

# STELLA and FLASH therapy

Manjit Dosanjh

JAI Advisory Board Meeting  
24 April 2025

# Update on STELLA and VHEE

- **STELLA** (Smart Technologies to Extend Lives with a Linear Accelerator)
  - global multidisciplinary collaboration with CERN, Oxford, Lancaster, STFC, Europe, USA, Canada and ART Study under the umbrella of ICEC (International Cancer Expert Corps) an NGO
  - 1.75M\$ funding from DOE to ICEC , collaboration between ICEC, CERN, Oxford, Cambridge, Lancaster and African partners
  - One year STELLA Status and Strategy **9-10 July**, CERN
  - Linac and MLC fault analysis: Oxford, Exeter and Cambridge
  - ML and AI in speeding up treatment
- **SAPPHIRE** (Supra-African Physics Partnership for Health Innovation and Radiotherapy Expansion)

Funded by STFC for training grant for £492,000 for 2 years lead by Oxford with Cambridge and Lancaster to **train young medical/physicists in state of art radiation therapy technologies in Pretoria, South Africa and Ghana.**
- **VHEE FLASH Activities** (Very High Energy Electrons (50-250 MeV))
  - CLEAR Collaborations with Geneva, UVIC and others
  - VHEE UHDR Dosimetry and Beam Monitoring
  - VHEE Dose Delivery

## The Project STELLA is dedicated to:

- Expanding access to high-quality cancer treatment globally
- Developing an innovative and transformative radiation therapy treatment system
- Driving down the cost out of RT and cancer care
- An enhanced training, education and mentoring program that catalyses RTT implementation in the global context



International  
Cancer  
Expert Corps



Science and  
Technology  
Facilities Council

Lancaster  
University 



UNIVERSITY OF  
OXFORD

 UNIVERSITY OF  
CAMBRIDGE



# STELLA – Current Status

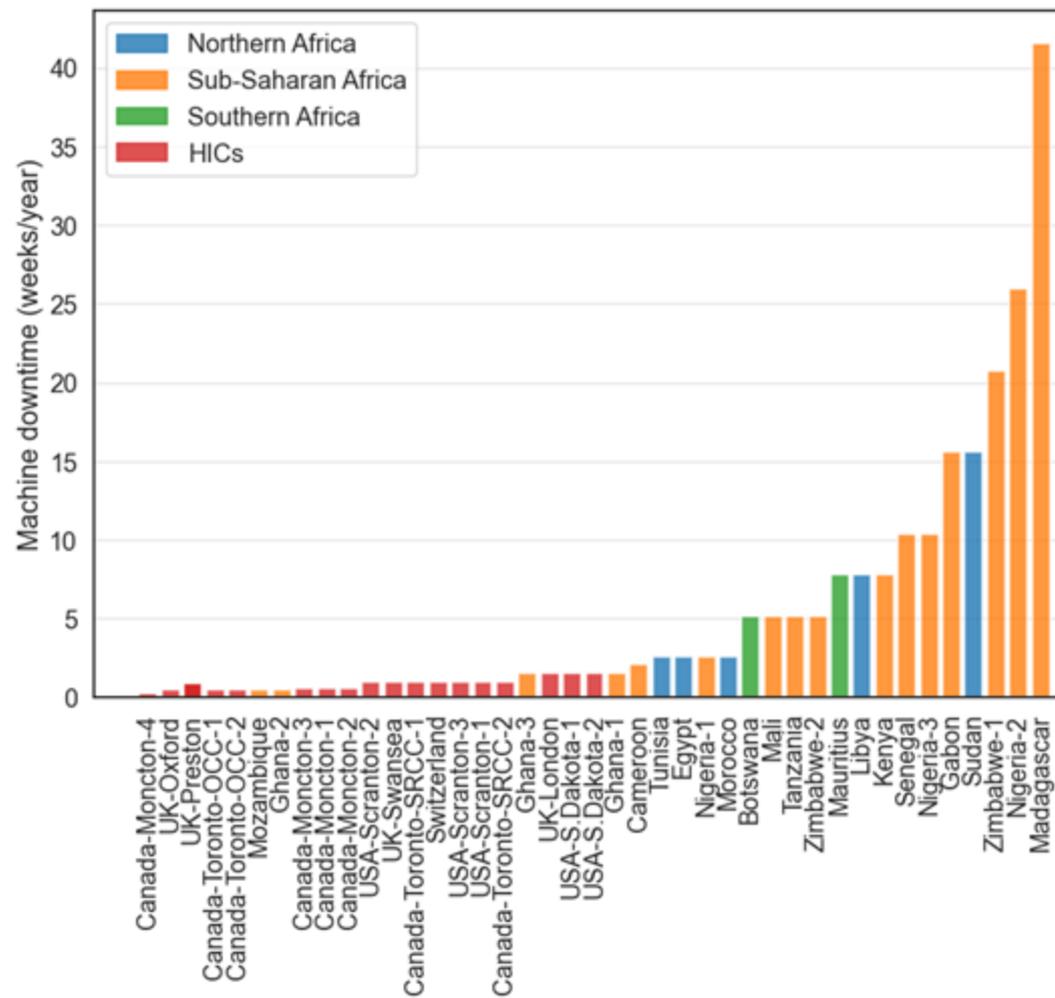
- Funded for 1.75 Million\$
- **MD** is the STELLA coordinator, **Steinar Stapnes**, CERN is accelerator lead, **Raj Jena**, Cambridge for software lead, and **ICEC** mentoring lead
- Kick-off at CERN, **May 2024**

