Improvements to Z Vertex Finding Algorithm

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Motivation

- Large disagreement in the vertex used for JET-CLU clustering and tight electron Z0 in offline W events.
- Table below shows the fraction of W events with a “bad” jet clustering vertex – more than 10cm from the electron Z0:

DataSet	Offline	% Bad Jet Vertices
bhel08hpte	4_10_4 dev 240	10.00%
bhel0d	5_3_1 dev 242	3.00%

Root Cause: ZVertexMaker

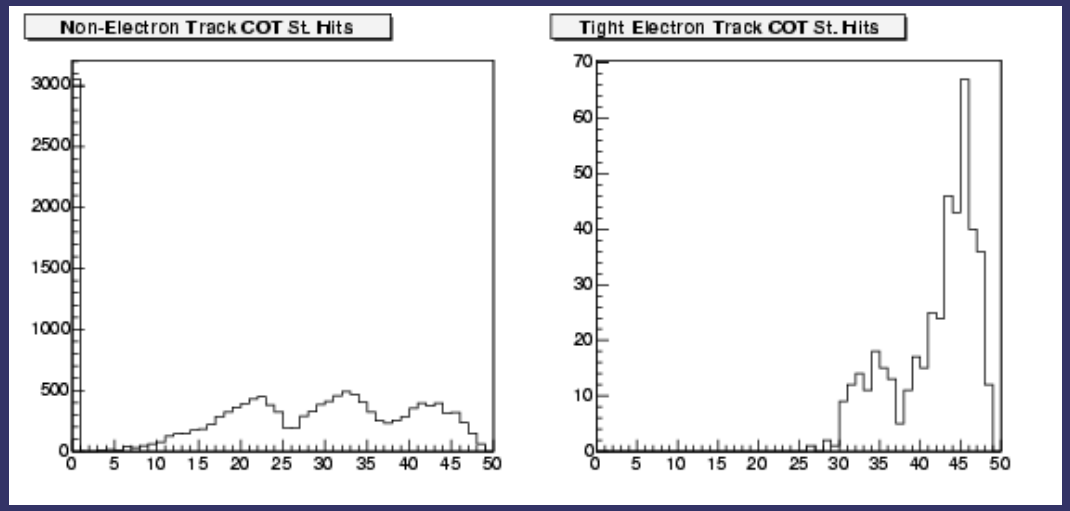
- All offline Jet Clustering Algorithms use Jet/fillVertexLink to define Z vertex used for clustering.
- fillVertexLink looks in ZVertexColl for highest sum Pt vertex, preferably quality 12 or greater, but if none exist then it will use any quality.
- ZVertexColl is filled by VertexAlg/ZVertexMaker.
- In a W->eυ event the electron track, if well re-constructed and far from any other vertex, should define its own vertex.

In 3% of 5.3.1 W Events – ZVertexMaker fails to write tight electron vertex, or assigns quality ≤ 12.

Workings of 5.3.1 ZVertexMaker (i)

- Loops over CdfTrackView, attempts to match in Z tracks of a minimum quality with PV and/or COT vertices. If some minimum number of tracks (default 3) have dz<5cm (COT) or <1cm (PV) then the vertex is "seeded".

Track quality requirements:
min Pt = 300 MeV
min COT Stereo hits ≥ 25
OR
At least two Si hits, axial or stereo (not valid if strategy = 3).



Workings of 5.3.1 ZVertexMaker (ii)

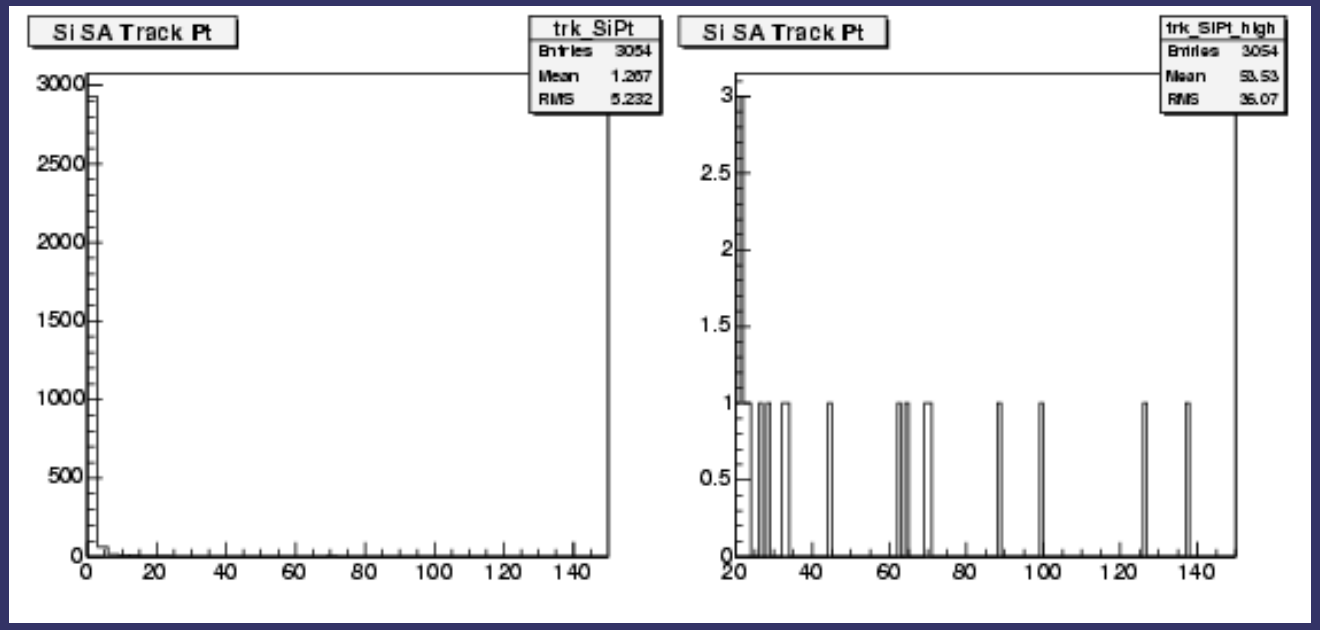
- Each track may only seed one vertex, and PV vertices are considered for seeding first.
- During seeding the vertex Z position, error and sum Pt is modified by the tracks matched to it.
- Each seeded vertex is then assigned a quality according to the number of tracks within 3 sigma in Z. This differentiates between Si SA and COT defined tracks.
- Put simply a vertex has to have more than one COT track within 3 sigma for quality ≥ 12.
- The vertex is then written to ZVertexColl. However, COT vertices are only written if they are >3 sigma from all PV vertices.
- If by the end no vertex has been found then a vertex is “seeded” using the max Pt track Z0, preferably a COT track, but if none then Si SA will be used. This vertex is ALWAYS written as quality 0.

The “Strategy” Input Parameter

- Input Parameter: “strategy” specified in tcl.
- Determines whether PV only, COT only or PV and COT vertices are considered for seeding:
  - default strategy = 0: Use both COT and PV
  - strategy = 3: Use both COT and PV but don't consider Si SA tracks.

