WP4
Low Energy nuSTORM

Maja Olvegård

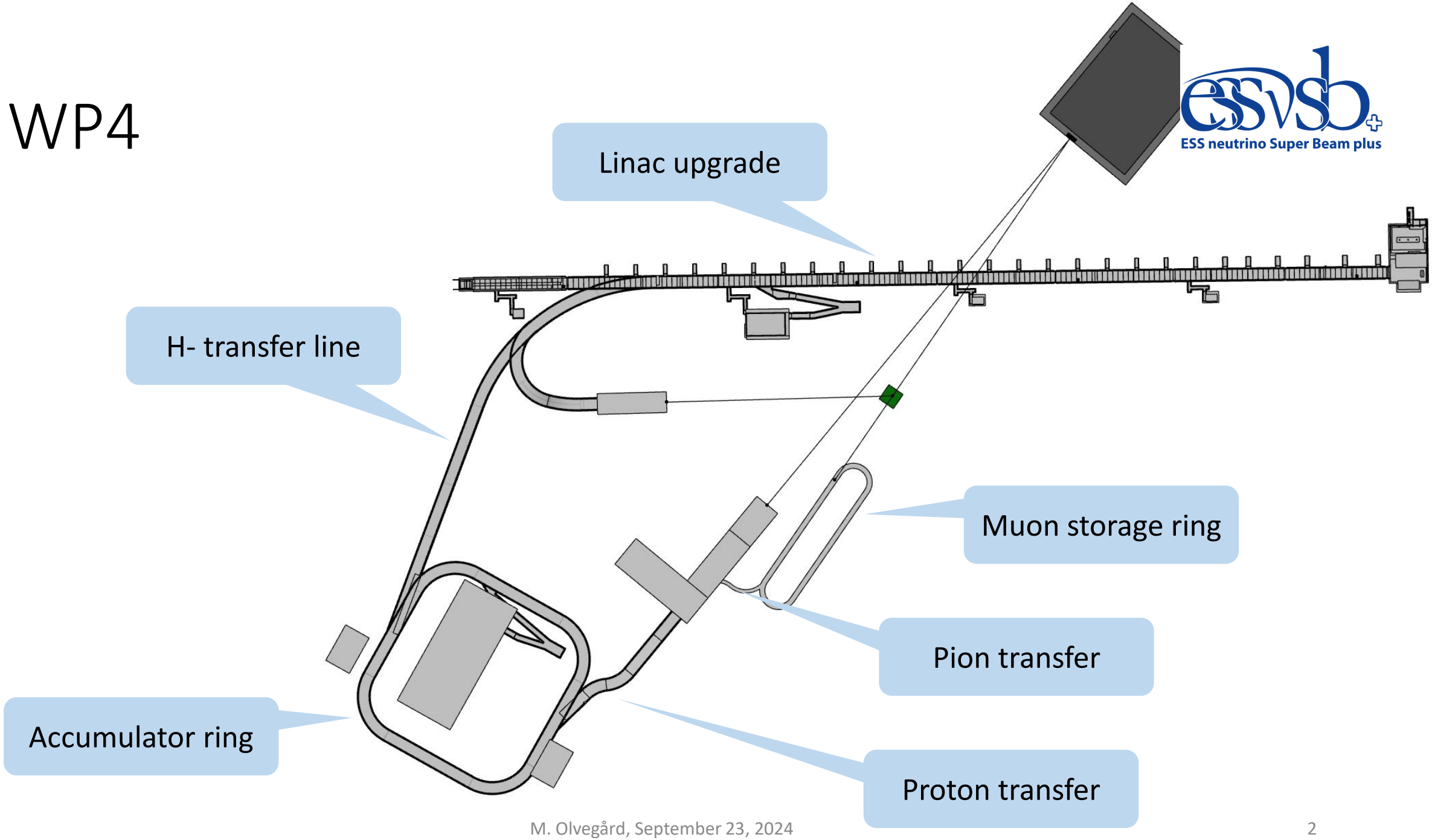
Uppsala University

On behalf of WP4

Co-funded by
the European Union

ESS neutrino Super Beam plus

WP4


Linac upgrade
H- transfer line
Muon storage ring
Pion transfer
Accumulator ring
Proton transfer

Recruitment and Resources

Plan:

- Postdoc at CERN start late 2023.
- Postdoc at UU start August 2023
- Postdoc at ESS start summer 2024

Reality:

- Max Topp-Mugglestone started Jan. 2024
- Wietse Van Goethem, starts November 2024
- Elham Salehi, expected December 2024

Other human resources

UU: Ting Wing Choi, Maja Olvegård

ESS: Natalia Milas, other ESS specialists

CERN: Ilias Efthymiopoulos

ESSB: Juan Luis Muñoz, Ibon Bustinduy

IPHC: Elian Bouquerel

Milestones and Deliverables

MS 4.1 (month 18) Evaluation of the LEnuSTORM requirements and parameter range

D4.1: (month 24) Review of the LEnuSTORM operation scheme

MS 4.2 (month 30) Preliminary racetrack ring lattice design

MS 4.3 (month 33) First estimate of the neutrino flux from LEnuSTORM

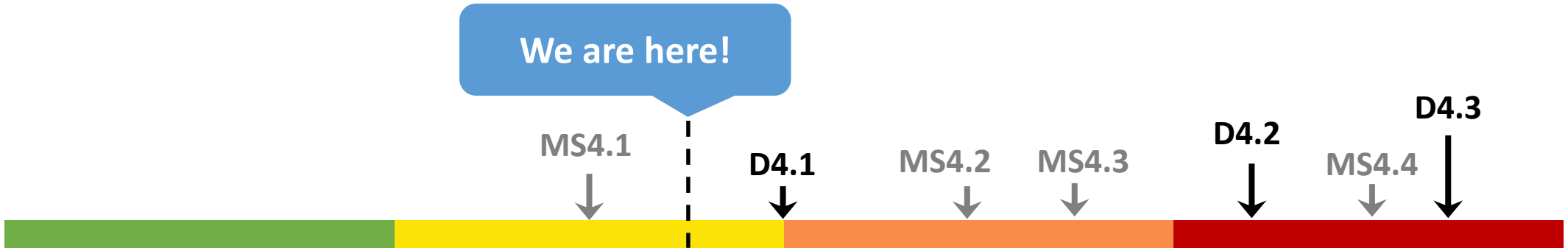
D4.2: (month 38) Racetrack ring design

MS 4.4 (month 42) Updated design of the linac, accumulator ring and transfer lines

