Towards measuring the Jet Cross Section Ratio: $\sigma(pp \rightarrow n\ njets+X\ n \geq 3) / \sigma(pp \rightarrow n\ njets+X\ n \geq 2)$

P.Kokkas, **I.Papadopoulos**, **C.Fountas**, **I.Evangelou**,
N.Manthos

University of Ioannina, Greece

QCD High p_T meeting 2/4/2009

Outline

- Towards measuring the Jet Cross Section Ratio:
  $\sigma(pp \rightarrow$ n njets+X $n \geq 3) / \sigma(pp \rightarrow$ n njets+X $n \geq 2)$
  - Motivation
  - The measurement
  - Analysis Plan
- Software tools and MC Data used.
- Define the measured cross section at hadron level
  - Pseudorapidity study
  - p_T resolution study
- The Ratio R32
- Trigger study
- Summary & plans

Towards measuring the Jet Cross Section Ratio: $\sigma(pp\rightarrow n\ njets+X\ n\geq3)/\ \sigma(pp\rightarrow n\ njets+X\ n\geq2)$

- Motivation:
  - Measure the ratio as a function of H_T and compare with pQCD predictions with goals:
    - To establish that we understand multi-jet physics and measurement at the LHC environment.
    - Extend the phase space of the measurements in a regime that goes above the Tevatron.
    - Demonstrate that we understand QCD at LHC energies and therefore we understand the backgrounds we face for a number of exotic physics channels.
    - Comparisons of the measured ratio at hadron level with the predictions of pQCD (parton level), after accounting for hadronisation corrections uncertainty will measure the QCD coupling constant α_s at a scale never measured before.
  - We measure the ratio because we expect that:
    - It will be less sensitive than absolute cross section measurements to a number of experimental systematics such as the jet energy scale or for example the uncertainty in the luminosity measurement.
    - The pQCD predictions for the ratio may be less sensitive to uncertainties due to the renormalization and factorization scales which hamper the absolute cross section predictions particularly at low jet-Pt scales.

The measurements may be shown as:

D0 PRL 86, p1955 (2001)

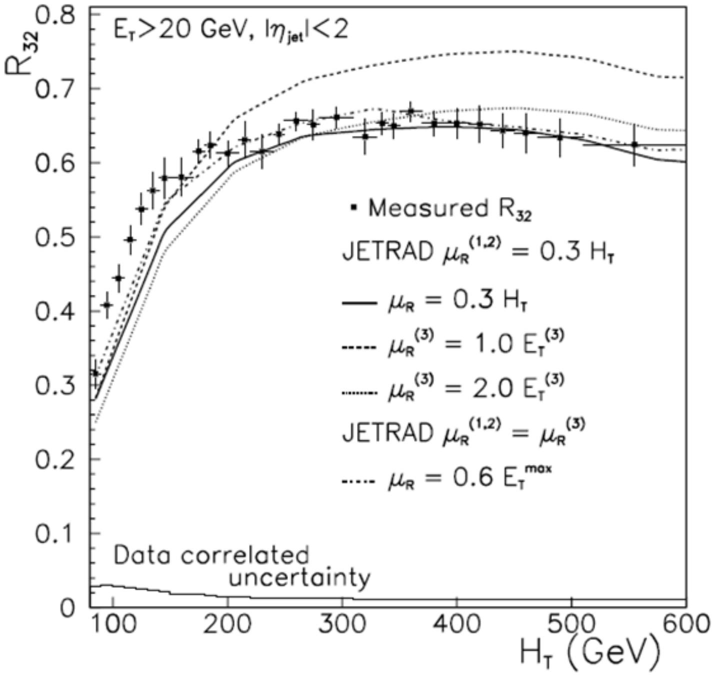


FIG. 2. The ratio R_{32} as a function of H_T, requiring jet $E_T > 20$ GeV and $|\eta_{\text{jet}}| < 2$. Error bars indicate statistical and uncorrelated systematic uncertainties, while the histogram at the bottom shows the correlated systematic uncertainty. The four smoothed distributions show the JETRAD prediction for the renormalization scales indicated in the legend.

We should be able to extend this up to an H_T~ 1.5 TeV
(σ(2J) = 1 pb @ Pt-hat = 700 GeV)

- Additional plots to support the main result:
  - Detailed comparisons of the jet kinematics with PYTHIA and HERWIG.
  - Jet profile measurements and evidence to understand the jet energy scale.
  - Detailed study of the renormalization scale uncertainty.

Analysis Plan

- Study the pseudorapidity and p_T resolution and define the 2 Jet and 3 Jet kinematic cuts which define the measured cross section at hadron level.

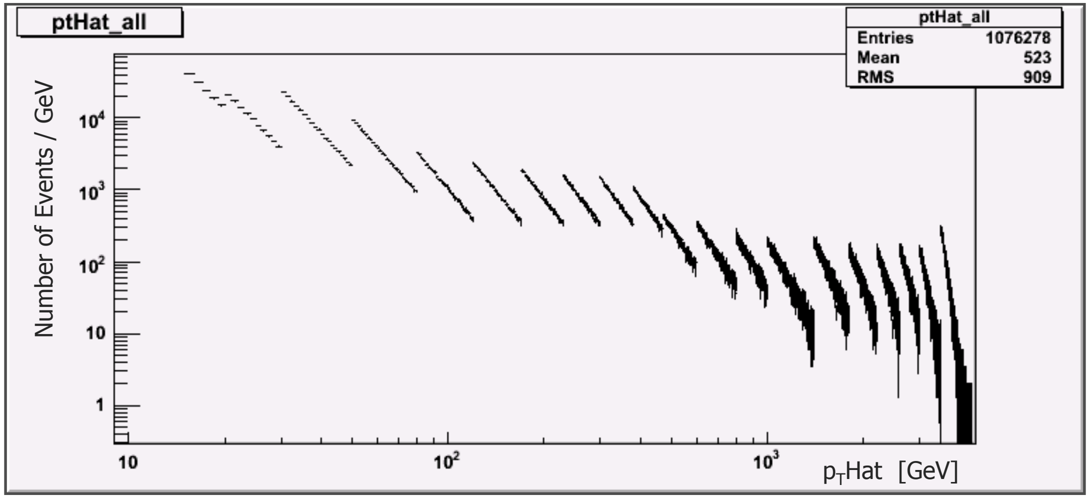
  → $\sigma(p_T \geq X; |\eta|\leq Y)$
- See how to collect the events we need based on the available triggers at Lvl-1 and HLT.
  - Compute trigger efficiencies with MC initially.
  - Come up with a plan to do it with data.
- Estimate the dominant systematics on the experimental measurement (Jet energy scale…)
  - For this study use the MC and compute corrections to hadron level
  - Use the known resolutions and information on systematic shifts in p_T to estimate:
    - The Systematics of the 2 jet and 3 jet cross sections.
    - Demonstrate the level off cancellation of these errors on the measured R_{32}
    - Investigate data driven methods to reduce these.
- Estimate the magnitude of hadronisation correction
  - Need to use several hadronisation models.
- Compute the theoretical rate with NLO programs and estimate the uncertainty due to μ_R, μ_F

