The Color Glass Condensate in AA and pA collisions at the LHC

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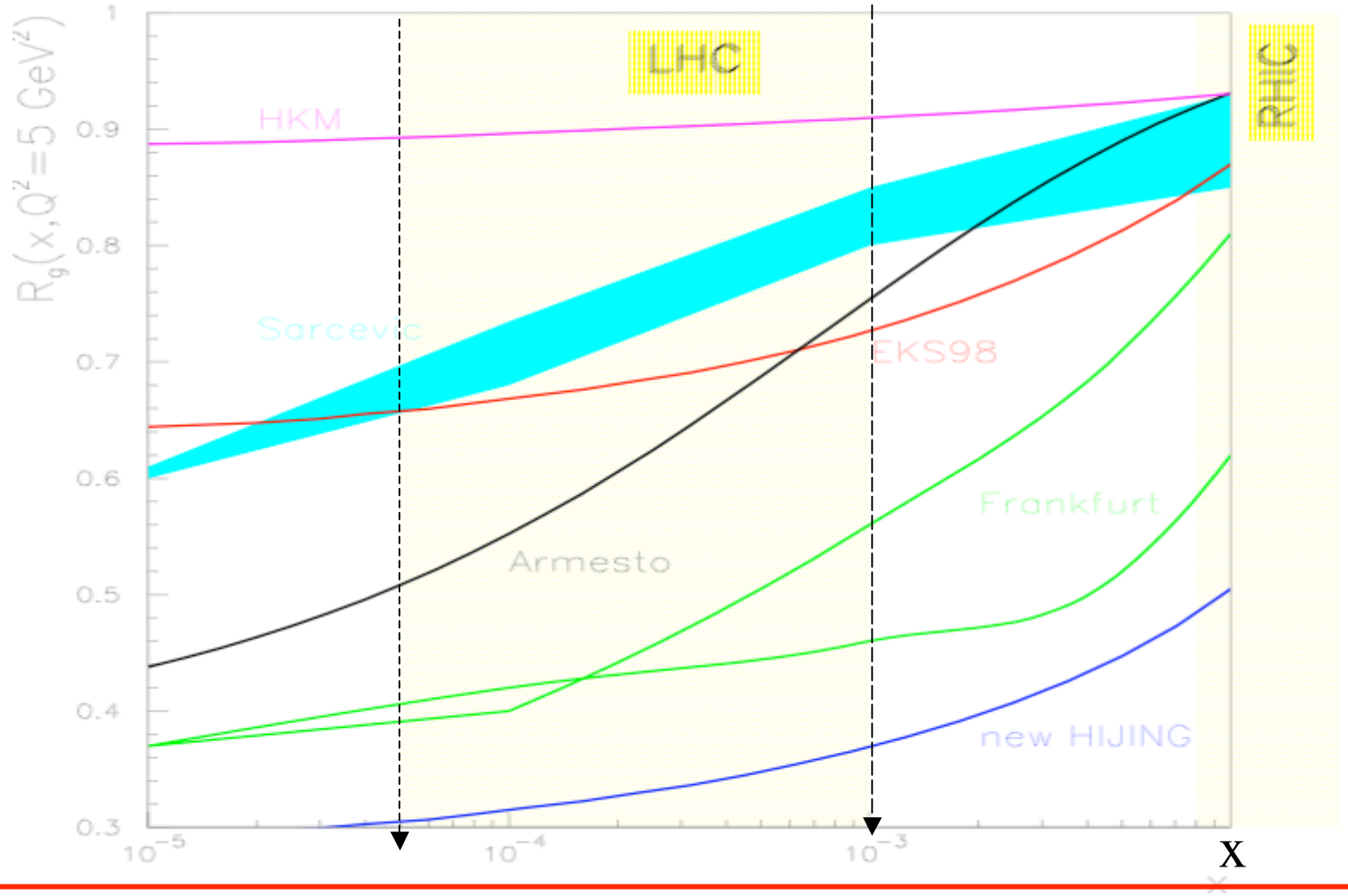
