Forward quark scattering at LHC

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- Suppression of forward scattering on a dense target
- Forward scattering on nucleus in colliders and air showers
  application to air showers
- Suppression of forward scattering in pp at LHC
  use as centrality trigger

Black Body Limit

When probing large gluon densities at small x, interactions reach the Black Disk Limit, where interaction probability is close to 1.
In this field partons get a high pt-momentum kick

We model qA scattering
within color glass condensate approach
(McLerran Venugopolan-model)

$$\frac{d\sigma^{el}}{d^2 b} = \left(1 - e^{-Q_s^2/4\pi\Lambda_{QCD}^2}\right)^2$$

$$\frac{d\sigma^{tot}}{d^2 b} = 2\left(1 - e^{-Q_s^2/4\pi\Lambda_{QCD}^2}\right)$$

Dumitru, Jalilian-Marian
PRL 89 (2002)

→ Suppression of soft physics

Gerland, Dumitru, Strikman
PRL 90 (2003)

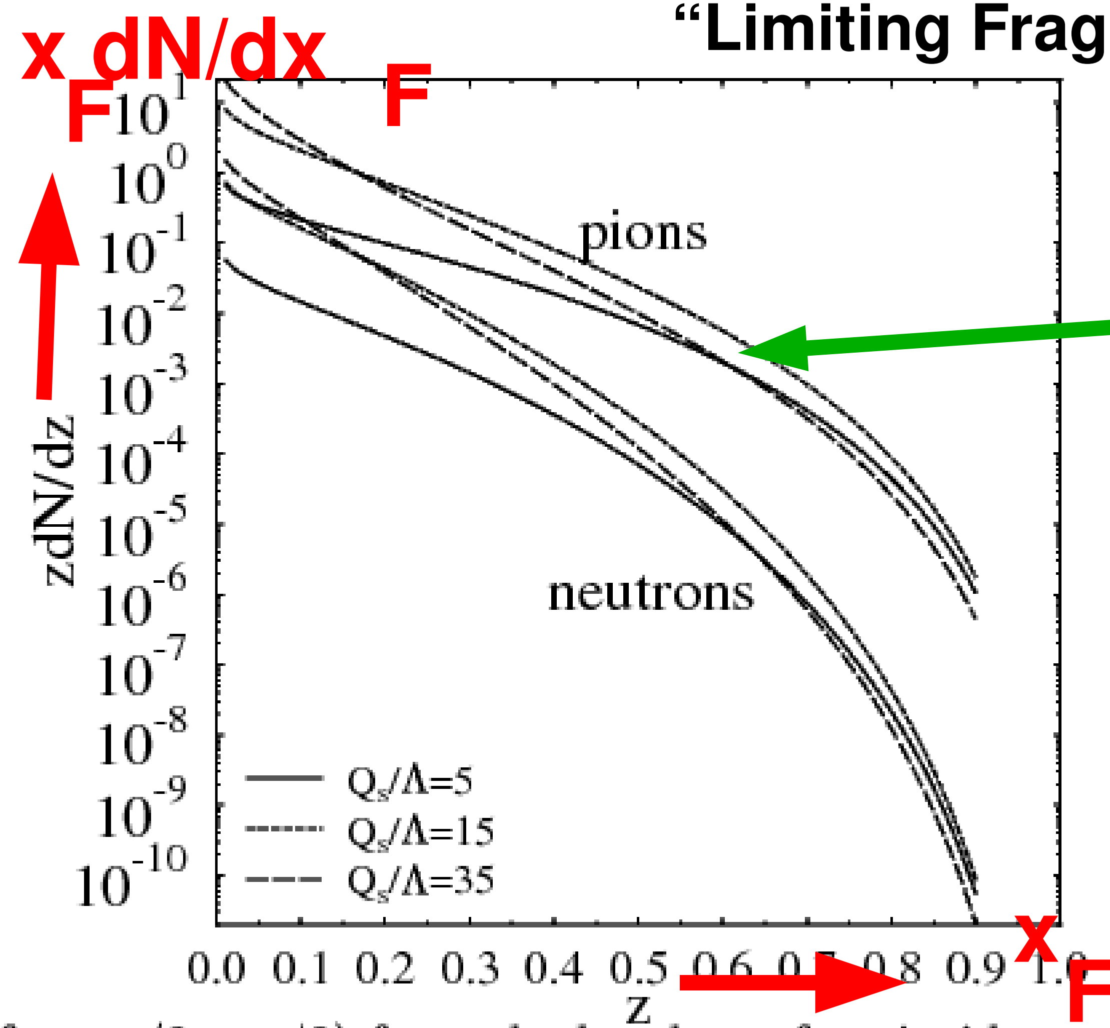
→ Suppression of forward scattering
(no leading particle)

We neglect energy loss of scattered partons

If one assumes indep. fragm. of scattered partons :

$$x_F \frac{d\sigma^{pA\to hX}}{dx_F\, d^2k_t\, d^2b} = \underbrace{\int_{x_F}^{1} dx\, \frac{x}{x_F}\, f_{q/p}(x, Q_s^2)\, D_{h/q}(\frac{x_F}{x}, Q_s^2)}\; \frac{d\sigma^{qA}}{d^2q_t\, d^2b}$$

