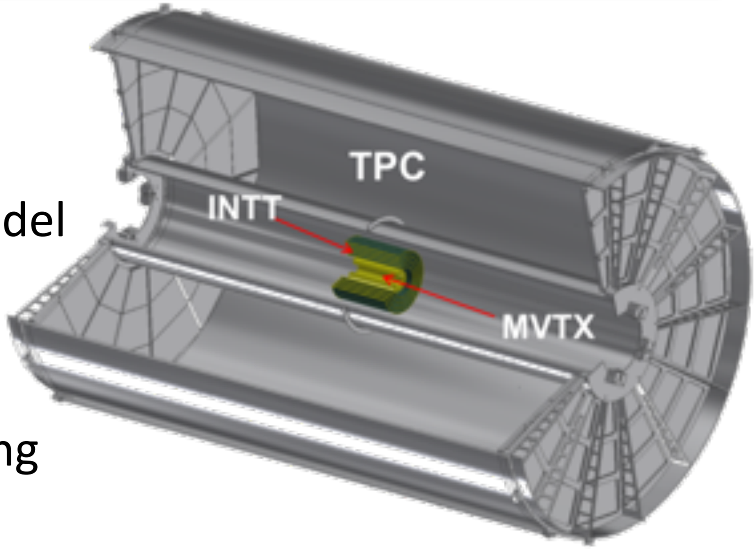
sPHENIX Director's Review
Tracking Simulations

August 2-4, 2017

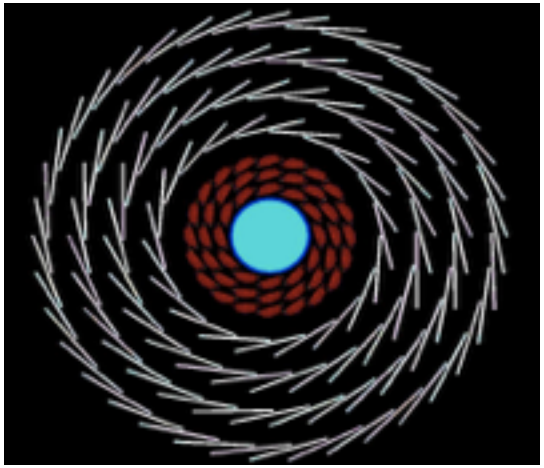
BNL

Tracking Simulations



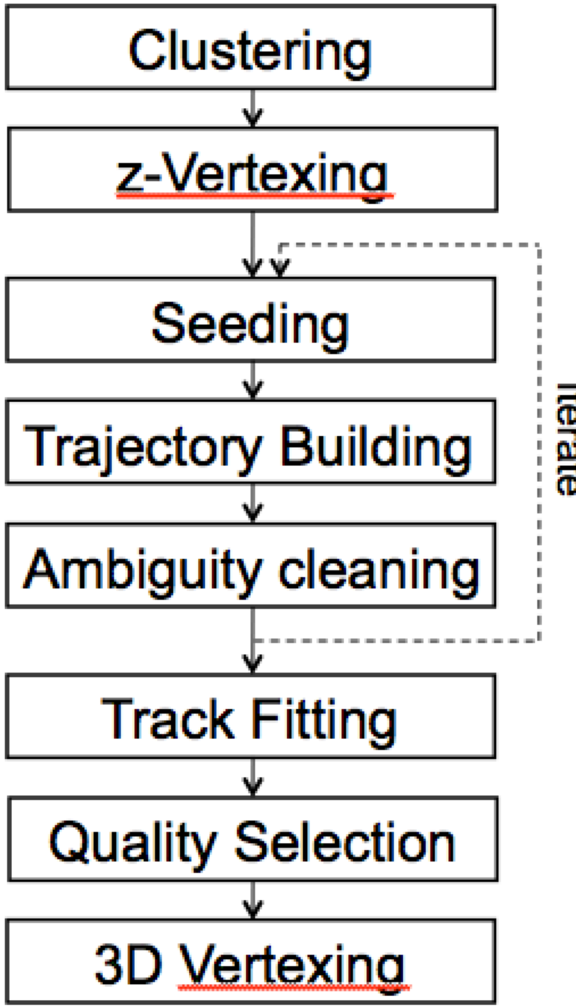
- GEANT 4 model of the sPHENIX tracker
  - MVTX - three layers, copy of ALICE ladder model
    - 0.3% X_0 per layer
    - Pixel size 30 µm x 30 µm
    - Cluster resolution 5 µm with charge sharing
  - INTT - realistic four layer ladder model
    - 1.0% X_0 per layer
    - Strip size 78-86 µm x 1.6-2.0 cm
    - Cluster resolution ~28 µm(rϕ) x length/√12 (Z)
  - TPC - 40 layer cylindrical gas model (for now)
    - Charge distortions from simulations
    - Corrections from ALICE input
    - Electron drift and readout response estimated
    - Cluster resolution (average) 130 µm x 170 µm

End view of MVTX and INTT ladders from GEANT 4 model



Tracking Software Overview

- All subsystems provide a standard cluster format
  - Weighted mean + full covariance matrix
- Initial Z-Vertexing presently uses the truth information, smeared by 100 μm
- Seeding uses a Hough transformation on 7 equally spaced layers of the TPC
  - presently only one seeding iteration is used
- Track fitting uses the state of the art GENFIT package
  - There is an option for a final track refit where the reco event vertex is included in the track fit
  - Useful for prompt signals such as Upsilons



Collaborators

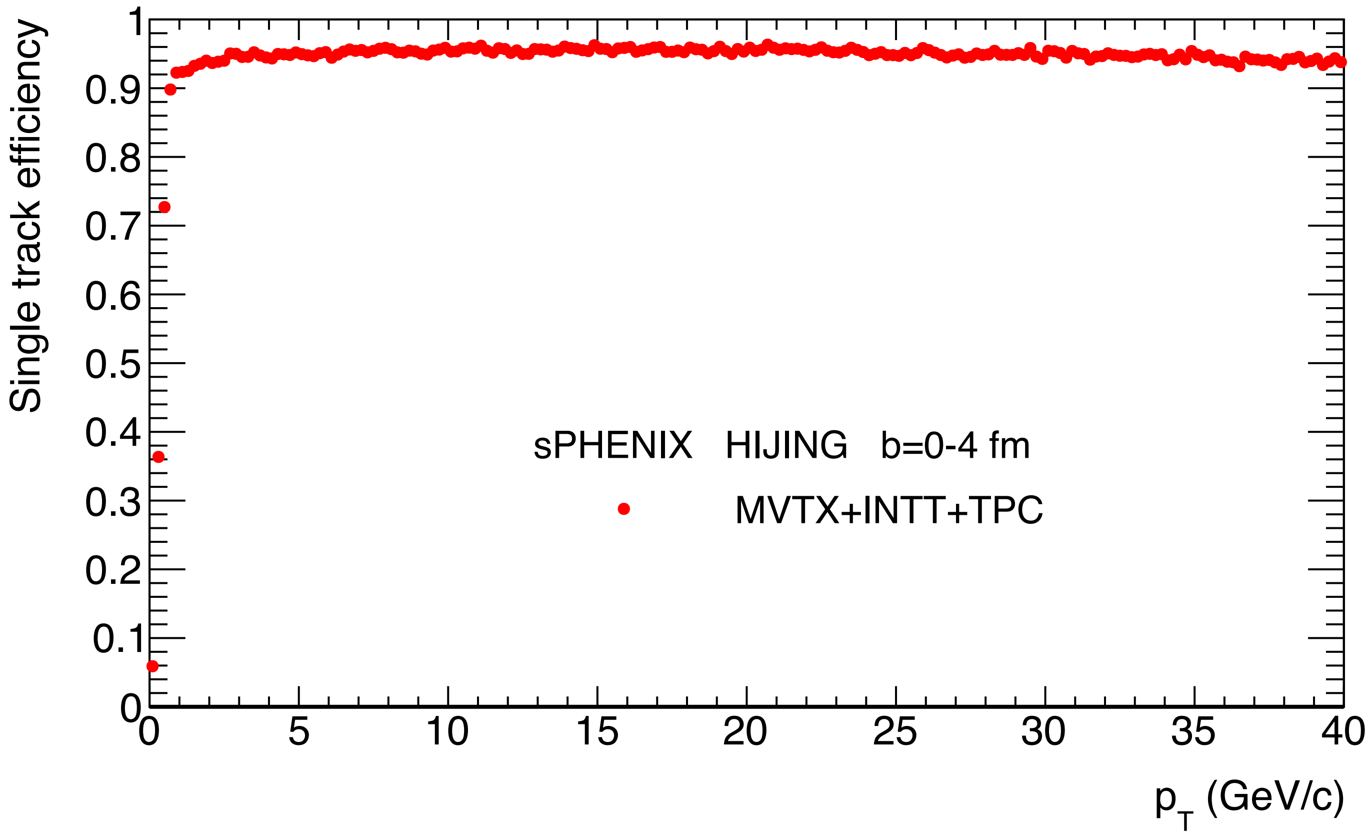
- Anthony Frawley, Florida State U. (MVTX simulations, coordination)
- Jin Huang, BNL (consultant)
- Sanghoon Lim, LANL (vertexing)
- Sookhyun Lee, Iowa State University (tracking)
- Gaku Mitsuka, RIKEN (INTT simulations)
- Carlos Perez, SUNY SB (TPC simulations)
- Christof Roland, MIT (Tracking)
- Veronica Canoa Roman, SUNY SB (TPC simulations)
- Sourav Tarafdar, Vanderbilt University (QA)
- Yorito Yamaguchi, RBRC (pileup studies)
- Haiwang Yu, New Mexico State University (Tracking)

