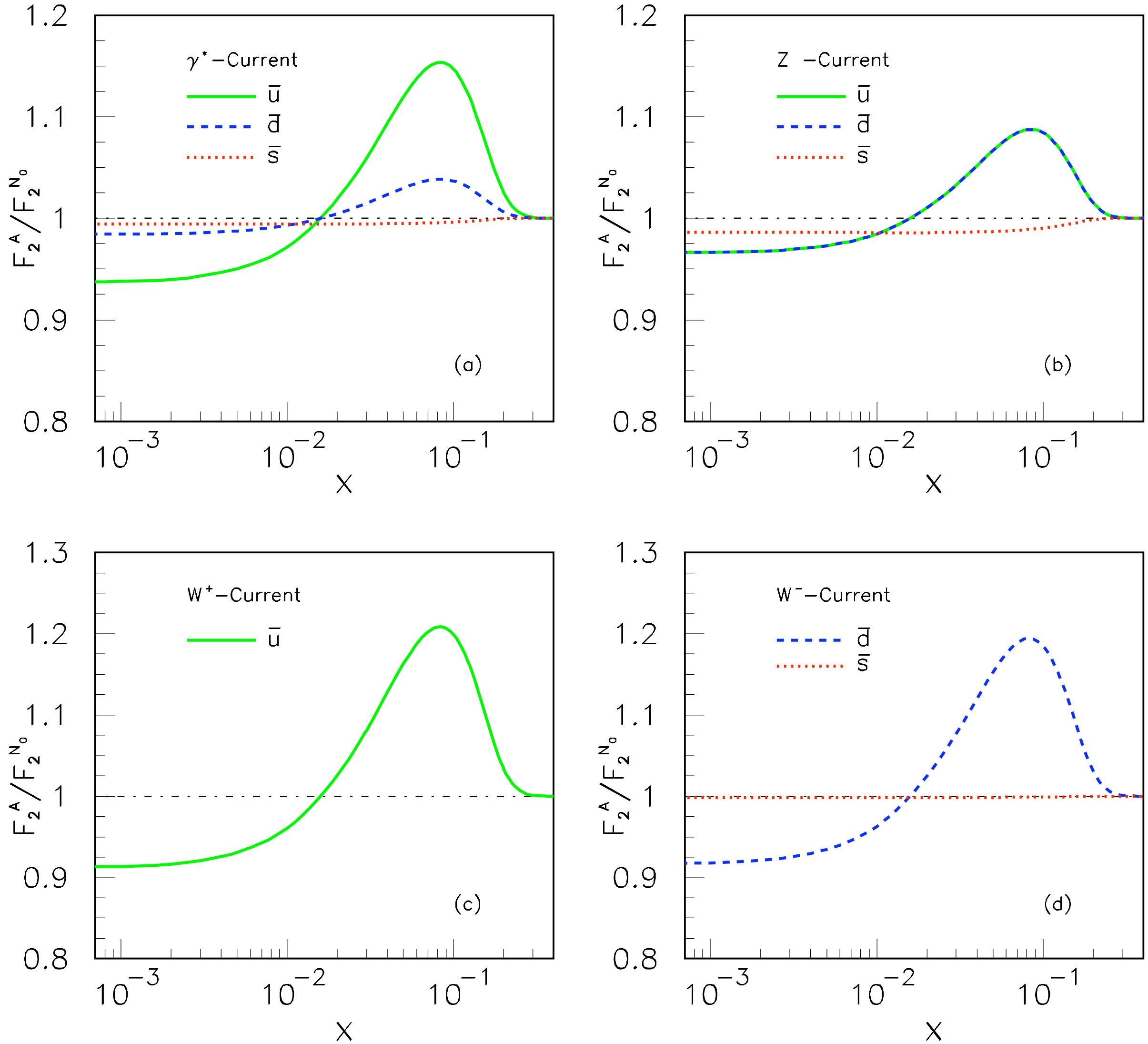


Nuclear Effect not Universal !

Shadowing and Antishadowing in Lepton-Nucleus Scattering

- Shadowing: Destructive Interference of Two-Step and One-Step Processes *Pomeron Exchange*

- Antishadowing: Constructive Interference of Two-Step and One-Step Processes! *Reggeon and Odderon Exchange*

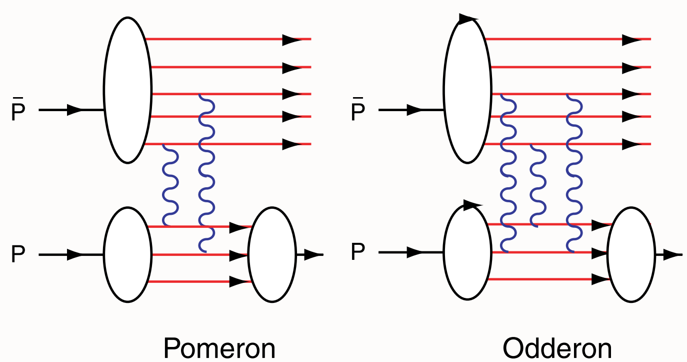
- Antishadowing is Not Universal! Electromagnetic and weak currents: different nuclear effects ! Potentially significant for NuTeV Anomaly}

Jian-Jun Yang
Ivan Schmidt
Hung Jung Lu
sjb

The Odderon

Merino, Rathsman, sjb

- Three-Gluon Exchange, C= -, J=1, Nearly Real Phase *BFKL*
- Interference of 2-gluon and 3-gluon exchange leads to matter/antimatter asymmetries
- Asymmetry in jet asymmetry in $\gamma p \to c\bar{c}p$ *e-p collider test*
- Analogous to lepton energy and angle asymmetry $\gamma Z \to e^+e^-Z$
- Pion Asymmetry in $\gamma p \to \pi^+\pi^- p$



Odderon: Another source of antishadowing

$$|p,S_z> = \sum_{n=3} \Psi_n(x_i,\vec{k}_{\perp i},\lambda_i)|n;\vec{k}_{\perp_i},\lambda_i>$$

sum over states with n=3, 4, ...constituents

The Light Front Fock State Wavefunctions

$$\Psi_n(x_i,\vec{k}_{\perp i},\lambda_i)$$

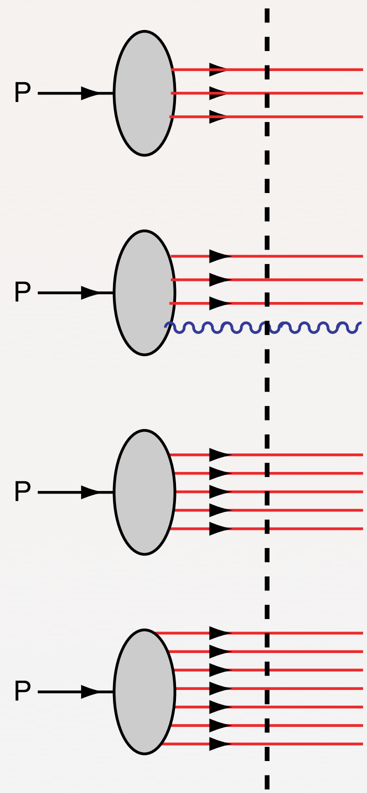
are boost invariant; they are independent of the hadron's energy and momentum P^μ.

The light-cone momentum fraction

$$x_i = \frac{k_i^+}{p^+} = \frac{k_i^0 + k_i^z}{P^0 + P^z}$$

are boost invariant.

$$\sum_i^n k_i^+ = P^+, \ \sum_i^n x_i = 1, \ \sum_i^n \vec{k}_i^\perp = \vec{0}^\perp.$$



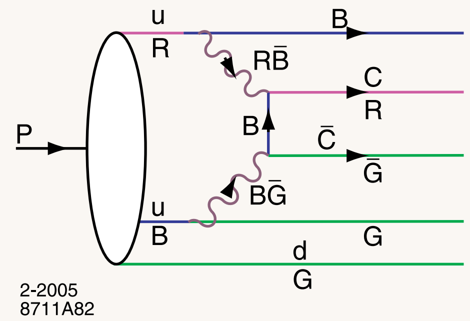
Fixed LF time

Intrinsic heavy quarks, $\bar{s}(x) \neq s(x)$

$\bar{u}(x) \neq \bar{d}(x)$

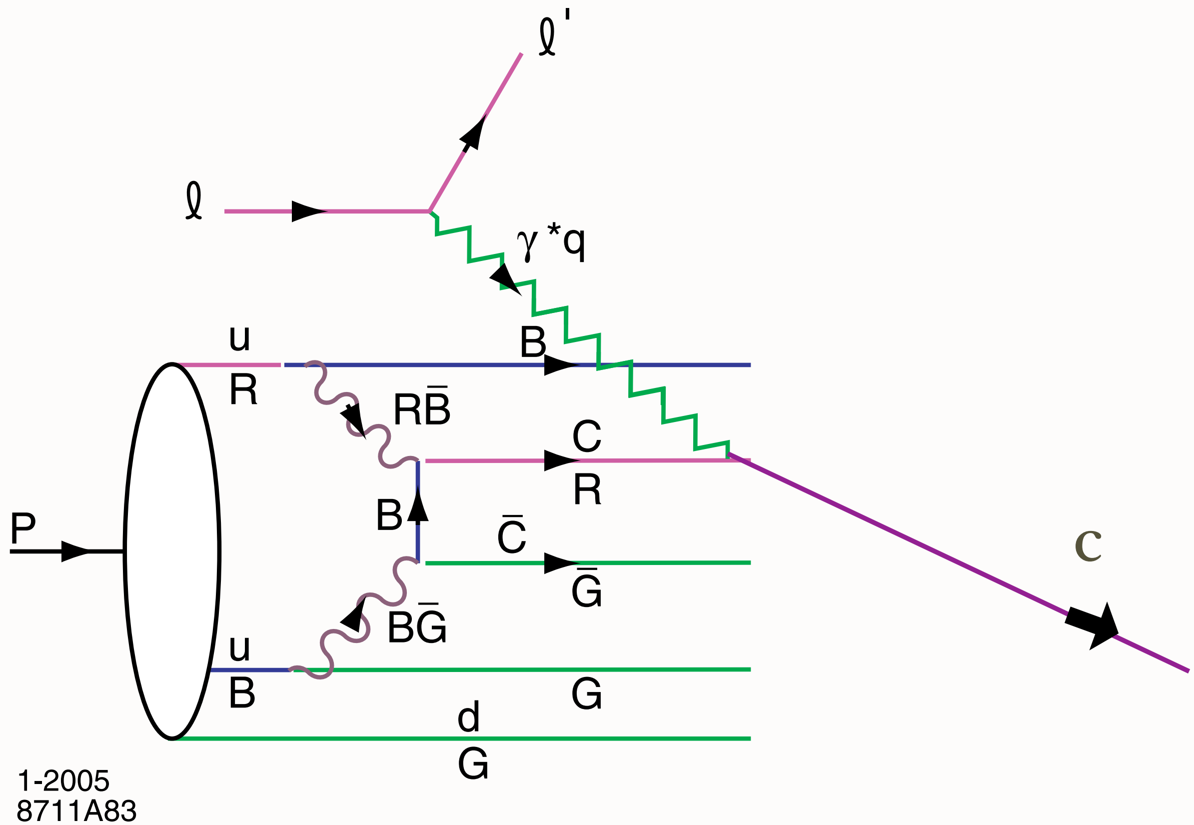
Hoyer, Peterson, Sakai, sjb

Intrinsic Heavy-Quark Fock States



- Rigorous prediction of QCD, OPE
- Color-Octet Colo-Octet Fock State!
- Probability $P_{Q\bar{Q}} \propto \frac{1}{M_Q^2}$ $P_{Q\bar{Q}Q\bar{Q}} \sim \alpha_s^2 P_{Q\bar{Q}}$ $P_{c\bar{c}/p} \simeq 1\%$
- Large Effect at high x
- Greatly increases kinematics of colliders such as Higgs production (Kopeliovich, Schmidt, Soffer, sjb)
- Severely underestimated in conventional parameterizations of heavy quark distributions (Pumplin, Tung)
- Many empirical tests

