UrQMD+Thermus

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Motivation:

-- lfspectra analyses show a centrality dependence of (<μ_B>,<T>)…
Using the GCE, central collisions freeze out at higher (<μ_B>,<T>) values than do peripheral collisions.

why?
can a transport model calculation reproduce this?
SCE vs GCE?

-- CP search via moments analyses tacitly assumes that centrality selection alone tightly constrains (μ_B,T) in that sample of events.

is this true?
what is the variance of the E-by-E (μ_B,T) values in single centrality bins
is, *e.g.*, 0-5% significantly different than 5-10% in terms of (μ_B,T) values?

…Couple Thermus to UrQMD and see what comes out…

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

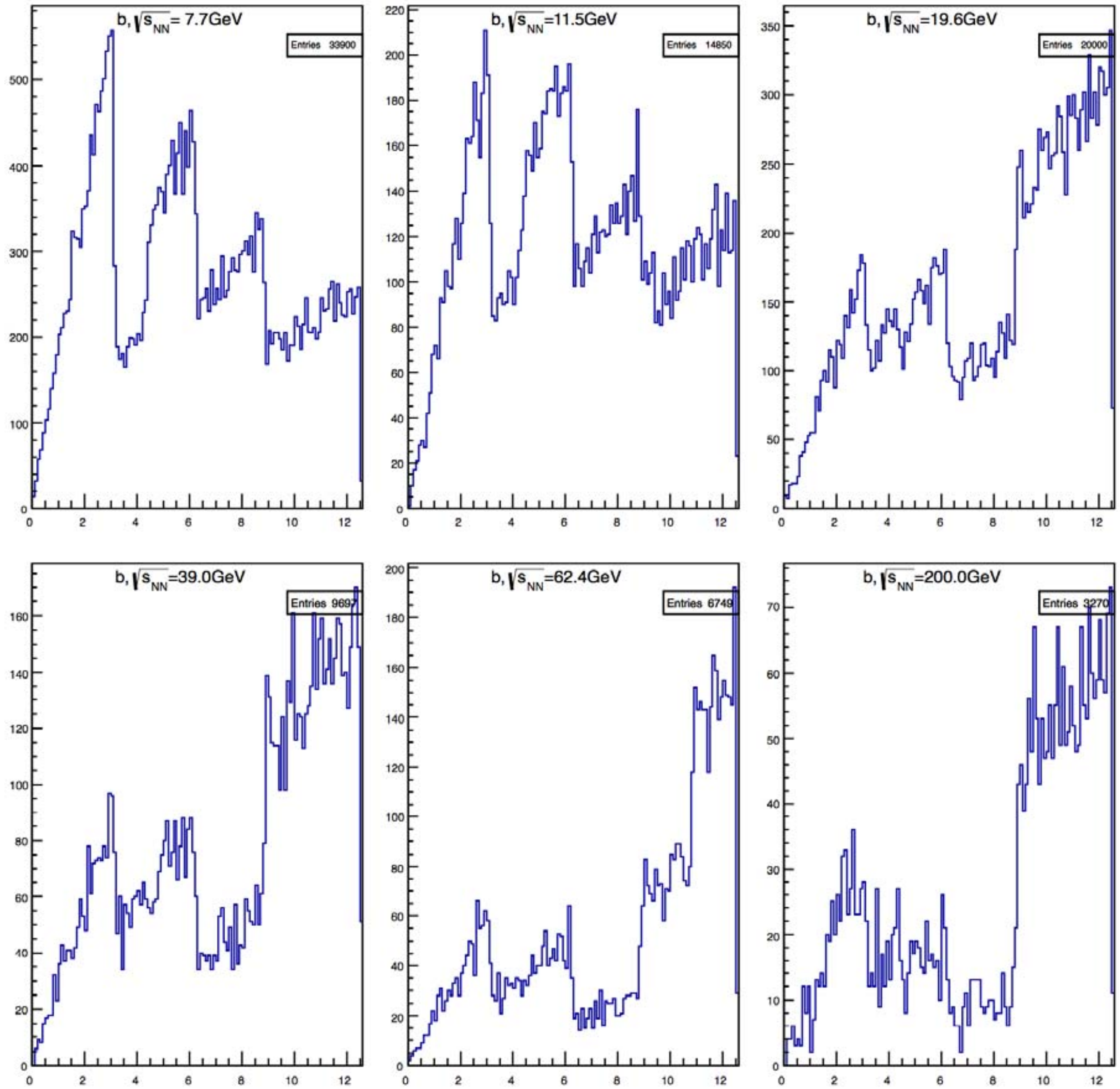
- Standalone application that reads the UrQMD files and
  - fits the multiplicity ratios in every timestep in every event
- Grand Canonical Ensemble, fit parameters: (T, μ_B, μ_S, γ_S)
- 12 ratios considered ($\pi\pm$, $K\pm$, $p\pm$, $\Lambda\pm$)
- Mult errors in each time step & evt taken as Poisson ($\sim\sqrt{N}$) – 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 (μ_B,T) space
- plot the trajectories of averaged events in (μ_B,T) space
- plot the distributions of (T, μ_B, μ_S, γ_S) in centrality-selected events

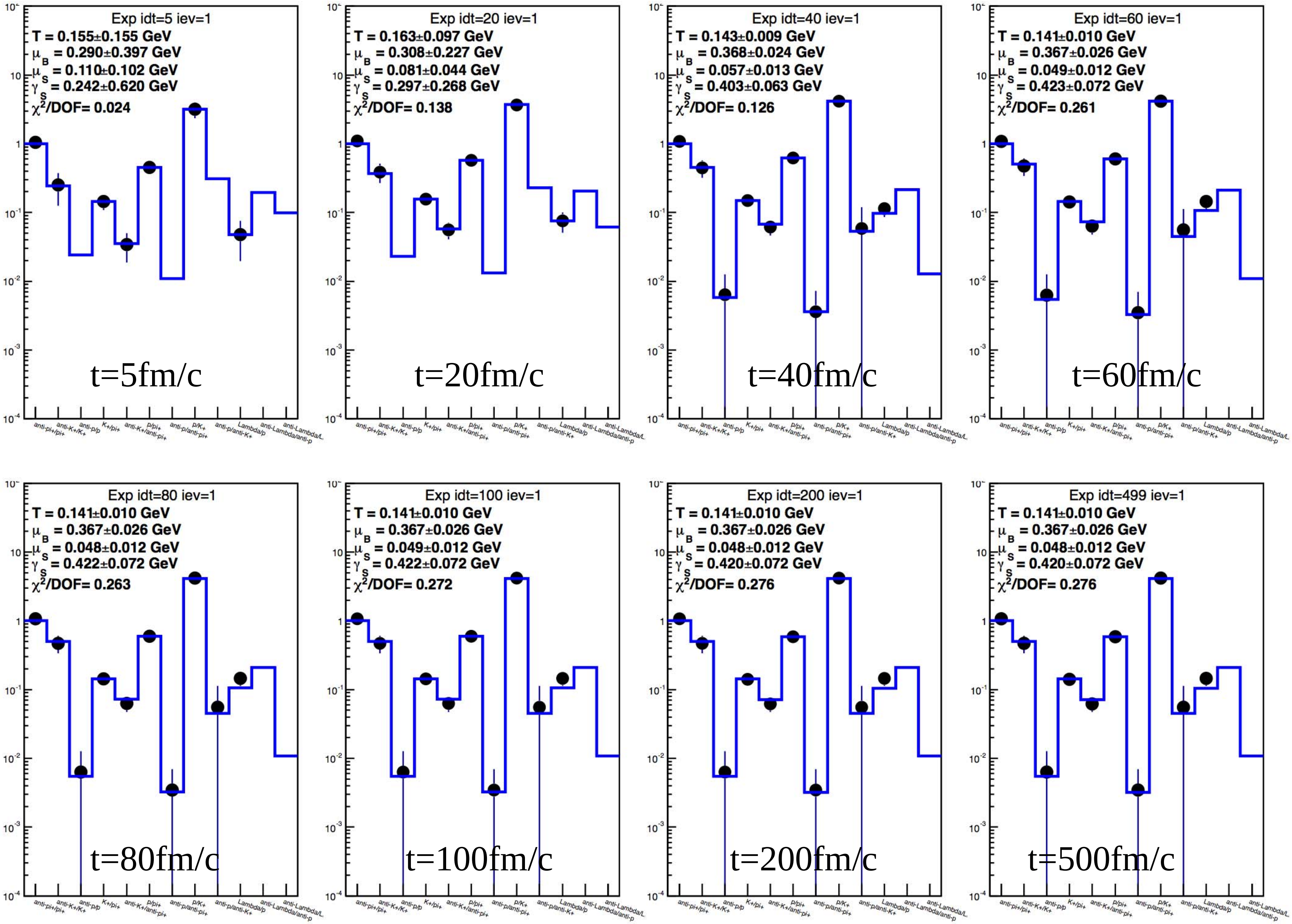
Impact Parameters

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 CPU…
Few 100 to few 1000 evts in each root-s and centrality bin…

