Black–body limit in central pp/pA collisions at LHC

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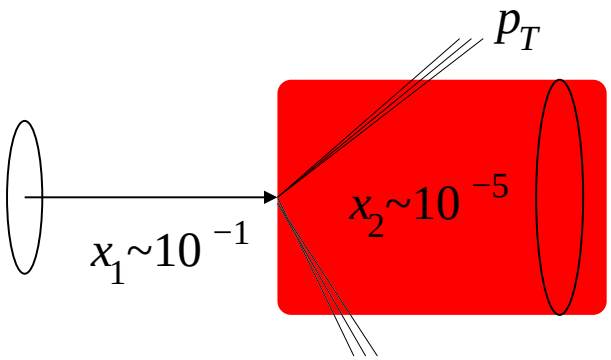


- Interaction of large–x_1 partons with small–x_2 gluons approaches "black–body" (unitarity) limit

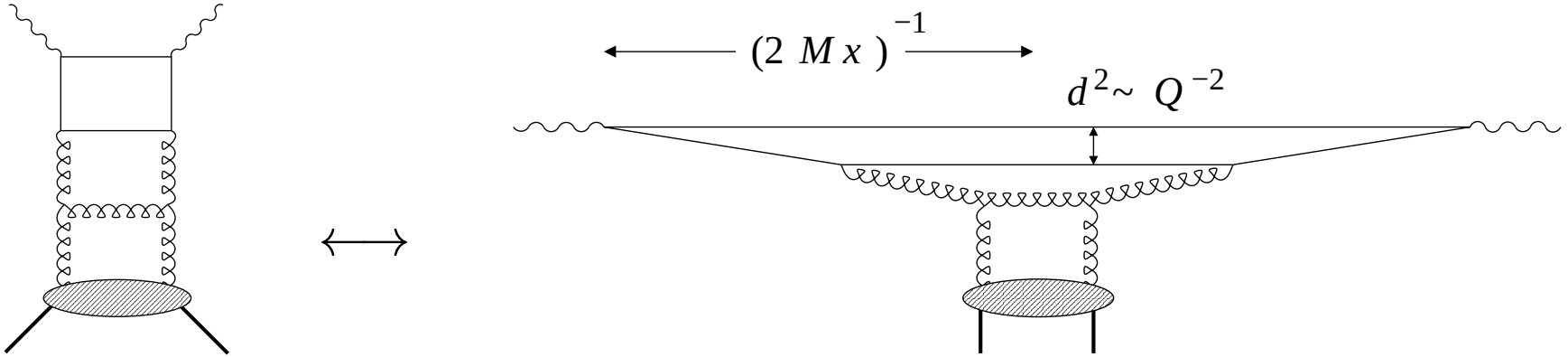
  $\rightarrow$ large $p_\perp \gg \Lambda_{\rm QCD}$

  $\rightarrow$ modified forward hadron production

  $\rightarrow$ affects pp events with new particle production (Higgs)

- Ingredients: HERA data on $G(x,Q^2)$, transverse size
  QCD factorization (DGLAP) $\longleftrightarrow$ dipole picture

- Small–x scattering in target rest frame [Brodsky et al. 94; Frankfurt, Radyushkin, Strikman 96]



$\longleftrightarrow$

LO DGLAP $\longleftrightarrow$ $\alpha_s \ln(Q^2/Q_0^2)$

$$\sigma^{\text{dipole}} = F^2\, d^2\, \alpha_s(Q^2_{\text{eff}})\ \ xG_T(x, Q^2_{\text{eff}})$$

$$Q^2_{\text{eff}} = \text{const} \times d^{-2}$$

- DGLAP evolution: Strong rise of gluon density at small x [HERA data]

  . . . What about unitarity?

