Monte Carlo Simulation for the Heavy Flavor Tracker at STAR

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- ✔ MC results & Discussion
  - ➢ Results up to proposal
  - ➢ Improvements
  - ➢ Pile-up effect in PIXEL
- ✔ Summary and To do

Motivation

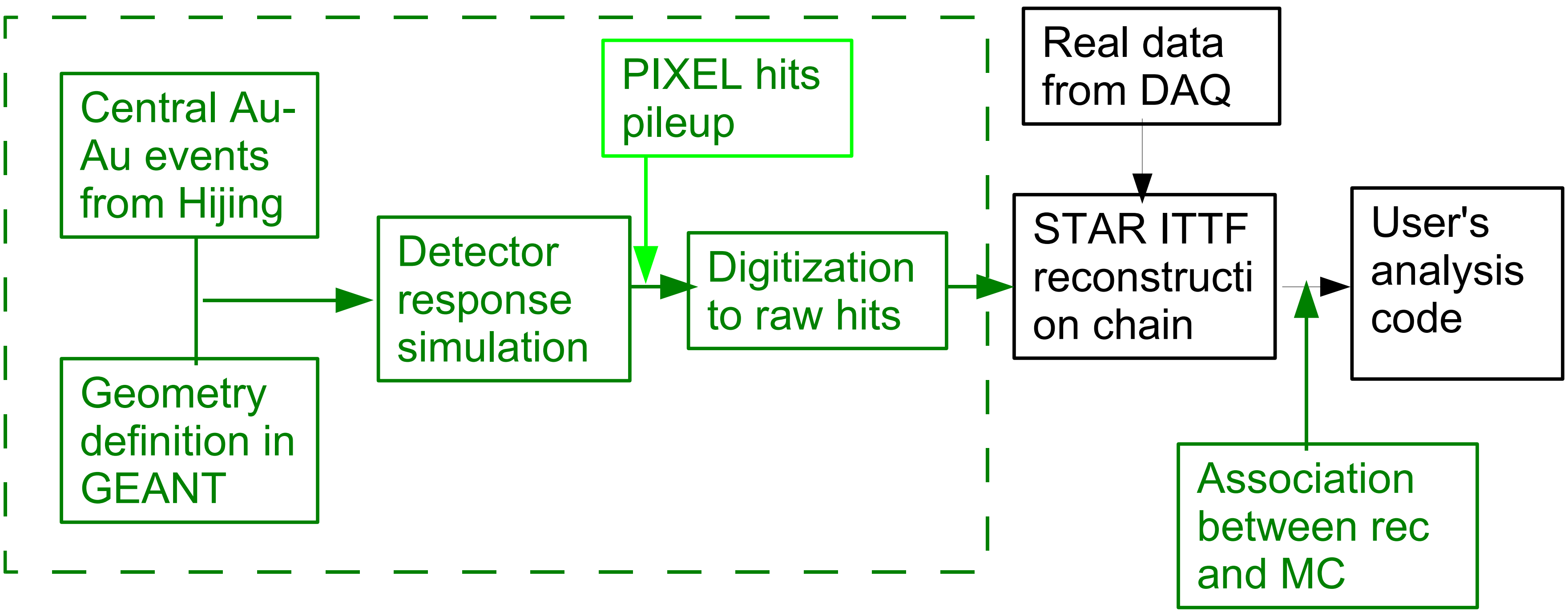
Understand the HFT performance in the STAR tracking (ITTF) environment

- tracking (matching) efficiency
- ghosting hits/tracks
- pointing resolution & its impact on charm hadron secondary decay vertex
- charm hadron reconstruction efficiency & signal / background estimation
- performance under RHICII luminosity (pile-up effect on PIXELs)
- performance in small systems (p+p)

At RHICII luminosity, the total piled-up hit density in Pixel detectors
in p+p collisions is approximately equivalent to that in central Au-Au collisions

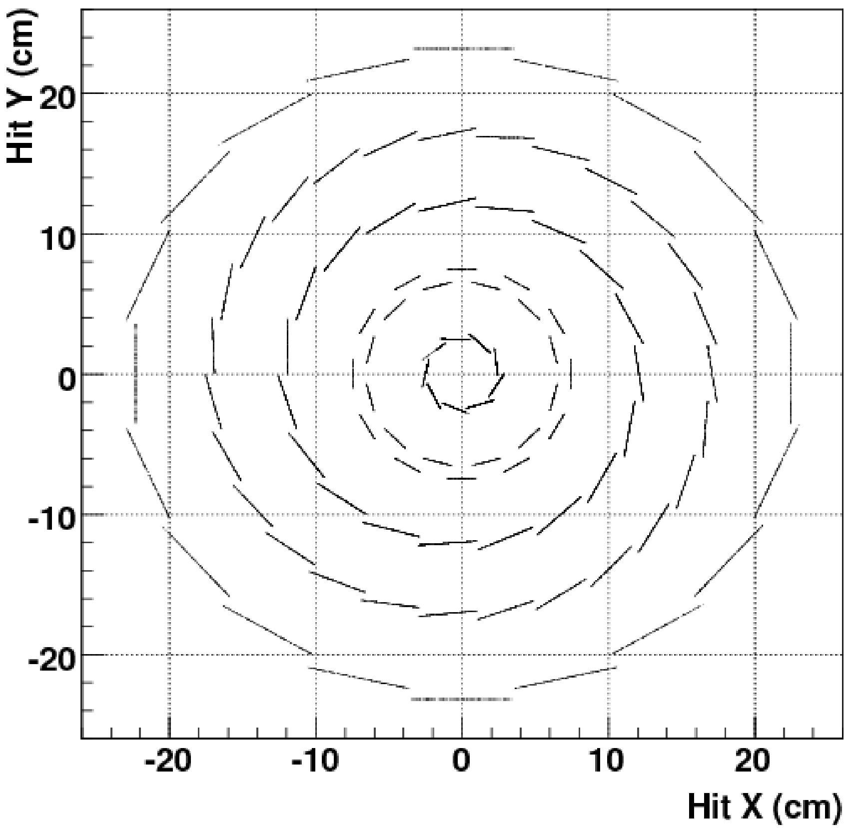
We will focus on the simulation in central Au-Au collisions.

Monte Carlo Simulation Strategy



Geometry definition in simulation

Hit position in silicon layers from MC



Segment sizes and resolutions

all numbers are in microns

	Dimension ($r\phi \times z$)	$\sigma_{r\phi} \times \sigma_z$
SSD	95 x 4200	30 x 699
IST2-B	60 x 4000	17 x 1100
IST2-A	4000 x 60	1100 x 17
IST1	60 x 2000	17 x 550
PXL2	30 x 30	8.7 x 8.7 *
PXL1	30 x 30	8.7 x 8.7 *

* errors for tracking are different

Event Samples and Some definitions

Central (b=0-3 fm) Au-Au Hijing + 10 D^0 per event (flat p_T, eta) |Vertex_z|< 15 cm

Pointing resolution:

Ghosting hit: the hit picked up in this track is not the real MC hit

Ghosting track: the track reconstructed doesn't have an associated MC track

Track efficiency: possibility of reconstructing a MC track (including geometric acceptance and track quality cut eff)

D^0 efficiency: possibility of reconstructing a MC D^0 (including acceptance and track quality cut eff for daughters and other pair quality cuts for D^0 candidates)

Background: not from D^0, hijing tracks.

D^0 signal: a good reconstructed D^0 with both daughters have the correct associated MC tracks (no mis-PID for daughters)

D^0 background: either of the rec. daughter is not from a MC daughter of MC D^0

No mis-PID

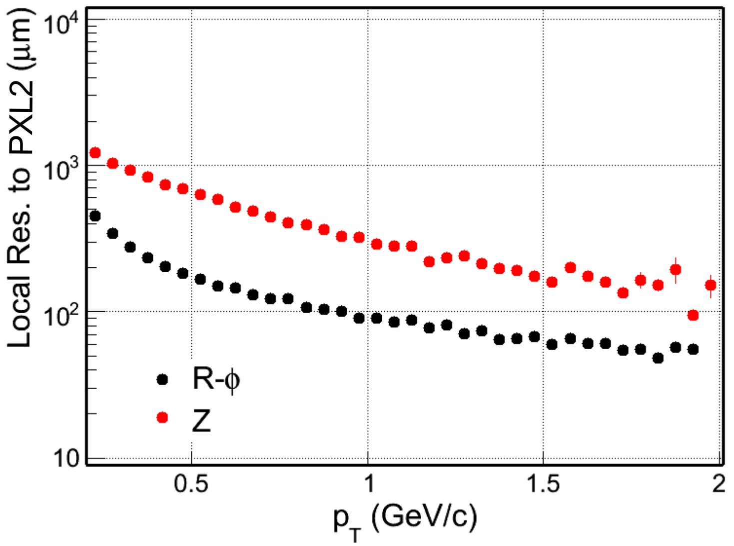
neither of daughters is from D0
either is not from D0, the other is from bg
two daughters are from different D0

