The High Power Target Workshop

MAP Friday Meeting

July 22, 2011

Harold G. Kirk
Brookhaven National Laboratory

The Workshop Venue

Hosted by the European Spallation Source (ESS)

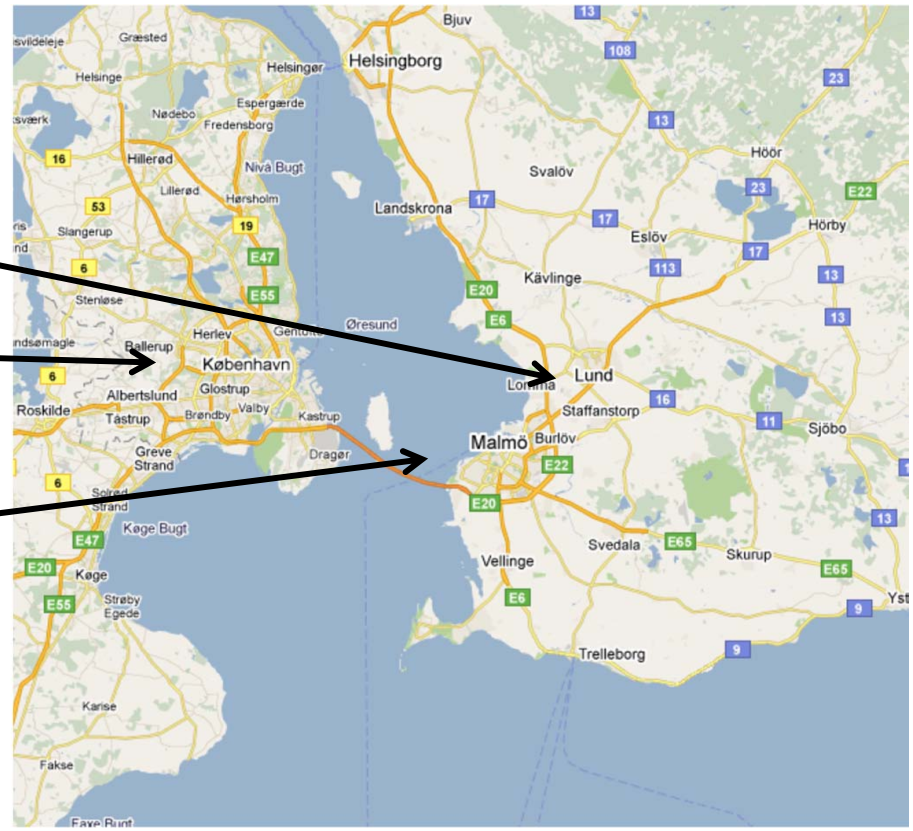
Malmö, Sweden

May 2-6, 2011

ESS (Lund)

Copenhagen

Malmö



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http://ess-scandinavia.eu/hptw

Selected Presentations of Interest to MAP

Operational Experience of Target Systems for Neutrino Facilities C. Densham, RAL

Operational Experience for High Power Spallation Targets, W. Wagner. PSI

T2K Beam Window Design, M. Rooney, RAL

Proton Beam Window for High Power Target Application, M. Butzek (Jülich)

Thin liquid lithium targets for high power density applications, C.Reed (ANL)

Radiation Effects on Fusion Magnet Components, H.W. Weber (TU Vienna)

The High-Power Target System for a Muon Collider or Neutrino Factory, K.T. McDonald, Princeton

Key Target Issues

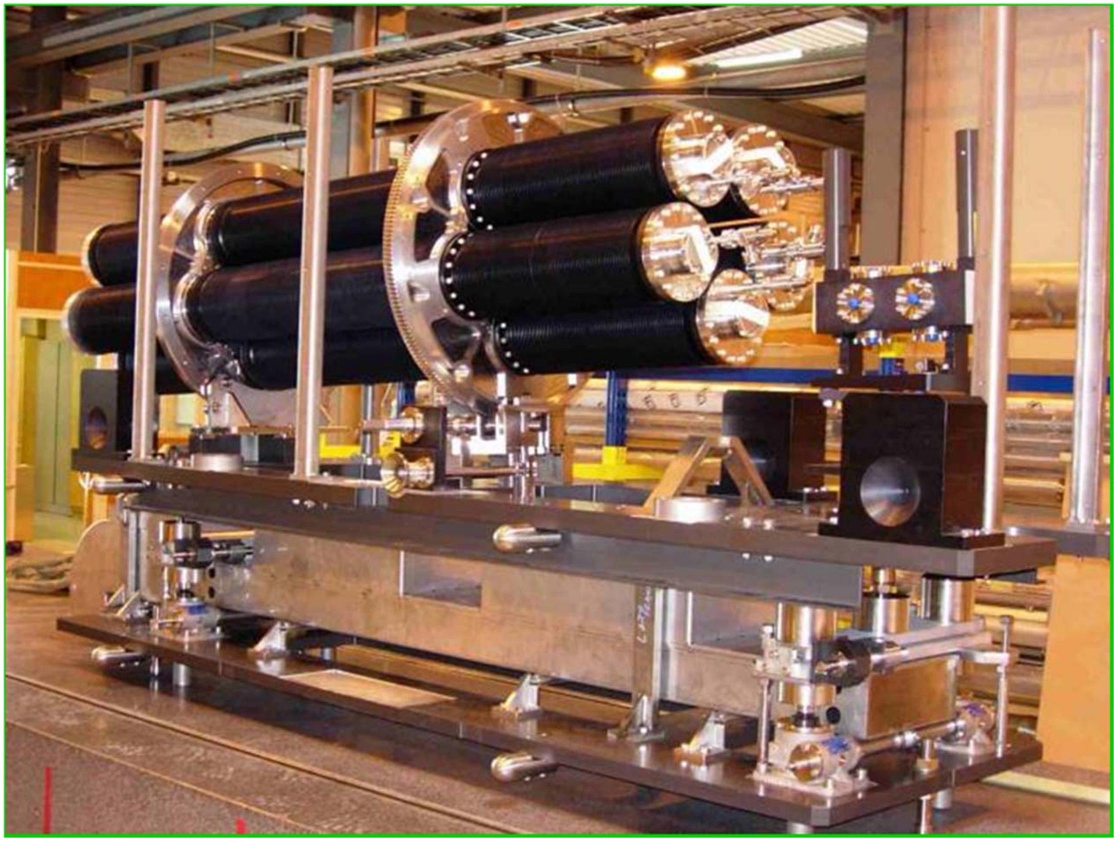
High Radiation Environment

- Remote Handling
- Radiation-induced damage

Pulsed Operation

- Thermal Management
- Thermal Shock

CNGS – M. Calviani

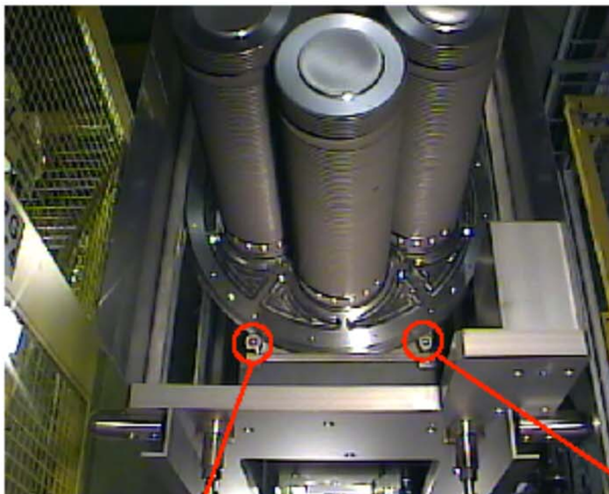


Maximum Beam Power to date 510kW

Unexpected teething problems: CNGS

Target motorization failure

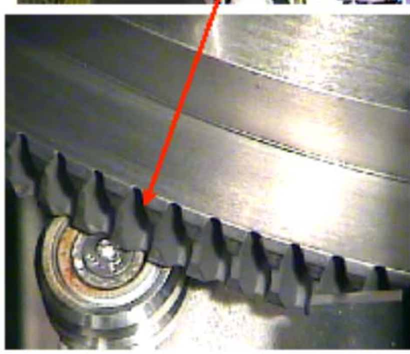
33 In-situ inspection (April 8-9, 2008)

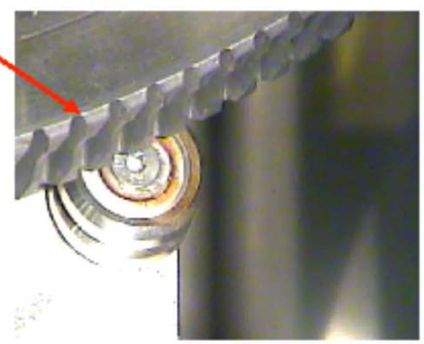


Summary of observations:

- all four ball-bearings have signs of rust
- 3 turn when the barrel moves but with difficulty
- 1 doesn't turn at all in one direction (at least at startup)

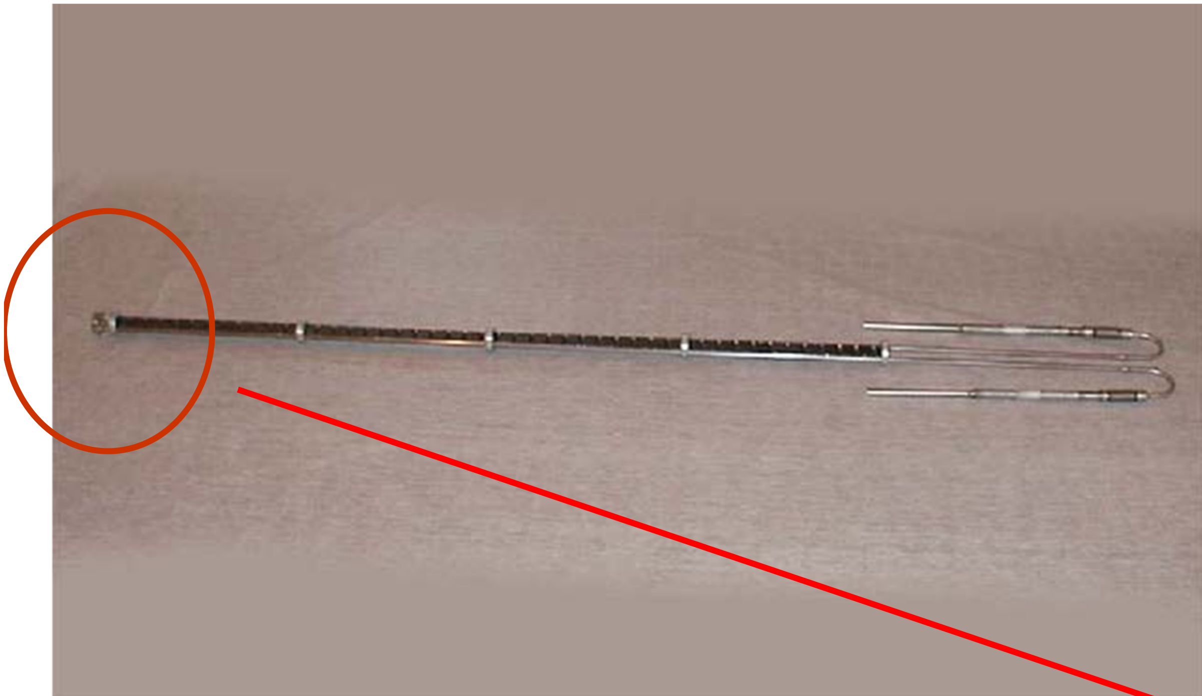
- Discussing again with the supplier we discovered that contrary to the specifications, the pieces delivered were treated with a lubricant (YVAC3) thought to be radiation hard

