Coupled Beam-Target-Moderator Optimization for the Second Target Station

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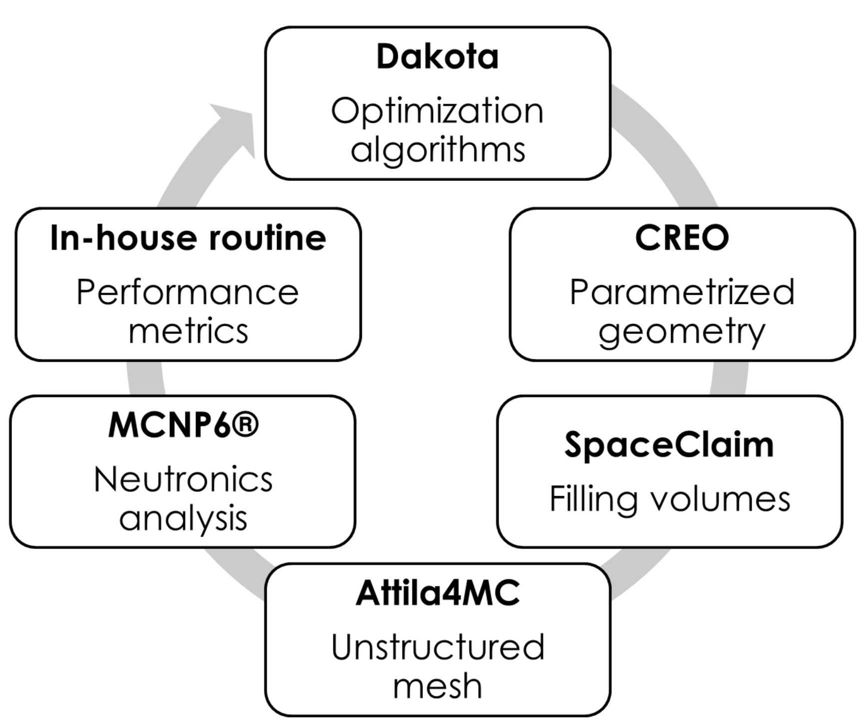
Introduction

- The Second Target Station, currently in preliminary design phase at Oak Ridge National Lab, will provide the **highest peak brightness of cold neutrons (5Å)** in the world
- A state-of-the art optimization workflow has been developed to efficiently optimize moderator and target design with high fidelity

Methodology



- High-fidelity geometry with unstructured mesh models in MCNP6.2
- Starts from parametrized Creo models from engineers
- Efficient optimization using algorithms in Dakota
- Fully automated – no user intervention required

