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MEDICAL RADIOISOTOPE PRODUCTION PLATFORM

Supplying the fight against cancer

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No patient should be denied the cancer care they need simply because some options are in **short supply** or **unavailable.**

Breakthrough, patented ion source capable of producing a wide range of **DIAGNOSTIC** and **THERAPEUTIC** radioisotopes.

Supplying the fight against cancer by:

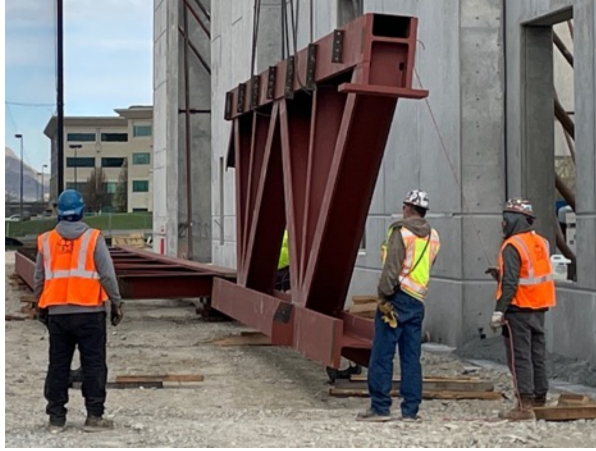
- Stabilizing supply chains
- Enabling innovation
- Providing unprecedented flexibility
- Increasing manufacturing capacity

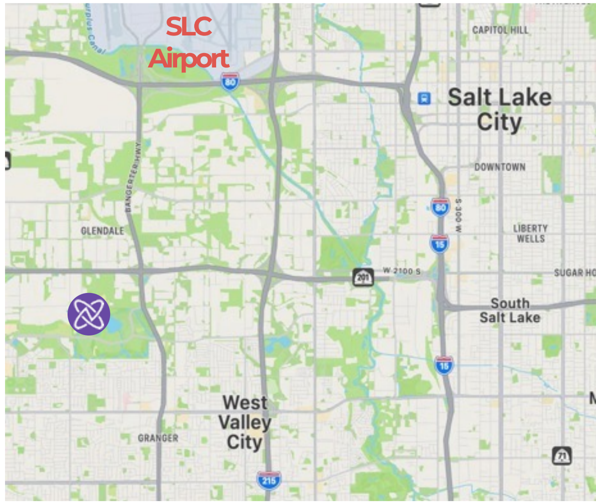
Location:

- Production facility opening Q1 2025 in West Valley City, Utah (Salt Lake City)

Production plant sited & progressing ahead of schedule

West Valley City, UT





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Nusano's proprietary, high-current ion source technology:

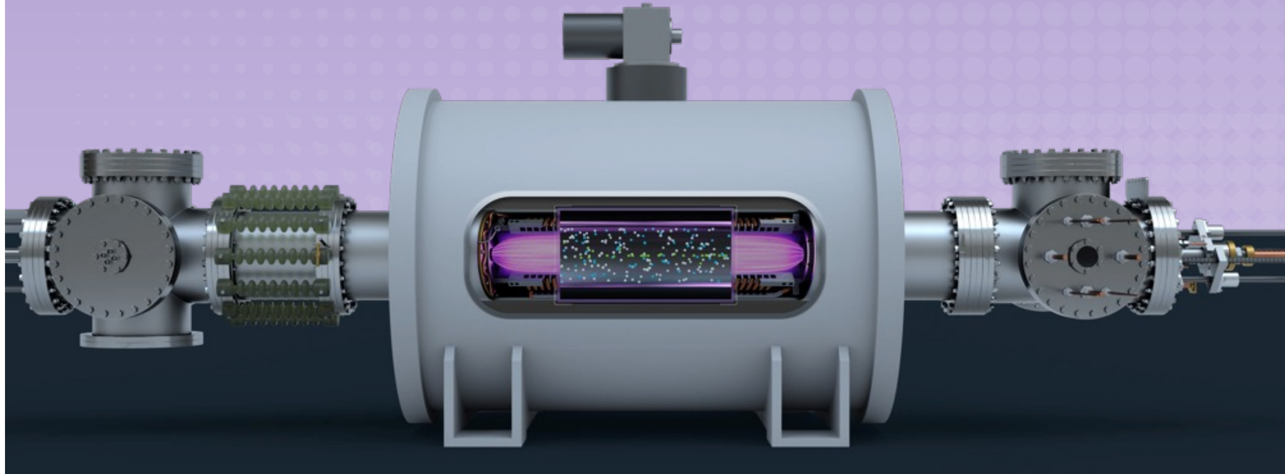
- Generates heavy ions, He^{++} & $^{2}H^{+}$, to greatly increase yield & efficiency
- Beam enables production of broad array of radioisotopes
- Annual preventive maintenance vs. monthly downtime