Why does ZVertexMaker fail to find electron vertex? (i)

- Default is strategy = 0. Means that Si SA tracks can be used to seed vertices – these can be poorly reconstructed (only require min. two Si hits) and thus have anomolously high sum Pt.



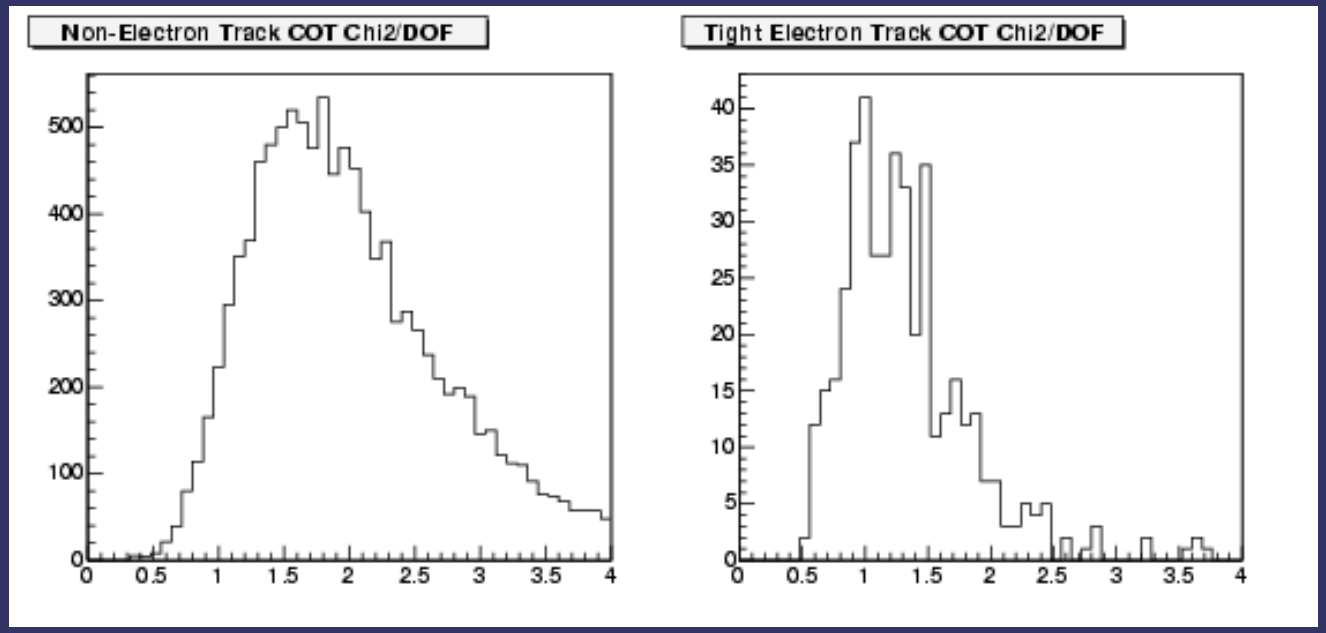
Pt distribution for SA Si tracks in W Events. 19 tracks have Pt > 20GeV.

Why does ZVertexMaker fail to find electron vertex? (ii)

- The electron seeds a vertex but is the only track to do so – thus the vertex doesn't make the min. number associated tracks requirement.
- The electron vertex is seeded but the electron is the only track within 3 sigma, thus quality < 12.
- Electron fails to seed PV vertex but instead seeds COT vertex – however, COT vertex is too close to PV to be written.

Modifying 5.3.1 ZVertexMaker(i)

- Change COT track quality cuts:
  - χ^2/DoF<3
  - Number segments(≥5 hits) ≥ 2 stereo and axial



Track COTχ^2/DoF for W Events in central electron sample.

Non-electron tracks

Tight electron tracks

Modifying 5.3.1 ZVertexMaker(ii)

- Use strategy 3 (ignore Si SA tracks in seeding).
- Identify the max Pt COT track (i.e. the electron):
  - Any vertex within dz of max pt track only needs this track to be seeded.
  - If by end no vertex has been seeded by max pt track we force seeding using track Z0 – this is always assigned quality = 12.
  - If a COT and PV vertex are too close only write that vertex seeded by the max pt track.
- Changed quality assignment – now quality ≥ 12 only requires one COT track.

Results for W Events using Revised Code

Here the jet clustering vertex is considered “bad” if it is > 3cm from tight electron Z0.

DataSet	Offline	Strategy	W events “bad” jet vtx
bhel0d	5_3_1	0	20/437 = 4.6%
bhel0d	5_3_1	3	14/437 = 3.2%
bhe0d	revised	3	4/437 = 0.9%

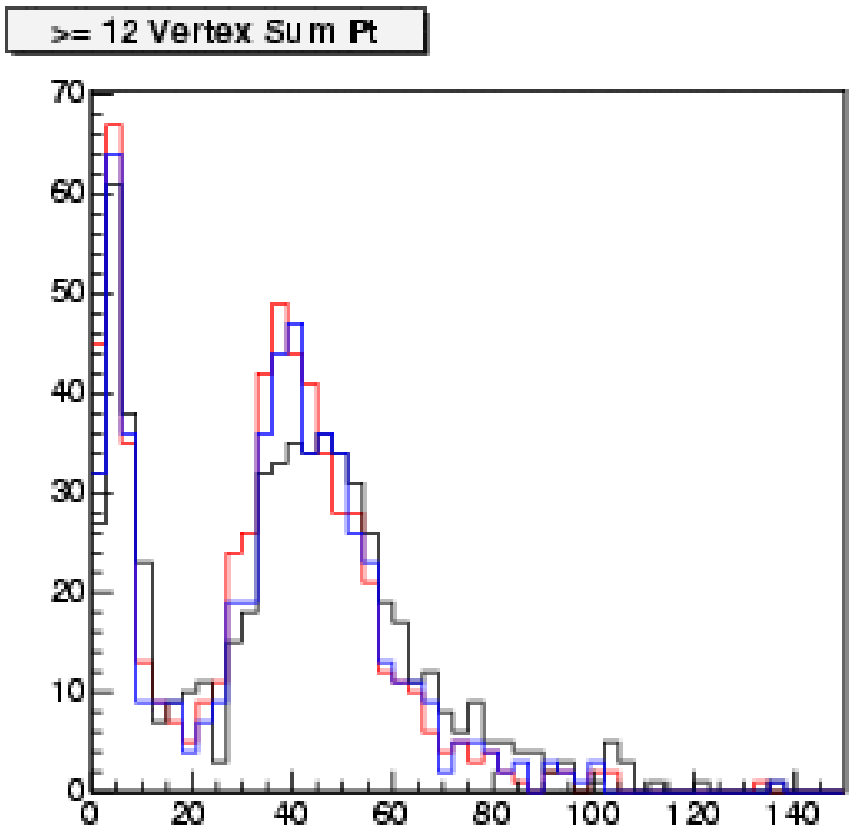
In 4 events the max pt quality ≥ 12 vertex is more than 3cm from the tight electron Z0 using revised code.

