TOF in the Beam Energy Scan
+ Nuclear Fragment Production

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BES Workshop, BNL, Dec 17-18, 2008

TOF efficiencies (start & stop sides) versus the beam energy are unclear
→ geant simulations of UrQMD events

UrQMD does not produce fragments

Used existing events, and generated new ones (UrQMD version 2.3)
- modified to save geant IDs to output file (*.f13, with freezeout information)
- $\sqrt{s}$ = 5.0, 6.3, 7.6, 8.7, 9.2, 12.3, 17.3, 30, 45, 62, 200 GeV
- min. bias (0-14 or 16 fm), 0-4fm, 4-8fm, & 8-12fm
- UrQMD with default parameters + prohibit decays, simulation total time = 100ns

TOF (MRPCs + upVPD) geometry is exact, but STAR simplified → 'ideal acceptance'

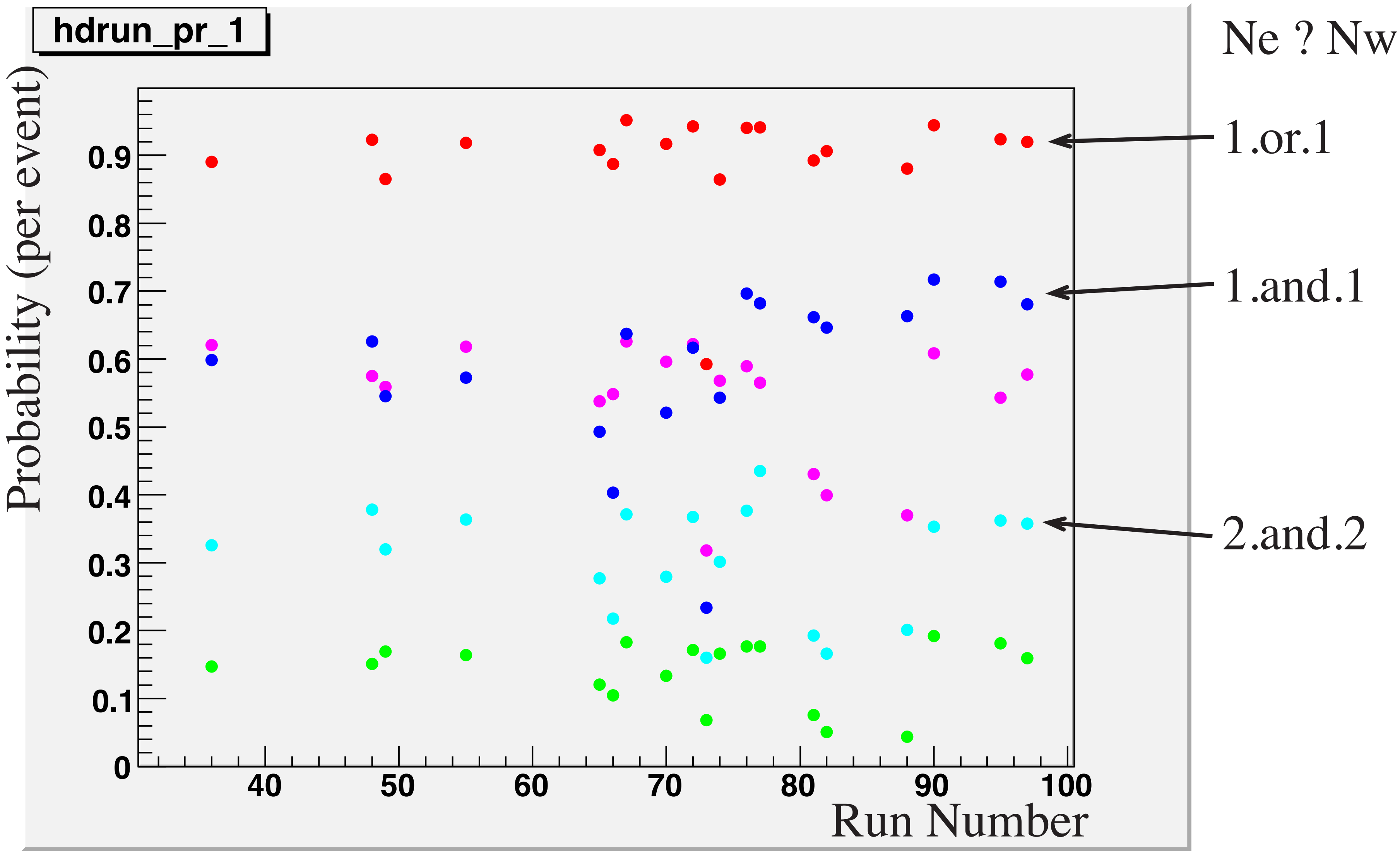
Coalescence afterburner to produce d and dbar from UrQMD events

Outline:
- Reminder of upVPD efficiencies in Run-8 at 9.2 GeV
- Simulations geometry & UrQMD events
- upVPD efficiencies
- TOF efficiencies
- Fragment production
    - motivation & coalescence algorithm
    - very preliminary results
- Joblist

