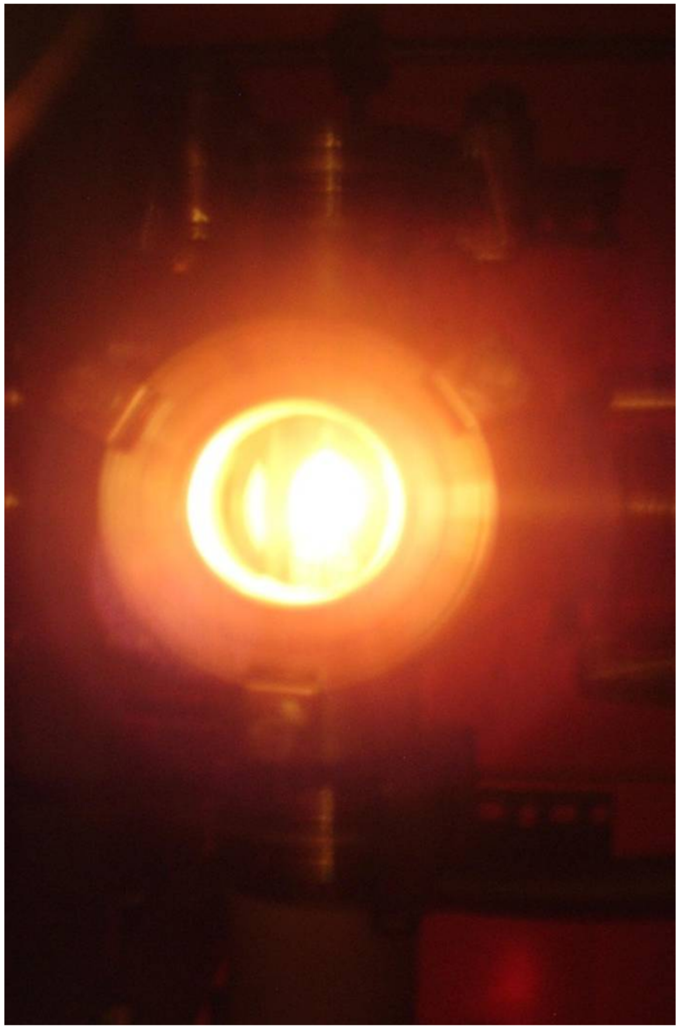
Solid Target Studies for NF

Rob Edgecock

22 Sept. 2010



On behalf of:

J.Back, R.Bennett, S.Gray, A.McFarland, P.Loveridge & G.Skoro

Tungsten wire at 2000K

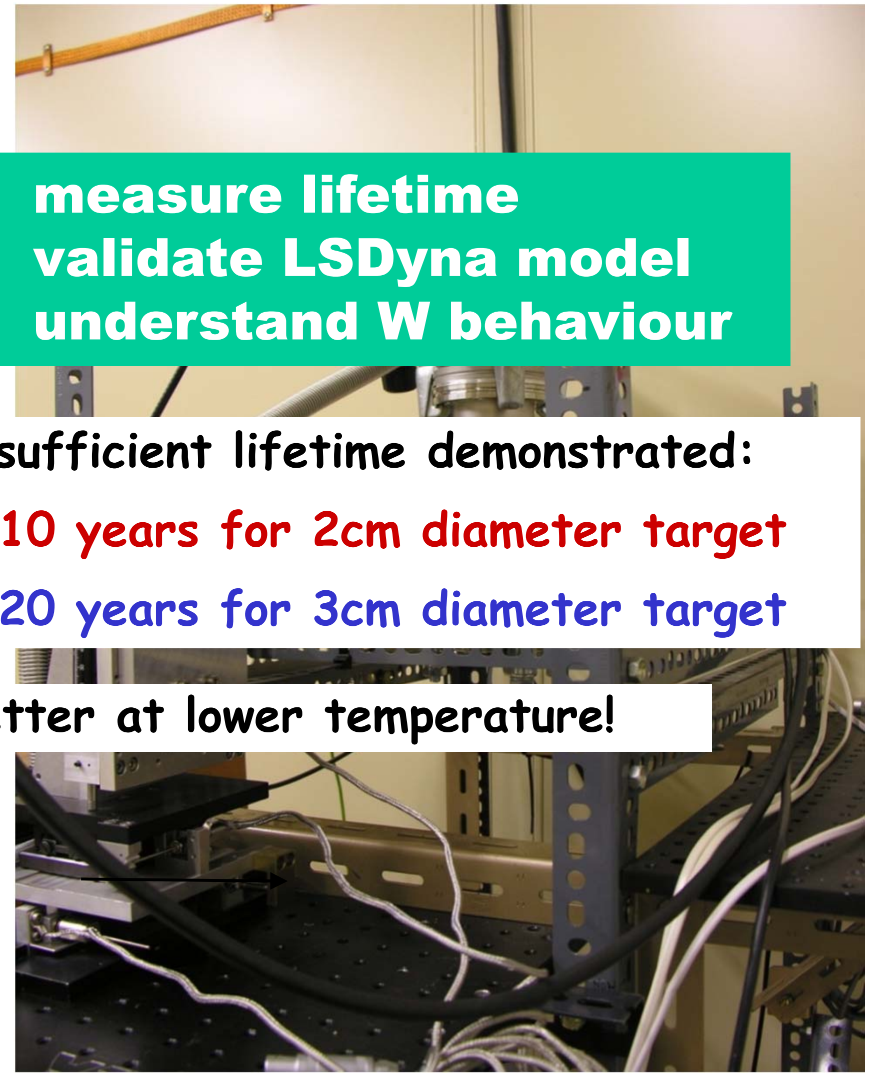
Reminder

- **Solid means**
  - **tungsten bars, each ~2x20cm**
  - **150-200 bars**
  - **changed between beam pulses**
  - **cooled radiatively or possibly by helium/water**
- **Why?**
  - **lots of experience world-wide & safer**
  - **already have a license at RAL**
- **Issues for solids:**
  - **shock – original show-stopper**
  - **radiation damage**
  - **target change**
- **Focus has been on shock - but now moving on**

Shock

- **Was solid show-stopper: one of main reasons for liquids**
- **Impossible to lifetime test with proton beam, so**

60kV, 8kA PSU, 100ns rise time



Aims: measure lifetime
validate LSDyna model
understand W behaviour

More than sufficient lifetime demonstrated:

› 10 years for 2cm diameter target

› 20 years for 3cm diameter target

Better at lower temperature!

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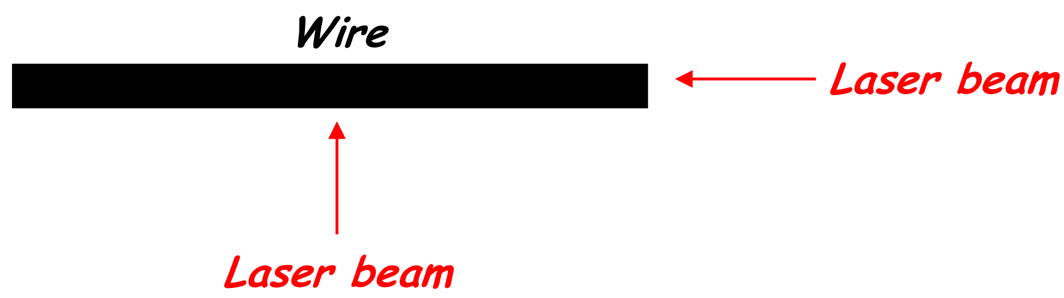
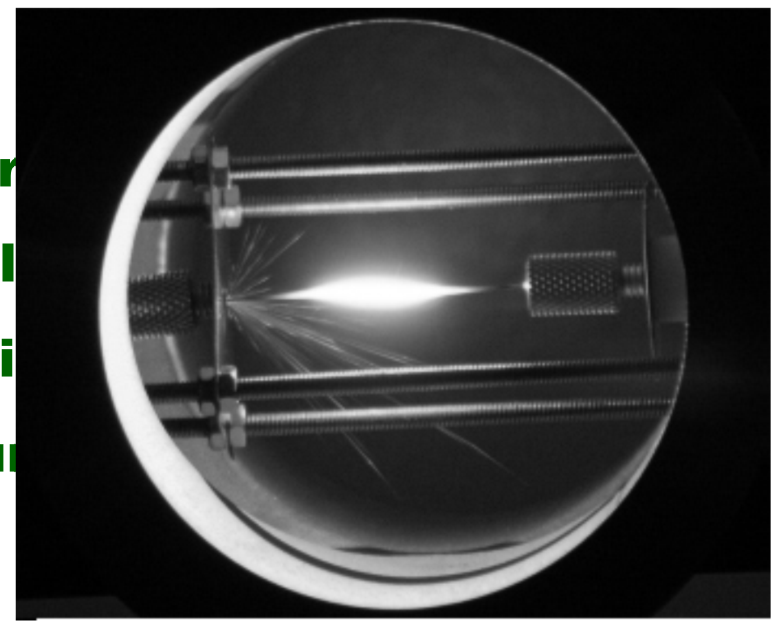
Laser Doppler Vibrometer

