# Constraining COT Track $t_0$

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## Tracking Meeting

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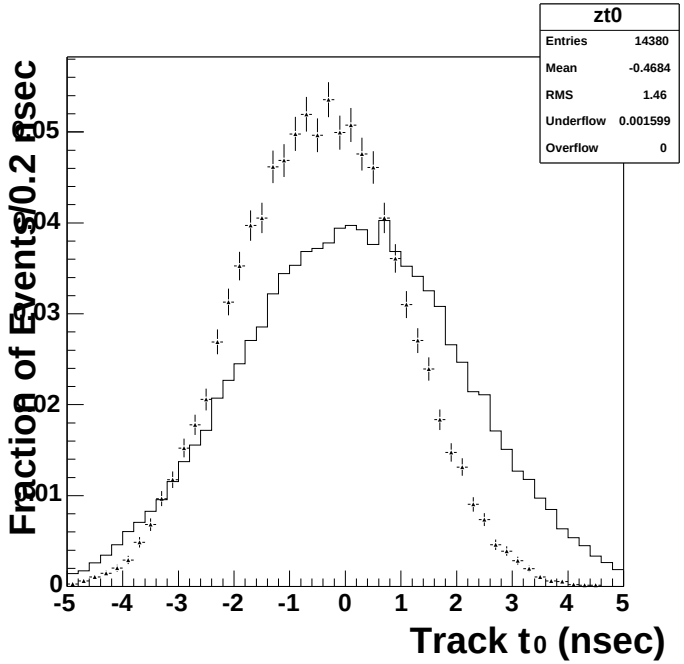
# Motivation

$t_0$ calibrated for each run

Event vertices have $\sim$1.5 ns spread in $t_0$

- 30 cm ($=$1 ns) luminous region
- Multiply by $\sqrt{2}$ for bunch-bunch overlap in time
- Z muons show 1.5 ns RMS (track $t_0$ resolution $\sim$0.4 ns)




$Z$ muons have unexplained 0.5 ns offset

1 ns $\sim$ 50 microns

*$t_0$ constraint could remove 75 $\mu$m contribution to resolution and 25 $\mu$m systematic*

# Algorithm

## Step 1: Create vertex seeds

- Loop over tracks and create new vertex if no existing vertex within 1 ns, 4 cm
- Add tracks to vertices within 1 ns, 4 cm

## Step 2: Merge vertices

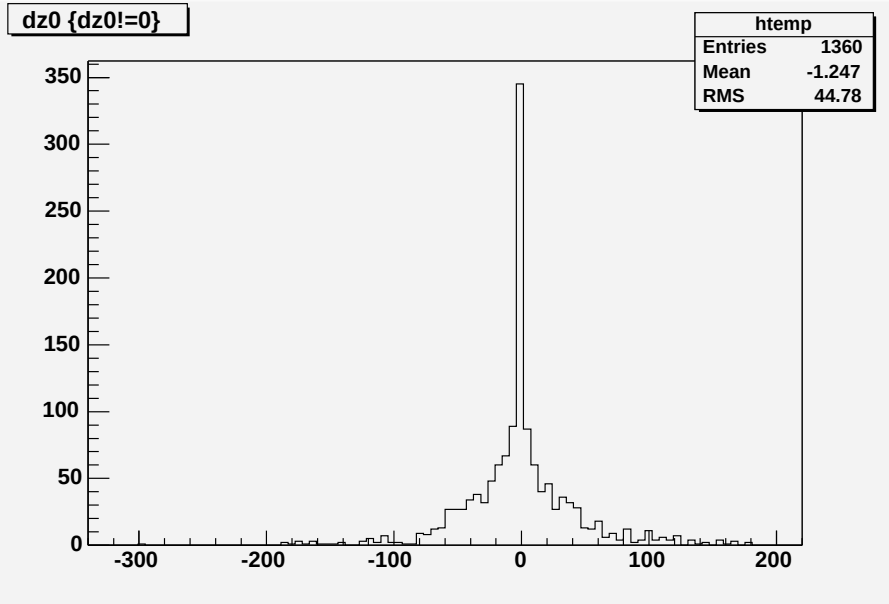
- Combine all vertices within 1.5 ns and 6 cm
- Keep only vertices with $\geq$3 tracks

