Evaluation of Novel Materials for High-Intensity Beam Diagnostics

P. Alexaki [a,b]

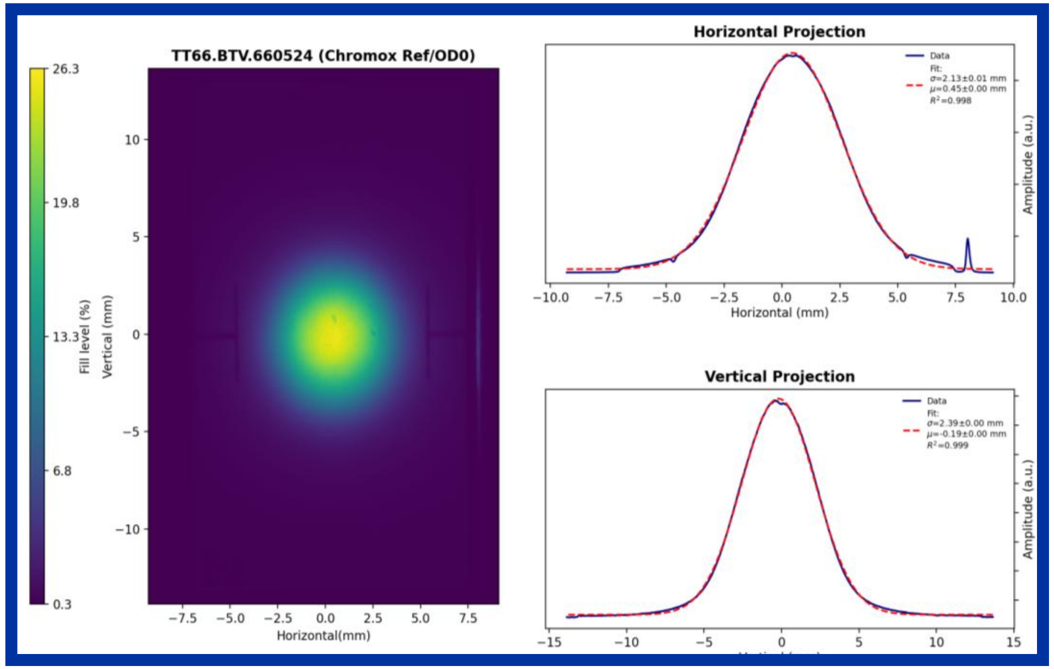
Supervisors: Prof. C. Touramanis [b] **, Prof. N. McCauley** [b] **, Dr. N. Charitonidis** [a]

[a] CERN, BE-EA
[b] University of Liverpool

Year 1 High Energy Physics PhD Students Presentations, 16th June 2026

Motivation

- **Future accelerators push materials to their limits**
  - HL-LHC and FCC require **increasingly bright beams**
  - Beam diagnostics rely on intercepting devices to measure beam properties
  - Specifically, **beam profile monitors use light emitting screens** to determine the size, shape and position



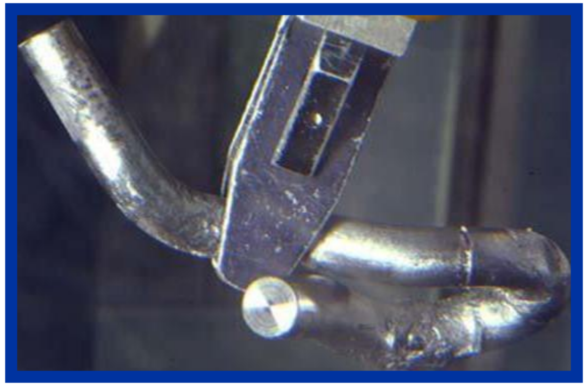
- **Materials must simultaneously:**
  - Produce strong signal (light yield)
  - Minimize beam interception
  - Survive extreme beam conditions

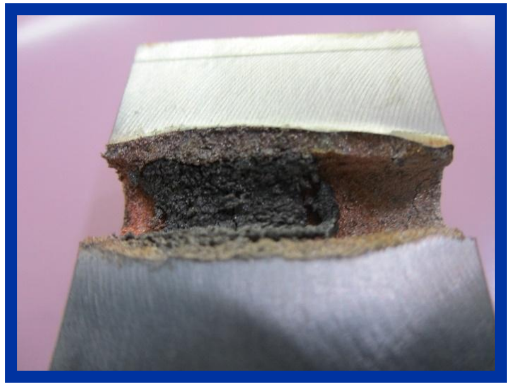
This PhD thesis aims to perform the HRMT-74 (BTVmat) experiment: a systematic irradiation and characterization of beam imaging materials under fast, high-energy proton beams.