## **Work on-going in Developing STELLA facility:**

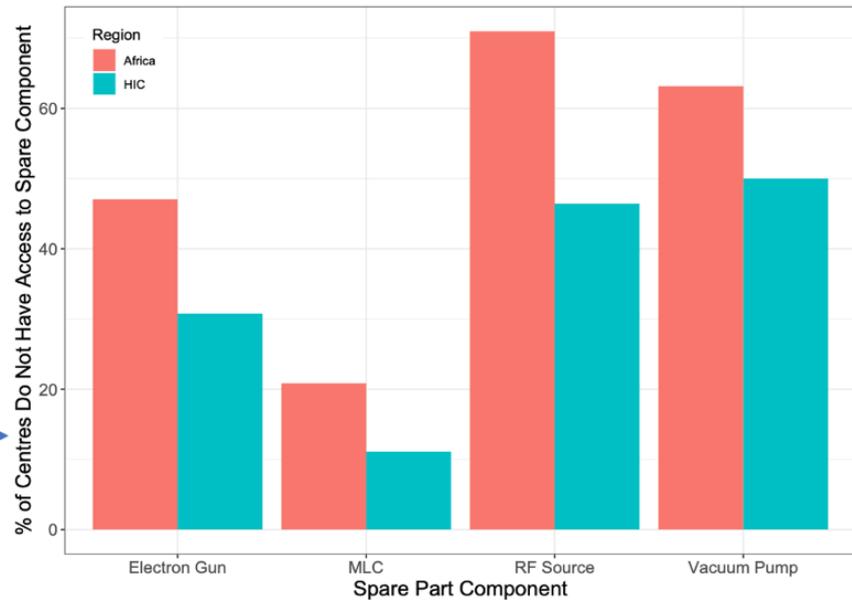
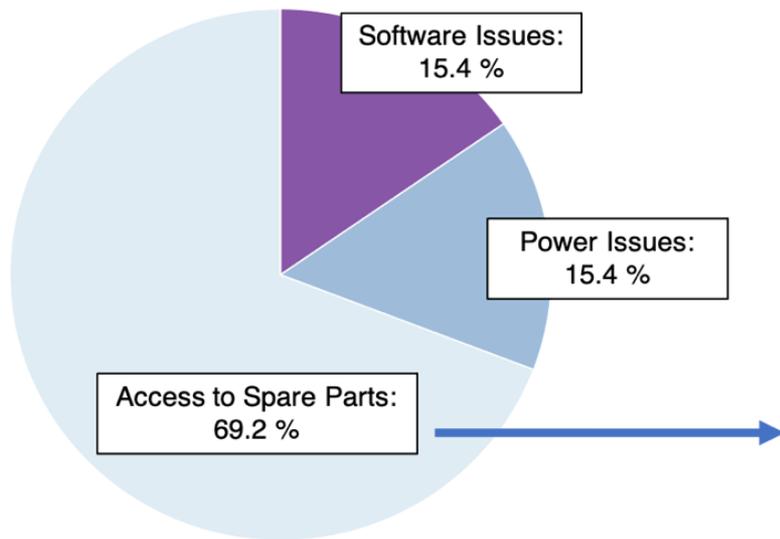
- Design specification of the STELLA machine: hardware (accelerator, Collimator, Gantry, Imaging etc)
  - Designing an AI powered smarter radiotherapy machine: increase reliability and reduce the number of experts needed
  - Developing a software prototype
- **One year status meeting and next steps at CERN, 9-10 July, 2025**