Simulations

- Focus on performance in central Au+Au collisions
  - Central HIJING event (b = 0-4 fm)
  - Embed 100 pions
  - Embed 1 Upsilon(1S)
- Simulations with and without the MVTX
- Compare
  - Tracking efficiency
  - Transverse momentum resolution
  - DCA resolution
  - Upsilon mass resolution
- Tracking cuts
  - Primary track
  - > 20 layers per track (47 possible)
  - Track quality (related to χ^2)
  - DCA($r\phi$) and DCA(Z) < 1 mm
  - Require track has hit in all MVTX layers for DCA plots

Status and Highlights

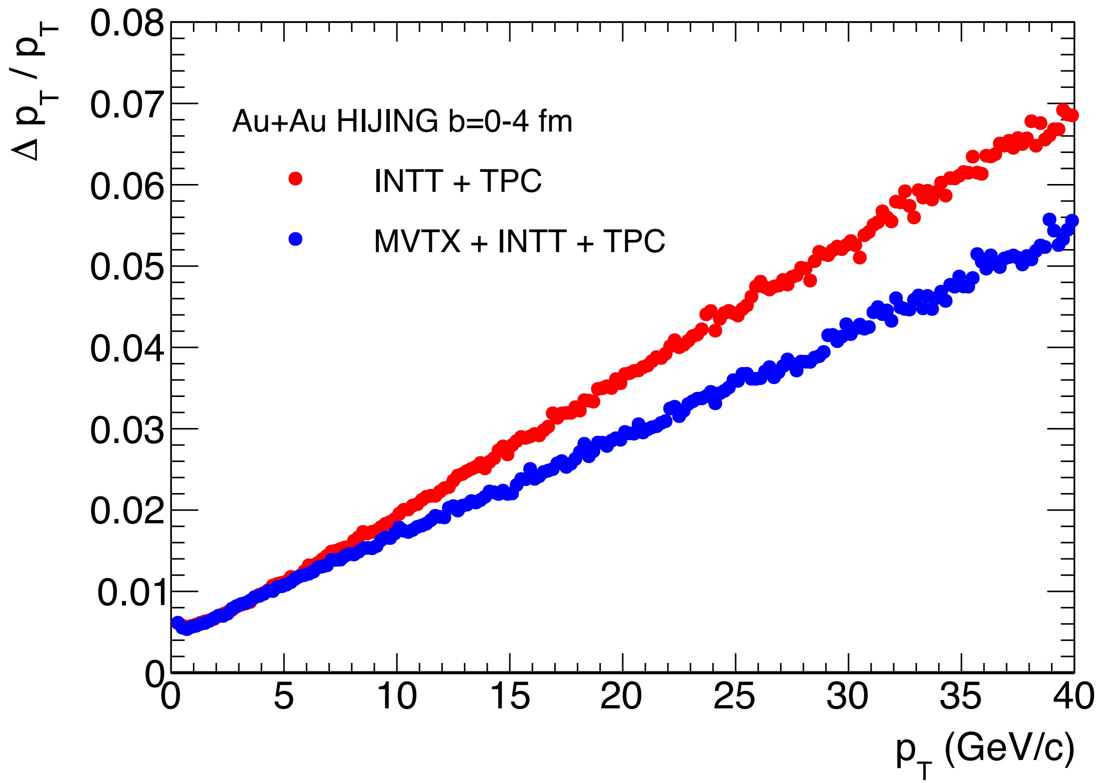
- Tracking efficiency for embedded pions in central HIJING events.
- 92% at p_T = 1 GeV/c
- 95% at higher p_T



Status and Highlights

Transverse momentum resolution with and without the MVTX

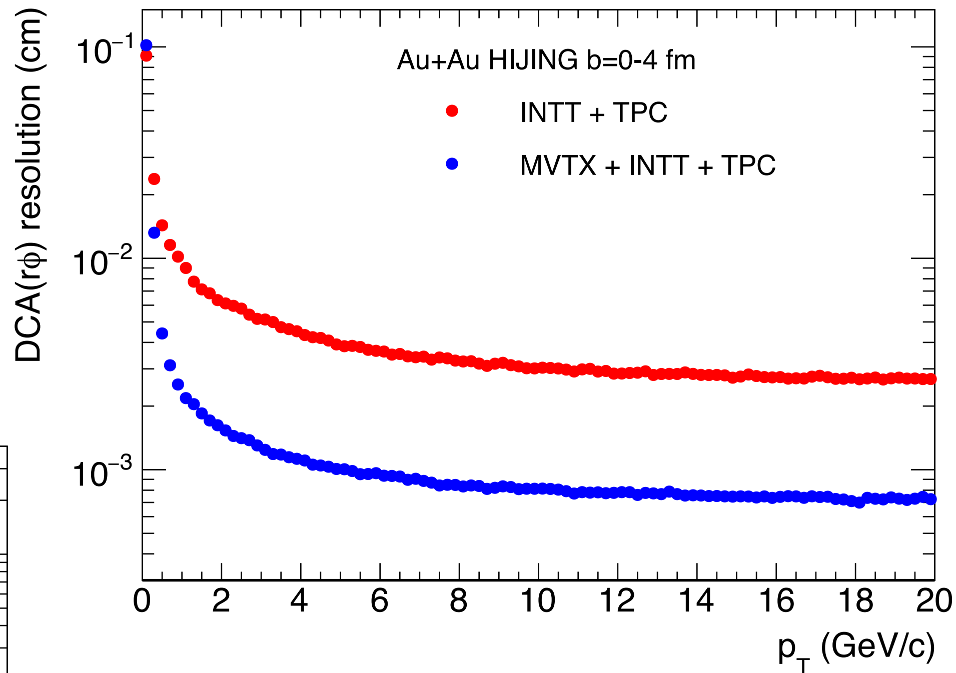
The resolution in the range 2-10 GeV/c is critical for the Upsilon measurement
In that range the Kalman filter does a good job of compensating for multiple scattering due to the mass of the inner tracker

