WP2 Heavy Ions

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871072

Instrumentation for the CBM experiment at ESFRI landmark FAIR

Participants: FAIR, WUT, Wigner RCP, NPI CAS, EKUT

eurizon
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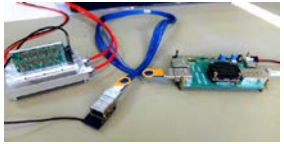
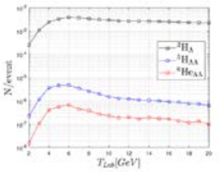
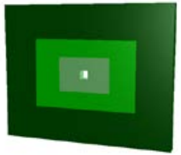
for developing new horizons for RIs







WP2.1: Preparation of the Silicon Tracking System for CBM/FAIR [FAIR, EKUT], Task Leader: [Johann Heuser, FAIR/GSI]

WP2.2: Developments for the data acquisition chain, for data preprocessing and computing for mCBM and CBM at FAIR [WUT, FAIR], Task Leader: [Wojciech Zabolotny, WUT]

WP2.3: Development of software packages for simulation and data analysis, participation in physics performance studies for CBM experiment at FAIR [FAIR, Wigner RCP] Task Leader: [Ilya Selyuzhenkov, FAIR/GSI]

WP2.4: Development and construction of beam monitors, target chamber and beam pipe for the CBM experiment at FAIR [FAIR, NPI CAS] Task Leader: [Peter Senger, FAIR/GSI]

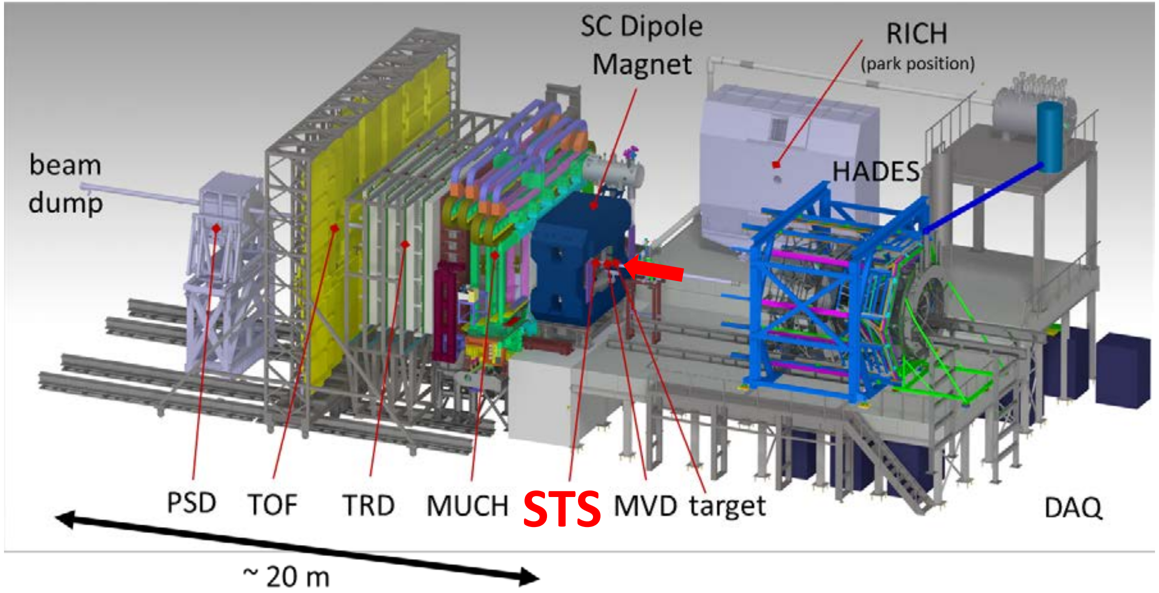
WP2.5: Development of new PSD detector for CBM [NPI CAS] Task Leader: [Andrej Kugler, NPI CAS]

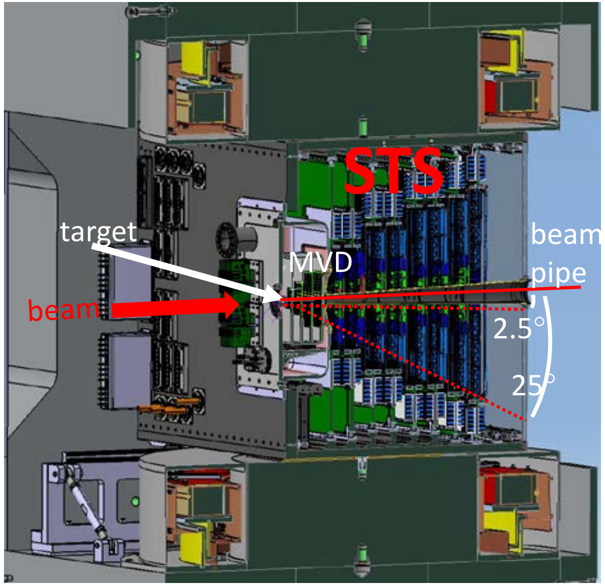
WP2.1 Silicon Tracking System (STS) for CBM/FAIR

- STS = main CBM detector for charged-particle trajectory measurement
- installed in dipole magnet's gap
- thousands of high-tech components

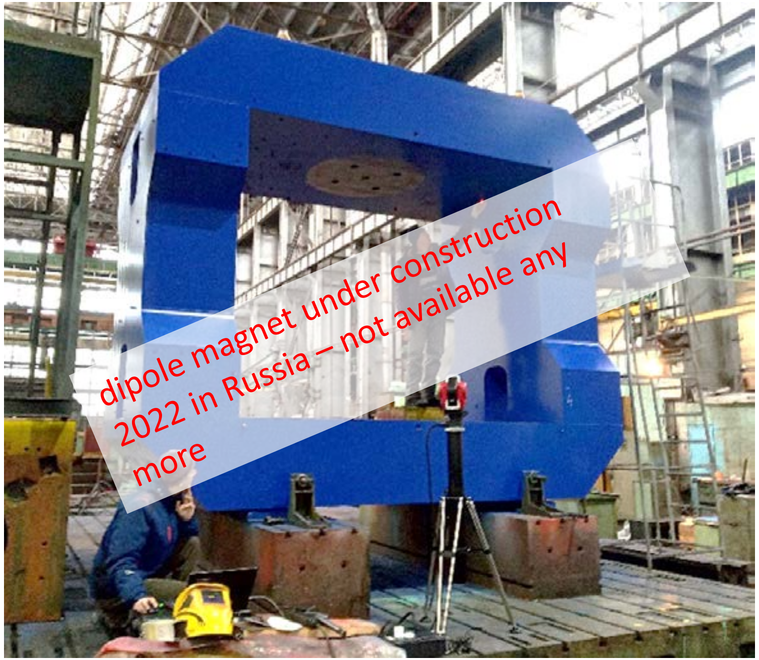
J. Heuser for
the STS group

The CBM experiment





WP2.1 New dipole magnet – improved STS



- unavailability of the original dipole magnet requires new acquisition effort (tender ongoing)
- this opens opportunity for geometrical changes:
  - *larger magnet gap*
  - *to fit a somewhat enlarged STS detector*
    - *with enhanced modular integration*
    - *and upgrade perspectives*

