Light Nucleus Production in p+p & d+Au

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☆ Collaboration Meeting, BNL
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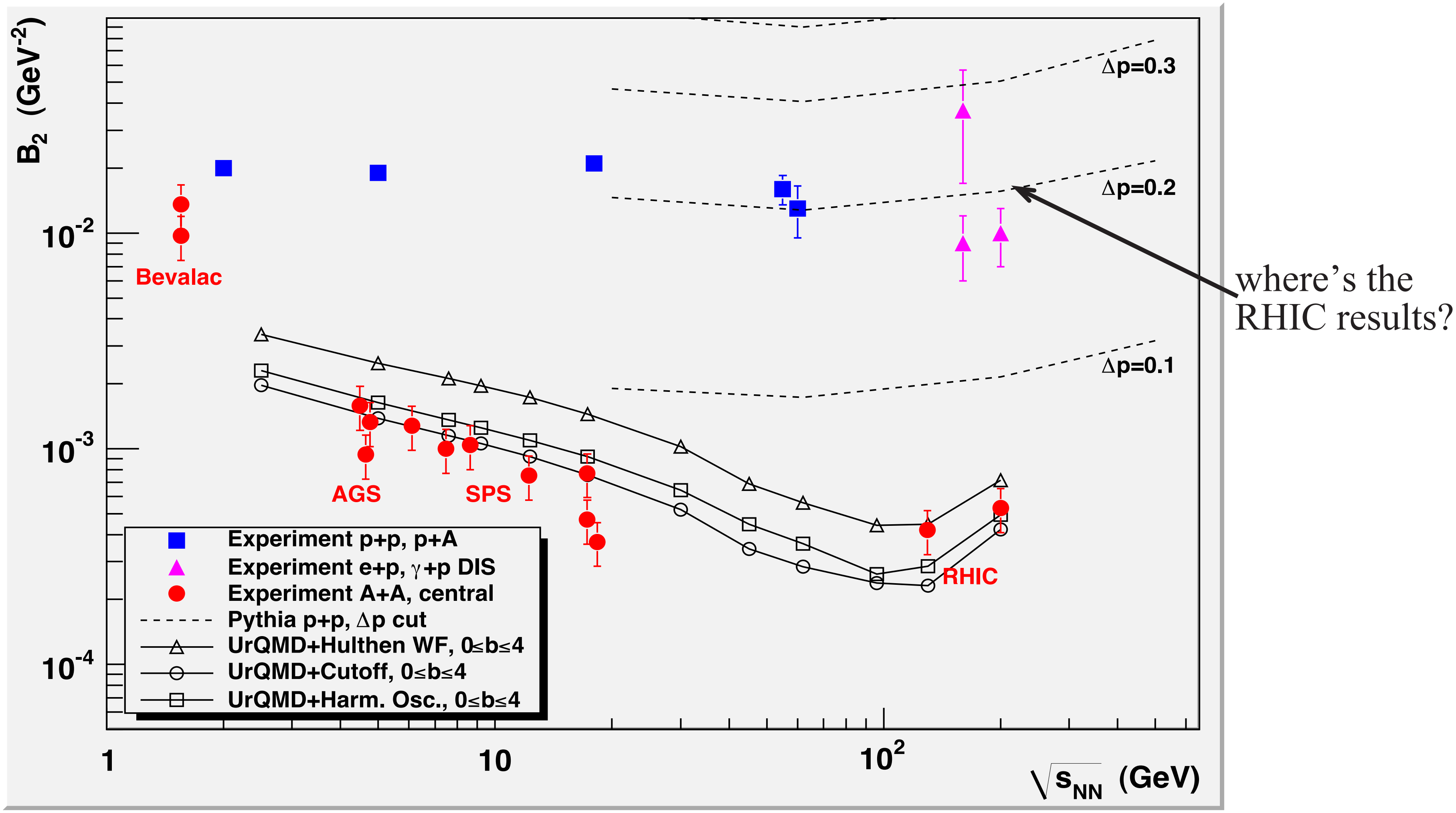
Existing Results on B_2

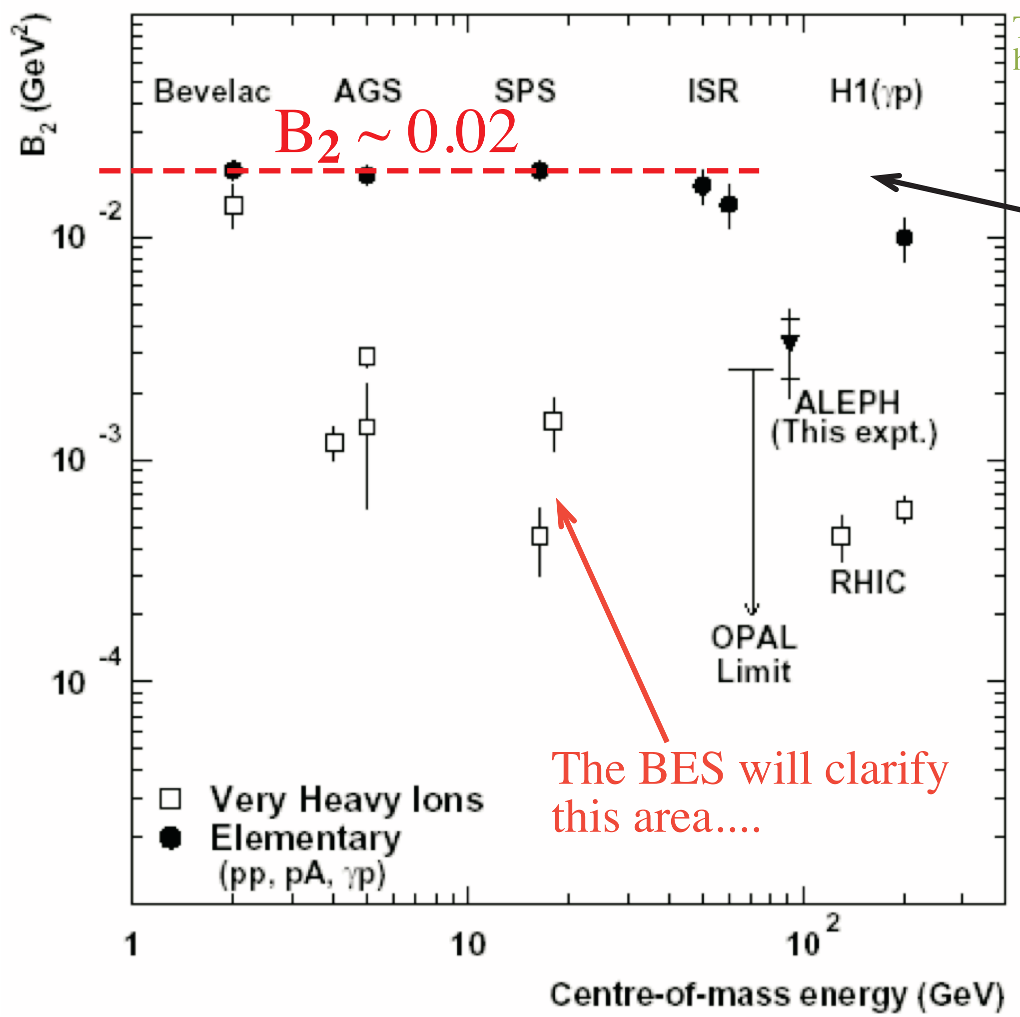
$B_A = \sigma_A / [\sigma_N]^A$ where the cross-sections are evaluated at same momentum

$B_A = d/p^2$ where cross-sections are formed at same P_T/A & y=0, Δy=1.0



deuterons relative to protons is largest in “elementary collisions”...

- factor of ~40 larger than in A+A according to the trend (blue squares)
- essentially independent of beam energy ... also unlike A+A



T. Sloan, GDR Meeting Paris April 2006
http://www.lpta.univ-montp2.fr/GDR/documents/reunion2_2006/sloan.ppt

where does the RHIC data fall?

...we have p+p @ 62, 200, & 500 GeV
& d+Au @ 200 GeV

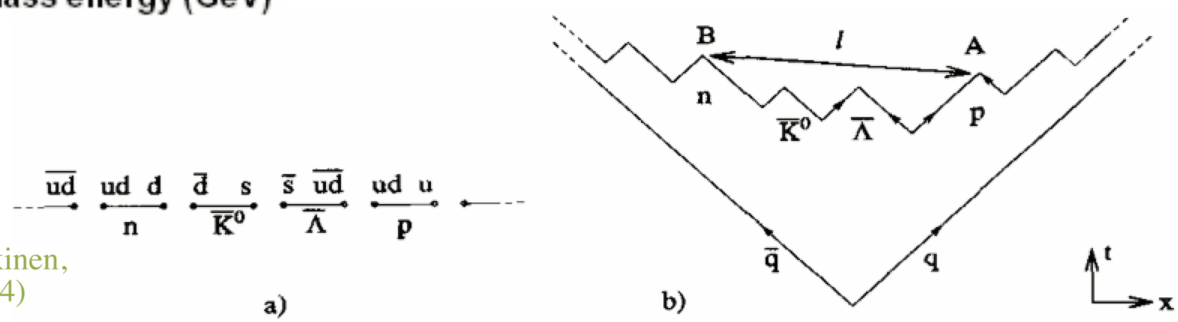
Conventional Wisdom:

p+p: several strings stretched between 2 hadrons
...B2 ~ 0.02

γ+p: fewer strings
...B2 ~ 0.01

e+e: only one string
...B2 ~ 0.003

A+A: lots of strings, but strong rescattering kills all d's except those that form very late
...B2 ~ 0.0003



Gosta Gustafson, Jari Haikkinen,
Z. Phys. C 61,683-687 (1994)

Fig. 3a, b. a Possible string breakup process with a *pn* pair. **b** Space-time structure of the breakup

Why B_A ?

$$\frac{d^3N_A}{d^3p_A} = B_A \, [\frac{d^3N_p}{d^3p_p}] \, [\frac{d^3N_n}{d^3p_n}] \sim B_A \, [\frac{d^3N_p}{d^3p_p}]^2$$

$$\frac{d^3N_x}{d^3p_x} = \frac{1}{2\pi P_T} \frac{1}{N_{ev}} \frac{d^2N_x}{dP_T dy}$$

B_A (GeV^2) is related to the source "size" at freeze-out.

$$B_A = \frac{2S_A+1}{2^A} R_{np}^N \begin{cases} \frac{1}{N!Z!} \, [\frac{4\pi p_o^3}{3\gamma m_p}]^{(A-1)} & \text{Das Gupta \& Mekjian} \\ A^{3/2} \, [4\pi \frac{\nu_A \nu}{\nu_A + \nu}]^{\frac{3}{2}(A-1)} & \text{Sato \& Yazaki} \end{cases}$$

S_A	composite spin	p_o	coalescence momentum cutoff
N,Z,A	composite neut, prot, mass number	ν_A	composite Gaussian size (1/fm^2)
R_{np}	n/p ratio in entrance channel (≡1)	ν	source Gaussian size (1/fm^2), $R_{rms}=\sqrt{3/(2\nu)}$
m_p	proton mass		
γ	composite Lorentz factor		

deuterons......

$$B_2 = \frac{3}{4} \, [\frac{4\pi}{3} \frac{p_o^3}{\gamma m_p}] = [\frac{\pi p_o^3}{\gamma m_p}] \rightarrow p_o = \sqrt[3]{\frac{\gamma m_p B_2}{\pi}}$$

$$R^3 = \frac{9\pi^2}{2} (\hbar c)^3 \frac{m_d}{m_p^2} \frac{1}{B_2} \quad \text{(hard sphere)} \qquad [Note: \frac{4\pi p_o^3}{3} = \frac{(2\pi)^3}{V}]$$

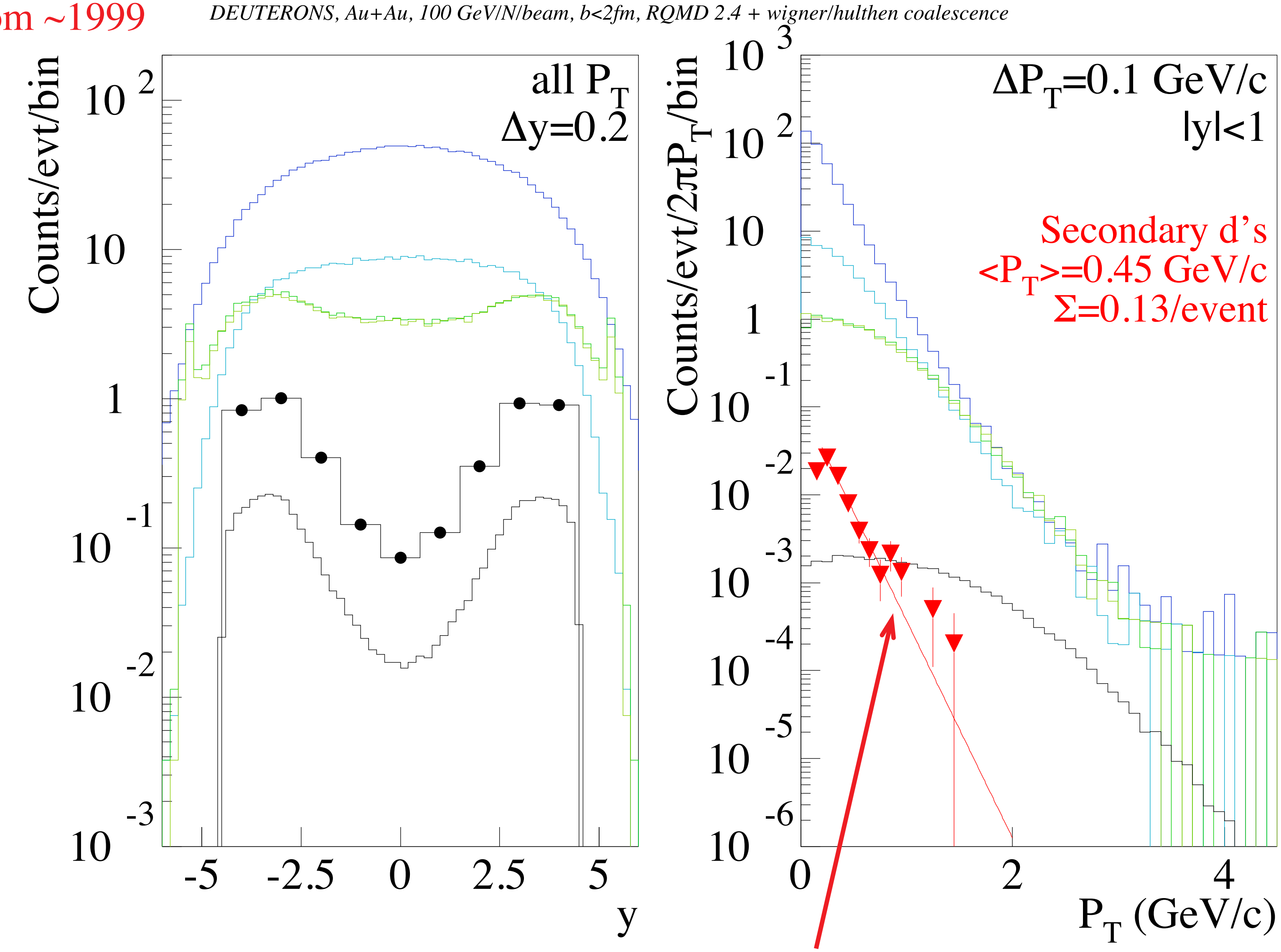
...evaluate for B_2=0.02 GeV^2.....

