Chapter 1

Drift Chamber 05

Drift Chamber 05 (DC05) is a large-area planar drift chamber 05. It was constructed in 2014 and 2015 at the University of Illinois and Old Dominion University and was then shipped to CERN for final assemble. DC5 was installed to the large angle spectrometer of COMPASS during the spring of 2015.

The DC5 detector was an import tracking detector, successfully collected data from 2015 through 2018 and will continue to be an important component for track reconstruction in future measurements. The author of this thesis helped with the construction at Illinois and the assembly at CERN and as well for performing calibrations and maintaining DC5.

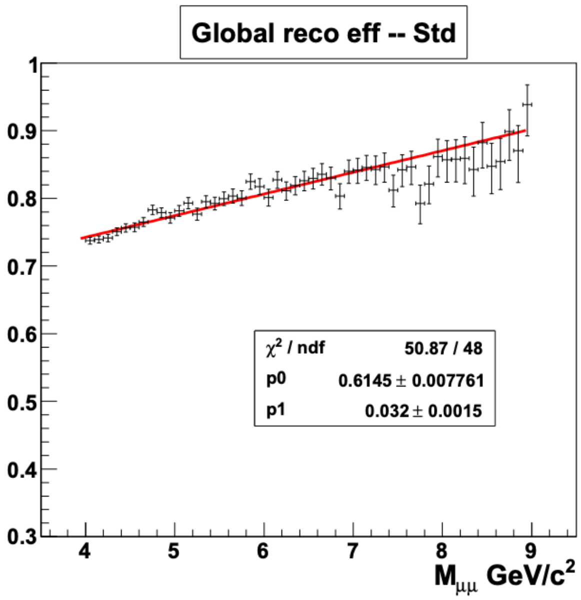
1.1 Motivation for Drift Chamber 05

Simulations of the COMPASS spectrometer for Drell-Yan measurements determined that 96% of all events include a track in the large angle spectrometer [1]. For this reason the Drell-Yan trigger system was setup only to record events with at least one track in LAS. As DC5 was installed in LAS it is therefore very important in track reconstruction for Drell-Yan measurements. Additional simulations with the Drell-Yan setup and this corresponding COMPASS Drell-Yan trigger showed that the global reconstruction efficiency drops below 30% without DC5 and half of another large area tracker in LAS [2]. That is to say the spectrometer reconstruction efficiency is very poor without DC05 and half of an unstable detector. Fig. **??** shows the nominal global reconstruction efficiency and the worst case scenario for Drell-Yan measurements. For these reasons it was very important to have DC05 installed and working reliably.

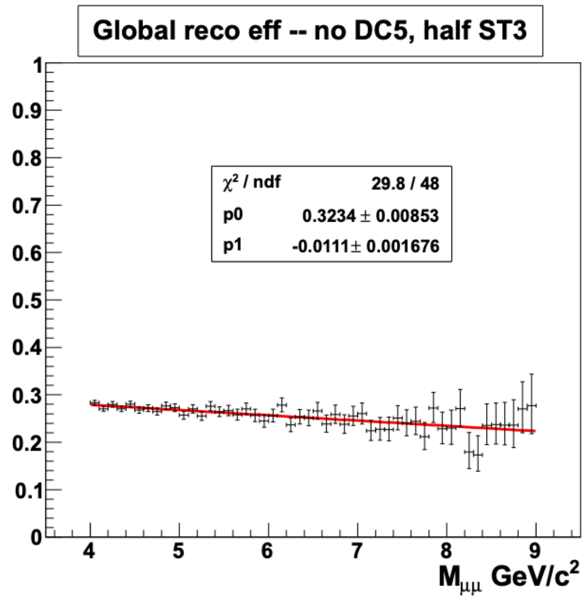
1.2 Preparation for DC05

To prepare for constructing DC05, the detector response was simulated using Garfield [4].

In preparation for the construction of DC05 the detector was simulated and two prototypes were built. The simulations were performed using Garfield [4] and the purpose of these simulations was to determine an operating threshold capable of achieving a 200 μm position resolution. With this position resolution goal



(a) Global reconstruction efficiency with all detectors working. This image was taken from [3]



(b) Global reconstruction efficiency without DC05 and half of another LAS large area tracker. This image was taken from [3]

in mind, Garfield simulated the electric potential field in each drift cell and as well the arrival times for ionized electrons as a function of the number of primary ionized electrons for detection. The variance of the electron arrival times was then used to determine the position resolution as a function of the number of primary electrons detected. The results of the simulation are shown in figure **??**. The conclusion from the simulations was that the threshold should be tuned to detect the amplification of the 5th primary electron corresponding to approximately a 4 fC threshold. This was accordingly one of the main design goals for the front-end electronics.

In addition two prototypes were constructed for training and testing. To start a clean room was built at the Nuclear Physics Lab (NPL) at UIUC and this is where the two prototypes were built as well as where much of the actual detector was built. The first prototype was named prototype A and consisted of 1 plane, eight sense wires, 9 field wires and was built to a length of 50 cm. Protoype B was the second detector constructed and consisted of two planes with 16 sense wires per plane and a length of 163 cm. Prototype A had the opportunity to be tested with beam at DESY and was shown to achieve 200 μm resolution [**?**]. Both of these prototypes were built using similar materials and construction techniques as the full size detector. In particular these two prototypes were the needed experience for working with sense wires having a diameter of 20 μm.

