Underlying event studies in d+Au collisions at $\sqrt{s_{NN}}$=200 GeV from STAR

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Abstract:

Description of heavy-ion collisions, where modifications of the fragmentation functions due to interaction of partons with the hot and dense medium are expected, is a challenging task and requires a detailed understanding of small collision systems such as p+p and d+Au. Comparison of measurements in p+p and d+Au collisions can be further used to disentangle initial state effects from cold nuclear matter effects.

Particles produced in p+p and d+Au collisions originate not only from hard scatterings, but soft and semi-hard multiple parton interactions and initial- and final-state radiation combine to produce particles at mid-rapidity which constitute the so called underlying event. The STAR collaboration at RHIC recently presented first results on underlying event properties in p+p collisions at $\sqrt{s}$ =200 GeV. We extend these studies and investigate in detail properties of underlying event in d+Au collisions at $\sqrt{s_{NN}}$ =200 GeV. The analysis is based on the large d+Au data sample collected by the STAR experiment in year 2008. The extracted underlying event properties are compared to those from p+p collisions. The obtained results will serve as input to Monte Carlo models.

What is an Underlying Event (UE) ?

p+p events are more than just hard scattering. They contain:

- soft/semi-hard multiple parton interactions (MPI)
- initial/final state radiation (ISR/FSR)
- beam-beam remnants

UE is everything but the hard scattering.

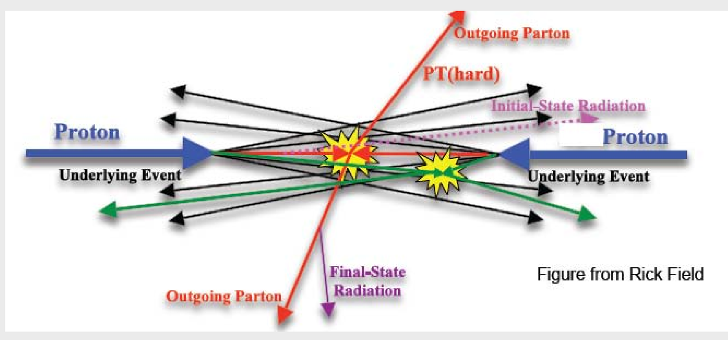


Figure from Rick Field

d+Au collisions:
Does cold nuclear matter modify properties of the underlying event?

R. Field, RHIC/AGS Users Meeting 2009

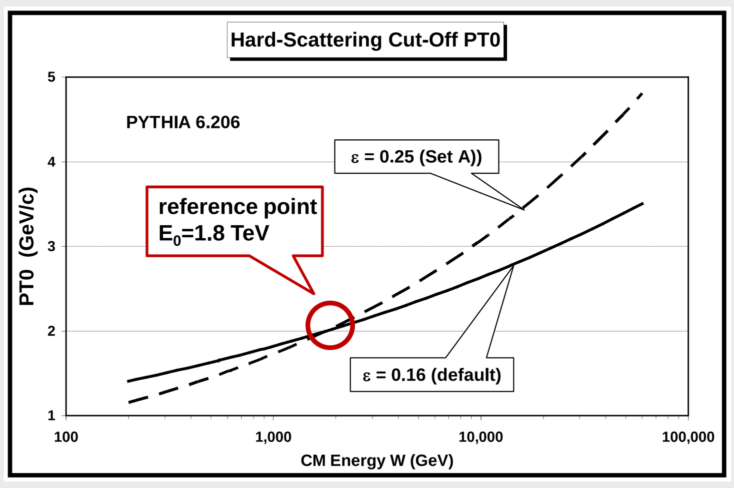
PYTHIA is tuned to $\sqrt{s}$ =1.8 TeV. How well does it describe data measured at other $\sqrt{s}$?

