Hall D Tagging Spectrometer

and

Photon Beamline

Review

Jefferson Lab

January 23 – 24, 2006

Executive Summary

A review of the conceptual design for the Hall D Tagging Spectrometer and Photon Beamline was conducted at Jefferson Lab on January 23-24, 2006. The review committee consisted of Juergen Ahrens (University of Mainz, chair), Bernhard Mecking (JLab), and Alan Nathan (University of Illinois).

The Hall D bremsstrahlung tagging system will create a tagged photon beam with a high degree of linear polarization between 8.4 and 9.0 GeV. This beam will be used in combination with the GlueX detector in Hall D to search for mesons with exotic quantum numbers due to gluonic excitations.

The tagging system consists of two bending magnets, a large size vacuum chamber, electron detectors, collimators and sweeping magnets, and diagnostic equipment for the electron and photon beams.

At the review, the design philosophy and the technical features of all system components were presented in detail. The committee was impressed with the effort of the Collaboration to define the experimental requirements and to work out the optimal solution for the tagging system.

Based on the material presented at the review, the committee has come to the conclusion that the conceptual design of the tagger magnet and the hodoscope systems are well motivated by the Hall D physics goals, and are adequate to achieve those goals. The committee is also convinced that the design parameters of the photon beamline are optimized to achieve the highest possible linear polarization at the envisioned high tagging rates.

The specifications for the incident electron beam need to be better coordinated with the 12 GeV Accelerator Project Team to insure that the properties of the electron beam and the Hall D requirements are matched. Also, the planned assembly and alignment strategy for the tagging system components needs to be consistent with the layout of the tagger area and the capabilities and best practices of the rigging and alignment services available at JLab.

1. Introduction

A review of the conceptual design for the Hall D Tagging Spectrometer and Photon Beamline was conducted at Jefferson Lab on January 23-24, 2006. The review committee consisted of Juergen Ahrens (University of Mainz, chair), Bernhard Mecking (JLab), and Alan Nathan (University of Illinois). The charge to the committee and the agenda of the review are attached to this document.

The Hall D bremsstrahlung tagging system will create a tagged photon beam with a high degree of linear polarization between 8.4 and 9.0 GeV. This beam will be used in combination with the GlueX detector to search for mesons with exotic quantum numbers due to gluonic excitations.

The tagging system consists of two bending magnets, a large size vacuum chamber, electron detectors, collimators and sweeping magnets, and diagnostic equipment for the electron and photon beams.

At the review, the design philosophy and the technical features of all system components were presented in detail. The committee was impressed with the Collaboration effort in defining the experimental requirements as they impact the electron beam, the photon beam, and the tagging system. The committee would like to take this opportunity to thank the presenters for their well-prepared talks and for the frank and open discussions.

2. Experimental Requirements and Layout

The requirements for the electron beam, the photon beam, and the tagger are driven by the GlueX physics program, the goal of which is to map out the spectrum of hybrid mesons produced in photon-induced reactions on the proton and to identify their J^{PC}. Reaching a hybrid mass up to 2.5 GeV requires a photon beam in the energy range of (8-10) GeV, which requires a primary electron beam of energy 12 GeV. The J^{PC} identification requires a partial wave analysis, which in turn requires linearly polarized photons. To achieve these goals, the Hall D Collaboration proposes to use a tagged coherent bremsstrahlung beam in the energy range (8.4-9.0) GeV with 40% linear polarization, an initial intensity of 10^7 tagged photons/s, with a clear upgrade path to 10^8 tagged photons/s. All these parameters were justified with convincing arguments.

The coherent bremsstrahlung photon beam is achieved with a diamond radiator which can be oriented to produce a peak in the photon energy spectrum between 8.4 and 9.0 GeV. Tight collimation of the photon beam (3.4 mm diameter opening at a distance of 80 m) reduces significantly the incoherent unpolarized photons without cutting into the coherent peak. Such tight collimation places stringent (but probably realistic) requirements on the emittance, positioning, and stability of the primary electron beam. There was some discussion of the electron beam halo and its effect on the experiment, leading to the following recommendation:

> **Recommendation:** The Collaboration should work closely with the 12 GeV Accelerator Project Team to insure that the electron beam emittance, positioning, stability, and halo match the requirements of the experiment.

An active collimator in the photon beam (outside of the beam-defining collimator) provides feedback to keep the virtual focus of the electron beam centered on the collimator. This active collimator uses known technology based on a tungsten "pin-cushion" detector.

