



# **Towards the development of a HEP-style detector system for the Muon Cooling Demonstrator**

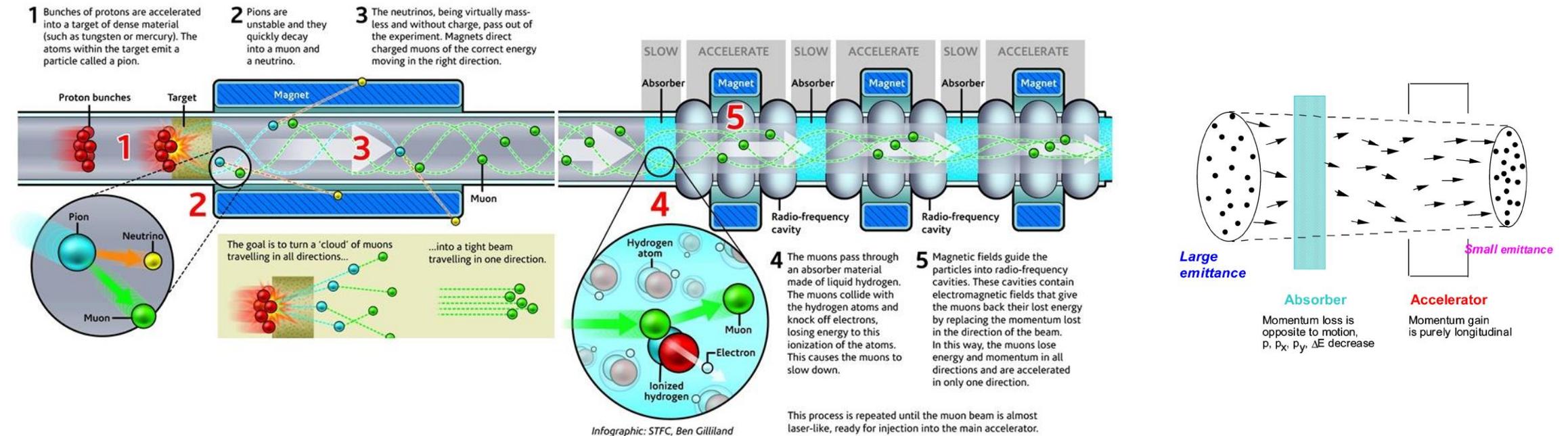
Palombini L.

Credits: Zuliani D., Mazzi A., Lucchesi D., Jurj P. B. and many others



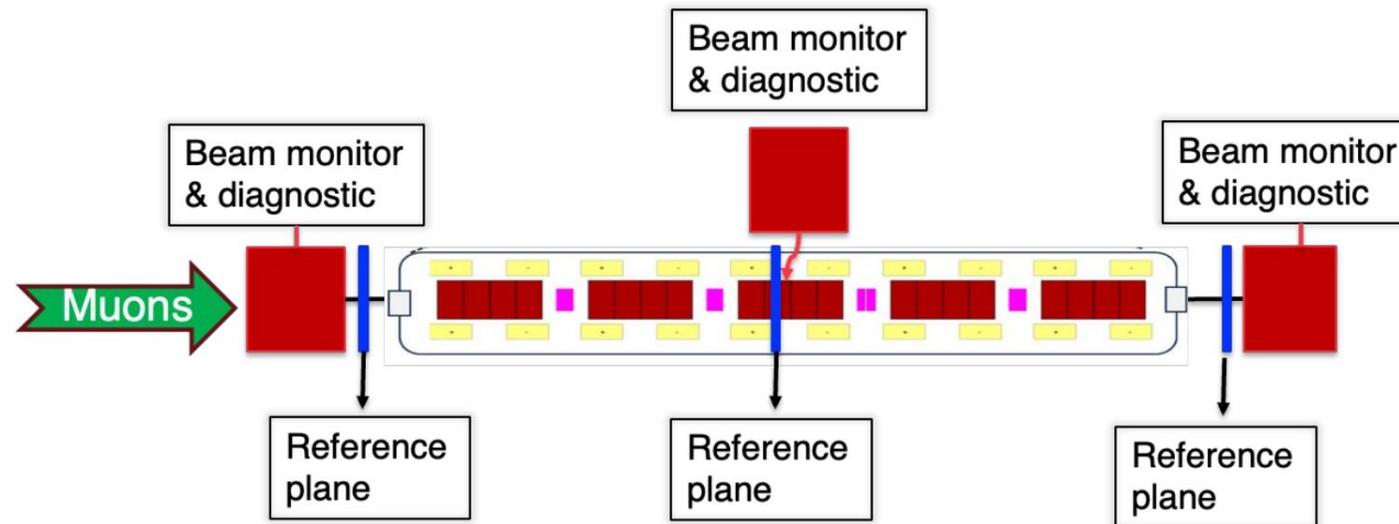
# Muon ionization cooling demonstrator

- Demonstrate the technical feasibility of a muon beam cooling channel for a high-energy Muon Collider



