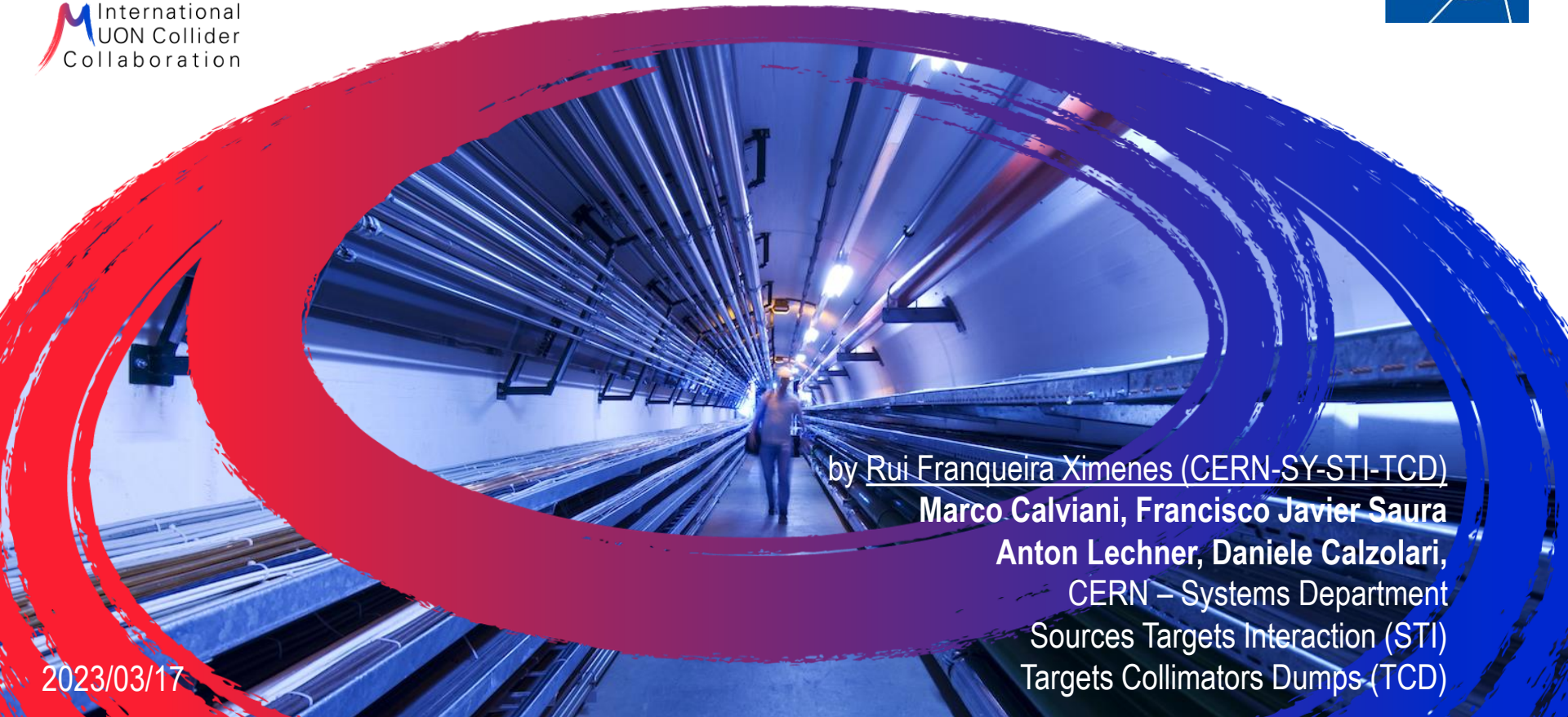
Target Parameters

Proton complex Monthly Meeting



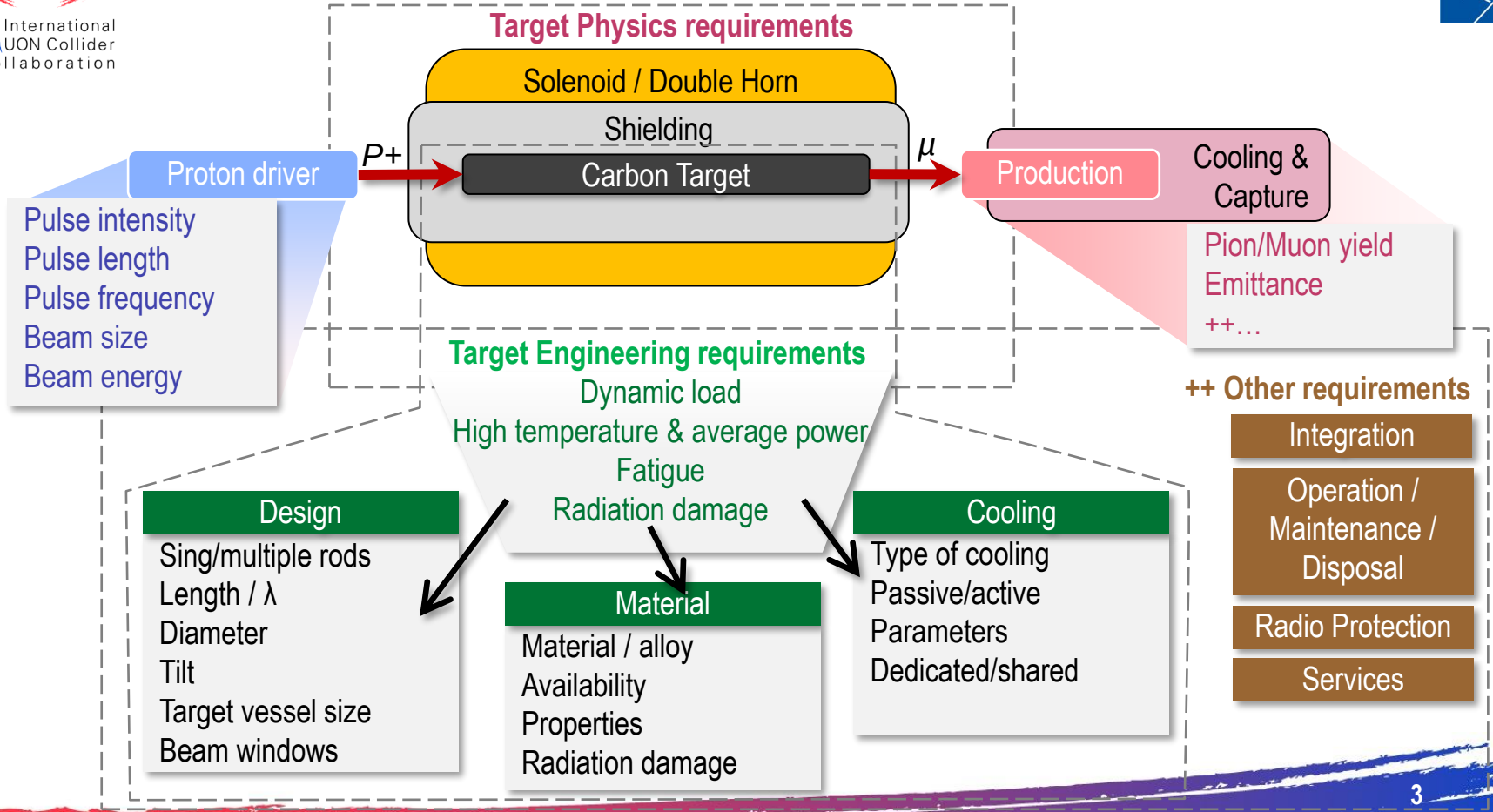
by Rui Franqueira Ximenes (CERN-SY-STI-TCD)
Marco Calviani, Francisco Javier Saura
Anton Lechner, Daniele Calzolari,
