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NHS Foundation Trust

Update on the Ocular Proton therapy Service at Clatterbridge Cancer Centre

Lucy Partridge 9th November 2023

Overview

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- Introduction and background
- Challenges
- Hardware
- Planning system
- QA devices
- Conclusions

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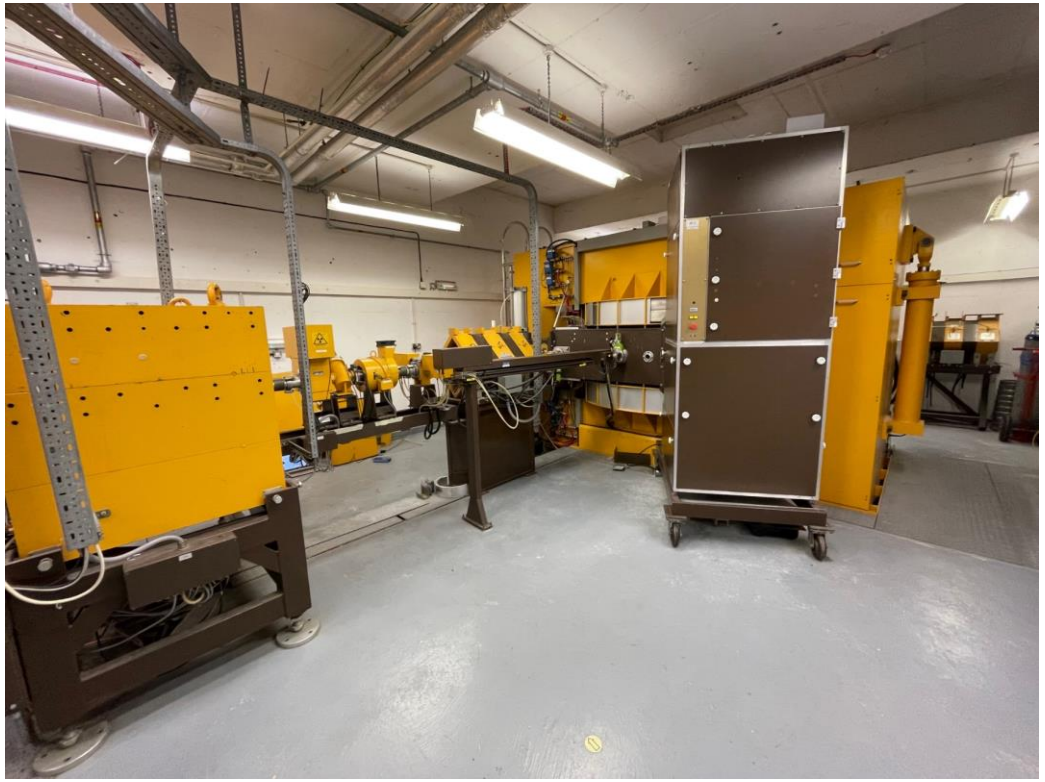
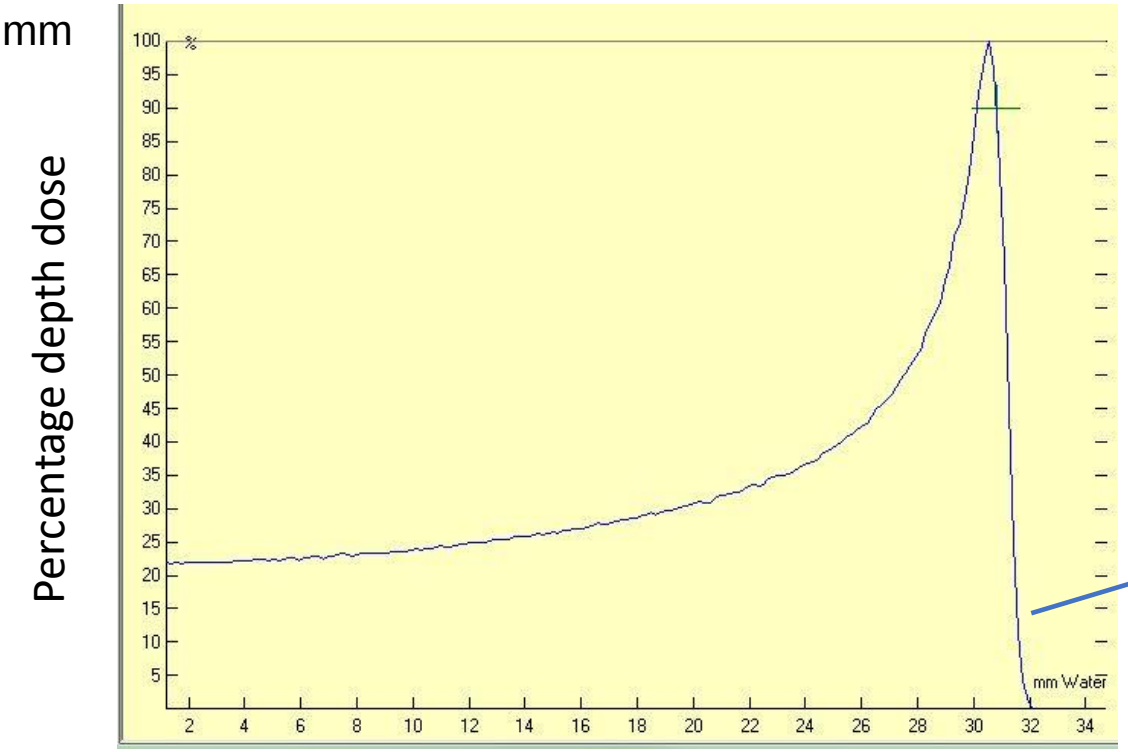
Introduction

- Ocular tumours have been treated using protons at Clatterbridge Cancer Centre since 1989.
- The cyclotron was manufactured by Scanditronix and produces a 60 MeV beam.



