IMCC Annual Meeting 2023 – Orsay

Perspective for the demonstrator from the Target point of view

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CERN – Systems Department, Sources Targets Interaction (STI), Targets Collimators Dumps (TCD)

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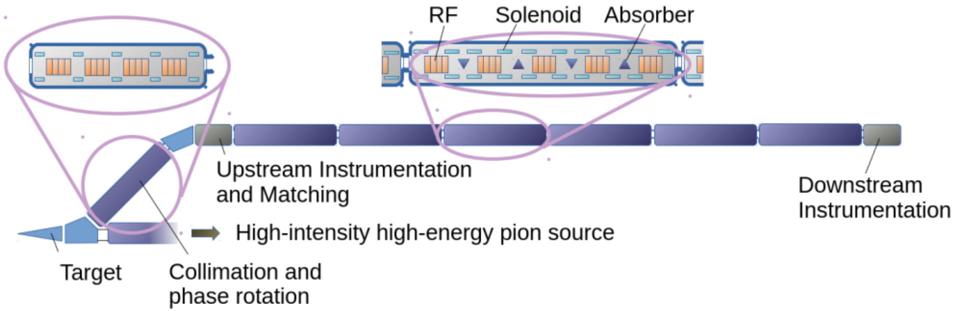
Contents

- BIDs
- Recap CERN options
- Targetry possibilities
- Absorber / Beam windows
- Conclusions

Targetry & BIDs at the demonstrator

- **Muon Production Target**
- P+ dump / shielding
- Collimators for the high energy muons at the beam preparation system
- **Proton beam windows**
- **Beam windows in the cooling line.**
- **Cooling absorber**
- Magnetic Horn
- p+ beam delivery BID's (collimators, beam-stoppers, etc)
- Potentially other ?



C. Rogers and D. Schulte, "A Demonstrator For Muon Ionisation Cooling", WEPOPT027

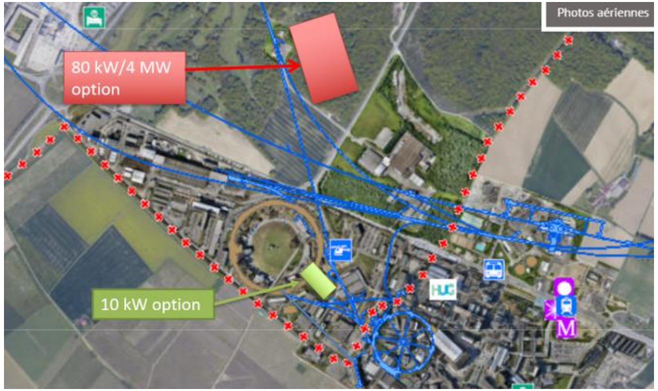
Demonstrator at CERN

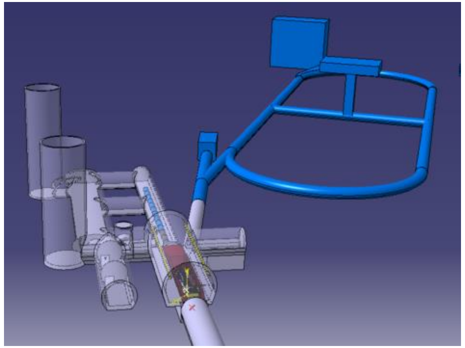
Recap of the two main options at CERN:

TT7 & ISR complex

- Low Cost. Reduced CE
- Existing TT7 infrastructure
- Limited space and beam power **~10kW**
- Surface. Radio Protection limitations.
- Compatible with demonstrator, but not with final facility nor nuSTORM.

First ideas proposed by M. Calviani in the 1st Community meeting. ***TT10 line option seen as most attractive*** *(R. Losito presentation).*



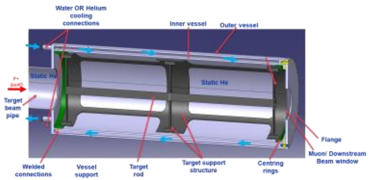


TT10

- Beam from PS (10^{13} p+ @26 GeV in 7ns)
- Underground (~40m, in the molasse), allowing O(80kW)
- Staging possible to final facility & nuSTORM integration.
- High Cost.

