Solid Target Studies in the UK

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On behalf of:

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Introduction to Solid Targets

- Why solid?
  - lots and lots of experience
  - both liquid targets: looking at solids again
- Candidate materials – strong at high temperature
  - tantalum
  - tungsten
- Issues:
  - shock
  - radiation damage
  - temperature rise……..changing target, target station, etc
- Possibilities:
  - a number (150-500) of ~2x20cm bars
  - particle jet

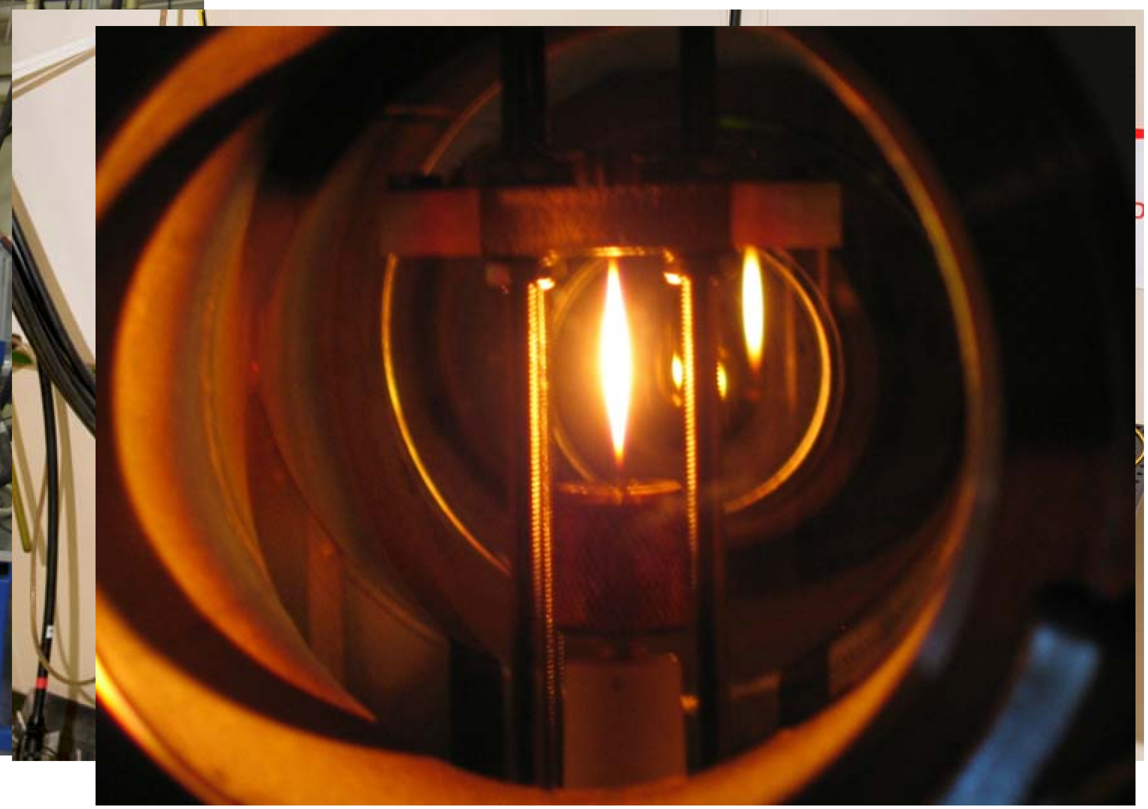
Radiation Damage

- ISIS:
  - used tantalum for > 10 years, tungsten ~5 years
  - targets changed after ~12dpa
  - ~2-5 years at NF, depending on # of targets
  - no signs of swelling or embrittlement
  - Ta examined in detail; W still to be done
- Still to be done
  - tensile strength after irradiation
  - will be done by Nick Simos at BNL