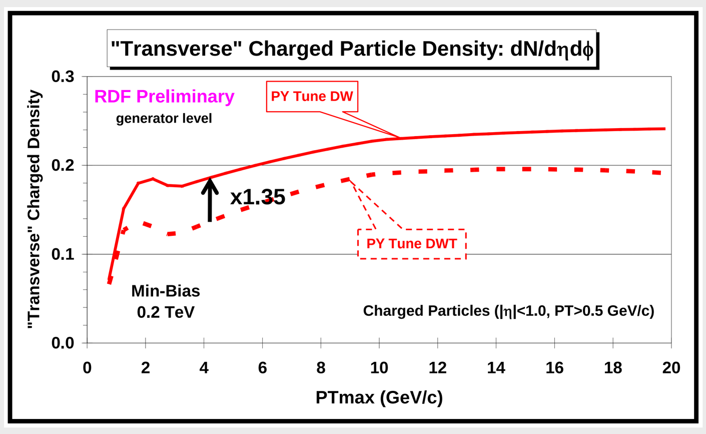
The important energy scaling factor is the hard scattering cut-off parameter for the multi-parton interaction in UE:

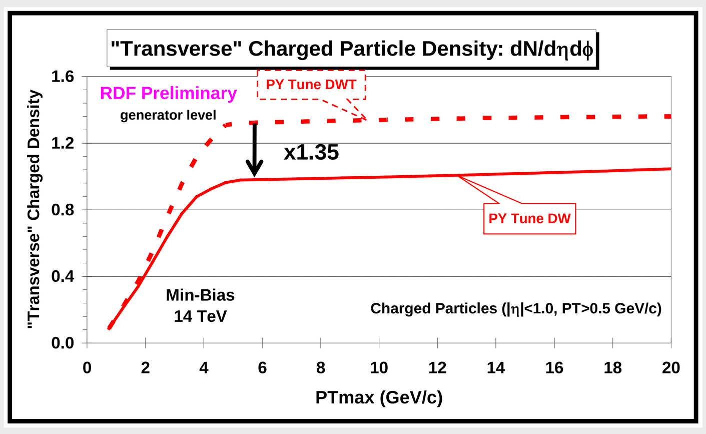
$$P_{T0}(E_{cm})=P_{T0}(E_{cm}/E_0)^{\varepsilon},$$

where ε = 0.16 (default, Pythia tune DWT),
ε = 0.25 (suggested by 630 GeV Fermilab data, Pythia tune DW).

This is a measurable effect both at RHIC and LHC energies.

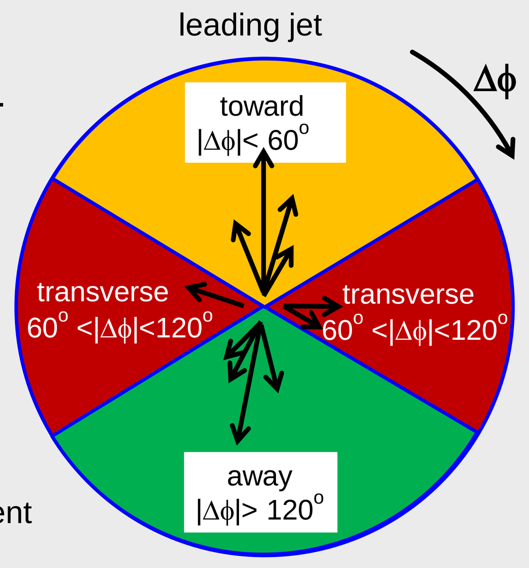






Characterization of the UE properties:

In a given event a leading jet (di-jet) is found and underlying event properties are studied in transverse region relative to jet (di-jet) axis. The transverse region is split to two parts
TransMax – transverse region with highest $\sum p_T$, $\sum N_{track}$
TransMin – transverse region with least $\sum p_T$, $\sum N_{track}$



Two types of analysis:
- leading jet in the acceptance
- di-jet: $|\Delta\phi|$>150°, $p_T^{away}/p_T^{leading}$>0.7 (suppression of initial and final state radiation effects)

TransMax:
enhanced probability of containing hard initial/final state radiation component
TransMin:
sensitive to beam-beam remnants and multiple parton interactions