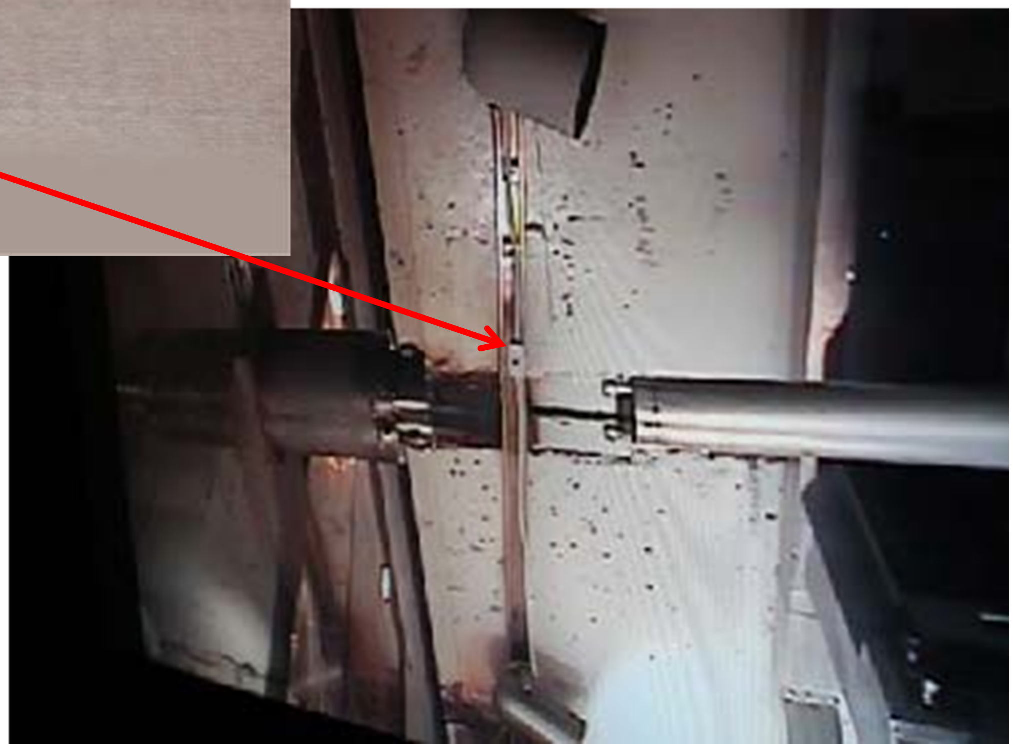




I.Efthymiopoulos, CERN, NBI2010

NUMI – J. Hylen





Maximum Beam Power 375KW

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T2K – M. Rooney

Designed for 750kW

Operated up to 135kW

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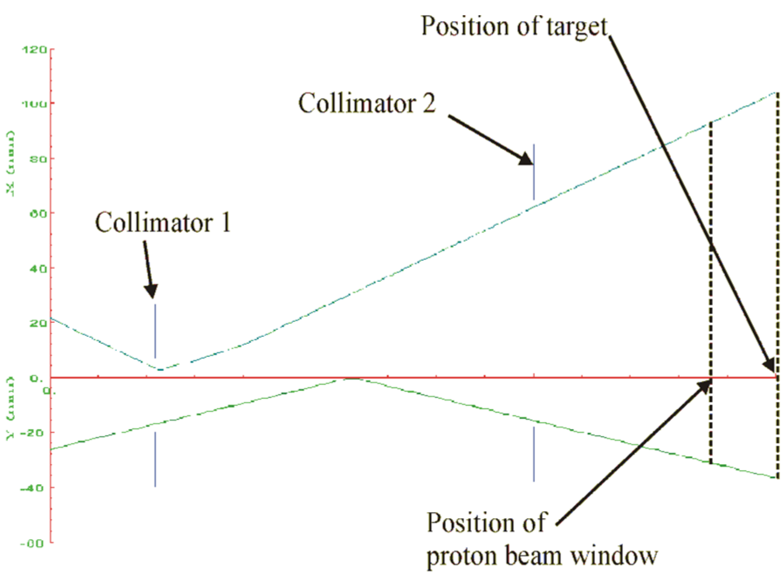
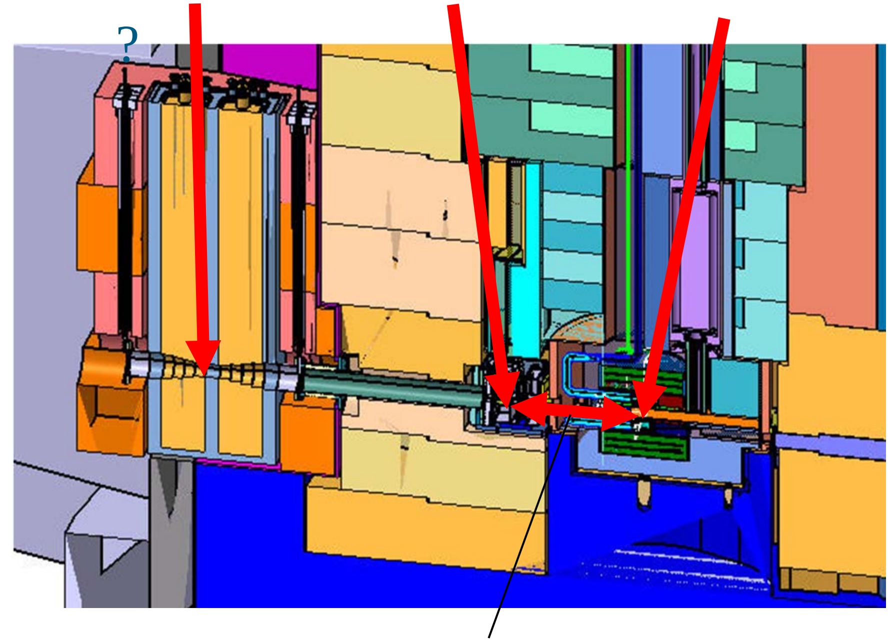
The Proton Beam Window in the ESS Target Station



