

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

Paolo Bernardini, Lecce

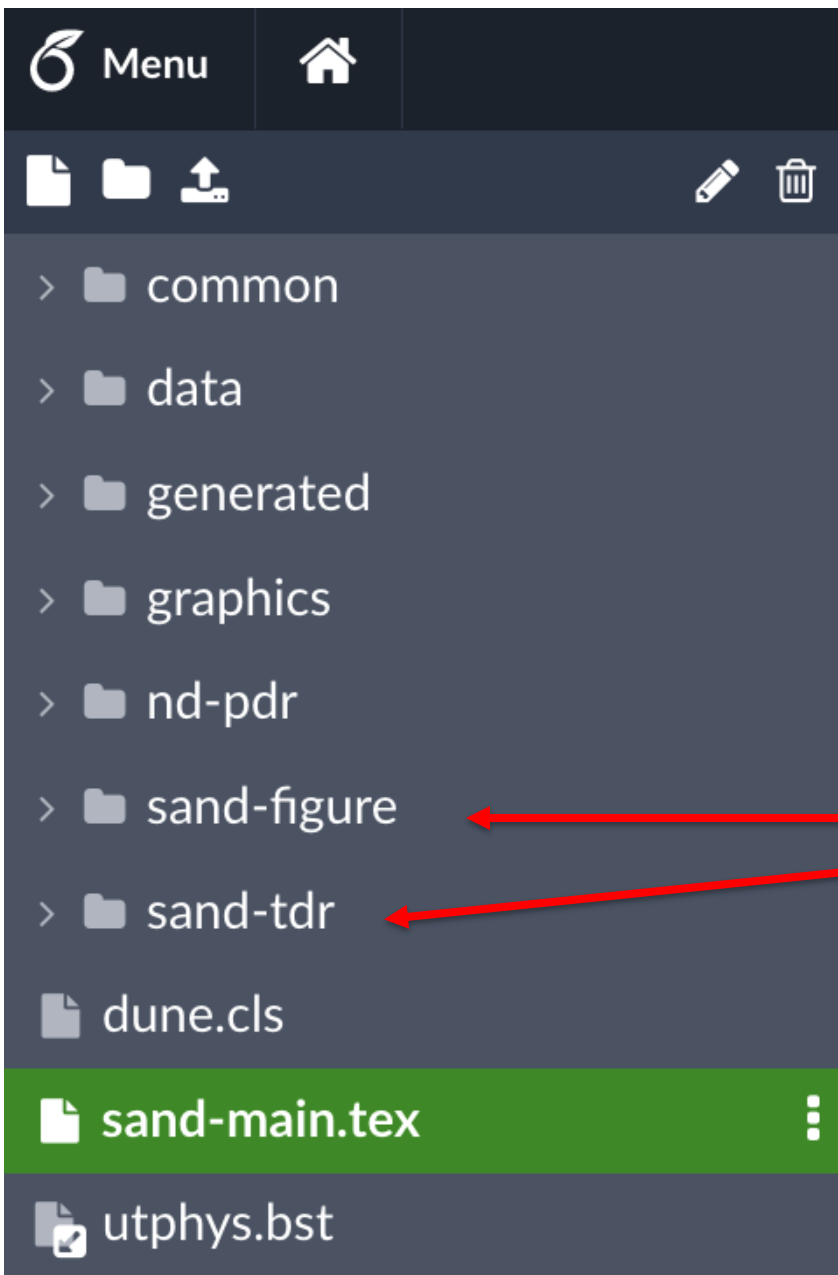
DUNE, Italian Collaboration Meeting

October 30<sup>th</sup>, 2024



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DEL SALENTO  
*L'Ateneo tra i due mari*



