Light Nucleus Production in p+p and the BES

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Outline:

Quick overview of major directions of this analysis

- Fragment spectra in p+p collisions
  - B_2 and source radii (first measurement at RHIC)
  - UE vs in-Jet differences, & dependence on Jet Energy (first measurement anywhere)
- Fragment production in BES
  - antinucleus production cross-sections and B_2 at low root-s (first measurement anywhere)
  - source radii from B_2 vs P_T & $\sqrt{s_{NN}}$ (some RHIC results at high-$\sqrt{s_{NN}}$, but not at BES/SPS energies)
    - direct comparison to HBT (existing results from SPS, but not RHIC)
  - (anti)baryon density vs $\sqrt{s_{NN}}$ (significant extension in P_T using TOF, and in $\sqrt{s_{NN}}$ in BES data)
- Direct comparison to models (urqmd 2.3/3.3p1, AMPT, Pythia)
  - millions of events (from SUG@R & davinci) + coalescence

Major effort recently has been on all the corrections

- Absorption
- Feeddown
- Reconstruction Efficiency
- TOF Matching
- PID Efficiency

…an astoundingly rich data set
from an awesome detector!

Datasets Analyzed with the same code:

11 = p+p	62GeV	run-6	no TOF
12 = d+Au,	200GeV	run-8	no TOF
13 = p+p	200 GeV	run-8	no TOF
14 = p+p	500 GeV	run-9	partial TOF
15 = p+p	200 GeV	run-9	partial TOF
16 = Au+Au	200 GeV	run-10	full TOF
17 = Au+Au	62.4 GeV	run-10	full TOF
18 = Au+Au	39 GeV	run-10	full TOF
19 = Au+Au	7.7 GeV	run-10	full TOF
20 = Au+Au	11.5 GeV	run-10	full TOF
23 = Au+Au	19.6 GeV	run-11	full TOF
25 = Au+Au	27 GeV	run-11	full TOF

Data	Nev	pythia	ampt	ampt(SM)	urqmd2.3	urqmd3.3p1
pp 200 Run9	183M	653M				
AuAu 200 Run 10	51.4M		84k	73k	663k	136k
AuAu 62.4 Run 10	48.2M		248k	246k	636k	256k
AuAu 39 Run 10	37.9M		328k	298k	836k	236k
AuAu 27 Run 11	46.2M		759k	696k	1.74M	390k
AuAu 19.6 Run 11	27.8M		1.02M	690k	1.73M	410k
AuAu 11.5 Run 10	15.5M		456k	280k	1.84M	492k
AuAu 7.7 Run 10	4.8M		984k	708k	4.92M	2.74M

Experimental Goals:

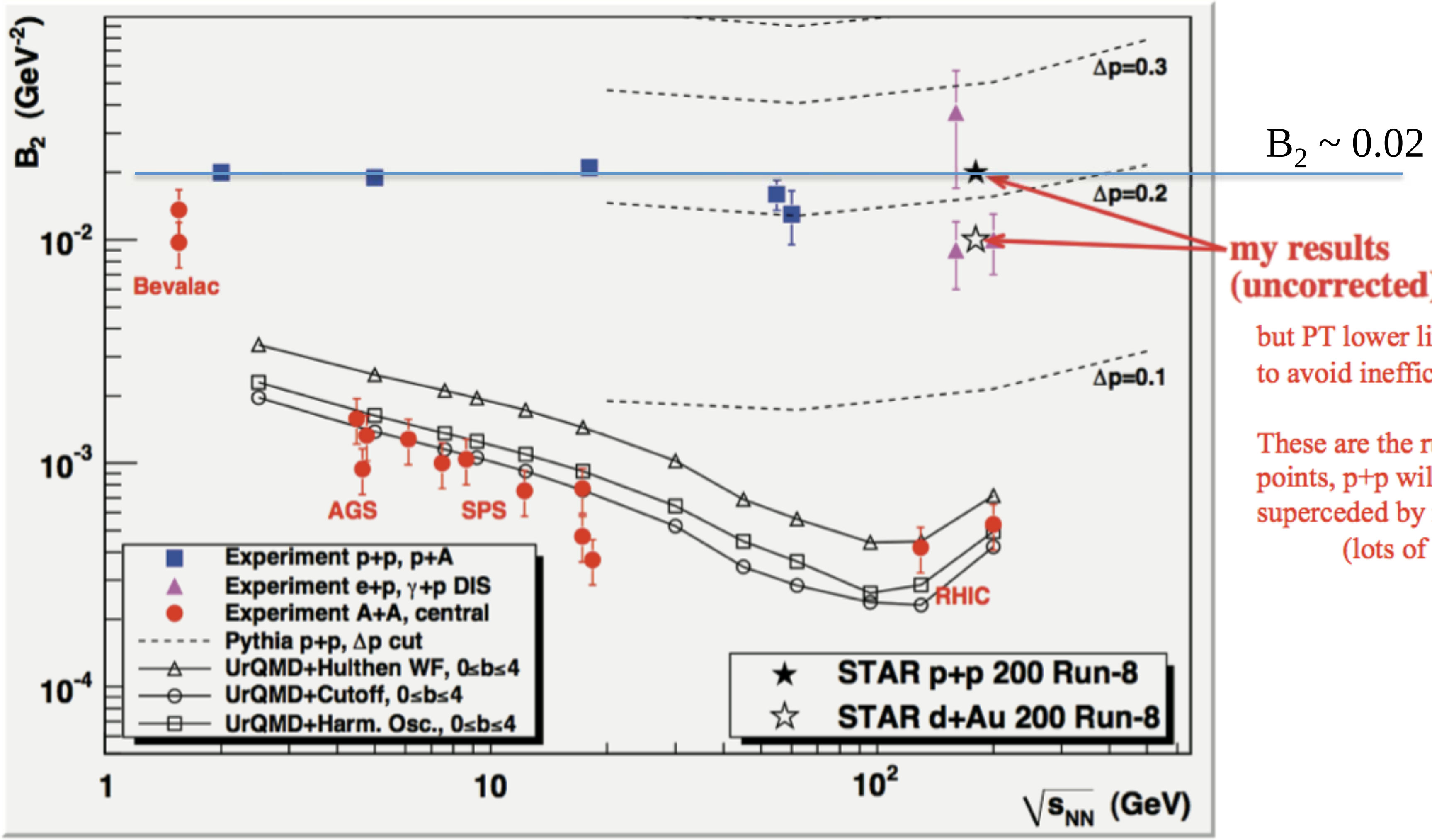
- Cross-sections for p, d, t (^{3}He, α) versus P_T and P_T/A
  - in p+p, cross-referencing of tracks in jets to jet energy, angles, etc
- Coalescence ratios: B_A vs P_T/A
  - interpretable in terms of source volumes
- Spectra ratios: d/p & t/p vs M_T/A
  - (net baryon density)

Theory:

- 6-D Dynamic Coalescence using various models.... Pythia, AMPT, UrQMD
- Source radii directly from B_A vs P_T/A.... several prescriptions & compare to HBT

World's Data on B_2 in various entrance channels

Comparisons to world's data.....

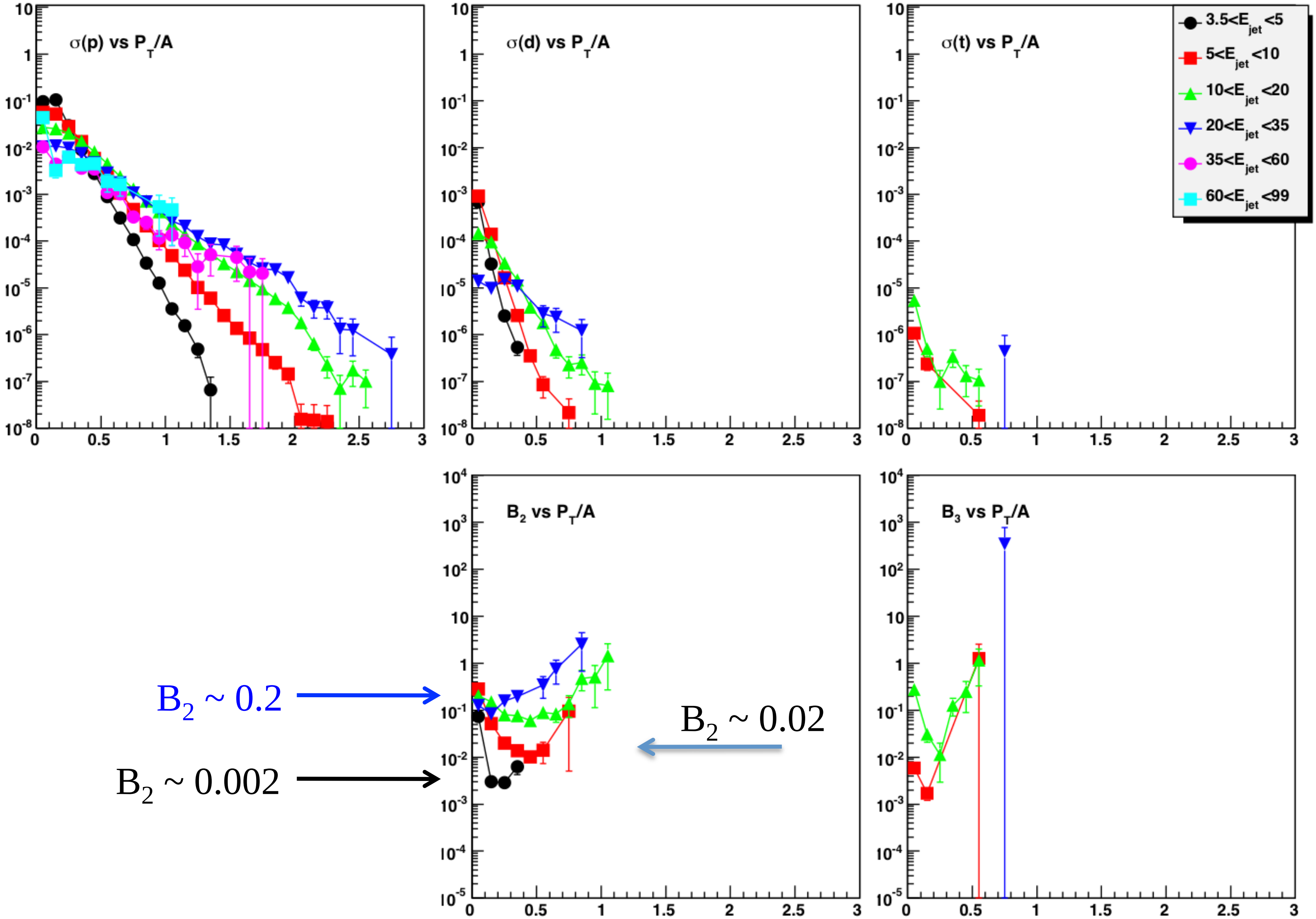


but PT lower limit
to avoid inefficiency

These are the run-8
points, p+p will be
superceded by run-9
(lots of TOF)

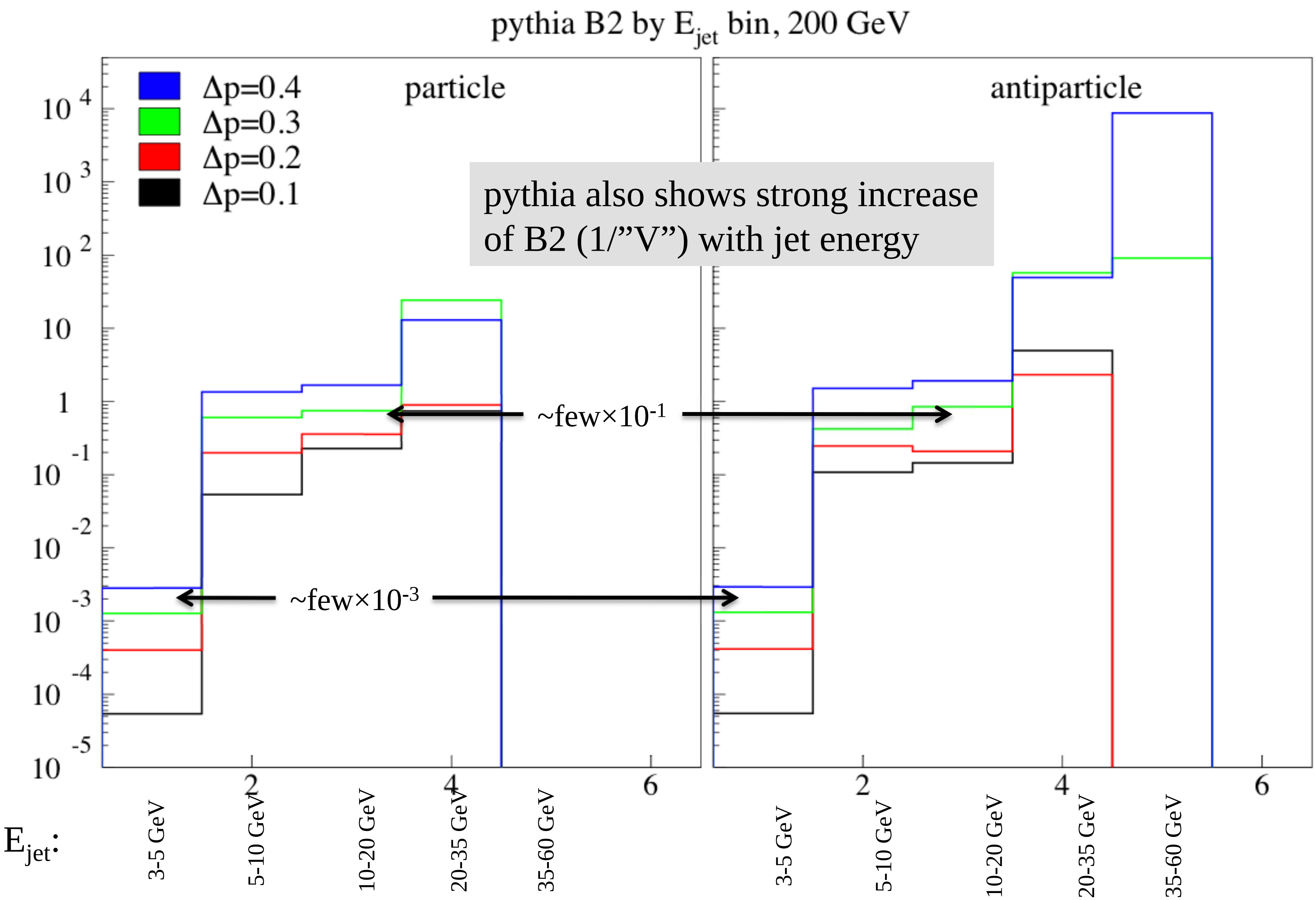
Summary* so far:	Experiment	Coalescence Picture:	Pythia+Δp
p+p, 200 GeV, Run-8:	$B_2 = 0.02$ GeV^2	R ~ 3.3 fm, $p_o \sim 180$ MeV	Δp ~ 210 MeV
d+Au, 200 GeV, Run-8:	$B_2 = 0.01$ GeV^2	R ~ 4.2 fm, $p_o \sim 150$ MeV	Δp ~ 180 MeV

