Measurement of the Jet Cross Section Ratio: $\sigma(pp\rightarrow n \text{ njets}+X \ n\geq3)/ \sigma(pp\rightarrow n \text{ njets}+X \ n\geq2)$

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Outline

- Measurement of the Jet Cross Section Ratio:

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

  - Motivation
  - Analysis plan
- Software tools and MC Data used.
- Define the measured cross section at hadron level.
  - Pseudorapidity studies
  - p_T resolution studies

  } Define eta and p_T cut
- The Ratio R32
  - H_T resolution studies
  - R32 at 10 pb^{-1}
- Trigger studies
  - Combine Single Jet HLTs
- Summary & plans

Motivation

- Motivation: Measure the ratio R32 vs H_T and compare with pQCD predictions with goals:
  - Extend the phase space of the measurements in a regime that goes above the Tevatron.
  - 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.
  - Demonstrate that we understand QCD at LHC energies and therefore we understand the backgrounds we face for a number of exotic physics channels.
- 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-P_T scales.

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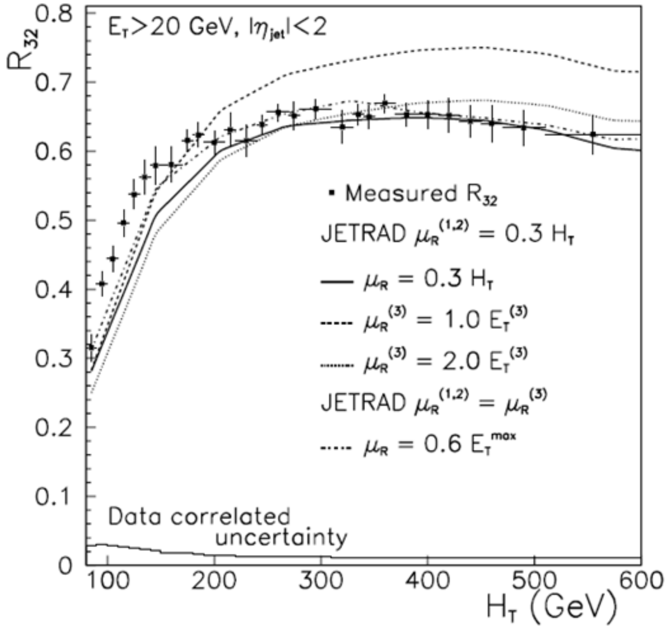


FIG. 2. The ratio R_{32} as a function of H_T, requiring jet $E_T >$ 20 GeV and $|\eta_{\text{jet}}| < 2$. Error bars indicate statistical and uncorrelated systematic uncertainties, while the histogram at the bottom shows the correlated systematic uncertainty. The four smoothed distributions show the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

Jet finder radius 0.7
We should be able to extend this up to an H_T~ 1.5 TeV
(σ(2J) = 1 pb @ Pt-hat = 700 GeV)

Analysis Plan

- Definition of the measured cross section at hadron level $\sigma(p_T \geq X; |\eta| \leq Y)$
  - Pseudorapidity studies
  - p_T resolution studies

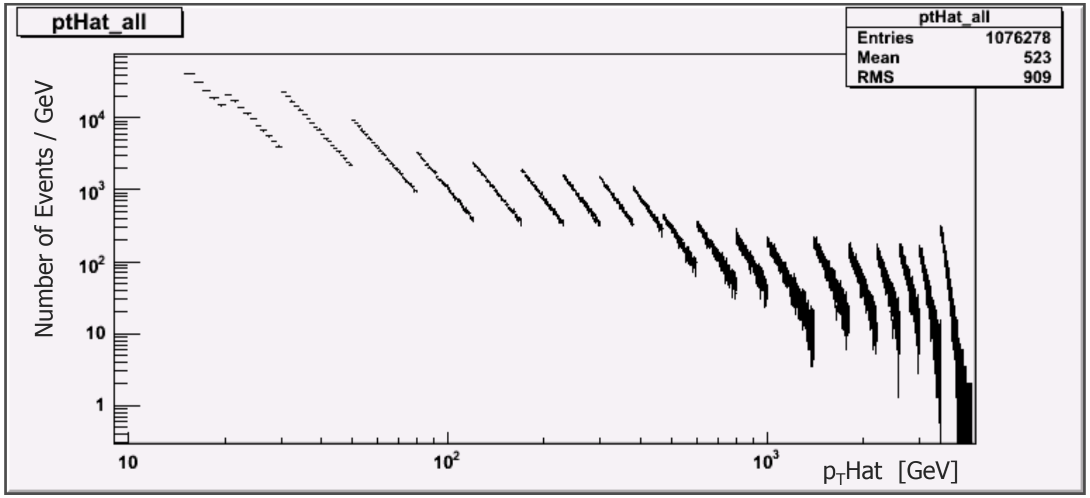
  Define the 2 Jet and 3 Jet kinematic cuts.
  - Jet finder studies sisCone7, sisCone5.
- Trigger studies of available HLT's, to select the right scheme
  - Compute trigger efficiencies.
  - Combine triggers to have R32.
- Estimate the dominant systematics (Jet energy scale…)
  - Use the known resolutions 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}
- 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

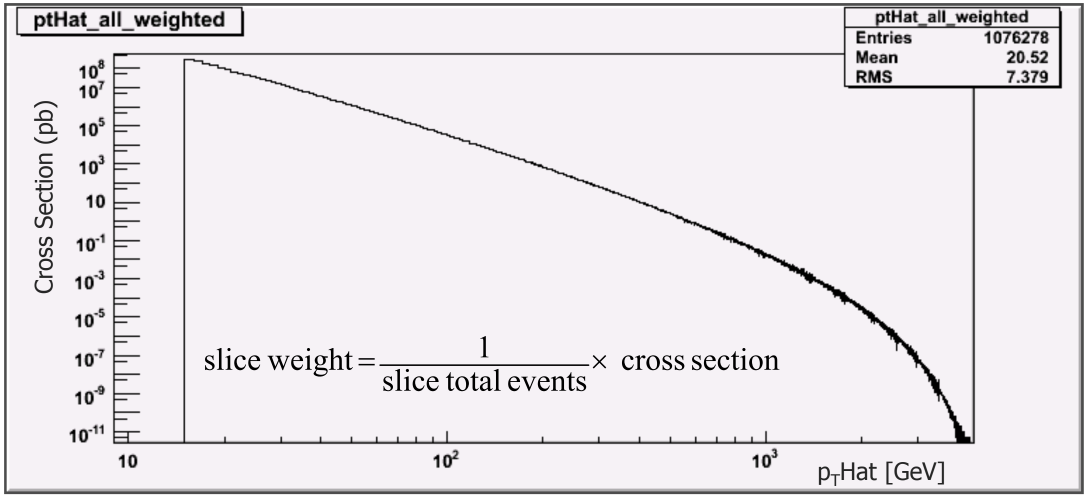
Tools and MC Samples used

Analysis done using version CMSSW_2_2_6

- QCD DiJet Summer 08
- Jet Algorithm: sisCone7
- Jet Energy Corrections: L2L3
- 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





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

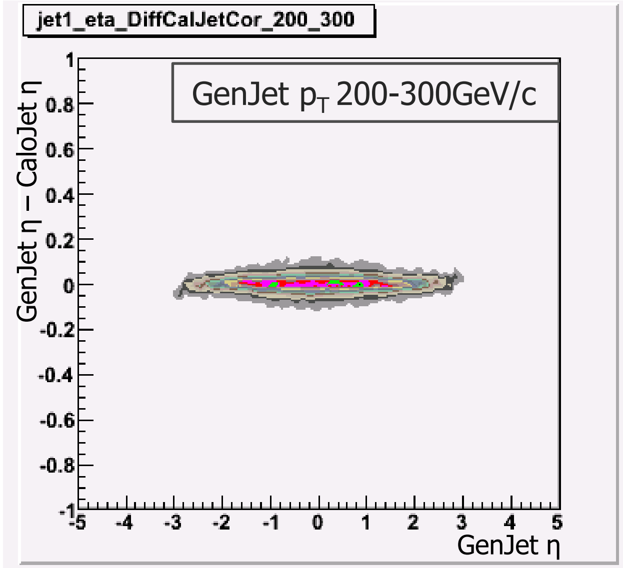
Pseudorapidity studies

To define the measured cross section at hadron level:

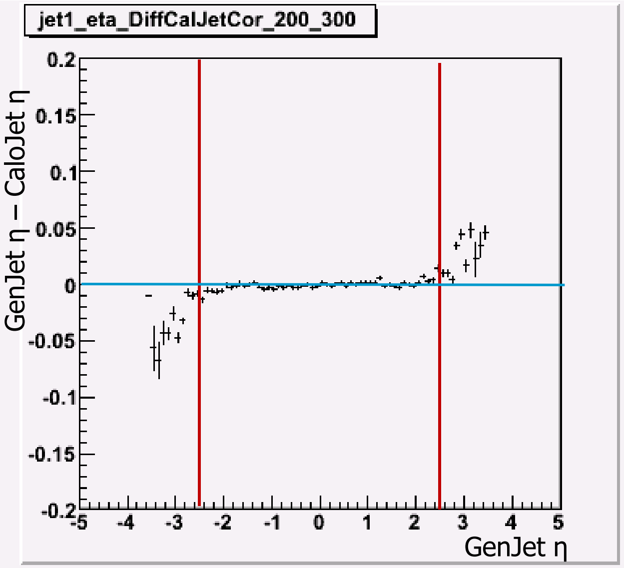
- Define a cut on eta of Jets

Plot the difference: (GenJet η – CaloJet η) vs (GenJet η)