Results from Run-8 9.2 GeV

data from fastoffline files

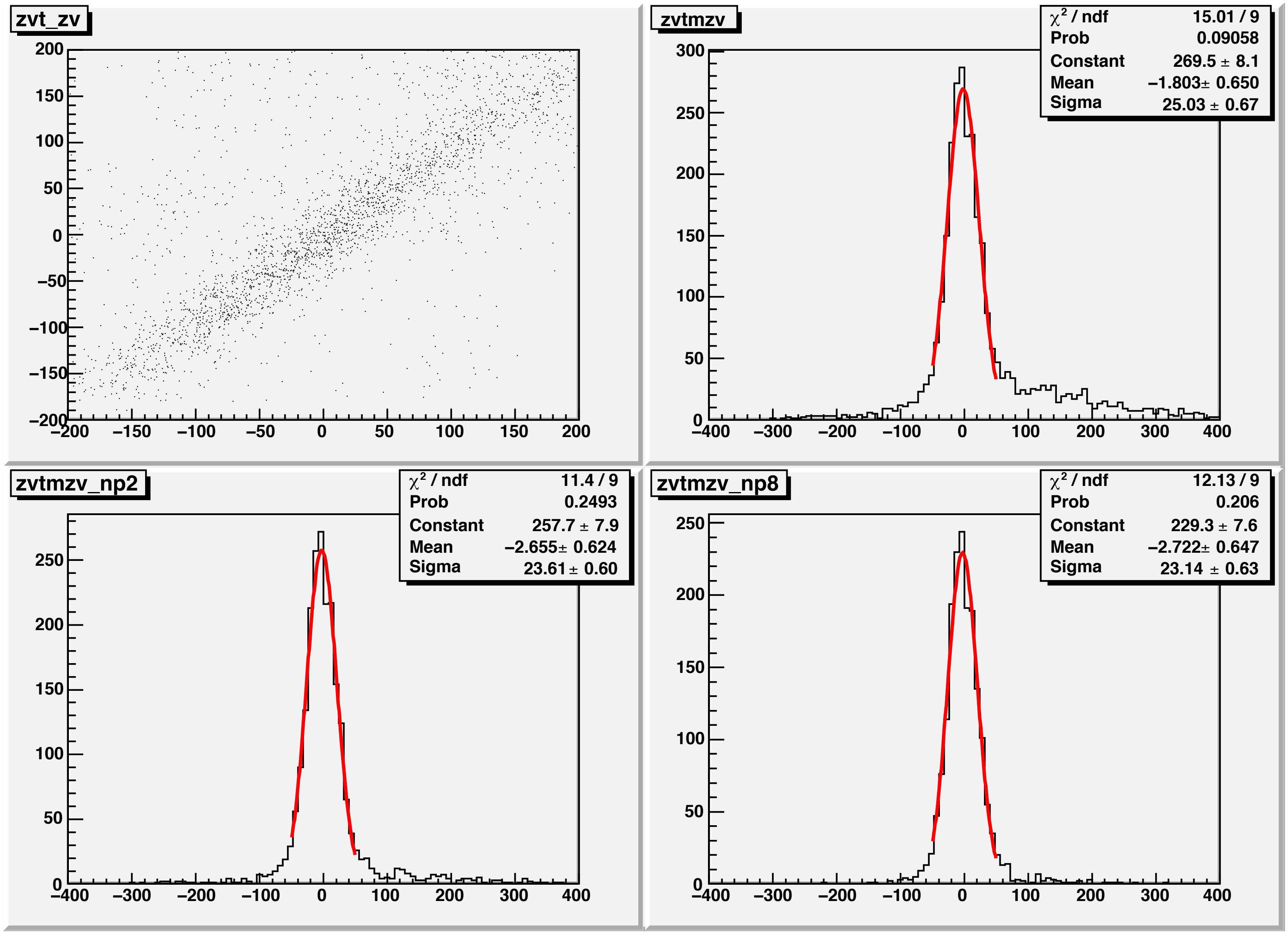
require nprimary>0



upVPD 1.and.1 efficiency ~ 60% for CTB triggers

These 1.and.1 events are not completely junk...

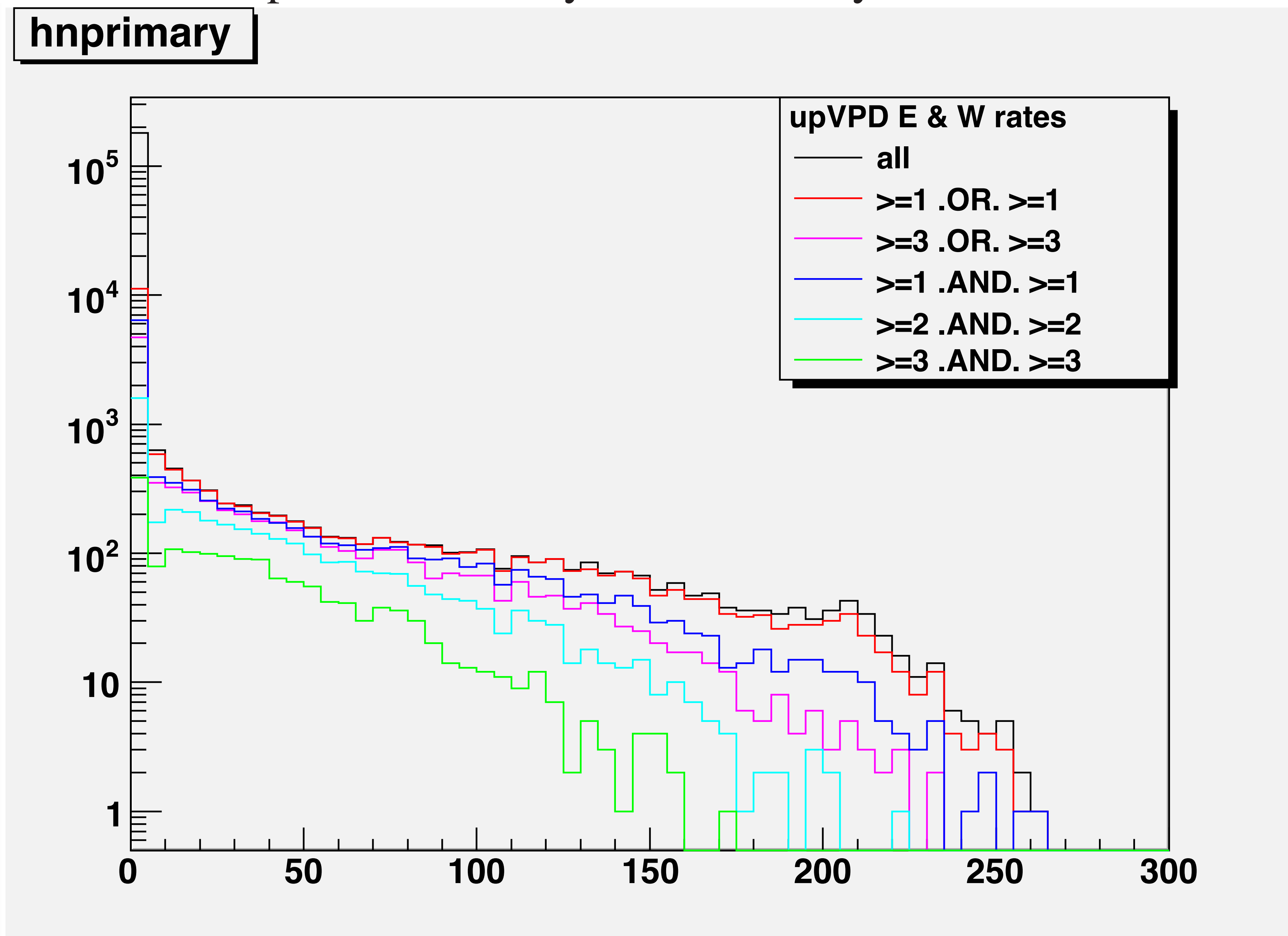
Correlations of Zvtx from tracking to Zvtx from upVPD Teast-Twest



σ ~ 20-25cm is consistent with a single detector time resn of ~1ns

which is the expected value in absence of a slewing/offset correction (not enough events)

Correlation of upVPD efficiency with centrality



Increasing requirement on activity in upVPD decreases centrality

→ questions of √s & centrality dependence of upVPD efficiency become relevant!