1.3 Design

The design of DC05, figure **??**, was based off a previous large-area tracker at COMPASS. DC05 has an active area of 249x209cm^2 and consists of eight planes with a total of 2304 sense wires and 2312 field wires. The eight planes of DC05 correspond to four views, where each view measures a coordinate. The coordinates measured from DC05 are the horizontal, vertical and $\pm$ 10° with respect to the horizontal. The horizontal and vertical coordinates consist of 2x256 sense wires and the offset to horizontal coordinates each consist of 2x320 wires for increased acceptance. Each plane was made from a G-10 frame and five frames stacked together constituting a view. The whole detector was closed in with two precision, stainless steel stiffening frames, which were assembled with aluminized mylar as a gas window.

The views of DC05 consisted of three cathode layers and two anode layers. The cathodes layers were made from carbon paint sprayed on a 25 μm thin mylar layer. There were two single-layer cathodes layers and one layer with carbon on two sides within each view. Additionally a 30 cm circular so-called beam killer was added to the cathodes to control the efficiency in the central part of the detector. The cathodes were nominally set to -1675 V and the beam killer voltage was set to -900 V for zero efficiency in the high flux central region. The voltage on the beam killer can however be raised above the amplification threshold if the beam flux is reduced and it is desirable to study the central region.

The anode layers were made from alternating 20 μm gold-plated tungsten sense wires and 100 μm gold-plated copper beryllium field wires, as shown in figure **??**. The field wires were also placed at -1675 V and the sense wires were at 0 V. The gas used was made of: 45% argon, for amplification; 45% ethane, for quenching; and 10% CF_4, to reduce aging effects. All these properties corresponded to a gain of approximately 10^4.

1.4 Construction

The construction of DC05 was carried out as precisely as possible starting with the precision from the stainless steel stiffening frames. The stiffening frames where cut with the highest relative accuracy by cutting the two frames on top of each other to a precision of 50 μm everywhere in their plane. The precision from the stiffening frames was then transferred to the anode and cathode frames through 40 positioning pins. The G-10 frames were milled from strips at the NPL using a precision milling machine. Each four strips were then epoxied together on top of one of the stiffening frames.

The cathodes had mylar stretched and epoxied to them using a custom built stretching machine at CERN. An external company then spray painted carbon on them to make a resistance of approximately 30 $k\Omega/m$. All the sense and field wires were hand soldered and sequently verified for position using a microscope. It was estimated the position placement of each sense wire was at least as good as half the diameter of a sense wire or precise to 10 μm. The final assemble was done at CERN. This consisted of stacking each of the 21 G-10 frames on top of the stiffening frame and attaching copper electronic shielding all along the exterior of the detector to reduce electronic noise.

There were various tests performed throughout the construction process for quality assurance before the final installation. The starting tests were measuring thickness and position of important cuts on the G-10 strips using a micrometer. G-10 strip thicknesses were iteratively milled until they reached better than 50 μm in thickness accuracy. The thickness deviation of the whole detector including the stainless steel stiffening frames was better than 750 μm. The mechanical tension of the sense wires was tested for stability by ensuring the voltage difference between sense and field wires could reach as high as 2400 V in air. In addition the wire tension was cross-checked by determining the resonance frequency with which the wires vibrated. The resonance frequency was determined by placing the wires in a constant magnetic field and varying a sinusoidal current across each wire till the wires vibrated maximally. The leakage current between sense and field wires was verified to be less than 100 nA at nominal voltage in air. Finally amplification tests were first performed using a strontium-90 source and verifying the counts per electronics board increased below the radioactive source.

1.5 2015 Performance

The overall performance of DC05 was checked using the COMPASS reconstruction software CORAL. In all cases the view of study was excluded from the reconstruction algorithm and the individual hit information for the view of interest was saved to get an unbiased measurement. The efficiency was found to be between 85% and 90% depending on the plane. Using the so called RT relation, figure **??**, the location of a track within a drift cell can be most accurately determined. This RT relation needs to be tuned as a calibration to minimize the track residuals. The RT relation also varies depending on the beam type, intensity and the trigger type.

The double layer residual was used to determine the position resolution. The double layer residual is the radial difference between the expected x/y positions of the two planes in a view. This double layer residual is independent of the track resolution and only depends on the variance addition of the two individual planes. For the 2015 Drell-Yan physics taking the resolution achieved was approximately 430 μm. This was determined by fitting the double residual with a Gaussian to extract the variance and assumed equal variance per plane in a view.

1.6 Conclusion

The large-area DC05 was constructed at Illinois, Old Dominion University and CERN. It was built to upgrade the spectrometer performance at COMPASS and over its two year construction period, involved the colaboration from students, technicians and professors from five continents. DC05 is a stable detector that has been in use for two years and will continue to collect useful data for future physics data taking at COMPASS.

References

[1] F Gautheron et al. COMPASS-II Proposal. 2010.

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[4] R. Veenhof.