Dependence of B_2 for p,d in Jets vs Jet energy

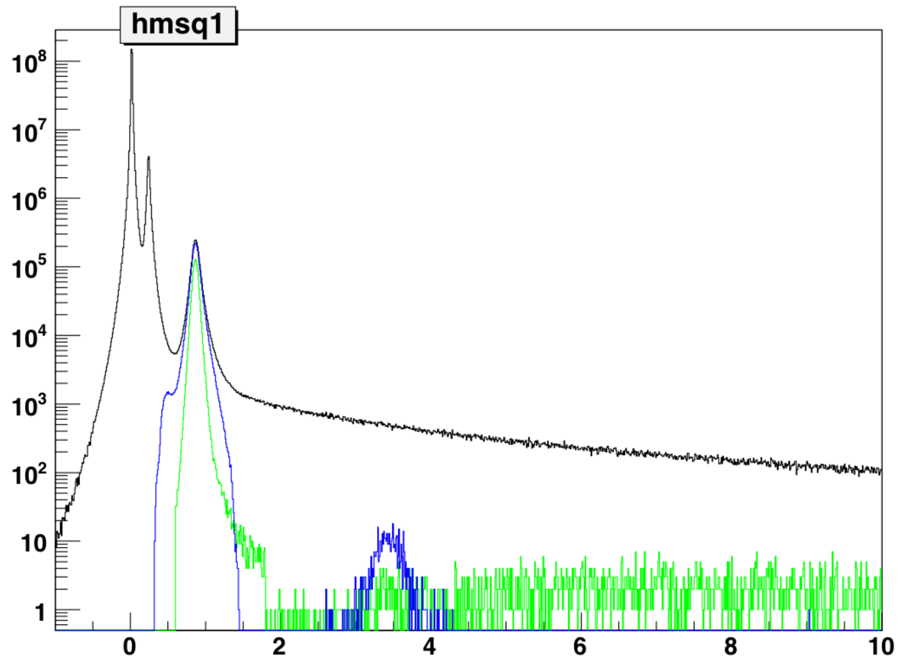


strong increase in B_2 (strong decrease in "source volume") with inc. E_{jet}

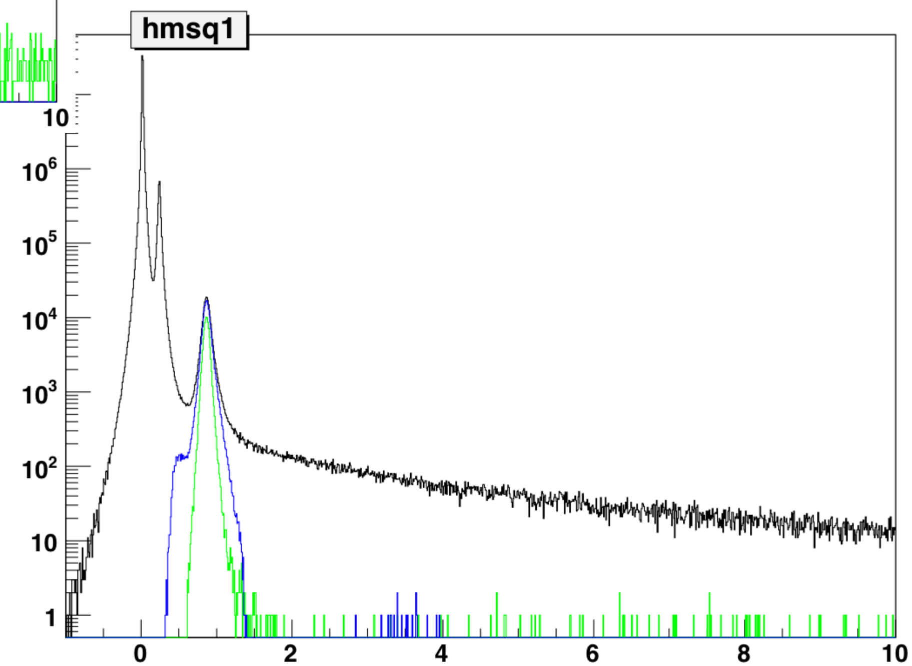
Dependence of B_2 for p,d in Jets vs Jet energy, from Pythia



Antinucleus Production at very low (~SPS) root-s



dbar spectra, and dbar/pbar & B_2 ratios at these very low root-s values not reported by any of the SPS experiments



Cuts and PID

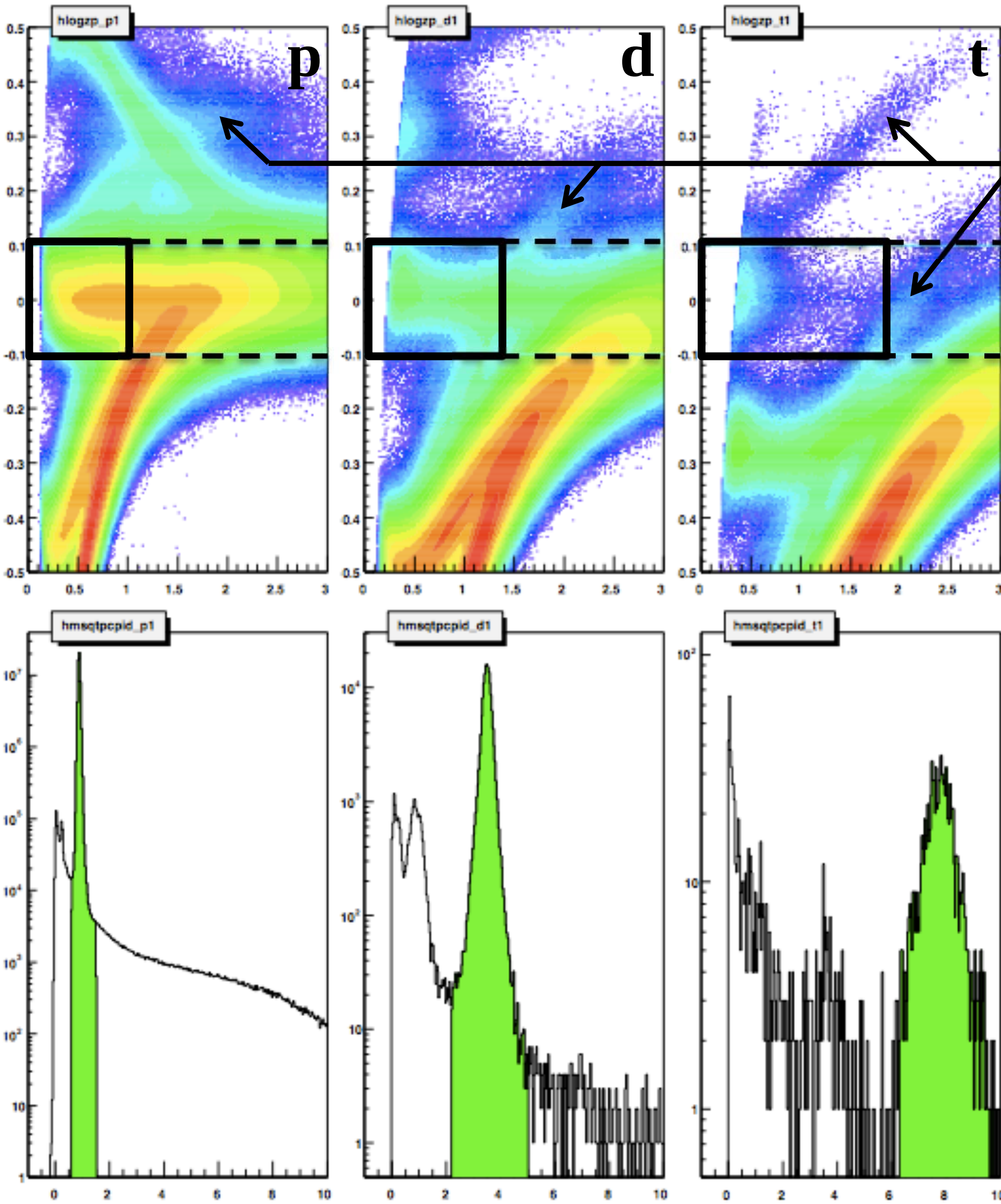
Event Cuts:
$|Z_{vtx}|<50$, $R_{vtx}<2$, $|\eta_{asym}|<5$, $|\eta_{asymTOF}|<5$, $N_{tofmatch}>5$
refmult centrality
minimum bias trigger in st_physics stream

Track Cuts:
flag=301, $N_{hitsfit}/N_{hitsposs}>0.52$
"cuts set1": $N_{hitsfit}>15$, $N_{hitsdedx}>10$, gldca<2
"cuts set2": $N_{hitsfit}>25$, $N_{hitsdedx}>15$, gldca<1
TOF: matchflag>0, |ylocal|<1.8, $\beta>0$

PID:
"dE/dx-TOF": log-Z cut on POI, p<0.9 (p), p<1.3 (d), p<1.7 (t)
if TOF info exists (~65-70%), require that M^2 is consistent with POI
full efficiency but mom'n limited, uses TOF to clean up dE/dx where possible

"dE/dx+TOF": log-Z cut on POI, no momentum upper limit
require TOF info exists, and require that M^2 is consistent with POI
65-70% as efficient, but much wider mom'n reach

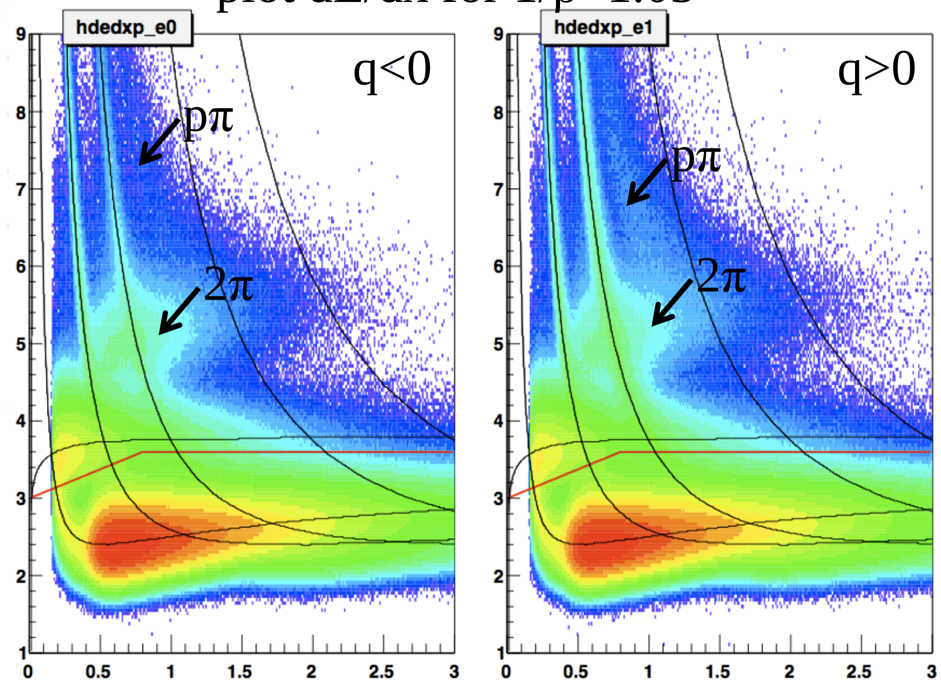
log(Z) =log[dE/dx(track)]/[dE/dx(Bichsel)] *vs.* momentum…



what's this junk?

It's merged tracks!

plot dE/dx for 1/β<1.03



rate can be large compared to Abar rate!

TOF kills these quite effectively…

Corrections Introduction

absorption

- pbar handled by geant/embedding
- Abar cannot be done w/ geant, need to use an empirical approach

feeddown

- simulation/reconstruction of full events from some model

reconstruction efficiency

- embedding

TOF matching

Not done yet:
PID Efficiency
Sector 20

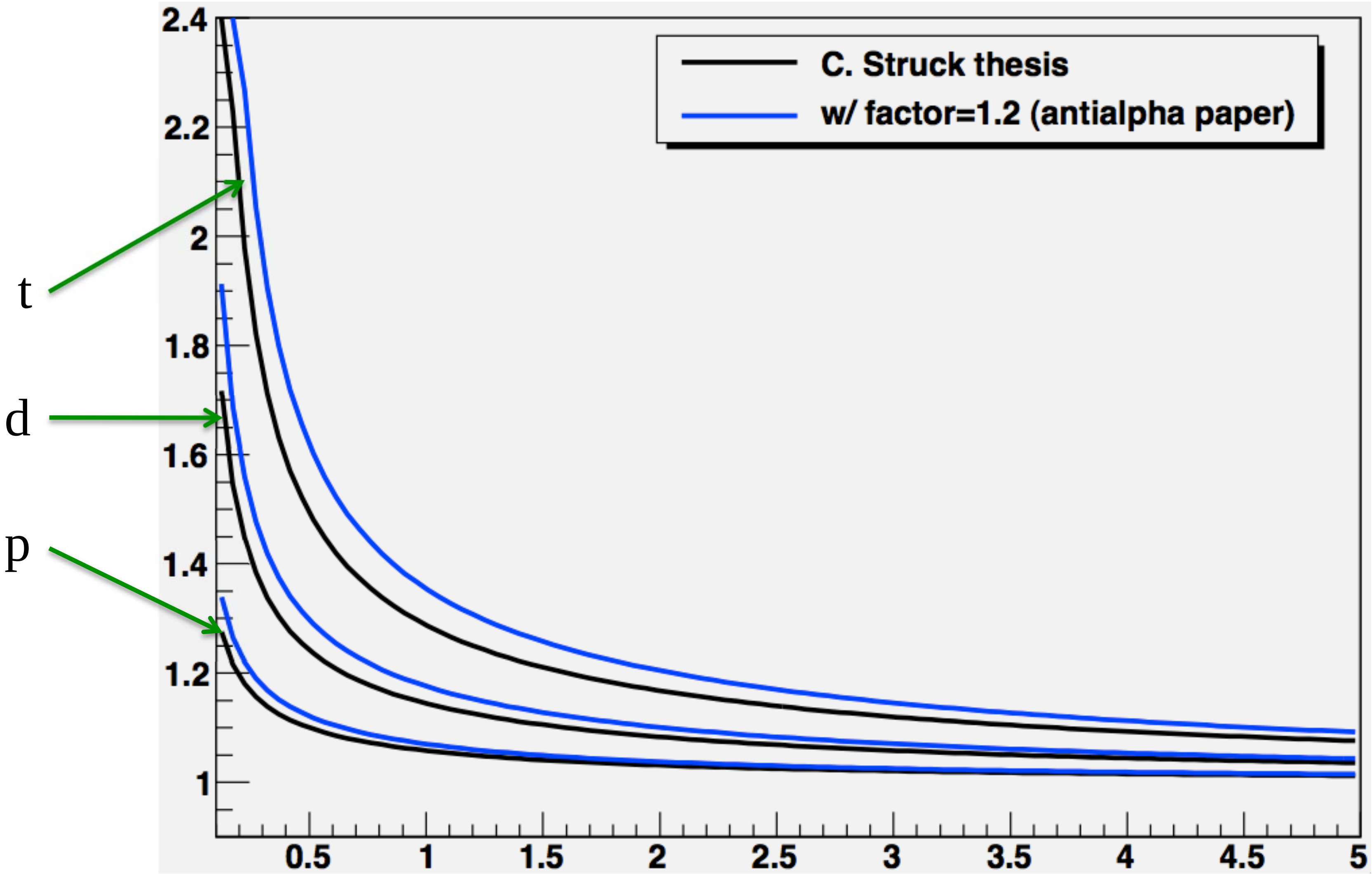
Absorption

geant does not know how to interact antinuclei w/ arbitray materials

so use prescription described in Christof Struck's thesis…

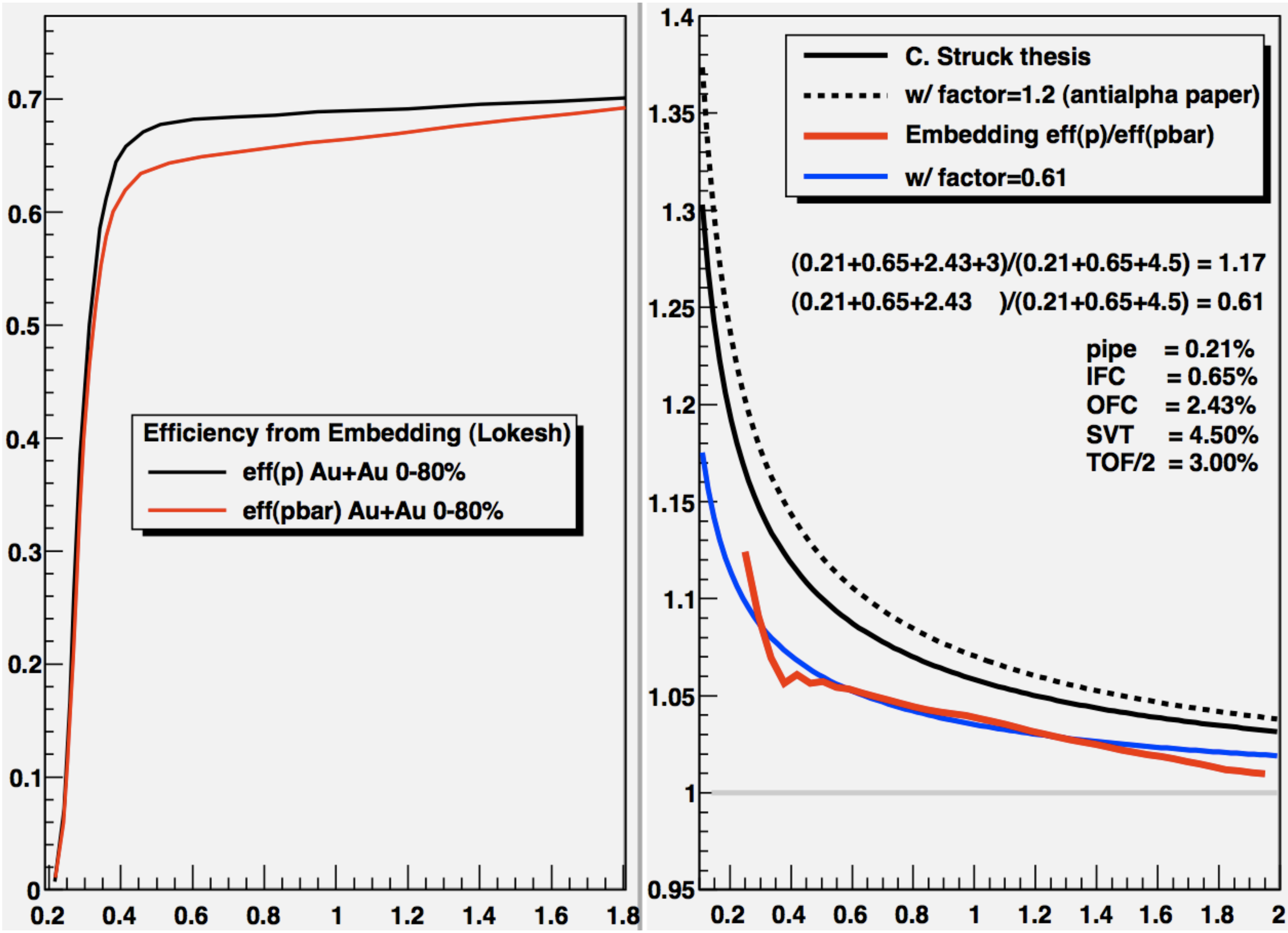
same prescription used in recent antialpha paper after scaling the materials