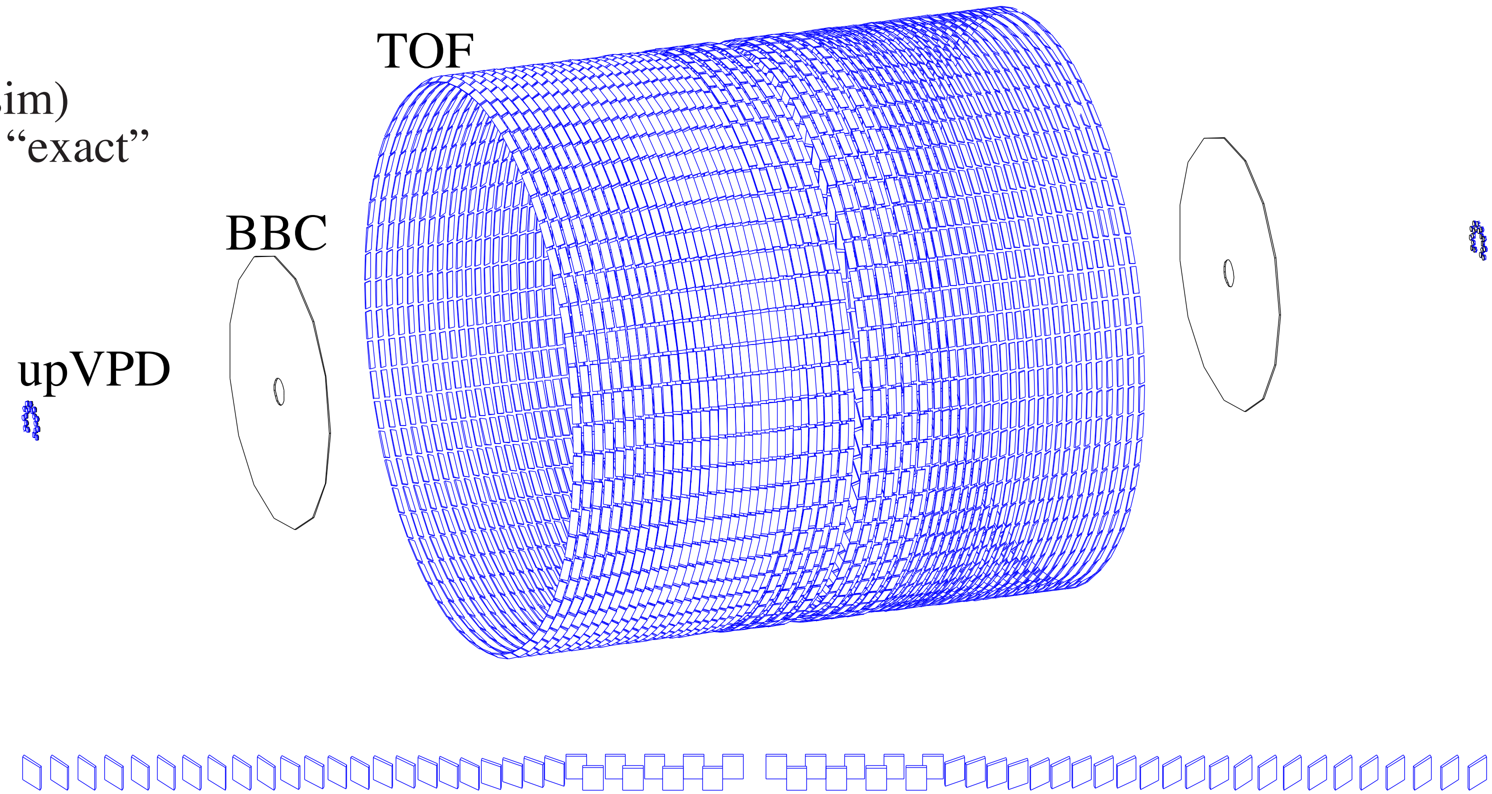
geant simulations

standalone code (not starsim)
TOF & upVPD geometry "exact"

5T field, sharp cutoff

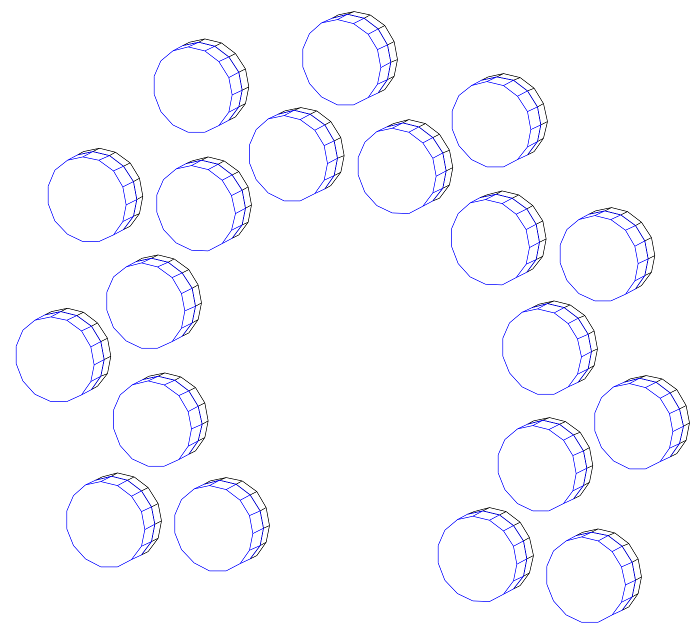
vacuum cave

Physics:
 MULS
 DCAY
 LOSS
+ in upVPD Pb:
 PAIR
 COMP
 PHOT

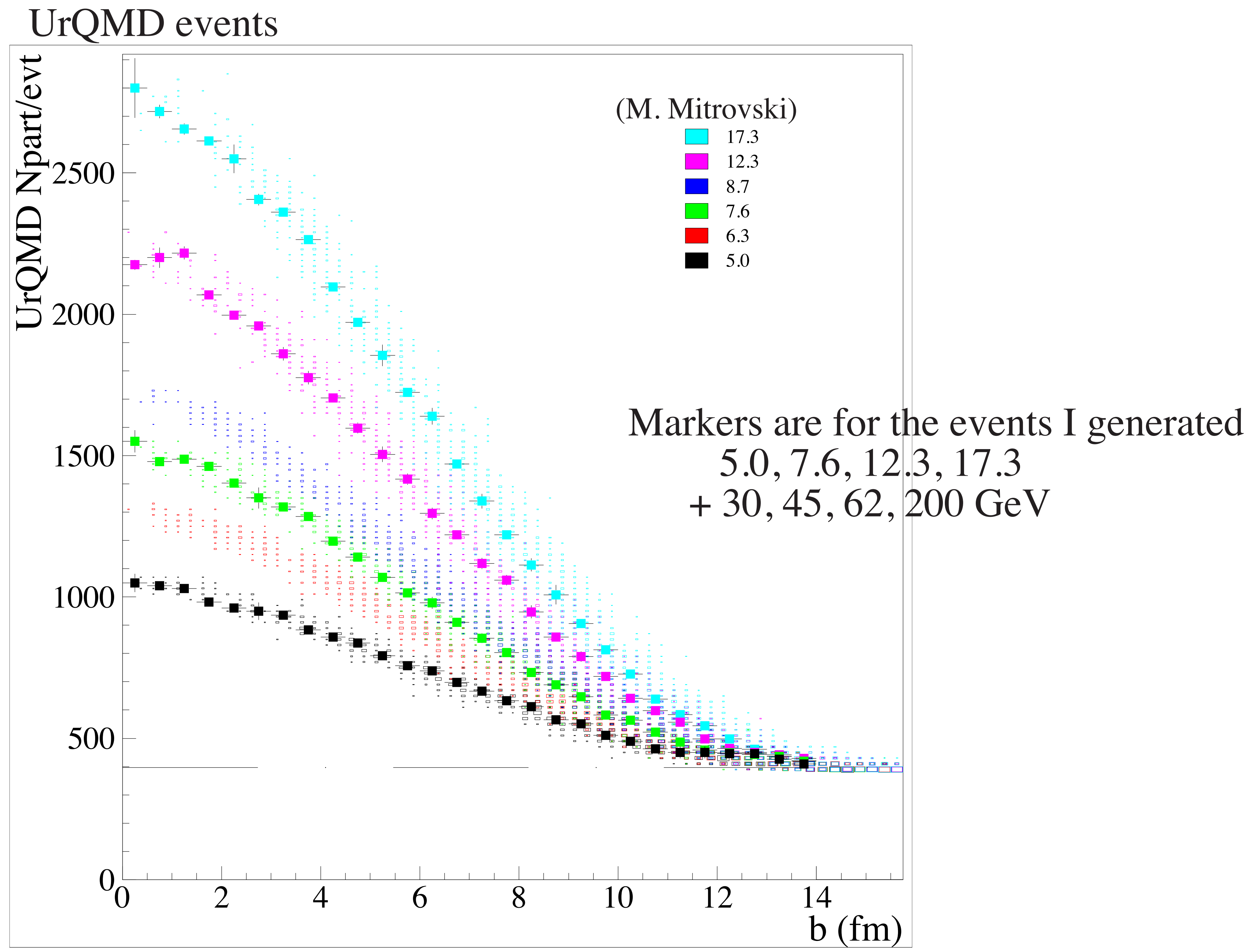


generate full UrQMD events
record hits in detectors
calculate probabilities per event

