Rapidity gap survival in central exclusive diffraction: Mechanisms and uncertainties

C. Weiss (JLab), DIS2009 Diffraction, 27–Apr–09

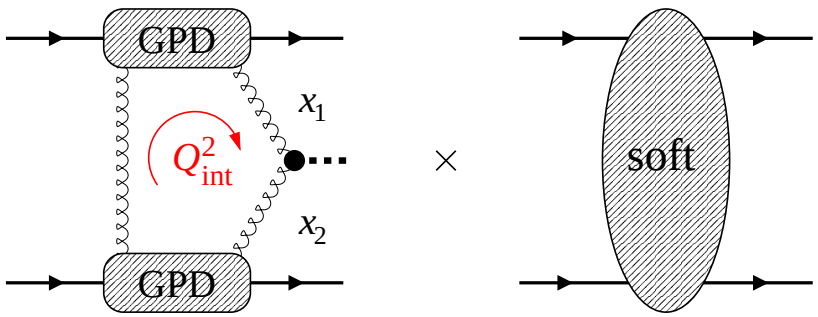
Partonic description of interplay
hard process $\leftrightarrow$ spectator interactions

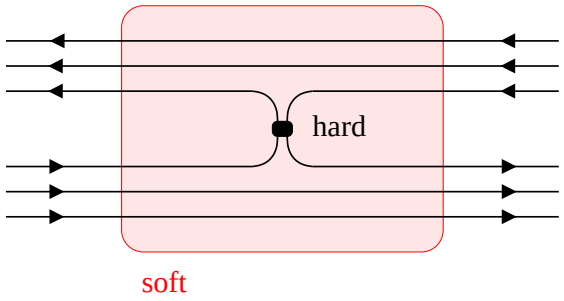
- Mean–field approximation: Hard/soft independent
  - Model–independent formulation
  - Uncertainties: Gluon GPD, pp elastic amplitude

- Correlations between hard process and spectator interactions
  - Fluctuations of parton densities
  - Absorption of hard spectators in black–disk regime $\leftarrow$ Substantial effect on RGS probability for LHC Higgs!
  - Transverse correlations between partons

Frankfurt, Hyde, Strikman, Weiss, PRD **75**:054009, 2007. FSW + Treleani, PRL **101**:202003, 2008. SW, arXiv:0903.3861

Hard–soft interplay in $pp \to p + H + p$





Different time/distance scales!

FHSW, PRD **75**:054009, 2007

- H produced in hard process

  $\mu^2_{\rm soft} \ll Q^2_{\rm int} \ll M^2$ [Khoze et al. 97+]

  $x_{1,2} \sim \frac{M}{\sqrt{s}} \sim 10^{-2}$ Higgs at LHC

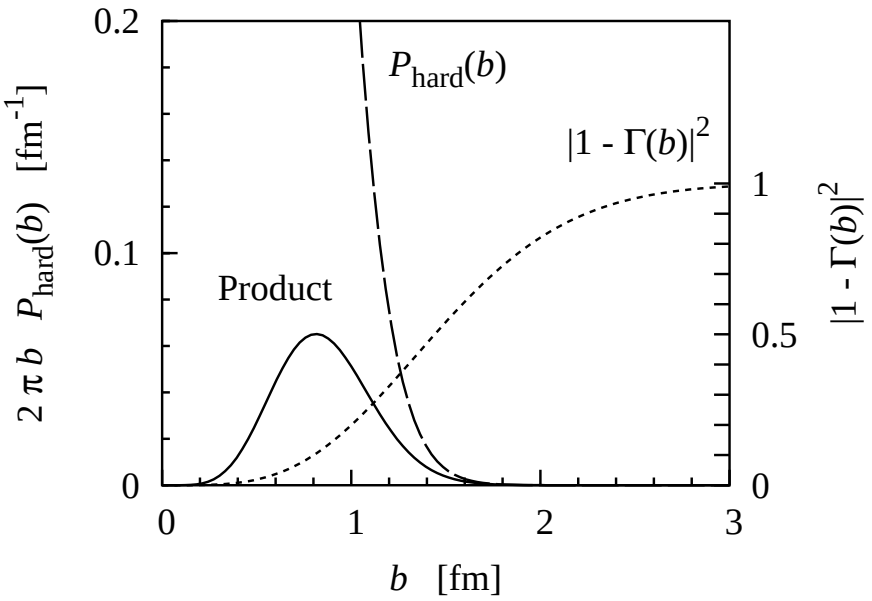
- Soft spectator interactions must not produce particles

