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WP5 Progress - Physics

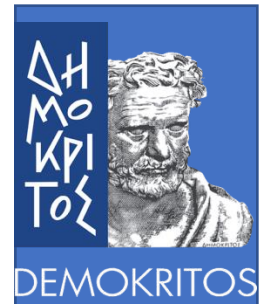
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4st ESSnuSB+ annual meeting
05 October 2026



WP5+ Milestones

- MS3: Identification of requirements for LEnuSTORM /monitored beam near detector
Led by: NCSR D and AUTH
Achieved on: 2023-12-21
- MS5: Identification of non-beam physics scenarios (WP5)
Led by: IRB, Roma Tre and KTH
Achieved on: 2024-05-22
- MS8: Identification of LEnuSTORM physics scenarios
Led by: IRB, Roma Tre and KTH
Achieved on: 2024-10-18
- MS10: MC simulation framework for all detectors is set up
Led by: Sofia
Achieved on: 2024-12-17
- MS11: Development of ML approach finished and implemented for a data test sequence
Led by: Lund
Achieved on: 2024-12-11

- MS14: Update of the physics reach framework
Led by: IRB, Roma Tre and KTH
Achieved on: 2025-03-21
- MS16: Preliminary estimation of cross-section measurement precision
Led by: NCSR D and AUTH
Achieved on : 2025-05-21
- MS21: First estimate of the neutrino flux from LEnuSTORM
Led by: WP4:
Achieved on : 2025-09-27
- MS19: Preliminary estimate of the neutrino flux in the monitored neutrino beam
Led by: WP6
Achieved on : 2025-12-31

- All milestones are achieved
- Available in docdb

WP5+ Deliverables

- D1.3: Initial facility parameters

Led by: All groups

Achieved on: 2023-08-29

- D5.1: Preliminary design of the LEnuSTORM / monitored beam near detector

Led by: NCSR D and AUTH

Achieved on: 2024-05-22

- D5.2 Sensitivity of ESSnuSB far detectors to non-beam physics

Led by: IRB, KTH and Roma Tre

Achieved on: 2025-11-25

- D5.3 Performance of neutrino interaction cross-section measurement

Led by: NCSR D and AUTH

Achieved on: 2026-06-26

- D5.4 Sensitivity of END and LMND to sterile neutrinos and other new physics

Led by: IRB and Roma Tre

Achieved on: 2026-07-27

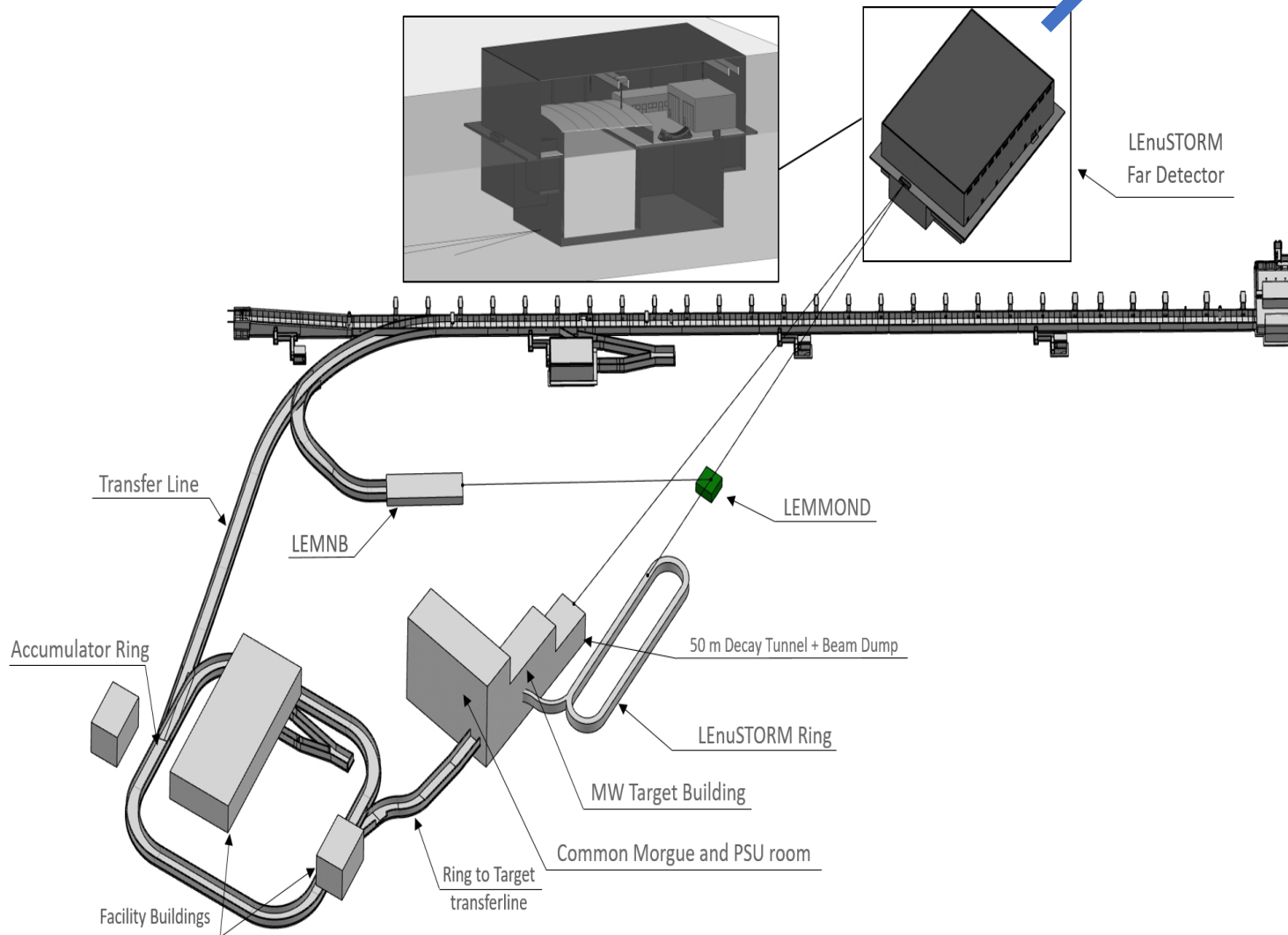
- D5.5 Effect of the ML approach on event reconstruction performance for ESSvSB and error analysis

