Silicon Tracking Systems for BM@N and MPD experiments at NICA

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For JINR STS team & CBM Collaboration
JINR LHEP

International Session-Conference of SNP PSD RAS “Physics of Fundamental Interactions”
STS for BM@N experiment

Mutual interest by CBM groups from Germany and Russia to install, commission and use
4 CBM-like Silicon Tracking Stations in BM@N in 2020.

Au beams up to 4.5 GeV/u

"Reconstructable" tracks

Invariant mass: $\Lambda \rightarrow p + \pi^-$

Dementev Dmitrii, International Session-Conference of SNP PSD RAS “Physics of Fundamental Interactions”
At the maximum design luminosity, the event rate in the BM@N interaction region is about \(10\) MHz with \(1\%\)X target; the total charged particle multiplicity exceeds 500 in the most central \(Au+Au\) collisions at \(E = 4.65\) GeV/n.

As the average momentum of the particles produced in a collision at Nuclotron energies is below \(1.5\) GeV/c, the detector design requires a low material budget.

In 2015 MoU of CBM STS participation in BM@N experiment at Nuclotron (4 STS CBM-like stations by 2020) as a “Phase 0” CBM STS experiment.
6.2 x 2.2 cm²  
6.2 x 4.2 cm²  
6.2 x 6.2 cm²

**CiS**

**Hamamatsu**

**Quality assurance of the sensors**

- Final product inspection at the vendors: detailed data
- Quality inspection at JINR has been advanced:
  - Full inspection during prototyping, sample tests during series production
  - Sophisticated optical and electrical methods established
  - Charge collection tests before/after irradiation, S/N determination

400 sensors are already ordered and arrived at JINR

By E. Lavrik (Universität Tübingen)
STSXYTER ASIC

- 128 channels + 2 test channels
- Self triggered architecture
- Maximum data rate: 250 kHz/channel
- 5-bit amplitude measurement
  - $\text{shaper}_{\text{slow}} + \text{ADC}$
- Time stamp measurement
  - $\text{shaper}_{\text{fast}} + \text{discriminator}$
- Dynamic range: 16 fQ
- Noise performance: 1000 enc at 30 pF input
- Time stamp resolution: 1 ns

Produced in 9/2016

Test bench for characterization of the ASIC

Test socket for the ASIC-tab-bonds

FEB board with 1 STSXYTER ASIC

FEB board with 8 ASICs (3D-view, V.Kleipa)
Modules

Mockups of the STS modules

Operation time for 1 module mock-up ~ 3 - 3,5 person/day
About 420 components are in assembly process at different stages

Microcables from Al-polyimide

Measurement:
\[ C_{\text{line}} = 0.38 \text{pF/cm} \]

distance between traces varies from 74 to 82 µm

Wirebonder F&K Delvotec G5

TabBonder Planar EM-437
Module assembly site at JINR LHEP

The main room (90m²) is class 7 ISO (less than 10 000 p/ft³ < 0.5 mkm)

4 technicians are currently involved in module assembling
Ladder assembly

Material: CF prepreg M55J/ 334EU
Modulus of composite 32800Gpa
Total weight: 10,4 g/m

40 CF frames were already produced (this is already enough for BM@N, production for the CBM@FAIR is under discussion)

The precision of the sensor orientation:
- X coordinate ±50 mkm
- Y coordinate ±15 mkm on 1200 mm base
  ±12 mkm on 180 mm base
- Z coordinate ±50 mkm
DAQ scheme

Proposed by Dr. C.J. Schmidt and Dr. D. Emschermann (GSI)

- 300 Gbit/s data throughput
- Expected maximum data rate: ~100 Gbit/s

Si sensor

Al cable

FEBs with 8 STSXYTERs

8x 80 Mbps e-links + 1 clk

~10 m

Up to 7 FEBs

GBTxEMU-1/80

~30 m

Opt. link 10 Gbps

FLIB board

x7

x15

PC server

Computer farm

uTCA crate

Inside BM@N Magnet

Radiation hard environment

uTCA crate

TFC (timing and fast control)

Limitation on the data rate per channel: 12.5 KHz
Instead of 250 KHz
Due to inaccessibility of GBTx ASIC

(Forbidden to import in Russia)

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Beam properties:
- Deuteron beam with $E_{\text{kin}} = 2.95$ GeV/n
- Intensity: $2 \times 10^5$ p/s

Clusters amplitudes on the **P side**

- $S/N$ for N side: $23.4 \pm 0.5$
- $S/N$ for P side: $24.5 \pm 0.5$

Clusters amplitudes on the **N side**

Test bench setup:
2 hodoscopes + 4 STS stations + GEM set-up + electronics tests

2,4 GeV proton beam
ITS for MPD Experiment

Stage 2: 2022-2023

Installation of ITS and thin wall Be beam pipe

JINR appeals for the Know-How transfer to build 6-layer ITS of the ALICE ITS Upgrade type with increased length of ladders to fit the NICA/MPD Interaction diamond parameters. MoU is on agreement.

