R&D on Straw Tube detector for CBM Muon Chamber

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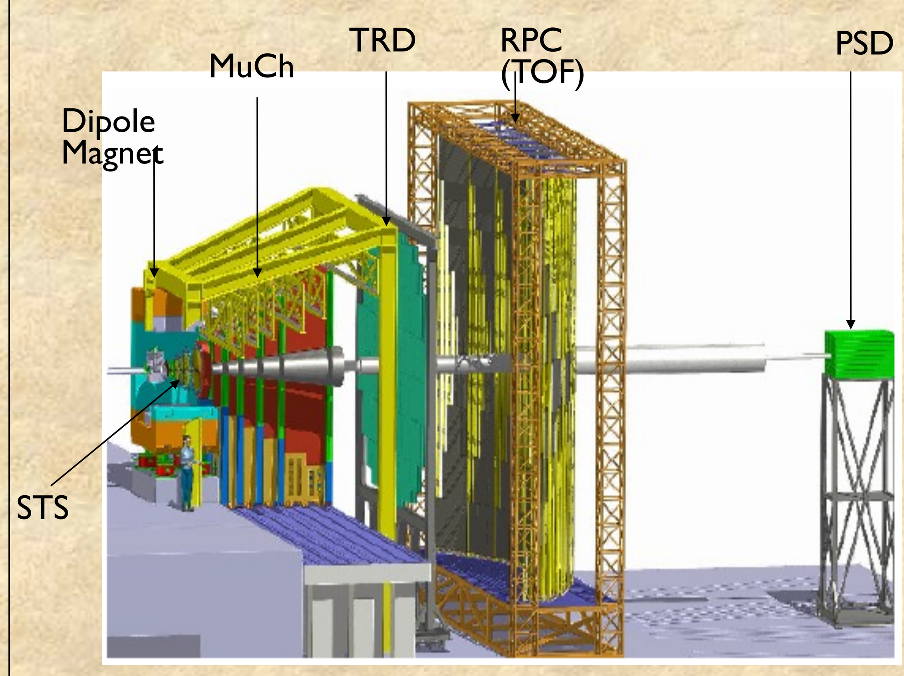
Introduction

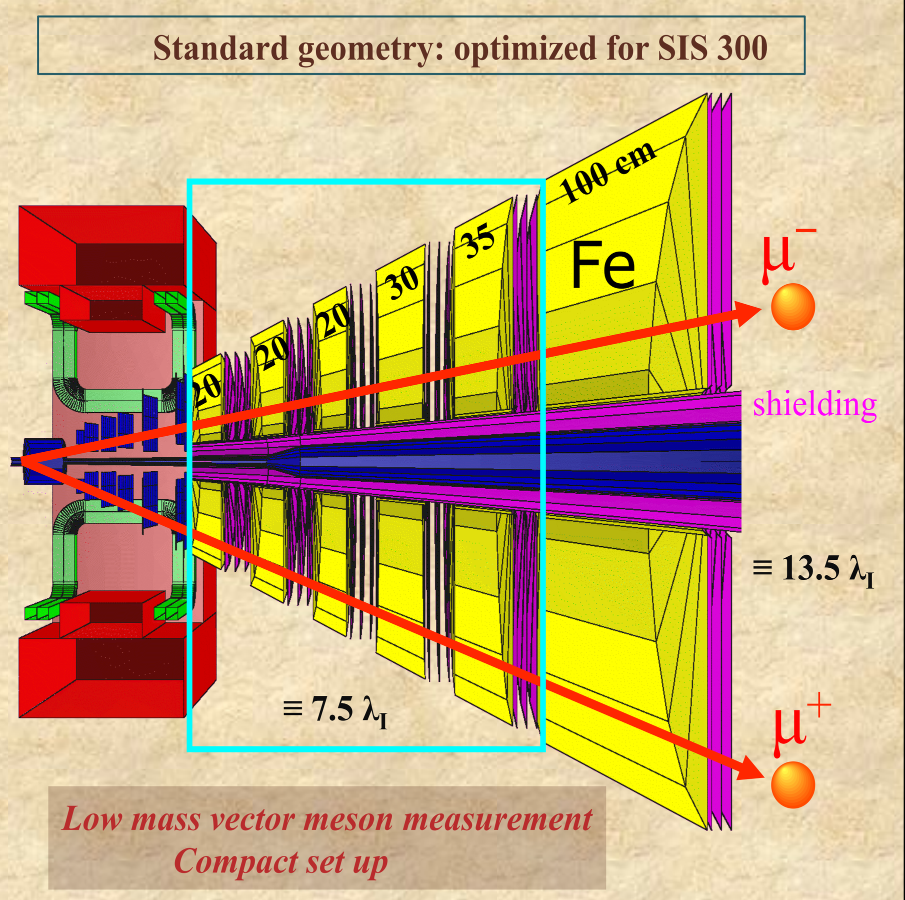
The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) will use proton and heavy ion beams to study matter at extreme compression. The CBM experiment is designed to explore the QCD phase diagram in the region of high baryon densities. Matter in the form of highly compressed nuclear matter exists in neutron stars and in the core of supernova explosions. In the laboratory, super-dense nuclear matter can be created in the reaction volume of relativistic heavy-ion collisions. The baryon density and the temperature of the fireball reached in such collisions depend on the beam energy. So, by varying the beam energy one may, within certain limits, produce different states and phases of strongly interacting matter. In the CBM experiment, particle multiplicities and phase-space distributions, the collision centrality and the reaction plane will be determined.

