

Star Pinch Power and Life Scaling

PLEX LLC

Brookline, MA

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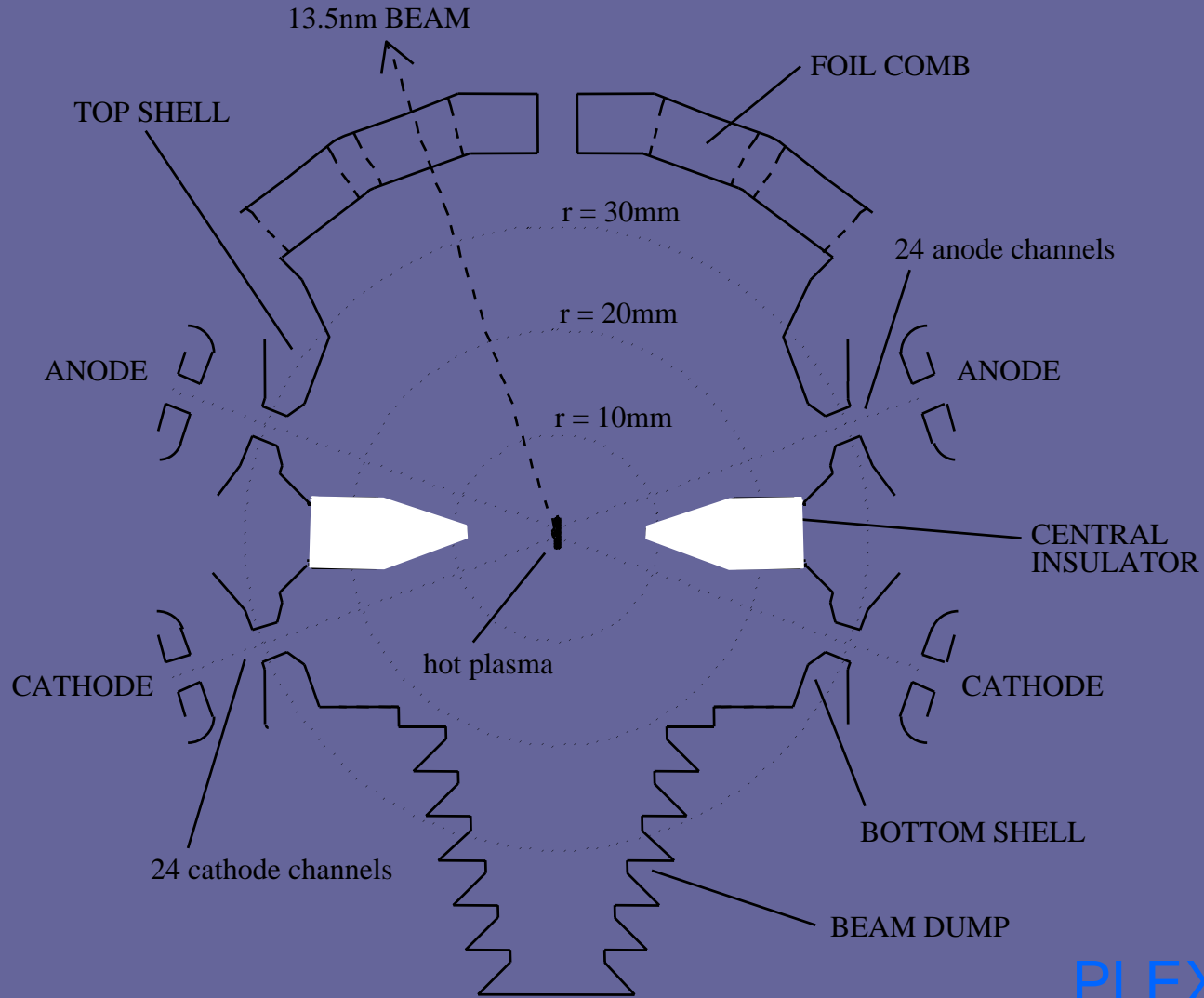
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work supported by Venture Capital and DARPA

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Star Pinch EUV Source: Schematic View of Chamber



Note: For proprietary reasons details not exact.



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“FLYING CIRCUS” visit 12-03 verified PLEX Antwerp Data

(see talk later today by Eric Louis)

UPGRADE SINCE VISIT:

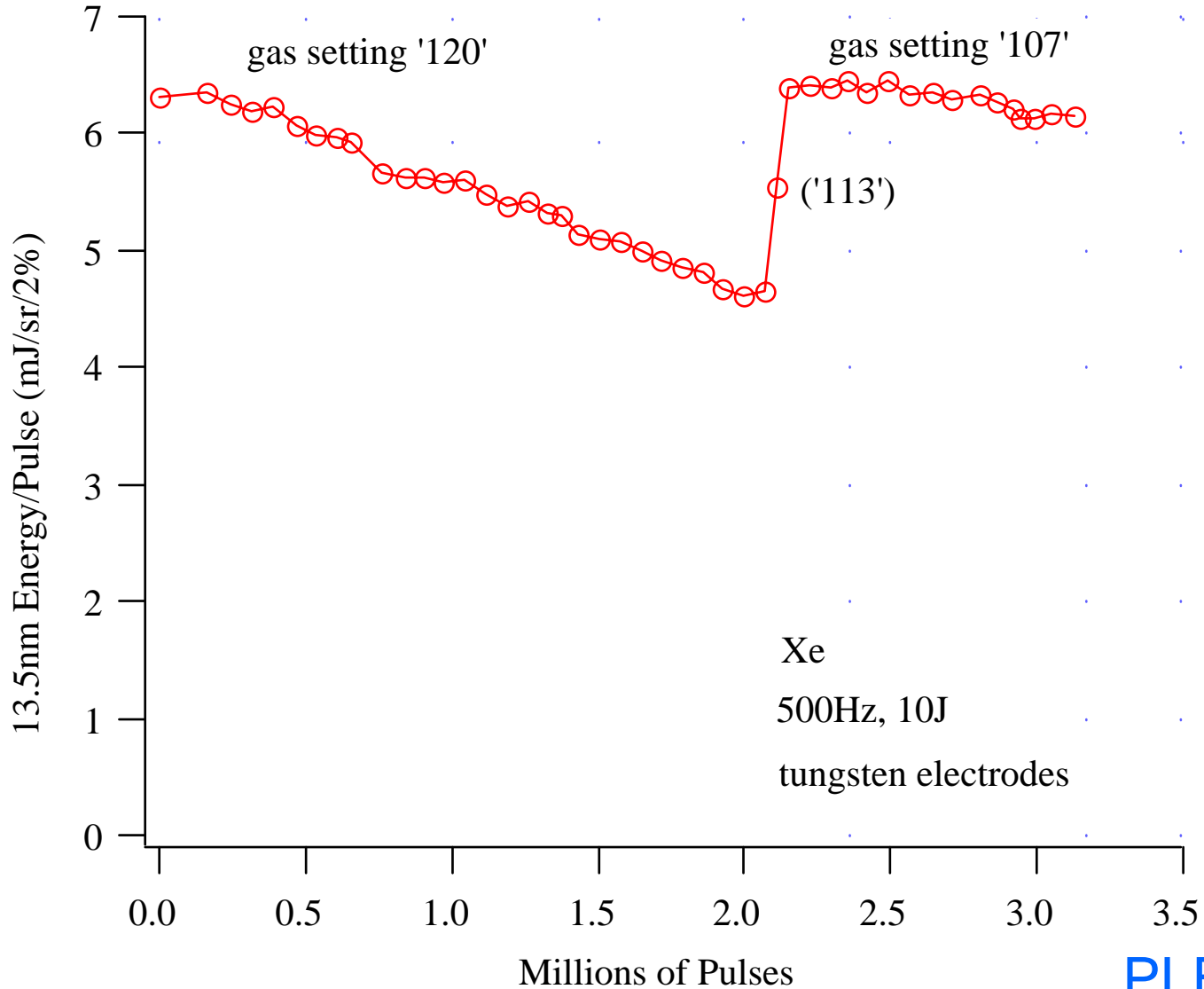
Copper to Tungsten electrodes and better gas distribution

--> Decrease in Plasma Size by 20%

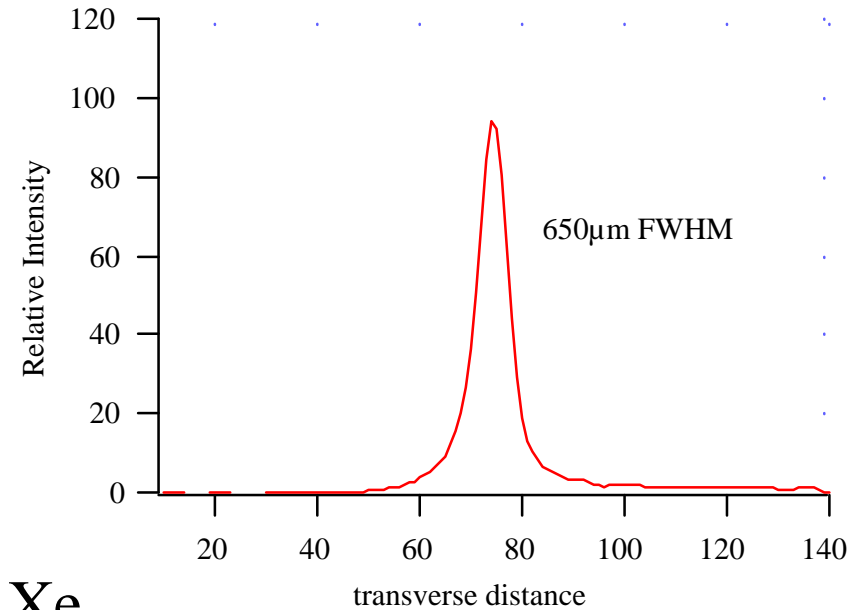
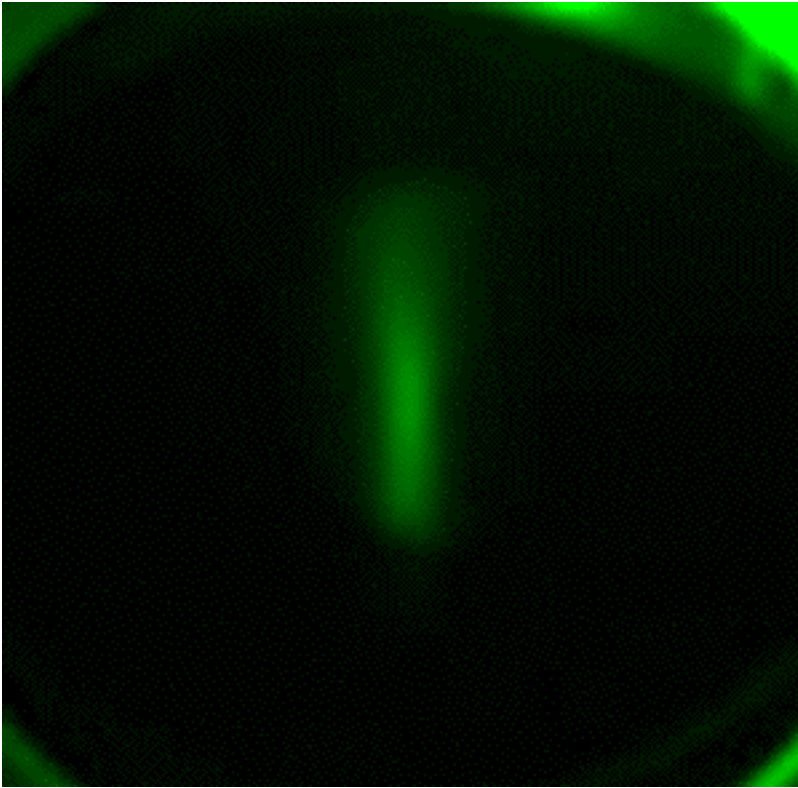
--> Excellent Positional Stability

