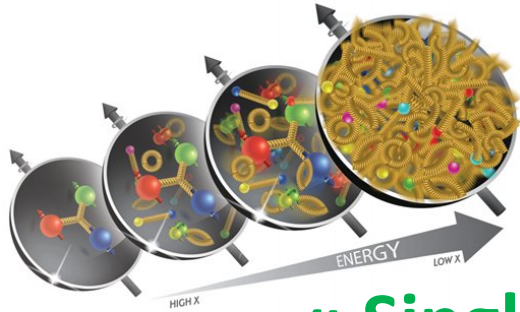




GDR Groupement
de recherche

QCD Chromodynamique quantique

2021 - 2024



Working Group #1:

« Single and Multi Parton Scattering »

General Assembly, May 27th-29th, 2024 –Tours

**Zaida
Conesa Del Valle**

« Experimentalist »

CNRS scientist

Collaboration:



Main interests:

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

conesa@ijclab.in2p3.fr



**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



**Dominique
Marchand**

« Experimentalist »

CNRS scientist

Collaborations:

Jefferson Lab (USA)



Main interests:

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

marchand@ijclab.in2p3.fr



WG1: Main scientific interests

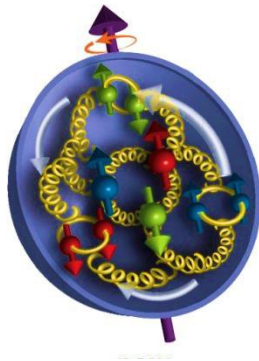
From high to very high energy particle physics
 understanding of **hadron structure**
 through

- 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

masse →	≈2.3 MeV/c ²	≈1.275 GeV/c ²	≈173.07 GeV/c ²	0	≈126 GeV/c ²
charge →	2/3	2/3	2/3	0	0
spin →	1/2	1/2	1/2	1	0
	u up	c charm	t top	g gluon	H boson de Higgs
QUARKS					
	≈4.8 MeV/c ²	≈95 MeV/c ²	≈4.18 GeV/c ²	0	
	-1/3	-1/3	-1/3	0	
	1/2	1/2	1/2	1	
	d down	s strange	b bottom	γ photon	
	0.511 MeV/c ²	105.7 MeV/c ²	1.777 GeV/c ²	91.2 GeV/c ²	
	-1	-1	-1	0	
	1/2	1/2	1/2	1	
	e électron	μ muon	τ tau	Z boson Z ⁰	
	≈2.2 eV/c ²	≈0.17 MeV/c ²	≈15.5 MeV/c ²	80.4 GeV/c ²	
	0	0	0	±1	
	1/2	1/2	1/2	1	
	ν_e neutrino électronique	ν_μ neutrino muonique	ν_τ neutrino tauique	W boson W [±]	
LEPTONS					


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?

