KF Vertex Finder (present status)

Y.Fisyak (BNL)
I.Kisel, M.Zyzak, I.Kulakov (GSI)

Outline

- What vertex finders do we have ?
- Why do we need a new vertex finder ?
- What vertex finder we need ?
- How ? KFParticle and adaptive vertex fitter with annealing ➔ KFVertexFitter.
- Proposed schema.
- Results and conclusions.

What vertex finders do we have ?

- There are recent reviews of the present STAR Vertex finders:
  - Matthew Cervantes (TAMU)
    http://drupal.star.bnl.gov/STAR/meetings/star-analysis-meeting-2009-mit/opening-computing-plenary-session/minuit-vertex-finder-recent-development
  - CHEP09, R.Reed et al.
    http://iopscience.iop.org/1742-6596/219/3/032020/pdf/1742-6596_219_3_032020.pdf
- Briefly: STAR has currently two primary vertex finders
  - Minuit for heavy ion collision which minimizes χ^2_{total} (fit with "robust potential")

  $\chi^2_{total} = \Sigma_i\, \zeta(1 - e^{-\chi^2_i/\zeta})$, with ζ (=100) as a dumping factor for outliers. The sum (i) is taken over a sample "good" tracks (R_{dca} < 6 cm, No. of fit points ≥ 20).
  - vertex finders for pp-collisions:
    - StiPPVertex, 1D fit with beam constrain and STAR fast detector matching (ToF, BEMC, EEMC)
- The whole point is that we have as separated steps
  - Global track reconstruction,
  - Fit primary vertices from the "good" global tracks, and
  - Fit global tracks to those primary vertices as primary tracks without any reference from what "good" global tracks these primary vertices have been reconstructed.

Why do we need a new vertex finder ?

There are two main demands:

•Pileup:

- The RHIC luminosity is increasing. The pile-up has become more and more important issue for primary vertex reconstruction and its tagging.
- In Run XII the highest BBC coincidence rate is up to ~4 MHz
- This corresponds to ~320 pile-up collisions during TPC sensitivity time (±40 μsec × 4 MHz) and this means that we have to handle up to 640 primary vertices.
- This rate means also that we have probability ~50% to have two or more interactions in the same bunch crossing i.e. for ~50% events even the fast detectors cannot help to resolve primary vertex ambiguities.
- There is a problem of proper association tracks to vertex ➔ ghost primary tracks.

•The Heavy Flavor Tracked (HFT).

1. The main goal of HFT is to reconstruct secondary vertices from decay of charm and beauty.
2. This implies reconstruction of primary vertices and identification tracks which don't belong to primary vertices to form secondary ones.

What vertex finder we need ?

1. We would like to have the same treatment for primary and secondary vertices, including decays and conversions and secondary interactions with detector materials.
2. To make beam line constrain natural part of the vertex finder i.e. to treat a beam line as an additional track which can be used in the primary vertex finding.
3. We would like to improve vertex ranking as belonging to the triggered interaction.
4. Kinematical fit for decay vertices has to be a natural part of vertex finder.

How ? KFParticle

- KFParticle class (developed by GSI team, see https://www.gsi.de/documents/DOC-2010-Jun-126-1.pdf) provides:
  - Simple construction of the vertices from the tracks or other particles formed by secondary vertices (for example, decays).
  - Adding measurements (tracks or particles) to the reconstructed mother vertex.
  - Simple access to the parameters of the vertex.
  - Transport of the particles (even in the non uniform magnetic field).
  - Impact parameter calculation to the vertex or other particle.
  - Adding vertex constrain to track (fit global track with a vertex constrain ➔ primary track and primary vertex fit)
  - Kalman techniques is used for vertex finding, fitting and smoothing.
  - There is a possibility to add mass constrain to fit decay vertices.

How ? Adaptive vertex fitter with annealing.

The most recent reference: “Track and vertex reconstruction: From classical to adaptive methods", Are Strandlie and Rudolf Frühwirt, Rev. Mod. Phys. 82, 1419-1458 (2010).

- Annealing:
  - The main idea is that we don’t really know errors of track parameters.
    - For STAR we fit tracks with π mass hypothesis.
    - For π we can more or less trust track parameters but
    - the track can be generated by K, proton or electrons and for those particles the errors will be underestimated.
  - Deterministic Annealing helps to reach the optimal solution.
    - We heat the system i.e. start with high temperature (at $T \gg 1$) by increasing track parameter errors,
    - fit vertex and
    - reiterate fit with decreasing temperature.
    - The final value is $T \rightarrow 1$.

