שורק

Accelerator targets design -
The challenge of high power density

Ido Silverman

DAPNIA visit

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Layout

- SARAF
- High power targets design
- High heat flux cooling
- Examples
  - SARAF beam dump
  - LiLiT
  - Palladium target

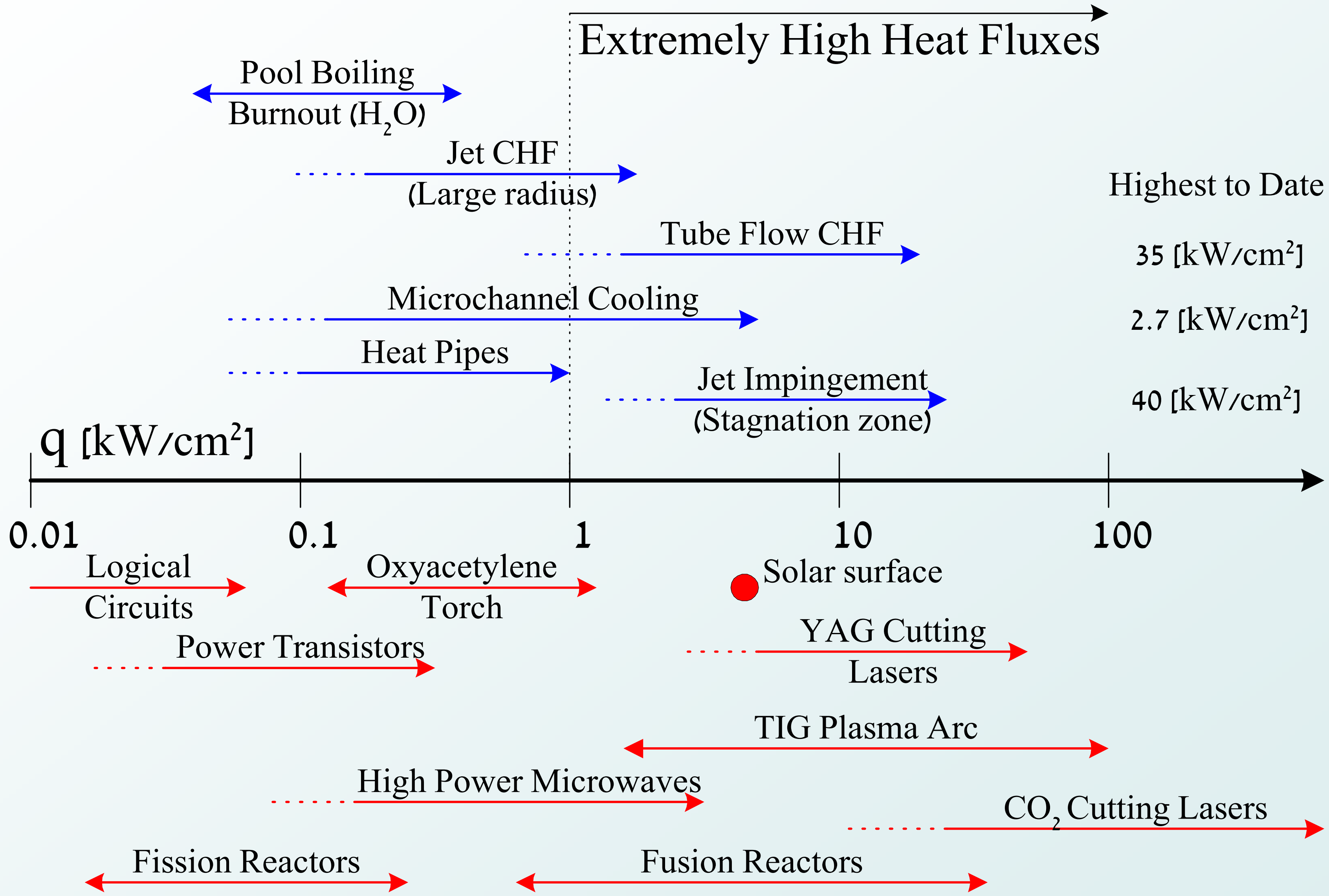
SARAF

- Nuclear research with neutrons and primary beam
- Production of radio-isotopes for medical applications

High power targets design

- Material issues (high temperature, high radiation dose)
- High heat flux
- Thermal stress
- Safety !!!

High heat flux cooling



Example – Phase A SARAF beam dump

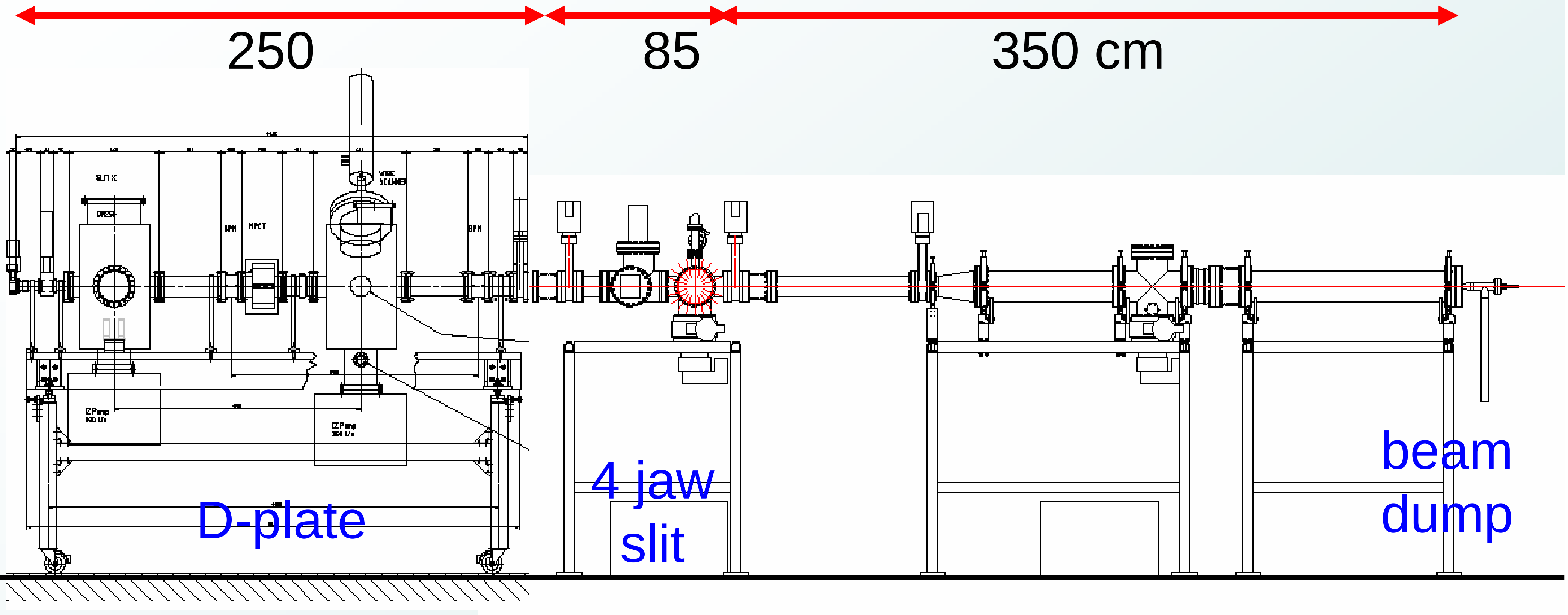
- Simple and safe solution
- No size limitation
- Long exposure time
- Very low activation limit with 100% beam loss
- 2-10 MeV protons and deuterons