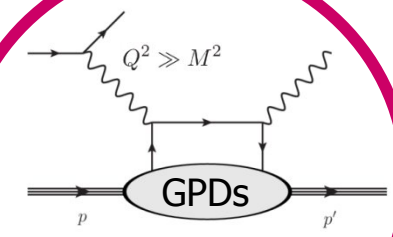
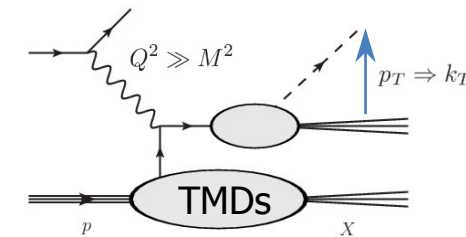
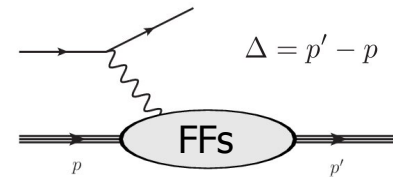
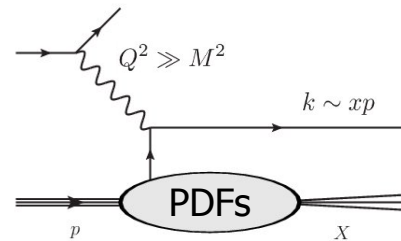
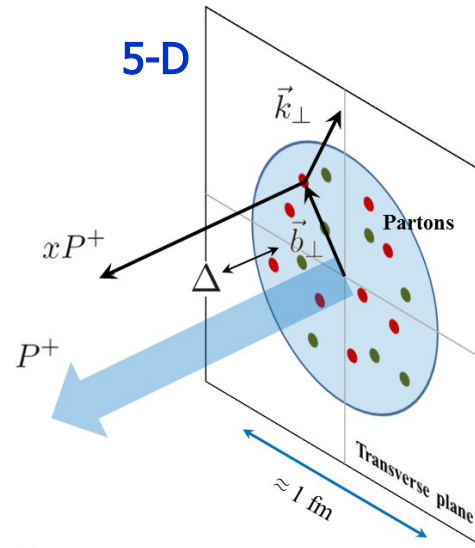
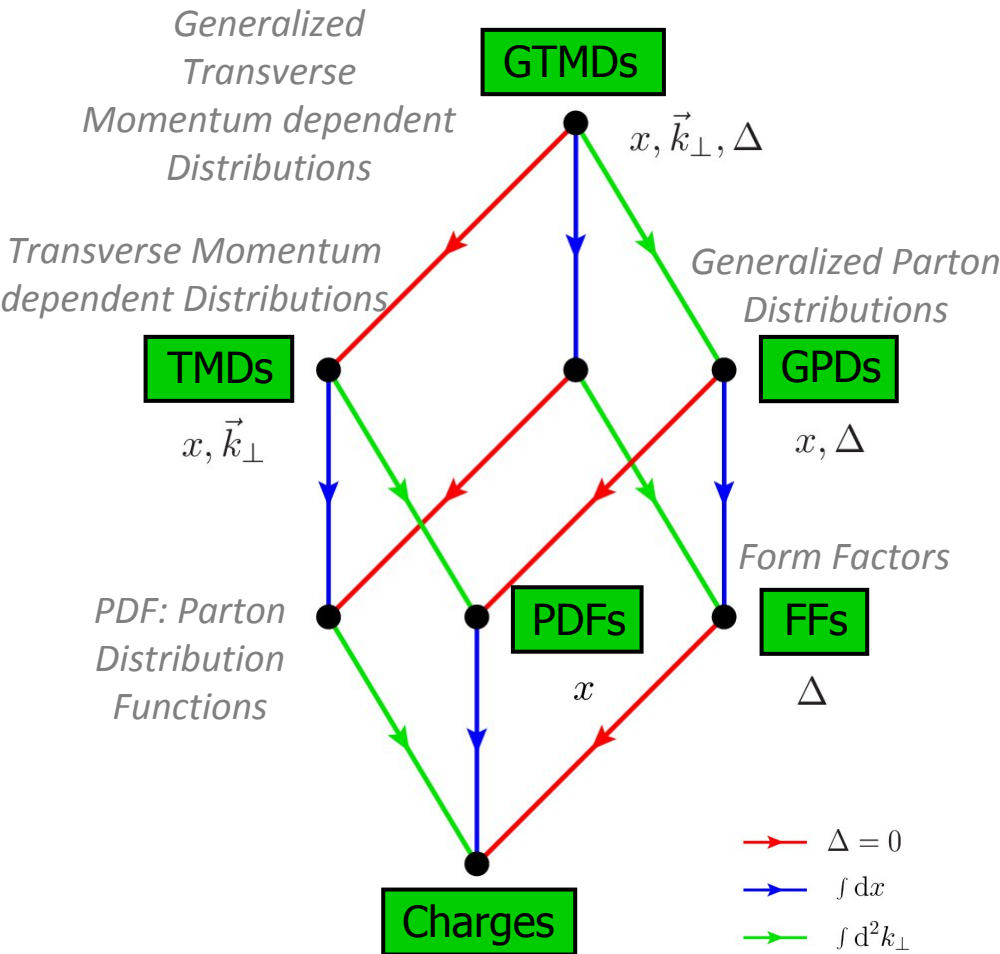
How gluon distributions in the non perturbative regime benefit to LHC?