(remove SVT, add half-depth of TOF)



Absorption

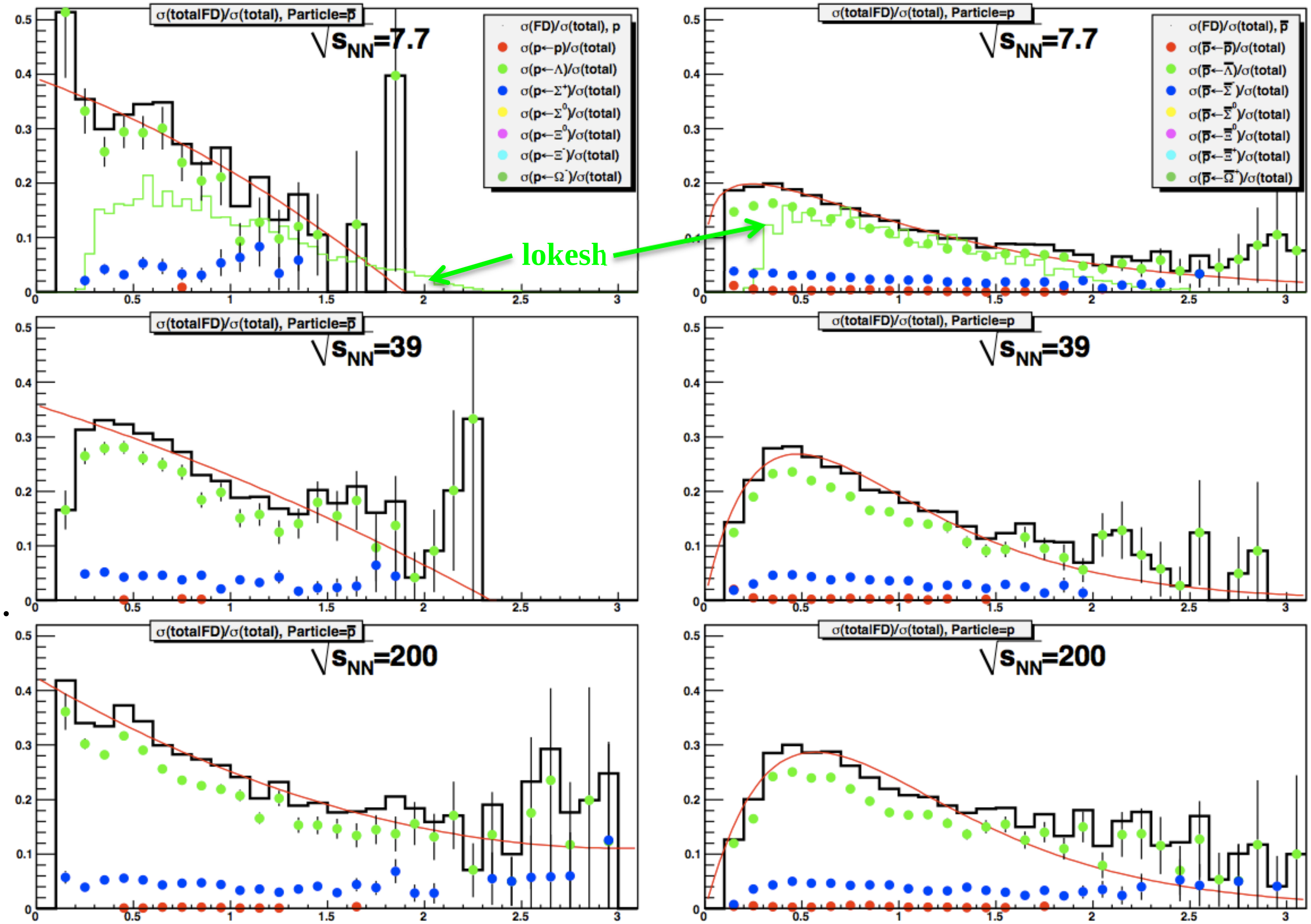
geant *does* know how to interact pbars, so one can test the absorption prescription using embedding data!



Feeddown

UrQMD 3.3p1
starsim & Y2010c
 geom repairs
 realistic σ_{Zvtx}
bfc.C
 TpcRS
 MiniMcMk

TpcRS is **slow**
but most realistic…
no dE/dx fudging!



Uncovered problems in trs
 unknown species was given a geantID=0, and then no energy loss, and then no rec. tracks
Fix entailed changes to trs and StarClassLibrary to properly include light antinuclei…
 see RT Ticket #2157.

Embedding Introduction

Lots of technical problems in many different codes….

(many thanks to Hiroshi, Xiangli, Geraldo, Xianglei, Gene, Jason, & Victor!)

Block 1:

dbar in p+p, 200 GeV, run-9	20101704	DONE
dbar in Au+Au, 200 GeV, run-10	20101706	DONE
dbar in Au+Au, 11.5 or 39, run-10	20101708	DONE

OOPS! These were done in SL11c.
Comparison to the newly available SL10k_emb shows different glDCA distributions & efficiencies
….need to repeat the Block 1 requests (underway)

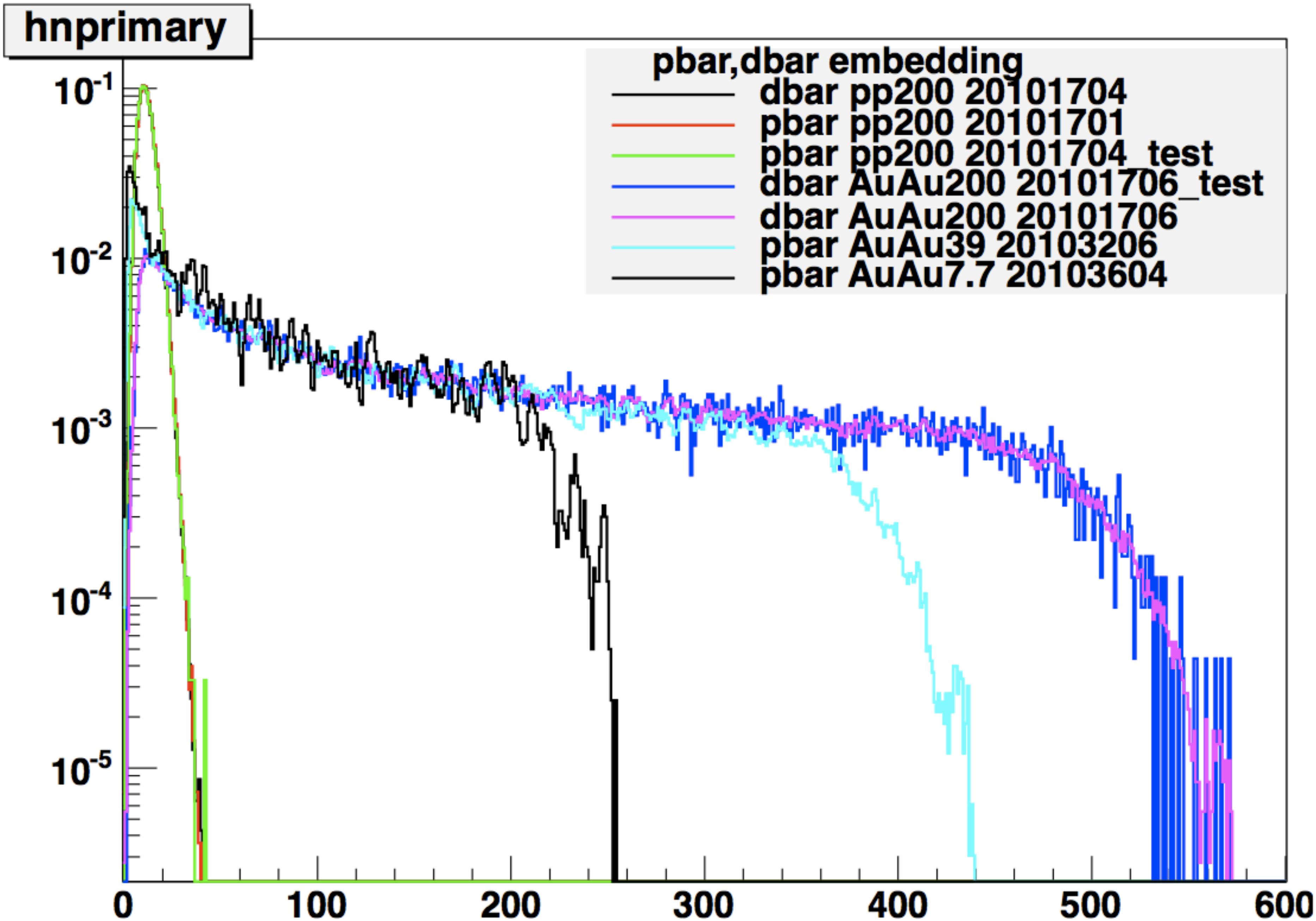
Block 2:

tbar in p+p, 200 GeV, run-9
dbar in Au+Au, 200 GeV, run-10
tbar in Au+Au, 11.5 or 39, run-10
pbar in p+p, 200 GeV, run-9
pbar in Au+Au, 200 GeV, run-10
pbar in Au+Au, 11.5 or 39, run-10

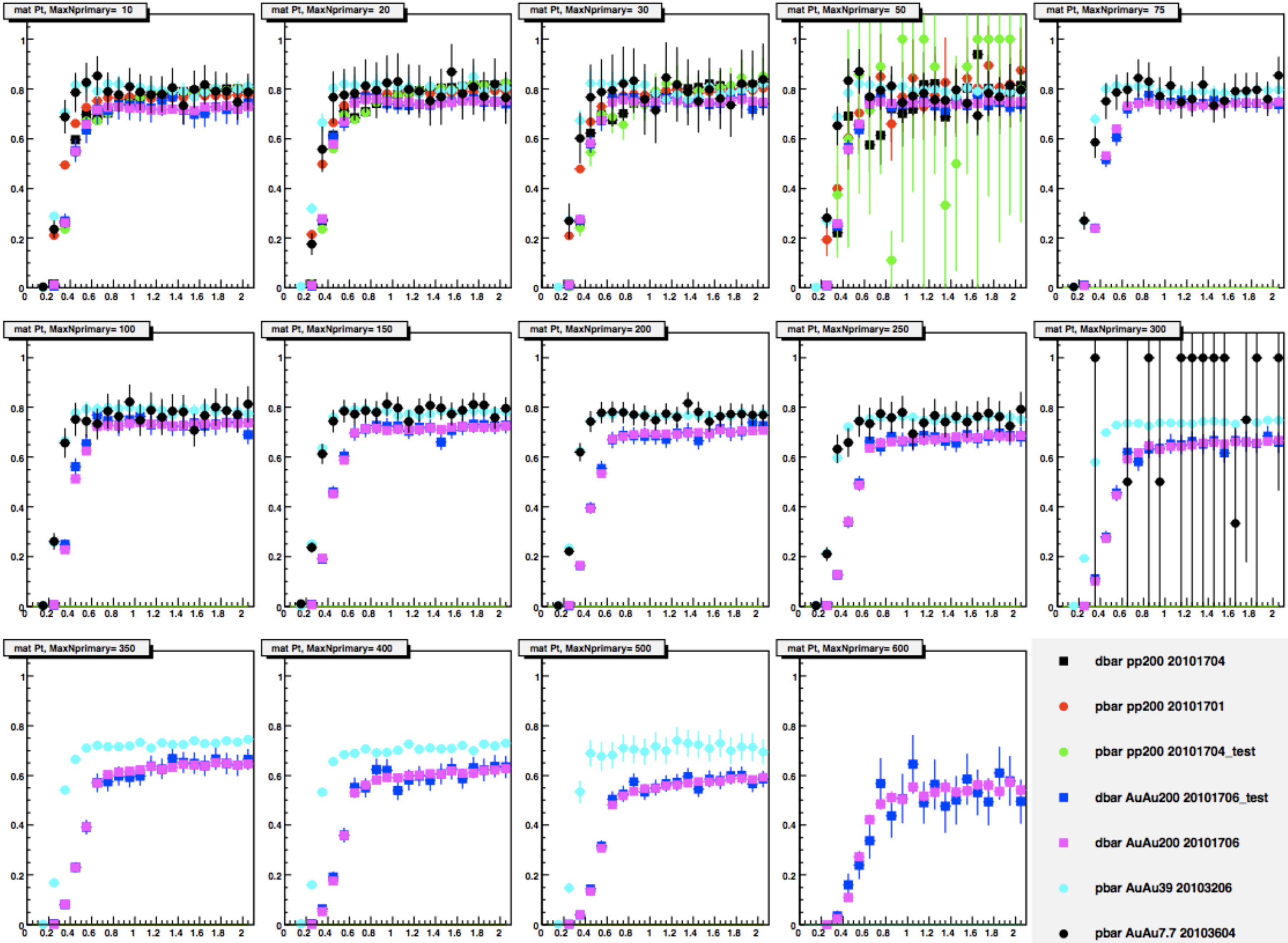
I also found some existing embedding productions laying around….

pbar	p+p	200GeV	20101701
pbar	Au+Au	39GeV	20103206
pbar	Au+Au	7.7GeV	20103604

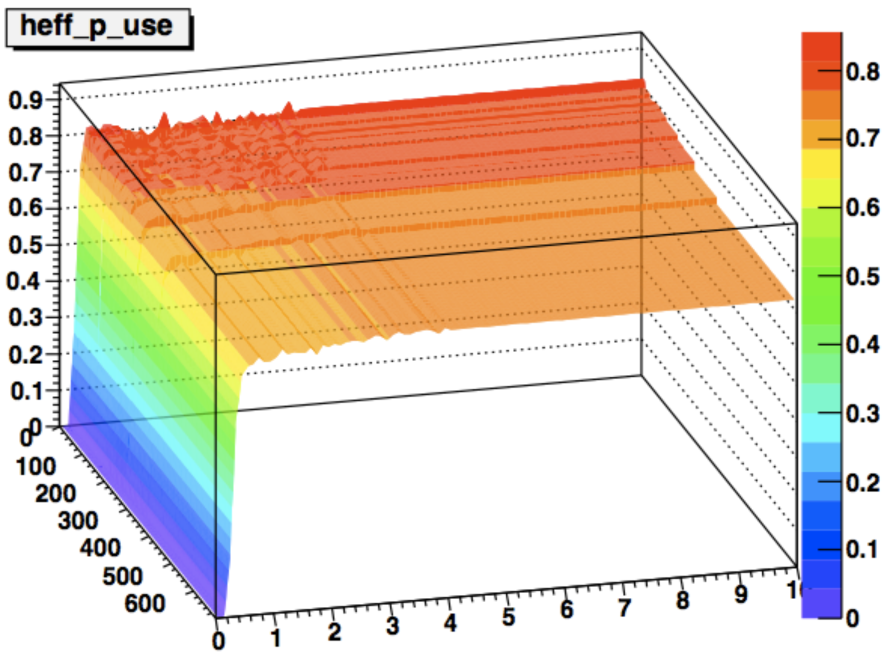
Embedding

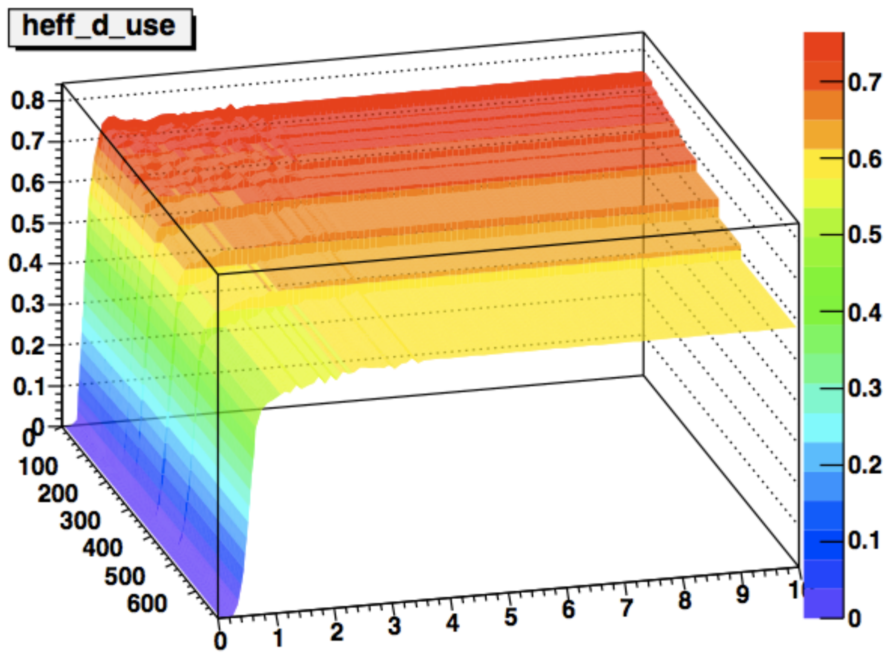

hnprimary
pbar,dbar embedding
dbar pp200 20101704
pbar pp200 20101701
pbar pp200 20101704_test
dbar AuAu200 20101706_test
dbar AuAu200 20101706
pbar AuAu39 20103206
pbar AuAu7.7 20103604
10-1
10-2
10-3
10-4
10-5
0
100
200
300
400
500
600