SARAF beam dump - Activation

- The heat removal design of the beam dump necessitate use of material which can be machined
- This material should minimize prompt radiation and activation at beam energies of < 10 MeV

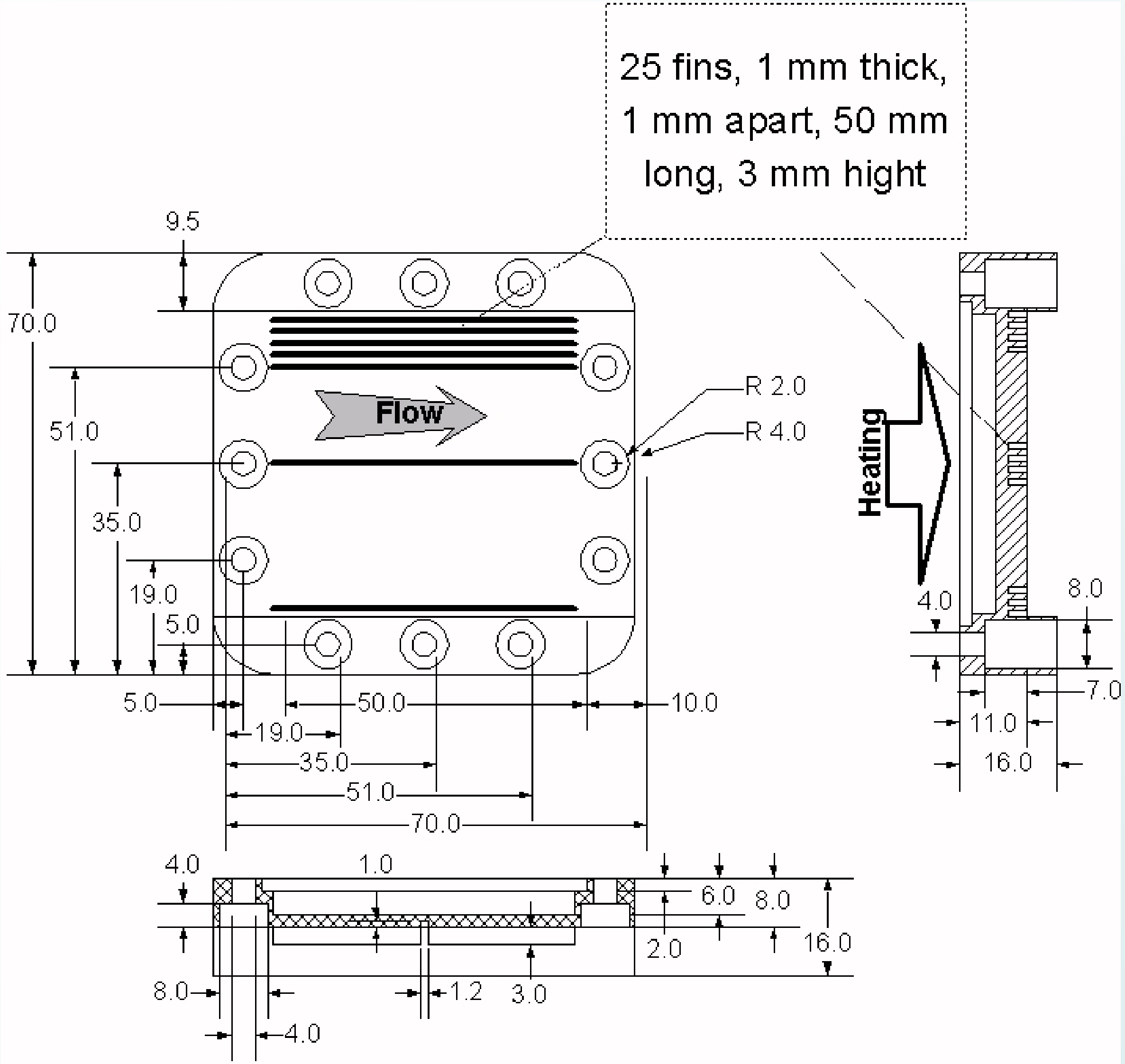
- Prototype I – heavy metal (97% W)
- Current design – Tungsten over copper backing

SARAF beam dump

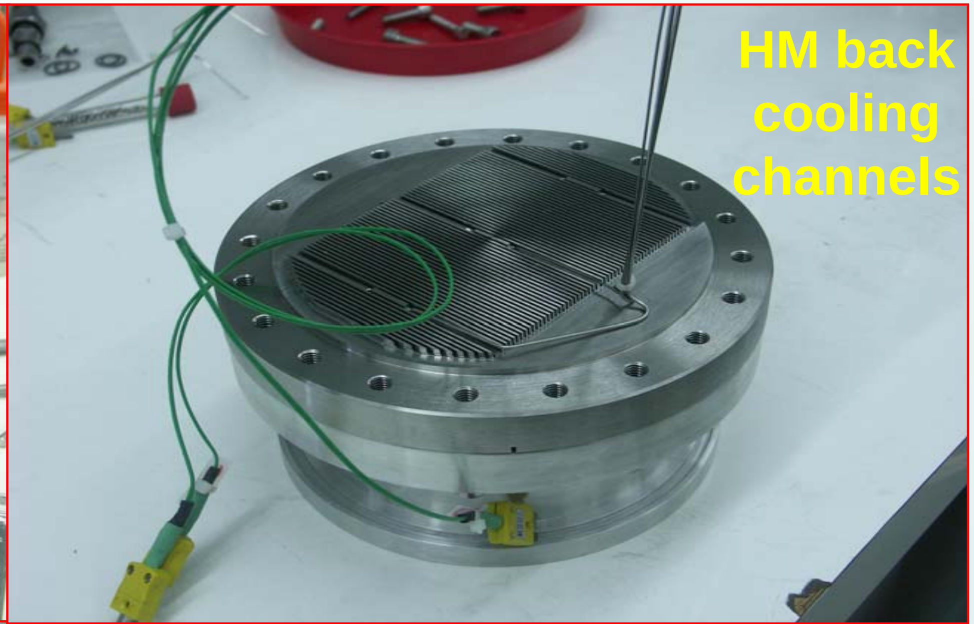


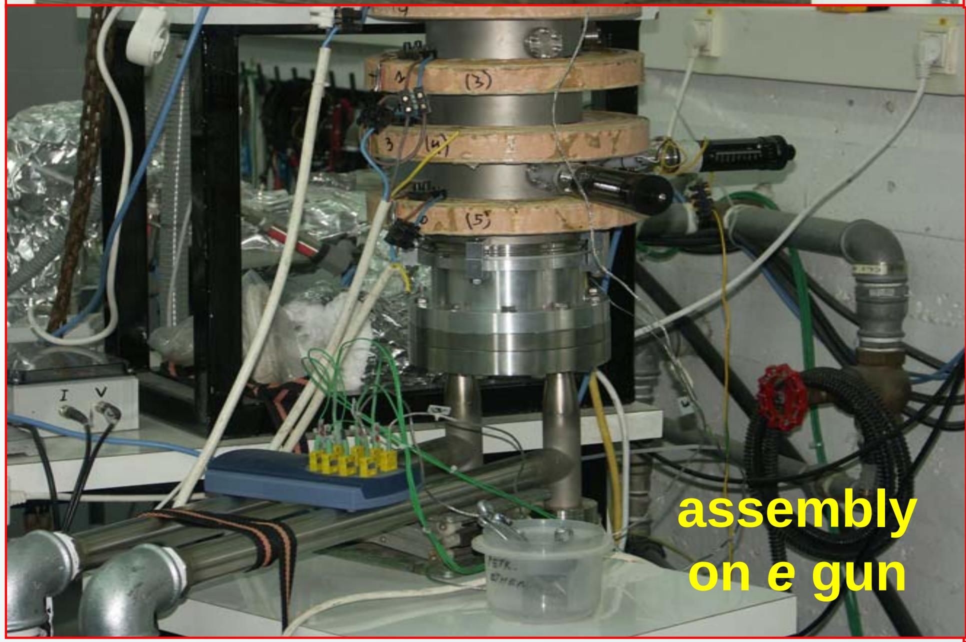
A layout of the BD arrangement. The beam enters from the left side.

