MPD and SPD for NICA project

Questions and Answers

Advanced Studies Institute (ASI), SPIN-Praha-2014, 14 Feb, 2014
The CBM experiment at FAIR
The CBM experiment at FAIR
CBM Silicon Tracking System (STS)

• CBM’s central detector system
• largest detector project at GSI for FAIR
  – 8 high-tech tracking stations
  – 2 m³ volume in dipole magnet
  – 2.5 M channels, 40 kW dissipation
  – 10 MHz event rate, 1 TB/s data

• International project:
  – 14 CBM member institutes from Germany, Russia, Poland, Ukraine
  – GSI has project leadership
  – partner project at JINR (BM@N)
NICA megaproject
MPD detector at NICA

Magnet: 0.5 T
T0, Trigger: FFD
Centrality & Event plane: ZDC
Tracking (|η|<2): TPC
PID: TOF, TPC, ECAL

Stage 1 (2017)
TPC, Barrel TOF & ECAL, ZDC, FFD

Stage 2: IT + Endcaps(tracker, TOF, ECAL)
MPD ITS status

Computer model simulations by V.P.Kondratiev and N.Prokofiev, SPbSU together with A.I.Zinchenko and V.A.Vasendina
BM@N Silicon Tracking System

STS in magnet
The CBM experiment at FAIR

- Dipole Magnet
- Ring Imaging Cherenkov Detector
- Silicon Tracking System
- Micro Vertex Detector
- Transition Radiation Detectors
- Resistive Plate Chambers (TOF)
- Electro-magnetic Calorimeter
- Projectile Spectator Detector (Calorimeter)

Two configurations:
- electron-hadron
- muon setup

Diagram showing the layout of the CBM experiment with labels for MVD, STS, micro-strips, MAPS, and vacuum coordinates.
STS design constraints

• **Coverage:**
  - rapitidies from center-of mass to close to beam
  - aperture $2.5^\circ < \Theta < 25^\circ$ (less for BM_N)

• **Momentum resolution**
  - $\delta p/p \cong 1\%$
  - field integral 1 Tm, 8 tracking stations
  - 25 $\mu$m single-hit spatial resolution
  - material budget per station $\sim 1\% X_0$

• **No event pile-up**
  - 10 MHz interaction rates
  - self-triggering read-out
  - signal shaping time < 20 ns

• **Efficient hit & track reconstruction**
  - close to 100% hit eff.
  - > 95% track eff. for momenta >1 GeV/c

• **Minimum granularity**
  @ hit rates < 20 MHz/cm$^2$
  - maximum strip length compatible with hit occupancy and S/N performance
  - largest read-out pitch compatible with the required spatial resolution

• **Radiation hard sensors**
  compatible with the CBM physics program
  - $1 \times 10^{13}$ $n_{eq}/cm^2$ (SIS100)
  - $1 \times 10^{14}$ $n_{eq}/cm^2$ (SIS300)

• **Integration, operation, maintenance**
  - compatible with the confined space in the dipole magnet
STS concept

- Aperture: $2.5^\circ < \Theta < 25^\circ$ (some stations up to $38^\circ$).
- 8 tracking stations between 0.3 m and 1 m downstream the target.
- Built from double-sided silicon microstrip sensors in 3 sizes, arranged in modules on a small number of different detector ladders.
- Readout electronics outside of the physics aperture.
Microstrip sensors

- double-sided, p-n-n structure
- width: 6.2 cm
- 1024 strips at 58 µm pitch
- three types, strip lengths: 2, 4, 6 cm, 4 cm
- stereo angle front-back-sides 7.5°
- integrated AC-coupled read-out
- double metal interconnects on p-side, or replacement with an external micro cable
- operation voltage up to few hundred volts
- radiation hardness up to $1 \times 10^{14} \text{n}_{eq}/\text{cm}^2$

4” and 6” wafers, 300 µm thick test and full-size sensors
Assessment of tracking stations - material budget

station 4

front view

sensor: 0.3% $X_0$

r/o cables: 2×0.11% $X_0$

electronics

side view
Assessment of tracking stations – sensor occupancy

sensor occupancy := ratio “nb. of hit strips : nb. of all strips“ in a sensor

station 1
Assessment of tracking stations - hit cluster size

cluster of strips := number of adjacent strips in a sensor that fire simultaneously

distribution for full STS in station 4

mean: 2.7
Track reconstruction performance studies

track reconstruction efficiency

momentum resolution

⇒ Ongoing layout improvements:

- aperture improvements to be done in some of the stations: better coverage around beam pipe
- optimize number and type of modules and their deployment in the stations

25 AGeV Au+Au central
Modern fast and high precision instrumentation based on microstrip sensors

Supermodule („the ladder“)= Sensitive modules on light weighed CF support frames with FEE in cooled containers at the rare ends
The CBM-MPD STS Consortium Since Nov 2008 till 2013
CBM-MPD STS Consortium

