# UrQMD+Thermus

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## & data+Thermus


Motivation:
-- Transport model view of lfspectra centrality dependent (<$\mu_B$>,<T>)…
-- 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.* measure moments products gated on pbar/p?

Bulkcorr presentations:
http://wjllope.rice.edu/fluct/protected/urqmdthermus_20120905.pdf
http://wjllope.rice.edu/fluct/protected/urqmdthermus_20120912.pdf

Basic overview
…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)

## Approach and codes

UrQMD 3.3p1

- Default parameters, only set impact parameter range and `ecm` only
  - centrality set on impact parameter in "standard" percentages assuming $b_{max}$=14fm
- 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

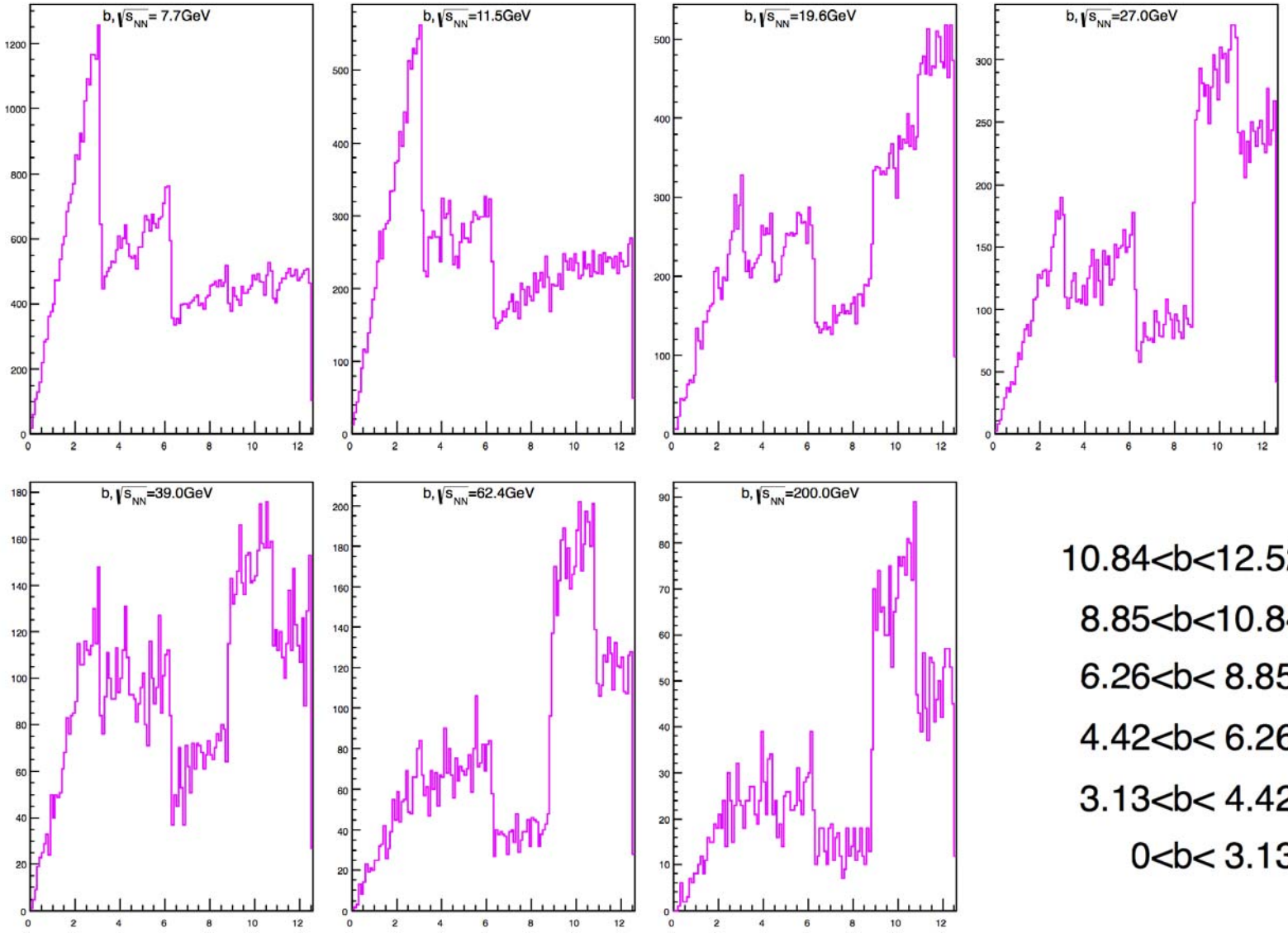
- Standalone application that reads the UrQMD files and
  - fits the multiplicity ratios in every timestep in every event
- Grand Canonical Ensemble, fit parameters: ($T$, $\mu_B$, $\mu_S$, $\gamma_S$)
- 9 or 12 ratios considered ($\pi\pm$, $K\pm$, $p\pm$, $\Lambda\pm$)
- Covariance from MINUIT, $N_{DOF} = N_{yields} - 1$
- 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

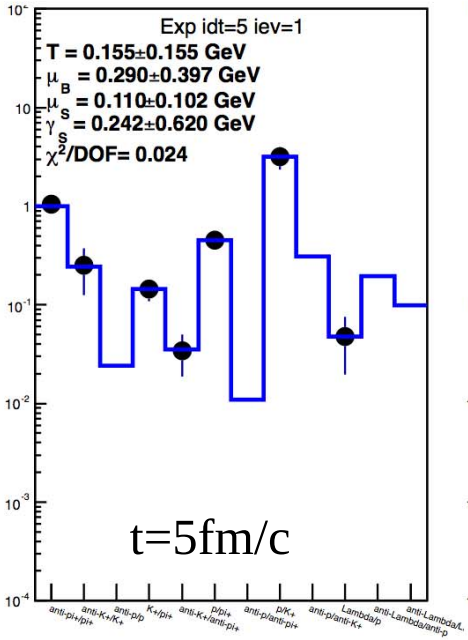
# Impact Parameters

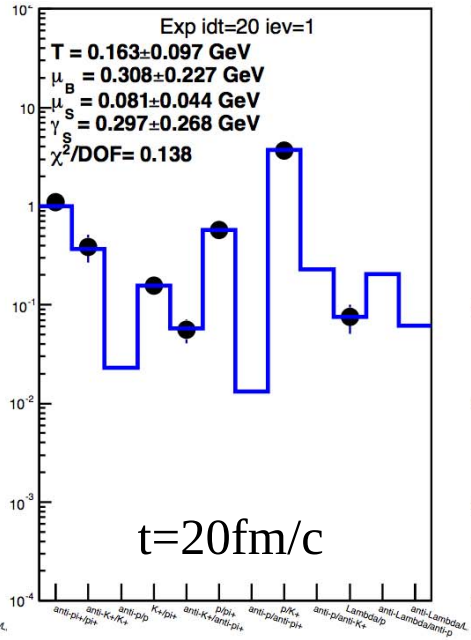
Codes run on the DAVINCI farm at Rice, generally 50-100 nodes available each day…
Run as many events through thermus as fits in 24hrs of wall clock time…
Few 100s to few 1000s evts in each root-s and centrality bin…

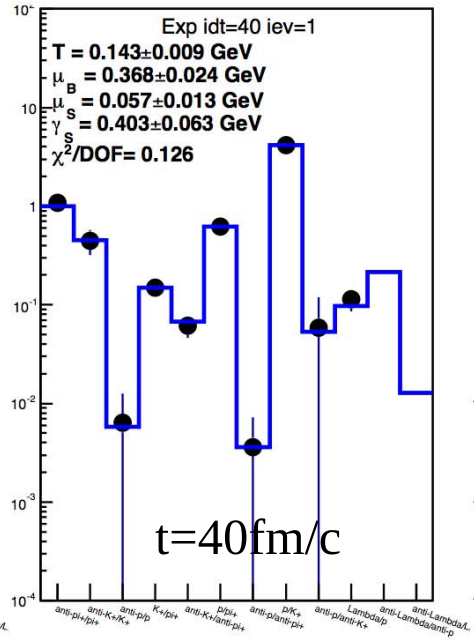


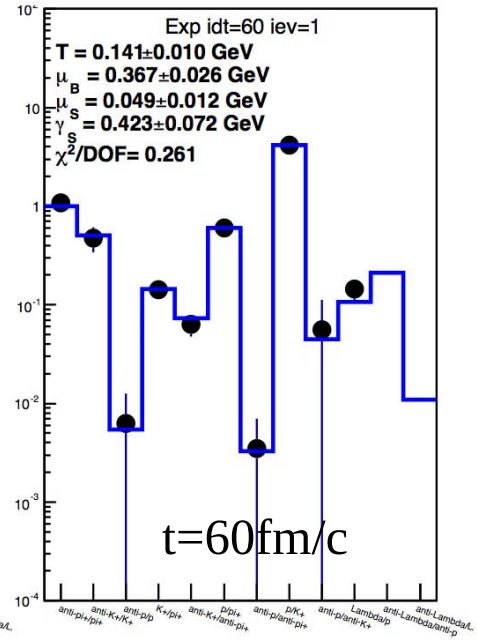

10.84<b<12.52 (60-80%)
8.85<b<10.84 (40-60%)
6.26<b< 8.85 (20-40%)
4.42<b< 6.26 (10-20%)
3.13<b< 4.42 (5-10%)
0<b< 3.13 (0-5%)

