FTOF NIM Paper Status

The CLAS12 Forward Time-of-Flight System

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Abstract

The Forward Time-of-Flight system for the large-acceptance CLAS12 spectrometer in Hall B at the Thomas Jefferson National Accelerator Facility is described. The system is positioned at distances in the range from 6.2 m to 7.2 m from the beam-target interaction point and spans laboratory polar angles from 5° → 45° and nearly the full azimuth. The system consists of 540 individual scintillation counters with double-ended readout that range in length from 17 cm to 426 cm of discrete widths of 6 cm, 15 cm, and 22 cm, and of discrete thicknesses of 5 cm and 6 cm. The effective counter time resolution for passing charged particles varies from 50 ps for the shortest counters at small angles to 200 ps for the longest counters at large angles. The detectors are part of the forward-angle particle identification system for CLAS12 during offline event reconstruction and are a component of the online data acquisition trigger to select final state event topologies with forward-going charged particles.

PACS:29.40.Mc
Keywords: CLAS12, time of flight, plastic scintillator, particle identification

1. Overview of CLAS12

The Thomas Jefferson National Accelerator Facility (JLab) recently completed a project to double the maximum energy of its electron accelerator from 6 GeV to 12 GeV. The experimental equipment in Hall B forms the large-acceptance CLAS12 spectrometer that is designed to operate with beam energies up to 11 GeV at a beam-target luminosity of up to 10^{35} cm^{-2}s^{-1} to allow for precision measurements of exclusive reactions with polarized beam and both unpolarized and polarized targets. This spectrometer is based on two superconducting magnets, a solenoid in the central region around the target and a toroid at forward angles.

The CLAS12 torus magnet has a six-fold symmetry that divides the forward azimuthal acceptance in the polar angle range from 5° to 35° into six 60°-wide sectors. The torus produces a field primarily in the azimuthal direction of strength $\int B d\ell$ at its nominal full current of 2.8 Tm at 5° and 0.5 Tm at 35°. A set of three multi-layer drift chambers in each sector (before the field, within the field, and after the field) and a forward micromegas vertex tracker are used for charged particle tracking to measure momenta. Downstream of the torus each sector is instrumented with a Cherenkov counter for π/K separation (four sectors are instrumented with low threshold gas Cherenkov counters, one sector is instrumented with a ring-imaging Cherenkov counter, and the final sector will eventually be instrumented with a second ring-imaging Cherenkov counter), three planar layers of scintillation counters for charged particle time measurements called the Forward Time-of-Flight (FTOF) system, and an electromagnetic calorimeter system for electron and neutral particle identification. Just upstream of the torus is a large-volume high-threshold gas Cherenkov counter for electron identification and a tagging system to detect electrons and photons at polar angles below 5°.

The CLAS12 solenoid spans the central angular range from 35° to 125° and has a uniform 5 T central field at its nominal full current. The solenoid serves to focus the low-energy Møller background down the beam pipe to the beam dump away from the acceptance of the spectrometer. The detectors mounted within the

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Outline:

1. Overview of CLAS12
2. CLAS12 Forward Detector Particle Identification
3. Overview of the FTOF System
4. FTOF System Design
5. FTOF Performance
6. Summary

Review Status:

- Reviewer: Beni Zihlmann (Hall D)
  - Comments received 9/10/19
  - Reply to comments 9/29/19
  - Review completed 10/8/19

Remaining Work to Complete Paper:

- None

FTOF NIM Paper Status

Specs: 90-160 ps 60-110 ps 145-160 ps

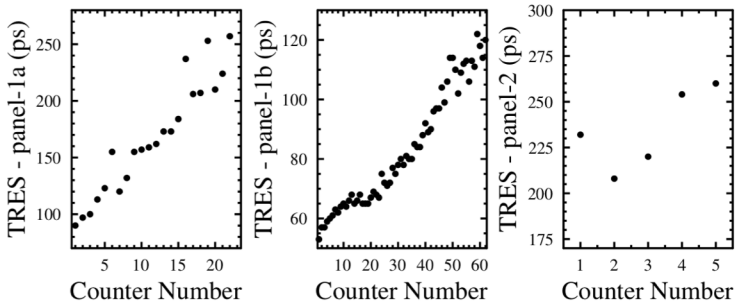

Figure 25: The measured effective time resolution (ps) vs. counter number for each of the FTOF counters in sector 1 as determined using final state leptons and pions for panel-1a and panel-1b and pions and protons for panel-2.

