

Design of the MuST-CiADS Rotating Graphite Target

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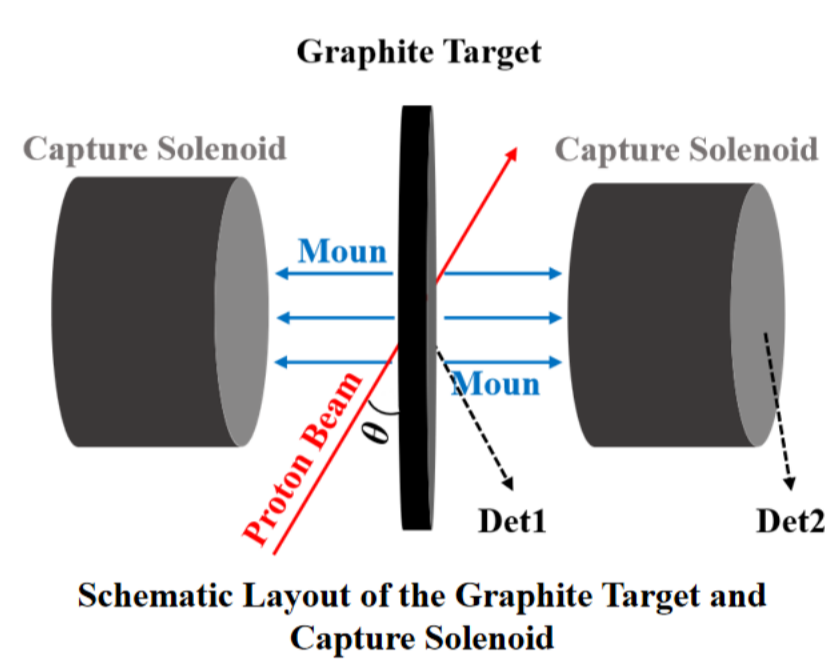
Motivation

The China initiative Accelerator Driven System (CiADS) will be the world's first megawatt-level ADS facility. Downstream of the superconducting proton linac, a muon experimental terminal named Muon Science and Technology application platform (MuST) is planned, which includes two target stations and four muon beam lines. The first target station features a thin rotating graphite target configuration.

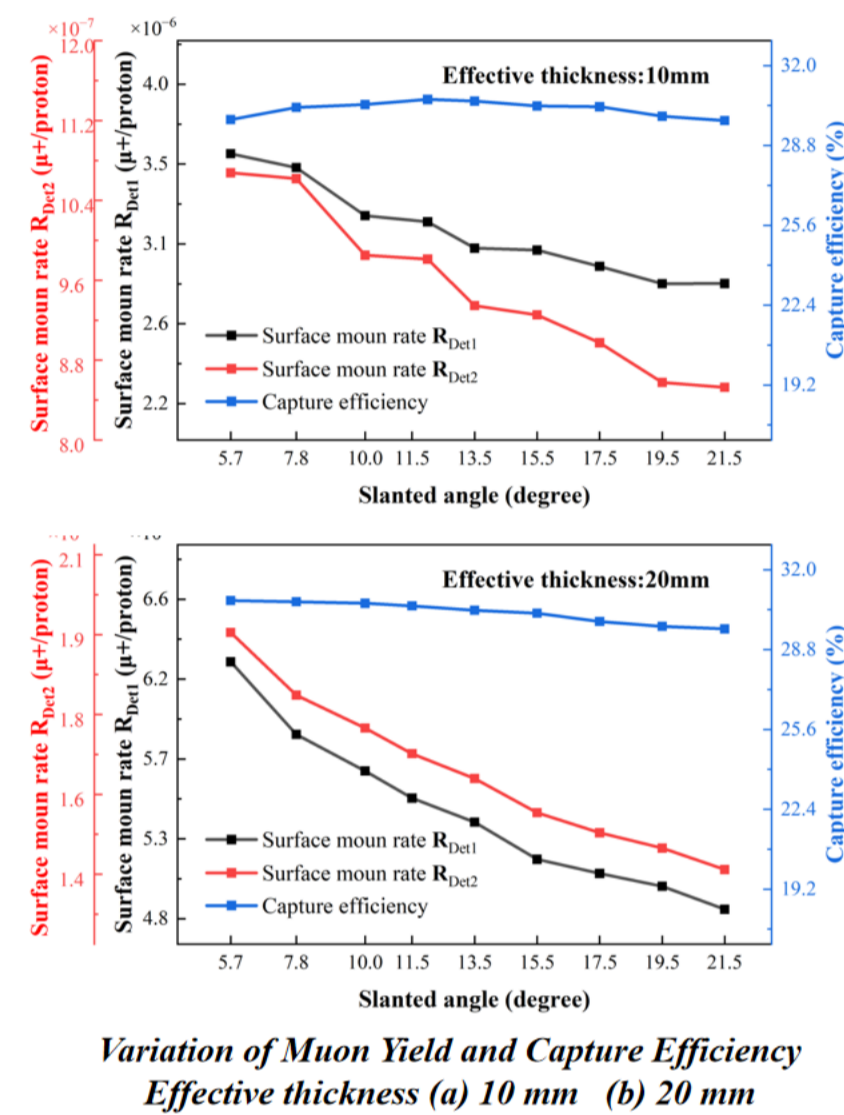
We conducted on critical factors including effective target thickness, beam impact position, radiation damage, and target-induced beam loss. A novel structure for the rotating graphite target was developed. Thermal-structural coupling simulations demonstrate that this optimized structure meets the requirements for stable operation under a 600 MeV, 2 mA proton beam at a rotation speed of 1 Hz. We propose a feasible design configuration for the muon target system at CiADS.