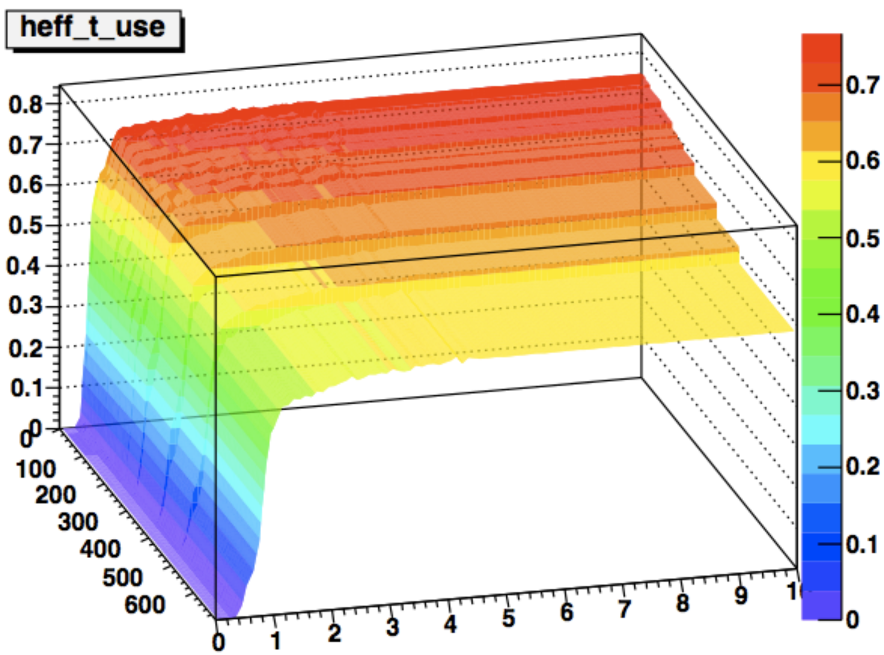
Embedding


mat Pt, MaxNprimary= 10
mat Pt, MaxNprimary= 20
mat Pt, MaxNprimary= 30
mat Pt, MaxNprimary= 50
mat Pt, MaxNprimary= 75
mat Pt, MaxNprimary= 100
mat Pt, MaxNprimary= 150
mat Pt, MaxNprimary= 200
mat Pt, MaxNprimary= 250
mat Pt, MaxNprimary= 300
mat Pt, MaxNprimary= 350
mat Pt, MaxNprimary= 400
mat Pt, MaxNprimary= 500
mat Pt, MaxNprimary= 600
dbar pp200 20101704
pbar pp200 20101701
pbar pp200 20101704_test
dbar AuAu200 20101706_test
dbar AuAu200 20101706
pbar AuAu39 20103206
pbar AuAu7.7 20103604

Embedding

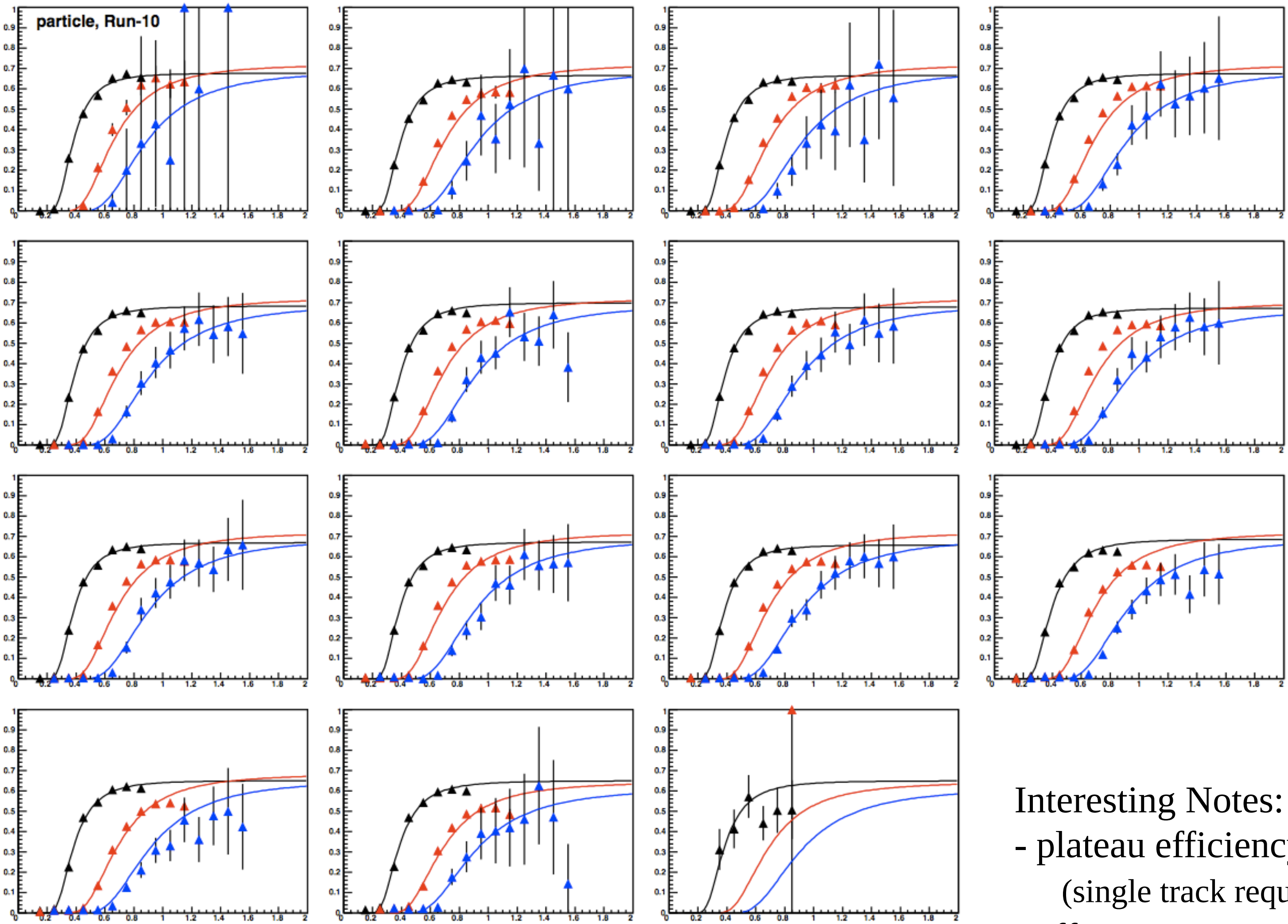






TOF Matching

1σ cut on dE/dx, then plot probability there is a TOF match for this track *vs.* P_T….



different boxes are refmult bins (same as for embedding)

p d t

heavier particles start matching to TOF at higher P_T

results in 3×2×3 functions vs P_T…

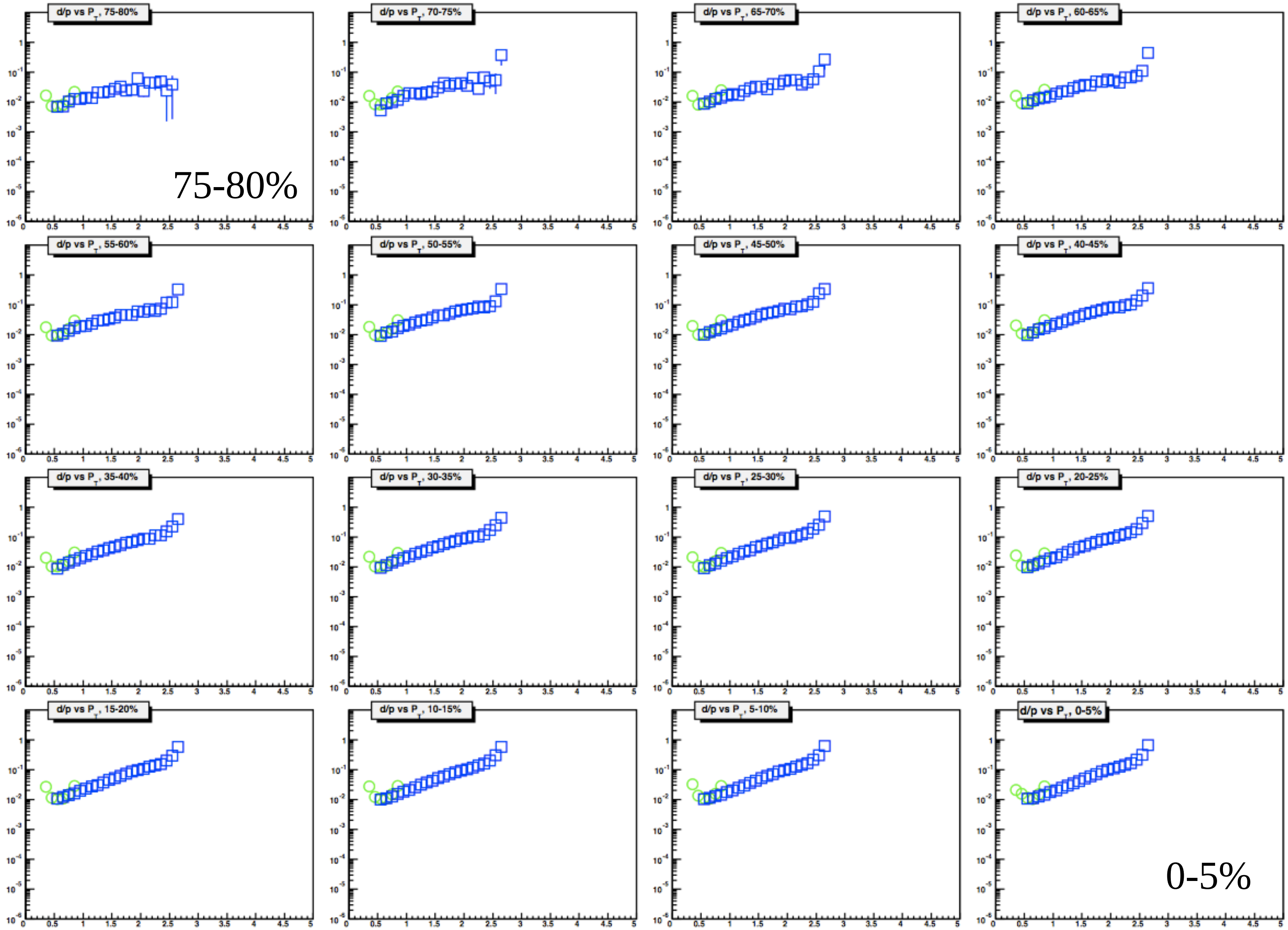
(p,d,t) (+,-) (run9,10,11)

Interesting Notes:

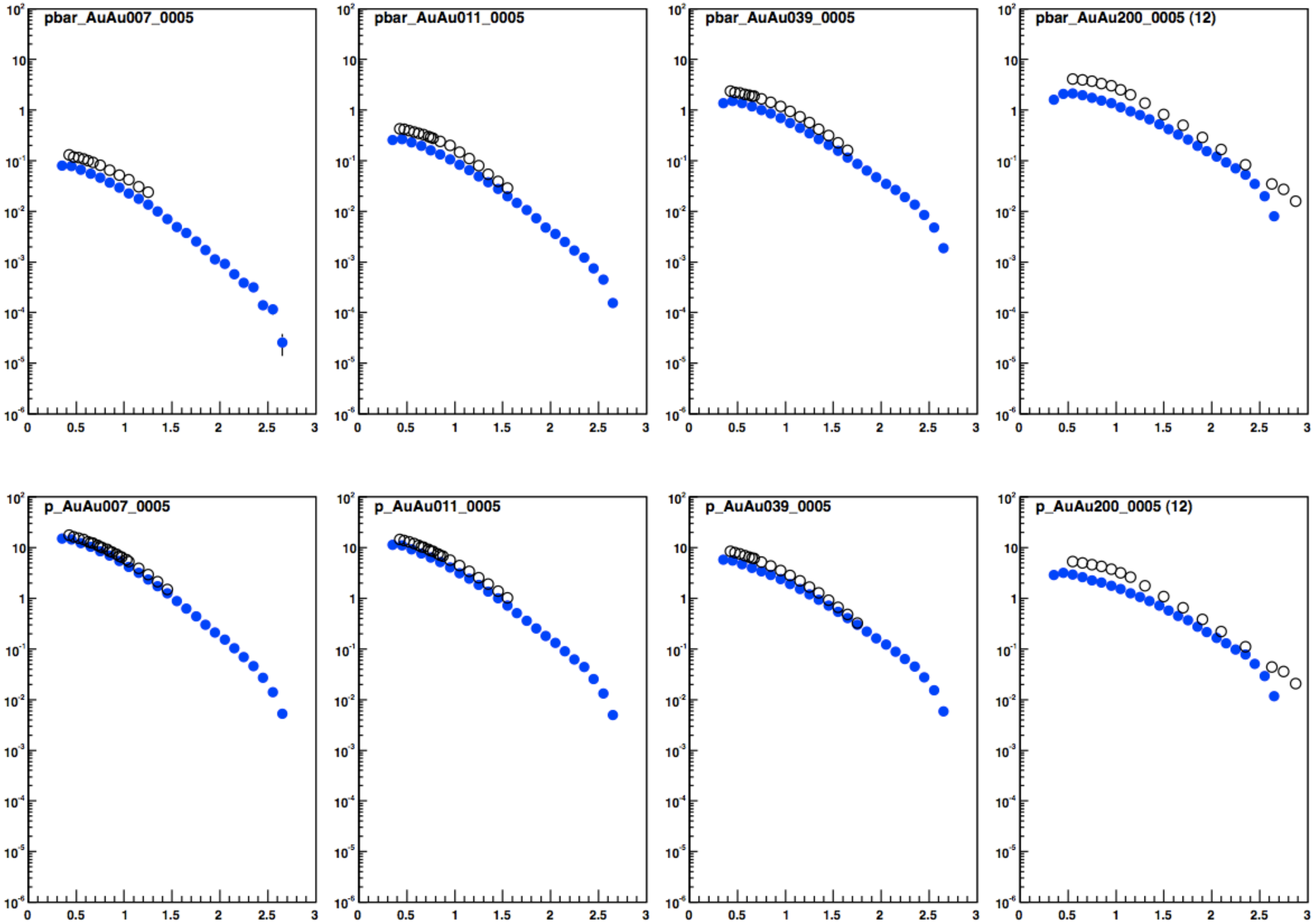
- plateau efficiency decreases with refmult
  (single track requirement in BTofMatchMaker)
- efficiency: Run-11 > Run-10
- efficiency: antiparticle < particle
  (absorption in OFC, TPC rail, TOF box)

d/p ratios

If TOF match efficiencies are correct, then dE/dx-TOF results and dE/dx+TOF results should lie on top of each other in the overlapping P_T range

