Gap survival and the transverse structure of the nucleon

Ch. Weiss (Jefferson Lab), TeV4LHC Workshop, Feb. 3–5, 2005

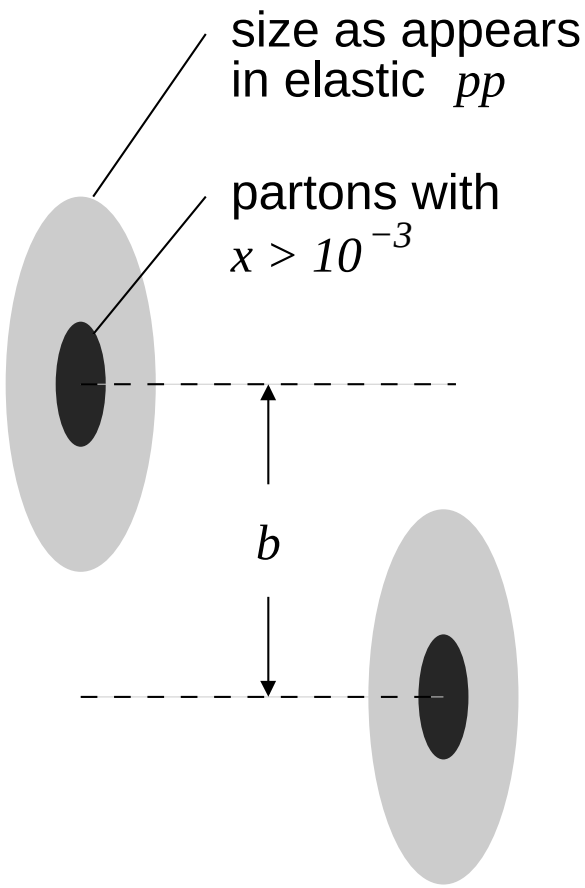
- Two–scale picture of transverse structure

$$R^2(\text{hard partons } x \geq 10^{-3}) \;\ll\; R^2(\text{soft interactions})$$

- Diffractive Higgs production $pp \to p + H + p$

$\to$ Understand interplay of hard and soft interactions
$\to$ Estimate gap survival probability

- Two–scale picture of transverse structure [Frankfurt, Strikman, CW 03]

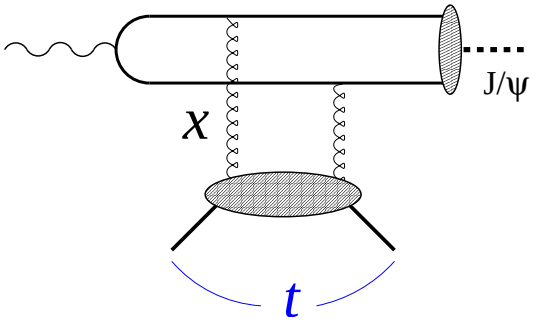


$$R^2(\text{partons } x \geq 10^{-3}) \ll R^2(\text{elastic})$$

– significant difference at Tevatron

– becomes more pronounced at LHC

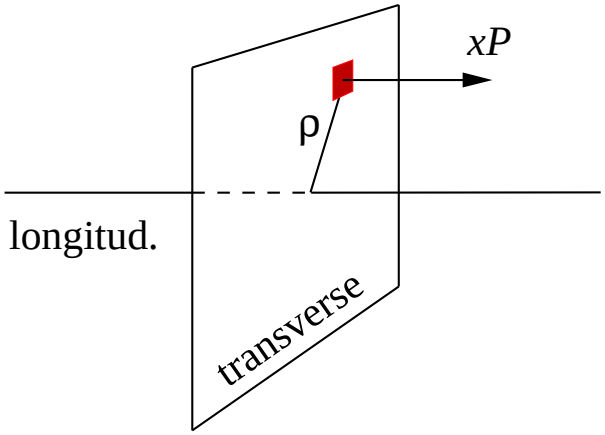
- Transverse distribution of hard partons



$$g(x,t) \quad = \quad \int d^2\rho \; e^{-i\vec{\Delta}_\perp \cdot \vec{\rho}} \; g(x,\rho)$$

