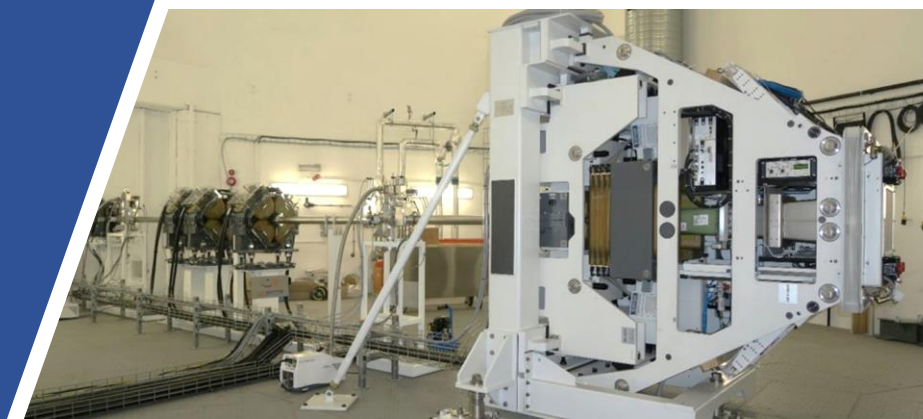
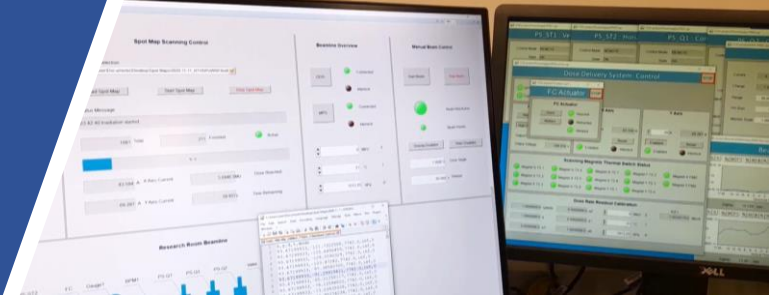


## SOMMAIRE

- Introduction
- The Christie Project
- Beamline Design et spécifications
- Système production
- Système installation & commissioning
- Acceptance avec faisceau
- Conclusion



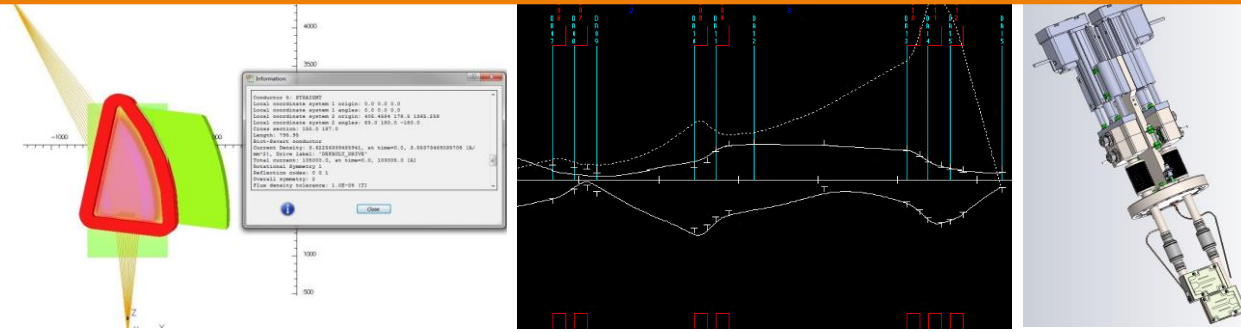
Virgile LETELLIER  
Project Leader & Medical Physicist  
vletellier@sigmaphi.fr



# Sigmaphi Beamlines Systems:

## Turnkey systems – From beam optics... to commissioning

2017



- Heavy ion beamlines
- Beamlines for prontontherapy
- Other beamlines ...



- ✓ Beam optics
- ✓ Magnetic design for all magnets/optimization with power supplies
- ✓ Mechanical supports and positioning structures
- ✓ Vacuum line design and equipment (pumps, gauge...) down to  $10^{-11}$  mbar
- ✓ Power supplies
- ✓ Diagnostic systems (slits, collimators, scintillators, BPM, faraday cup...)
- ✓ Control system (software and hardware integration)
  
- ✓ Installation of the complete beamline
- ✓ Alignment of the supports and magnets
- ✓ Commissioning with or without beam

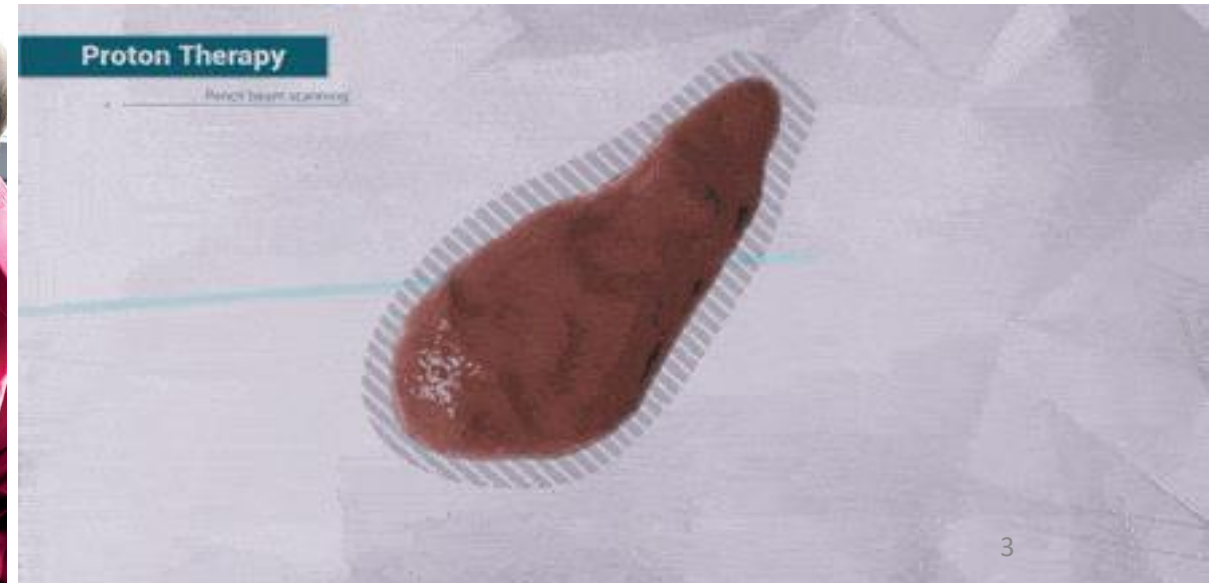
# The Christie NHS Foundation Trust Proton Beam Therapy