D4.3: (month 44) Design of the capture, transport and injection system

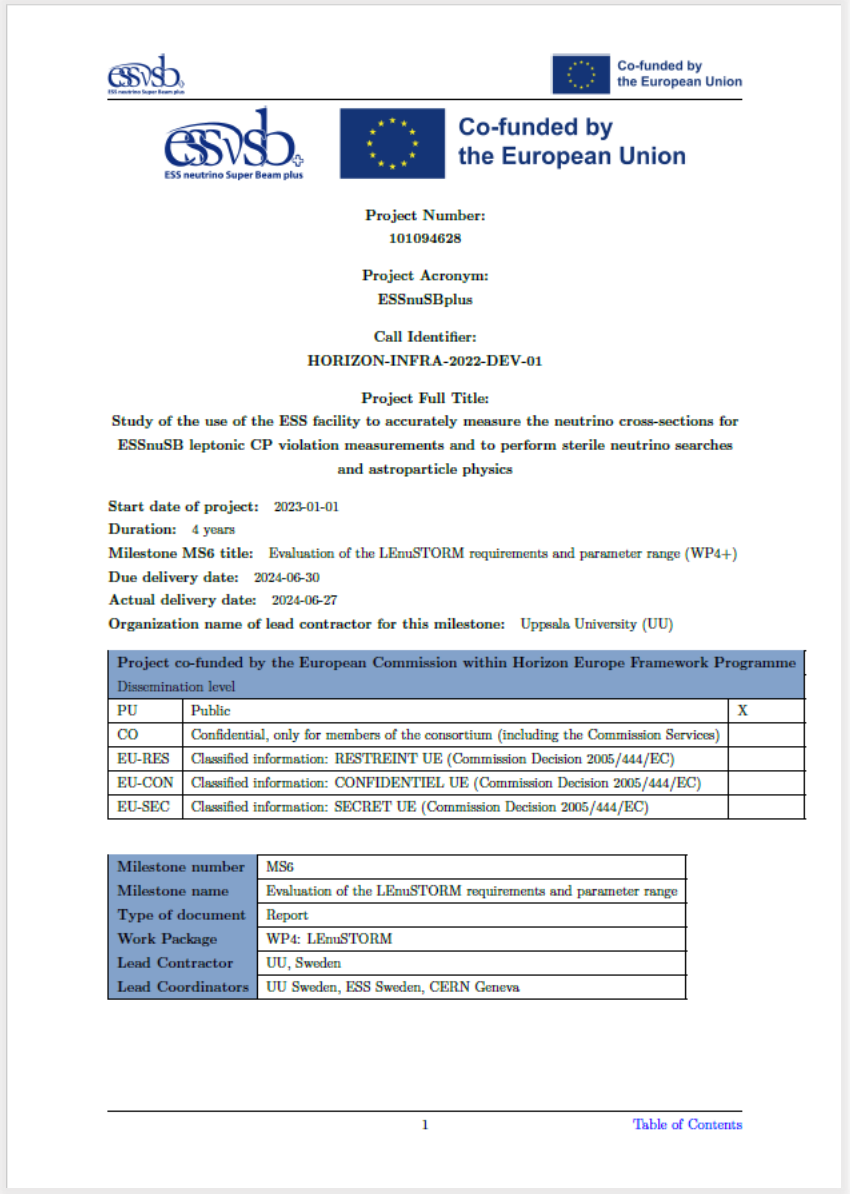
Delivered June 2024

Due in 3 months



Milestone 4.1 = MS6

Available on docDB:
https://essnusb.eu/DocDB/private/ShowDocument?docid=1812



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ESS neutrino Super Beam plus

Co-funded by the European Union

Project Number:
101094628

Project Acronym:
ESSnuSBplus

Call Identifier:
HORIZON-INFRA-2022-DEV-01

Project Full Title:
Study of the use of the ESS facility to accurately measure the neutrino cross-sections for ESSnuSB leptonic CP violation measurements and to perform sterile neutrino searches and astroparticle physics

Start date of project: 2023-01-01
Duration: 4 years
Milestone MS6 title: Evaluation of the LEnuSTORM requirements and parameter range (WP4+)
Due delivery date: 2024-06-30
Actual delivery date: 2024-06-27
Organization name of lead contractor for this milestone: Uppsala University (UU)

Project co-funded by the European Commission within Horizon Europe Framework Programme Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including the Commission Services)	
EU-RES	Classified information: RESTREINT UE (Commission Decision 2005/444/EC)	
EU-CON	Classified information: CONFIDENTIEL UE (Commission Decision 2005/444/EC)	
EU-SEC	Classified information: SECRET UE (Commission Decision 2005/444/EC)	

Milestone number	MS6
Milestone name	Evaluation of the LEnuSTORM requirements and parameter range
Type of document	Report
Work Package	WP4: LEnuSTORM
Lead Contractor	UU, Sweden
Lead Coordinators	UU Sweden, ESS Sweden, CERN Geneva

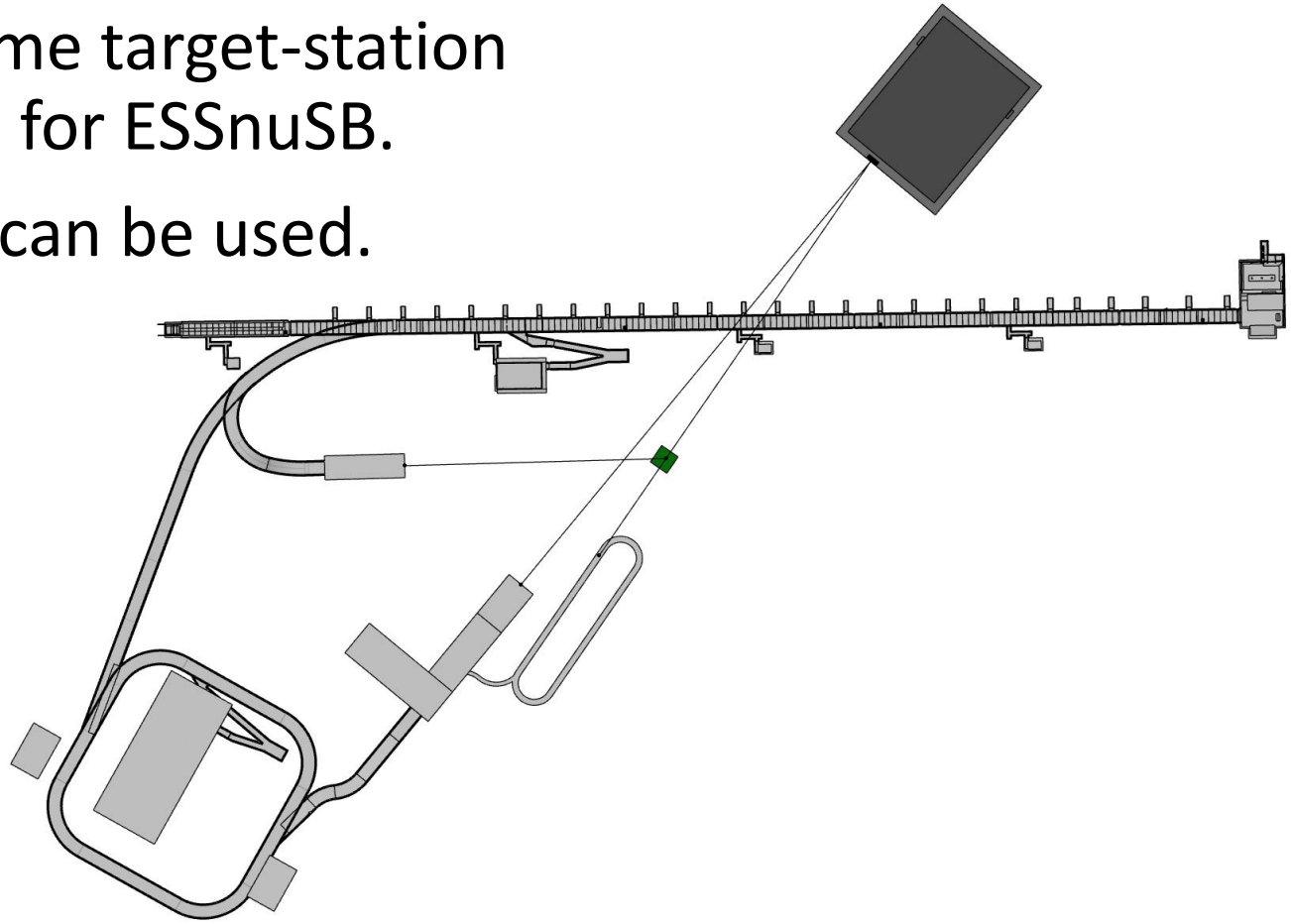
1 Table of Contents

At this time last year….

…everything was possible!

