Space-time description of hadronization in DIS

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1. Physical picture of hadronization

2. Experimental Tools & Observables

3. Data



process by which energetic quarks evolve into hadrons.



Confinement process isn't finished yet, these are *colored* **pairs:**



• How do we get to *colorless* systems?



Kopeliovich, Nemchik, Predazzi, Hayashigaki, Nuclear Physics A 740 (2004) 211-245

Physical picture of hadronization (in vacuum)



Production time τ_p is time required to form a color singlet prehadron, "lifetime of the deconfined quark".

Formation time ${}^{h}\tau_{f}$ is time required to form full sized hadron.

In-medium hadronization

Hadronization can occur *outside* the medium as well as *inside* the medium.

- partonic multiple scattering \rightarrow medium-stimulated gluon emission
- prehadron interaction with medium \rightarrow hadron attenuation





Experimental tools and observables

Semi-Inclusive Deep Inelastic Scattering (SIDIS)



four-momentum transferred by the electron;

 $Q^2 = -Q^2$

p_T

φ

v=*E*-*E*'

 $\mathbf{Z} = E_{hadron} / \mathbf{v}$

energy transferred by the electron, = Initial energy of struck quark; the fraction of the struck quark's initial energy that is carried by hadron; hadron momentum transverse to virtual photon direction; angle between lepton scattering plane and photon-hadron plane.

CLAS CEBAF Large Acceptance Spectrometer



Jlab Measurement: CLAS EG2

- Targets: deuterium, carbon, iron, lead.
- Deuterium and solid target in beam simultaneously for improved systematics:



- Luminosity $\sim 10^{34} \, \mathrm{s}^{-1} \mathrm{cm}^{-2}$
- Beam energies: 4 and 5 GeV

Experimental observables

1. Hadronic multiplicity ratio



Experimental observables

2. Transverse momentum broadening



Connection of the production and formation times to the observables

How long can a light quark remain deconfined? Quark is deconfined, emits gluons during production time t_p Measure t_p via medium-stimulated Δp_T

How long does it take to form a color field of the hadron? Hadrons interact with the medium during formation time t_f^h Measure t_f^h via hadron attenuation R_h in medium.

Present and future e+A facilities



Courtesy of A.Accardi

Preliminary data from CLAS for π^+





Can we measure production time

= quark lifetime?!

Prehadrons formed on short time scales!

$$<\Delta p_T^2> = 2 C \rho_A L$$





Kopeliovich et al. NPA 740(2004) 211, W.Brooks, Trento workshop talk

Conclusion

- The microscopic information on space-time characteristics of hadronization can now be accessed via DIS using nuclear medium as an analyzer.
- -Studies of hadronization are characterized by rich
- complexity (color field restoration, gluon bremsstrahlung,
- extraction of confinement quantities)
- -Hadronization mechanisms can be tested, and extraction
- of production times and formation times is now feasible

