Major comments to the second version of the DUNE ND CDR

Deep Underground Neutrino Experiment (DUNE)

Near Detector Conceptual Design Report

July 13, 2020

The DUNE Collaboration

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Table 1.7 SAND Capabilities Requirements

CDR July 13, 2020 (v2)

Table 1.7: Capability requirements for SAND.

Label	Description	Specification	Rationale	Ref. Req
ND-C5.1	Statistics of identified ν_μ CC events	For p_μ>20 tons, $E_\nu > 5$ tons	SAND must collect and identify enough ν_μ CC interactions to perform beam monitoring on a weekly basis.	ND-M8
ND-C5.2	E_ν, p_μresolution	<1 GeV for either	SAND must have sufficient muon resolution to detect spectral variations in ν_μ CC events from a representative set of variations in a week.	ND-M9
ND-C5.3	Vertex reconstruction	<50 cm	SAND must have the ability to vertex neutrino interactions into upper/lower, left/right regions relative to the nominal beam center.	ND-M9
ND-C5.4	Track timing	<20 ns in tracker, <400 ps on hits in ECAL	SAND must have timing to identify and separate activity occurring within the neutrino beam delivery window.	ND-M9, ND-M10

Table 1.2: Measurement requirements for ND .

Label	Description	Spec.	Rationale	System	Ref. Req.
ND-M8	Monitor the rate of neutrino interactions on-axis	<1% in a week	The ND must have a component that remains on-axis where beam monitoring is most sensitive and collects a sufficient number of ν_μ CC events.	SAND	ND-O5
ND-M9	Monitor the beam spectrum on-axis	N/A	The ND must use spectrum information to detect representative changes in the beam line.	SAND	ND-O5
ND-M10	Assess External Background	N/A	The ND must measure external backgrounds, which include cosmic and beam-induced activity.	ND-LAr, ND-GAr, SAND	ND-O6

CDR May 12, 2020 (v1)

Table 1.7: Capability requirements for SAND .

Label	Description	Specification	Rationale	Ref. Req
ND-C5.1	Statistics of identified ν_μ CC events	< 1% across p_μ bins each week	SAND must collect and identify enough ν_μ CC interactions to perform beam monitoring on a weekly basis.	ND-M8
ND-C5.2	Muon resolution		SAND must have sufficient muon resolution to detect spectral variations in ν_μ CC events from a representative set of variations in a week.	ND-M9
ND-C5.3	Vertex reconstruction		SAND must have the ability to vertex neutrino interactions into upper/lower, left/right regions relative to the nominal beam center.	ND-M9

Our Proposed changes (submitted May 21, 2020)

Table 4: Capability requirements for System for on-Axis Neutrino Detection (SAND) .

Label	Description	Specification	Rationale	Ref. Req
ND-C5.1	Statistics of identified ν_μ CC events	< 1% across p_μ bins each week	SAND must collect and identify enough ν_μ CC interactions to perform beam monitoring on a weekly basis.	ND-M8
ND-C5.2	Lepton Identification		SAND must be able to identify and reconstruct the change and momentum of $\mu^\pm$ and $e^\pm$ for beam monitoring and redundant on axis flux measurements	ND-M9, ND-M3, ND-M4, ND-M5, ND-M6
ND-C5.3	Muon reconstruction		SAND must have sufficient momentum resolution to detect variations in the beam settings from the reconstructed neutrino energy.	ND-M9, ND-M4, ND-M5
ND-C5.4	Charged hadron reconstruction		The large fraction of ν inelastic interactions implies the need of an accurate reconstruction of charged hadrons	ND-M9, ND-M4, ND-M5, ND-M6
ND-C5.5	Neutral particle reconstruction		SAND must be able to detect π^0, γ, K_0 and neutrons for an accurate reconstruction of the neutrino energy	ND-M9, ND-M4, ND-M5, ND-M6
ND-C5.6	Vertex reconstruction		SAND must reconstruct the vertex neutrino interactions with high accuracy	ND-M9, ND-M10
ND-C5.7	Timing resolution		SAND must have high time resolution to reject external background	ND-M9, ND-M10

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ND-C5.3	Vertex reconstruction	<50 cm	SAND must have the ability to vertex neutrino interactions into upper/lower, left/right regions relative to the nominal beam center.	ND-M9
ND-C5.4	Track timing	<20 ns in tracker, <400 ps on hits in ECAL	SAND must have timing to identify and separate activity occurring within the neutrino beam delivery window.	ND-M9, ND-M10

Our General Comment

With the specifications given in the table SAND cannot perform the monitoring of the beam variations on weekly basis.

As demonstrated by dedicated studies (e.g.DocDB 13262), it is necessary to measure the neutrino energy with adequate resolution to be sensitive to most of the considered beam variations in one week. With the muon energy alone SAND sensitivity to several variations would be lost/greatly reduced.