mis-PID

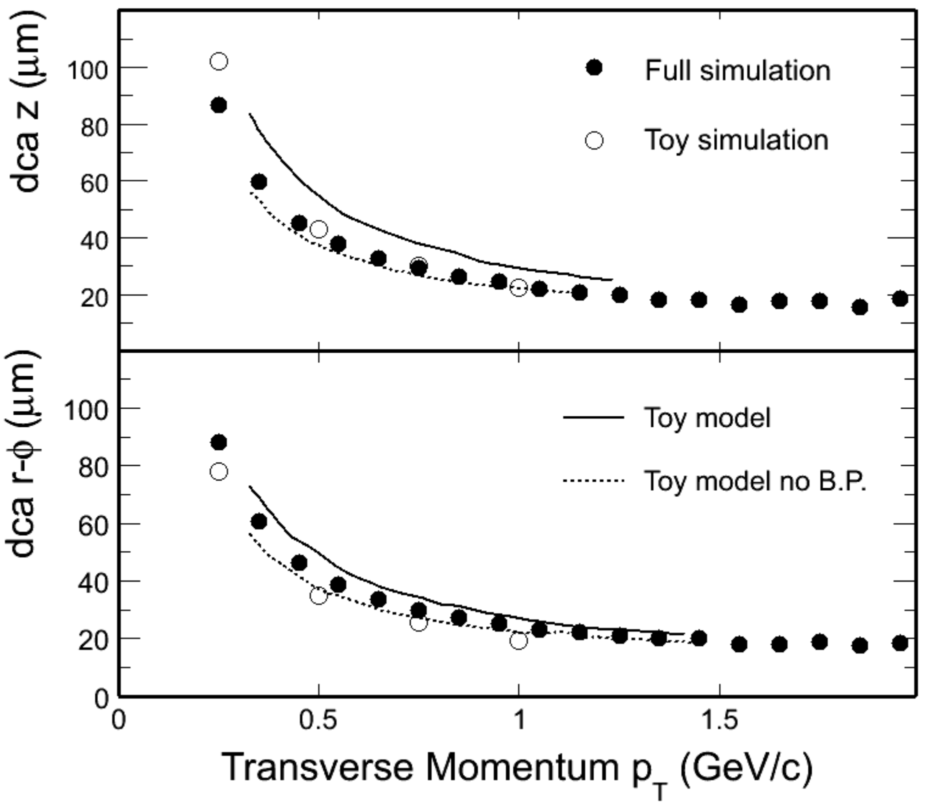
neither is from D0, and both mis-Ided
either is from D0, but mis-Ided, the other is from bg
two daughters are from different D0, and mis-Ided
both daughters are from the same D0, but both mis-Ided

