BLIP 2017 Summary and 2018 Plans

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4th RaDIATE Collaboration Meeting

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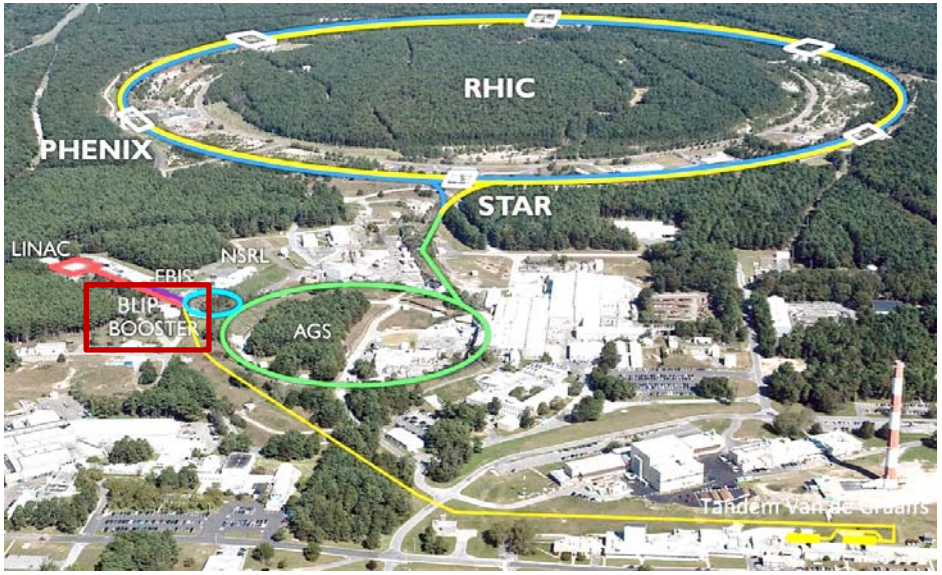
Outline

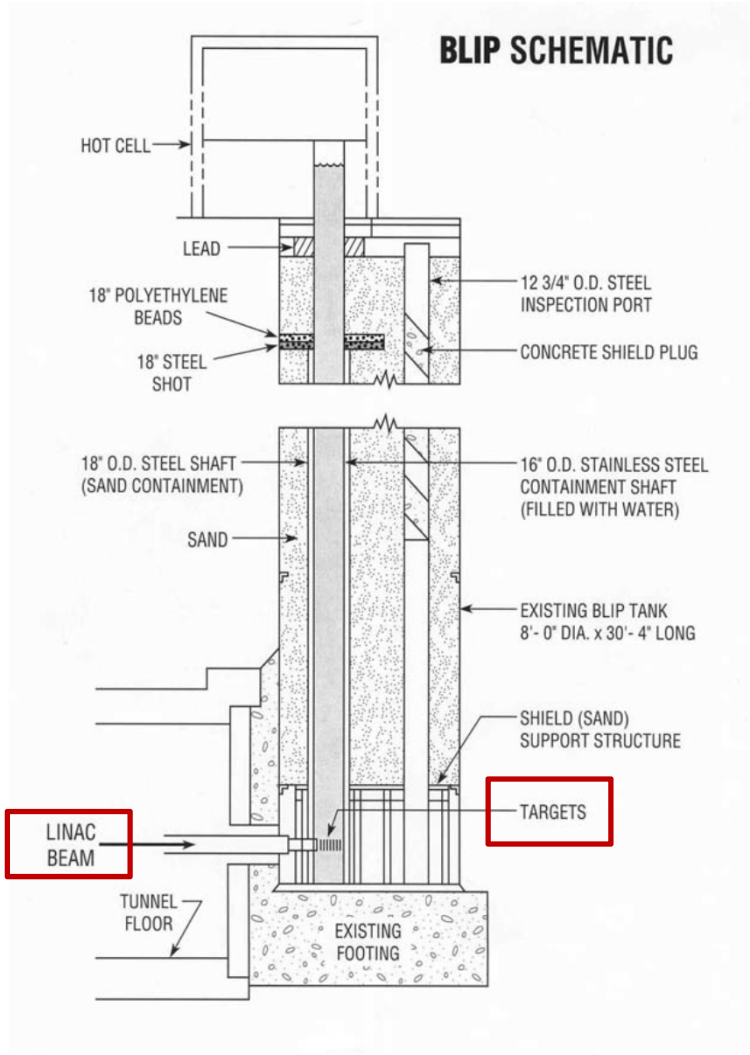
- Overview of BLIP irradiation
- 2017 irradiation run update
- Capsule status and plans
- 2018 irradiation plans
- Next steps

