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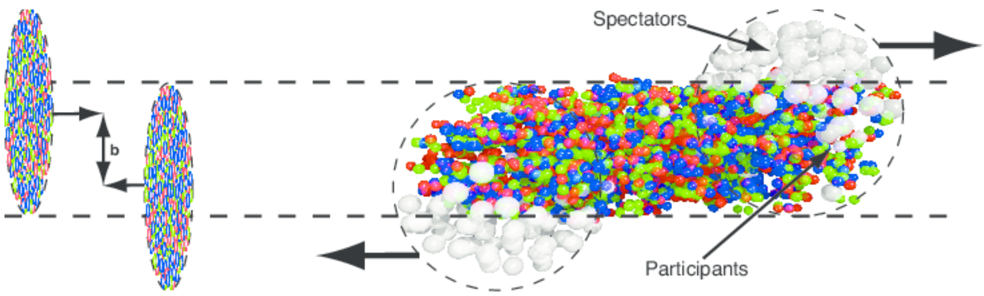
WP2.5: Development of FSD for the CBM experiment at FAIR

1. Feasibility studies of new projectile spectator detector for CBM

The detection of projectile spectators is required for the characterization of the heavy-ion reaction, i.e. they provide important information on the centrality of the collision and the orientation of the reaction plane. The Projectile Spectator Detector (PSD) originally planned for the CBM experiment was based on hadron calorimetr modules to be produced at INR RAS. In the period from 01/08/2021–08/04/2022, after the succesfull test of prototype PSD module at miniCBM setup, the production of all modules for PSD were lunched as well as production of modules of FHCal for BM@N. During the end of the 2021 FHCal were installed at BM@N and its through testing was started. Experience obtained during these activities at Dubna was assumed to help during installation of similar PSD modules at CBM in forthcoming years. However, due to restrictions introduced by sanction due to Russian invasion of Ukraine this never happen and all produced PSD modules for CBM except one remained in Moscow INR. Consequently, the work within WP2.5 has been re-defined to focus fully on the development of the Detector Systems of the CBM experiment at FAIR alone.

The original PSD detector was designed to measure the centrality and orientation of the collision plane for individual nuclear collisions. For many physical processes, accurately measuring these fundamental observables for each collision is essential. In nuclear collisions, centrality, essentially the geometric overlap of colliding nuclei, can be determined by detecting (ideally measuring the energy of) so-called "spectators" – nucleons that do not participate in the collision and continue in their original flight direction even after the collision:



It was proposed that as replacement of PSD new Forward Spectator Detector (FSD) - a scintillator hodoscope will be build. The first studies on physics performance and electronics design started in fall of 2022 with the aim to optimize the detector design. During the year 2023 the project proposal of the Forward Spectator Detector was accepted as an official detector development project of the CBM collaboration lead by the Czech group.   During the 2023 the FSD group in CBM has grown significantly including members from GSI, Tuebingen University, and Bochum University. This allowed to start working in multiple main directions of development.

