STRONG-2020: Project Review
High energy frontier
28 September 2022

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High energy frontier: Working groups

JRA5- Generalized Parton Distributions (**GPD-ACT**)

JRA4- 3D structure of the nucleon in momentum space (**TMD-neXt**)

JRA6- Challenges for next generation DIS facilities (**next-DIS**)

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

JRA2- Fixed Target Experiments at the LHC (**FTE@LHC**)

NA3- Quark Gluon Plasma characterisation with jets (**Jet-QGP**)

NA7- Quark Gluon Plasma characterisation with heavy flavour probes (**Hf-QGP**)

JRA1- Inter-experiment combination of heavy-ion measurements at the LHC (**LHCCombine**)

High energy frontier: (JRA) GPD-ACT

Objectives: Perform the 3D-imaging of the nucleon via the extraction of Generalized Parton Distributions (GPDs) from deep exclusive data

- Extraction of GPDs from new high-precision QCD analyses of novel high-statistics e-p and p-p measurements at fixed-target and collider energies

Achievements in 2nd year:

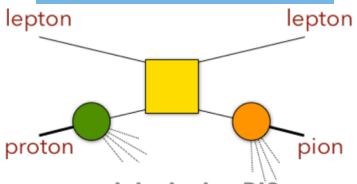
- Jefferson Lab - Hall A 11 GeV: Deep Virtual Photon Scattering experiment (e p → e p π0 xsection) → access to transversity GPDs of the proton — Phys.Rev.Lett 127 (2021) 15, 152301
- Jefferson Lab - CLAS12 11 GeV: First-time observation of Timelike Compton Scattering → test of universality of GPDs — Phys.Rev.Lett 127 (2021) 26, 262501
- CERN COMPASS 2016 (CERN): Transverse extension of partons in the sea-quark range — DVCS analysis to be published soon
- Theory/Phenomenology: Charged current electroproduction of a charmed meson at an eIC → Exclusive D_s production cross-sections accessible at future eIC for GPDs extraction — Phys. Rev.D 104 (2021) 9, 094002

High energy frontier: (JRA) TMD-neXt

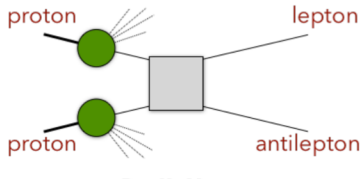
Objectives: Improve the mapping distributions of partons inside hadrons in 3D momentum space (TMDs), including their dependence on spin.

- Extraction of unpolarized and polarized TMDs and parton fragmentation functions (FFs)
- New high-precision QCD analyses of novel high-statistics measurements at e+e-, e-p and p-p at fixed-target and collider energies

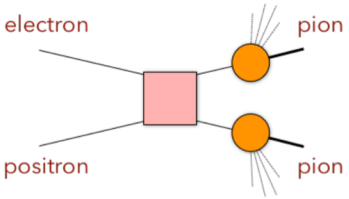
How to access TMDs



semi-inclusive DIS



Drell-Yan



e⁻e⁺ to pions

Where to access TMDs

Tasks:

Analysis of Drell-Yan data of partons from COMPASS and CMS

- Analysis of Drell-Yan data: essentially COMPASS(2018) and CMS (2016)
- Analysis of semi-inclusive DIS data: COMPASS (2016) and CLAS

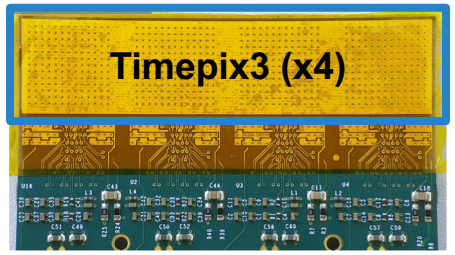
Phys.Rev.Lett 128 (2022) 6, 062005

- Analysis of electron-positron annihilation: Belle
- Quark TMD extractions
- Gluon TMD studies

