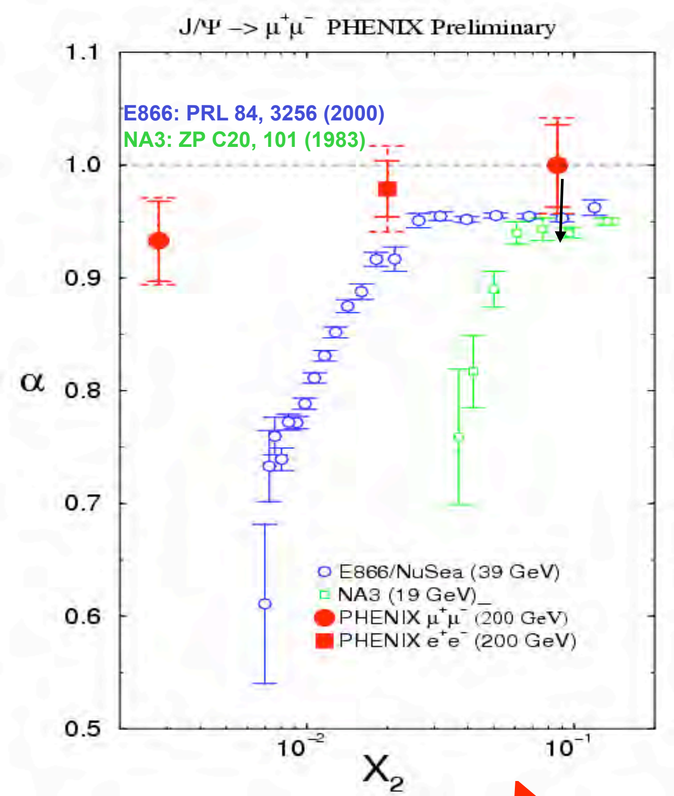
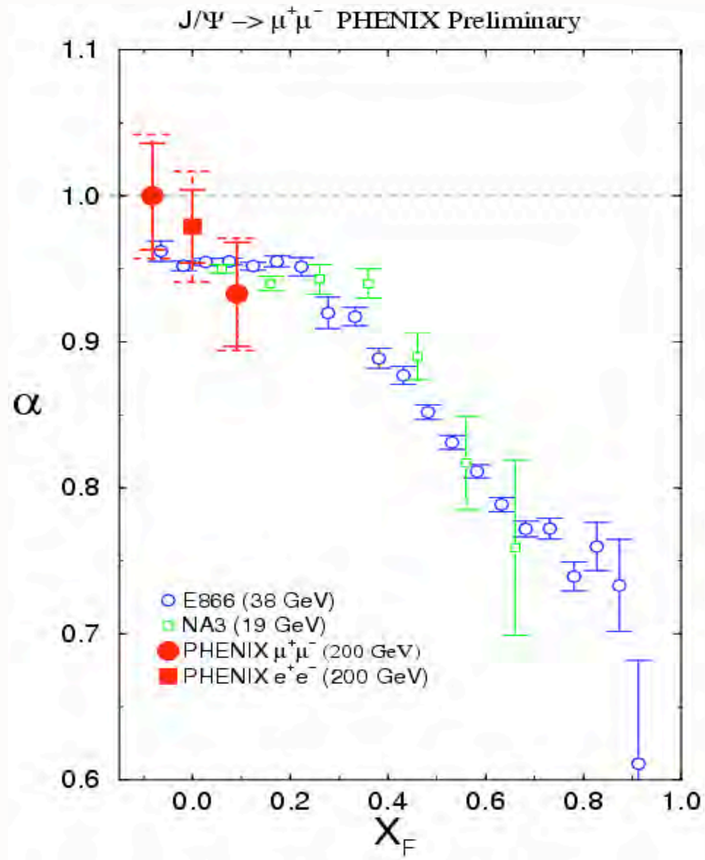
J/ψ nuclear dependence vrs rapidity, x_{Au}, x_F

M.Leitch

PHENIX compared to lower energy measurements





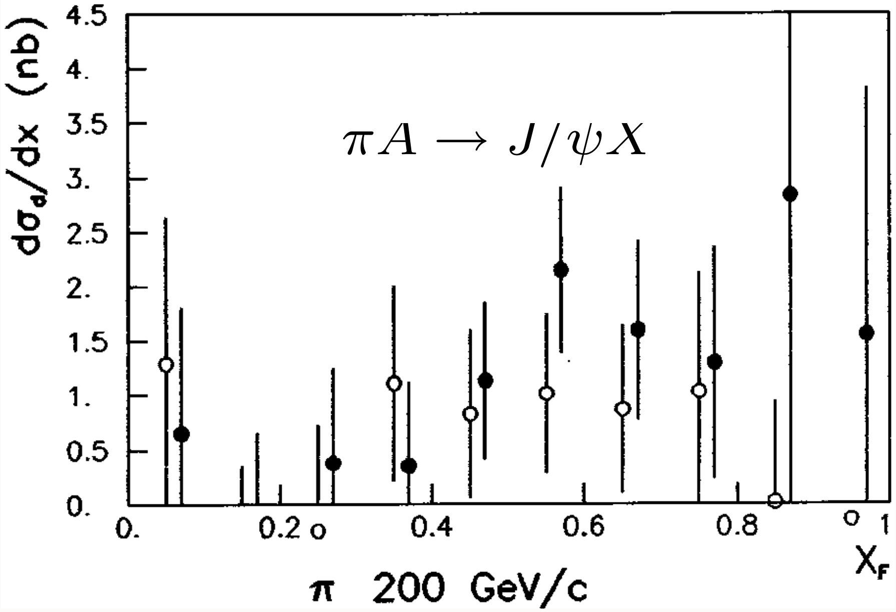
Klein,Vogt, PRL 91:142301,2003
Kopeliovich, NP A696:669,2001

Huge "absorption" effect

Violates PQCD factorization!

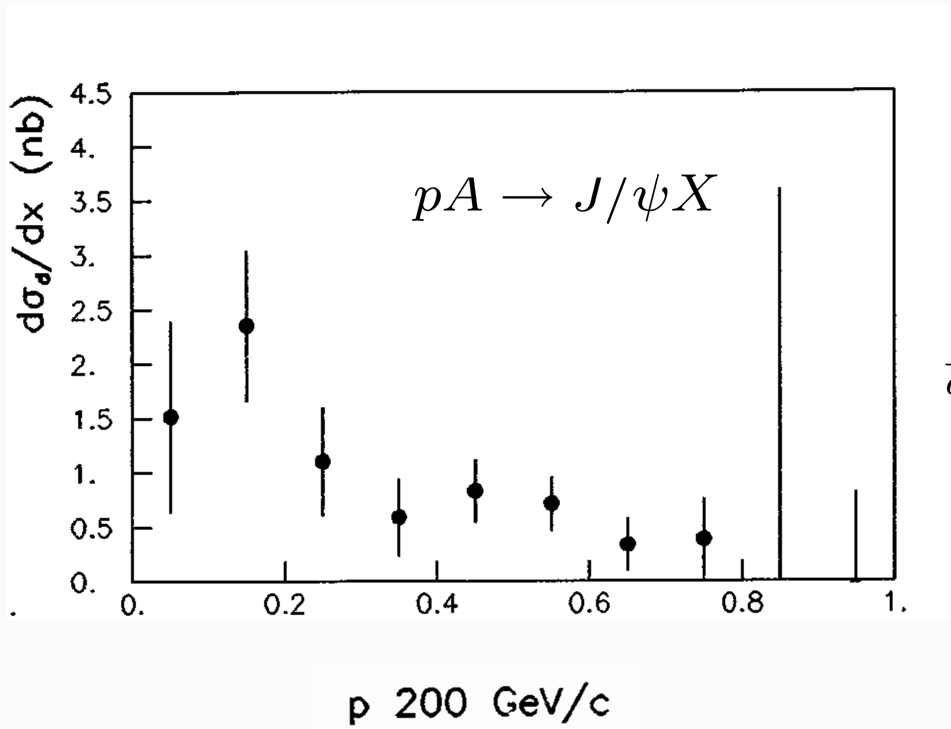
$$\frac{d\sigma}{dx_F}(pA \to J/\psi X)$$

Hoyer, Sukhatme, Vanttinen



$A^{2/3}$ component

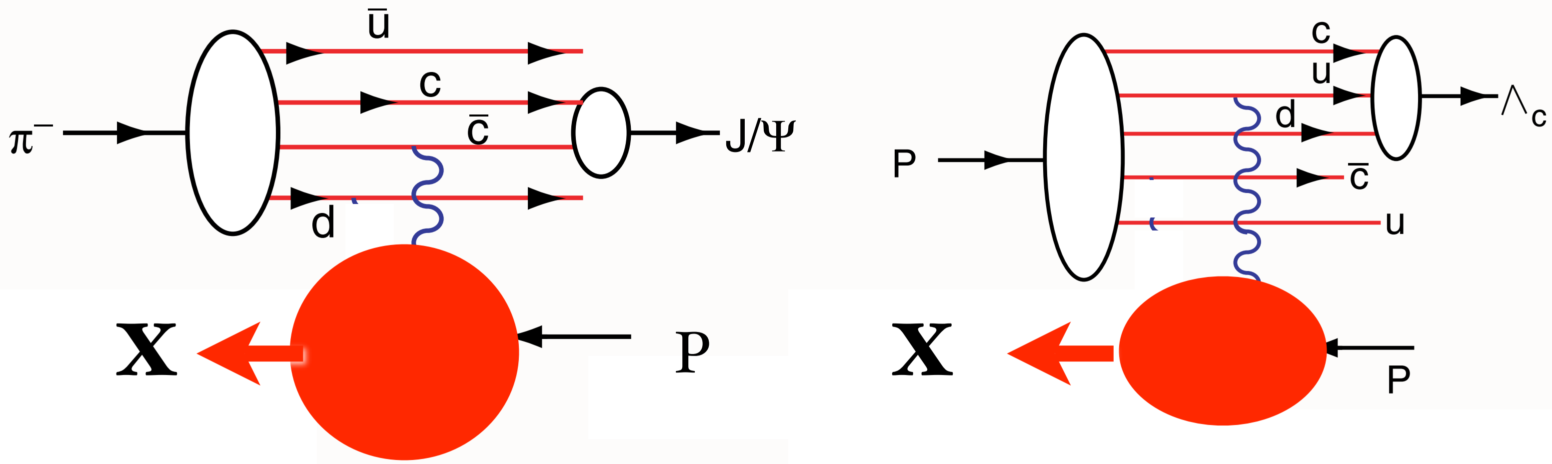
J. Badier et al, NA3



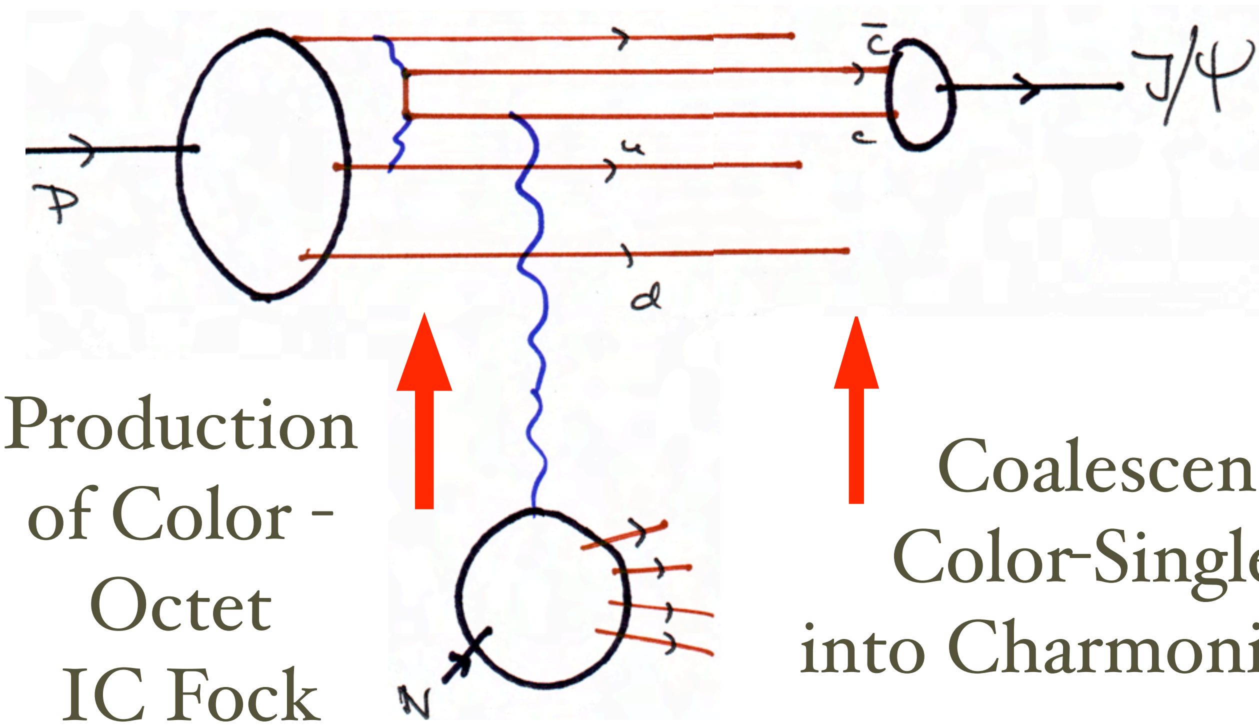
$$\frac{d\sigma}{dx_F}(pA \to J/\psi X) = A^1 \frac{d\sigma_1}{dx_F} + A^{2/3} \frac{d\sigma_{2/3}}{dx_F}$$

Excess beyond conventional PQCD subprocesses

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



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

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

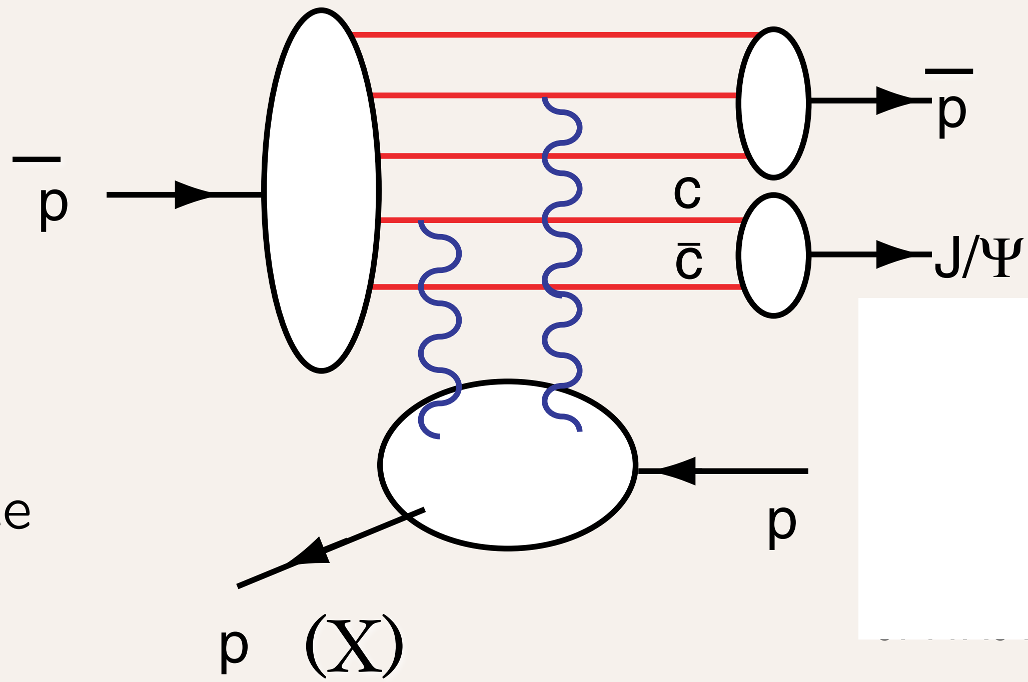
Key QCD Experiment at FAIR

Measure diffractive hidden charm production at forward x_F

Even close to threshold

$$\frac{d\sigma}{dt_1 dt_2 dx_F}(\overline{p}p \to \overline{p} + J/\psi + p)$$

$$\frac{d\sigma}{dt dx_F}(\overline{p}p \to \overline{p} + J/\psi + X)$$

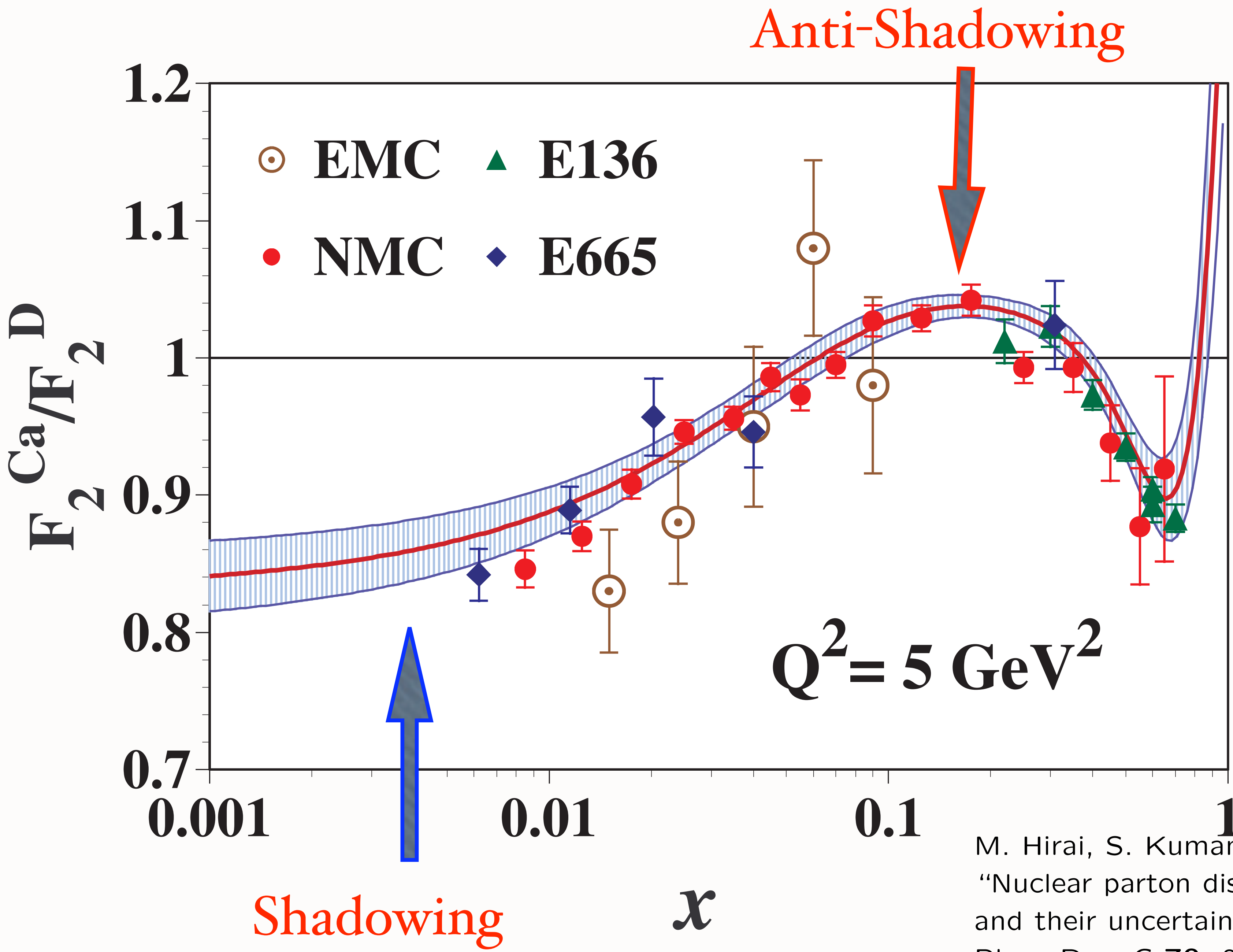


Anomalous nuclear dependence

$$\frac{d\sigma}{dx_F}(\overline{p}A \to J/\psi + X)$$

$A^{\alpha(x_2)}$ versus $A^{\alpha(x_F)}$

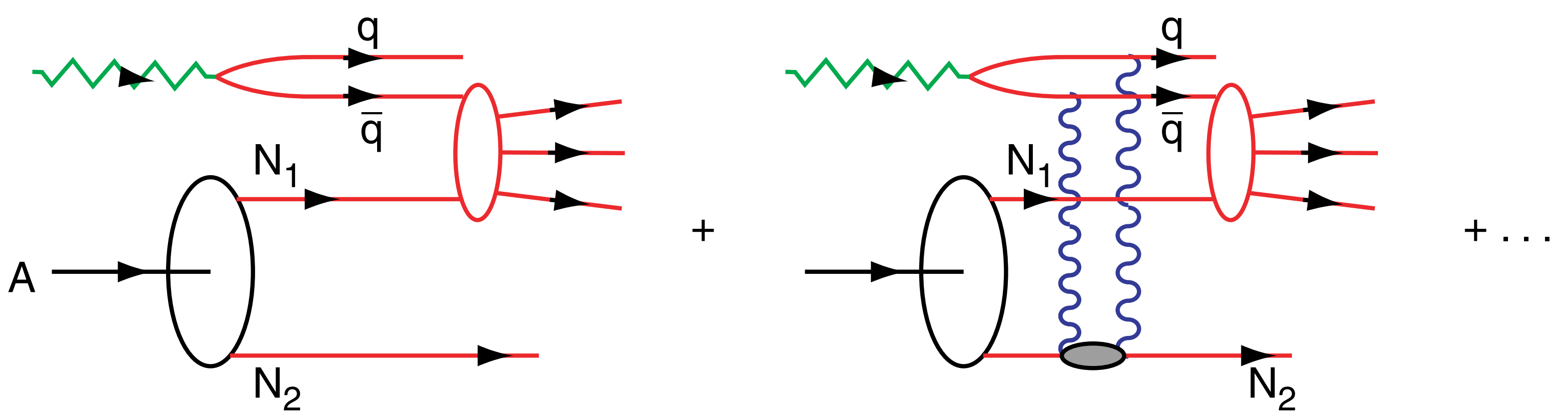
Important Tests of Intrinsic Charm



M. Hirai, S. Kumano and T. H. Nagai, "Nuclear parton distribution functions and their uncertainties," Phys. Rev. C **70**, 044905 (2004) [arXiv:hep-ph/0404093].

