Online measurement and monitoring of the beam spot using fast vertexing

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Motivation and goals

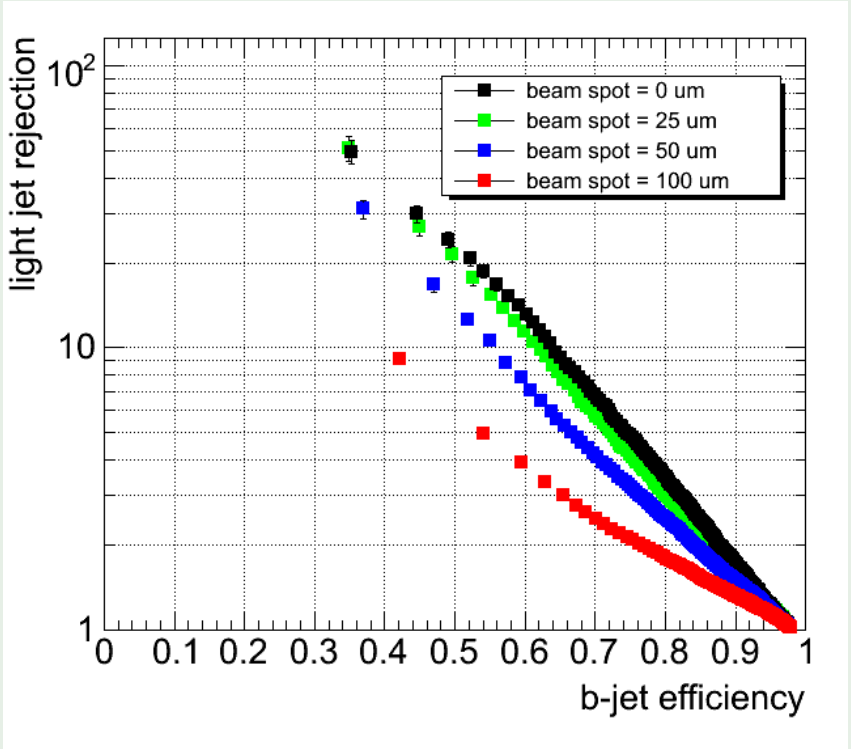
Primary motivation and Goals

- Provide feedback for L2 b-tagging
  - Must know nominal beam position for impact parameter calculation
- Provide beam info to LHC

How we do it

- Use L2 vertexing to fit tracks into primary vertices
- Histogram parameters and monitor on ∼lumi block time-scale
- Gather statistics from many HLT nodes and feedback
- Pass requested parameters to LHC (tilt, luminous region centroids, X, Y, Z profile)

L2 b-tagging



Light quark jet rejection vs. b-jet efficiency for beam spot offset (0,25,50,100 μm)

Design of the L2 beam spot algorithm

Online and offline

Both offline and online (i.e. " High Level Trigger") versions of the beam spot measurement with primary vertices are available for testing.

Design

1. Run preferentially on ROI's selected for track reconstruction
   - Beam spot finder may need to initiate track reco for fraction of ROI's if "seed" slices (e.g. *b*-jet) are pre-scaled or off
2. Implement internal track selection criteria
3. Utilize `L2PrimaryVertexFitter` for fast vertexing on selected tracks (see next slide)
4. Bin resulting fit parameters in X vs. Z and Y vs. Z
   - Measure beam profile at each Z, extract beam tilt angle
5. Results delivered to monitoring infrastructure in form of 1D/2D histograms
   - Light weight for collective result extraction

Use of tracking and vertexing online

Tracking

1. L2 Tracks assumed to be reconstructed already (in current version)
2. Loop over all tracks, select via kinematic and quality criteria
   - configurable in job options
3. Monitored variables (kinematics, tracking) stored, counters updated

Vertexing

1. Using selected tracks only, cluster in Z using high p_T "seed" track
2. Iterate until tracks in cluster rejected or collected
   - stick into 2D vector: vector of track clusters
3. Fit tracks in each cluster with `L2PrimaryVertexFitter`
   - (`ATL-DAQ-CONF-2007-028`)
   - cluster skipped if fit does not converge
   - Runs in linear time with N_{track} to be fitted
4. Monitored variables stored
5. Vertex selection via fit quality, precision, kinematics
6. 2D histogram of X and Y vs. Z filled for selected vertices

First look at L2 online beamspot vertexing algorithm

Fast primary vertex fit timing

Fit	**Mean** (ms)	**RMS** (ms)	$N_{iterations}$	$\langle N_{track} \rangle$
PrimaryVertexFit	0.225875	0.631937	32	15

`PrimaryVertexFitter`

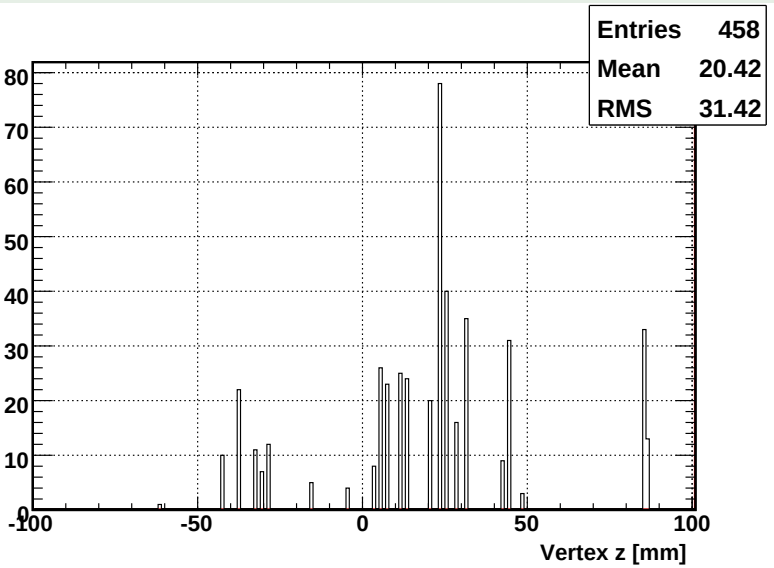
Fast L2 primary vertex fitter is adapted from the *B*-physics group's (Dmitry Emeliyanov's) fast secondary vertex fitter which is optimized for the specific structure of the L2 tracks and low track multiplicity vertices.

- Utilizes only 2×2 symmetric sub-matrices of the fit covariance matrix
- No smoothing pass is needed: as soon as the last track is processed the full estimate of the fit is available

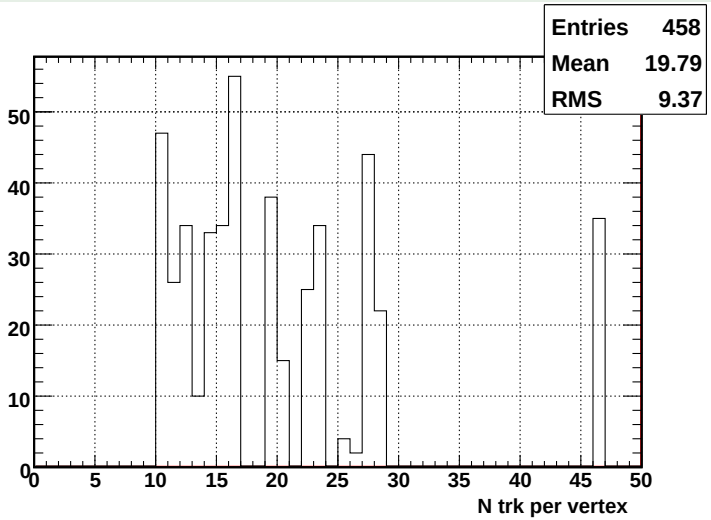
- Trigger element used to seed the vertexing for tests: `L2_eNoCutID`
- Simply gave lots of tracks, this will of course have to be optimized, accounted for and recorded