Pointing Resolution

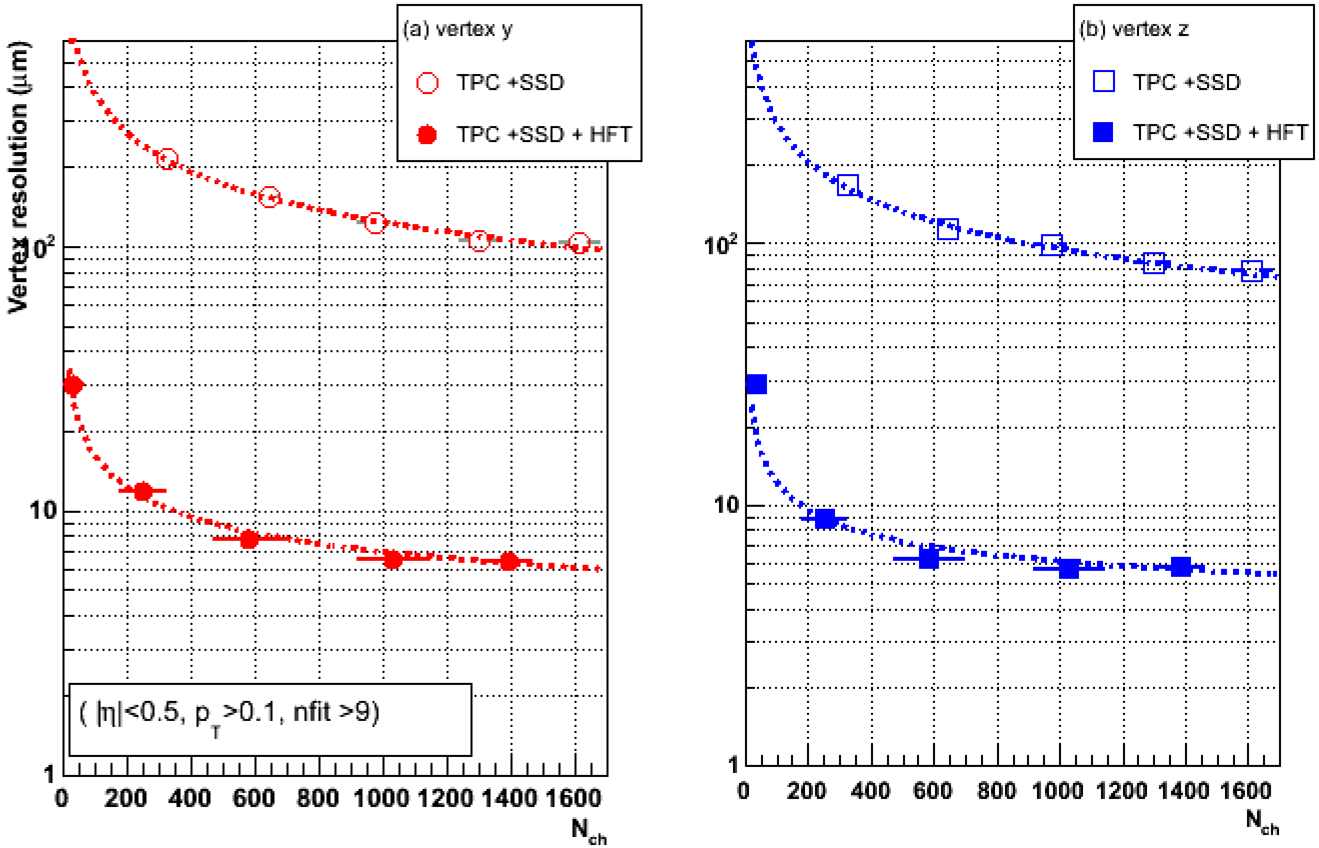
From outer layers to PIXEL 2



From all hits to primary vertex

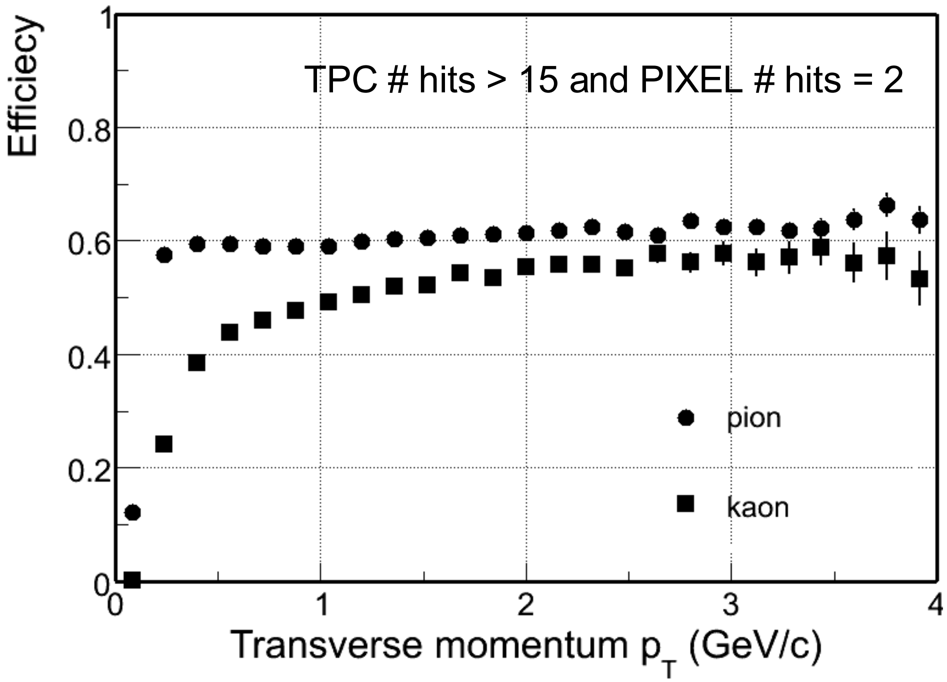


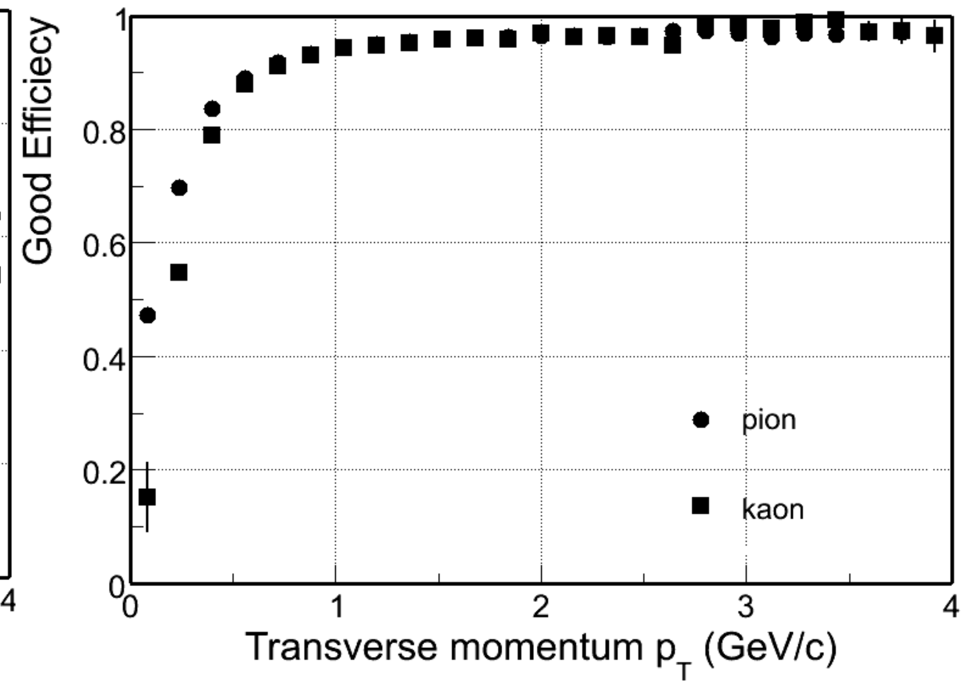
Primary vertex resolution



The vertex resolution nicely follows $a \oplus \dfrac{b}{N}$

Single Track Efficiency



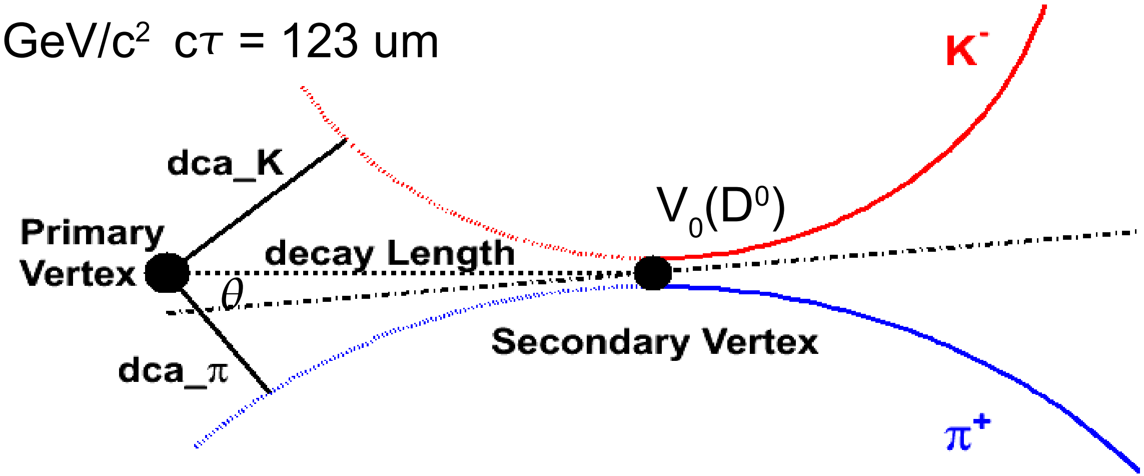


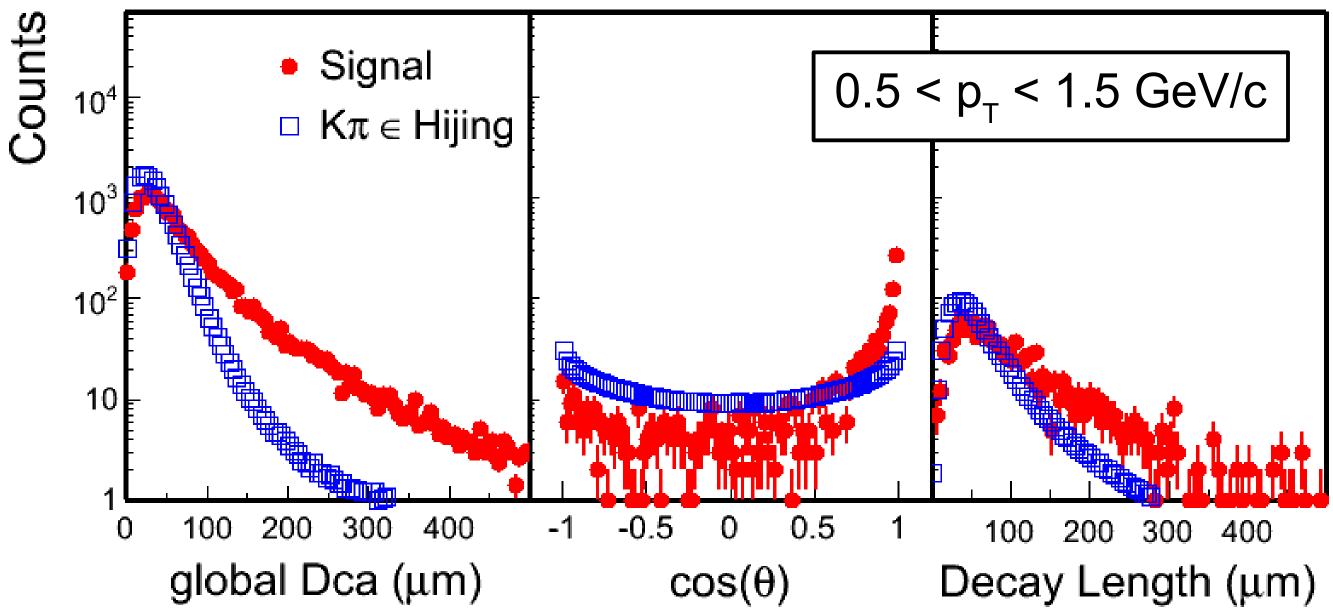
Au + Au central collisions @ 200 GeV

- TPC tracking efficiency ~80-85%
- Good Efficiency = 1 – Ghosting rate