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 distributions

🦋 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

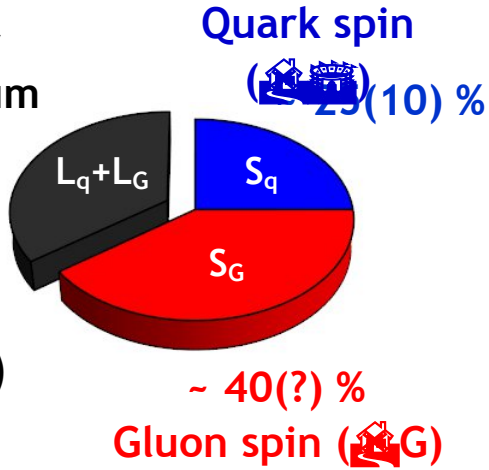
Orbital angular momentum

?

nDVCS
(Jlab/CLAS12)

 GPD E (+ H)

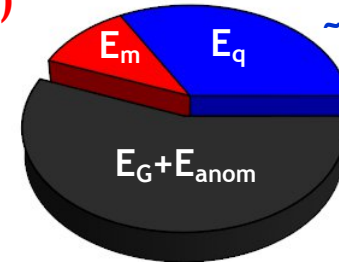
 L_q



Nucleon Mass

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

Quark kinetic and potential energies
~ 33(1) %



?

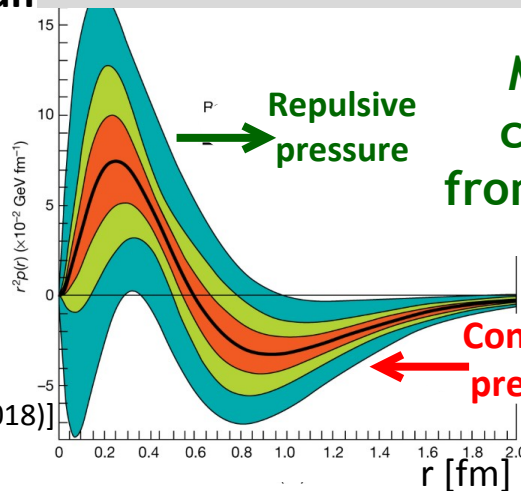
Gluon kinetic and potential energies
(trace anomaly?)

Pressure distributions inside nucleons

QCD Energy-Momentum tensor

GPDs

 D-Term



P → Repulsive pressure

Mostly coming from quarks

← Confining pressure

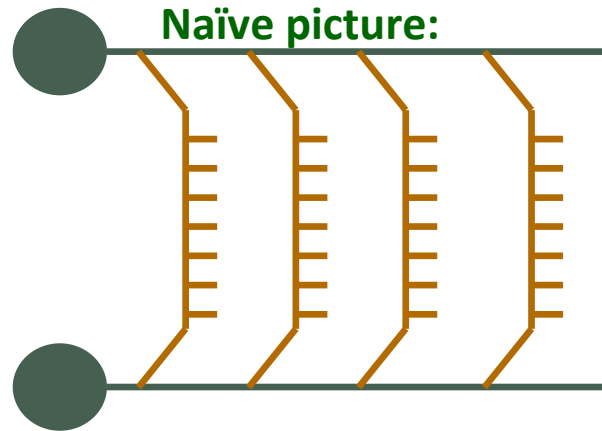
Mostly coming from gluons

[C. Lorcé]

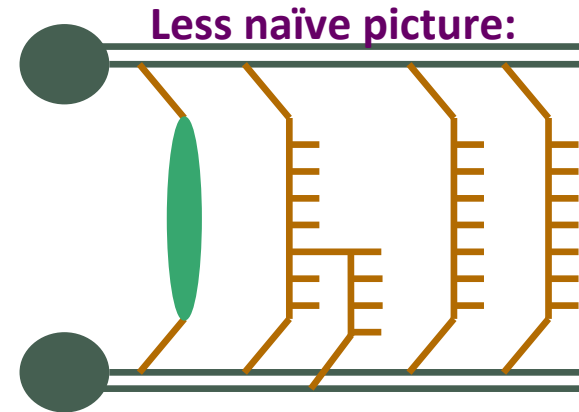
Other issue: Multiple Parton Interaction in collisions at very high energy (LHC)

