Introduction and workplan

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1st ESSnuSB+ WP5 in-person meeting
18 May 2023

WP5 Groups

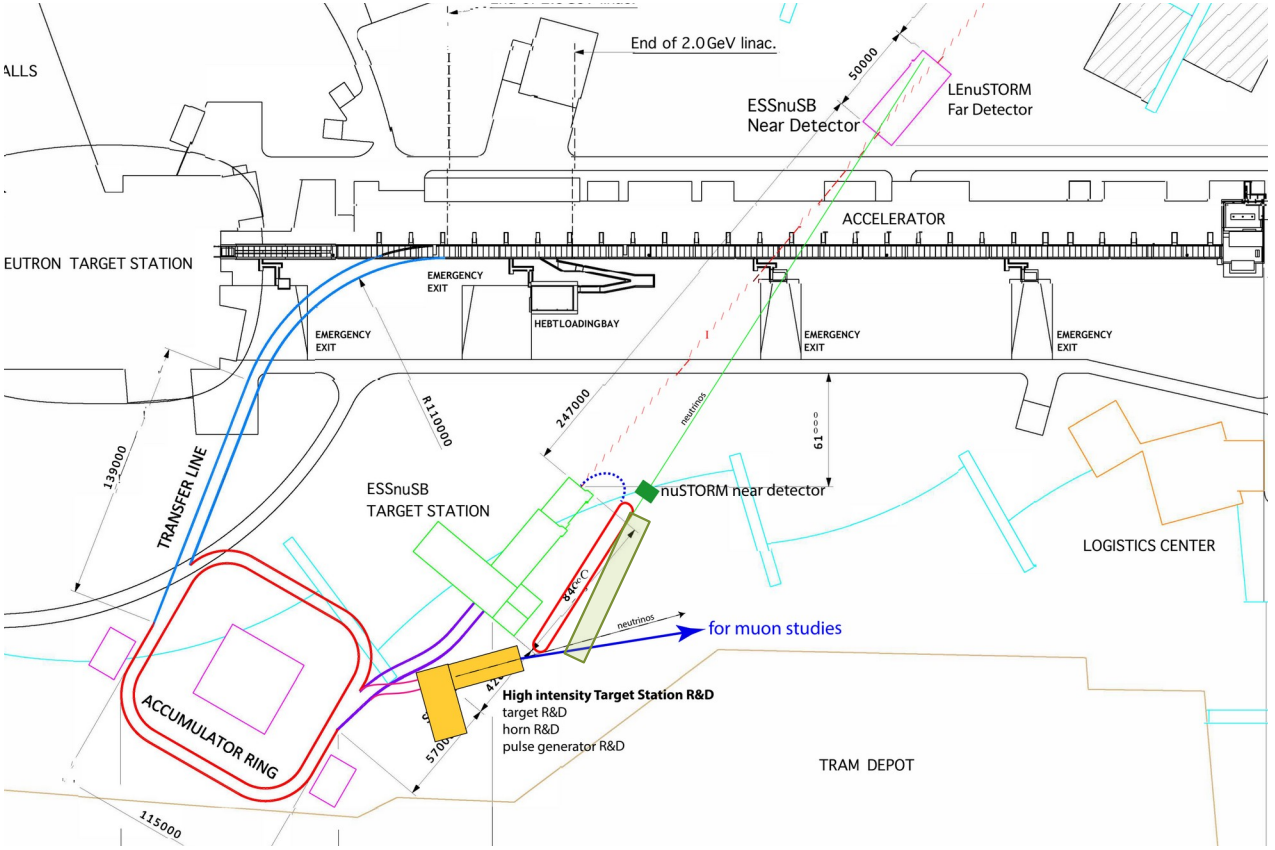
Group	Person months (PM)
Zagreb (RBI)	58
Stockholm (KTH)	24
Lund (Lunds Universitet)	10
Sofia (St. Kliment Ohridski Univ.)	24
Athens (Demokritos)	32
Adana (Cukurova Univ.)	36
Rome (Univ. Roma Tre)	22
Thessaloniki (AUTH)	22
Uppsala (Uppsala Universitet)	2
Nagoya (Nagoya Univ.)	7