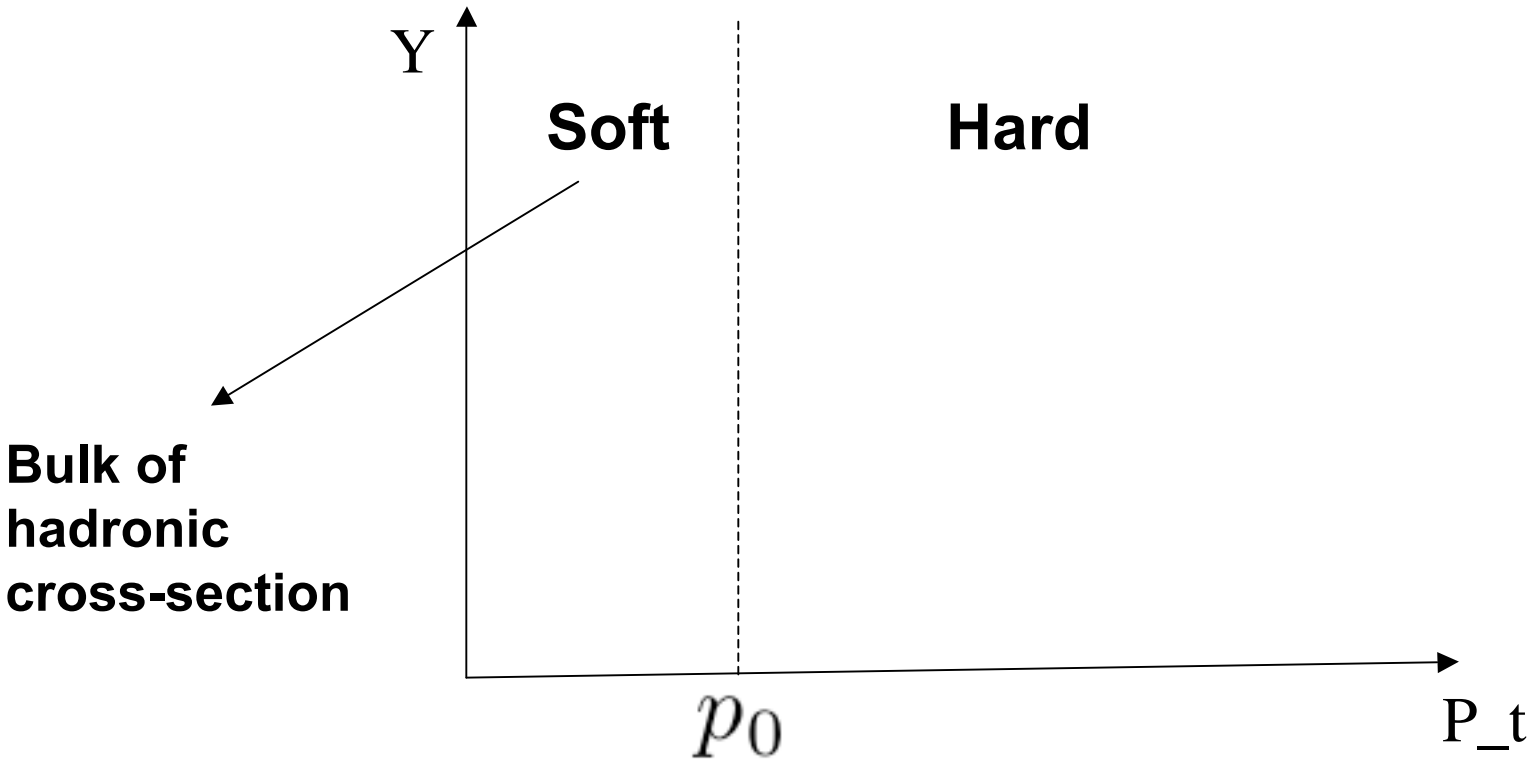
Ratio of Gluon densities in Lead to Proton at $Q^2 = 5\,\mathrm{GeV}^2$ in x range $10^{-2} - 10^{-5}$

