The powering scheme of the CBM Silicon Tracking System: concept and first implementations

Anton Lymanets[1] (a.lymanets@gsi.de), Maksym Teklishyn[1,2], Oleksandr Kshyvanskyi[2] *for the CBM Collaboration* | [1]GSI Darmstadt, [2]Kiev Institute for Nuclear Research

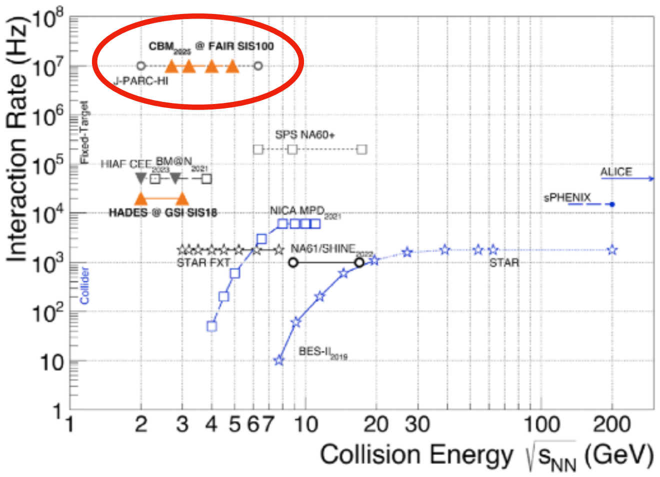
Abstract

The Silicon Tracking System (STS) is planned to be the principal tracking detector of the future CBM experiment at FAIR. It will perform charged-particle track measurement with momentum resolution better than 2% in a 1 Tm dipole-magnetic field. A main challenge for the STS is to maintain high track reconstruction efficiency throughout the projected lifetime of the experiment which means being exposed to an accumulated fluence of up to 10^{14} n_{eq}/cm^2, expected to be reached in beam-target interaction rates of 10 MHz. Therefore, front-end electronics with self-triggering architecture needs to have sufficient signal-to-noise ratio (S/N>10) which requires an ultra-low noise system design.

The STS will consist of eight tracking stations comprising 876 double-sided silicon detector modules installed onto 106 carbon fibre ladders with a total of 1.8 million readout channels. Operation of the system requires a detailed understanding of the electrical scheme at different hierarchical levels, including: low and high voltage systems, copper data lines from the front-end electronics to the read-out and data combiner boards, signal path, as well as grounding and shielding concepts. The performance parameter of the system is equivalent noise charge (ENC) value measured by the front-end electronics.

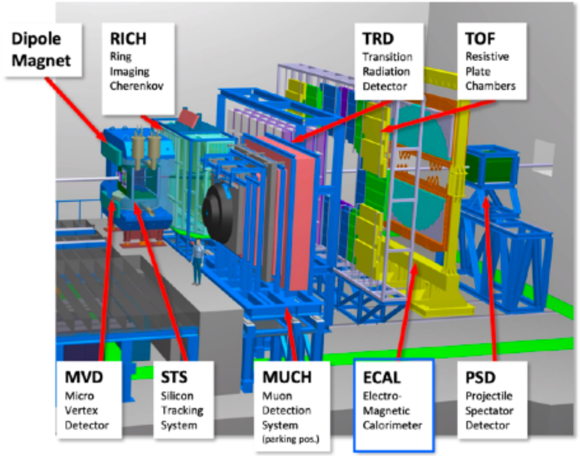
The electrical scheme of the system as well as its experimental validation in the laboratory and beam will be presented.