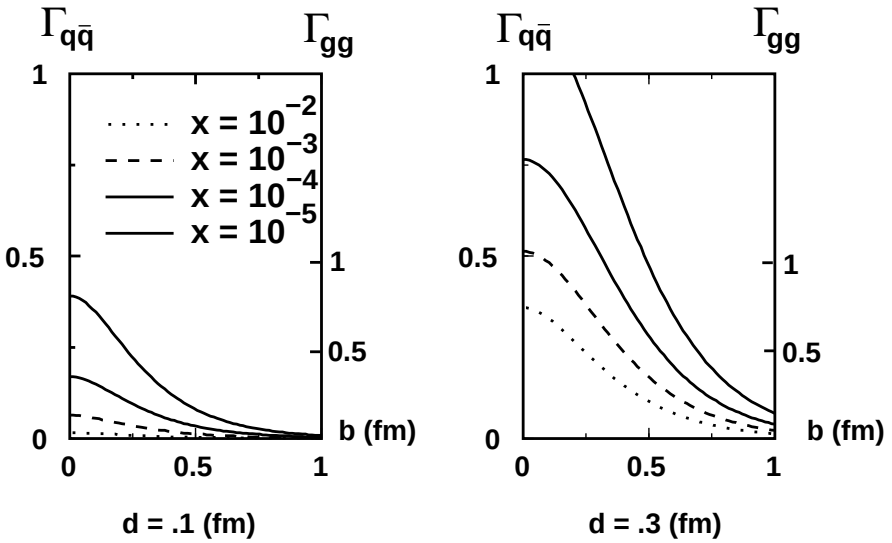
- "Optics" of dipole–hadron scattering

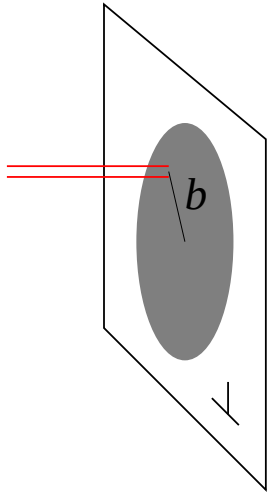
$$A^{\text{dip}}(s,t) \;=\; \frac{i}{s}\int d^2b\; e^{i(\boldsymbol{\Delta}_\perp \boldsymbol{b})}\;\; \Gamma^{\text{dip}}(s,b)$$

elastic scattering amplitude in impact parameter representation $(t = -\boldsymbol{\Delta}_\perp^2)$

$$\Gamma^{\text{dip}} \to 1: \qquad P_{\text{inel}}(b) \;=\; 2\,\text{Re}\,\Gamma^{\text{dip}} - |\Gamma^{\text{dip}}|^2 \;\to\; 1$$

probability of inelast. scattering at impact parameter b





DGLAP approximation predicts "blackening" of the interaction of small dipoles with nucleon (nucleus) at high energies

[Frankfurt, Guzey, Strikman 02; Frankfurt, Strikman CW 03; Rogers, Strikman 04]

- "Particle–based" interpretation

  Leading partons in dipole (large x_1)
  interact with dense medium of gluons in target (small x_2)

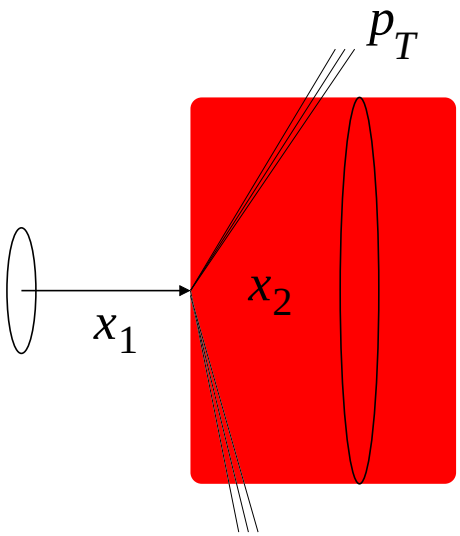
$$x_2 = \frac{4p_\perp^2}{x_1\, s} \qquad \left.\begin{array}{l} x_1 = 0.1 \\ \sqrt{s} = 14 \text{ TeV} \\ p_\perp = 2 \text{ GeV} \end{array}\right\} \quad x_2 = 10^{-6}$$

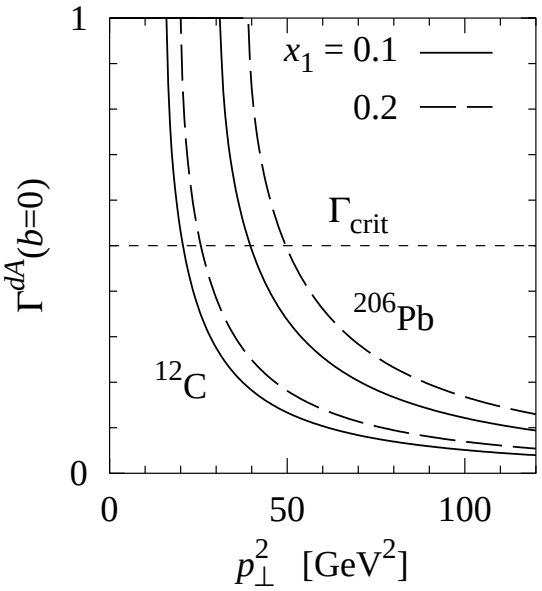
$\rightarrow$ Multiple inelastic interactions (splittings)