L2 fast vertexing is functioning, but work to do

Vertex Z distribution



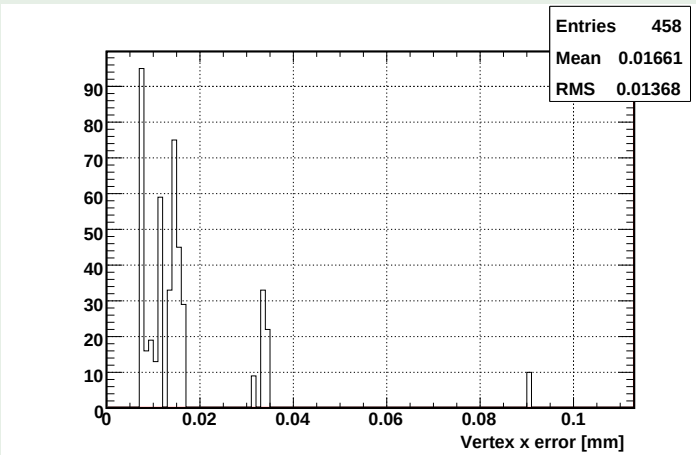
Vertex track multiplicity



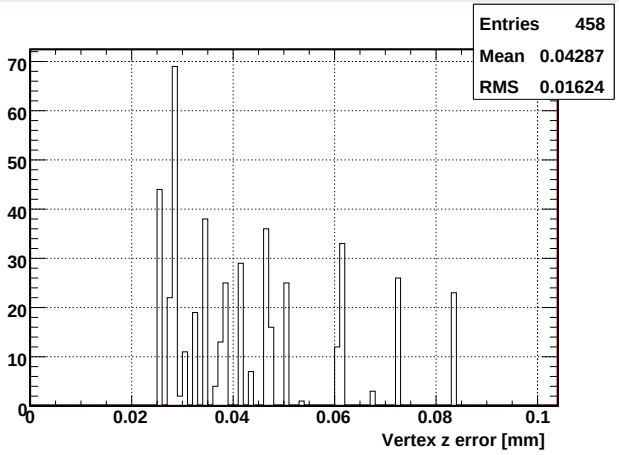
- These data contain **di-jet (J4)** events produced with no beam offset and misaligned geometry, reconstructed with Release 14.0.0.
- Redundant tracks found by several trigger elements needs to be accounted for (currently is not).
- Bug in loop over clusters causes some to appear many (10's) of times (see spikes in plot). Fixed.

Vertex fit quality

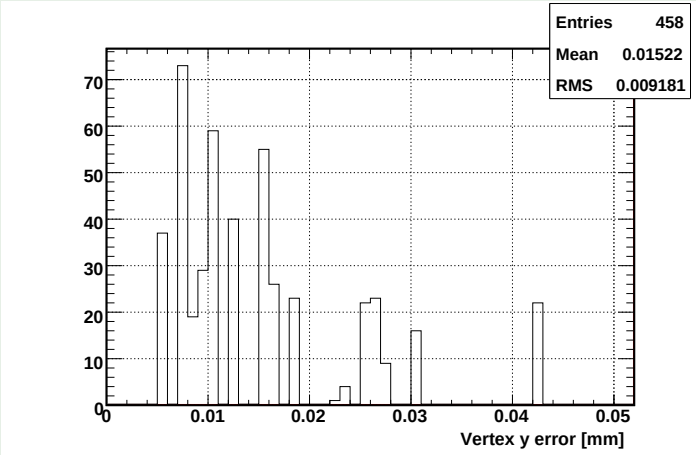
σ_x [mm]



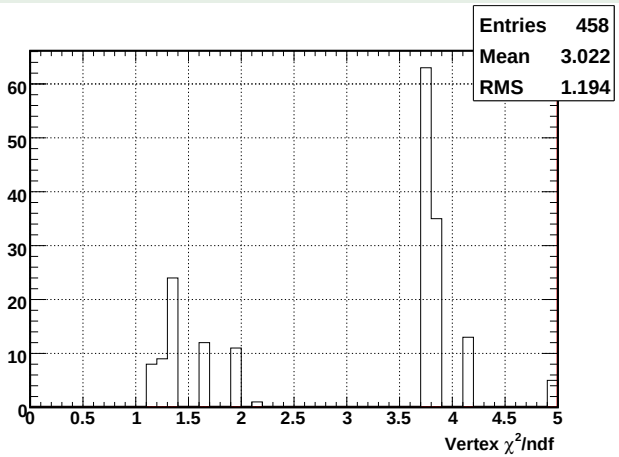
σ_z [mm]



σ_y [mm]

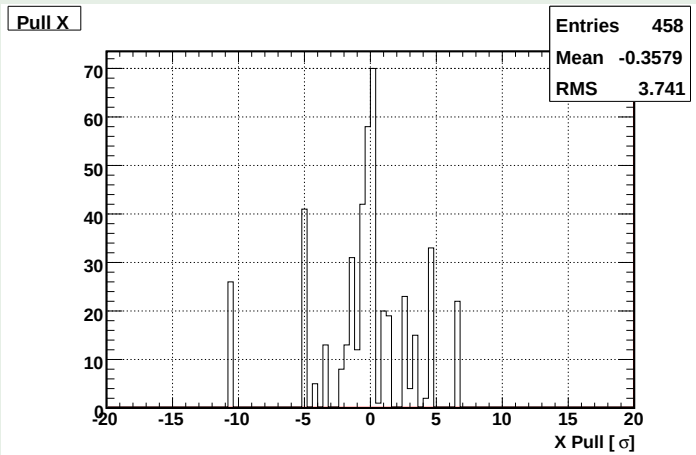


Fit χ^2/NDF

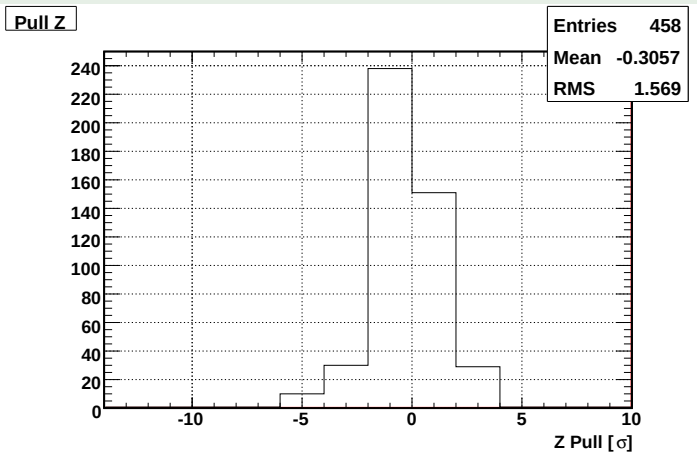


Vertexing precision

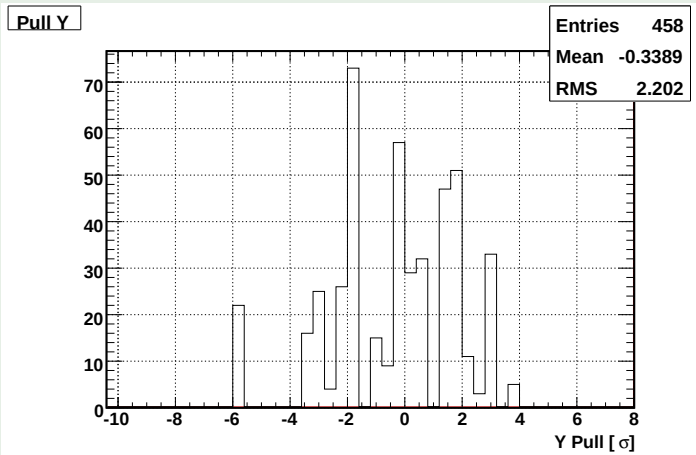
X pull ($\frac{x_i - x_{MC}}{\sigma_x^i}$)



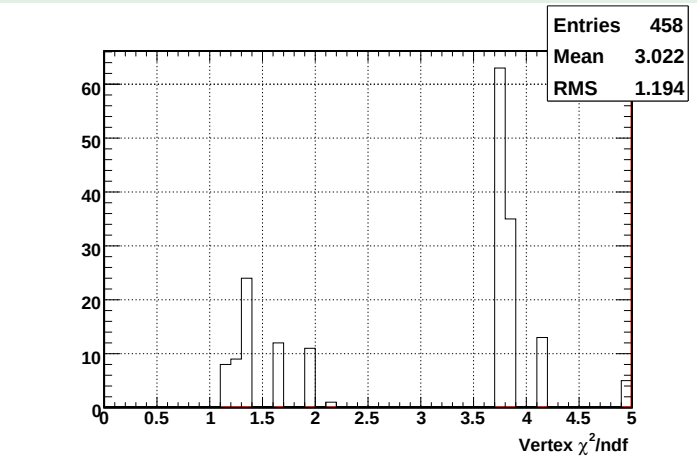
Z pull ($\frac{z_i - z_{MC}}{\sigma_z^i}$)