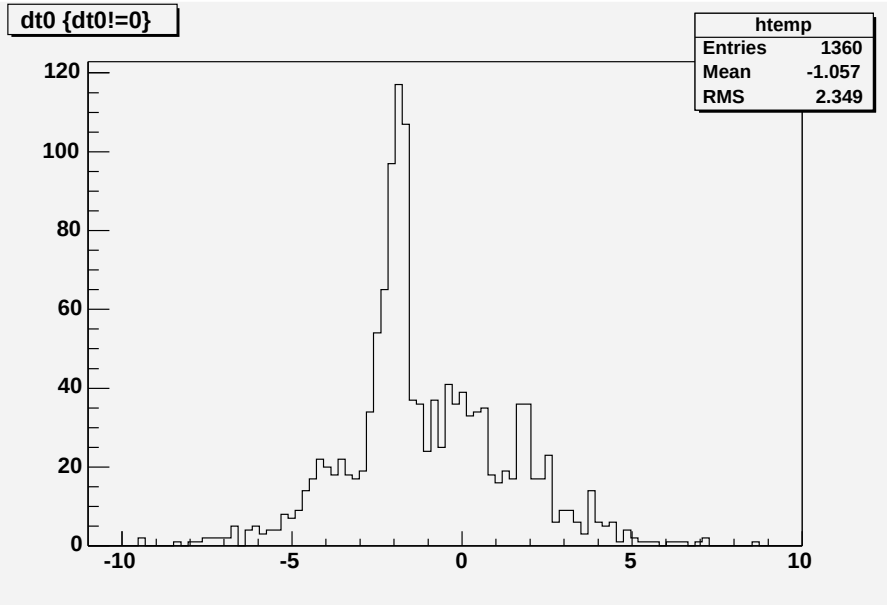
## Step 3: Constrain tracks

- Constrain track to best vertex within 1.5 ns and 6 cm

# Vertices

## $\Delta z_0$ and $\Delta t_0$ for vertices




## Large number of $\Delta z_0$ ∼0 vertices:

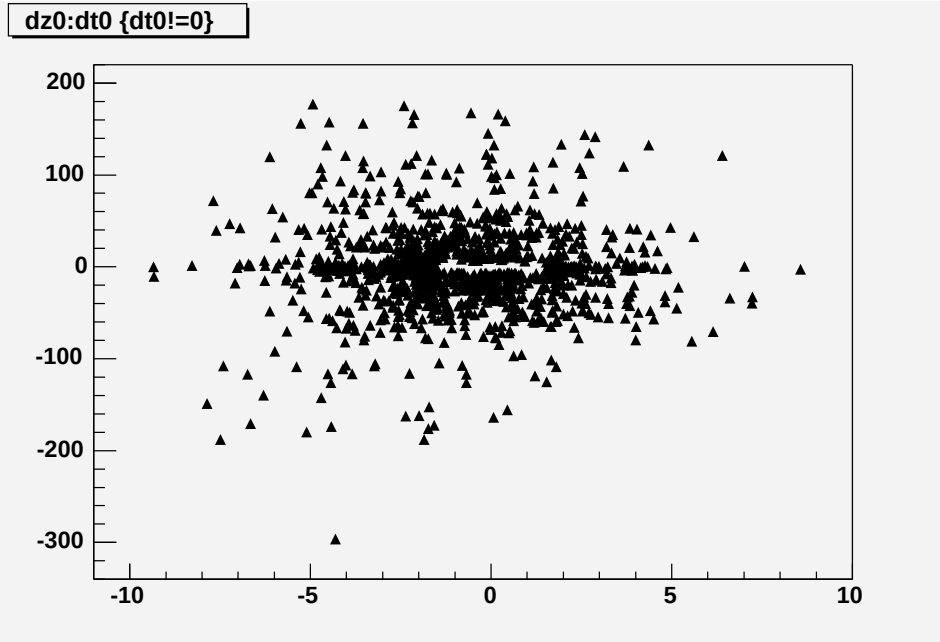
- Multiple vertices created from same collision vertex