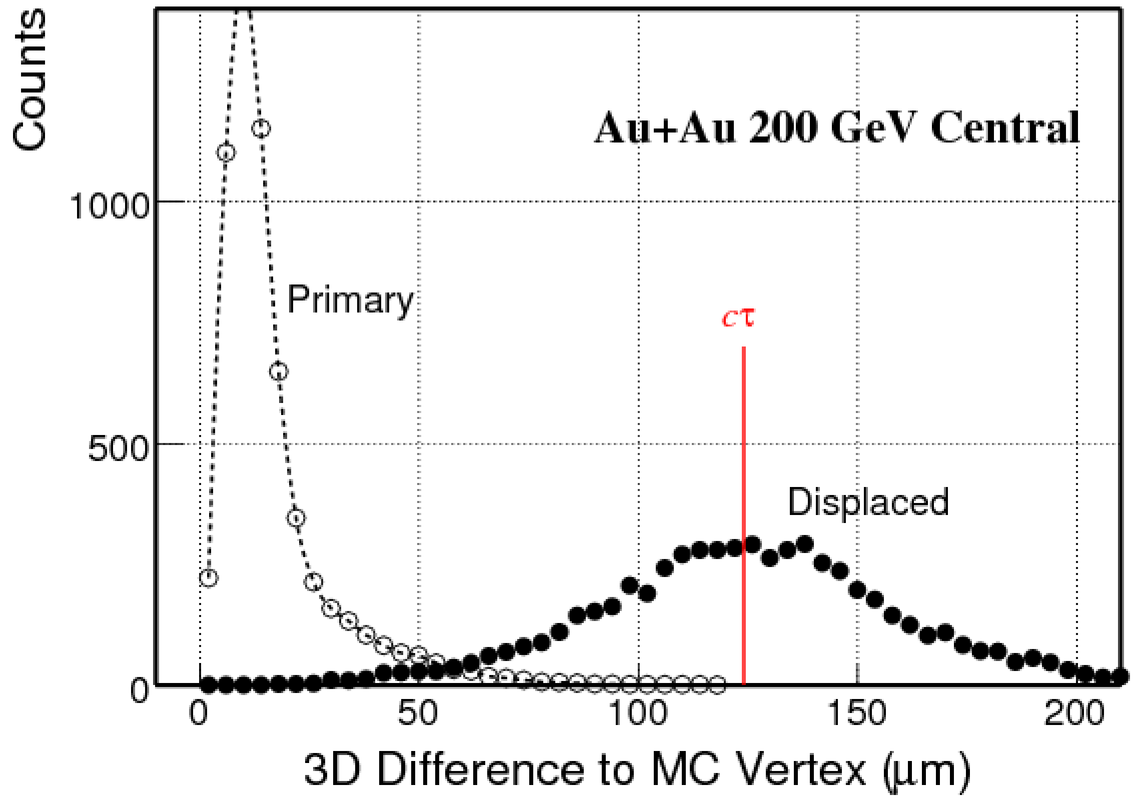
D^0 reconstruction

M_{D0}= 1.8645 GeV/c² cτ = 123 um



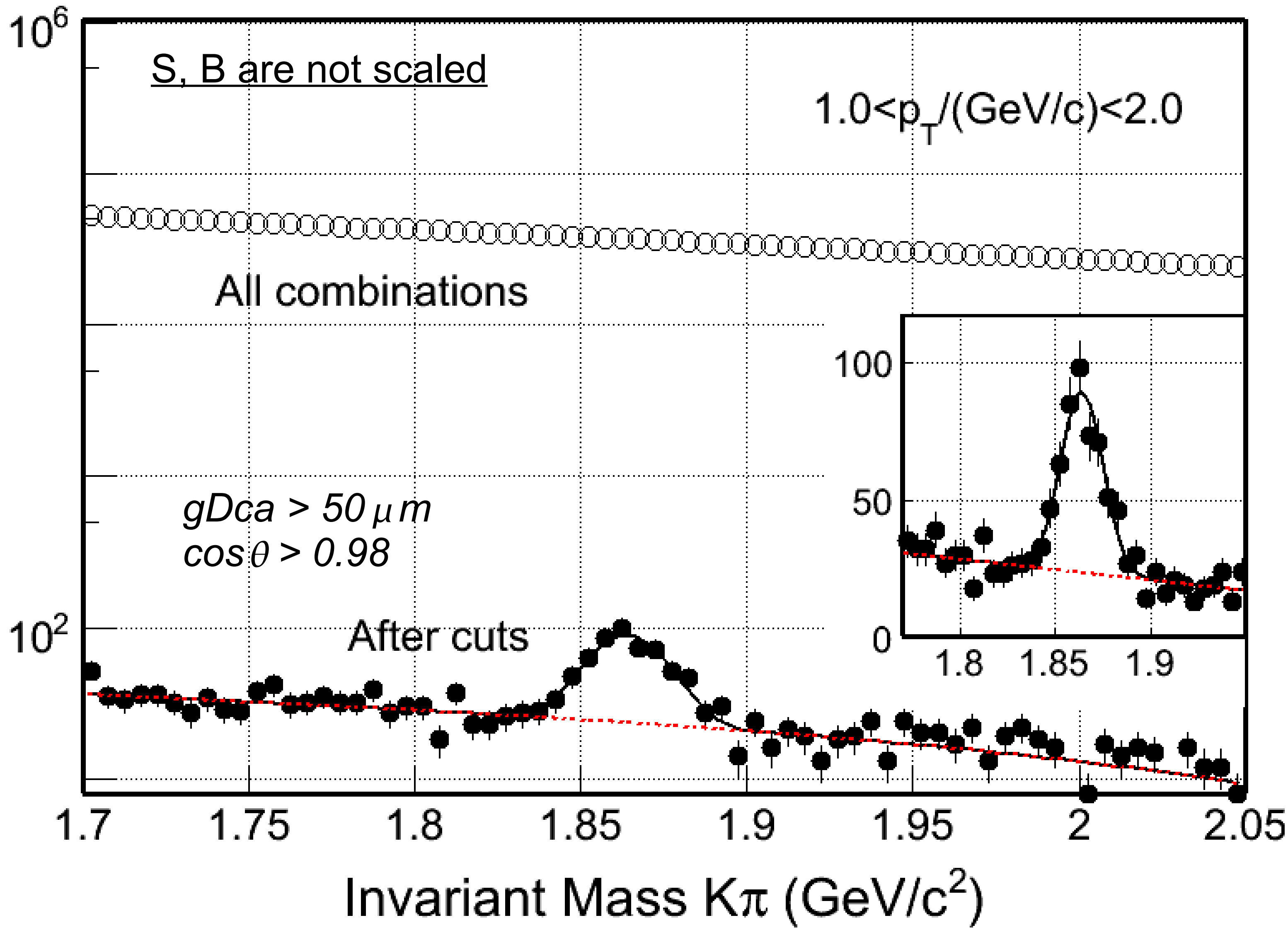


Secondary Vertex Resolution

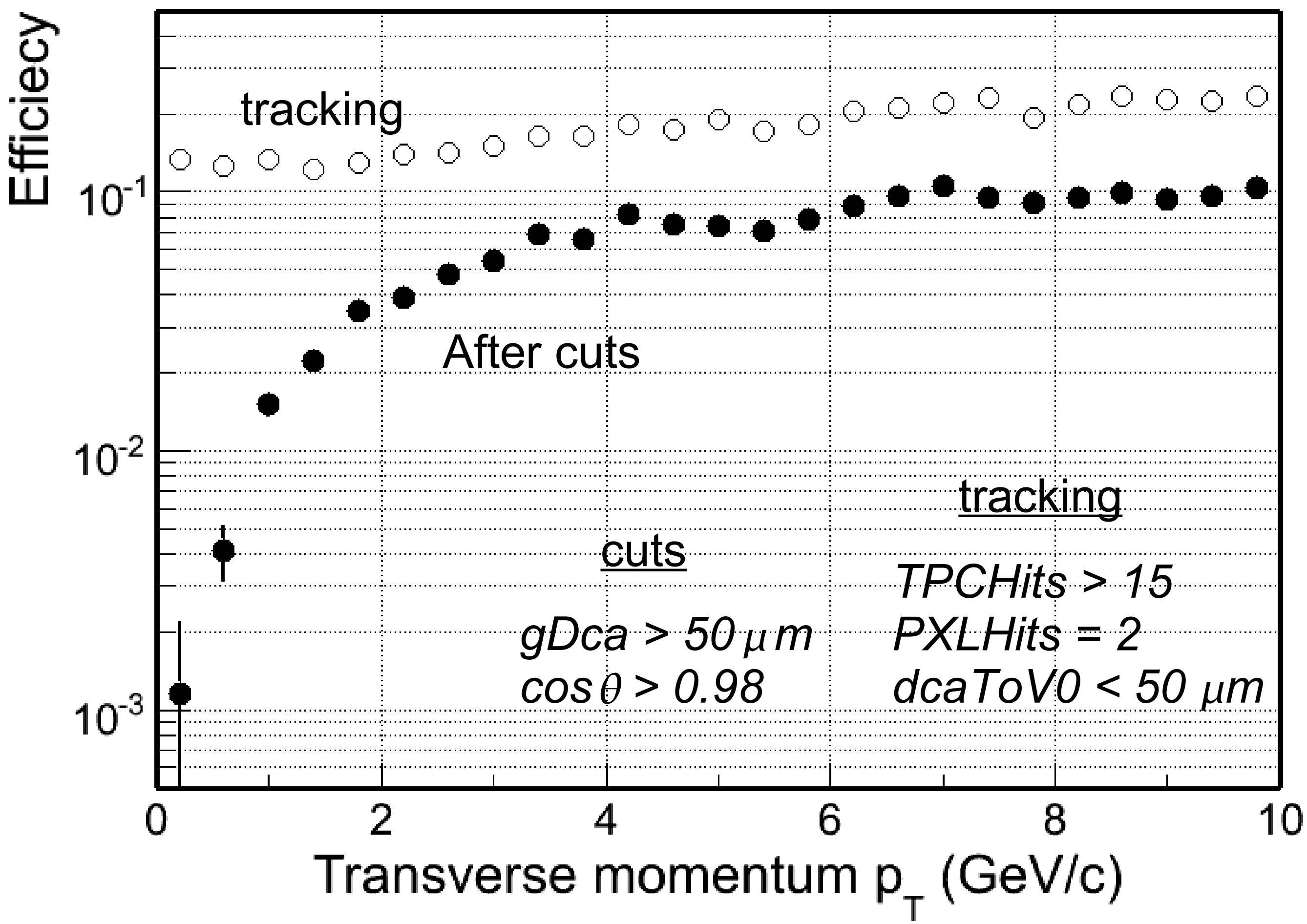


- All D^0 were scaled by a factor of $1/\beta\gamma$
- In central AuAu collisions, D^0 secondary vertex is clearly separated from the primary vertex

D^0 invariant mass plot from MC sample

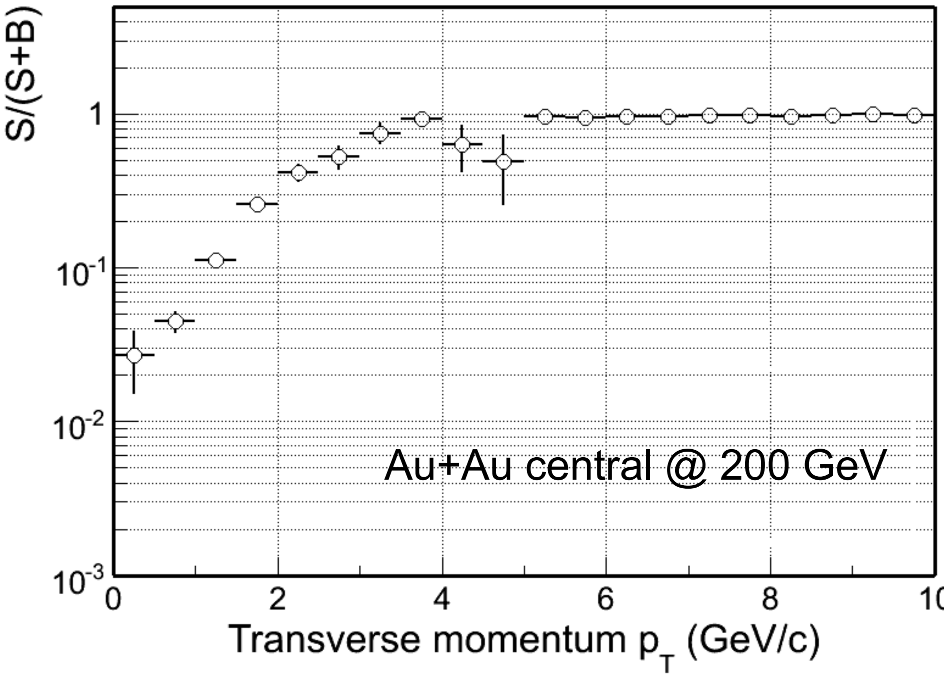


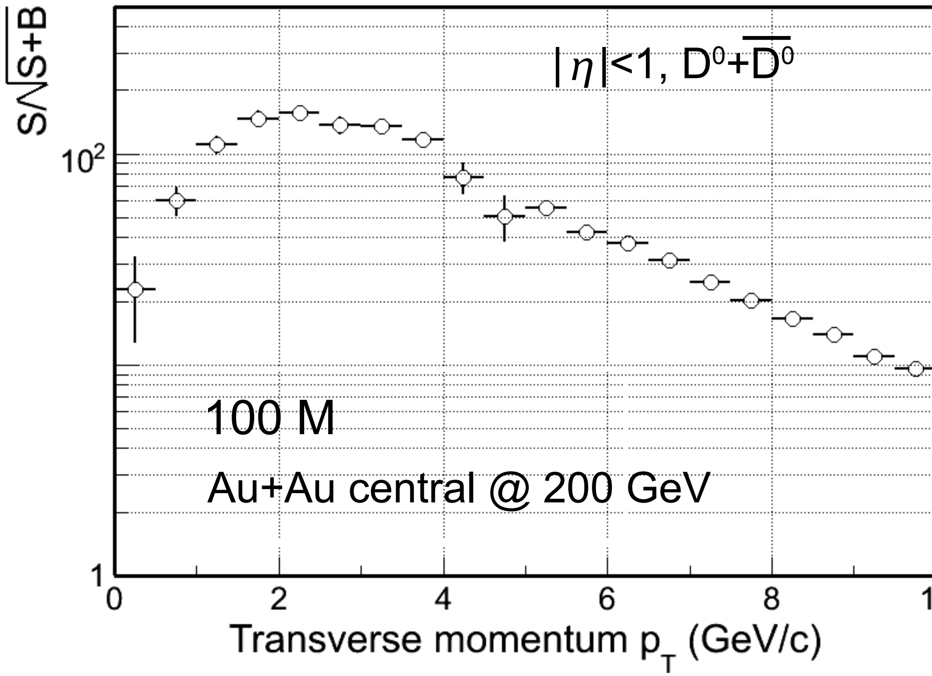
D^0 efficiency



Kinematic cuts may be optimized after systematic studies.

