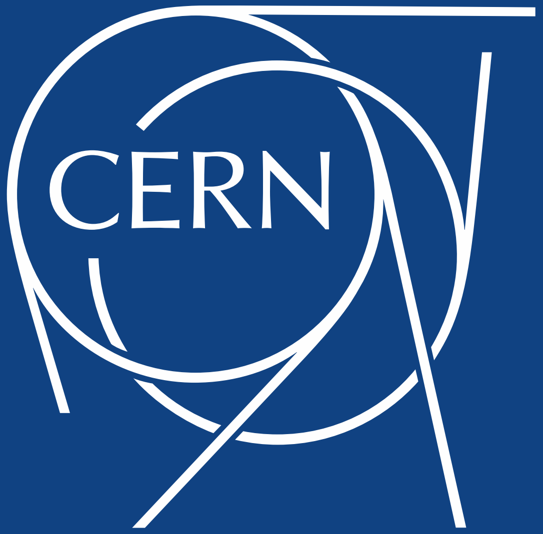

CERN

Low-Z electrostatic septa

J. Borburgh

With valuable input from: B. Balhan, B. Goddard, M. Fraser, L. Stoel, C. Theis, H. Vincke, W. Weterings

Outline

- **Low-Z septum wire/foil**
- Low-activation vacuum tanks and engineering materials for septa.
- Activation reduction, complementary approaches:
- Required idealised prototype septum

Need for low activation septa at CERN

- Based on an exchange of the 4th electrostatic septum in the SPS 9/2/2016, cool down time needed before intervention was 1.5 months to stay below ALARA III level (i.e. < 5 mSv collective dose, < 1 mSv per individual [1].
- Reduction of intervention time to 1 week would be reasonable.

C-wire status and possible issues

To reduce the interaction between the beam and the septum

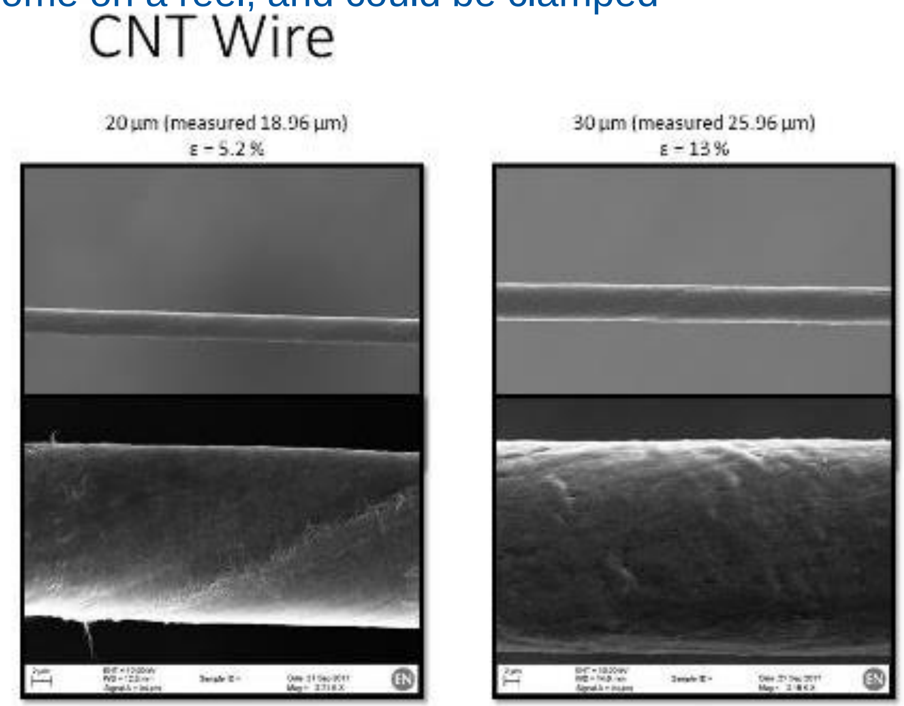
→ due to low beam impact also ΔT of anode expected

Carbon Anode wires

- Already studied in KEK [2], for a diffusor
  - Individual 7 μm wires bundled into ~100 μm threads.
- Nanotubes most promising, Japanese colleagues aimed to produce 70-80 µm wires in 2016. CERN BE/BI group received stranded 100 µm nanotubes in summer 2017.
- Better yield stress than W/Re wire (300 kg/mm)
- Difficult to clamp mechanically, but nanotubes come on a reel, and could be clamped (as done on CERN electrostatic septa in SPS)
- No HV test results…key issue….