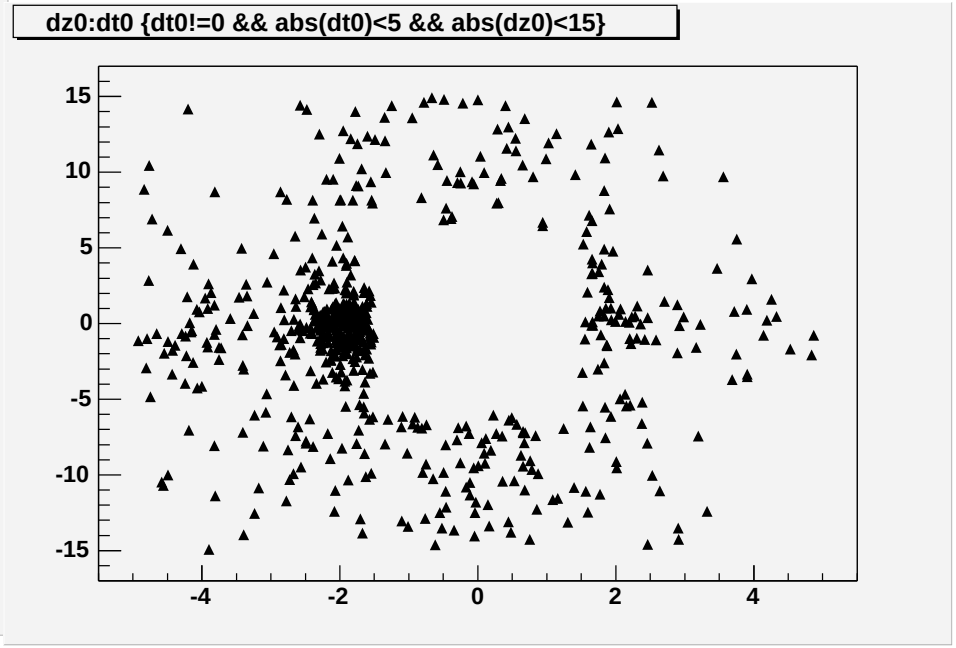
## Large peak in $\Delta t_0$ at -2 ns

- Vertices ordered by # tracks
  - Vertices with fewer tracks have higher $t_0$
  - *Same collision vertex: vertices with fewer tracks from $\beta < 1$ particles*

# Vertices

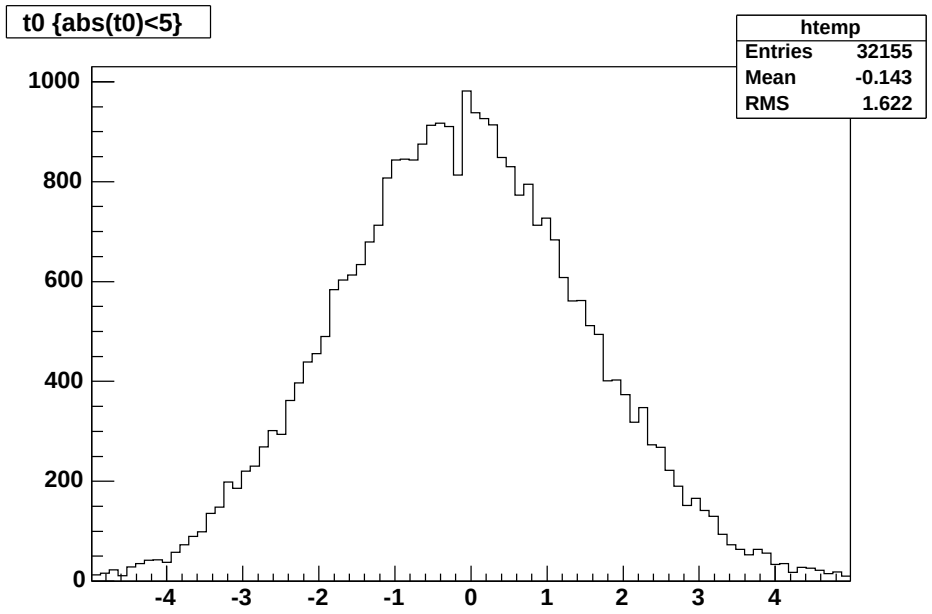
## $\Delta z_0$ vs $\Delta t_0$ for vertices