- **Used to measure wire surface velocity & CF LS-Dyna**

Longitudinal and radial mesurements possible

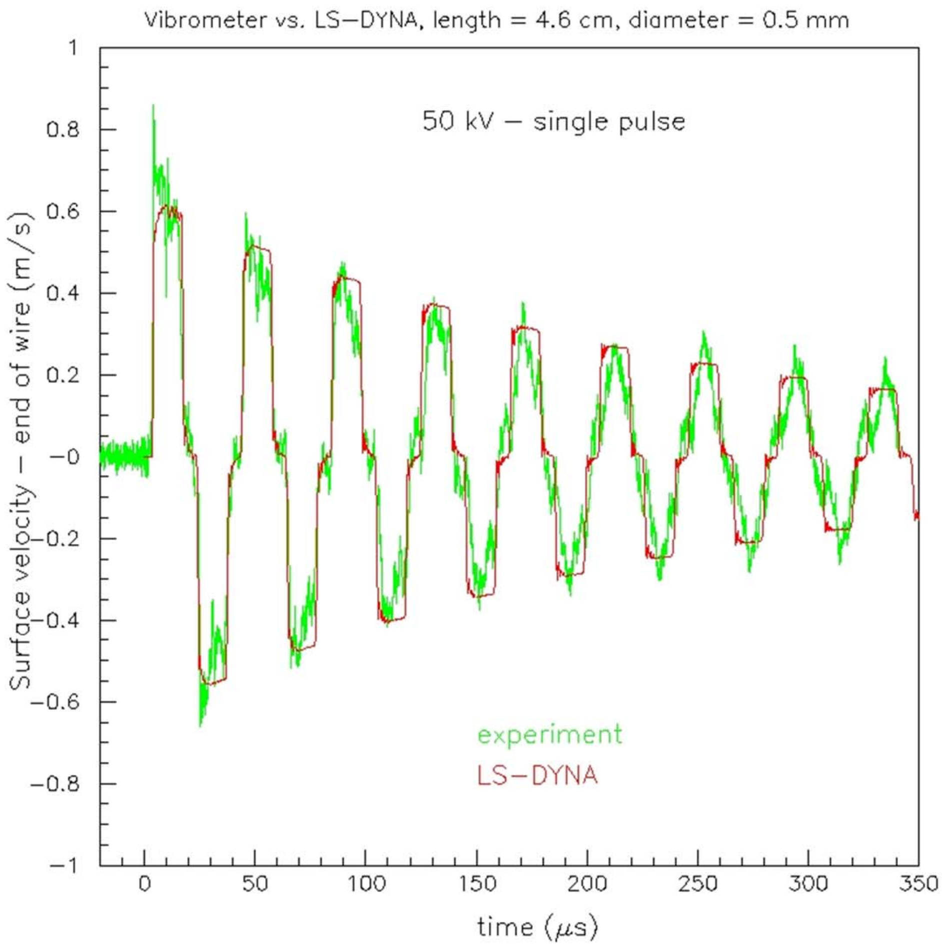


- **Longitudinal**
  - **Bigger oscillations: ~μm; lower**
  - **But.....temperature variation al**
  - **Wire fixed at one end, constrai**
  - **Oscillations more difficult to u**

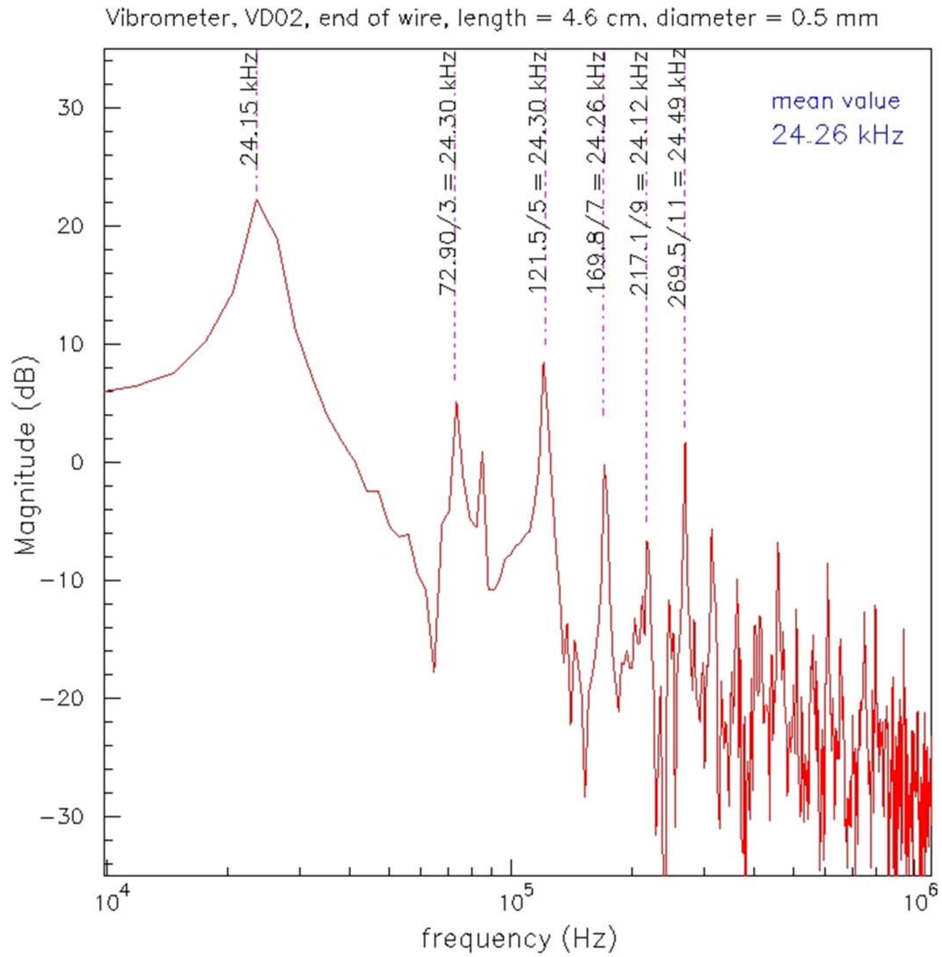


- **Radial**
  - **Smaller oscillations: 50-100nm; higher frequency: ~12MHz**
  - **But......fixed temperature**
  - **Easier to model**

