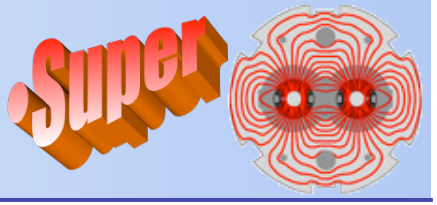




# SLHC Simulation Studies Status

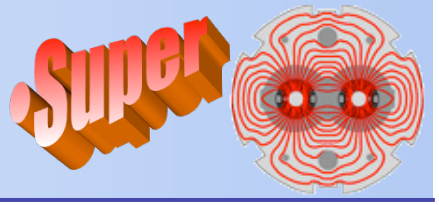
Michael Weinberger

September 15, 2009

# Current Status

- Two main Strawmen available
  - https://twiki.cern.ch/twiki/bin/view/CMS/SLHCTrackerSimuSoftTools#Quick_Links
- Hybrid and Longbarrel
- Can add in tracker trigger stubs and tracklets
- Can add in SLHC Calorimeter Clusters
  - Gives isolated and non Electrons and Taus
  - Tunable parameters for creation of clusters
- Material still needs to be put in correctly in Fullsim, then tuned in Fastsim
- Currently in CMSSW_2_2_6
  - Will move to 3_1_X after Oct Workshop

# Modifiable options in layout

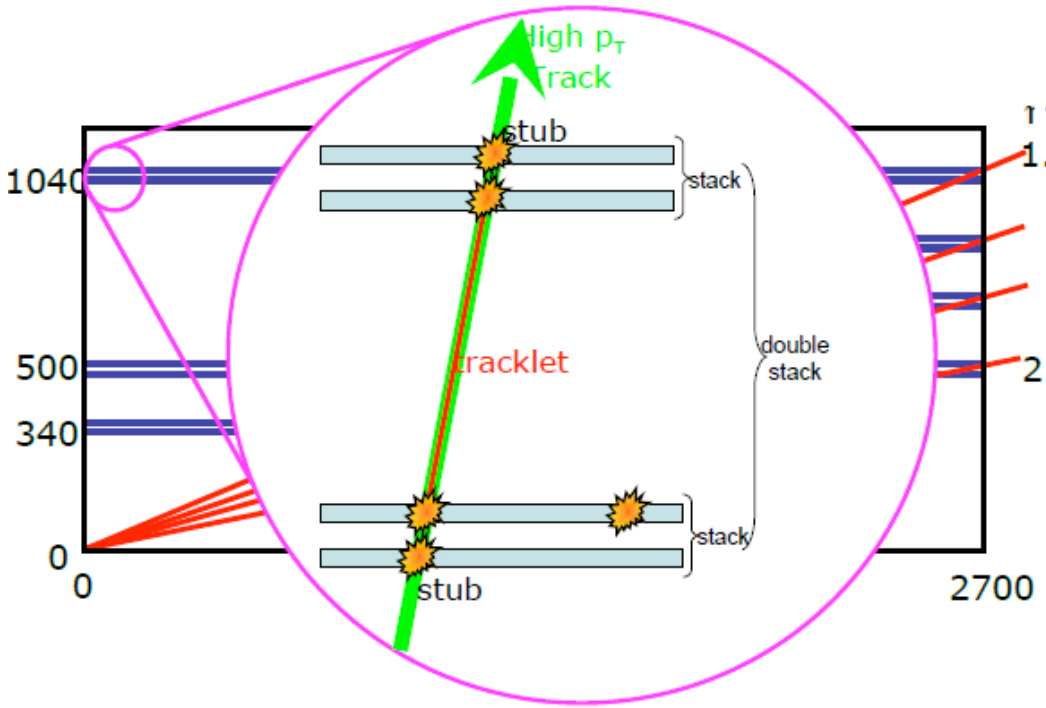



- Geometry code has been modified so that all changes can now be made in xml files, now the .cc or .h files
- Work on implementing inefficiency is in progress and almost done
- Directions on Twiki to remove or add layers

- Layer
  - Radius
  - Number of Ladders
- Ladder
  - Length
  - width
  - Number of modules
- Stack
  - Distance between stack layers
- Modules
  - Size of Module
  - Number of chips in X and Y
  - Number or rows/columns in a chip
- Pixel size
  - Not a direct parameter, calculated from number of rows/columns per chip, Chips in X and Y, and module size [either width, or length of ladder and number of modules]

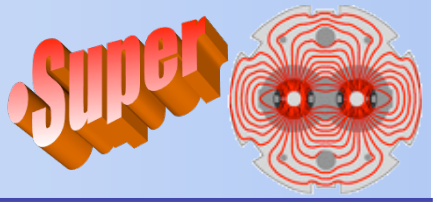
# Introduction

- Track Trigger Primitive Terminology




Stack:pair of closely spaced sensors (~1mm)
Stub:correlated pair of hits in stub
Double stack:Two stacks separated by few cm.
Tracklet A matched pair of stubs.

A layer is one stack in this talk.

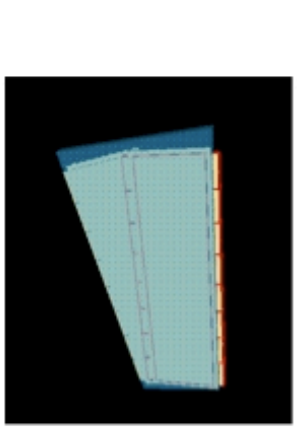

# Tracking Performance Results from Simulation Studies of Phase 2 Upgrade Geometries

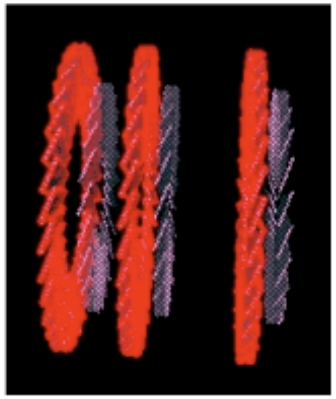
*Harry Cheung* (*Fermilab*)

# Phase 1 Forward Pixel Geom

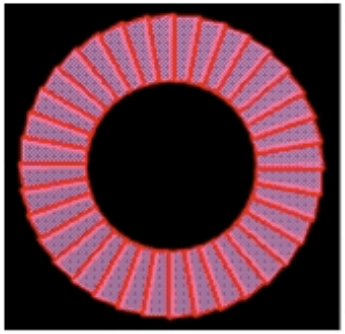
## Progress on Phase 1 FPIX

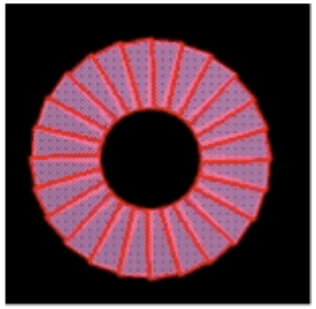
- First version of "real" Phase 1 FPIX geometry, Iguana plots (preliminary)





Blades arranged into inner and outer disks (YZ plane and XY plane)





Blade: Two 2x8 modules on opposite side of TPG substrate

Layout of inner and outer disks

Pratima Jindal

Tracker Upgrade Phase 2 Layout Intermediate Review 24 July 2009, H. W. K. Cheung (FNAL) 9

First FPIX done in end of July. Still need material implementation.

Need to fully test in the Full simulation and make it work in the Fast Simulation

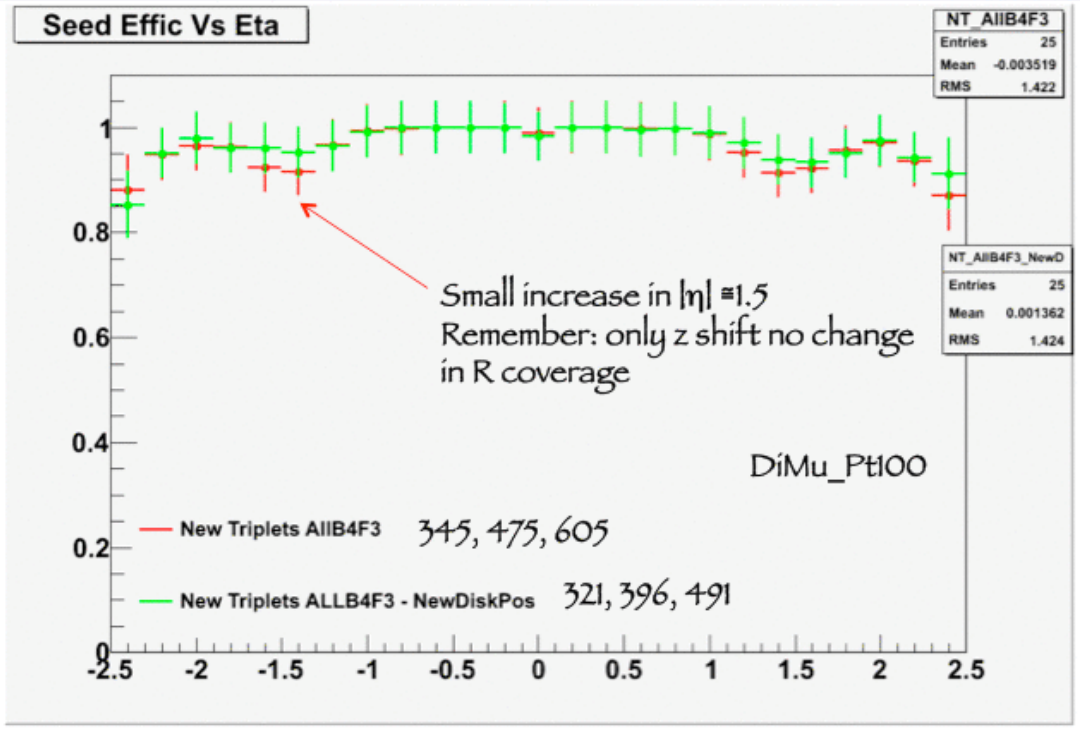
Need work on the BPIX geometry

Have identified additional manpower: Xingtao Huang and Angel Lopez (Univ. of Puerto Rico). They are trying to get the drawings and numbers.

# Phase 1 Summary

- Results from initial/quick Phase 1 geometry implementation
  - Seeding, tracking, b-tagging

## Efficiency: effect of z disk position

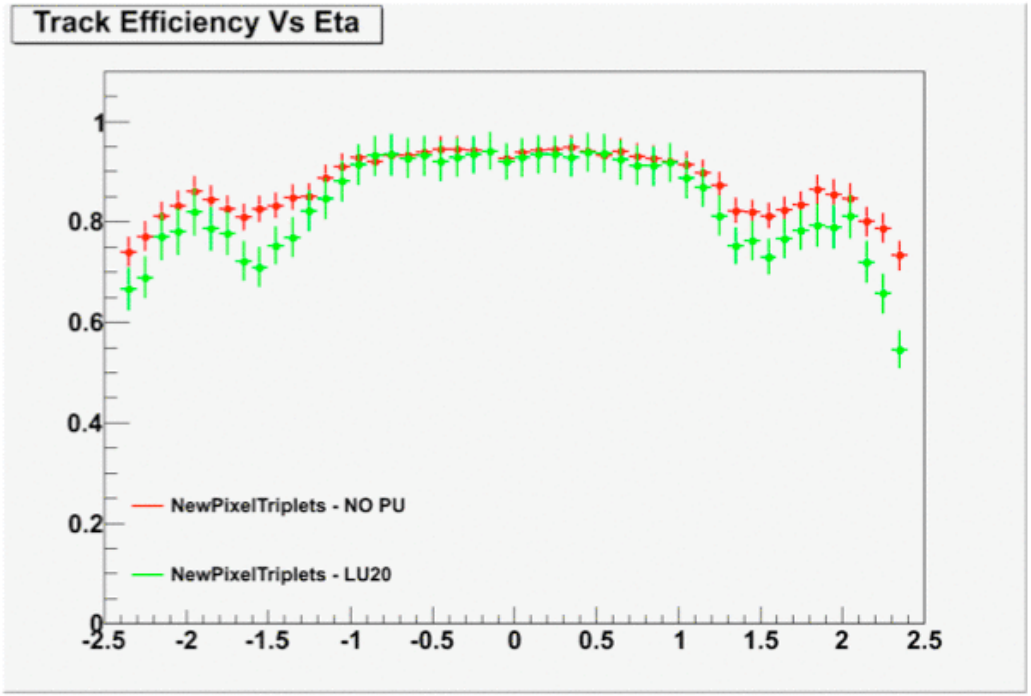



Tracker Upgrade Simulation, 3 Sept 2009 A. Tricomi (Catania) 13

# Phase 1 Summary

- Results from initial/quick Phase 1 geometry implementation
  - Seeding, tracking, b-tagging

