

# Thorium Target Development Update

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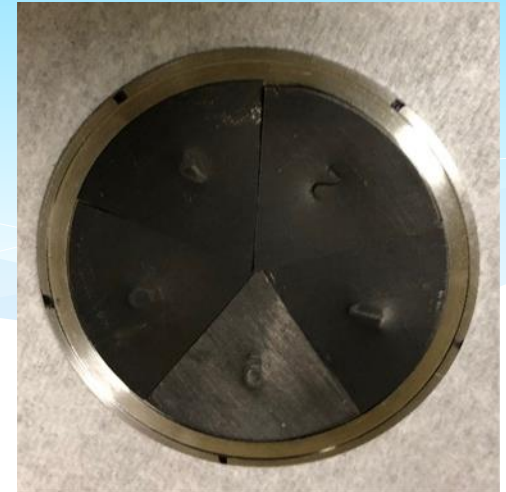
**July 25, 2020 site visit**

## BNL Technical Goals on targetry demonstration under Tri-lab Ac-225 production project

- Carry out production irradiations of Th targets for DMF and customer distribution at 50-100 mCi levels (Stage 2) of Ac-225 delivered
- Finalize and test the design of targets for ~1Ci levels (Stage 3) of Ac-225 delivered

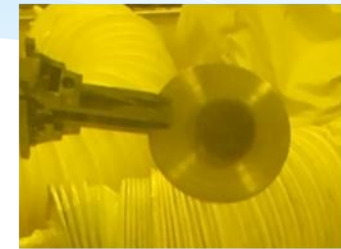
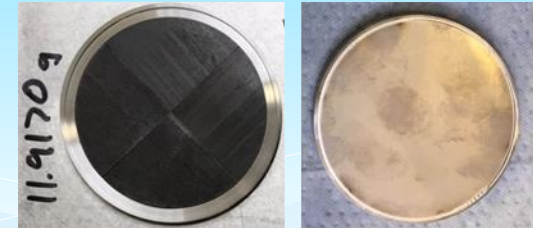
## BNL Stage 2 and 3 Target Design Status

- Stage 2 targets (50-100 mCi delivered)
  - Design and fabrication is finalized:
    - 60.3×0.3 mm thick Th foil, ~13 g, 5 sectors
    - EB welded in Inconel capsule
- Stage 3 targets (1Ci delivered)
  - Design and fabrication process was finalized in 2019:
    - 60.3×3 mm Th puck, ~103g
    - laser welded (under Helium) in Inconel capsule



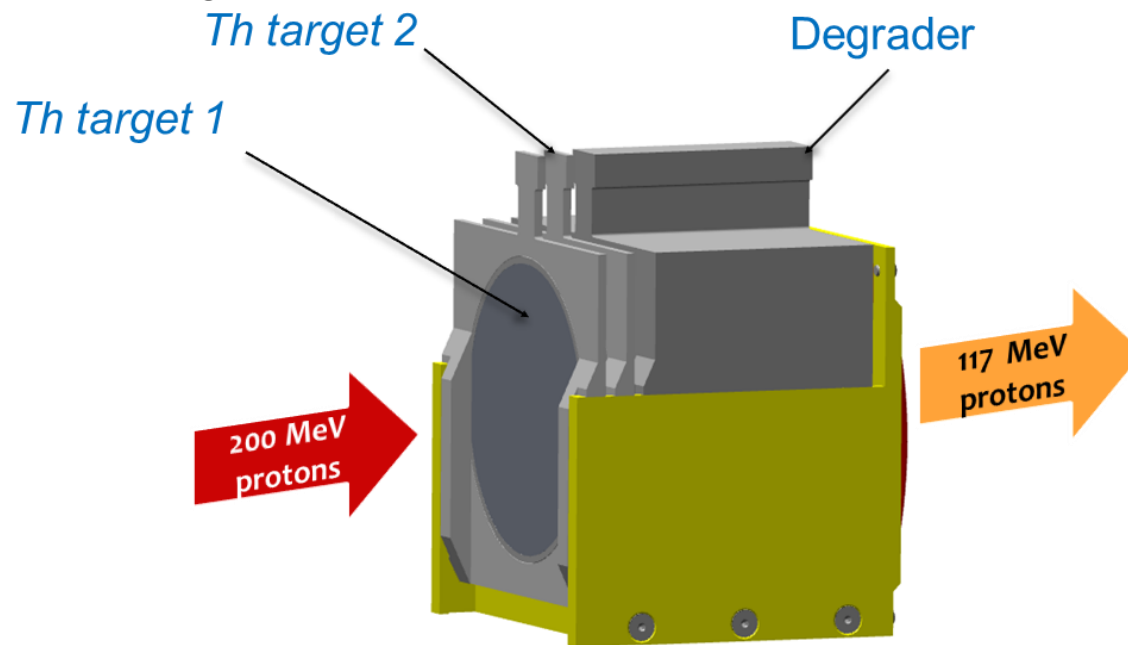
# Workflow of a typical Ac-225 production campaign at BNL to date

