# Vertex Finders in STAR

## Xin Dong

Lawrence Berkeley National Laboratory

 With helps from:

Jan Balewski, Jonathan Bouchet, Matt Cervantes, Zilong Chang, Yuri Fisyak, Anthony Kesich, Ivan Kisel, Rosi Reed, Justin Stevens, Anthony Timmins, Yan Yang …

More material can be found:
http://www.star.bnl.gov/protected/common/PAC/VF/

# Outline

- Introduction

- MinuitVF
  - Performances and Issues

- PPV
  - Performances and New Modifications

- KFParticle (proposal)
  - Proposed scheme and status

- Discussion of path forward

# Current Vertex Finders in STAR

Reconstruction procedures:

Global track reconstruction,
Fit primary vertices from the "good" global tracks
- issues with pileup tracks
Fit global tracks to those primary vertices as primary tracks

Requirements to STAR vertex finders:

Rejection of pileup tracks (AA vs pp different levels)
High efficiency and low contamination

A+A/d+A Collisions          Minuit Vertex Finder

p+p Collisions              Pile-up Proof Vertex Finder (PPV)

R&D proposal:  KFParticle Vertex Finder (for all systems)

- FixedVertexMaker:   often used in embedding now

# TPC Pileups

TPC electron drift time + electronic integration time: 40 us    = 25 KHz (100% dead)
Au+Au collision rate: ~ 50 kHz (Run11)
d+Au collision rate:   ~ 300 kHz (Run8)
p+p collision rate:   ~1 MHz (200 GeV)  ~ 4 MHz (500 GeV) (160 collisions per TPC event)
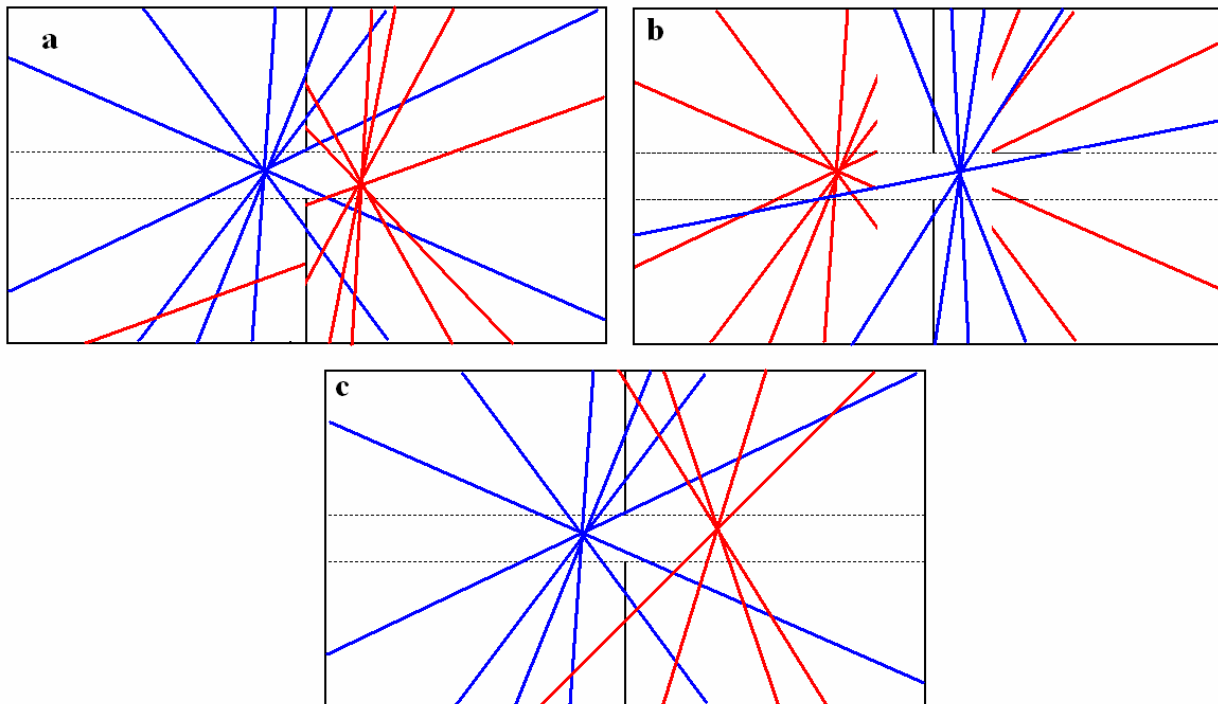


fig. a: Post-Crossing (red pile-up vertex occurs after the blue triggered vertex).

