The COMPASS spectrometer: status and performance

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INFN, Trieste

COMMON
MUON and
PROTON
APPARATUS for
STRUCTURE and
SPECTROSCOPY
THE COMPASS COLLABORATION

Bielefeld, Bochum, Bonn (ISKP), Bonn (PI), Burdwan and Calcutta, CERN, Dubna (LPP and LNP), Erlangen, Freiburg, Heidelberg, Helsinki, Mainz, Moscow (INR), Moscow (LPI), Moscow (State University), München (LMU), München (Technical University), Nagoya, Protvino, Saclay, Tel Aviv, Torino (University and INFN), Trieste (University and INFN), Warsaw (SINS), Warsaw (TU)

More than 200 physicists from 26 Institutes
Nucleon spin structure

- Gluon polarization $\Delta G(x)$
- Flavour-dependent helicity functions $\Delta q(x)$
- Transverse-spin distribution functions $\Delta_T q(x)$
- Spin-dependent fragmentation ($\Delta D^{\Lambda}_q$)

Spectroscopy

- Primakoff reactions
  - Polarizability of $\pi$ and $K$
- Glueballs and hybrids
- Charmed mesons and baryons
  - Semileptonic decays
  - Double-charmed baryons
2002 run:
160 GeV $\mu^+$ beam
$2.8 \cdot 10^8 \mu$ /spill (4.8 s)

2 stage spectrometer: LAT, SAT
tracking: VSAT, SAT, LAT
calorimetry: Ecal1, Hcal1, Ecal2, Hcal2
PID: RICH-1, $\mu$–wall1, $\mu$–wall2
Polarised Target
LARGE MECHANICAL STRUCTURES

SOME EXAMPLES
SAS + SM2 in the hall
ECAL1 frame
POLARIZED TARGET
Target system

$^3$He – $^4$He dilution refrigerator (T~50mK)

Superconducting solenoid (2.5 T)

Two 60 cm long target cells with opposite polarisation

+ dipole magnet (0.5T)
$^6$LiD Target

Dynamic Nuclear Polarization

Dilution factor $\sim$50%

Maximum $P$ values

$- 49\% \quad + 57\%$

Spin relaxation time:

- Longitudinal spin (2.5 T): too long to be measured
- Transverse spin (0.5 T): $>1000$ hours
$^6$LiD Target Polarization 2002

Future Physics @ COMPASS

26-27 September 2002

S. Dalla Torre
TRACKERS

VERY SMALL ANGLE TRACKERS
Scintillating Fiber Detectors

- 9 stations, 21 coordinates, 2668 fibre ch.s, 4008 discr. ch.s
- Efficiency: typically 99%
- Time resolution: 450 to 550 ps
- Enormous rate capability: 5 MHz per fiber
- Spatial resolution: 130 to 250 μm

Beam profiles on SF4

Number of hits
Mean ~ 1.6

Number of clusters
Mean ~ 1.2

Time difference “SF1X - SF1Y”
(Time resolution SF1: σ ~ 520 ps)

730 ps
SciFi

Position-Sensitive Photomultiplier (PSPM):
- H6568MOD (HAMAMATSU)
  - 16 ch Multi-Anode
  - Booster for the last 4 stages of dynodes

Sensitive area:
7-layers of Kuraray SCSF-78MJ 0.5 mm Ø

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Silicon trackers

- 2 stations, i.e. 4 double sided silicon detector operated in 2002
- strip pitch 50 \( \mu \text{m} \)
- dimensions 50 x 70 mm\(^2\)
- time resolution 2.5 ns
- efficiency \( \sim 99\% \)
TRACKERS

SMALL ANGLE TRACKERS
MicroMegas
(Micro Mesh Gas Detectors)

Novel gaseous detector

Conversion
Micromesh
Amplification
Strips

Ionizing particle

40x40 cm²,
dead zone: 5 cm Ø

2002 run:
3 stations,
4 planes each

40 cm

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MicroMegas

spatial resolution below 70 $\mu$m

Efficiency: $\varepsilon = 98.2\%$

time resolution below 10 ns

@COMPASS
GEMs

- novel gaseous detector

2002 run:
10 stations,
2 detectors each
 corresponding to 40 coord.s

2 dimensional read-out

50 µm

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GEMs

- two dimensional read-out
- spatial resolution ~50 $\mu$m
- time resolution ~ 12 ns
- efficiency ~ 96 – 97%

Distance from Track Y

Ch12 / ndf = 34.17 / 33
Prob = 0.4191
Constant = 92.61 ± 4.903
Mean = 0.03069 ± 0.002235
Sigma = 0.05764 ± 0.002088

30 x 30 cm$^2$

amplitude correlation
TRACKERS

LARGE ANGLE TRACKERS
Drift Chamber (SDC)
Drift Chamber (SDC)

- Large Area Tracking in SAS
- 3 chamber in 2002
- Each chamber provides 8 coordinates with resolution ~170 μm
- Efficiency 95 – 99.8 %
STRAWss