$p_o = 0.180$ GeV $\quad R = 3.3$ fm $\quad$ (R_d^{rms}=2.1 fm)

similar but alternative interpretations: Scheibl&Heinz, Llope&Pratt *et al*...

Significant spallation backgrounds are well-known....

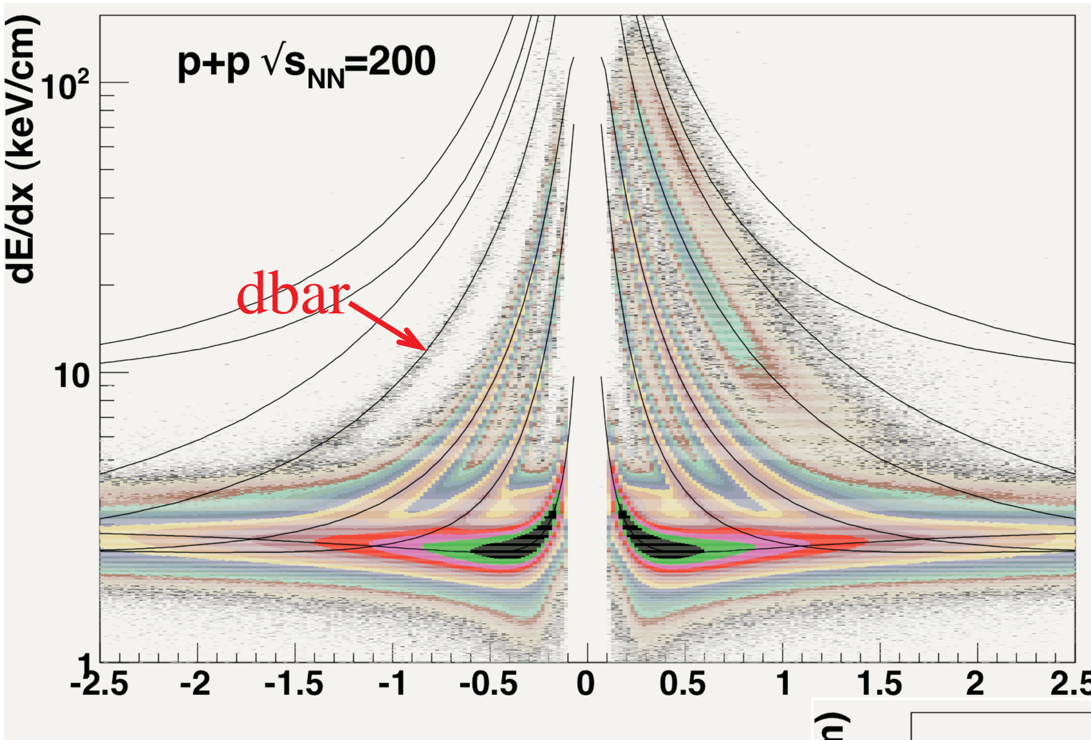
from ~1999



background d calculation by Dave Hardtke

see also J. Nystrand, DIS2004, nucl-ex/0409006

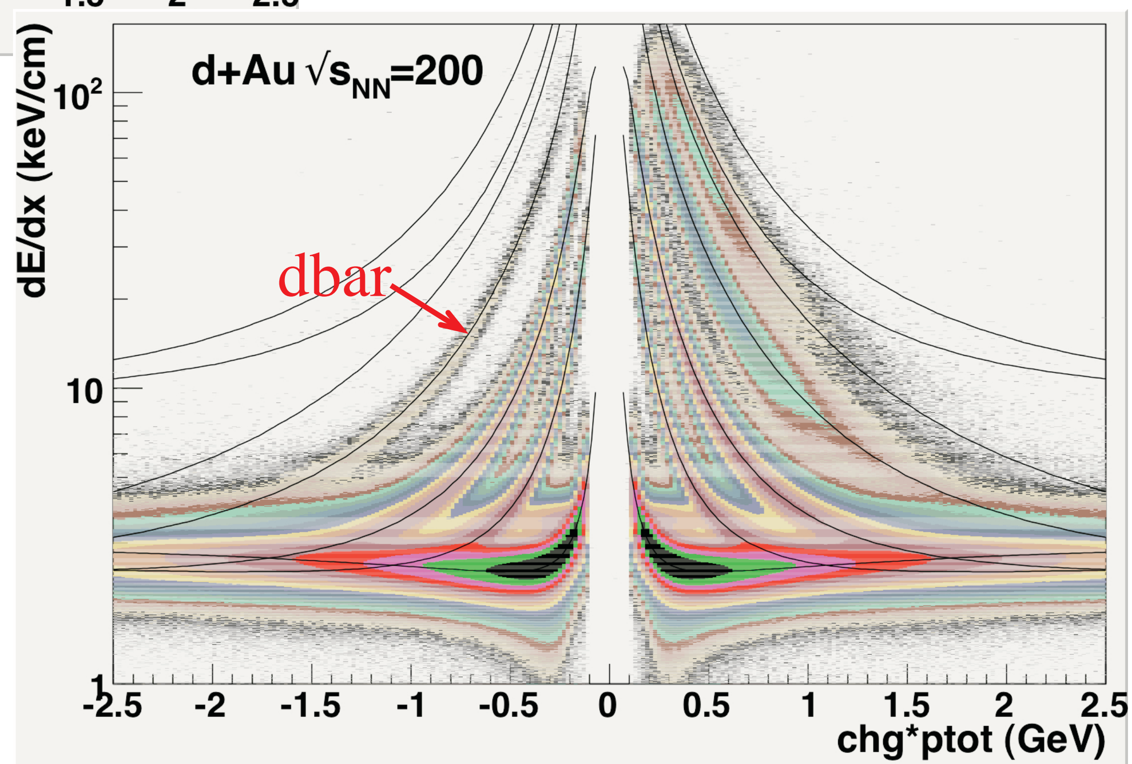
Thus, concentrate on antinucleus production (much cleaner signal)....



d/dbar is huge... (spallation in ☆)

Significant dbar signal in our
p+p and d+Au data.....

Some tbars and He-3's too...
(hard to see here though)



Goals:

- extract cross-sections and coalescence parameters for pbar, dbar, and tbar production
  & compare to:
    trends implied by the existing lower-energy data....
    UrQMD or Pythia "dynamical coalescence" calculations with coalescence afterburner...
- Include direct Jet-finding & investigate fragment production in and out of jets...
- Source radii from "coalescence" d/p/p & t/p/p/p ratios

Data:

Run-6	p+p	62 GeV	4.8 M events
Run-8	p+p	200 GeV	36.1 M events
Run-8	d+Au	200 GeV	75.8 M events

Cuts:

Require that a Primary Vertex was found...
Nfitpts > 15, Nfitpts/Nhitsposs > 0.52, DCAglobal < 1.0cm
Presently, use only TPC dE/dx for PID....

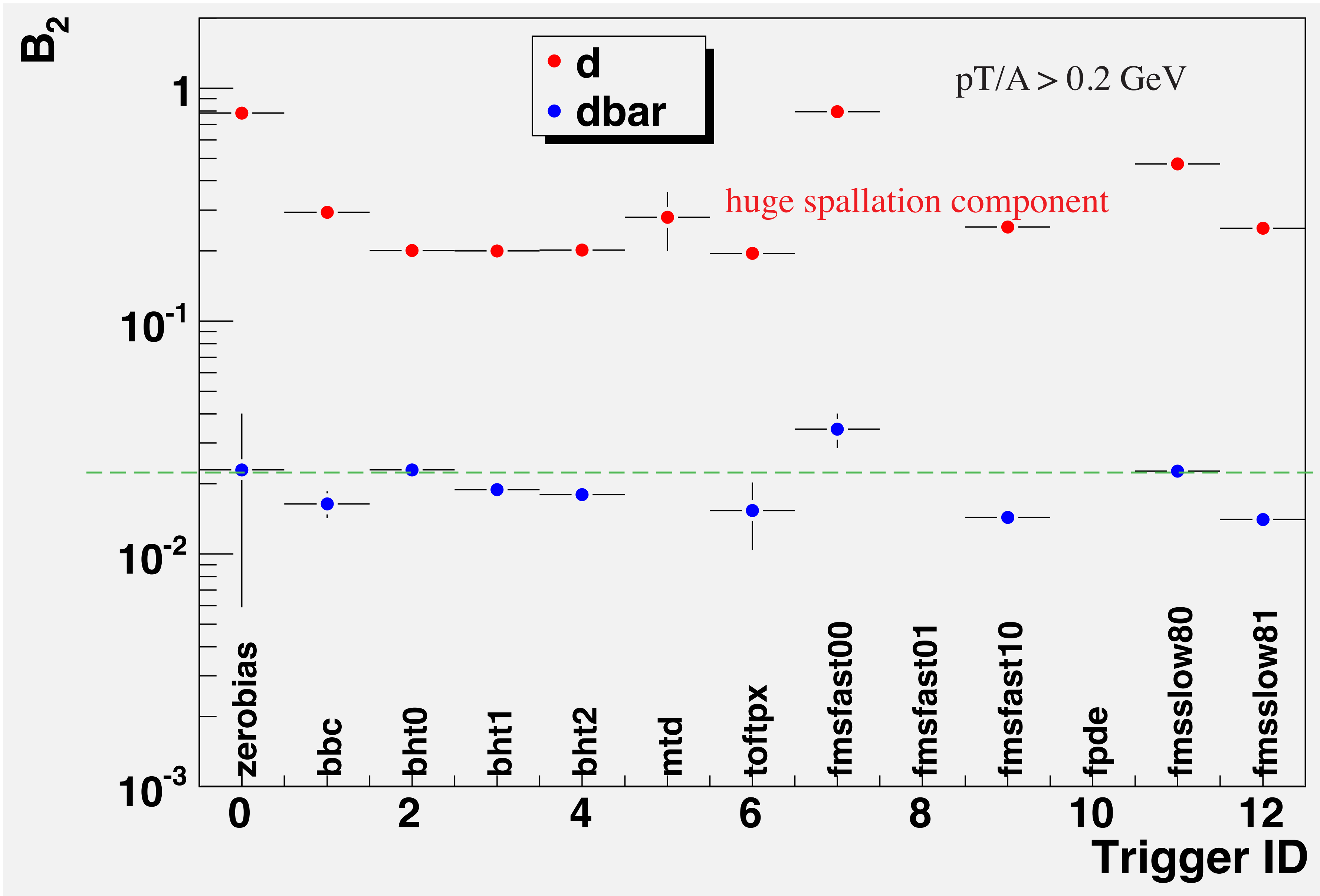
A.S.A.P....

Include PID from the significant TOF coverage in the Run-9 data....
Produce plots for the Run-9 500 GeV data....

This Talk:

Modified cross-section and BA calculation in jets (via S. Pratt at UT-Austin analysis mtg)
V0 reconstruction in the same events and proton feed-down from antilambdas
Draft embedding request