Physics Parameter Study of Beam-Target

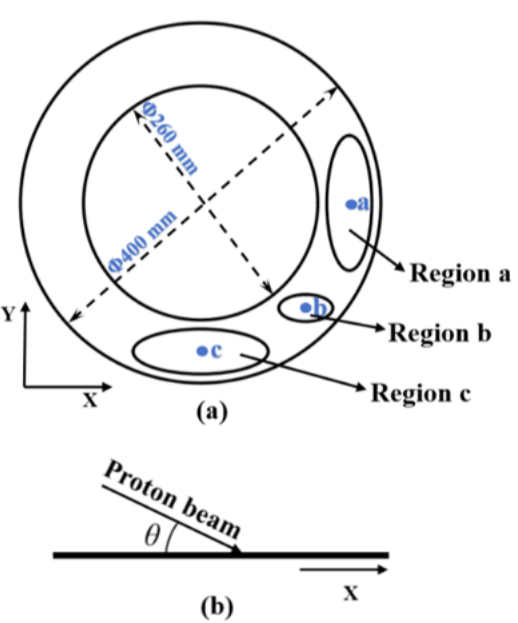
Study of Muon Production and Capture Processes



- As the incident angle increases, the muon yield increases noticeably, while the charge capture efficiency is not significant.
- The optimal target thickness is thinner, favoring muon escape; however, this leads to a muon distribution that is unfavorable for capture.



Optimization of Beam-Target Configuration



Key Optimization Strategy

Beam Striking at 6 o'clock
The solid position of the beam spot is strictly constrained, avoiding beam loss off-target.

Rotating Target Design
The heat-handled annulated region is enlarged, enabling angled incidence of a larger beam spot and reducing radiation damage.

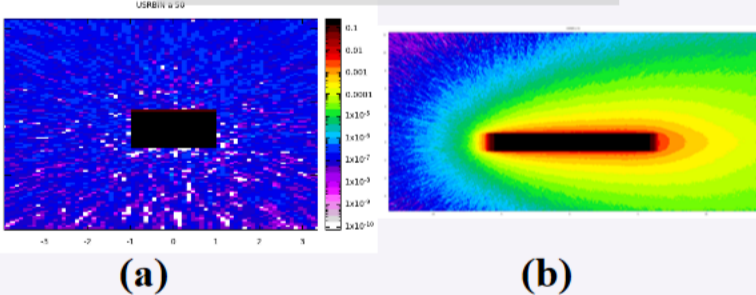
Investigation Focus

Parameter Analysis
Comprehensively analyze key factors such as beam broadening effects and radiation damage (DPA).