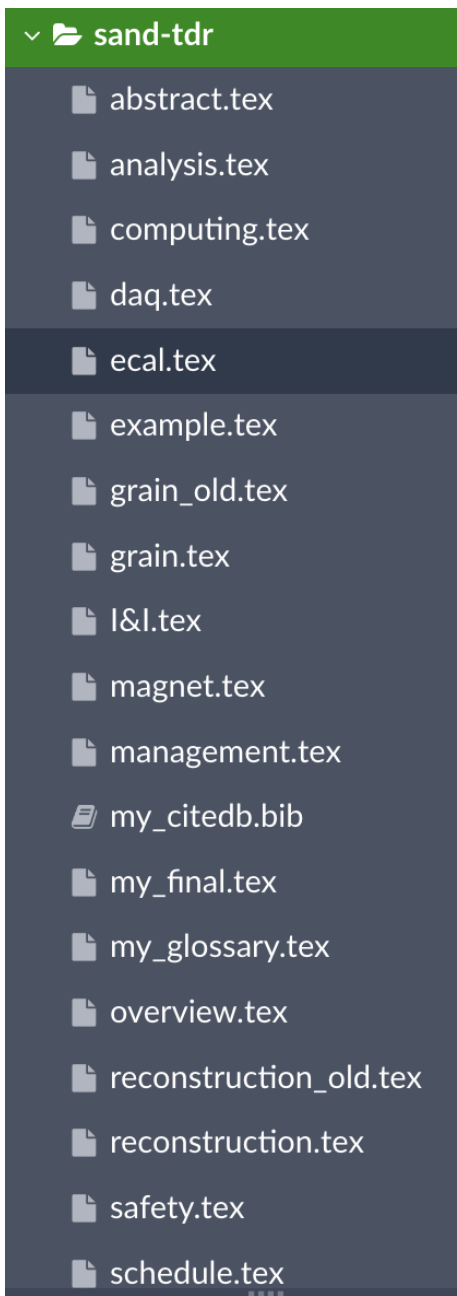


An overleaf is adopted according to  
LATEX conventions for LBNF/DUNE documents

shared with SAND people  
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  
my\_citedb.bib

New DUNE words and new references  
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
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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

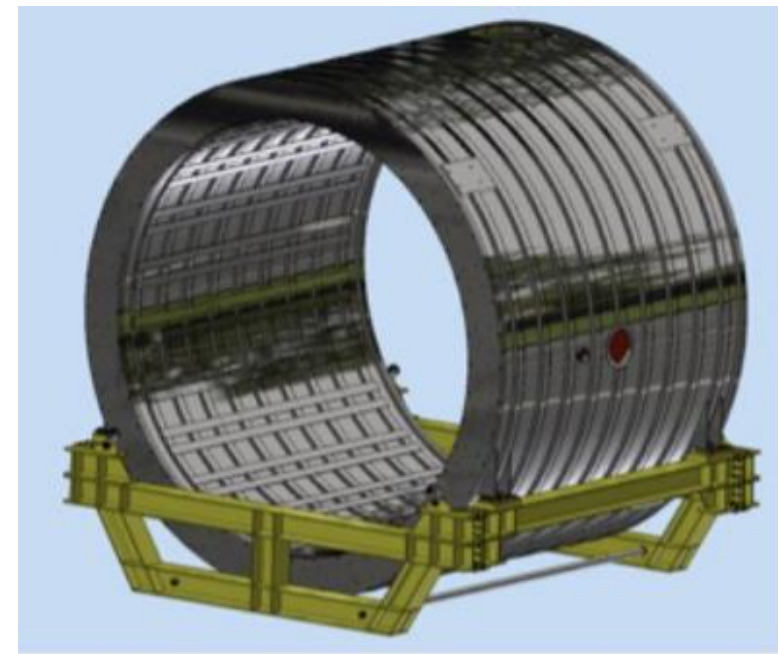
Gantt & milestones to be updated

Talk by  
Antonio D.D.

**Refinements expected within October 31**

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



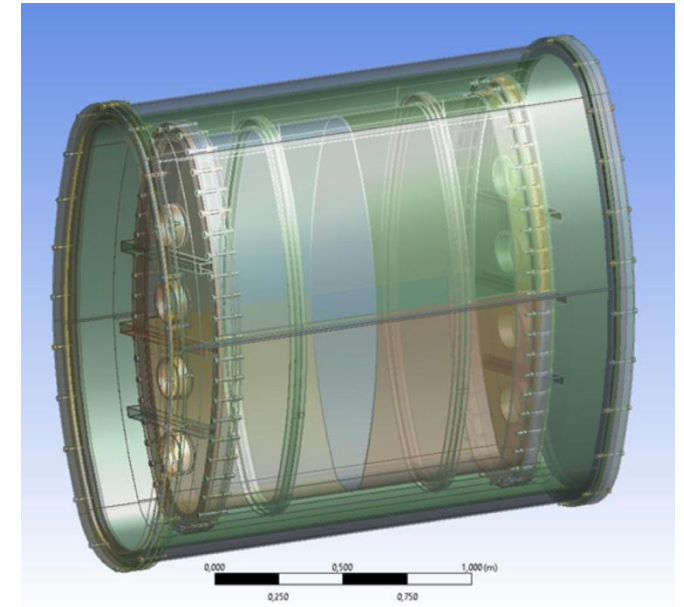
- ✓ Draft available in time
- ✓ July 22-23, 2024 - Preliminary Design Review (PDR)
- To be updated according to recommendations
- Update of design, dismounting and shipping of the yoke
- Possible improvements (mainly in Sec.s 1.3.4, 1.3.5, 1.3.6)

**Refinements expected within October 31**



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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

28 pages



**Present**

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

**To be completed**

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

\* another section ?