Mini-channel cooling

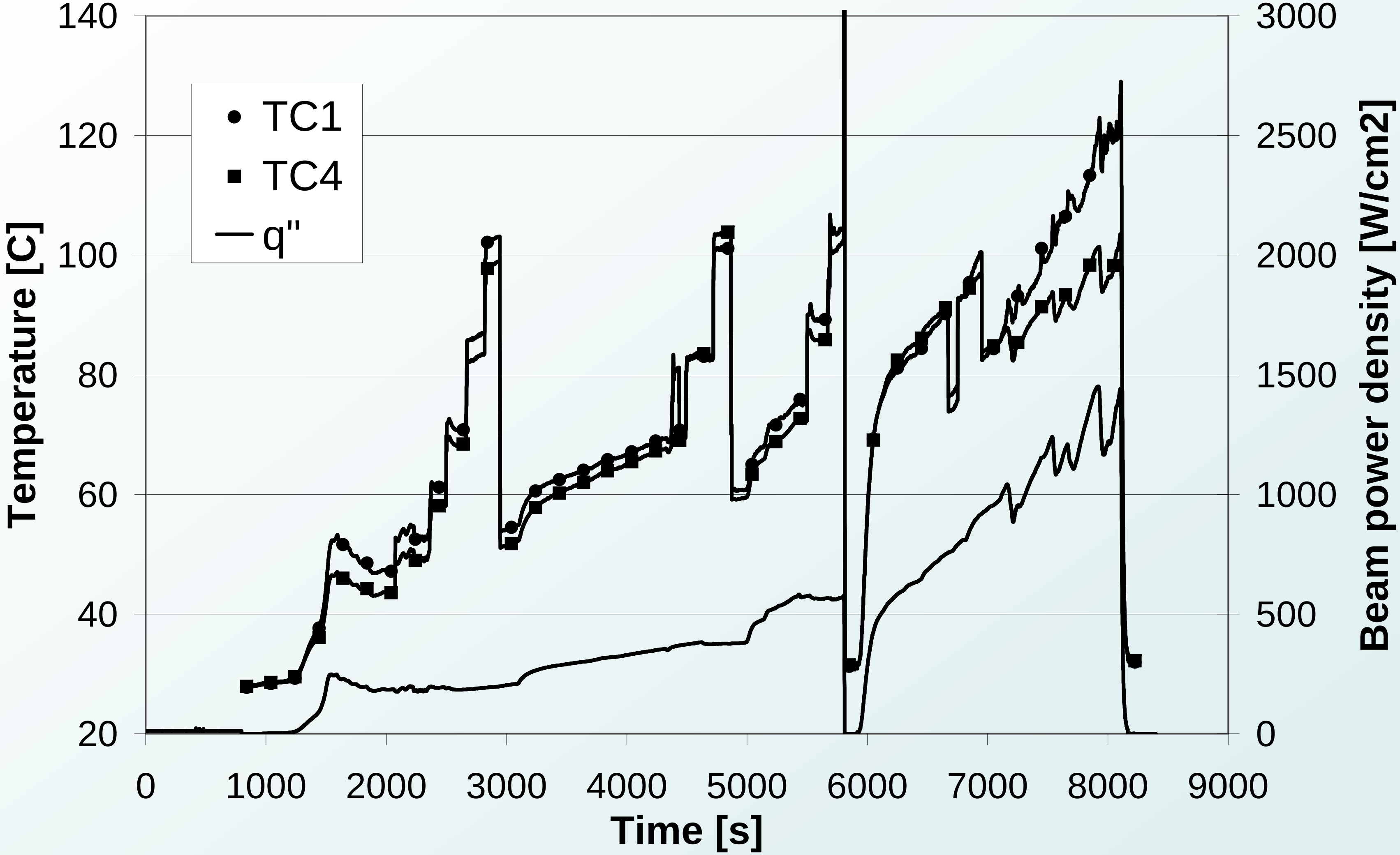


20 kW p/d Heavy metal dump

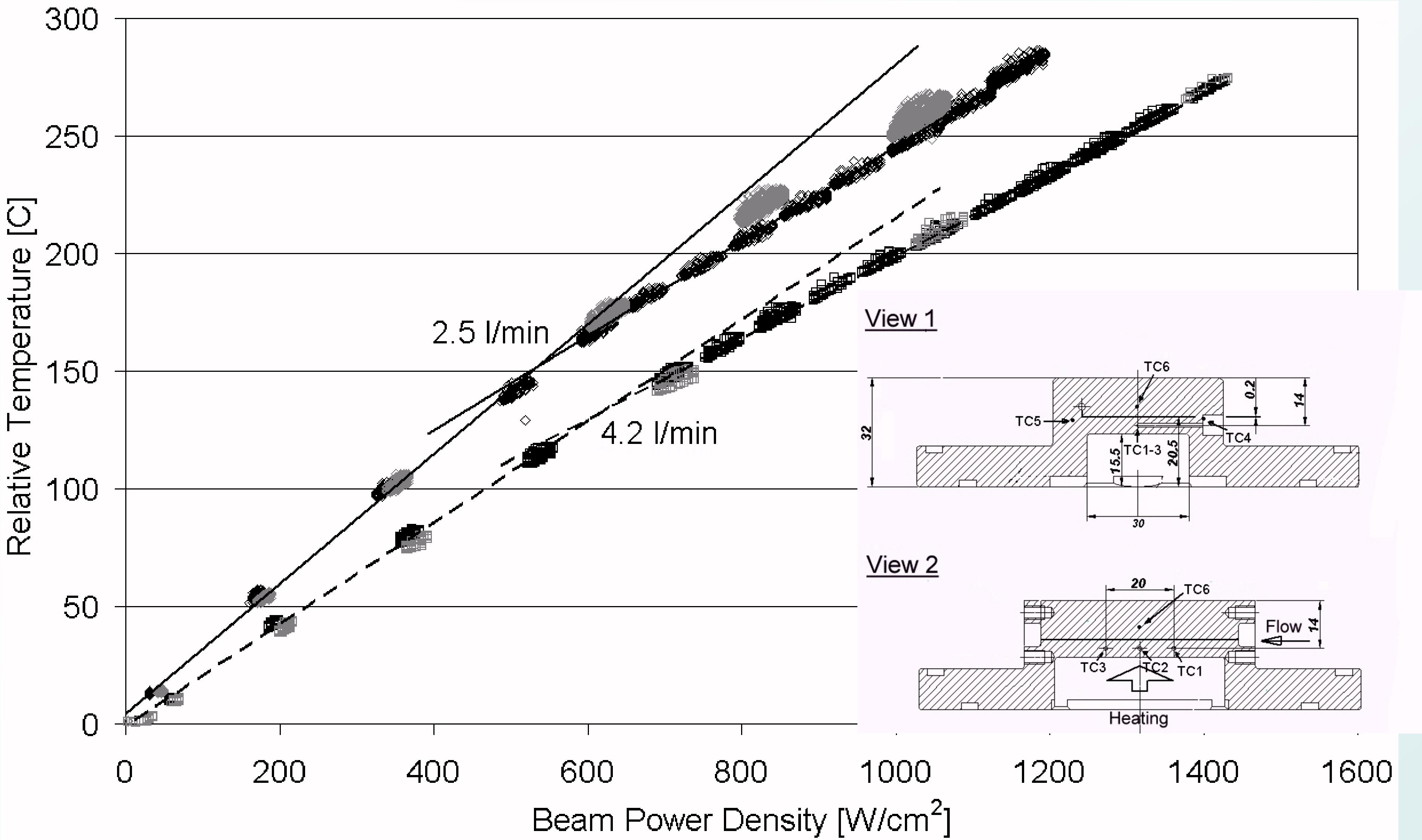




Mini-channels cooling capability



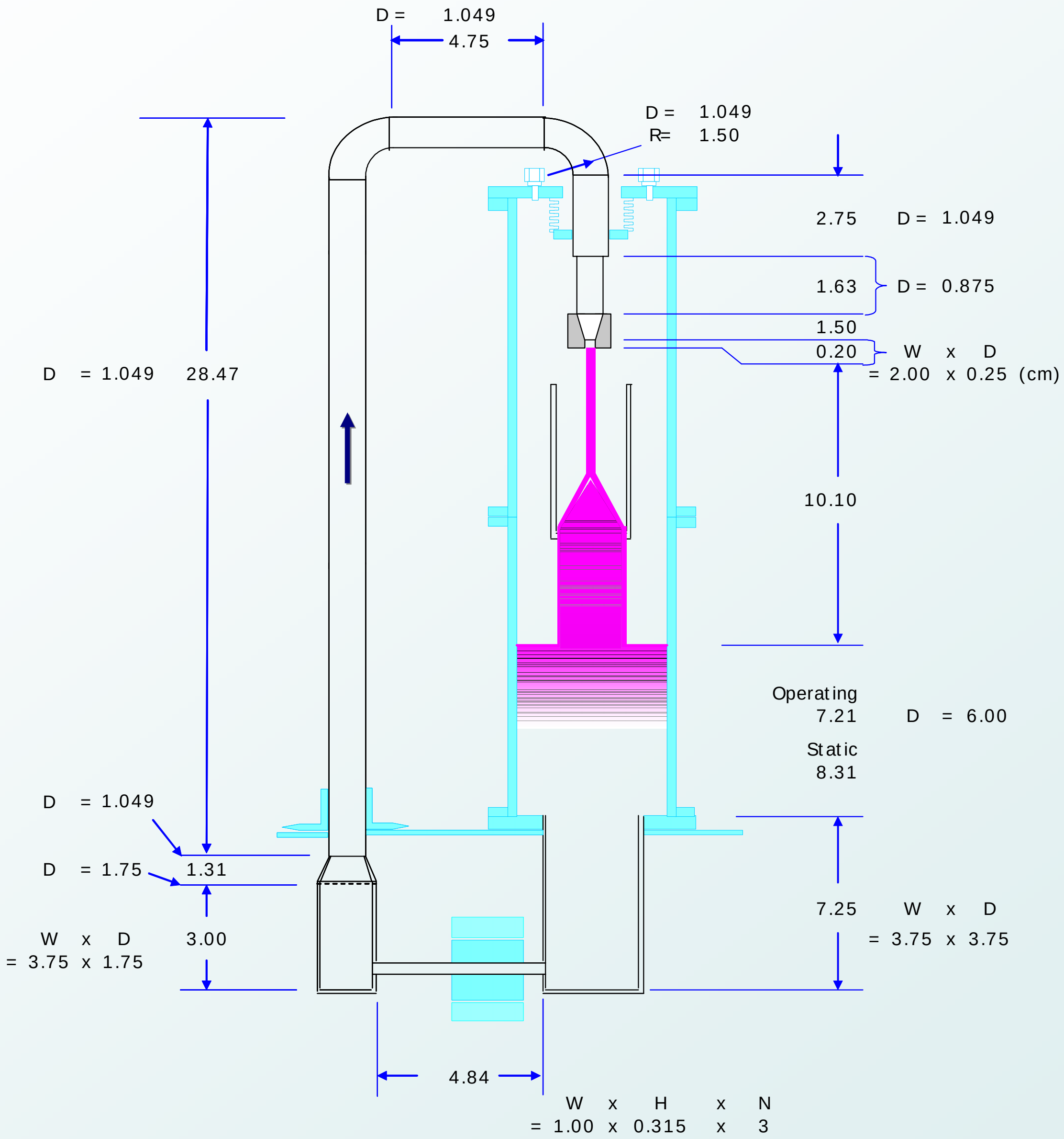
Micro-channels cooling capability