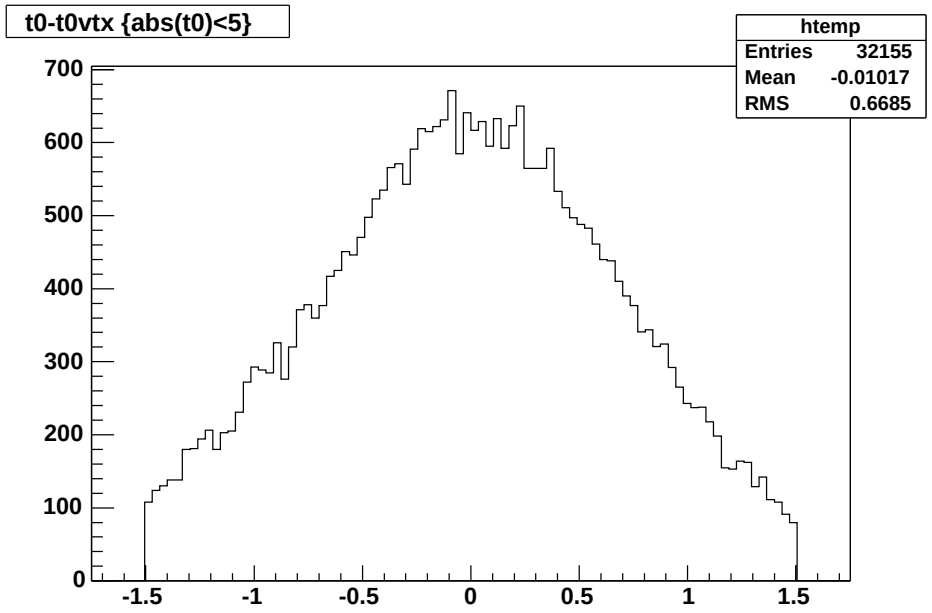


# Constrained Tracks

## Track $t_0$ and track-vertex $\Delta t_0$

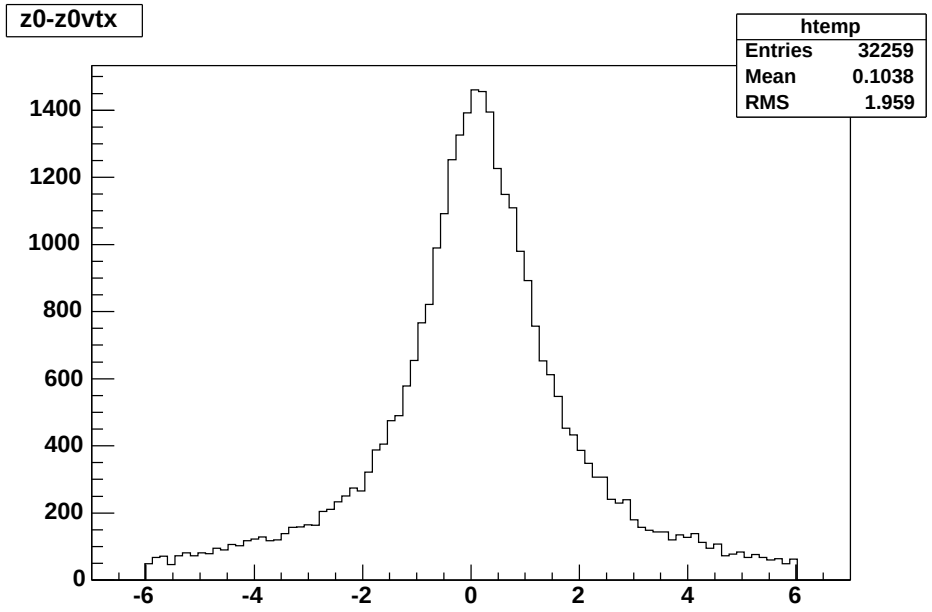


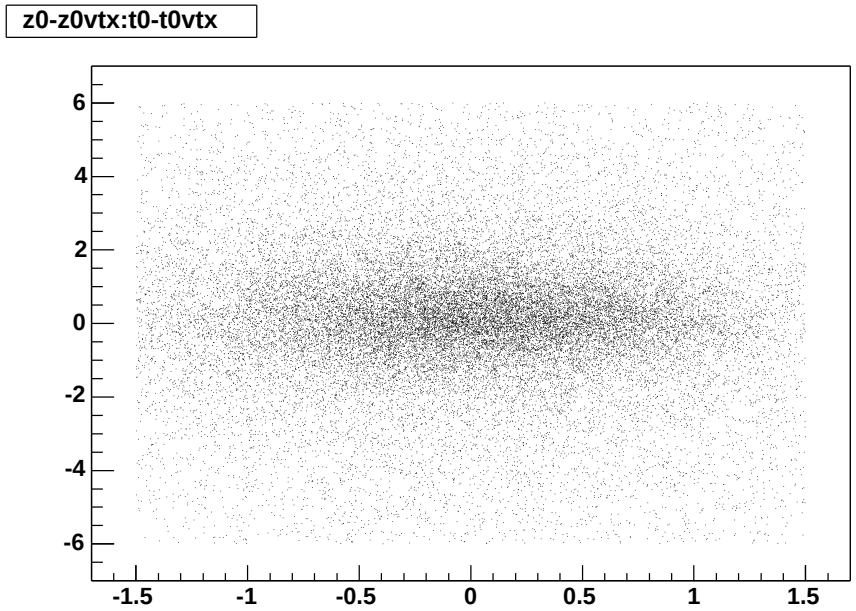




## Gaussian fit to $\Delta t_0$: $\sigma$=0.75 ns

# Constrained