In 3 of these 4 events the electron track fails the χ^2/DoF<3 cut.

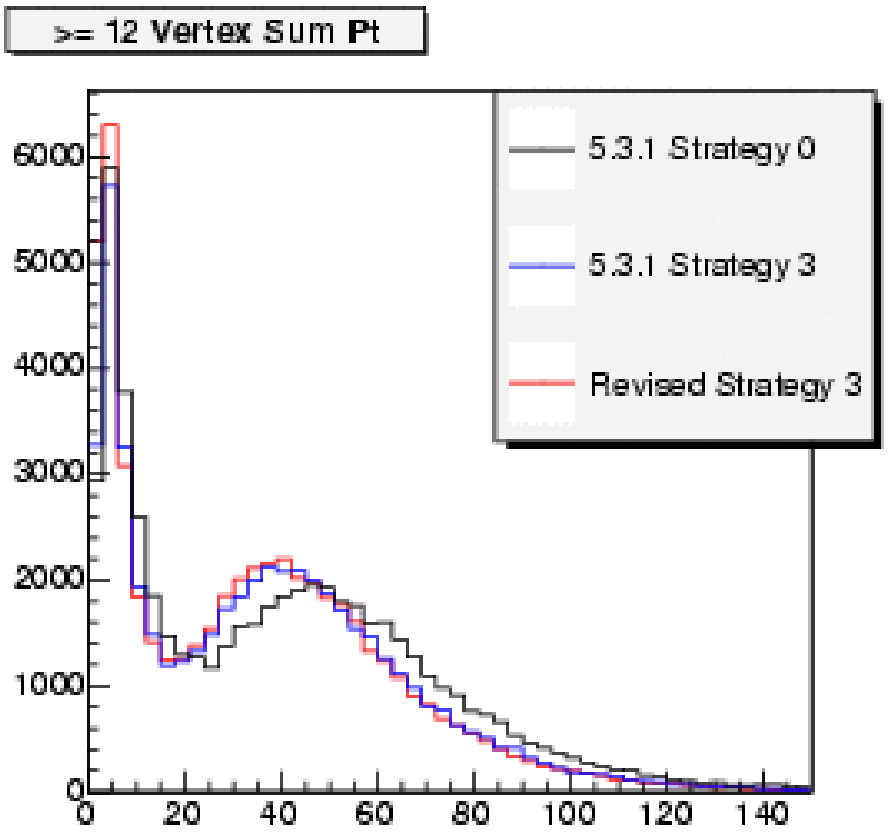
Remaining event falls just outside 3cm.

Vertex Sum Pt distributions

W Events



All Events



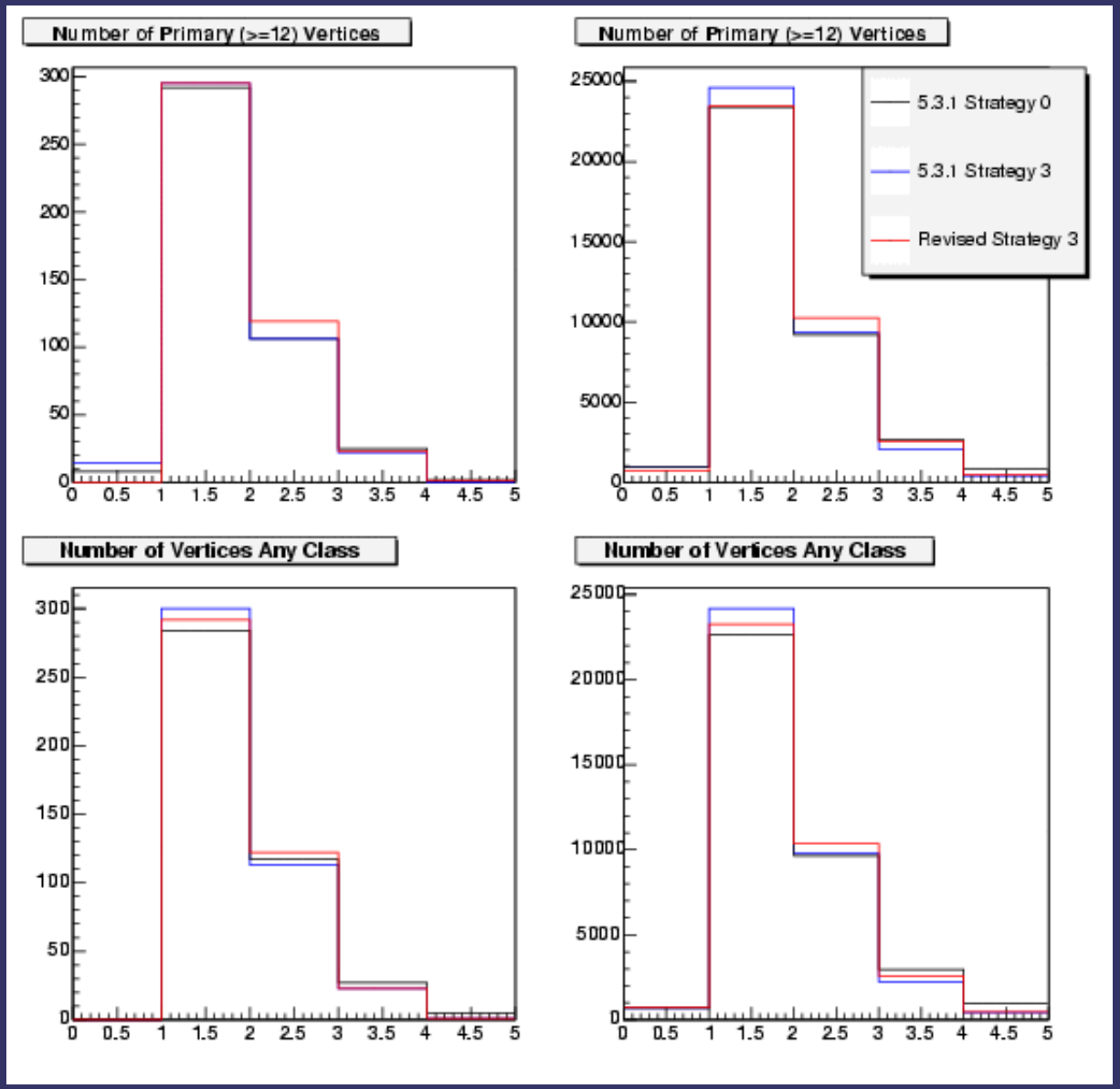
Sum Pt distribution for primary vertices softer in revised code due to the elimination of high pt SA track seeded vertices.

