

A Novel Two Stage Collimation Unit for Fermilab Booster

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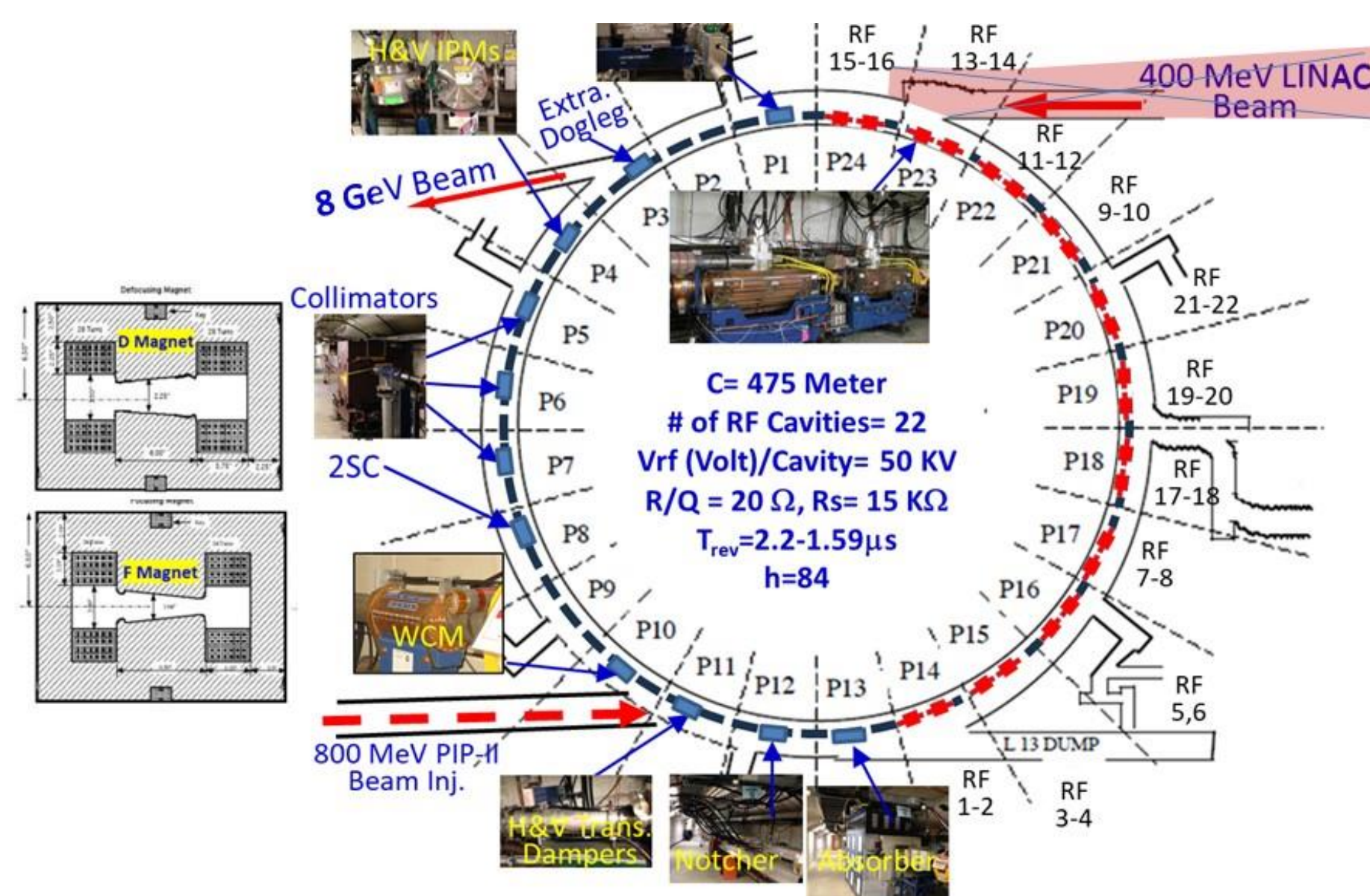


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A new two-stage collimation unit (2SC) for Fermilab Booster will be installed during 2024 summer. It is a supplementary collimator for existing single stage Booster collimators. Design details of this 2SC adapted to Booster conditions are described. Results from beam dynamics simulations on collimation efficiency and evaluation of collimator shielding with MARS code on this new system are presented.

