Design Window for Chamber with Tungsten/Steel First Wall

Jake Blanchard, Don Haynes, Jerry Kulcinski

Fusion Technology Institute

University of Wisconsin

NRL

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Goal

- Determine operating windows for a chamber with a first wall with tungsten on an ODS ferritic steel
- Approach
  - Take energy splits from Bucky
  - Take deposition profiles from UCSD plots (and simplify)
  - Find temperatures using 1-D ANSYS runs (transient, temperature dependent properties)

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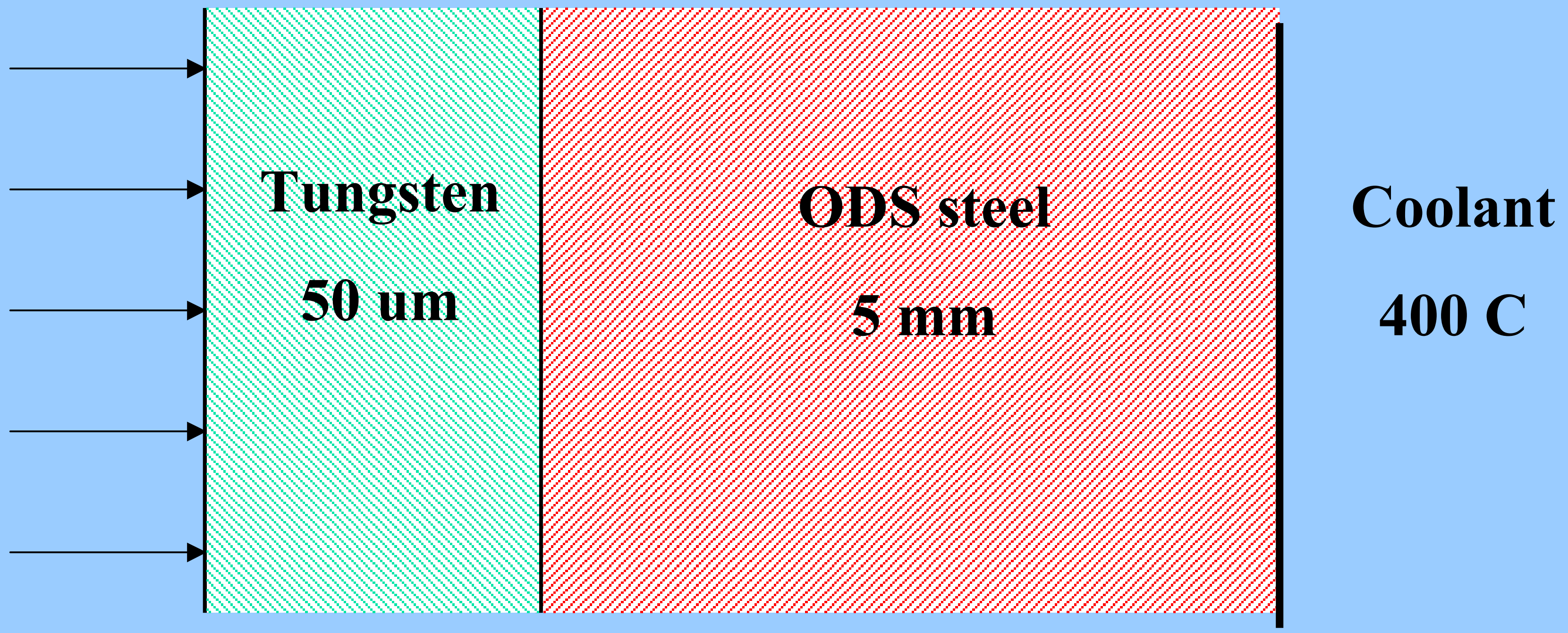
Wall Design