Septum multi layer Graphene sheets [3]

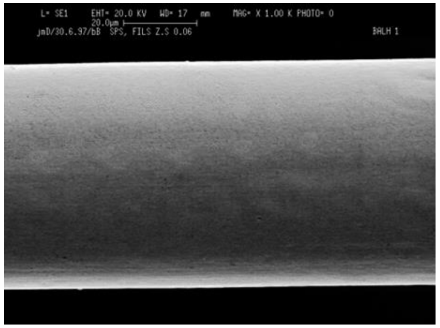
- Very thin (1 – 3 µm)
- Robustness?
- Clamping?
- Resistance to sparking?



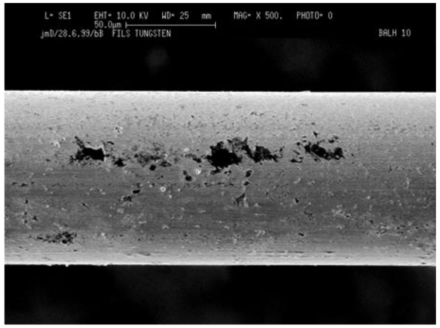
Courtesy A. Mariet CERN BE/BI/ML

Wire surface rugosity

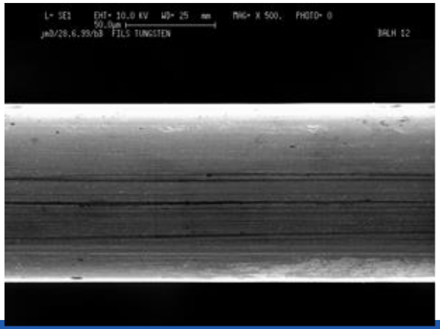
60 µm WRe wire



Desired surface finish after polishing

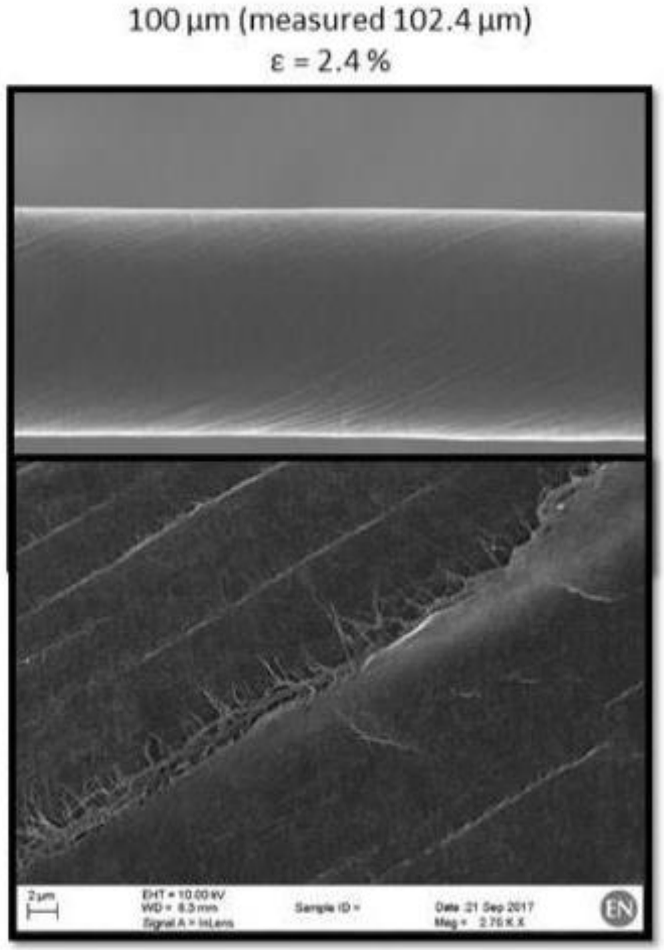


Non-acceptable surface finish (pollution)



Non-acceptable surface finish (traces of drawing process)