Adaptive vertex fitter with annealing (cont.)

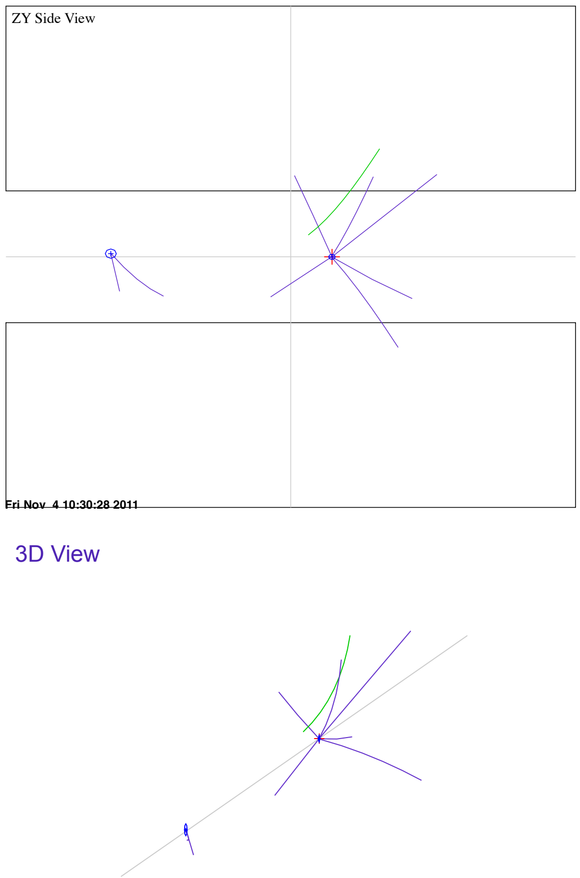
- Adaptive fit means that we can allow multiple tracks to be shared between multiple vertices with weight depending on
  - $P_{ik} = \exp(-\chi^2_{jk}/2T) / (\exp(-\chi^2_{cut}/2T) + \exp(-\chi^2_{jk}/2T))$,
    - X^2_{jk} – measured distance of track j from vertex k
    - X^2_{cutt} –the cut-off parameters
    - T – the annealing factor (temperature)
  - The fit means finding minimum of
    $\chi^2_{total} = \Sigma_k\{p - T\bullet\Sigma_j \log(P_{ik})\}$,
    where $p = 10^3$ is penalty factor for adding vertex.
  - The final step would be unique association tracks to the vertices depending on above weights.

Proposed schema

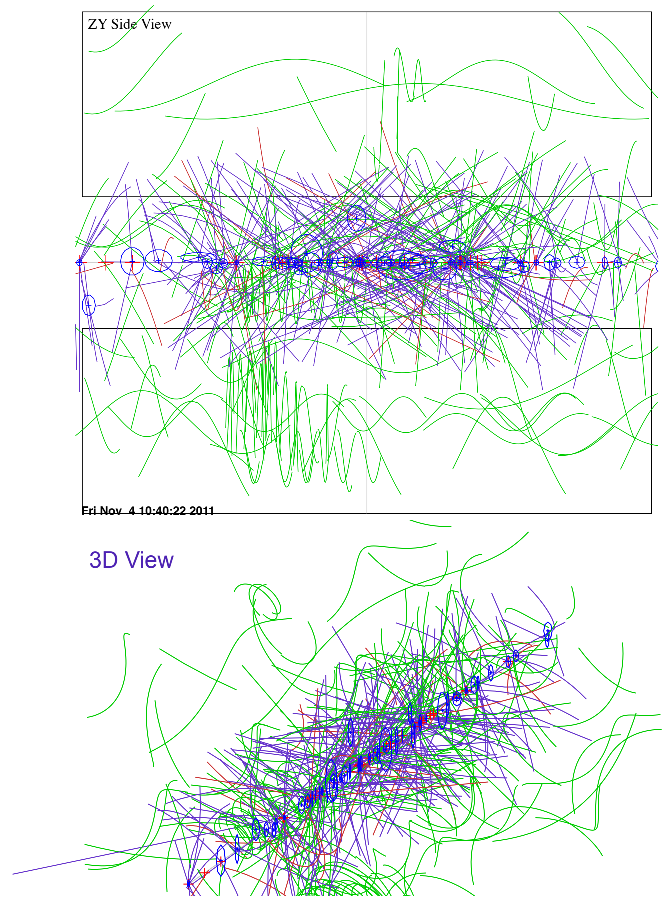
1. For all global tracks:
   1. histogram tracks Z at DCA with respect to Z axis (X=Y=0) with sliding window ±2 cm,
   2. With TSpectrum find statistical significant peaks as primary vertex seeds.
   3. Fit vertices with these seeds with respect to temperature (T).
   4. Make unique association tracks to vertex based on adaptive weights, mark tracks as associated with a given vertex.
2. For tracks not associated with any vertex:
   1. Repeat step 1.
   2. Merge duplicate vertices.
3. For tracks not associated with any vertex:
   1. try to find any tracks intersections (without constrain to be close to beam) to form a secondary vertex. The tracks are associated if
      1. the distance between them is < 5 cm, and
      2. for two track combination we also require that fit gives a reasonable probability (>0.1%).
   2. Merge duplicate vertices.
   3. Fit them.
   4. Make unique association tracks to all vertices.
4. Kinematical fit of decay vertices and refit primary vertices (still under development).