36mA
ALPHA BEAM CURRENT

≥36mA
DEUTERIUM BEAM CURRENT

288 – 720x
GREATER ALPHA PRODUCTION
than existing alpha ion beams

10,000+
HOURS RUNTIME



Performance

Particles

$^{2}H^{+}$

$^{3}He^{2+}$

$^{4}He^{2+}$

$^{7}Li^{3+}$

3-5

MILLIAMP

AVERAGE CURRENT ON TARGET*

Particle Energy

25 MeV

37.5 MeV

50 MeV

87.5 MeV

* Li beam ~1 mA

Production Capabilities 25+ isotopes

DIAGNOSTIC

- 64 Cu — **Copper-64**
- 18 F — **Flourine-18**
- 67 Ga — **Gallium-67**
- 68 Ga — **Gallium-68** via Ge-68 gener.
- 111 In — **Indium-111**
- 123 I — **Iodine-123**
- 124 I — **Iodine-124**
- 203 Pb — **Lead-203**
- 82 Rb — **Rubidium-82** via Sr-82 gener.
- 99m Tc — **Technetium-99m** via Mo-99 gener.
- 89 Zr — **Zirconium-89**

THERAPEUTIC

- 225 Ac — **Actinium-225**
- 211 At — **Astatine-211**
- 131 Cs — **Cesium-131** via Ba-131 gener.
- 67 Cu — **Copper-67**
- 131 I — **Iodine-131**
- 192 Ir — **Iridium-192**
- 212 Pb — **Lead-212**
- 177 Lu — **Lutetium-177 n.c.a.**
- 103 Pd — **Palladium-103**
- 223 Ra — **Radium-223** via Th-227 gener.
- 186 Re — **Rhenium-186**
- 47 Sc — **Scandium-47**
- 89 Sr — **Strontium-89**
- 117m Sn — **Tin-117m**

GENERATOR

- 131 Ba — **Barium-131** → Cs-131
- 68 Ge — **Germanium-68** → Ga-68
- 211 Rn — **Radon-211** → At-211
- 82 Sr — **Strontium-82** → Rb-82
- 227 Th — **Thorium-227** → Ra-223

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^{211}At: Worldwide Production

Table 1
Current ^{211}At production sites. Facilities that have reported production of ^{211}At during the last 5 years.

Location		Facility	Cyclotron manufacturer	Model and target	Production parameters	Current production status
North America	Durham, USA	Duke University Medical Center	CTI	CS-30 cyclotron, Internal target system	28 MeV, 100 µA	Max 9.3 GBq in 4-h
	Seattle, USA	University of Washington Medical Center	Scanditronix	MP-50, External target system	29.0 MeV, 58 µA	Max 4.3 GBq in 4-h
	Philadelphia, USA	University of Pennsylvania	Japan Steel Works (JSW)	BC3015, External Target	28.4 MeV, 10 µA	Max 395 MBq in 5-h
	Bethesda, USA	National Institutes of Health	CTI	CS-30 cyclotron, Internal target system	29.8 MeV, 43 µA	Max 1.71 GBq in 1-h
	College Station, USA	Texas A&M University	In house	K150 variable energy cyclotron	28.8 MeV, 7 µA	1.5 GBq in 9-h
Europe	Copenhagen, Denmark	Copenhagen University Hospital	Scanditronix	MC-32, Internal target system	29 MeV, 20 µA	Max 3–4 GBq in 4-h
	Nantes, France	Arronax	IBA	Cyclone 70	28 MeV, 15 µA	Production since 2020, 0.5–1 GBq capacity
Asia	Osaka, Japan	RCNP-Osaka University	In house	K140 AVF cyclotron	28.2 MeV	3 GBq expected after upgrade
	Chengdu, China	Sichuan University	CTI	CS-30	28 MeV, 15–20 µA	Max 200 MBq in 2-h
	Takasaki, Japan	QST-Takasaki, (TIARA)	In house	AVF (K110)	28.1 MeV, 4.5 µA	300 MBq in 3 h
	Chiba	QST-NIRS	In house	AVF-930	28.5 MeV, 10–13 µA	0.74–1.11GBq in 5-h
	Wako Saitama, Japan	IPCR Riken	In house	AVF	29 MeV, 40 µA	1.3 GBq in 1-h
	Fukushima City, Japan	Fukushima Medical University	Sumitomo	CYPRIS MP-30, External target system	29 MeV, 20 µA	Max 2 GBq in 4-h