form factor of gluons with longitudinal momentum xP

transverse spatial distribution

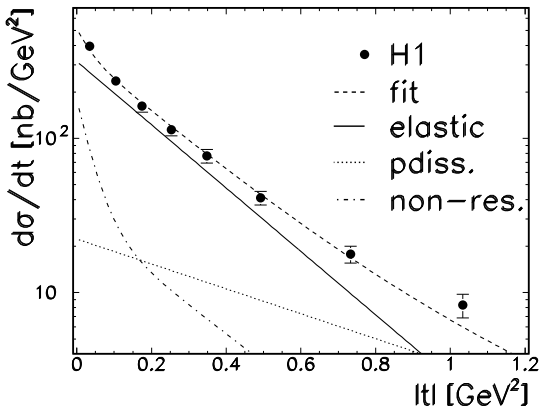


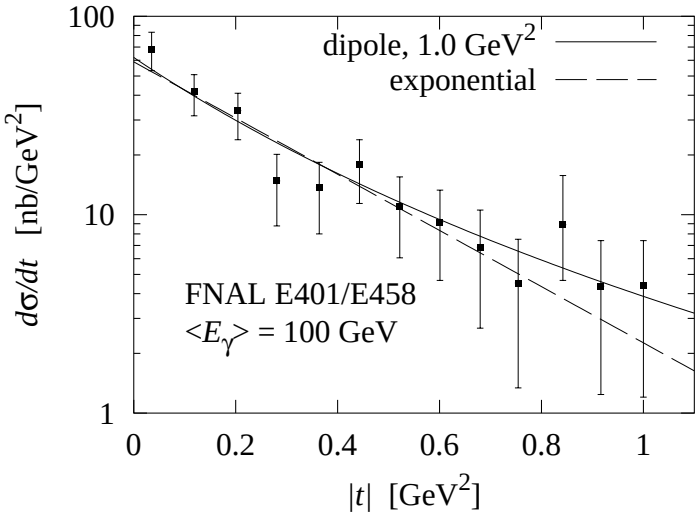
$$\int d^2\rho \; g(x,\rho) \; = \; g(x)$$

total gluon density

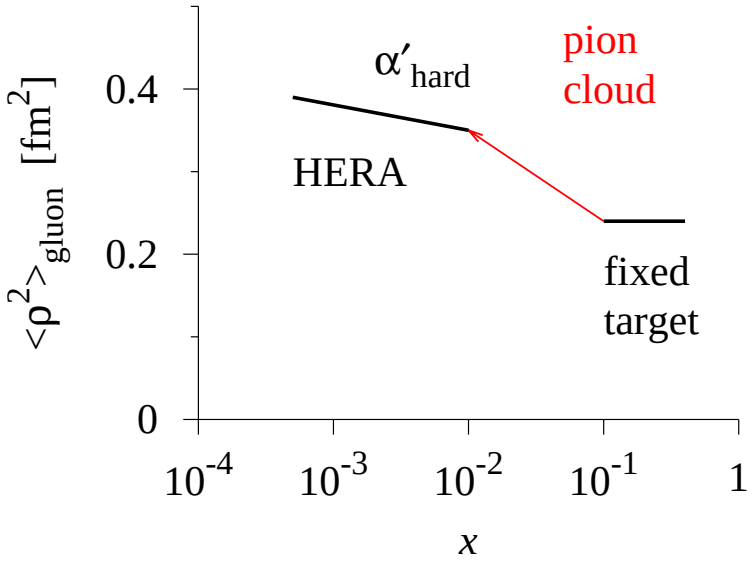
$$\langle \rho^2 \rangle_x \; = \; 4 \, \frac{\partial}{\partial t} \; \frac{g(x,t)}{g(x,t=0)}$$

transv. gluonic size of nucleon, x–dependent!



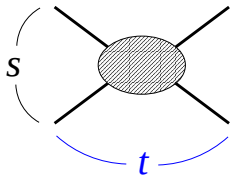


also: ZEUS 04



- Pion cloud contributes for $x < \dfrac{M_\pi}{M_N}$
- Slow log increase at small x: $\alpha'_{\rm hard} \approx 0.5 \times \alpha'_{\rm soft}$
- Phenom. parametrization of $g(x, \rho)$ [Frankfurt Strikman, CW 03/04]

- Transverse size in generic inelastic pp collisions



$$A(s,t) \;=\; \frac{is}{4\pi}\int d^2b\, e^{-i\vec{\Delta}_\perp\cdot\vec{b}}\,\Gamma(s,b)$$

pp elastic amplitude in impact parameter representation ($t=-\Delta_\perp^2$)

$$\sigma_{\rm el}(s) \;\sim\; |A|^2 \;=\; \int d^2b\,|\Gamma(s,b)|^2 \qquad \text{elastic}$$