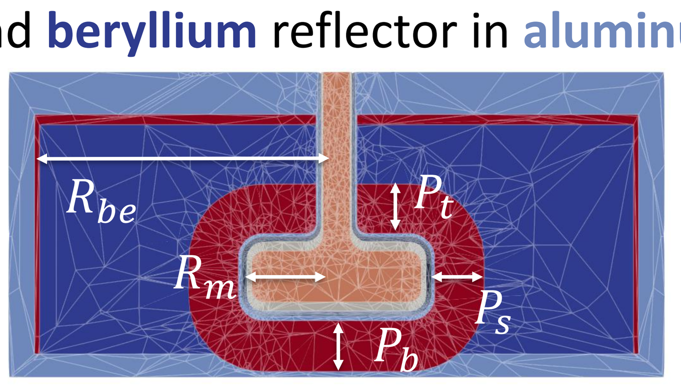
Zavorka, NIMA 1052 (2023) 168252

Ghoos, NIMA 1060 (2024) 169035

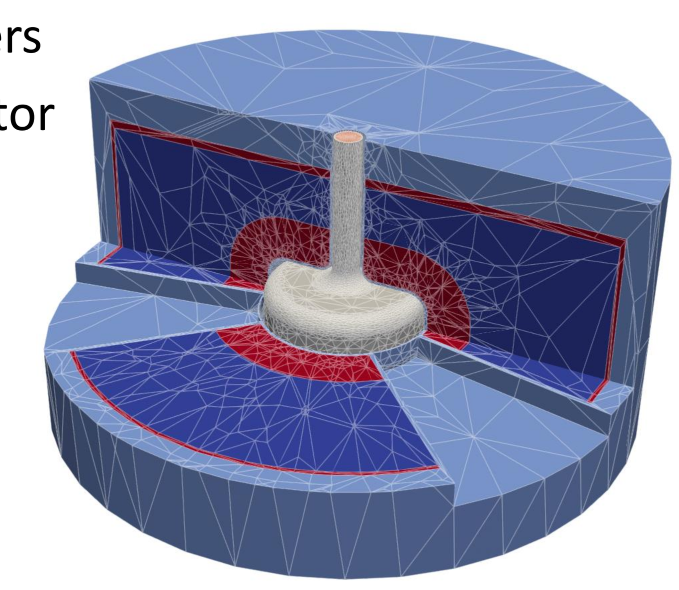
Model: geometry and parameters

- **Cylindrical moderator**: 6 independent parameters

Parahydrogen moderator with water pre-moderator and beryllium reflector in aluminum vessels

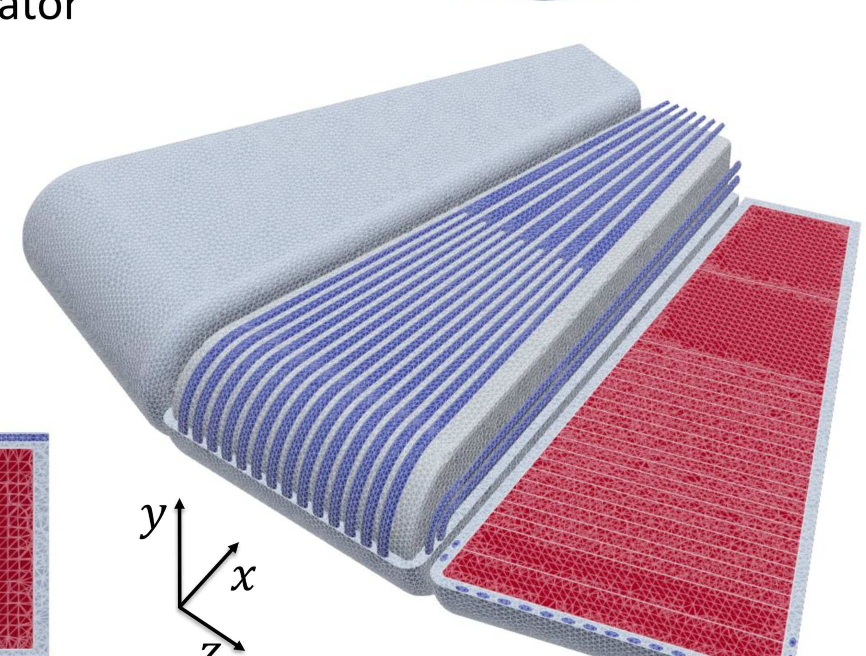


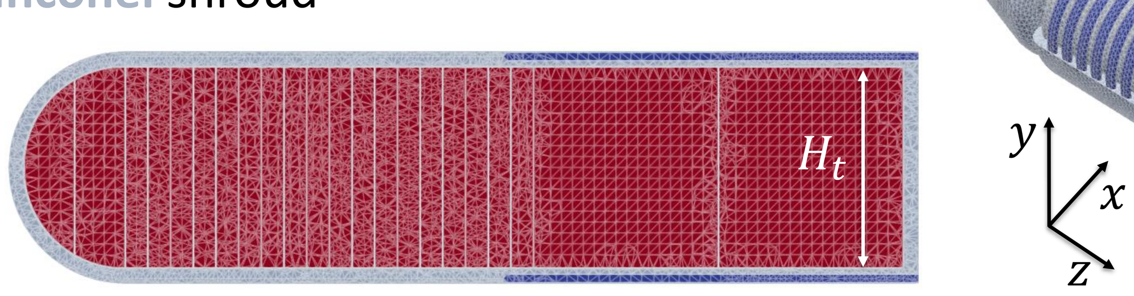
X_m (position of the moderator w.r.t. the target)