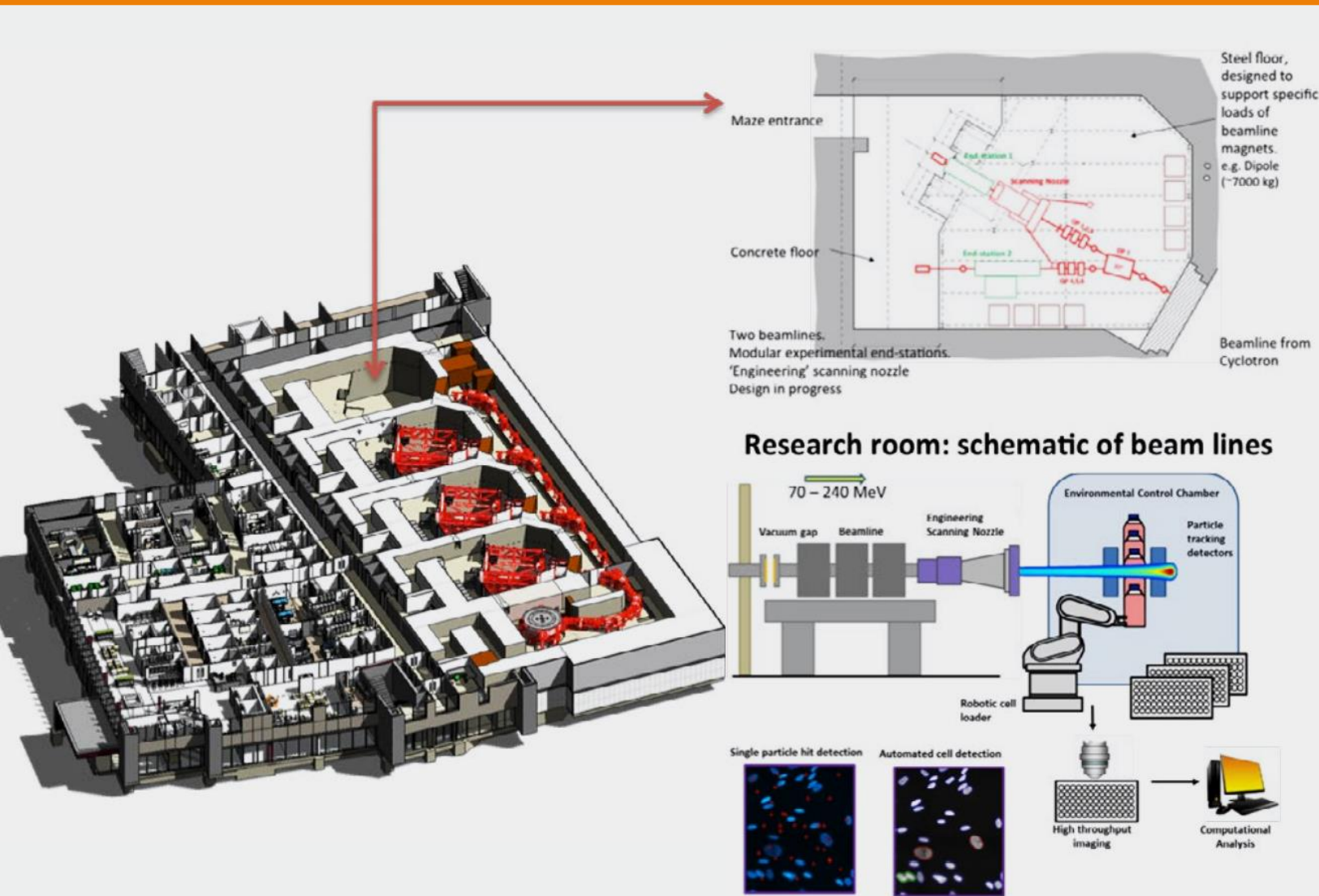
- Protontherapy center in Manchester UK
- First treatments in 2018
- Adults and pediatrics cancer treatments
- VARIAN® 4 rooms solution with 240 MeV cyclotron and 3 gantry rooms
- Pencil Beam Scanning system
- 4<sup>th</sup> room designed for research and funded by The Christie charity



