

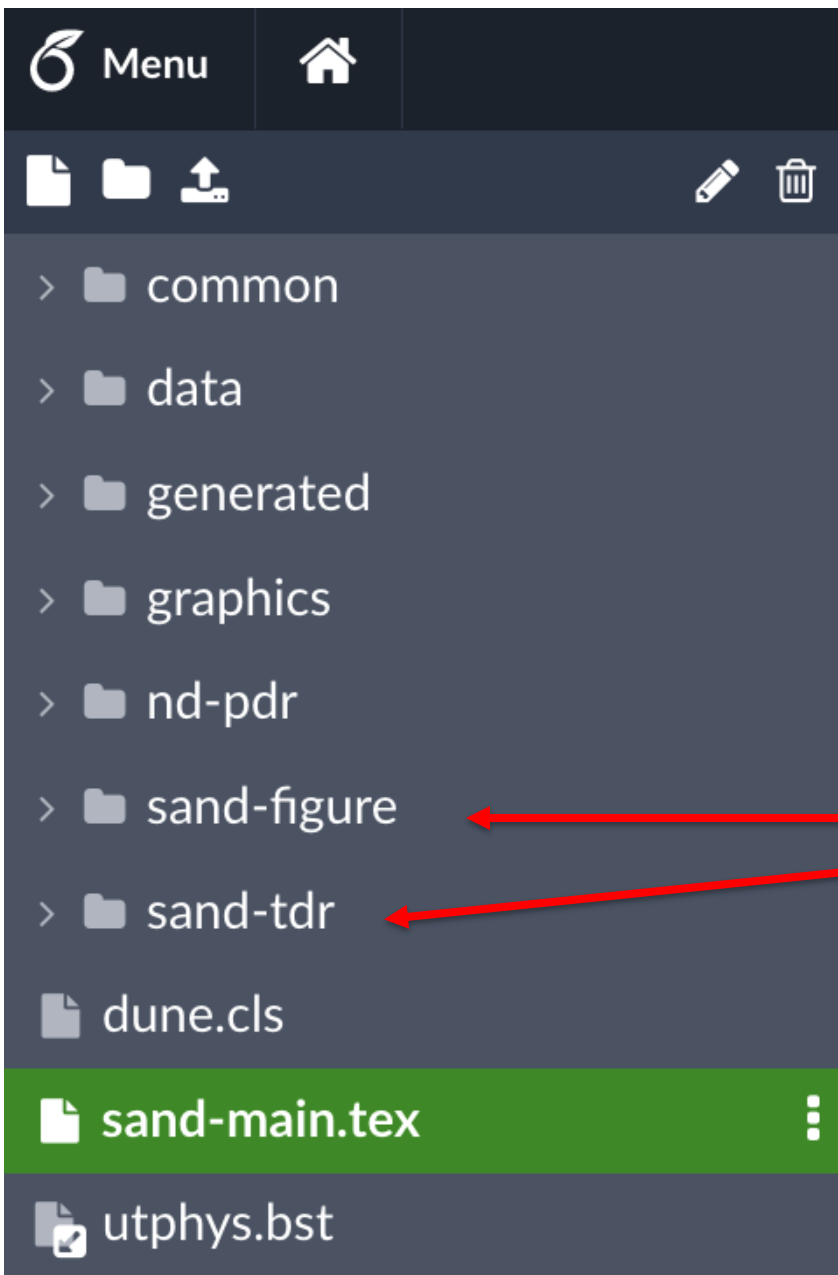
# The Technical Design Report (TDR) for SAND in the ND complex