This will only be possible with the application of advanced instrumentation, including highly segmented and fast gaseous detectors. The ambitious goal to measure rare probes in high multiplicity events at relatively low beam energy is, from the detector point of view, rather challenging: the low, sub-threshold cross sections have to be compensated by high interaction rates. This, in turn, puts rather stringent constraints onto the detector performance: stable performance in a high rate, high multiplicity environment, superior position and momentum resolution for precise tracking. Hence, detector development and characterization is one of the chief challenges of this experiment.

Here we will give a short description of the sub detector of the CBM experiment which is relevant to this work: the muon spectrometer (MUCH), which will be (partly) instrumented with Straw Tube based tracking chambers. The aim of MUCH is to detect the dimuon signals arising from the decay of the low mass vector mesons and from the decay of charmonia produced in the heavy ion collisions at FAIR.

Muon detection system in CBM





Schematic view of the CBM experiment: Muon set up (left). Implementation of the muon detection system in GEANT (right).

Straw tube detector

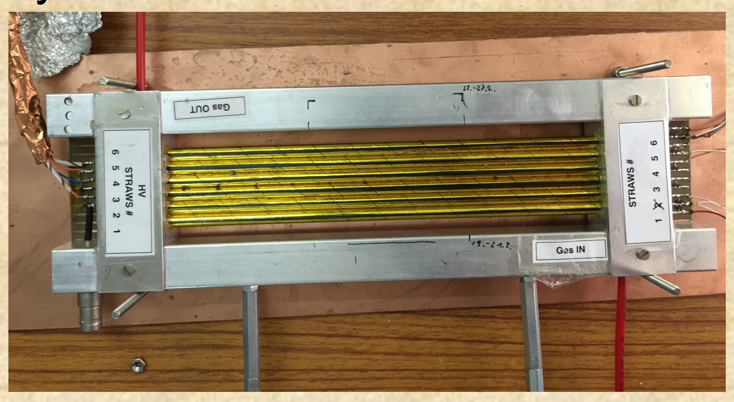
Straw tube is typically prepared from a kapton film, one side containing a conductive layer of 1000-3000 Å Al + 4 μm carbon-loaded kapton and the other side containing a thermoplastic polyurethane layer of 3 μm. Two kapton film tapes (4-8 mm wide) are wound in spiral at a temperature ~ 200 °C. The thickness of the straw wall is around 60 μm.

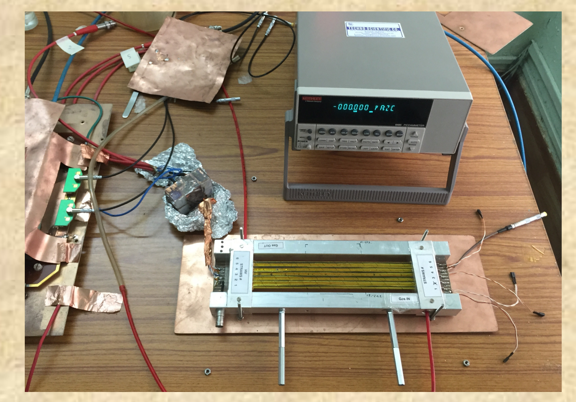
Working Principle of Straw tube detector

A straw tube detector is basically a gas filled single channel drift tube with a conductive inner layer as cathode and a wire stretched along the cylindrical axis as anode. When high voltage is applied between the wire and the tube an electric field is generated in the gas filled region. The electric field separates electrons and positive ions produced by an incident charged particle along its trajectory through the gas volume. The wire is kept at positive voltage and collects the electrons while the ions drift towards the cathode. By choosing thin wires, with a diameter of a few tens of μm, the electric field strength near the wire is made high enough to create an avalanche of electrons. Depending on the high voltage and the gas composition a gain of about $10^4 - 10^5$ can be achieved. The specific energy-loss (dE/dx) of a charged particle in the straw gas volume can be used to identify the particle species and can be derived from the number of ionization electrons per track length (dx) for the generated straw signal. Main idea of using straw tube in a tracking system is reduction of material budget.