PIP-II ERA BOOSTER LAYOUT

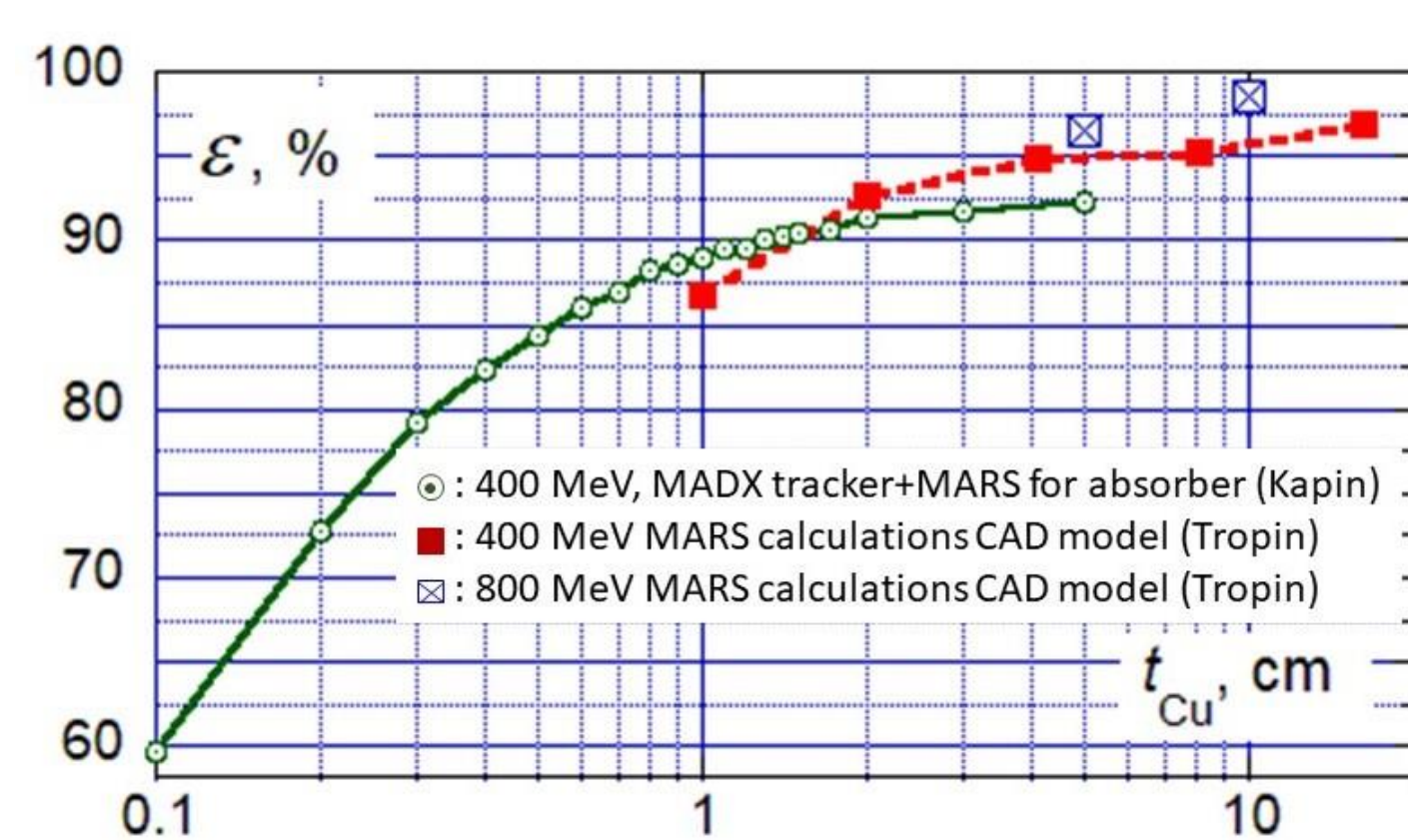


2SC ASSEMBLED ON TEST BUNCH