Stodolsky
Pumplin, sjb
Gribov

Nuclear Shadowing in QCD



Shadowing depends on understanding leading twist-diffraction in DIS

Nuclear Shadowing not included in nuclear LFWF !

Dynamical effect due to virtual photon interacting in nucleus

Reggeon Exchange

Phase of two-step amplitude relative to one step:

$$\frac{1}{\sqrt{2}}(1-i)\times i = \frac{1}{\sqrt{2}}(i+1)$$

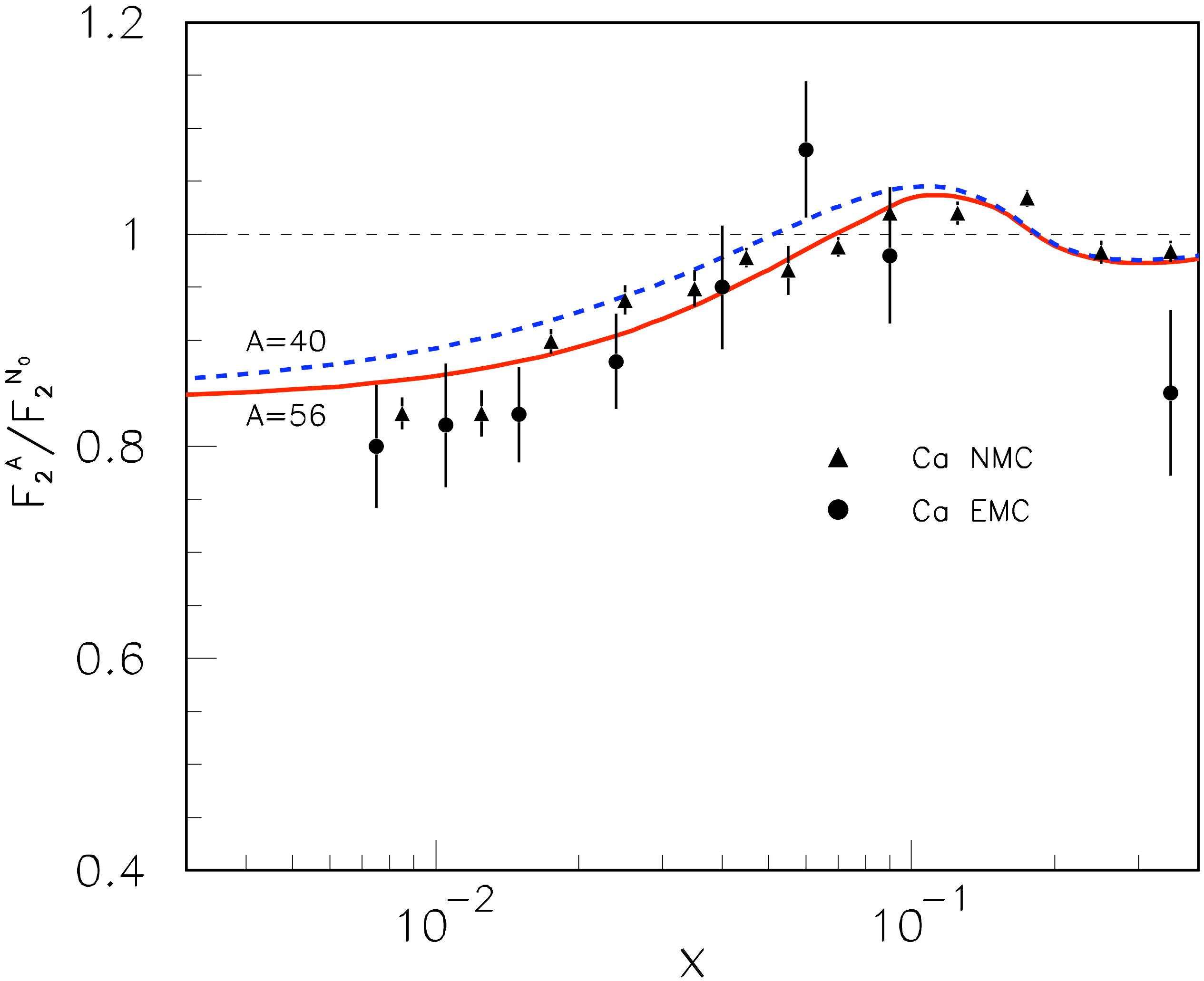
Constructive Interference

Depends on quark flavor!

Thus antishadowing is not universal

Different for couplings of $\gamma^*, Z^0, W^\pm$

Crtical test: Tagged Drell-Yan



Predicted nuclear shadowing and and antishadowing at $Q^2 = 1\ \text{GeV}^2$

S. J. Brodsky, I. Schmidt and J. J. Yang, "Nuclear Antishadowing in Neutrino Deep Inelastic Scattering," Phys. Rev. D 70, 116003 (2004) [arXiv:hep-ph/0409279].

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

Schmidt, Yang, sjb

Key QCD Experiment at FAIR

Measure Non-Universal Anti-Shadowing in Drell-Yan

$$\bar{p}A \to \ell^+\ell^- X$$

$$Q^2 = x_1 x_2 s \qquad x_1 x_2 = .05, x_F = x_1 - x_2$$

$$A^{\alpha}(x_1) = \frac{2\frac{d\sigma}{dQ^2 dx_F}(\bar{p}A \to \ell^+\ell^- X)}{A\frac{d\sigma}{dQ^2 dx_F}(\bar{p}d \to \ell^+\ell^- X)}$$

Flavor
u, d tag

Higher twist effects at high x_F:

Deviations from $(1 + \cos^2\theta)$

$\cos 2\phi$ correlation.

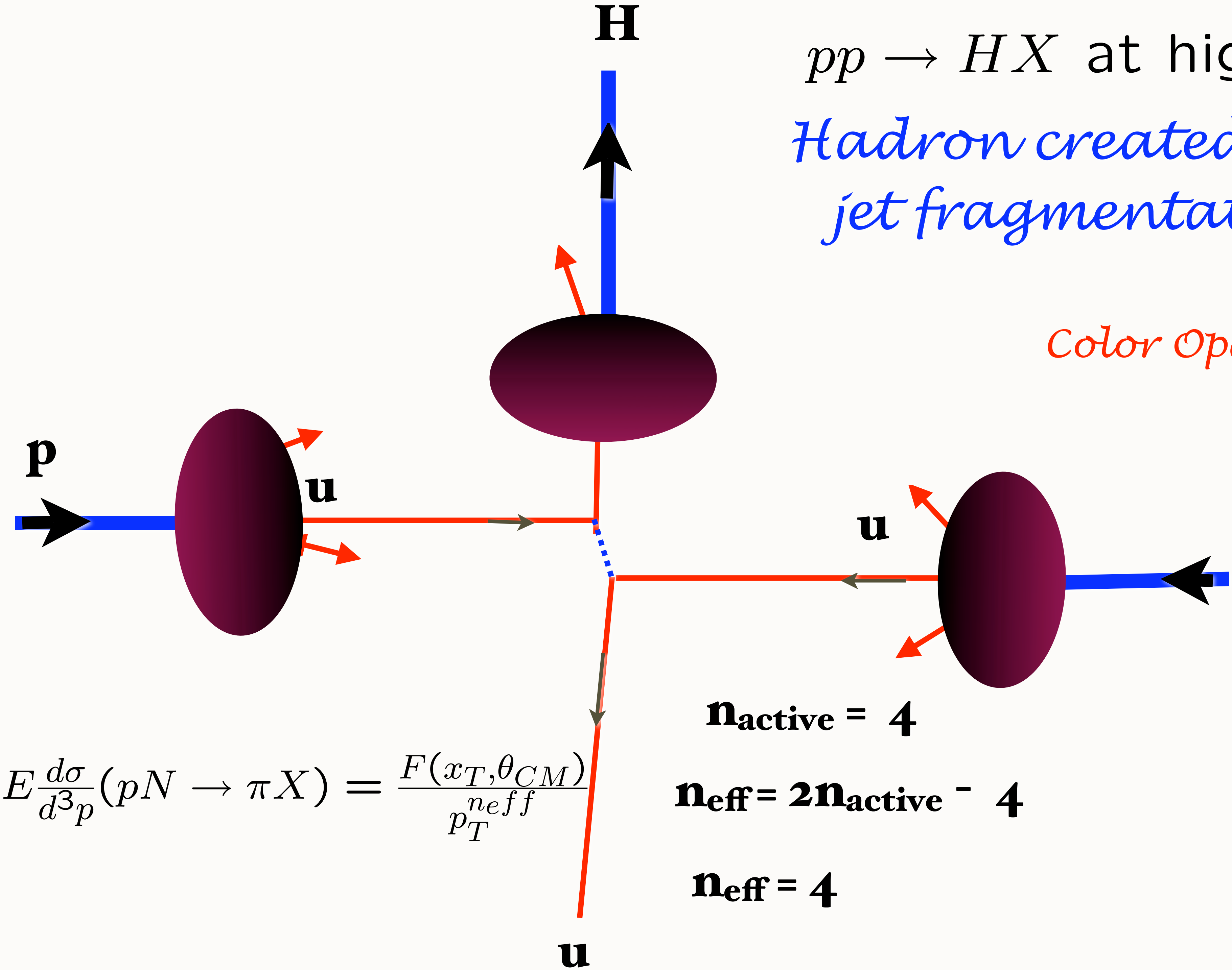
Topics for FAIR in Inclusive High Pt Reactions

Counting Rules at fixed $x_T = \frac{2p_T}{\sqrt{s}}$ and θ_{CM}

- Leading Twist vs Higher Twist Processes
- Charm at Threshold and QCD Schwinger-Sommerfeld Correction

$pp \longrightarrow HX$ at high p_T

Hadron created from jet fragmentation



Color Opaque

$$E\frac{d\sigma}{d^3p}(pN \rightarrow \pi X) = \frac{F(x_T, \theta_{CM})}{p_T^{neff}}$$