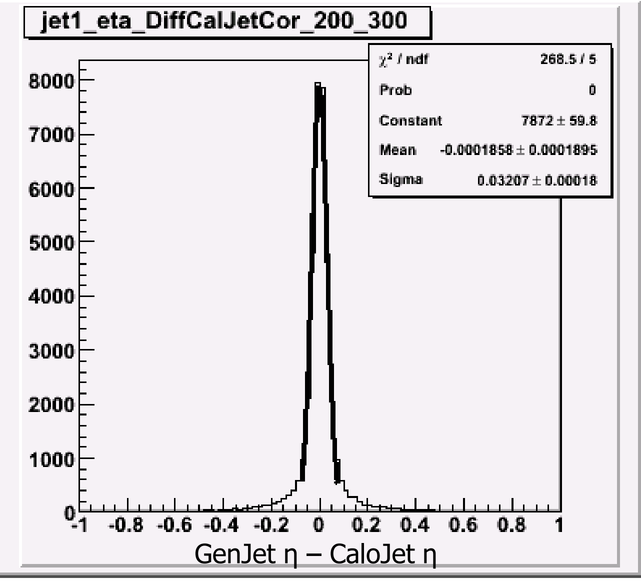
- For various bins of GenJet p_T
- Jet Algorithm sisCone7



Scatter Plot

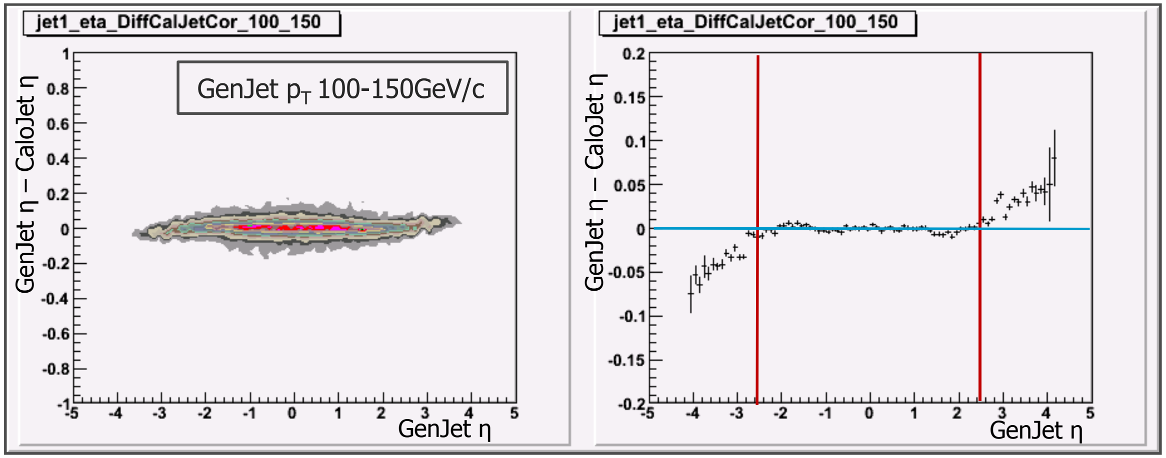


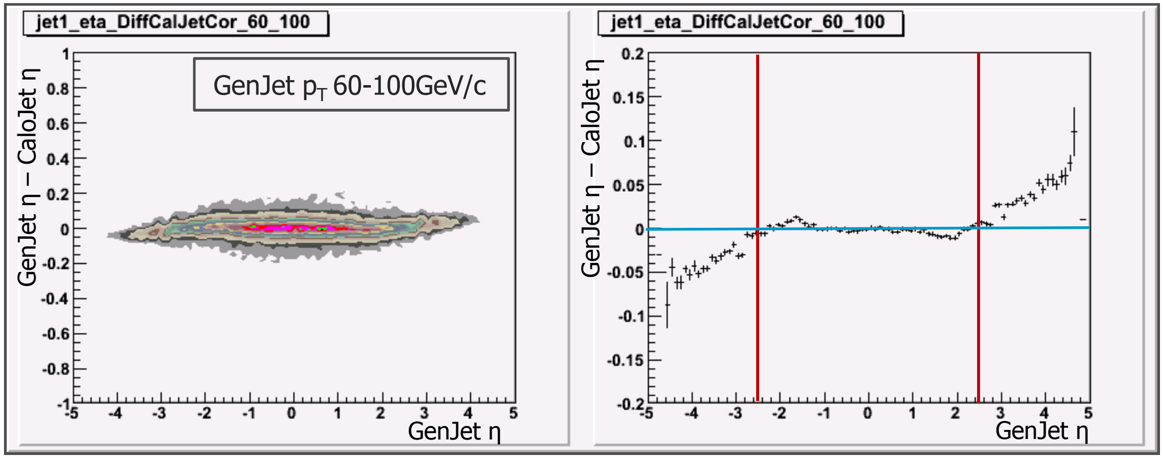
Profile



YProjection

Pseudorapidity studies





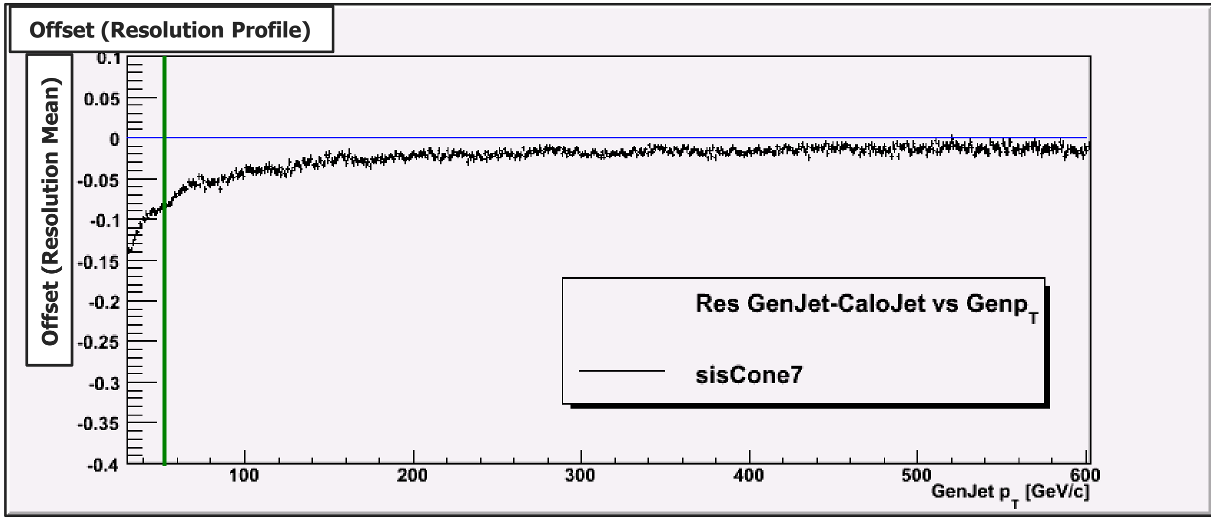
Distributions are flat
for |η|≤2.5
(Barrel + EndCap regions)

Reasonable cut on eta
of Jets: |η| ≤2.5

Jet p_T resolution studies

Jet p_T resolution studies at GenJet-CaloJet level:

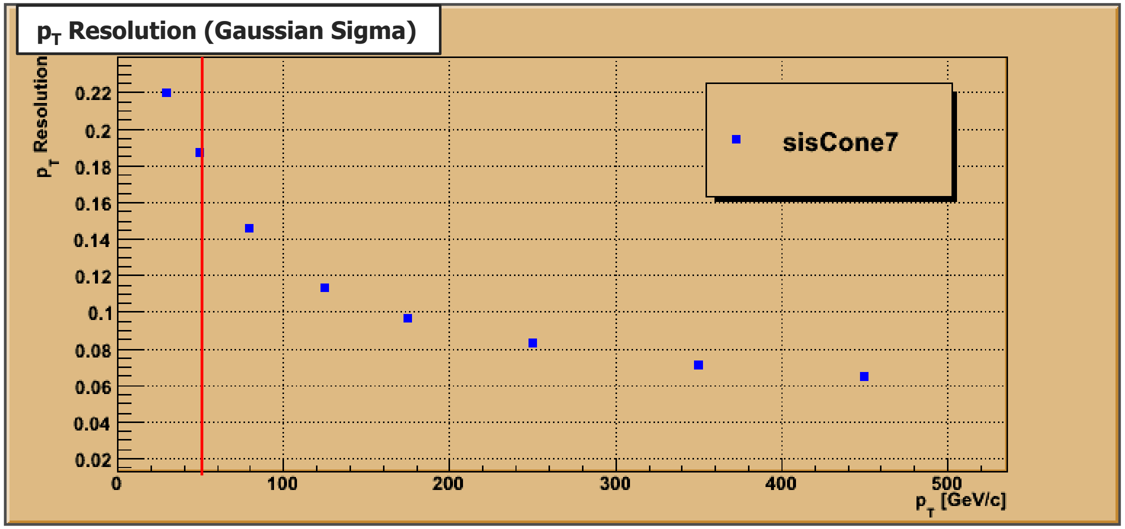
$$p_T \text{ Resolution} = \frac{\text{GenJet } p_T - \text{CaloJet } p_T}{\text{GenJet } p_T}$$



At $p_T \approx 50$ GeV/c mean value is shifted by 8%
(CaloJet is overestimated)

