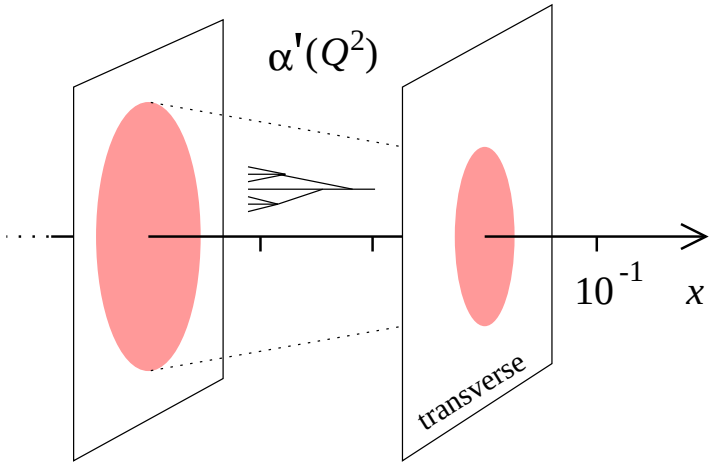
Transverse nucleon structure and Regge–like dynamics at small x

C. Weiss (JLab), Transverse Spin Phenomena — GaryFest, JLab, 27–28 Oct 10



Partonic structure, GPDs
DGLAP evolution

↕

Regge–like concepts
Effective slope α'

- Transverse size in soft high–energy scattering

  Regge slope α' and growth of R^2

- Transverse spatial distribution of gluons

  Hard exclusive processes $\gamma^* N \to V + N$

  Gluonic radius from present/future data
  HERA, COMPASS, JLab12, EIC → Talk Ent

  DGLAP evolution and $\alpha'(Q^2)$

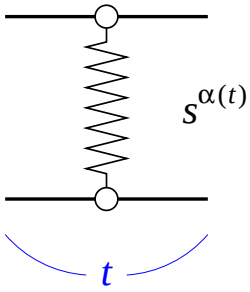
- Applications to pp@LHC

  Two–scale picture $R^2(\text{soft}) \gg R^2(\text{hard})$

  Hard processes as centrality trigger

  Event structure and correlations

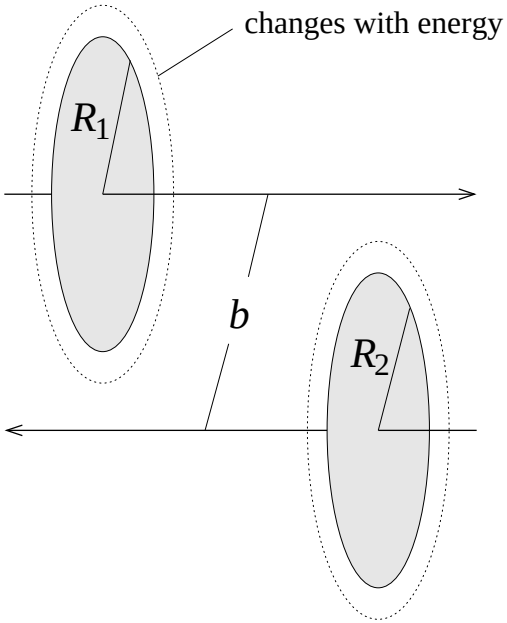
Transverse size: Soft high–energy scattering



- Transverse sizes increase with energy

  Regge exchange $d\sigma/dt \sim e^{2\alpha' \log s \times t}$

  Effective size of interacting systems
  $R^2(s) = R^2(s_0) + \alpha' \log(s/s_0)$



- Model–independent: Impact parameter representation of elastic amplitude $\Gamma(s, b)$

