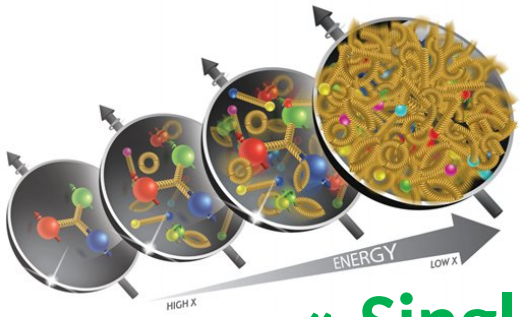
GDR Groupement de recherche

QCD Chromodynamique quantique

2021 - 2024



Working Group #1:

« Single and Multi Parton Scattering»

General Assembly, September 27-29, 2023 – Strasbourg

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@ijclab.in2p3.fr

IJCLab Irène Joliot-Curie Laboratoire de Physique des 2 Infinis

cnrs

université PARIS-SACLAY

Renaud Boussarie

« Theorist »

CNRS scientist

Main interests:

- Nucleon internal structure
- 3D, 5D Parton distributions (GPDs, TMDs, GTMDs)
- Gluon tomography
- Gluonic saturation and higher twist effects
- Spin decomposition : rare observables and theoretical resummations

renaud.boussarie @polytechnique.edu

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

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WG1: Main scientific interests

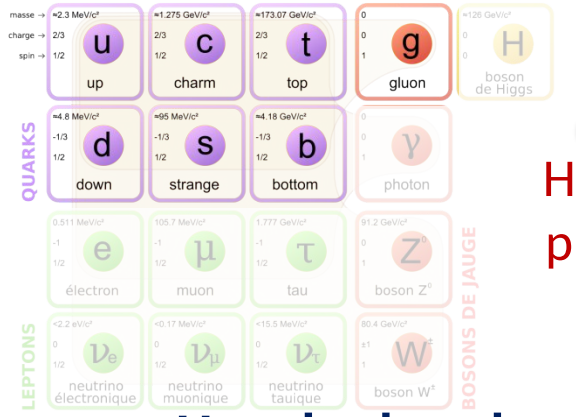
From high to very high energy particle physics

➢ **understanding of hadron structure**

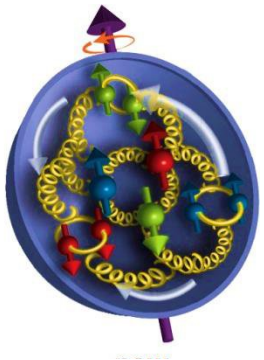
through

- **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?