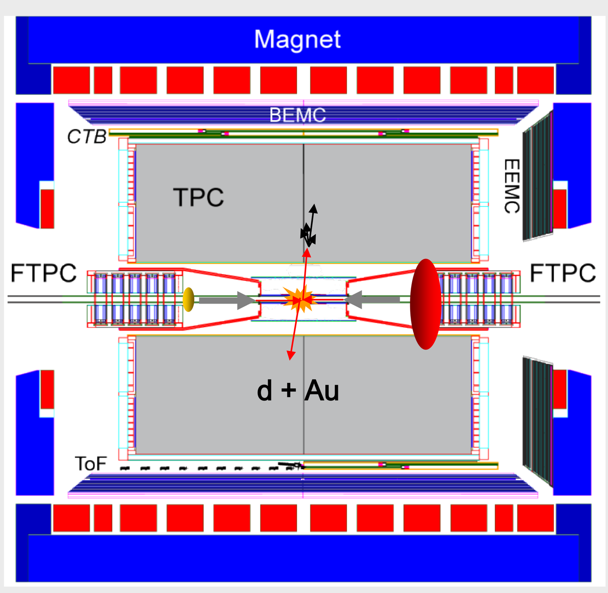
Goal: compare "TransMin" and "TransMax" data from leading and di-jet samples
→ information about large angle ISR/FSR

STAR experiment:

Time Projection Chamber (TPC):
- charged particle tracking
- for jet and UE analysis charged particles with p_T =0.2-15 GeV/*c* are used

Barrel ElectroMagnetic Calorimeter (BEMC):
- neutral energy contribution
- tower size in (η,ϕ) is 0.05x0.05
- trigger

- acceptance: full azimuthal, $|\eta|$ < 0.9
- 100% hadronic correction: p_T of charged track pointing to a BEMC tower subtracted off the tower E_T to avoid double counting *(MIP, electrons, hadronic showers).*



Data analysis:

Data sample:
- d+Au collisions at $\sqrt{s_{NN}}$ =200 GeV measured in Run8
- 20% highest multiplicity events of minimum biased and BEMC triggered collisions analyzed

BEMC threshold	Number of events
E_T>2.64 GeV	4.6 M
E_T>3.6 GeV	4.5 M
E_T>4.3 GeV	6 M
E_T>8.4 GeV	0.5 M

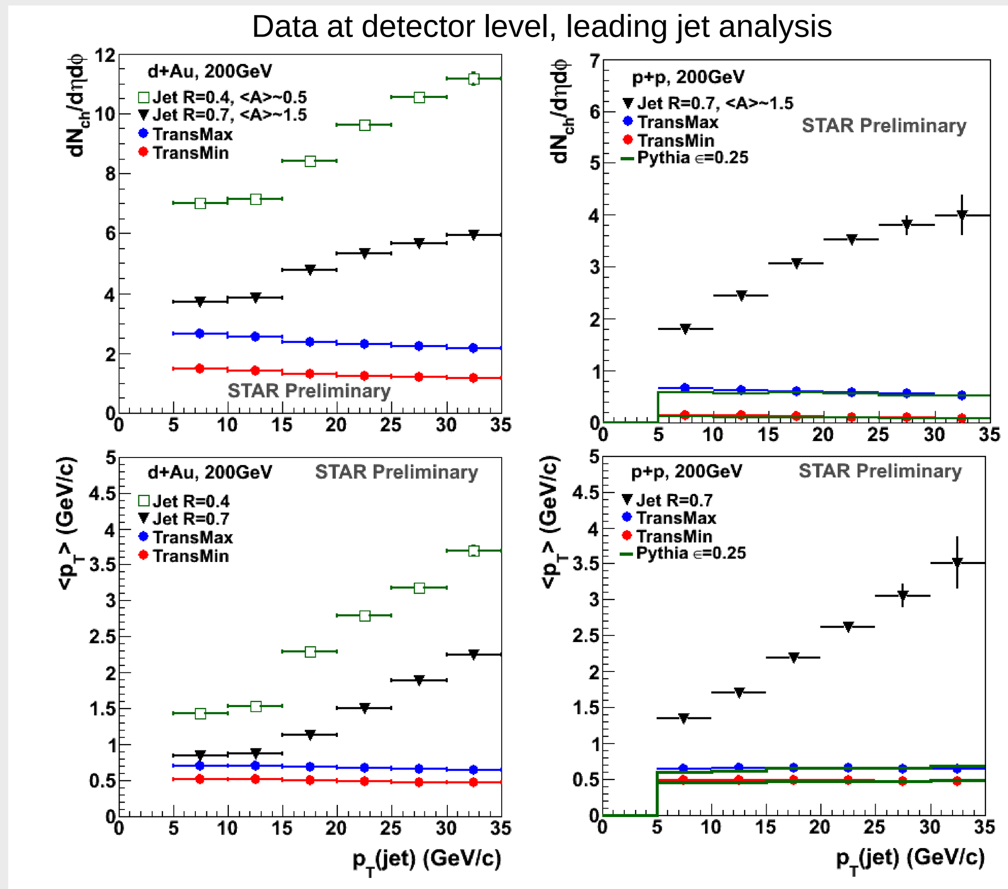
Jet reconstruction:
- infrared safe SISCone algorithm and sequential recombination algorithms k_t and anti-k_t implemented in the Fastjet package used [1-2] .
- resolution parameter R=0.4 and R=0.7 → fiducial jet acceptance in pseudorapidity: $|\eta|$ < 1-R
- neutral energy fraction in jets: NEF= 0.1-0.9.
- reconstructed jet p_T is corrected for underlying event background [3]:

$$p_T(\text{jet}) = p_T(\text{raw}) - \rho \times A \pm \sigma\sqrt{A}$$

A = active jet area, ρ = background density calculated per event using k_t algorithm, σ = background fluctuations

Further jet analysis details and jet related results in d+Au collisions can be found in [4].
The UE properties are within errors consistent for all jet finders used. The results shown are for the anti-k_t algorithm.
The p+p UE results are from [5].

Charged particle density and average transverse momentum in UE and jets



Underlying event:

Charged particle density and $\langle p_T \rangle$ in UE is approximately independent of jet p_T in both p+p and d+Au collisions at RHIC.

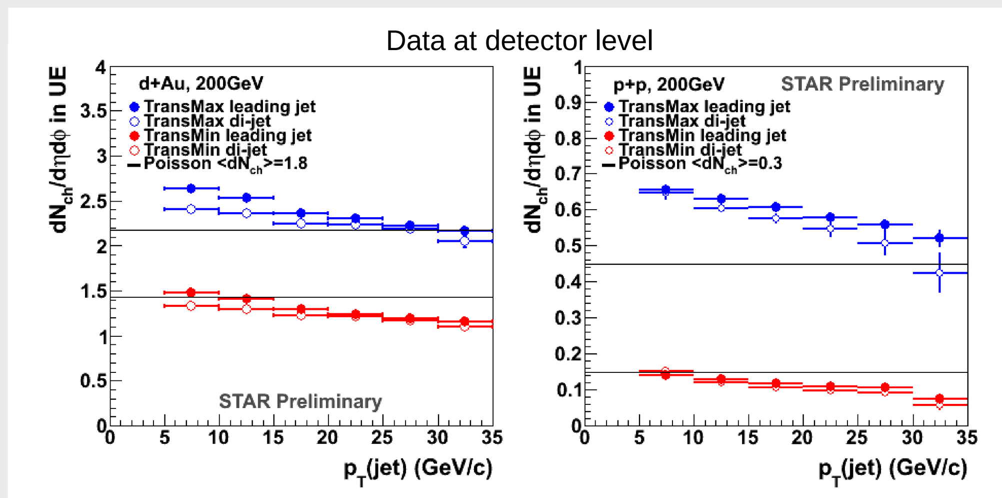
The charged particle density in d+Au collisions is about 5 times larger than in p+p collisions, while $\langle p_T \rangle$ is only slightly higher than in p+p collisions.

