# IMCC Annual Meeting 2023 – Orsay

## Proton beam delivery to target & integration with target complex


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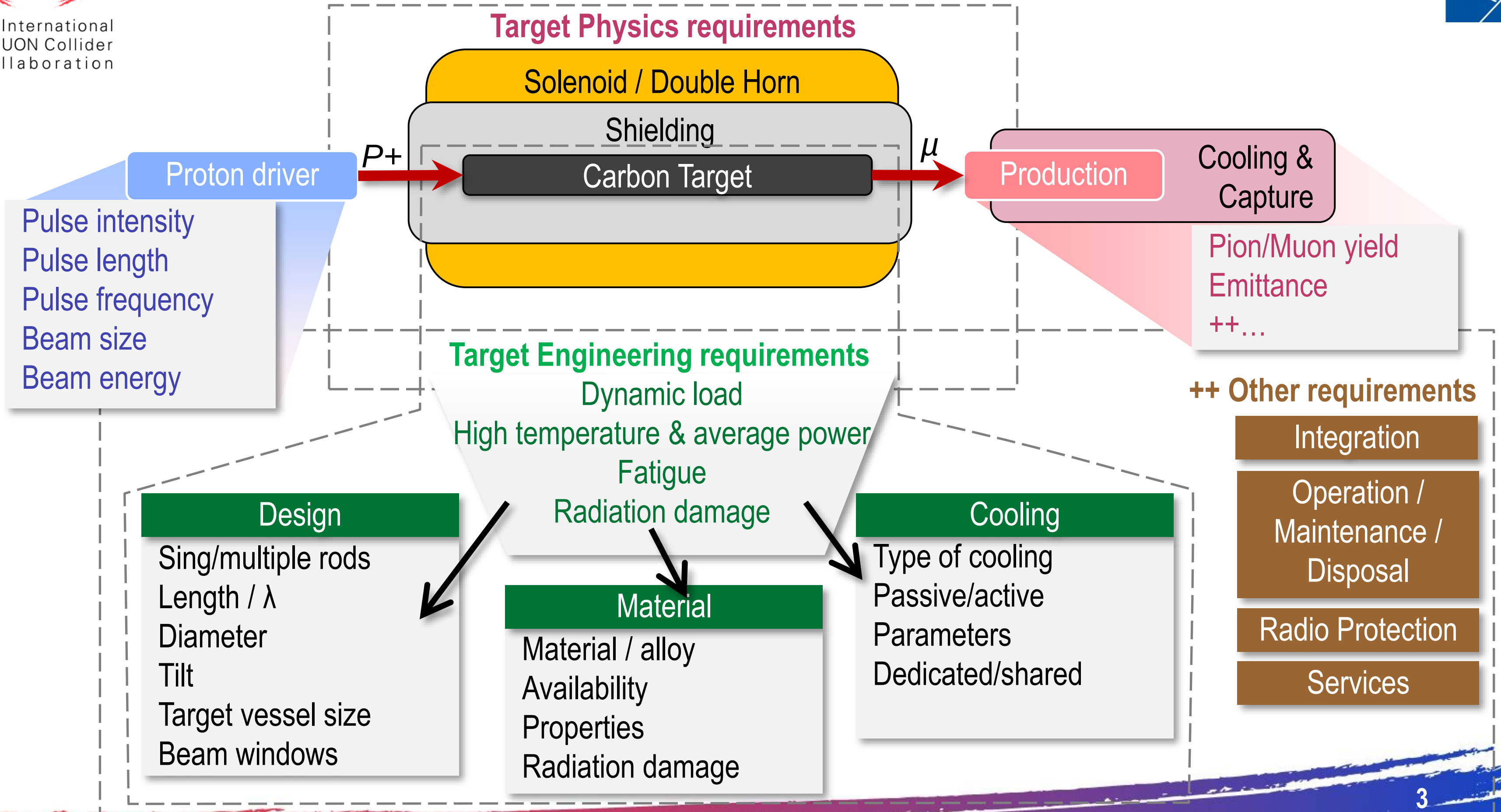
# Outline