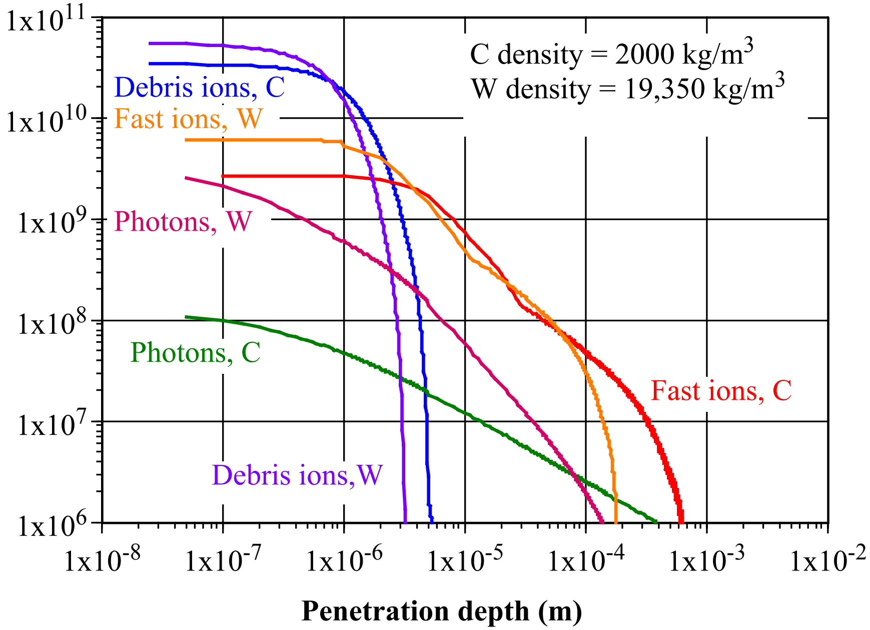
Energy Splits (MJ)

Source	Low Yield	High Yield
X-rays	2	6
Burn ions	19	49
Debris ions	25	65
Neutrons	108	280
TOTAL	154	400

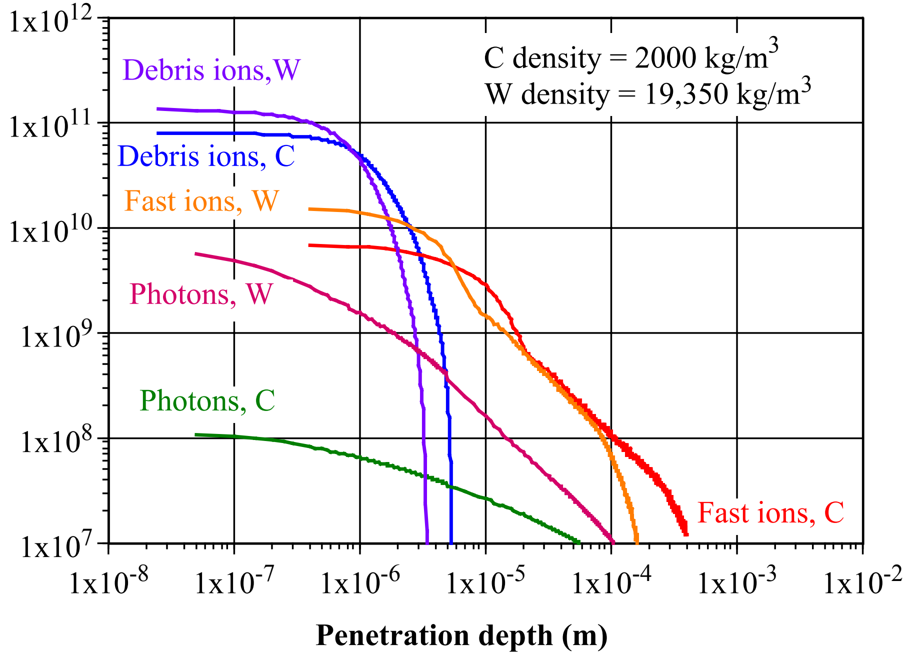
Spatial Profile of Volumetric Energy Deposition in C and W for Direct Drive Target Spectra

