Study of Cold Superdense Baryon Matter by Cumulative Processs

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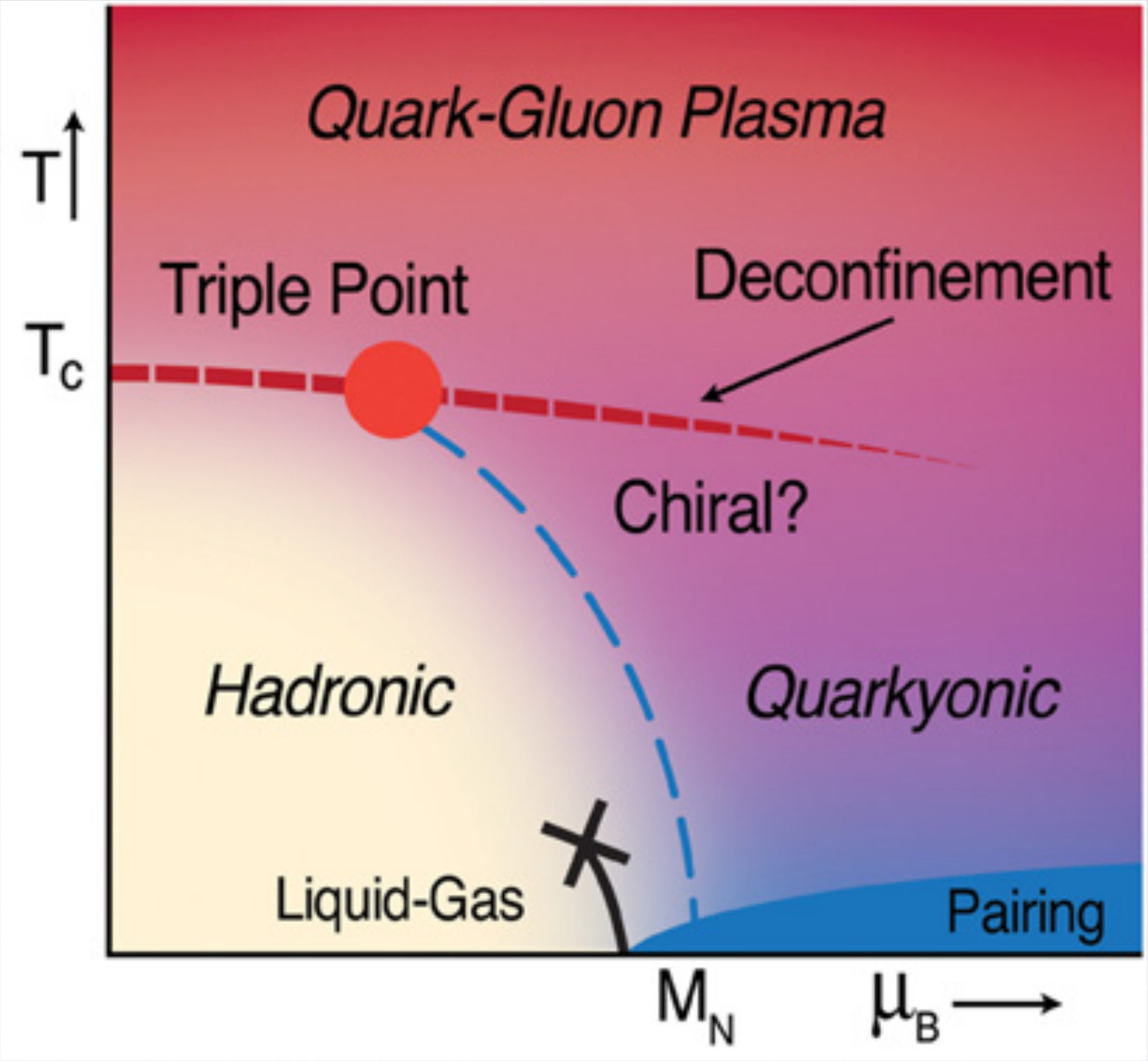
Outline:

- **Motivation**
- **Cumulative processes: a brief overview**
- **Flucton model: nuclear structure functions at large X**
- **Fluctons as Cold Superdense Baryon Matter**
- **Summary**

Cold Superdense Baryon Matter



L.McLerran & L.McLerran & R. Pisarski (07)
V. Braguta et al. (16)

Cumulative Processes: definition

definition:

processes beyond one free-nucleon kinematics

- **fixed nucleus target: backward particle production**
  data: G.Leksin et al. (57), M.Mescheryakov et al. (57)

- **nucleus projectile fragmentation:**
  particles with momentum > momentum per nucleon
  scaling: A.Baldin (1971), data: V.Stavinsky et al. (1971)

Efremov's classification:

Hot models:

rescattering, resonances, fireballs, final state interaction, ⋯

V. Kopeliovich, ⋯

Cold models:

fluctons, short-range nucleon correlations, multiquark bags, ⋯

D. Blokhintsev, V. Lukyanov, A. Efremov, V. Burov, A. Titov, L. Kaptari,
L. Frankfurt, M. Strikman, A. Kaidalov, VK, G. Lykasov, ⋯

Cumulative Processes: scaling properties

How to distinguish "hot" and "cold" models?