Shock

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

60kV, 8kA PSU, 100ns rise time



0.5mm diameter wire

Material	Current (A)	ΔT (K)	Max. T (K)	Pulses to failure	Eq. power
Tantalum	3000	60	1800	0.2×10^6	
Tungsten					
	5560	130	1900	4.2×10^6	2.7/5.0
Connector failed	5840	140	2050	$>9.0 \times 10^6$	3.0/5.4
	7000	190	2000	1.3×10^6	4.3/7.8
	6200	160	2000	10.1×10^6	3.3/6.1
	8000	255	1830	2.7×10^6	6.1/>13
Cable #6 failed	7440	230	1830	0.5×10^6	5.2/11.4
	6520	180	1940	26.4×10^6	4.1/8.7
	4720	77	1840	$>54.4 \times 10^6$	2.1/4.5
	6480		~600	$>80.8 \times 10^6$	4.0/8.6

For 200 targets: 10.6 years in 2cm
>22 years in 3cm
better at lower temperature

Shock – current/next steps

- VISAR
  - Velocity Interferometry System for Any Reflector
  - Surface displacements ~100nm; velocity ~1m/s
  - Two main problems:
    Noise!
    Moving target
  - Signals now being seen – new delay line required
- Protons
  - Two possibilities: ISIS, ISOLDE
  - Crucial measurement: VISAR

Temperature Rise

- ΔT ~100K/pulse; ~5000K /second
- Must change target between pulses:
  - 150-500 targets, swapped between pulses
  - particle jet
- Two (and a bit) methods investigated

Chain:

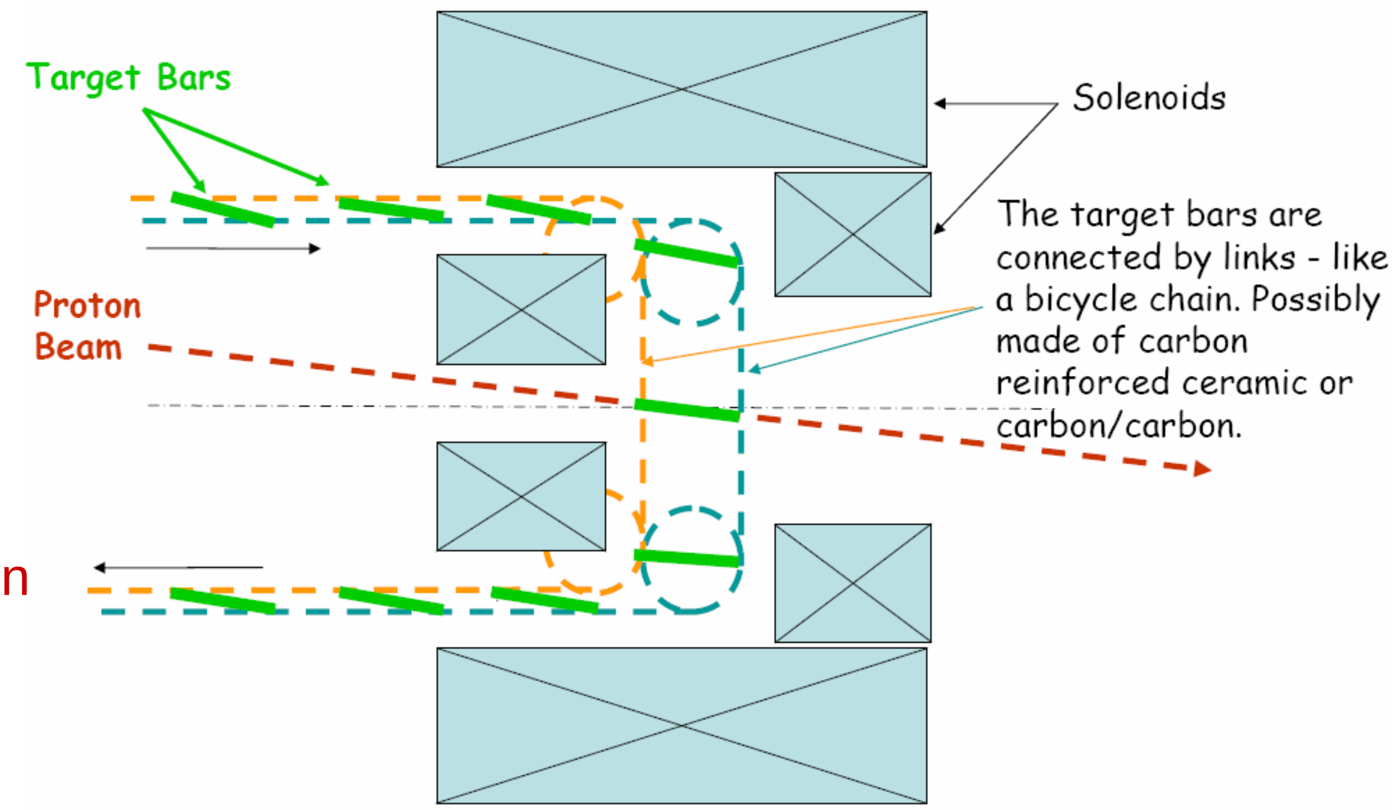
Speed: ~5m/s

Eddy currents: ok

Forces: ok

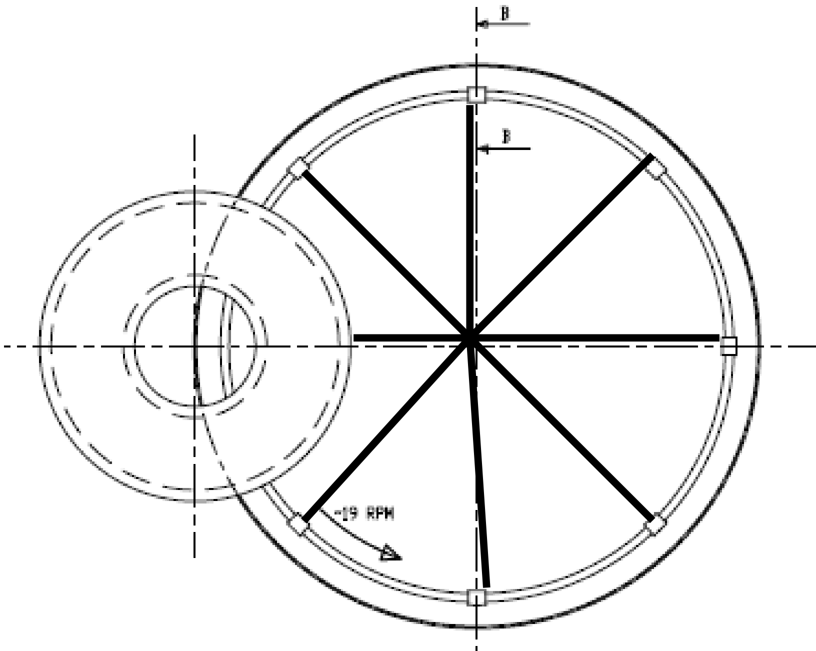
B-field: ok

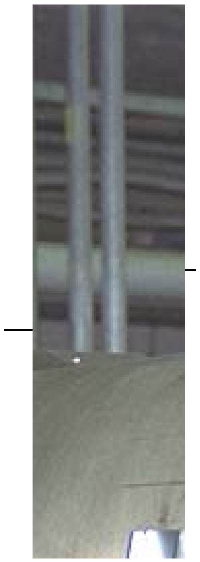
Problems:
moving parts high radiation
meshing with chains