Paolo Bernardini, Lecce  
SAND General Meeting  
November 12<sup>th</sup>, 2024



UNIVERSITÀ  
DEL SALENTO  
L'Ateneo tra i due mari





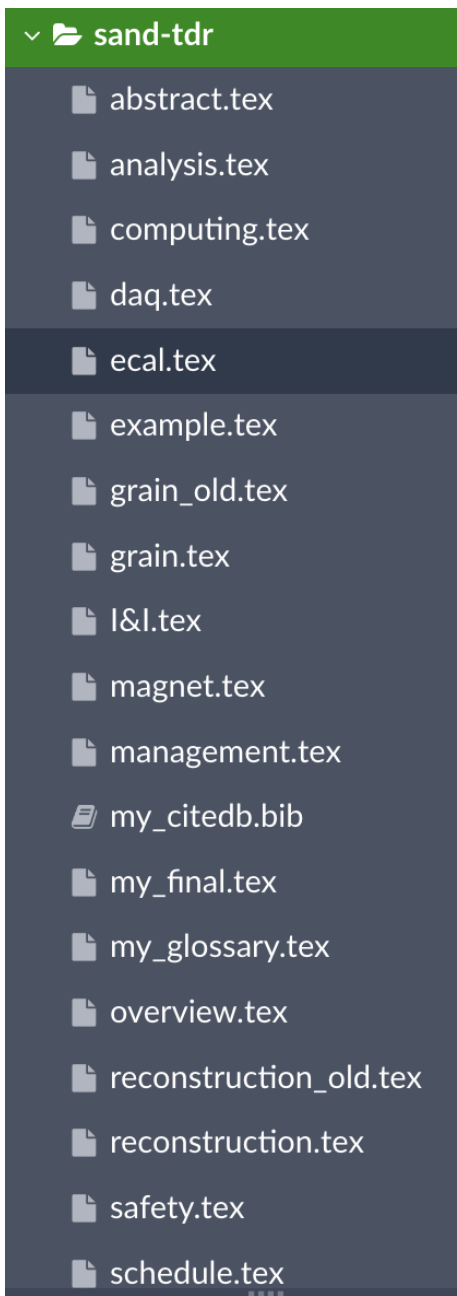
An overleaf is adopted according to  
**LATEX conventions for LBNF/DUNE documents**

shared with **SAND people + J. Lewis**  
**H.A. Tanaka (ND tech. coordinator)**  
**A.E. Heavey (scientific editor)**

The figures in **sand-figure** and the files in **sand-tdr**  
are input for **sand-main.tex**

Dedicated overleaf for **GRAIN**  
and **SOFTWARE Working Groups**,  
periodically copied in main overleaf





# Sections in the SAND chapter

- 1. Overview (requirements & opportunities)
- 2. Lead/Scintillating-Fiber Calorimeter (ECAL)
- 3. Superconducting Magnet
- 4. Liquid Argon Active Target (GRAIN)
- 5. Tracker
- 6. Data Acquisition (DAQ) Architecture
- 7. Detector Control (DCS)
- 8. Detector Safety System (DSS)
- 9. Software & Computing
- 10. Event Reconstruction
- 11. Analysis
- 12. Installation & Integration
- 13. Safety
- 14. Organization & Management
- 15. Time Schedule
- 16. Possible Upgrades

*Calibration spread  
in several sections*

*my\_glossary.tex* ← New DUNE words and new references  
*my\_citedb.bib* ← in evidence (at the file end)

1.1	Overview . . . . .		<u>1</u>
1.1.1	Requirements and SAND Role . . . . .		<u>2</u>
1.1.2	The Overall Design of SAND . . . . .	7 pages	<u>3</u>
1.1.3	Derived SAND Capabilities . . . . .		<u>4</u>
1.1.4	Opportunities for SAND . . . . .		<u>6</u>

Updated according to the task-force document  
(approved in DUNE general meeting, May 2024)

To do: careful reading and corrections (LS e CM)

Possible improvements (mainly in Sec. 1.1.4)

1.2	Lead/Scintillating-Fiber Calorimeter (ECAL)	8
1.2.1	Design and Structure	8
1.2.2	Performance in KLOE Experiment	12
1.2.3	Requirements for ECAL	18
1.2.4	Calibration and Monitor System	18
1.2.5	Electronics	19
1.2.6	Dismounting Procedures	54
1.2.7	Revamping and Test before SAND Installation	66
1.2.8	Installation & Integration	69
1.2.9	Risk Management	70
1.2.10	Schedule and Milestones	72