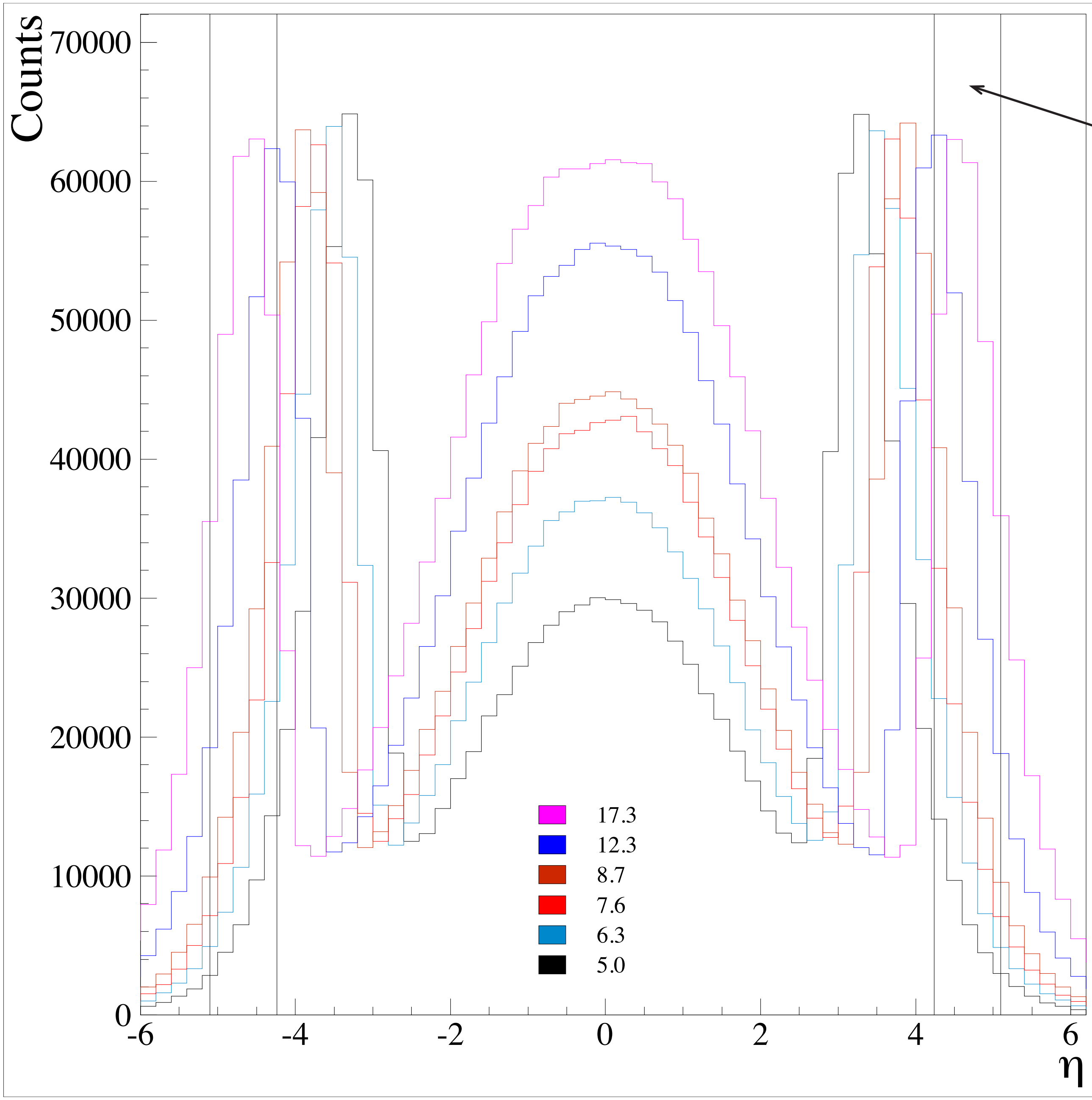
→ "ideal geometrical acceptance"



not yet implemented:
Zvtx smearing ("small" effect)


UrQMD events
UrQMD Npart/evt
(M. Mitrovski)
17.3
12.3
8.7
7.6
6.3
5.0
Markers are for the events I generated
5.0, 7.6, 12.3, 17.3
+ 30, 45, 62, 200 GeV
0
500
1000
1500
2000
2500
0
2
4
6
8
10
12
14
b (fm)

Pseudorapidity distributions: existing events

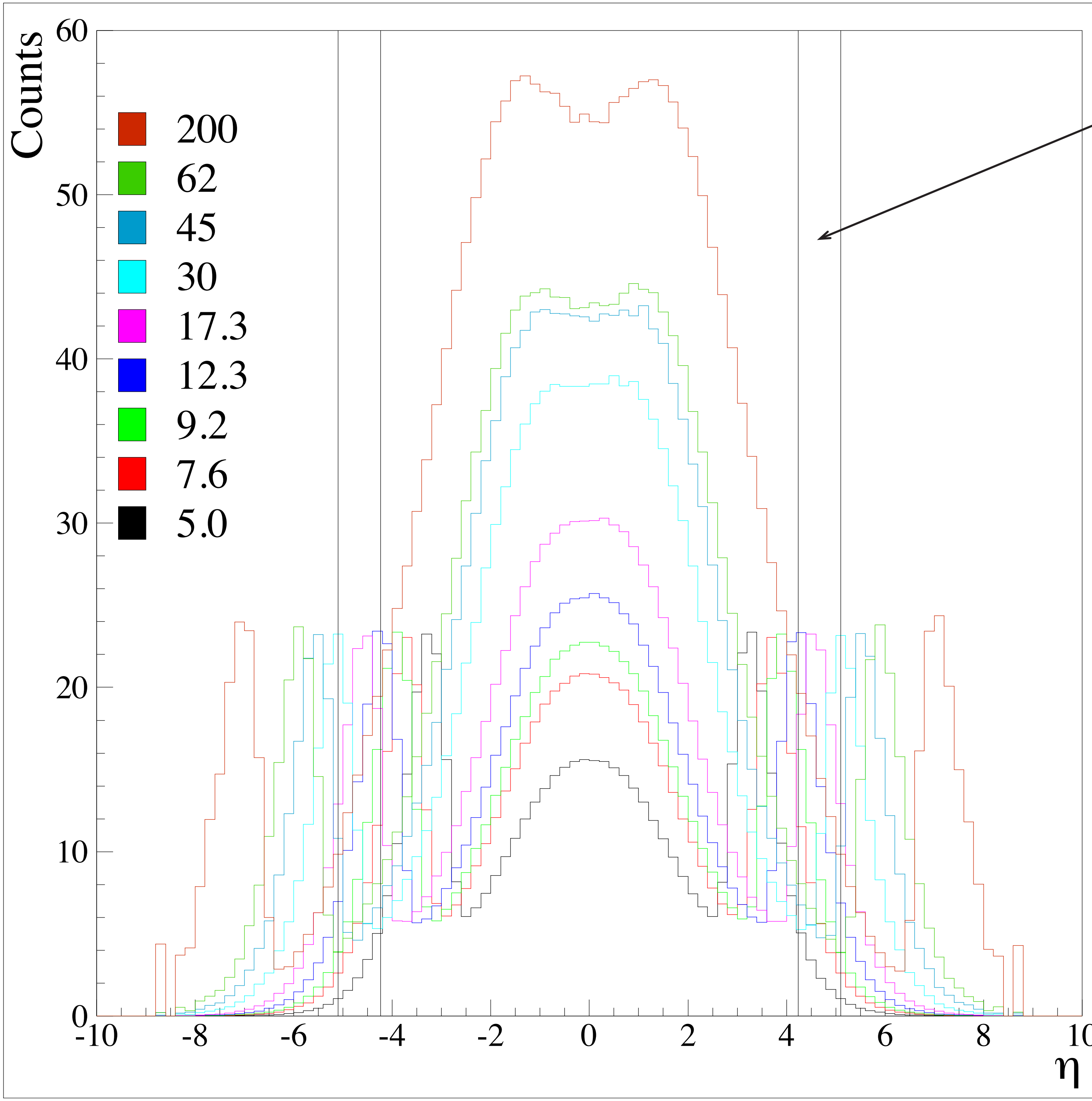


upVPD acceptance:
4.24 < |η| < 5.1

√s < 10 GeV
upVPD sees high tail of spectator zone

√s ~ 10-20 GeV
spectators are *baking* the upVPD

note UrQMD does not produce fragments!