🐞 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-Olesen (KNO) scaling



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



- 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

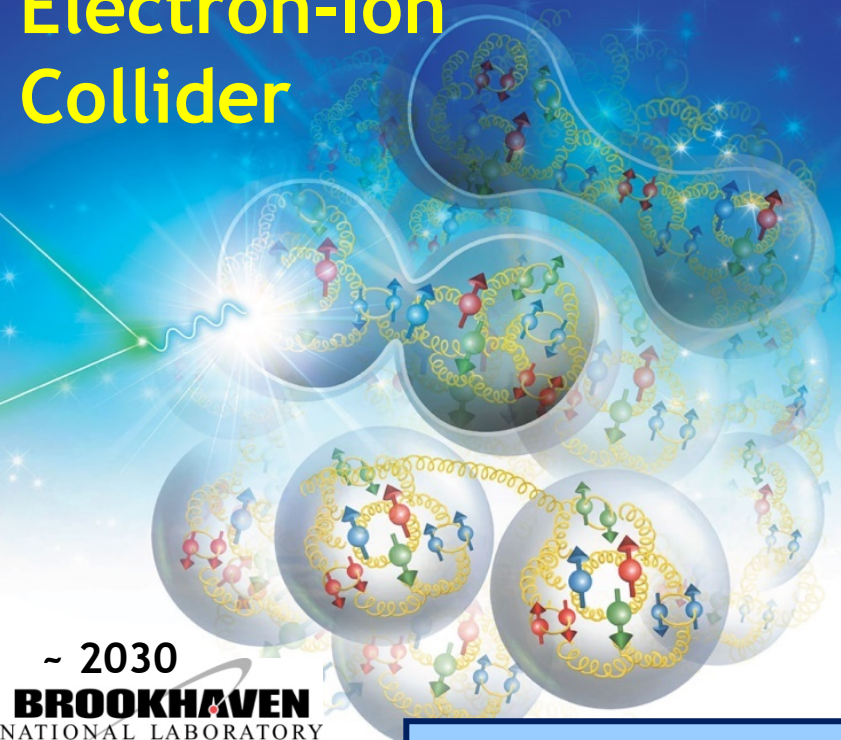
[S. Porteboeuf-Houssais]

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

- 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!

Expression of Interest supported by French theorists and experimentalists

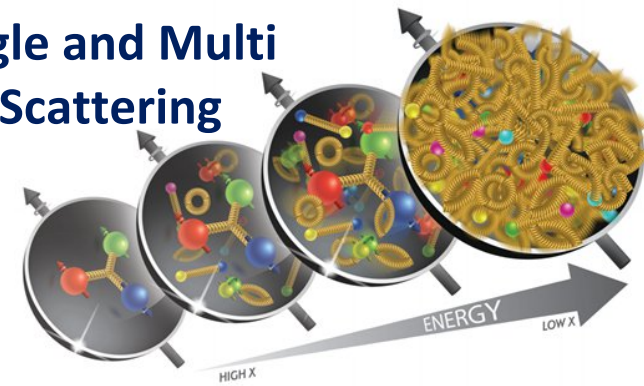
Time to join and contribute to EIC detectors to address the excited physics program!

March '21

arXiv:2103.05419
[physics.inst-det]

