High-energy QCD at the LHC and the future EIC

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on behalf of
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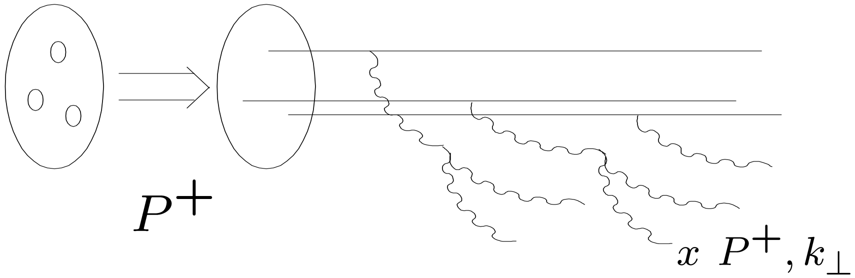
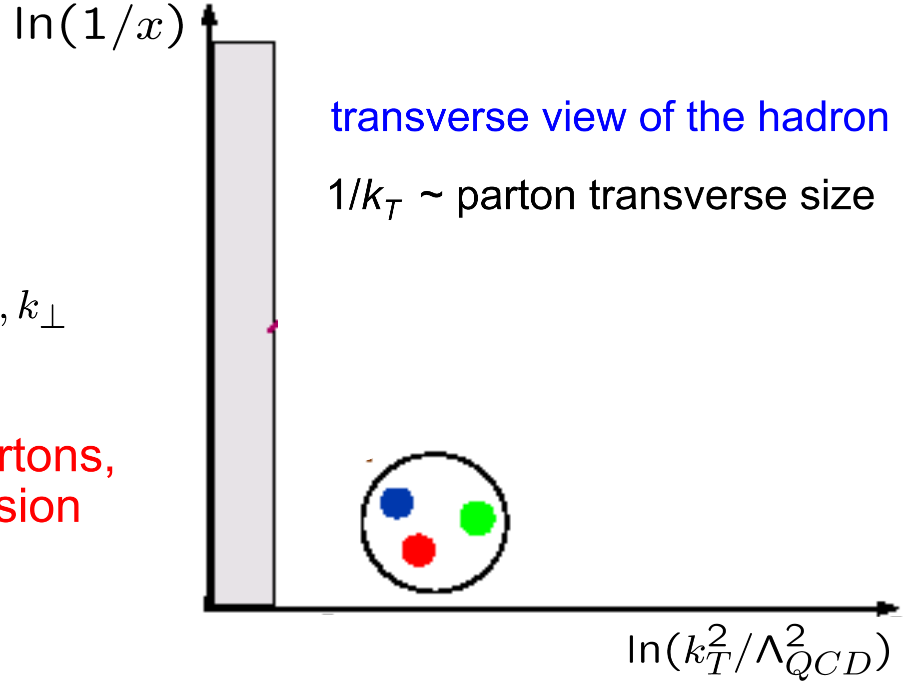
Edmond Iancu, François Gelis, Grégory Soyez (IPhT)

From independent partons...

the parton content of high-energy hadrons:



when a hadron is a dilute system of partons, they interact incoherently during a collision



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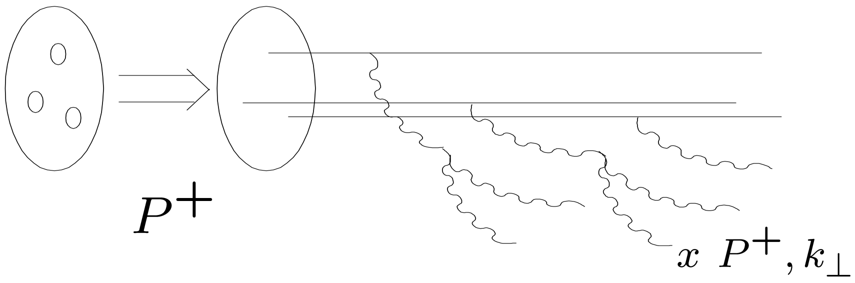