Central Electron Sample N Vertex Distributions

W Events ↓ All Events ↓

Quality ≥ 12 →

Any Quality →



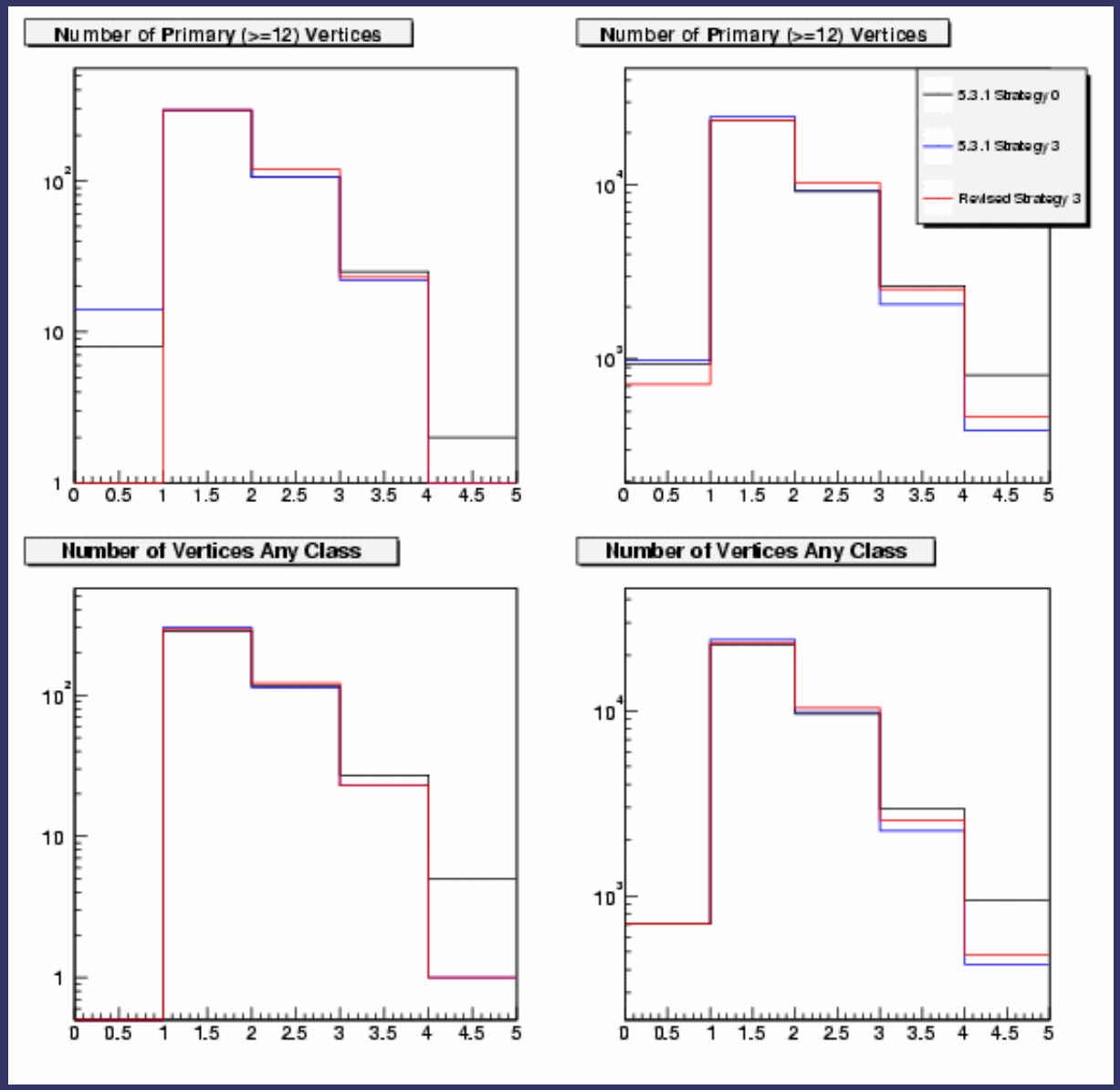
- Revised Code always finds a ≥12 vertex in W events.
- In addition to electron vertex, Revised Code can also find a low pt vertex.This dissapears if use original track quality requirements.

