

# $\pi/K/p$ spectra, Au+Au for 7.7, 19.6, 27 GeV in UrQMD

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Anna Kraeva  
National Research Nuclear University MEPhI

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Statistics: ~2M

Track cuts:

- PDG ( $\pi^\pm = \pm 211$ ,  $K^\pm = \pm 321$ ,  $p$  ( $p$ -bar) =  $\pm 2212$ )
- $|y| < 0.1$

Bin width for spectra: 50 MeV/c

Centrality was calculated using multiplicity.

# Variation of $T_{\text{kin}}$ with $\langle\beta\rangle$ for different centralities and energies

**Simultaneous** fit of the  $\pi^\pm$ ,  $K^\pm$ ,  $p$ , and  $\bar{p}$  spectra across all the BES energies.

Experimental results from: [Phys. Rev. C 96, 044904 \(2017\)](#)

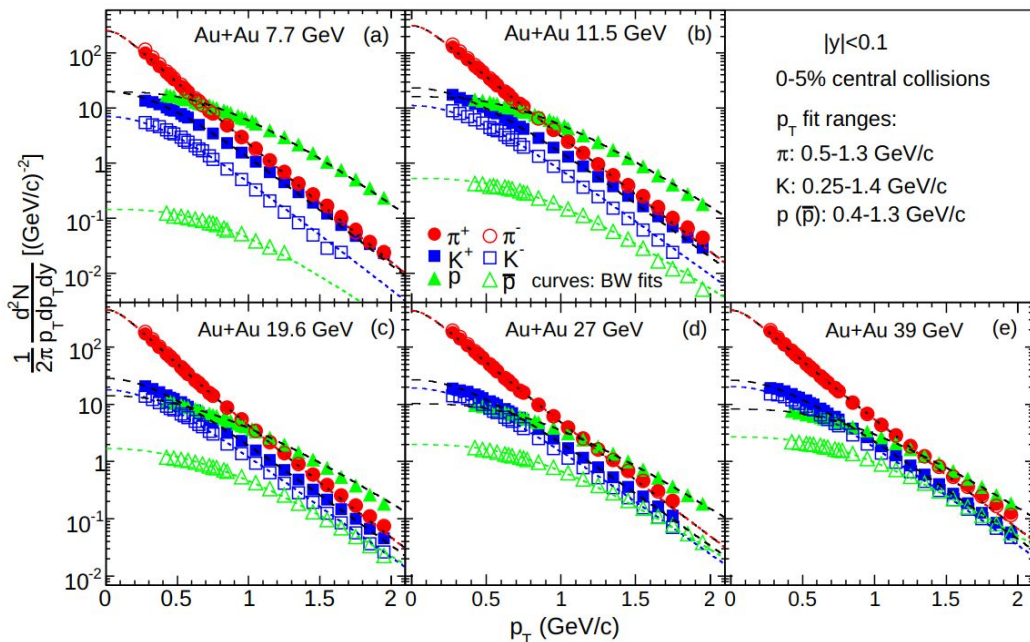


FIG. 36: (Color online) Blast wave model fits of  $\pi^\pm$ ,  $K^\pm$ ,  $p$  and  $\bar{p}$   $p_T$  spectra in 0-5% central Au+Au collisions at  $\sqrt{s_{NN}} =$  (a) 7.7 GeV, (b) 11.5 GeV, (c) 19.6 GeV, (d) 27 GeV, and (e) 39 GeV. Uncertainties on experimental data represent statistical and systematic uncertainties added in quadrature. Here, the uncertainties are smaller than the symbol size.

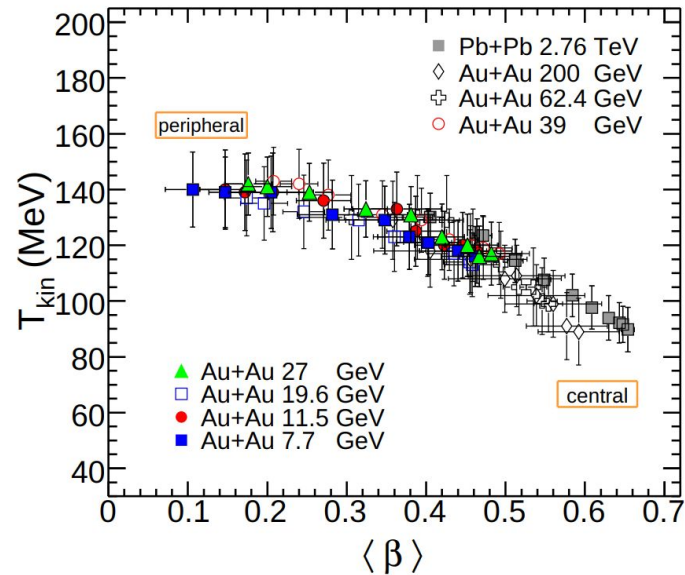


FIG. 37: (Color online) Variation of  $T_{\text{kin}}$  with  $\langle\beta\rangle$  for different energies and centralities. The centrality increases from left to right for a given energy. The data points other than BES energies are taken from Refs. [43, 66]. Uncertainties represent systematic uncertainties.

## Blast wave fit

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$$\frac{dN}{p_T dp_T} \propto \int_0^R r dr m_T I_0 \left( \frac{p_T \sinh \rho(r)}{T_{\text{kin}}} \right) \\ \times K_1 \left( \frac{m_T \cosh \rho(r)}{T_{\text{kin}}} \right),$$

$m_T$  - transverse mass

$\rho(r) = \tanh^{-1}(\beta)$

$I_0, K_1$  - Bessel functions

$\beta = 2 * \beta_s / (2+n)$

$\beta_s$  - surface velocity

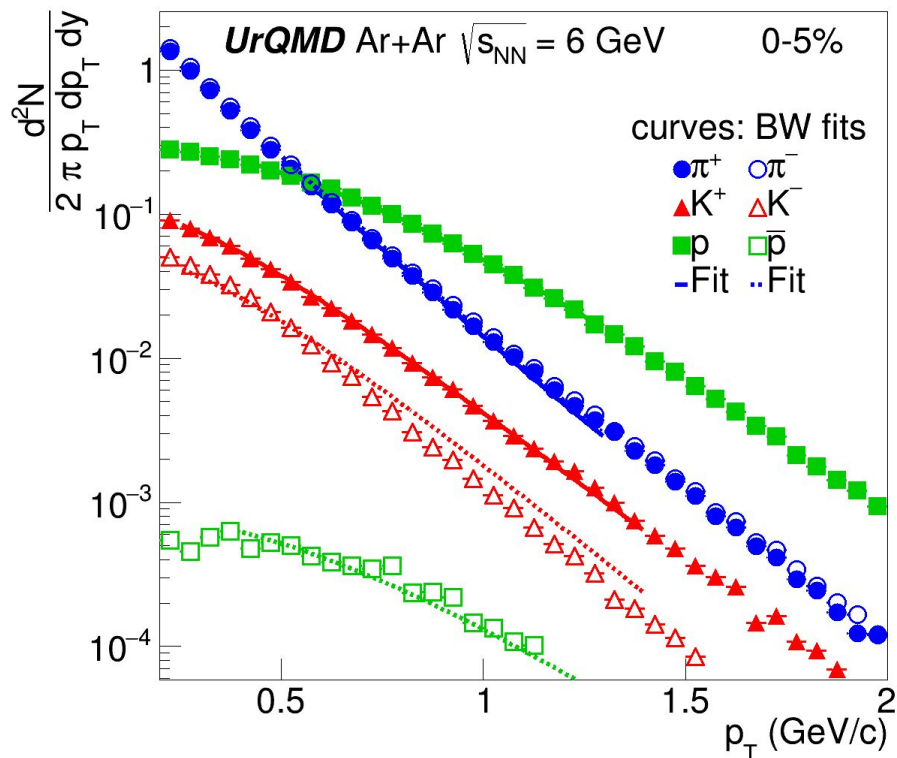
$n$  - exponent of flow velocity profile

Fit parameters:  $T_{\text{kin}}, \beta$

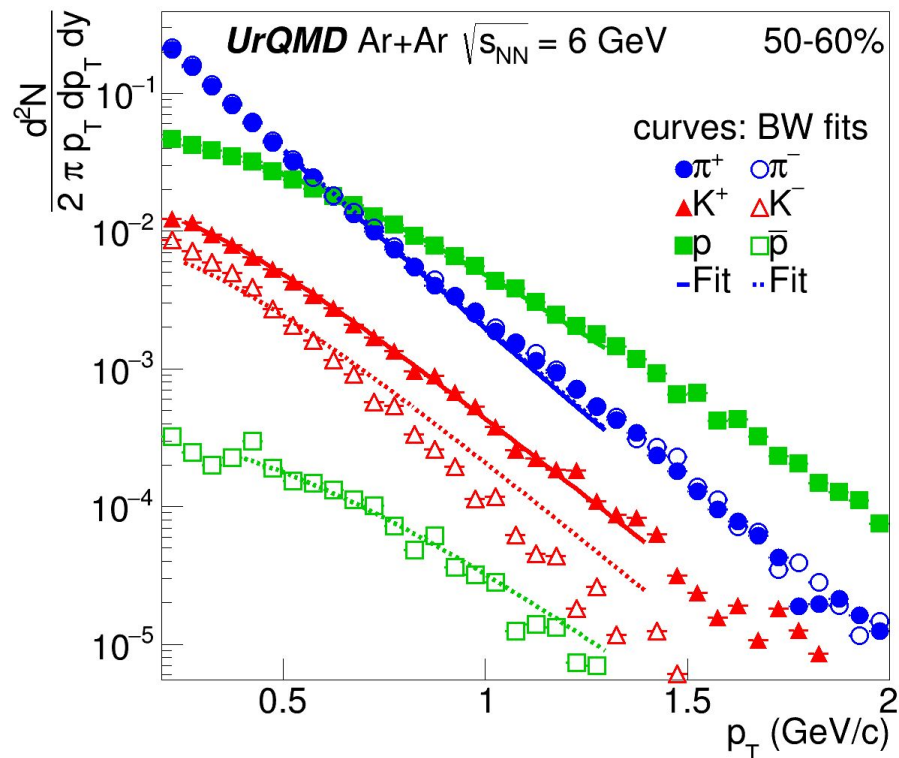
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ and $p\bar{p}$ $p_T$ spectra for Ar+Ar 6 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



$T_{kin} \approx 74$  MeV

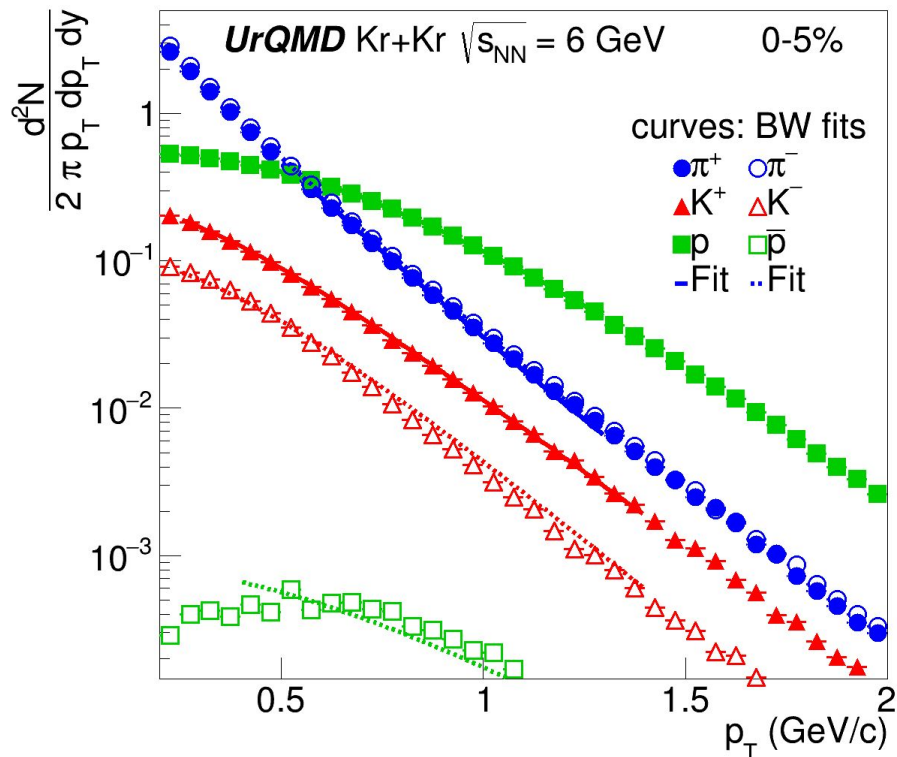


$T_{kin} \approx 72$  MeV

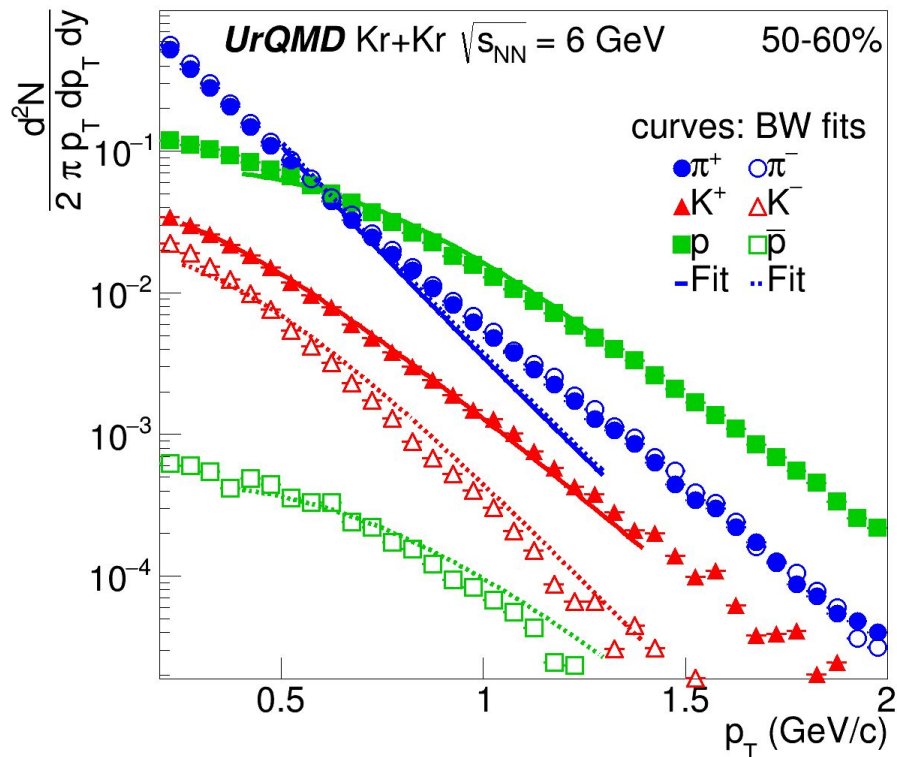
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , p and pBar $p_T$ spectra for Kr+Kr 6 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3] GeV/c



