BONuS12 Geometry for CLAS12

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Abstract

This document details the nominal geometry of BONuS12 RTPC for the CLAS12 spectrometer.

1 Introduction

Run Group F (E12-06-113 (BONuS12) and E12-06-113A) has been approved to collect 35 PAC days (100% efficiency) of data on gaseous deuterium target with 11 GeV electron beam and another five days on hydrogen and Helium-4 targets at 2.2 GeV beam energy for calibration purposes. The 40 cm long target filled with 7 atm deuterium gas at room temperature and the 200 nA electron beam will yield a combined nuclear luminosity of about $2\times10^{34}\text{cm}^{-2}\text{s}^{-1}$, about a factor of five below the standard CLAS12 nominal luminosity.

For the detection of the low-energy recoiling protons, Run Group F is going to install a new and enlarged radial time projection chamber (RTPC) and target gas cell assembly, very similar to the ones used by the BONuS6 (E03-012) and EG6 (E08-024) experiments. The RTPC will detect proton recoil momenta down to a lower limit of 50 MeV/c while being insensitive to minimum ionizing particles. The BONuS12 RTPC will be replacing the central detector's silicon tracker and barrel micromegas, while keeping an updated version of the forward micromegas (FMT). In the updated version of the FMT, only three layers of micromegas will be kept to improve the electron's reconstructed vertex resolution while reducing the material in the path of the electrons.

2 The CLAS12 Spectrometer

The CLAS12 spectrometer is designed to operate with 11 GeV beam at an electron-nucleon luminosity of $\mathcal{L} = 1 \times 10^{35}$ $\text{cm}^{-2}\text{s}^{-1}$. The baseline configuration of the CLAS12 detector consists of the forward detector and the central detector packages. The CLAS12 Central Detector (CD) is designed to detect various particles over a wide momentum and angular range. The main CD package includes:

- Solenoid Magnet: provides a central longitudinal magnetic field up to 5 Tesla, which serves to curl emitted low energy Møller electrons and determine particle momenta through tracking in the central detector.

- Central Tracker: consists of 3 double layers of silicon strips and 6 layers of Micromegas. This will be replaced by the BONuS12 RTPC for RG-F.

- Central Time-of-Flight (CTOF): an array of scintillator paddles with a cylindrical geometry of radius 26 cm and length 50 cm; the thickness of the detector is 2 cm with designed timing resolution of $\sigma_t = 50$ ps, used to separate pions and protons up to 1.2 GeV/c.

In addition to the CTOF, the CLAS12 Central Detector has been upgraded with the Central Neutron Detector (CND) for the detection to improve the neutrons' detection.

The scattered electron, other charged particles, photons, and some neutrons will be detected in the forward detector which consists of the High Threshold Cherenkov Counters (HTCC), Drift Chambers (DC), the Low Threshold Cherenkov Counters (LTCC), the Time-of-Flight scintillators (TOF), the Forward Calorimeter and the Preshower Calorimeter. The charged particle identification in the forward detector is achieved by utilizing the combination of the HTCC and TOF arrays with the tracking information from the Drift Chambers. The HTCC together with the Forward Calorimeter and the Preshower Calorimeter will provide a pion rejection factor of more than 2000 up to a momentum of 4.9 GeV/c, and a rejection factor of 100 above 4.9 GeV/c. The photons and the neutrons are detected using the calorimeters.

3 BONuS12 RTPC

The new CLAS12 RTPC (BONuS12) is 400 mm active length cylinder of 160 mm diameter. The electric field is directed perpendicularly to the beam direction, such that drifting electrons are pushed away from the beam line. These electrons are amplified by three layers of cylindrical gas electron multipliers (GEM) and detected by the readout system on the external shell of the detector as illustrated in Figure 1. The BONuS12 RTPC covers almost 100% of the azimuthal angle range.

We detail here the different regions shown in Figure 1 starting from the beam line towards larger radius:

- The 7 atm Deuterium gas target extends along the beamline forming the detector central axis. It is a 6 mm diameter aluminized Kapton straw with a 62 μm wall of 492 mm length such that its entrance and exit (15 μm aluminum windows) are placed outside of the detector volume. The detector and the target are placed at the center of the solenoid aligned with the beamline.