CERN – Systems Department
Sources Targets Interaction (STI)
Targets Collimators Dumps (TCD)

2023/03/17

Outline

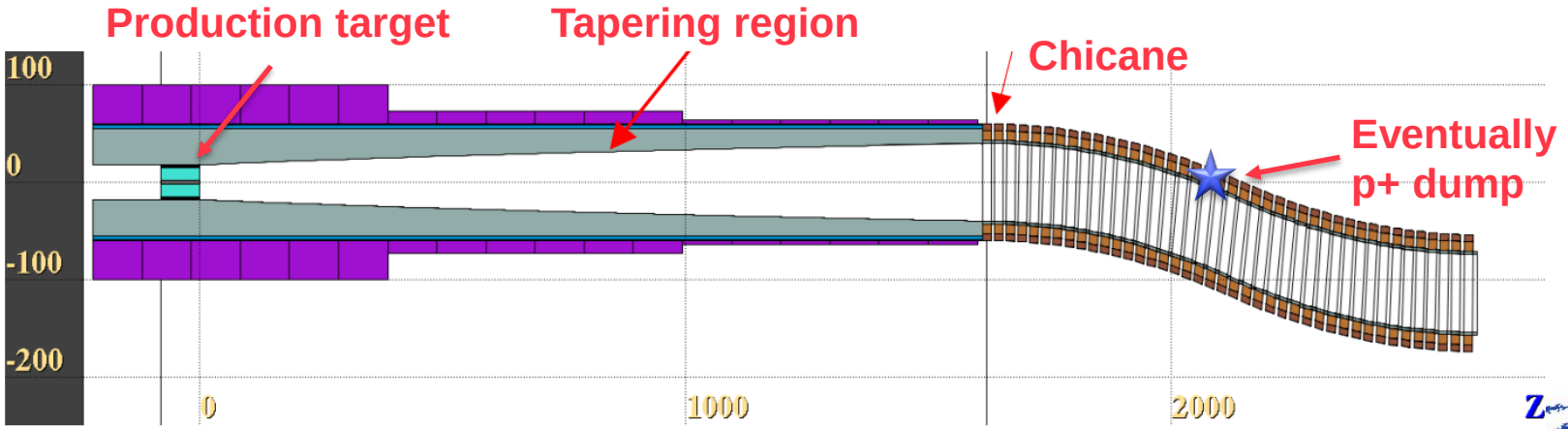
- Parameters sensitivity study
- Parameters of the C-Target Conceptual Design
- AOB