The Christie  
NHS FOUNDATION TRUST

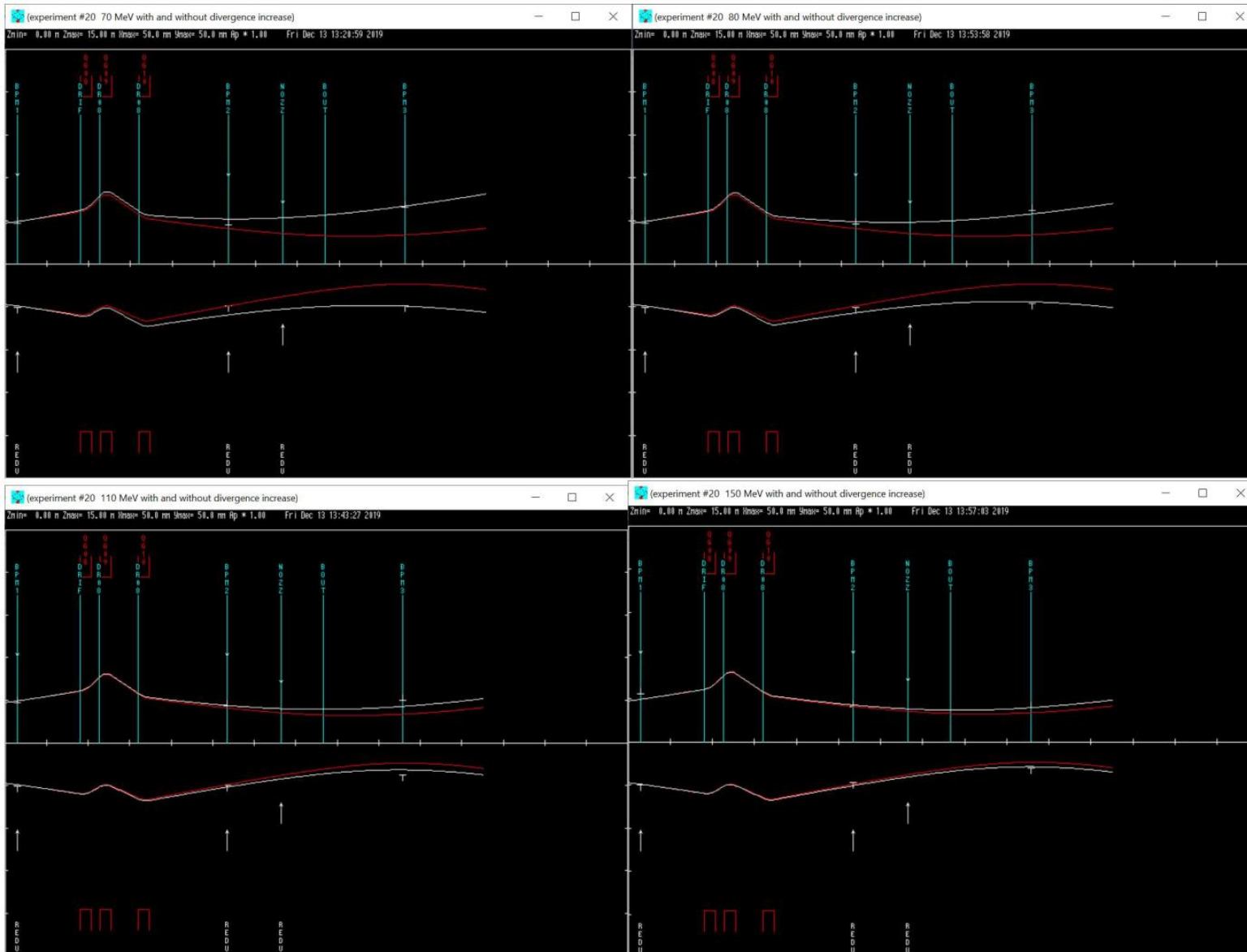


# Scope of Proton Research Beamline



- Turnkey Proton Beamline for physics and biology research. From Optic design to... Commissioning with beam
- Beam monitoring: 2x BPM and 1 Faraday Cup
- Vacuum system capable of maintaining a pressure below  $1 \times 10^{-6}$  mbar
- Complete Control and Command system
- Beam ballistic equivalent to the medical system at isocenter (target):
  - Energies from 70 to 240 MeV
  - Max Field size  $300 \times 400 \text{mm}^2$
  - Spot spacing  $< 2 \text{mm}$
  - Horizontal scan speed  $> 20 \text{m} \cdot \text{s}^{-1}$
  - Vertical scan speed  $> 10 \text{m} \cdot \text{s}^{-1}$
  - Spot size between 2 and 7mm sigma
  - Absolute Spot position accuracy  $< 0,5 \text{mm}$
  - Homogeneity Index  $< 3\%$  inside  $100 \times 100 \text{mm}^2$
  - Absolute Dose accuracy  $< 2\%$  (above 0,1Gy/layer)