D^0 signal / background





- S, B are scaled close to real situation
- central, no pile-up
- Assume perfect PID

S: D^0 yield $dN/d\eta = 2$
power-law with $\langle p_T \rangle = 1 GeV/c$, n=11

B: Combinatorial background from
Hijing and D^0 decay daughters
Hijing shape for background ext.

Improvements

D^0 Measurements: dN/dy per NN collision ~ 0.004 (STAR)
we take half of it as the estimation

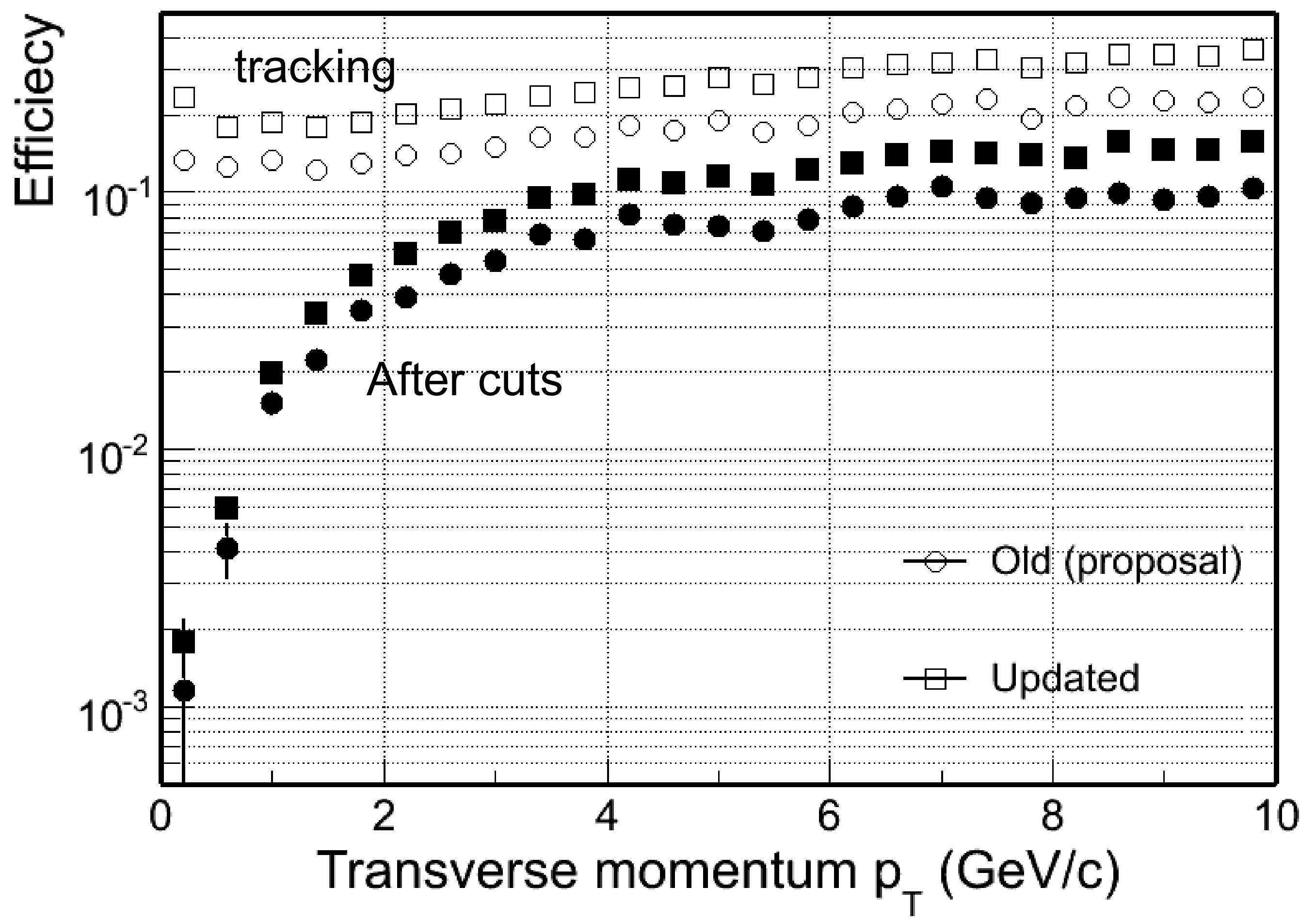
Hits selection in PIXEL: MC hits and Rec hits can be > 2
we include those tracks

D^0 Background: K from D and pi from others -- important in high p_T
D^0 -> K$^-$ + X (53%), as well as kaon from other charm hadrons.

→ Update version

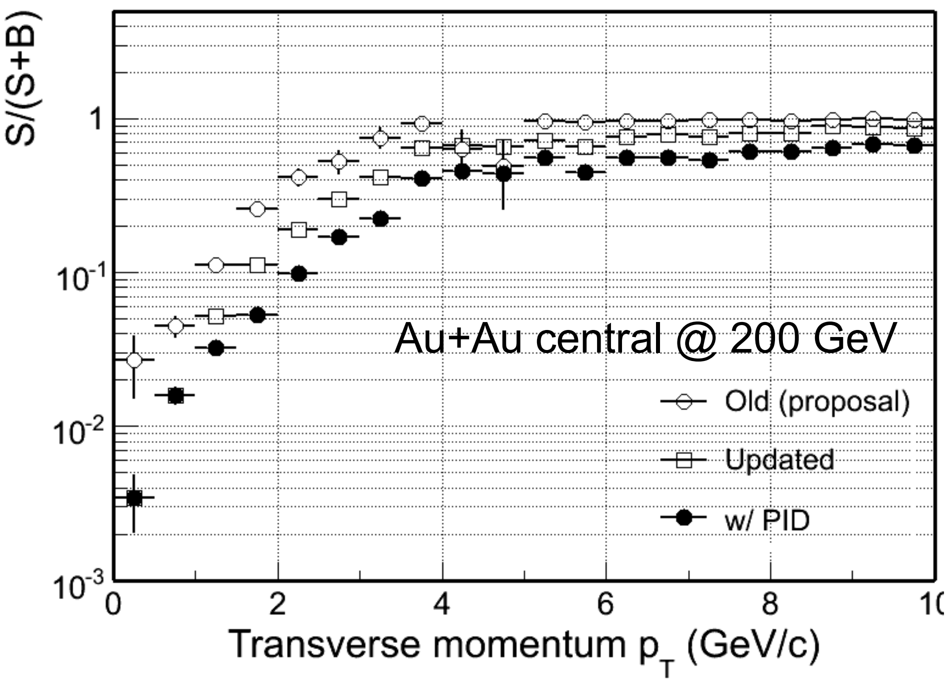
PID with TOF:
Assume perfect K/pi at p_T<1.5 GeV/c, no PID for K/pi beyond that.
Background estimation also includes PID contamination.