Objectives

- Evaluate radiation damage effects from high energy protons in various accelerator materials
  - Beam windows, secondary particle production targets, beam dumps
- Expose several material specimens to high energy protons at the BNL BLIP facility
- Perform PIE activities: measurement of strength (tensile, bend, fatigue), thermal properties (CTE, conductivity), annealing effects, microstructural analysis (SEM, TEM, EBSD, etc.)
- Characterize property changes due to proton irradiation damage

BNL BLIP facility



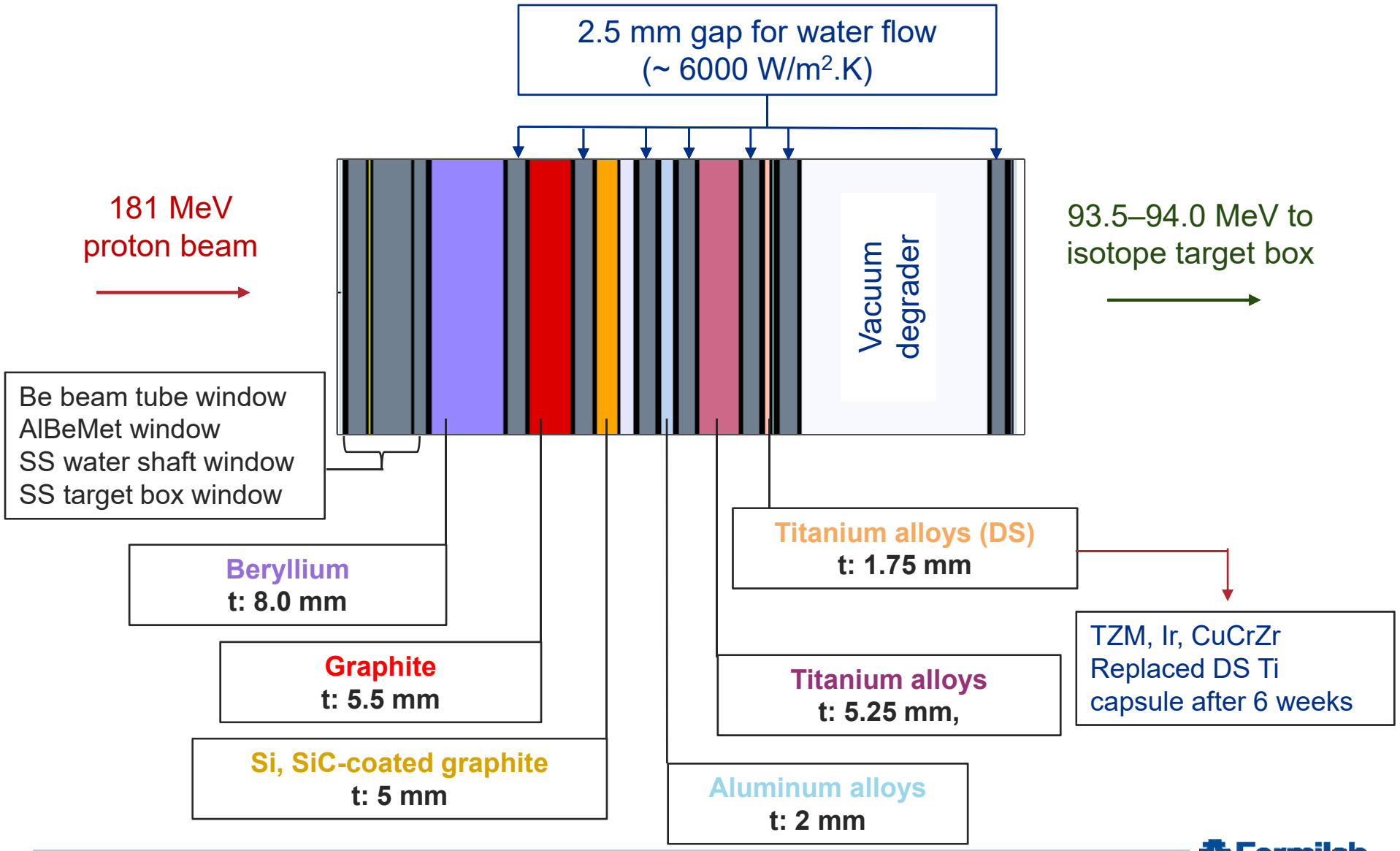


- **BLIP's primary mission is medical isotope production**
- **High energy protons from the Linac**
  - Energy: 66 < E < 200 MeV
  - Peak current: 165 μA
- **Material irradiation** runs in tandem and upstream of isotope targets
  - Optimized target array needed to deliver precise beam energy and flux for isotope production

RaDIATE irradiation run 2017

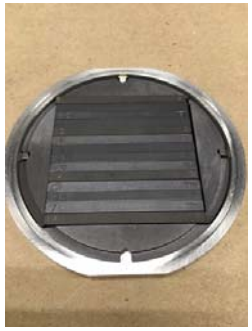
- Multiple capsules containing different materials
  - **Capsule 1:** Beryllium (FNAL)
  - **Capsule 2:** Graphite (FNAL)
  - **Capsule 3:** Silicon, SiC-coated graphite, Expanded graphite (CERN, KEK)