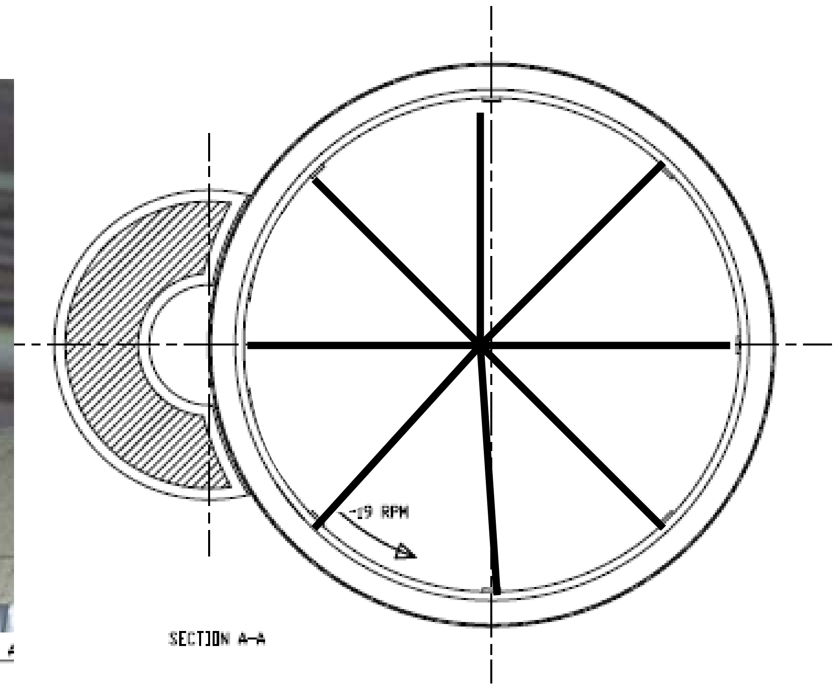


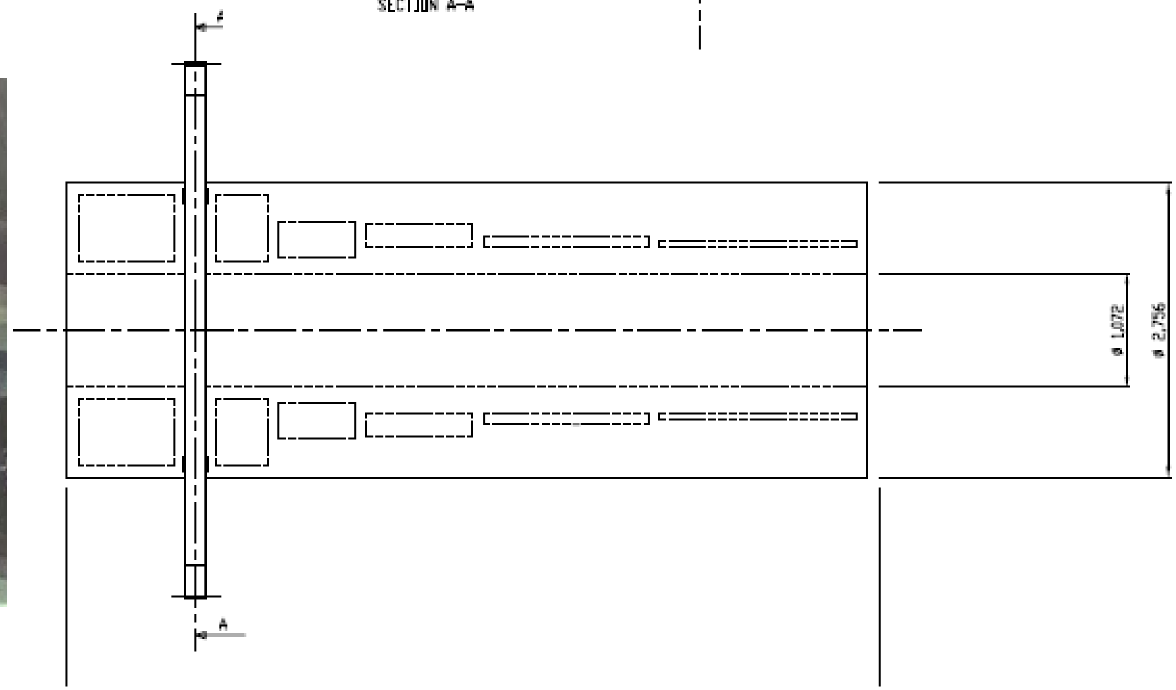
Temperature Rise

- Wheels









Spoked wheel

Moving parts out of radiation

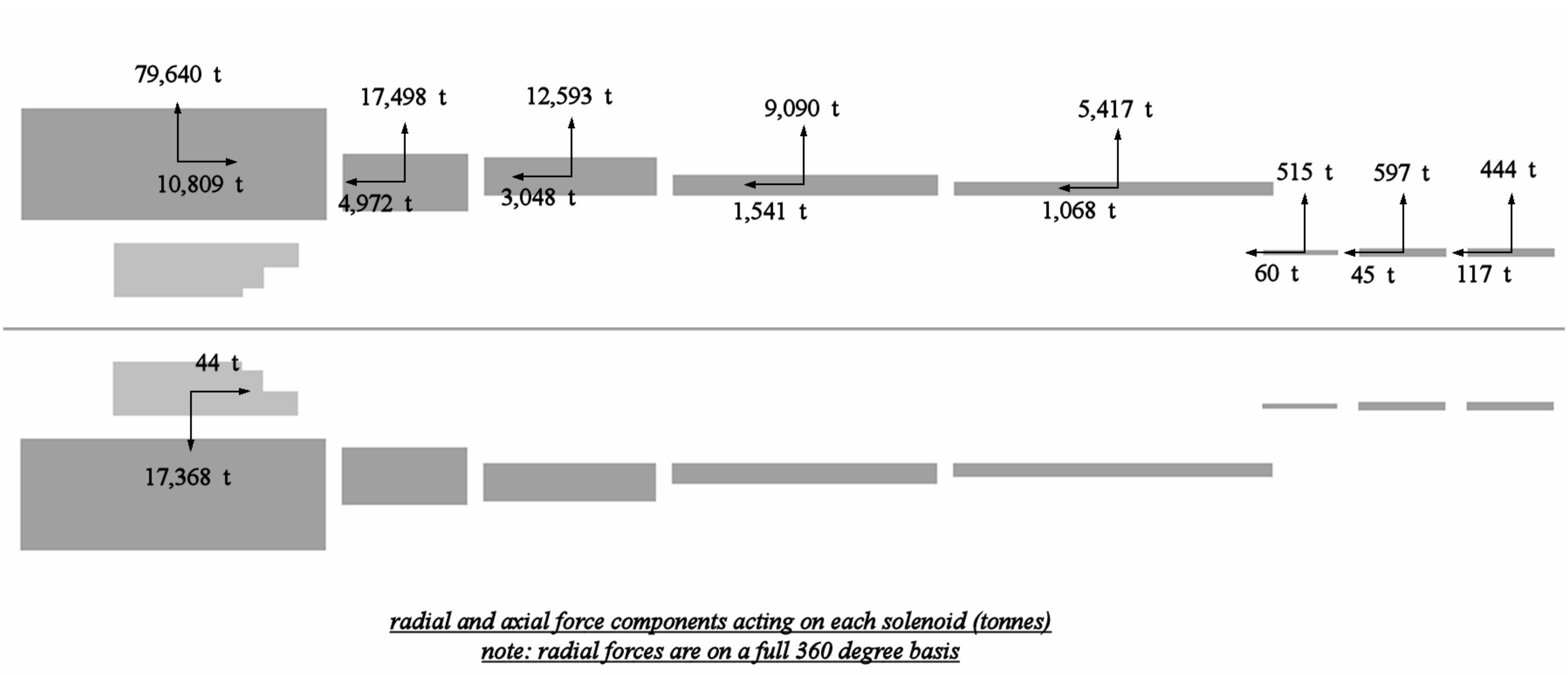
Structurally ok

Radiation shielding