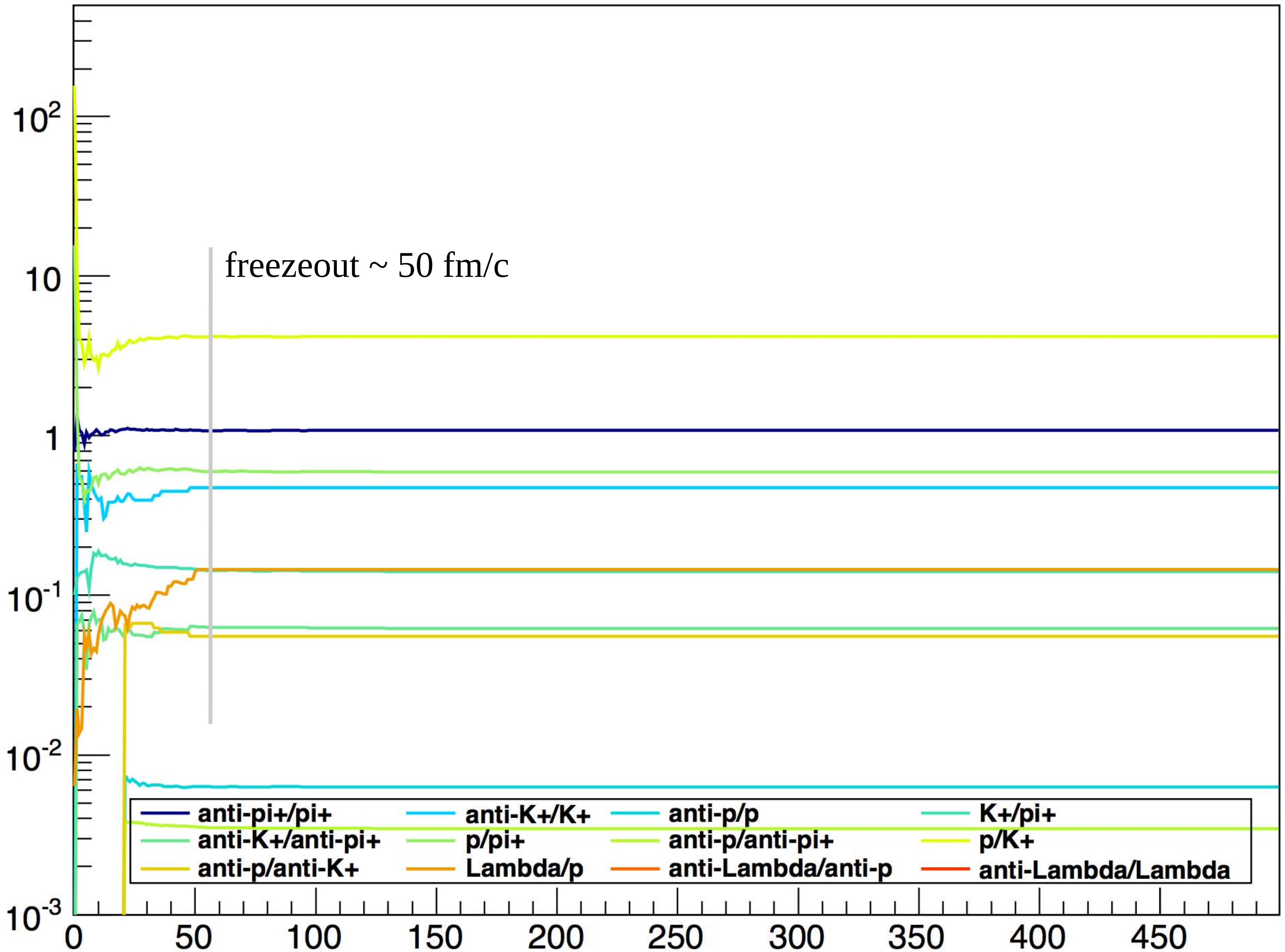


10.84<b<12.52 (60-80%)
8.85<b<10.84 (40-60%)
6.26<b< 8.85 (20-40%)
4.42<b< 6.26 (10-20%)
3.13<b< 4.42 (5-10%)
0<b< 3.13 (0-5%)