Targetry at the demonstrator

❖ **C-Target studies for final 2 MW facility at 5Hz (5e14 ppp), 5 GeV, 5 mm 1σ, 2ns**

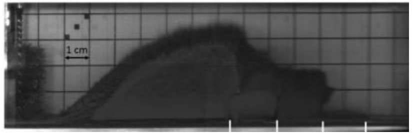


<u>Assuming Demonstrator with PS's 10e13 ppp @26 GeV in 7ns</u>

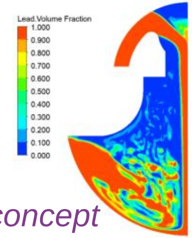
- Demonstrator C-Target can likely be a very identical concept to final proposal
- With beam on target O(.5) mm 1σ → **Test can be used to assess dynamic stresses** response of the target
- **Low average power** (~10kW in TT7) → will limit operating temperature
  - Reduced cooling system &/or eventually dedicated heating may be employed to push demonstrator target to high temperature (2-3K Celsius range)
  - Reduced services (cooling, wrt to final MuC).
- High cyclic assessments (>>10^5 cycles ?) e.g. HiRadMat usually bound to few pulses.
- Benchmark engineering and Fluka calculations

Targetry at the demonstrator

- **Demonstrator can(shall ?) be a multi-target test facility**. Either in parallel with cooling experiment or ad-hoc. Feasibility of the different concepts can be pursued
  - C-Target
  - Fluidized W &/or static W powder target
  - (HLM) Pb curtain target &/or liquid lead pool
- **Possibility to (re)test spent targets.**
  - CNGS? (probe dpa + MuC pulse conditions)
  - Other (e.g. RADIATE samples ?)
- **Test beam window materials & designs**
- **Design/integration/remote handling proof of concept.**
- **Opportunity to develop magnetic horns and test them at CERN.**
- **Test the SC solenoid around the target and alike**
- CERN sitting allows direct access to services and capabilities



W powder tests.



Pb curtain concept

CNGS Target

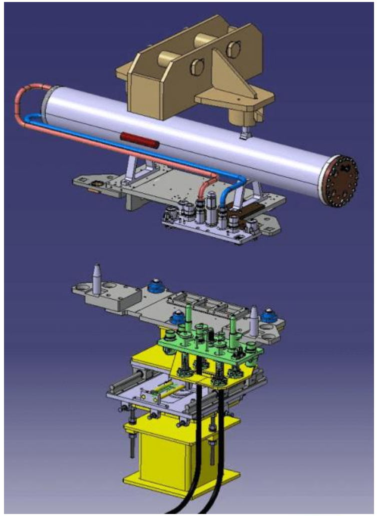
AD-T Horn at CERN

Targetry at the demonstrator

	Protons	^{208}Pb Ions
Beam Momentum	440 GeV/c	173.5 GeV/n (36.1 TeV per ion)
Pulse Energy	up to 2.4 MJ	up to 21 kJ
Minimum Bunch Intensity	$5 \cdot 10^{9}$ protons	$3 \cdot 10^{7}$ ions
Maximum Bunch Intensity	$1.2 \cdot 10^{11}$ protons	$7 \cdot 10^{7}$ ions
Number of Bunches	1 to 288	52
Maximum Pulse Intensity	$3.46 \cdot 10^{13}$ protons	$3.64 \cdot 10^{9}$ ions
Bunch Length	11.24 cm	11.24 cm
Bunch Spacing	25 ns	100 ns
Pulse length	7.95 us	5.2 us
Cycle length	22.9 or 40.8 s	13.2 s
Beam Size at Target	variable around 1mm^2	variable around 1 mm^2

What other testing platforms can we already use @ CERN ?

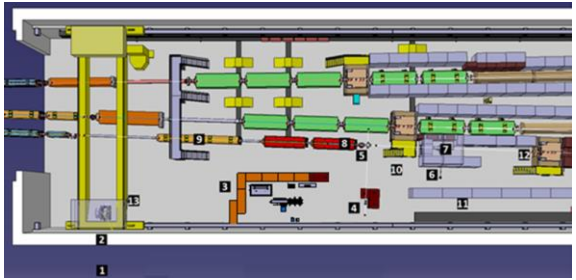
- The HiRadMat facility (https://hiradmat.web.cern.ch/hiradmat-facility)