Forces on coils

Forces

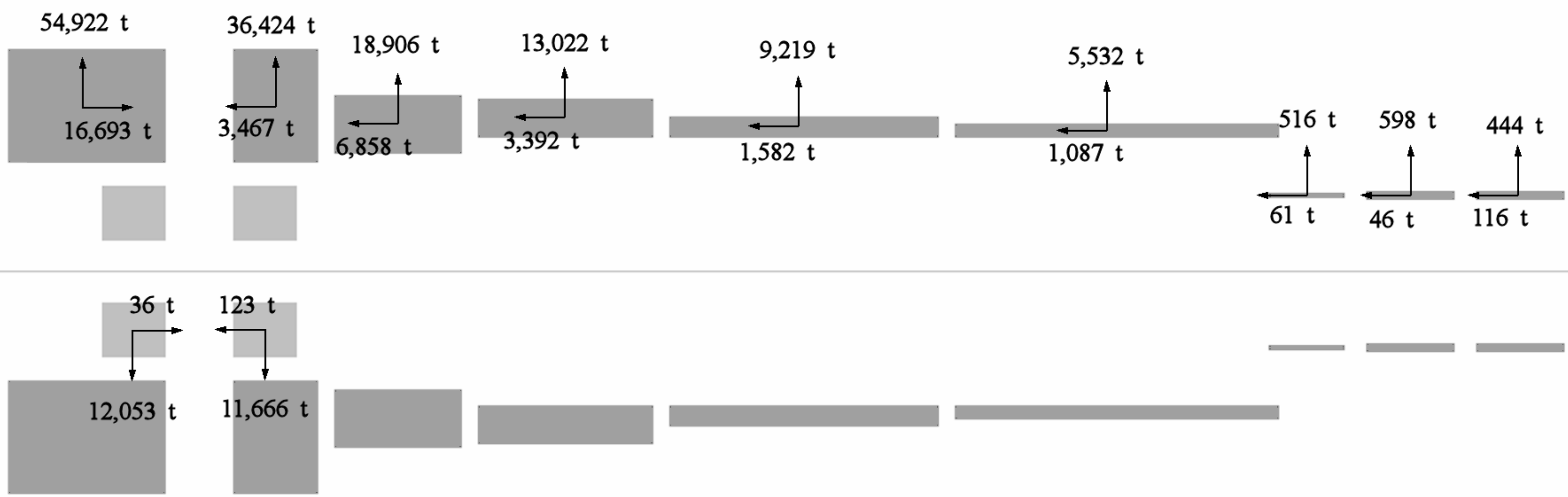
Study 2 solenoids



Main problem: radial and hoop stress exceed Cu tensile strength noted as problem in study 2

Forces

"Helmholtz"

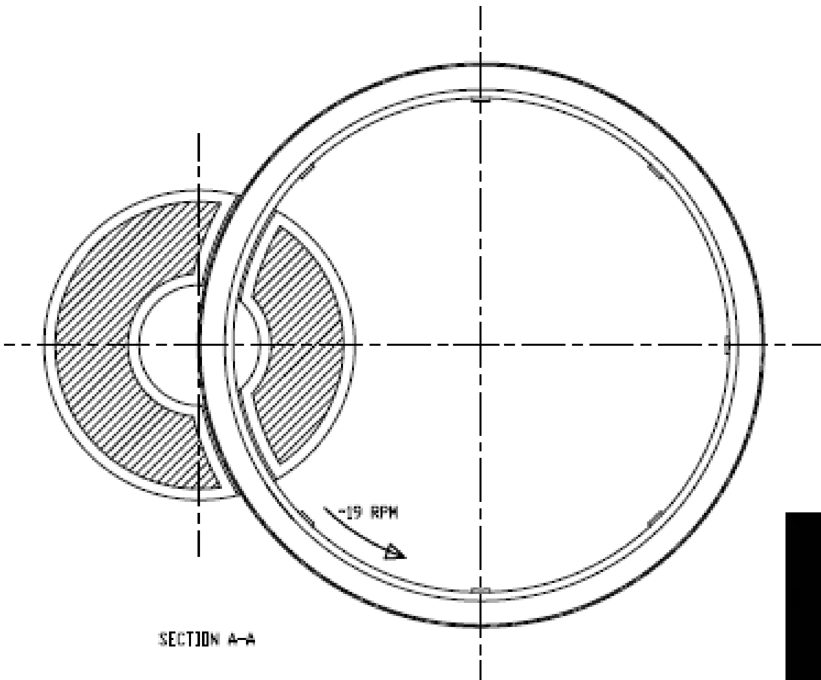


radial and axial force components acting on each solenoid (tonnes)
note: radial forces are on a full 360 degree basis

~7kt bending force: "very difficult"

Possible solutions: pulsed NC magnets
smaller B-field (B^2 effect)
spokeless wheel......