Measure c(x) in Deep Inelastic Lepton-Proton Scattering

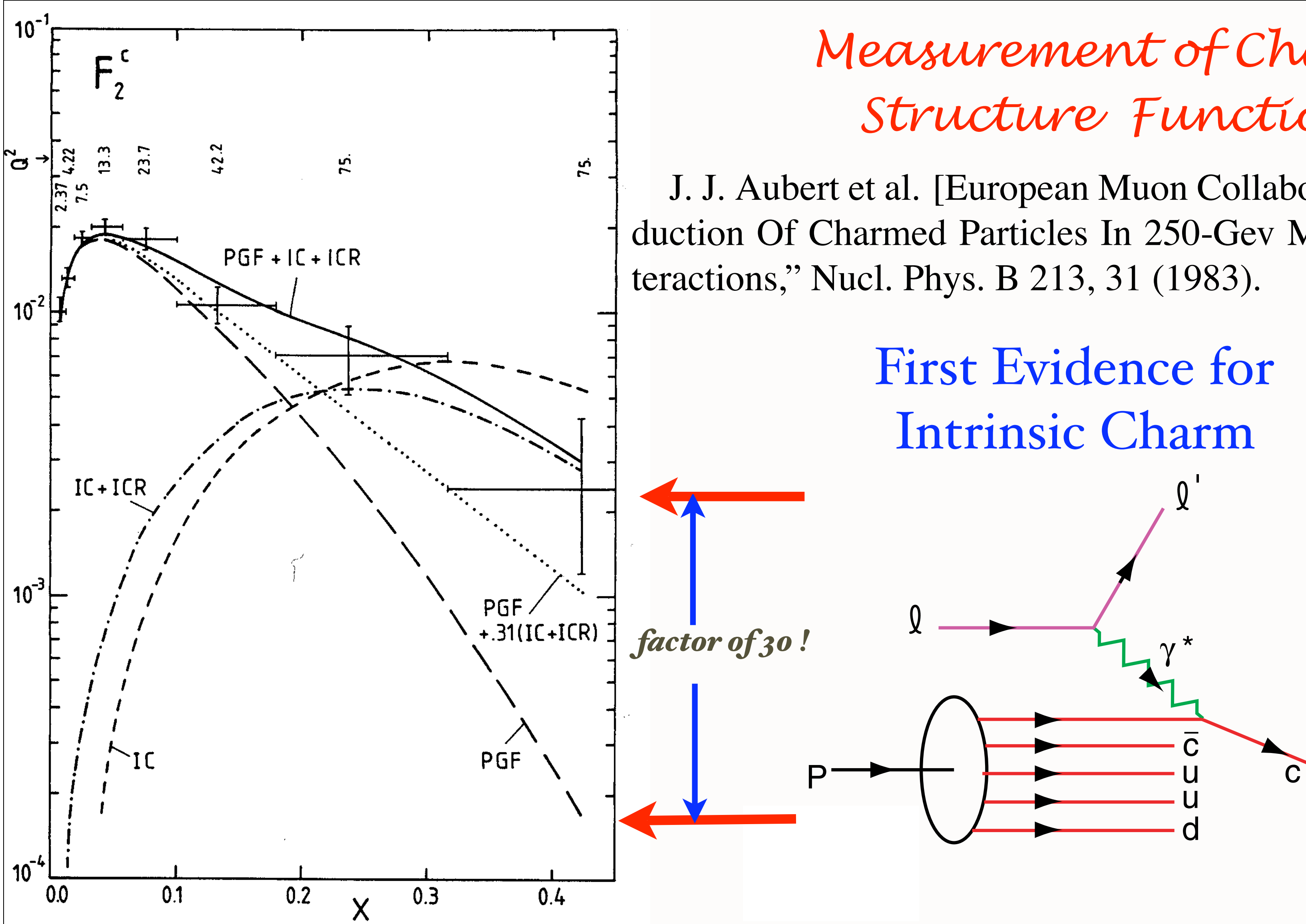


Hoyer, Peterson, SJB

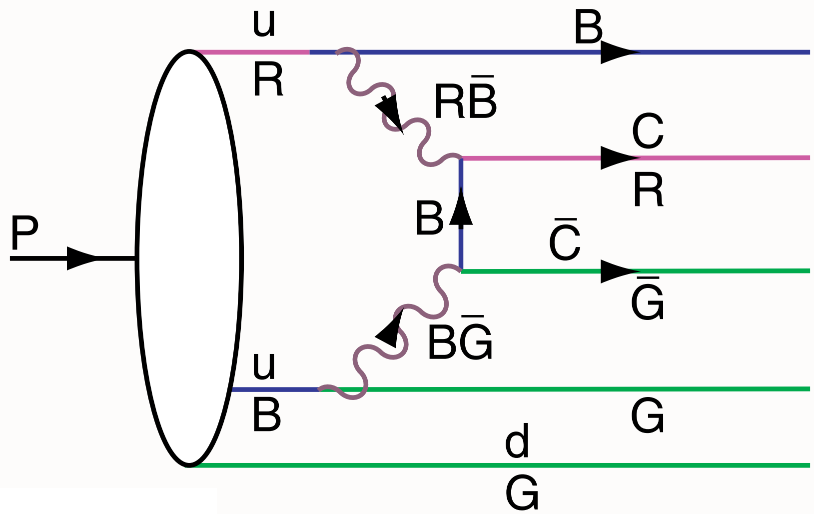
Measurement of Charm Structure Function

J. J. Aubert et al. [European Muon Collaboration], "Production Of Charmed Particles In 250-Gev Mu+ - Iron Interactions," Nucl. Phys. B 213, 31 (1983).

First Evidence for Intrinsic Charm



DGLAP / Photon-Gluon Fusion: factor of 30 too small



$|uudc\bar{c}>$ Fluctuation in Proton

QCD: Probability $\frac{\sim\Lambda^2_{QCD}}{M^2_Q}$

$|e^+e^-\ell^+\ell^->$ Fluctuation in Positronium

QED: Probability $\frac{\sim(m_e\alpha)^4}{M^4_\ell}$

OPE derivation - M.Polyakov et al.

$< p|\frac{G^3_{\mu\nu}}{m^2_Q}|p >$ vs. $< p|\frac{F^4_{\mu\nu}}{m^4_\ell}|p >$

$c\bar{c}$ in Color Octet

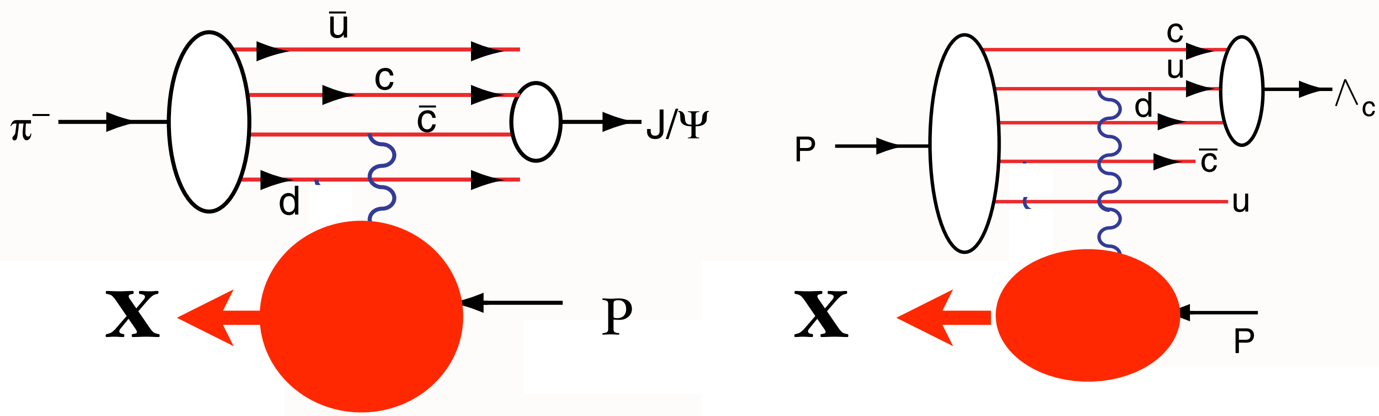
Distribution peaks at equal rapidity (velocity)
Therefore heavy particles carry the largest momentum fractions

$$\hat{x}_i = \frac{m_{\perp i}}{\sum_j^n m_{\perp j}}$$

High x charm!

Hoyer, Peterson, Sakai, sjb

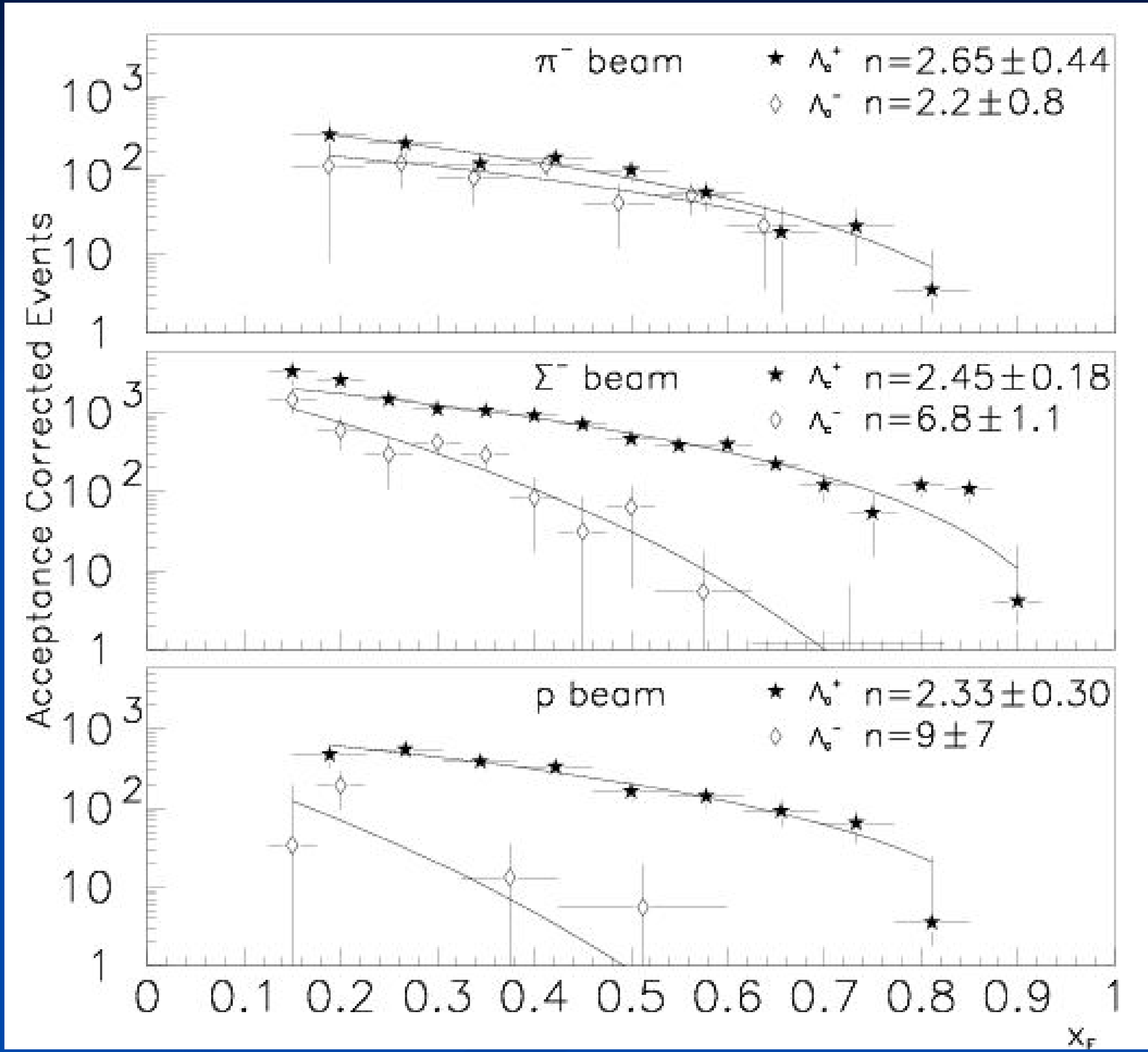
Leading Hadron Production from Intrinsic Charm