KF Vertex reconstruction illustration:
blue lines - associated tracks, blue circles – reconstructed vertices, red crosses – MC vertices.

Proton-proton w/o pile-up



Proton-proton with pile-up



Results

- For performance comparison 2012 pp 500 with (filtered, i.e. passed STAR acceptance cuts) W embedded in zero biased events with highest Run XII luminosity (~4 MHz) has been made.
- Compared PPV and KFV vertex finders:
  - PPV was run with ToF matching and reduced requirement on ration no. of fit points to no. of possible ones from 0.7 to 0.51 (the last proposed update for PPV).
  - KFV:
    - accepted only vertices with
      - Two or more tracks,
      - two or more matches to fast detectors (ToF and EMC) and
      - matched to beam line,
    - Default rank is calculated as (veto = 1, match = 4) :

Rank = $-\chi^2/NDF$, where χ^2 and NDF for vertex fit,

Rank -= veto *postx, where postx is no. of post crossing tracks @ vertex,

Rank += match*prompt, where prompt is no. of tracks with prompt hits

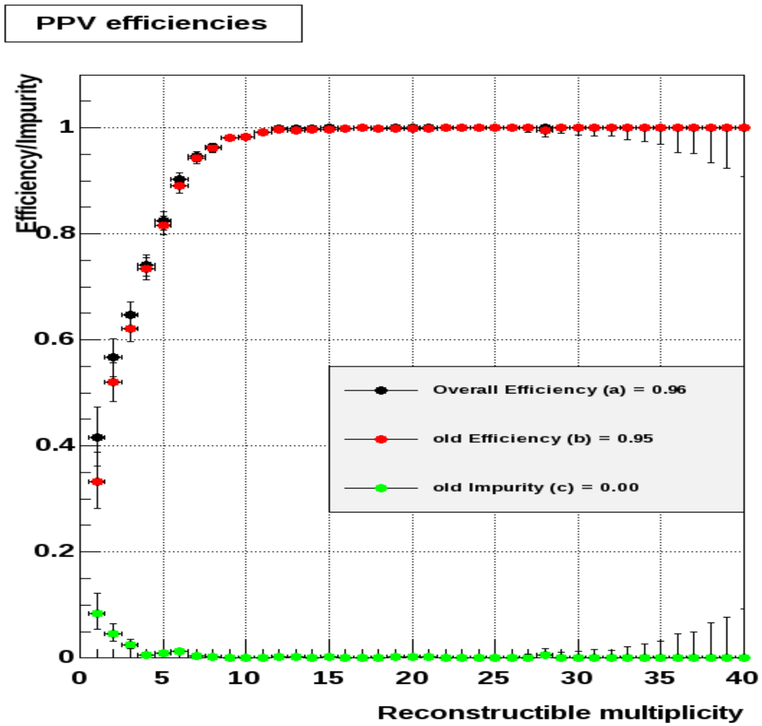
Rank += match*cross, where cross is no. of membrane crossing tracks,