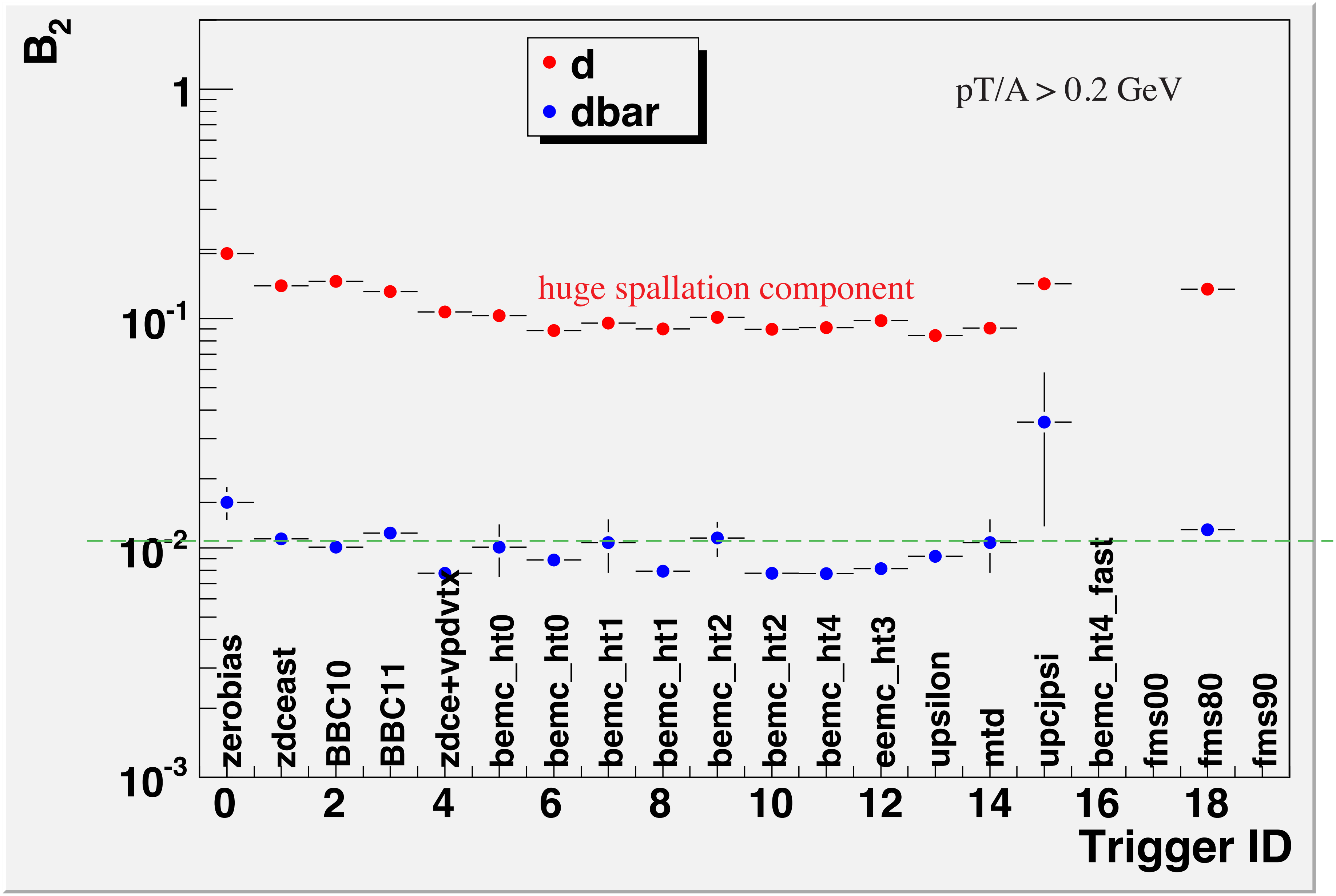
Run-8 p+p 200 GeV



...very close to that in the lower-energy p+p data: B2 ~ 0.02 GeV^2

....implies hard sphere R ~ 3.3 fm

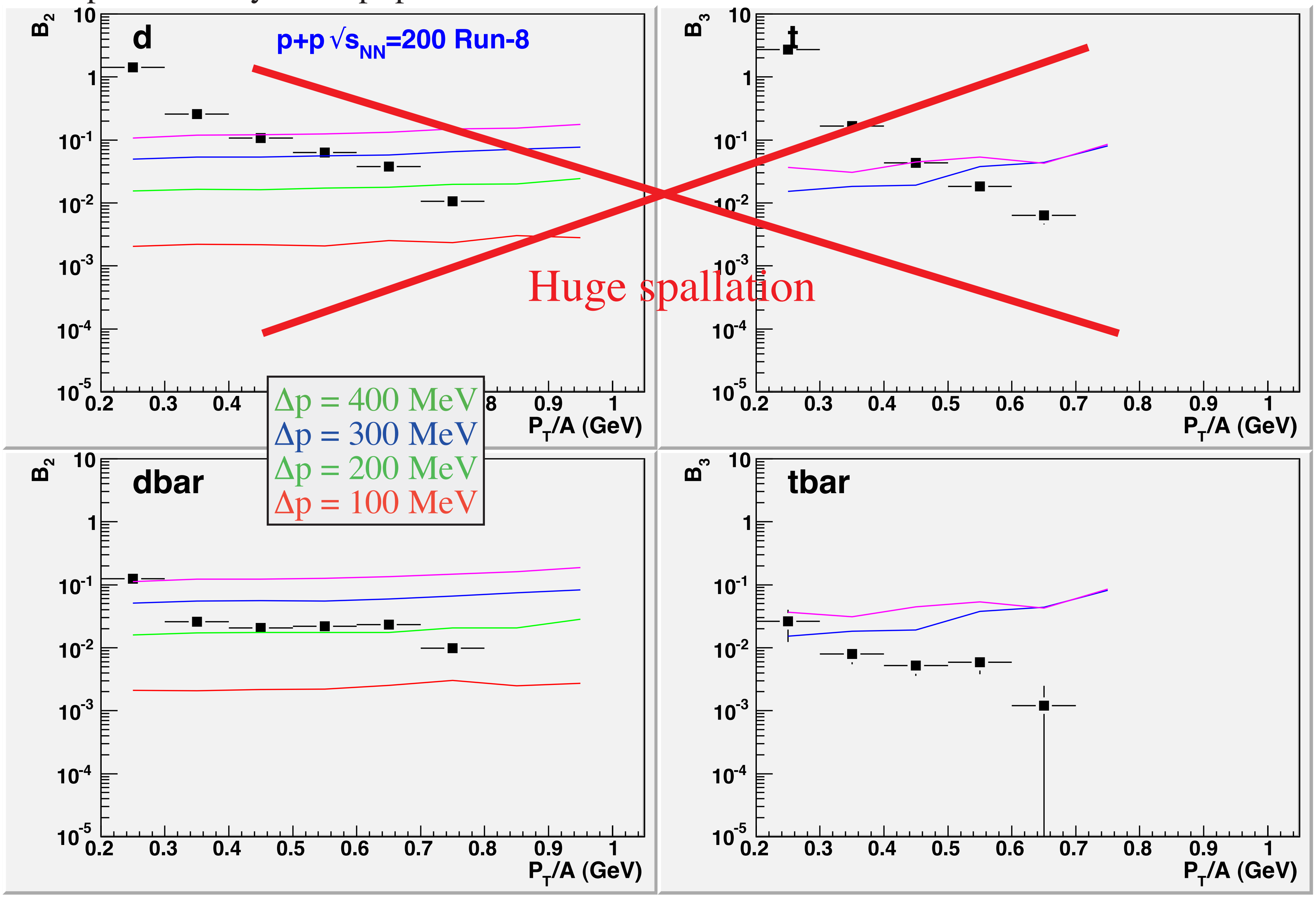
Run-8 d+Au 200 GeV



....Here B2 ~ 0.01 GeV^2

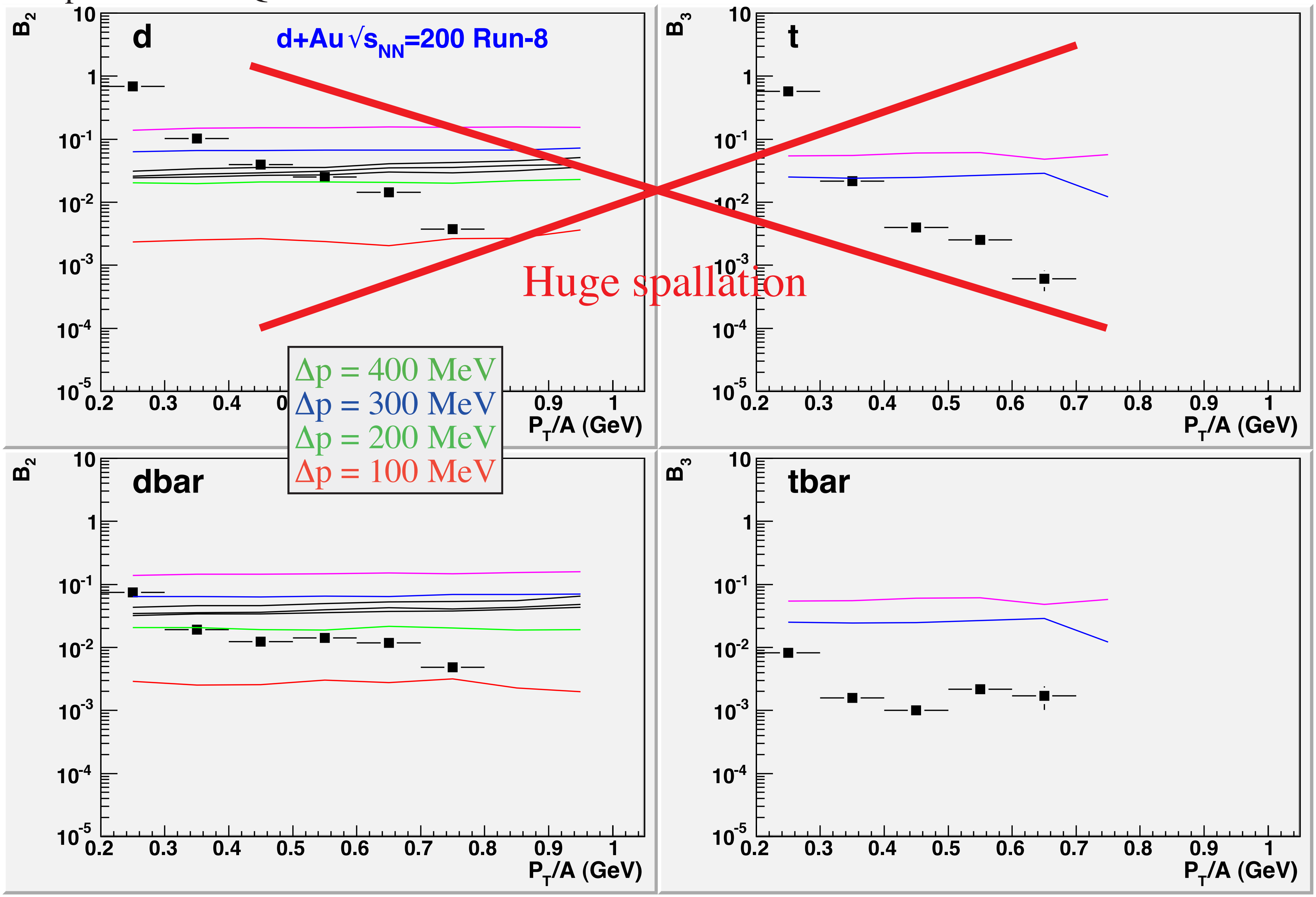
R ~ 4.2 fm

Comparison to Pythia -- p+p 200 GeV



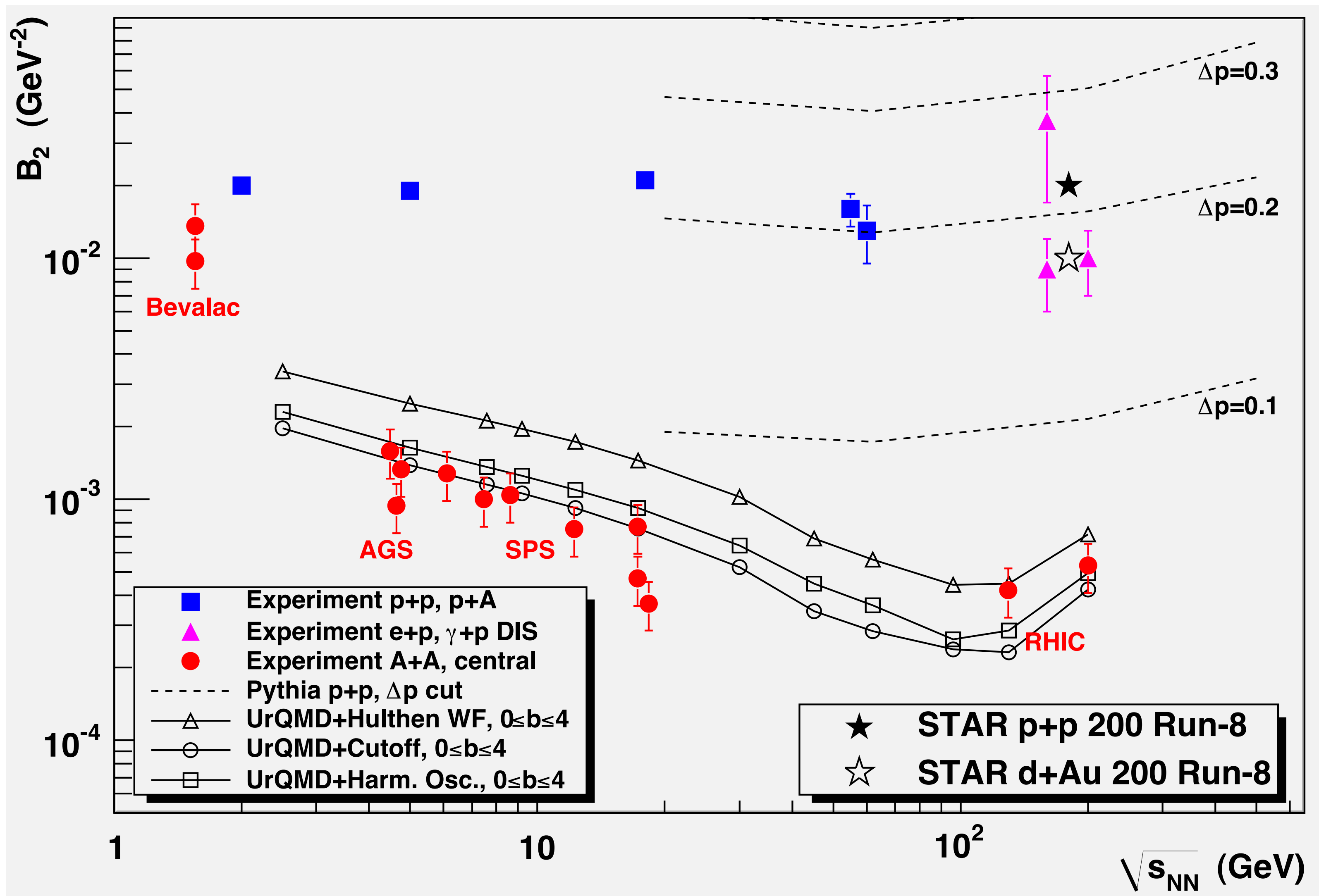
experimental dbar B_2 implies Pythia Δp Dynamic Cutoff ~ 210 MeV… consistent with coalescence assumptions! ($B_2 \sim 0.02 \rightarrow p_o \sim 180$ MeV)

Comparison to UrQMD -- d+Au 200 GeV



dbar B2 implies Δp ~ 180 MeV for d+Au, 200 GeV

Comparisons to world's data.....



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

(*) No tracking & PID efficiency, absorption, or feeddown corrections yet!

Light nucleus production & Jets in p+p and d+Au....

Plot proton & deuteron cross-sections and B_A values separately for

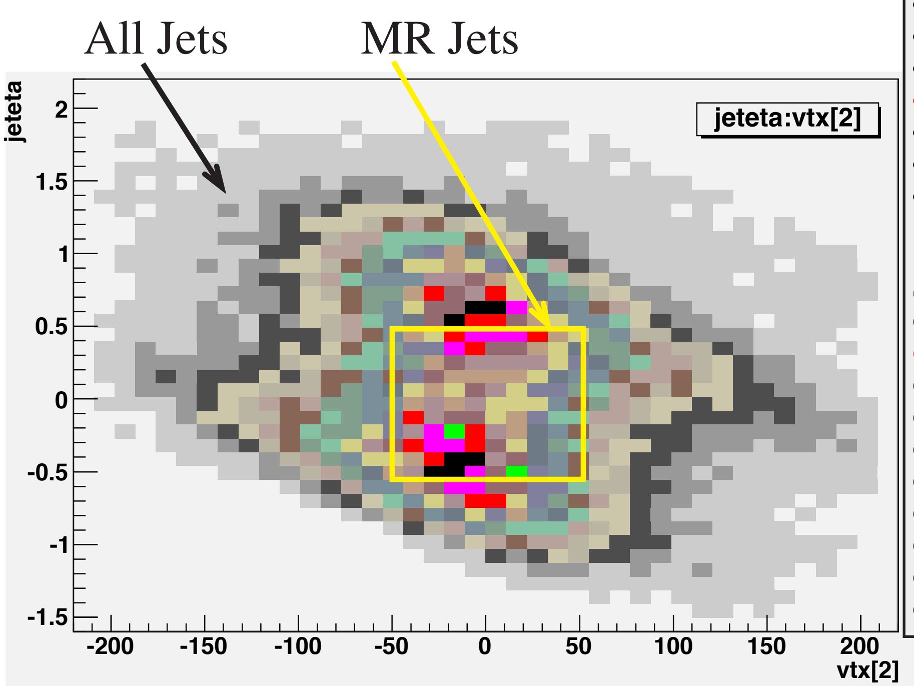
- events in which no jet(s) reconstructed... "UE"
- tracks not associated with a Jet...
- tracks associated with a Jet... "Jet"

Does B_A depend on UE vs Jets?

