Driving innovation through integrated solutions

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30th September 2020

Overview

1. Introduction – RF Power at Teledyne e2v, the core products, markets and customers
2. RF subsystems R&D
3. Resultant new product developments

RF Power at Teledyne e2v

- English Electric Valve Company (EEV) was founded in 1947
  – we've been in many markets from the beginning
- 7 locations globally
  - 4 engineering, manufacturing and assembly
  - 3 local sales/customer support
- ~550 Employees
- Through technical innovation and development of new products we become designed into customer's platforms
- Work closely with customers from system concept, through design, manufacture and integration
- Significant investment in facility modernisation

Teledyne e2v HQ in Chelmsford, UK

Teledyne e2v in Beijing

Facility modernisation

Core commercial products

S band Magnetrons

X band Magnetrons

Magnetron Accessories S&X Band

Spark Gap

Thyratrons

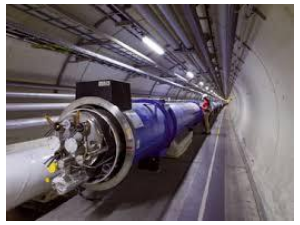
Modulators

RF Systems

IOT's

Markets and customers

- Radiotherapy
  - High-voltage switching and microwave sources for cancer treatment
- Commercial Radar
  - Microwave sources and components for large-vessel and airborne radar
- Security & Science
  - High-voltage switching and microwave sources for cargo scanning and high-energy physics
- Broadcast & Industrial
  - Inductive output and Gridded tubes for TV broadcast and industrial heating applications
- Defence
  - Travelling-wave and high-power microwave sources for military applications