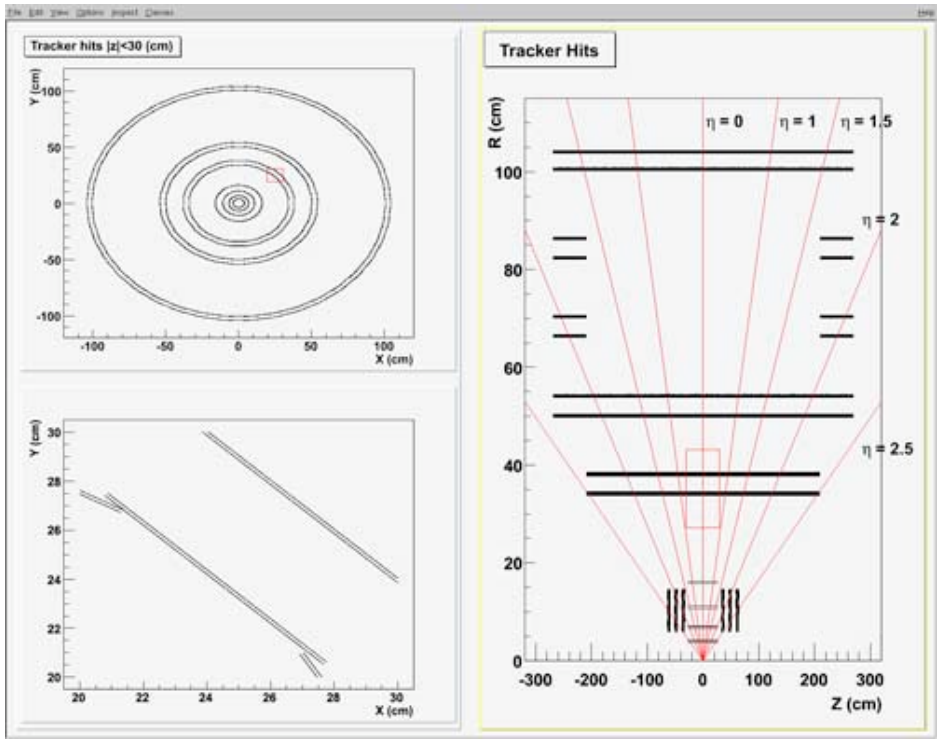
## Tracking efficiency: TTBar vs PU




Tracker Upgrade Simulation, 3 Sept 2009 A. Tricomi (Catania) 17

# Phase 2 Geometries

- New default Long barrel layout (less # of pixel channels)
  - Inner pixels - as in initial Phase 1 implementation
  - $p_T$ layers: pixels
    - Size 250μm × 2.0mm
    - Thickness 200 μm
    - Sensor z-gap = 0.8mm
  - 780M pixels
  - Labeled as ***SMPX*** in plots
- Old Long barrel layout:
  - $p_T$ layers: pixels
    - Size 100μm × 1.0mm
    - Thickness 285 μm
    - Sensor z-gap = 4mm
  - 3500M pixels

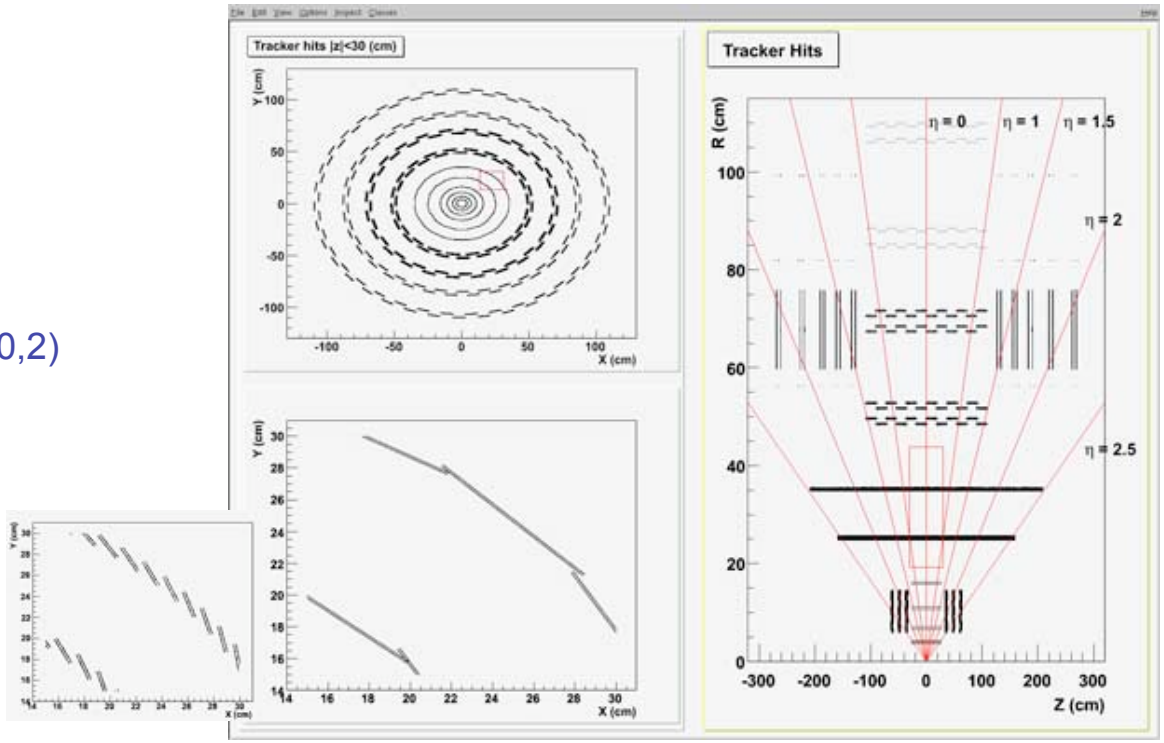



Eric Brownson, Harry Cheung, Carlo Cinvinini,
Ivan Reid, Alessia Tricomi, Mike Weinberger

# Phase 2 Geometries

- New default Hybrid layout ($p_T$ construction as in LB, inner-outer vs pinwheel, etc.)
  - Inner pixels - as in initial Phase 1 implementation
  - pT layers: pixels
    - Size 100μm × 2mm
    - Thickness 200 μm
    - Sensor z-gap = 0.8mm
  - OB: short strips
    - TOB1,2,5,6 (1/4 length)
    - Stereo: 183μm × 4.5cm
    - SS: 122μm × 4.5cm
  - Endcap: short strips
    - TEC1,3,5,7,9 (no rings 0,2)
    - Increased granularity in z-phi rings
  - 270M pixels, 12M strips
- Old Hybrid layout
  - pT layers: pixels
    - Size 100μm × 2.35mm
    - Thickness 285 μm
    - Sensor z-gap = 4mm
  - 260M pixels, 12M strips

Labeled as ***NEW*** in plots

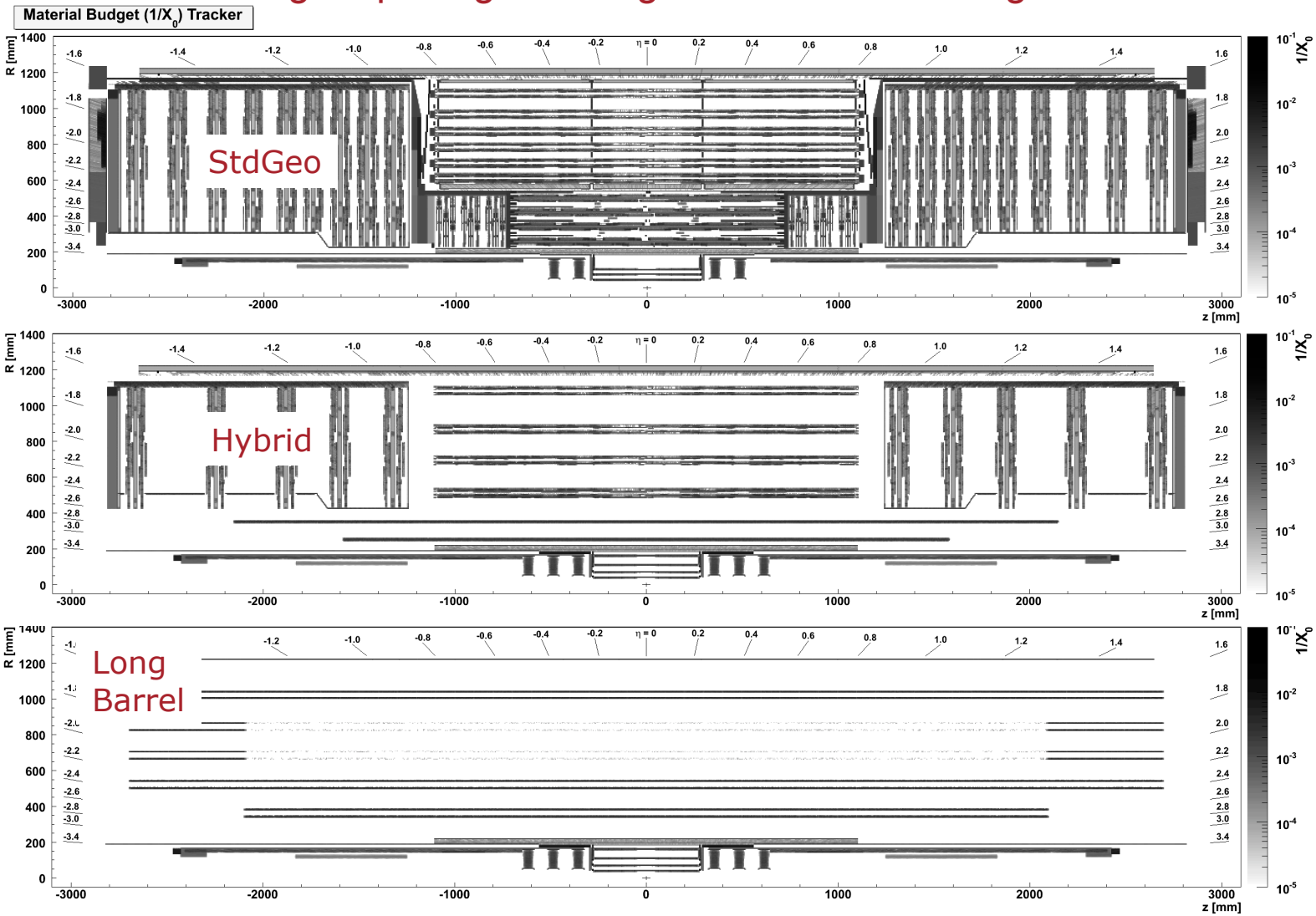



Eric Brownson, Harry Cheung, Carlo Cinvinini,
Ivan Reid, Alessia Tricomi, Mike Weinberger

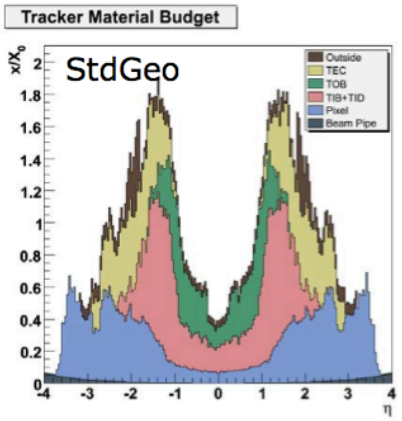
# Geometries as Implemented

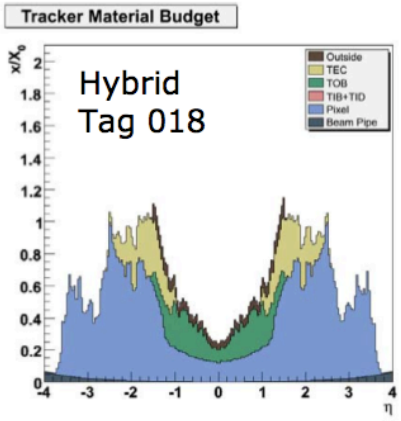
- We are still working on putting in the right material in these geometries

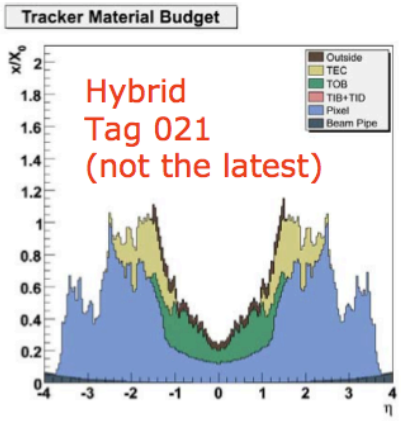
Contributions to Phase 2 geometry: Eric Brownson, Harry Cheung, Carlo Cinvinini, Mario Galanti, Mark Pesaresi, Ivan Reid, Alessia Tricomi, Mike Weinberger



# Material Budget Check: $x/X_0$




- **Hybrid (not latest design)**
- Pixel size = 100μm x 2.35mm
- Thickness = 285 μm
- z-gap = 4 mm

- Not looked at new hybrid yet

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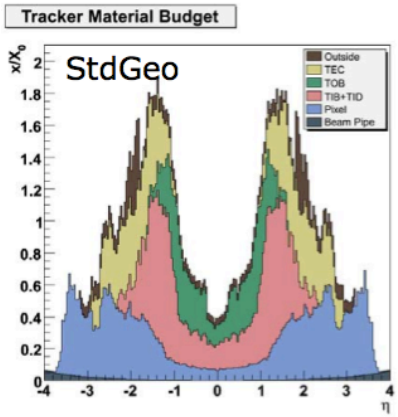
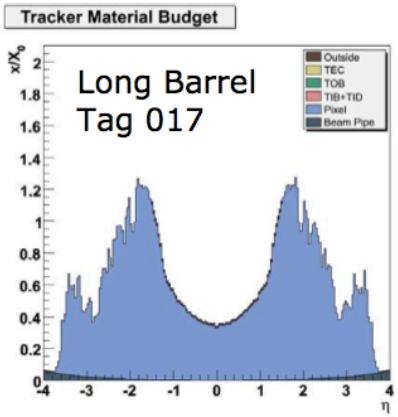
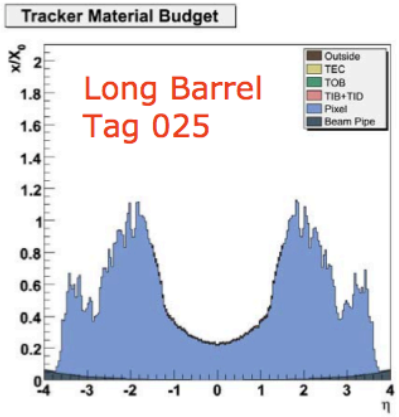
# Material Budget Check: $x/X_0$




