How to include CGC into Pythia/Angantyr

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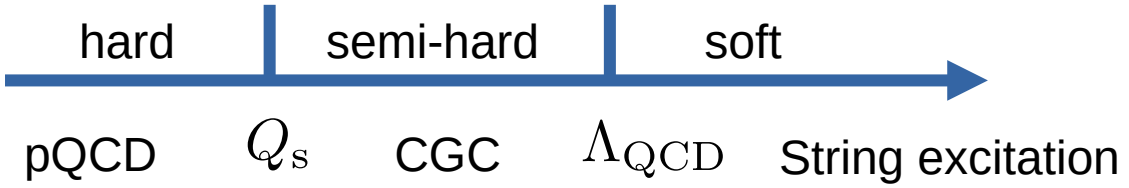
- How to implement coherent gluon production in an event generator for AA collisions?
- How to include CGC in Pythia? Separate hard and semi-hard?
  Hard: collinear pQCD semi-hard (saturation scale) CGC soft: string excitation



How to include CGC into Pythia/Angantyr

Modeling CGC:

- Classical Yang-Mills equation
- Particle + classical YM (Vlasov equation for gluons)
- Based on kt-factorization formula (KLN, rcBK evolution)
  - First attempt: BBL (Black-Body limit) H.J. Drescher, A. Dumitru, M. Strikman, Phys.Rev.Lett. 94 (2005) 231801 and hep-ph/0501165 [hep-ph]
  - MC-KLN, MC-Kt, Drescher,(2007),Albacete(2013)
- Hybrid formula (DHJ) + Lund string fragmentation
  W.Deng,et.al PRD91,014006(2015)

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pp and pA collisions

DHJ formula for pp and pA collisions at forward gluon productions:

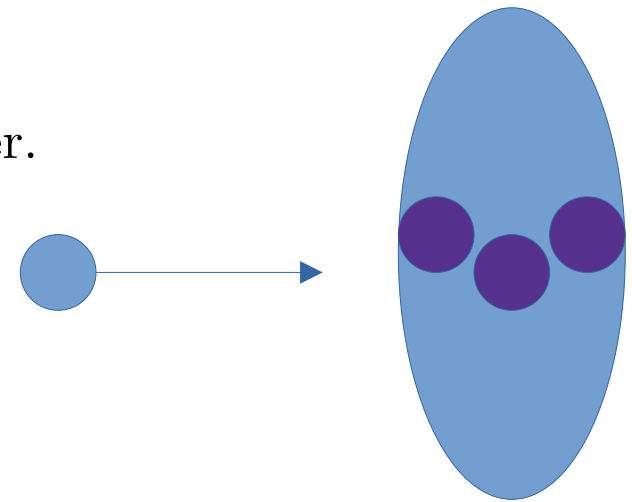
$$\frac{dN}{dyd^2p_\perp} = \frac{K}{(2\pi)^2} f_{i/p}(x_1, p_\perp^2) N_i(p_\perp, x_2) \quad + \quad \text{Lund fragmentation}$$