- **Tabulated data from SRIM for ion stopping power used as input**

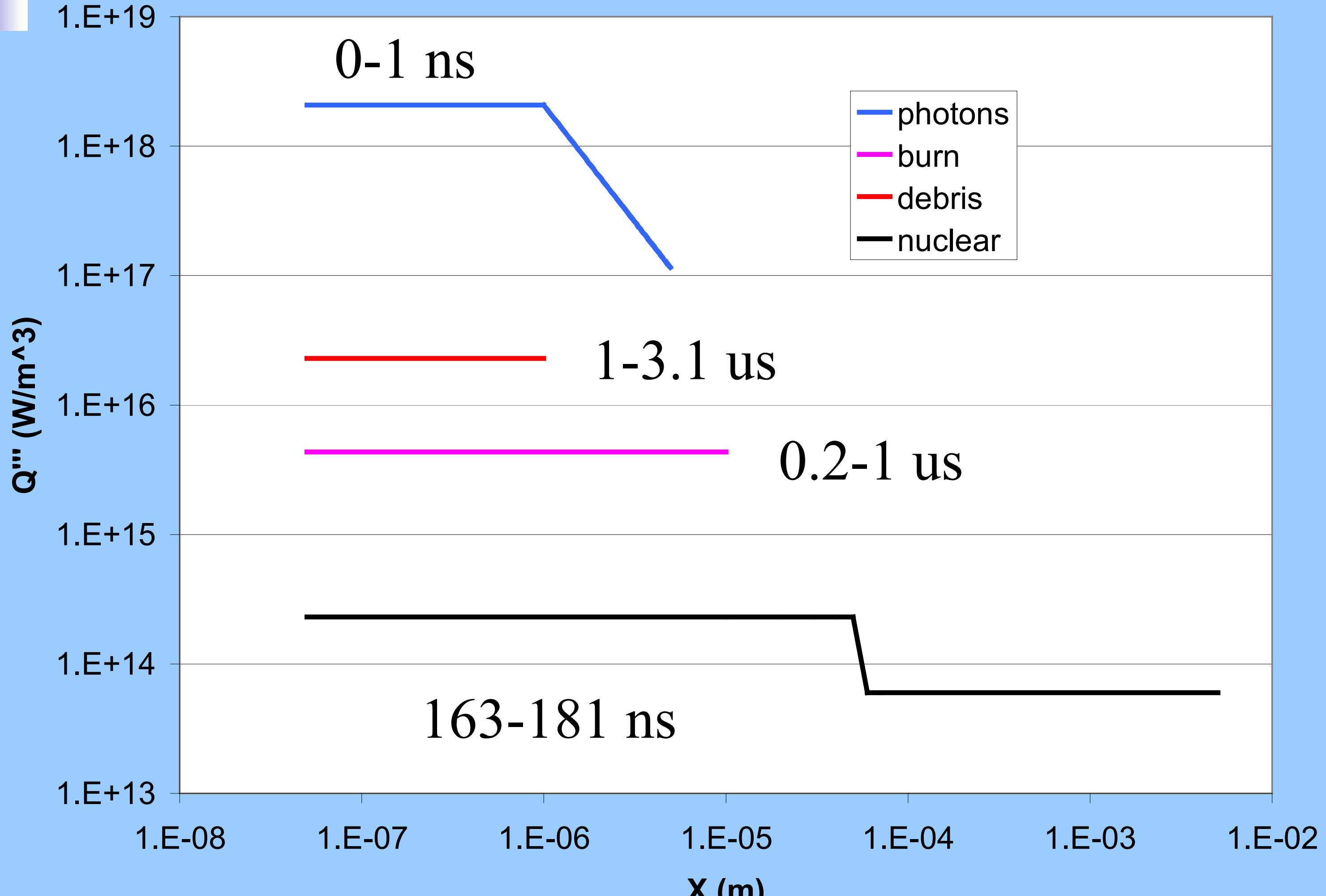
Energy Deposition as a Function of Penetration Depth for 154 MJ NRL DD Target



Energy Deposition as a Function of Penetration Depth for 401 MJ NRL DD Target



Sample Heating Distributions
Low Yield – 6.5 m Chamber – No Gas



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Cases Considered

- Chamber Radius: 5.5-10 m
- Tungsten Thickness: 50 and 100 microns
- Chamber Xe Gas Pressure: 0, 10, and 20 mTorr
- High Yield and Low Yield Targets
- 5 Hz rep rate

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Properties

- W
  - Properties are Temp. dependent
  - T_{melt}=3310
- ODS FS
  - K=33 W/m-K
  - Cp=500 J/kg-K
  - Density=7800 kg/m^3
  - T_{max}=800 C
- Coolant
  - h=10,000 W/m^2K
  - T_{bulk}=400 C
- Geometry
  - 50 microns W
  - 5 mm ODS FS

