Deep Underground Neutrino Experiment (DUNE)

Technical Proposal

Volume 2: *The Single-Phase Far Detector*

December 19, 2017

DEEP UNDERGROUND NEUTRINO EXPERIMENT

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Design Motivation

1.1 ??

Chapter 2

Overview of the Single-Phase Detector Module Design

:fdsp-ov

2.1 ??

sp-ov-??

Include an image of the entire module, indicating its parts.

Chapter 3

Anode Plane Assemblies

3.1 Overview of Anode Plane Assemblies

Some initial text suggested by Anne (in fact the APA section in the protodune SP TDR has a lot of good descriptive text)

3.1.1 Introduction

Anode Plane Assemblies (APAs) are the far detector elements utilized to sense ionization created by charged particles traversing the liquid argon volume inside the single-phase TPC. The planes are interleaved with Cathode Plane Assemblies (CPAs), as shown in Figure..., to establish the required electric fields and form drift volumes for the charged particles.

Include an image of the overall system, indicating its parts. Show how the system fits into the overall detector.

The operating principle is illustrated in Figure... (add figure)

An APA consists of a rectangular framework with a fine wire mesh stretched across it, over which are wrapped four layers of sense and shielding wires... ...

3.1.2 Design Considerations

The APA design must enable identification of minimum-ionizing particles (MIPs). This is a function of several detector parameters, including: argon purity, drift distance, diffusion, wire pitch, and Equivalent Noise Charge (ENC). DUNE-SP requires that MIPs originating anywhere inside the active volume of the detector be reconstructed with 100% efficiency. The choice of wire pitch, of $\sim$5 mm, for the wire layers on the APA, combined with key parameters for other TPC systems (described in their respective sections of the TDR), is expected to enable the 100% MIP identification efficiency.

DUNE-SP requires that it be possible to determine the fiducial volume (via analysis) to <1%, which in turn requires reaching a vertex resolution of $\sim$1.5 cm along each coordinate direction. (The fiducial volume, among other factors, determines the number of target nucleons, which is a component in cross section measurements.) The fine granularity of the APA wires enables excellent precision in identifying the location of any vertices in an event, (e.g., the primary vertex in a neutrino interaction or gamma conversion points in a π^0 decay), which has a direct impact on reconstruction efficiency. In practice, the resolution on the drift-coordinate (x) of a vertex or hit will be better than that on its location in the $y - z$ plane, due to the combination of drift-velocity and electronics sampling-rate...

...

Anne suggests: Within this section add ref to requirements document when it's ready, and maybe list the most important half dozen in a table here). E.g.,

Table 3.1: Important requirements on the APA design (Sample only!)

Requirement
The APA wire spacing shall be chosen to provide high efficiency in distinguishing electron shower from photon showers
The APA wire planes shall be oriented relative to each other to optimize the measurement of high energy and low energy tracks from accelerator
...

By the end of the volume, for every requirement listed in this section, there should exist an explanation of how it will be satisfied.

3.1.3 Scope

The scope of the Anode Plane Assembly (APA) system includes the continued procurement of materials for, and the fabrication, testing, delivery and installation of the following systems:

- stainless steel APA frame, 150 per module
- wire mesh that covers the frame on both sides, ...

3.2 Design of Anode Plane Assemblies

3.2.1 Frames

Include an image of the subsystem (frame), indicating its parts. Show how the system fits into the overall system (APA).

3.2.2 Boards

Include an image of the subsystem (boards), indicating its parts. Show how the system fits into the overall system (APA).

3.2.3 Wires

Include an image of the subsystem (wires), indicating its parts. Show how the system fits into the overall system (APA).

3.2.4 Quality Assurance

3.3 Production and Assembly of Anode Plane Assemblies

3.3.1 Wire Winding Machine

3.3.2 Tooling

3.3.3 Assembly Procedures

3.4 Anode Plane Assembly Interfaces

Include an image of each interface in appropriate section.