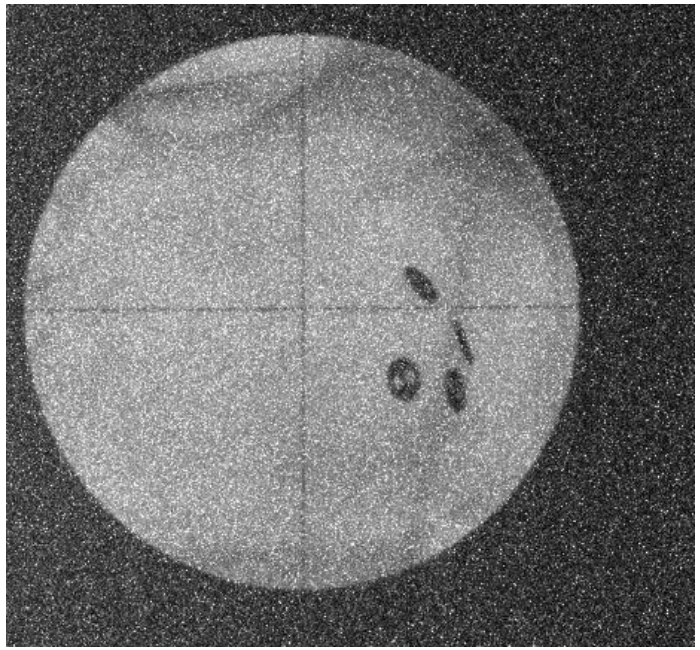
Introduction

- The beam has a range in water of approximately 31 mm.
- Distal fall-off is very steep, low entrance dose 21%
- Low side scatter, penumbra 1.5 mm
- Ideal for ocular tumours

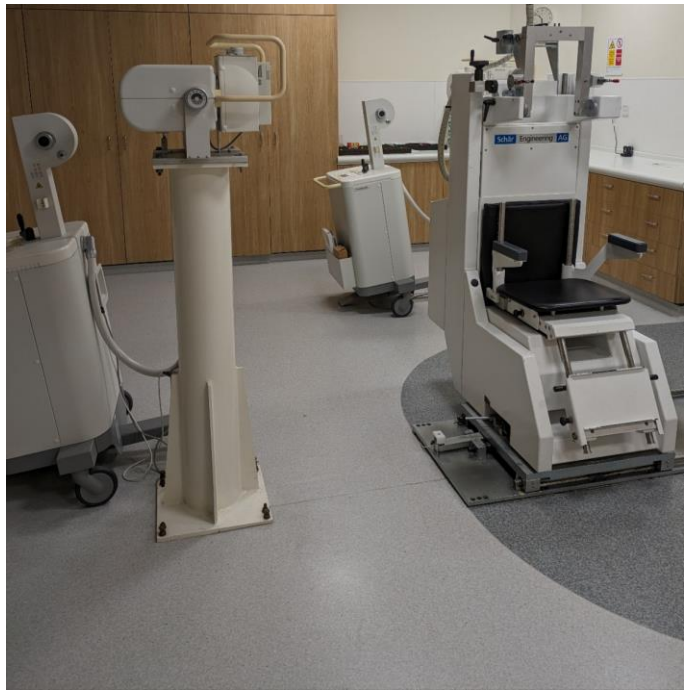


Introduction

- Prior to attending Clatterbridge treatment patients have tantalum markers inserted to delineate the tumour base.
- An orthogonal pair of kV x-rays are used for planning, and treatment verification.



Anterior-posterior

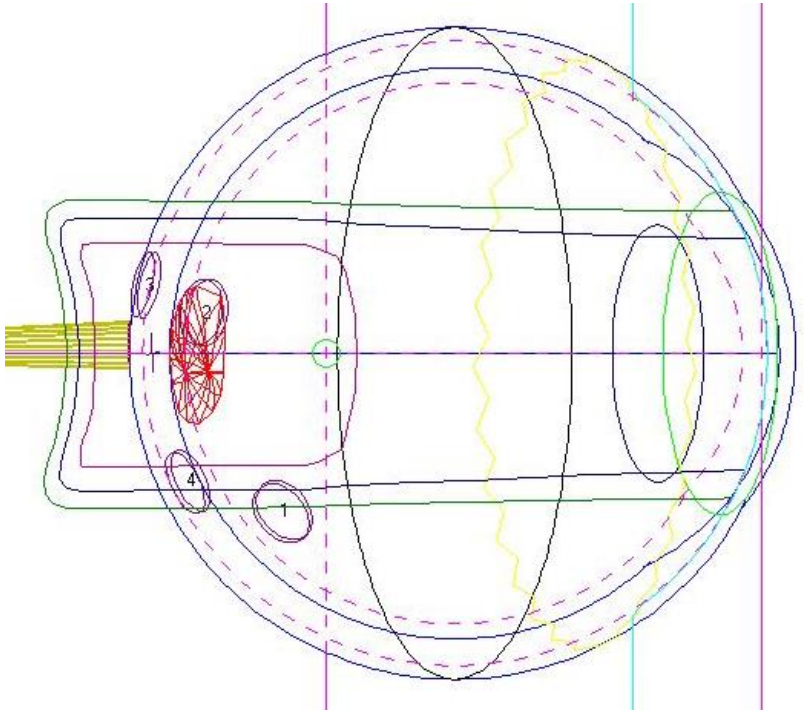


X-ray sets in the treatment room

Introduction

- The planning System used is EyePlan, developed in house.
- EyePlan allows the registration a fundus photograph and the digitisation of the clips.
- Dose is calculated using lookup tables.