Beam Envelope ESS 2003 LP

Collimator PBW Target

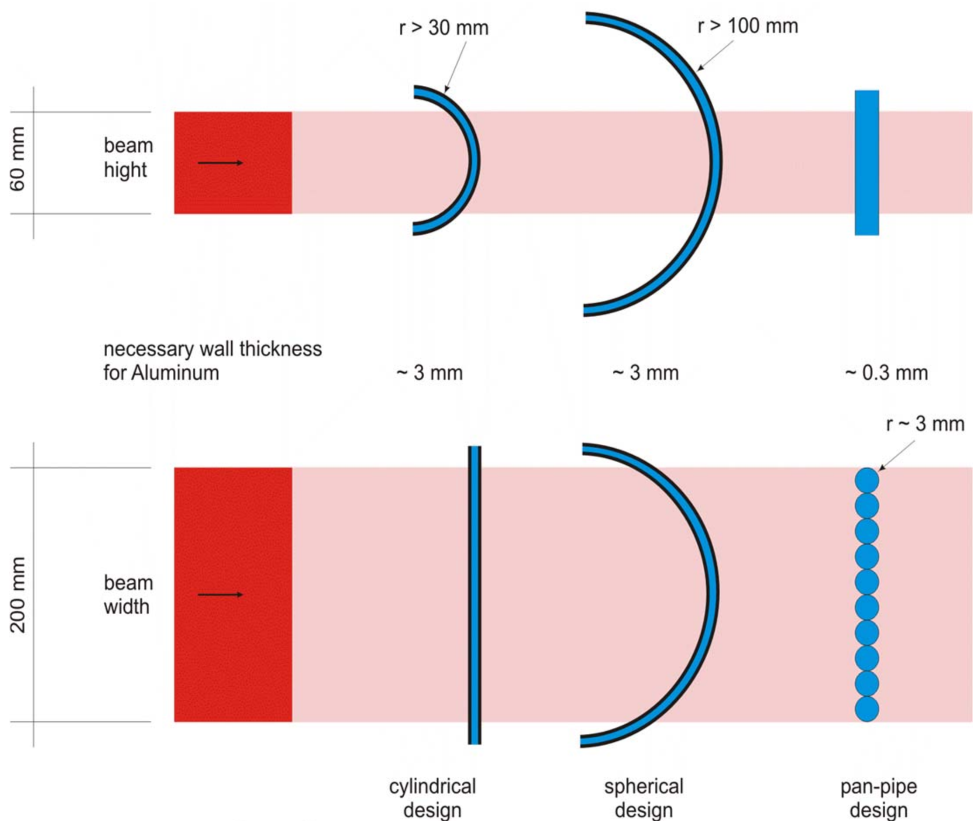


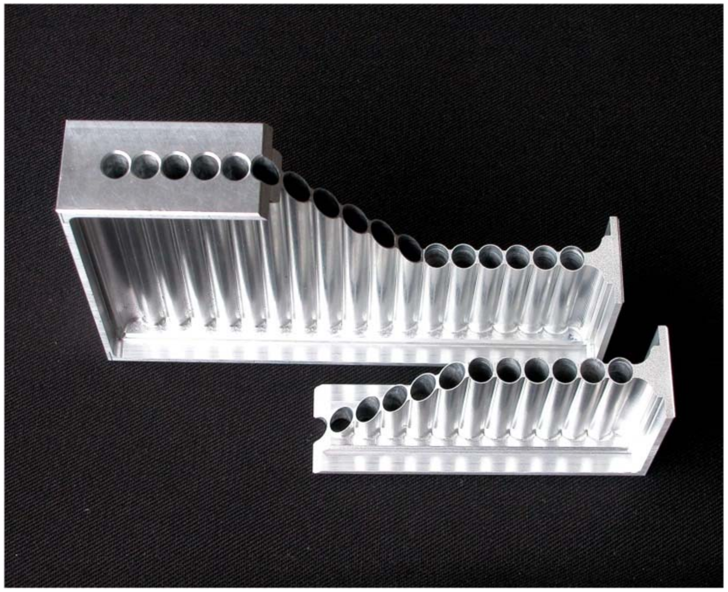
~ 1.5 m

2011 ESS design approach for rotating Target

Design principle of the PBW

Reduce wall thickness by reducing radius to minimize heat deposited in window





proof of manufacturing sample

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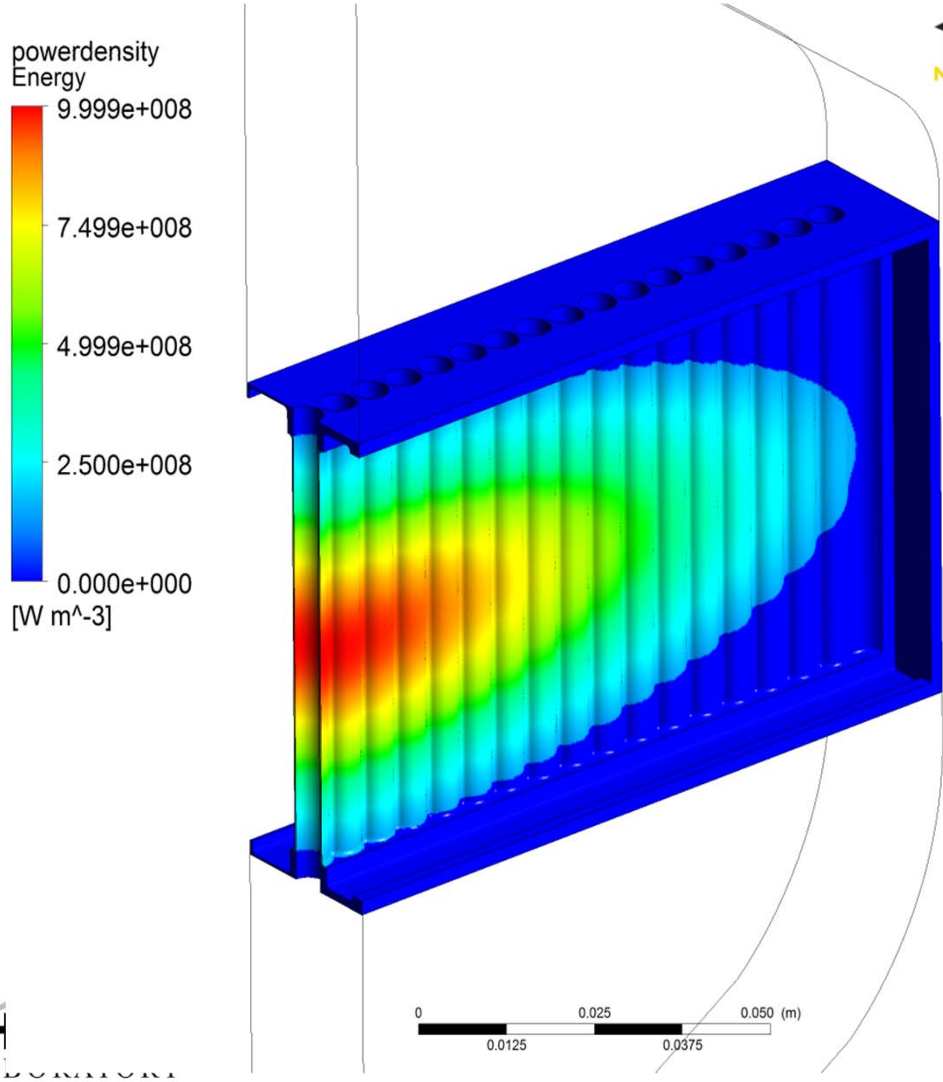
Heat load used for Calculation

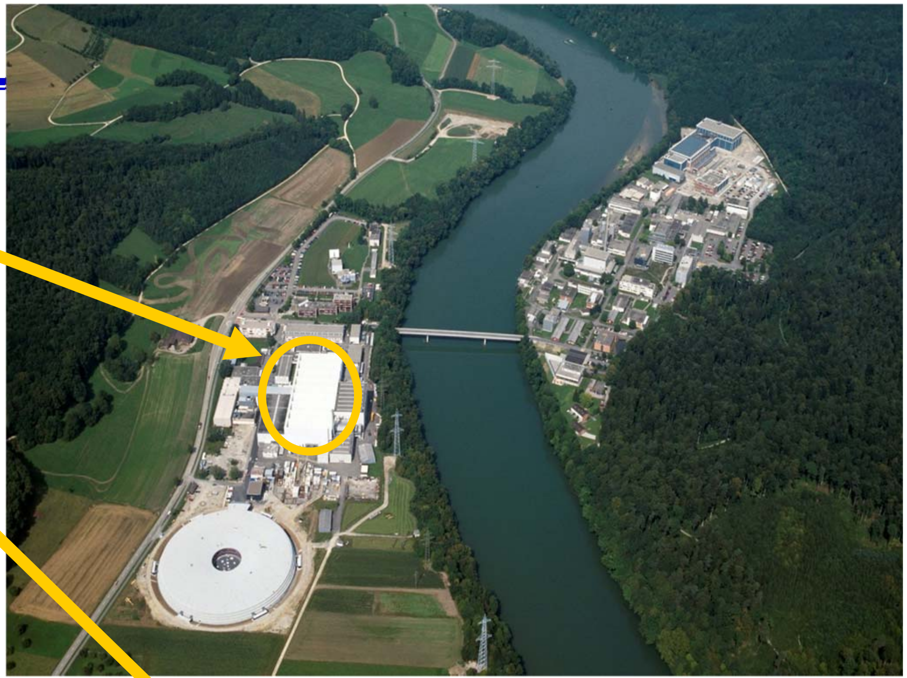


Gaussian profile
$\kappa_\sigma=2$, $P_0 = 1kW/cm^3$
($\pm 2 \cdot \sigma$ within beam footprint)

Al 6061 – T6

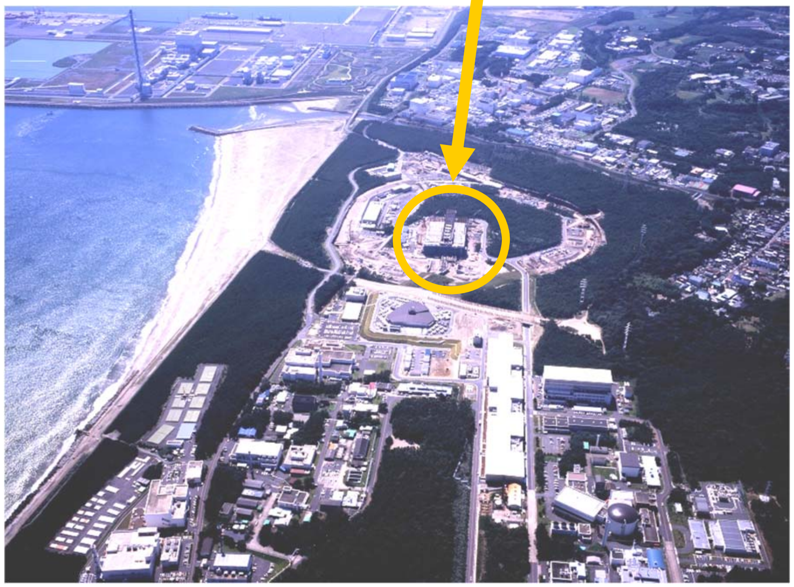
MW-Class Spallation Targets

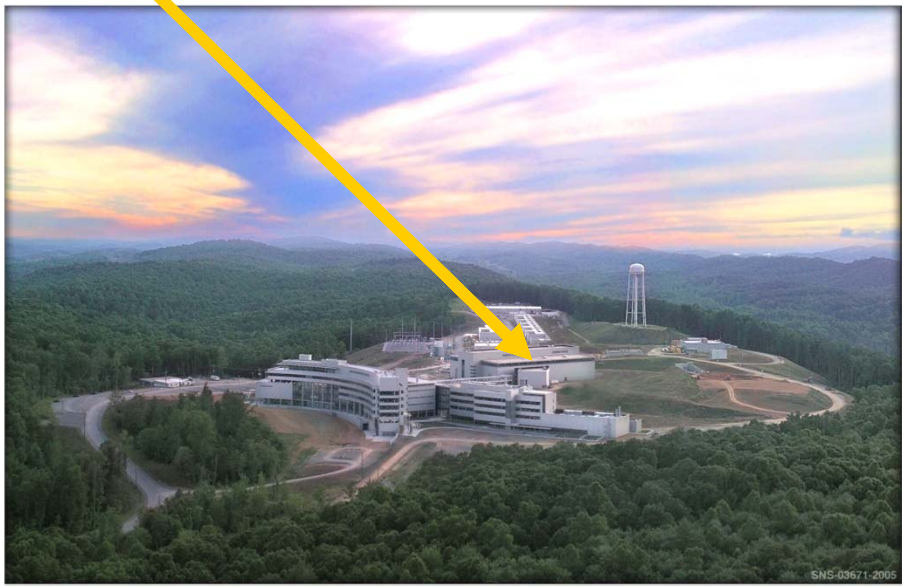
SINQ at the Paul Scherrer Institut (PSI)



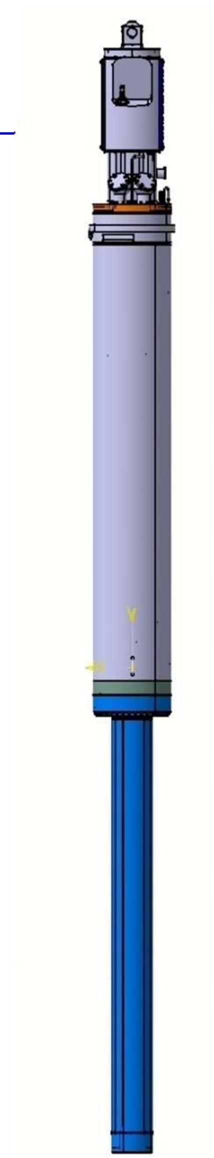
SNS at the Oak Ridge National Laboratory (ORNL)

JSNS at the Japan Atomic Energy Agency (JAEA)





MEGAPIE
A liquid metal target for SINQ

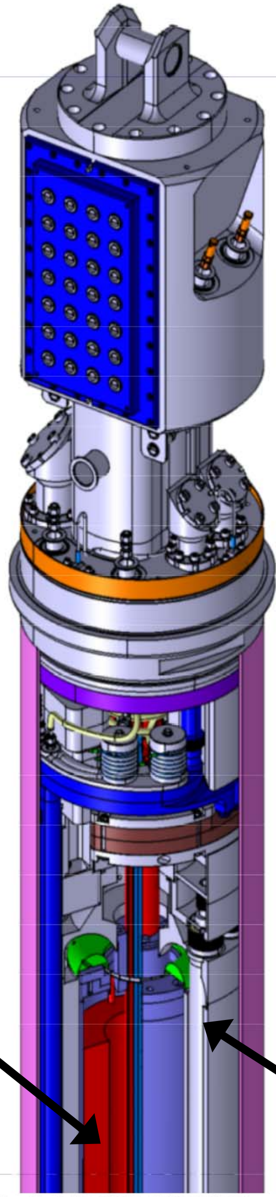


MEGAwatt Pilot Experiment:

- **Lead-Bismuth-Eutectic (LBE, T_m=125°C)**
- **Increase the neutron flux at SINQ**
- **Demonstrate the feasibility of a liquid metal target for high-power spallation and ADS applications**