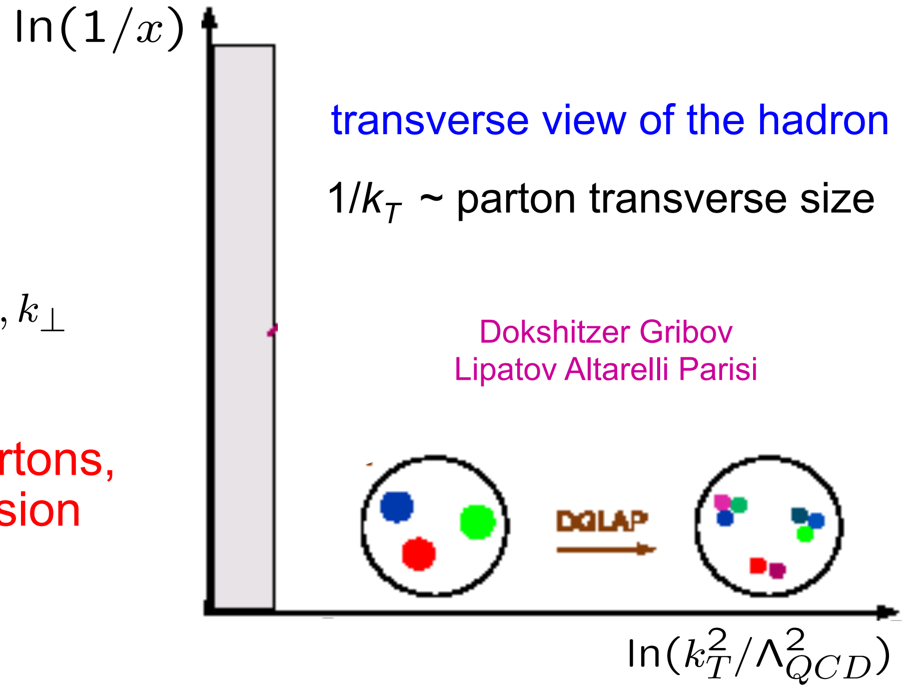

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standard QCD evolution: as k_T increases, the hadron gets more dilute

standard QCD factorization: probabilistic sum of partonic cross-sections

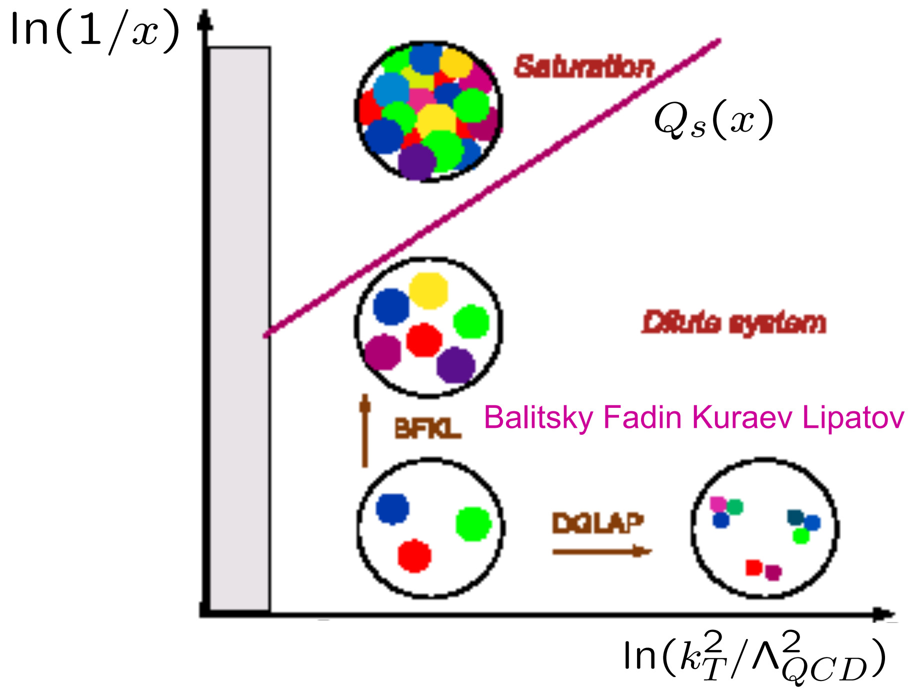
$$d\sigma_{AB\to X} = \sum_{ij} \int dx_1 dx_2\ f_{i/A}(x_1,\mu^2) f_{j/B}(x_2,\mu'^2)\ d\hat{\sigma}_{ij\to X} + \mathcal{O}\left(\Lambda_{QCD}^2/M^2\right)$$