Spokeless Wheel

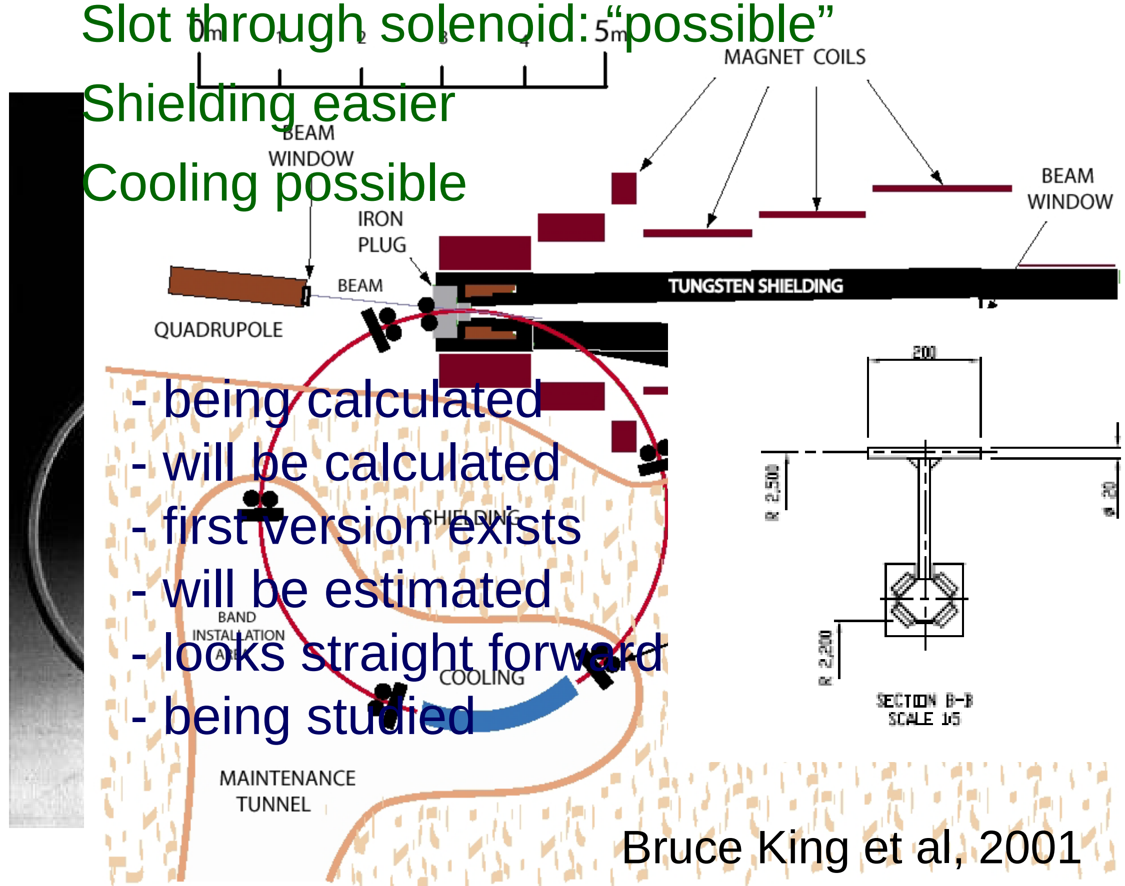


Outer diameter:	5m
Speed at rim:	5m/s
Revolution time:	3.14s
Target spacing:	100mm
# of targets:	157

Slot through solenoid: "possible"

Shielding easier

Cooling possible



Issues:

Eddy currents	- being calculated
Structural support	- will be calculated
Target mounting	- first version exists
Radiation damage to support	- will be estimated
Drive system	- looks straight forward
Tritium in water	- being studied

Bruce King et al, 2001

Particle Jet

Advantages

- **Solid**
  - Shock waves constrained within material – no splashing, jets or cavitation as for liquids
  - Material is already broken
  - Reduced chemistry problems compared with the liquid
- **Fragmented**
  - a near hydrostatic stress field develops in the particles so high pulsed energies can be absorbed before material damage
  - Better for eddy currents ?
  - Favourable (activated) material disposal through verification
- **Moving/flowing**
  - Replenishable
  - Favourable heat transfer
  - Decoupled cooling
  - Metamorphic (can be shaped to convenience)
- **Engineering considerations:**
  - Could offer favourable conditions for beam windows?
  - It is a mature technology with ready solutions for most issues
  - Few moving parts away from the beam!