Carbon Nano Tube wire



Nanotube strands visible on wire surface

Zoom

Courtesy A. Mariet CERN BE/BI/ML

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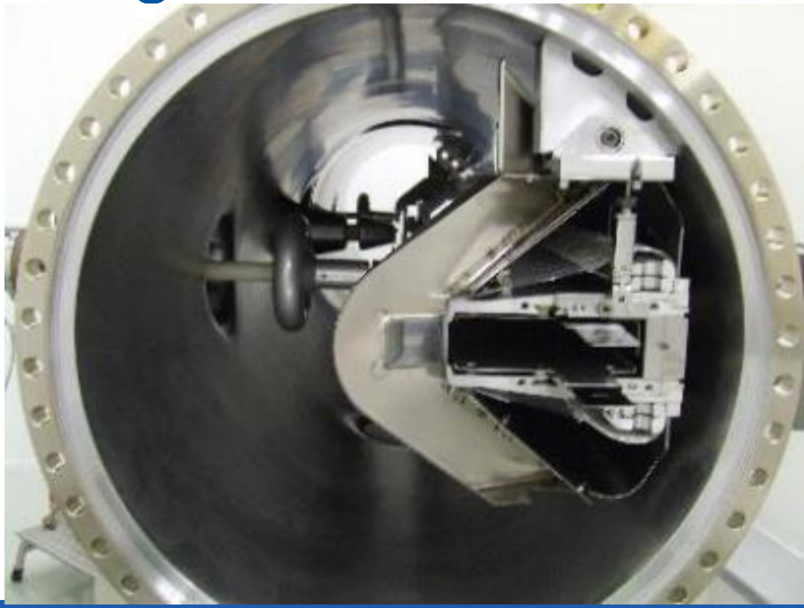
Case study: E.S. in SPS (ZS)

- Tank: 3.2m x Ø0.6m tank made of stainless steel 304L, 6 mm thick sheet.
- Anode support: 3.1m x 200 x 94 mm C-shaped support made of Invar or stainless steel.
- Accessories and supports neglected.



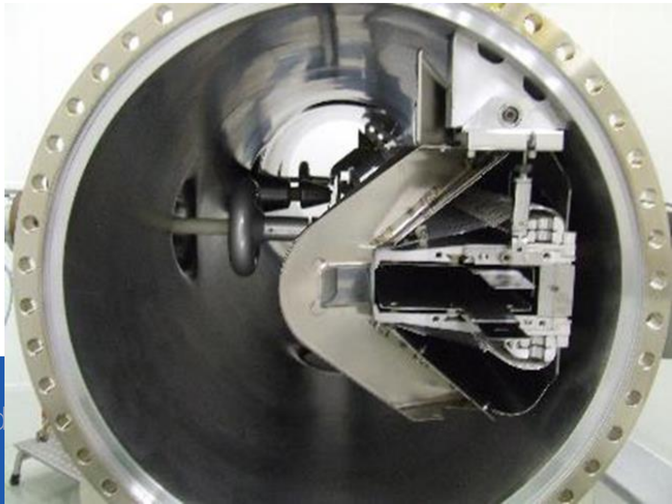
Case study: alternatives considered

Tank

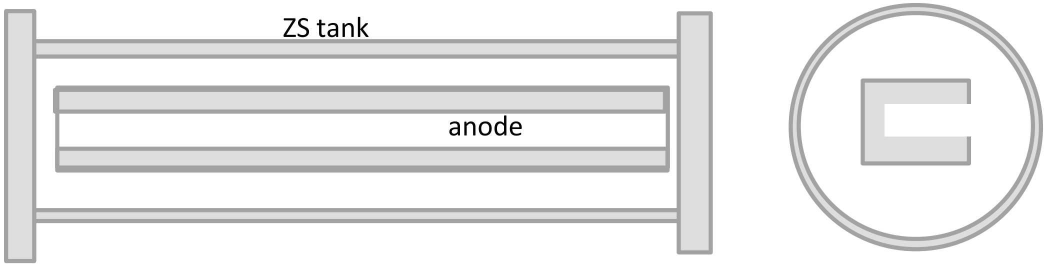
- Stainless steel: dimensions as present
- Aluminium: 67% thicker material (10 mm tank body, 50 mm covers)
- Titanium: 33% thinner material (4 mm tank body, 25 mm covers)

Anode (dimensions identical for all cases)

- Stainless steel
- Invar
- Titanium



Case study: Modelling with Actiwiz [6]



	Tank		Anode	
	Weight [kg]	Volume [dm³]	Weight [kg]	Volume [dm³]
Stainless steel	367	47	239	30
Aluminium	211	78	n.c.	n.c
Titanium	146	33	135	30
Invar	n.c.	n.c.	245	30

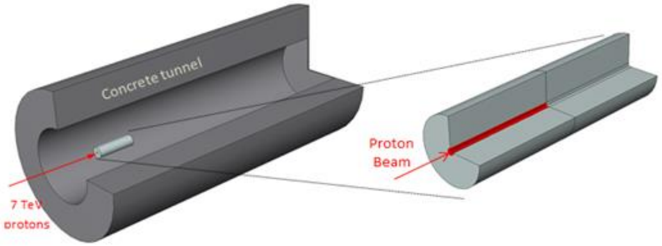


Figure 2: Irradiation situation used for the beam impact area activation calculations. The red cylinder (l= 100 cm, r =3 cm) indicates the detector volume used to score the particle fluence which is utilized to be further processed for activation studies.