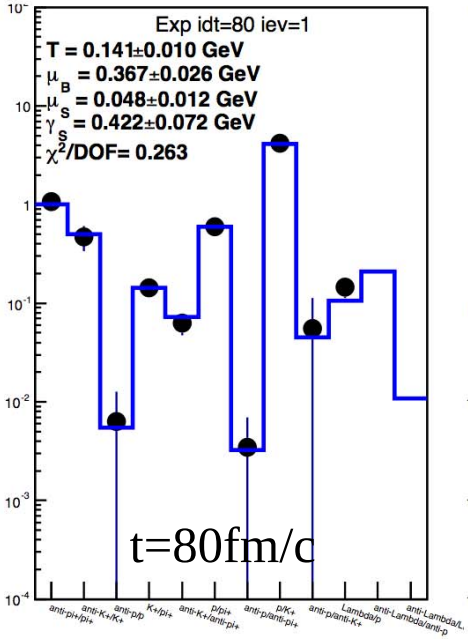
# Example Fits, 19.6 GeV, 0-5%

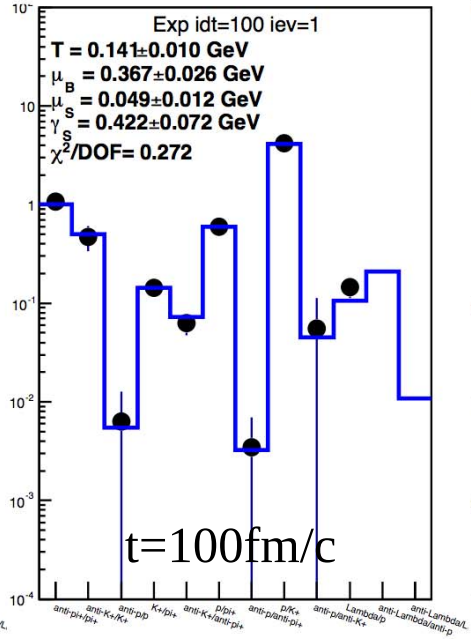


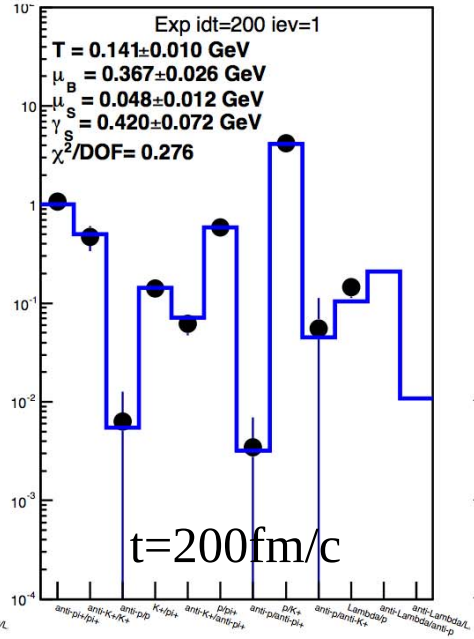



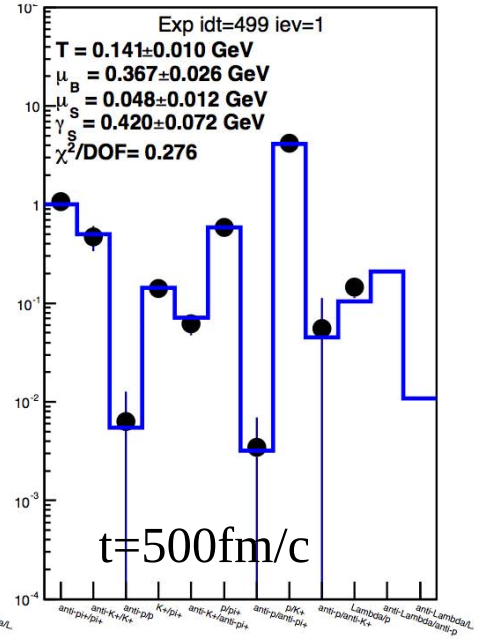



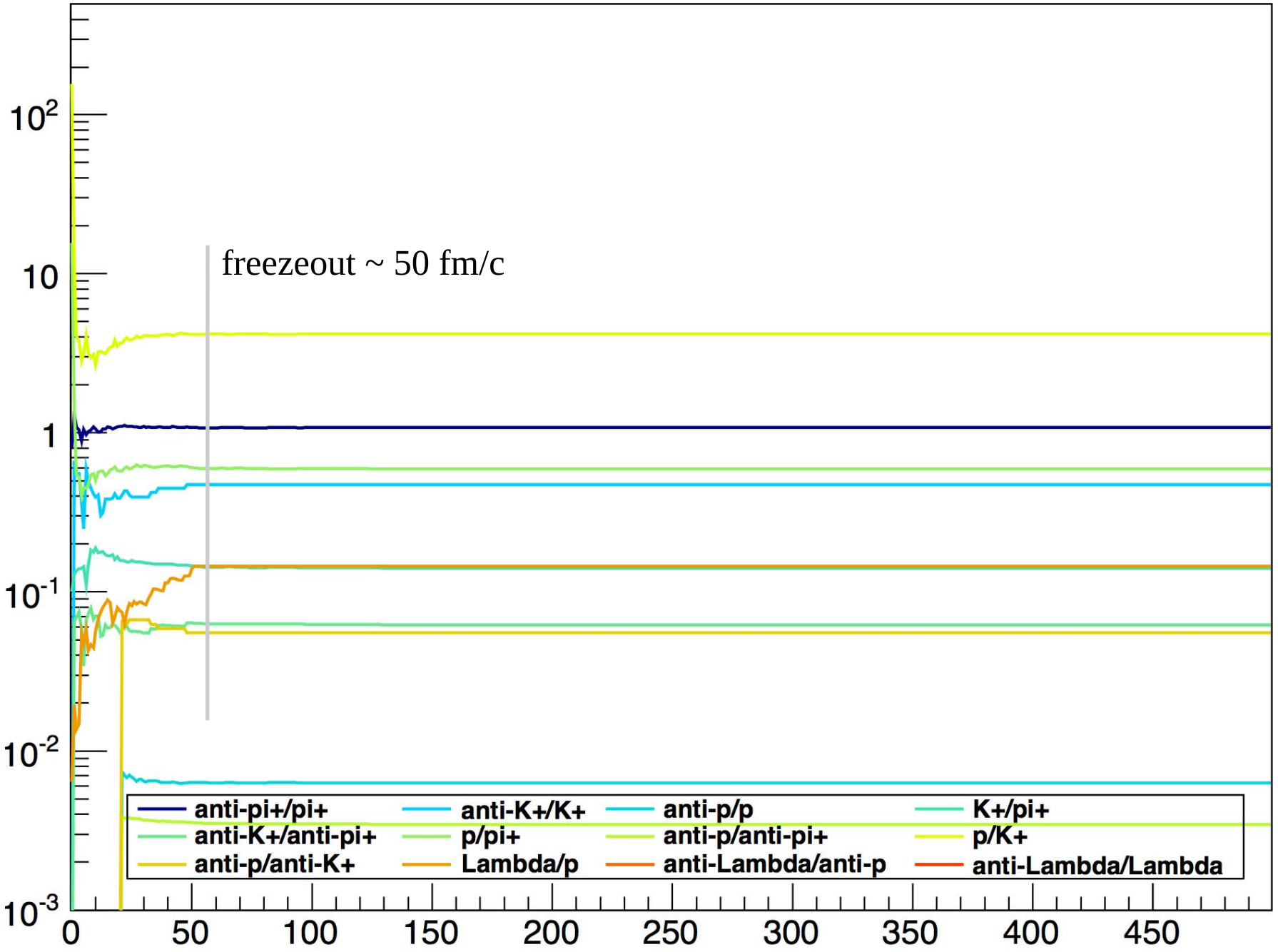



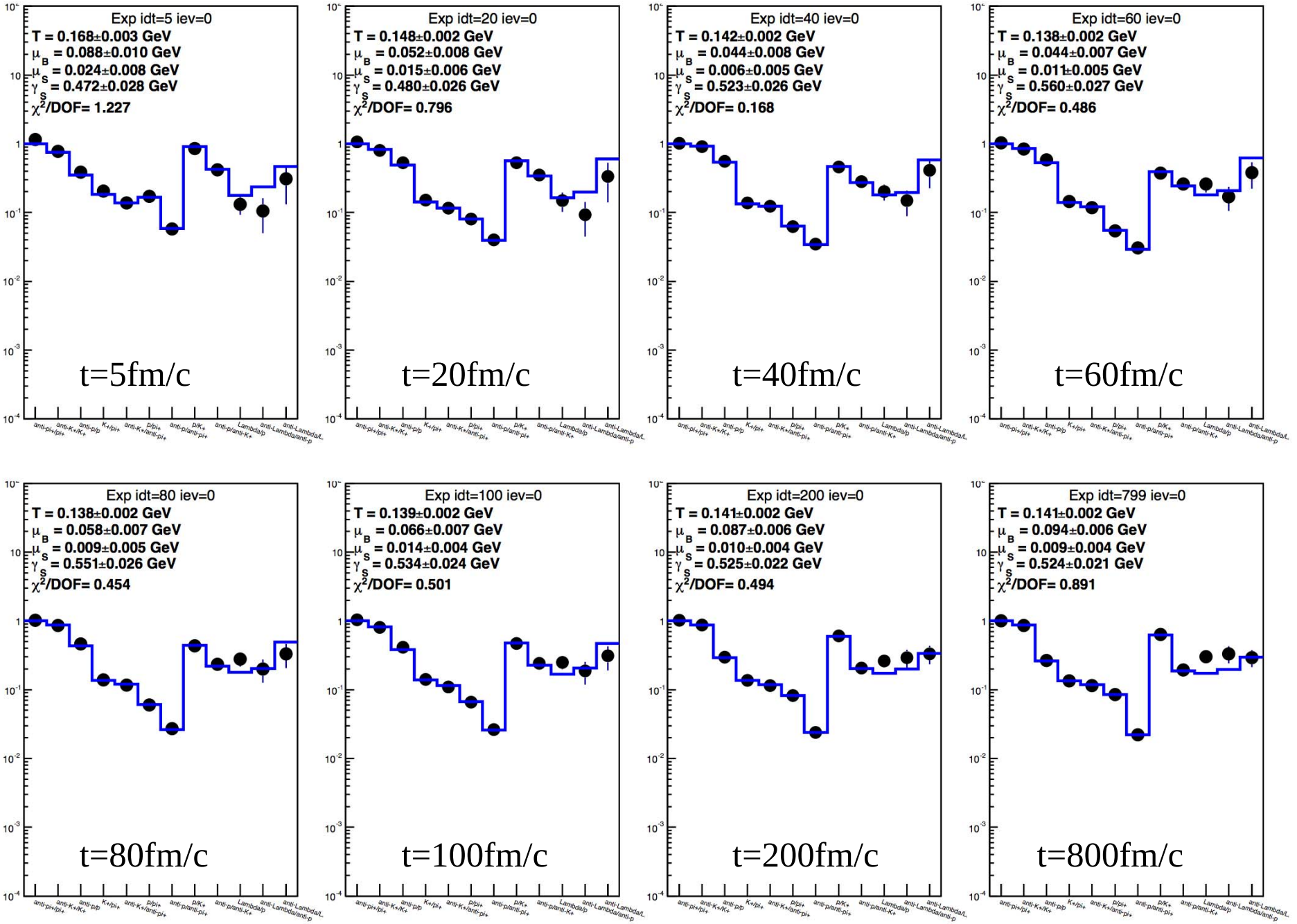



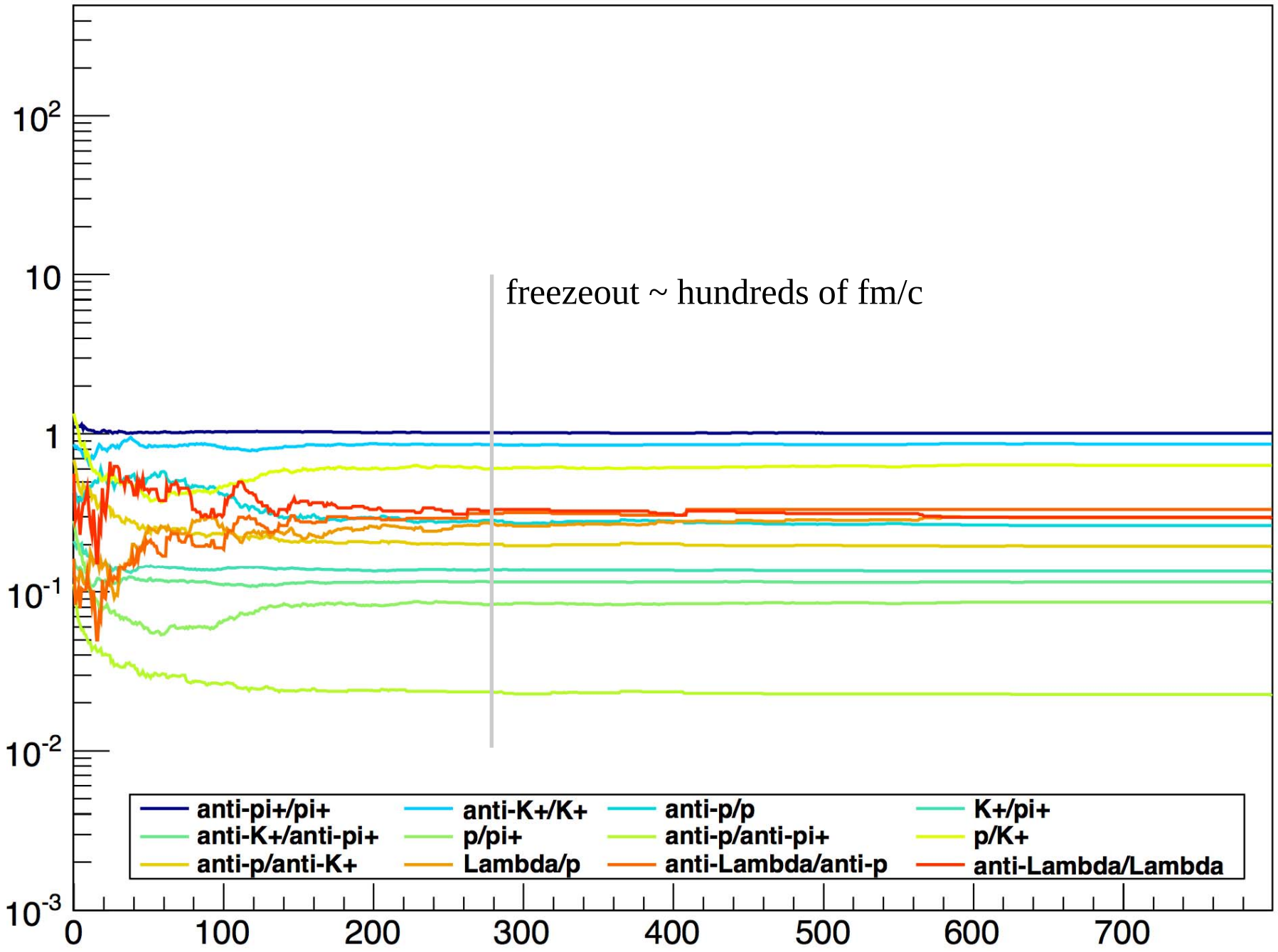
# Example time dependence of the ratios, 19.6 GeV, 0-5%