Different nucleus production mechanisms?

Are R & p_o different?

(thanks to Renee, Ilya, and David for helpful comments!)



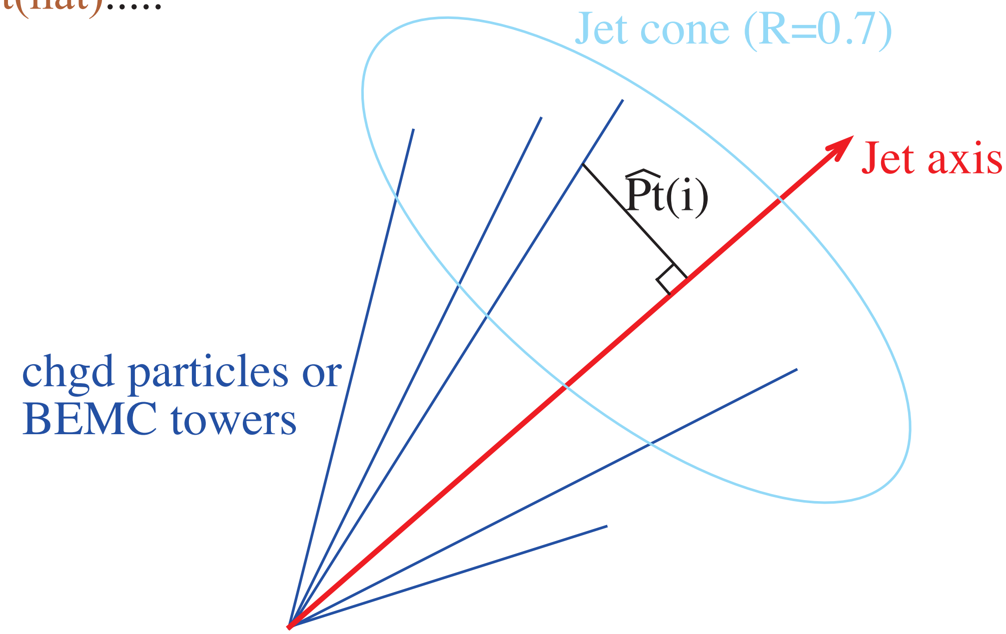

```
StppAnaPars* anapars = new StppAnaPars();
anapars->setFlagMin(0);        // track->flag() > 0
anapars->setNhits(12);         // track->nHitsFit()>12
anapars->setCutPtMin(0.2);     // track->pt() > 0.2
anapars->setAbsEtaMax(2.0);    // abs(track->eta())<2.0
anapars->setJetPtMin(3.5);
anapars->setJetEtaMax(100.0);
anapars->setJetEtaMin(0);
anapars->setJetNmin(0);
//
//---- Setup the cone finder for measured particles
StConePars* cpars = new StConePars();
cpars->setGridSpacing(105, -3.0, 3.0, 120, -pi, pi);
cpars->setConeRadius(0.7);
cpars->setSeedEtMin(0.5);
cpars->setAssocEtMin(0.1);
cpars->setSplitFraction(0.5);
cpars->setPerformMinimization(true);
cpars->setAddMidpoints(true);
cpars->setRequireStableMidpoints(true);
cpars->setDoSplitMerge(true);
cpars->setDebug(false);
```

At previous meetings, I showed that B2 for dbar in p+p and d+Au is
factors of >4 larger for particles in jets compared to no jets, or not in jets
and B2 increases with the jet energy

A discussion with S. Pratt at the UT Analysis meeting resulted in a revision....

I was using $1/(2\pi.Pt.Nev)dN/dPt$ for the cross-sections used in the BA calculations...

Need to replace Pt with Pt(hat).....

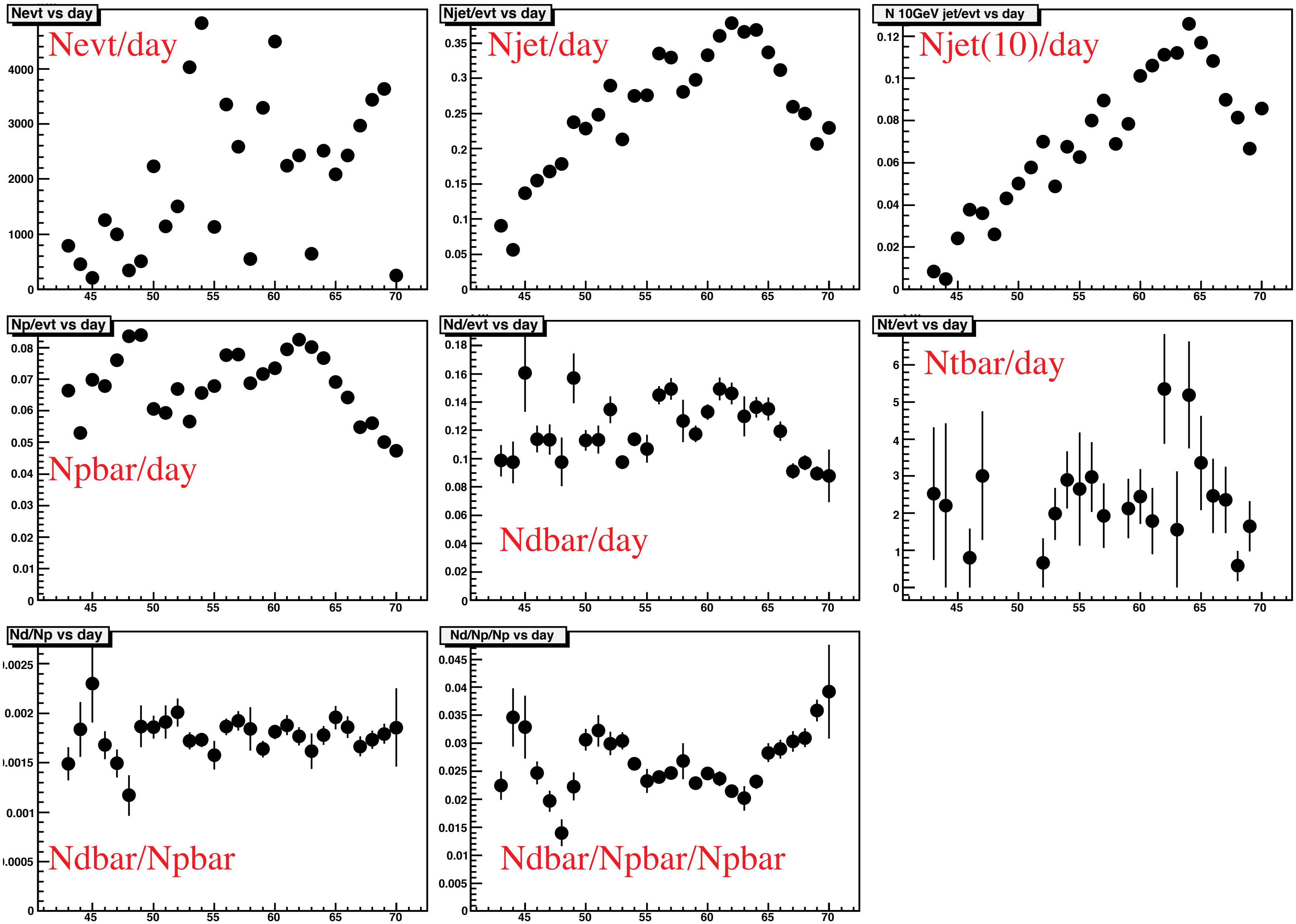


the same analysis strategy is typically used when doing HBT in jets...

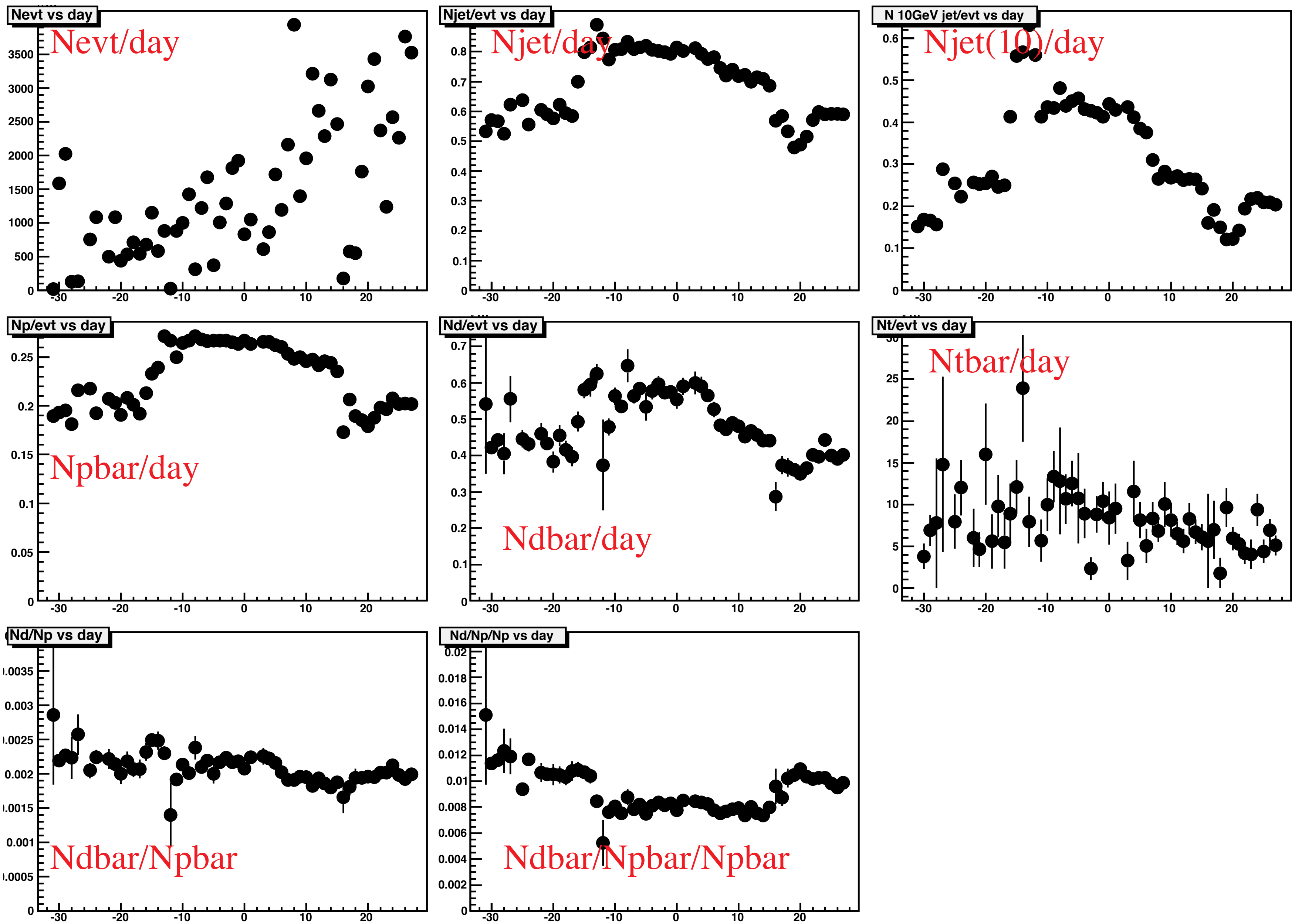
can also use $1/(Pt.Nev.d\phi)dN/dPt/d\phi$ and set ϕ via jet axis

So, I started off fresh with a brand new analysis code. Started by looking at raw rates/day...

p+p, 200 GeV, run-8



d+Au, 200 GeV, run-8

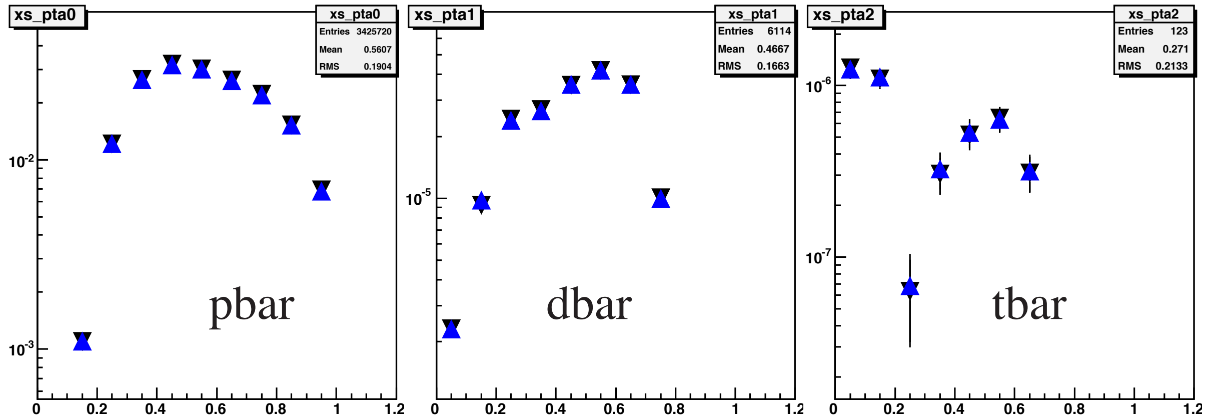


Cross-sections and B2 vs pT/A

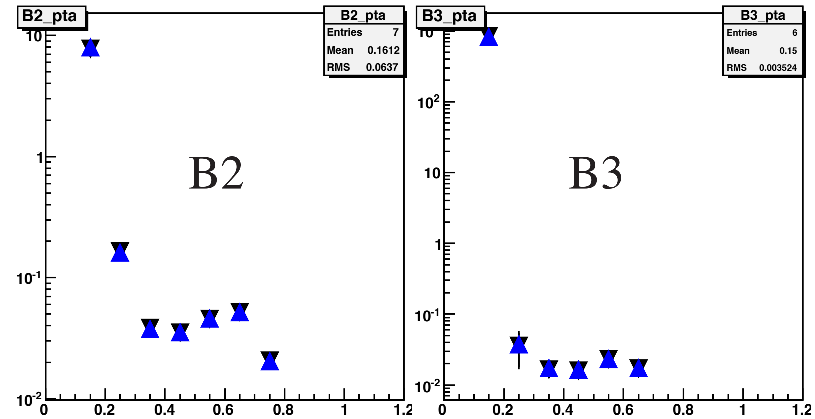
no jet selection yet

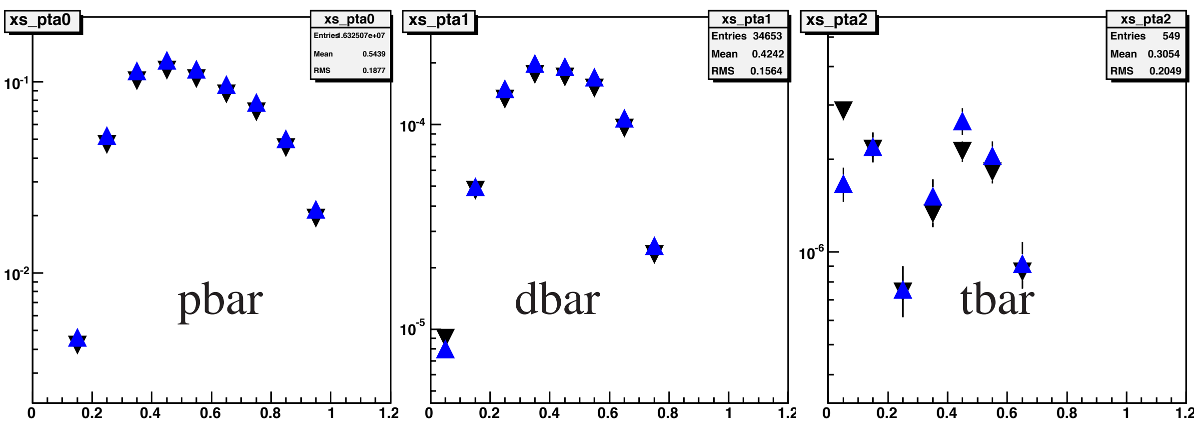
results consistent with those shown at previous meetings