Source: Yutian Feng, Michael R. Zalutsky. (2021). Production, purification and availability of 211At: Near term steps towards global access. *Nuclear Medicine and Biology, Volumes 100–101*, Pages 12-23. https://doi.org/10.1016/j.nucmedbio.2021.05.007.

~350 µA

combined worldwide alpha current being used to produce ^{211}At **in the last 5 years**

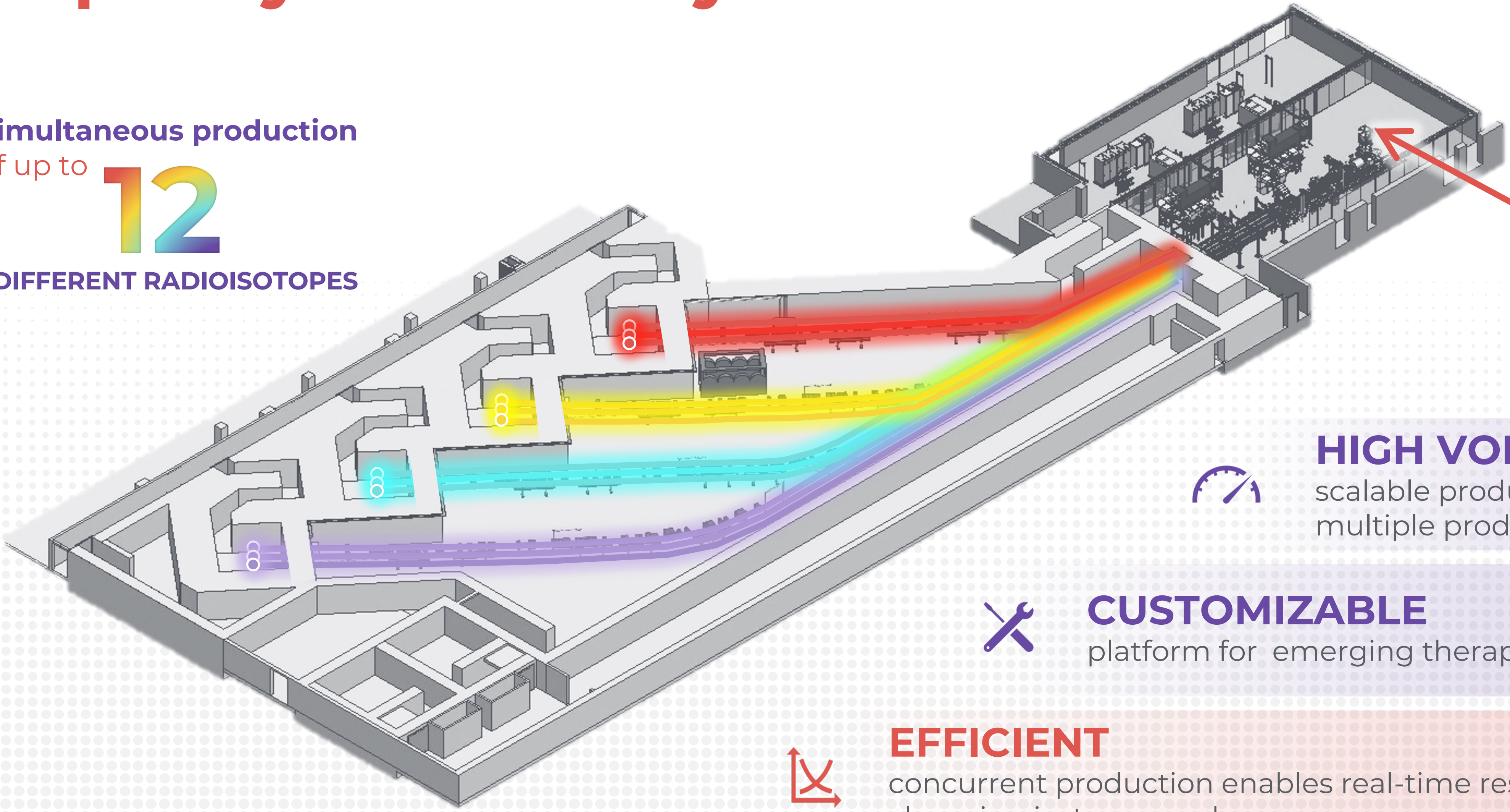
Nusano's single facility will have an

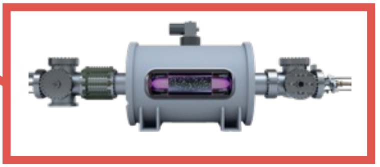
ORDER of MAGNITUDE

greater current than current worldwide capacity

Unprecedented production capacity & flexibility

Simultaneous production of up to **12** DIFFERENT RADIOISOTOPES





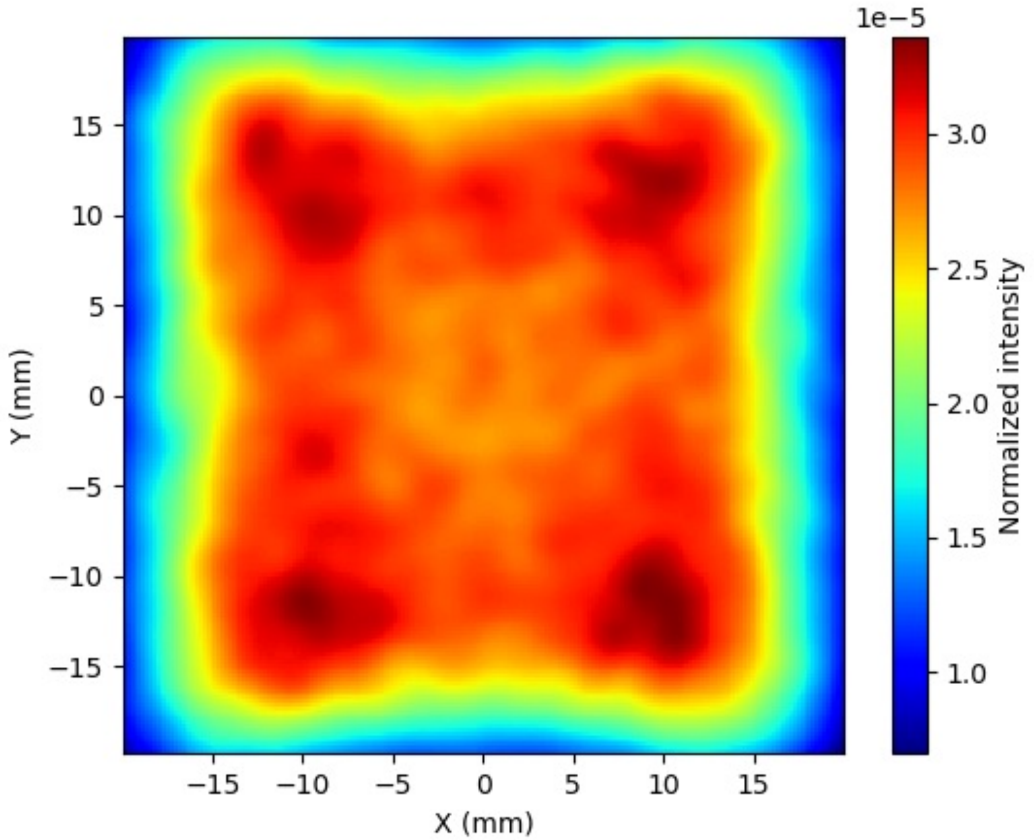
HIGH VOLUME
scalable production supporting multiple product lines at launch

CUSTOMIZABLE
platform for emerging therapeutics needs

EFFICIENT
concurrent production enables real-time response to changing isotope needs

Octupole Transformation

- Used to create a more homogenous distribution over square target than the incoming gaussian beam distribution
  - **Reduces peak heat loads and improves target survivability**
- The transformation takes the outer edges of the beam and folds them back on the body of the beam.
- square target area.
- Spot sizes of 2X2, 3X3, 4X4, or 5X5 cm^2.
  - Smaller spot sizes used for expensive target materials.
  - Larger spot sizes for less expensive and/or poor thermally conductive materials.