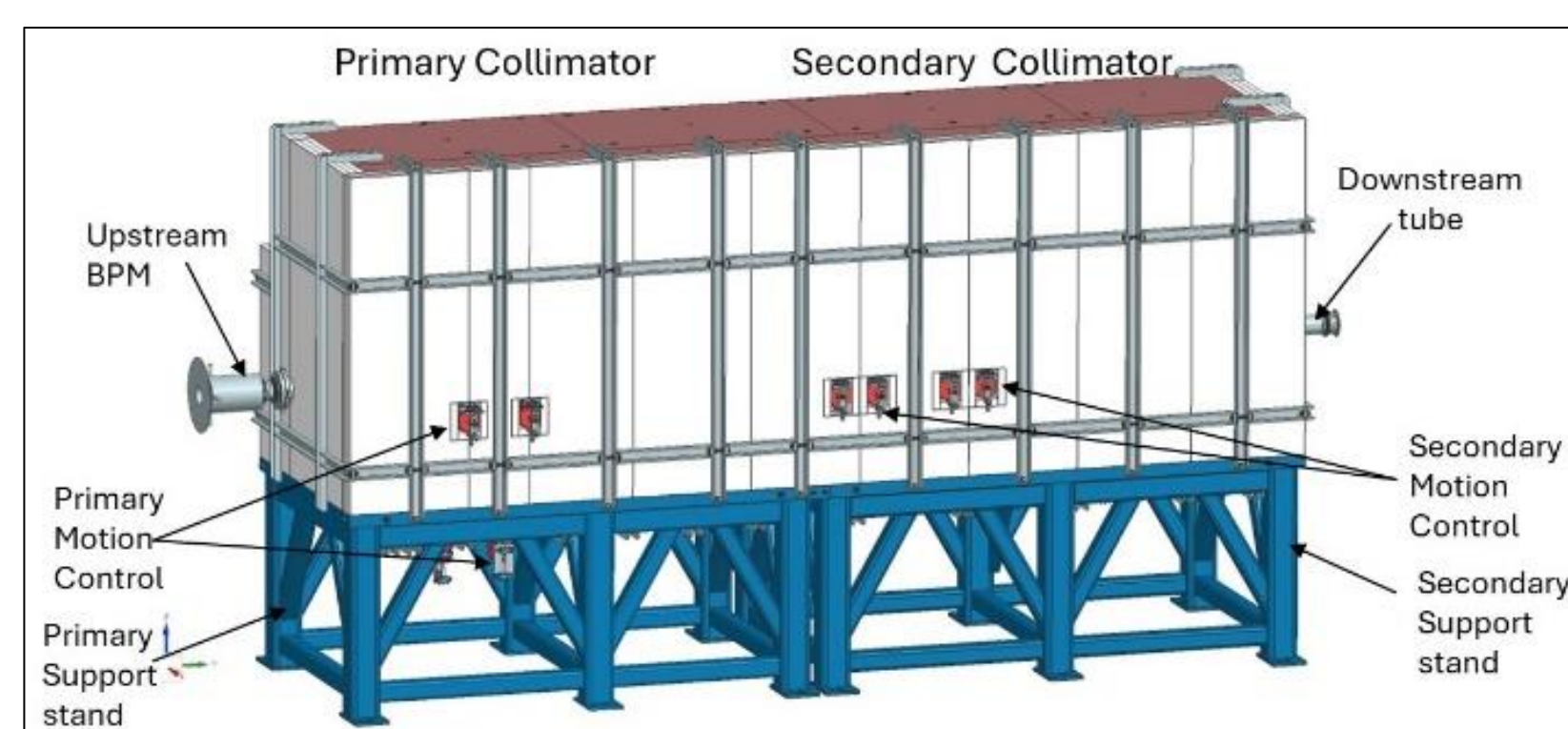
Shown are outer steel shielding with multiple collimator controllers.