- Thorium material machined and cut into 5 pieces at LANL
- Pieces shipped to BNL, assembled and EB welded at EB industries (Farmingdale, NY)
  - 0.3 mm (0.015 in) thick (~11g ) Th foil
  - Inconel capsule
- BLIP irradiation
  - 200 MeV at 150-165  $\mu$ A, 3-5 days
- After irradiation and cool off target opened and packaged for shipment, each piece in an individual drum
- Shipped to Oak Ridge National Laboratory
  - White glove service, 5 Type A drums
- Chemical processing and dispensing of Ac-225 (up to 50 mCi) product is done at ORNL
- FY2019: 3 irradiation campaigns were completed



## FY2020: approach to 100 mCi Ac-225 batch milestone

- Irradiate stack of two Stage 2, 0.3 mm thick Th targets
- Conditions: 200 MeV for 11-12 days at 150-165  $\mu$ A
- Shipping in ten (10) Type A containers
- A total of ~20 days between EOB and calibration date for cool off and chemical processing



# FY 2020 progress to milestone

Hardware	#	Status
Cu degrader, vacuum, 200 MeV	1	completed
Cu degrader, vacuum, 180 MeV	1	completed
Target basket	1	completed
Target holder	2	completed
Stage 2 Th target	2	carried over from 2019



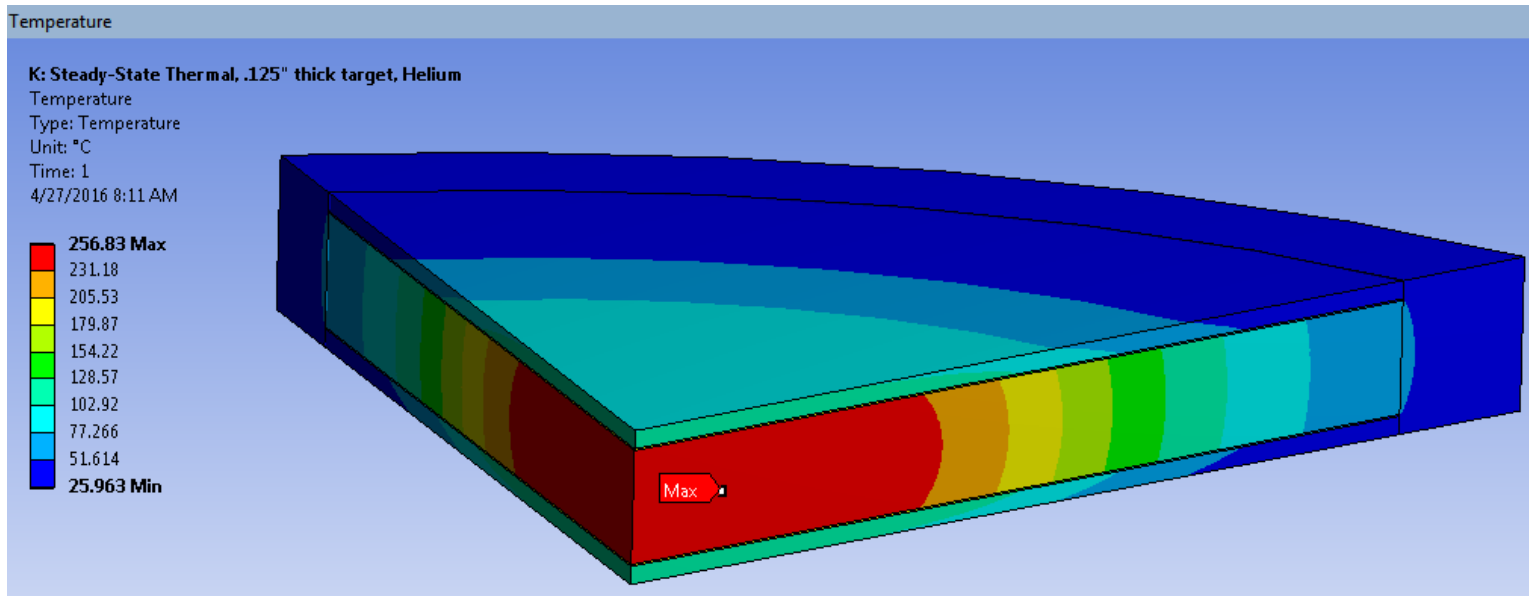
## Design of Stage 3 (up to 2 Ci, 3 mm thick, 100 g) Th target