Configuration Comparison
Compare the solid beam spot constraint (fixed) vs. the larger heat-handled area (rotated) for optimal coupling.

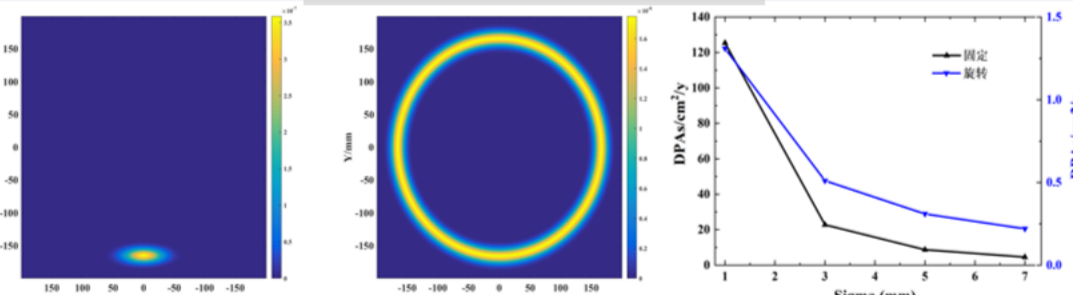
Beam Position

Energy Deposition



(a) Energy Deposition Broadening Caused by Beam Incidence
(a) Initial Beam Spot
(b) Energy Deposition on the Target

DPA Comparison



(a) DPAs Deposition on Fixed Target; (b) DPAs Deposition on Rotating Target; (c) Curve of DPA-sigma

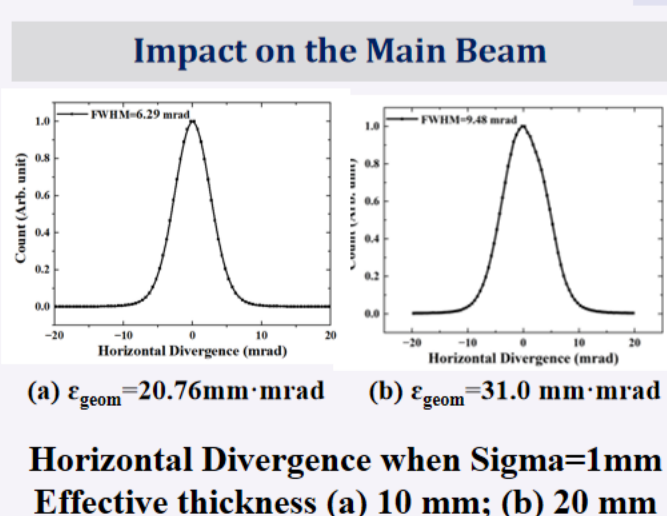
Comparison of Instantaneous Peak DPA

Beam Position	Sigma (mm)	Peak DPAs/y (fixed)	Peak DPAs/y (rotating)
6:00	7	5.16	0.42
	5	9.91	0.62
	3	25.87	1.07
4:30	5	Out of target	
	3	26.15	0.28
	1	153.71	0.58
3:00	5	Out of target	
	3	25.87	0.2
	1	139.19	0.45

Conclusion--Beam strikes at 6 o'clock

- The beam spot can be strictly constrained radially to avoid missing the target;
- Larger broadening area, support larger beam spot.

