Underlying Events and Jet Observables

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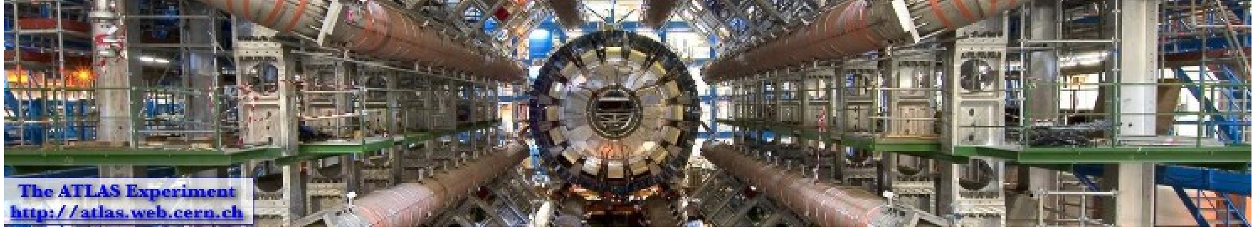
Few words about me...



Activities in Pisa in the ATLAS Collaboration:

•**Measurement** with the **ATLAS** detector of the **inclusive jet** production in the first LHC interactions.

- Studies of the experimental systematic uncertainties expected in the first period of data-taking.
- Studies of some of the theoretical uncertainty in this measurement (using MC generators and Next to Leading Order Monte Carlo).

Studies of the **performances** in the measurements of jet in ATLAS.

- Comparison of the performances of different jet algorithms (ATLAS-cone, SISCone, Kt, AntiKt) in QCD events.
- Data/MC Comparison of the performances of the calibrations procedures.
- Strategies to check the jet energy calibration in the high P_T region (above 300 GeV) balancing multi-jet events.

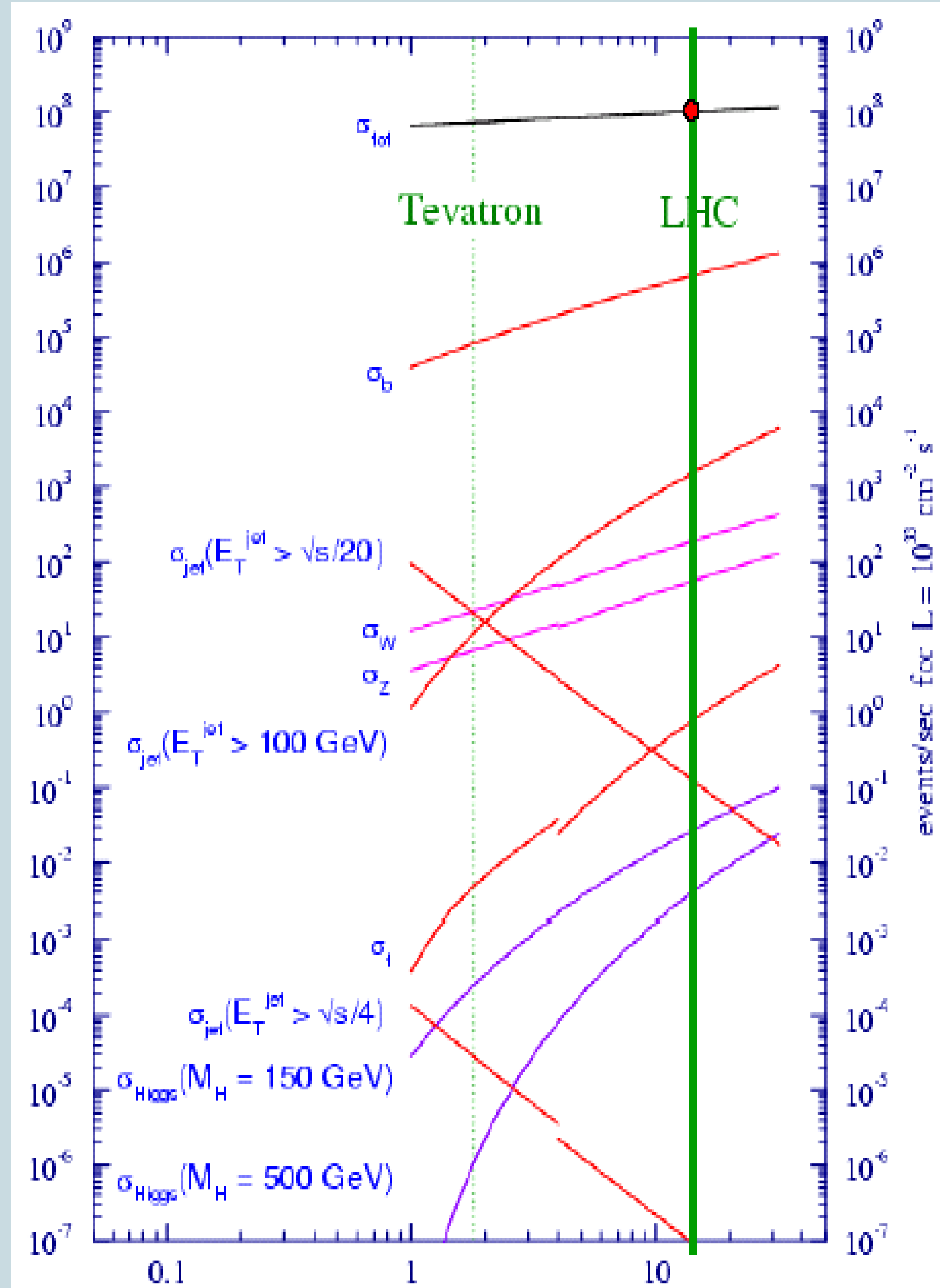
These studies rely on the predictions done by the Monte Carlo generators. Part of the **uncertainties** is due to the **modelling** of effects, such as the Underlying Event and the Fragmentation**.**

Cross section @ LHC

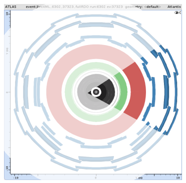
Cross sections:
The QCD background is ~ 5-6 order of magnitude bigger than the cross section of interesting processes (i.e. Higgs)

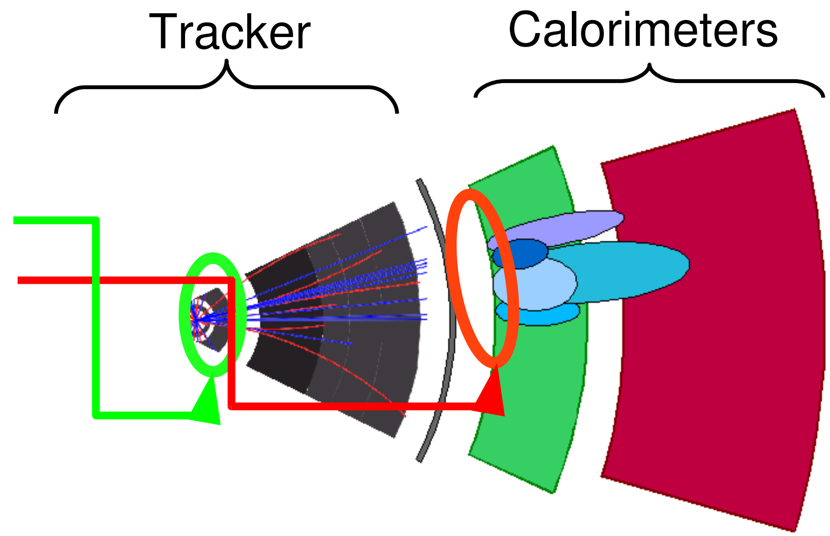
A good knowledge of jet reconstruction and performance is essential and it has an impact on analyses of interesting processes.

We should demonstrate that we have this background under-control



Experimental point of view





In all the measurements of observables with jets, the systematic due to the uncertainty of the energy of the jets (or P_T) usually dominates.

The final goal is to reach a calibration with an uncertainty of the order of few percent (1% or even better).

Experimentally, a lot of efforts are spent to calibrate as well as possible the energy measurements of the jets, and to cross-check with the data the calibration.

Almost all the strategies (to calibrate or to check the calibration) rely on the description of the hadronic final state of the Monte Carlo generators. Having under control these effects is crucial

Jet Definition

Strategies:

- **Reduce the effect of this non perturbative effects using a jet algorithm that is relatively insensitive to them.**

- **Tune the generators to reproduce the measurements of observables sensitive to non perturbative effects.**

The discussion of jet algorithms has been an area of development and debate for at least the last 20 years.

Snowmass 1990

- Simple to implement in an experimental analysis
- Simple to implement in the theoretical calculation
- Defined at any order of perturbation theory
- Yields finite cross section at any order of perturbation theory
- Yields a cross section that is relatively insensitive to hadronization (and non perturbative effects)

Jets and non-perturbative interactions

Comparison of different jet algorithms aimed at the understanding of the effect of the non-perturbative interactions

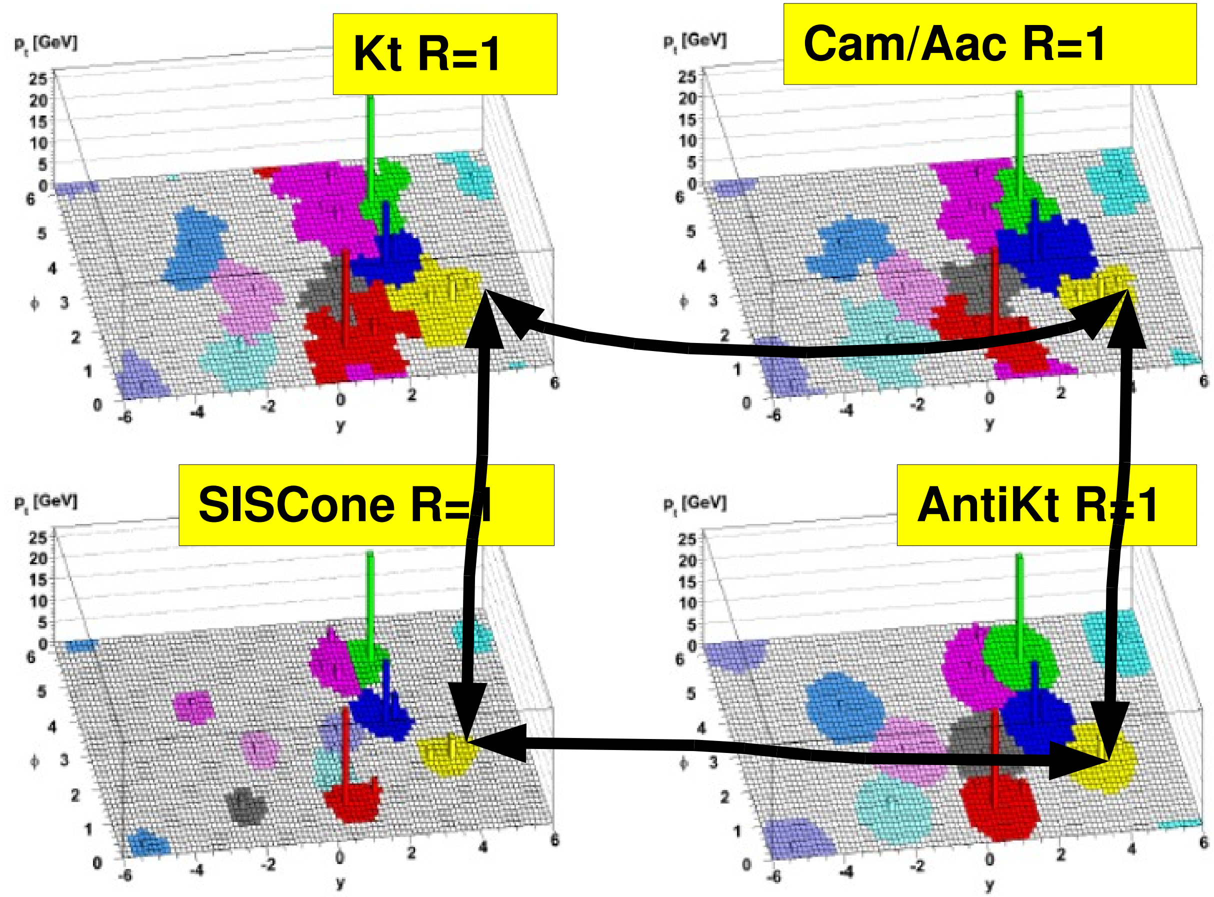
Classify a special class of jets that are affected by these effects

“Suggest” observables related to this jets that can be used to discriminate the different models.