Around 50 Gev/c p_T resolution ~18%

For our analysis we apply a cut on Jet $p_T \geq 50$ GeV/c



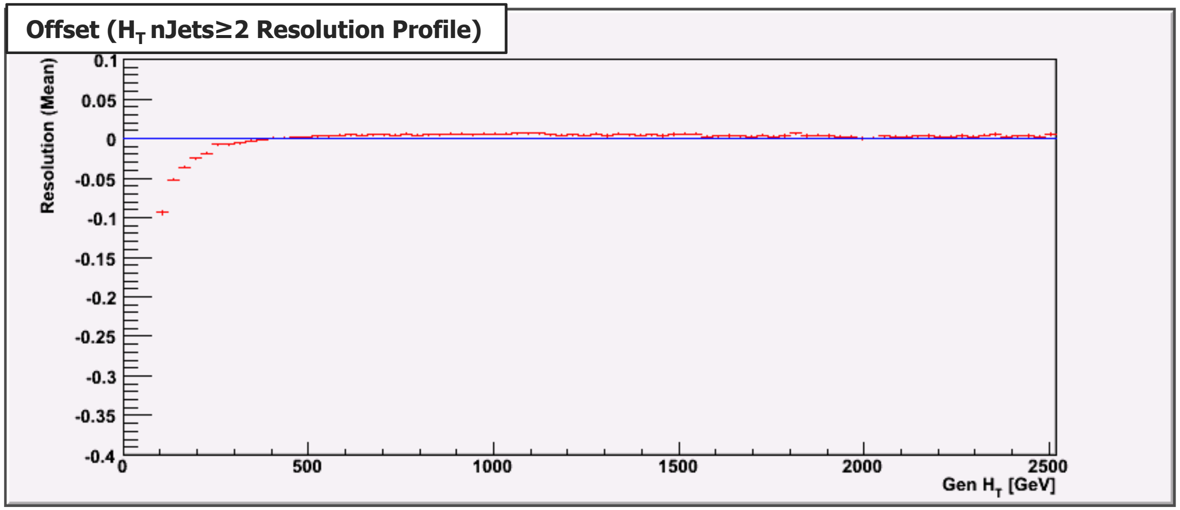
H_T resolution studies

$$H_T \text{ Resolution} = \frac{\text{Gen } H_T(\text{nJets} \geq 2) - \text{Calo } H_T(\text{nJets} \geq 2)}{\text{Gen } H_T(\text{nJets} \geq 2)}$$

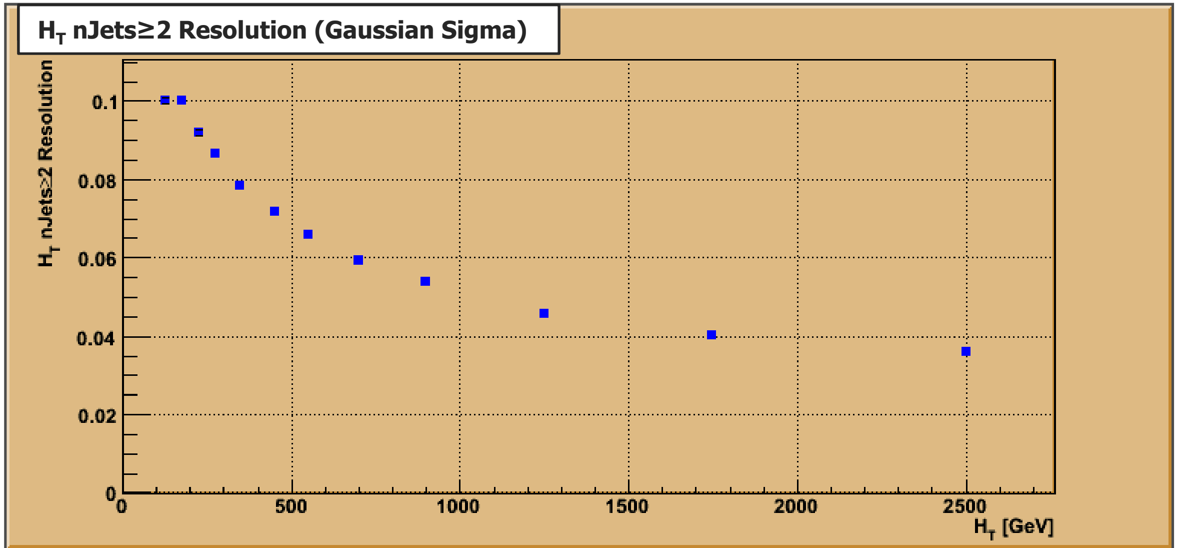
Important study to define the binning for the ratio R32.

Below 400 GeV mean value is shifted to negative values (Calo H_T is overestimated)

Around 200 Gev H_T (nJets ≥2) resolution ~10%



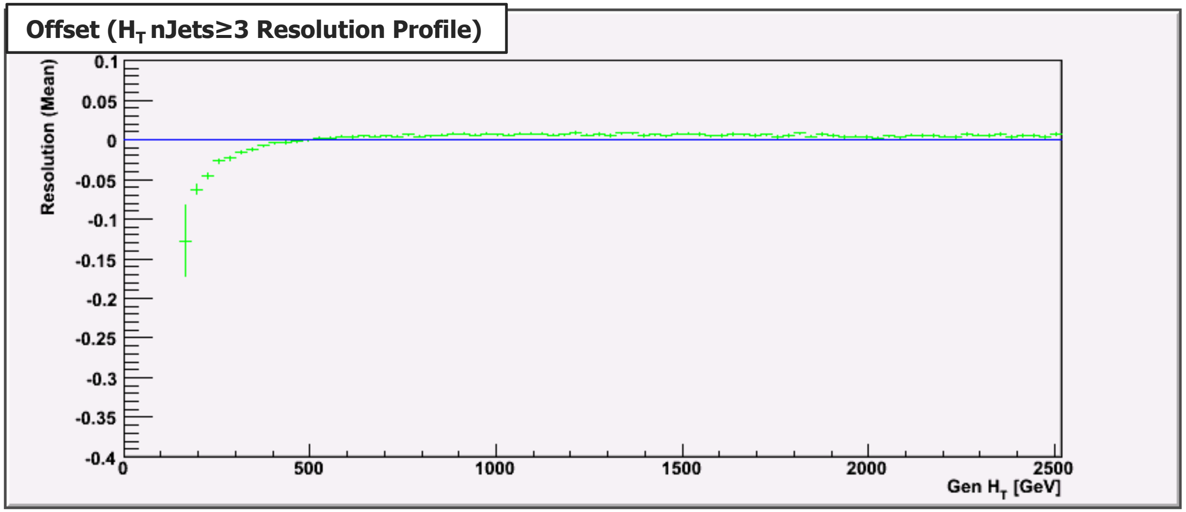
Offset (H_T nJets≥2 Resolution Profile)



H_T nJets≥2 Resolution (Gaussian Sigma)

H_T resolution studies

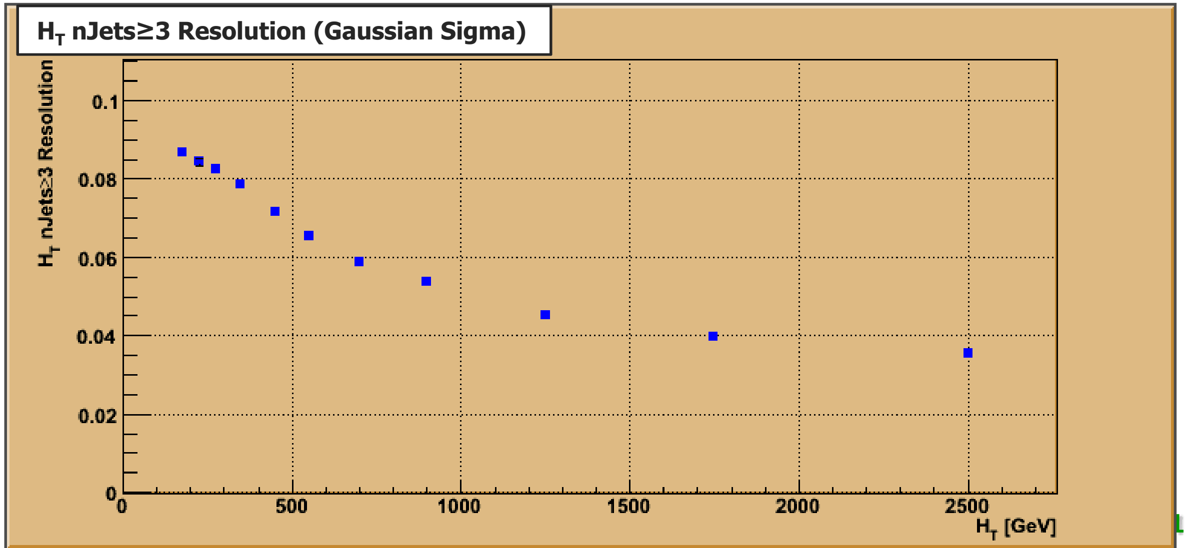
$$H_T \text{ Resolution} = \frac{\text{Gen } H_T(\text{nJets} \geq 3) - \text{Calo } H_T(\text{nJets} \geq 3)}{\text{Gen } H_T(\text{nJets} \geq 3)}$$



Below 400 GeV mean value is shifted to negative values

(Calo H_T is overestimated)

