COMPASS experiment at CERN. Status and perspectives.

Sergei Gerassimov*
On behalf of COMPASS Collaboration.

* Technische Universitaet Muenchen. On leave from Lebedev Physical Institute (Moscow)
“COMPASS” is ...

- … Common Muon and Proton Apparatus for Structure and Spectroscopy

- … Fixed target CERN experiment NA58 on SPS accelerator beams \((\mu,\pi,p)\)

- … collaboration of more than 200 physicists from institutes of 11 countries:

  Bielefeld, Bochum, Bonn (ISKP, PI), Burdwan and Calcutta, CERN, Dubna, Erlangen, Freiburg, Heidelberg, Helsinki, Lisbon, Mainz, Moscow (INR, LPI, MSU), Munich (LMU, TU), Nagoya, Prague, Protvino, Saclay, Tel Aviv, Torino (Univ., INFN), Trieste (Univ., INFN), Warsaw (SINS, TU)
Physics program

• With muon beam
  (data taking has started in 2002)
  • Quark and gluon polarization in polarized nucleons
  • Polarization transfer in fragmentation
  • Transverse spin distribution

• With hadron beam(s)
  (data taking will follow)
  • Polarizability of kaons and pions
  • Glueballs
  • Semi-leptonic decays of charmed hadrons
  • Double-charmed baryons spectroscopy
Experiment layout for muon physics

COMPASS Layout 2002 (Topview)

Target
SciFi
Silicons
Veto Trigger
MicroMegas SciFi SDC

Straws
GEM SciFi SDC

MWPC GEM SciFi

MW1 (Drift-Tubes)

Muon-Filter 1

SM1

SM2

RICH

Hadron-Calorimeter 1

Hadron-Calorimeter 2

Muonic Filter 2

Outer Trigger

Inner Trigger

MWPC MW2 (Drift-Tubes)

Middle-Trigger

Ladder Trigger

Inner Trigger

Ladder Trigger

Outer Trigger

0 10 20 30 40 50 m
Polarized $^6$LiD target

- Two 60 cm long target cells with opposite polarisation
- Polarization is inverted every 8 hours
- $^3$He – $^4$He dilution refrigerator (T~50mK)
- Superconducting solenoid (2.5 T)
- Dipole magnet (0.5T)
Detectors

- Tracking detectors:
  - Scintillating Fibres
  - Silicon microstrips
  - MicroMegas
  - GEMs
  - Drift chambers
  - MWPCs
  - Drift tubes
  - Straws

- Calorimeters
  - 2 hadron calorimeters
  - electromagnetic calorimeter

- Ring Image Cherenkov detector
Detectors: new developments

**GEM**
*(Gas Electron Multiplier)*
- Size: 30x30 cm²
- Time resolution: 12 ns
- Space resolution: 50 µm
- Double side X-Y readout

**MicroMegas**
*(MicroMesh Gaseous Structure)*
- Size: 40x40 cm²
- Time resolution: < 10 ns
- Space resolution: 70 µm
Calorimetry

Hadron Calorimeter 1 (500 ch)
sandwich: Fe + scintillator

$$\pi : \frac{\sigma}{E} = \frac{59.4\%}{\sqrt{E}} \oplus 7.6\%$$

Hadron Calorimeter 2 (200 ch)
sandwich: Fe + scintillator

$$\pi : \frac{\sigma}{E} = \frac{65\%}{\sqrt{E}} \oplus 4\%$$

Electromagnetic Calorimeter 1
(\sim 1000 ch of GAMS detector)

$$\frac{\sigma}{E} = \frac{5.8\%}{\sqrt{E}} \oplus 2.3\%$$
• 80 m³ $C_4F_{10}$ radiator
• 116 mirrors
• 5.3 m² of Cherenkov photon detectors
  • MWPC CsI photo-sensitive cathodes
  • 8x8 mm² pads
• 84000 readout channels (10-bit ADCs)
Trigger system

Trigger: \((H_4 \times H_5) \times (H_{cal1} \cup H_{cal2})\)

Kinematics ranges of triggers
Frontends and Data Acquisition System

- **only 4 types** of front-end chips (COMPASS development) for readout of all detectors.
- **only 2 types** of front-end interface modules (with identical output protocol)
- “pipeline” readout architecture
- ~ 250,000 channels
- event size ~ 50 kB
- trigger rate: up to 5 kHz
- data rates 220 MB/s in spill (60 MB/s average)
Central Data Recording

It is “experimental hall” ⇒ “CERN mass storage” data transfer hardware + software.

Design value: 35MB/s

3TB/day

260 TByte in ~100 days

5 billion events

2003: up to 6TB/day

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Sergei Gerassimov TU - Muenchen / ФИАН Москва
Event reconstruction

1) Track finding and fit. 2) RICH reconstruction. 3) Calorimeters reconstruction. 4) Beam momentum determination. 5) Vertex reconstruction.