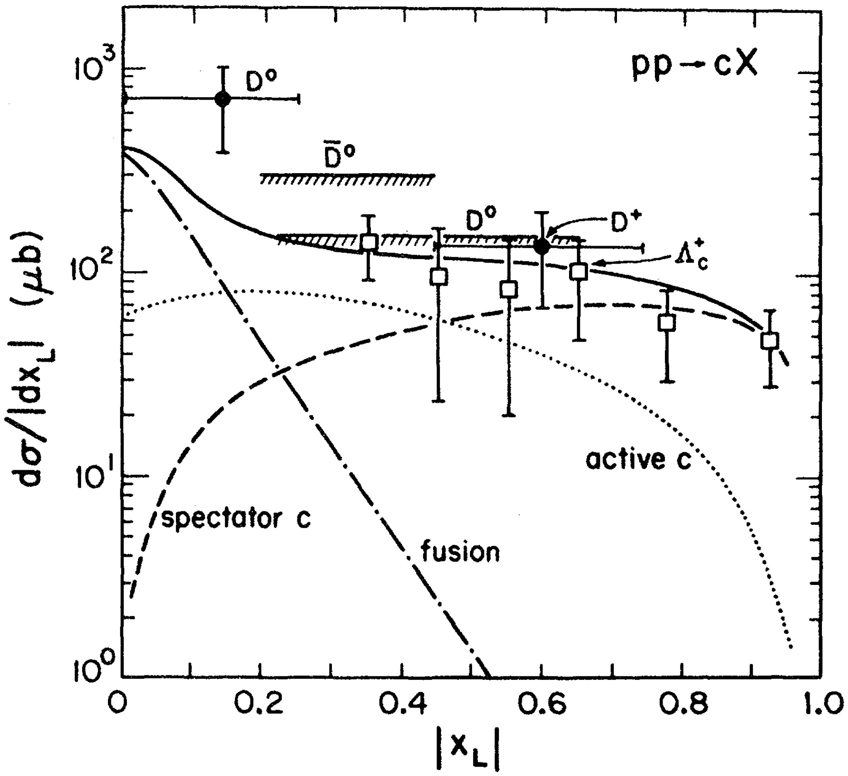


Coalescence of Comoving Charm and Valence Quarks Produce J/ψ, Λ_c and other Charm Hadrons at High x_F

SELEX Λ_c^+ Studies – Momentum Dependence

- Production similar for baryon, antibaryon from π beam at all x_F
- Baryon beams make antibaryons chiefly at small x_F but not large x_F: *not* simply fragmentation
- High statistics Σ data suggest cross section enhancement at very large x_F – idea originally from Pythia color drag.





Model similar to Intrinsic Charm

Predictions for Inclusive Charm ProductionDistributions at the ISR. Assumes active and spectator charm distribution in proton patterned on IC, plus coalescence of valence and charm quarks.

V. D. Barger, F. Halzen and W. Y. Keung,
"The Central And Diffractive Components Of Charm Production,"
Phys. Rev. D 25, 112 (1982).

- EMC data: $c(x, Q^2) > 30 \times$ DGLAP
  $Q^2 = 75$ GeV^2, $x = 0.42$

- High x_F $pp \to J/\psi X$

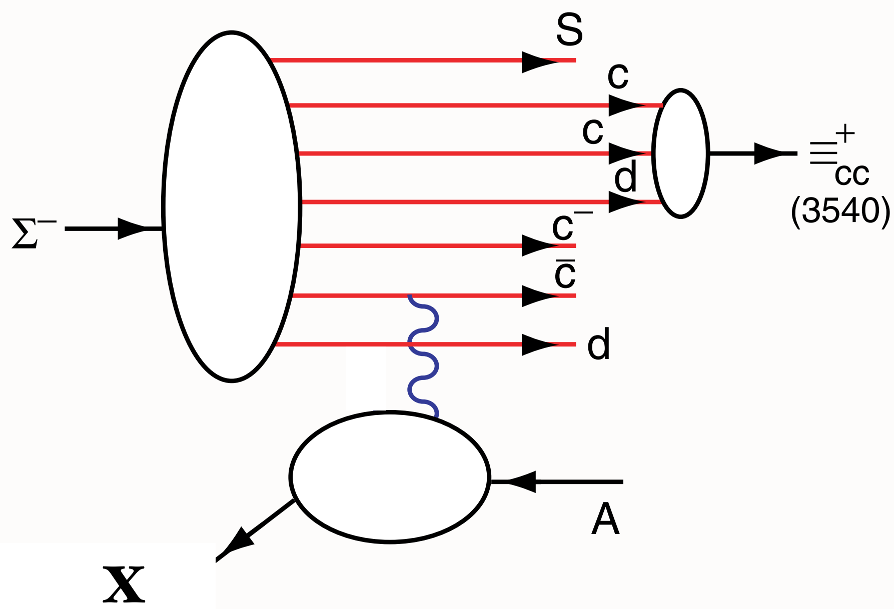
- High x_F $pp \to J/\psi J/\psi X$

- High x_F $pp \to \Lambda_c X$

- High x_F $pp \to \Lambda_b X$

- High x_F $pp \to \Xi(ccd) X$ (SELEX)

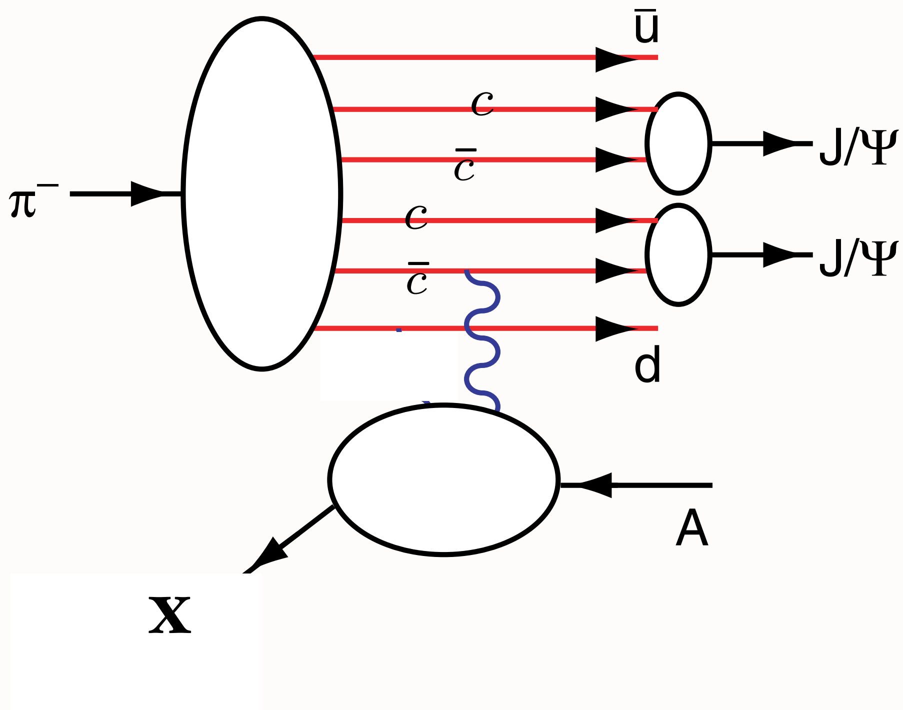
C.H. Chang, J.P. Ma, C.F. Qiao and X.G.Wu, Hadronic production of the doubly charmed baryon Xi/cc with intrinsic charm," arXiv:hep-ph/0610205.



Production of a Double-Charm Baryon

SELEX high x_F $\quad < x_F >= 0.33$

Production of Two Charmonia at High x_F



All events have $x^F_{\psi\psi} > 0.4$!

Excludes color drag model

$\pi A \to J/\psi J/\psi X$

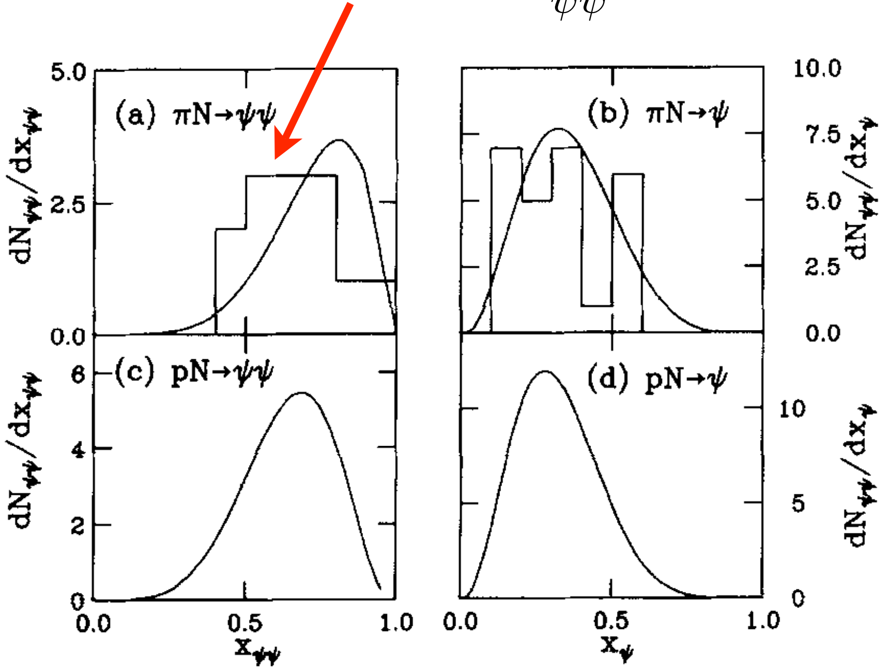


Fig. 3. The $\psi\psi$ pair distributions are shown in (a) and (c) for the pion and proton projectiles. Similarly, the distributions of J/ψ's from the pairs are shown in (b) and (d). Our calculations are compared with the $\pi^- N$ data at 150 and 280 GeV/c [1]. The $x_{\psi\psi}$ distributions are normalized to the number of pairs from both pion beams (a) and the number of pairs from the 400 GeV proton measurement (c). The number of single J/ψ's is twice the number of pairs.

NA3 Data

Intrinsic charm contribution to double quarkonium hadroproduction ★

R. Vogt [a], S.J. Brodsky [b]

The probability distribution for a general n-parti intrinsic $c\bar{c}$ Fock state as a function of x and k_T written as

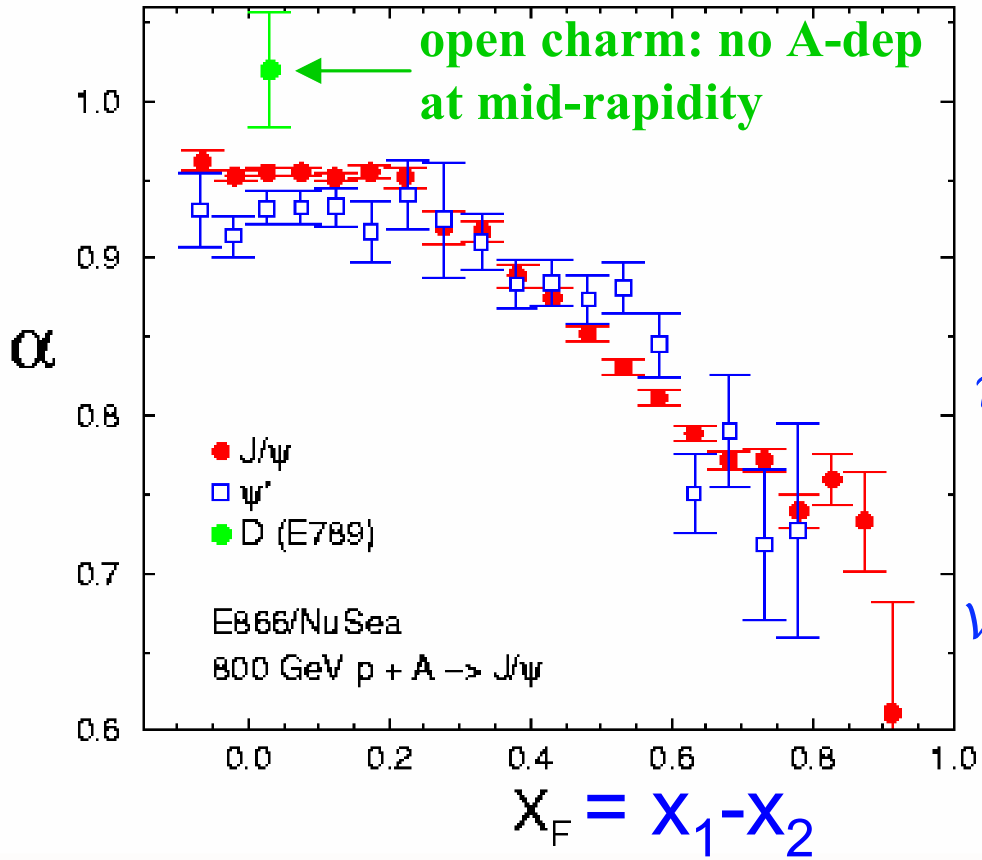
$$\frac{dP_{\rm ic}}{\prod_{i=1}^n dx_i d^2k_{T,i}}$$

$$= N_n \alpha_s^4(M_{c\bar{c}}) \frac{\delta(\sum_{i=1}^n k_{T,i})\delta(1 - \sum_{i=1}^n x_i)}{(m_h^2 - \sum_{i=1}^n (m_{T,i}^2/x_i))^2},$$

800 GeV p-A (FNAL) $\sigma_A = \sigma_p * A^\alpha$

PRL 84, 3256 (2000); PRL 72, 2542 (1994)

M. Leitch



$$\frac{d\sigma}{dx_F}(pA \to J/\psi X)$$

Remarkably Strong Nuclear Dependence for Fast Charmonium

Violation of PQCD Factorization!