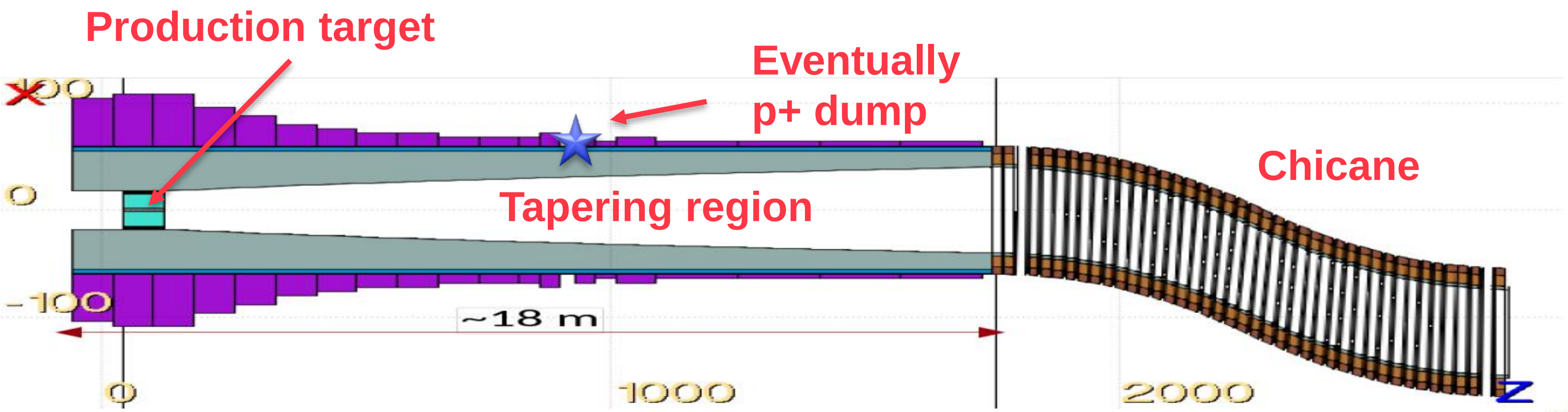
- Parameters sensitivity study
- Carbon Target: engineering feasibility
- Summary
- Other aspects

# Carbon target & target systems considerations



# Carbon target & target systems considerations

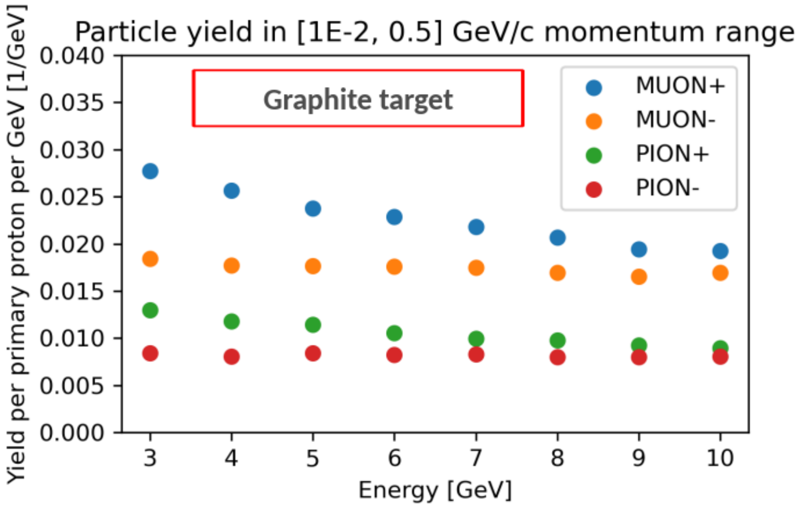
- Energy deposition/dpa studies on the Target, windows, shielding, magnets, chicane
- Parameterization study / optimization of beam parameters
- (Conceptual) Engineering study of Target & Target Systems, shielding, p+ dump -> feasibility
- ++ iteration loops with p+ driver, magnets, cooling