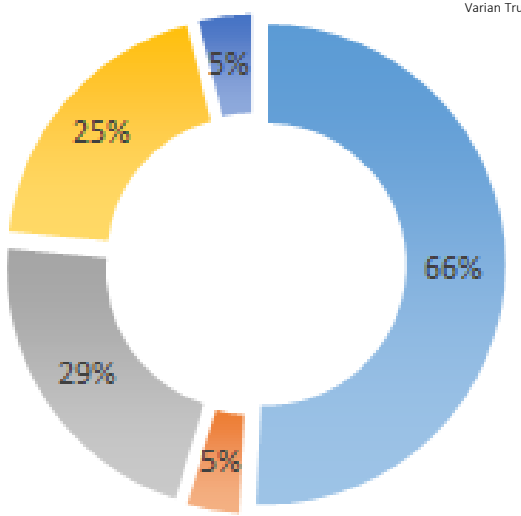


CERN

Varian Truebeam

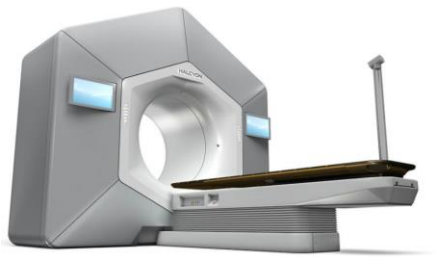
Furuno|

Nuctech



Radiotherapy trends

Latest generation of medical systems

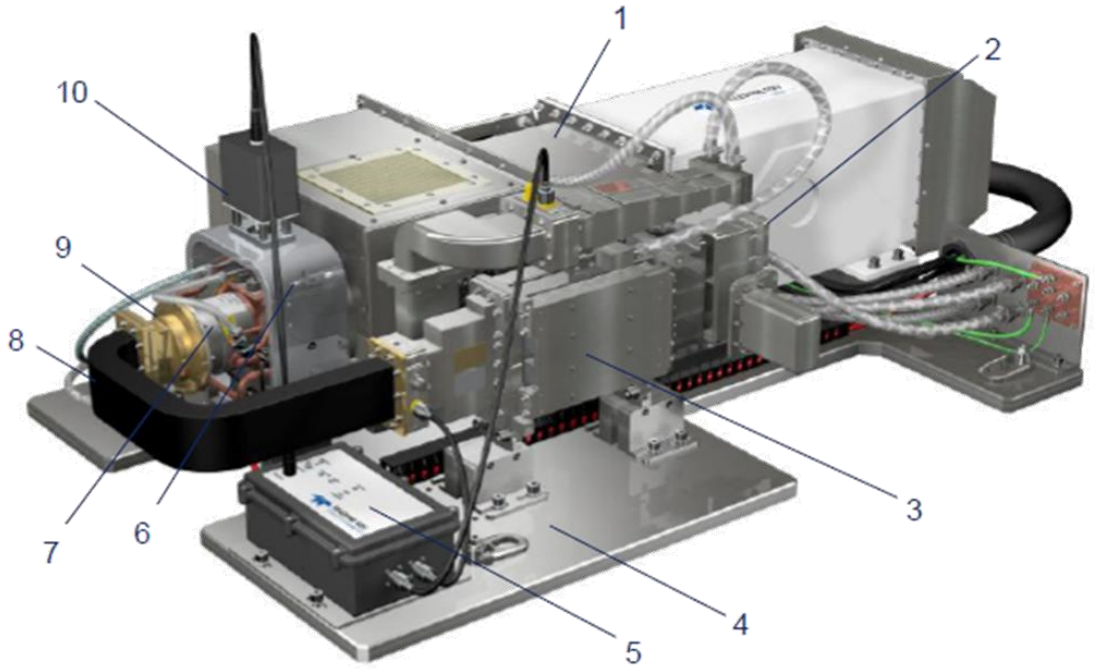


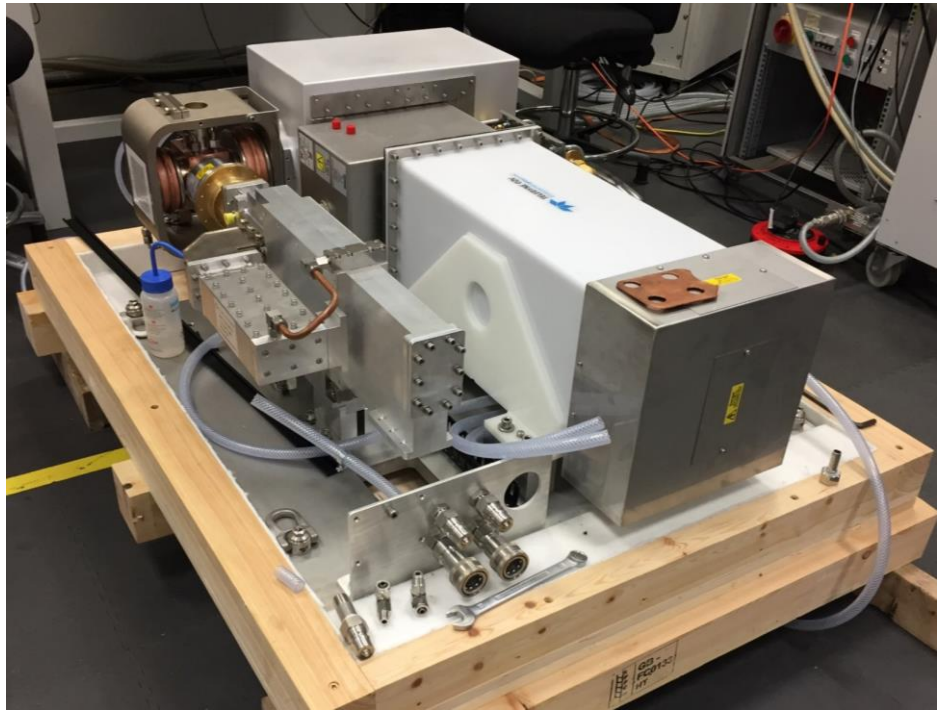
- **Different energies for different treatments**
  - → Trend to low energy workhorse systems (smaller, simpler systems for most treatments)
- **Alternative imaging techniques**
  - → MVCT removes kVCT components but requires more dynamic range from RF source
  - → MRI gives high quality real-time image but requires more RF power due to loss through cryostat
- **Advanced treatment delivery**
  - → Increased stress on beam generation system
  - → Solid-state modulators replacing PFN modulators
- **Faster patient throughput**
  - → Higher dose rates require higher mean power from the RF source
  - → Faster rotational speed requires a ring gantry
  - → Flattening filter free (FFF) operation

Suppliers of RF

- Recognise that the customer objective is not to purchase a particular type of hardware (magnetrons / IOTs / TWTs etc.) but to reliably and cost-effectively generate RF with the characteristics they need
- Teledyne e2v has a broad range and high level of experience and capability in this space
- Customers would welcome the provision of full RF subsystem solutions which have been developed as such