COLLIMATION EFFICIENCY

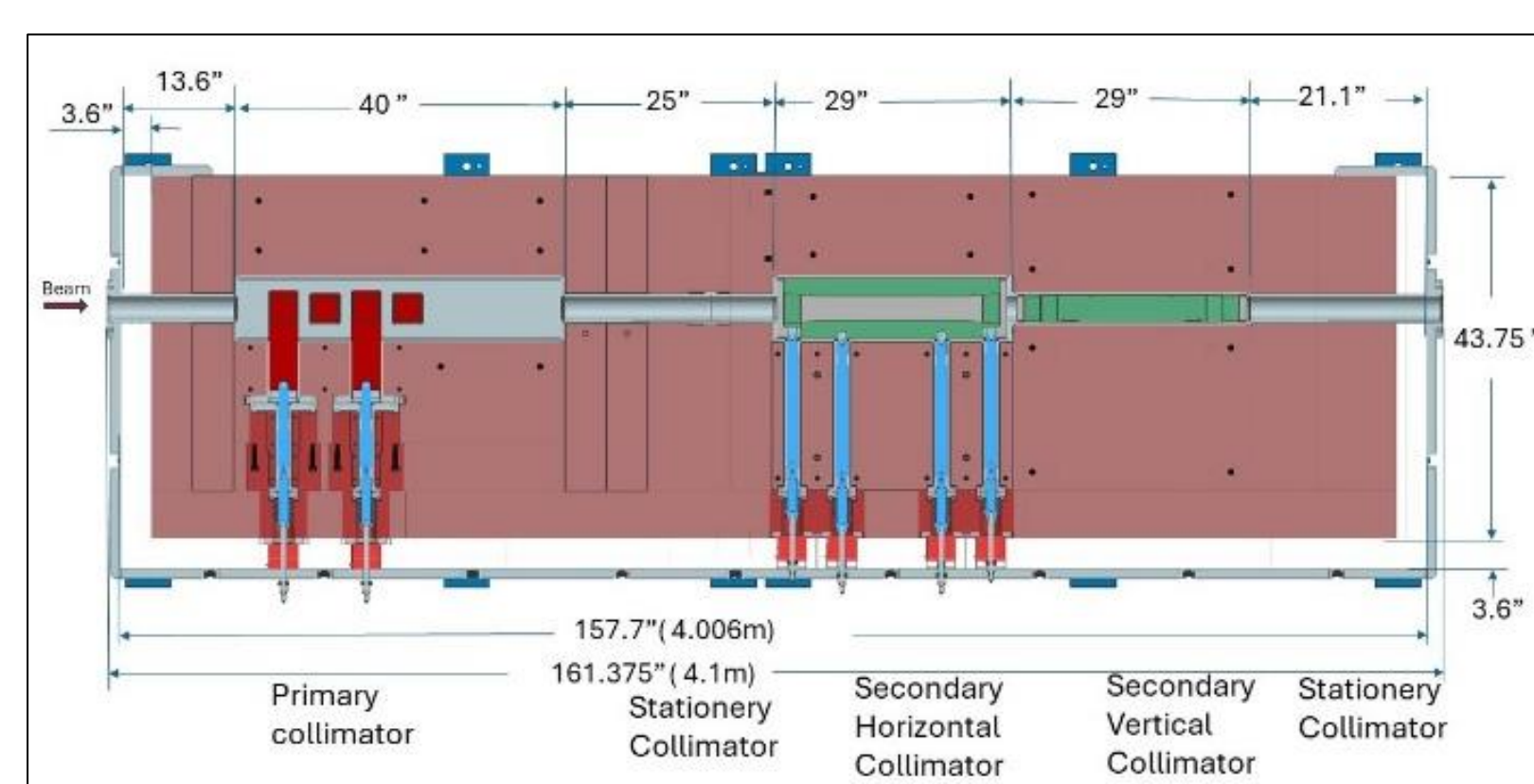


Collimation efficiency ϵ vs the primary copper jaw thickness t_{Cu} .