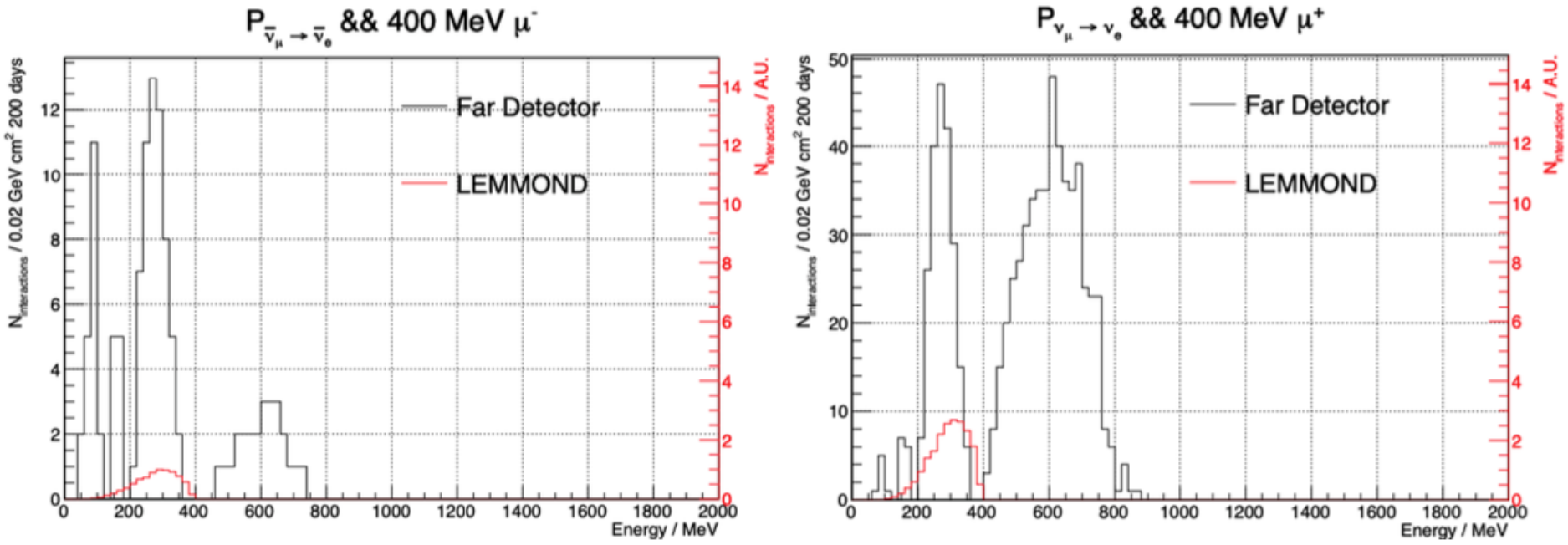
LEnuSTORM Operation Parameters

- Staged approach, using the same target-station infrastructure for nuSTORM as for ESSnuSB.
- The same proton transfer line can be used.



LEnuSTORM: muon momentum

- Nominal muon momentum: 400 MeV/c

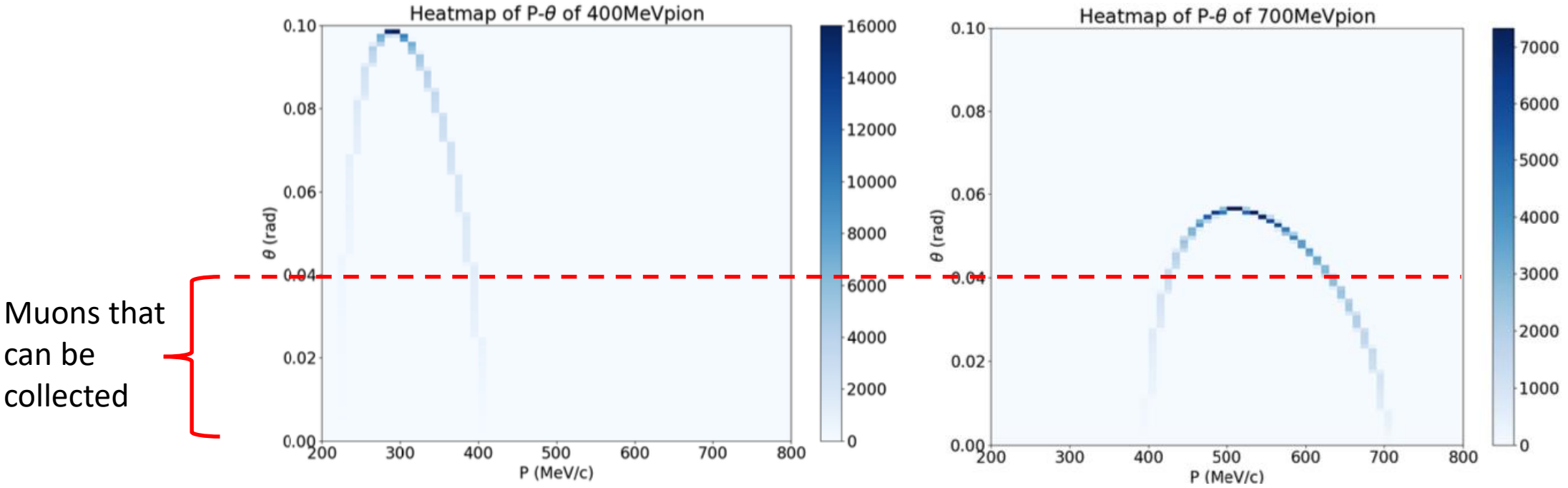


(a) Muons (b) Anti-muons

Ting Wing Choi, Leon Halic

LEnuSTORM: pion momentum?

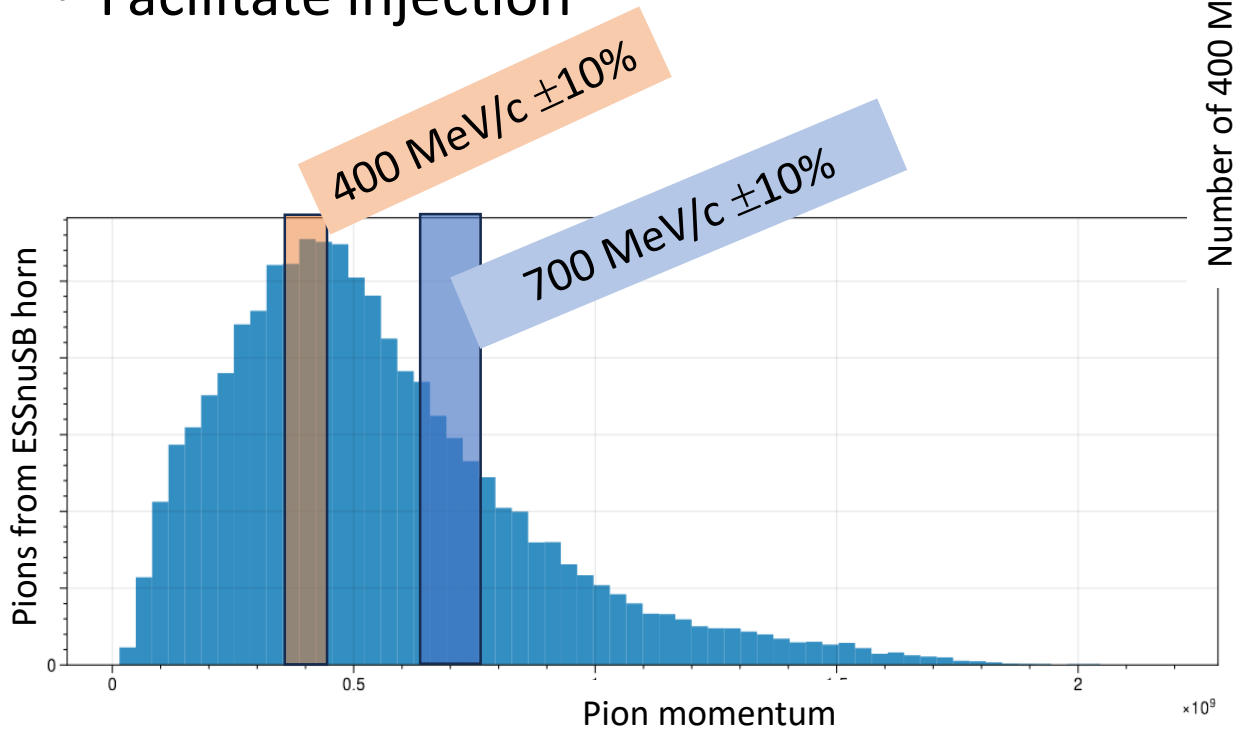
- Pion momentum?