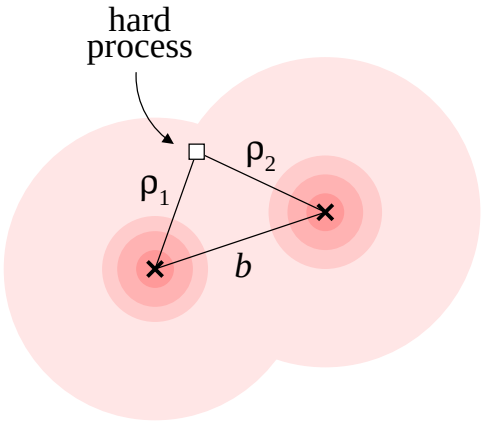
  $S^2 \equiv \dfrac{\sigma_{\rm diff}({\rm full})}{\sigma_{\rm diff}({\rm no\ soft})}$ Gap survival probability

- Mean–field approximation: $[V_{\rm hard}, H_{\rm soft}] = 0$ independent, closure of partonic states

- Amplitude calculable in terms of
  - Gluon GPD, unintegrated
  - pp elastic S–matrix

Mean–field approximation: Survival probability





$P_{\text{hard}}(b)$: Overlap of normalized transverse gluon densities (squared)

- Gap survival probability

$$S^2 = \int d^2b \quad P_{\text{hard}}(b) \quad |1 - \Gamma(b)|^2$$

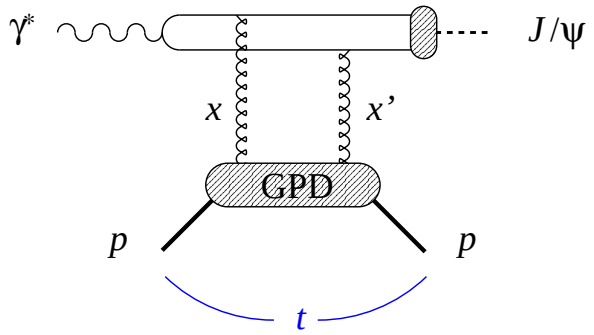
Probability for two–gluon collision	Probability for "no inelast. interaction"
favors small b	favors large b

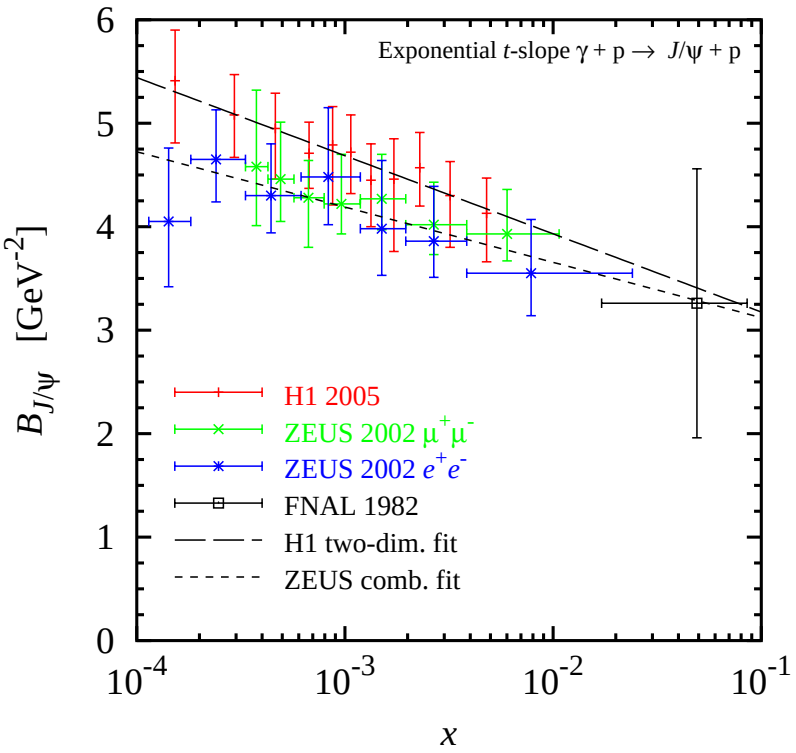
- "Blackness" of pp amplitude $\Gamma(b) \sim 1$ suppresses diffraction at small b