Carbon target & target systems considerations

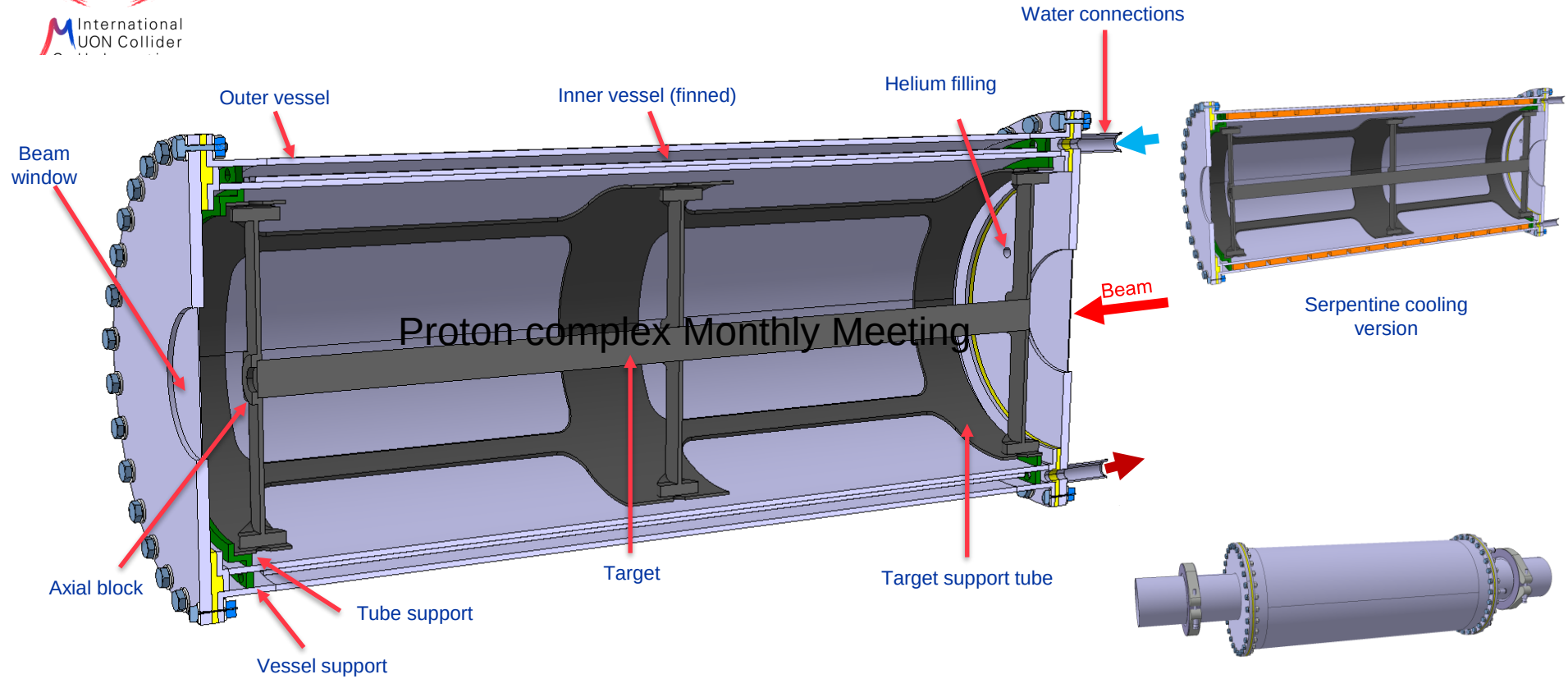


Carbon target & target systems considerations

- Energy deposition/dpa studies on the Target, windows, shielding, magnets, chicane
- Parameterization study / optimization of beam parameters
- (Conceptual) Engineering study of Target & Target Systems, shielding, p+ dump -> feasibility
- ++ iteration loops with p+ driver, magnets, cooling



