EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Bundesministerium für Bildung und Forschung

CBM

The Silicon Tracking System of the CBM Experiment at FAIR

Group Report

02.03.2018, Evgeny Lavrik

Outline of the presentation

1. Introduction
2. STS silicon sensors
3. Detector modules
3. System integration
4. COSY and mCBM campaigns
5. Conclusions

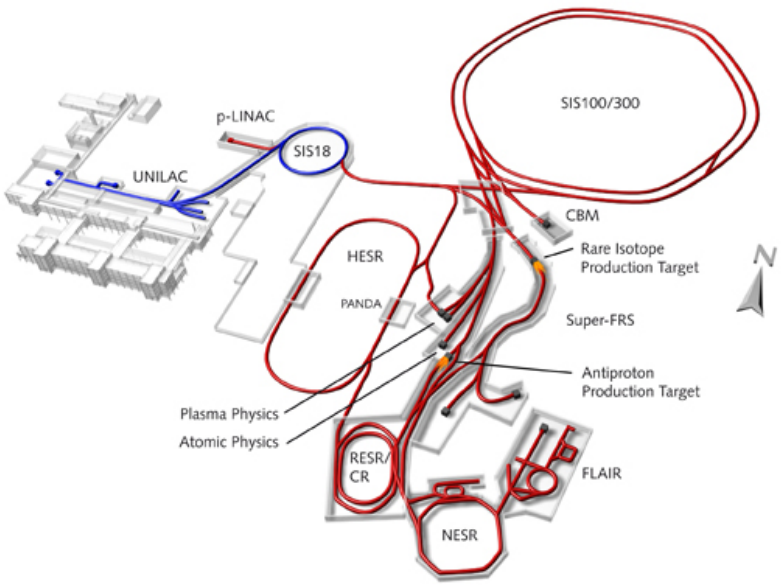
Future Facility for Antiproton and Ion Research (FAIR)

FAIR is an international research facility located based in GSI

Ion beams from proton to uranium will be provided

CBM is one of 4 major experimental pillars

Expected start of operation 2024



A conceptual view of the future FAIR facility

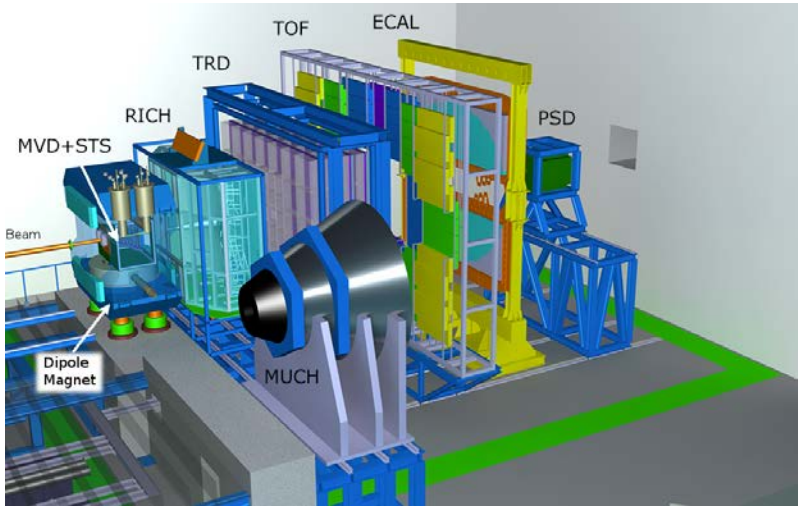
Compressed Baryonic Matter (CBM) experiment

10 MHz interaction rate allows high statistics for rare and exotic probe detection

Caveat: no hardware trigger on complex particle decays is possible

Challenging solution: free-streaming read-out electronics with real-time software triggers

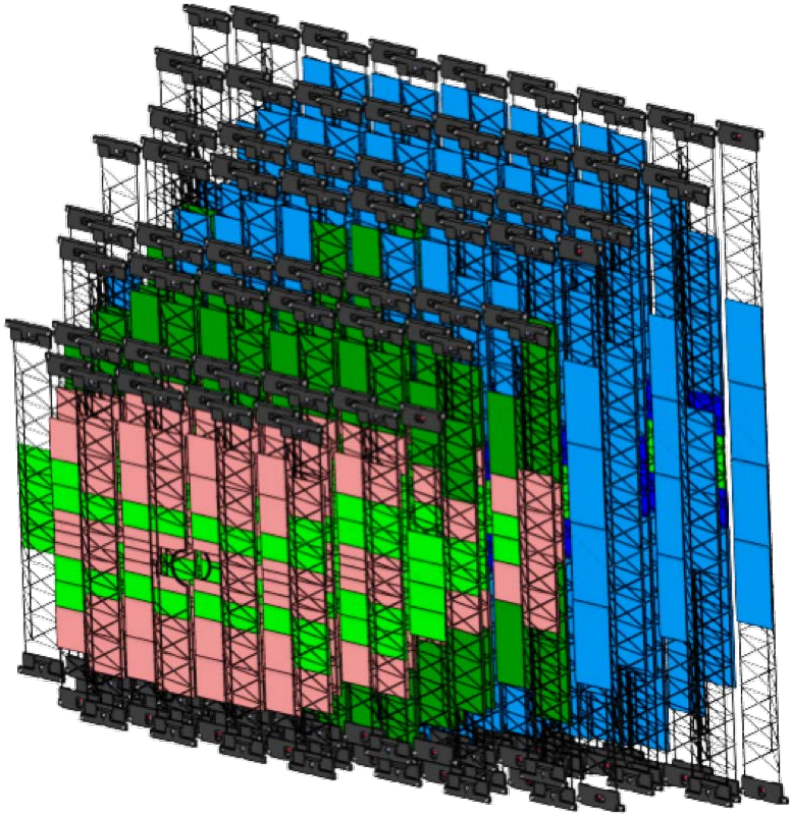
Physics analysis is done on high performance computing farms



The CBM experimental setup including, from left to right, Dipole Magnet, MVD, STS, RICH, MUCH, TRD, TOF, ECAL and PSD detector systems