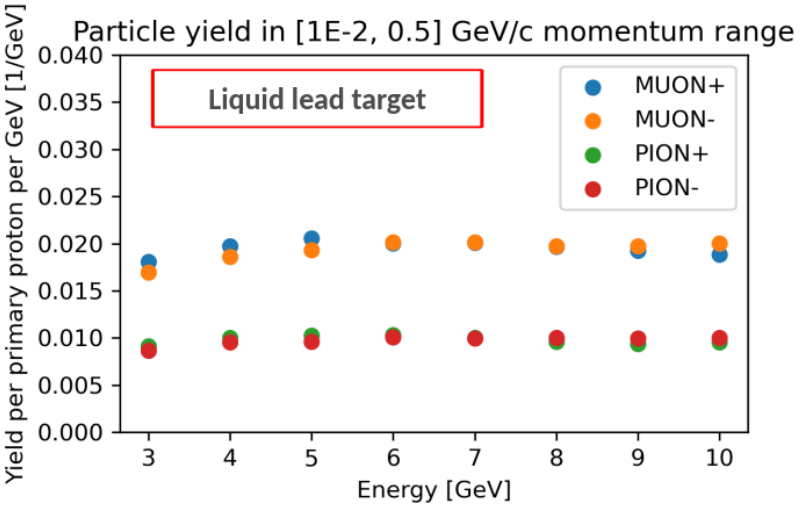


# Parameters sensitivity study

**Beam energy**

- Muon yield is calculated summing up all the muons produced up to 500 MeV/c
- Small yield reduction with Energy (for low Z target) reduction



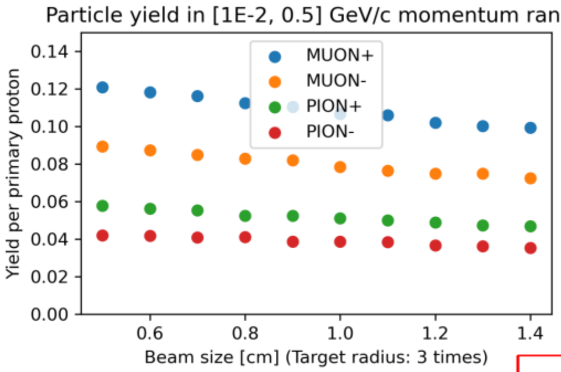



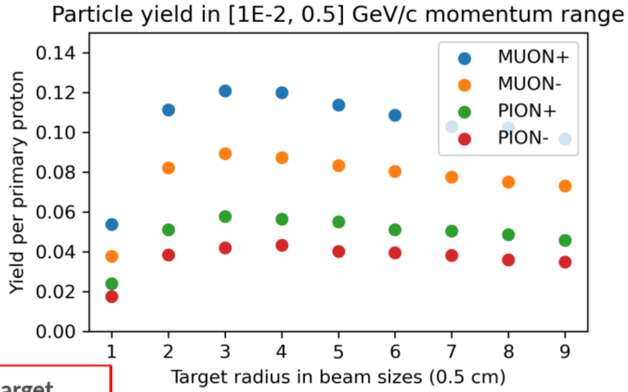

by Daniele Calzolari and Anton Lechner https://indico.cern.ch/event/1237101/

# Parameters sensitivity study

## Beam size & Target transverse size

- Muon yield. The smaller the better, but larger beam size is ideal trade-off parameter for target design
- C.Rogers (https://indico.cern.ch/event/1290683/ ). But bunch radius increase results in slight performance degradation
- Target transverse size optimum at 3σ