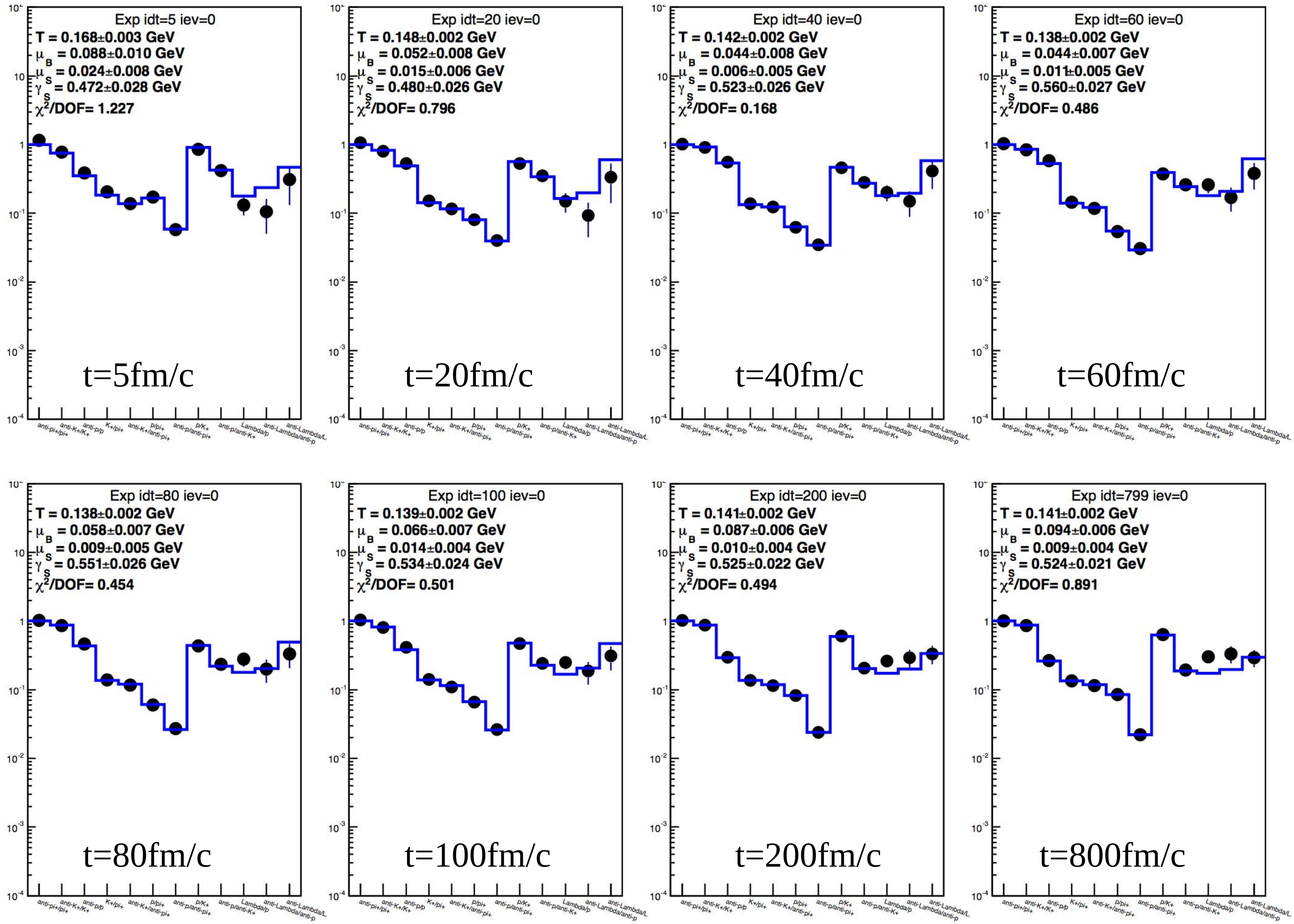
Example Fits, 19.6 GeV, 0-5%



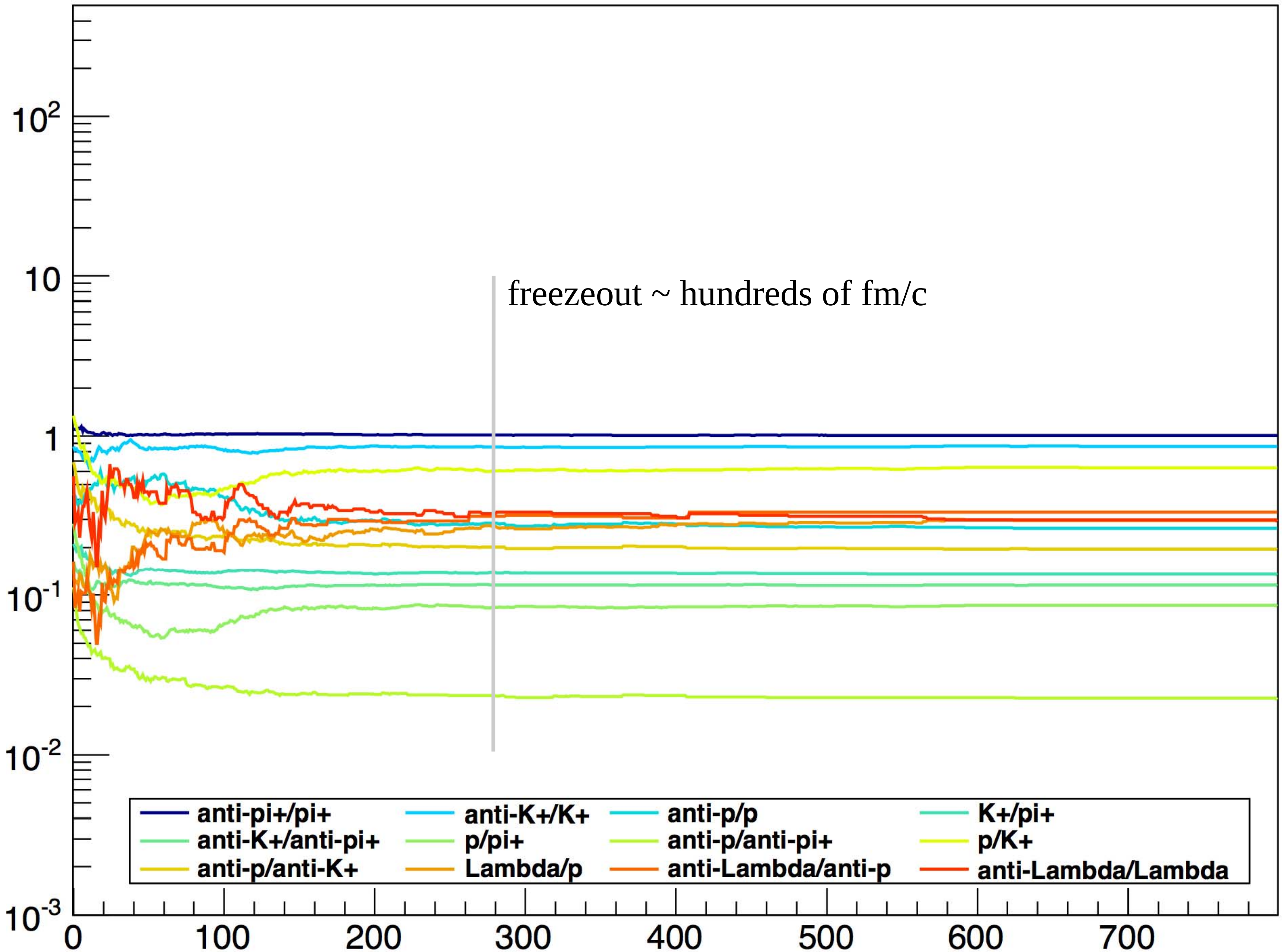
Example time dependence of the ratios, 19.6 GeV, 0-5%