Small decrease in material in Long Barrel




- **Old Long Barrel**
- Pixels size = 100μm x 2mm
- Thickness = 285 μm
- z-gap = 4 mm




- **New Long Barrel**
- pixels size = 250μm x 2mm,
- Thickness = 200 μm
- z-gap = 0.8 mm

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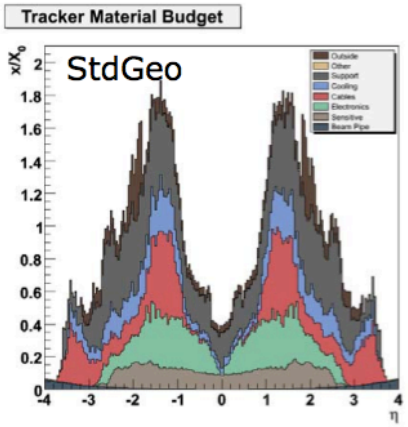
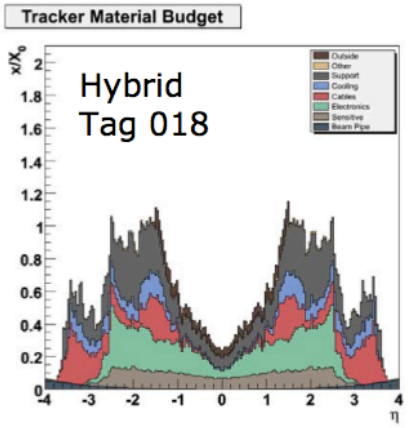
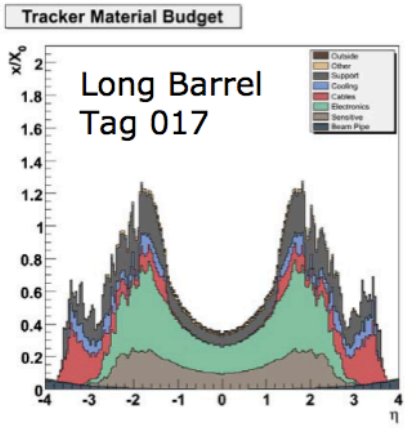
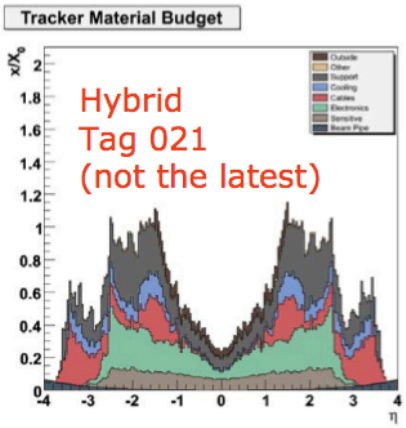
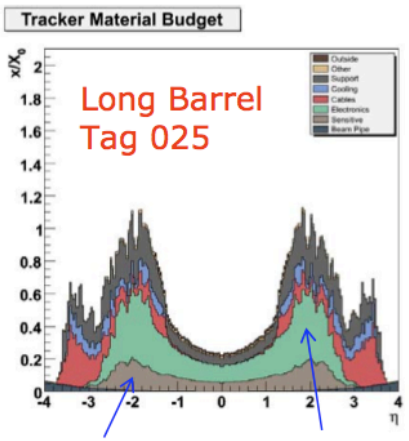
# Material Budget Check: $x/X_0$




Small decrease in material in Long Barrel
- *sensor thickness smaller*
- *pixel size larger*

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# Implemented Geometries

- Numbers from simulation geometries
  - Using modified ModuleInfo.cc from Eric Brownson

StdGeo

75M channels

| | Active Surface [cm2] | # ROCs | # channels | # modules |
|---|---|---|---|---|
| Barrel - Pixels (PXB) | 7,558.26 | 11,520.00 | 47,923,200.00 | 768.00 |
| Endcap - Pixels (PXF) | 2,834.36 | 4,320.00 | 17,971,200.00 | 672.00 |
| Barrel - Strips (TIB + TOB) | 1,103,896.70 | 38,160.00 | 4,884,480.00 | 7,932.00 |
| Endcap - Strips (TID + TEC) | 902,046.70 | 34,624.00 | 4,431,872.00 | 7,216.00 |
| | 2,016,336.02 | 88,624.00 | 75,210,752.00 | 16,588.00 |

New Hybrid

278M channels

| | Active Surface [cm2] | # ROCs | # channels | # modules |
|---|---|---|---|---|
| Barrel - Pixels | 319,348.85 | 52,672.00 | 240,024,320.00 | 4,544.00 |
| Endcap - Pixels | 4,251.54 | 6,480.00 | 26,956,800.00 | 1,008.00 |
| Barrel - Strips | 669,696.00 | 74,880.00 | 9,584,640.00 | 15,360.00 |
| Endcap - Strips | 396,820.50 | 16,320.00 | 2,088,960.00 | 2,720.00 |
| | 1,390,116.89 | 150,352.00 | 278,654,720.00 | 23,632.00 |

Long Barrel SMPX (smaller pixel size)

781M channels

| | Active Surface [cm2] | # ROCs | # channels | # modules |
|---|---|---|---|---|
| Barrel - Pixels | 3,318,364.85 | 363,232.00 | 754,694,720.00 | 35,600.00 |
| Endcap - Pixels | 4,251.54 | 6,480.00 | 26,956,800.00 | 1,008.00 |
| Barrel - Strips | 0.00 | 0.00 | 0.00 | 0.00 |
| Endcap - Strips | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3,322,616.39 | 369,712.00 | 781,651,520.00 | 36,608.00 |

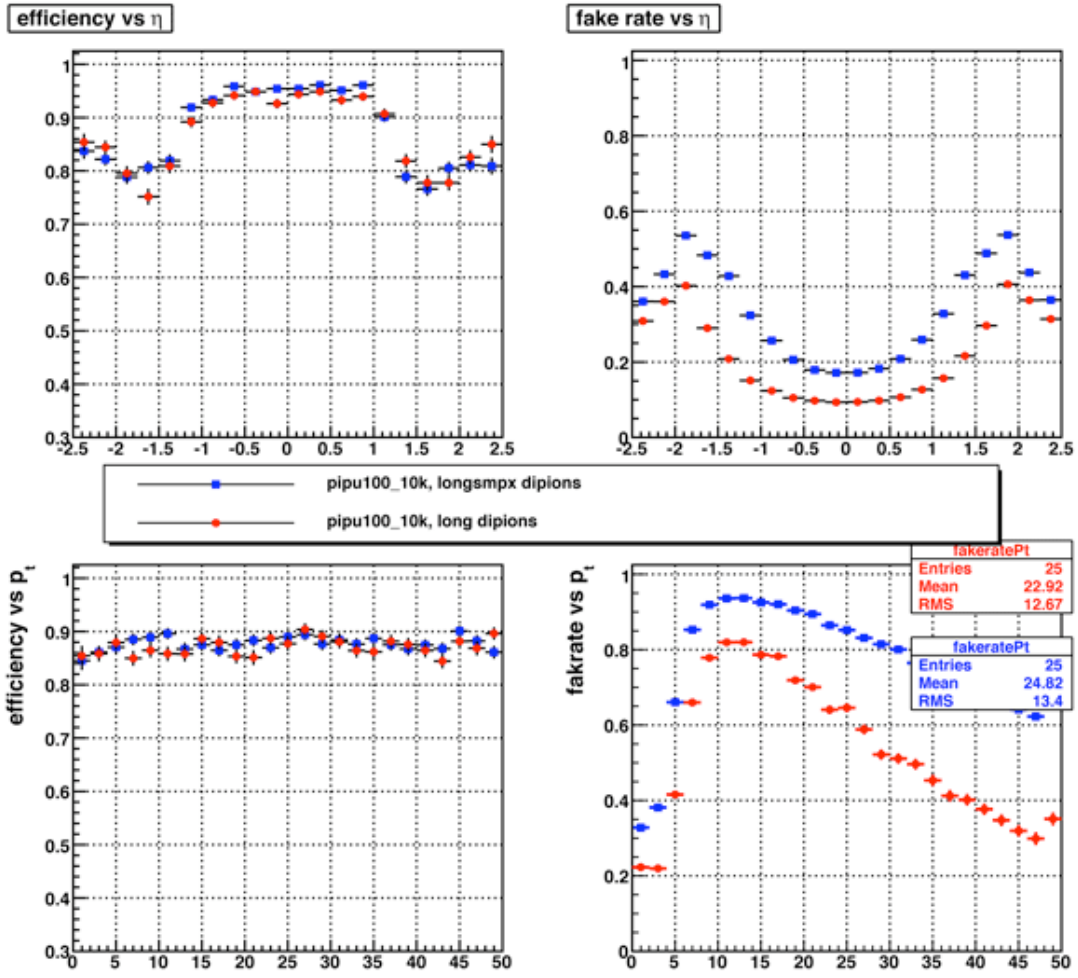
Long Barrel

3,567M channels

| | Active Surface [cm2] | # ROCs | # channels | # modules |
|---|---|---|---|---|
| Barrel - Pixels | 3,218,152.85 | 363,232.00 | 3,509,726,720.00 | 35,600.00 |
| Endcap - Pixels | 4,251.54 | 6,480.00 | 26,956,800.00 | 1,008.00 |
| Barrel - Strips | 0.00 | 0.00 | 0.00 | 0.00 |
| Endcap - Strips | 0.00 | 0.00 | 0.00 | 0.00 |
| | 3,222,404.39 | 369,712.00 | 3,536,683,520.00 | 36,608.00 |

# Effect of Higher Granularity

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds
  - Large difference at pile average = 100 (#hits/reco track >= 3 (default))

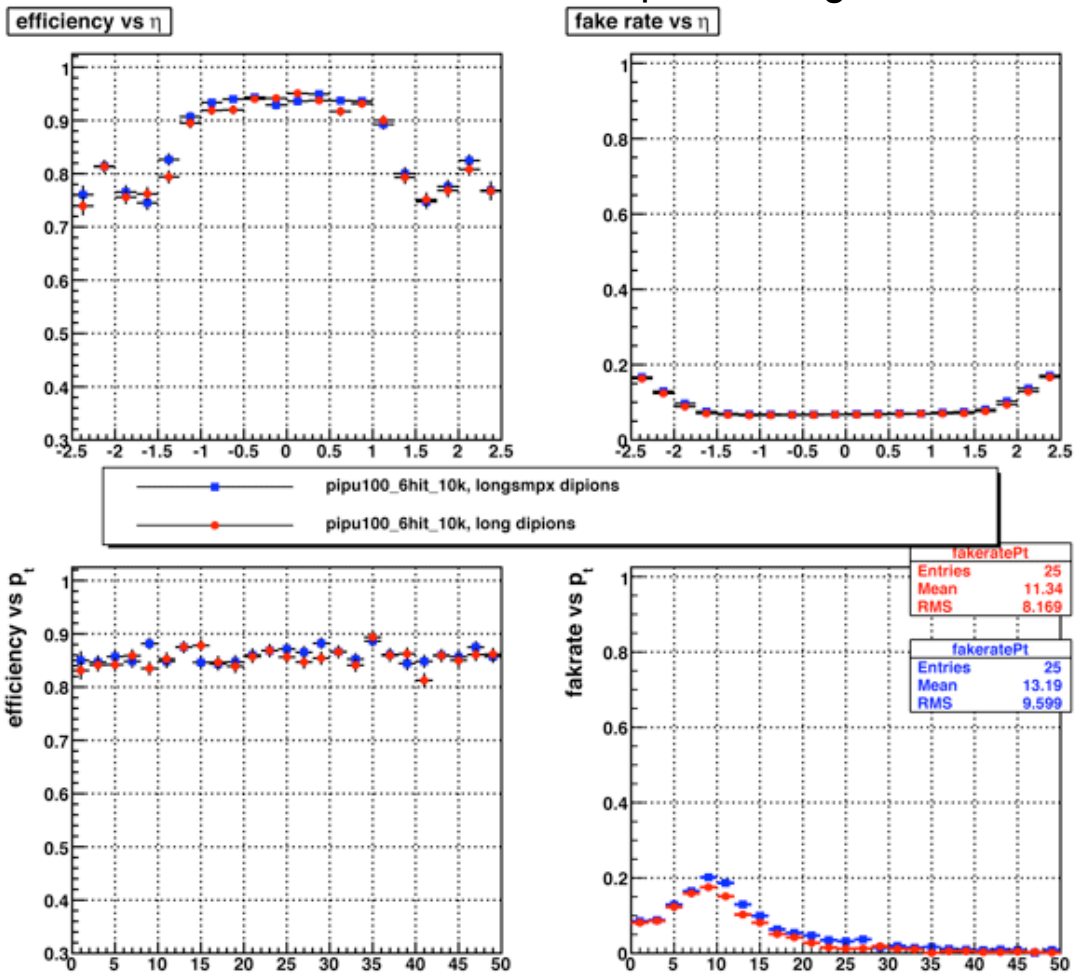



**Long Barrel SMPX (larger pixel size)**

**Long Barrel**

# Effect of Higher Granularity

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds, #hits >=6
  - Still ~ no difference at pile average = 100 with #hits/reco track >= 6