66 pages



Draft available in time



July 22-23, 2024 - Preliminary Design Review (PDR)

To be updated according to PDR recommendations

Expand hazard & risk analysis, shipping details, resources loaded schedule and cost analysis Gantt & milestones to be updated

**Refinements expected within November 30**

1.3	The Superconducting Magnet	74
1.3.1	Magnet Specification	74
1.3.2	Magnet Maintenance and Revamping Options	78
1.3.3	Activities at Laboratori Nazionali di Frascati	86
1.3.4	Installation & Integration at Fermilab	91
1.3.5	Risk Management	94
1.3.6	Schedule and Milestones	97

25 pages

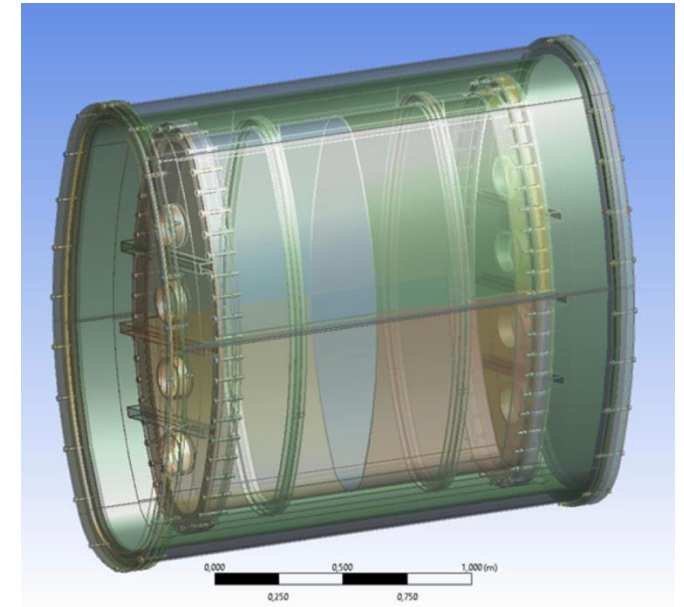


- ✓ Draft available in time
- ✓ July 22-23, 2024 - Preliminary Design Review (PDR)
- To be updated according to recommendations
- Update of design, dismounting and shipping of the yoke
- Possible improvements (mainly in Sec.s 1.3.4, 1.3.5, 1.3.6)

**Refinements expected within November 30**

1.4	LAr Active Target (GRAIN)	98
1.4.1	Introduction and Physics Requirements	98
1.4.2	Mechanical Design	98
1.4.3	Optical Detector	100
1.4.4	Readout System	102
1.4.5	Data Acquisition and Slow Control System	105
1.4.6	Neutrino Event Reconstruction	105
1.4.7	Calibration System	124
1.4.8	Cryogenic System	124
1.4.9	First Commissioning in Laboratori Nazionali di Legnaro	124
1.4.10	Integration and Installation in SAND	124

30 pages



**Present**

- physics requirements
- SiPM arrays
- mechanics
- ASIC requirements
- lens description

**To be completed**

- coded mask description
- 3D reconstruction\*
- reconstruction with voxels\*
- performances

\* in another section ?