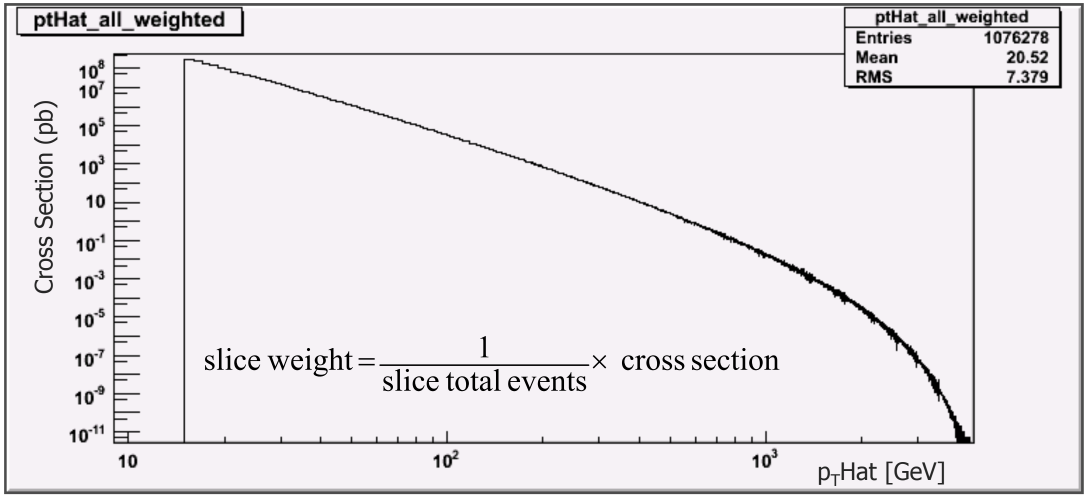
Tools and Samples used

Analysis done using version CMSSW_2_2_6

- Jet Algorithms: sisCone7 and sisCone5
- Jet Energy Corrections: L2L3
- QCD DiJet Summer 08
- Bin p_THat:0-15 GeV not used

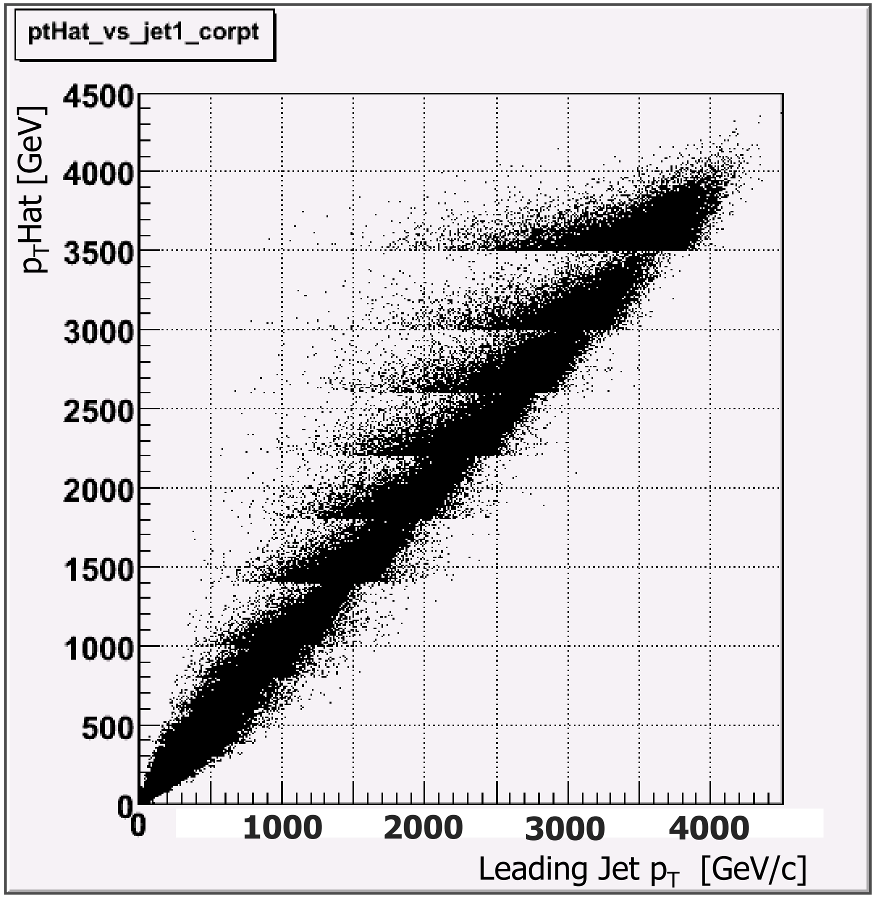
	P_THat bin [GeV]	Number of events	Cross section [pb]	Equivalent Luminosity [pb^{-1}]
1	0-15	103860	51562800000	2.01E-06
2	15-20	129600	949441000	1.37E-04
3	20-30	101880	400982000	2.54E-04
4	30-50	169200	94702500	1.79E-03
5	50-80	103545	12195900	8.49E-03
6	80-120	51300	1617240	3.17E-02
7	120-170	50085	255987	0.19
8	170-230	51840	48325	1.07
9	230-300	54000	10623.2	5.08
10	300-380	60048	2634.94	22.79
11	380-470	51840	722.099	71.79
12	470-600	27648	240.983	114.73
13	600-800	28620	62.4923	457.98
14	800-1000	20880	9.42062	2.22E03
15	1000-1400	24640	2.34357	1.05E04
16	1400-1800	27744	0.156855	1.77E05
17	1800-2200	22848	0.013811	1.65E06
18	2200-2600	22560	0.00129608	1.74E07
19	2600-3000	22800	0.00011404	2.00E08
20	3000-3500	20880	0.0000084318	2.48E09
21	3500-inf	34320	0.00000018146	1.89E11