Conclude:

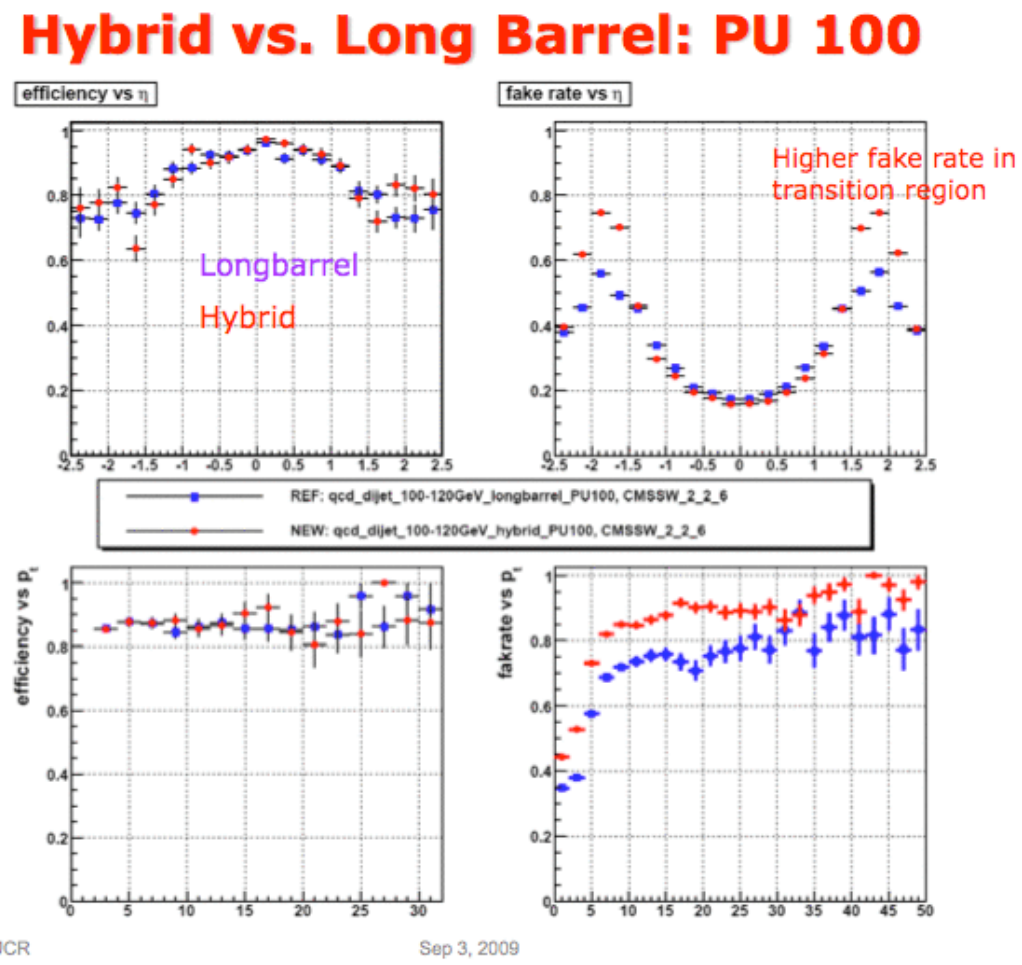
- Pixel size of 100μm × 1mm *vs* 250μm × 2mm matters in fake rate for PU > 25 (pions)
- But not with #hits/trk >=6 except for highest PU = 250
- Some lost in efficiency at larger η with #hits/trk >=6

**Long Barrel SMPX (larger pixel size)**

**Long Barrel**

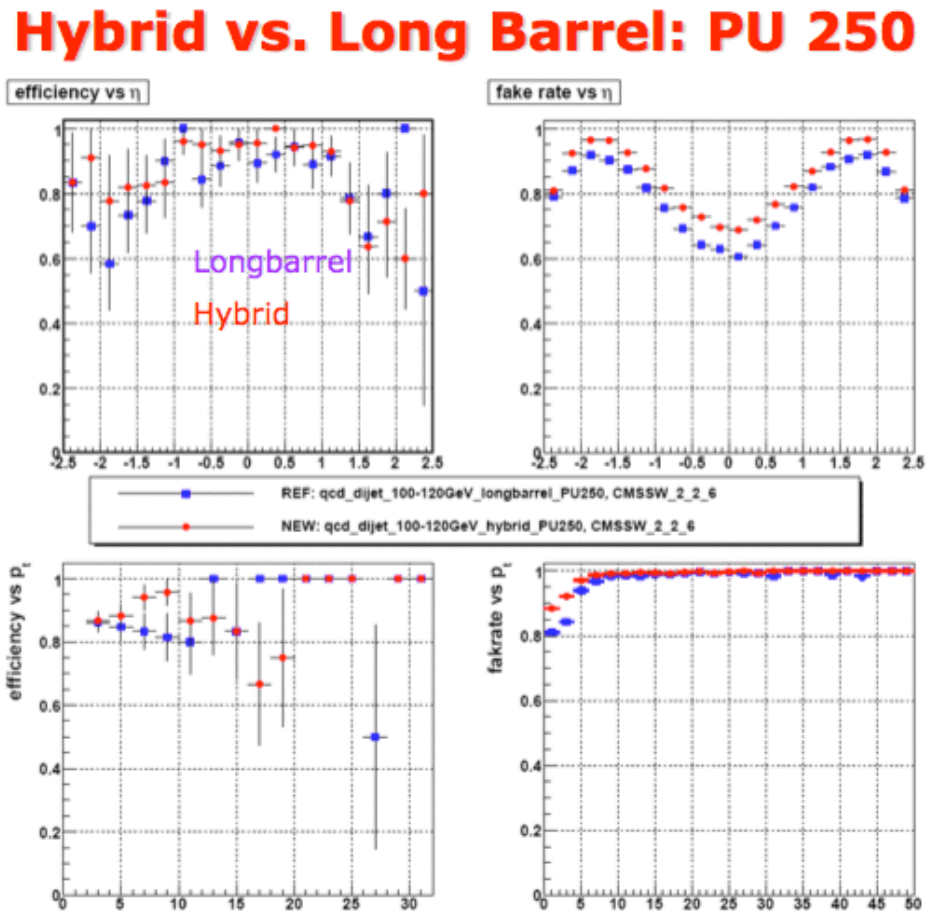
# Comparing Geometries

- QCD Jets 100-120 GeV $p_T$, 1_8_4 tracking, 3-of-4 triplet seeds



# Comparing Geometries

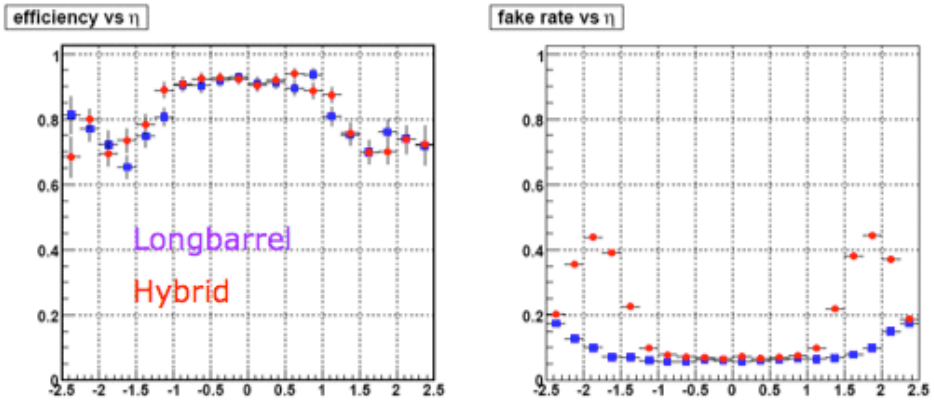
- QCD Jets 100-120 GeV $p_T$, 1_8_4 tracking, 3-of-4 triplet seeds



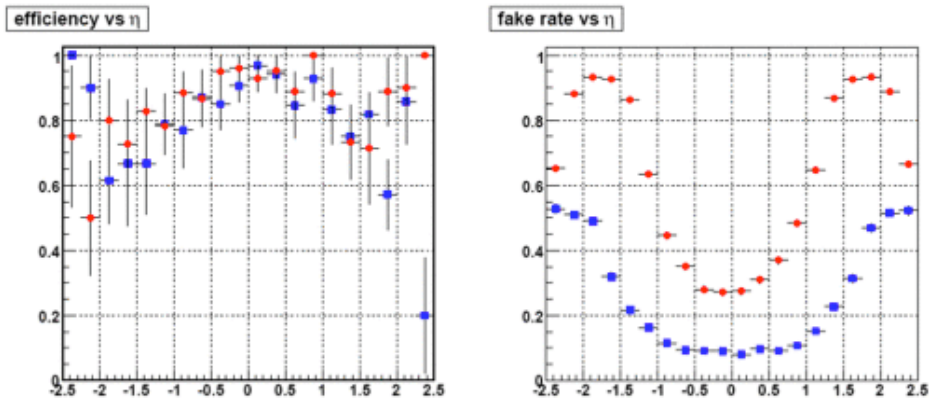
# Comparing Geometries

- QCD Jets 100-120 GeV $p_T$, 1_8_4 tracking, 3-of-4 triplet seeds

## Effect of 6-hit Requirement




- **Pileup 100**
- Fake rate reduced by factor ~2 with not much loss in efficiency




- **Pileup 250**
- Fake rate reduced by factor ~5 at eta=0
- Hybrid fake rate much higher than Long Barrel

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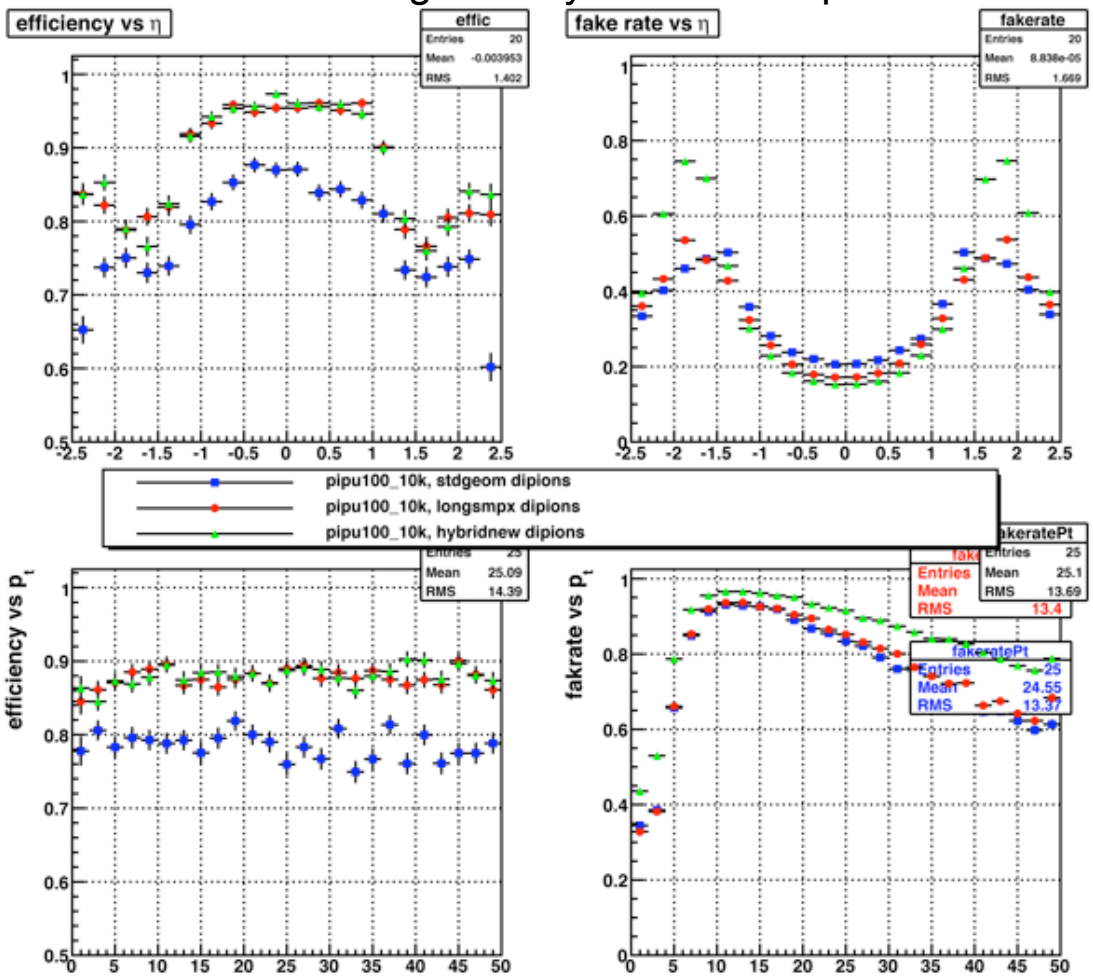
# Comparing Geometries