# Why is instrumentation necessary?

- Measure the beam parameters throughout the cooling (especially its emittance)
  - Beam diagnostic
  - Show emittance reduction compared to simulation
  - [Requirements](#) by C. Rogers



# Simulation framework

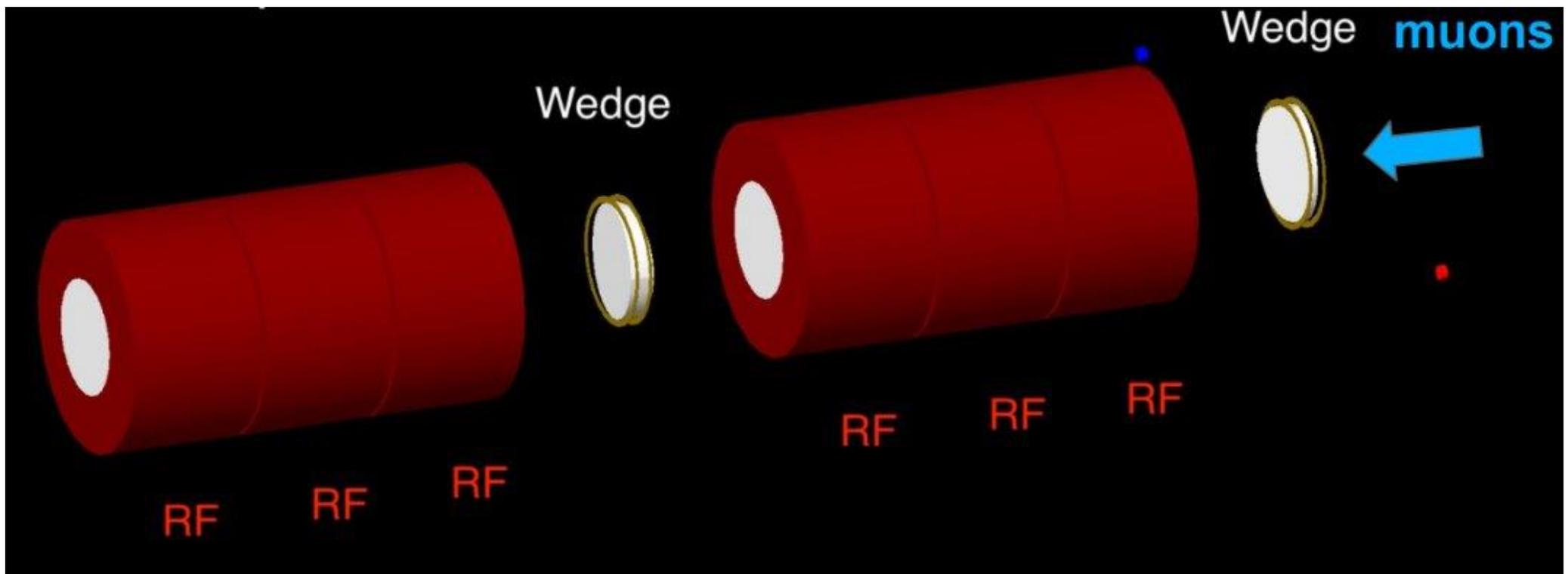
- G4Beamline (by Muons Inc.) to simulate the propagation of the muon beam
- Use the latest version of the cooling setup ([link GitHub](#)): 100 cells = 200 m

Absorber (wedge)	
Material	Lithium Hydride
Wedge angle	10 degrees
Wedge thickness	25 mm on axis

Magnetic field (solenoids)	
From file	Solenoid_field_map.txt

RF cavities	
RF cell center-to-center distance	188.6 mm
Gradient	30 MV/m
Number of RF cells	3
Frequency	704 MHz
Synchronous phase	20 degrees

