DRAFT for conceptual design studies
Updated: 5/7/07 (superseding all previous versions)

Hall D Tagged Photon Spectrometer
Technical Description and Specification

General Description

The items which make up the complete spectrometer system are as follows:

1. Two identical dipole magnets including coils.
2. Power supply for dipole magnets.
3. Vacuum box.
4. Quadrupole magnet and stand plus power supply.
5. Strongback support structure for the dipoles.

Note: The detector hodoscope and electronics are separate and are not part of this description.

1. Two dipole magnets and coils.

The Hall-D Tagger consists of two "C" type identical dipole magnets. They are conventional room temperature magnets with copper conductor coils. Both magnets have rectangular pole faces and all the magnet yokes are made from simple rectangular shapes. These two magnets are placed in series, and the separation between them is around 40 cm. The two dipole magnets are not exactly parallel. The angle between them is 0.892 degrees. Each of the magnets has its own focal plane; and these two focal planes join together with no overlap. The two magnets are designed to operate at 1.5 Tesla but enough margin has been left for operating at 1.8 T if required in the future. When the magnets are running at 1.5 T, a 12 GeV main electron beam will be bent through an angle of 13.4 degrees after traversing the two magnets. The front face of the first magnet is positioned at a distance of 3.0 m from the radiator target, rotated by 5.9 deg from the normal to the primary, undeflected beam direction.

Due to the large electron beam energy, the energy degraded electrons have a small characteristic angle, so the Hall-D Tagger does not need a large pole gap. A 30 mm pole gap is used in the design.

The pole shoes have a simple rectangular shape with rounded edges. There is a small step around each pole shoe, which provides a sealing surface between the pole shoe and the vacuum chamber. Detailed pole profiles can be found in an AutoCAD drawing of the spectrometer. A three-dimensional field calculation has been done by using the same dimensions as are in the AutoCAD drawing. The effective field boundary is found to be approximately 2.5 cm outside the pole stem. **Accurate field measurements of 5 parts in 10^4 will be required over the whole magnetic field region, in particular the regions near the field boundary and between the magnets have to be mapped with high resolution and accuracy in order to ensure the required accuracy of focal plane parameters in the energy region of interest.**

Material and fixations, e.g. bolt positions, have to be chosen such that the requirements listed in items 10 to15 can be met. Therefore, high quality steel (AISI 1006 or equivalent) is assumed for the pole shoes.

The second magnet hosts a vacuum pipe for the photon beam, located exactly along the primary, undeflected beam direction. The photon beam pipe is directly attached to the vacuum chamber between the two magnets without any entrance window.

<u>Specifications</u>

1). Main beam momentum	12 GeV/c
2). Momentum range of analyzed electrons	0.6 GeV/c to 9 GeV /c
3). Main beam radius	26.685 m
4). Main beam bending angle	13.4 deg
5). Entrance face angle for the first magnet	5.9 deg
6). Magnetic field	15.0 KGauss
7). Pole gap	30 mm

8). Proposed coil parameters

There are a total of 4 racetrack shaped coils for the two dipole magnets, which are connected in series. These coils are constructed from square section copper conductor (11×11) mm^2 with a central water channel 7 mm in diameter. The total number of ampere turns is chosen to provide a maximum field of 18 KGauss.

Total number of ampere turns for each magnet	61560
Conductor configuration of each coil	7×12
Current density for 61560 amp turns	4.44 amp /mm^2
Electrical resistance of each coil	0.124 •
Current in conductor	366.43 amps
Voltage drop across 4 coils connected in series	181.7 volts
Total power consumption	67 KWatt
Cooling circuits per coil	7
Total flow rate for 20 deg. Centigrade rise	80 l/min
Water supply pressure drop	2.0 atms

Outside dimension of each coil	(92×152) mm^2

The coils should be vacuum impregnated.

9). The pole shoe edges should be rounded by more than three times the O-ring diameter used to provide the vacuum seal.
10). The gap between the pole edge and the inner surface of the coils is 20 mm and should vary by less than ± 1mm.
skip (manufacturers always can argue against this because of material imperfection, etc): 10). The discrepancy between the calculated and measured effective field boundary (obtained from a field map for the two dipoles) should be less than 1.0 mm along the pole edges for the analysed electrons. This requirement is in particular important for the region near the edges and between the magnets in order to ensure the required accuracy of focal plane parameters in the energy region of interest.