**28 African country study was published in 2024: showing key challenges to be overcome in the STELLA design**

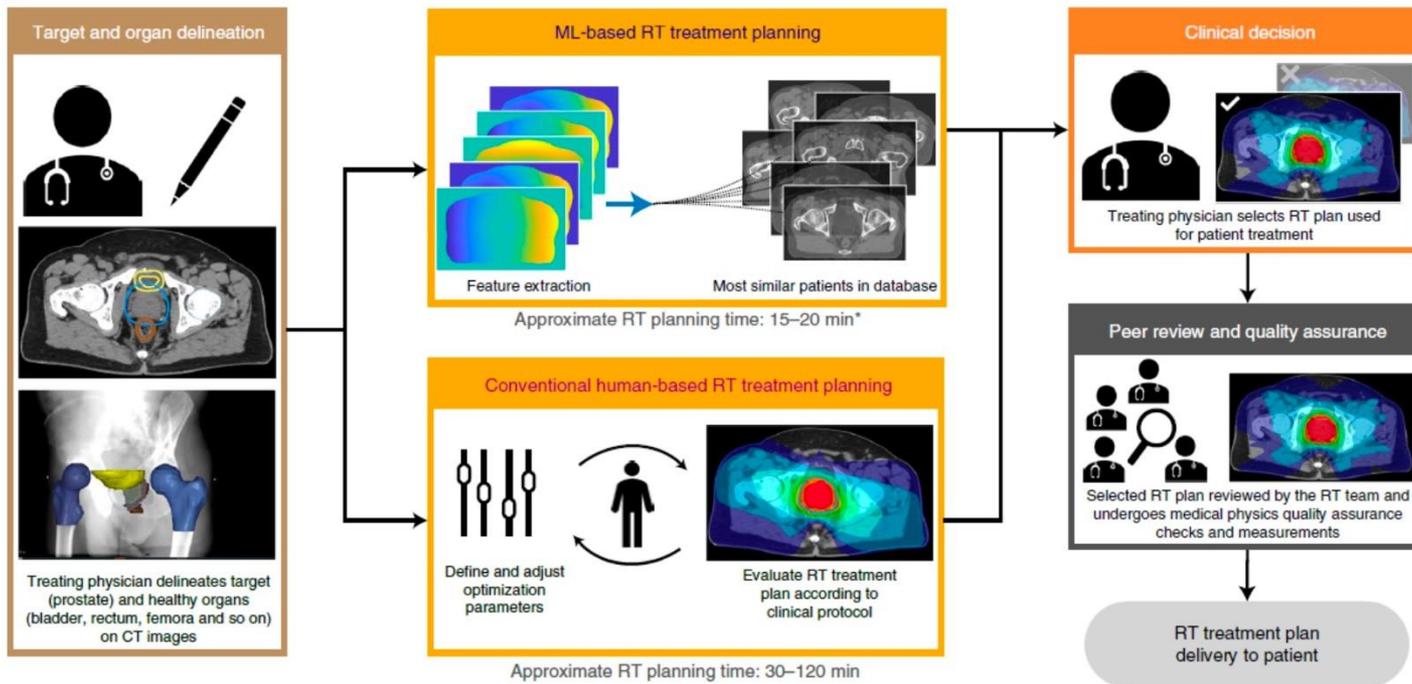
# Data from all African Countries that have RT and downtime comparison with HIC



# Main Reason for LINAC Downtime: Access to Spare Parts



# How can AI and ML help in improving cancer treatment



Equivalent performance to a human but results ready 3 days sooner.

# STELLA and use of AI and ML

- The STELLA RT system will incorporate a federated knowledge system that combines information from patient referrals, scans, and reports with AI to profile patients and create best-practise treatment plans.
- Use AI to reduce total staff time needed to run a STELLA RT system will be approximately **50% less than conventional systems**.
- Both the **downtime** and **service contracts** will be reduced resulting in improving access, greater uptime, more patient treated and reducing cost.

# Examining role of AI and ML in cancer treatment

STELLA Collaboration between Cambridge, Exeter, Oxford and CERN



Raj Jena, Cambridge



Xin (Doris) Du, Cambridge



Torsten Liebig, Royal Devon NHS, Exeter



Wioletta Kozłowska



Samuel Leadley, Oxford



Manjit Dosanjh, Oxford

# Fault prediction in radiotherapy LINACs

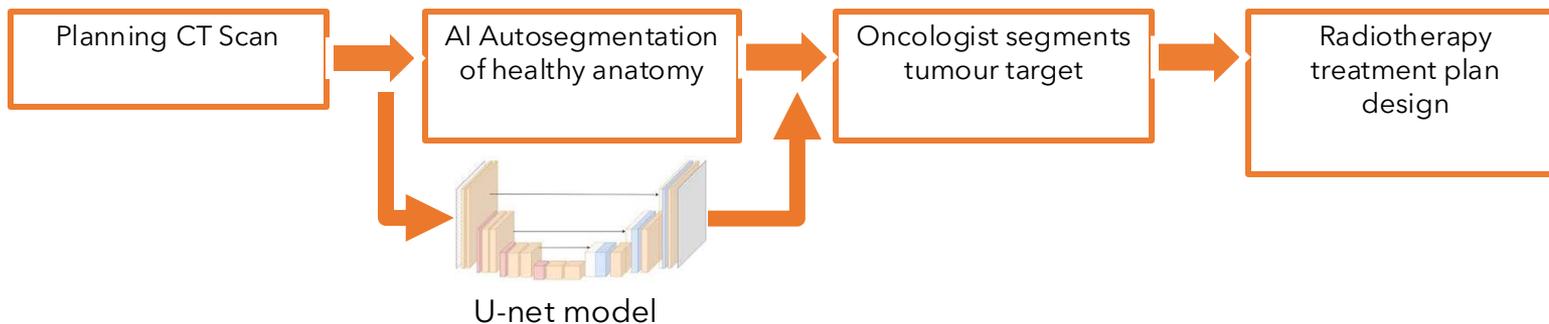
(Sam Leadley)