Central Electron Sample N Vertex Distributions Log Scale

W Events ↓ All Events ↓

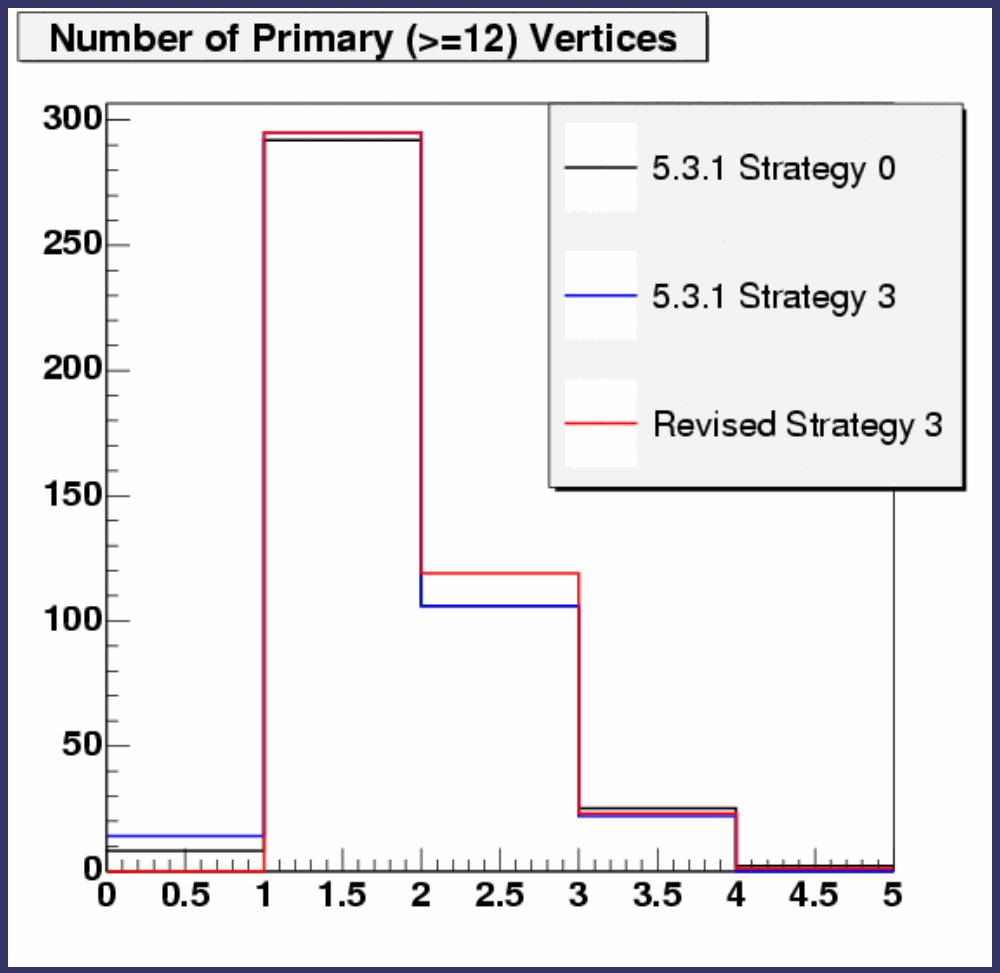
Quality ≥ 12 →

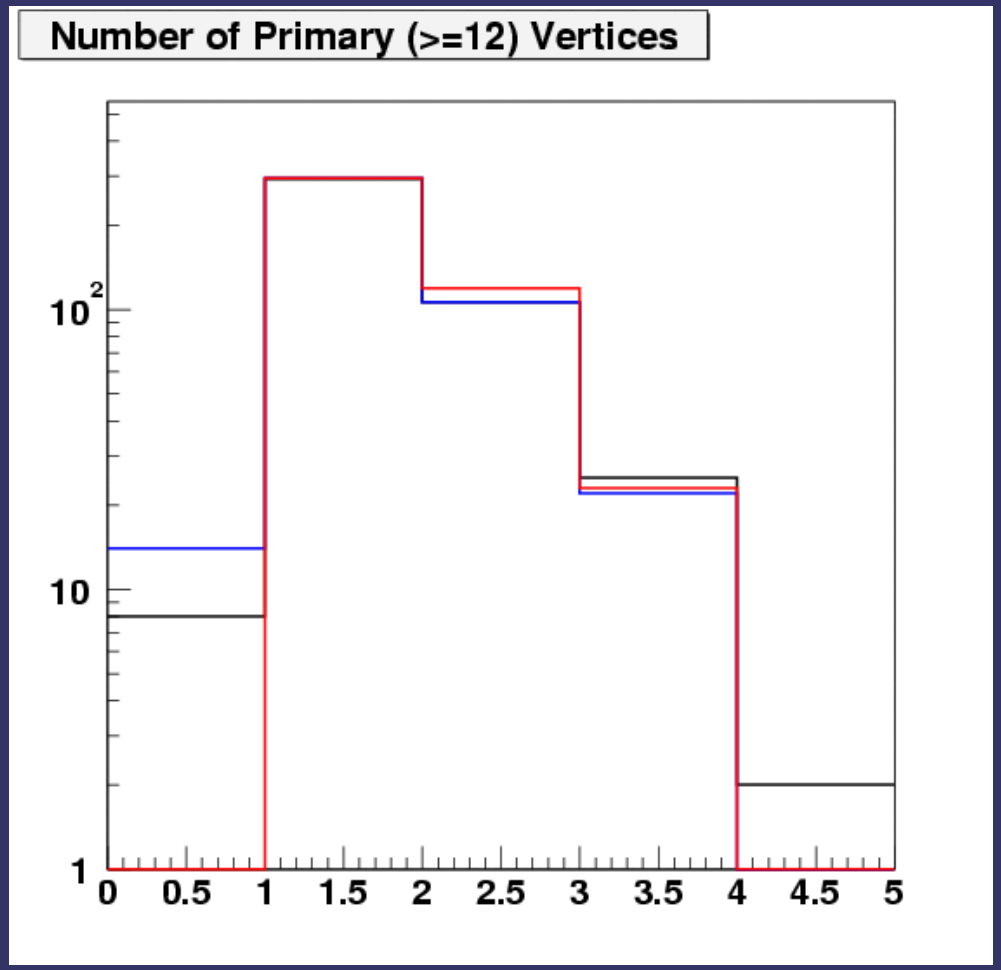
Any Quality →



- Revised Code finds fewer events with 4 or more vertices.

Quality ≥ 12 Nvtx Distribution for W Events Only

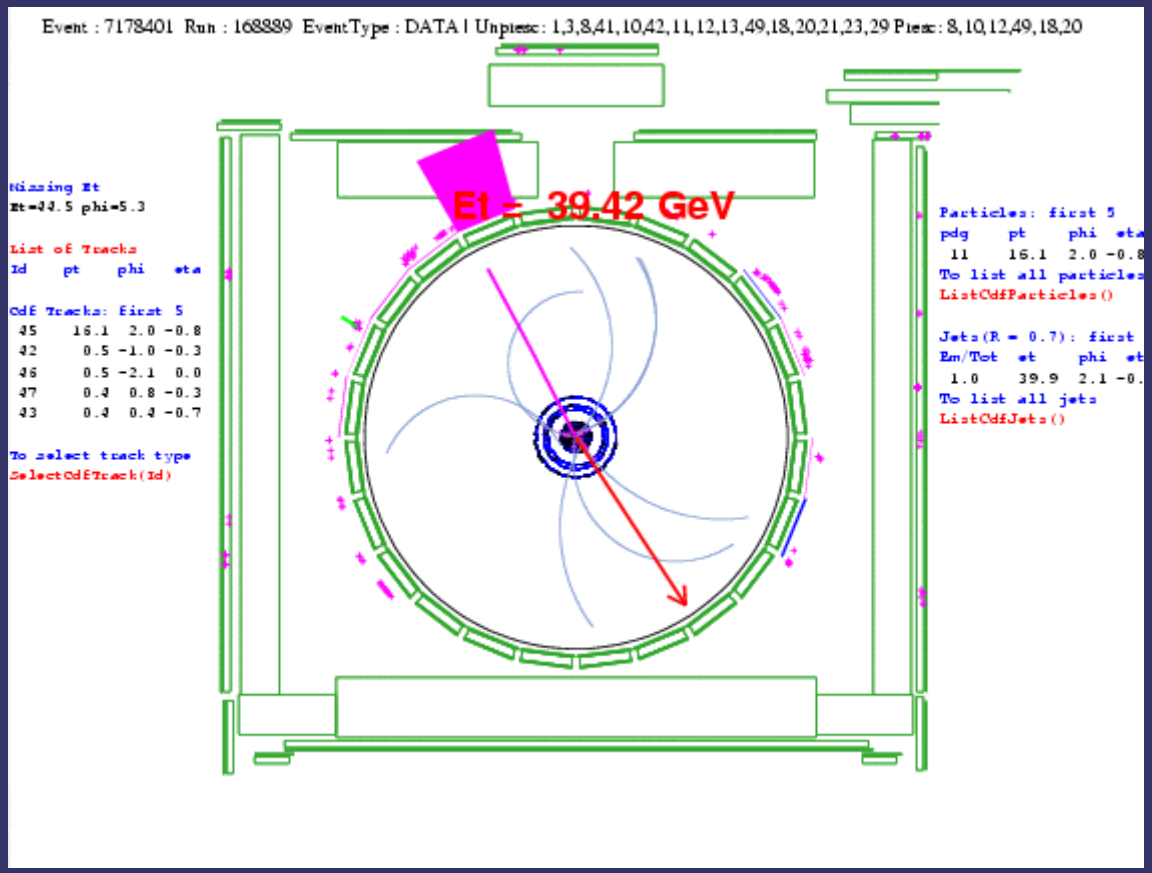




Just a blow up of the top left hand plot on previous pages

Zero ≥12 Vertex W Events in 5.3.1

- 8 W Events which have zero ≥12 vertices in 5.3.1, but all these events have a vertex in the revised code.