- 8 institutes
- 5 countries

- GSI, Darmstadt, Germany
- JINR, Dubna, Russia
- IHEP, Protvino, Russia
- MSU, Moscow, Russia
- KRI, St.Petersburg, Russia
- SPbSU, St.Petersburg
- SE SRTIIE, Kharkov, Ukraine
- NCPHEP, Minck, Belarus Rep.
- PI AS, Prague, Czech Rep

Components
- Sensors
- Modules assembly
- Ladder assembly
- Radiation tests
- In-beam tests

CBM in Darmstadt
MPD and BM@N in Dubna
The STS

Stations + Mainframe Mechanics + Thermo isolation

The station

Ladders + Movable Station Mechanics

The ladder

Ladder CF Frame + Ladder HP positioning units + Modules + Temporary Transportation Fixture

The module

Sensor + L-lockers + Cable + STS ASIC + FEB PCB + Temporary Transportation Fixture

The components

Sensors, Ladder CF Frame, Ladder HP positioning units, L-lockers, Cables, STS ASIC, FEB PCB, FEB Boxes with Heat Sink, Transportation Fixtures, Movable Station Mechanics, Mainframe Mechanics, Thermo isolation
## Components Readiness: The sensors

<table>
<thead>
<tr>
<th>Prototype</th>
<th>Year</th>
<th>Vendor</th>
<th>Processing</th>
<th>Size [cm²]</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBM01</td>
<td>2007</td>
<td>CiS</td>
<td>double-sided</td>
<td>5.5 × 5.5</td>
<td>±7.5 deg</td>
</tr>
<tr>
<td>CBM03</td>
<td>2010</td>
<td>CiS</td>
<td>double-sided</td>
<td>6.2 × 6.2</td>
<td>±7.5 deg</td>
</tr>
<tr>
<td>CBM03’</td>
<td>2011</td>
<td>CiS</td>
<td>Single/CBM03</td>
<td>6.2 × 6.2</td>
<td>test for CBM05</td>
</tr>
<tr>
<td>CBM05</td>
<td>2013</td>
<td>CiS</td>
<td>double-sided</td>
<td>6.2 × 6.2</td>
<td>7.5/0 deg full-size</td>
</tr>
<tr>
<td>CBM05H4</td>
<td>2013</td>
<td>Hamamatsu for GSI</td>
<td>double-sided</td>
<td>6.2 × 4.2</td>
<td>7.5/0 deg full-size</td>
</tr>
<tr>
<td>CBM05H2</td>
<td>2013</td>
<td>Hamamatsu for JINR</td>
<td>single-sided</td>
<td>6.2 × 2.2</td>
<td>7.5/0 deg full-size</td>
</tr>
</tbody>
</table>

Components under study: replacement for integrated 2\textsuperscript{nd} metal layer; external on-sensor cable.
## Components Readiness: The Cables

<table>
<thead>
<tr>
<th>Components type</th>
<th>Q-ty for STS (+20%), pcs</th>
<th>Material</th>
<th>View</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog connecting layer</td>
<td>34400</td>
<td>FDI-A-24</td>
<td><img src="image1.png" alt="Image" /></td>
</tr>
<tr>
<td>Meshed spacer</td>
<td>38700</td>
<td>Polyimide</td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>Shielding layer</td>
<td>2150</td>
<td>FDI-A-24</td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>Daisy –chain cable</td>
<td>778</td>
<td>FDI-A-20 (24)</td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
<tr>
<td>Interstrip cable</td>
<td>1464</td>
<td>FDI-A-24</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
</tbody>
</table>
Components Readiness: Readout ASIC

full-size prototype dedicated to signal detection from the double-sided microstrip sensors in the CBM environment

fast $\iff$ low noise $\iff$ low power dissipation

new w.r.t. n-XYTER architecture: effective two-level discriminator scheme

design V1.0 @ AGH Kraków
UMC 180 nm CMOS

produced 2012
die size 6.5 mm $\times$ 10 mm
second round planned for fall 2014

<table>
<thead>
<tr>
<th>Channels, pitch</th>
<th>128 + 2 test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel pitch</td>
<td>58</td>
</tr>
<tr>
<td>Input signal polarity</td>
<td>+ and -</td>
</tr>
<tr>
<td>Input current</td>
<td>10 nA</td>
</tr>
<tr>
<td>Noise at 30 pF load</td>
<td>900 e-</td>
</tr>
<tr>
<td>ADC range</td>
<td>16 fC, 5 bit</td>
</tr>
<tr>
<td>Clock</td>
<td>250 MHz</td>
</tr>
<tr>
<td>Power dissipation</td>
<td>$&lt; 10$ mW/channel</td>
</tr>
<tr>
<td>Timestamp resolution</td>
<td>$&lt; 10$ ns</td>
</tr>
<tr>
<td>output interface</td>
<td>$4 \times 500$ Mbit/s LVDS</td>
</tr>
</tbody>
</table>
module is building block of ladders smallest assembled functional unit