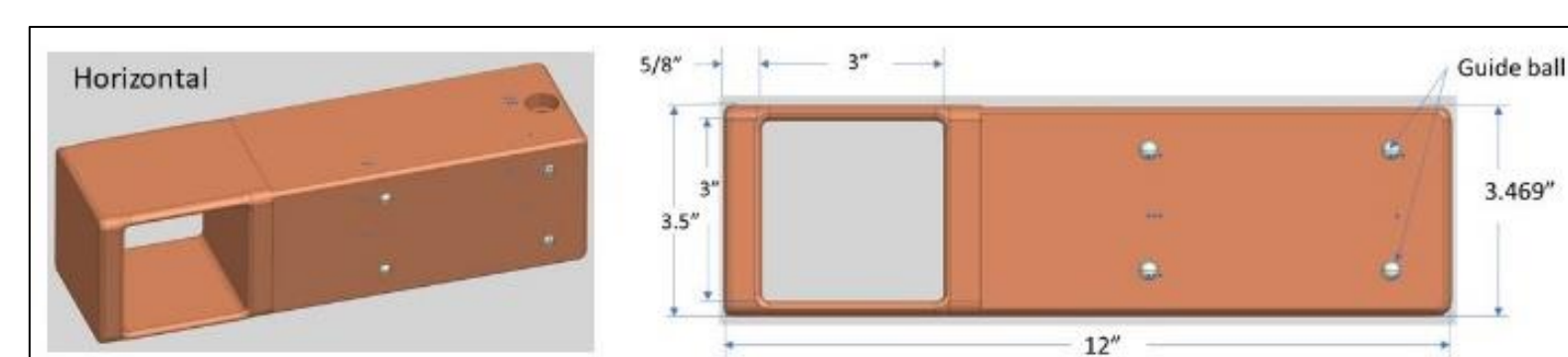
3D CAD OF 2SC



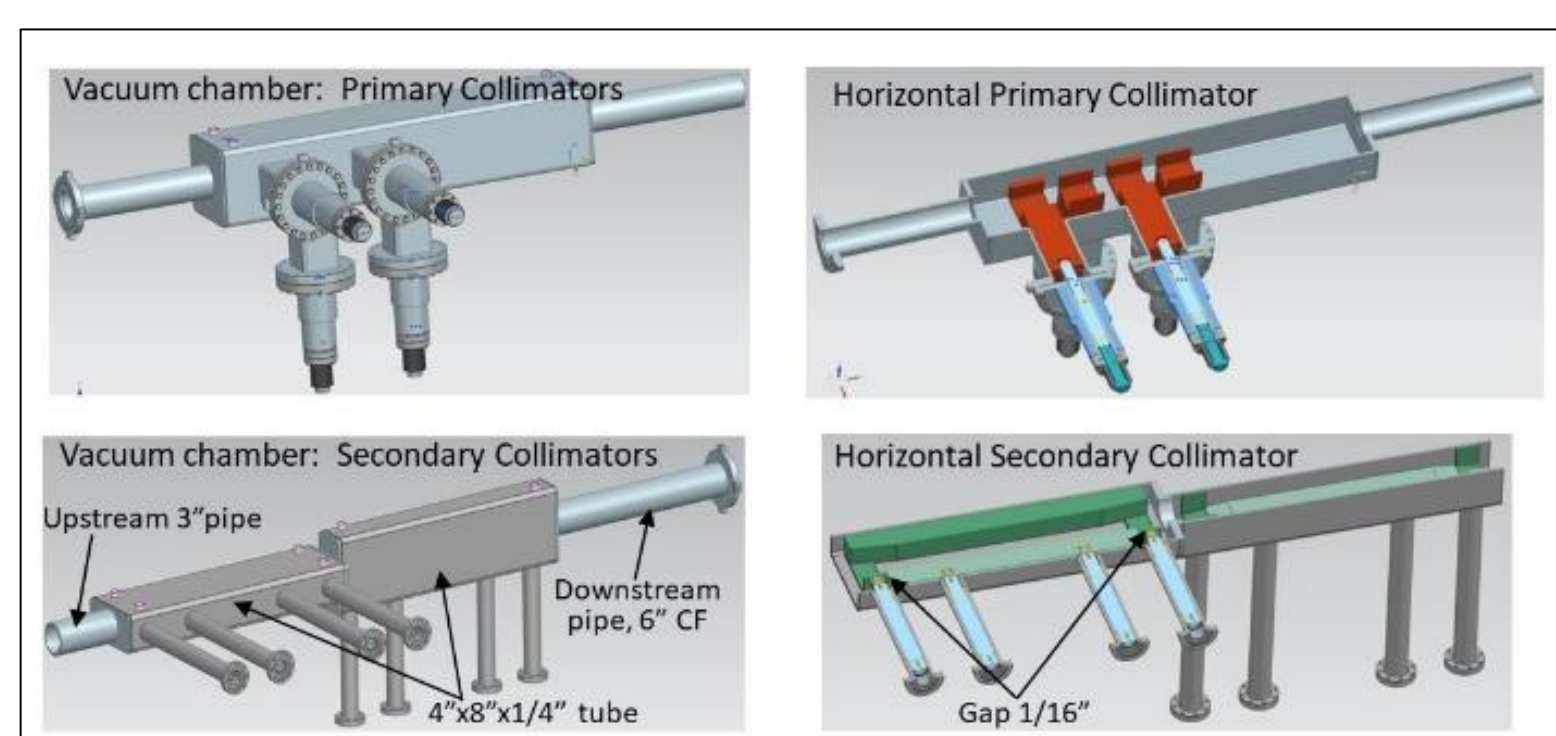
2SC to be assembled in the Booster tunnel.



The 2SC with the horizontal primary and secondary jaws



A view of the primary horizontal copper collimator.