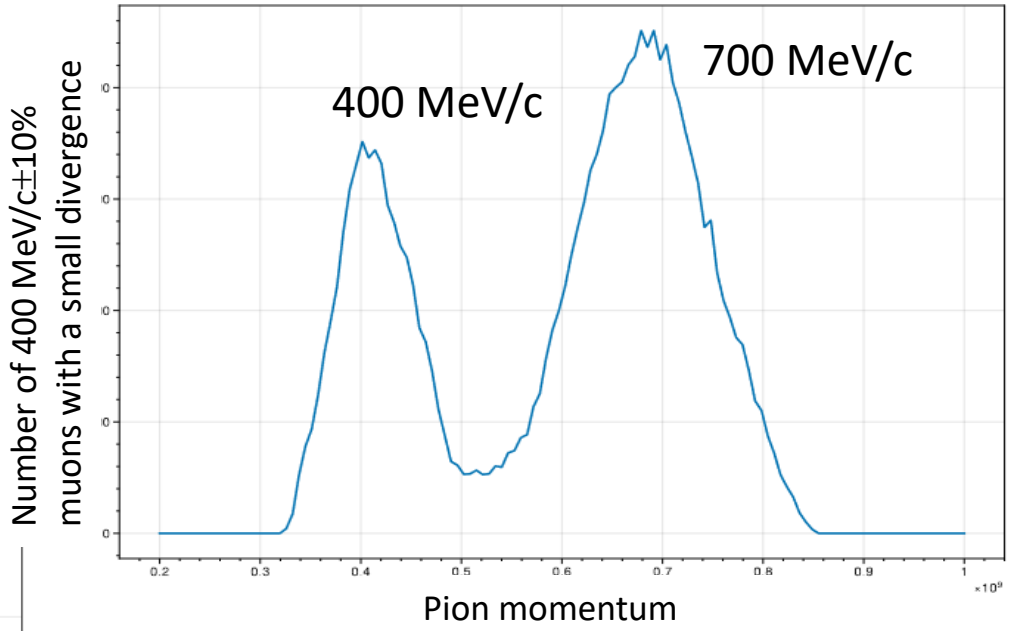


Ting Wing Choi

LEnuSTORM: pion momentum

- Nominal pion energy: ~700 MeV/c
  - Maximize muon yield
  - Facilitate injection

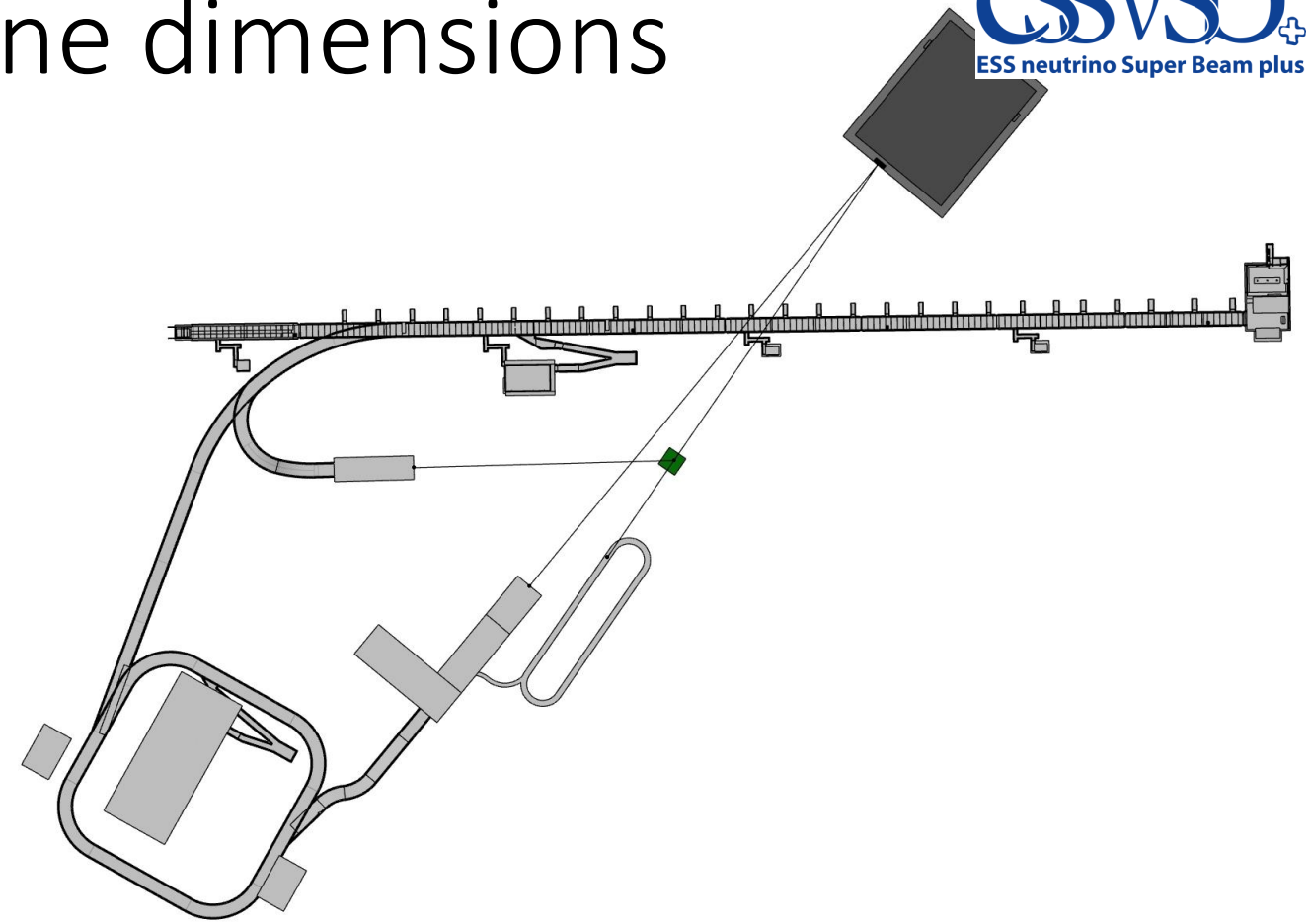




Max Topp-Mugglestone, Ting Wing Choi

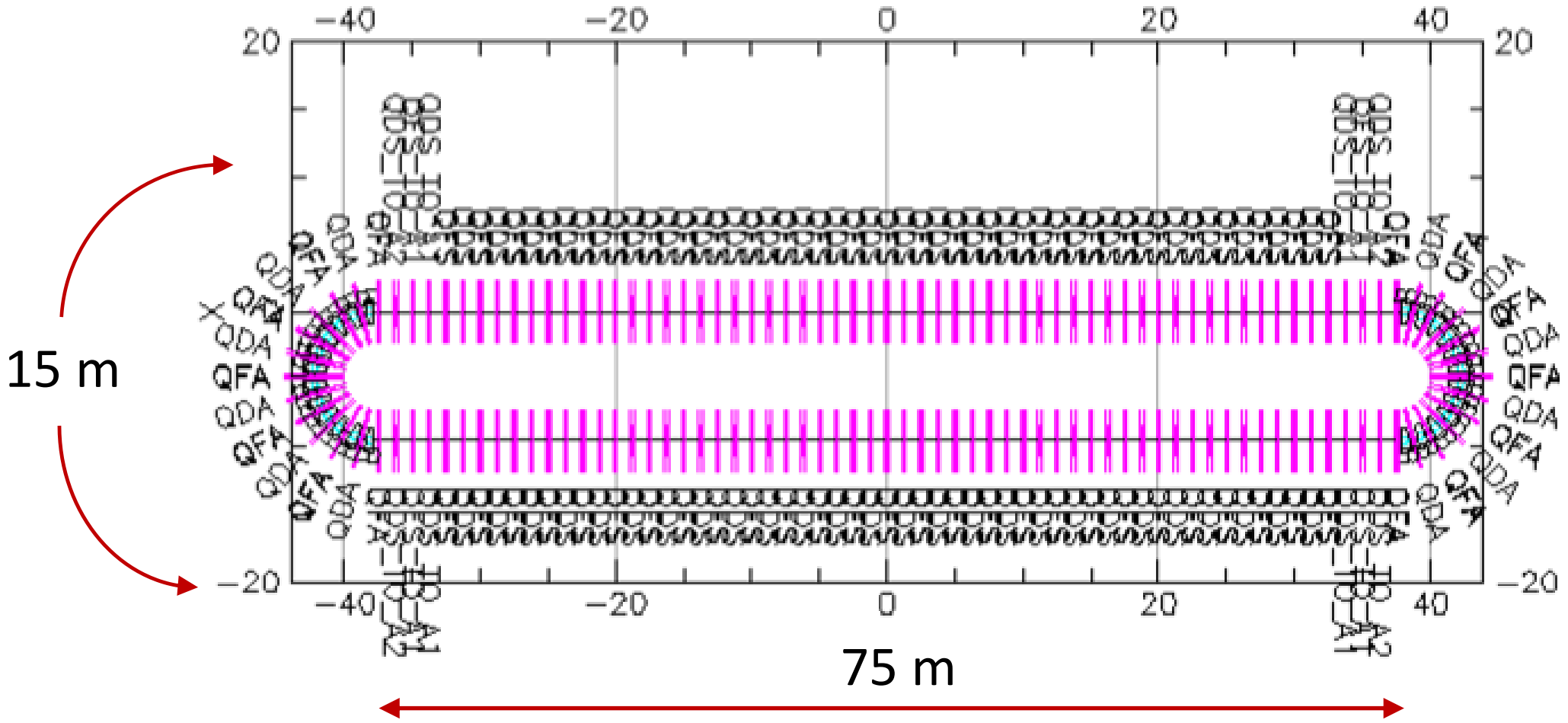
LEnuSTORM: beamline dimensions

- We are targeting a
  - < 20 m long pion transfer line
  - ~75 m long straight section
  - 15-20 m long arc
  - ~0.4 m full beam aperture