Studies done on samples of QCD di-jet simulated with Herwig++2.3.0 and Pythia8.120

Some Ideas

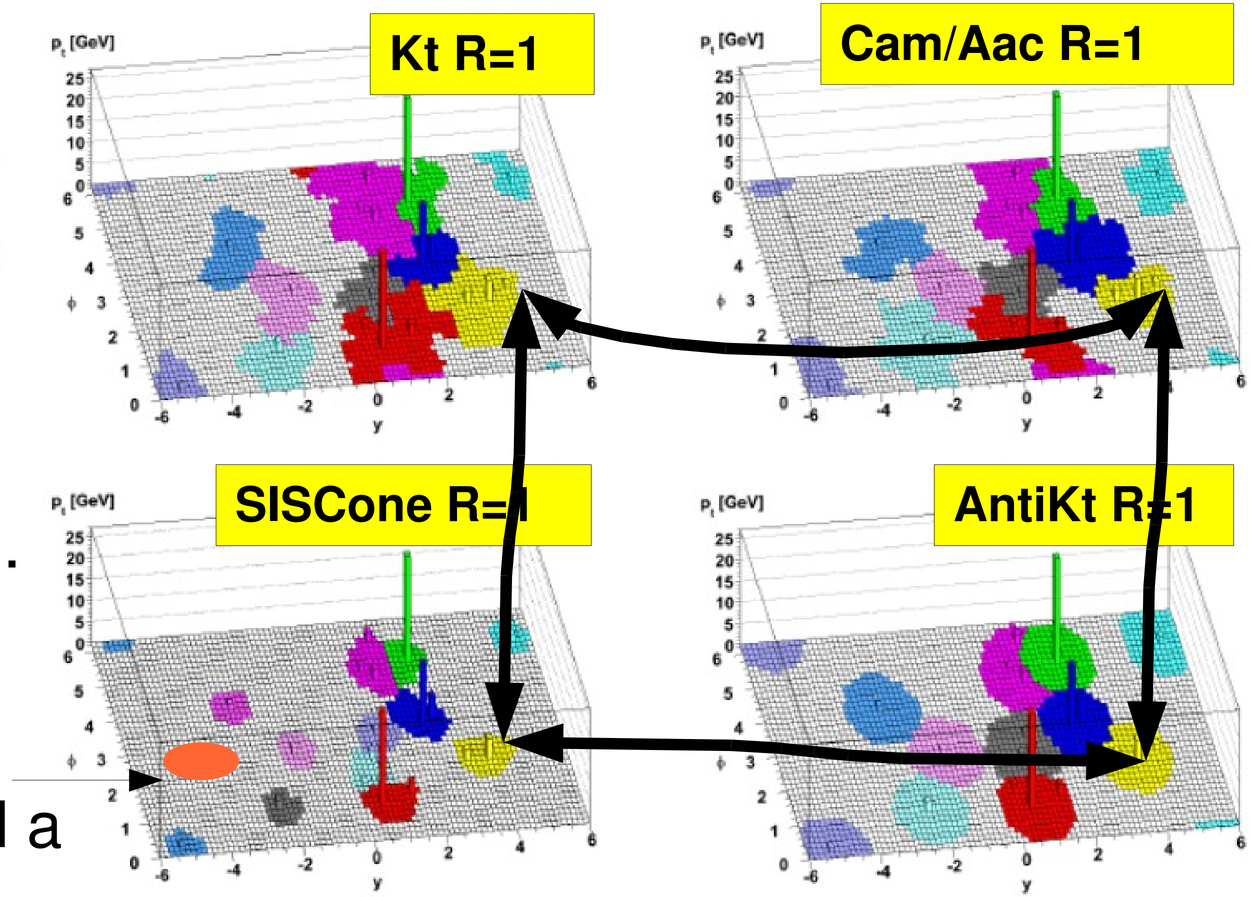
If a region in (y,φ) is interested by a spray of particles produced in a high energy interaction, all the jet algorithms should be able to find something in that region.



Some Ideas

If a region in (y,φ) is interested by a spray of particles produced in a high energy interaction, all the jet algorithms should be able to find something in that region.

In some special cases, only one of the jet algorithms find a jet. Of which kind?



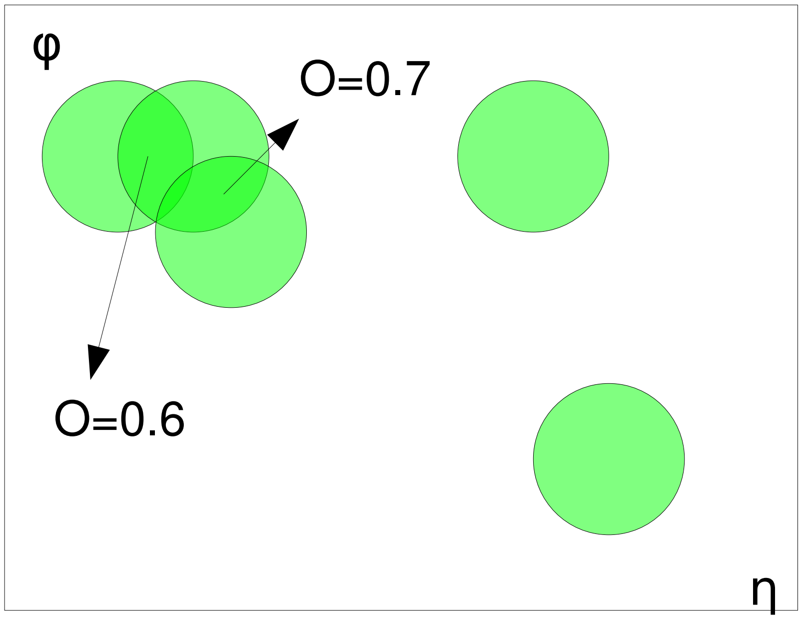
We started the study using the SISCone. The split/merge parameter of the SISCone should be tuned to reduce the effect of the non perturbative interactions.
Usually 0.75 is a good choice, 0.5 is more affected.

SISCone: The split and merge procedure

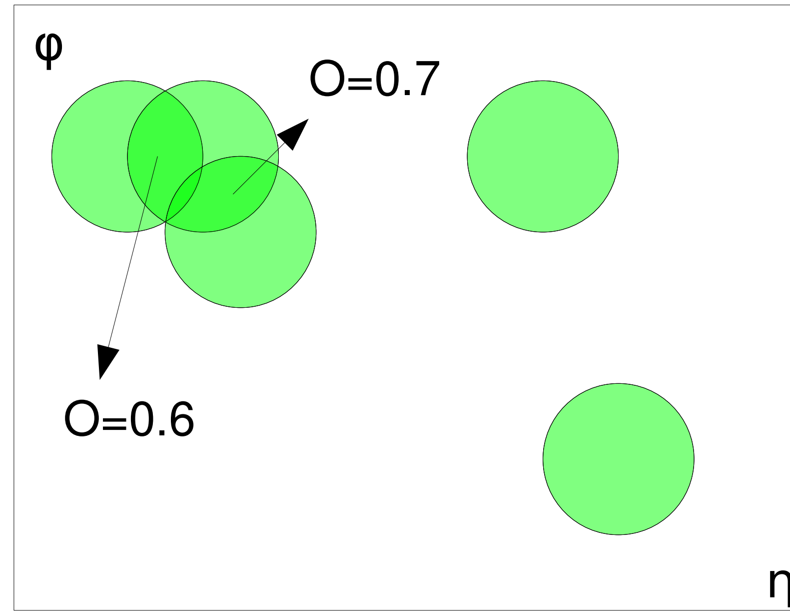
- Calculated overlap fraction (O): O $=P_{T,shared} / P_{T,2}$

if O < f , split along axis at center of two PJs

if O > f merge the two PJs to one PJ.



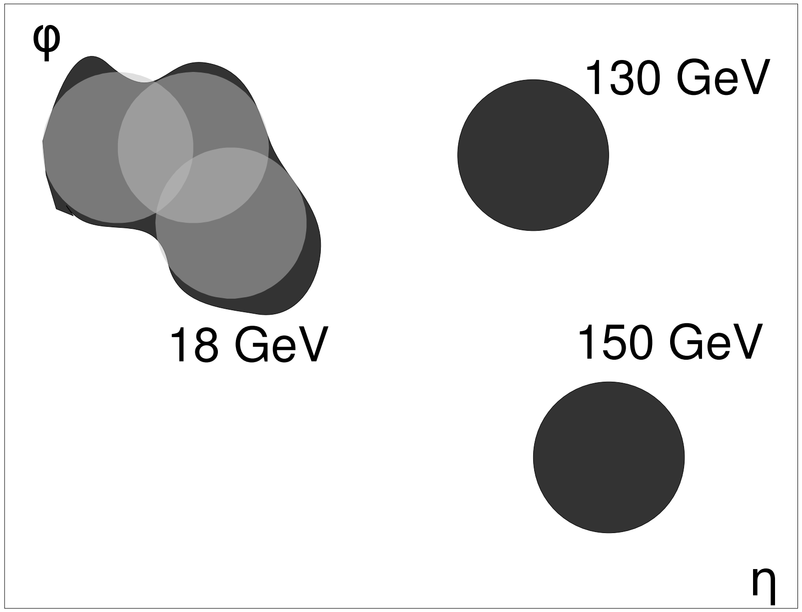
Resolving the Overlap:
Split/Merge Parameter: **0.5**