Silicon Tracking System (STS) Detector

- Key detector to reconstruct particle tracks and resolve their momentum with $\Delta p/p \approx 1\text{-}2\%$
- Built out of ~900 silicon microstrip sensors forming 8 tracking stations
- Fast electronics produce up to 40 kW of thermal power in the close vicinity of the sensors
- Very limited overall volume (~2m^3) requires very efficient cooling



View of the STS detector without thermal enclosure and services

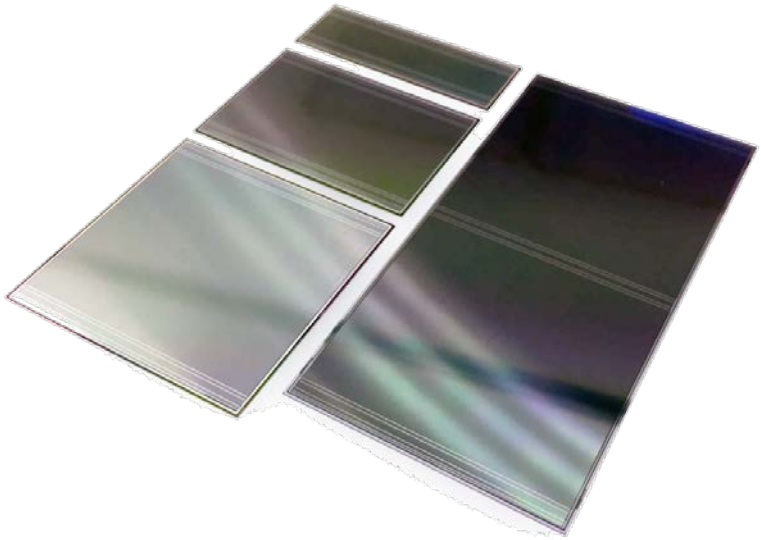
Silicon microstrip sensors

State of the art microstrip technology

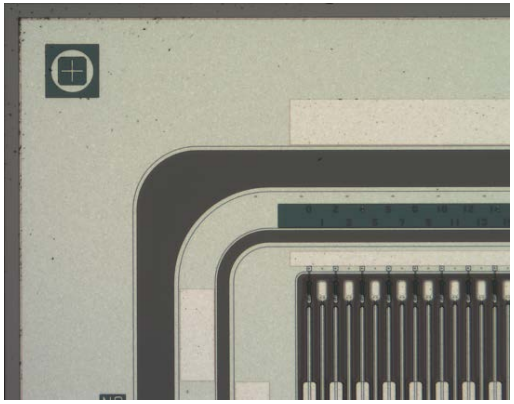
Provide spatial hit resolution of about 25 µm

Come in 4 different sizes, 2 manufacturers

Rich microscopic structure is prone to manufacturing errors and defects



A photograph of prototype silicon sensors. 4 different sensor sizes are shown.



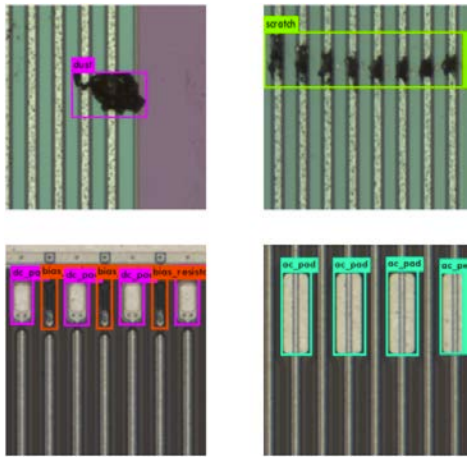
A feature rich corner region of the STS sensor

Quality assurance of the sensors

- Optical (all) and electrica (fraction)l QA of the sensors is required
- Optical:
  - allows to identify surface defects, such as scratches, strip and implant defects, control electrical element integrity, etc.
  - Based on a machine vision and machine learning algorithms for recognition

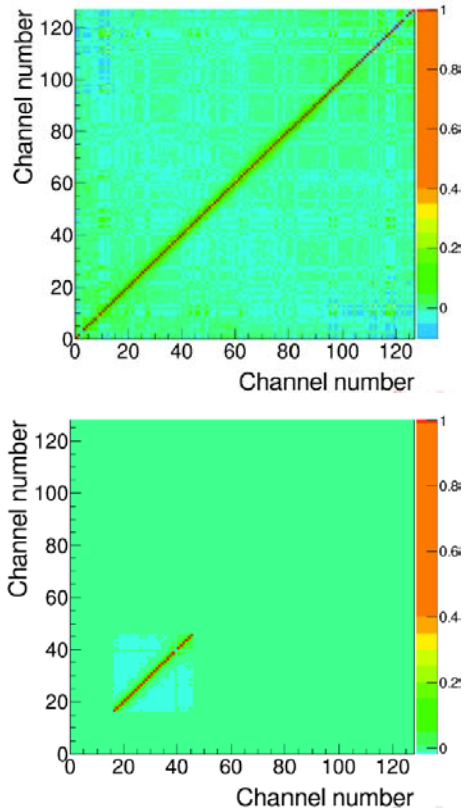
- Electrical:
  - Allows to perform the global and per-strip measurements of a sensor, e.g. IV, CV dependencies, etc.
  - Employs a custom build probe station
  - Exhaustive QA procedures allow to identify pinholes, strip breaks and shorts, leaky strips, breakdown behavior, etc.