Carbon target concept



Parametric scan: beam parameters

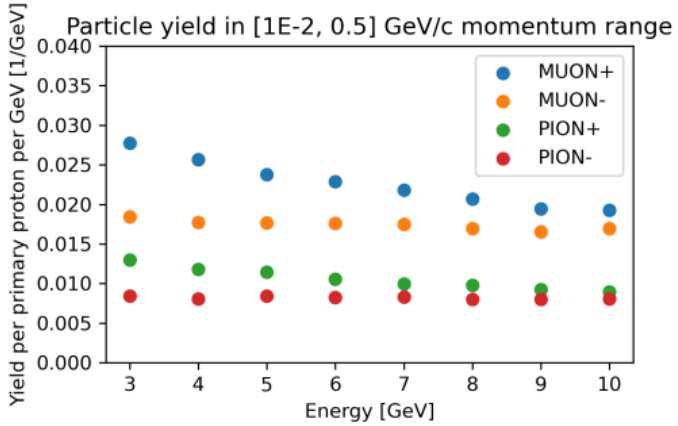
by Daniele Calzolari and Anton Lechner

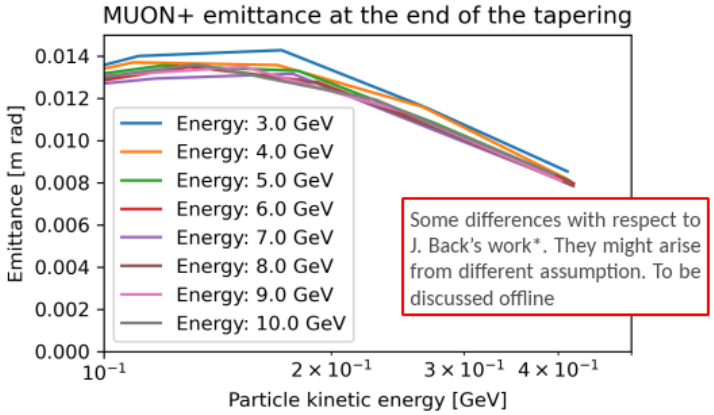
https://indico.cern.ch/event/1237101/contributions/5204412/attachments/2575066/4440149/angle_dpa_updateJan23.pdf

- The muon yield is calculated summing up all the muons produced up to 500 MeV/c momentum. The emittance is calculated from the 4D emittance formula (determinant of the covariance matrix).

Proton beam energy:

We will continue to assume the 5 GeV as fixed parameter. Nevertheless, we observed an asymmetry in the mu+/mu- production and larger starting emittances at lower energies



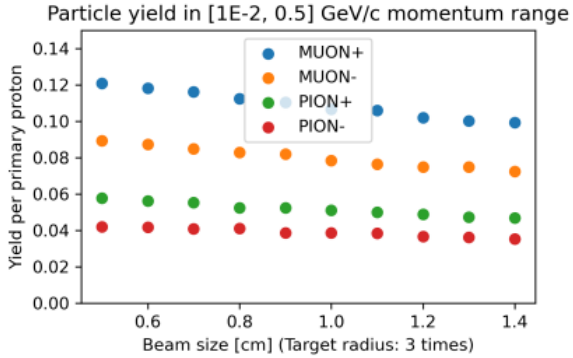


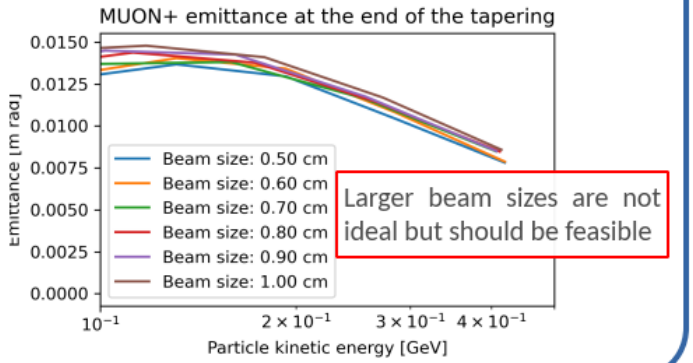
*https://indico.cern.ch/event/1175126/contributions/5024015/

Parametric scan: beam size and transverse target size

Proton beam size:

The default case is a 5 mm beam size, and the target size is always 3 times the beam size