fig. b: Pre-Crossing occurs before triggered vertex.

fig. c: Same bunch pile-up is not separable

# Minuit VF

- □ 3D, $\chi^2$ minimization
- □ Start from "good" global tracks ($R_{dca}$ < 6 cm, No. of fit points ≥ 20).
- □ Vertex candidates found via z-distribution of DCA to beam-line
- □ Crude peak-search performed w/ these tracks
- □ Minuit minimization routine and vertex rank
- □ Ranking depends on:
  - ✓ **\<dip angle\> track vs. z-position of vertex**
  - ✓ Number of vertex tracks which are **matched to EMC hits**
  - ✓ Number of vertex tracks which **cross the TPC membrane**

*Anthony Timmins, Matt Cervantes*

# Performances and Issues

- Efficiency around 90% for Cu+Cu 200 GeV
- (Tested in recent data sets?)
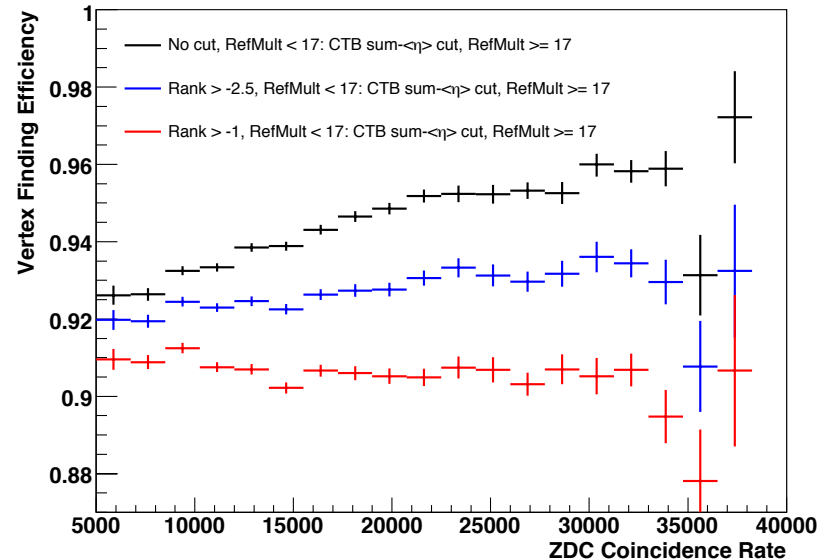


- Ranking system works very well, but was not perfect…
  - ✓ Small overlap in ranking (Triggered/Pile-up)
  - ✓ When triggered event is not reconstructed, the pile-up vertex will automatically have the highest ranking…

- Vertex Splitting issue
- Occasionally (< 4%), vertex finder identifies two vertices from same event
- The larger the vertex, the more likely the splitting….
- Secondary vertex typical only a few tracks…