$n_{active} = 4$

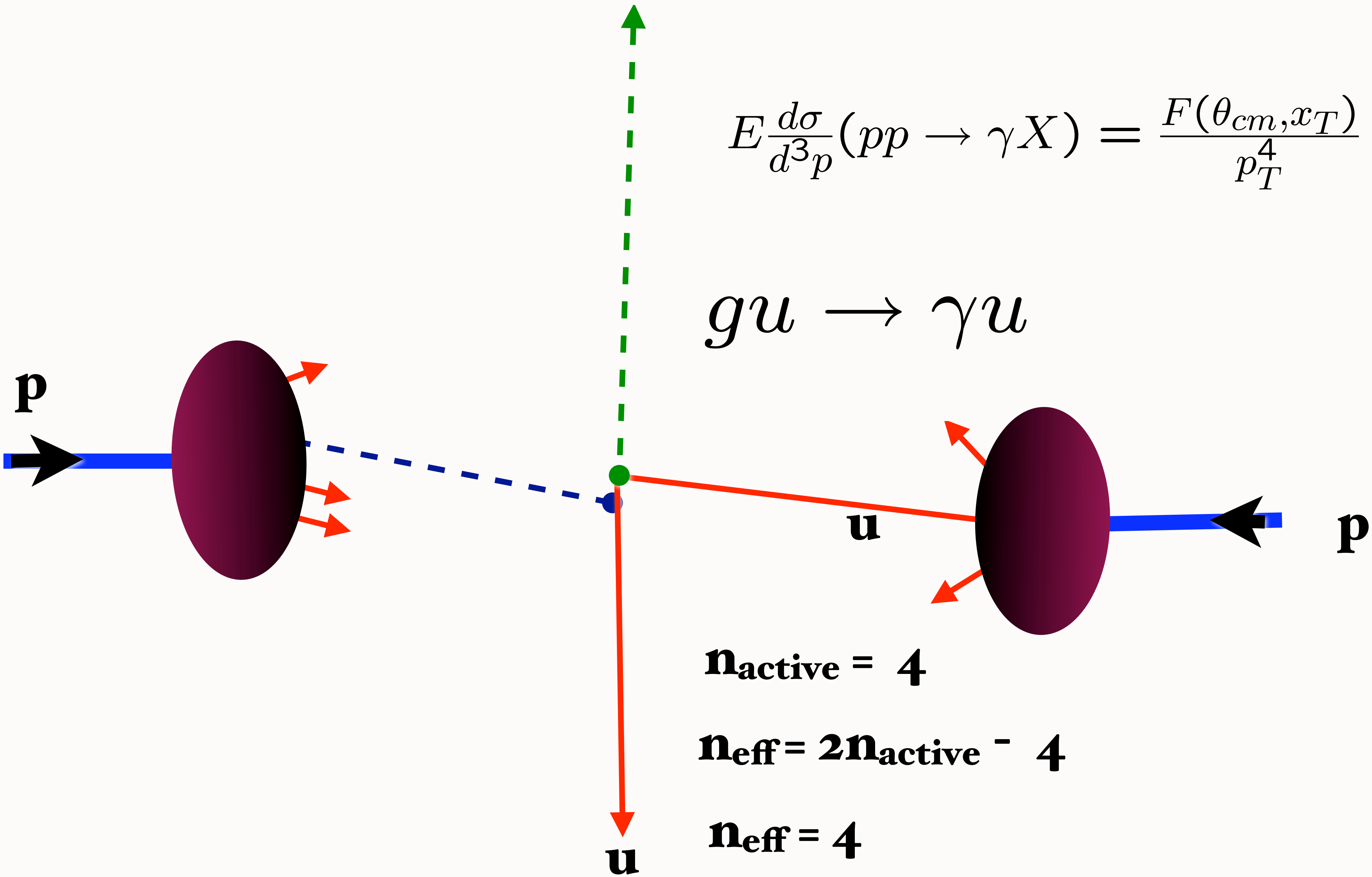
$n_{eff} = 2n_{active} - 4$

$n_{eff} = 4$

$$pp \to \gamma X$$

$$E\frac{d\sigma}{d^3p}(pp \to \gamma X) = \frac{F(\theta_{cm}, x_T)}{p_T^4}$$

$$gu \to \gamma u$$



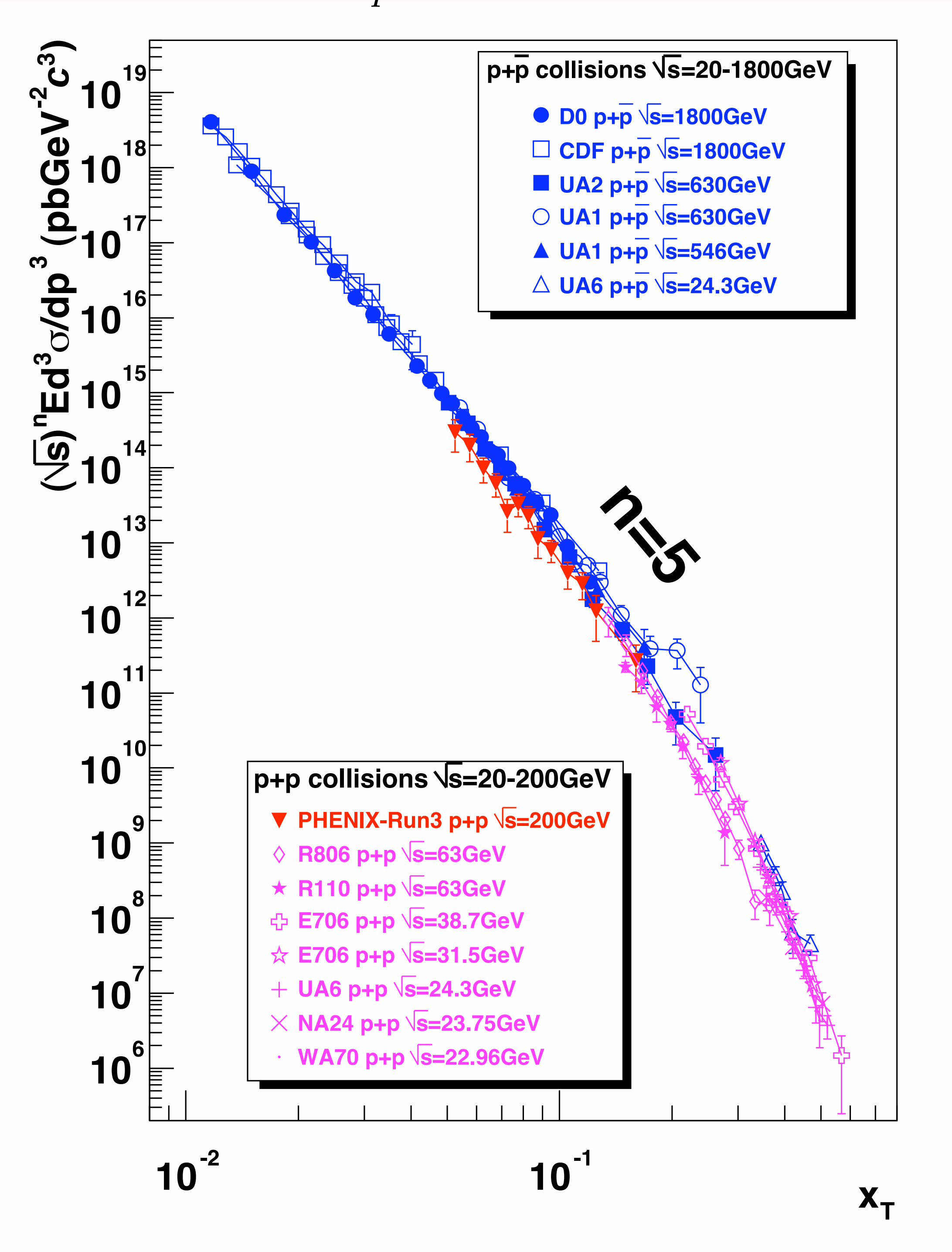
$n_{active} = 4$

$n_{eff} = 2n_{active} - 4$

$n_{eff} = 4$

$\sqrt{s}^n E\frac{d\sigma}{d^3p}(pp \to \gamma X)$ at fixed x_T

Tannenbaum



x_T-scaling of direct photon production is consistent with PQCD

Crucial Test of Leading -Twist QCD: Scaling at fixed x_T

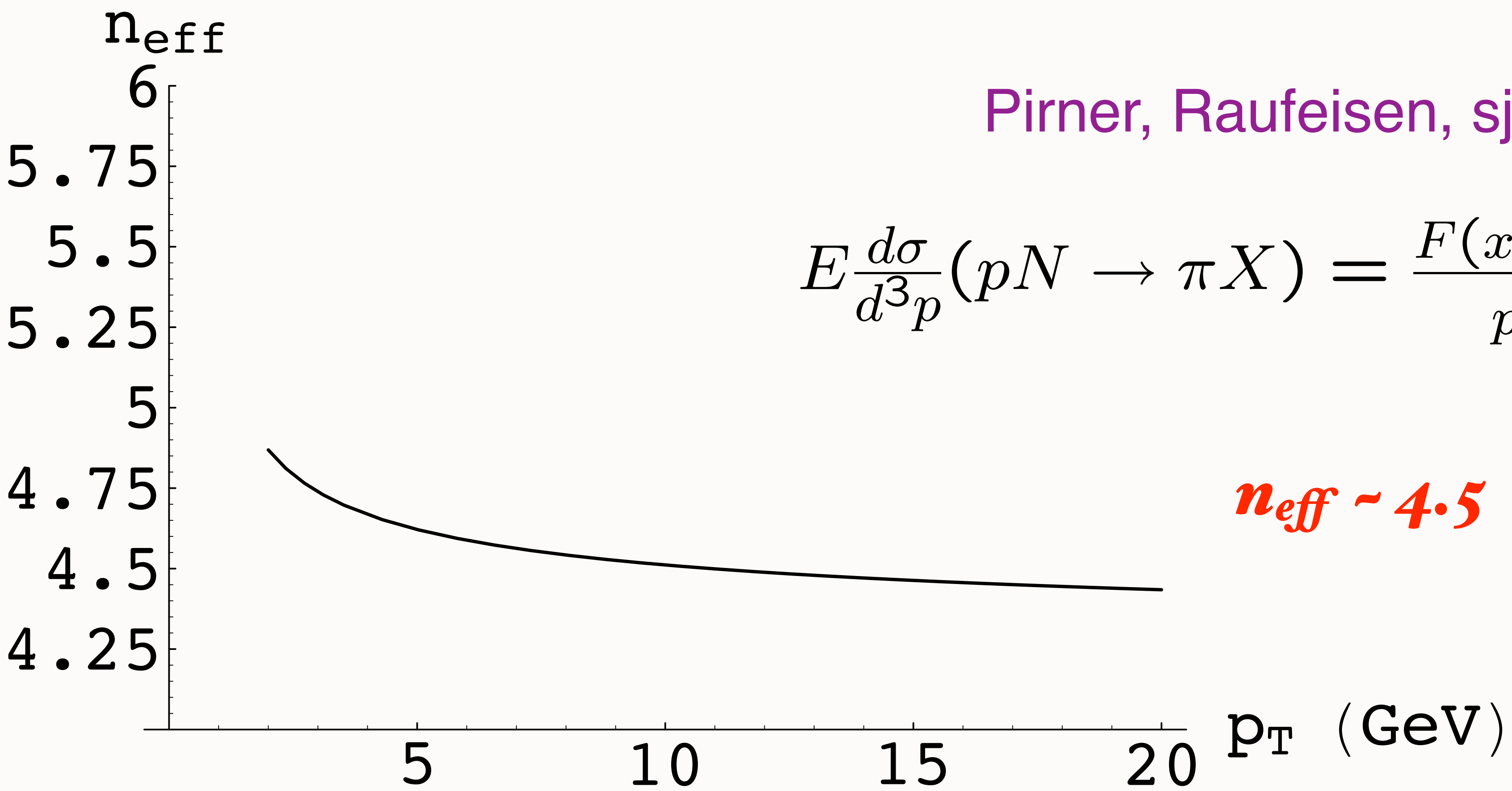
$$E\frac{d\sigma}{d^3p}(pN \to \pi X) = \frac{F(x_T,\theta_{CM})}{p_T^{neff}}$$

n_{eff} = 4

Bjorken scaling

Conformal scaling: n_{eff} = 2 n_{active} - 4

PQCD prediction: Modification of power fall-off due to DGLAP evolution and the Running Coupling



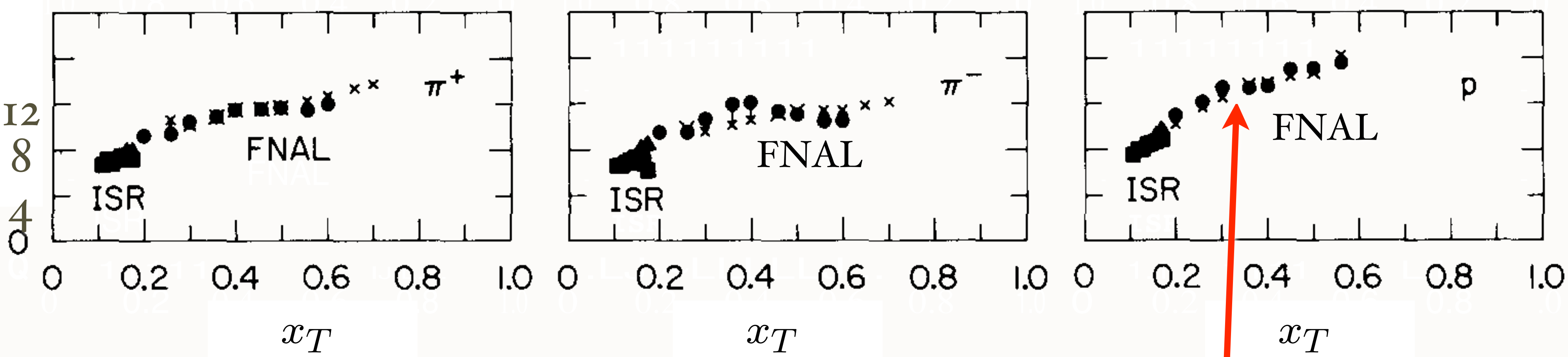
Pirner, Raufeisen, sjb

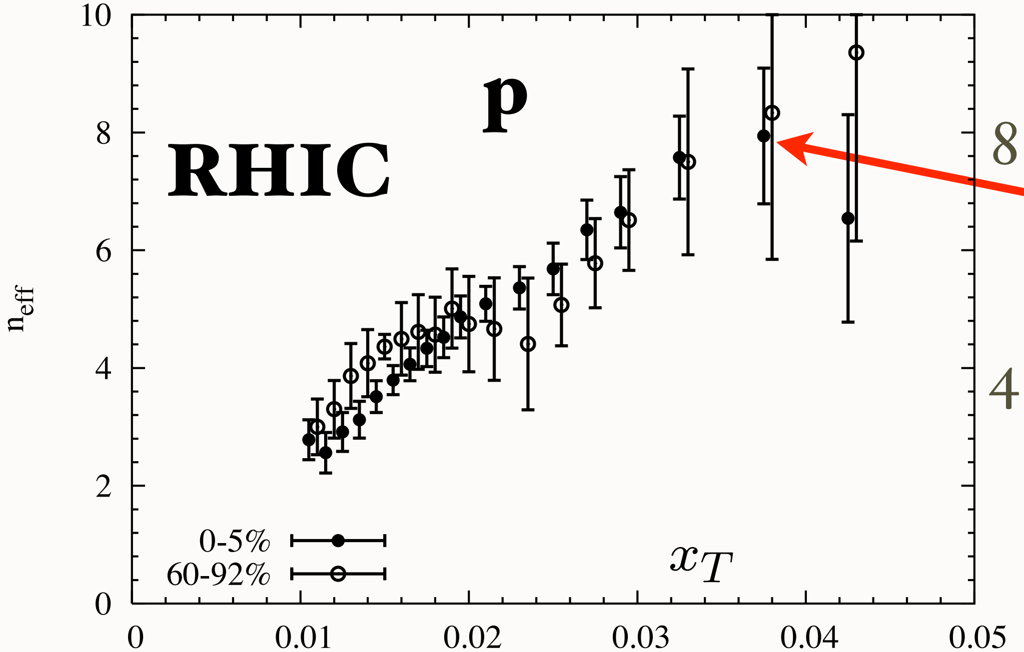
$$E\frac{d\sigma}{d^3p}(pN \to \pi X) = \frac{F(x_T,\theta_{CM})}{p_T^{neff}}$$

n_{eff} ~ 4.5

Key test of PQCD: power fall-off at fixed x_T

$$E\frac{d\sigma}{d^3p}(pp \to HX) = \frac{F(x_T, \theta_{CM})}{p_T^{n_{eff}}}$$





$$E\frac{d\sigma}{d^3p}(pp \to pX) = \frac{F(x_T, \theta_{CM})}{p_T^{12}}$$

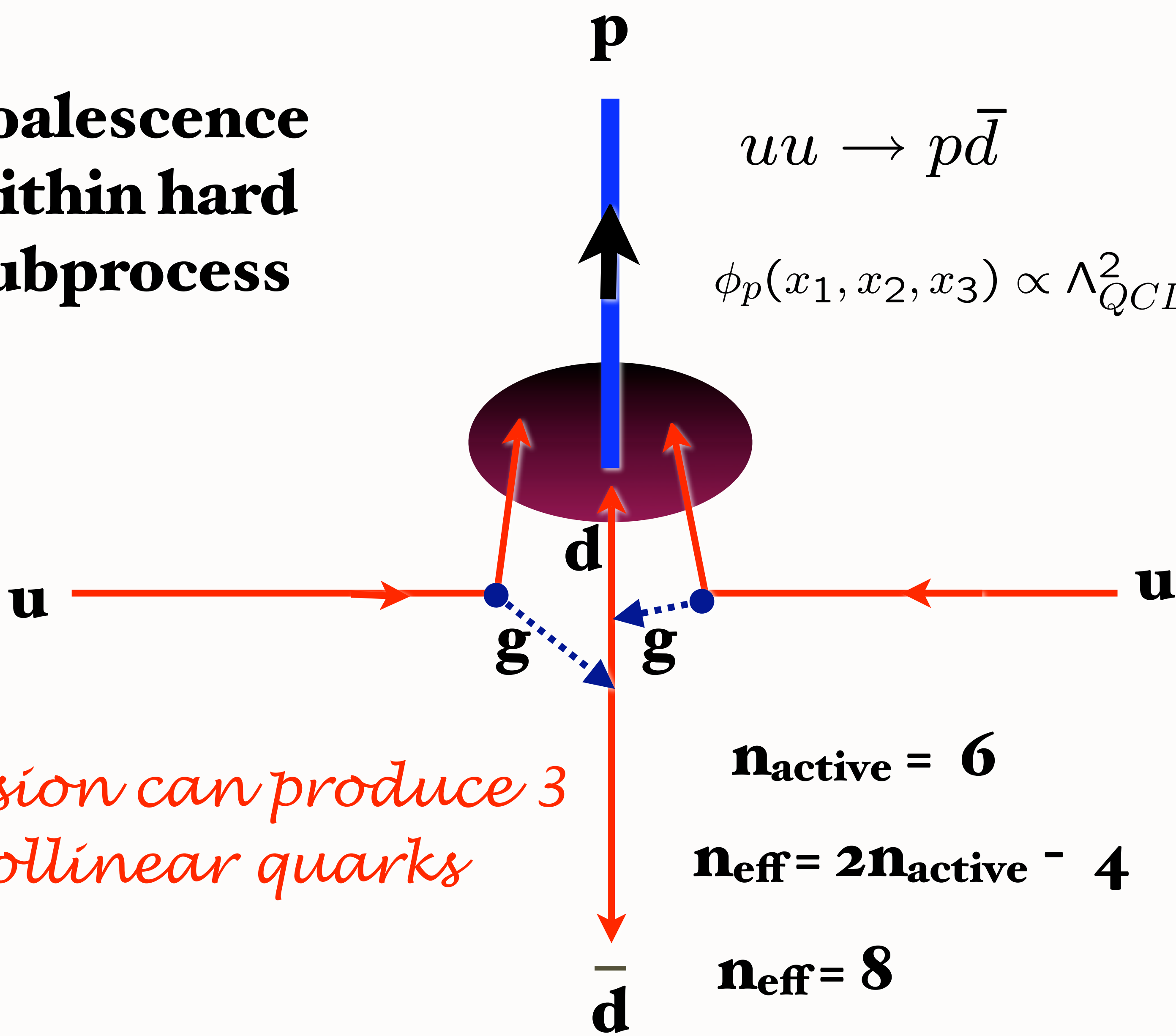
$$E\frac{d\sigma}{d^3p}(pp \to pX) = \frac{F(x_T, \theta_{CM})}{p_T^{8}}$$

Trend consistent with RHIC at small x_T

Baryon can be made directly within hard subprocess

Bjorken
Blankenbecler, Gunion, sjb
Berger, sjb
Hoyer, et al: Semi-Exclusive

Coalescence within hard subprocess



$$uu \to p\bar{d}$$

$$\phi_p(x_1, x_2, x_3) \propto \Lambda^2_{QCD}$$

Collision can produce 3 collinear quarks

$\mathbf{n_{active} = 6}$

$\mathbf{n_{eff} = 2n_{active} - 4}$

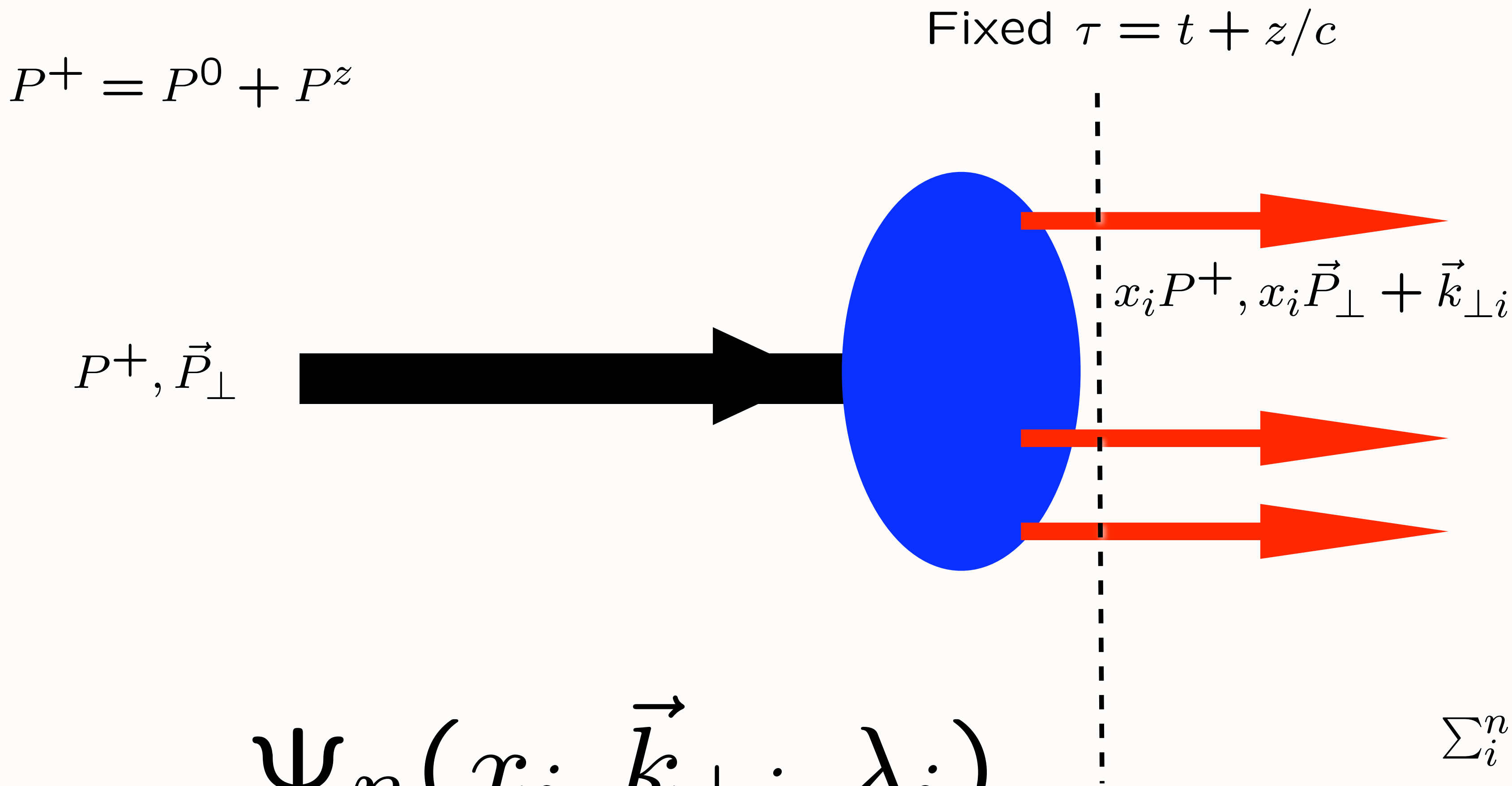
$\mathbf{n_{eff} = 8}$

$$qq \to B\bar{q}$$

Evidence for Direct, Higher-Twist Subprocesses

- Anomalous power behavior at fixed x_T
- Protons more likely to come from direct subprocess than pions
- Protons less absorbed than pions in central nuclear collisions because of **color transparency**
- Predicts increasing proton to pion ratio in central collisions
- Exclusive-inclusive connection at $x_T = 1$

Light-Front Wavefunctions



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

$\sum_i^n x_i = 1$

$\sum_i^n \vec{k}_{\perp i} = \vec{0}_\perp$

Invariant under boosts! Independent of P^μ

Hadron Dynamics at the Amplitude Level

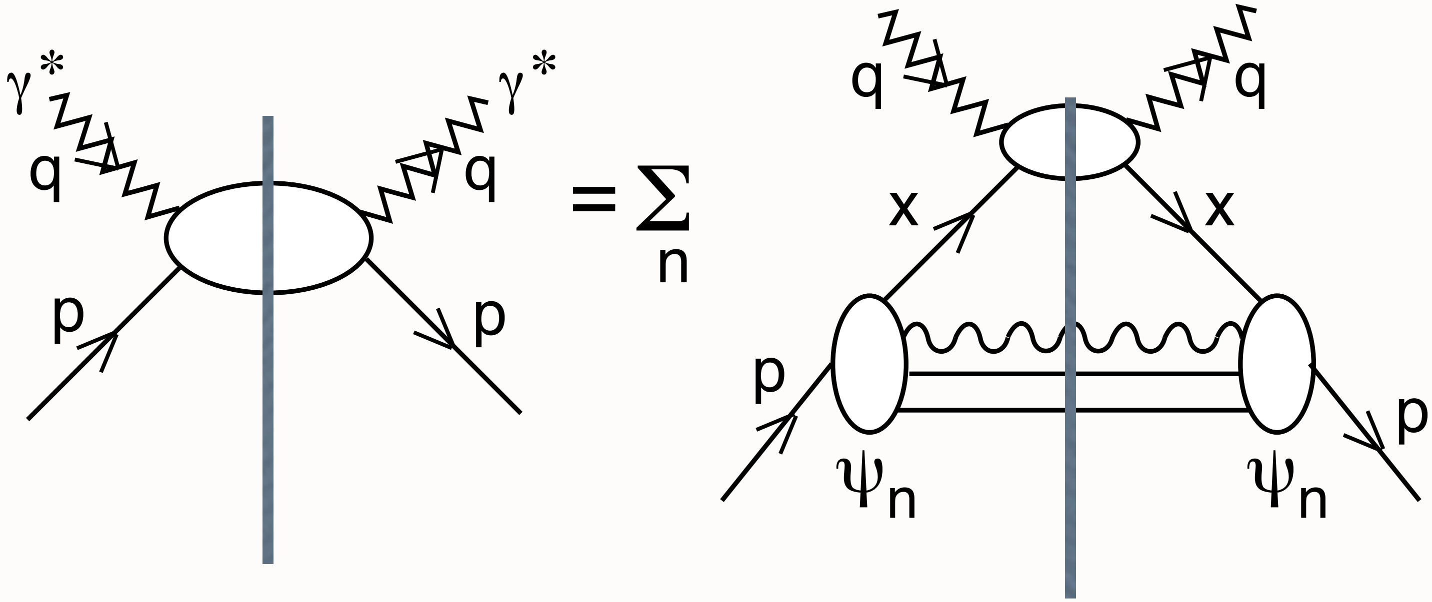
- LFWFS are the universal hadronic amplitudes which underlie structure functions, GPDs, exclusive processes.