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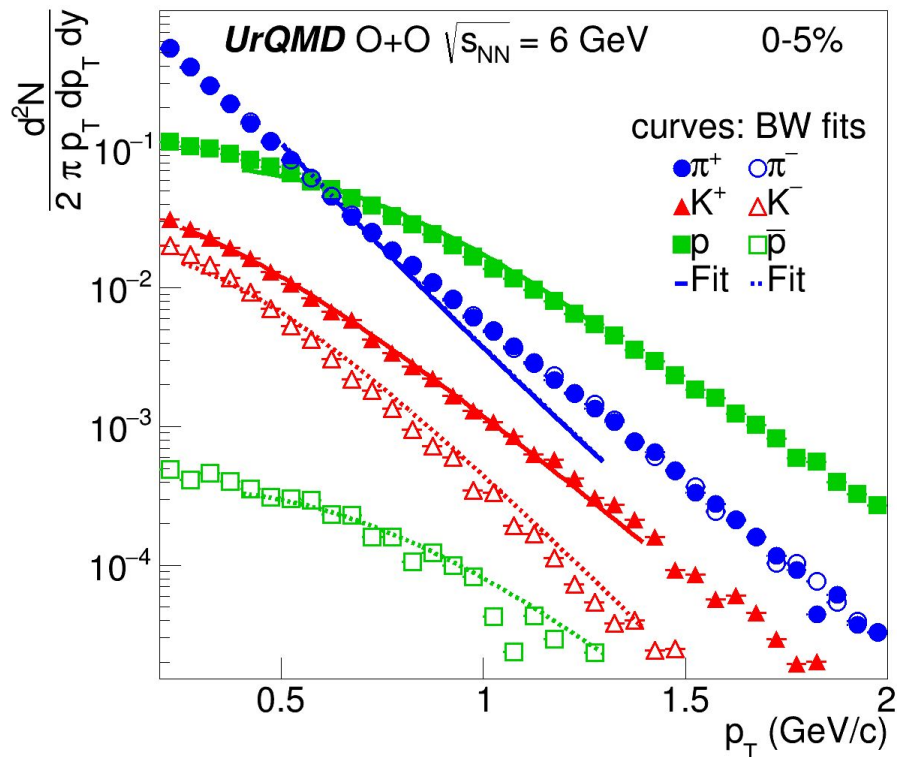


$T_{kin} \approx 72$  MeV

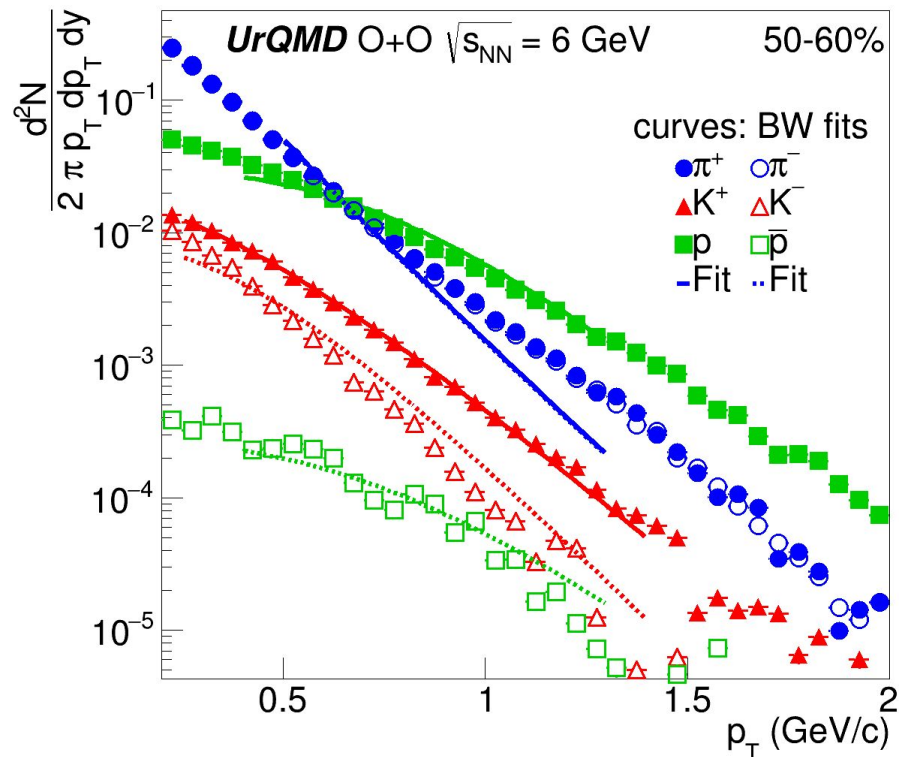
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$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 74$  MeV

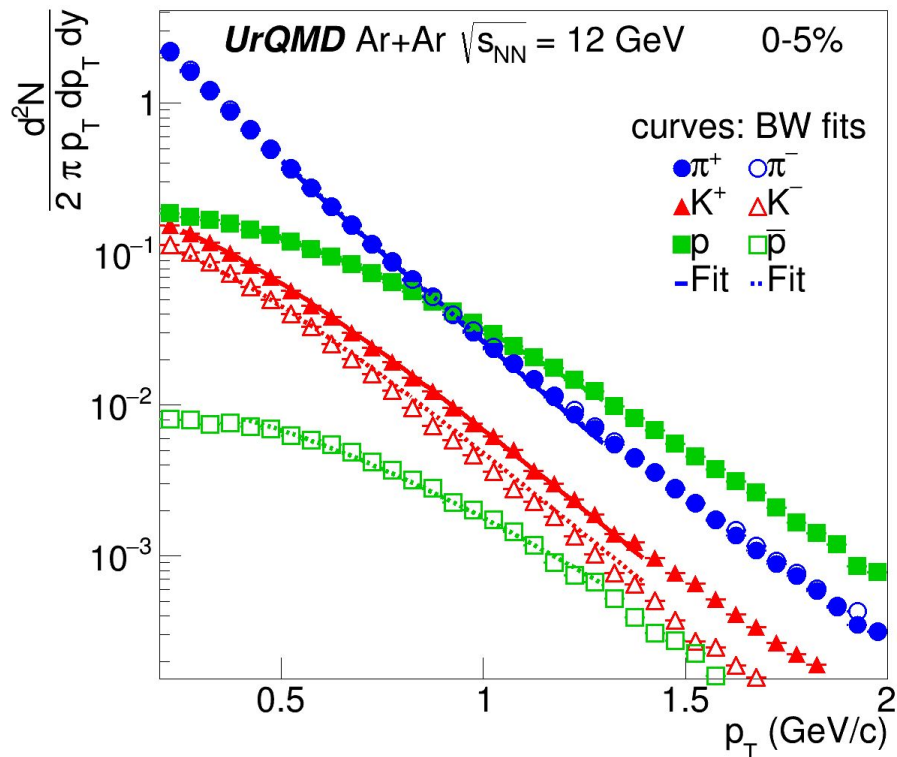


$T_{kin} \approx 72$  MeV

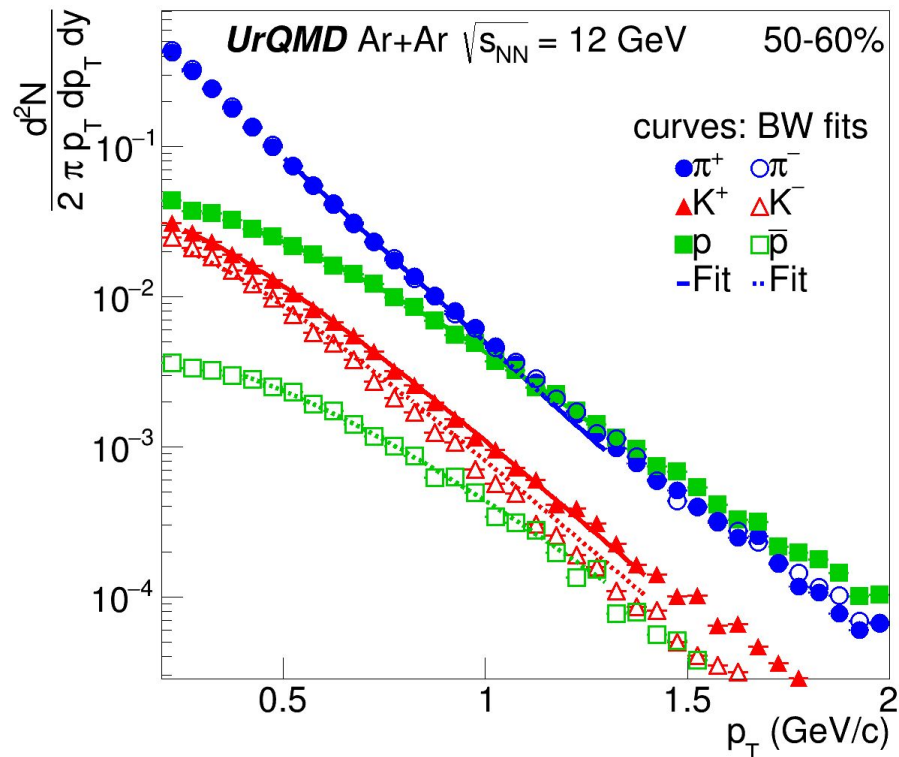
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ and $p\bar{p}$ $p_T$ spectra for Ar+Ar 12 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



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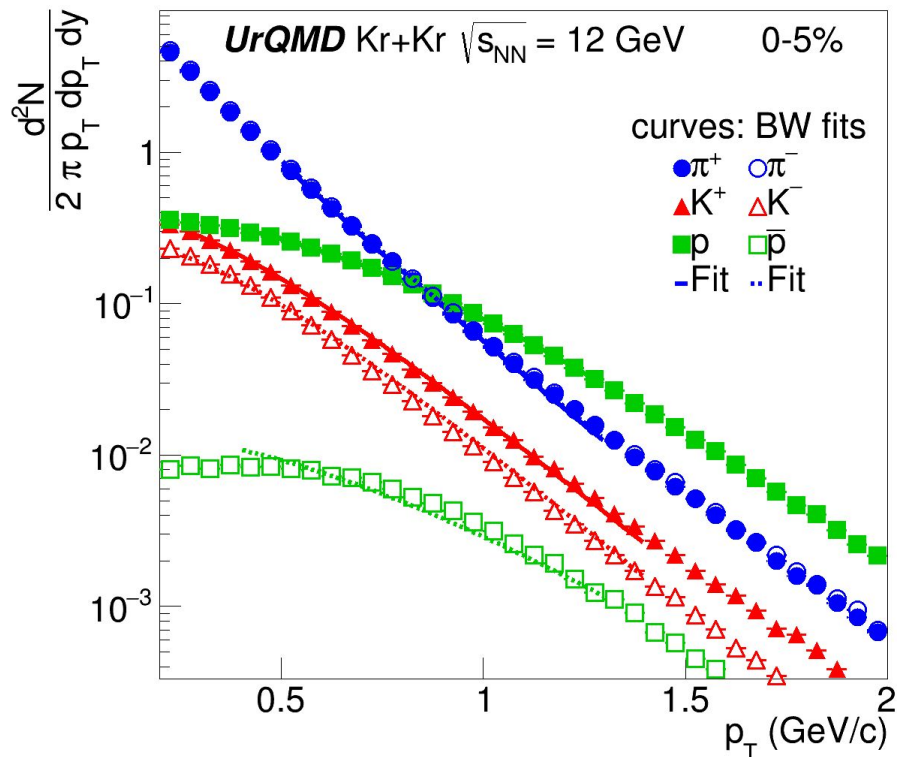
$T_{kin} \approx 72$  MeV



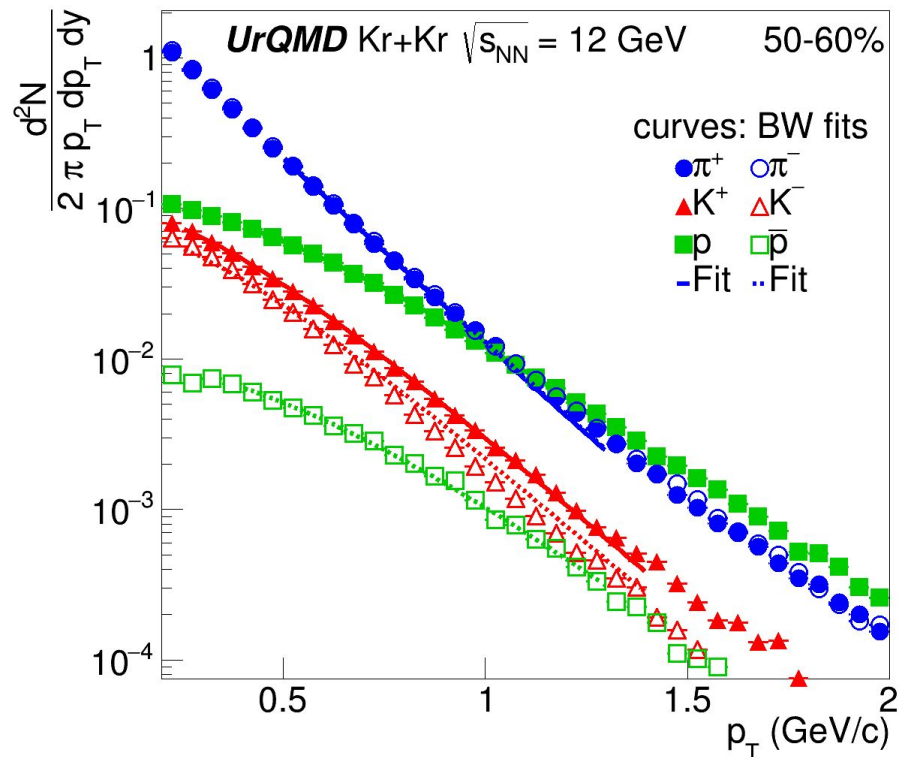
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$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