Longitudinal oscillations

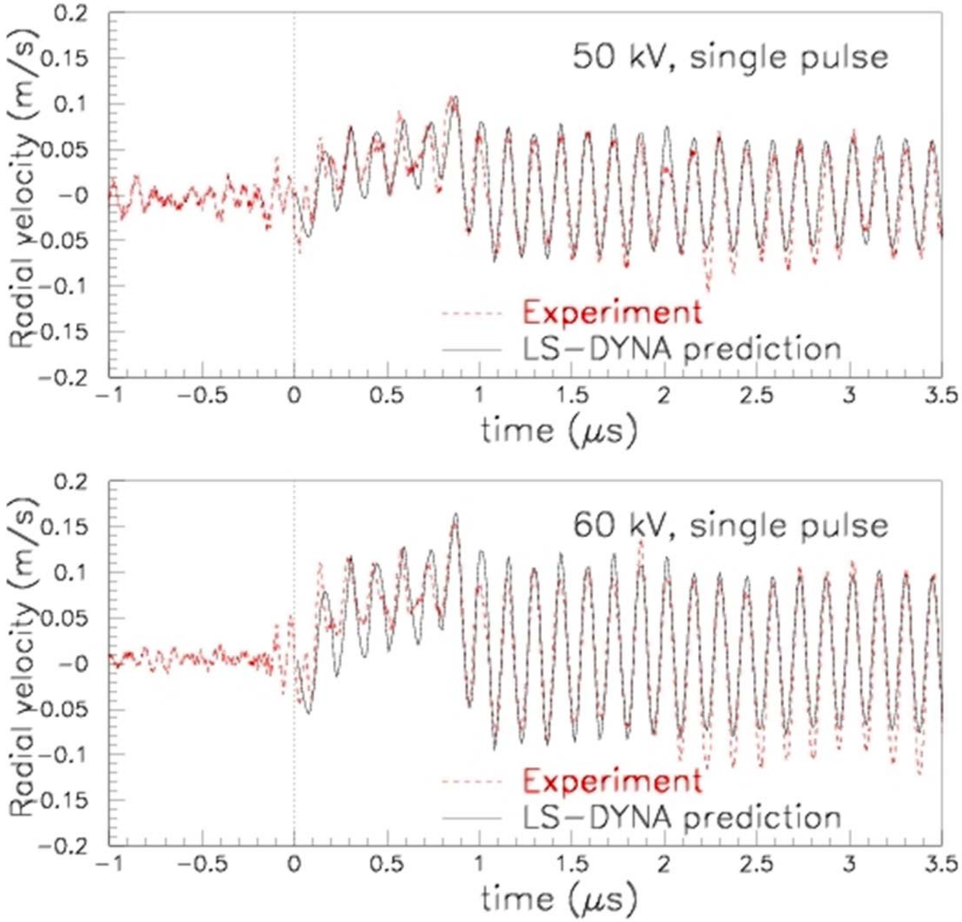


Longitudinal oscillations vs LSDyna

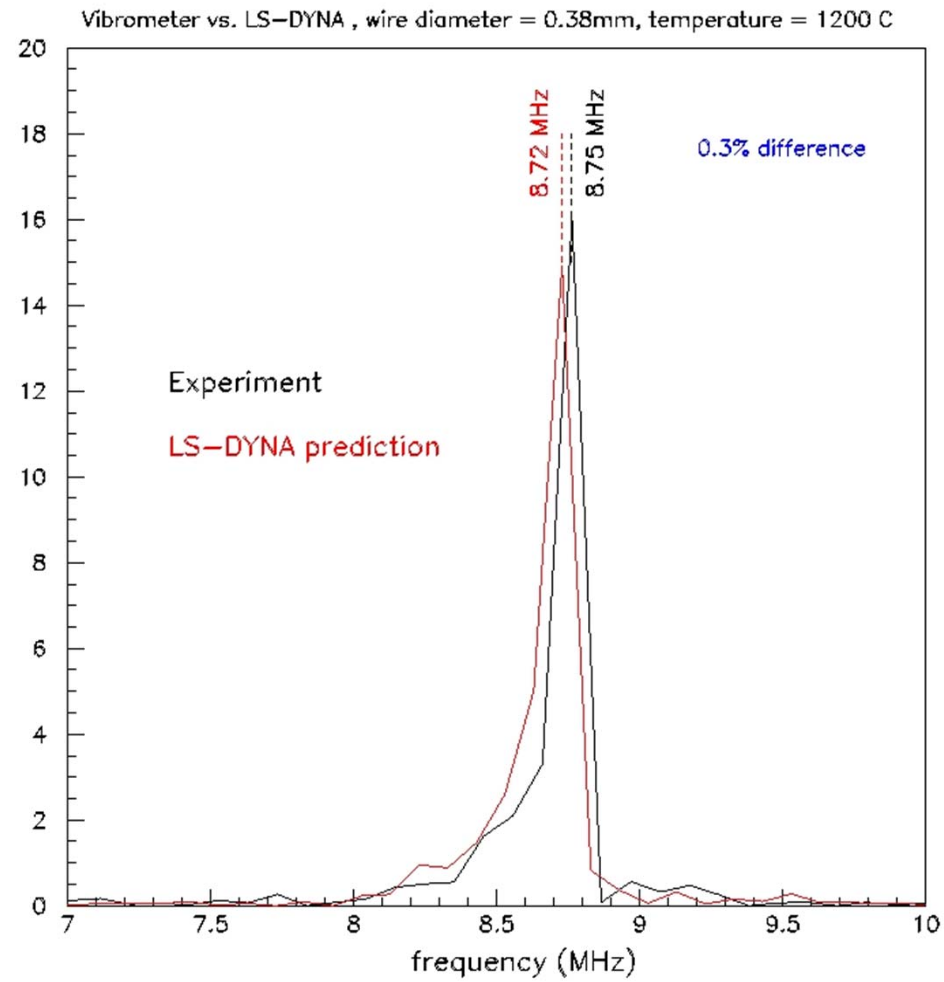


Frequency analysis

Radial oscillations

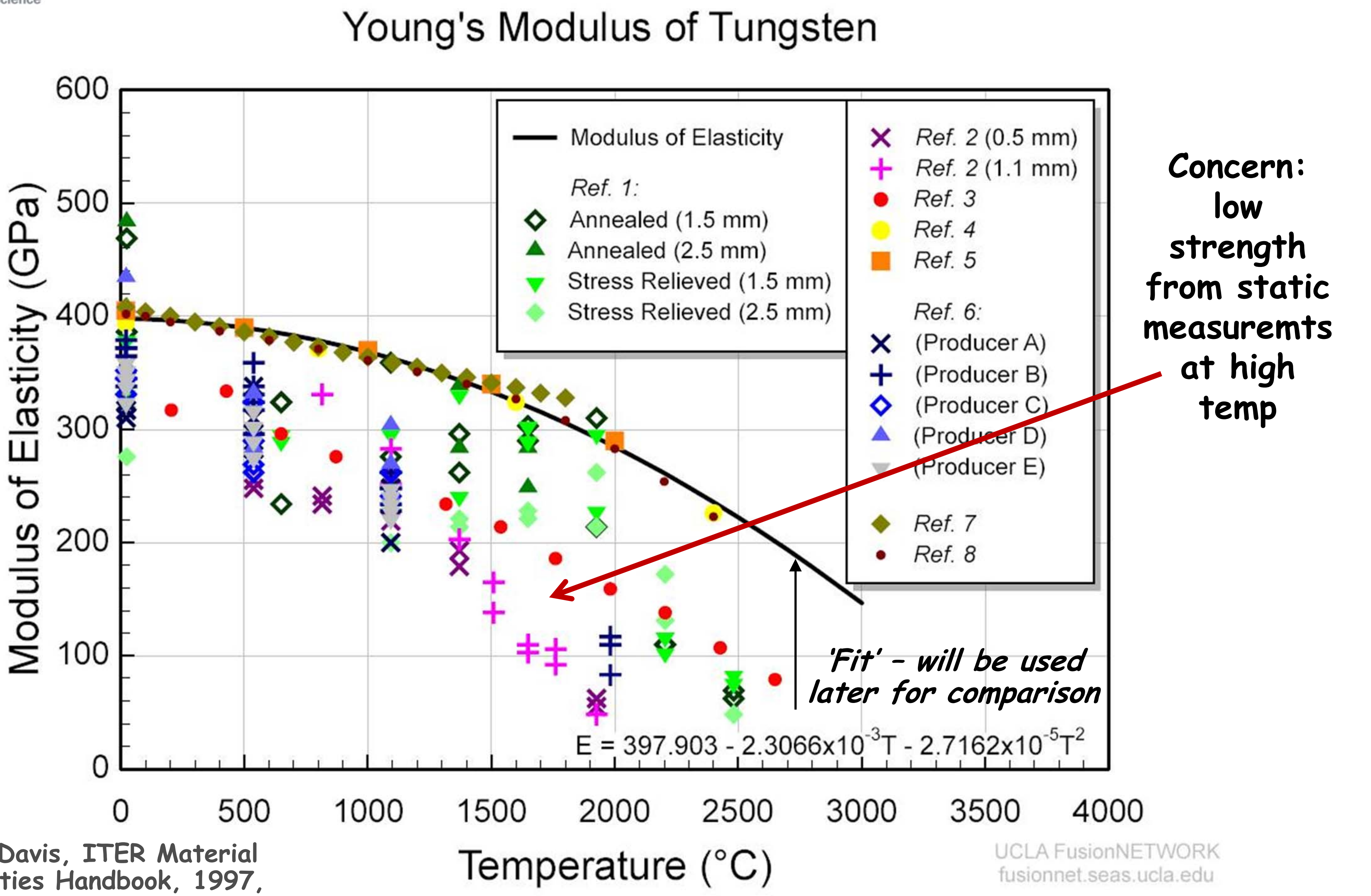


Radial oscillations vs LSDyna



Radial oscillations: frequency analysis vs LSDyna

Comparison with Measurements



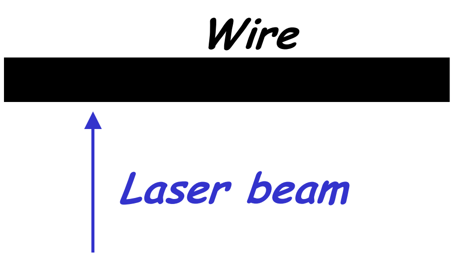
J.W. Davis, ITER Material Properties Handbook, 1997, Volume AM01-2111, Number 2, Page 1-7, Figure 2

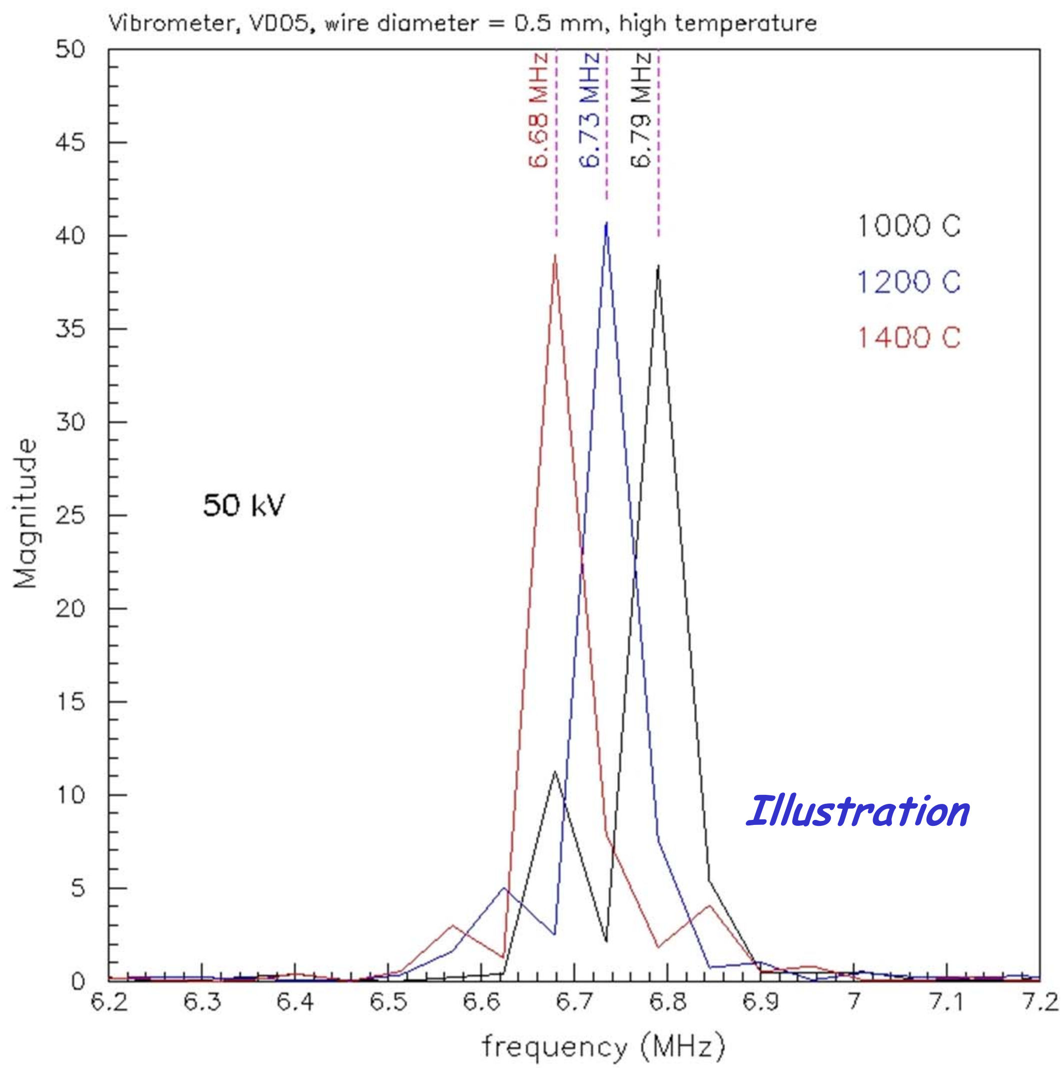
Measurement in Wire Tests

If we know the Poisson's ratio μ, density ρ, root of corresponding Bessel function ζ, wire radius r and measure the frequency f as a function of temperature then:

$$E = \frac{(2\pi f)^2 r^2 \rho}{\zeta^2} \frac{(1-\mu^2)(1+\mu)(1-2\mu)}{(1-\mu)}$$

