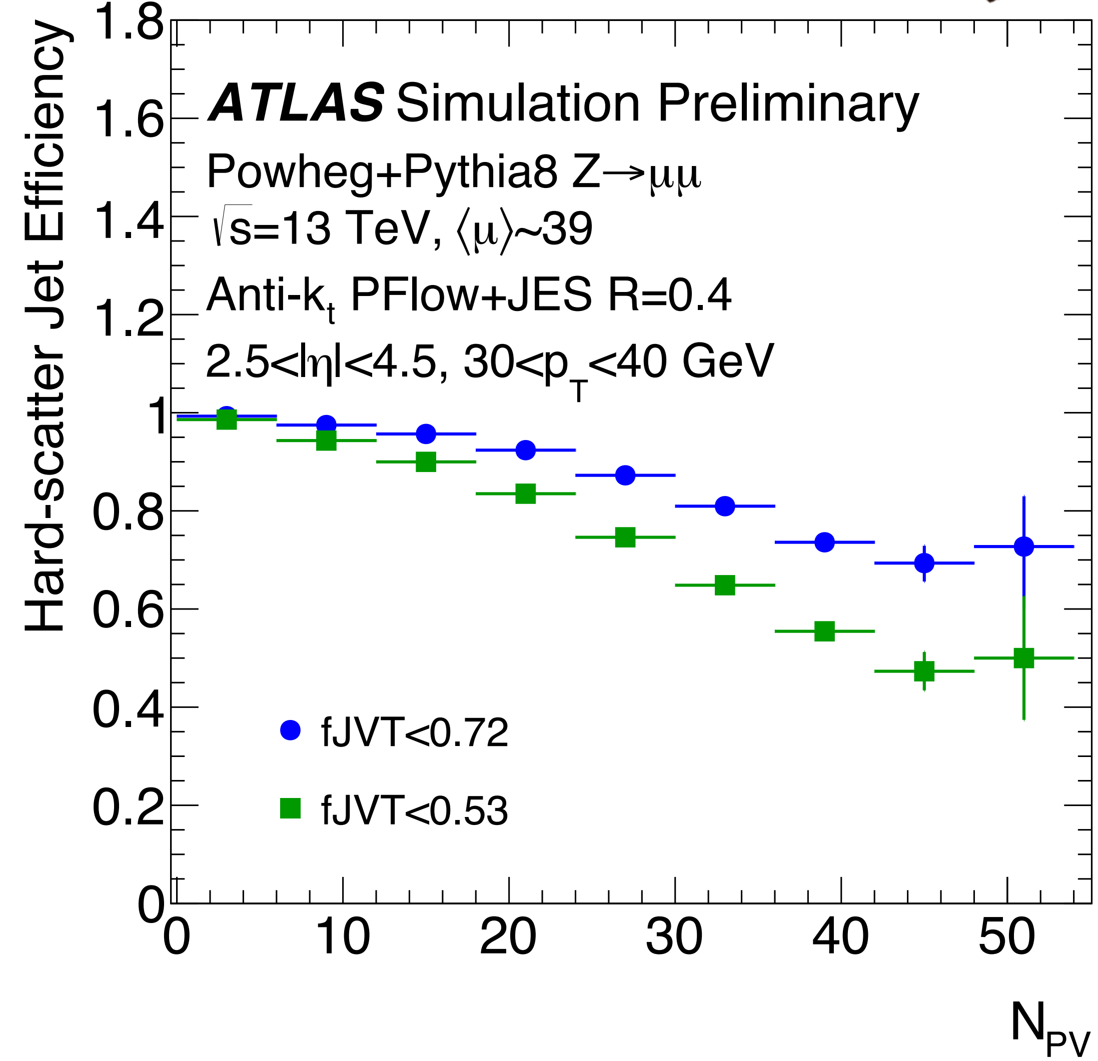
Performance



- PU jet efficiency as a function of HS jet efficiency while varying the fjvt cut and for different p_T bins
- Performance is improving with p_T as expected