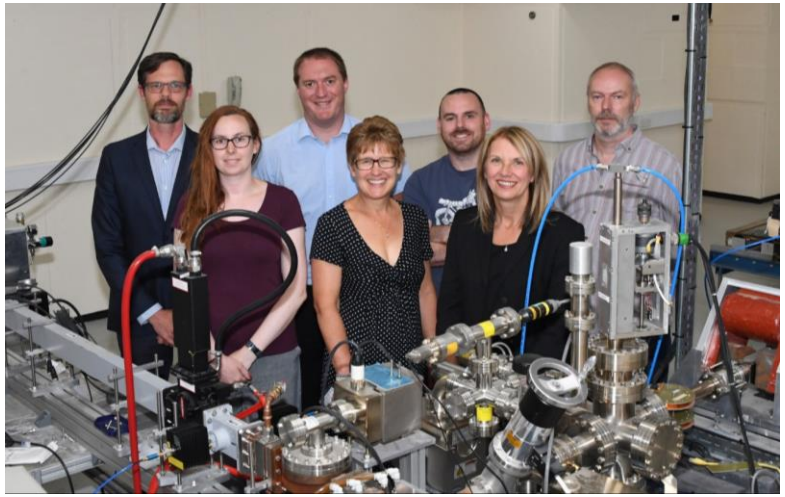
RF subsystems





1 – Modulator
2 – Waveguide Output Interface
3 – Circulator Assembly
4 – Base Plate
5 – AFC Control Unit
6 – Magnet
7 – Magnetron
8 – Waveguide
9 – Transition
10 – AFC Motor Unit

System level R&D – STFC collaboration



TELEDYNE e2v Everywhereyoulook™

- Enhance product development
- Provide solutions tailored to applications

Science & Technology Facilities Council

- Collaboration with other industrial users
- Engagement with academic research

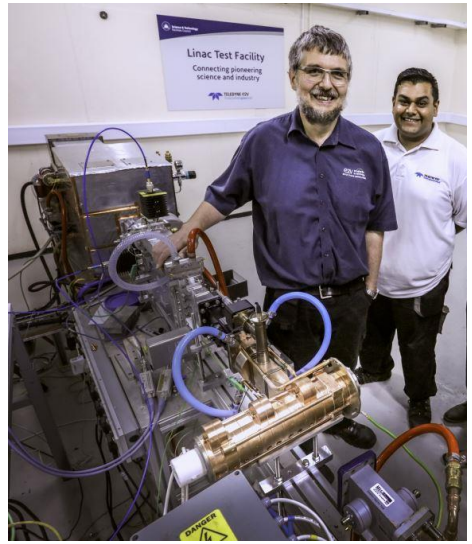
How does this work in practice?

Provision of test facilities at Daresbury Laboratory by STFC to Teledyne e2v

- Infrastructure of the Linac Test Facility
- STFC staff expertise in commissioning and operating Linacs