Resolving the Overlap:
Split/Merge Parameter: **0.75**

Studying the SISCone overlap threshold

f=0.5 merges more than f=0.75
f=0.75 splits more than f=0.5



Resolving the Overlap:
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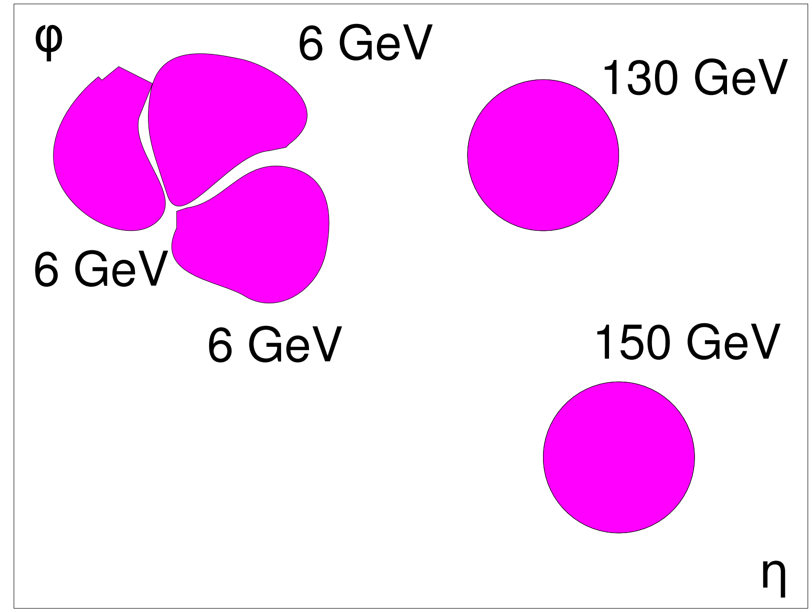
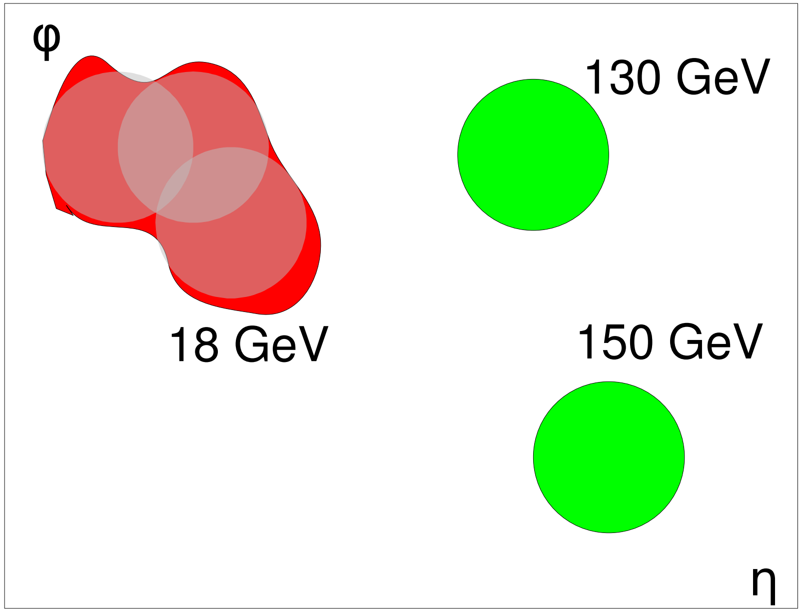


Resolving the Overlap:
Split/Merge Parameter: **0.75**

Studying the SISCone overlap threshold

Cut: Pt> 7 GeV



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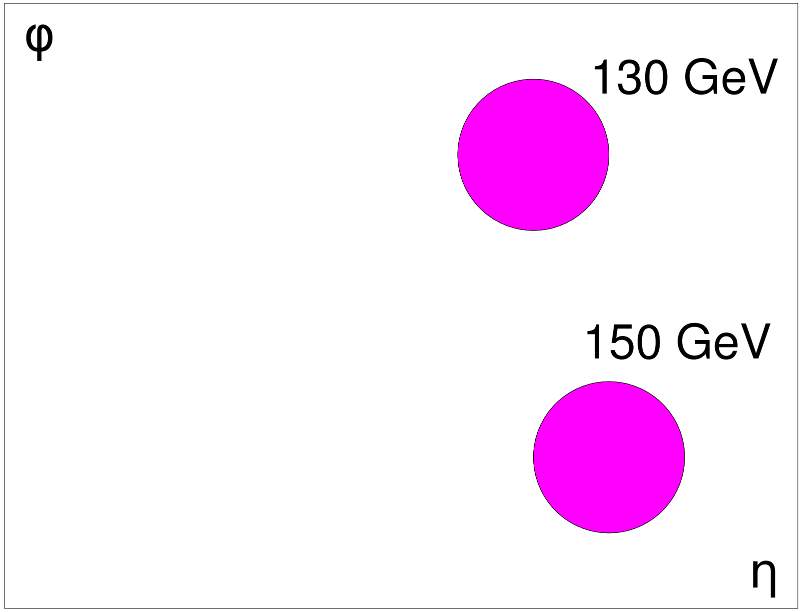


Resolving the Overlap:
Split/Merge Parameter: **0.75**

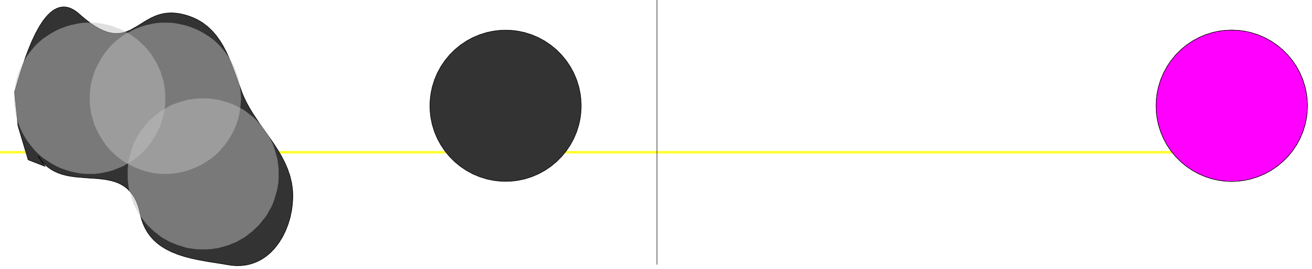
Only the SISCone f=0.5 find the red jet.