# Design and Beam Optics



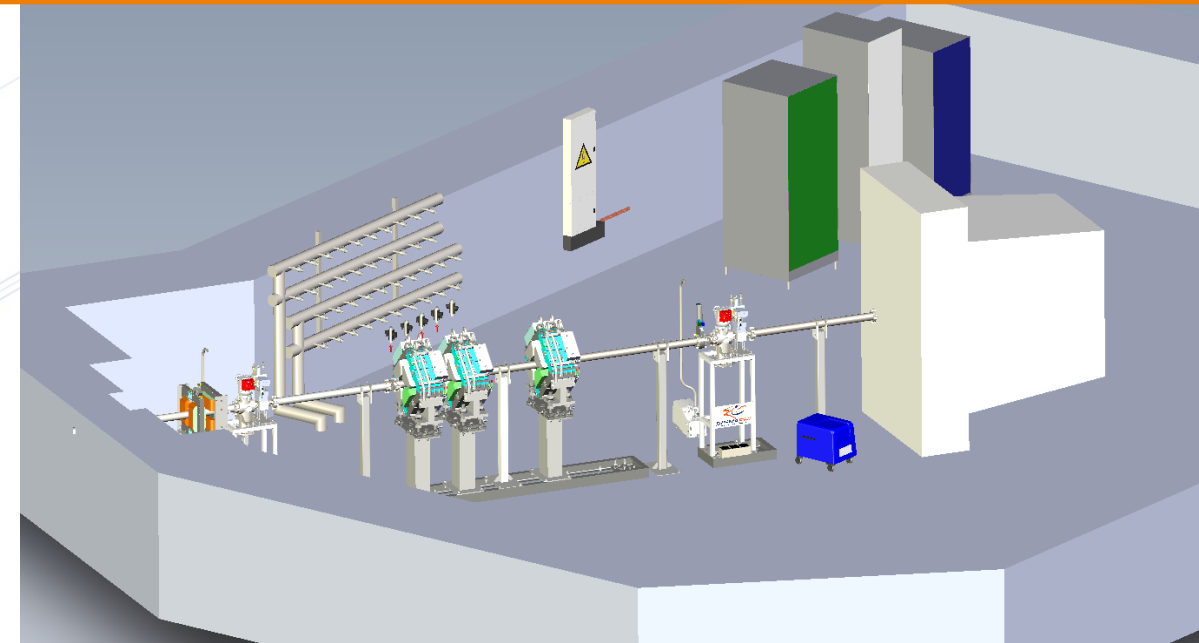
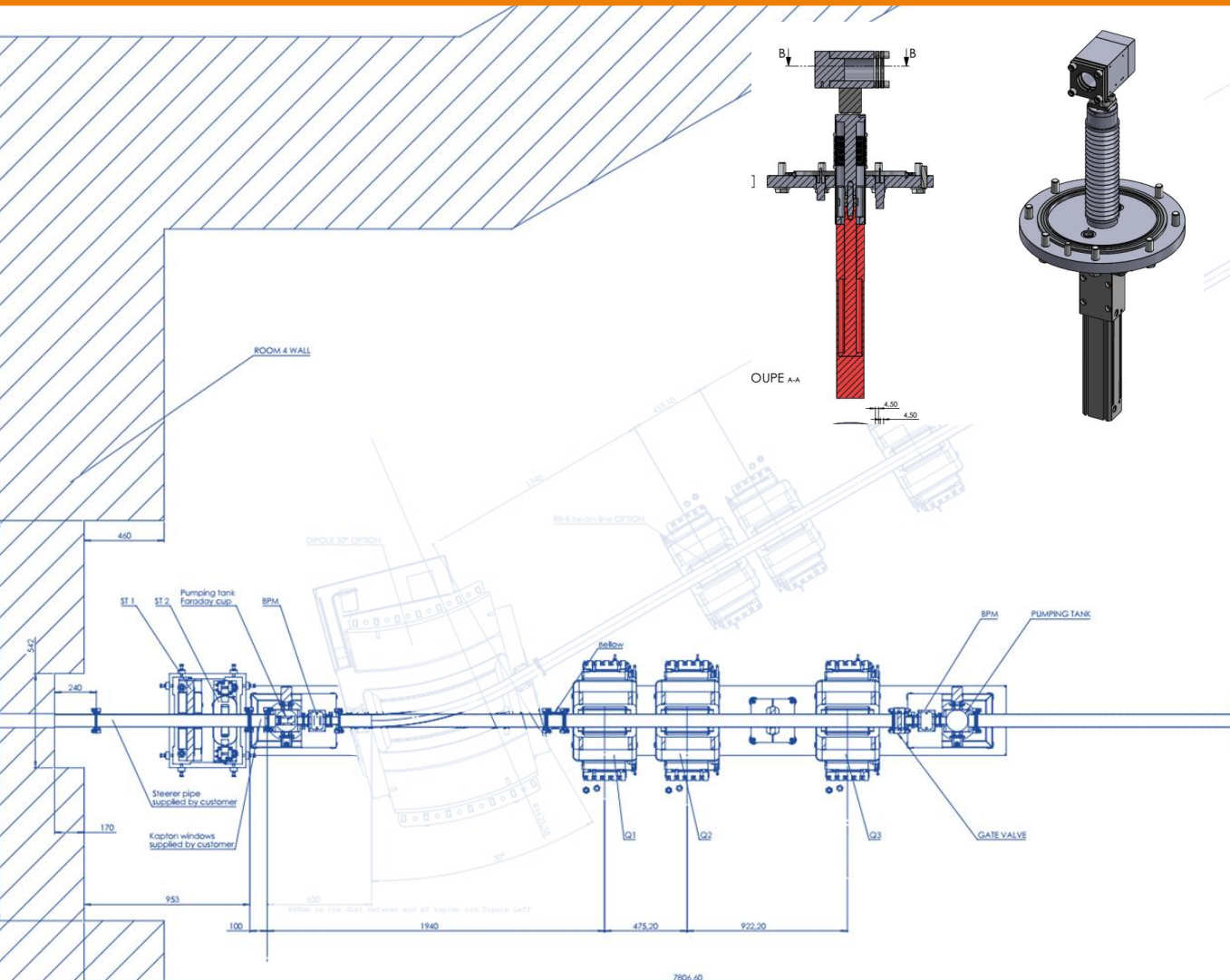
## Objectives:

- Optic tuning to fit Customer needs
- Position optimization of homemade or supplier's diagnostics devices
- Optimisation of the characteristics of the magnets
- Optimization of the couple magnet - power supplies
- Overall cost optimization

## The Christie setup:

- Nozzle and Scanning magnets are already installed – position is fixed

# Design and Beam Optics



- Design of the complete beamline
- Design of the Faraday cup
- Specification of the cabling
- Specification/Integration of the:
  - 2x BPM
  - Vacuum system and electronic
  - DC & AC power supplies