10 Groups
Total PM: 237

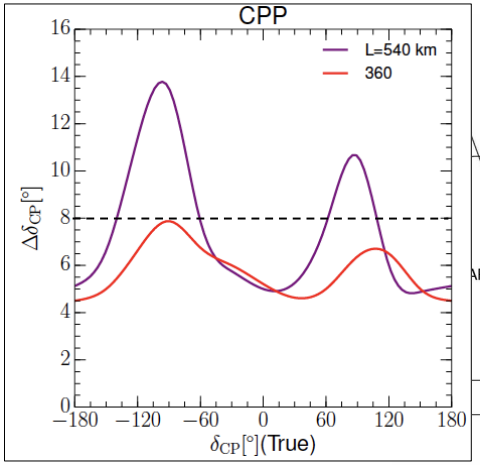
Objectives

- Study the effects of gadolinium doping to sensitivity and performance of the ESSνSB Water Cherenkov detectors (near and far).
- Study the sensitivity and performance of the ESSνSB far detectors for physics not related to the neutrino beam.
- Design single near detector for LEnuSTORM and LEMNB beam and optimise its performance.
- Determine the expected precision of neutrino interaction cross-section measurement with the full setup.
- Study the sensitivity of the setup for new physics searches.
- Develop an advanced analysis for the estimation of physics reach on the above topics using full MC chain for all detectors (analysis beyond GLoBES).