Examples - LiLiT

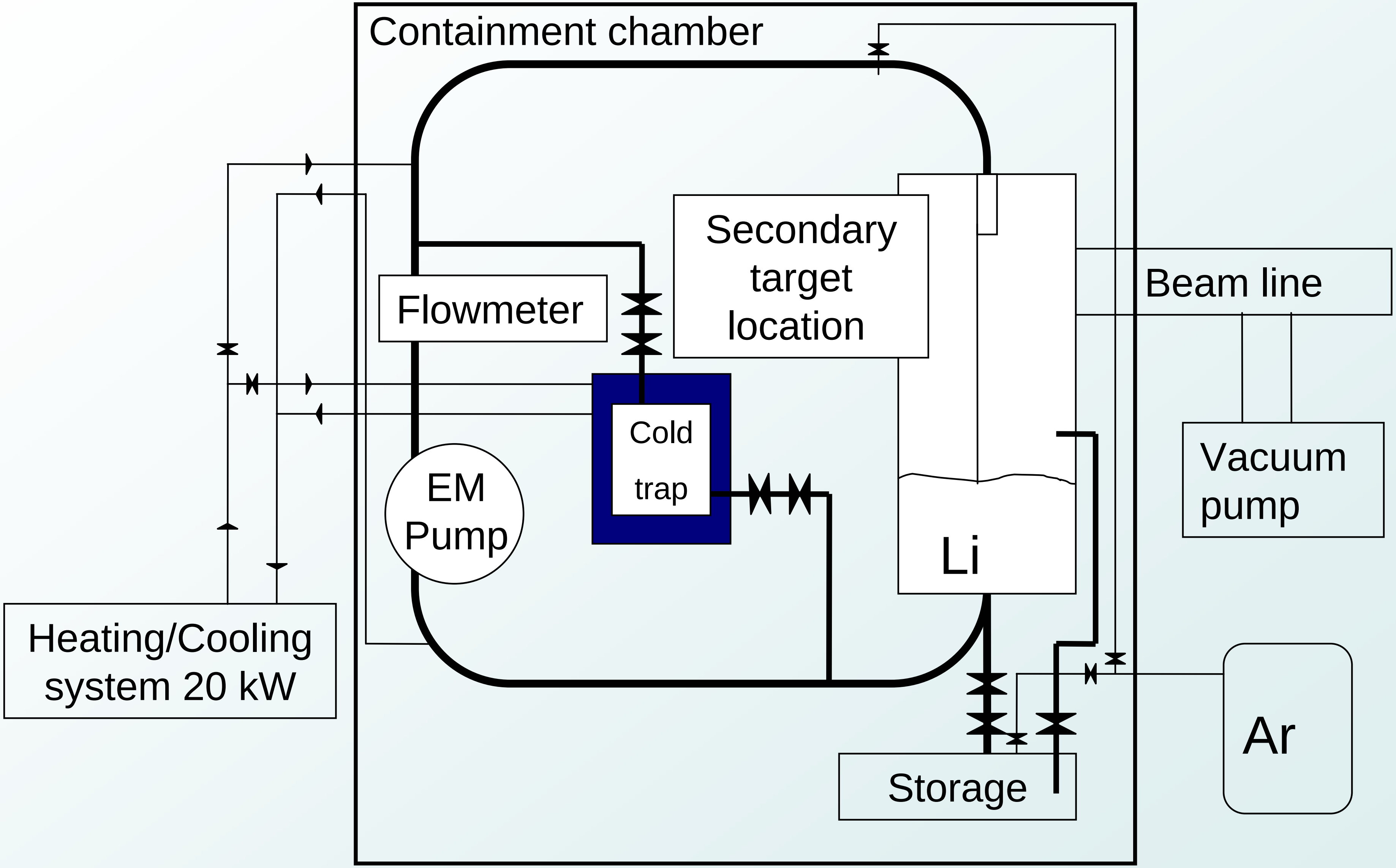
- High power *Li*quid *Li*thium *T*arget
- 4 – 10 kW beam power
- R_{rms} = 1 - 1.5 mm
- Design issues –
  - Surface shape
  - Be-7
  - Li boiling and generation of bubbles

