GDR Groupement de recherche
QCD Chromodynamique quantique
2021 - 2024

Working Group #1:

« Simple and Multiple Interactions between Partons »
(SMIP)

Dominique Marchand, March 8th, 2021

General Assembly, March 08 - 10, 2021

Zaida Conesa Del Valle

« Experimentalist »

CNRS scientist

Collaboration:

ALICE

CERN

Main interests:

- Quark-gluon plasma physics
- Multiple parton interactions
- Initial stage of the collision
- Heavy flavor, quarkonia, and electroweak bosons

conesa@ipno.in2p3.fr

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

cnrs université PARIS-SACLAY

Cédric Lorcé

« Theorist »

Professor at Ecole Polytechnique

Close collaboration with experimentalists

Main interests:

- Nucleon internal structure
- Mass and spin decomposition
- QCD energy-momentum tensor and pressure forces
- Relativistic quantum phase-space (Wigner) distributions
- Parton distributions (FFs, PDFs, GPDs, TMDs, GTMDs)

cedric.lorce@polytechnique.edu

l'X ÉCOLE POLYTECHNIQUE CPHT Centre de Physique Théorique

cnrs

Dominique Marchand

« Experimentalist »

CNRS scientist

Collaborations:

Jefferson Lab (USA)

Electron Ion Collider @ BNL (USA)

Main interests:

- Nucleon internal structure
- General Parton Distributions (Deep Virtual Compton Scattering experiments - DVCS)
- Proton charge radius

marchand@ipno.in2p3.fr

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

cnrs université PARIS-SACLAY

GDR Groupement de recherche
QCD Chromodynamique quantique

SMIP Main scientific interests

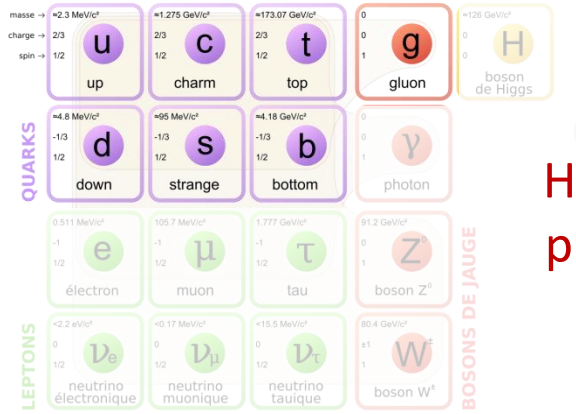
From high to very high energy particle physics

➢ **understanding of hadron structure**

through

- **lepton and hadron scatterings at high energy**
- **pp /pA / heavy ion collisions at very high energy**
- **theoretical formalisms and models**

Standard Model of particle physics



Hadron physics

Systems

- quantum
- relativistic
- strongly coupled
- non-linear
- undetermined # of ***partons***

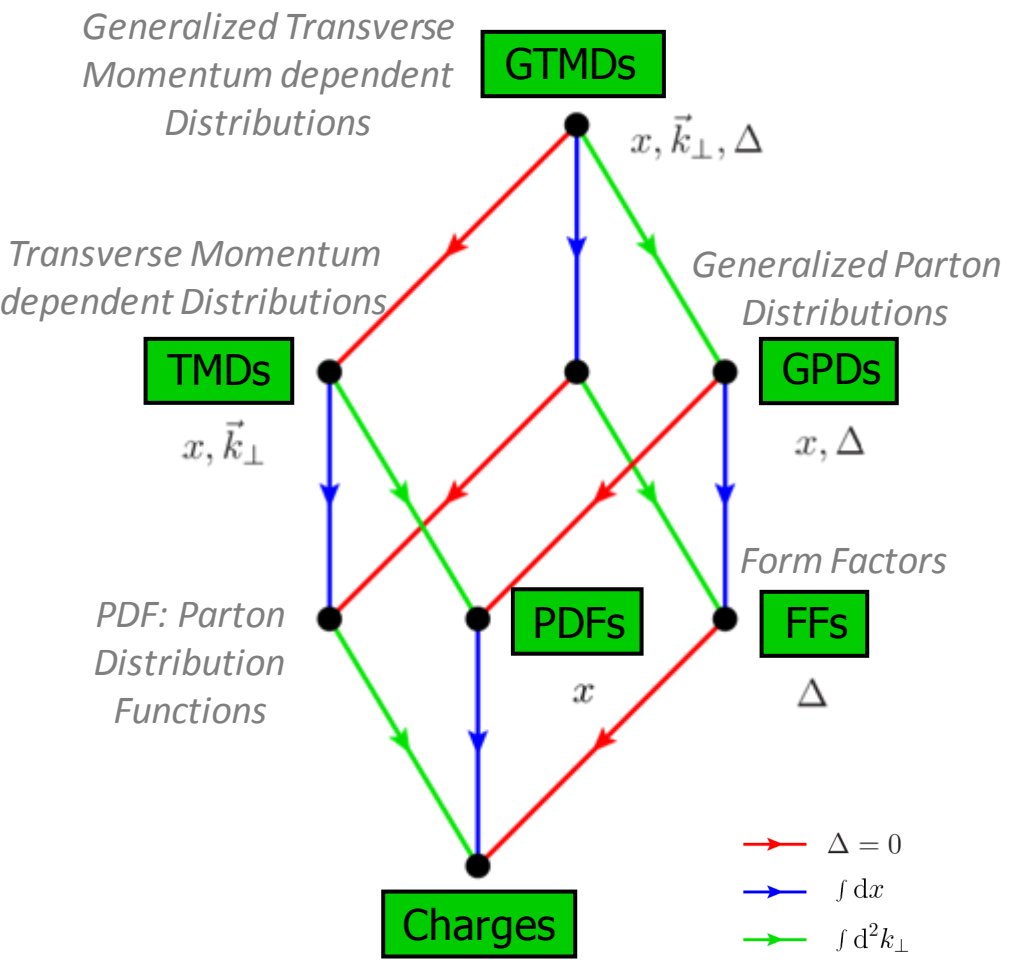
How hadron basic properties emerge from partons?