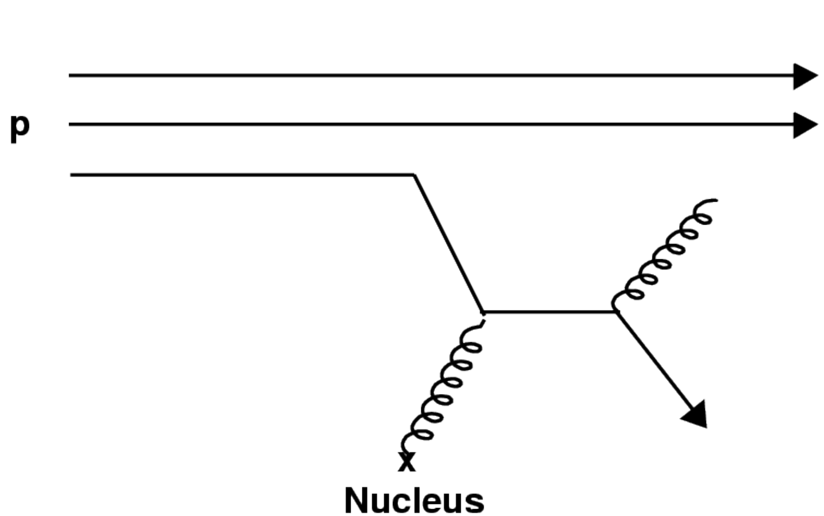
“Limiting Fragmentation” curve in BBL



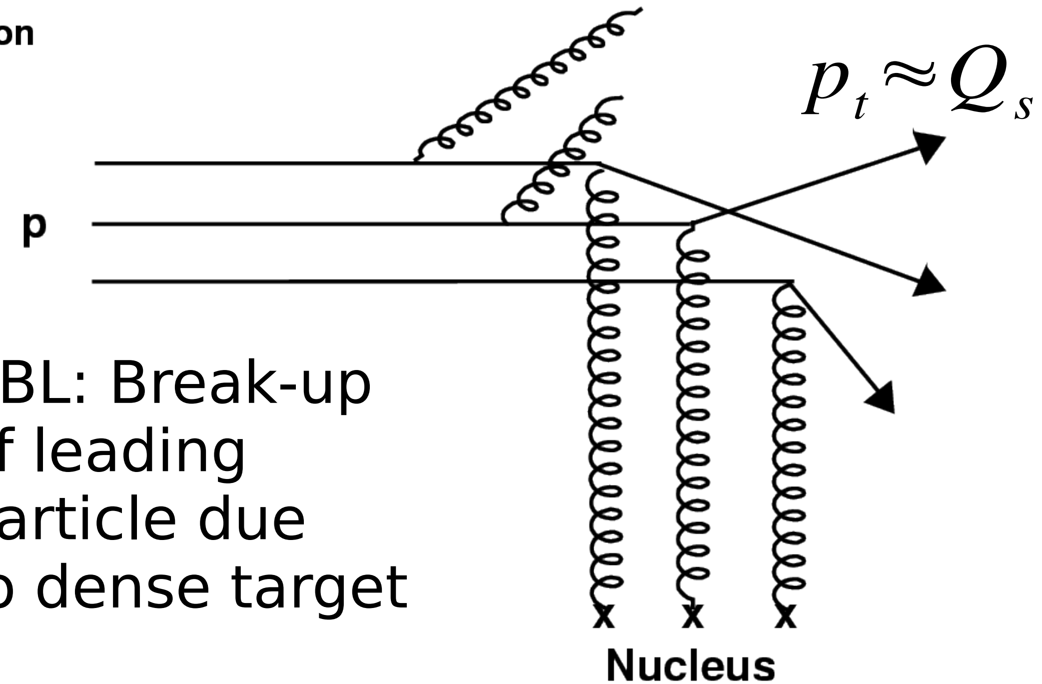
Long. distribution steepens

Gerland, A.D., Strikman, PRL 90 (2003)
see also
Frankfurt, Guzey, McDermott, Strikman: PRL 87 (2001)

BBL Monte Carlo for use in air shower calculations



Usual approach
with leading particle



BBL: Break-up
of leading
particle due
to dense target

Valence quarks,
gluon distribution:

$$P_i(x) = f_i(Q_s^2(x), x)$$

$$\langle p_t^2 \rangle \approx Q_s^2(x)$$

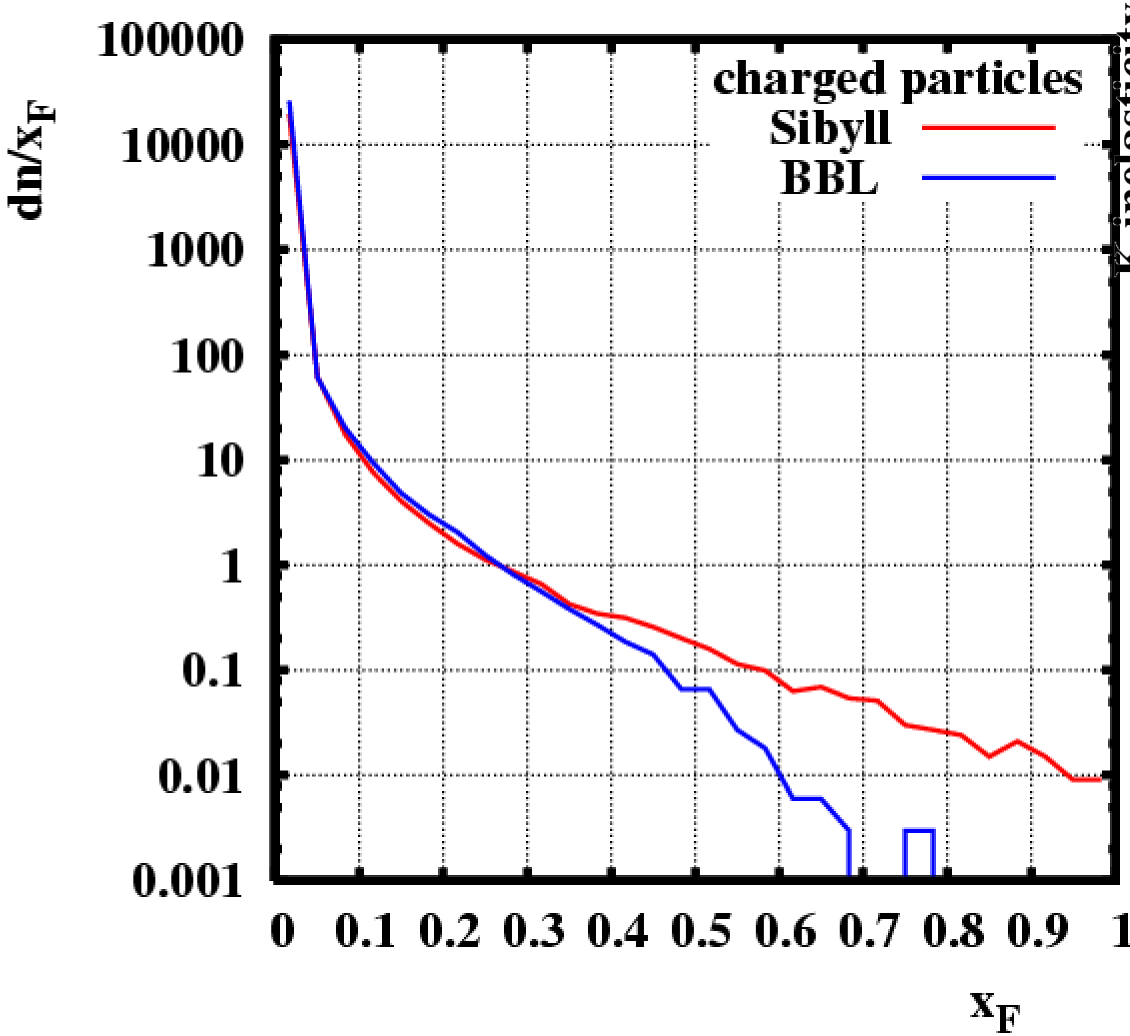
valence quarks: GRV94 PDF (xf(x) dominant at high x)

gluons: $$x\,g(x, q_t^2) \propto \frac{1}{\alpha_s} \min(q_t^2, Q_s^2(x))(1-x)^4$$

(Kharzeev, Levin, Nardi, NPA 2004)

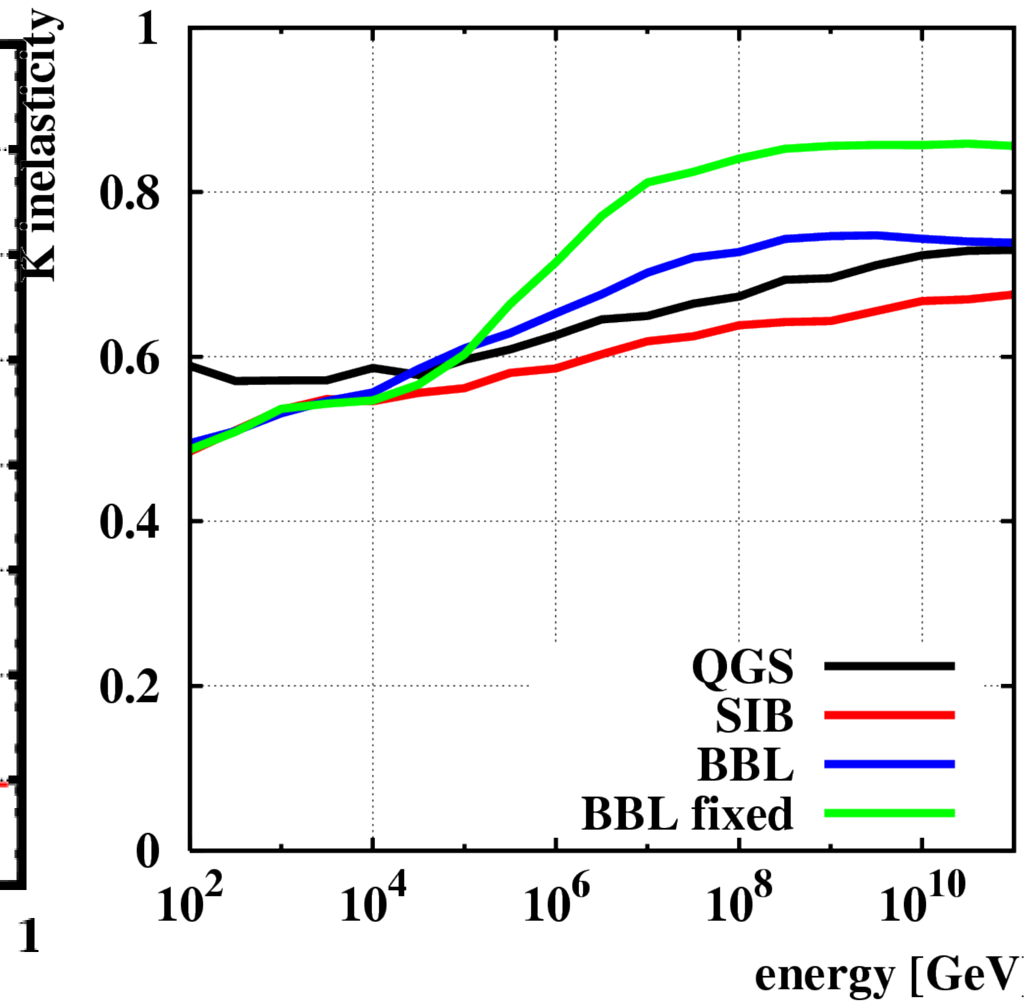
Forward scattering suppressed due to independent fragmentation of leading quarks