ANL Li target design

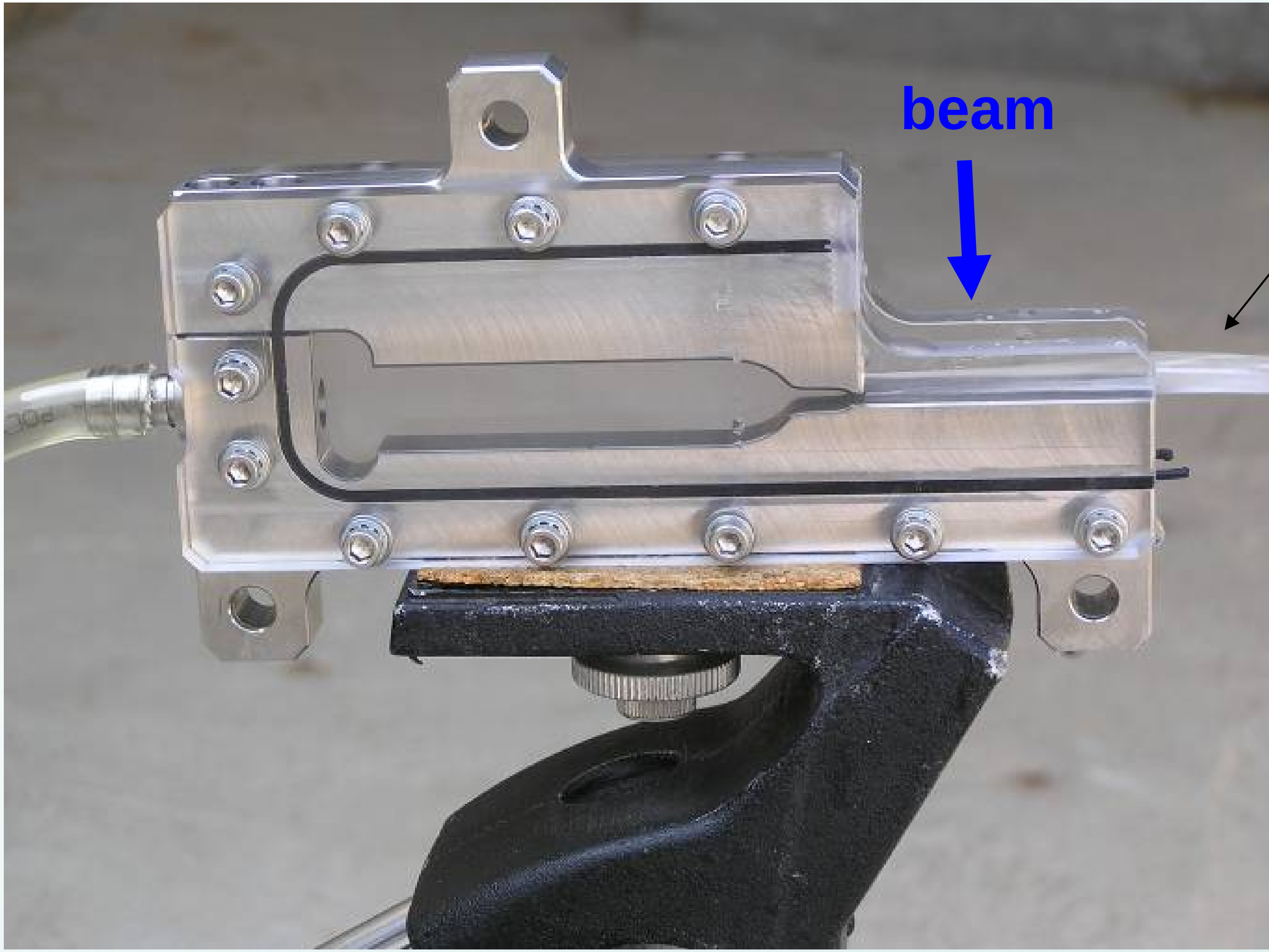


J. Nolen
RSI 2005

LiLiT preliminary design

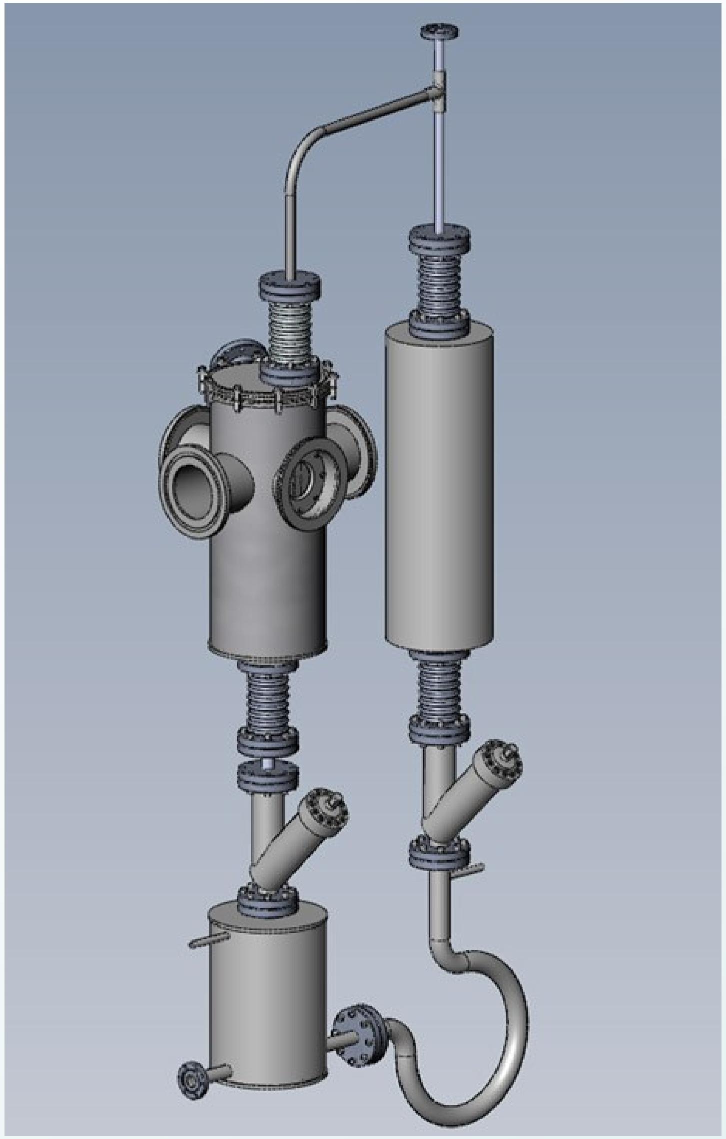


Nozzle design

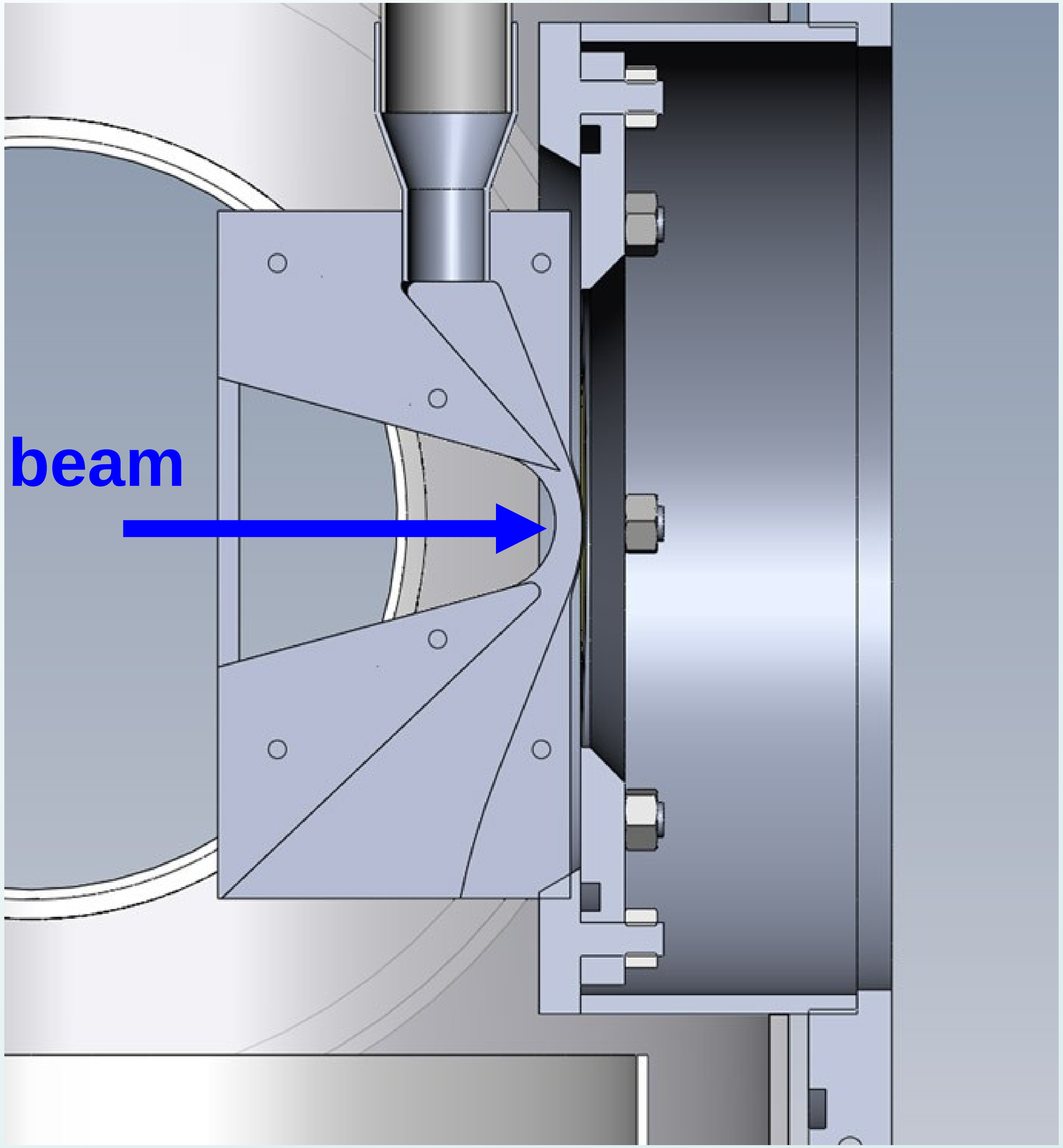


Water jet

Conceptual design



W. Gelbart ASD Inc.



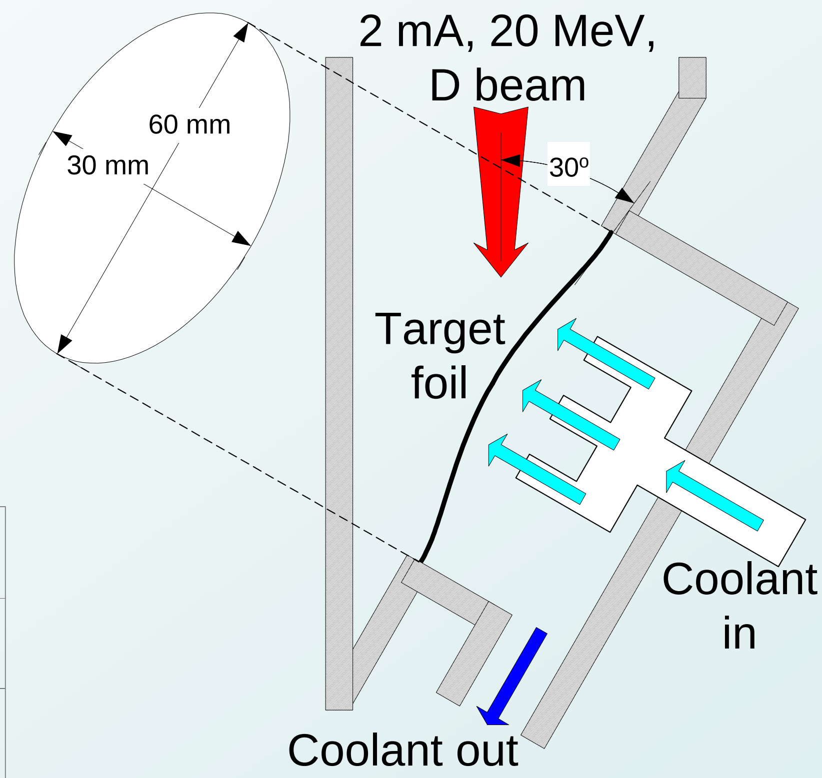
Example – Palladium target

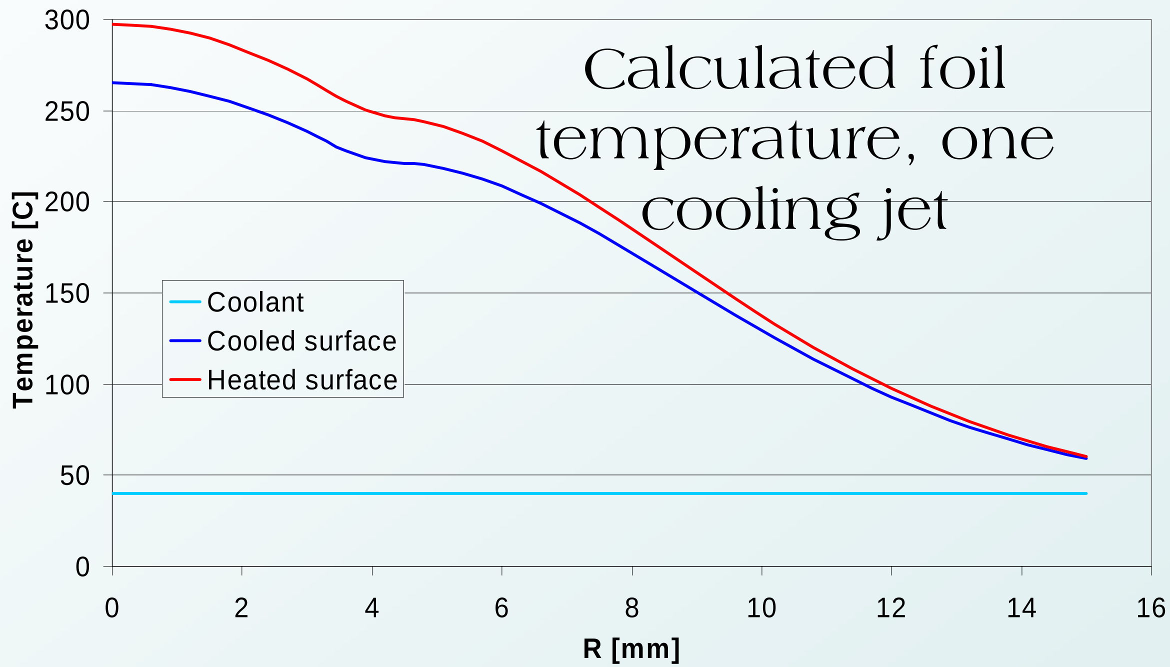
- Motivation
  - ^{103}Pd is commonly used radioisotopes for treating prostate cancer
  - Current irradiation techniques suffer from:
  - low production rates due to target cooling limitation
  - difficult electroplating process to prepare the target
- Method
  - Use of high heat flux liquid metal (LM) jet impingement cooling technique
  - Make target of self-supporting thin Rhodium foil
  - Use the $^{103}Rh(d,2n)^{103}Pd$ reaction with deuteron beam of 17-20 MeV