Tracks

## Track-vertex $\Delta z_0$ and $\Delta z_0$ vs $\Delta t_0$

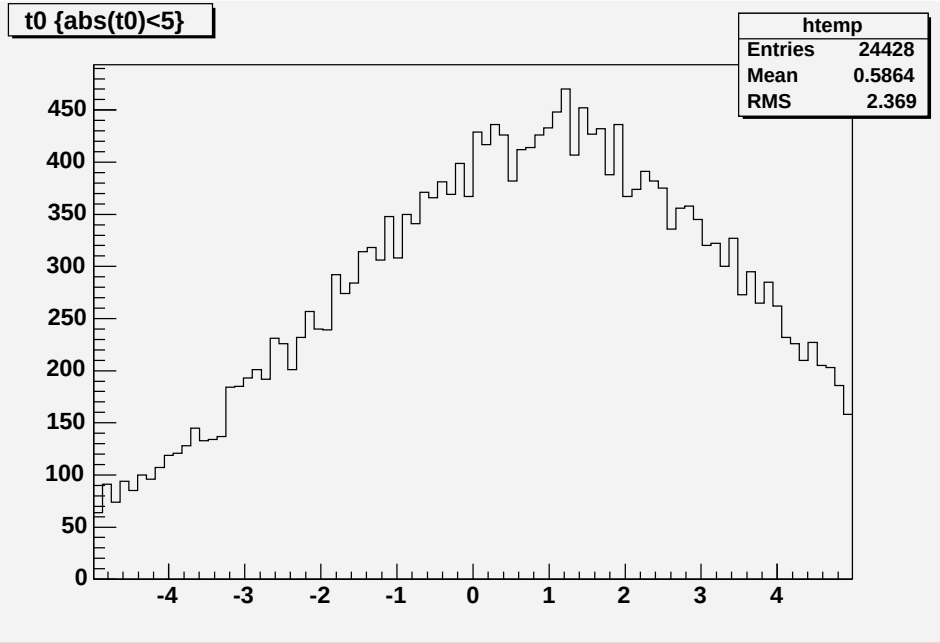


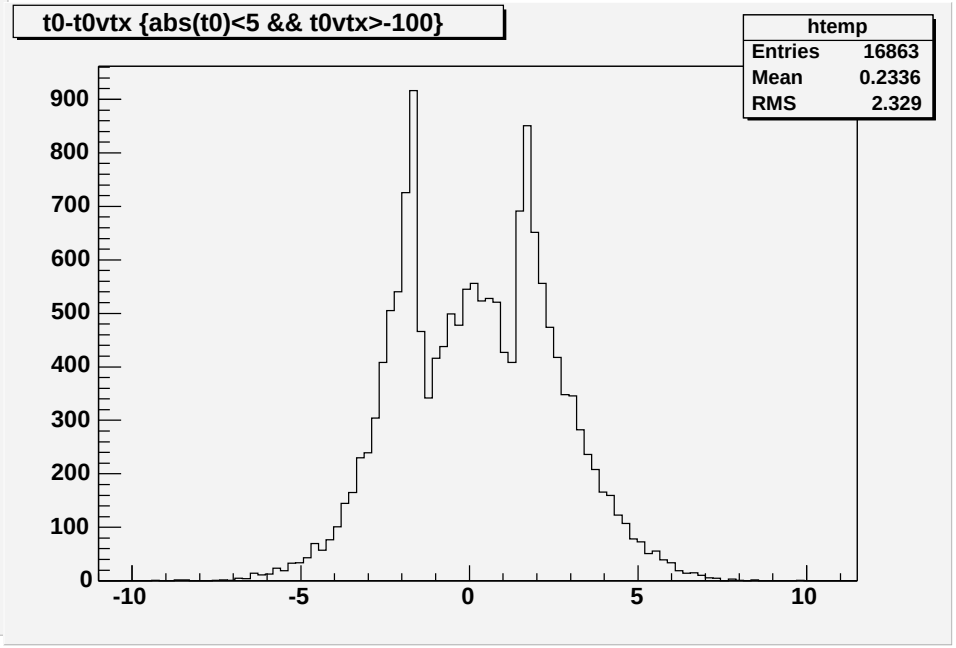




Gaussian fit to $\Delta z_0$ in $\pm 2$ cm range: $\sigma$=1 cm

# Unconstrained Tracks

## Track $t_0$ and