Fundus view



Vertical slice

Introduction

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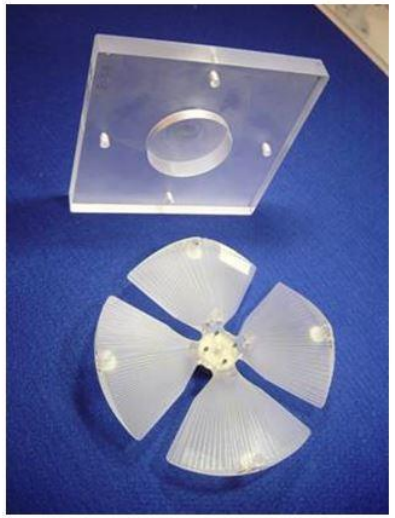
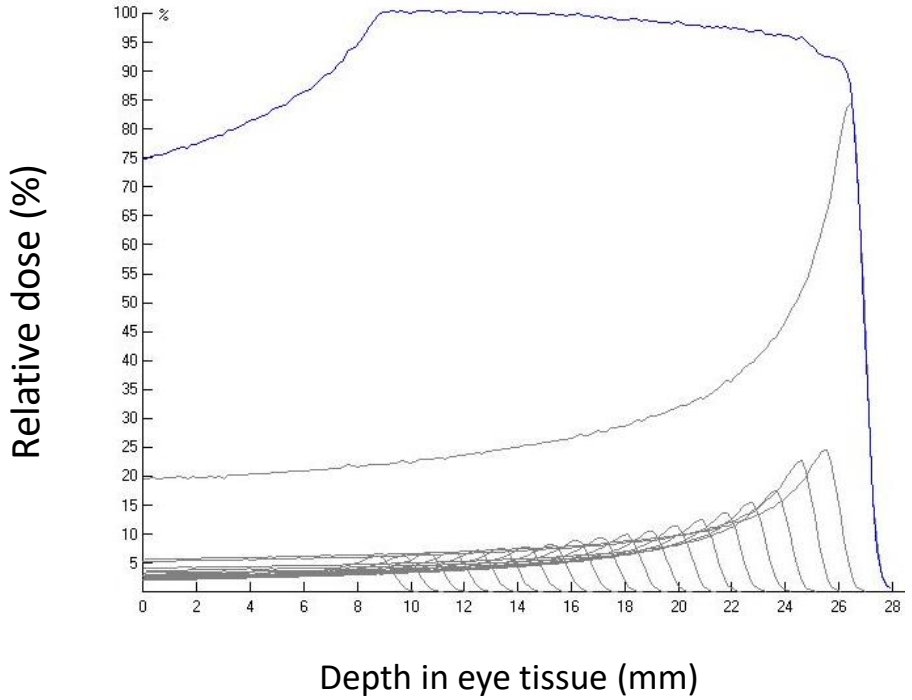
- To create clinically useful beams passive scattering is used
- Library of range shifters and modulators to create spread out Bragg peaks created in house

Range shifter and modulator





Challenges

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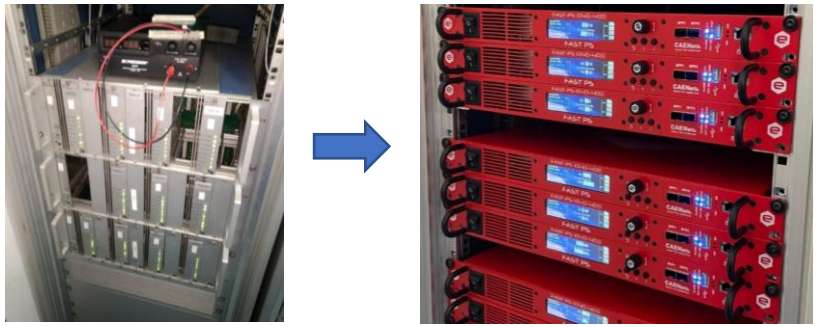
- Challenge 1 – Operational since 1989, has exceeded it's lifespan by many years and requires modernisation to continue providing a reliable beam.

- Challenge 2 - No support or future development provided for EyePlan. This brings the software to the end of its lifespan and another solution must be sought.

Challenge 1- Hardware

- Hardware upgrade programme: Extend the operational life of the cyclotron by 5 to 10 years to give time for a long term replacement
- Evaluate technical systems to produce a targeted list of required upgrades
- Purchase off the shelf components to replace obsolete parts with state of the art equivalents
- Work with Industrial partners to produce equipment where no off the shelf solution exists

Vacuum pumps (Leybold)



Magnet power supplies (CAEN-els)

Control System (Cosylab)

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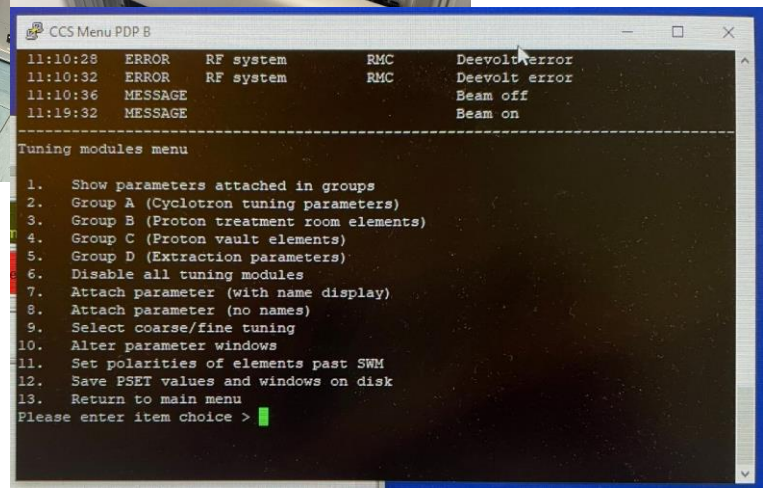
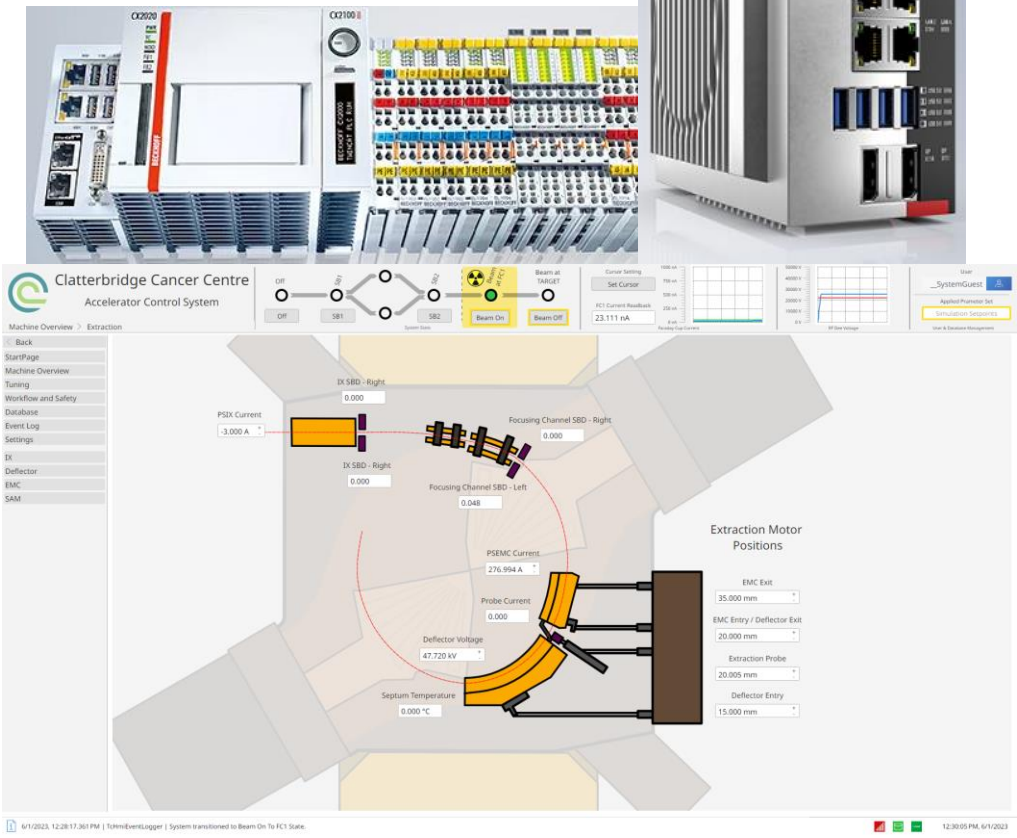
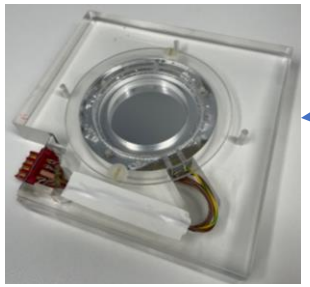
- Present system based on a PD11 computer of 1970s vintage and a logic controller of a similar age
- No support available and parts are difficult to find
- Cosylab are providing a bespoke control system based on modern computer technology