Y pull ($\frac{y_i - y_{MC}}{\sigma_y^i}$)



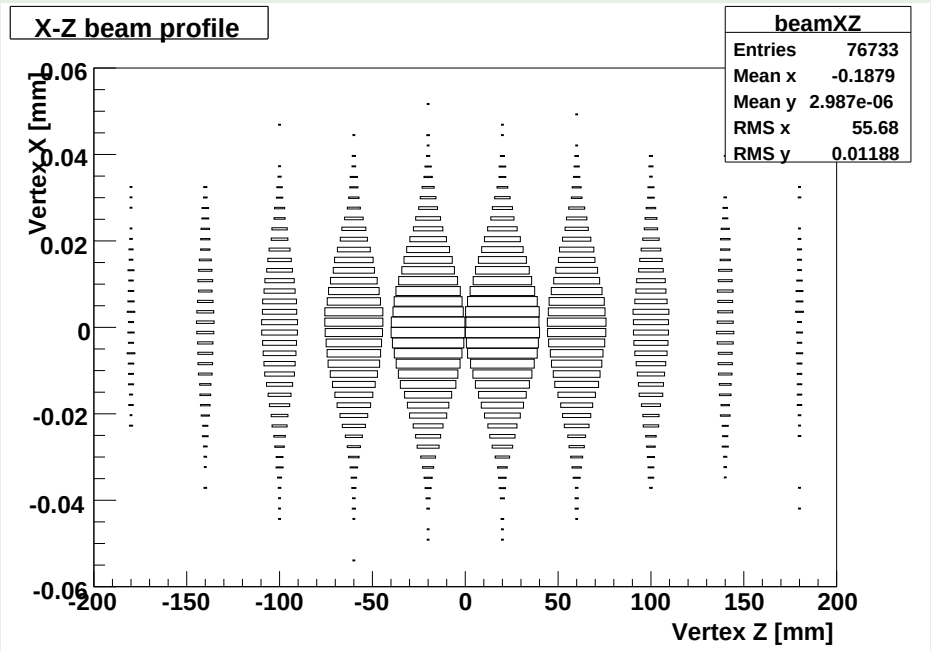
σ_x vs. Z [mm]



First look using offline algorithms in sim. & FDR-1

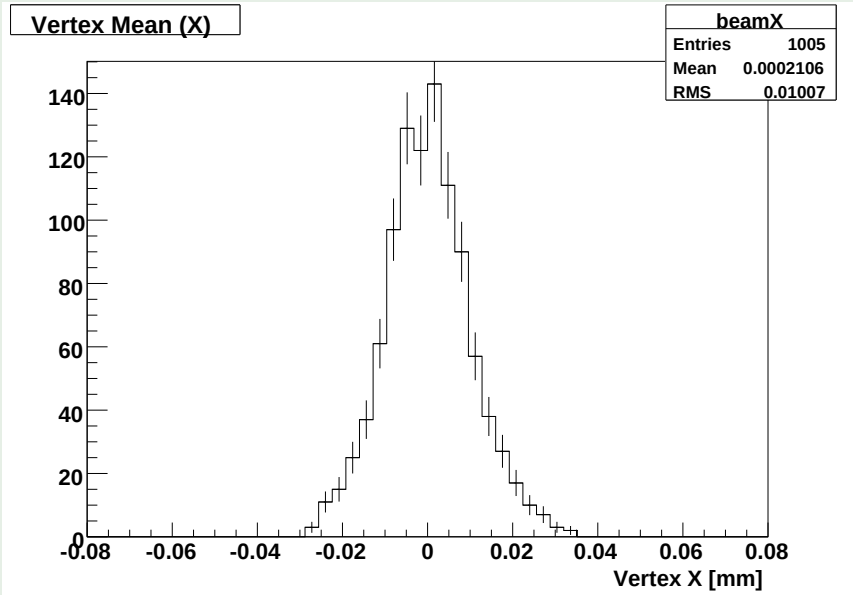
Can develop a feel for the beam spot measurements using offline version of algorithm

X vs. Z luminous region ($t\bar{t}$)



75K events (vertices)

Vertex X [mm] (selected vertices)



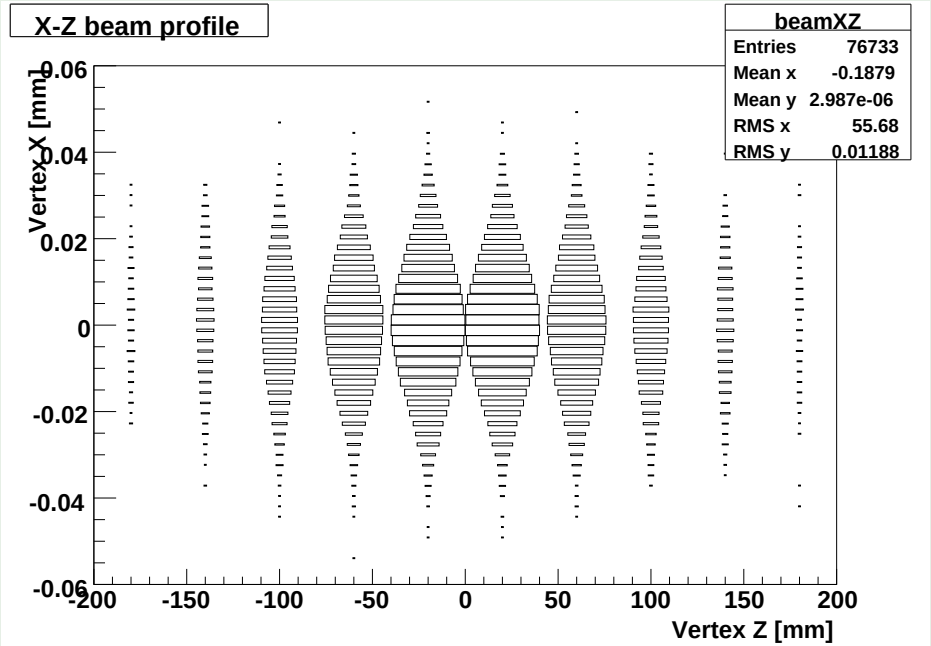
Error on mean = 0.32 μm
(1K events)

These data contain **di-jet (J3)** events produced with no beam offset and misaligned geometry, reconstructed with Release 13.0.30.

First look using offline algorithms in sim. & FDR-1

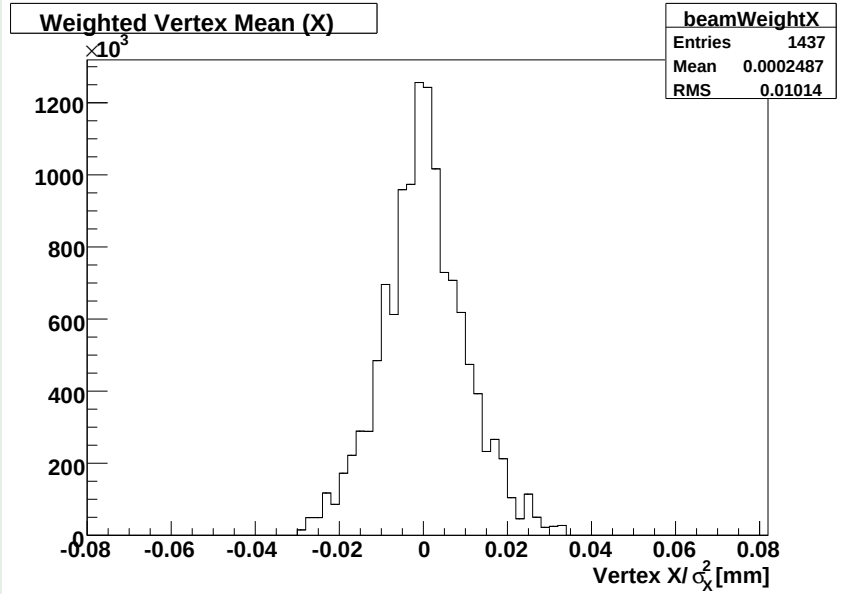
Can develop a feel for the beam spot measurements using offline version of algorithm

X vs. Z luminous region ($t\bar{t}$)



75K events (vertices)

Weighted by $\frac{1}{\sigma_x^2}$ [mm] (no selection)



