Timing Toy MC

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Caltech Group Meeting

Toy MC

- A Toy MC is developed which simulates leading jets and rechits.
- Output of Toy MC is a root file similar to the data files used by our code to reconstruct leading jet vertex. So its output could be directly processed by timing algorithm.
- Many features of this Toy MC such as timing device resolution are adjustable.

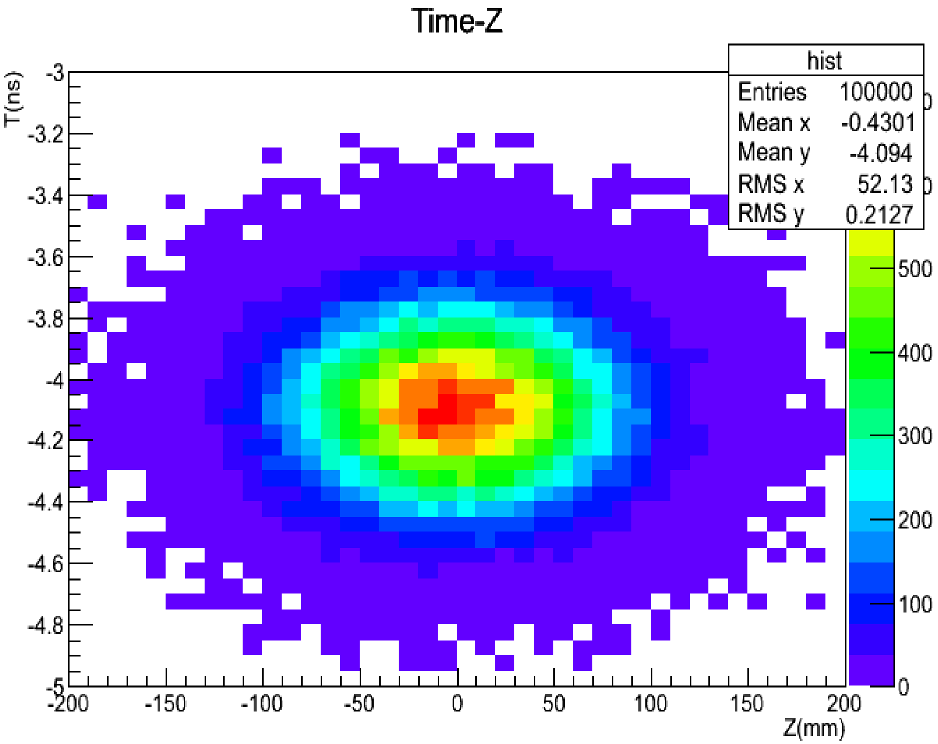
Vertex Distribution

- Two Gaussian bunches are crossing each other.
- Probability of existence of a vertex at a specific time and position is proportional to product of probability of existence of a proton in any of two bunches.
- So a Monte-Carlo simulation is performed to make the vertex distribution.

Vertex Distribution

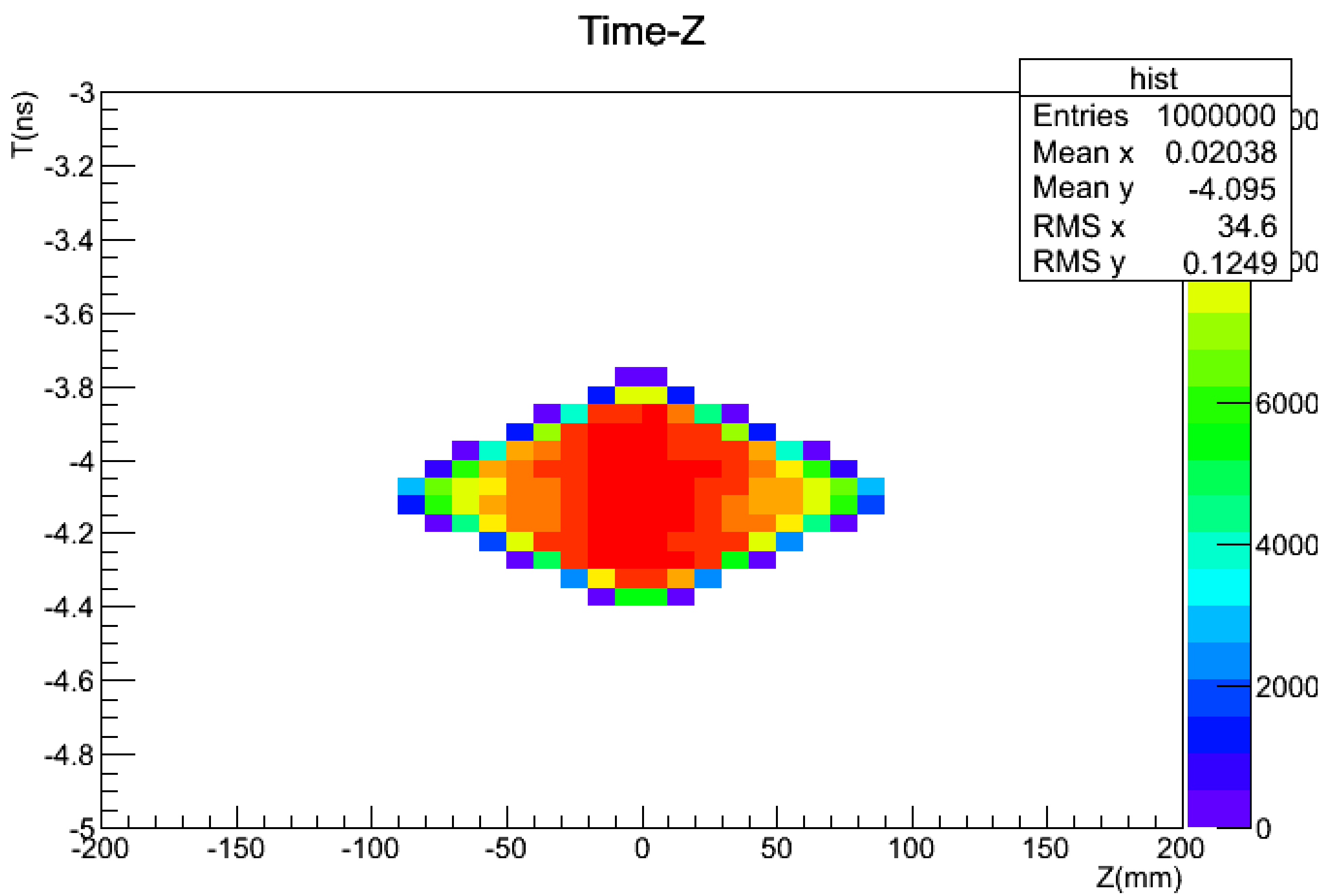
- Numbers are from: https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=208341
- PDF of protons inside a bunch is 3D Gaussian with

  σ⊥ = 19 μm and σ = 9 cm
- Total crossing angle = 295 μrad



Vertex Distribution

- Just for an example, If we had rectangular bunches:



Leading Jets

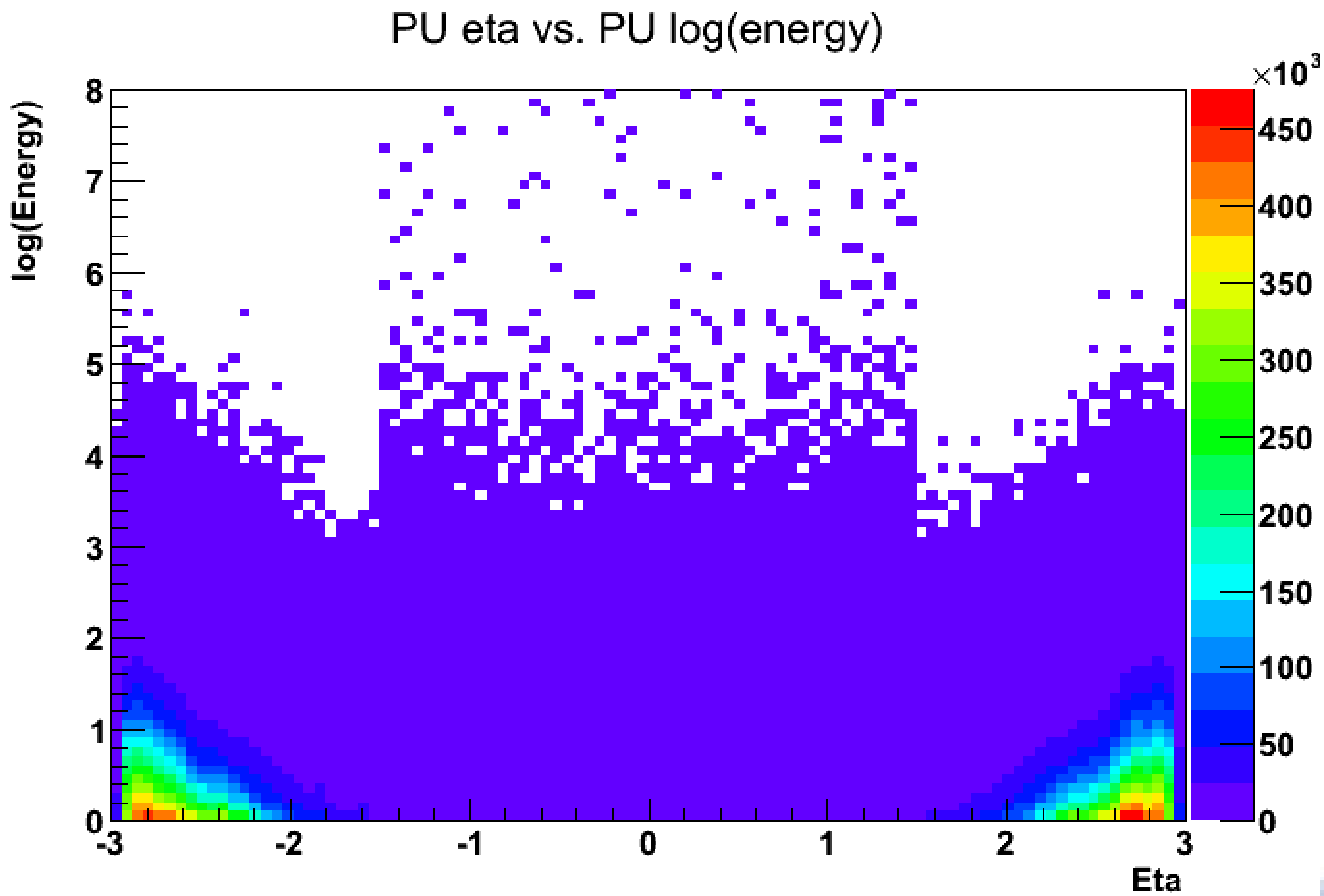
- Jet1 Eta vs Jet2 Eta in toy model→ Same as data
- Jet1 Phi vs Jet2 Phi in toy model→ Same as data
- Jet1 pT vs Jet1 #Rechits in toy model→ Same as data
- Jet2 pT vs Jet2 #Rechits in toy model→ Same as data
- Rechit Energy distribution → Same as data
- Tracker vertex distribution → From Vertex Distribution.
- Jets are wide, Rechits' phi distribution is a Gaussian with mean=Jet's Phi and Sigma=0.15
- Rechits' Eta distribution is a Gaussian with mean=Jet's Eta and Sigma=0.1
- Vertex Time → From Vertex Distribution.
- A Gaussian noise is added to each rechit time to simulate timing resolution.