THE GOAL



- Exploring the phase diagram of strongly interacting matter in the region of high net baryon densities and moderate temperatures
- Multi-strange hyperons and hyper-nuclei reconstruction with complex decay topology
- Required interaction rates 10^5-10^7 Au+Au collisions per second

COMPRESSED BARYONIC MATTER EXPERIMENT



- Detector subsystems for vertexing, tracking, PID and calorimetry
- Acceptance 2.5°< θ <25°
- STS for charged particle tracking in 1 Tm B-field
- Up to 700 tracks per collision
- Software-based trigger (HLT only)
- Free-streaming data acquisition system

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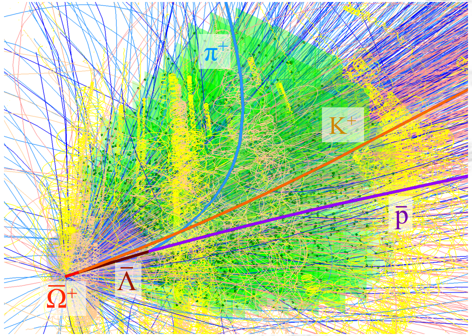
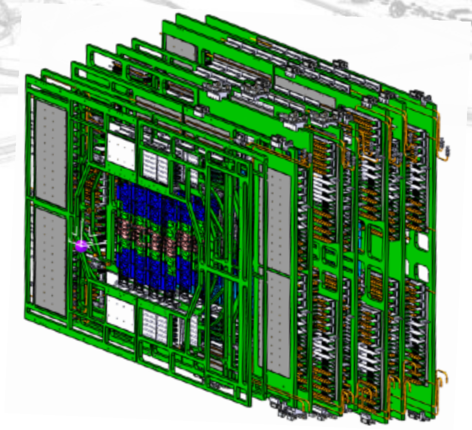
TRACKING CHALLENGE



UrQMD event transported through detector geometry

High track density per event and interaction rate demand particle tracking with high efficiency and precision as well as radiation tolerant detector design.

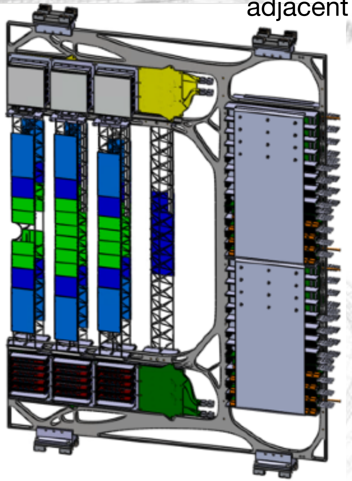
SILICON TRACKING SYSTEM



- 8 tracking stations based on double-sided silicon microstrip detectors (DSSD)
- 4 m^2 active area
- Material budget 0.3÷1.5 %X_0 per station
- Spatial resolution ≈15 μm

MECHANICAL UNIT

Carries detector ladders for two adjacent tracking stations



Provides electrical integration of
- front-end electronics
- power boards
- readout boards
- T/RH sensors
- supply cabling

- System design is driven by low material budget and low noise performance requirements.
- Powering scheme must include HV/LV, DAQ hardware, aux. pulsers, DC-DC converters, environment monitoring sensors, etc.
- Noise value is key performance parameter.