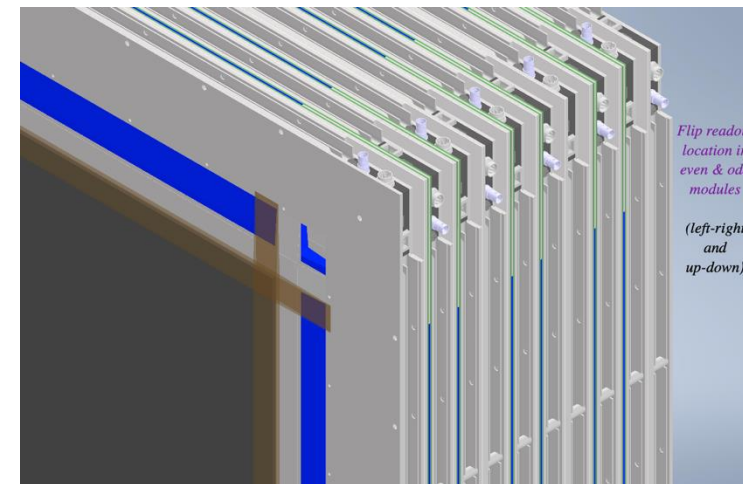
**To be written**

- prototypes
- calibration
- DAQ & slow control
- cryogenics
- calorimetry
- integration & installation

~~Next check: November 15~~      ~~Complete draft: November 30~~

1.5	Tracker	125
1.5.1	STT	125
1.5.2	Drift Chamber	129
1.5.3	Gas System	130

6 pages



Present - figures and tables about STT geometry

Missing - 14 subsections about STT  
 - subsection about Drift Chamber  
 - subsection about Gas System

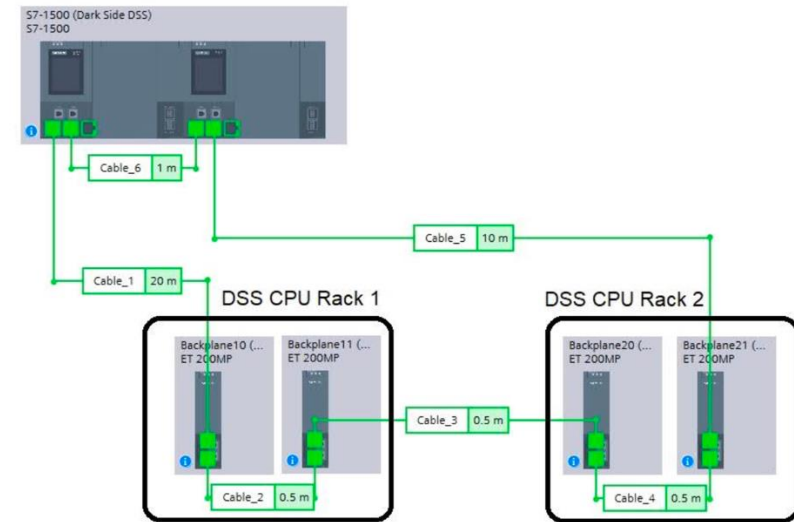
Next check: November 30

Complete draft: December 2024



1.6	DAQ Architecture	131
1.6.1	DAQ Interfaces	131
1.6.2	Synchronous Interfaces	132
1.7	Detector Control (DCS)	132
1.7.1	DCS Devices	133
1.7.2	DCS Unifying Standards	133
1.7.3	Detector Operation	134
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1.7.5	DAQ-DCS Interfaces	135
1.8	Detector Safety Systems (DSS)	135
1.8.1	DSS Devices	136
1.8.2	DSS Control Hardware	136
1.8.3	DSS Rack	137

8 pages



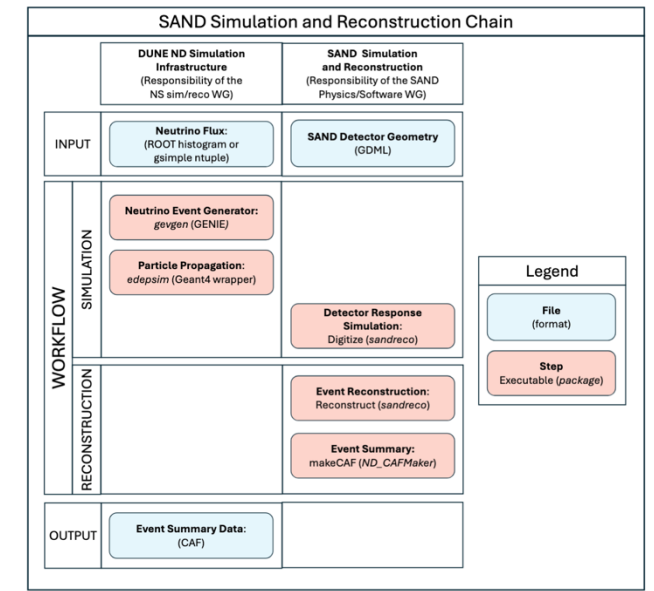
Ready draft - DSS

To be completed - DAQ (expected data rates, interfaces)  
 - DCS (preliminary layout, DAQ interfaces)

