Physics requirements for EIC forward detection

C. Weiss, Diffraction and Tagging WG, 30-Apr-2020. Informal summary of earlier discussions and assessments

- **Organize/prioritize processes for optimization and benchmarking**

  Many interesting processes with different requirements: need to identify clear targets for optimization, with specific requirements for detector coverage, resolution, efficiency

  Prioritization does not mean exclusion: many other processes will run without optimization

  Natural “grouping” of processes aligns physics and detector requirements: see summary table

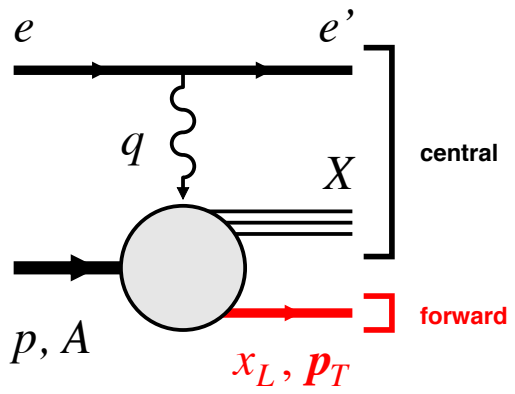
- **Process and kinematic variables**

  xL — longitudinal momentum fraction with respect to proton/ion beam

  pT — transverse momentum with respect to proton/ion beam, -> angle θ

  Note: Conventional physics variables are defined in photon-beam collinear frame; simple relation to (xL, pT) for scattering at small x(Bjorken)

  Note: (1 - xL) proportional to ξ ~ x(Bjorken)/2 in exclusive processes (“skewness”); coverage/resolution requirements specified in (1 - xL)



Summary: Physics processes and forward detection requirements

Processes	Beam -> Fwd	Rigidity Fwd/Beam	Coverage	Resolution (Charged)	Neutrals	Comments
Exclusive & diffractive scattering on proton	p -> p, n	1	pT = [0, ~2 GeV] xL = [~0.5, ~0.999] 1-xL = [~1E-3, ~0.3]	ΔpT ~ 50 MeV ΔxL/xL << 0.1 Δ(1-xL)/(1-xL) < 0.1	n Λ, Σ0	Inelastic diffraction physics & background
Coherent scattering on light nuclei	A -> A (A = D, He)	1	pT = [0, ~200 MeV] 1-xL = [~1E-3, ~1E-1]	ΔpT ~ 10-20 MeV Δ(1-xL)/(1-xL) < 0.1	none	Ion beam divergence (pT spread) significant
Spectator tagging in deuteron	D -> p (n)	1/2	pT = [0, ~500 MeV] xL = [~0.25, ~0.75]	ΔpT ~ 10-20 MeV ΔxL/xL << 0.1	(n)	Ion beam divergence (pT spread) significant
Breakup of light and heavy nuclei	A -> p, n, A-1	various	pT = [0, ~500 MeV] xL various	?	multiple n	Veto detection for heavy nuclei

Schematic classification of processes with estimated coverage/resolution requirements

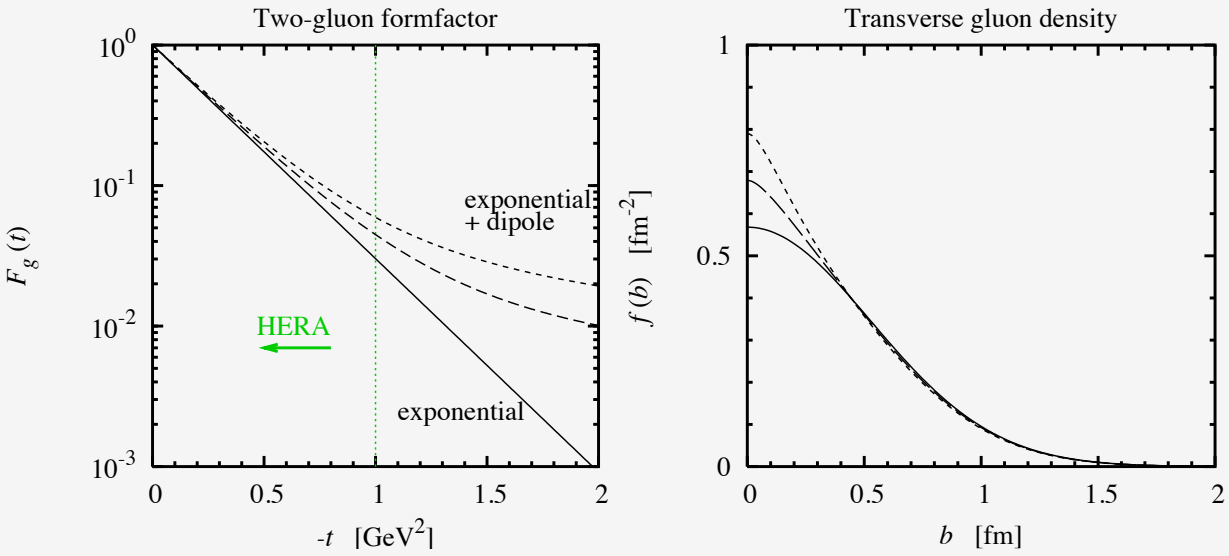
Numbers intended as reasonable starting values, to be substantiated/adjusted by detailed simulations