  - **Capsule 4:** Aluminum alloys (ESS)
  - **Capsule 5:** Titanium alloys (FRIB, KEK, Oxford, STFC, FNAL)
  - **Capsule 6:** TZM, Iridium, CuCrZr, Flexible graphite (CERN)
    - **Capsule 7** (replacement): Titanium alloys (KEK, Oxford, STFC, FNAL)
- Experiment designed for a total of **8-week** irradiation
  - Capsules 1 – 5: **8 weeks**
  - Capsule 6: **2 weeks**
  - Capsule 7: **6 weeks**

Target box schematic



Specimens and capsules assembly/installation

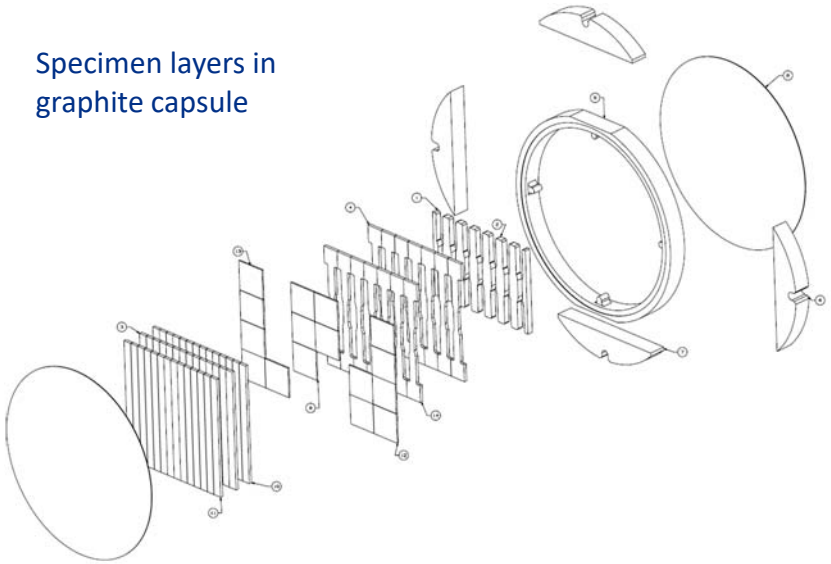
Graphite capsule



Beryllium capsule

Titanium capsule

Specimen layers in graphite capsule



Welded capsule in gas/vacuum

Capsule holder and basket

Target box and BLIP hot cell

Irradiation summary 2017

- Irradiation start: 4th April, 2017
- RF tank needed to increase energy to 181 MeV failed after 4 days
- Due to higher priority of RHIC, repair was postponed until end of May

- RaDIATE target inserted back in beam on June 6th
- Beam interruptions of about 14 days until BLIP shutdown (June 30th) due to
  - Dedicated isotope production runs
  - Linac repairs
  - Capsule exchange