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds, <PU> = 100
  - Standard geometry: 3-of-3 hit triplets



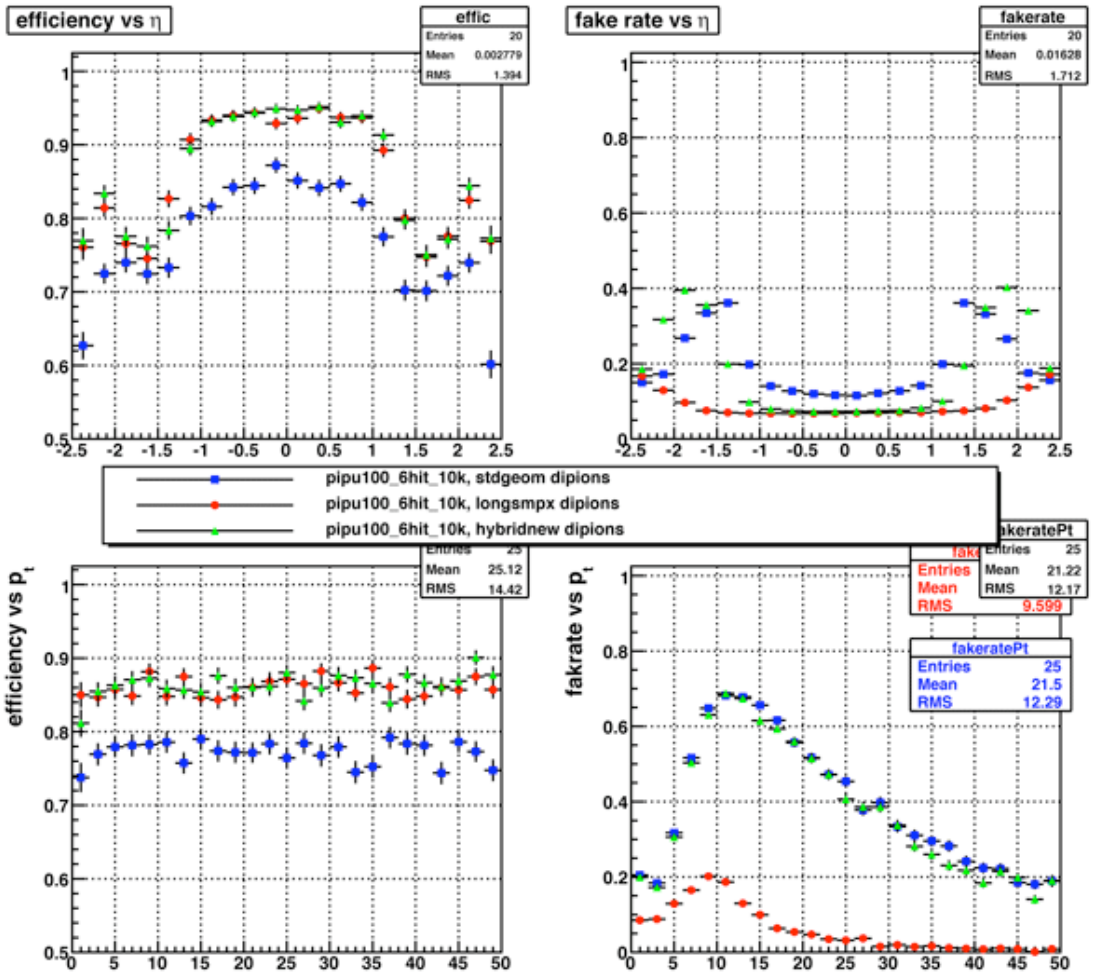

Need to require more hits than 3 even in the barrel region

Many questions on reasons for the various features and differences

**Standard Geometry**
**Long Barrel SMPX (larger pixel size)**
**New Hybrid**

# Comparing Geometries

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds, <PU> = 100
  - Standard geometry: 3-of-3 hit triplets



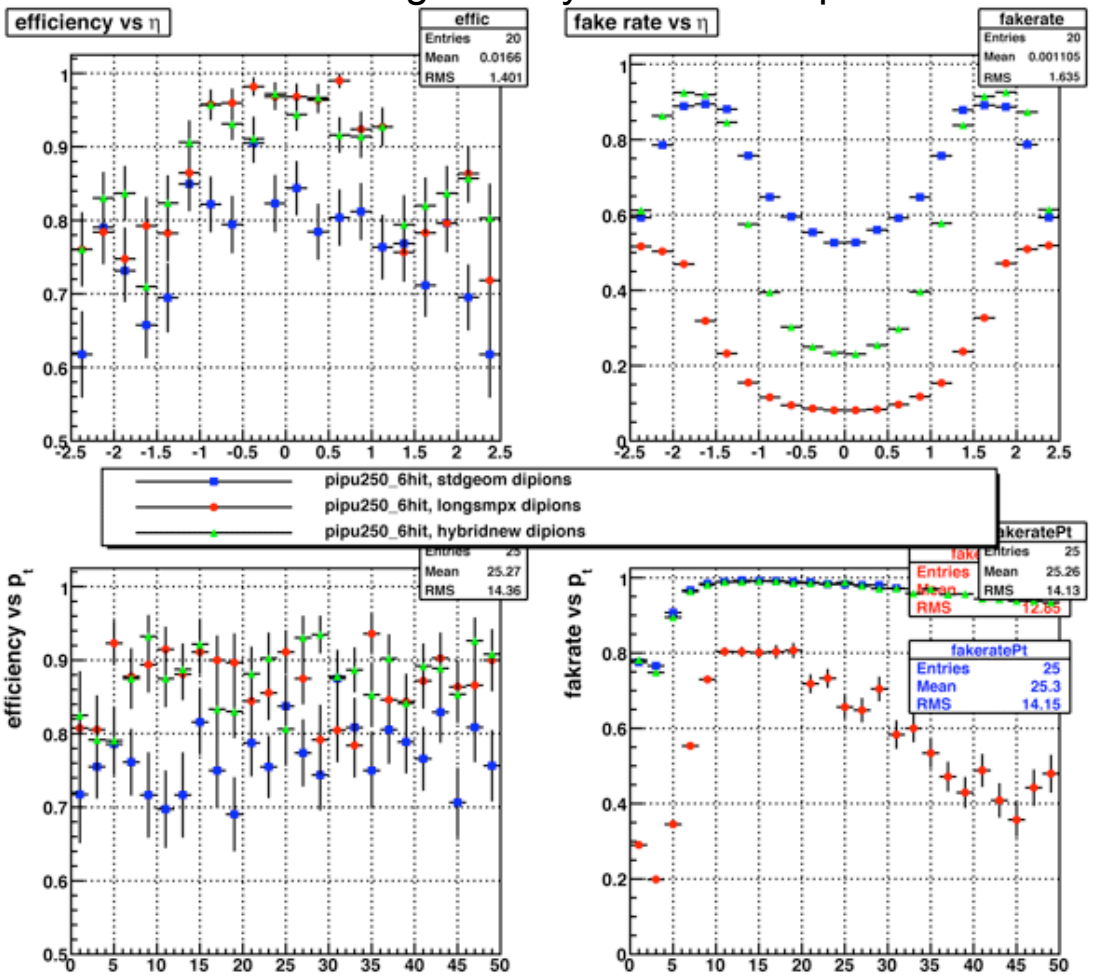

#hits/reco track >= 6

Standard geometry has larger fake rate still in the barrel region

**Standard Geometry**
**Long Barrel SMPX (larger pixel size)**
**New Hybrid**

# Comparing Geometries

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds, <PU> = 250
  - Standard geometry: 3-of-3 hit triplets



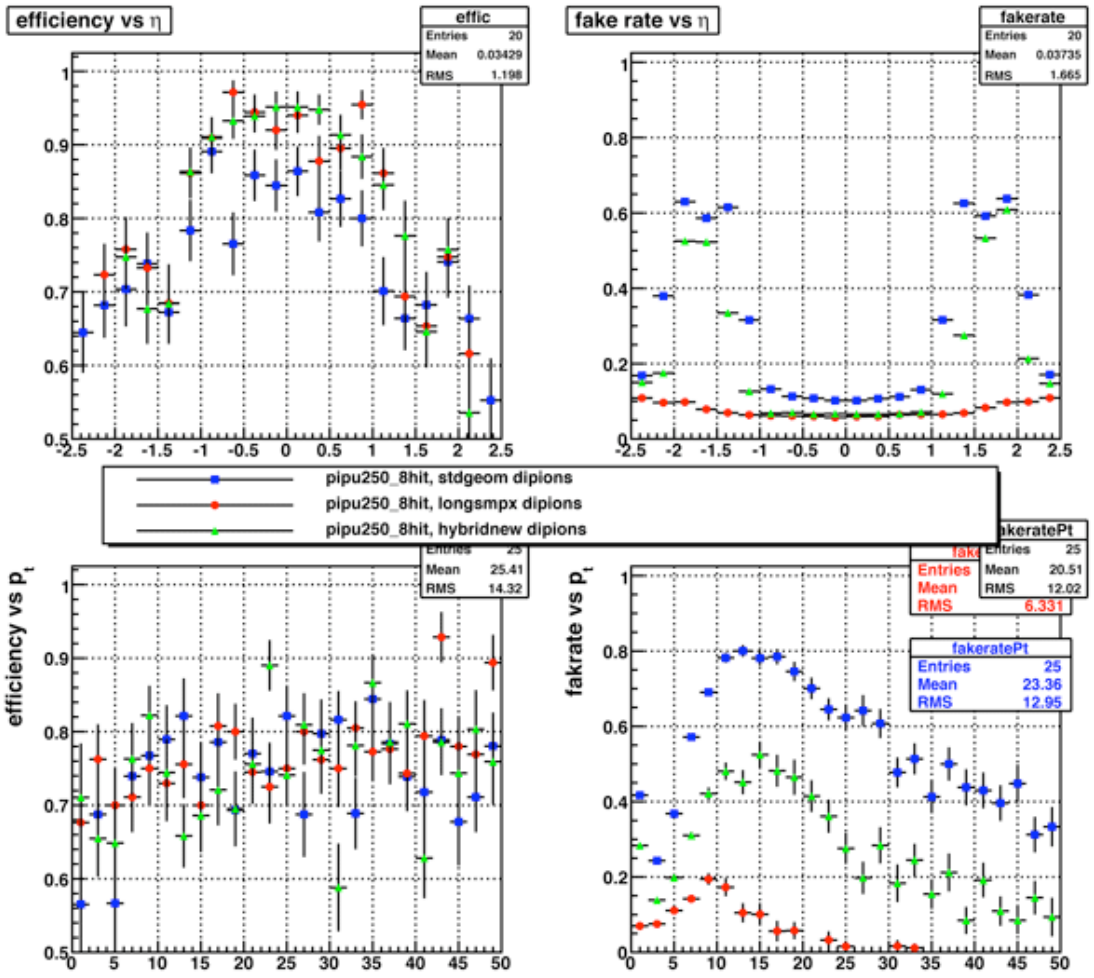

#hits/reco track >= 6

Even with at least 6 hits the fake rate is much too high for all geometries, though much better in the Long Barrel SMPX

**Standard Geometry**
**Long Barrel SMPX (larger pixel size)**
**New Hybrid**

# Comparing Geometries

- Dipions, 1-50 GeV $p_T$ gun, 1_8_4 tracking, 3-of-4 triplet seeds, <PU> = 250
  - Standard geometry: 3-of-3 hit triplets




#hits/reco track >= 8

Similar results and conclusions looking at QCD jet 120 GeV samples: see John Ellison's talk.

Need to determine the cause of the higher fake rate in the transition region vs highest eta

- Granularity?
- Endcap arrangement?
- Missing material?
- Tracking issue (more complicated navigation)?