- Approach:
  - Consider target power deposition under conditions with highest production rate of Ac-225 at BLIP:  $E(\text{LINAC})=200 \text{ MeV}$ ,  $165 \mu\text{A}$
  - Perform theoretical thermal analysis of the target
  - Test irradiate (3-4 h), open, and visually inspect target and windows (“cook and look” approach)
- Criteria for successful design:
  - Target capsule is intact after irradiation, no visible structural damage to windows or welding
  - No visible melting of Thorium or Inconel upon opening
  - No fusion/adherence of Th puck to the target windows
  - Thorium disk can be removed from the casing



# ANSYS thermal analysis of a 100g Th target

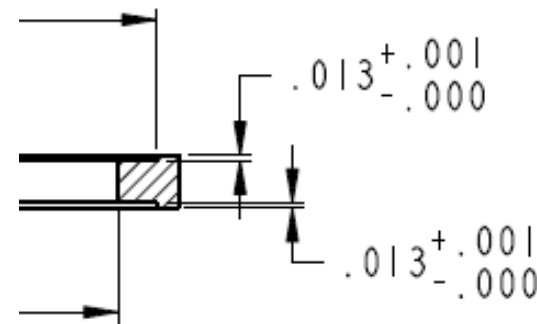
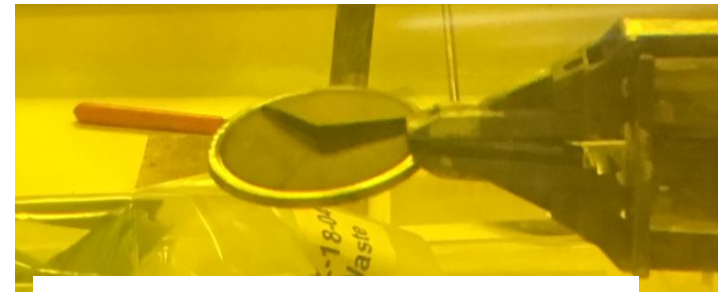
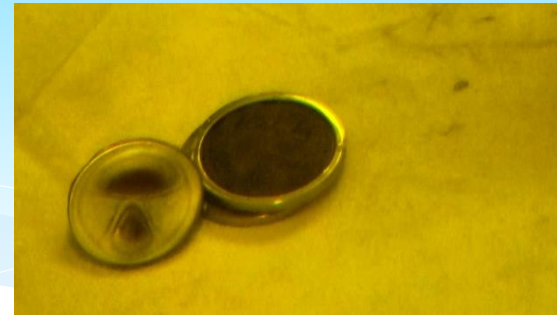
- Rastered beam profile
- Incident energy – 191.5 MeV, 165  $\mu$ A
- Max Th temperature 256.8  $^{\circ}$ C
- Inconel melting point 1390  $^{\circ}$ C
- Max Inconel temperature 80  $^{\circ}$ C
- Power deposited 1350 Wt