Primary and secondary collimator vacuum chambers with collimator jaws

BEAM POWER IN CURRENT AND PIP-II ERA BOOSTER

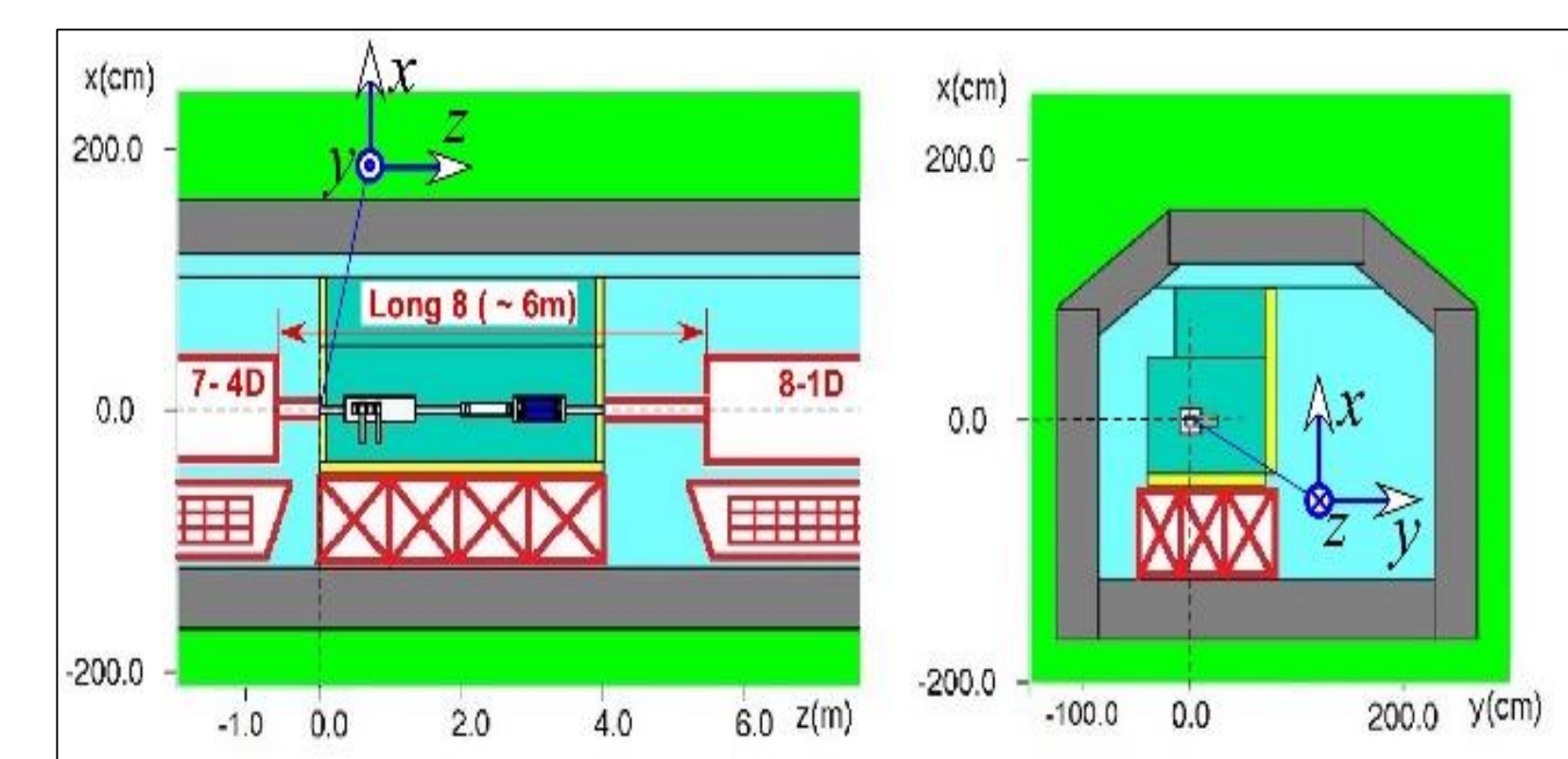
Parameter	Current	PIP-II	Units
Beam energy at inj.	400	800	MeV
Beam intensity at inj.	$4.54 \cdot 10^{12}$	$6.67 \cdot 10^{12}$	ppBc
Proton per hour at inj.	$2.45 \cdot 10^{17}$	$4.80 \cdot 10^{17}$	pph
Repetition rate	15	20	Hz
Beam power	4.4	17.1	kW
Assumed efficiency	94	98	%
Power lost	261.3	341.3	W
Fraction on collimators	0.5(of 6%)	0.5(of 2%)	-
Power on all collimators	130.7	170.7	W
Number of collimators	3	4	-
Power per collimator	43.6	42.7	W
Scraping rate for MARS	$8.8 \cdot 10^{11}$	$3.3 \cdot 10^{11}$	pps