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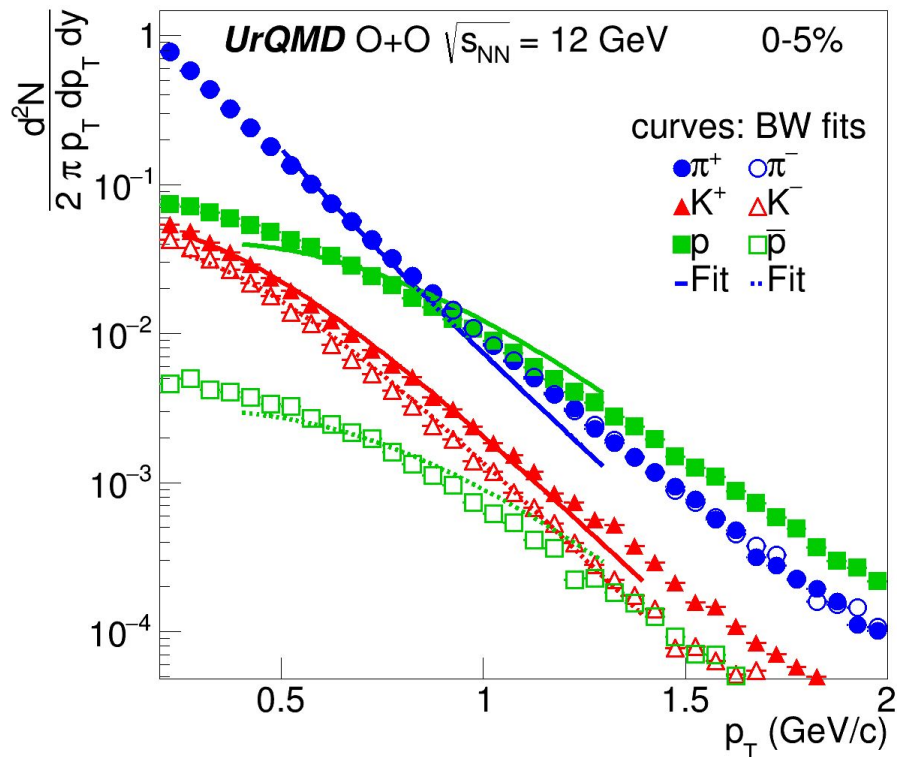


$T_{kin} \approx 72$  MeV

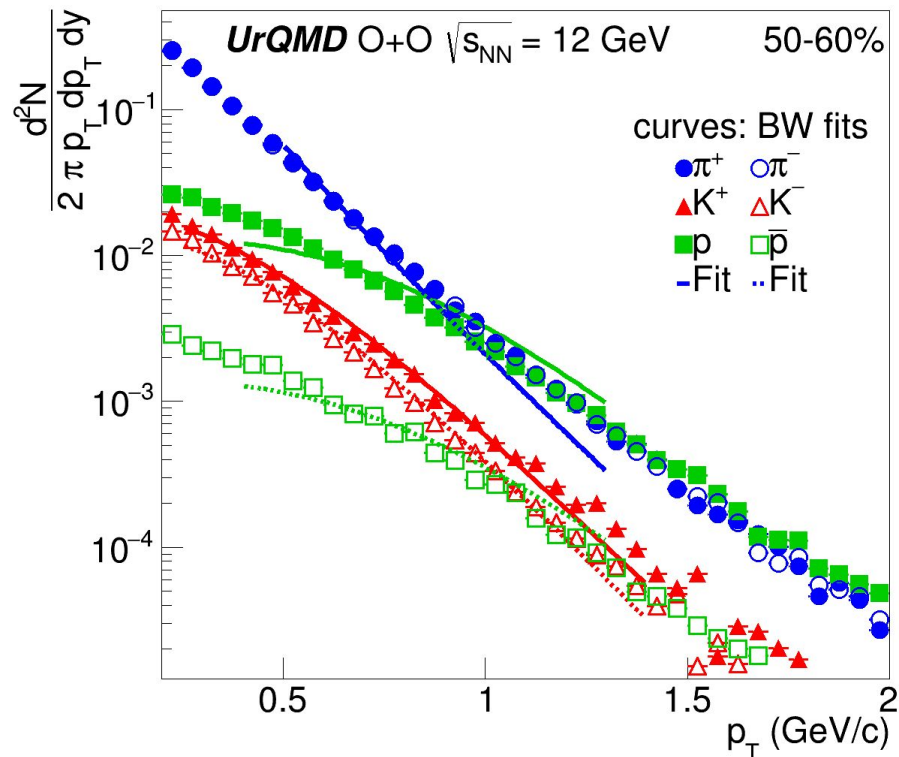
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$p_T$  fit ranges:  $\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3] GeV/c

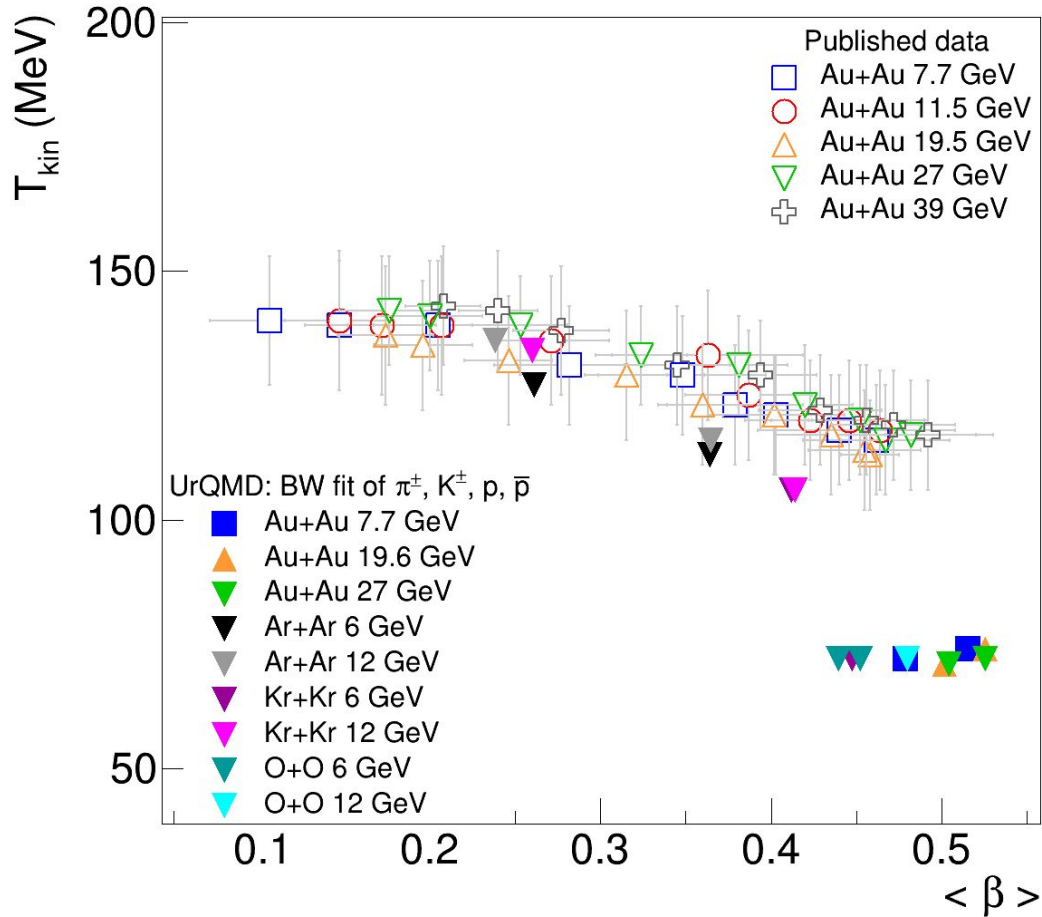


$T_{kin} \approx 74$  MeV



$T_{kin} \approx 72$  MeV

# Comparison of UrQMD and Publish results: $T_{kin}(<\beta>)$



$|y| < 0.1$

$p_T$  fit ranges:

$\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3]

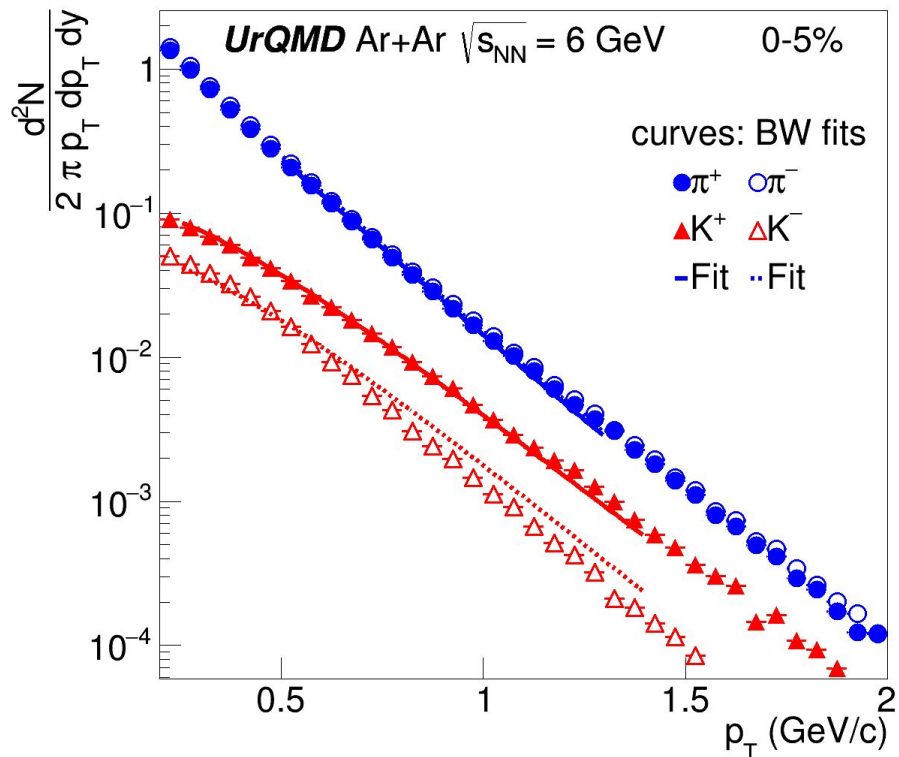
GeV/c

$T_{kin}$  and  $\langle\beta\rangle$  **underestimated** after BW fit for  $\pi^\pm, K^\pm, p$  and  $p\bar{p}$   $p_T$  spectra except Ar+Ar and KrKr

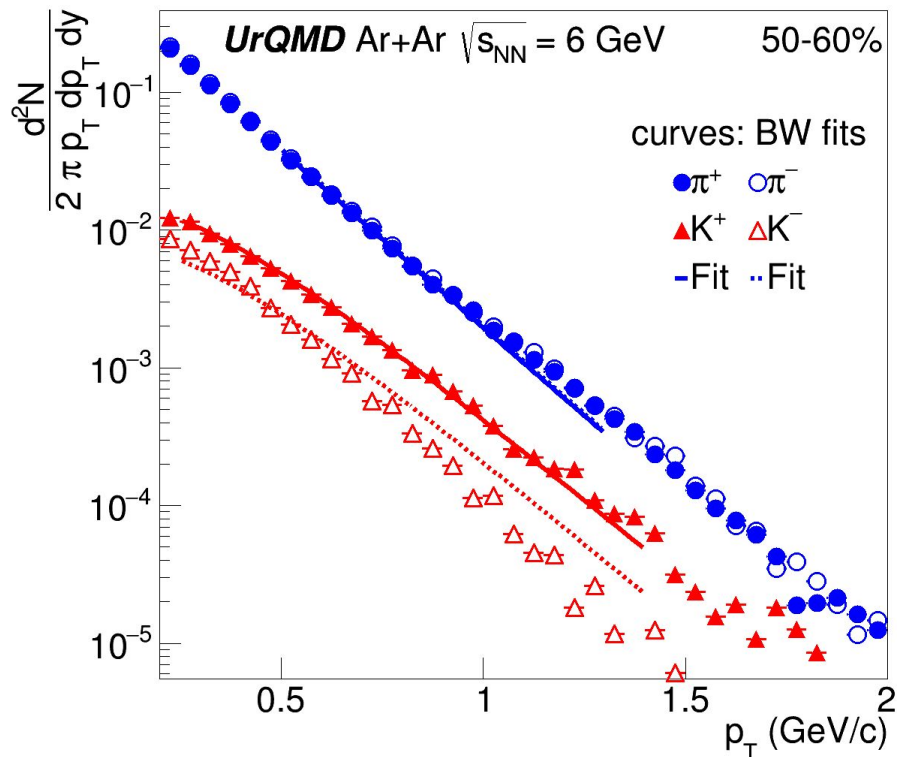
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$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 104$  MeV

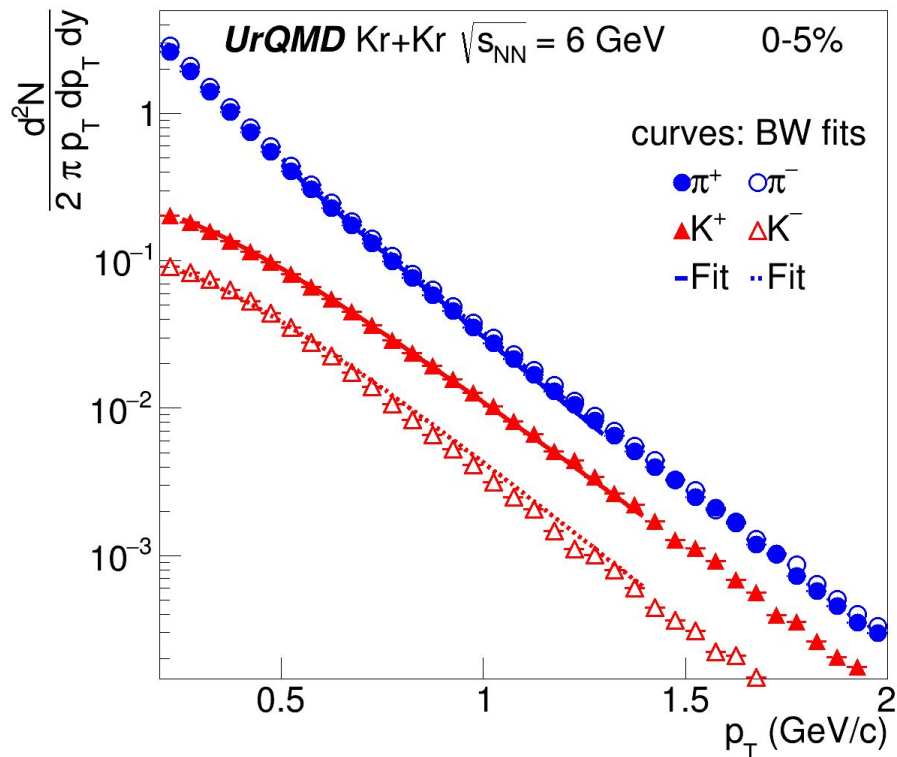


$T_{kin} \approx 131$  MeV

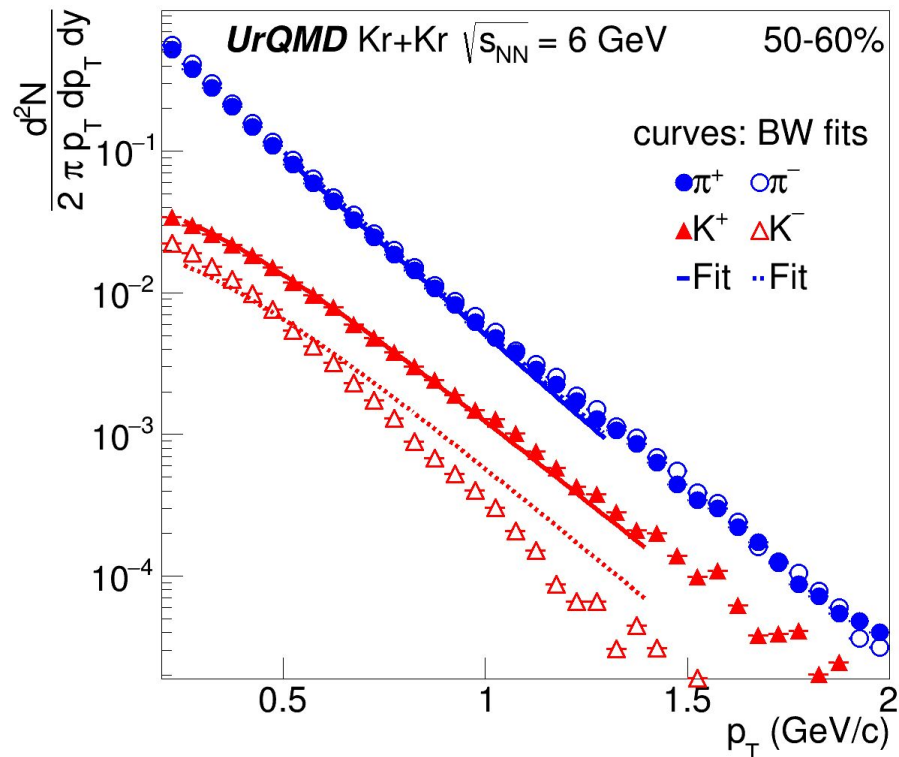
# Blastwave fits of $\pi^\pm$ , $K^\pm$ $p_T$ spectra for Kr+Kr 6 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 104$  MeV

