Design justification of the STS section of the CBM beam pipe

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The tracking setup of the CBM experiment consists of two principal subsystems: the micro-vertex detector (MVD) and the silicon tracking system (STS). The MVD is placed in the same vacuum volume as the target. The boundary of the vacuum volume has two parts crossed by an appreciable flux of the measurable particles, namely the window and the first section of the beam pipe connected through welding.

The beam pipe serves for the transport of the ion beam, scattered in the target without nuclear interactions, to the beam dump. The acceptable probability of an ion interaction with the beam pipe walls is not more than 10^{-4}.

It is important for the physical performance of the tracking system to minimize the number of secondaries produced by the measurable particles and their deflection in the pipe and window. For this reason the amount of the material in these elements should be minimized, and their shape and position should be optimized.

A figure of merit for vacuum chamber materials can be established from the elastic modulus E and the radiation length X_0 [1, 2]. For the case of a chamber under external pressure, this has been shown to be $X_0 E^{1/3}$. Beryllium is the best material by this criterion and is used in the most critical parts of the beam pipes of many experiments (LHCb Atlas, CMS, Alice, Belle, CDF, etc.). As a backup option, aluminium with stiffening pattern is considered.

The best shape of the beam pipe is a trade-off between minimum interference with measurable particles and low probability of ion interactions with walls. Several levels of analysis were performed for the optimization of the beam pipe shape, taking into account

- the integrated range (IR) of all the charged particles from one central UrQMD event in the bulk of the beam pipe wall $IR = \Sigma l_i \cdot q_i^2 \cdot n_e$, where l_i is the range of i-th particle, q_i its charge and n_e the electron concentration in the medium. This value is proportional to the total ionization losses in the material of the beam pipe;
- the number of hits per central event in the STS stations. This value allows to check effects of the position of welds and bellows position w.r.t. the STS stations;
- the momentum-dependent reconstruction efficiency for primary and secondary tracks, the number and momentum distribution of ghost tracks and the processing time per event;
- the parameters of reconstructed particles, e.g. $\Lambda \to p\pi^-$ and $K_s^0 \to \pi^+\pi^-$.

It was found that at each level of the analysis, the best configuration of the beam pipe is a narrow cylindrical tube connected to a thin spherical window. An important difference with respect to the results reported in e.g. [3] is that a cylindrical tube is better than a conical one. This is due to the presence of the magnetic field. Without a field, the best solution is a cone.

On the other hand, the ion beam downstream the target has a certain size and angular divergence. The beam pipe should be sufficiently wide for letting most of ions pass through without interactions. The relevant parameters are the beam emittance, the bending of the beam in the magnetic field and multiple scattering of beam particles in the target. The expected beam emittance at SIS-300 is 0.8 mm·mrad horizontal and 0.27 mm·mrad vertical. The tails of the spatial distribution can be reduced if a system of collimators is employed. For $8A$ GeV/c gold ion scattered in the 0.25 mm thick gold target, only $4.5 \cdot 10^{-5}$ ions are outside the angle of $1°$. The maximum bending of the beam particles in the magnetic field will be observed at the minimum extraction rigidity. In this case the angle after the passage of 1 Tm field is 0.9°.

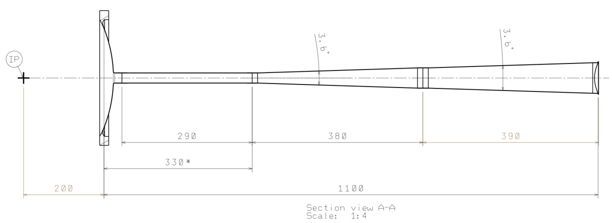

Figure 1: Tentative design of the STS beam pipe

On the basis of MC simulations, a shape composed of a spherical window, a cylindrical tube, and a cone was chosen. The dimensions of segments and welds were implemented according to the technical feasibility at JSC Kompozit, Moscow Region. The structure was subjected to mechanical analysis, and some parameters were iterated. The tentative design of the beam pipe is shown in Fig. 1. If the wide end of the beam pipe is supported, the safety factor against buckling is more then 4 for both the spherical window and the tube part.

References

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[3] The LHCb collaboration, *Beam pipe portrait*, CERN-Poster-2008-050