# MUCH beam-pipe for CBM experiment

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The Compressed Baryonic Matter (CBM) experiment, a future fixed target heavy ion collsion experiment scheduled to be at FAIR, Darmstadt Germany, will try to explore the QCD phase diagram in high baryonic density region within the energy range of 2-45 AGeV. Measurements of low yield rare probes, like charmoniun and low mass vector mesons (LMVM), have to be performed at very high reaction rates (∼10 MHz) which demand fast and radiation hard detectors with low material budget [1].

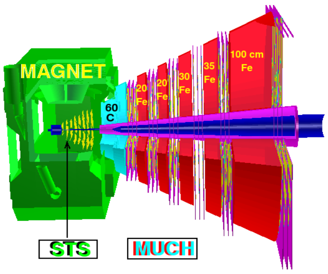
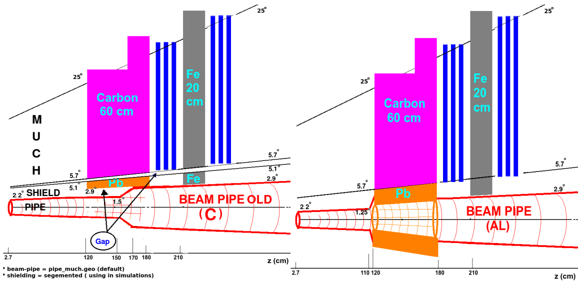



Figure 1: Muon Chamber set-up in CBM experiment for 25 AGeV collision energy

CBM-MUCH (Muon Chamber) detector is a sliced absorber system with detector chambers placed in between, which will be able to identify high and low momentum muons simultaneously from the decays of LMVM ($\rho, \omega, \phi$) and high mass charmonia ($J/\psi$) respectively. The full design of the muon detector system consists of 6 hadron absorber layers [60C, (20, 20, 30, 35, 100)Fe cm] first made of carbon rest five of iron as shown in Fig. 1. The 18 gaseous tracking chambers are located in triplets behind each hadron absorber.

The layout of the MUCH system has been optimized by simulating the response of the Au+Au collisions with background particles taken from the UrQMD and signal particles($\rho, \omega, \phi, J/\psi$ etc..) from PLUTO event generators with transportion of these particles throught set-up using the GEANT3. Primary track finding and reconstruction is carried at STS detector then these tracks are propagated in MUCH [1].

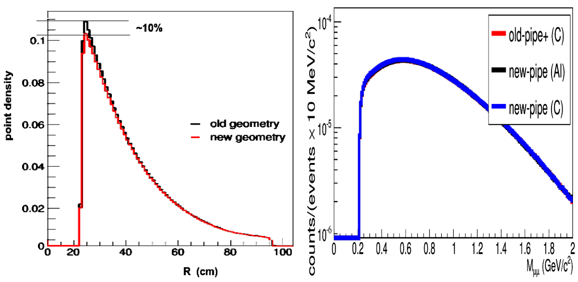
In CBM scenario only 1% of the beam-target interaction is expected which requires safe passage to 99% of the beam till beam-dump to avoid any radiation damage. While we have arrived at optimised geometry of the muon detector, we need to focus on beam pipe for MUCH. From the sketch of MUCH geometry as shown in Figure 2a which include beam-pipe and shielding, gaps between beam-pipe and MUCH can be seen which need to be filled to reduce detector occupancy.




(a) old beam-pipe (b) new beam-pipe

Figure 2: Sketch of Muon detector first two stations & absorber with: (a) old MUCH beam-pipe (left panel) & (b) new MUCH beam-pipe

In new configuration as shown in figure 2b we have filled all these unwanted gaps. Moreover, lead shielding below first MUCH absorber has been made part of the beam-pipe. Plot of the point-density for first detector station superimposed over the result of old-pipe is shown in figure 3a. It is seen that almost 10% reduction in hit density is there for first station near the beam-pipe region as expected due to filling up the gaps. Figure 3b shows that

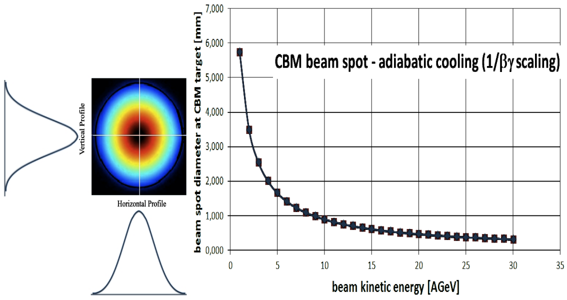



(a) old vs new (b) pipe materials

Figure 3: (a) Point density of first detector station of Much using two types of beam-pipe geometries (old & new).(b) reconstructed background for different type of beam-pipe materials

there is no effect on the reconstructed background if we use different type of beam-pipe materials. No effect is seen on the signal, hence S/B ratio is independent of beam-pipe meterial. We have choosen aluminium(Al) due to its cheaper cost.