# A cooling cell

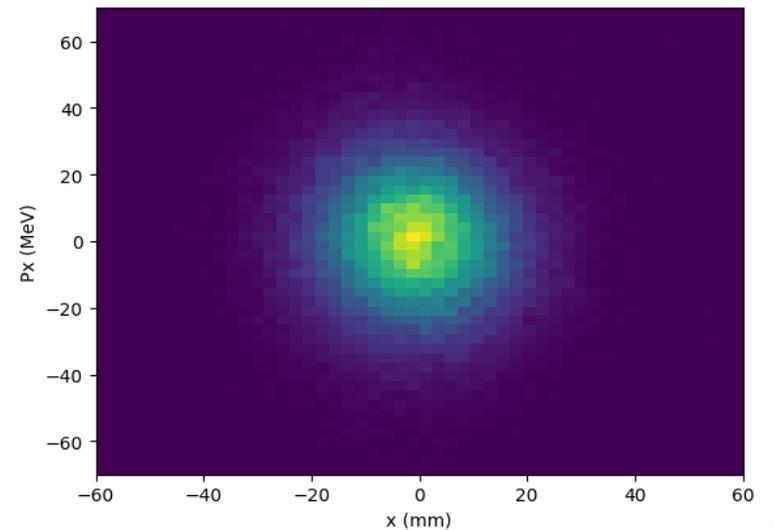
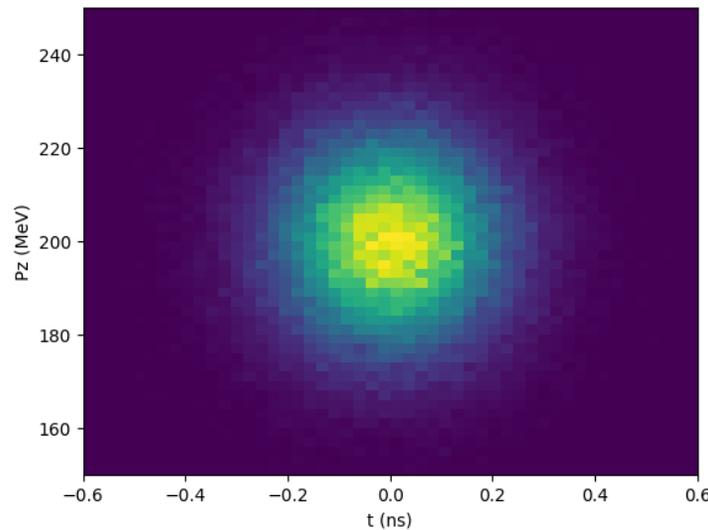
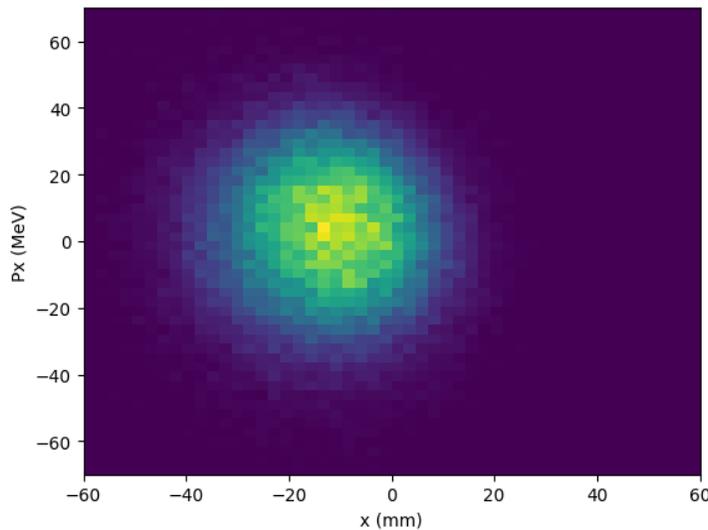


# The input beam

- Pure beam of  $\mu^+$  (credit P. B. Jurj)
- Generated from a covariance matrix

\*( $\alpha$ ,  $\beta$ ,  $\gamma=(1+\alpha)^2/\beta$ ) Twiss parameters

Beam parameters	
Avg momentum	200 MeV/c
Alpha*	0
Beta*	0.13 m
Time spread	0.140 ns
Long. momentum spread	0.015 GeV/c
Mean x offset	-0.01386 m
Mean y offset	-0.00107 m