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

Toward CD-2



PAST ACTIVITIES

- **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/>



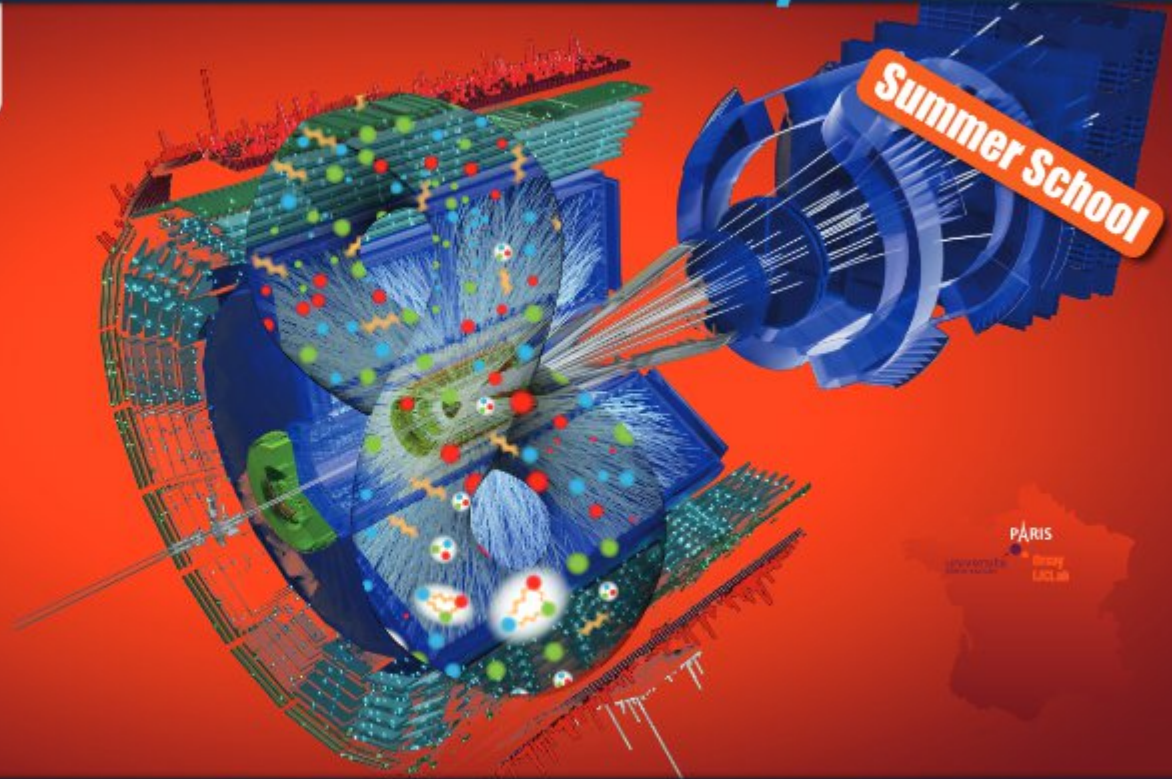
From Hadronic Structure to Heavy Ion Collisions

June 9-15th, 2024 IJCLab, Orsay (PARIS Region), France

cnrs **GDR** Groupement de recherche
QCD Chromodynamique quantique

Scientific topics:

- Partonic structure of protons and nuclei
- In-medium effects
- Collective effects
- Hands-on sessions



Organizing committee

<https://indico.in2p3.fr/e/GDRQCDSchool2024>

R. Boussarie (CPHT, France)
Z. Conesa del Valle (IJCLab, France)
E. Ferreira (U. Santiago de Compostela, Spain)
D. Marchand (IJCLab, France)
C. Marquet (CPHT, France)

C. Muñoz Camacho (IJCLab, France)
M. Nguyen (LLR, France)
S. Porteboeuf (LPC Clermont, France)
M. Winn (CEA Saclay/Irfu, France)