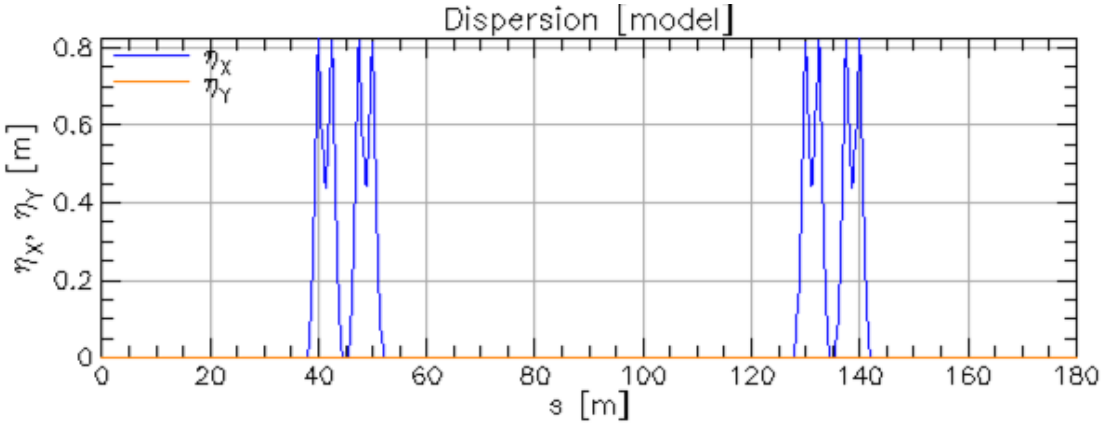


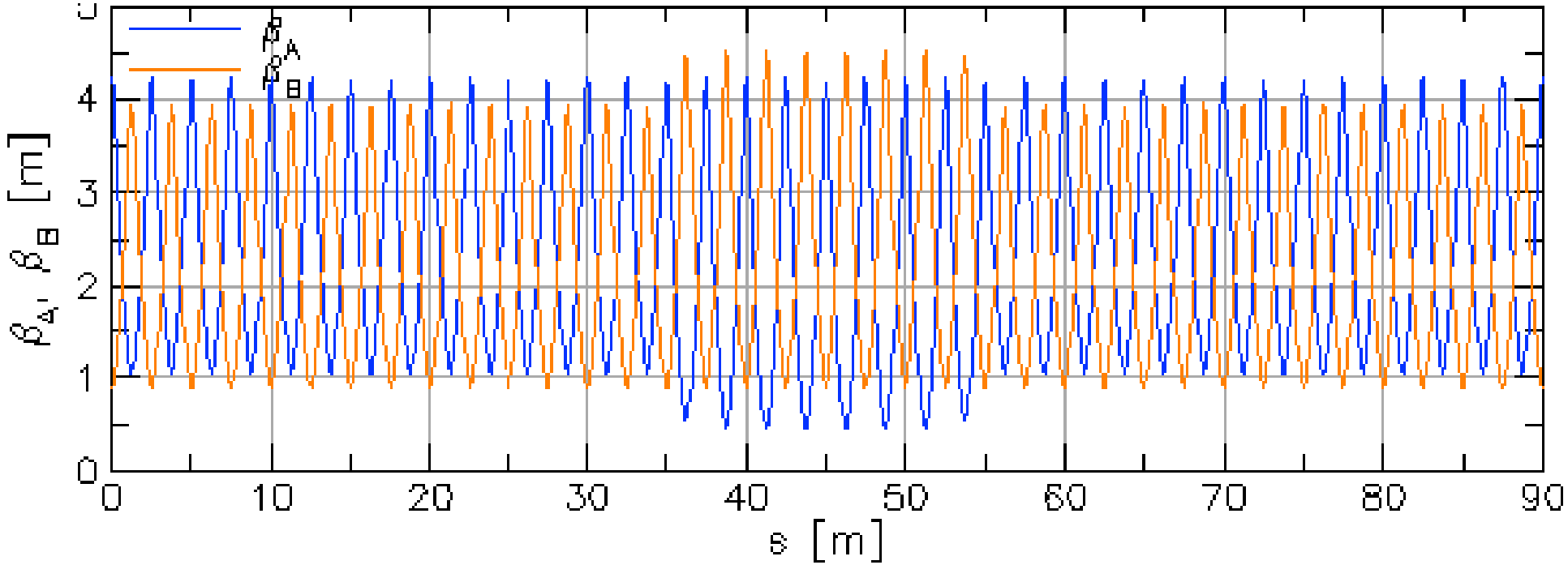
More details in the WP4 session on Tuesday morning and in the plenary session on Wednesday after the morning coffee break.

LEnuSTORM: Preliminary ring design



Preliminary ring design





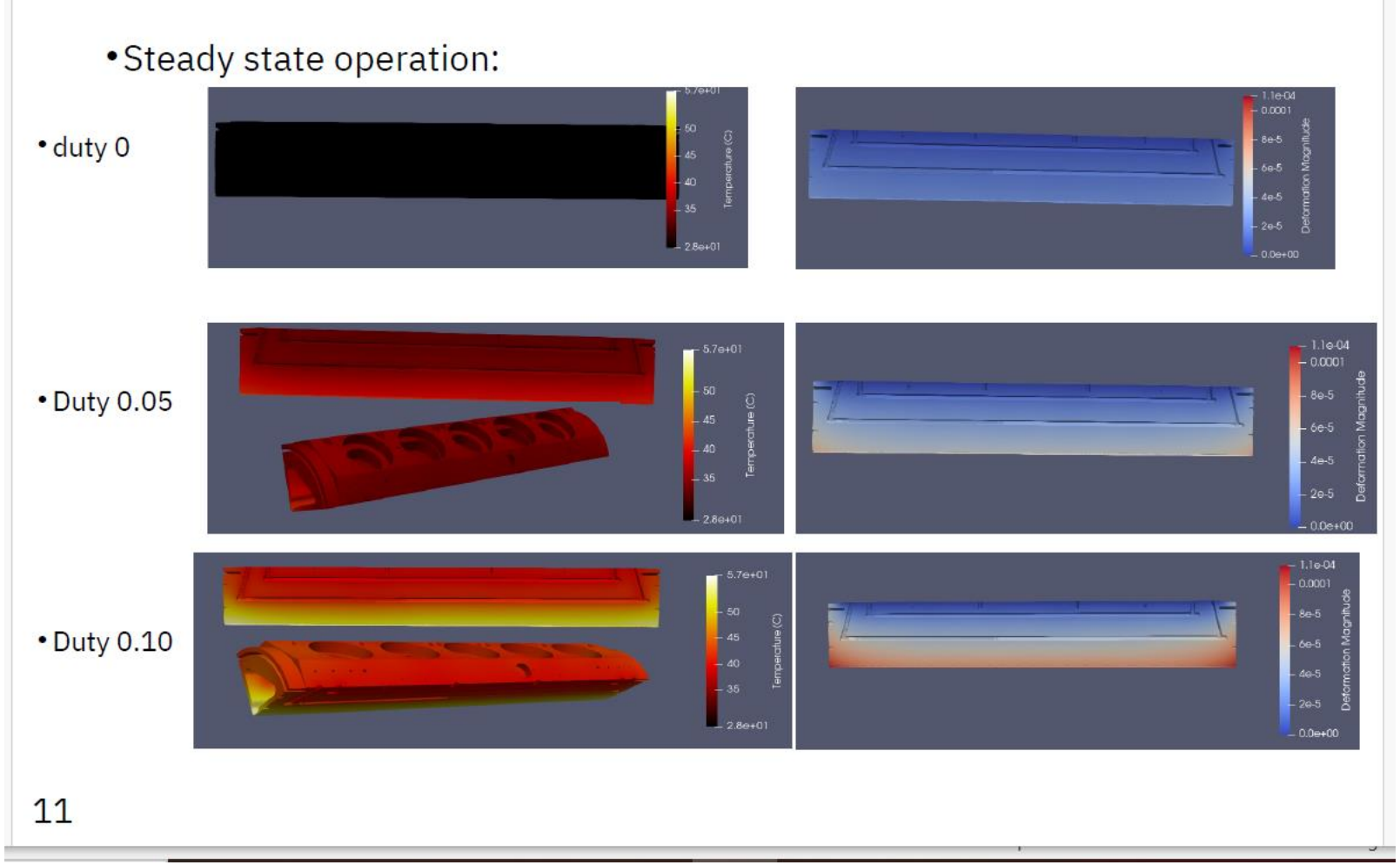
Neutrino flux?