In order to "tune" the orientation of the diamond crystal, it is necessary for the tagger to have a broad momentum acceptance so as to tag photons in the range (3-11) GeV (with a 12 GeV electron beam). The requirement of modest energy resolution over the (3-11) GeV range and the required much better resolution in the region of the coherent peak leads to the design of a two-hodoscope detector system. The design of the fixed broad-band hodoscope is driven by the requirement to align the crystal by identifying the characteristic structures in the photon energy spectrum expected from a diamond crystal; the hodoscope consists of 140 counters with a 60 MeV spacing. Convincing simulations were shown that such a hodoscope, along with the proposed goniometer, will allow adequate alignment of the crystal. The second hodoscope, which is called the "tagger microscope", covers the photon energy range (8.4-9.0) GeV of the focal plane in 0.1% steps. The segmentation is mainly driven by the desire to count at high rates, up to 500 MHz/GeV. A clever design is proposed that utilizes scintillating fibers in a vertical stack read out by SiPM, leading to signals that will provide more than adequate signal-to-noise ratio. The vertical stack consists of one fiber in the horizontal plane plus two above and two below the plane. By considering only electrons in the central fiber, the tagging efficiency is improved by about 30%, since the outer fibers detect only electrons whose associated photons do not make it through the photon beam collimator. The outer fibers are necessary for alignment and monitoring purposes. A conceptual design for the detector readout exists. The detector and associated readout electronics should be capable of both high counting rate and good time resolution; this leads to another recommendation:

> **Recommendation:** The Collaboration should revisit the time resolution requirement for the tagger hodoscope system to optimize the rejection of accidental coincidences ($\sigma \leq 200$ ps seems to be a reasonable goal).

The Collaboration has done an excellent job simulating potential sources of background in the microscope counters and demonstrating that their experiment can tolerate those backgrounds. The committee would like these calculations to be extended to the entire tagging plane, leading to the recommendation:

> **Recommendation:** Complete the Monte Carlo simulation of the background in the tagging counters caused by backscattering from the dump or the beam line.

3. Tagging System Design

The design of the tagger is fairly straightforward: it consists of two identical homogeneous rectangular magnets and a vacuum system in which the top and bottom pole pieces serve as parts of the vacuum enclosure.

Optics
The two-magnet system, in combination with the quadrupole in front, allows for a straight focal plane. It has a point-to-point focusing optics in the bend plane and it is defocusing vertically. The focusing properties, together with the segmentation required by the high tagging rates, easily allows for a resolution of 10^{-3} in photon energy.

Magnets
The two magnets are identical. They have rectangular pole surfaces and consist of parts that are simple to manufacture. No field clamps are required. The magnets weigh only 38 metric tons each.

Vacuum System
The pole shoes of the dipole magnets serve partly as top and bottom of the vacuum chamber. O-rings make a seal between a lip around the pole pieces and the corresponding surfaces of the vacuum chamber. Since the focal plane is a straight line which allows for a flat exit flange, the exit window for the electrons can be sealed with an O-ring, which can accommodate any window material. An aluminum foil will give better vacuum properties than Kapton. Note that a vacuum of 10^{-3} Torr in the chamber is sufficient.

> **Recommendation:** Consider a clamped Al foil with an O-ring seal for the vacuum chamber exit window.

Detector System
The detector system consists of a fixed hodoscope with moderate resolution that covers the whole length of the focal plane (3-11.4 GeV photon energy) installed 20 cm away from the true focal plane, such that a second movable system with good resolution can be installed directly in the focal plane. This "microscope" has high granularity (5 horizontal rows of 100 detector elements each) which will help to measure the vertical electron distribution and, by excluding the outer channels, to increase the tagging efficiency. During commissioning, the detector system can be energy-calibrated relative to the incoming electron energy by means of the pair spectrometer in the photon beam (equipped with borrowed high granularity devices, e.g. silicon microstrip detectors).

> **Recommendation:** To enable an online monitoring of the vertical electron distribution in the focal plane, the count rate distribution of (at least some of) the microscope detectors outside of the mid-plane should be read out, too.

> **Recommendation:** Include the energy calibration of the tagging system in the commissioning plan.

Assembly, Alignment, and Disassembly:
The optics calculations have shown that the relative positioning of the two magnets within ±2mm does not have an impact on the properties of the instrument. Precise alignment (±0.5mm) is, therefore, needed only for one purpose: to make the vacuum chamber match the two magnets. The present procurement strategy is based on a single vendor taking responsibility for the entire tagging spectrometer. The simple design of the spectrometer permits the system to be put together with low risk at JLab. Therefore, the parts (magnets, vacuum chamber) could be produced by different manufacturers and put together at JLab for the first time. The strategy for supporting, assembling, and aligning the tagging system components has consequences for the beam height and the dimensions of the tagger area (including the access routes). Rigging and alignment strategy and procedures need to be discussed with the relevant groups. Potential disassembly needs to be included in the design studies.

> **Recommendation:** Include as an option in the procurement strategy the possibility that different manufacturers produce the tagging spectrometer components, and that these components are assembled at JLab for the first time.

> **Recommendation:** The Collaboration should work closely with the 12 GeV Civil Construction Project Team to make sure that the tagger area dimensions and the access to the area are consistent with the planned assembly and alignment strategy for the tagging system components.