- 9 DLs operational in year 2002:
  1 full station (6 DLs) + 1 half station
  efficiency 85 – 98%
  spatial resolution ~ 270 μm
- construction in Dubna completed:
  all 15 DLs built

gluing of aluminized mylar foil

3250x2420 mm²

Assembly of first Straw Module (6 DL’s)

10 mm straws

Typical dimensions Of a Double Layer (DL)

6 mm straws

Hole

160 x 230 mm²

10 mm straws
STRAWs tracking results

6 mm straw
- RT relations
- residuals

10 mm straw

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MWPCs

- Backbone tracking system in SAS
- 11 stations installed for a total of 34 planes

- Gas mixture: 70% Ar, 20% CF₄, 10% CO₂
- High voltage: 4.25 kV
- Discr. threshold: 4fC

Mean efficiency 99.3%
W45: Large Area Drift Chambers for SAS
2 detectors, in total 8 planes
• **HCAL 1**
sandwich: Fe + scintillator + planar WLS for read-out
fully mounted and instrumented
\[
\pi : \frac{\sigma}{E} = \frac{59.4\%}{\sqrt{E}} \oplus 7.6\%
\]
\[
e : \frac{\sigma}{E} = \frac{24.3\%}{\sqrt{E}} \oplus 0.6\%
\]

• **HCAL 2**
sandwich: Fe + scintillator + WLS fibres for read-out
fully mounted and instrumented
\[
\pi : \frac{\sigma}{E} = \frac{65\%}{\sqrt{E}} \oplus 4\%
\]

• **ECAL 1**
lead glass (blocks from GAMS + OLGA)
not mounted (supports in production)
\[
\frac{\sigma}{E} = \frac{5.8\%}{\sqrt{E}} \oplus 2.3\% \quad \text{(GAMS)}
\]

• **ECAL 2**
lead glass (from GAMS, mounted) + sandwich
(pappardelle or shashlik)
LG mounted and partially instrumented
COMPASS PID
Muon Wall 1
Muon Wall 2
RICH1
Ring Imaging Cherenkov

- 80 m³ (3 m C₄F₁₀)
- 116 VUV mirrors (3.3 m focal length)
- 5.3 m² VUV detectors
  - MWPC CsI photon-sensitive cathodes
  - 8x8 mm² pads
- 84k channels of analog read-out
Photon detectors (PD): MWPCs with CsI photocathodes (5.3 m²), 84,000 analog read-out ch.s

VUV mirror wall, 21 m², 116 mirrors

an event from on-line display
**RICH-1, MORE WORK NEED FOR ...**

- Photon Detectors electrical stability
  - Run 2001: 2 PDs (over 8) OK
  - problem identified: local defects of anode wires
  - replacement of wires
  - Run 2002: 5 PDs (over 8) OK

- stability of mirror angular alignment:
  - misalignment up to 1.5 mrad, position correlated
  - repeated checks, RICH thermalisation,
  - on-line monitoring of mirror alignment being studied

- Radiator gas VUV trasparency:
  - raw gas cleaning
  - on-line gas filtering
  - gas consumption

*Future Physics @ COMPASS 26-27 September 2002*
calibration runs
(low beam intensity)

$\sigma_{\text{photon}} = 1.4 \text{ mrad}$

$\langle n \text{ photons/ring} \rangle = 14$

Csl –QE ~ design

mass spectrum

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PHYSICS RUNS

- Calibration run

- Photocathode image, superimposed events

- No cuts

- \( \Theta_{\text{trajectory}} > 40 \text{ mrad} \)
COMPASS TRIGGER
Trigger: \((H_4 \times H_5) \times (HCAL1 \lor HCAL2)\)

Trigger hardware:
- \(\sim 500\) channels
- discriminator boards with mean-timer
- matrix boards

Kinematic ranges for IT, LT, MT, OT

OT = Outer Trigger: new in 2002

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26-27 September 2002

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## DETECTOR SUMMARY:
Comparison with Initial lay-out

<table>
<thead>
<tr>
<th>Detector</th>
<th>In. Lay-out</th>
<th>2001 run</th>
<th>2002 run</th>
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<tbody>
<tr>
<td>Target</td>
<td>$^6$LiD</td>
<td>$^6$LiD</td>
<td>$^6$LiD</td>
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<td>COMPASS</td>
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<td>SMC</td>
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<td>GEM</td>
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<td>14</td>
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<td>Micromegas</td>
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<td>6</td>
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<td>Drift Chambers</td>
<td>16</td>
<td>8</td>
<td>24</td>
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<td>Straws</td>
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<td>W45</td>
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<td>Muon Walls</td>
<td>100%</td>
<td>10%</td>
<td>100%</td>
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<tr>
<td>HCAL</td>
<td>100%</td>
<td>10%</td>
<td>100%</td>
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<td>RICH mirrors</td>
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<td>RICH PDs</td>
<td>8</td>
<td>8</td>
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<tr>
<td>RICH radiator</td>
<td>100%</td>
<td>50%</td>
<td>100%</td>
</tr>
<tr>
<td>DAQ</td>
<td>100%</td>
<td>50%</td>
<td>100%</td>
</tr>
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</table>
**COMPASS**