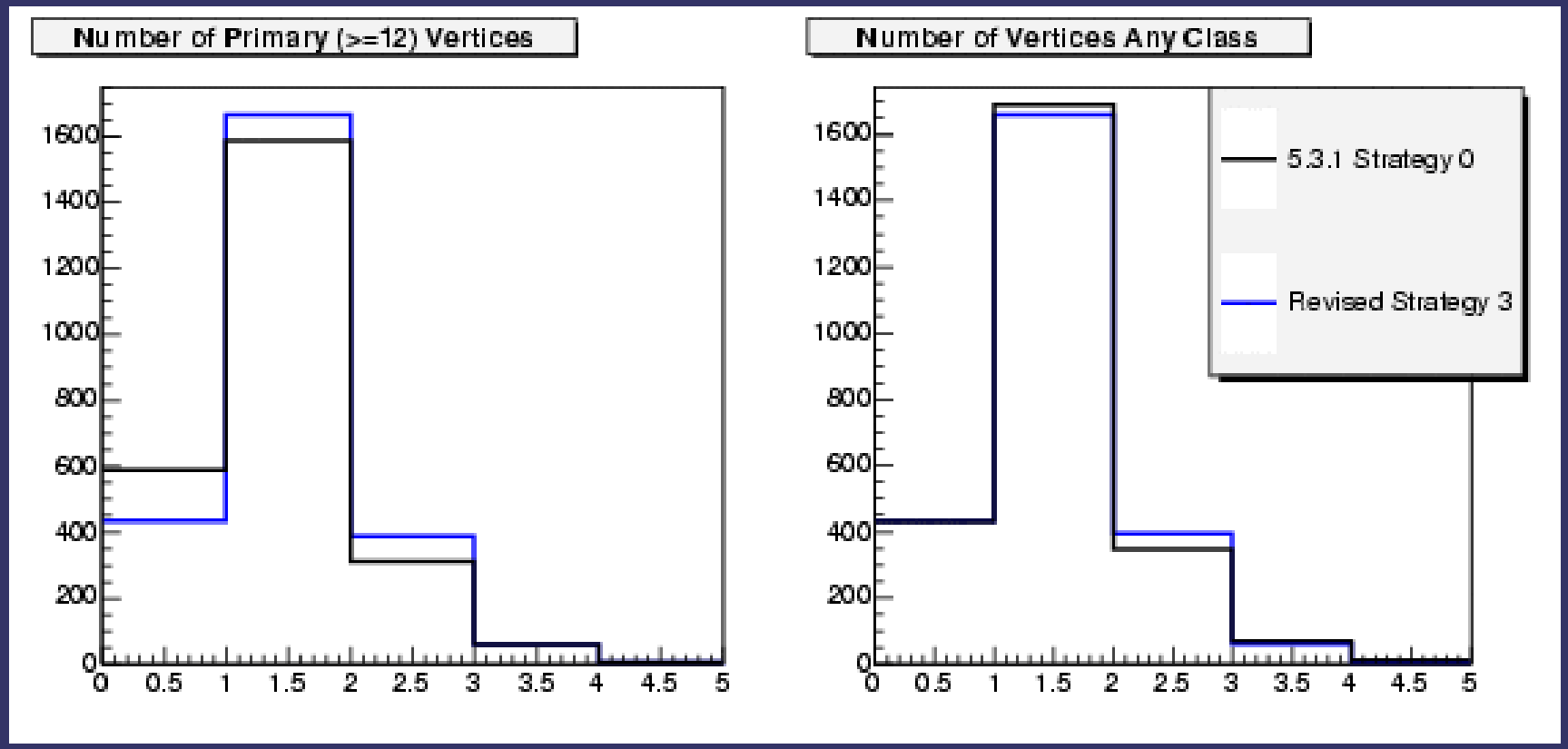
- All these events are “quiet” W events.
- Very few tracks in addition to that of the electron.
- In each of these events the ≥12 vertex that is found by the revised code is that of the tight electron.
- It is found by the new requirement that the max pt track must always seed a vertex.

Multiple ≥12 Vertex W Events in 5.3.1

- 4 W events where the default 5.3.1 code finds 5 vertices, but the revised code finds only 2 or 3. Are we throwing away good vertices?
- Most of the additional vertices are not “believable” for the following reasons:
  - They are seeded using tracks with large beam-constrained d0 or COT chi2.
  - and/or seeded using Si SA tracks with few svx hits.
- However, completely disregarding Si SA tracks with strategy 3 can result in the revised code missing a vertex that is seeded by a “good” Si SA track:
  - Si Axial hits ≥ 5
  - Si Stereo hits ≥ 3

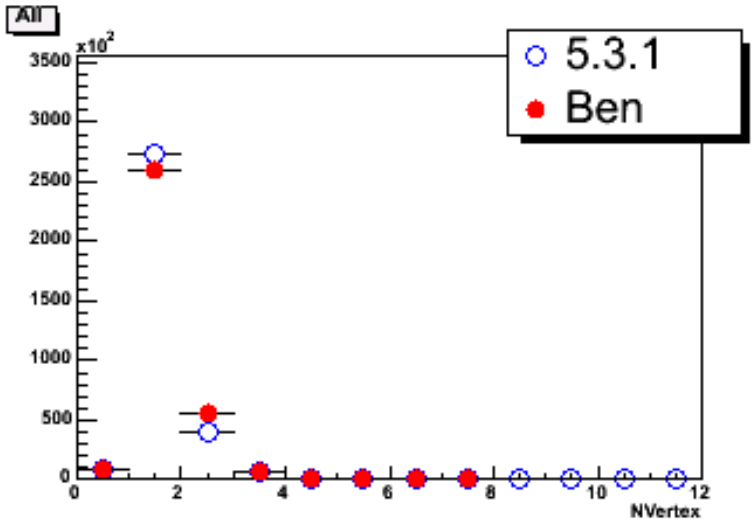
Without this additional Si SA track the vertex fails the min. number of seeding tracks requirement.

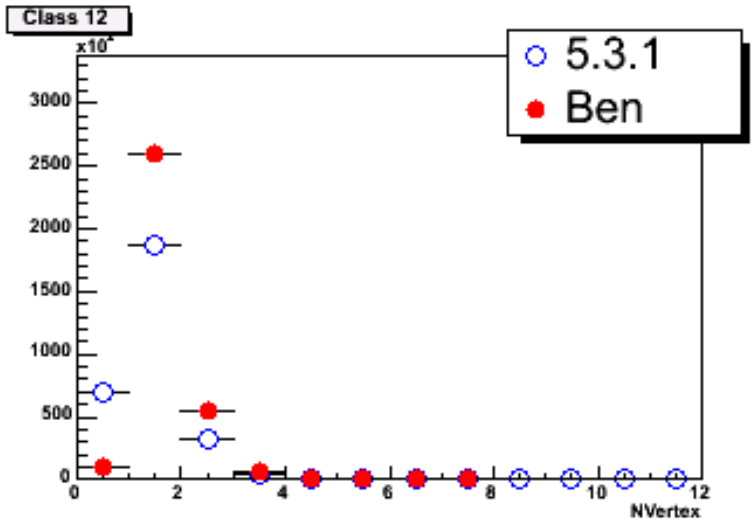
Plug Electron Sample N Vertex Distributions