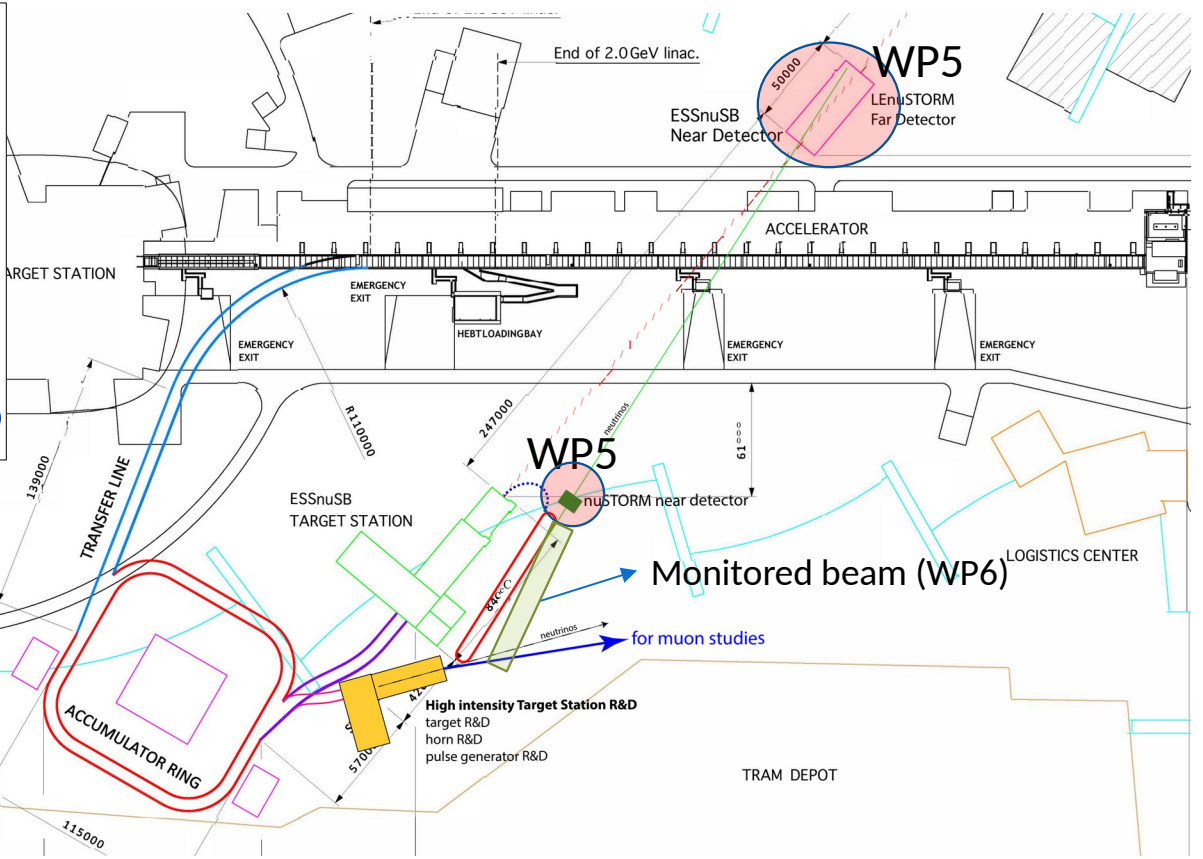
Objectives

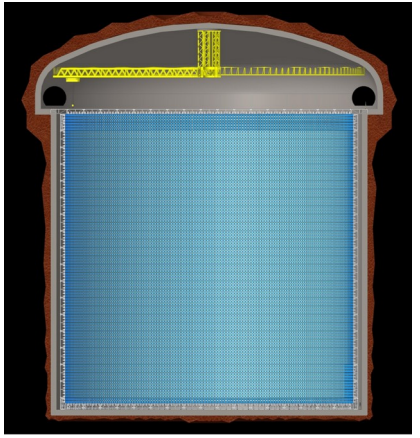

End of 2.0 GeV linac.
ESSnuSB
Near Detector
50000
LEnuSTORM
Far Detector
ACCELERATOR
EUTRON TARGET STATION
EMERGENCY
EXIT
HEBT LOADINGBAY
EMERGENCY
EXIT
EMERGENCY
EXIT
EMERGENCY
EXIT
R110000
247000
neutrinos
61000
139000
TRANSFER LINE
ESSnuSB
TARGET STATION
nuSTORM near detector
LOGISTICS CENTER
84000
neutrinos
for muon studies
High intensity Target Station R&D
target R&D
horn R&D
pulse generator R&D
ACCUMULATOR RING
TRAM DEPOT
115000

Objectives



WP5





WP5

Tasks

5.1. Coordination of the “Detectors and physics performance” WP (RBI)

5.2. Set up a full MC simulation chain for the far detector site (RBI, AUTH, NCSRD, CU)

5.3. Set up a unified MC simulation chain for the ESSνSB near detector (END) site to facilitate LEnuSTORM new physics searches (RBI, UniSofia, CU, NU)