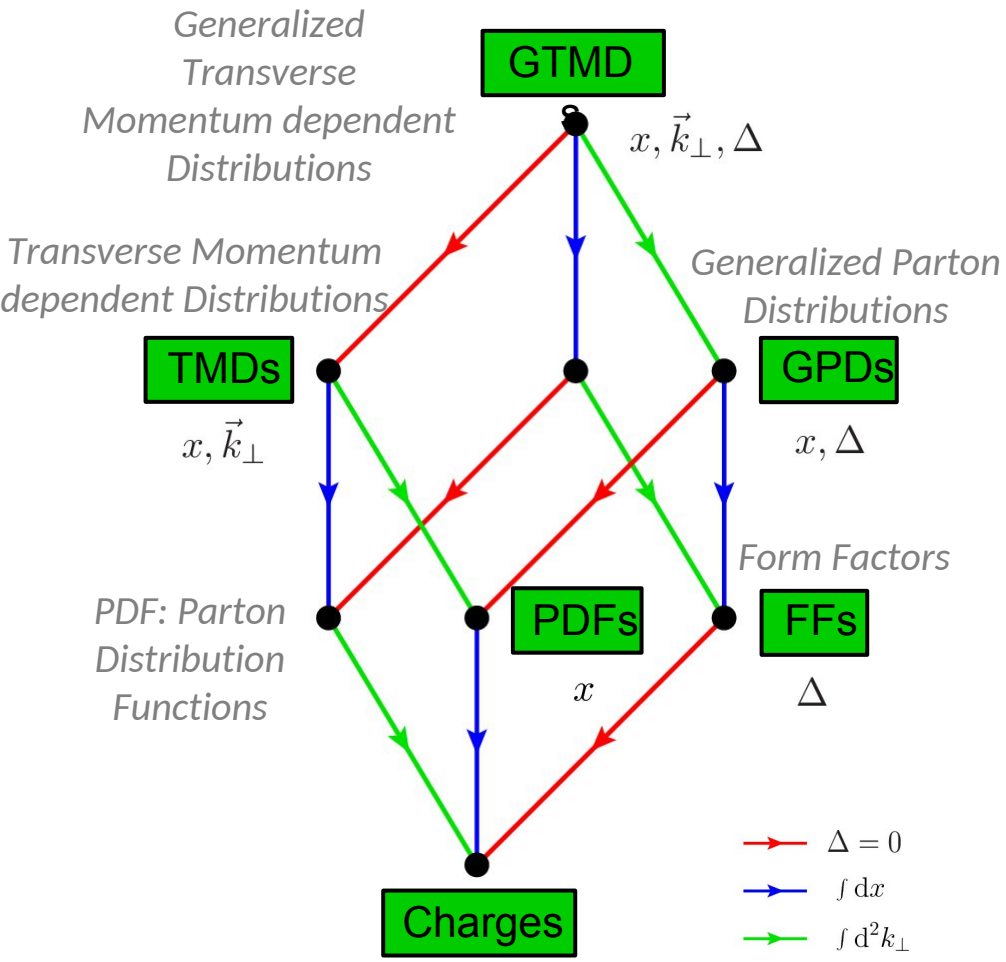
How gluon distributions in the non perturbative regime benefit to LHC?

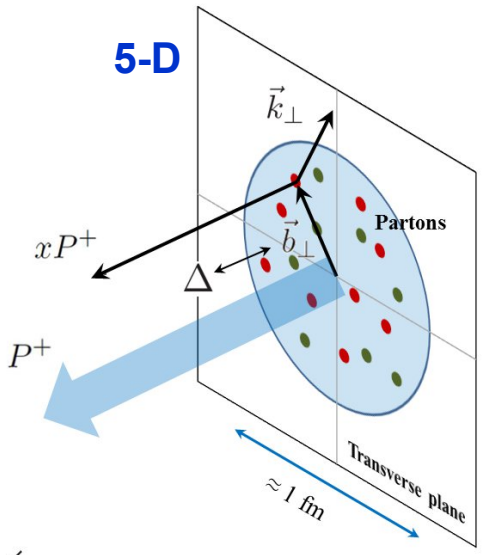
How to « modelize » multiple parton interactions in collisions at LHC?

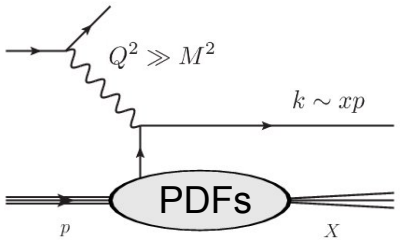
Hadron imaging based on a more and more comprehensive Parton Distribution formalism

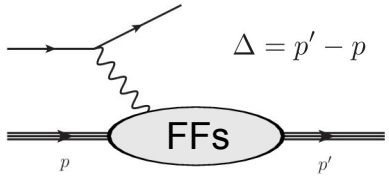
🎭 novel generations of experiments to access multi-dimensional parton distribtions

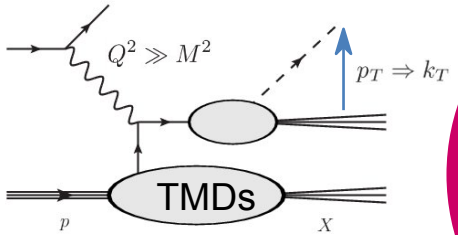
🐲 most valuable constraints for theoretical models

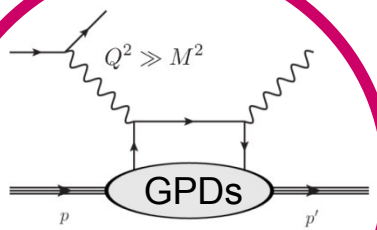












« *Zoology* » of parton distributions

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

[C. Lorcé, Pasquini, Vanderhaeghen]