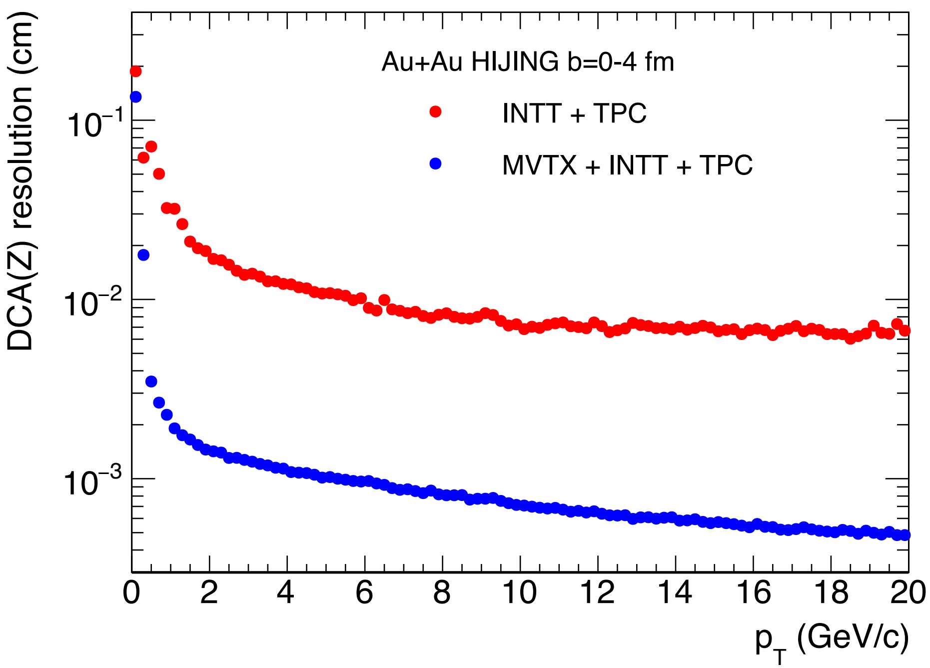


Status and Highlights

DCA ($r\phi$) resolution with and without MVTX

For MVTX case, requires hits in all MVTX layers



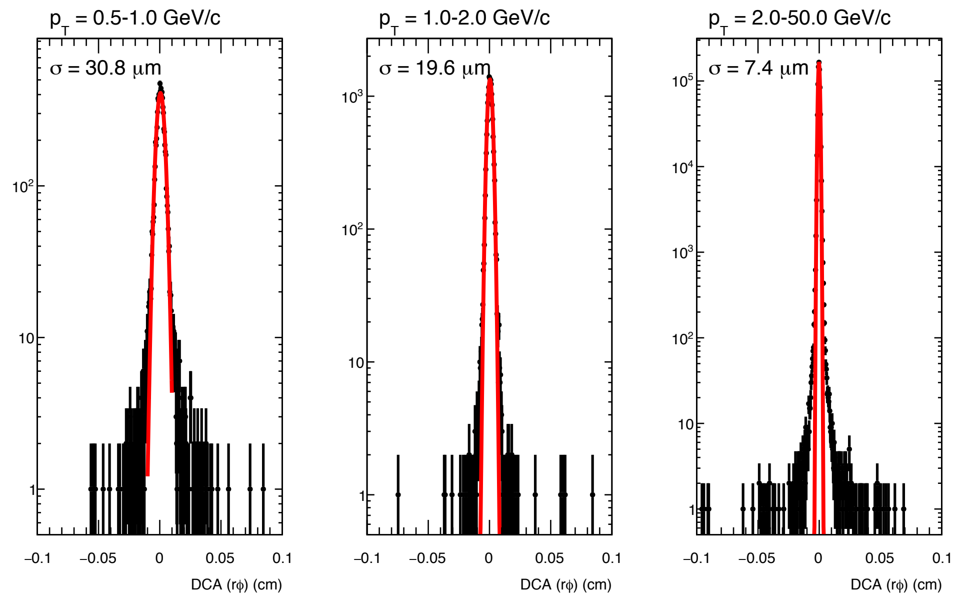


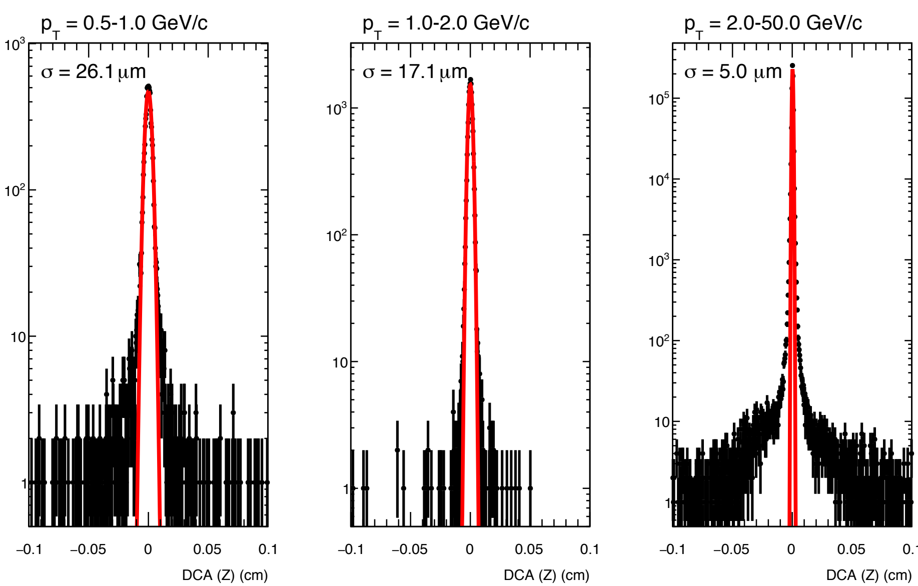
DCA (Z) resolution with and without MVTX

For MVTX case, requires hits in all MVTX layers

Status and Highlights

DCA (rϕ) distribution with the MVTX for embedded pions

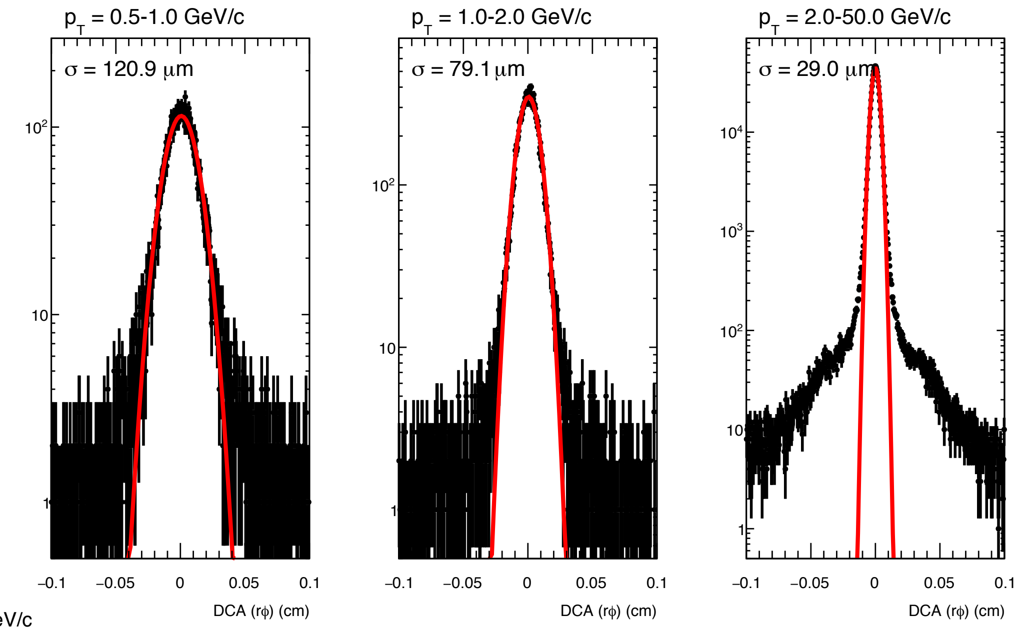


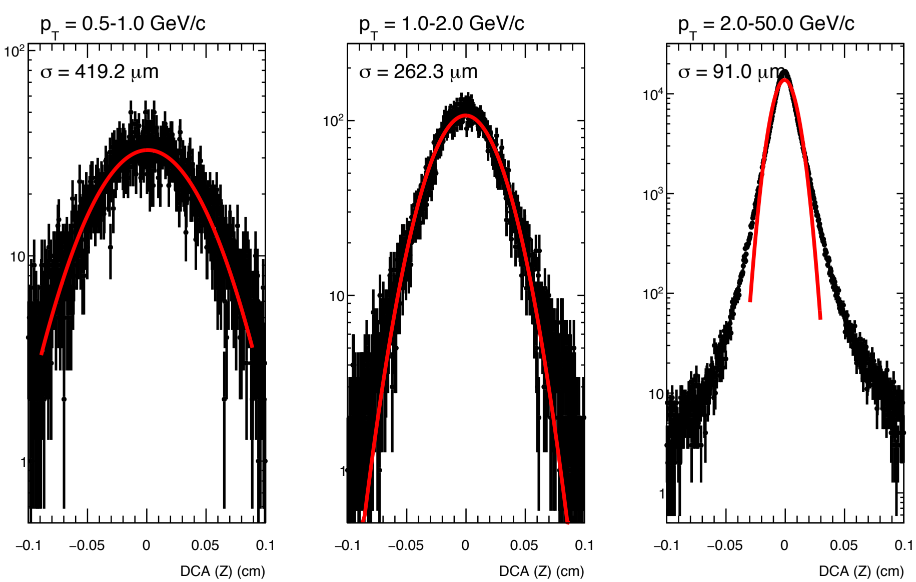


DCA (Z) distribution with the MVTX for embedded pions

Status and Highlights

DCA (rϕ) distribution with INTT + TPC only, for embedded pions in central Hijing events

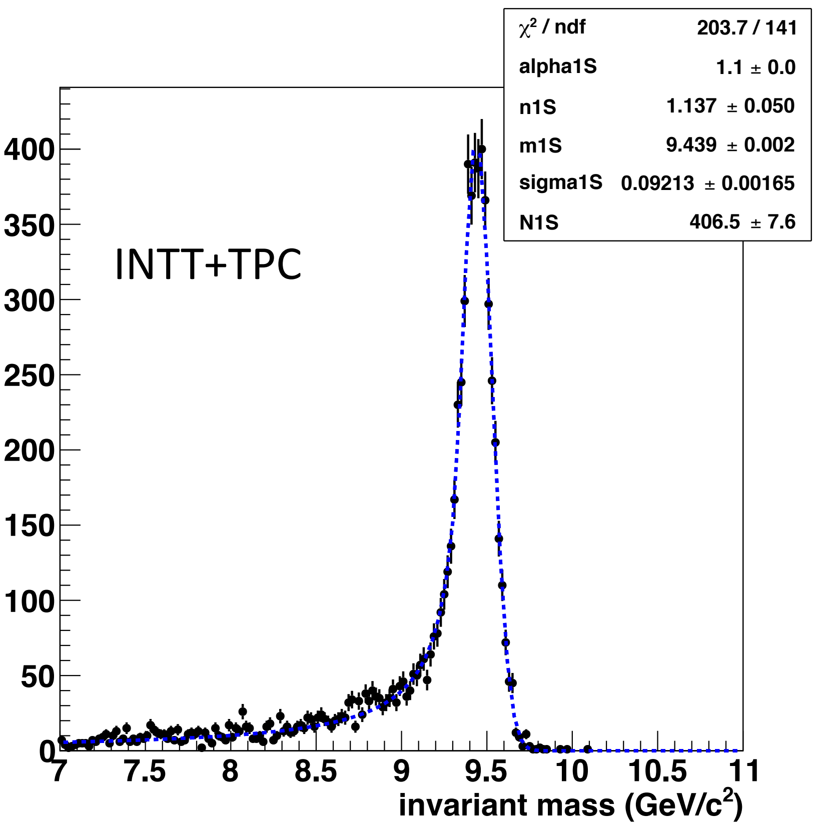


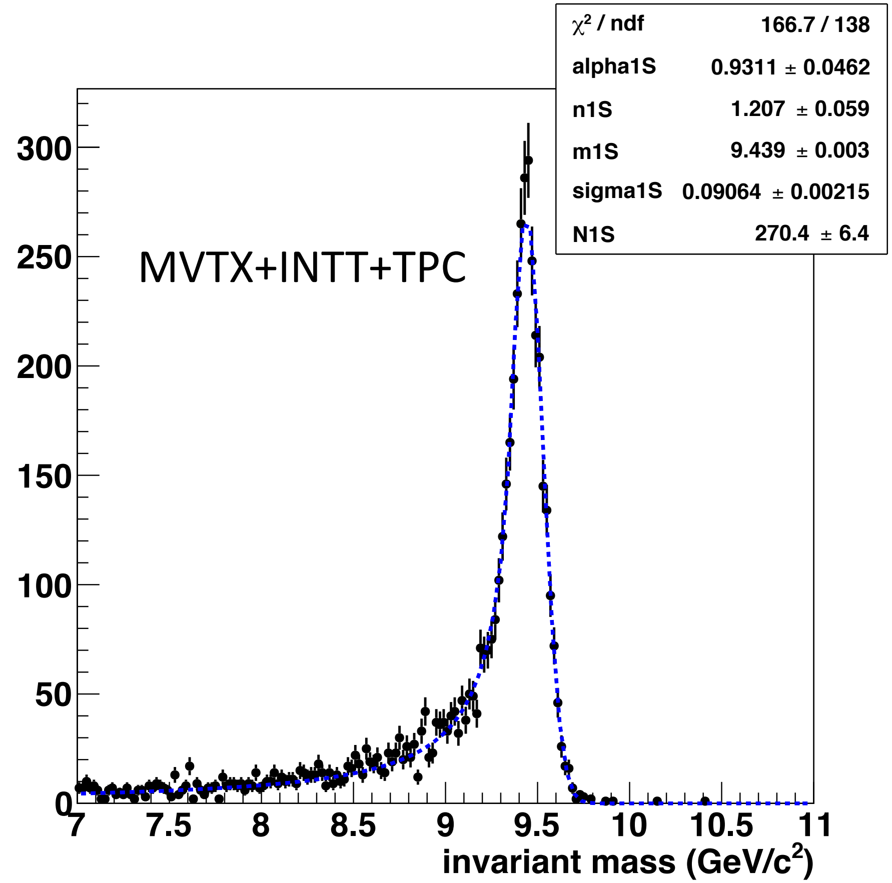


DCA (Z) distribution with INTT + TPC only, for embedded pions in central Hijing events