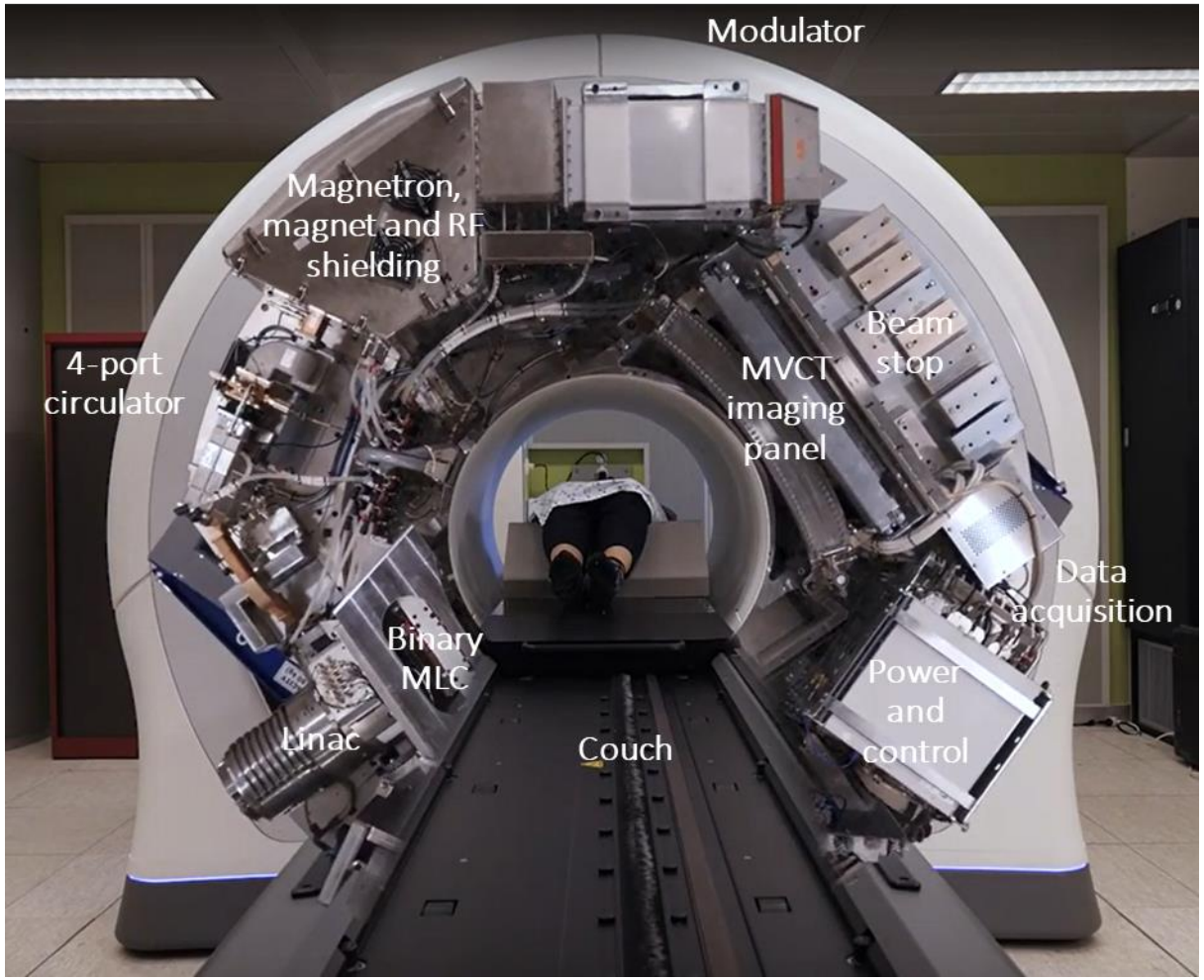
Support of Compact Linac by Teledyne e2v at STFC