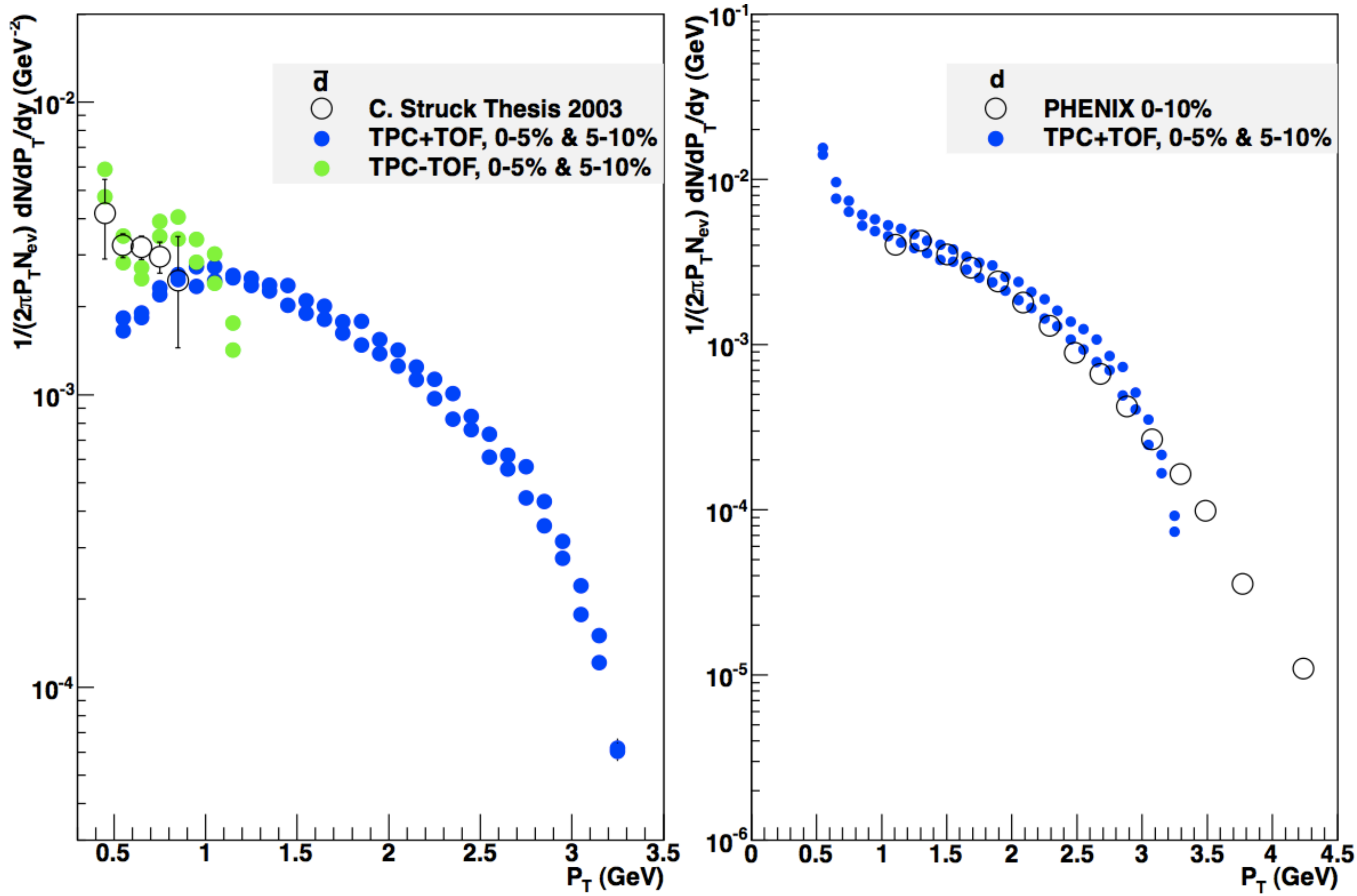


Comparison to Lokesh's protons

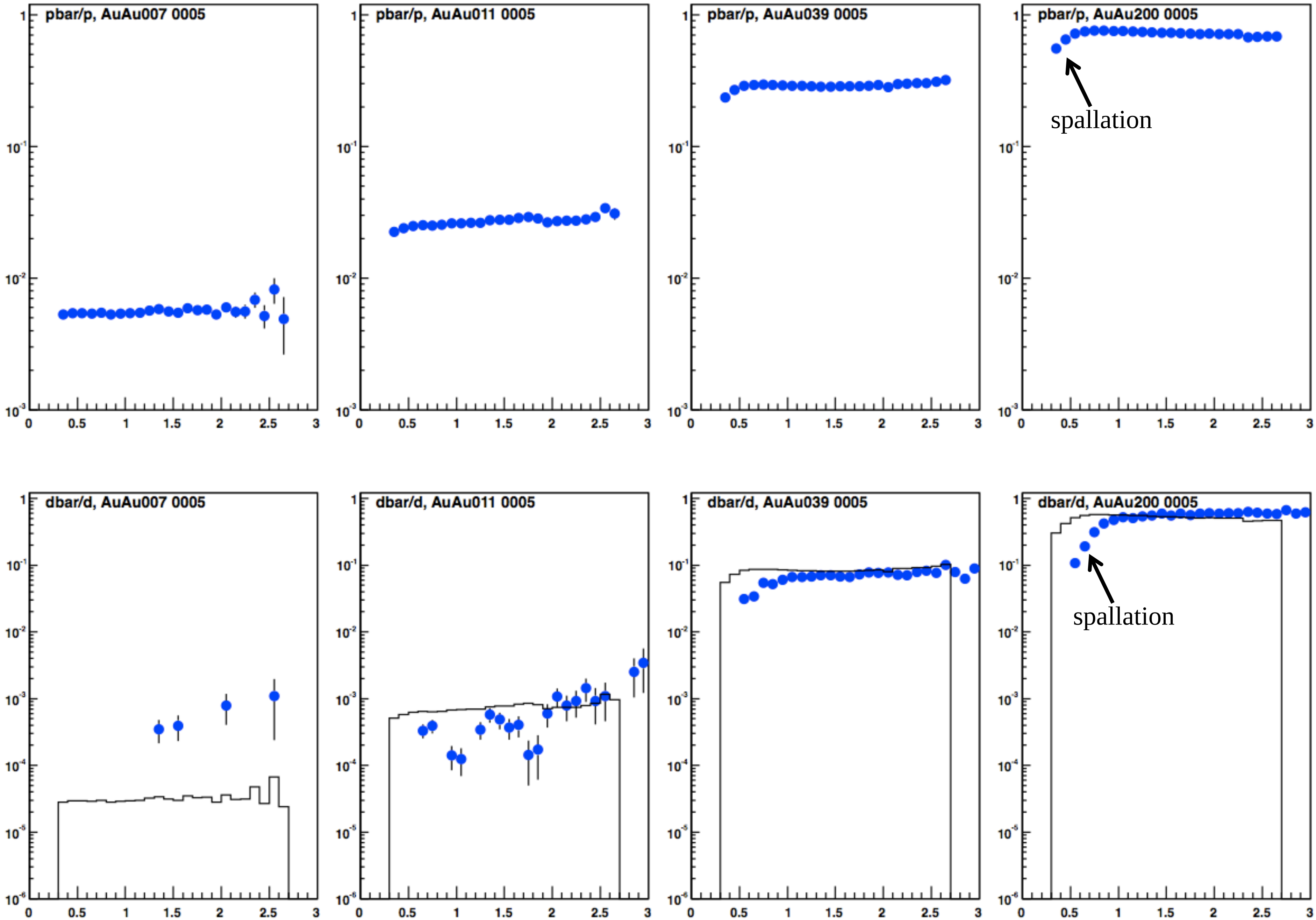


Lokesh's xsecs are not feeddown corrected, mine are.
My FD-uncorrected protons are dead on top of lokesh's p's, my pbar's ~20% less…

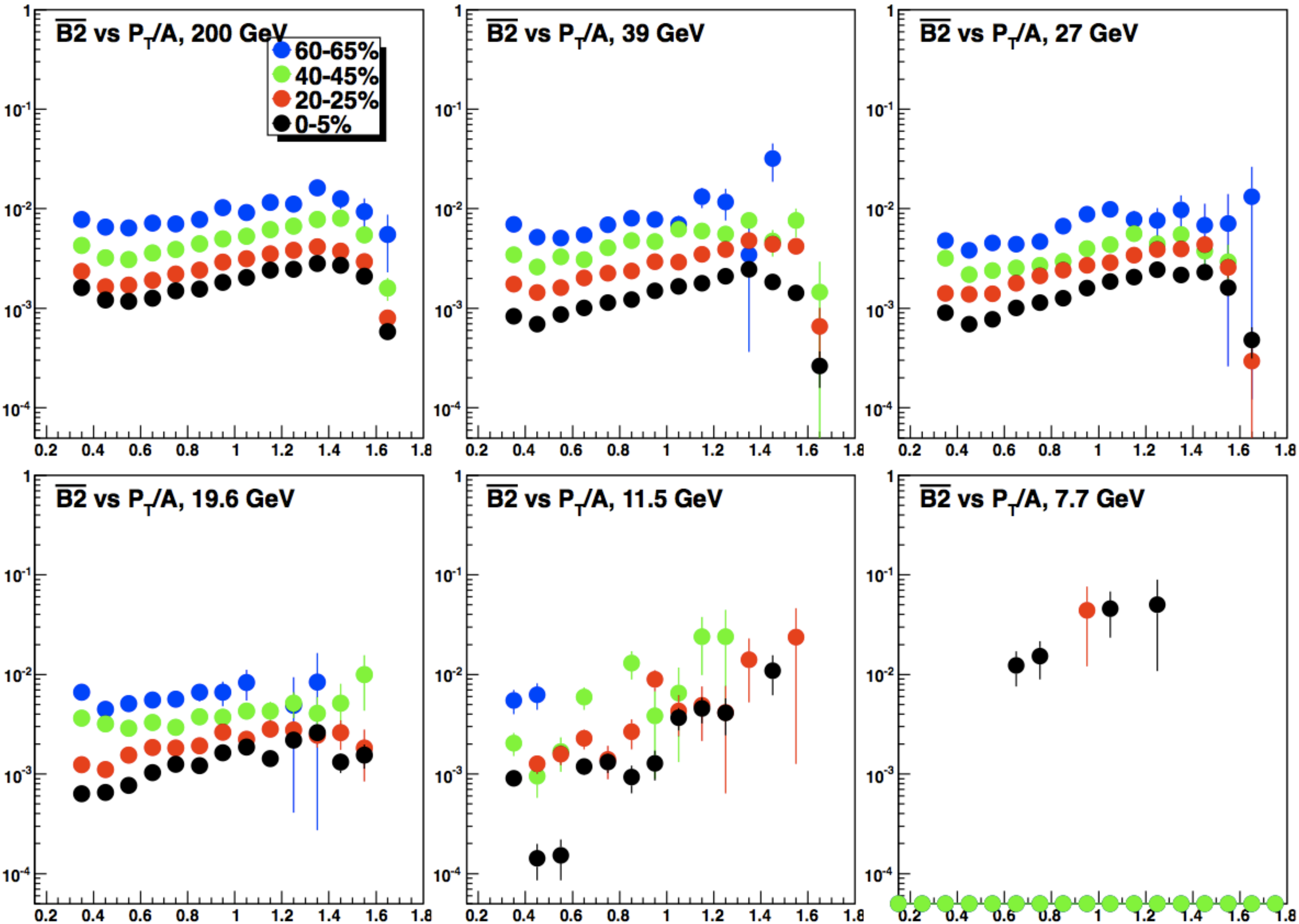
Comparison to published d's and dbar's



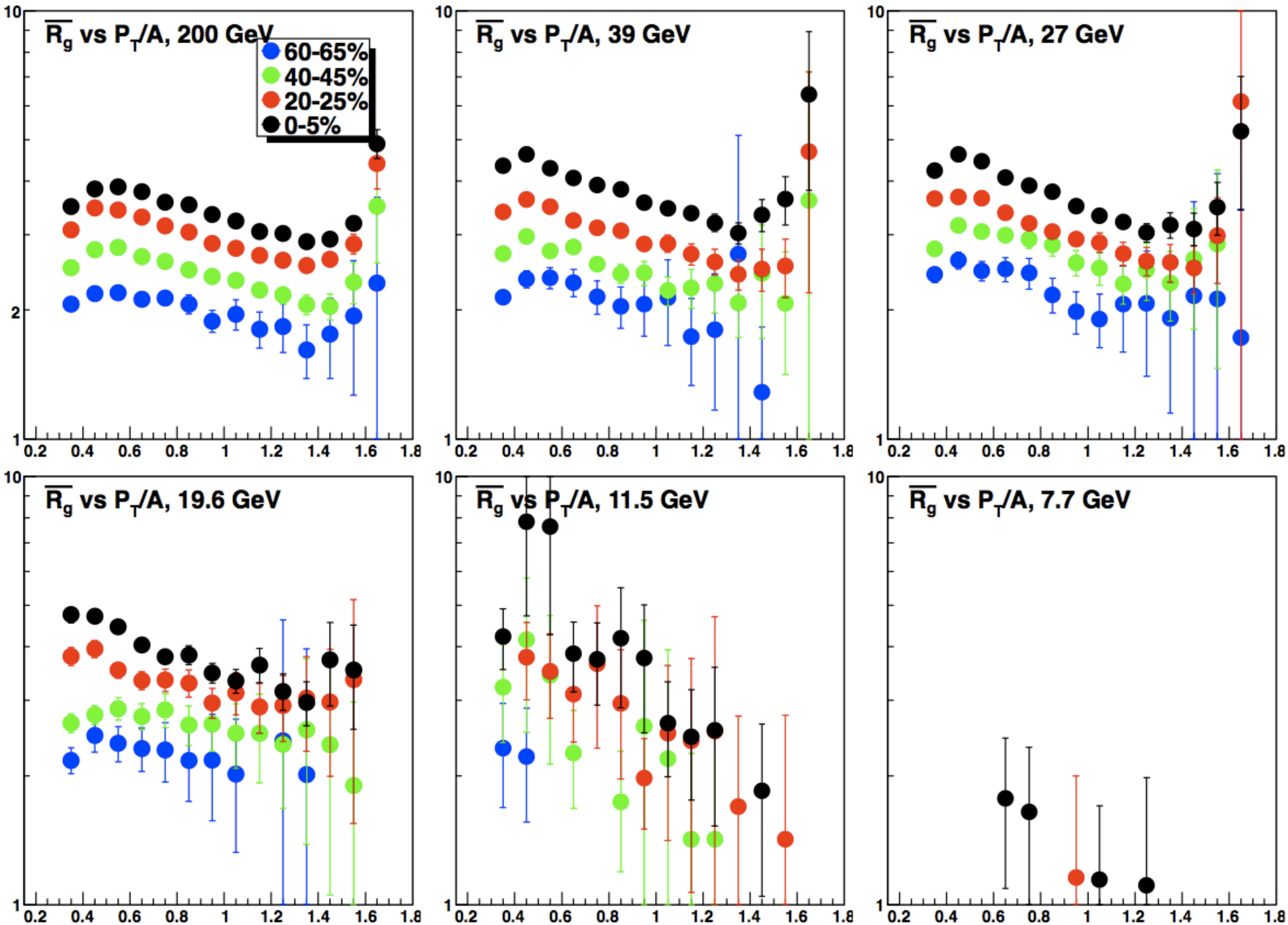
Ratio checks motivated by coalescence arguments



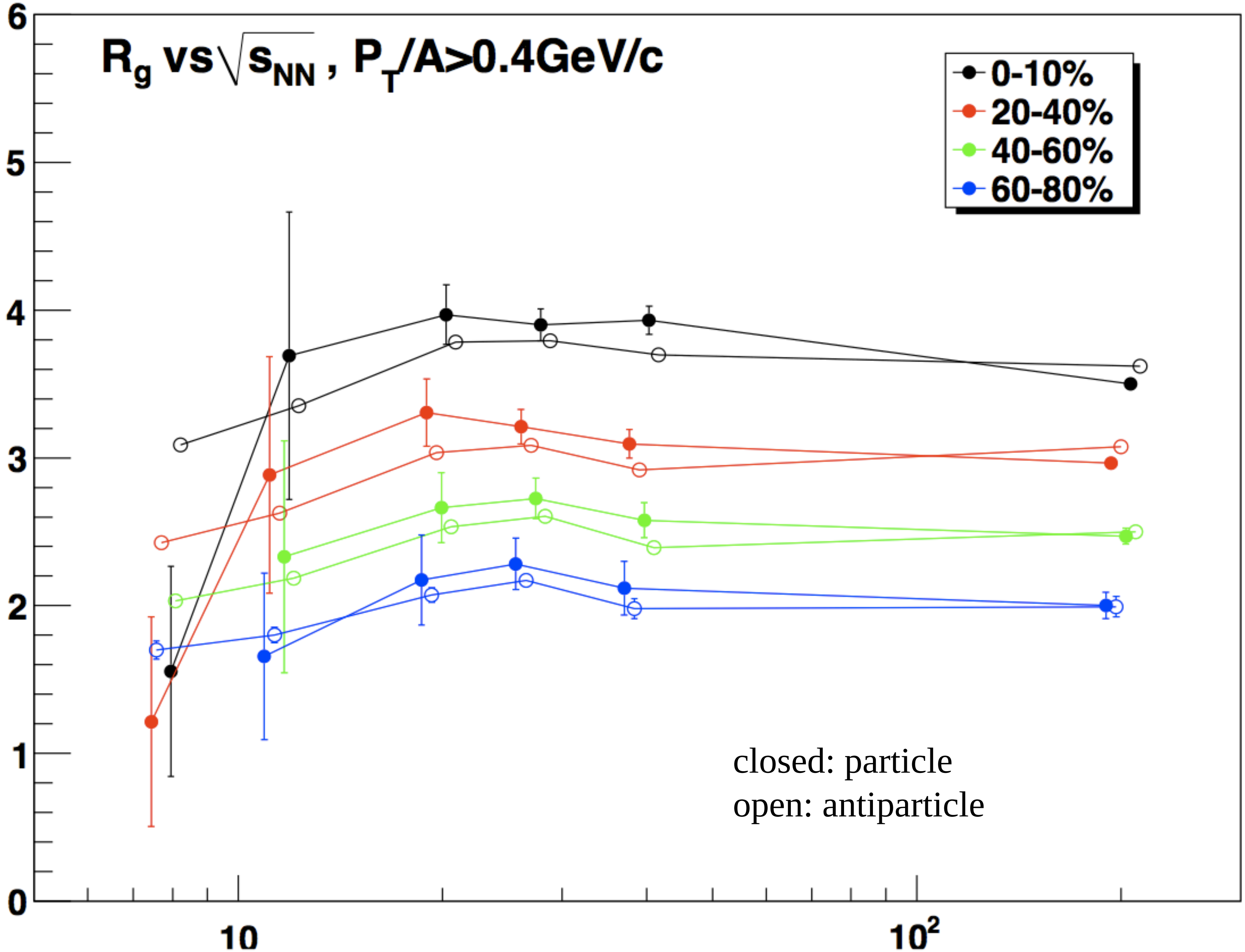
B_2 vs P_T/A by $\sqrt{s_{NN}}$ and centrality