Beam Incidence



Beam Thermal Deposition

Comparison by Incident Angle

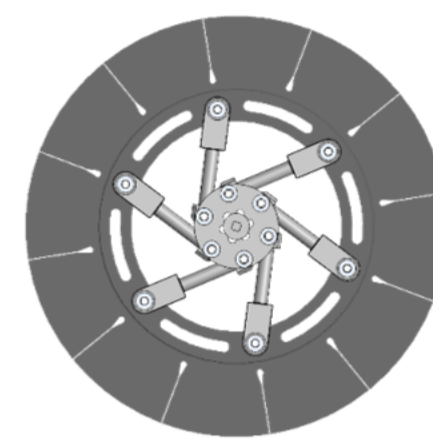
Target Configuration	Effective Thickness	Deposition
3.5mm @ 10°	20.16 mm	19.46 kW
3.5mm @ 20°	10.23 mm	9.76 kW

Radiation Damage (Graphite DPA)

Peak DPA/sy Comparison

Slant Angle (°)	Sigma (mm)	Peak DPAs/sy (Fixed)	Peak DPAs/sy (Rotating)
10	7	5.16	0.42
	5	9.91	0.62
	3	25.87	1.07
20	1	139.09	2.90
	7	5.17	0.25
	5	9.93	0.35
	3	26.01	0.58
	1	143.31	1.50

Optimized Target Design



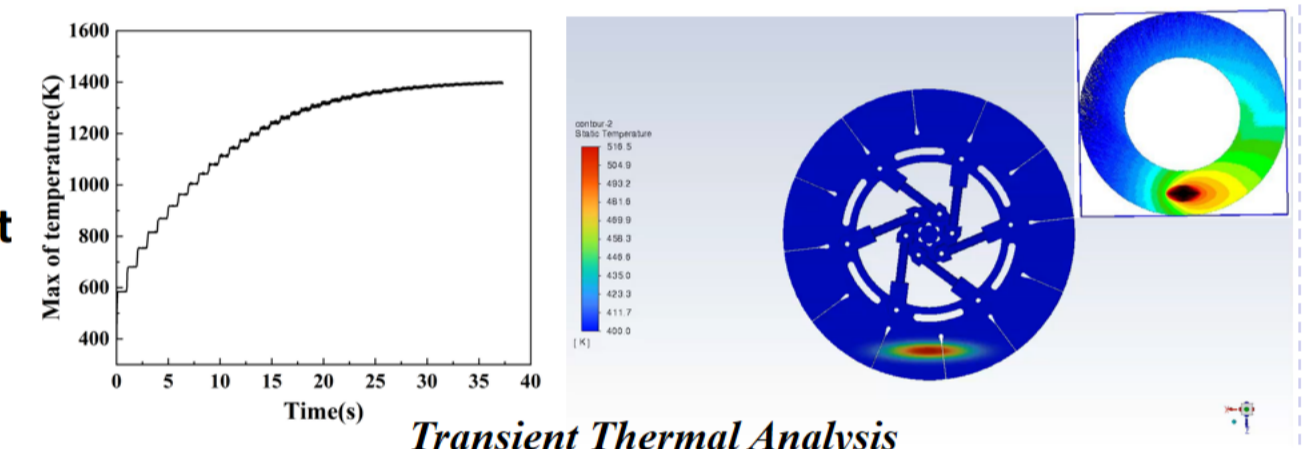
Structure of Target

Structural parameters:

- Integrated target disk design: outer diameter 400 mm, inner diameter 200 mm
- Thickened ring: total length 30 mm, thickness 5 mm local reinforcements;
- The spoke connection levels and air thermal insulation through holes are reserved.