Palladium target – proposed design

- 2 mA, 20 MeV D beam
- 30x60 mm Elliptic target
- 180 μm Rh foil
- Target to beam angle of 30º

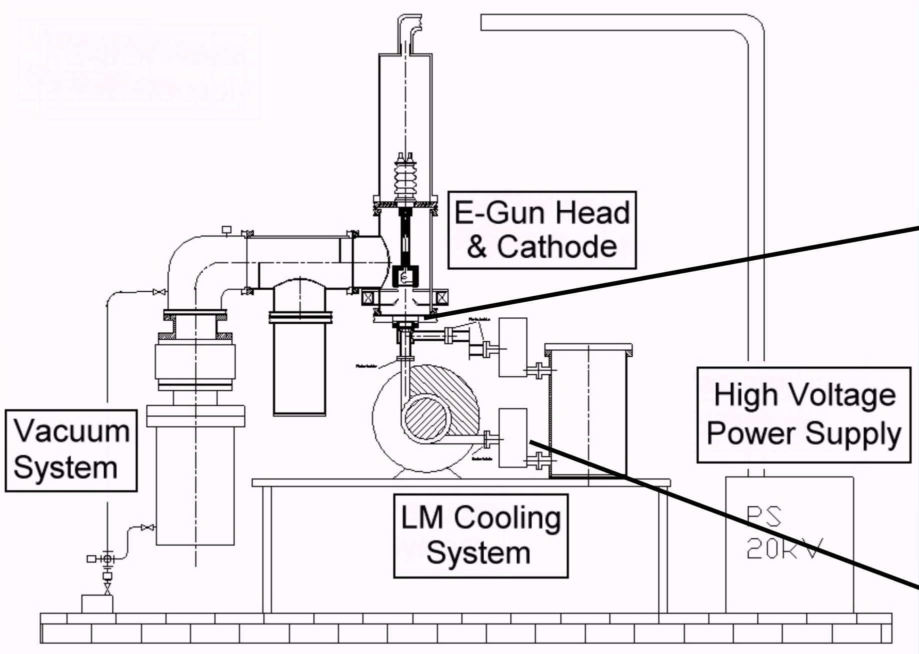
- Maximum heat flux from target – 6.2 kW/cm²
- Calculated maximum foil temperature < 300ºC