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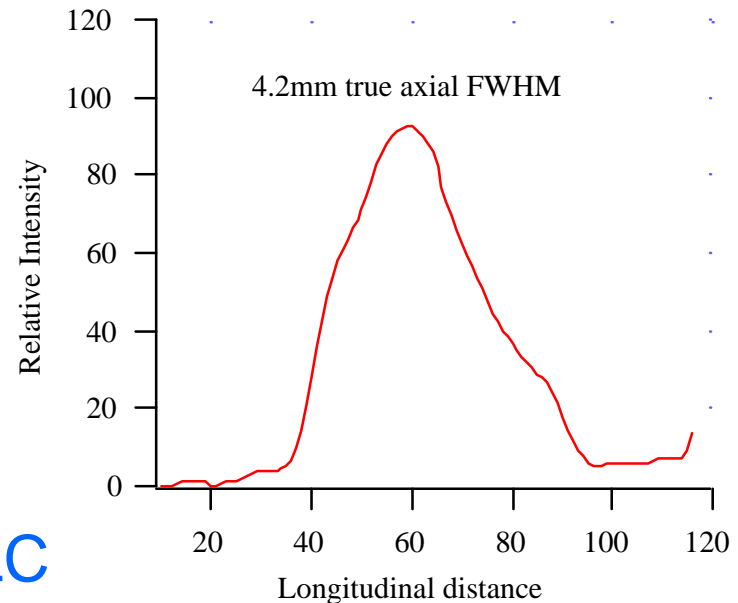
Tungsten Electrode Upgrade, 500Hz Run



40 deg image, tungsten electrode upgrade, 1kHz, 6.5mJ/sr/2%



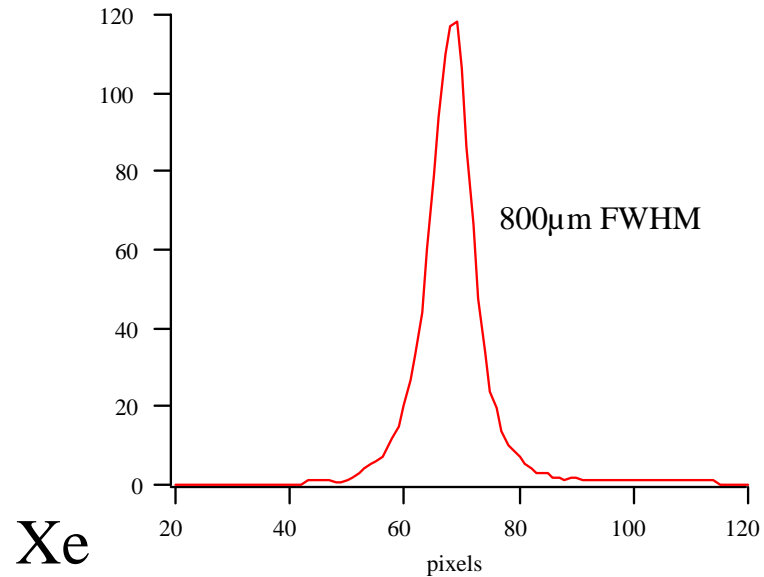
Xe



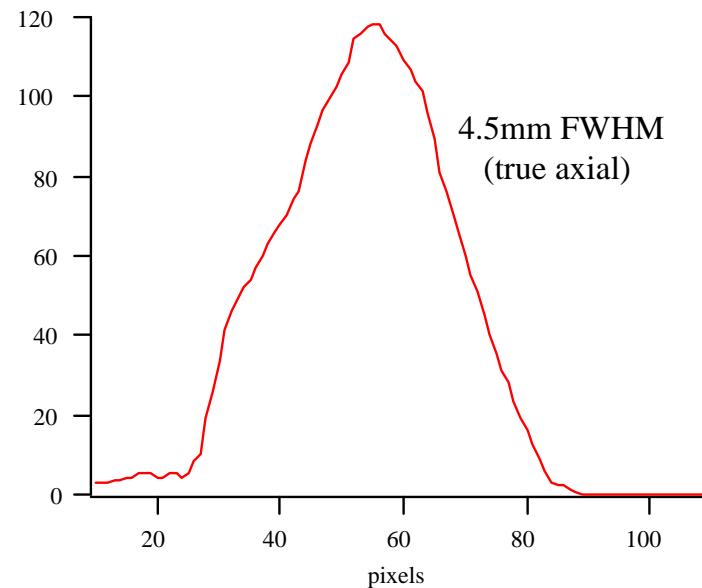
Lateral stability 68 μ m (1σ)
(from 10 measurements,
each comprising 250
pulses superimposed)

40 deg image, tungsten electrode upgrade, 2kHz , 6mJ/sr/2%

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.