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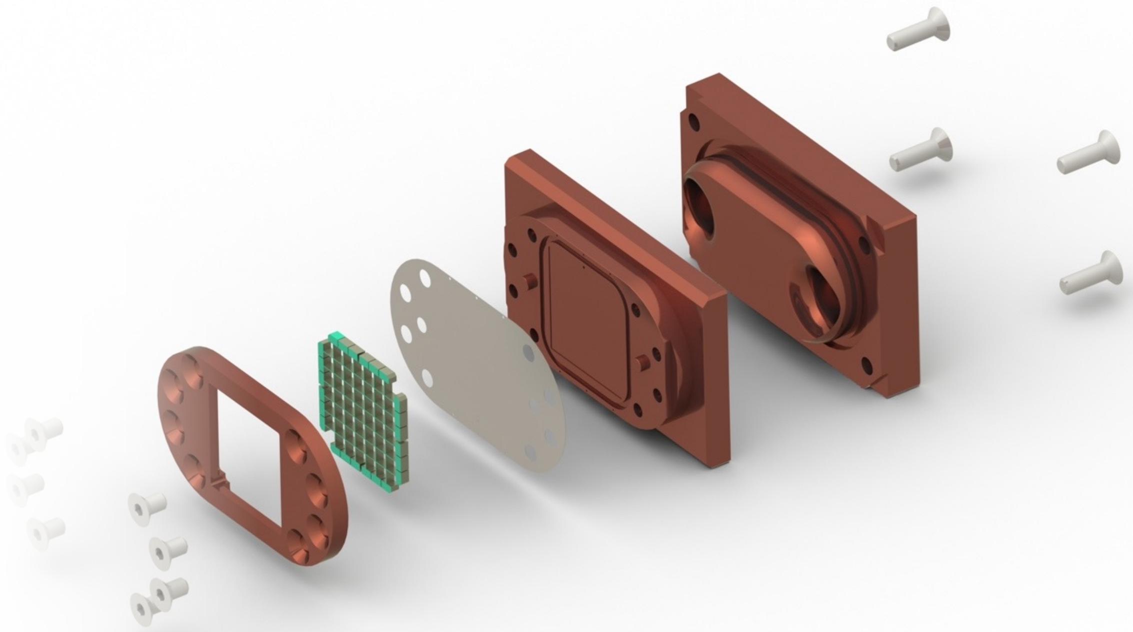
Nusano Targets

- Designed to withstand 250-500 μA average beam current (6.25 – 12.5 kW)
  - Potential for up to 1 mA current depending on target material and cooling methods
- Solid and liquid targets
- Cooled with water, cryogenic He gas, or both
- Housing materials selected for survivability
  - strength
  - thermal conductivity
  - radiation damage characteristics
  - impact on post-processing and chemistry
- Option to include window
  - prevents sublimation
  - controls beam energy
  - avoids material integrity as limiting factor on target survivability



Target Modeling Design Approaches

PRODUCTION YIELDS calculated using measured cross-sections in MCNP6.