STS module concept

sensor

read-out cables

front-end electronics board

10 – 50 cm

6 cm

2, 4, 6, (12) cm
Detector module composition

- Inter-stip cable 1pcs
- Multilayered connection cables 32pcs
- Shielding layer 2pcs
- Meshed spacer 4pcs
- Sensor
- FEB STS-chips

71 components for one module
(for double sensor module + 2 daisy chain cables)
Technological scheme of single-sensor module assembly

- Sensor (or Sensor assembly)
- Analogue cables with chips assembly
- PCB (FEB)
Technological scheme of chip with analogue cable assembling

1. US-bonding Bonds protection
2. Analogue cables
3. Chips
4. Testing (fast test, functional test)
Technological scheme of analogue cables with PCB assembling

- Gluing
- Analogue cables with chips
- Wire-bonding
- PCB (FEB)
- Testing

alignment with using of the sensor imitator
Technological scheme of analogue cables with sensor assembling

Sensor assembly

Analogue cables with FEB

US-bonding
Bonds protection

Testing
(fast test, functional test)

The opposite side is the same
CF Mechanics Readiness: Punch@Mould
Produced in SPb with ten CF space frames manufactured @ CERN

Punch and Mold for production of true CBM supporting frames
Demonstrators and prototypes
Prototype Device for ladder assembling manufactured at PLANAR, Minsk, Rep. of Belarus, 2012
Preparations for the in-beam tests at Nuclotron

• Equipment of JINR test bench with n-XYTER readout

• Mechanics preparation
• Slow Control for Protvino in-beam
• Logic Init for recording the external DAQ information into the ROC

Status: Preparations for the in-beam tests at Nuclotron
Timelines of CBM STS

1) STS Technischer Design Report (approved 8/2013)
2) Pre-production phase (2014): Technology decisions, module demonstrators
3) Production Readiness Review (7/2015)
4) Series production of sensors until ~ mid 2017:
5) STS commissioning (2018)
STS-BM@N-ITS Effort@ LHEP

**Manpower**
- Clean rooms
  - A design - 15.02.14
  - Reconstruction (stage 1) - just starting
  - Reconstruction (stage 2)
  - Installation

- Standard Equipment
  - Four heavy items in the storage
  - Procurement List #1 relayed to GSI
  - Procurement List #2 under preparation

**Infrastructure**
- Custom-designed Equipment
  - 95% of parts for sensor probe stations paid
  - Design of SSSD sandwich gluing device - 19.01.14
  - Contracts for design/manufacturing of Ladder assembling device
  - SSSD sandwich gluing device manufacturing

- In-GSI designed electronics for QA testing
  - None - Subject of discussion
STS and ITS FEE

CBM-xyter

- Self triggering
- High power consumption
- Too fast
- Not ready yet
- 5-bit ADC
Tentative Work Plan for 2014-15

<table>
<thead>
<tr>
<th>STS</th>
<th>MANAGEMENT</th>
<th>External EXPERTISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>assembling Lab Installation</td>
<td>Murin Yu.A. Asistants: Penkin V.A.- civil engineering, procurement Pavlyuk E.- bookkeeping</td>
<td>Merkin M.M. MSU</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Composite material parts production</th>
<th>Cryogenic and radiation sensor QA testing</th>
<th>Modules and ladders assembling</th>
<th>Assembling QA testing</th>
<th>Nuclotron in-beam tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CERN</strong> Igolkin S.N. + 2 technicians</td>
<td><strong>JINR</strong> Zamiatin N.I.+3</td>
<td><strong>STU,Ltd</strong> Borschov V.N.+6 <strong>JINR</strong> Elsha V.V. Budilov V.A. Berezin G.S. +2 technicians</td>
<td><strong>STU,Ltd</strong> Borschov V.N.+6 <strong>GSI</strong> Ch.Schmidt+3 <strong>JINR</strong> Bazylev S.N.+1 Dementyev D.V.</td>
<td><strong>JINR</strong> Murin Yu.A.+3 <strong>MSU</strong> Merkin M.M.+3 <strong>GSI</strong> J.Heuser+5</td>
</tr>
<tr>
<td><strong>JINR</strong> Budilov V.A.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Conclusions

- Through years 2008-2013 the CBM-MPD STS Consortium has accomplished 80-90% of R&D activity which could be successfully accomplished by mid 2015.

- In 2013 not only the targets but additional sources of budgeting of the common GSI-JINR project were indicated: GSI-JINR LHEP STS assembling Lab MoU signed with resources + draft of the FAIR-JINR-ROSATOM-CBM Contract for assembling four stations of CBM STS at LHEP is ready for signatures.

- To resolve the “manpower crises” administrative decision have been taken to organize a department of STS for CBM, BM@N and ITS.

- All young researchers are be in a joint working group which will built the core of team to yield the benefit of the STS being used at Nuclotron and NICA.
Questions

Difference between MPD and SPD Inner Tracking System:

- Single hit resolution
- Tracking resolution
- Tracking efficiency
- Secondary vertex resolution
- Momentum resolution
- Material budget
Thank you for your attention!

Thanks for courtesy of using the slides to J.Heuser, M.Protsenko, I.Tymchuk