- **Target**: 1 independent parameter

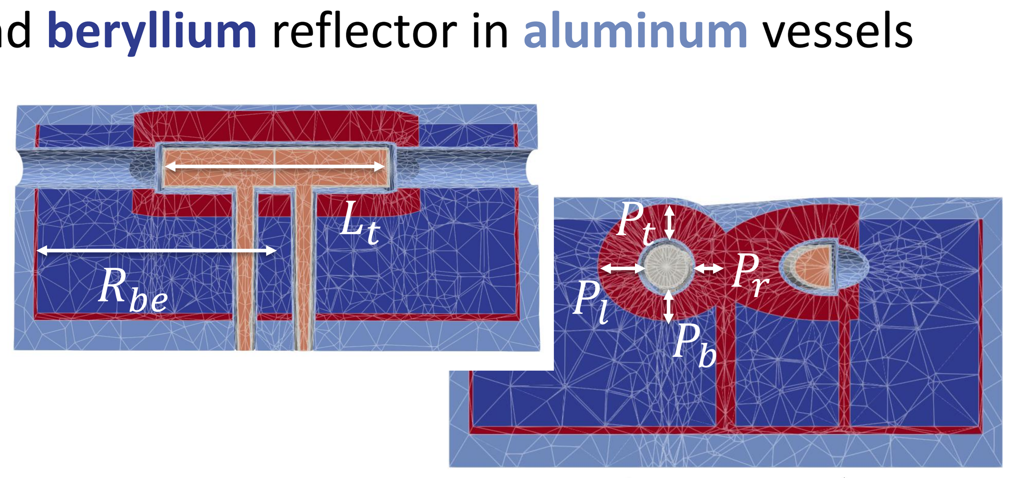
Tungsten blocks separated with copper plates surrounded by water-cooled Inconel shroud

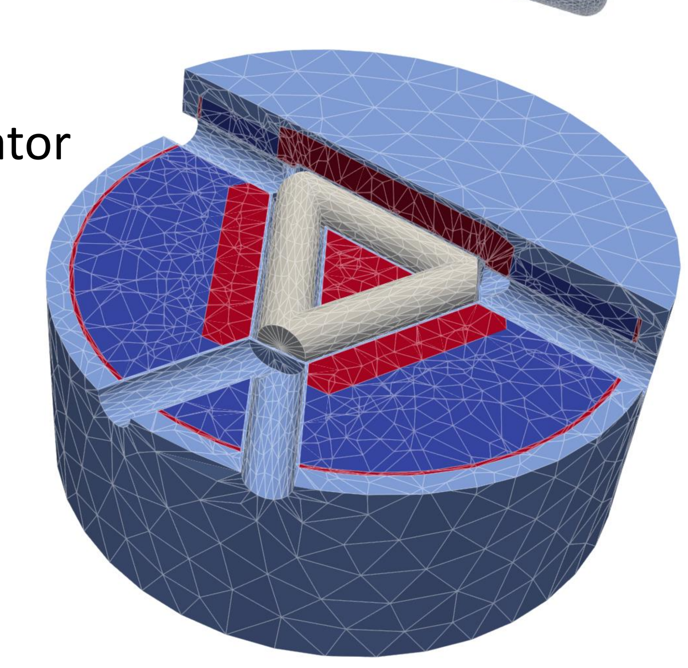




- **Tube moderator**: 7 independent parameters

Parahydrogen moderator with water pre-moderator and beryllium reflector in aluminum vessels



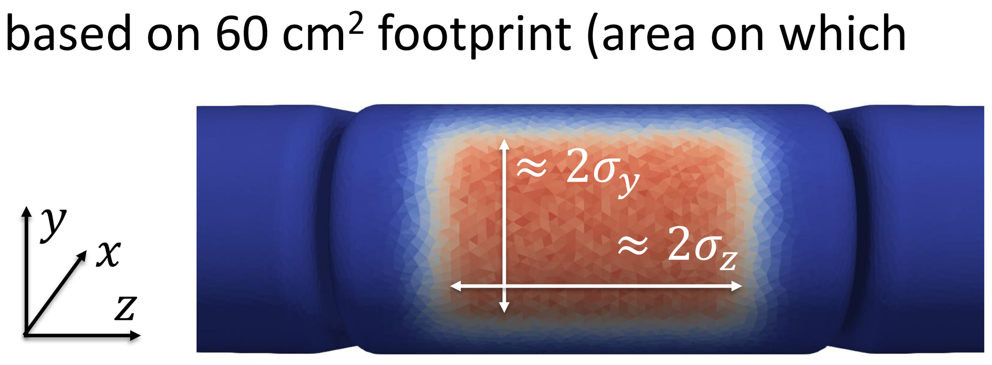


X_m (position of the moderator w.r.t. the target)

- **Proton beam**: 1 independent parameter

Super-gaussian beam profile: $P(y,z,\sigma_y,\sigma_z) = P_0\left(-\frac{1}{2}\left|\frac{y}{\sigma_y}\right|^{10} - \frac{1}{2}\left|\frac{z}{\sigma_z}\right|^{10}\right)$