Complete draft: December ??

1.9	Software and Computing	141
1.9.1	Code	141
1.9.2	Simulations	141
1.9.3	Algorithms for Reconstruction	151
1.9.4	Data Formats	161
1.9.5	Computing resources	165
1.9.6	Visualization	165
1.9.7	Integration	165

26 pages



**Present**

- GRAIN simulation
- ECAL simulation & clustering
- Kalman filter (with B)
- edep-sim output

**Missing**

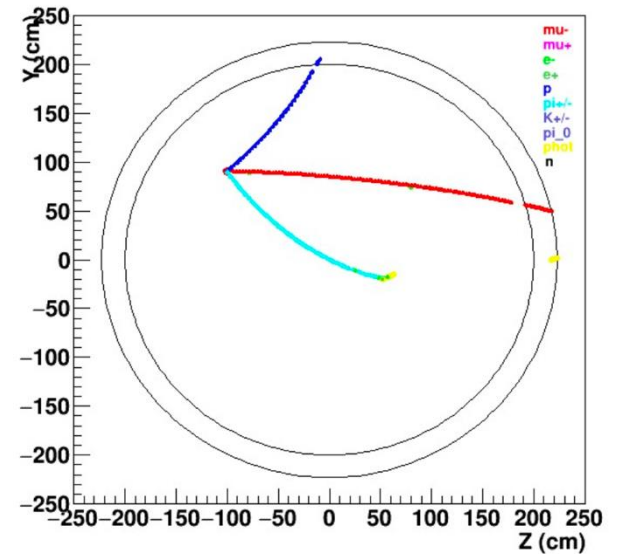
- simulation of  $\nu$  fluxes, geometries
- reconstruction in GRAIN\*, ECAL
- Common Analysis Files
- computing architecture
- event display
- integration

\* in another section ?

Complete draft: December 2024

1.10 Event Reconstruction (Performance)	163
1.10.1 Single Particle Reconstruction	163
1.10.2 Particle Identification	184
1.10.3 Neutrino Interaction Identification in the Spill	203
1.10.4 Event Reconstruction in GRAIN	203
1.10.5 Tracker and CC Acceptance for Muons, Protons, Pions	203
1.10.6 Event Reconstruction in STT	203
1.10.7 Neutrino Energy Reconstruction in Inclusive CC Events	206

52 pages



- Present**
- single particle reconstruction  
 $e, \pi^0, \gamma, p, n, K^0, \Lambda^0$   
helix 3D fit in STT and ToF method
  - particle ID ( $e, p, \mu, \pi$ )
  - neutrino energy reconstruction

- To write**
- reconstruction in GRAIN\*
  - approach to identify neutrino event in the spill