PDF

running coupling Balitsky-Kovchegov (rcBK) evolution

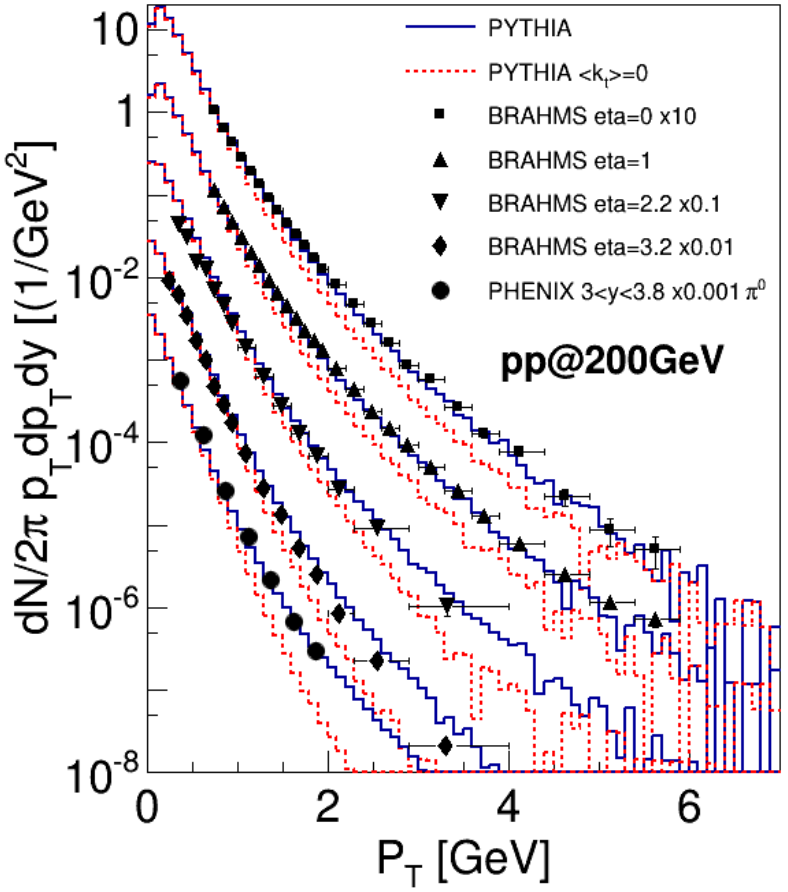
$$Q^2_{\mathrm{s0,nucleus}}(\boldsymbol{r}) = N(\boldsymbol{r}) Q^2_{\mathrm{s0,proton}}$$

$N(\boldsymbol{r})$ is the total number of nucleons to be scatter.

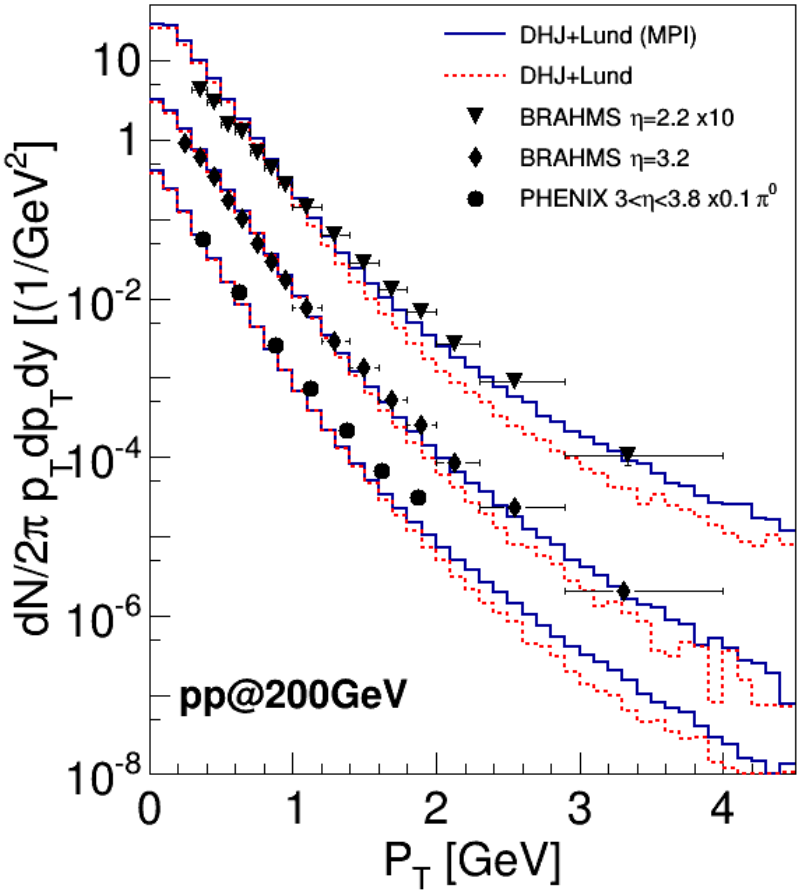


P + P@200GeV

W.Deng,et.al PRD91,014006(2015)



Intrinsic kt is not needed



MCKLN/MCkt way for AA collisions

Sample A and B nucleons according to the Woods-Saxon distribution, and estimate NN collisions using the NN cross section.