Dose Control System (Pyramid Technical Consultants)

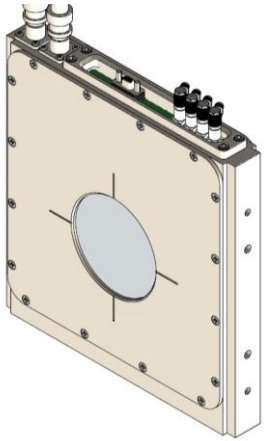
- Dose Control System Present system 38 years old and no longer supported. Not compliant with modern standards.
- Uses in house built ion chambers which require frequent replacement and electronics which are difficult to maintain



In house built ion chamber

- Pyramid Technical Consultants are providing new quadrant ION chambers based on their FX4 electrometer and dose control devices which will be integrated into a fully compliant dose monitoring and control system.

Quadrant ion chamber



Four channel precision electrometer, applications include

- Dose delivery control
- Beam stabilisation

Challenge 2 – Planning system

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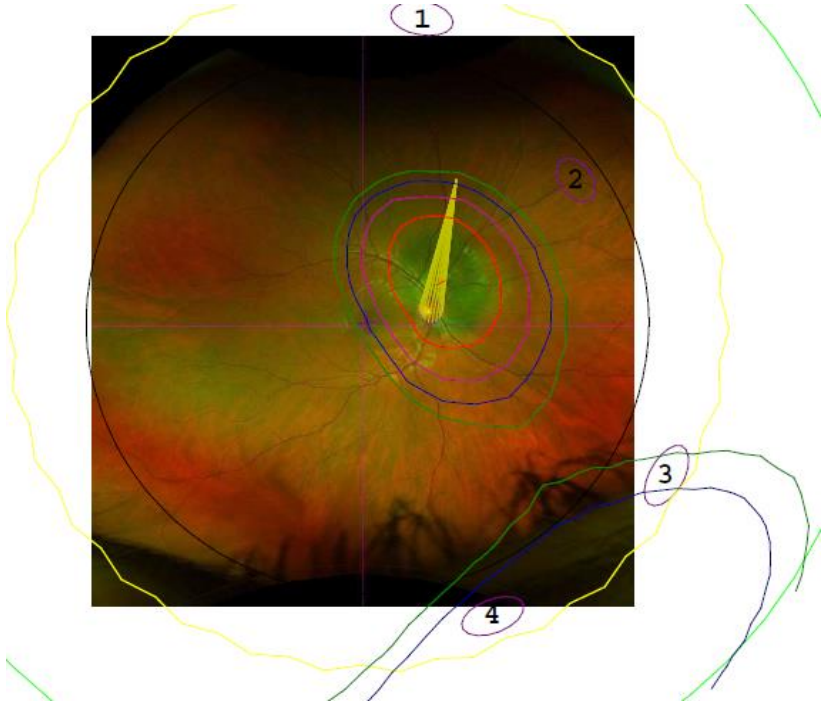
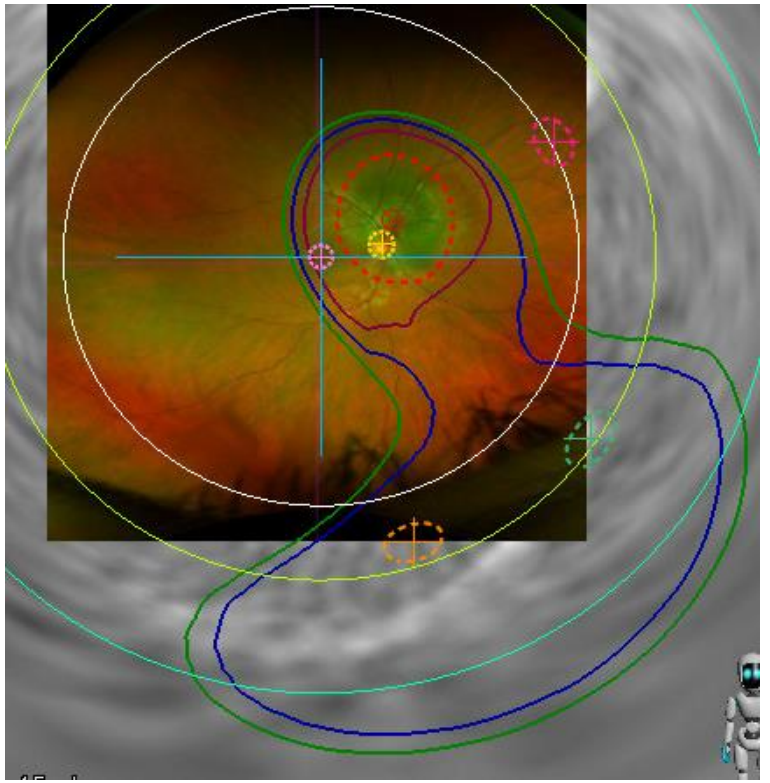
- Rayocular module of Raystation, a commercially available planning system has been chosen to replace EyePlan.
- It offers similar capabilities to EyePlan with the addition of CT/MR based eye model creation and pencil beam dose calculation.
- An evaluation the functionality of RayOcular in comparison with EyePlan for planning clipped ocular patients has been carried out.
- How the software and requirement for 3D imaging will integrate into the existing patient workflow will need to be addressed.