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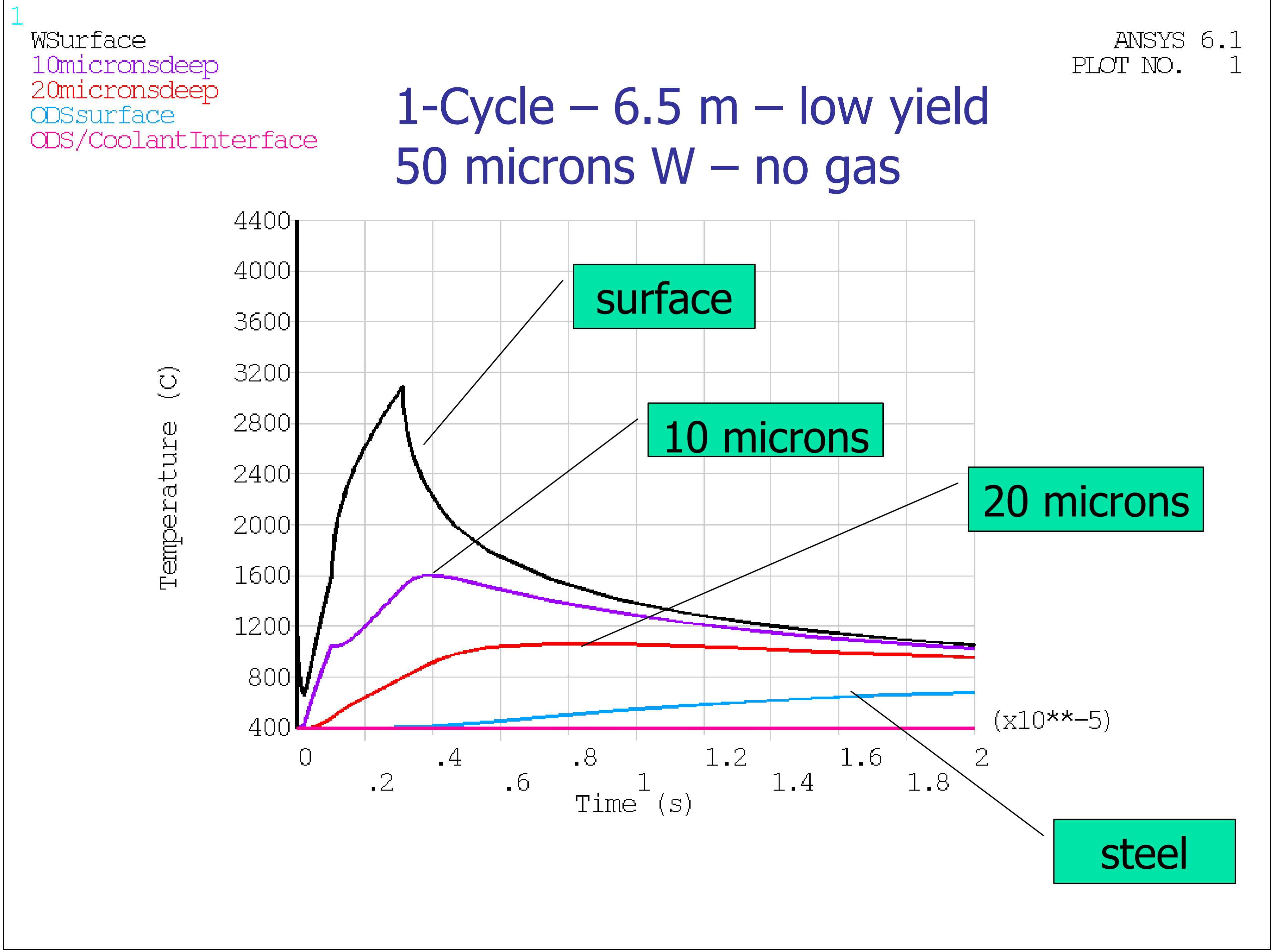