5.4. Design and optimise the near detector for LEnuSTORM and monitored beam (LMND) (RBI, AUTH, NCSRD, UniSofia)

5.5. Study sensitivity of far detectors to non-beam physics (RBI, KTH, UNIROMA3)

5.6. Study sensitivity of END and LMND to sterile neutrinos and other new physics searches (RBI, KTH, UNIROMA3)

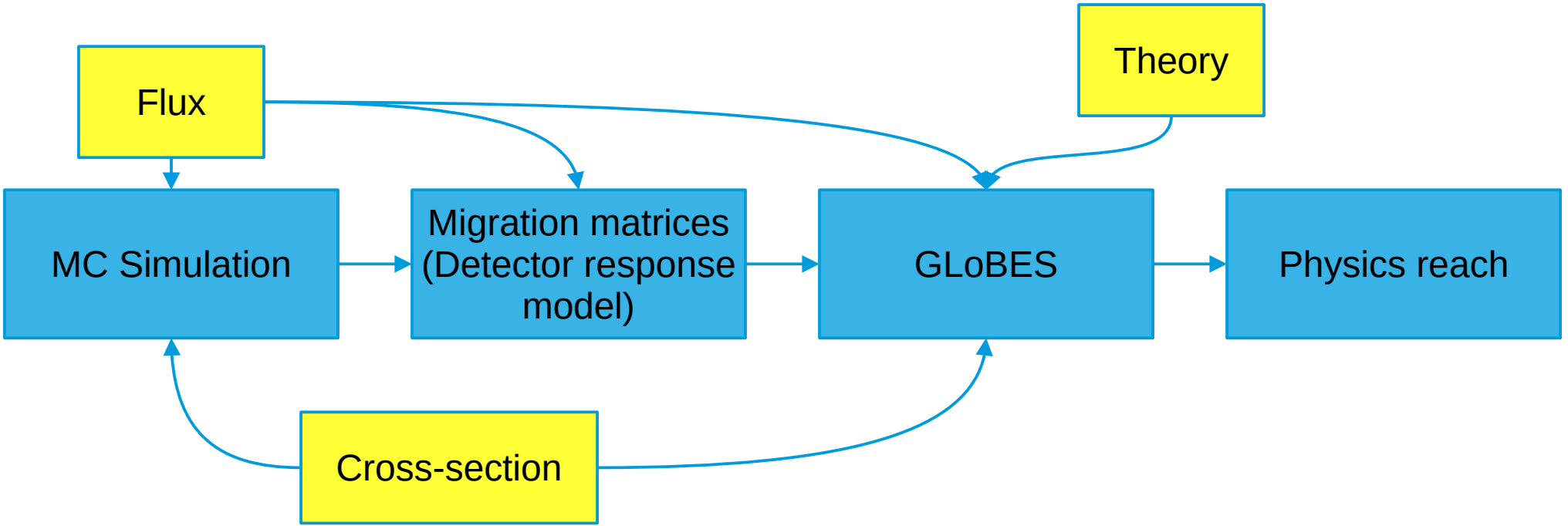
5.7. Estimate the expected precision of neutrino interaction cross-section measurement for all neutrino flavours using END, LEnuSTORM and monitored beam (RBI, AUTH, NCSRD, UniSofia, NU)

5.8. Event analysis for the ESSνSB water Cherenkov detectors using machine learning methods (ULUND, UU)

WP5 Deliverables and Milestones

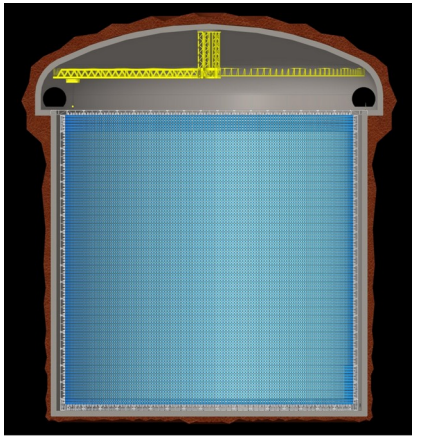
No.	Name	WPs	Due Month
D1.3	Initial facility parameters	1 (all)	8 (Aug 2023)
M1.1	Review of 1st year achievements, deliverables & costs	all	12 (Dec 2023)
M5.1	Identification of requirements for LEnuSTORM / monitored beam near detector	4,5,6	12 (Dec 2023)
M5.2	Identification of non-beam physics scenarios	5	17 (May 2023)
M4.1	Evaluation of the LEnuSTORM requirements and parameter range	4,5,6	18 (Jul 2023)
M5.3	Identification of LenuSTORM pysics scenarios	5	22 (Oct 2023)
D5.1	Preliminary design of the LEnuSTORM/monitored beam near detector (RBI)	5	23 (Nov 2024)
M5.4	MC simulation framework for all detectors is set up	5	24 (Dec 2024)
M5.5	Development of ML approach finished and implemented for a data test sequence	5	24 (Dec 2024)
M1.2	Review on interim milestones, deliverables & costs	all	24 (Dec 2024)
M5.6	Update of the physics reach framework	5	27 (Mar 2025)
M5.7	Preliminary estimation of cross-section measurement precision	5	29 (May 2025)
M6.5	Preliminary estimate of the neutrino flux in the monitored neutrino beam	5,6	30 (Jun 2025)
M4.3	First estimate of the neutrino flux from LEnuSTORM	4,5	33 (Sep 2025)
D5.2	Sensitivity of ESSνSB far detectors to non-beam physics (RBI)	5	35 (Nov 2025)
M1.3	Review of 3rd year milestones, deliverables & costs	all	36 (Dec 2025)
D5.3	Performance of neutrino interaction cross-section measurement (RBI)	5	40 (Apr 2026)
D5.4	Sensitivity of END and LMND to sterile neutrinos and other new physics (RBI)	5	43 (Jul 2026)
D5.5	Effect of the ML approach on event reconstruction performance for ESSνSB and error analysis (ULUND)	5	43 (Jul 2026)
M1.4	Cost and performance evaluation complete	all	48 (Dec 2026)