Detection of surface defects and electrical elements



Sensor cross-talk for second metal layer

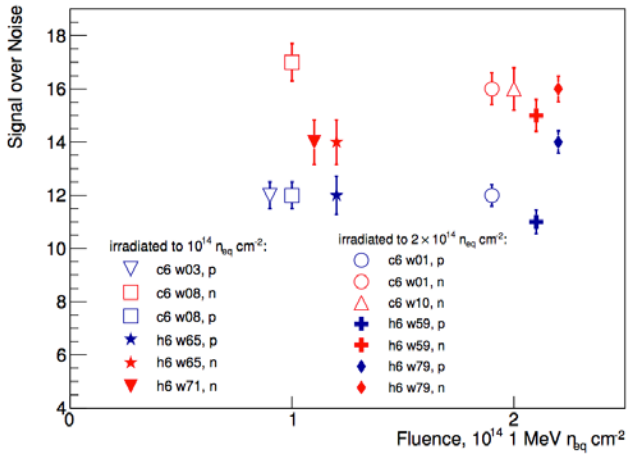
- Since we use the DSDM sensors, there is a possibility for cros-talk between read-out strips and second metal layer strips
- Cross-talk through second metal layer was studied with prototype modules with NXYTER chip (H. Malygina, M. Teklishyn)
- CIS sensor shows correlation between neighbors - charge sharing and cross-talk through IS capacitance
- HPK: no significant difference between single-metal and double-metal sensors



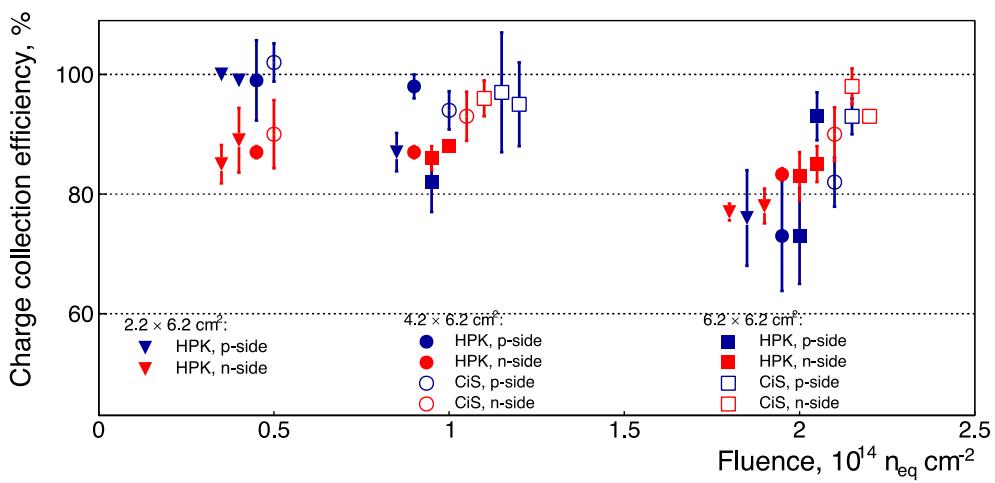
Channel signal correlation map for CIS (top) and HPK (bottom) sensors

Radiation hardness studies with protons

- The STS sensors were subjected to the NI irradiation doses of up to 2x lifetime
- Irradiation was done with E_{kin} = 22.9 MeV protons at KIT cyclotron
- Aim was to control the CCE, S/N ratio, IV and CV measurements



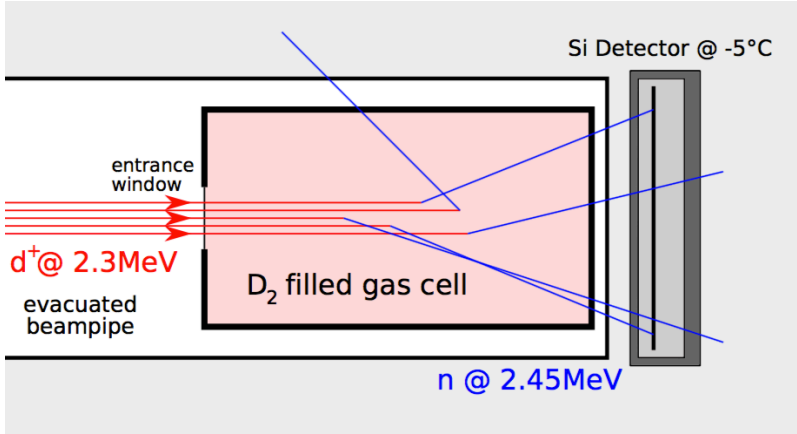
S/N ratio of the sensors vs fluence



SIS100 lifetime - no big decrease of CCE
SIS300 lifetime - 85-95 % CCE
2x SIS300 - drops to 75-90 %

Radiation hardness studies with neutrons

- The STS sensors will be exposed for a total non-ionizing dose of up to 10^{14} n_{eq}/cm^2 over 6 years of operation
- This project aims to study the long-term slow radiation damage to the sensors, monitor their electrical characteristics.
- A d-d fusion reaction is used to produce the neutrons to irradiate the silicon sensors
- A big irradiation campaign have taken place in the end of 2017
- Analysis ongoing

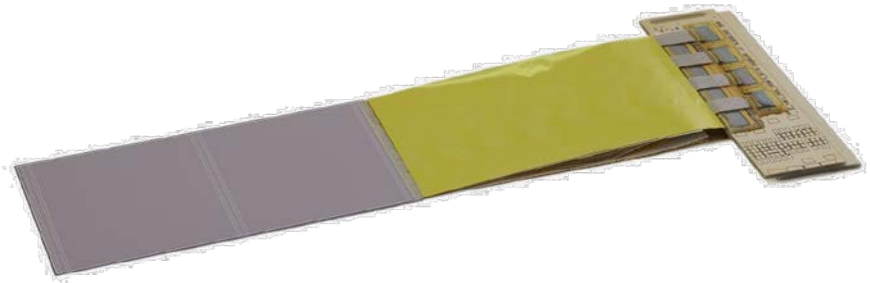


Neutron generation scheme to irradiate the sensors.