# Beamline Production Made in Vannes, France



## Sigmaphi Productions:

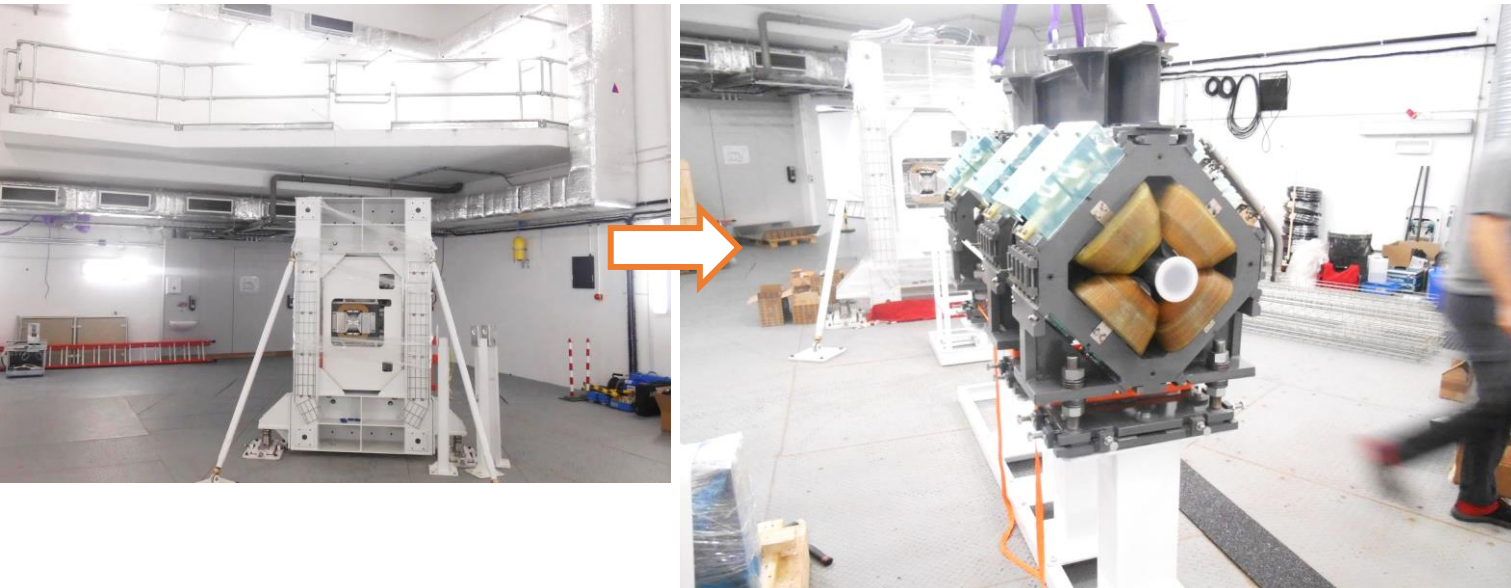
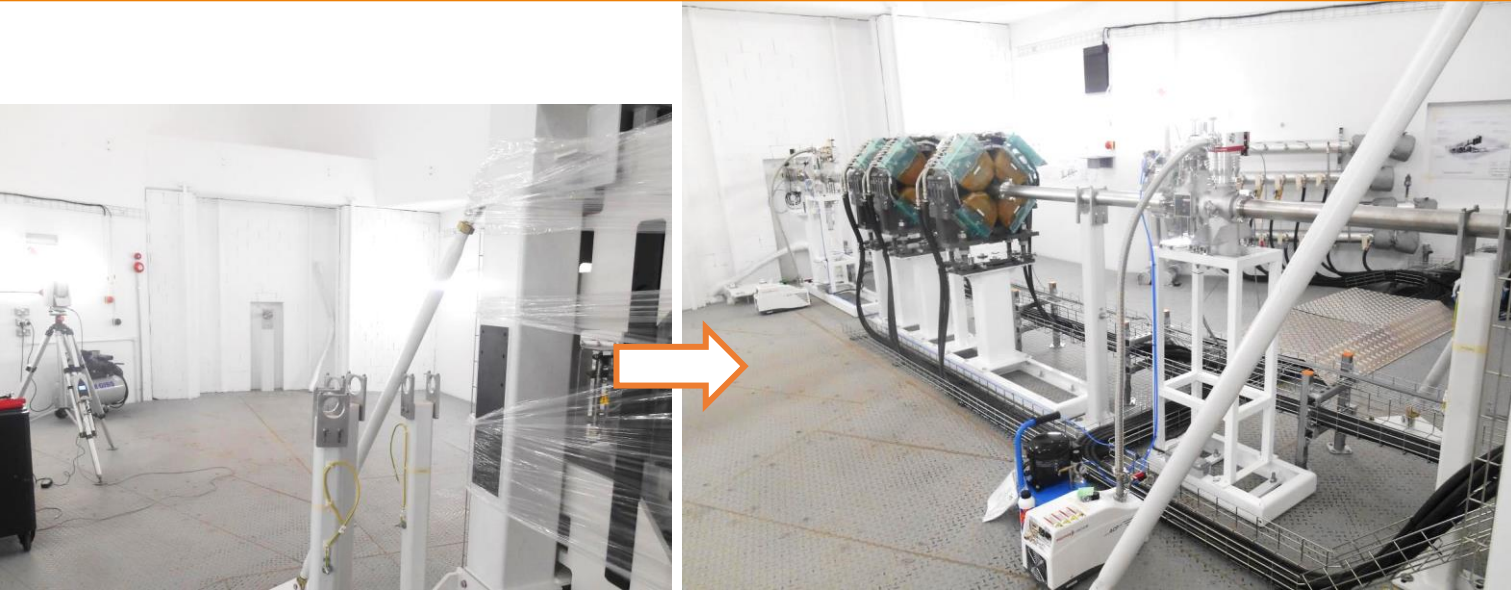
- Production of the magnets
- Production of vacuum chambers
- Production of the Faraday cup
- Assembly of the sub-systems
- Magnetic tests (mapping and harmonic)
- Vacuum leakage test
- Performance and Factory test without beam
- Documentation
- Packing and shipment of all equipment