RESIDUAL ACTIVATION IN CURRENT BOOSTER

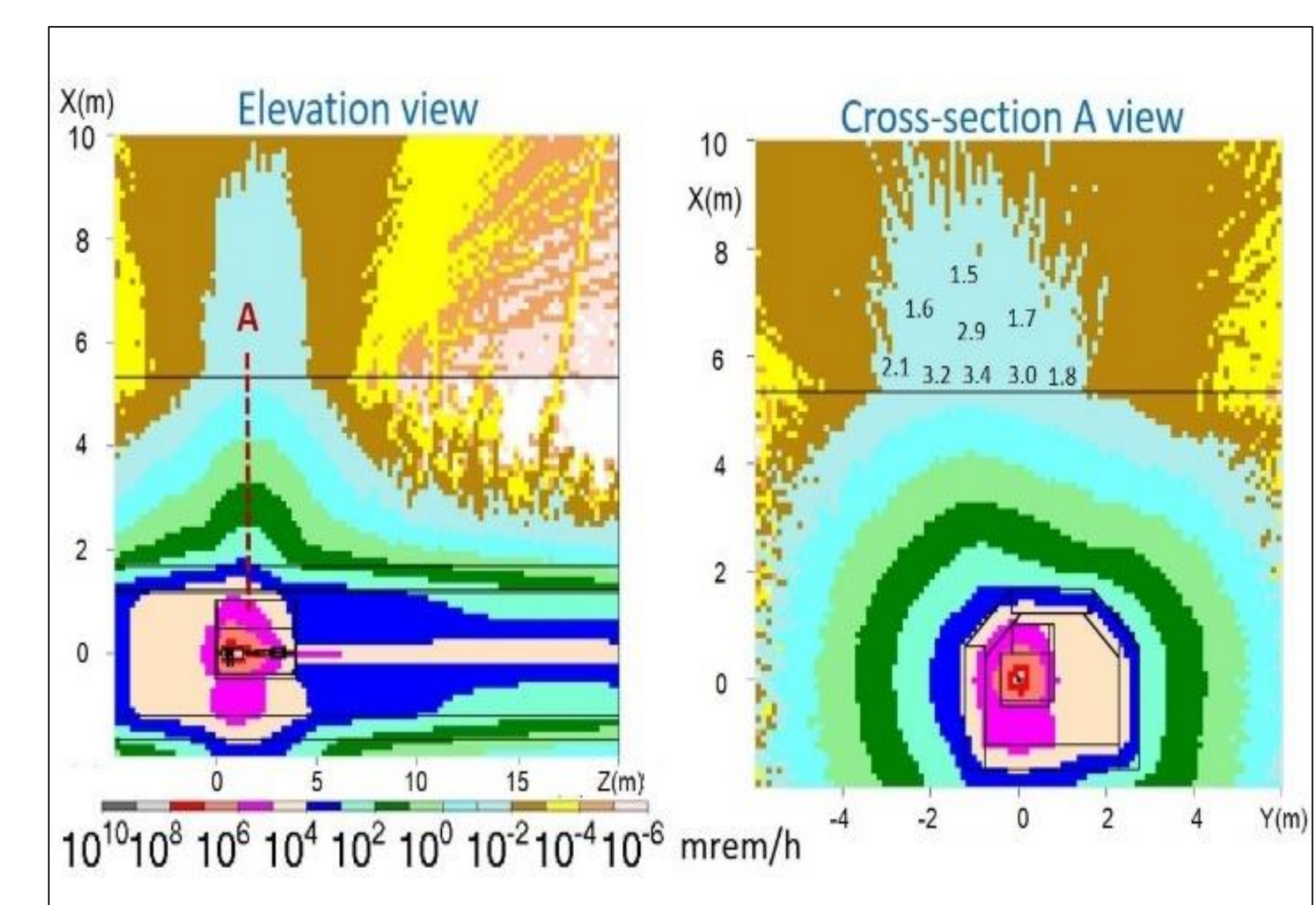
Measured residual activation levels at 1 foot from radiation survey after operating Booster for several hours at $2.45E17$ pph prior to tunnel access.