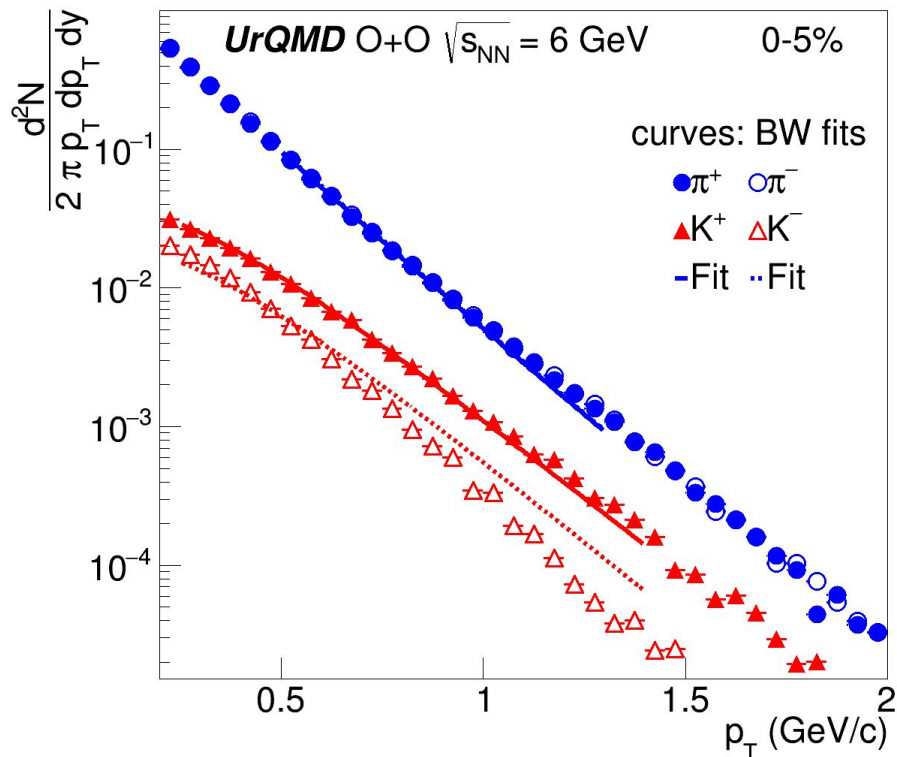


$T_{kin} \approx 131$  MeV

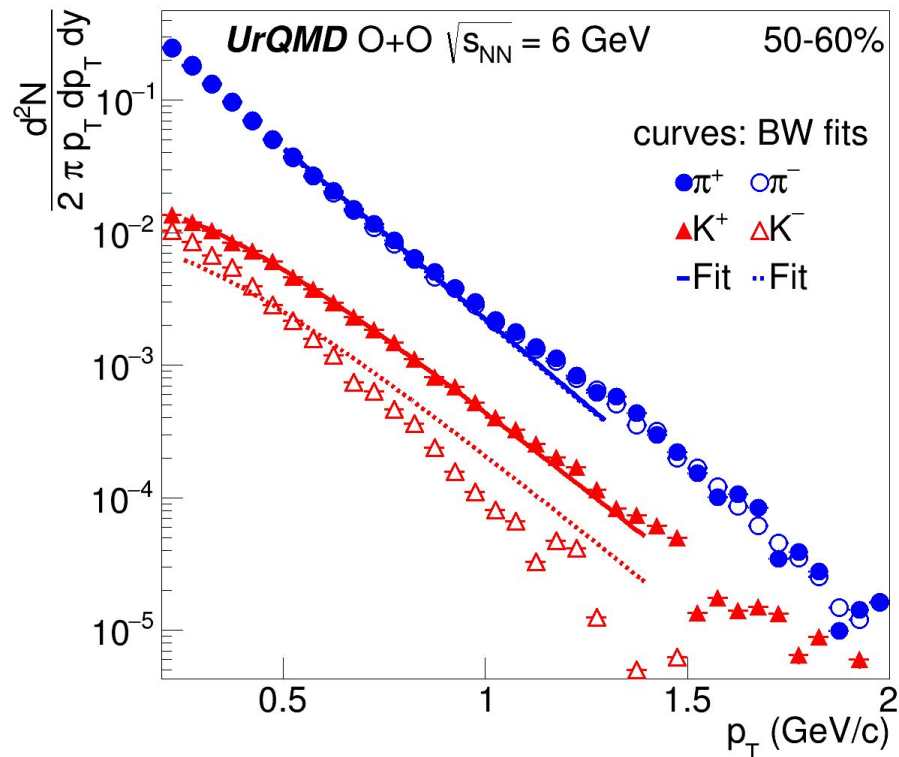
# Blastwave fits of $\pi^\pm$ , $K^\pm$ $p_T$ spectra for O+O 6 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 104$  MeV

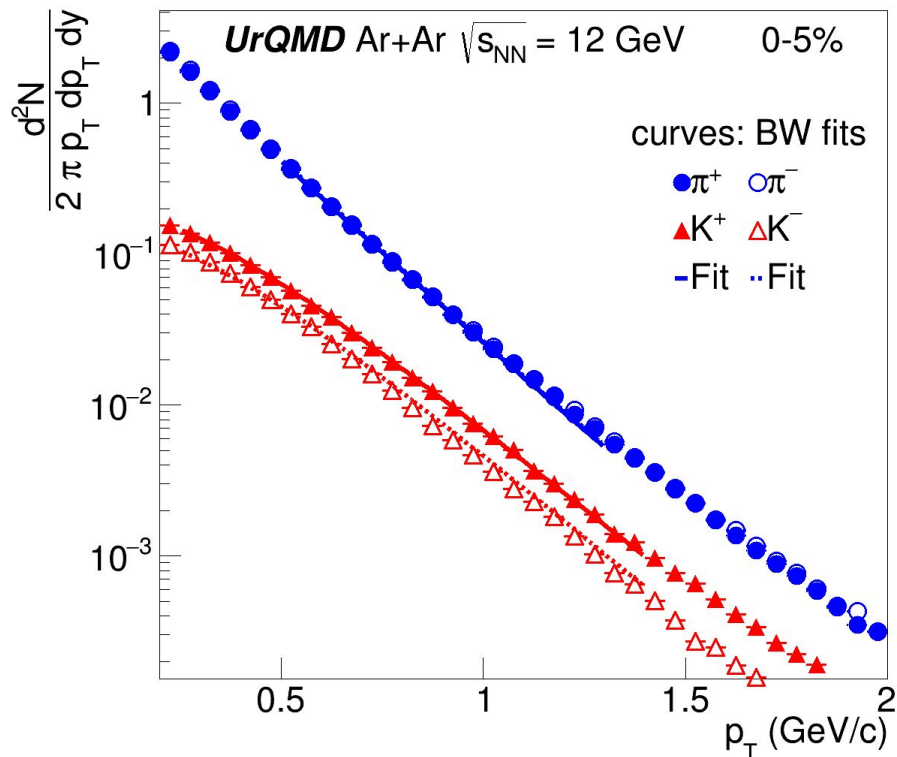


$T_{kin} \approx 131$  MeV

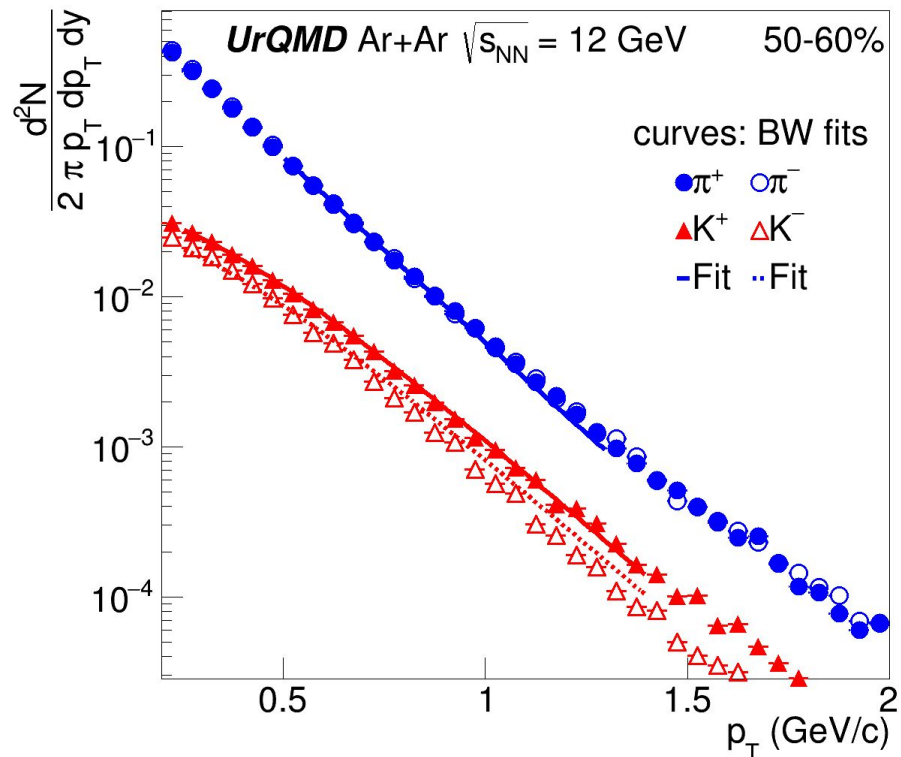
# Blastwave fits of $\pi^\pm$ , $K^\pm$ $p_T$ spectra for Ar+Ar 12 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