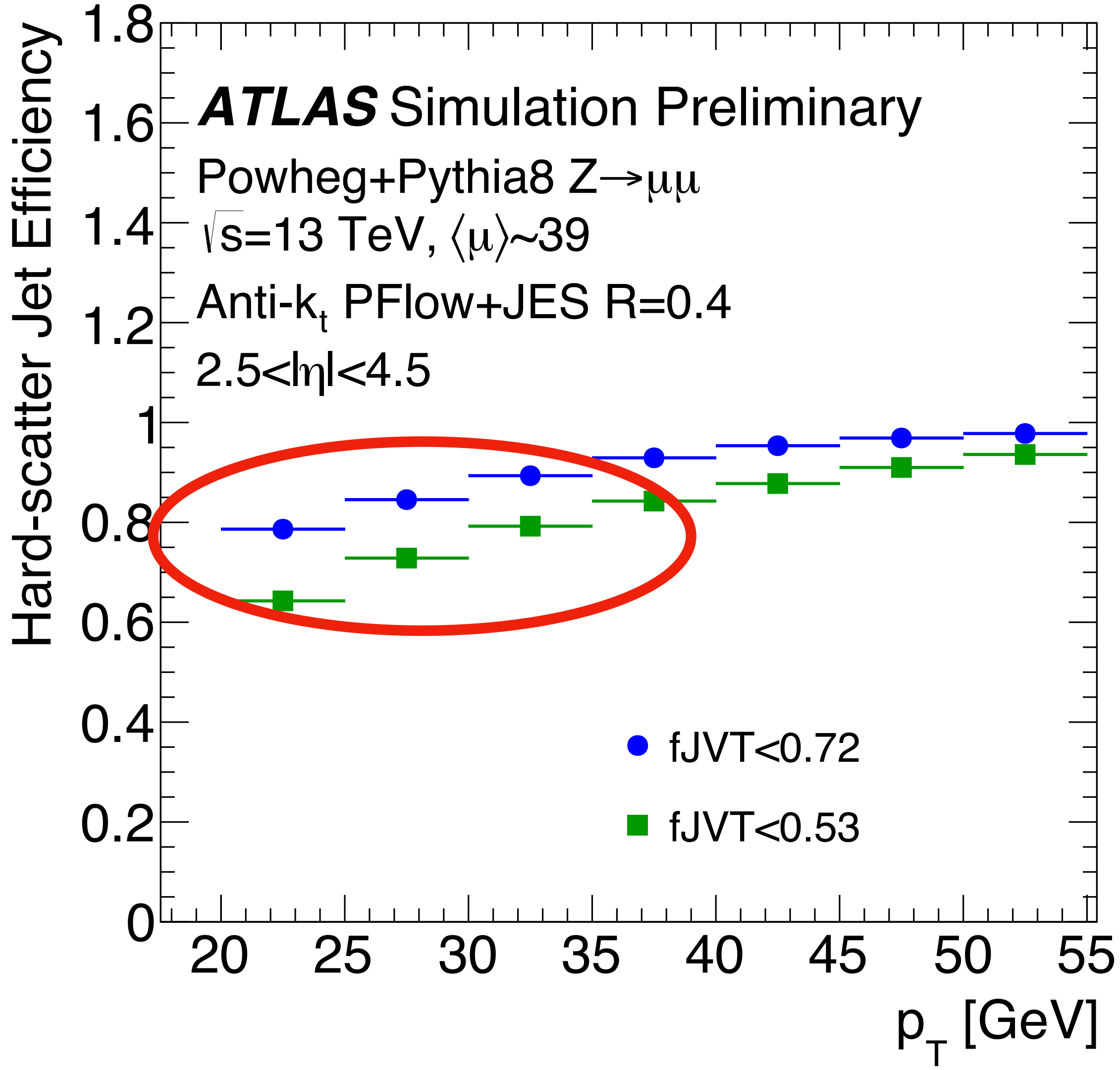
Efficiency with p_T, N_{PV}

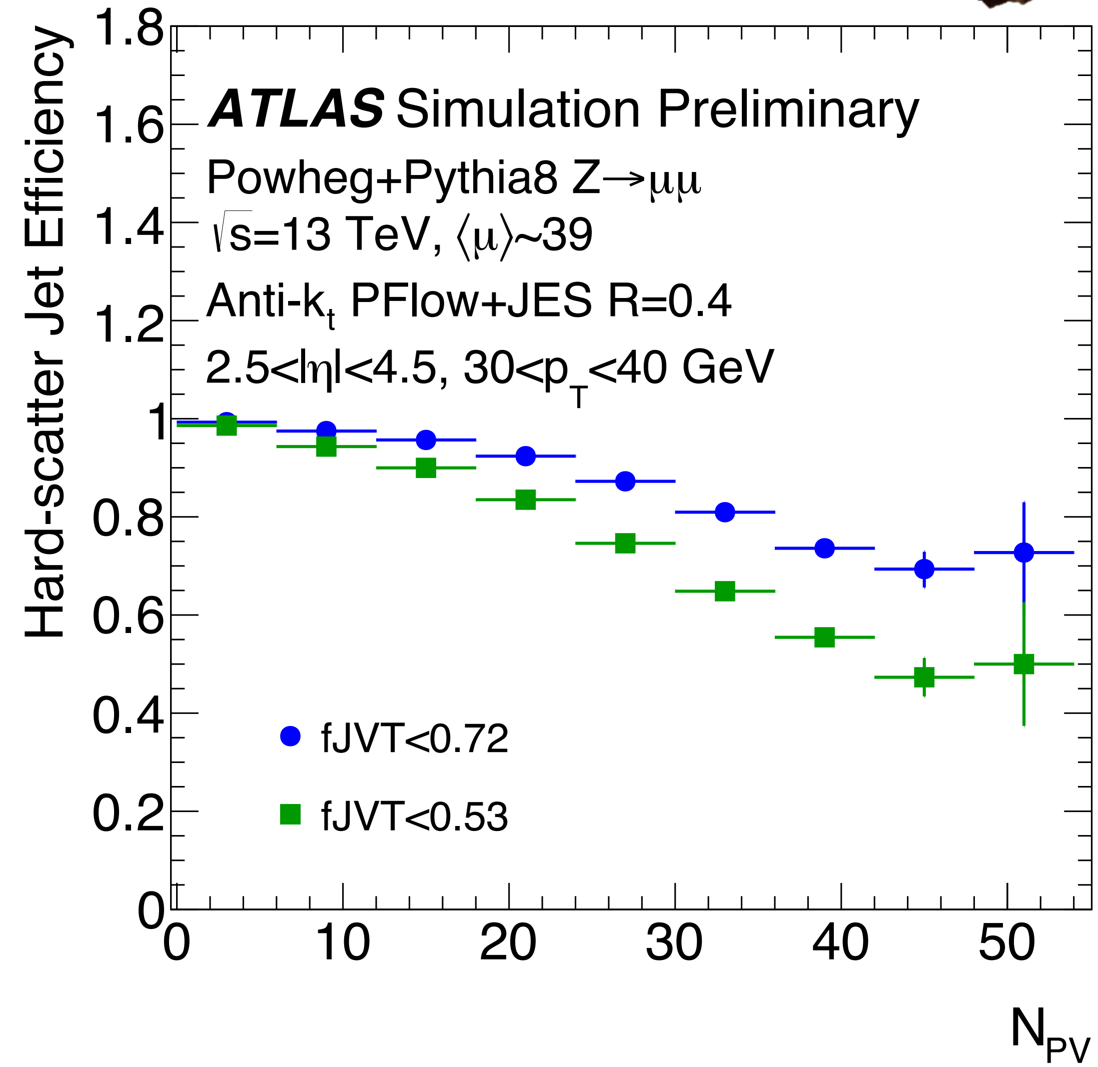




- Define tight and loose working points:
  - cut_{fJVT} = 0.53 and 0.72
  - Correspond to hs efficiencies of 80% and 90% for pu efficiencies of 50% and 68% for jets with 20<pt<60 GeV