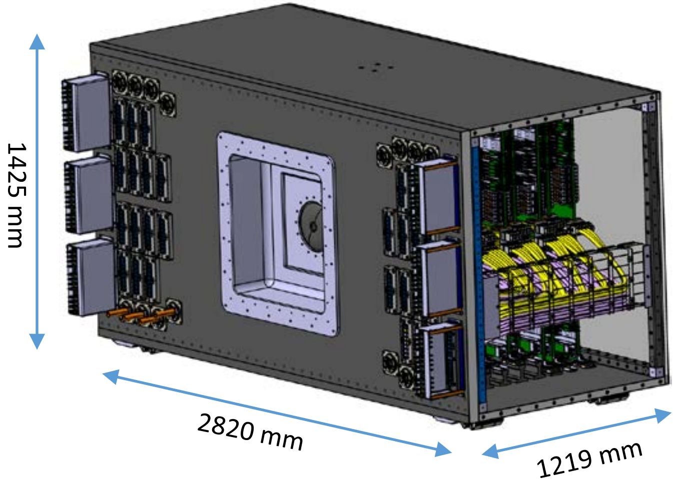
Highlights from WP2.1 efforts:

- *New modular STS has been developed*
- *Physics performance simulations are being done*
- *Pre-series STS module assembly has been achieved*

WP2.1

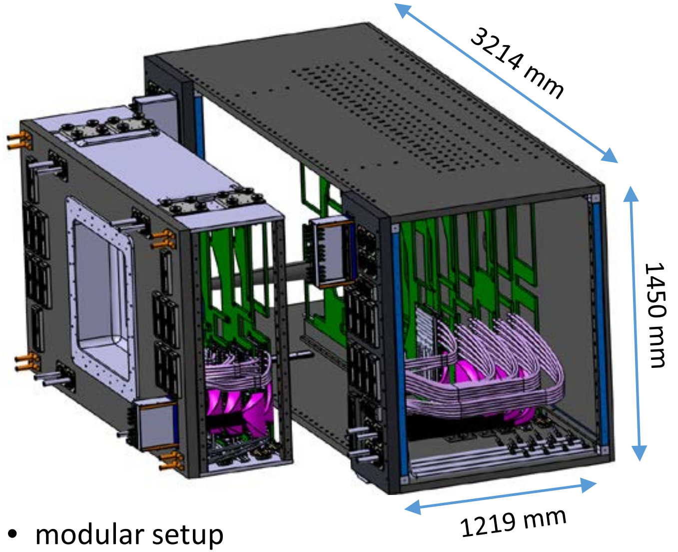
New modular STS

Old “monolithic” STS:



- monolithic construction
- once assembled no access
- maintenance, replacement, upgrade only by full disassembly
- very tight space constraints

New “modular” concept:



- modular setup
- units U00 – U03 can be moved separately from the rest U04 – U07
- additional rail system
- completely independent systems

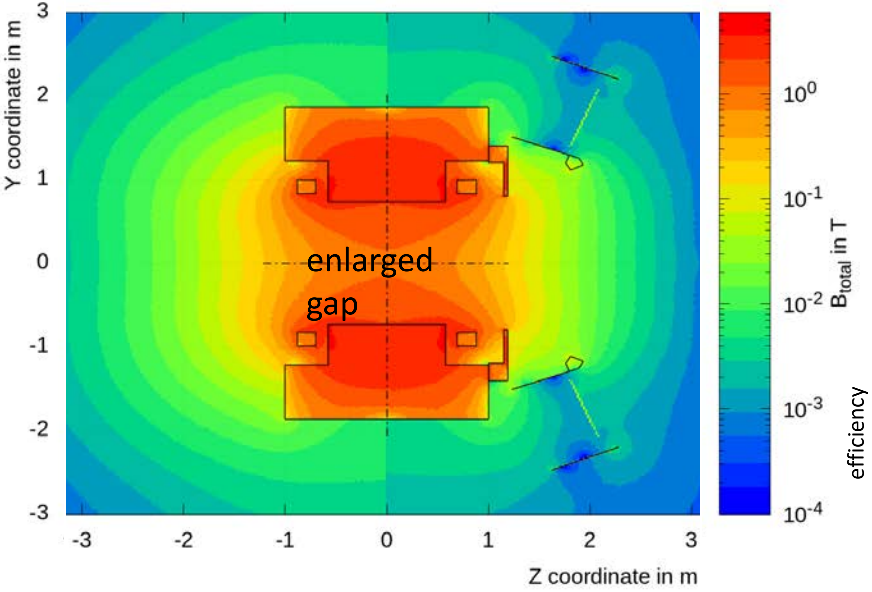
Internal designs are kept!

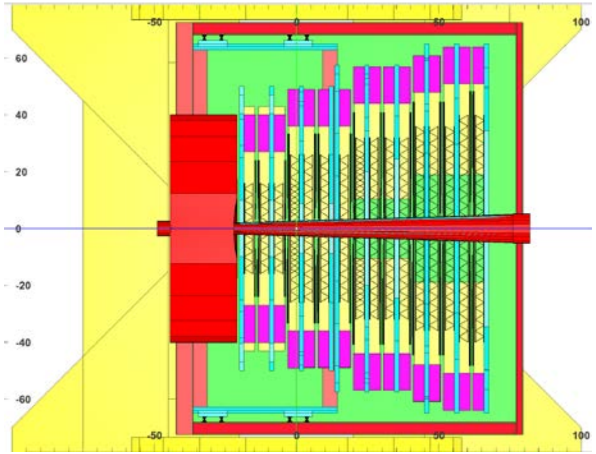
- Unit/station layout and all detector and module designs remain the same.
- Outer frames and cabling are adapted.
- Overall space requirements change:
  - height + 3 cm
  - width + 30 cm

⇒ expressed in the new magnet specifications gap: 2000 x 3300 x 1470 mm l/w/h

WP2.1 Modular STS – performance simulation studies

new dipole magnet:
field maps prepared by CBM Collaboration

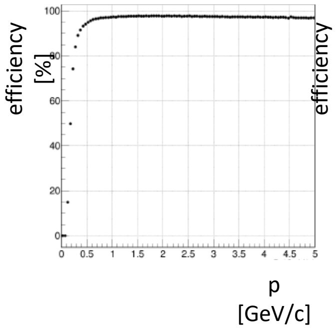




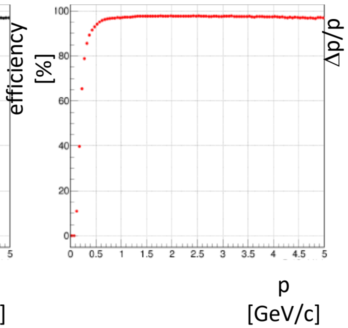
simulation geometry

physics performance remains high!

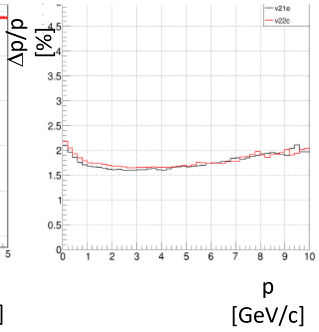
primary particles, B = 0.5 T



primary particles, B = 1 T



momentum resolution



WP2.1 Pre-series production of STS modules

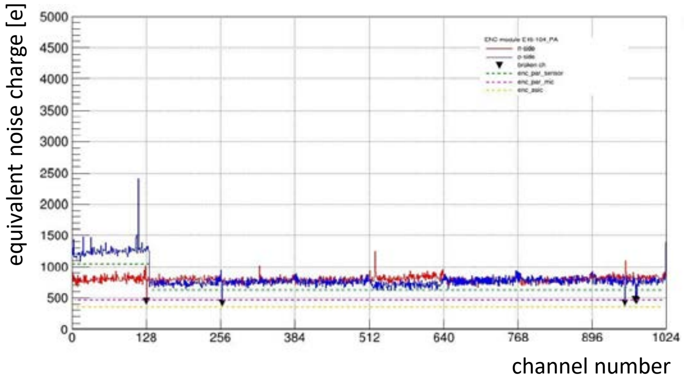
Pre-series assembly of STS modules has been achieved:

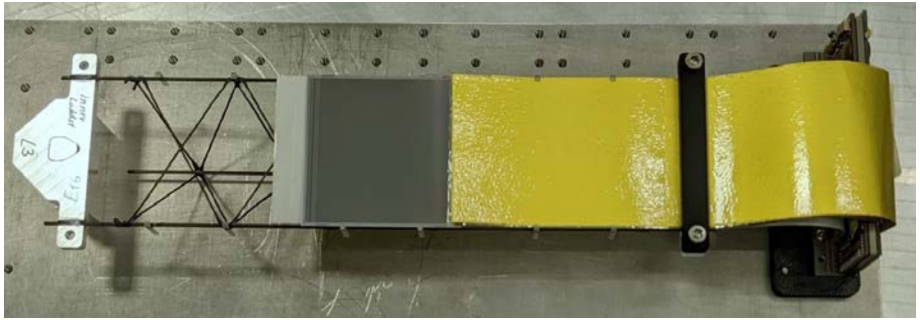
<u>10 modules assembled:</u>

- *test results during module assembly in clean room:*
  – *all in specs, (<< 3% missing channels, noise ~ 1000 e)*
- *mounting on ladder structures ongoing*

Application from 2023 in J-PARC E16 experiment (Japan)
for its upgrade with a silicon tracking layer

→ New WP2.1 MS7 *Production Readiness* (M36): will be reached
→ New WP2.1 D2.2 *System engineered* (M48): will be reached





WP2.2

W. Zabołotny, M. Gumiński, P. Loizeau WUT, FAIR

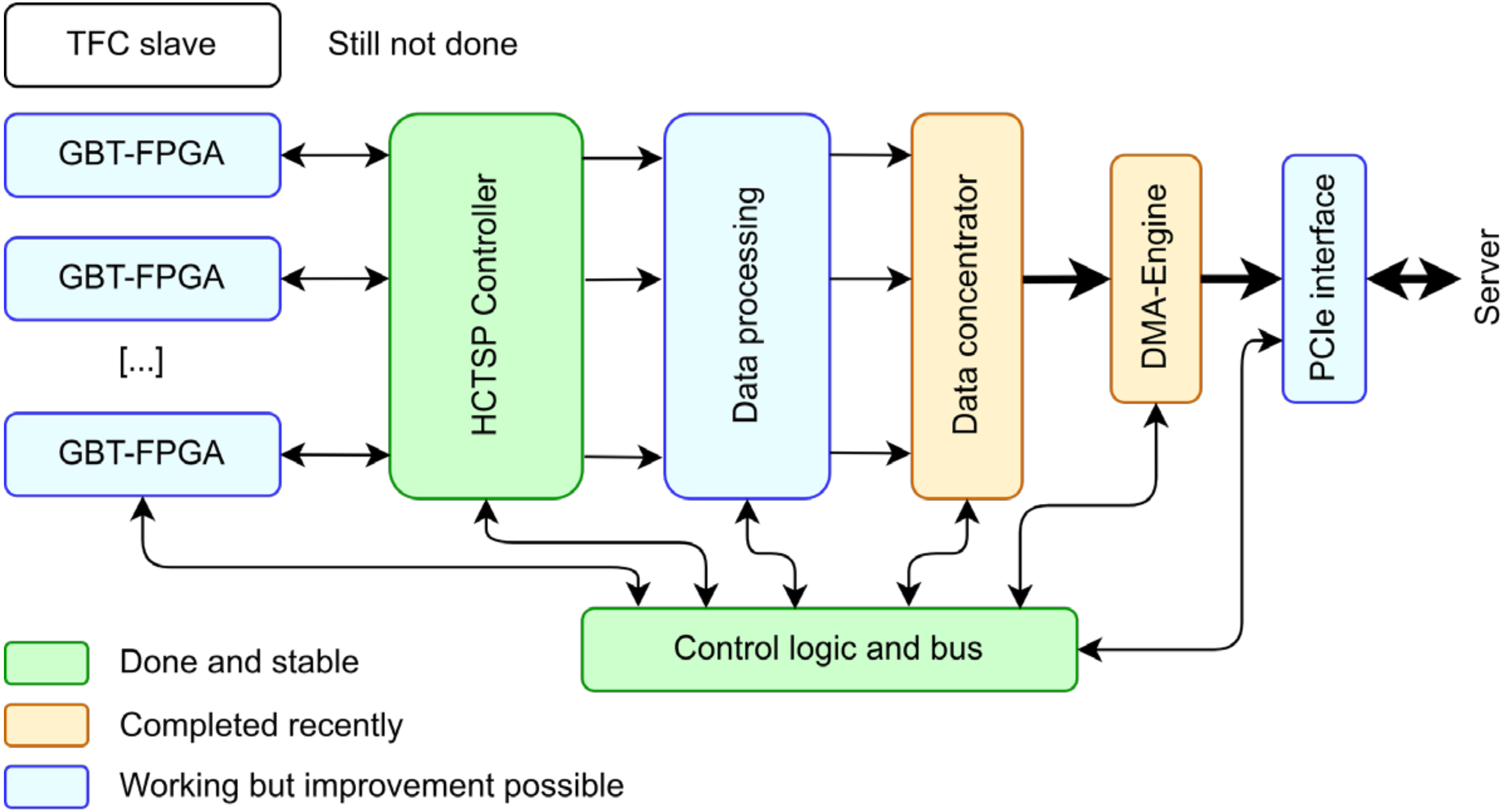
Developments for the data acquisition chain, for data preprocessing and computing for mCBM and CBM at FAIR

Development of the GERI+GBTxEMU based readout chain

Status in 2022

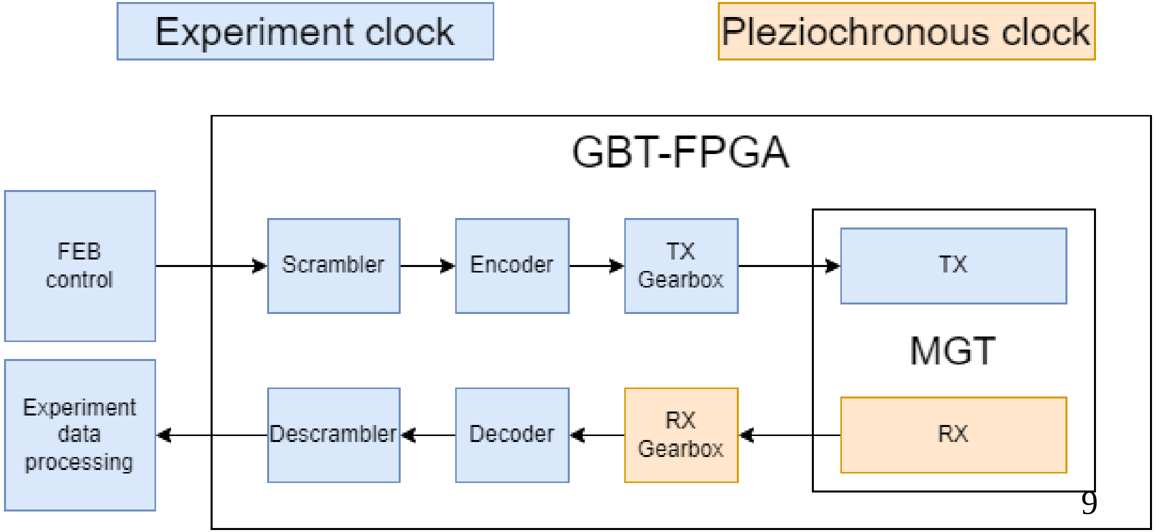
- Cooperation with JINR group stopped after February 24th
- Only WUT staff left involved in firmware development (Marek Gumiński and Piotr Miedzik as the project’s staff, Michał Kruszewski, Krzysztof Poźniak and Wojciech Zabołotny as volunteers)
- Tests planned in JINR in April 2022 were impossible. Development tasks related to application in BM@N experiment were suspended (abandoned in fact?)
- The package was reoriented for preparation of GERI+GBTxEMU based readout chain for mCBM, CBM and other experiments cooperating with FAIR
- GBTxEMU part completed (only maintenance, functionality adjustment, bug corrections needed)