- Developing a method for predicting fault modes of radiotherapy LINACs with existing machine logging data and methods in machine learning.
- Developed a Variational Autoencoder method for encoding machine fault data and predicting upcoming LINAC failure modes based on past logs.
- Data obtained through collaboration with Exeter and Oxford (Churchill) oncology centres.
- Current models are able to predict upcoming faults (labelled samples) at 60% accuracy, exceeding 80-90% when considering top 3 most likely fault modes.
- Work in progress for improving prediction

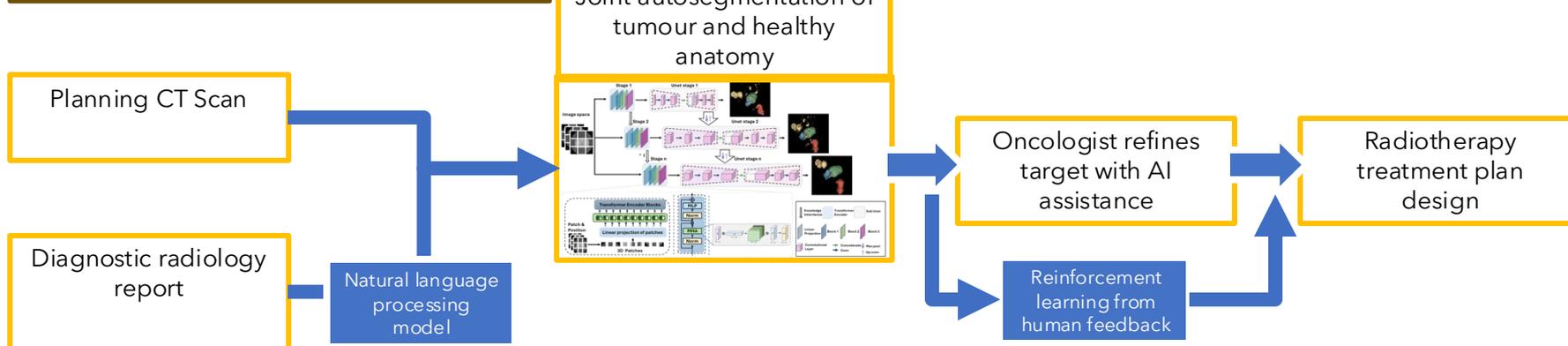
# Leveraging AI with images and radiology reports to accelerate RT planning

*Xin (Doris Du), Cambridge*

## Current radiotherapy workflow



## STELLA radiotherapy workflow



# STELLA AI – Federated knowledge system to democratise precision radiotherapy

## Secured data collection, storage and use for STELLA AI training



Data de-identified and compliant with HIPAA, GDPR

*Wioletta Kozłowska, consulting*

## **SAPPHIRE:** (Supra-African Physics Partnership for Health Innovation and Radiotherapy Expansion)

**SAPPHIRE** is research and training effort, which has just been funded by Africa-UK Physics Partnership programme to train young medical/physicists in state of art radiation therapy technologies from **Pretoria, South Africa and Ghana RT centres**. Lead by Oxford (Dosanjh) with Cambridge (Jena) and Lancaster (Burt)

- **Objective 1:** To identify junior medical physicists in Africa to train in data collection and analysis of usage and fault data from their own centres.
- **Objective 2:** To use gathered data to assess the cause and effect of faults of the key machine components and develop candidate component designs to mitigate these effects.
- **Objective 3:** To compare the performance of candidate designs with current-generation commercial Linac devices for treatment planning using actual clinical data.