Analysis flow



Far detector

- Simulation
  - Create a full simulation framework
    - include full geometry (detector + rock): needed to study neutrino interactions in the rock
  - implement multiple neutrino flux drivers in GENIE
    - needed to study different non-beam fluxes
  - simulate Gd doping
  - improve/replace WCSim
  - better/faster reconstruction – machine learning, ...
    - need to implement a “MC independent” reconstruction as a benchmark
- Perform as much of the studies from the proposal
  - atmospheric neutrinos, atmospheric muons, supernova neutrinos, diffuse supernova neutrinos, solar neutrinos, reactor neutrinos and geoneutrinos



Far detector studies

- **atmospheric neutrinos**
  - ν / $\bar{\nu}$ components
  - energy ~ 0.1–100 GeV
  - spherical source – use Honda 2-D fluxes
- **atmospheric muons**
  - correlated time of arrival (muon bundles) – needs full CORSIKA sumulation
  - muon tomography of the mine
- **supernova neutrinos**
  - mostly $\bar{\nu}$, smaller ν component
  - point source – known scattering angle
  - enregy ~ 0.5–100 MeV

Far detector studies

- **diffuse supernova neutrinos**
  - isotropic source
  - energy to be figured out
- **solar neutrinos**
  - direction known
  - energy ~0-20 MeV
- **reactor neutrinos**
  - antineutrinos
  - multi-point source
  - energy ~ 1.8-8 MeV
- **geoneutrinos**
  - antineutrinos
  - from below?
  - energy ~ 1.8-3 MeV

LEMND detector

- **LE**nuSTORM and **M**onitored beam **N**ear **D**etector
  - Lemon-D?
- Design from scratch
- Requirements (TBD)
  - not too exotic
  - water target
  - ν / $\bar{\nu}$ discrimination
  - good timing
  - required ν energy resolution?
  - ...

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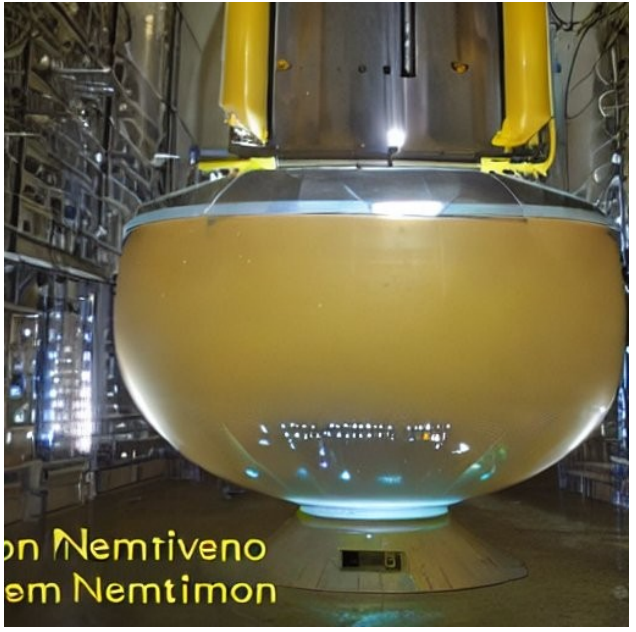


Stable diffusion: “lemon neutrino beam detector”

END detectors

- END - ESSnuSB Near Detectors
- detectors
  - water cherenkov
    - simulate Gd doping
    - implement ML reconstruction (+ “traditional”)
  - SFGD
    - optimize PID / momentum / nu energy reconstruction
    - connection with WC and νiking
  - νiking (emulsion)
    - optimize for ESSnuSB energies
- set up full MC simulation of all detectors and surrounding rock
- atmospheric muon background study
  - synnergy with FD atm. muon study