upVPD acceptance:
$4.24 < |\eta| < 5.1$

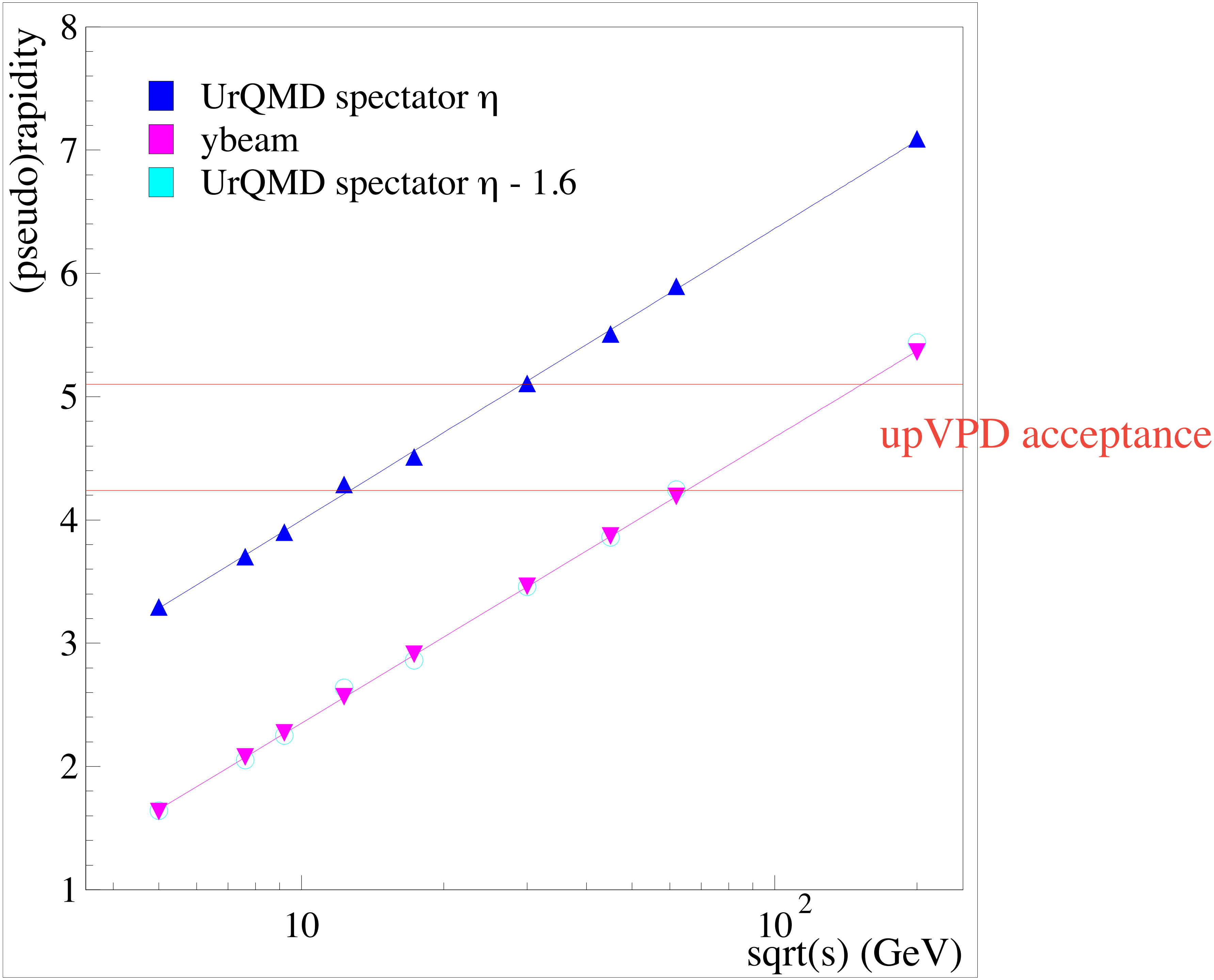
$\sqrt{s} < 10$ GeV
upVPD sees high tail of spectator zone

$\sqrt{s} \sim 10\text{-}30$ GeV
spectators are *baking* the upVPD

$\sqrt{s} > 30$ GeV
upVPD sees high tail of participant zone

good agreement w/ existing events (difference is simply 0<b<16fm vs 0<b<14fm setting)

