





### The Silicon Tracking System of the CBM Experiment at FAIR

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# Facility for Antiproton and Ion Research

- · Beam intensities up to 1000x w.r.t. current facility
- Simultaneous operation of different experimental programs:
  - heavy ions
  - antiprotons
  - rare isotopes



#### <u>SIS-100</u>

- protons: 30 GeV
- Au: 11 GeV/nucleon

#### Commissioning start in 2025

### FAIR construction status



# CBM physics goal

Explore the QCD phase digram of nuclear matter at high baryon densities



#### Physics cases

- existence of critical endpoint
- 1st order phase transition and exotic phases
- QCD equation of state
- chiral symmetry restoration at high  $\mu_{\rm B}$

#### **Observables**

- strangeness
- charm
- (multi)-strange hypernuclei
- dileptons
- collective flow
- fluctuations and correlations

# **Compressed Baryonic Matter experiment**



- Vertexing: MVD
- Tracking: STS, MUCH, TRD, ToF
- Particle ID: RICH, TRD, ToF
- Calorimetry:
   ECAL, PSD

- fixed traget geometry with polar angle coverage [2.5°; 25°]
- electron and muon configuration
- free-streaming DAQ

 online event selection using high level triggers

# Silicon Tracking System

STS is a main tracking detector that will reconstruct up to 700 charged particle per collision.



#### Features:

- located inside 1 Tm dipole magnet
- 8 tracking stations
- active area about 4 m<sup>2</sup>
- 896 sensors installed onto 106 carbon fibre ladders
- low material budget <1.5%X<sub>0</sub> per station
- fast self-triggering readout
- radiation tolerance up to 1014  $n_{eq}cm^{-2}$

#### **Requirements**:

- fast and radiation hard detectors
- self-triggering electronics
- 4D event reconstruction

# Double-sided silicon microstrip sensors

- n-type bulk
- 320 ± 15µm thick
- 1024 strips per side
- 58µm strip pitch
- 0/+7.5° stereo angle for n/p side
- second metallisation layer to interconnect edge strips
- width: 6.2 cm
- length: 2.2, 4.2, 6.2, 12.4 cm (strip length): granularity is matched to the hit density in the STS aperture

Sensor series production started.





### Microcables

- signal layer: 64 AI lines of 116 µm pitch
   Cu alternatively under study
- thickness: 10  $\mu$ m thick on14  $\mu$ m polyimide
- length up to 55 cm



Material budget: 0.228 X<sub>0</sub> (equivalent to 213  $\mu$ m Si)



microcable stack structure



signal layer TAB-bonded to the ASIC

# STS-XYTER: custom ASIC with self-triggering architecture



#### ASIC architecture

channels	128, polarity +/-		
noise	1000 e <sup></sup> at 30 pF load		
ADC range	16 fC, 5 bit		
clock	160 MHz		
power	< 10 mW/channel		
timestamp	< 5 ns resolution		
out interface	(15)×320 Mbit/s LVDS		



#### STS-XYTER ASIC

- designed for high capacitive load
- fast branch (30 ns rise time): time-stamp latching
- slow branch (80 ns peaking time): signal digitization
- double-threshold discrimination: time stamp is vetoed if ADC produced no signal

### Module & ladder assembly



Basic functional unit: double-sided sensor + 2x16 microcable stacks + 2 front-end boards with 8 ASICs each. First full-size modules built.



Up to 10 modules are mounted on a carbon fibre ladder using L-legs.

# System integration concept



#### 896 detector modules including:

- 1.8M readout channels
- 14.3k readout chips
- 28.6k ultra-thin readout cable stacks
- 106 ladders
- 18 half-units

Infrastructure in the STS box:

- power distribution boards
- interface boards (electr. + opto)

of a dipole magnet

- cooling (electronics + sensors)
- feedthroughs for services

### Quality assurance of module/ladder components

Sensors

#### **Microcables**

**ASICs** 

Ladders



**Optical inspection** 



Yield determination



ASIC test socket



**CF** ladder metrology CF1-03



**Electrical QA** 



0.6 -0.6 -0.8 200 1000 400 600 800

### ASIC acceptance results

Extract mech. tolerance

X [mm]

# Module testing



Module test stand for S/N determination



Detector module inside the test stand



Measured noise performance for a detector module with  $6x6 \text{ cm}^2$ sensor and  $45 \text{ cm} \log \mu$ -cable is <2000 e.

# mSTS at mCBM

Long term campaign at SIS18: full system test with high-rate AA collisions at GSI/FAIR



- CBM pre-final detector systems
- free streaming read-out
- data transport to the mFLES (high performance computing farm)
- up to 10 MHz collision rate



mSTS box with C-frames holding carbon ladders with silicon strip detectors 4 modules (Feb' 2019)

# CBM readout chain Phase I (2019)



# CBM-STS project

#### **Key Participants of CBM-STS:**

#### Germany:

- Darmstadt, GSI Helmholtz Center (GSI)
- Karlsruhe Institute of Technology (KIT)
- Tübingen, Eberhard Karls University (EKU)

#### Poland:

- Krakow, AGH University of Science and Technology (AGH)
- Krakow, Jagiellonian University (JU)
- Warsaw University of Technology (WUT)

#### **Russia:**

Dubna, Joint Institute for Nuclear Research (JINR)

# Project timeline

- Technical Design Report approved in 2013
- Production readiness of silicon sensors in 2018
- mCBM run 2018-2022
- Production of components 2019 2024
- STS system assembly and commissioning in 2020 2023
- Installation in CBM cave in 2025. Commissioning with beam.