# PPV

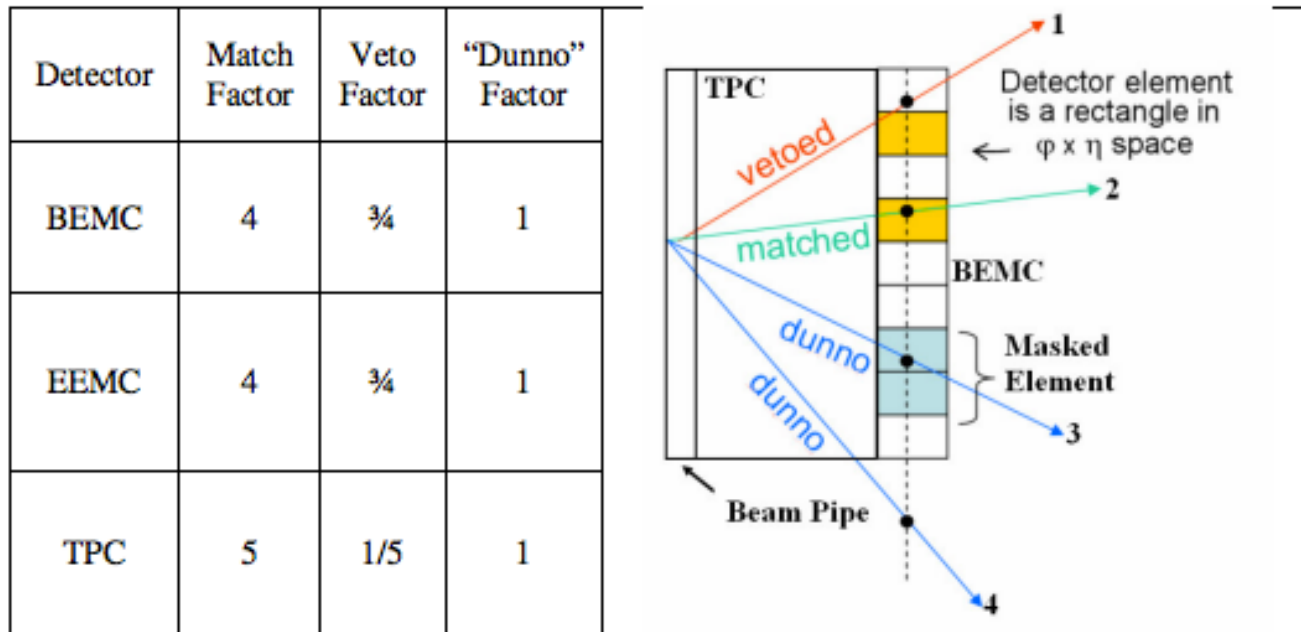1D with beam line constrain, use matches to fast detectors (BEMC, EEMC, BTOF)

Select "good" global tracks: $p_T > 0.2$ GeV/c, nHits/nPoss > 0.7, $DCA_{xy} < 3$cm
Weight tracks according to matching conditions to fast detectors, TPC central membrane
Use cumulative likelihood function scan along z direction with windows of 3cm widths
Valid primary vertex requires 2 matched tracks
Ranking based on likelihood (based on track qualities) and matches to fast detectors



| Detector | Match Factor | Veto Factor | "Dunno" Factor |
|----------|--------------|-------------|----------------|
| BEMC | 4 | ¾ | 1 |
| EEMC | 4 | ¾ | 1 |
| TPC | 5 | 1/5 | 1 |