# Test irradiations of a 100 g Th target at BLIP

- 2016 design: 0.020 Inconel windows EB welded front and back. Backfilled with He and sealed at SIGMA facility. Target did not come out from the capsule after irradiation
- 2017 design: windows reduced to 0.012 inch: standard for BLIP . Same result
- 2018 the target was sectioned to ensure removal piece by piece. No adherence to the back window was observed
- 2019 increased inner diameter of the ring, welding carried out at EB industries, Farmingville, NY (April 15 run)



## 2019 Stage 3 test

- Test of the 4<sup>th</sup> generation target design was a success
- Target came out from the body
- Irradiation for 3 h, 1486 W

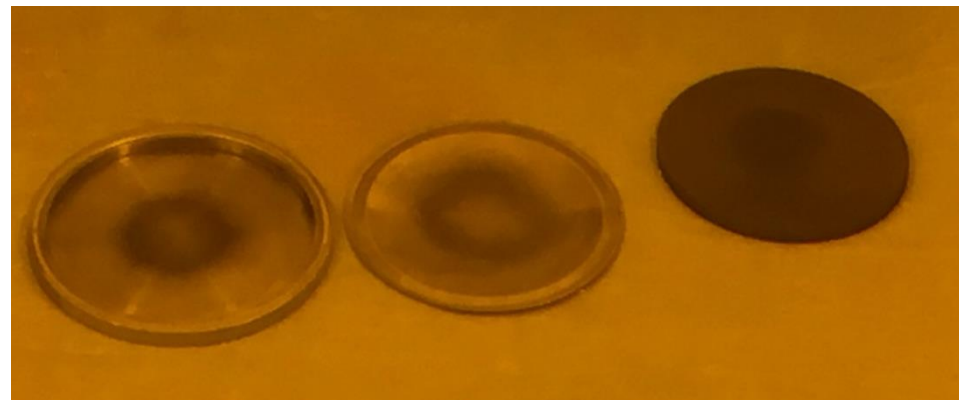
5	Box #1 window SS	8.00	0.020	0.5080	196.320	195.01	1.31
6	water gap	1.00	0.200	5.0800	195.010	192.68	2.33
7	Aluminum deg window	2.70	1.684	42.7700	192.680	147.10	45.58
8	Vacuum	11.70	0.267	6.7800	147.100	147.10	0.00
9	Aluminum deg window	2.70	0.376	9.5500	147.100	135.70	11.40
10	water gap	1.00	0.200	5.0800	135.700	132.69	3.01
11	Inconel	8.43	0.012	0.3048	132.690	131.60	1.09
12	Thorium target	11.70	0.120	3.0480	131.600	120.97	10.63
13	Inconel	8.43	0.012	0.3048	120.970	119.81	1.16
14	water gap	1.00	0.319	8.1000	119.810	114.53	5.28
15	Box#1 back window SS	8.00	0.020	0.5080	114.530	112.63	1.90

Targets Thorium - CDG - "cook and look"