Status and Highlights

Y(1S) mass spectrum with MVTX primary vertex (σ < 1 μm) in fit
σ_{mass} = 91 ± 2 MeV





Y(1S) mass spectrum without MVTX primary vertex (σ = 12 μm) in fit
σ_{mass} = 92 ± 2 MeV

Summary

- Tracking efficiency in central Hijing events is 92-95% for tracks above p_T = 1 GeV/c in central Hijing events
- Momentum resolution is somewhat poorer at high p_T without the MVTX, but quite good enough for the Upsilon and jet programs
- Excellent Upsilon mass resolution with or without the MVTX.
  - When using reconstructed event vertex in the track fits
- DCA resolution with the MVTX is good in rϕ and Z, DCA tails are small for embedded prompt tracks

Ongoing Work (next few months)

- More realistic TPC GEANT model (C. Perez)
- Initial vertexing algorithm (S. Lee)
- More advanced track seeding package (S. Lee)
- Event pileup (Y. Yamaguchi)
  - Multiple collisions in a crossing
  - TPC and MVTX integration time
- Multiple event vertexing (S. Lim)
- Work ongoing on iterative tracking (H. Yu, C. Roland)
  - Displaced track identification
  - Low p_T tracking

Planned Work

- Improved MVTX cluster simulation - cluster finding at low p_T (A. Frawley, C. Roland)
  - Understand details of cluster formation physics
  - Cluster shape templates
- Dedicated electron track reconstruction (A. Frawley, C. Roland)
  - Gaussian sum filter approach
- CPU performance optimization (All)

Back Up

Event pileup due to integration times

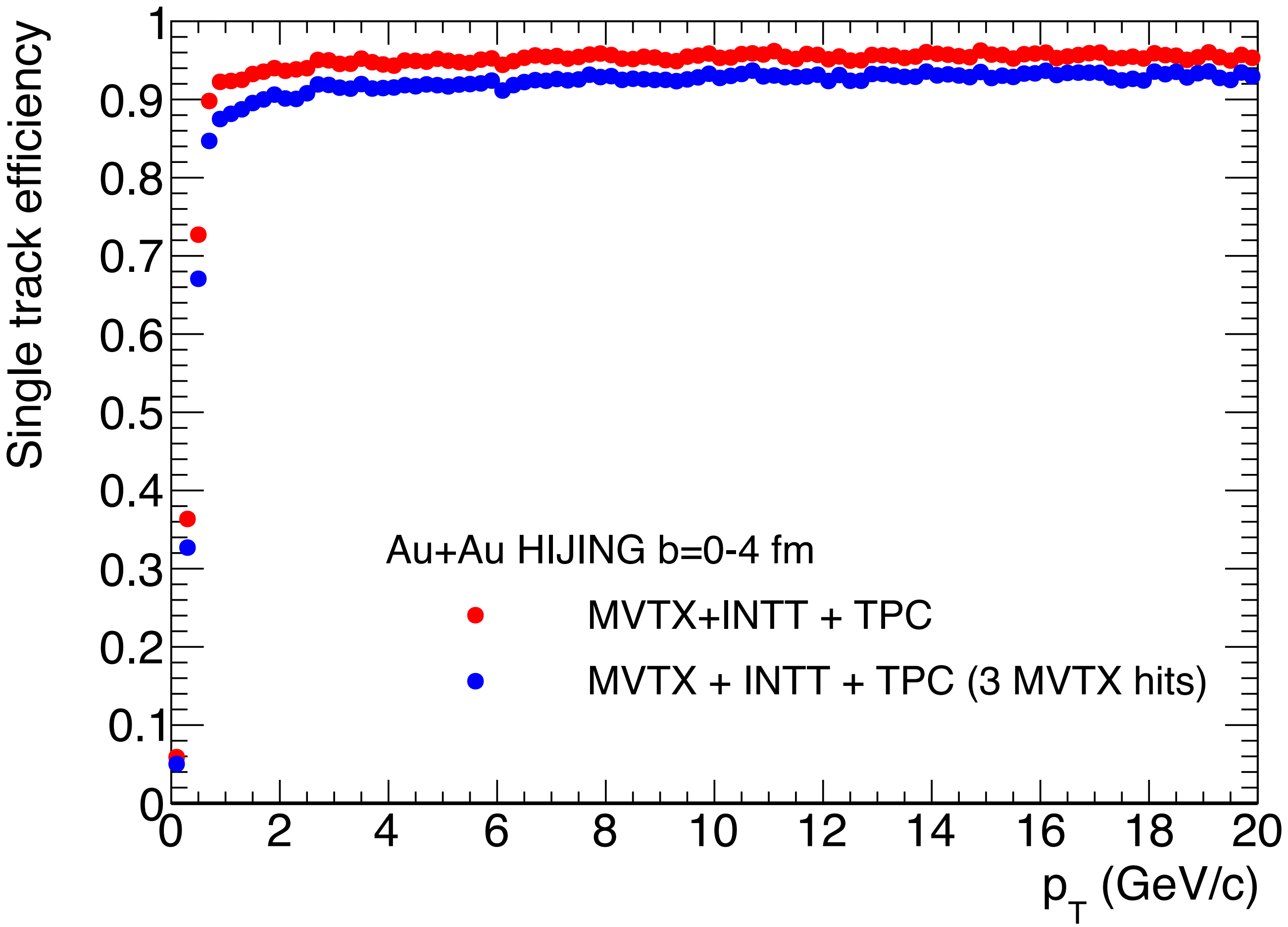
- The electron drift time in the TPC from the center membrane to the readout plane is 17.5 μs. As a result, when an event is triggered there will be tracks in the TPC from up to 17.5 μs before or after the event, depending on the location of the track in the TPC.
- The readout polling for the MVTX takes 2 μs, so hits will be read out from up to 2 μs before or after the event.
- The INTT readout time, on the other hand, is shorter than the time between beam crossings.

A very important function of the INTT will be to verify that a track in the TPC or MVTX is associated with the triggered event.

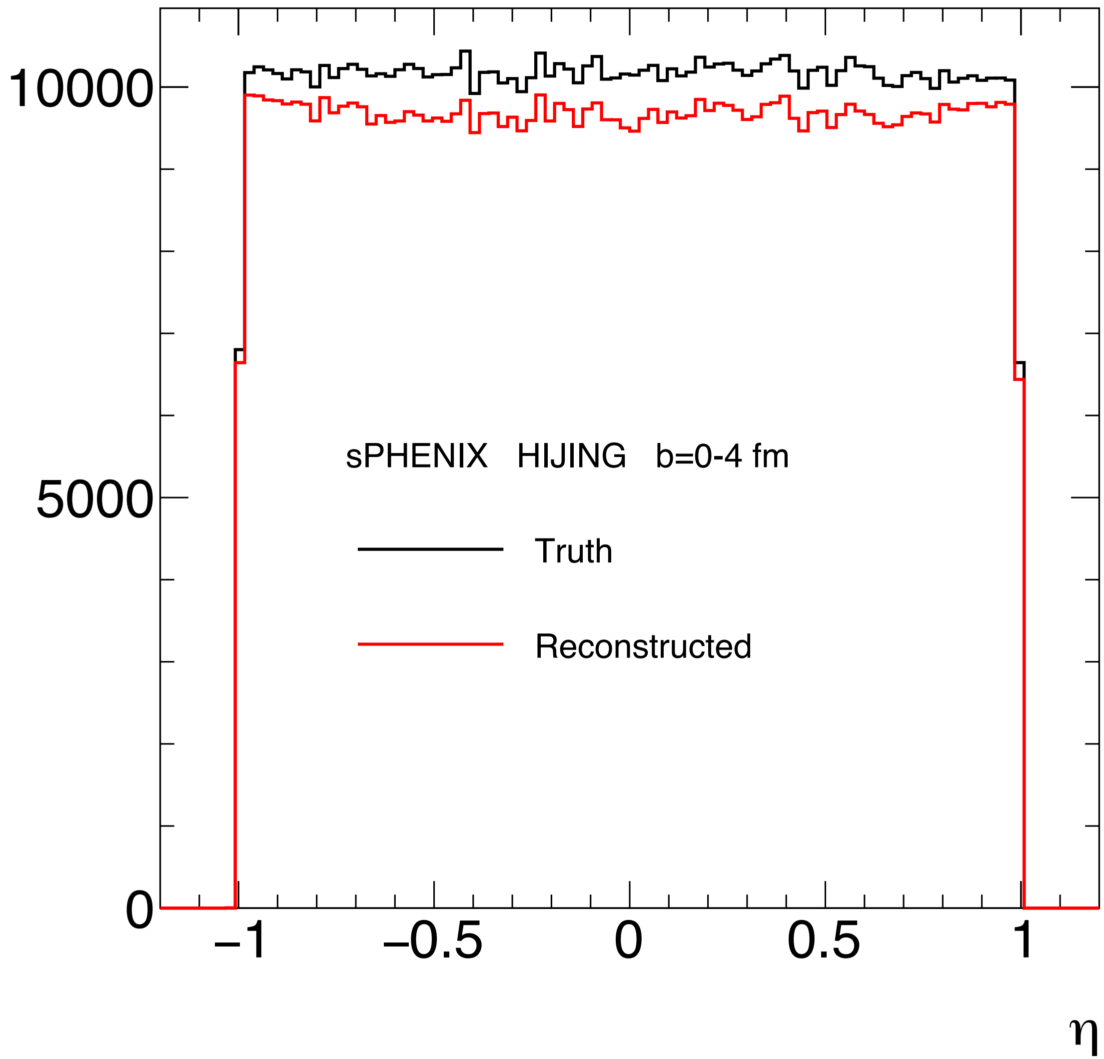
Subsystem	Timing window (ns)
MVTX	-2,000 to +2,000
INTT	-40 to +60
TPC	-17,500 to +17,500

Tracking Efficiency requiring 3 layers of MVTX hit

Requiring tracks to have hits in all three MVTX layers currently reduces the tracking efficiency by ~ 2%. We are looking into this.



