NIBS 2018

High Current Results from the 2X Scaled Penning Source

Dan Faircloth

Low Energy Beams Group Leader

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Budker INP Novosibirsk

BINP Novosibirsk 4th September 2018

Science & Technology Facilities Council

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ISIS Spallation Neutron Source

Rutherford Appleton Laboratory, Oxfordshire UK

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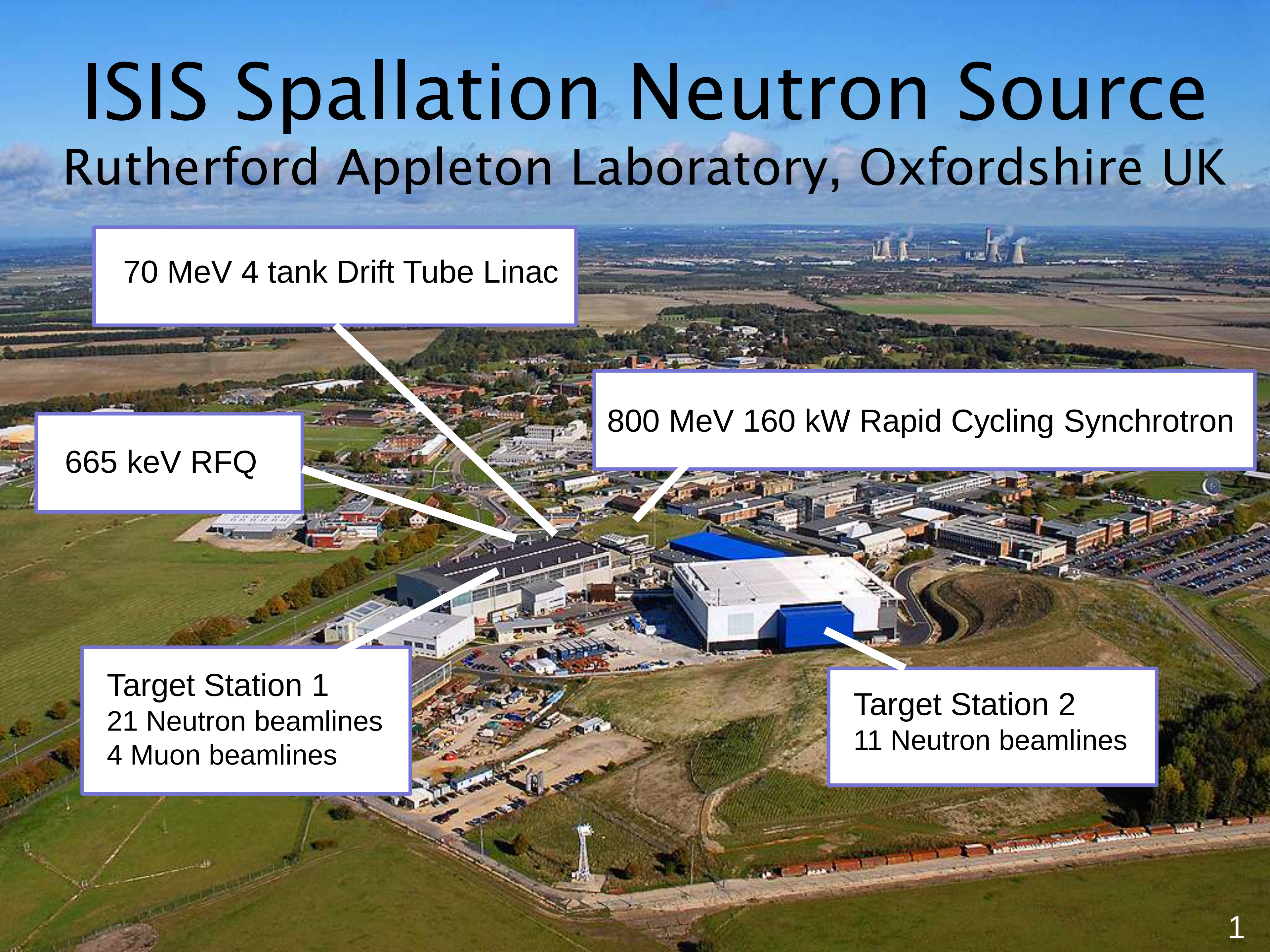

Low Energy Beams Group

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Technician

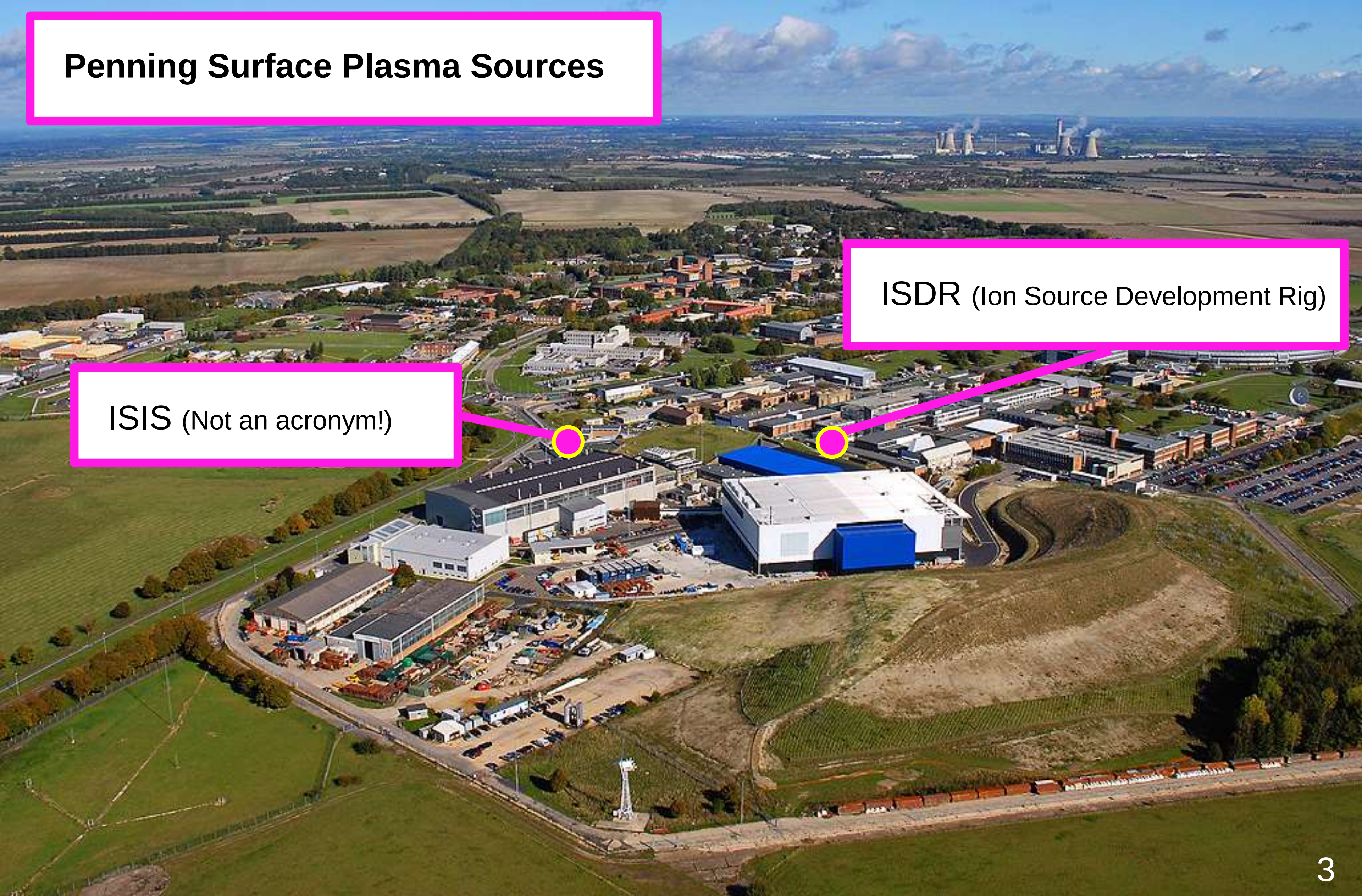
Trevor Wood
Technician

Tiago Sarmento
Physicist

Rob Abel
RF Engineer

?
Technician

Low Energy Beams Group Sources



All operational sources are pre-tested
Also used for ancillary equipment tests

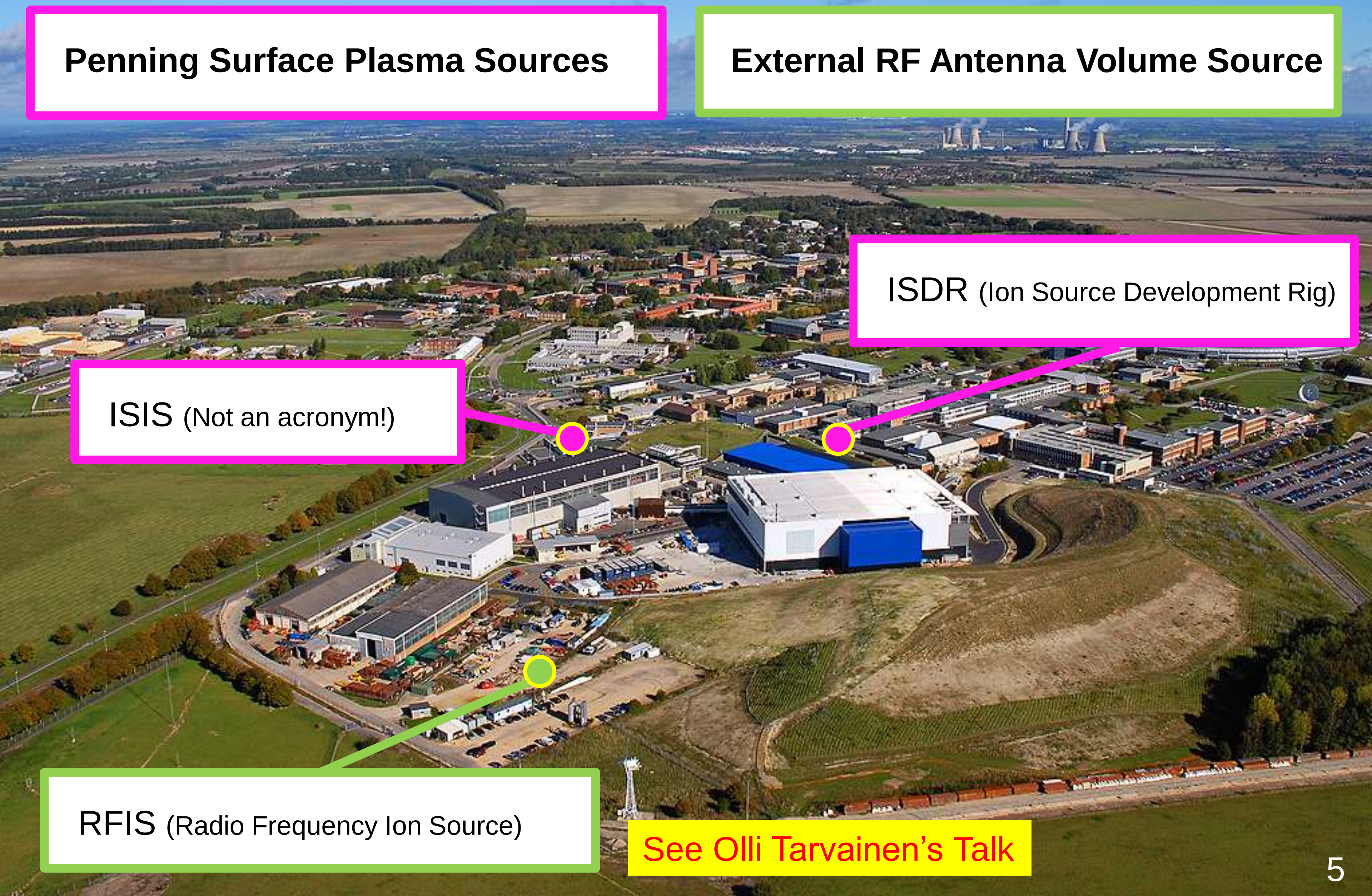
Operational sources run for 2-3 weeks before scheduled changes

Sources routinely produce
55 mA 250 μs 50 Hz H^- beams

However only 25 mA is transported through LINAC tank 1 because there is no MEBT!