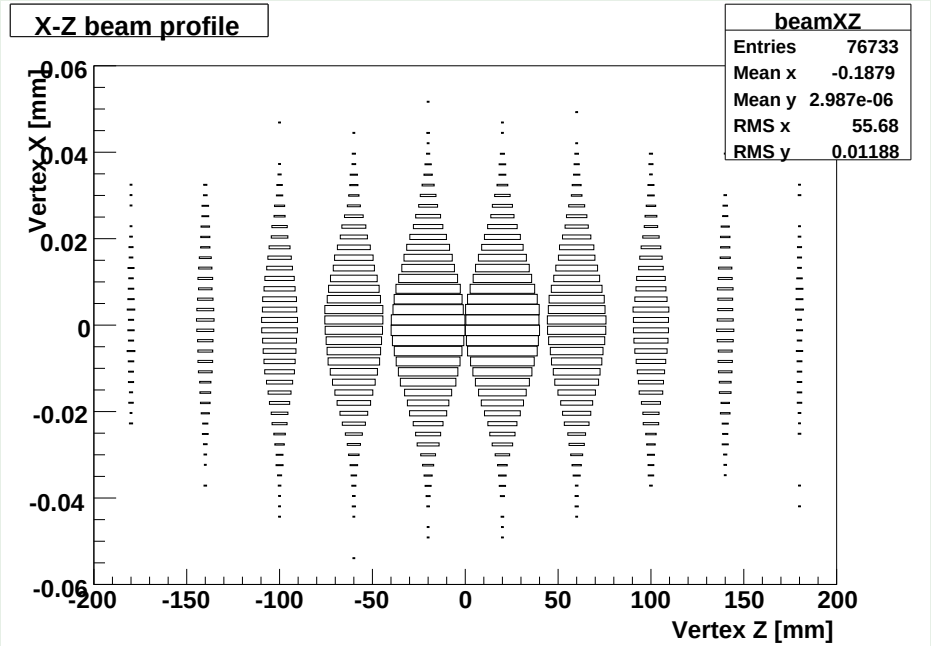
Error on mean = 0.31 μm
(1K events)

These data contain **di-jet (J3)** events produced with no beam offset and misaligned geometry, reconstructed with Release 13.0.30.

First look using offline algorithms in sim. & FDR-1

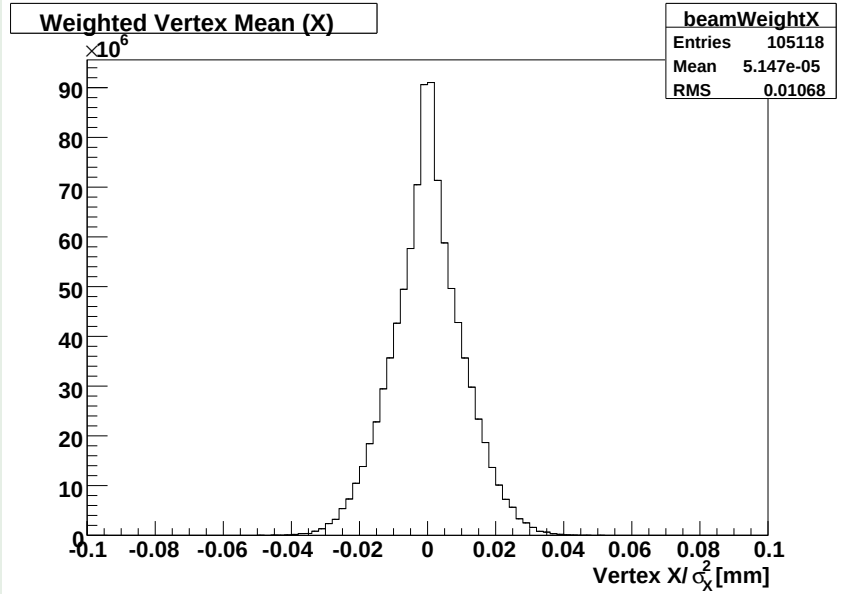
Can develop a feel for the beam spot measurements using offline version of algorithm

X vs. Z luminous region ($t\bar{t}$)



75K events (vertices)

Weighted by $\frac{1}{\sigma_x^2}$ [mm] (no selection)

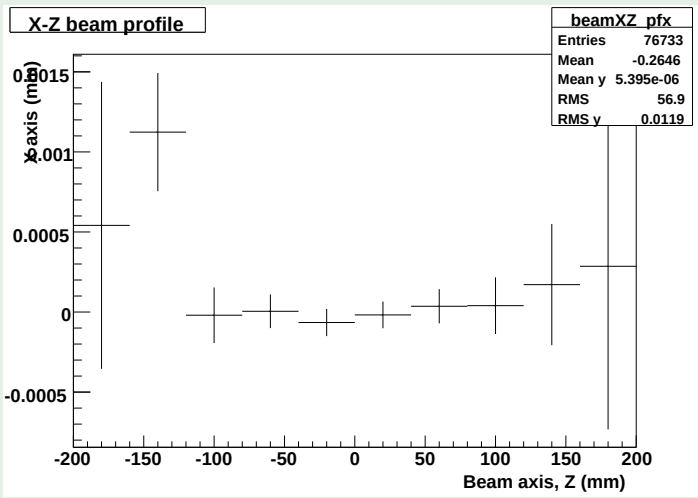


Error on mean = 0.038 μm
(75K events)

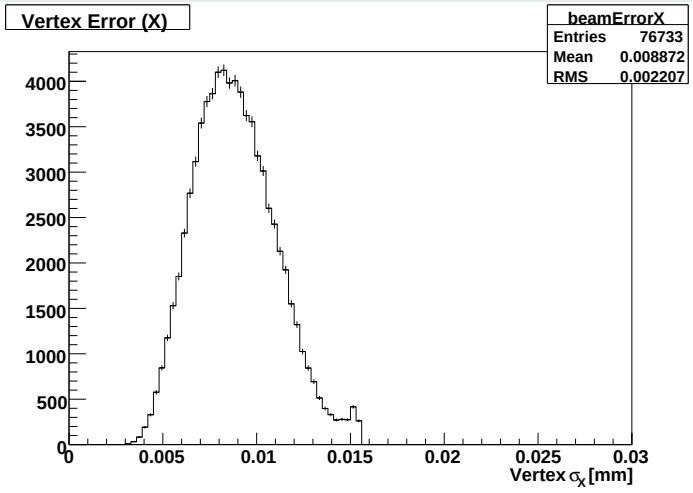
These data contain **di-jet (J3)** events produced with no beam offset and misaligned geometry, reconstructed with Release 13.0.30.

Beam spot precision: 75K $t\bar{t}$ events

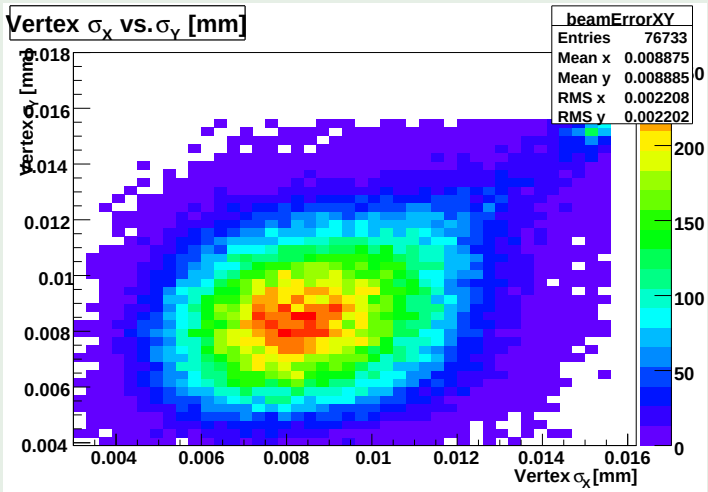
Vertex X distribution [mm]



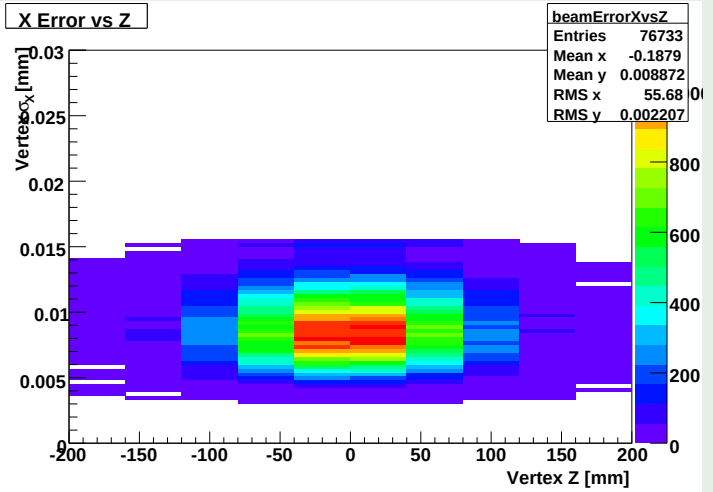
Vertex σ_x [mm]