Examples following

- The following are examples of physics arguments, not the complete set
- Aimed at rough estimates; precise numbers to be determined by simulations
- Intended to show how arguments could be conducted, not precise numbers

Exclusive/diffractive scattering on proton: pT coverage > 1 GeV

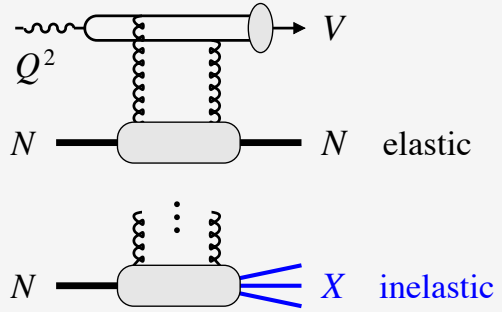
Transverse nucleon imaging



[CW, EIC Collaboration Meeting CUA 2010]

- Power-like t-dependence expected at large t: Where does it start?
- |t| > 1 GeV2 not covered at HERA
- Imaging nucleon center b < 0.3 fm requires |t| > 1 GeV2

Elastic vs. inelastic diffraction



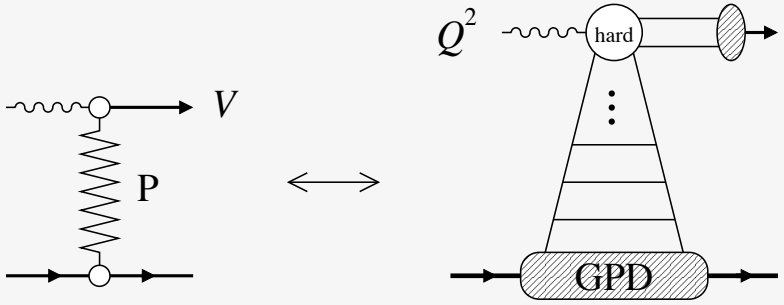
$$\frac{d\sigma/dt\ [\text{dissoc}]}{d\sigma/dt\ [\text{elast}]} \sim e^{(B_{\text{elast}}-B_{\text{dissoc}})|t|}$$

$$B_{\text{elast}} - B_{\text{dissoc}} \approx 5\ \text{GeV}^{-2} \quad [\text{HERA}]$$

- Inelastic diffraction grows rapidly with |t|
- Background to elastic processes, GPD measurements
- Physics in inelastic diffraction at |t| = 0: Quantum fluctuations of gluons **[Talk EICUG Meeting Temple 2020]**