4/30/19 1006 - 1311

200 MeV & 140 uA, Rastered

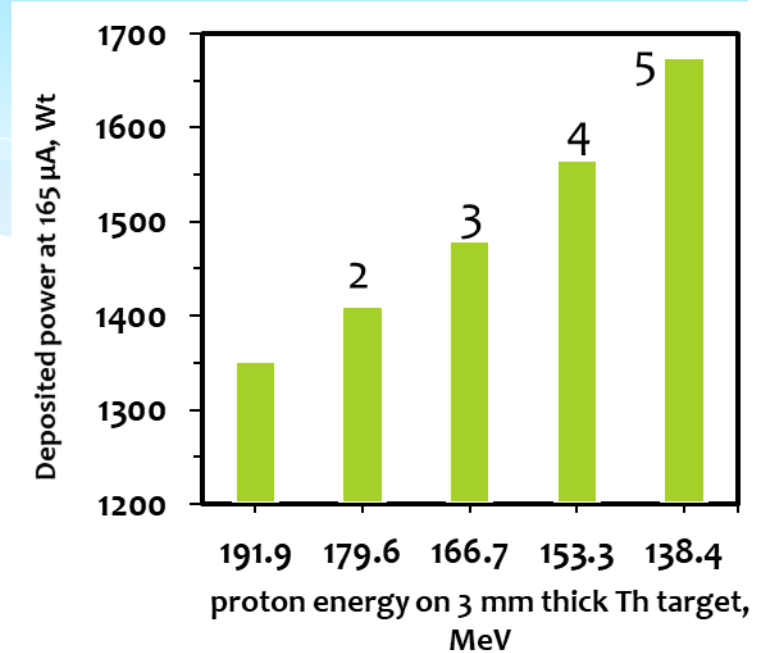
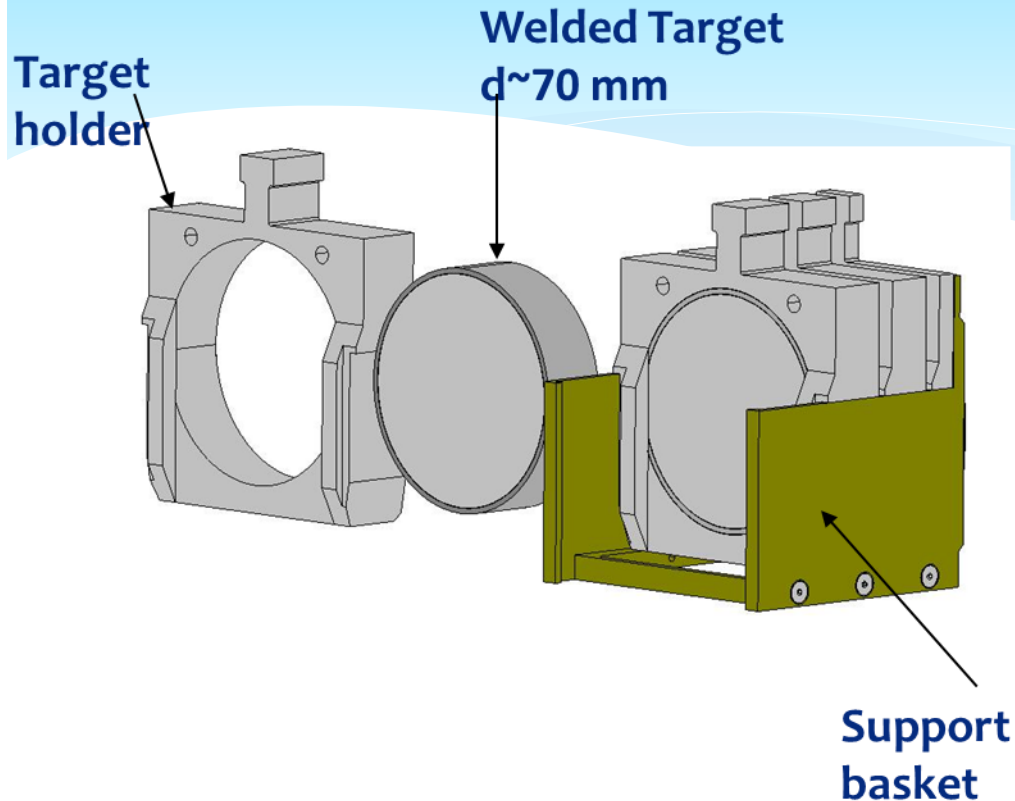
Total uA's	430.63
Total Hr's	3.08
Total Days	0.13
Avg. current	139.81