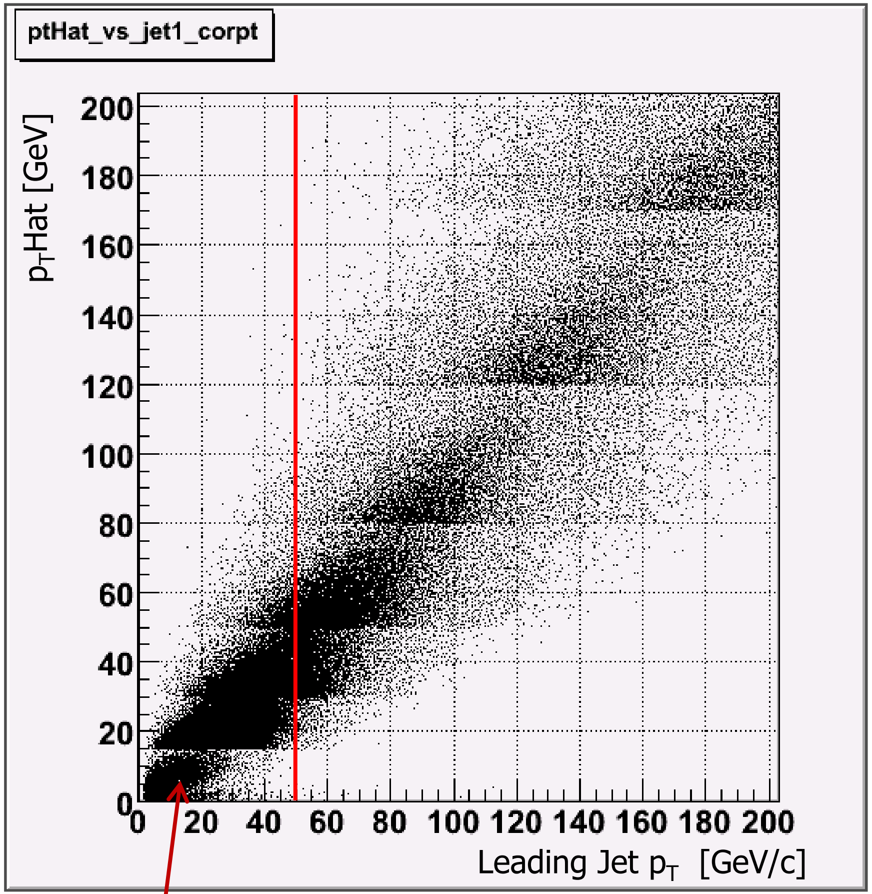




$$\text{slice weight} = \frac{1}{\text{slice total events}} \times \ \text{cross section}$$

p_THat vs Jet1 p_T



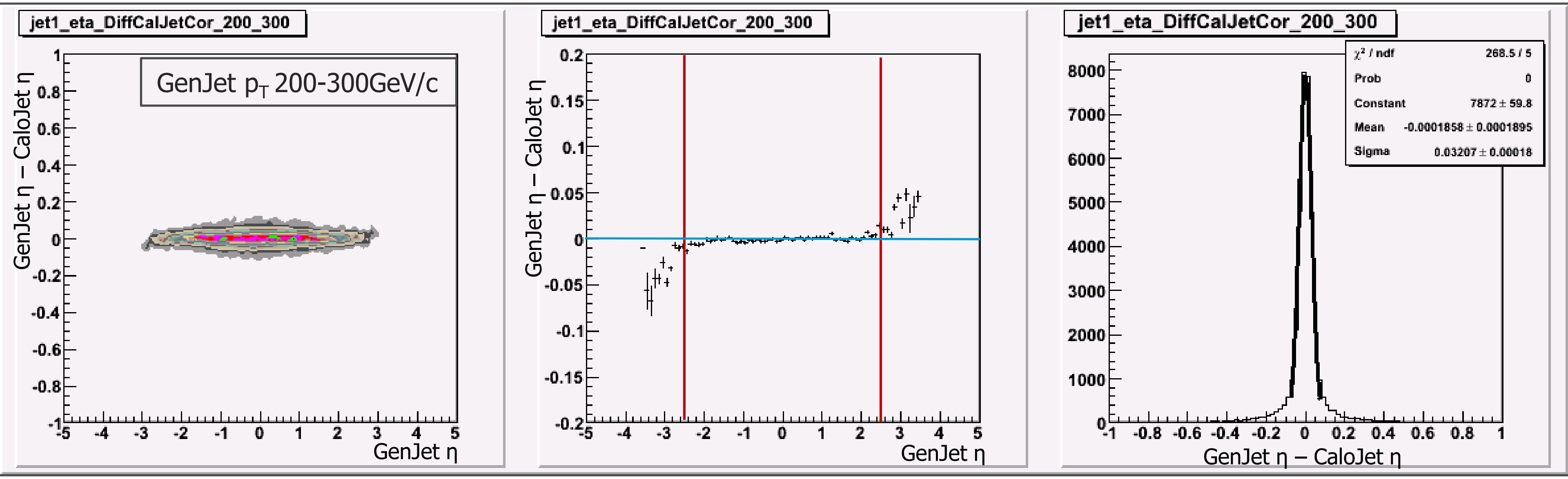


By setting a cut on Jet p_T around 50 GeV/c the contribution of the $p_T$hat bin 0-15 is practically very small.

Pseudorapidity study

To define a cut on η Jet we plot:

- The difference: (GenJet η – CaloJet η) vs (GenJet η)
- For various bins of GenJet p_T.
- Following plots are for sisCone7 (similar plots for sisCone5)

