SIMULATIONS OF EFFECTS OF DETECTOR MATERIALS AND GEOMETRY TO THE BEAM PROPERTIES OF SUPER-FRS

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Abstract

The Superconducting Fragment Separator (Super-FRS) will be built as part of the Facility of Antiproton and Ion Research (FAIR). For the slow-extraction part of the beam diagnostics system a total of 36 detectors are needed for the beam monitoring, tracking and characterization of the produced ions. GEM-TPC detectors are planned to be used for the diagnostics at slow extraction mode of the separator. The detectors will be placed in focal planes along the separator. Simulations have been made to study the effects of the detector materials and geometries in order minimize their influence to the performance of the separator. Results of these simulations are presented in this paper.

INTRODUCTION

The Super-FRS will perform in-flight separation of secondary ejectiles produced in fragmentation reactions and fission of relativistic primary beams up to uranium. The separator consists of two separation stages, pre and main, and three branches connecting different experimental areas [1-2].

The separator will be the first part of the experimental setup for most of the experiments located in the branches. The beam particles entering the different branches have to be identified and their momentum properties should be known. The beam detection system used in this task should have minimal interference with the beam.

One detector type that could be used in the diagnostics is Time Projection Chamber with Gas Electron Multiplier as an amplification stage (GEM-TPC). The GEM-TPC detectors can have a minimal material budget on beam line. They can operate over wide dynamic range and can be used in the online identification and tracking of the fragments.

The detectors will be placed on beam diagnostics stations in before and after the focal planes of the Main-Separator. Layout of the Main-Separator with focal points marked with MF with corresponding number can be seen in Figure 1. Each focal point in the middle of the separator will be surrounded by four GEM-TPC detectors, two before and two after the focal point. The total number of GEM-TPC detectors required to occupy the detector spots in the diagnostics stations is 36.

GEM-TPC DESIGN

The field cage of the GEM-TPC detector for the Super-FRS diagnostics will have to cover the size of the beam pipe. Thus the width of the field cage has to be at least 40 cm and the height at least 20 cm. The thickness is determined by the remaining space left from other detectors and separator components at the diagnostics stations. In the simulations gas volume thickness of 5 cm was used.

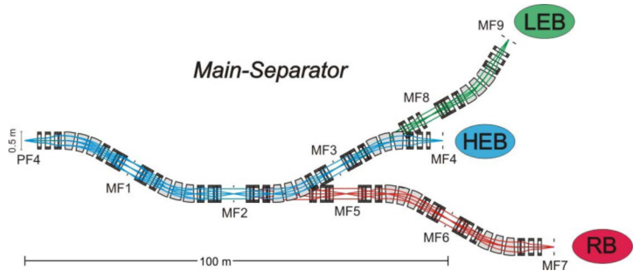

Figure 1: Layout of the Main-Separator of the Super-FRS. The detection systems will be placed on front and back of each focal point marked as MF with numbering from 1 to 9. Low energy branch has three more focal points outside the area of this layout.

A prototype GEM-TPC detector was built by groups in Helsinki Institute of Physics and Comenius University Bratislava [3-4]. The detector was based on the TPC design developed in Bratislava for the FRS separator in GSI [5]. The drift space of the detector is formed by a high-voltage cathode and field forming Mylar strips that are metalized on both sides. The Mylar strips have a thickness of 30 μm and they are 3 mm wide. The strip pitch is 5 mm.

The GEM-amplification part was constructed in the Detector Laboratory in Helsinki. In the first prototype, triple-GEM structure with 2 mm transfer and induction gaps was used. Picture of the first prototype GEM-TPC assembled in laboratory in Bratislava is shown in Figure 2.

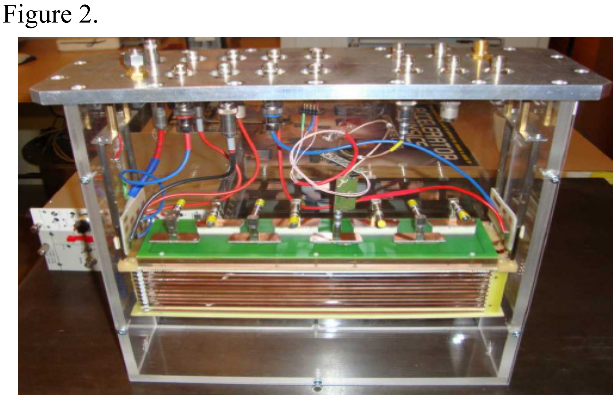

Figure 2: First GEM-TPC prototype assembled in laboratory.