Violation of factorization in charm hadroproduction.

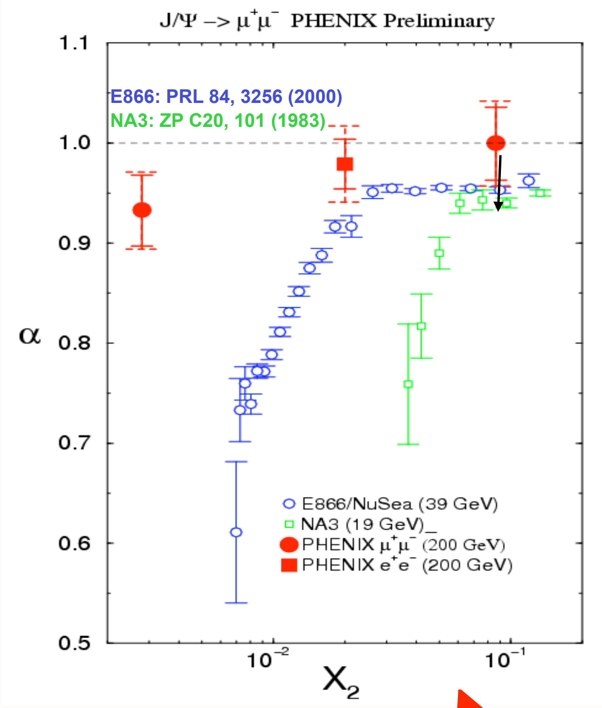
P. Hoyer, **M. Vanttinen** (**Helsinki U.**) , **U. Sukhatme** (**Illinois U., Chicago**) . **HU-TFT-90-14, May 1990. 7pp.**

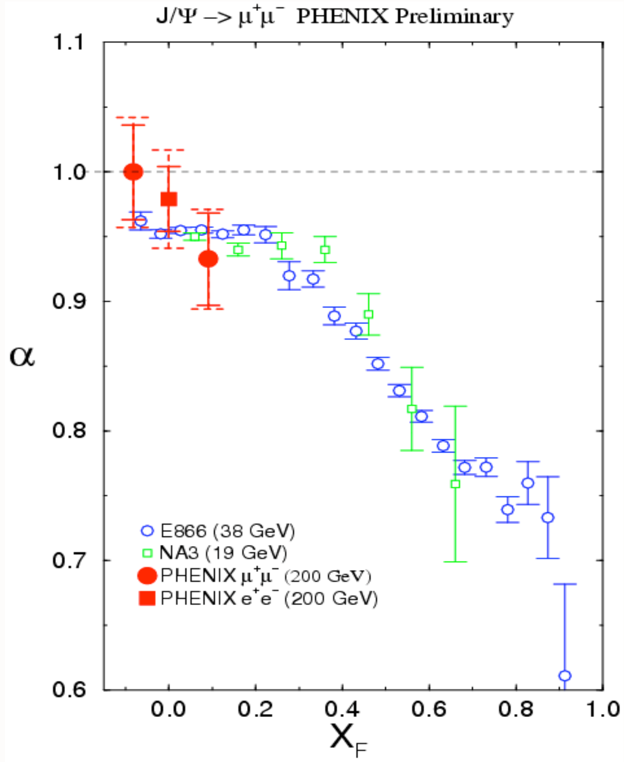
Published in Phys.Lett.B246:217-220,1990

J/ψ nuclear dependence vrs rapidity, x_{Au}, x_F

M.Leitch

PHENIX compared to lower energy measurements





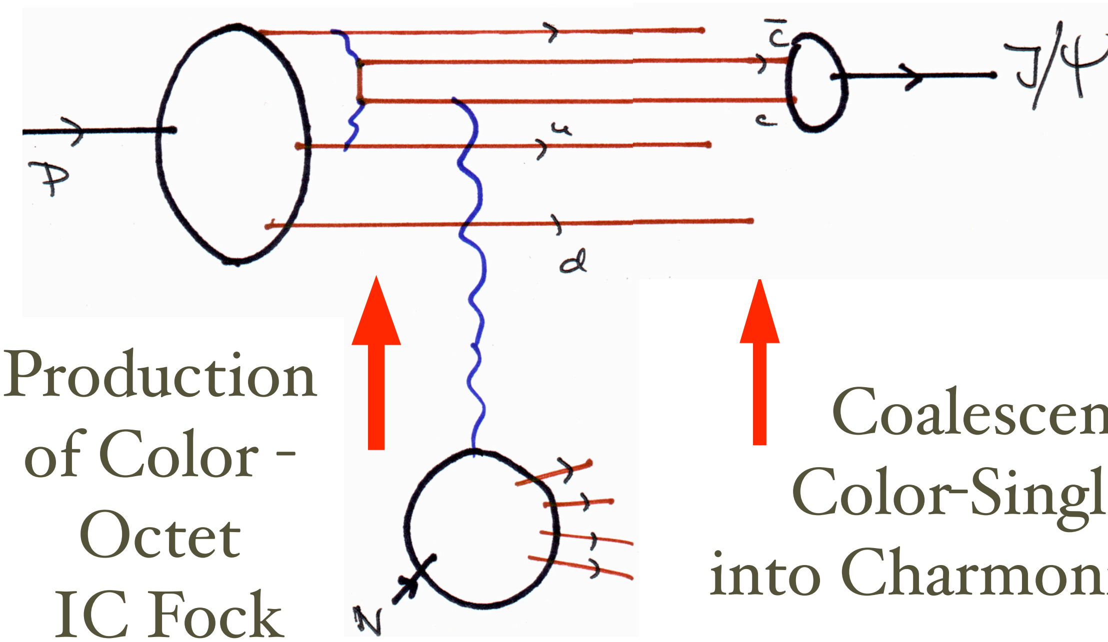
Klein,Vogt, PRL 91:142301,2003
Kopeliovich, NP A696:669,2001

Huge "absorption" effect

Violates PQCD factorization!

$$\frac{d\sigma}{dx_F}(pA \rightarrow J/\psi X)$$

Hoyer, Sukhatme, Vanttinen



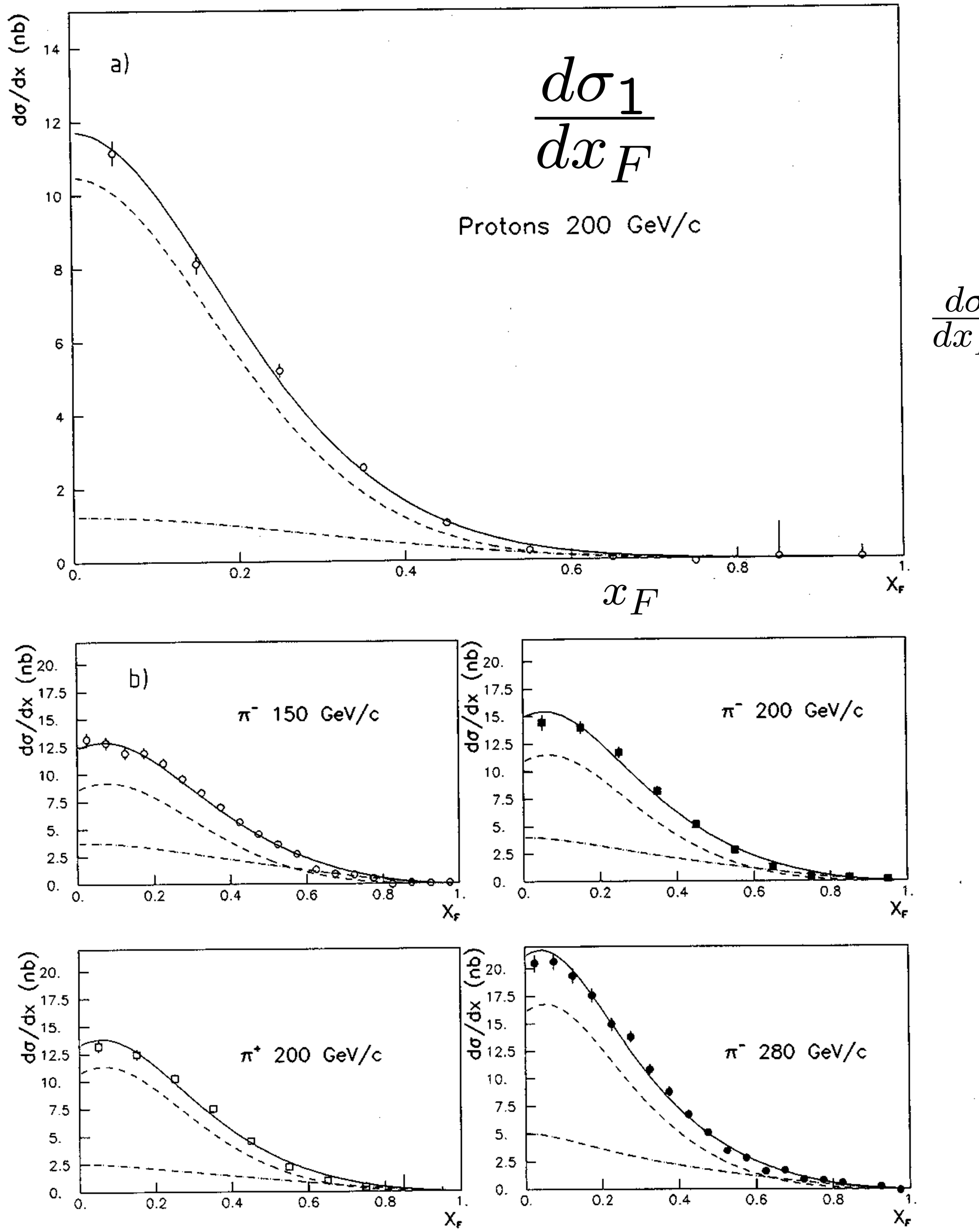
Production of Color - Octet IC Fock State

Coalescence of Color-Singlet Pair into Charmonium State

Scattering on Nucleon via one Gluon

In nuclear case, Color-Octet IC Fock state absorbed on front surface

$$\frac{d\sigma}{dx_F}(pA \to J/\psi X) = A^{2/3} \times \frac{d\sigma}{dx_F}(pN \to J/\psi X)$$