- Quality of performance
- Continuity of operation



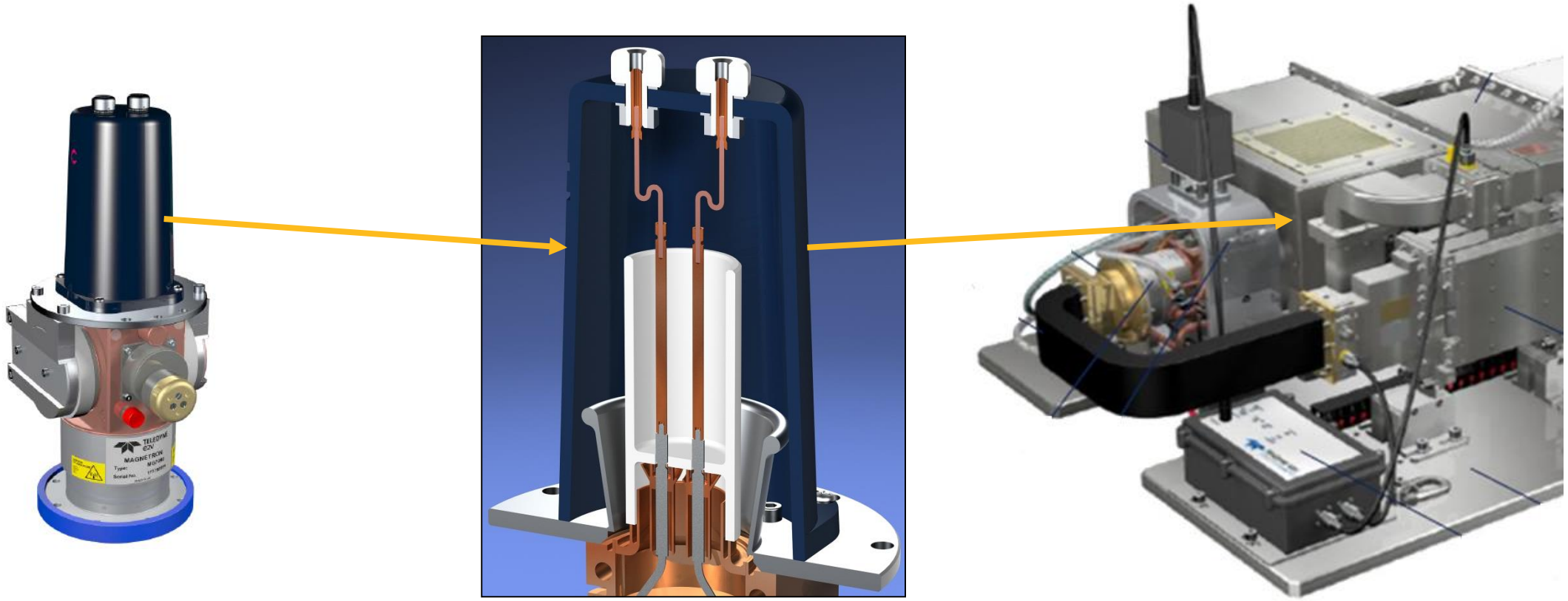
Magnetron module development

Consideration 1 – space is at a premium



Magnetron module development

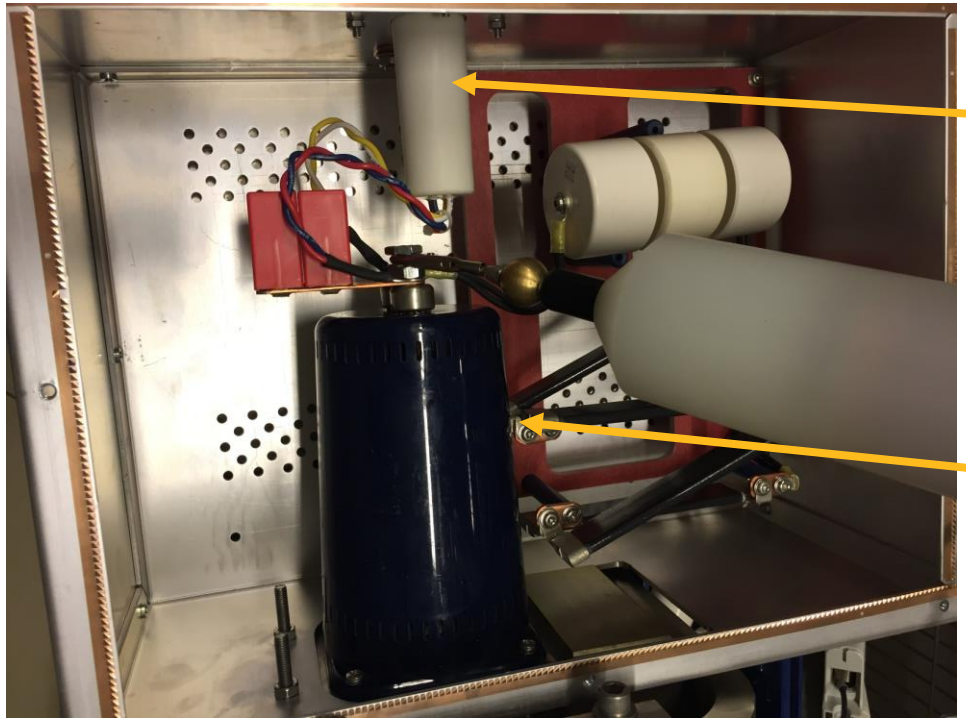
Why the need for RF shielding?



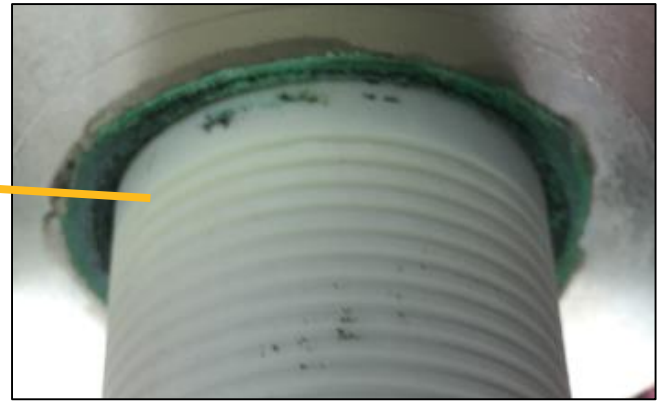
Objective 1: Bring the shielding closer to the source.