See Olli Tarvainen's Talk

Low Energy Beams Group Sources



See Olli Tarvainen's Talk

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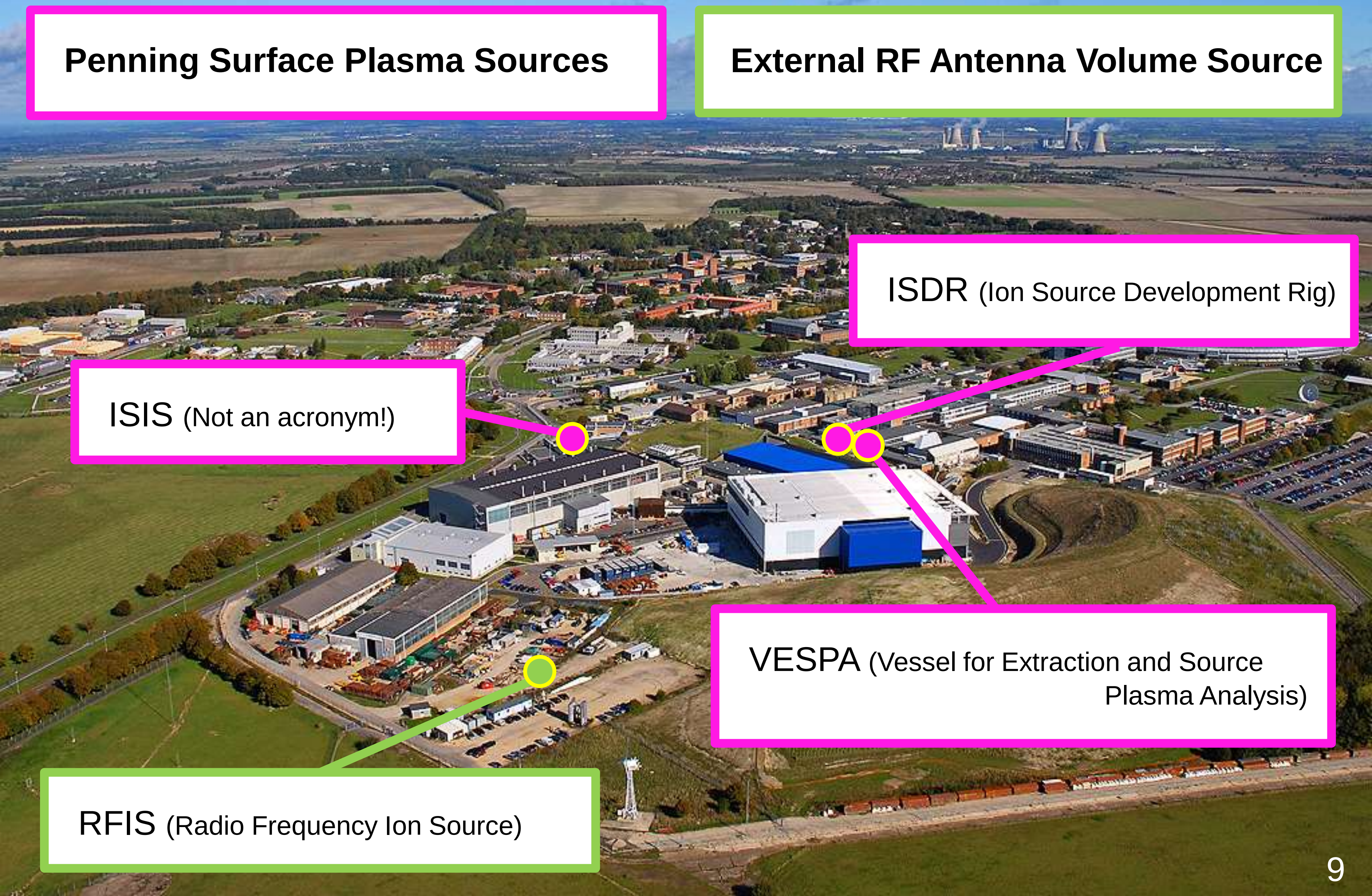
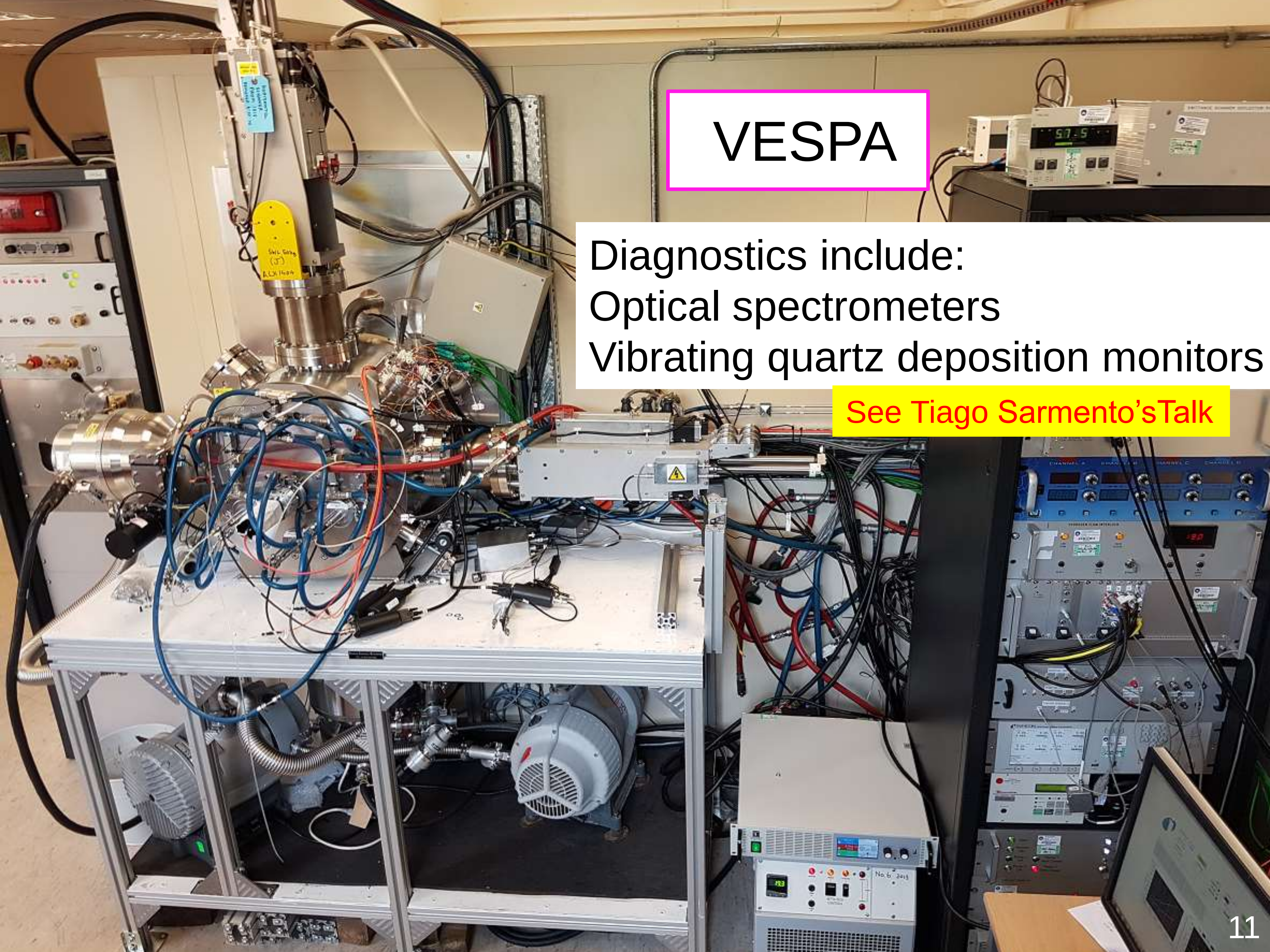
Low Energy Beams Group Sources