*Jan Balewski, Rosi Reed*

# Proposed Change I – Adding BTOF

Proposed change for Run12 pp200 production -

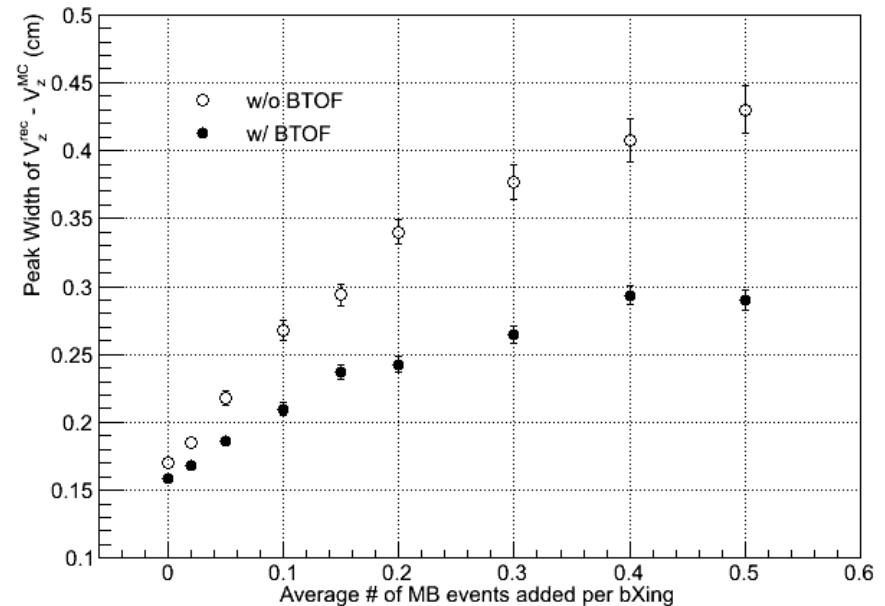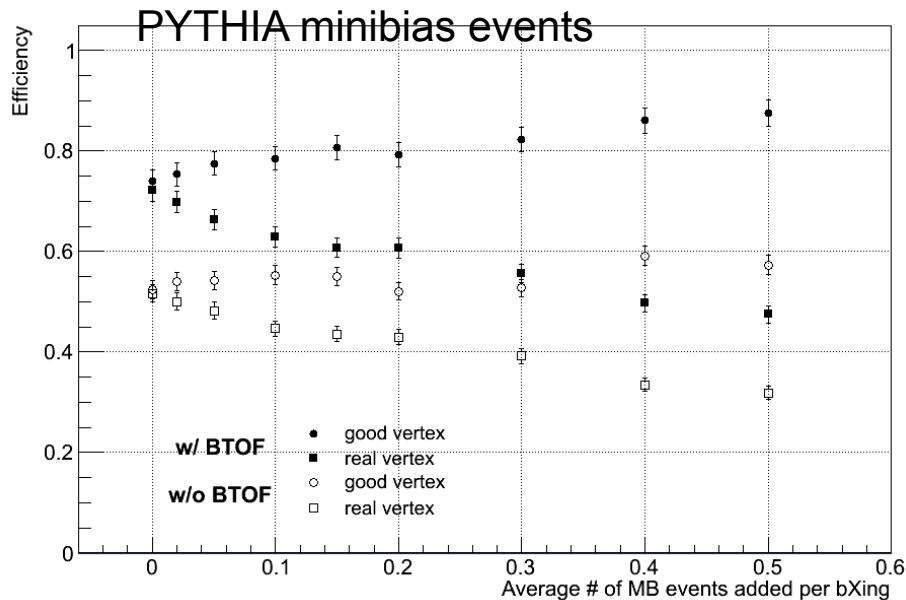Add BTOF match/veto in PPV – similar as BEMC
  - particularly benefit the vertexing efficiency for pp minibias events

MC study with Run12 geometry
http://drupal.star.bnl.gov/STAR/blog/yyang/2012/nov/28/mc-study-ppv-with-btof-run-12-geometry
Test with Run12 real data for different triggers
http://drupal.star.bnl.gov/STAR/blog/yyang/2012/nov/06/ppv-test-w-and-wo-btof-with-run12-real-data-three-trigger-rate-levels-and-serveral-triggers



PYTHIA minibias events

*Yan Yang*

# Proposed change II – change of track cuts

• Propose change for run12 pp500 W production
http://drupal.star.bnl.gov/STAR/event/ 2012/12/19/software-and-computing-meeting/ ppv-modification-2012-w-production

    DCAxy Max:  3 cm -> 2 cm
    nFit/nPoss ratio Min:  0.70 -> 0.51

• Test with jet embedding events (PYTHIA jets into pp500 zero-bias events)
http://people.physics.tamu.edu/changzl/ directory/STAR/01_2013_PPV/ ppvstudy.html

pp 200? Together with BTOF addition?