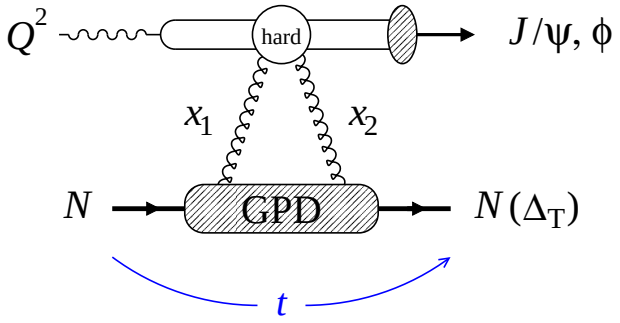
  Islam, Luddy, Prokudin 02; Bourrely, Soffer 70's

$$\langle b^2 \rangle_{pp,\mathrm{inel}} = 1.4\,\mathrm{fm}^2 \quad \text{at} \quad \sqrt{s} = 500\,\mathrm{GeV}$$
$$2.7\,\mathrm{fm}^2 \qquad\qquad 14000\,\mathrm{GeV}$$

- What about hard processes?
  QCD, partonic structure, . . .

α' describes growth of transverse area

Transverse gluon distribution: Hard processes

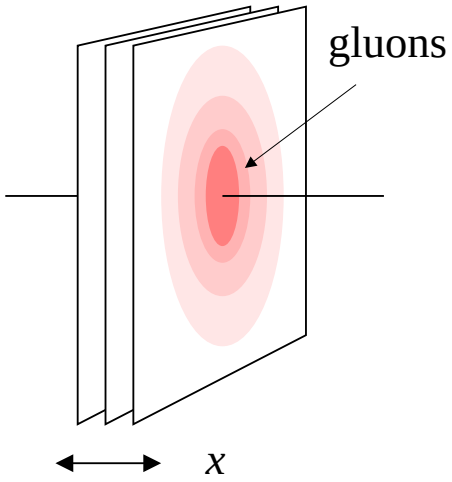


- $Q^2, M^2 \gg$ hadronic scale: Meson produced in small–size configuration

  QCD factorization theorem $Q^2_{\rm eff} \gg |t|$
  Collins, Frankfurt, Strikman 96

  GPDs: Gluonic form factor of nucleon, universal, process–independent Ji 96, Radyushkin 96

  Operator definition $\langle N' |\, \text{twist-2} \,| N \rangle$, renormalization, non-pert. methods



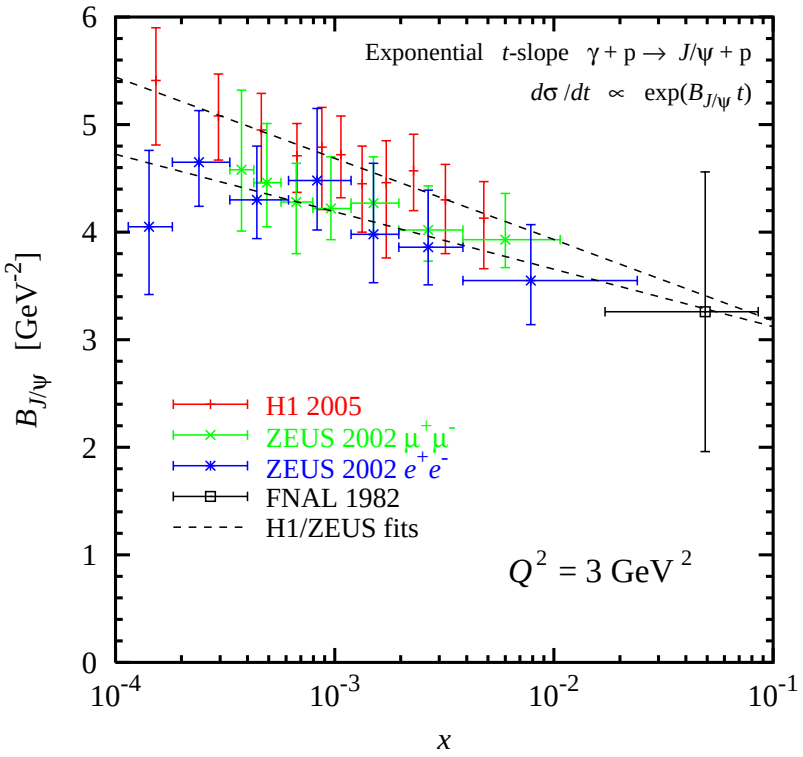
- Transverse spatial distribution of gluons