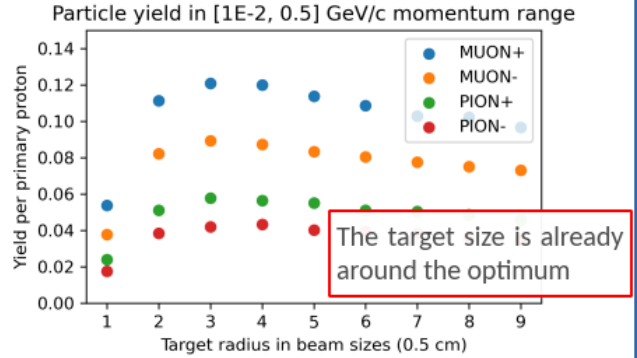




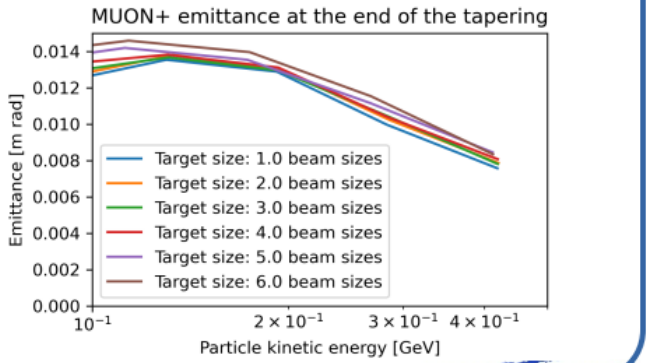
Larger beam sizes are not ideal but should be feasible

Target transverse size:

The default case is 3 times the beam size, and the beam size is always 5 mm



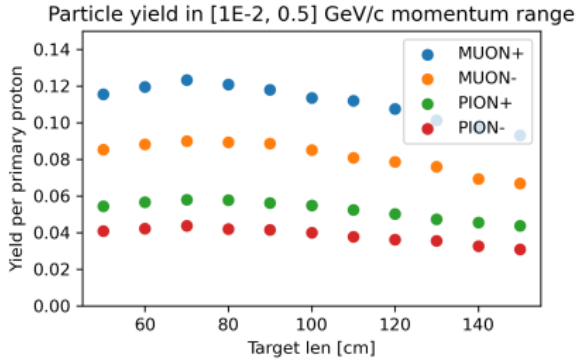
The target size is already around the optimum

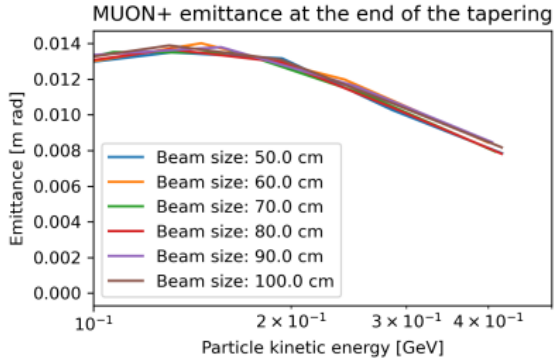


Parametric scan: target length and shielding aperture

Target length:

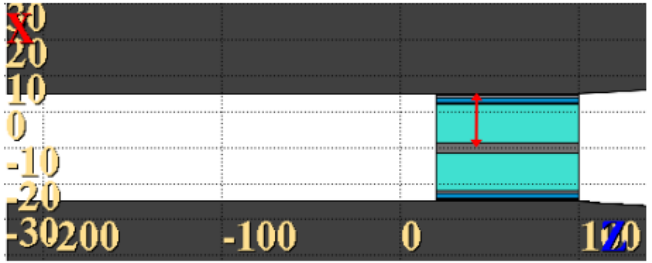
The default case is a 80 cm graphite rod