R_G vs P_T/A by $\sqrt{s_{NN}}$ and centrality

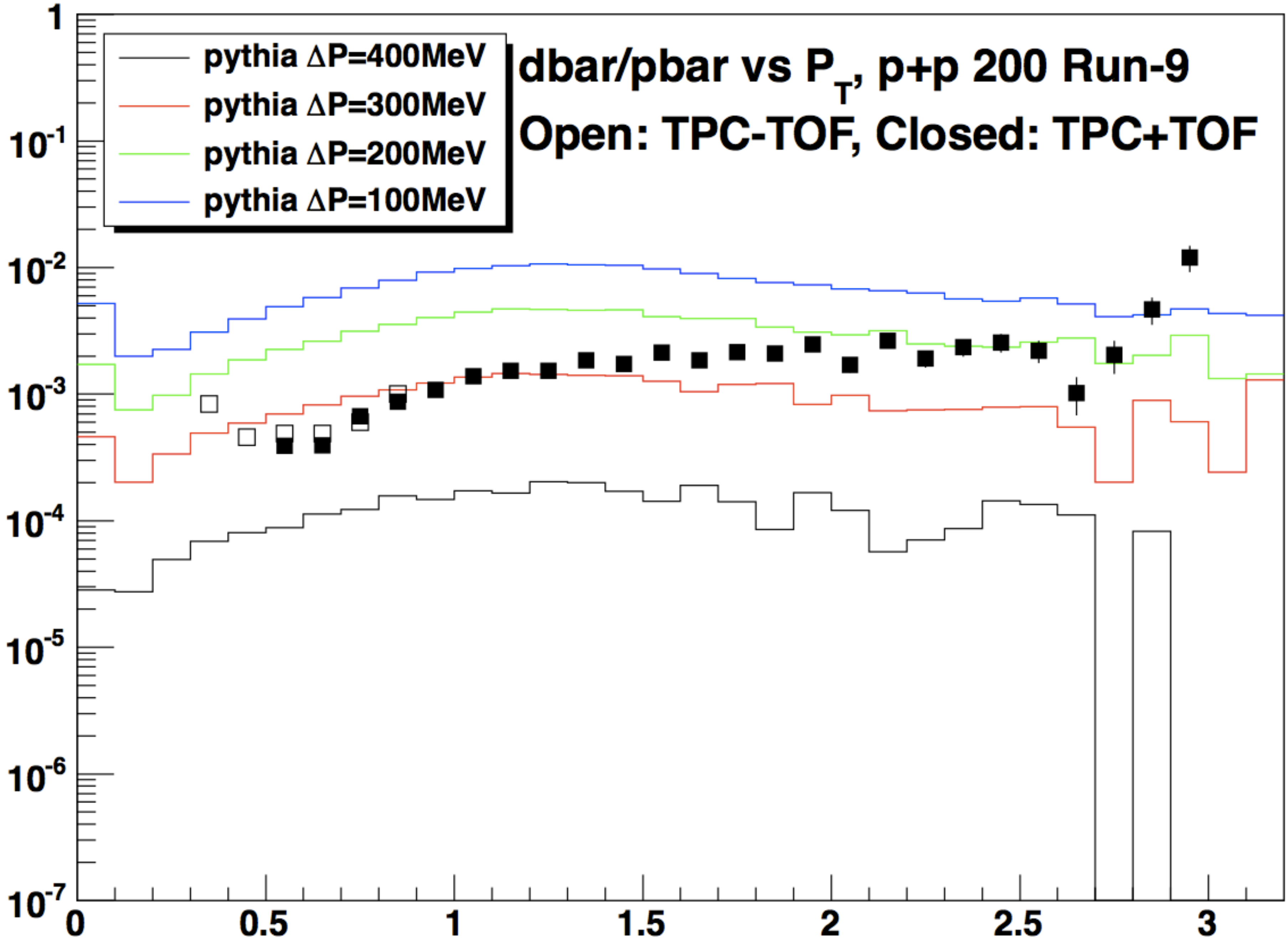


R_G vs P_T/A by $\sqrt{s_{NN}}$ and centrality



closed: particle
open: antiparticle

dbar/pbar vs. P_T, comparison to Pythia+coalescence



Summary

Trying to produce p(bar) and A(bar) cross-sections with all corrections for all Au+Au data sets plus p+p

Lots of corrections, and not all are easy to get.
…Getting close though…

Must be careful with PID, merged tracks, TOF-matching, *etc.*

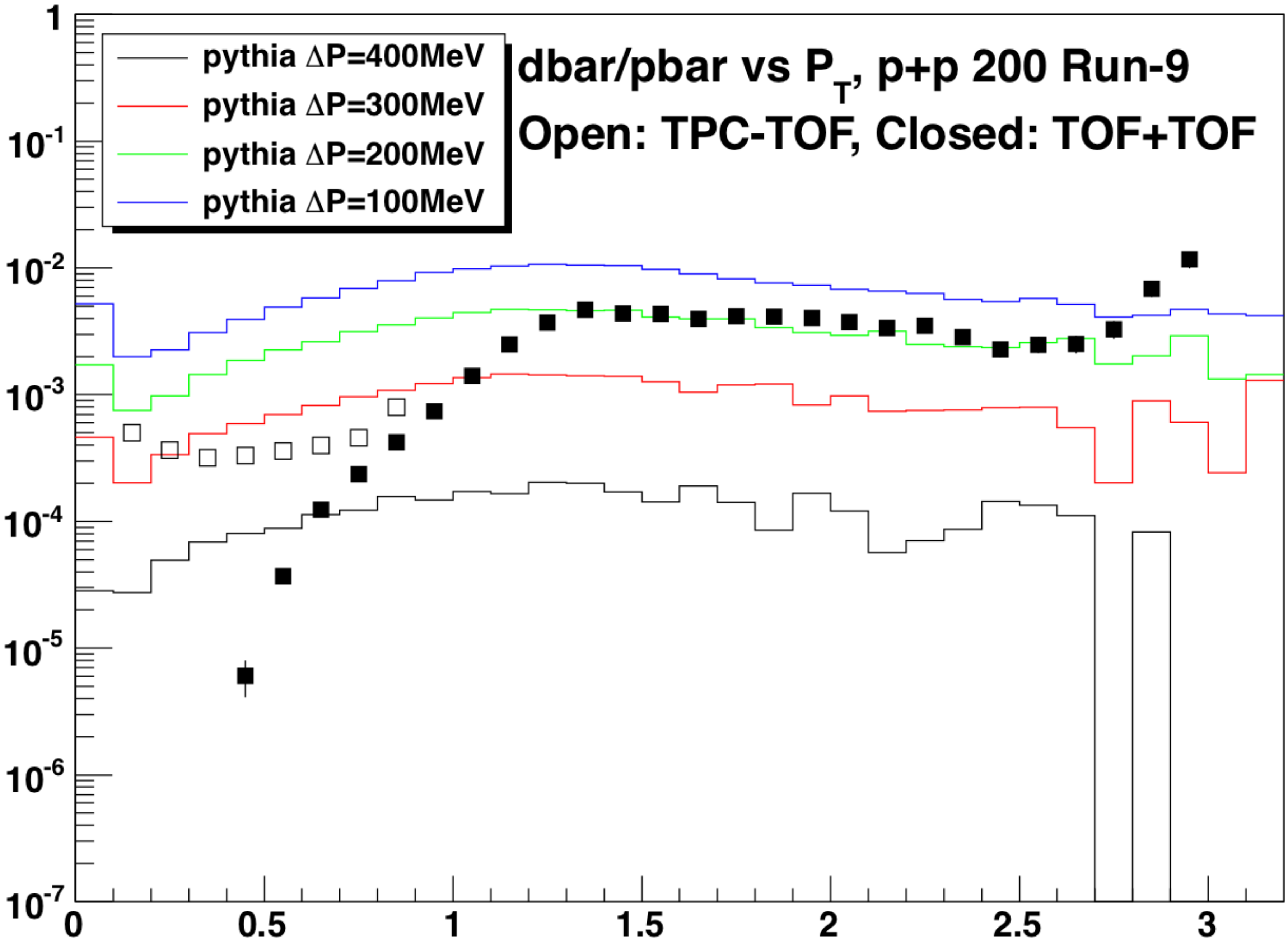
The corrected cross-sections lead to

- B_A ratios and source radii, comparison to HBT (Φ_{RP}-dependence?)…
- d/p ratios and baryon densities…
- source density profiles, degree of equilibration, & other inferences…
- *etc*…

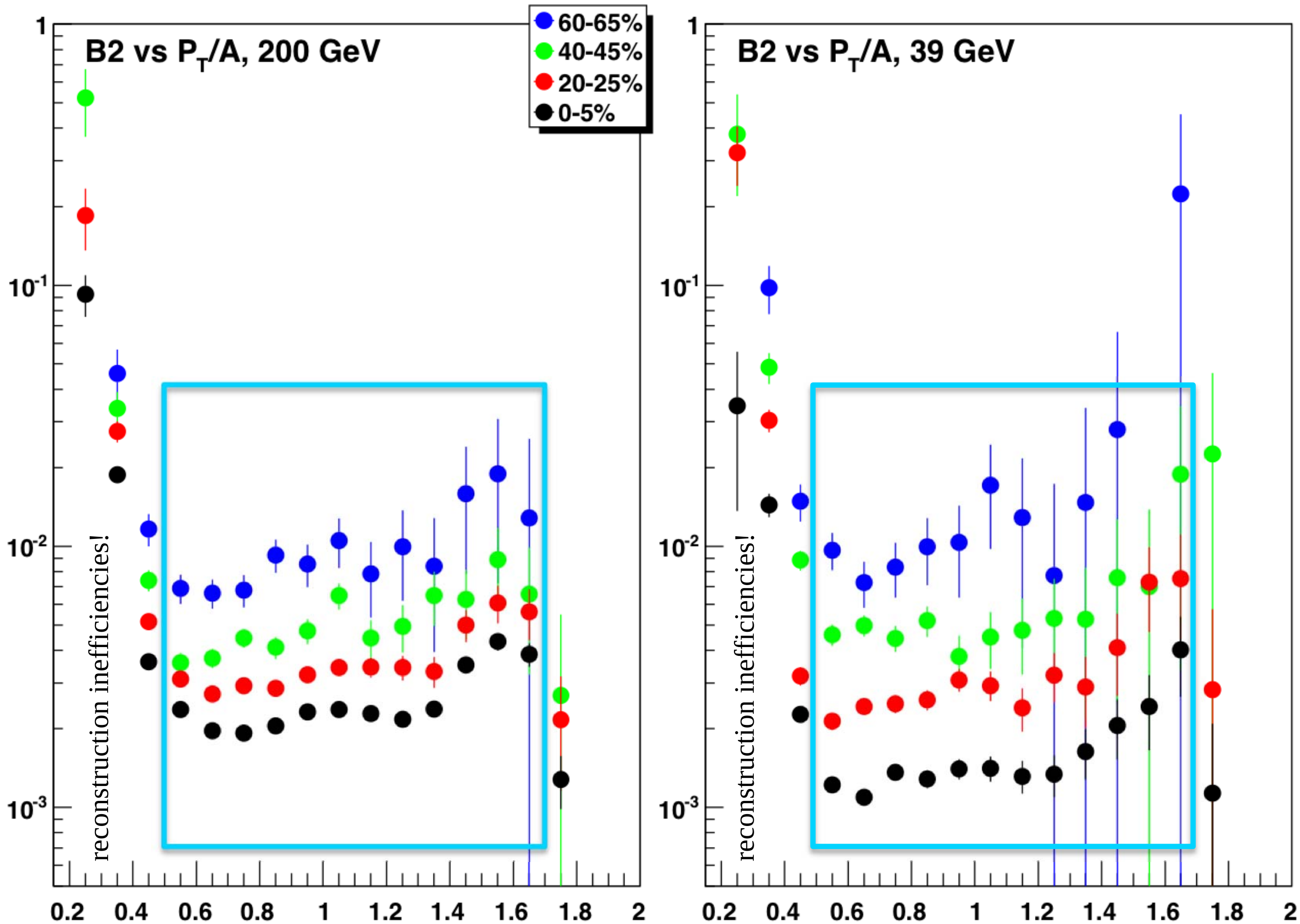
widest & most detailed root-s measurement in a single & wide acceptance
first measurement of spectra & B_A for antinuclei at low end of SPS range
first observation of dependence of B_2 on jet energy