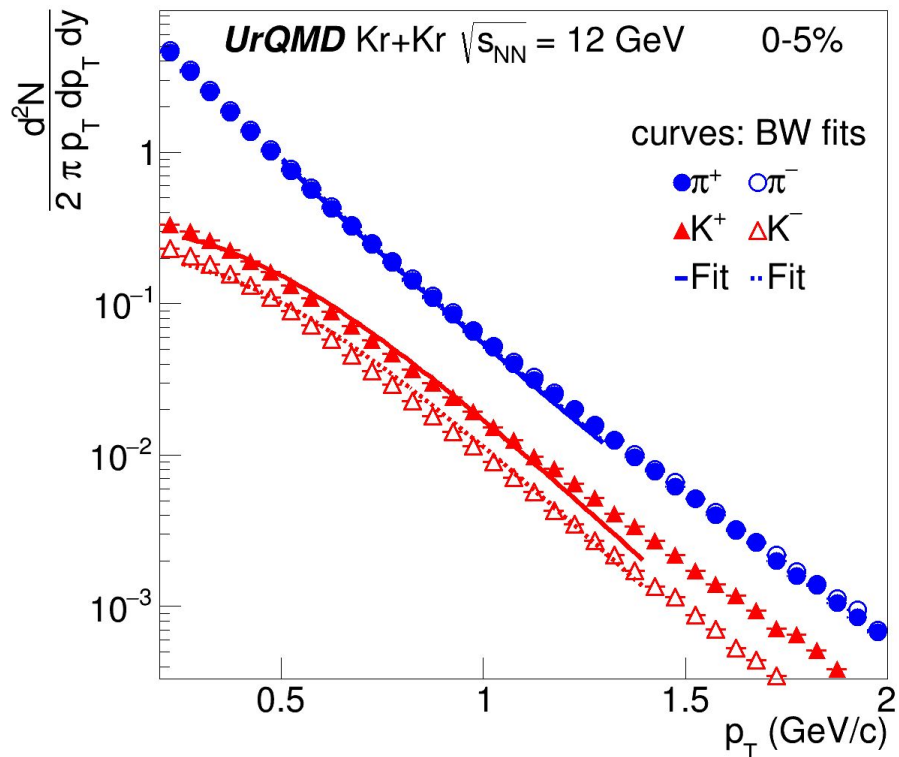
$T_{kin} \approx 104$  MeV



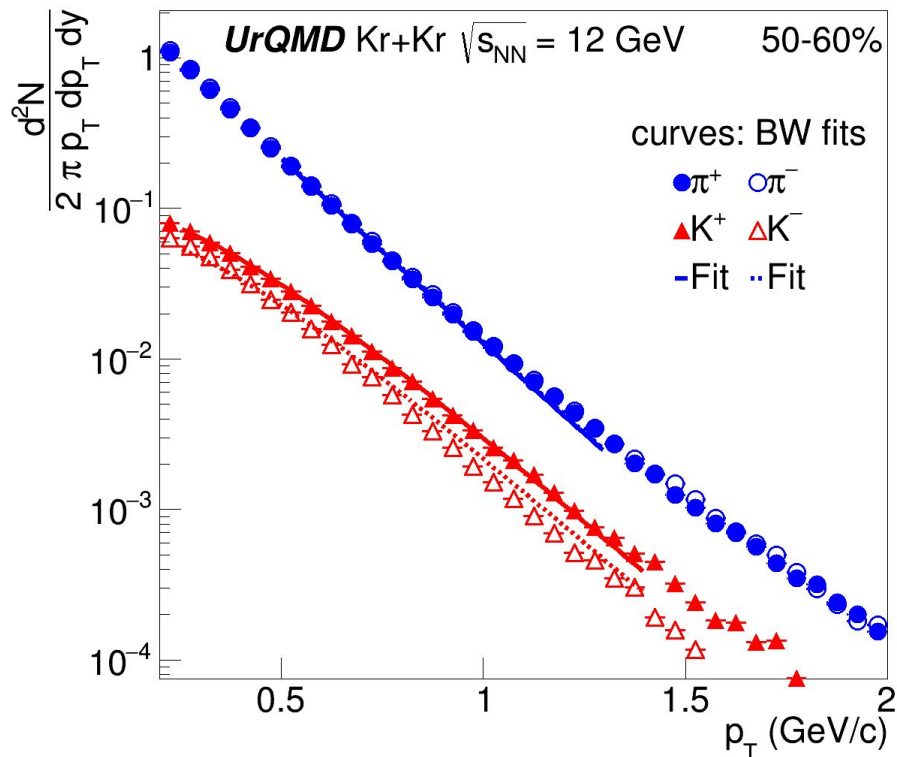
$T_{kin} \approx 131$  MeV

# Blastwave fits of $\pi^\pm$ , $K^\pm$ $p_T$ spectra for Kr+Kr 12 GeV

$|y| < 0.1$   $p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 104$  MeV



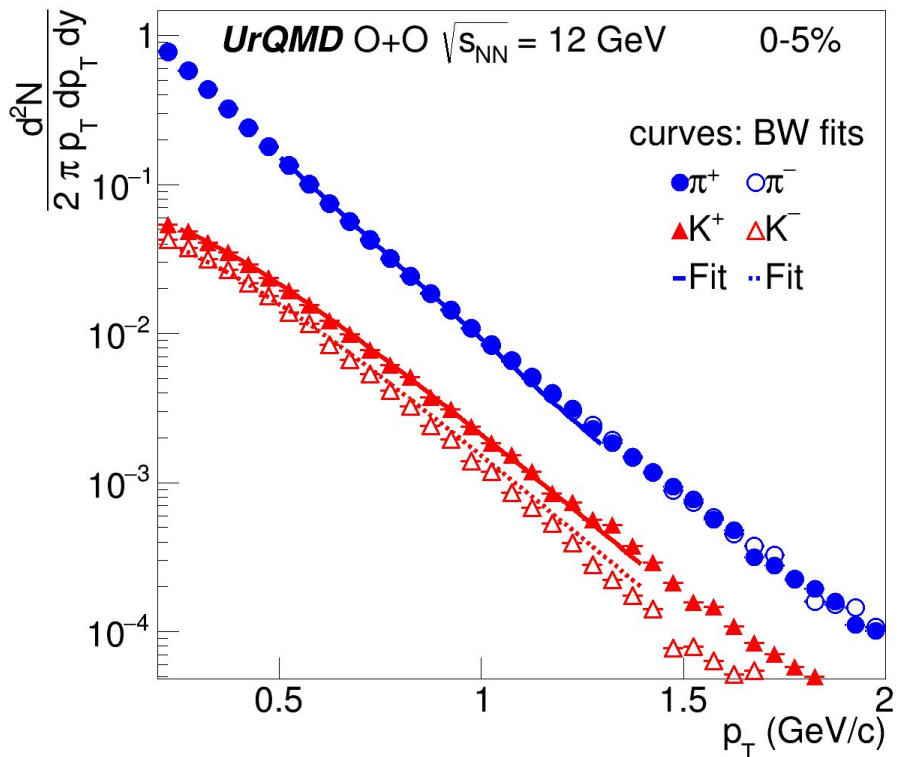
$T_{kin} \approx 131$  MeV



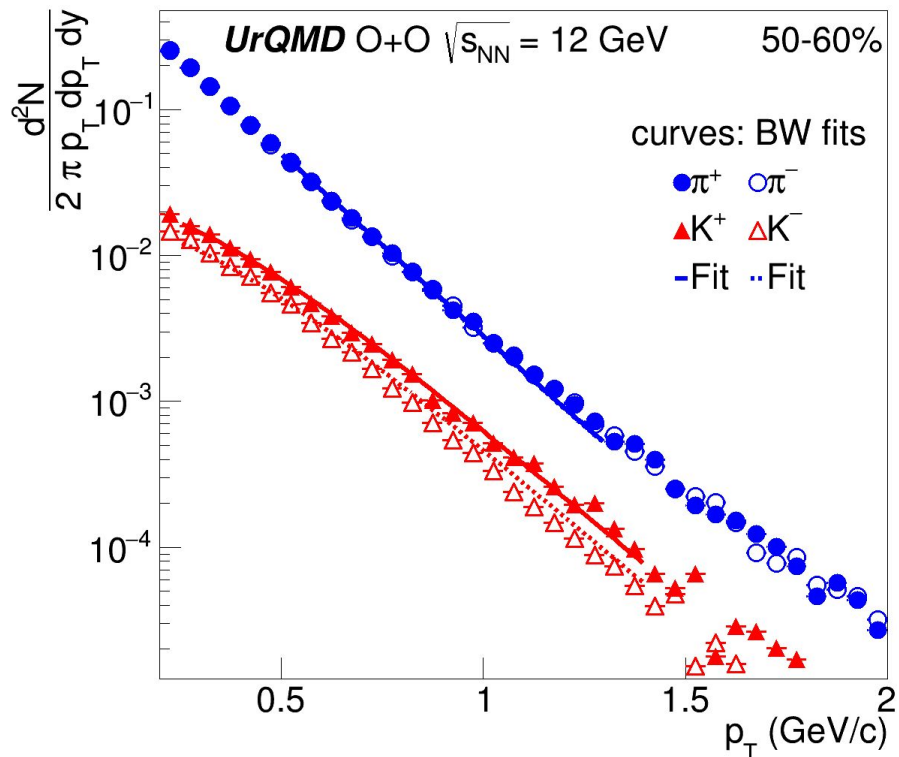
# Blastwave fits of $\pi^\pm$ , $K^\pm$ $p_T$ spectra for O+O 12 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c

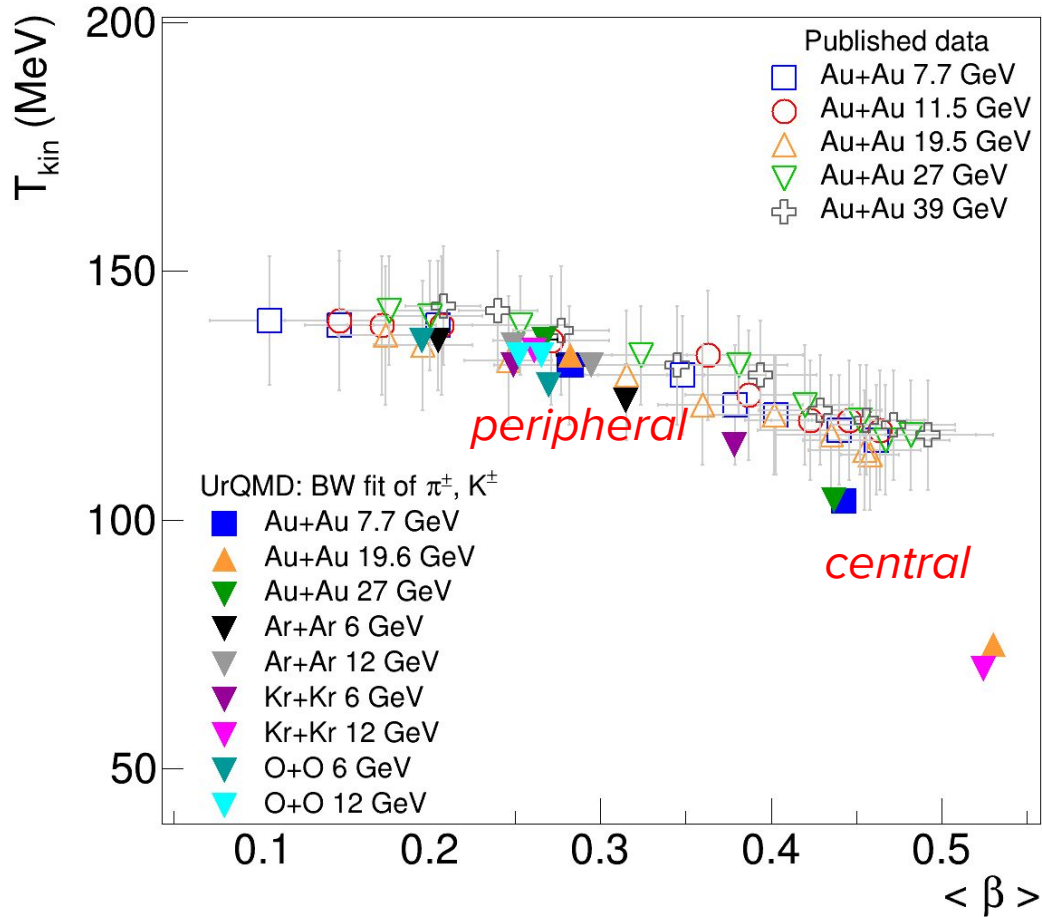


$T_{kin} \approx 104$  MeV



$T_{kin} \approx 131$  MeV

# Comparison of UrQMD and Publish results: $T_{kin}(\langle\beta\rangle)$



$|y| < 0.1$

$p_T$  fit ranges:

$\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3]

GeV/c

$T_{kin}$  and  $\langle\beta\rangle$  **underestimated for central collisions for Au+Au 19.6 GeV and KrKr 12 GeV** after BW fit for  $\pi^\pm, K^\pm$   $p_T$  spectra

# Conclusion

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- Spectra for the  $\pi^\pm$ ,  $K^\pm$ , p and pBar were constructed using UrQMD
  - The spectra were fitted using the BlastWave (BW) model
  - Extracted fit parameters  $T_{kin}$  and  $\langle\beta\rangle$  compared with published data from STAR:
    - BW fit for  $\pi^\pm$ ,  $K^\pm$ , p and pBar underestimated  $T_{kin}$  and  $\langle\beta\rangle$  except Ar+Ar and KrKr
    - BW fit for  $\pi^\pm$ ,  $K^\pm$  underestimated  $T_{kin}$  and  $\langle\beta\rangle$  for AuAu 19.6 GeV and KrKr 12 GeV in central collisions

To do:

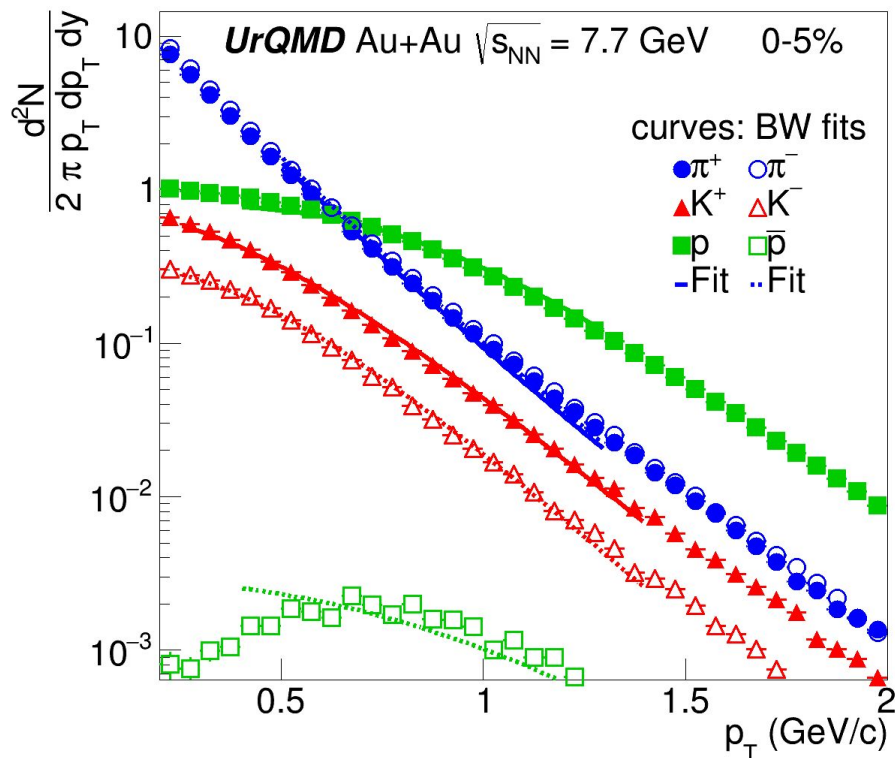
- BW fit of experimental data

backup

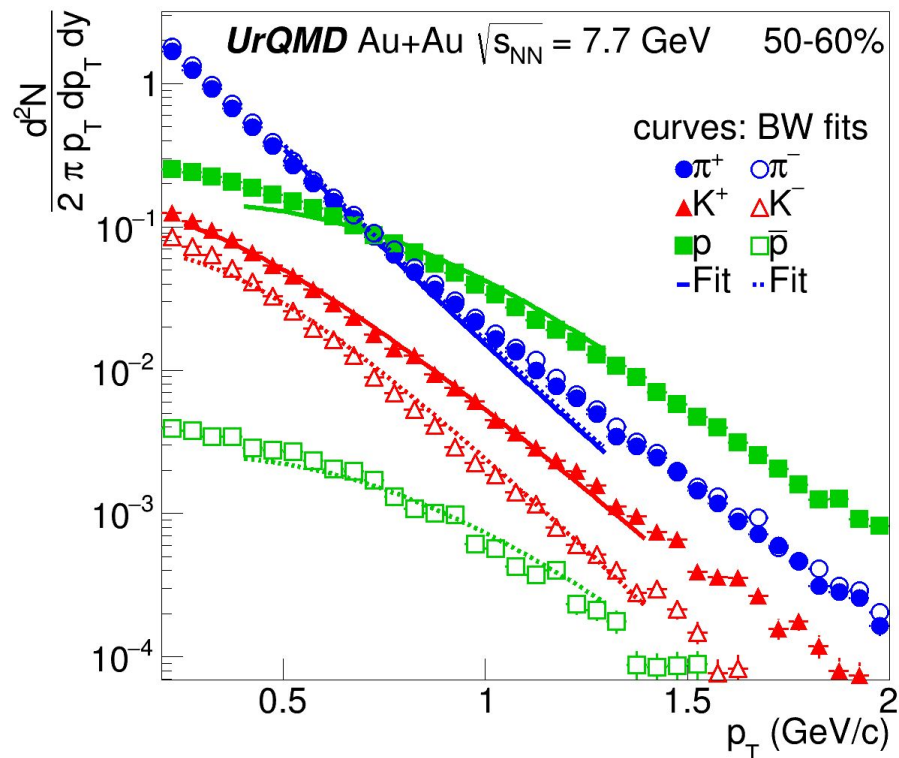
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ and $p\bar{p}$ $p_T$ spectra for 7.7 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