2D correlation: σ_y vs. σ_x [mm]

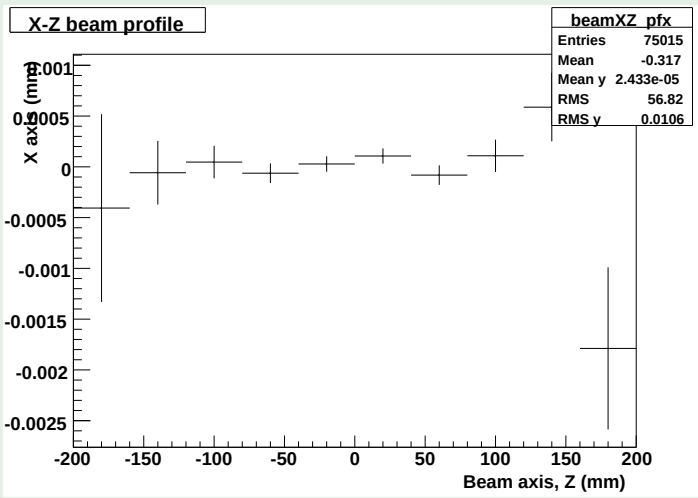


σ_x vs. Z [mm]

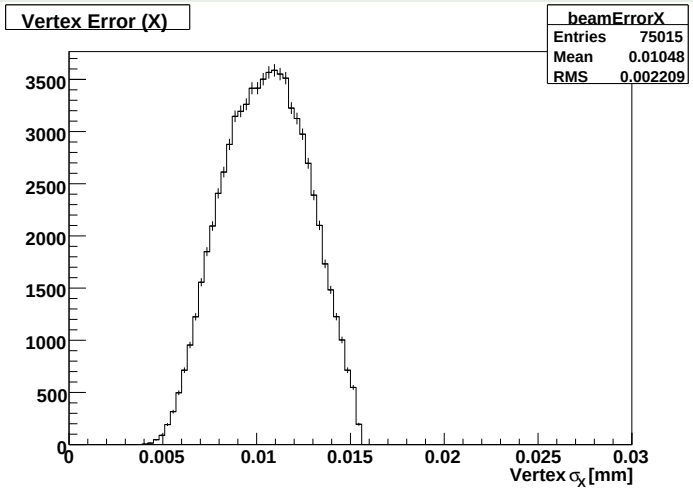


Beam spot precision: 75K *J*3 events

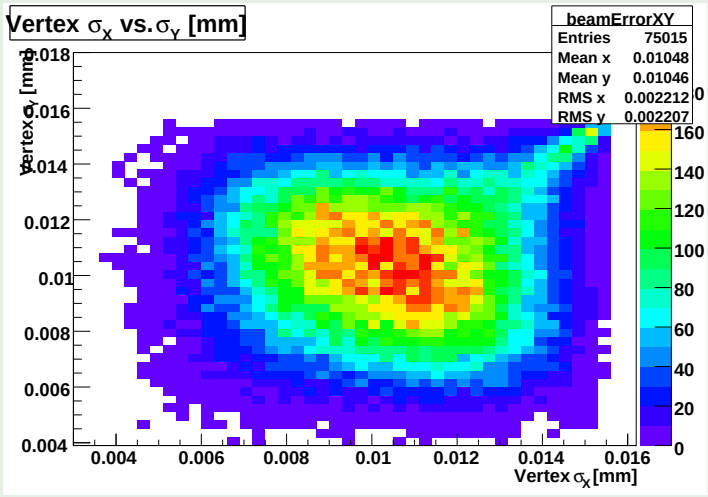
Vertex *X* distribution [mm]



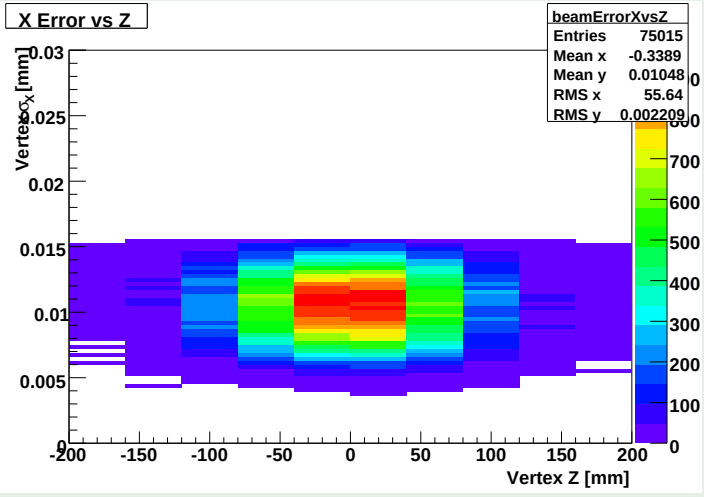
Vertex σ_x [mm]



2D correlation: σ_y vs. σ_x [mm]

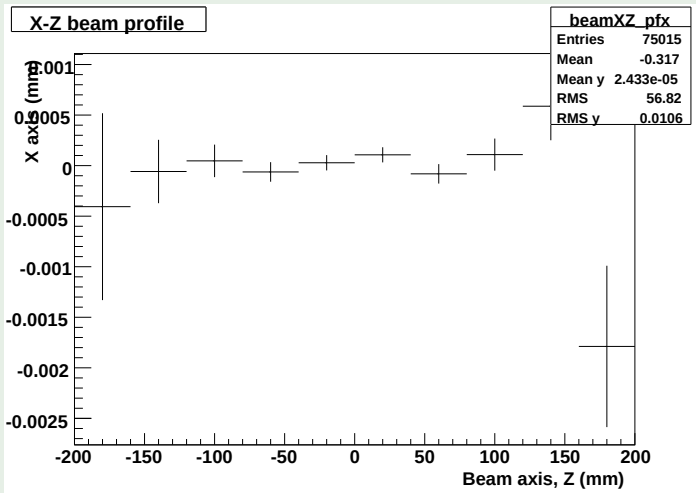


σ_x vs. *Z* [mm]

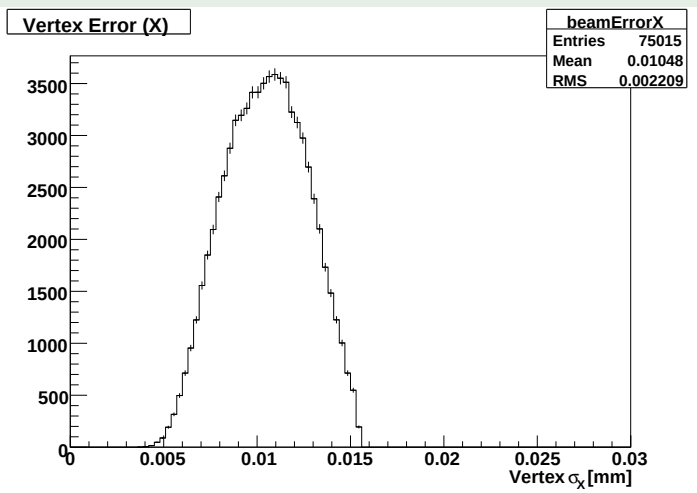


Beam spot precision: 75K *J*3 events

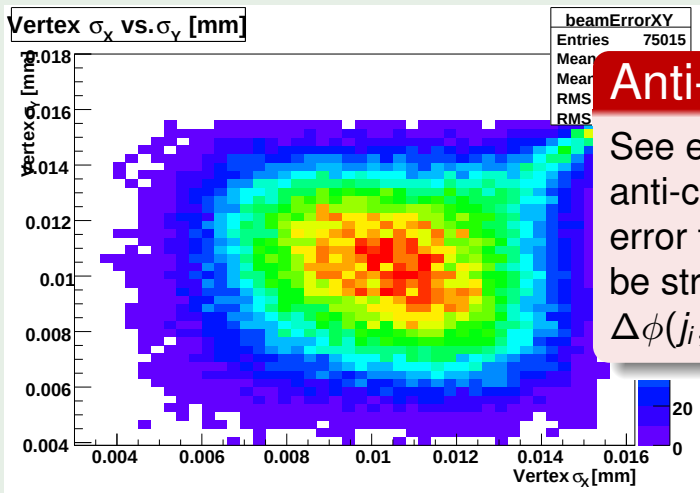
Vertex *X* distribution [mm]