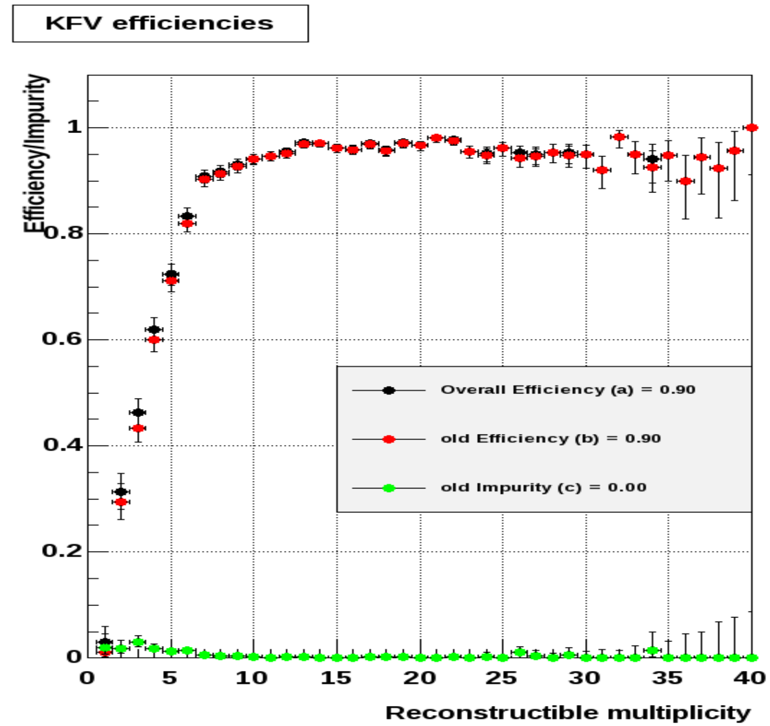
Rank += match*tof - veto *notof, tof and notof no. of tracks which are matched or not matched with ToF,

Rank += match*(BEMC + EEMC) -veto *(noBEMC + noEEMC), -”- with EMC,

Rank += match*nWE, where nWE is minimum no. of tracks reconstructed only in west or east part of TPC.

Efficiencies, no pileup (TPC distortions for 4HMz BBC coincidence rate).