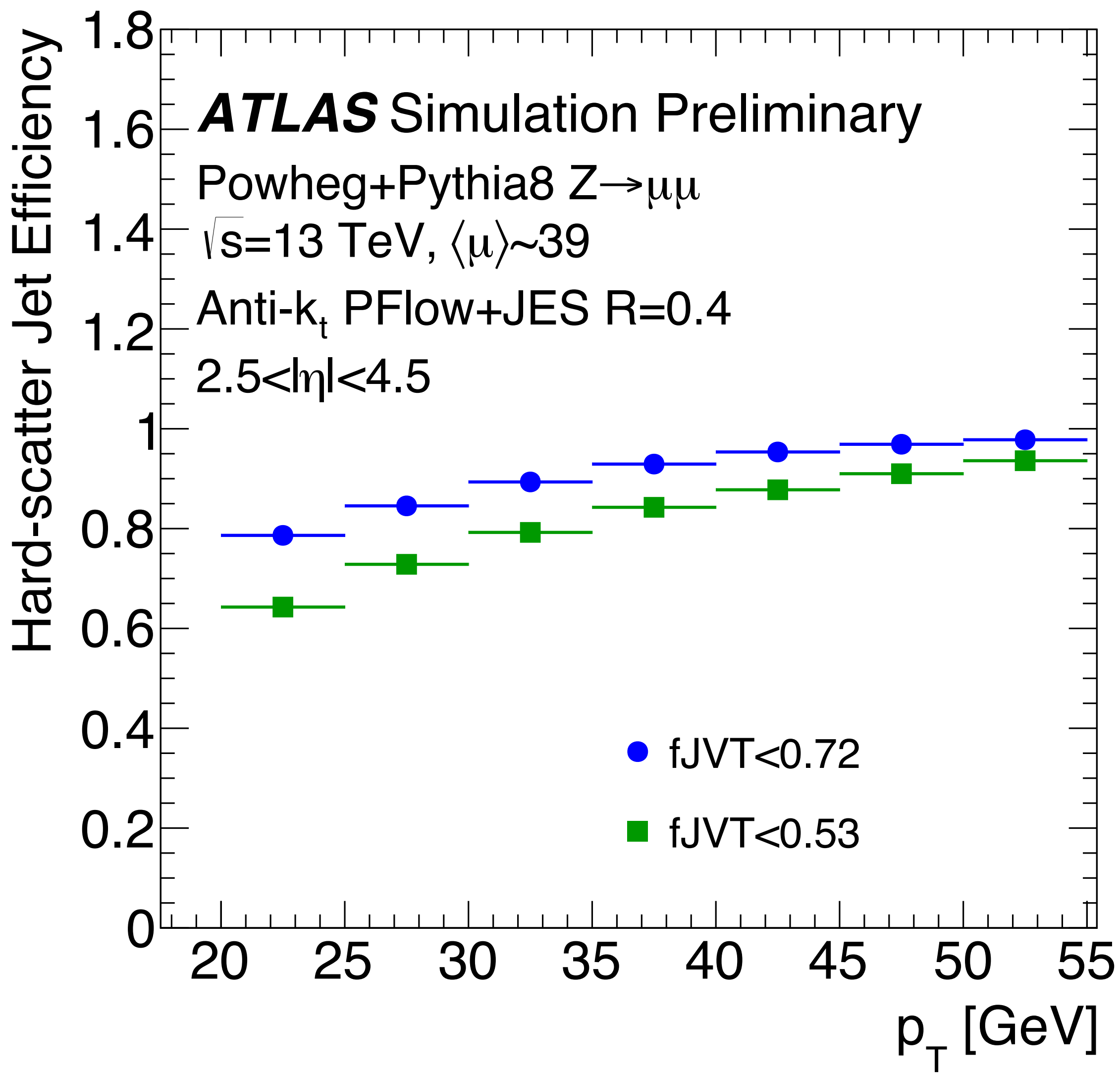
Efficiency with p_T, N_{PV}

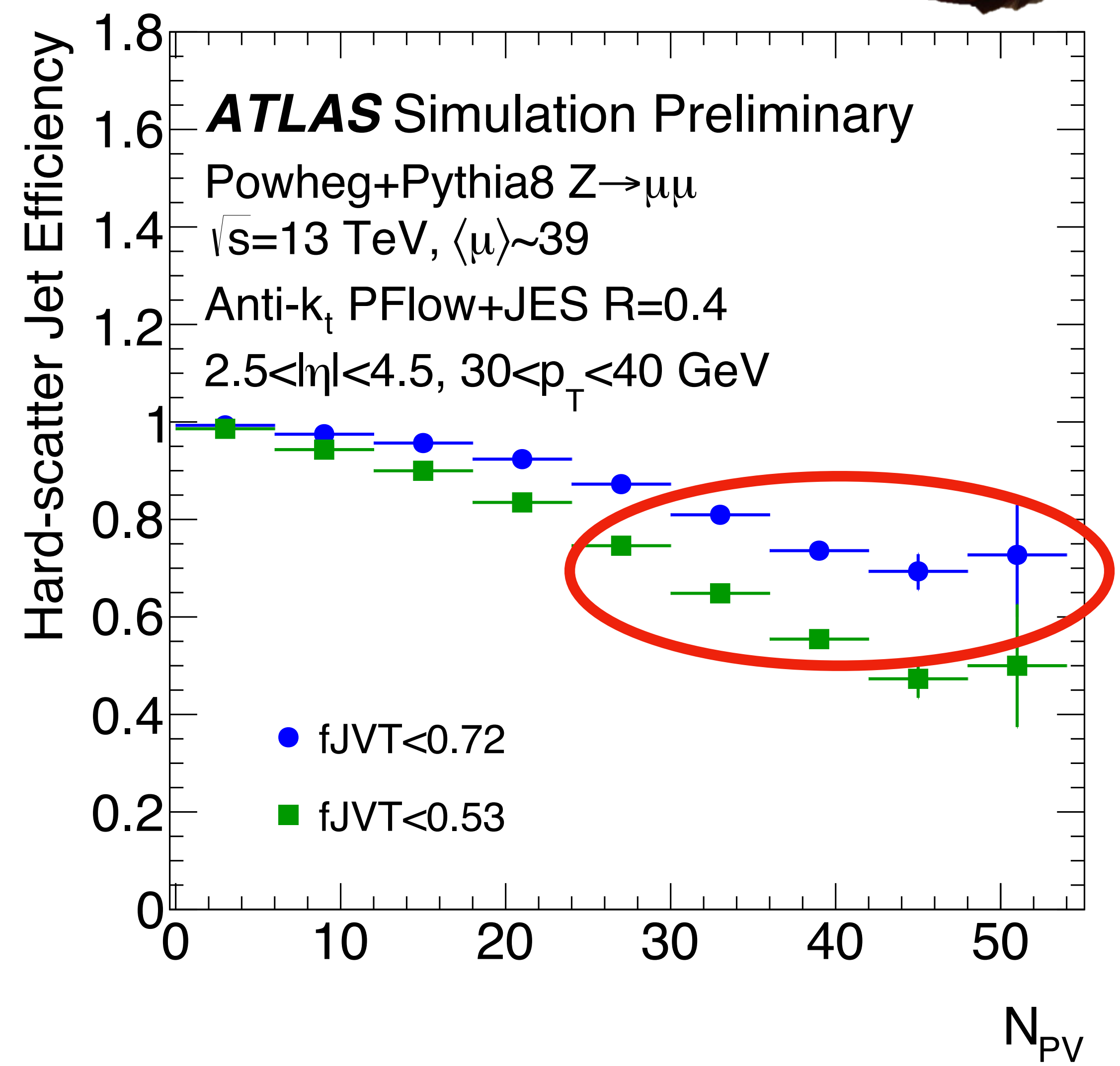




The probability of an upward fluctuation in the fJVT value is more likely in low pt bins → lower efficiencies

Efficiency with p_T, N_{PV}





busier pile-up conditions increase the chance of accidentally matching the hard-scatter jet to a pile-up vertex


I GOT 99 PROBLEMS
BUT TAGGING
FORWARD JETS AIN'T ONE
imgflip.com

Do we need fJVT?