With support of IJCLab "Event" department

Scan me



cnrs NUCLÉAIRE & PARTICULES

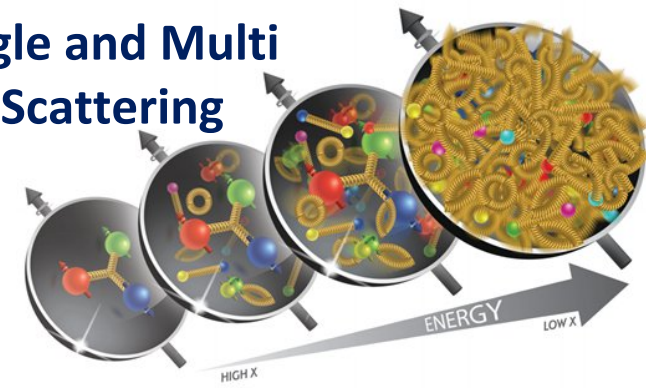
cea irfu

IJCLab
Institut Joliot-Curie
Laboratoire de Physique
à l'Orsay

université
PARIS-SACLAY

EMMI

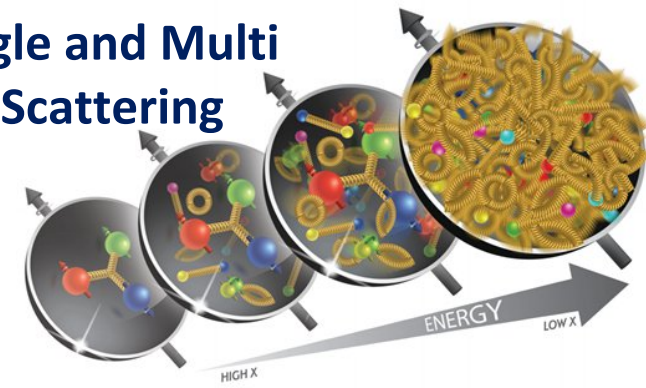
MDPCC



GDR SUMMER SCHOOL 2024

- 9th-15th June 2024 (Satellite meeting of SQM)
- **55 confirmed participants (of which 13 local)**
- **9 confirmed speakers**
 - Carlota Andres (LIP, Lisbon)
 - Nestor Armesto (IGFAE, Santiago de Compostela)
 - Katarina Gajdosova (CTU, Prague)
 - Pol-Bernard Gossiaux (Subatech, Nantes)
 - Charlotte Van Hulse (Alcala)
 - Jean-Yves Ollitrault (IPhT, Saclay)
 - Marta Verweij (Utrecht)
 - Jing Wang (CERN)
 - Klaus Werner (Subatech, Nantes)
- **Thanks to sponsors (mainly the GDR) only 150€ fee, 250€ with full housing**

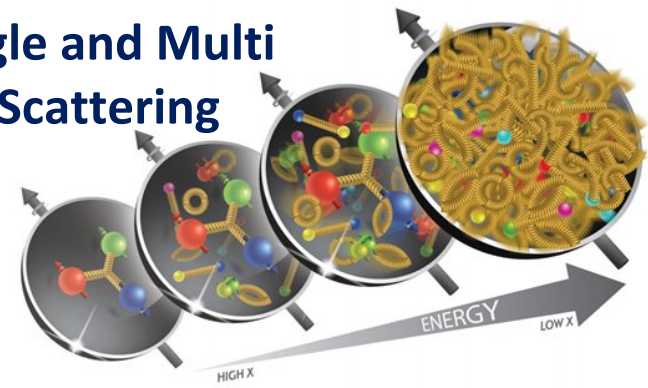
We are grateful to IJCLab's communication services for their support



GDR SUMMER SCHOOL 2024

Preliminary Timetable

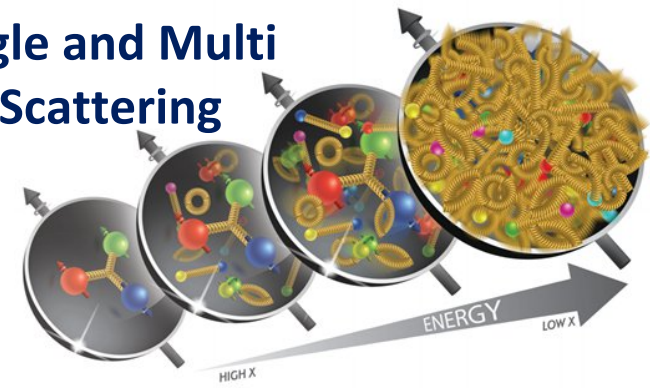
	Monday June 10th	Tuesday June 11th	Wednesday June 12th	Thursday June 13th	Friday June 14th
8:00					
8:30	Registration & breakfast	Breakfast	Breakfast	Breakfast	Breakfast
9:00	Hydrodynamics, Theo	Hydrodynamics, Theo	Partonic struc & small x Theo	Partonic struc & small x Theo	Partonic struc & small x Theo
10:00	Hadrons, focus on flow Exp	Hadrons, focus on flow Exp	Partonic struc & small x Exp	Partonic struc & small x Exp	Partonic struc & small x Exp
11:00	Coffee break	Coffee break	Coffee break	Coffee break	Coffee break
11:30	HQ and quarkonia Theo	HQ and quarkonia Exp	Partons in medium Theo	Partons in medium Theo	Monte Carlo tools
12:30	Lunch	Lunch	Lunch	Lunch	Lunch
14:30	HQ and quarkonia Theo	HQ and quarkonia Exp	Jets in medium Exp	Jets in medium Exp	Monte Carlo tools
15:30	Discussion	Discussion	Discussion	Discussion	Discussion
16:30		Poster session & Cocktail	Poster session & Cocktail	Visit Sciences-ACO (1st group)	
17:30		Poster session & Cocktail	Poster session & Cocktail	Visit Sciences-ACO (2nd group)	
18:30	Welcome cocktail				
19:30		Dinner	Dinner	School Dinner	Dinner