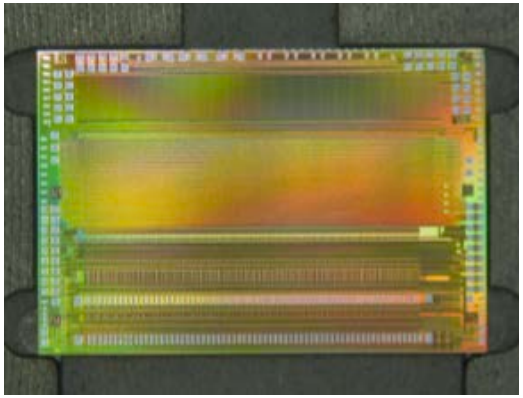
See talk of Eduard Friske shortly after

Detector modules

- Modules consist of a sensor, a bundle of microcables and ASICs placed on the Front-End-Board
- Each sensor side is tab bonded to 8 micrcables, which in turn are bonded to 8 STS-XYTER ACICS
- Module assembly workflow was developed and established (GSI Detector Lab, C. Simons)
- Assembly tools were designed, manufactured and supplied to the production sites (GSI, JINR)



Prototype detector module assembled in GSI



STS-XYTER chip developed in AGH, Krakow

Detector modules (continued)

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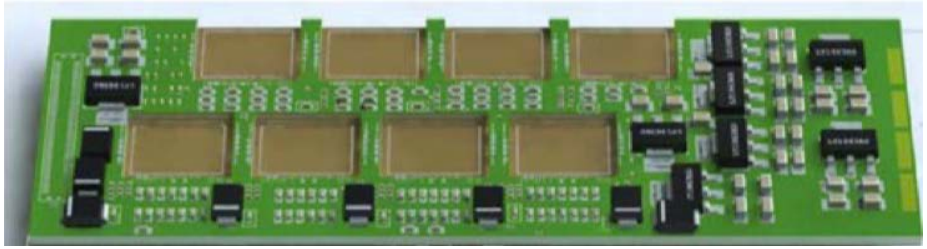
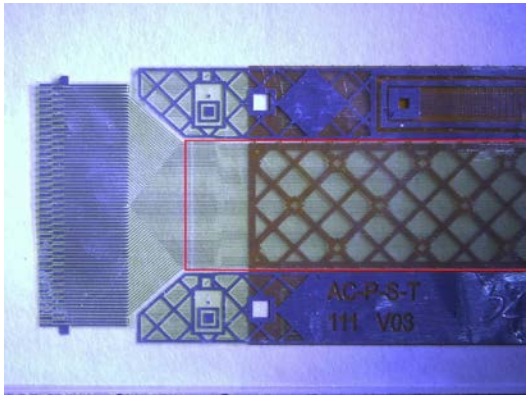


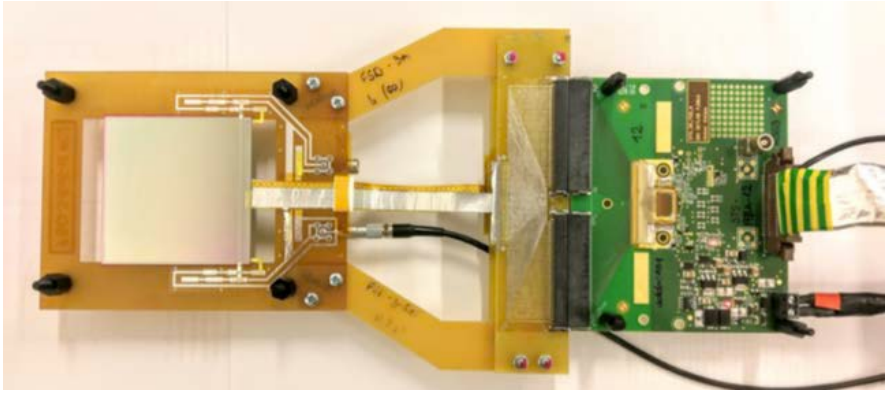
FEB PCB
L. Mik, W. Kucewicz (AGH), V. Kleipa (GSI)

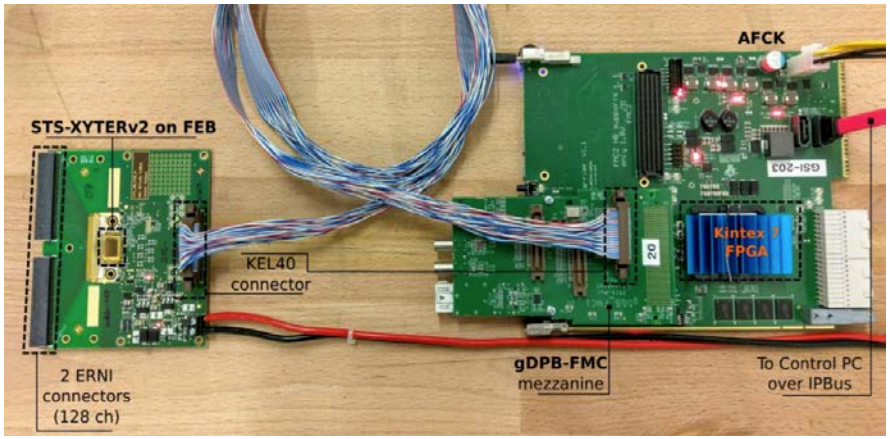


Microphotograph of the Alu-microcable before cutting
Produced at LTU, Kharkov

Detector read-out chain

- The prototype read-out chaing for silicon sensors with STS-XYTER chip was developed in GSI (J. Lehnert, A. Rodriguez-Rodriguez)
- Provides means for ADC calibration processes
- Allows the noise estimation with real silicon sensors