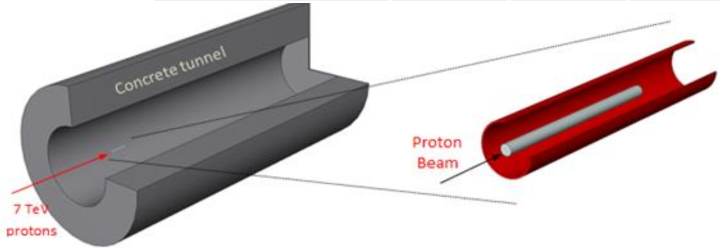


Figure 12: Irradiation situation used for the activation calculations considering locations at a lateral distance of 10 cm to the target. The red hollow cylinder (l= 150 cm, thickness: 1 cm) indicates the detector volume used to score the particle fluence which is utilized to be further processed for activation studies.

Case 1: Activation occurring at the beam impact area

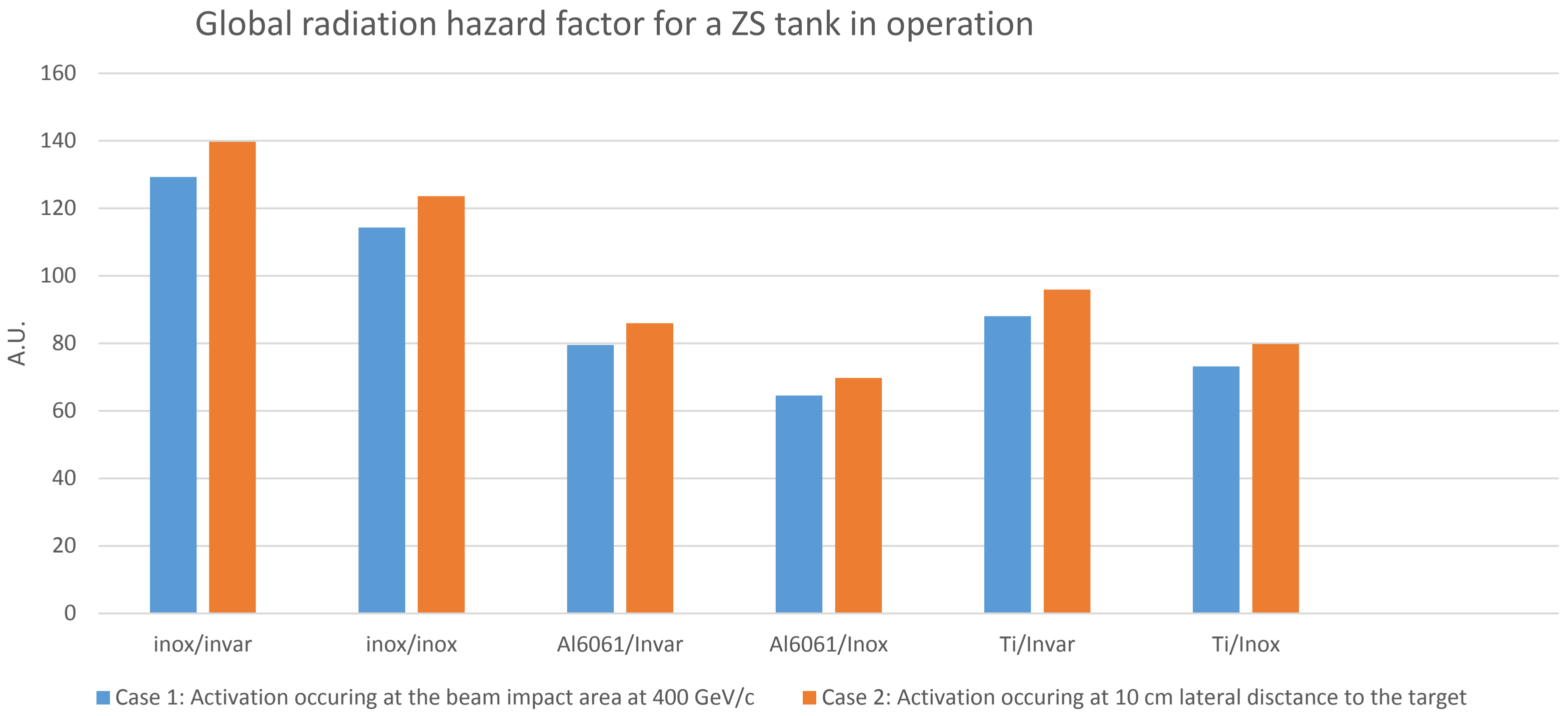
Case 2: Activation occurring at 10 cm lateral distance to the target