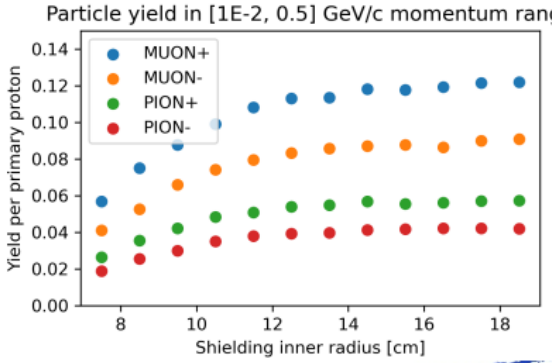




Shielding aperture

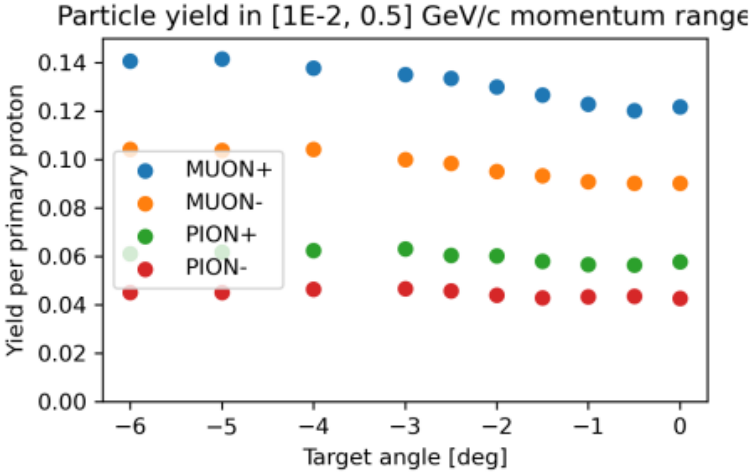
The default case is 17.8 cm

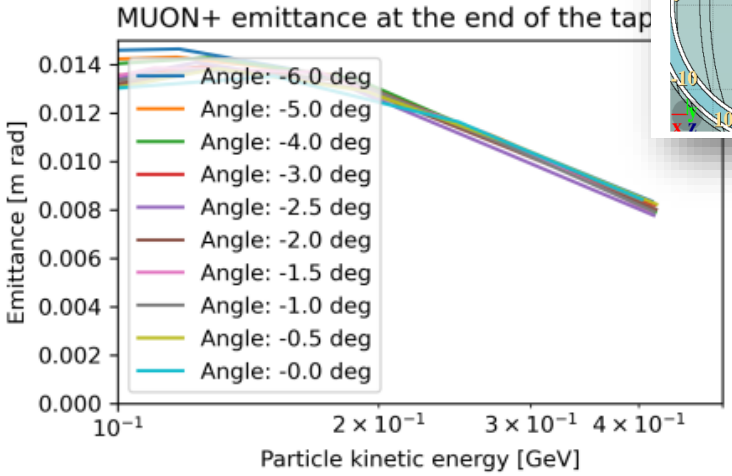


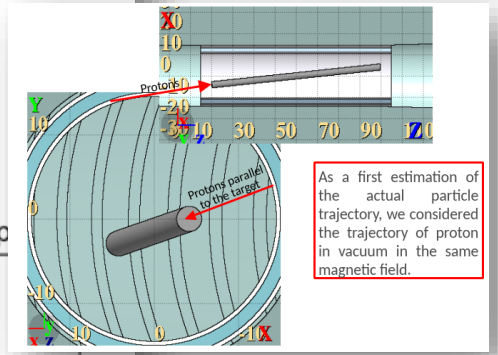


Effect on the muon yield

- Considering the amount of muons produced and their emittance, having a tilted proton beam has small effect on the yield.