Huge spike in BA at low momentum from low tracking efficiency at low pT

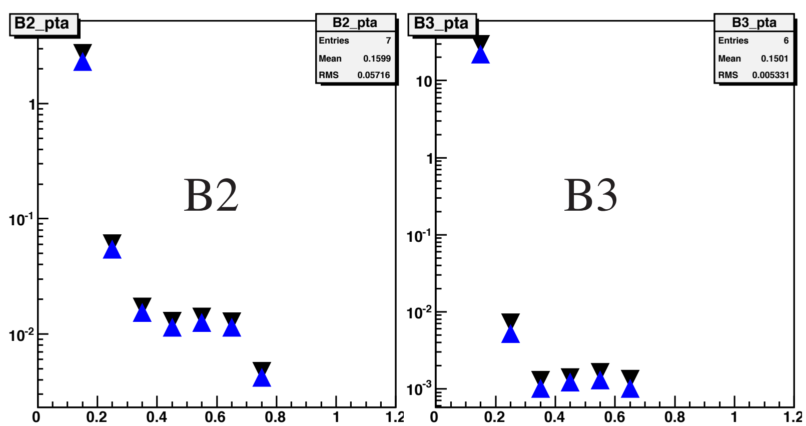


p+p, 200 GeV





d+Au, 200 GeV

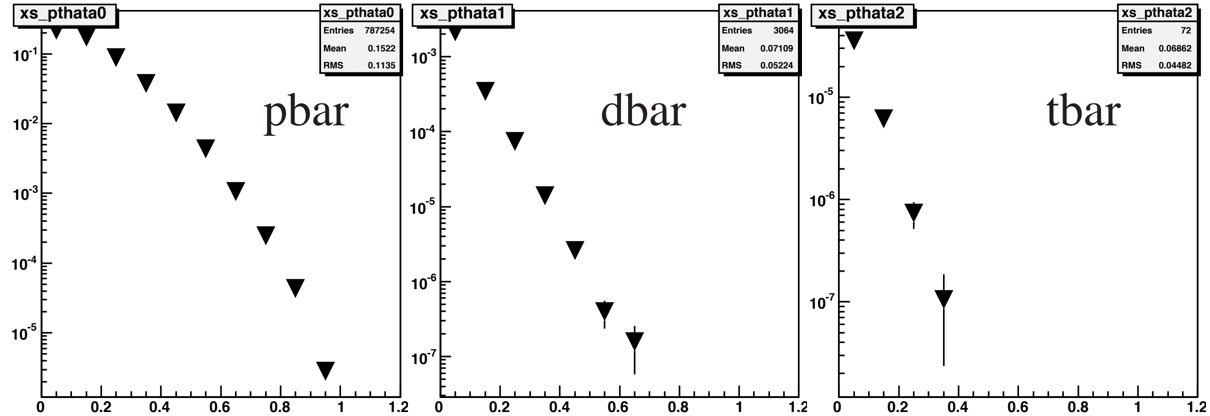


embedding simulations crucial to get low-pT/A behavior correct!