Virtual kick-off took place on **21 February**, face-to-face at **Oxford** soon

# The FLASH Effect – still gaining momentum

# Studies in CLEAR



*clear*



*R. Corsini,  
Head of CLEAR  
Facility*

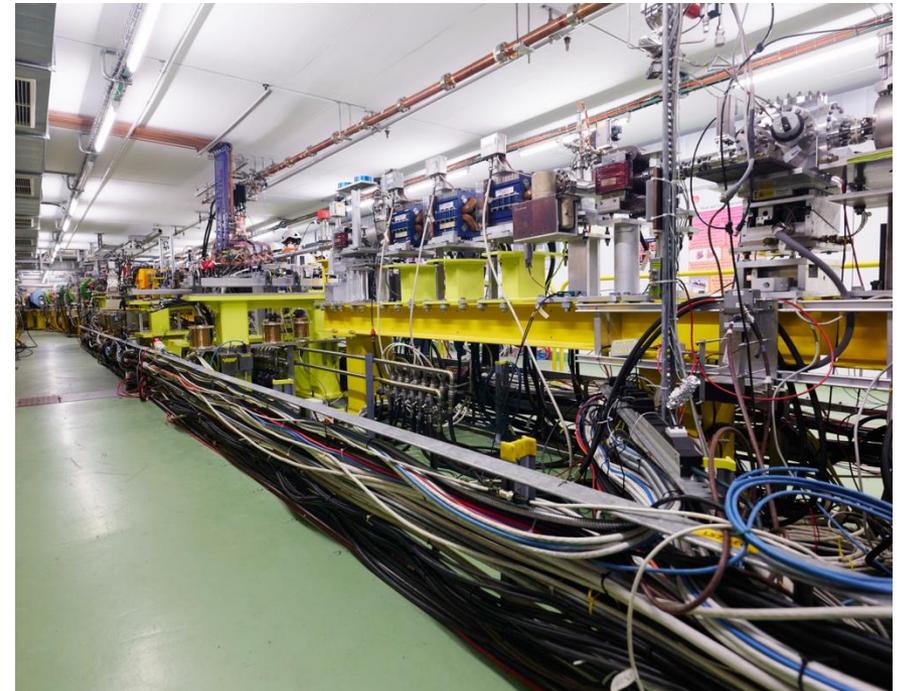


*P. Korysko  
JAI Oxford Postdoc &  
CLEAR*

# CLEAR Accelerator and Beam Parameters (CERN Linear Electron Accelerator for Research)



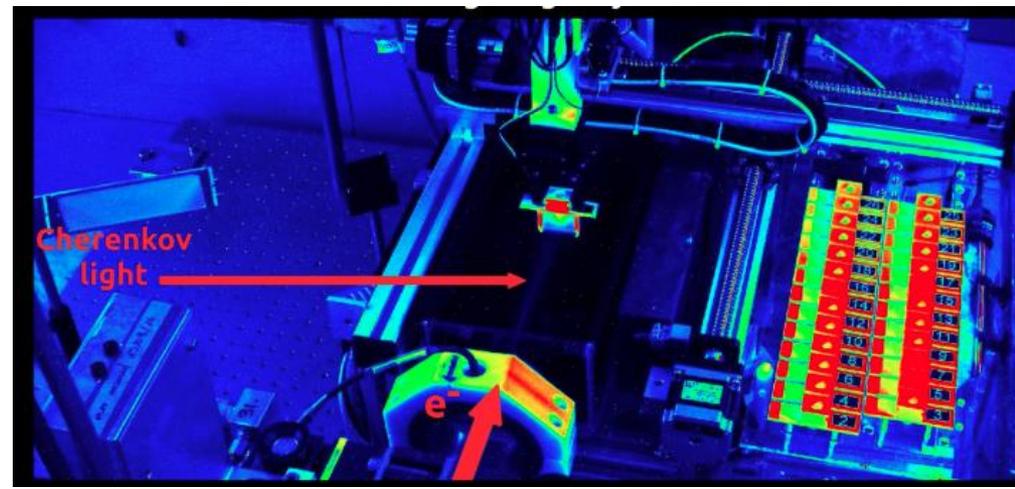
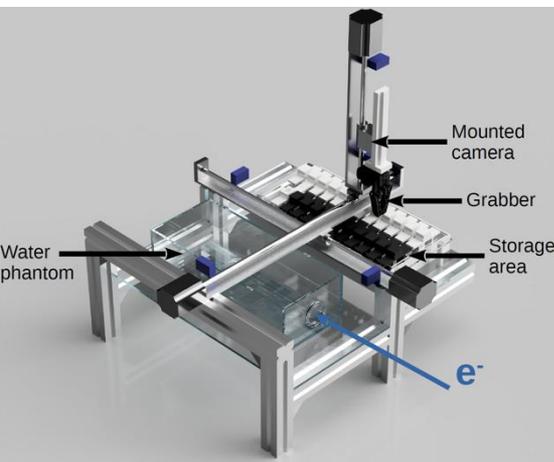
Parameter	Value
Energy	<b>60 – 220 MeV</b>
Energy spread	< 0.2 % rms (< 1 MeV FWHM)
Bunch length	<b>0.1 – 10 ps RMS</b>
Bunch charge	10 pC – 1.5 nC
Normalised emittance	3 – 20 $\mu\text{m}$
Bunches per pulse	1 – 200
Max. charge per pulse	<b>86 nC</b>
Repetition rate	<b>0.833 – 10 Hz</b>
Bunch spacing	1.5 or 3.0 GHz



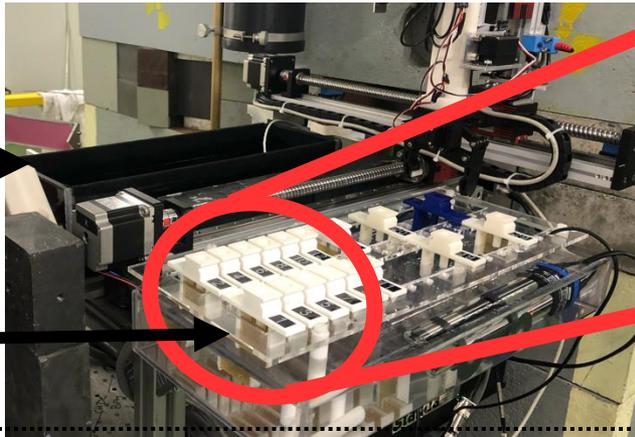
Great to hear and report that CLARA is going to be available very soon for FLASH studies

# CLEAR VHEE FLASH Experiments

- More and more **users** are studying the **FLASH effect**, **Irradiation Methods** and **Dosimetry** in CLEAR, leading to:
  - **16 weeks** of beam dedicated to **medical applications** in **2024**.
  - A new robot, the **C-Robot 2.0** was **built**. The CLEAR team is helping to build 3 similar robots for PITZ in **Germany**, the Australian Synchrotron in **Australia** and IHEP in **China**.
  - **New beam** line with flexible beam parameters, particularly suited for **medical applications**.
  - **11 Medical Application Experiments** performed in **2024** (anatomical phantoms, gold nanoparticles and plasmids studies, flash diamond detectors, Beam Scanning Spatially Fractionated RT Studies etc)