(Armesto-Salgado)

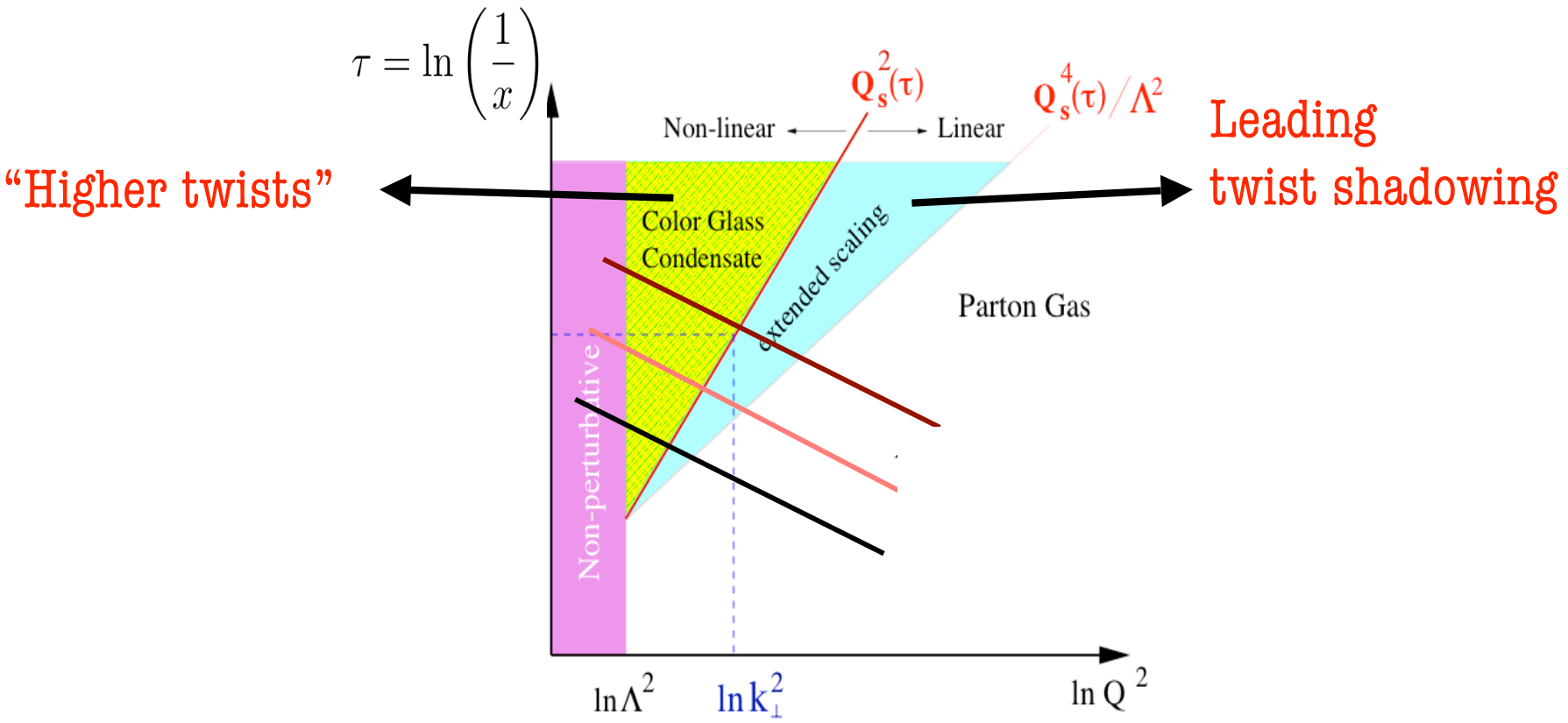


Factor 3 uncertainity in glue PDF sets => Factor 9 uncertainity in semi-hard HI-parton cross-sections at LHC

❖ “Pre-RHIC” understanding of initial conditions



Novel regime of QCD at high energies

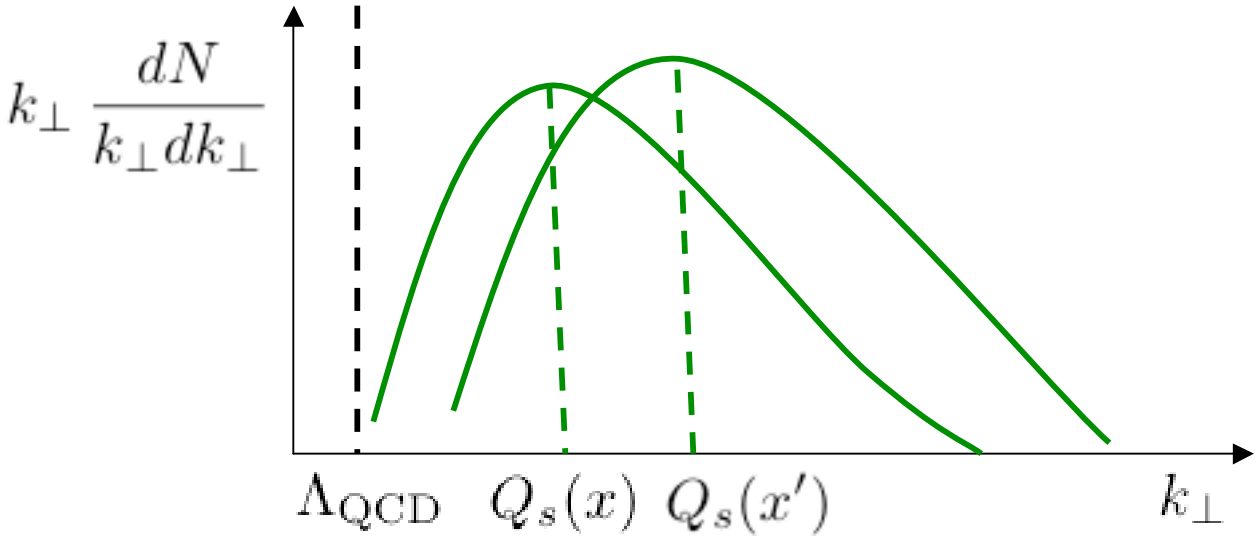


$Y_{\mathrm{RHIC-central}} = 0 \ (x = 10^{-2}, Q_s = 1.4\,\mathrm{GeV})$

$Y_{\mathrm{RHIC}} = 3, Y_{\mathrm{LHC-central}} = 0 \ (x = 5 \cdot 10^{-4}, Q_s = 2.2\,\mathrm{GeV})$