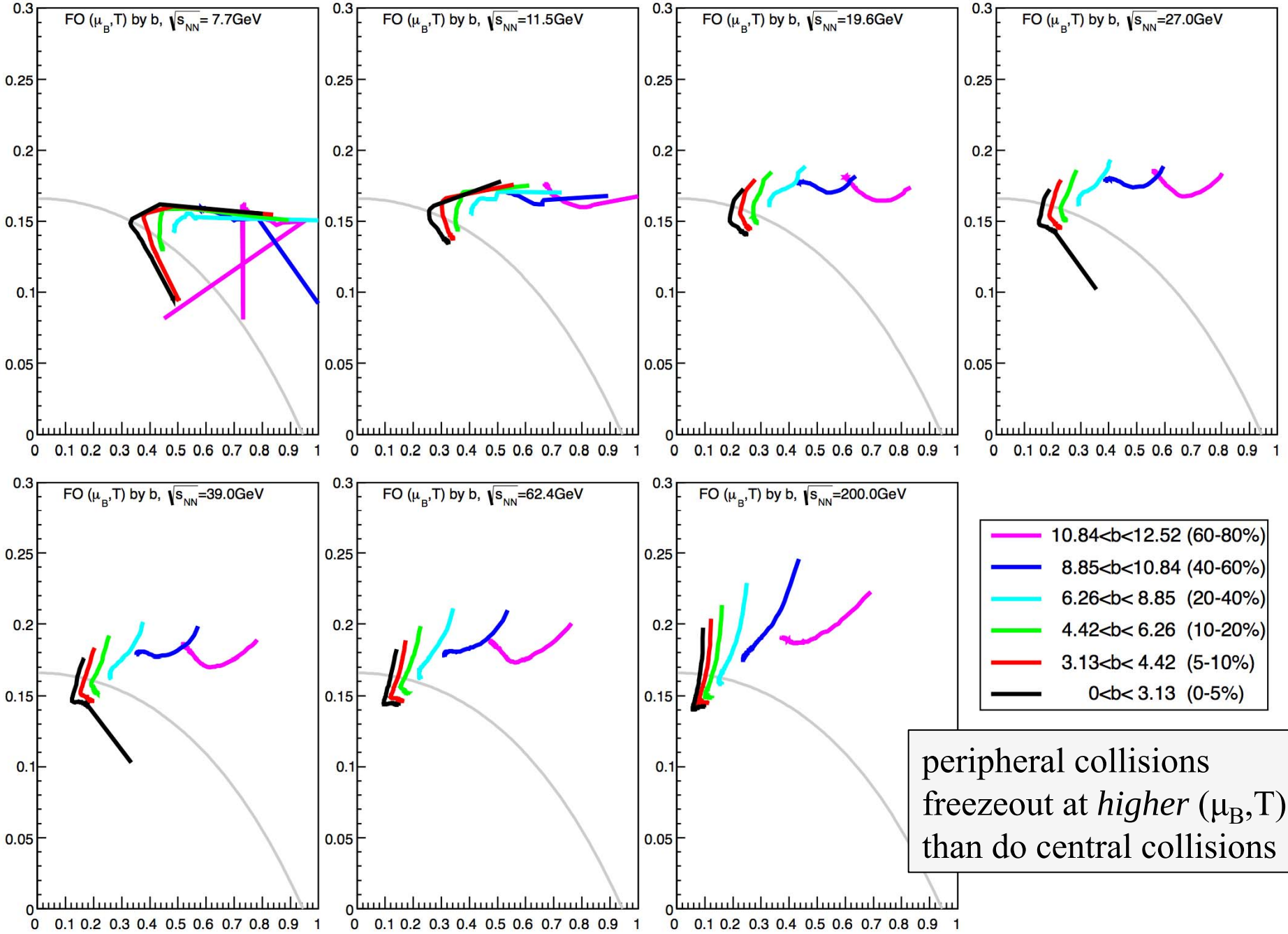
# Example Fits, 200 GeV, 0-5%



# Example time dependence of the ratios, 200 GeV, 0-5%

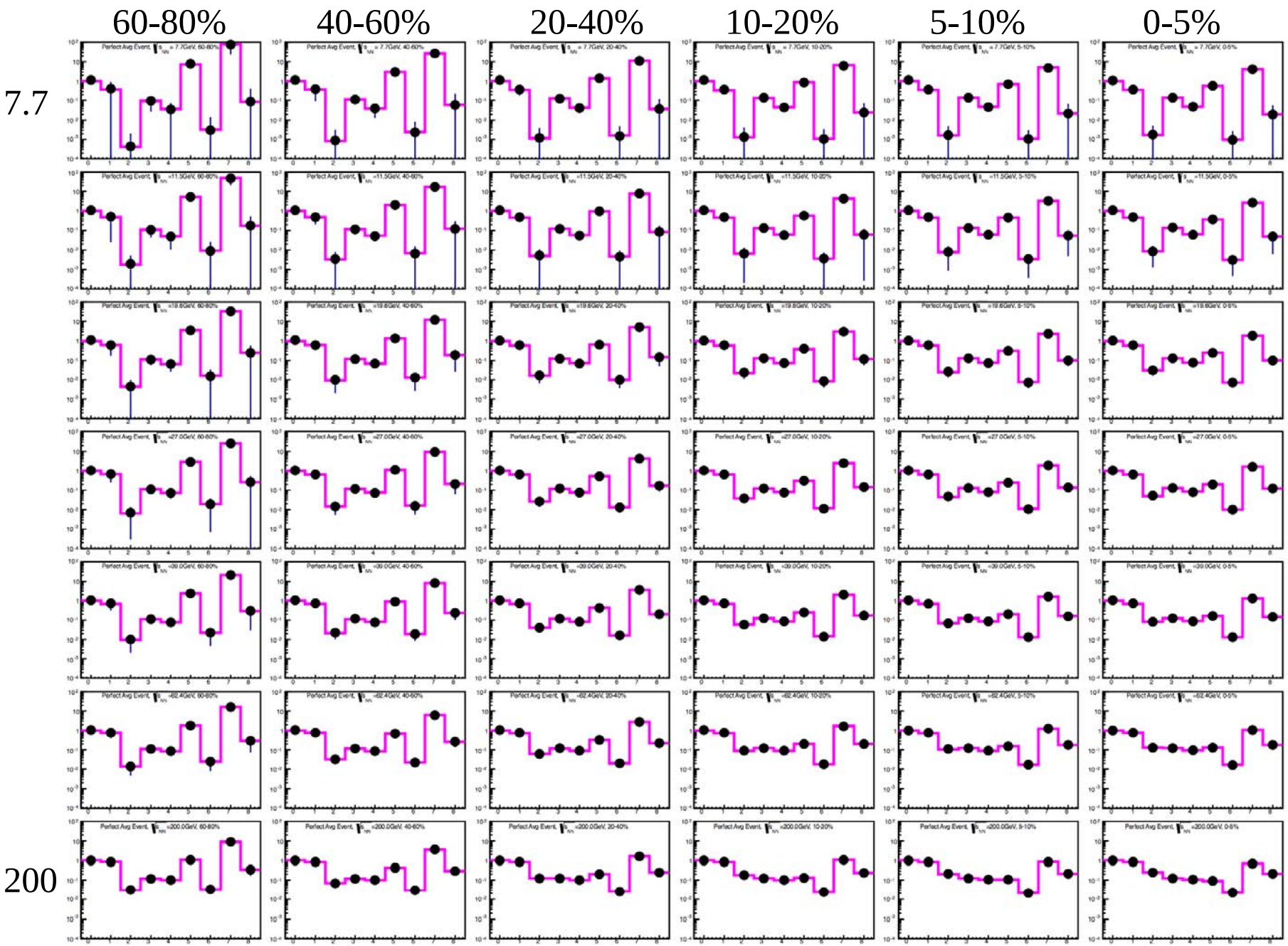


# Time Trajectories of "Average Events"

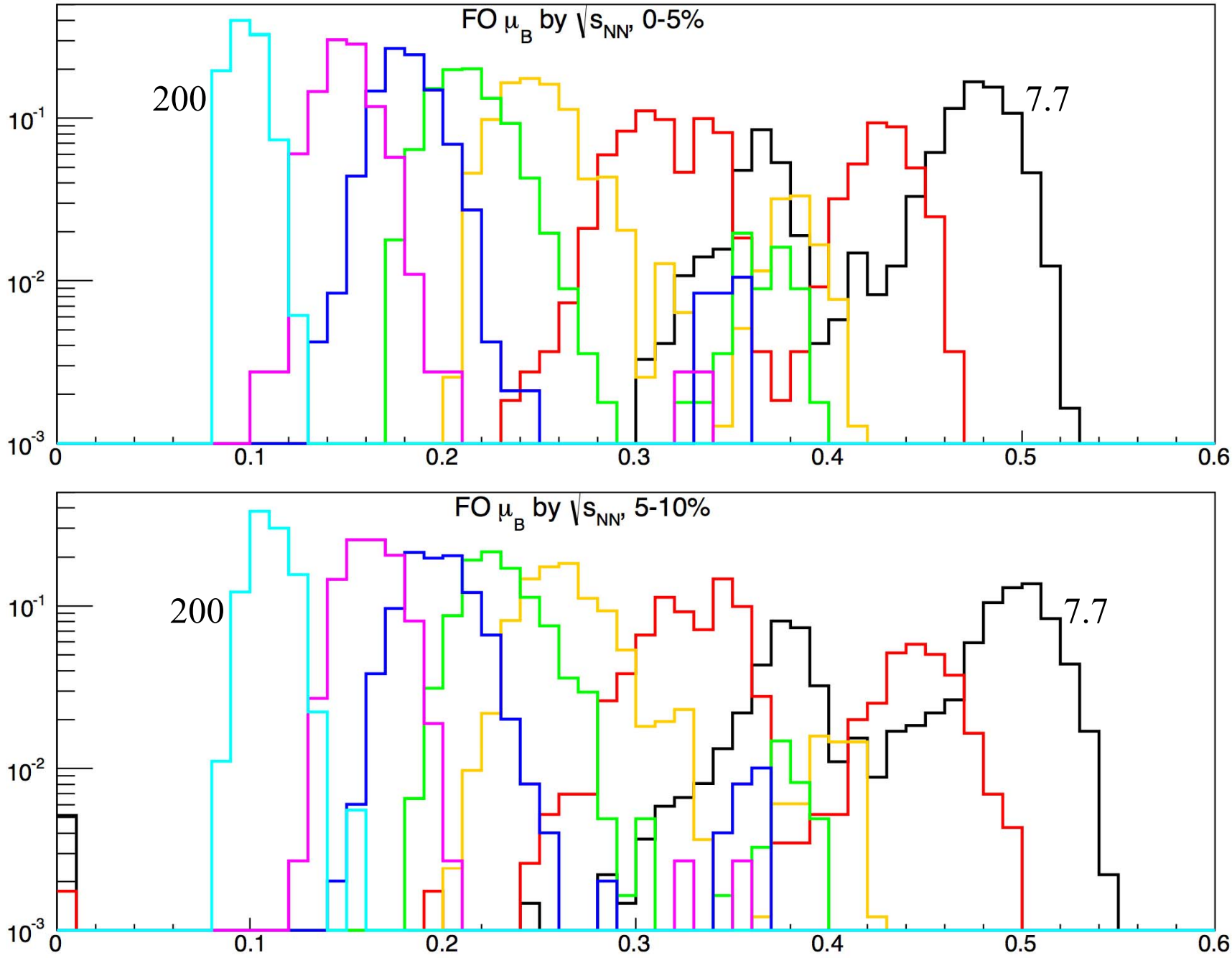



peripheral collisions freezeout at *higher* ($\mu_B$,T) than do central collisions

# Fit Examples, UrQMD by root-s and centrality

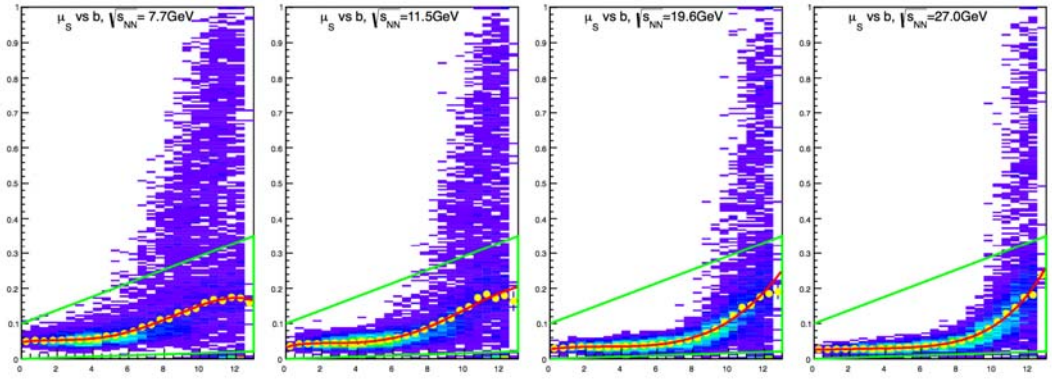


# $\mu_B$ distributions, 0-5% and 5-10% central

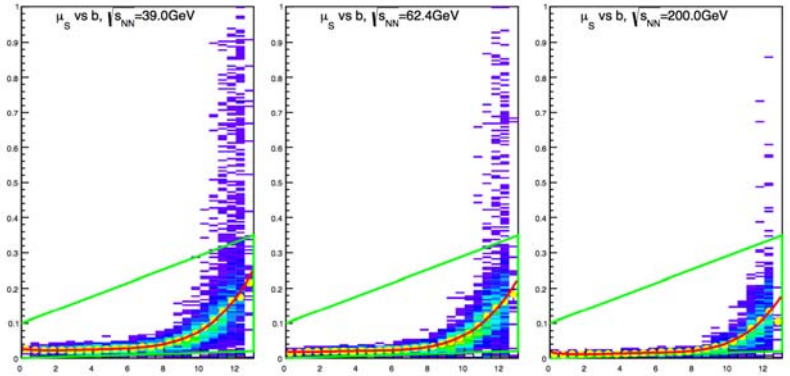


# Constrain $\mu_S$ and $\gamma_S$ and Fit (T, $\mu_B$), GCE

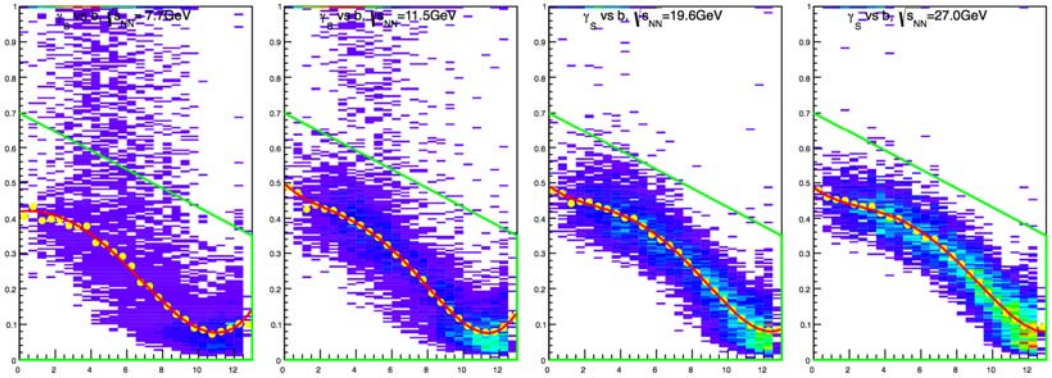
In previously presented slides, (T, $\mu_S$, $\mu_B$, $\gamma_S$) were allowed to vary freely…
Resulted in some events with $\gamma_S$ pegged at 1, and others w/ low values
and two peaks in $\mu_B$ for non-peripheral collisions at low root-s

