Motivation:
-- Transport model view of lfspectra centrality dependent \(<\mu_B,\langle T\rangle>\)…
-- Explore bulkcorr assumption that centrality selection alone tightly constrains \((\mu_B,T)\)…
-- Explore possibility of constraining \((\mu_B,T)\) event-by-event with suitable cuts…
e.g. net and total pion moments products gated on pbar/p…

This is a follow-up to last week’s presentation:
http://wjllope.rice.edu/fluct/protected/urqmdthermus_20120905.pdf

Here:
…in UrQMD+Thermus (E-by-E and in 1fm/c steps), constrain \(\mu_S\) and \(\gamma_S\), 2 par fit, GCE
…on the Number of degrees of freedom (with Evan Sangaline)
…data+Thermus (with Daniel McDonald)
…STAR acceptance- & efficiency-filtered UrQMD+Thermus (eff from Evan Sangaline)
UrQMD 3.3p1
Default parameters, only set impact parameter range and $\text{ecm}$ only.
Centrality set on impact parameter in “standard” percentages assuming $b_{\text{max}}=14\text{fm}$
Output in 1 fm/c timesteps in each event.
500-800 timesteps total depending on root-s
In each timestep, ignore spectators
And count multiplicity of 20 different particles (light hadrons and hyperons)

Thermus
Standalone application that reads the UrQMD files and
fits the multiplicity ratios in every timestep in every event.
Grand Canonical Ensemble, fit parameters: $(T, \mu_B, \mu_S, \gamma_S)$
12 ratios considered ($\pi\pm, K\pm, p\pm, \Lambda\pm$)
Mult errors in each time step & evt taken as Poisson ($\sim \sqrt{N}$) – but not that important
Also fit “averaged events” (in a given centrality bin) in each time step

Can thus
Plot the trajectories of individual events in $(\mu_B, T)$ space
Plot the trajectories of averaged events in $(\mu_B, T)$ space
Plot the distributions of $(T, \mu_B, \mu_S, \gamma_S)$ in centrality-selected events
In previously presented slides, $(T, \mu_S, \mu_B, \gamma_S)$ were allowed to vary freely… Resulted in some events with $\gamma_S$ pegged at 1, and others w/ low values and two peaks in $\mu_B$ for non-peripheral collisions at low root-s

Constrain $\mu_S$ and $\gamma_S$ and Fit $(T, \mu_B)$, GCE

now constrain $(\mu_S, \gamma_S)$ values to the red curves and fit only $(T, \mu_B)$….
Constrain $\mu_s$ and $\gamma_s$ and Fit $(T, \mu_B)$, GCE

0-5%, 5-10%, 10-20% give ~same T distributions…

$<T>$ decreases as $b$ decreases…
UrQMD+Thermus

Constrain $\mu_S$ and $\gamma_S$ and Fit ($T$, $\mu_B$), GCE

Double peaks disappear...
still significant overlap in 0-5%, 5-10%, 10-20%...
$\mu_B$ decreases as $b$ decreases...
Constrain $\mu_S$ and $\gamma_S$ and Fit ($T, \mu_B$), GCE, Event-Avg Trajectories

FO $\mu_B$ decreases as $b$ decreases…

look quite different at low root-s compared to free 4 parameter fits…

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UrQMD+Thermus

Constrain $\mu_S$ and $\gamma_S$ and Fit ($T, \mu_B$), GCE

Here: 0-5% central

trend holds for less central events w/ non-zero $p_{bar}$ and $p$ multiplicities

$p_{bar}/p = \exp(-14\mu_B)$

This is the same trend as seen in the 4 parameter fit…

error bars here are the RMS values! $(\pm 1\sigma$ about mean)
For $N$ non-zero yields, one can form $\sum_{i=1}^{N} i$ ratios…

i.e. for $\pi^{\pm}, K^{\pm}, p^{\pm} \rightarrow$ up to $N=6$ non-zero yields $\rightarrow$ 15 non-zero ratios possible

Of these 15 non-zero ratios from $N$ non-zero yields, $N-1$ are independent…

Now, I am only fitting events if $N-1 \geq N_{\text{par}}$

Evan’s simulation:
how probable is it to measure $b$ if normal distributed
with means $m$ and covariance $C$.
$(b-m)^{T}C^{-1}(b-m)$ is $\chi^2$ distributed with k DOF

only yields….
$k=5$ measurements are independent
plot diagonal-only $\chi^2$ sum

$m =$ meas (vector with k values)
$b =$ model (vector with k values)
$C =$ meas covariance (k×k matrix)
$v =$ meas variances (diagonal of C)

all ratios….
plot diagonal-only $\chi^2$ sum for 5! ratios
…mean~10, $k-1<\text{mean}<5!$