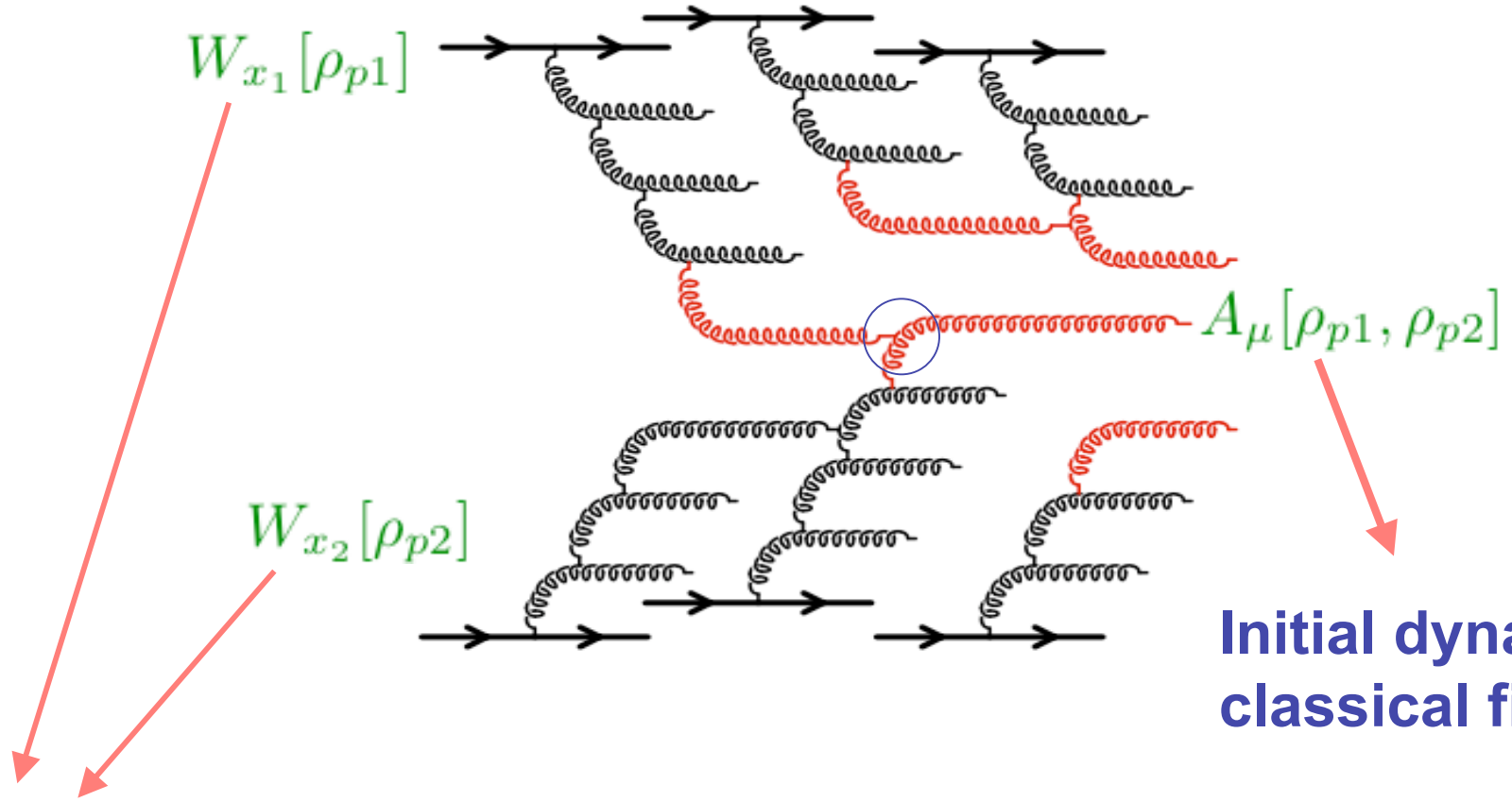
$Y_{\mathrm{LHC}} = 3 \ (x = 3 \cdot 10^{-5}, Q_s = 3.4\,\mathrm{GeV})$

COLOR GLASS CONDENSATE



- ✓ **Gluons are colored**
- ✓ **Random sources evolving on time scales much large than natural time scales-very similar to spin glasses**
- ✓ **Bosons with large occupation # ~ $\frac{1}{\alpha_S}$ - form a condensate**
- ✓ **Typical momentum of gluons is Q_s**

HADRONIC COLLISIONS: MELTING THE CGC

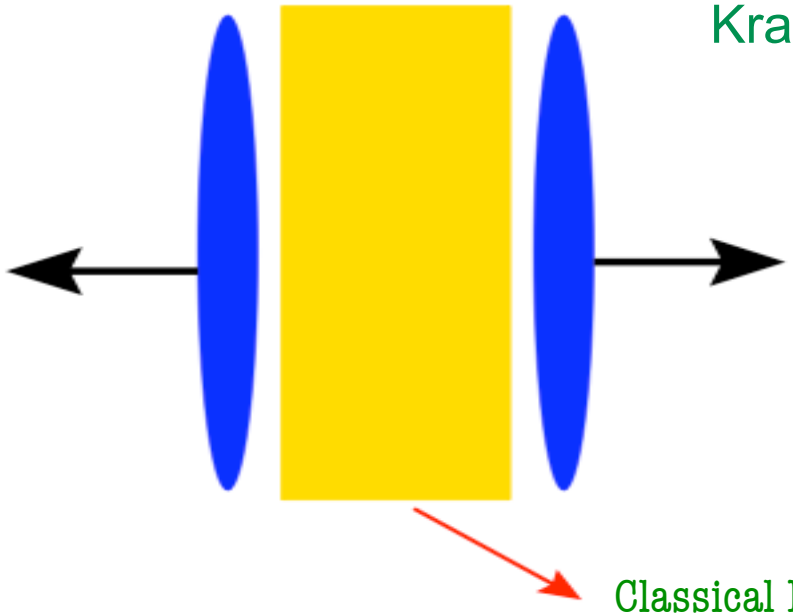


Initial dynamics-classical fields

Frozen glassy configurations of wee partons -evolution with energy described by RG JIMWLK and BK equations