$T_{kin} \approx 74$  MeV

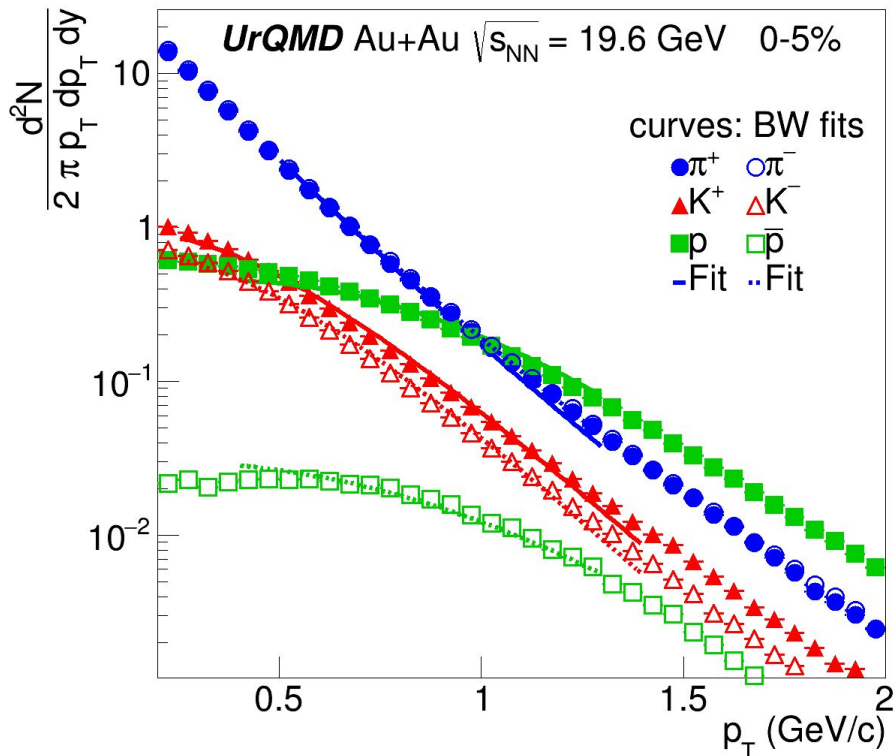


$T_{kin} \approx 72$  MeV

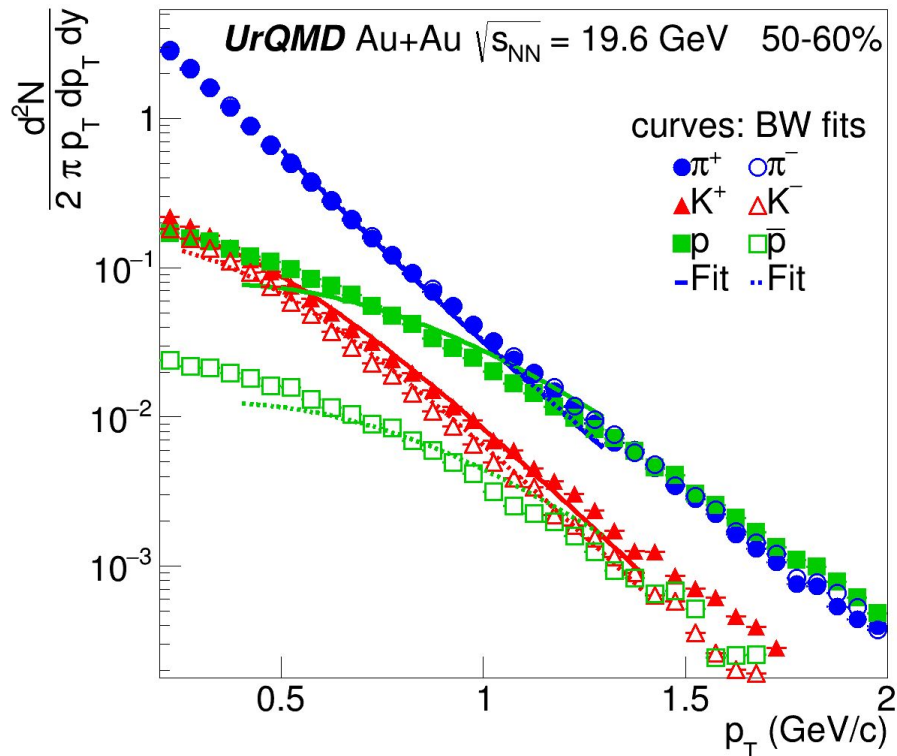
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$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



$T_{kin} \approx 74$  MeV

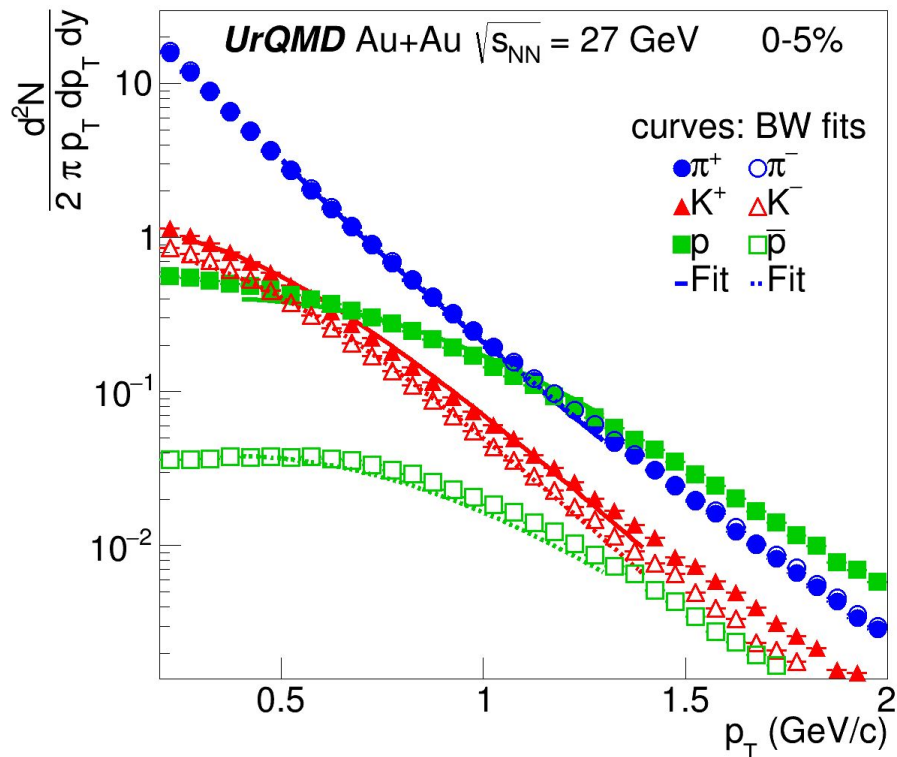


$T_{kin} \approx 71$  MeV

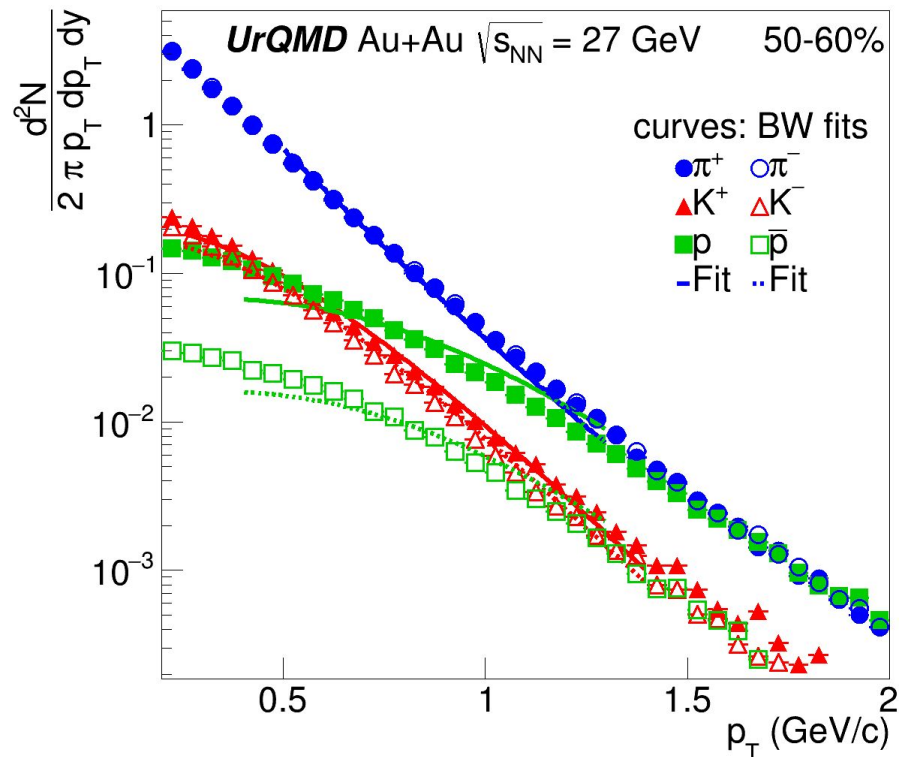
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ and $p\bar{p}$ $p_T$ spectra for 27 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p\bar{p}$ ) [0.4-1.3] GeV/c



$T_{kin} \approx 72$  MeV

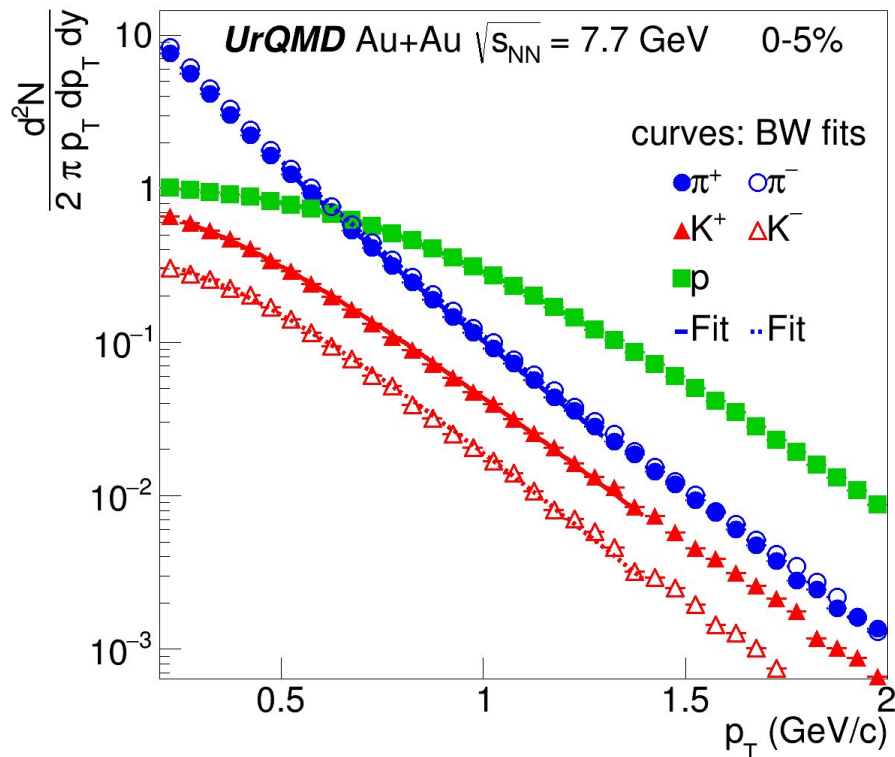


$T_{kin} \approx 71$  MeV

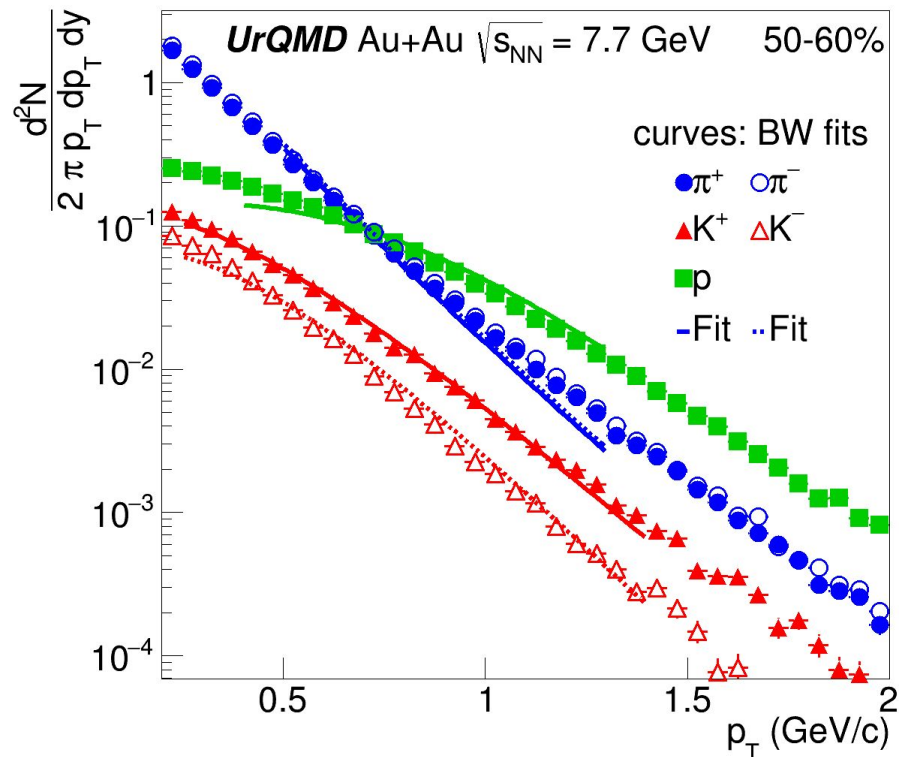
# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ $p_T$ spectra for 7.7 GeV