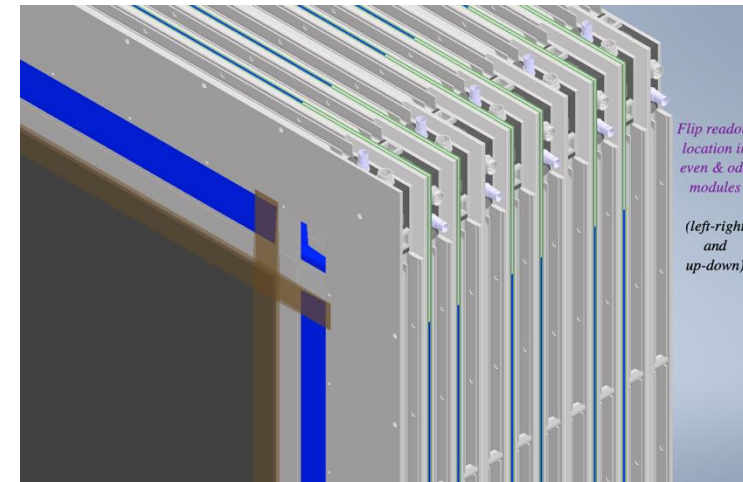
**To be written**

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

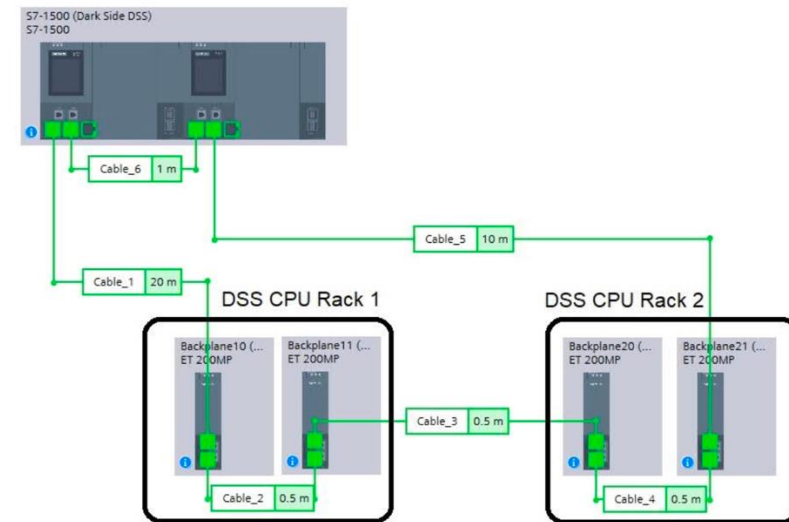
Next check: November 31

Complete draft: December 2024



1.6	DAQ Architecture	131
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1.7	Detector Control (DCS)	132
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1.8	Detector Safety Systems (DSS)	135
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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)

Next check: ??

Complete draft: ??

1.9	Software and Computing	141
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1.9.3	Algorithms for Reconstruction	151
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1.9.7	Integration	165

25 pages

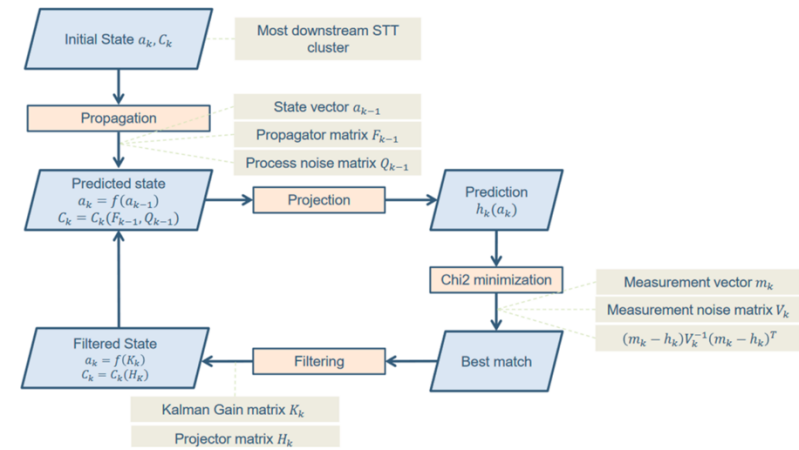


Figure 1.108: Flow chart of the EKF algorithm.