11). At 1.5 T, the magnetic field inhomogeneity should be less than 1 part in 10^3 (was: 5 parts in 10^4) along any 100 mm length lying inside an area defined by a line drawn round a pole surface which is two gaps in from the pole stem. Within this area the maximum variation in the magnetic field should be less than 1 percent (was: 5 parts in 10^3).
12). The pole faces should be parallel such that the variation in the pole gap be less than 0.02 mm along any 100 mm length on a pole surface. The variation in gap size should be less than 0.2 mm over the complete area of the poles. (relaxed by factor 2).
13). The pole surfaces, which form part of the vacuum system, should have a protective covering, e.g. Ni impregnation.
14). The poles for both magnets should have small alignment holes defining the input, output and central ray trajectories: i.e. 3 trajectories per magnet. The position of the alignment holes will be defined later.
15). The variation in the pole gap between zero field and a field of 15 KGauss should be less than 0.2 mm at any point on the pole surface.
16). There should be tapped holes for attaching jacking supports to the dipole yokes for use in the assembly and disassembly of the dipoles.

2. Power supply for dipole magnet

The coils of the two dipoles will be connected in series. So we need only a single power supply together with a small auxiliary power supply to balance the fields in the two dipoles. The power supply should have the following specifications:

Power output	80 KW
Voltage output	200 volts
Current output	400 amps

The current should be stable to a few parts per million over a period of 48 hours.

skip (not important for Hall D): The supply should have a zero field option, e.g. it should be capable of maintaining a field of less than 5 ± 0.5 gauss in the magnet by means of feed-back loop controlled by a magnetic field probe.)

3. Vacuum box

It is proposed to use the poles as parts of the vacuum system. Details of the vacuum box are shown in the AutoCAD drawing.

The magnet poles have a lip running around their circumference, and the vacuum box is essentially “wrapped around” each pole with a rubber O-ring seal being made between the top or bottom surface of the vacuum chamber and the lip. Pressure can be applied along the seal by means of tightening brackets which are attached to the yokes. The O-ring should have a diameter of at least 10 mm allowing for compression of 2-3 mm.

The vacuum box extends the vacuum system out to the focal plane of the spectrometer. In addition to an entrance port for the incoming beam, located near the radiator target, and an exit port for the main beam, the vacuum box has a large exit window allowing the analyzed electrons to pass through to the focal plane detectors.

The photon beam pipe inside the second magnet is part of this vacuum system. The exact shape of the vacuum box around the main beam exit port still has to be finalised.

The vacuum box should have three ports for vacuum pumping stations and two ports at the front face of the first magnet and back face of the second magnet for inserting Hall probes to monitor the field in the magnets.

The materials for the vacuum box should be non-magnetic. Stainless steel and aluminium could be the suitable materials. However, since welding can alter the magnetic properties of stainless steel, great attention should be paid to avoid the welds distorting the magnetic field at critical points. For aluminium, since the thermal expansion coefficient of aluminium is significantly different from that of iron, it is probably not acceptable. The box will require external strengthening ribs to prevent it collapsing when the system is under vacuum.

4. Quadrupole magnet , power supply and support.

The main specifications of the quadrupole are as follows:

Aperture diameter	30 mm
Magnetic length	400 mm
Max magnetic field gradient	20 T/m

The coil design and the choice of power supply are left to the manufacturer. The magnetic axis and geometrical axis should be co-incident to <0.05 mm along the magnetic length of the quadrupole.

A table support is needed for the quadrupole magnet

5. Strong-back support structure.

A single support structure (strongback) is needed for the two dipoles and vacuum chamber, because once they are aligned no relative motion between the two dipole magnets is allowed due to the requirement of precision alignment, vacuum seals, etc, although in addition the entire assembly should be adjustable as a unit. This support structure should also provide the ability to allow accurate adjustment of the magnets. It should be designed to allow independent movement of the magnet by ± 20 mm in the x, y, z direction for each magnet. The final positioning in any direction should be accurate to 0.2 mm (was: 0.1 mm). The spectrometer will be mounted horizontally. The nominal beam height is 1.8 m from the floor. The manufacturer should provide a design for the strongback.

6. Assembly

Drawings of the assembly and alignment of the magnets in the Hall-D tagger building are required to verify that all components can be transported and assembled to the required tolerances. The possibility that the system will be disassembled should also be included in the design studies.

(Comments - to be removed after the discussion round:
in red: changes to Hall_D_Tagger_Spec_v3 (11/29/06)
in magenta: changes to draft of 5/2/07
in blue: short comments or previous text
In principle, all requirements could be further relaxed. However, for quality control and accuracy of focal plane parameters for low energetic electrons (esp. those exiting the first magnet near the downstream pole edge, i.e E~4.3-4.4 GeV) set the requirements for the first magnet.)