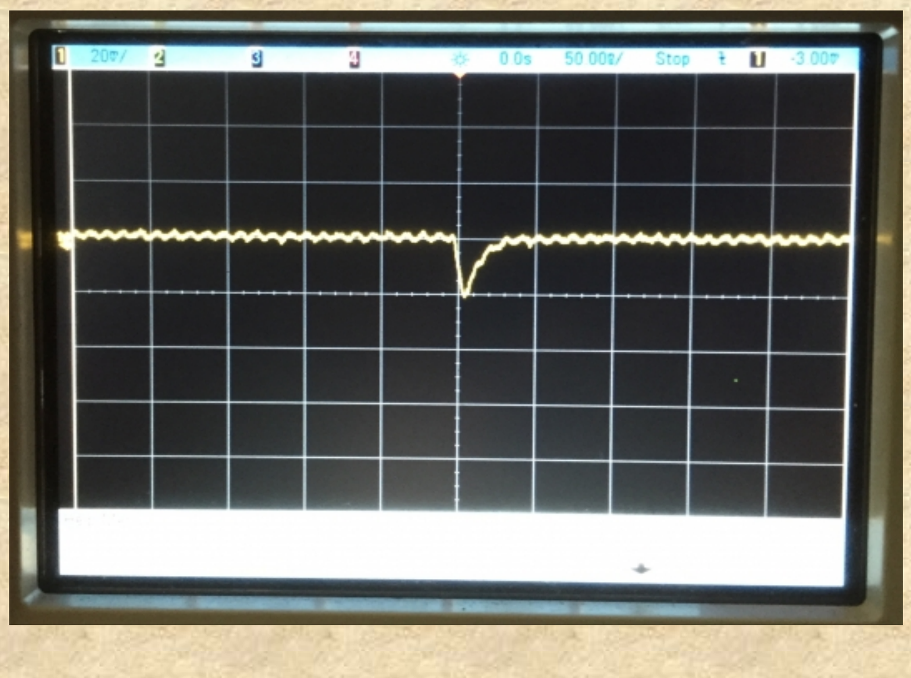
Experimental set-up

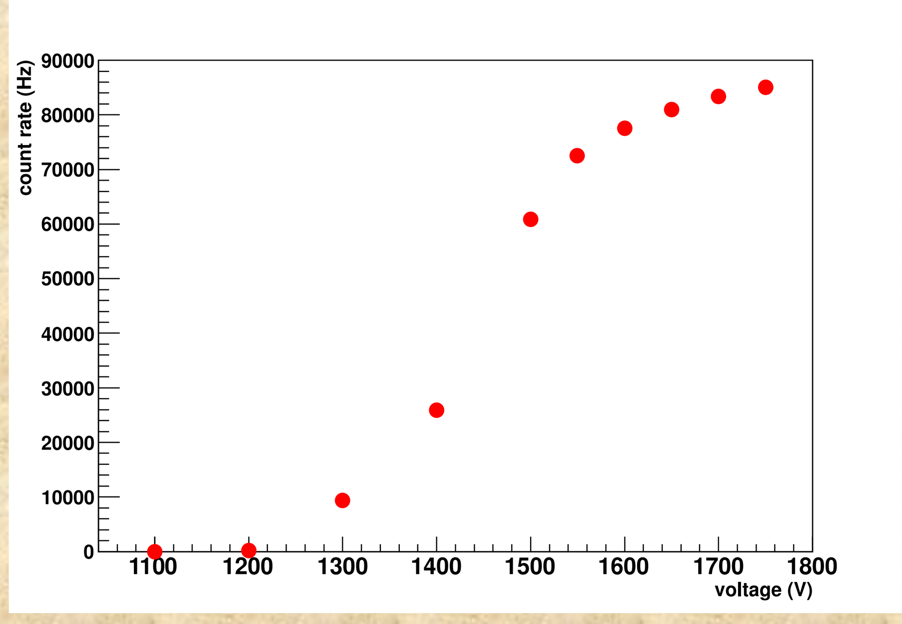
A straw tube prototype is obtained from JINR, Dubna, Russia with 6 straws of diameter 6 mm and length 25 cm. There is a provision to collect signals from the straws through LEMO output. A premixed gas of Argon and CO_2 in 70/30 volume ratio is flown in a rate of 3 lt/h. The positive high voltage (HV) is applied to one end of the central wire of the straws using a HV filter box and the signal is collected from the other end through a capacitor. A single HV channel is used for each straw tube. The output signal from the straw is fed to a pre-amplifier and the output of the pre-amplifier is put to a timing SCA (Single Channel Analyzer). The SCA is operated in integral mode and the lower level in the SCA is used as the threshold. The count rate (i.e. counts per second) of the detector is obtained by a Fe^{55} X - ray source. The threshold scan is first done at a constant HV of 1700 V and it is found that the threshold of 1 V at the SCA is enough to cut all the noise. The source is kept on the straw and the count is measured for 10 minutes with and without the source for a voltage setting from 1100 V to 1750 V. The count rate is then calculated for the source only.





Experimental results





The Fe^{55} signal in the oscilloscope at 1600 V (20 mV/Div, 50 ns/Div, 50 Ω load)

The counting rate as a function of applied HV for Fe^{55} source

- **The count rate for Fe^{55} X-ray source is measured as a function of the applied high voltage**
- **It is seen that a plateau is obtained from about 1600 V onwards**

Summary and outlooks

- **One straw tube prototype is tested with Ar/CO_2 gas in 70/30 ratio using conventional NIM electronics.**
- **The count rate plateau is obtained for Fe^{55} source.**
- **The next step is to study the chamber with PADI electronics used by CBM Time of Flight (TOF) group.**

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