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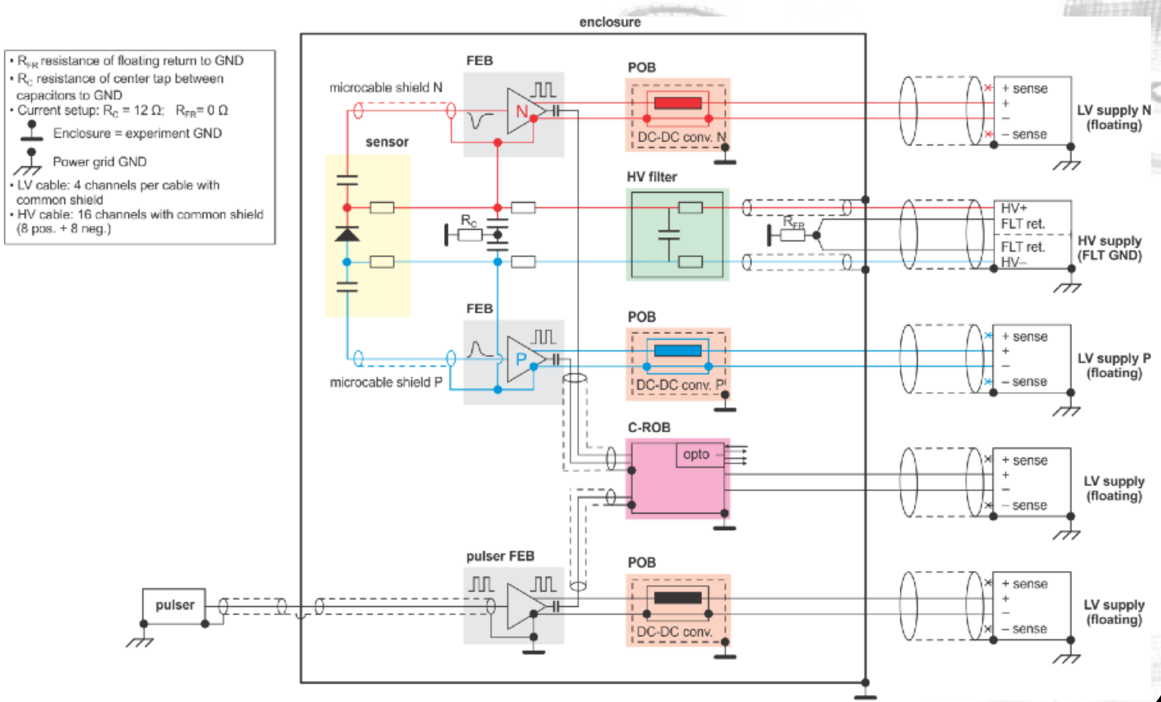
POWERING SCHEME



PROPERTIES

- Every detector module is read out by two front-end boards (FEBs).
- Module structure includes shielding, filtering, signal return path.
- Individual floating LV channels are referenced to the P- and N-side potentials.
- Individual floating HV channels (two channels per sensor) with grounded common point.
- Enclosure is grounded and forms a hermetic shield.
- Measurable figure of merit: system noise in the lab, effect of environment (in the cave)

GROUNDING AND SHIELDING

- Detector enclosure is a grounded Faraday cage
- Floating power supply outputs
- Consistent grounding without loops; single connection to earth
- Cable shields are connected to their respective power supply, not to the enclosure.
- All conductors inside the enclosure are referenced to it.

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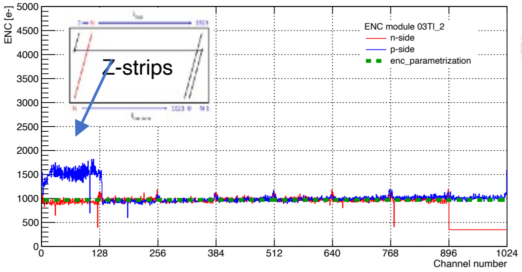
SCHEME VALIDATION USING NOISE MEASUREMENT IN LAB AND BEAM SETUPS

PULSE HEIGHT SCANS

Scan threshold dynamic range with test pulses to extract ENC value in all channels

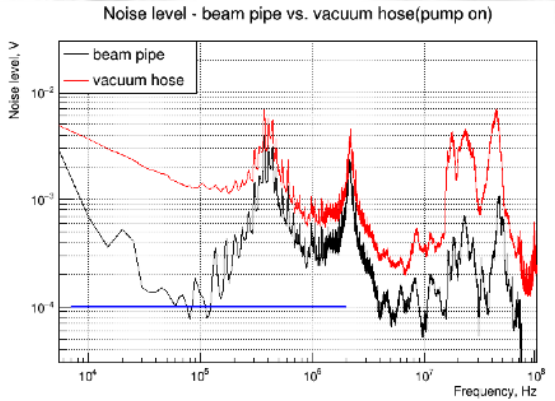


Noise measurement using pulse heigh scans is sensitive to:

- power supply noise level
- errors in grounding (loops, bad topology)
- external interference (pumps, switching activity, antennas, etc.)