Lateral stability 50µm (1σ)
(from 4 measurements,
each comprising 500
pulses superimposed)



PERFORMANCE WITH XENON

Life Test to 30million pulses at 10J

Light Erosion projects --> 10^9 pulses at 5J

7mJ/pulse/2%BW/sr, efficiency 0.5%

5sec at 2kHz (20kW), continuous at 1kHz (10kW)

Very Stable Plasma Location

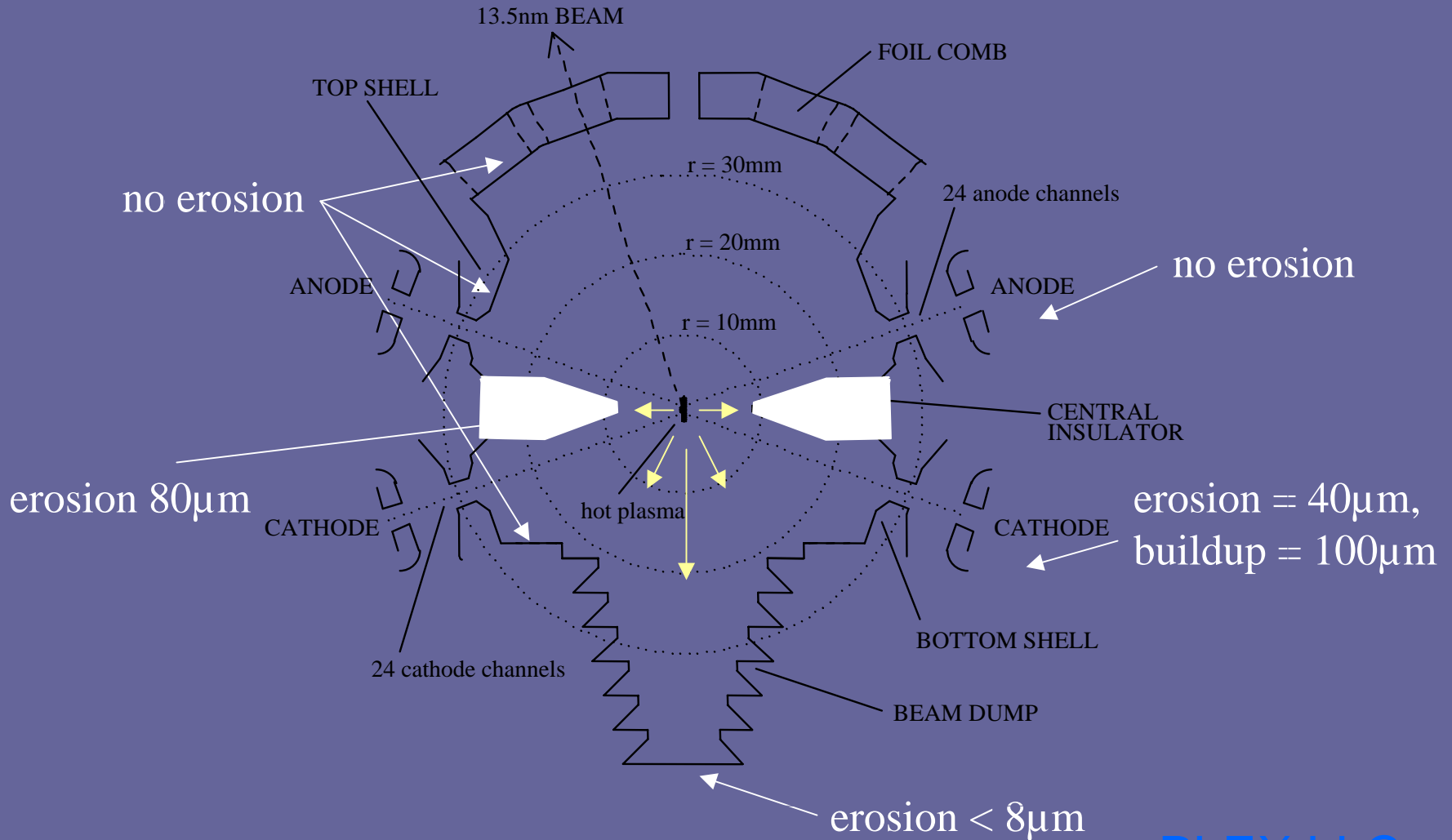
Plasma Diameter 650 μ m

Plasma Length 4mm --> 7W I.F. at 2kHz

Collection angle 2.5sr

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Life Testing, Data from 30 million pulses



LIFE EQUATION (SPUTTER LIMIT)

$$N = 3 \times 10^4 \times \frac{r^2 \delta U}{ES}$$

N = number of pulses to erosion depth δ (mm)

r = distance from plasma to nearest surface (mm)