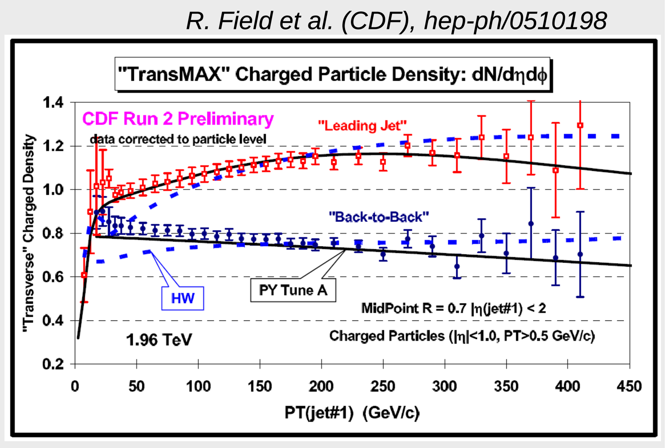
The p+p data at $\sqrt{s}$ = 200 GeV support MPI scaling factor ε=0.25.

Jet:
Charged particle density and $\langle p_T \rangle$ rise with jet p_T. In d+Au collisions the underlying event influences significantly the properties of jets and needs to be corrected for.

Size of initial and final state radiation effects at RHIC

R. Field et al. (CDF), hep-ph/0510198



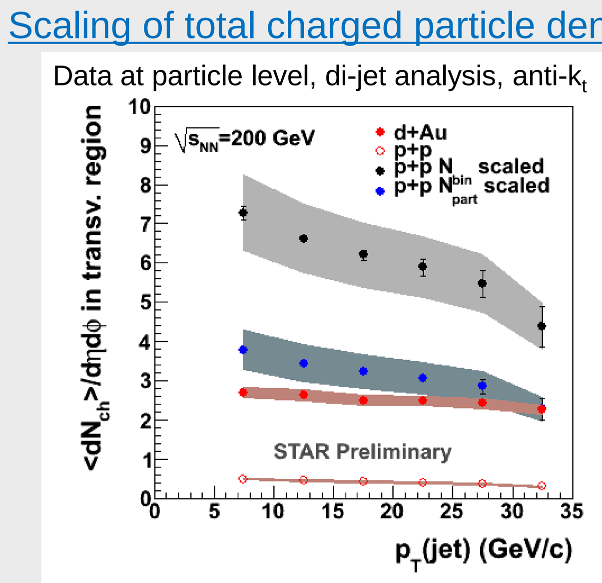


Comparison of $dN_{ch}/d\eta d\phi$ in leading and di-jet samples in p+p and d+Au collisions at RHIC shows a small size of initial and final state radiation effects. Difference between TransMax and TransMin regions follows approximately Poisson sampling.

At Tevatron ($\sqrt{s}$=1.96 TeV) the charged particle density measured in leading jet sample is by ~50% larger than in di-jet sample → significant ISR/FSR at large angles.