VESPA
BODY
CATHODE
TRANS CTRL
TRANS MON
HEATERS
MAINS
BOILER
ION SOURCE CONTROL AND STATUS

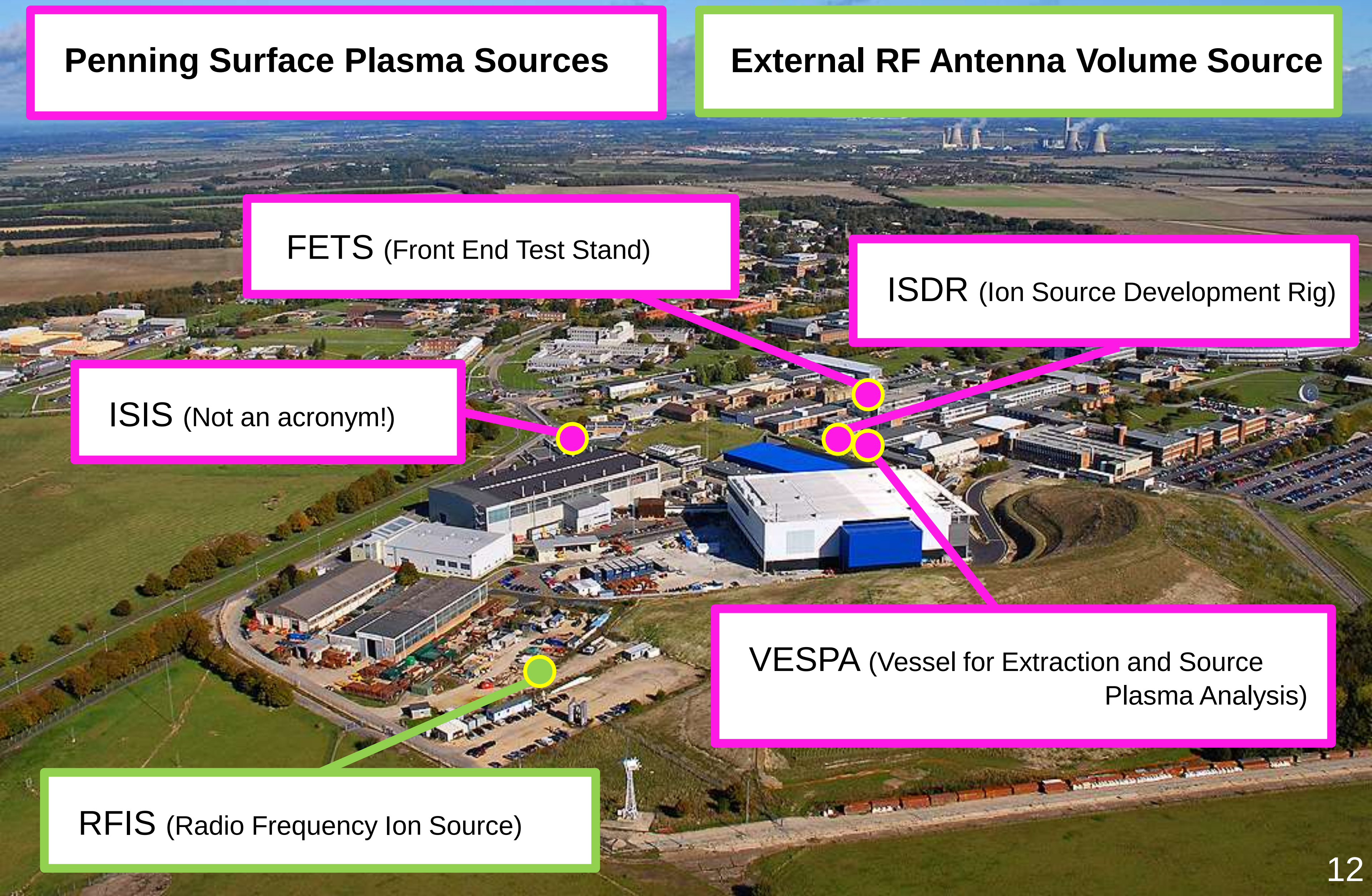
VESPA



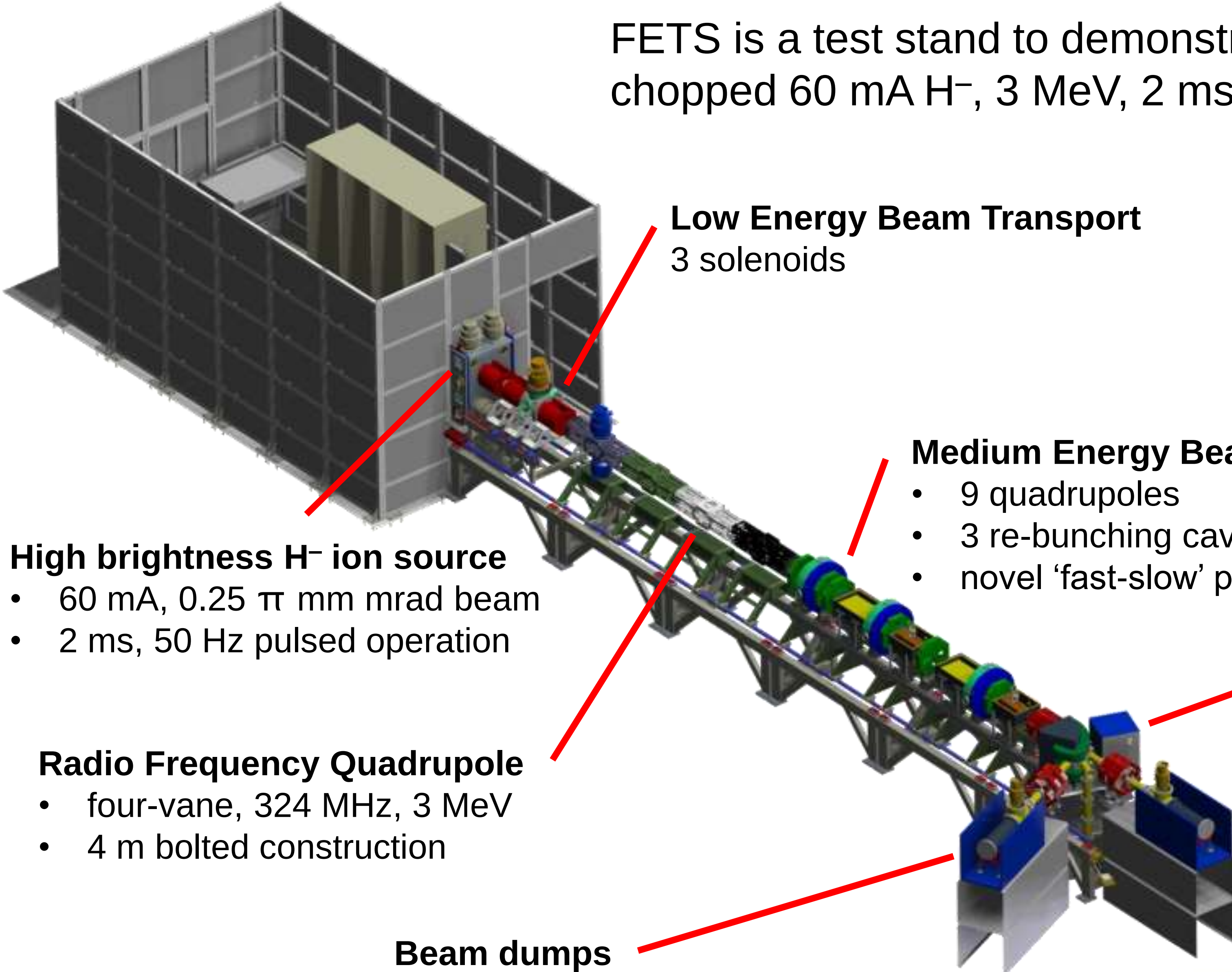
Diagnostics include:
Optical spectrometers
Vibrating quartz deposition monitors

See Tiago Sarmento'sTalk

Low Energy Beams Group Sources



FETS is a test stand to demonstrate a perfectly chopped 60 mA H⁻, 3 MeV, 2 ms, 50 Hz beam



Low Energy Beam Transport
3 solenoids

Medium Energy Beam Transport
- 9 quadrupoles
- 3 re-bunching cavities
- novel ‘fast-slow’ perfect chopping

High brightness H⁻ ion source
- 60 mA, 0.25 π mm mrad beam
- 2 ms, 50 Hz pulsed operation

Diagnostics
- non-interceptive
- BPM’s
- CT’s
- laser-based

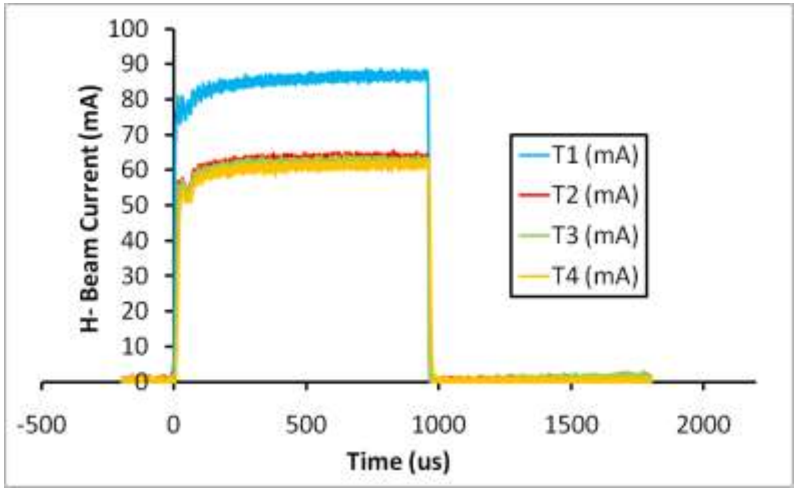
Radio Frequency Quadrupole
- four-vane, 324 MHz, 3 MeV
- 4 m bolted construction

Beam dumps
- defocussing quads
- water cooled pure Al cones

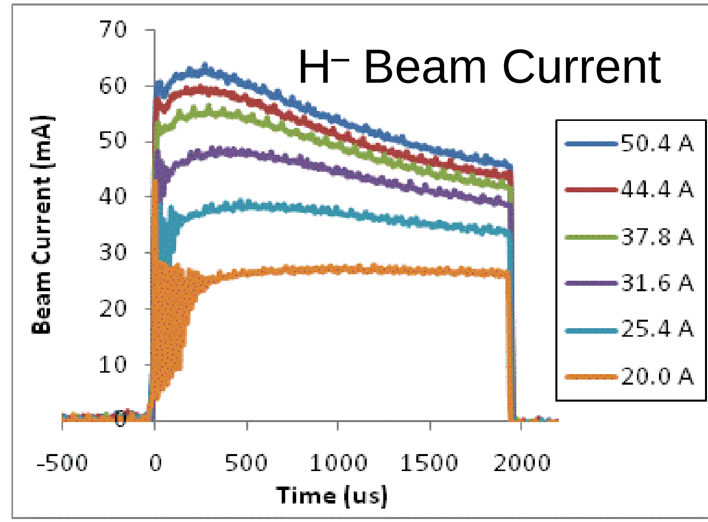
FETS September 2018
RFQ is being installed