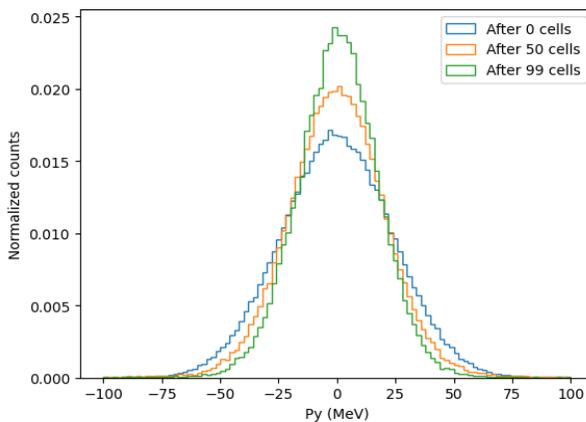
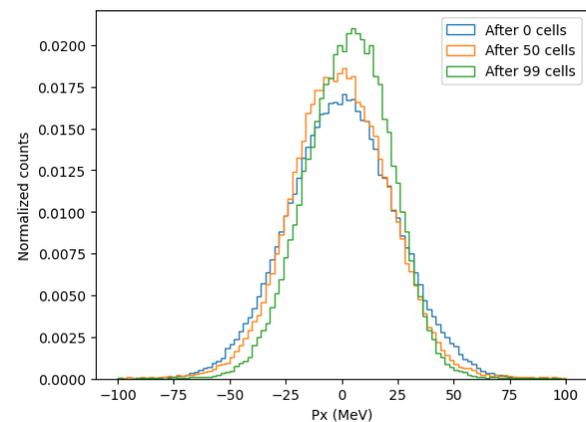


# Our procedure

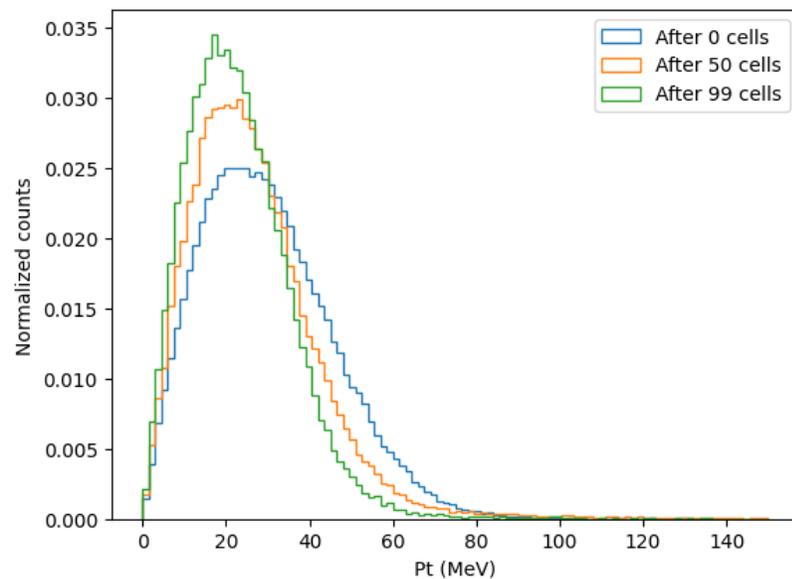
- Simulate  $10^6$  muons ( $\sim$  expected beam intensity in baseline scenario) extendable
- In our configuration, we can:
  - Switch on/off the decay of muons
  - Simulate the interaction of particles with the materials
  - Track all particle species (now cut at  $p = 500$  keV, tunable)
- Transverse emittance computed as:
$$\varepsilon = \frac{1}{m_\mu c} |\Sigma|^{\frac{1}{4}}$$
  - Where  $\Sigma$  is the covariance matrix of  $(x, p_x, y, p_y)$
- 0th-order : add a scoring plane for each cell
  - Virtual plane (just shows the particles it is crossed by)
  - Silicon layer (same as virtual + energy deposition and realistic material interaction)

# Some plots (no silicon layers)

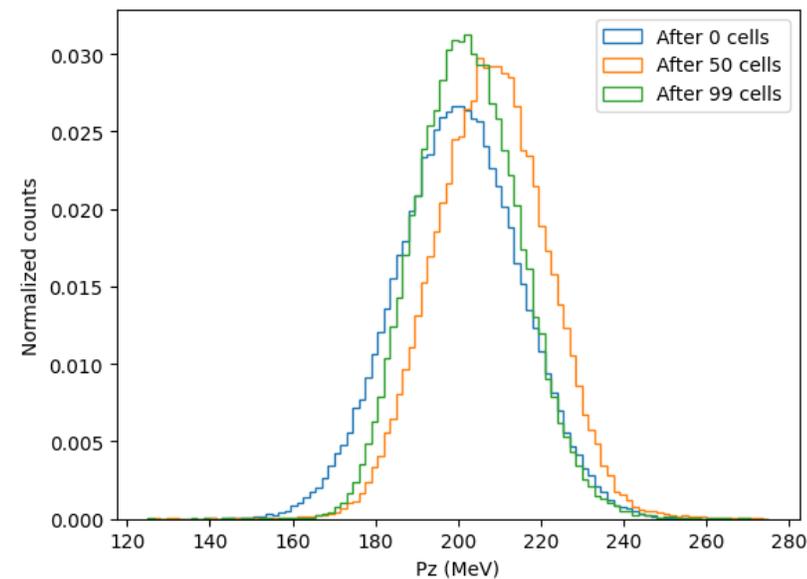
- Muon decay and full particle propagation ON