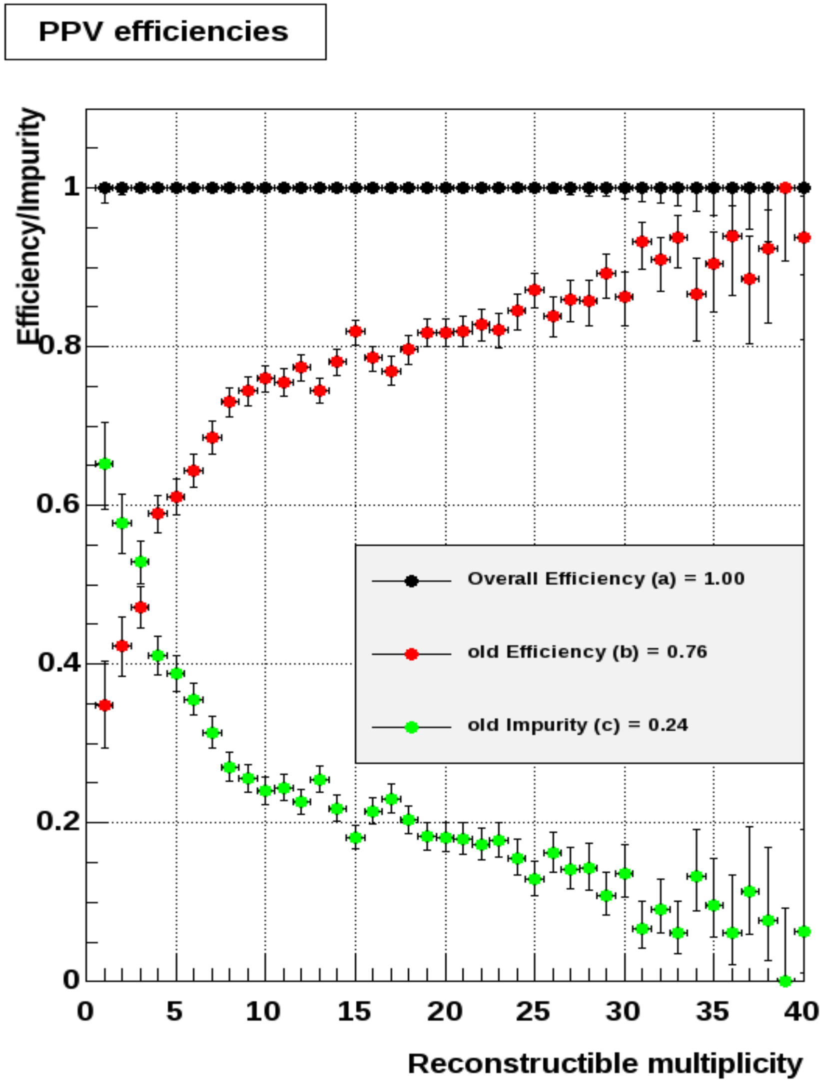


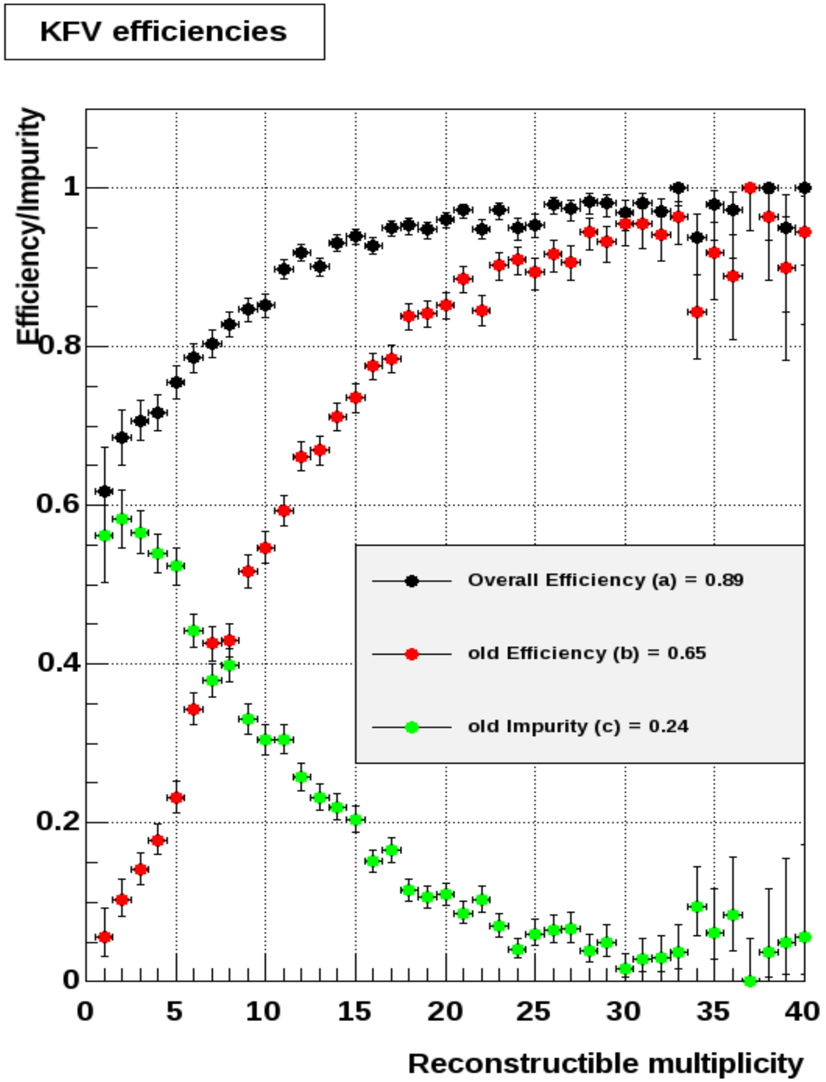
Reconstructible multiplicity is MC track multiplicity which can be reconstructed in TPC (no. reconstructed hits >= 10).