RayOcular

- Planning evaluation: using five patient datasets (kV simulation images, fundus and 3D data) were used to investigate the process in RayOcular and quantify the differences with respect to EyePlan.
- Fundus images with overlaid dose distribution for EyePlan (L) and RayOcular (R).





RayOcular

- The table below shows the comparison between EyePlan and RayOcular

Parameter	EyePlan	RayOcular
Simulation imaging	Fundus only	Fundus & 3D required
Clip modelling	Planar x-ray	CT / MR
Fundus imagery	No adjustable options for scaling	4 customisable parameters to be adjusted per camera
Macula position	Assumes posterior pole	No assumption
OD – Fovea distance	Fixed – Fovea is 4mm lateral to OD	Measurement required
Eye coats	0.6mm thick retina, rest of thickness of coats assigned as sclera	Custom – can assign any values
Optic nerve position	Fixed medially at distal end	Fixed orientation with respect to eye
Dose reporting	Length of optic nerve, area of OD & Fovea receiving X% dose	Volumetric reporting. Recommended metrics provided in Espensen et al (1)
Eyelids	Modelling available	No eyelid modelling available
Dose calculation	Lookup tables	Pencil beam algorithm

- Developing a planning process comparable to EyePlan is complicated the fact there are more degrees of freedom in RayOcular requiring decisions about parameters that are not customisable in EyePlan.
- E.g. relationship between macula and disc and camera settings for the fundus image.
- Many of the dose reporting parameters are not comparable
- Initial results show that the clips patterns and dose distributions are qualitatively similar.

(1) Dose-Response and Normal Tissue Complication Probabilities after Proton Therapy for Choroidal Melanoma"; Espensen et al, Opthalmology Vol 128, Issue 1, Jan 2021)

RayOcular

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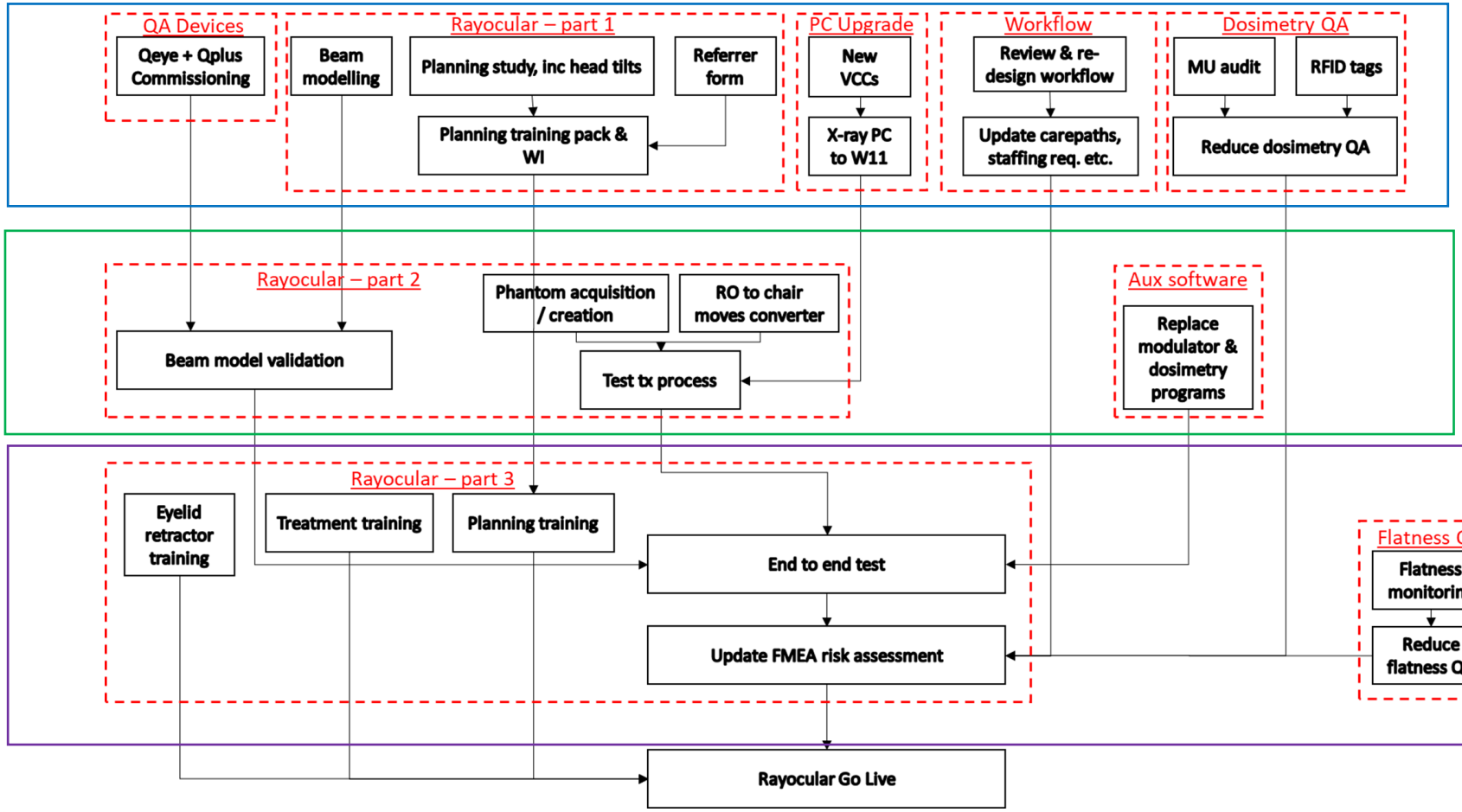
- Includes nine ‘sub’-projects, shown on the next slide
- The addition of CT/MR brings greater certainty in the placement of registration of clips
- Increased complexity of the eye model will result in increased planning time therefore other efficiency savings will need to be explored.
- By reducing the amount and time taken to complete pre-treatment QA and/or reviewing workflow.