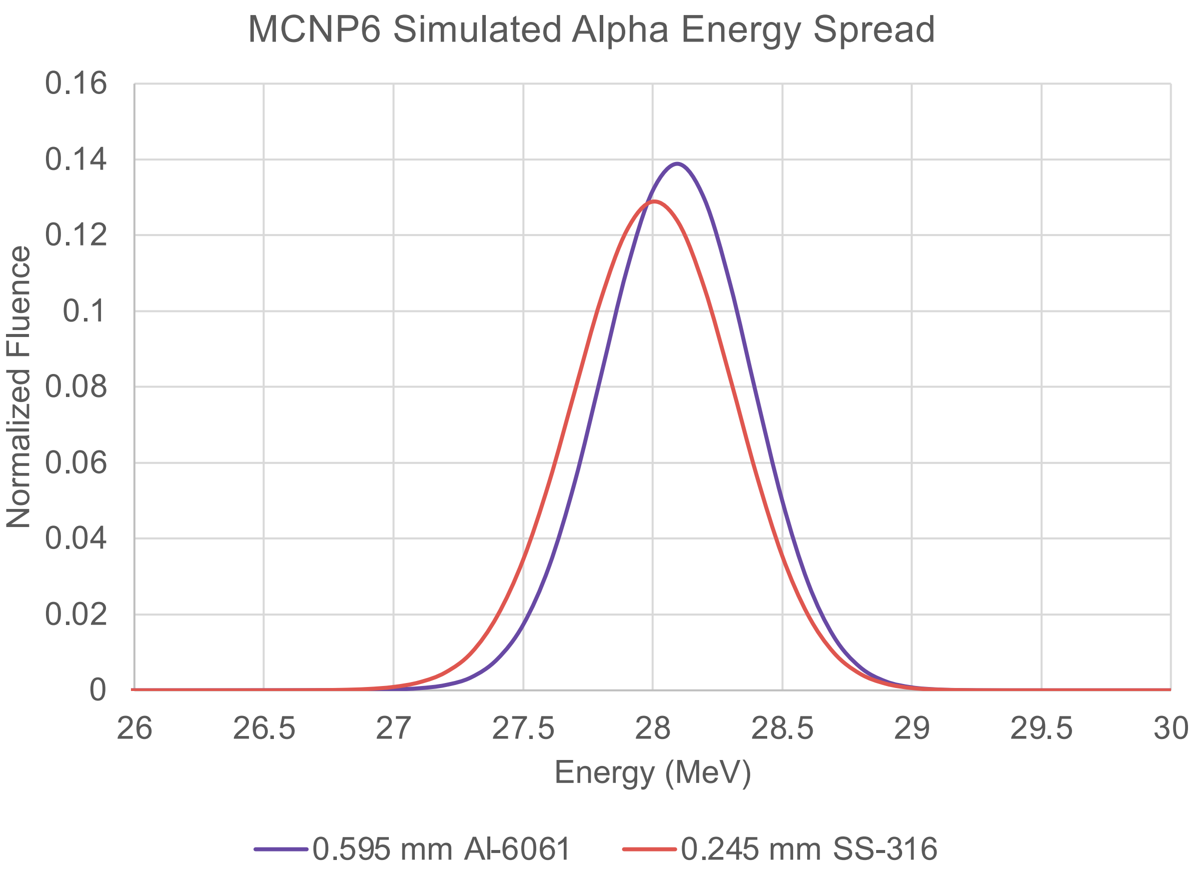
TARGET HEAT LOADS with DEPTH calculated with MCNP6.

2D BEAM DISTRIBUTION AT TARGET SURFACE calculated using beam optics simulation tool Elegant. Combined with the MCNP6 result to make a 3D heat load in the target.

COOLING FLOW & HEAT TRANSFER simulated with ANSYS Fluent code.

^{211}At Targetry

- Vertical, windowed design to moderate beam to <29 MeV
- 4 cm x 4 cm (16 cm^2) or 5 cm x 5 cm (25 cm^2) spot size
  - 12.0 cm x 1.8 cm (21.6 cm^2) target at U. of Washington external target[1] – gaussian, less distributed beam
- ^{209}Bi thickness: 0.1 mm
- Bismuth melted in place with similar methods to Gagnon *et al* 2012[1]
- Water cooling with option for cryogenic cooling