Colliding Sheets of Colored Glass

Krasnitz,Nara,RV(KNV); Lappi



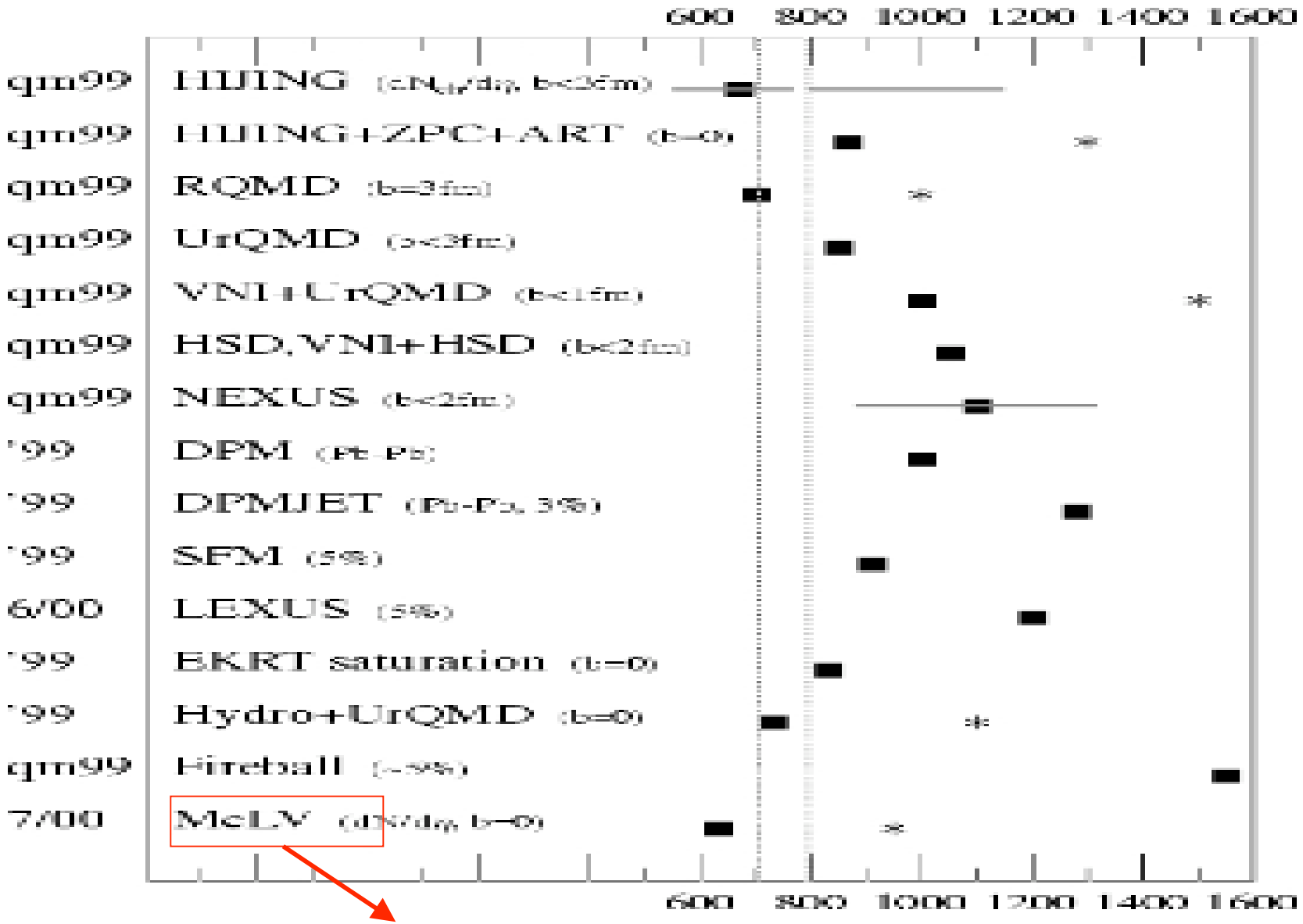
Classical Fields with occupation # f= $\frac{1}{\alpha_S}$

Initial energy and multiplicity of produced gluons depends on Q_s

$$\frac{1}{\pi R^2}\frac{dE}{d\eta} = \frac{0.25}{g^2} Q_s^3 \qquad \frac{1}{\pi R^2}\frac{dN}{d\eta} = \frac{0.3}{g^2} Q_s^2$$