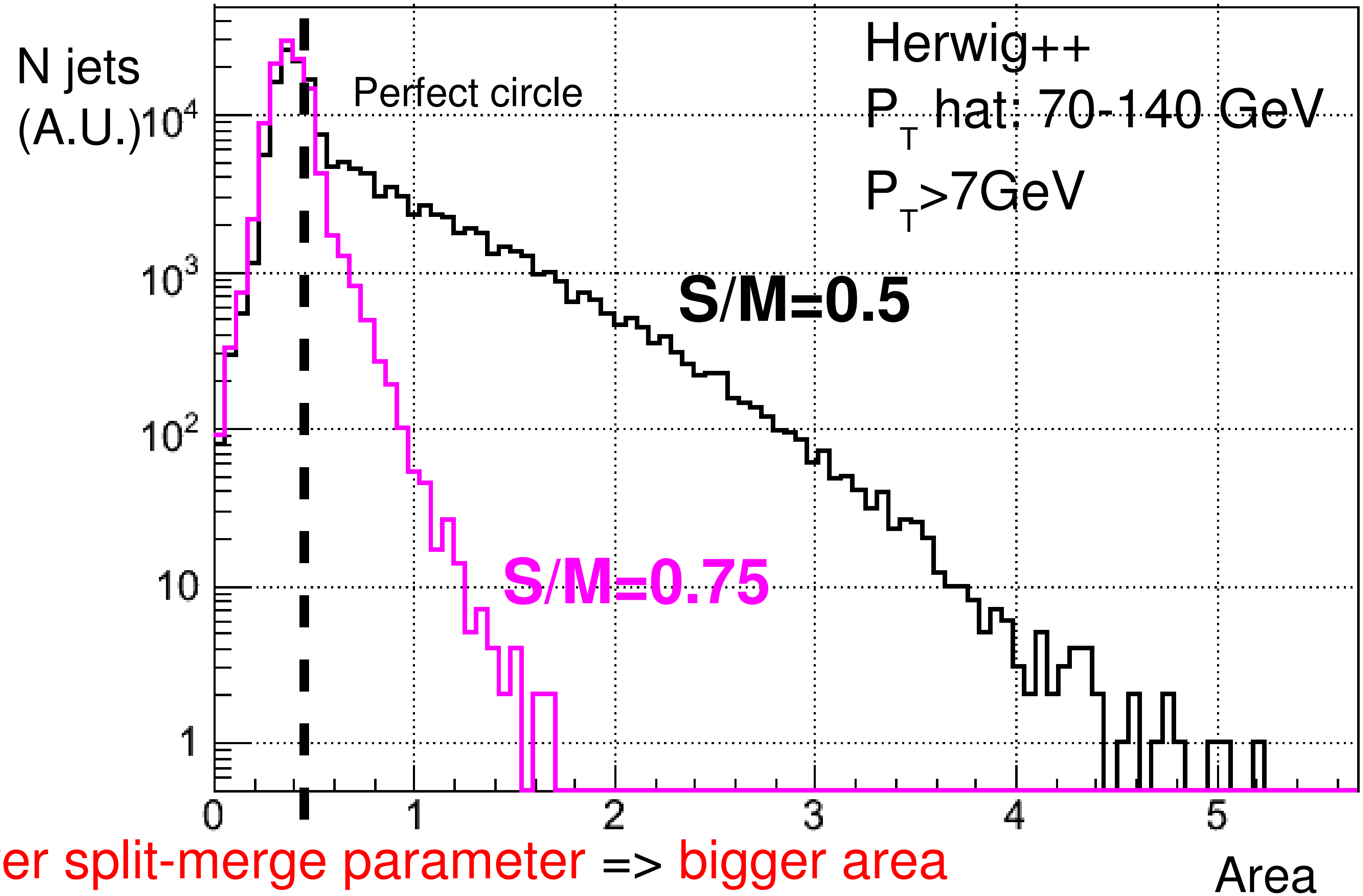
Studying the properties of the red jet

Passive Area

SISCone R=0.4 f=0.5

SISCone R=0.4 f=0.75



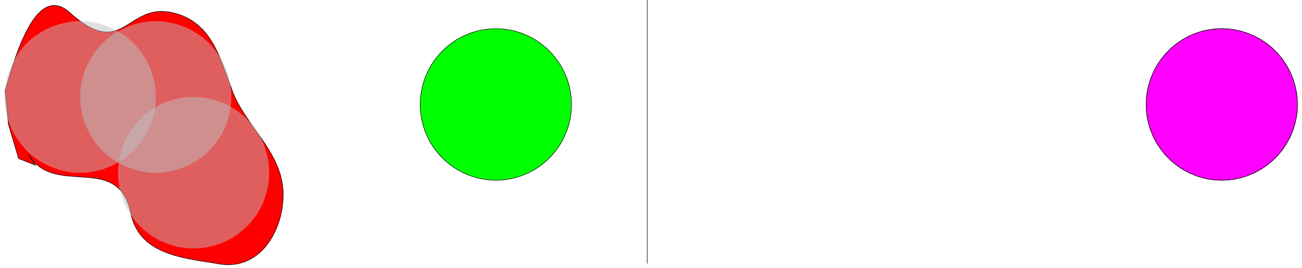


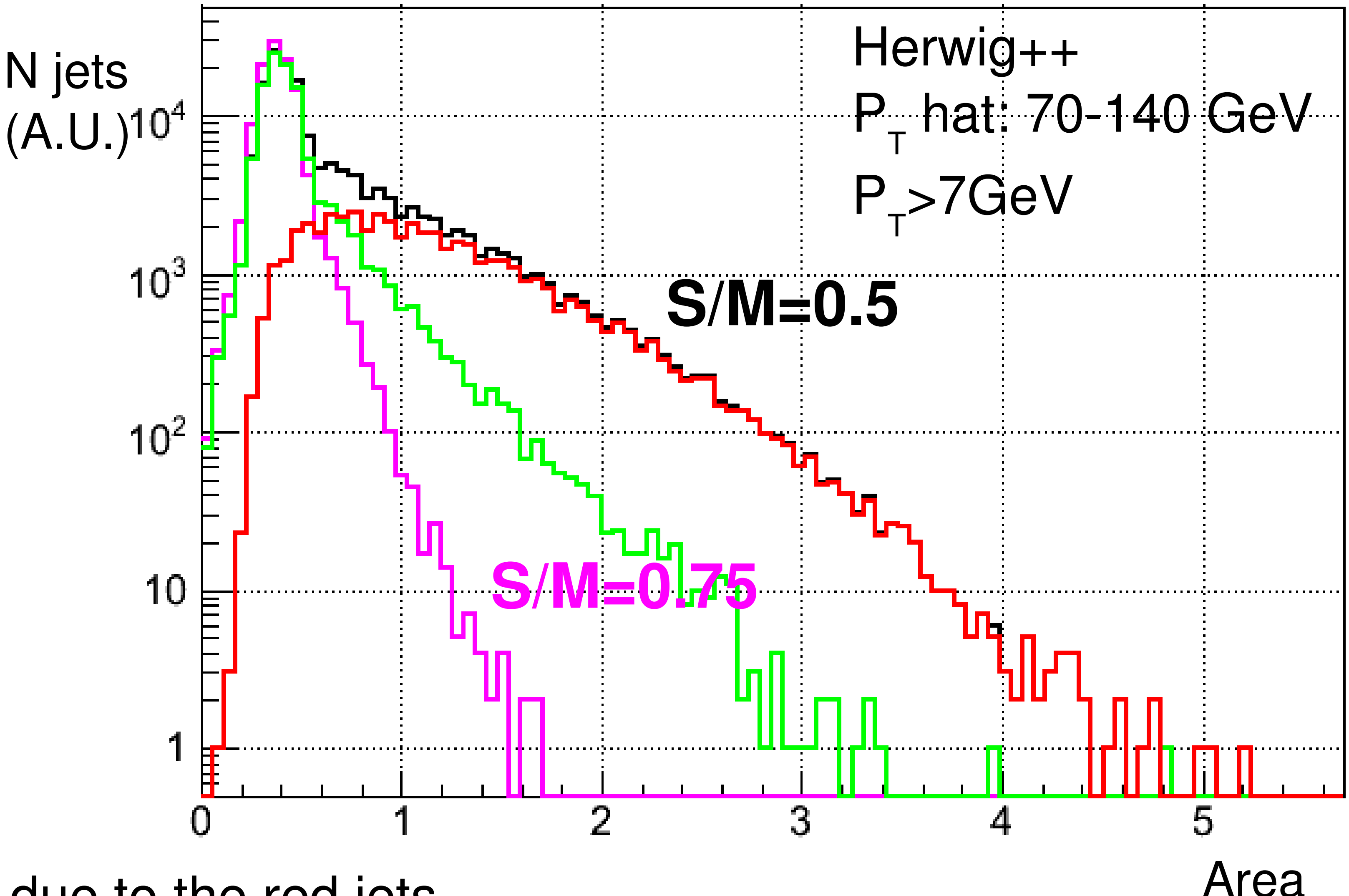
lower split-merge parameter => bigger area (merging different protojets).

Passive Area

SISCone R=0.4 f=0.5

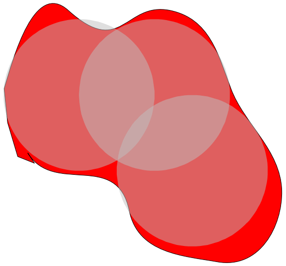
SISCone R=0.4 f=0.75



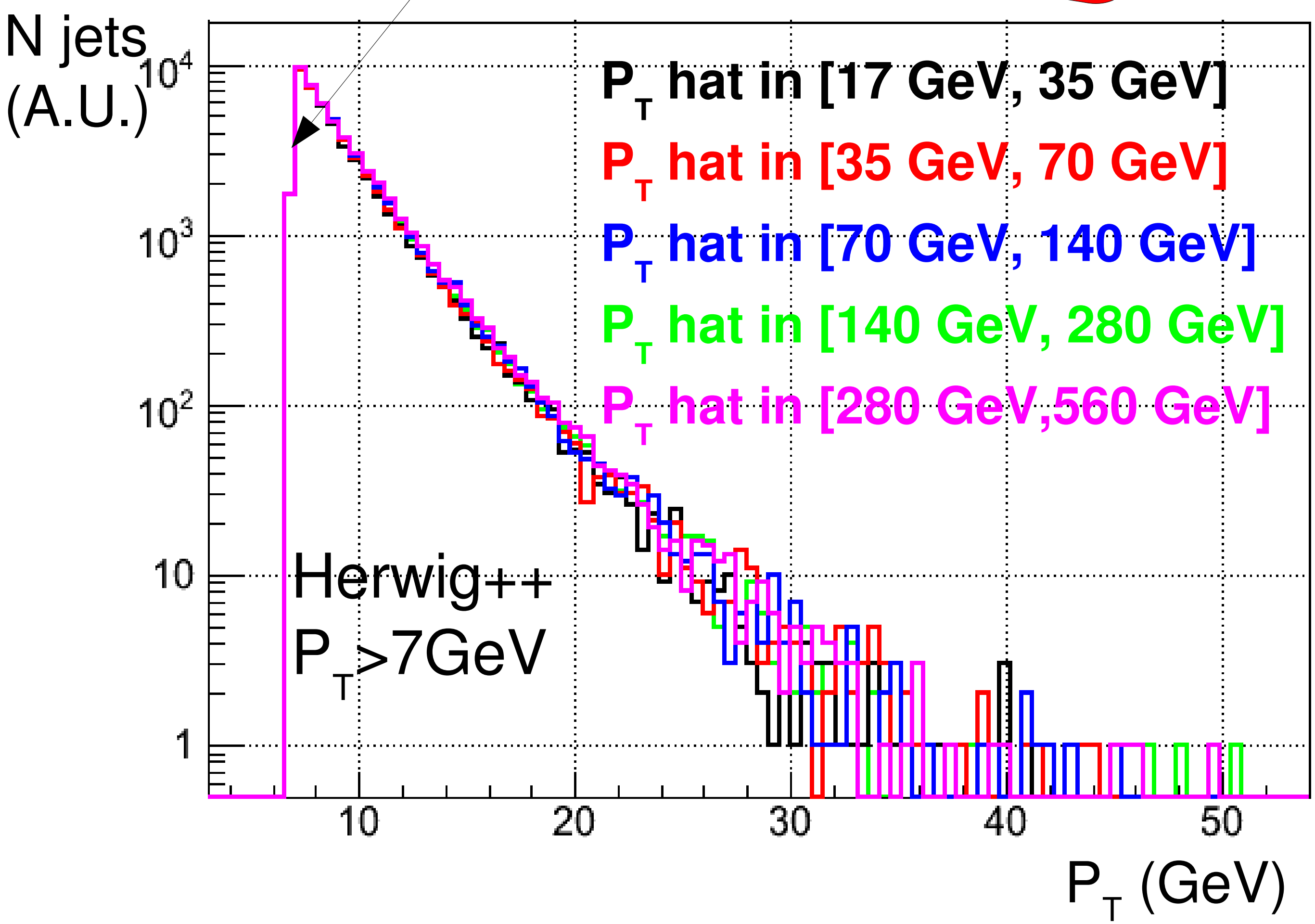


Tail due to the red jets.

P_T for the red jets



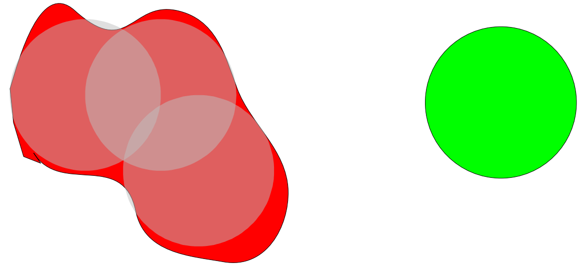
NOTE: cut @ 7GeV

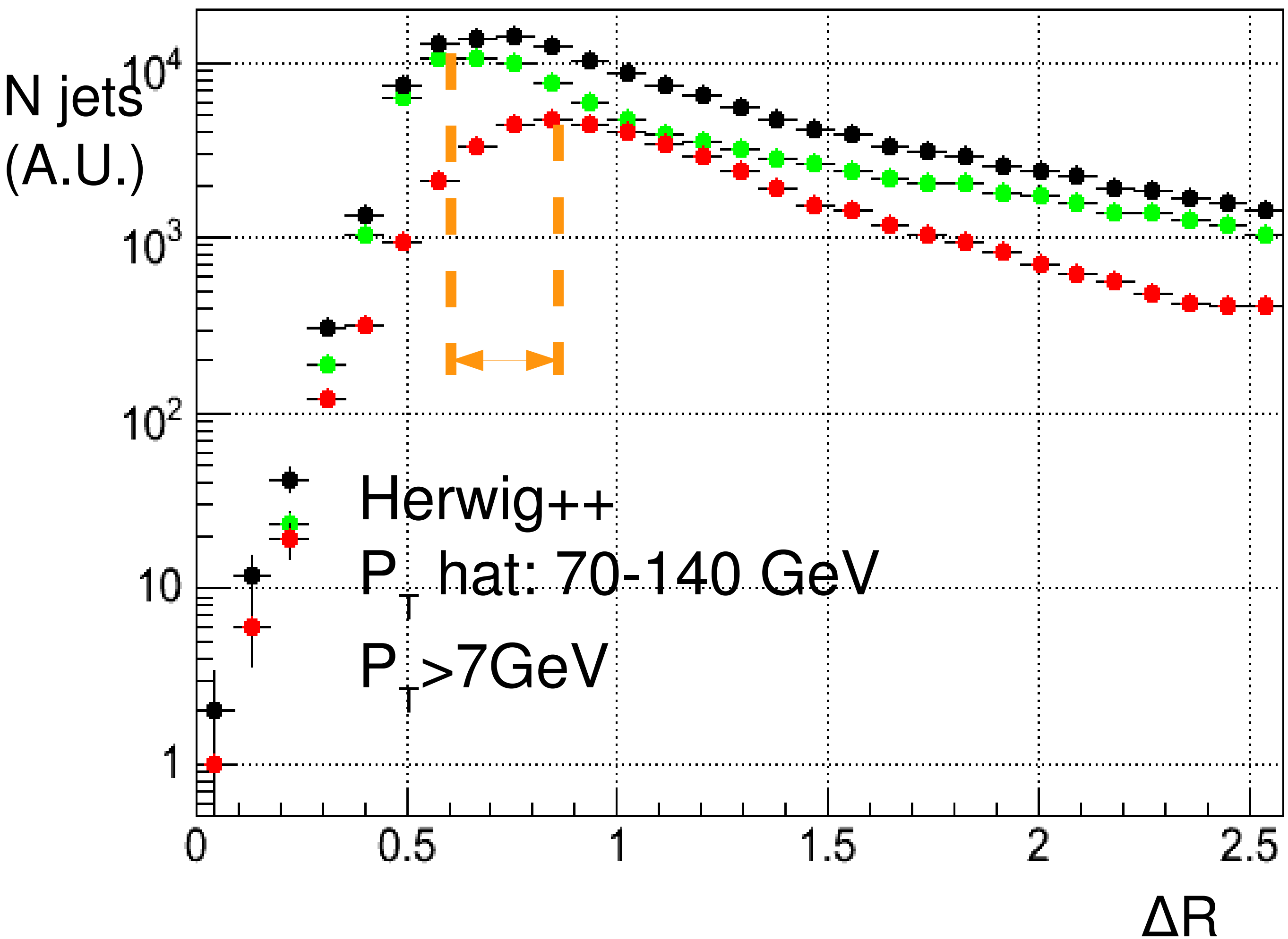


Simulated events in different windows of P_T hat (the scale of the hard scattering ~ leading jet in the event)

The distributions are almost exponential and they do not depend on the scale of the hard scattering.