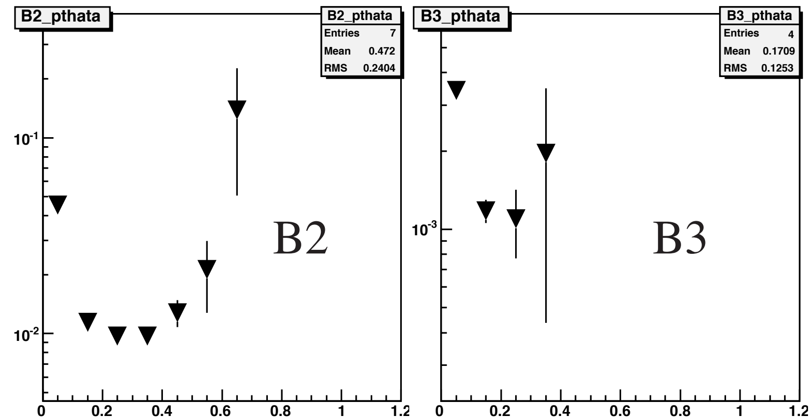
Cross-sections and B2 vs pT/A

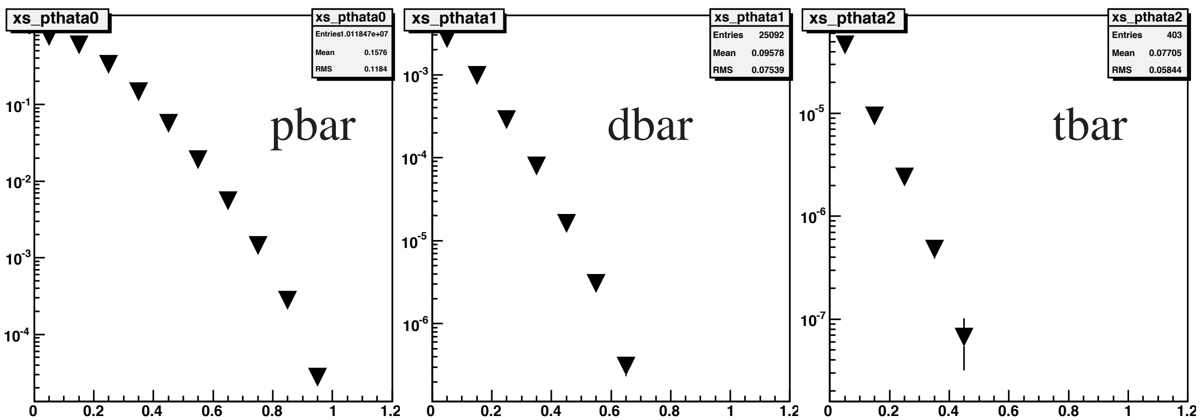
particles in jets, all jet energies

Huge spike in BA at low momentum from low tracking efficiency at low pT

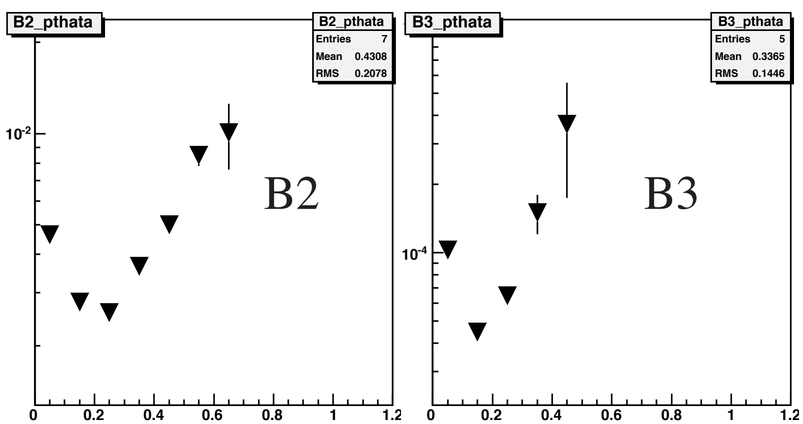


p+p, 200 GeV





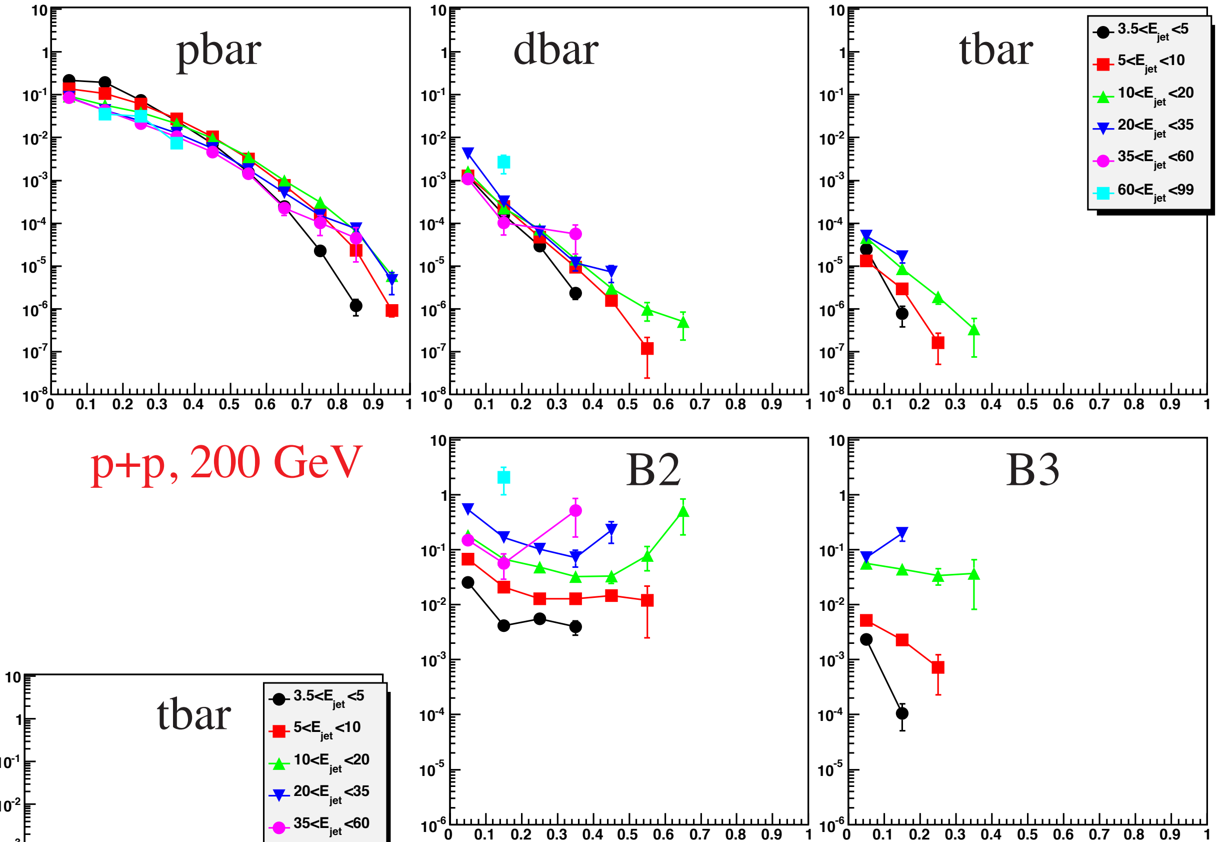
d+Au, 200 GeV



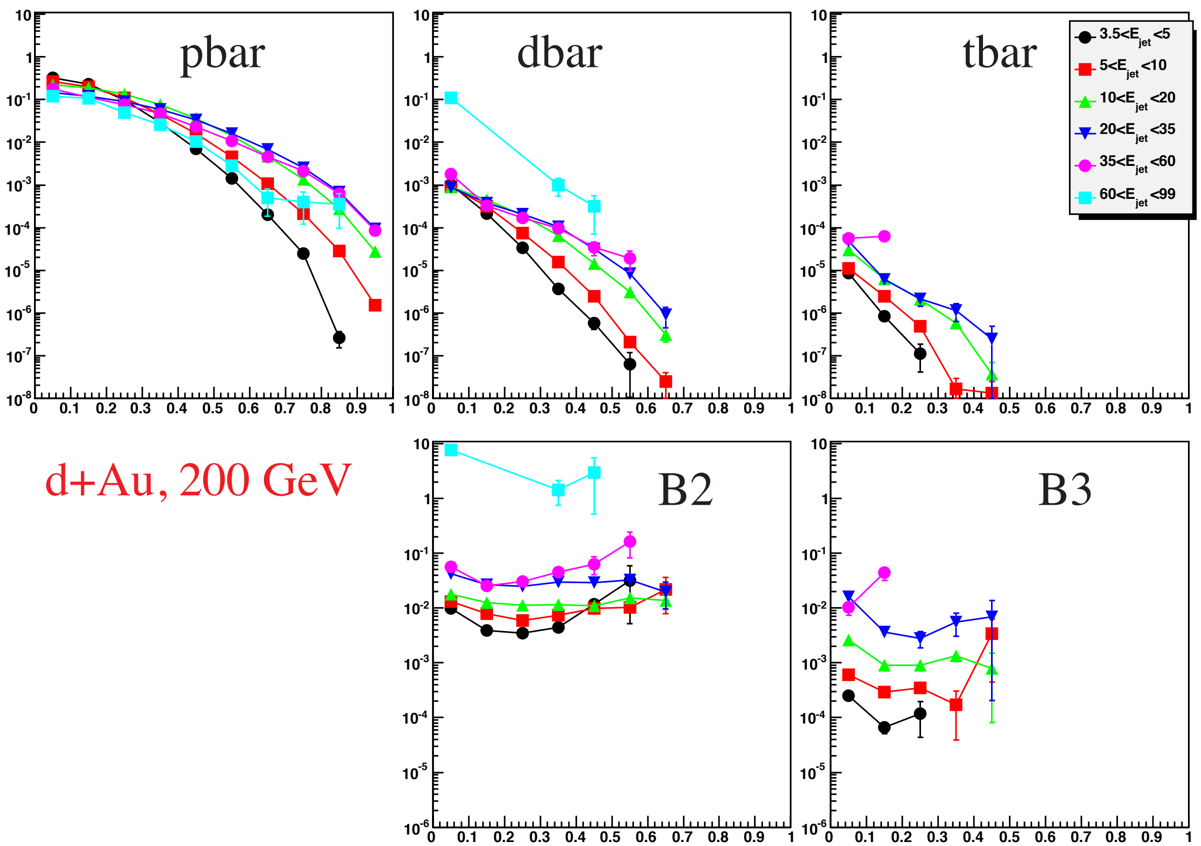
Cross-sections and B2 vs pT/A

particles in jets, by jet energy

Huge spike in BA at low momentum
from low tracking efficiency at low pT

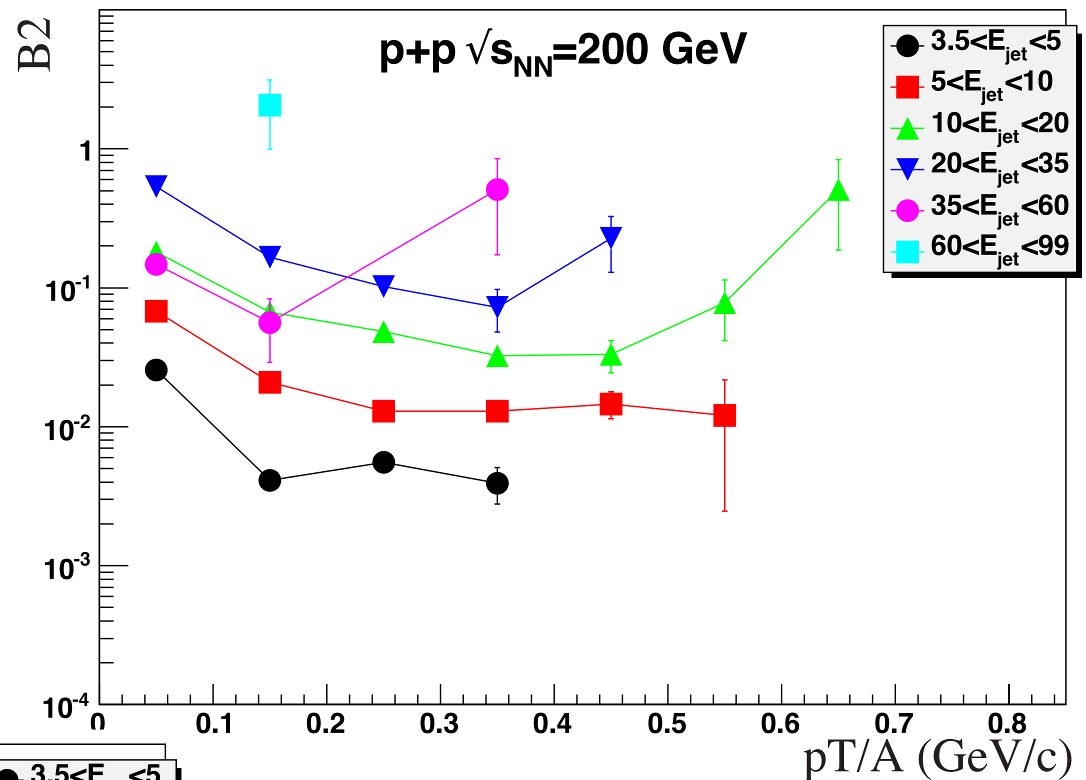


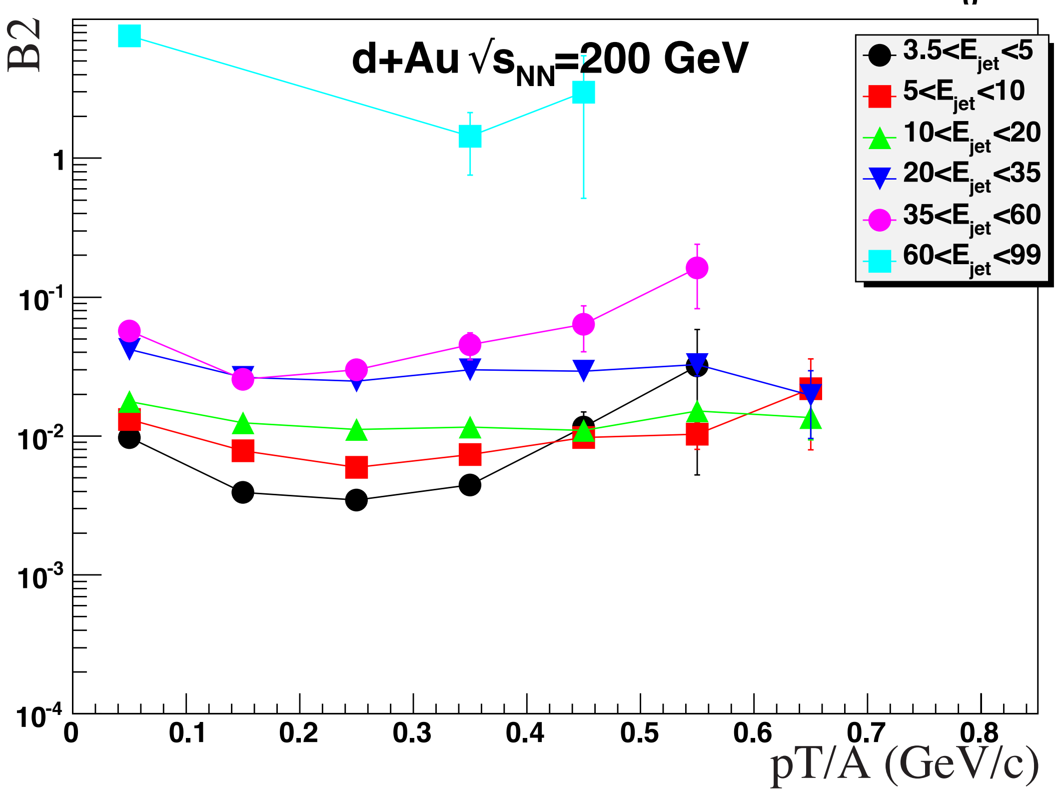
p+p, 200 GeV



d+Au, 200 GeV

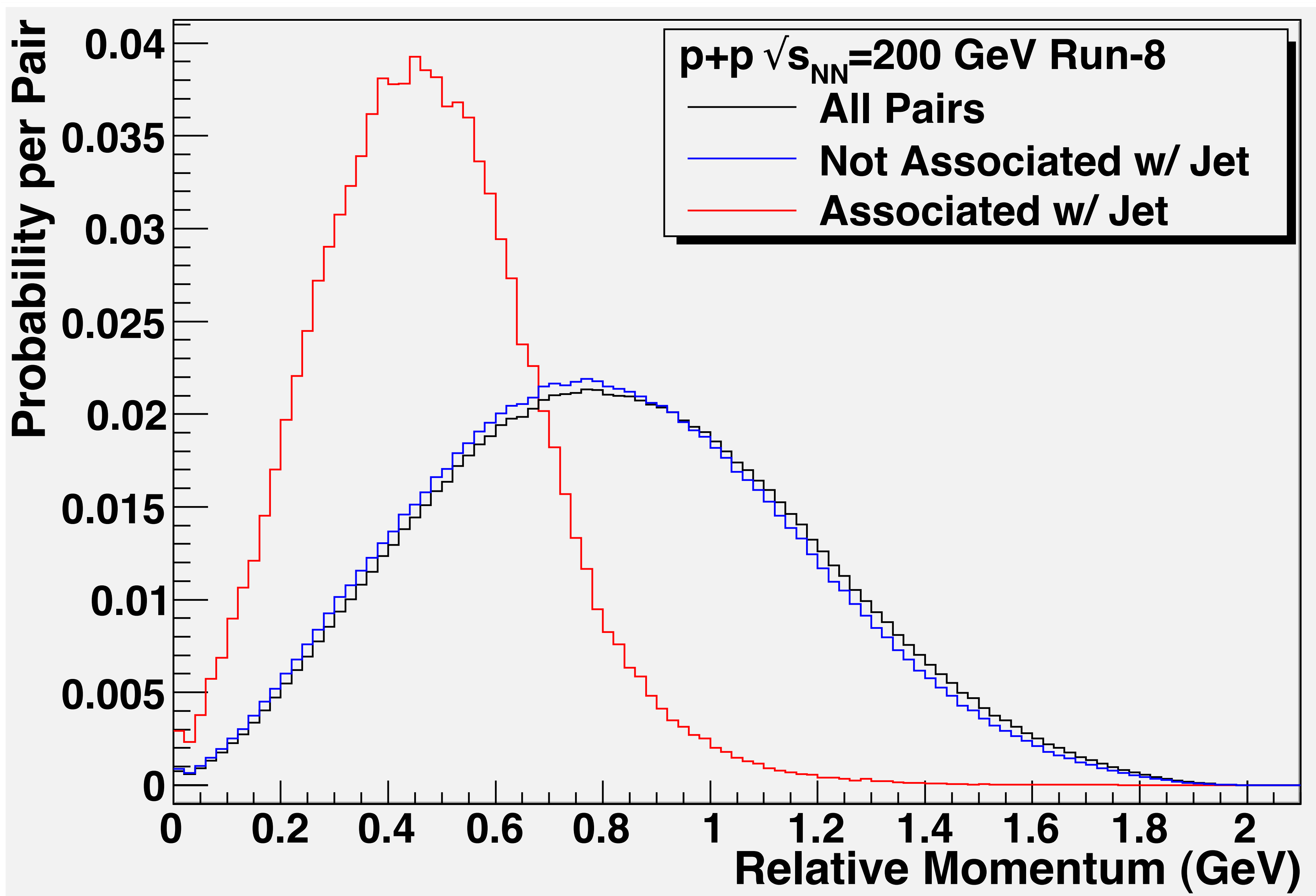
Large increase in BA
with increasing Jet Energy
for (anti)nucleons & nuclei
in Jets remains!



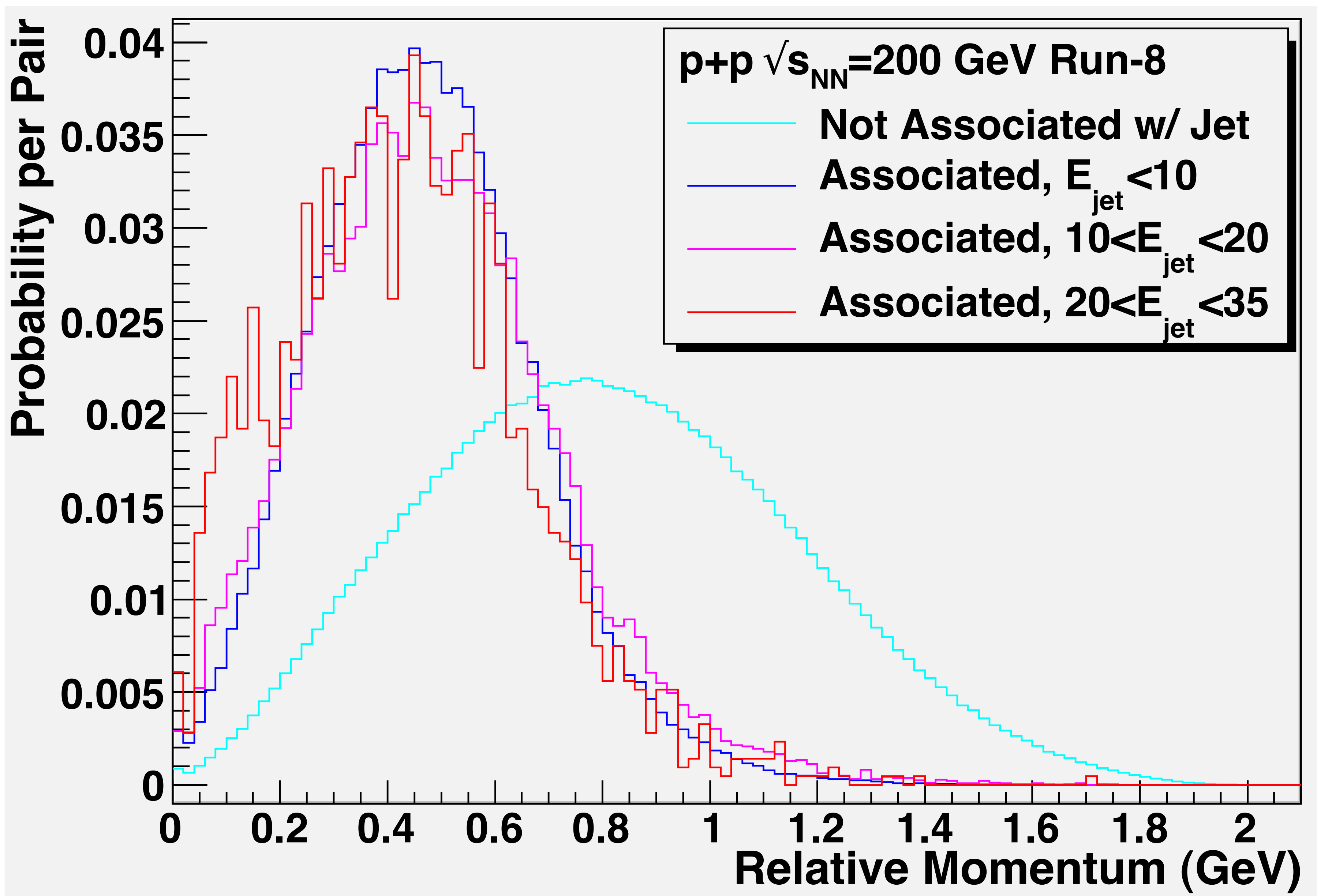


Pair Normalized 2 “proton” relative momentum distributions

max Δp is 2.0 GeV due to dE/dx PID cut



Pair Normalized 2 “proton” relative momentum distributions, now gating on Jet Energy



Primary goal now is the CORRECTIONS!!

- tracking efficiency (from embedding)
- PID efficiency (from data)
- absorption correction...
- feeddown correction...
- ~~spallation correction...~~ (just concentrate on pbar,dbar,tbar?)

Absorption

- geant does not have an engine for light nucleus dissociation/annihilation etc...
  - get the density profile of STAR from geant
  - simulate & calculate the pbar annihilation
  - scale this to the light nucleus annihilation...

Feeddown ("subtract" protons from Λ decays...)