- We have made a first estimate of the efficiency of each stage:
  - From proton on target
  - Pion collection, energy and phase space selection
  - Acceptance of beamlines
  - Injection efficiency
  - Beam losses
  - Conversion ”efficiency” (decays)
  - Acceptance of LEMMON-D.

- With first ring design we will refine these numbers.

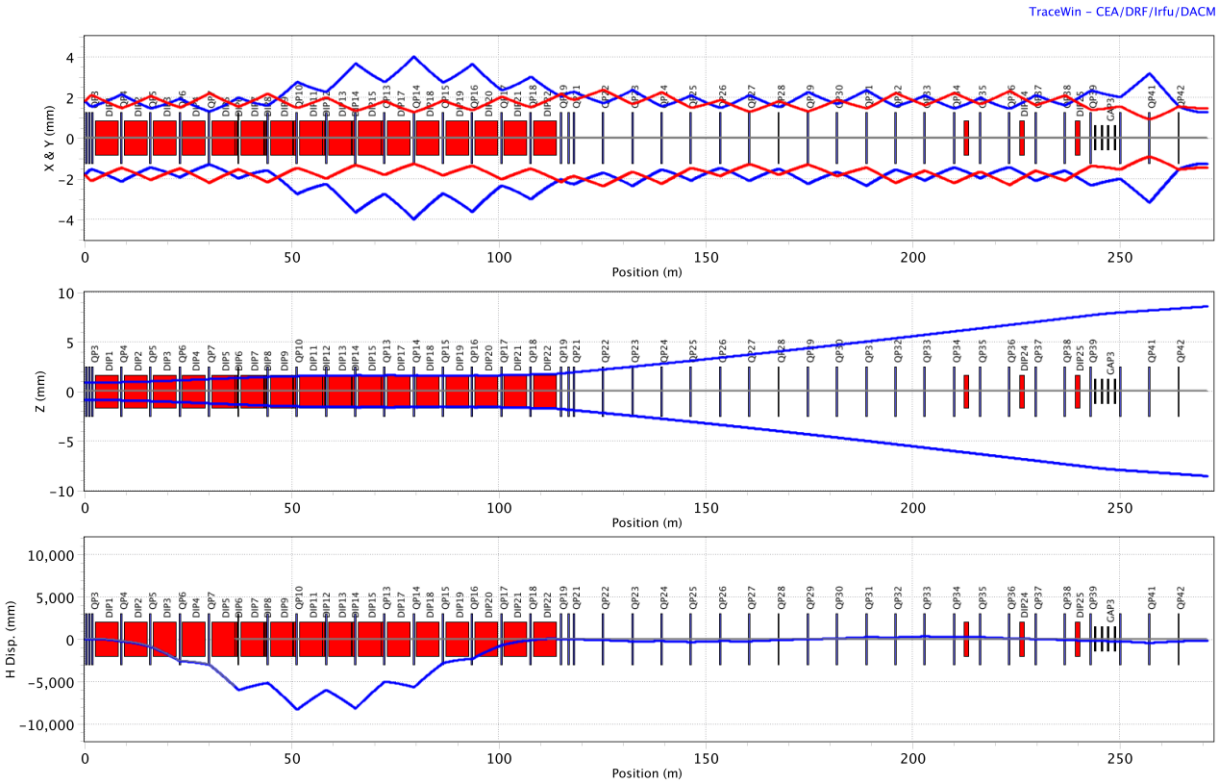
RFQ assessment

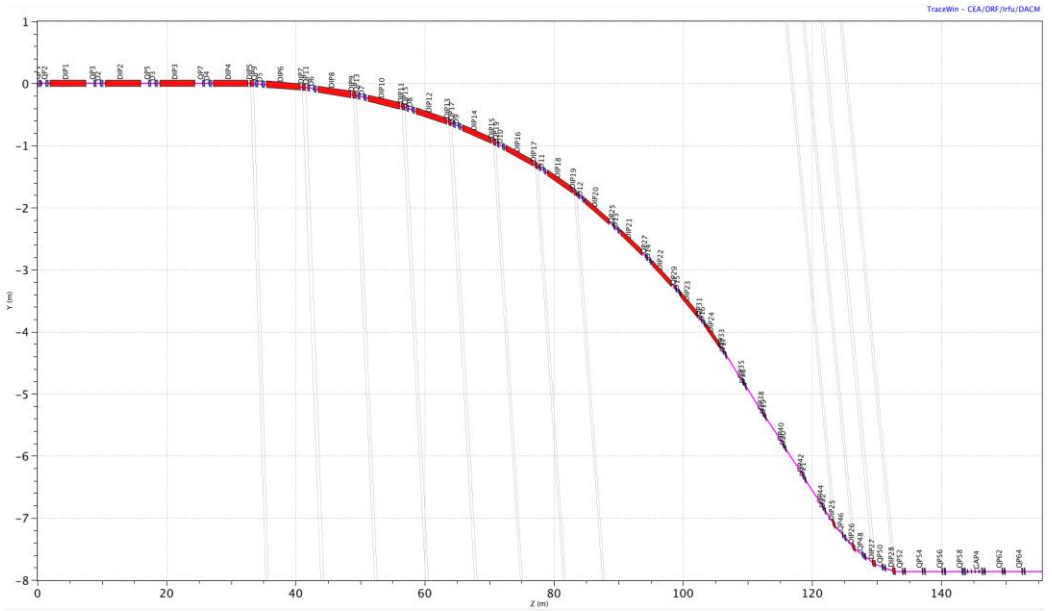
Checking the tuning capabilities (through cooling) of the RFQ at 10% duty cycle.



Juan Luis Munoz

New H- transfer line design





Goals:

- Simplify construction
- Reduce cost
- Improve the design

Natalia Milas

WP4 Tasks: quick status update

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4.1: Coordination — Six WP meetings + one general meeting since last annual meeting + project review

4.2: Proton transfer to LEnuSTORM target — New line not needed.

4.3: Pion and Muon beamlines

- Pion transfer — Ongoing at CERN
- Pion injection — Started at UU, to be coordinated with CERN
- Ring lattice — New design based on refined parameters, constantly evolving
- Muon and neutrino flux — First rough estimate presented, evolves with the design.

4.4: Update existing design — New design transfer line
Waiting for two new postdocs to accelerate this task.

IAP comments

IAP comment: proton or H^- injection?

(**finding**) Proton injection with a tilted septum has been demonstrated if the final emittance is allowed to be about 3 time larger the than H- injection.

(**recommendation**) Although the magnet aperture of the accumulator ring (AR) has to be increased accordingly, the benefit of avoiding a H- source and the risks associated with the H- beams could be huge. Further simulation work with space charge effects will tell us if it is feasible in practice.

We recommend keeping the proton injection study as a high priority item. It is also recommended that the selection of the injection method, whether protons or H-, should be made within a reasonable time frame (1~2 years).

(**response**) This has been kept as a high priority item, but due to the difficulties in recruiting qualified postdocs for the project it remains to be done. Currently, we estimate that the work on the proton injection will resume early 2025 when the ESS postdoc has come up to speed with the project.

IAP comment: Laser stripping

(**finding**) In the previous phase, H- injection with a foil is studied in details. Now the project moves to the feasibility study of laser injection.

(**recommendation**) Progress of the laser development is fast. The H- injection system implementation becomes more promising. The experiment at SNS will continue and a new experiment at J-PARC shall start in a year time.