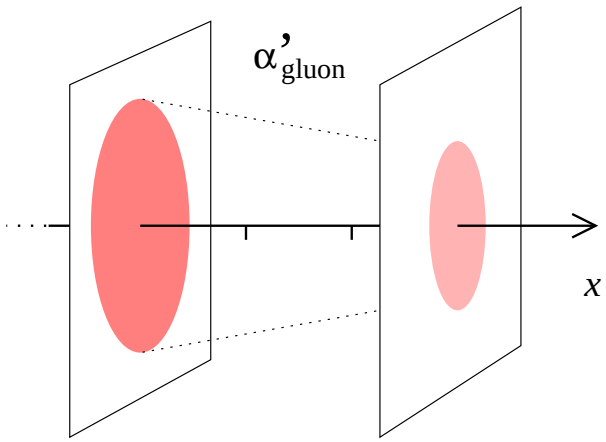
  Fourier $\boldsymbol{\Delta}_T \to b$ of GPD$(x_1 = x_2)$

  Tomographic images of nucleon at fixed x, changes with x and Q^2!

- Large x: Quark GPDs, polarization, longitudinal momentum transfer $x_1 \neq x_2$
  JLab12: DVCS, meson production

Transverse gluon distribution: Data





- Transverse spatial distribution from exclusive J/ψ (also ϕ, ρ)

  Reaction mechanism, QCD–based description tested at HERA

  Transverse distribution from *relative* Δ_T dependence

- Interesting observations

  Gluonic transverse radius $\langle b^2 \rangle_g$ much smaller than soft nucleon size

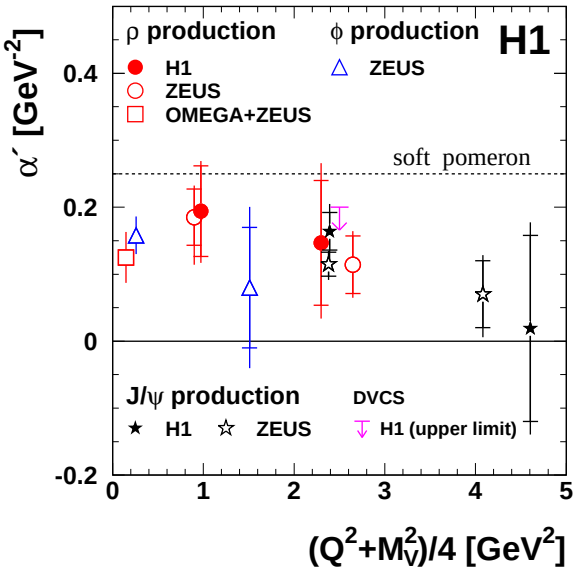
  Regge–like growth with slope $\alpha'_g < \alpha'_{\rm soft} = 0.25\,{\rm GeV}^{-2}$

- Q^2 dependence: DGLAP evolution
  Frankfurt, Strikman, CW, 04

  Partons decay locally in transverse space

  Initial partons at $x_0 > x$ sit at smaller transverse distances

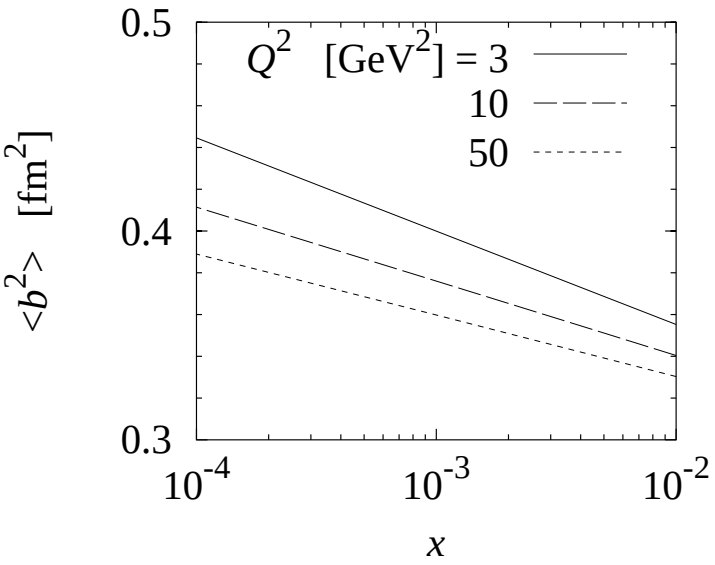
Transverse gluon distribution: DGLAP evolution