- Relation of spin, momentum, and other distributions to physics of the hadron itself.

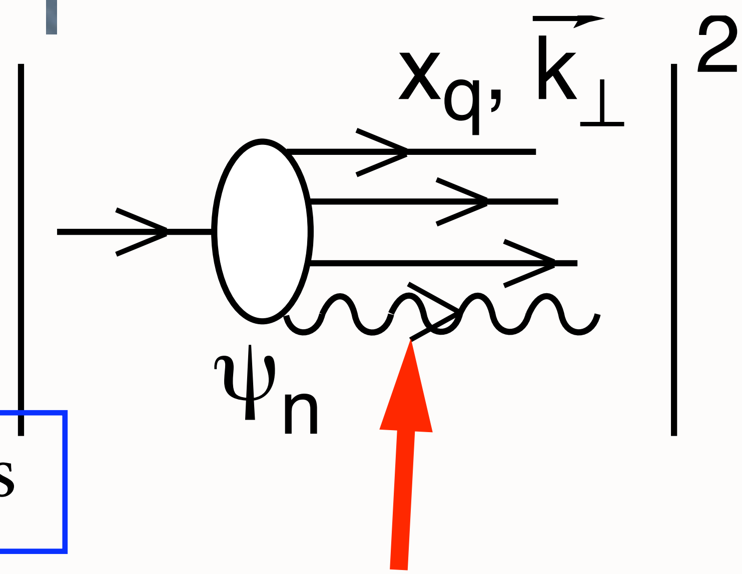
- Connections between observables, orbital angular momentum

- Role of FSI and ISIs--Sivers effect

Deep Inelastic Lepton-Proton Scattering



Imaginary Part of
Forward Virtual Compton Amplitude



$q(x, Q^2) = \sum_n \int^{k_\perp^2 \leq Q^2 \perp} d^2k_\perp \, |\Psi_n(x, k_\perp)|^2$

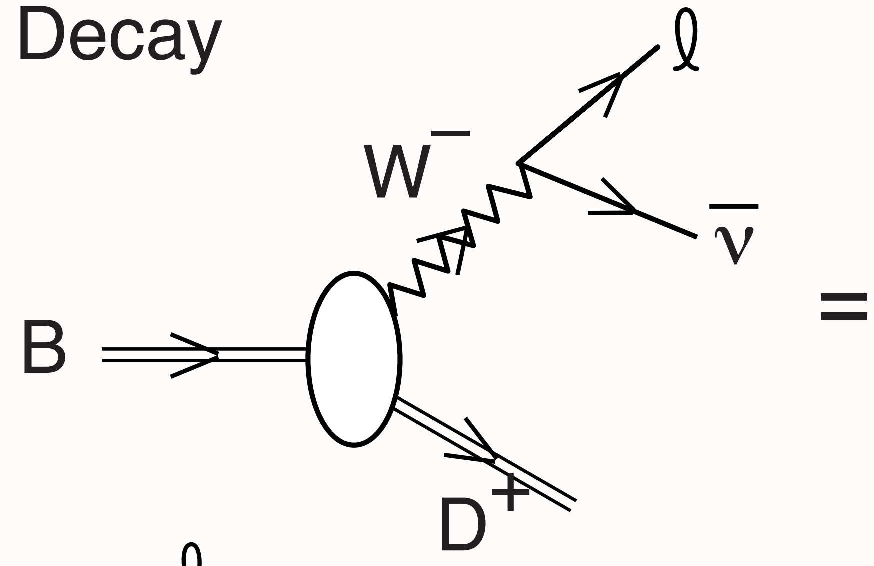
$x = x_q$

All spin, flavor distributions

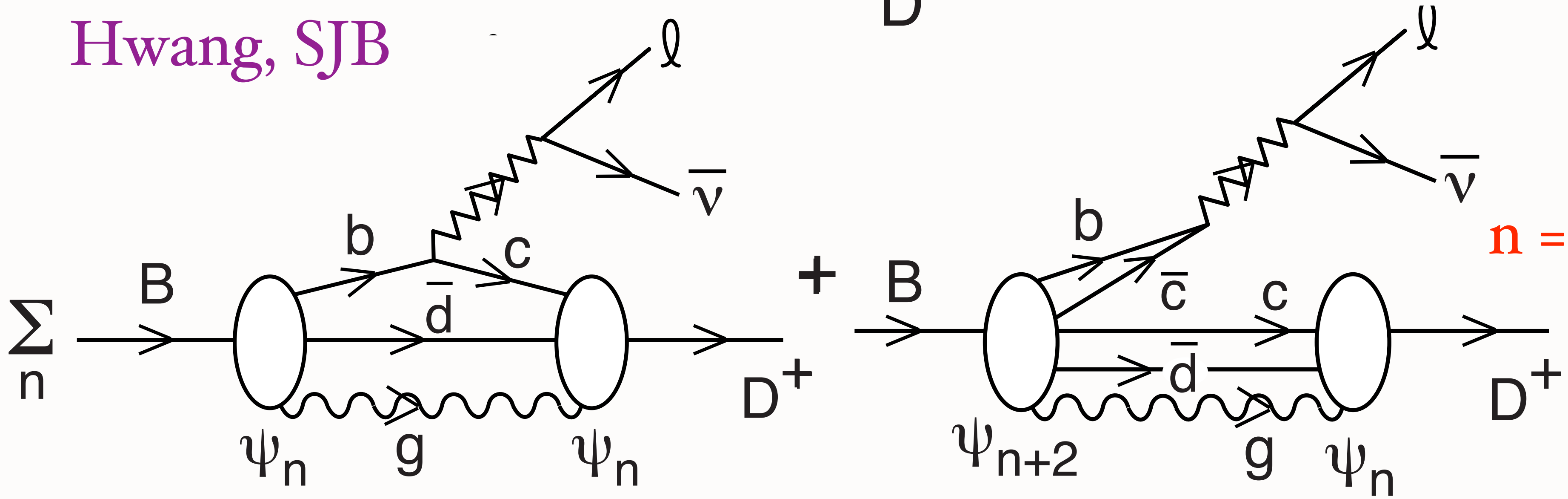
Light-Front Wave Functions $\psi_n(x_i, \vec{k}_{\perp i}, \lambda_i)$

Weak Exclusive Decay

$\langle D | J^{+}(0) | B \rangle$



Exact Formula
Hwang, SJB



n = n' + 2

Annihilation amplitude needed for Lorentz Invariance

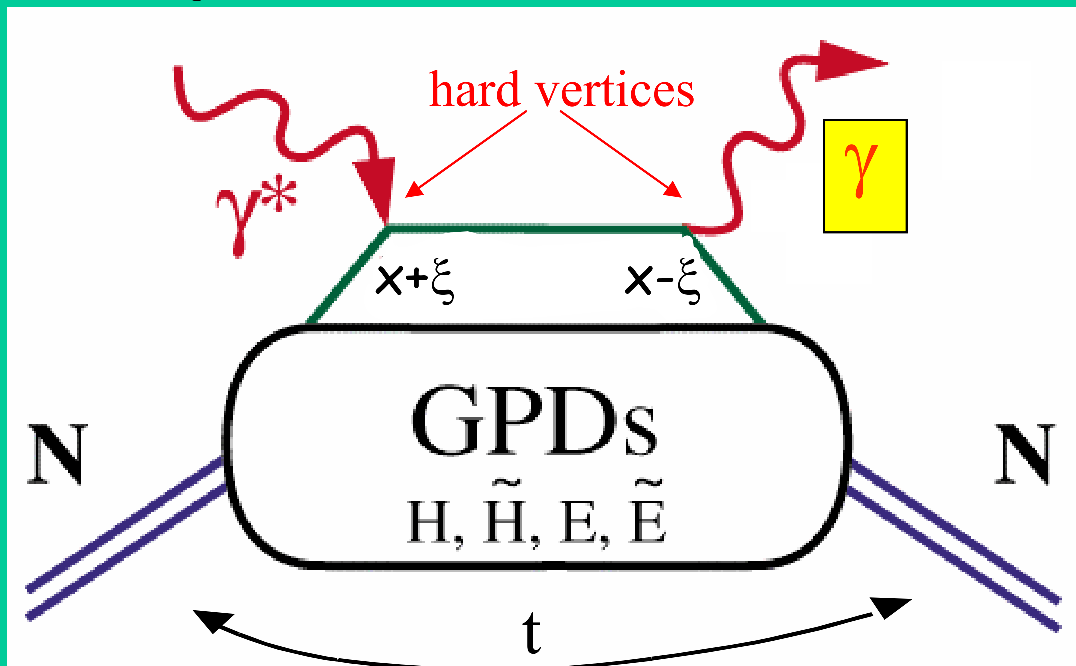
Consequences of AdS/CFT for Antiproton physics

- Analytic form for form factors, GPDs, distribution amplitude
- Matrix elements and LFWFs for baryon scattering amplitudes: Quark Counting Rules!
- Orbital angular momentum in baryon wavefunction for Pauli form factor, SSAs
- Dominance of quark interchange at short distances
- Effective Regge trajectories
- Regge intercepts at negative integers at large t

GPDs & Deeply Virtual Exclusive Processes

"handbag" mechanism

Deeply Virtual Compton Scattering (DVCS)



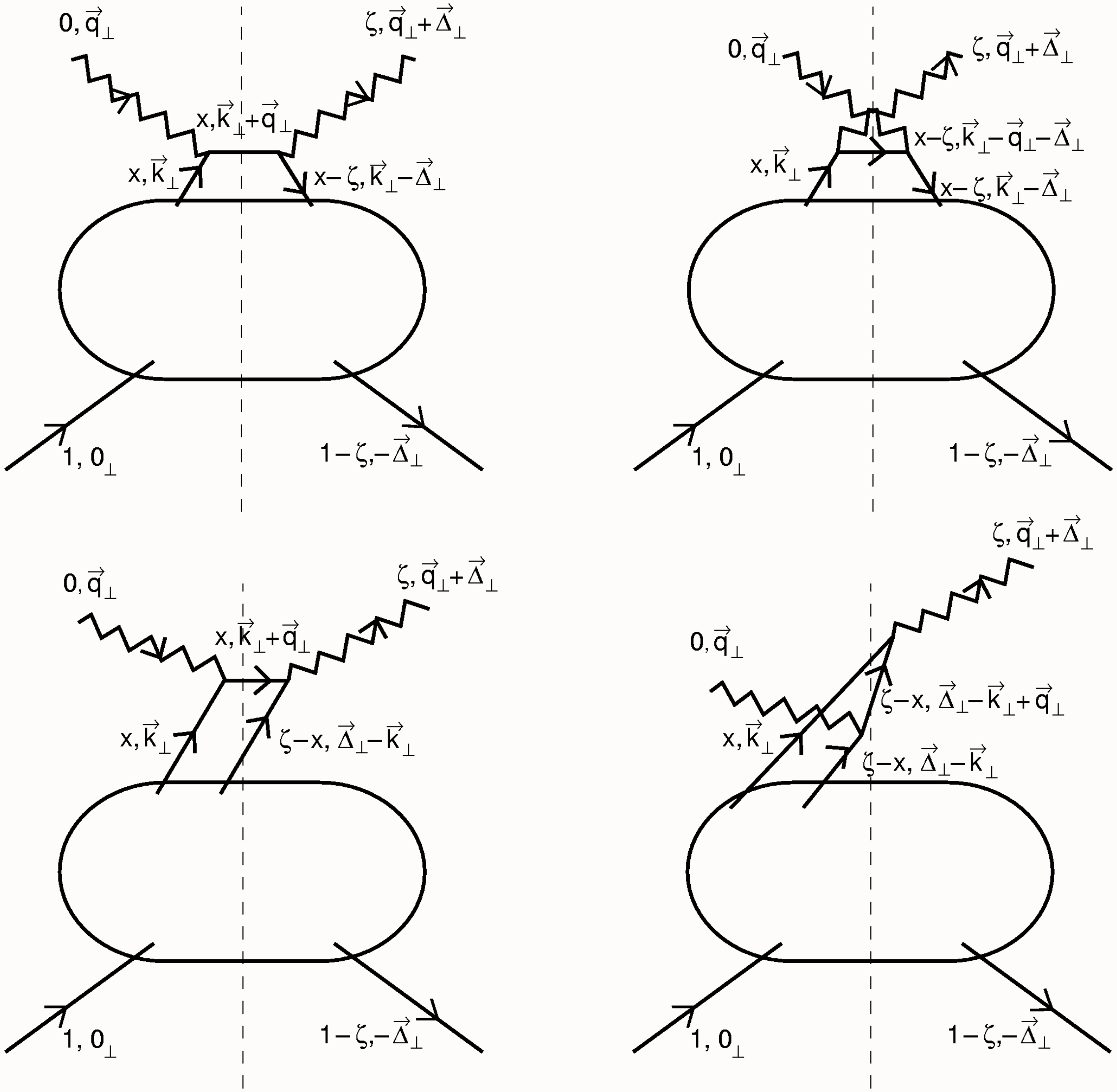
x – longitudinal quark momentum fraction

2ξ – longitudinal momentum transfer

$\sqrt{-t}$ – Fourier conjugate to transverse impact parameter

$H(x,\xi,t), E(x,\xi,t), \ldots$

$$\xi = \frac{x_B}{2 - x_B}$$



Light-cone wavefunction representation of deeply virtual Compton scattering ☆

Stanley J. Brodsky [a], Markus Diehl [a,1], Dae Sung Hwang [b]

Example of LFWF representation of GPDs (n => n)

Diehl,Hwang, sjb

$$\frac{1}{\sqrt{1-\zeta}} \frac{\Delta^1 - i\Delta^2}{2M} E_{(n\to n)}(x,\zeta,t)$$

$$= \left(\sqrt{1-\zeta}\right)^{2-n} \sum_{n,\lambda_i} \int \prod_{i=1}^{n} \frac{\mathrm{d}x_i\, \mathrm{d}^2\vec{k}_{\perp i}}{16\pi^3}\, 16\pi^3 \delta\left(1 - \sum_{j=1}^{n} x_j\right) \delta^{(2)}\left(\sum_{j=1}^{n} \vec{k}_{\perp j}\right)$$

$$\times\, \delta(x - x_1)\, \psi^{\uparrow *}_{(n)}(x'_i, \vec{k}'_{\perp i}, \lambda_i)\, \psi^{\downarrow}_{(n)}(x_i, \vec{k}_{\perp i}, \lambda_i),$$

where the arguments of the final-state wavefunction are given by

$$x'_1 = \frac{x_1 - \zeta}{1-\zeta}, \qquad \vec{k}'_{\perp 1} = \vec{k}_{\perp 1} - \frac{1-x_1}{1-\zeta}\vec{\Delta}_\perp \quad \text{for the struck quark,}$$

$$x'_i = \frac{x_i}{1-\zeta}, \qquad \vec{k}'_{\perp i} = \vec{k}_{\perp i} + \frac{x_i}{1-\zeta}\vec{\Delta}_\perp \quad \text{for the spectators } i = 2, \ldots, n.$$

Link to DIS and Elastic Form Factors

DIS at $\xi = t = 0$

$$H^q(x,0,0) = q(x), \quad -\bar{q}(-x)$$

$$\widetilde{H}^q(x,0,0) = \Delta q(x), \quad \Delta\bar{q}(-x)$$

Form factors (sum rules)

$$\int_{-1}^{1} dx \sum_q \left[H^q(x,\xi,t)\right] = F_1(t) \quad \text{Dirac f.f.}$$

$$\int_{-1}^{1} dx \sum_q \left[E^q(x,\xi,t)\right] = F_2(t) \quad \text{Pauli f.f.}$$

$$\int_{-1}^{1} dx\, \widetilde{H}^q(x,\xi,t) = G_{A,q}(t), \quad \int_{-1}^{1} dx\, \widetilde{E}^q(x,\xi,t) = G_{P,q}(t)$$

$$H^q, E^q, \widetilde{H}^q, \widetilde{E}^q(x,\xi,t)$$

Verified using LFWFs

Diehl, Hwang, sjb

Quark angular momentum (Ji's sum rule)

$$J^q = \frac{1}{2} - J^G = \frac{1}{2}\int_{-1}^{1} x\,dx \left[H^q(x,\xi,0) + E^q(x,\xi,0)\right]$$

X. Ji, Phy.Rev.Lett.78,610(1997)

New Perspectives in QCD from AdS/CFT

- Need to understand QCD at the Amplitude Level: Hadron wavefunctions!
- Remarkable new insights from AdS/CFT, the duality between conformal field theory and Anti-de Sitter Space

Goal:

- **Use AdS/CFT to provide an approximate, covariant, and analytic model of hadron structure with confinement at large distances, conformal behavior at short distances**

- **Analogous to the Schrodinger Equation for Atomic Physics**

- *AdS/QCD Holographic Model*

New Way to Model QCD: AdS/CFT

- Start with Maldacena Correspondence
- Mathematical Representation of Lorentz Invariant and Conformal (Scale-Free) Theories
- Add new 5th space dimension to 3+1 space-time
- Add Confinement: Holographic Model with Color Confinement and Quark Counting Rules