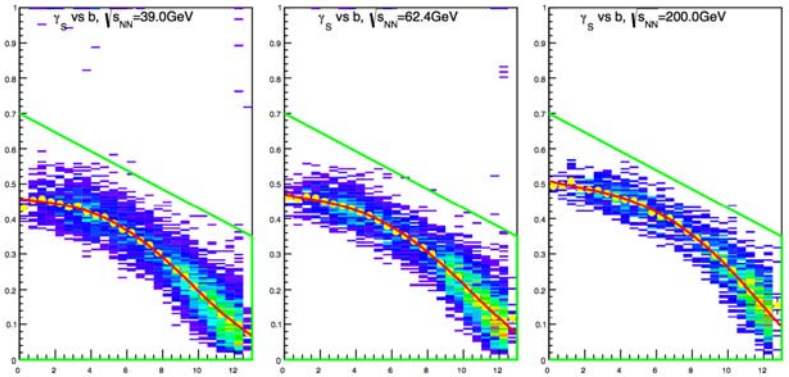



$\mu_S$ *vs* b and root-s from 4 par fits



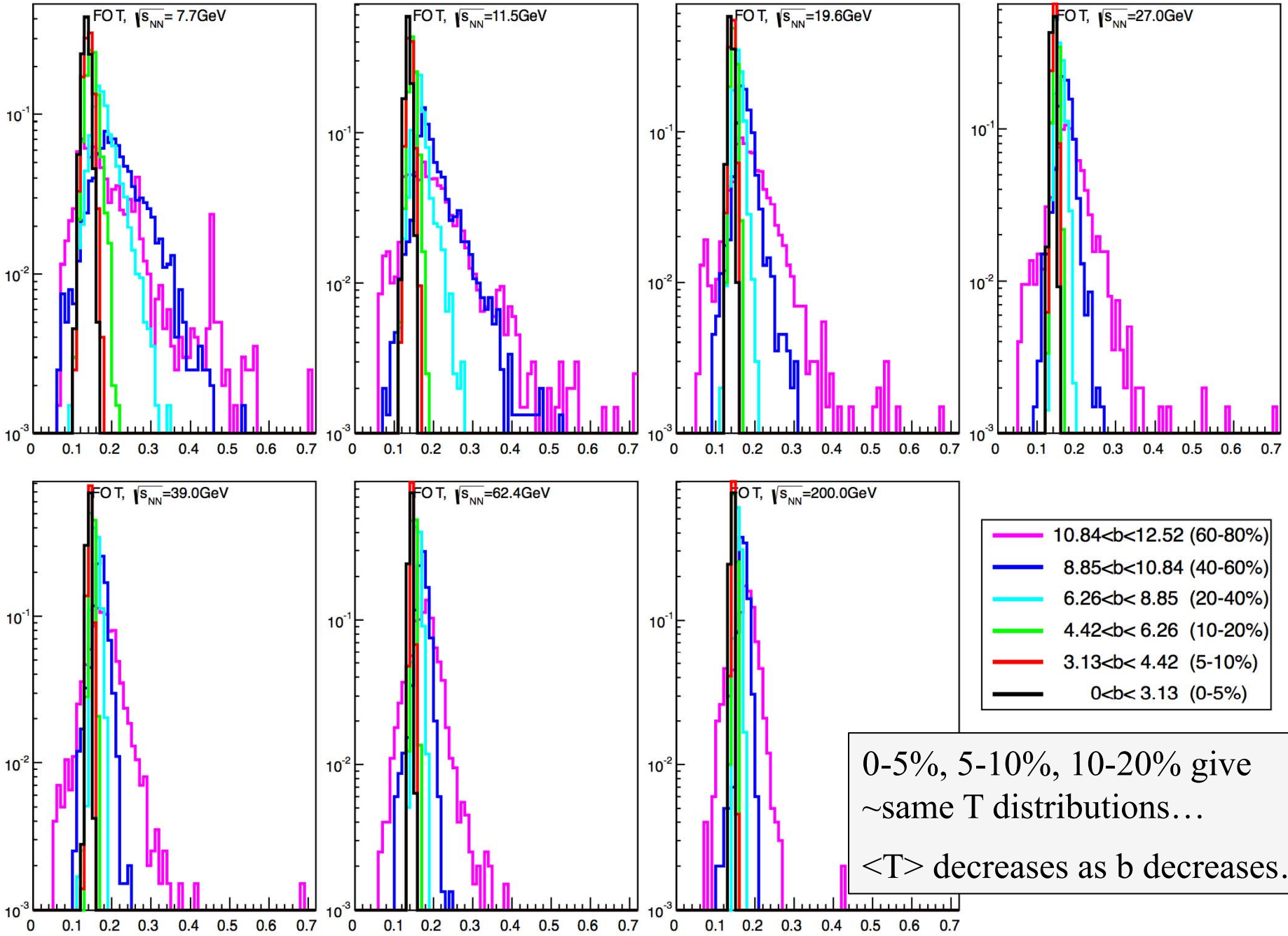

$\gamma_S$ *vs* b and root-s from 4 par fits




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

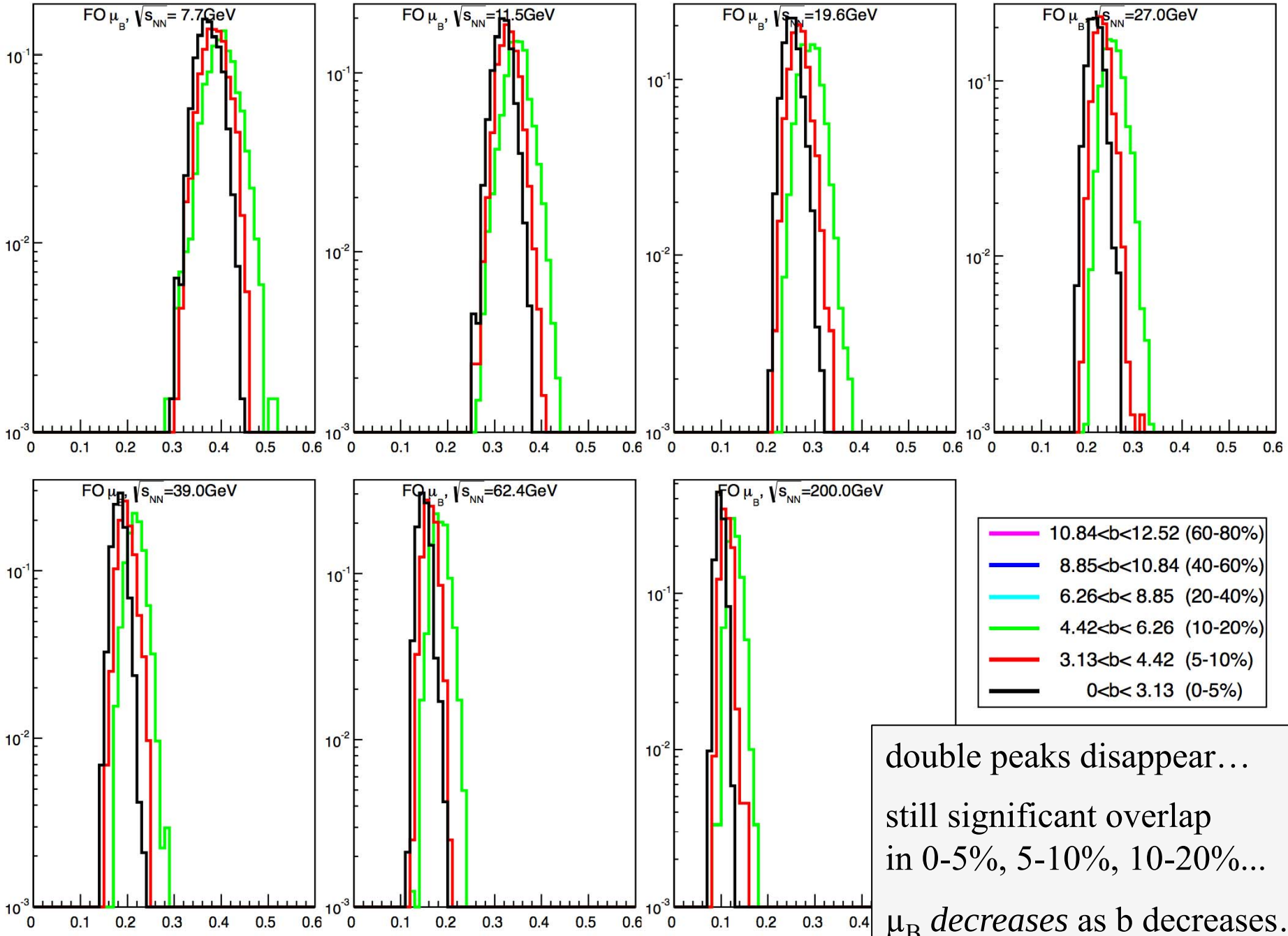
# Constrain $\mu_S$ and $\gamma_S$ and Fit (T, $\mu_B$), GCE




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

<T> decreases as b decreases…

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

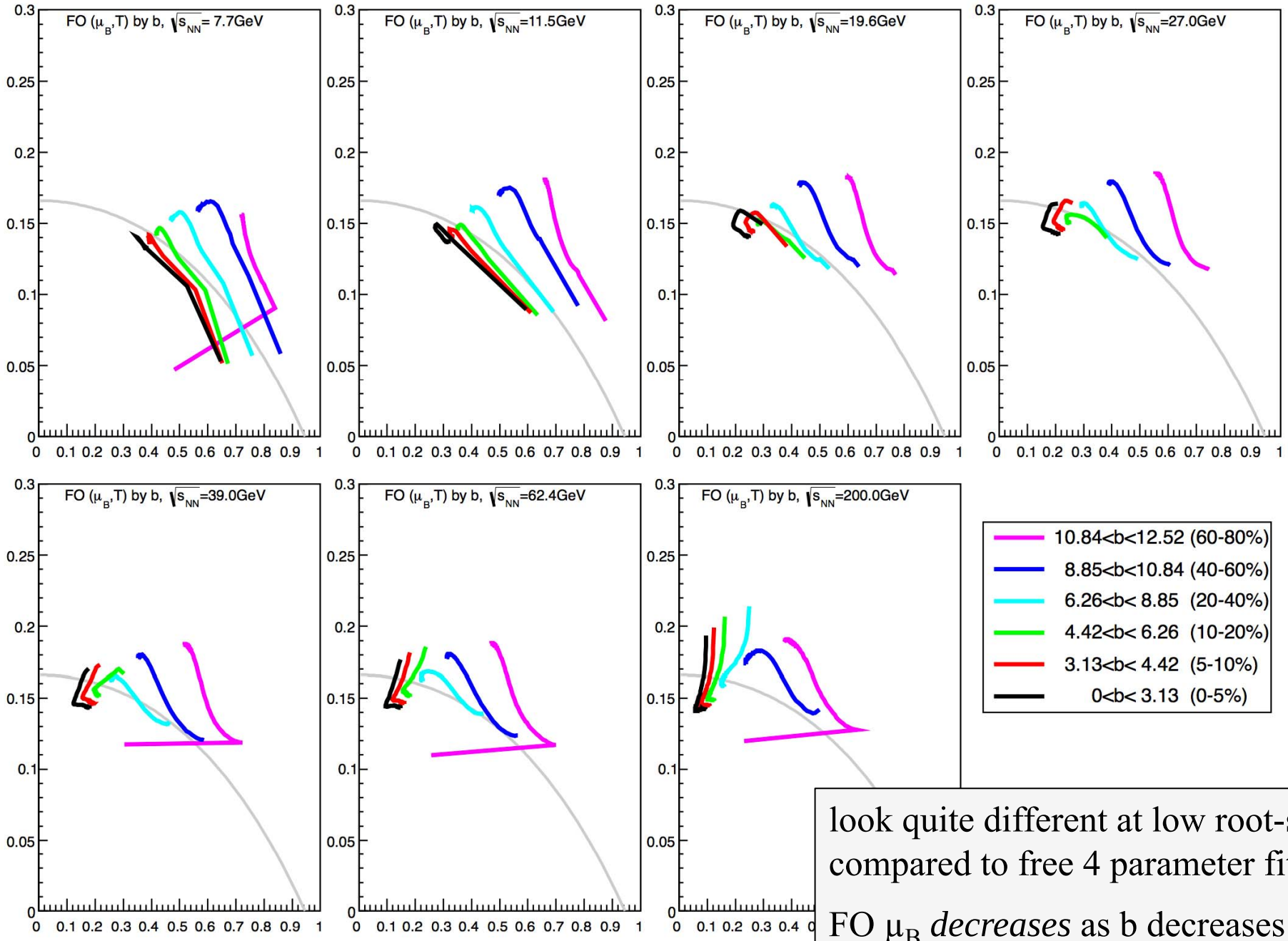



double peaks disappear…

still significant overlap
in 0-5%, 5-10%, 10-20%...