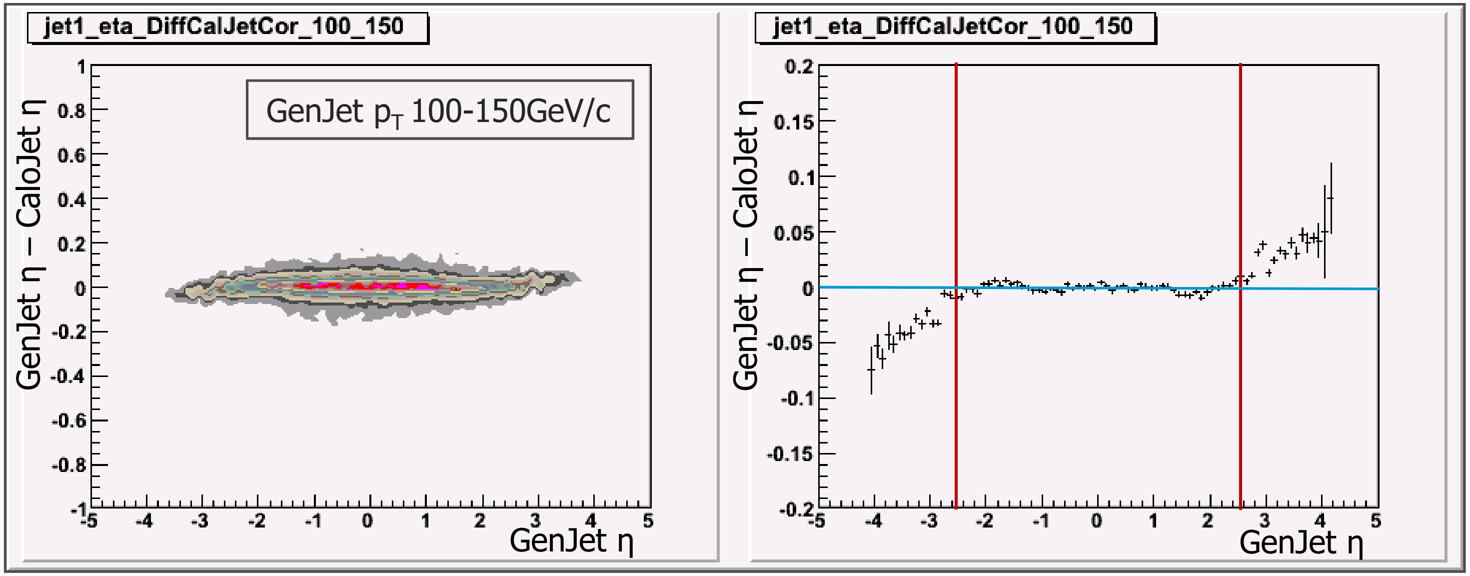


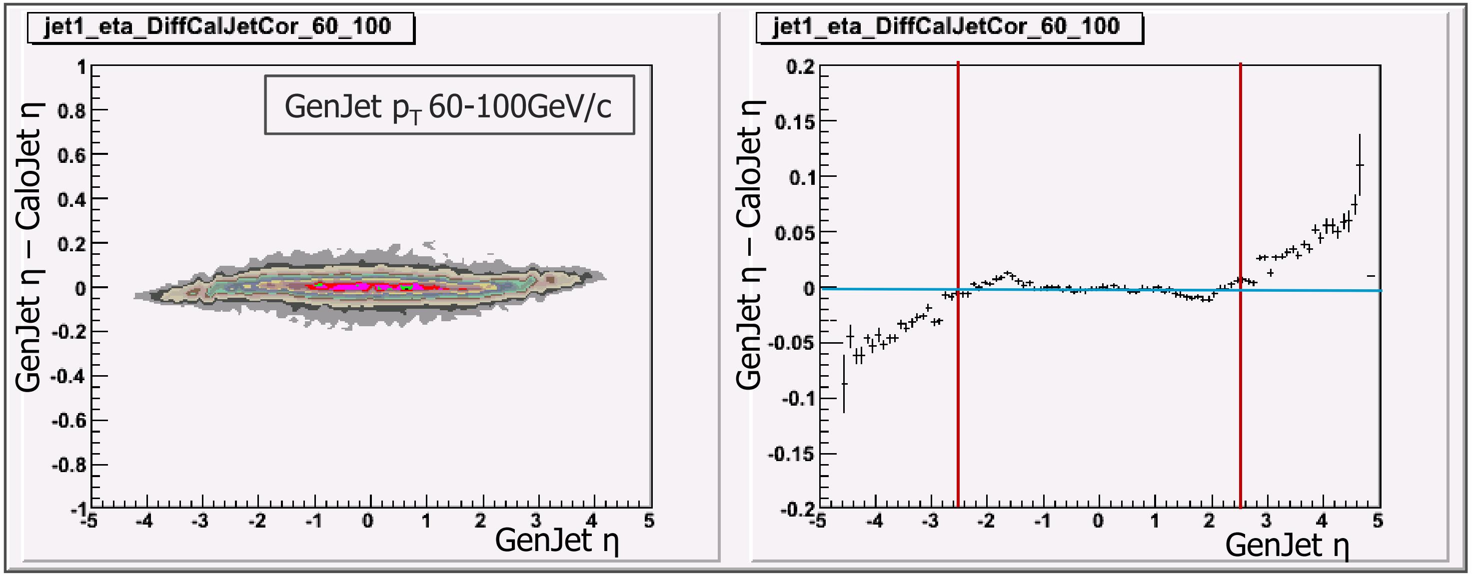
Scatter Plot

Profile

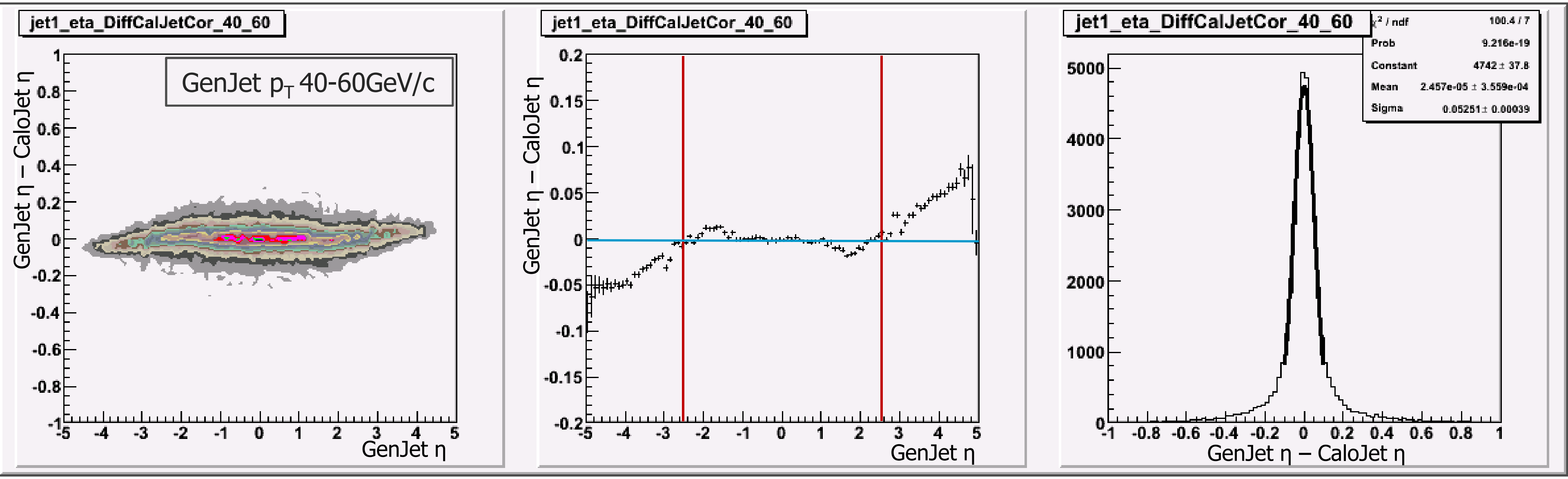
YProjection

Pseudorapidity study





Pseudorapidity study

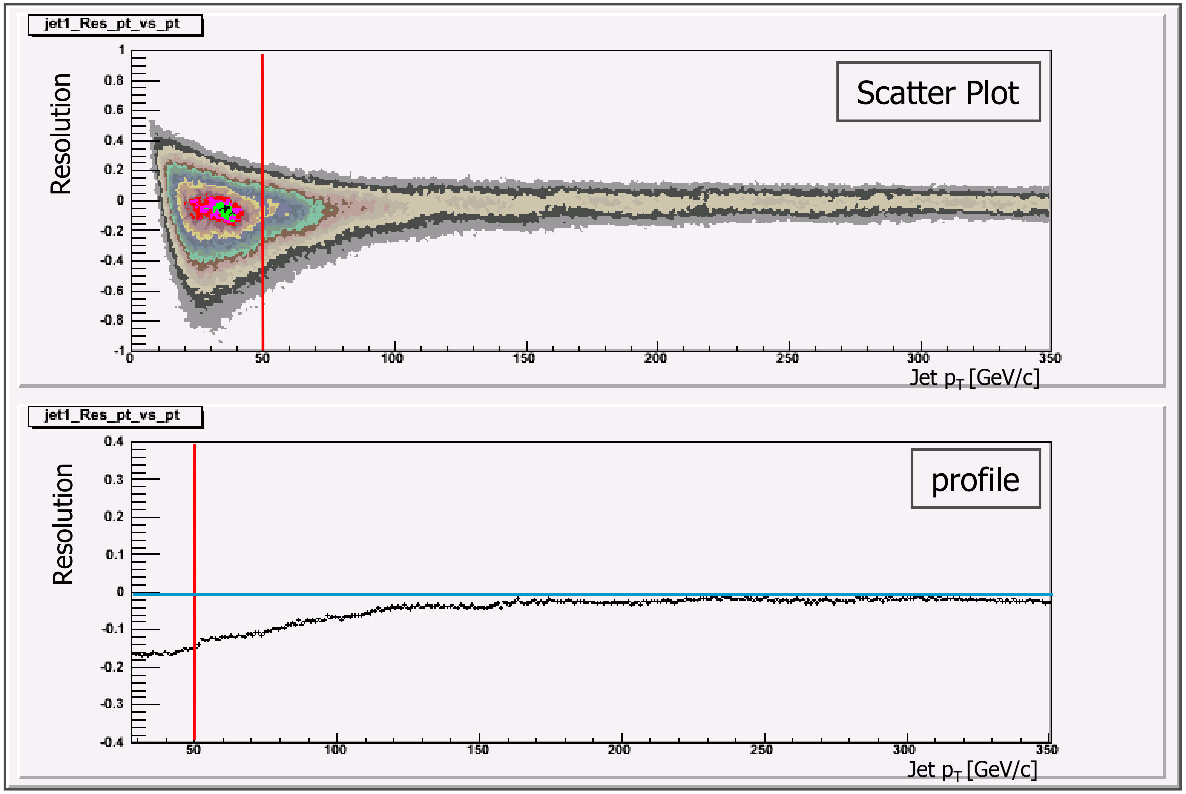


Resonable cut on eta Jet: $2.5 \leq |\eta|$