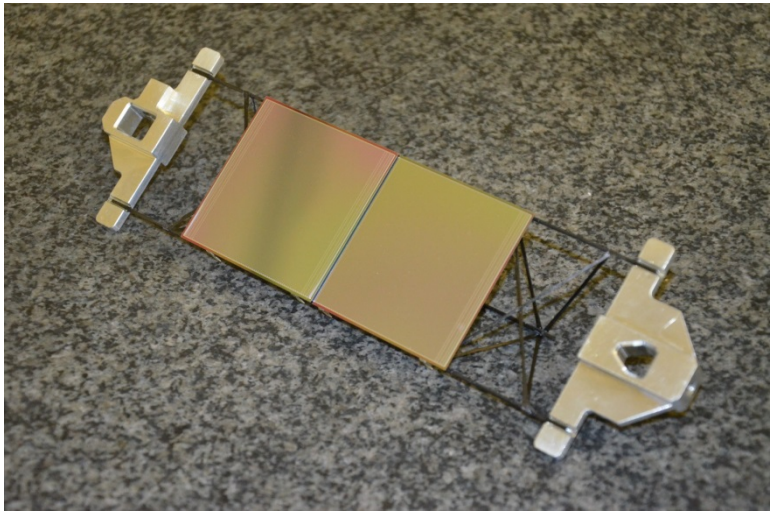


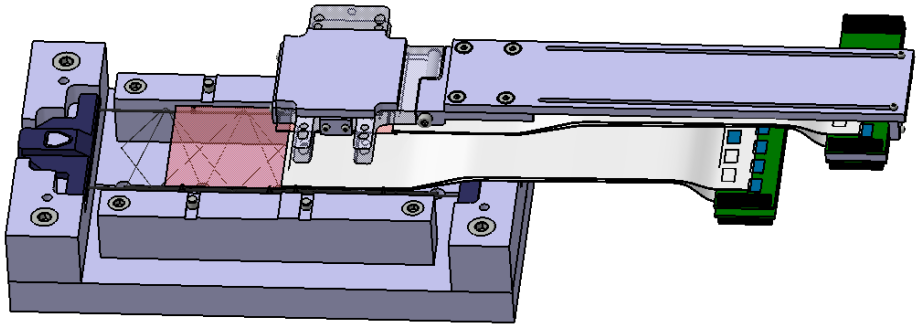


Detector read-out chain with a sensor connected to a STS-XYTER chip on a FEB-B (top) and the FEB-B to data processing board with an uplink to the control PC

Sensor Ladders

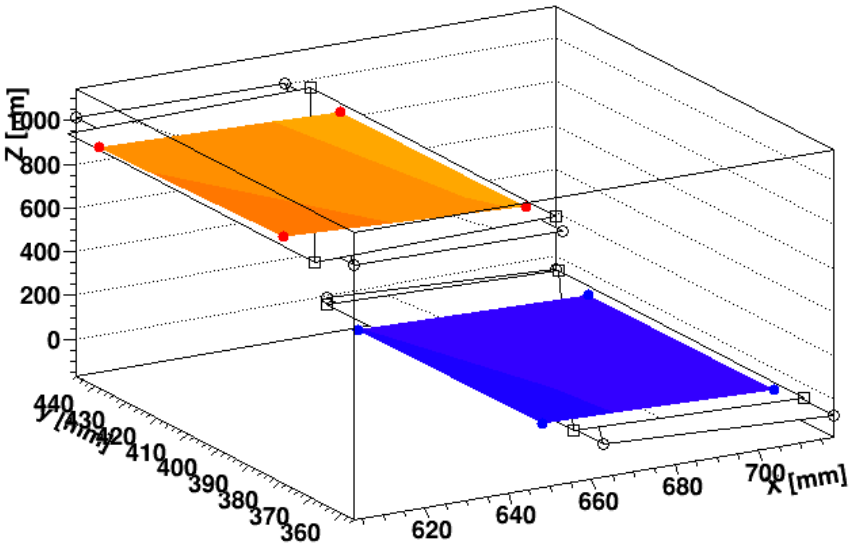
- The carbon fiber ladders will provide the means to arrange the sensors in units and stations
- The sensors are mounted to the ladders with special fixtures – fiber-glass L-Legs
- The assembly fixtures were developed (O. Vasylyev) allowing for high mechanical placement precision





Sensor Ladder Inspection

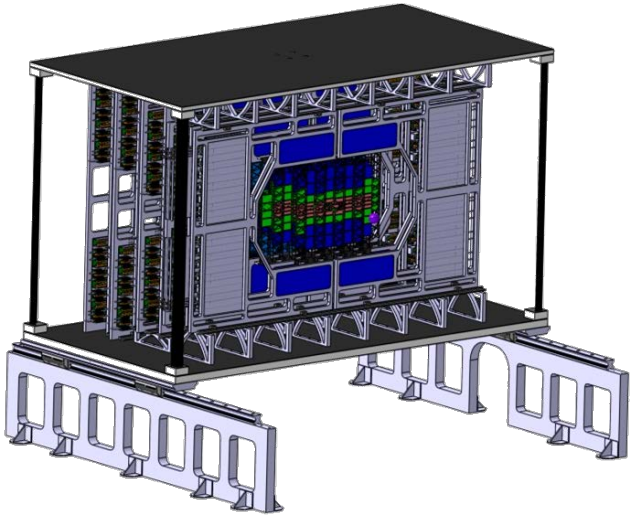
- The sensors placed on the ladder are inspected for their placement precision by the means of optical survey
- The coordinates of the sensors are measured in 3D contactless by the autofocusing measurements
- The placement precision w.r.t. base plane is measured by reconstructing the spatial configuration of the sensors

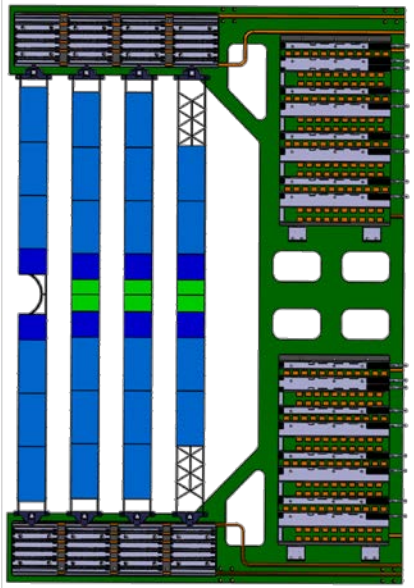


Output of the ladder survey.
Spatial configuration of the sensors is reconstucted.
By E. Lavrik, U. Frankenfeld, S. Mehta