Straight forward extrapolation from HERA => RHIC : Q_s = 1.4 GeV

LHC : Q_s = 2.2 GeV

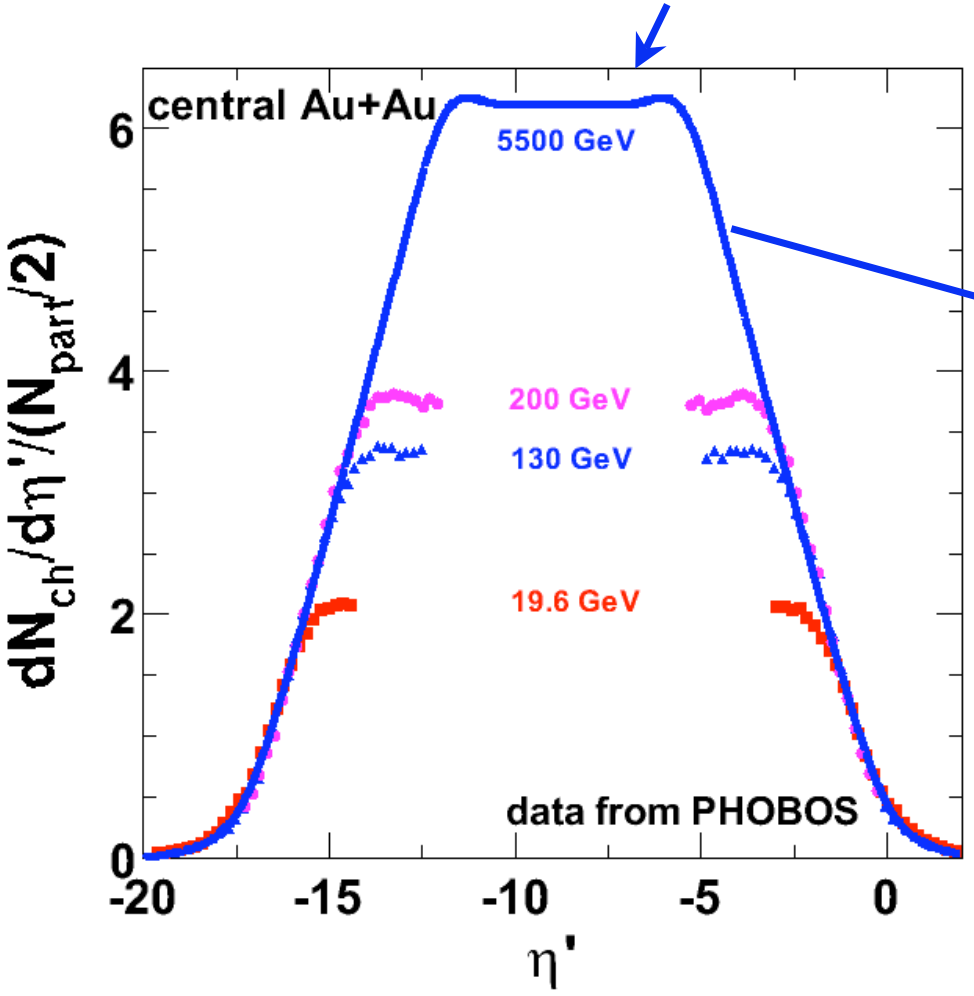


KNV estimate of multiplicity at RHIC

dN/deta extrapolations to LHC

Central Pb+Pb collisions at LHC energy

Assuming: dN/dη grows ∝log(s) and *linear* scaling at high η holds



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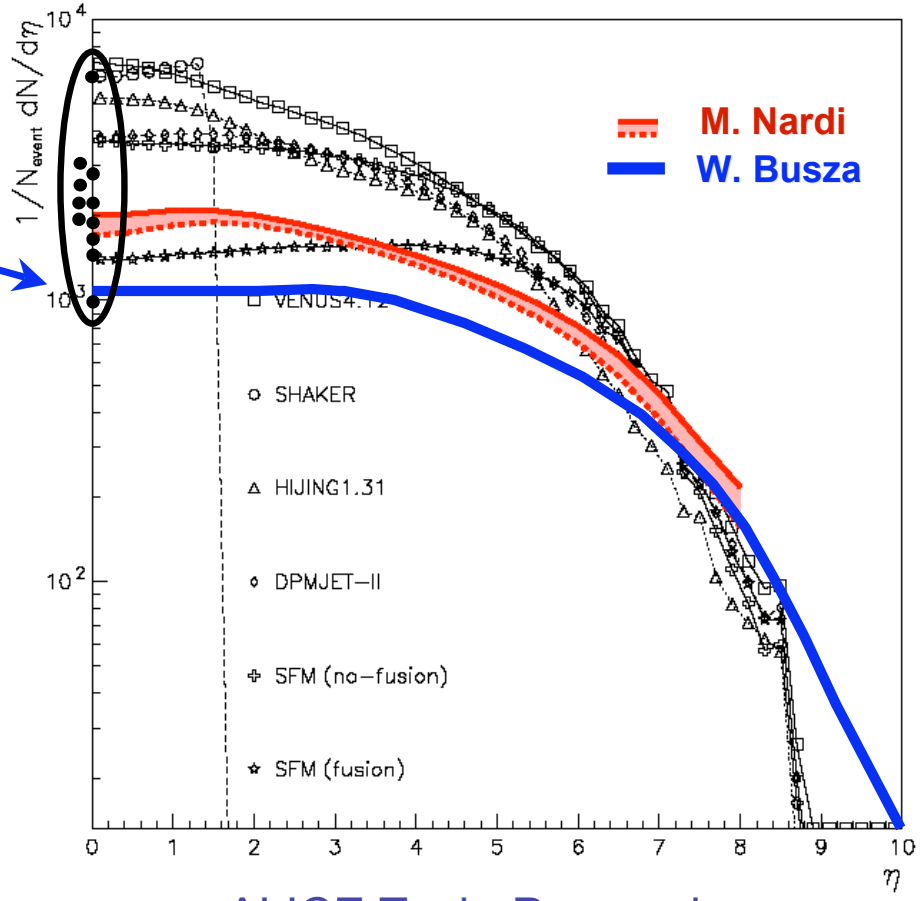