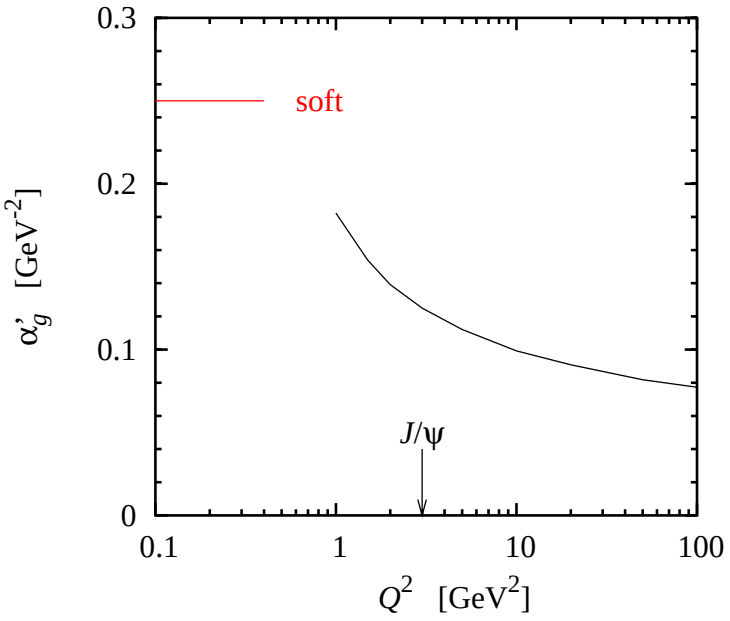


- Transverse distribution of partons changes through DGLAP evolution

  Transverse size decreases with increasing Q^2

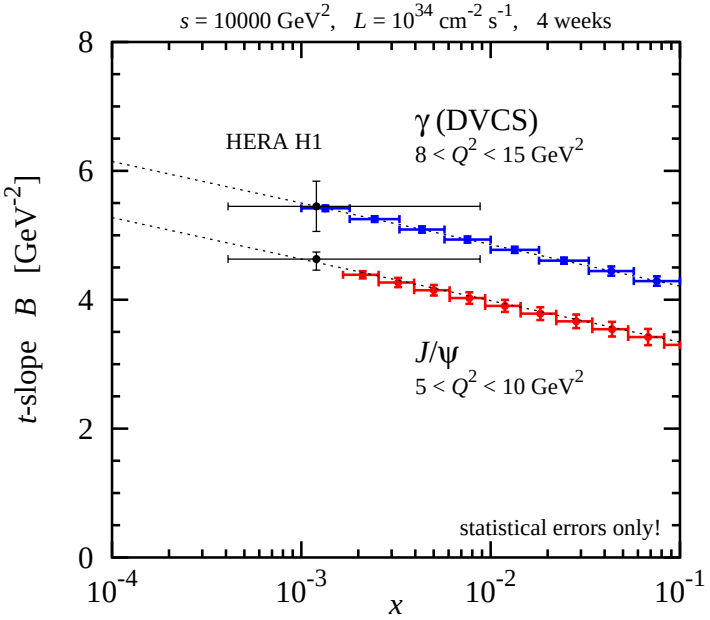
  Effective Regge slope α'_g decreases with Q^2