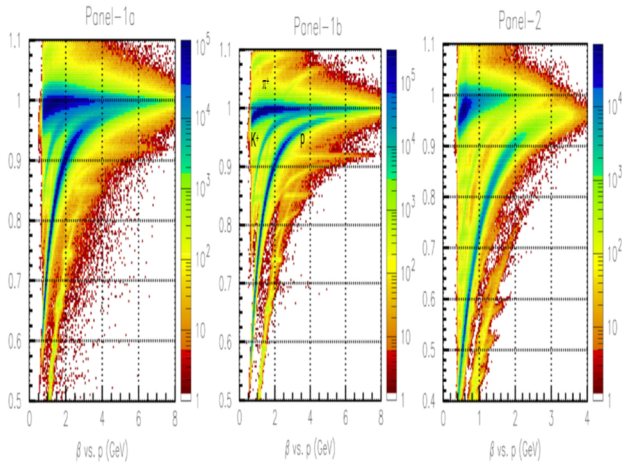

Figure 30: Velocity of positive hadrons (β) versus momentum (GeV) for all counters in panel-1a (left), panel-1b (middle), and panel-2 (right) from beam data with a 10.6 GeV electron beam incident on a liquid-hydrogen target.

Specs (4σ)	
π/K	2.8 GeV
K/p	4.8 GeV
π/p	5.4 GeV

Main performance results shown:

- Counter time resolution
- β vs. p (pos)
- M^2 (pos) vs. p
- Overview paper includes:
  - M^2 (pos, neg)
  - β vs. p (pos) p1b only

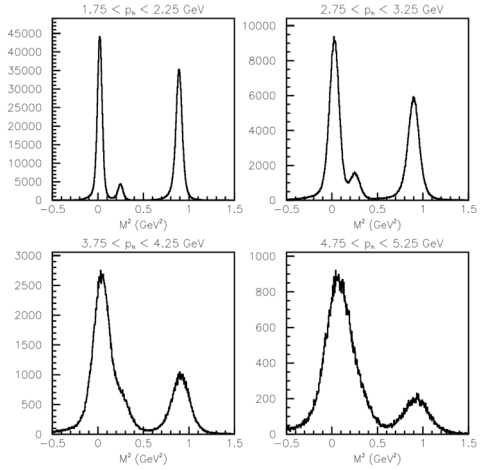

Figure 31: Reconstructed mass squared (GeV^2) for positively charged particles from the timing in the panel-1b FTOF counters from beam data with a 10.6-GeV electron beam incident on a liquid-hydrogen target. The data are sorted into four bins in hadron momentum (UL) [1.75:2.25] GeV, (UR) [2.75:3.25] GeV, (LL) [3.75:4.25] GeV, and (LR) [4.75:5.25] GeV and are based on the current CLAS12 detector calibrations, detector alignments, and knowledge of the torus and solenoid field maps.

CTOF NIM Paper Status

The CLAS12 Central Time-of-Flight System

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Abstract

The Central Time-of-Flight system for the large-acceptance CLAS12 spectrometer in Hall B at the Thomas Jefferson National Accelerator Facility is described. The system consists of a hermetic barrel of 48 scintillation counters at a radius of 25 cm from the beamline. The wedge-shaped counters are 3.4 cm wide, 3.0 cm thick, and 90 cm long, and span a range of polar angles relative to the center of the nominal target location from roughly 35° to 125°. The counters reside in the 5-T field of the CLAS12 superconducting solenoid. The bars are read out via bent light guides 1 m long on the upstream end of the counters and 1.6 m long on the downstream end. The phototubes are shielded by a multi-layer dynamical magnetic shield system to reduce the local fringe fields in the range from 400 G to 1000 G down to the level of 0.2 G at the location of the photocathodes. The average effective time resolution of the counters is 80 ps.

PACS:29.40.Mc
Keywords: CLAS12, time of flight, plastic scintillator, particle identification

1. Overview of CLAS12

The Thomas Jefferson National Accelerator Facility (JLab) recently completed a project to double the maximum energy of its electron accelerator from 6 GeV to 12 GeV. The experimental equipment in Hall B forms the large-acceptance CLAS12 spectrometer that was designed to operate with beam energies up to 11 GeV at a nominal beam-target luminosity of 1×10^{35} cm^{-2}s^{-1} to allow for precision measurements of exclusive reactions with polarized beam and both unpolarized and polarized targets. This spectrometer is based on two superconducting magnets, a solenoid in the central region about the target and a toroid at forward angles. See Ref. [1] (and references therein) for more complete information on CLAS12 and its individual subsystems.

The CLAS12 torus has a six-fold symmetry that divides the forward azimuthal acceptance in the polar angle range from 5° to 35° into six 60°-wide sectors. The torus produces a field primarily in the azimuthal direction of strength $\int B d\ell$ at its nominal full current of 2.8 Tm at 5° and 0.5 T at 35°. A set of drift chambers in each sector and a forward vertex tracker are used for charged particle tracking to measure momenta. Downstream of the torus each sector is nominally instrumented with a Cherenkov counter for π/K separation, a scintillation counter hodoscope for charged particle time measurements, and an electromagnetic calorimeter system for electron and neutral particle identification. Just upstream of the torus is a large-volume high-threshold gas Cherenkov counter (HTCC) [2] for electron identification and a tagging system to detect electrons and photons at polar angles below 5°.