It is a good idea to keep up with the latest development elsewhere. On the other hand, it is essential to establish a parameter table when it is applied to the ESS AR. Because the linac beam energy is higher than SNS, the system could be simpler and easily achievable than anywhere else

(**response**) We have kept contact primarily with SNS on this subject. The beam parameter table for the accumulator has been established since long but needs to be extended to include the relevant laser parameters.

IAP comment: nuSTORM parameters

(**finding**) The first version of the nuSTORM lattice was designed by scaling of the previous design at Fermilab and CERN.

(**recommendation**) The meaning of optimization and breakdown of steps toward the optimized design should be clarified. There are many possible paths to obtain the maximum neutrino flux. The minimum and maximum divergence, tune choice, momentum acceptance, transverse acceptance are among the obvious parameters to be explored. It is, however, important to know the physical mechanism behind, that limits each parameter area. This should be emphasized when the optimization heavy relies on the genetic algorithm.

(**response**) We have performed a first round of assessment of the physical limitations to the parameters that govern the ring beamline designs. It has been summarized in Report MS6.

By looking at the pion distribution provided by WP3 that we can expect from the target and horn at this point in the project it looks as if we primarily need to maximize the transverse pion and muon acceptance, rather than optimize for a large momentum acceptance. However, the optimization of the horn for the LEnuSTORM has only recently been started so we are waiting for more reliable input to the study.

IAP comment: options for transfer lines

(**finding**) Beam transport lines (linac to AR, AR to targets) are reviewed and several alternative options are proposed.

(**recommendation**) Good to have many options on the table. On the other hand, it is difficult to judge which is the best option at the moment because there are many unknowns, e.g. the time table of the whole project (to be mentioned somewhere else), the number of targets, proton or H- injection, impact on the neutron users, etc. It is important to consider ahead how the design impacts on the commissioning and operation. This includes the diagnostics needs, whether a collimator at upstream is effective, a realistic magnet aperture of the beam line.

(**response**) We are considering H- injection to be the baseline for the project, at least initially. Since we have not been able to recruit postdocs we have not been able to proceed as planned with the refinement of the existing design.

Addition: Some of the ideas presented at the last annual meeting have been discarded due to the risk imposed on the ESS primary function. We keep, for now, the overall layout as before.

WP4

Looking forward to lively discussions!

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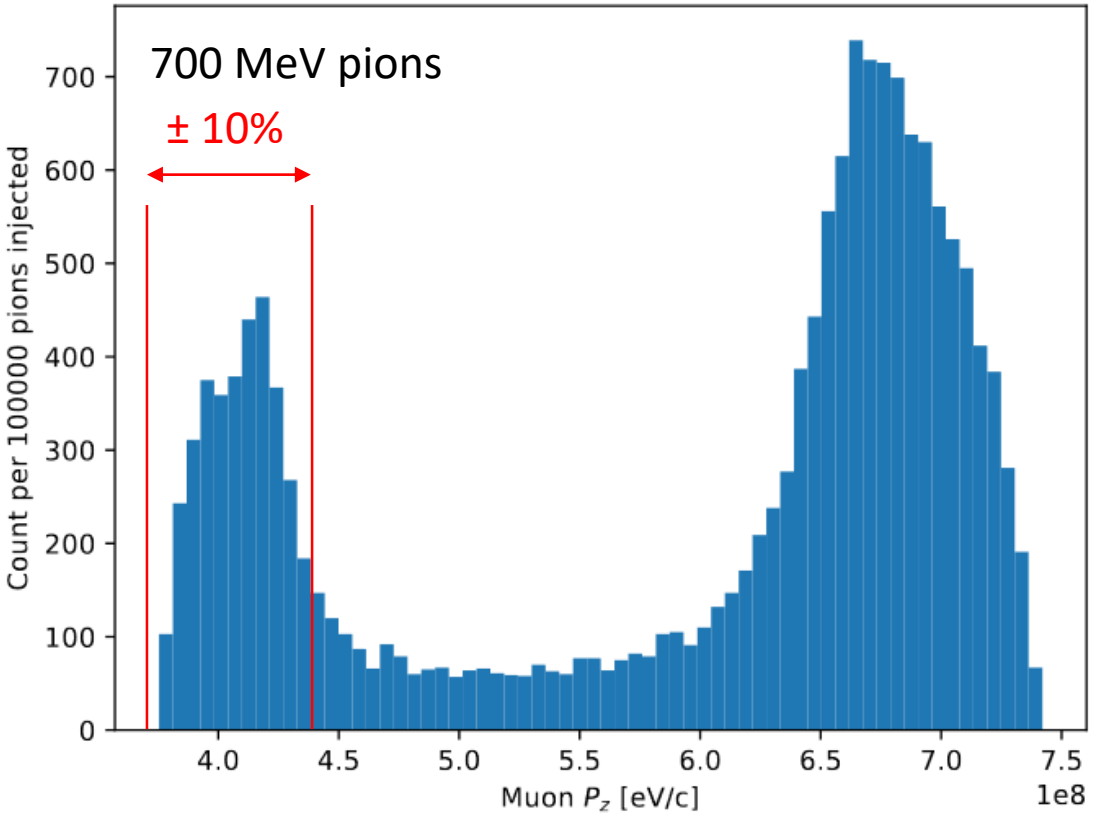
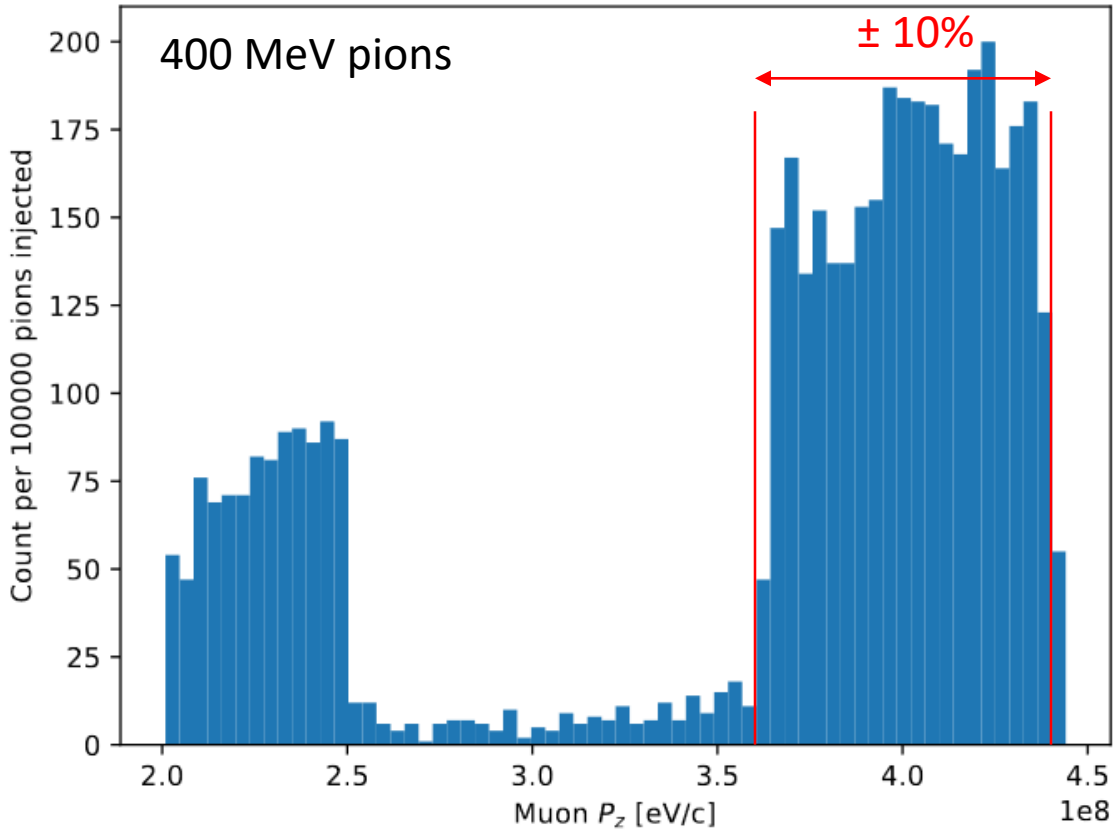
Muon production