WP2.2 Structure and status of the GERI firmware



GBT-FPGA

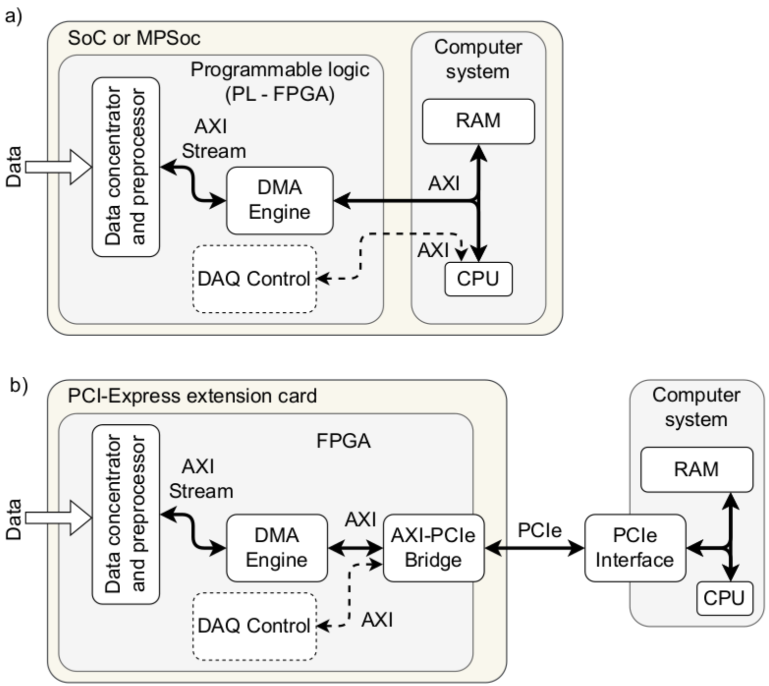
- Serial communication interface developed for HEP readout chips
https://gitlab.cern.ch/gbt-fpga
- FEC encoding and latency determinism for FEB control
- Synchronisation of FE boards
- Up to 4.8 Gbps throughput for experiment data readout



WP2.2

Versatile DMA engine

- Core part implemented in HLS
- Compatible with PCIe-connected FPGAs and AXI-based MPSoCs
- Efficient memory management even in standard Linux. Starting and stopping acquisition in multiple boards without rebooting.
- Full utilization of multiple cores in host machine
- Described in a paper accepted for publication, preprint available at https://www.preprints.org/manuscript/202301.0328
- The design is open-source and available at https://gitlab.com/WZabISE/hls_dma

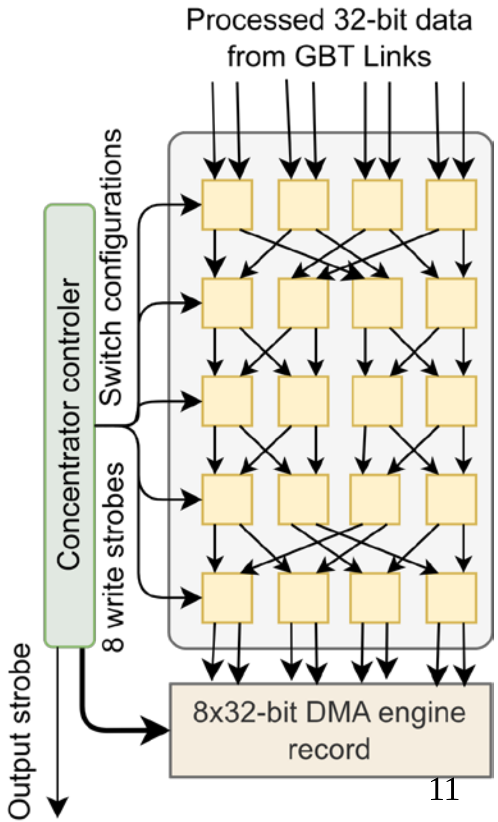


WP2.2

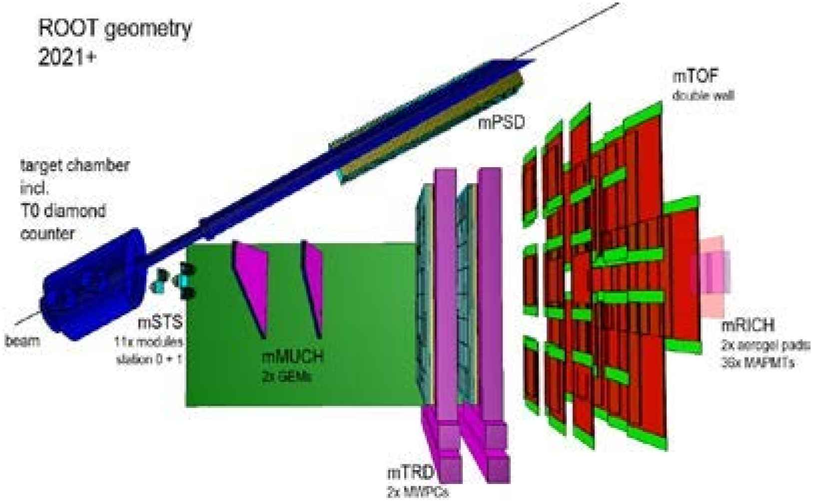
Efficient data concentrator

- Solves the problem of efficient high-speed data concentration from multiple low-width words to a single high-width word required by the DMA system.
- Optimal in a sense that does not require high-speed local clock, and ensures that the “holes” are eliminated from the output stream even if they present in the input streams.
- Design based on so-called Beneš network (technology from 60’s but applied to the new problem).
- Efficient implementation in FPGA.
- Paper describing the solution is in preparation.
- The design will be open-sourced after the publication.