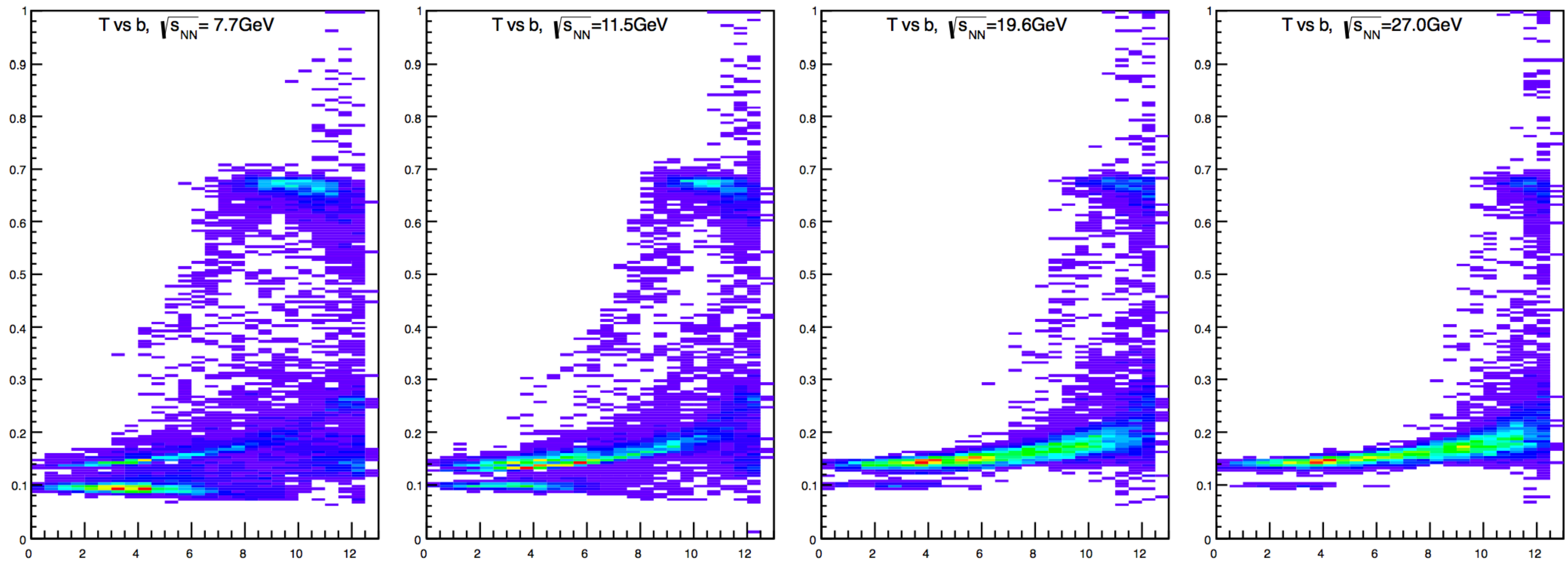
Example Fits, 200 GeV, 0-5%

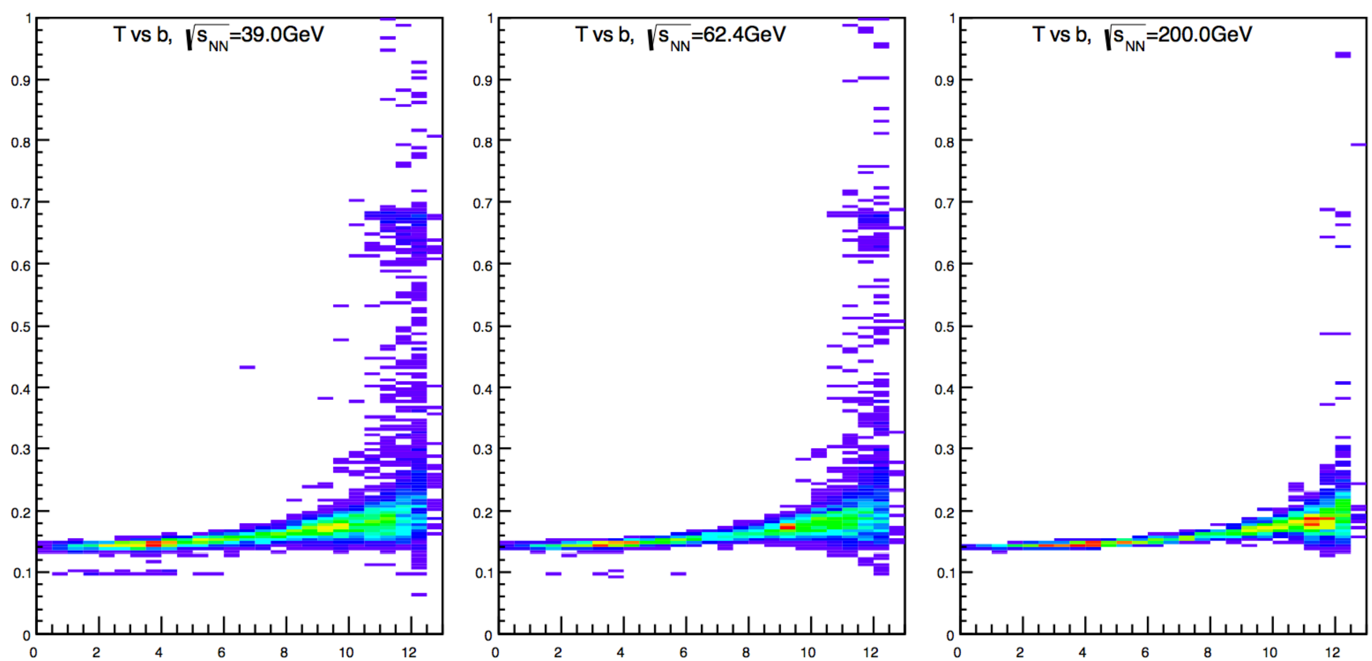


Example time dependence of the ratios, 200 GeV, 0-5%



Centrality dependence of T

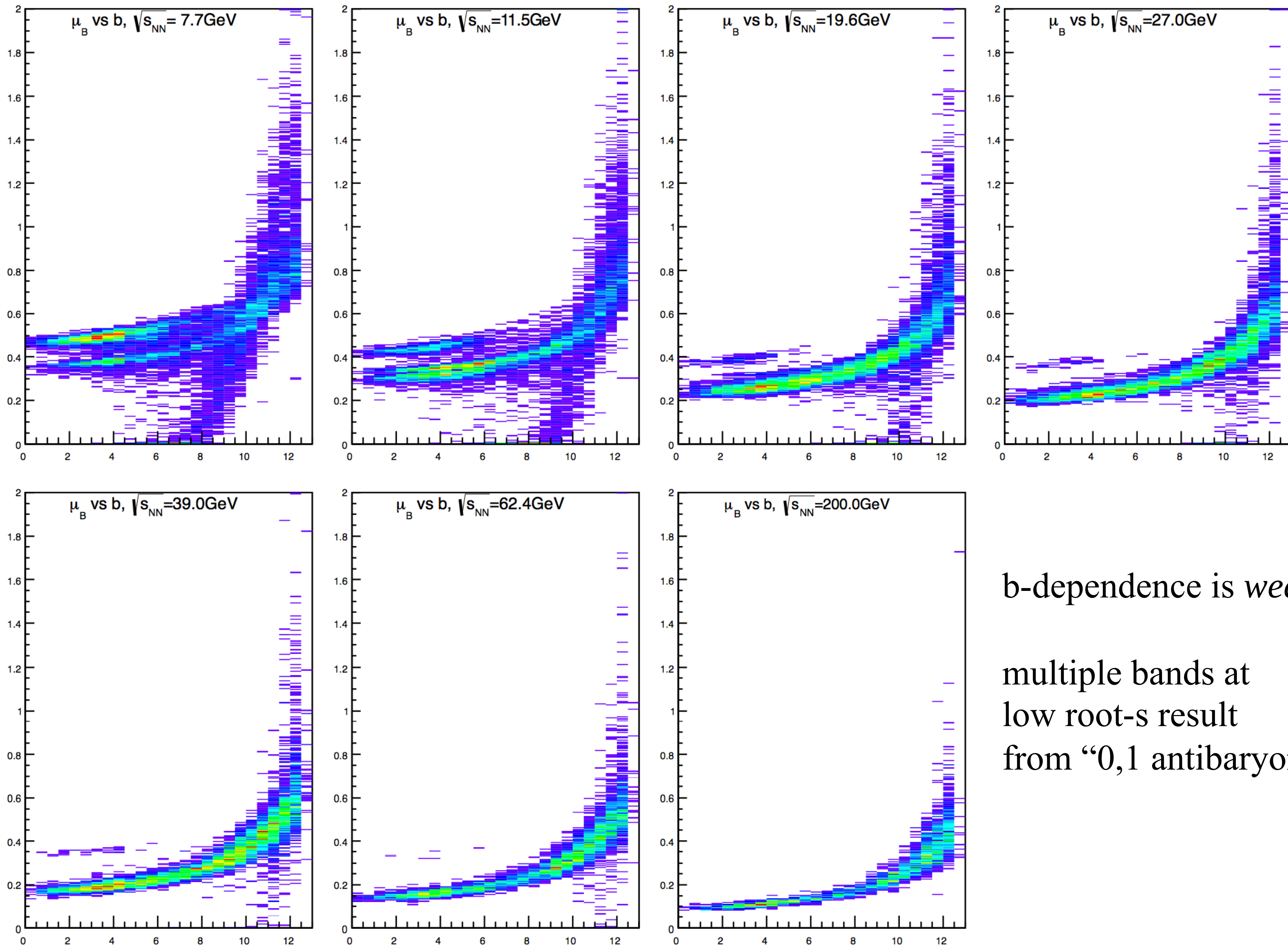




b-dependence is *weak*

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

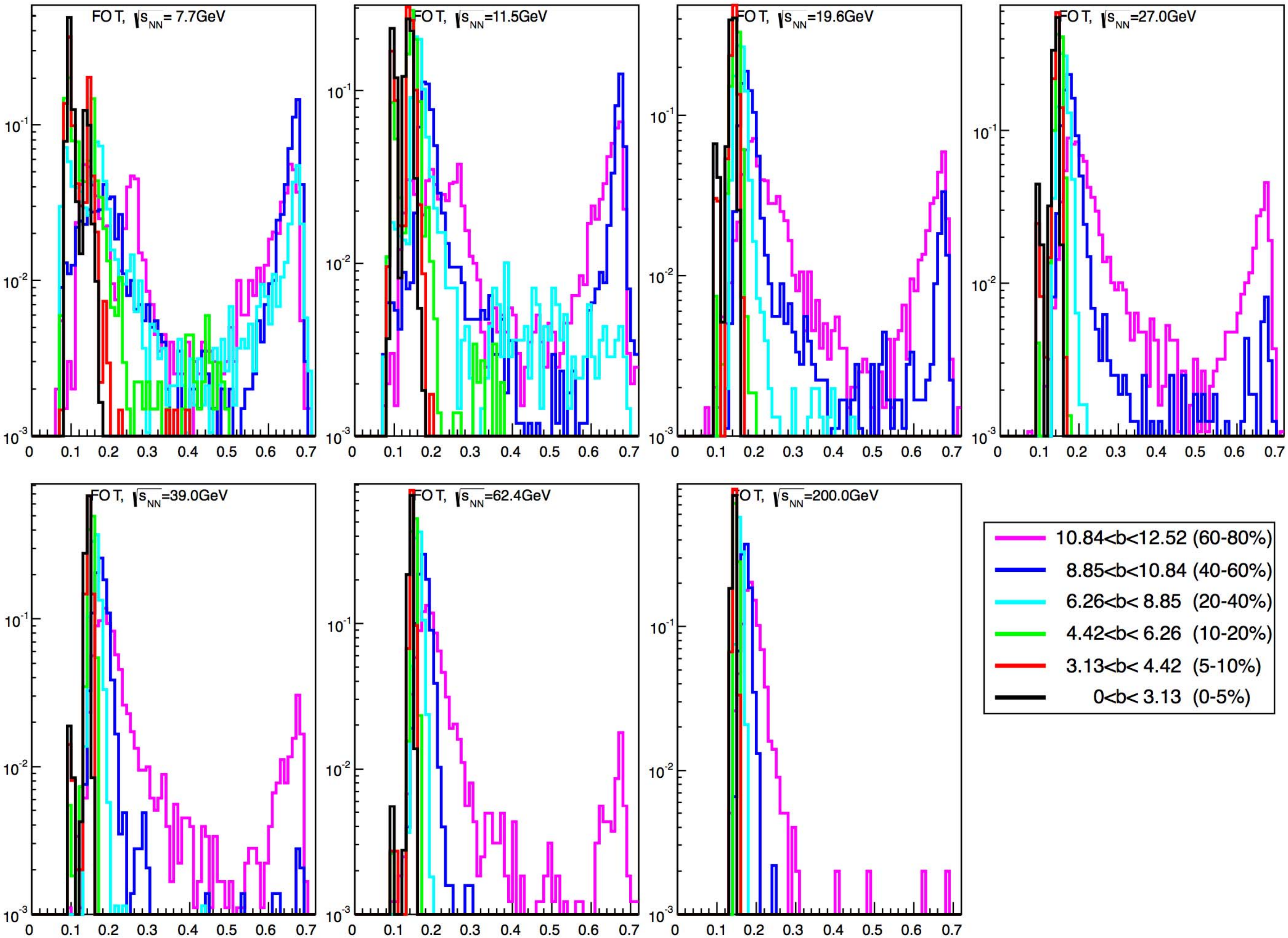