**Present**

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

**Missing**

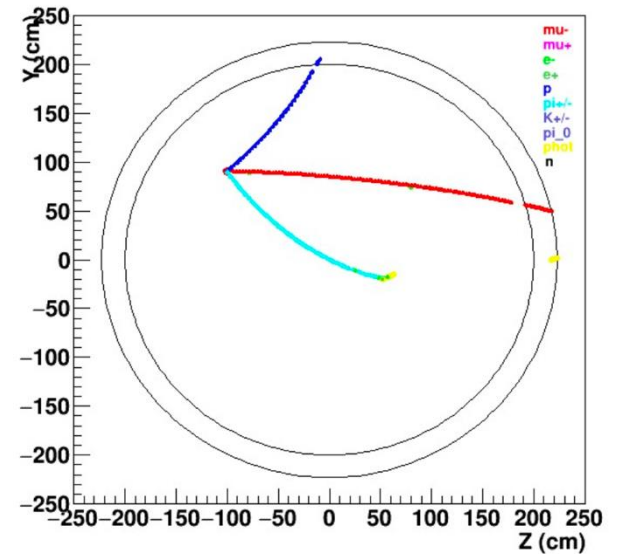
- simulation of  $\nu$  fluxes, geometries
- reconstruction in GRAIN\*, ECAL
- Common Analysis Files - computing architecture
- event display - integration

\* another section ?

Complete draft: December 24

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

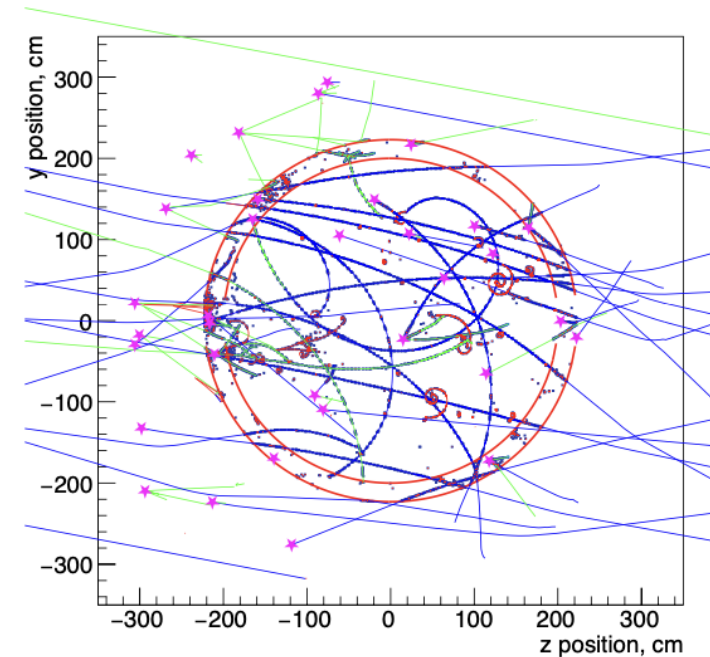
**To write** - reconstruction in GRAIN\*

**Future** - identification of 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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1.11.4 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 ?)
  - possible new topics

From the document  
DUNE-doc-13262-v7

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

# To be written

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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 31  
See talk by C. Montanari

Present: time schedule from the single sections

Next check: November 30

Complete draft: December 2024

**Present:**  
**316 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) 28 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 25 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 responsible his/her section 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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# 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>

# 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.”



# 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

- ❖ Write-up of SAND-TDR has started (February 2024) and is going on
- ❖ Main part of data are available, it's just a matter of writing
- ❖ First review about ECAL+magnet in July 2024
- ❖ 2024 end as deadline for a first complete draft
- ❖ What measurement to evaluate the TDR progress ?

Number of pages: 315 !  
Text quality ? Difficult answer

- ❖ To do:

- Some sections to be written and completed
- Editing according to DUNE rules
- SAND internal reading to "measure" the text quality
- When a first draft in DUNE-docdb ? Soon !!!

# Backup slides

## 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



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**Hiro Tanaka, September 9, 2024  
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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

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

### Review of TDR chapter draft

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