- DS Ti capsule replaced with High-Z capsule after accumulating ~10 days of irradiation

- Dedicated RaDIATE BLIP run from June 30th to July 3rd
  - To meet minimum dose requirement (~13days) for High-Z capsule

- Irradiation of Si, DS Ti & High-Z capsules complete
  - Received minimum dose to proceed with PIE

Irradiation profile – 2017 run

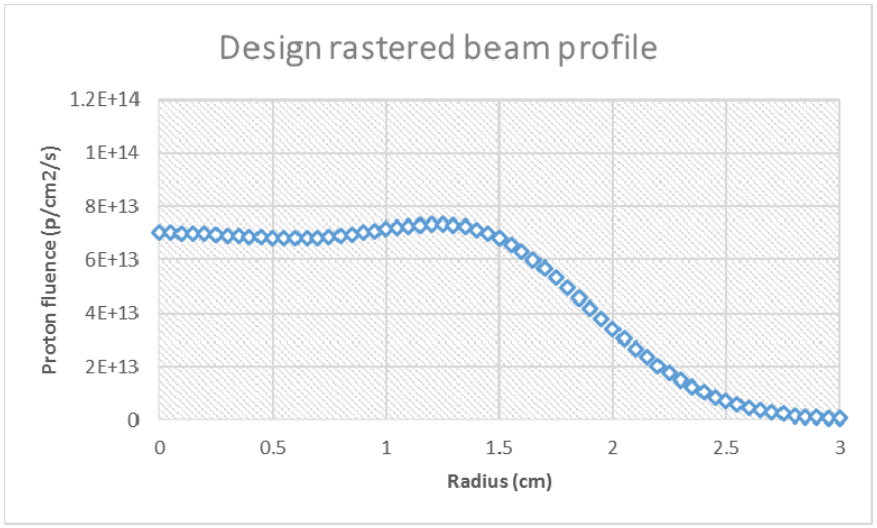
- Many thanks to our BNL colleagues
  - N. Simos, D. Medvedev, L. Mausner, C. Cutler, D. Raparia et al.
- Total protons on target: 1.76e21 (~22 days @ 146 µA avg.)
  - ~10 days for DS Ti capsule
  - ~13 days for high-Z capsule

	Event	Start date	End date	Irrad. time (days)	Total µAhrs	Current (µA)	POT	Cool-down (days)
With DS Ti capsule	**Run**	4/26/2017	5/1/2017	3.91	13095.62	139.55	2.94651E+20	-
	Linac trouble and repair	5/1/2027	6/6/2017					37
	Run	6/6/2017	6/7/2017	1	3325	138.54	7.48125E+19	-
	Thorium run	6/7/2017	6/12/2017					5
	Source repair	6/12/2017	6/13/2017					1
	Run	6/13/2017	6/17/2017	4.52	16043.87	147.90	3.60987E+20	-
	Swap to high-Z capsule	6/17/2017				***Phase 1 Total***	***7.30451E+20***	-
With High-Z capsule	**Run**	6/17/2017	6/21/2017	4.48	17075.48	158.81	3.84198E+20	-
	Source repair	6/21/2017	6/23/2017					2
	Run	6/23/2017	6/26/2027	3	10518.1	146.08	2.36657E+20	-
	Dedicated runs	6/26/2017	6/27/2017					1
	Run	6/27/2017	7/3/2017	5.14	18021	146.08	4.05473E+20	-
	End of Run 1					***Phase 2 Total***	***1.02633E+21***	