Centrality dependence of μ_B



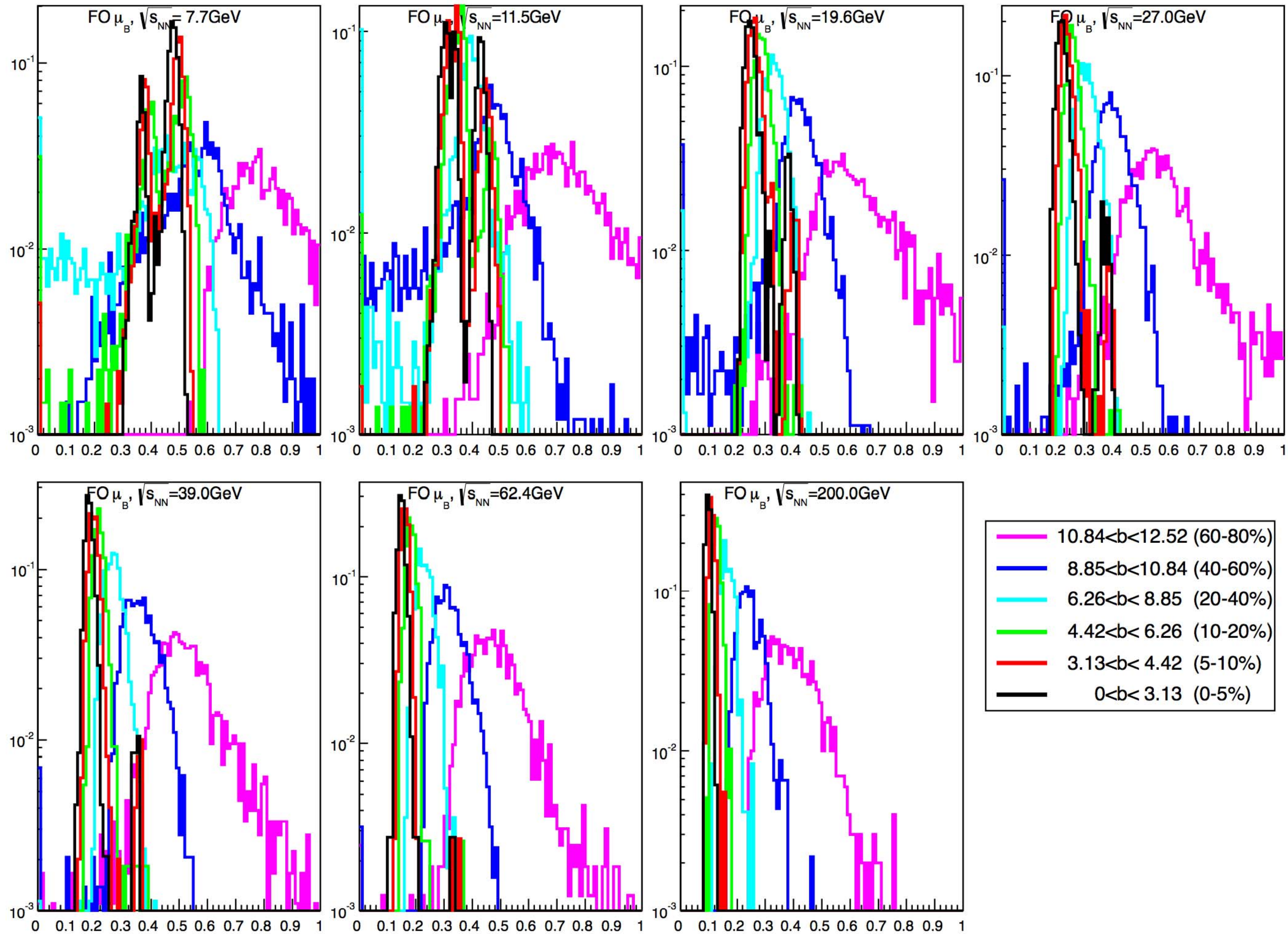
b-dependence is *weak*

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

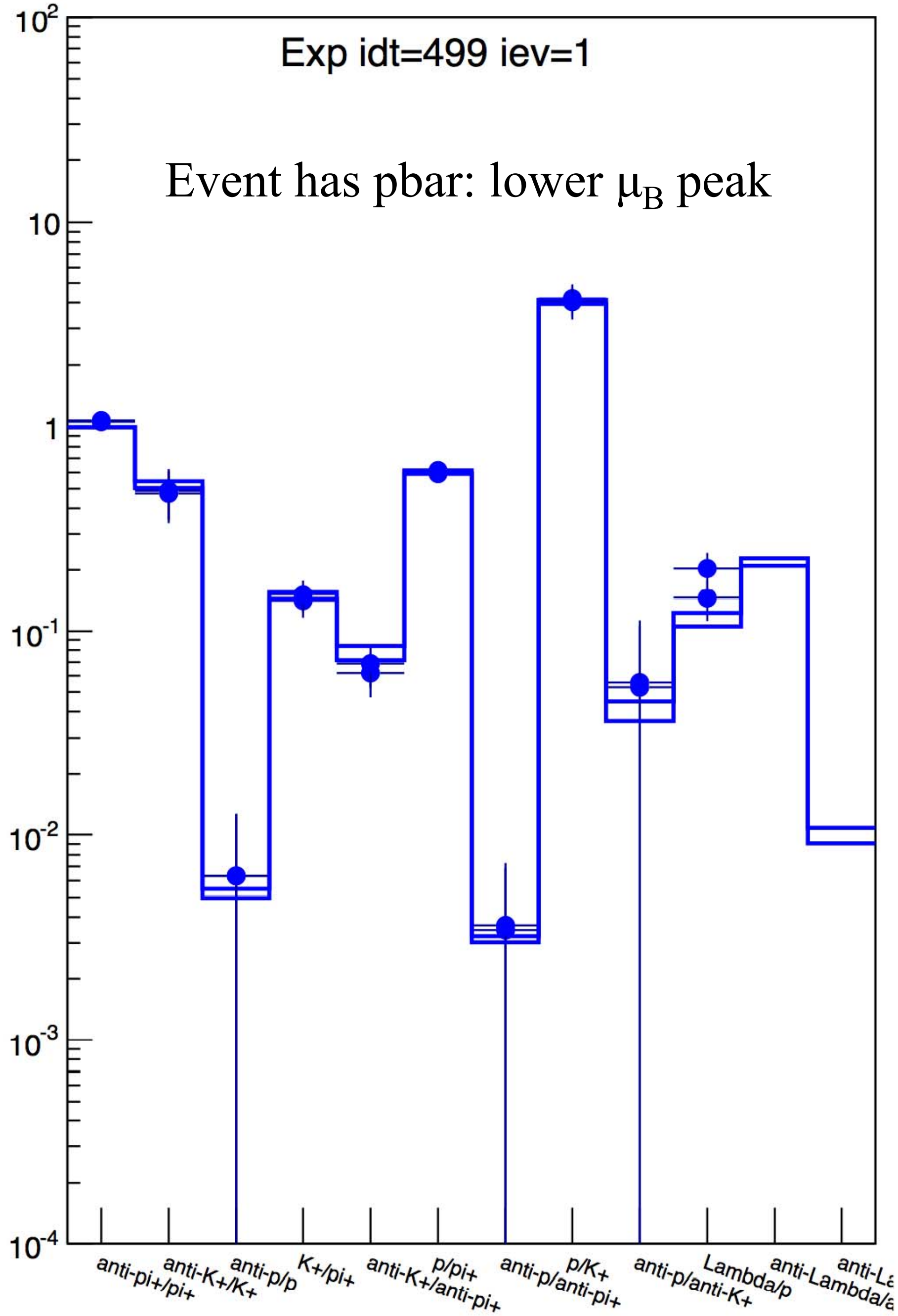
1D T distributions by centrality bin

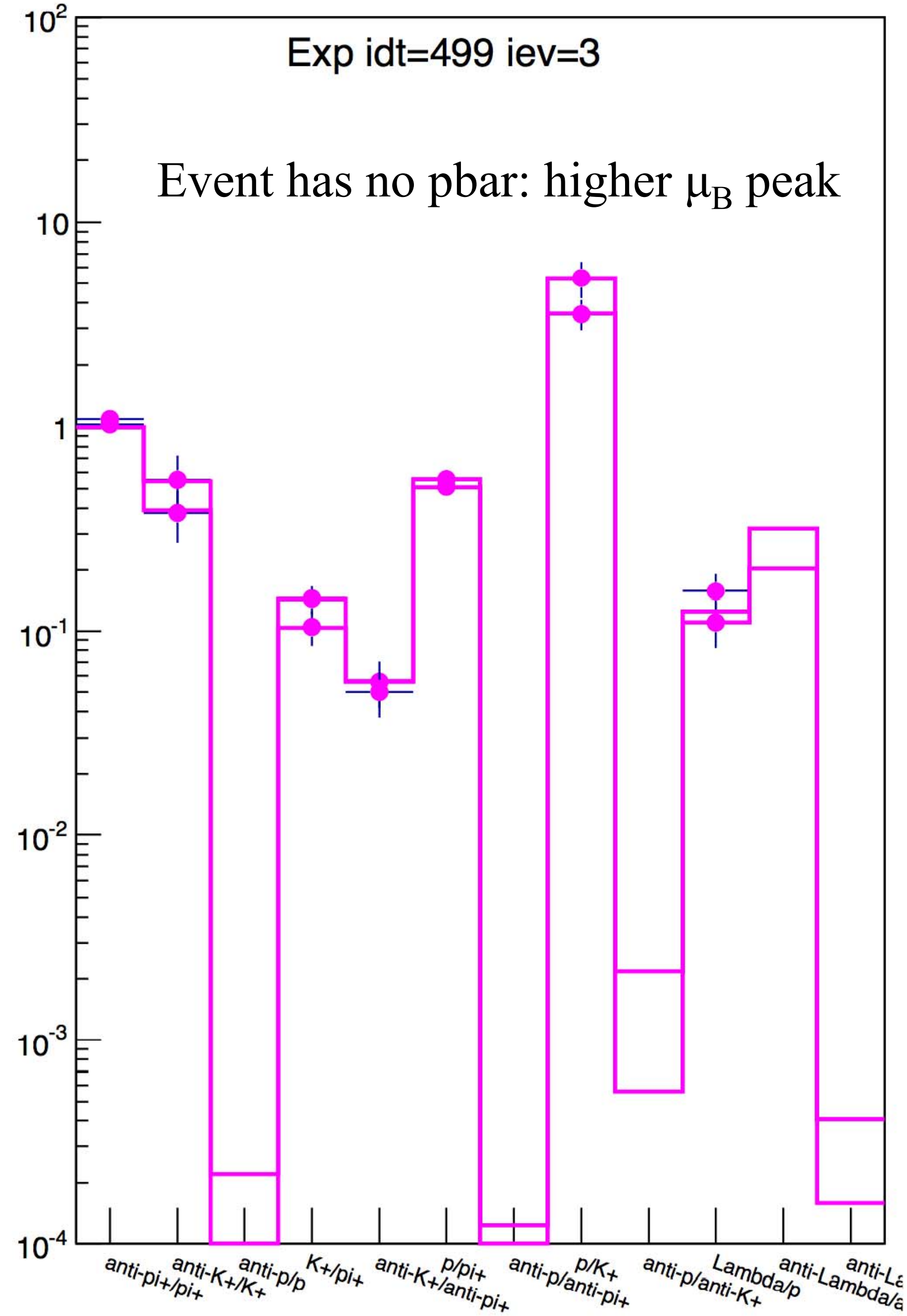


1D μ_B distributions by centrality bin