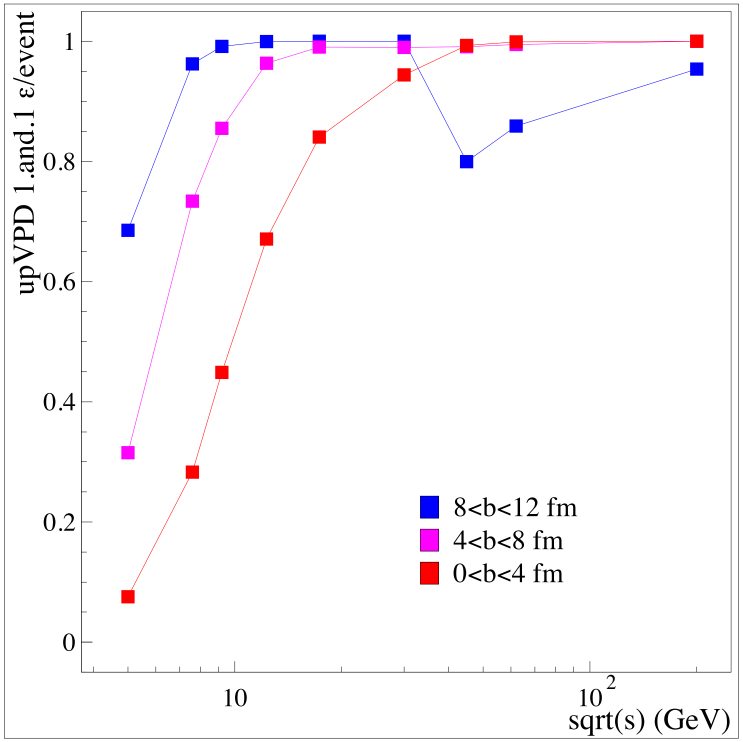
UrQMD spectator rapidities

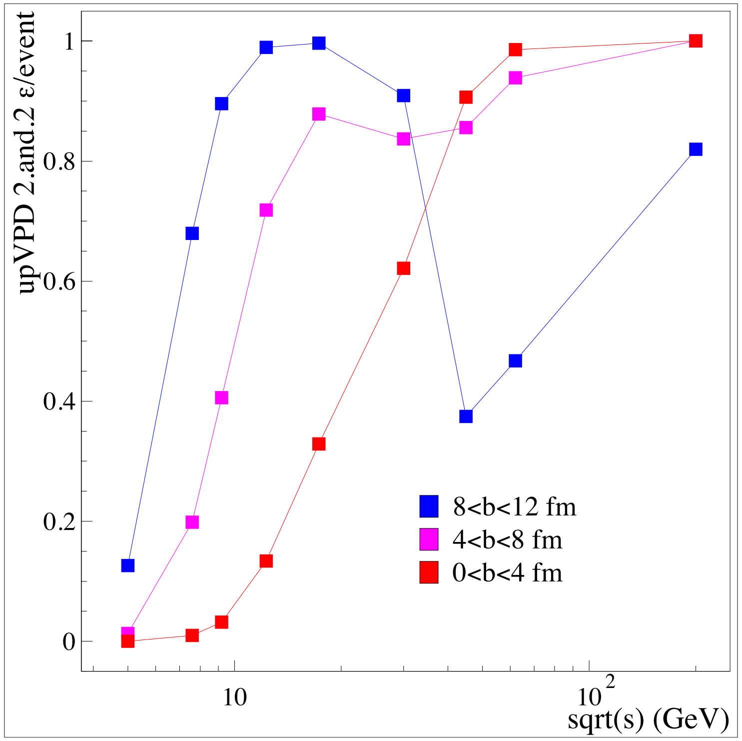


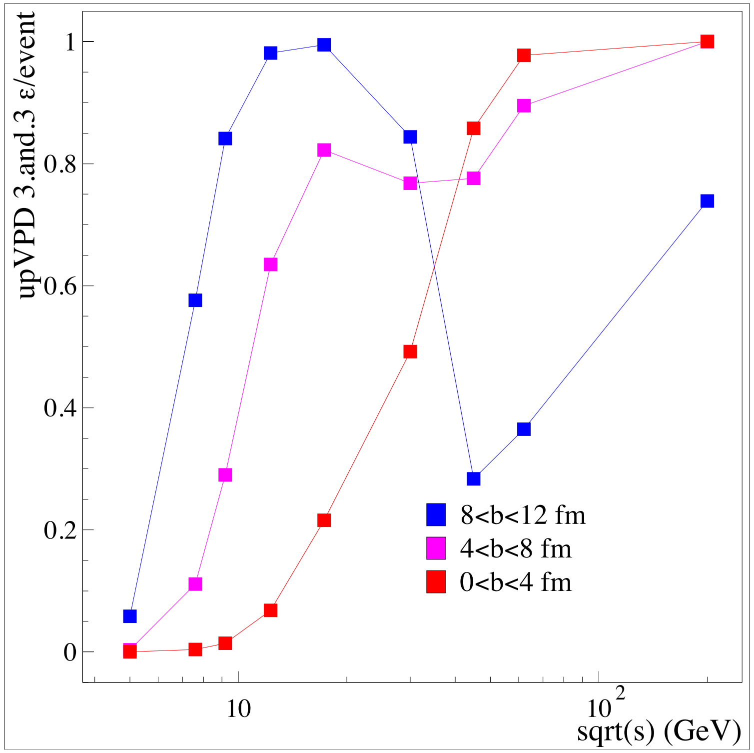
upVPD "N.and.N" efficiency vs √s

peripheral collisions
    trends follow spectator-η trend

central collisions
    near-zero efficiency for lowest √s







upVPD will be inefficient per event in (mid)central events at low $\sqrt{s}$

60% for ~min. bias (nprimary>0) was measured in Run-9 at 9.2 GeV
I need to make the plots for upVPD efficiency per event w/ cuts on nprimary.

but TOF's ☆ Software requires a upVPD Start time and a TOF Stop time to do PID!

so should you be worried about TOF PID being available at low $\sqrt{s}$? No!

present software approach:
- slew & offset correct upVPD (does not require tracking, just TOF data itself)
- require tracks extrapolate to beamline consistent with Zvtx(upVPD) & Zvtx(TPC)
- match (primary) tracks to singly-struck TOF cells
- select pions (dE/dx or TOF $1/\beta$) and form $1/\beta$(TOF) - $1/\beta$(expected)
- slew & offset correct this $\Delta(1/\beta)$

→ TOF PID

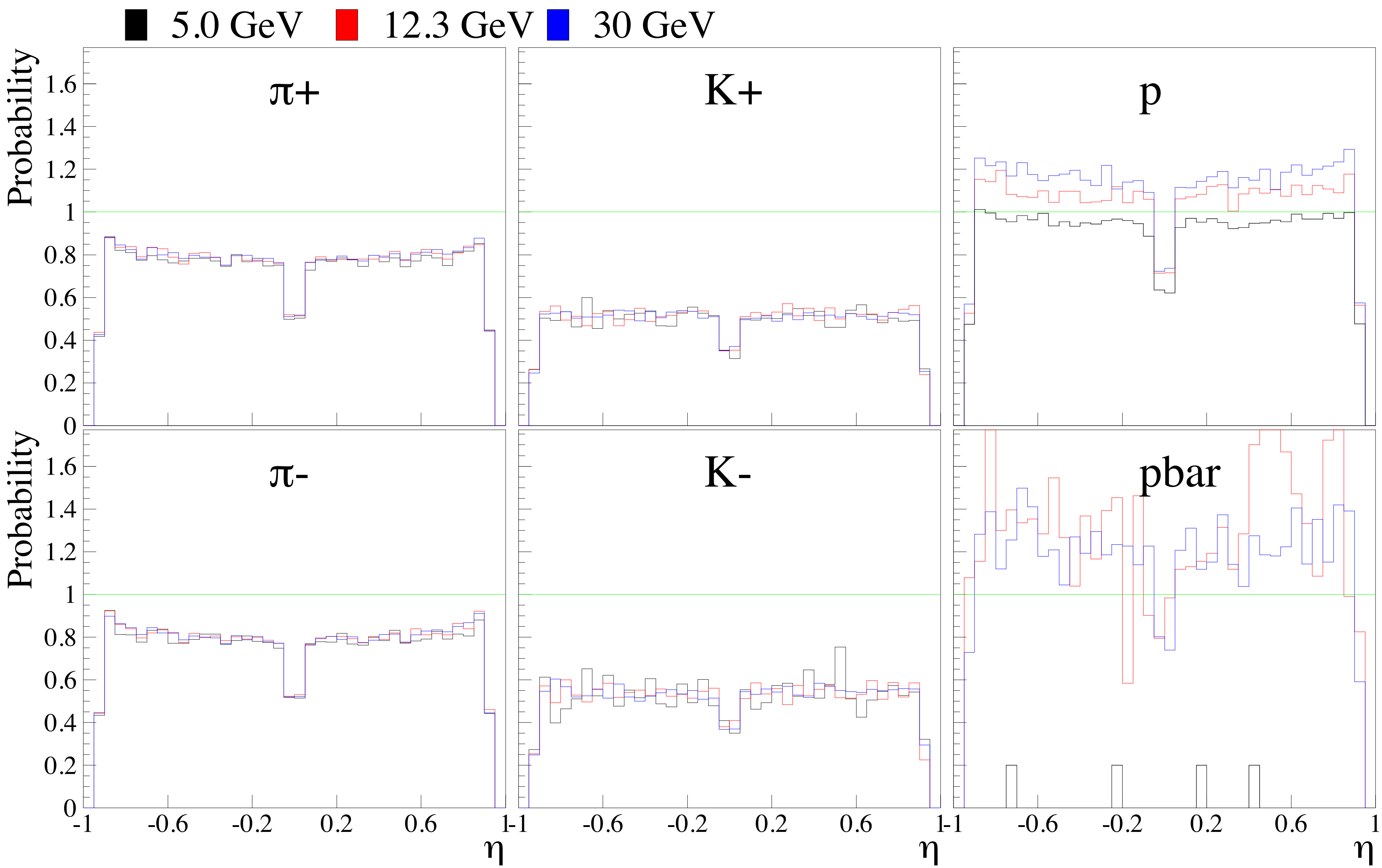
A straightforward (and already simulated) reshaping of this code would allow one to
infer the start time from the stop times.