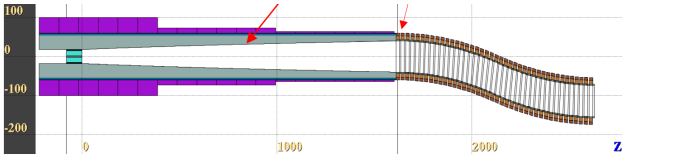


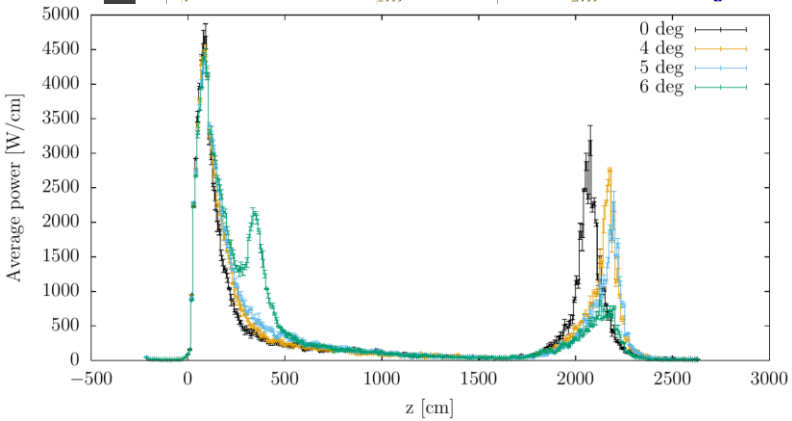


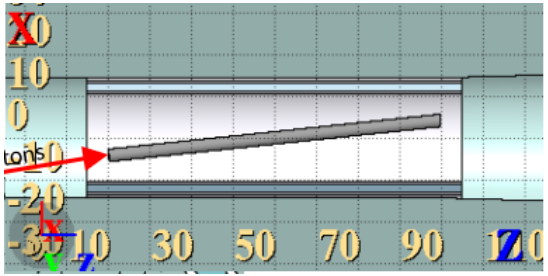


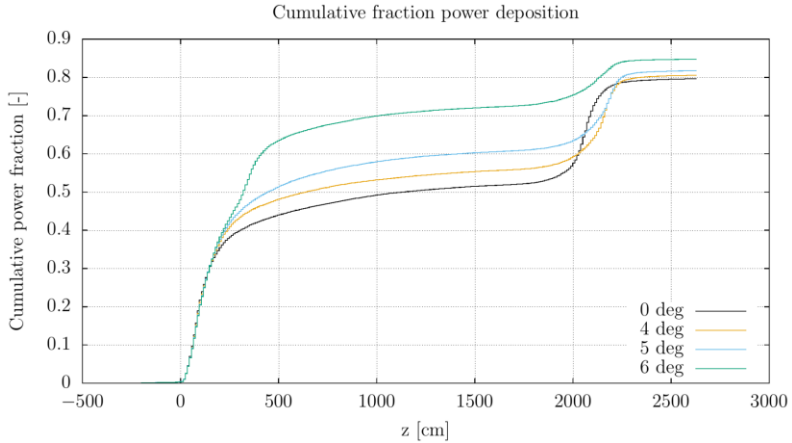
Carbon Target: pion/muon yield parameterization & energy deposition studies

- Energy deposition/ dpa studies









Carbon Target: engineering feasibility

Carbon Target

Study considerations

- Simple C-rod (L800 mm, 1.79 nuclear inelastic scattering lengths)
- Beam energy (5 GeV), bunch length (2ns) and average beam power (1.5 – 3 MW)

↓

- Sensitivity study: thermal behavior as a function of beam sigma and frequency → How much do we gain by playing with these beam parameters?
- Studied cooling concepts:
  - Only radiation cooling
  - Natural convection + radiation cooling → How can we cool it?
  - Forced convection cooling
- Structural calculation → Does it 'survive'?

Note: Not coupled with any pion-muon physics optimization → purely thermo-mechanical feasibility assessment.

Carbon Target: engineering feasibility

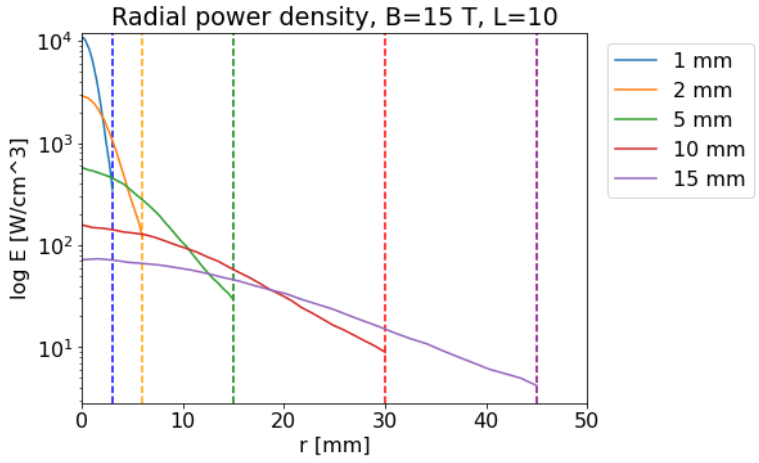
International MUON Collider Collaboration

Carbon Target

*Maximum temperature and power deposition for **1.5 MW** as function of the beam sigma.*

Considering only radiative heat dissipation

T peak (°C)	Transient				Steady state	Power deposited
σ_{beam} (mm)	5 Hz	10 Hz	20 Hz	50 Hz	Average	(W)
1	4301	3908	3735	3641	3583	44832
2	3318	3221	3177	3152	3135	59000
5	2740	2721	2713	2708	2704	90632
10	2305	2297	2293	2290	2288	129207
15	1947	1943	1940	1938	1938	163214



- Beam size is driving parameter of target temperature (for a given average power)
- However, larger target D increases cooling requirements (for a given Radius – beam σ ratio)
- Pulse frequency (thus pulse intensity) driving parameter for thermal gradient and consequently dynamic stress of the target.
- **Beam sizes of >5mm (1σ) recommended (on a thermal perspective. +info later)**

Carbon Target: engineering feasibility

Direct cooling considerations

Temperature (°C)		sigma 5/5Hz – 1.5MW
Only radiation	T max	2801
	T max surf	2240
Radiation + natural convection	T max	2768
	T max surf	2207
Radiation +Forced convection (He, 20 bar, 0.1 kg/s)	T max	573
	T max surf	278

*Maximum temperature and power deposition for **1.5 MW** as function of the beam sigma.*