Case study: radiation hazard results

Approach used:

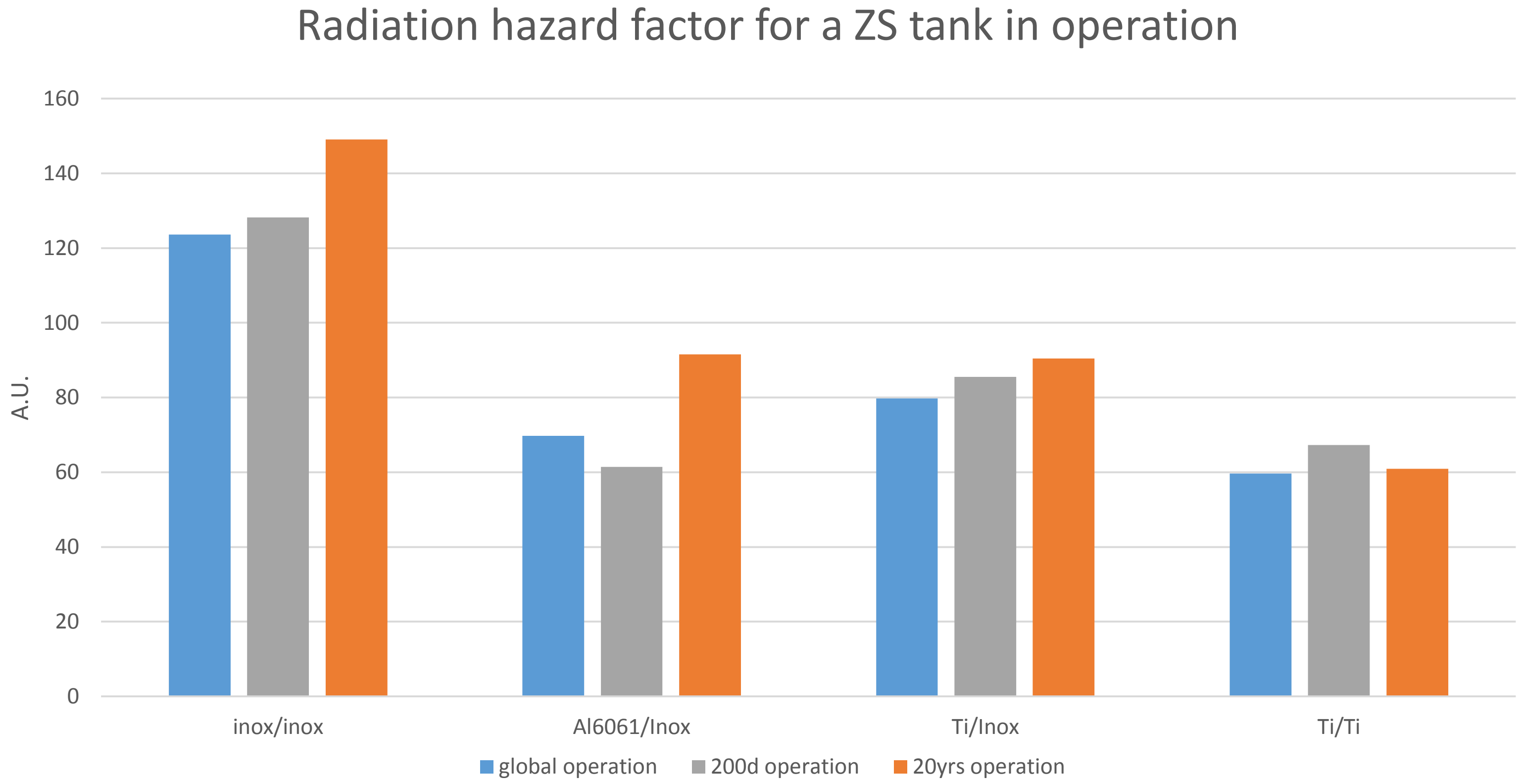
- Influence of the irradiation case on the results
- Global hazard results vs. 1 and 20 yrs operation results
- Optimal material choice