$k_{\text{eff}} \sim 5$

mean~10

poor fit

closer to $\chi^2$ distribution w/ $k-1$ DOF
then 5! DOF but not exactly the same
Used same Thermus code to fit experimental $\pi^\pm,K^\pm,p^\pm$ yield ratios event-by-event

Yields from Daniel McDonald
- Detailed bad-run and bad-event rejection
- Same event and track cuts as he uses in his moments analyses
- Centrality from refmult2corr
- $dE/dx+$TOF plus spallation $P_T$ cut for $p$
- $N=6\:\:\:\pi^\pm,K^\pm,p^\pm$ yields calculated for all directly identified tracks with $|\eta|<0.5$

But, BTW, there is a problem re: feeddown contributions to the observed yields….

Thermus can be run in two modes.
- No Decays: *i.e.* Input yields do not include any feeddown contributions
  (this is how I appropriately run the UrQMD+Thermus simulations)
- Allow Decays: *i.e.* Input yields include 100% of the possible feeddown
  from all particles known to Thermus (fit or not) with known branching fractions

AFAIK, our data is not consistent with either case
- we can estimate feeddown but we don’t generally measure all the necessary parent yields
- or we can completely ignore feeddown, but there is typically a 1-3fm dca cut applied

…I’ll just run Thermus in both modes and will provide both sets of results…
Here, using 4 parameter fits – which look fine in general – non-zero ratios are reproduced…

μ_B decreases w/ increasing root-s

essentially no difference between
0-5%, 5-10%, and 10-20%
$\mu_B$ from data+Thermus fits, Complete feeddown

General trend is as expected $\mu_B$ decreases with increasing root-$s$

~Central $\mu_B$ distributions at a given root-$s$ are wide and significantly overlap with data from neighboring root-$s$ values
UrQMD+Thermus

μ_B from data+Thermus fits, Zero feeddown

general trend is as expected
μ_B decreases w/ inc. root-s
~central μ_B distributions at a
given root-s are wide and
significantly overlap with data
from neighboring root-s values
values ~10% smaller with zero
feeddown compared to complete
feeddown
data+Thermus fits, 0-5% central

\[ \langle \text{anti-}p/p \rangle \text{ vs } \mu_B \text{ (GeV)} \]

- complete feeddown
  - error bars here are the RMS values! (±1σ about mean)

\[ \rho/p = e^{(0.0)+(-14.0)\mu_B} \]

...same pbar/p=exp(-14μ_B) trend is seen when fitting the yields from the experimental data...
UrQMD+Thermus

data+Thermus fits, complete feeddown, T vs. refmult2corr

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data+Thermus fits, complete feeddown, $\mu_B$ vs. refmult2corr

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 7.7\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 11.5\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 19.6\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 27.0\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 39.0\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 62.4\text{GeV} \]

\[ \mu_B \text{ vs } b, \sqrt{s_{NN}} = 200.0\text{GeV} \]

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UrQMD+Thermus

data+Thermus fits, complete feeddown, $\mu_S$ vs. refmult2corr
UrQMD+Thermus fits, complete feeddown, $\gamma_S$ vs. refmult2corr
In progress now: Apply “STAR” acceptance & efficiency filter to UrQMD
Compare perfect, $4\pi$, participant-only simulation results to those we might measure E-by-E…
refmult, refmult2 and refmult3 vs. impact parameter with and without the filter
yields in $|\eta|<0.5$, $P_T>0.2$ GeV, and including a parameterized tracking efficiency
(parameterized tracking efficiencies from Evan Sangaline)

jobs running now…
plot $X_{\text{perfect}}$ vs $X_{\text{meas}}$
where $X=T, \mu_B, \mu_S, \gamma_S$
Perfect $4\pi$ participant-only UrQMD+Thermus simulations:

Constraining $(\mu_S, \gamma_S)$ values and fitting only $(T, \mu_B)$ makes the fits more stable…

Significant overlap in TD pars for ~3 most central bins remains

~central selection alone does not tightly constrain $(T, \mu_B)$...

$p\bar{p}/p = \exp(-14\mu_B)$

Changed how $N_{DOF}$ is calculated for each fit

Require sufficient number of non-zero yields: $N-1 \geq N_{par}$

Began to fit the experimental yields E-by-E

TD parameter distributions are very wide, ~central bins are very similar…

~central selection alone does not tightly constrain $(T, \mu_B)$...

$p\bar{p}/p = \exp(-14\mu_B)$

To-do

Plots from application of STAR acceptance & efficiency filter and direct comparison of the TD pars event-by-event

GCE vs SCE in perfect detector and STAR detector simulations

How to handle the feeddown question?

Implement $p\bar{p}/p$ gating in net- and total-pion moments analyses