Silicon Tracking System as a Part of Hybrid Tracker of BM@N Experiment

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Nuclear physics technologies“
11-17 October 2020, Online

Work supported by RFBR 18-02-40047 grant
Hybrid Tracking System of BM@N

➢ Track point measurement for Au+Au collisions with energies up to 4.5A GeV and beam intensities up to $5 \cdot 10^6$ Hz

➢ 4x STS stations based on CBM-type modules and developed in collaboration with CBM STS group

➢ 7x GEM planes (partially already exists)

➢ Momentum resolution $\Delta P/P \approx 0.6\%$ ($P > 0.5$ GeV/c)

➢ Reconstruction efficiency is $\approx 88\%$
Track reconstruction efficiency

➢ **STS only:** efficiency >90% for the momentum > 0.6 GeV/c

➢ **STS+GEM:** efficiency >90% for the momentum of about 1-2.5 GeV/c and 80% for the momentum >4 GeV/c

The reason for the lower efficiency of the STS+GEM system is the low granularity of the GEMs, which leads to a large number of clone hits being misinterpreted as real hits.

Reconstruction efficiency as function of momentum for primary tracks with minimum 4 hits in the STS stations only (red histogram), and in STS + GEM stations (blue histogram)
Momentum resolution

Momentum resolution for primary tracks emitted in central Au+Au collisions at a beam kinetic energy of 4A GeV reconstructed in the STS+GEM setup (left), and in the STS (right).

- STS only: $\Delta p/p = 1.5\%$
- STS + GEM: $\Delta p/p = 0.6\%$

Momentum resolution for primary tracks emitted in central Au+Au collisions at a beam kinetic energy of 4A GeV reconstructed in the STS+GEM setup as function of momentum.
Lambda reconstruction

Lambda reconstruction efficiency is slightly above 10 % for the STS+GEM and about 2.6% for STS only.

Number of reconstructed lambdas using 4 silicon stations only (red), and using the 4 STS + 6 GEM stations (blue).

Proton-pion invariant mass spectra using 4 silicon + 6 GEM stations (left), and using 4 silicon stations only (right).
Radiation level in the detector regions

For STS: the ionizing dose ~10 Gy after 2 month, lifetime dose ~ 100 Gy => mild damage of the central sensors. The equivalent neutron fluence is below $10^{10}$ $n_{eq}/cm^2$ after 2 months, life time fluence of $10^{11}$ $n_{eq}/cm^2$, which is well within the radiation tolerance of the sensors.

For GEM: the ionizing dose ~1 Gy after 2 month of beam on target, corresponding to a life time dose of 10 Gy. The equivalent neutron fluence is below $10^{10}$ $n_{eq}/cm^2$ after 2 months, corresponding to a life time fluence of $10^{11}$ $n_{eq}/cm^2$. Both values can be tolerated by the GEM detectors.
The Silicon Tracking System

4 Stations

16 Quarter-Stations

34 ladders

292 modules
Layout of the STS stations

Layout of the STS with sensors 42 x 62 mm² (green) and 62 x 62 mm² (blue)

Hit density per cm² and event in the four STS stations

The hit density is below 0.02 hits/cm²/event. For an inner sensor of size 42 x 62 mm² this value corresponds to a strip occupancy of about $5 \times 10^{-4}$ per event.
Double sided sensors

- Vendors: CiS (Germany) and Hamamatsu (Japan)
- Double-sided sensors with 1024 strips per side
- Three different geometries: 42*62mm², 62*62mm² and central sensors with round cut 42*62mm²
- Pitch of one strip: 58 μm
- Thickness: 300 μm (285 μm at CiS and 320 μm at Hamamatsu)
- Stereo angle: 7.5°

Measurements of charge collection efficiency (ratio of detected charge in irradiated to non-irradiated sensors) for samples of Hamamatsu and CiS sensors

CiS and Hamamatsu allow operating the sensors up to $2 \times 10^{14}$ neutrons/cm² fluence
STS modules

Noise/channel distribution

Performance:
➢ noise: 1090 ±150 e (N-side)
➢ 1350 ±200 e (P-side)
➢ r/o threshold: 7000 e
➢ signal mean: 16720 e (N-side)
➢ 20300 e (P-Side)
➢ signal-to-noise: 15±3
➢ hit detection eff.: > 95%

More details in the talk by A. Sheremetyev
CF frame and bearings

Bearings for the precise positioning of the ladder on ruby-balls pins

Developed by Van den Brink A.

CF-truss with bearings

CF-truss position repeatability test
Ladder assembly Device

LAD consists of:
• optical system, which is used for the monitoring of the sensor position in a horizontal plane and has an accuracy of 2\(\mu\)m.
• different sets of sensor positioning tables with micro-screws
• lift unit for the vertical displacement of the ladder sensor supporting CF truss.
• Device is installed on the heavy diabase table to avoid vibrations of the LAD during operation.

LAD should provide the following accuracy of the sensor positioning:
- X coordinate: ±15 \(\mu\)m on 1200 mm along the truss;
- Y, Z coordinates: ± 50 \(\mu\)m across the truss;
Assembly of the ladder

Lifting down the CF frame on pre-aligned sensors

Gluing of sensors to CF truss
First assembled mockup of the ladder

Mockup of the ladder

Fiducial marks on sensors

Measured deviations of X coordinates of the fiducial marks on the sensors from the mean value.
Readout electronics

GBTxEMU
FPGA based emulator of CERN GBTx serializer and data combiner chip 48 x 80 Mbit/s to 3.84 Gbit/s optical

elinks 2.35 MHit/s/elink

Data, Synch, commands

48 e-links 3 x Sensors

Hardware developments: GSI Detector Lab, JINR, MSU

BM@N trigger

Computing System

GBTxEMU

Data, Synch, commands

Gbit opt.

GERI-Board
FPGA based PCIe Interface to computer system

BM@N Data center

Data center

Firmware GBTxEMU, GERI: WUT Warshow, W. Zabolotny

Firmware TFC: KIT Karlsruhe, Vladimir Sidorenko

TFC Timing and Fast Control

NUCLEUS – 2020, 11-17 October 2020, Online
Readout chain

BM@N FEBs

FEB-panel

Microcoax cable
~0.7 m long

Patch panel
STS box

Twinax cable
~10 m long

GBTxEmu in crate

Eye diagram of the Up-link signal at 160 MHz Clk

Eye diagram of the Dwn-link signal at 80 MHz Clk
Timelines

➢ Start of serial module production -2021
➢ First operational ladder – 2021
➢ Pilot system with Stations 1+2 based on 42 modules – 2022
➢ Full STS system with 292 modules - 2023*

* on availability of funds of the GSI-NICA Roadmap Cooperation Agreement workplan

Work supported by RFBR 18-02-40047 grant
Thank you for your attention!