Case study: influence of the irradiation case on the results



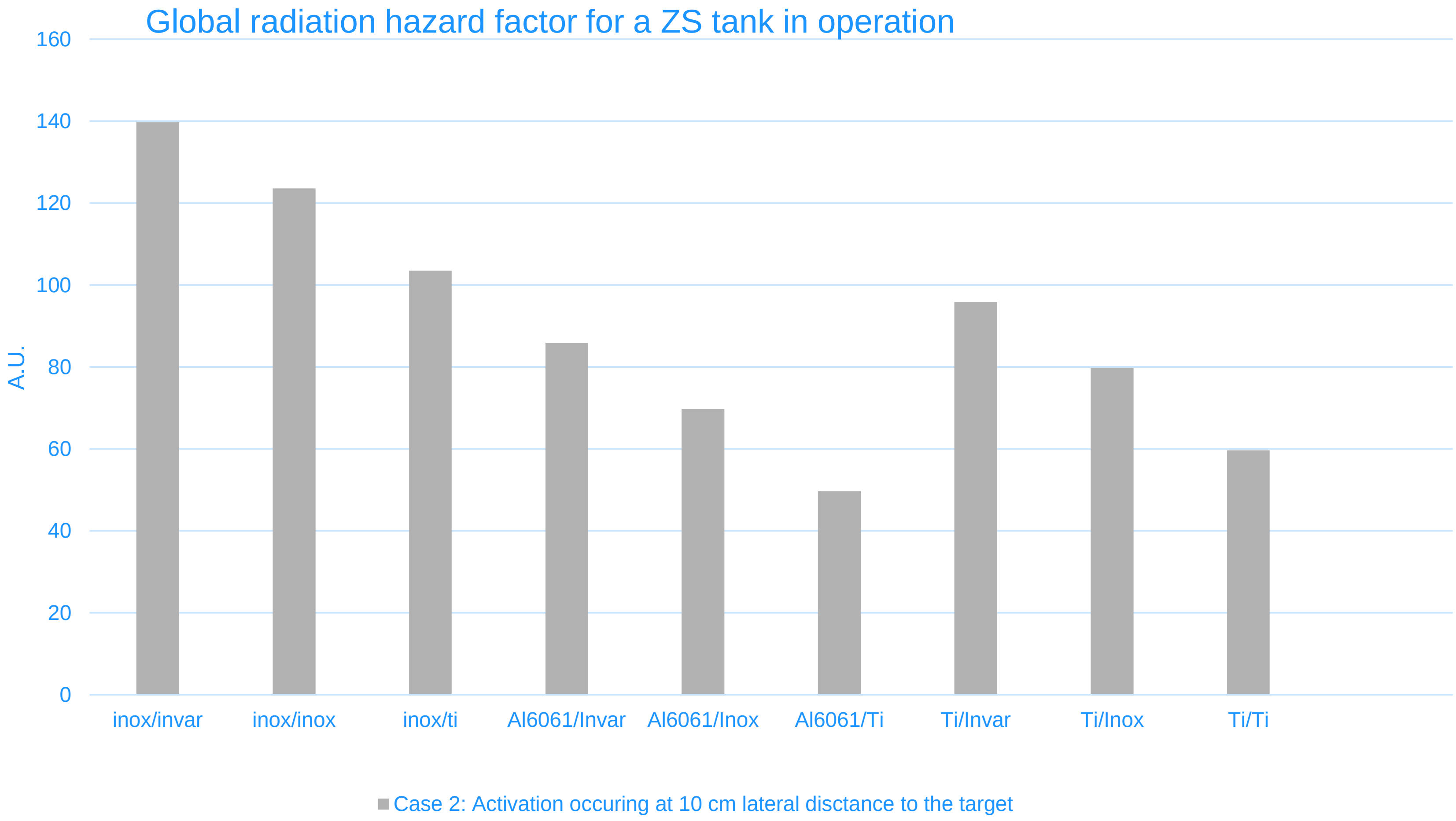
Although absolute values differ between the 2 cases, comparison of topologies within each case provide coherent indications of activation.