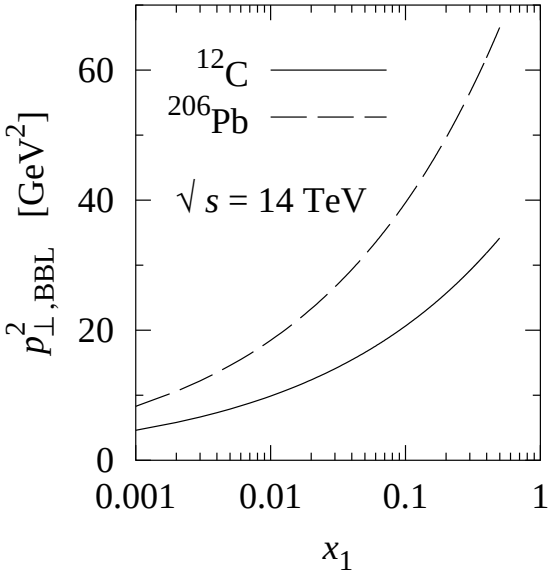
$\rightarrow$ Partons acquire large transverse momenta $p_{\perp,\text{BBL}} \gg \Lambda_{\text{QCD}}$
until interactions cease to be "black"

$\rightarrow$ Increased energy loss

- Black–body limit in central pA collisions at LHC [FSW 05]







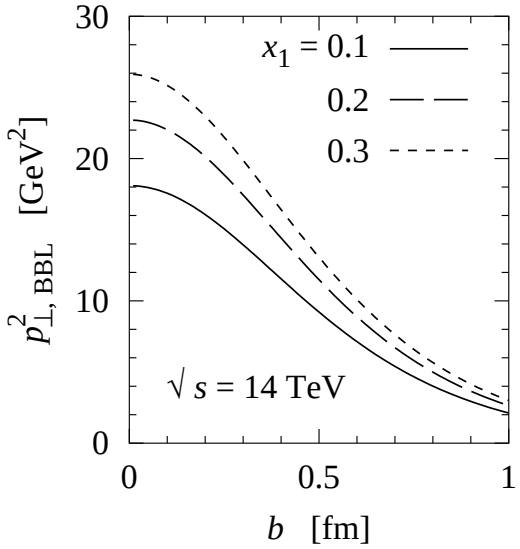
Nuclear PDF parametrization
[Frankfurt, Guzey, Strikman]

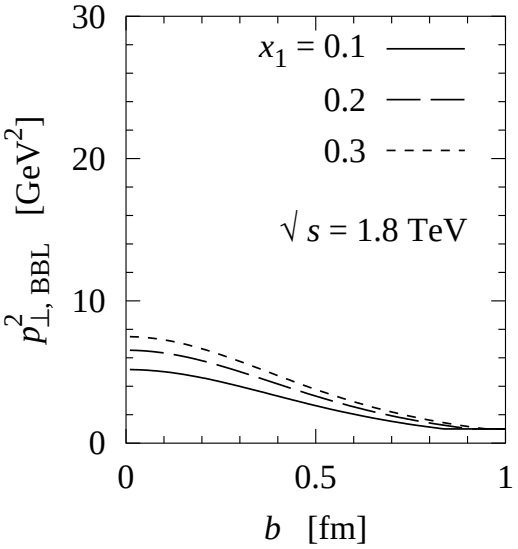
– Treat leading partons as constituents of small dipole $(gg, q\bar{q})$

– Find maximum $p_\perp$ for which $\Gamma^{\text{dip-}A} > \Gamma_{\text{crit}}$

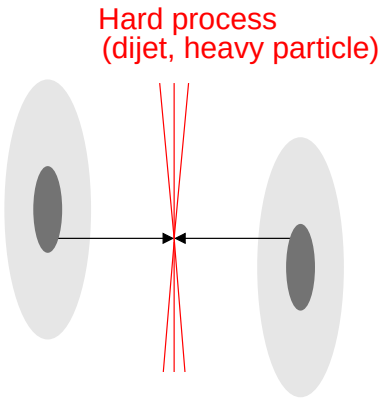
Leading partons acquire $p_\perp^2 \sim$ several 10 GeV^2

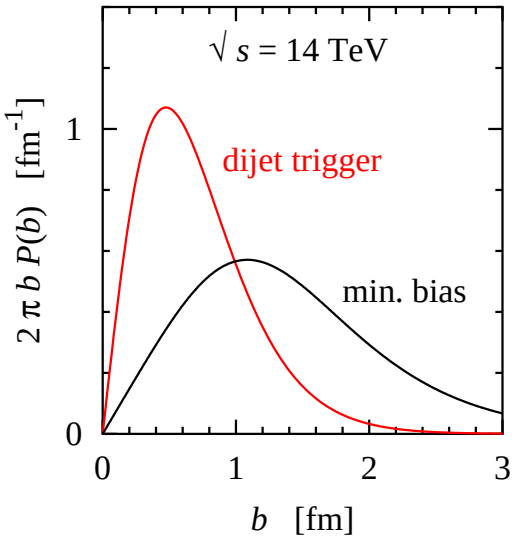
- pp collisions: Impact parameter dependence [FSW 03]