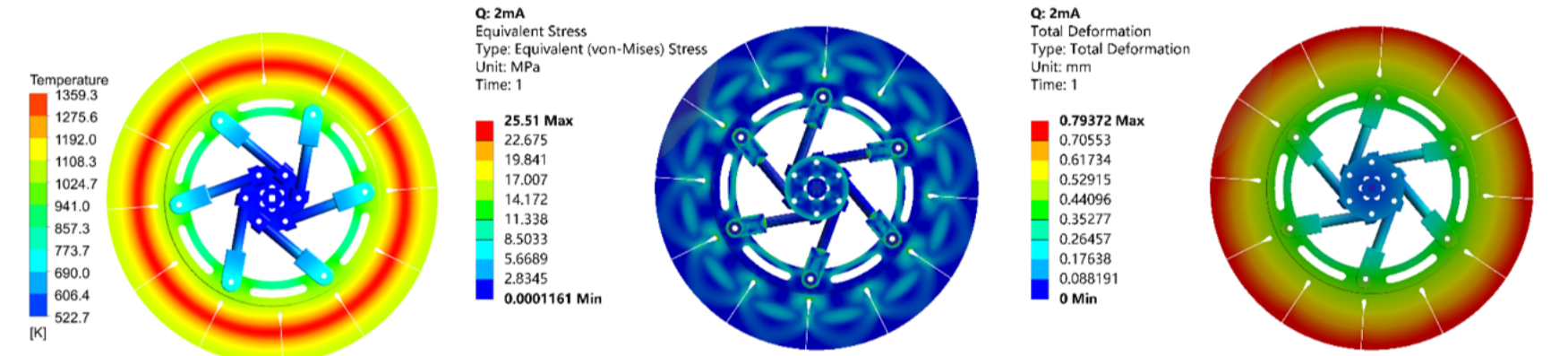
Multiphysics Coupling Analysis

- Simulation condition
0.5mA~2mA 600MeV
FLUKA heat source input
rotational speed 1Hz



Transient Thermal Analysis

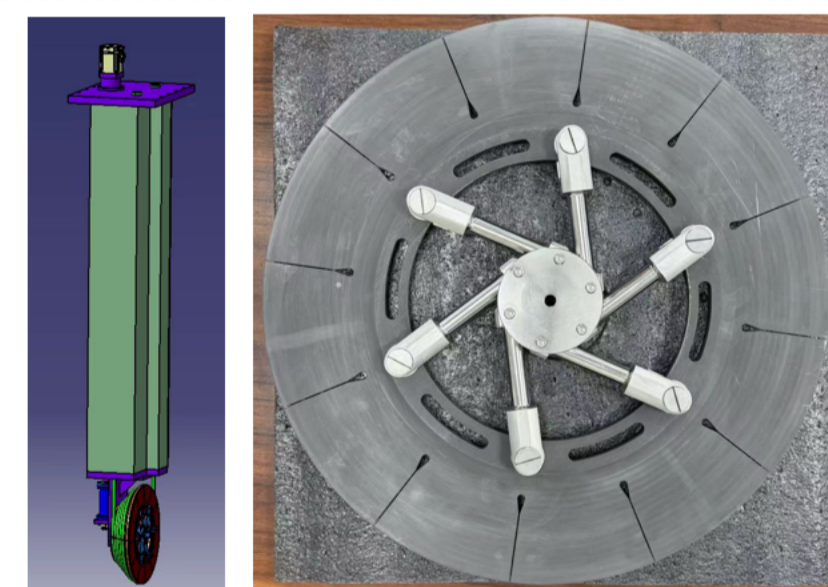
- Target V2 is capable of 2mA(1.2MW) beam;
- Peak temperature ~1359.3K, peak stress ~23.8MPa (PSI26MPa)



Steady Thermal Analysis

Key results under different current on target

Beam current (mA)	Rotating graphite disk			Connecting spokes		
	Peak temperature (K)	Peak stress (MPa)	Maximum deformation (mm)	Peak temperature (K)	Peak stress (MPa)	Maximum deformation (mm)
0.5	622	8.8	0.5	340	11.4	0.34
1	1096.4	14.9	0.64	705	17.6	0.43
2	1359.3	23.8	0.79	812.7	25.5	0.52



Assembly Structure of Optimized Design

- compact design;
- long lifetime bearings-WS₂ bearings;
- maintenance scheme.

Summary

- Based on the preliminary beam-target physics analyses (study of muon production and capture processes, optimization of the beam-target coupling configuration), prototype development of the target body, process testing of graphite samples, and multiphysics coupling simulation, an integrated rotating graphite target insert scheme for high-power beam irradiation has been developed.
- The realization of the research objective of a high-power rotating graphite target system capable of withstanding a 2 mA beam current.