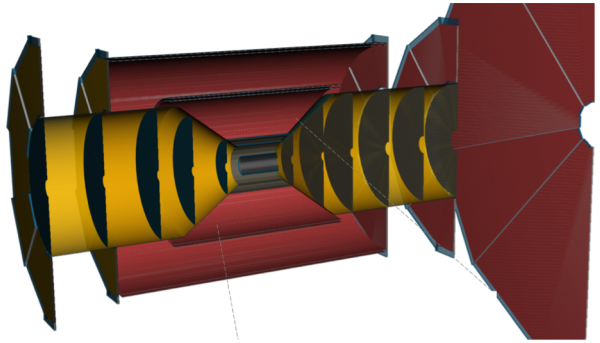
High energy frontier: (JRA) next-DIS

Objectives: Perform the simulation and the detector R&D in order to design the detectors for the next generation Deep Inelastic Scattering machines world-wide and in particular at the electron-ion collider (EIC) in the USA.

- Development of new Monte Carlo tools and studies of benchmark channels, for e-A collisions at future deep-inelastic experiments. Optimisation of associated detector designs for high-resolution tracking, vertexing, photon, and PID.



interface board



Achievements in 2nd year

- Simulation and Timepix based R&D for far-forward/backward regions
- TPC readout with low IBF
- Dual Radiator RICH detector
- Silicon Vertex and Tracking detector

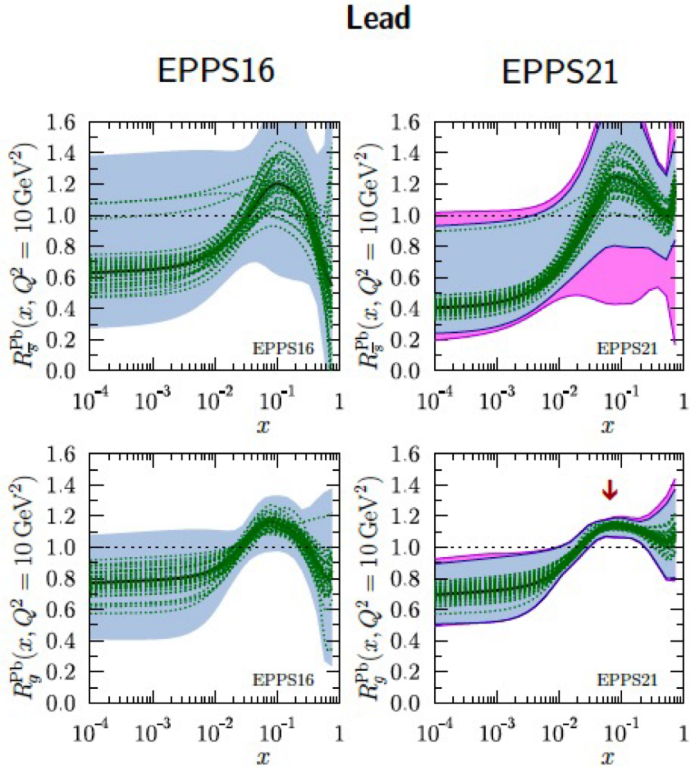
High energy frontier: (NA) Small-x

Objectives: Strengthening the communication and collaboration between the groups involved in theoretical and phenomenological studies in small-x physics both for p-p and A-A collisions

- Extraction of high-precision nuclear parton distribution functions
- Extension of current gluon-saturation calculations to NLO accuracy
- Calculation of multi-particle correlations

Achievements in 2nd year

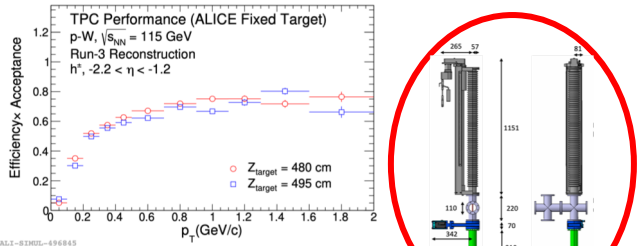
- EPPS21 nuclear PDF with new LHC run 2 data plus proton baseline uncertainties
- Real corrections to forward dijet production in pA as a step towards full result (virtual corrections ongoing)
- Multiparticle correlations in the CGC, up to 4 particles, connection with the Wigner function