**Standard Geometry**
**Long Barrel SMPX (larger pixel size)**
**New Hybrid**

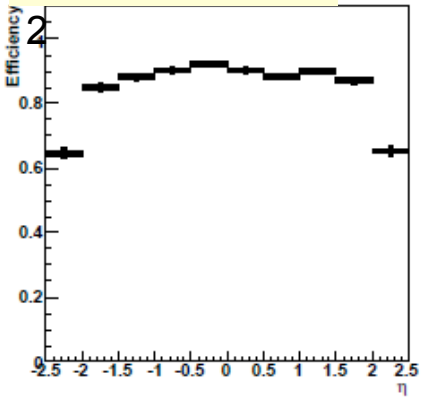
# Track-Trigger Primitive Studies

Laura Fields

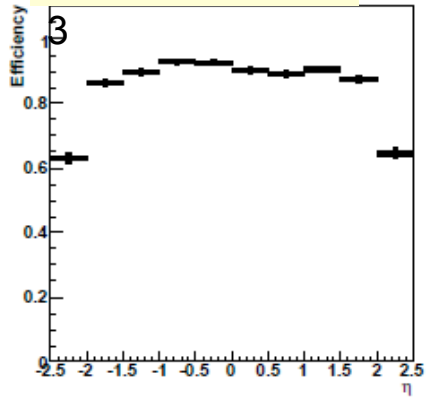
# Track-Trigger Primitive Example Plots

- Sample Tracklet Efficiencies:

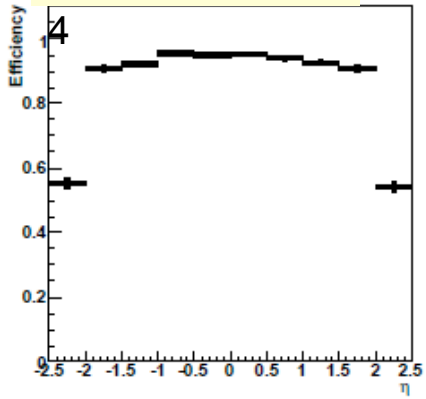
•Stack 1+ Stack 2




•Stack 2+ Stack 3



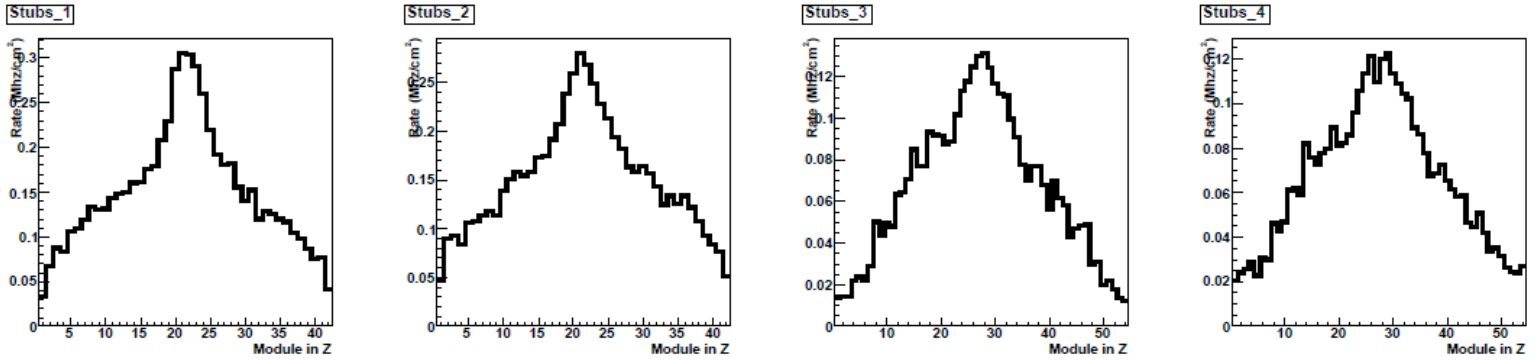

•Stack 3+ Stack 4




•2-10 GeV Muon Efficiency vs. eta for 1st 4 layers of LB Geometry (No pile-up)

- Maximum tracklet efficiencies are 90-95%
- Inefficiencies are primarily due to gaps between modules in z

# Track-Trigger Primitive Example Plots




•Stub rates vs. module in z for 1st 4 layers of LB Geometry w/ 200 PU

- Sample Stub Rates:
-

# Electron Studies: Procedure

- The Procedure:

- **Following the current HLT SiStrip algorithm, we start with L1 electron candidates from the calorimeter**

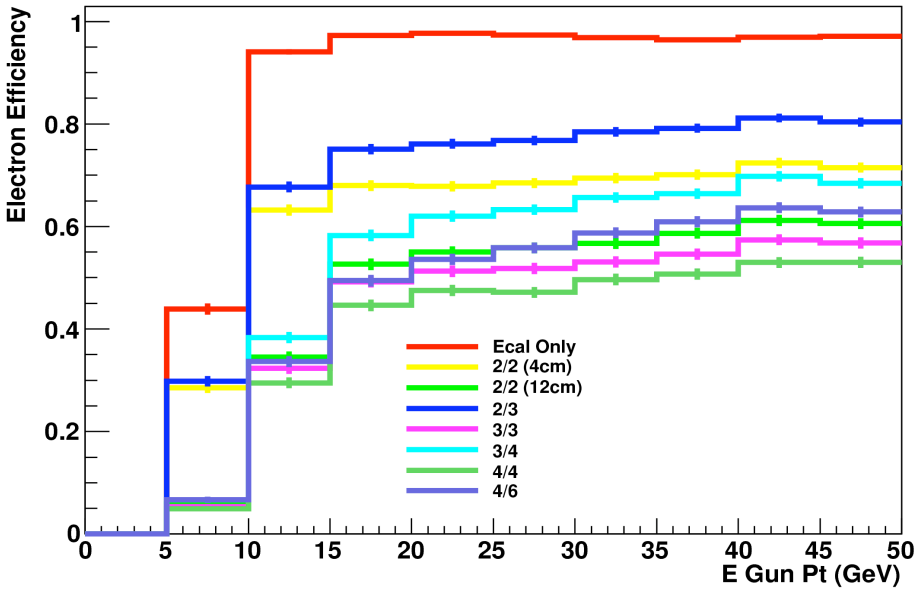
- **First step: Look for *single* stubs consistent with L1Electron**
  - Define two paths (one for each charge hypothesis) through tracker using Ecal position and Et.

- **Second step: Match stubs into *pairs* consistent with L1Electron**
  - Require that the difference in phi between the two stubs is consistent with calorimeter Et (assuming track came from r-phi origin)
  - Require that the two stubs point towards the calorimeter object in r-z

- **Third Step: Combine 2-point tracklets with common stubs to form 3- and 4-point tracklets**

# Electron Studies: Efficiency Results

- **Efficiencies**




•Efficiencies for reconstructing electrons with various stub requirements

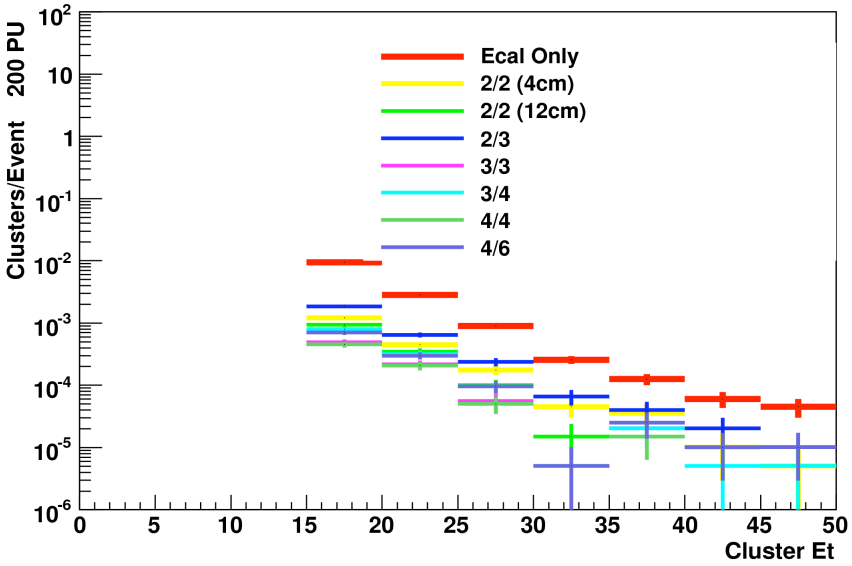
| Configuration | Efficiency for 20<Et<50 GeV |
|---|---|
| 2/2 (Layers 1/2 – 4cm sep) | 70% |
| 2/2 (Layers 2/3– 12 cm sep) | 58% |
| 2/3 (Layers 1/2/3) | 79% |
| 3/3 (Layers 1/2/3) | 54% |
| 3/4 (Layers 1/2/3/4) | 63% |
| 4/4(Layers 1/2/3/4) | 45% |
| 4/10 (all layers) | 55% |

•Requiring stubs on 2/3 layers yields highest efficiency;

•Requiring stubs on 4/4 layers yields lowest efficiency

# Electron Studies: Rate Results

- **Rates**




•Efficiencies for reconstructing electrons with various stub requirements

| Configuration | Rate supression for 20<Et<50 GeV |
|---|---|
| 2/2 (Layers 1/2 – 4cm sep) | 7.0 |
| 2/2 (Layers 2/3– 12 cm sep) | 9.4 |
| 2/3 (Layers 1/2/3) | 4.7 |
| 3/3 (Layers 1/2/3) | 17.1 |
| 3/4 (Layers 1/2/3/4) | 10.8 |
| 4/4(Layers 1/2/3/4) | 18.5 |
| 4/10 (all layers) | 11.6 |

•Requiring stubs on 2/3 layers yields lowest rate supresssion

•Requiring stubs on 4/4 layers yields highest rate supression

# Tau Triggers Studies using Stack Tracker TPGs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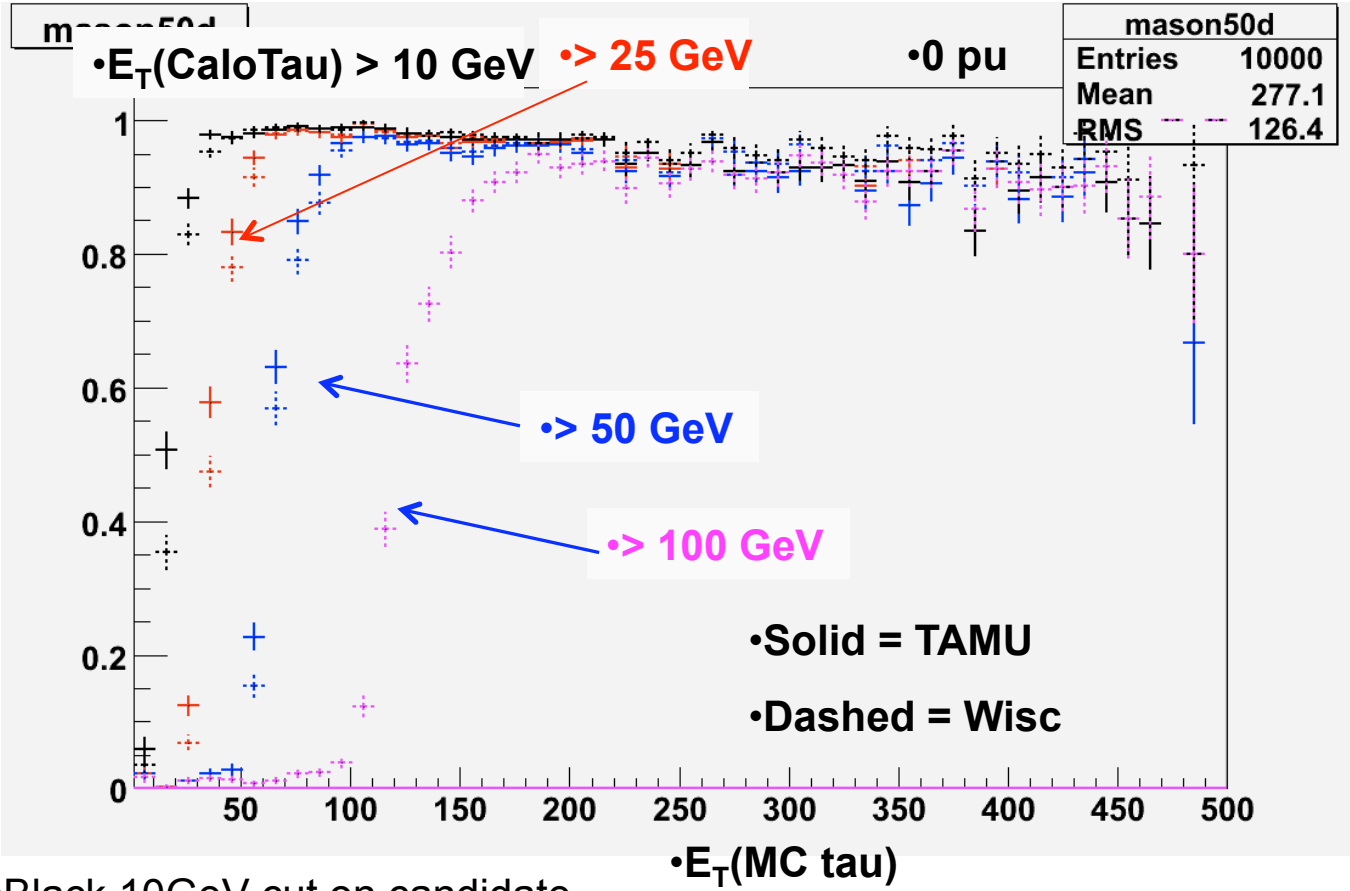
# Reconstruction Efficiency