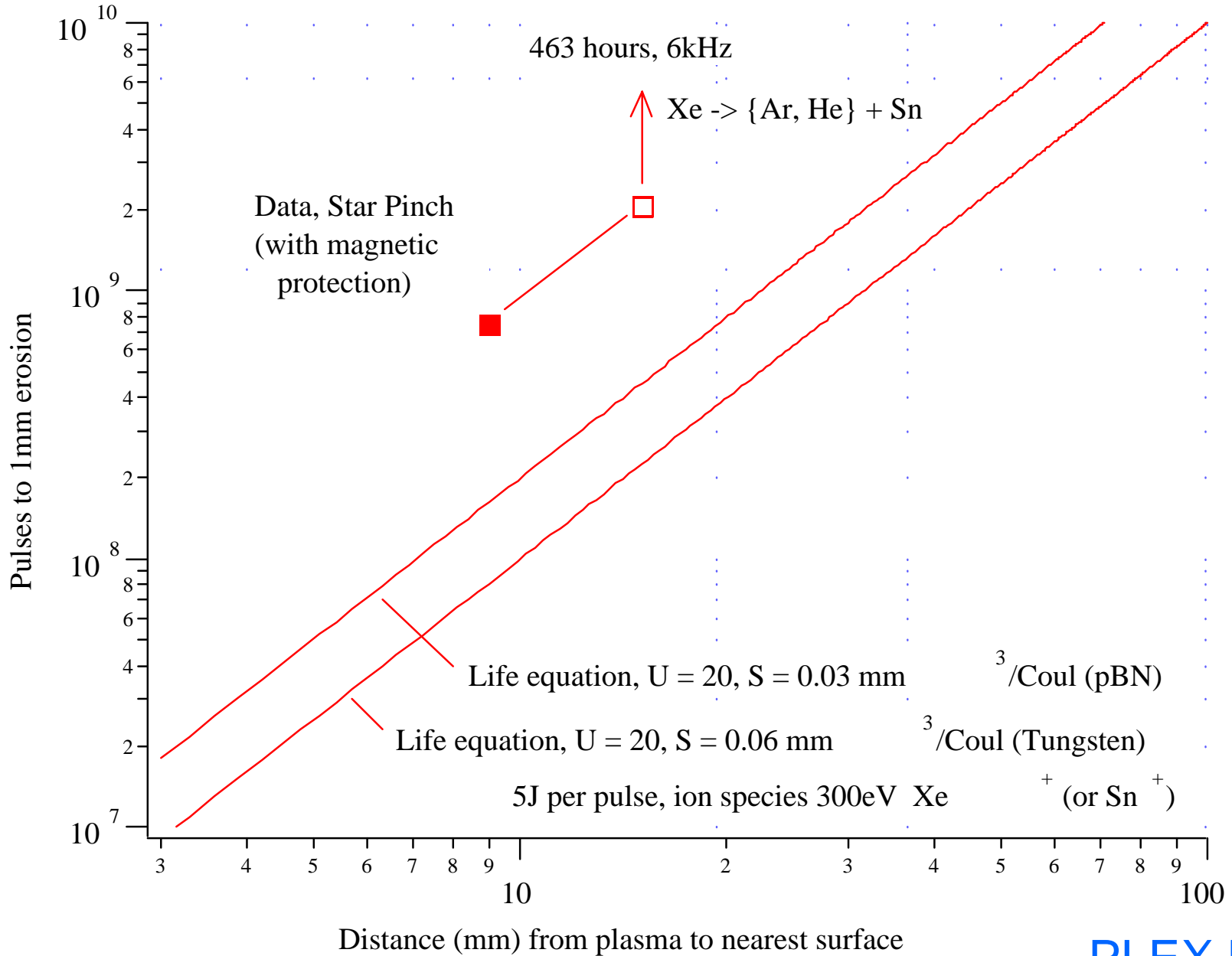
U = ion utilization factor

E = discharge pulse energy (Joules)

S = Sputter coefficient (mm^3/Coul)

Number of plasma ions = $E/(2.5\text{keV}) \times (1/U)$

STAR PINCH LIFE SCALING



Calorimetry

Fractional power:

Cathode 8%

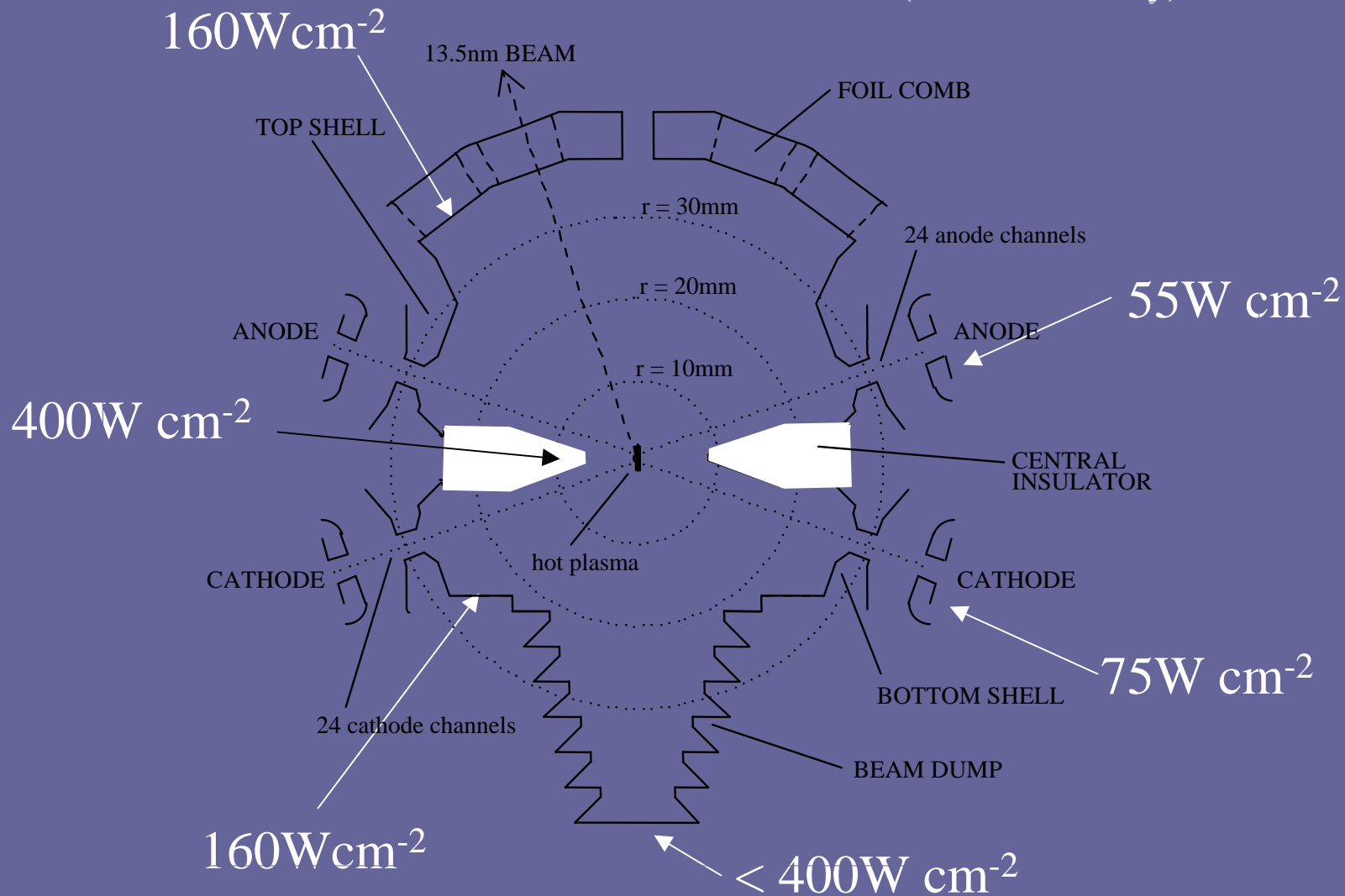
Anode 6%

Foil Comb 13%

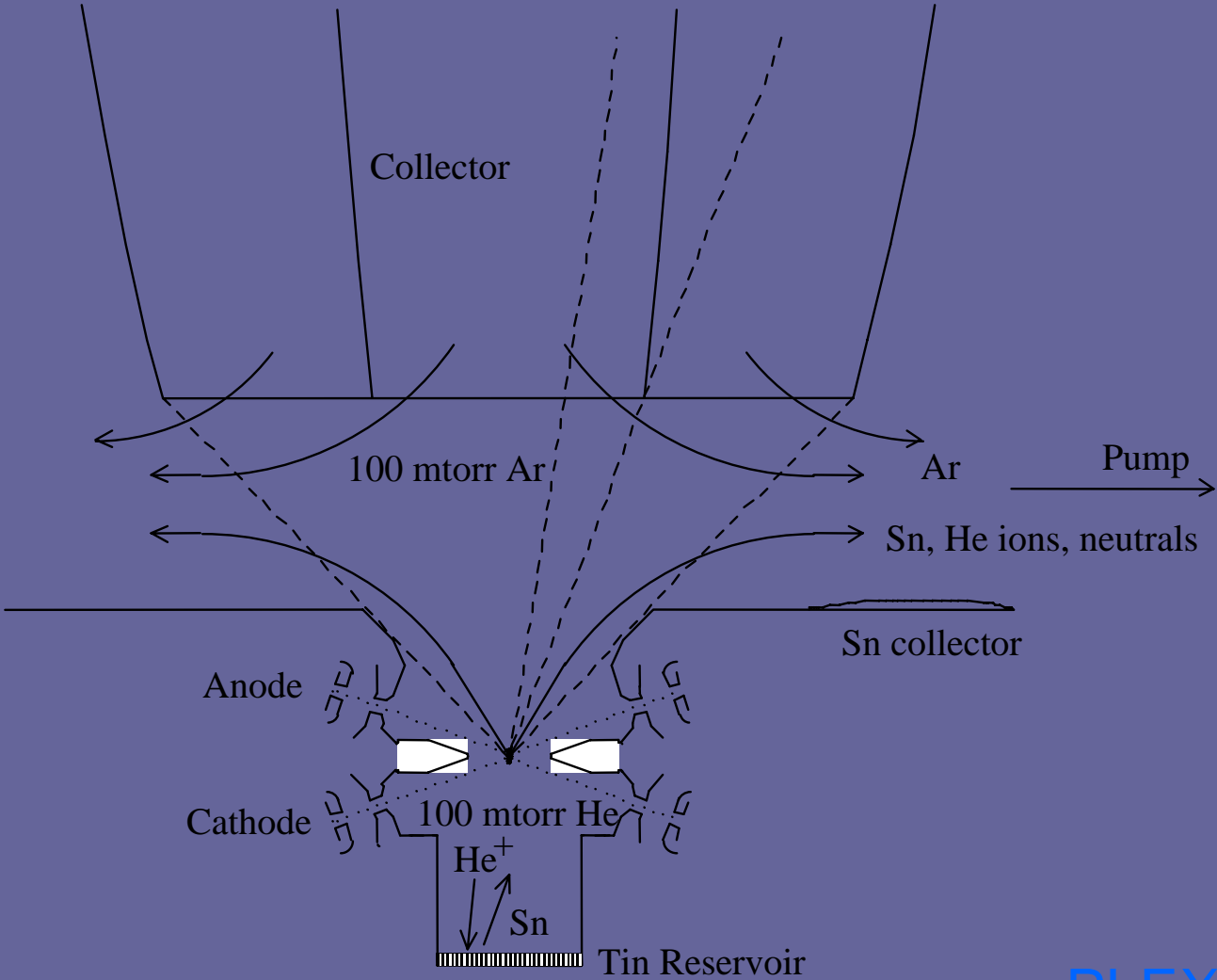
Chamber 73%

Heat Loads at 30kW Dissipated (120W clean at 1st Focus)