Magnetron module development

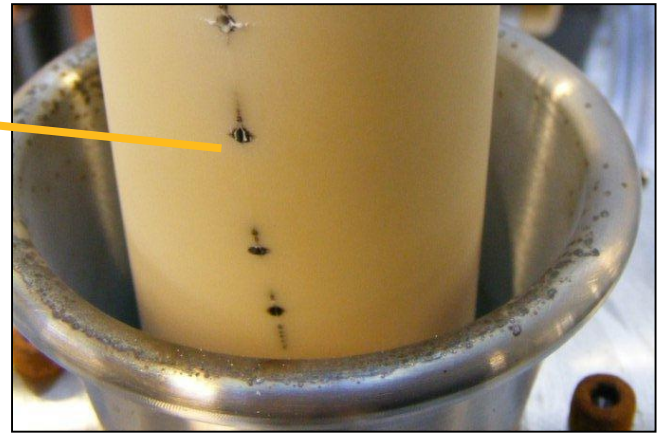
Consideration 2 – clearances and profiles matter



Example Faraday cage.



Corrosion caused by ozone generation around connectors.



Puncturing of insulator caused by external conductors coming too close to the high voltage structure.

Objective 2: Provide increased protection against external components causing voltage breakdown.

Objective 3: Design shielding to handle operation at altitude.

Magnetron module development

Consideration 3 – ease of installation

The top 3 causes of service call-outs on radiotherapy systems are related to (1) MLC motors, (2) loose nuts and bolts, (3) loose cables.

Side panel of Faraday cage needs to be removed to get access to internal connections.

Screws must be removed from magnetron terminals.

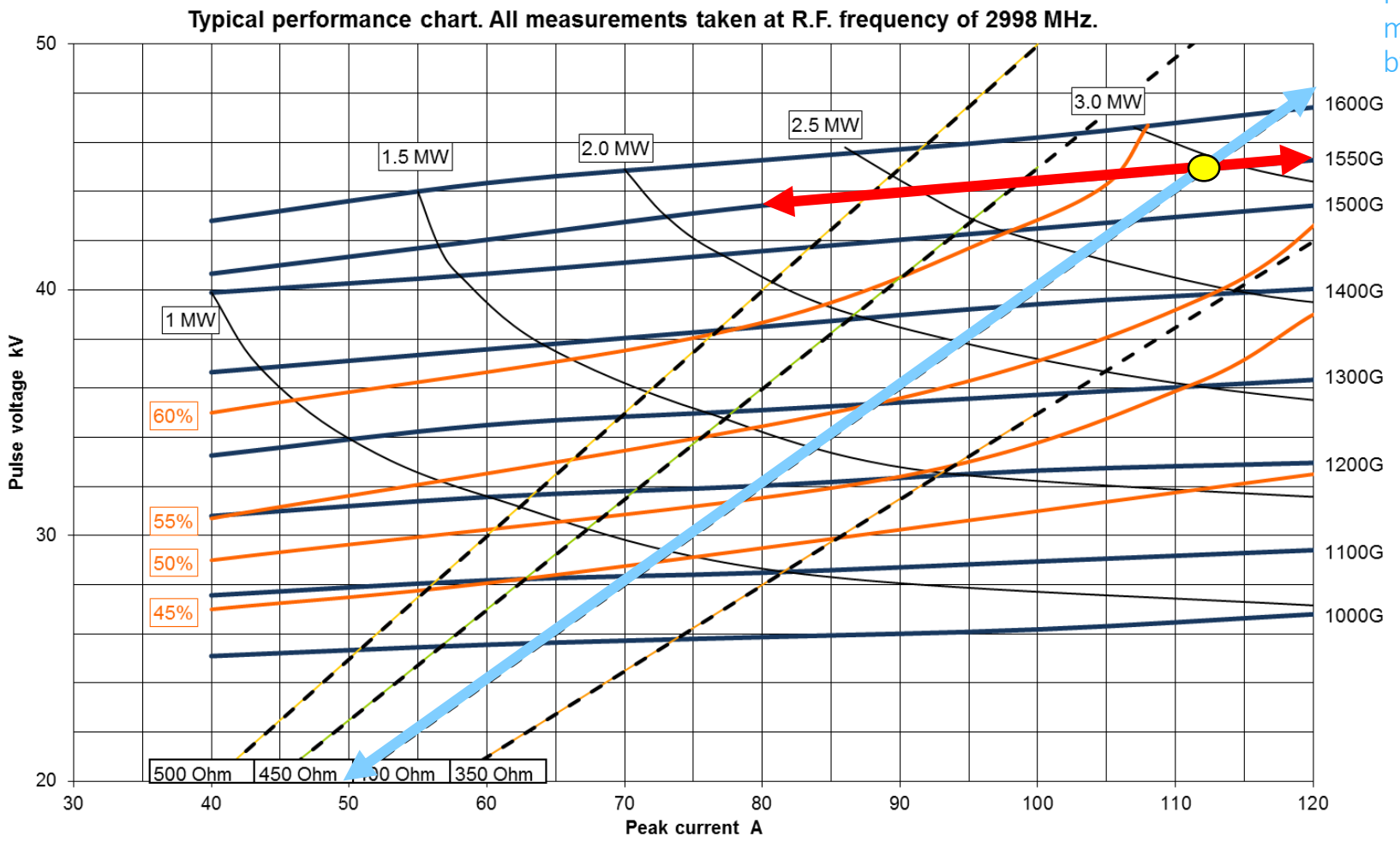
Magnetron output connects to RF waveguide run so entire Faraday cage must be lifted off to remove the magnetron.