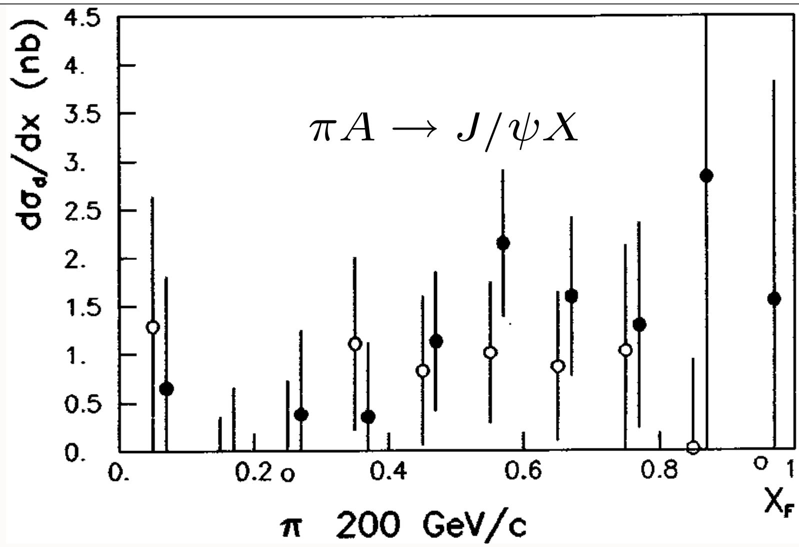
$\frac{d\sigma_1}{dx_F}(\pi A \to J/\psi X)$

J. Badier et al, NA3

$$\frac{d\sigma}{dx_F}(pA \to J/\psi X) = A^1 \frac{d\sigma_1}{dx_F} + A^{2/3} \frac{d\sigma_{2/3}}{dx_F}$$

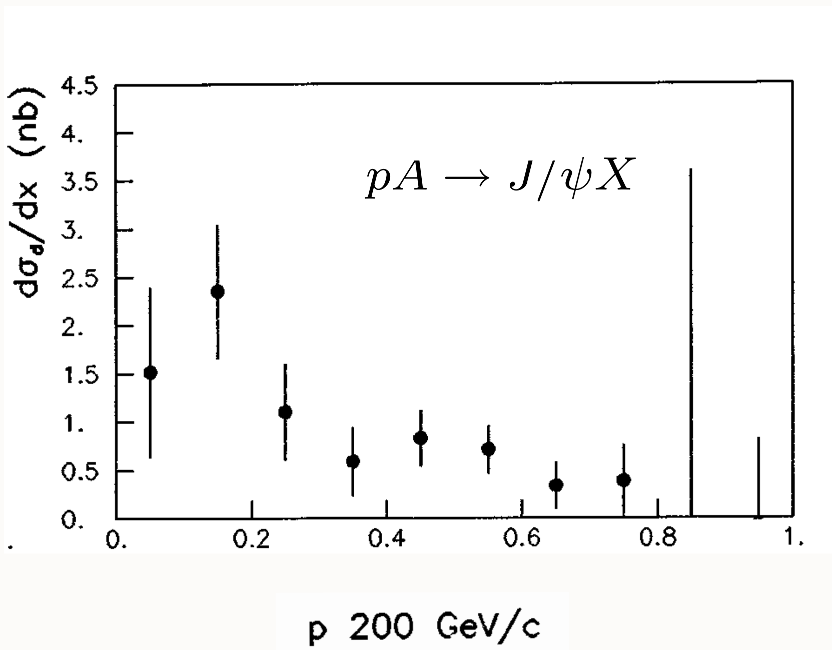
A^1 component

Fits conventional PQCD subprocesses



$A^{2/3}$ component

J. Badier et al, NA3



$$\frac{d\sigma}{dx_F}(pA \to J/\psi X) = A^1 \frac{d\sigma_1}{dx_F} + A^{2/3} \frac{d\sigma_{2/3}}{dx_F}$$

Excess beyond conventional PQCD subprocesses

- IC Explains Anomalous $\alpha(x_F)$ not $\alpha(x_2)$ dependence of $pA \rightarrow J/\psi X$
(Mueller, Gunion, Tang, SJB)

- Color Octet IC Explains $A^{2/3}$ behavior at high x_F (NA3, Fermilab)
(Kopeliovitch, Schmidt, Soffer, SJB)

Color Opaqueness

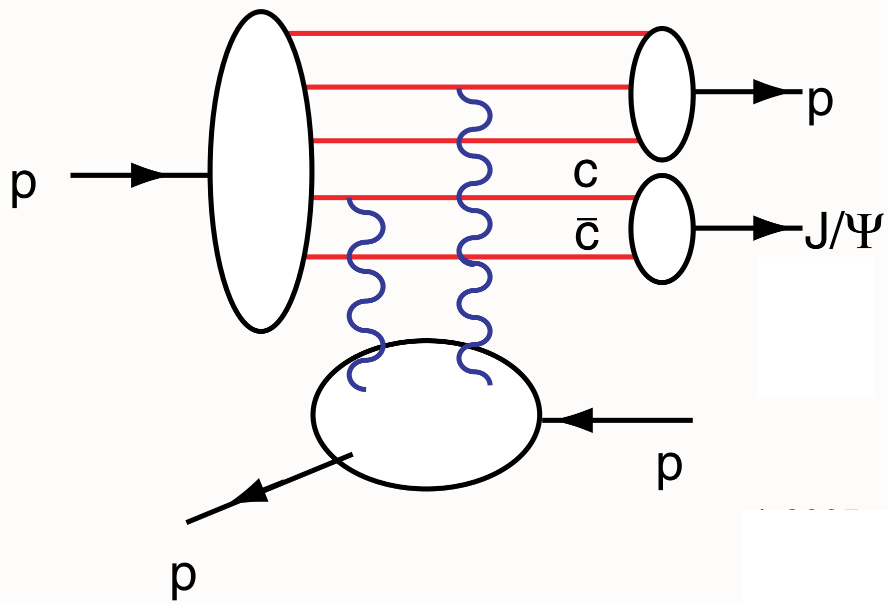
- IC Explains $J/\psi \rightarrow \rho\pi$ puzzle
(Karliner, SJB)

- IC leads to new effects in B decay
(Gardner, SJB)

Higgs production at x_F = 0.8

Kopeliovitch, Schmidt, Soffer, sjb

Intrinsic Charm Mechanism for Exclusive Diffraction Production



$$pp \rightarrow p + J/\psi + p$$

$$x_{J/\psi} = x_c + x_{\bar{c}}$$

Produces $(C = -)$ $J/\psi, \Upsilon$

Same IC mechanism explains $A^{2/3}$ high x_F J/ψ hadroproduction

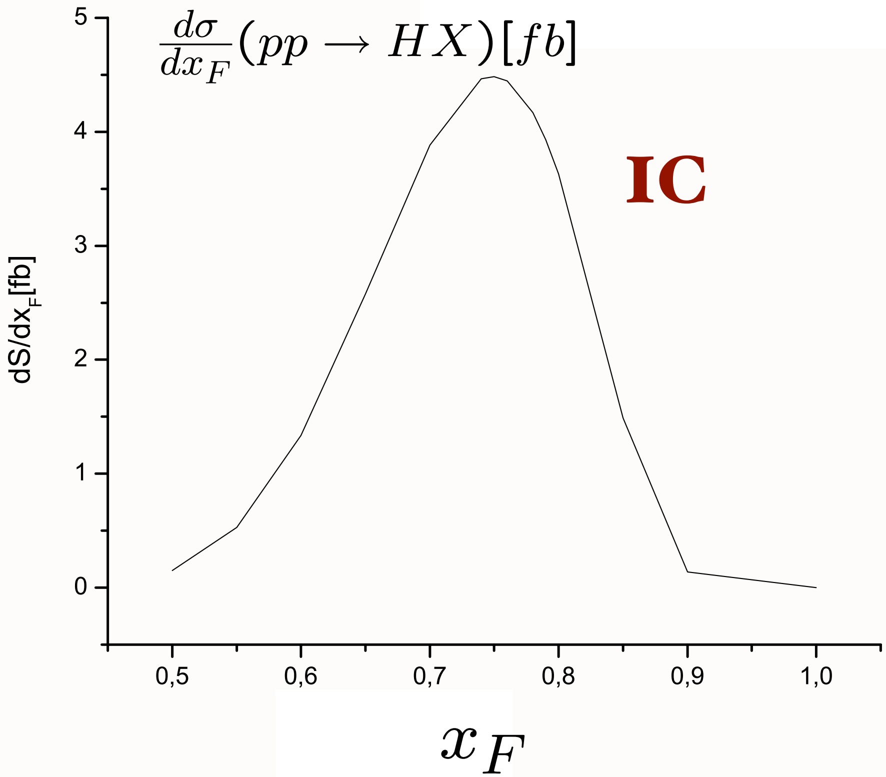
Intrinsic $c\bar{c}$ pair formed in color octet 8_C in proton wavefunction Large Color Dipole

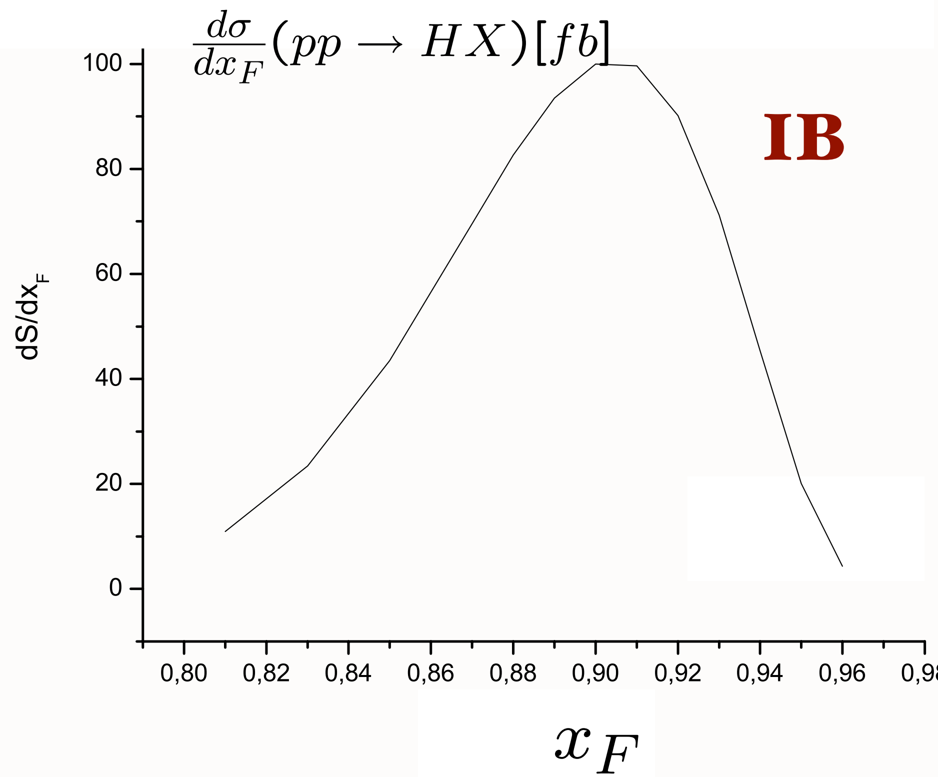
Collision produces color-singlet J/ψ through color exchange