backup

B_2 from Data and from Dynamic Coalescence on Pythia events



B_2 vs P_T/A vs centrality

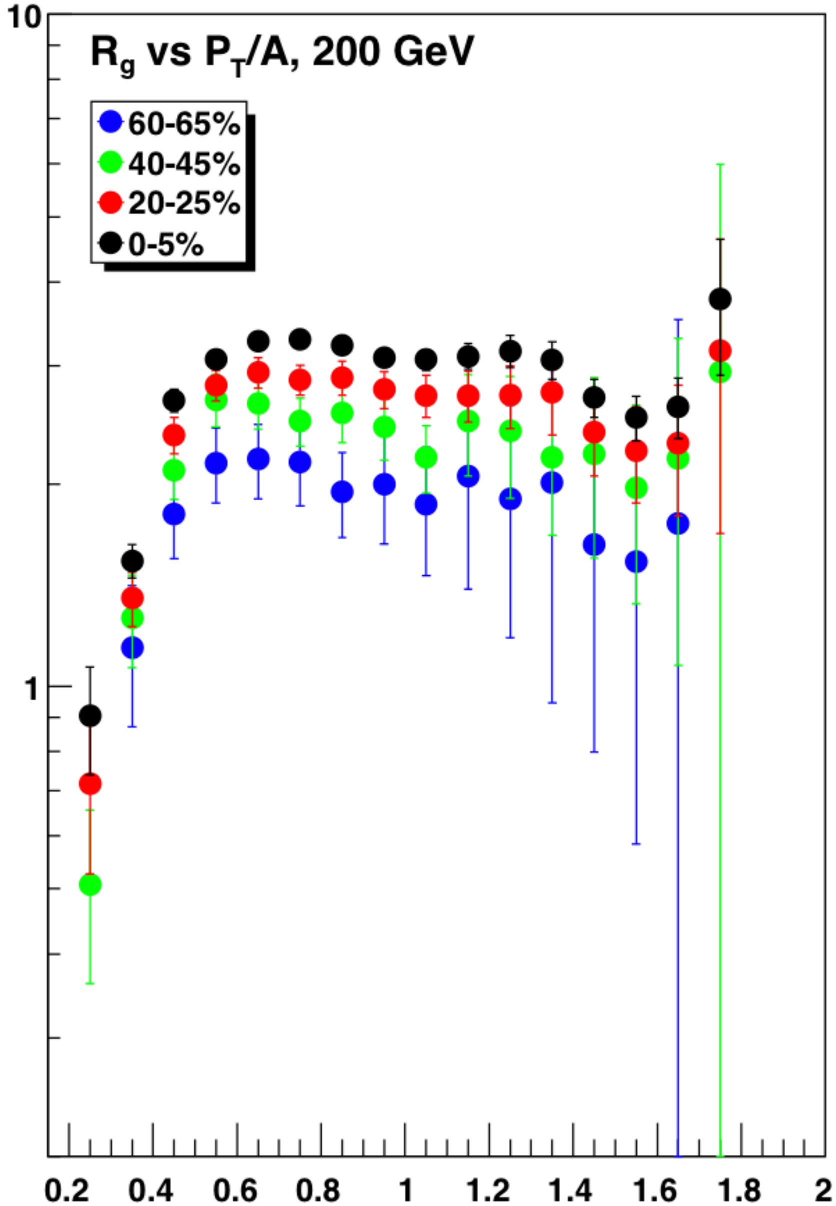


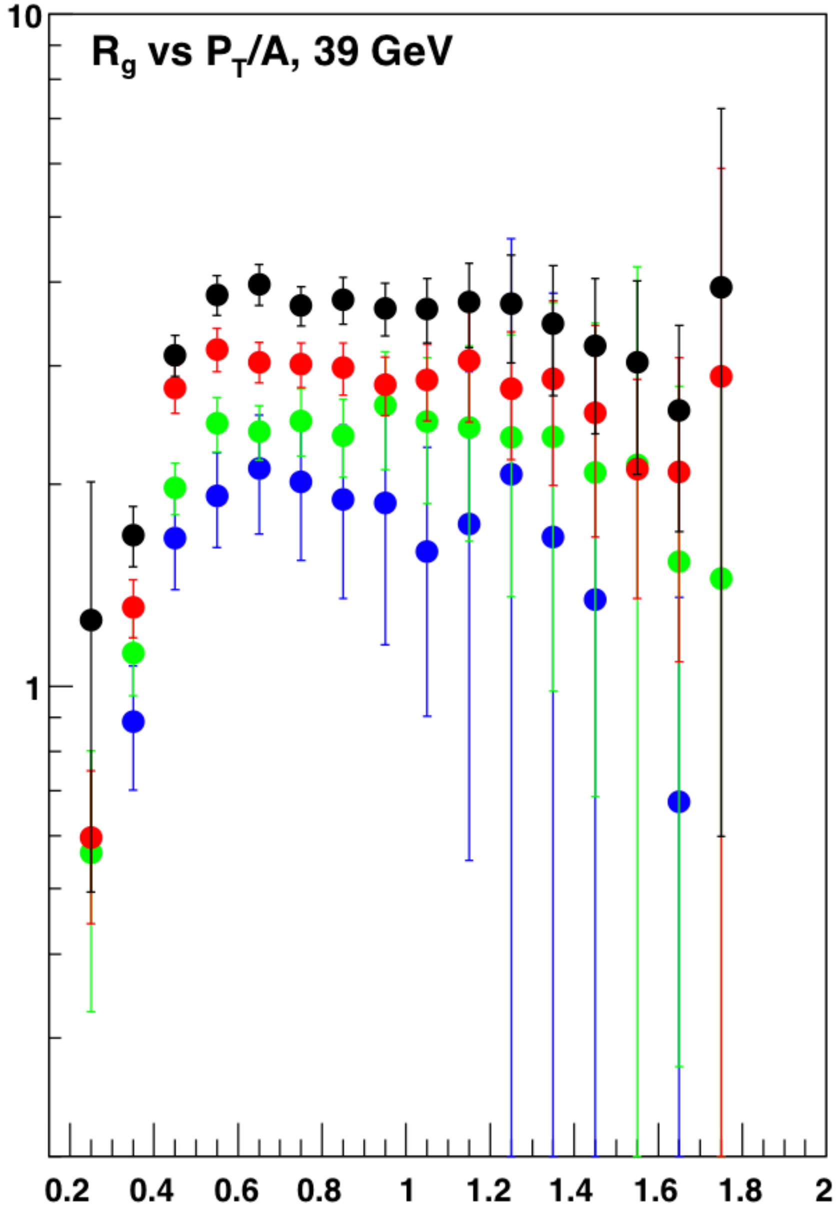
B2 increases ("V" decreases) as collisions get more peripheral

Source Radius at freezeout from B_2 values

hard-sphere $R = 2.2R_G$

conversion of B_A into R_G done via WJL *et al.*, PRC **52**, 2004 (1995).





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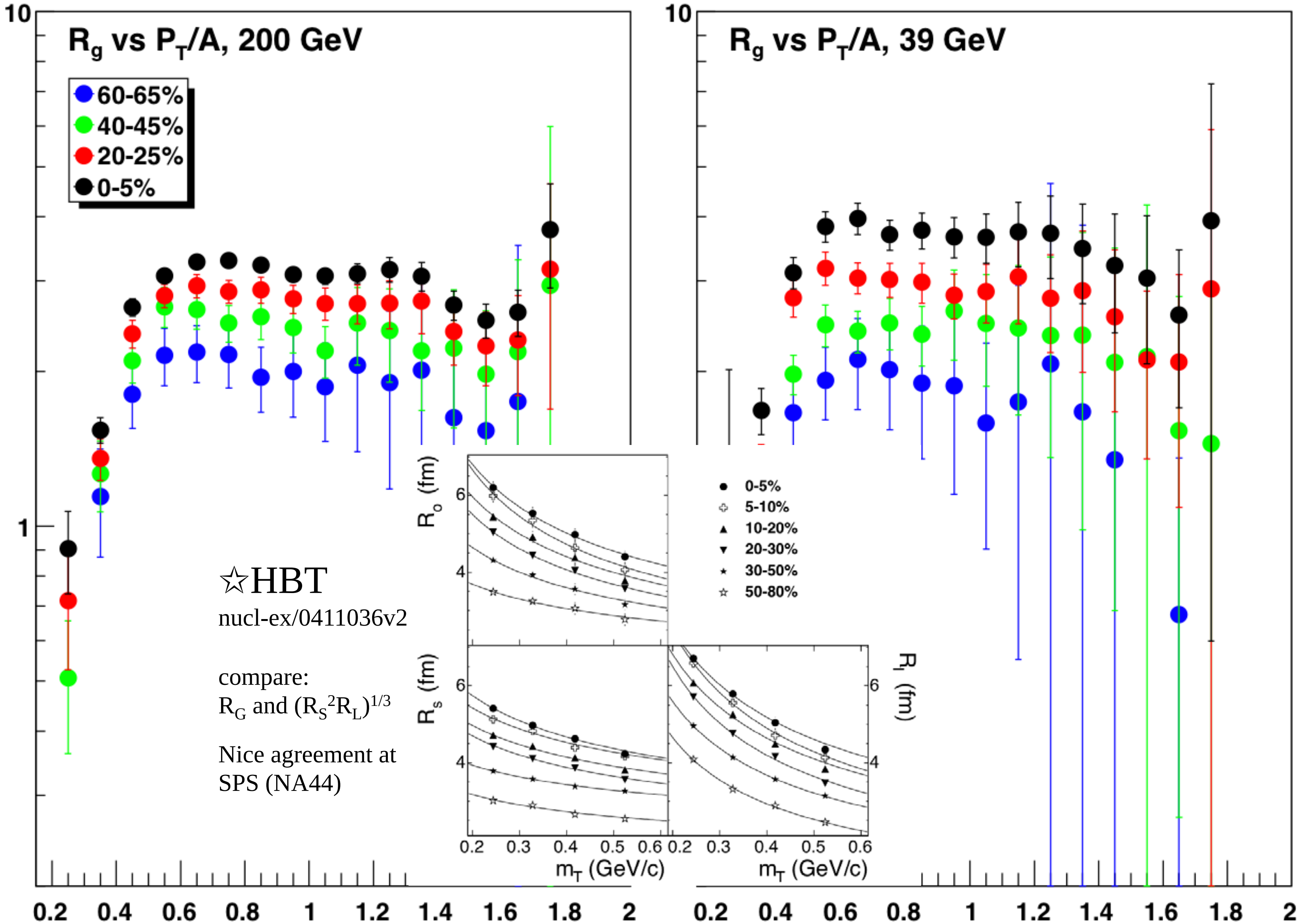


☆HBT

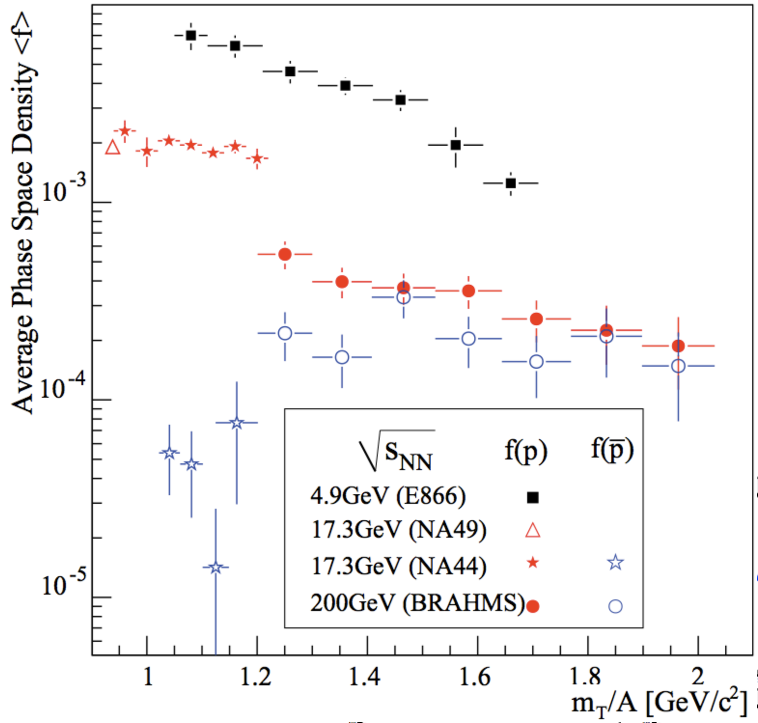
nucl-ex/0411036v2

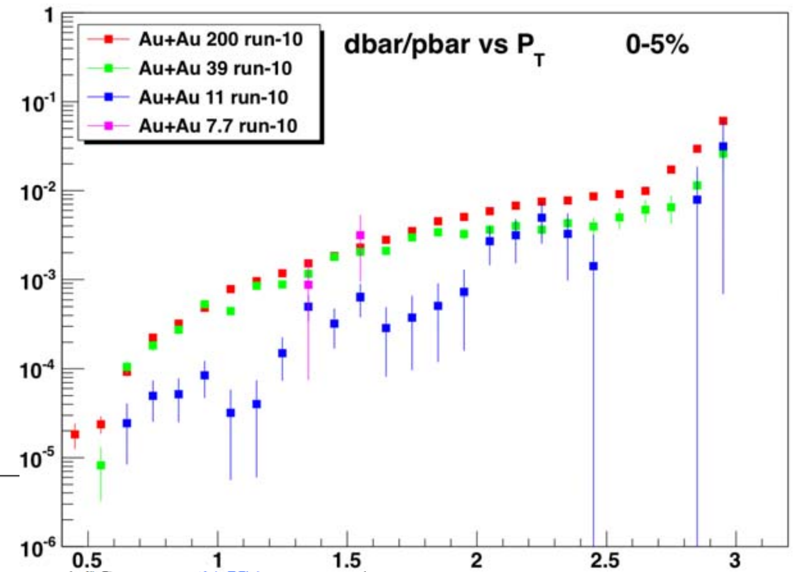
compare:

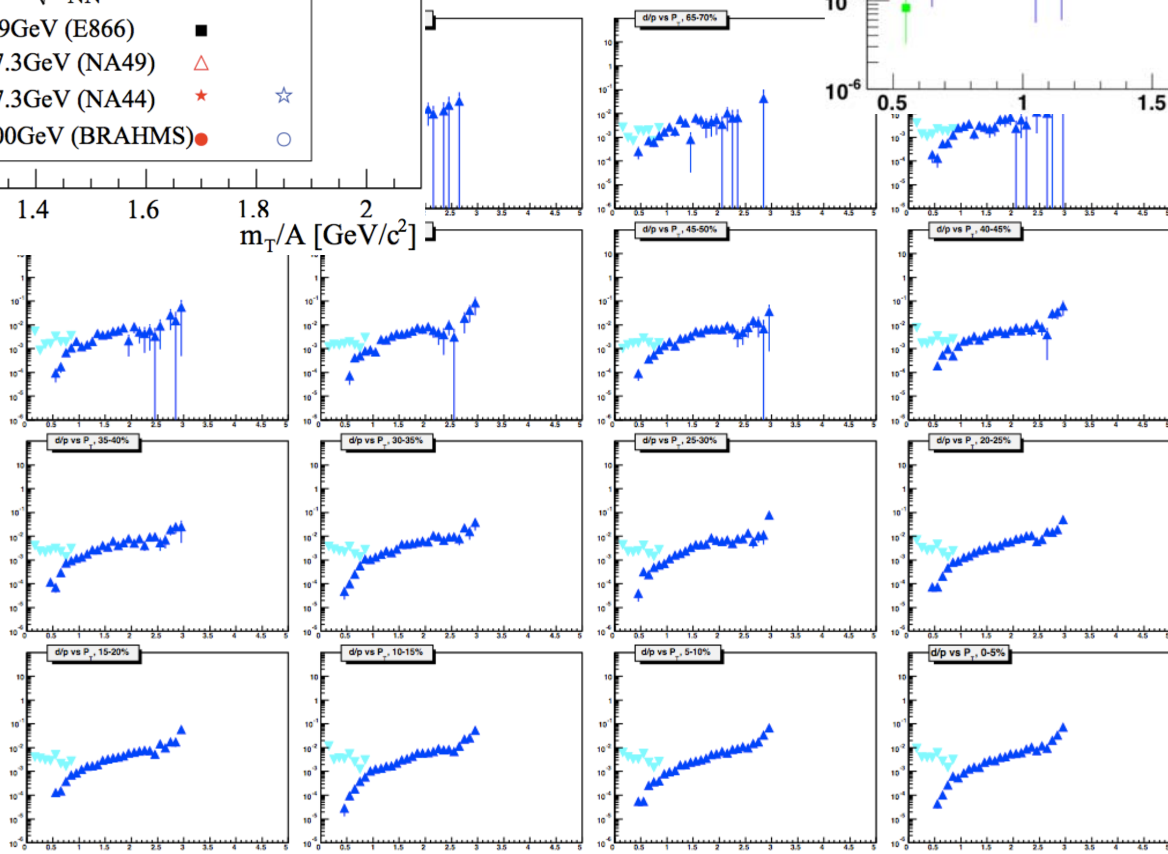
R_G and $(R_S^2 R_L)^{1/3}$

Nice agreement at SPS (NA44)

Baryonic Phase Space Density (d/p with a simple prefactor)

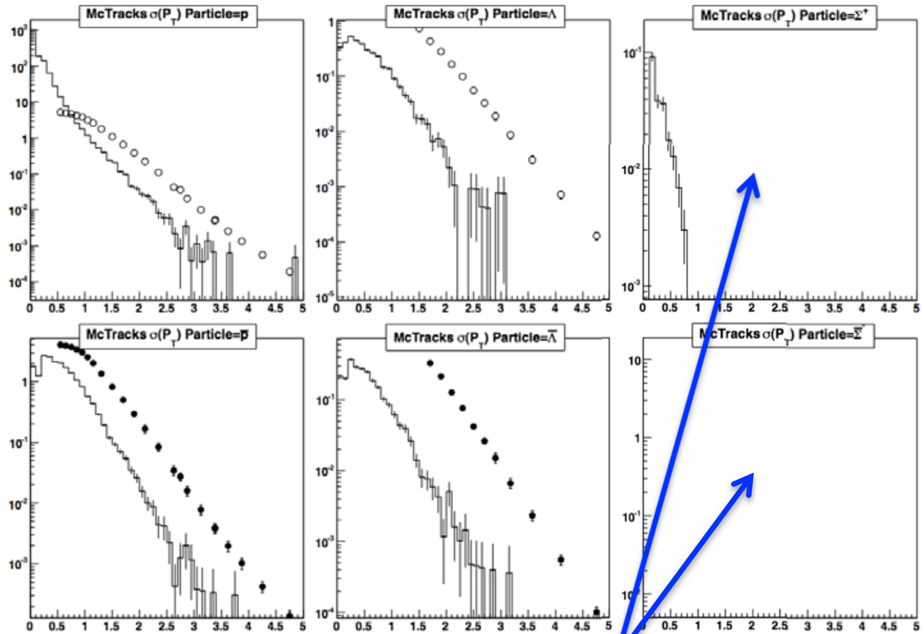






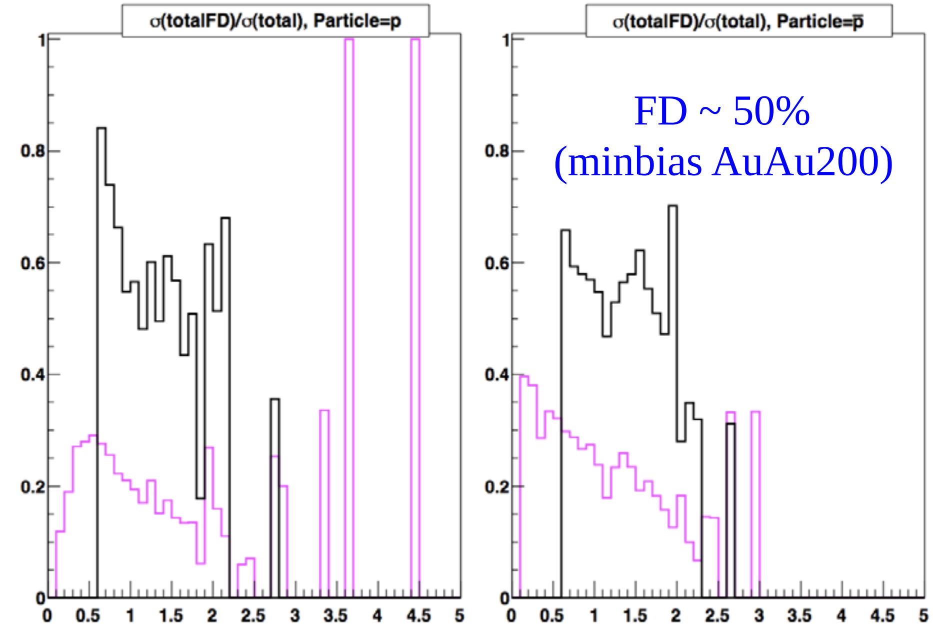
Feeddown (continued)

