Plan of COMPASS II Experiment

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Introduction

Motivation, interests

“Clarification of the origin of nucleon spin”

How do we represent $s=1/2$ of nucleon?

- **the old days ~**
  Quark model and quark spin 1/2

- **after spin crisis ~**
  Taking into account for contribution of
  - gluon spin
  - orbital angular momentum of quark/gluon
Introduction

History of COMPASS

EMC, SMC, etc

1996 Starting up!
Common Muon and Proton Apparatus for Structure and Spectroscopy

1998 Accepted.
Construction.

2002 Starting data taking.
6-months / year

2011 Closed.

2012 Starting up COMPASS II experiments.
Deeply virtual compton scattering run
COMPASS II Project

Plan of measurements

- Single Polarized Drell-Yan reaction (2014)
Generalized Parton Distributions (GPDs)

Parton momentum relation between longitudinal and transverse direction along incident beam direction.

GPDs : $H, E, \tilde{H}, \tilde{E}$

the Ji relation

$$\lim_{t \to \infty, \xi \to 0} \frac{1}{2} \int_{-1}^{1} x \left[ H^q(x, \xi, t) + E^q(x, \xi, t) \right] dx = \frac{1}{2} \Delta q + L_z^q$$

$L_z^q$ can be obtained.

GPD $H$

→ obtained by use of

Deeply Virtual Compton Scattering (DVCS)

$\mu^+ p \rightarrow \mu'^+ p' \gamma$ reaction is measured.
Measurement of $\mu p \rightarrow \mu' p' \gamma$ reaction

Scattering amplitude is represented by sum of DVCS and BH process.

Cross section

$$d\sigma_{(\mu p \rightarrow \mu' p' \gamma)} = d\sigma^{BH} + d\sigma^{DVCS}_{unpol} + P_{\mu} d\sigma^{DVCS}_{pol} + e_\mu \text{Re}(I) + e_\mu P_{\mu} \text{Im}(I)$$

$\rightarrow$ Extracting GPD $H$.

DVCS reaction

$Q^2 >> 1 \text{ GeV}^2$

$-t < 1 \text{ GeV}^2$

$\mu_0$ $\mu'$ $\gamma^*$ $q$ $q'$ $\gamma$

GPDs

$\mu_0$ $\mu'_0$

$\sigma^{BH}$: well-known
$I$: interference term
$e_\mu$: charge of $\mu$
$P_{\mu}$: polarization of $\mu$

R. Hashimoto, “Plan of COMPASS II Experiment”
Single Polarized Drell-Yan reaction

\[ \pi^- p^\uparrow \rightarrow \mu^+ \mu^- X : \text{The world's first polarized Drell-Yan measurement.} \]

Extraction of Sivers function \( f_{1T,DY} \)
Comparing with Sivers function of semi-inclusive deep inelastic scattering \( f_{1T,SI} \)

According to Collins (PLB, 532(2002)43),
\[ f_{1T,DY} \perp = - f_{1T,SI} \perp \]
Verified in this experiment. → Establishing an existence of contribution from orbital angular momentum of quark.
Experimental Setup

Experiment @CERN - SPS
Experimental Setup

Beam: p (primary), μ, π, K (Secondary, production target: Be)
Target: polarized proton target (NH₃)
        polarized deuteron target (⁶LiD)
        liquid hydrogen target
        thin-plate nuclear target
Currently, electromagnetic calorimeter ECAL 1 is installed in front of HCAL 1.
Cherenkov angle is related with particle velocity.
→ PID can be done by measurement of ring radius.
Pol-DY Setup

$\pi^- p^\uparrow \rightarrow \mu^+ \mu^- X$: The world’s first polarized Drell-Yan measurement

Side view of the upstream part

- Absorber will be installed downstream of the target.
- Target cell will be changed.
  - COMPASS: 3 cell
  - COMPASS II: 2 cell
Polarized target

Dilution refrigerator
achieving temperature: 50 mK
cooling power:
350 mW @300 mK

High-frequency wave
Extended Interaction Oscillator
(20 W)

Magnetic field
longitudinal polarization
solenoid: 2.5 T
transversal polarization
dipole: 0.6 T

Polarization of proton: ~90%

3 cell → 2 cell for COMPASS II
Upgrade for GPD measurements

\[ \mu + p \rightarrow \mu' + p' + \gamma \]

- \( \mu' \): Spectrometer & tracker
- \( p' \): Recoil Proton Detector (RPD)
- \( \gamma \): EM calorimeter

LH\(_2\) target

E = 160 GeV

(80% polarized)

\( \sim 260 \) MeV
Recoil Proton Detector (RPD)

2-layer PS hodoscope

Outer hodoscope

Inner hodoscope

Installation was finished.
A Large LH$_2$ Target

Japanese group is working for preparation of a large LH$_2$ target.
Coordinator: N. Doshita @ Yamagata Univ.
A Large LH$_2$ Target

Schematic view of the target system

- LH2 target L:2610mm OD:40mm (3.1L)

Important point
- Reducing quantity of matter between the target and detectors.