Loss Location	Loss level mrem/hr	Activation Distribution
Injection Area	300-400	14% (23%)
Collimation Area	300-700	48% (55%)
Extraction Area	500	20% (0%)
Rest of ring	< 50	18% (21%)

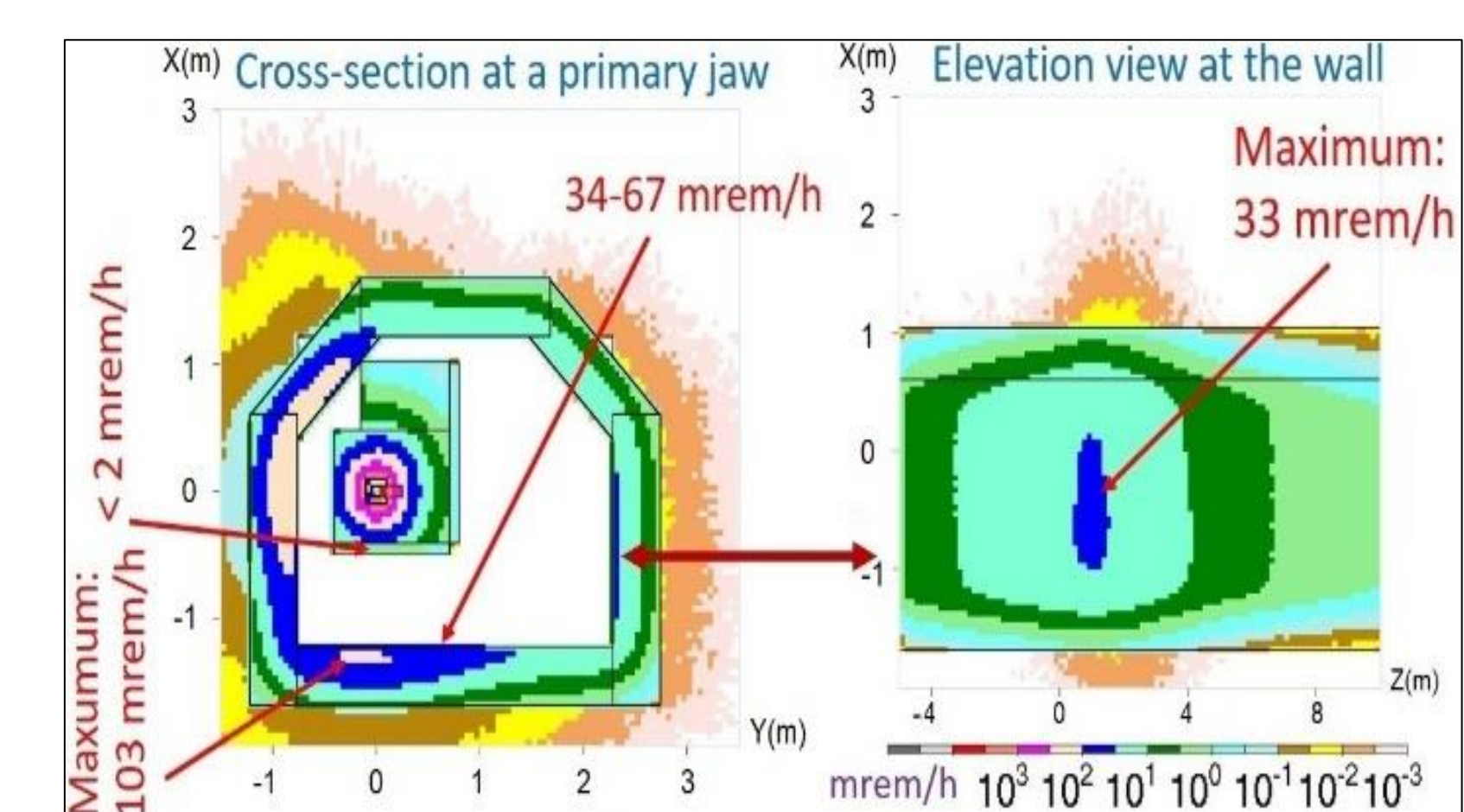
MARS SIMULATIONS AT 800 MeV



Side and front view of the 2SC for MARS model



The prompt dose distribution around the 2SC



Cross-sectional and wall view of the residual dose distribution around 2SC

SUMMARY

The analysis on beam dynamics shows that the planned 2SC system will help to collimate up to about 1% of the beam in a controlled way and, prompt and residual activation meet Fermilab Radiological Limits in current as well as during the PIP-II era high intensity operation of the Booster.

ACKNOWLEDGEMENTS

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