- Numerical results in mean–field approx. $S^2 \sim 0.03 - 0.04$ Higgs at LHC

Gap survival: "Transverse geometry"

Mean–field approximation: Uncertainties





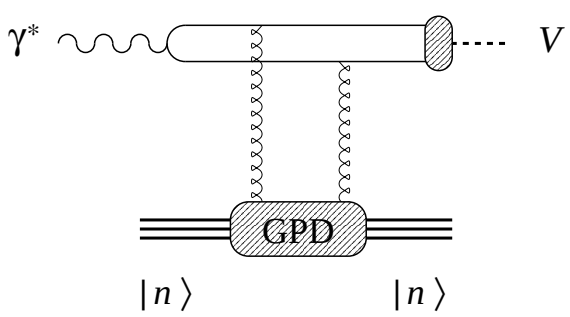
- S^2: Only t–dependence of gluon GPD
  $\rightarrow$ normalized transverse distribution!
- Experiment: Exclusive J/ψ production

  $$R^2(\text{gluons } x \sim 10^{-2}) \ll R^2(\text{soft})$$
- Uncertainties from t–dependence

Parameter in $\exp Bt$	$\sim 30\%$ in S^2
Functional form	$\sim 30\%$
- Uncertainty from pp elastic amplitude:
  Data allow $\Gamma(b=0) < 1$, but
  other effects remove small b
  (hard spectator interactions $\rightarrow$ later)

Details: SW, arXiv:0903.3861

Correlations: Fluctuations of parton density

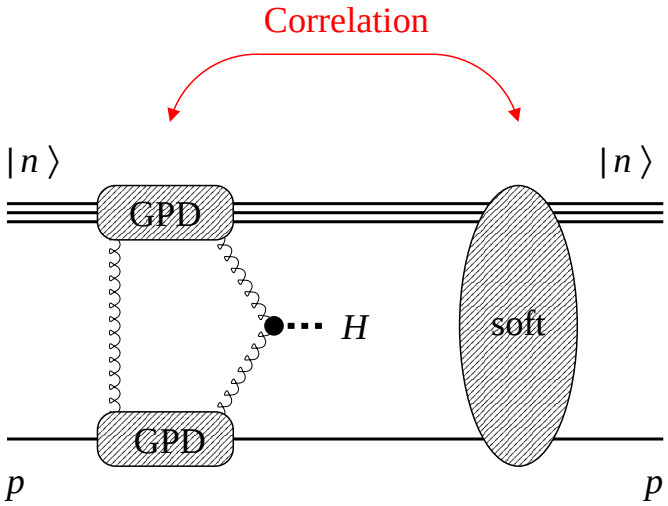


- Fluctuations of gluon density in hard diffraction $ep \to e + V + X$:

$$\omega_g = \frac{\langle G^2 \rangle - \langle G \rangle^2}{\langle G \rangle^2} = \left. \frac{d\sigma/dt\ (\text{inel})}{d\sigma/dt\ (\text{el})} \right|_{t=0}$$

New sum rule!

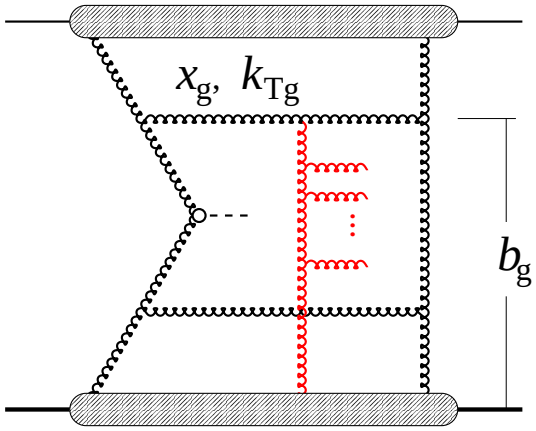
Scaling model of nucleon:
$\omega_g \sim 0.1$ at $Q^2 = 3\,\text{GeV}^2,\ x = 10^{-2}$