Central p-N scattering



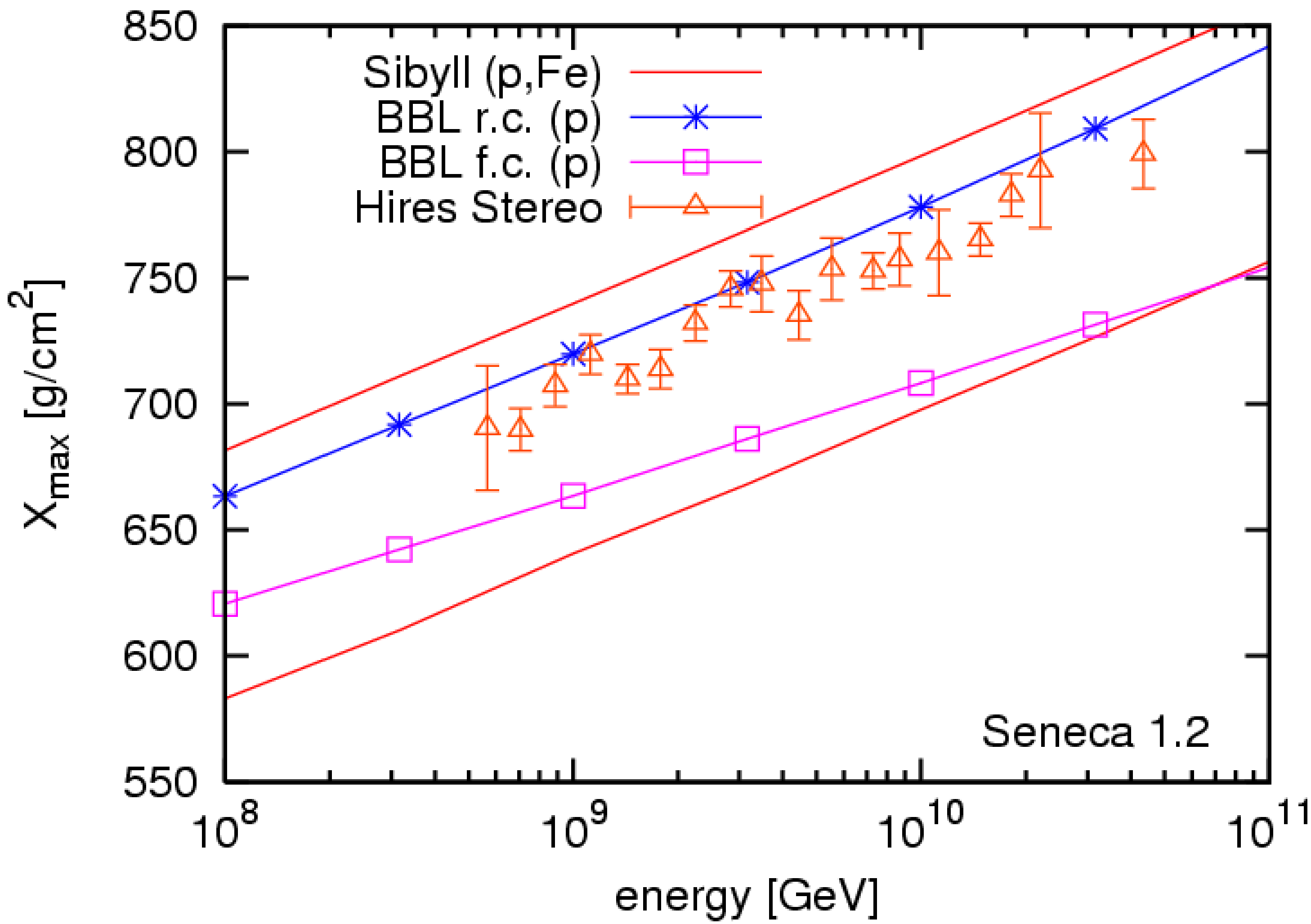
Min. bias p-N

K=1-<x_F of fastest particle>



Xmax of air showers

Phys.Rev.Lett. 94:231801,2005



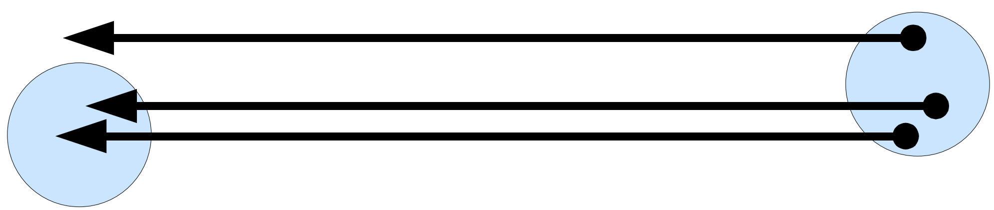
=> Xmax Sensitive to forward scattering

Forward quark scattering for proton-proton at LHC

For central p-p collisions density in forward region is high enough to get same effect as in pA scattering.