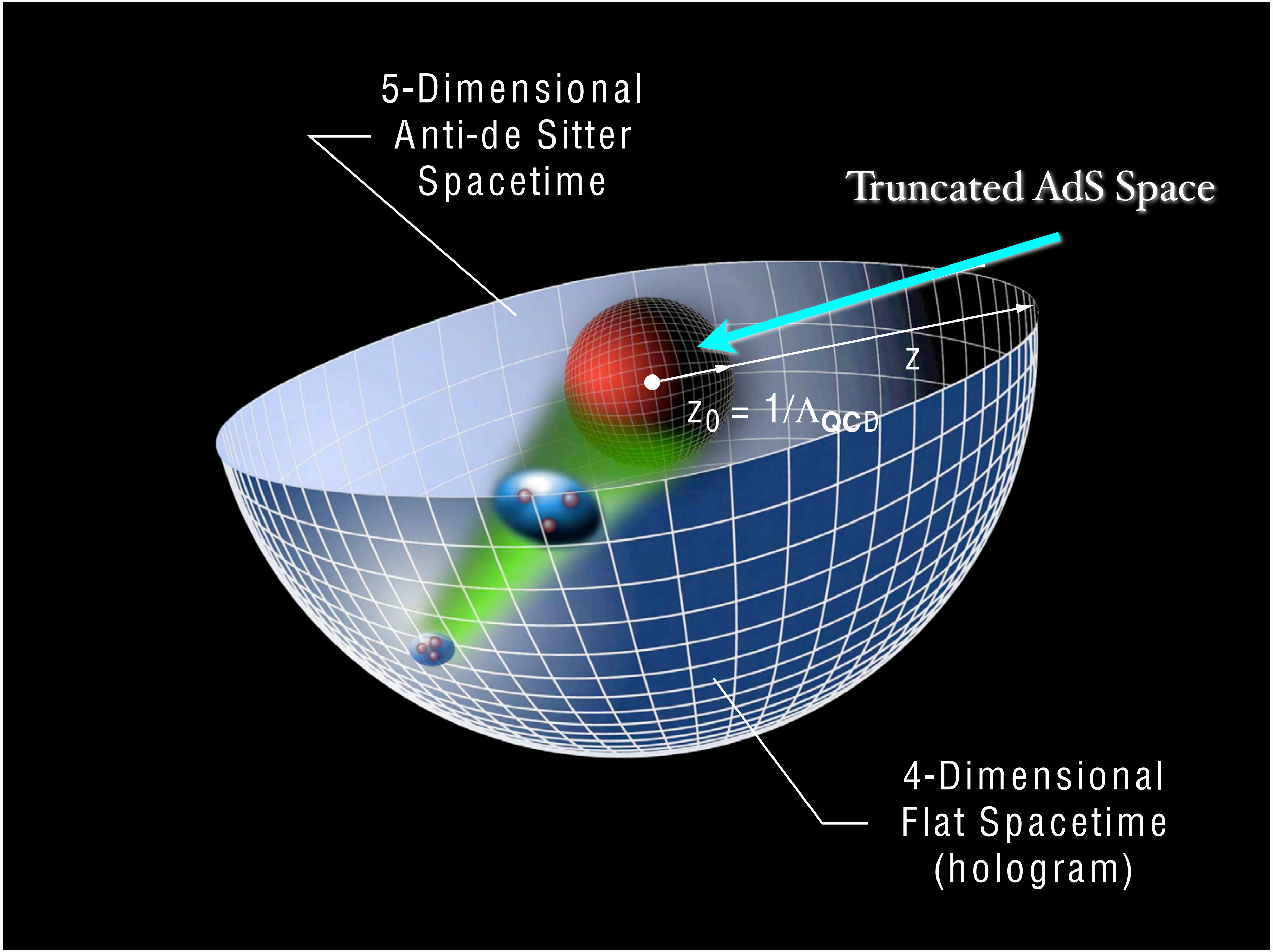
de Teramond, sjb

Conformal Theories are invariant under the Poincare and conformal transformations with

$$\mathbf{M}^{\mu\nu}, \mathbf{P}^{\mu}, \mathbf{D}, \mathbf{K}^{\mu},$$

the generators of SO(4,2)

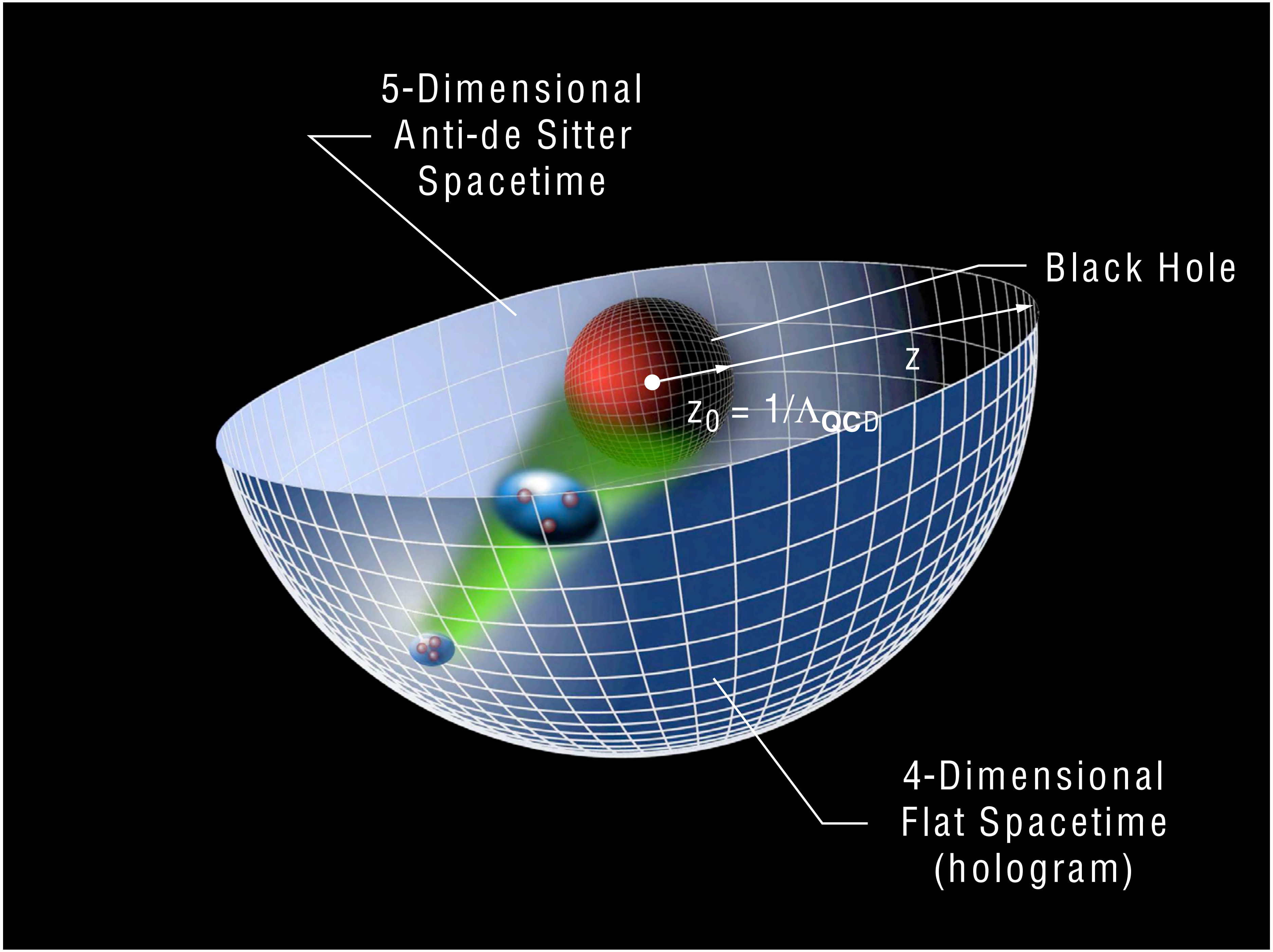
SO(4,2) has a mathematical representation on AdS5

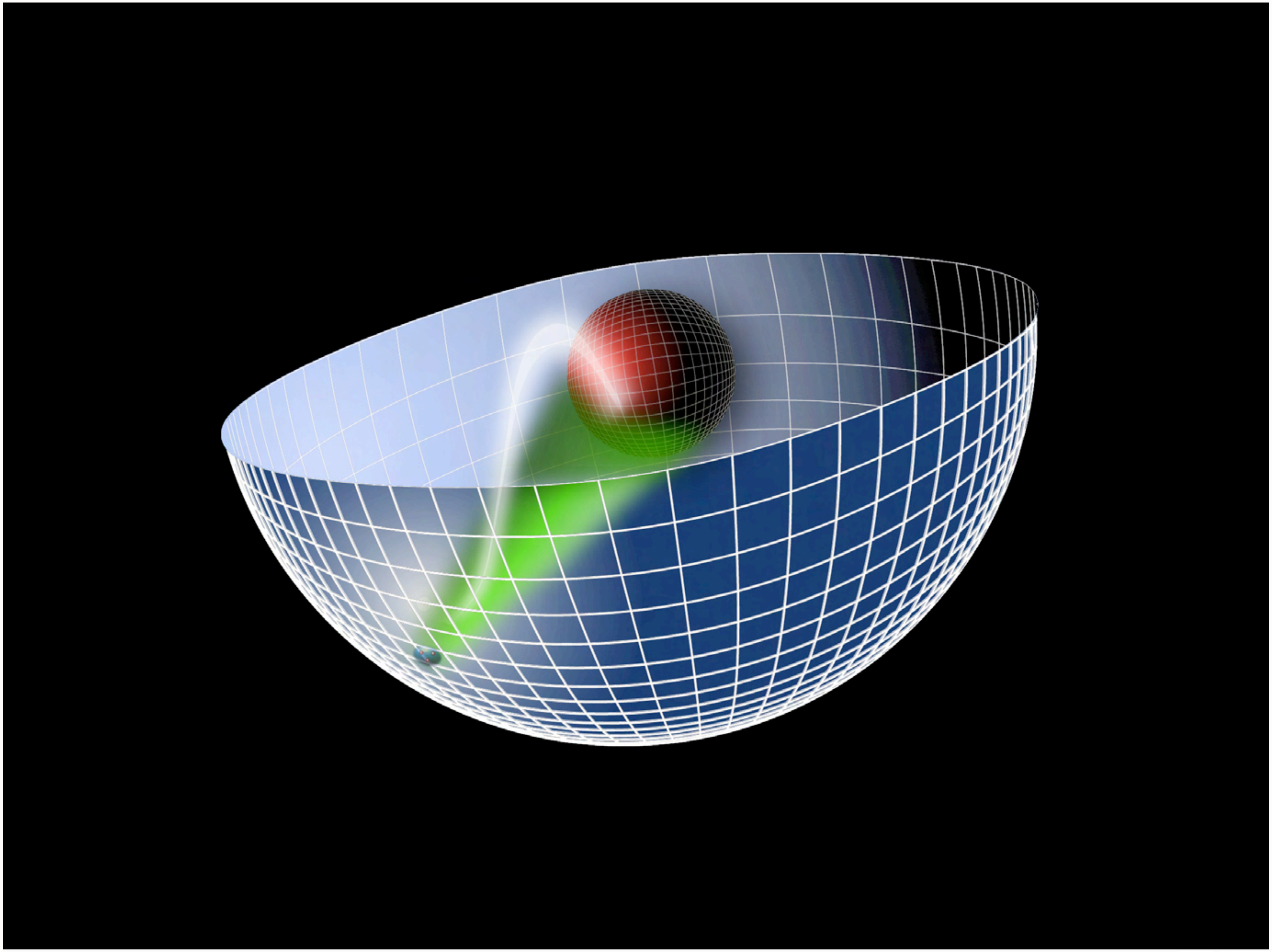

5-Dimensional
Anti-de Sitter
Spacetime
Truncated AdS Space
z
$z_0 = 1/\Lambda_{QCD}$
4-Dimensional
Flat Spacetime
(hologram)

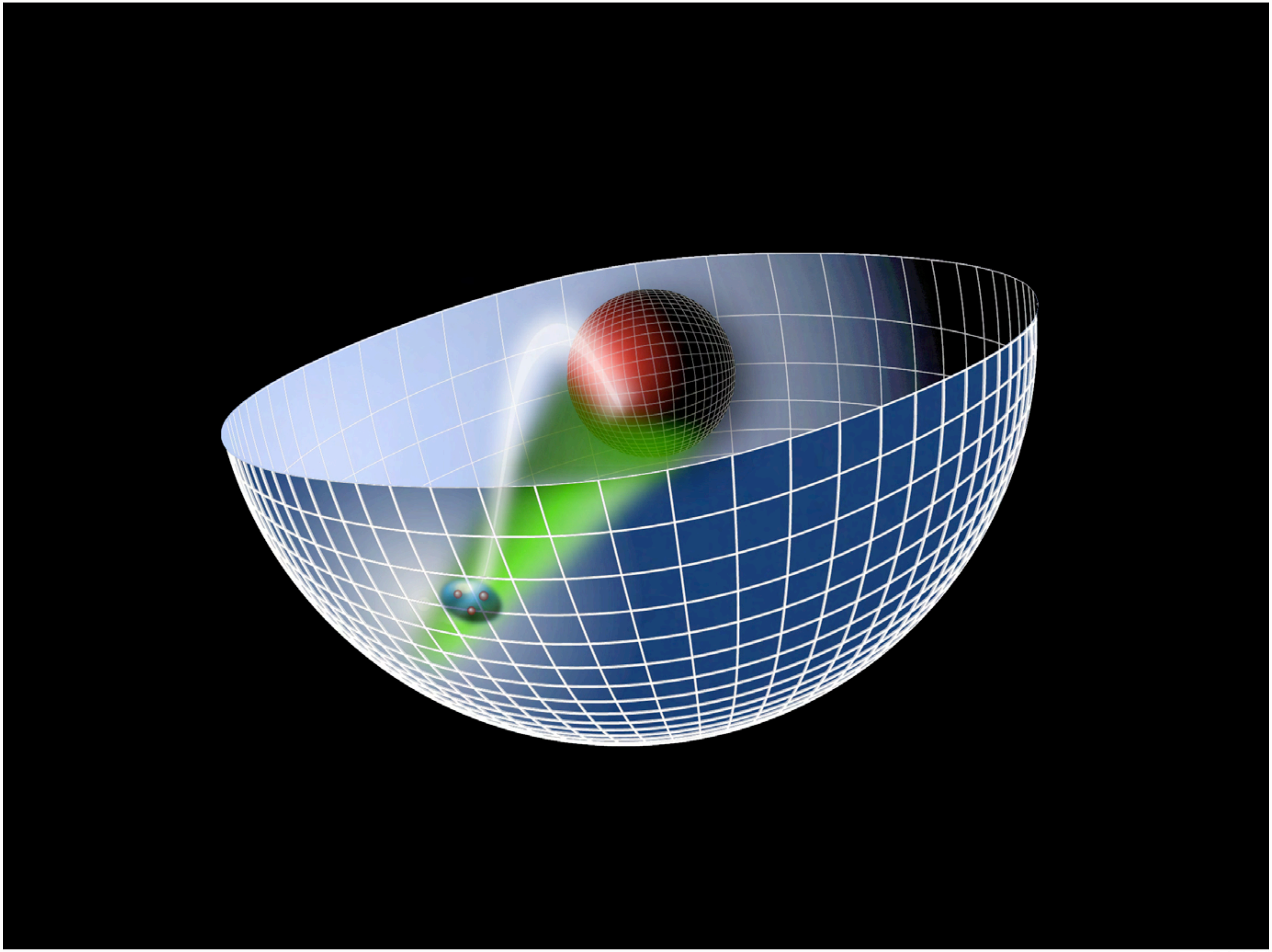
New Way to Solve QCD: AdS/CFT

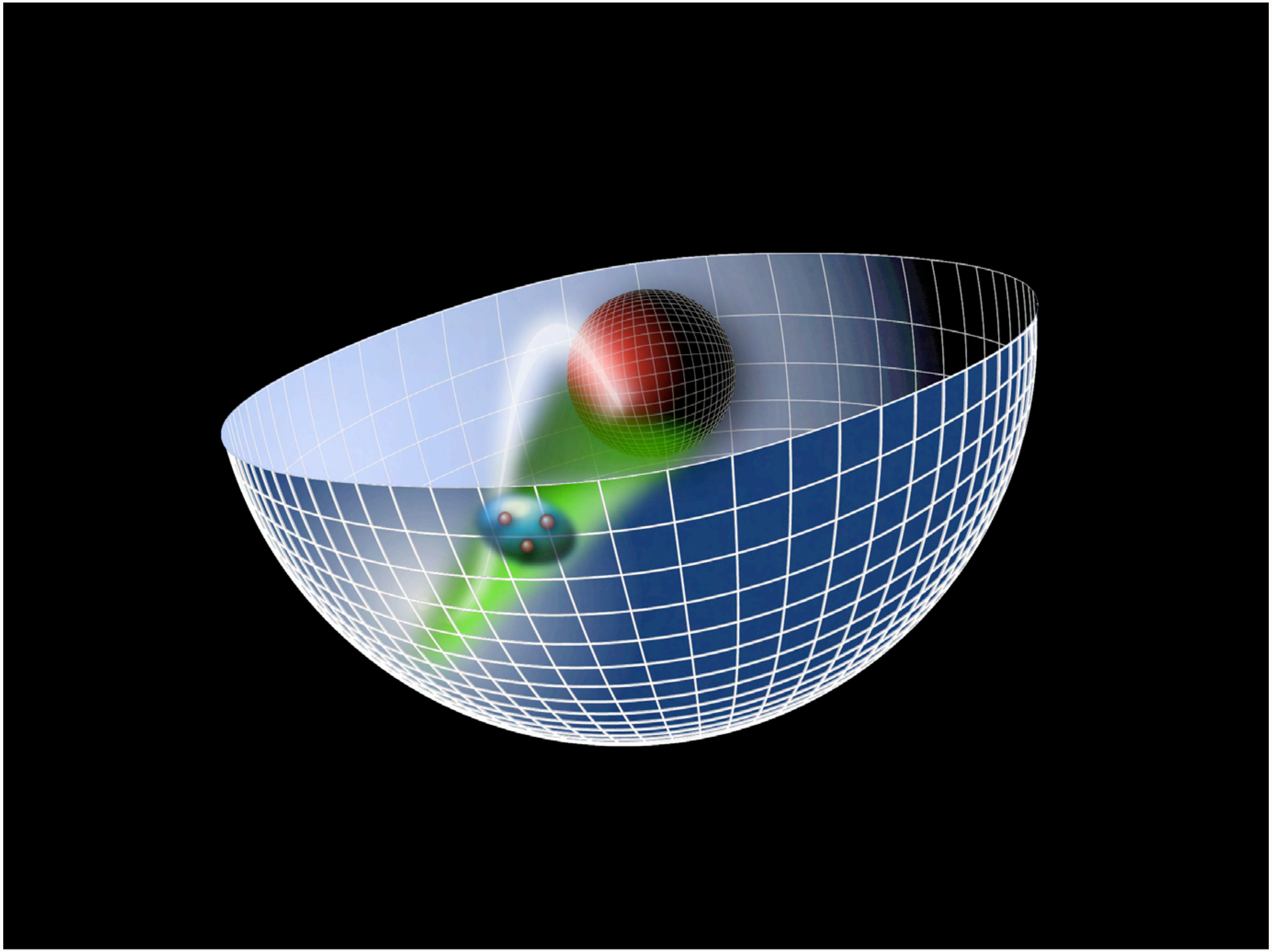
- Maldacena Correspondence
- Mathematical Representation of Lorentz Invariant and Conformal (Scale-Free) Theories
- Add new 5th space dimension to 3+1 space-time
- Holographic Model with Color Confinement and Quark Counting Rules