ALICE Tech. Proposal,
M. Nardi, various models and fits

Gabor Veres (QM 2005)

RHIC AA bulk data consistent with CGC initial state

- **Multiplicity distributions**

  Kharzeev, Levin, Nardi

- **Centrality dependence**

  KLN, KNV

- **Energy/centrality ``factorization”**

  Armesto, Salgado, Wiedemann

- **Limiting fragmentation**

  Jalilian-Marian

- **E_T / N consistent with requirement for PdV flow**

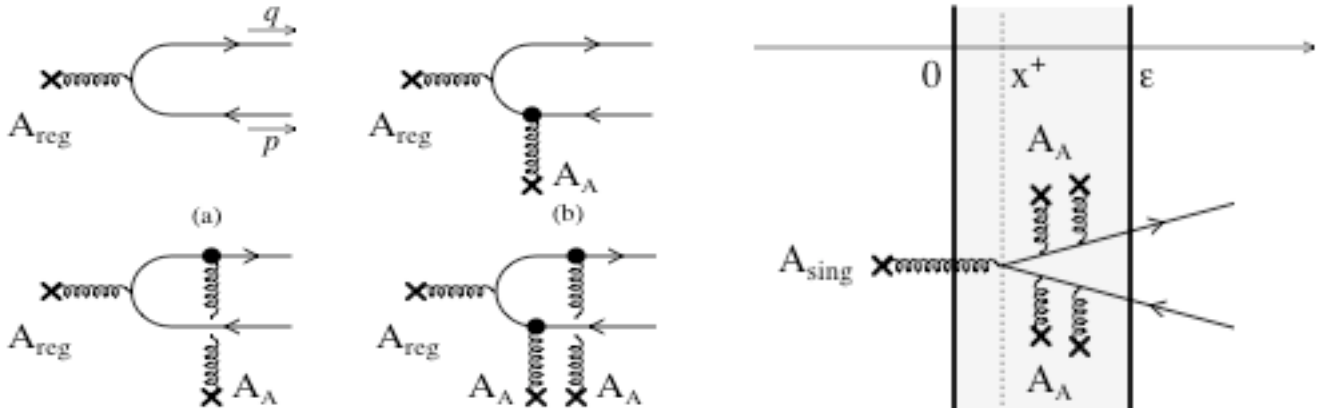
  Hirano, Nara

Expect other qualitative features of RHIC soft physics to be enhanced…

- **Limiting fragmentation over wider rapidity range-- deviations contain important physics information to distinguish different saturation models**