MEGAPIE (Pb-Bi) Target Features

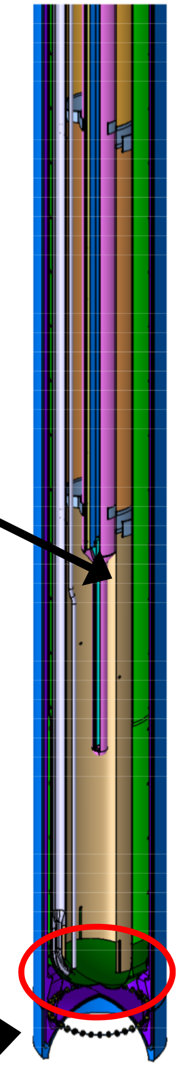
target head



electro-magnetic pumps

heat exchanger

central flow guide tube



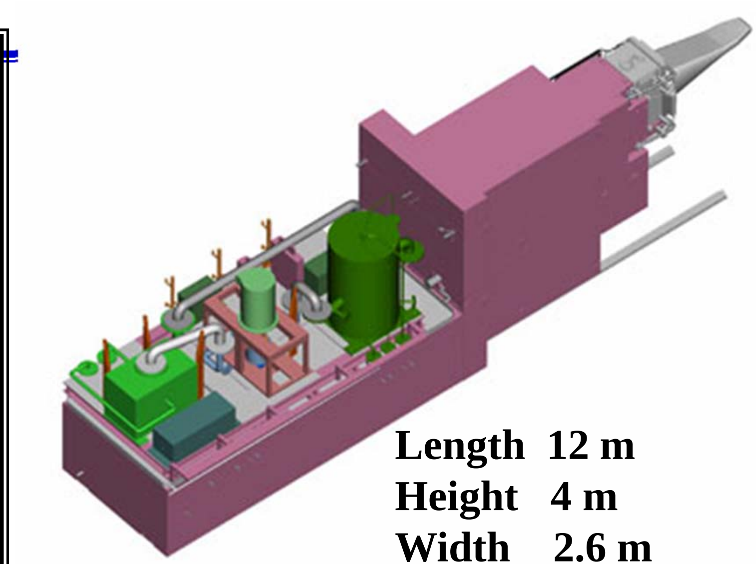
safety hull

lower target assembly

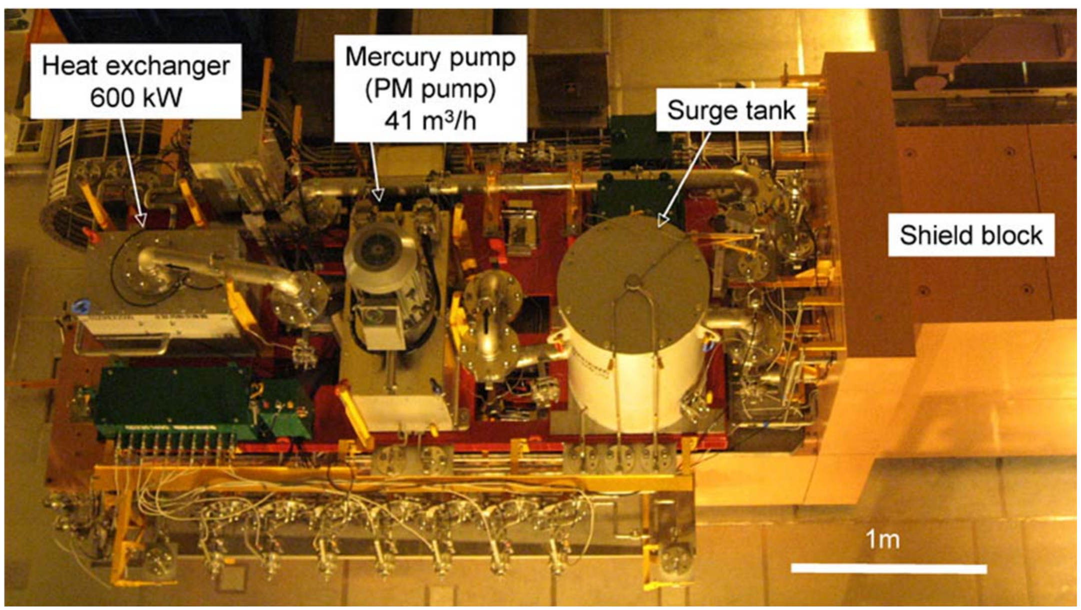
beam window

JSNS Hg Target

- **Proton Beam (design parameters):**
  - **3 GeV, 25 Hz rep rate, 0.33 mA ⇒ 1 MW**
- **Hg Target:**
  - **Cross-flow type, with multi wall vessel**
  - **Hg leak detectors between walls**
  - **All components of circulation system on trolley**
  - **Hot cell : Hands-on maintenance**
  - **Vibration measuring system to diagnose pressure wave effects**

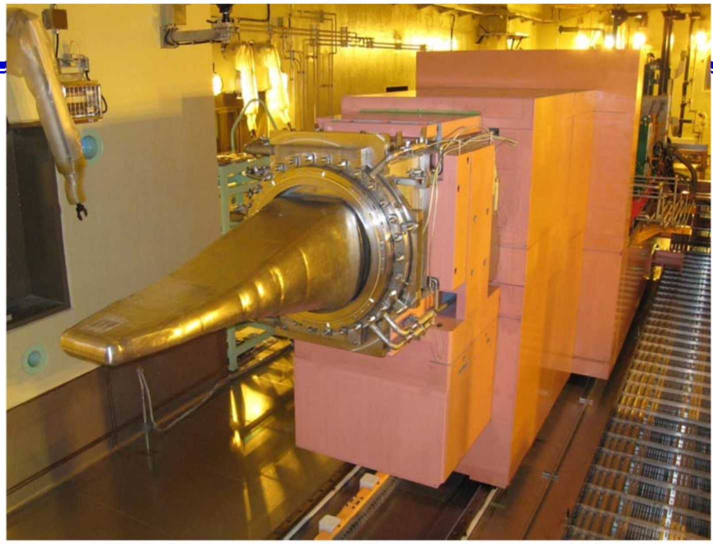


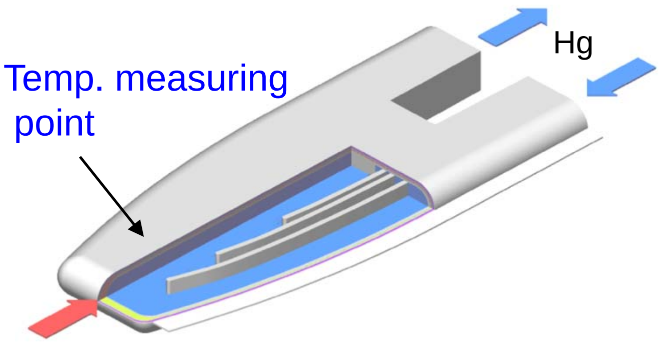
Length 12 m
Height 4 m
Width 2.6 m
Weight 315 ton

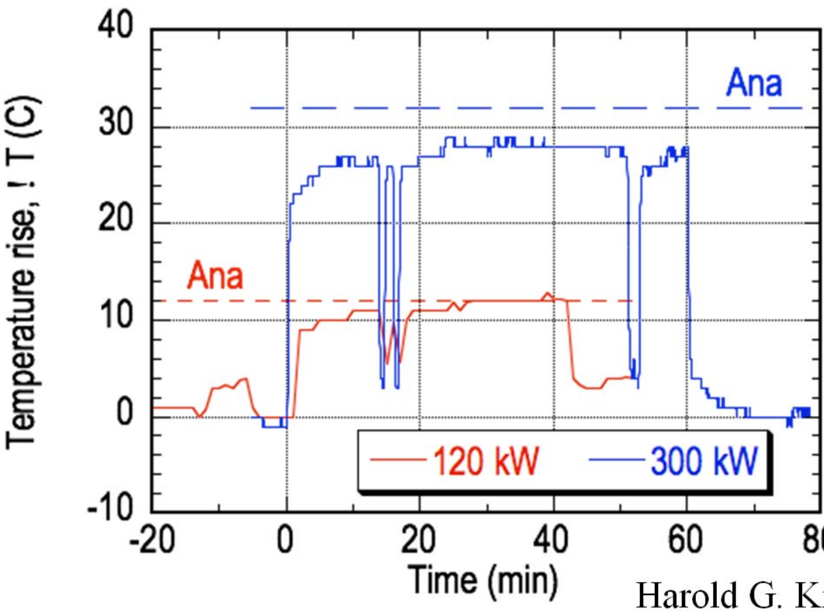


target system design

- **Temperature rise of mercury vessel for 120 kW & 300 kW beam power agreed with estimates**
  - **Confirmed operation of the mercury circulation system ; EM pump, heat exchanger, etc.**







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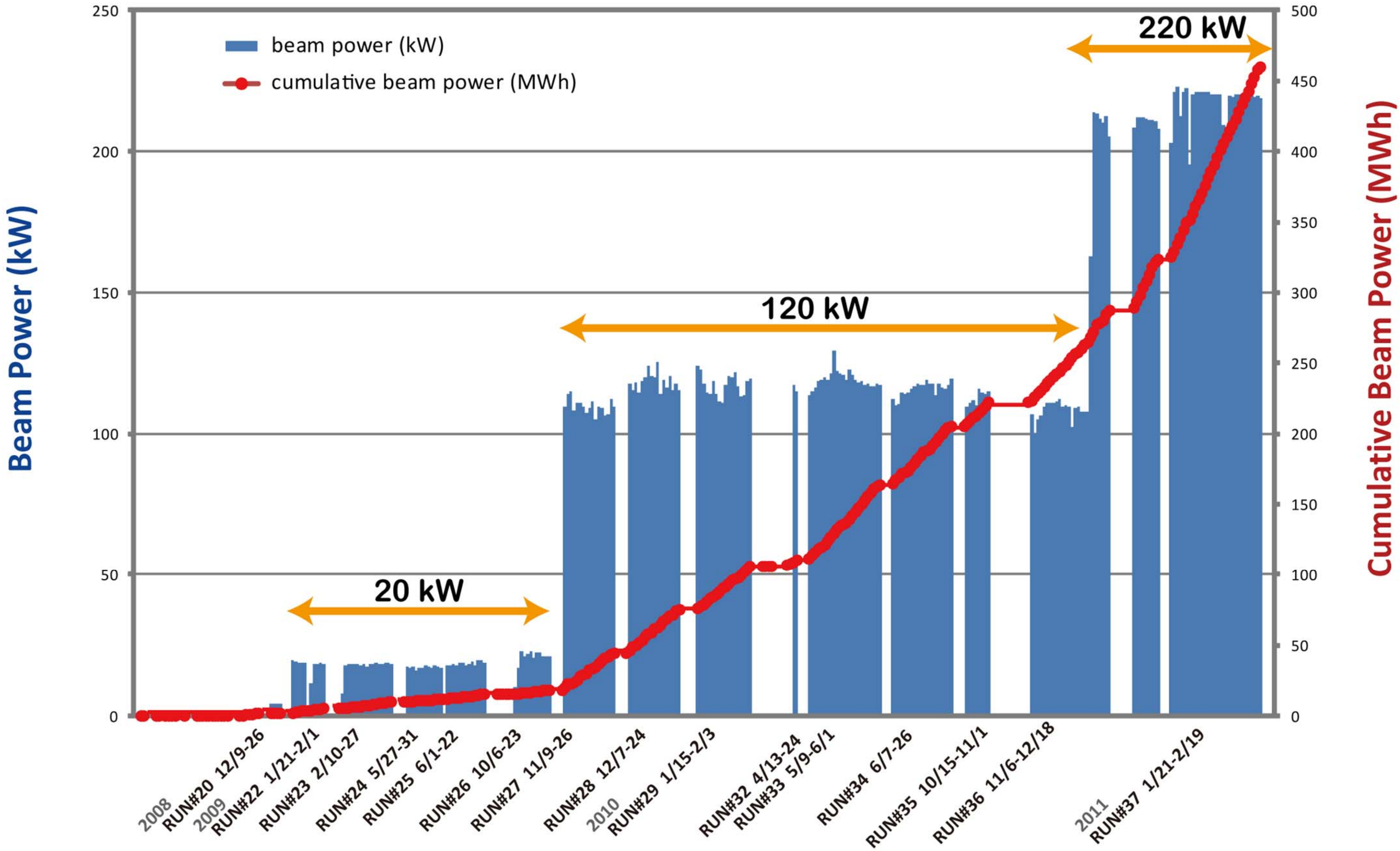
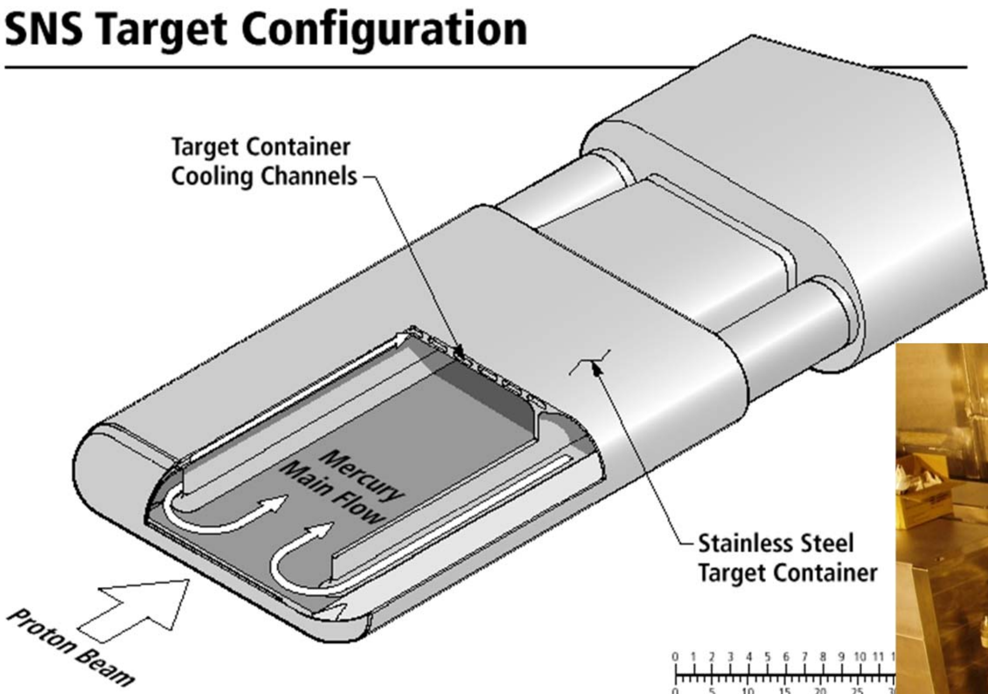
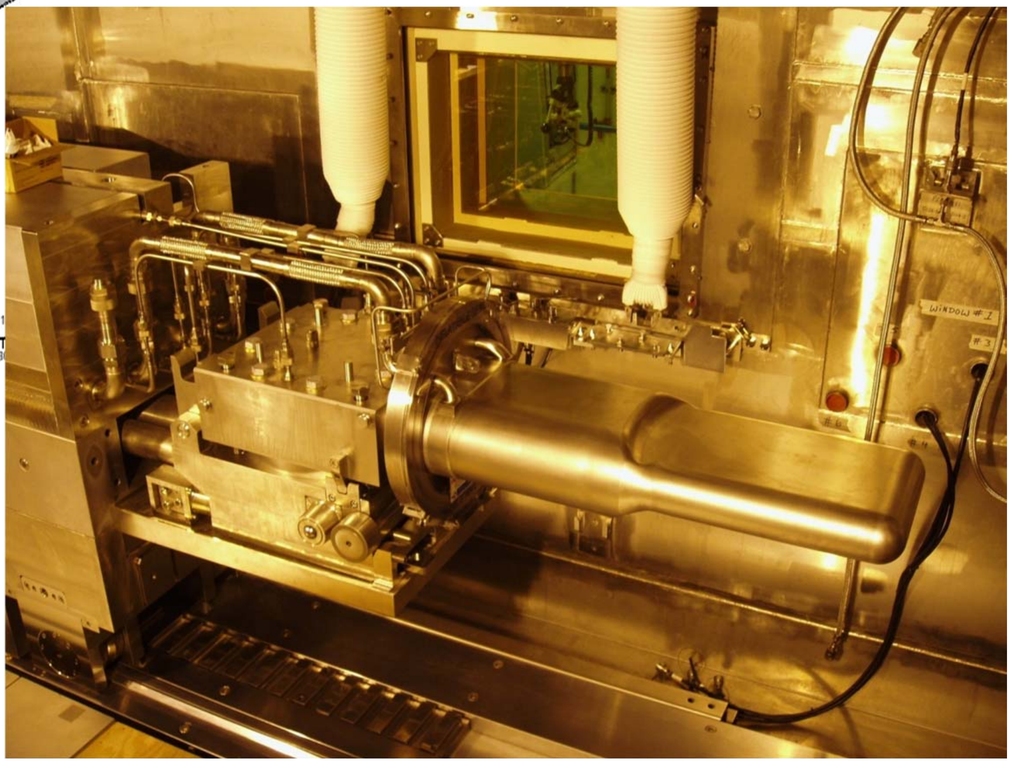
Beam power on JSNS target