**FEATURES**
- Pipelined readout architecture
- Fully extendable
- Data transfer via S-Link
- Buffering of burst (SPS duty cycle ~30%)
- Network event-builders

**REQUIREMENTS AND PERFORMANCES**
- Channels: 191 k
- Trigger rates: 5 kHz,
  dead time: 7%
- Event size ~ 40kB
- Data rates: 220 MB/s in spill, 60 MB/s DC

**DAQ SOFTWARE:** based on ALICE DATE

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**DAQ & FRONTEND DURING 2002 RUN**

FRONTEND & DAQ stability improved during the run:

- Uptime of FE & DAQ:
  - 6-8 July: 57%
  - 26-27 Aug.: 85%

in particular:

- Limitations in Central Data Recording
  - Total data rate $\geq$ maximum originally planned
  - at EOR, $\sim 2 \times$ unforeseen rate

![Graph showing GB/day](Graph.png)

**Total:** 260TB, i.e. 5 G events
Frontend and DAQ Performance

- 5 kHz trigger rate
- Dead time: 13μs, 5 triggers in 300 μs → 7% dead time
- improved performances coming
NECESSARY COMPLEMENTS
OF A MODERN EXPERIMENT
DETECTOR CONTROL SYSTEM (DCS)

COMPASS DCS uses
Framework, based on PVSS,
CERN designed for LHC
experiments

COMPASS DCS has 3 layers:

- **supervision layer** (PVSS II
SCADA system running on
Linux PC)
- **process management layer**
(PCs work stations with Linux
and NT systems, VME CPUs)
- **device level** using
fieldbuses (like VME, CAN
bus, Profibus, serial RS232
lines)

**aims:**

- operator control of HV, LV,
  ...
- monitoring and long-term
  periods archiving of
  parameters (HV, LV, crates,
gas system, P and T sensors,
data taking, cooling systems,
data from SPS)
- **alarm** handling and
  information **visualisation**
Status

- **system started with large support from CERN/IT division**
- **sub-systems included**
- **only basic functionality implemented**
- **optimisation required** to make it more stable and fast

### Detectors

<table>
<thead>
<tr>
<th>Detector</th>
<th>CAEN HV</th>
<th>CAEN LV</th>
<th>ISEC HV</th>
<th>WIENER LV</th>
<th>Gas Monit</th>
<th>AMS</th>
<th>DAQ Crates</th>
<th>DCS connect</th>
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<td>Nodoscopes</td>
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<td>BMS</td>
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<td>20 V</td>
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<td>SciFi J</td>
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<td>SciFi G</td>
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<td>GEM</td>
<td>20 ch</td>
<td>100 ch</td>
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<td>Silicon</td>
<td>16 ch</td>
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<td>16 T</td>
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<tr>
<td>MM/DC</td>
<td>40 ch</td>
<td>6 crates</td>
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<td>PLC2</td>
<td>33 T/H</td>
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<td>STRAW</td>
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<td>160 ch</td>
<td>PLC2, 2</td>
<td>PLC1, 2</td>
<td>16 T</td>
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<td>RICH</td>
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<td>mW1</td>
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<td>3 V</td>
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<tr>
<td>Total</td>
<td>958 ch</td>
<td>116 ch</td>
<td>160 ch</td>
<td>15 crates</td>
<td>2 PLC</td>
<td>294 ch</td>
<td>16 crates</td>
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</table>
ON-LINE DATA MONITORING

COOOL

up-to-date on-line monitoring
code in C++
built on ROOT libraries
sharing decoding with off-line software

data from DAQ farm (event builder PCs)

~ 80 events/burst (over~25000)
analyzed
Begin of the shift: Saturday 07 September

Crew members:
F.-H. Heinsius
R. Jahn
D. Beshevakinov
G. Reichelt

Target shift:

Summary of the shift:

0:25 re-boot of percom6.
Trigger H.V was off, therefore too high trigger rate.
1:00-6:00 DAQ-Frontend Rate Tests.
6:00-7:00 Test of physics run.
7:10-7:55 Silicon tuning scan.

RICH PD4 tripped and brought back up after 2 hour wait.
Recording most of the time disabled to speed DST production.

General comments submitted during this shift:

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<thead>
<tr>
<th>Comment #</th>
<th>Time</th>
<th>Author</th>
<th>Domain</th>
<th>Details</th>
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<tr>
<td>3112</td>
<td>01:11</td>
<td>F.-H. Heinsius</td>
<td>Trigger</td>
<td>All HV for Hodoscan switched on on PVSS.</td>
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</table>

Future Physics @ COMPASS 26-27 September 2002
CONCLUSION: COMPASS DATA TAKING EFFICIENCY
THANK YOU