SIMULATIONS

The beam properties throughout the separator were simulated using LISE++ software [6]. In the simulations

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presented in this paper transmission of ^{132}Sn from 1500 MeV/u ^{238}U projectile hitting carbon target was studied at focal point MF7. To reduce the CPU time required for the calculations only 16 most numerous fragments were included.

The results of the beam calculations obtained from LISE++ were used as basis of Geant4 [7] simulations. Separate models for different wall materials and geometries were built using CAD software. These were then converted to GDML and incorporated into Geant4.

Different configurations are shown in Figure 3. A represents the structure which was used in the prototype GEM-TPC. In the simulations 3 mm strip pitch was used instead of the 5 mm of the prototype. The strip material is aluminium coated Mylar. In B the strip are interlocked between the sides of the gas volume. In C a double strip structure was used. The gap between the intersecting strips is 2 mm. In D the Mylar strips were replaced with structure that was made from copper coated Kapton. Kapton covers the full wall area. The copper strip width is also 3 mm but the pitch is 1 mm. In each model the depth of the gas volume is 5 cm. For the comparison, the simulations were made also with 5 cm gas volume without wall material.

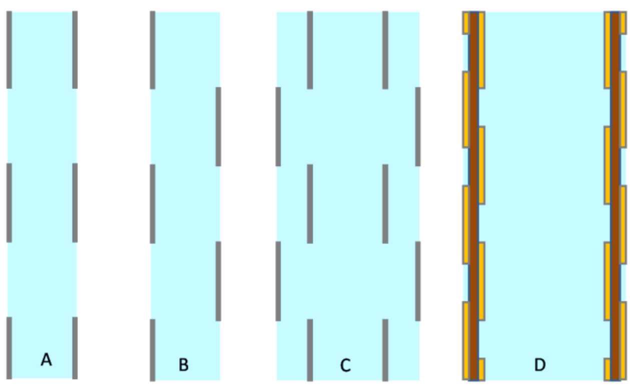

Figure 3: Different detector wall geometries used in the simulations. The dimensions of the elements are not in scale. A represents the configuration used in the prototype GEM-TPC, B with interlocked strips, C with double strips and D with strips etched on copper coated Kapton foil.

The gas used in the simulations was P10. Other gases were not used in the simulations but their effects were estimated using SRIM software [8]. Though not performed here, further studies of the effects of the gases to the beam properties should be made.

RESULTS

Figure 4 shows an example distribution of the ions passing through the detector gas volume at MF7. From the distributions we obtain the XY-parameters for the beam. These values are shown in Table 1. We can see that the addition of different geometries in front of the beam have only small effects in comparison to the plain 5 cm gas volume of P10.

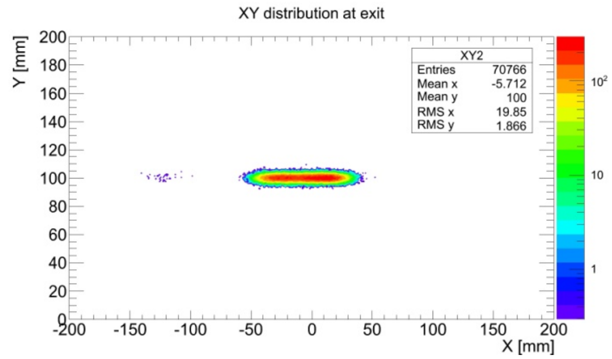

Figure 4: XY-distribution of fragments after flying through GEM-TPC gas volume of P10.

The A and B geometries presented in Fig. 3 have minimal difference in terms of the parameters presented and are thus treated as same structure in the table. The C geometry or the double structure has the largest deviation from the plain gas properties.

Table 1: Beam properties for different field cage materials.

	Mean X	RMS X	Mean Y	RMS Y
P10	-5.71	19.85	100	1.9
Single	-5.75	19.85	100	1.9
Double	-5.51	19.82	100	1.9
Polyimide	-5.76	19.84	100	1.9

By comparing the energy loss due to the different geometries, larger deviations can be seen. In Figure 5 we can see the energy loss of the fragments at MF7 traversing the 5 cm gas volume filled with P10.

In the plots the number of entries for all fragments is scaled to one. We can see that for plain gas the energy loss for the ^{132}Sn fragments is about 43 MeV.

Figure 6 shows the energy loss after the fragments have traversed through the single strip Mylar structure and the gas volume. The strips introduce a secondary peak in the distribution. For ^{132}Sn the mean value of the secondary peak is about 51 MeV.