$\mu_B$ *decreases* as b decreases…

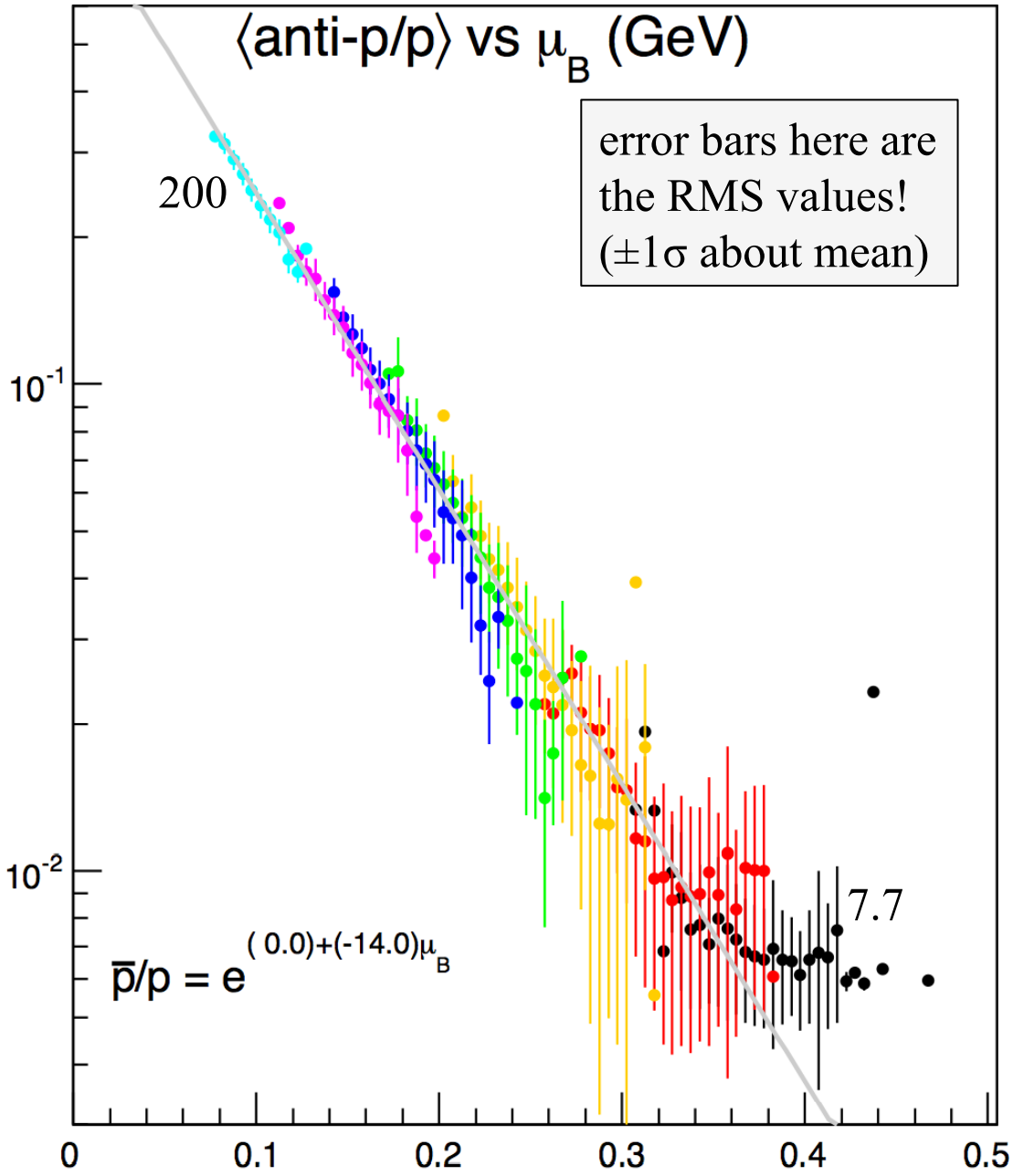
# Constrain $\mu_S$ and $\gamma_S$ and Fit (T, $\mu_B$), GCE, Event-Avg Trajectories




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

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

# 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 pbar and p multiplicities

pbar/p = $\exp(-2\mu_B/T)$
2/T~14, T~130 MeV

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

Significant overlap in $\mu_B$ distributions from different root-s values even in 0-5% central collisions

Use pbar/p to gate moments analyses

Need a new "baseline" though due to finite number counting stats...

For N non-zero yields, one can form $\sum_{i=1}^{i<N} i$ ratios…

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

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

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

Evan's simulation:

how probable is it to measure **b** if normal distributed with means **m** and covariance C.

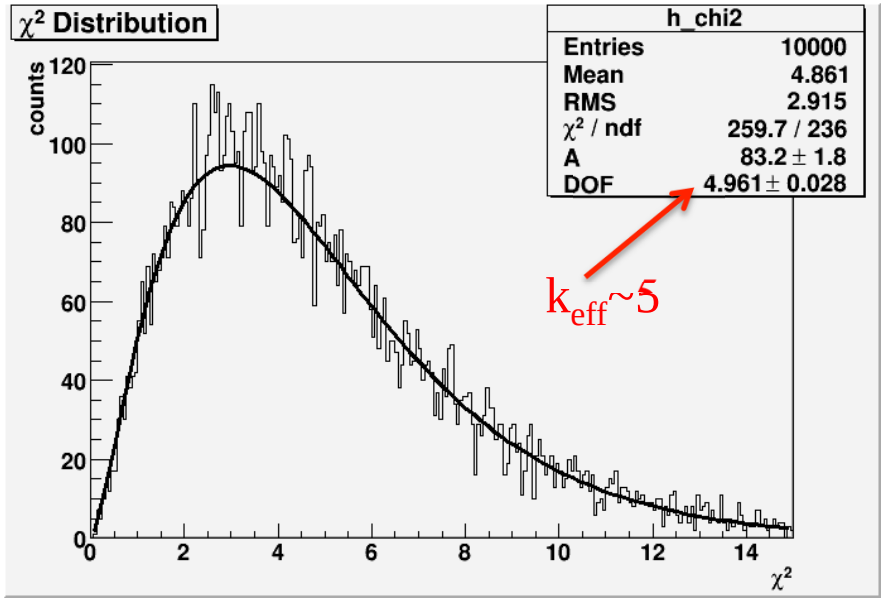
$(\mathbf{b}-\mathbf{m})^T C^{-1} (\mathbf{b}-\mathbf{m})$ is $\chi^2$ distributed with k DOF

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

only yields….

k=5 measurements are independent

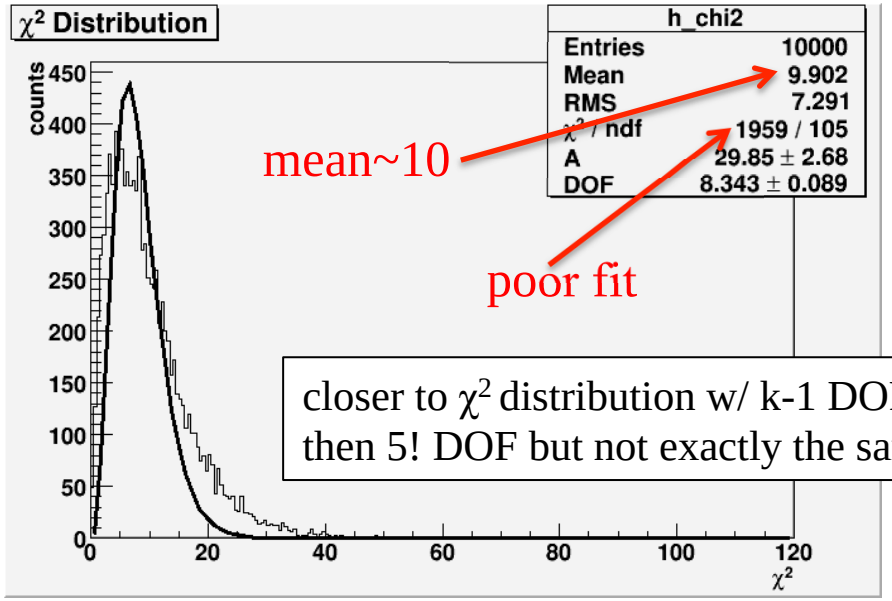
plot diagonal-only $\chi^2$ sum




all ratios….

plot diagonal-only $\chi^2$ sum for 5! ratios

…mean~10, k-1<mean<5!




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

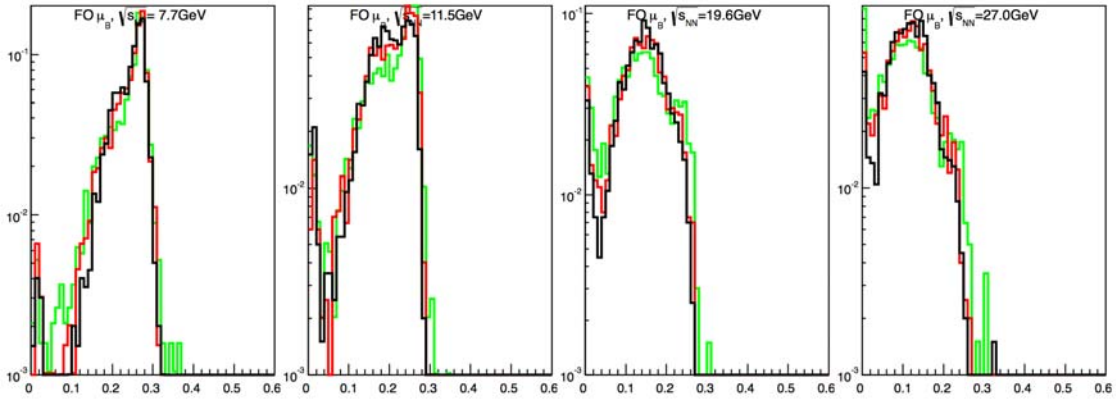
AFAIK, our data is not consistent with either case

- 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

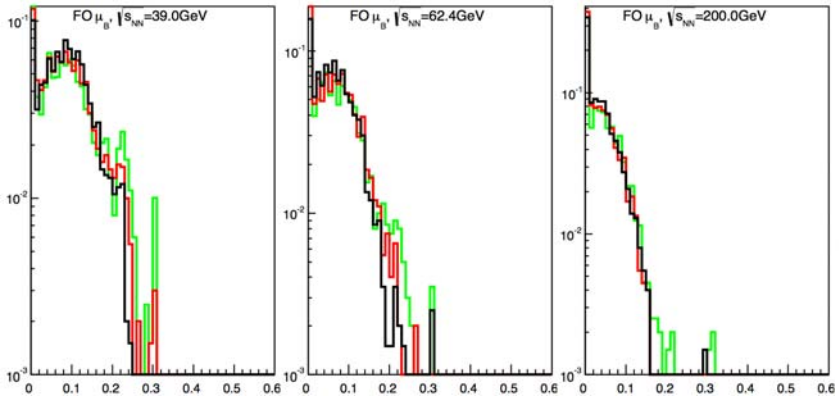
…I'll just run Thermus in both modes and will provide both sets of results…

## $\mu_B$ from data+Thermus fits: 0-5%, 5-10%, and 10-20% centrality only

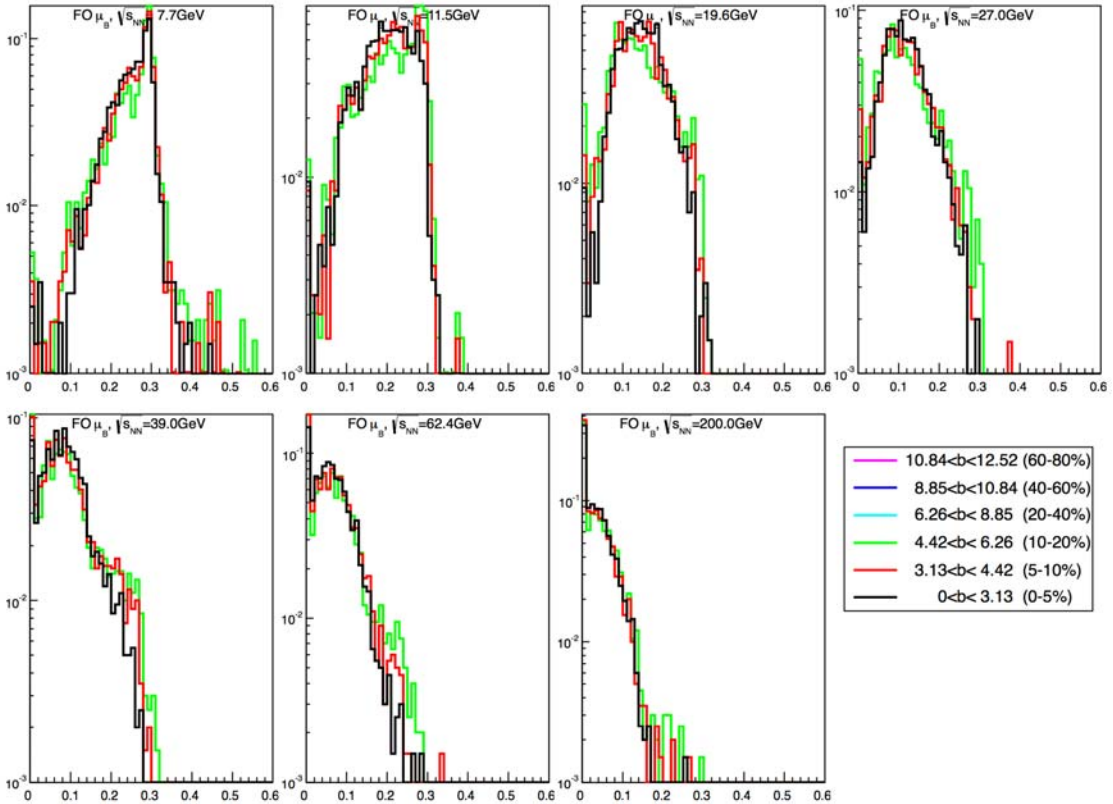
Here, using 4 parameter fits – which look fine in general – non-zero ratios are reproduced…




DK off (zero feeddown)