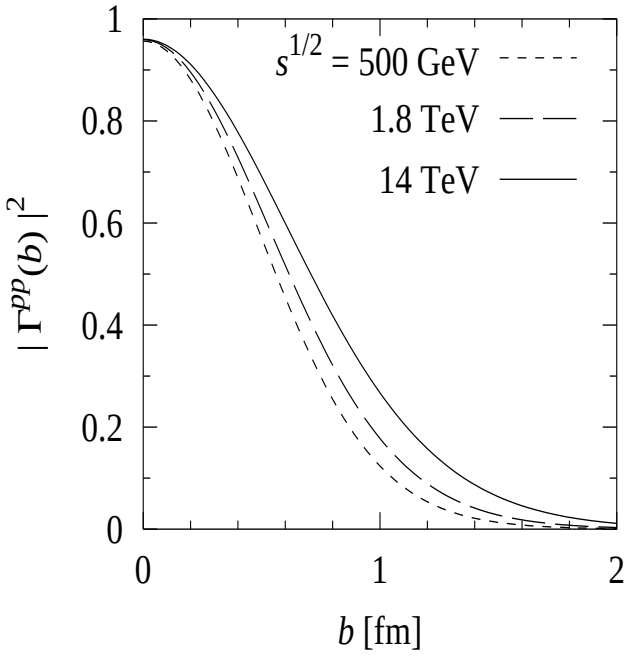
$$\sigma_{\rm tot}(s) \;\sim\; \text{Im } A \;=\; \int d^2b\;\; 2\,\text{Re }\Gamma(s,b) \qquad \text{total}$$

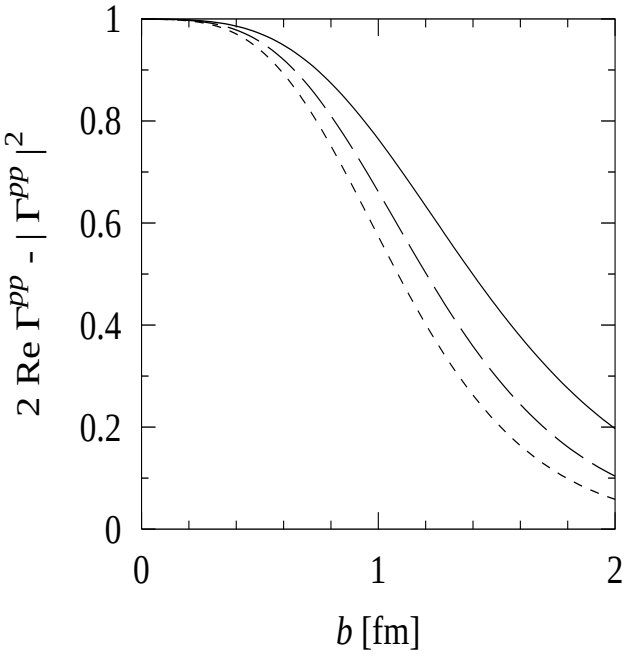
$$\downarrow$$

$$\sigma_{\rm in}(s) \;=\; \int d^2b\quad \underbrace{\left[2\,\text{Re }\Gamma - |\Gamma|^2\right]} \qquad \text{inelastic}$$

b–distribution of inelastic cross section

$$P_{\rm in}(b)$$



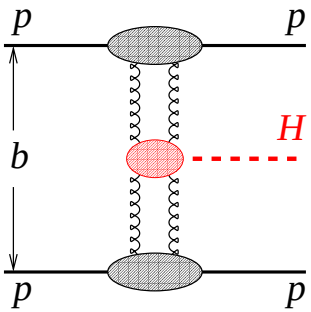


Parametrization of $\Gamma^{pp}(s,t)$ [Islam et al. 02]

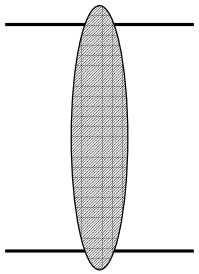
	$\sqrt{s}$ [TeV]	$\langle b^2 \rangle$ [fm^2]
LHC	14	2.7
Tevatron	1.8	1.8
RHIC	0.5	1.43

- Effective impact parameters in generic inelastic events grow with s
- Dominated by soft interactions

- Diffractive Higgs production [Frankfurt, Strikman, CW 04/05]



$\times$



hard partonic process

soft interactions (must preserve rapidity gaps!)