RayOcular

- Wide ranging service upgrade project has begun which includes nine different ‘sub’ -projects



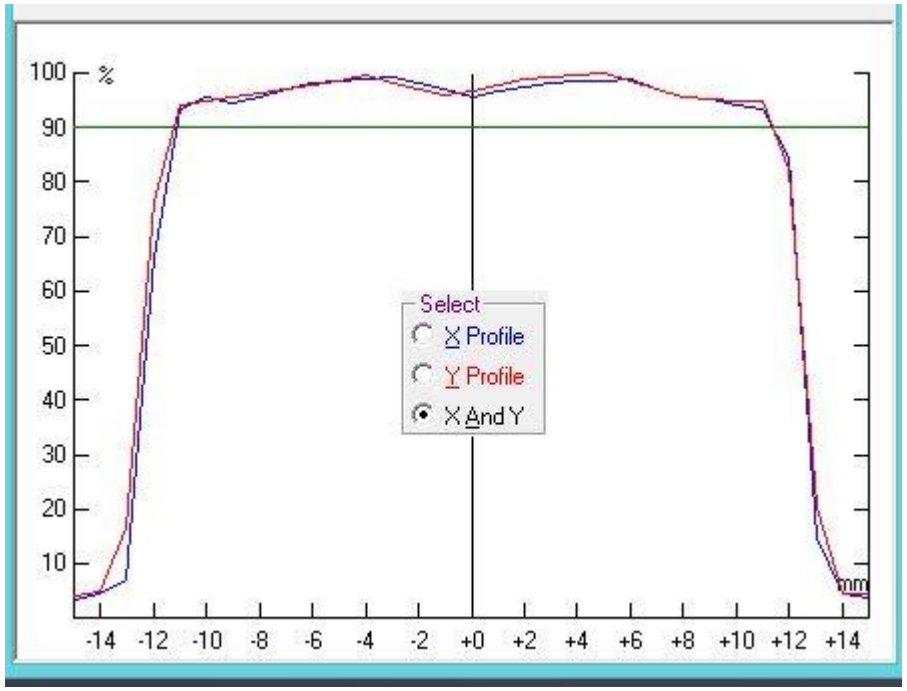
QA devices

- Beam profiles and depth doses are measured for each patient before treatment.
- The current QA devices are made in house, the scanner and Bragg wheel
- These QA devices are going to be replaced by QEye and QPlus devices manufactured by DE.TEC.TOR (Devices and Technologies Torino)
- Commissioning is underway

QEye and QPlus

QA devices

- Scanner measures X and Y profiles, uses a single diode which ‘scans’ across the beam.
- Profiles are measured before each fraction and is a time consuming process
- Can add significant amount of time to the treatment



QA devices

- The QPlus is designed to measure lateral beam profiles in a single beam shot
- This should reduce time taken for pre-treatment QA considerably
- The device contains a planar ionisation chamber which generates the profile.

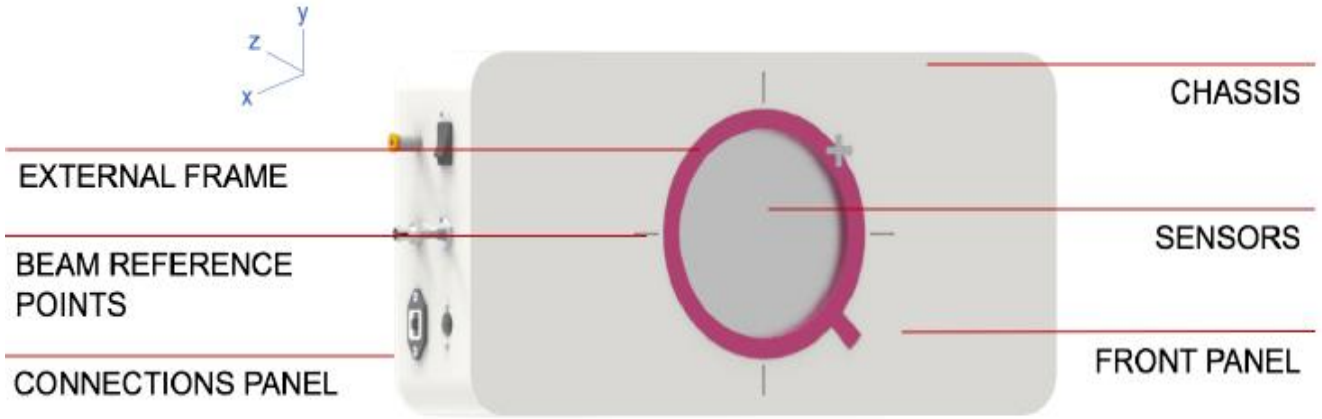
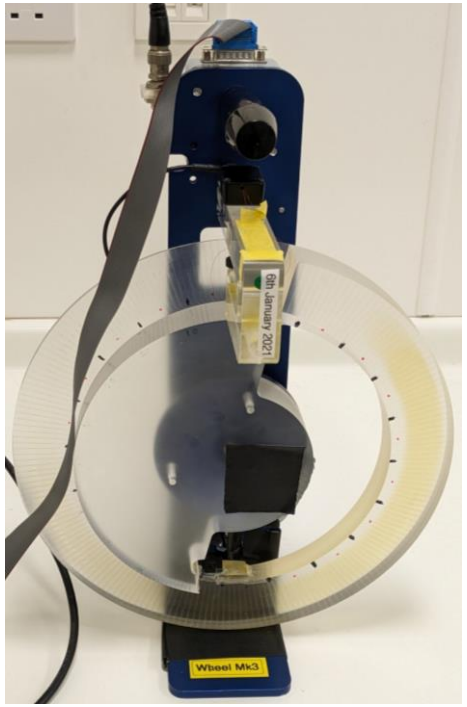
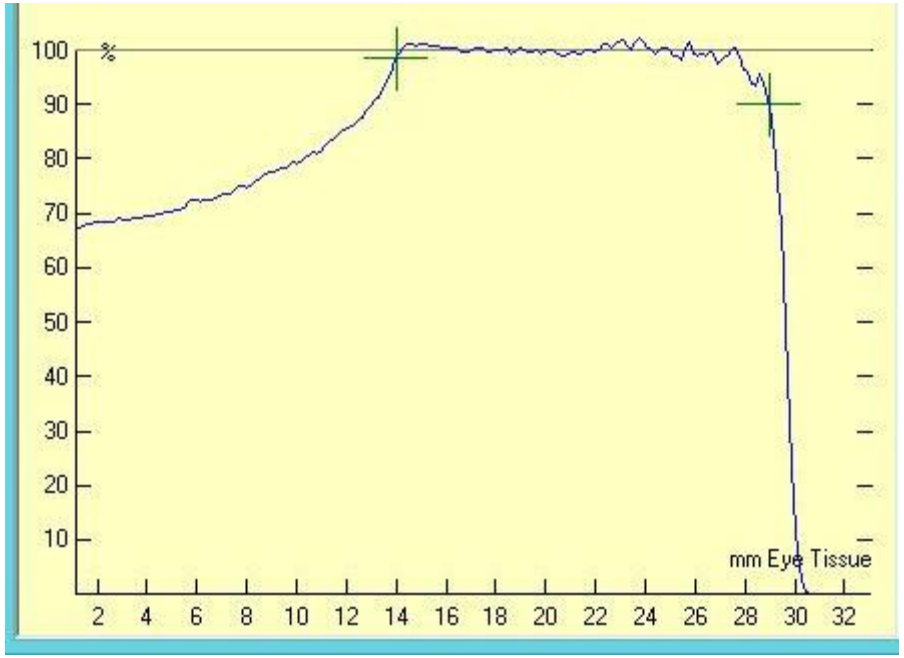