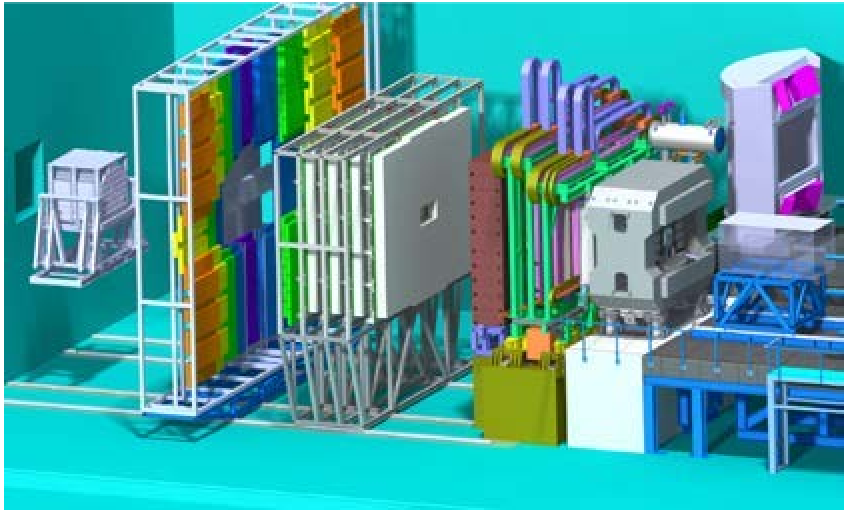
New Deliverable: D2.4 “Functional tests of the developed readout solution” (report at M48)



Development of common software packages for simulation and data analysis, participation in physics performance studies of the CBM & mCBM experiments at GSI/FAIR



mCBM data taking started in 2019



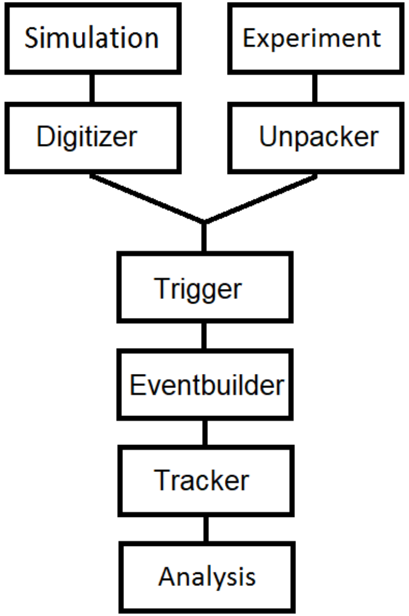
CBM operation planned for > 2028

WP2.3 Scientific/technical highlights - I

Dominik Smith, Volker Friese

Online software for CBM

Goal: Make readout chain „online ready“



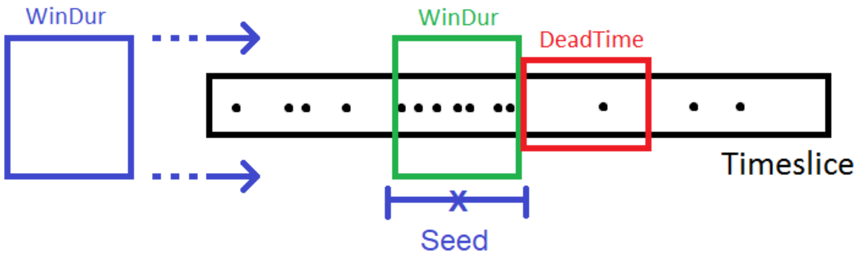
- Implement „algo“ classes in cbm::algo namespace.
- Smallest (algorithmically) possible detector unit (parallelizable).
- ROOT-free, optimize for speed, separate monitoring.

Unpacking:

- Translate detector messages to universal format.
- In cbm::algo: One unpacker per timeslice component.
- Completed: STS, MUCH, TOF, Tzero
- Ongoing: TRD

Triggering:

- „Time cluster trigger“ algorithm in cbm::algo.
- Shift „sliding window“ through digi stream.
  Trigger when digi count exceeds threshold.



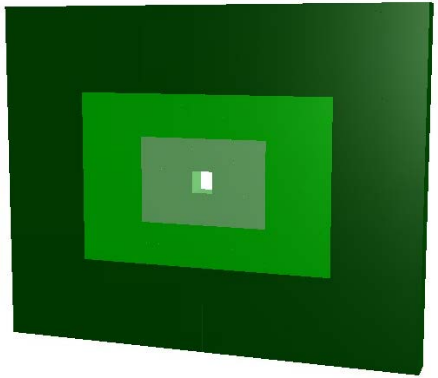
WP2.3 Scientific/technical highlights - II

Lukas Chlad, Ilya Selyuzhenkov

Annual Meeting 2023
09-10 February, Darmstadt, Germany

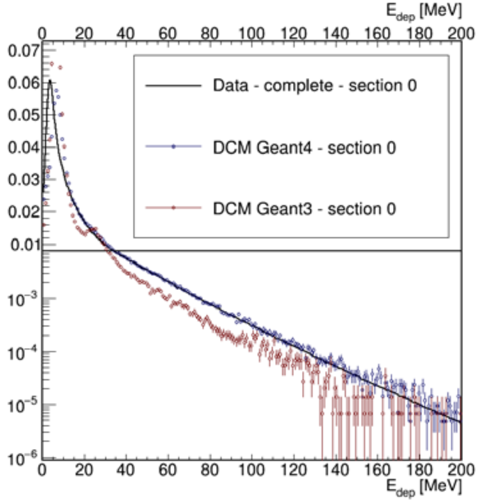
Monte-Carlo studies for new CBM Forward detector

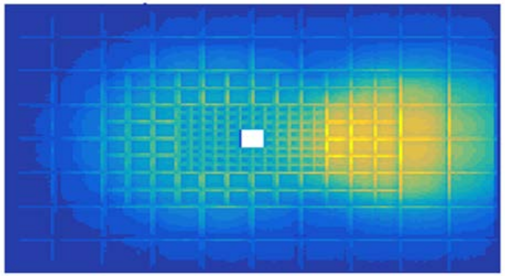
- Spectator fragments detection
  for beam momenta pbeam = 3.3−12 AGeV/c
- Operation at beam intensities up to 10^9 Au ions per second
- Reaction plane determination with an accuracy better than 40 degree
- Determination of collision centrality classes with an accuracy better than 10%



Simulations

- DCM-QGSM-SMM
  model with fragments
- Geant4
- Operational background from
  Beam paprticles and
  detector materials (beam pipe, etc)

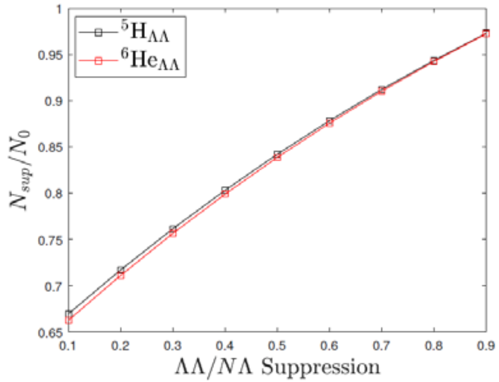




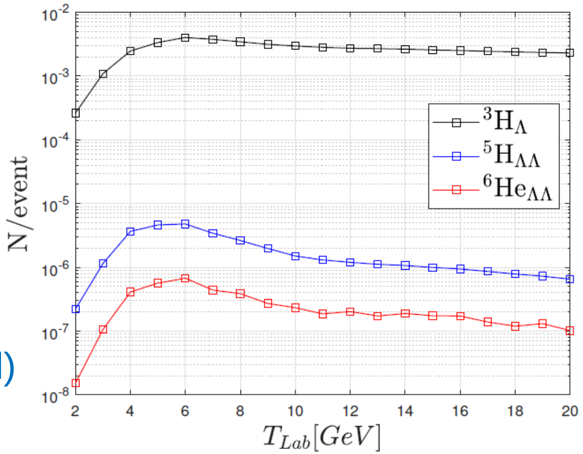
WP2.3 Scientific/technical highlights - III

Gábor Balassa & György Wolf [WUT]

- Hypernuclei production in 0-10% central Au+Au collisions
- ΛN interaction strength from measurements
- ΛΛ interaction strength estimated from:
  - ΛΛ=ΛN
  - ΛN=k*ΛN , k<1



- The energy dependence and expected yields are comparable with other calculations



The deliverables remain unchanged
D2.5 Simulation results for selected observables - Month 24 (achieved)
D2.6 Physics performance for major observables - Month 48