Slightly lower efficiency for KFV with respect to PPV explains by:

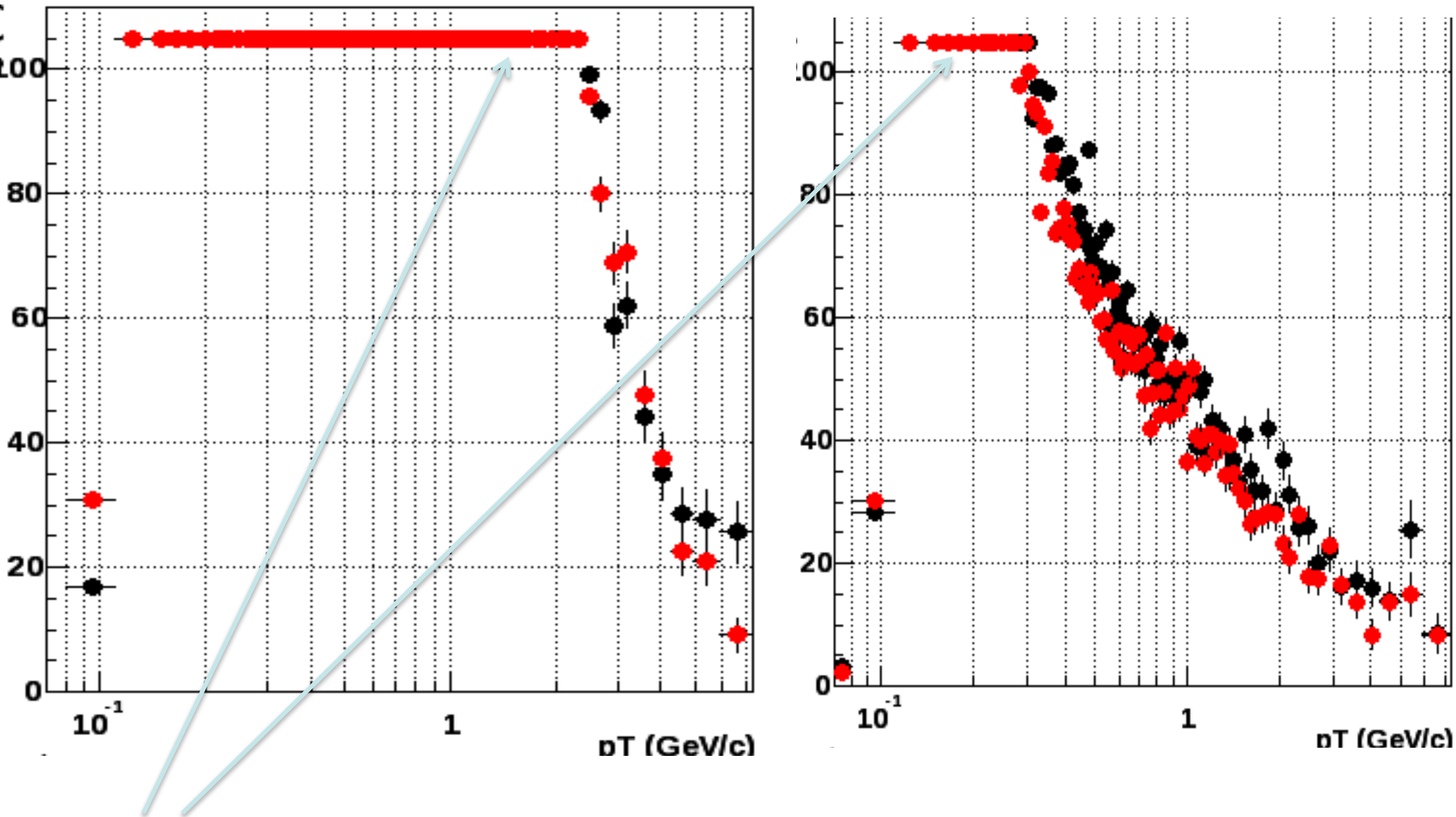
- Beam line constrain, not all simulated vertices are matched with beam line (not final distortions)
- Requirement for two or more tracks matching with fast detectors is more strict for KFV with respect to PPV (because many ghost tracks assigned to PPV vertex, and this increases probability to have confirmation from fast detectors).