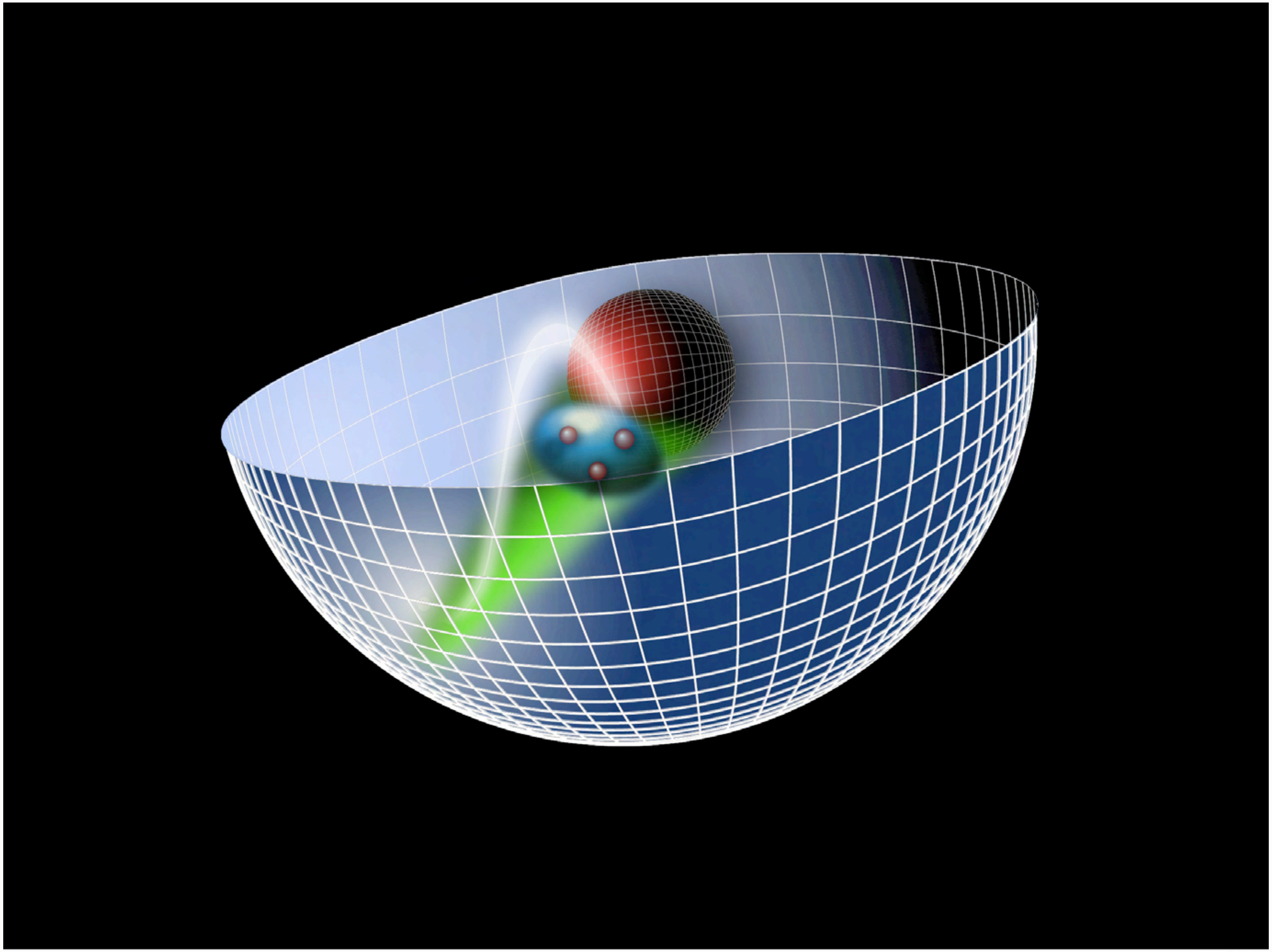
de Teramond, sjb

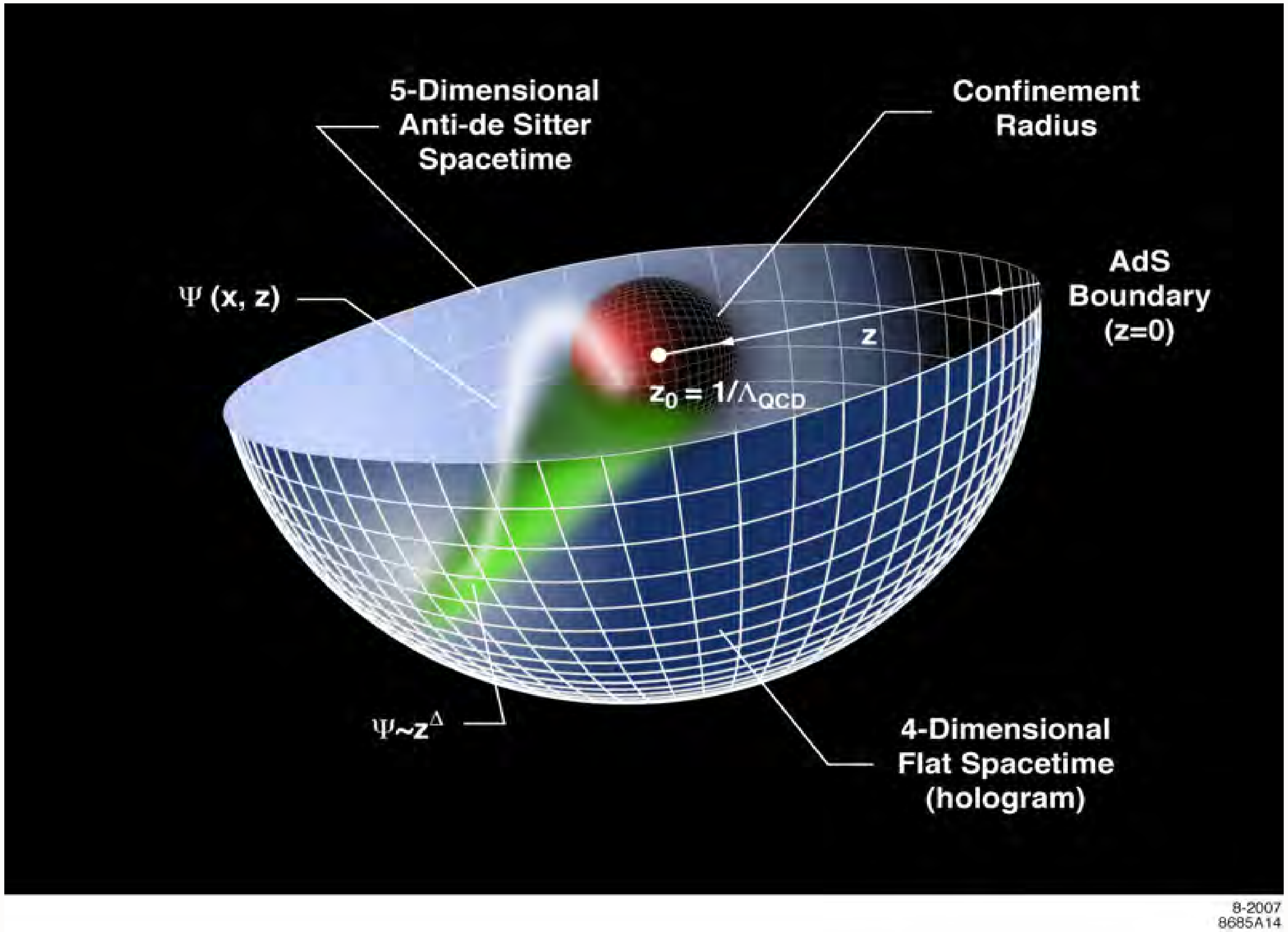

5-Dimensional
Anti-de Sitter
Spacetime
Black Hole
z
$z_0 = 1/\Lambda_{QCD}$
4-Dimensional
Flat Spacetime
(hologram)











- Truncated AdS/CFT (Hard-Wall) model: cut-off at $z_0 = 1/\Lambda_{\rm QCD}$ breaks conformal invariance and allows the introduction of the QCD scale (Hard-Wall Model) Polchinski and Strassler (2001).
- Smooth cutoff: introduction of a background dilaton field $\varphi(z)$ – usual linear Regge dependence can be obtained (Soft-Wall Model) Karch, Katz, Son and Stephanov (2006).

We consider both holographic models

Predictions of AdS/CFT

Only one parameter!

Entire light-quark baryon spectrum

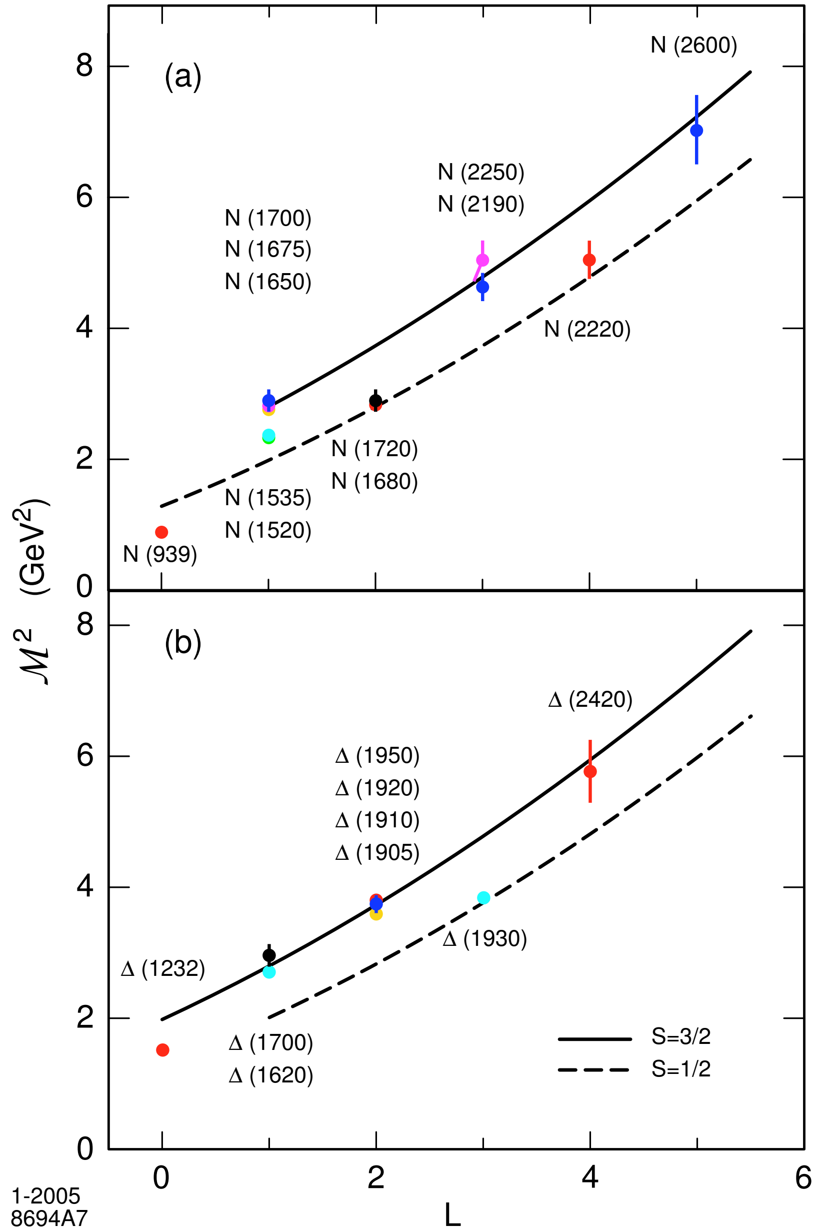


Fig: Predictions for the light baryon orbital spectrum for Λ_{QCD} = 0.22 GeV

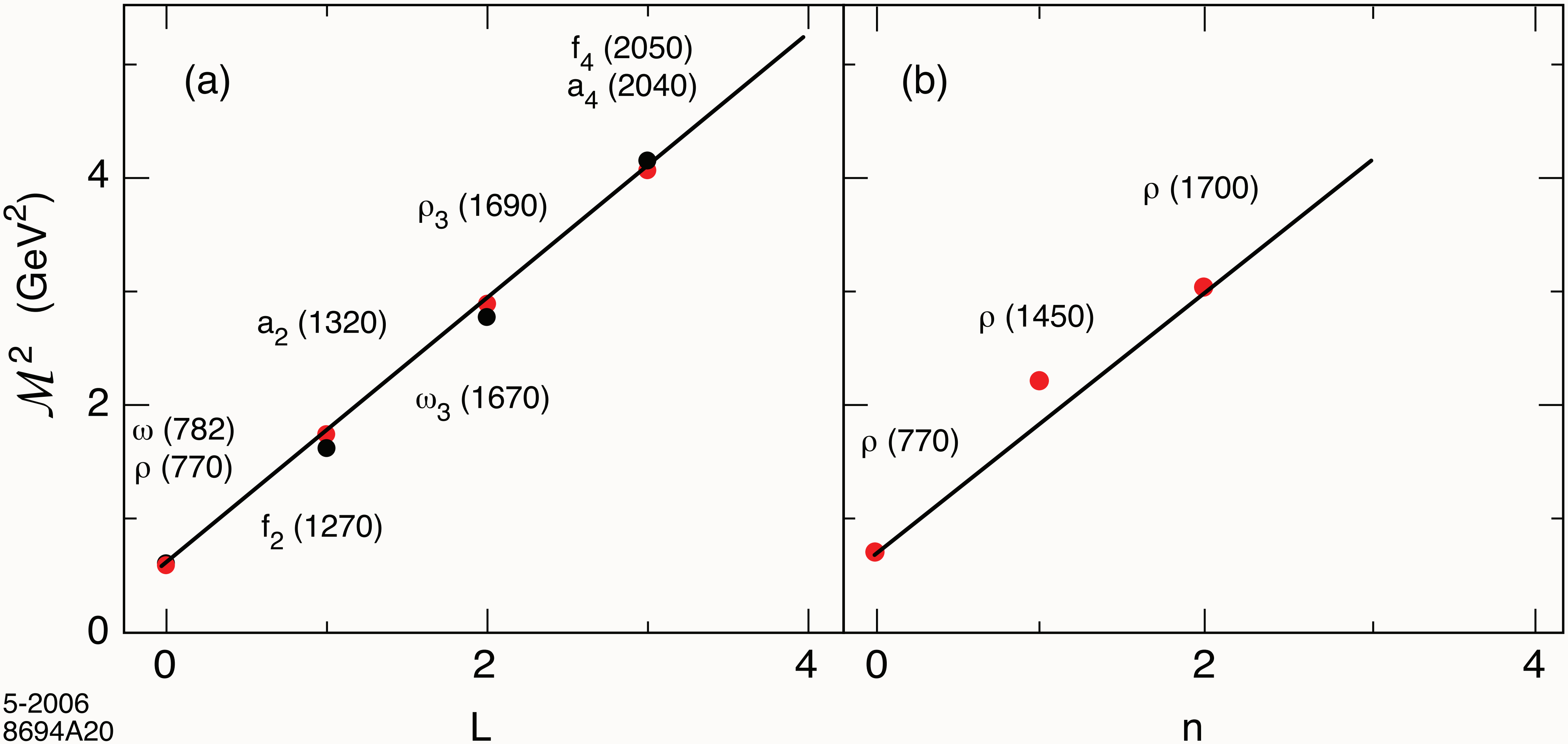
Guy de Teramond
SJB

Phys.Rev.Lett. 94:201601,2005

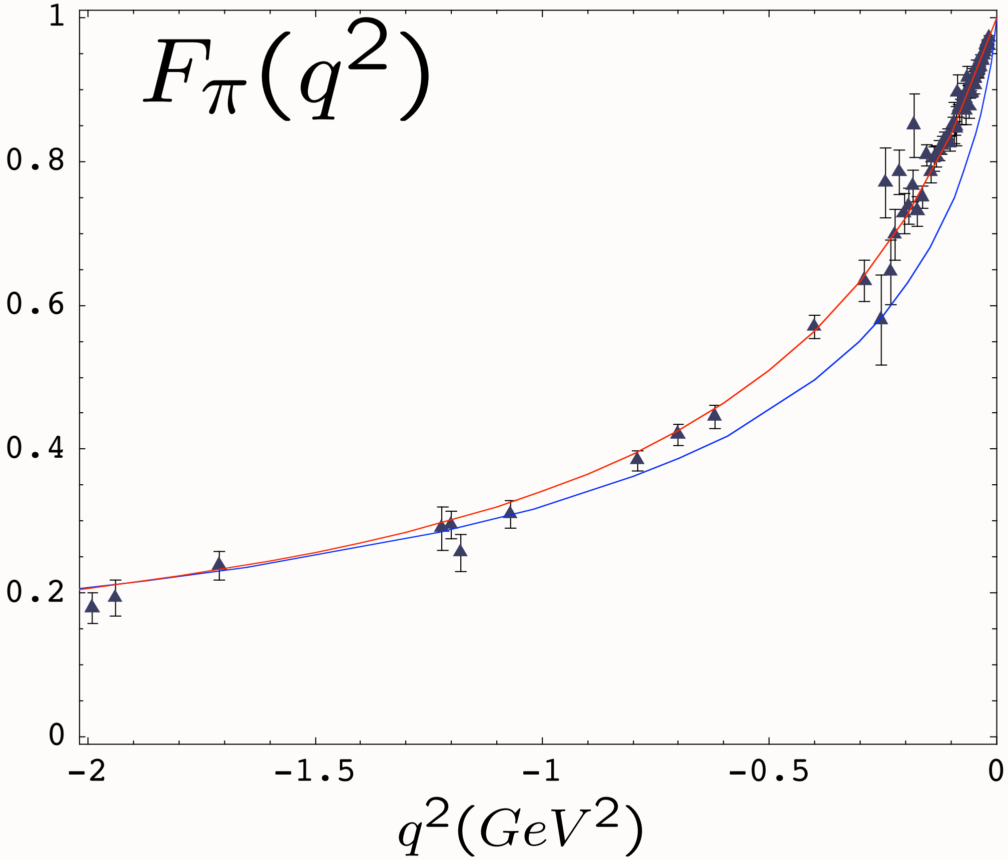
hep-th/0501022

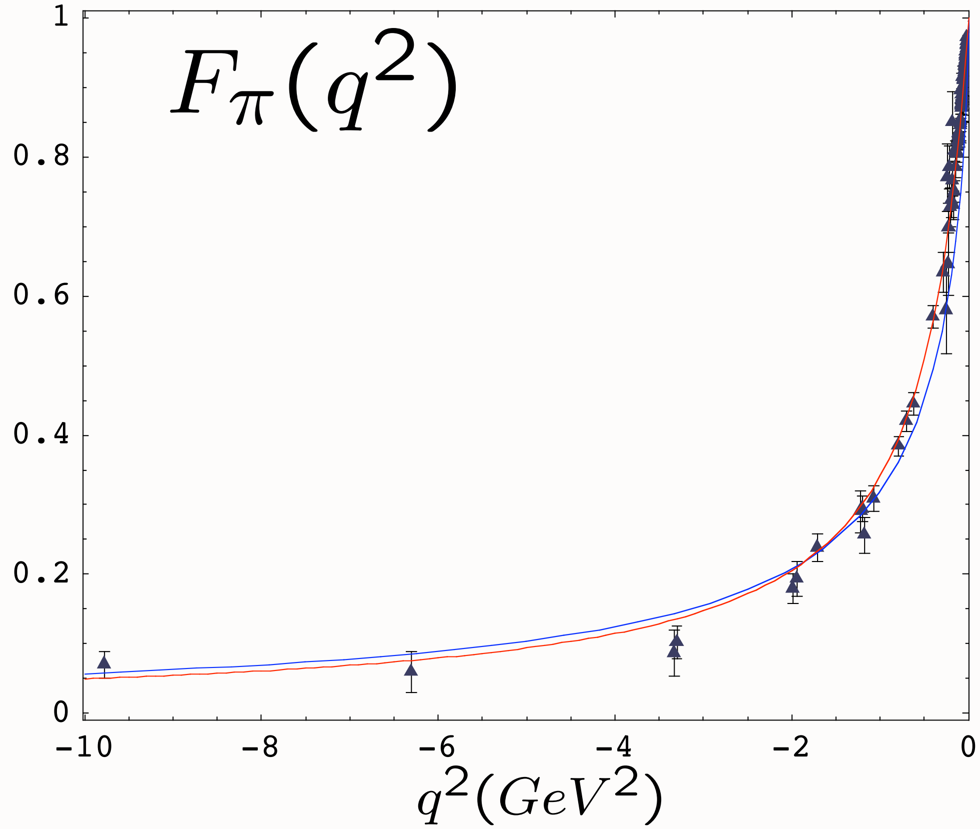
$$\mathcal{M}^2 = 2\kappa^2(2n + 2L + S).$$