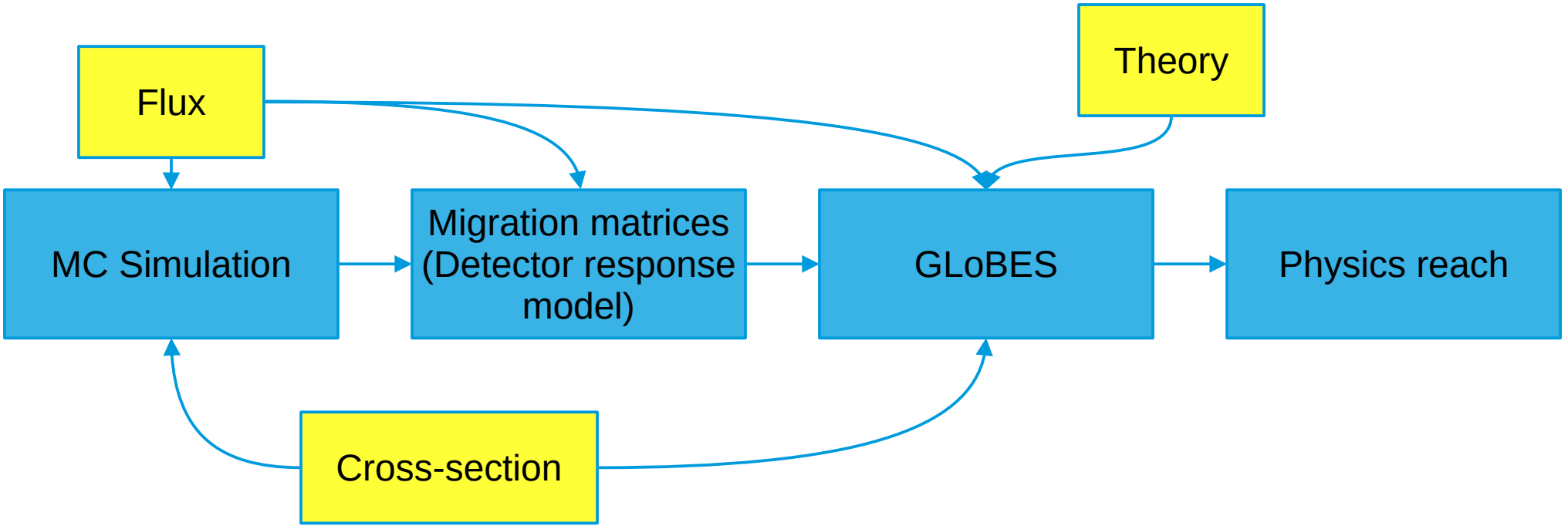
LEMND / END physics study

- neutrino source: LenuSTORM
  - also monitored beam?
- physics scenarios:
  - sterile neutrinos
  - other new physics