High energy frontier: (JRA) FTE@LHC

Objectives: Investigate and implement fixed-target experiments at the LHC with the ALICE and LHCb detectors, and to develop the associated theoretical or phenomenological tools

- Development of novel gas-target techniques to be able to carry out the most energetic fixed-target collisions at ALICE and LHCb.
- Evaluation of the novel expected constraints on PDFs at high-x in the proton and nucleus, parton spin dynamics, as well as QGP properties via unique quarkonia measurements



FT @ ALICE

SMOG2 @ LHCb

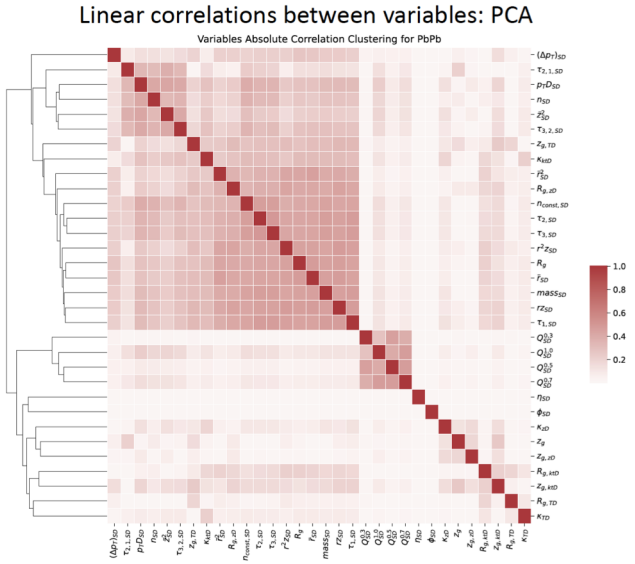
Achievements in 2nd year

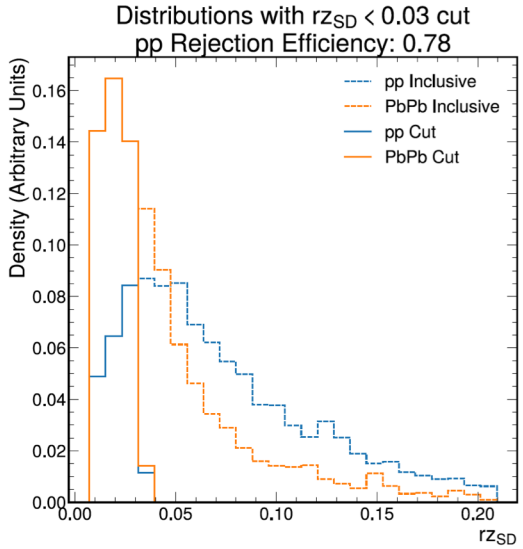
- Developments and performance studies for Fixed Target mode in ALICE
- Full installation of SMOG2 in LHCb
- Phenomenology: Longitudinal flow decorrelation (FTE @ LHC 2021 Workshop)

High energy frontier: (NA) Jet-QGP

Objectives: developing and deploying for jet physics in heavy ion collisions, novel tools techniques on both experimental and theoretical sides.

- Development of novel experimental and theoretical techniques for jet physics in A-A collisions, providing a reference implementation of jet interactions in a QGP via a full heavy-ion Monte Carlo event generator.
- Definition of new observables and development of new tools with increased sensitivity to mechanisms involved in jet-QGP interactions.