goldW per 1/pb
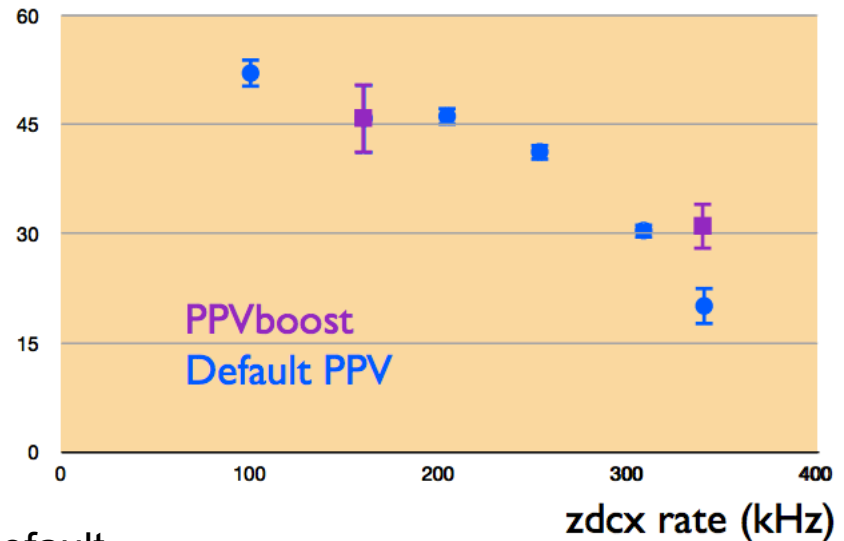


Default

| Run Number | ZDCX (kHZ) | MC Events | JP0 Events | Good Primary Vertex |
|---|---|---|---|---|
| 13108054 | 14.7 | 300,000 | 10,468 | 10,009 (95.6%) |
| 13078014 | 130 | 300,000 | 12,382 | 11,250 (90.8%) |
| 13099025 | 380 | 300,000 | 17,068 | 8,979 (52.6%) |

PPVboost

| Run Number | ZDCX (kHZ) | MC Events | JP0 Events | Good Primary Vertex |
|---|---|---|---|---|
| 13108054 | 14.7 | 300,000 | 10,468 | 10,163 (97.1%) |
| 13078014 | 130 | 300,000 | 12,382 | 11,357 (91.7%) |
| 13099025 | 380 | 300,000 | 17,068 | 13,067 (76.7%) |

*Justin Stevens, Zilong Chang*

# KFV – KFParticle Vertexer

KFParticle class - developed by GSI team,

*https://www.gsi.de/documents/DOC-2010-Jun-126-1.pdf*

Allow fit to all vertices in the same time with Kalman techniques (including secondary vertices)

Simple access to vertex parameters

Adaptive vertex fitter with annealing (Rev. Mod. Phys. 82, 1419-1458 (2010))

(hard to know errors of track parameters, annealing helps to reach the optimal solution.)

- start with high temperature (at $T \gg 1$) by increasing track parameter errors,-

- fit vertex

- reiterate fit with decreasing temperature.

- the final value is $T \rightarrow 1$.

KFV accepted only vertices with

Two or more tracks,
two or more matches to fast detectors (ToF and EMC) and
matched to beam line,