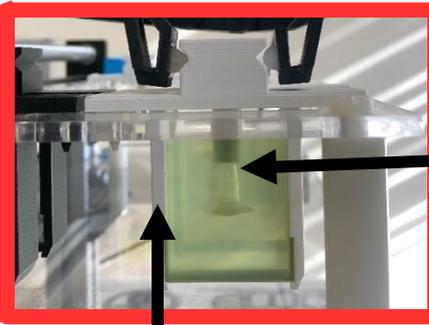


# Experimental Setup & Dosimetry for VHEE at UHDR irradiations

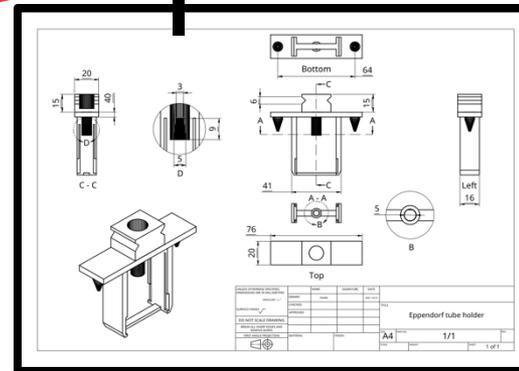


Beam water tank

Heated storage water tank



Eppendorf tube with sample to irradiate



**3D printed** holder with 2 films: one before and one after the sample

**Laser cut**

Radiochromic films to measure the delivered dose

Dose range:  
 $\uparrow = 100$  Gy



Before irradiation



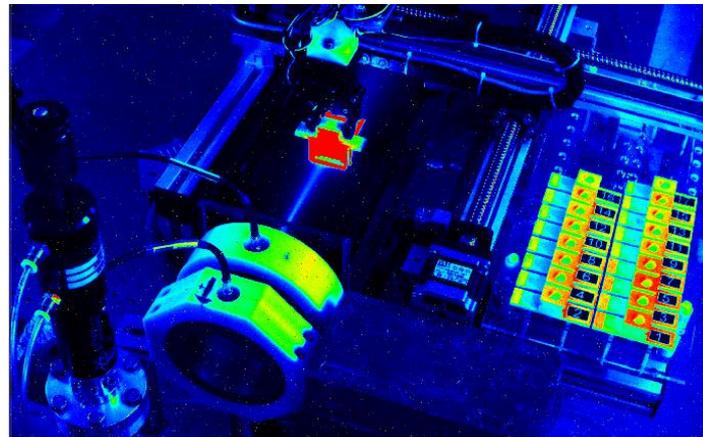
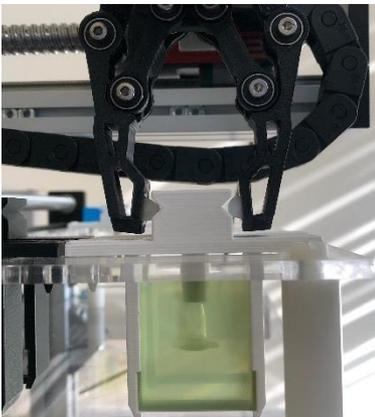
After irradiation

[V. Rieker et al 2024 Nucl. Instrum. Methods Phys. Res.](#)

## LiRR lab UNIGE Collaboration

### *VHEE FLASH Radiobiology and Physico-Chemistry Experiments*

- VHEE FLASH Radiobiology Studies: Investigating Mechanisms Behind the FLASH Effect.
- Water Radiolysis: Measurement of ROS generation in water following FLASH and CONV-RT.
- DNA Damage Assessment: Plasmid irradiations to quantify radiation-induced DNA lesions.
- Zebrafish Embryos as Biodosimeters: Modelling normal tissue sparing post-FLASH-RT.
- Cell Irradiation Studies: Comparative analysis of normal and cancerous cell responses.
- Manuscript currently under review.

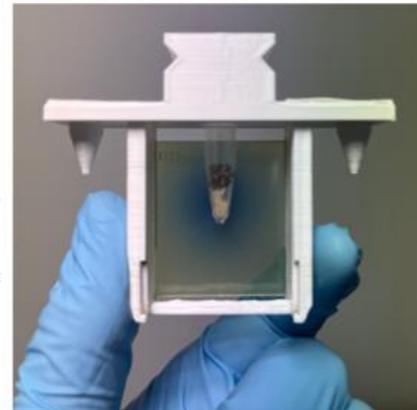
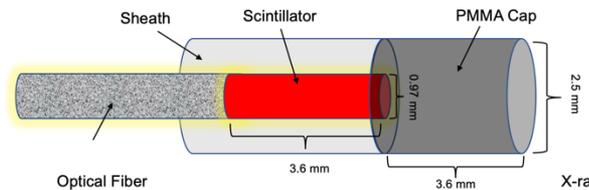
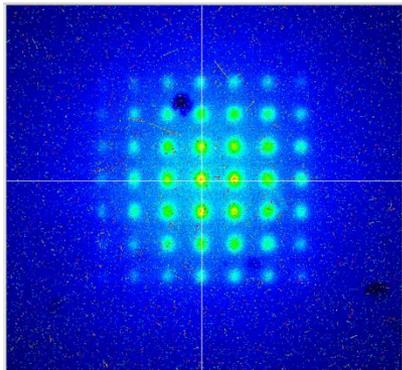