Pile-Up

- From ZeroBias data we have:
  - Average of rechits with energy > 4GeV per PU Vertex = 0.58
- Number of PU Vertices: 20 for Current LHC and 140 for HL_LHC.
- We throw PU rechits with the same eta and energy distribution as data.

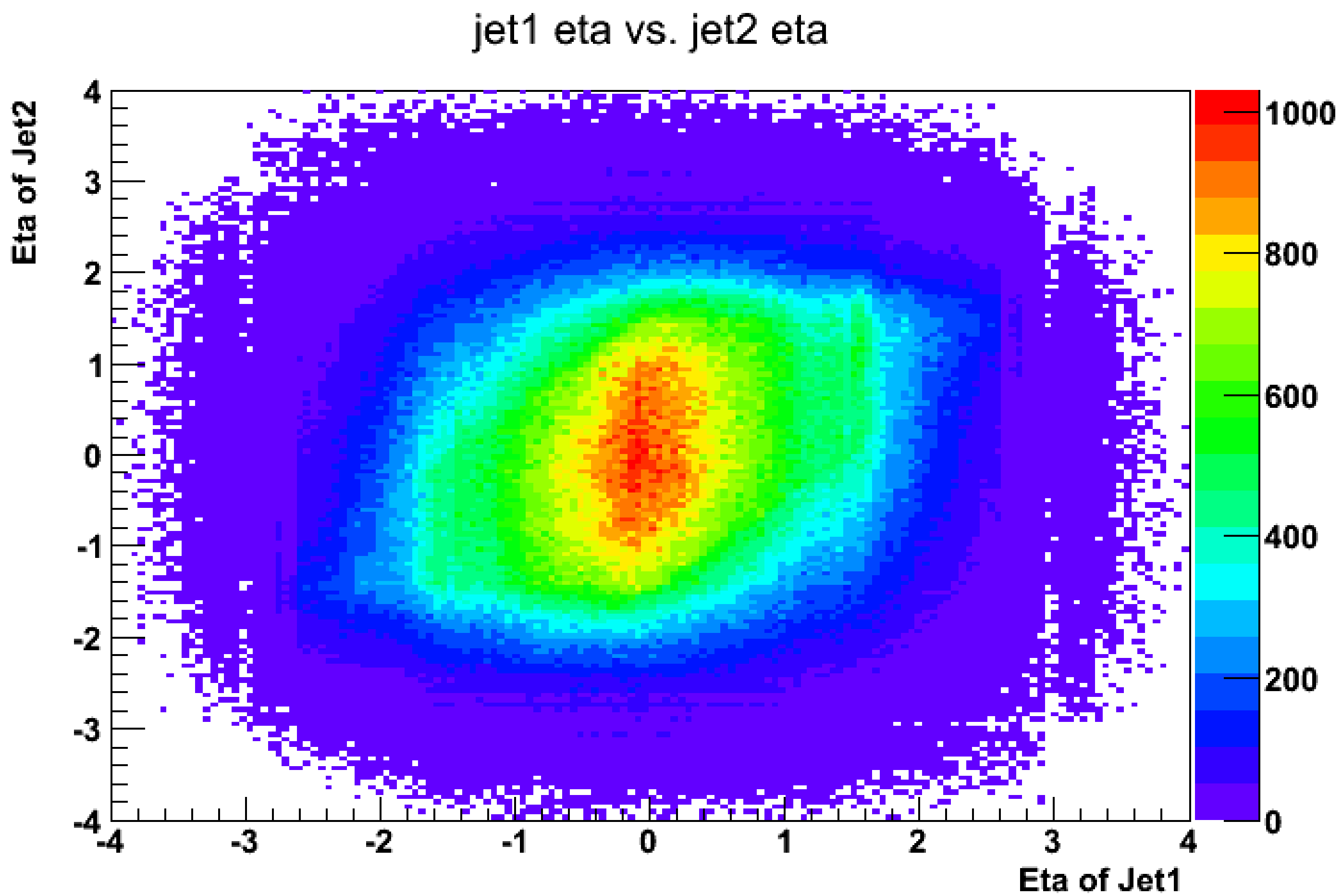
Pile-UP

- Eta and Energy Distribution :
- Most of Pile-UP Rechits are in endcaps.



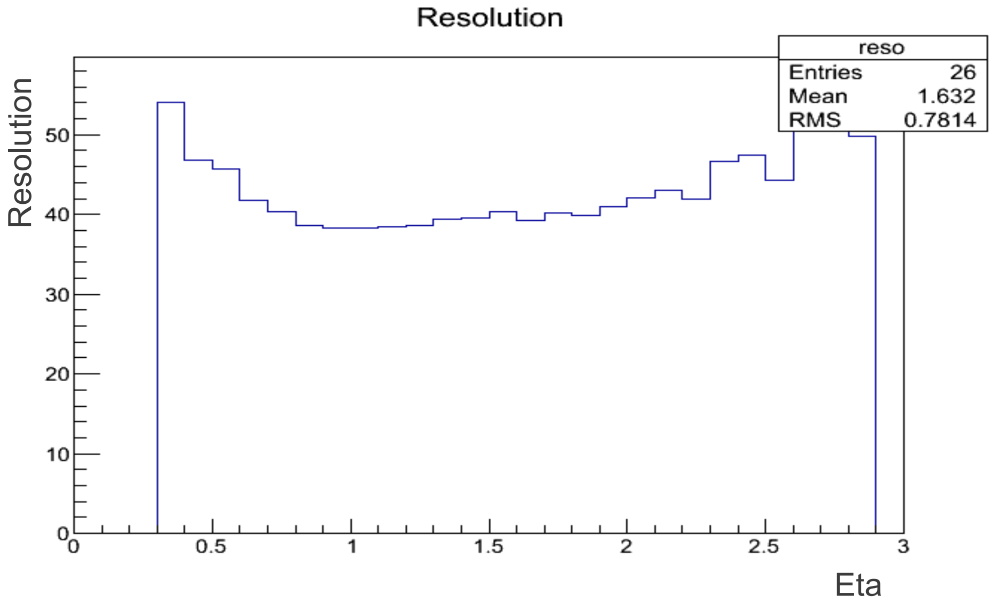
Jet's Eta

- But pile-up rechits' distribution is totally different from leading jets' eta distribution:



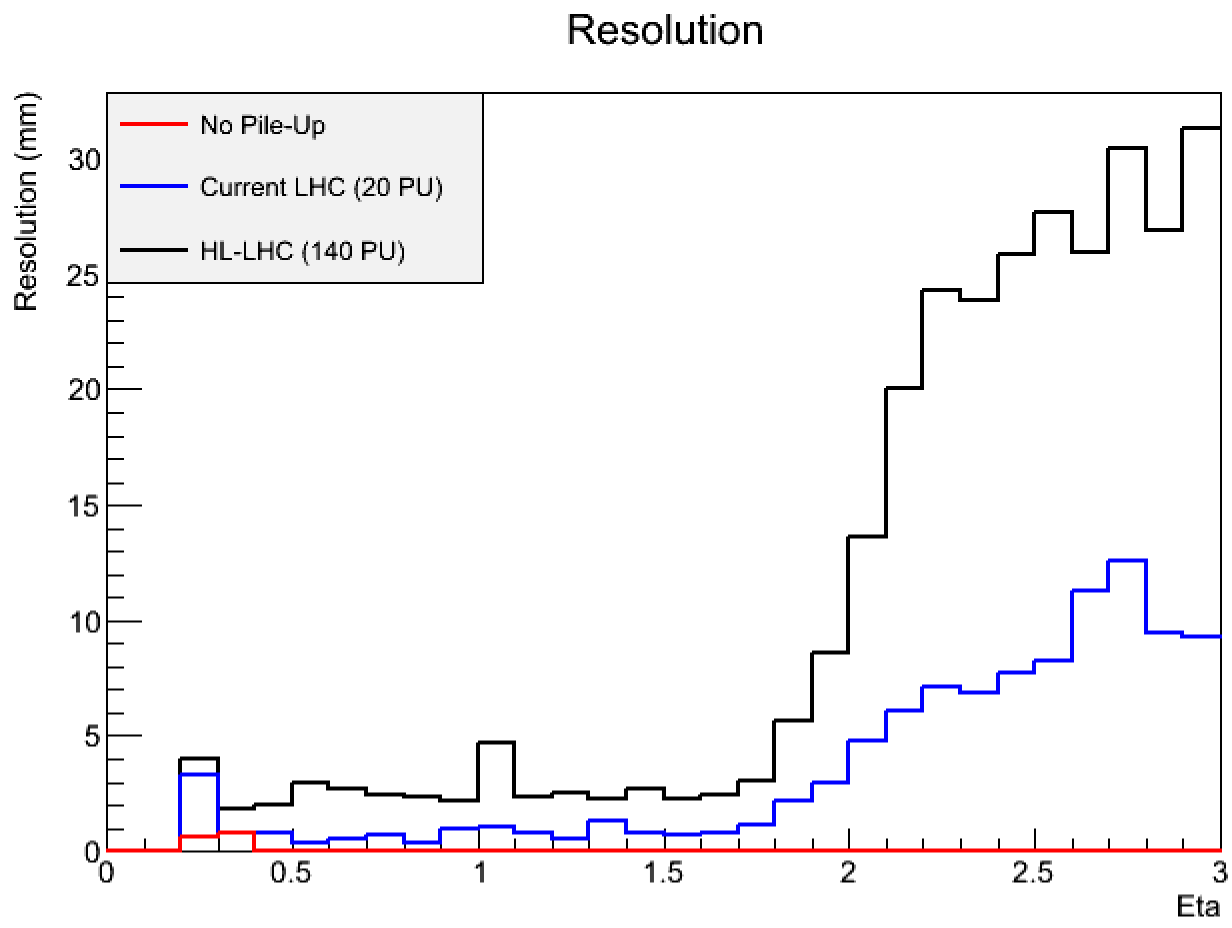
Results

- Results are shown as Resolution vs. Eta diagrams for different timing device resolutions and for different PU vertex numbers.
- In the following slides we assume that two leading jets are back to back with uniform eta distribution instead of real distribution to have good resolution vs. eta plots.
- For future comparison to results from data it is a sample from data:

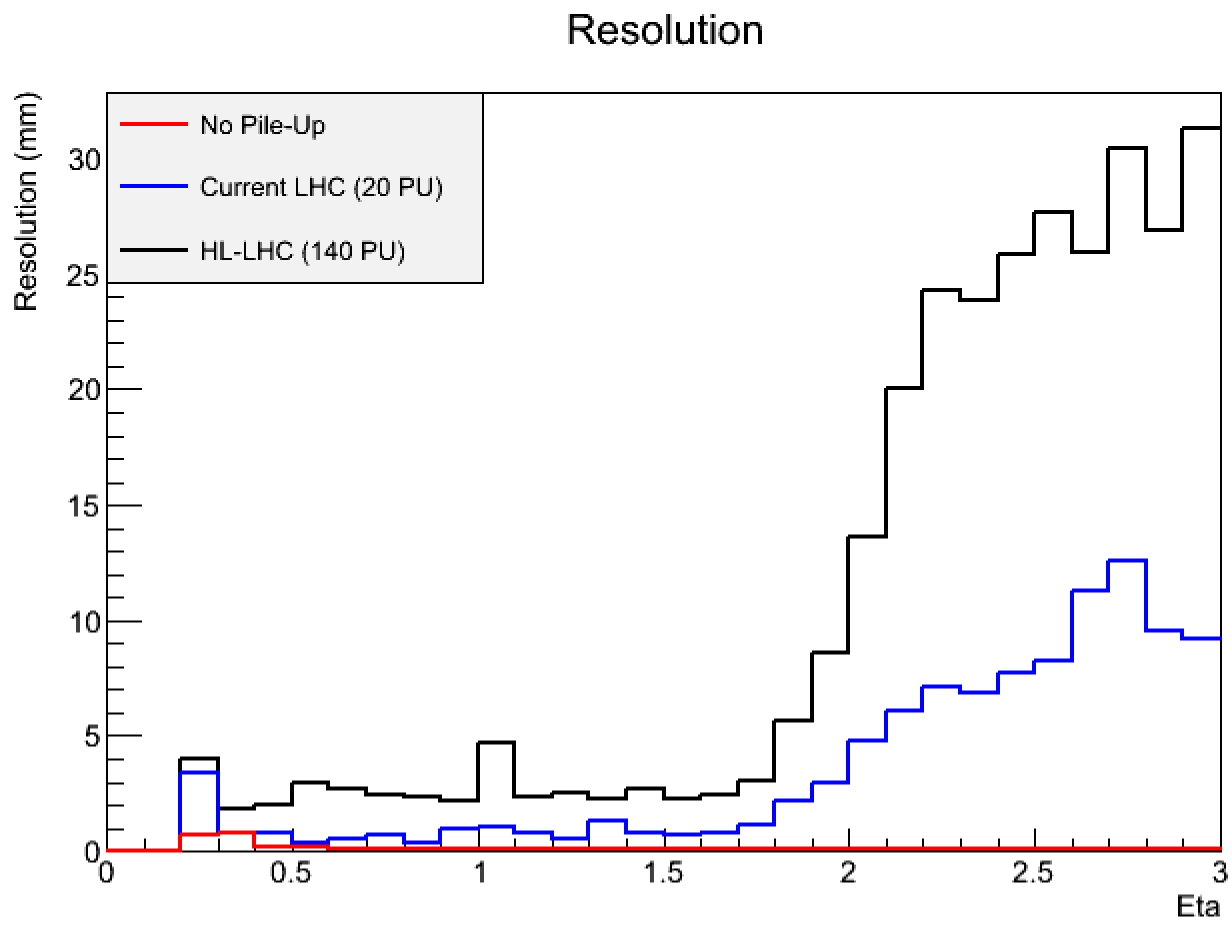


Results- Device Resolution = 0ns

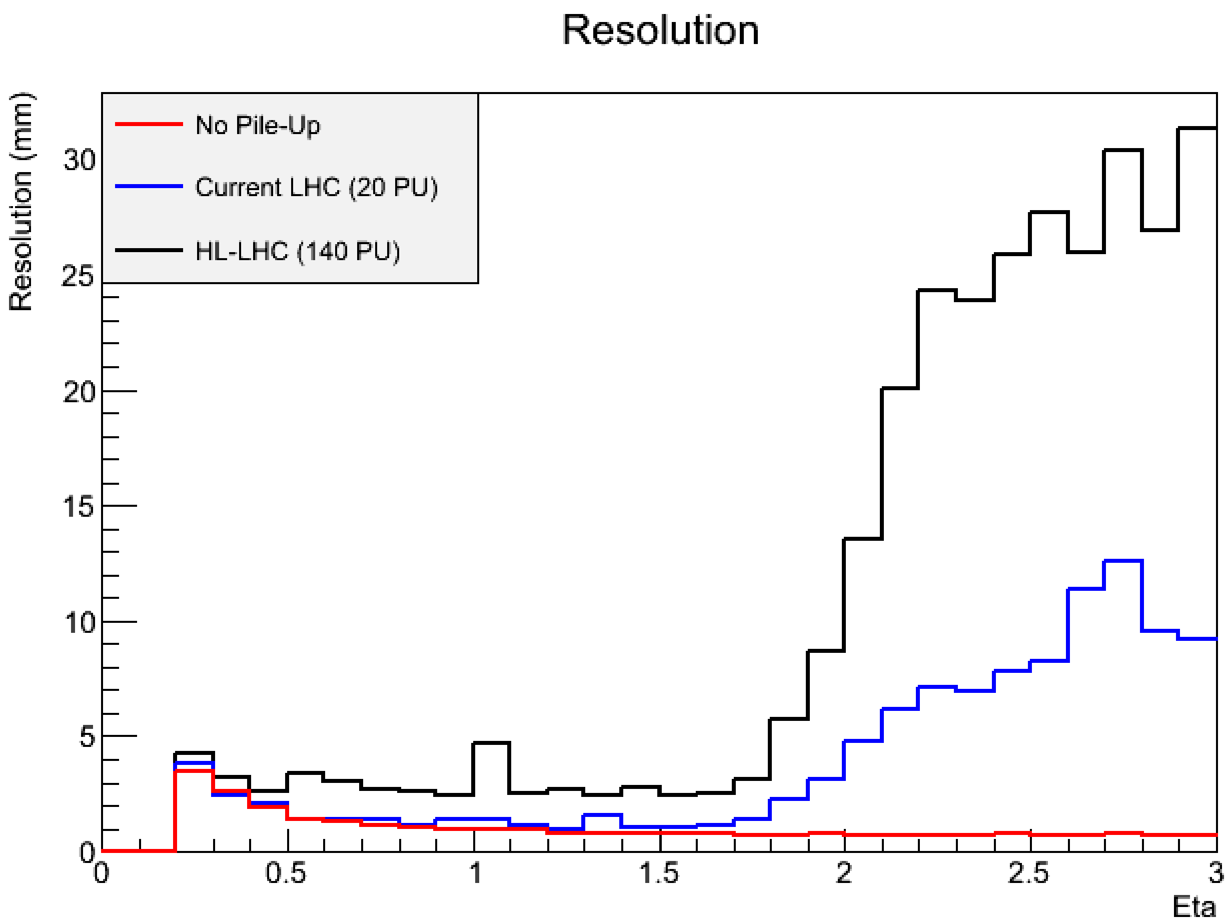
Pile-Up activity deteriorates resolution for large eta.