$$\mu = 0.279 + 1.0893 \times 10^{-5} \cdot T[C]$$





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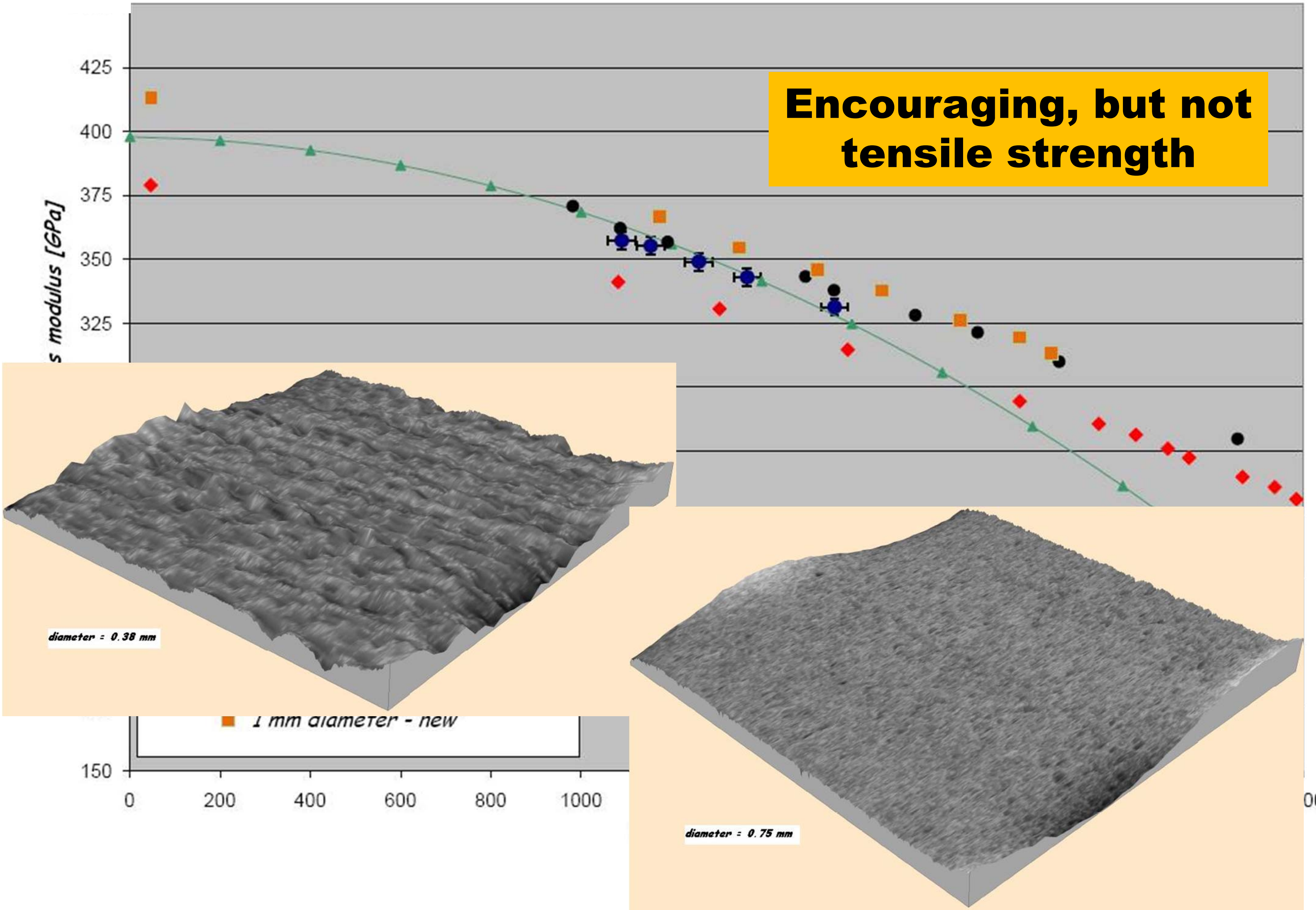
Tungsten Young's Modulus

Encouraging, but not tensile strength



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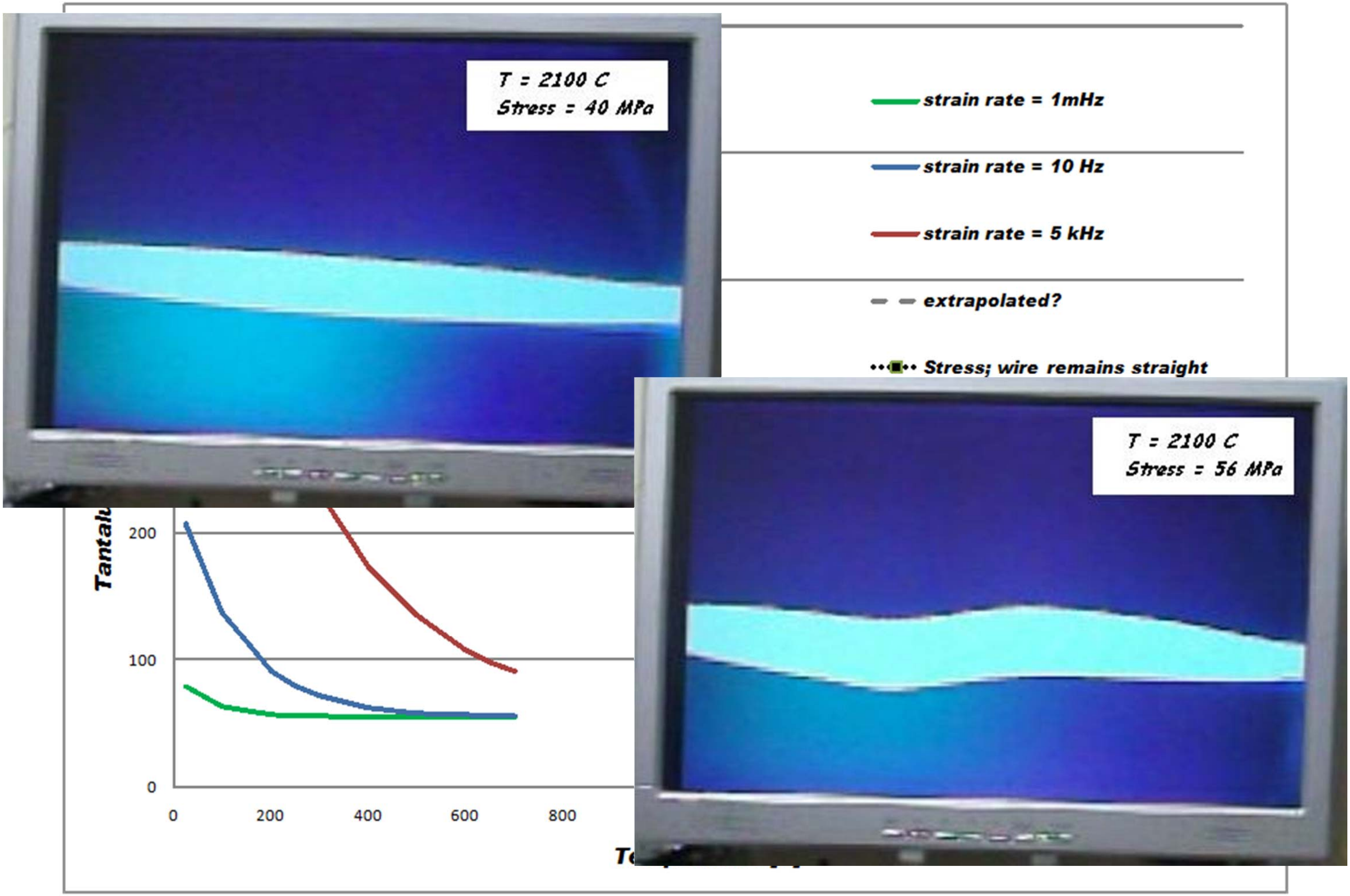
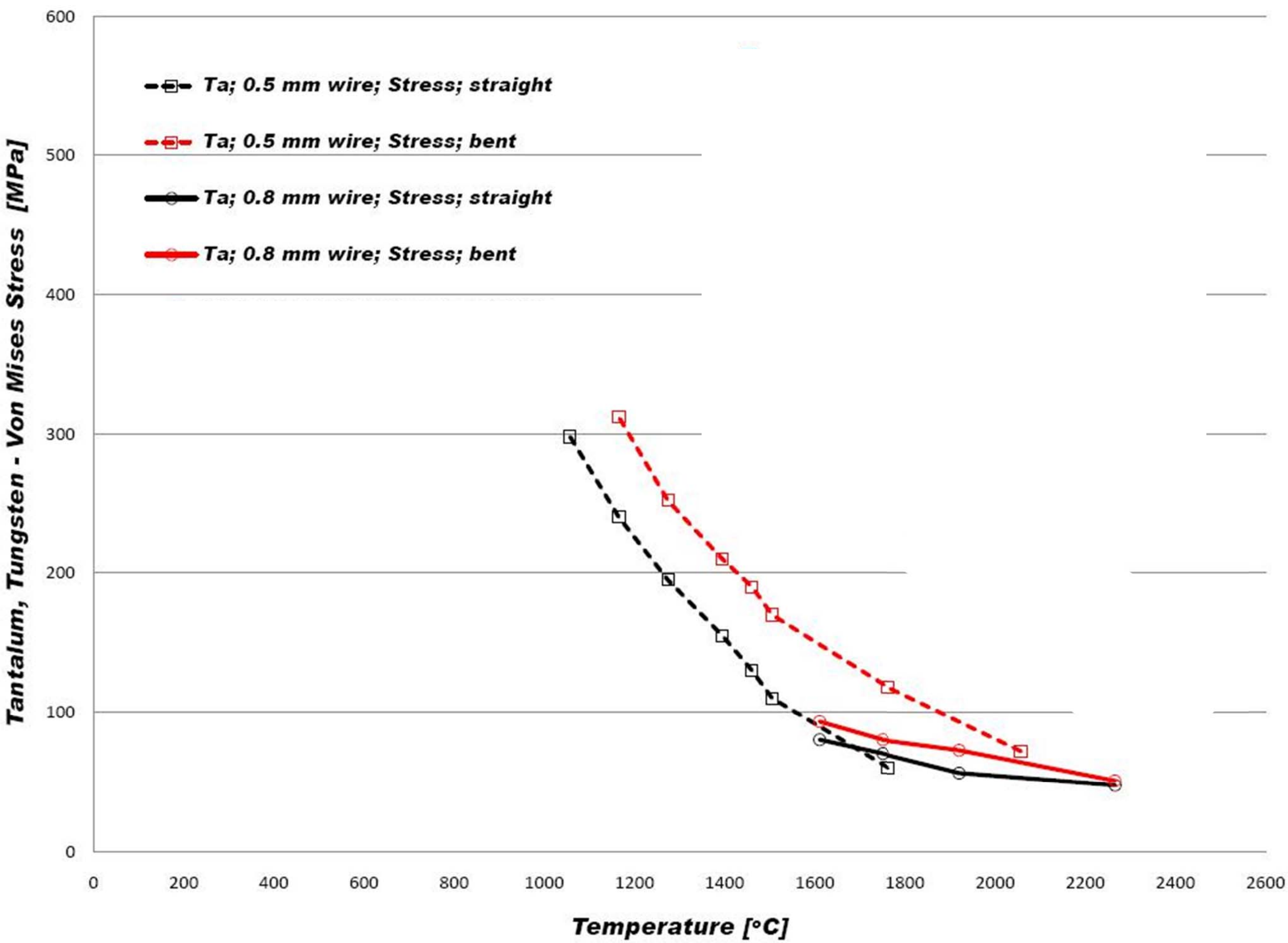
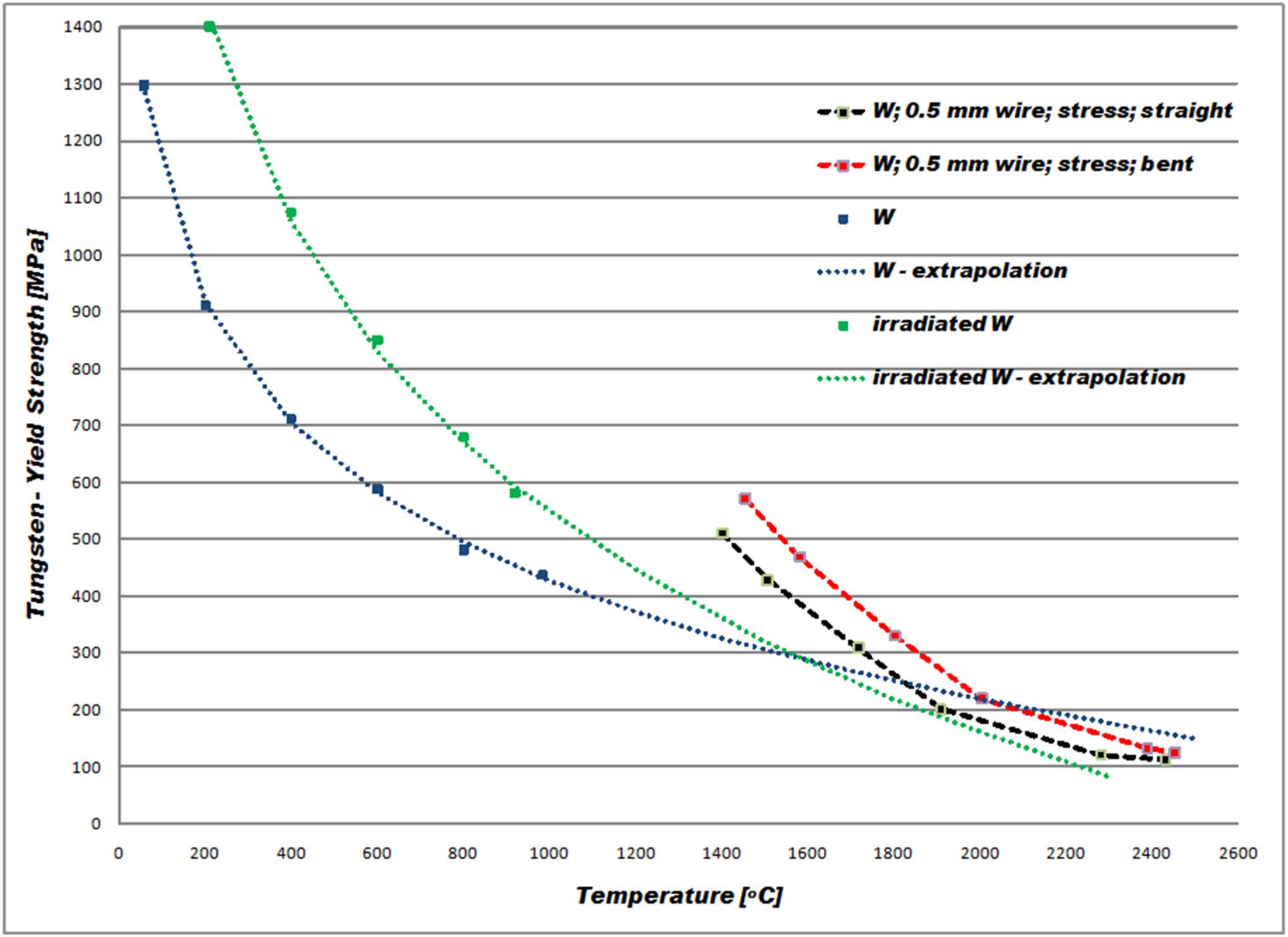
Tensile Strength of Tantalum