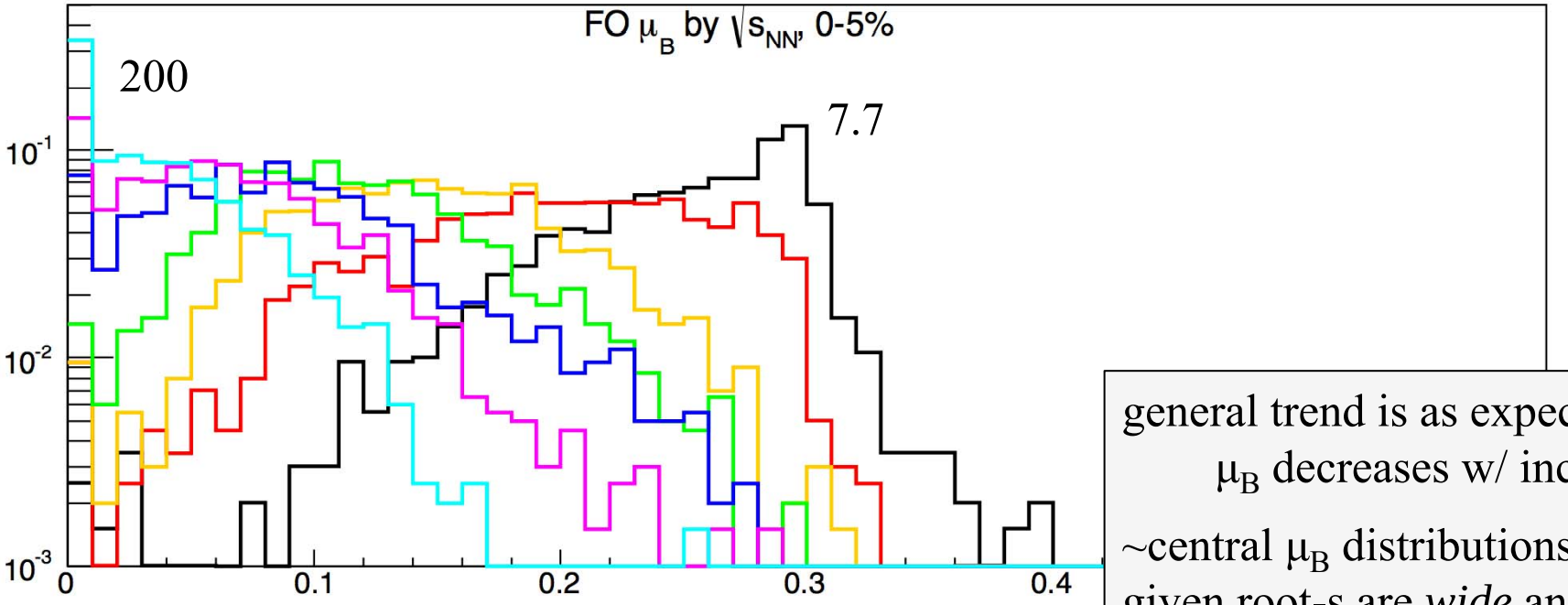

DK on (complete feeddown)

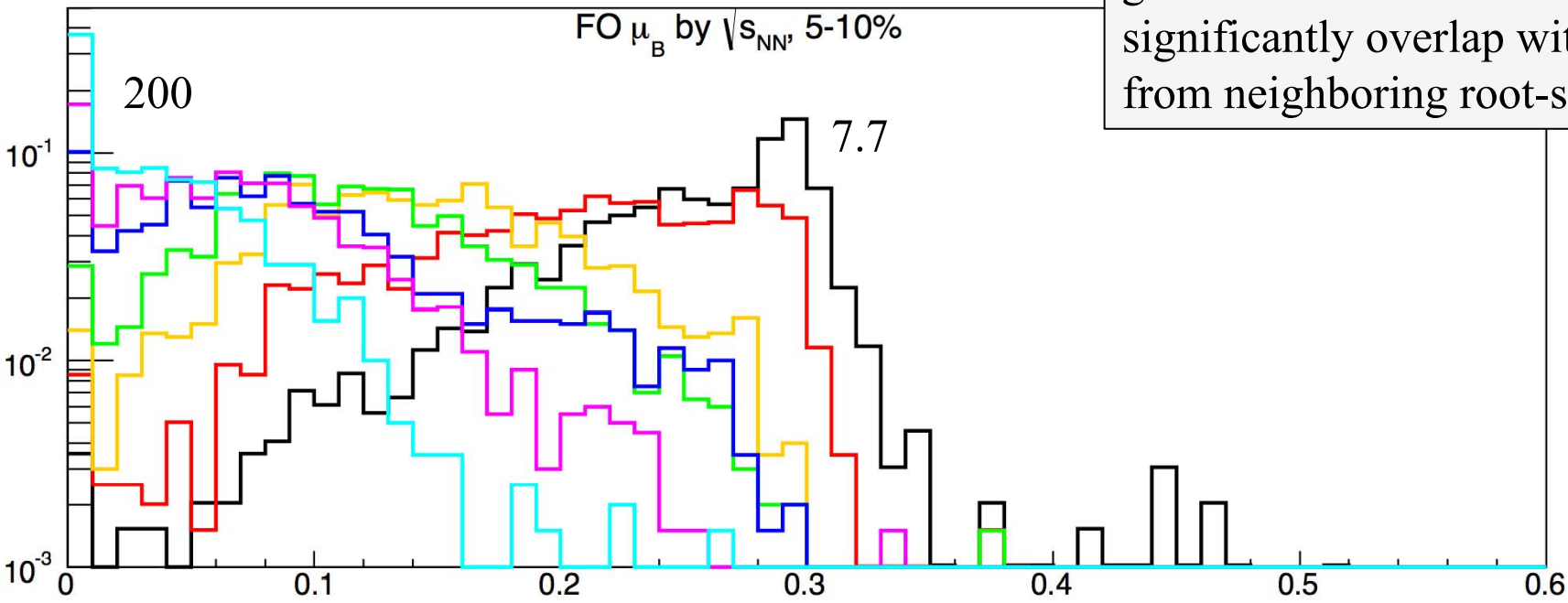



general trend is as expected
$\mu_B$ decreases w/ increasing root-s

essentially no difference between
0-5%, 5-10%, and 10-20%

# $\mu_B$ from data+Thermus fits, Complete feeddown

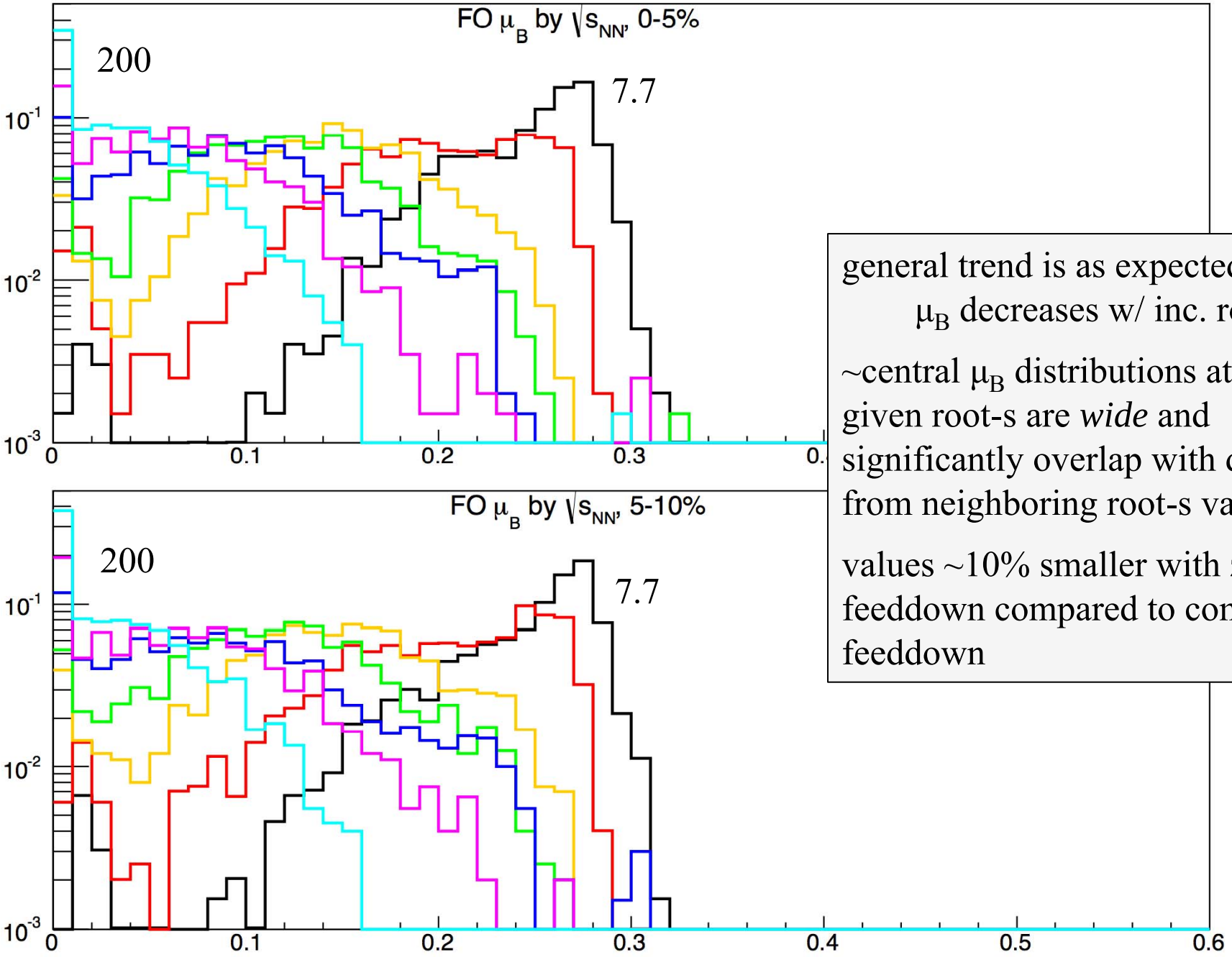



general trend is as expected
$\mu_B$ decreases w/ inc. root-s

~central $\mu_B$ distributions at a given root-s are *wide* and significantly overlap with data from neighboring root-s values

# $\mu_B$ from data+Thermus fits, Zero feeddown

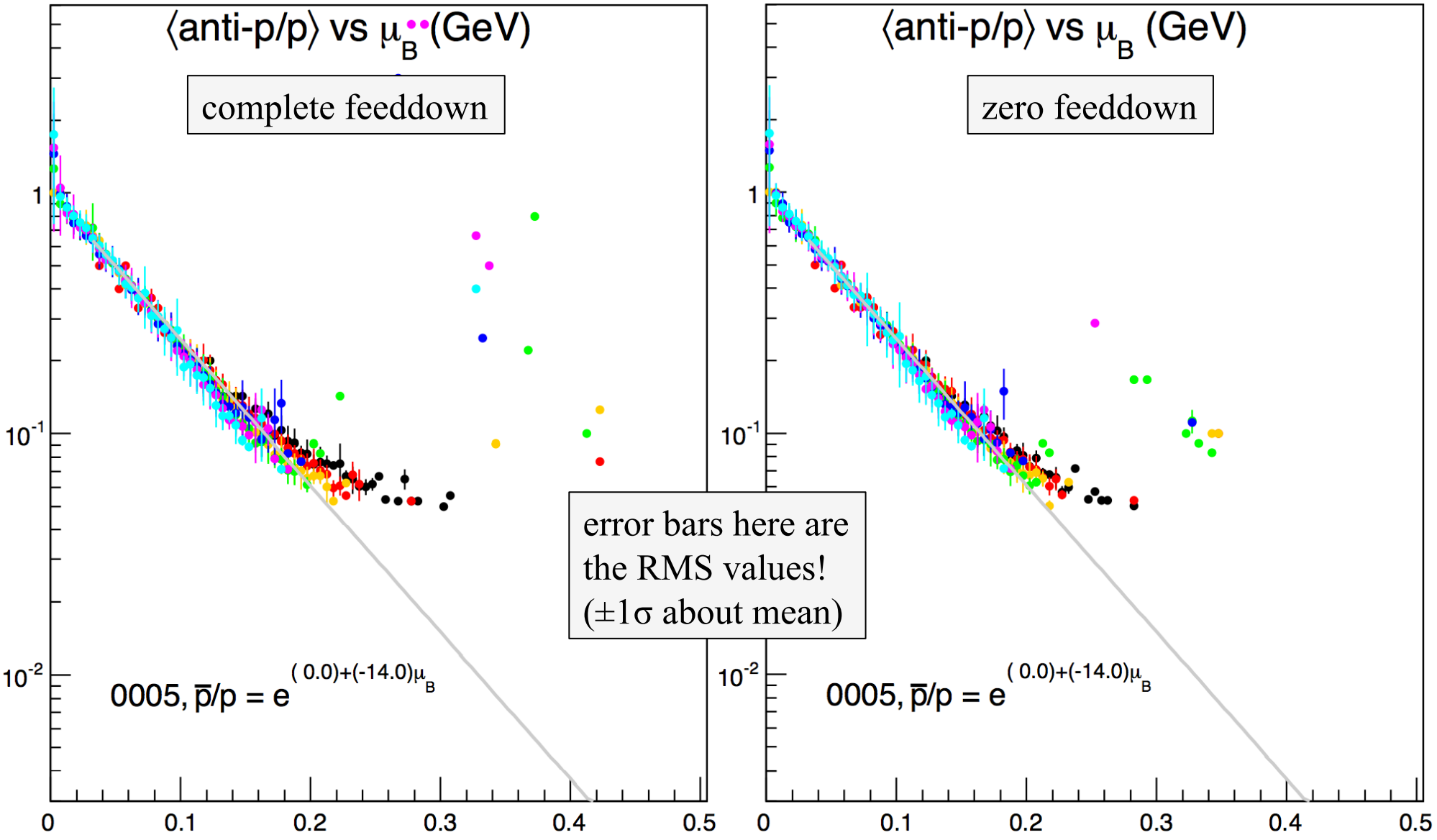



general trend is as expected
$\mu_B$ decreases w/ inc. root-s

~central $\mu_B$ 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




…same pbar/p=exp(-14$\mu_B$) trend is seen when fitting the yields from the experimental data…