RHIC Experiment

Kopeliovitch, Schmidt, sjb

Intrinsic Charm and Bottom Contribution to Inclusive Higgs Production

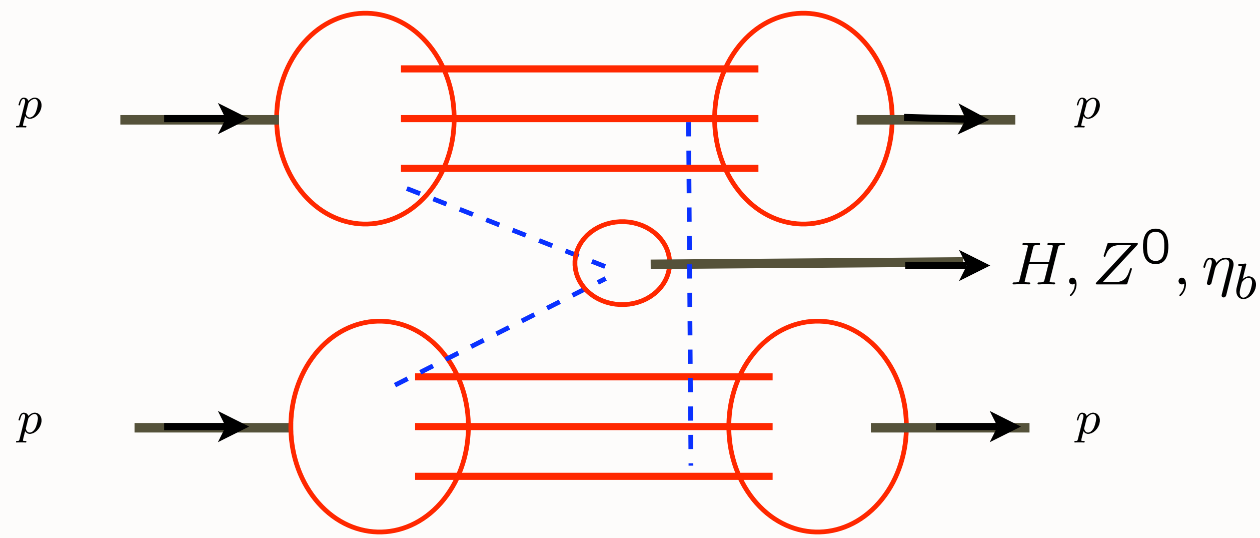




Doubly diffractive Higgs production

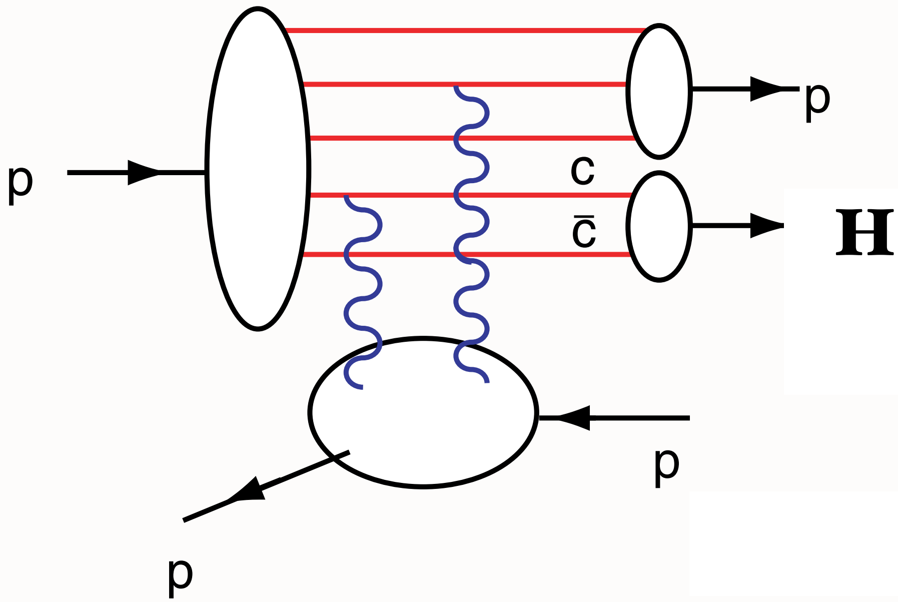
$$pp \to p + H + p$$

Nucleus-Nucleus at the LHC



De Roeck, V.A. Khoze, A.D.Martin, R.Orava M.G.Ryskin,

Intrinsic Charm Mechanism for Exclusive Diffractive High-X_F Higgs Production



$$pp \rightarrow p + H + p$$

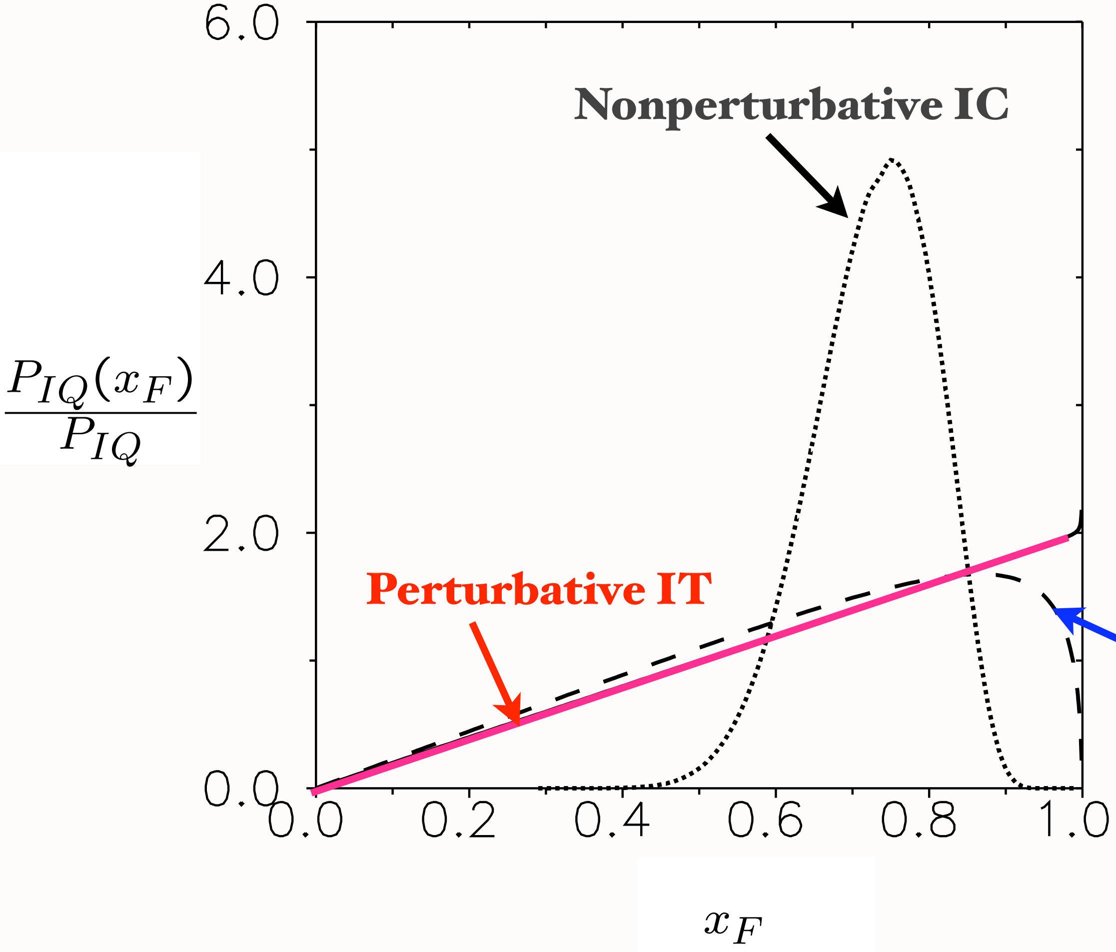
Also: intrinsic bottom, top

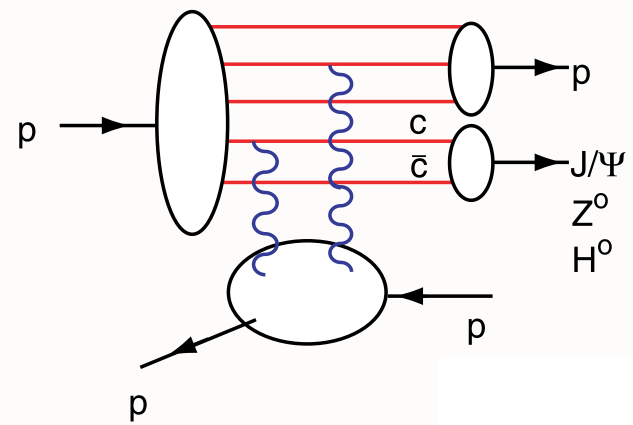
Kopeliovitch, Schmidt, Soffer, sjb

Higgs can have 80% of Proton Momentum!

