Heavy-ion collisions and single diffractive events

Harsh Shah

Department of Astronomy and Theoretical Physics
Lund University

MCNet meeting, April 2017

Outline

Outline

Motivation: Why HI collisions

- Unlike pp interactions, it ranges over energies from $\sqrt{s}$ to lower
- Quark-Gluon-Plasma: a dense state of deconfined quarks and gluons
- Configuration of large amount of energy concentrated in small space-time region can provide insight of particle production and medium effects e.g. strangeness enhancement, jet quenching etc.
- QGP is also considered as similar to very early Universe $\sim 1\mu$s after big bang

Outline

Heavy-ion experiments

- Currently at RHIC (BNL) with $\sqrt{S_{NN}} \leq 200 GeV$ and LHC (CERN) ($\sqrt{S_{NN}} \leq 5 TeV$)
- Beams of HI can be understood as clouds of partons in disks and collisions occur at various impact parameter ranges

Heavy-ion experiments

- Currently at RHIC (BNL) with $\sqrt{S_{NN}} \leq 200 GeV$ and LHC (CERN) ($\sqrt{S_{NN}} \leq 5 TeV$)
- Beams of HI can be understood as clouds of partons in disks and collisions occur at various impact parameter ranges
- Deposition of large amount of E_k in the center produces dense fireball like structure, which has yet to achieve equilibrium

Heavy-ion experiments

- Currently at RHIC (BNL) with $\sqrt{S_{NN}} \leq 200 GeV$ and LHC (CERN) ($\sqrt{S_{NN}} \leq 5 TeV$)
- Beams of HI can be understood as clouds of partons in disks and collisions occur at various impact parameter ranges
- Deposition of large amount of E_k in the center produces dense fireball like structure, which has yet to achieve equilibrium
- interaction among trapped partons thermalise the medium and produce QGP like state.

Heavy-ion experiments

- Currently at RHIC (BNL) with $\sqrt{S_{NN}} \leq 200 GeV$ and LHC (CERN) ($\sqrt{S_{NN}} \leq 5 TeV$)
- Beams of HI can be understood as clouds of partons in disks and collisions occur at various impact parameter ranges
- Deposition of large amount of E_k in the center produces dense fireball like structure, which has yet to achieve equilibrium
- interaction among trapped partons thermalise the medium and produce QGP like state.
- Hadrons decouple from the rest of the system after kinetic freeze out ($\sim 10 - 15 fm/c$ after collision) and move towards detectors

Outline

Experimental draw backs

- Two major observables : elliptic flow and jet quenching
- In actual experiments the magnitude and orientation of impact parameter fluctuate from event-to-event and are not directly measurable. This initial geometry can affect the distribution of final states
- Different experiment- different definition of centrality e.g. at ALICE ZDC (Zero degree calorimeter) is used to detect spectators and via that to define centrality of the event. The multiplicity may also be used to define centrality
- Hence, observables are highly detector dependent

Outline

Theory models

- Initial states: Glauber model or CGC (Color Glass Condensate)

Theory models

- Initial states: Glauber model or CGC (Color Glass Condensate)
- Intermediate evolution: Theory of relativistic fluid + QCD equations of partonic and hadronic phases

Theory models

- Initial states: Glauber model or CGC (Color Glass Condensate)
- Intermediate evolution: Theory of relativistic fluid + QCD equations of partonic and hadronic phases
- end evolution = hadron rich medium to freeze out : based upon relativistic transport theory

Theory models

- Initial states: Glauber model or CGC (Color Glass Condensate)
- Intermediate evolution: Theory of relativistic fluid + QCD equations of partonic and hadronic phases
- end evolution = hadron rich medium to freeze out : based upon relativistic transport theory
- Major problems are inadequate knowledge of sub-nucleonic interactions in the initial state and event-to-event fluctuations in the nuclei

Outline

Glauber model

- Wounded nucleons: a way of extrapolation from pp to AA
- Particle formation time = the minimum possible formation time: $\tau_0 = \frac{1}{m_t}$ Boost to lab frame: $\tau = \gamma\tau_0$
- For low enough p_T and via calculations of τ, it can be concluded that the multiplicity depends mainly upon the number of wounded nucleons.
- More details about Glauber inspired models, and about various modifications to introduce initial state fluctuations, can be read in the work of Christian, Leif and Gösta, published in arXiv:1607.04434