$P_{\rm hard}(b)$

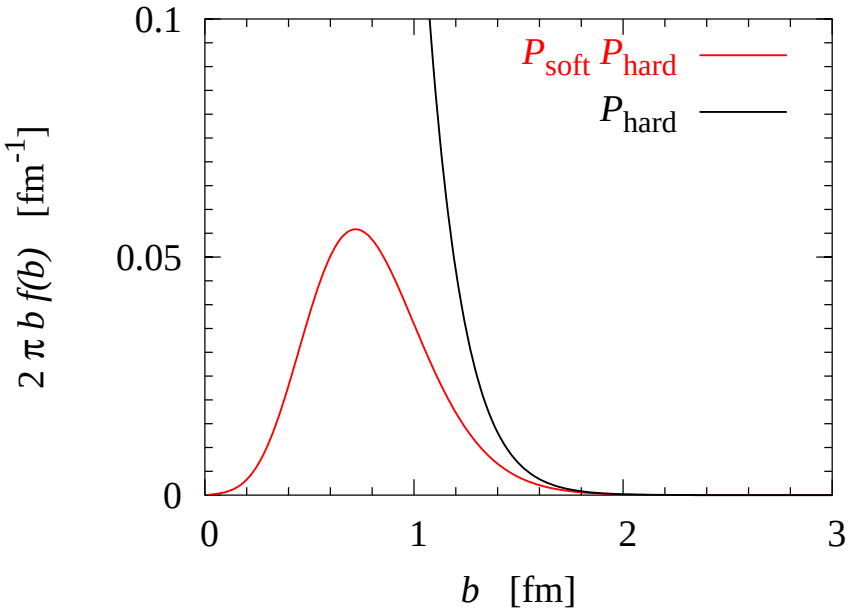
$P_{\rm soft}(b)$

$$\equiv \Big[\int d^2\rho_1\, d^2\rho_2 \times \delta(\boldsymbol{b} - \boldsymbol{\rho}_1 + \boldsymbol{\rho}_2) \times g(x_1,\rho_1)\; g(x_2,\rho_2) \Big]^2$$

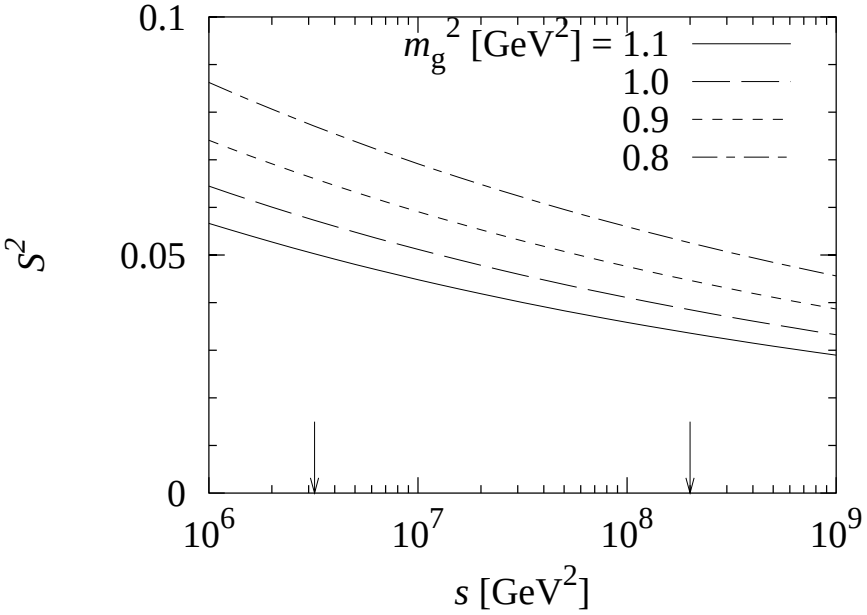
$$\equiv |1 - \Gamma(b)|^2$$

Overlap of gluon dist'ns

"No inelastic interactions"

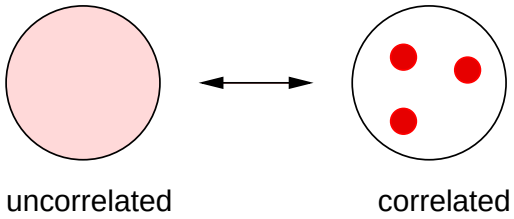


- Soft interactions suppress small impact parameters ("no chance to survive")
- Dominated by intermediate values $b \sim 0.7\,\mathrm{fm}$



- Gap survival probability $S^2 = \int d^2b\; P_{\rm hard}(b)\; P_{\rm soft}(b)$
- Decreases slowly with s
- Estimates agrees well with double pomeron model [Khoze et al. 00]

– Correlations in transverse position of hard partons?



CDF data on dijet + photon production
indicate significant correlations
[Frankfurt, Strikman, CW 04]

– Investigate dependence on momentum transfers to protons: t_1, t_2
[Frankfurt, Strikman, CW; in preparation]

– Approach can be extended to other diffractive processes

inclusive diffraction $\rightarrow$ diffractive PDF's

Summary and Outlook

- Transverse structure of nucleon key ingredient
  in understanding high–energy pp collisions

$$R^2(\text{partons } x \geq 10^{-3}) \quad \ll \quad R^2(\text{elastic})$$

- Accurate measurments of pp elastic scattering needed
  to model soft interactions via $\Gamma(s, b)$

$$\text{large } b \quad \leftrightarrow \quad \text{small } t$$

- Transverse spatial distribution of hard partons
  probed in exclusive ep scattering

  JLab at 12 GeV: Large–x quark distributions