"Hot" models:

rescattering, resonances, fireballs, final state interaction, …
may "ingnite" hot medium, etc. ->
dependence on projectile hadron/nucleus

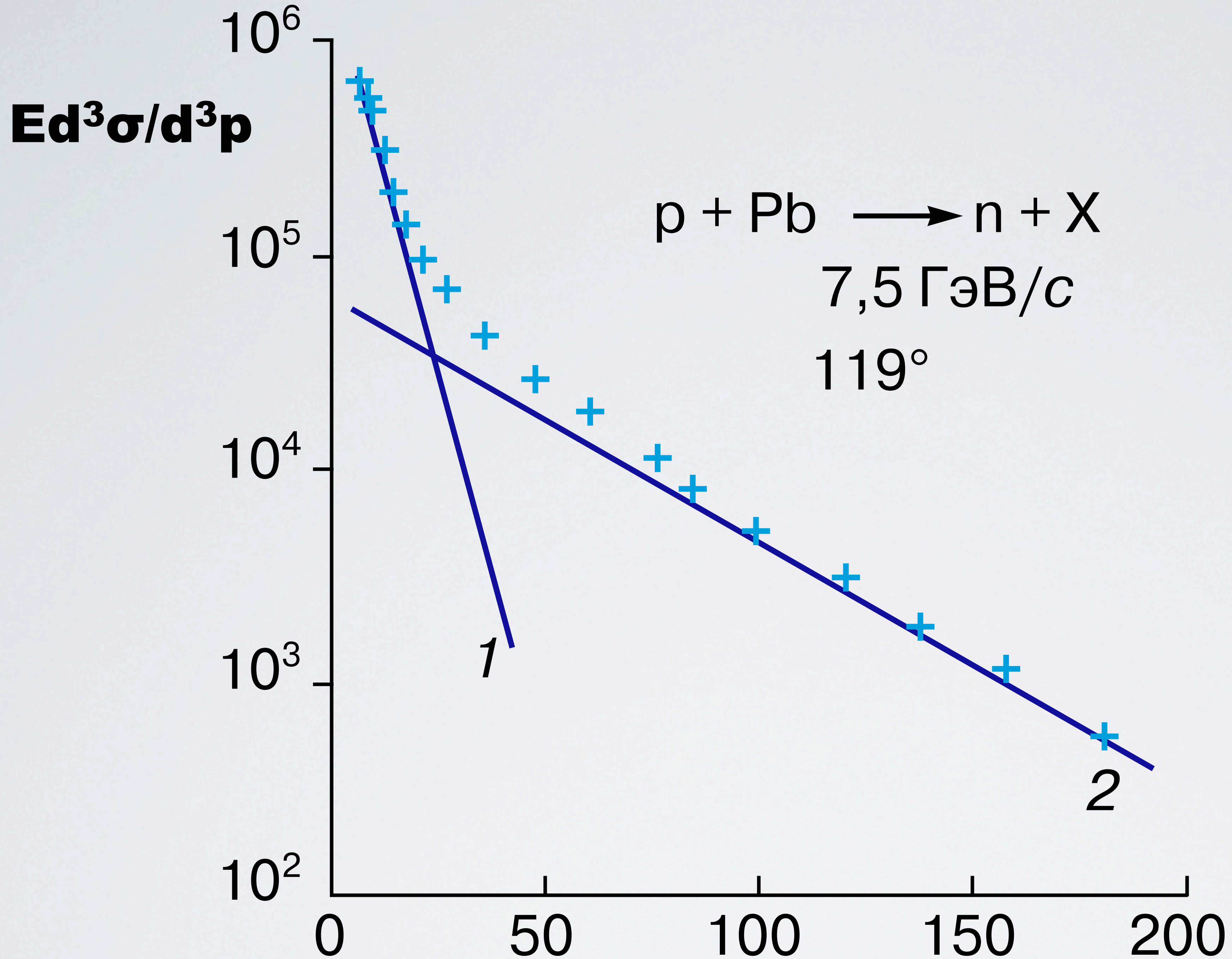
nonlocal interactions ->
no scaling properties !