- method 1: measure Λ spectra directly, then see how many pbar duaghters are “primary”
- method 2: plot DCA dists from simulated protons and Λ

Spallation (for nuclei only - no contribution to antiprotons or antinuclei)

proton yield = [(pbar yield, dca<3cm)/(pbar yield, dca<1cm)] * (p yield, dca<1cm)

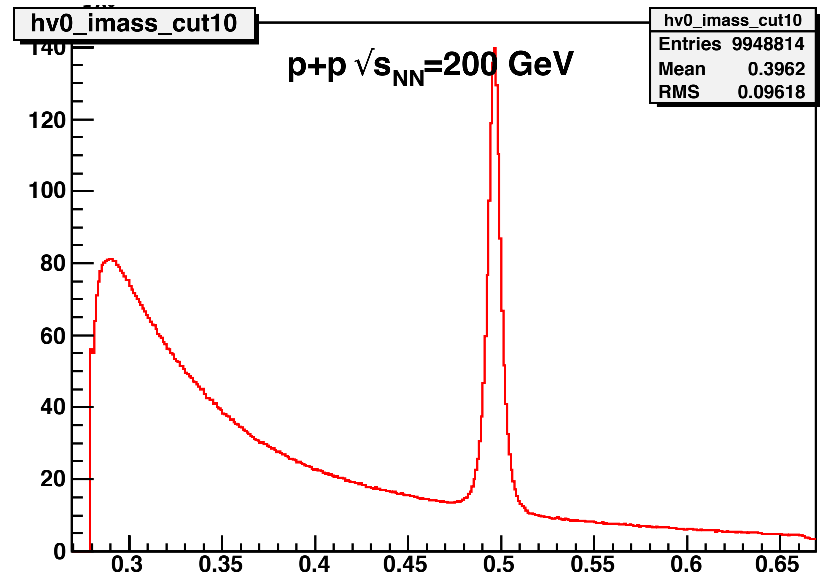
Will discuss the proposed embedding request shortly

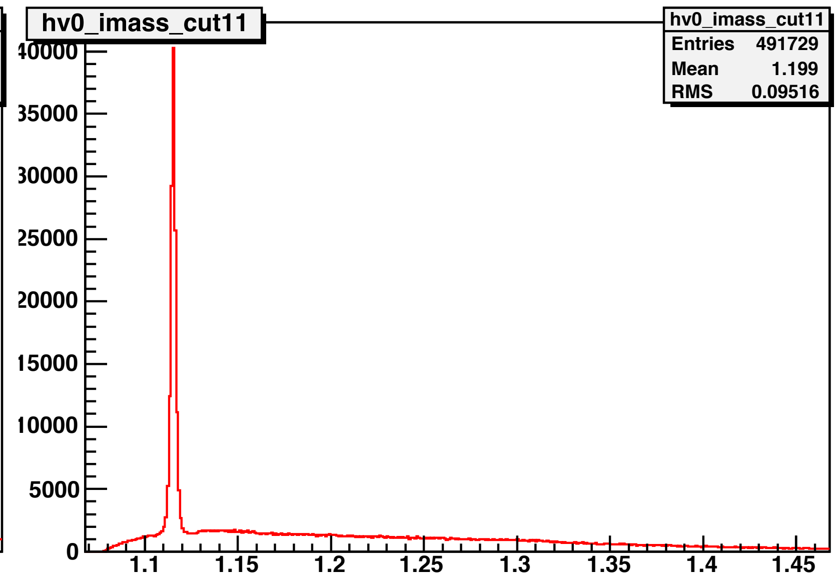
Will discuss “feeddown method 1” now (reconstruct V0s using very open cuts and look @ DCAs)

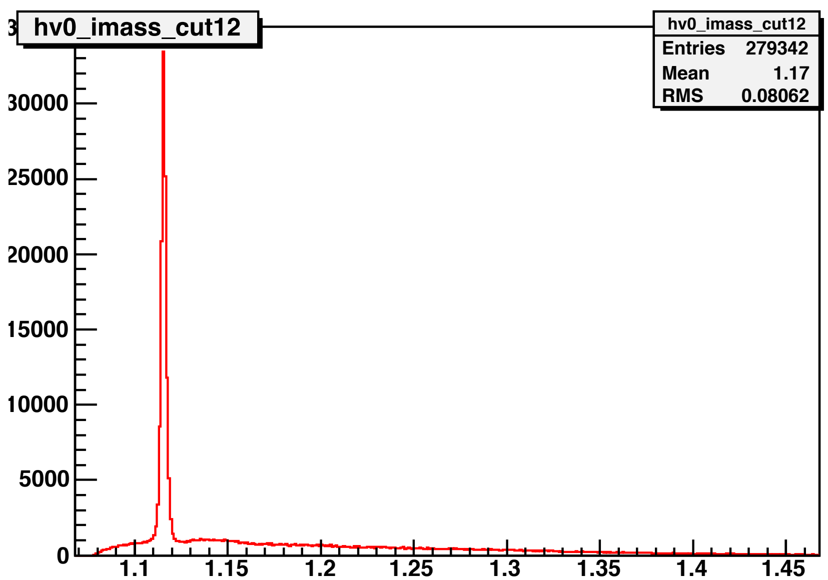
Absorption via starsim is on the to-do list....

Feed-down via reconstructed V0 s

use MuDstV0 bank in same MuDst files...
single tracks can be in multiple V0s, sort & keep V0 tracks on basis of smallest trkDCA.



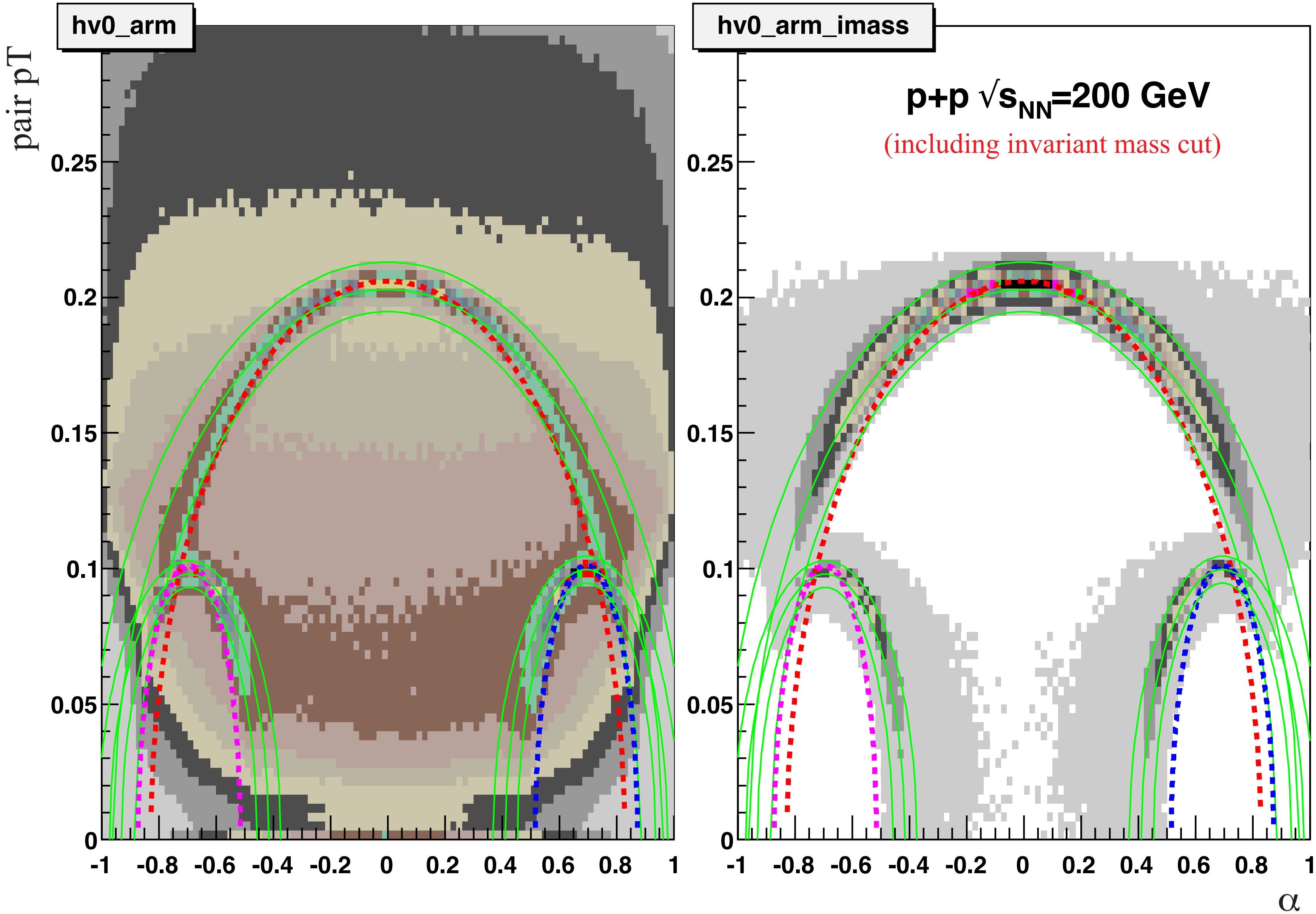




Use Open Cuts (esp. decay distance!)

```
Int_t av0::DoV0Cuts(Int_t ivzero){
    Int_t kPassed = 0;
    if (v0vtxdcapv[ivzero]<1.0
    &&  v0trkdca[ivzero]<0.8
    &&  v0dkdist[ivzero]>=0.
    && (v0ndedxpos[ivzero]>10
      &&v0ndedxneg[ivzero]>10)){
        kPassed = 1;
    }
    return kPassed;
}
```

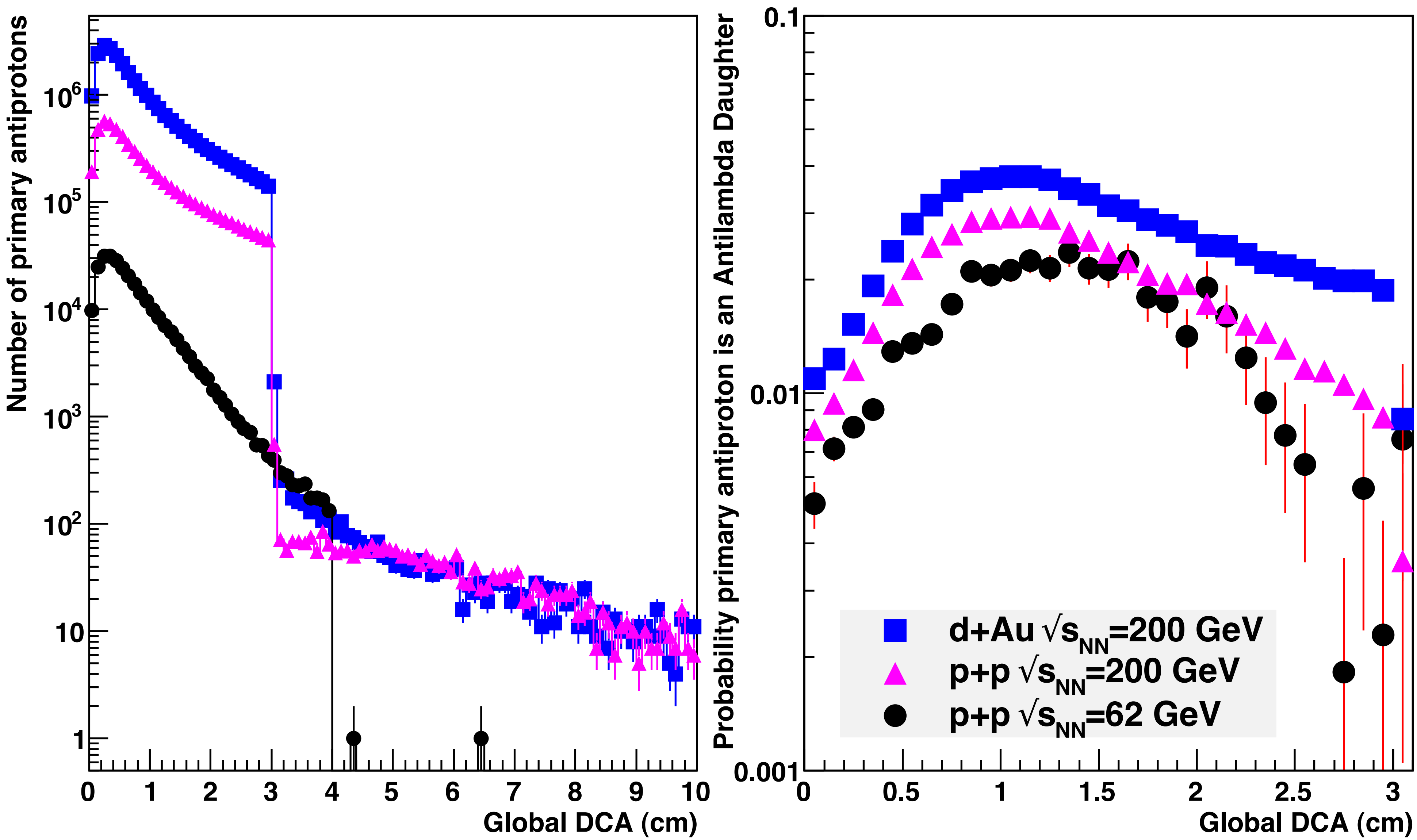
Aside: Armenteros puzzle.....



Right frame is the Armenteros plot including a cut on the invariant mass
ellipses are too wide!   (how can this be?)

see also S. Kabana, Proceedings 20th WWND (2003) - her Figure 1 shows the same thing... (?)

Probability that primary antiproton is also the daughter of an antilambda.......



feeddown correction appears to be at most 4% (d+Au) and ~1-2% in p+p

Proposed Embedding Request

- I've been running the macros to learn about the machinery using Chitrasen's Run-8 files (thanks Chitrasen!)
- Renee is looking for any existing embedding files (I'm sure she won't find any, but we'll see)

1.	pbar, dbar, & tbar	p+p	62 GeV, Run-6	P06ie
2.	pbar, dbar, & tbar	p+p	62 GeV, Run-8	P08ie
3.	pbar, dbar, & tbar	d+Au	200 GeV, Run-8	P08ie

Considering 3 particles per event with random $\phi = \phi_{\mathbf{use}}$ for pbar, $\phi_{\mathbf{use}}+2\pi/3$ for dbar, $\phi_{\mathbf{use}}+4\pi/3$ for tbar

Max pT: 1.5 GeV for pbar
3.0 GeV for dbar
4.5 GeV for tbar

Eta range Include EEMC: $-1.5 < \eta < 2.0$

No special treatment of jets in terms of placing simulated particles in specific events....

Need to specify run numbers in specific periods of each run (see rate vs day plots in this talk)...