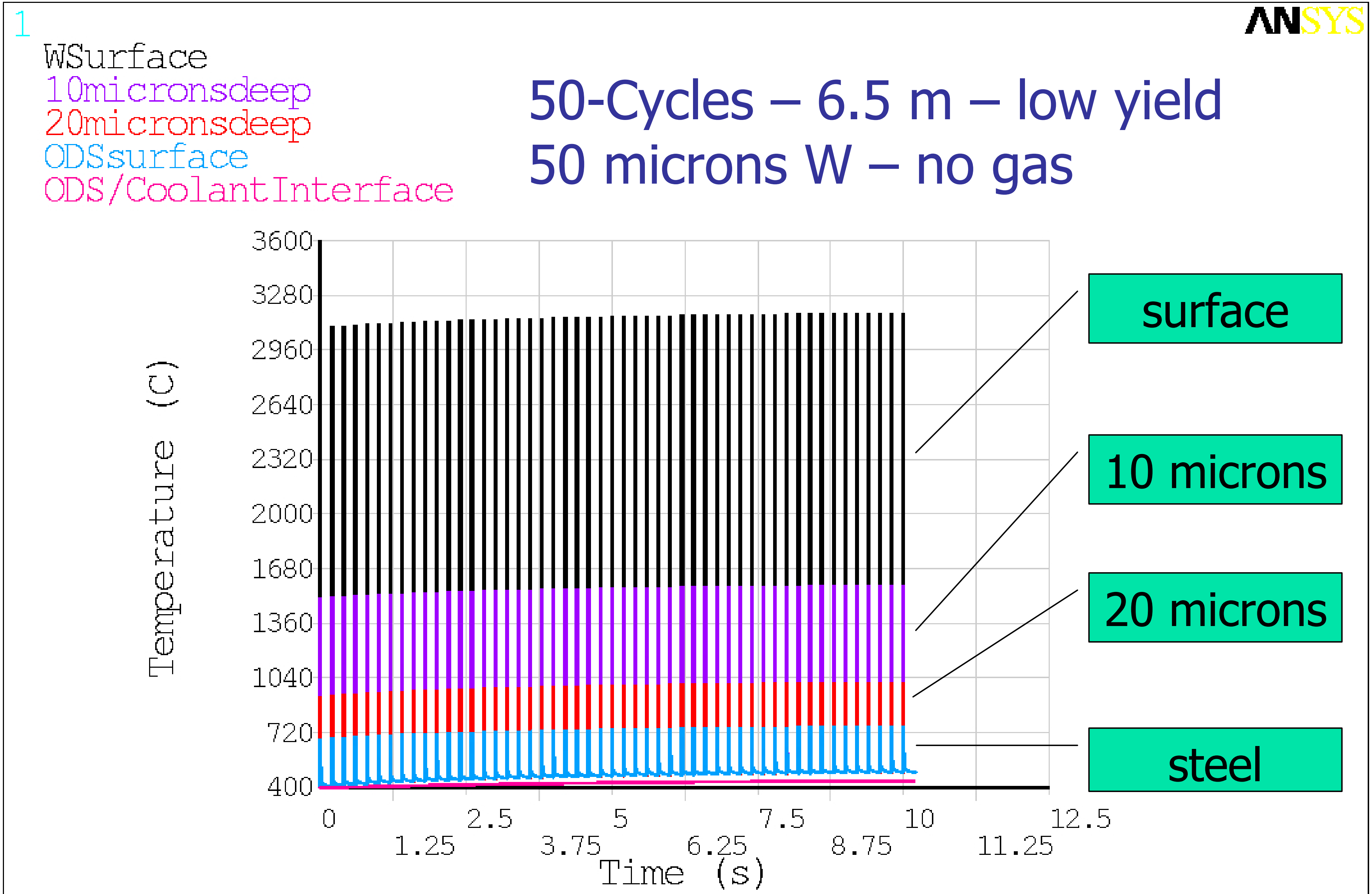
Including Chamber Gas