...to collective behavior

when x gets smaller and smaller, the hadron is no longer dilute, the partons start interacting coherently

the Λ^2_{QCD}/M^2 power corrections get enhanced by $x^{-\lambda}$

for heavy-nuclei, those density effect are further amplified by $A^{1/3}$



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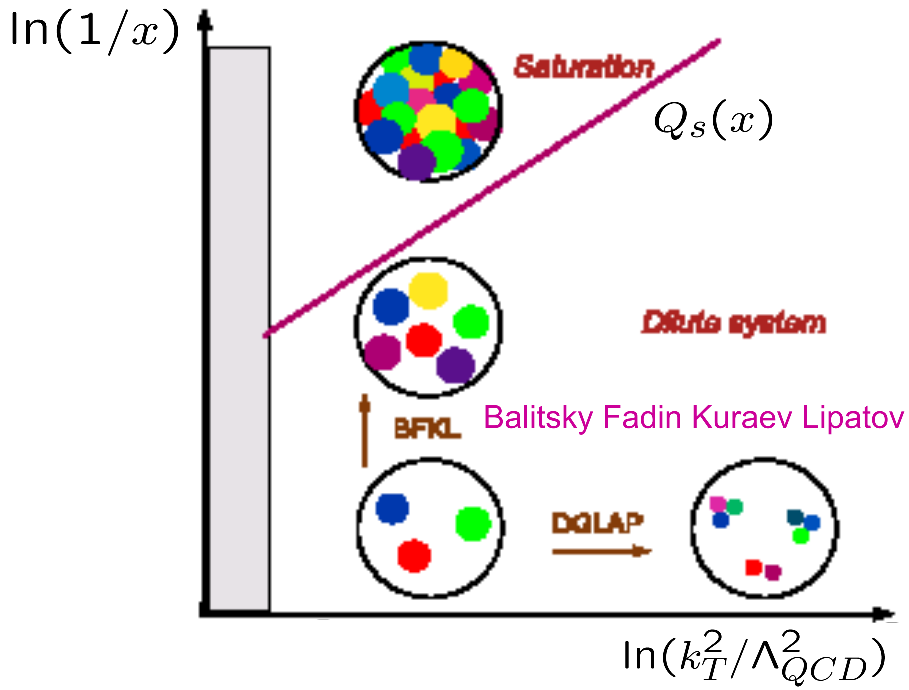