p_T Resolution study : GenJet-CaloJet

- p_T Resolution Study

$$p_T \text{ Resolution} = \frac{\text{GenJet } p_T - \text{CaloJet } p_T}{\text{GenJet } p_T}$$



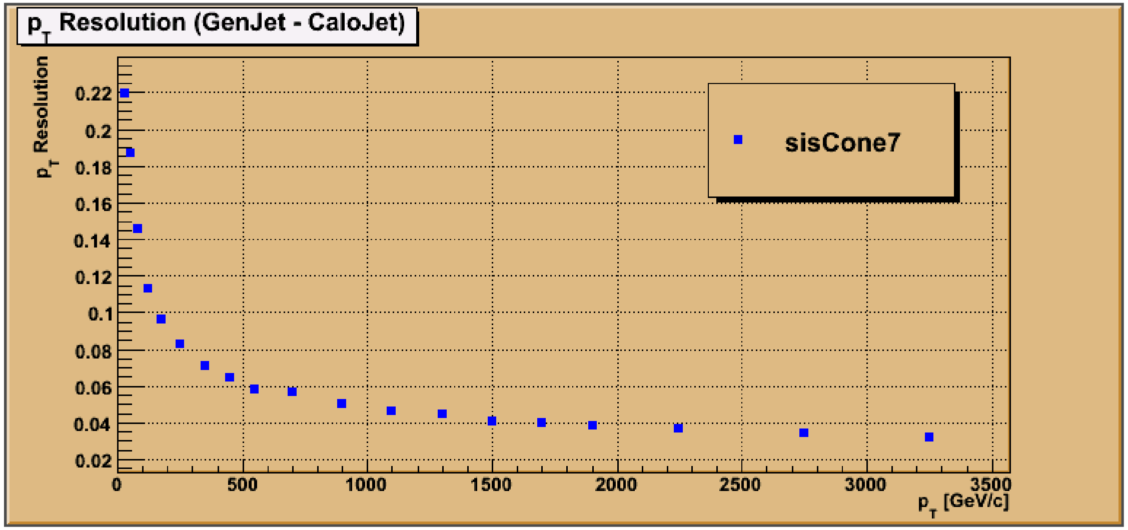
For p_T<125 GeV/c CaloJet is over estimated since CaloJet>GenJet.

Can $E_T$flow improve this? More work is needed here.