- For 6.5 m chamber – 10 mTorr
  - Photon power is reduced by 9%
  - Burn ion power is reduced by 1%
  - Debris ion power is reduced by 29%
- Reductions are 16, 2, and 48% for 20 mTorr
- All timing and spatial deposition inputs are retained
- Heat in gas re-radiated to surface from 300-700 microseconds



1
WSurface
10micronsdeep
20micronsdeep
ODSsurface
ODS/CoolantInterface
ANSYS 6.1
PLOT NO. 1
1-Cycle – 6.5 m – low yield
50 microns W – no gas
surface
10 microns
20 microns
steel
Temperature (C)
4400
4000
3600
3200
2800
2400
2000
1600
1200
800
400
0
.2
.4
.6
.8
1
1.2
1.4
1.6
1.8
2
(x10**-5)
Time (s)



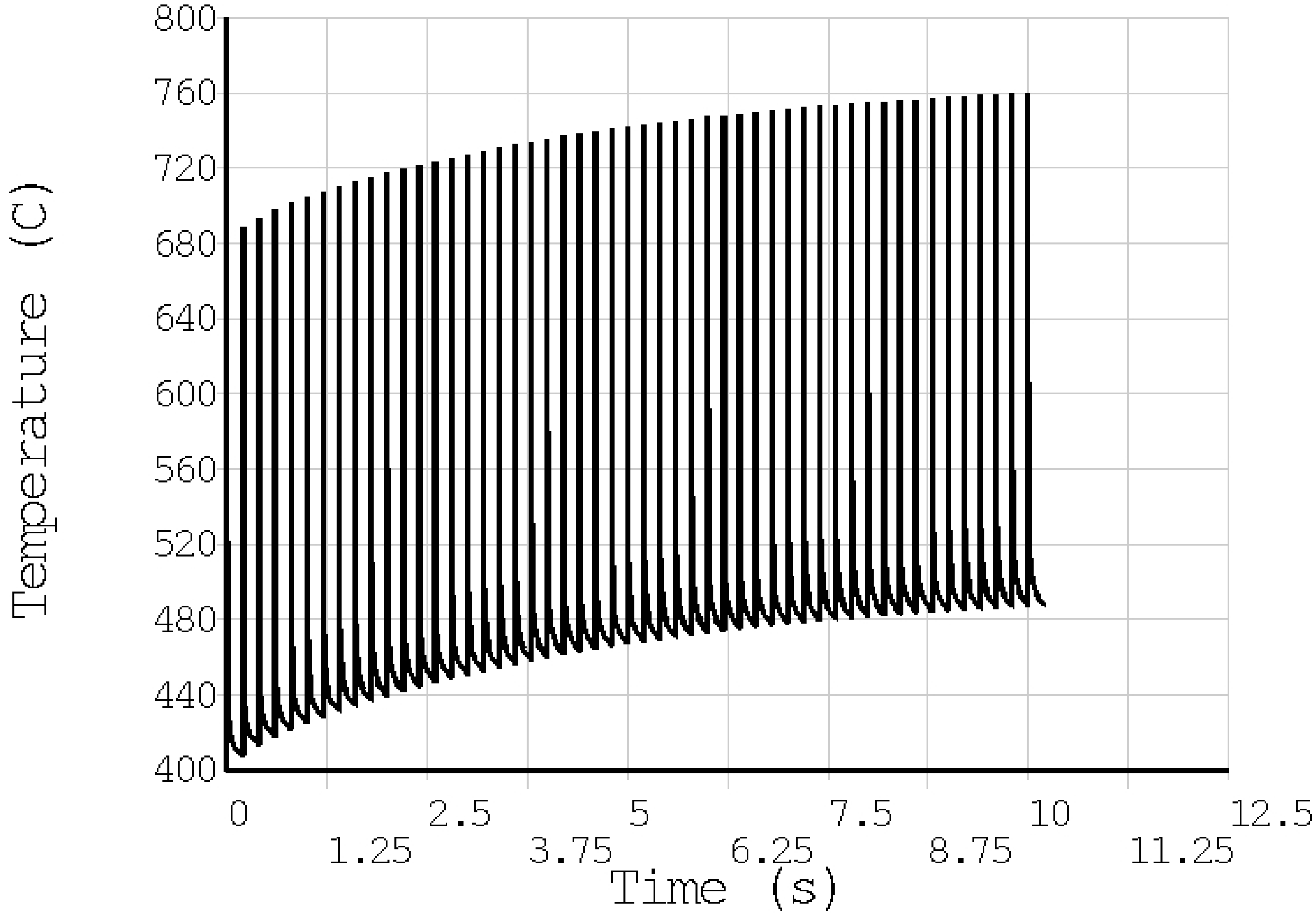
1
ANSYS
WSurface
10micronsdeep
20micronsdeep
ODSsurface
ODS/CoolantInterface
50-Cycles – 6.5 m – low yield
50 microns W – no gas
Temperature (C)
3600
3280
2960
2640
2320
2000
1680
1360
1040
720
400
0
1.25
2.5
3.75
5
6.25
7.5
8.75
10
11.25
12.5
Time (s)
surface
10 microns
20 microns
steel