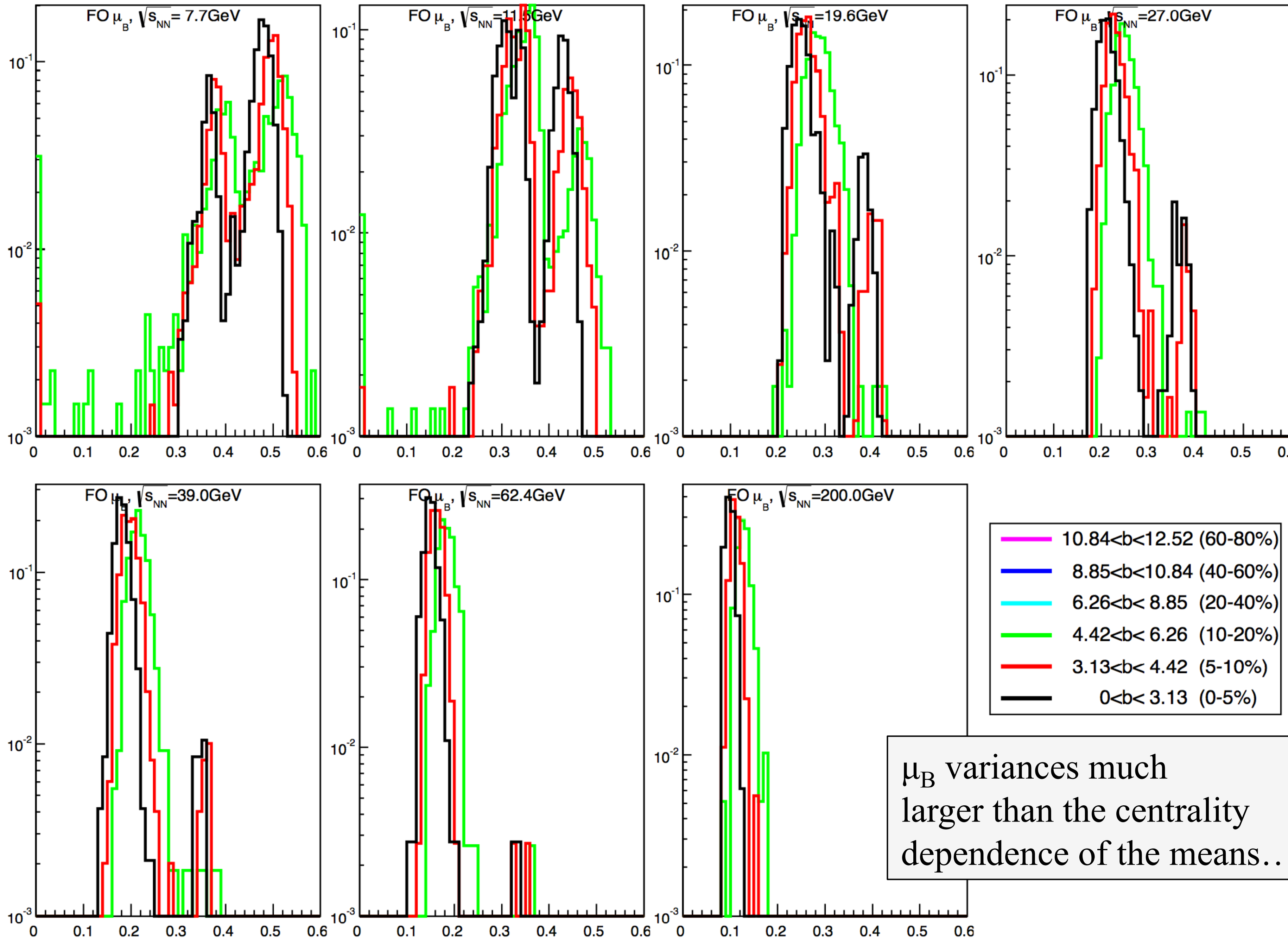


Double-peaked FO μ_B at lowest root-s (7.7 GeV, 0-5%)



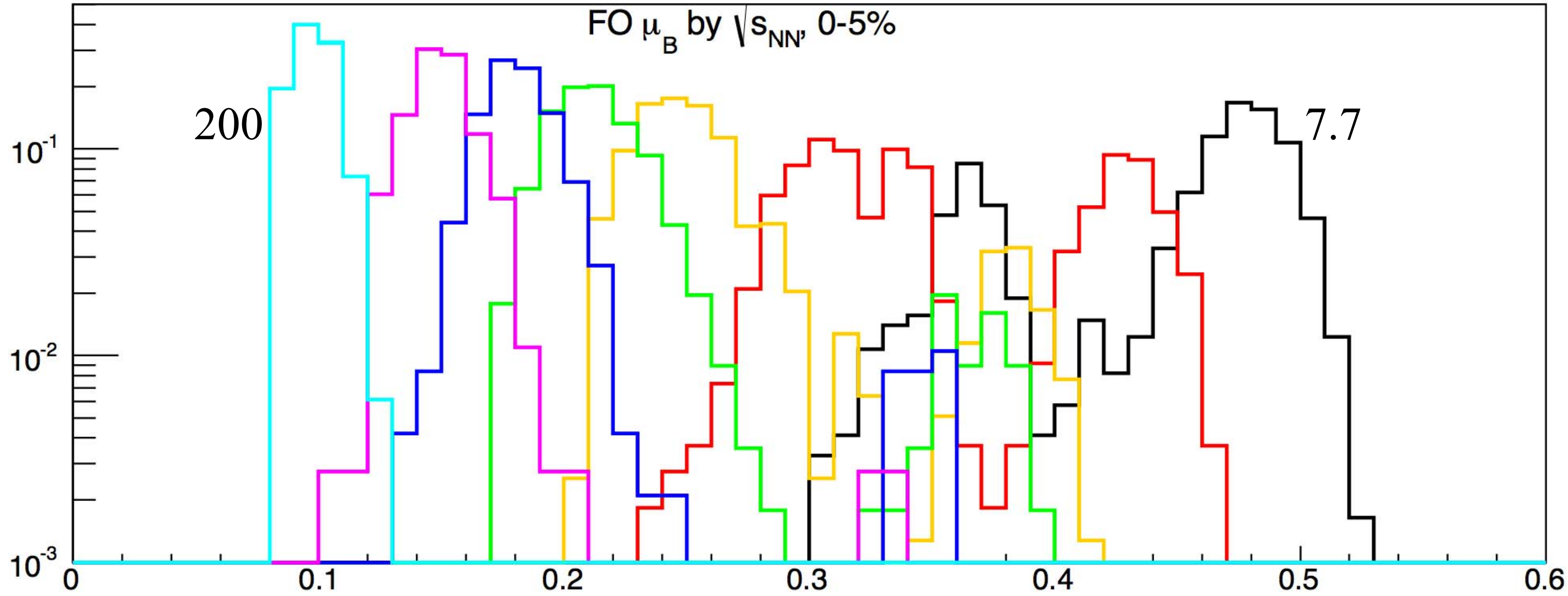


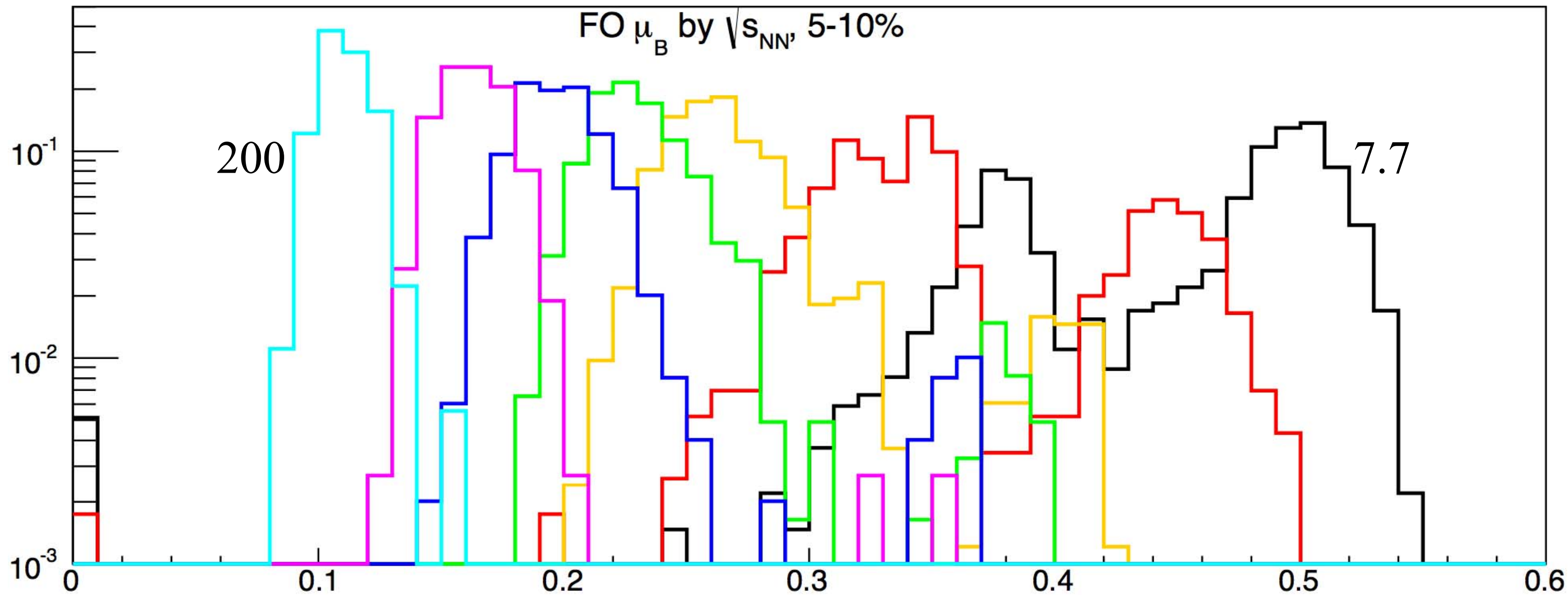
Concentrate on central 0-20% collisions…



μ_B variances much larger than the centrality dependence of the means…

μ_B distributions, 0-5% and 5-10% central





New idea?