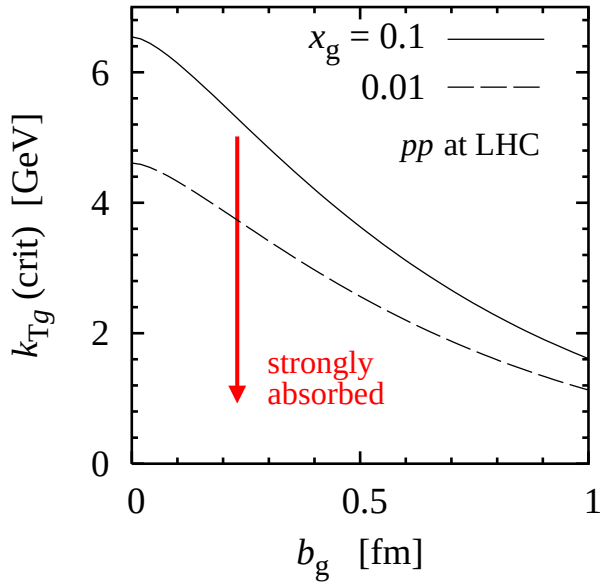


- Correlation with fluctuations of soft interaction strength (cf. Good–Walker)
  - Model: S^2 at LHC reduced by $\sim 20\%$
  - Inelastic diffraction already included in mean–field: Closure of partonic states

Frankfurt, Strikman, CW, Treleani, PRL **101**:202003, 2008

Correlations: Absorption of hard spectators



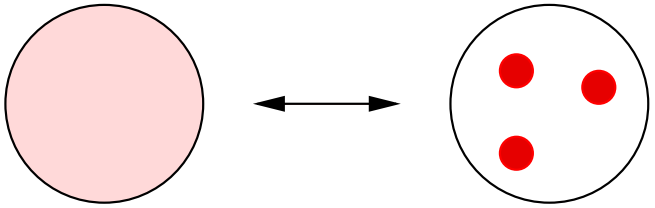


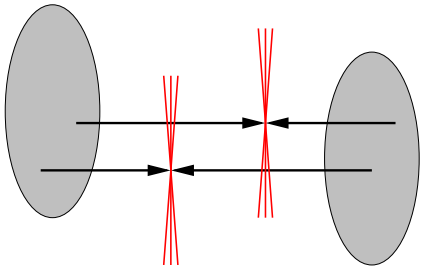
- Black–disk regime of QCD:
  Parent partons in evolution experience strong absorptive interactions with small–x gluons in other proton
  - Critical k_T and impact parameter dependence from QCD dipole model (gluon dipoles!)
  - No emissions: Possible, but Sudakov–suppressed
- Reduces S^2 at LHC by at least factor ~ 3, much weaker effect at Tevatron
- Larger impact parameters
  $\rightarrow$ steeper p_{1T}, p_{2T} dependence!

Important, should be studied in detail

FHSW, PRD **75**:054009, 2007

Correlations: Nucleon structure





- Indications for significant non–perturbative transverse correlations between partons
  - CDF data $p\bar{p} \to \text{dijet} + \gamma + X$
  - "Constituent quarks" of size $r \sim 0.3\,\text{fm}$ from chiral symmetry breaking in QCD
    cf. Instanton vacuum [Diakonov, Petrov 86]
- General trend: Correlations reduce RGS probability: Increased local opacity!
  Examples see FHSW, PRD **75**, 054009 (2007)

Potentially large effect on S^2, requires detailed modeling

Summary

- RGS in mean–field approximation

  $\rightarrow$ Model–independent: Gluon GPD, pp elastic amplitude
  $\rightarrow$ Numerical results comparable to Khoze et al. (eikonalized pomeron)
  $\rightarrow$ Uncertainty $\sim$ factor 2

- New effect: Hard spectator interactions in black–disk regime

  $\rightarrow$ Reduces RGS probability at LHC by at least factor ~ 3
  $\rightarrow$ Marginal at Tevatron — careful with extrapolation!

- Need detailed modeling including impact parameter dependence, parton radiation "history," unitarity effects, and non-perturbative parton–parton correlations in wave function

Survival probability for Higgs at LHC: $S^2 < 0.01$