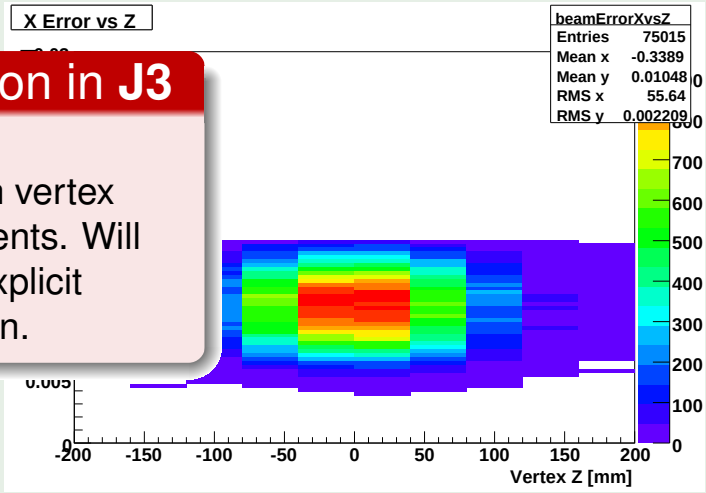
Vertex σ_x [mm]



2D correlation: σ_y vs. σ_x [mm]



σ_x vs. *Z* [mm]

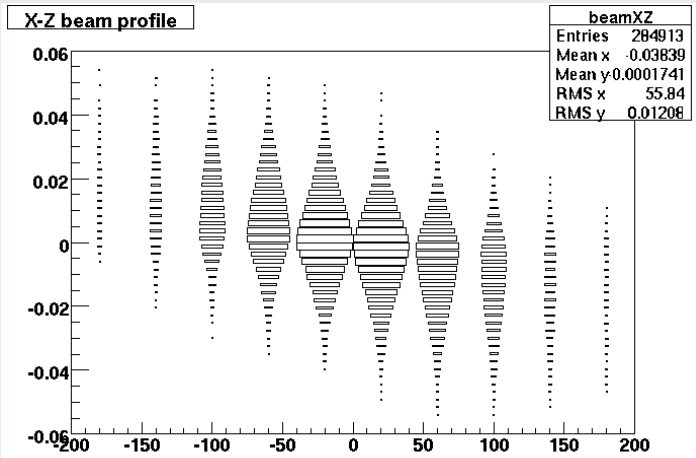


Anti-correlation in **J3**

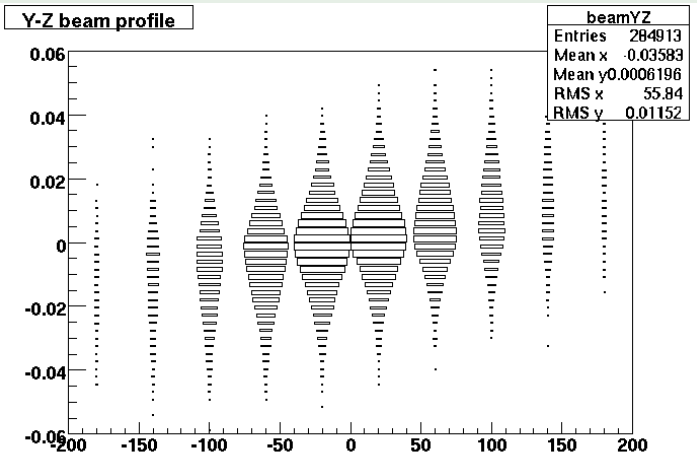
See expected anti-correlation in vertex error for di-jet events. Will be stronger for explicit $\Delta\phi(j_i, j_2)$ selection.

Beam tilt angle distributions in FDR-1

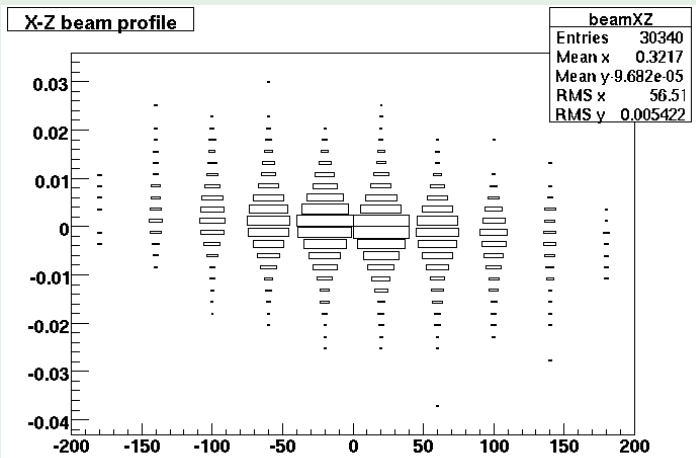
Jet stream (X vs. Z)



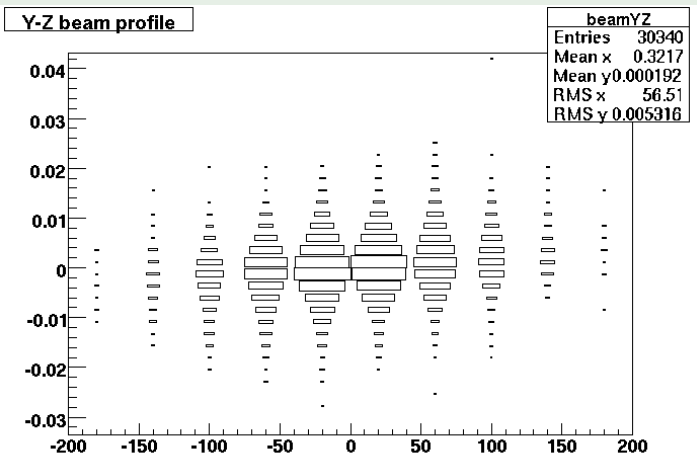
Jet stream (Y vs. Z)



Min bias stream (X vs. Z)

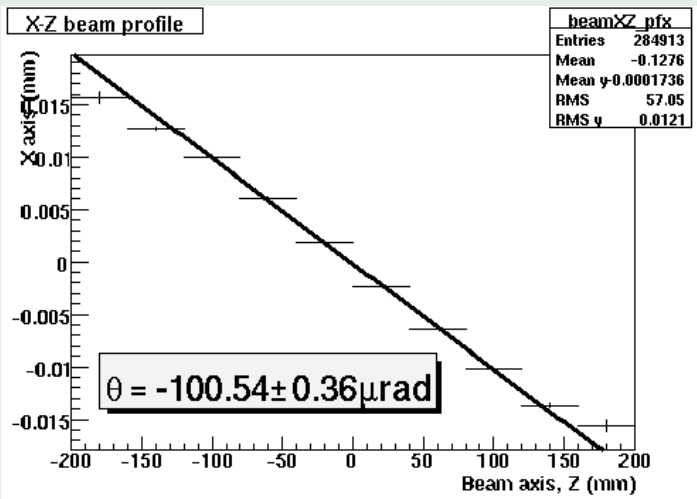


Min bias stream (Y vs. Z)

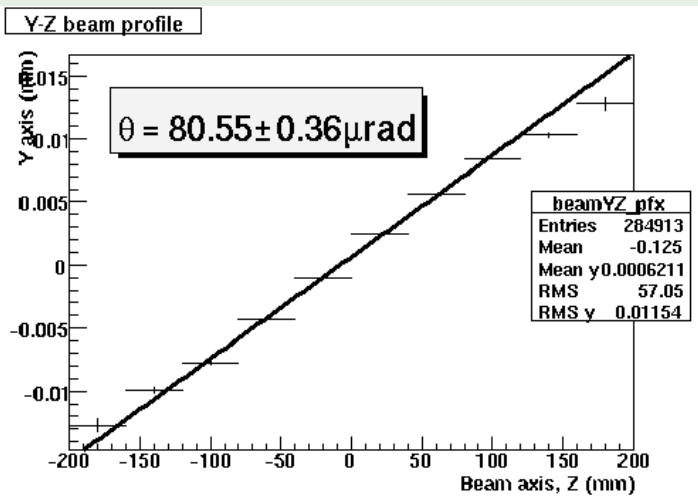


Beam tilt angle in FDR-1: difference between streams!