(Alternatively, the entire magnetron is housed within the Faraday cage – even bigger!)

Objective 4: Minimise the number screws and cables used to install/remove the magnetron.

Magnetron module development

Consideration 4 – ease of set-up



Pulse transformer impedance matched conditions determined by drive electronics.

Operational space set by magnetic field.

All components might meet specification but integrated performance is sensitive to tolerances in the magnet, the magnetron and the matching network.

Objective 5: Tighten performance at a module level – plug-and-play.

Summary of objectives

1. Bring the shielding closer to the source to reduce footprint.
2. Provide increased protection against external components causing voltage breakdown.
3. Design shielding to handle operation of full module at altitude.
4. Minimise the number of screws, cables etc. used to install/remove magnetron module.
5. Tighten performance at a module level – plug-and-play.

Socket magnetron and integrated modules

Integral high voltage socket for ease of connection and coax cable with earthed outer

Integrated RF shielding makes the solution compact and quick to service

Integrated electronics for filament protection and impedance matching to the drive system

Earthed conducting exterior – no exposed voltages, improving safety and allowing close proximity to other system elements

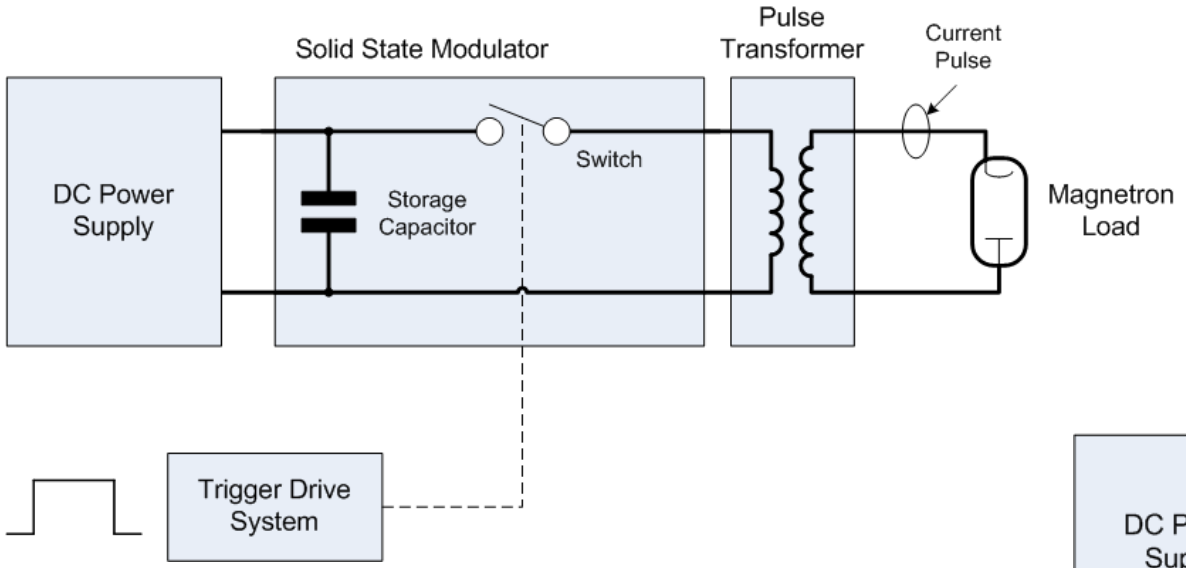
Design considers altitude requirements to ensure deployment is not limited