New ALICE ITS layout

By Yu. Murin (JINR)
ITS for MPD Experiment

MPD ITS based on ALICE type staves

Reconstructed $\Lambda$-hyperon invariant mass spectrum ($p_t<0.6$ GeV)
A. Zinchenko et al

Identification of open charm particles

Simulations by Valery Kondratiev, SpBSU, SpB
Example of 10 D0-decays in 5 pixel layers ITS

\[ D^0 \rightarrow K^- + \pi^+ \]

CT = 123 μ Eff 2%

D – black
K – red
π – blue
Monolithic PIXEL chip using Tower Jazz CMOS 0.18 μm

- Chip size: 15mm x 30mm
- Pixel pitch ~ 30 μm
- Spatial resolution ~ 5 μm
- Power density < 100 mW/cm²

Automated machine for module assembly

Our group already ordered one machine

By L. Musa (CERN)
Conclusion

• Mutual interest by CBM groups from Germany and Russia to install, commission and use 4 CBM-like Silicon Tracking Stations in BM@N in 2020

• Our group is already close for production readiness for BM@N STS. Production will start at the end of 2018.

• We initiated contacts with ALICE ITS Upgrade team to build 6-layers ITS ALICE type based on a ALPIDE sensors.

First mini work meeting with the head of ALICE ITS team L. Musa was held at JINR 13-15 Apr 2017

Workshop at JINR dedicated to the BM@N and CBM STS setups. 22-23 May 2017
THANK YOU FOR YOUR ATTENTION!
BACKUP SLIDES
JINR STS Department

- The head of the department is Yu. Murin
- Quality assurance of sensors: N. Zamyatin (LHEP) + M. Merkin (SINP)
- Silicon Tracking Systems (STS+ITS)
  - Assembly of modules and super-modules: A. Sheremetyev +4
  - Mechanics of Composite Materials: A. Voronin, Igolkin as a consultant (CERN)
  - Bench and in-beam testing group: D. Dementev + 2 students
- Administration, civil construction and procurements support: V. Penkin + S. Udovenko
- Industry partners: lrd. LTU (Kharkov), Planar enterprise (Minsk)
Sandwich concept:
- Lightweight and stiff
- Parameters depend on filler material
- Versatile configuration

Further development requires:
- Thermal testing
- Requirement summary
- Coordination with industrial manufacturers

Further CAD development:
- Finalize cabling concept
- Schematic cable routing
- Integrated design

By J. HEUSER
LV/HV Powering Scheme: one sensor

In the box (radiation+mag.field)

Outside of the box (NO radiation+NO mag.field)

FLOATING!

+200V

HV PS

~ 1A

-200V

HV PS

~ 1A

LV feedthrough

+200V

~ 1A

-200V

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Physics motivation for a study of charm production at NICA

Heavy charm quarks are produced at the very initial stage of the collision of the heavy ions to witness the CBM(NICA,FAIR) or QGP (RHIC,CERN). C-quarks re-scattering by CBM is the right way to study CBM at NICA.

C-quarks interaction with cold nuclear matter has an exciting perspective at NICA since the estimated yields for the production of the hypothetical light supernuclei \(^{3}\text{He}\) and \(^{4}\text{He}\) indicated feasibility of the experimental search at NICA and not anywhere else at the moment.

From the experimental point of view production of open-charm particles in the energy range of NICA is a complete terra incognita.
Expected yields of the C-probes

At the highest energies NICA luminosity will reach values of $L=10^{27}$ cm$^2$s$^{-1}$ and the gold-gold collision rate of 5 kHz with the estimates for the number of registered open-charm particles in a two-week run of NICA/MPD as follows

<table>
<thead>
<tr>
<th>Decay</th>
<th>Multiplicity</th>
<th>$c$, $\mu$</th>
<th>BR,$%$</th>
<th>Eff,$%$</th>
<th>Number of events</th>
</tr>
</thead>
<tbody>
<tr>
<td>$D^0 \rightarrow K^\pi^-$</td>
<td>0,1</td>
<td>123</td>
<td>4</td>
<td>2</td>
<td>$48 \times 10^3$</td>
</tr>
<tr>
<td>$D^{*0} \rightarrow K^\pi^+$</td>
<td>0,1</td>
<td>123</td>
<td>4</td>
<td>2</td>
<td>$48 \times 10^3$</td>
</tr>
<tr>
<td>$D^+ \rightarrow K^\pi^-$</td>
<td>0,1</td>
<td>312</td>
<td>7</td>
<td>1,5</td>
<td>$63,5 \times 10^3$</td>
</tr>
<tr>
<td>$D^{*+} \rightarrow K^\pi^+$</td>
<td>0,1</td>
<td>312</td>
<td>7</td>
<td>1,5</td>
<td>$63,5 \times 10^3$</td>
</tr>
<tr>
<td>$D^{*0} \rightarrow K^\pi^+$</td>
<td>0,1</td>
<td>150</td>
<td>3</td>
<td>1,5</td>
<td>$27,2 \times 10^3$</td>
</tr>
<tr>
<td>$\Lambda^0 \rightarrow pK^\pi^-$</td>
<td>0,1</td>
<td>60</td>
<td>6</td>
<td>0,1</td>
<td>363</td>
</tr>
<tr>
<td>$\bar{\Lambda}^0 \rightarrow p\bar{p}K^\pi^+$</td>
<td>0,1</td>
<td>60</td>
<td>6</td>
<td>0,1</td>
<td>363</td>
</tr>
<tr>
<td>$\chi_c(3) \rightarrow d+pK^\pi^-$</td>
<td>0,1</td>
<td>60</td>
<td>?</td>
<td>?</td>
<td>$3,6 \times 10^3$</td>
</tr>
<tr>
<td>$\chi_c(4) \rightarrow t+pK^\pi^-$</td>
<td>0,1</td>
<td>60</td>
<td>?</td>
<td>?</td>
<td>$0,36 \times 10^3$</td>
</tr>
</tbody>
</table>