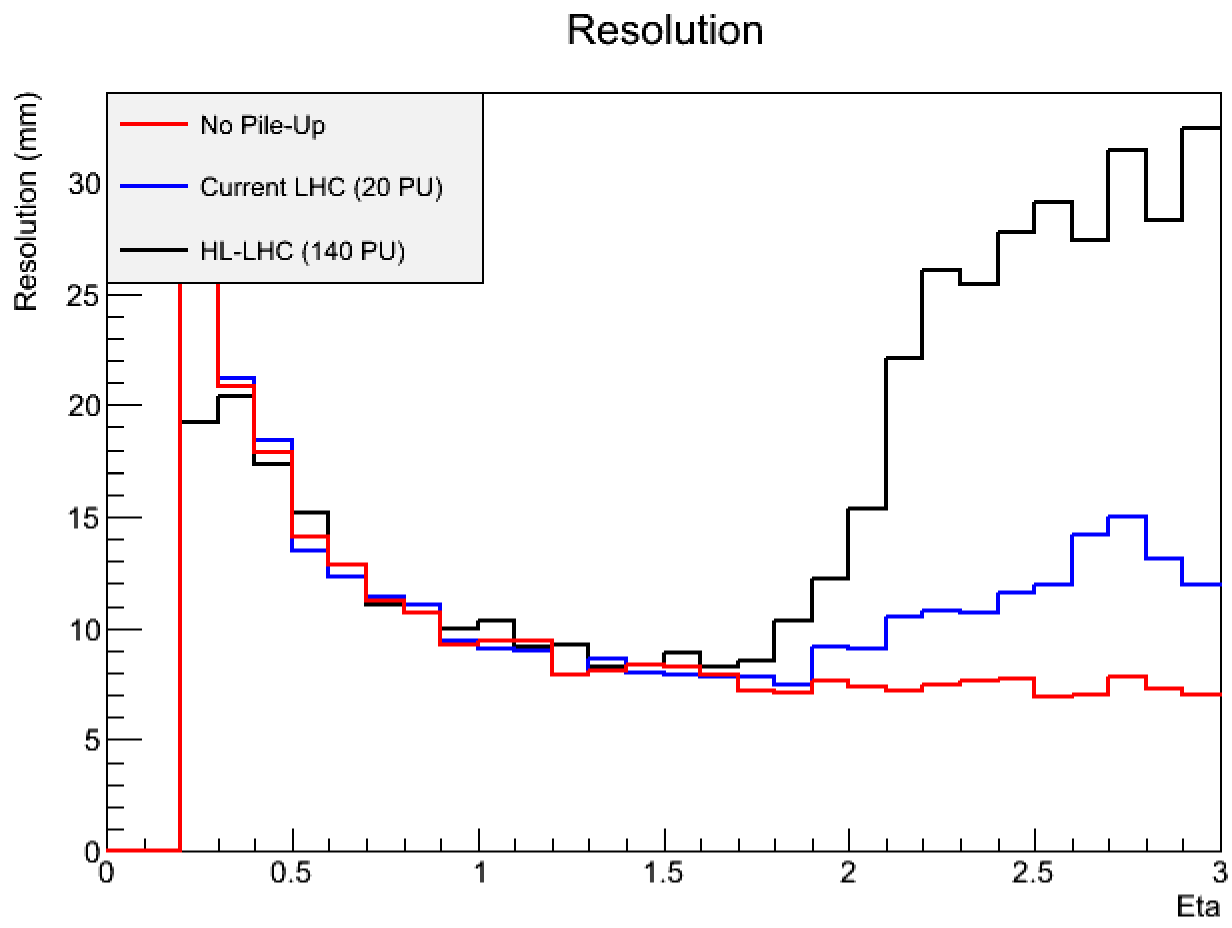
Results- Device Resolution = 0.001ns



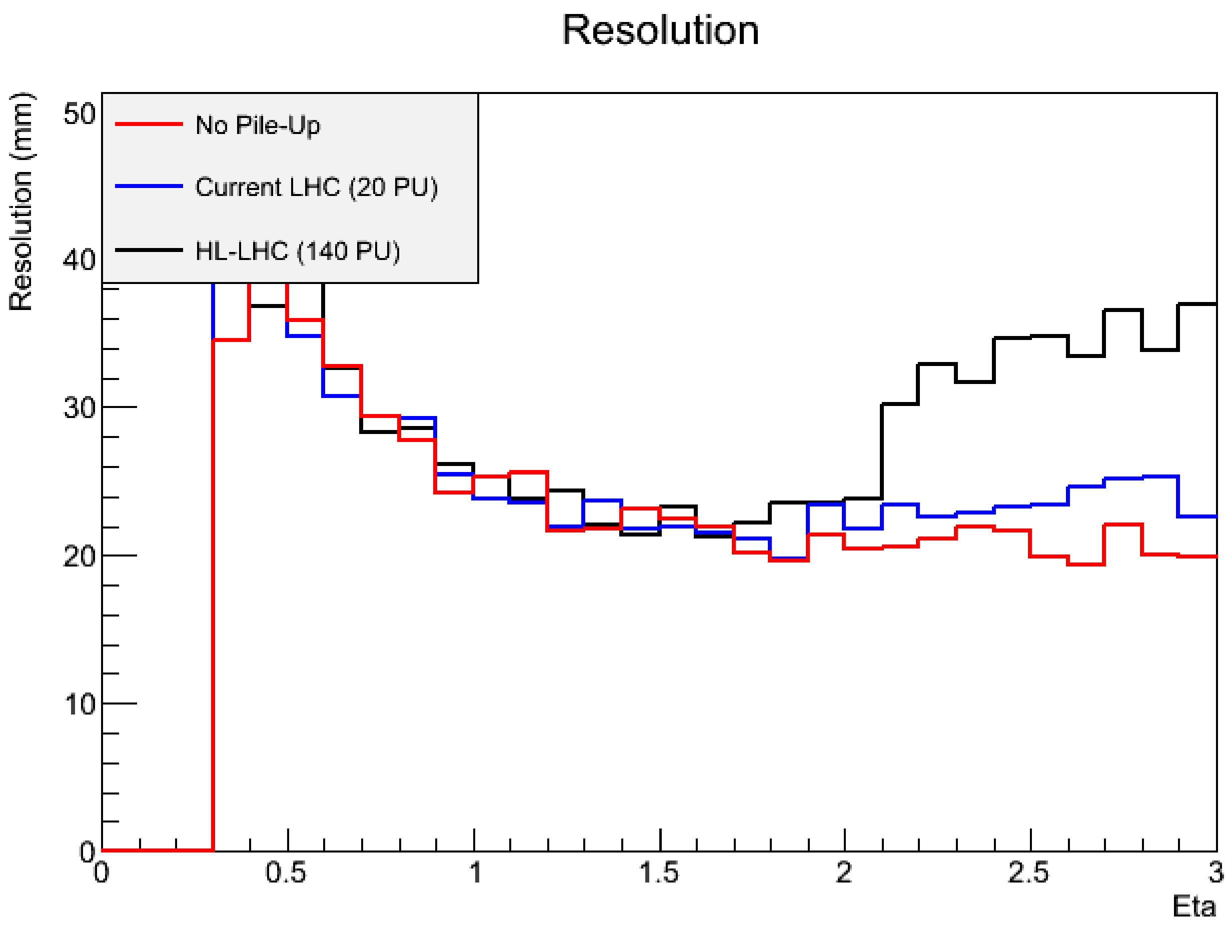
Results- Device Resolution = 0.01ns



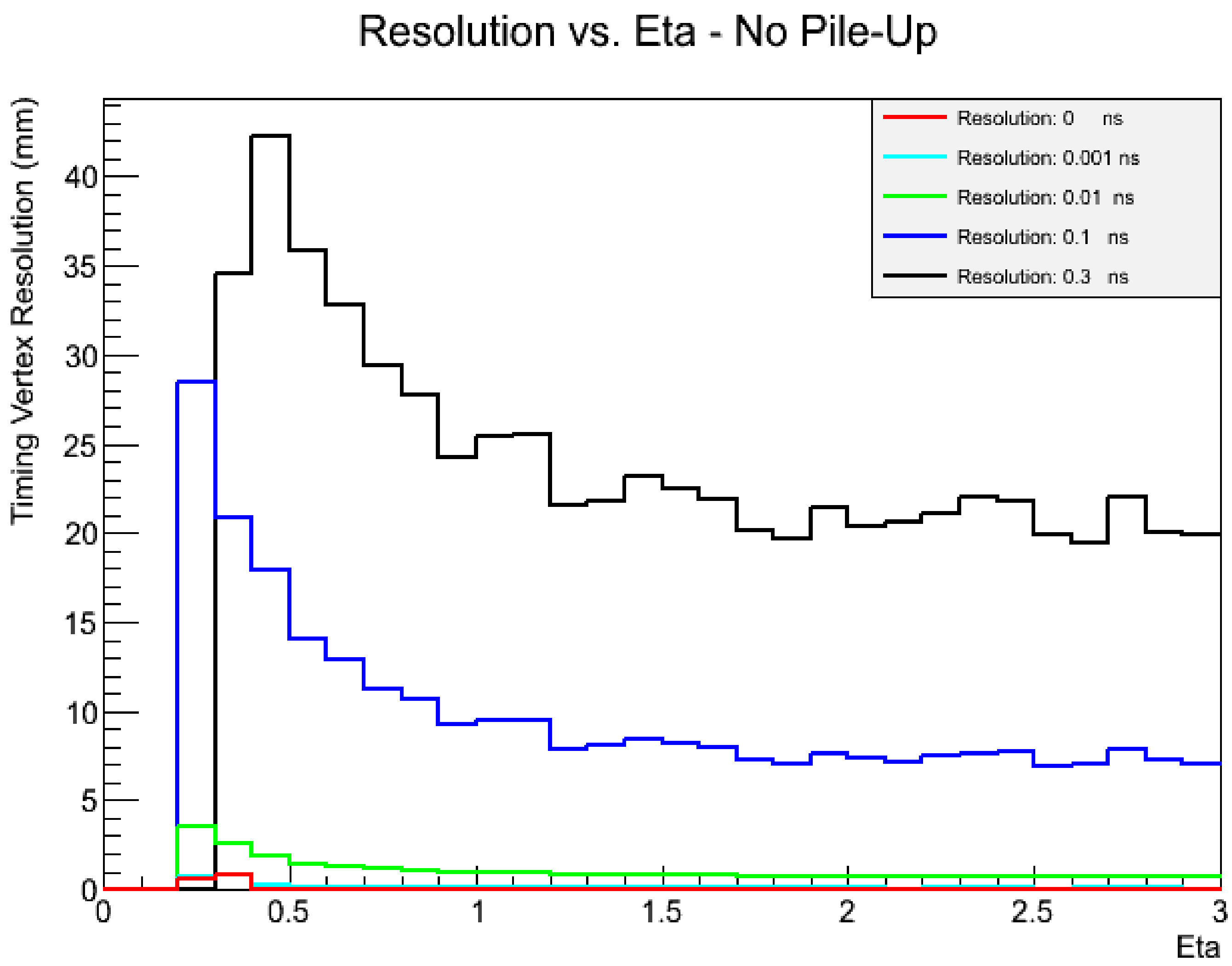
Results- Device Resolution = 0.1ns



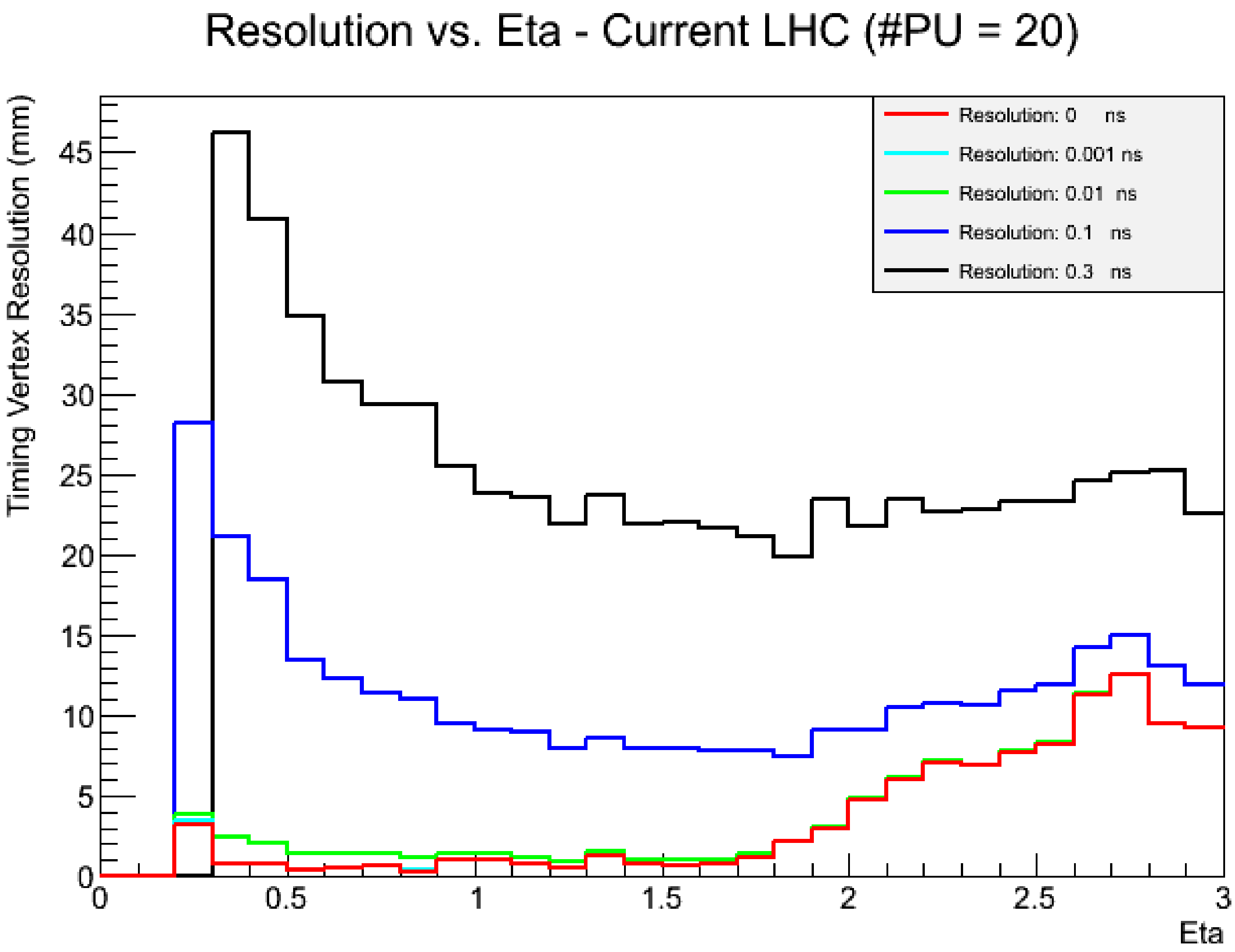
Results- Device Resolution = 0.3ns



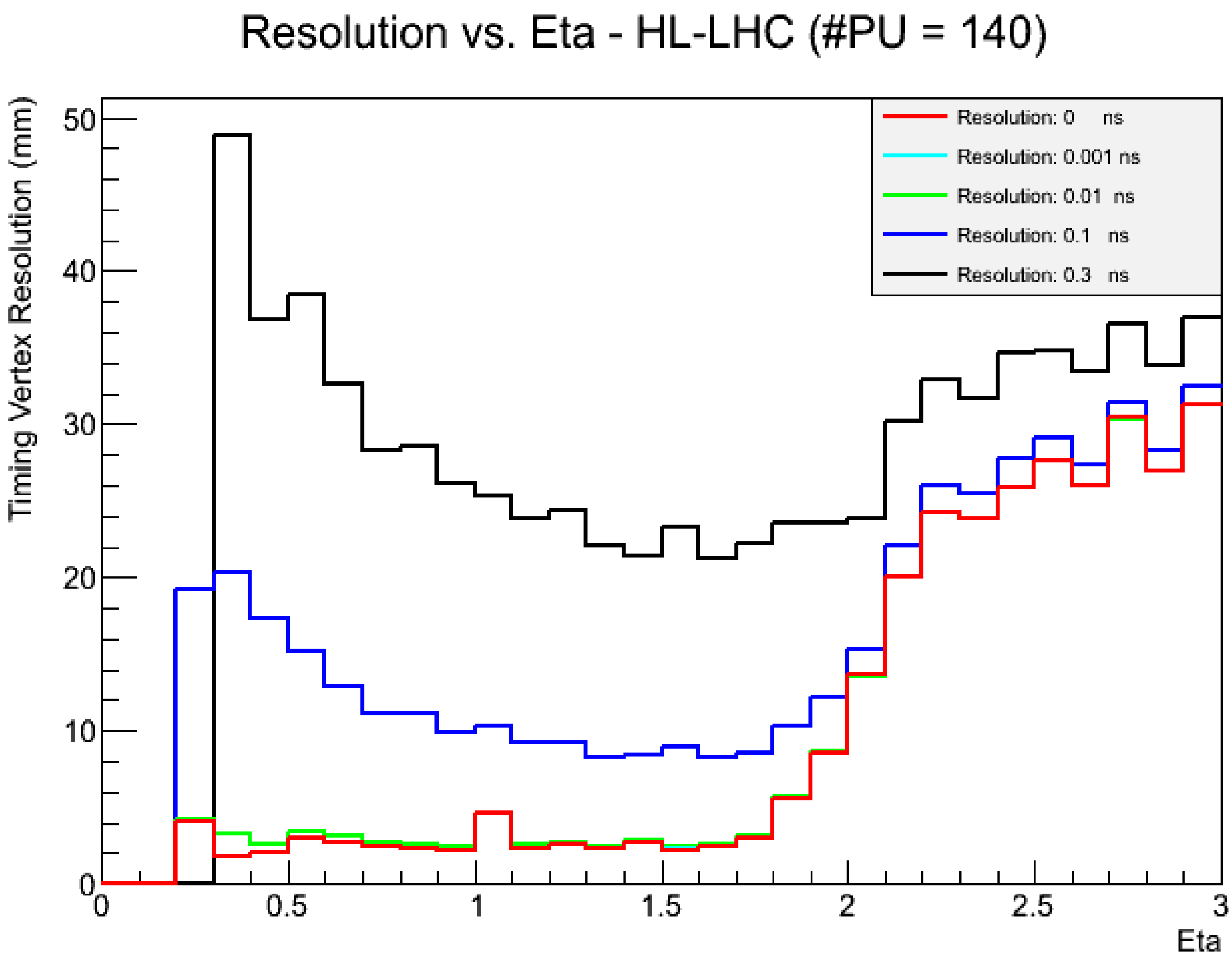
Results- No Pile-Up



Results- 20 Pile-Up Vertices

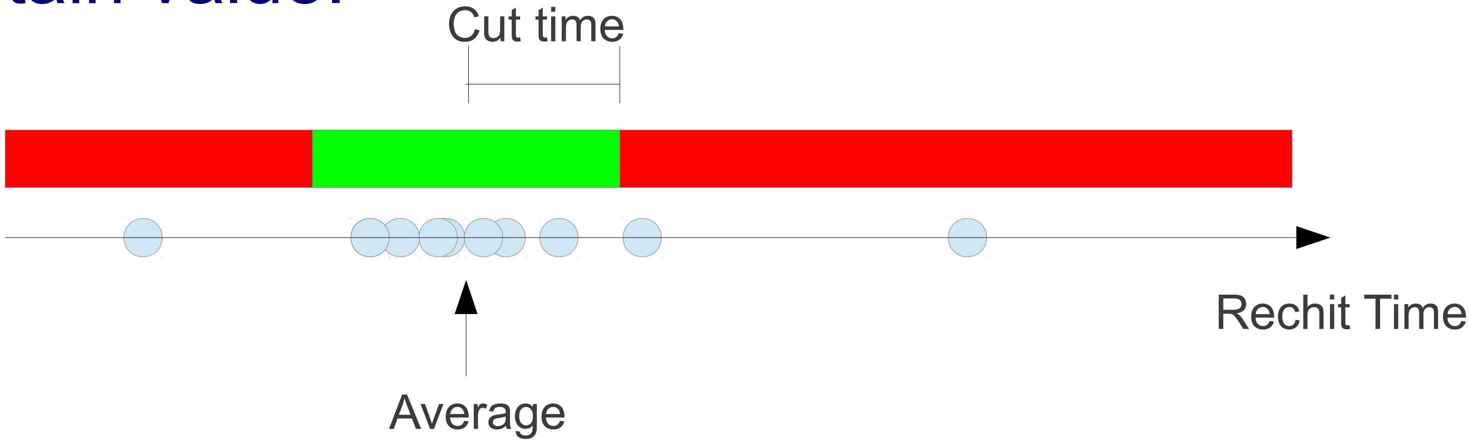


Results- 140 Pile-Up Vertices