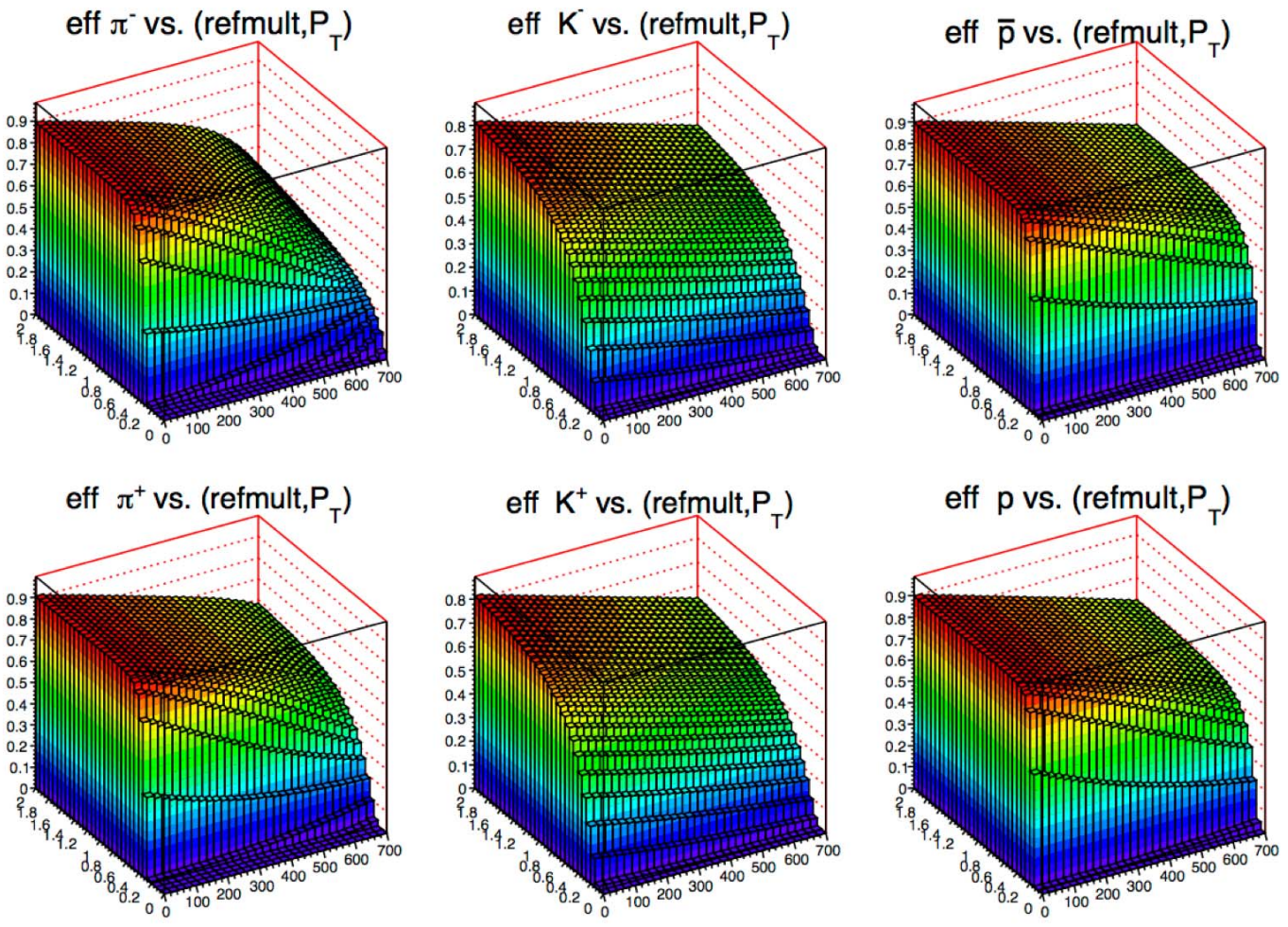
# Filtered UrQMD+Thermus simulations…

Apply “STAR” acceptance & efficiency filter to UrQMD

Compare perfect, 4π, participant-only simulation results to those we 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)