(semi-)inclusive processes

DVCS

exclusive processes

Imaging quark and gluon contributions to QCD energy-momentum tensor

Some opened questions

Nucleon Spin

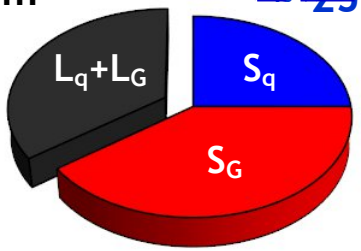
Orbital angular momentum

?

nDVCS (Jlab/CLAS12)

GPD E (+ H)

L_q



Quark spin (S_q) 25(10) %

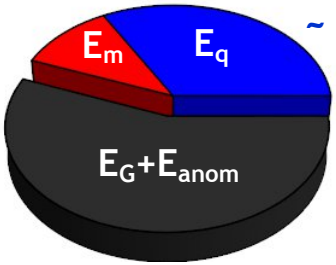
~ 40(?) %

Gluon spin (S_G)

Nucleon Mass

Quark mass (Higgs mechanism & condensate) ~ 11(1) %

Quark kinetic and potential energies ~ 33(1) %



?

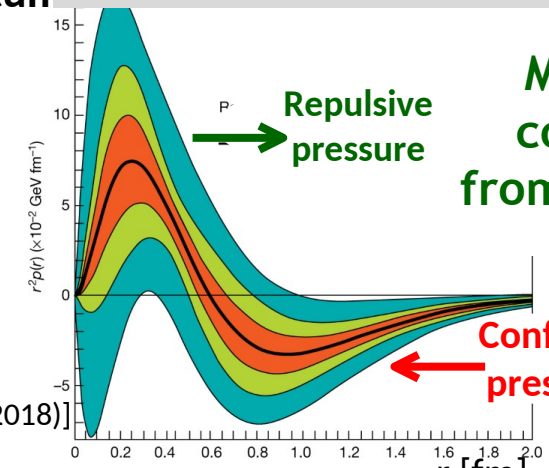
Gluon kinetic and potential energies (trace anomaly?)

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]

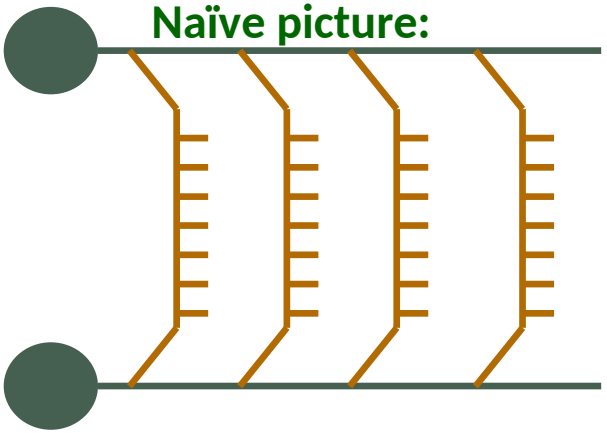
[V. D. Burkert, etal., Nature 557, 396-399 (2018)]
[C. Lorcé (2018)]

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

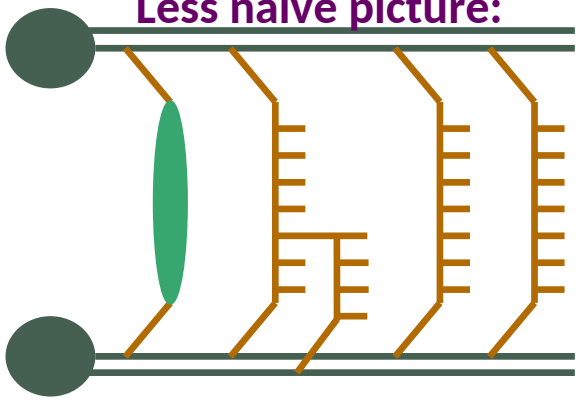
Naïve picture:



➢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 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)

March '21
arXiv:2103.05419
[physics.inst-det]

- 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!