Rejecting Pile-Up Rechits

- We can find weighted average of time of rechits for each jet.
- Weight function is square root of rechit energy.
- Having this mean time, we could reject rechits that their time difference to mean time is larger than a certain value.



Simulation

- In our ToyMC we can mark PU Rechits, so we could easily identify them and check efficiency of our algorithm for rejecting PU Rechits.
- In this simulation we just consider jets with more than 8 rechits in *high pile-up events (#PU vertices = 140)*
- There are two important values that we could plot vs. time of cut:

1. Average number of wrong rejection of jet rechits.
2. Average number of PU Rechits which are not filtered.

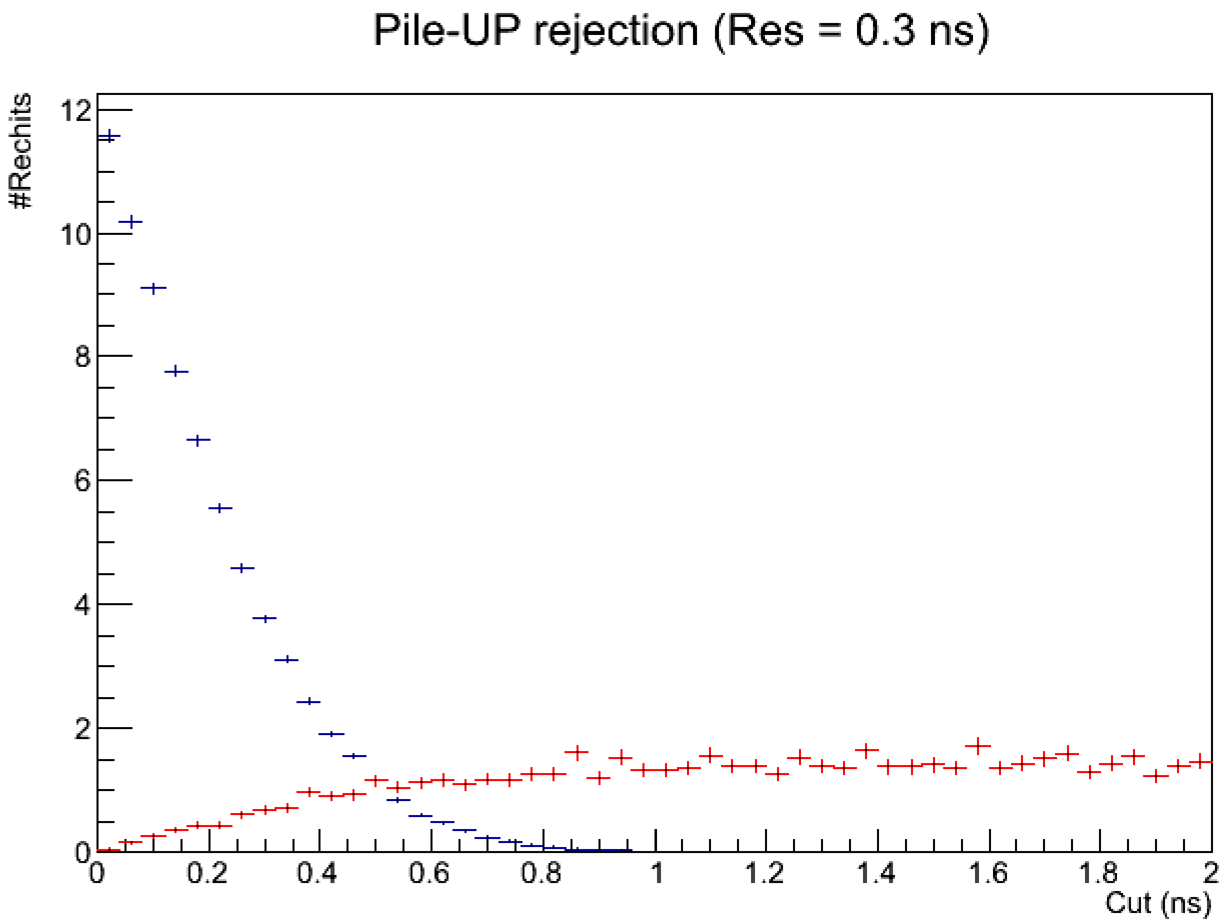
- **We must aim to minimize these two numbers.**

Simulation Results:

#Rechits vs. time of cut (if ***|rechit time – mean time| > time of cut*** rechit will be rejected) – Timing device Resolution = 0.3 ns.