Exclusive/diffractive scattering on proton: pT coverage > 1 GeV

Emergence of Regge dynamics from QCD

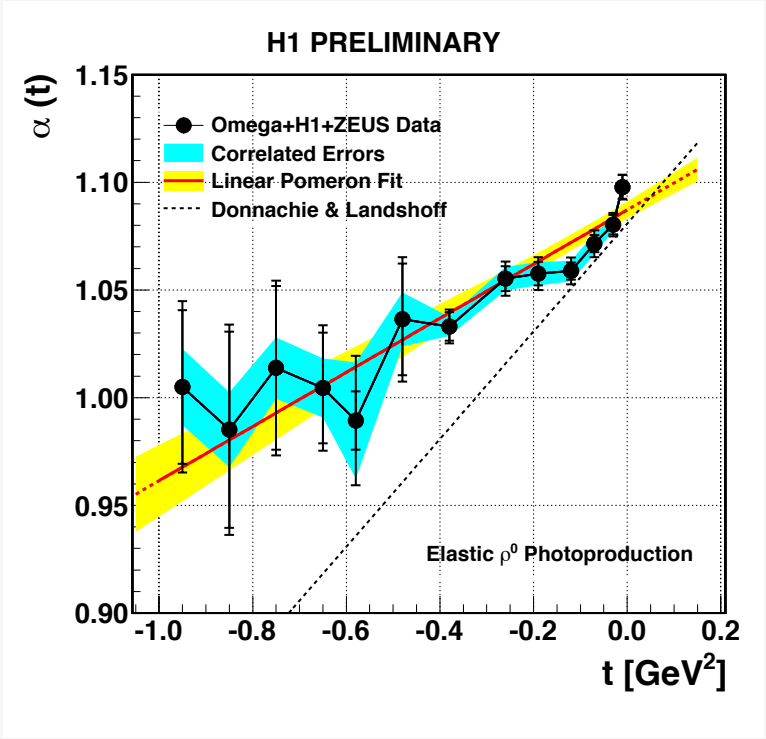


- Soft processes: Reggeized hadronic exchange
  Hard processes: Partonic ladder from soft to hard scale

- Energy dependence at |t| = 0: $W^{4(\alpha_P - 1)} \leftrightarrow [G(x, Q^2)]^2$

- Transition as function of Q2: Change of effective trajectory with Q2, QCD evolution DGLAP/BFKL

- Transition as function of |t|: Expect flattening of trajectory at |t| >> (soft scale). Suppression of diffusion.
  Blok, Frankfurt, Strikman 10