Muons with, $J_x < 0.01m$

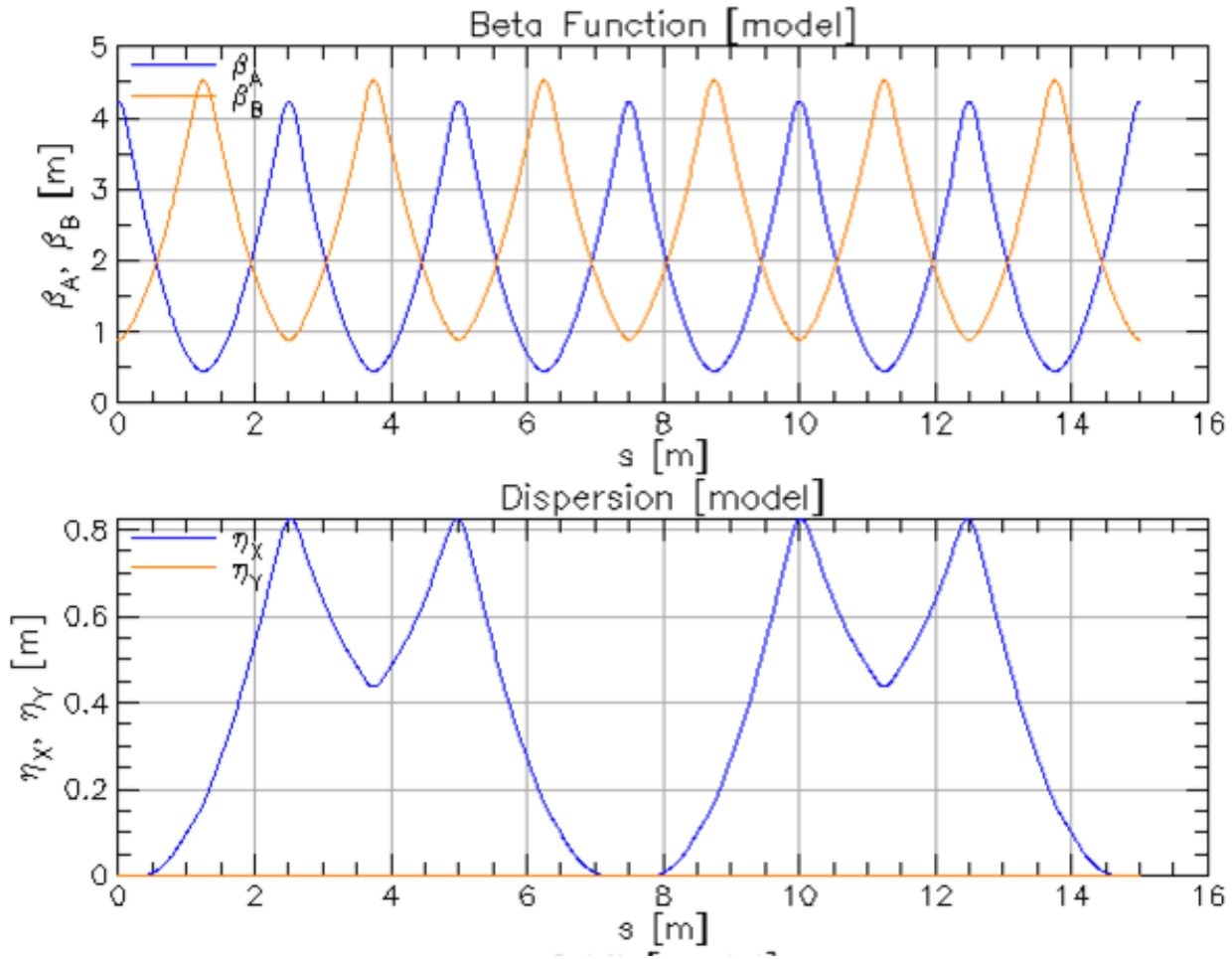


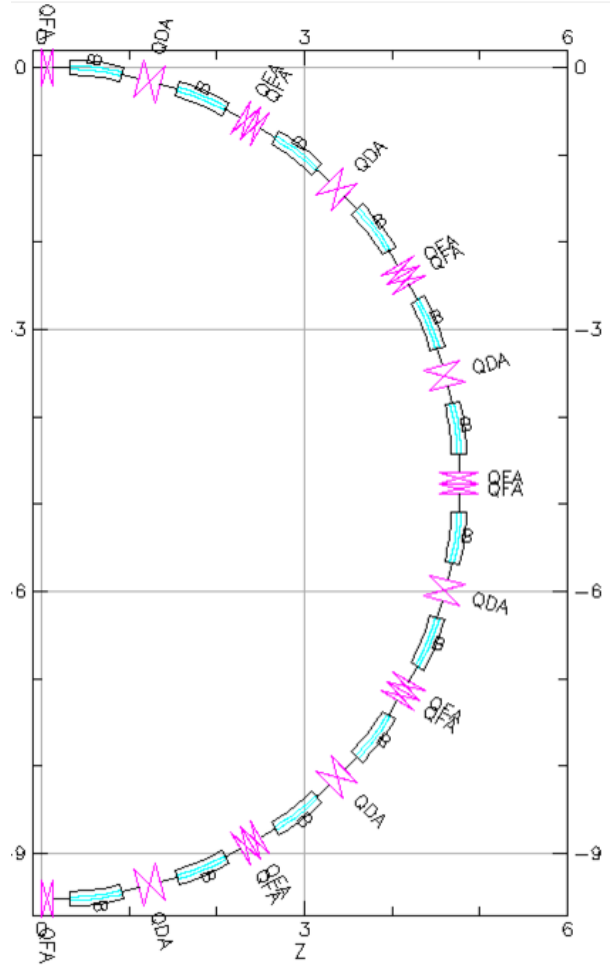
3541 muons



3340 muons

The LEnuSTORM arc design



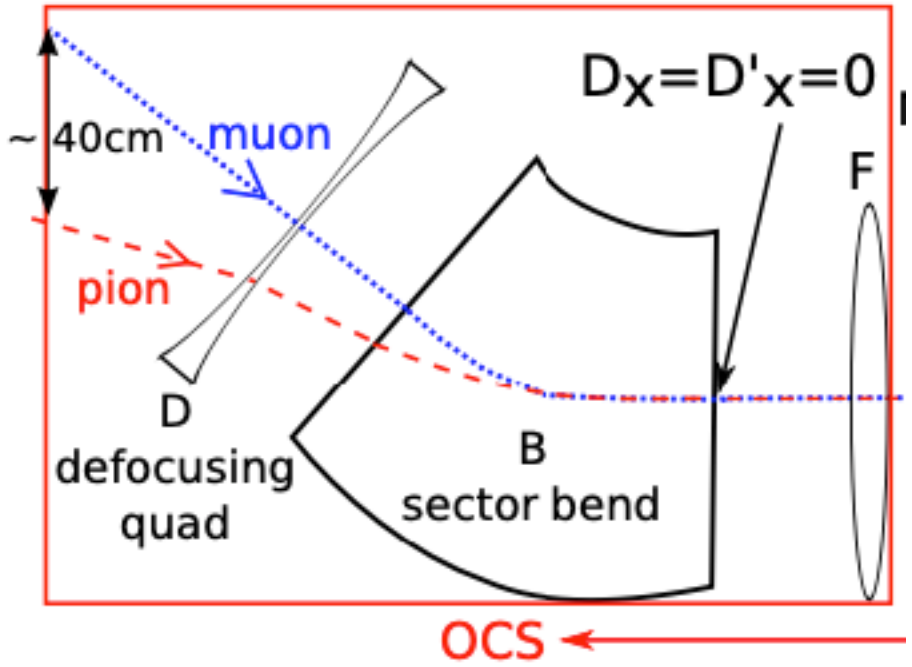


Injection

If stochastic injection:

- 15 m arc
  - 0.09 -0.276 rad (16°)
  - 20 cm drift

- 20 m arc
  - 0.11 -0.234 rad (13°)
  - 45 cm drift



Probably we will need to use a septum magnet.

Tasks

4.1: Coordination of the accelerator work package (UU, ESS)

4.2: Design an extraction line from the ring-to-target transfer line and a transfer line up to the special target station

4.3: Conceptual design of the racetrack ring for LEnuSTORM

4.4: Study the compatibility of LEnuSTORM and ESSvSB and modify the original design accordingly.