Works when there are lots of stop times when the upVPD is unlit -exactly the case here!
inferred σ(start) ~ σ(stop)/$\sqrt{\text{Nstops}}$ ~ 100ps/$\sqrt{\text{Nstops}}$ ~10 primary stops → σ(start)~50ps

i.e.
- match (primary) tracks to singly-struck TOF cells
- select pions (dE/dx) and form $1/\beta$(TOF) - $1/\beta$(expected)
- these will cluster around an absolute time w.r.t. the TOF master clock (51 us)
- subtract this offset (→$\Delta(1/\beta)$~0 but with poor resolution), & slew/offset correct the stop times
- improve the inferred start time using improved stop times, rinse and repeat.

Stop side acceptance

denominator: eta from momentum components by generated PID
numerator: eta from hit position components in MRPCs (→ratio includes decays & feed-down)



η~0 gap less pronounced when there is Zvtx smearing
but MRPC efficiencies then depend on Zvtx (gaps same side, 2 MRPC tracks opposite side)

Nuclear Fragment Production vs. $\sqrt{s}$

Motivation:

useful tool at Bevalac, NSCL, AGS, SPS, RHIC, ...

d and dbar are the simplest composite objects
their production rates reflect expansion, correlations, & flow...

weakly bound
- secondary interactions diminish cluster yields vs. $\sqrt{s}$ and A+A
- counterbalanced by flow which focus nucleons in phase space

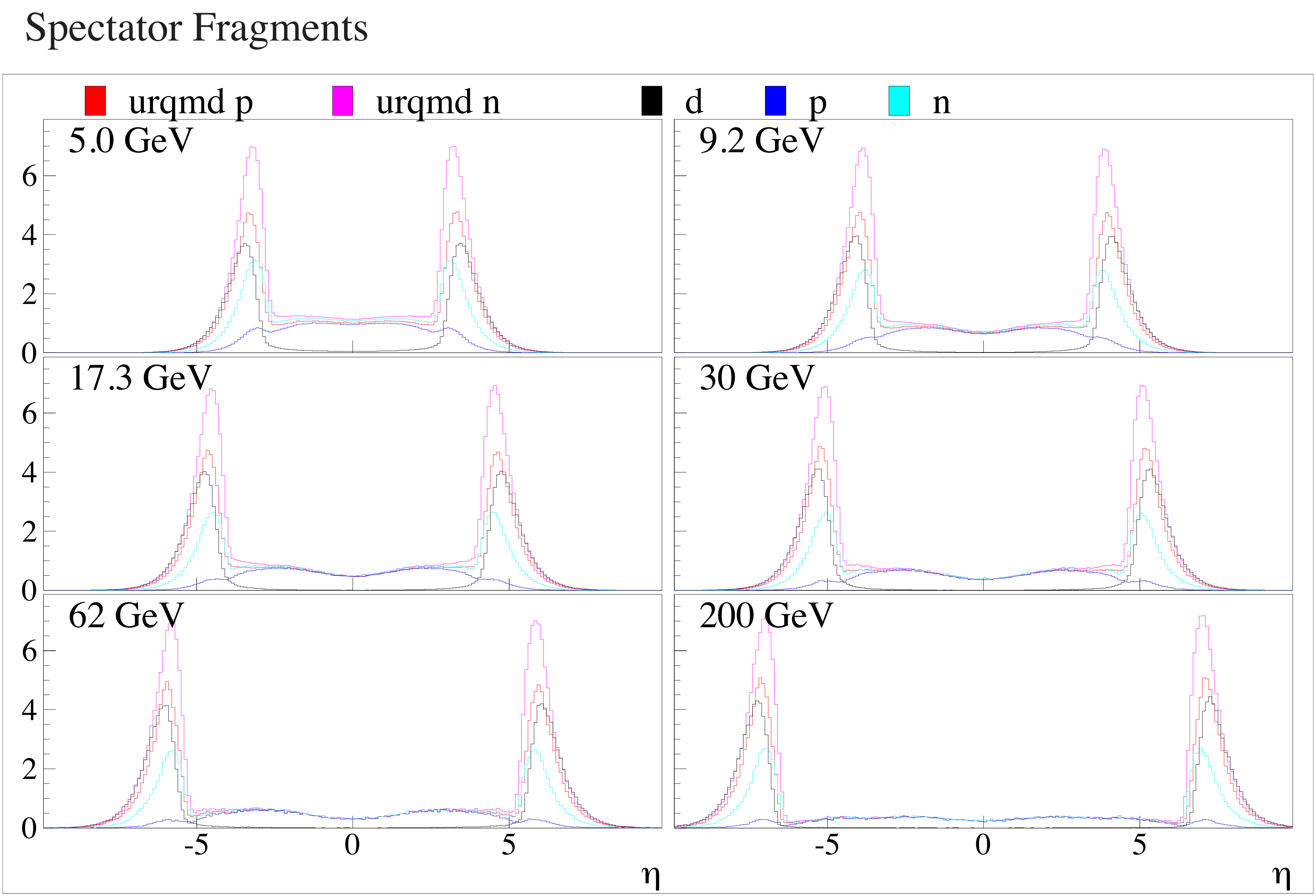
complement singles spectra and interferometry to understand space-time geometry @ freezeout
radii (or "lengths of homogeneity"), and T via multiple channels to same fragments