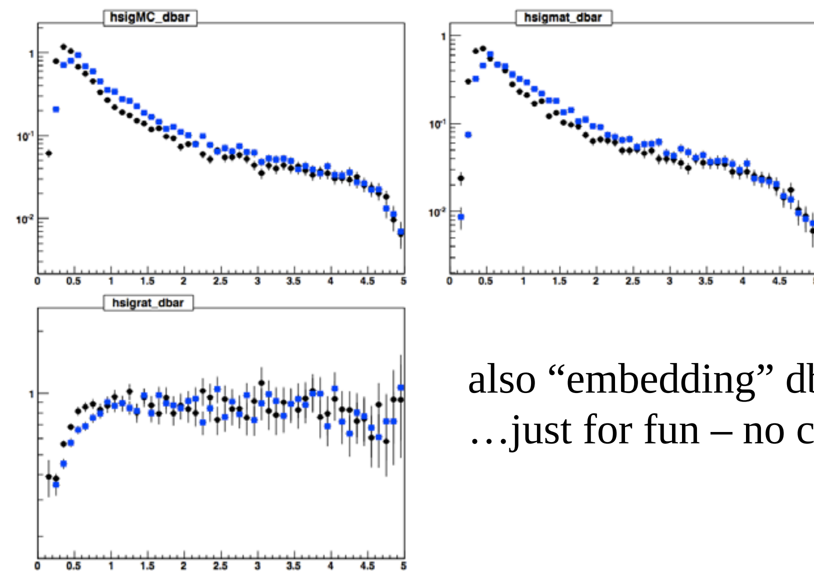
then scale the sim x-secs to measured x-secs



no measured Σ±
…scale by Σ/Λ…

then scale the sim FD ratios…



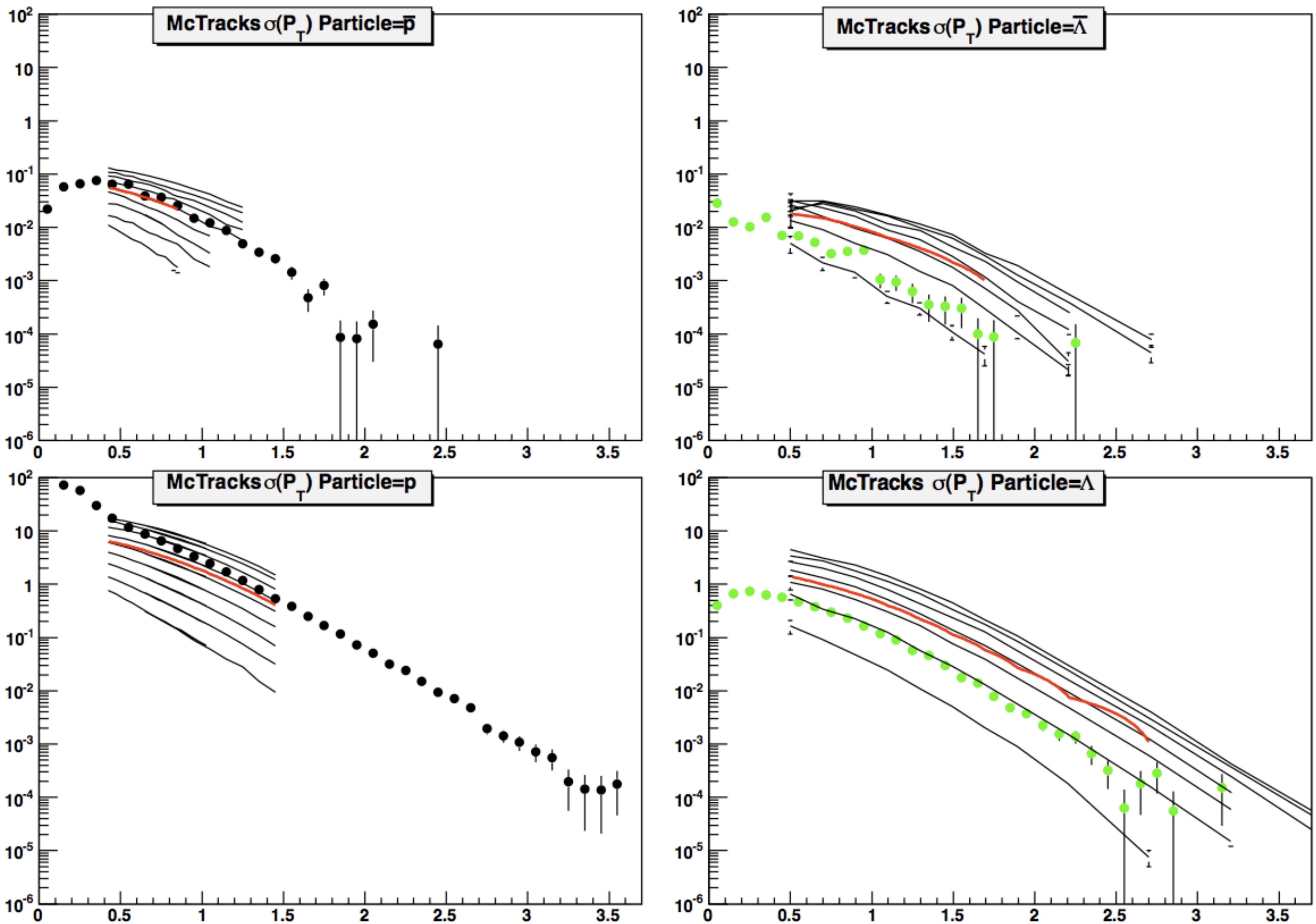


also "embedding" dbar,tbar
…just for fun – no cost…

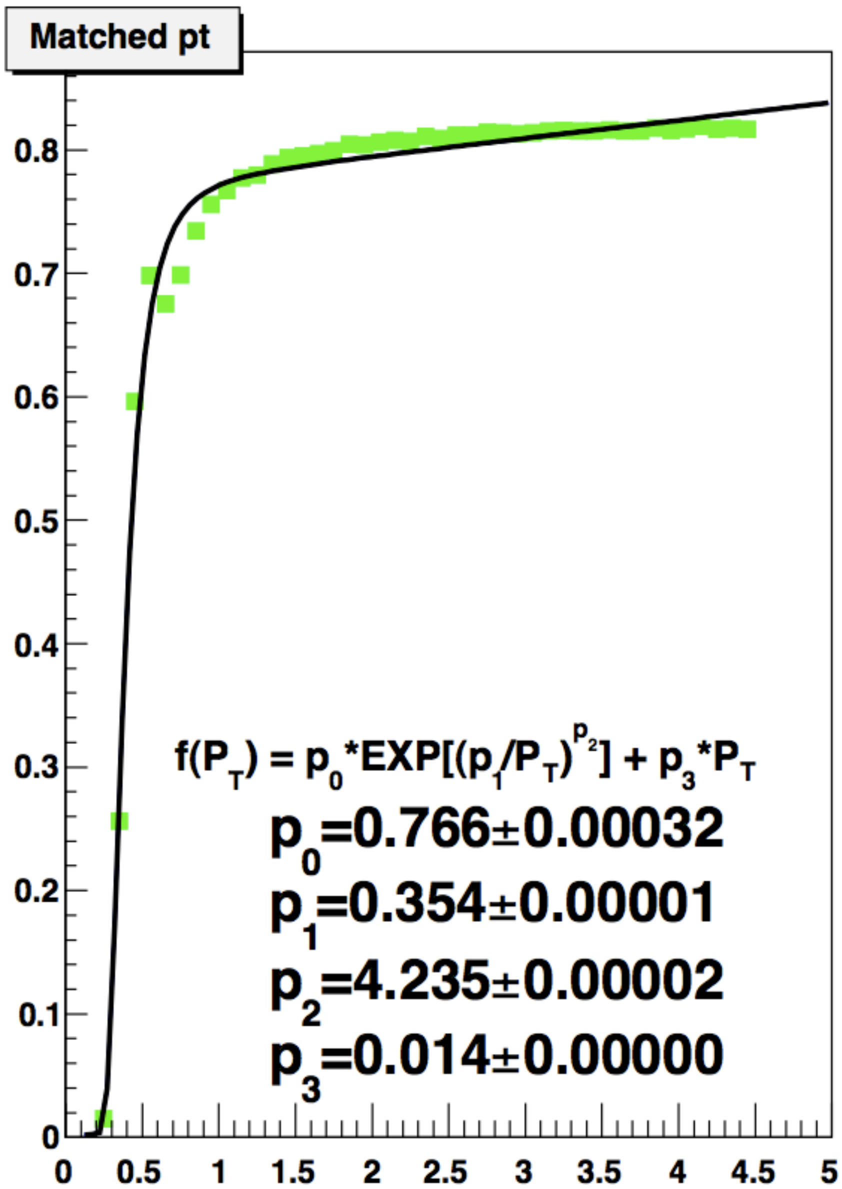
extremely CPU intensive…

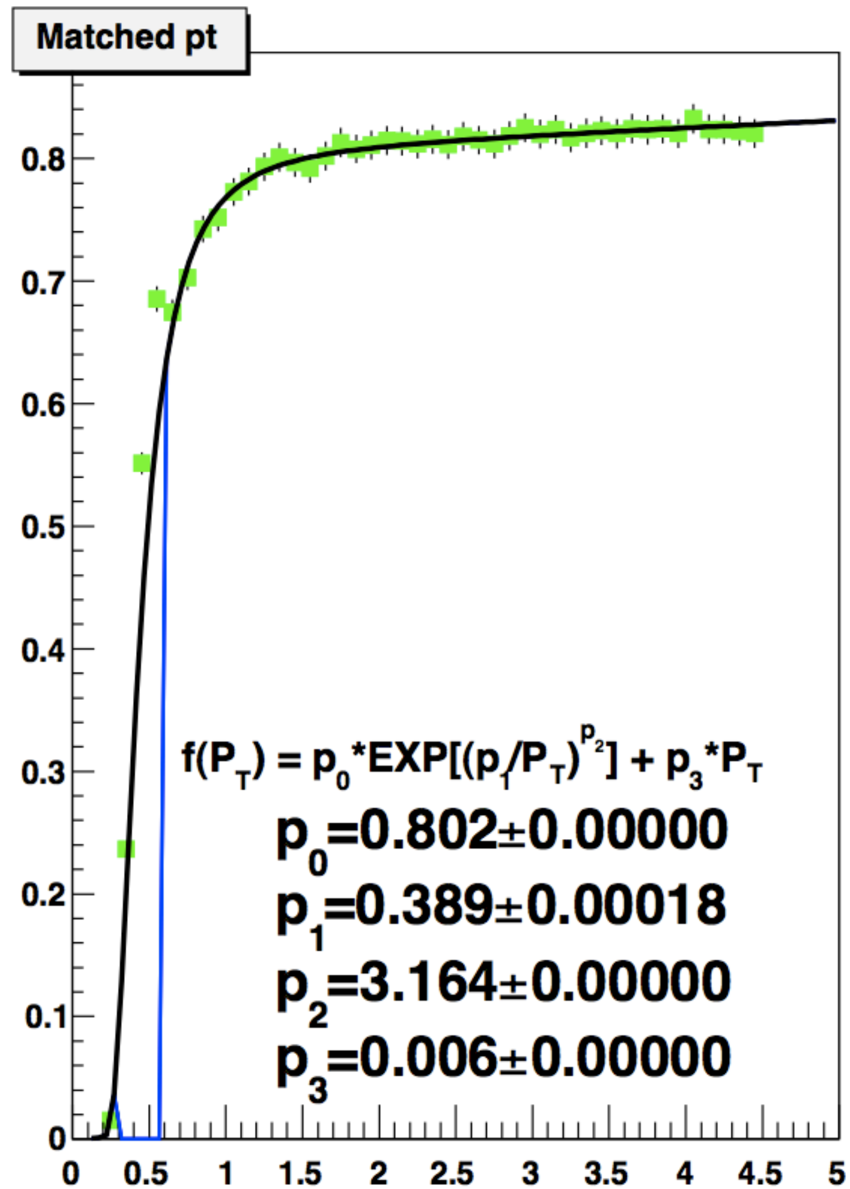
will need to pick a few root-s values
and then interpolate…

feeddown (continued)

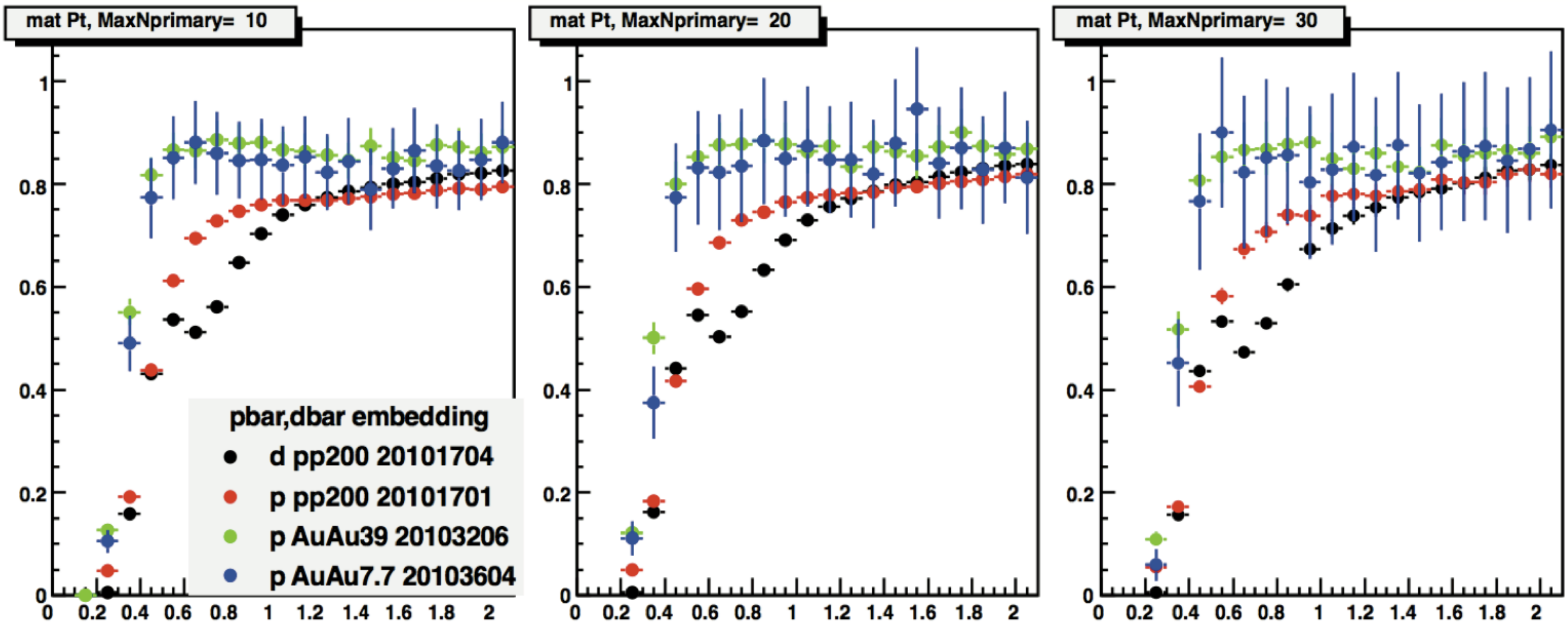


Embedding, dbar in p+p 200GeV Run-9 20101704





Embedding (weird shape of dbar eff in p+p 200GeV Run-9 20101704)



dbar efficiency follows pbar efficiency up to ~0.5GeV/c (?!?)