"Cold" models:

fluctons, short-range nucleon correlations, multiquark bags, …

local interactions ->
scaling properties !
nuclear parton struction function

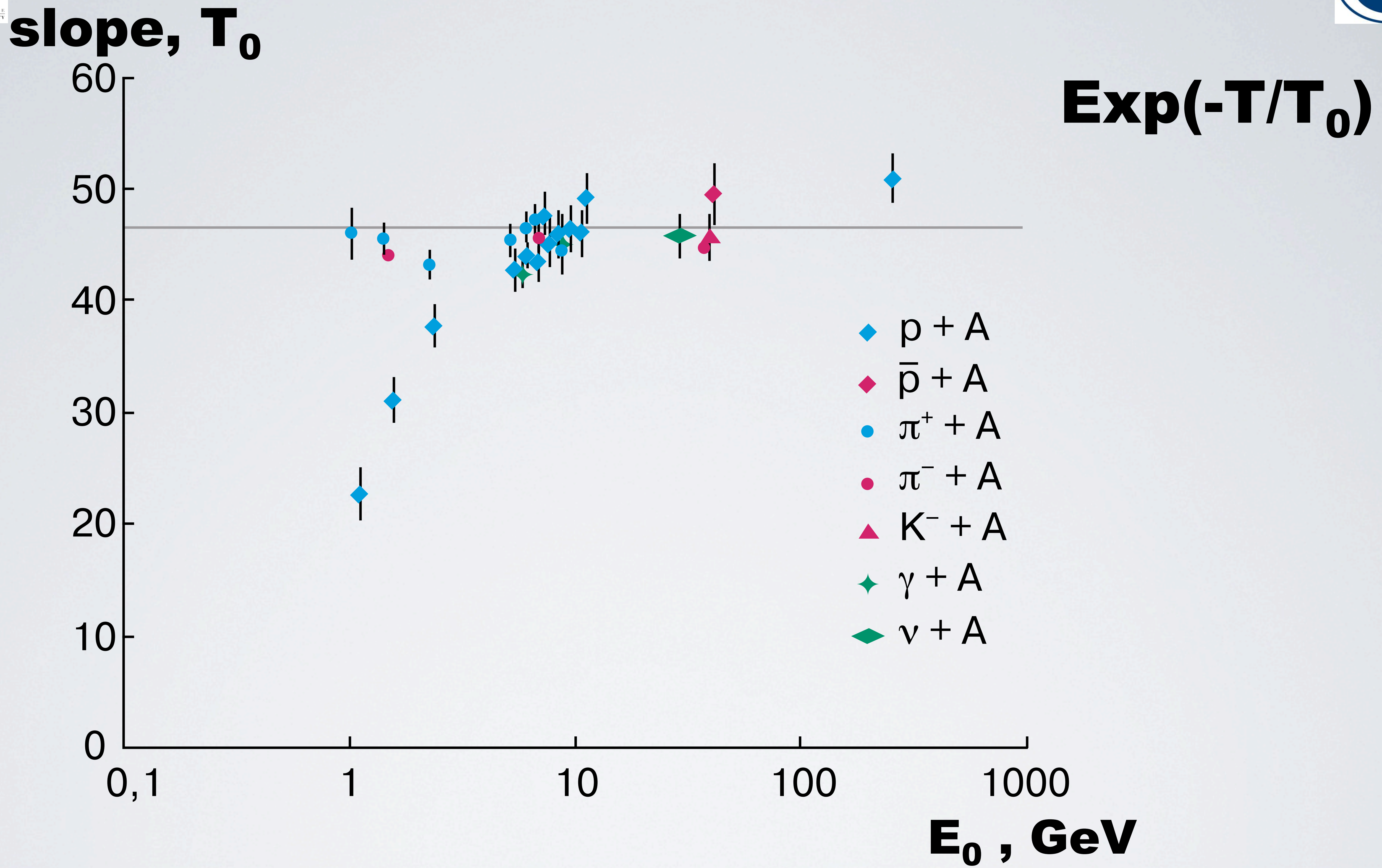
Cumulative processes: backward particles



$Exp(-T/T_0)$

1 – evaporation
2 – cumulative

Cumulative processes: projectile particles



Energy of projectile E_0

Perturbative QCD for hard processes

$Q^2/s = x$ – fixed, $s \rightarrow \infty$ (Bjorken limit)