SNS Mercury Target

SNS Ultimate Parameters
- 1 GeV protons
- 2 MW average beam power
- Pulse duration ~ 0.7 μs
- 60 Hz rep rate





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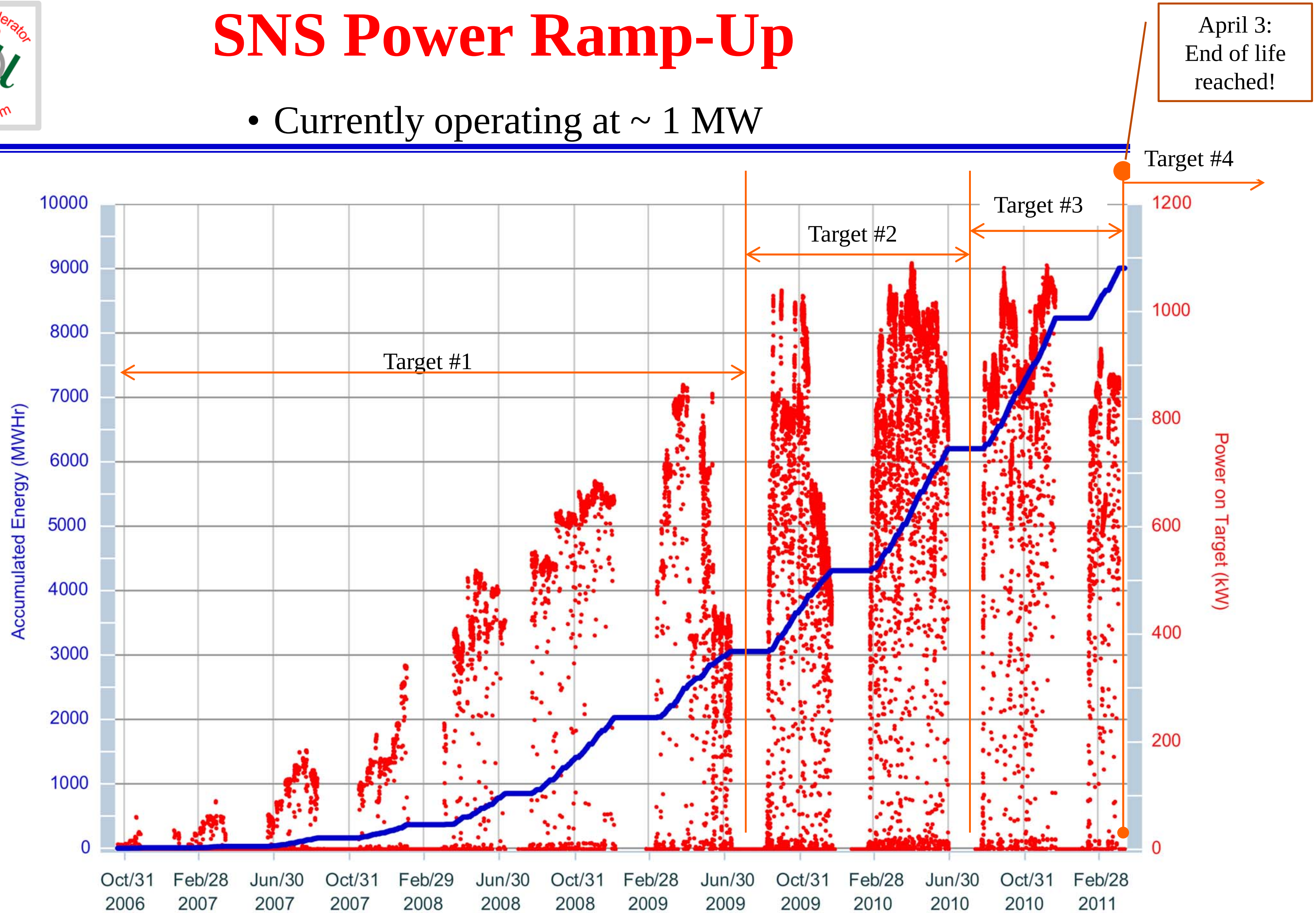
SNS Power Ramp-Up

- Currently operating at ~ 1 MW



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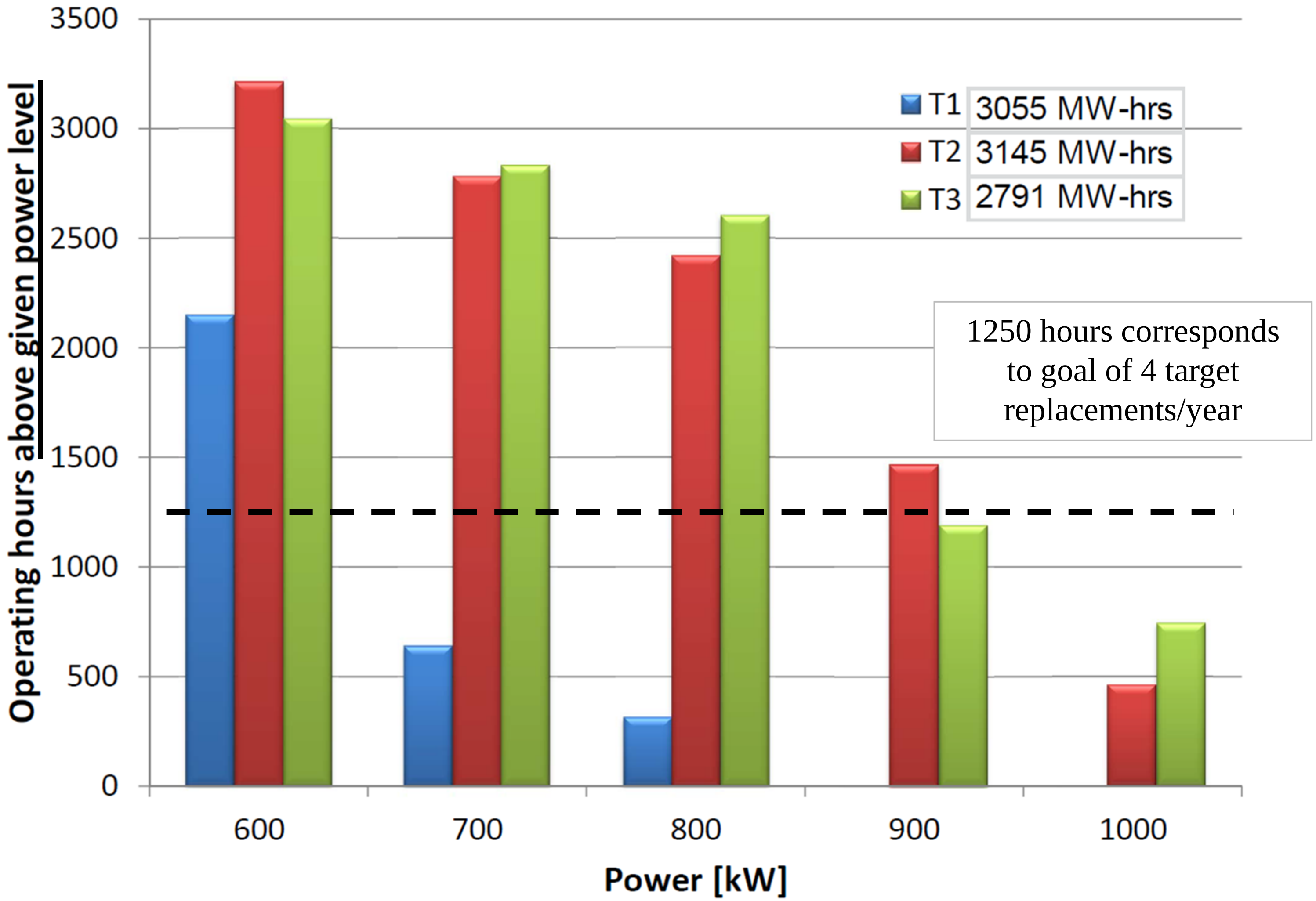
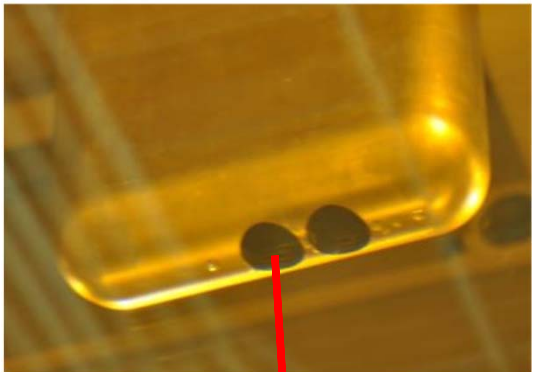
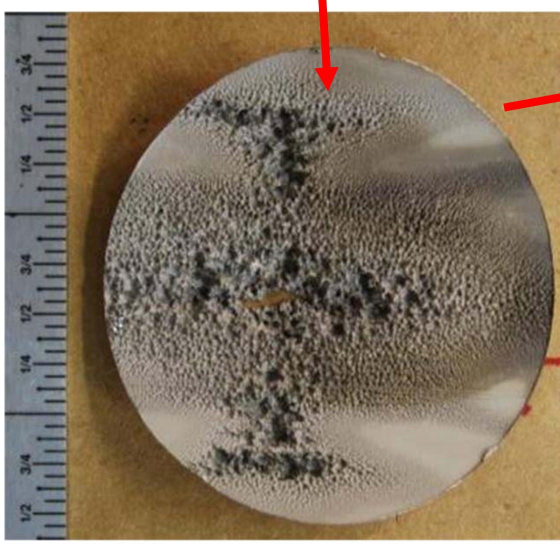
Mercury target module lifetime remains uncertain