track-vertex $\Delta t_0$

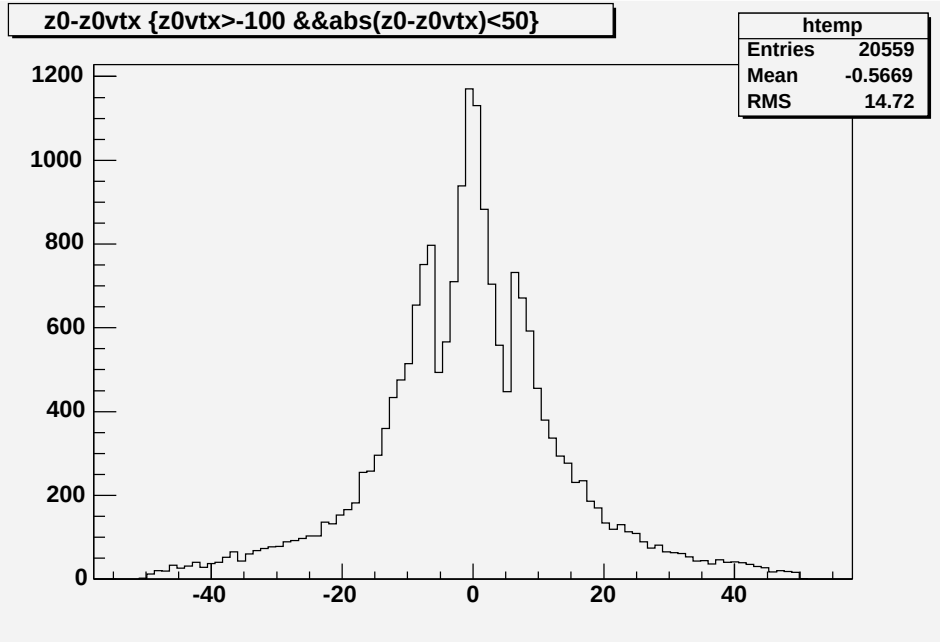


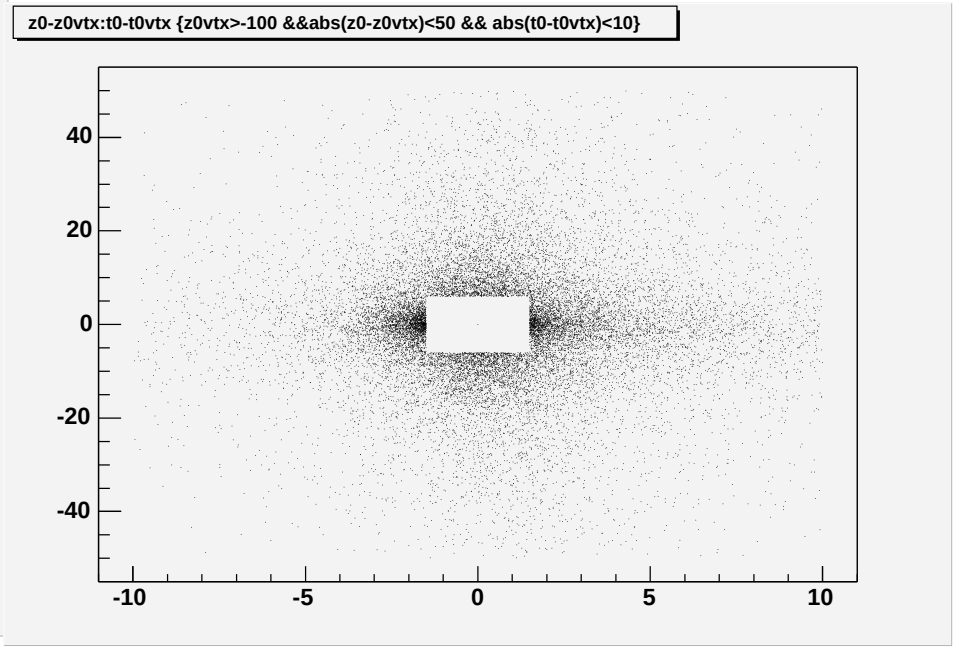




Mean positive $t_0$: slow tracks that do not make a vertex

# Unconstrained Tracks

## Track-vertex $\Delta z_0$ and $\Delta z_0$ vs $\Delta t_0$

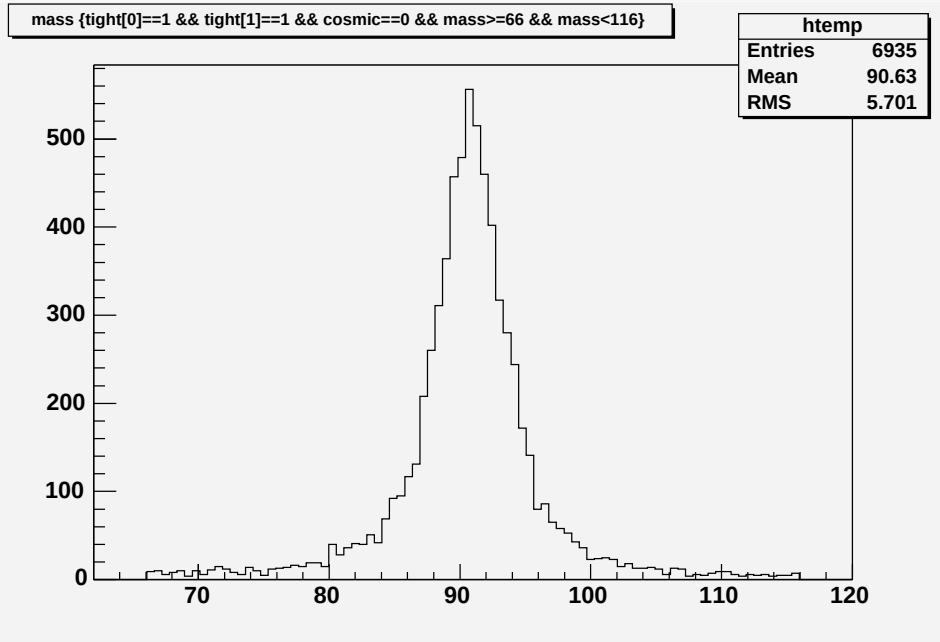