E-by-E variation in μ_B can be large compared to the centrality dependence of the mean values

0-5% and 5-10% bins strongly overlap

5-10% and 10-20% bins strongly overlap

μ_B R.M.S. in any given ~central centrality bin is strongly root-s and centrality dependent

lower-end root-s & central collisions: μ_B distributions can be ~100-200 MeV wide

Note that this variance is directly from a pure transport model.

i.e. "perfect, 4π, & participant-only detector"

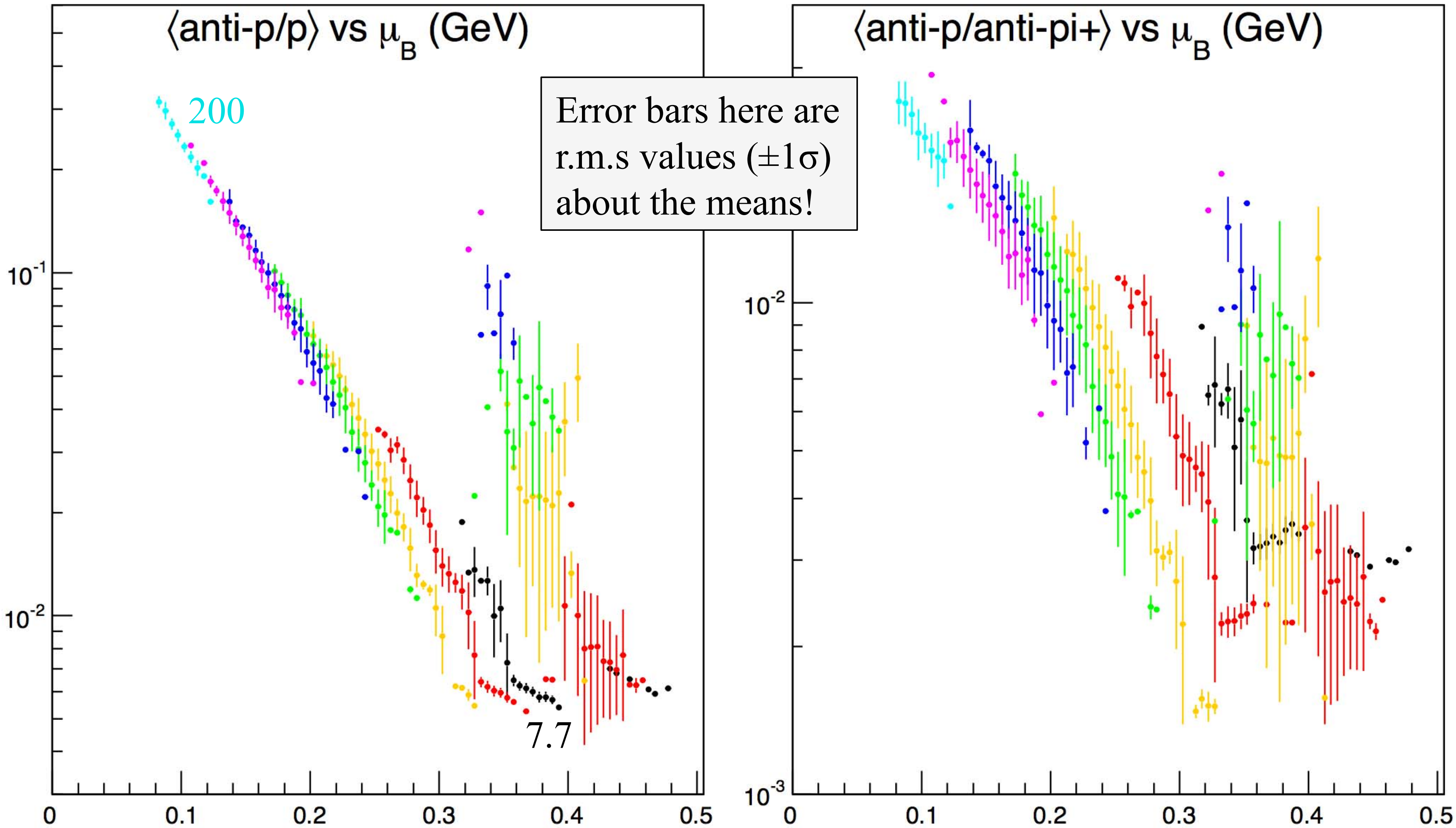
One might assume that experimental inefficiencies could lead to additional smearing…

Can we constrain (μ_B,T) in each event?

i.e. do full & standard moments analyses for *e.g.* total pions but do separate analysis runs gated on *e.g.* pbar/p in each event...

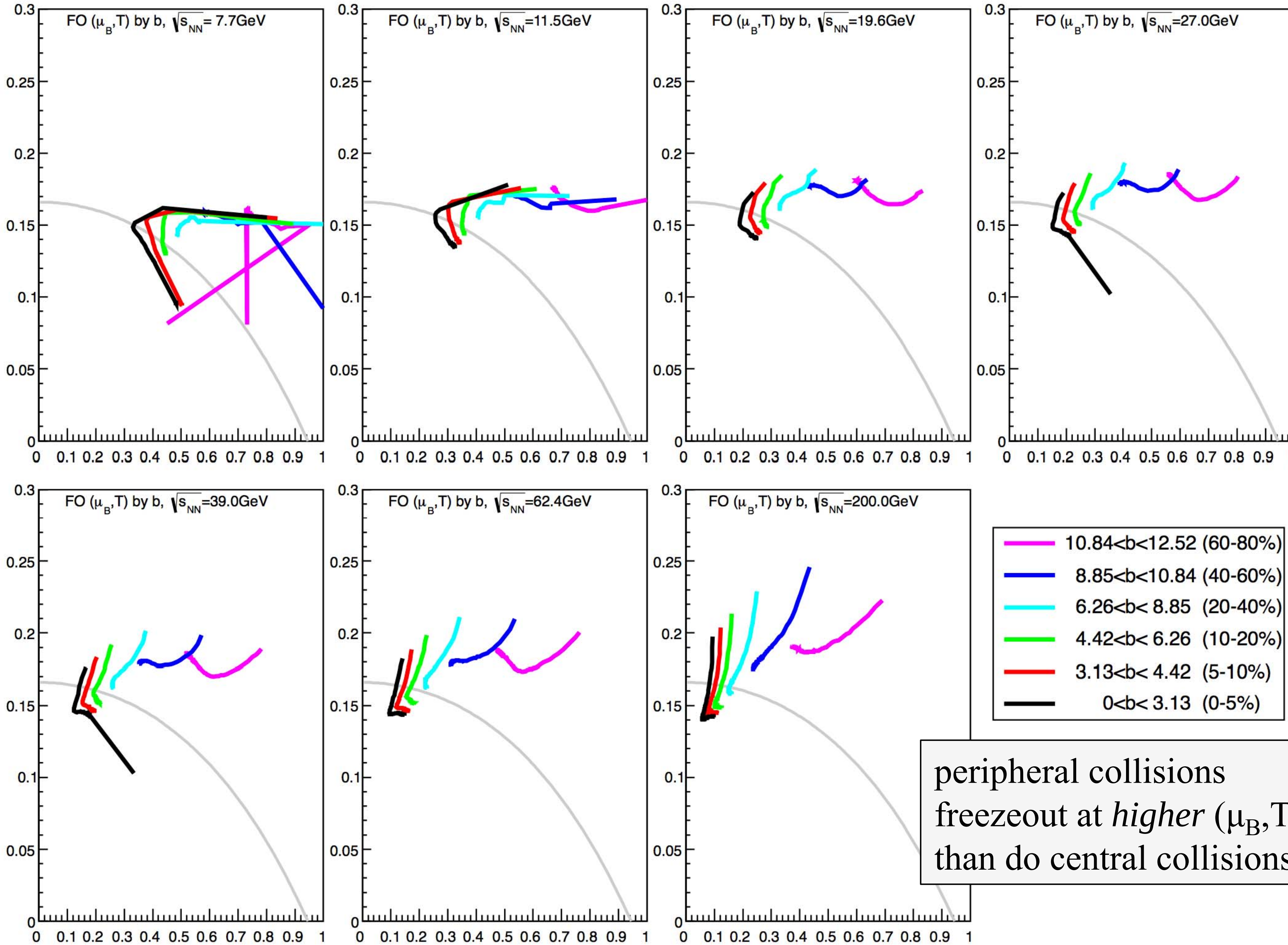
Daniel McDonald & I are now exploring this direction with the data…