Momentum perp. to the beam direction

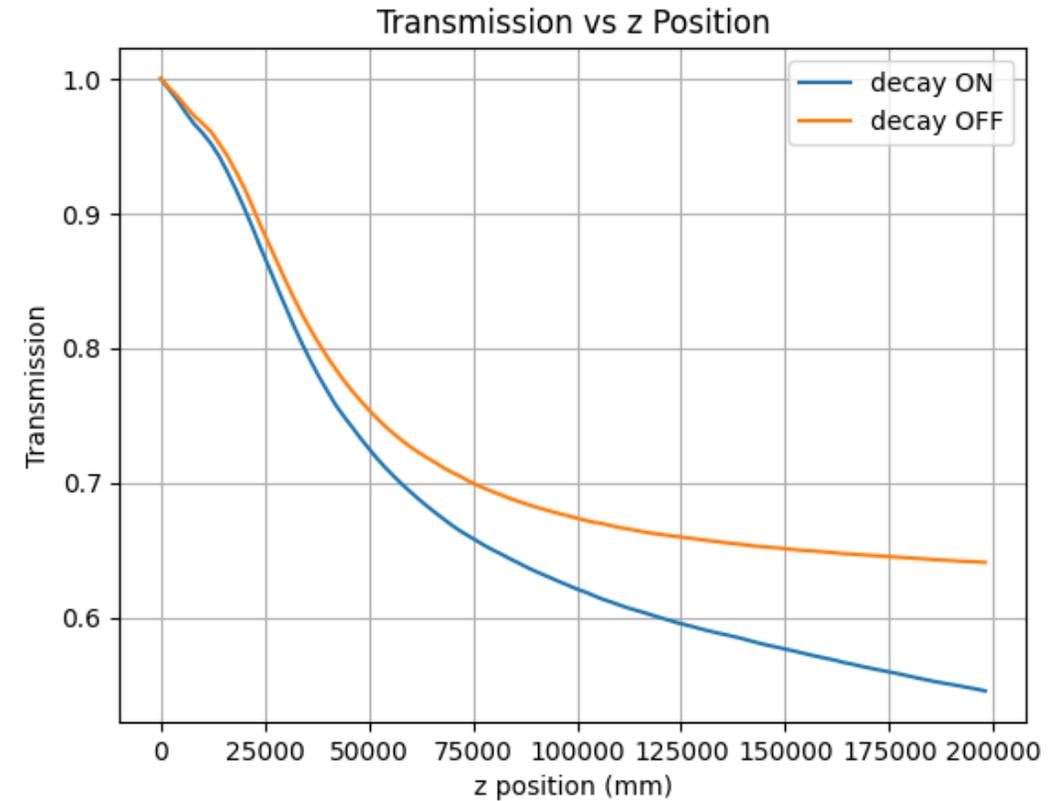
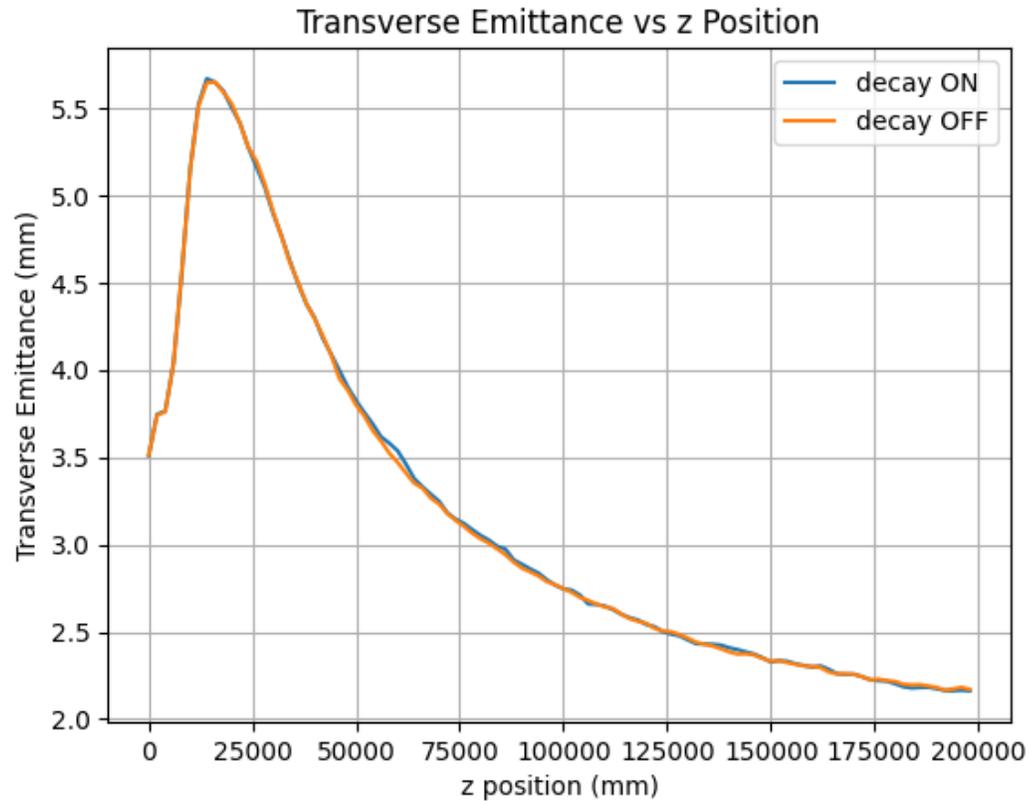