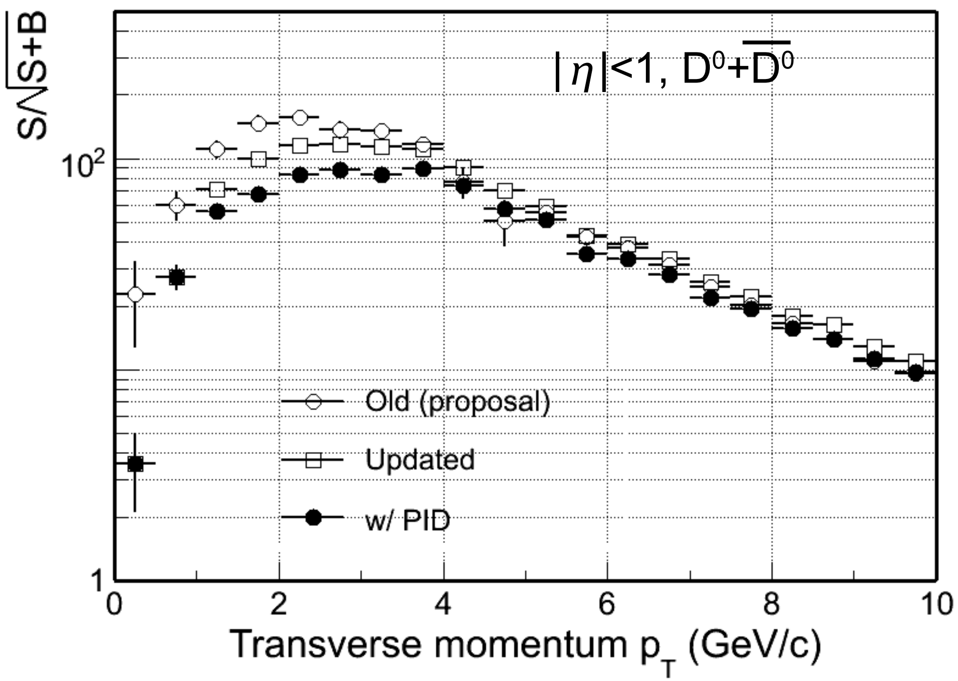
Improvement on Efficiency



Single track efficiency improved by ~20-30%
-- # of hits selection in PIXELs

Improved understanding of D^0 signal / background



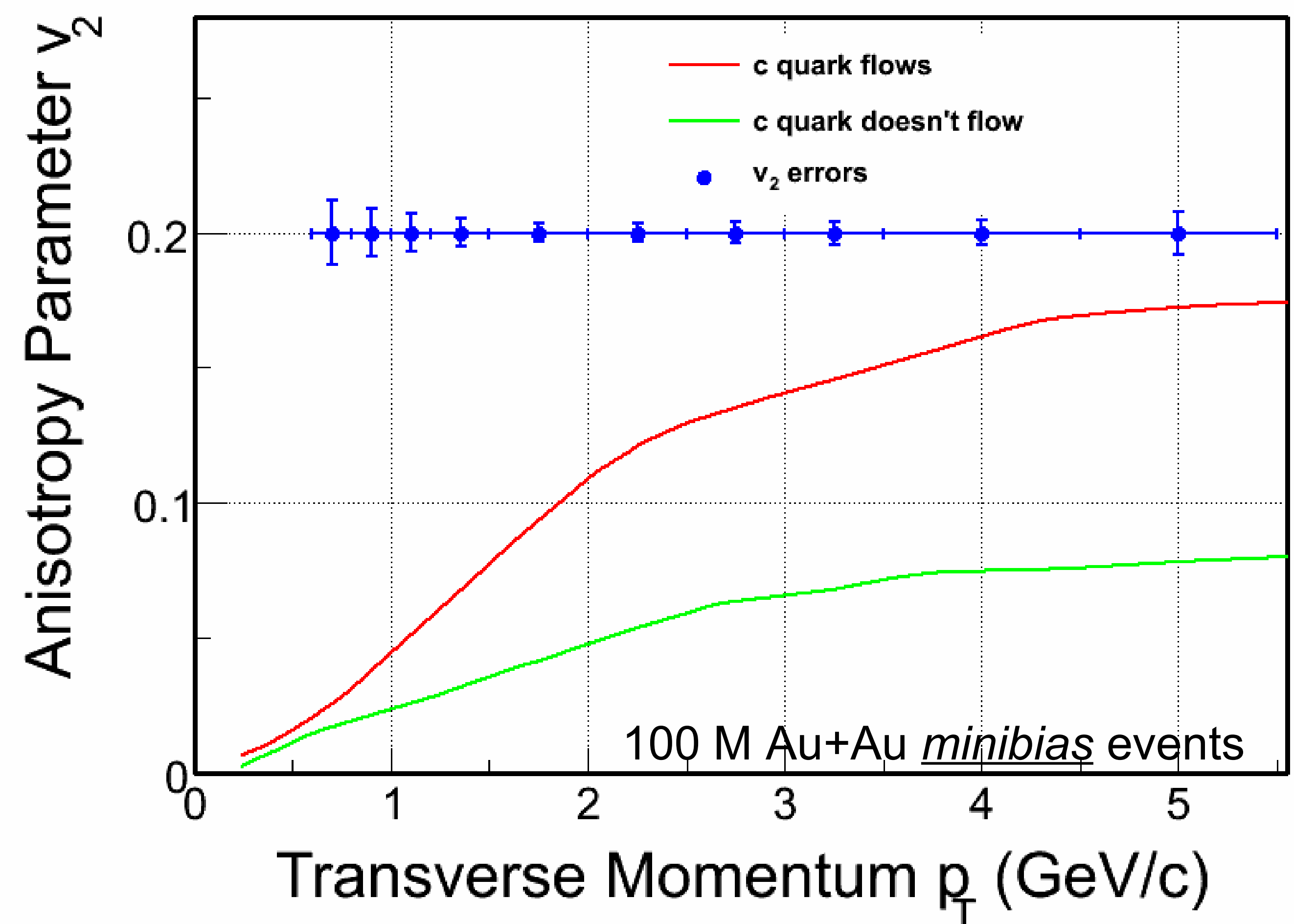


100 M Au+Au central @ 200 GeV

- S, B are scaled close to real situation
- central no pile-up
- Assume perfect PID at p_T<1.5 GeV
- and no PID at p_T>1.5 GeV/c

S: D^0 yield $dN/d\eta = 2$
B: Combinatorial background from Hijing and D^0 decay daughters

v_2 sensitivity



From central to minimum bias, assume:

- D^0 scaled by N_{bin}
- Hijing background scaled by N_{part}.

Pile-up in PIXEL

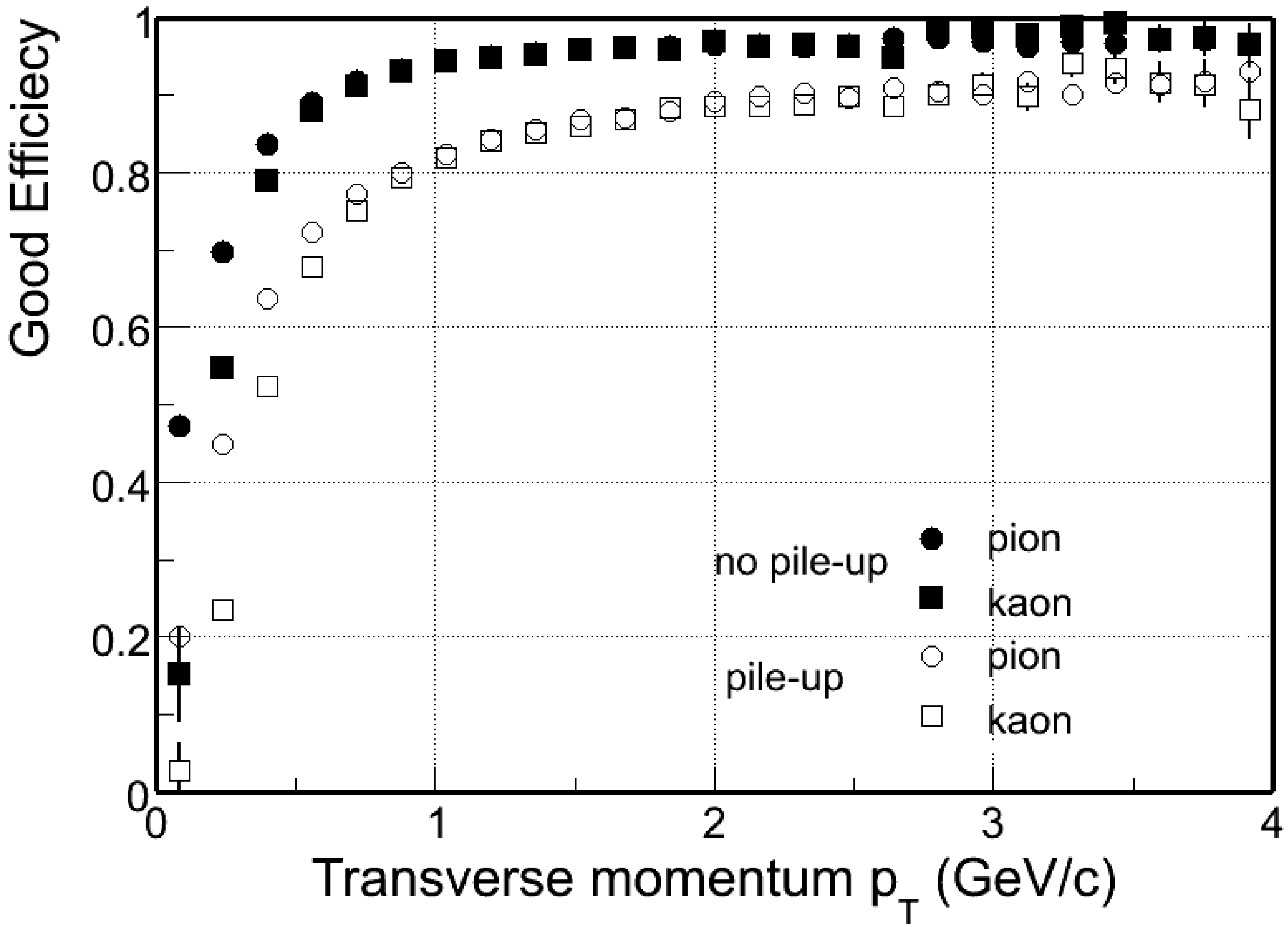
One central Au+Au event + pile-up at 1x RHICII luminosity level in PIXEL

Beam diamond sigma = 15 cm
minibias collision rate = 80 kHz
PIXEL chip integration time = 200 us