Based on 3 detector proposals submitted end '22, EIC Detector-1 under design
Toward CD-2

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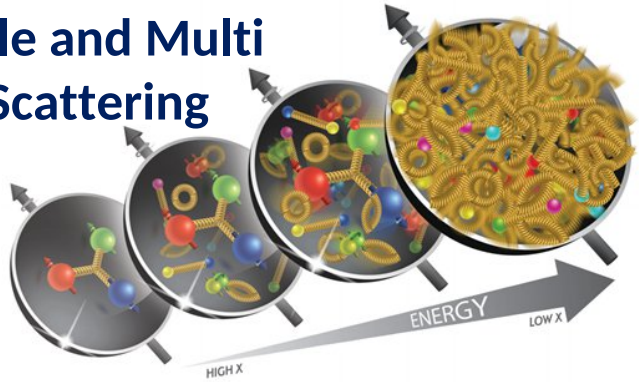
QCD Chromodynamique quantique

WG1: Single and Multi Parton Scattering



2022 ACTIVITIES (past)

- **2 topical seminars :**
  - **« The extraction of light cone parton distributions from lattice quantum chromodynamics »**
    by Savvas Zafeiropoulos (Centre for Theoretical Physics, CNRS, Univ. Aix-Marseille, Univ. Toulon)
    Feb. 3rd, 2022: https://indico.in2p3.fr/event/26169/ Attendance: 33 persons

  - **« Deeply Virtual Compton Scattering off the neutron with CLAS12 at Jefferson Lab»**
    by Mostafa Hoballah (IJCLab Orsay, CNRS, Univ. Paris-Saclay, Univ. de Paris)
    May 12th, 2022: https://indico.in2p3.fr/event/27163/ Attendance: 28 persons

- **Contribution to Ecole Joliot-Curie « Nuclear Matter under Pressure »**
  Sept. 4 – 9, 2022, Oléron Attendance: 40 persons
  https://ejc2022.sciencesconf.org

- **Contribution to « Heavy flavours from small to large systems » workshop**
  Joint effort with other GDR WGs and STRONG-2020 Attendance: 85 persons
  October 3-21st, 2022, Orsay : Institut Pascal, Univ. Paris-Saclay
  https://indico.ijclab.in2p3.fr/event/7656/

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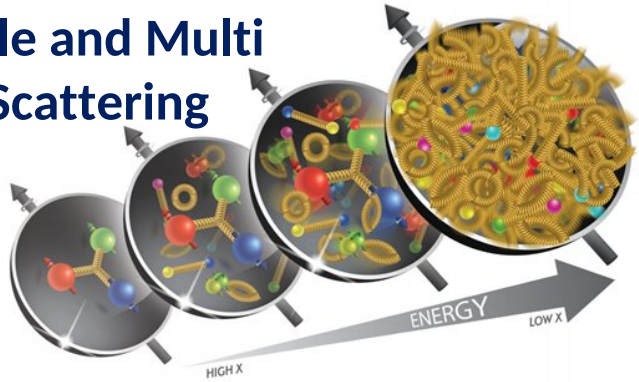
WG1: Single and Multi Parton Scattering



FUTURE ACTIVITIES

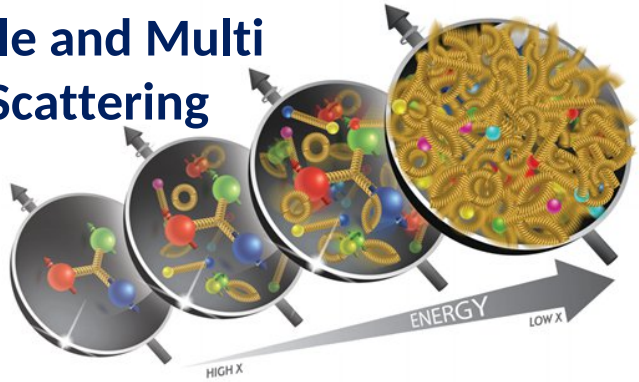
- A topical seminar (hybrid format) at IJCLab
  Topic/date to be defined

- *Organization of the GDR International School in 2024 ?*
  Tentative title : Disentangling initial and final state effects from proton-proton to heavy-ion collisions
  Possible dates : Orsay, 9-15 June 2024 (satellite of SQM to be held in Strasbourg?)