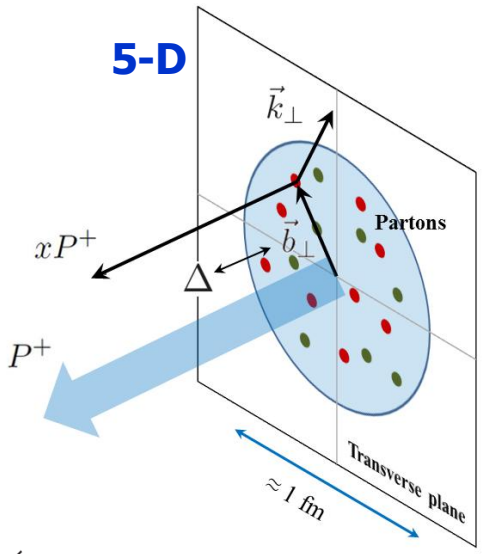
How a better understanding of nucleon structure serves LHC problematics?

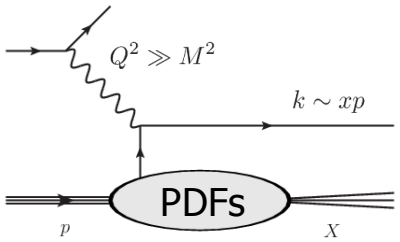
How gluon distributions in the non perturbative regime benefit to LHC?

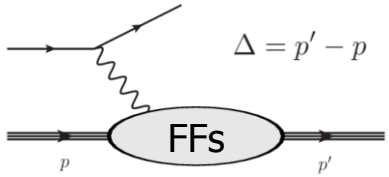
How to « modelize » multiple parton interactions in collisions at LHC?

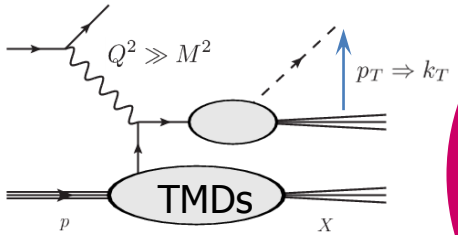
Hadron imaging based on a more and more comprehensive Parton Distribution formalism
→ novel generations of experiments to access multi-dimensional parton distribtions
⇒ most valuable constraints for theoretical models



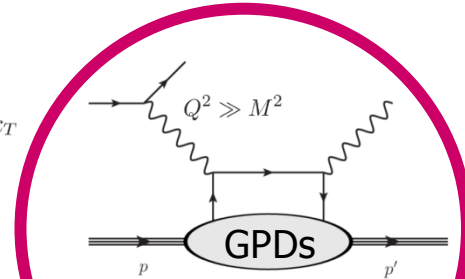








(semi-)inclusive processes



DVCS

exclusive processes

« *Zoology* » of parton distributions

(many other also exist: DAs, TDAs, nPDFs, DPDFs, …)

[C. Lorcé, Pasquini, Vanderhaeghen]

Imaging → quark and gluon contributions to QCD energy-momentum tensor

Some opened questions

Nucleon Spin

Orbital angular momentum

?