$$S = 1$$



Spacelike pion form factor from AdS/CFT





Data Compilation from Baldini, Kloe and Volmer

Harmonic Oscillator Confinement

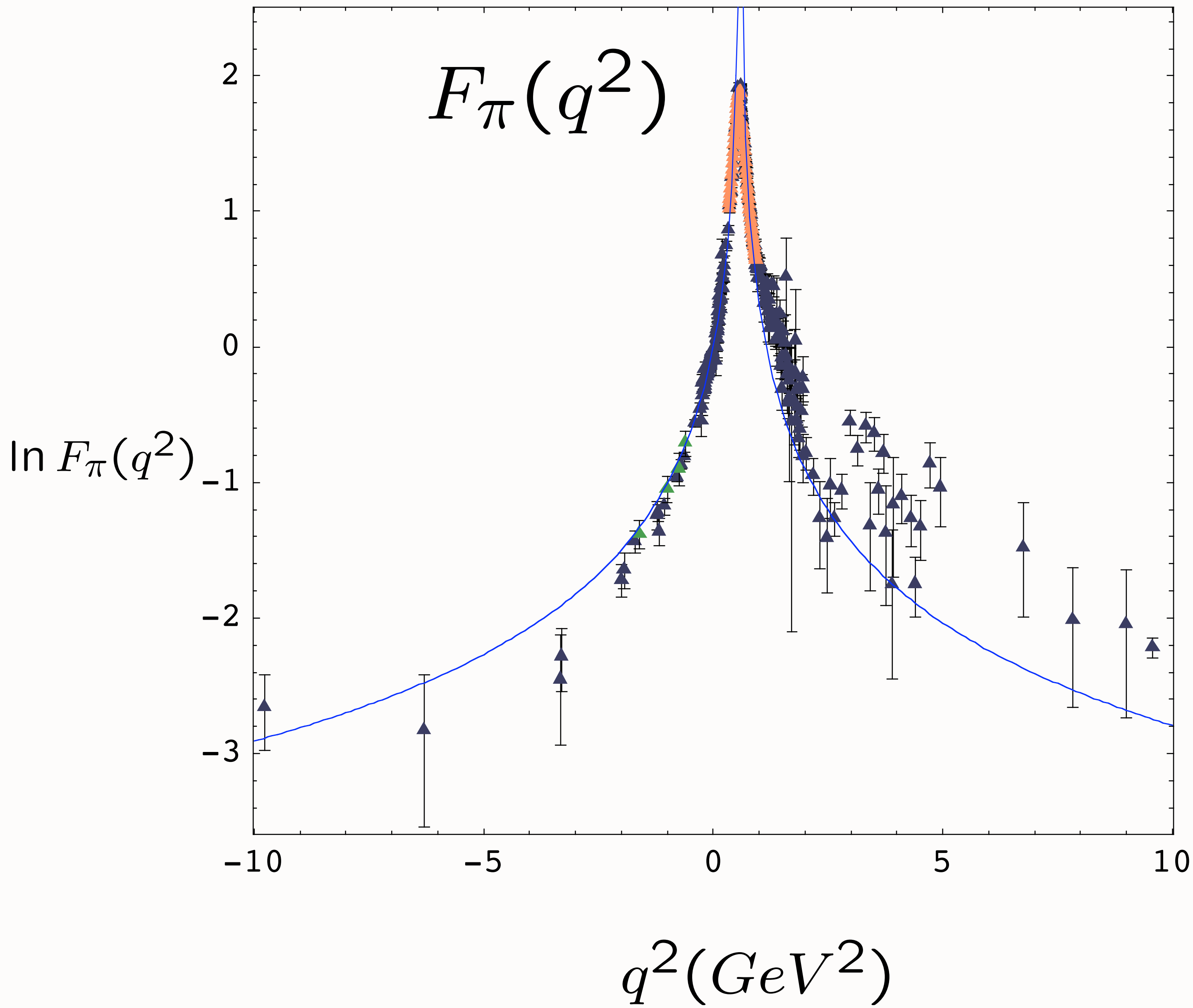
Truncated Space Confinement

One parameter - set by pion decay constant

G. de Teramond, sjb

Spacelike and Timelike Pion form factor from AdS/CFT

G. de Teramond, sjb

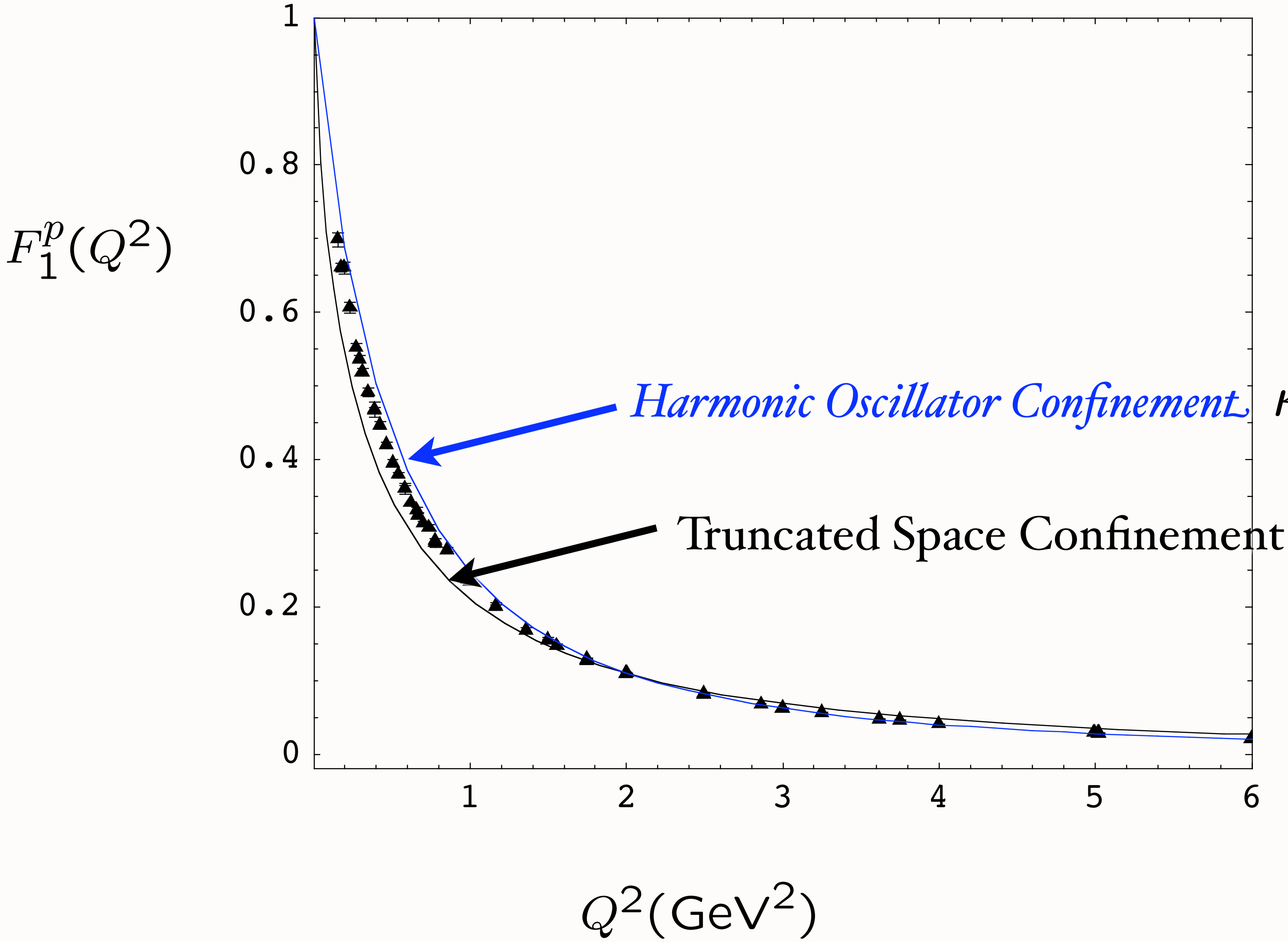


Harmonic Oscillator Confinement scale set by pion decay constant

$\kappa = 0.38$ GeV

G. de Teramond, sjb

Preliminary



$\kappa = 0.424$ GeV

$\Lambda = 0.2$ GeV

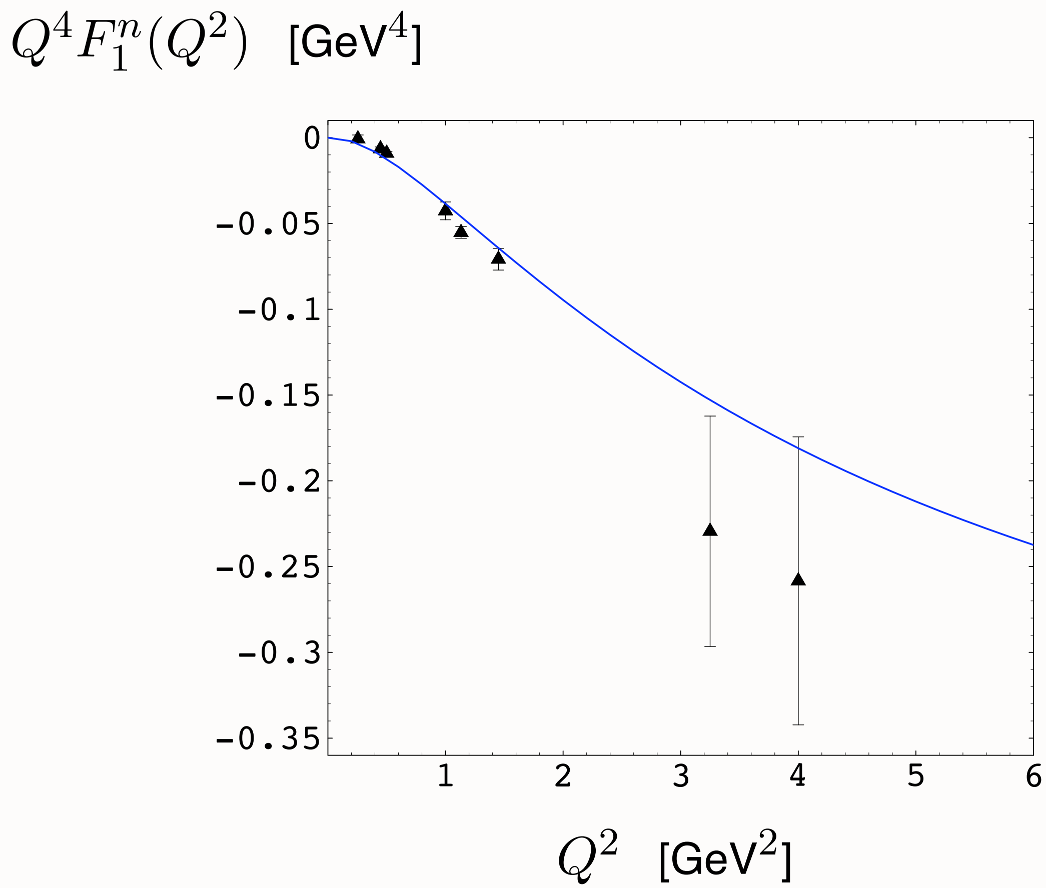
Current modified by metric

$$F_1(Q^2)_{I\to F} = \int \frac{dz}{z^3}\Phi^{\uparrow}_F(z) J(Q,z) \Phi^{\uparrow}_I(z)$$

Dirac Neutron Form Factor

(Valence Approximation)

Truncated Space Confinement

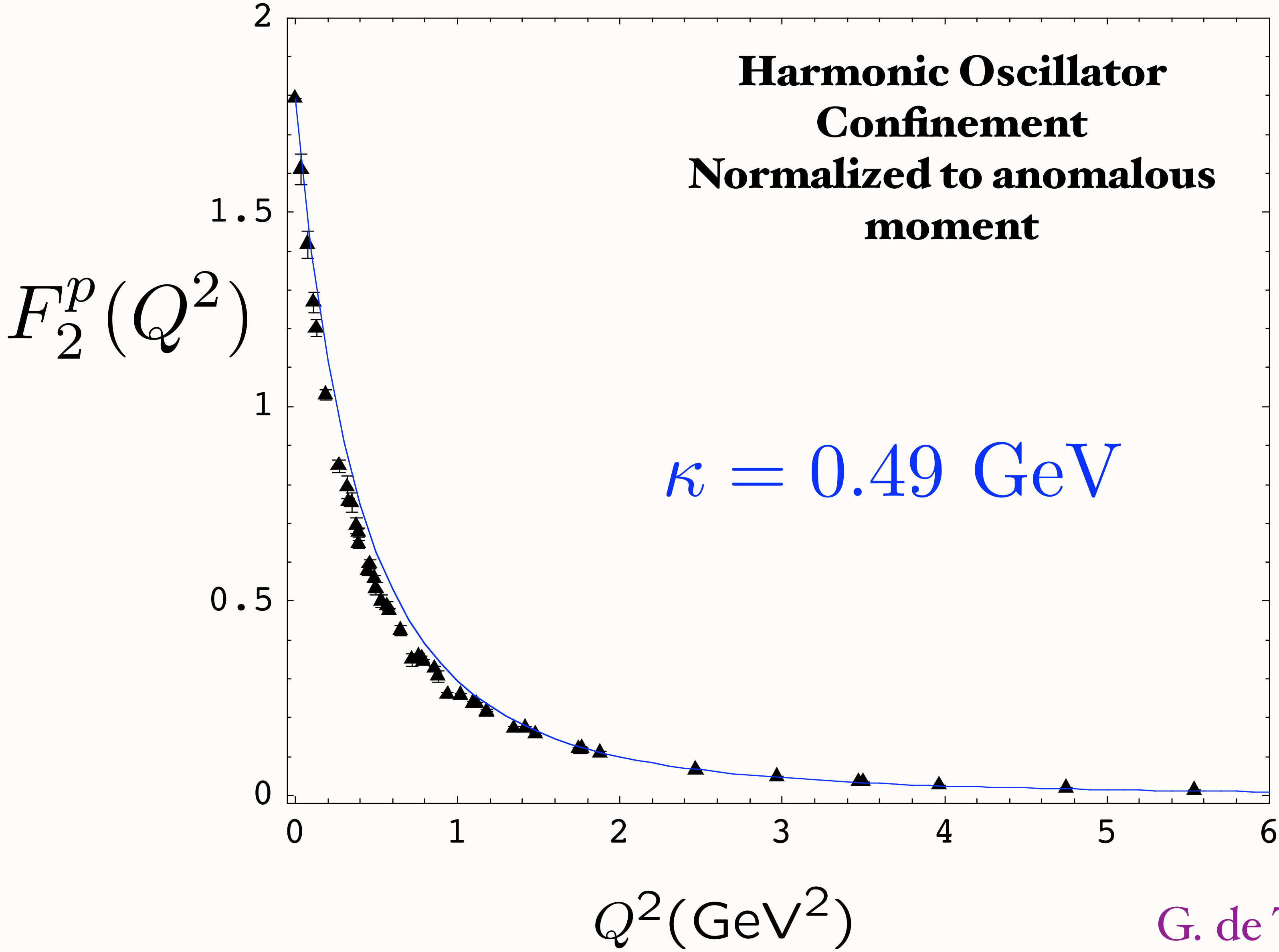


Prediction for $Q^4 F_1^n(Q^2)$ for $\Lambda_{\text{QCD}} = 0.21$ GeV in the hard wall approximation. Data analysis from Diehl (2005).

Spacelike Pauli Form Factor

Preliminary

From overlap of $L = 1$ and $L = 0$ LFWFs



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Note: Contributions to Mesons Form Factors at Large Q in AdS/QCD

- Write form factor in terms of an effective partonic transverse density in impact space $\mathbf{b}_\perp$

$$F_\pi(q^2) = \int_0^1 dx \int db^2 \, \widetilde{\rho}(x, b, Q),$$

with $\widetilde{\rho}(x, b, Q) = \pi J_0 \left[b\, Q(1-x)\right] |\widetilde{\psi}(x, b)|^2$ and $b = |\mathbf{b}_\perp|$.

- Contribution from $\rho(x, b, Q)$ is shifted towards small $|\mathbf{b}_\perp|$ and large $x \rightarrow 1$ as Q increases.

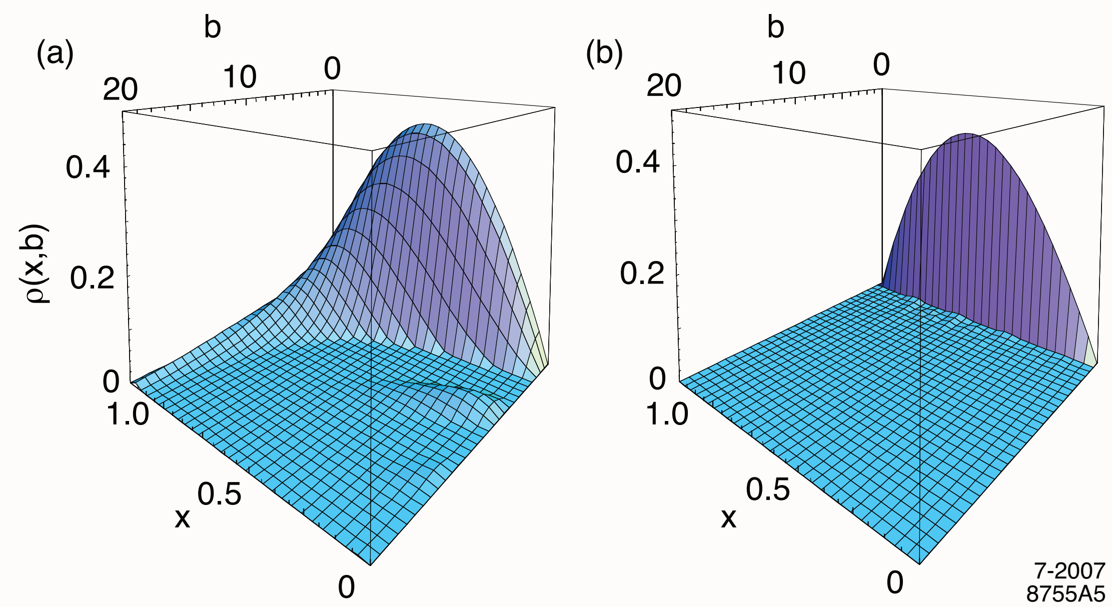


Fig: LF partonic density $\rho(x, b, Q)$: (a) Q = 1 GeV/c, (b) very large Q.