RHIC Experiment

Intrinsic Charm Mechanism for Exclusive Diffraction Production





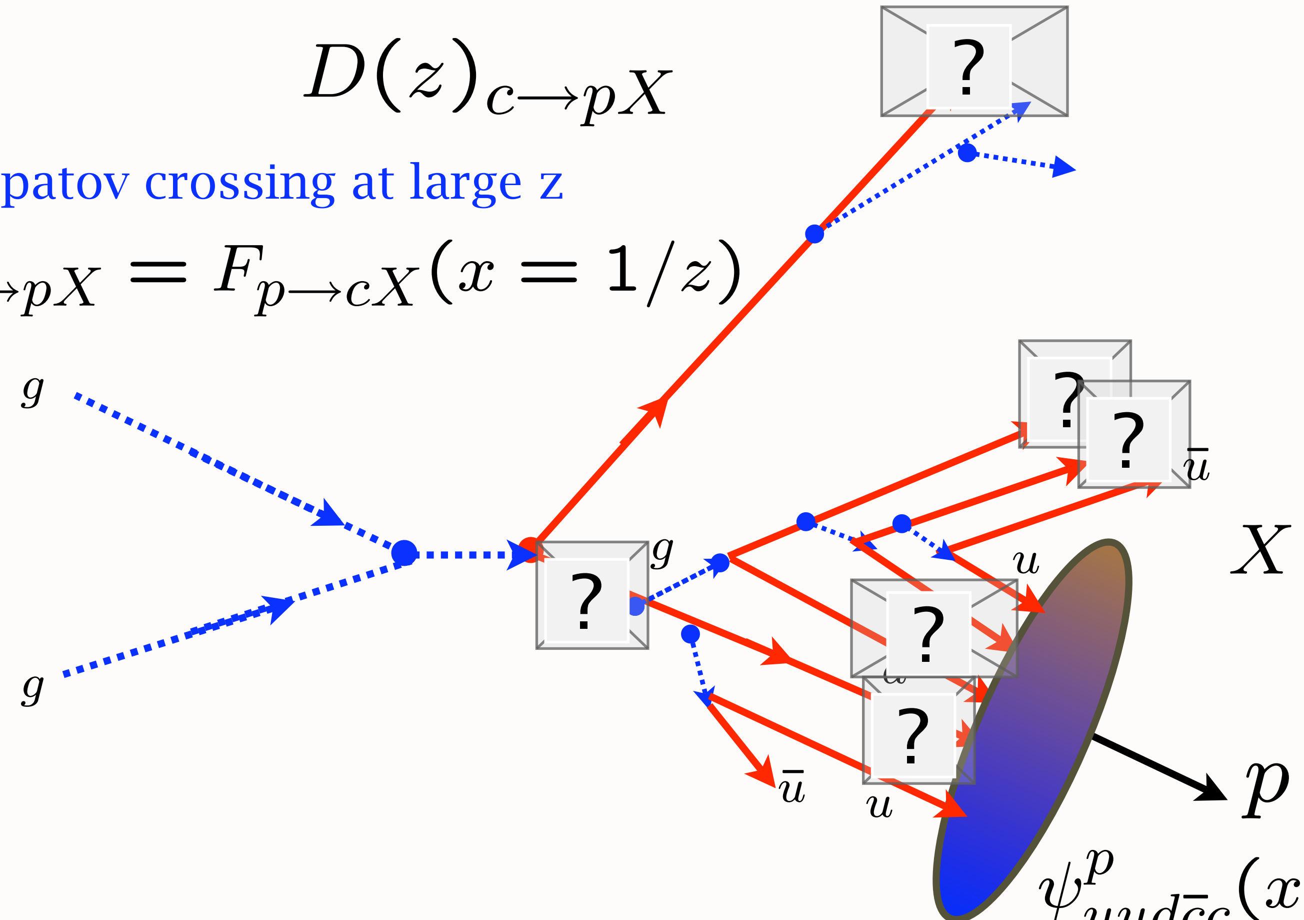
Kopeliovitch, Schmidt, Soffer, sjb

Timelike Test of Charm Distribution in Proton

$$D(z)_{c \to pX}$$

Gribov-Lipatov crossing at large z

$$zD(z)_{c \to pX} = F_{p \to cX}(x = 1/z)$$



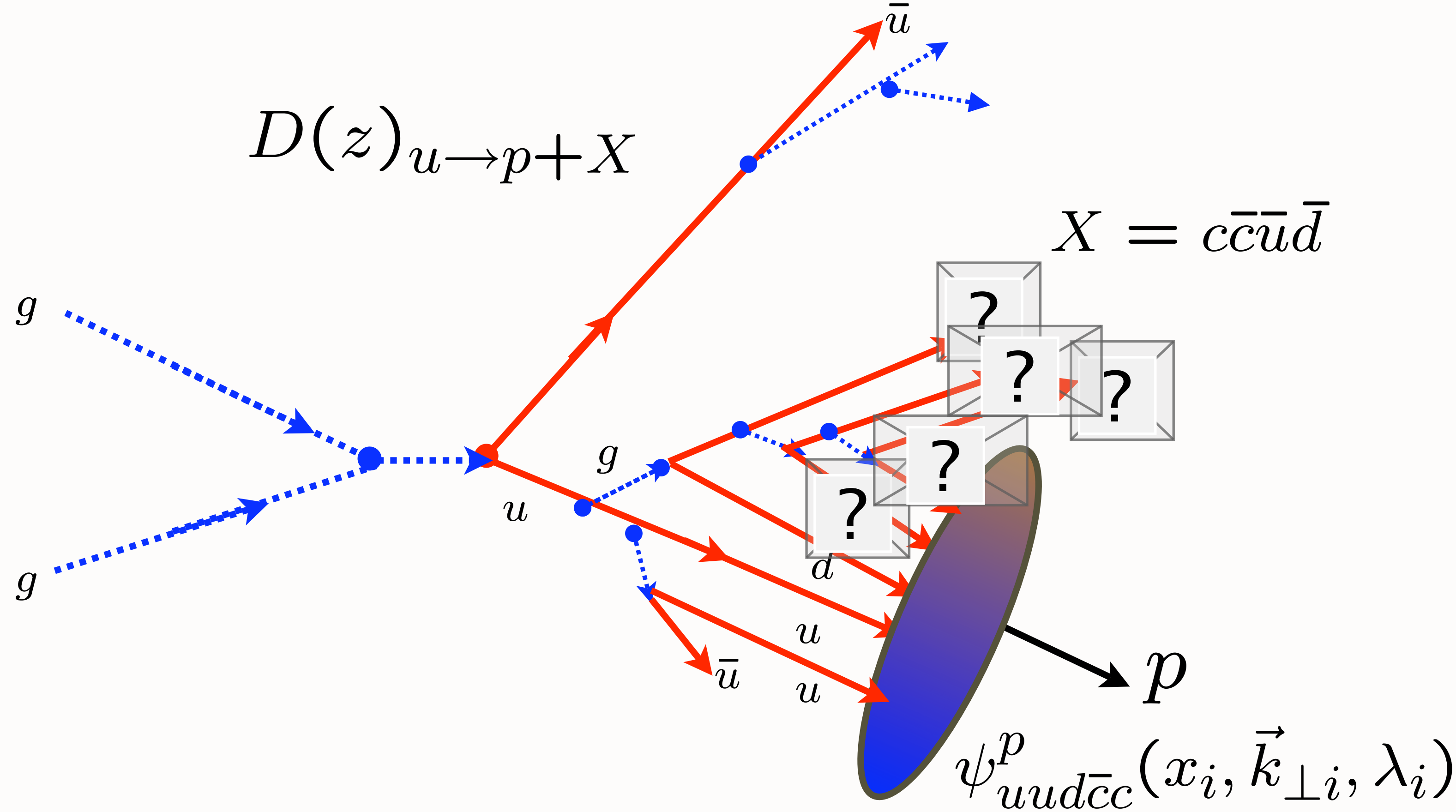
$$X = c\bar{u}\bar{d}\bar{u}$$

$$\psi^p_{uud\bar{c}c}(x_i, \vec{k}_{\perp i}, \lambda_i)$$

Intrinsic charm model:
predict proton at same rapidity as charm quark: high z

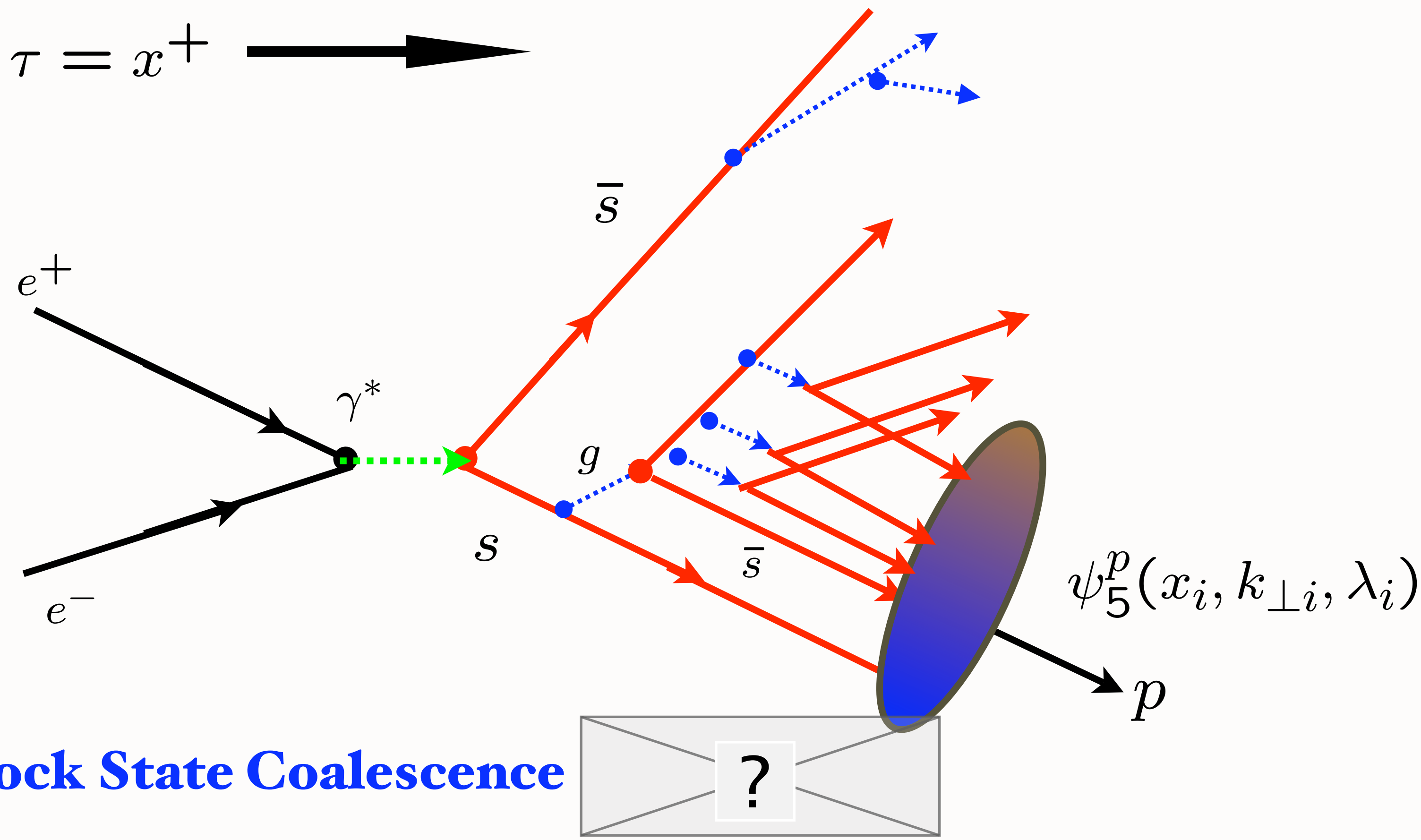
$$z_i \propto m_{\perp i} = \sqrt{m_i^2 + k_\perp^2}$$

Distribution of spectators in X reflects proton bound-state structure



Intrinsic charm model: predict dual spectator charm hadrons at same rapidity as proton: high z

Hadronization at the Amplitude Level

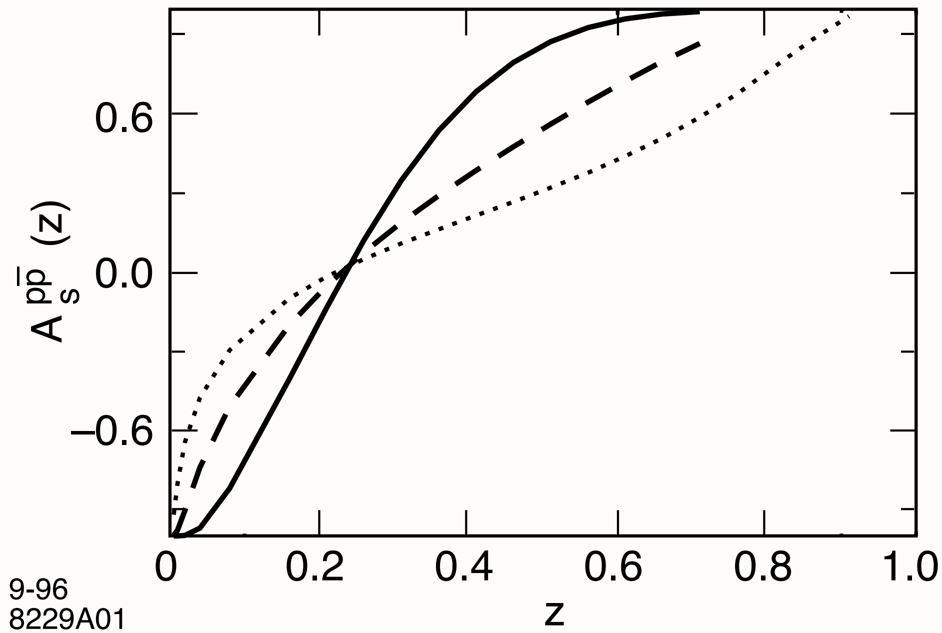


Higher Fock State Coalescence

Asymmetric Hadronization ! $D_{s\to p}(z) \neq D_{s\to\bar{p}}(z)$

B-Q Ma, sjb

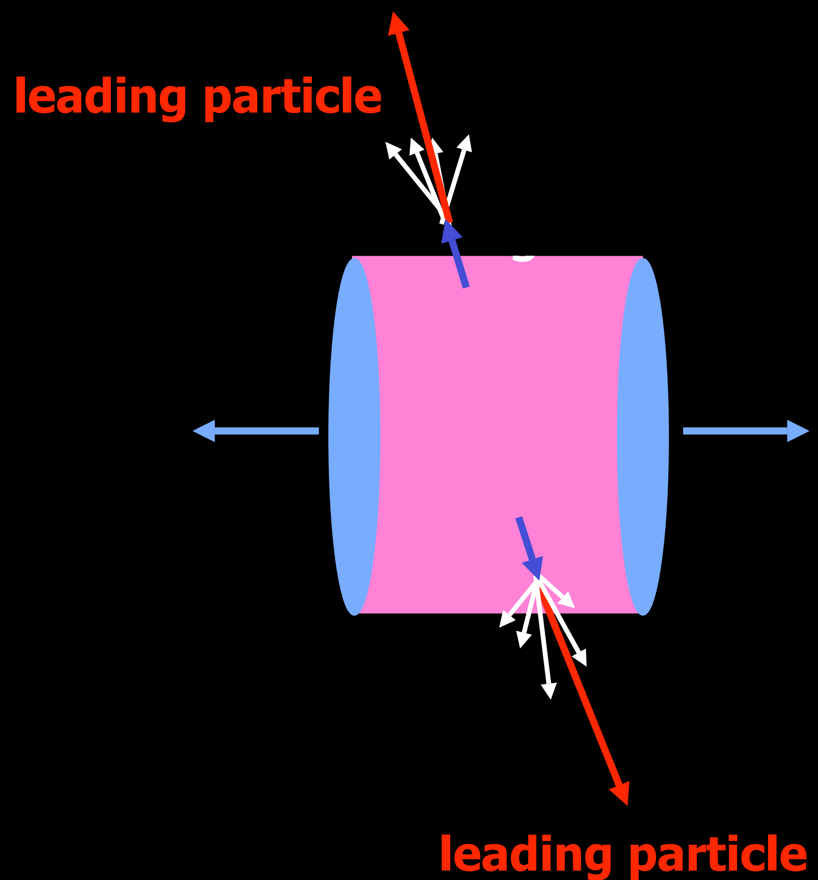
$$D_{s\to p}(z) \neq D_{s\to\bar{p}}(z)$$