Case study: global hazard factor vs. 1 year and 20 yrs of operation



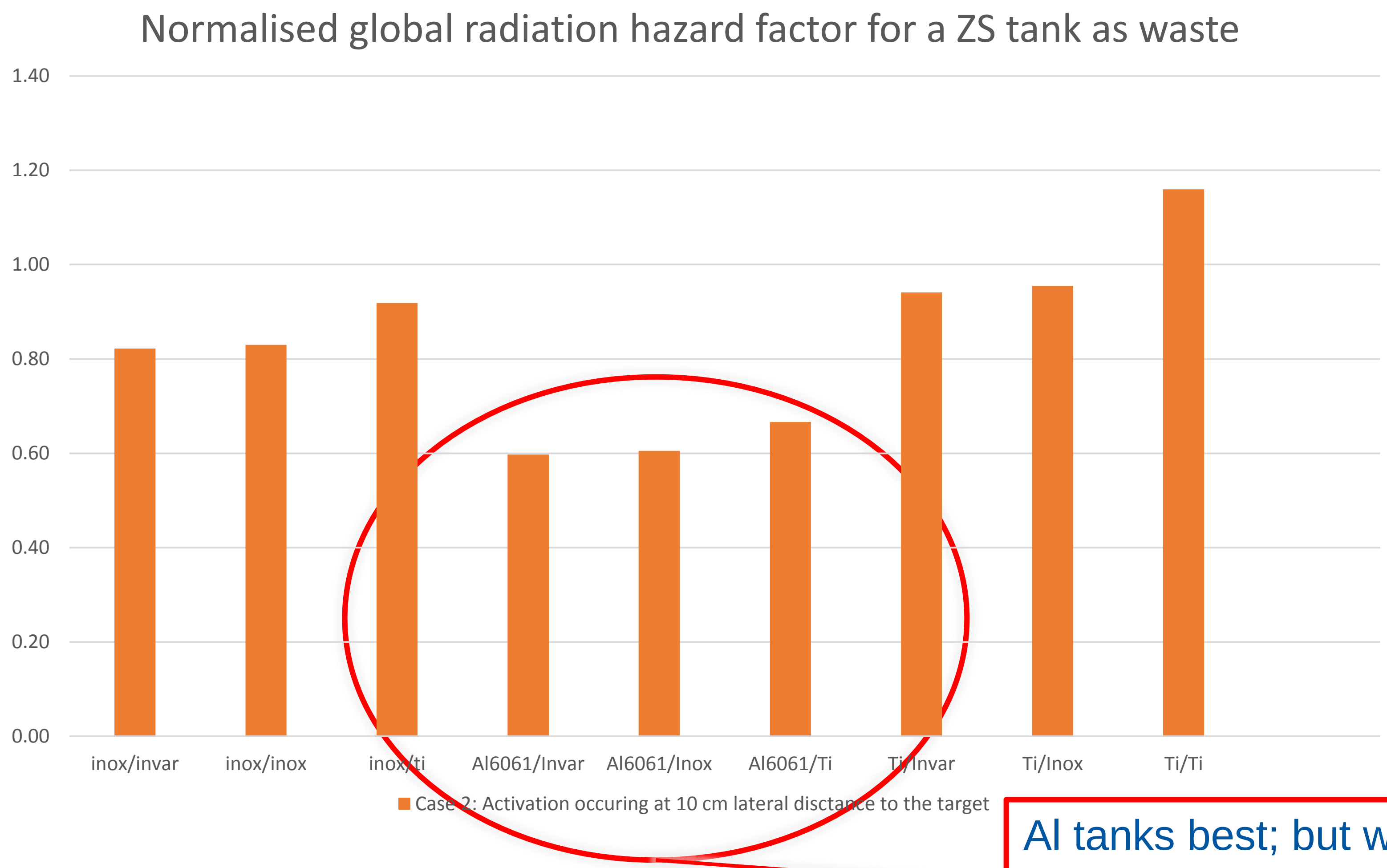
Global hazard factor correlates well with cases of 20 yrs of operation.
For 1 yr operation and in particular for titanium some small differences are visible.

Case study: activation in operation



Hazard of tank/anode support material combination

Case study: global radiation hazard



Al tanks best; but waste factors for Al being reviewed by RP.

Hazard of tank/anode support material combination

Low-Z anode supports

Use hollow electrodes, deflectors: sheet metal work is these days not a widely available skill anymore with the widespread use of CNC milling machines.