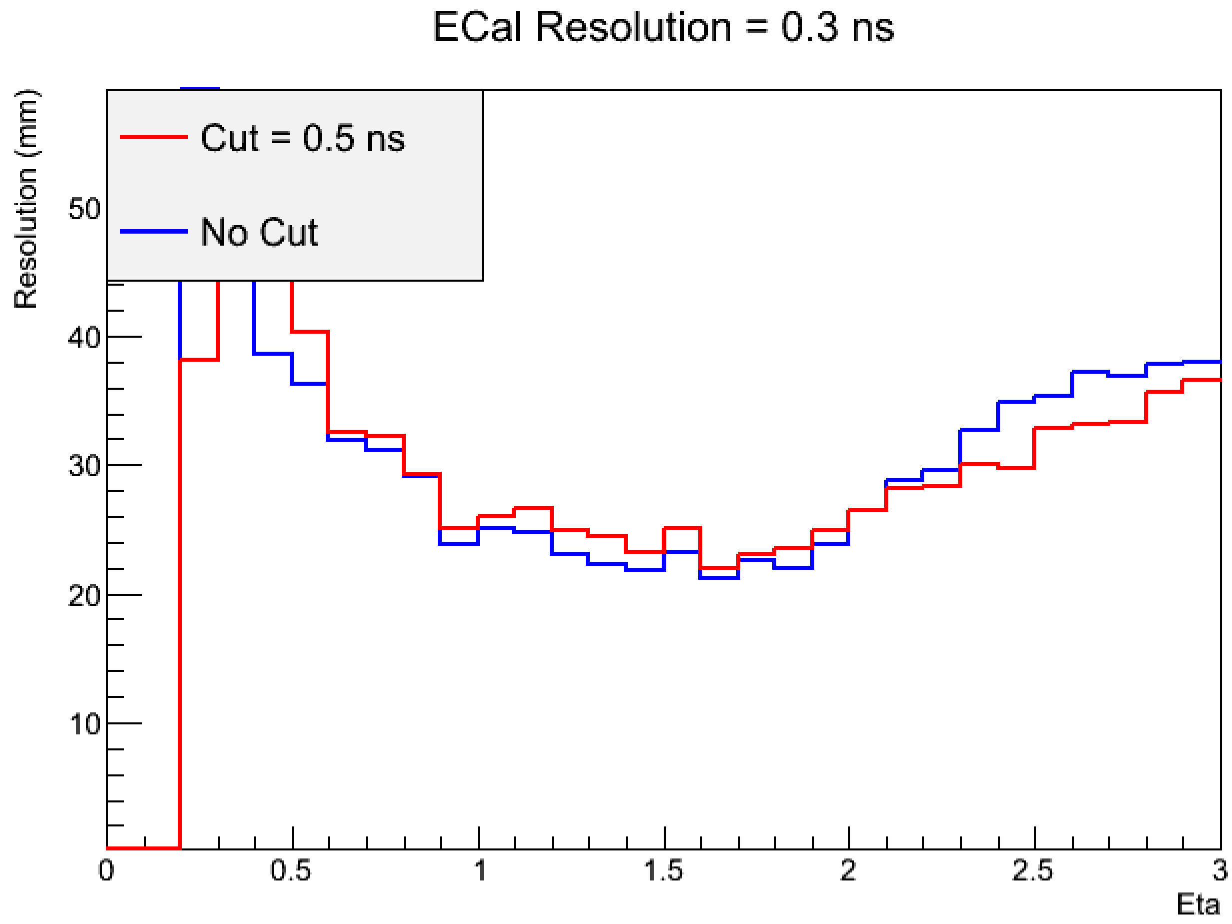
- Blue: Average number of wrong rejection of jet rechits.

Red: Average number of PU Rechits which are not filtered.



Simulation Results:

- Resolution = 0.3 ns. Cut = 0.5 ns.
- Number of reconstructed vertices reduced by a factor of 0.88 .

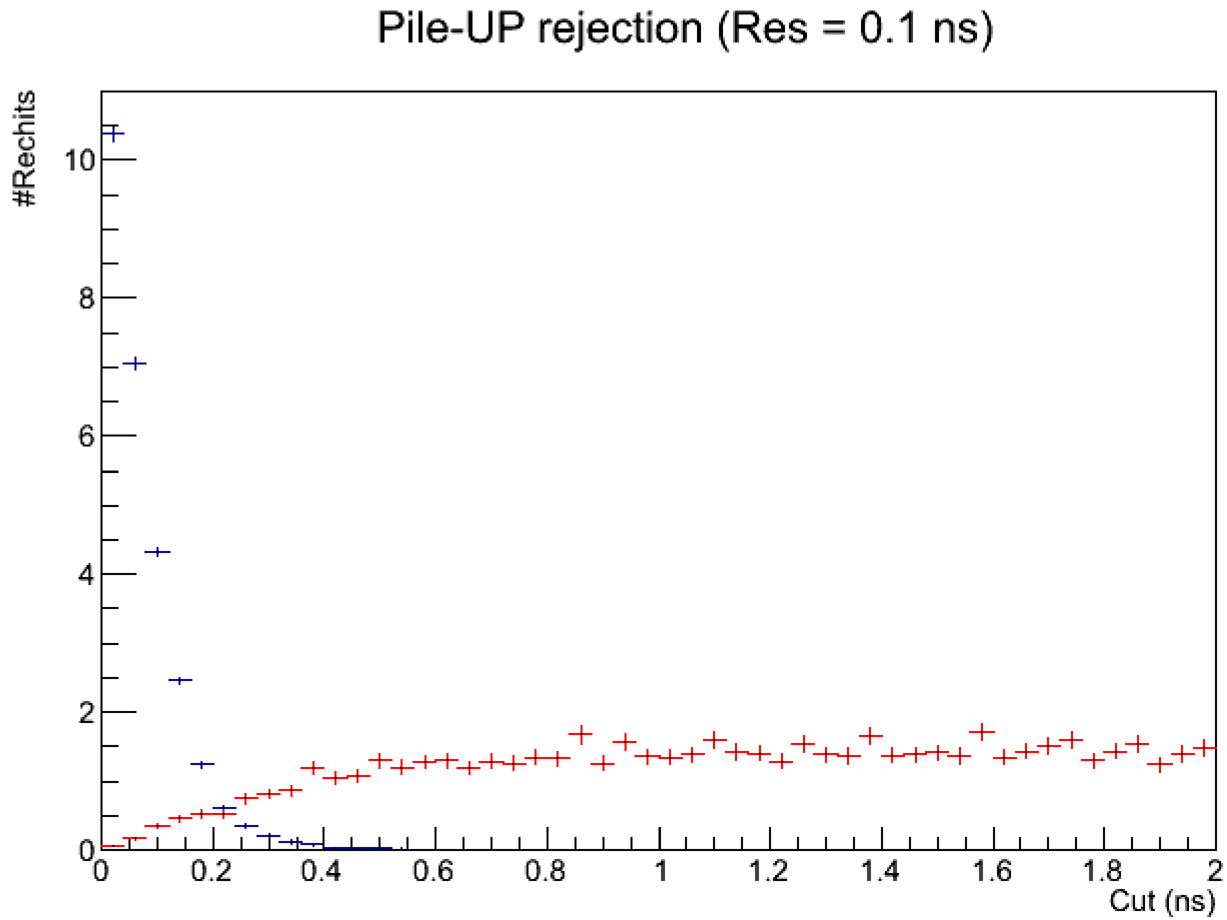


Simulation Results:

#Rechits vs. time of cut (if ***|rechit time – mean time| > time of cut*** rechit will be rejected) – Timing device Resolution = 0.1 ns.

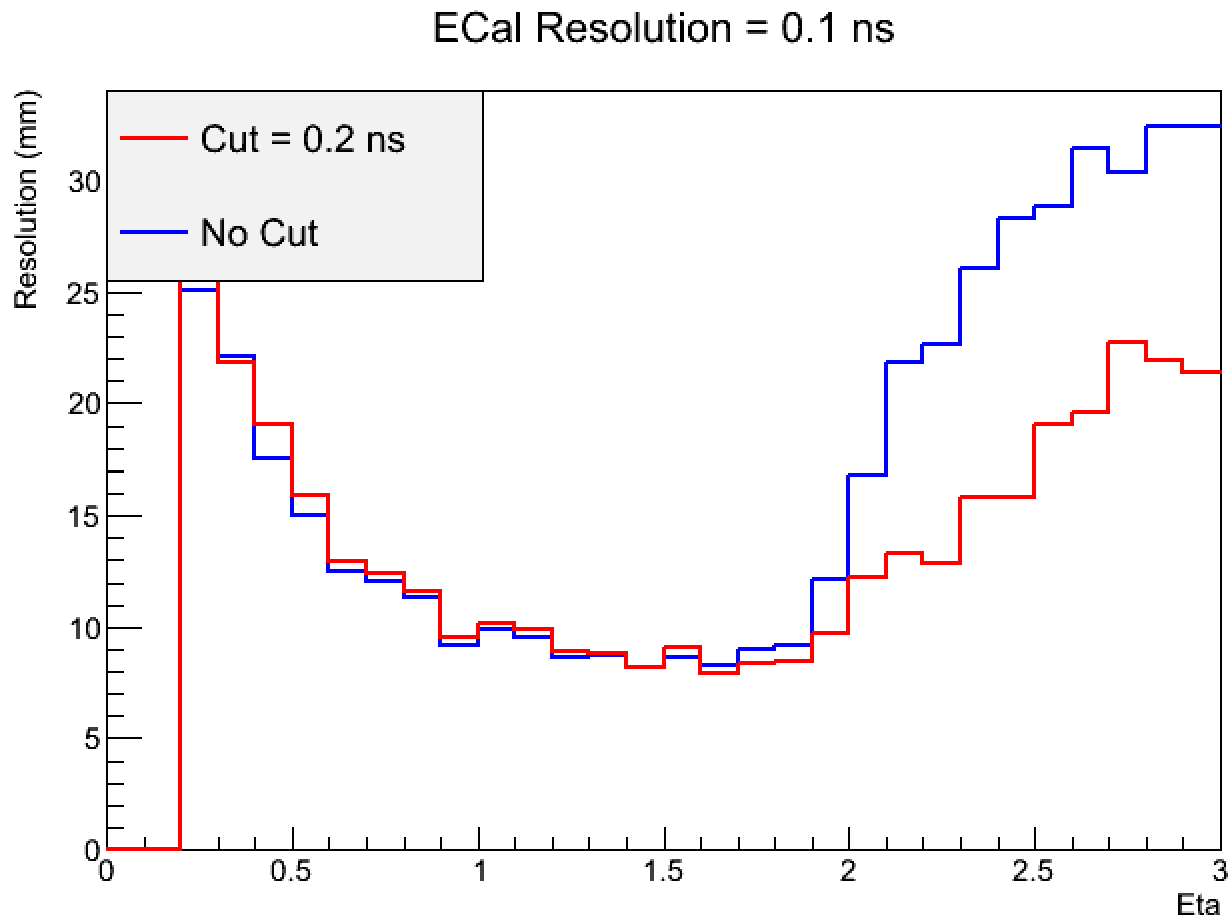
- Blue: Average number of wrong rejection of jet rechits.