Distance from the other jets

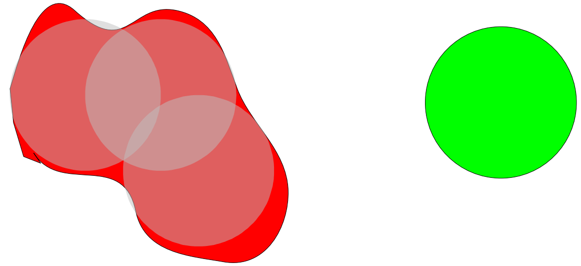


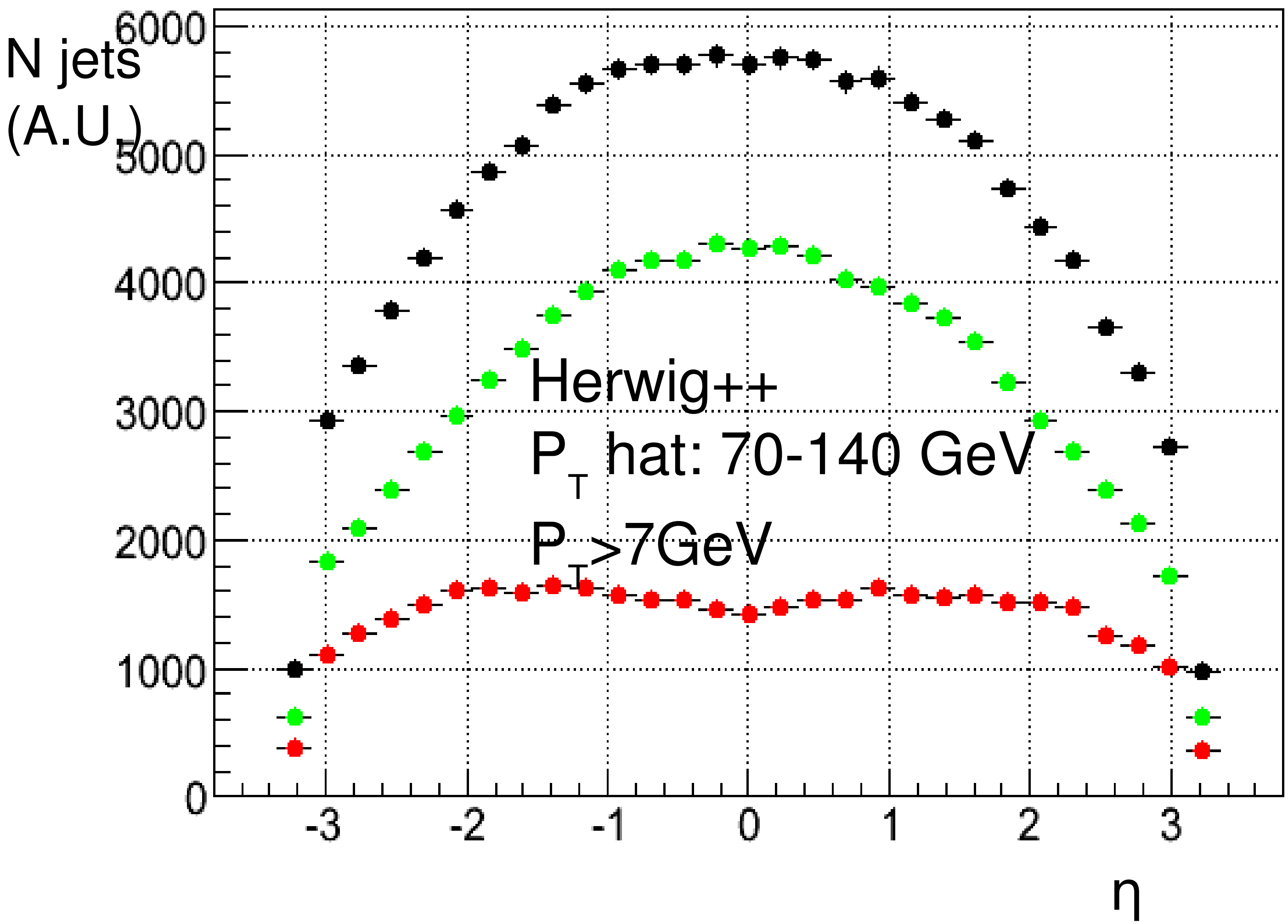


The distance with the closer jet in ΔR shows that usually (the peak) the isolation for the red jets is bigger than for the other.

This means that usually the red jets are isolated in ΔR

η for the red jets





The distribution in pseudo-rapidity is more flat for the red jets.

There may be a structure in the red distribution driven by the topology of the leading jets

Considerations:

- Diffuse P_T density (only S/M=0.5 picks up the jet)
- Bigger area if compared with all the other jets
- Relatively small P_T distribution (not dependent on the scale of the hard scattering)
- Isolated (if compared with the other jets)
- Pseudo-rapidity distribution almost flat.

These characteristics are similar to what we expect for the underlying event.
Can we use these jets to study the underlying event?

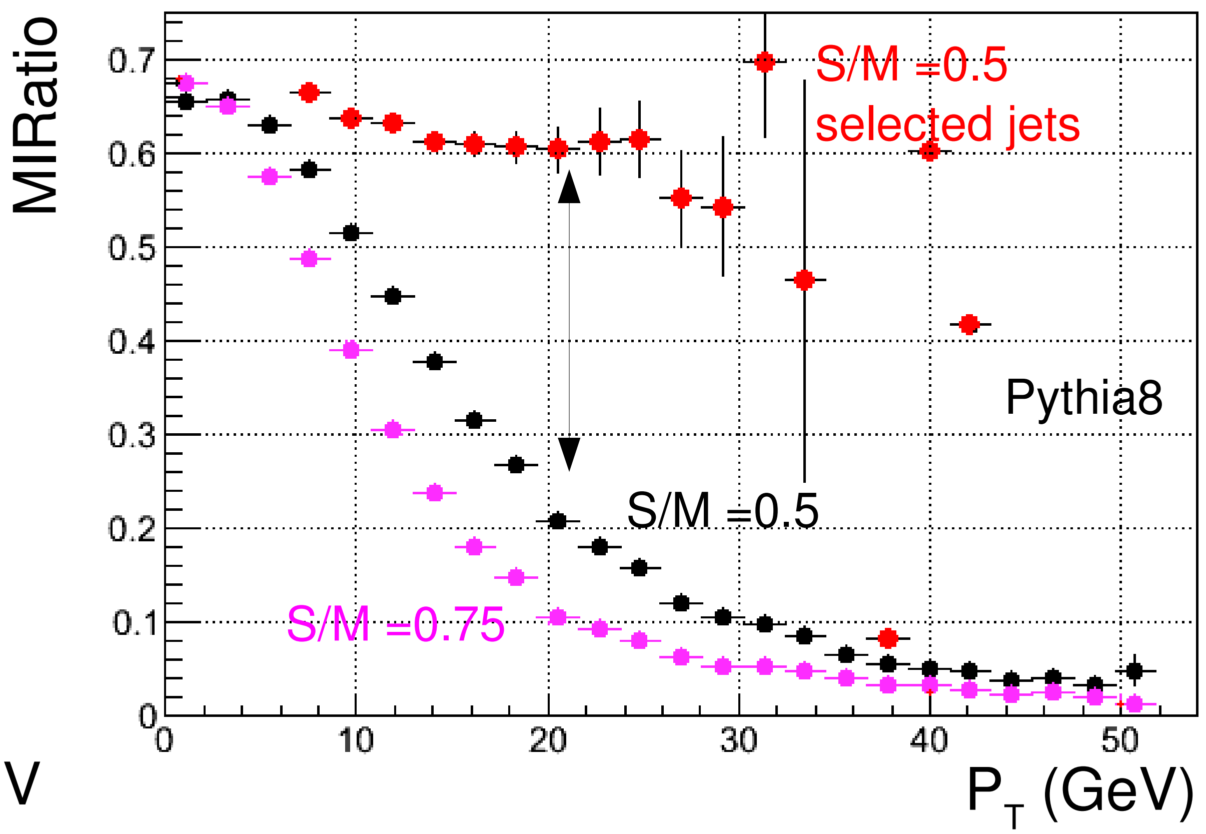
Contribution from the multiple interactions

PARTON LEVEL: In a jet we have the contribution of partons coming from both the leading interaction and the multiple interactions

Surfing back the history in the parton shower of a final parton, we can separate the **contribution** coming from the **leading partonic interaction** and the contribution from the **other partonic interactions**.

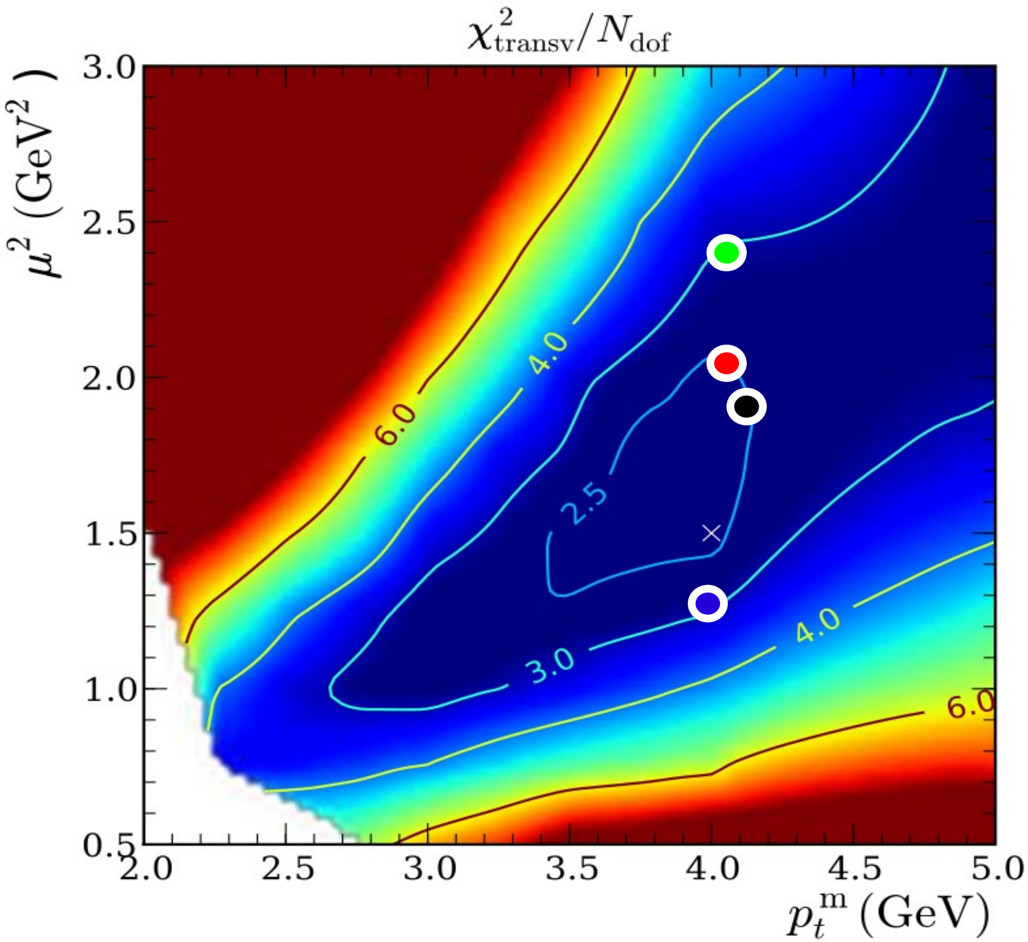
MIRatio is the contribution to the final P_T, for a certain jet, carried by the non leading multiple interactions.