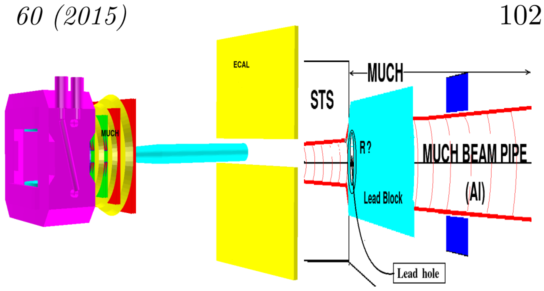
As already discussed, lead shielding below first absorber is proposed to be part of beam-pipe, so optimisaion of its opening-hole is needed. For the purpose we have used CBM-ION generator for gold ions whose shape is determined by the four gaussians, two gaussians represent the spatial distribution [vertical and horizontal (x,y)] and other two gaussians represent angular distribution (Px/P, Py/P). Parameters for gaussian are taken from figure 4a which shows the beam spot diamtere at different incident beam energies. For energies 4 GeV and 8 GeV used in our analysis, beam-spot radius are expected to be 1 mm and 0.5 mm respectively. For the simple case we have first started beam transport using GEANT3 just after the target under magnetic field.




(a) beam spot (b) beam spot size

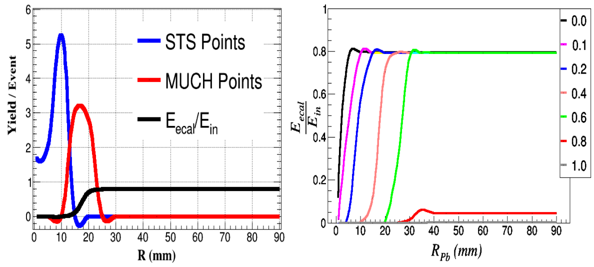
Figure 4: Sketch of Muon detector first two stations & absorber with: (a) old MUCH beam-pipe (left panel) & (b) new MUCH beam-pipe

We have used CBM-MUCH setup with ECAL (electromagnetic calorimeter) as shown in Figure 5a. Figure 5b shows view of lead part of beam pipe with opening. Only gold ions are allowed to pass through beam pipe while lead-hole radius is varied in steps. After beam passes though beam-pipe it deposits its whole energy on ECAL. We integrate out energy deposited on ECAL then take its ratio with incident energy ($E_{ecal}/E_{in}$). Moreover, we analyse the hits on both sides of the lead-hole on detector STS (downstream) and MUCH first station (upstream) to look for secondaries if any produced which gives hint of beam and lead-hole interaction on either side. From Figure 6a its seen that till radius say 20mm of lead-hole there is an interaction of beam with lead at incident energy of 4 AGeV producing hits upstream on STS mostly on last detector station. While if we keep increasing the radius of lead-opening there is reduction on STS hits but hits on MUCH starts increasing till some value ($\sim$ 30mm) due to interaction of beam inside and downstream the lead-hole. From the same reasoning we expect loss in the energy ($E_{ecal}$) deposited on the ECAL till 30mm. This is exactly what has been observed from the ratio $E_{ecal}/E_{in}$ plot in Fig. 6a. Beam finds safe passage without any loss of energy above 30mm radius of lead-opening. It must




(a) MUCH+ECAL (b) lead opening view

Figure 5: (a) MUCH detector layout with ECAL in the set-up. (b) lead-opening view




(a) Hits Vs lead hole (b) Energy loss Vs lead hole

Figure 6: (a) Hits(points) of STS & MUCH Sketch, and ECAL over incident energy range for different lead-hope radius at 4 GeV. (b) ECAL/ INCIDENT energy ratio with lead-hole radius at different magnetic field strengths ( scale 1 corresponds to 2 Tesla)

be mentioned here since we have started beam just after the target so in case of beams interacting with the target we expect safer limit to be higher than the above. We usually take $3^o$ outer acceptance angle of the beam-pipe which is safest limit in any case.

For beams having incident energies greater than 8 AGeV we usually take full strength of magnetic field ($\sim$ 2 $Tesla$) in our simulations but for lower energies say at 4 AGeV magnetic field strength and its effects need to be studied interms of beam deflection and halo formation. Magnetic field strength was varied in steps and corresponding energy $E_{ecal}/E_{in}$ ratio has been analysed with lead-hole radius. Fig. 6b shows that upto 0.6 field scale there exists lead-hole radius above which there is almost no loss in beam-energy. Above 0.6 field scale beam is lost reflected by zero energy ratio. Disappearance of beam is not seen at 8 AGeV energy irrespective of field scale. In conclusion, for lower energies like 4 AGeV field strength need to be below 0.6×2 Tesla. We take the value of 0.4×2 Tesla of Magnetic field for 4 AGeV incident beam energy.

## References

[1] S. Ahmad et.al, NIM A 775, 139–147 (2015)