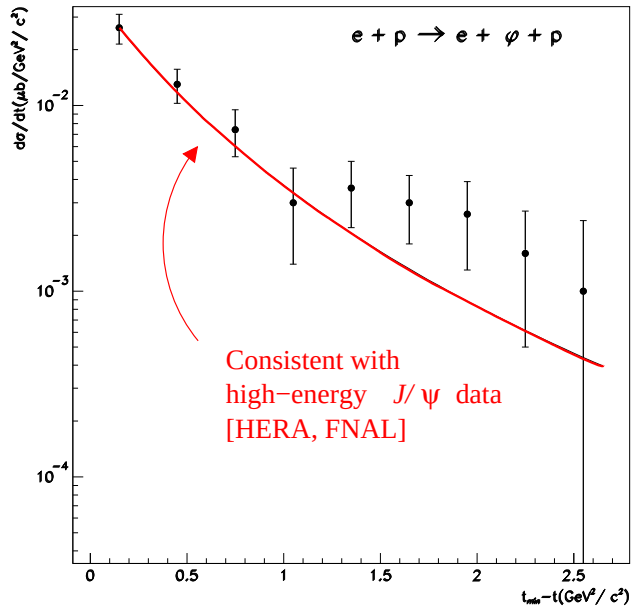




Frankfurt, Strikman, CW, PRD 69, 114010 (2004)

Transverse gluon distribution: Future facilities





- COMPASS: Exclusive $J/\psi, \gamma(\mathrm{DVCS})$

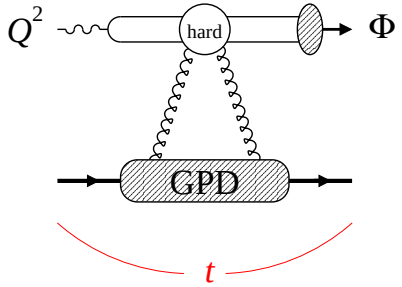
  Unexplored region $10^{-2} < x < 10^{-1}$

- EIC: Gluon imaging of nucleon/nuclei

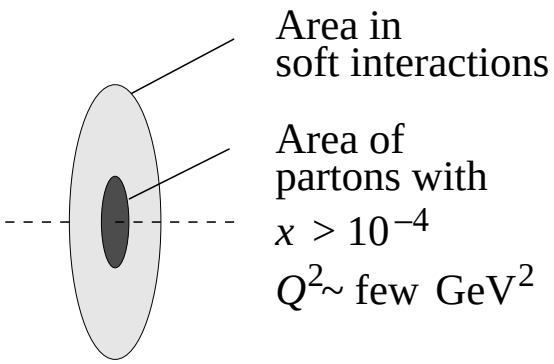
  High luminosity enables differential measurements

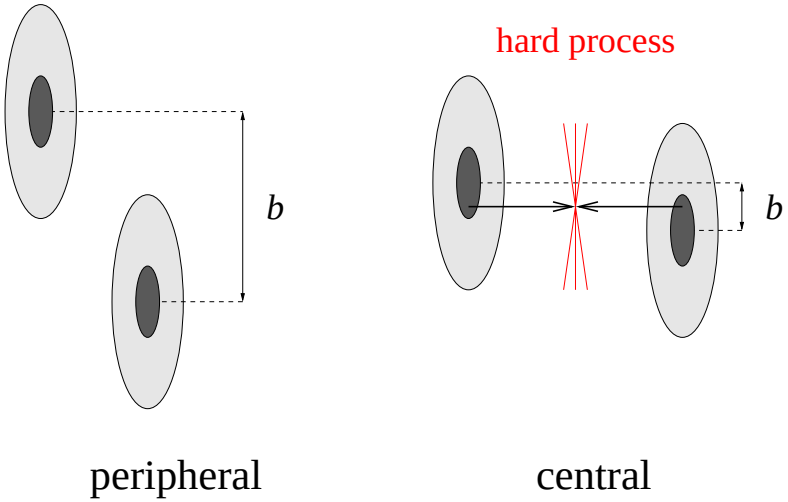
- JLab 12 GeV: Transverse distribution of valence gluons with exclusive ϕ

  t–dependence measured at 6 GeV consistent with extrapolation of small–x data



Transverse structure: Two–scale picture





- Two–scale picture

  $$R^2(\text{partons } x > 10^{-4}) \ll R^2(\text{soft})$$

- Two classes of pp collisions FSW 04

"peripheral"	account for most of inelastic cross section
"central"	high probability of hard process