Demonstrated power limit is now > 900 kW

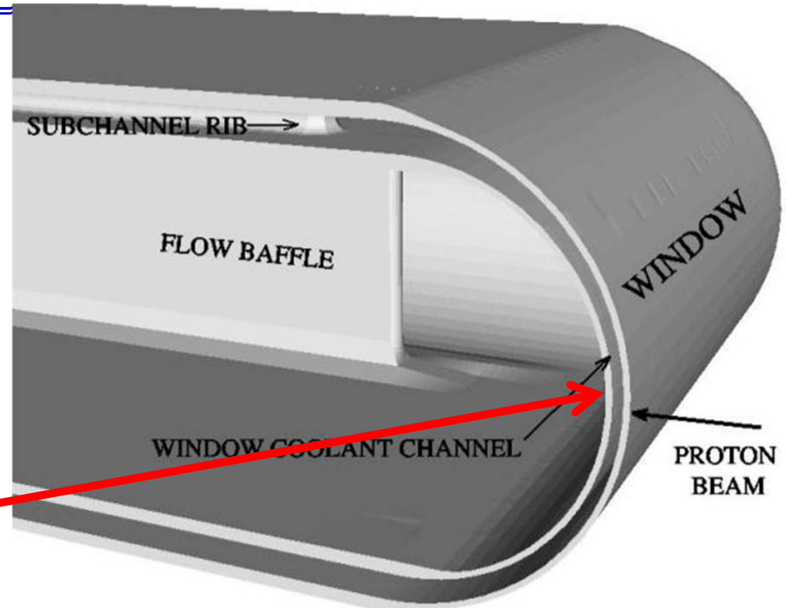
Results of Post-Irradiation Examination of Hg Target Module #1





60 mm

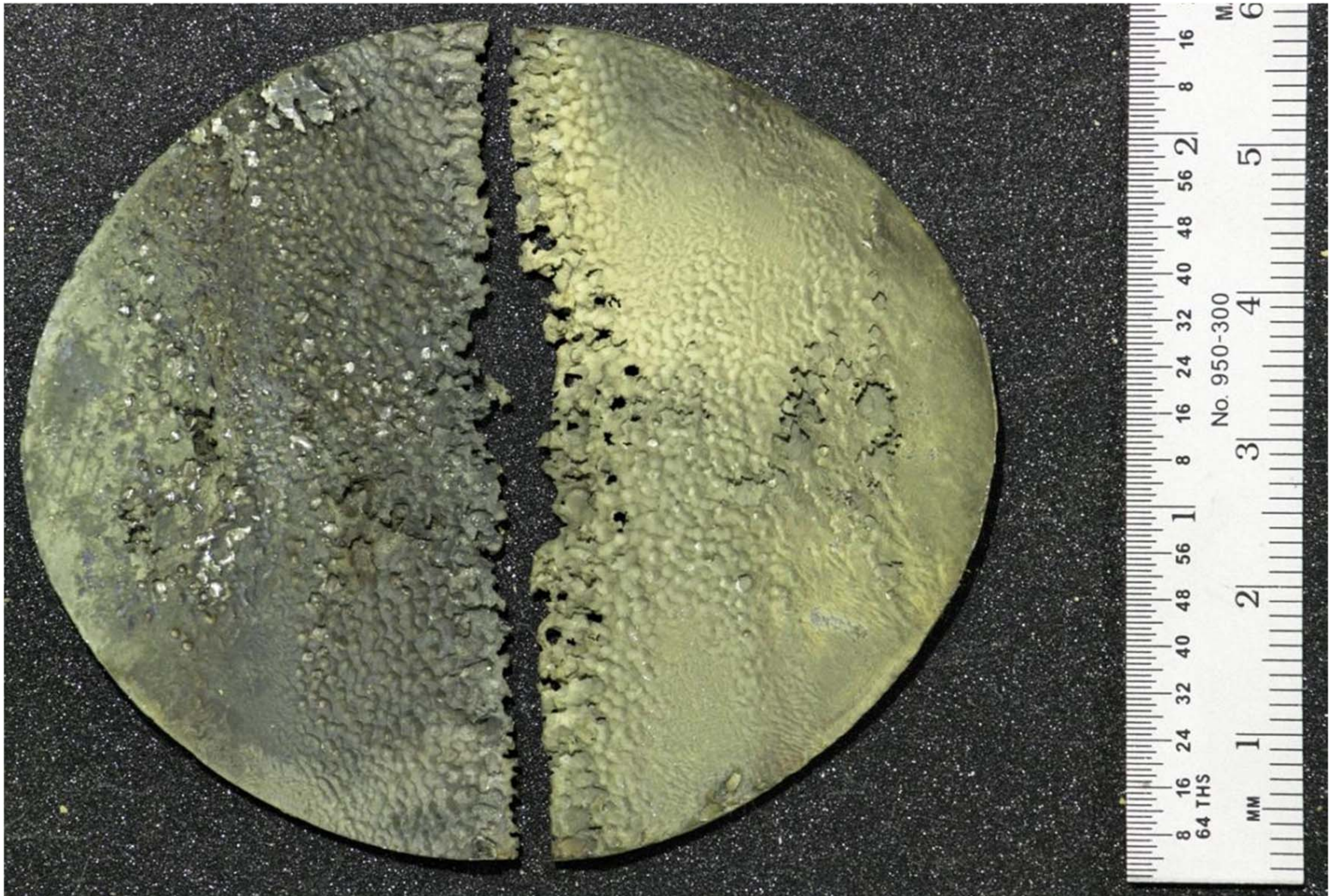
Inner surface of wall between bulk Hg and



- Target #1:
  - Cavitation damage phenomenon confirmed on inner wall at center of target
  - Outer wall fully intact; inner wall at off-center location shows little or no damage
  - Damage region appears to correlate with regions of low Hg velocity, but not such a clear distinction on Target #2

Target #2 survived through planned operating period but inner wall suffered more damage