- Slow Extraction (SX) TCC2 testing area @ CERN's North Area

NA SX TCC2 Testbench

- 400 GeV/c p+
- Up to 4e13 ppp
- SX (1s) but maybe fast SX (~20ms) is possible.
- Plugin-in table. Thought for fully remote interventions



https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.22.123001

Cooling absorber / windows

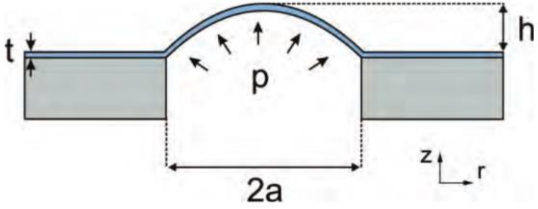
by Jose A. F. Somoza

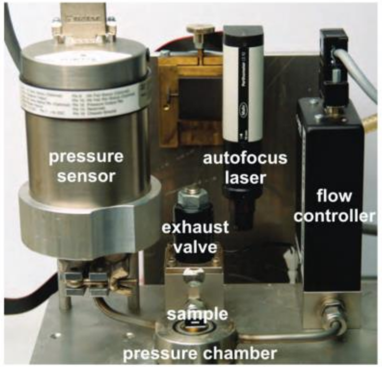
Usual windows will significantly perturb the beam at the last cooling stages:

- Thin film windows allow thickness <1μm with significant mechanical strength
- Possible materials: Si_3N_4, SiC, C, etc.
- Already started: Mechanical characterization of windows at different temperature (from cryogenic to high temperature) ➔ Bulge tests [1]

Demonstrator

- Required: benchmark thermomechanical simulations with muon beams → Demonstrator
- Integration window + absorber not yet available ➔ Integrity of the window exposed to repetitive pulsing





[1] B. Merle, Mechanical Properties of Thin Films Studied by Bulge Testing (FAU University Press, Erlangen, 2013).

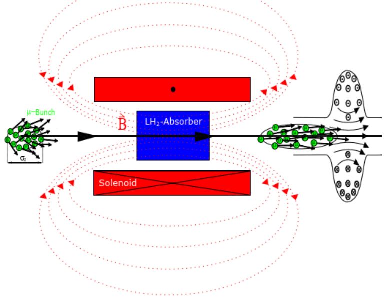
Cooling absorber / windows

by Jose A. F. Somoza

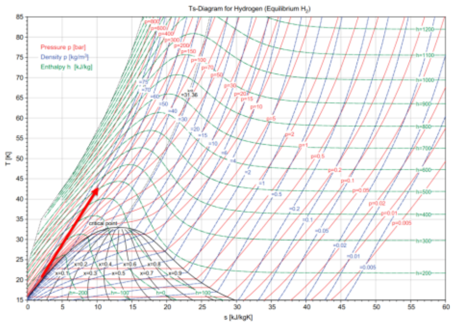
- **Cooling absorber** → Hydrogen is best absorber

$$\epsilon_{min,N} \propto \frac{E}{BL_R(dE/ds)}$$

- Contradictory requirements:
  - **High density** → to limit the length of the superconducting solenoid (<50 cm)
  - **Low density** → to limit the pressure increase after power deposition and allow the use of thin windows (<1 to 5 bar depending on the diameter)



- **Conceptual design** of absorber at final cooling **still under development**
  - Possible concepts to be evaluated: density gradient driven by temperature, H_2 bubble next to window, solid H_2, any other?



[2] CERN-TC-GEN-64-5 Liquid hydrogen safety code (1964)

Demonstrator

- Demonstrator to test relevant muon beams
- Study self-contained system. Safety [2] similar to H_2 storage equipment for simplicity

Conclusions

- If tailored as such, Demonstrator can be a strategic platform for proof-of-concept target designs for the final collider, material testing, benchmarking studies.

Targetry

- At first sight, no major showstopper nor critical pre-experimental program required for the demonstrator.
- **Possible challenges ?** → multi target, particularly if considering C, fluidized W, HLM – may be challenging to integrate and include all in the Demo program. Services (cooling, HLM & fluidized W circuits pumping circuits) can likely be eased for a Demo. To what extent ?
- **Pre-experimental program ?** → Will depend on the maturity and likely offline testing & characterization of the Targetry options.
- **What can we learn ?** → Full suite assessment of pulse response, operational conditions, integration constrains, simulation benchmark, etc

Windows & absorbers: Readiness of the Cooling absorber & beam windows strongly dependant on ongoing studies. → Possibly requiring a dedicated experimental program ?

Other: Possibly Horn design/testing in synergies with target developments ?

International MUON Collider Collaboration

CERN

Thank you

very much for your attention