Tracking Efficiency dependence on η



η coverage of inner tracker for event at Z = 10 cm

We would like the inner tracker layers to cover the acceptance of the outer TPC for all events with Z-vertex inside |Z| < 10 cm.

In fact the outer two MVTX layers do not quite extend to the full TPC acceptance for events at the very edge of |Z| < 10 cm.

But the resulting loss of acceptance is very small, and essentially only in the MVTX outer layer.

For an event at Z = +10 cm

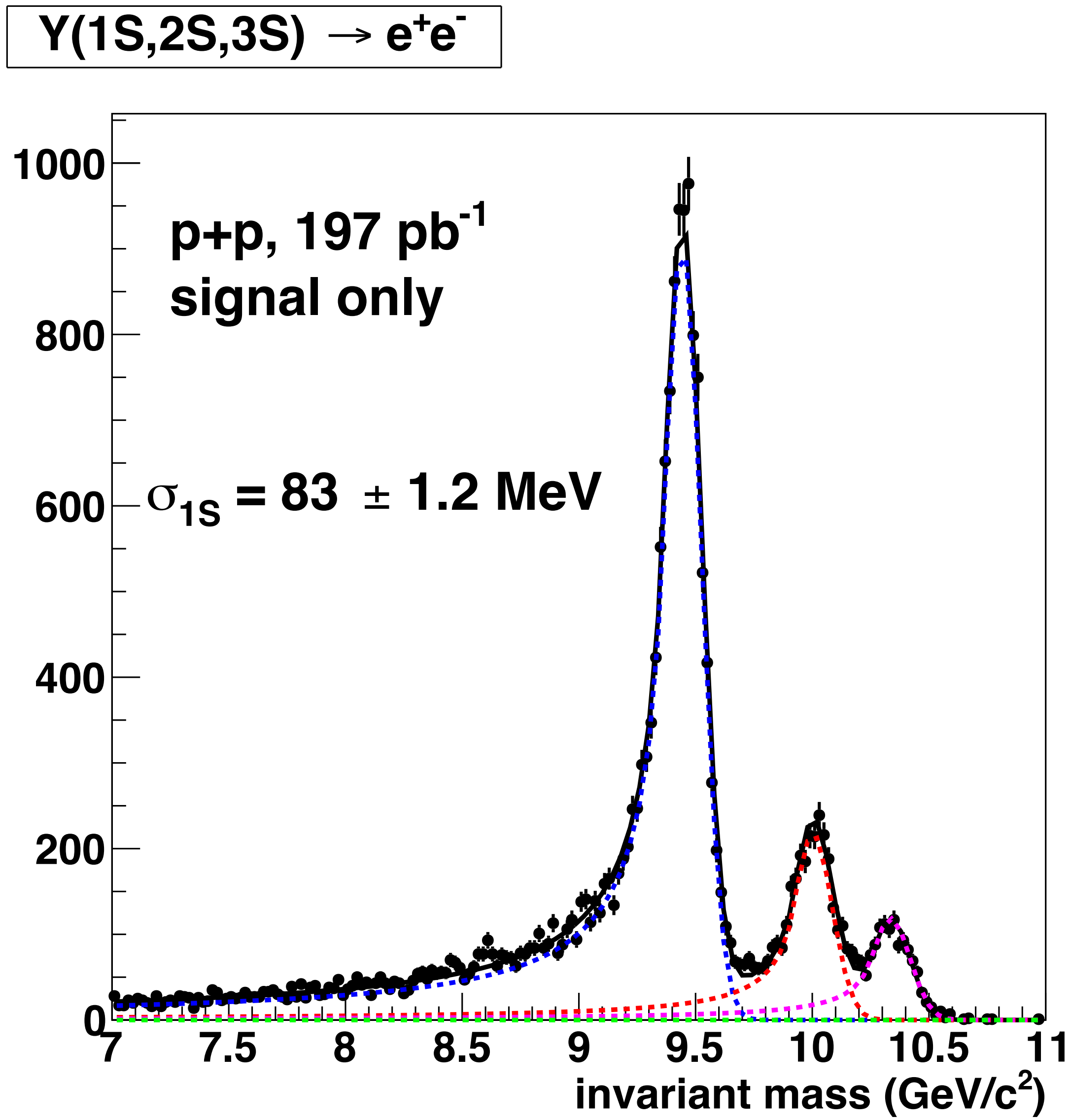
Layer	Radius(cm)	Length (cm)	η min	η max
0	2.34	27.0	-3.0	1.19
1	3.15	27.0	-2.7	0.96
2	3.93	27.0	-2.5	0.80
3	6	40	-2.3	1.3
4	8	50	-2.2	1.4
5	10	50	-1.96	1.19
6	12	50	-1.79	1.05
TPC outer	78	210	-1.18	1.03

Upsilon mass spectrum in p+p

Mass spectrum for the three Upsilon states in p+p collisions in sPHENIX, with Crystal Ball fits.

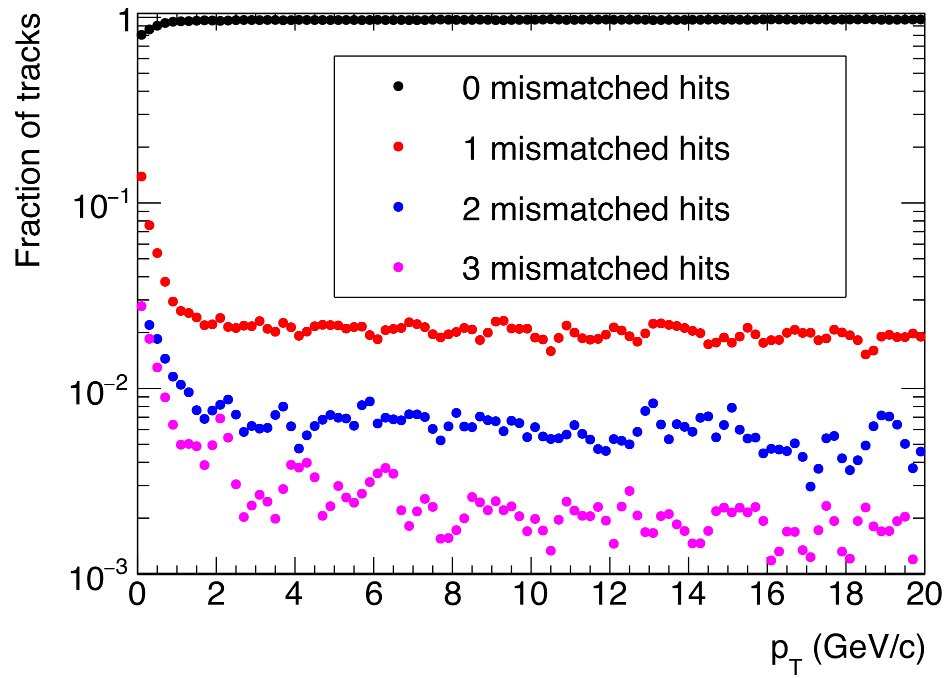
The integrated luminosity is for 35 weeks over 2 years for collisions inside |Z| < 10 cm.

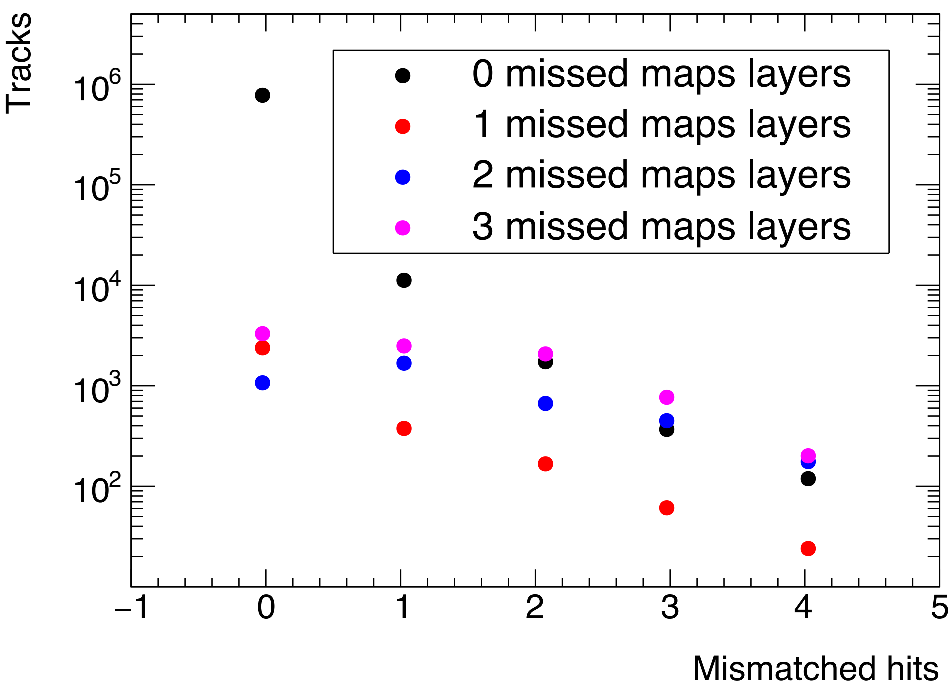
This is the Upsilon signal only.