The CLAS12 solenoid spans the central angular range from 35° to 125° and has a uniform 5 T central field. The solenoid serves to focus the low-energy Møller background down the beam pipe to the beam dump away from the acceptance of the spectrometer. The detectors mounted within the solenoid include a thick scintillation counter barrel for neutron identification called the Central Neutron Detector (CND) [3], a barrel of thin scintillation counters for charged-particle time measurements called the Central Time-of-Flight (CTOF) system, and the central tracking system (composed of the Silicon Vertex Tracker [4] and the Barrel Micromegas Tracker [5]) about the target.

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Outline:

1. Overview of CLAS12
2. Overview of the CTOF System
3. Design of the CTOF System
4. CTOF Performance
5. Summary

Review Status:

- Reviewer: Brian Raue (FIU)
  - Comments received 9/18/19
  - Reply to comments 10/10/19
  - Review completed 10/21/19

Remaining Work to Complete Paper:

- None

CTOF NIM Paper Status

Specs: 80 ps

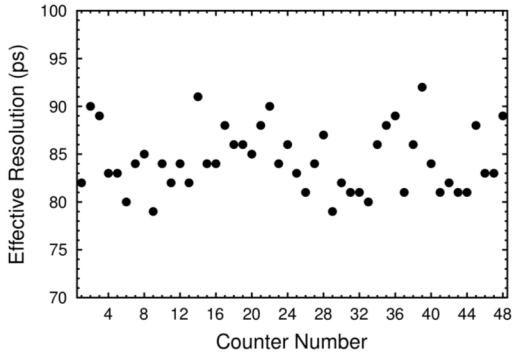

Figure 30: The measured effective time resolution (ps) vs. counter number for each of the CTOF counters from beam data for a 10.6 GeV electron beam incident upon a liquid-hydrogen target with the solenoid at full field.

Main performance results shown:

- Counter time resolution
- β vs. p (pos, neg)
- M^2 (pos, neg)
- M vs. p (pos)
- Overview paper includes:
  - M^2 for pos, neg
  - β vs. p (pos) p1b only

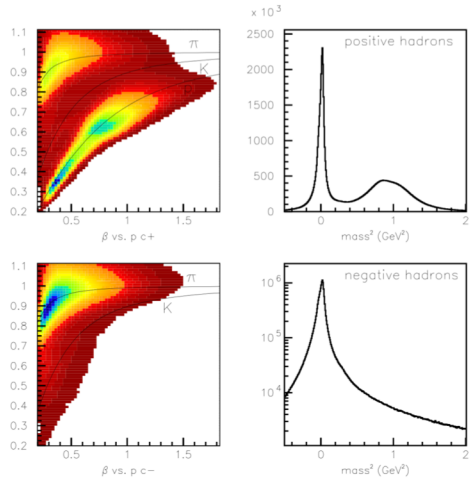

Figure 34: Reconstructed β vs. momentum (GeV) (left) and mass squared (GeV^2) (right) distributions for positively charged particles (top) and negatively charged particles (bottom) for all CTOF counters from beam data with a 10.6 GeV electron incident upon a liquid-hydrogen target. The overlaid curves show the expected locations of charged pions (π), kaons (K), and protons (p).

Specs (3σ)	
π/K	0.58 GeV
K/p	0.93 GeV
π/p	1.14 GeV

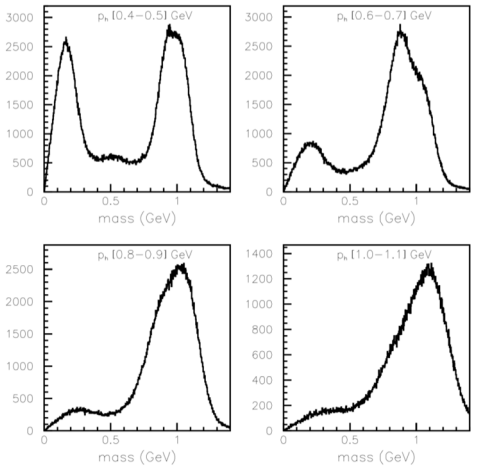

Figure 35: Reconstructed mass (GeV) for positively charged particles from the timing in CTOF counters from beam data with a 7.5-GeV electron beam incident on a liquid-hydrogen target. The data are sorted into four bins in hadron momentum as indicated and are based on the current CLAS12 detector calibrations, detector alignments, and event reconstruction.