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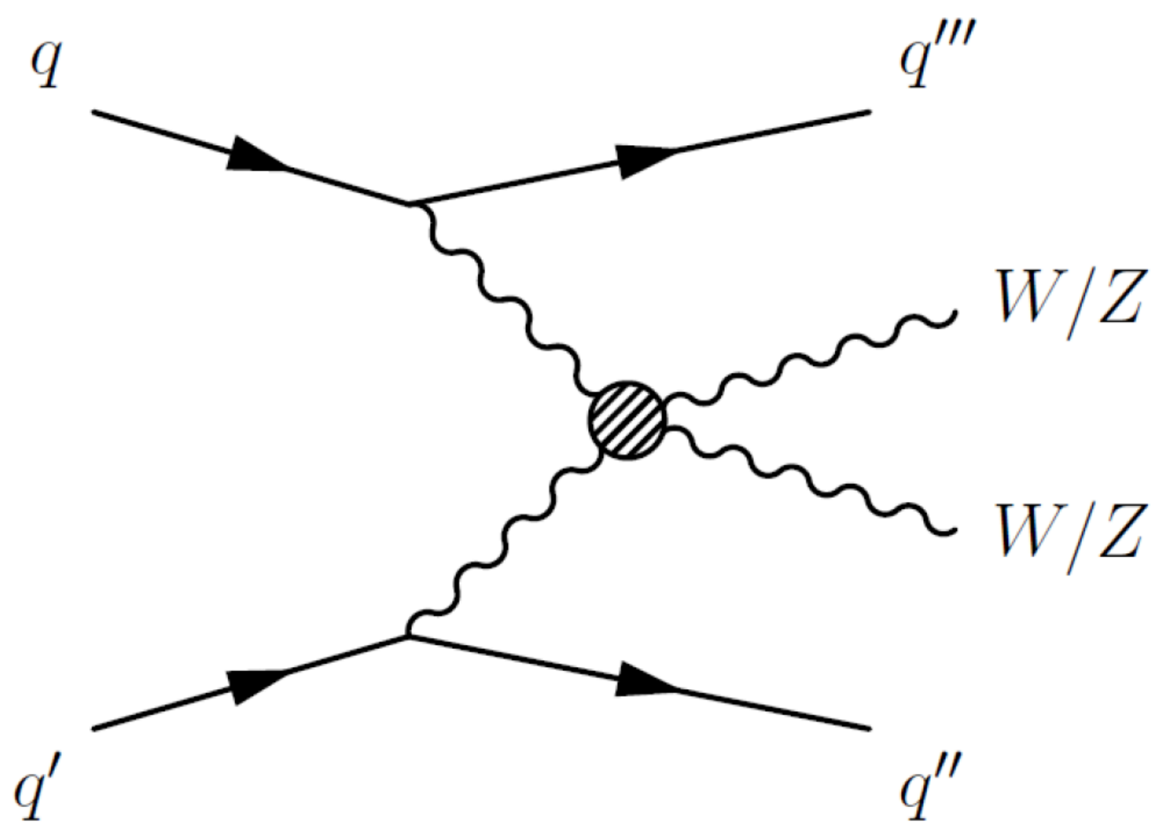
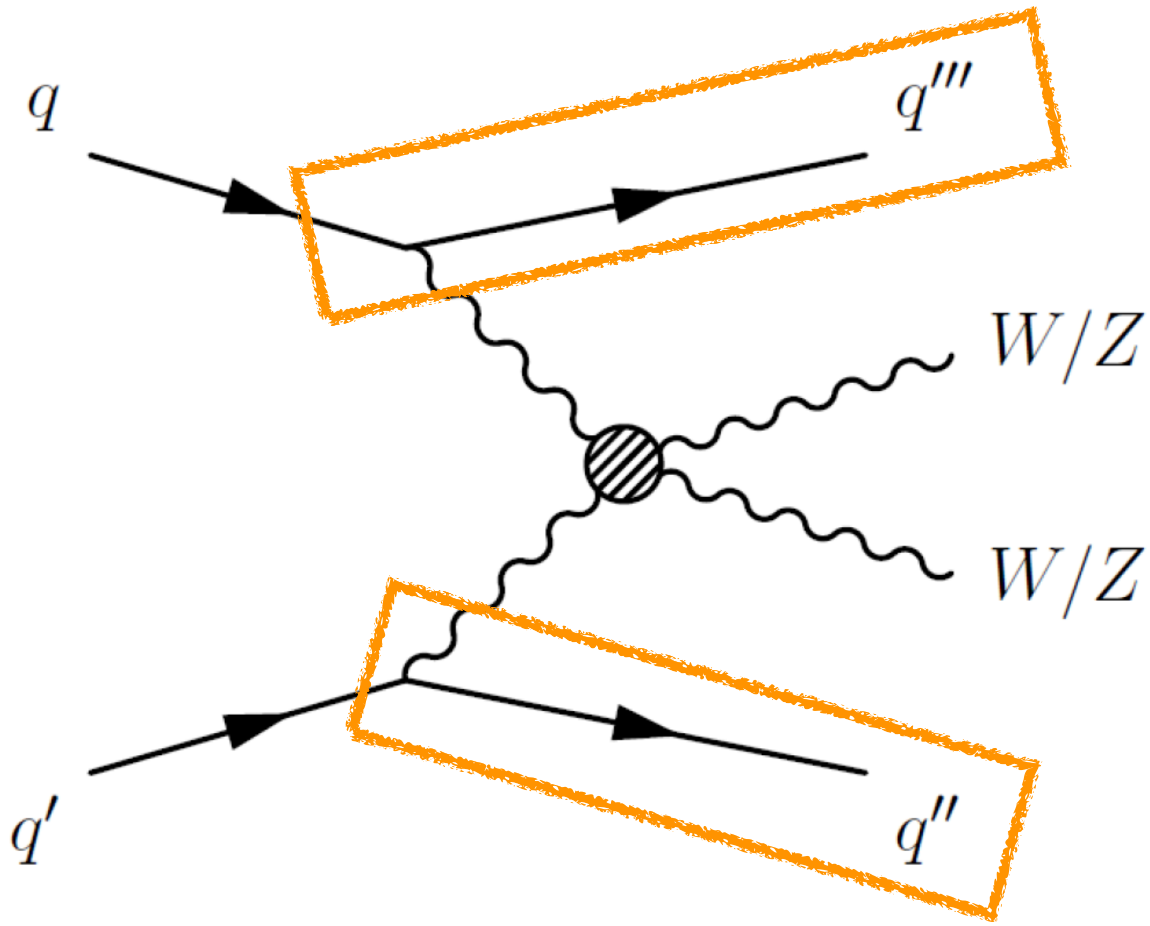
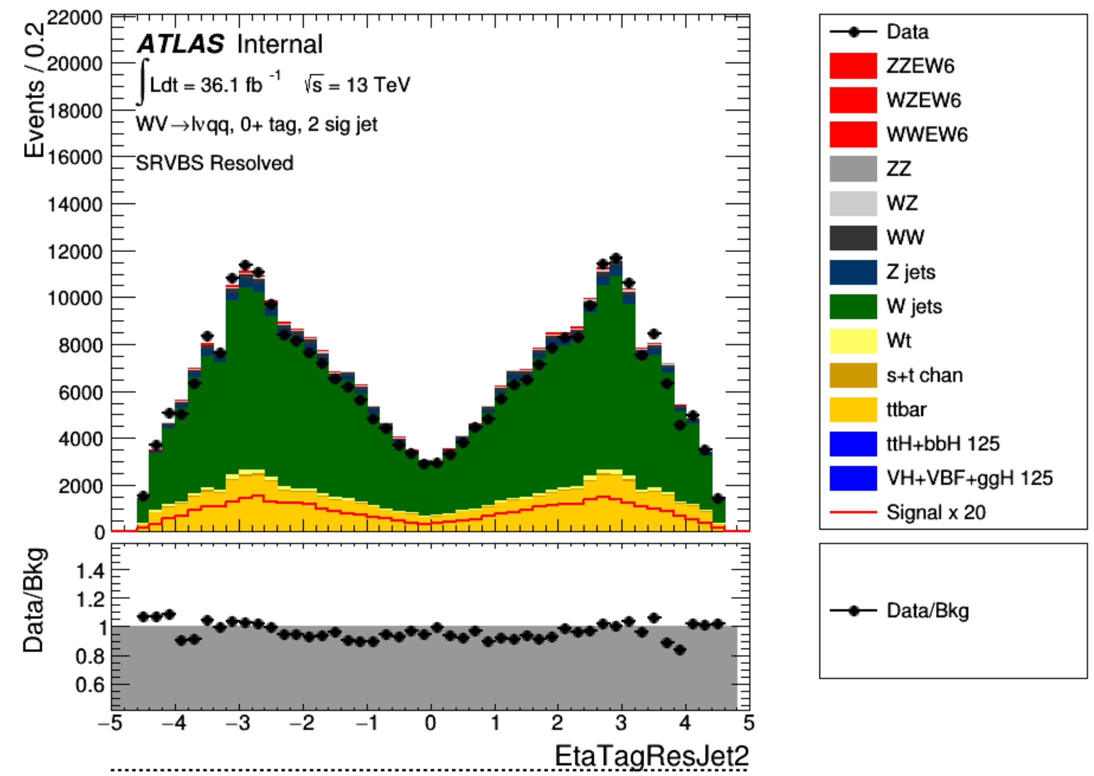


- **Many physics processes in LHC involve forward jets**
- **As an example here : Vector Boson Scattering**
  - ✦ Basic process: VV→VV
  - ✦ Observe leptonic or hadronic decay of bosons VV
  - ✦ Accompanied by 2 quark forward jets = tagging jets
  - ✦ Tagging jets help us separate this process signature from other VV productions in LHC

Do we need fJVT?





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END OF PRESENTATION
THANK YOU VERY MUCH FOR LISTENING-I REALLY ENJOYED TELLING YOU GUYS THIS STUFF THAT I RANTED ON ABOUT FOR QUITE A BIT. BUT I HOPE YOU LIKED IT.

If you are interested to learn more about fjvt :

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