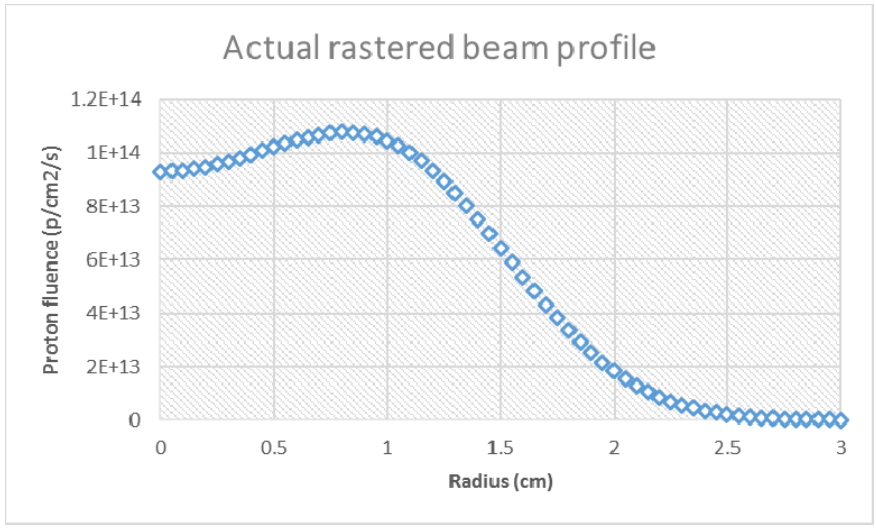
Rastered beam profile

- Actual rastered beam parameters were slightly different to design parameters
  - 1 x inner sweep + 5 x outer sweep, 6.67 Hz
  - Beam sigma of 0.51 cm and inner sweep radius of 0.55 cm unchanged
  - **Outer sweep radius changed from <u>1.5 cm to 1.2 cm</u>**

- Higher peak fluence (~30% increase) but reduced flat profile area



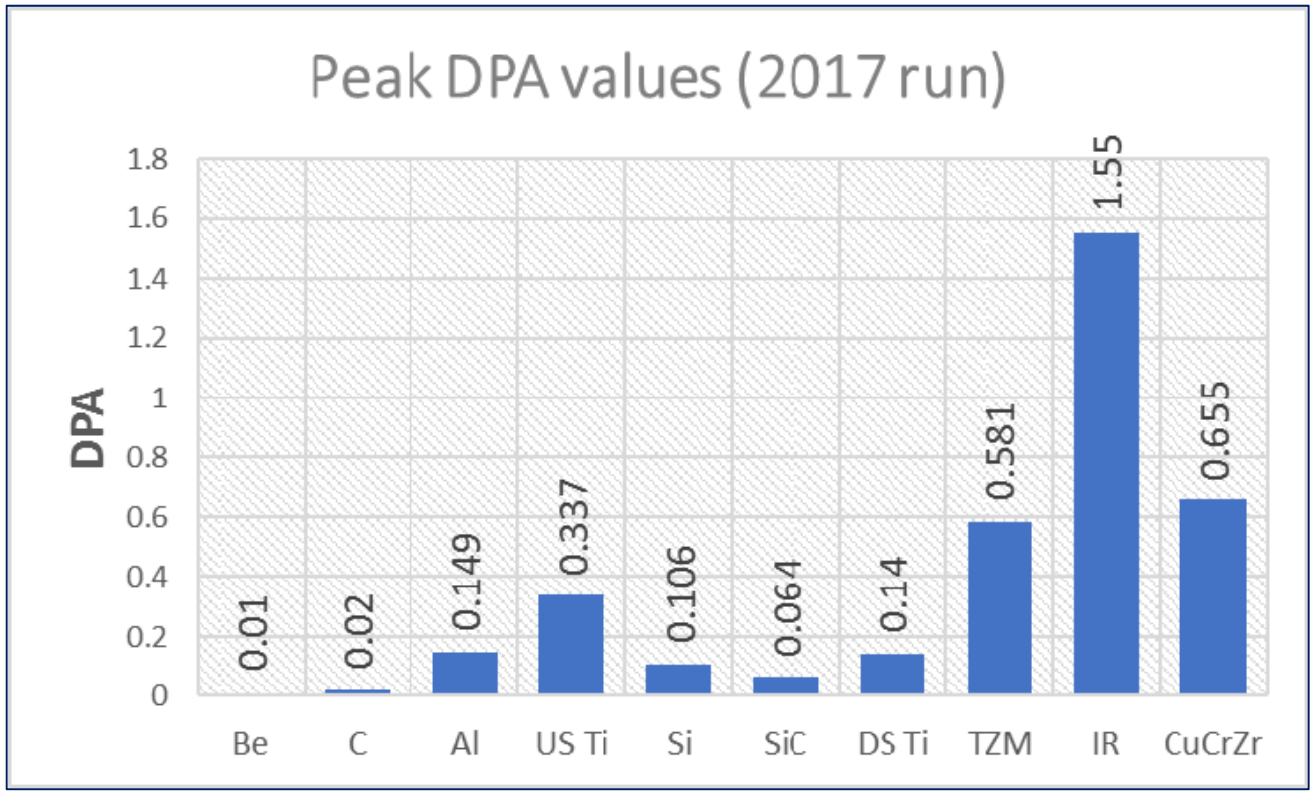
Inner sweep: 0.55 cm, outer sweep: 1.5 cm