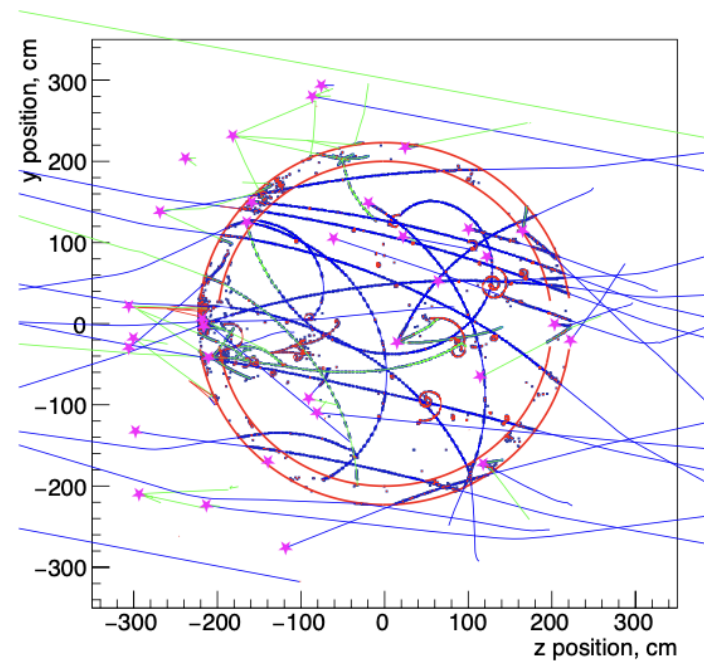
Mainly from the document  
DUNE-doc-13262-v7

"A Proposal to Enhance  
the DUNE Near-Detector  
Complex"

GEANT & FLUKA

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1.11.1 Selection of CC Interactions	215
1.11.2 Measurements of $\nu(\bar{\nu})$ -Hydrogen Interactions	235
1.11.3 Determination of Relative and Absolute Fluxes	242
1.11.4 Constraining the Nuclear Smearing in Ar	247
1.11.5 $\nu$ -e Elastic Scattering	250
1.11.6 Coherent $\pi^\pm$ Production	252
1.11.7 $\nu_e/\nu_\mu$ & $\bar{\nu}_e/\bar{\nu}_\mu$ Flux Ratios	253
1.11.8 On-Axis Beam Monitoring	254
1.11.9 External Backgrounds	263

80 pages



**Present**

- selection of CC interactions ( $\nu_\mu$ , anti  $\nu_\mu$ ,  $\nu_e$ , anti  $\nu_e$ )
- $\nu$ -H interactions - measurement of fluxes
- nuclear smearing in Ar -  $\nu$ -e scattering
- coherent  $\pi$  production - on-axis beam monitoring
- $\nu_e/\nu_\mu$  ratio - external backgrounds

**To do**

- careful reading and corrections (volunteers are welcome)
- possible new topics

From the document  
DUNE-doc-13262-v7

"A Proposal to Enhance  
the DUNE Near-Detector  
Complex"

# To be written

1.12	Installation & Integration	296
1.12.1	Organizational Structure and Sharing of Responsibilities	296
1.12.2	Transport and Handling	296
1.12.3	Experimental Hall and Facilities	296
1.12.4	Cryogenics and Gas Distribution	296
1.12.5	Installation Sequence	296
1.12.6	Critical and Special Lifts	296
1.12.7	Commissioning	296
1.12.8	Safety	299
1.12.9	Risk Matrix and Risk Management	299
1.13	Safety	300
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1.15.5	Schedule-Related Risk Mitigation and Management	304
1.16	Possible Upgrades	305
1.16.1	GRAIN Charge Readout	305
1.16.2	New Targets	305

Present: tables about sizes, weights and storage @ FNAL of yoke, coil and calorimeter

Expected: November 30

Present: time schedule from the single sections

Complete draft: December 2024

**Present:  
318 pages**

**259 figures  
65 tables**

1. Overview **7 pages - to be checked**
2. Lead/Scintillating-Fiber Calorimeter (ECAL) } **91 pages - to be updated**
3. Superconducting Magnet
4. Liquid Argon Active Target (GRAIN) **30 pages - in progress**
5. Tracker **6 pages - at the beginning**
6. Data Acquisition (DAQ) Architecture } **8 pages - to be completed**
7. Detector Control (DCS)
8. Detector Safety System (DSS)
9. Software & Computing **26 pages - at the beginning**
10. Event Reconstruction **52 pages - to be completed**
11. Analysis **80 pages - to be checked**
12. Installation & Integration } **At the very beginning (some tables)**
13. Safety } **1-2 pages for each section**
14. Organization & Management } **Indexes and keywords are defined**
15. Time Schedule
16. Possible Upgrades



## Long todo-list

Essentially missing or wrong references

Standardize (as possible) quantity names,  
reference systems and so on

Each author is responsible of his/her section  
He/she introduces update when necessary

## Check priorities

Physics and coherence

English language

Rules of the DUNE documents

but ...