Mismatched hits

Number of mismatched hits per track (all layers) expressed as a fraction of the total tracks vs p_T



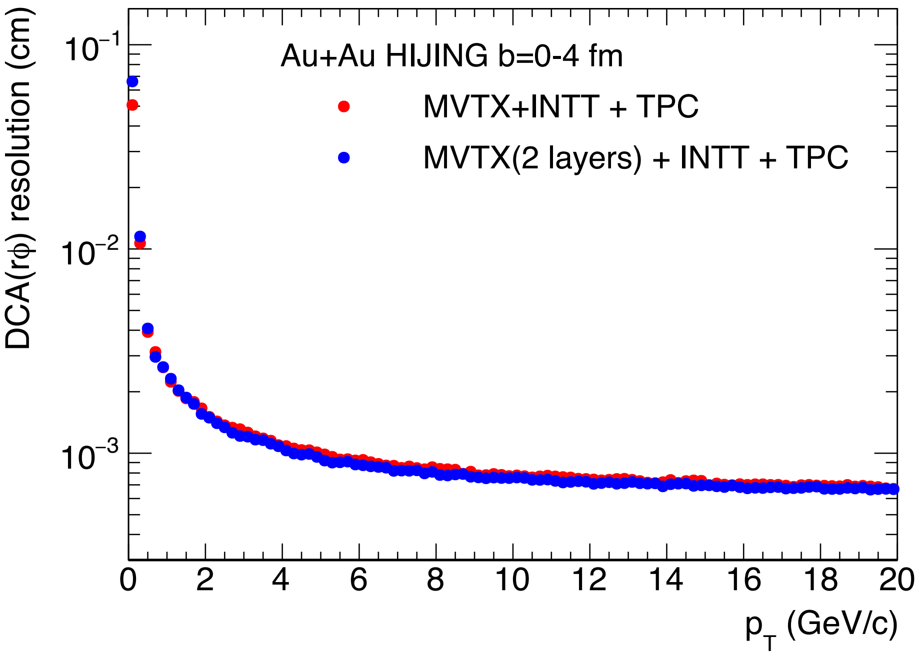


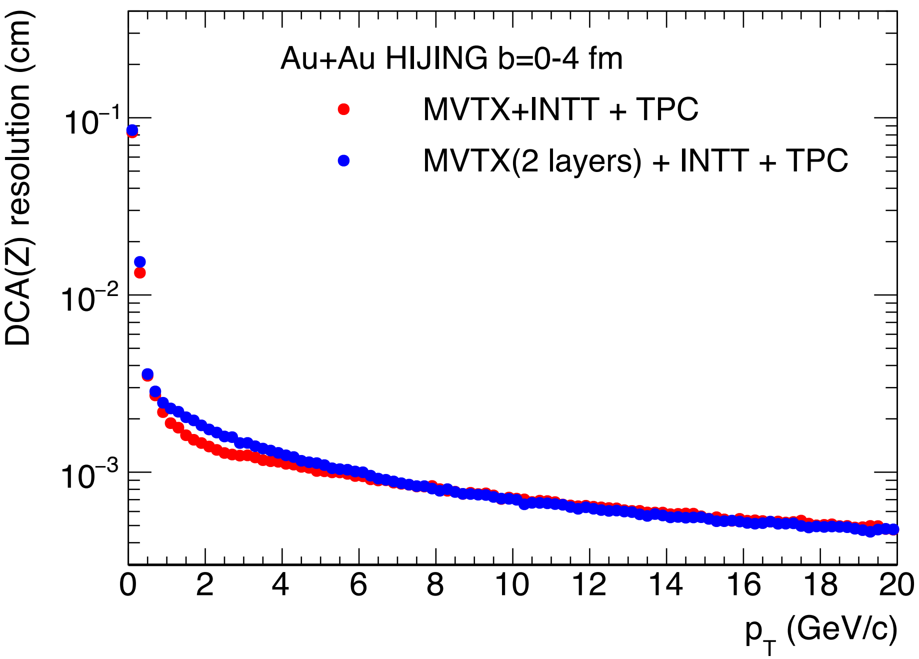
Number of tracks with missed MVTX layers vs mismatched hits per track

Note ~1% of tracks with no mismatched hits miss 1 or more MVTX layers

Reducing MVTX to two layers (2.34, 3.15 cm)

Little effect on DCA (rϕ)

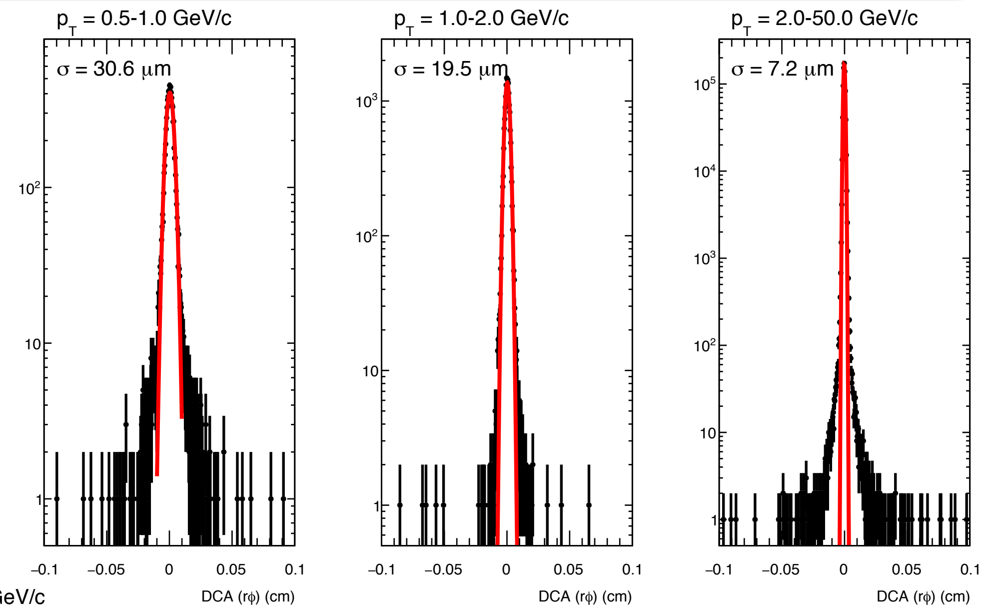




Greater, but still small, effect on DCA (Z)

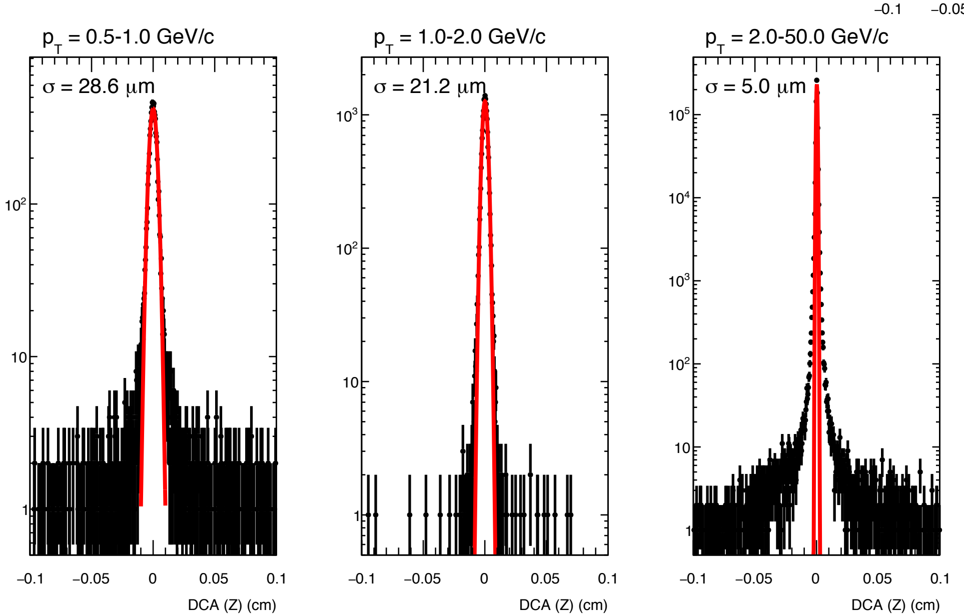
Reducing MVTX to two layers (2.34, 3.15 cm)