Around 200 Gev H_T (nJets ≥3) resolution ~9%



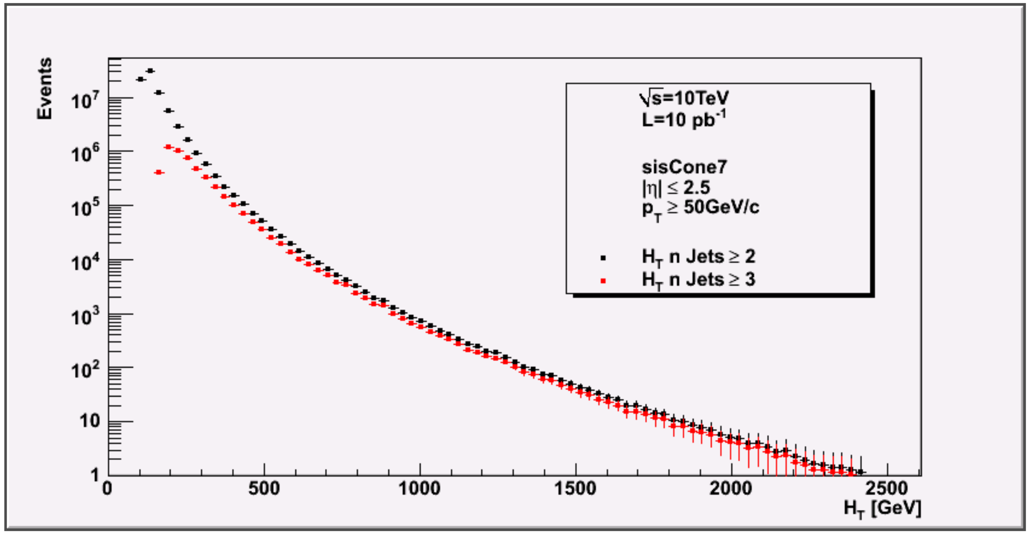
Ratio R32

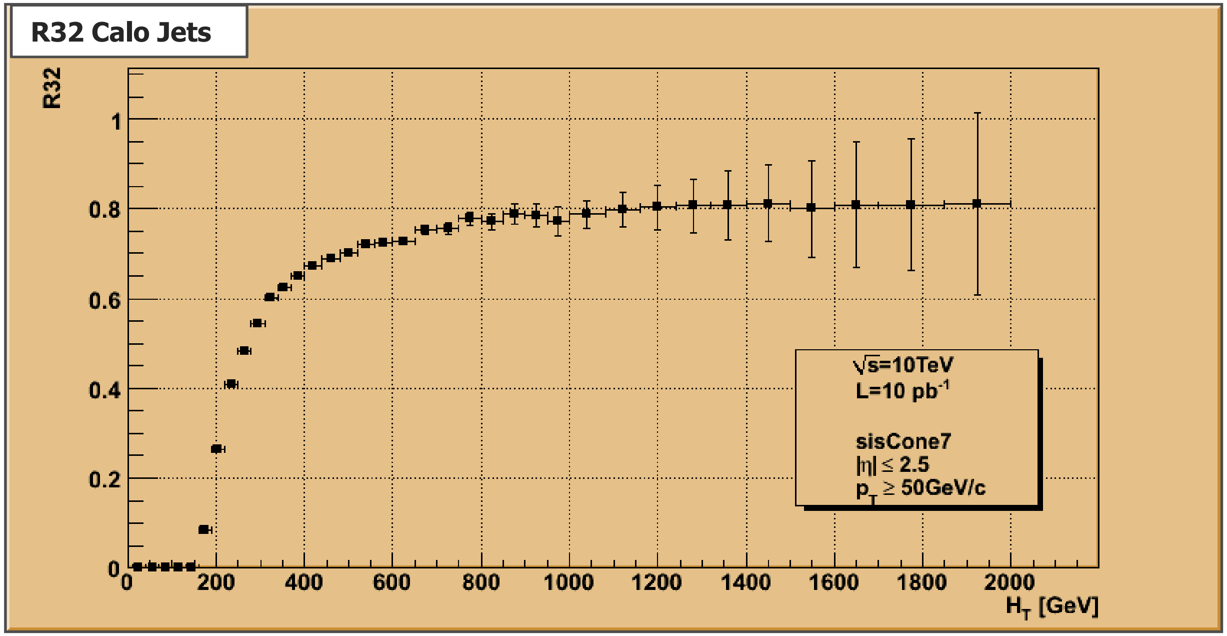
Evaluation of 3Jet/2Jet Ratio vs H_T.

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

Event Selection cuts:

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

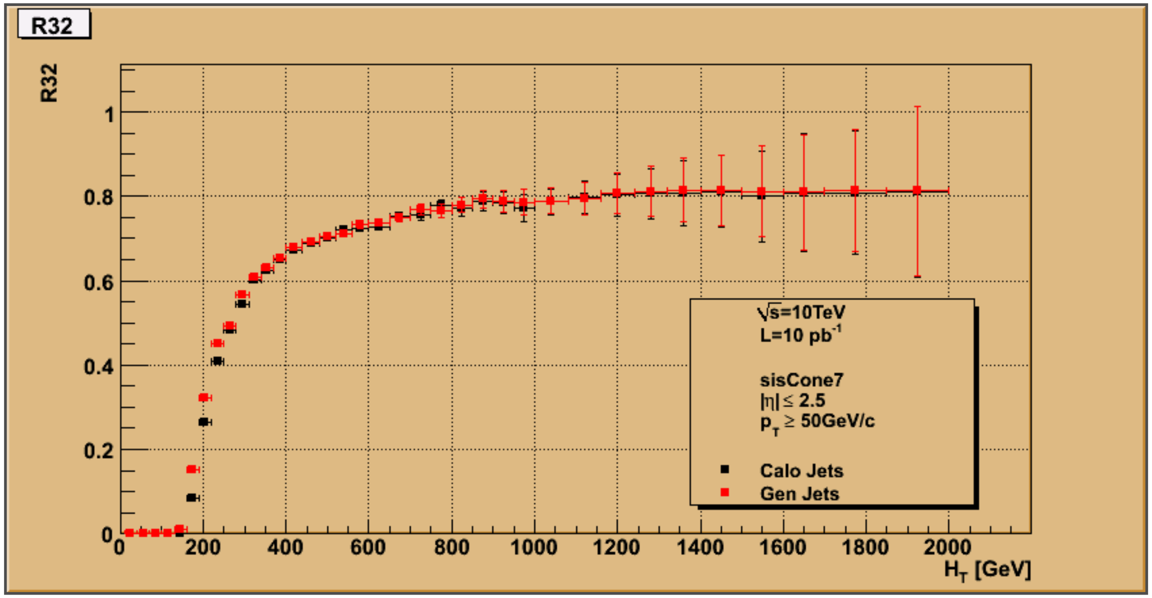


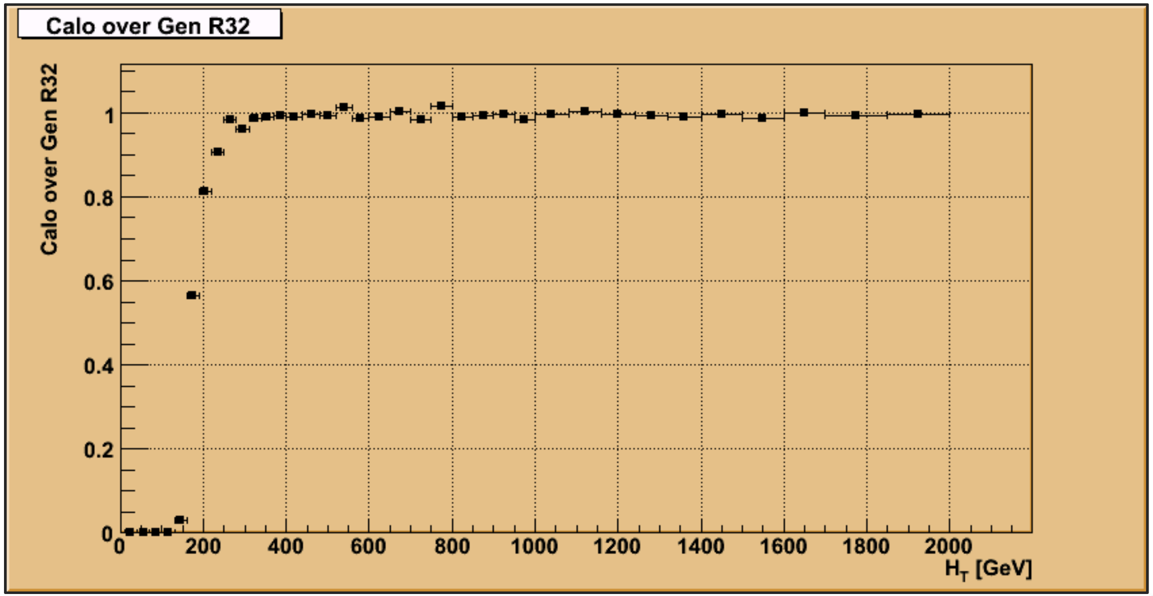


Ratio 32: Calo over Gen

The shift of jet p_T mean value taken into account when plotting the ratio using GenJets

Above 300 GeV practically no detector effect.