Choose σ_y, then calculate σ_z based on 60 cm² footprint (area on which 95% of particles impinge)

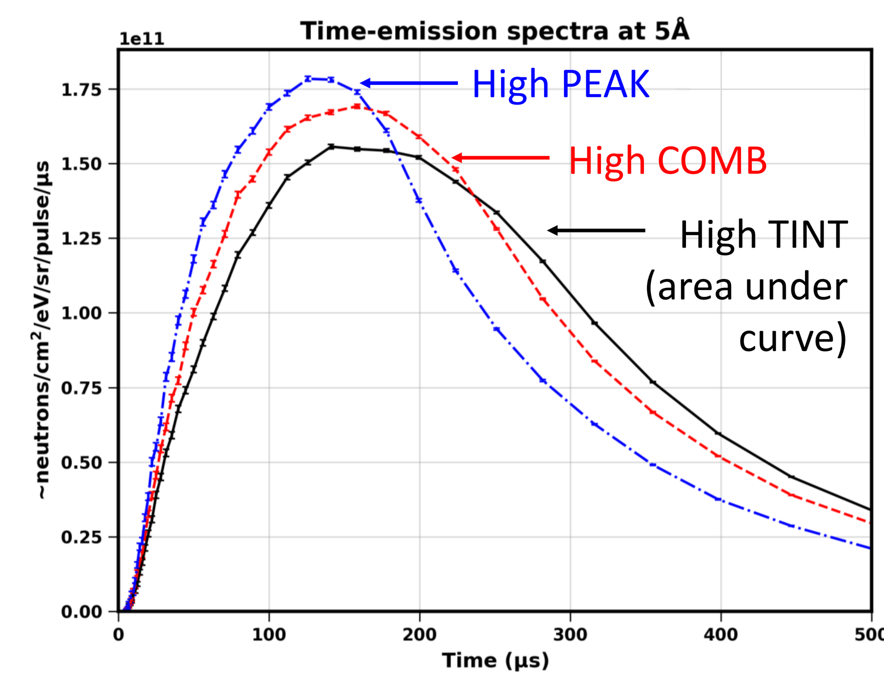


Model: neutron brightness figures-of-merit

We calculate the optimal designs for three figures-of-merit:

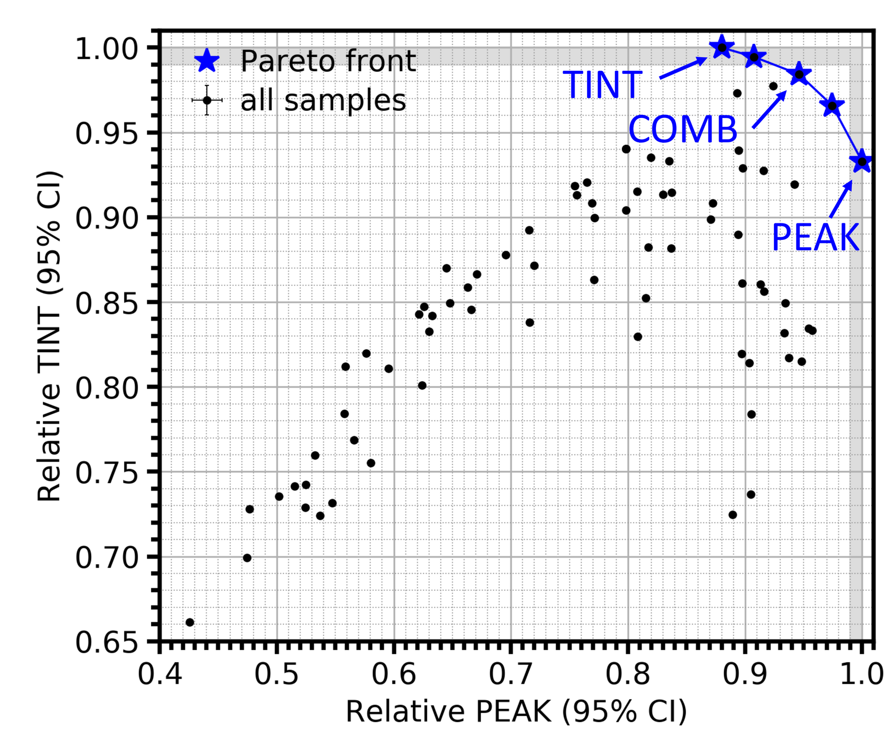
- **PEAK** = highest value for brightness as a function of time
- **TINT** = highest neutron intensity per pulse integrated over time
- **COMB** = highest combination of PEAK and TINT