> **Recommendation:** Contact rigging and alignment services at JLab to make sure that the planned assembly and alignment strategy for the tagging system is feasible and consistent with the best practices of those groups.

> **Recommendation:** The possibility that the system will have to be disassembled should be included in the design studies.

4. Summary

A review of the plans for the Hall D Tagging Spectrometer and Photon Beamline was conducted at Jefferson Lab on January 23-24, 2006. The system will create a tagged photon beam with a high degree of linear polarization between 8.4 and 9.0 GeV which will be used in combination with the GlueX detector to search for mesons with exotic quantum numbers due to gluonic excitations.

The major components of the tagging system are two bending magnets, a large size vacuum chamber, electron detectors, collimators and sweeping magnets, and diagnostic equipment for the electron and the photon beam.

At the review, the design philosophy and the technical features of all system components were presented in detail. The committee was impressed with the effort of the Collaboration to define the experimental requirements and to work out the solution for the tagging system.

Based on the material presented at the review, the committee has come to the conclusion that the conceptual design of the tagger magnet and the hodoscope systems are well motivated by the Hall D physics goals, and are adequate to achieve those goals. The committee is also convinced that the design parameters of the photon beamline are optimized to achieve the highest possible linear polarization at the envisioned high tagging rates.

The specifications for the incident electron beam need to be coordinated with the Accelerator Project Team to insure that the properties of the electron beam and the Hall D requirements are matched. Also, the planned assembly and alignment strategy for the tagging system components needs to be consistent with the layout of the tagger area and the best practices of the rigging and alignment services at JLab.

5. Summary of the Recommendations

1. The Collaboration should work closely with the Accelerator Project Team to insure that the electron beam emittance, positioning, stability, and halo match the requirements of the experiment.

2. The Collaboration should revisit the time resolution requirement for the tagger hodoscope system to optimize the rejection of accidental coincidences ($\leq$200 ps seems to be a reasonable goal).

3. Complete the Monte Carlo simulation of the background in the tagging counters caused by backscattering from the dump or the beam line.

4. Consider a clamped Al foil with an O-ring seal for the vacuum chamber exit window.

5. To enable an online monitoring of the vertical electron distribution in the focal plane, the count rate distribution of (at least some of) the microscope detectors outside of the mid-plane should be read out, too.

6. Include the energy calibration of the tagging system in the commissioning plan.

7. Include as an option in the procurement strategy the possibility that different manufacturers produce the tagging spectrometer components and that these components are assembled at JLab for the first time.

8. The Collaboration should work closely with the 12 GeV Civil Construction Project Team to make sure that the tagger area dimensions and the access to the area are consistent with the planned assembly and alignment strategy for the tagging system components.

9. Contact rigging and alignment services at JLab to make sure that the planned assembly and alignment strategy for the tagging system is feasible and consistent with the best practices of those groups.

10. The possibility that the system will have to be disassembled should be included in the design studies.

Hall D Tagging Spectrometer and Photon Beamline Review Charge

January 23-24, 2006

The scope of this review is the Hall D coherent bremsstrahlung beamline, including the photon tagging system. You are asked to address the following questions:

1. Is the conceptual design of the tagger magnet and hodoscope systems reasonable and adequate to achieve the Hall D physics goals?

2. Have the design parameters of the complete photon beamline been optimized for maximum physics impact? For example, will this design achieve maximal linear polarization up to the highest envisioned rates? Are the beamline diagnostics adequate?

3. Are the specifications for the incident electron beam sufficiently well-defined, reasonable, and consistent with achieving the Hall D physics goals?

Please note that the Hall D detector, electronics, and data acquisition systems have been reviewed previously and these are therefore not the focus of this review. You will be supplied with the reports from these earlier reviews along with your briefing materials.

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January 23-24, 2006

CEBAF Center L102/104

Monday, January 23

8:30 am	**Executive session with lab management**
9:00	Charge – *Will Brooks* [15 minutes]
9:15	Overview – *Elton Smith* [30+15 minutes]
10:00	Photon beam – *Richard Jones* [45+15 minutes]
11:00	**Break** [30 minutes]
11:30	Simulation and backgrounds – *Richard Jones* [30+15 minutes]
12:15 pm	**Lunch** [1:45 minutes]
2:00	Tagger magnet design – *Jim Kellie* [30+15 minutes]
2:45	Tagger spectrometer optics – *Guangliang Yang* [20+10 minutes]
3:15	Fixed array and photon beam monitoring – *Franz Klein* [20+10 minutes]
3:45	**Break** [30 minutes]
4:15	Tagger microscope – *Richard Jones* [20+10 minutes]
5:15	**Executive session** – *Committee prepares questions*
6:00	Questions given to team

Tuesday, January 24

8:30 am	**Executive session with lab management**

09:00 Response to questions, milestones – *Elton Smith* [60 minutes]

10:00 Report writing and presentations as needed – *Committee*

2:00 pm **Executive session with lab management**

3:00 **Closeout**