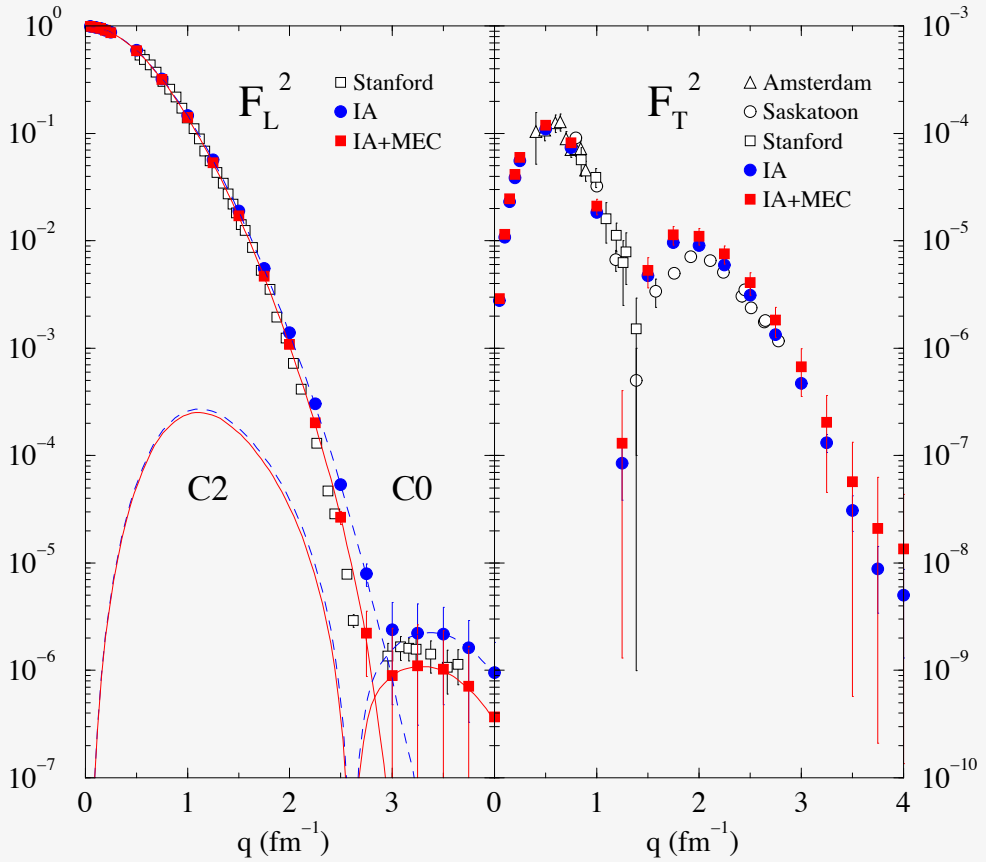


- Seen in HERA ρ data: H1 2010

- Can be studied with EIC measurements at |t| > 1 GeV2

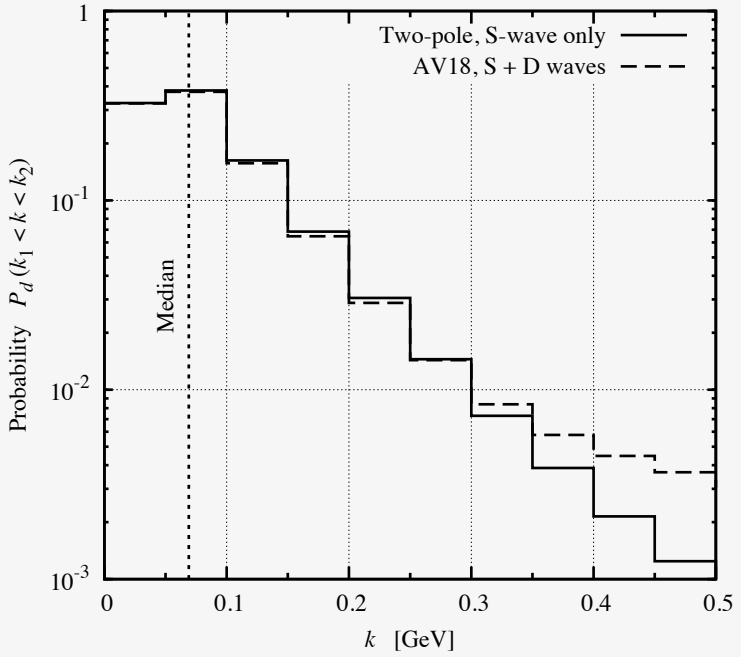
- Fundamental question of QCD dynamics

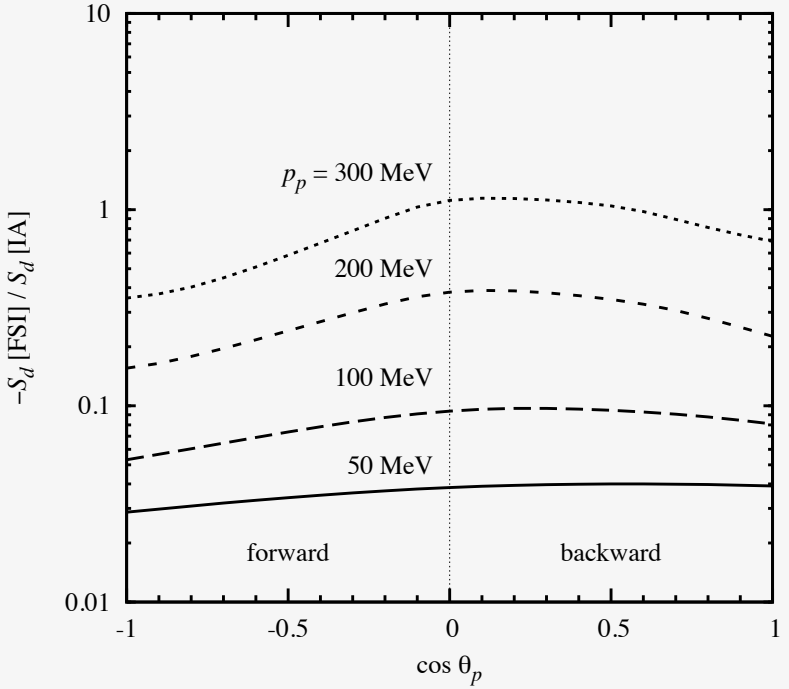
Coherent scattering on light nuclei: pT coverage and resolution

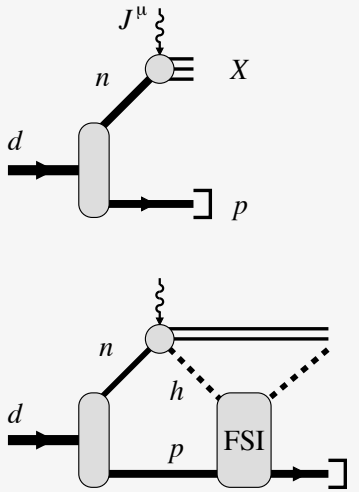


- Form factors and GPDs of light nuclei have pT dependence on scale ~ few 10 MeV
- Example: Li6 elastic and transition FF [Wiringa, Schiavilla 98]
- Need coverage pT = [0, ~200 MeV] resolution ΔpT ~10-20 MeV
- Challenging: pT spread in ion beam (angular divergence)

Deuteron and spectator tagging: xL and pT coverage







- Nucleon momentum distribution in deuteron
  80% of nucleons at k < 100 MeV
  95% of nucleons at k < 200 MeV

- Final-state interactions in tagged DIS
  FSI/IA ~< 0.1 at p_p < 100 MeV
  FSI/IA ~ 1 at p_p >~ 300 MeV

[Strikman, Weiss, PRC 97 (2018) 3, 035209]

- p_T coverage at <100 MeV essential for extraction of neutron structure with spectator tagging

- Detailed simulations in progress: Zh. Tu, A. Jentsch et al.