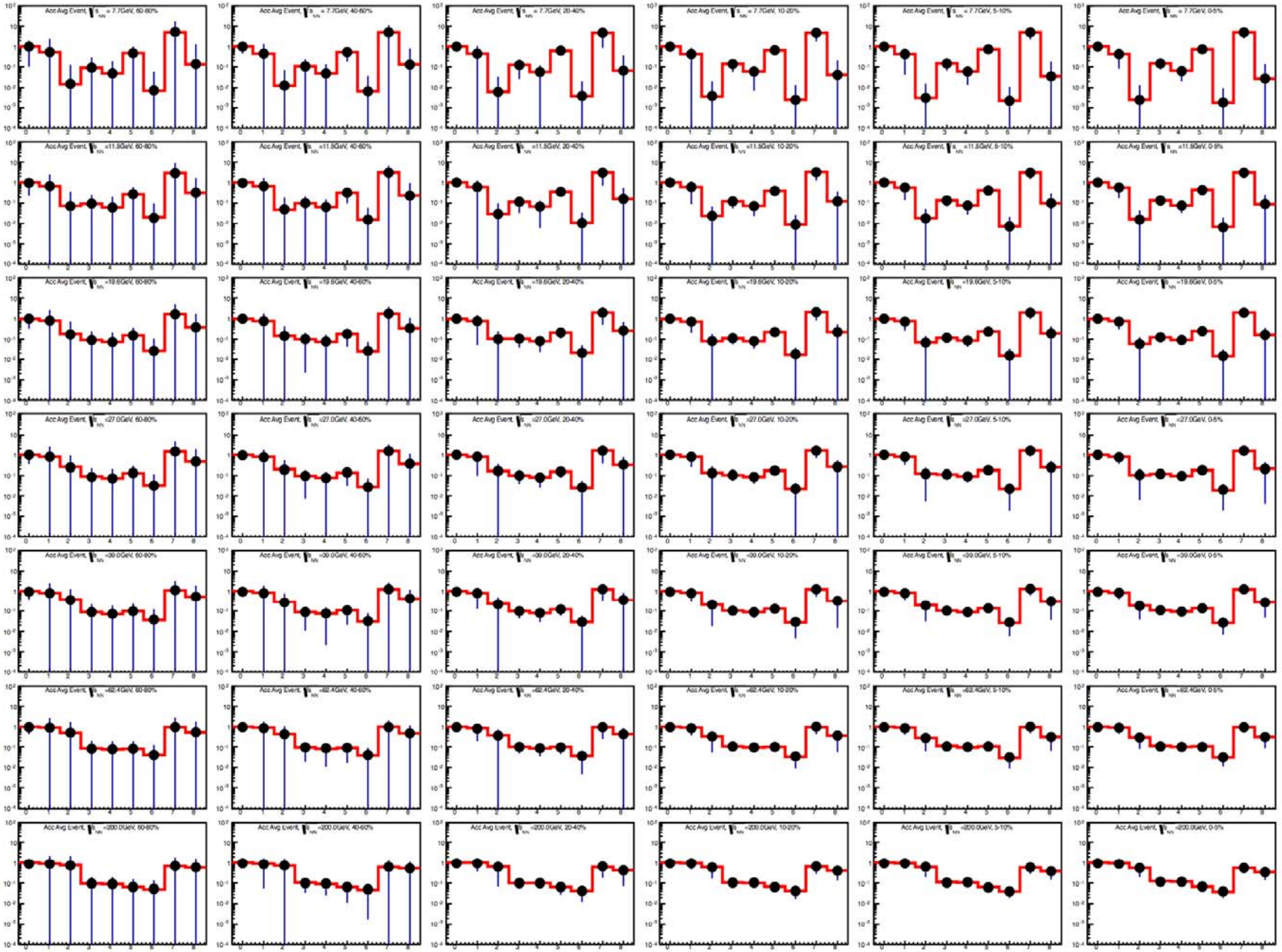


# Fit Examples, UrQMD by root-s and centrality, Acceptance Filtered

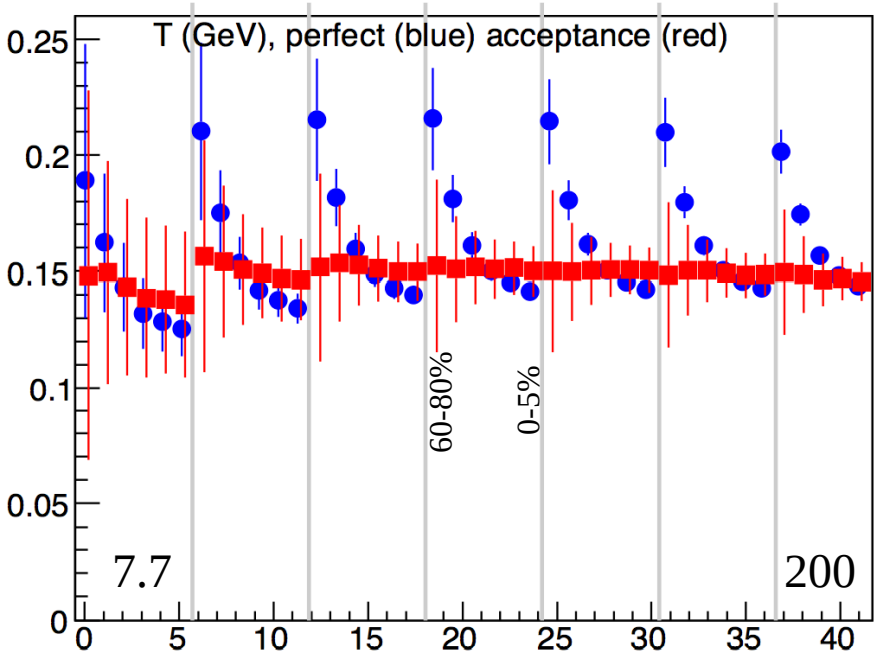
60-80% 40-60% 20-40% 10-20% 5-10% 0-5%

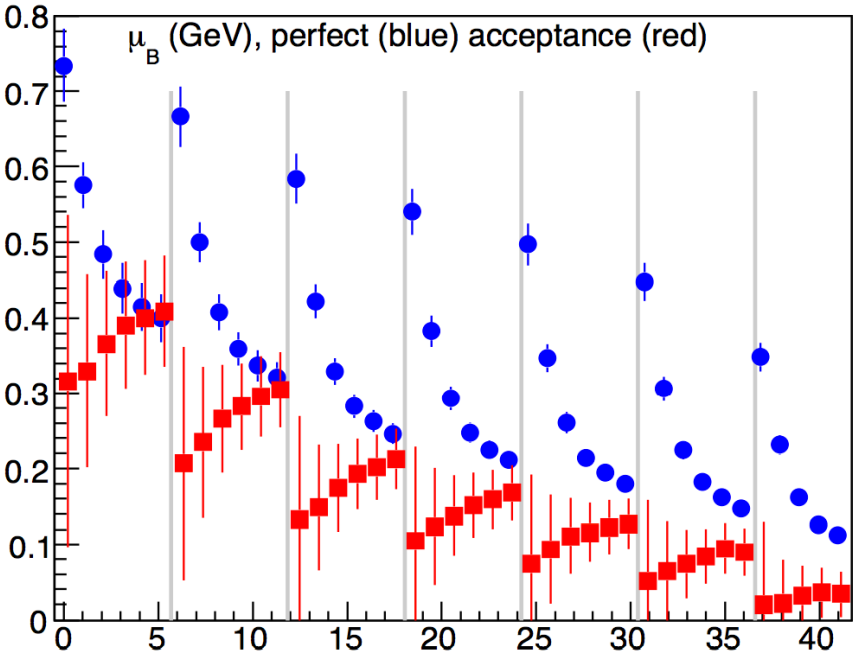
7.7

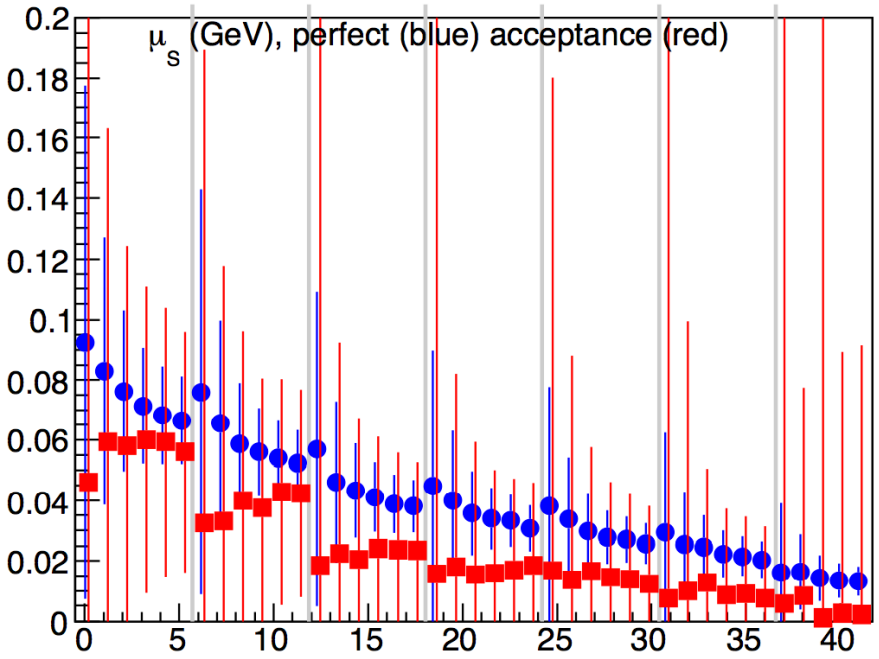
200

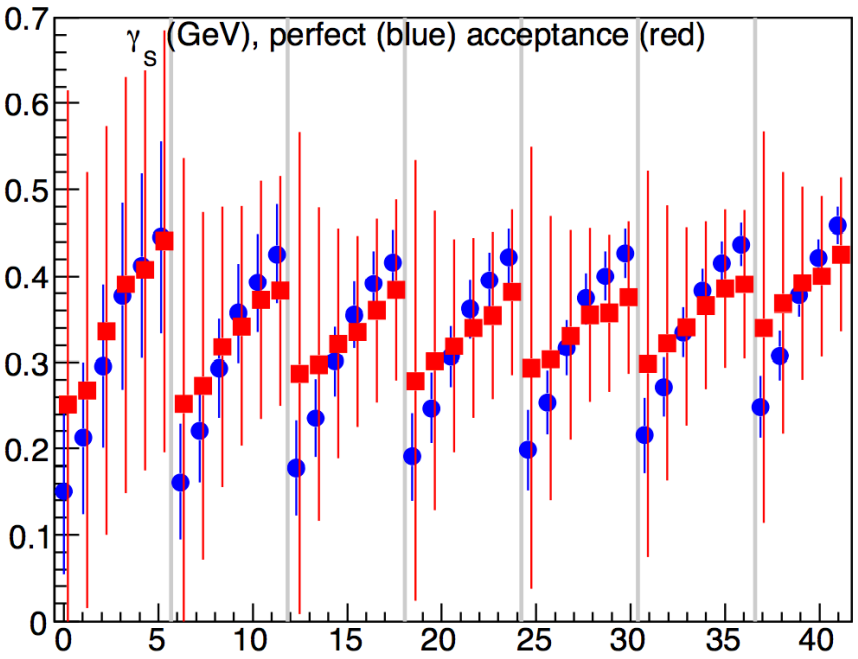


# Effect of Acceptance on TD pars in UrQMD events



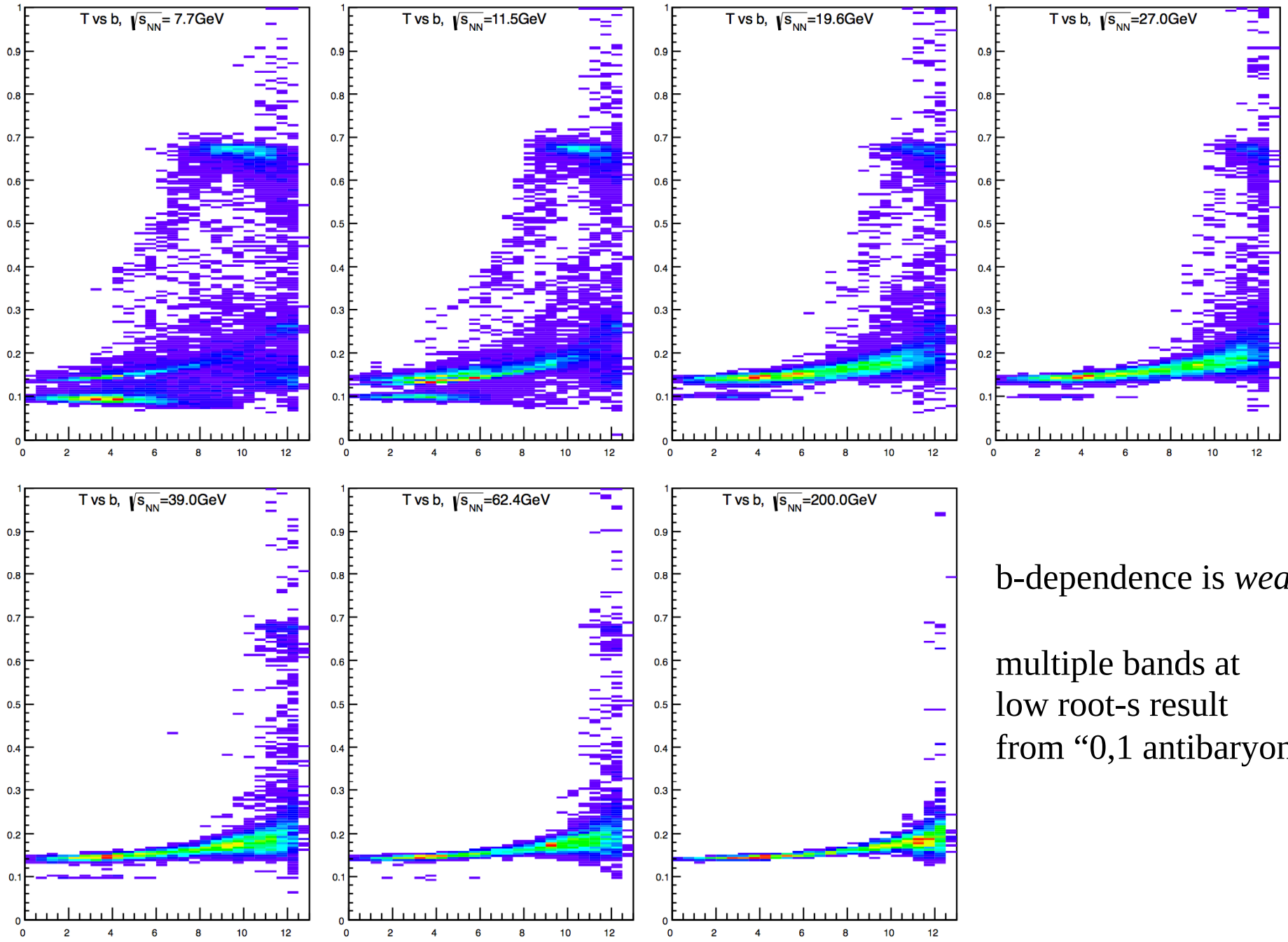



# ~~ backup ~~

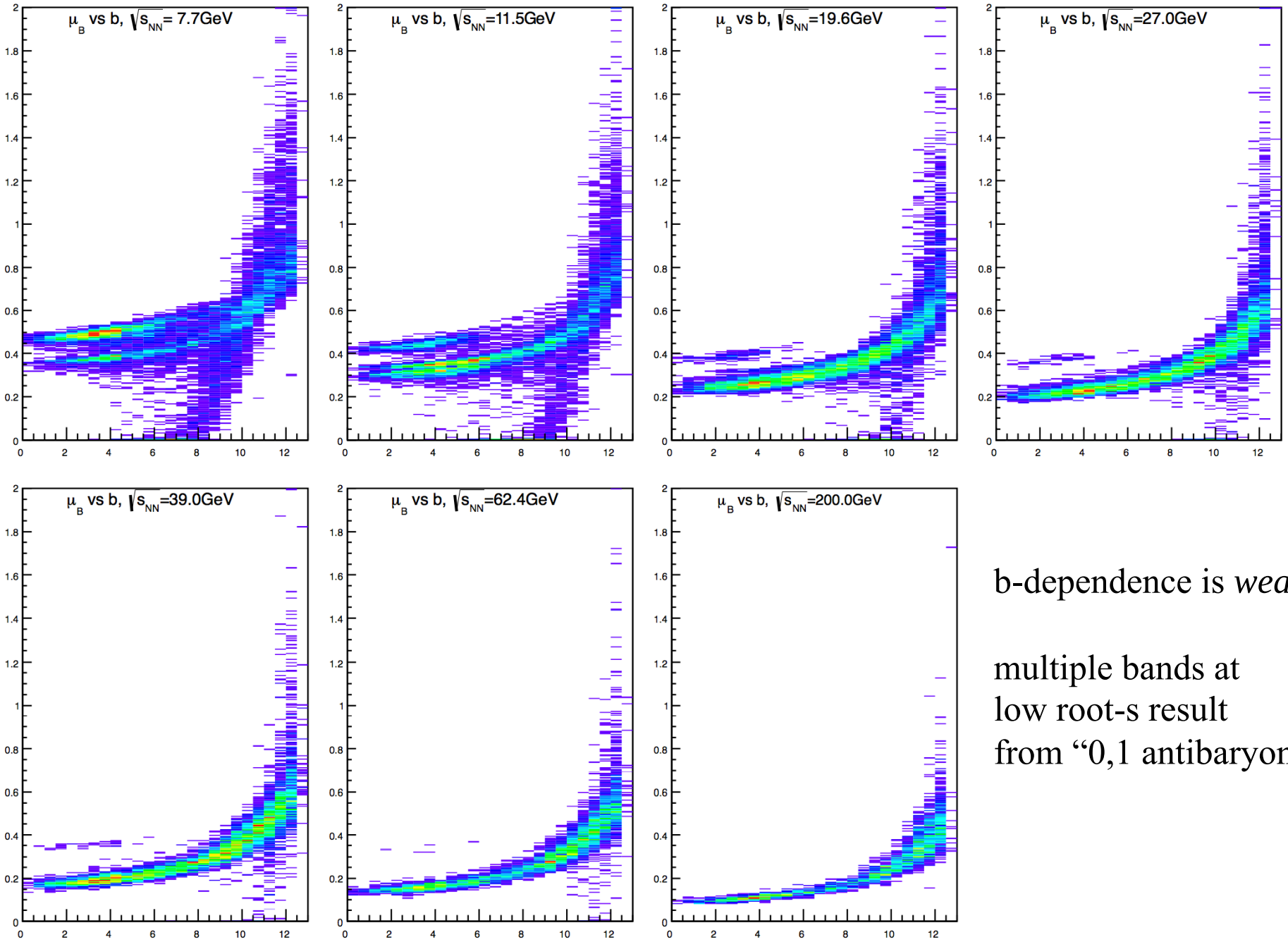
# Centrality dependence of T




b-dependence is *weak*

multiple bands at
low root-s result
from “0,1 antibaryon”

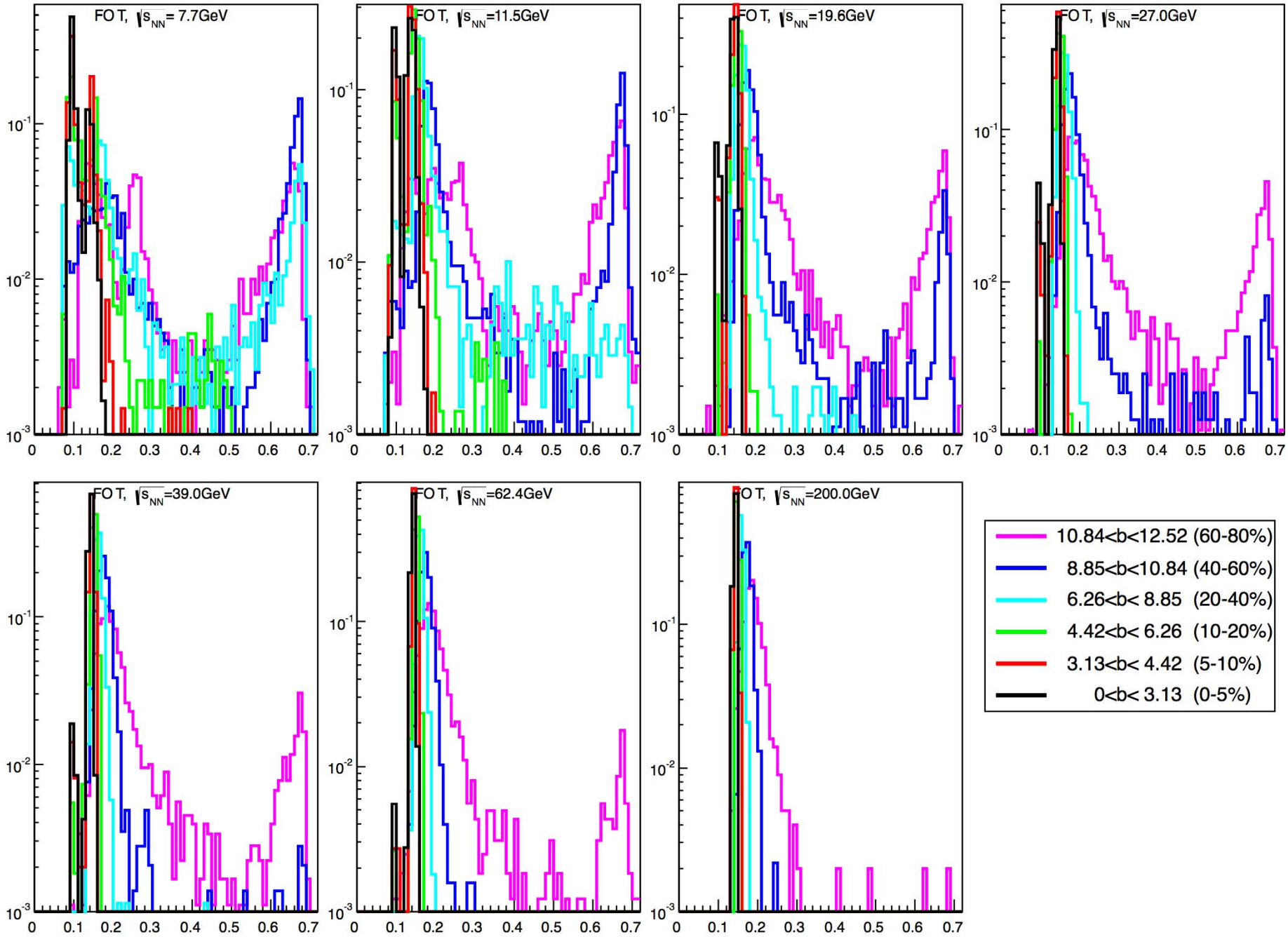
# Centrality dependence of $\mu_B$




b-dependence is *weak*

multiple bands at
low root-s result
from "0,1 antibaryon"

# 1D T distributions by centrality bin



# 1D $\mu_B$ distributions by centrality bin