Momentum parallel to the beam direction



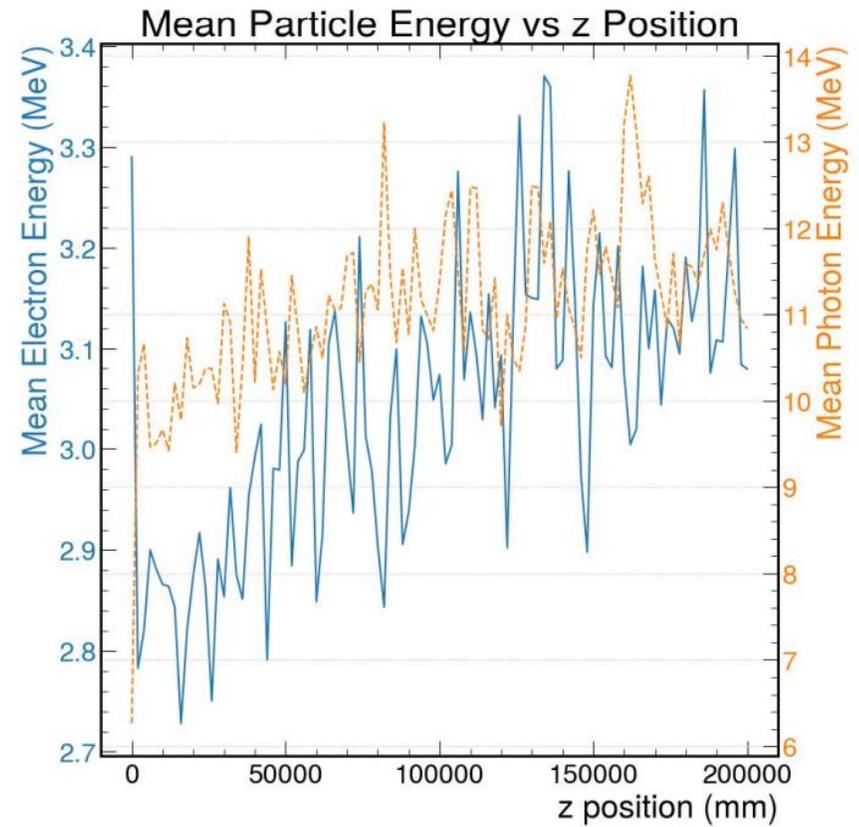
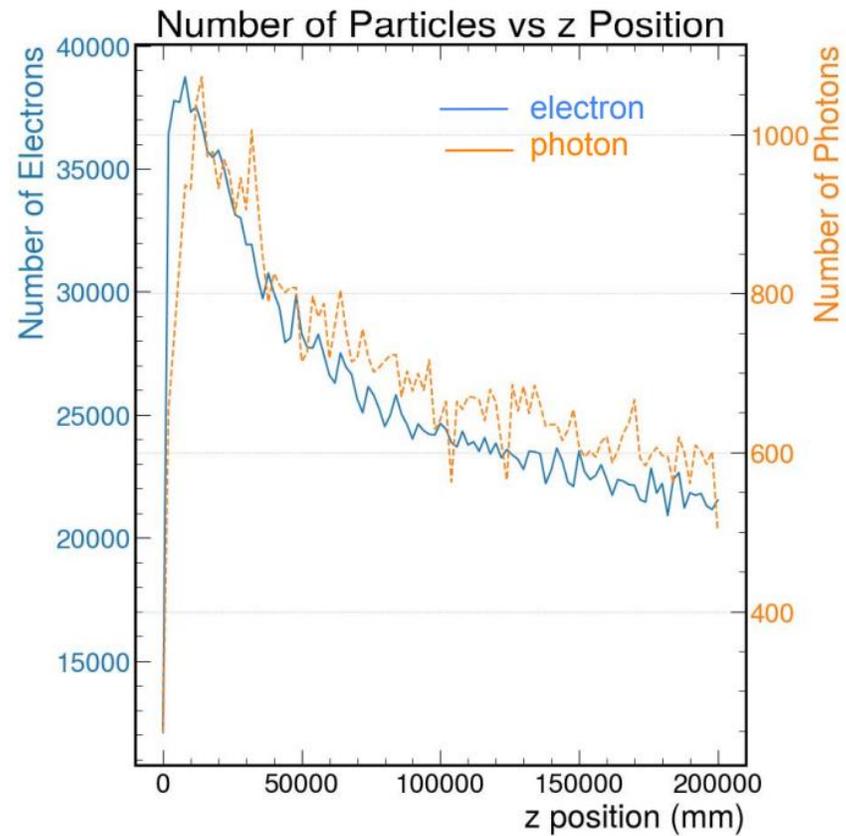
# Some plots (no silicon layers)