- WG1 « *in person* » workshop *(2 - 3 days)* , *Spring 2024*, *location to be defined*
  « Event Classification in hadronic collisions » (2-3 days)
  This event organisation depends on the school organisation (topic related).

GDR Groupement de recherche
QCD Chromodynamique quantique
2021 - 2024

WG1: Single and Multi Parton Scattering

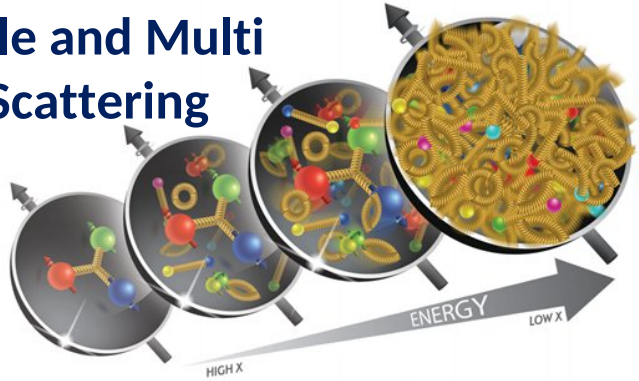


Summary

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

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

conesa@ijclab.in2p3.fr ; renaud.boussarie@polytechnique.edu ; marchand@ijclab.in2p3.fr



Backup

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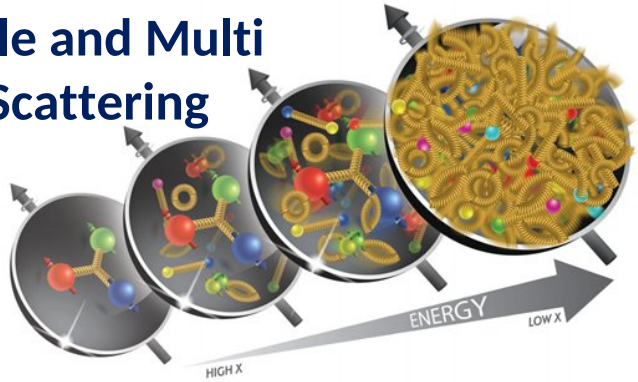
QCD Chromodynamique quantique

WG1: Single and Multi Parton Scattering



2021 ACTIVITIES

2 remote events

✓ **WG1 Kick-off meeting: June 21 - 23,** https://indico.in2p3.fr/event/24174/

3 half-days: 9:30 - 12:30

June 21st: 4 contributions *Attendance: 28 - 36 persons*

June 22nd: 4 contributions *Attendance: 16 - 19 persons*

June 23rd: 7 contributions *Attendance: 25 persons + Aussois*

Joint session with Aussois Quarkonia and QCD meeting (J.-P. Lansberg)

✓ **Topical seminar on Rivet Monte-Carlo Toolkit: July 1st (11:00 - 12:30)**

https://indico.in2p3.fr/event/24502/

Jointly organized with WG2 (Antonin Maire, IPHC)

- ***Louie Corpe*** *(CERN):* ***Introduction to Rivet*** *(11:00 - 11:45)*
- ***Andrii Verbytskyi*** *(Max Planck Institut für Physik, München):* ***HEPMC Standards and the Path Forward*** *(11:50 - 12:30)*

Attendance: 20 persons

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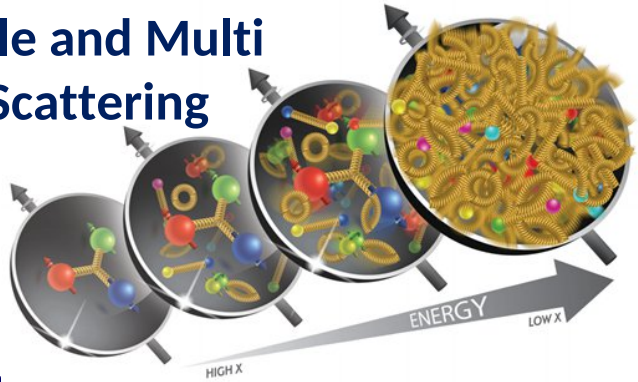
WG1: Single and Multi Parton Scattering