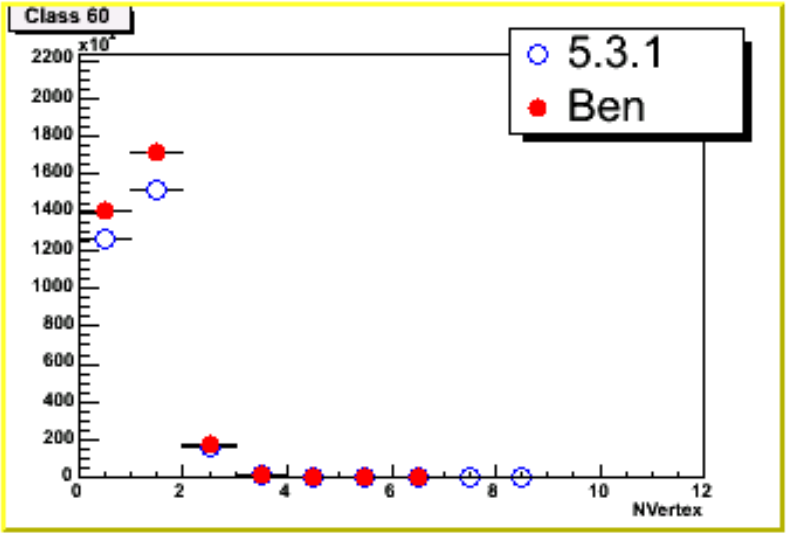


A fileset from the 5.3.1 validation plug electron sample.
Total number of events = 2553.
No apparent drop in efficiency when use Revised Code.

Min. Bias Sample Nvtx Distributions



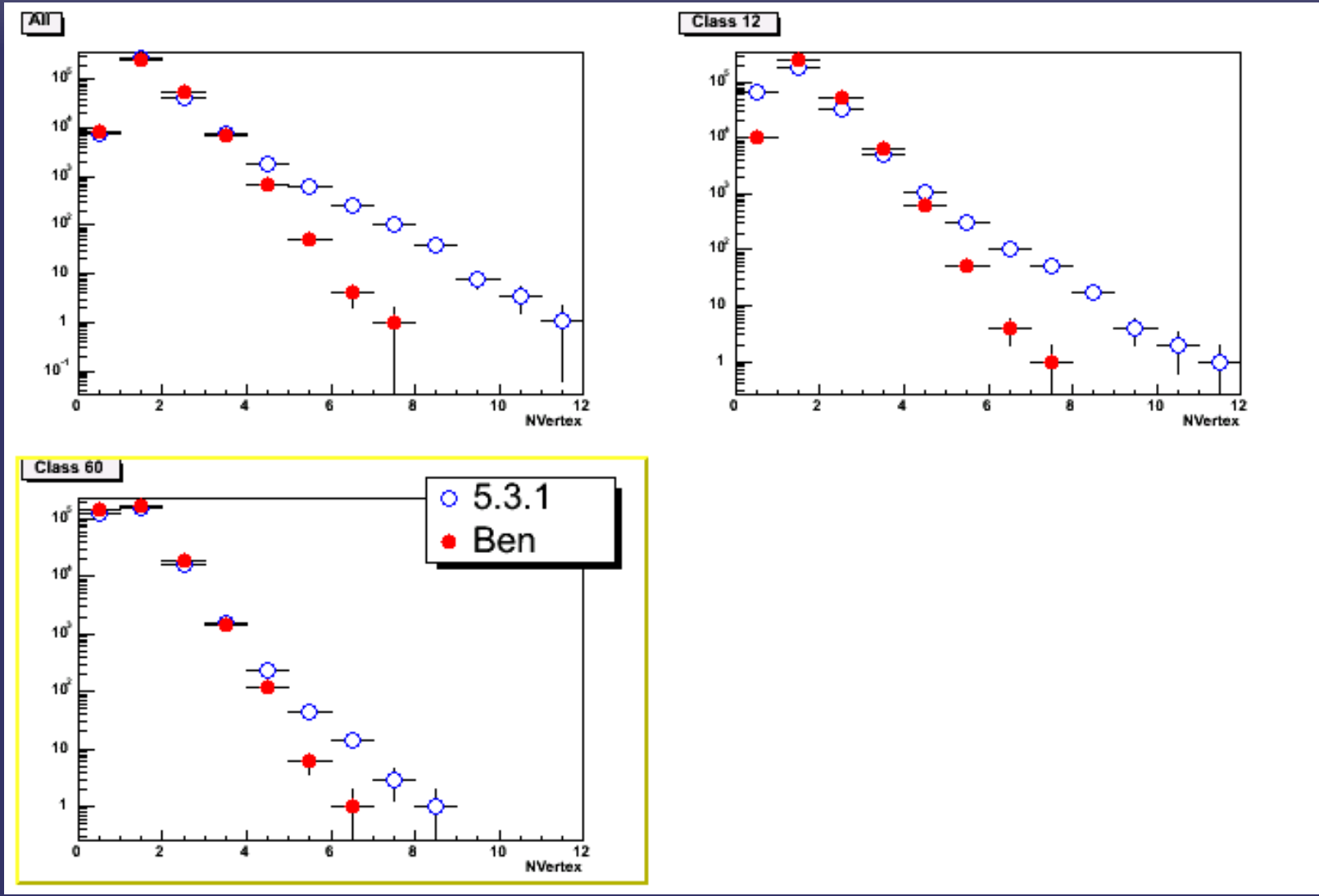




thanks to Beate for making these plots.