WP2.4: Beam detectors and beam pipe for CBM

Peter Senger, FAIR/GSI

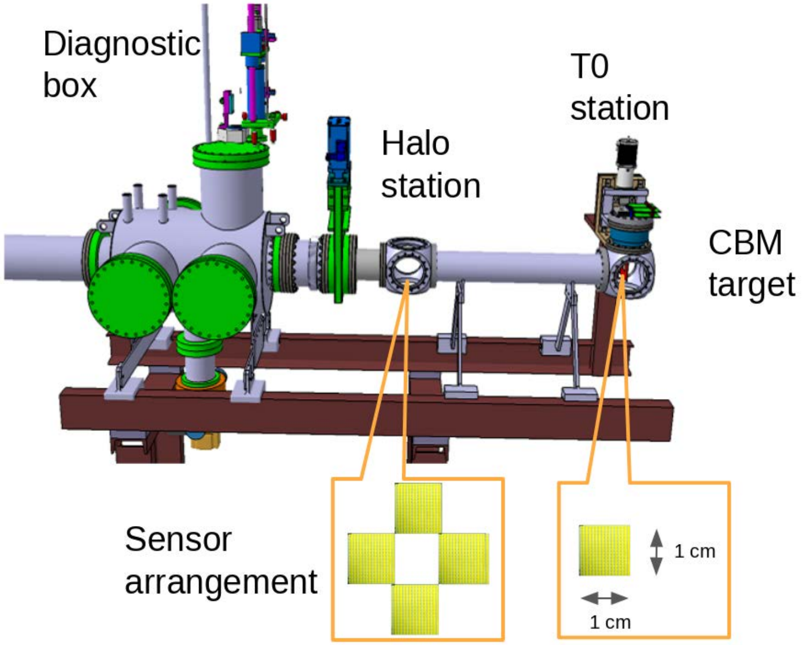
T0 and beam detectors for CBM

A. Rost FAIR

Applications and requirements:

- ➔ Measure start time of reaction (T0) with precision of 50 ps (RMS) at beam intensities up to 10^7 ions/s
- ➔ Beam quality monitoring: position (< 50 µm resolution), halo, time structure, …
- ➔ Part of fast beam abort system
- ➔ Low material budget and in-vacuum operation

- T0 and HaloBAS detector stations will employ pcCVD diamond technology
- Detector stations installed in vacuum, in front of the CBM target
- Conceptual design report: Ready in Q3 2023



WP2.4

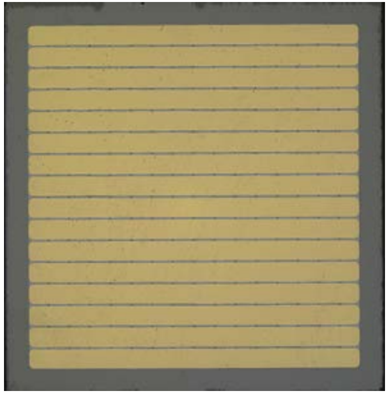
A. Rost FAIR

Sensor technologies

Diamond for heavy ions

Profit from a long experience with HADES:

- High purity sc/pcCVD material,
- Radiation damage well known



pcCVD diamond sensor: 10 mm x 10 mm x 80 µm, 16 stripes (300 µm) on each side

Pro: Radiation hard
Cons: small samples, price

Low Gain Avalanche Diode technology for MIPs

Profit from R&D for HADES, S-DALINAC and Medical application:

- New sensor technology
- Successfully used as T0 in HADES production beam-time

HADES LGAD sensor (FBK) 2 cm x 2 cm, 96 ch, 50 µm thick

Pro: large sample, price
Cons: radiation hardness

T0 detector demonstrator

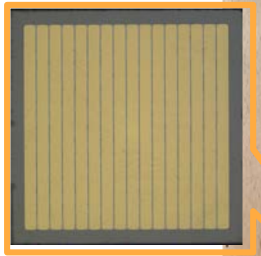
- T0 demonstrator used in mCBM beam-times in summer 2022
- Readout-system based on PADIX discriminator and GET4 TDC
- Used for online beam monitoring during the beam-time

→ Beam-time data is currently being analyzed

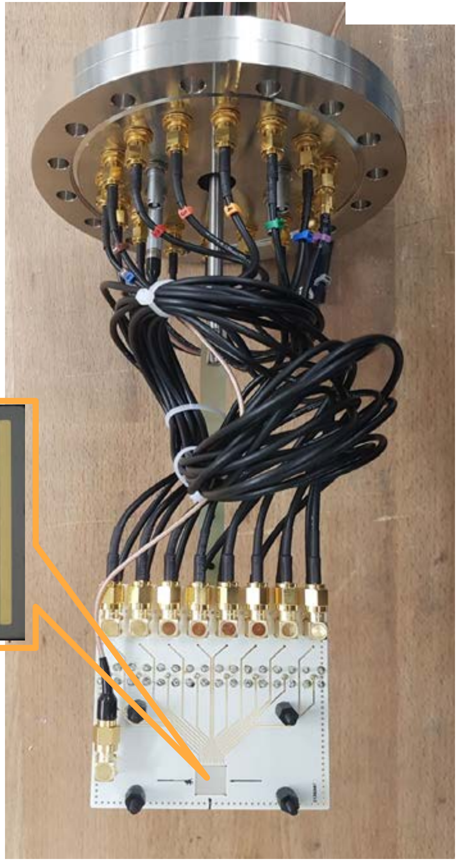
Next steps:

- Preparation of 16+16 ch. (both side read-out) pcCVD T0 demonstrator for the upcoming mCBM campaigns 2023/2024

- Preproduction of the CBM HaloBAS + T0 stations and test with α-source in the laboratory



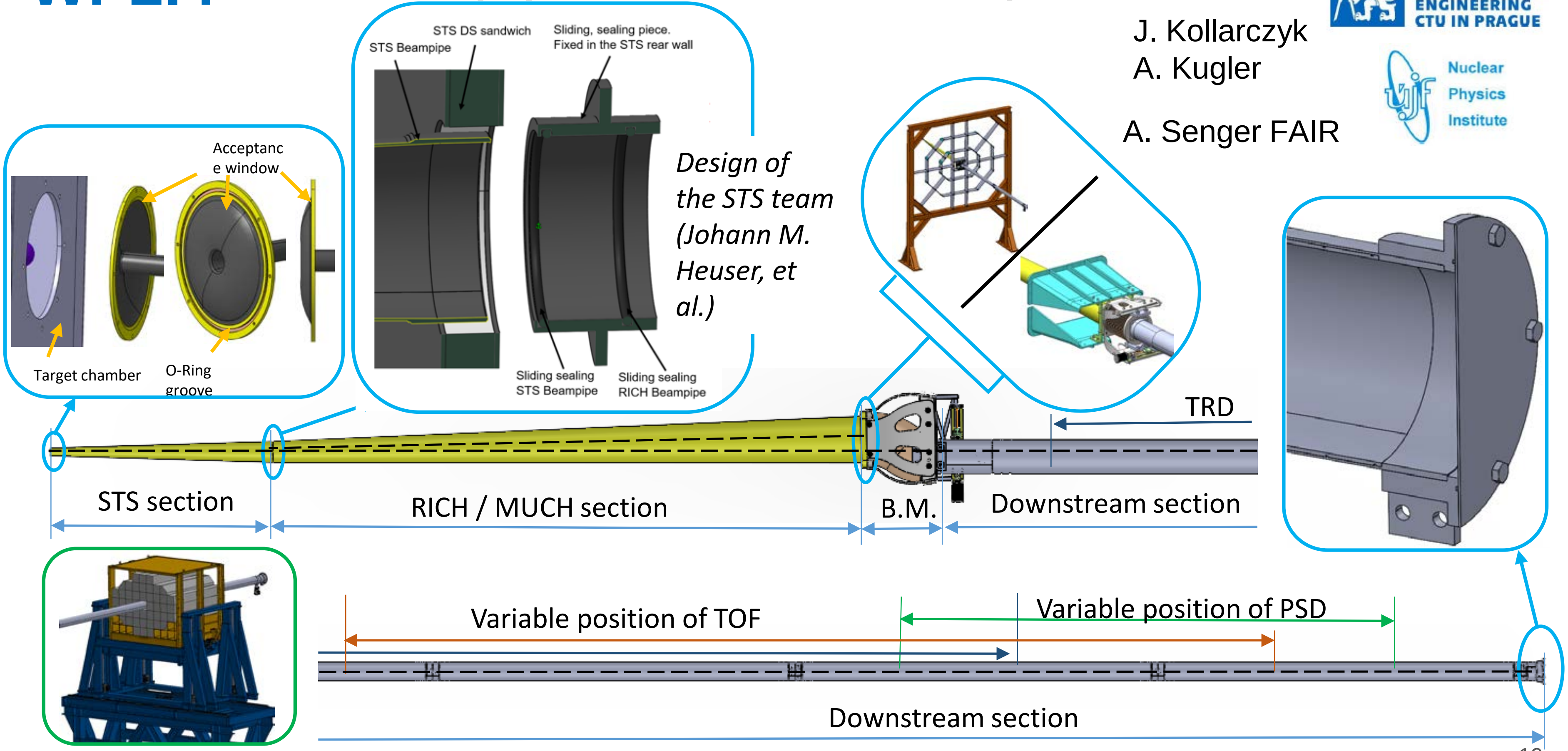
New 10 mm x 10 mm x 80 μm 16-channels pcCVD diamond sensor