System Integration & Cooling

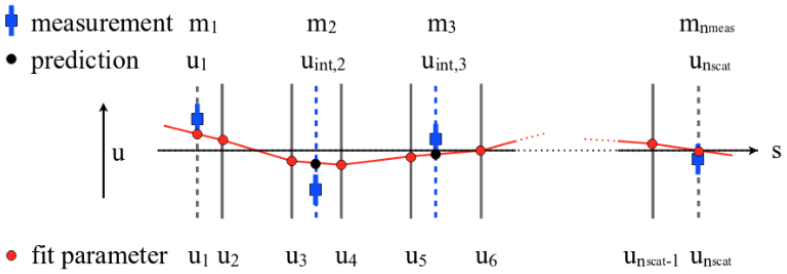
- STS is a compact detector with high degree of component density
- The conceptual engineering design (by O. Vasylyev, see pictire) is highly developed
- Activities towards prototype station assembly
- Thermally insulated and air tight to prevent condensation
- Thermal management is carried out by K. Agarwal (see upcoming talk)
- Use of evaporative bi-phase CO_2 cooling due to space constraints



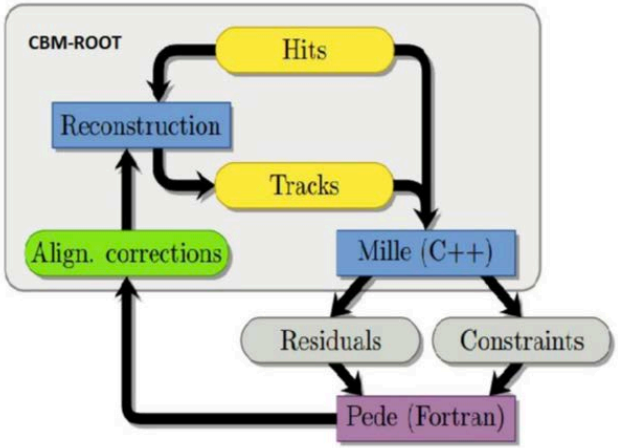


Track-Based Detector Alignment

- Limited mechanical precision of ~100µm requires advanced techniques for precise alignment
- Approach is based on minimisation of track hit residuals
- The data from ladder optical survey might be used as an initial input for the alignment



Input parameters for alignment algoritms



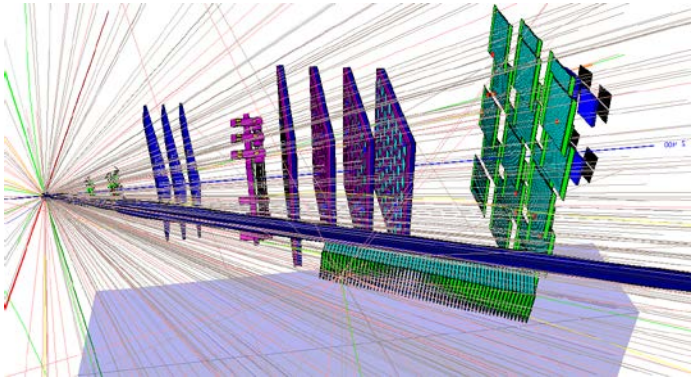
Workflow diagram of the track-based alignment, see talk of S.Das

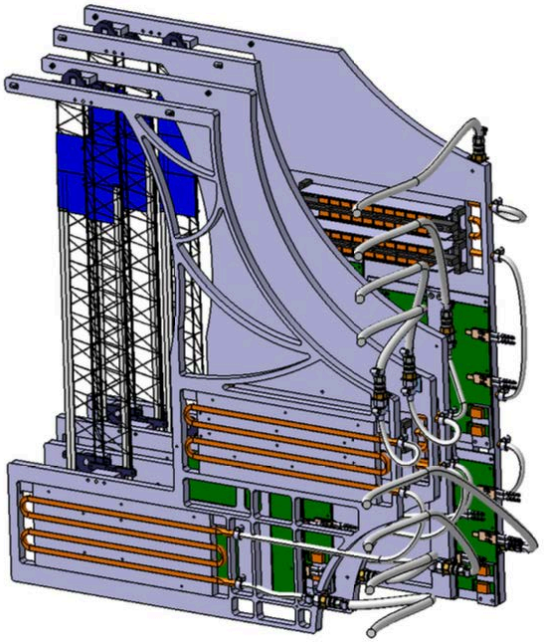
mSTS in the mCBM@SIS18 campaign

- mCBM is a piloting project employing the mini-versions of all detector systems of CBM experiment, joint effort of all groups involved

- mSTS will consist of 2 stations - (4 units)

- Hence minimalistic design, all components from the final version of the STS detector will be used

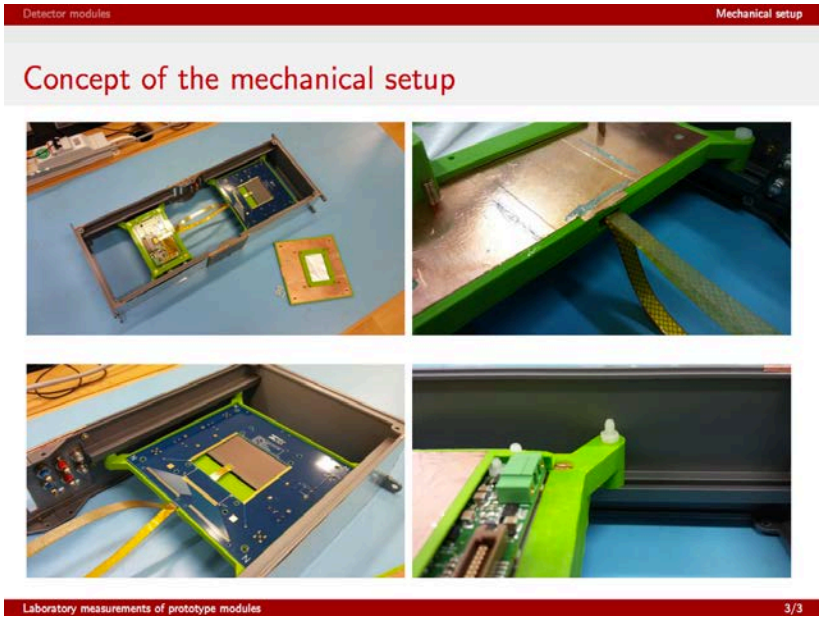




Integration concept of mSTS
by O. Vasylyev

Beamtime at COSY

- This week the beamtime campaign at COSY is ongoing
- Aim is to test the prototype sensors, sensor modules and readout chain in realistic irradiation conditions
- Additionally the noise performance of the assembled modules is studied