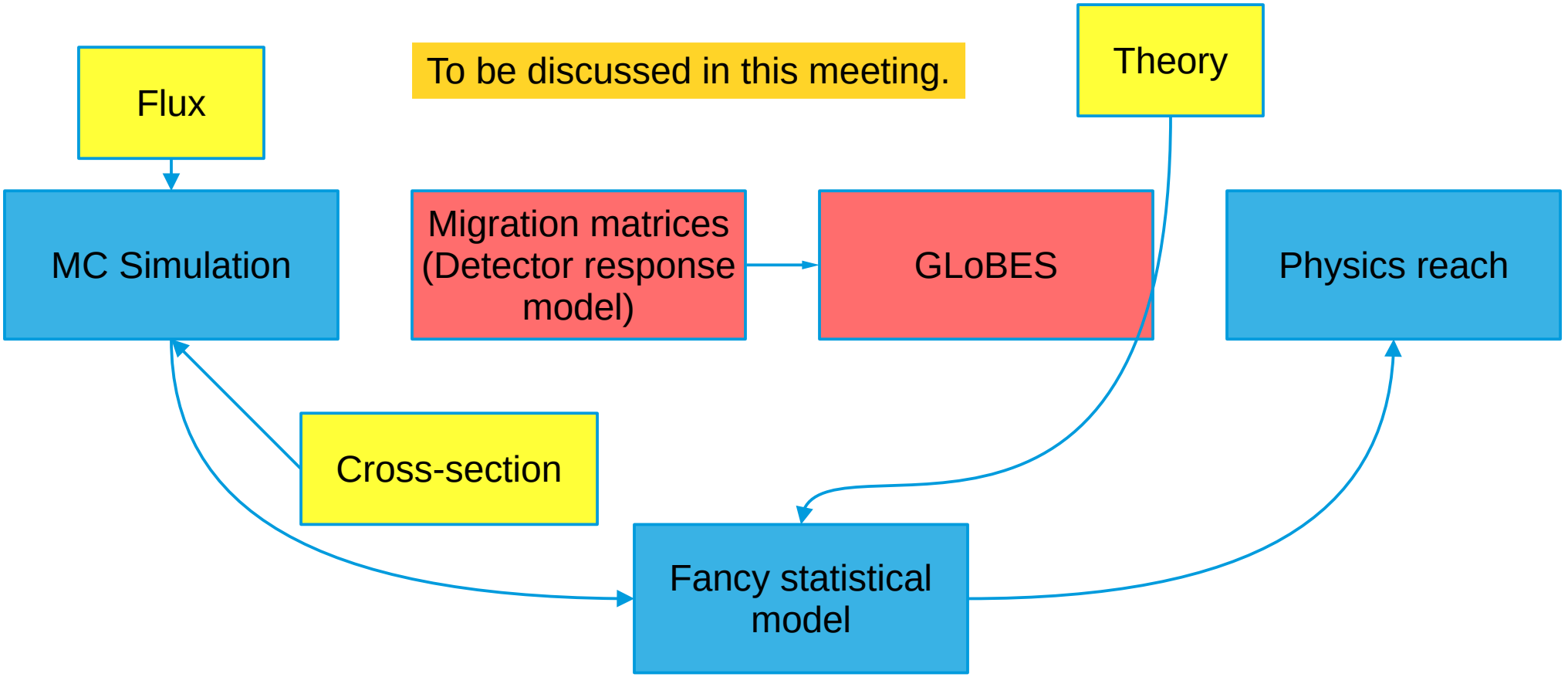
Cross-section measurement

- **Major goal of this project:** measure neutrino-water interaction cross-section(s)
- Questions we need to answer:
  - which xsecs will we be able/want to measure?
    - NC, CC (which flavours), total, differential (w.r.t. which variable), …
  - how exactly do we plan to do it?
- To be discussed in this meeting

Analysis flow



Analysis flow (advanced)



Initial facility parameters

- D1.3 “Initial facility parameters”
  - due August 2023
  - **internal deadline 1 June 2023**
- ESSnuSB version can be found here:
  - https://essnusb.eu/DocDB/private/ShowDocument?docid=674
  - let’s take a look..
- WP5 input must be finalized in this meeting

Things we should do while here

- Finalise:
  - D1.3 Initial facility parameters
  - Text for the WP5 part of ESSnuSB web page
    - old ones here: https://essnusb.eu/wp5/ https://essnusb.eu/wp6/
- Discuss / start
  - MC software framework
  - detector design / optimization: lemon-D, viking, SFGD, Gd doping, Far detector, …
  - phenomenology:
    - near detectors: steriles, new phyiscs
    - far detectors: atmospherics, supernova, diffuse supernova, solar, reactor, geoneutrinos, ...
  - measurement of the cross-section: fundamentals, statistical approach, …
  - analysis beyond GLoBES: MC samples, reweighting, statistics, …
  - …and more

Conclusion

- There is a lot to do with limited resources
  - we must avoid duplication of work and function as a team

- **Let the games begin!**

The end