- **Plasma is hotter, flows more strongly, lives longer,…**

Quark pair production to all orders in pA



Blaizot, Gelis, RV
Fujii, Gelis, RV
Nikolaev,Schafer, Zakharov

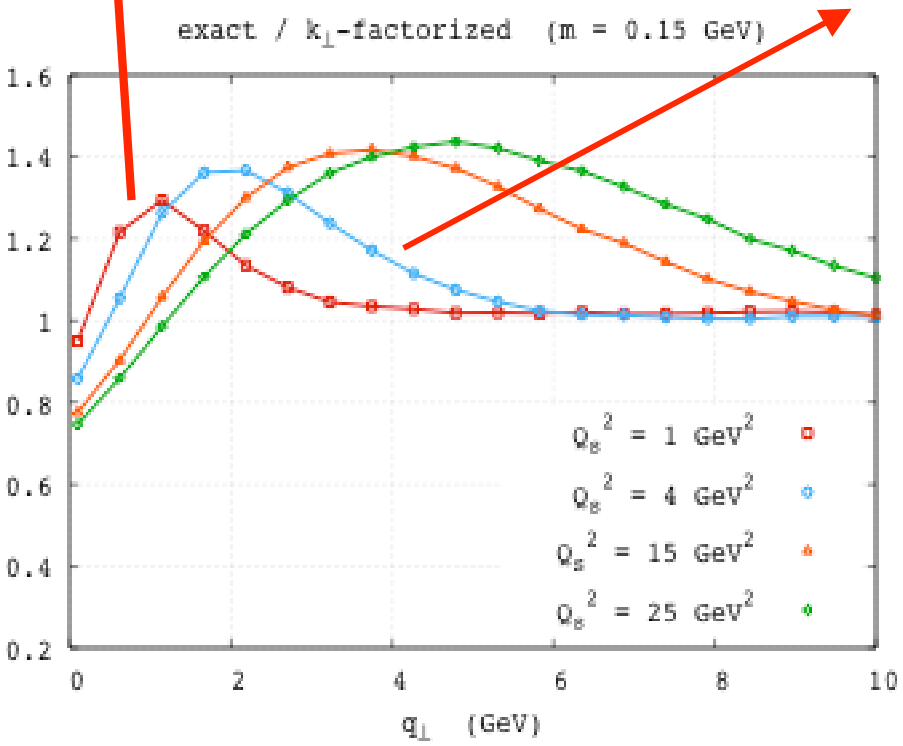
$$\frac{d\sigma^{pA\to q\bar{q}X}}{dy_p dy_A d^2p_\perp q_\perp} \propto \phi_p \times [A\phi_{g,g} + (B\phi_{g;q\bar{q}} + c.c) + C\phi_{q\bar{q};q\bar{q}}]$$

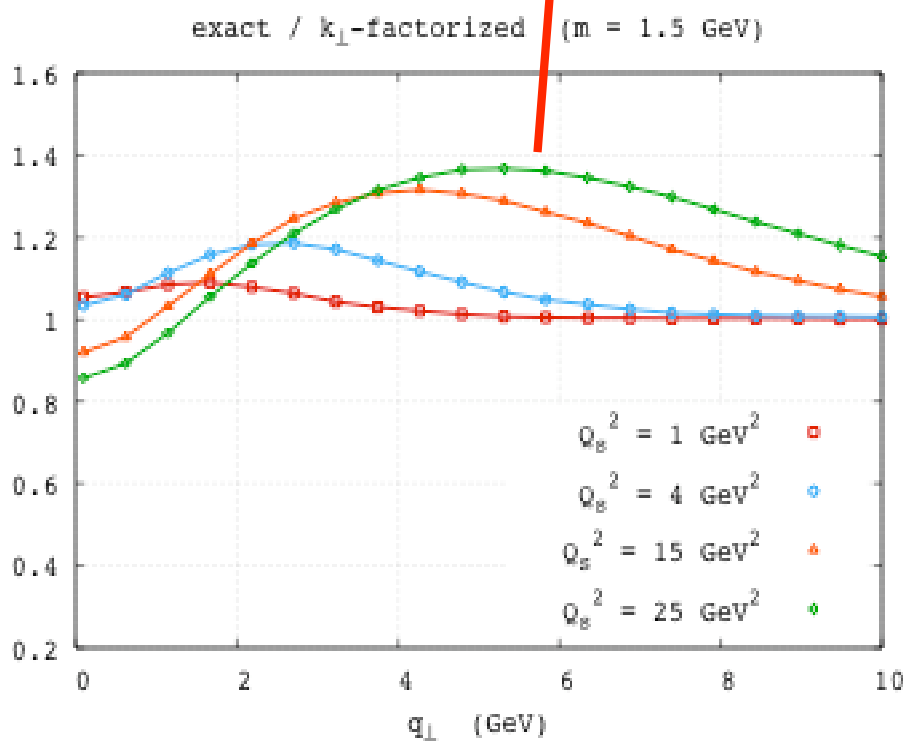
Novel unintegrated "multi-parton" distributions - sensitive probe of QCD dynamics

RHIC - CENTRAL RAPIDITY

LHC CENTRAL RAPIDITY

LHC FORWARD RAPIDITY





Results show violation of widely used k_t factorization ansatz
- for strange and charm quark production respectively.

The demise of the Structure function

- Dipoles (and multipole) operators may be more relevant observables at high energies

Jalilian-Marian, Gelis;
Kopeliovich et al;
Kovner, Wiedemann
Blaizot, Gelis, RV
Jalilian-Marian, Kovchegov

- Are universal-process independent.

Collins, Jung

- RG running of these operators - detailed tests of high energy QCD.

Predictions for ``semi-hard" LHC physics - quarkonia, "jets" EM-probes will differ significantly from collinear factorization

Why small x physics is interesting:

- Interplay of relativity and quantum mechanics in coherence & decoherence of wavefunctions- **Thermalization?**

- Universal ``vacuum" properties of theory: Reggeons, Pomerons, Odderons-**quasi-particle excitations** relevant for elastic and diffractive scattering.

- Remarkable correspondences to statistical physics: spin glasses, travelling wavefronts, percolation.

- Initial conditions for all soft and ``semi-hard" physics

LHC - the CGC machine!