Outline

Assumption

- In arXiv:1607.04434, they proposed that non-diffractively and diffractively excited nucleons will contribute to final state in pA and AA collision similar to wounded nucleons.
- Preliminary results with a modified Glauber-Gribov model for pA collisions have been presented based on this assumption, using PYTHIA8

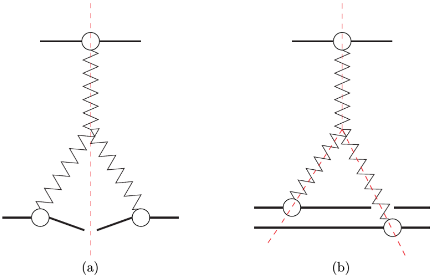


Figure: a) diffractive excitation in p-p b) non-diffractive in p-d

Assumption-extended to pA

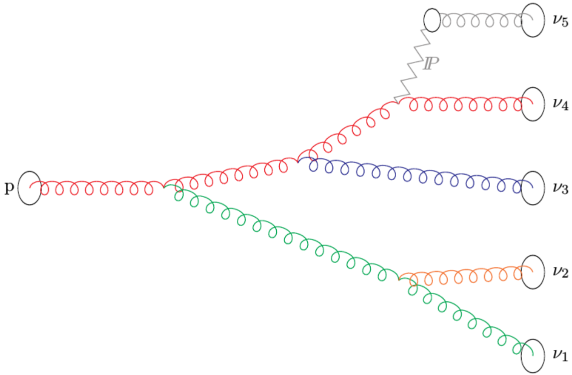
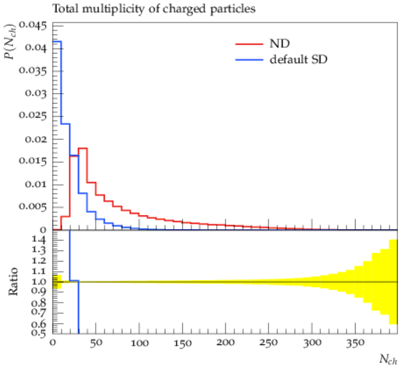
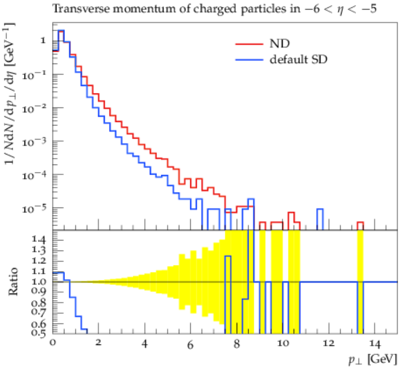


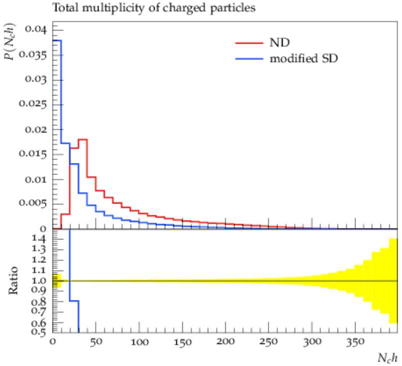
Figure: Cartoon of pA type collision. $v_1 ... v_5$ partons within nucleus A.

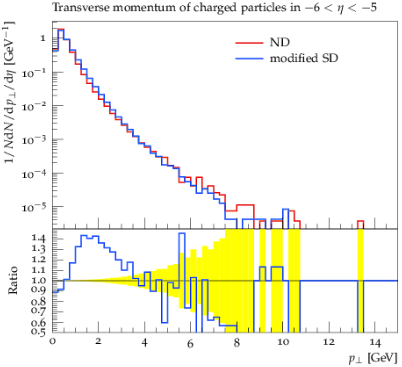
Default PYTHIA8

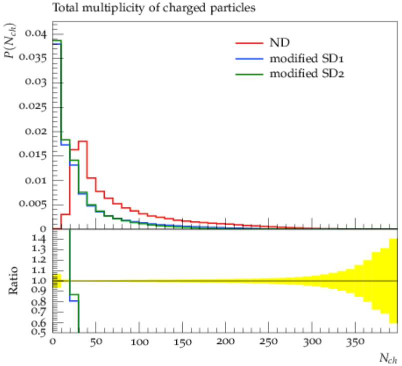
- I am investigating this assumption thoroughly via applying various tunes to generate single diffractive events in PYTHIA8 and comparing various observables (e.g. multiplicity, p_T distribution, $\langle p_T \rangle$ etc.) with non-diffractive events in different pseudo rapidity ranges