1

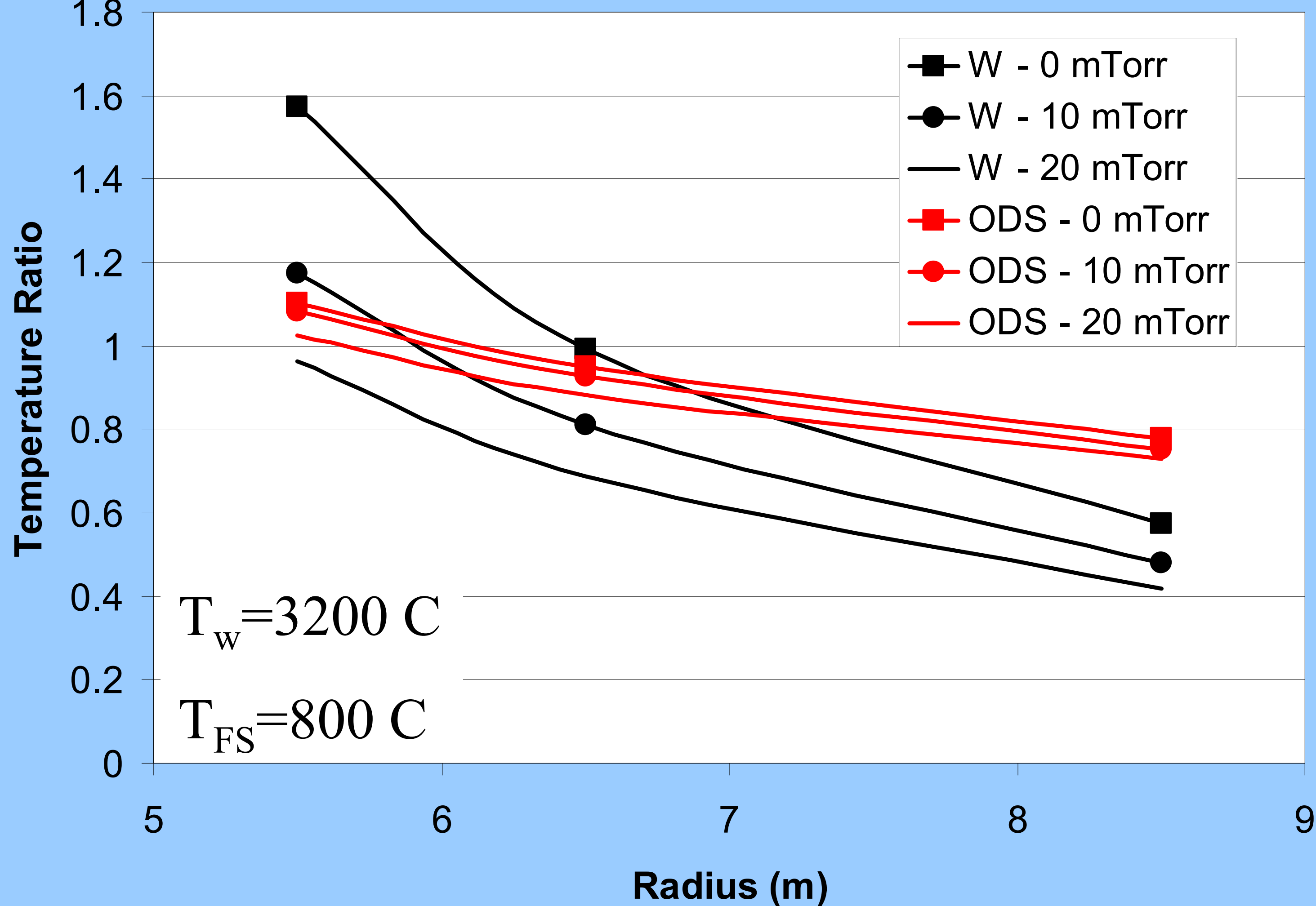
ODSsurface

ANSYS

50-Cycles - Steel Temperature – 6.5 m – low yield - 50 microns W – no gas



Effect of Varying Radius (and gas pressure)