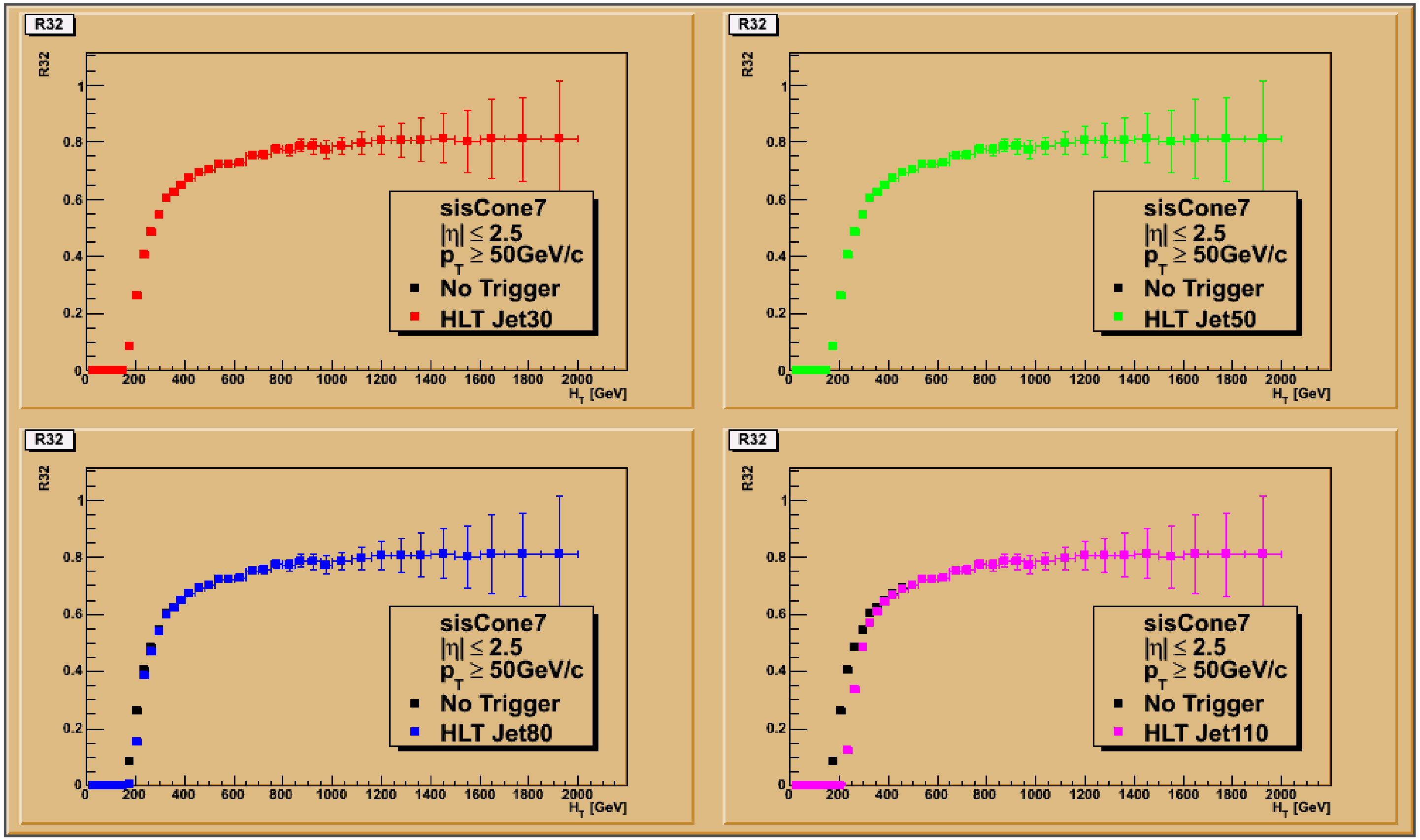


Trigger study: Single Jet Triggers

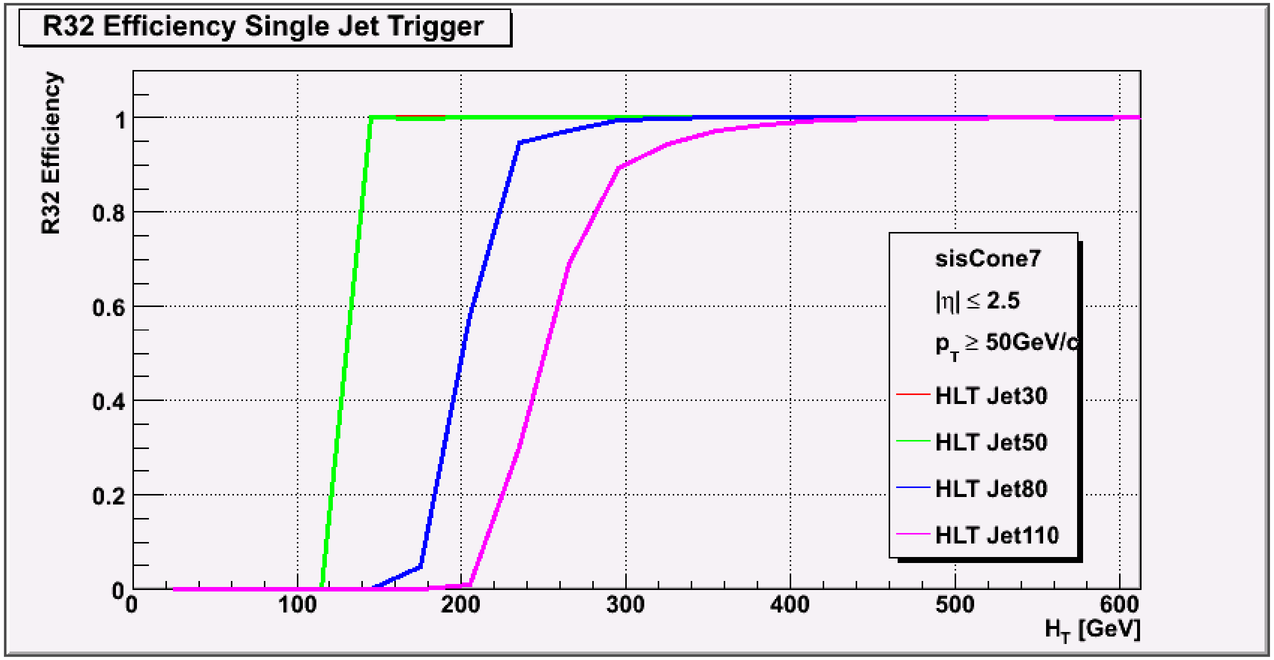
Study of Single Jet HLTs.

- Plot R32 after applying the HLTs
- Evaluate trigger efficiency for ratio R_{32}

Path name	L1 Trigger
HLT Jet30	L1_SingleJet15
HLT Jet50	L1_SingleJet30
HLT Jet80	L1_SingleJet50
HLT Jet110	L1_SingleJet70



Trigger study: Single Jet Triggers

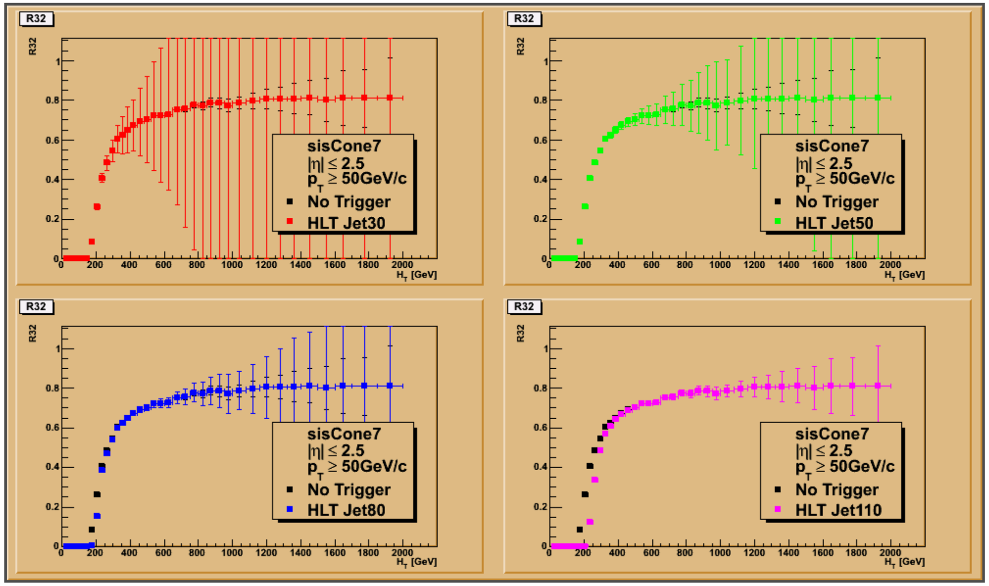


Trigger Path name	Threshold (100% efficient)
HLT Jet30	150
HLT Jet50	150
HLT Jet80	350
HLT Jet110	500