$\rightarrow$

- **Factorization of hard and soft contributions**

A.Efremov & A.Radyushkin,
A.Mueller, J.Collins, D.Soper, G. Sterman, …

$$\sigma_{HARD} = \sigma_{parton} \times F(x, Q^2) + (1/Q^2)$$

- **GLAPD Q^2-evolution**

V.Gribov, L.Lipatov, G. Altarelli, G.Parisi, Yu.Dokshitzer

Nuclear structure function: deep inelastic scattering

Factorization of hard and soft contributions for DIS on free nucleon and nucleus:

$$\sigma_{HARD} = \sigma_{parton} \times F_N(x, Q^2) \ + (1/Q^2)$$

$$\sigma_{HARD} = \sigma_{parton} \times F_A(x, Q^2) \ + (1/Q^2)$$

$$F_A(n, Q^2) = \int_C^1 x_A^{n-1} F_A(x, Q^2) dx_A = \sum C_\alpha \left(n, \frac{Q^2}{\mu^2}, \alpha(\mu^2)\right) f_{\alpha/A}(n, \mu^2) + O\left(\frac{1}{Q^2}\right)$$

$$f(n) = \int_0^1 dx\, dx^{n-1} f(x);$$

Nuclear structure function: deep inelastic scattering

$$F_A(n,Q^2) = \int_C^1 x_A^{n-1}\, F_A(x,Q^2)dx_A = \sum C_\alpha\left(n,\frac{Q^2}{\mu^2},\alpha(\mu^2)\right) f_{\alpha/A}(n,\mu^2) + O\left(\frac{1}{Q^2}\right)$$

$$f(n) = \int_0^1 dx\, dx^{n-1} f(x);$$

$$\frac{d\, f_{a/A}(n,\mu^2)}{d\ln\mu^2} = \sum_b \gamma_{ab}\big(n,\alpha(\mu^2)\big) f_{b/A}(n,\mu^2)\,;$$

$$\mu^2 = Q^2;$$

$$V_a = q_a - \bar{q}_a\,, \quad f_1 = q^s(n,Q^2) = \sum_a (q_a + \bar{q}_a), \quad f_2 = G(n,Q^2);$$

$$\frac{dV_\alpha(n,Q^2)}{d\ln Q^2} = \gamma_{qq}^{NS}\big(n,\alpha(Q^2)\big) V_\alpha(n,Q^2);$$

$$\frac{df_i(n,Q^2)}{d\ln Q^2} = \gamma_{ik}^{S}\big(n,\alpha(Q^2)\big) f_k(n,G^2)\,, \quad i,k = 1.2$$

Nuclear structure function: EMC-effect and “collective” nuclear sea

$$f_A^{\pm}(2,Q^2) \;=\; \int\limits_0^1 dx\, x\Big(q_A^S(x,Q^2) + G_A((x,Q^2)\Big) \;=\; 1\,,$$

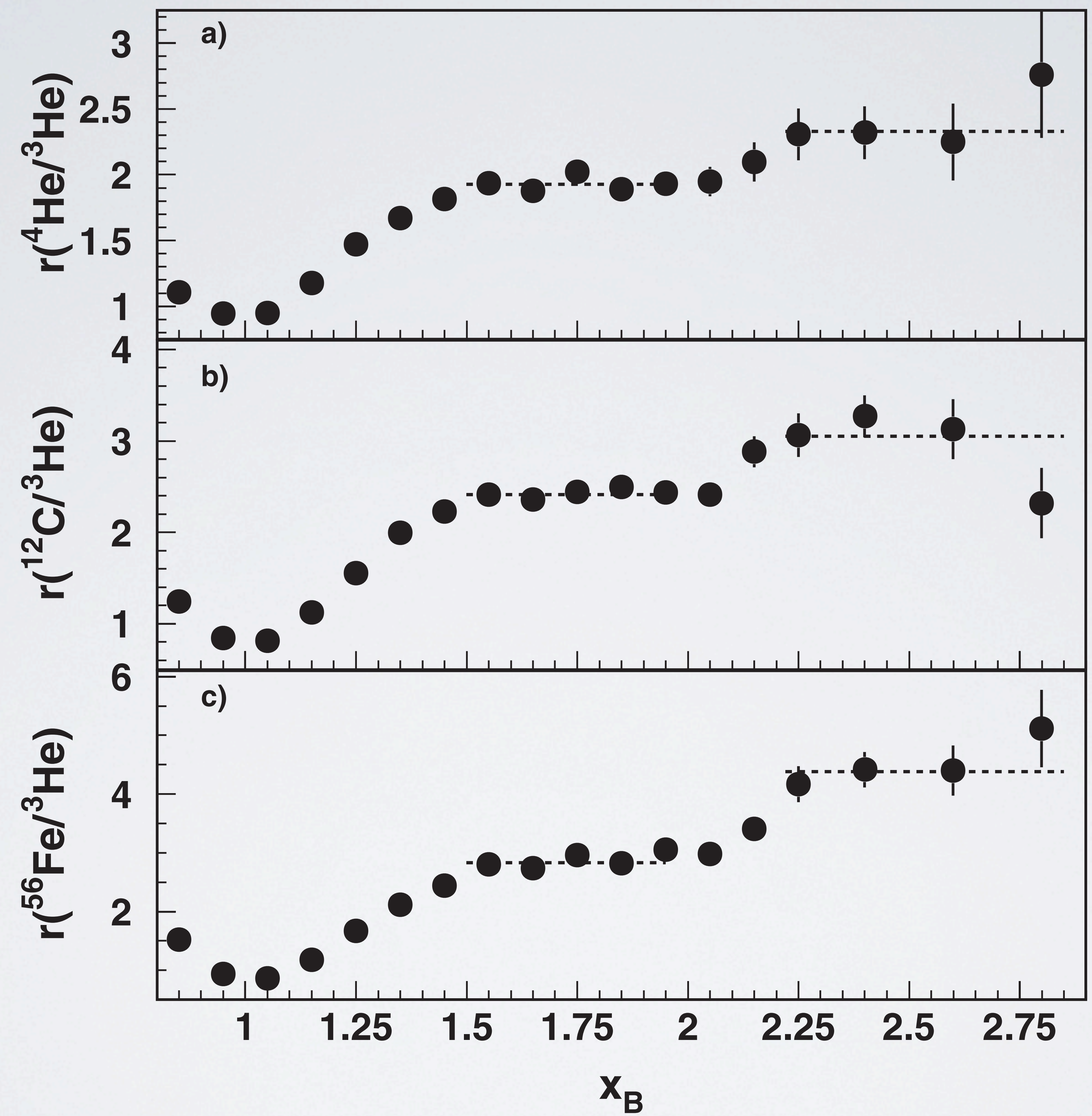
$$f_N^{+}(2) \;=\; 1 \;\Rightarrow\; \int\limits_0^A dy\, y\, T^{+}(y) \;=\; 1 - \frac{\varepsilon_A}{m}\,,$$