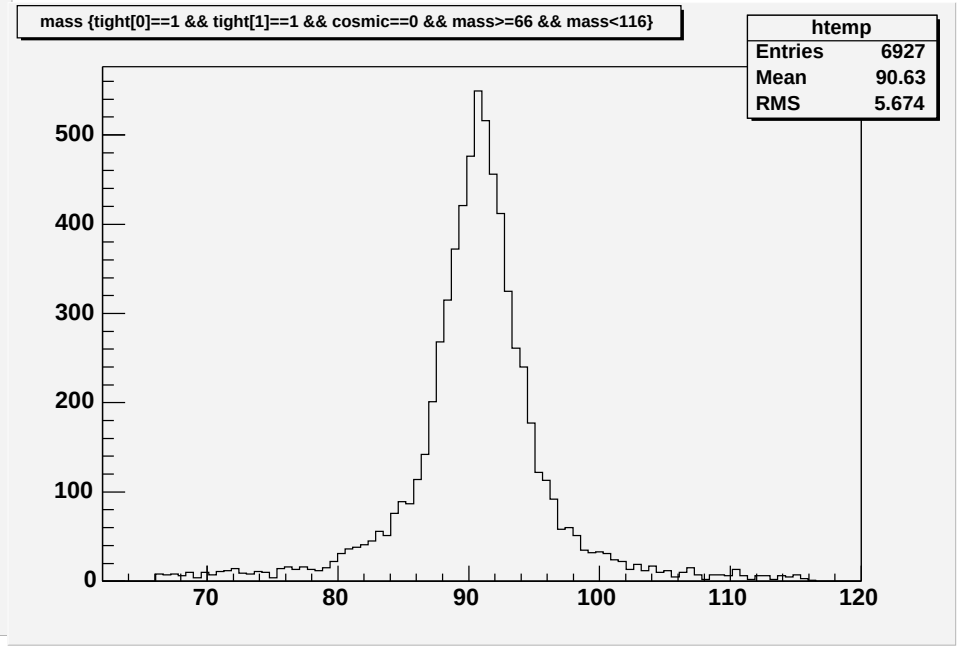




## More tracks with positive $\Delta t_0$ for small $\Delta z_0$

# Performance

Test reconstruction with (left) and without (right) constraint using $Z \rightarrow \mu\mu$ events