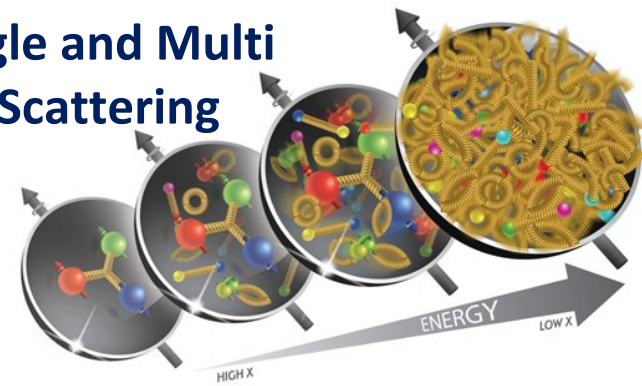
Summary

- To **S**trengthen 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 interaction between GDR working groups

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



Backup

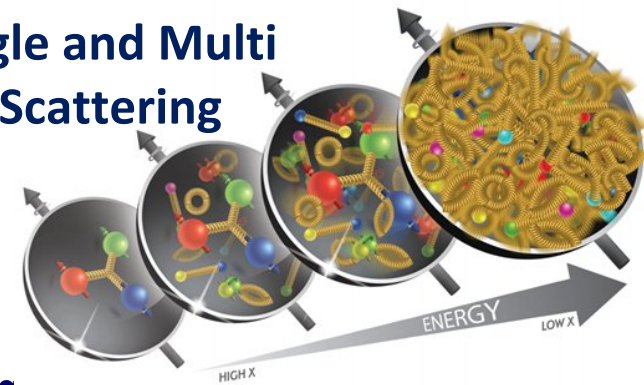


2021 ACTIVITIES

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*

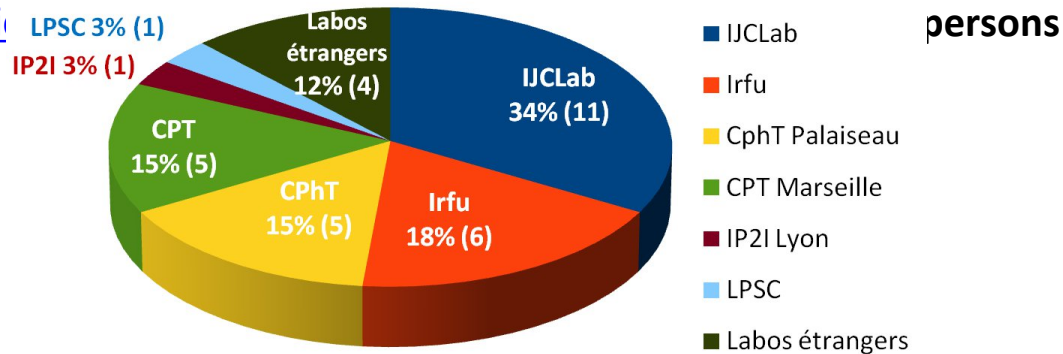


2022 ACTIVITIES (past)

So far 2 topical seminars (remote)

- « 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/12000/120000>



- « 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/12000/120000>