Led by: Lund

Achieved on: 2026-07-27

- All deliverable are achieved
- Available in docdb

Recap: Physics Goals



A. Non-beam physics at FD

- Atmospheric neutrino
- Solar neutrino
- Supernova neutrino

B. New physics at NDs (LEMMOND and END)

- Sterile neutrino
- NSI

C. Additional physics studies

- cross-section models and CP sensitivity
- New Physics scenario at FD using ESS beam
NSI, Decoherence, Long-Range Force etc

Update on atmospheric neutrino

Led by KTH

- Physics within **standard scenario** has been studied: JHEP **10** (2024), 187, arXiv:2407.21663
- Physics with **NSI** has been studied : JHEP **05** (2026), 109, arXiv:2508.18103
- **Complementarity with beam** has been studied, arXiv: 2603.02836 (submitted to PRD)

Comments from IAP members: **Further synergy studies with neutrino beams** are encouraged:

Our Reply: **..we have investigated** the complementarity between atmospheric and super-beam neutrinos at ESSnuSB. This work has been submitted to arXiv....

More by Sandhya in this meeting

Update on supernova neutrino

Led by IRB

- **Capability to distinguish different flux models** has been studied

Universe **12** (2026), 280187, arXiv:2606.27007

Comments from IAP members: Please clarify **what energy threshold** on the prompt interaction has been considered? Do the results assume Gd-Loading for neutron detection?

Our Reply: ..energy threshold of **1.8 MeV** for the inverse beta decay (IBD) interaction.
..this work **do not** assume Gd-loading..

Comments from IAP members: What would be the physics potential on SN **without Gd doping**?

Our Reply: ..this work do not assume Gd-loading...it will mainly **improve the efficiency**...can be understood **from our...paper**.. .where...have shown the **sensitivity as a function of efficiency**.

Update on supernova neutrino

Comments from IAP members: Could **other interaction channels** be exploited as well, such as ES or CC/NC on 16O?

Our Reply: ..event numbers from these channels are much smaller.... for a supernova at 10 kpc using the Livermore model.... IBD events is **148,686,.....8,530** for CC-16O, **1,929** for ES....

Comments from IAP members: We recommend defining not only the total number of expected events, but also in **what time window** - this poses stringent requirements on the detector trigger scheme.

Our Reply: ...**event numbers... are integrated** over the full duration of the supernova neutrino burst....such a study has been **carried out for the T2HK.....**we expect a **similar time-dependent behavior** of the event rates.

Update on solar neutrino

Led by Roma Tre and IRB

- Sensitivity for **upturn, hep discovery, day-night asymmetry** has been studied
- **Manuscript under preparation**, will be soon sent for internal review

Comments from IAP members: Provide evaluation of the discovery potential for **HEP neutrinos**.