2022 ACTIVITIES (past)

So far 2 topical seminars (remote)

- « The extraction of light cone parton distributions from lattice quantum chromodynamics »
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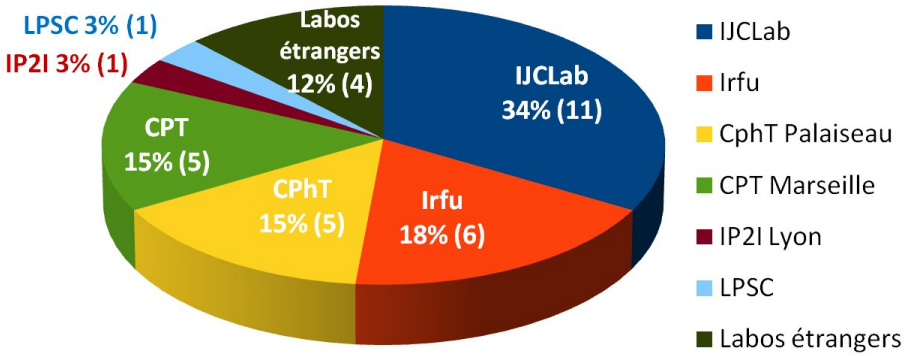
  Feb. 3rd, 2022: https://indi… persons



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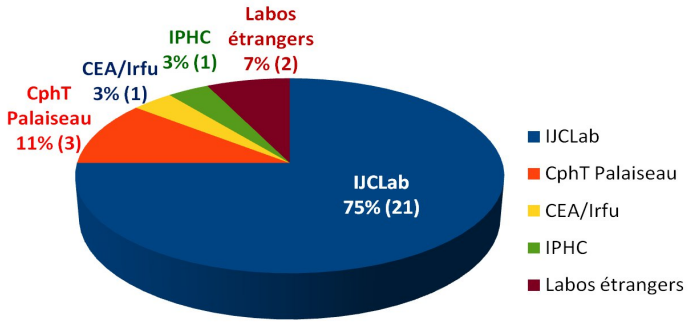

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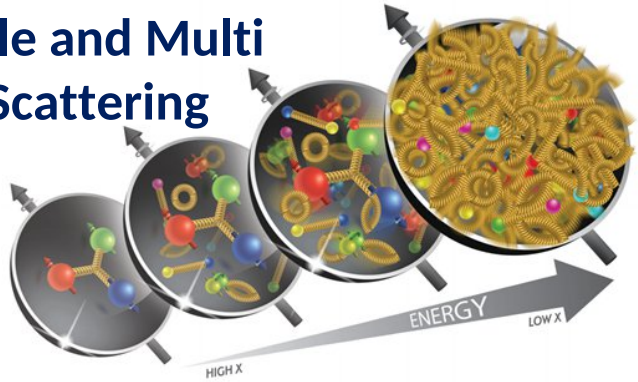
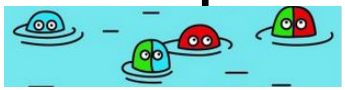


2022 FORESEEN ACTIVITIES

- **Contribution to Ecole Joliot-Curie « Nuclear Matter under Pressure »**
  Sept. 4 – 9, 2022, Oléron

- **A topical seminar (Hybrid format) in Sept. 2022, IJCLab**
  Topic to be defined: possibly QCD parton dynamics inside nucleon and hadronization in high energy collision

- **Contribution to « Heavy flavours from small to large systems » workshop**
  Institut Pascal, Univ. Paris-Saclay , Oct. 3 – 21, 2022
  Joint effort with other GDR WGs, Gluodynamics and STRONG-2020



- **WG1 *« in person »* workshop (2-3 day duration), IJCLab, Dec. 7 - 9, 2022**
  Subject to be defined: possibly « Opened questions on nucleon properties »

cnrs 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!