→ **Fully efficient from 150 GeV**

Trigger study: Single Jet Triggers

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

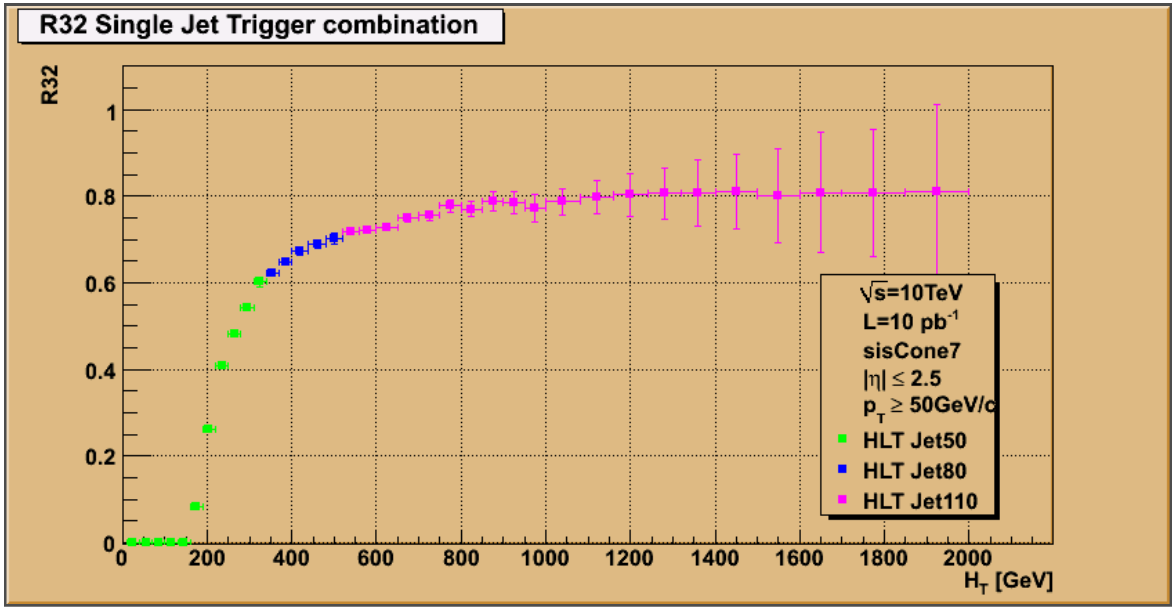


Combine Single Jet HLTs for data collection :

- HLT Jet50 (prescale 50x1)
- HLT Jet80 (prescale 5x2)
- HLT Jet110 (prescale 1)

Trigger scheme fully efficient from ≥150 GeV

Trigger HLT Jet50 can be tested using trigger HLT Jet30


R32 Single Jet Trigger combination

Summary & Plans

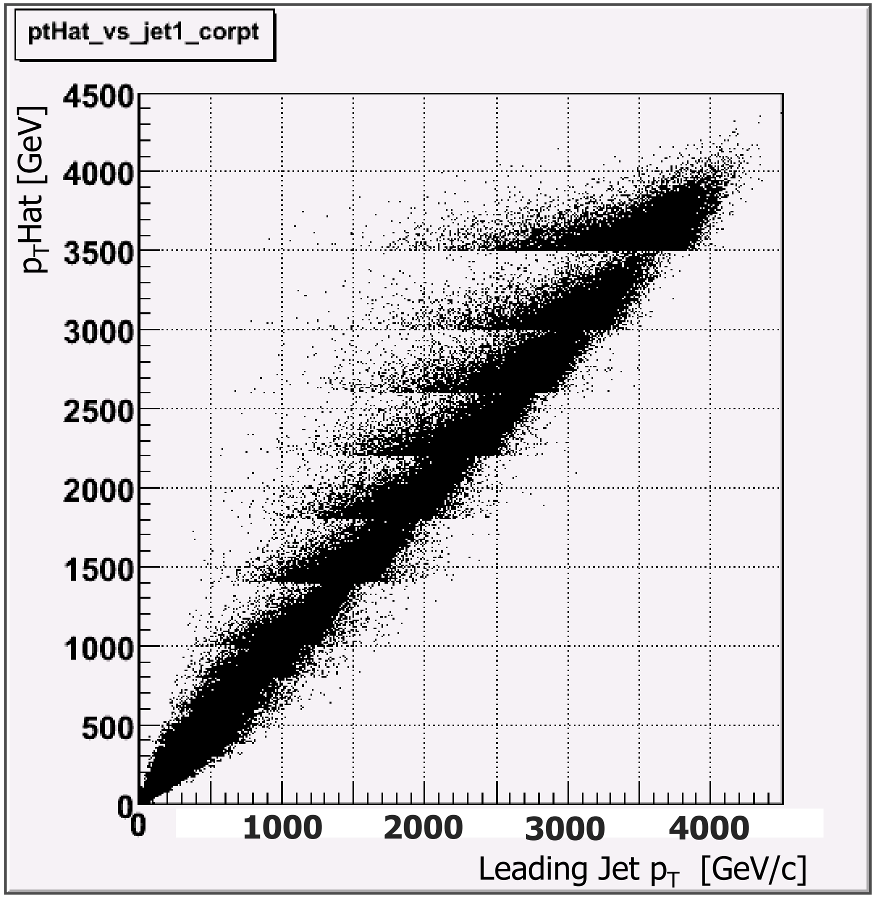
- Measurement of 3Jet/2Jet cross section ratio vs H_T using
  - QCD DiJet Summer 08
  - Jet Algorithm: sisCone7
  - Jet Energy Corrections: L2L3
- Definition of the measured cross section at hadron level
  $\rightarrow \sigma(p_T \geq 50$ GeV/c; $|\eta| \leq 2.5)$
- With a Luminosity of $10pb^{-1}$ is possible to extend the measurement of the ratio up to H_T~1500 GeV (~3 times the scale of Tevatron).
- The ratio can be measured with a combination of three Single Jet HLTs : (HLT Jet50, HLT Jet80, HLT Jet110).

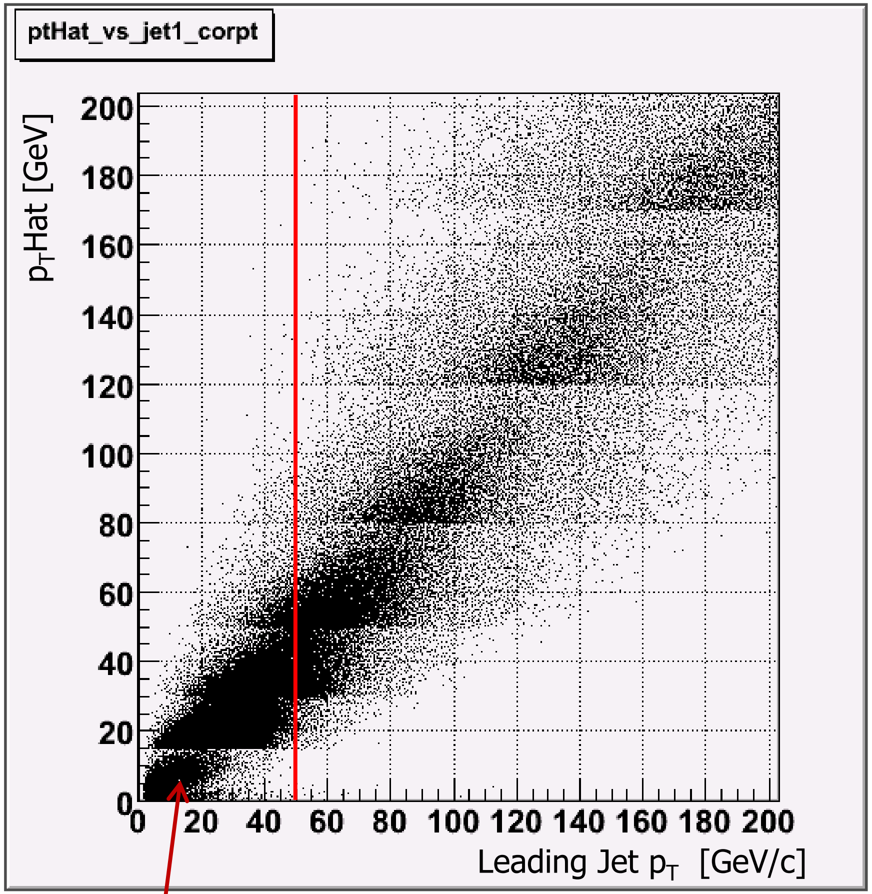
Next steps (following the initial plan):

- 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

Spare

p_THat vs Jet1 p_T



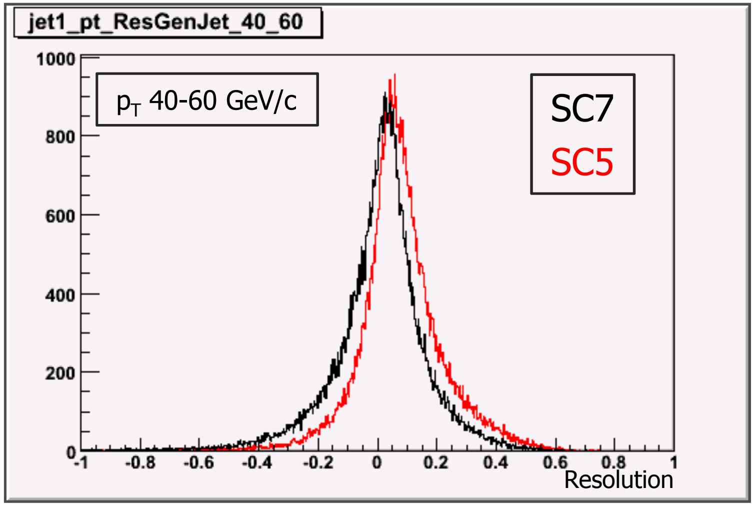


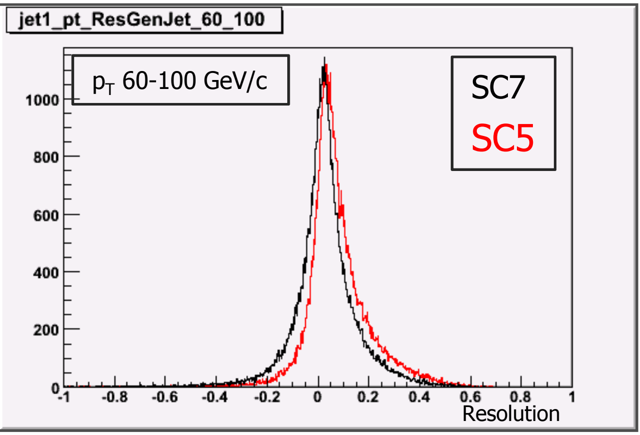
By setting a cut on Jet p_T around 50 GeV/c the contribution of the $p_T$hat bin 0-15 is practically very small.