Gluon densities are comparable to heavy ion collision

Valence quarks: high x_F



Small x probed in target

$$x_T = \frac{Q^2}{x_P s} \approx \frac{2}{0.1 \cdot 14000^2} \approx 10^{-7}$$

We construct a very simple model to show the qualitative features of this approach

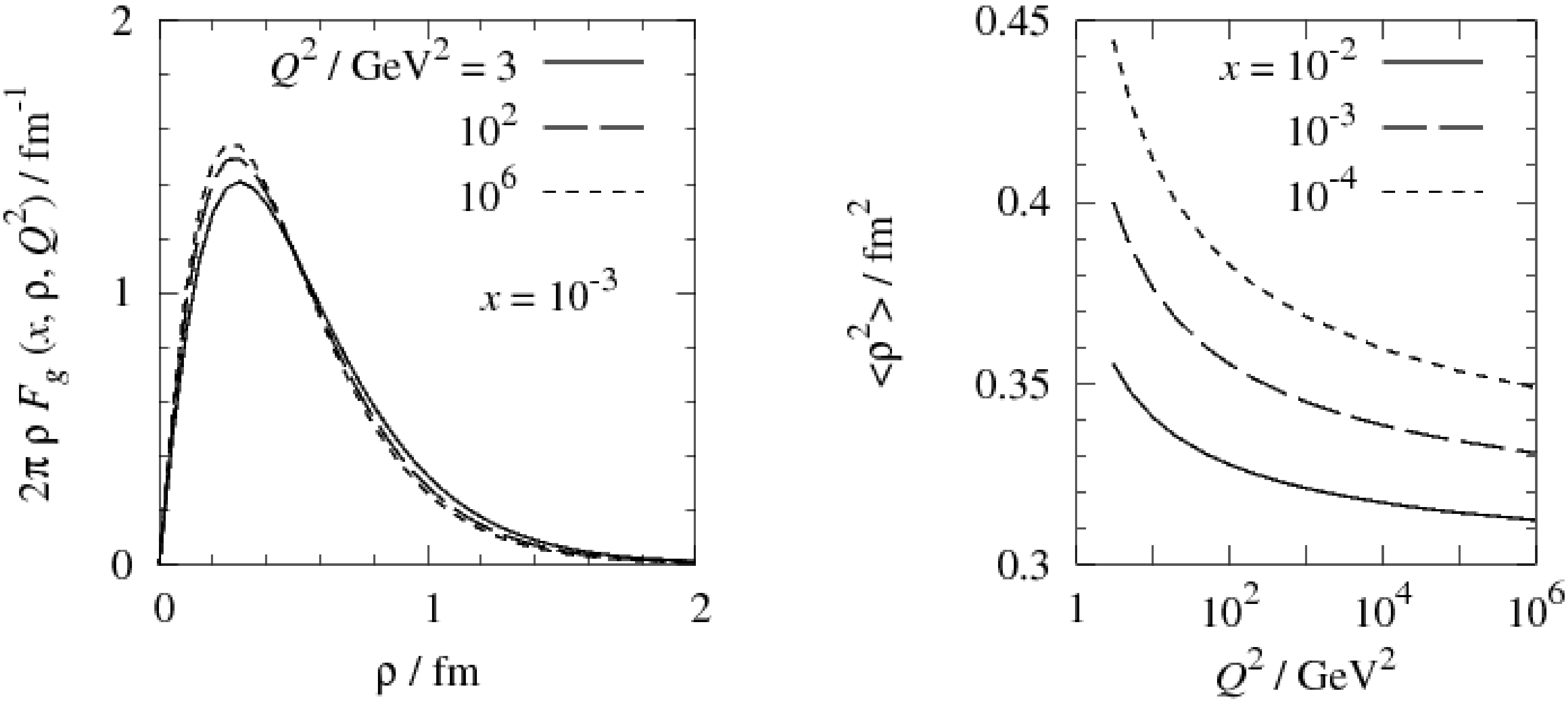
Generalized PD

Density in target and projectile modeled by two-gluon form factor gives spatial distribution of gluons in transverse plane

$$g(x,t,Q^2)=g(x,Q^2)F_g(x_P,t,Q_s^2)$$

$$F_g(x,\rho)=\frac{m_g^2}{2\pi}\left(\frac{m_g\rho}{2}\right)K_1(m_g\rho)$$

Frankfurt, Strikman, Weiss
Phys.Rev.D69:114010,2004



Determine q_t for each scattered quark

$$g(x, r_P, Q^2) = g(x_P, Q^2)\, F_g(x_P, r_P, Q_s^2)$$ GPD

$$Q_s^2(x_T, r_T) = Q_{s,0}^2 \left(\frac{x_T}{x_0}\right)^{\lambda} F_g(r_T, Q_s^2, x_T)$$ Solve with iteration