$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 97$  MeV

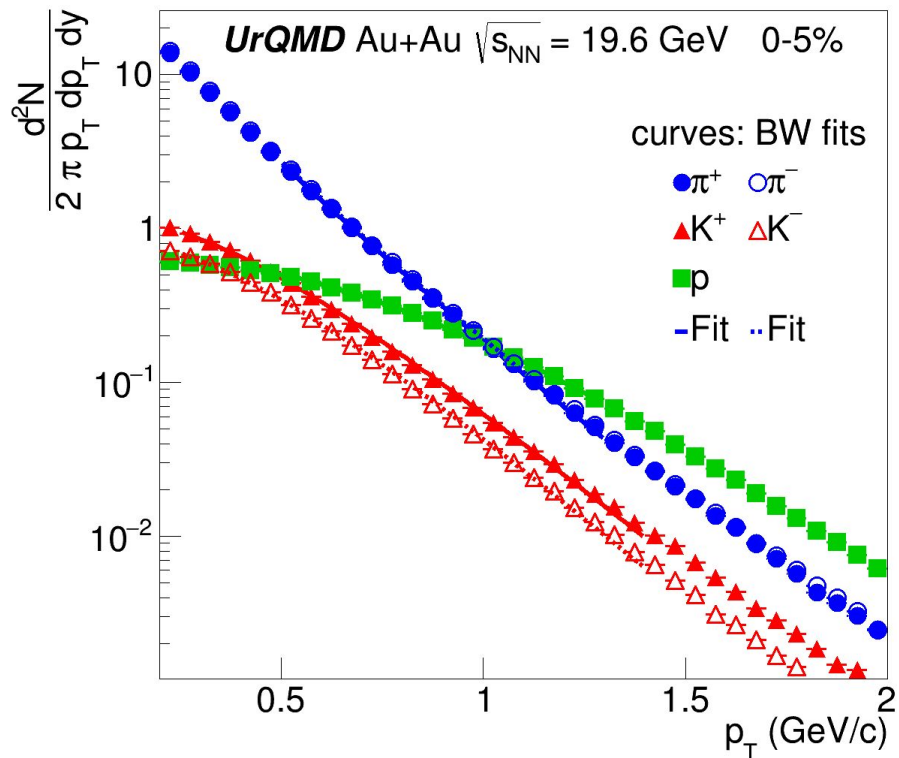


$T_{kin} \approx 73$  MeV

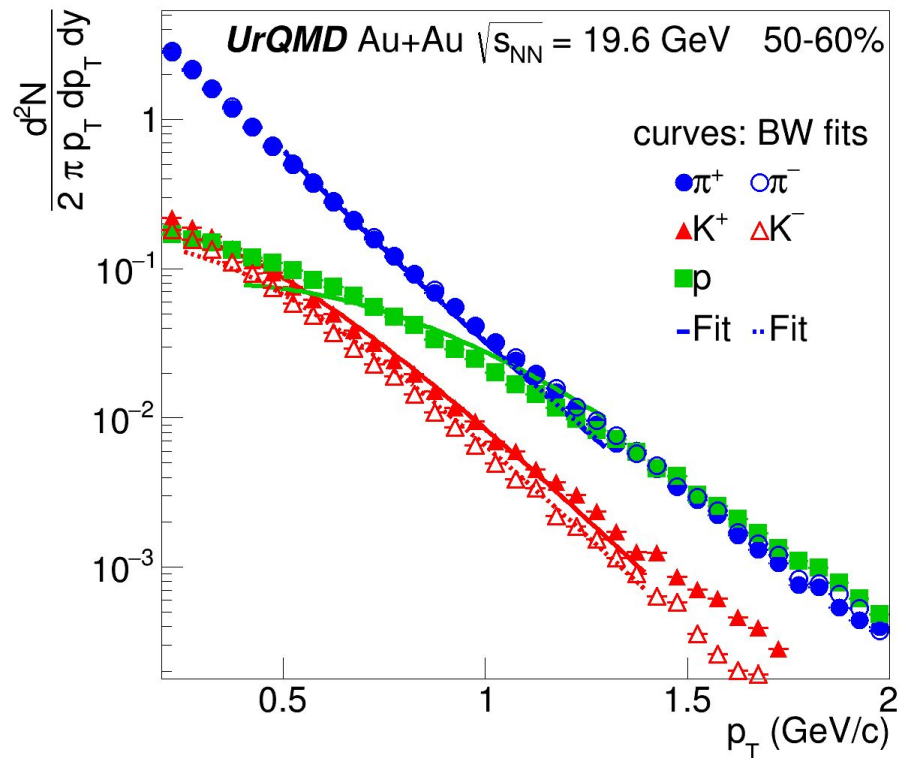


# Blastwave fits of $\pi^\pm$ , $K^\pm$ , $p$ $p_T$ spectra for 19.6 GeV

$|y| < 0.1$   $p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c



$T_{kin} \approx 97$  MeV

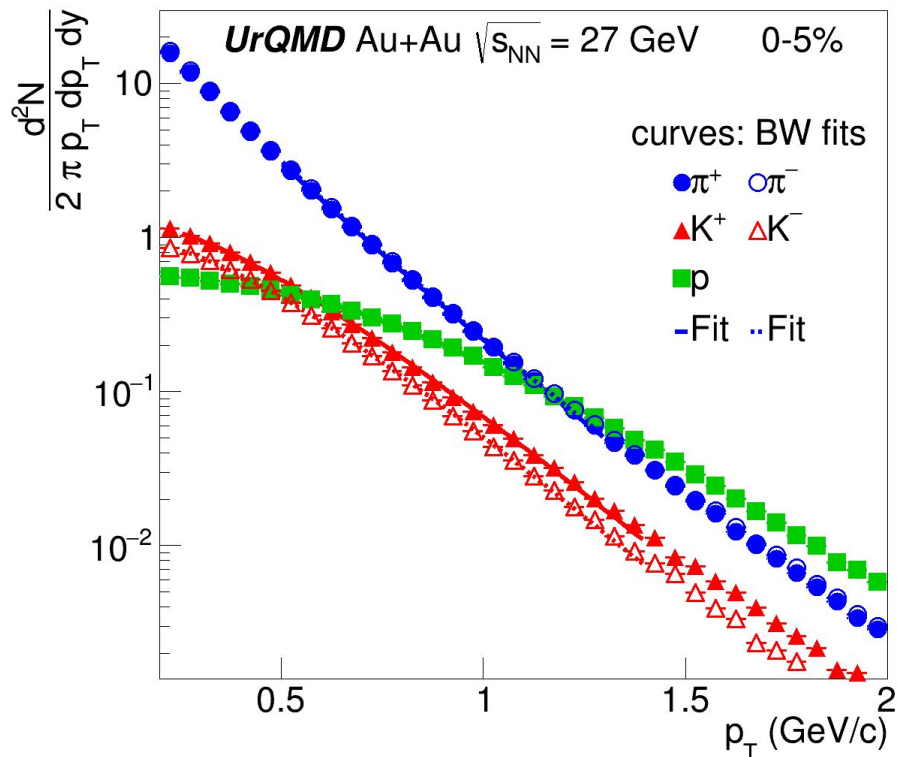


$T_{kin} \approx 73$  MeV

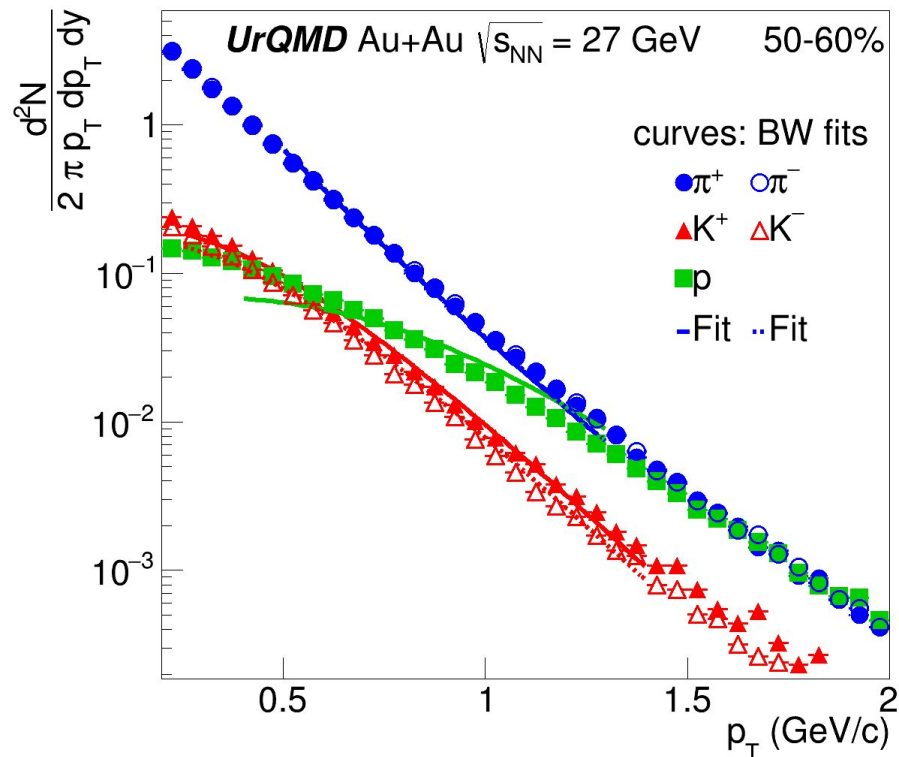
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$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  (p bar) [0.4-1.3] GeV/c

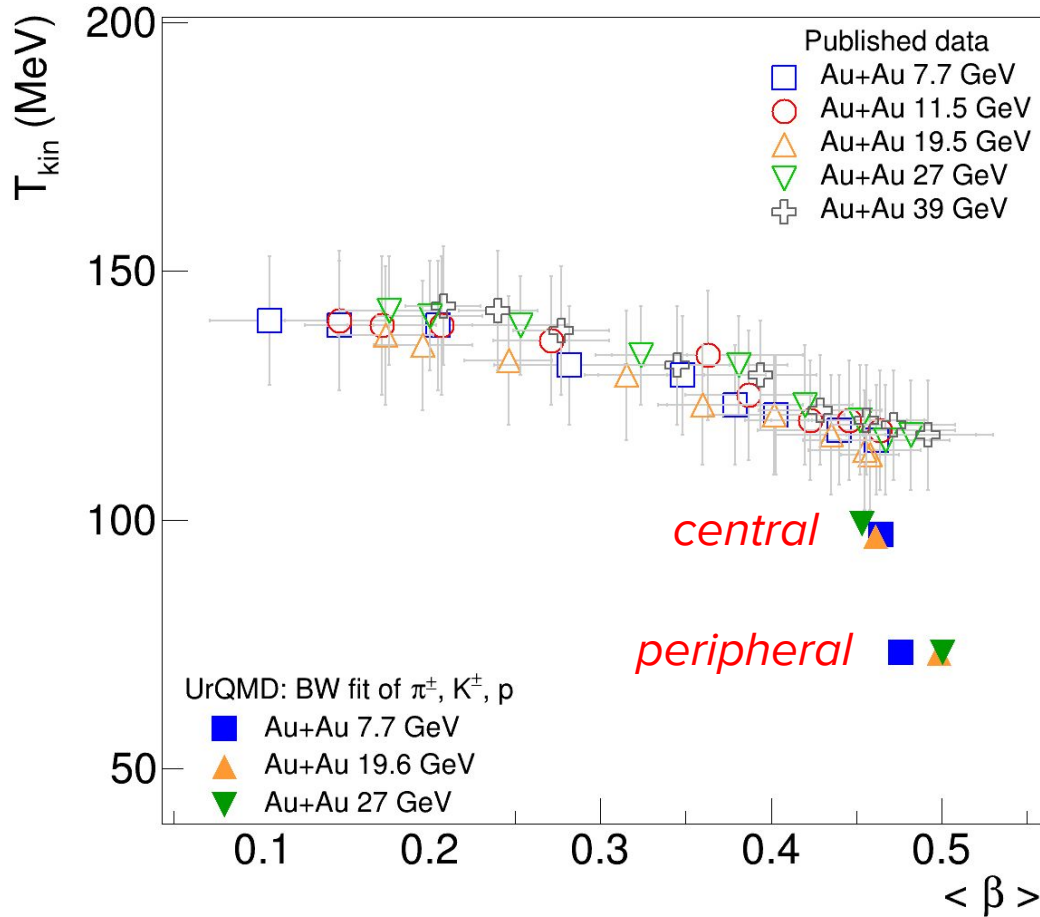


$T_{kin} \approx 99$  MeV



$T_{kin} \approx 73$  MeV

# Comparison of UrQMD and Publish results: $T_{kin}(\langle\beta\rangle)$



$|y| < 0.1$

$p_T$  fit ranges:

$\pi$  [0.5-1.3], K [0.25-1.4], p (p bar) [0.4-1.3]

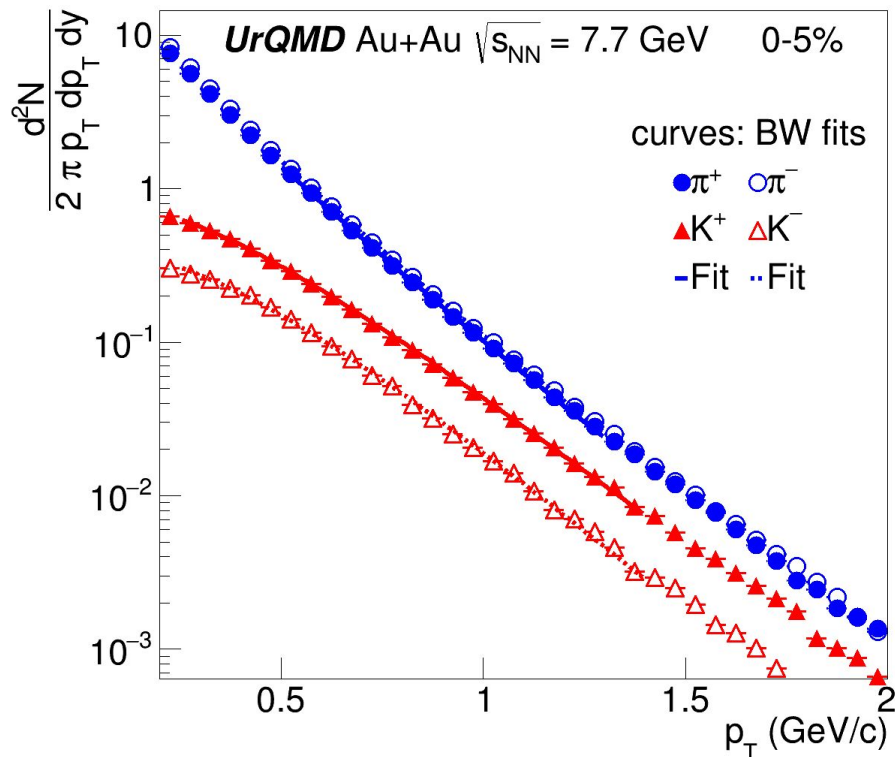
GeV/c

$T_{kin}$  and  $\langle\beta\rangle$  **underestimated for peripheral collisions** after BW fit for  $\pi^\pm, K^\pm, p$   $p_T$  spectra

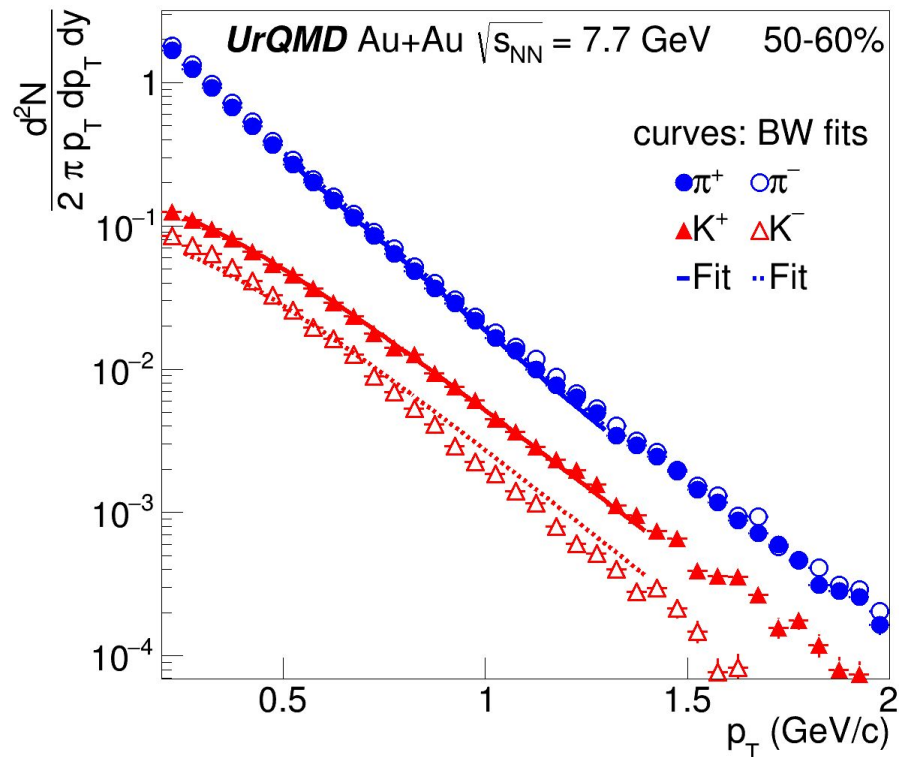
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$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p$  bar) [0.4-1.3] GeV/c