Limit of the 1X Source

either

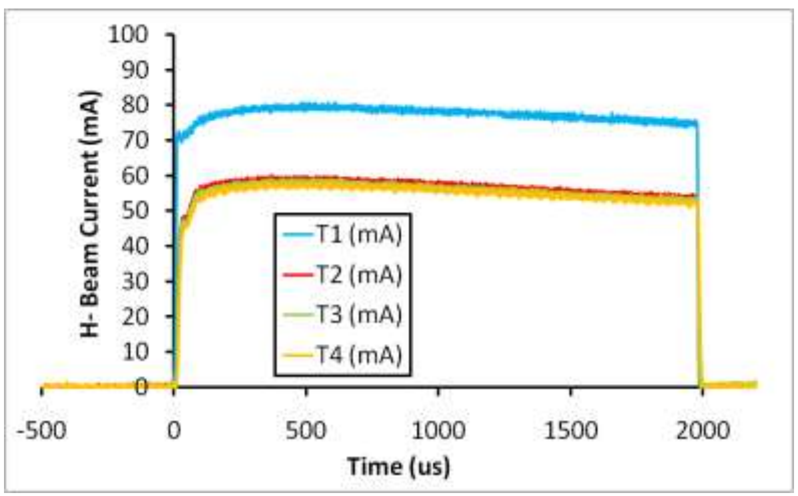


60 mA 1 ms 50 Hz



Droop is unavoidable at 50 Hz 2 ms

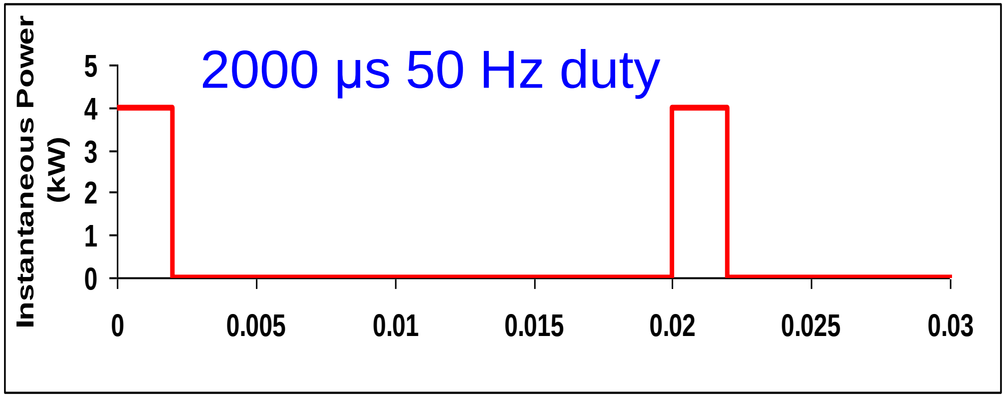
or

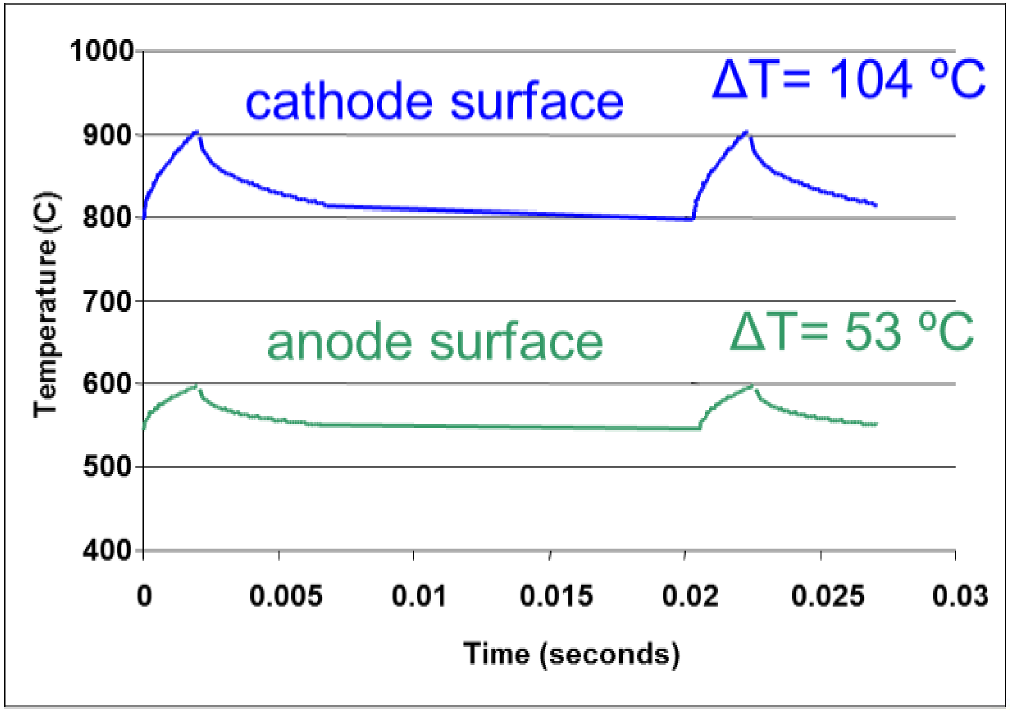


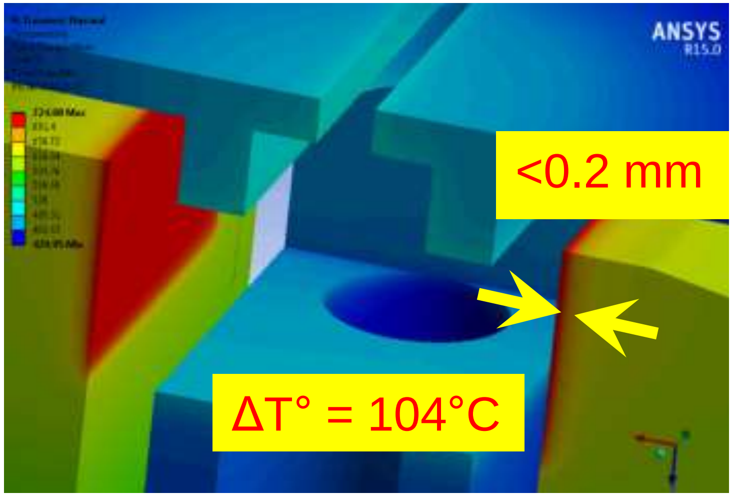
60 mA 2 ms 25 Hz

Duty factor limited thermal problems:

1. TRANSIENT PROBLEM







Transient surface temperature rise occurs in a very thin layer

SOLUTION

Reduce plasma power density by increasing surface area = Scaling

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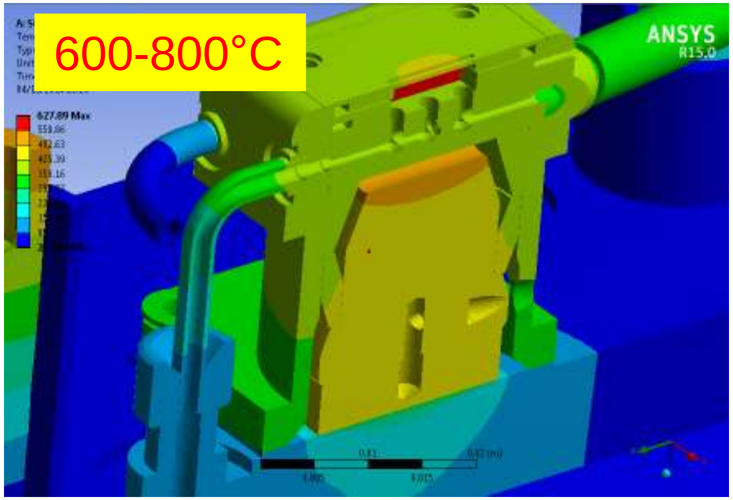
Duty factor limited thermal problems:

2. STEADY STATE PROBLEM



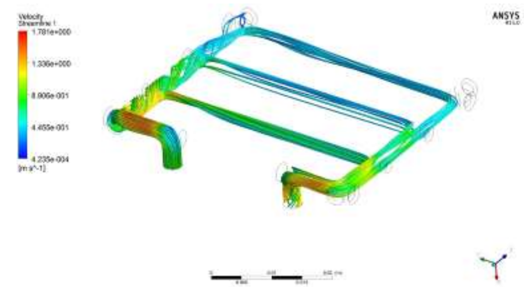
Average surface temperatures must be maintained at increased duty cycles

SOLUTION

Improve cooling:

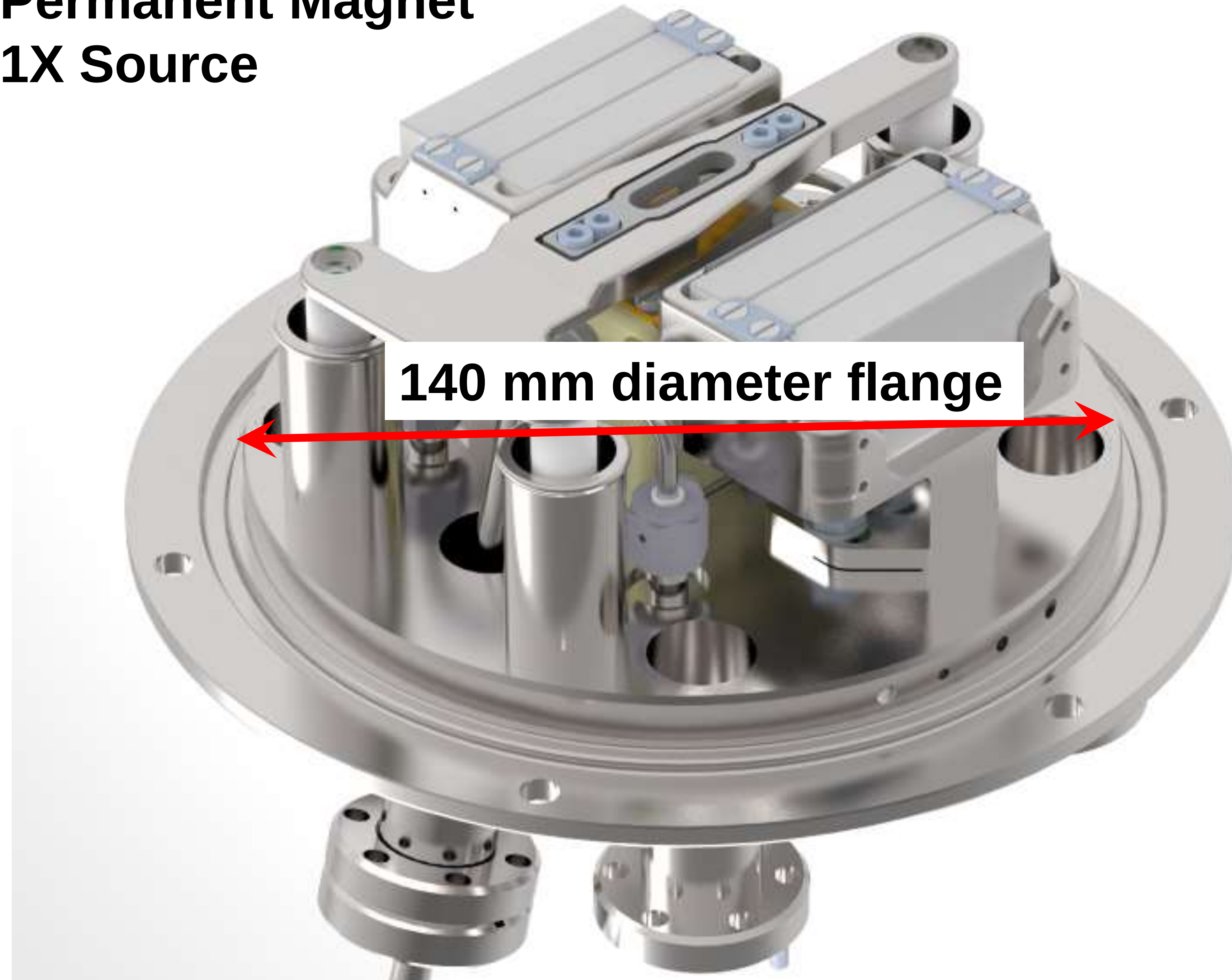
CFD cooling simulations

Head cooling- switched from air to water

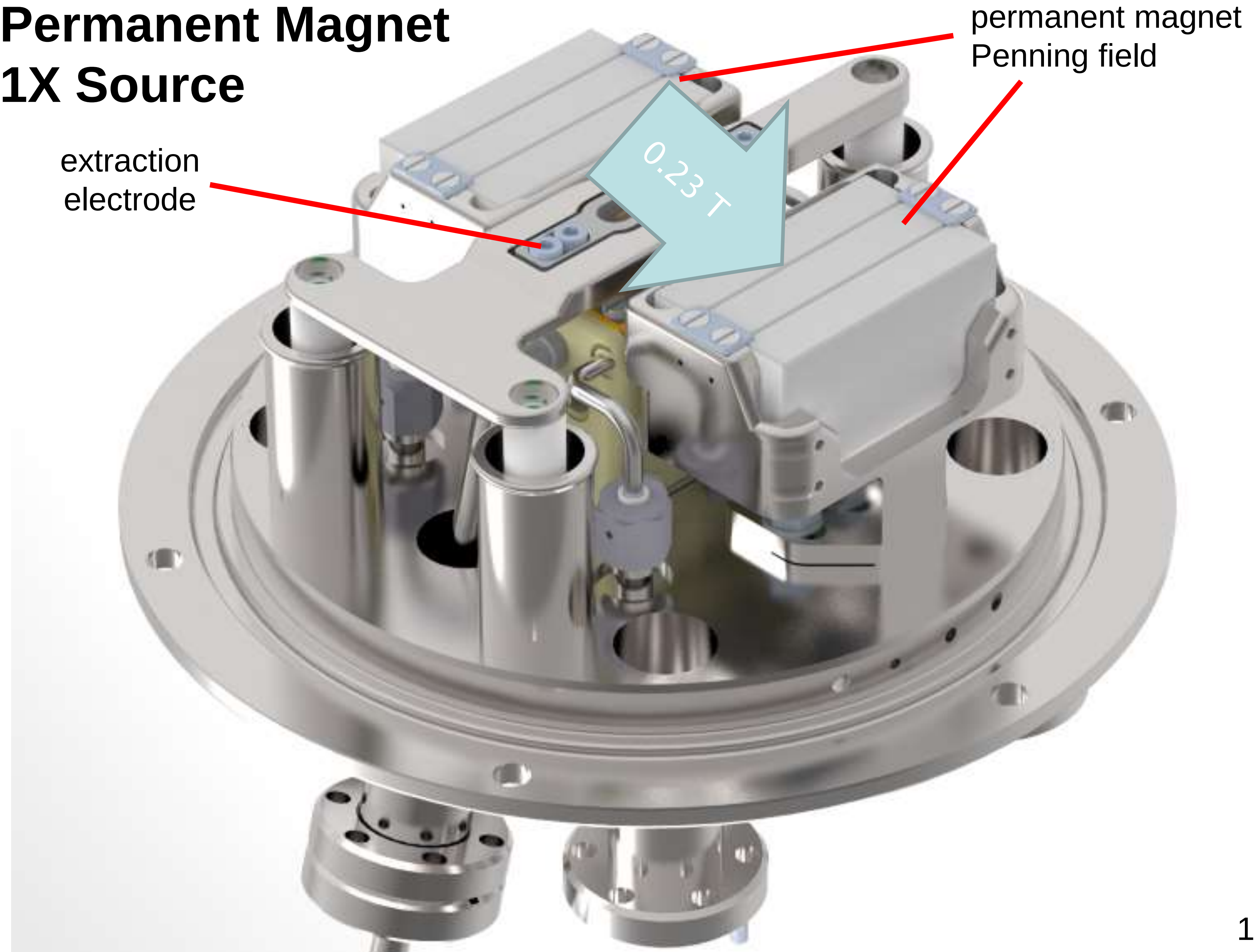


Flange cooling- extra parallel water channels

Permanent Magnet
1X Source

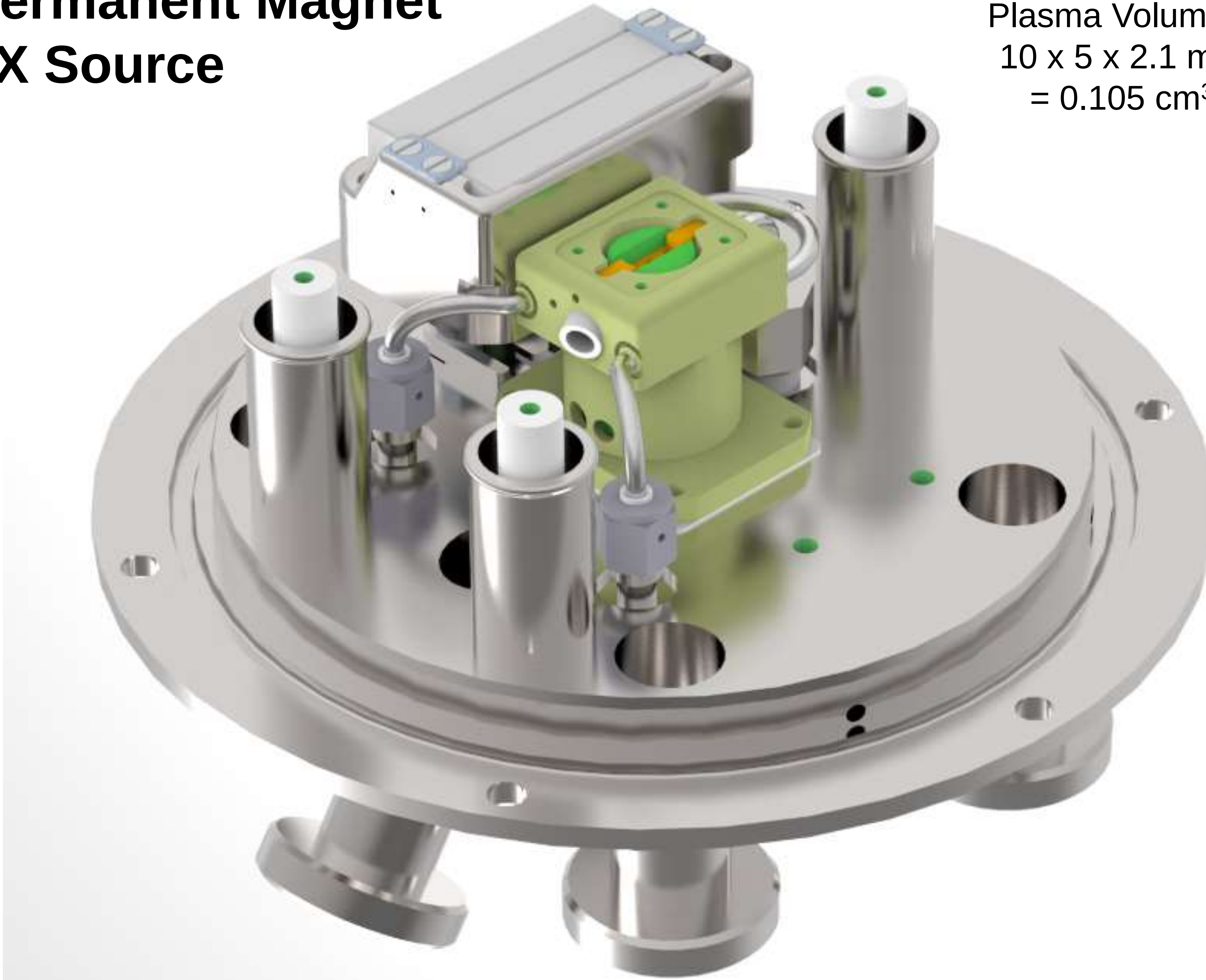


Permanent Magnet 1X Source

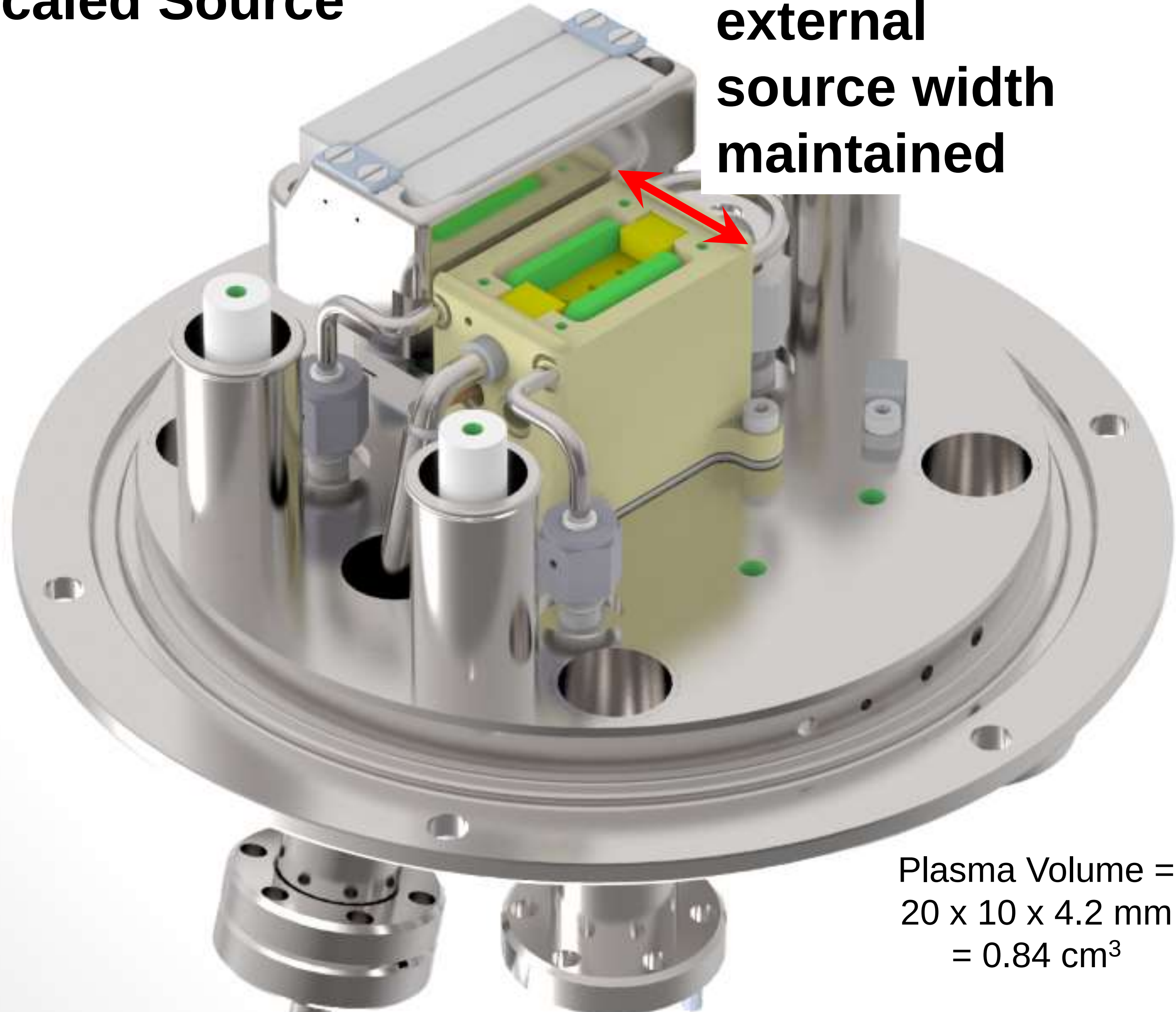


Permanent Magnet 1X Source

Plasma Volume =
10 x 5 x 2.1 mm
= 0.105 cm^3



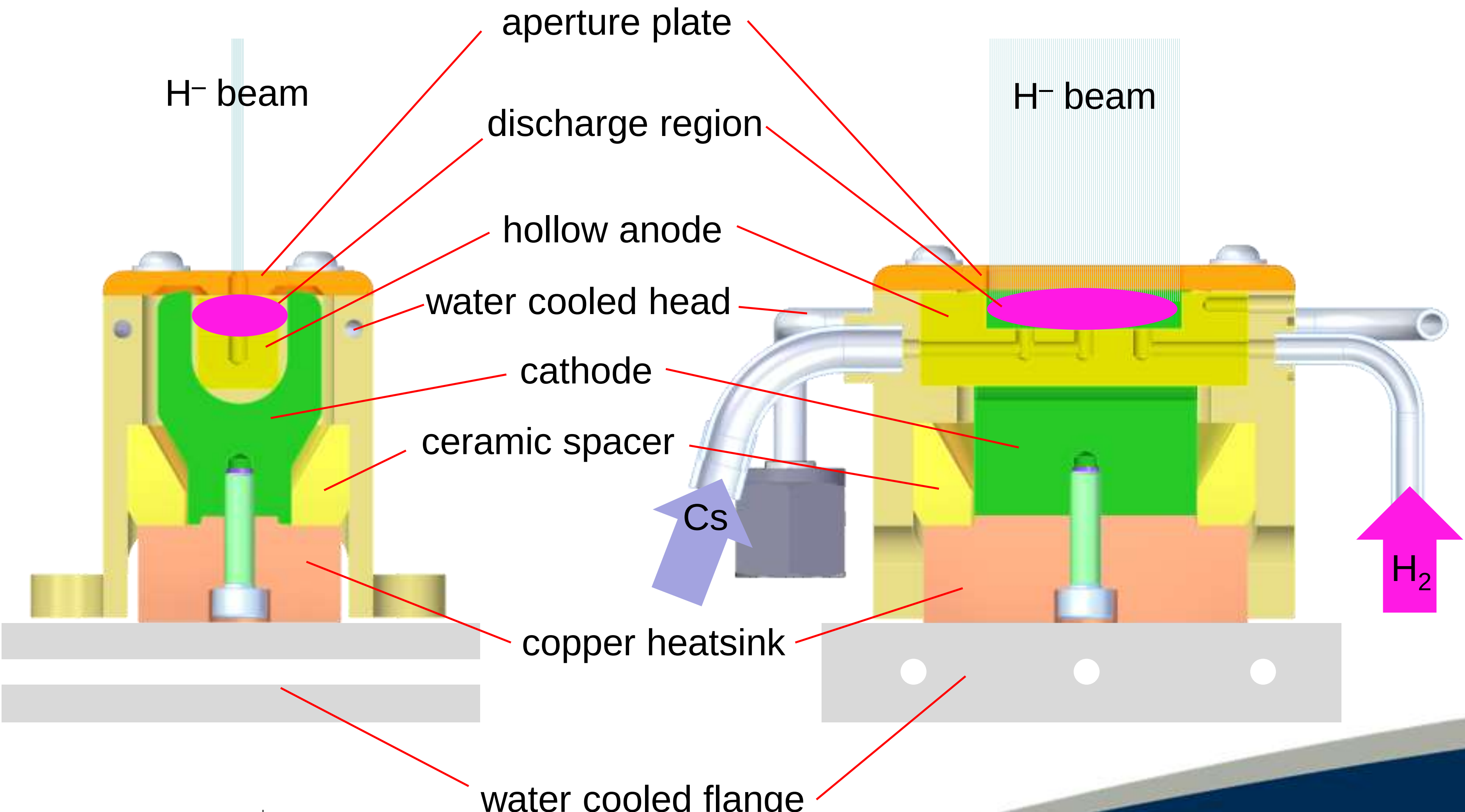
2X Scaled Source

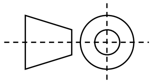


external source width maintained

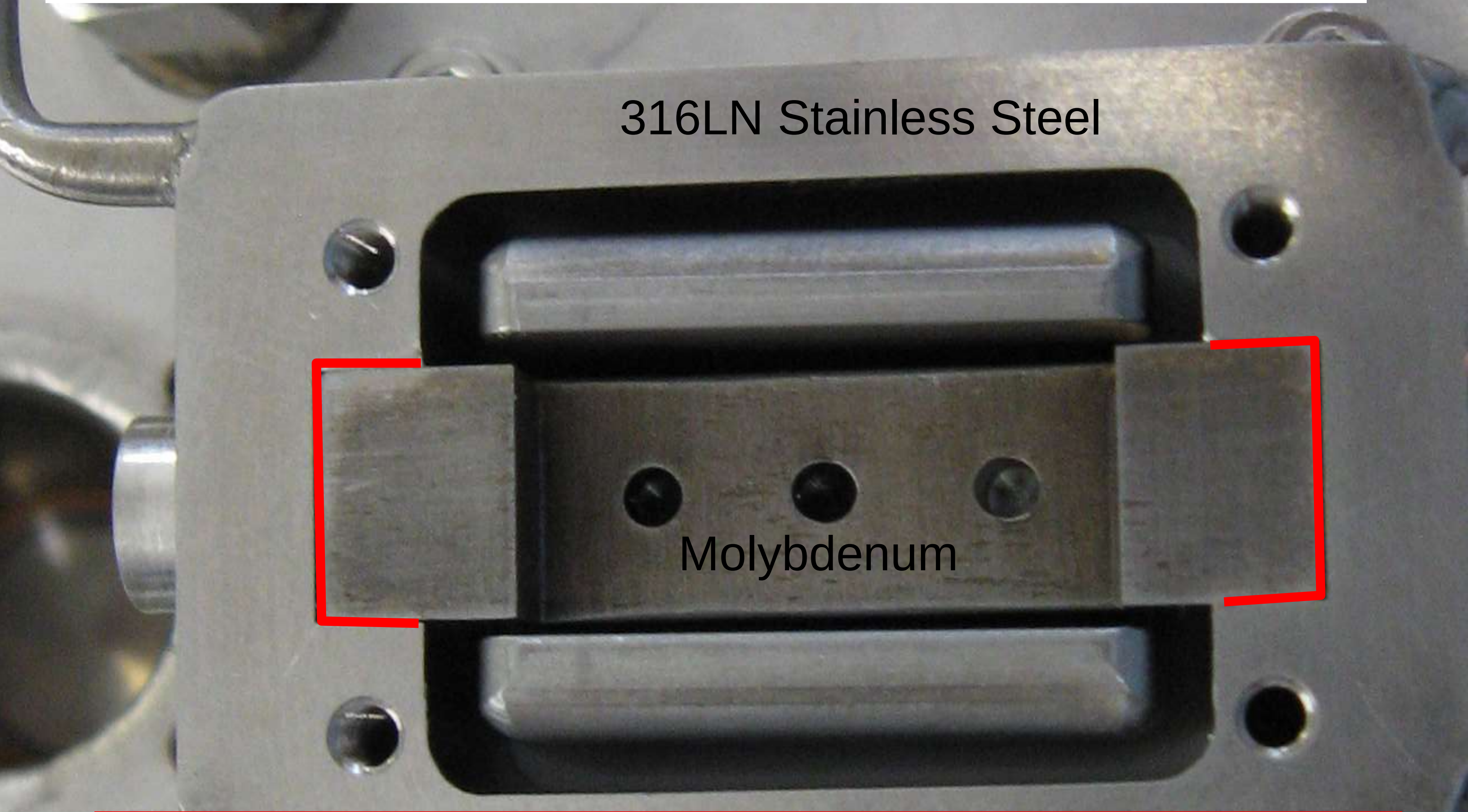
Plasma Volume =
20 x 10 x 4.2 mm
= 0.84 cm^3

2X Source Cross-sections