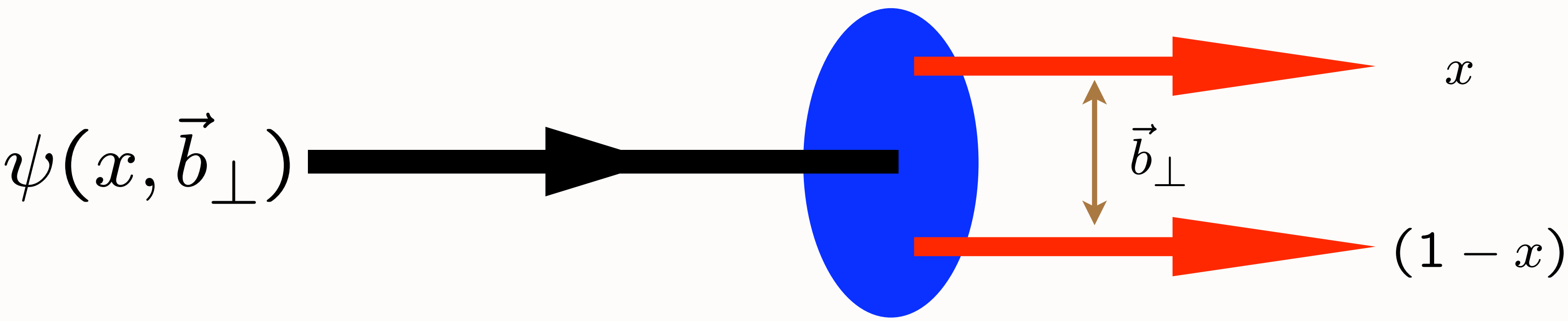
New Perspectives on QCD Phenomena from AdS/CFT

- AdS/CFT: Duality between string theory in Anti-de Sitter Space and Conformal Field Theory
- New Way to Implement Conformal Symmetry
- Holographic Model: Conformal Symmetry at Short Distances, Confinement at large distances
- Remarkable predictions for hadronic spectra, wavefunctions, interactions
- AdS/CFT provides novel insights into the quark structure of hadrons

LF(3+1) $\qquad$ AdS_5

$$\psi(x, \vec{b}_\perp) \longleftrightarrow \phi(z)$$

$$\zeta = \sqrt{x(1-x)\vec{b}_\perp^2} \longleftrightarrow z$$



$$\psi(x, \zeta) = \sqrt{x(1-x)}\,\zeta^{-1/2}\phi(\zeta)$$

Holography: Unique mapping derived from equality of LF and AdS formula for current matrix elements

Holography: Map AdS/CFT to 3+1 LF Theory

Relativistic radial equation: *Frame Independent*

$$\left[-\frac{d^2}{d\zeta^2} + V(\zeta)\right]\phi(\zeta) = \mathcal{M}^2\phi(\zeta)$$

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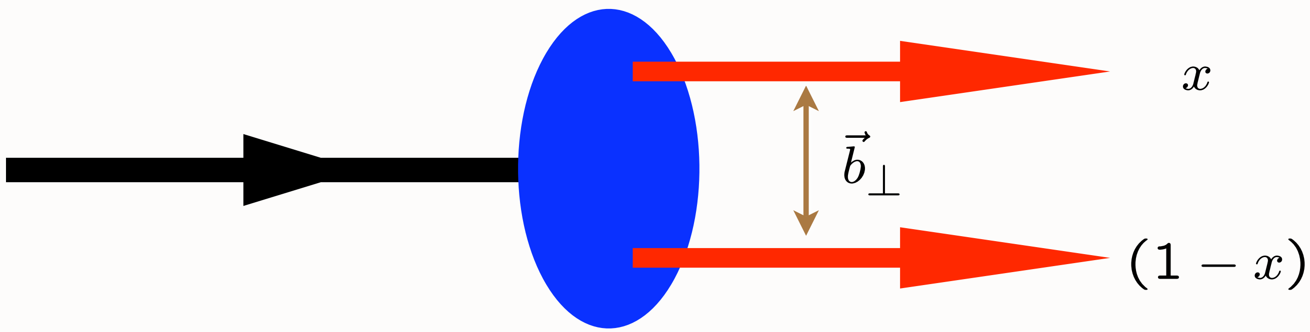
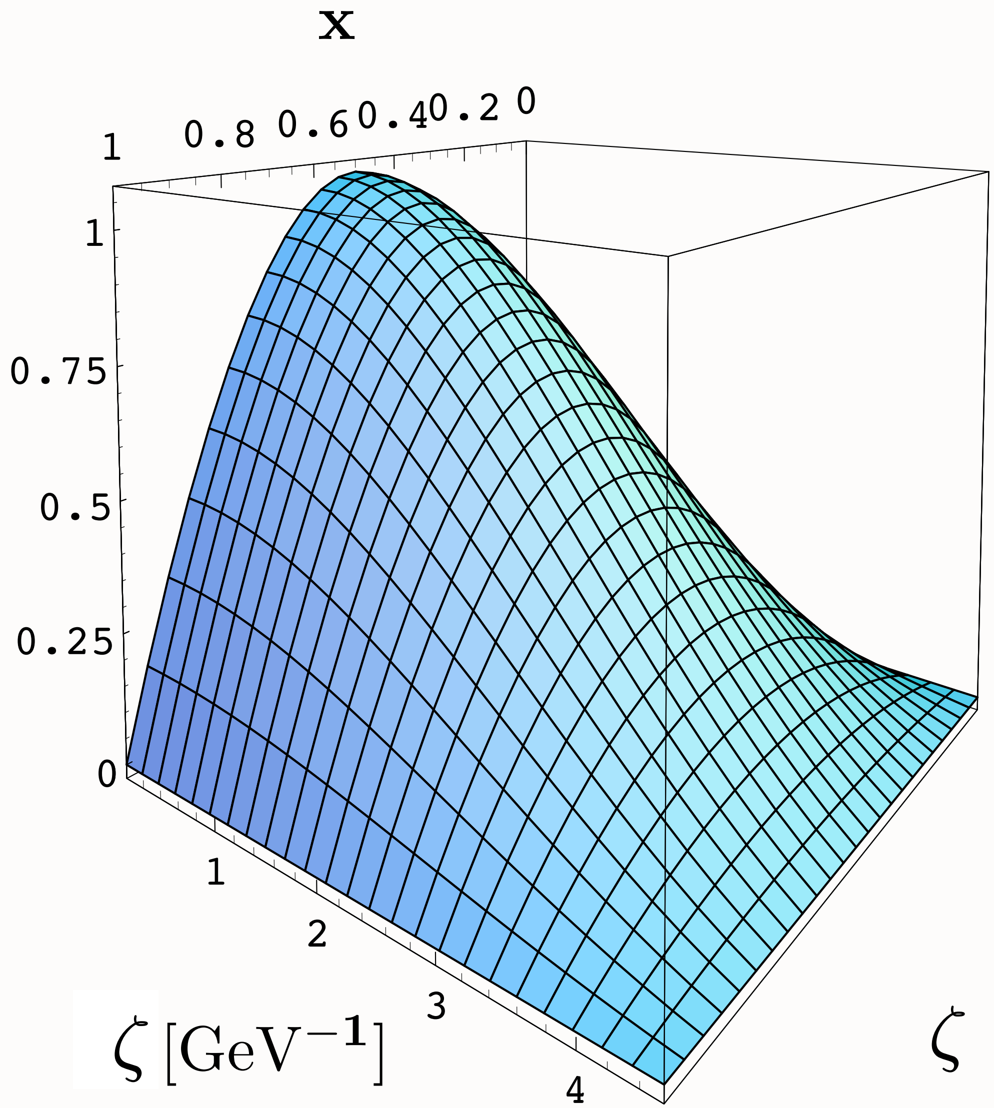
$$\zeta^2 = x(1-x)\mathbf{b}_\perp^2.$$



Effective conformal potential:

$$V(\zeta) = -\frac{1-4L^2}{4\zeta^2}.$$



AdS/CFT prediction for meson LFWF

Holographic Model

Guy de Teramond
SJB

$$\zeta = b\sqrt{x(1-x)}$$

Two-parton ground state LFWF in impact space $\psi(x, b)$ for a for $n = 2, \ell = 0, k = 1$.

String Theory

↓

AdS/CFT

Mapping of Poincare' and Conformal SO(4,2) symmetries of 3+1 space to AdS5 space

↓

Goal: First Approximant to QCD

Counting rules for Hard Exclusive Scattering
Regge Trajectories
QCD at the Amplitude Level

AdS/QCD

Conformal behavior at short distances
+ Confinement at large distance

↓

Semi-Classical QCD / Wave Equations

↓

Holography

Boost Invariant 3+1 Light-Front Wave Equations

J =0,1,1/2,3/2 plus L

↓

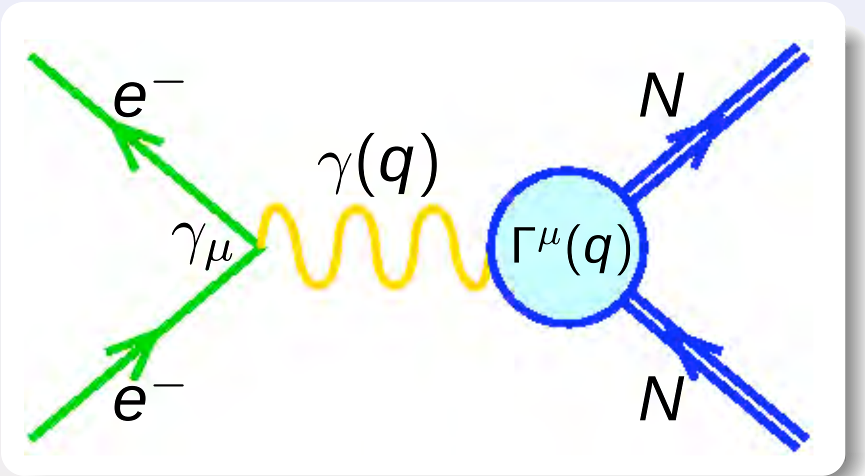
Integrable!

Hadron Spectra, Wavefunctions, Dynamics

Novel Dynamical Tests of QCD at FAIR

- Characteristic momentum scale of QCD: 300 MeV
- Many Tests of AdS/CFT predictions possible
- Exclusive channels: Conformal scaling laws, quark-interchange
- $\bar{p}p$ scattering: fundamental aspects of nuclear force
- Color transparency: Coherent color effects
- Nuclear Effects, Hidden Color, Anti-Shadowing
- Anomalous heavy quark phenomena
- Spin Effects: A_N, A_{NN}

Nucleon Form Factors



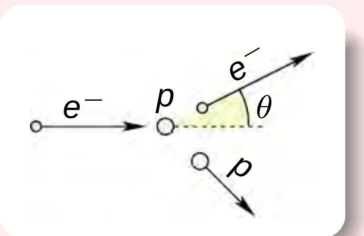
Nucleon current operator (Dirac & Pauli)

$$\Gamma^\mu(q) = \gamma^\mu F_1(q^2) + \frac{i}{2M_N}\sigma^{\mu\nu}q_\nu F_2(q^2)$$

Electric and Magnetic Form Factors

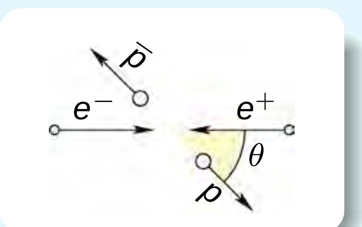
$$G_E(q^2) = F_1(q^2) + \tau F_2(q^2) \qquad \tau = \frac{q^2}{4M_N^2}$$

$$G_M(q^2) = F_1(q^2) + F_2(q^2)$$



Elastic scattering $\qquad ep \longrightarrow ep$

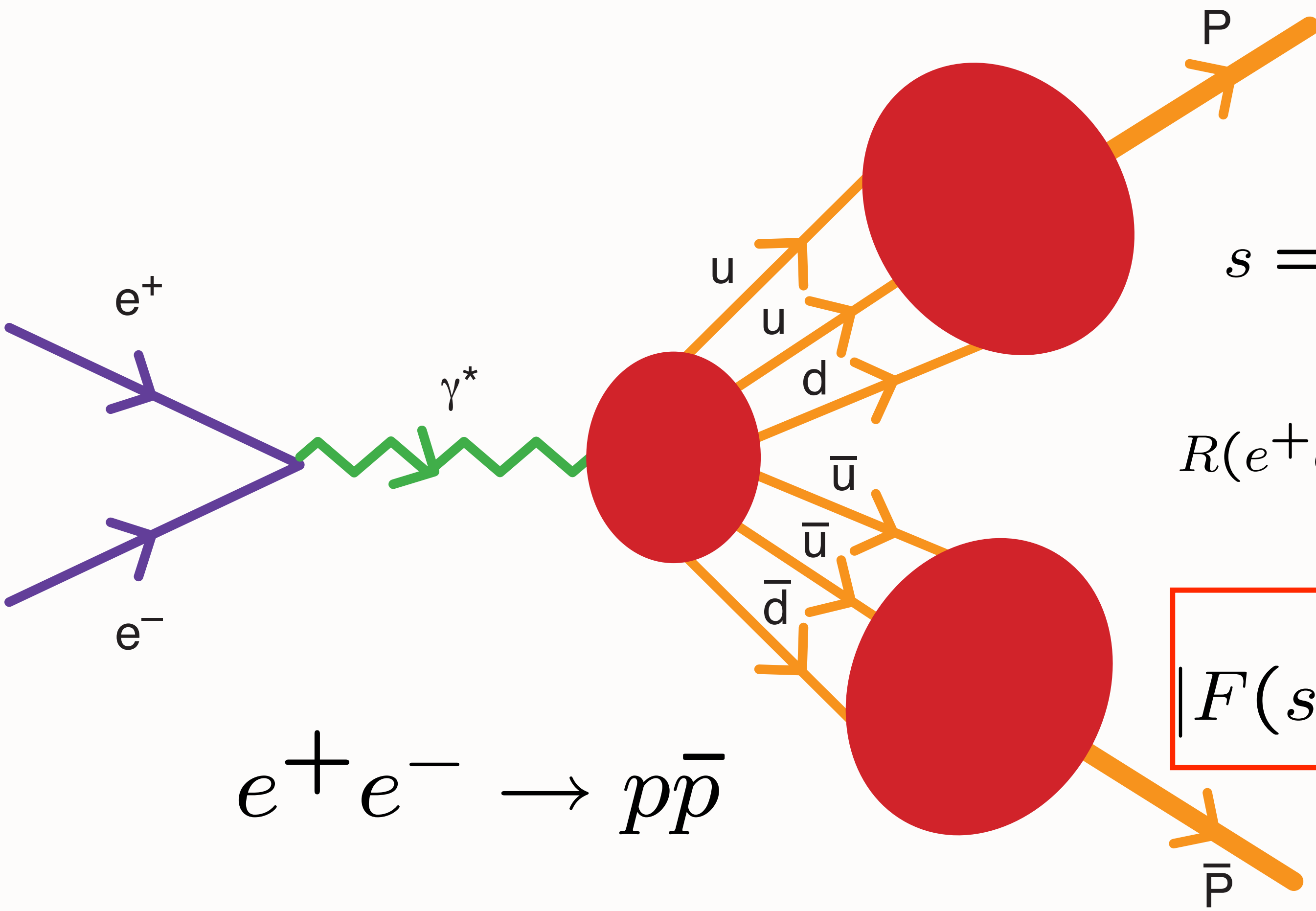
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2 E_e' \cos^2\frac{\theta}{2}}{4E_e^3 \sin^4\frac{\theta}{2}}\left[G_E^2 + \tau\left(1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right)G_M^2\right]\frac{1}{1+\tau}$$



Annihilation $\qquad e^+e^- \longrightarrow p\bar{p}$

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2\sqrt{1-1/\tau}}{4q^2}\left[(1+\cos^2\theta)|G_M|^2 + \frac{1}{\tau}\sin^2\theta|G_E|^2\right]$$

Exclusive Processes



$$e^+e^- \to p\bar{p}$$

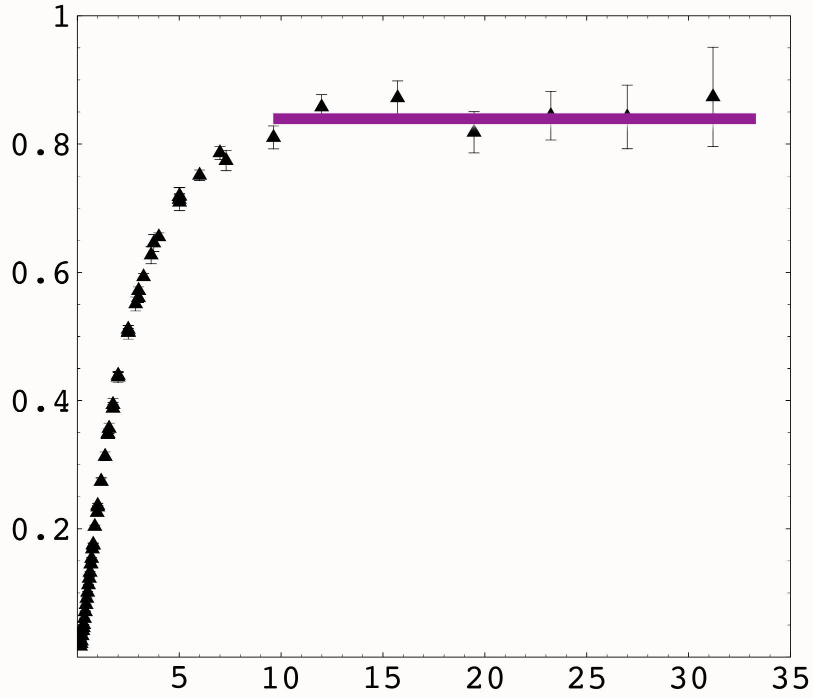
$$s = (E_{e^+} + E_{e^-})^2$$

$$R(e^+e^- \to H\bar{H}) \propto |F(s)|^2$$

$$|F(s)| \propto [\tfrac{1}{s}]^{n_q - 1}$$

Probability decreases with number of constituents!

$Q^4 F_1^p(Q^2)$ [GeV^4]



Q^2 [GeV^2]

$$F_1(Q^2) \sim [1/Q^2]^{n-1}, \quad n = 3$$

measured in electron-proton elastic scattering

From: M. Diehl *et al.* Eur. Phys. J. C **39**, 1 (2005).

- Phenomenological success of dimensional scaling laws for exclusive processes

$$d\sigma/dt \sim 1/s^{n-2}, \quad n = n_A + n_B + n_C + n_D,$$

implies QCD is a strongly coupled conformal theory at moderate but not asymptotic energies
Farrar and sjb (1973); Matveev *et al.* (1973).

- Derivation of counting rules for gauge theories with mass gap dual to string theories in warped space (hard behavior instead of soft behavior characteristic of strings) Polchinski and Strassler (2001).

Quark Counting Rules for Exclusive Processes

- Power-law fall-off of the scattering rate reflects degree of compositeness
- The more composite -- the faster the fall-off
- Power-law counts the number of quarks and gluon constituents
- Form factors: probability amplitude to stay intact
- $F_H(Q) \propto \frac{1}{(Q^2)^{n-1}}$ n = # elementary constituents

PQCD and Exclusive Processes

Lepage; SJB
Efremov, Radyuskin

$$M = \int \prod dx_i dy_i \phi_F(x, \tilde{Q}) \times T_H(x_i, y_i, \tilde{Q}) \phi_I(y_i, Q)$$

- Iterate kernel of LFWFs when at high virtuality; distribution amplitude contains all physics below factorization scale
- Rigorous Factorization Formulae: Leading twist
- Underly Exclusive B-decay analyses
- Distribution amplitude: gauge invariant, OPE, evolution equations, conformal expansions
- BLM scale setting: sum nonconformal contributions in scale of running coupling
- Derive Dimensional Counting Rules/ Conformal Scaling