- Muon decay and full particle propagation ON



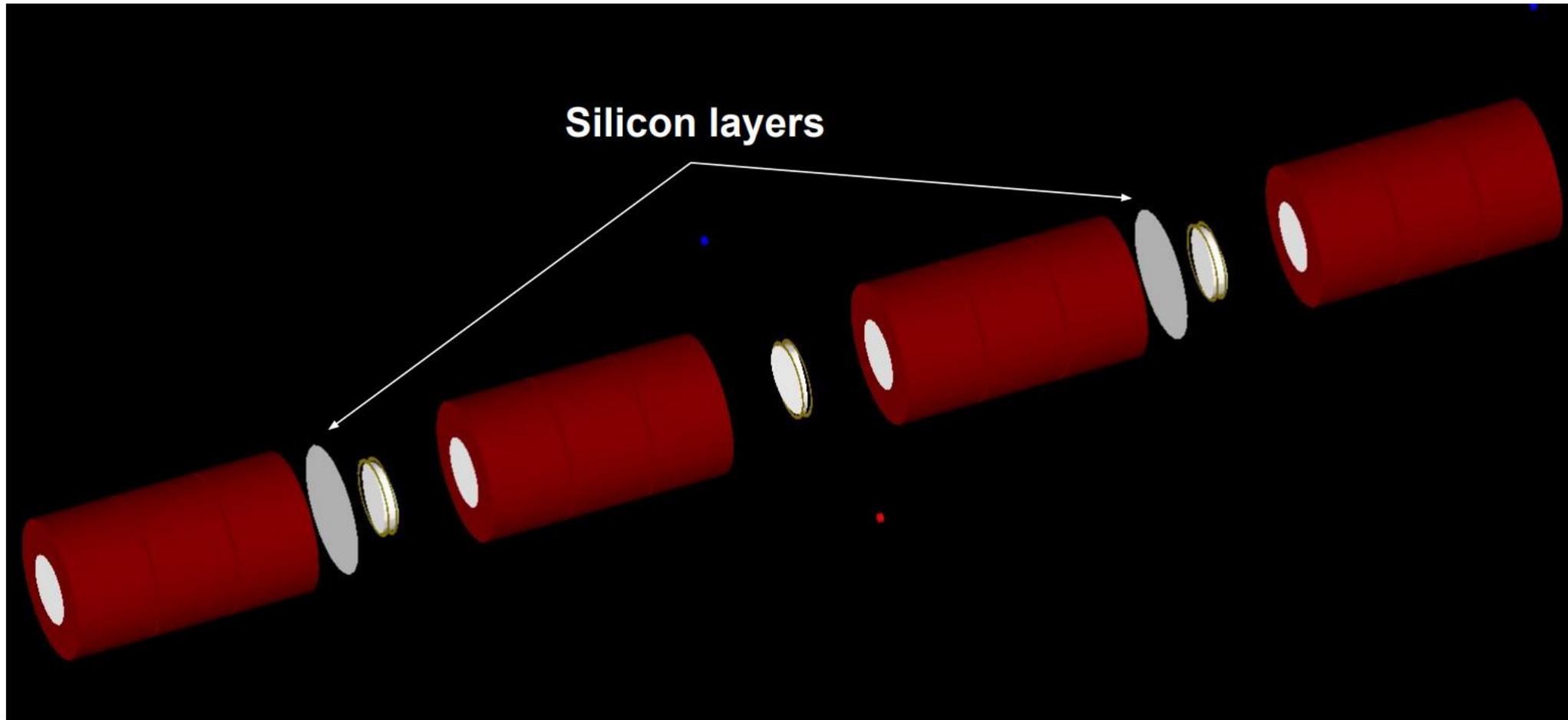
# Some plots (no silicon layers)