T peak (°C)	Transient				Steady state	Power deposited
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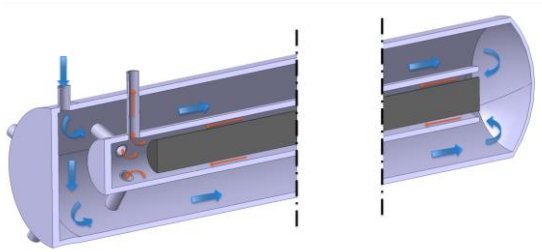
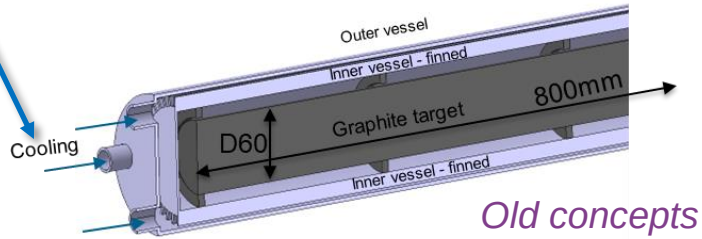




Old concepts

Target Cooling

- Due to high T and sublimation of graphite, an enclosed 'pressurized' atmosphere is required.
- However, active cooling can be made indirectly. Heat dissipation mostly via radiation and natural convection. → target confinement / separation of cooling system is advantageous (maintenance, RP, disposal, cooling services requirements).

Carbon Target parameters

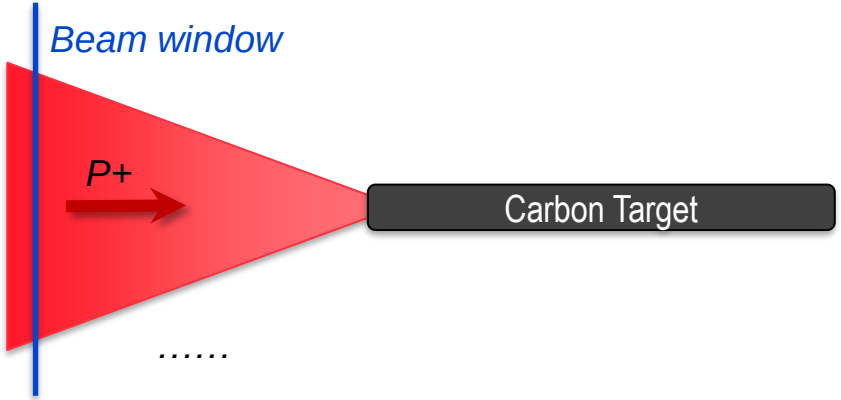
- Beam power (1.5 – 3 MW) – 2 MW
- Pulse length – 2 ns
- Pulse frequency (5 – 50 Hz) – 5 Hz
- Proton energy (3 – 10 GeV) – 5 GeV
- Proton beam size (0.1 – 1.4 cm) – 5 mm (1σ)
- Target angle with the solenoid axis (0 – 6deg) – 0deg (but under discussion)
- Other…

- Target diameter (1 – 9 beam sizes) - 3σ
- Target length (50 – 150cm) – 80 cm
- Shielding aperture (r 7 – 19 cm)

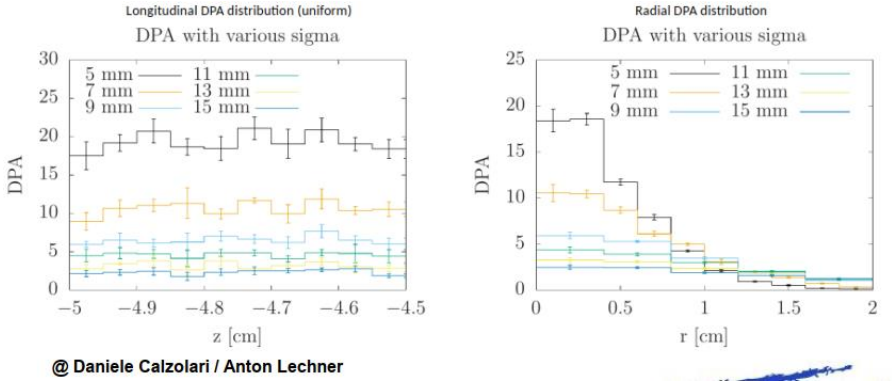
…

AOB

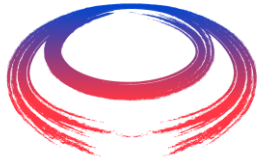
- Great challenge is the high dpa at the windows. Maybe envisaged having a larger beam few meters upstream the target.



Conceptual proposal do dilute radiation damage on upstream window



DPA on windows for 1 MW and baseline proton beam parameters



Thank you very much for your attention