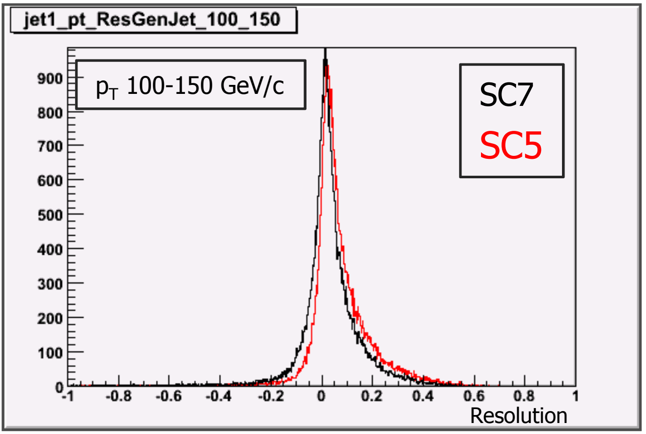
Jet p_T resolution: Parton-GenJet Level

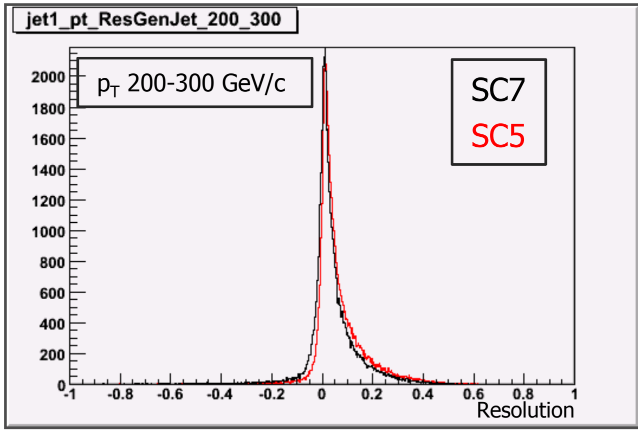
$$p_T \text{ Resolution} = \frac{\text{Parton } p_T - \text{GenJet } p_T}{\text{Parton } p_T}$$

- Splitting Parton p_T interval into bins.
- Non Gaussian shapes
- Tails on the right.

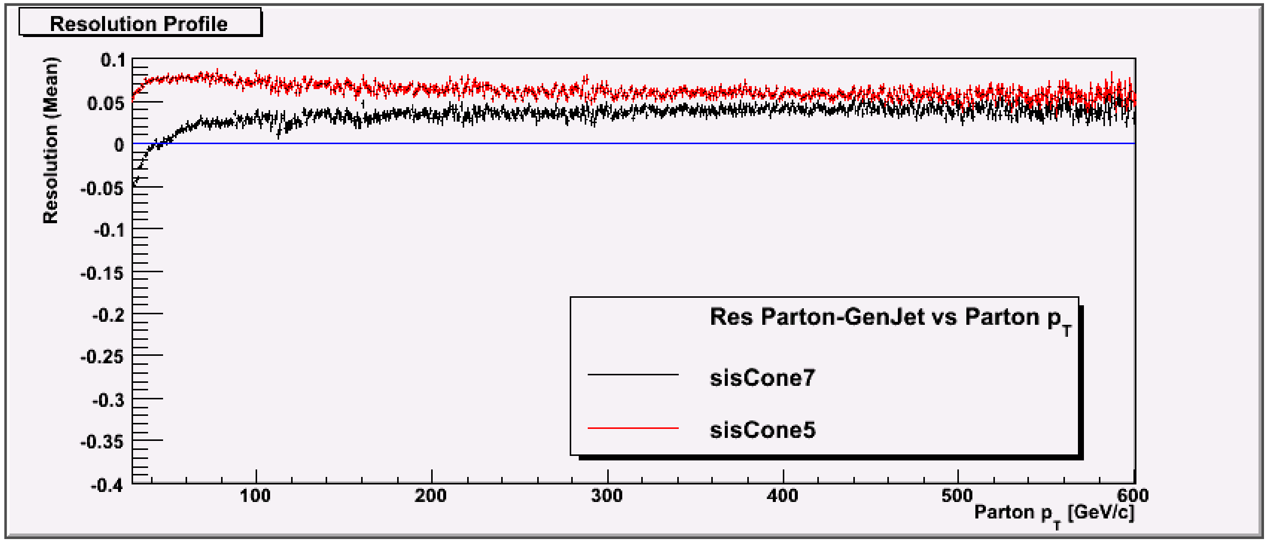




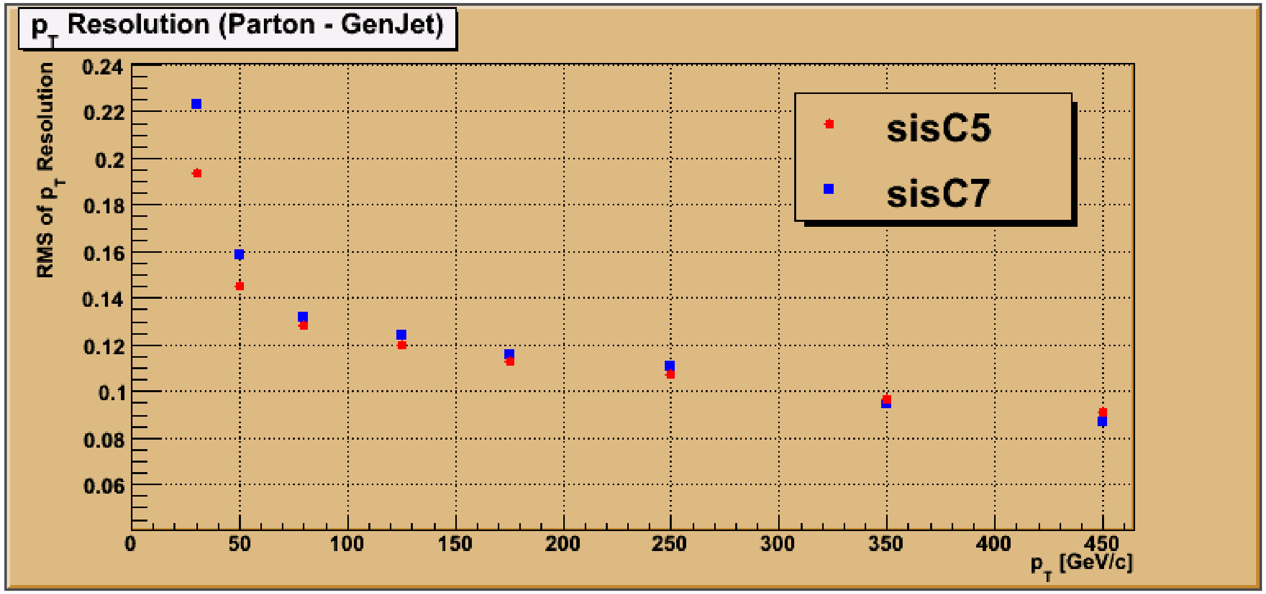




Jet p_T resolution: Parton-GenJet Level



sisCone7 algorithm produces smaller shift than sisCone5 as expected



For p_T>75 GeV/c no difference for sisCone7 - sisCone5

Jet p_T resolution: GenJet-CaloJet Level

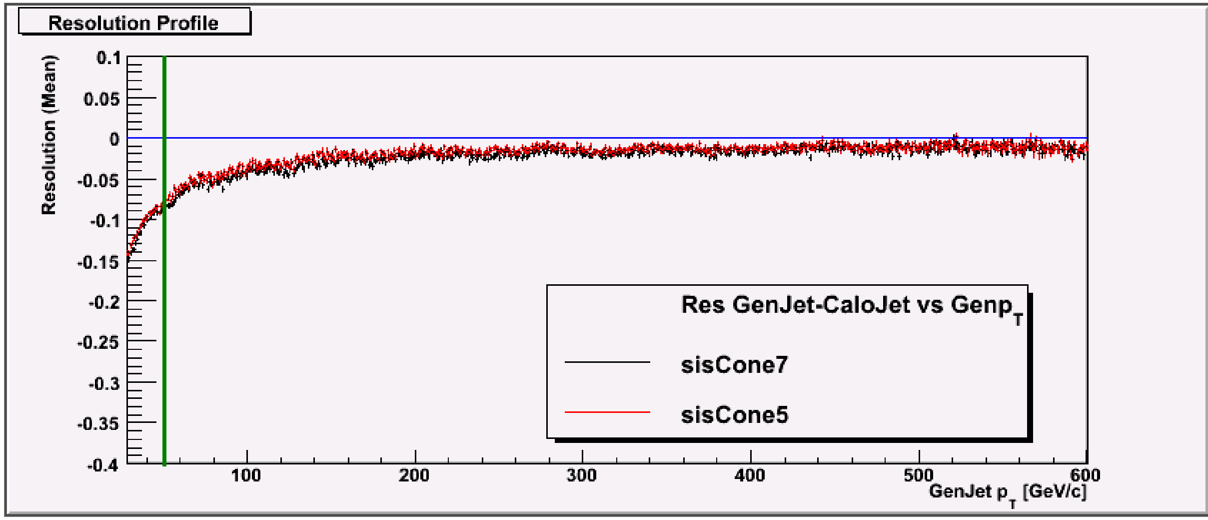
$$p_T\ \text{Resolution} = \frac{\text{GenJet}\ p_T - \text{CaloJet}\ p_T}{\text{GenJet}\ p_T}$$