Chitrasen's Run-8 d+Au pbar request:

```
Request type:          Standard Embedding request (particle in real events)
Number of events       625000 = 625 K
Magnetic Field         Reversed Full-Field
Collision Type         dau 200GeV
Centrality             ---- SELECT CENTRALITY ----
BFC tags
Production             ---- SELECT PRODUCTION TAG ----
Geometry: simu         ---- SELECT GEOMETRY ----
Geometry: reco         ---- SELECT GEOMETRY ----
Library                ---- SELECT STAR LIBRARY ----
Vertex option          Force vertex as MC vertex,
                       pick vertex from tag file for simulated data
Pileup option          No
Particle                                            PBar
Particle settings                                   Flat in Pt
Particles per event                                 1
Vertex Z, cm                                        0 < Vertex < 0
Gaussian sigma in X,Y,Z, if applicable              0, 0, 0
Vertex offset: x, mm                                0
Vertex offset: y, mm                                0
 (phi), radian                                      0 < ϕ < 6.39
 (eta)                                              -1.5 < η < 1.5
Pt, GeV                                             0.1 < Pt < 5
```

Christof Struck Ph.D. Thesis 2003 (Au+Au data)

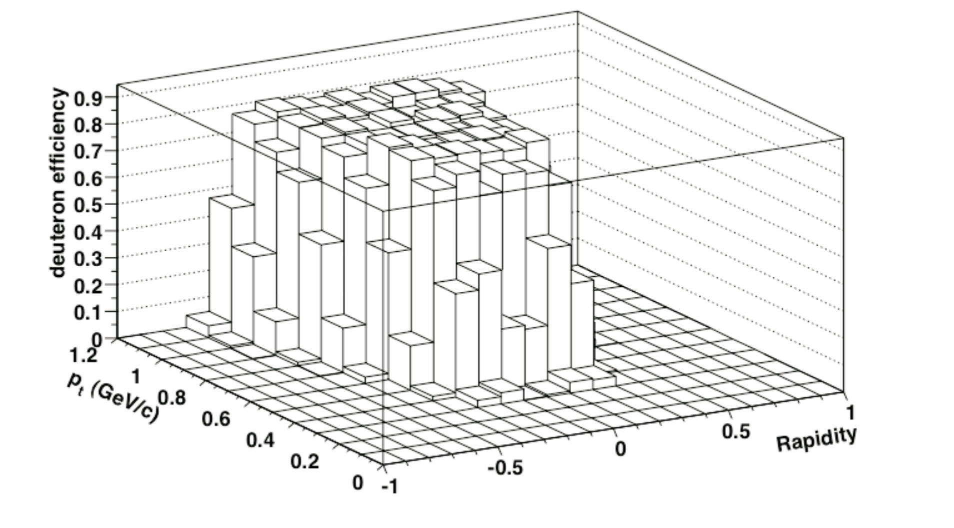


Figure 6.12: Deuteron reconstruction efficiency as a function of transverse momentum and rapidity.

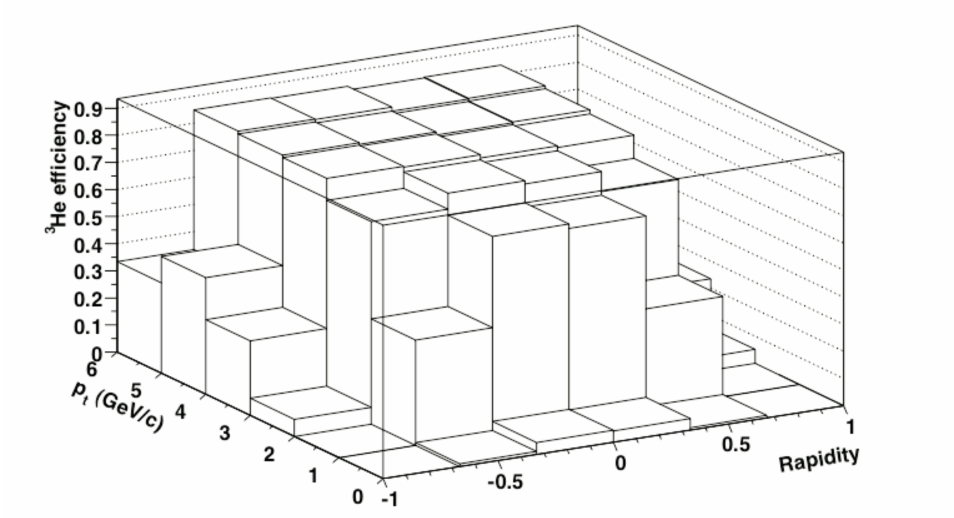


Figure 6.13: ^{3}He reconstruction efficiency as a function of transverse momentum and rapidity.

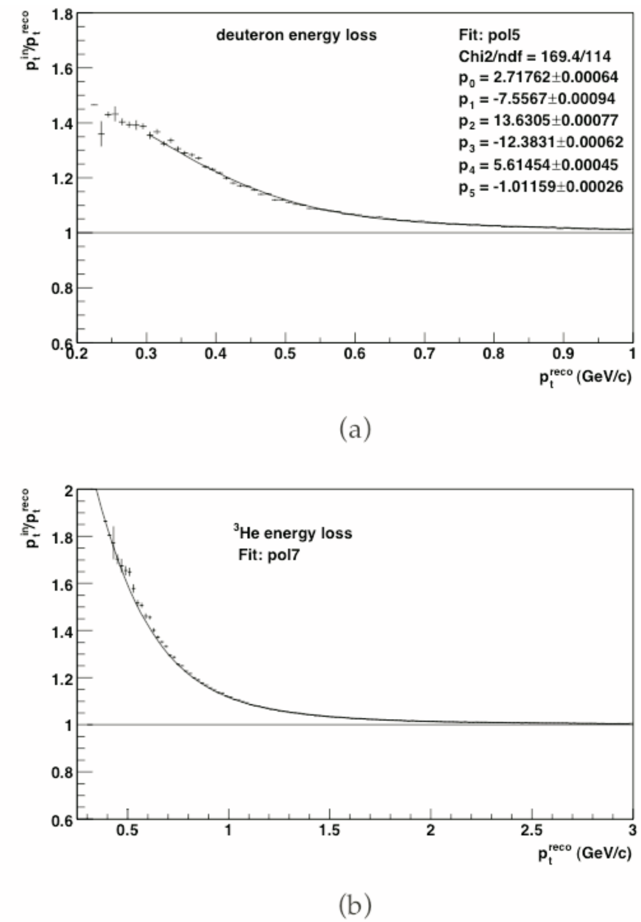


Figure 6.5: Energy loss correction: Ratio of input to reconstructed transverse momentum p_t^{in}/p_t^{rec} as a function of p_t^{rec} for d (a) and ^{3}He (b).

Christof Struck Ph.D. Thesis 2003 (Au+Au data)

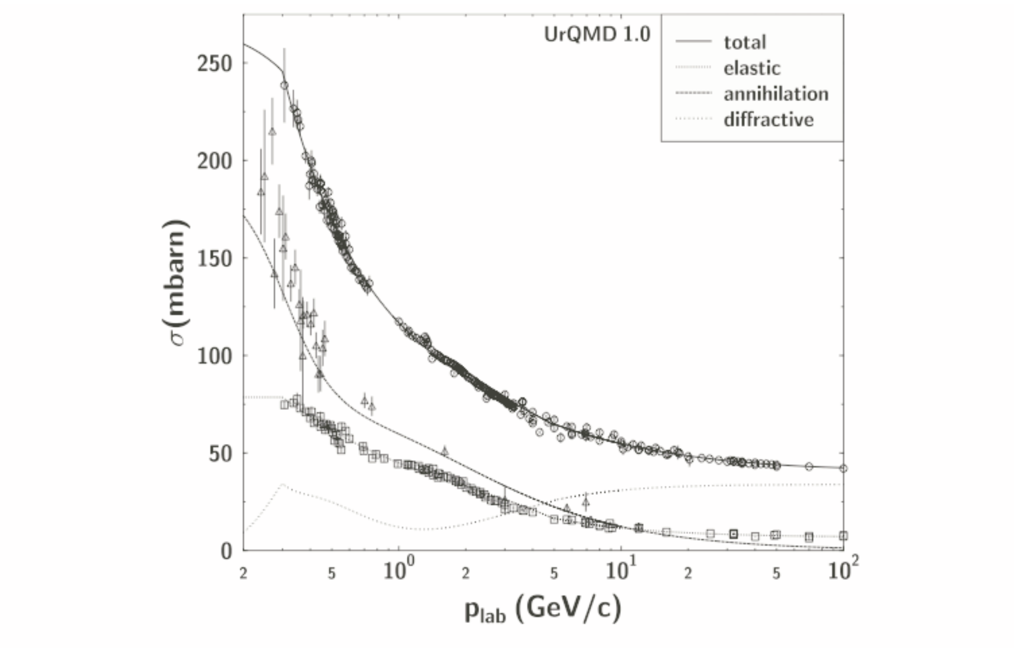


Figure 6.14: Antiproton/proton total, elastic and annihilation cross section. Lines show the parametrizations used in UrQMD [58].

for $\bar{p}$, get detector density distribution from geant and use known cross-sections...

$$abs(p) = 1 - e^{-\sigma_{anni}\ \rho_t\ p\ /\ p_t}$$

$$\sigma_{anni} = 1.2\ \sigma_{total}\ /\ \sqrt{s}$$

$$\sigma_{total} = 120\ p^{-0.65}$$

$$abs^{\bar{p}}_{corr}(p) = exp[\frac{0.089}{\sqrt{1+\gamma}}\ p^{-0.65}\ \frac{p}{p_t}]$$

where ρ_t is the transverse density profile

for light fragments, only σ_{anni} changes...
so, use this pA→AA scaling:

$$\sigma_{inel}(A = 2, 3) = (\sqrt{(2)}, 2)\ \sigma_{inel}(p)$$

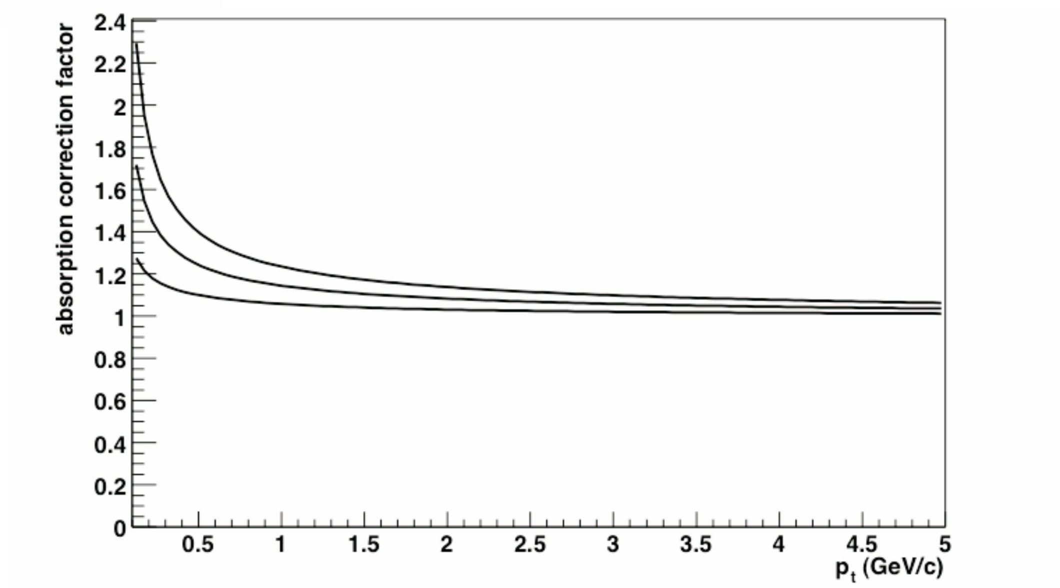


Figure 6.15: Absorption correction factor at mid-rapidity as a function of transverse momentum for $\overline{p}$ (lower curve), $\overline{d}$ (middle curve) and $^3\overline{He}$ (upper curve).

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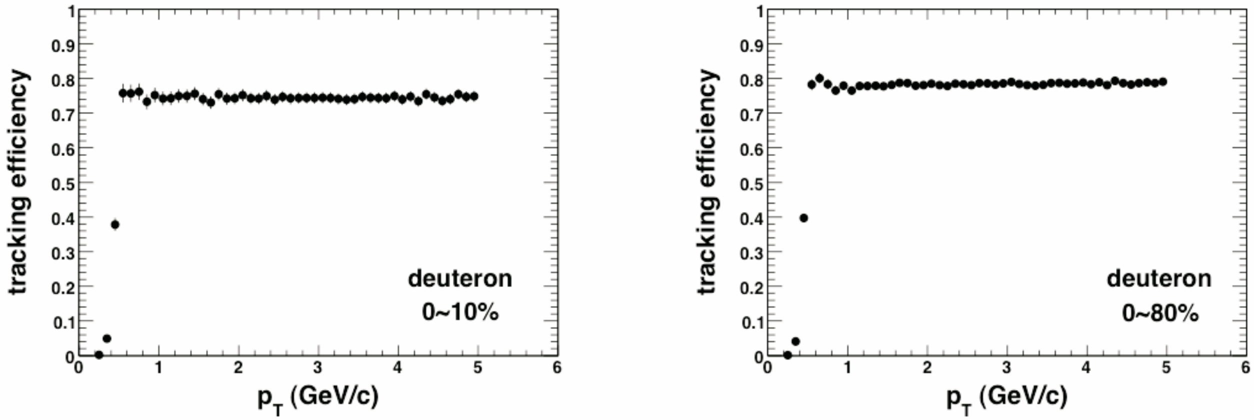

Figure 3.15: Deuteron tracking efficiency as a function of p_T. The left panel is for 0-10% centrality and the right panel is for 0-80% centrality.

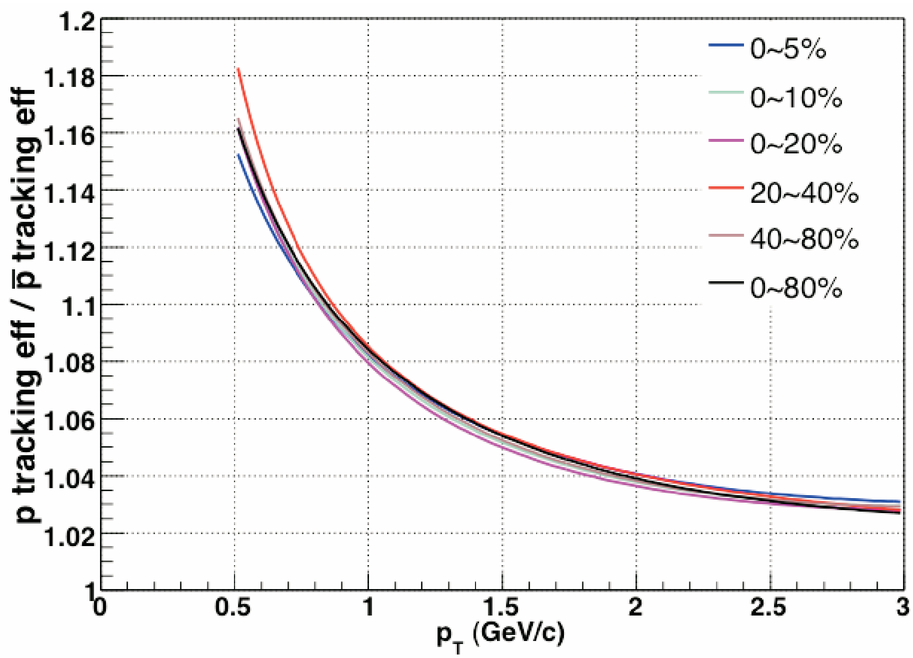

Figure 3.16: p tracking efficiency over $\bar{p}$ tracking efficiency as a function of p_T in different centrality bins.