Our Reply: We have moved beyond interaction rates to a **full discovery - significance analysis for hep**.

Comments from IAP members: Further study of **different physics goals using ^8B solar neutrinos** – as mentioned in the presentation!

Our Reply: **Realistic detector performance and backgrounds for ^8B**

More by Alessio in this meeting

Update on sterile Neutrino and NSI

Led by IRB and Roma Tre

- Sensitivity to **sterile neutrino with LEMNB – LEMMOND** has been studied
- Manuscript under **internal review** by Fabio

Sensitivity to **sterile neutrino** with

- LEnuSTORM – END
- ESS - END

has been studied

- Sensitivity to **NSI** with

- LEMNB - LEMMOND
- LEnuSTORM - END
- ESS - END

has been studied

- Planning to write paper

More by Doris in this meeting

Additional Physics Studies: Cross-section theory

Led by RBI and Ughent

- Impact of different QE cross-section models in the CP sensitivity has been studied
- Manuscript under preparation
- Study regarding influence of 2p2h effects in progress
- More by Natalie and Marco in this meeting

Led by RBI and University of Geneva

- Possibility to probe superscaling cross-section variable at ESSnuSB
- More by Elena in this meeting

Publications

WP5 id	Title	Corresponding authors	Type of publication (WP or collaboration)	arXiv id	Journal name	DOI	Status
1	Study of non-standard interaction mediated by a scalar field at ESSnuSB experiment	William Brorsson, Sandhya Choubey, Monojit Ghosh and Deepak Raikwal	Collaboration	arXiv:2310.10749	Phys. Rev. D	10.1103/PhysRevD.109.115010	Published
2	Decoherence in neutrino oscillation at ESSnuSB experiment	Monojit Ghosh, Alessio Giarnetti, Aman Gupta and Davide Meloni	Collaboration	arXiv:2404.17559	JHEP	10.1007/JHEP08(2024)063	Published
3	Exploring atmospheric neutrino oscillations at ESSnuSB	Sandhya Choubey, Tommy Ohlsson and Sampsa Vihonen	Collaboration	arXiv: 2407.21663	JHEP	10.1007/JHEP10(2024)187	Published
4	Classification of Electron and Muon Neutrino Events for the ESSySB+ Near Water Cherenkov Detector using Graph Neural Networks	Kaare Endrup Iversen, Peter Christiansen, Joakim Cederkäll, Alexander Burgman and Joochun Park	Collaboration	arXiv: 2503.15247	JINST	10.1088/1748-0221/20/08/P08030	Published
5	Exploring Long-Range Force in Neutrino Oscillation at ESSnuSB Experiment	Monojit Ghosh, Alessio Giarnetti, Aman Gupta and Davide Meloni	Collaboration	arXiv: 2504.10480	JHEP	10.1007/JHEP07(2025)186	Published
6	Searching non-standard interactions with atmospheric neutrinos at ESSnuSB	Sandhya Choubey, Tommy Ohlsson and Sampsa Vihonen	Collaboration	arXiv: 2508.18103	JHEP	10.1007/JHEP05(2026)109	Published
7	Complementarity between atmospheric neutrinos and super-beam neutrinos at ESSnuSB	Sandhya Choubey, Tommy Ohlsson and Sampsa Vihonen	Collaboration	arXiv: 2603.02836	Phys. Rev. D		With the journal
8	Study of Supernova Neutrinos at ESSnuSB Experiment	Monojit Ghosh, Rukmani Mohanta and Papia Panda	Collaboration	arXiv: 2606.27007	Universe	10.3390/universe12090280	Published
9	Exploring ESSySB Near Water Cherenkov Detector Designs Through Graph Neural Network Flavour Identification	Kaare Endrup Iversen, Peter Christiansen, Joakim Cederkäll, Alexander Burgman and Joochun Park	Collaboration	arXiv: 2608.23773	JINST		With the journal
10	Effect of decay pipe in 3+1 scenario using LEMNB-LEMMOND setup within ESSnuSB+	Doris Barčot, Antonio Branca, Monojit Ghosh, Alessio Giarnetti and Davide Meloni	Collaboration				With the collaboration
11	Study of Solar Neutrinos at ESSnuSB Experiment	Doris Barčot, Monojit Ghosh, Alessio Giarnetti and Davide Meloni	Collaboration				In progress
12	A CRPA based cross-section model for ESSnuSB experiment	Monojit Ghosh, Rudra Majhi, Natalie Jachowicz and Marco Vanderpoorten	Collaboration				In progress

- 12 Publications so far
- 7 Published
- 2 Under journal review
- 1 Under internal review
- 2 in progress