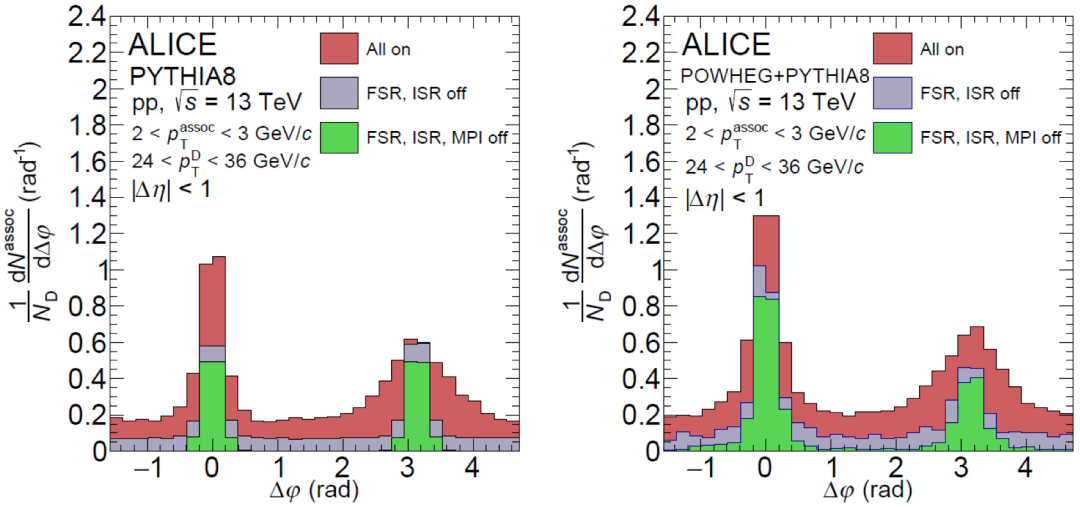
Achievements in 2nd year

- Identified event generator (JEWEL)
- Map correlations: PCA for linear and Deep-learning Autoencoder for non-linear
- Surveying jet observables with 3 main categories (angularities, dynamical grooming measures, jet charge)
- 4-5 promising variables with large overlap in sensitivity

High energy frontier: (NA) Hf-QGP

Objectives: identify the relevant mechanisms of heavy flavour production and interaction with the QGP then systematically compare different theoretical approaches in order to reproduce the final heavy mesons observables.

- Extraction of QGP transport coefficients from new high-precision theoretical calculations and experimental measurements of the production of open and closed heavy flavour (HF) quarks.
- Accurate measurements of total c-cbar, b-bbar cross sections in p-p, p-A and A-A collisions at the LHC.
- Development of a new data-theory interface to compare event-by-event experimental results to MC predictions



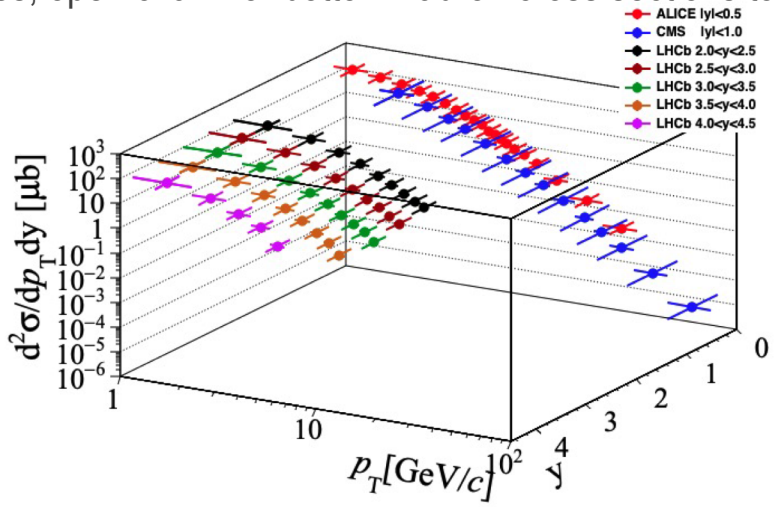
Achievements in 2nd year

- 14 highlight publications during second period (both experimental and theory)
- Open charmed meson angular correlation
- Quarkonium polarisation
- Agreement on RIVET (updated toolkit) as comparison framework