Note: x_T = 0.2
p_T(jet)=20 GeV at RHIC
p_T(jet)=200 GeV at Tevatron

Scaling of total charged particle density in UE at RHIC



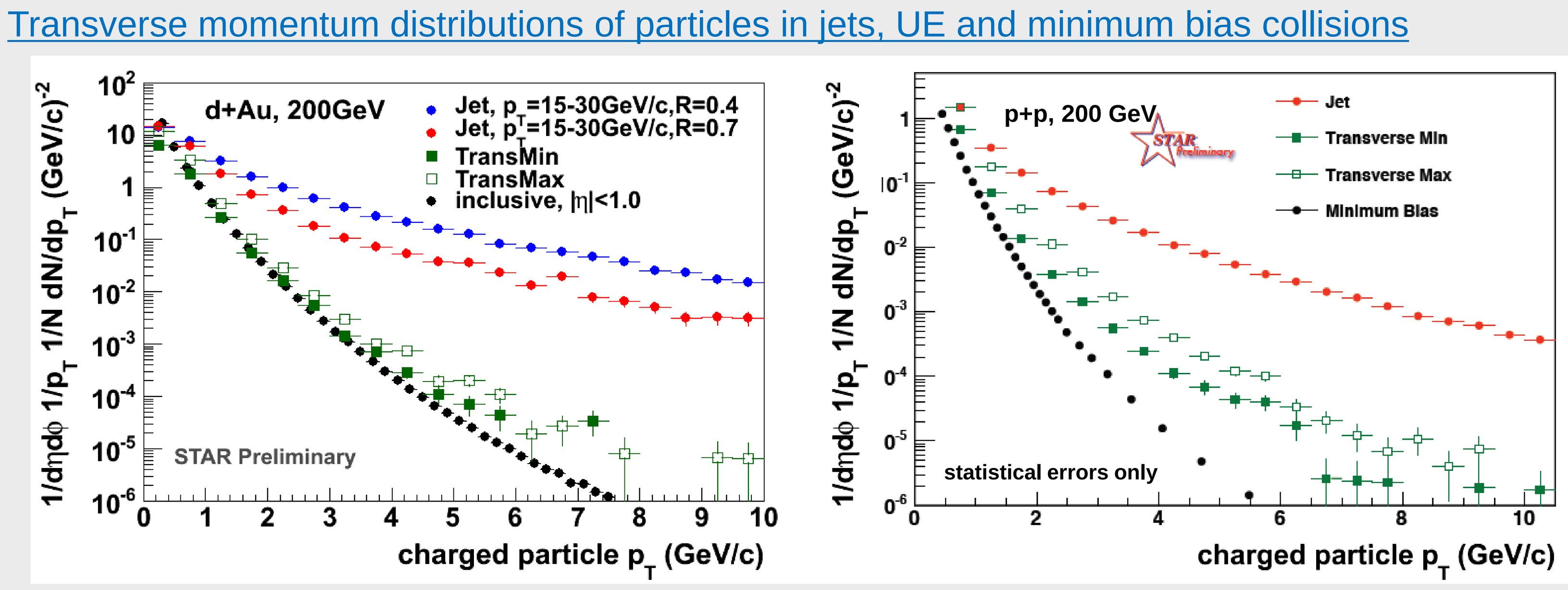
Glauber calculation for 0-20% central d+Au collisions:
N_{bin} = 14.6 ±1.7 (syst.)
N_{part} = 15.2 ± 1.8 (syst.)
p+p collisions: N_{bin}(p+p)=1, N_{part}(p+p)=2

Data corrected for reconstruction efficiency in TPC at $\langle p_T \rangle$ of UE.

Systematic errors:
- reconstruction efficiency: 5% in p+p and d+Au
- Glauber calculation uncertainty for N_{part} and N_{bin}

Charged particle density in UE in d+Au collisions scales approximately with N_{part}.

Transverse momentum distributions of particles in jets, UE and minimum bias collisions



In d+Au collisions, the p_T spectra of particles in TransMax and TransMin regions are very close to each other and approach the inclusive spectrum. In p+p collisions, the p_T spectrum of particles in TransMax region is harder than in TransMin region and both are harder than in minimum bias collisions. This difference is probably due to increased multiplicity in the UE in d+Au collisions relative to p+p collisions.

Conclusions:

The properties of underlying event in d+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV were studied for the first time at RHIC. The comparison with p+p data shows that the UE in d+Au collisions has by a factor five larger charged particle density which scales approximately with number of participants. The $\langle p_T \rangle$ in d+Au underlying event is only slightly higher than in p+p collisions. p_T distributions of particles in TransMax and TransMin UE regions are similar to inclusive particle distribution in minimum bias events in d+Au collisions while they are harder in p+p collisions. No significant ISR/FSR effects at large angles are observed in p+p and d+Au collisions at RHIC in contrast to studies in p+$\bar{p}$ collisions at Tevatron ($\sqrt{s}$=1.96 TeV).

References:

1. G. P. Salam, G. Soyez, JHEP 0705 (2007) 086.
2. G. P. Salam, G. Soyez, JHEP 0804 (2008) 063; M. Cacciari, G. P. Salam, Phys. Lett. B641 (2006) 57.
3. M. Cacciari, G. P. Salam, G. Soyez, JHEP 0804 (2008) 005.
4. J. Kapitan *et al.* (STAR Collaboration), Poster 428.
5. H. Caines *et al.* (STAR Collaboration), *arXiv: 1012.5008.*