## Todo list

complete the sentence . . . . .	65
an example of the relevant safety standards at Fermilab . . . . .	70
per o for ?? . . . . .	93
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reference ? . . . . .	101
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BOLOGNA now . . . . .	103
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to be completed ? . . . . .	135
to be completed ? . . . . .	135
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correct ? . . . . .	232

# Instructions for the authors

- Insert the reference in the bibliography (bibitex format)
- Check if some word is present in the glossary and use it
- Insert new words in the glossary
- Check the reference to equations, figures, tables
- Write your name in the text %% author ?
- Take into account the DUNE editing rules

<https://dune.bnl.gov/docs/guidance.pdf>



# SAND: Design Milestones

SYSTEM	DECISION	Date
SAND	GRAIN inner cryostat material	2024
SAND	Tracker technology	2025 Q3
SAND	ECAL readout	2025 Q1
SAND	GRAIN outer vessel material	2025 Q4
SAND	GRAIN readout configuration	2025 Q4

H. A. Tanaka  
Neutrino Scope Group  
23 October 2024

- SAND is on the path to preliminary design.
  - A few major decisions (Tracker, GRAIN readout configuration) remain pending prototyping results
- Some elements (Magnet, ECAL) are built and undergoing refurbishment
  - Close coordination is needed to ensure smooth compliance and testing process at FNAL.

## RECENT AND UPCOMING REVIEWS

SYSTEM	Review	Date
SAND	KLOE-2-SAND Preliminary Design Review	2024 Q2
ND-LAr Cryostat	Preliminary Design Review	2024 Q3
TMS	Preliminary Design review	2025 Q1
PRISM	Preliminary Design review	2025 Q1
ND-LAr	Final Design Reviews start	2025 Q1
ND-LAr/TMS	ND Director's Review and IPR status review	2025 Q2
SAND	GRAIN readout configuration	2025 Q4

**Hiro Tanaka, September 9, 2024  
Collaboration Meeting**

	Chapter Draft	Design Review	Ready for LBNC
Intro/Physics	Jun 24	N/A	<b>Jul 24</b>
ND-LAr (final)	Nov 24	Dec 24	<b>Feb 25</b>
TMS	Nov 24	Jan 25	<b>Feb 25</b>
SAND*	Jun 24-Feb 25	Jul 24-Mar 25	<b>Apr 25</b>
ND-LAr Cryostat	Jun 24	Jul 24	<b>Aug 24</b>
NS LAr Cryogenics	Jun 24	N/A	<b>Aug 24</b>
DUNE-PRISM	Nov 24	Dec 24	<b>Jan 25</b>
ND DAQ	Nov 24	Jan 25	<b>Feb 25</b>
ND Slow Control			<b>Feb 25</b>
ND I&I	Nov 24	Dec 24	<b>Jan 25</b>

\* SAND will divide process into KLOE-2-SAND, Tracker, GRAIN, Integration



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# Final remarks

- ❖ Main part of data are available, it's just a matter of writing
  - Some sections to be written and completed
  - Go on with the editing according to DUNE rules
  - Involve other people as authors, when necessary
- ❖ What measurement to evaluate the TDR progress ?
  - Empty sections !
  - Number of pages: 319 !
  - Text quality ? SAND internal reading to “measure” the text quality
- ❖ **Within 2024 end:** first complete draft to be read and corrected (**in DUNE-docdb**)

# Backup slides

# Glossary

 my\_glossary.tex

**Insert new DUNE words and new DUNE abbreviations  
at the end of this file**

**Check if the word is already present**

To define a DUNE term that has no abbreviation use:

```
\newduneword{label}{term}{description}
```