Results ECAL+STT - 1 week

Proton beam parameter	Variation	ECAL				ECAL+STT			
		$\sqrt{\Delta\chi^2(E_\nu)}$ true	$\sqrt{\Delta\chi^2(E_\nu)}$ rec	$\sqrt{\Delta\chi^2(E_\mu)}$ true	$\sqrt{\Delta\chi^2(E_\mu)}$ rec	$\sqrt{\Delta\chi^2(E_\nu)}$ true	$\sqrt{\Delta\chi^2(E_\nu)}$ rec	$\sqrt{\Delta\chi^2(E_\mu)}$ true	$\sqrt{\Delta\chi^2(E_\mu)}$ rec
Horn current	+3 kA	10.4	8.7	5.1	5.0	12.6	10.3	6.1	6.0
Water layer thickness	+0.5 mm	4.6	4.0	2.9	2.9	5.5	4.7	3.5	3.4
Decay pipe radius	+0.1 m	6.5	5.9	3.5	3.4	7.9	6.9	4.1	4.1
Proton target density	+2%	5.9	5.3	4.3	4.2	7.0	6.1	5.0	4.9
Proton beam sigma	+0.1 mm	4.2	3.8	3.0	3.0	5.1	4.4	3.5	3.4
Proton beam off set X	+0.45 mm	5.0	4.1	3.0	3.0	5.8	4.7	3.5	3.4
Proton beam theta phi	0.07 mrad θ, 1.57 ϕ	0.7	0.4	0.2	0.2	0.9	0.5	0.3	0.3
Proton beam theta	0.070 mrad	0.8	0.5	0.3	0.3	1.0	0.6	0.3	0.3
horn 1 X shift	+0.5 mm	4.0	3.3	2.1	2.0	4.8	3.8	2.4	2.4
horn 1 Y shift	+0.5 mm	4.5	3.7	2.4	2.4	5.3	4.2	2.7	2.7
horn 2 X shift	+0.5 mm	0.6	0.4	0.3	0.3	0.8	0.5	0.4	0.4
horn 2 Y shift	+0.5 mm	0.6	0.3	0.2	0.2	0.7	0.4	0.3	0.2

Cylindrical symmetry, X assymetry, Y assymetry

There is a significative difference between true and reconstructed → resolution is important.

Neutrino energy is more sensitive with respect to muon momentum.

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Row 1 Column 3 : the specification should be given in number of events

Row 2 Column 3: an energy resolution of 1 GeV would completely wash out any spectral variation.
Split the specifications in two separate ones, for E_nu and p_mu,
" p_mu resolution <5%. E_nu resolution <20%"

Row 3 Column 2: "vertex reconstruction"
Change to " vertex position resolution"

Row 3 Column 3: a vertex reconstruction with an accuracy of 50 cm is incompatible with the requirement of ND-M9.
Change to "Vertex resolution < 5 cm"

Row 4 Column 2 "Track timing"
Change to "Time resolution"

Row 4 Column 3 In a 20 ns time interval tracks can cross the entire detector: impossible to separate external background.
Change to "Time resolution < 1ns in tracker, 250 ps in ECAL"

Chapter 1: Introduction/Overview of the Near Detector

1-6 lines 23-29 SAND consists of a massive plastic scintillator target surrounded by low-mass tracking and an ECAL inside a large solenoidal magnet. The plastic scintillator target is the 3D scintillator tracker (3DST), which is made up of 1 cm cubes that are read out along each of three orthogonal dimensions. The design eliminates the typical planar-strip ambiguity common to detectors using scintillator, leading to improved acceptance for final state particles traveling at large angles relative to the beam direction.

Change to SAND consists of a solenoidal superconducting magnet, a 4π electromagnetic calorimeter, and an inner magnetized volume instrumented with a composite tracking and target system. The reference design includes a 3D scintillator tracker (3DST) system and a low-density tracker based either on time projection chamber (TPC) or on straw tube tracker (STT). The 3DST is made up of 1 cm cubes that are read out along each of three orthogonal dimensions.
An alternative tracker design is based on filling the entire magnetic volume with orthogonal planes of straw tubes interleaved with interchangeable targets. The reference and alternative options for the tracking and target system are all under active consideration, and continuing studies will allow a final decision on tracker and target system technology for the ND technical design report. Both tracking configurations are also complemented by a thin liquid argon active target located inside the electromagnetic calorimeter and upstream of the tracking system.

(Already proposed in May22,2020)

5-135 Line 24 "sufficient muon energy resolution in nu_mu events"
Change to "sufficient neutrino energy resolution in CC neutrino interactions"

5-136 Line 1 "The muons emanating from those vertices must be reconstructed with good charge identification"

Change to "Charged particles originating from the interaction vertices must be reconstructed with good charge identification"

5-136 Lines 14-15 "Because SAND is required to measure the sign and momentum of muons it is also capable of similar measurements of charged hadrons.

Change to "SAND is required to measure the sign and momentum of muons and of charged hadrons"

5-137 Line 24 "The concept of a thin LAr target is also being considered for inclusion in both designs."

Change to "A thin LAr target is also foreseen in both designs."