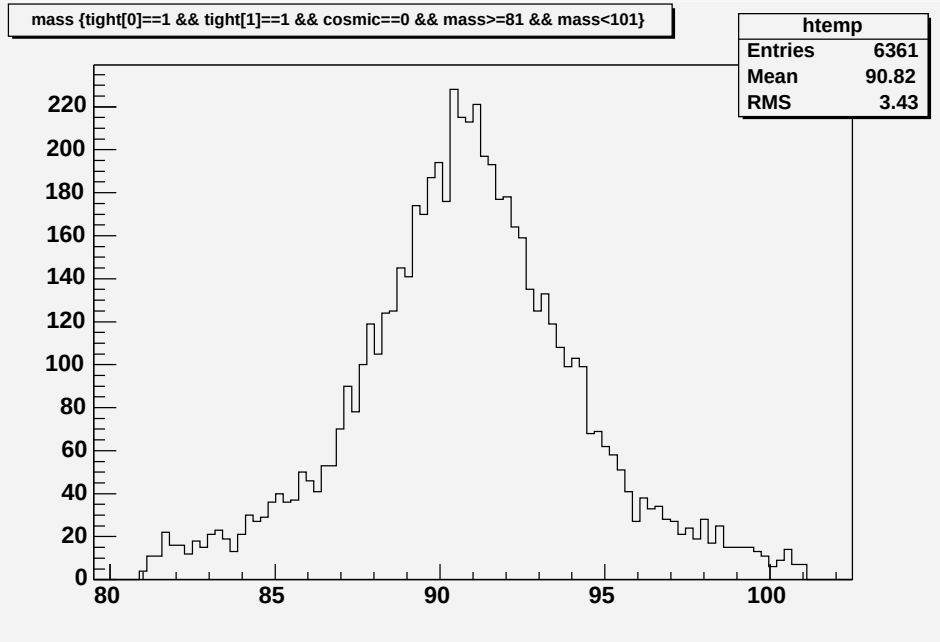


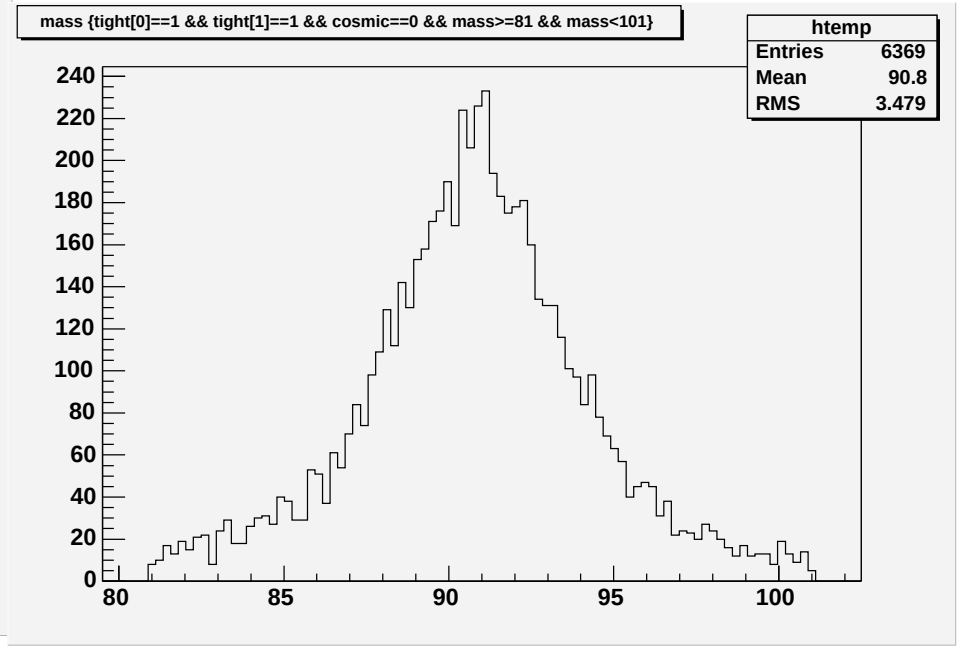




8 more events found with constraint (0.1% increase)

# Performance

Test reconstruction with (left) and without (right) constraint using $Z \rightarrow \mu\mu$ events




1.5% decrease in RMS (0.6 GeV contribution to resolution)

# Summary

Algorithm developed to constrain track $t_0$

- Side-effect: Hypothesis for $t_0$ offset in $Z \rightarrow \mu\mu$ events
  - Stage 0 includes slow particles in calibration fit, shifting $t_0$ positive

Fine-tuning parameters for vertex reconstruction

- Limited by track $t_0$ resolution
- CAF working on 0.5 ns/3 cm seeding, 1 ns/6 cm constraint window

Current algorithm shows small improvement in resolution

- Tighter definition of vertex $t_0$ should increase performance

Plan to expand tests to J/$\psi$'s and signed impact parameter