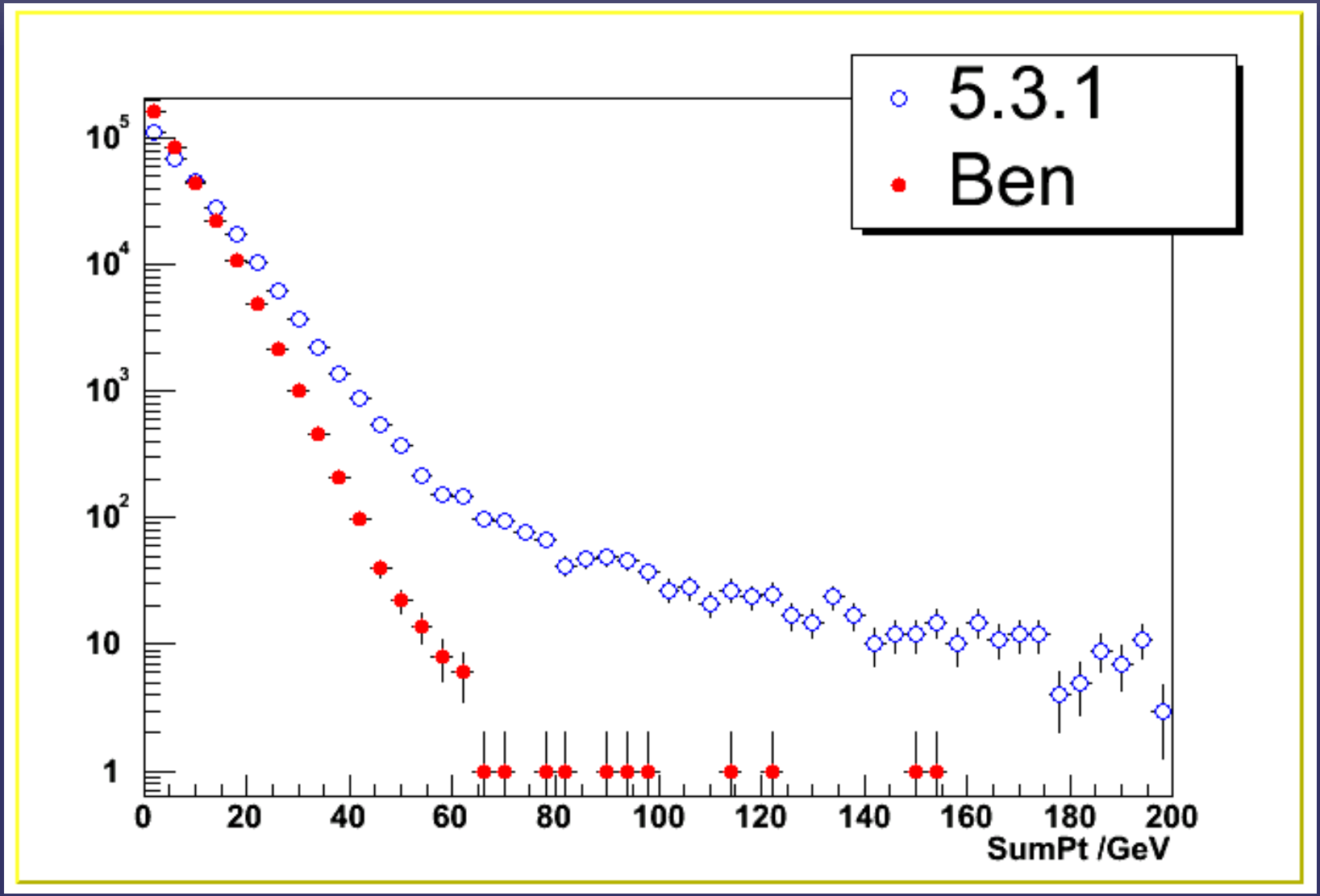
- Improved efficiency for class 12 vertices.
- Slightly worse efficiency for “all” vertices.

Min. Bias Sample Nvtx Distributions



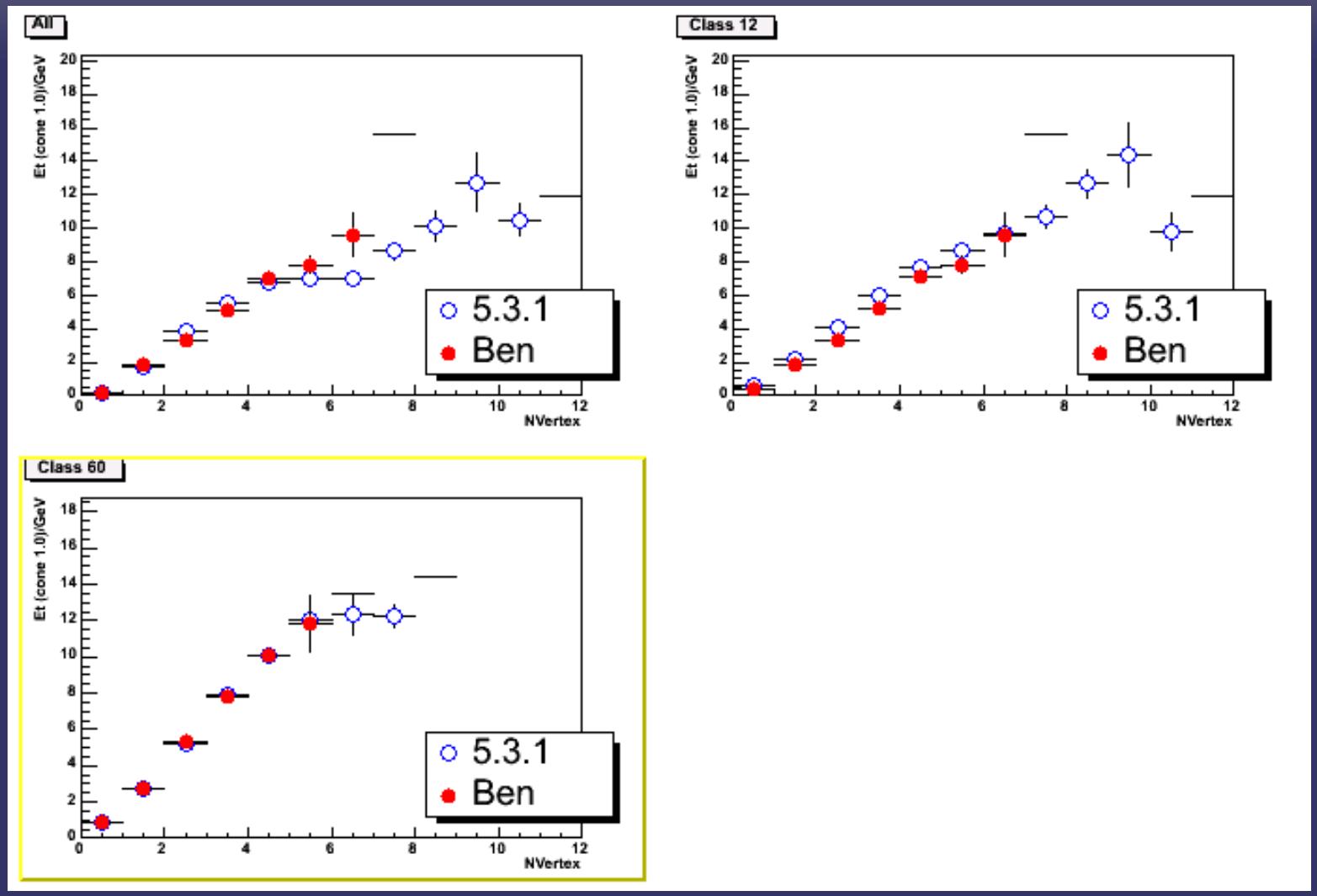
- Greatly reduced fake rate for all types of vertices.

Min. Bias Sample Vertex Sum Pt



- Sum Pt of all tracks used to seed the vertex
- High value tail due to standalone tracks – removed in revised code.

Impact On Jet Corrections?



- Et in cone = 1 around η=0.5 and ϕ=0.5 plotted against nvtx.
- Excellent agreement – can again see reduced “any quality” fake rate.

Further Improvements

- Impose an additional beam-constrained impact parameter cut on the tracks used for seeding.
- Allow “good” Si SA to seed vertices – switch back to strategy 0 but impose Si SA track quality cuts.
- Decrease the minimum number of tracks required to seed a vertex.
- These are currently under investigation and it is not yet clear what effect they could have.
- Eventually one becomes limited by the current structure of the code.

Conclusions

- Further investigation using larger scale samples is required, but indications are that the efficiency of the 5.3.1 Z Vertex finding algorithm has been improved without a noticeable increase in fake rate.
- This has been demonstrated for central electron, plug electron and minimum bias samples.