Hadronic Physics @ Irfu
focus on the Quark Gluon Plasma
NuPECC Meeting, Oct 6th 2017
Research at DPhN: Nucleon Structure

Fundamental questions:

▶ What is the origin and dynamics of confinement? And so …
▶ How are quarks and gluons distributed in the nucleon?
▶ What is the origin of the nucleon mass and spin?
Two experimental sites at CERN & USA

Current program (2016-2017) for 3D nucleon tomography in the sea quark region

Program in 2017 for 3D nucleon tomography in the valence quark region

Prospectives ongoing for the future
From 2025 on, an Electron-Ion Collider project in the USA to study gluonic matter
Deeply VCS with COMPASS at CERN

Goal: observe the 3D structure of the proton

COMPASS DVCS at CERN:
220 physicists from 13 countries
160 GeV muon beam on LH2 target
Dedicated recoil proton detector (CAMERA)

Data taking: tests in 2012 and 2 x 6 months in 2016 and 2017

Transverse size of the proton

More to come…
Latest 6 GeV DVCS/π0 results Halls A/B data

Proton and Neutron π0 separated cross sections

Accurate DVCS cross sections

Energy-separated DVCS cross sections

Phenomenology using

\( \sigma_L, \sigma_T \)

\( p(e, e' \pi^0)p \)

\( t' \) [GeV\(^2\)]

\( d^2\sigma \) [nb/(GeV\(^2\))]

\( \phi \) \([0..2\pi] \)

Energy-separated DVCS cross sections


PRL117 (2016) 26, 262001

PRL118 (2017) 22, 222002

PRC92 (2015) 5, 055202

PRL115 (2015) 21, 212003

\( x_B = 0.37, \quad Q^2 = 2.36 \text{ GeV}^2, \quad t = -0.32 \text{ GeV}^2 \)
State-of-the-art CLAS12 lightweight tracking

Installation and integration with Silicon tracker in June 2017

Dream: Dead-timeless Read-out Electronics ASIC for Micromegas

Dedicated ASIC developed for high-capacitance detectors

+ R&D for the Electron Ion Collider

- 18 barrel cylinders
- 6 forward disks
- 25000 channels, DREAM readout
- 10MHz singles rates, 5T magnetic field
- 1.2M€ investment
Research at DPhN: Quark Gluon Plasma

Fundamental questions:

- How the QGP is formed?
- What are the properties of the QGP?
- What are the most appropriate probes to study it?
The Quark Gluon Plasma (QGP)

- Deconfined phase of the nuclear matter
  - Quarks and gluons are the degrees of freedom (instead of nucleons)

- Phase transition: Hadronic matter -> QGP
  - T ~ 200 MeV and/or $\varepsilon \sim 1$ GeV/fm$^3$
  - These conditions can be reached in Ultrarelativistic Heavy Ion collisions @ LHC

- LHC is a Heavy Flavor Factory => Quarkonia
  - Heavy quarks are produced in the early stage of the collision (hard scat)
  - Sensitive to the hot medium formed in the ultrarelativistic HI collision
The ALICE experiment

- Saclay deeply involved in the Muon Spectrometer
  - hardware, software, physics analysis, upgrades

Stations 3, 4 & 5 CPCs
J/Psi suppression vs enhancement

- J/Psi largely suppressed at RHIC @ $\sqrt{s} = 200$ GeV/n
- Less suppression observed at LHC @ $\sqrt{s} = 200$ GeV/n
  - The regeneration component is observed at LHC (mainly at low $p_T$)
J/Psi Elliptic Flow

The $v_2$ is sensitive to the interactions of the quarks with the medium.

If there is quark regeneration (in transport models) => non-zero $v_2$

Fourier distribution

$$E \frac{d^3N}{d^3p} = \frac{1}{2\pi} \frac{d^2N}{p_T dp_T dy} \left( 1 + \sum_{n=1}^{\infty} 2v_n \cos(n(\phi - \psi_{RP})) \right)$$

$v_2$ is the elliptic flow
J/ψ in pp at LHC energies

• Good understanding of the J/ψ production in pp
  ‣ From 2.76 to 13 TeV
Psi (2S)

- Psi (2S) more suppressed than J/Psi
  - Difficult analysis => first preliminary results in Pb-Pb
  - Need more statistics

More to come with Pb-Pb in 2018
• Upsilon
  ‣ Compatible with $\Upsilon(2S,3S)$ full suppression
  ‣ Models fairly reproduce data

More to come with Pb-Pb in 2018
The Upgraded MUON Spectrometer

• After the LS2 (2019/2020)
  ‣ Upgraded Pb-Pb luminosity: $L = 6 \times 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ => 50 kHz of interaction rate (but peak at 100 kHz)
  ‣ Nominal LHC luminosity in Pb-Pb: $L = 10^{27} \text{ cm}^{-2}\text{s}^{-1}$ (8 kHz of interaction)

• Need to upgrade the FEE & readout of MUON Trigger and Tracking

• Add the new Muon Forward Tracker (MFT) => improved physics program
Alice Muon Tracking Upgrade

- Improved physics programs (with MFT)
  - Improved J/Ψ measurement (separation prompt/non-prompt)
  - Improved Ψ (2S) measurement
  - Open charm & open beauty down to low pT
  - Low mass with better mass resolution

- Electronics Upgrade
  - New Front-End based on SAMPA chip (all-in-one)
  - New readout based on GBT technology -> SOLAR boards

Saclay responsible of SOLAR boards
Muon Tracking Upgrade coordination
MFT

- Tracker located in front of the Muon Arm
  - High spatial resolution (~5 μm)
  - Secondary vertex capabilities
- 5 planes of CMOS sensor
  - Technology: Tower Jazz 0.18 microns
  - Pixel size: 29x27 μm²
  - Thickness: ~0.7% X/X₀ per plane
  - 920 pixel sensors, 280 ladders, ~0.4 m²

Ladder assembly machine @ CERN

Saclay participates in the sensor and ladder assembly Technical Coordination