sectional views

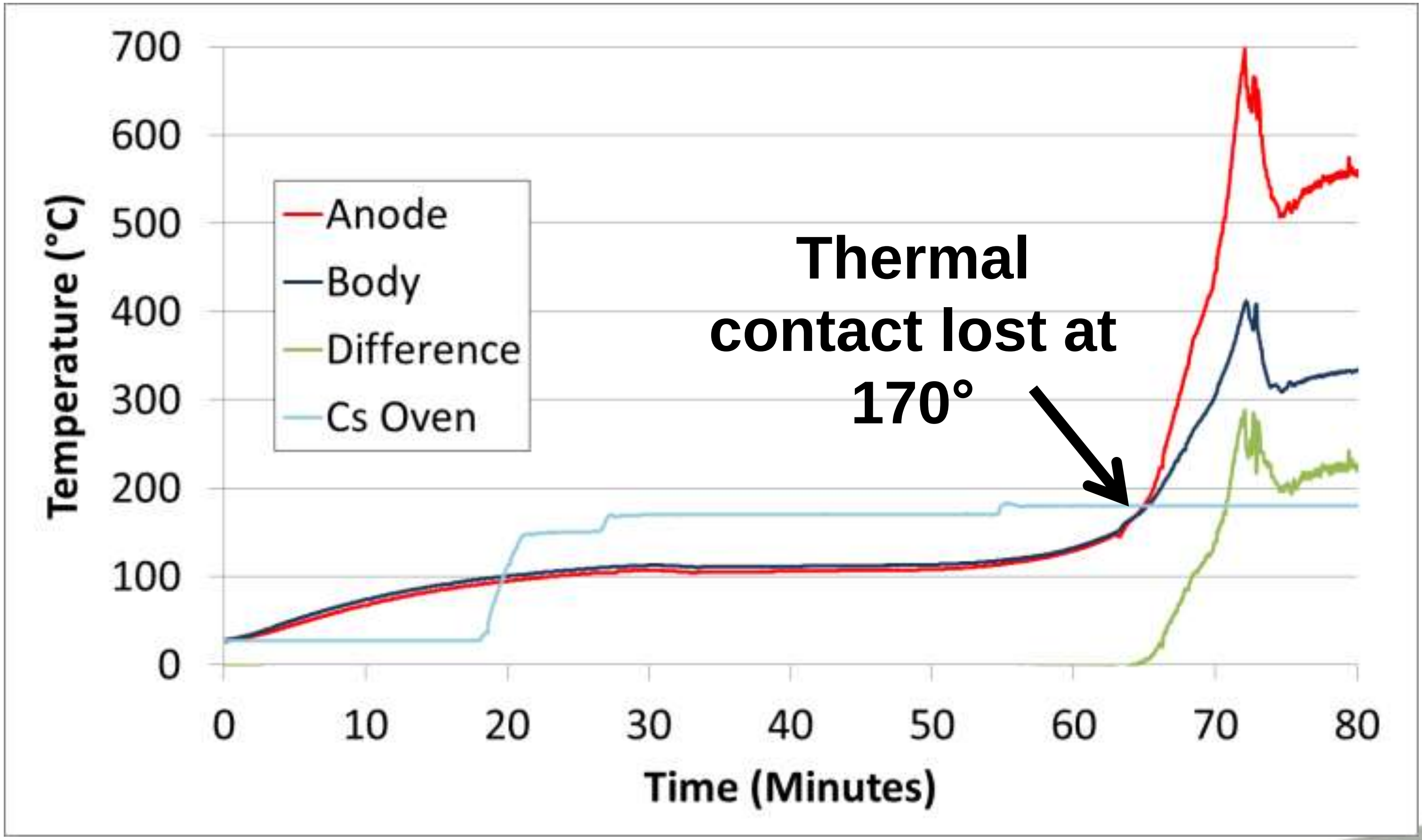
Thermal Contact Resistances



Anode cooling relies on good contact between the molybdenum anode and the stainless steel source body head


Anode Press

Anode Cooling



Dissimilar Expansion Coefficients and Mechanical Tolerances

Component	Length	Tolerance	Width	Tolerance
Anode	33.5	+0.02/+0.01	8.5	+0.028/+0.020
Source Body	33.5	+0.02/-0.00	8.5	+0.01/-0.00

20	C		
Most clearance		Length	Width
	Anode	33.51	8.52
	Source body	33.52	8.51
	Difference	0.01	-0.01
	Inter/Clear	Clearance	Interference
Least Clearance			
	Anode	33.52	8.528
	Source body	33.5	8.5
	Difference	-0.02	-0.028
	Inter/Clear	Interference	Interference