$T_{kin} \approx 104$  MeV

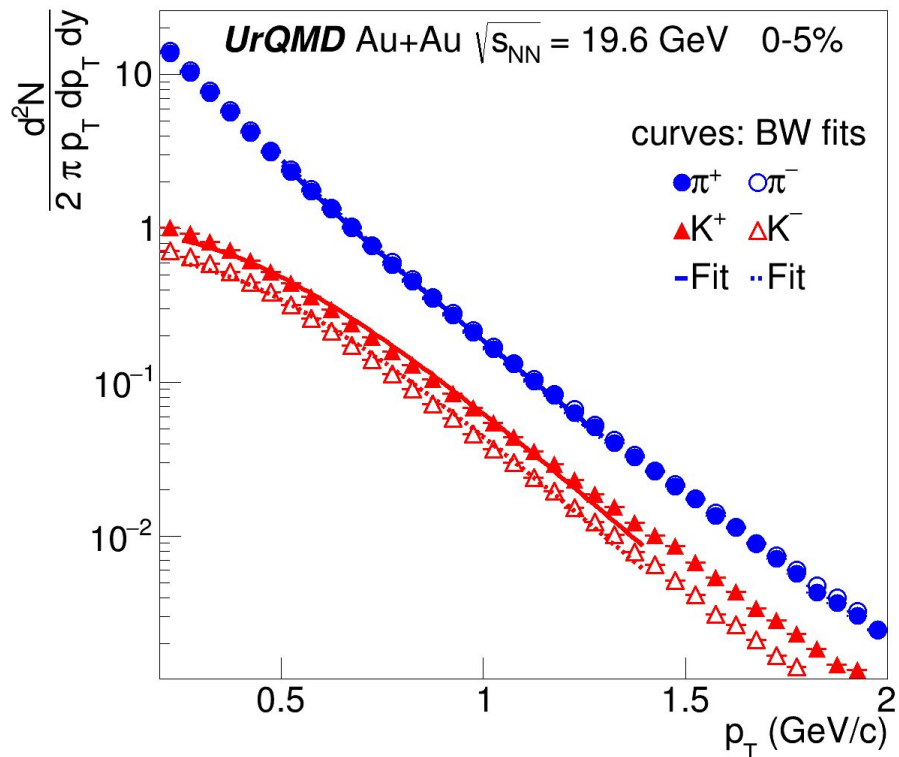


$T_{kin} \approx 131$  MeV

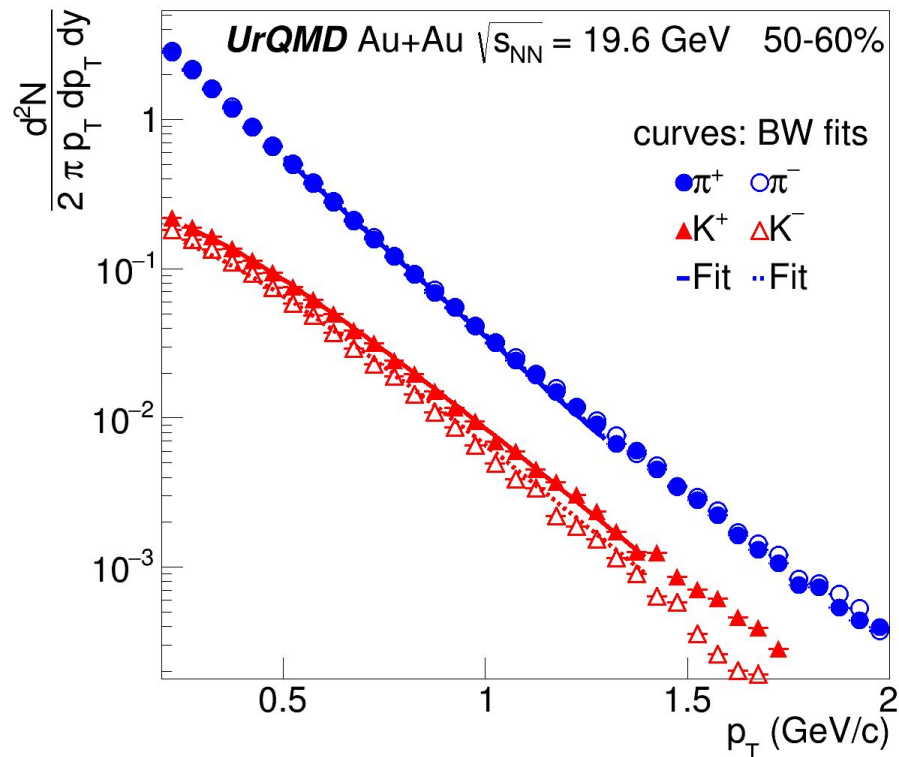
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$|y| < 0.1$

$p_T$  fit ranges:  $\pi$  [0.5-1.3],  $K$  [0.25-1.4],  $p$  ( $p$  bar) [0.4-1.3] GeV/c



$T_{kin} \approx 75$  MeV

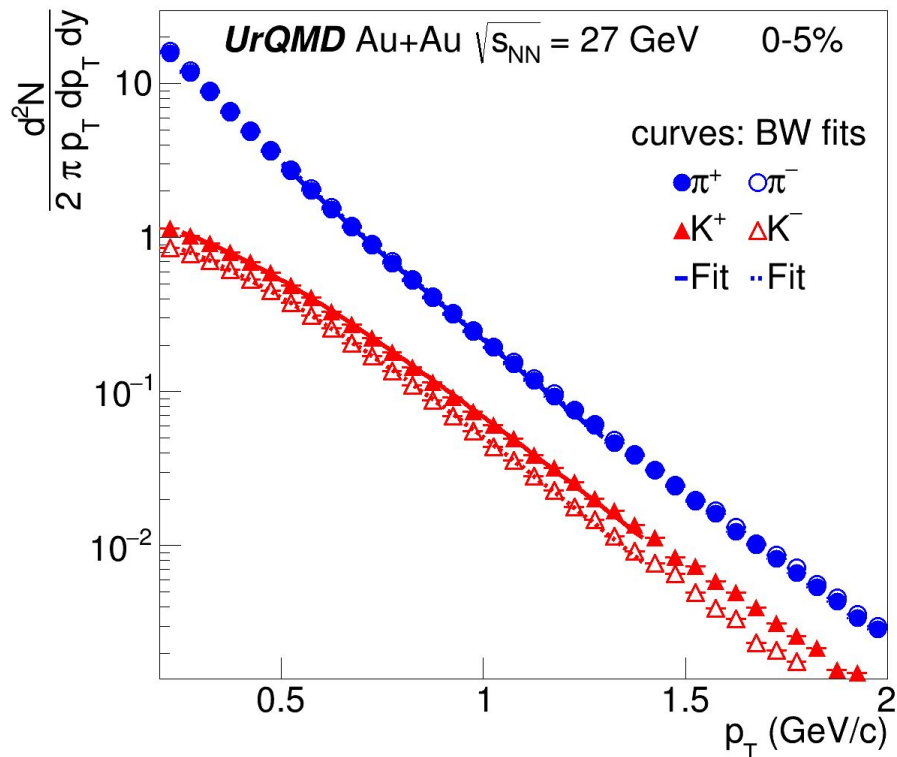


$T_{kin} \approx 133$  MeV

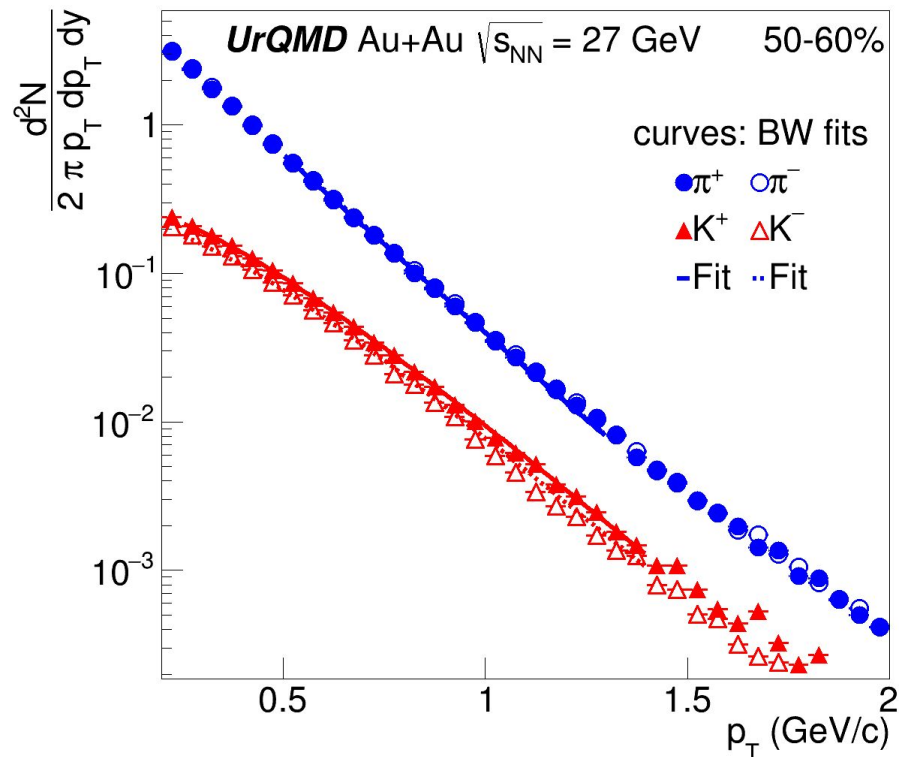
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$T_{kin} \approx 104$  MeV



$T_{kin} \approx 136$  MeV

## Ar+Ar, 6 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$27 \leq \text{mult} < 59$	0.0520445	0.0520445
5-10	$22 \leq \text{mult} < 27$	0.0533346	0.105379
10-20	$16 \leq \text{mult} < 22$	0.0918974	0.197276
20-30	$11 \leq \text{mult} < 16$	0.108931	0.306208
30-40	$8 \leq \text{mult} < 11$	0.0900016	0.396209
40-50	$5 \leq \text{mult} < 8$	0.128027	0.524236
50-60	$4 \leq \text{mult} < 5$	0.059269	0.583505
60-70	$3 \leq \text{mult} < 4$	0.0736831	0.657189
70-80	$2 \leq \text{mult} < 3$	0.090777	0.747966

## Ar+Ar, 12 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$40 \leq \text{mult} < 86$	0.0527676	0.0527676
5-10	$33 \leq \text{mult} < 40$	0.0507145	0.103482
10-20	$24 \leq \text{mult} < 33$	0.0928397	0.196322
20-30	$17 \leq \text{mult} < 24$	0.0999263	0.296248
30-40	$12 \leq \text{mult} < 17$	0.0974738	0.393722
40-50	$8 \leq \text{mult} < 12$	0.108798	0.50252
50-60	$6 \leq \text{mult} < 8$	0.0751109	0.57763
60-70	$4 \leq \text{mult} < 6$	0.100201	0.677832
70-80	$2 \leq \text{mult} < 4$	0.135268	0.8131



## Kr+Kr, 6 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$61 \leq \text{mult} < 107$	0.04849	0.04849
5-10	$50 \leq \text{mult} < 61$	0.0512868	0.0997768
10-20	$34 \leq \text{mult} < 50$	0.103855	0.203632
20-30	$24 \leq \text{mult} < 34$	0.0925625	0.296194
30-40	$16 \leq \text{mult} < 24$	0.102028	0.398222
40-50	$10 \leq \text{mult} < 16$	0.109802	0.508025
50-60	$7 \leq \text{mult} < 10$	0.0772563	0.585281
60-70	$4 \leq \text{mult} < 7$	0.114553	0.699834
70-80	$2 \leq \text{mult} < 4$	0.121508	0.821342

## Kr+Kr, 12 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$91 \leq \text{mult} < 162$	0.0510938	0.0510938
5-10	$76 \leq \text{mult} < 91$	0.0471259	0.0982197
10-20	$52 \leq \text{mult} < 76$	0.103778	0.201997
20-30	$36 \leq \text{mult} < 52$	0.0973497	0.299347
30-40	$24 \leq \text{mult} < 36$	0.101204	0.400551
40-50	$16 \leq \text{mult} < 24$	0.0938084	0.494359
50-60	$10 \leq \text{mult} < 16$	0.101203	0.595562
60-70	$6 \leq \text{mult} < 10$	0.101854	0.697416
70-80	$3 \leq \text{mult} < 6$	0.12037	0.817786

## O+O, 6 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$11 \leq \text{mult} < 29$	0.0472652	0.0472652
5-10	$9 \leq \text{mult} < 11$	0.0473229	0.0945881
10-20	$7 \leq \text{mult} < 9$	0.078286	0.172874
20-30	$5 \leq \text{mult} < 7$	0.12268	0.295554
30-40	$4 \leq \text{mult} < 5$	0.0849122	0.380467
40-50	$3 \leq \text{mult} < 4$	0.1081	0.488567
50-60	$2 \leq \text{mult} < 3$	0.13536	0.623927

## O+O, 12 GeV

Centrality, %	Multiplicity	Percent in this bin	Cumulative percent
0-5	$16 \leq \text{mult} < 41$	0.0458375	0.0458375
5-10	$13 \leq \text{mult} < 16$	0.0494368	0.0952743
10-20	$9 \leq \text{mult} < 13$	0.120674	0.215949
20-30	$7 \leq \text{mult} < 9$	0.0926219	0.308571
30-40	$6 \leq \text{mult} < 7$	0.0586195	0.36719
40-50	$4 \leq \text{mult} < 6$	0.150213	0.517403
50-60	$3 \leq \text{mult} < 4$	0.0946435	0.612046
60-70	$2 \leq \text{mult} < 3$	0.108377	0.720423
70-80	$1 \leq \text{mult} < 2$	0.117956	0.838379