Inner sweep: 0.55 cm**, outer sweep: 1.2 cm**

DPA accumulation so far

- Based on actual irradiation time and updated rastered beam profile



Current status of capsules

- Target box currently cooling down in BNL building 801 hot cell
  - Measured dose rate from target box lower than initially calculated
- Currently planning shipment of completed capsules to PNNL
  - Type A container borrowed from ORNL (bore size: 6” diameter, 33” long)
  - Proposing one shipment for Silicon, DS Ti & High-Z capsules in December 2017 (non-inclusive shipment)
    - Predict <2 mSv/hr & sum of radionuclide ratios ~0.7
- PIE work will begin in 2018
- PIE and capsule shipment preparatory work ongoing at PNNL
  - Capsule loading, packaging and paperwork
  - Shipment receipt and specimen sorting
  - Capsule opening device design/fabrication
  - Testing plans for capsules

More details in D. Senor presentation

BLIP run 2 - 2018

- BLIP currently scheduled to start during the first week of 2018
- Plan to resume RaDIATE target box irradiation as early as possible
  - To allow installation of specimens in HiRadMat experiment in Sept. 2018
- 4-5 weeks irradiation run to complete 8-week irradiation goal
  - No cost-sharing with RHIC, which will not be using protons until March 2018.
  - Expect higher beam time cost
- **Opportunity to add new capsules during second run**
  - Silicon and DS Ti/High-Z capsule slots vacant
  - Specimen space availability:
    - DS Ti/high-Z slot: 1.75 mm
    - Si slot: 5 mm
  - Energy budget: 15 MeV

New DS Ti capsule (KEK, RAL, FNAL)

- New DS Ti capsule
  - Same specimen thickness as first DS Ti capsule: 1.75 mm
  - Energy budget: 4.8 MeV (incl. SS windows)
- KEK will provide all the specimens
- FNAL to fabricate SS capsule and coordinate welding at EB industries, NY

Proposed material specimen layers

- 3 layers of tensile specimens (3 x 0.5 mm)
- 3 layers of microstructural specimens (3 x 0.5 mm – fits in between tensiles)
- 2 layers of meso-scale fatigue specimens (2 x 0.125 mm)

Ti alloy candidates

- Unalloyed Ti ASTM Grade 2
- Ti-5Al-2.5Sn ASTM Grade 6
- Ti-3Al-2.5V ASTM Grade 9
- Ti-6Al-4V ASTM Grade 5
- Ti-6Al-4V ASTM Grade 23(ELI)
- Ti-15V-3Cr-3Al-3Sn, AMS 4914

More details in T. Ishida presentation

New CERN capsule

- New CERN capsule to replace Si capsule
  - Specimen thickness: **4.5 mm** (0.5 mm less than Si capsule)
  - Energy budget: ~10 MeV (incl. SS windows)
- CERN will provide final assembled/welded capsule

Proposed material specimen layers

- 1 layer of Ta2.5W (1 x 0.5 mm)
- 2 layers of Mo-coated MoGR and CfC (2 x 1.5 mm)
- 1 layer of pure Si (1 x 1 mm)
- **Expect to consume 10 MeV (incl. SS windows)**

More details in E. Fornasiere presentation

Next steps – 2018 run

- Finalize contents of new capsules and provide info to BNL
  - Specimen thickness
  - Material composition data
  - Specimen/capsule drawings
- Update and submit safety document for BNL BLIP safety review
  - FLUKA analysis iterations to optimize target box (BNL)
- Specimen and capsule preparation
  - Design and fabrication of specimens and capsules
  - Specimen assembly and capsule welding
  - Capsule shipment to BNL
  - Design and fabrication of new vacuum degrader and capsule holders (BNL)

Need to be ready for irradiation in early Jan. 2018