(2.5% efficiency)



Star Pinch Operates with Tin



Preliminary Tin Data from Star Pinch

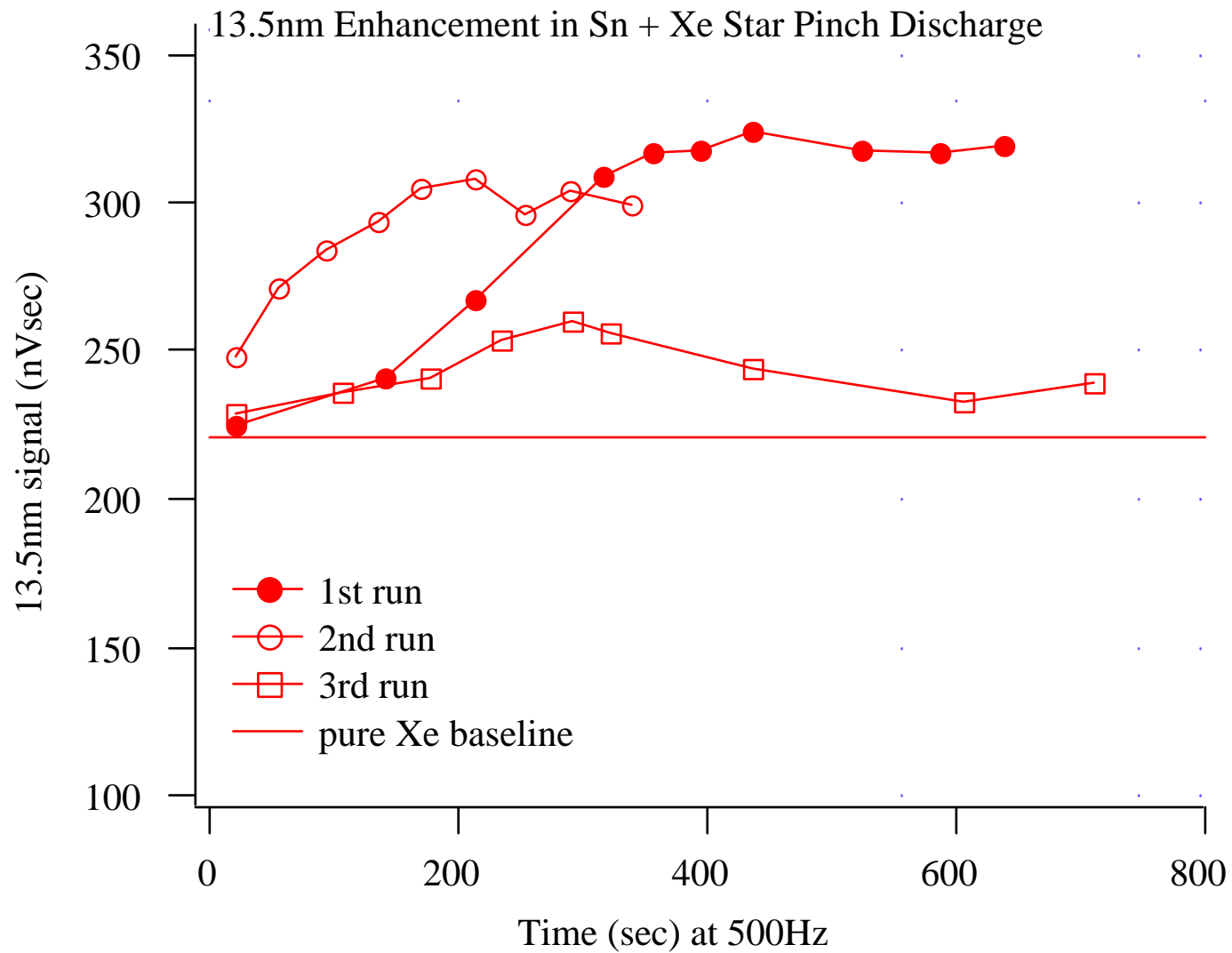
Sputter tin source demonstrated using Xe