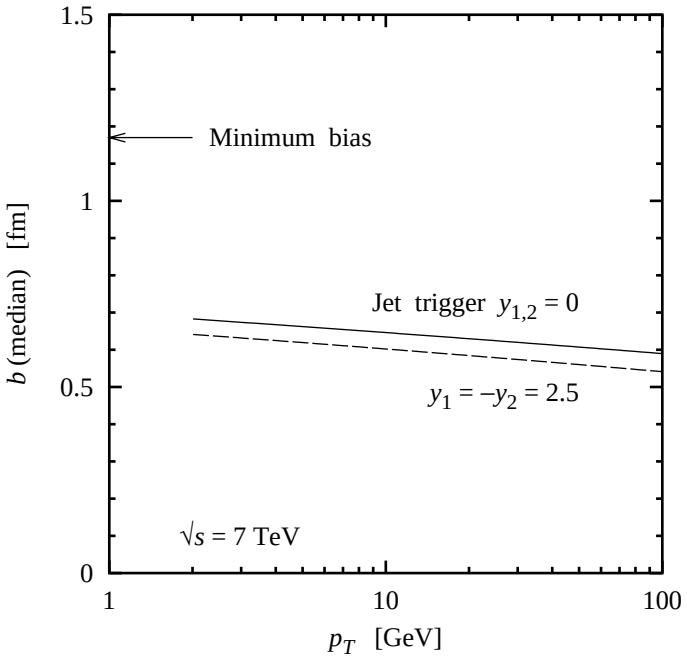
- Hard processes "select" central events

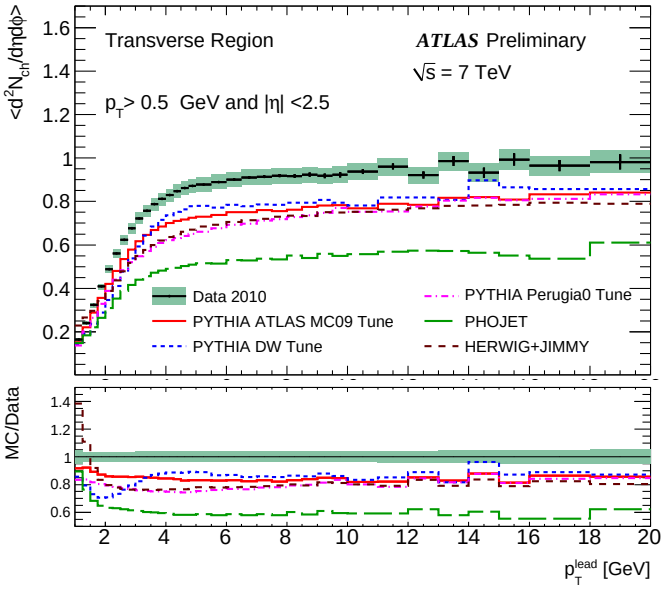
  Spectator interactions, underlying event very different from min. bias

  Not included in present MC generators! Affects new particle search $gg \to H$, etc.

  Trigger on central pp collisions

Transverse structure: pp@LHC





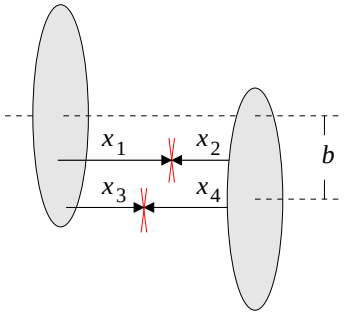
- New insights into reaction dynamics
  FSW, arXiv:1009.2559

  Effective impact parameters
  as function of trigger p_T

  Diagnostic: Transverse multiplicity in dijet events increases with centrality

- Multiple hard processes

  Access parton–parton correlations



- Exclusive diffraction $pp \to p + H + p$, rapidity gap survival FHSW 06

Summary

- Transverse distribution of gluons at $Q^2 \sim$ few GeV^2 measureable in hard exclusive processes $(J/\psi, \phi, \rho^0)$

  Much known already, more data expected

- Nucleon's gluonic radius grows slowly with decreasing x: $\alpha'_g(Q^2) \ll \alpha'_{\rm soft}$

  Slope Q^2–dependent, not universal. . . no "pomeron" for hard processes!

- Two–scale picture of transverse structure essential tool for modeling pp collisions with hard processes