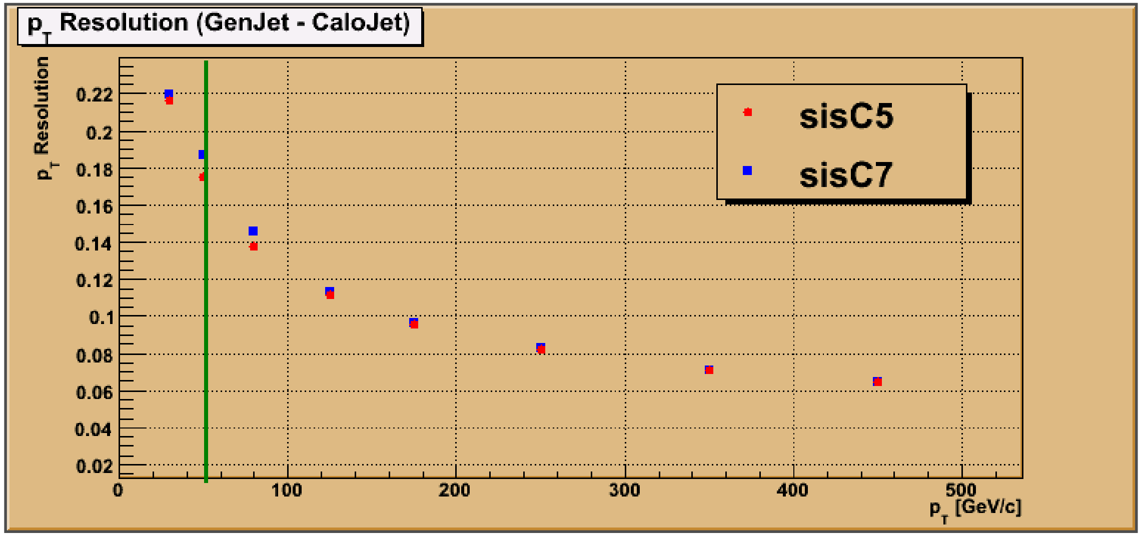
sisCone7 and sisCone5 algorithms do behave the same

At $p_T \approx 50$ GeV/c mean value is shifted by 8%

(CaloJet is overestimated)

Around 50 Gev/c p_T resolution ~18%





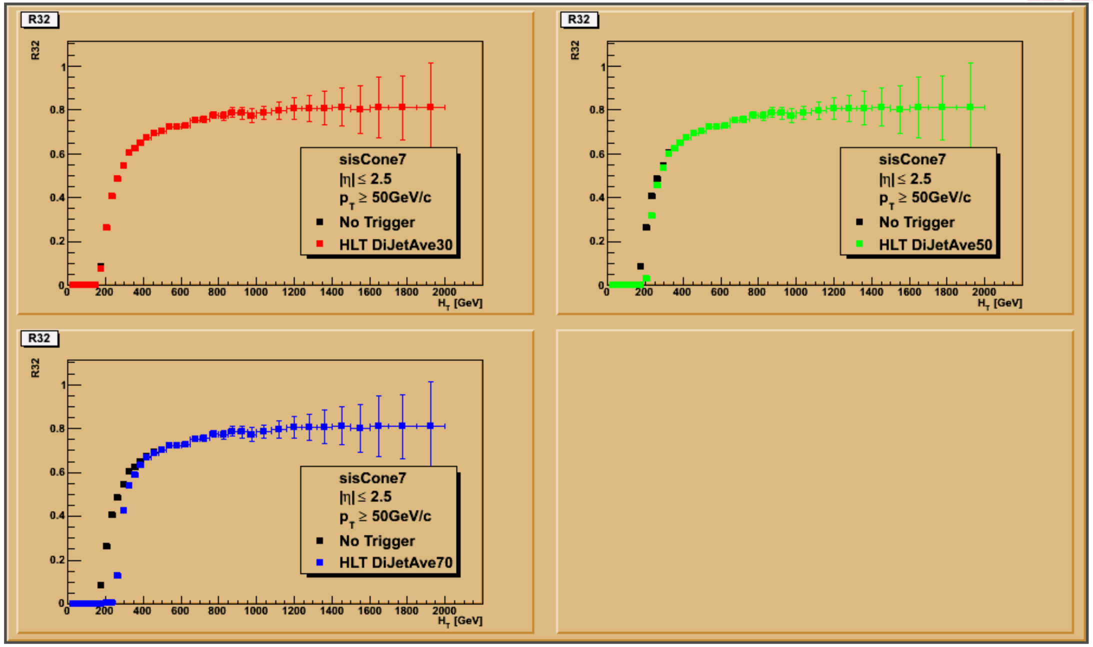
DiJetAve HLTs study

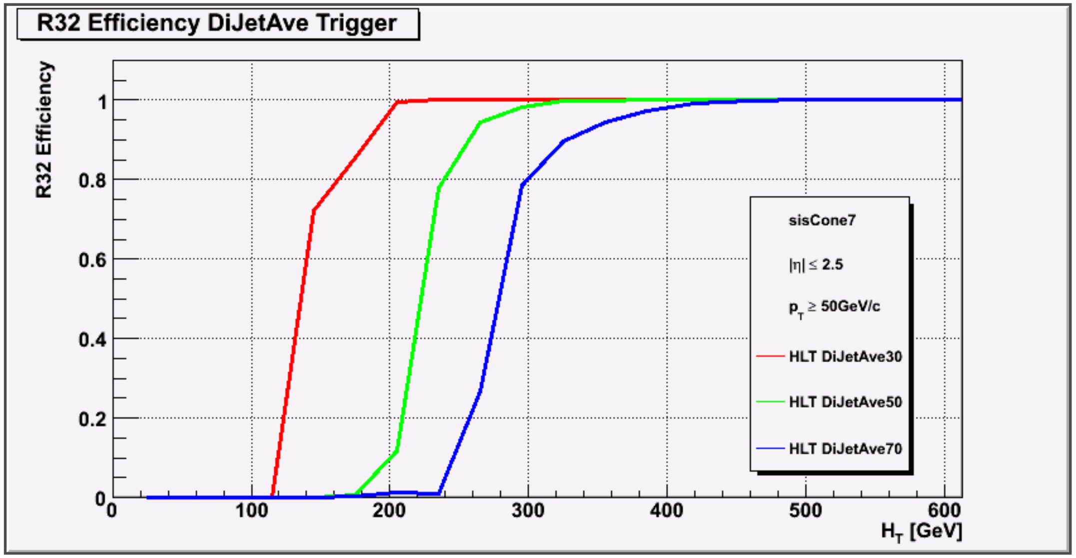
Study of DiJet HLTs.

- HLT DiJetAve30
- HLT DiJetAve50
- HLT DiJetAve70

Plot R32 after applying the HLTs

Evaluate trigger efficiency for ratio R_{32}



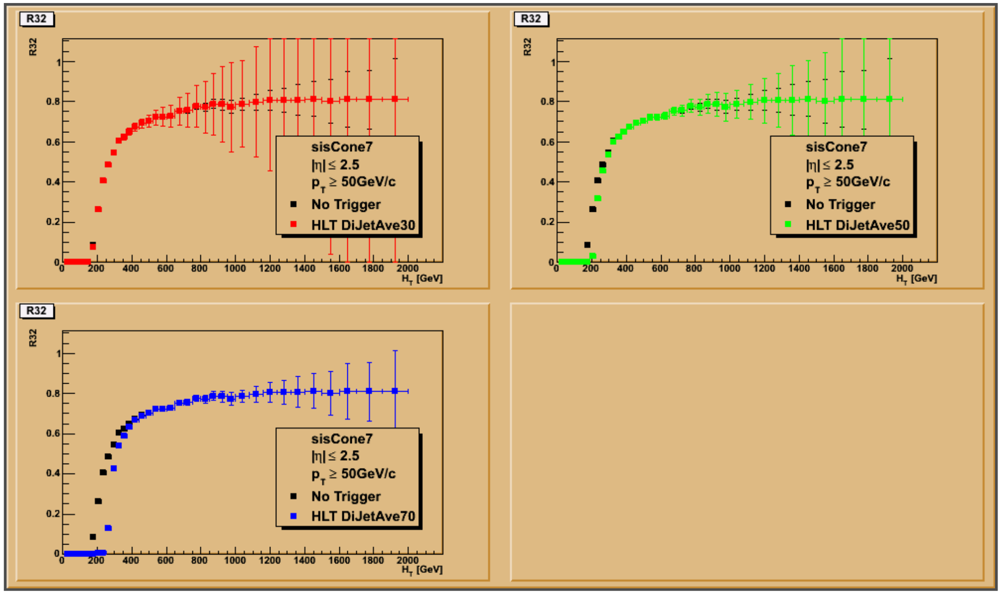


Trigger Path name	H_T [GeV] (100% efficient)
HLT DiJetAve30	200
HLT DiJetAve50	360
HLT DiJetAve70	500

Fully efficient from 200 GeV

DiJetAve HLTs study

Path name	L1 Trigger	Prescale (L1xHLT)
HLT DiJetAve 30	L1_SingleJet30	50x1
HLT DiJetAve 50	L1_SingleJet50	5x1
HLT DiJetAve 70	L1_SingleJet70	1



Combine DiJetAve HLTs for data collection:

- HLT DiJetAve30 (prescale 50x1)
- HLT DiJetAve80 (prescale 5x2)
- HLT DiJetAve110 (prescale 1)

Trigger scheme fully efficient from ≥200 GeV