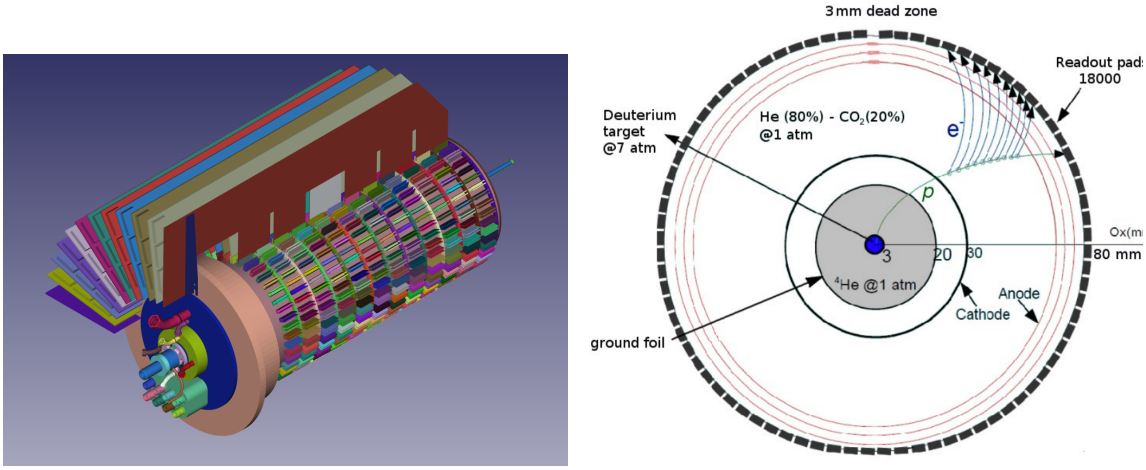

Figure 1: (Left) Schematic layout showing BONuS12 RTPC showing the readout padboard and few adaptor boards in addition to the gas lines. (Right) Schematic drawing of the CLAS RTPC in a plane perpendicular to the beam direction. See text for description of the elements.

- The first gas gap covers the radial range from 3 mm to 20 mm. It is filled with ^{4}He gas at 1 atm to minimize secondary interactions from Møller electrons scattered by the beam. This region is surrounded by a 6 μm thick window made of grounded aluminized Mylar.
- The second gas gap region extends between 20 mm and 30 mm and is filled with the gas mixture of 80% ^{4}He and 20% CO_2. This region is surrounded by a 6 μm thick window made of aluminized Mylar.
- The drift region is filled with the same ^{4}He-CO_2 gas mixture and extends from the cathode to the first GEM, 70 mm away from the beam axis.
- The electron amplification system is composed of three GEMs located at radii of 70, 73, and 76 mm.
- The readout board has an internal radius of 79 mm and collects charges after they have been multiplied by the GEMs. The board has a total of 17280 pads (=180 (in $\phi, \Delta\phi = 2^\circ$) $\times$ 96 (in z, Δz= 4mm). Adaptor and protection circuit boards are plugged directly on the outer side and transmit the signal to the Hitachi cables connected to the standard MVT DREAM electronics.

4 BONuS12 in CLAS12 Coordinates

The center of the BONuS12 RTPC will be aligned with the center of the solenoid, which is 1.303 m to the left of Hall-B center. Figure 2 shows the detailed coordinates of all the beamline elements in RG-F with respect to Hall-B's center. Figure 3 presents the geometry and the coordinates of the BONuS12 RTPC, the FMT, and the Moller cone with respect to the center of the solenoid.

The geometry database will contain 6 parameters to describe the actual location of the RTPC relative to this ideal setup:

- Displacements in x, y, and z in mm.
- Pitch ($\frac{\Delta y}{\Delta z}$), yaw ($\frac{\Delta x}{\Delta z}$), and roll ($\Delta\phi$ between the zero-degree mark on the padboard, its seam, and the ϕ= 0 direction in the CLAS12 coordinate system, beam left pointing to sector 1).