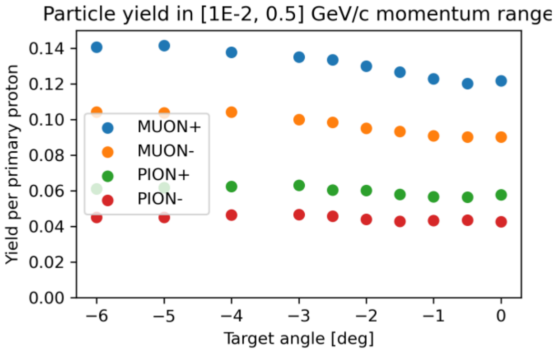

Graphite target

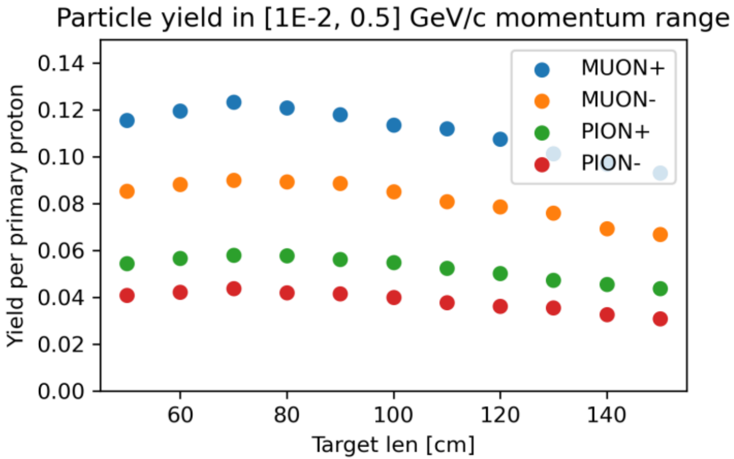
by Daniele Calzolari and Anton Lechner *https://indico.cern.ch/event/1237101/*

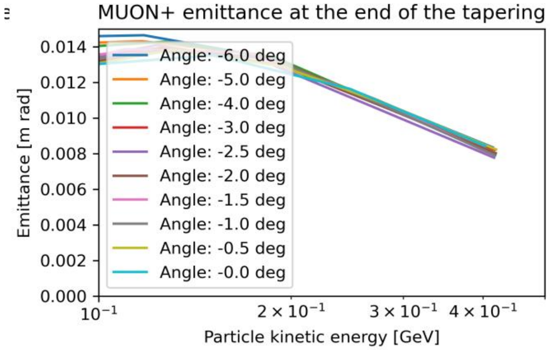
# Parameters sensitivity study

**Target length & Angle of incident proton beam**

- Baseline of 80cm near best point
- Tilted proton beam has small effect on emittance.



# 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
  - Forced convection cooling

  → How can we cool it?
- Structural calculation → Does it 'survive'?

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

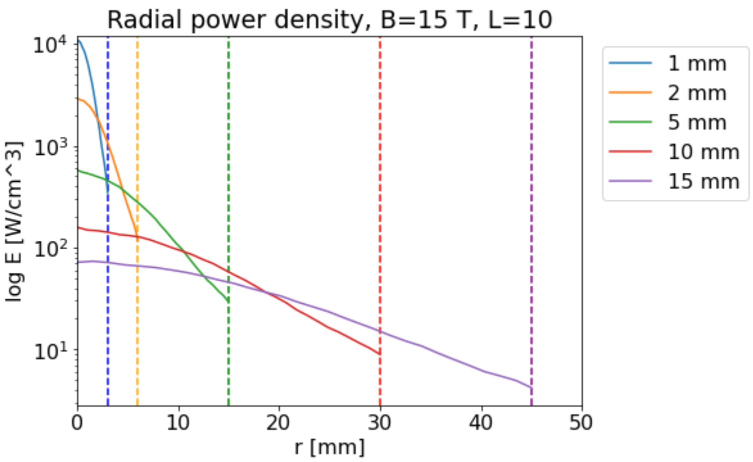
# Carbon Target: engineering feasibility