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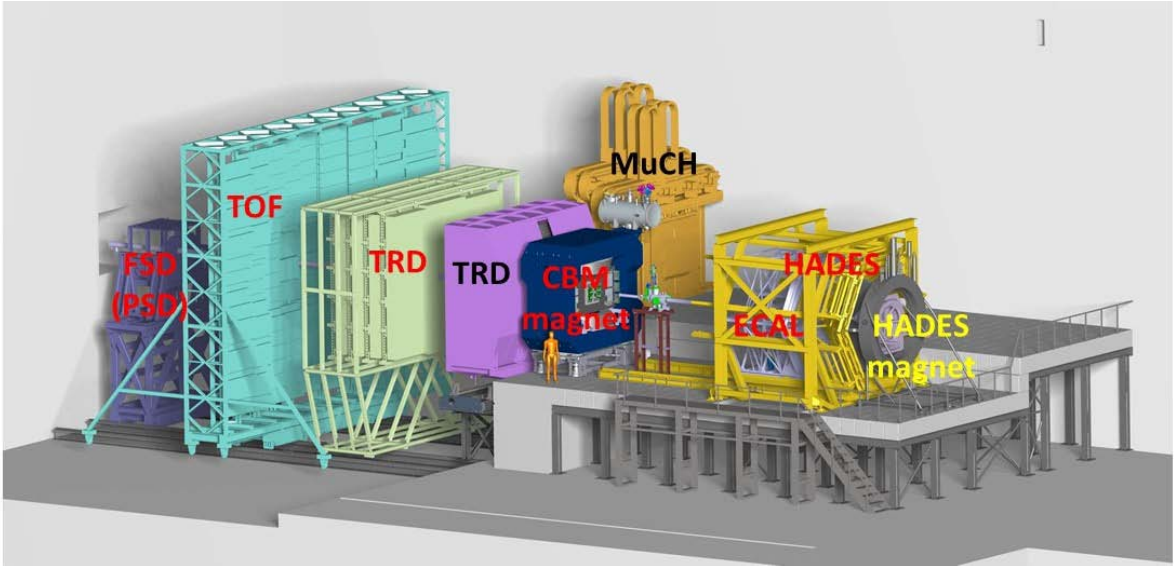
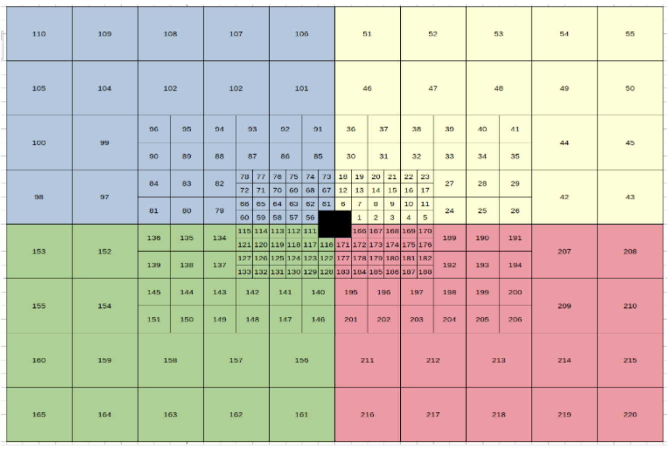
1.1. Design of the CBM FSD

The planned FSD detector is designed as a scintillation hodoscope, situated approximately 10 meters from the primary target at the same place as was the previous PSD detector.



It will closely surround the accelerator tube. The design and function of the FSD detector will be quite similar to the Forward Wall (FWALL) detector of the HADES experiment. The basic considered detector geometry is depicted as follows:



The detector will have dimensions of approximately 1.6 x1.3 m and will consist of scintillation modules, with sizes increasing from the center of the detector outward. Proposed plastic FSD for CBM consisting from three sizes of modules, Small: 4x4 cm2, Medium: 8x8 cm2 and Large: 16x16 cm2 The simulations described below serve to choose the best granularity on measurement quality. The discussion about the ideal thickness is related to the discussion about dynamic range, which is addressed below.

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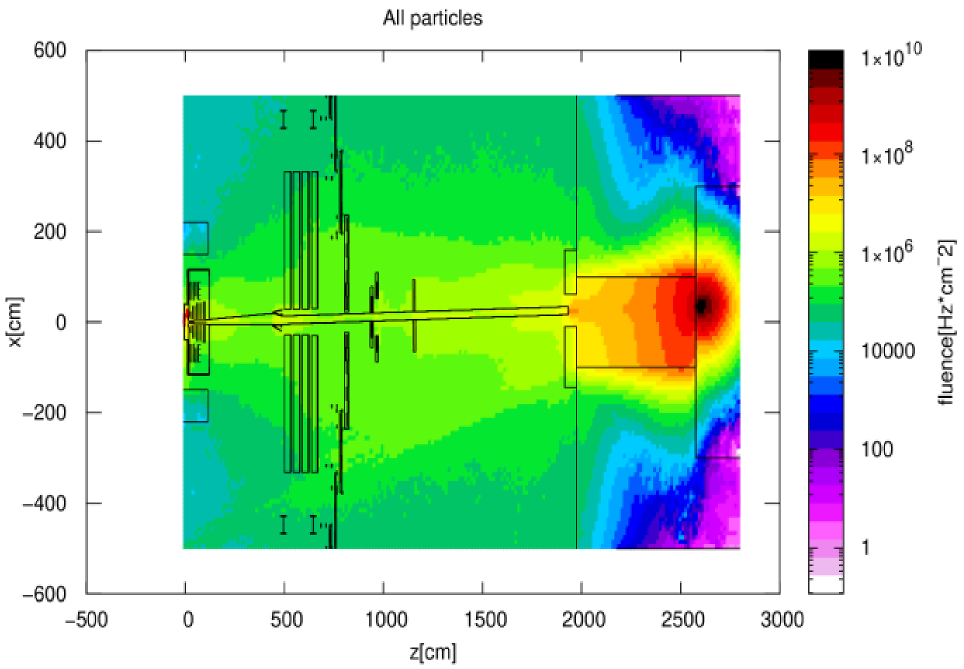
1.2. The Expected Particle Fluxes and Radiation Load in FSD

Second source are slow neutrons which come mainly from behind the detector and originate from the beam dump. Although the beam dump:



Both of these sources of neutrons will be a significant source of damage to the electronics of the detector and are considered in the selection process of scintillator material as well as readout electronics. This is especially important for the case of considered readout using Silicon Photo Multipliers (SiPM).