DCA (rϕ) (2 MVTX layers



Some increase in tails, but performance still good

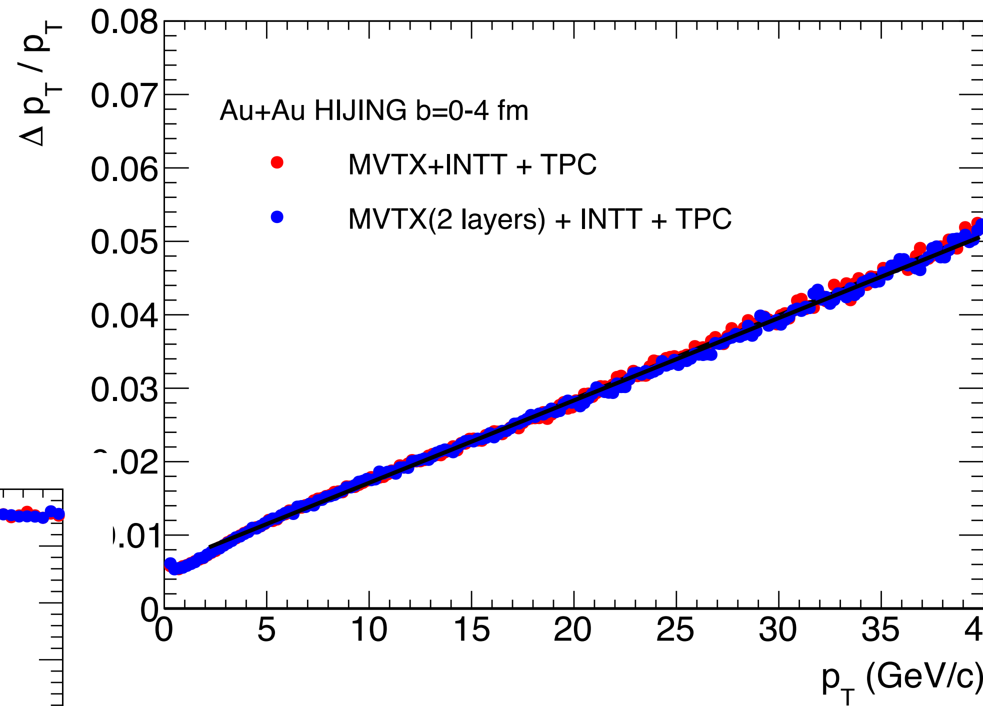
But would lack redundancy

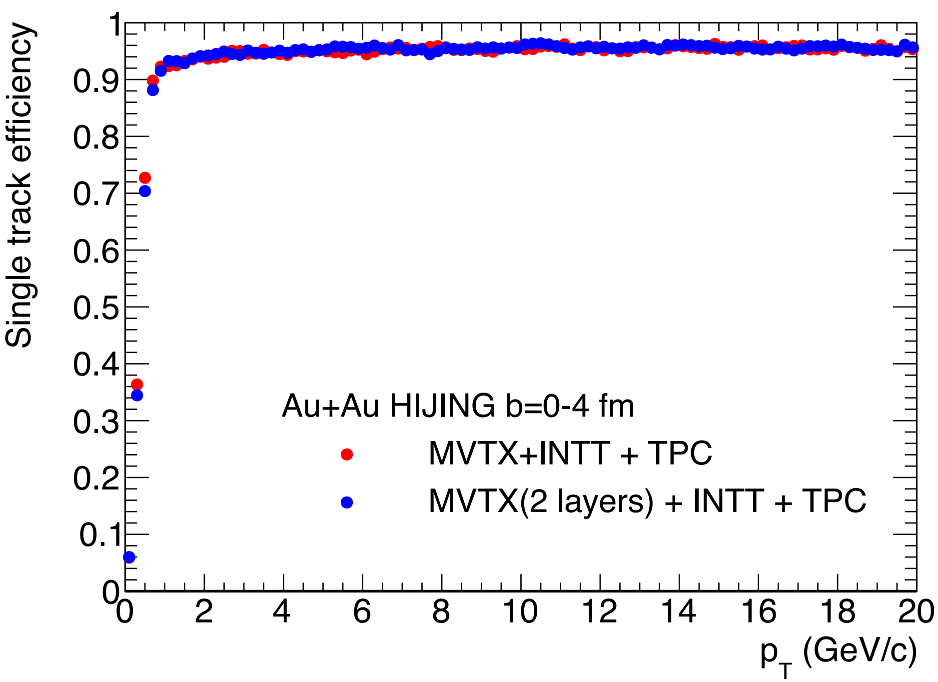


DCA (Z) (2 MVTX layers)

Reducing MVTX to two layers (2.34, 3.15 cm)

p_T resolution unchanged

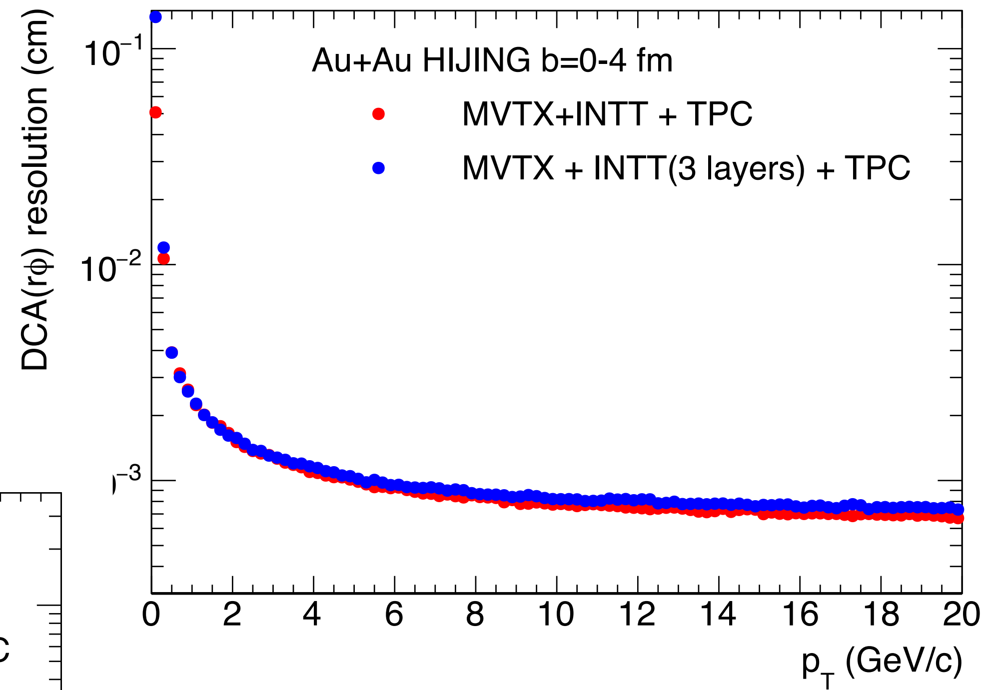


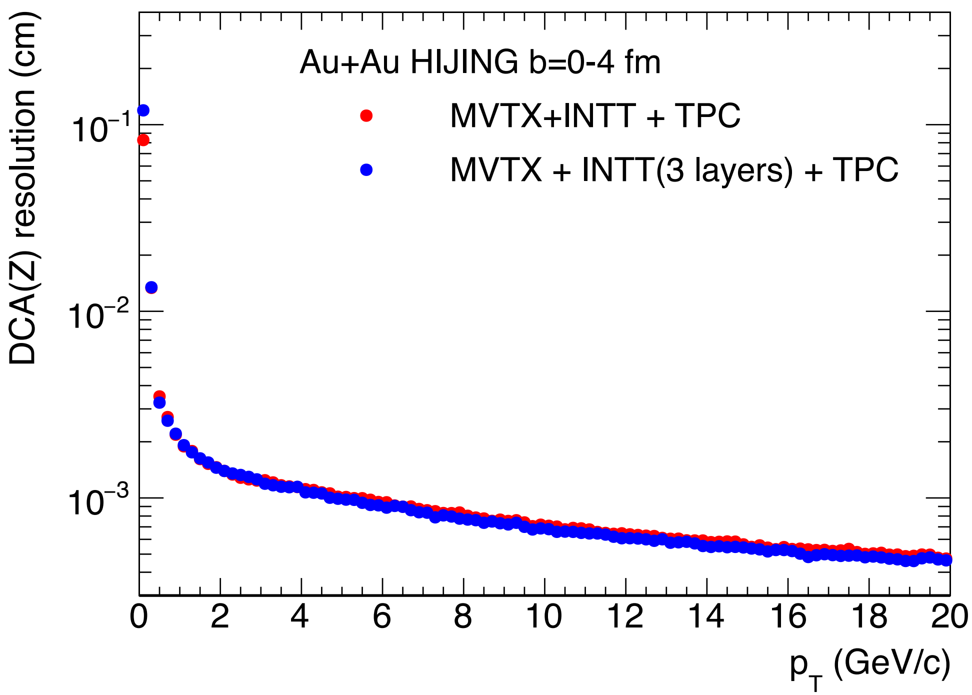


Little effect on tracking efficiency

Reducing INTT to three layers (6, 8, 10 cm)

Little effect on DCA (rϕ)