## Selected suppliers:

- Vacuum system – primary and secondary pumping from Pfeiffer®
- Beam profile monitors and electronics from Pyramid Technical Consultants®
- Scanning Power supply from Copley-Analogic®
- Control and command system from Cosylab®

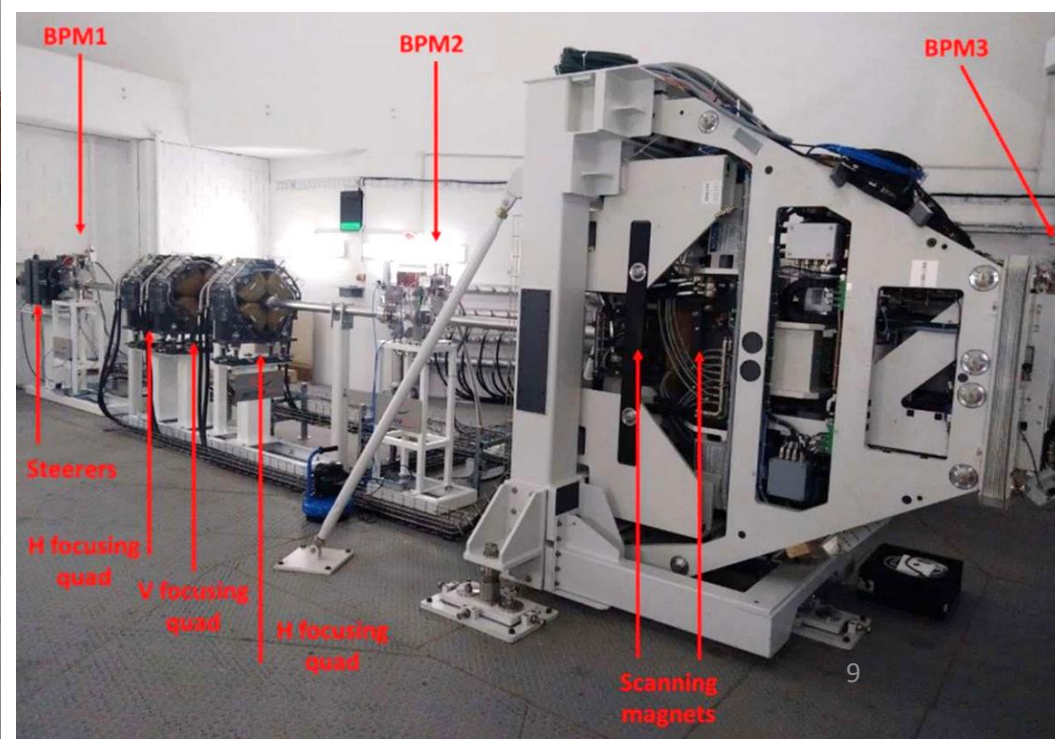
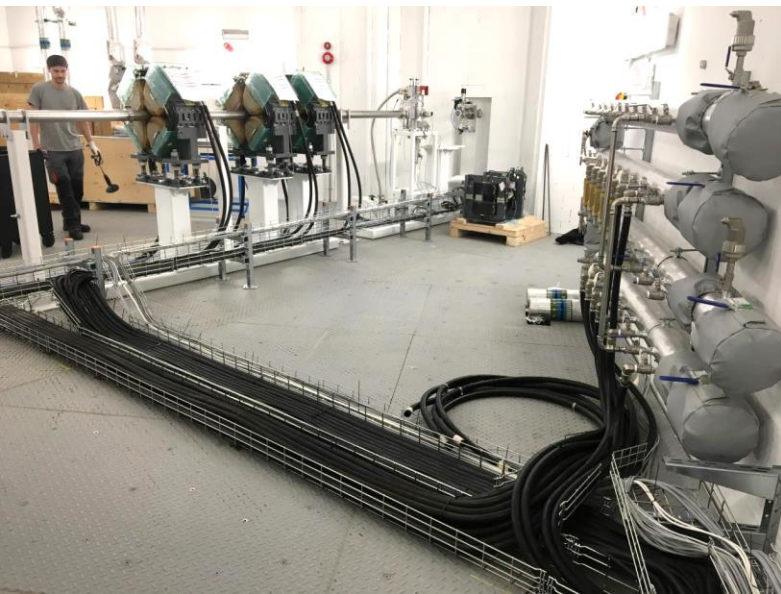
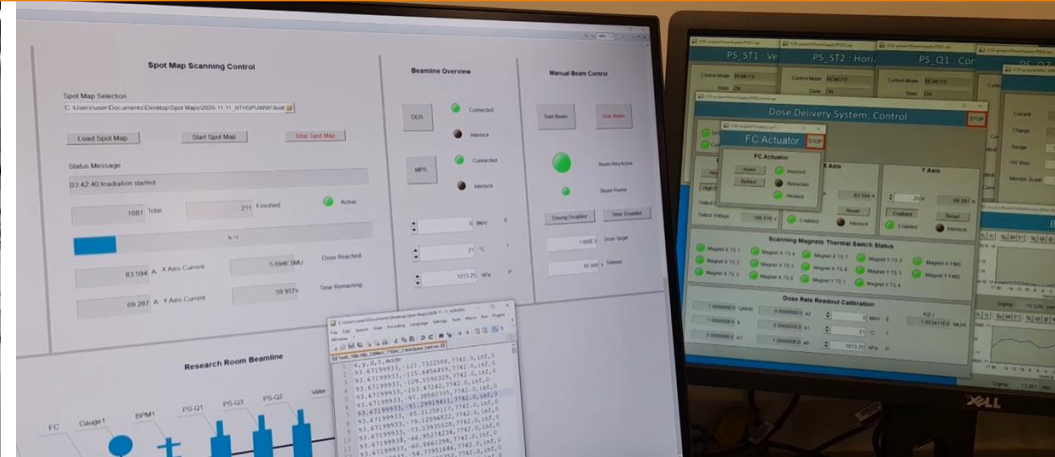
# Beamline Installation & Commissioning