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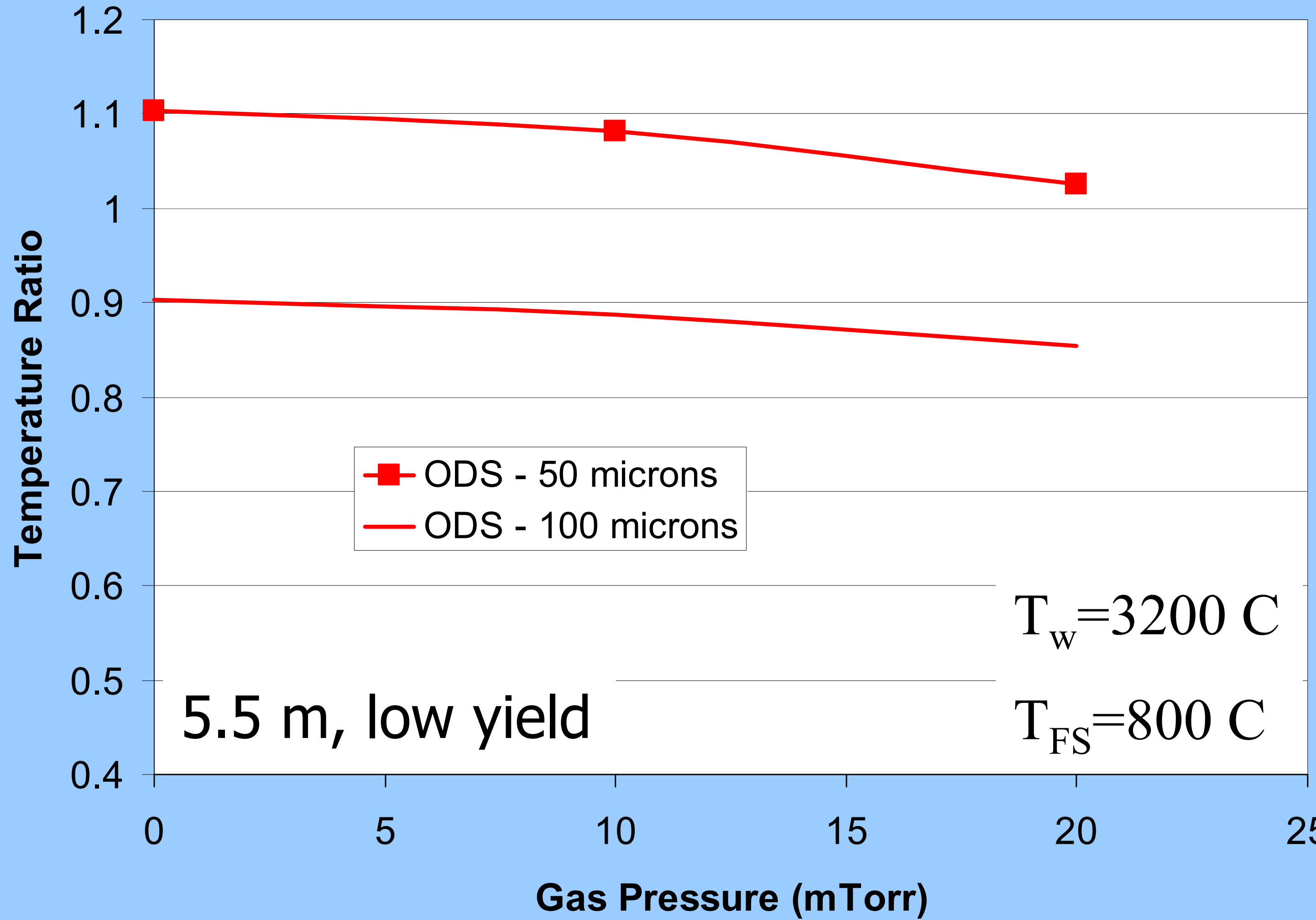
Effect of Varying Gas Pressure (and W thickness) on ODS Temp.



Summary
Low Yield Target

R (m)	W thickness (microns)	Gas pressure (mTorr)	T_w (C) Max	T_{ods} (C) Max	$T_{interface}$ (C) Max
8.5	50	0	1838	623	423
6.5	50	0	3176	760	438
5.5	50	0	5034	883	452
5.5	100	20	3075	683	454

$T_{\text{bulk coolant}} = 400\ °C$

Chamber can be as small as 5.5 m radius with reasonable inputs

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Summary
High Yield Target

R (m)	W thickness (microns)	Gas pressure (mTorr)	T_w (C) Max	T_{ods} (C) Max	$T_{interface}$ (C) Max
9	100	10	3163	723	458
10	50	0	3006	807	443

$T_{\text{bulk coolant}} = 400\ °C$

Chamber can be as small as 9 m radius with reasonable inputs

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Successful Designs

Target	Design
Low Yield	5.5 m, 100 microns W, 20 mTorr gas pressure
Low Yield	6.5 m, 50 microns W, No gas
High Yield	9 m, 100 microns W, 10 mTorr gas pressure
High Yield	10 m, 50 microns W, No gas

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Conclusions

- Debris ion heating dominates the peak temperatures in the tungsten
- Gas in the chamber reduces the tungsten temperature, but has little effect on the steel temperature
- Increasing the tungsten thickness reduces the steel temperature
- The low yield target can be used with a chamber as small as 5.5 m radius
- The high yield target can be used with a chamber as small as 9 m radius

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