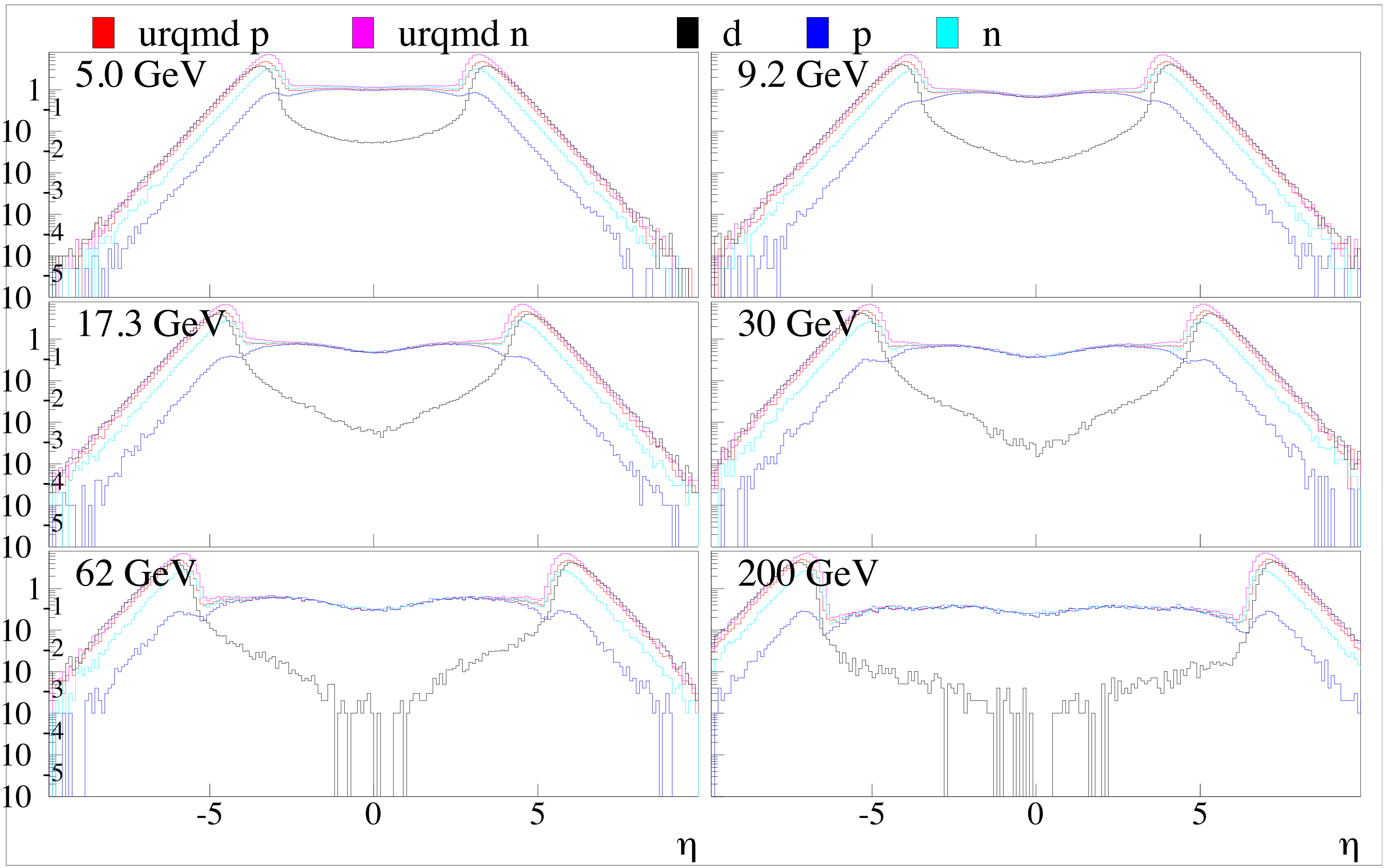
collective motion, temperatures, and position densities reflected in fragment production rates
are related to entropy production and pressures, which will be highly $\sqrt{s}$ dependent

Algorithm

get nucleon freeze-out information from UrQMD
consider all p(bar) + n(bar) pairs in each event
- propagate to common time
- calculate Δr and Δp at common time
- calculate coalescence probability
  - sharp cut-off, harmonic oscillator potential, Hulthen wave function

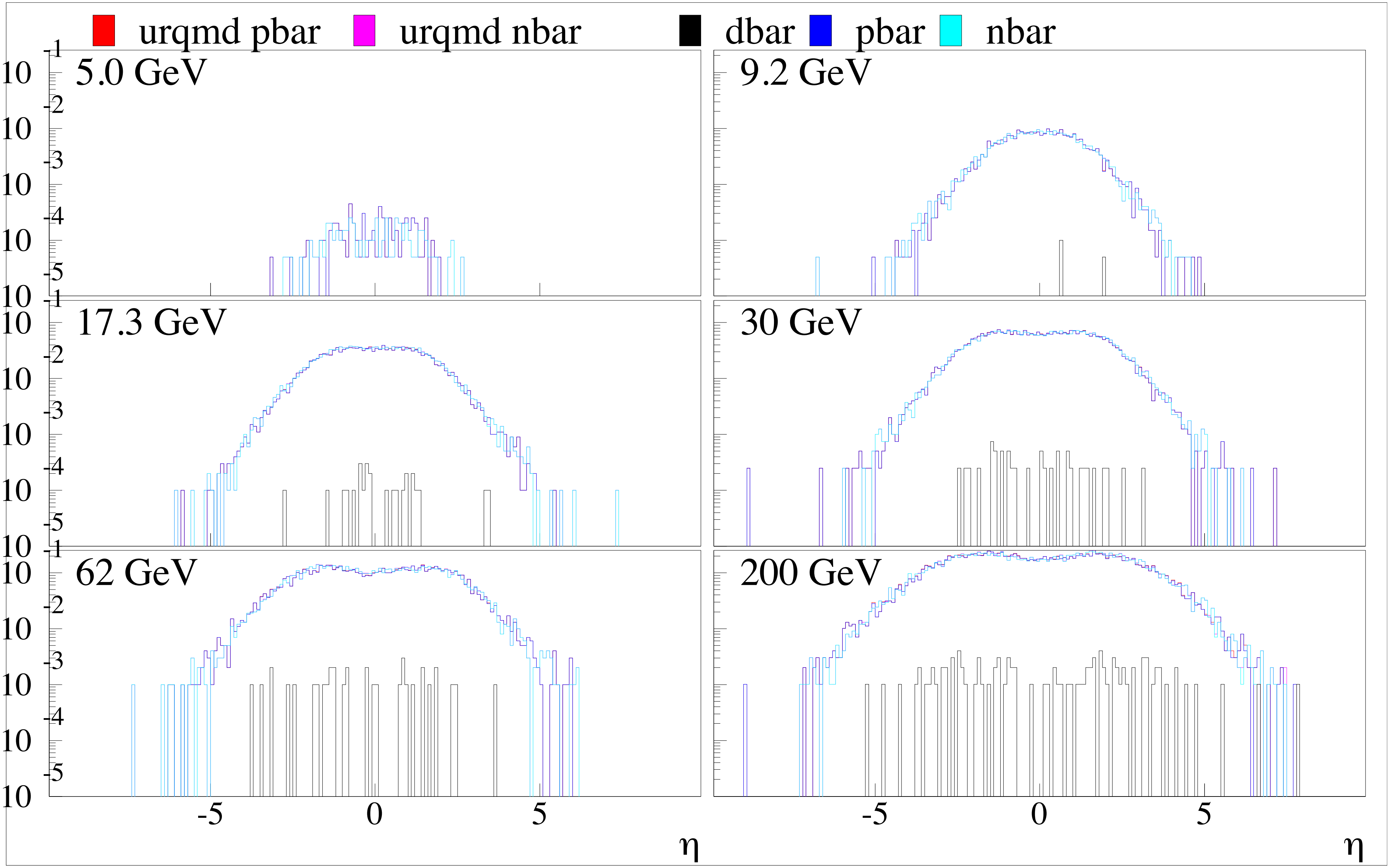
if d(bar) formed, calculate composite p,x vector & remove these 2 nucleons from the event
plot spectra


Spectator Fragments
urqmd p
urqmd n
d
p
n
5.0 GeV
9.2 GeV
17.3 GeV
30 GeV
62 GeV
200 GeV
0
2
4
6
-5
0
5
η



urqmd p
urqmd n
d
p
n
5.0 GeV
9.2 GeV
17.3 GeV
30 GeV
62 GeV
200 GeV
1
10^-1
10^-2
10^-3
10^-4
10^-5
-5
0
5
η

Anti-Fragments



Joblist

respin run-8 at 9.2 GeV data
    calculate upVPD efficiencies with rough centrality cuts

understand UrQMD better
other models

more events for fragment production predictions (SUG@R cluster)

include t, 3-He, alpha, ... rates via fragment coalescence model

redo TOF efficiency calculations separating decays & feeddown
redo upVPD efficiencies considering spectator fragment formation?
Zvtx smearing

develop modifications to TOF offline software
    get the start-time from the stops

TOF+upVPD detectors in good shape. ~3/4 of TOF is installed now.