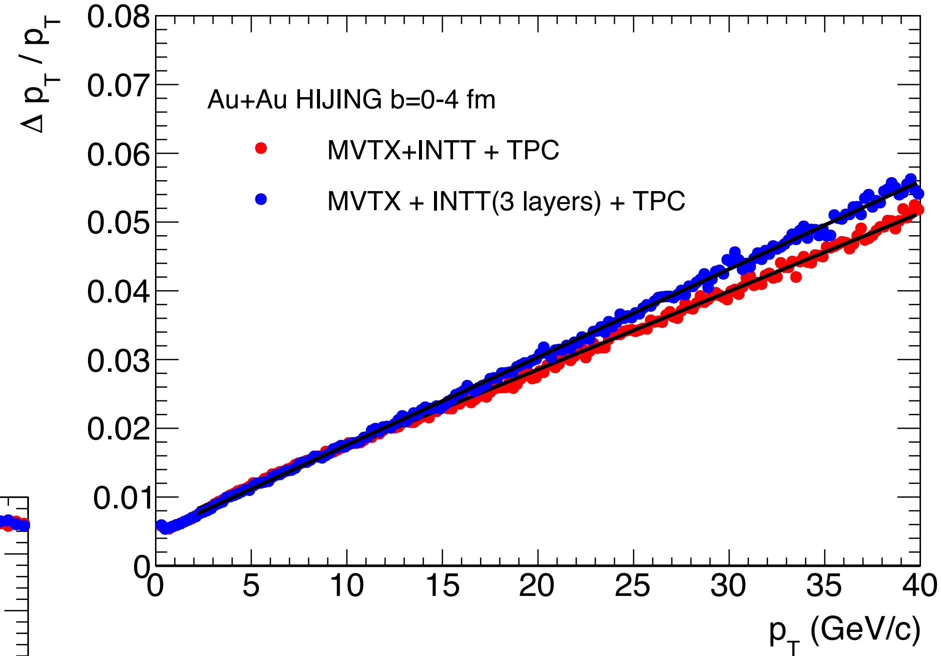


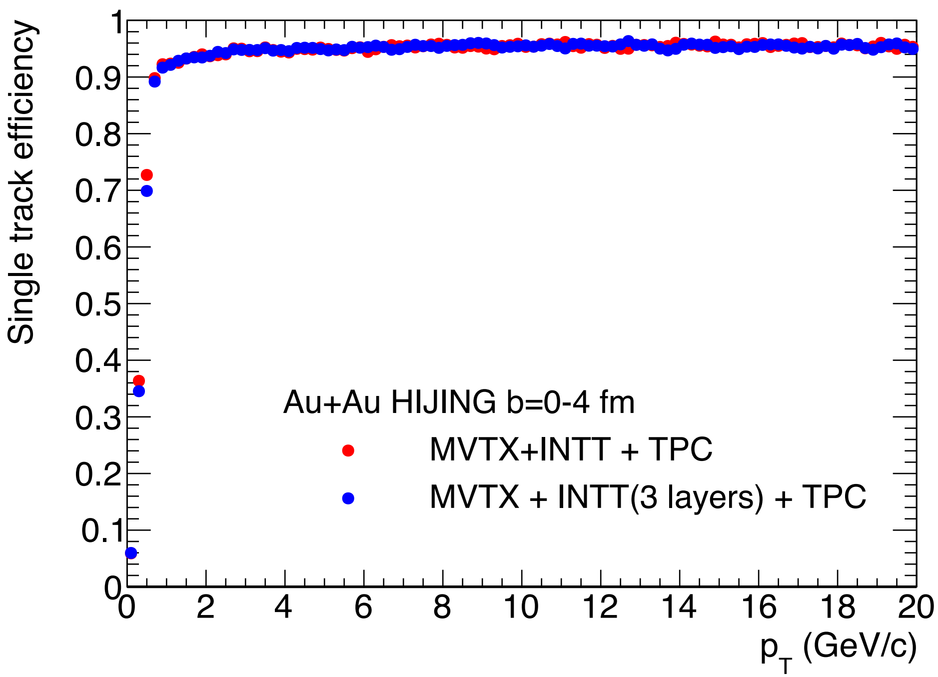


Little effect on DCA (Z)

Reducing INTT to three layers (6, 8, 10 cm)

small effect on p_T resolution

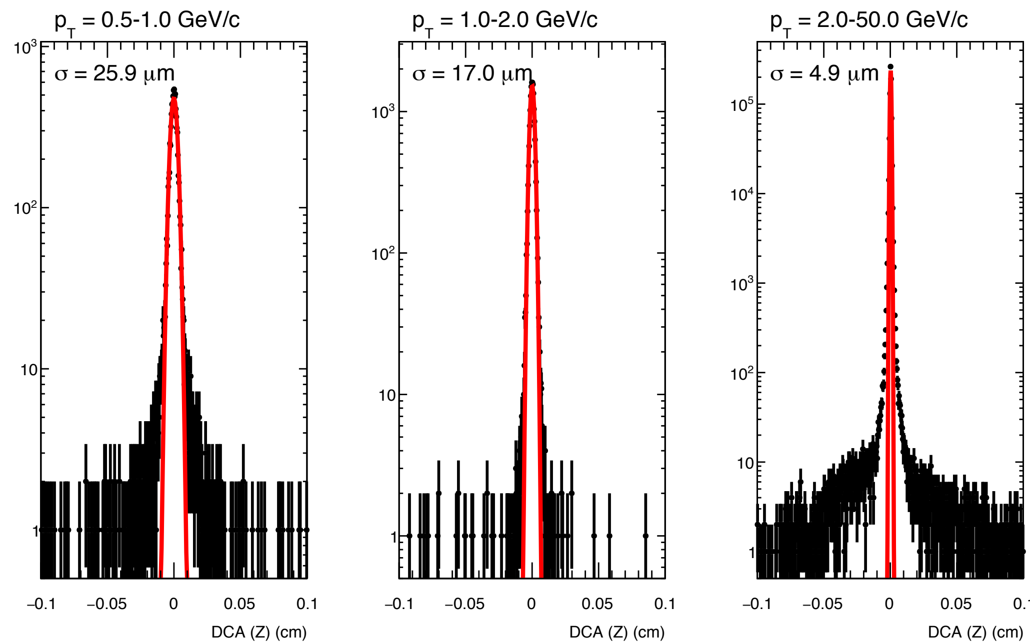


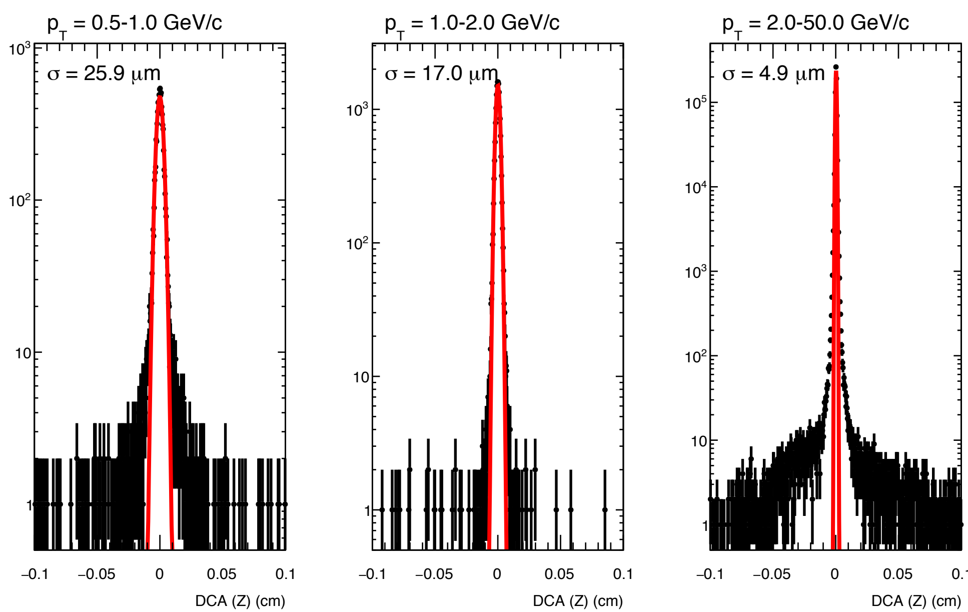


Little effect on tracking efficiency

Reducing INTT to three layers (6, 8, 10 cm)

pions embedded in Hijing: DCA (rϕ)

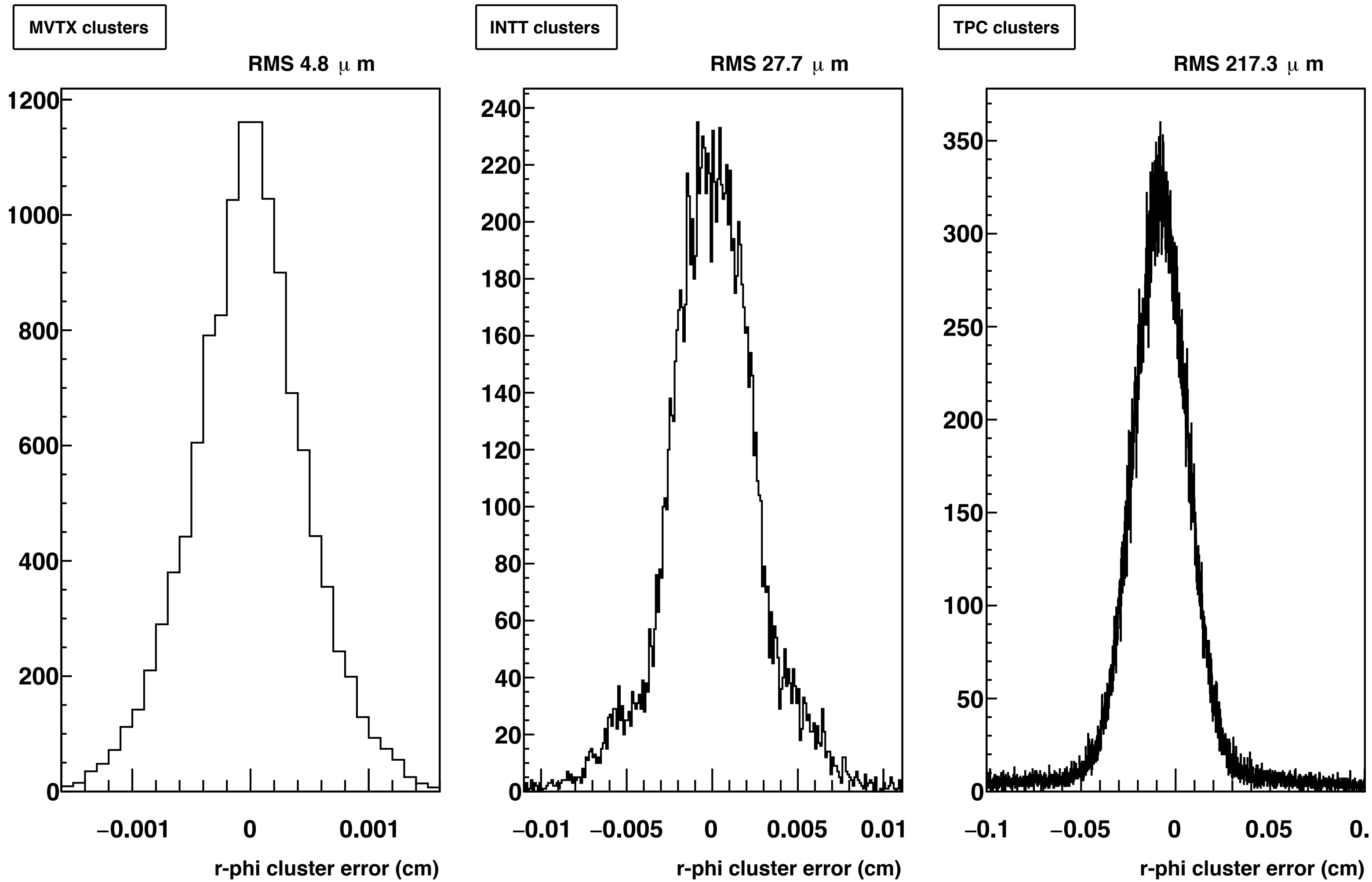




pions embedded in Hijing: DCA (Z)

Cluster Resolution in rϕ plane ($|\eta| < 0.2$)

Pions embedded in central HIJING events



Cluster Resolution in Z plane (|η| < 0.2)

Pions embedded in central HIJING events