- Installation and alignment of the stands & magnets with laser tracker
- Installation of the vacuum chambers
- Installation & commissioning of the 2x BPM
- Installation & commissioning of the vacuum system
- Interface to the customer system
- Installation of the electrical cables
- Installation of the Cooling pipes
- Installation & commissioning of the DC power supplies of Quadrupoles and Steerers
- Installation & commissioning of the scanning power supply
- Installation & commissioning of the control and command system

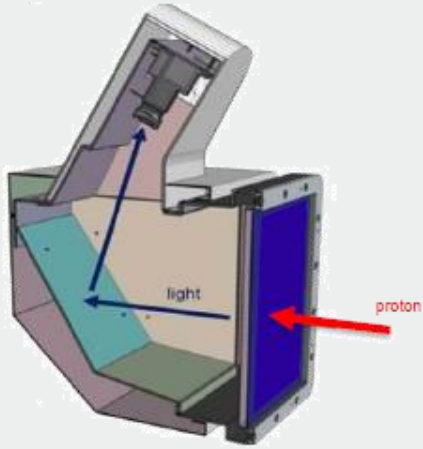


# Beamline Installation & Commissioning

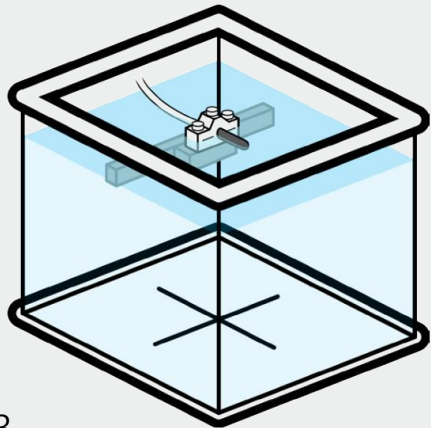


# Acceptance with beam

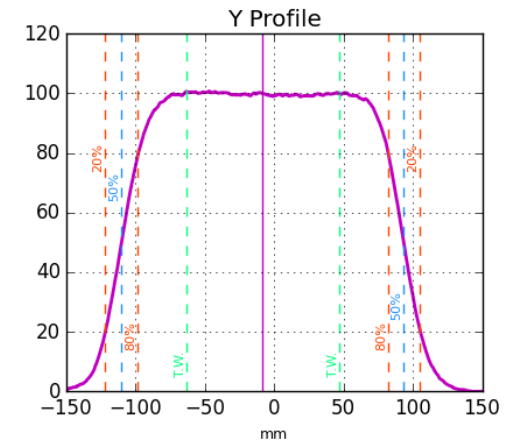
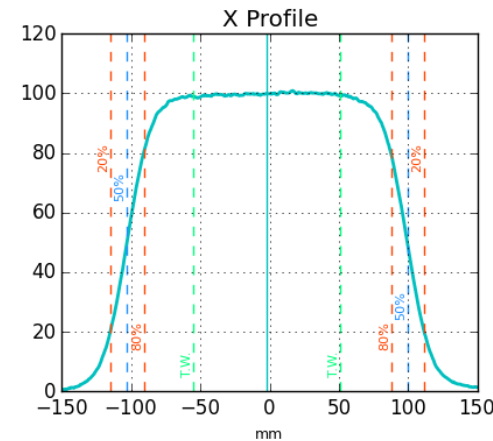
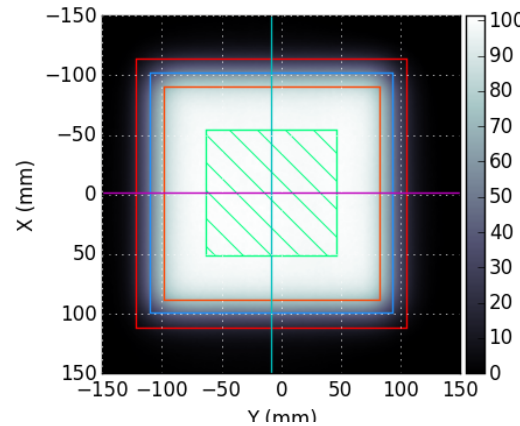
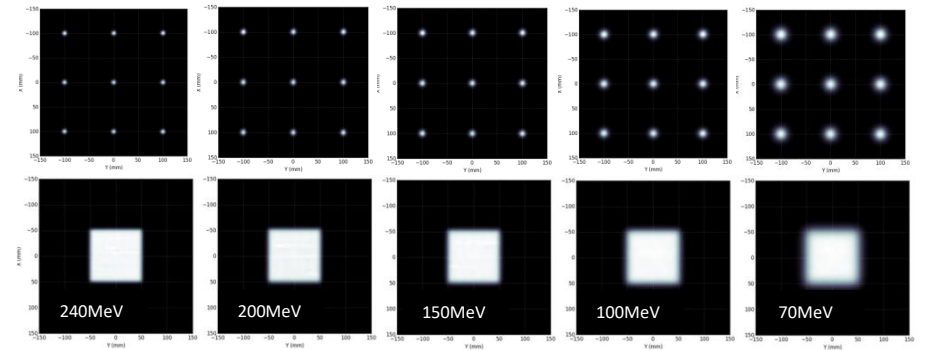
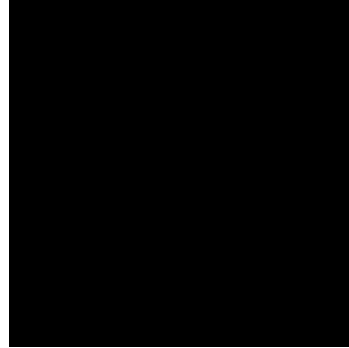
Equipment used:



IBA LynxPt  
2D scintillator 300x300mm<sup>2</sup> 0.5mm resolution



PTW MP3  
Water tank with ionisation chambers



X Results

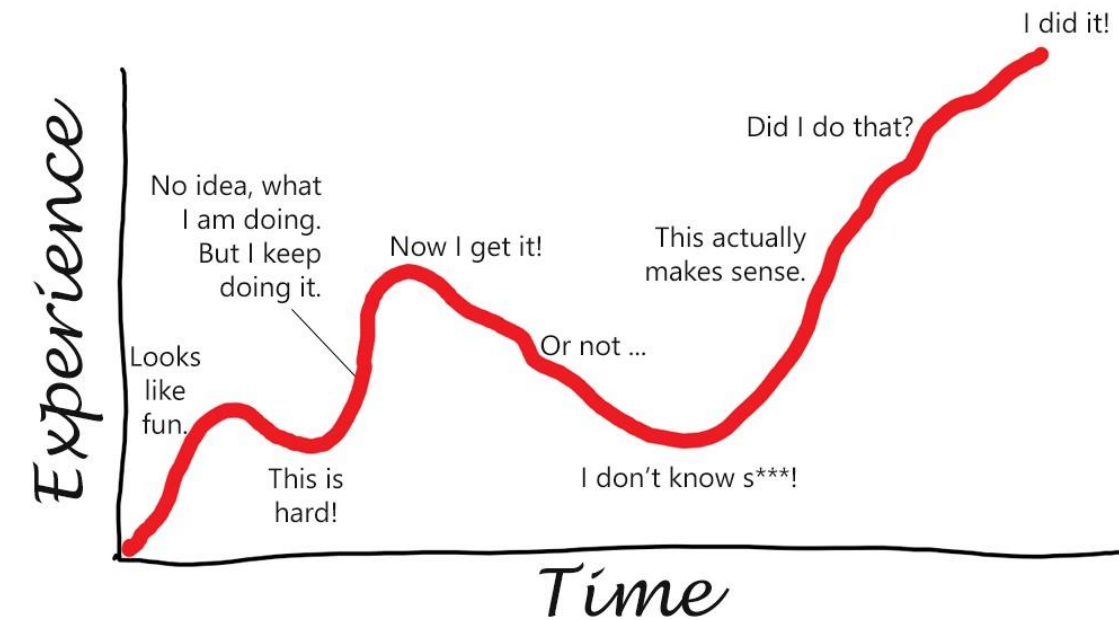
Center [mm]	-1.71
FS50 [mm]	202.12
FS90 [mm]	164.66
LP80-20(-) [mm]	24.06
LP80-20(+) [mm]	24.0
T.W. [mm]	106.0
Homog. T.W.[%]	1.22
Homog. 2D T.W. [%]	1.68
Symmetry [%]	0.13

Y Results

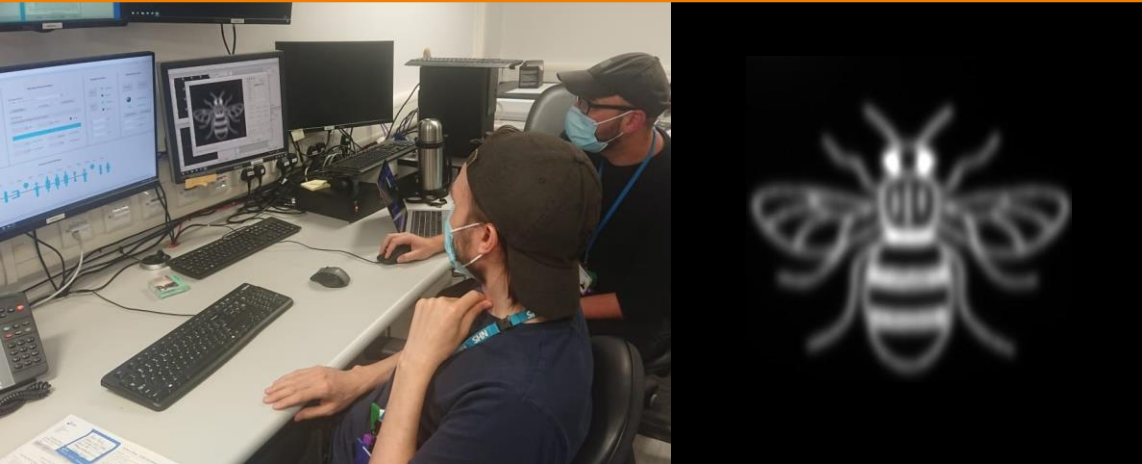
Center [mm]	-8.34
FS50 [mm]	203.68
FS90 [mm]	167.32
LP80-20(-) [mm]	23.73
LP80-20(+) [mm]	23.24
T.W. [mm]	109.72
Homog. T.W.[%]	0.9
Homog. 2D T.W. [%]	1.68
Symmetry [%]	0.08



# Conclusion



- Commissioning and upgrades finished in 14 months
- Beamline accepted by customer after remote dosimetry acceptance
- Sigmaphi improved its management of scanned beamline turnkey system project for medical customers
- Sigmaphi increased its knowledge in the beam dosimetry field and enlarged its beamline team strength
- Sigmaphi is currently working with The Christie for future updates and additional beamlines projects
- Sigmaphi is working on similar projects with clinical centers and laboratories in order to improve protontherapy treatments



- Customer commissioning done (planning system)
- Proton Robotic Hypoxia Cabinet implemented
- Mechanistic Modelling of DNA Damage & Repair



*Merci pour votre attention*