EMI SEARCH

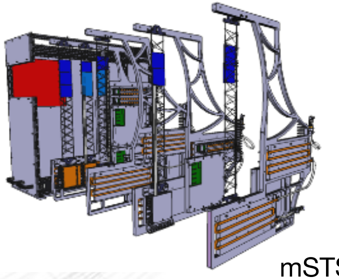
Obtain frequency spectra of e/m interference using AC current probes; compare to the FEE dynamic range.



- Near-field probe for sensing EMI in the wires (LV)
- Provides an EMI spectrum in a wide frequency range
- Good for real-time search of noise sources
- To be correlated with front-end bandwidth

mSTS

- Heavy ion beams at mCBM experiment from SIS18
- Two tracking stations arranged in four mechanical units: 12x12 cm² and 18x18 cm²
- Realistic operation conditions: beam intensities, collision systems, etc.




mSTS detector setup

Serves for testing the powering schemes and system integration concepts

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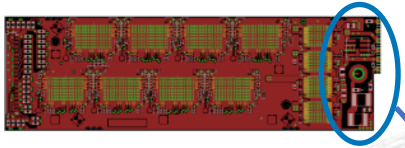
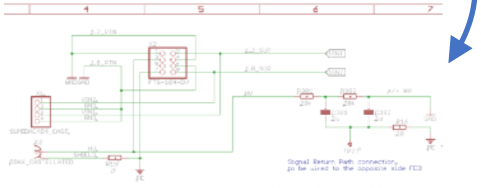
FRONT-END BOARD: CIRCUIT PARAMETER OPTIMIZATION

FRONT-END BOARD

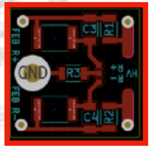


On-board LV connector, HV filter and signal return path

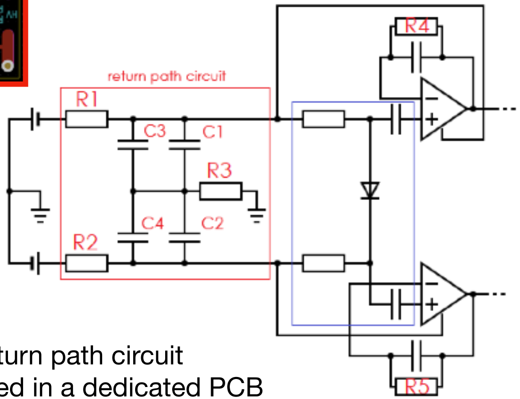


- RC-type filter for HV implemented on the FEB
- Return path circuit with reference to GND
- Signal return path circuit parameters optimised for best noise performance

TEST WITH PROTOTYPE PCB



Goal: optimize circuit parameters



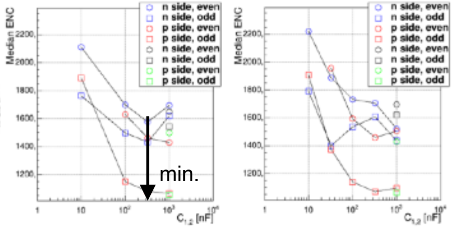
HV filter/return path circuit implemented in a dedicated PCB

Conclusion

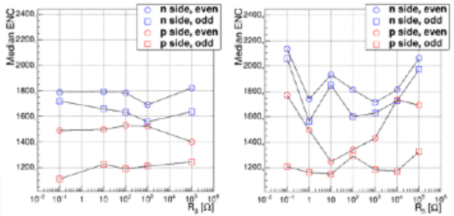
- Powering scheme developed and tested in lab and beam
- Performance evaluation tools developed and validated
- Finalising detector module design towards production readiness

CIRCUIT PARAMETER SCANS

$C_{1,2}$ parameter scan



R_3 parameter scan



- Find optimal circuit parameters for best performance
- Observable: ENC noise value