T0 diamond interface PCB with pneumatic drive

Beam pipe for CBM: Components

J. Kollarczyk
A. Kugler
A. Senger FAIR
FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE
Nuclear Physics Institute



WP2.4 Beam pipe for CBM: Bending concept

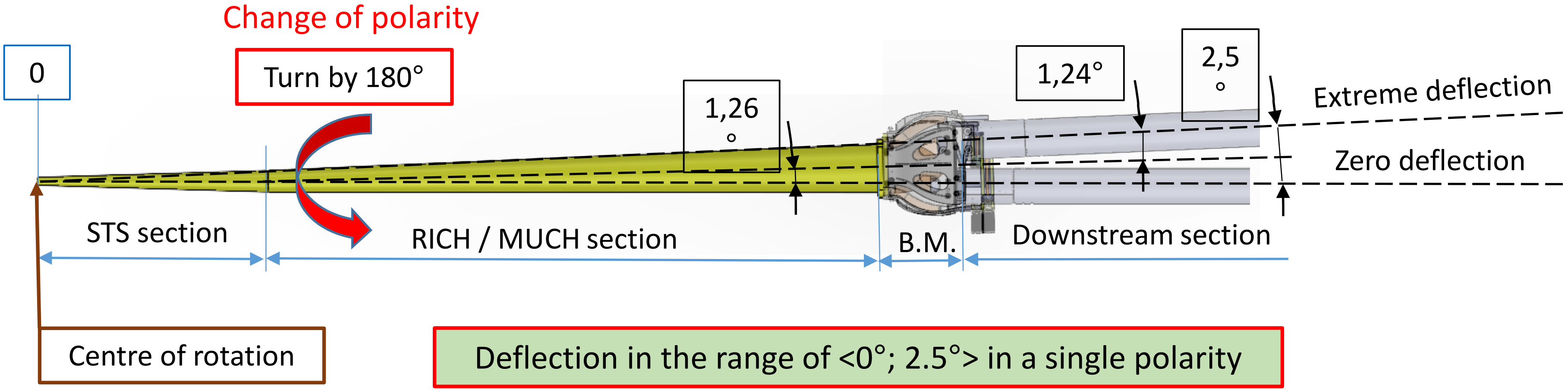
FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE

J. Kollarczyk
A. Kugler

Nuclear Physics Institute

A. Senger FAIR

Downstream beam pipe with deflection:



Deflection in the range of <0°; 2.5°> in a single polarity

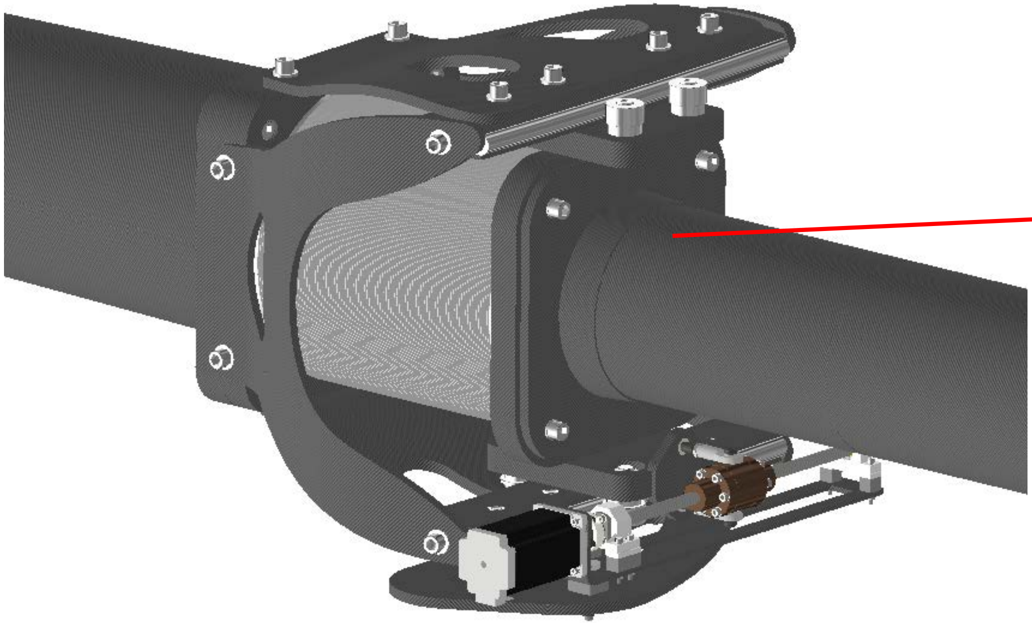
WP2.4 Beam pipe for CBM: Bending mechanism

J. Kollarczyk
A. Kugler

FACULTY OF MECHANICAL ENGINEERING CTU IN PRAGUE
Nuclear Physics Institute

Downstream beam pipe with bending mechanism:

- *Need of further research*



Latest approach

WP2.4 Beam pipe for CBM: Prototype tests

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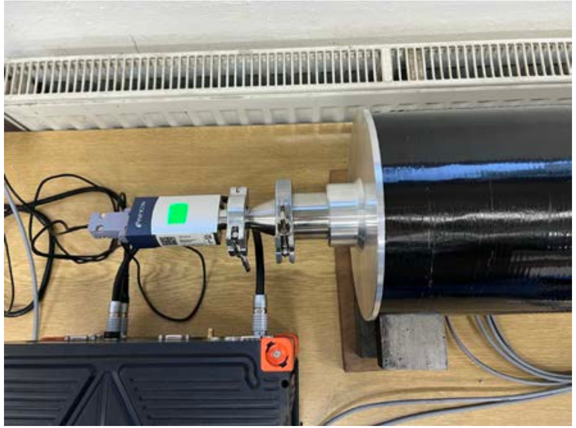
Cylindrical downstream beam pipe:

- *Stability demonstration*
- *Vacuum conditions*
- *Thickness = 3 mm*
- *Length = 3 350 mm*
- *Strain measurements*
- *Inner vacuum: 10^{-5} mbar*



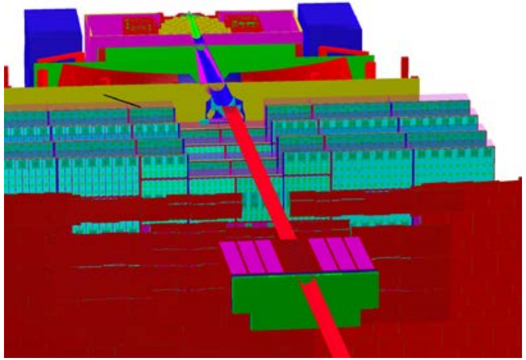
WP2.4 Implementation of beam pipe design into simulation environment

Petr Chudoba, Eoin Clerkin

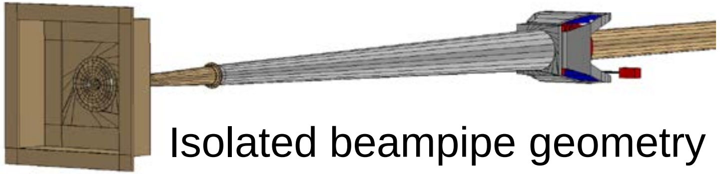
Delivered:

An extenisve simulation beampipe geometry solution capable of handling beam energies from 3 → 12 AGeV and ranges through the entire length of the CBM detector subsystem, consisting of the following pseudo-independent but integrated parts:

- Downstream cylinderical section
- Bellow assembly mechanism
- Conical RICH/MUCH section
- STS backwall flange
- Toroidial beam window and upstream section.
- Target/MVD chamber.



Integrated with other CBM subsystems



Isolated beampipe geometry

Milestones and deliverables:

M10: Technical design of beam monitors, target chamber and beam pipe for CBM: Month 36

D2.7: Design of beam monitors, target chambers and beam pipes: Month 12 (achieved)

D2.8: Beam monitors, target chamber and beam pipe for CBM constructed: Month 48

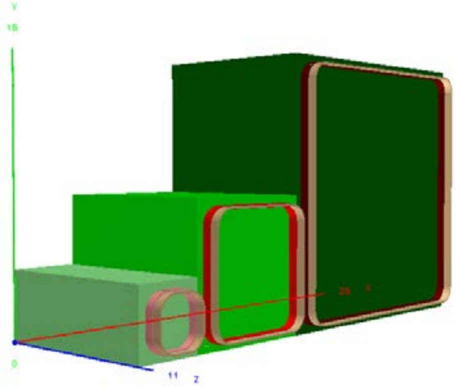
WP2.5: Development of new PSD detector for CBM

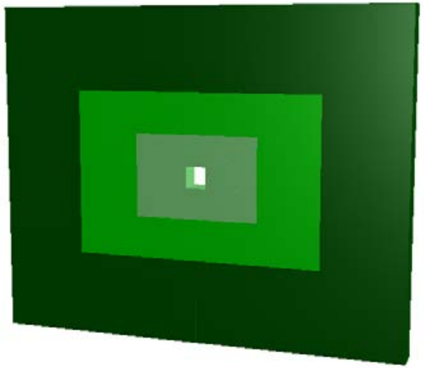
Software integration - Geometry

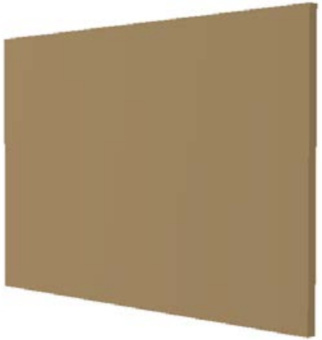
L. Chlad
A. Kugler

Nuclear Physics Institute

- aims to be flexible to fit all requirements put on the FWall
- starting with 3 sizes of cells
- for study purposes use very fine granularity (1x1 cm^2) without any hole
  - this will be used to set minimum criteria on final design to meet the reaction plane resolution
  - also with this setup we can determine what size of hole might be optimal in order to not lose the heavy fragments (keeping in mind also limits coming from irradiation of the material)





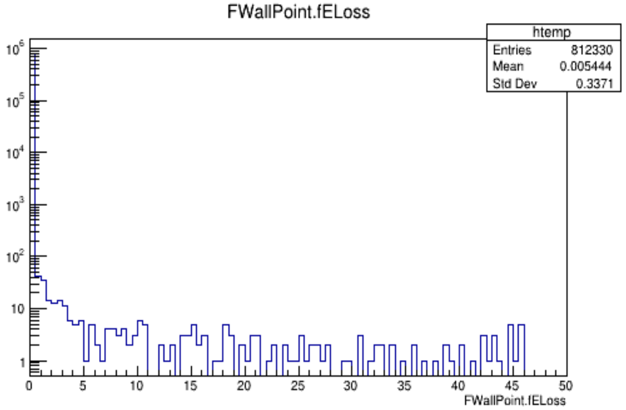


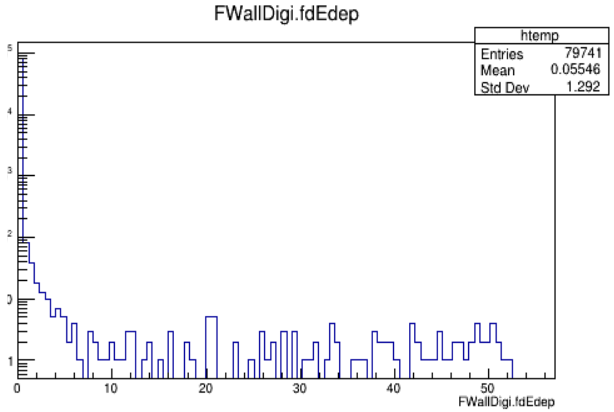
WP2.5

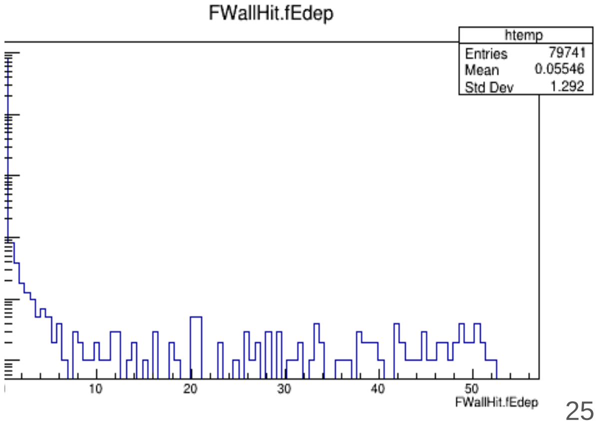
Software integration - simulation chain

L. Chlad
A. Kugler
Nuclear Physics Institute

- TRANSPORT using Geant engines - store information of energy loss of charged tracks within active material (scintillator)
- DIGITIZATION before we will know outcome of material study with Geant 4 physics list and test beamtimes only simple summing of energy deposition within cell is possible
- HIT RECONSTRUCTION for now ideal case is used = copy digi level







WP2.5

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Nuclear Physics Institute

Hardware status

- plastic scintillators for testing to be obtained from Nuvia company
- preparation of read-out electronics based on RICH read-out (TRB5sc + DiRich concentrator boards)
- SiPMs main criteria is time resolution + radiation hardness (review of recent progress in the field is ongoing)

New Deliverable D2.10: Feasibility studies of new projectile spectator detector for CBM: Month 36

New Deliverable D2.11: Technical design of new projectile spectator detector for CBM: Month 48.