an alternate long-distance/short-distance factorization scheme is needed

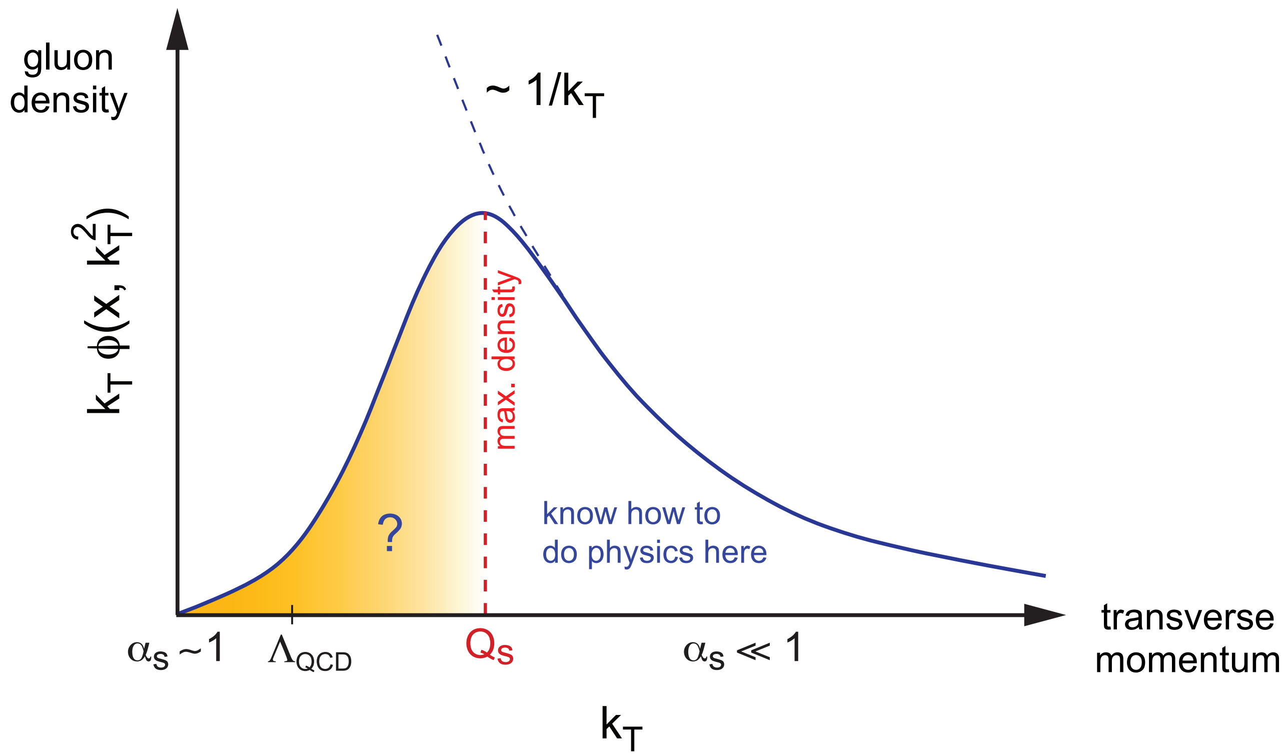
it involves effective degrees of freedom (Wilson lines, Reggeized gluons, …), new operators governed by an effective action (Color Glass Condensate, Lipatov's action, …)

→ an approximation of QCD suited to describe physics at large parton densities

The saturation scale

The saturation scale $Q_S(x)$ is the momentum scale which characterizes the transition between the dilute and dense regimes

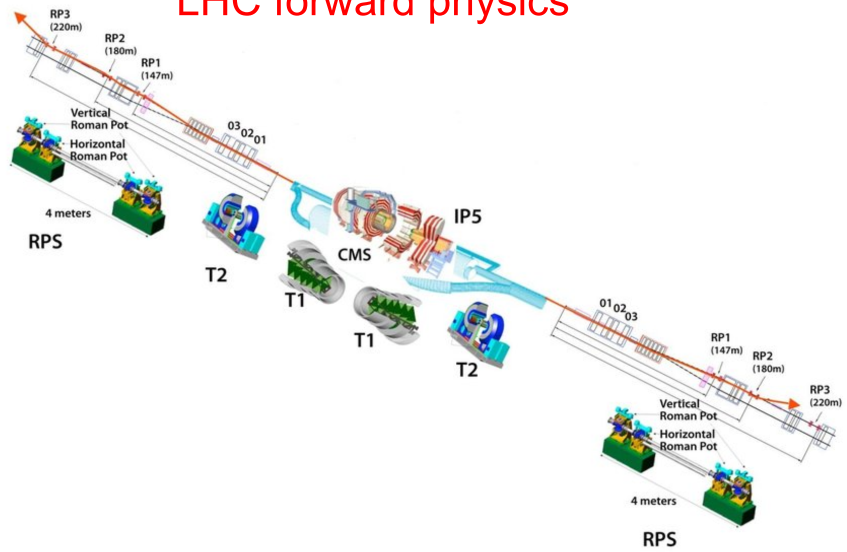
at small-x, the typical gluon transverse momentum is no more Λ_{QCD} , it is instead $Q_S(x)$



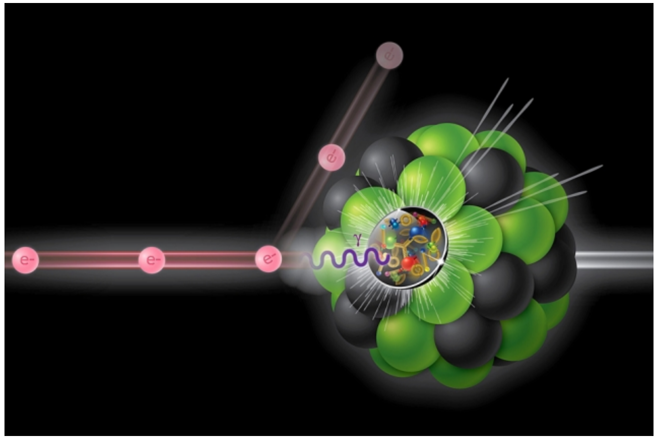
the dynamics is non-linear, but the theory stays weakly coupled $\alpha_s(Q_s) \ll 1$

Where it is important ?