Prototype STS sensor module for beamtime. A. Lymanets, E. Momot, M. Teklyshyn, A. Rodriguez[2]

Key project institutes

GSI-FAIR, Darmstadt, Germany; JINR, Dubna, Russia;
Univ. Tübingen, Germany; KIT, Karlsruhe, Germany;
AGH, Cracow, Poland; JU, Cracow, Poland;
WUT, Warsaw, Poland.
Assembly Centers: GSI-FAIR, JINR -VBLHEP

Project Timeline:

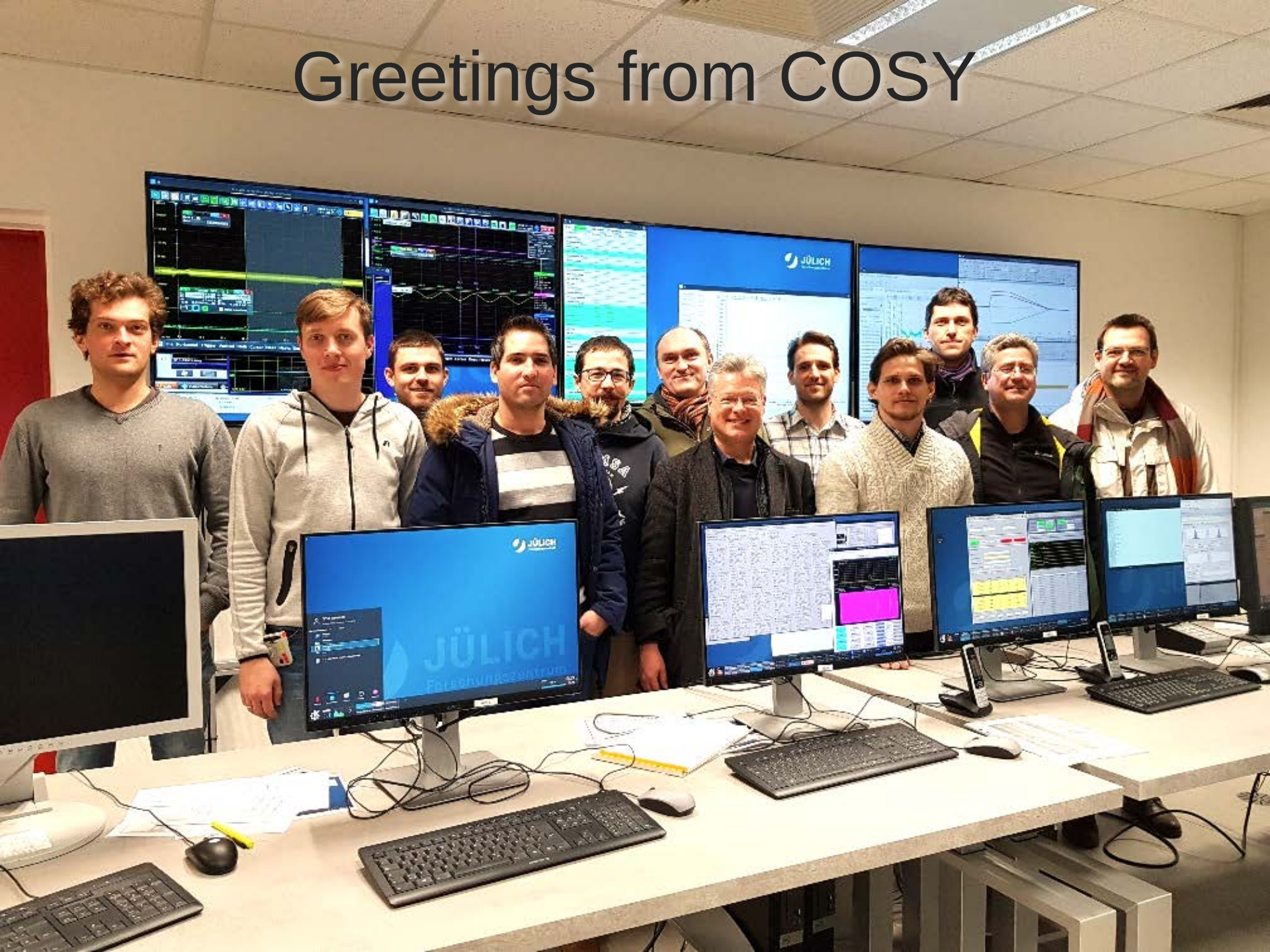
- 2013 – Technical Design Report
- 2017-2018 – Production Readiness
  (Sensors, Electronics, System Integration)
- Detector construction until 2022
- Commissioning until 2023

Conclusions and outlook

- The sensor development is to be concluded with mass ordering
- QA procedures were developed and ready to assess quality of the manufactured sensors
- Irradiation studies show adequate sensor performance at the 1x and 2x lifetime of a sensor in terms of radiation exposure
- Module and ladder assembly procedures were developed and to be applied on batches of sensors
- Mechanical design of the STS detector box and services is developed and to be tested on prototype assemblies
- Cooling and thermal management of the detector is assesed
- Track based alignment development is ongoing and to be concluded in 2018
- mSTS project is a nice opportunity to integrate all the individual projects and test the performance of the detector

Big thanks to the whole STS team!