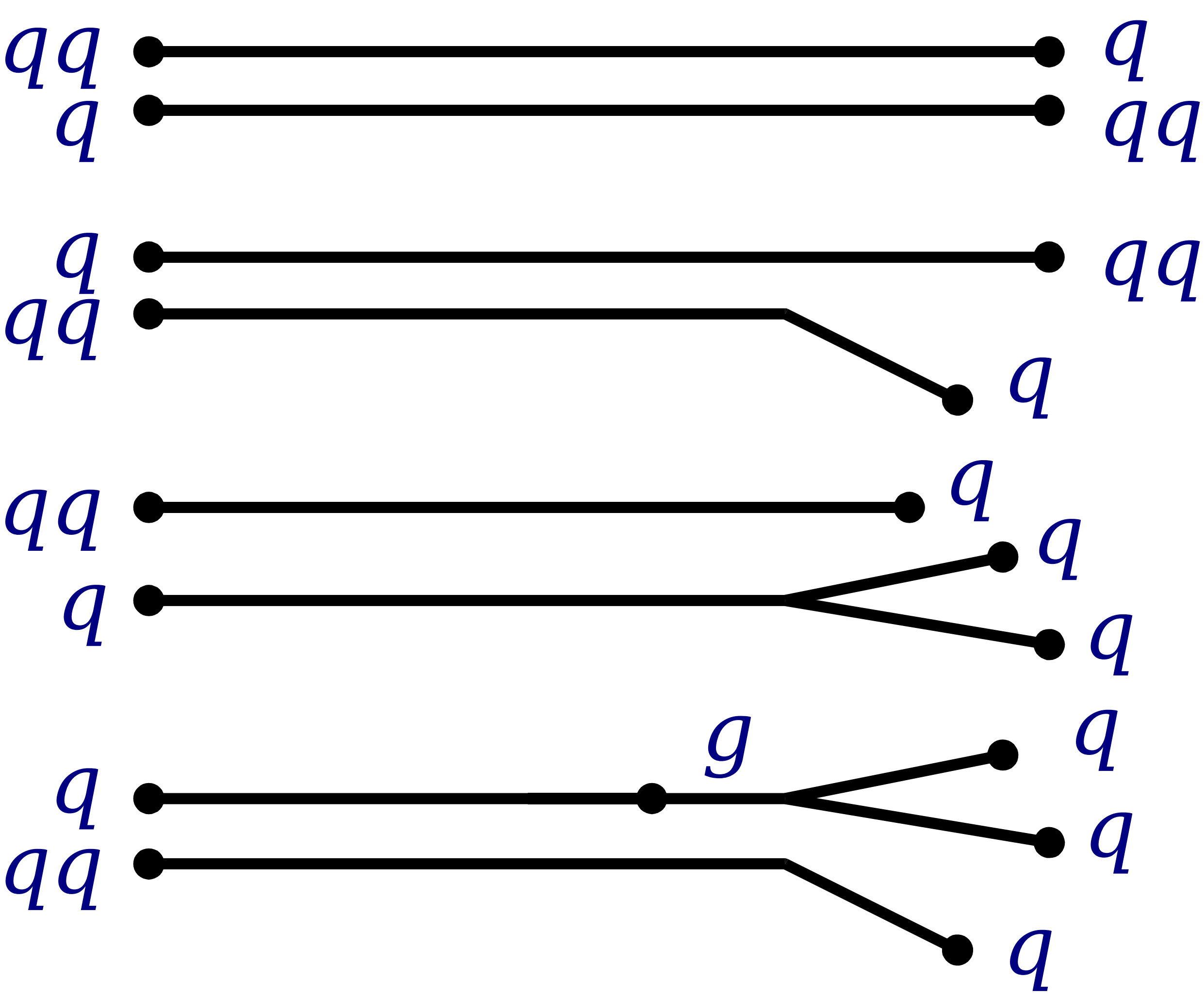
$$\frac{d\sigma}{d^2 q_t} \sim \frac{1}{Q_s^2 \log(Q_s/\Lambda)} \exp\left(\frac{-\pi q_t^2}{Q_s^2 \log(Q_s/\Lambda)}\right)$$