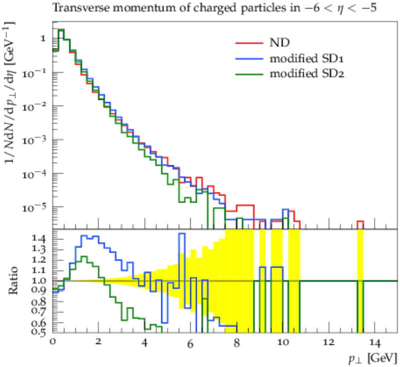





Total multiplicity of charged particles
P(N_ch)
ND
modified SD
Ratio
N_ch


Transverse momentum of charged particles in −6 < η < −5
1/N dN/dp⊥/dη [GeV−1]
ND
modified SD
Ratio
p⊥ [GeV]


Total multiplicity of charged particles
ND
modified SD1
modified SD2
$P(N_{ch})$
Ratio
N_{ch}


Transverse momentum of charged particles in $-6 < \eta < -5$
ND
modified SD1
modified SD2
$1/N dN/dp_\perp/d\eta$ [GeV^{-1}]
Ratio
$p_\perp$ [GeV]

Summary

- At HI experiments centrality is highly detector dependent
- Adequate knowledge of initial state fluctuations is important
- At Lund we shown some preliminary results with initial state fluctuations using GG model
- I am testing underlined assumption

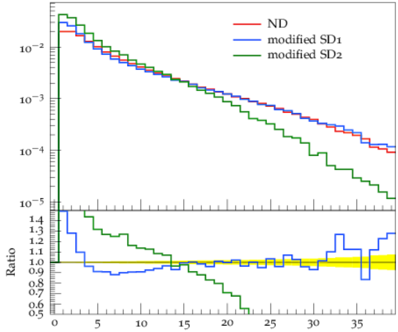


Figure: ND and modified SD charge multiplicity distribution in -0.5 $< \eta <$ 0.5

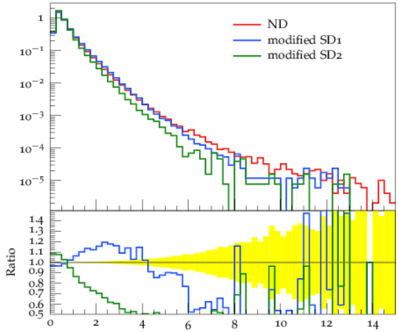


Figure: P_t distribution in -0.5 $< \eta <$ 0.5

extra-2

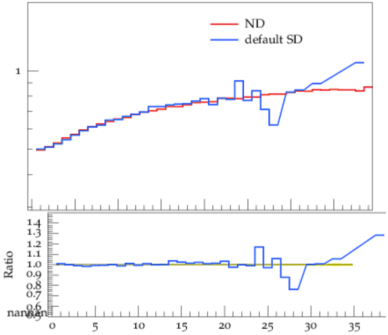


Figure: Default PYTHIA8 $< P_t >$/particle distribution in -0.5 $< \eta < 0.5$

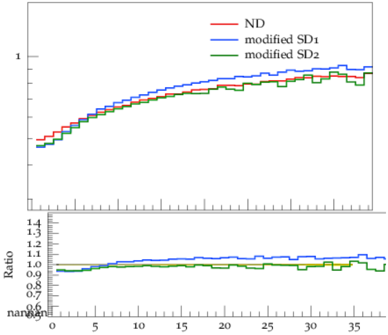


Figure: Modified PYTHIA8 $< P_t >$/particle distribution in $-0.5 < \eta < 0.5$