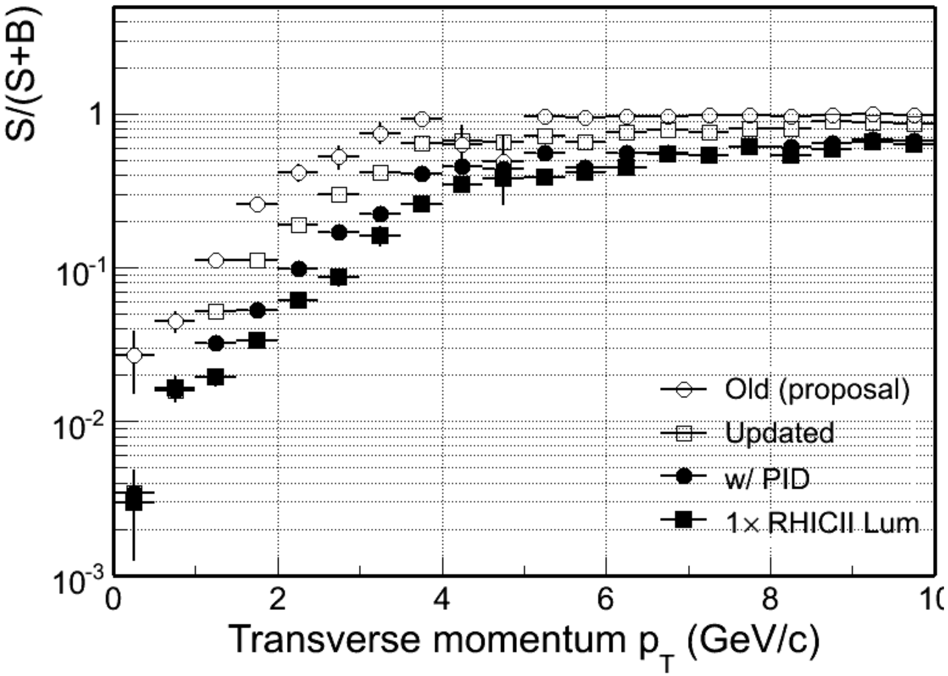
Pile-up hit density (cm^{-2})

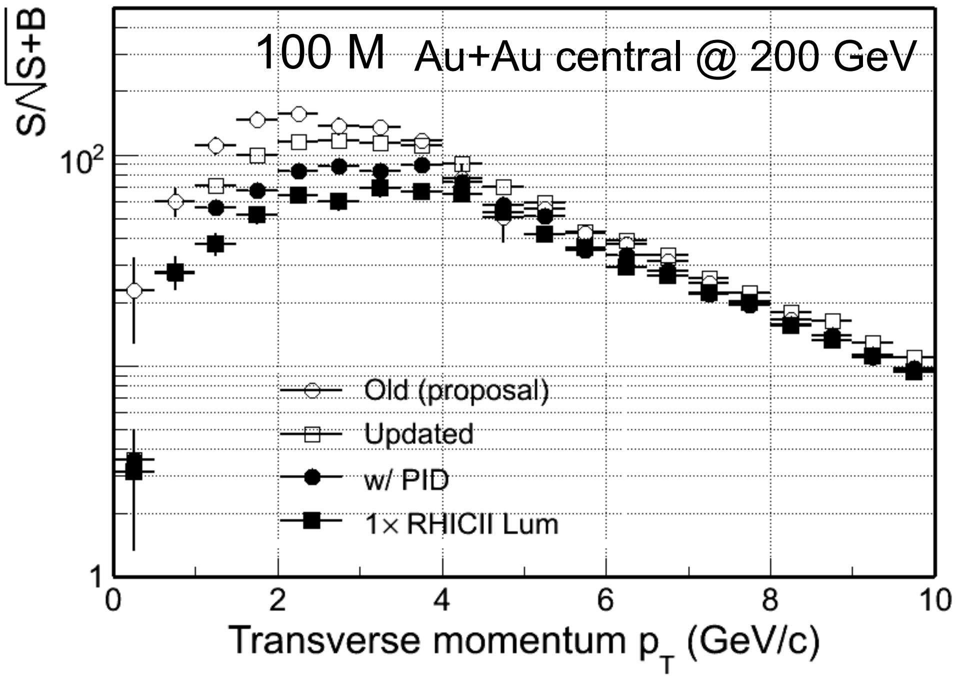
Pile-up level	PIXEL1	PIXEL2
0.5x	21	3
1.x	43	6
2.x	86	12
3.x	129	18
AuAu central	19	2.4

Ghosting increases!



D^0 signal / background @ RHIC II luminosity

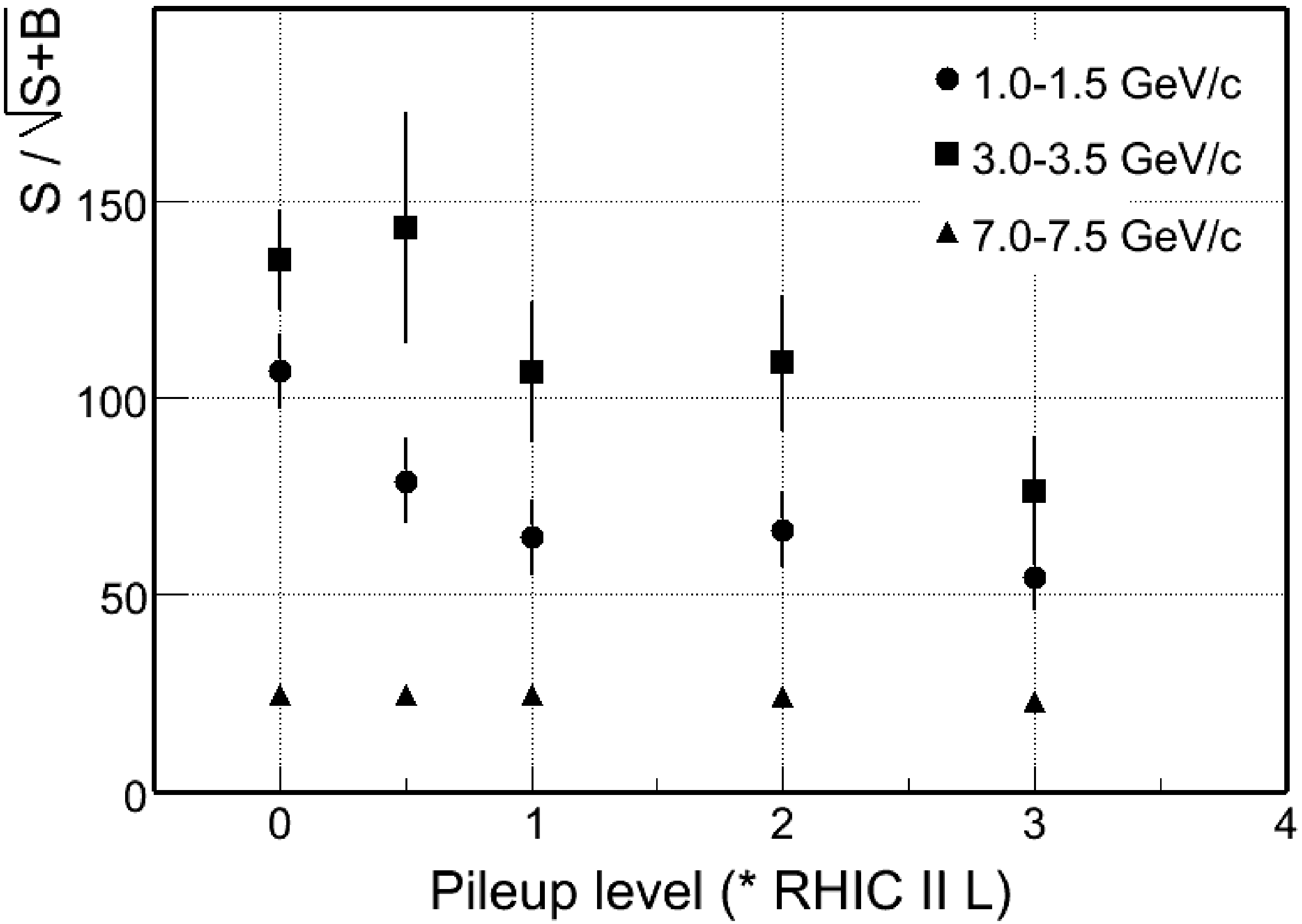




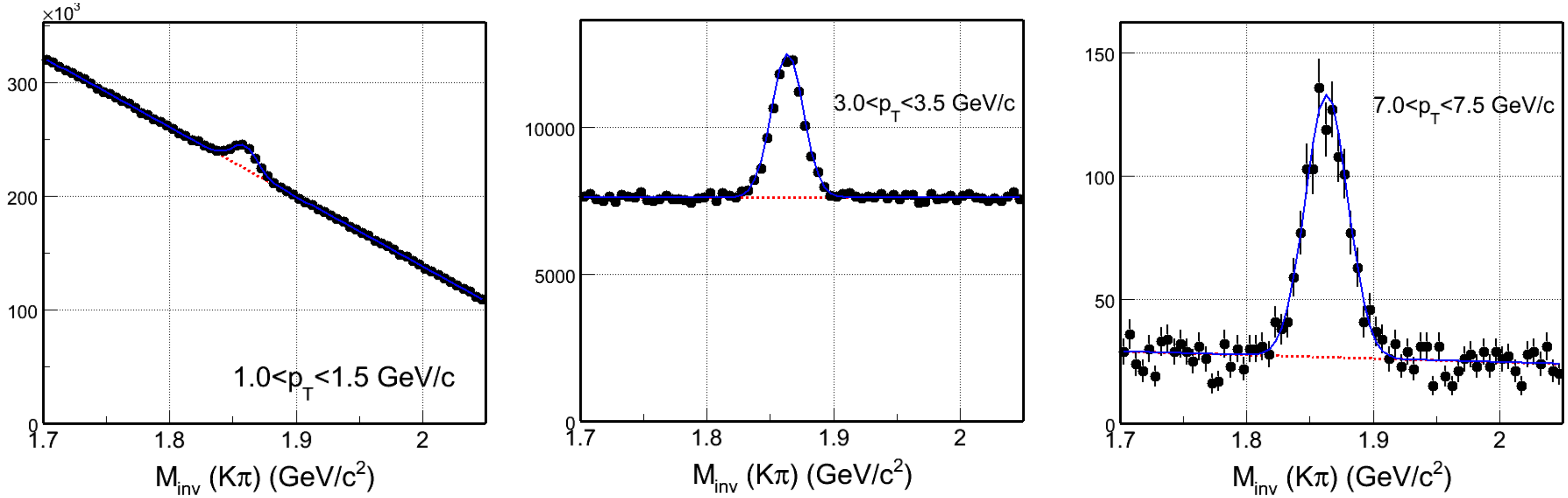
Slightly decrease in the S/B ratio!