Condition for large q_t-kick

$Q_s > 1$ GeV and $q_t > 0.75$ GeV

String modeling for n quarks scattered

n=0 generic inelastic



n=0 $\frac{1}{\sqrt{x_q}}(1-x_q)^{\frac{3}{2}}$

n=1

n=2

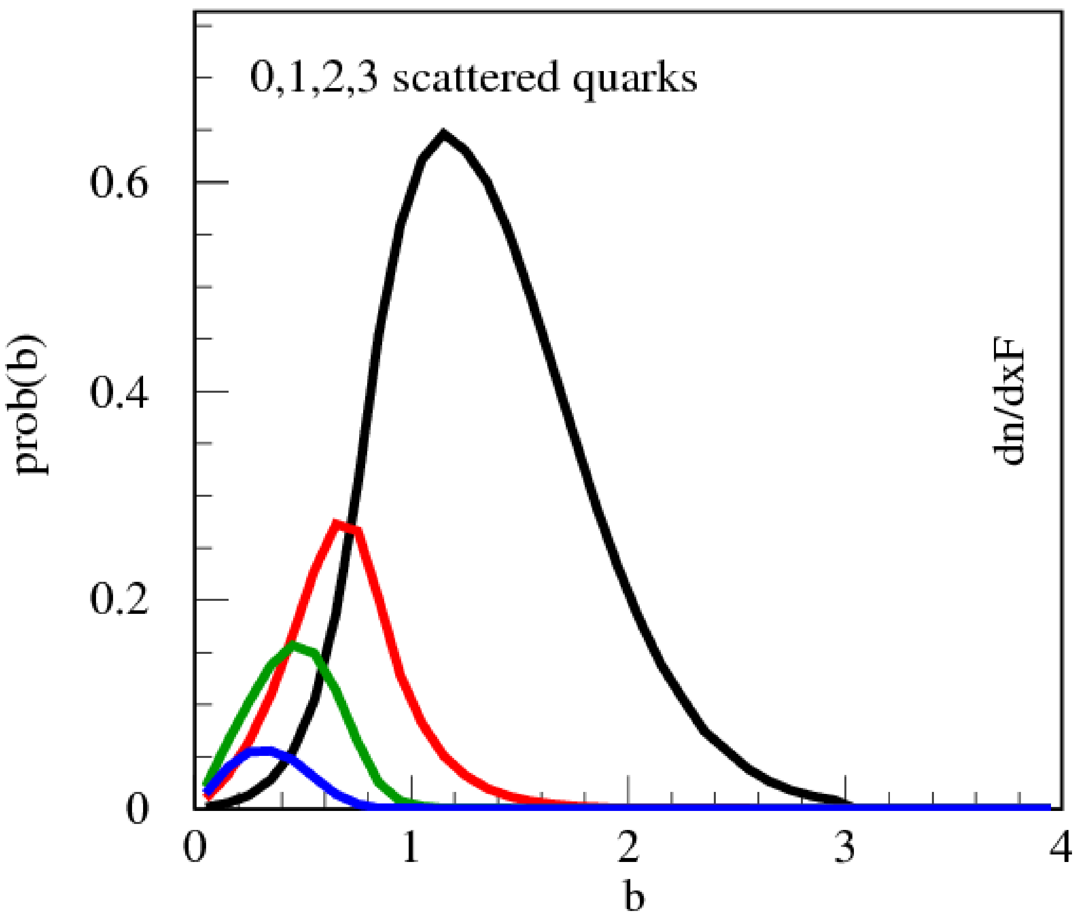
n=3

Use of Junction for n=2,3

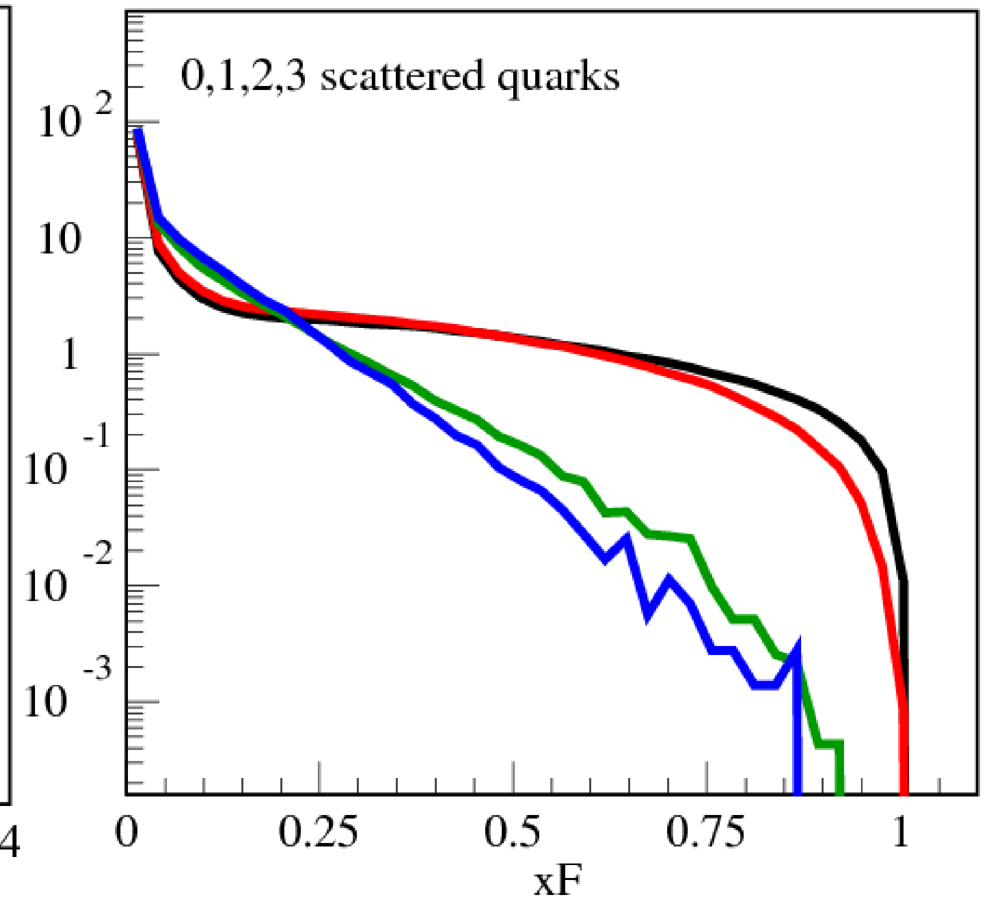
valence gluon for remaining Energy

Strings fragment via Lund model (Pythia)