$$\begin{aligned} S_A &= T_A \otimes S_N + S'_A \\ G_A &= T_A \otimes G_N \otimes G_N + G'_A \end{aligned} \quad\left|\quad \begin{aligned} f_A^{\pm} &= q^S + C^{\pm} G \\ f_A^{\pm} &= q_A^S + C^{\pm} g_A \\ g_A S &= T_A^{\pm} f_N^{\pm} - C^{\pm} g_A \;= \\ &= T_A^{\pm} f_N^{\pm} - C^{\pm}(T_A^{\pm} g_N + \tilde{g}_A) \end{aligned}\right.$$

prediction: hard “collective” quark sea in nuclei

A.Efremov, A.Kaidalov, VK, G.Lykasov, N.Slavin (88)

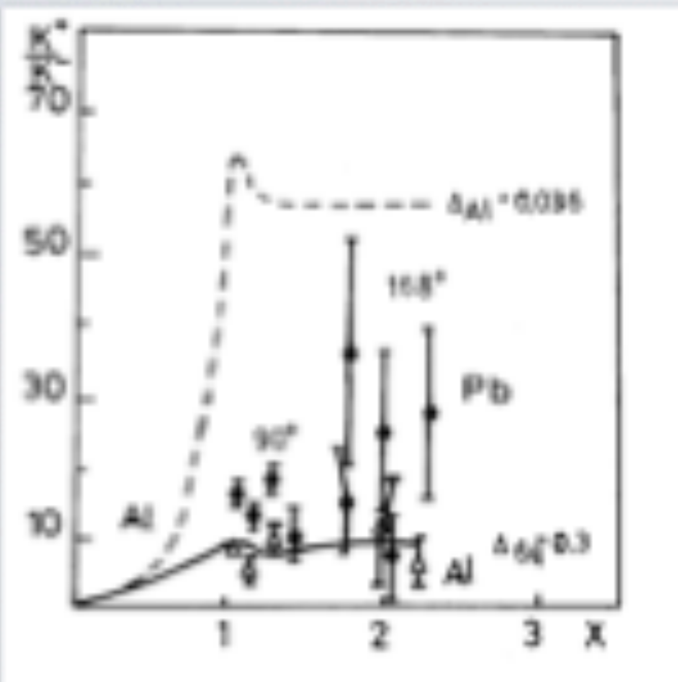
Nuclear structure function at X > 1

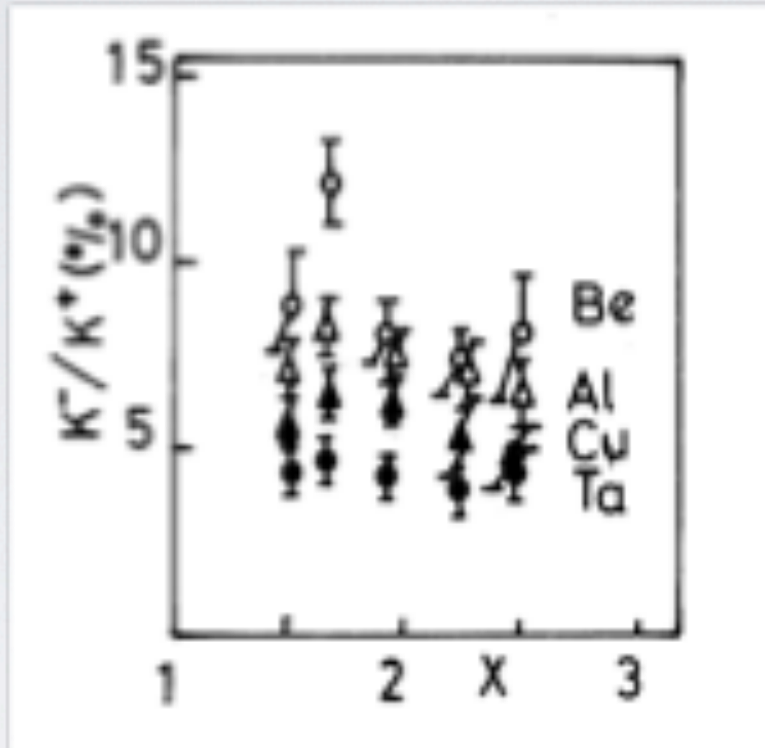


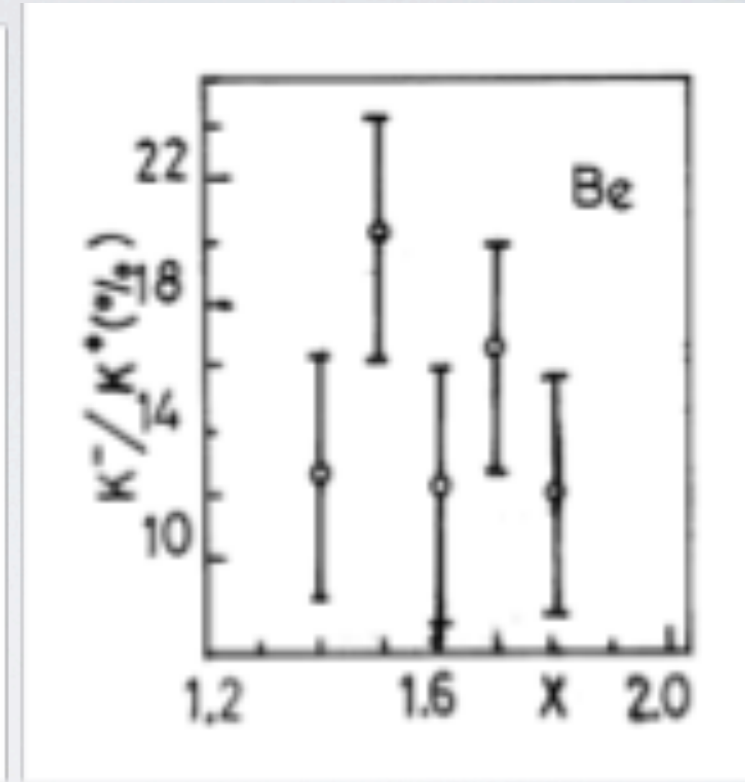
CLAS Coll. K. Egiyan (06)

Cumulative processes:
hard “collective” nuclear sea at X > 1

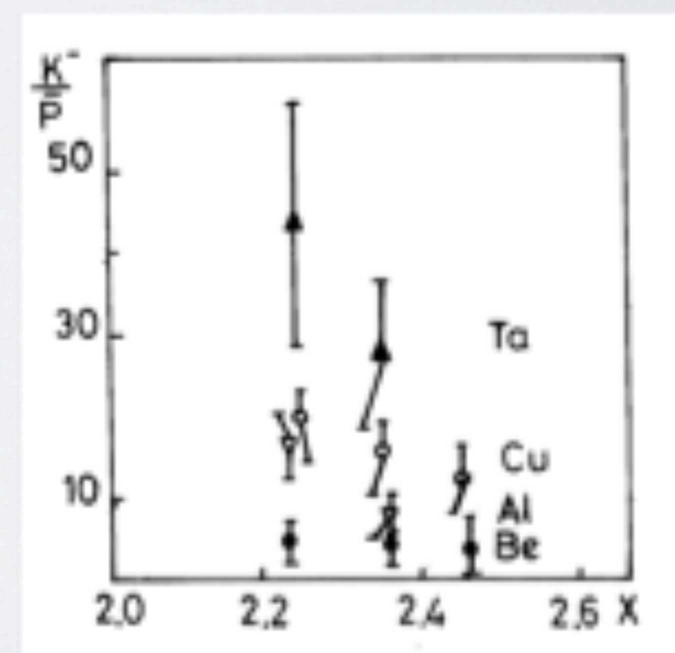
hard “collective” quark sea in nuclei confirmed by data