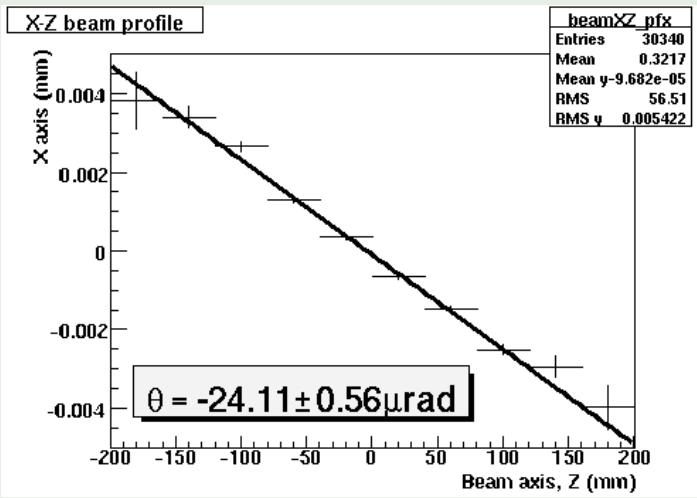
Jet stream (X vs. Z)



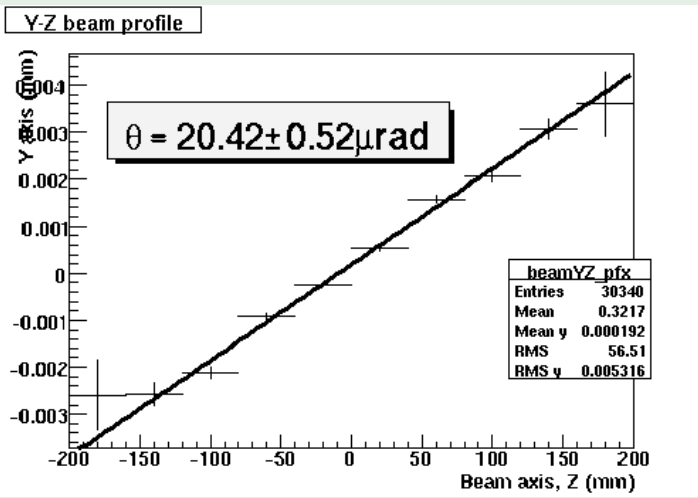
Jet stream (Y vs. Z)



Min bias stream (X vs. Z)

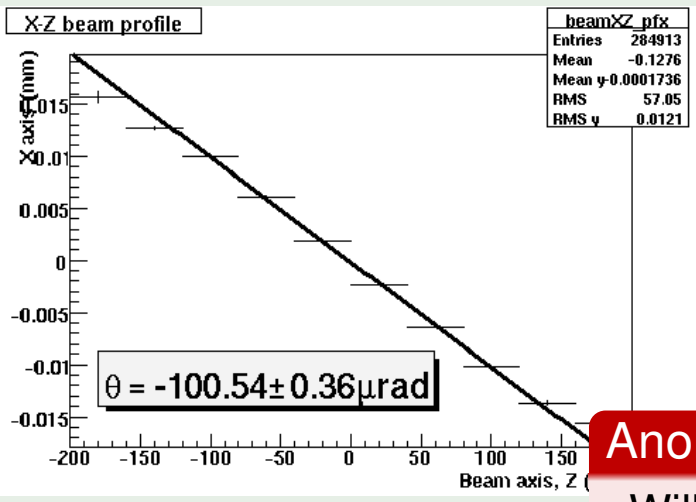


Min bias stream (Y vs. Z)

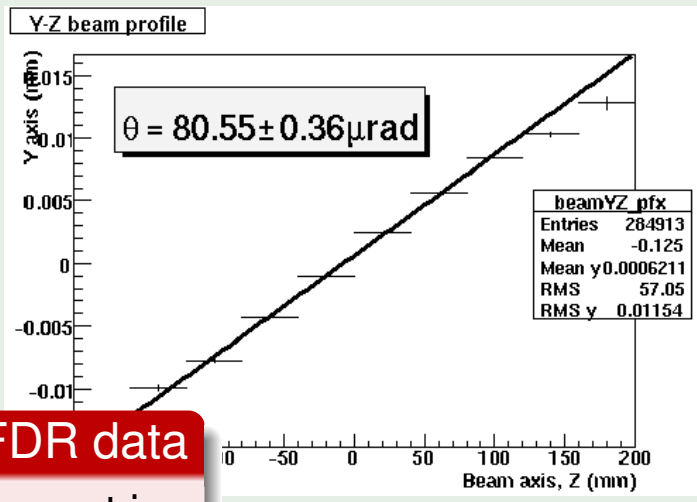


Beam tilt angle in FDR-1: difference between streams!

Jet stream (X vs. Z)



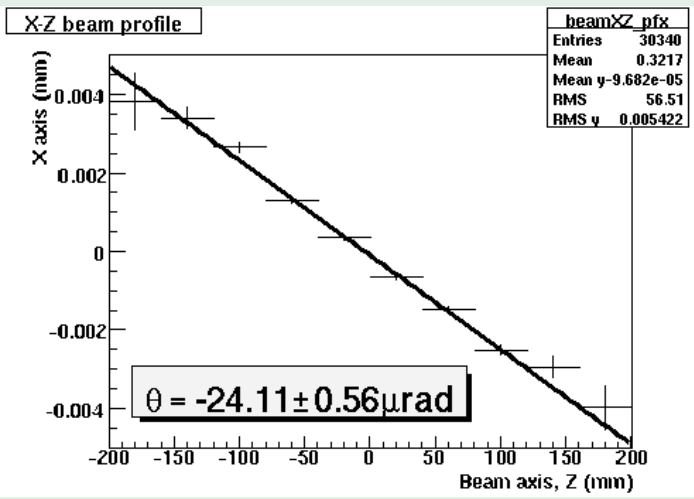
Jet stream (Y vs. Z)



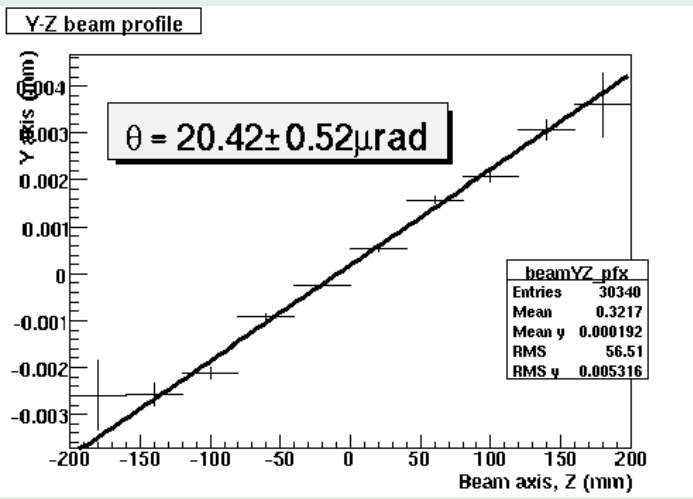
Anomaly in FDR data

Will not be present in real data!