- Muon decay and full particle propagation ON



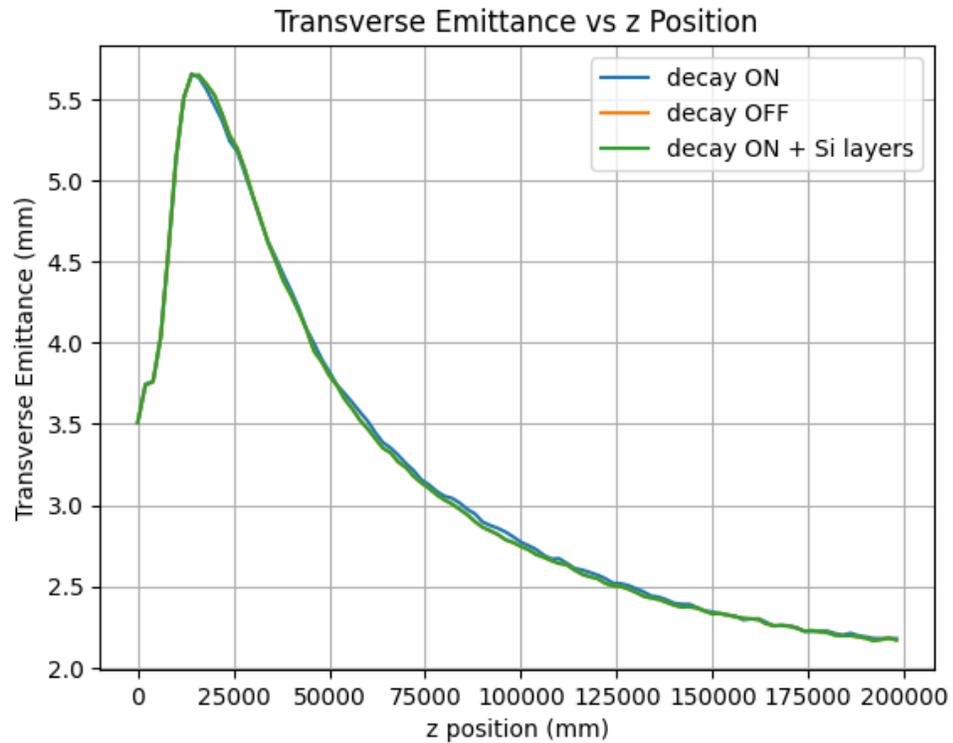
# Silicon layers in the simulation

- After each cooling cell, with an example thickness of 20  $\mu\text{m}$



# Some plots (with silicon layers)

- Muon decay and full particle propagation ON



# The known unknowns

A baseline evaluation of the detector requirements implies:

- A realistic beam simulation → not only muons, possibly (many?) contaminating particles
- An indication of the space available in the cooling engineering design

That should bring us to an understanding of the viable sensor technology

- Sensor thickness, space/time resolution, granularity, radiation hardness
- Which can be fed back to the simulation to optimize the positioning and check possible effects on the beam dynamics

# The (un)known unknowns

Decisions from the (possibly) hosting facilities strongly influence the path towards a cooling demonstrator :

- ? Different muon beam properties (CERN/FNAL)
- ? Different scale of the demo (fundings)
- ? Different beam altogether (e.g. protons if a dedicated muon beam is unavailable)

Different scenarios can be imagined and considered in this study