Permanent magnet optimised for best magnetron performance into the system and for 'plug-and-play' consistency

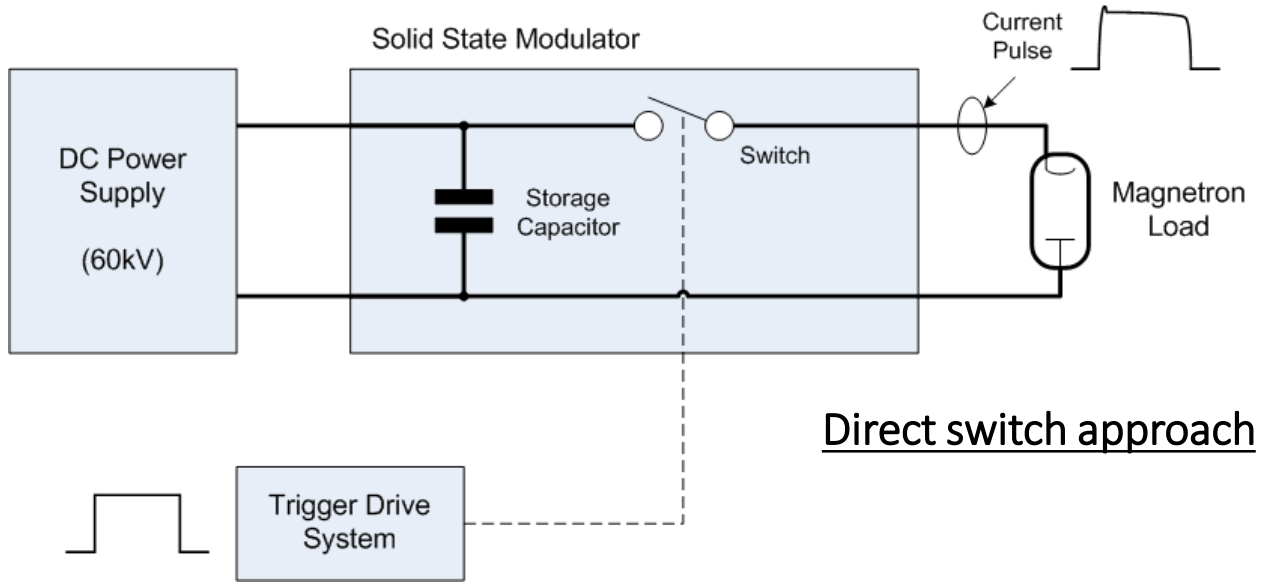
RF waveguide transition for output into standard rectangular guide

Option for integration of tuner motor assembly

Advantages of a direct switch modulator



Transformer approach



Direct switch approach

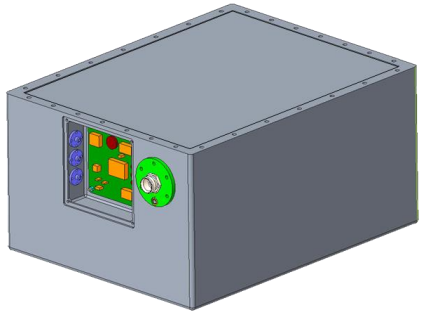
Next generation solid-state modulator

Current offering:

- AMM1 solid-state modulator system
- 20-years of successful history in ~500 systems globally
- Leading product in the market for a generation of systems
- Based on direct-switch technology – best for magnetrons
- Performance remains strong but a new generation is needed

Under development:

- Building on years of experience and learning
- We are listening to customer needs and feedback
- Designed using learning from other R&D, such as STFC
- Part of a coordinated RF system development – designed to give best performance throughout



- Massive reduction in size, weight and input power
- Impedance matching elements no longer required
- Improved reliability and EMI screening
- Gives best magnetron performance and reliability
- Simple integration

Summary

- Teledyne e2v has a breadth and depth of capability and experience in RF generation
- Collaboration with STFC has enabled Teledyne e2v to drive innovation through the integration of components
- Teledyne e2v is uniquely placed to address both the integration challenge and the fundamental component design
- Whilst this presentation has focused on developments for the radiotherapy market, we have similar ambitions in our other markets

ANY QUESTIONS?