1.3. The FSD granularity

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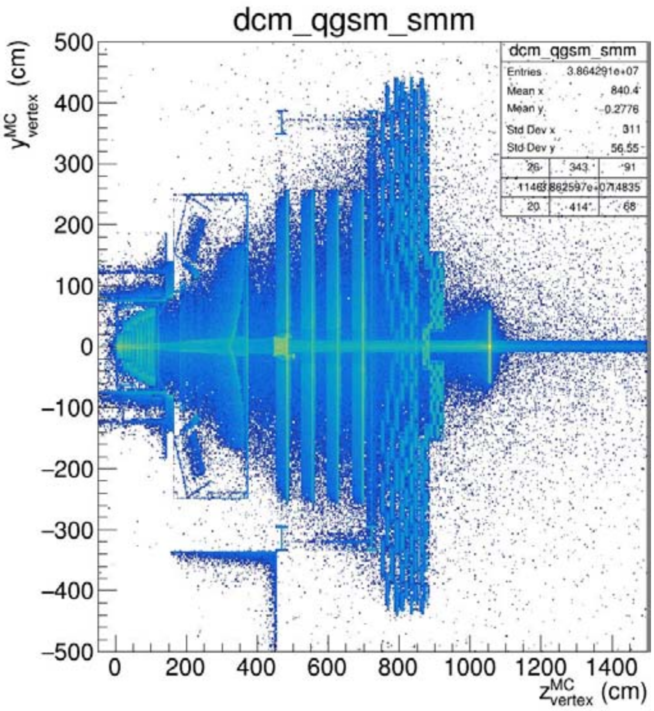
The key question to answer for the design of the detector is what should be the granularity, ie. The sizes of and distribution of the individual scintillator pads. It is expected that the rescattering of the particles in the material of the target, detector and most importantly of the beam pipe and its tilting mechanism will affect significantly the resolution of the angle under which the particles are detected and hence put lower limit on the granularity of the detector. Simulation of the beam and produced particle fluxes were performed showing that 2-3 mrad divergence of the incoming particles is caused by the target material which means that given the fact that the FSD is about 10m from the position of the target, the pad size smaller than 3x3 cm should not be considered. For the effects of the material budget and FSD granularity a full fledge physics GEAN-based simulation is needed. For this reason a GEANT model of detector was included in the CBM geometry and the FSD detector response simulator was developed. In the following figure the full GEAN simulation show the origin of the produced



particles in the material of the detector

The full GEANT simulation will further be used to study effects of the detector material nd FSD granularity on the resolution of reconstruction of event plane and measured centrality of the collision.

Summary and Outlook

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Since February 2023 viable replacement for the PSD will be developed by Czech group. This means we will designed a detector which is able to measure collision centrality and event plane in harsh radiation conditions and with trigger-less readout. The Czech group decided to take this opportunity and propose to build low cost new scintillator-based forward detector with similar geometry as HADES FW, but with silicon photomultiplier (SiPM) readout, like STAR EPD detector. The properties of various scintillating materials will be studied as well as their readout by embedded wavelength shifter with SiPM which will be compared to direct readout by standart PMT. For this we will cooperated with local developer of plastic scintillators NUVIATech (www.nuviatech-instruments.com). In the same time performance and radiation dose simulations were done. Further these ideas and prototypes will be tested on currently existing FW detector at HADES, which Czech group will be preparing for forthcoming HADES experiment planned for spring of 2024.

Acknowledgements

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- NPI CAS Nuclear Physics Institute of the Czech Academy of Sciences (Czech Republic)
- CTU FNSPE Czech Technical University in Prague, Faculty of Nuclear Sciences and Physical Engineering (Czech Republic)
- GSI-FAIR (Germany)
- Tuebingen University (Germany)
- Bochum University (Germany)

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[2] SENGER Peter, FRIESE Volfgang, CBM Collaboration: CBM Progress Report 2022 [online], 2. 5. 2023 cit[26. 01. 2023], page 140 – 141, GSI Darmstadt, doi: 10.15120/GSI-2023-00384, available on: https://repository.gsi.de/record/336786