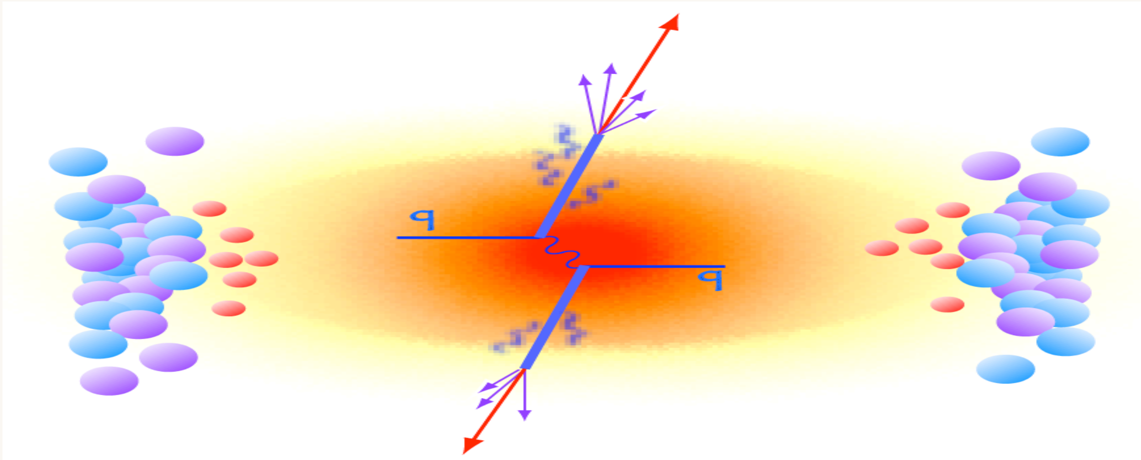
$$A_s^{p\bar{p}}(z) = \frac{D_{s\to p}(z) - D_{s\to\bar{p}}(z)}{D_{s\to p}(z) + D_{s\to\bar{p}}(z)}$$

Consequence of $s_p(x) \neq \bar{s}_p(x)$ $\quad |uuds\bar{s} > \simeq |K^+\Lambda >$

Probing Hot QCD Matter with Hard-Scattered Probes



What is the dynamical mechanism which creates the QGP?



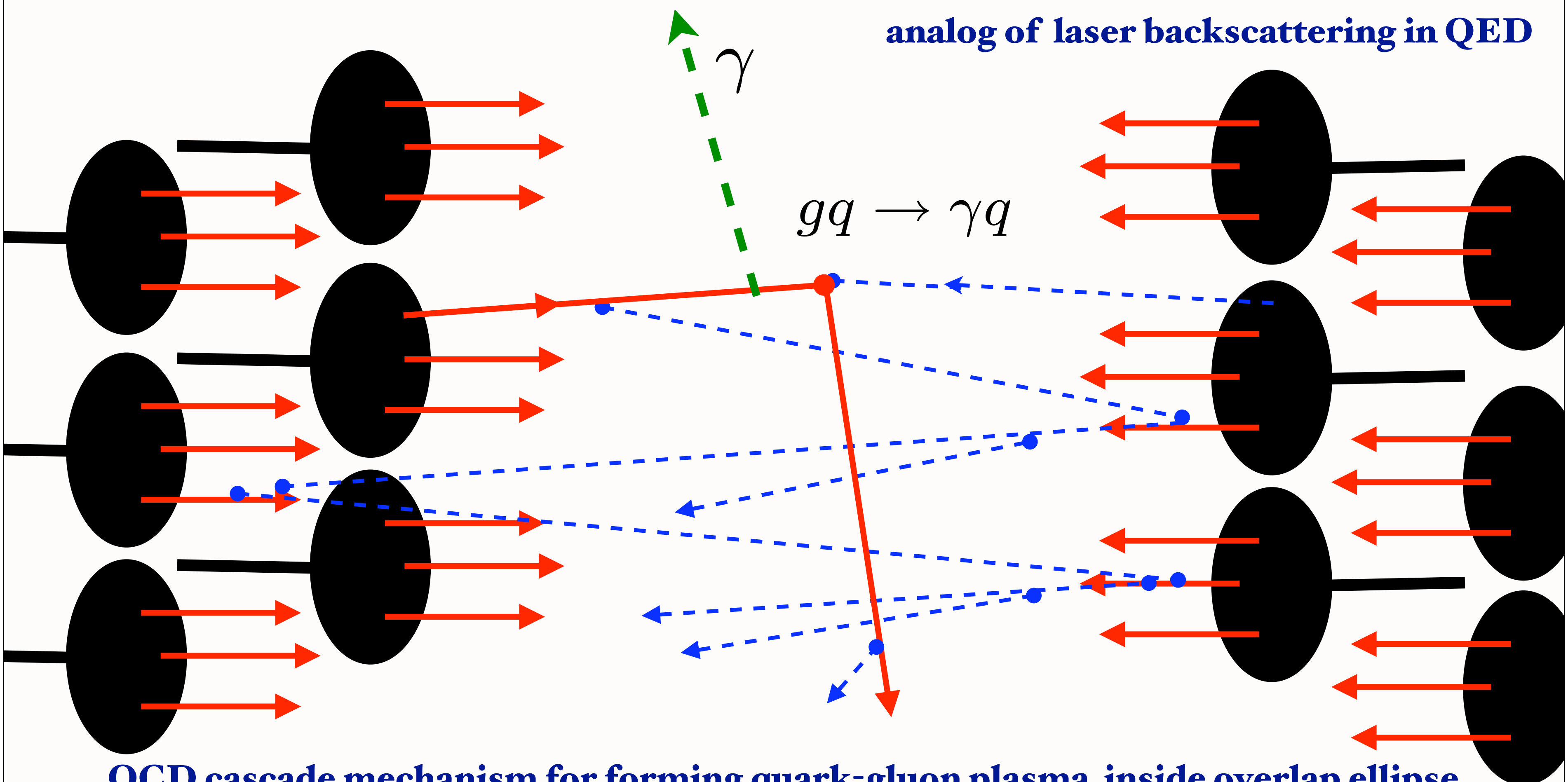
- How do the parameters of the QGP depend on the initial and final state conditions?

- A dynamical model: "Gluonic Laser"

Gluonic Laser

Gluonic bremsstrahlung from initial hard scattering backscatters on nuclear ``mirrors"

analog of laser backscattering in QED



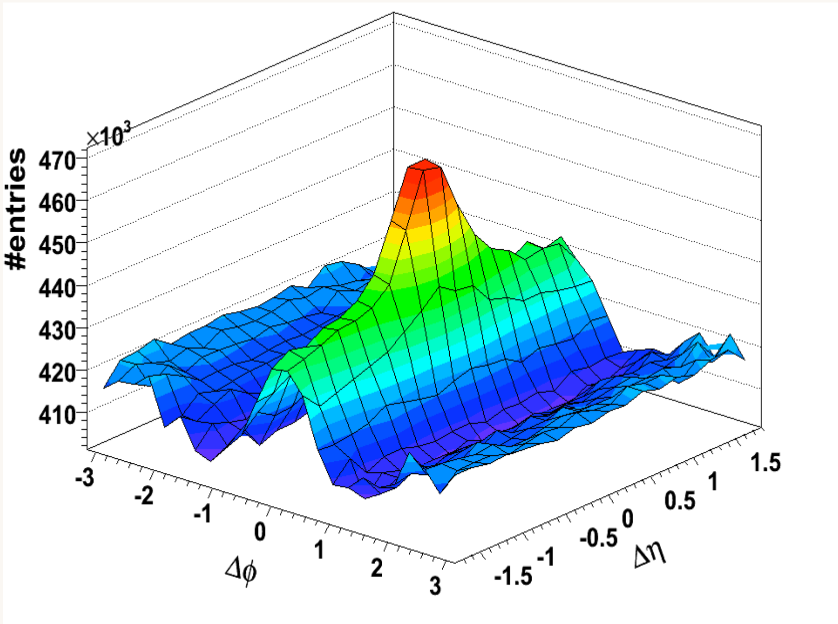
QCD cascade mechanism for forming quark-gluon plasma inside overlap ellipse

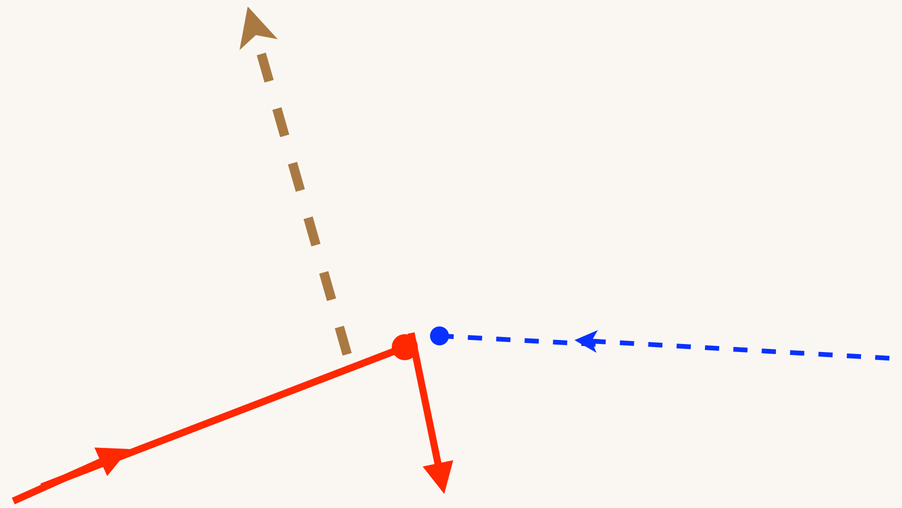
energy loss from stimulated radiation of away-side jet

Possible time sequence of a RHIC Ion-Ion Collision

- **Nuclei collide; nucleons overlap within an ellipse**
- **Initial hard collision between quarks and/or gluons producing high p_T trigger hadron or photon**
- **Induced gluon radiation radiated from initial parton collision**
- **collinear radiation back-scatters on other incoming partons**
- **Cascading gluons creates multi-parton quark-gluon plasma within ellipse, thermalization**
- **Stimilated radiation contributes to energy loss of away-side jet**
- **Sidewise pressure creates hadronic energy along minor axis -- yields planar $\cos 2\phi$ correlation: v_2**
- **Same final state for high p_T direct photons and mesons**
- **Baryons formed in higher-twist double-scattering process at high x_T; double induced radiation and thus double v_2.**

Consequences of Gluon Laser Mechanism





Ridge created by trigger bias (Cronin effect)

Momenta of initial colored partons biased towards trigger

Soft gluon radiation from initial state partons emitted in plane of production; fills rapidity

Many Heavy-Ion Two-Photon Tests

- All Exclusive Final States
- Inclusive Reactions from Photon Structure Function
- Virtuality of photon limited by nuclear size
- Test of Pomeron, Odderon
- Charge asymmetry from Photon-Pomeron or Higher Order QED interference
- Coulomb-diffractive on one nucleus
- Pure QED from Light-by-Light

QCD Opportunities at B-Factories

- **Fundamental tests of hadron structure, dynamics, and wavefunctions**
- **Tests of novel nonperturbative and perturbative QCD phenomena**
- **Hadronization at the amplitude level**
- **Scale-fixed predictions, commensurate scale relations**
- **Tests of AdS/CFT holography**
- **Production of new gluonium, heavy quark, and C=+ states**
- **Novel diffraction, spin, and fractional charge tests**

Topics

- Hadronization at the Amplitude Level and AdS/CFT
- Diffractive Dijets and LFWFs
- Direct Processes
- Intrinsic Heavy Quark Distributions and Novel Higgs Production Mechanisms
- Theory of Shadowing and AntiShadowing
- Leading Twist Diffraction
- Fixed x_T scaling
- Dangling Gluons
- Gluon Laser