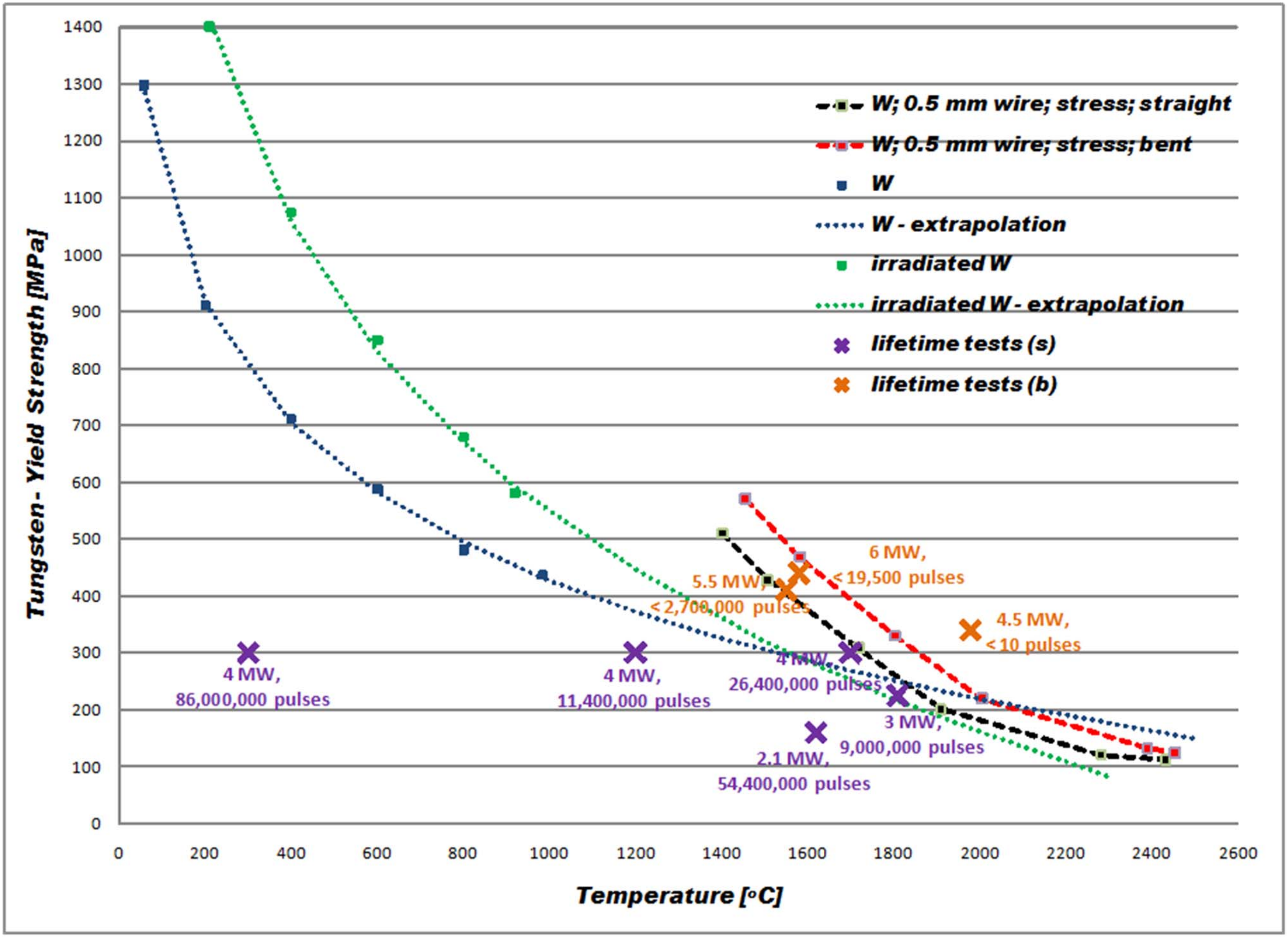
Tensile Strength of Tantalum



Tensile Strength of Tungsten



Tensile Strength of Tungsten



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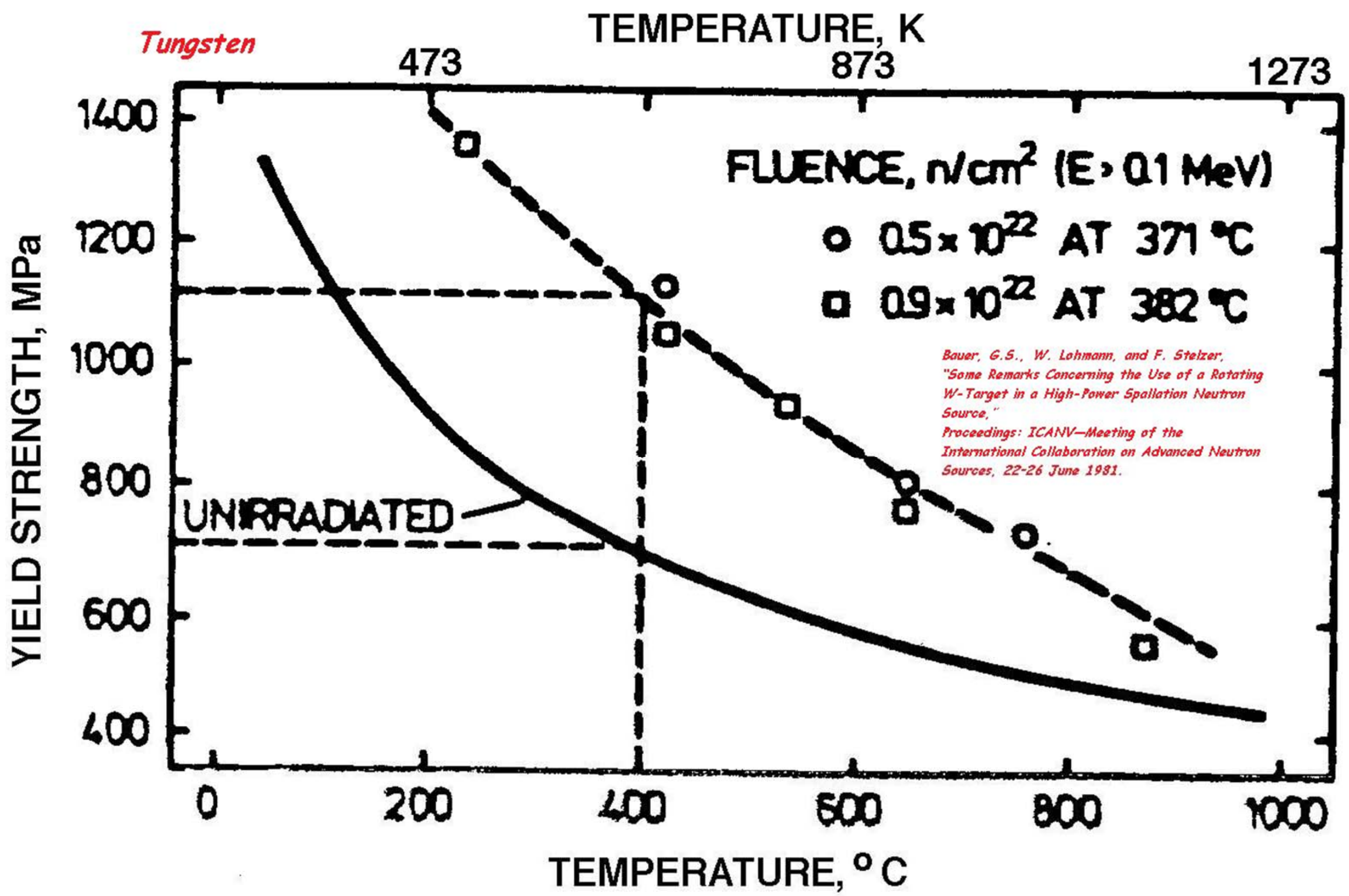
Shock Conclusions

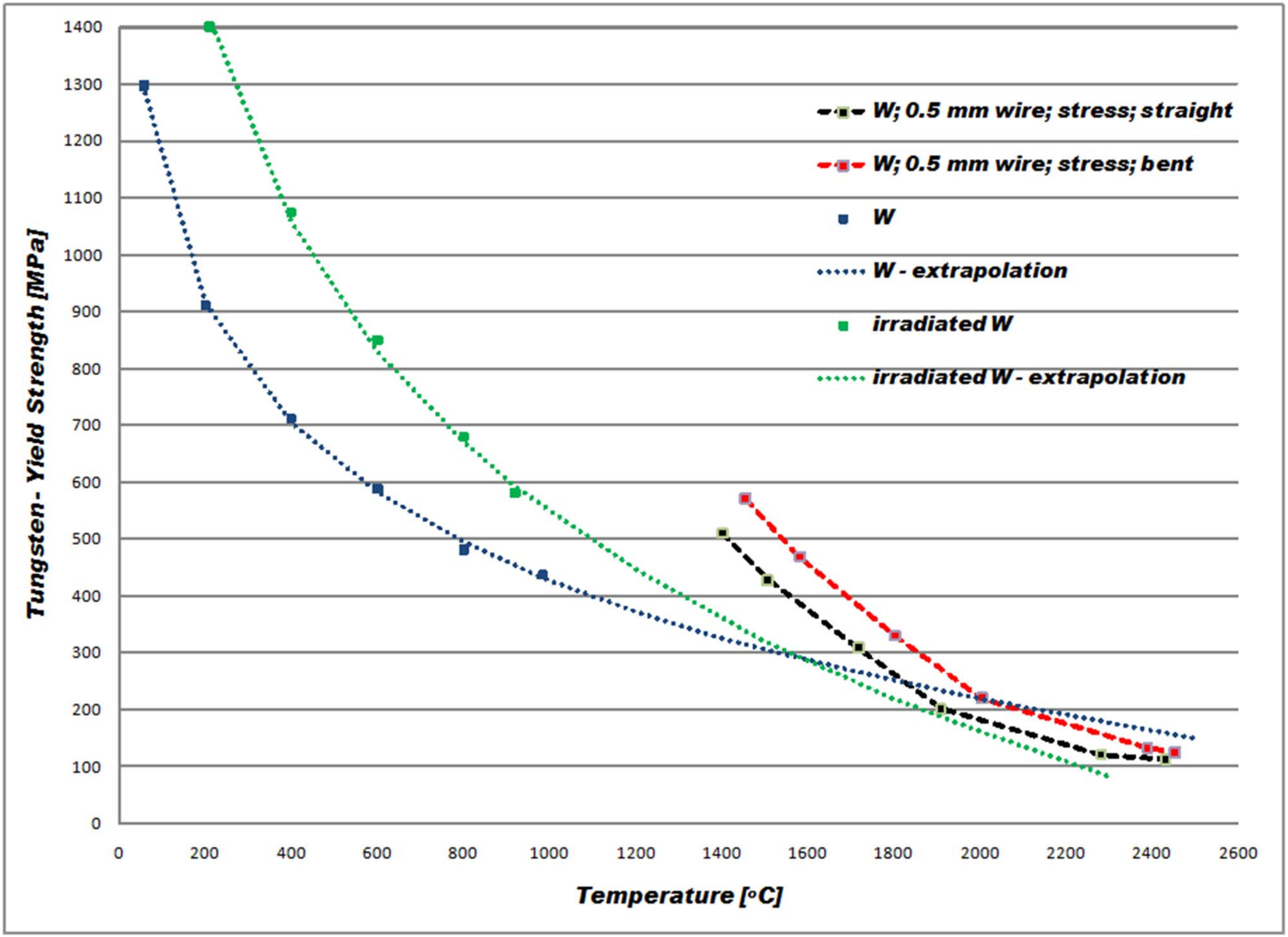
- **We have demonstrated:**
  - **LS-Dyna model we are using is correct**
  - **Tungsten is strong enough at high temperature**
  - **It has a more than sufficient lifetime**
- **What still needs to be done:**
  - **Use beams to confirm bulk samples**
  - **Measure with LDV to cf LSDyna**
  - **Most likely: use Ilias's facility at CERN**
  - **Measure strength after irradiation…….**

Radiation Damage



NB Static measurements.