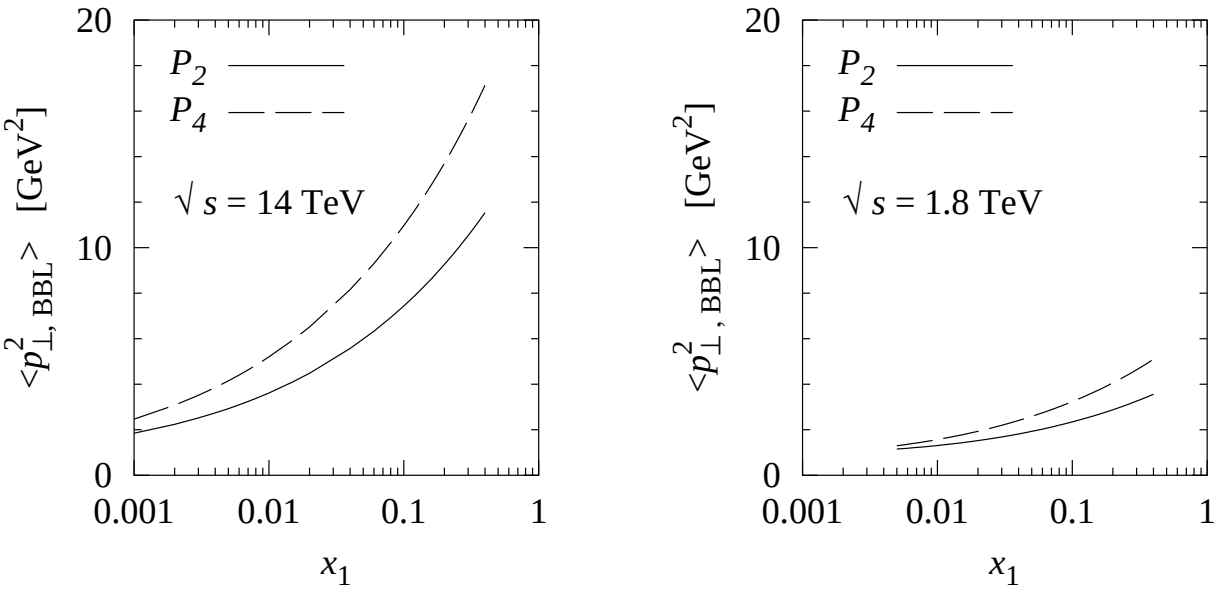


Trigger on
central collisions:
Hard processes
near zero rapidity





- Black–body limit in central pp collisions



  - Marginal effect at Tevatron

  - BBL effects in pp collisions at LHC
    can be studied with dijet trigger [CMS/TOTEM]

  - BBL stronlgly affects pp events with new particle production (Higgs)!

- Implications of BBL for final–state properties
  - Leading partons lose coherence, fragment independently (projectile "shattered")

    $\rightarrow$ Large $p_\perp$ of leading hadrons ($\gg 1\,\mathrm{GeV}^2$)

    $\rightarrow$ Suppression of leading hadrons (esp. nucleons)

$$\frac{1}{N}\frac{dN^h}{dz} \approx \sum_{a=q,g} \int dx \;\; x f_a(x, Q^2_{\text{eff}}) \;\; D^h_a(z/x, Q^2_{\text{eff}})$$

$Q^2_{\text{eff}} = 4\, p^2_{\perp,\text{BBL}}$ [Dumitru, Gerland, Strikman 03]

  - Significant increase of energy loss

  - Central rapidities: Increase of soft particle multiplicities due to increased production of color charge in multiple inelastic collisions

Strong modifications of hadron production
. . . should be incorporated in MC event generators!

- Other implications of BBL

  – Affects interaction of high–energy cosmic–ray particles (near GZK–cutoff) with atmospheric nuclei [Drescher, Dumitru, Strikman 04]

  – Explains observed "blackness" of $pp/\bar{p}p$ elastic scattering amplitude for small impact parameters at Tevatron energies [Frankfurt, Strikman, Zhalov 04]

- Summary

  Black–body limit: New small–x phenomenon, expected to be standard feature of central pA/pp collisions at LHC!