Factors which make tracking one of the most CPU consuming parts of event reconstruction:

• 2-stage spectrometer with more than 200 detector planes of different type, different size and resolution.
• significant multiple scattering all over setup
• large beam pileup and halo ⇒ high detector occupancies
• 3 magnets. Complex superposition of target solenoid and magnet #1 fields

Average time to process one event on CERN Linux farm: 600 ms. ⇒ Processing of year 2002 data took ~ 200 days on 200 CPUs (almost completed now)
Analysis of 2002 data

Main directions:

- $\Lambda$ and $\bar{\Lambda}$ production and polarization
- Vector meson production: $\rho$, $\varphi$
- $\Delta G/G$ from open charm production
- $\Delta G/G$ from high-$p_T$ hadron pairs
- Flavour decomposition of polarized parton distribution function
- Transversity and Collins asymmetry
Lambda production

Armenteros-Podolanski plot:

for $V^0$ vertices  \[ P_T \text{ vs. asymmetry } \alpha = \frac{P_L^+ - P_L^-}{P_L^+ + P_L^-} \]
Lambda polarization (?)

\( Q^2 > 1 \text{GeV}^2 \)

0.2 < \( y \) < 0.9

1/6 of 2002 data

COMPASS 2002 data show good potential for \( \Lambda \) polarization measurements

Real data / Monte Carlo ratio
Exclusive $\rho^0$ and $\phi$ production

Skew shape of $\rho^0$ peak is due to interference between resonant $\rho^0$ production and “Drell type” background processes.

$$\Delta E = \left( \frac{M_X^2 - M_P^2}{2M_P} \right)$$
Angular distributions for $\rho^0 \rightarrow \pi\pi$

- Check polarization of vector meson:
  - small $Q^2$ – transversal polarization (as $\gamma^*$)
  - larger $Q^2$ – longitudinal polarization
- Confirm s-channel helicity conservation (all $\gamma^*$ polarization goes to vector meson)
- First good data for small $Q^2$ (quasi real photon)

$\rho^0$ polarization

$\pi^+\pi^-$ emission in $\mu$-scattering plane

Cuts:
$P_T > 0.15 \text{ GeV}$
$Q^2 > 0.05 \text{ GeV}^2$
Open charm production

\[ D^{*\pm} \rightarrow D^0 + \pi^\pm_{\text{slow}} \quad \text{(Br = 67.7 \%)} \]
\[ \rightarrow K + \pi \quad \text{(Br = 3.8\%)} \]

Selection criteria:

- \( Z_{D^0} > 0.2 \)
- \( |\cos(\Theta^*)| < 0.85 \)
- \( 10 < P_K < 35 \text{ GeV} \)
- \( K \) is identified by RICH
$D^{*\pm}$ and $D^0\bar{D}^0$ signals

$$\Delta m = M(K\pi\pi_{\text{slow}}) - [M(K\pi) + M(\pi)] = M_{D^*} - M_{D^0} - M_{\pi} = 5.85\text{ MeV (PDG)}$$

| $| M(K\pi) - M_{D^0} | < 30\text{ MeV} $ | $3.1 < \Delta m < 9.1\text{ MeV} $ |

It is the first step towards extraction of gluon polarization in polarized nucleon ($\Delta G/G$)
Future physics in COMPASS with hadron beams

Hadron beams 150-280 GeV/c

- Tests of $\chi$PT using Primakoff production ($\pi$ scattering off virtual photons)

- Light meson spectroscopy:
  - search for gluonic excitations (‘glueballs’)  
  - search for exotics (‘hybrids’)

- Central Production of gluonic excitations of hadrons
Double-charmed baryons

Spectroscopy
- System in ground state is B-like (separate slow motion of heavy and fast motion of light quarks)
- charmonium-like excitation via c-c excitation (tests dynamics of confinement)
- Mass spectrum calculable rather reliably

Lifetimes
- Prediction: $\tau(\Xi_{cc}^+) \leq \tau(\Omega_{cc}^+) \ll \tau(\Xi_{cc}^{++})$ where $\tau(\Xi_{cc}^+) \sim 400$ fs
- First observation by SELEX experiment: $\tau(\Xi_{cc}^+) \sim 30$ fs
Summary

Status and perspectives

- COMPASS is up and running.
- Lots of high statistics data to come.
- First interesting results and good perspectives for physics with polarized target and polarized muon beam.
  - First glance at open charm production via photon-gluon fusion: key to measure $\Delta G/G$!
- Exciting program in hadron physics will follow.
- Physics program is broad and apparatus is flexible ⇒ open to new ideas