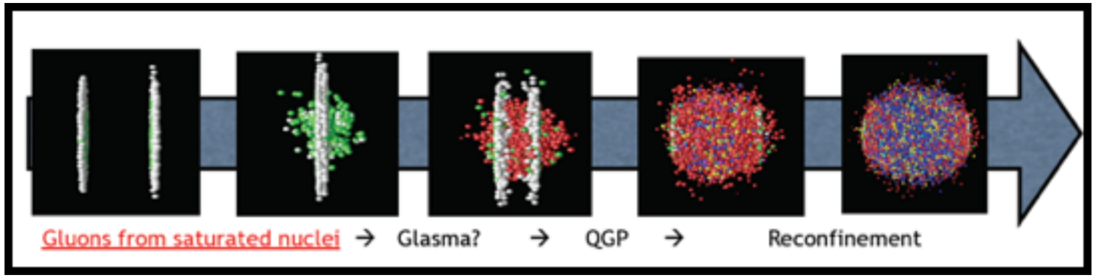
LHC forward physics

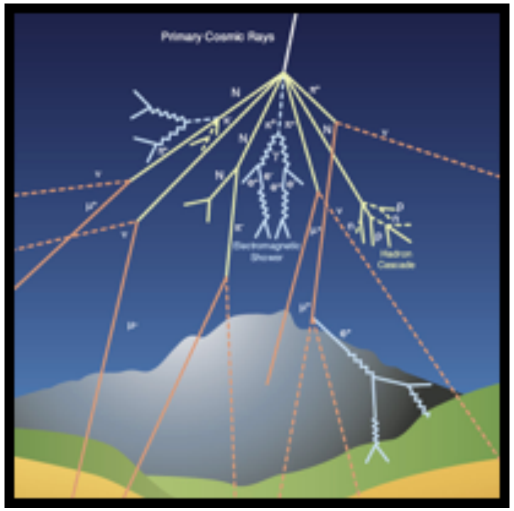


Electron
Ion
Collider
(EIC)



initial stages of heavy-ion collisions





high-energy cosmic rays

Future Prospects I

the field of high-energy QCD has recently entered the NLO era:
higher-order corrections of several kinds to be computed

- next to leading order in α_S: essential to prove factorization and assess robustness of predictions

in most cases, perturbation theory must be done in conjunction with all-order resummations of various large logarithms

- next-to-eikonal corrections: energy-suppressed but give access to spin-dependent observables