To define a DUNE term with an abbreviation use:

```
\newduneabbrev{label}{abbrev}{term}{description}
```

## Examples

```
\newduneword{detmodule}{detector module}{The entire DUNE far detector is segmented into four modules, each with a nominal  $\text{SI}_{10}$  fiducial mass}
```

```
\newduneabbrev{adc}{ADC}{Analog Digital Converter}{A sampling of a voltage resulting in a discrete integer count corresponding in some way to the input}
```

# Bibliography

 my\_citedb.bib

**Insert references (bibtex format) at the end of this file**

**Check if the reference is already present**



## DUNE Words from the [glossary](#)

`\dfirst{fnal}`      first time      Fermi National Accelerator Laboratory (Fermilab)

`\dword{fnal}`      following times      Fermilab

### More informations in the glossary

**Fermi National Accelerator Laboratory (Fermilab)** U.S. national laboratory in Batavia, IL. It is the laboratory that hosts Deep Underground Neutrino Experiment (DUNE) and serves as its near site. [1](#)

`\dfirst{nd}`      near detector (ND)      *with link*

`\dword{nd}`      ND      *with link*

`\dlong{nd}`      near detector      *w/o link*

`\dshort{nd}`      ND      *w/o link*

`\dword`      singular      `\dwords`      lower case & plural

`\Dword`      capital      `\Dwords`      capital & plural



`common/units.tex` to define commands for units

Examples

“m” is written `\si{\meter}`

**bare units**

“V” is written `\si{\volt}`.

“123.456” is written as `\num{123.456}`.

**bare numbers**

“ $1 \pm 2i$ ” is written as `\num{1+-2i}`.

“ $3 \times 10^{45}$ ” is written as `\num{3e45}`.

“ $0.3 \times 10^{45}$ ” is written as `\num{.3e45}`

“120 GeV” is written as `\SI{120}{\GeV}`,

**numbers and units**

“4850 ft” is written as `\SI{4850}{\ft}`,

# Figures

**JPEG** use for photographs

**PDF** use of any line drawings, plots, illustrations

**PNG** use due to some inability to produce proper JPEG or PDF (contact editors)

**Please, complete the plots with axis labels and measurement units**

# English

- Use American spelling: e.g., ionization (not ionisation), flavor (not flavour) and so on.
- In general, avoid use of first person (e.g., I, we, our). “We” may appear in introductory sections.
- Avoid use of second person, i.e., “you.”





## Many many rules/instructions in the writing of DUNE documents :

<https://github.com/DUNE/document-guidance/releases/>

Latex structure

<https://ctan.mirror.garr.it/mirrors/ctan/macros/latex/contrib/siunitx/siunitx.pdf>

units

<https://dune.bnl.gov/docs/technical-proposal/dune-words.pdf>

DUNE words

<https://ctan.mirror.garr.it/mirrors/ctan/macros/latex/contrib/glossaries/glossaries-user.pdf>

glossary

**An almost synthetic guidance (49 pages)**

<https://dune.bnl.gov/docs/guidance.pdf>

**Help by Anne Heavey, scientific editor at FNAL**



**Anne Heavey**

Scientific editor  
Fermilab, United States

**Hiro Tanaka, September 9, 2024  
Collaboration Meeting**

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ND DAQ	Nov 24	Jan 25	Feb 25
ND Slow Control			Feb 25
ND I&I	Nov 24	Dec 24	Jan 25

\* SAND will divide process into KLOE-2-SAND, Tracker, GRAIN, Integration

## More details for SAND

### Preliminary Design Review

✓ Jul 2024	topics
Nov 2024	ECAL + magnet
Dec 2024/Jan 2025	I & I
Mar 2025	GRAIN
	Tracker

### Review of TDR chapter draft

	reviewer
Jan 2025	SAND consortium
Feb 2025	DUNE collaboration
Mar 2025	LBNC