Red: Average number of PU Rechits which are not filtered.



Simulation Results:

- Resolution = 0.1 ns. Cut = 0.2 ns.
- Number of reconstructed vertices reduced by a factor of 0.83 .

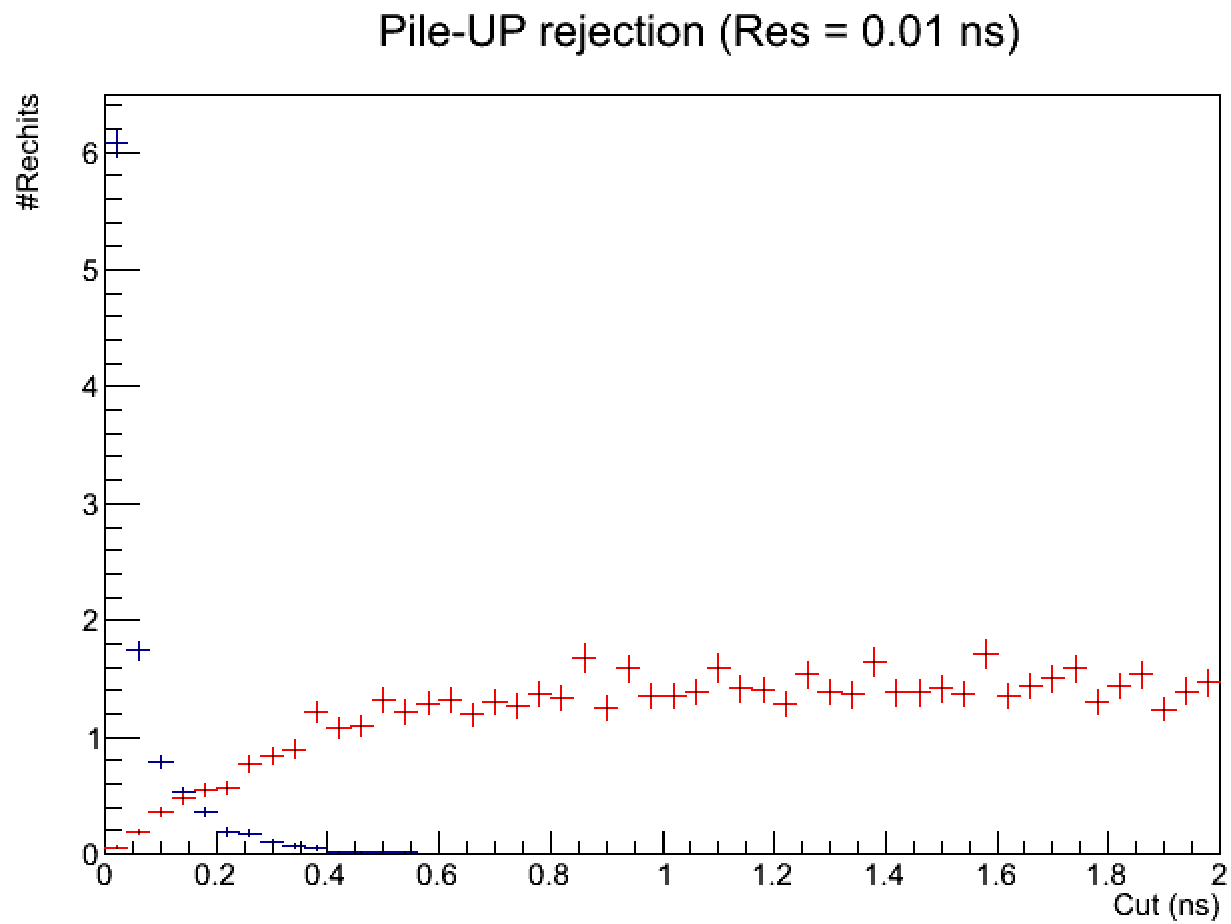


Simulation Results:

#Rechits vs. time of cut (if ***|rechit time – mean time| > time of cut*** rechit will be rejected) – Timing device Resolution = 0.01 ns.

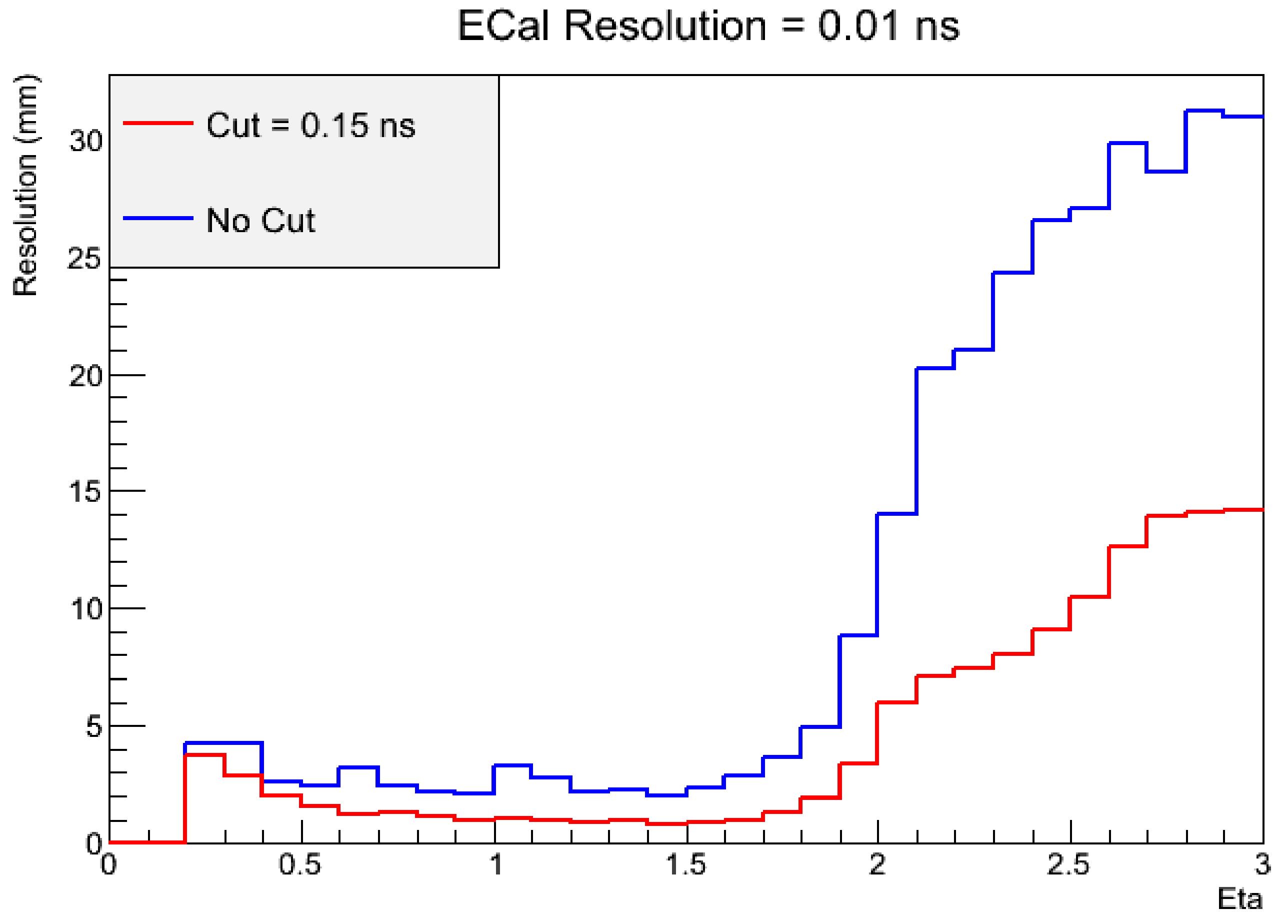
- Blue: Average number of wrong rejection of jet rechits.

Red: Average number of PU Rechits which are not filtered.



Simulation Results:

- Resolution = 0.01 ns. Cut = 0.15 ns.
- Number of reconstructed vertices reduced by a factor of 0.84 .



Simulation Results:

It seems that we should have a better timing resolution in order to have a good filter.

Next

- Considering rechits with energy < 4GeV.
- Better timing algorithm to reject pile-up rechits.