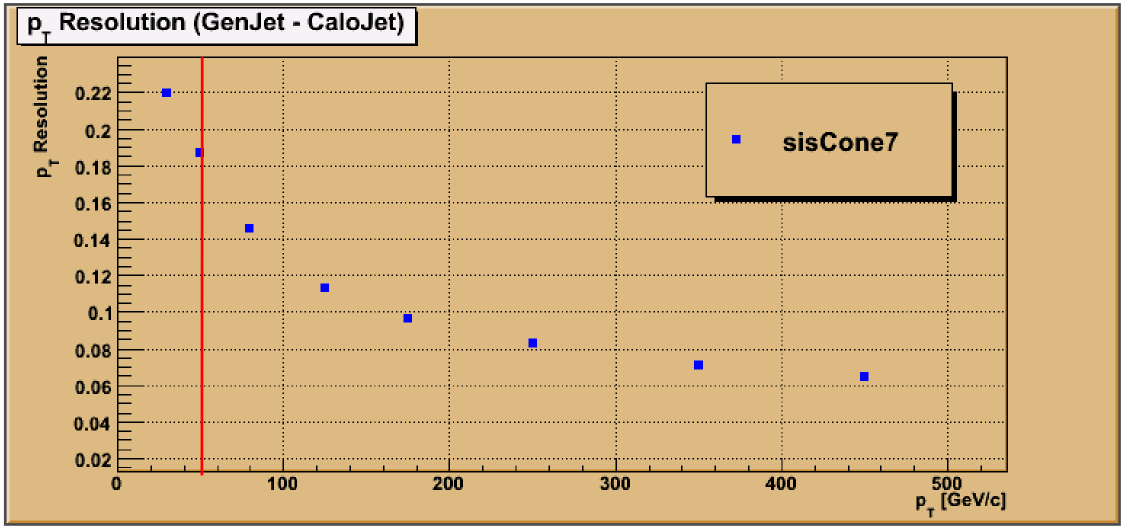
Systematic error for p_T<125 GeV/c is different and has to be studied carefully.

Sigma p_T Resolution : GenJet-CaloJet

- Splitting GenJet p_T interval into bins.
- Fit p_T bins to Gaussian distribution.
- Evaluate Resolution (sigma).



- Around 50 Gev/c p_T resolution ~18%



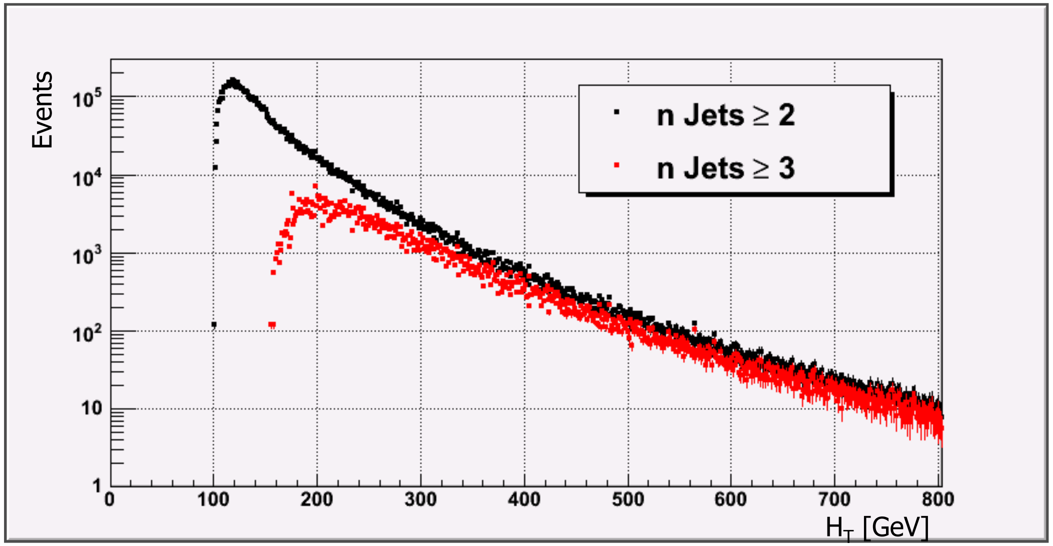
Ratio R32

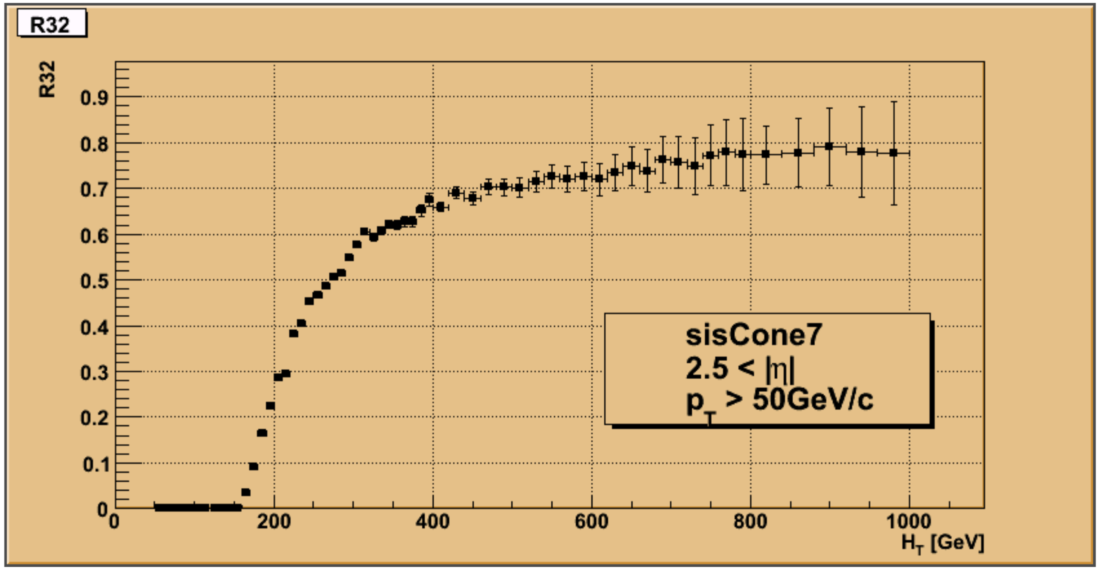
Evaluation of 3Jet over 2Jet Ratio vs H_T.

$$R_{32} = \frac{\sigma_3}{\sigma_2} = \frac{\sigma(pp \to n\ \ \text{jets}\ + X;\ n \ge 3)}{\sigma(pp \to n\ \ \text{jets}\ + X;\ n \ge 2)}$$

Event Selection cuts:

$|\eta|<2.5$ and Jet $p_T \geq 50$ GeV/c

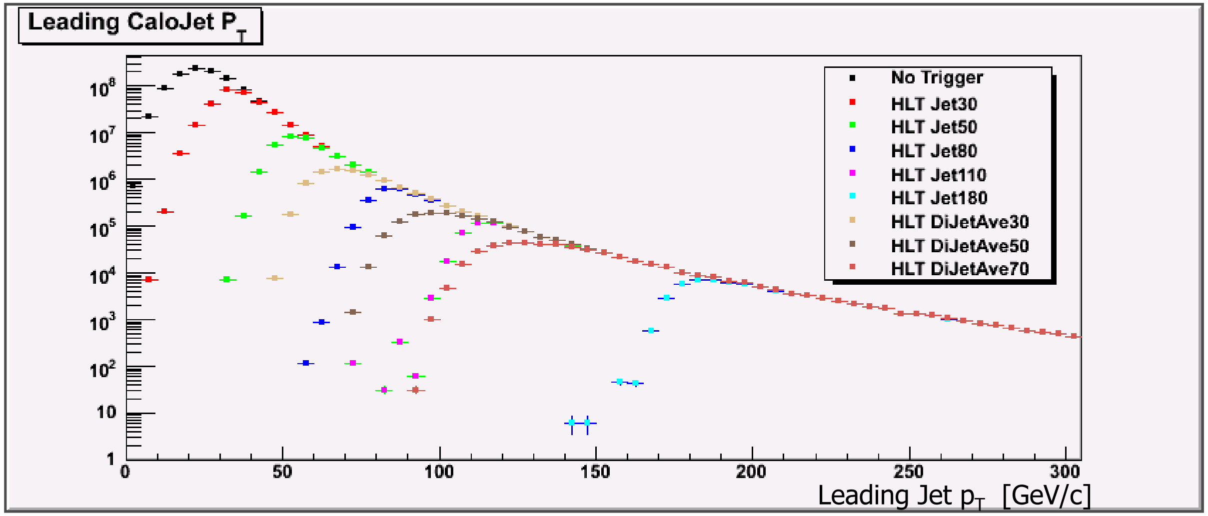


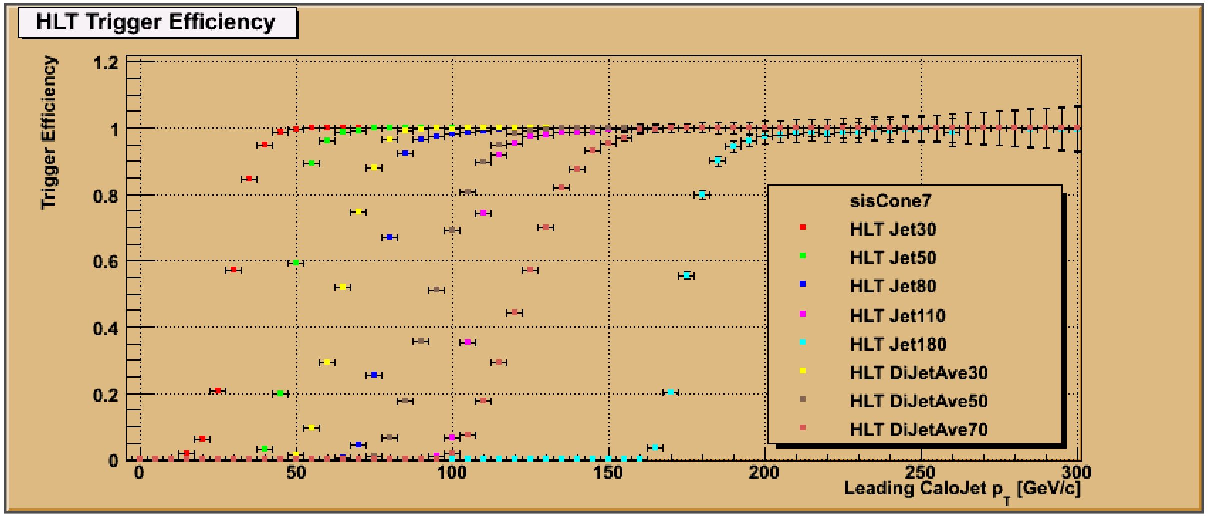


Trigger Study : Leading Jet

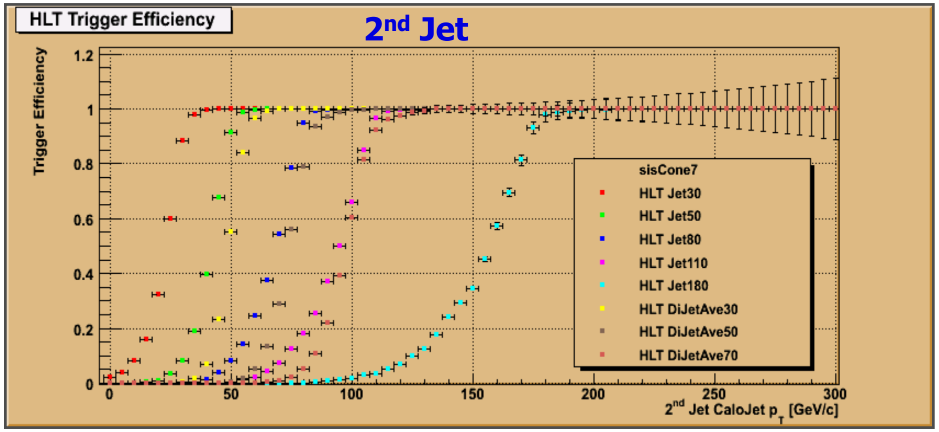
Efficiencies for the following HLT triggers were evaluated:

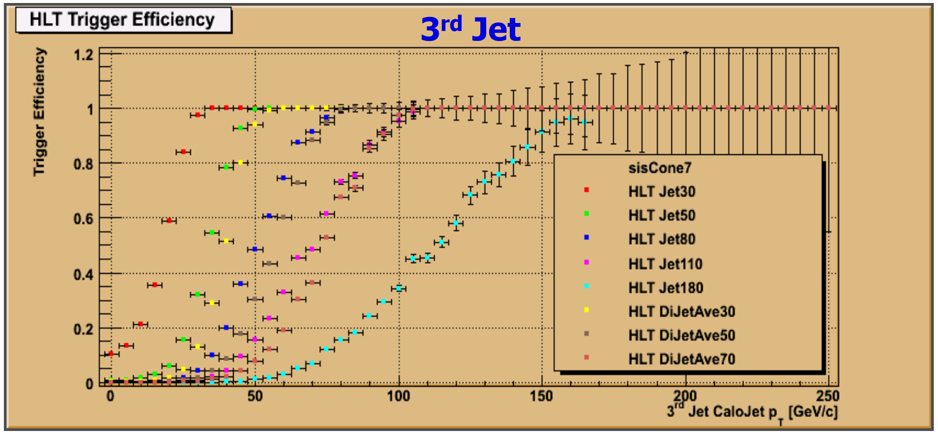
Path name	L1 Trigger	Prescale (L1xHLT)
HLT Jet30	L1_SingleJet15	500x5
HLT Jet50	L1_SingleJet30	50x1
HLT Jet80	L1_SingleJet50	5x2
HLT Jet110	L1_SingleJet70	1
HLT Jet180	L1_SingleJet70	1
HLT DiJetAve 30	L1_SingleJet30	50x1
HLT DiJetAve 50	L1_SingleJet50	5x1
HLT DiJetAve 70	L1_SingleJet70	1





Trigger Study : 2nd & 3rd Jet



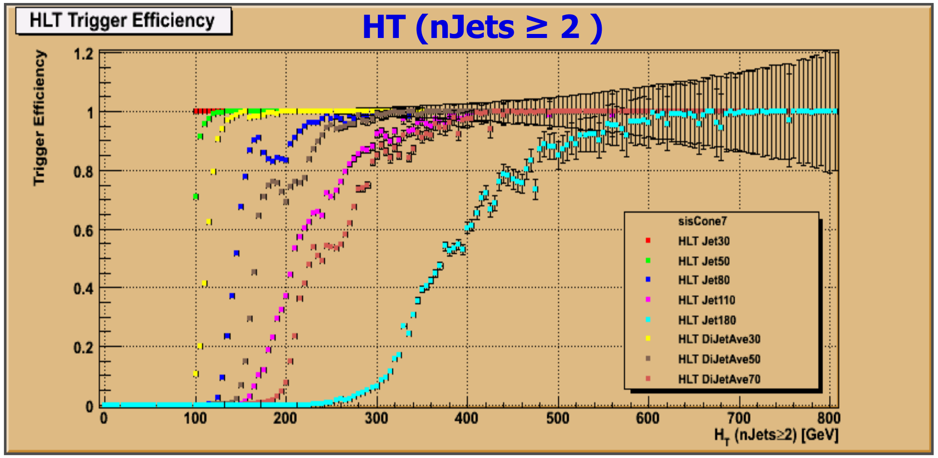


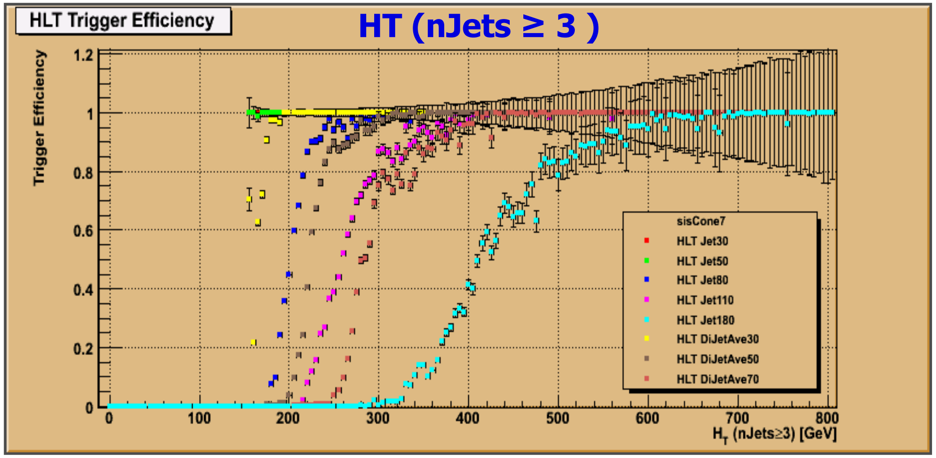
Trigger	Leading Jet Threshold (99% efficient)	2nd Jet Threshold (99% efficient)	3rd Jet Threshold (99% efficient)
HLT Jet 30	50 GeV	40 GeV	35 GeV
HLT Jet 50	70 GeV	60 GeV	50 GeV
HLT Jet 80	110 GeV	85 GeV	80 GeV
HLT Jet 110	150 GeV	115 GeV	110 GeV
HLT Jet 180	235 GeV	190 GeV	170 GeV
HLT DiJetAve 30	85 GeV	65 GeV	55 GeV
HLT DiJetAve 50	125 GeV	100 GeV	80 GeV
HLT DiJetAve 70	160 GeV	130 GeV	105 GeV

Possible triggers for data collection

- Single Jet Triggers:
  - HLT Jet50 (prescale 50x1)
  - HLT Jet110 (prescale 1)
- DiJetAve Triggers:
  - HLT DiJetAve 30 (presc 50x1)
  - HLT DiJetAve 70 (presc 1)

Trigger Study : HT (nJets ≥ 2 & nJets ≥ 3)





Trigger	HT (nJets≥2) Threshold (99% efficient)	HT (nJets≥3) Threshold (99% efficient)
HLT Jet 30	100 GeV	155 GeV
HLT Jet 50	120 GeV	155 GeV
HLT Jet 80	240 GeV	300 GeV
HLT Jet 110	390 GeV	410 GeV
HLT Jet 180	600 GeV	620 GeV
HLT DiJetAve 30	150 GeV	195 GeV
HLT DiJetAve 50	300 GeV	315 GeV
HLT DiJetAve 70	410 GeV	410 GeV

HLT Jet50 fully efficient from 155 GeV.
HLT DiJetAve30 fully effic. from 195 GeV.

⇩

More suitable for data taking the Single Jet (50 & 110) triggers than the DiJetAve (30 & 70)

Summary & Plans

- To define the measured cross section at hadron level
  → $\sigma(p_T \geq X; |\eta| \leq Y)$
  studies on pseudorapidity and p_T resolution were done.
- A first study of the trigger efficiency was performed to estimate the lowest p_T and H_T that can be measured with 100% efficiency.
- Plot the ratio R32 with event selection cuts:
  $|\eta|<2.5$ and Jet $p_T \geq 50$ GeV/c

Next steps (follow the initial plan):

- Estimate the dominant systematics on the experimental measurement (Jet energy scale…)
- Estimate the magnitude of hadronisation correction
- Compute the theoretical rate with NLO programs and estimate the uncertainty due to μ_R, μ_F