Figure 1 Perspective view of QPLUS

QA devices

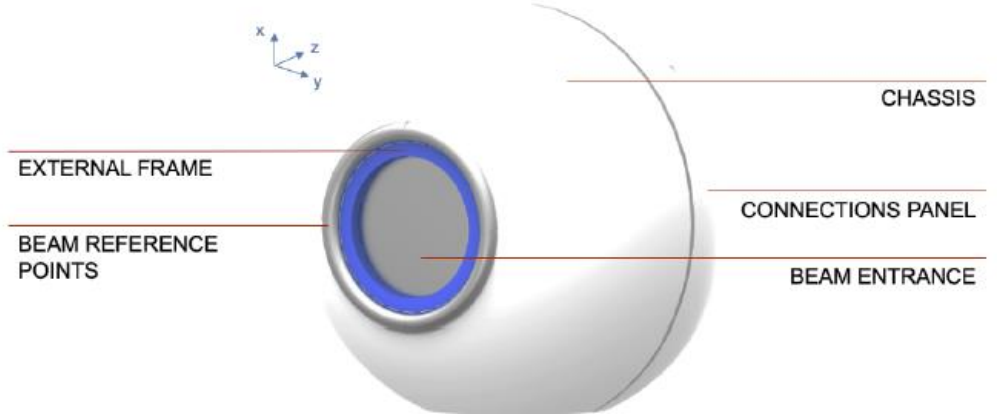
- Bragg wheel used for measuring depth doses
- Uses a single diode
- Depth doses are measured for each patient prior to treatment
- Can be time consuming particularly if measurements with different combinations of range shifters and modulators are required.





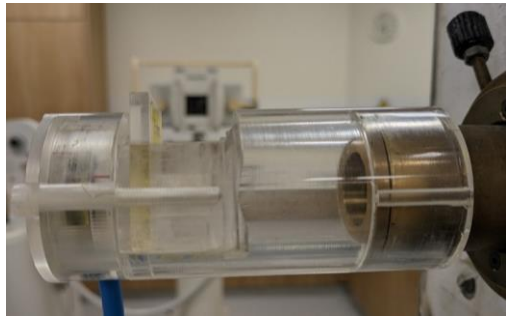
QA devices

- The QEye measures depth doses, using a multi-leaf Faraday Cup consisting of 512 copper sensors, spaced with insulating films. Designed to measure the entire energy range required for ocular treatments



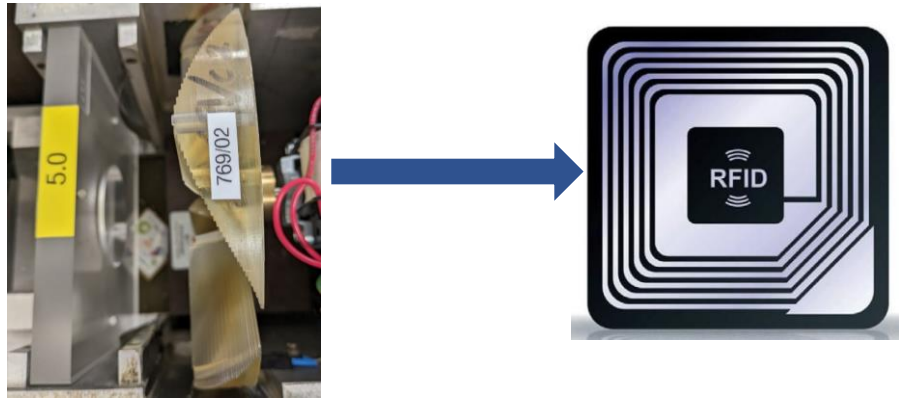
Dosimetry QA

- Currently the monitor units required prior to each fraction are measured for each patient using an Advanced Markus chamber.



Advanced Markus chamber in a jig on the end of the beam line

- Investigating ways of reducing the dosimetry QA
- For example measuring the monitor units for the first fraction and applying an output correction factor.
- Also serves as a safety check that the correct combination of beam modifiers are present
- Move to using RFID tags to track range shifters and modulators.
- Remove the need to measure monitor units for each fraction