S,B evolution with different pileup levels

Need update



Expected invariant mass distributions



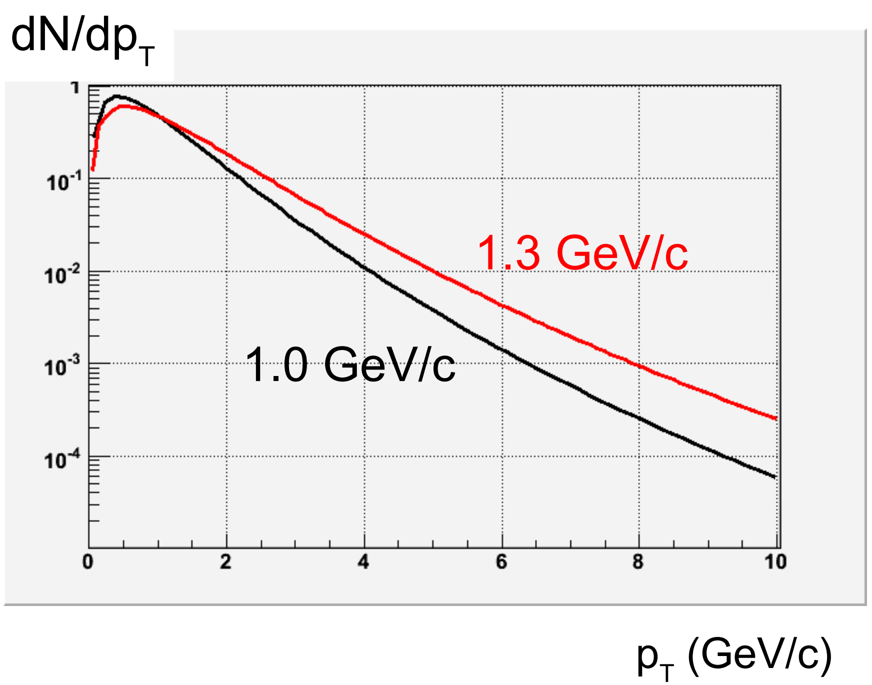
p_T

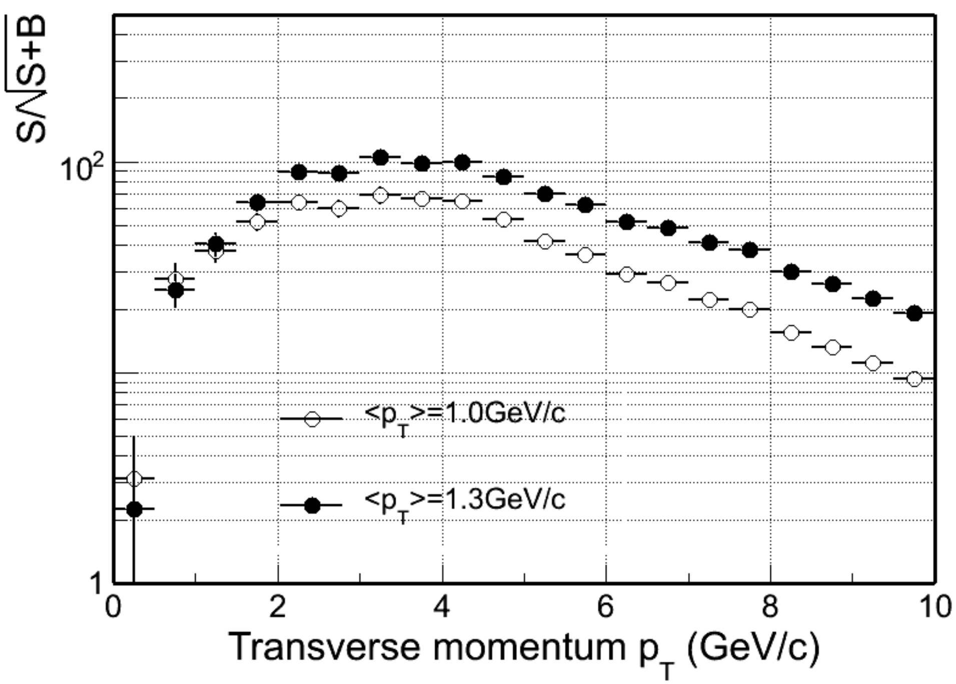
For 100 M Au+Au central collisions at RHIC II luminosity

p_T distributions for S/B at high p_T are just guesses.
D^0 Background slope at high p_T could be uncertain due to limited statistics in MC

Could be better at high p_T !

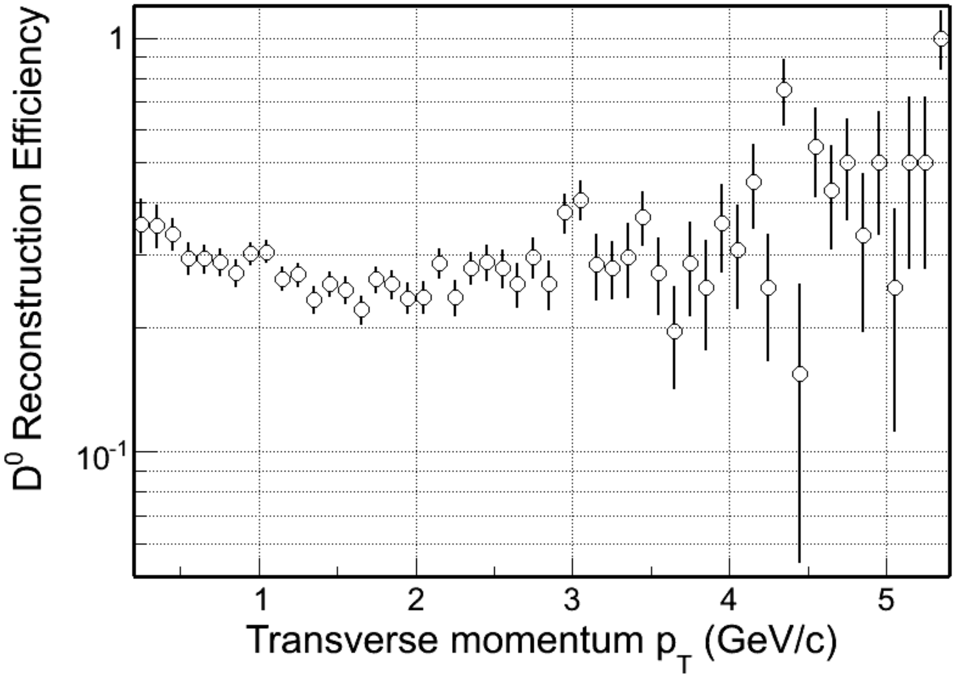
D^0 p_T spectrum, power-law extrapolation: $\frac{dN}{p_T dp_T} = A(1+\frac{p_T}{p_0})^{-n}$ $p_0 = \frac{n-3}{2} < p_T >$





D^0 simulation in p+p collisions

- A first estimation on the D^0 efficiency in p+p collisions
- PYTHIA charm events only + GEANT simulation, no QCD background simulation yet



Statistical error on R_{AA}

P_T (GeV/c)	Δp_T (GeV/c)	R_{AA} relative error (%)
4.5	1.0	1.0
5.5	1.0	1.8
6.5	1.0	2.8
7.5	1.0	4.3
8.5	1.0	6.4
9.5	1.0	9.3

- 1.0 pb^{-1} analyzed data in $|v_z|$<15cm
- error in central AuAu neglected
- Background not included yet

Summary

A full Monte Carlo simulation + reconstruction chain with HFT in STAR has been set up.

With the HFT at STAR, we are able to achieve:

- ✔ primary vertex resolution better than 10 um.
- ✔ D^0 secondary vertex well separated from primary vertex (not very low p_T).
- ✔ comprehensive precision measurements on open charm hadrons because of
  - High efficiency
  - High S/B
  - High S/sqrt(S+B)

in future RHIC II environment.

Unsolved questions:

- ➢ tracking algorithm well understood or not?
- ➢ ghosting rate at low p_T
- ➢ Improvement on the D^0 efficiency at low p_T?
- ➢ p+p pile-up and vertex finders

To do

Optimize the ITTF tracking algorithm and HFT simulation package

- Fully understand the single track efficiency / pointing resolution
- Optimize D^0 analysis cuts
- Systematic D^0 background study
- other charm hadrons
- p+p collisions