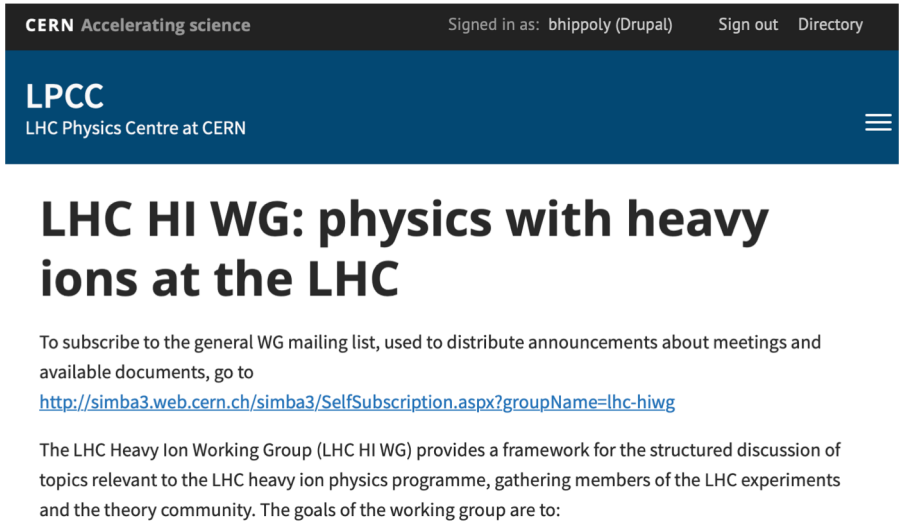
High energy frontier: (JRA) LHCCombine

Objectives: define a common structure for LHC experiments for improving intra-communication channels in the field of heavy-ion studies and establish an LHC data-combination working group exploiting their complementary capabilities.

- Combination of key LHC (ALICE, ATLAS, CMS, LHCb) measurements in p-p, p-A, and/or A-A collisions to achieve high-precision constraints on nuclear PDFs, QGP properties, SM parameters, and/or searches of physics beyond the SM.
- Examples include gauge bosons and jets differential cross sections to constrain nPDF, light-by-light scattering to constrain new physics searches, open charm or bottom hadron cross sections to determine QGP transport coefficients



example: open charm cross section (total + differential)



High energy frontier: Impact

STRONG-2020 gathers a large fraction of the community interested in the 3D-imaging of the nucleon in both momentum and position spaces, and in the quest for the understanding of the low-x gluon dominated sector. Its JRAs and NAs aim at creating, developing and stimulating the link between experiment and theory. They also aim at preparing for the next generation experiments, both in collision and fixed target modes, through theoretical progress, simulation and detector R&D.

This second period of reporting is characterized by a large number of experimental, theoretical and phenomenological publications. We can highlight that **STRONG-2020** allowed for a release of a new set of nuclear parton distribution functions, which will be used for all experimental heavy-ion groups at CERN or at RHIC. Within the framework of **STRONG-2020**, the initiated activities led to strengthen exchanges within the community and to establish sustainable structures such as a new working group within the LHC Physics Center at CERN.

High energy frontier: Impact

Research activities within **STRONG-2020** have been instrumental in demonstrating the feasibility of a fixed target programme at the LHC, and even started its implementation. After establishing a reference for Jet-QGP dynamics, key jet substructure observables have been identified via machine learning techniques.

On the aspect of R&D, **STRONG-2020** has been at the cornerstone of all studies made during this reporting period to design the future detectors for the fixed-target measurements, for both ALICE and LHCb at CERN, and for the American Electron-Ion Collider EIC. In that respect, the timing of **STRONG-2020** is perfect and its impact is decisive for all current developments.

Thank you for your attention