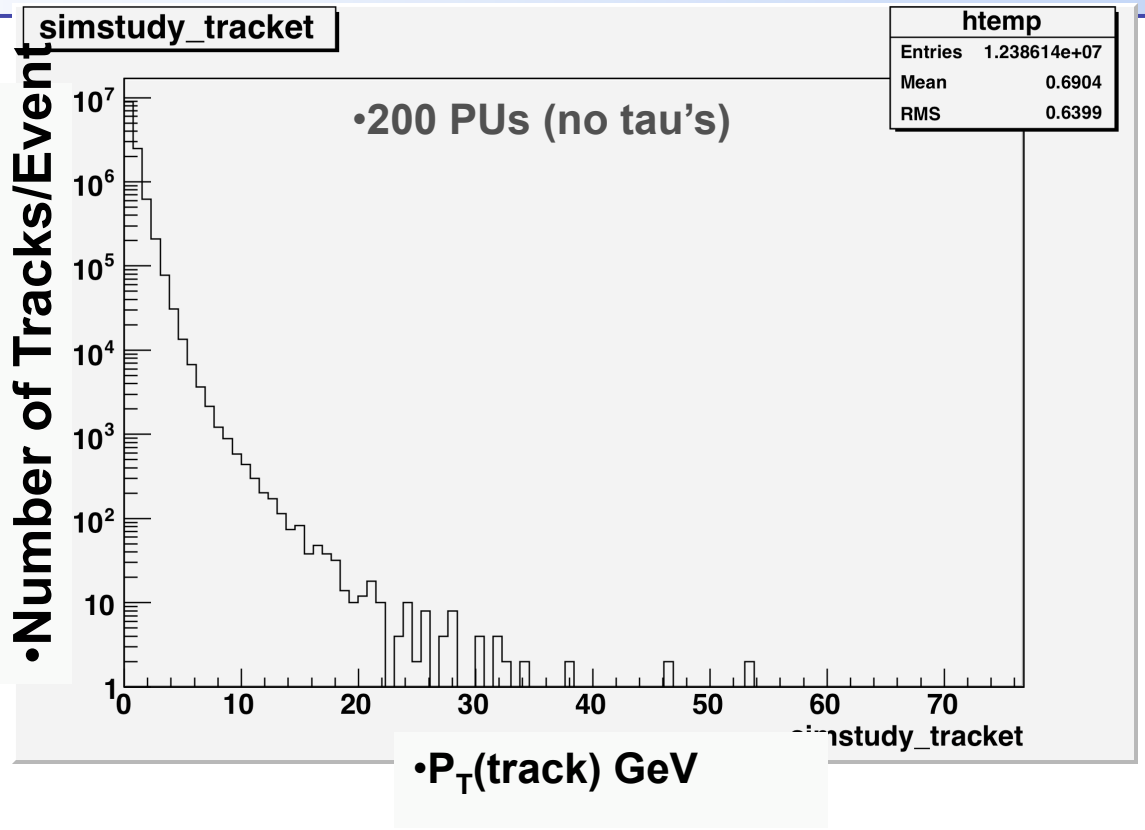



- Black 10GeV cut on candidate
- Red 25GeV cut
- Blue 50GeV Cut



Michael Weinberger

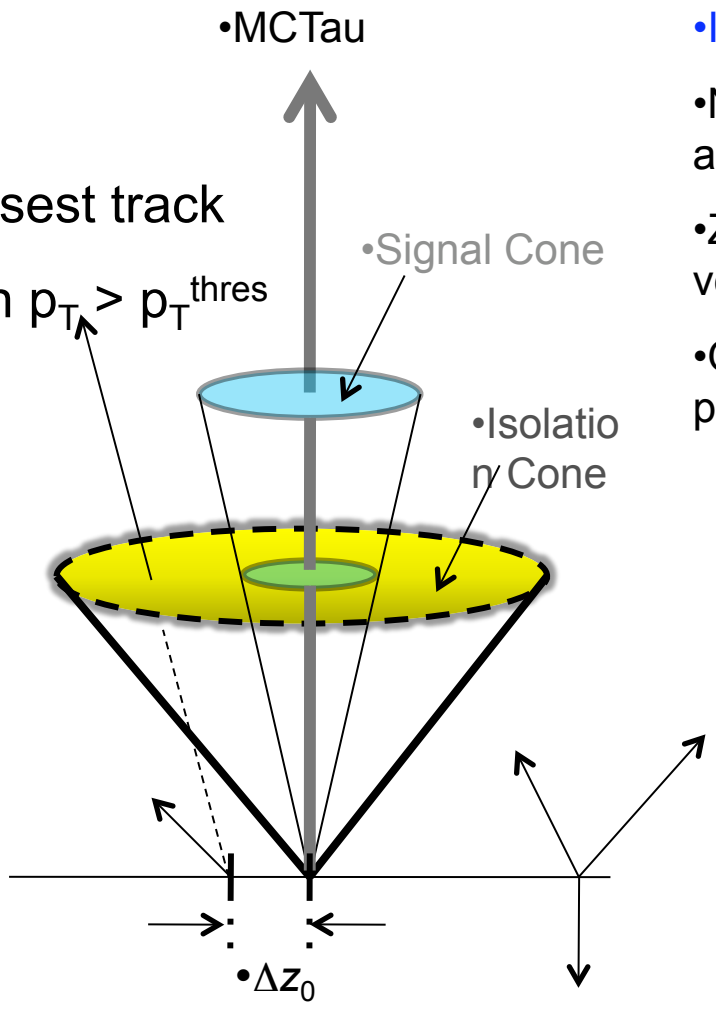
# Estimate Number of Tracks




•$P_T$ > 5 GeV → 60 tracks/event ; $P_T$ > 10GeV → 3.5 tracks/event

**•Each of these tracks could be a fake-tau track to produce a seed if matches a calo tau**

# •Probability of Accepting Tau




•Importance of z0 resolution

•Need to be able to associate the tracks with appropriate vertex

•Z0 resolution determines distance we can tell the vertexes apart

•Otherwise will get tracks in isolation cone from pileup events

- Method

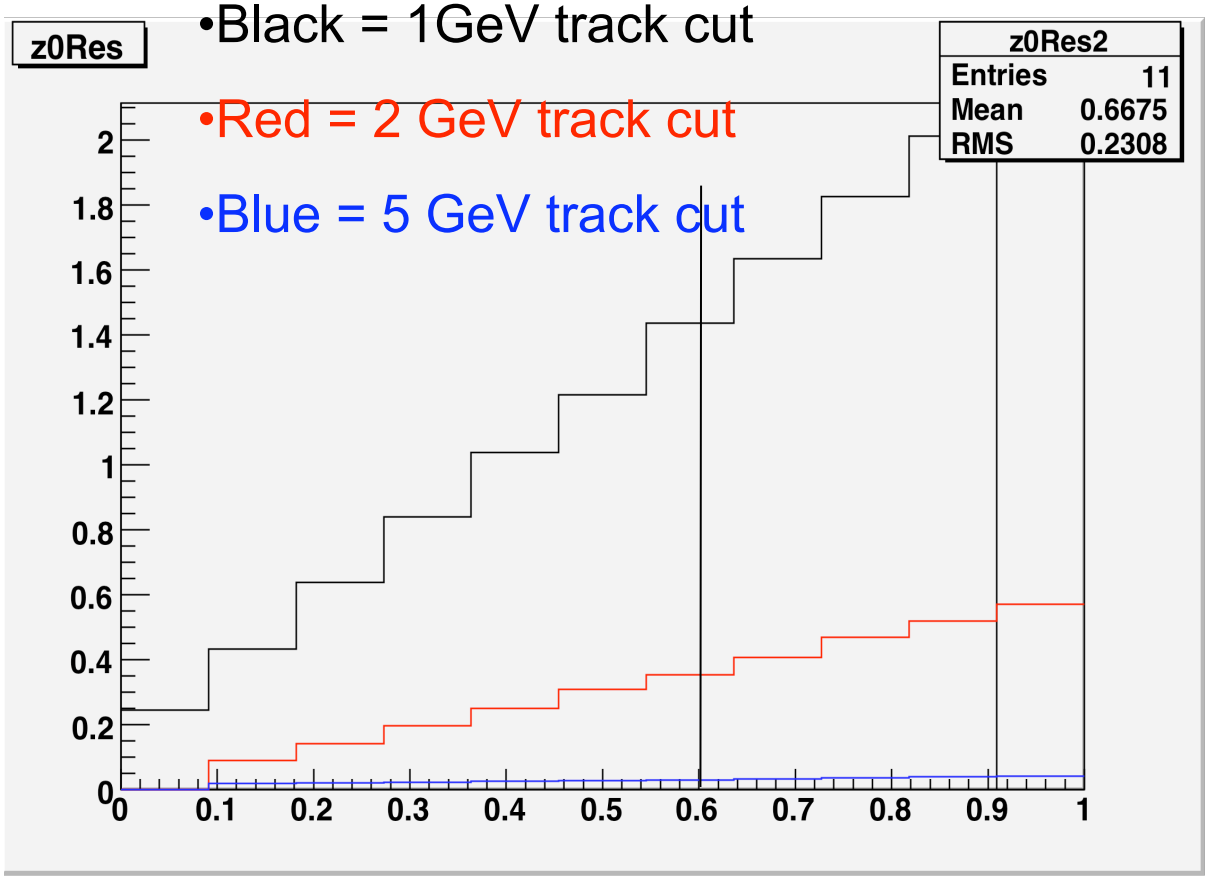
•Use Mctau to get tau direction and z0

•Loop all tracks and propagate them to x=y=0 to get z0

•Keep the track within the isolation annulus that is the closest to the tau vertex in z

•Use this to test isolation reductions with varying cuts on Delta z0

# Number of tracks in iso vs z0 cut



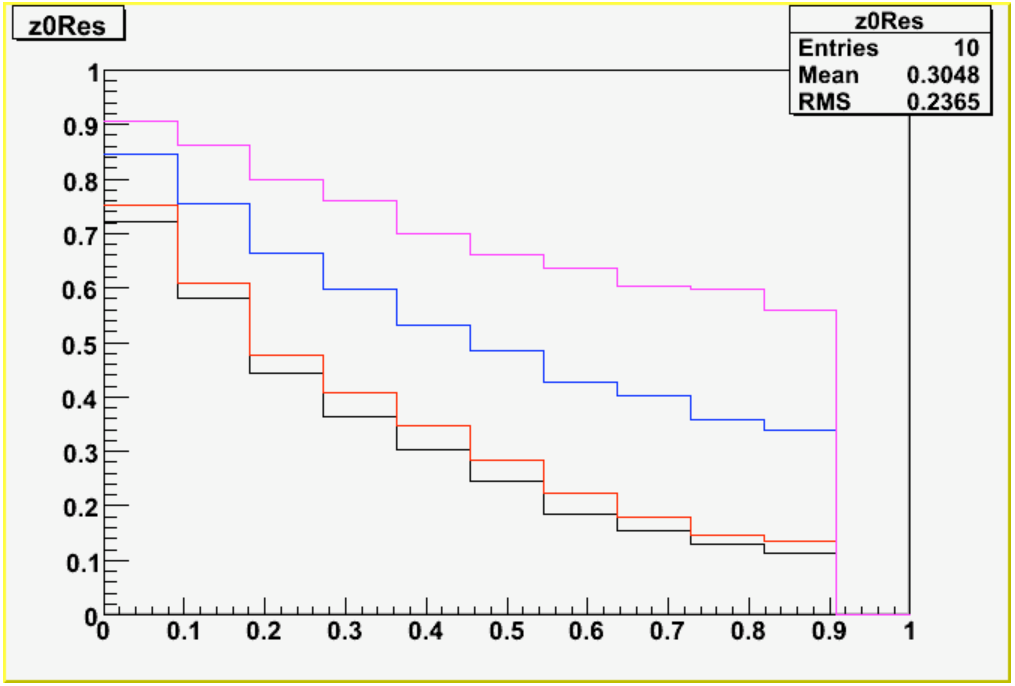

- Black = 1GeV track cut
- Red = 2 GeV track cut
- Blue = 5 GeV track cut

- Cut on Z0 [cm]

- Estimate 0.6cm resolution for first layer old longbarrel geometry
- 1.4 tracks/candidate at 1GeV
- 0.5 tracks/candidate at 2GeV
- <0.1 tracks/candidate at 5GeV

# All samples for 1GeV track cut

•As expected the more tracks you remove from the event, the better the probability of passing the cut