He

H$_2$ gas ( ~ 3.6 m$^3$ tank)

Operation ~ 1 bar
A Large LH$_2$ Target

Schematic view of the target system

Important points
- Reducing quantity of matter between the target and detectors.

LH$_2$ target L:2610mm OD:40mm (3.1L)
A Large LH$_2$ Target

Schematic view of the target system

- Reducing quantity of matter between the target and detectors.

Important points:

- H$_2$ gas (~ 3.6 m$^3$ tank)
- Operation ~ 1 bar
- CFRP chamber: T : 1mm  OD : 80mm  L : 2710mm (including endcap)
- End cap: L : 35mm  t : 2mm  (Mylar t : 0.35mm)
Previous instance of CFRP chamber

A liquid hydrogen target for FOREST @ELPH

LH$_2$ target system

~ CFRP ~

inner diameter 110 mmø
total length 1650 mm

Trends of making a LH$_2$ target

~ Target cell ~
inner diameter 61 mmø
thickness 45 mm (holding LH$_2$)
Using for meson photoproduction experiments. 

*For instance*

\[ \gamma p \rightarrow \omega p (\omega \rightarrow \pi^+ \pi^- \pi^0) \]

\( p, \gamma\gamma \) pair \((\pi^0)\) and 2 charged particles are required.
Construction of a CFRP chamber

@Japan
- Leak test for a CFRP duct.
- Vacuum test for a CFRP duct
- Coating with nano-Ag for blocking a LH₂ target from heat radiation and reducing out gas)
- Strength test for a CFRP duct
- Combining a CFRP duct with a mylar endcap.

@CERN
- Install.
- Vacuum test.
- DVCS test run. (from Oct. 2012)
Leak test

Setup

A CFRP duct was covered by bubble wrap.

Leak detector

Al conversion flange was combined by use of araldite.

Al blind flange was combined by use of araldite.
Leak test

Scenery of a leak test

Background level before this test
0.0 × 10^{-9} \text{ Pa} \cdot \text{m}^3/\text{sec}

Check 1: Spraying He gas from the endcap side.
0.0 × 10^{-9} \rightarrow 0.1 × 10^{-9} \text{ [Pa} \cdot \text{m}^3/\text{sec}]

Check 2: Spraying He gas from the leak detector side.
0.1 × 10^{-9} \rightarrow 0.2 × 10^{-9} \text{ [Pa} \cdot \text{m}^3/\text{sec}]

There were no terrible leak.
Vacuum test

Yamagata : Now running
CERN : Finished.
Strength test

The most important test
Individual difference should be estimated.

Measurements

- Pressurized 1.4 bar from outside × 5 ducts.
- Pressurized 3.0 bar from inside/outside × 1 duct.
Strength test (1.4 bar)

Blind type endcap was used. Connection of endcap-CFRP was ensuring by tight-wrapped vinyl tape.
Strength test (1.4 bar)

Measurement procedures

- Inflowing $^4$He gas to test chamber.
- Keeping 1.4 bar (differential pressure; gauge1 – gauge0).
- Keeping this condition during 3 minutes.

5 CFRPs have been done same test. It has not happened any problems during a trial.
Strength test (3 bar)

Setup1: Pressurized from inside of a CFRP

- Bourdon-tube pressure gauge-0 for measuring vacuum.
- Combined with a rotary pump.
- Bourdon-tube pressur gauge-1 for measuring gas pressure.

Gas lines were constructed with Cu-pipe’s combined by swageloks.
Strength test (3 bar)

Measurement procedures

- Vacuuming outside of a CERP (the gauge-0 measures).

- Inflowing $^4$He gas to the inside of the CFRP.

- Keeping $^4$He pressure more than 2.0 bar during 2 minutes.

Any anomalies could not find up to finishing the test.
Strength test (3 bar)

Setup2: Pressurized from outside of the CFRP
Exchanging the gas-line and vacuuming line.

He tank

Test chamber

Combined with a rotary pump.

Bourdon-tube pressure gauge-1
for measuring gas pressure.

Bourdon-tube pressure gauge-0
for measuring vacuum.
Strength test (3 bar)

Measurement procedures

- Vacumming inside of a CERP (the gauge-0 measures).

- Inflowing $^4$He gas to the inside of the test chamber.

- Keeping $^4$He pressure more than 2.0 bar during 2 minutes.

Any anomalies could not also find up to finishing the test.
Current status @CERN

The CFRP chamber was installed to a LH$_2$ target system.
  ・ Amount of out gas is measured.
    → not so many.
  ・ Leak check → no problem

Making up a LH2 target
  ・ Operation was done stably.
  ・ Irradiating $\pi$ beam during operation.
    → Trigger rate was increased gradually.
    Increase of LH$_2$ was observed.

DVCS test experiment is running now.
Summary

• COMPASS experiments were finished in 2011. In this year, preparing of COMPASS II experiments were done.

• At first, the RPD and a large LH₂ target were installed. Measurement of DVCS reaction are running now.

• In the next phase, measurement of single polarized Drell-Yan reaction is proposed. A polarized target will be remodeled and μ absorber will be installed in order to sophisticate this reaction.