RayOcular to chair moves converter

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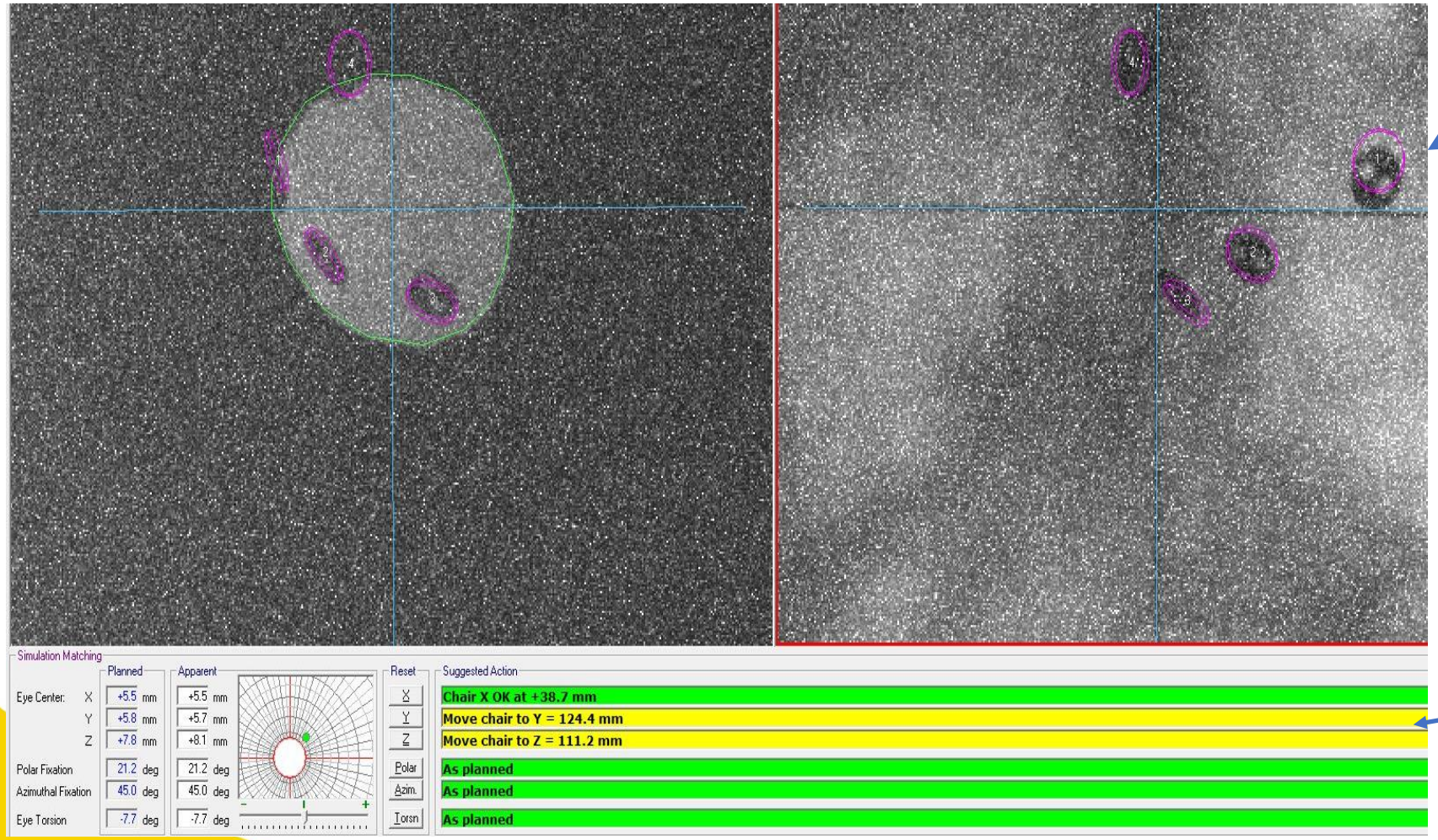
- EyePlan is also used for treatment verification.
- Calculates chair moves based on clip positions on verification images



Clips

New chair positions

RayOcular to chair moves converter

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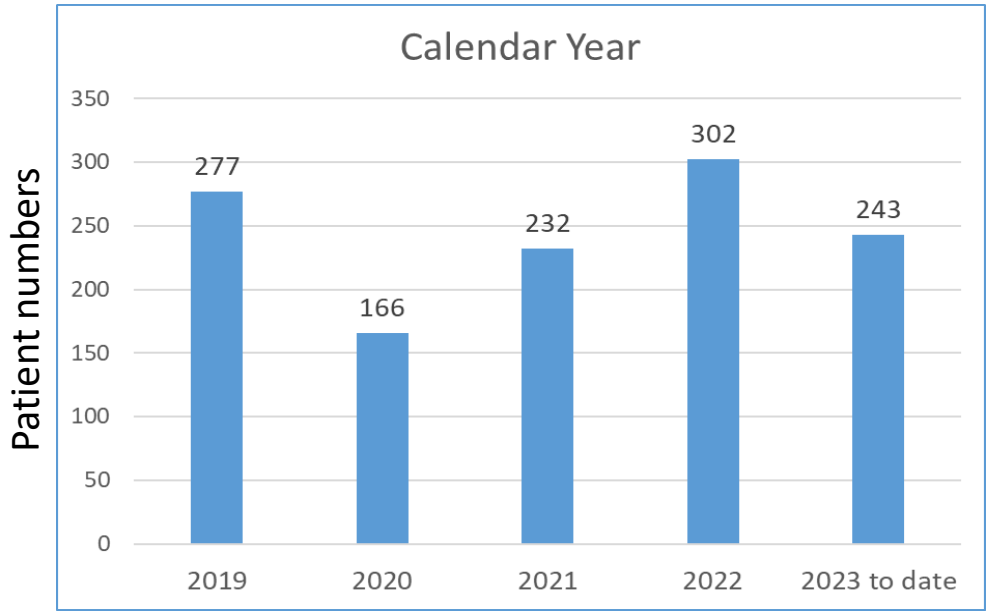
- RayOcular does not have this functionality
- Different solution needs to be sought
- Options are
  - Third party bespoke software.
  - In-house solution which will require manual transcription and extra checks.
- Patient numbers have been increasing steadily since 2020 back to pre-COVID patient numbers.
- Efficient solution is required.



Conclusions

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- Cyclotron has exceeded it’s recommended lifespan by many years.
- Modernisation is required to maintain a reliable and stable beam.
- Service upgrade underway to replace outdated and obsolete components with off the shelf commercially available products
- Where no product exists work with industry partners to create state of the art equivalents
- EyePlan is no longer supported. RayOcular has been chosen to replace EyePlan.
- Commissioning has started however the increased complexity means transitioning to RO will not be straightforward.
- Several different sub-projects have been identified.
- The increased complexity in the planning process will extend planning time therefore efficiency savings will have to be identified elsewhere in the process.
- Such as workflow, QA and treatment verification.
- Still a lot to do before the upgrade is complete!

Acknowledgements

- Linda Mortimer
- Rob Brass
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- Chris Lee
- Laura Howard
- Cyclotron Team!

Thank you for listening!

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