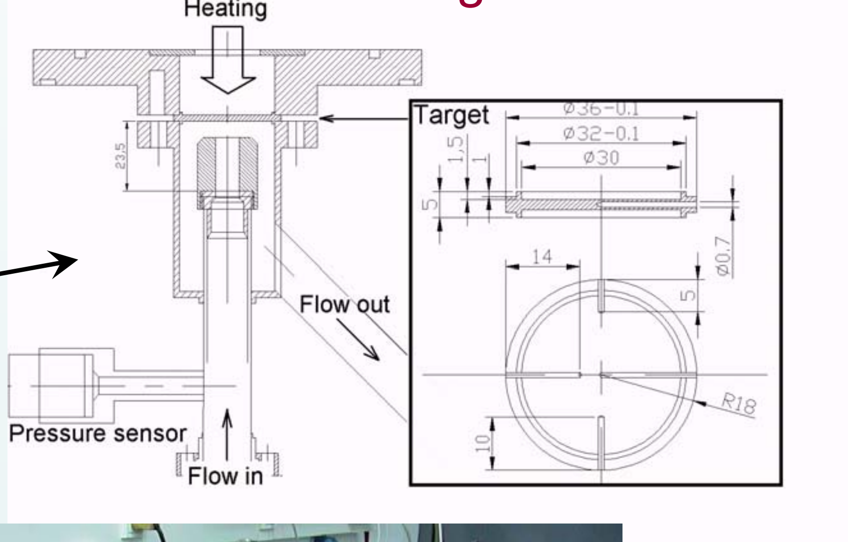


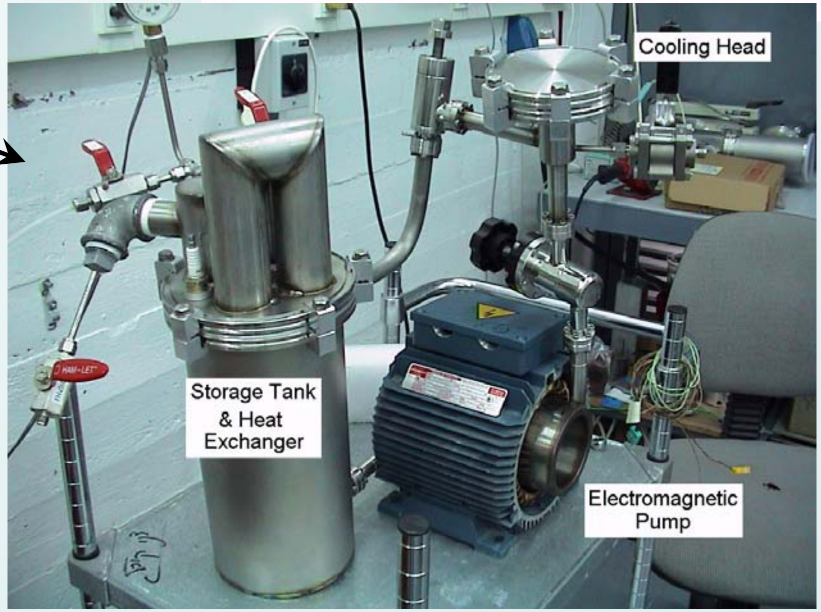
LM cooling loop

Schematic drawing of the experimental liquid-metal cooling system



The jet impingement cooling head and details of the target disk

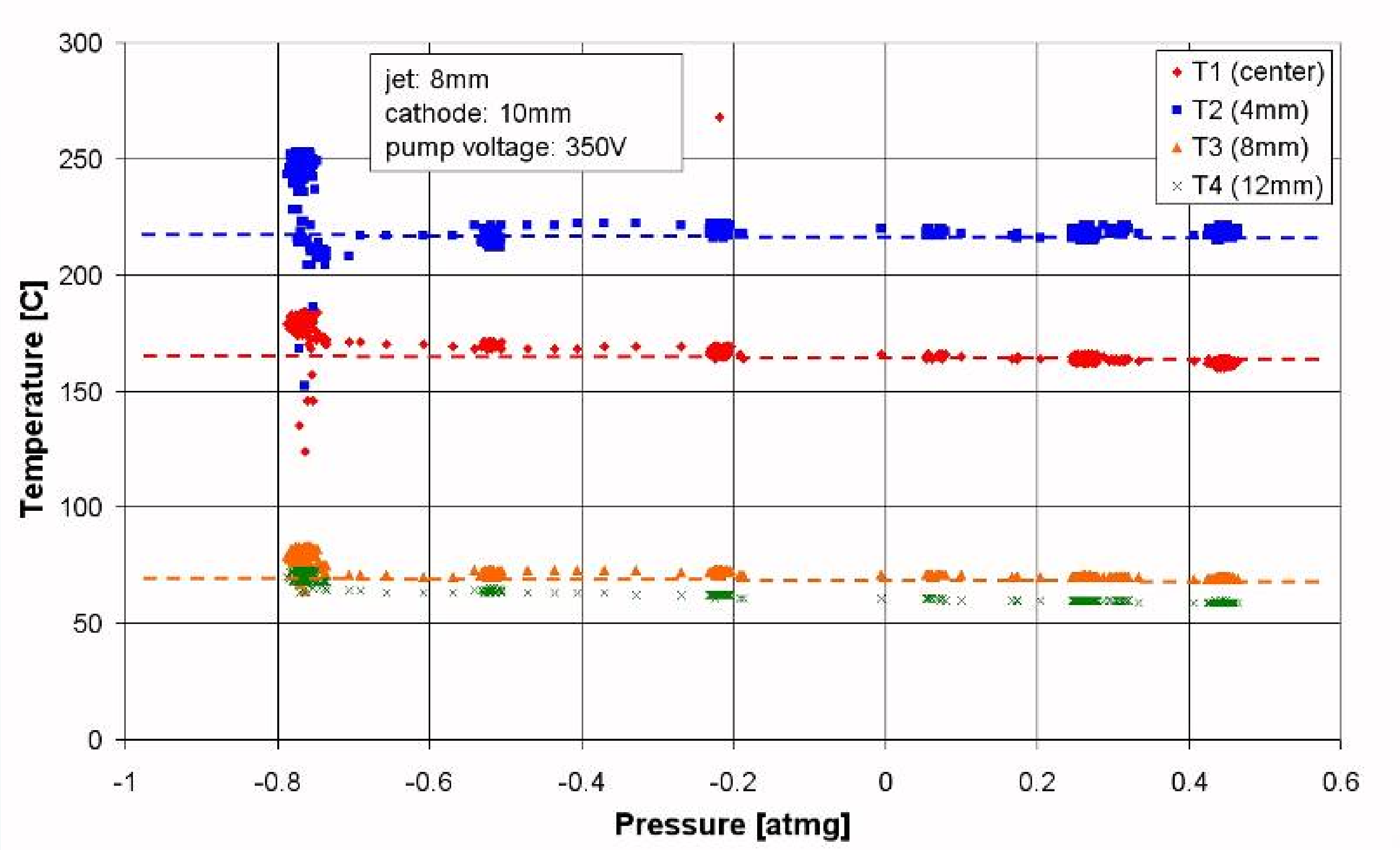




The liquid metal jet impingement cooling system during a vacuum test

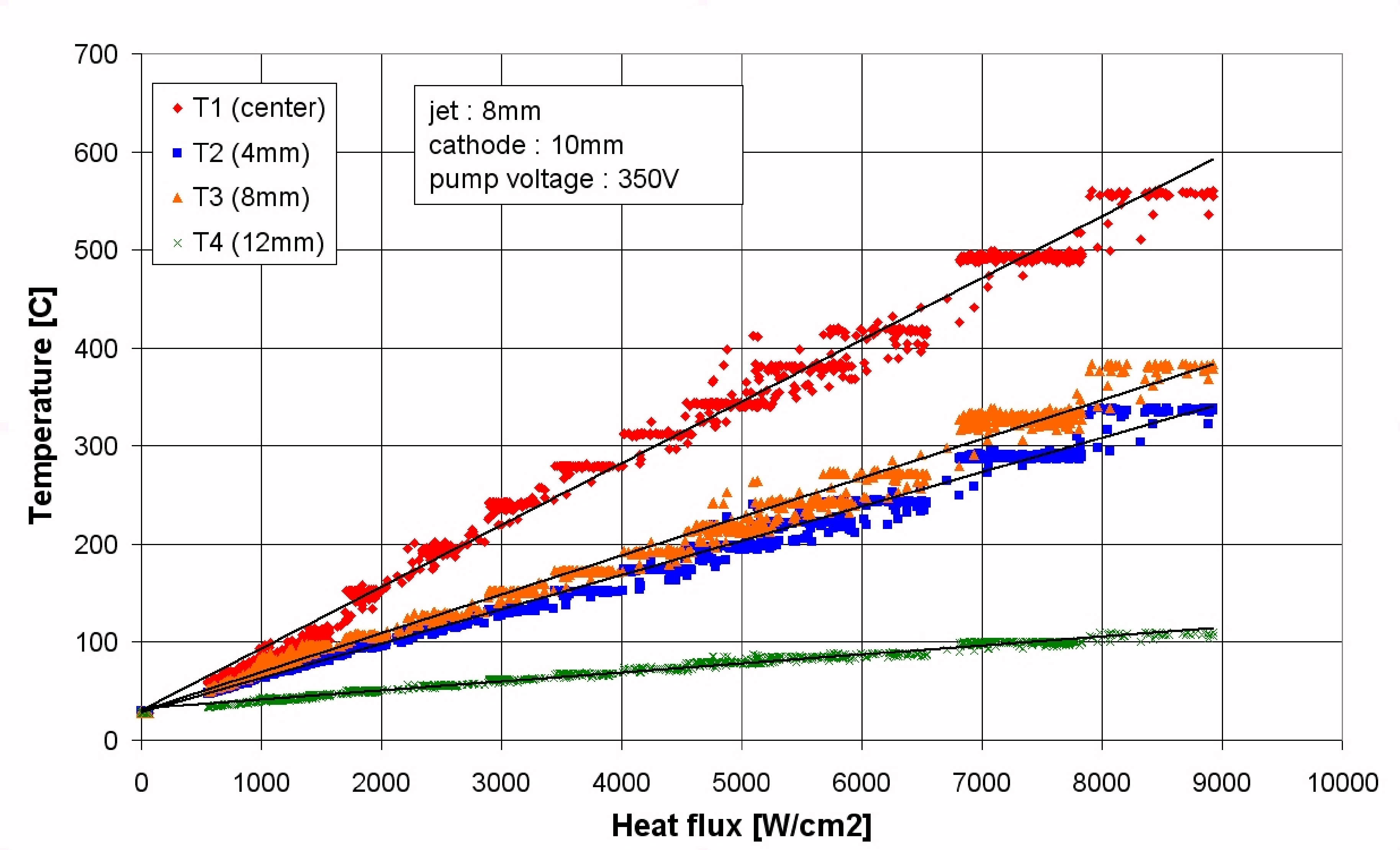
I. Silverman *et al.* NIM B 241(2005)1009

High power cooling with LM



I. Silverman *et al.* NIM B 261(2007)747

High power cooling with LM



Rh foil strength

250 μm thick Rh foil has been demonstrated to be strong enough to hold the expected LM cooling system pressure for several days, even at the high temperature calculated to exist during the irradiation process

Foil thickness* [μm]	Temperature [C]	Pressure [atm]	Test time [hr]	Breaching
100	450	13	1	+
250	450	29	288	-
250	650	10	10	+
250	650	15	0.5	+

*** Foil dimensions: Race track, 100x12 mm**