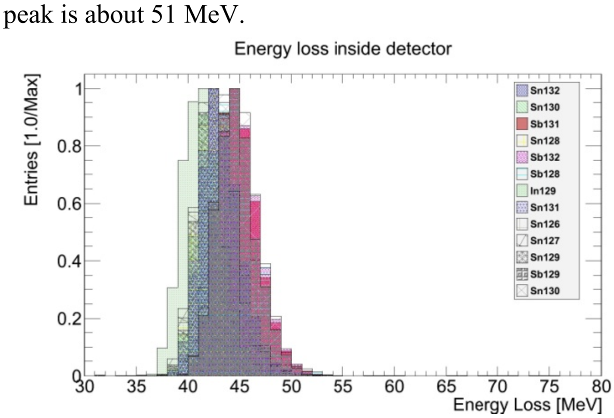

Figure 5: Energy loss inside gas volume of GEM-TPC.

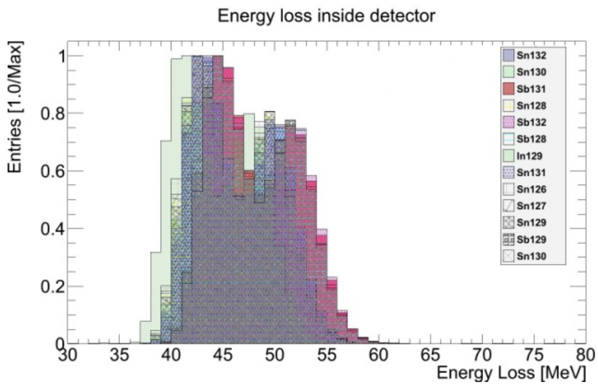

Figure 6: Energy loss of the fragments after traversing through gas volume and single Mylar structure.

For double strip structure the effects from the strips begin to dominate in the energy loss distribution. Figure 7 shows the energy loss of the fragments traversing through the double strip structure and the gas volume of the detector. A tertiary peak is introduced at 59 MeV broadening the full energy loss distribution. The secondary peak is still at 51 MeV as with single strip structure.

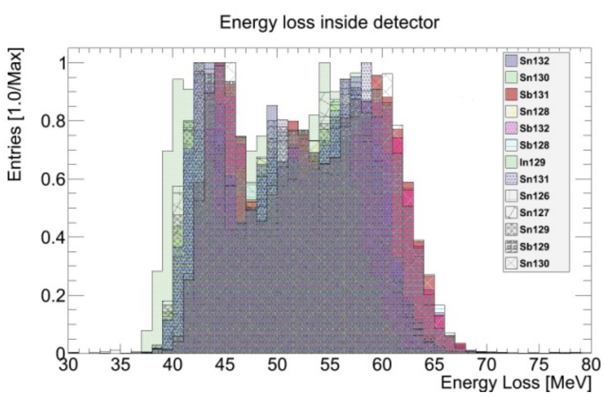

Figure 7: Energy loss of the fragments after traversing through gas volume and double Mylar structure.

For the polyimide wall structure a secondary peak is shifted to 60 MeV for ^{132}Sn. The primary peak originating from the gas is clearly separable. This can be seen in Figure 8.

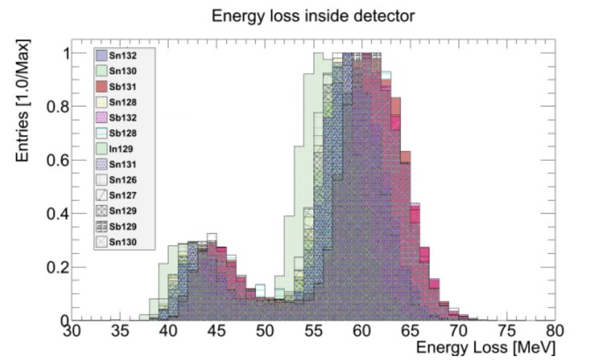

Figure 8: Energy loss of the fragments after traversing through gas volume and polyimide with copper strips.

CONCLUSIONS

Effects of different GEM-TPC detector wall geometries to the beam properties and the detector performance have been studied using combination of simulation tools. From the simulations it can be seen that the effect of GEM-TPC materials to the traversing beam are small.

By looking at the energy loss inside the detector it can seen that the selections of the materials may have larger effect on the performance of the detector itself. The energy loss due to different geometries is small but all the materials introduce secondary peaks to the total energy distribution. This reduces the resolution that can be obtained with the detector.

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