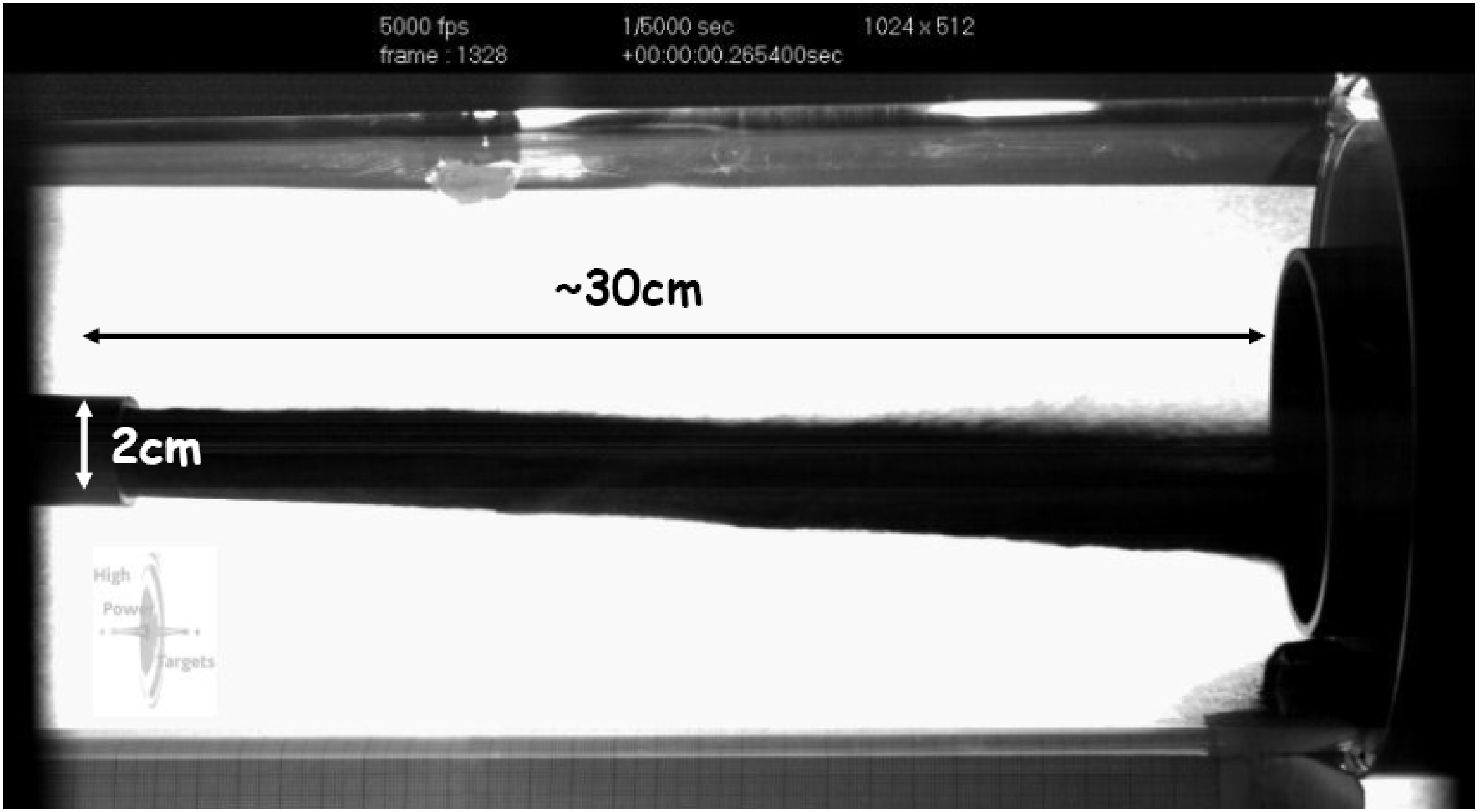
Particle Jet

Issues

- Is W fluidisable and does it flow?
- What density can be achieved?
- Effects of magnetic field
- Effects of electric charge:
  - frictional electrostatic charge
  - beam charge
- Elastic stress waves and thermal expansion
- Erosion and ware of rig and W particles
- Storage and disposal of radioactive powder

First tests at Gericke Ltd

Particle Jet



- W powder, <250μm particle size
- 3.9bar driving pressure

- Is fluidisable
- Does flow
- Density ~29% v/v

New Test Rig at RAL

Study, in particular:
- long term erosion and wear
- density
- heat transfer
- optimum rig arrangement

Conclusions

- Solid:
  - Shock: looks OK, but VISAR & protons needed
  - Radiation damage: looks OK, but detail needed
  - Spokeless target wheel: early days!
  - NB: most information known or calculable
    no large R&D projects required
- Particle jet:
  - Looks interesting
  - Much work required, but this is starting
  - Use of radioactive powder needs careful study