Radiation Damage



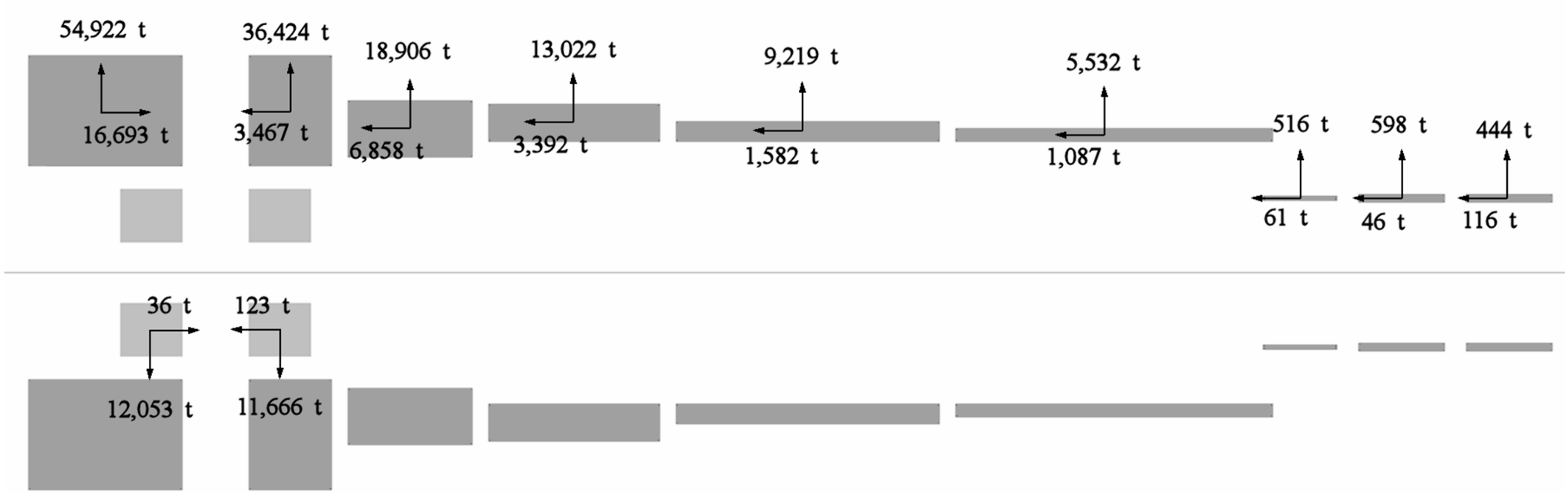
Target Change

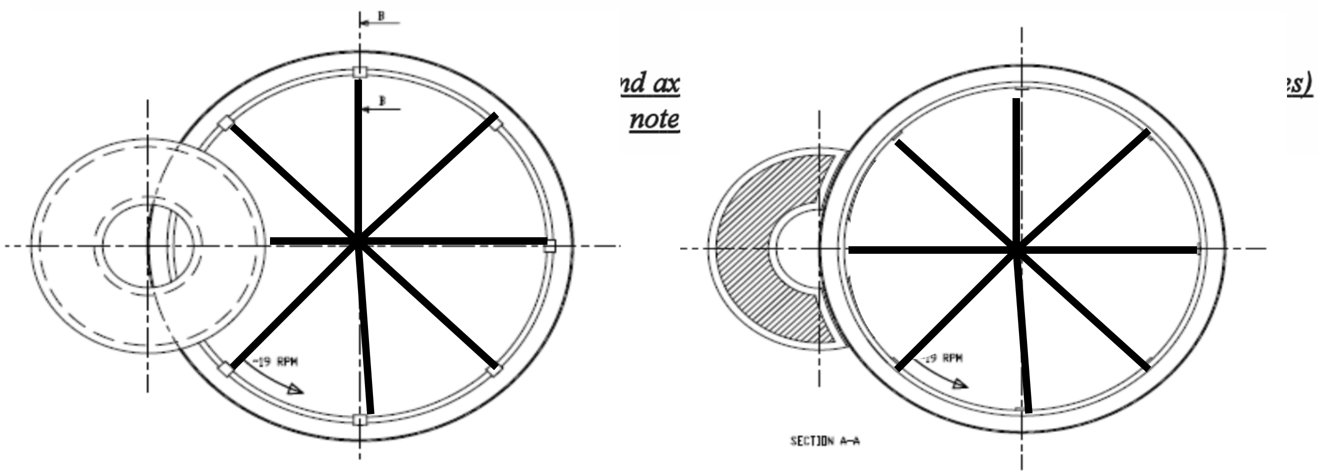
- Targets must be changed between beam pulses, i.e. 50Hz
- Must:
  - have minimal impact on pion production
  - have minimal effect on shielding
  - be reliable
  - allow the replacement of individual targets remotely
  - not be damaged by heat or radiation
  - be based as much as possible on existing technology
- Various options studied by a small group:

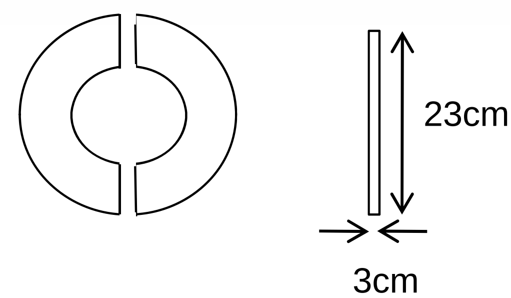
Roger Bennett
Dave Bellenger
David Jenkins
Leslie Jones

Target Change

- **Focus until recently: target wheel**
- **Helmholtz coil looks difficult due to forces**