Possible clearance above 130 °C

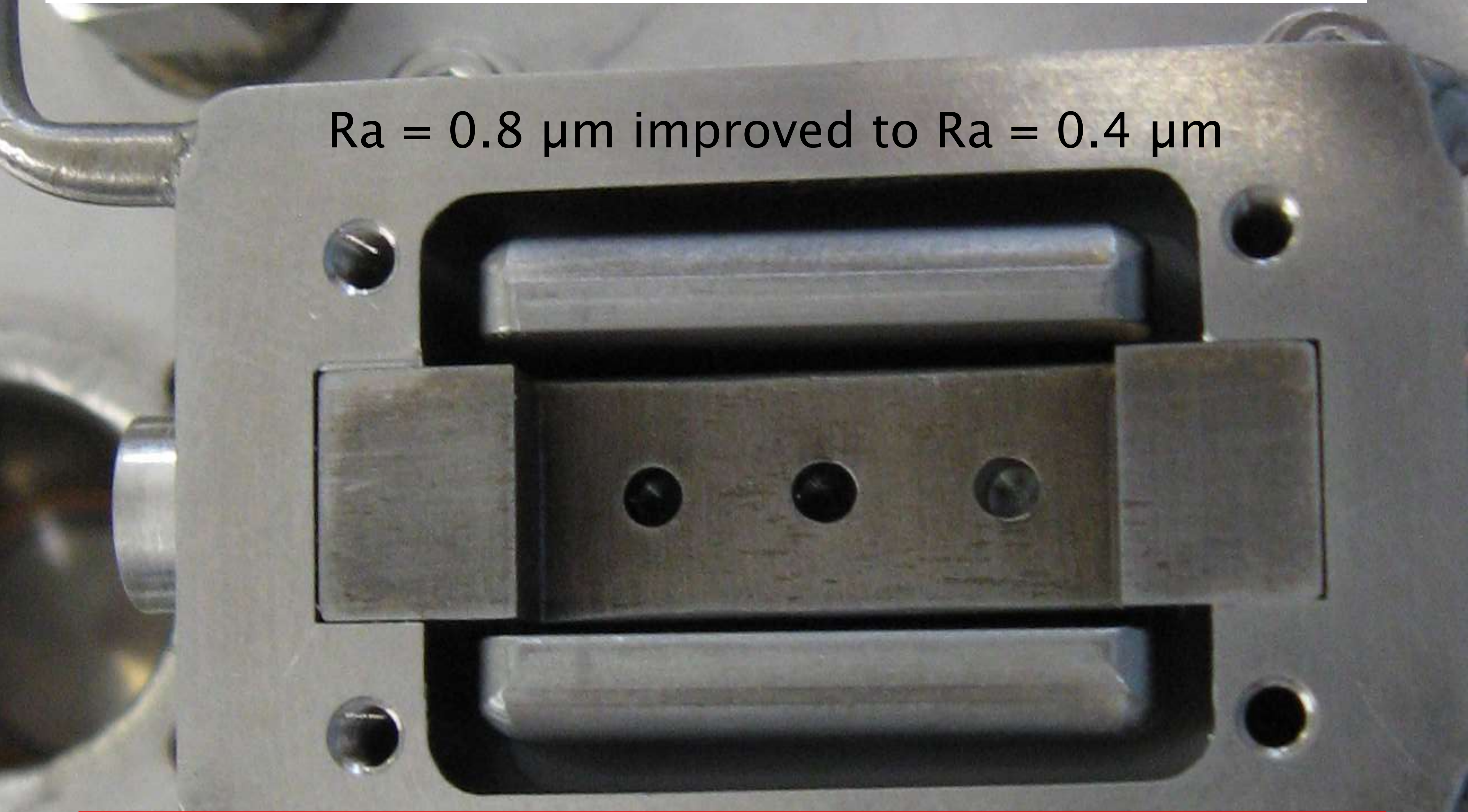
130	C		
Most clearance		Length	Width
	Anode	33.528	8.525
	Source body	33.579	8.525
	Difference	0.051	0.000
	Inter/Clear	Clearance	Clearance
Least Clearance			
	Anode	33.538	8.533
	Source body	33.559	8.515
	Difference	0.021	-0.018
	Inter/Clear	Clearance	Interference

Guaranteed clearance above 320 °C

320	C		
Most clearance		Length	Width
	Anode	33.560	8.533
	Source body	33.681	8.551
	Difference	0.121	0.018
	Inter/Clear	Clearance	Clearance
Least Clearance			
	Anode	33.570	8.541
	Source body	33.661	8.541
	Difference	0.091	0.000
	Inter/Clear	Clearance	Clearance

Anode length and width tolerances modified to:
+0.04/+0.03 and +0.048/+0.038

Thermal Contact Resistances



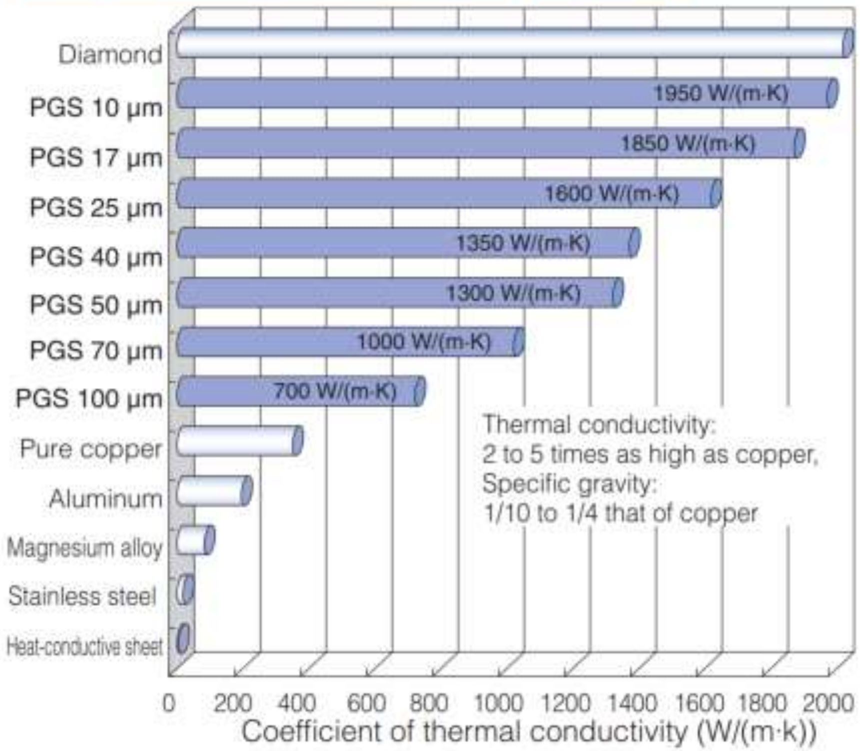
Aperture plate cooling relies on good thermal contact

overheating aperture plate

Panasonic

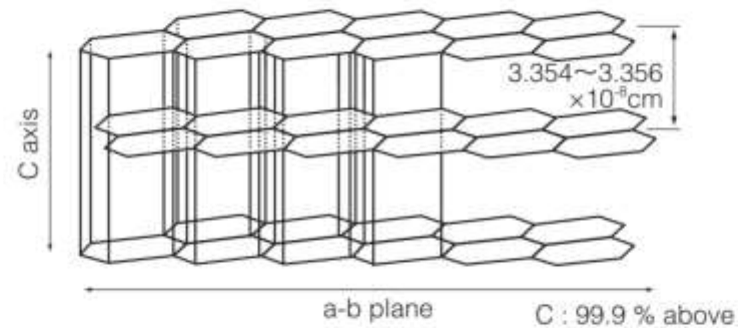
"PGS" Graphite Sheets

Comparison of thermal conductivity (a-b plane)



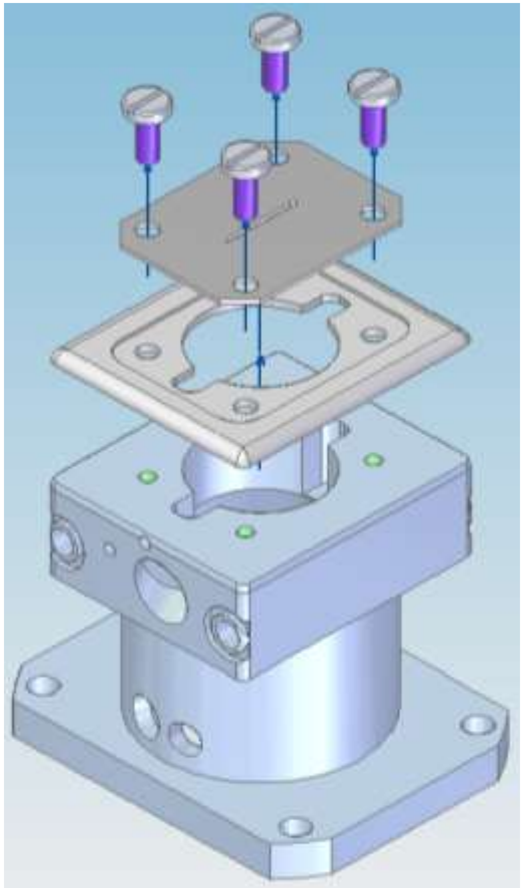
2.5x conductivity of copper!