Prof. M. C. Vozenin  
Head of Radiobiology and  
Radio-oncology, HUG, Geneva

# University of Victoria Collaboration

## *VHEE Spatial Fractionation – Scintillator Dosimetry – Drosophilae Biodosimeters*

- VHEE Spatial Fractionation using tungsten GRID collimator.  
*(paper published in Phys. Med. Bio.)*
- VHEE UHDR Real-time dosimetry using plastic scintillator-coupled fibres at MedScint™ CCD spectrometer.  
*(paper published in IEEE Sensors)*
- *In vivo* radiobiology studies on drosophila melanogaster larvae as biodosimeters to investigate VHEE RBE and FLASH mechanisms/parameter space.



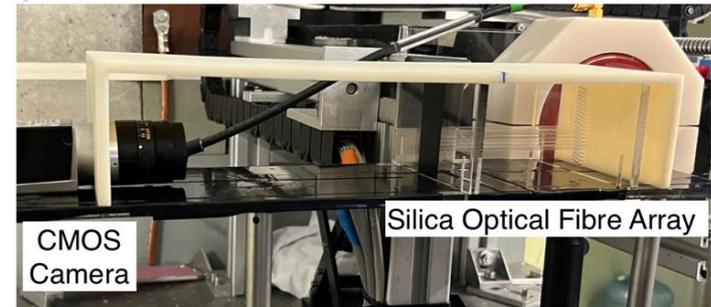
*Prof. M. Bazalova-Carter  
Head of XCITE Lab, UVic,  
Canada*

# Fibre Optic FLASH Monitor (Bateman)

- Developed and tested first prototype of the Fibre Optic FLASH Monitor (FOFM) – a novel detector for real-time beam profile and dose monitoring at ultrahigh dose rates for VHEE-FLASH RT.
- Multiple experiments conducted at the CLEAR facility to dosimetrically characterise the detector and evaluate its feasibility for VHEE FLASH beam profile and dose monitoring.
- Published in PMB and second in preparation for ESTRO physics journal



*J. Bateman*  
*JAI Oxford Graduate*  
*(Now postdoc at UCL)*



*A. Gerbershagen*  
*PARTREC, Groningen*



*R. Corsini*  
*CLEAR, CERN*



*I. Ortega Ruiz*  
*BI, CERN*

# VHEE UHDR Beam Dosimetry @ Oxford

- Started collaboration with Simon Hooker's group where we are using the expertise and fibre optic monitor for VHEE UHDR dosimetry at CLEAR for initial dosimetric characterisation of Oxford LWFA (Laser Wakefield Accelerator) beam.
- MPhys student (Emma Stratford) is working on characterising fibre array detector using Monte Carlo simulations and preparations for initial measurements at Oxford LWFA
- Initial measurements planned to be taken soon.



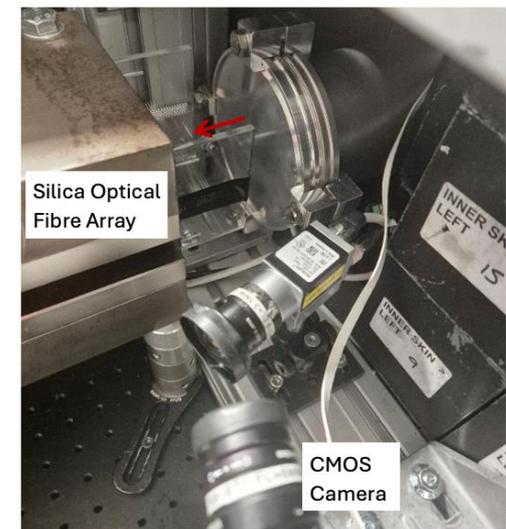
*J. Bateman*  
JAI Oxford Graduate  
(Now postdoc at UCL)



*E. Stratford*  
Oxford MPhys 4<sup>th</sup>  
year



*L. Feder*  
Oxford PDRA



# VHEE Dual-Scattering Systems (Cameron)

- Beam magnification and flattening for conformal VHEE Radiotherapy - passive scattering
- Extensive MC simulation work on impact of particle production, energy spread and losses on dose
- Modelling of flattened beams with or without collimation
- Dual-scattering foil design and optimisation at 200MeV



*Cameron Robertson,  
JAI Oxford Graduate  
(NHS Radiotherapy  
Physics Trainee)*