Min bias stream (X vs. Z)

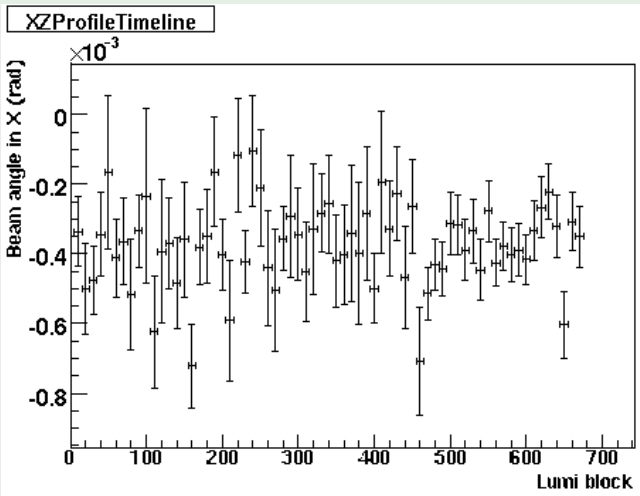


tream (Y vs. Z)

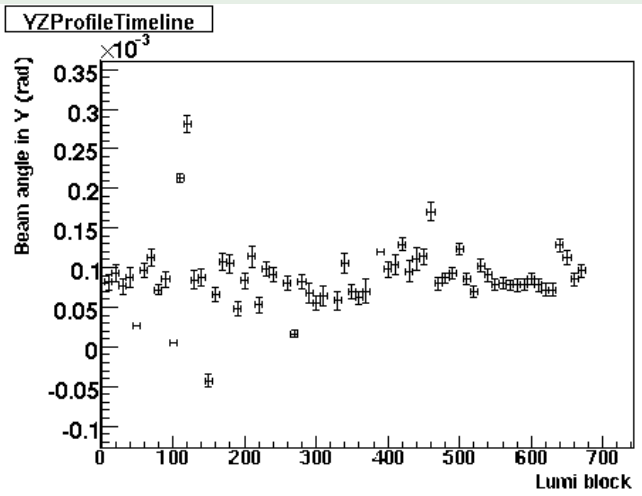


Beam tilt angle timeline (FDR-1, steps of 10 LB)

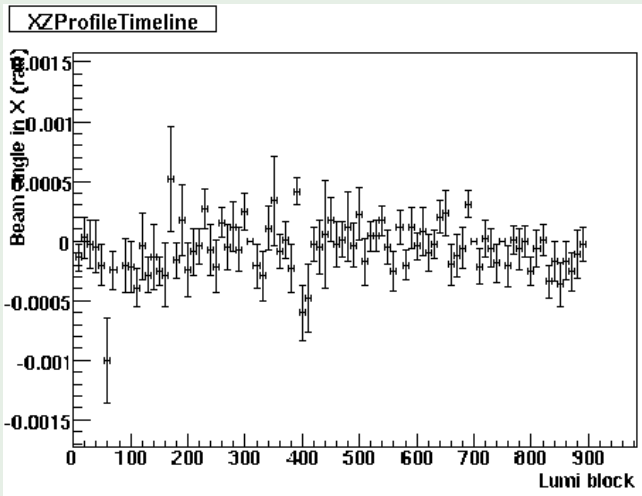
Jet stream (X vs. Z)



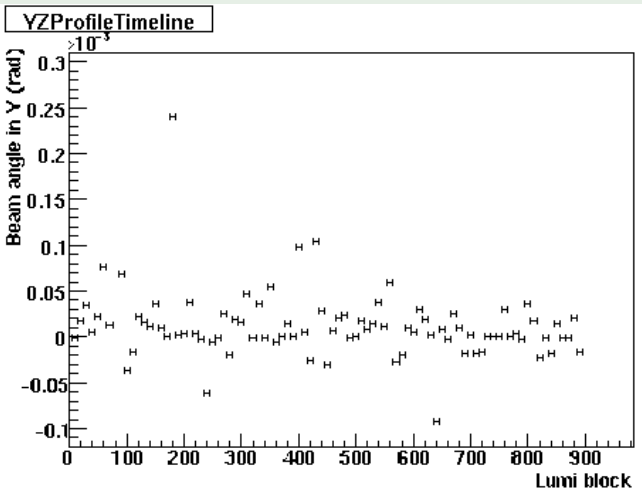
Jet stream (Y vs. Z)



Min bias stream (X vs. Z)

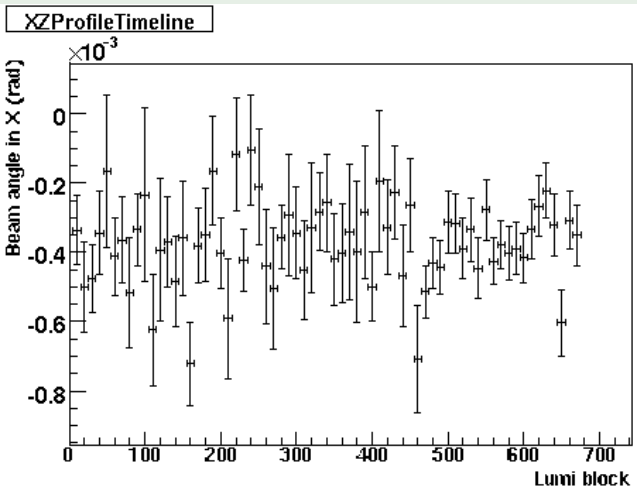


Min bias stream (Y vs. Z)

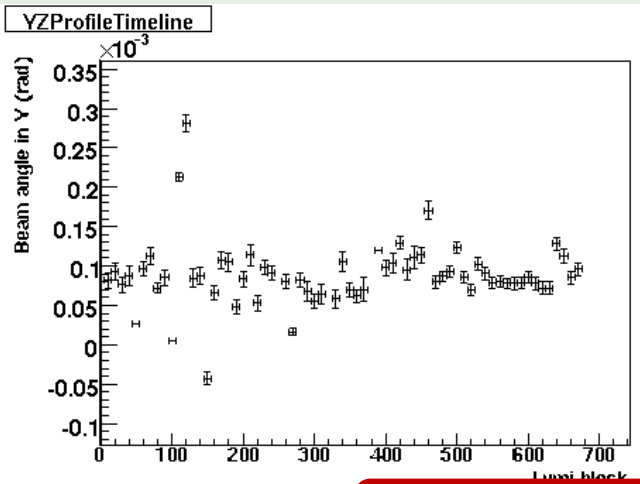


Beam tilt angle timeline (FDR-1, steps of 10 LB)

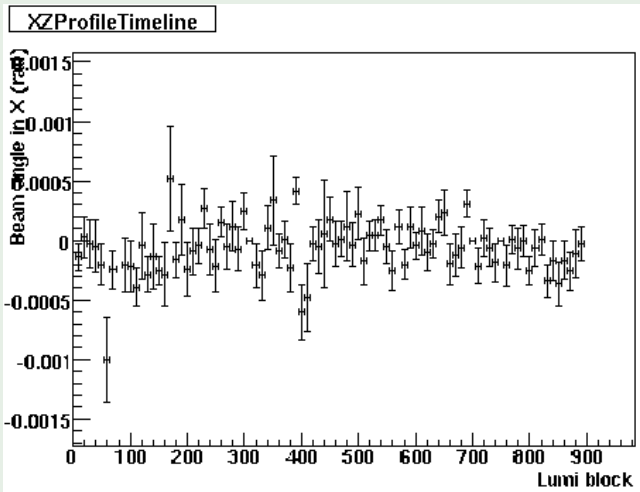
Jet stream (X vs. Z)



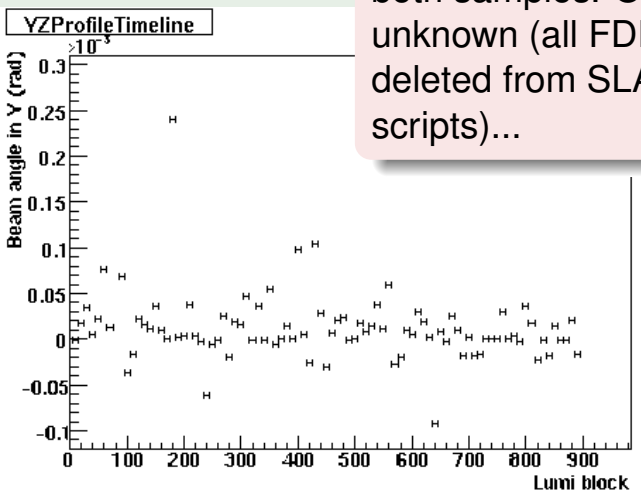
Jet stream (Y vs. Z)



Min bias stream (X vs. Z)



Min bias stream



Shift in beam angle

Shift in beam angle seen for both samples. Origin still unknown (all FDR data were deleted from SLAC by Tier2 scripts)...

Conclusions

Status

- Online algorithm is under testing (bugs already found)
- Rapid development and testing is needed to meet urgent schedule
- Precision and timing look very promising for L2

Next steps

- Must ensure robustness against misalignment and “random” initial position of beam
  - very important for track selection, for example
- Infrastructure for monitoring, persistification of beam spot results, and feedback to LHC and L2 seen as most crucial action items
  - Formalize specifications for gatherer, parameter extraction and distribution
  - Standardize usage of beam spot measurement results in HLT algos
- Determination of optimal TE configuration necessary
  - From jet rates, get 75K events (above `L1_J35`) in $\sim$2.5 minutes $\approx$ 1 LB
- Thorough algorithm execution time and optimization (especially with respect to L2 vertexing with many tracks) crucial