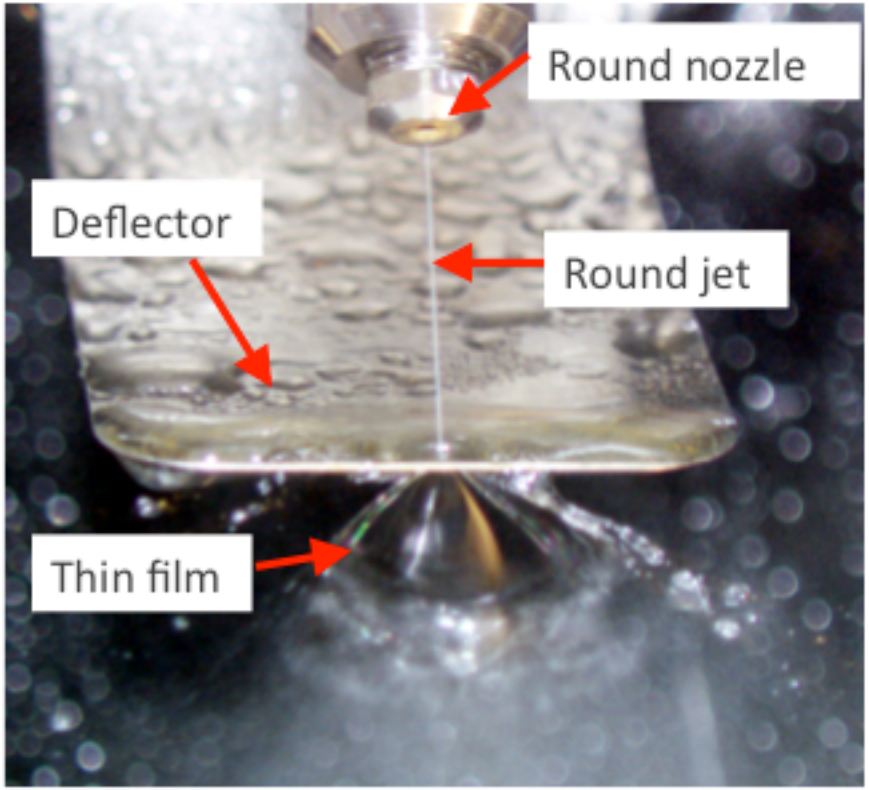
Horizontal operating orientation

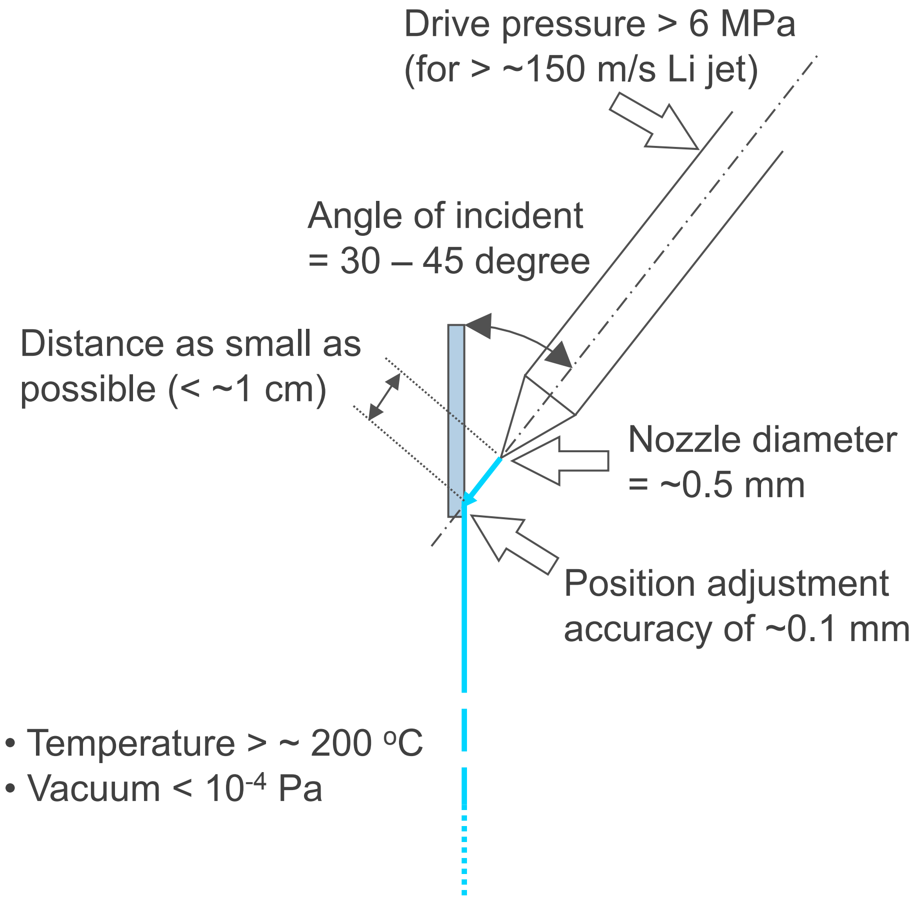


Bulk Hg Flow Surface - UNCLEANED

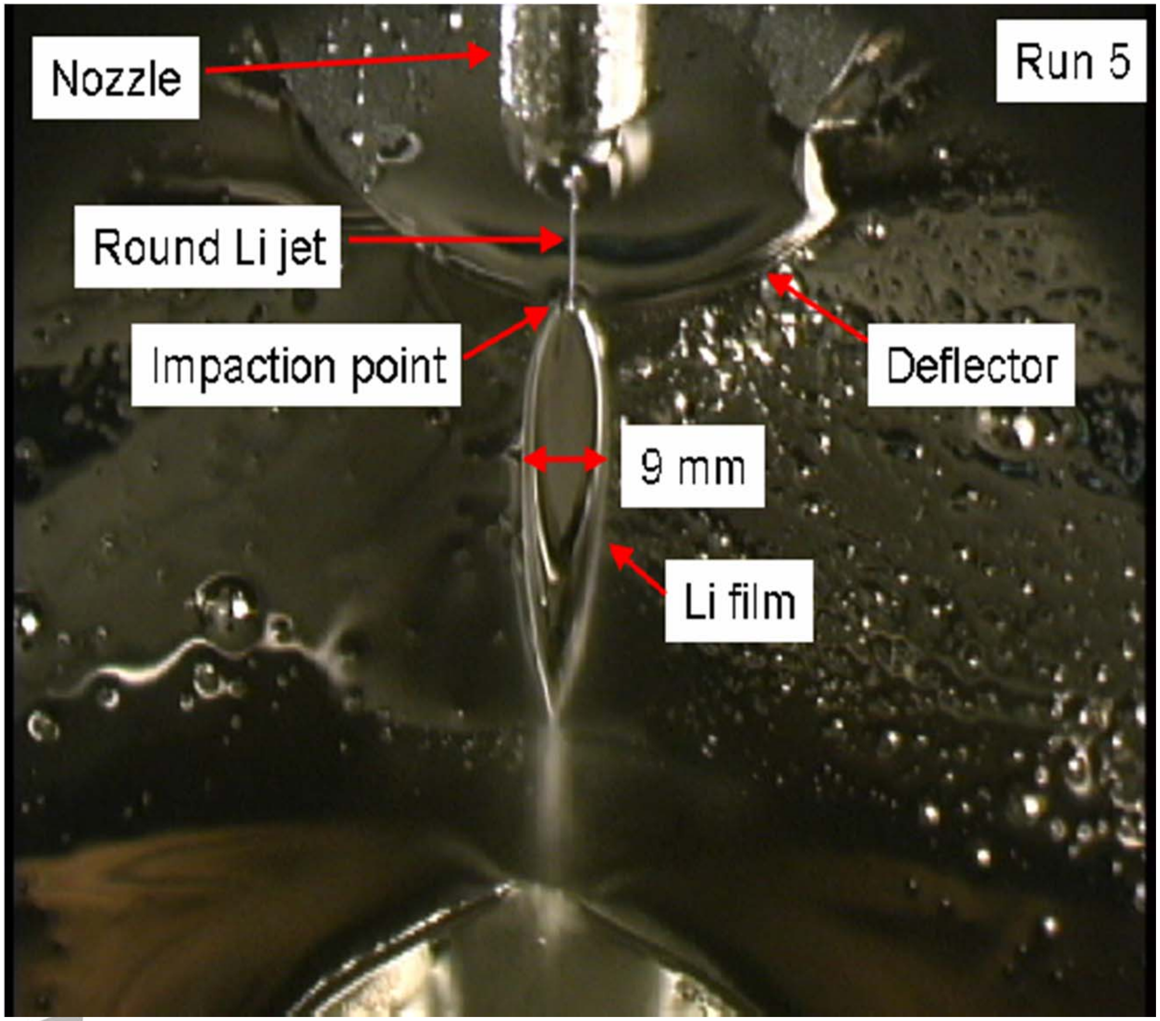
Thin film formation scheme & parameters

- Critical design parameters
  - Determined based on these 1st and 2nd phase experiments.