Pareto front gives the designs with optimal weighted combination of PEAK and TINT

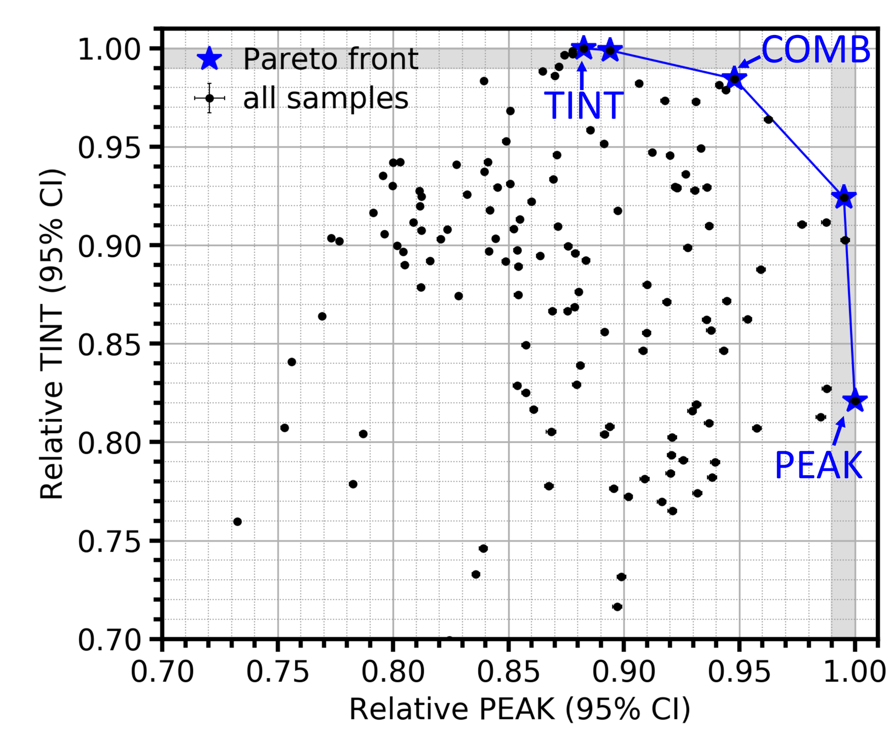


Optimization results

Cylindrical moderator



Tube moderator



- Optimal designs for cylindrical moderator (dimensions in mm)

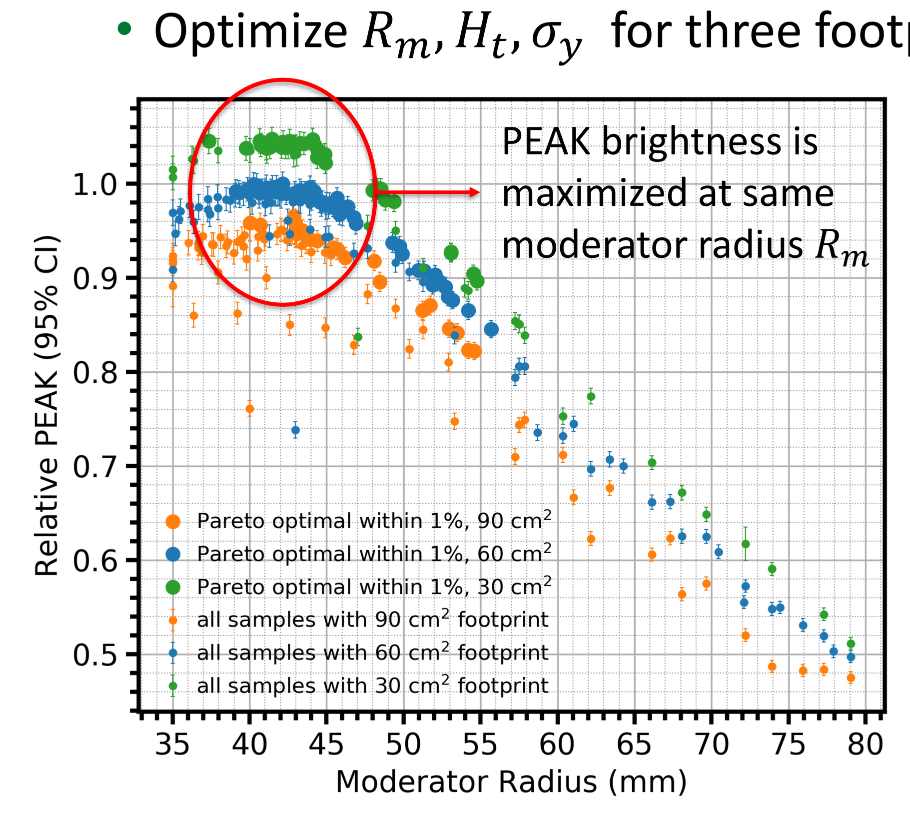
	R_m	P_s	P_b	P_t	R_{be}	X_m	H_t	σ_z	σ_y
TINT	51.4	37.9	31.4	29.8	184	6.6	70	51.0	29.8
COMB	47.5	31.6	30.0	28.7	184	6.6	70	49.4	30.7
PEAK	44.4	25.0	29.2	16.1	175	20	75	45.2	33.6