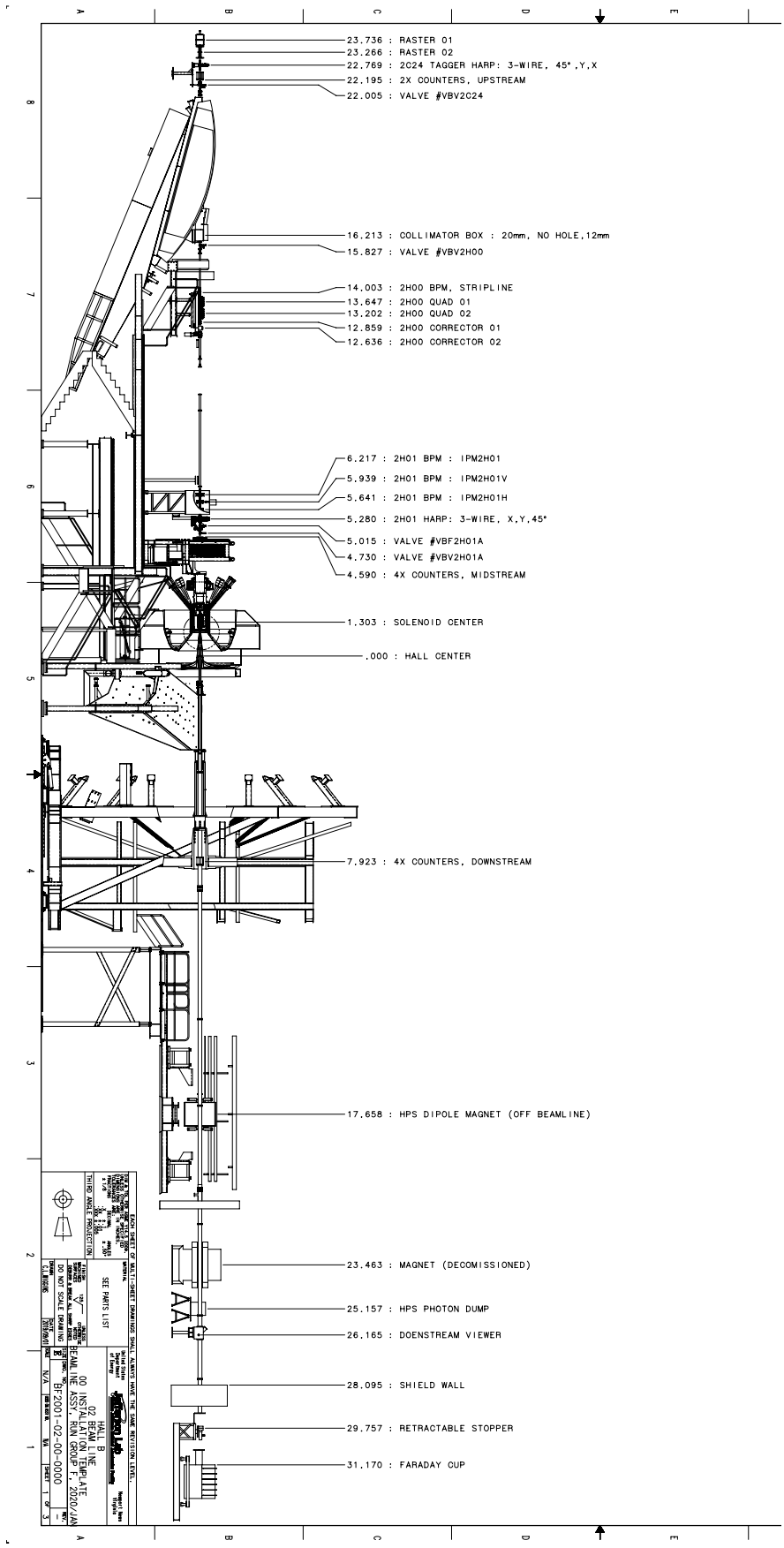

Figure 2: Beamline drawing showing the coordinates of all the beamline elements with respect to the center of Hall-B in RGF setup.