In the red jets 60% of the P_T is due to the multiple interactions.
Almost flat in P_T up to 30 GeV



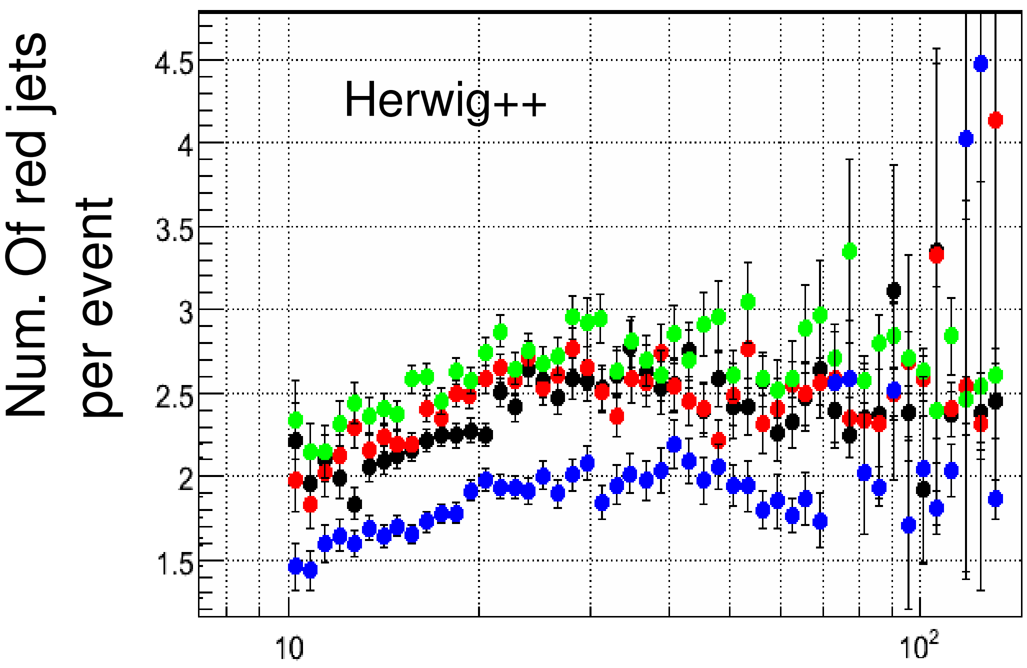
Underlying Event

The first idea is to count the number of red jets produced per event, as a function of the P_T of the leading jet in the event. (Plots for Herwig++)



μ^2: Matter distribution

p_t^m: it separates the hard interactions and the soft interactions



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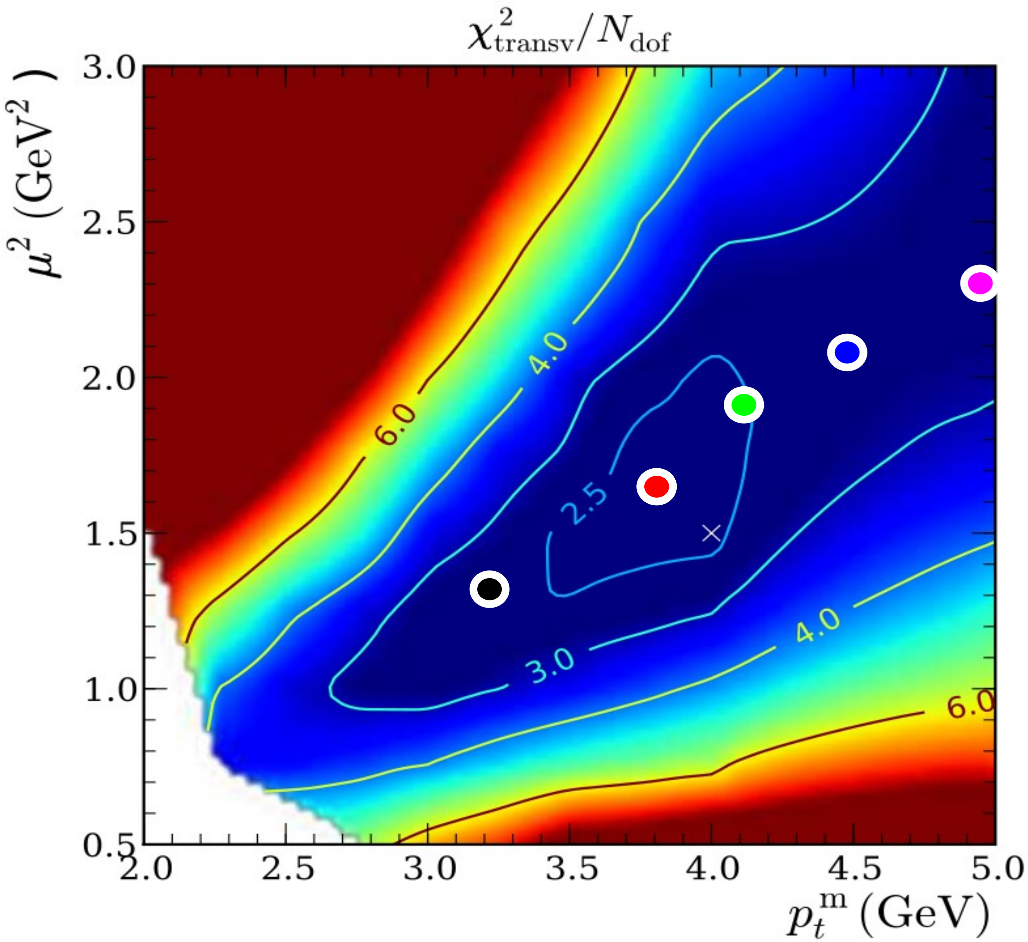

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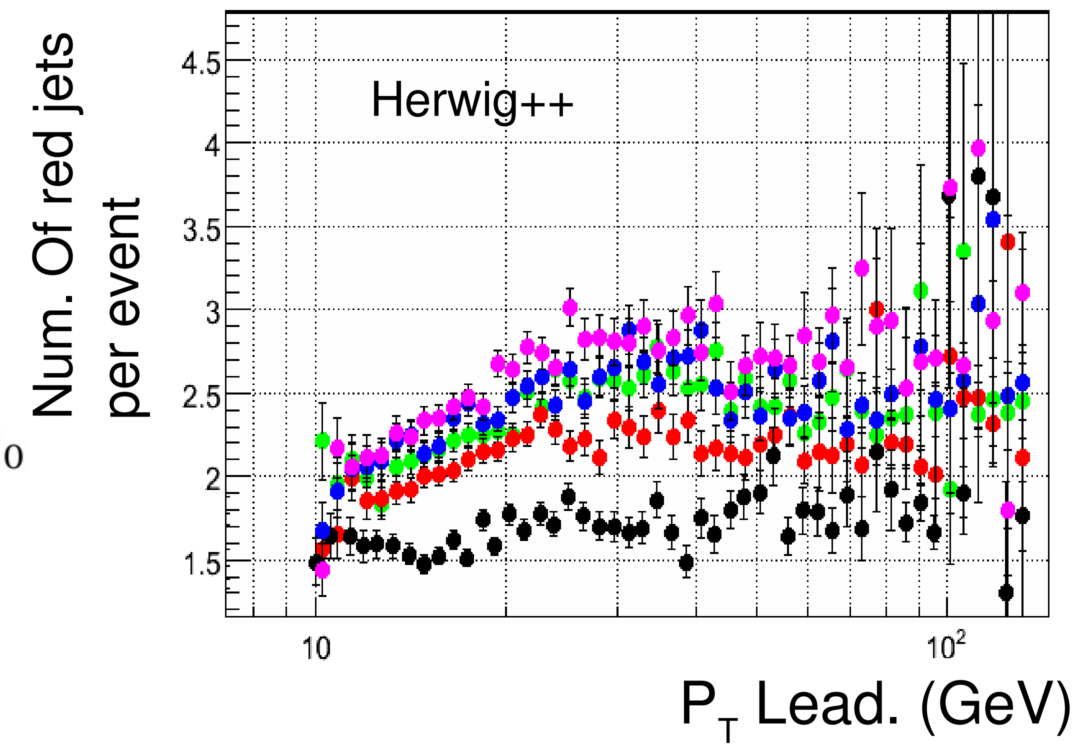
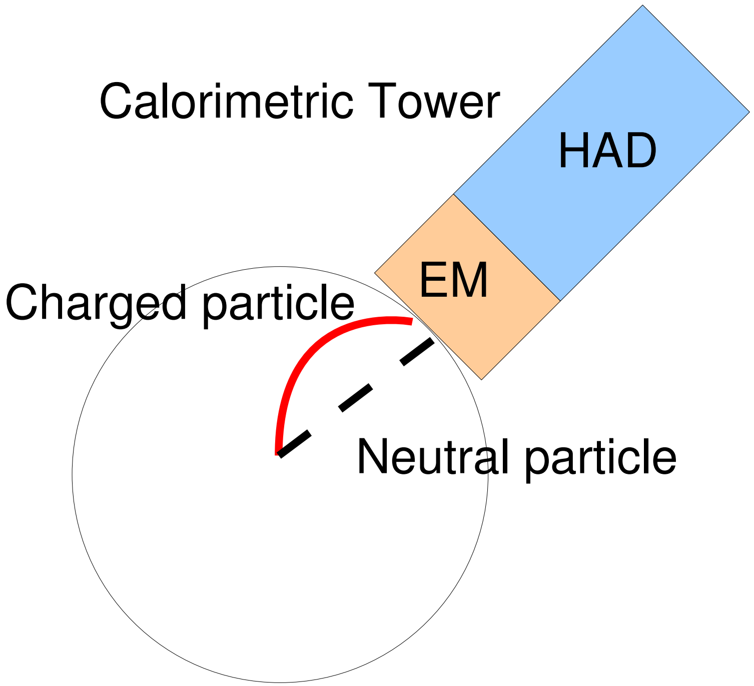


Can we measure these jets?