Ratios vs μ_B and root-s, 0-5%



pbar/p ratios overlap across multiple root-s values and form a universal trend…

Time Trajectories of “Average Events”



peripheral collisions freezeout at *higher* (μ_B,T) than do central collisions

Summary & future work…

UrQMD+Thermus calculations *vs* root-s, centrality, and time in 1 fm/c steps out to FO
use 12 ratios from light hadrons and Λ's
use GCE and fit $(T, \mu_B, \mu_S, \gamma_S)$

Central collisions freeze-out at lower (μ_B, T) values than do peripheral collisions
opposite trend than that from the real data+thermus(GCE) fits…

Significant overlap in the (μ_B, T) distributions for 0-5% and 5-10% and 10-20% central
at all root-s values

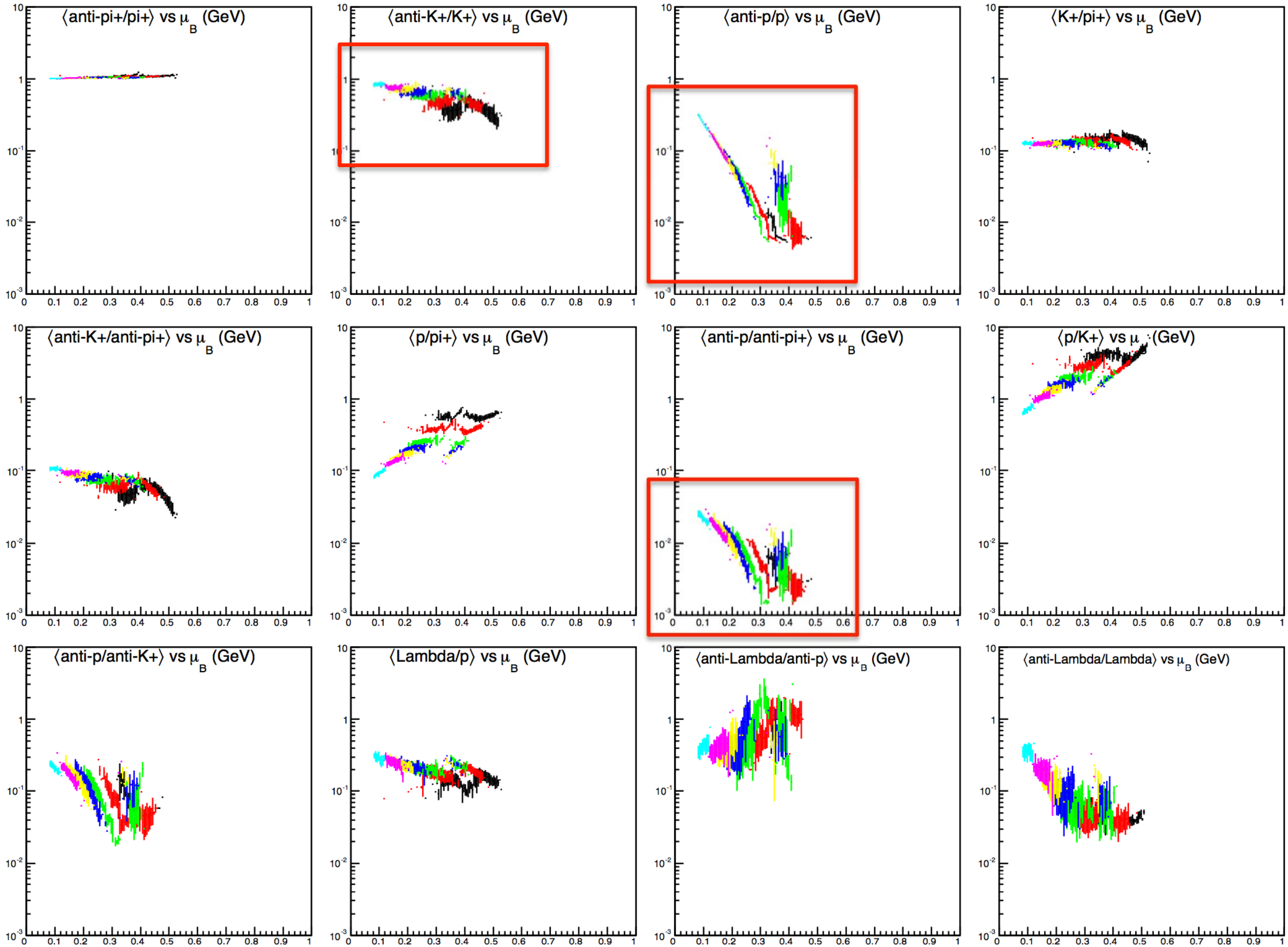
Existence or not of an antibaryon in the event at the lower-end root-s values leads
to widely separated "islands" with distinct (μ_B, T) values
…~200 hundred MeV-wide distributions of μ_B in central collisions in lower-end root-s data

E-by-E gating on a "3rd axis" could constrain the (μ_B, T) values beyond the centrality cuts
e.g. pbar/p ratio bins for net-π and total-π moments
or π+/p ratio bins for net-K, *etc.*

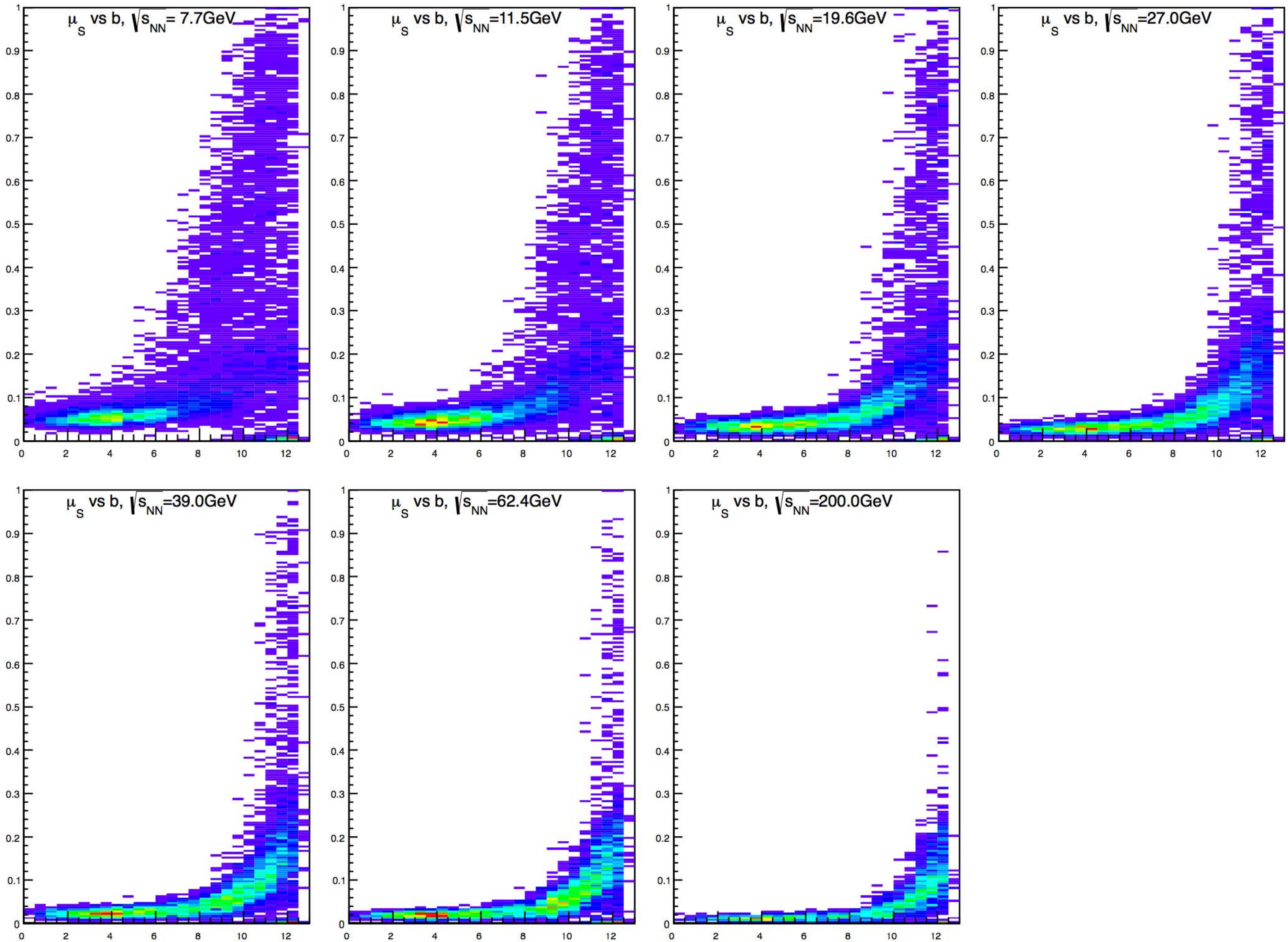
Some To-dos:
SCE – same trends with centrality as when using the GCE?
AMPT… also gives time dependence in single events
but Kaons are only generated in the last time step…
Mock up the experimental inefficiencies?
Constrain multiplicities to mid-rapidity?

BACKUP

Ratios vs μ_B and root-s, 0-5%



Centrality dependence of μ_S



Centrality dependence of γ_S