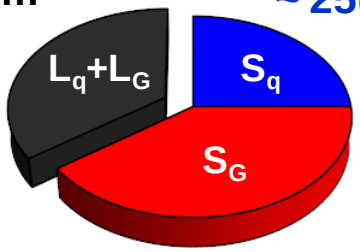
nDVCS (Jlab/CLAS12)

→ GPD E (+ H)

⇒ L_q

Quark spin (ΔΣ)

~ 25(10) %



~ 40(?) %

Gluon spin (ΔG)

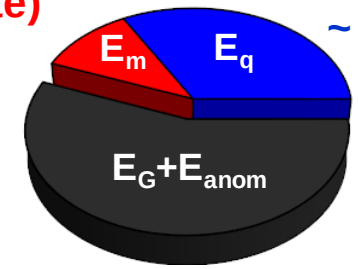
Nucleon Mass

Quark mass (Higgs mechanism & condensate)

~ 11(1) %

Quark kinetic and potential energies

~ 33(1) %



?

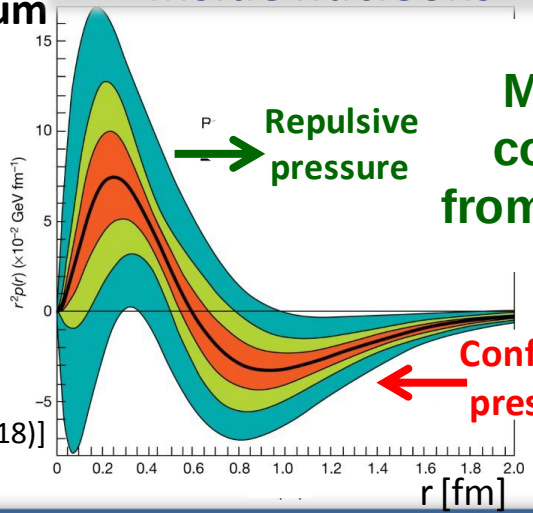
Gluon kinetic and potential energies (trace anomaly?)

Pressure distributions inside nucleons

QCD Energy-Momentum tensor

GPDs

⇒ D-Term



Repulsive pressure

Mostly coming from quarks

Confining pressure

Mostly coming from gluons

[C. Lorcé]

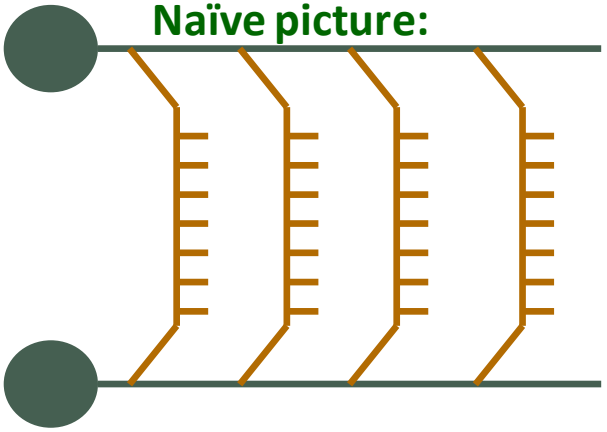
[V. D. Burkert, etal., Nature 557, 396-399 (2018)]

[C. Lorcé (2018)]

Other issue: Multiple Parton Interaction in collisions at very high energy (LHC)
→ Impact production yields and angular distributions

At $\sqrt{s_{\{NN\}}} > 200$ GeV, evolution of the charged particle multiplicity distribution in pp collisions deviate from Koba-Nielsen-Oleson (KNO) scaling

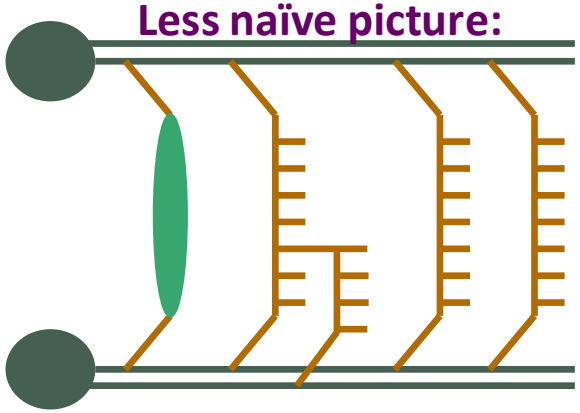
Naïve picture:



➢several (hard or soft) interactions occur
➢ particle multiplicity is related to the number of elementary interactions
➢ for hard processes : particle yield increases with multiplicity

[S. Portebeouf-Houssais]

Less naïve picture:



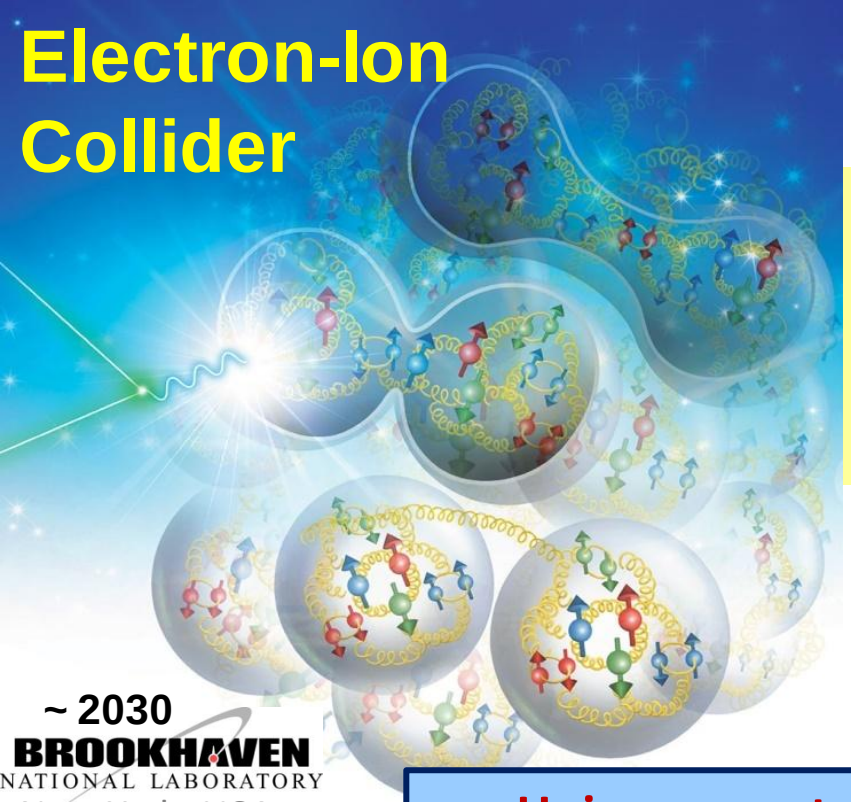
➢ some of the parallel interactions are soft, some are hard
➢ re-interaction of partons : ladder splitting, screening (initial state), saturation (initial state), color reconnection (final state)
➢ hadronic activity (initial or final state radiation) around hard processes

In **pp collisions** (reference system):

★Full description of **initial conditions of the collision**: crucial

⇒ test interaction between **hard and soft components**

Electron-Ion Collider



~ 2030
BROOKHAVEN
NATIONAL LABORATORY
New York, USA

Since January 2020 a **real** project
to be hosted at **BNL** *(RHIC)*

electrons (10 - 18 GeV, **~70 %** polar.)
⇒ **protons** (275 GeV, **~70%** polar.)
or
⇒ **ions** (light - deuterium - to heavy - Au, Pb, U)

- ✶ Variable center-of-mass energies:
  20 - 100 GeV [140 GeV]
- ✶ High collision $\mathcal{L}$ **10^{33} - 10^{34}** ep cm $^{-2}$ s $^{-1}$
- ✶ **1 (2) interaction point(s)**

Unique oppotunity to access/probe/image/quantify/qualify
the **gluonic, valence and sea quark content** of hadrons (low x)

Finalized, to be available
very shortly on ArXiv

- ➢ Dynamic of quark - gluon confinement
- ➢ Nucleon detailed comprehensive 3D-tomography
- ➢ Missing gluon contribution to nucleon spin and mass
- ➢ Complementarity / inputs to LHC problematics

And many more!

Epression of Interest supported by French theorists and experimentalists

Time to join and contribute to EIC detectors to address the excited physics program!

Call for Collaboration Proposals for EIC Detectors: **released**
Submission deadline, Dec. 1th, 2021

GDR Groupement de recherche
QCD Chromodynamique quantique

2016 - 2020: Raphaël Dupré, Hervé Moutarde, Sarah Portebeouf-Houssais

Thank you!

SMIP foreseen activities 2021 - 2024

- **Kick-off meeting**, tentatively by June 2021 to adress main SMIP topics

- **Workshops (1 to 2 / year) - 2 or 3 days**
  - First workshop in Automn 2021 (hopefully in person): « **Event Classification in Hadronic Collisions** » *(scheduled in 2020, canceled due to CoViD)*

- **Topical Seminars (~ 1 / 2 Months remotely)**
  - First one in Spring dedicated to **Rivet toolkit**: a collaborative sofware suite to validate MC Event Generators

- SMIP topics part of the next **GDR QCD International School**

Suggestions are very welcome!

GDR Groupement de recherche
QCD Chromodynamique quantique
2021 - 2024

SMIP Summary

- To **S**trenghten interactions within the QCD community: theorists and experimentalists
- To **M**eet on a regular basis (seminars, workshops, international QCD schools, …)
- To **I**nteract closely with other GDR working groups
- To **P**lay a key role in prospectives linked to LHC upgrades scientific programs and the physics at the Electron Ion Collider (BNL, USA), …

Look forward to receiving your suggestions!
The working group is **YOURS**

Look forward to meeting you all again remotely and the sooner as possible lively in person!

conesa@ipno.in2p3.fr ; cedric.lorce@polytechnique.edu ; marchand@ipno.in2p3.fr