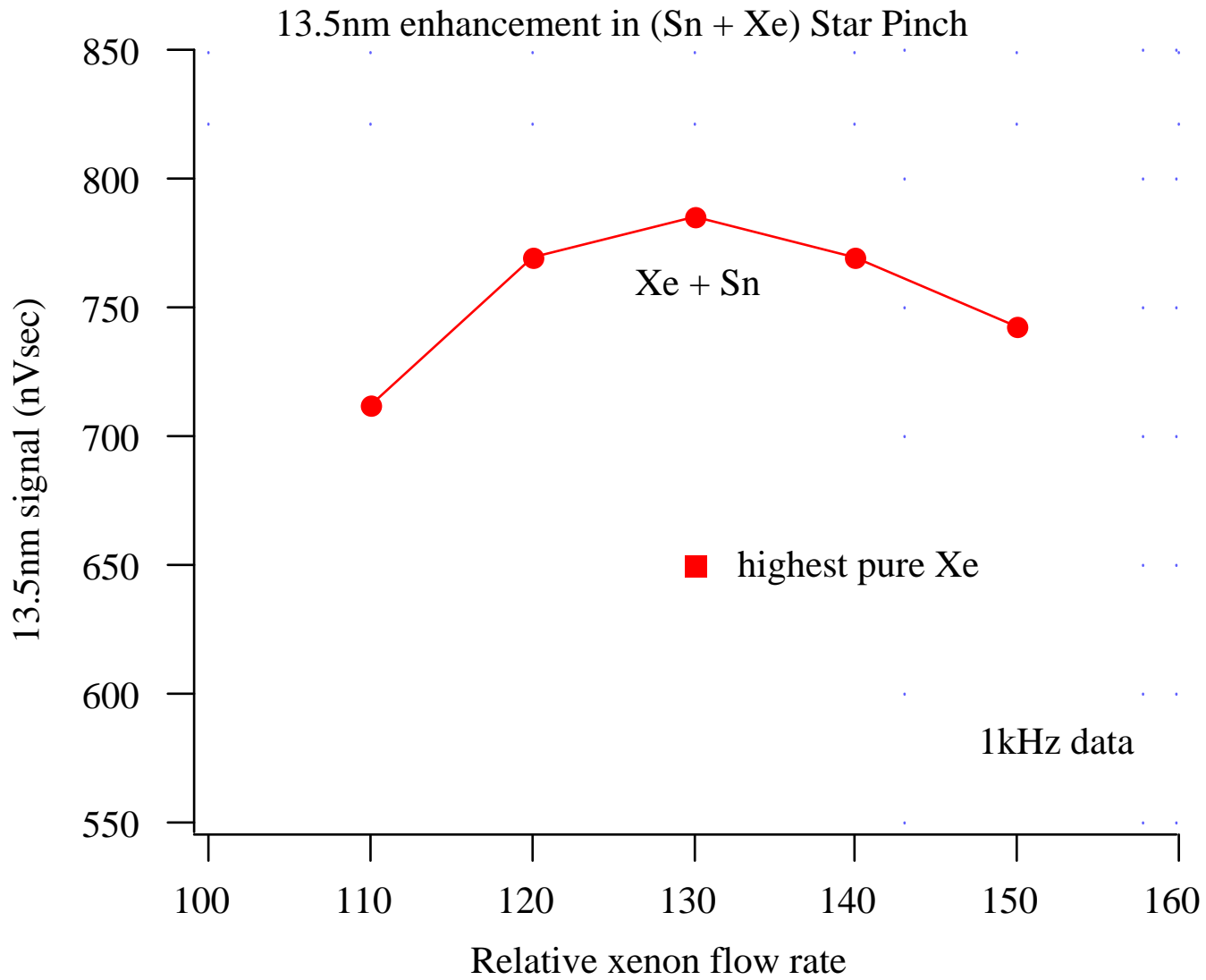
(Experiment using helium did not sputter enough Sn)

Pure Xe working gas + Sn surface layer on beam dump

Efficiency enhancements of 21 - 44% over pure Xe

Decay after approx 30min operation (500Hz and 1kHz)
due to complete removal of Sn layer by sputtering





FUTURE 120W SYSTEM COMPARISON

	STAR PINCH GDP	LPP
Efficiency	2.5%	2.5%
Diameter (Sphere)	0.7mm	0.5mm
Collection	2sr	3sr
Debris shield	0.8	0.8
Collector	0.6	0.6
Drive efficiency	0.8	0.1
Plasma Power	31kW	21kW
Wall-Plug	39kW	210kW
Life at 5J/pulse	10^{10}	?

120W SYSTEM COMPARISON (ctd.)

	STAR PINCH GDP	LPP
Rep. Rate	>6kHz	>6kHz
Capital cost	\$1.5m	?
Operating cost	\$90K/yr	?
Footprint	2 squ m	?
Future	>200W I.F.	?

CONCLUSIONS

Sn runs cleanly in Star Pinch, less Plasma Power needed

Star Pinch Life at Sputter Limit is 10^9 Pulses today

Clear Path exists to 10^{10} pulse Life:-

Extension to 15mm (12.5mm shown) and Xe \rightarrow Ar/He

Reduction of plasma size to 0.7mm sphere underway

Power supply upgrade 20kW to 40kW underway

Star Pinch will be Effective and Inexpensive in HVM

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