COMPRESSED BARYONIC MATTER EXPERIMENT	CBM Collaboration STS Note 2018-1 v 1.0 August 22, 2018	Compressed Baryonic Matter Experiment FOR	CBM Collaboration STS Note 2015/02 28 August 2018
Production Readiness Review for the Silicon Sensors of the CBM Silicon Tracking System         O. Berlin <sup>1</sup> , E. Frick <sup>2</sup> , U. Frankfell <sup>1</sup> , J. M. Hesser <sup>1</sup> , E. Lavik <sup>2</sup> ,         P.A. Loizeau <sup>1</sup> , J. Lehnert <sup>1</sup> , A. Lymanet <sup>1</sup> , E. Monord <sup>1</sup> , J. P. Bassenich <sup>2</sup> , V. Pagatch <sup>1</sup> , A. Rodriguez <sup>1,1</sup> H. R. Schmidt <sup>1,2</sup> , C. Simoli, <sup>1</sup> , C. Simoli, <sup>1</sup> , C. Simoli, <sup>1</sup> , C. Simoli, <sup>1</sup> , Telkishyk <sup>6,1</sup> , <sup>1</sup> <sup>1</sup> GSI, Damstad, <sup>2</sup> Universitif Training <sup>1</sup> , <sup>2</sup> C. Simoli, <sup>1</sup> , Simoli, <sup>1</sup> , Telker, <sup>1</sup> <sup>1</sup> GSI, Damstad, <sup>2</sup> Universitif Traininge, <sup>3</sup> XIN, K. Kes, <sup>1</sup> Universitif Frankfur, <sup>1</sup> FAIR, Damstad <sup>1</sup> now at Université catholique de Louvain, Belgium         Editors: J. M. Hesser, V. Pugatch, HR. Schmidt <b>Datrat</b>	Evaluation of the STS sensor prototypes brachaded with 23 MeV proton beam using relativistic β-electrons         EVENTS         CHAPT         Magnetia Monest <sup>1,4</sup> , Malyar Telisleyt <sup>1,4</sup> , Aton Lymanets <sup>2</sup> , Olga Bertin <sup>4</sup> , Johan Heuser <sup>2</sup> <sup>1</sup> Order University Frankfurt, Frankfurt an Main, Germany <sup>1</sup> Datility for Antiproton and Ion Besarch, Durnstah, Germany <sup>1</sup> Datility for Antiproton and Ion Besarch, Durnstah, Germany <sup>1</sup> Datility for Nuclear Besarch of NASU, Kyv, Ukraine	Conceptual Design Report of the STS Cooling System K. Agarwal <sup>1</sup> , M. Kis <sup>2</sup> , P. Kuhl <sup>2</sup> , H. R. Schmidt <sup>1,2</sup> , O. Vasylyev <sup>2</sup> <sup>1</sup> Eberhard Karls Universität Tübingen, Tübingen (DE) <sup>2</sup> GSI Helmholtz Centre for Heavy Ion Research, Darmstadt (DE) Emsi: Kabiti Agarwal/9Uus/Tuebingen.de Emsi: Haus-Rudolf Schmidt@Uni-Tuebingen.de Emsi: Haus-Rudolf Schmidt@Uni-Tuebingen.de	Report on the production of prototype STS ladders <b>CBM-ST tem</b> GS, Darmstaft, Germany and JNR-VBLREP, Dubas, Rasia . Effer: Johann M. Heuer, GSI March
senoro of the CBM Sinco Tracking System, which took place on 23 April 2018. It accounts for the updated source design the sensor thickness onto the performance fugures, sensor QA and acceptance criteria, the impact of the sensor thickness onto the performance fugures, sensor QA and acceptance criteria, the impact of the sensor thickness onto the performance fugures, sensor QA and acceptance criteria, the impact of the sensor thickness onto the performance fugures, sensor QA and acceptance criteria, the impact of the sensor thickness on the performance fugures, sensor QA and acceptance criteria, the impact of the sensor thickness on a subserved.		ber 30, 2019' and describes the counserted design and the status of the cooling systems for the Silican Tracking yourne [391]. The could are of the Silica Tracking and the status of the cooling electronic (< 40 4047) and gas cooling to remove the funderated heat produced by the sensor themselves (< 6 4070'''''') is a corptance region. While the RAD for the biplance cooling, which comprises essentially the layout and design of the various heat endances and thermal interfaces to sense the optimal heat transfer to the biplance (C), is essentially done, the sense of the sense of the sense sense in the sense of the sense of the sense of the flow, and thus the heat transfer coefficient. The RAD for the pass cooling in cognitor, a read- iot to thermal demonstrator is being head with the value of the sense sense for , and thus the heat transfer coefficient. The RAD for the pass cooling in cognitor, a read- iot to thermal demonstrator is being head with while value to the transfer and the flow to cool the senses sufficiently to avoid thermal runnersy.	devende 1 of the popiet's work package 3-36 new cooperation with the NICA solidar facility in the field of ton beams and heavy ion physics.

Frechnical Design Report

for the CBM

Silicon Tracking System (STS)
The CBM Collaboration
The CBM Collaboration
Silicon State Content of the CBM

Sensor production readiness Rad. hardness

Cooling

Ladders

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