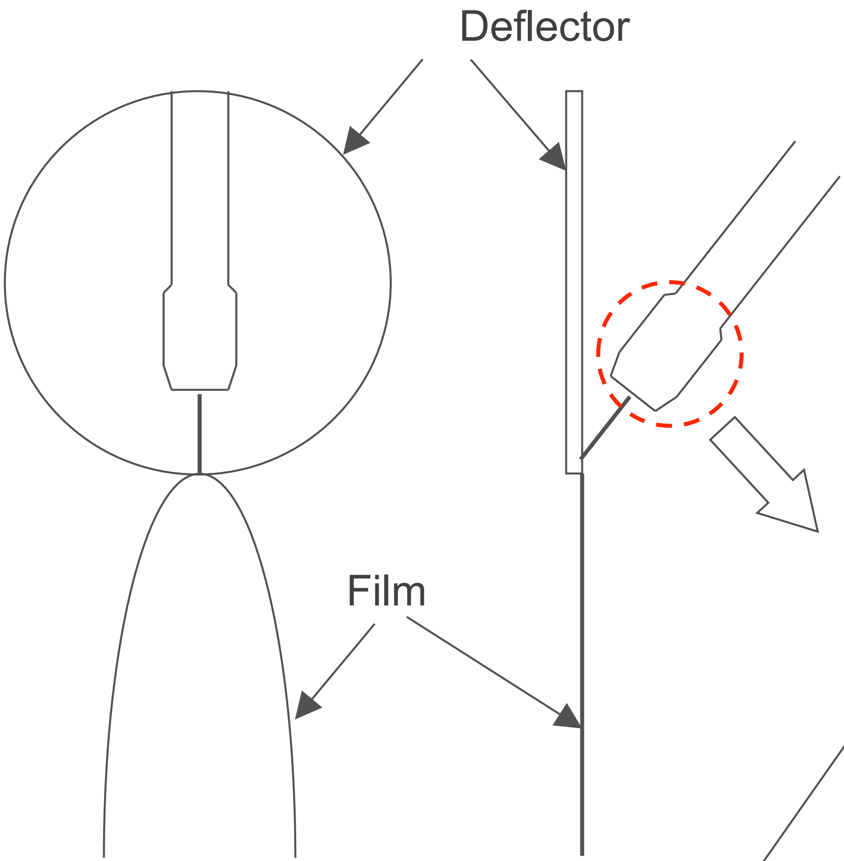


Producing the Li Film

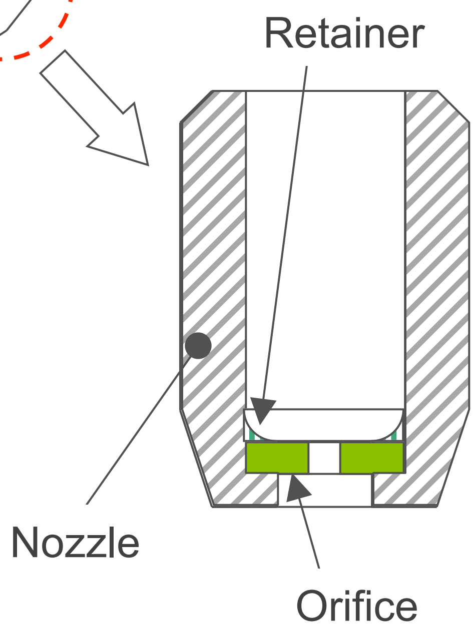


Film formation issues

- 3 fundamental issues

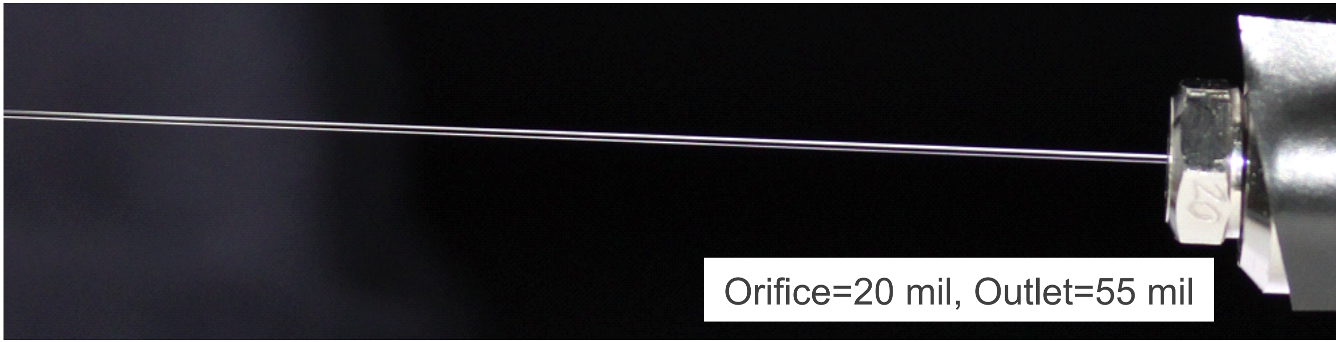


1. Effects of nozzle inlet and outlet design
2. Orifice design, material, and finish
3. Deflector design and finish

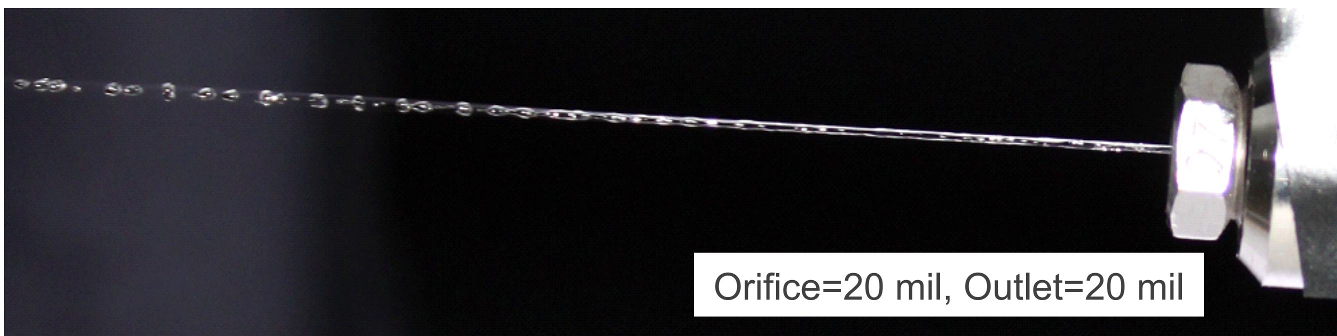


Nozzle development

- Effects of nozzle inlet and outlet design



20 mil Al_2O_3
File:100-265

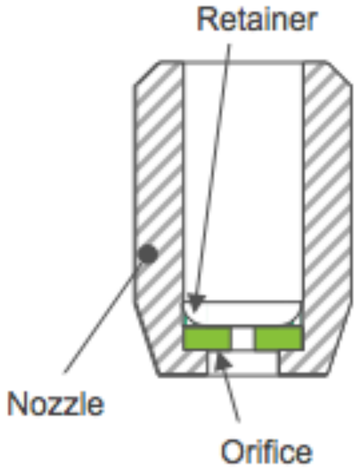


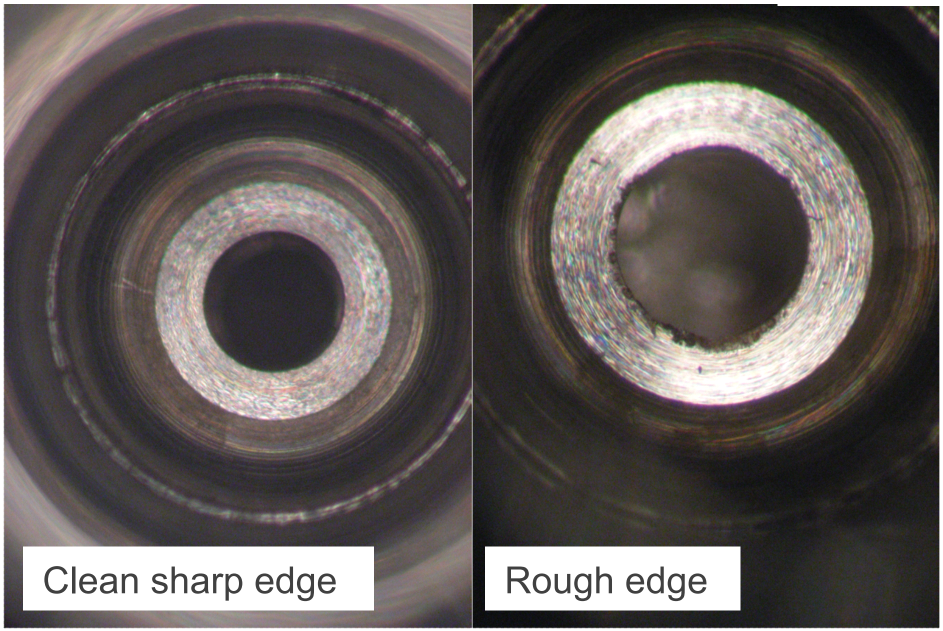
20 mil SS
File:100-275

Nozzle development

- Orifice design, material, and finish

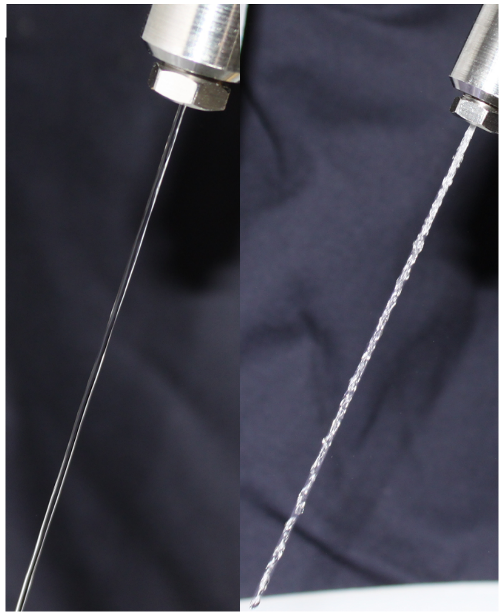
1. Well defined orifice
2. Stainless steel, orifice
3. Three-piece design





40-40 mil SS X

40-40 mil SS (2)

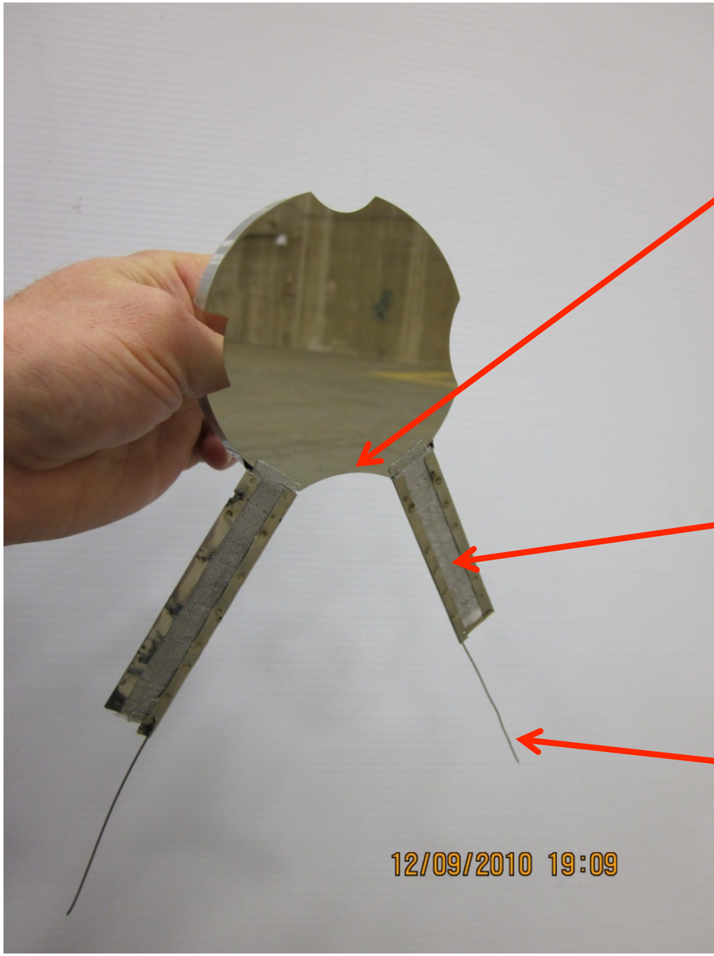


20 psi

40-40 mil SS X
File:100-452

40-40 mil SS (2)
File:100-528

4-Profile Deflector With Wicks

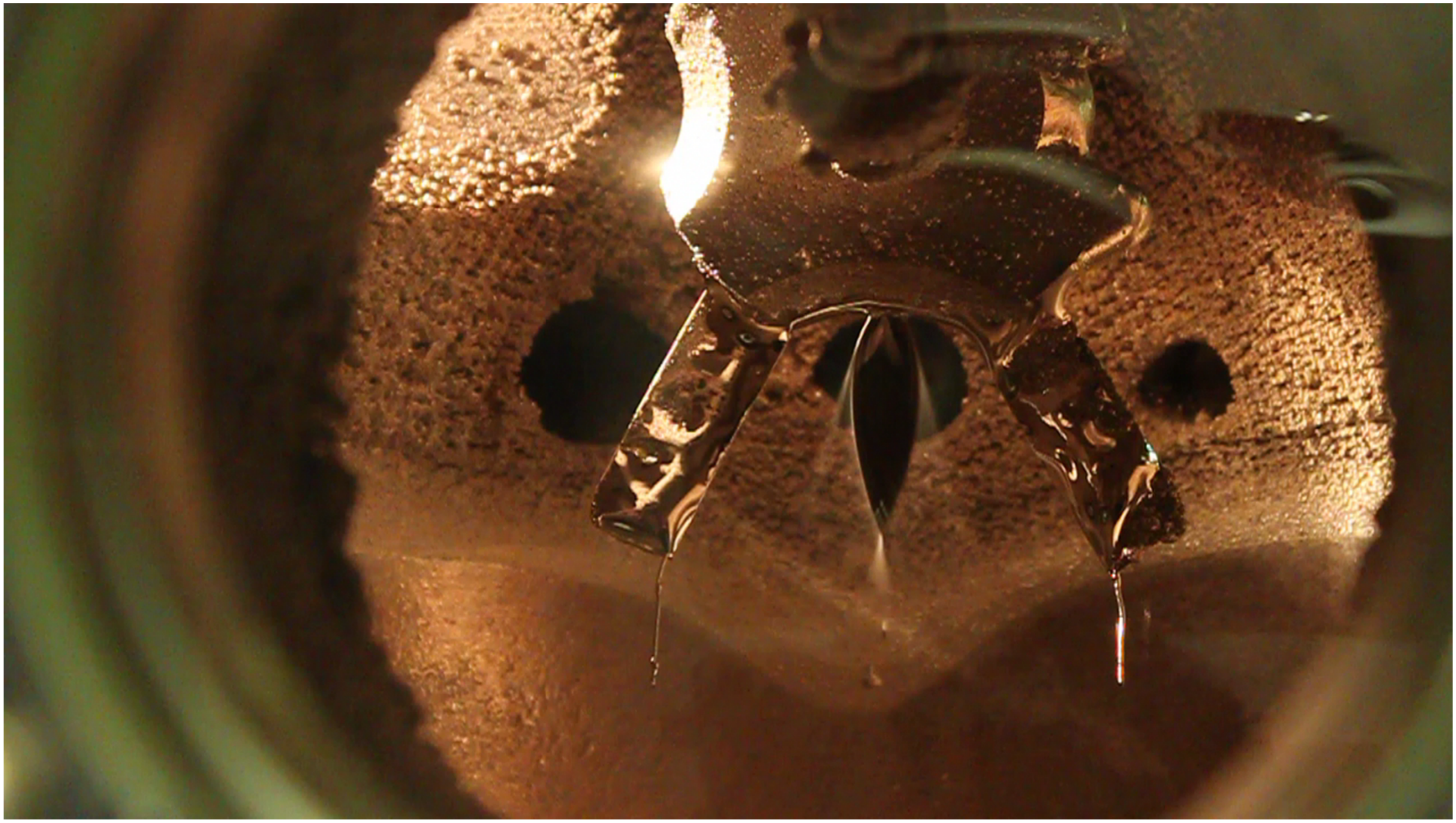


1 µ diamond polish on face and both sides of knife edge

Stainless steel mesh wicking to "pull" Li from deflector face and reduce puddling

Stainless steel wire to guide Li droplets down and away from film

The Stabilized Li Film



ITER Conductor– Harald Weber

Irradiation Effects on ITER Conductors

- Superconductors
  - NbTi
  - Nb_3Sn
- Stabilizers
- Insulation

INSULATION

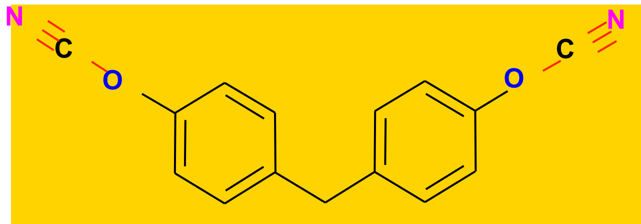
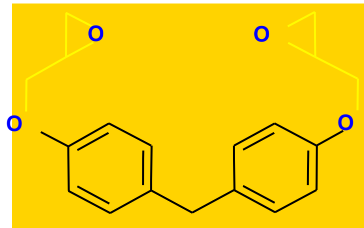
Most critical component of the magnet in a radiation environment

Has to provide **electrical insulation** **(✓)**

Has to provide **mechanical strength** and to withstand thermal contraction / expansion and Lorentz forces

Must be suitable for a vacuum-pressure impregnation process – "pot life"

CE / epoxy blend

	AroCy L-10 	PY 306 
Safety precautions	Avoid local overheating (hot spots) Store in sealed containers in dry rooms Provide sufficient air exchange Take necessary actions to avoid static electricity	Provide sufficient air exchange Take necessary actions to avoid static electricity Avoid strong acids and bases
Viscosity	$\eta_{25\ °C}$ = 120 mPa s $\eta_{60\ °C}$ = 17 mPa s	$\eta_{25\ °C}$ = 1200-1600 mPa s
Pot life at high quantities	Dependent upon type and concentration of co-catalyst and catalyst used	Can be handled

SUMMARY and CONCLUSIONS

- LT Superconductors: No problems regarding radiation effects expected for ITER
- Stabilizer: Degradation must be kept in mind
- Insulators: Excellent solution found – industrial tests completed; qualification of materials from different suppliers under way