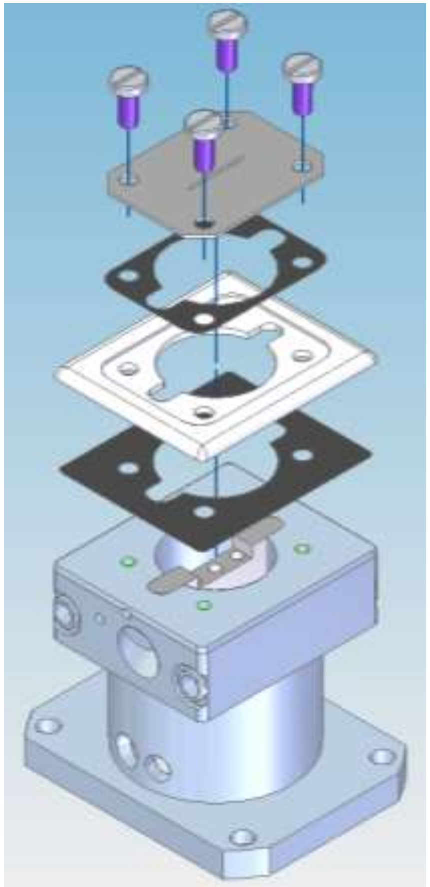
Layered structure of PGS



Laser cut 70 µm thick PGS thermal interface gasket

PGS allows biasable aperture plate

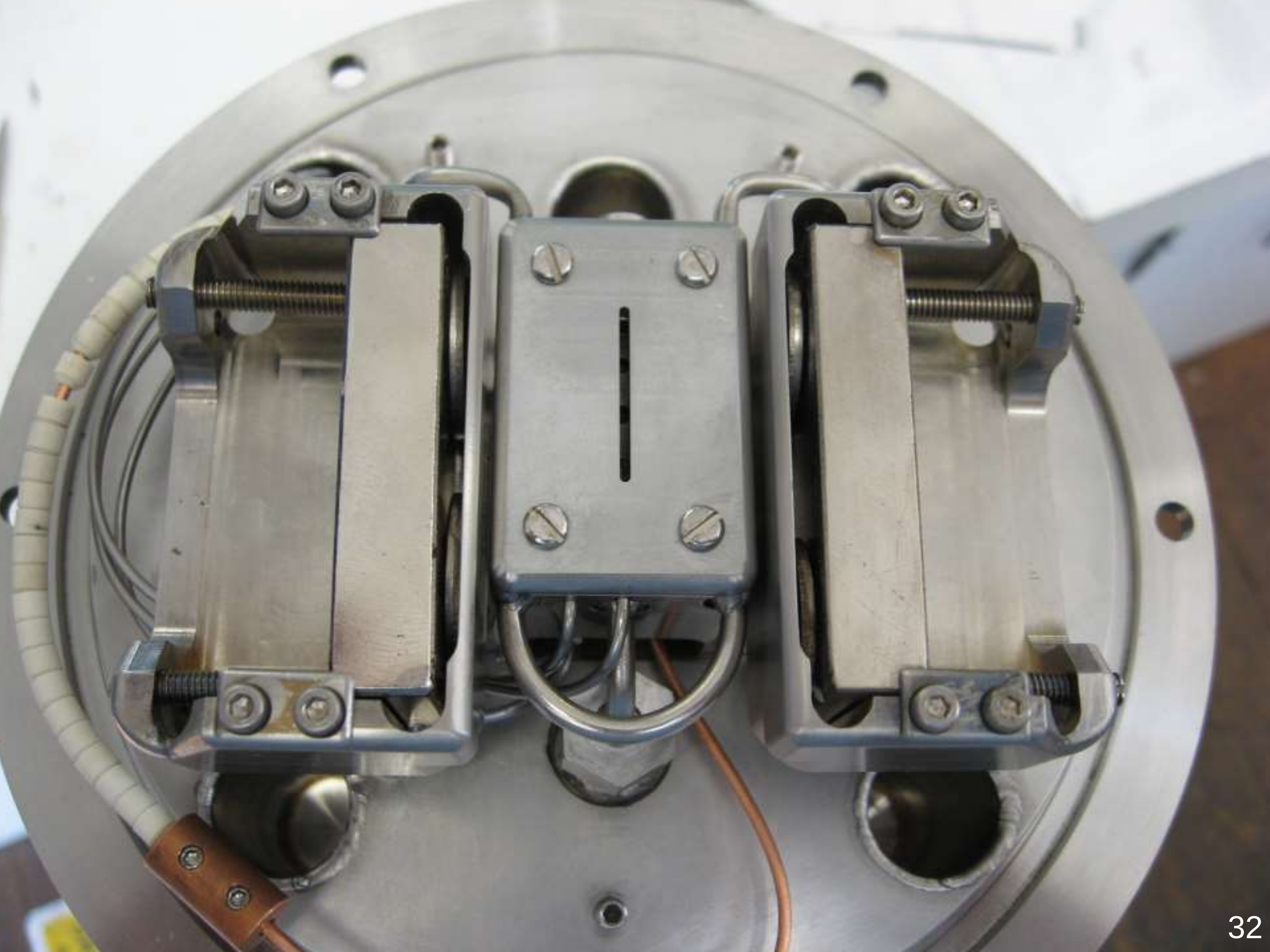




Not implemented on scaled source

Magnetic Penning Field

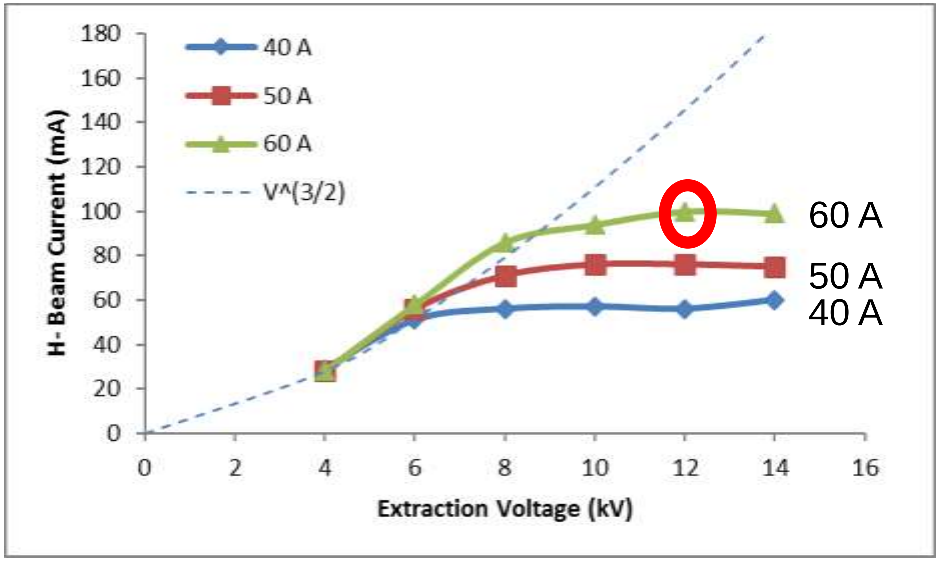
- Cathode separation is doubled in the 2X source
- Penning field should be halved
- 0.084 T found to be best after experimentation

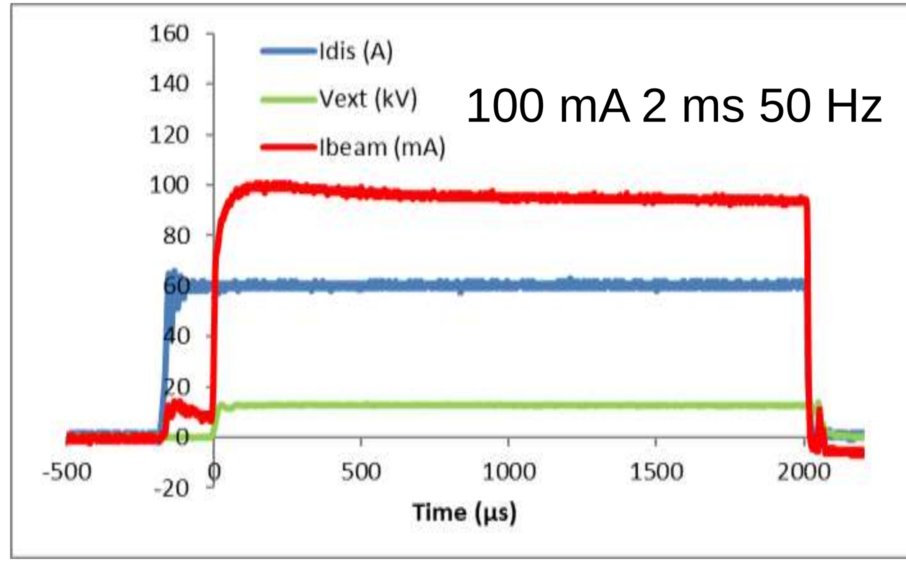


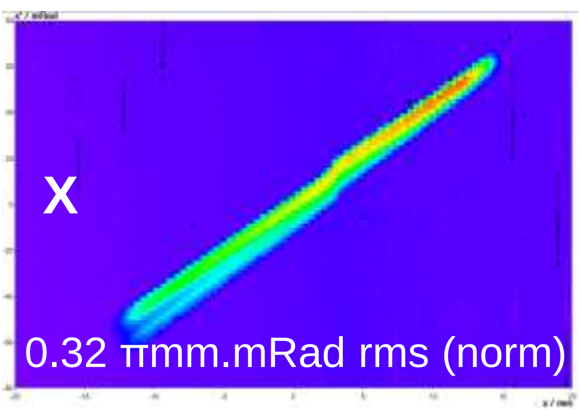
Power Supply Upgrades

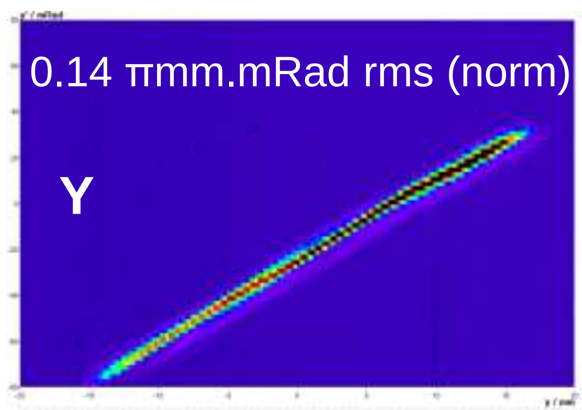
- Extraction and discharge power supplies both had to be upgraded to operate at full 2 ms 50 Hz duty cycle

Full Duty Cycle Results









60 A discharge
12 kV extraction voltage
35 keV beam
210ºC Cs oven!

See Tiago Sarmento'sTalk

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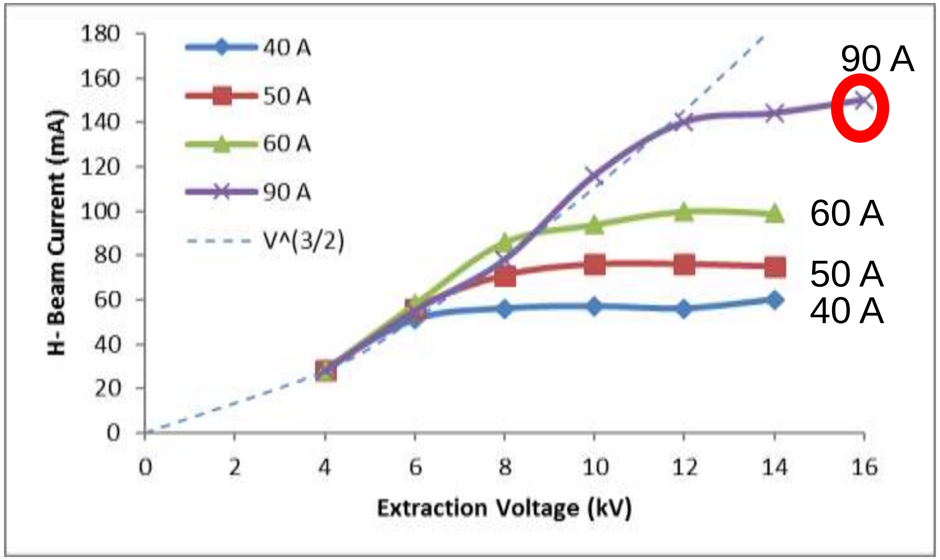
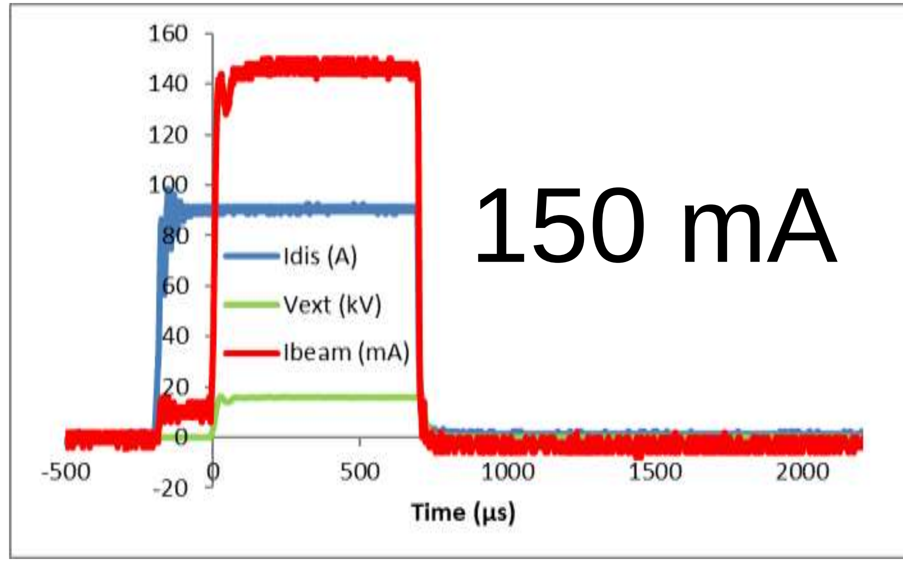
Shorter 700 μs Pulse at 90 A





90 A discharge
16 kV extraction voltage
35 keV beam
210ºC Cs oven
150 mA 700 μs 50 Hz

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Next Steps

- Integration on to FETS
- Lifetime tests
- Investigate high caesium/noise problem
- Investigate scaling laws
- Deliver a scaled source to Fermilab

Acknowledgements:
Phil Wise,Theo Rutter, Bradley Kirk
Joe Sherman, Vernon Smith
Vadim Dudnikov

Thank you for your attention

Questions, Comments?

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