# Scaling up Ac-225 production beyond Stage 3 quantities: single target

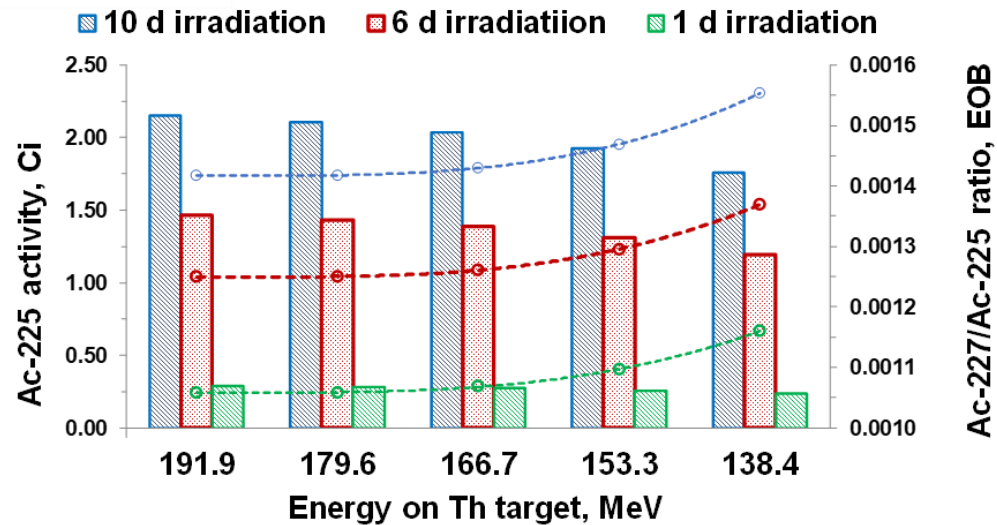
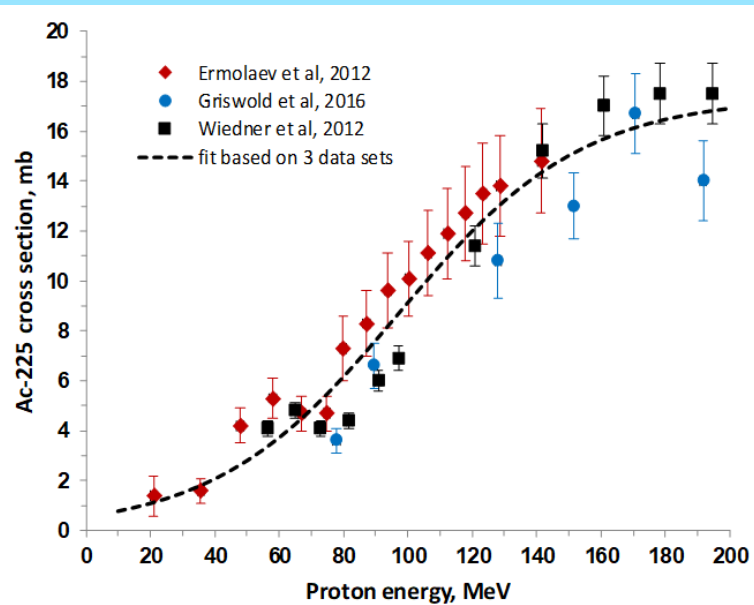
Beam power test for a single 100 g target	ANSYS modeled max window temperature	Status
1350 W (165 $\mu$ A, 191.9 MeV)	80°C	Experimental test completed at 1486 W
1753 W	129°C, heat flux acceptable	Thermal analysis completed
2923 W	192°C, heat flux acceptable	Thermal analysis completed

# Scaling up Ac-225 production – a stack of 100 g targets



- Five 100 g Th targets can fit in the basket
- Test irradiation to test target survival under conservative thermal load (1) commenced

# Projected activity per target at 165 $\mu$ A based on latest data



# Summary

- Unique target fabrication techniques for Thorium targets have been established.
- BNL Stage 2 and 3 target design has been completed
- Preparation for a 100 mCi Ac-225 batch milestone has commenced via irradiation of two Stage 2 targets
- Current design of Stage 3 target BNL offers a substantial increase in production capacity over Stage 3 capability through current increase and/or multi-target stack capability
- Looking ahead for a 100g target:
  - longer irradiation
  - higher thermal loads