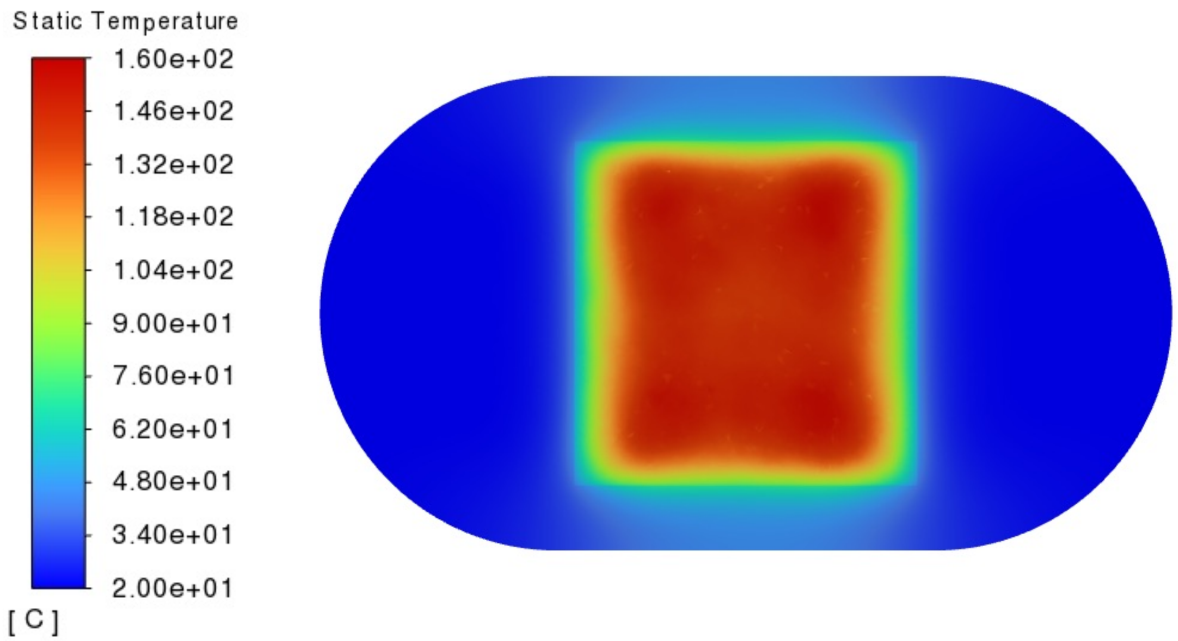


*0.03% of alpha fluence with energy >29 MeV in each case

[1]Source: Gagnon et al. (2012). Design and evaluation of an external high-current target for production of 211At. *J. Labelled Compounds and Radiopharmaceuticals, Volume 55*, Pages 436-440. DOI: 10.1002/jlcr.2968

^{211}At Targetry – ANSYS Thermal Modeling

- Temperature distributions simulated in target using ANSYS
  - 0.595 mm Al6061 (or 0.245 mm SS316, 0.1 mm ^{209}Bi layer, and Al6061 backing
  - Steady-state conditions – 250 µA
  - 56 lpm cooling water flow
  - Thermal contact resistance between window and Bi set to $1x10^{-4}$ m^2K/W
- Max temperature in Bi <160 °C for 4 cm x 4 cm spot size

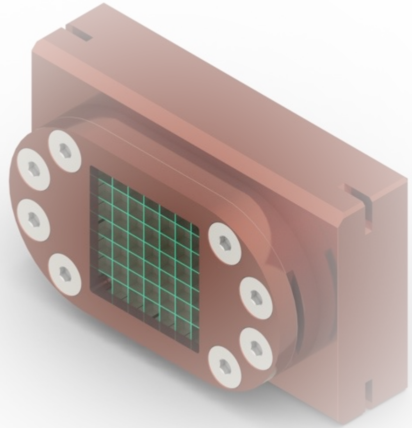


Bismuth max temperature remains well below the melting temperature

Target Design: Physical Testing

Measurements of the pressure drop across flow geometries used to validate the ANSYS Fluent results.

Target assembly methods development and testing to ensure thermal contacts can be repeatably achieved and material properties can be maintained



Oven tests for bonding

Irradiations at external facilities prior to Nusano's availability to confirm yields, co-production of contaminants, and early estimates of target survivability

Thermal interface measurements - the thermal contacts between materials are crucial to heat transfer in target.

Ramped approach to irradiation with Nusano's beam (i.e. slowly increasing average current and irradiation length)

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No patient should be denied the cancer care they need simply because some options are in **short supply** or **unavailable.**

THE NUSANO PLATFORM WILL:

Produce **25+ isotopes** on a commercial scale

Provide **flexibility, stability** & **scalability** to support global demand

Help **supply** the fight against cancer

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