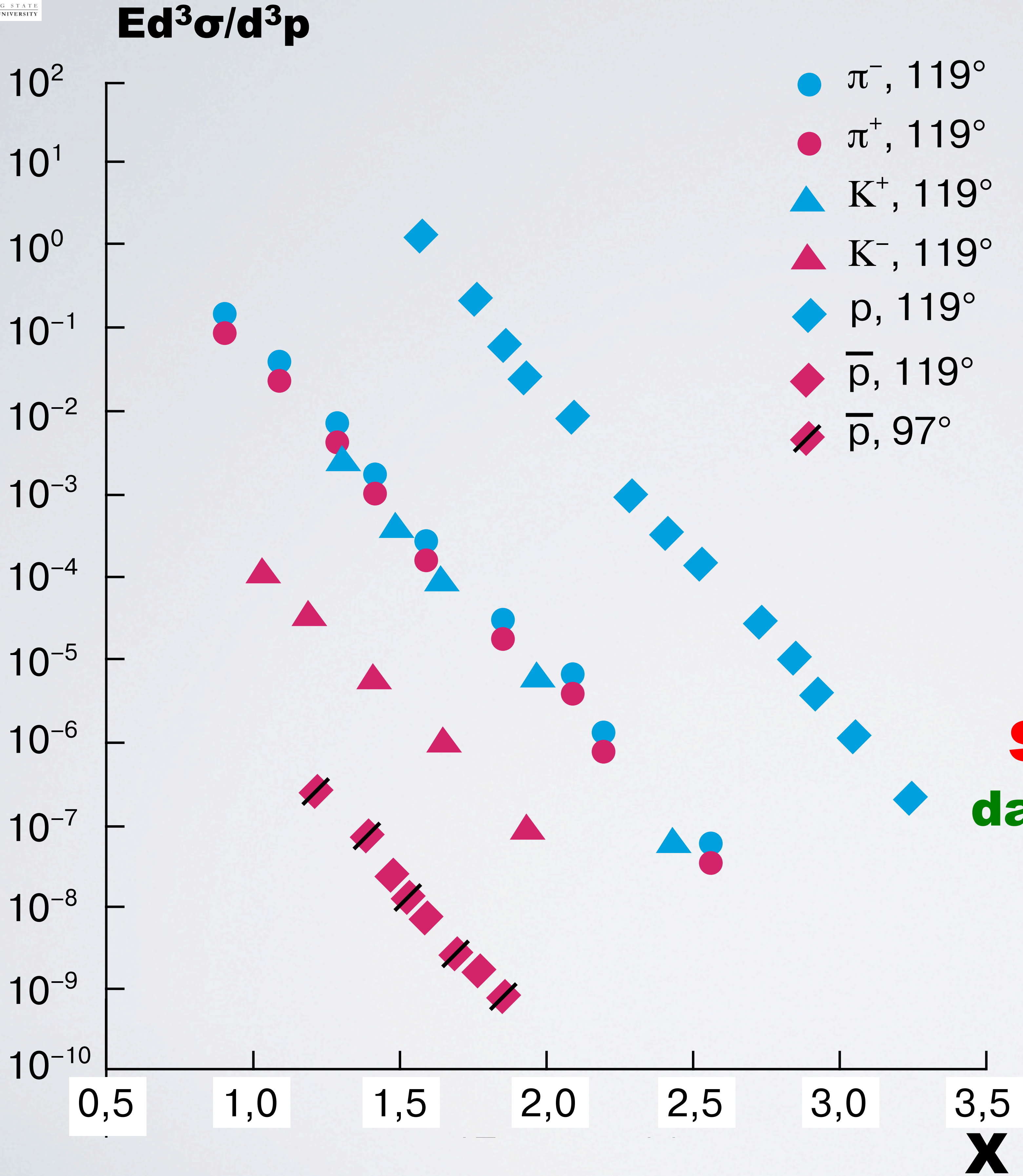




V. Stavinsky et al. (82) Yu. Kiselev et al. (89) L. Zolin et al. (92)



Cumulative proceess: superscaling !



A.Efremov, A.Kaidalov, VK, G.Lykasov, N.Slavin (1988)

Pure "sea" particles:

K⁻

antiproton

equal slopes: superscaling !

data: Leksin et al. (1989)

Cumulative processes at NICA: Cold Superdense Baryon Matter

How cumulative particle production will shed light on Cold Superdensed Baryon Matter?