3.4.1 LBNF Cryostat and Detector Support Structure

3.4.2 Photon Detection System

3.4.3 TPC Electronics

3.5 Anode Plane Assembly installation, Integration and Commissioning

3.5.1 Transport and Handling

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3.5.3 Calibration

3.6 Quality Control for Anode Plane Assemblies

3.6.1 Protection and Assembly (Local)

3.6.2 Post-factory Installation (Remote)

3.7 Anode Plane Assembly Safety

3.8 Anode Plane Assembly Organization

3.8.1 Consortium Organization

3.8.2 Planning Assumptions

3.8.3 WBS and Responsibilities

3.8.4 High-level Cost and Schedule

Chapter 4

High Voltage System

:fdsp-hv

4.1 Overview of High Voltage System

sp-hv-ov

Some initial text suggested by Anne (in fact the APA section in the protodune SP TDR has a lot of good descriptive text)

4.1.1 Introduction

hv-intro

The High Voltage System provides the bias voltage to the CPAs to create the 500 V/cm drift field... The system includes (whatever it includes), as shown in Figure....

Include an image of the overall system, indicating its parts. Show how the system fits into the overall detector.

The operating principle is illustrated in Figure figure-label **??**... (add figure)

Figure 4.1: required full caption (Credit: xyz) fig:figu

4.1.2 Design Considerations

s-consid

The HV system design must enable... ...

Anne suggests: Within this section add ref to requirements document when it's ready, and maybe list the most important half dozen in a table here). E.g.,

Table 4.1: Important requirements on the HV system design

Requirement
...

By the end of the volume, for every requirement listed in this section, there should exist an explanation of how it will be satisfied.

4.1.3 Scope

The scope of the HV system includes the continued procurement of materials for, and the fabrication, testing, delivery and installation of the following systems:

Whatever the items are...

- power supplies
- feedthroughs, ...

4.2 Design of the High Voltage System

Include an image of the subsystem, indicating its parts. Show how the system fits into the overall system).

not sure what subsections are needed: power supplies, feedthroughs?

4.2.1 ??

4.2.2 Quality Assurance

4.3 Production and Assembly of the High Voltage System

4.3.1 Power Supplies?

4.3.2 Feedthroughs?

4.3.3 Tooling

4.3.4 Assembly Procedures

4.4 High Voltage System Interfaces

Include an image of each interface in appropriate section.

Add in appropriate subsections for the pieces that HV interfaces with. These initial ones may not be right.

4.4.1 CPA and Field Cage

4.4.2 Photon Detection System

4.4.3 TPC Electronics

4.5 High Voltage System Installation, Integration and Commissioning

4.5.1 Transport and Handling

4.5.2 Integration with (CPA, FC???)

4.5.3 Calibration?

4.6 Quality Control for High Voltage System

4.6.1 Protection and Assembly (Local)

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4.7 High Voltage Safety

4.8 High Voltage System Organization

4.8.1 Consortium Organization

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4.8.4 High-level Cost and Schedule

Chapter 5

TPC Electronics

5.1 Overview of TPC Electronics System

Some initial text suggested by Anne (in fact the APA section in the protodune SP TDR has a lot of good descriptive text)

5.1.1 Introduction

The TPC Electronics System provides the ... The system includes (whatever it includes), as shown in Figure....

Include an image of the overall system, indicating its parts. Show how the system fits into the overall detector.

The operating principle is illustrated in Figure **??**... (add figure)

Figure 5.1: required full caption (Credit: xyz)

5.1.2 Design Considerations

The TPC Electronics system design must enable... ...

Anne suggests: Within this section add ref to requirements document when it's ready, and maybe list the most important half dozen in a table here). E.g.,

Table 5.1: Important requirements on the TPC Electronics system design

Requirement
...

By the end of the volume, for every requirement listed in this section, there should exist an explanation of how it will be satisfied.

5.1.3 Scope

The scope of the TPC Electronics system includes the continued procurement of materials for, and the fabrication, testing, delivery and installation of the following systems:

Whatever the items are...

- power supplies
- feedthroughs, ...

5.2 Design of the TPC Electronics System

Include an image of the subsystem, indicating its parts. Show how the system fits into the overall system).

not sure what subsections are needed: power supplies, feedthroughs?

5.2.1 ??

5.2.2 Quality Assurance

5.3 Production and Assembly of the TPC Electronics System

5.3.1 ?

5.3.2 Tooling

5.3.3 Assembly Procedures

5.4 TPC Electronics System Interfaces

Include an image of each interface in appropriate section.

Add in appropriate subsections for the pieces that TPC Electronics interfaces with. These initial ones may not be right.

5.4.1 ?

5.5 TPC Electronics System Installation, Integration and Commissioning

5.5.1 Transport and Handling

5.5.2 Integration with (???)

5.5.3 Calibration?

5.6 Quality Control for TPC Electronics System

5.6.1 Protection and Assembly (Local)

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5.7 TPC Electronics System Safety

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