→ Maybe 3D printing can become a valid contender in the future?

Present unknowns of 3D printed components:

- Structural strength homogeneity
- Porosity (vacuum)
- Printing geometry limitations
- Behaviour under radiation

Outline

- Low-Z septum wire/foil

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- **Activation reduction, complementary approaches**
  - Crystal scatterers (see talks W. Scandale, F. Velotti at this workshop)
  - Wire/foil diffusers (see Brennan’s talk at this workshop)
  - High precision under-vacuum mechanical positioning systems for electrostatic septa (More on this at next talk by Ryotaro Muto)
  - Mini electrostatic septum

- Required idealised prototype septum

High precision positioning systems for electrostatic septa

Loss mitigation strongly linked to alignment of septum w.r.t. beam.

- Anode straightness presently 30 µm (unstrung).
- Straightness under operation (heating) unknown, but loss pattern improved since Invar anodes were introduced.
- Positioning system based on DC motor and potentiometer position read out.
- Alignment of electrostatic septa: fudicialisation in laboratory, and alignment on girder verified using external target supports on top of tank. →need measurement of anode support possible in the ring.

Topic for further development.

mini-Electrostatic Septum

Ultra-thin ES to make opening in beam for ‘real’ ZS wires?

- Keep short for maximum straightness (and integration)
- Keep thin for minimum beam loss. 10 µm suggested in the past (U.Wienands, TRIUMF Kaon factory, aiming at 0.1% extraction loss.)
- Use drift to ES for opening in beam – as big as possible
- Kick angle needs to be larger than full natural angular spread in beam at this location: have to assume dynamic bump steering or Hardt condition to keep this small – assume we can come down from +/-25 to +/-5 µrad. Or better?
- Use present HT supply if possible, maybe slightly relax on field?

Some numbers

- Approx 50 cm long septum (field length)
- 22 mm gap, 220 kV, 10 MV/m
- 10 um blade width (15 um with alignment/heating/field)
- Kick is 12.5 urad for 400 GeV/c (reduced to 10.2 urad after 3.8m QF with 0.016 Tm-2)
- Opening at ZS (for zero divergence beam) is 75 um
- Opening at ZS for beam with 10 um angular spread in separatrix is 65 um! ZS wire is 60 um thick!!

Courtesy B. Goddard

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Prototype proposal

- To address the challenges to construct a low activation device, a prototype development is proposed.
- Let's aim for the following specification:
  - Aluminium tank; will need development of main tank flange. Bakeable?
  - Anode with Carbon Nano Tube (CNT) wire septum.
  - Thin walled cathode (3D printed?).
  - > 300 kV feedthrough.
  - Precision alignment of anode support (septum) with external alignment targets.
  - Plug-in (easy to install/remove) electrodes.
  - Compatible with remote handling techniques.
  - 1 meter length, tank ø 450 mm.
  - Anything we overlooked??

Conclusions

- CNT wire appears an attractive alternative to WRe wire. HV performance and behaviour under sparking to be determined.
- Changing presently used materials should allow reduction of the residual activation of the septa.
    - Titanium anode is favourable, but:
        - it is still unclear if the (thermal) stability is sufficient for using it instead of Invar.
    - Aluminium vacuum tank appears preferable over titanium, but:
        - Waste advantage over Ti to be confirmed.
        - Bi-metal CF flanges (stainless steel/ aluminium) are commercially available,
        - Conflat (CF) flanges made completely of Aluminium are being developed by CERN TE/VSC,
        - Larger diameter flanges to replace ‘Suchet’ or ‘Wheeler’ flanges need to be developed.
- To develop and pursue new technologies, a functional specification for a prototype septum is proposed.

References

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4. M. Tomizawa, “ Slow extraction at J-Parc”, GSI Slow extraction workshop 1-3- June 2016, Darmstadt
5. J. Borburgh, “Activation reduction due to different septum tank materials”, SLAWG #7, 28/9/2016, Indico event 570165
6. Actiwiz, actiwiz.web.cern.ch
7. L.N. Bloomberg et al., “Electrostatics and beam losses for a wire array septum”, BNL Accelerator Department internal report, 1971
8. B. Goddard et al., “ZS HW modifications: higher voltage/bigger gap on upstream ZS, carbon wires, low-Z anode and tank, ultra-thin foil”, SLAWG#5, 1 September 2016, Indico event 562757