•Black is regular cuts

•Red is with Small R vertex

•Blue is for hits Layer 1

•Purple is hits layer10



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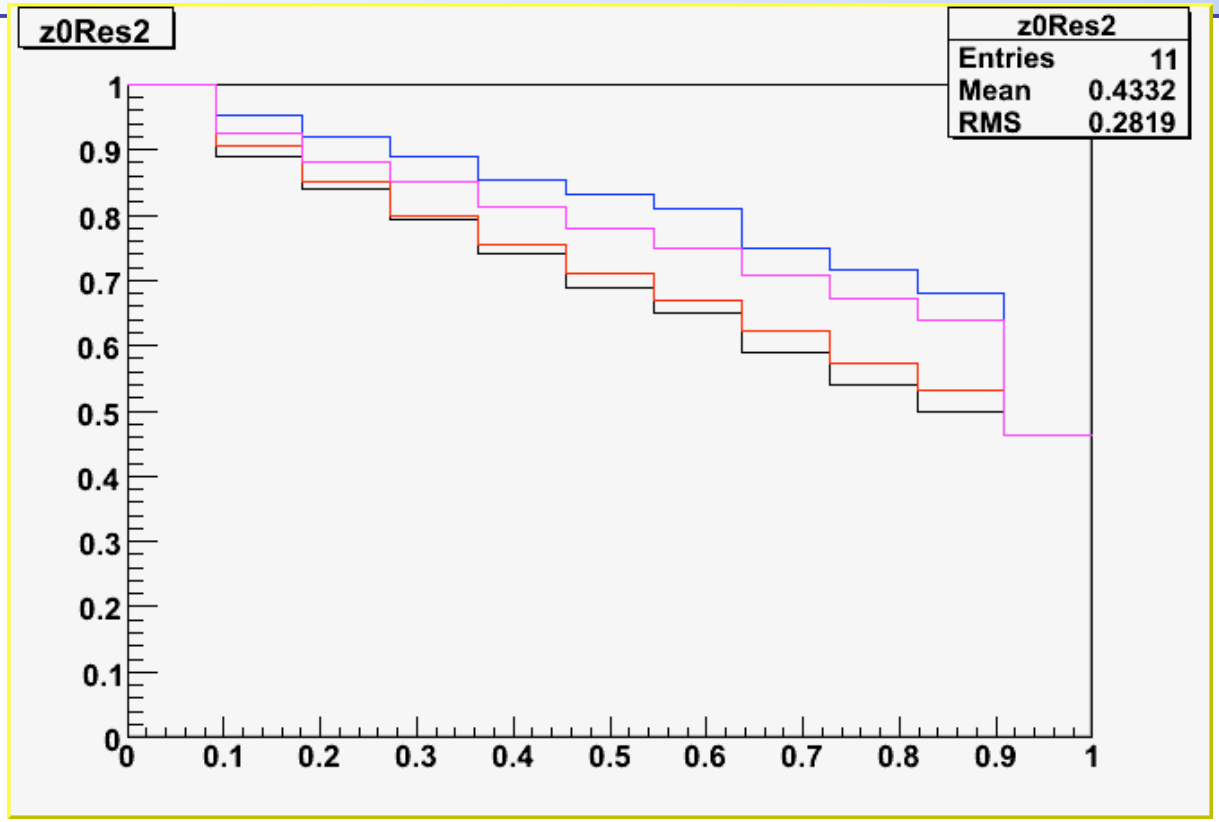
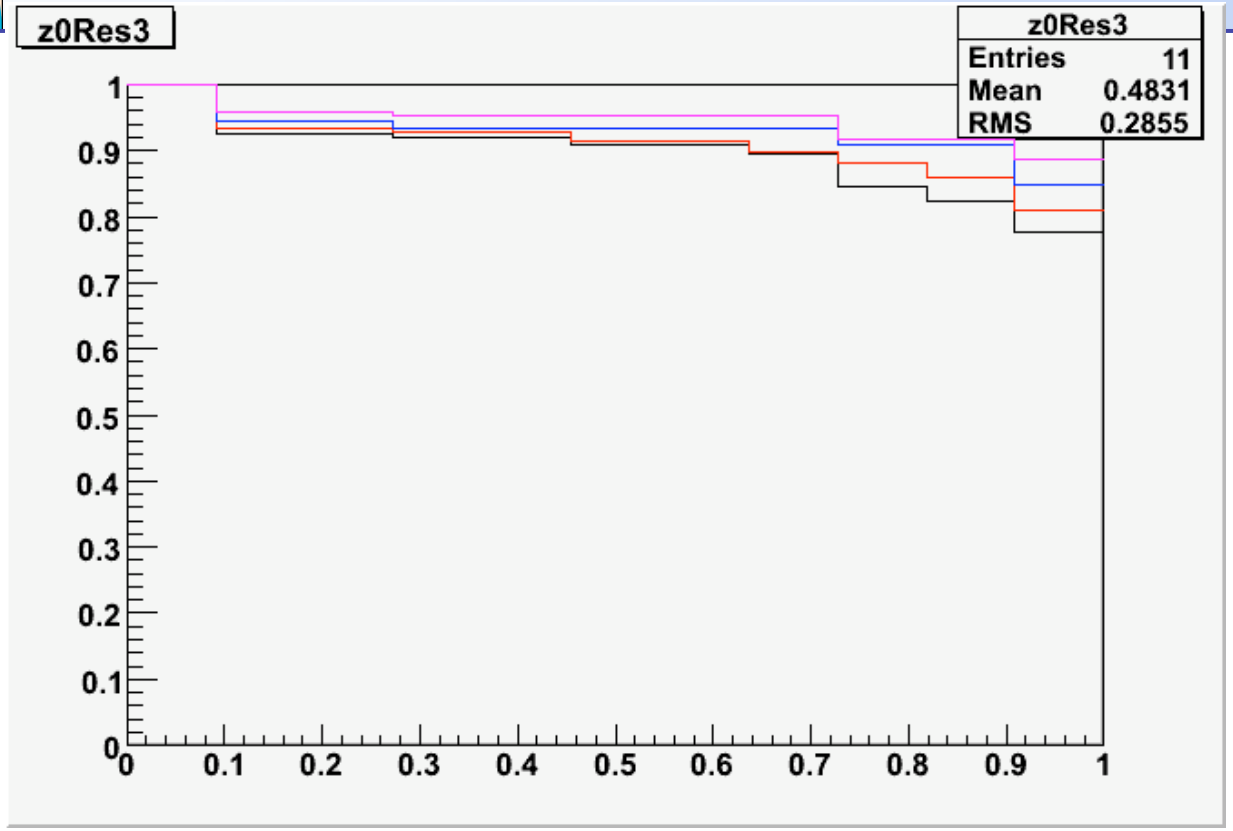
# All samples for 2GeV Track Cut



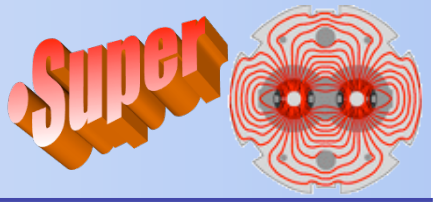

- Black is regular cuts
- Red is with Small R vertex
- Blue is for hits Layer 1
- Purple is hits layer10

# All samples for 5GeV Track Cut




- Black is regular cuts
- Red is with Small R vertex
- Blue is for hits Layer 1
- Purple is hits layer10

# Conclusions




- Geometries are fairly mature with two versions
  - Very configurable via xml files for what ever the user wants
- Still need to tune material
- Will need to move to CMSSW_3_1_X soon
- Studies have begun using the Tracker information to combine with Calorimeter information
  - Electron, tau and muon

# Backup Slides/Additional Info

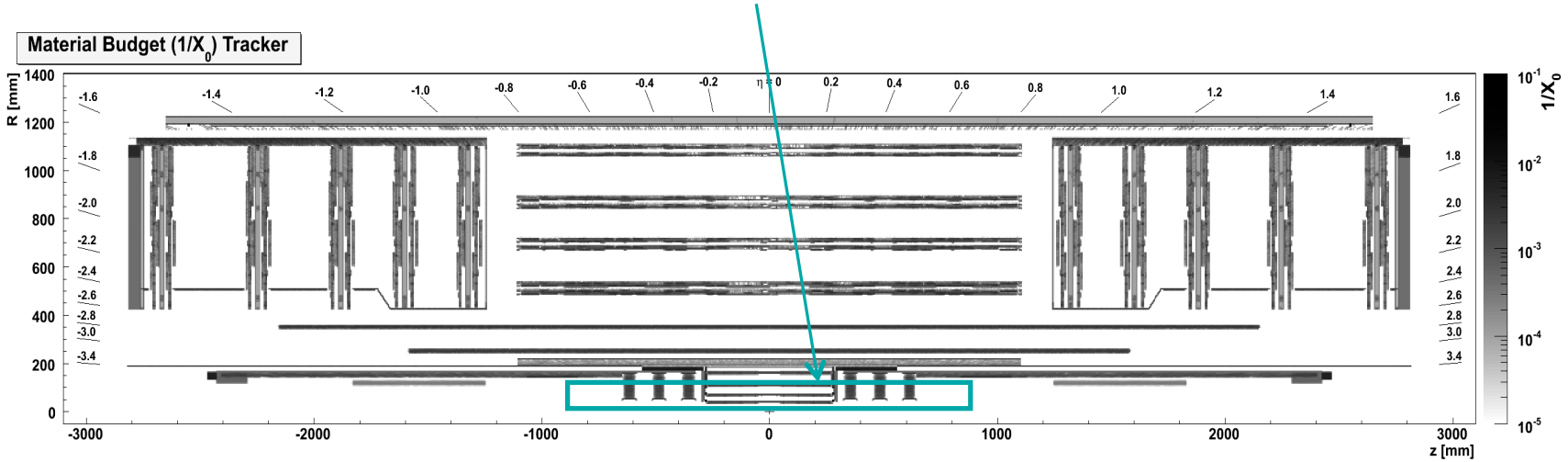
## Backup Slides

# Summary

- Tracking Performance for the two new Phase 2 default Geometries
  - New Hybrid with LB $p_T$ layer construction performance ~same as old Hybrid
  - LB c.f. Long Barrel with 4.5× less pixels (5× smaller pixel size)
    - Higher fake rates, but same for #hit/reco track >=6 except PU=250
    - Good compromise for LB geometry
      - must study track trigger performance, and binary readout
- Tracking Performance for different Pileup with pions
  - Using non-iterative tracking, requires 8 hits/reco track to make fake rates reasonable at highest PU
    - Some loss of efficiency for pions at high eta: need more hits/layers at high eta?
    - Need to study with iterative tracking, and look at other samples (electrons?)
- Comparison between Long Barrel and Hybrid Geometries
  - Significantly lower fake rates for Long Barrel geometry even in barrel region
    - Difference reduce when requiring more hits per reco track
  - Much higher fake rates for the Hybrid in transition region
    - Must study casue: Granularity? Endcap arrangement? Tracking complication?
  - Also need to study robustness (comparison) of tracking performance
    - Radiation damage and inefficiencies, and other samples, e.g. b-tagging

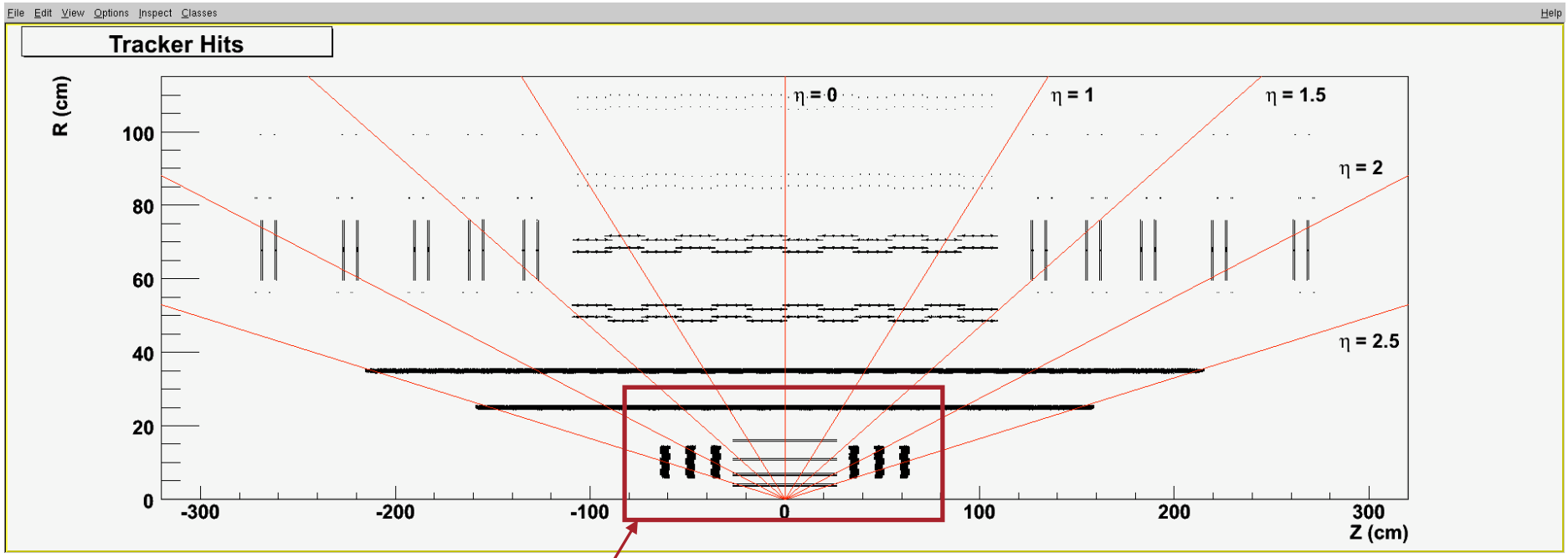
# Tracking Performance

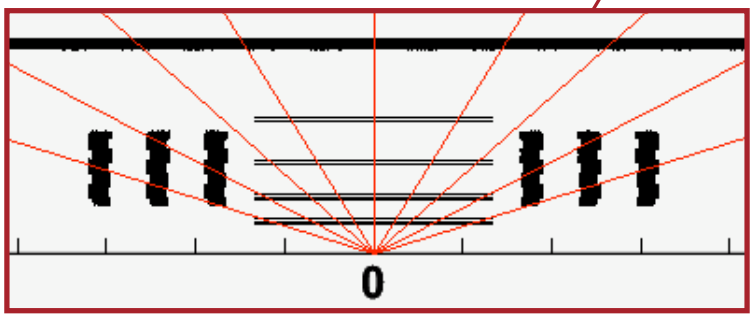
- Performance using the MultiTrackValidator package
  - Used by the Tracking DPG (https://twiki.cern.ch/twiki/bin/view/CMS/TrackingPerformancePlots)
  - Modifications for high pileup
    - TrackingTruthProducer
      - Builds TrackingParticle and TracingVertex collections
      - Searches for all vertices within whole tracking volume
      - Modification: restrict vertex search volume (for TPs)
        - » r < 10 cm and |z| < 90 cm from (0,0)



# 3-of-4 hit Triplet Seeding

- Rechits plot Illustrating “hole” in 3-of-4 triplet seeds in inner pixel geometry used




The $\eta$ ~ 1 to 1.5 is the region where the 4th inner barrel pixel layer cannot give hits for seeds. (The Phase 1 FPIX disks are larger which will improve this.)

This gives rise to lower tracking efficiency in this $\eta$ region.