Efficiencies (~4MHz pileup)





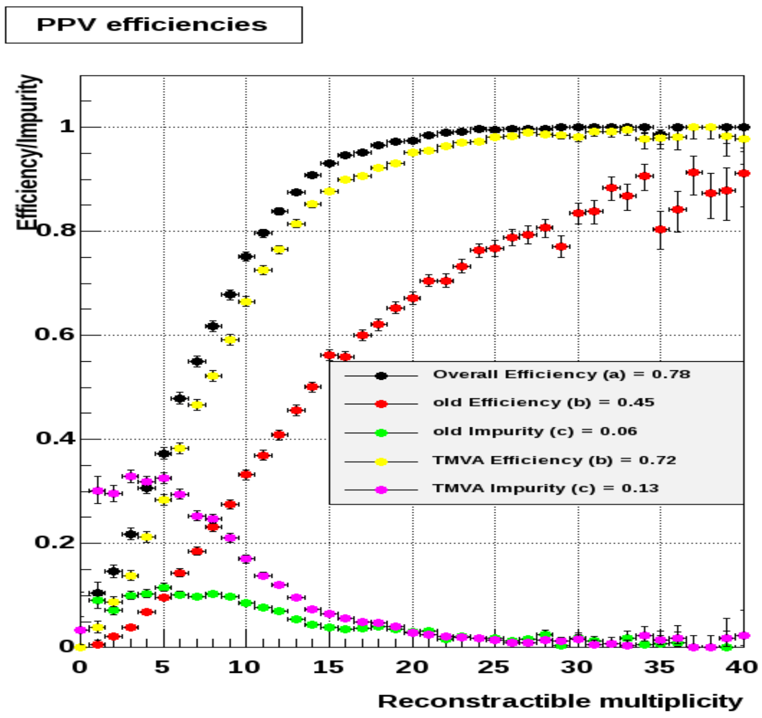
Ghosting, no. of ghost tracks per MC one (%) versus p_T

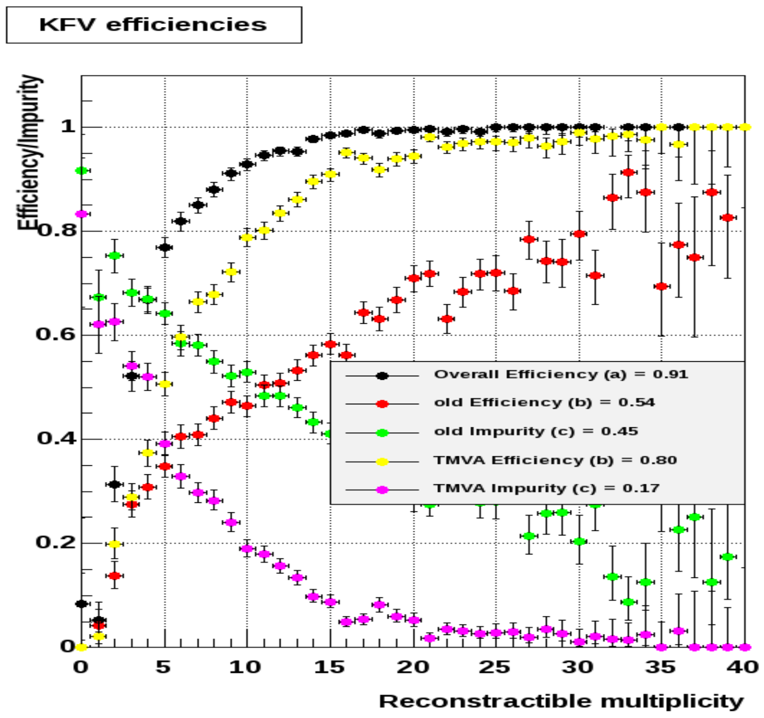


More than 1 ghost track per 1 MC one.

Ranking based on TVMA

Last summer Jonathan Bouchet and Amilkar Quintero have proposed to use TMVA (ROOT package for Multi Variable Analysis) scheme to (re) calculate primary vertex rank. Below it is presented their results obtained for MC events , pp 200 with 1MHz pileup. There is clear advantage of this method with respect to standard one. But this method also shows strong dependence on trigger and running conditions.
Thus proposal is to use this method on the level of analysis on MuDst.





Conclusion

- StKFVertexMaker for "Adaptive vertex fitter with annealing" based on KFParticle class has been developed.
- The maker has shown the expected performance.
- The next steps are:
  - Add kinematical fit for strange particle decay candidates.
  - Revised and add ranking scheme based on TMVA.
  - Ask collaboration for Vertex review.