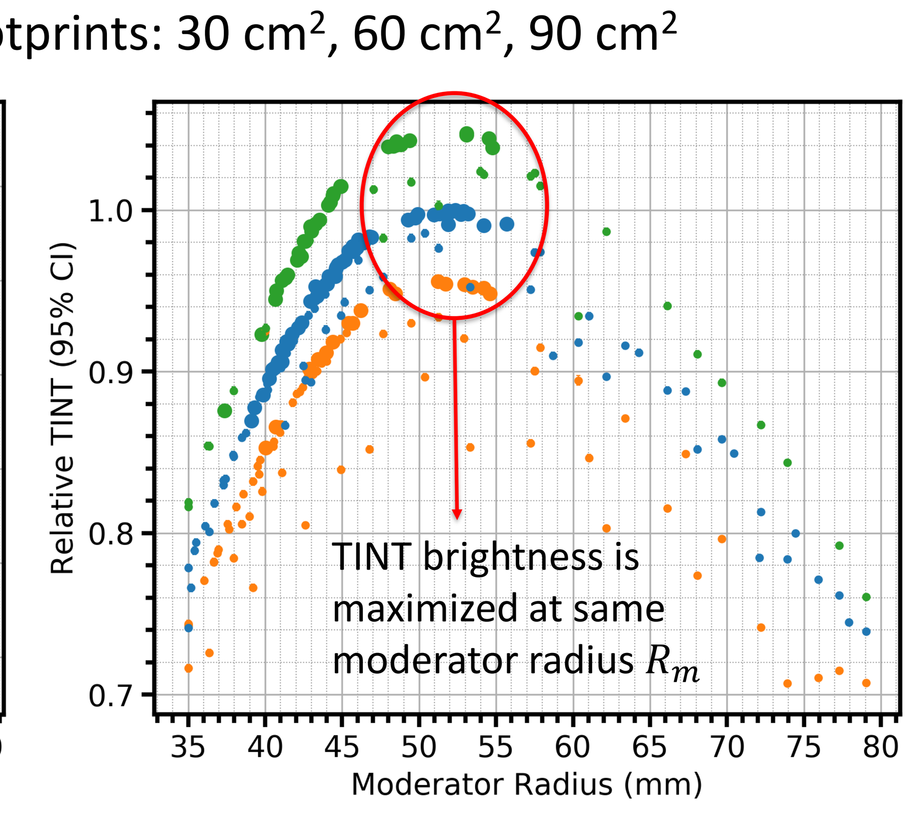
- Optimal designs for tube moderator (dimensions in mm)

	L_t	P_t	P_r	P_b	P_l	R_{be}	X_m	H_t	σ_z	σ_y
TINT	215	27.4	41.0	13.8	33.0	200	4.0	75	52.6	28.9
COMB	183	26.8	35.0	13.9	35.0	200	5.2	74	51.6	29.4
PEAK	128	25.9	31.6	19.8	25.6	181	5.0	70	54.0	28.1

Effect of proton beam footprint (cylindrical moderator)

- Optimize R_m, H_t, σ_y for three footprints: 30 cm², 60 cm², 90 cm²





- Performance increase/loss of 3% with a 30 cm² footprint change
- Optimal moderator radius is independent of beam footprint

Conclusion

- We demonstrated the use of an efficient, fully automated optimization workflow by simultaneously optimizing the dimensions of the moderators, the target height and the proton beam.
- A smaller beam footprint increases the performance, but does not change the optimal moderator radius

Related talks: Wed 3/20: Zavorka, 16.00, Tipton, 16.20

(3rd session on High-Power Accelerator Components and Targets)