Impact parameter distribution of scattered quarks



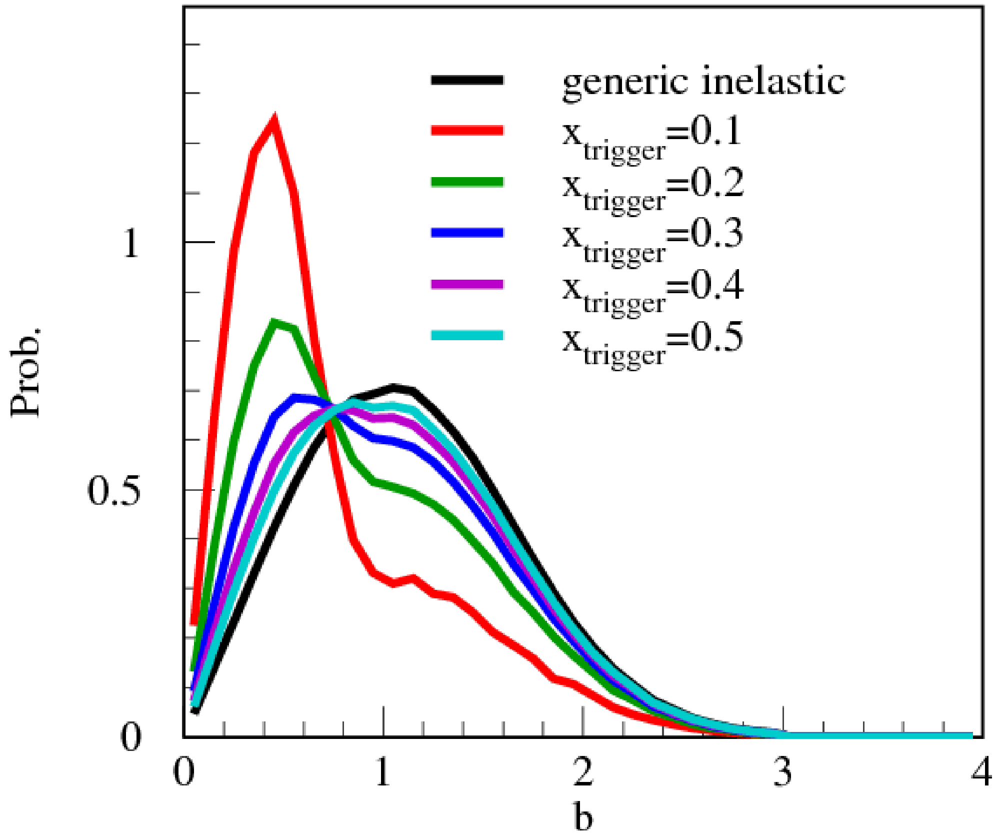
Feynman x of baryons



Our simple model is a full Monte Carlo model
forward scattering is strongly suppressed for n=2,3

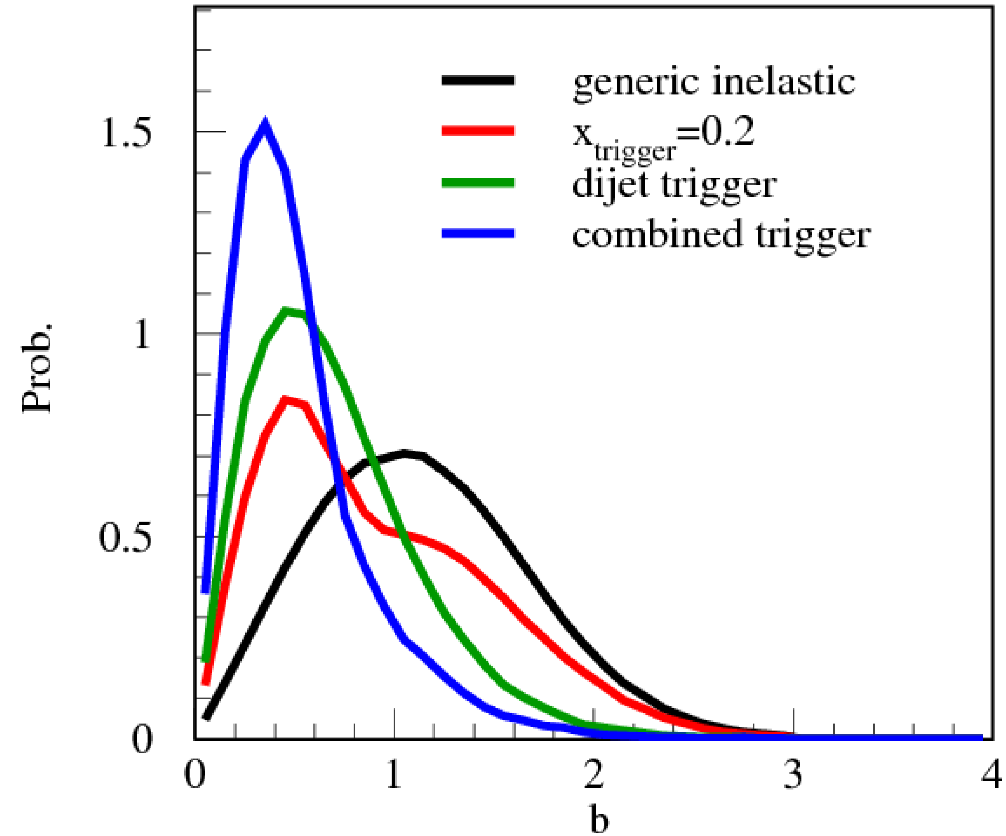
Use suppression of forward scattering as a centrality trigger at LHC

Trigger:
no baryon with $x_F > x_{Trigger}$



One-sided trigger = two sided neutron trigger

Combine with
dijet-centrality trigger:



New physics appears in central scattering (close to dijet trigger)

Conclusions

- Suppression of forward scattering should be visible at LHC in proton-proton scattering due to
  - high CMS energy
  - forward scattering

- Quarks scatter off dense target (small x) and fragment independently

- possible use of this information:
  - centrality trigger for pp collisions
  - Possibility to study pp collisions at high gluon densities
  - Study QCD background for central collisions where new particle production will show up