*Andrea Latina  
CERN*



*Alexander Gerb  
Groningen and PARTREC  
(Particle Therapy Research Center)*

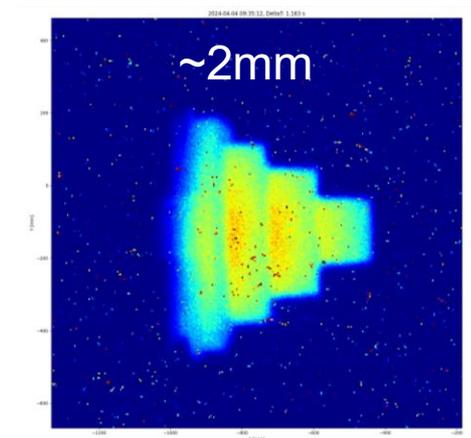
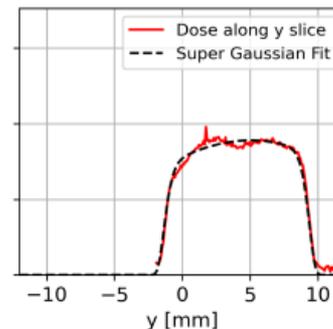
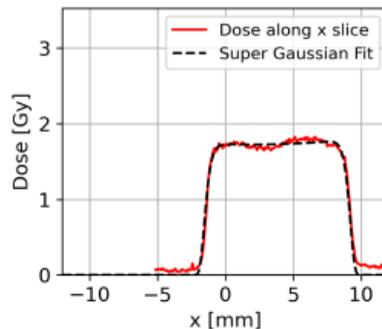
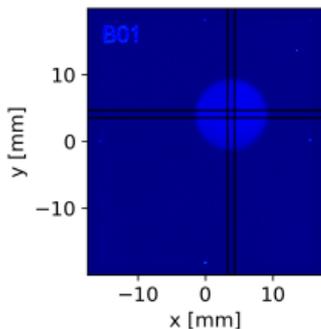


University Medical Center Groningen

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# VHEE Dual-Scattering Systems (Cameron)

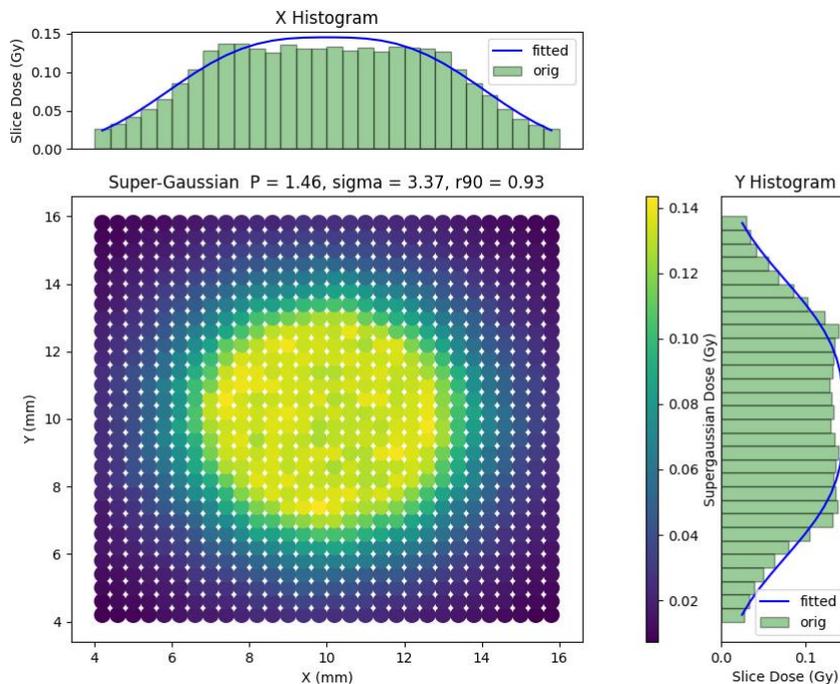
- Successful experiments demonstrating magnified, flattened dose distributions at CLEAR – publication under review
- **Permanent** in-vacuum CLEAR dual-scattering system developed and installed by operators in beamline
- System well characterised and operational with collimator to provide up to 1cm uniform beam profile for sample irradiations and conformal VHEE dose studies – now used as standard for CLEAR radiobiological studies
  - Low photon contamination verified by simulation and experiment
- Further publications on dose characterisation and uniform VHEE beam evolution in preparation



# VHEE Combined Scatter System

(Sabrina Wang, 1st Year DPhil and Cameron Robertson PhD )

- Modification or removal of first foil in dual-scattering system
  - Variable quadrupole strengths for more flexibility
  - Reduction of photon contamination
- TOPAS and RF Track simulation of 4 quadrupole + scatterer system



*S. Wang  
JAI Oxford 1st  
year DPhil*

# In Summary.....

**STELLA is progressing .....**

Next status meeting 9-10 July

**SAPPHIRE** funded and kicked-off in February 2025

**FLASH** still lots of interest and progress but much remains to be done, excellent news that **CLARA reached its full energy of 250 MeV** beginning of April and will help by providing beam for research and in vivo experiments that are not possible at CLEAR at CERN which are really needed

**Many invited talks and conferences in the last year**

**Around 20 Publications in the last year**