Magnetic Field	= 2 T
Inner Radius	= 1.5 m
EM Resolution	= 0.1/sqrt(Et)+0.003+ 0.1/Et
Had Resolution	= 0.5/sqrt(Et)+0.05+ 0.1/Et
η range	**=** [-3.2, 3.2], 64 bins
φ range	**=** [0,2π], 64 bins

Several effects can affect these observables:

Detector:

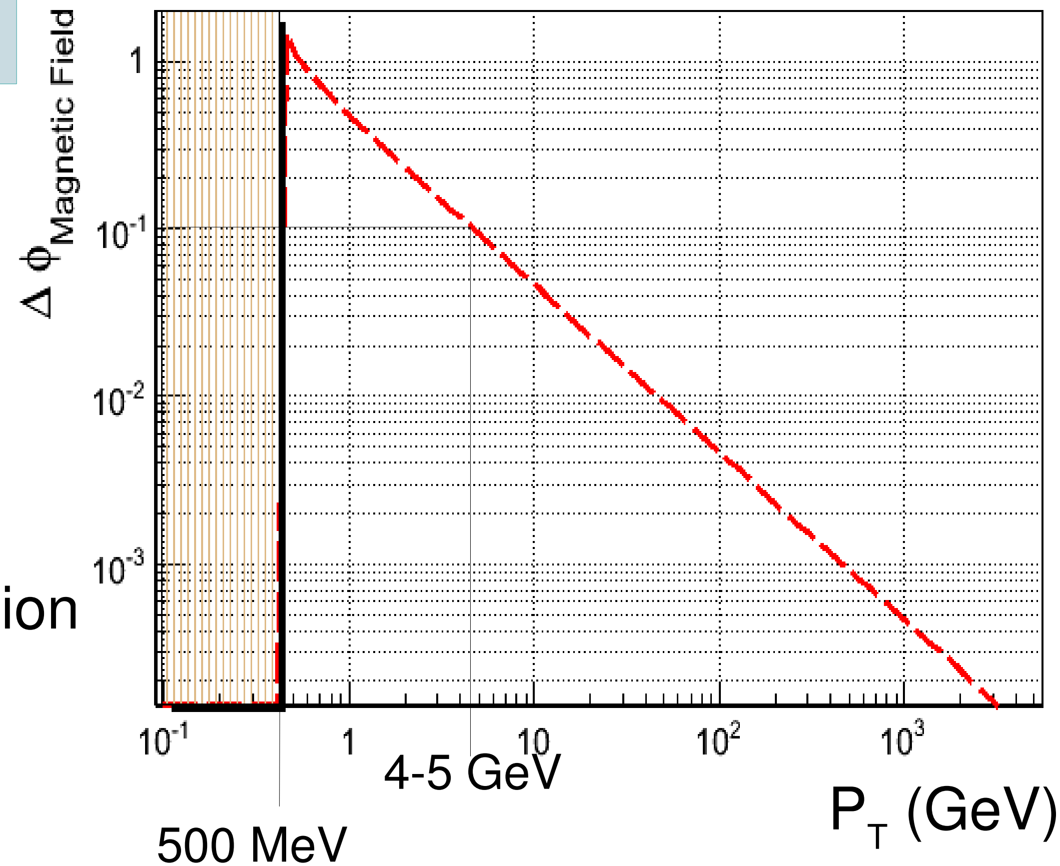
- **Dead Material:** Energy loss before reaching the calorimeter;
- **Energy calibration** and **resolution** in the detector (calorimeter);
- **Bending of the magnetic field.**

PileUp:

in a “realistic” scenario we expect <n>=O(4) interaction per bunch crossing at the beginning

Can we measure these jets?

Magnetic field - rough estimate:
•charged particles with P_T <500 MeV
do not reach the calorimeter
•charged particles with P_T < 4-5 GeV
in a different tower in φ.
Using the information from the tracker could improve the reconstruction



Pile Up:
The fluctuation of the pile-up could mimic the characteristic of the red jets.
If <n>=4, Prob(0) ~ 2%, so we can start with these events (counting the primary vertexes)

Calorimeter:
detailed studies to reconstruct the jets in the proper way are needed

Topic not mentioned

- Other observables related to these jets (P_T VS pseudo-rapidity)
- Studies on other jet algorithms (especially Cambridge Aachen) to find the same class of jets
- Using the densities of the jet to measure the property of the underlying event in different region of the detector
- Discussions on the how to handle the negative energy tower (coming from the fluctuation of the detector response) in the jet algorithm
- Studies of the shapes of the catchment area of a jet using the tools in FastJet.