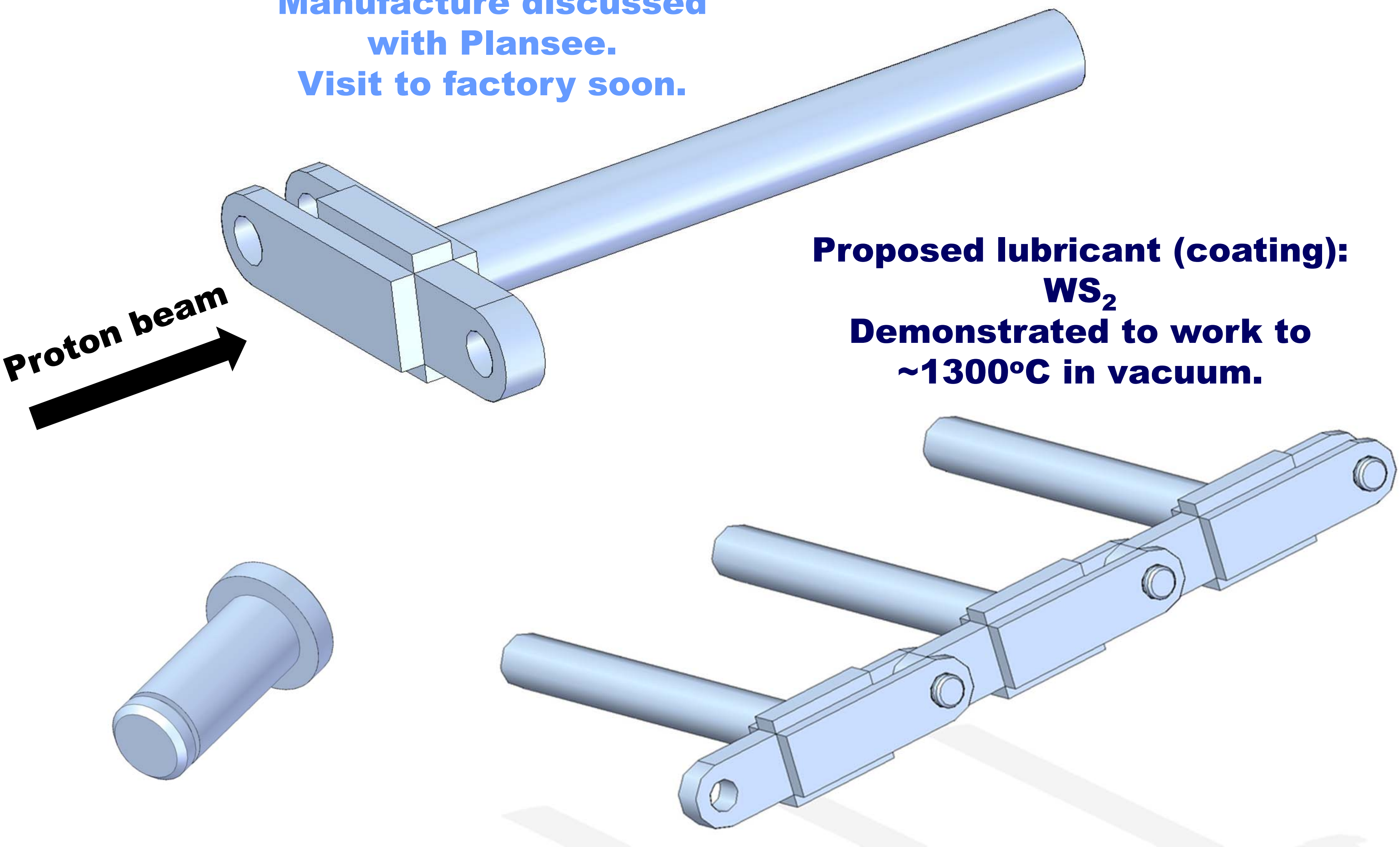




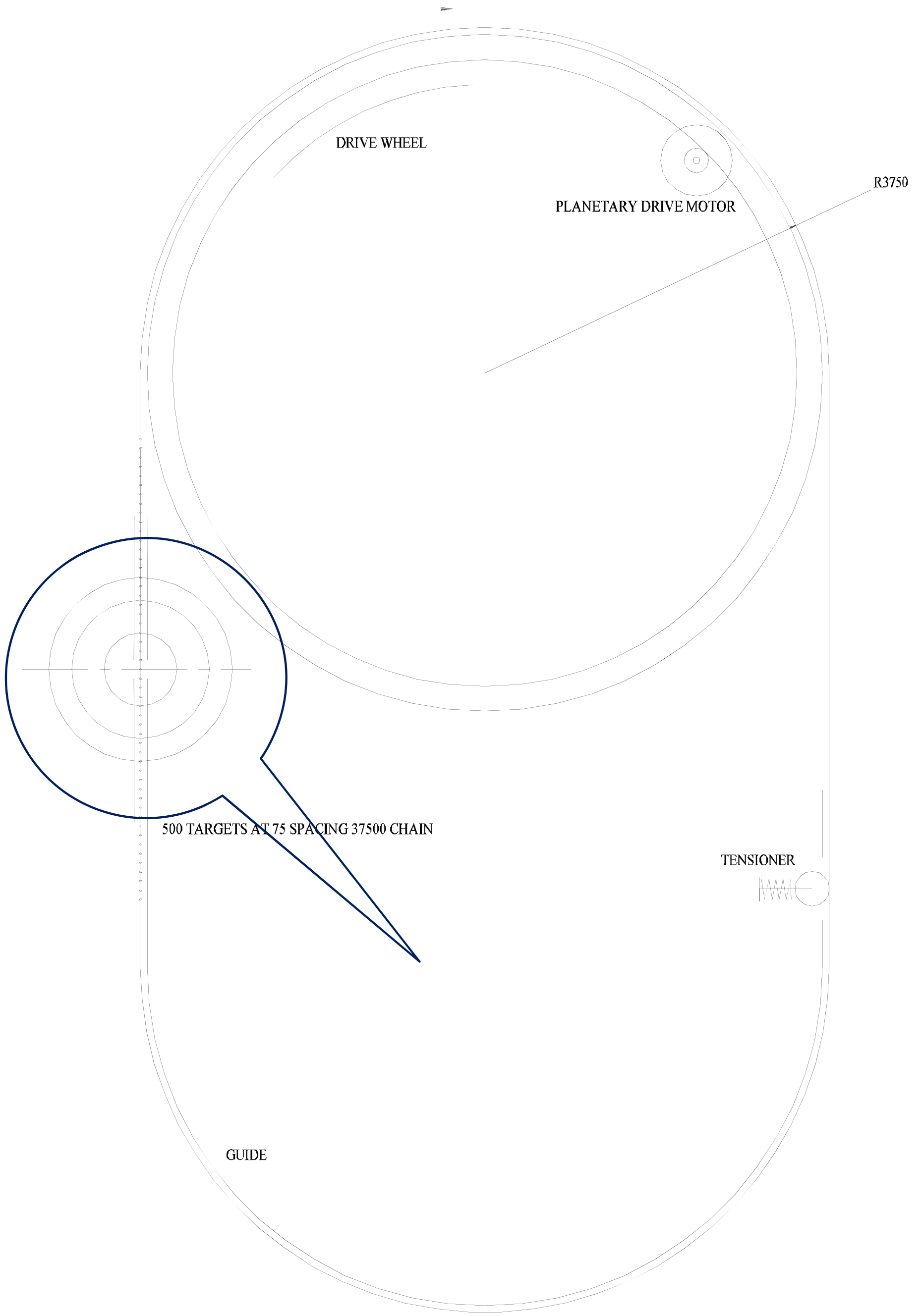
Target Change

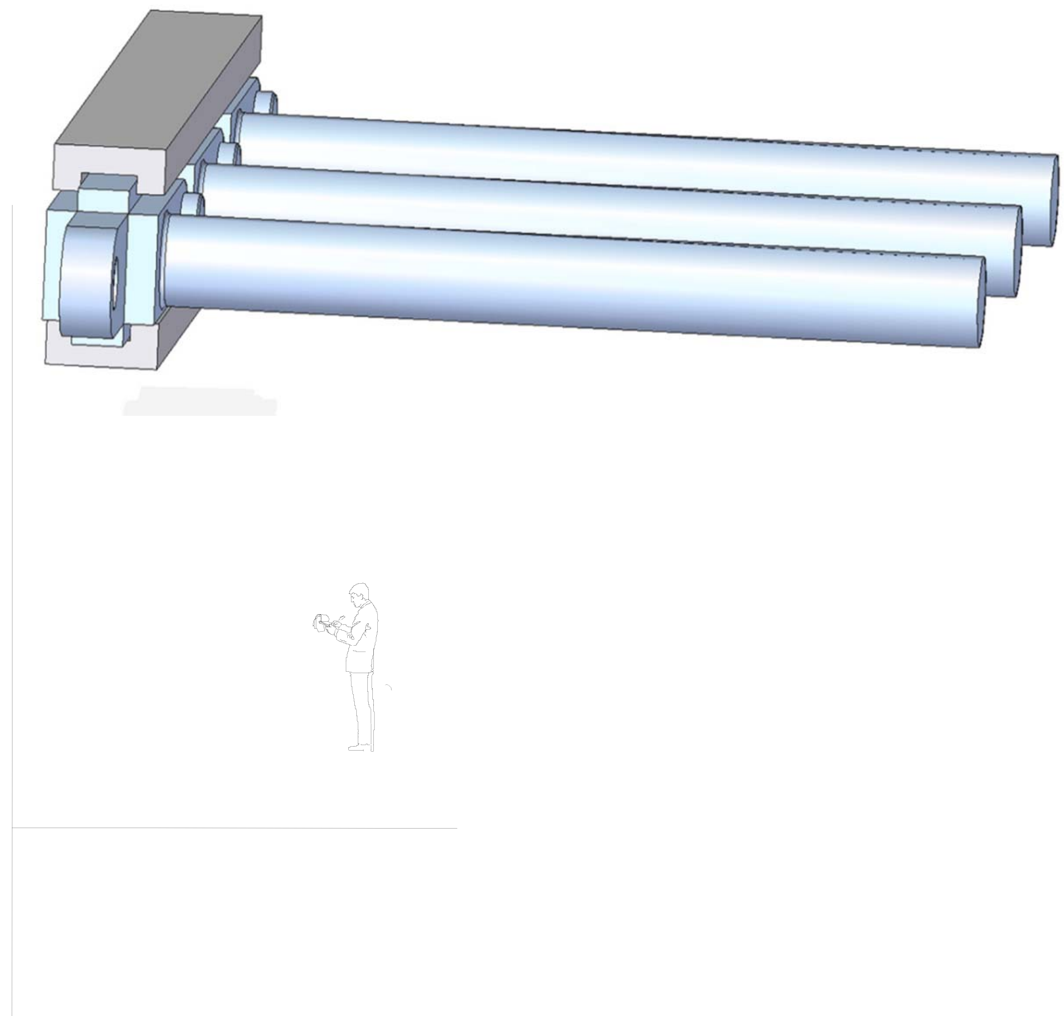
All tungsten.
Manufacture discussed with Plansee.
Visit to factory soon.

Proposed lubricant (coating): WS_2
Demonstrated to work to ~1300°C in vacuum.

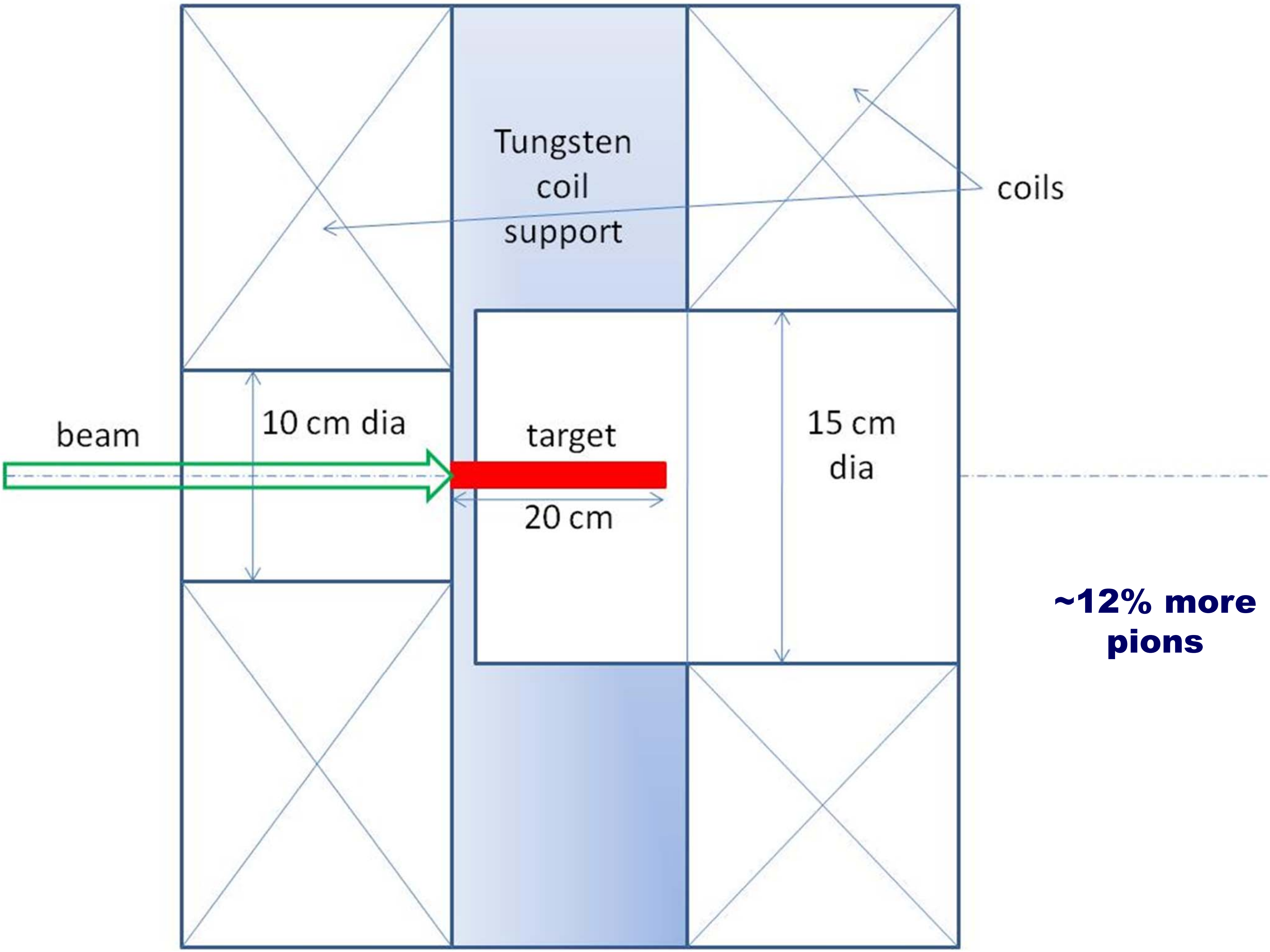


Target Change





Target Change



~12% more pions

Target Change

- **Early days**
- **Work planned to verify:**

1. Thermal Calculations on Chain/Target Design.	Goran
2. Thermal Shock Calculations on Chain/Target Design.	Goran
3. Yield Calculations and Optimisation.	John
4. Chain Design Optimisation – roller chain or alternative. Consult with Reynolds Chain, Plansee.	David
5. Calculate Strength of Helmholtz Insert.	David
6. Chain/Helmholtz Insert Design Optimisation. Friction Reduction – WS_2? Tests.	David
7. Chain/Helmholtz Insert Design Stress Analysis.	David
8. Chain Drive Motor and Timing Control Design.	Adrian?
9. Model of Chain. Running Tests – thermal - life.	Roger
10. Radiation, Activation, Shielding Analysis.	John
11. Radiation studies	All
12. Remote Handling, Replacement, Servicing.	David
13. Magnet Design.	Roger/?
14. Target Station Design.	David

Conclusions

- **Shock:**
  - **We've done this to death!**
  - **Don't believe it is a problem**
  - **Tests with beams to come**
- **Radiation damage:**
  - **Lots of local experience exists**
  - **Needs to be applied to our case**
  - **But existing data are encouraging**
- **Target change:**
  - **New scheme under study**
  - **Looks encouraging, but more studies required**