Ranking calculations consider vertex fit, matches/vetoes to fast detectors etc.
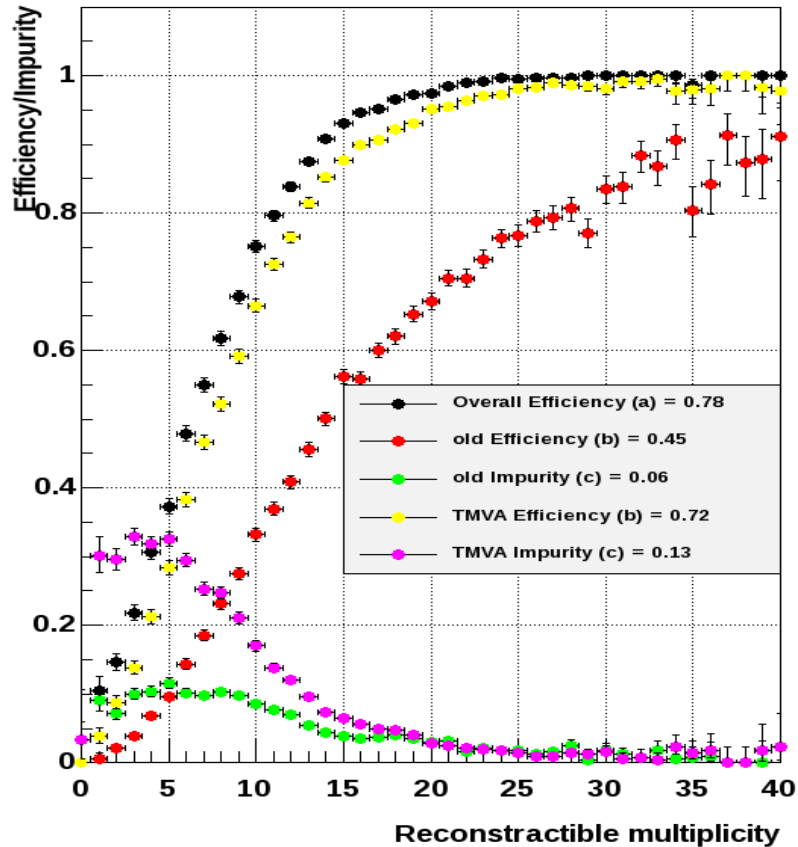
- New scheme using TMVA shows clear advantages with MC data, but depend on trigger/run condition
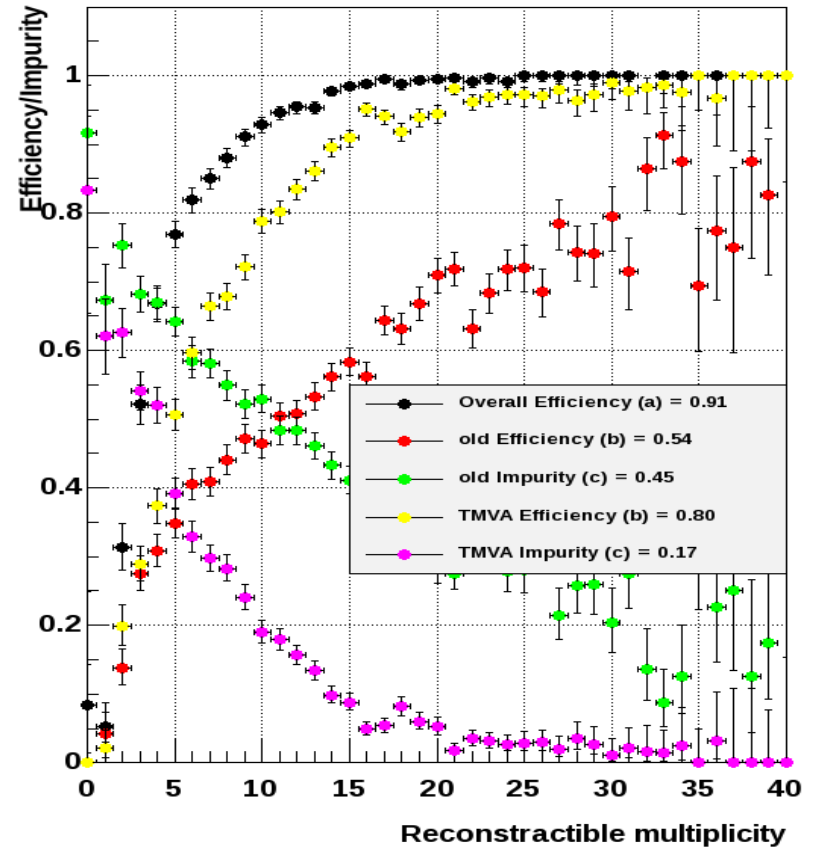
*Yuri Fisyak, Ivan Kisel*

# KFV Performance (vs. PPV)

Feb 25th, 2013    STAR Collaboration Meeting, BNL    X. Dong

# KFV Status and Proposed Plan

- StKFVertexMaker for "Adaptive vertex fitter with annealing" based on KFParticle class developed by proponents.

- Plans:

  - Add kinematical fit for strange particle decay candidates

  - Revised and add ranking scheme based on TMVA

  - Detailed performance comparison with the current Minuit+PPV

    - status ? ready for collaboration review?

# Discussion

**Situations:**

Pileup levels keep increasing
- RHIC projections at 2017

| | |
|---|---|
| Au+Au @200 GeV | ~60 kHz |
| p+p @200GeV | ~2 MHz |
| p+p @510GeV | ~15-25 MHz |

HFT, treatment of secondary vertices / primary vertices