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 |
|---|---|---|---|---|---|---|
| $\sigma_{beam}$ (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 |
|---|---|---|---|---|---|---|
| $\sigma_{beam}$ (mm) | 5 Hz | 10 Hz | 20 Hz | 50 Hz | Average | (W) |
| 1 | 4301 | 3908 | 3735 | 3641 | 3583 | 44832 |
| 2 | 331[illegible] | 3221 | 3177 | 3152 | 3135 | 59000 |
| 5 | 2740 | 2721 | 2713 | 2708 | 2704 | 90632 |
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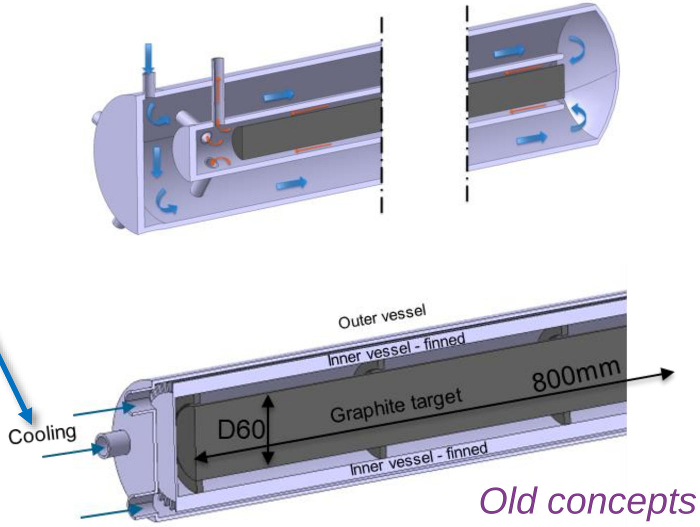


*Old concepts*

## 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).

# Summary

- Beam power (1.5 – 3 MW) – 2 MW
- *Pulse length – (1 – 2 ns) 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)
- Operation over 5 years, average 139d/y and max 200d/y
- Other…

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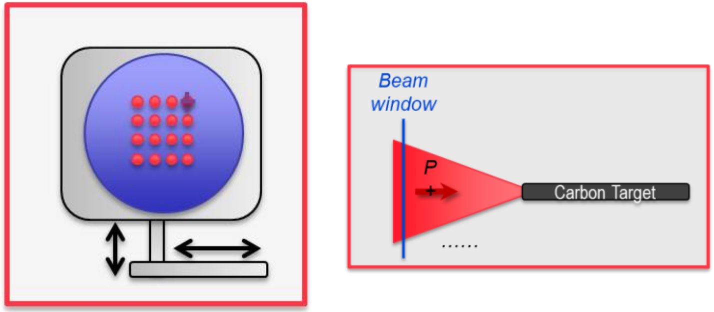
- Target diameter (1 – 9 beam sizes) - 3σ
- Target length (50 – 150cm) – 80 cm
- Shielding aperture (r 7 – 19 cm)

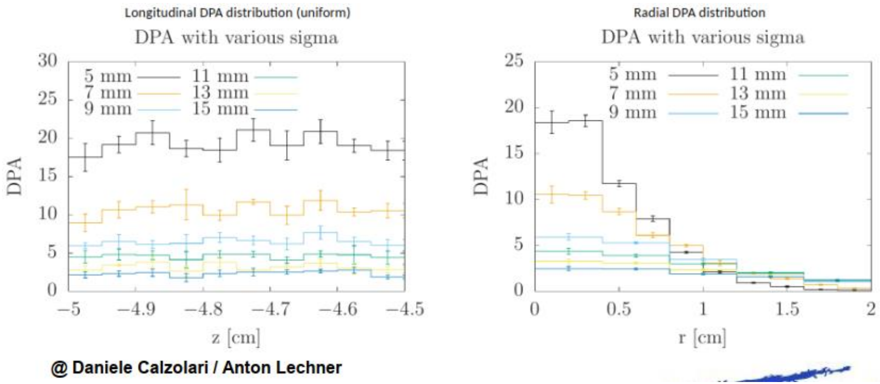
*C.Rogers (https://indico.cern.ch/event/1290683/ ). Smaller the rep rate & bunch length, the better.

# Other aspects

- Great challenge is the high dpa & operational conditions of the p+ beam window. Is envisaged to have a larger beam size at the target and windows.
- Further iterations between WP3 & WP4




*Conceptual proposal do dilute radiation damage on upstream window*




*DPA on windows for 1 MW and baseline proton beam parameters*

International
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***Thank you***
***very much for your attention***

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

- Energy deposition/ dpa studies