Apply kt-factorization formula (KLN, Kharzeev,Levin,Nardi) for each transverse grid

$$\frac{dN}{dyd^2p_\perp} \simeq \frac{1}{p_\perp^2}\int d^2k_\perp \alpha_s(Q)\phi_A(x_1,k_\perp^2)\phi_B(x_2,(p_\perp-k_\perp)^2)$$

Saturation scale: KLN parametrization of the saturation scale on the grid

$$Q^2_{\mathrm{s,nucleus}}(x,\boldsymbol{r}) = 2\mathrm{GeV}^2\left(\frac{T_A(\boldsymbol{r}_\perp)}{1.53}\right)\left(\frac{0.01}{x}\right) \qquad T_A(\boldsymbol{r}_\perp) = \frac{\text{number of nucleons}}{42\,\mathrm{mb}}$$

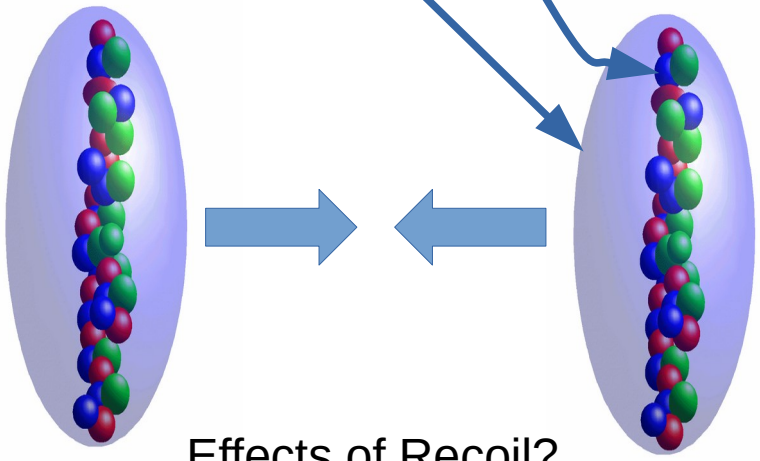
or solve BK (Mckt) with the initial condition:

$$Q^2_{\mathrm{s0,nucleus}}(x,\boldsymbol{r}) = (\text{number of nucleons}) \times Q^2_{s0,proton}$$

http://faculty.baruch.cuny.edu/naturalscience/physics/dumitru/CGC_IC.html

Collision of two CGC

$D_\mu F^{\mu\nu} = J^\nu$



Effects of Recoil?

J^μ : hard parton $x > 0.01$

$F^{\mu\nu}$: clound of small x gluon

solving Boltzmann-Vlasov equation for gluons: dynamics of fields and particles.

$$p^\mu \left(\frac{\partial}{\partial x^\nu} - g f^{abc} A^b_\nu Q^c \frac{\partial}{\partial Q^a} - g Q_a F^a_{\mu\nu} \frac{\partial}{\partial p_\nu} \right) f(x,p,Q) = I_{\rm coll}$$

Use Angantyr for the initial collisions of hard partons or covariant cascade?

How do you convert YM field to particles?

Schenke,NPA092(2019)
M. Greif,PRD103(2021)

$$\dot{\boldsymbol{x}}_i = \boldsymbol{v}_i, \quad \dot{\boldsymbol{p}}_i = g Q_i^a (\boldsymbol{E}^a + \boldsymbol{v}_i \times \boldsymbol{B}^a), \quad \dot{Q}_i = -ig v_i^\mu [A_\mu, Q_i]$$

$I_{\rm coll}$ is a collision term between hard partons.

B. Schenke,PRC79,034903(2009),PRC78,024909(2008)