Greetings from COSY

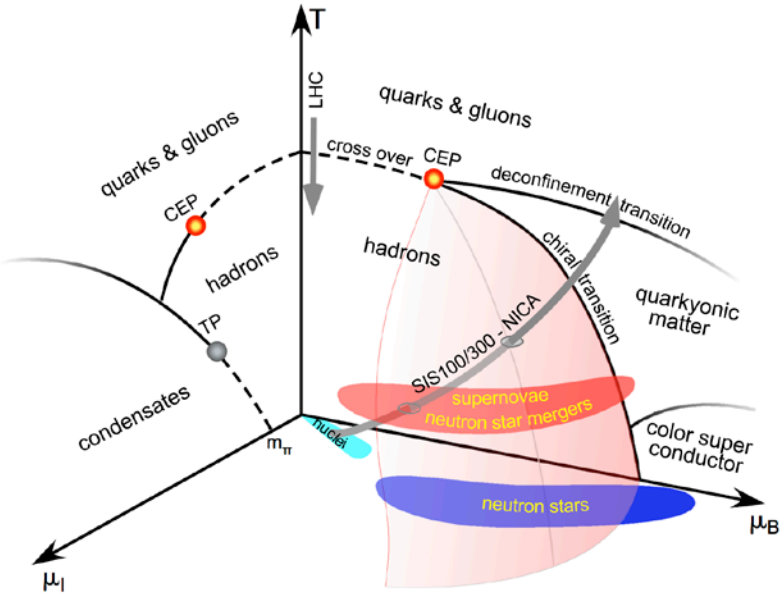


Backup

Introduction

Modern physics aims to investigate the phases of the QCD matter

- RHIC and LHC identify a cross over transition at vanishing μ_B and high T
- Deconfinement and partially restored chiral symmetry phases are expected at high μ_B ($\gtrsim 5\ \rho_0$)
- Dense matter similar to that in the cores of neutron stars and neutron star mergers can be probed in the CBM

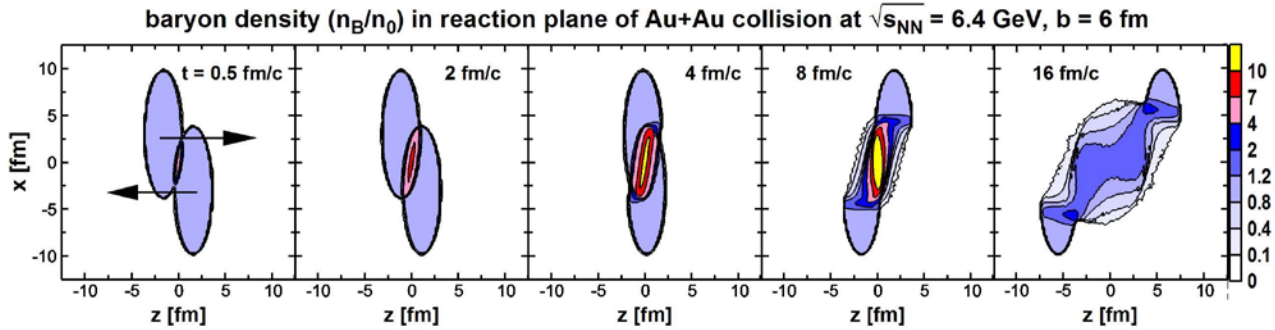


3-dimensional representation of the QCD phase diagram at high net-baryonic μ_B and moderate isospin μ_I chemical potentials.

Using Hydrodynamical event generator in CBM

- Based on THESEUS 3-fluid hydrodynamical model
- Supports different EOS
- Provides events for CBM energies at various impact parameters
- Particles are transported through the CBM detector setup
- Aim is to obtain the corresponding physics performance plots and compare them to UrQMD and PHSD generated events

- Presented at poster session by E. Volkova at Thursday

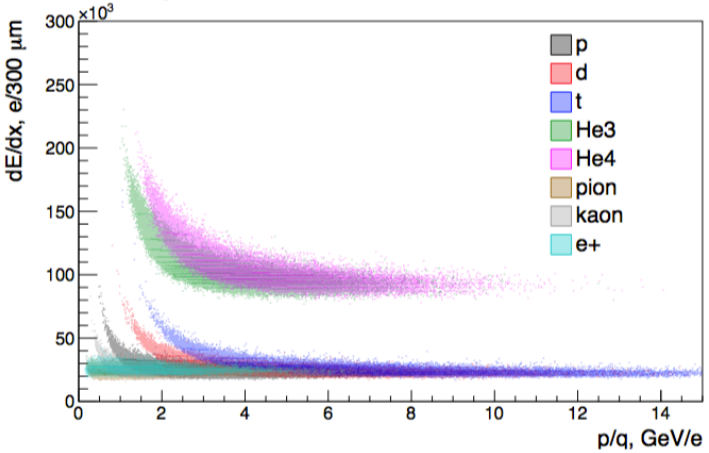


dE/dx Particle identification in STS

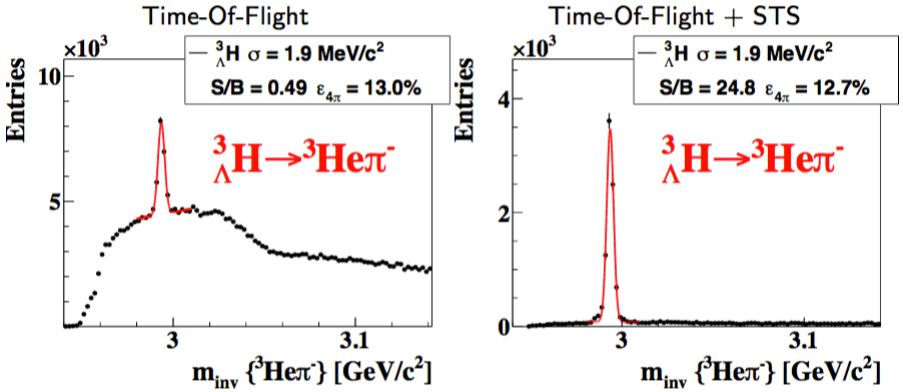
- STS is promising tool for PID of single- and double charged particles: perfect separation for the whole momentum range
- STS involving into global PID increase S/B for 3ΛH in 50 times(!) in comparison with TOF only

- Joint effort of H. Malygina, M. Teklyshin from STS and PWG Hadrons

10^5 of each particle generated for Au+Au @ 10 AGeV:



5 M central Au+Au events at 10 AGeV.



Maksym Zyzak, Iouri Vassiliev