Conclusions

S/M=0.5: is sensitive to UE models

bad choice for hard scatterings

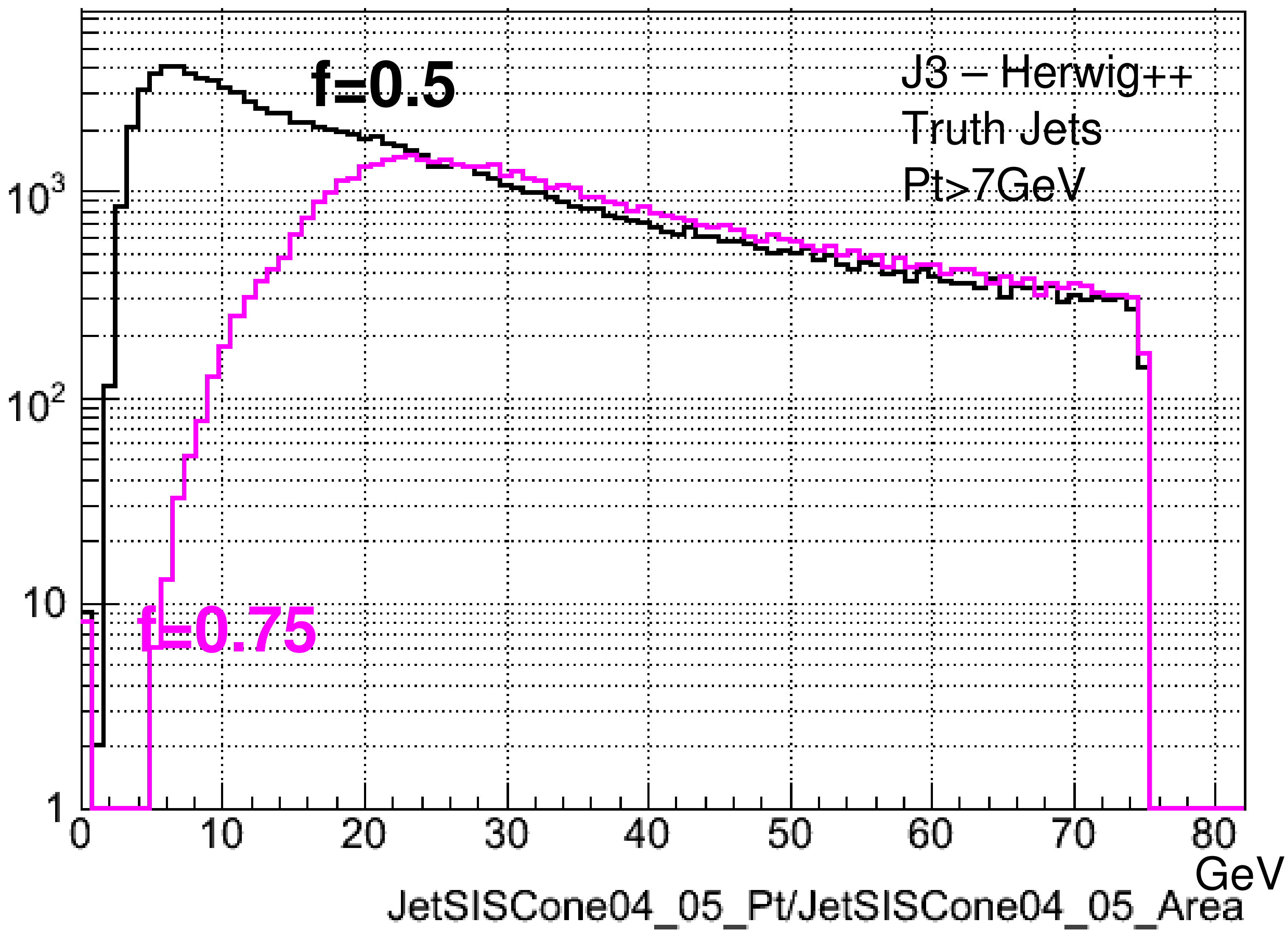
Comparing the result with S/M=0.75

(maybe) a good choice to investigate the UE

Detector: a strategy to measure properly these observables should be developed

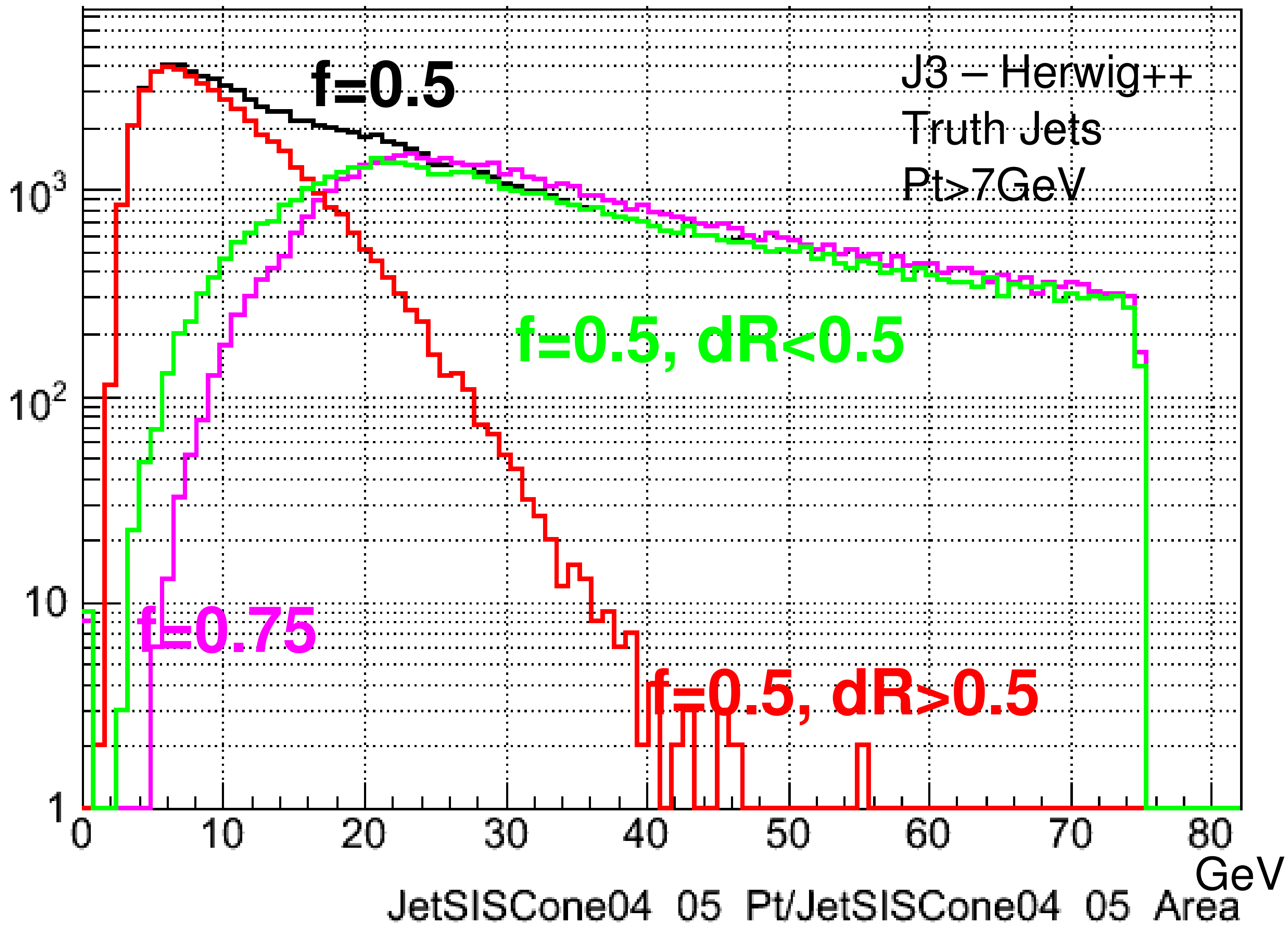
BACKUP

Densities

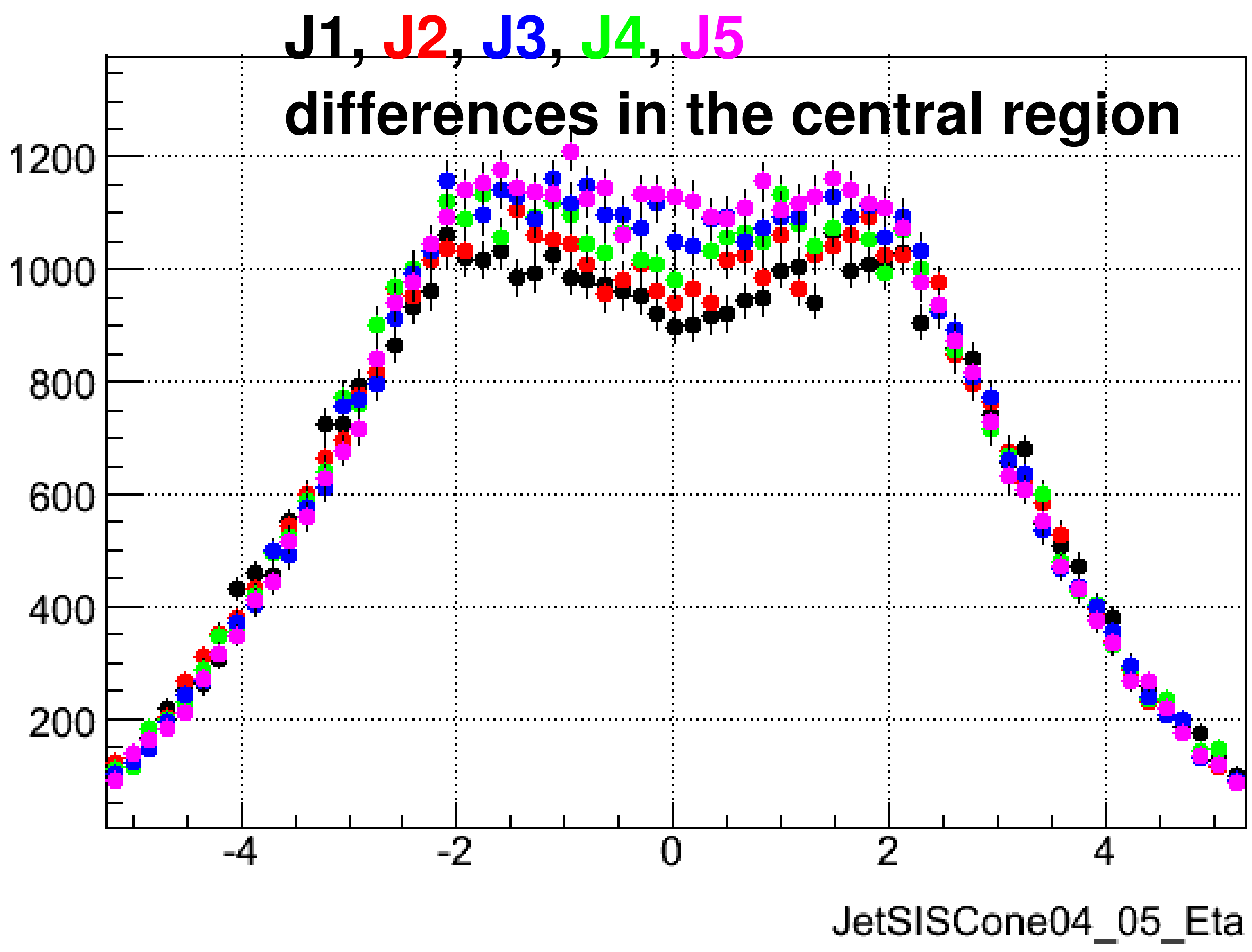


f=0.5
J3 – Herwig++
Truth Jets
Pt>7GeV
f=0.75
10^3
10^2
10
1
0
10
20
30
40
50
60
70
80
GeV
JetSISCone04_05_Pt/JetSISCone04_05_Area

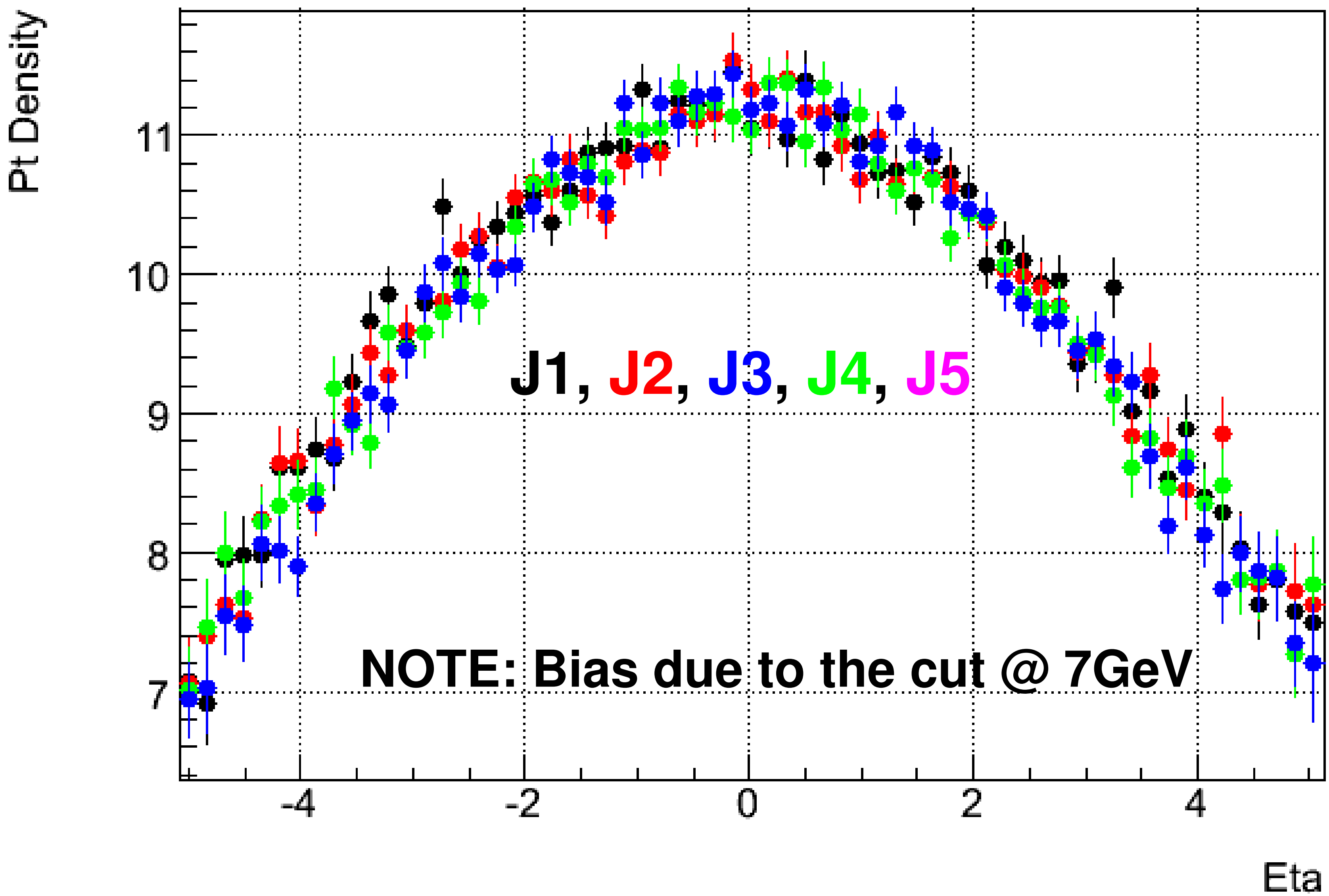
Densities


f=0.5
J3 – Herwig++
Truth Jets
Pt>7GeV
f=0.5, dR<0.5
f=0.75
f=0.5, dR>0.5
10^3
10^2
10
1
0
10
20
30
40
50
60
70
80
GeV
JetSISCone04_05_Pt/JetSISCone04_05_Area

Where is this jet?

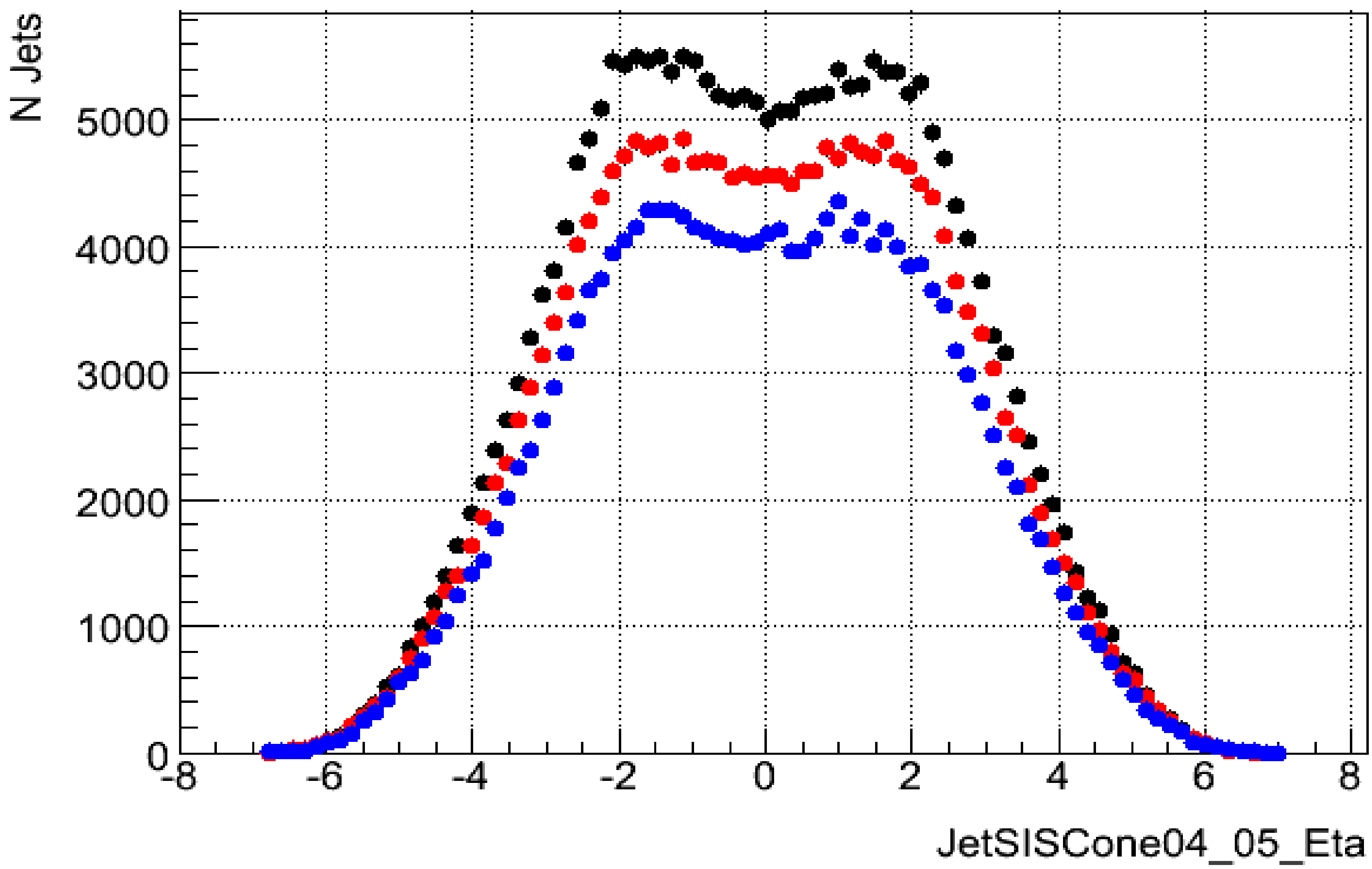


Pt density VS Eta



Where is this jet?

Different number of jets in the central region
Bias from the 7 GeV Cut?



Where is this jet?

Different density.
Probably the slope in the Pt distribution is different