Cumulative process at NICA:

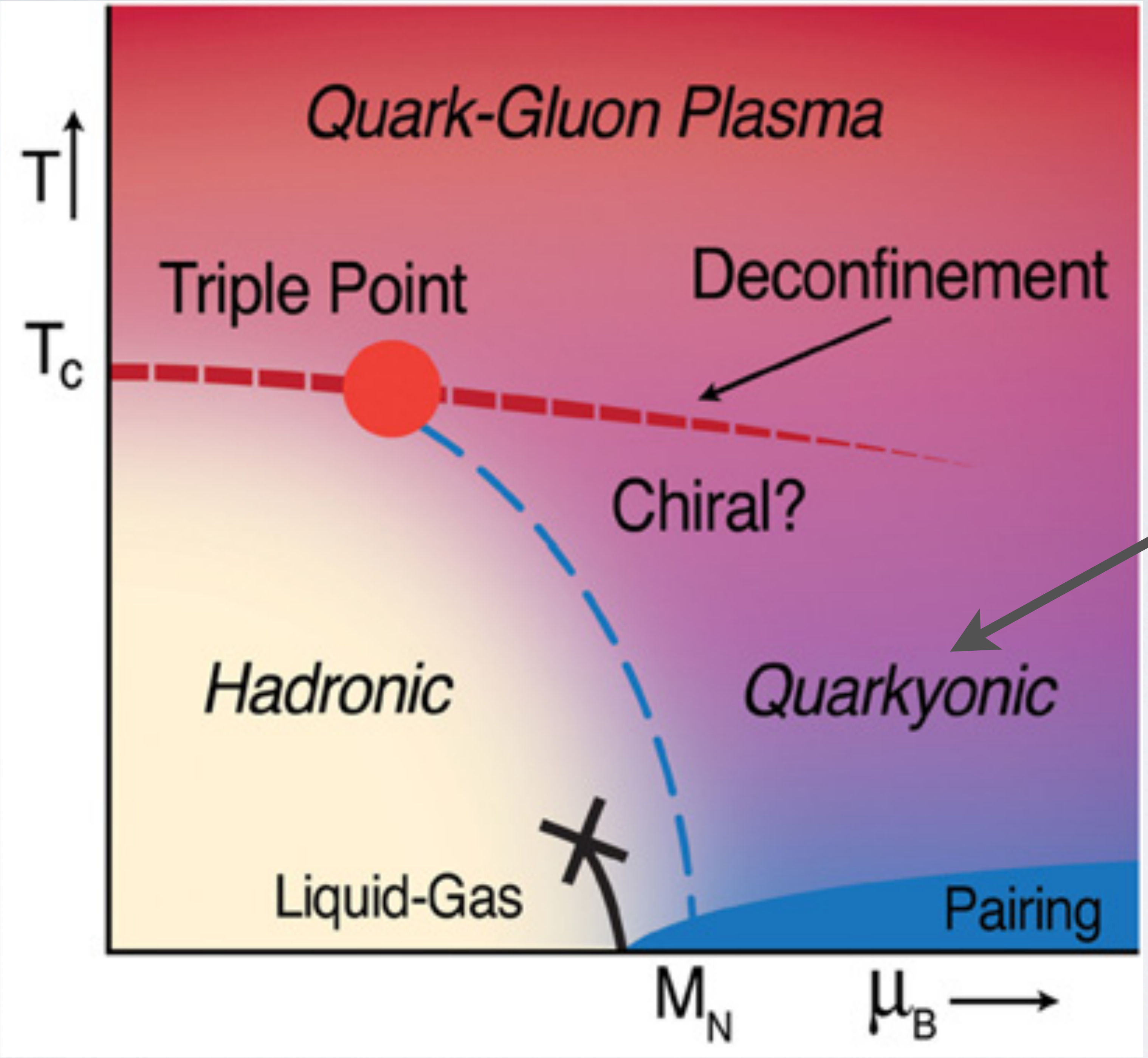
an estimate for BM@N experiment would reach X>5

Cumulative particle production and observables

A.Andrianov, M. Braun, VK, V. Vechernin et al.
A.Stavinsky, S.Shimansky et. al.
(PNPI, ITEP, SPbSU,SPbPU&JINR) in progress

MC event generator HARDPING with nuclei
Ya.Berdnikov, VK et al.

Cumulative processes at NICA:
Cold Superdense Baryon Matter



Cumulative
X > 5

L.McLerran & L.McLerran & R. Pisarski (07)

Lattice: quarkyonic at $\rho > 5\rho_0$ V. Braguta et al. (16)

Summary

- **Cumulative processes and Fluctons**

- **Multiquark flucton model:**
  Cumulative processes
  EMC effect
  Cronin effect

- **Flucton model and Cold Superdense Baryon Matter:**
  phase transition?
  chemical potential?
  quarkyonic phase?