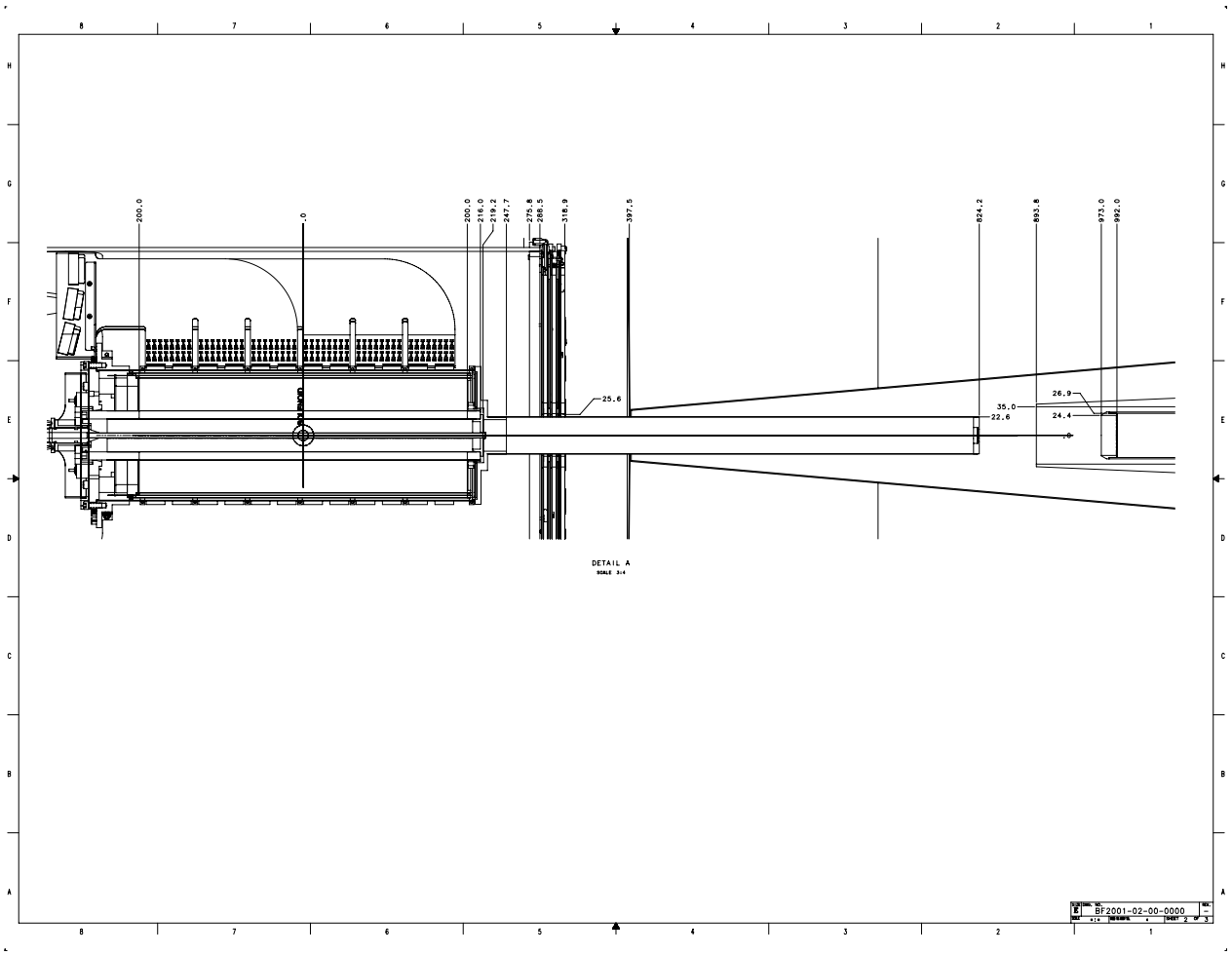

Figure 3: Beamline drawing showing the coordinates of the BONuS12 RTPC, FMT, and the Moller cone with respect to the center of the solenoid.