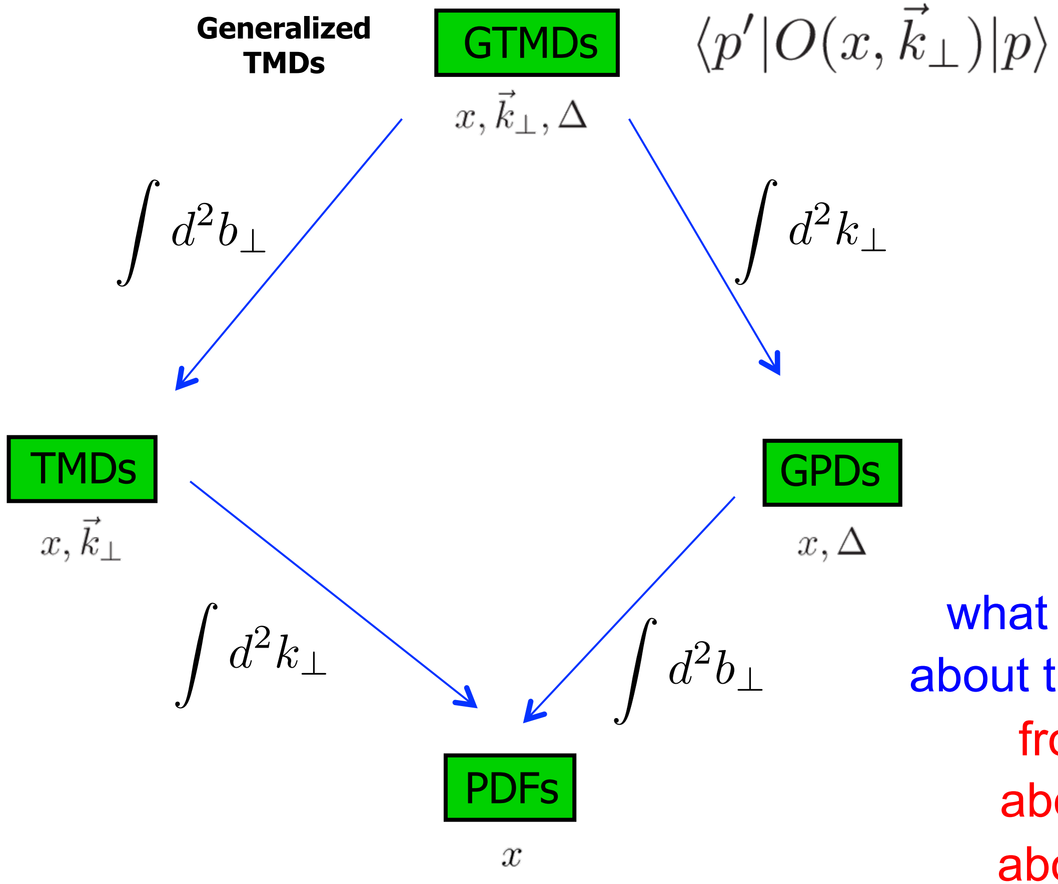
- next-to-planar corrections: going beyond the large-Nc limit

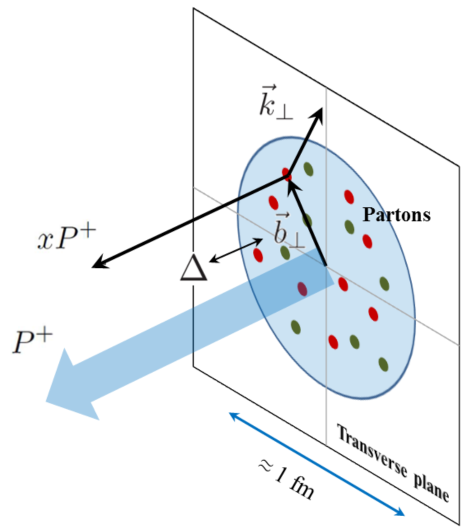
these must be addressed for less and less inclusive observables measured in experiments: exclusive and diffractive cross sections, correlation measurements, global event properties …

Future Prospects II

establish the connections with the “standard” hadron-structure lore

especially important in the context of the EIC





what does small-x physics has to say
about those various parton distributions?

from protons to heavy nuclei ?
about multi-parton distributions?
about multi-parton interactions ?

NA2 - Small-x Physics at the LHC and future DIS experiments

- Spokespersons: Néstor Armesto (Santiago de Compostela) and Tuomas Lappi (Jyväskylä).
- Participants: 15 institutions, 9 countries, 24 permanent researchers.

- Ben-Gurion University of the Negev, Beer Sheva, Israel.
- **Centre National de la Recherche Scientifique, France**.
- Czech Technical University, Prague, Czech Republic.
- ECT*, Trento, Italy.
- Henryk Niewodniczański Institute of Nuclear Physics, Krakow, Poland.
- **Commissariat à l'énergie atomique, Saclay, France**.
- National Centre for Nuclear Research, Warsaw, Poland.
- Universidad Autónoma de Madrid, Spain.
- Universidad de Granada, Spain.
- Universidade de Santiago de Compostela, Spain.
- Università della Calabria, Cosenza, Italia.
- Università de Firenze, Italia.
- University of Groningen, The Netherlands.
- University of Jyväskylä, Finland.
- University of Regensburg, Germany.