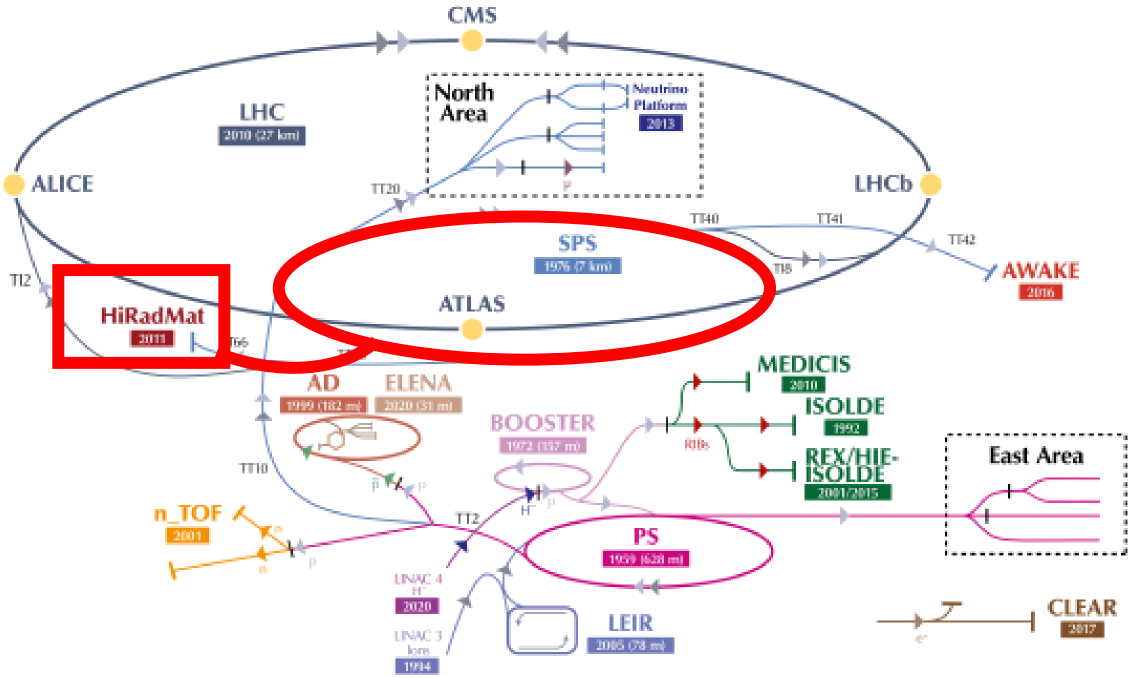
HiRadMat: a test-bench facility at CERN

- **HiRadMat is a unique facility at CERN, providing a high-energy, high-intensity, LHC-type beam to study beam–matter interactions under extreme conditions.**

- **The proton beam available in HiRadMat is extracted from the CERN Super Proton Synchrotron (SPS) :**
  - 440 GeV/c proton beam
  - Up to 6×10^{13} protons per pulse
  - 4.3 MJ deposited in only 7.95 µs







Photon Emission: Scintillation & OTR

Scintillation

Physical Properties:

- The proton beam deposits energy in the material
- Excited electrons & holes are created
- These excitation carriers migrate to luminescence centers
- Their radiative relaxation produces photons

Key characteristics:

- Light Yield depends on the material, deposited energy & particle type
- Response time from ns to ms

Optical Transition Radiation (OTR)

Physical Properties:

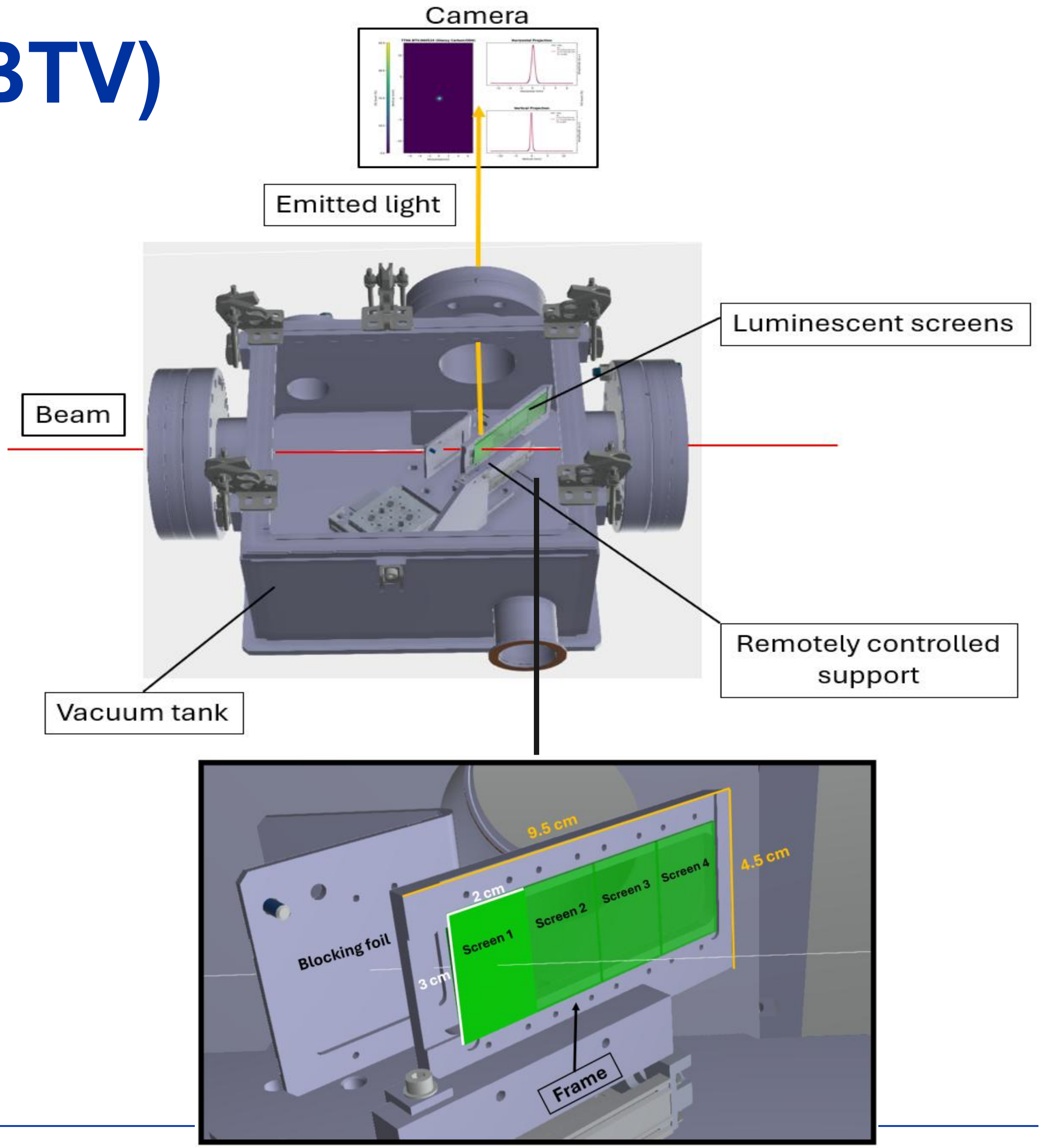
- Produced when a charged particle crosses the boundary between two media with different dielectric properties.
- Radiation is emitted in both forward the backward directions.
- OTR intensity peaks at an emission angle $\theta \approx 1/\gamma$, where γ is the Lorentz factor of the particle

Key characteristics:

- Prompt emission
- Light yield depends strongly on the surface reflectivity

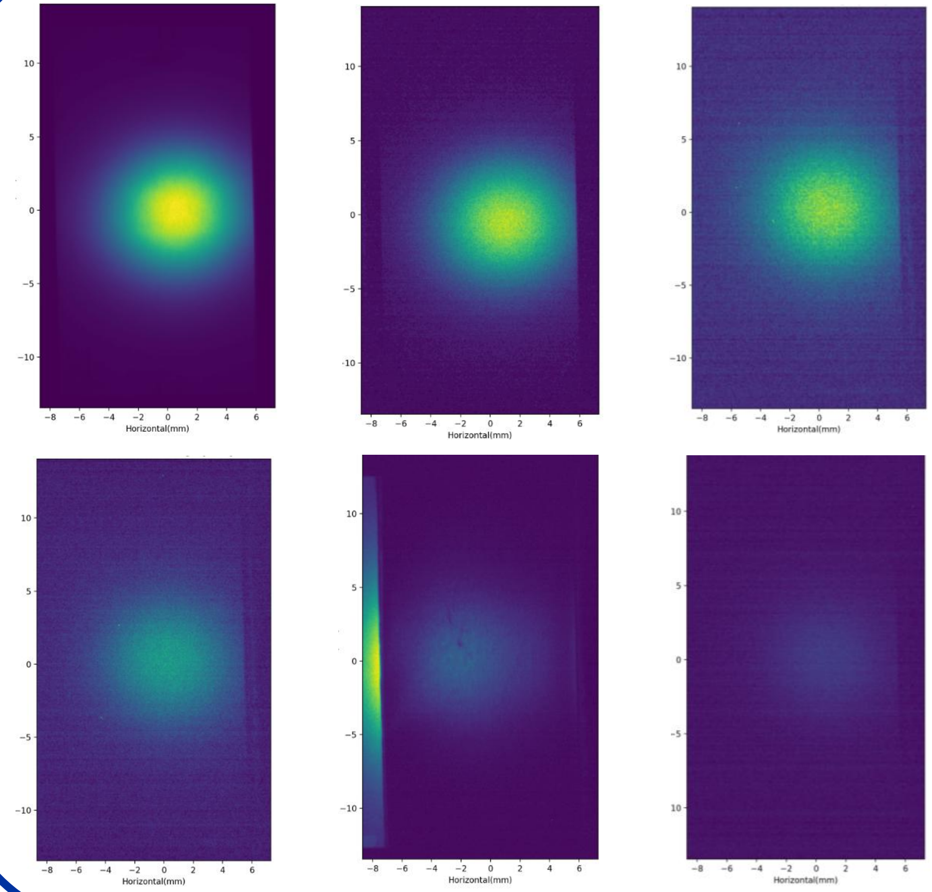
Beam Television System (BTV)

- Key device for transverse beam diagnostics.
- Over 200 devices installed across CERN accelerators.
- Operation principle:
  - ➢ the beam hits a 45º screen, producing light via **scintillation** and/or **Optical Transition Radiation** (OTR).
  - ➢ A camera captures the light to reconstruct the beam profile.

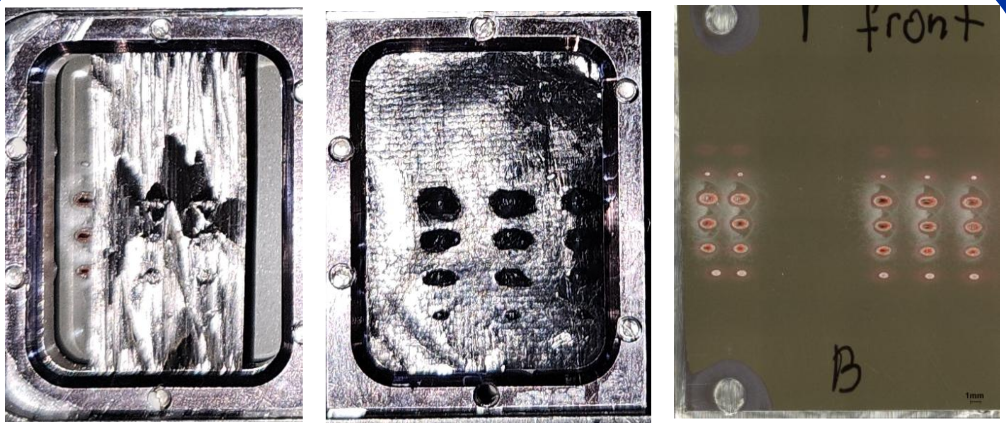


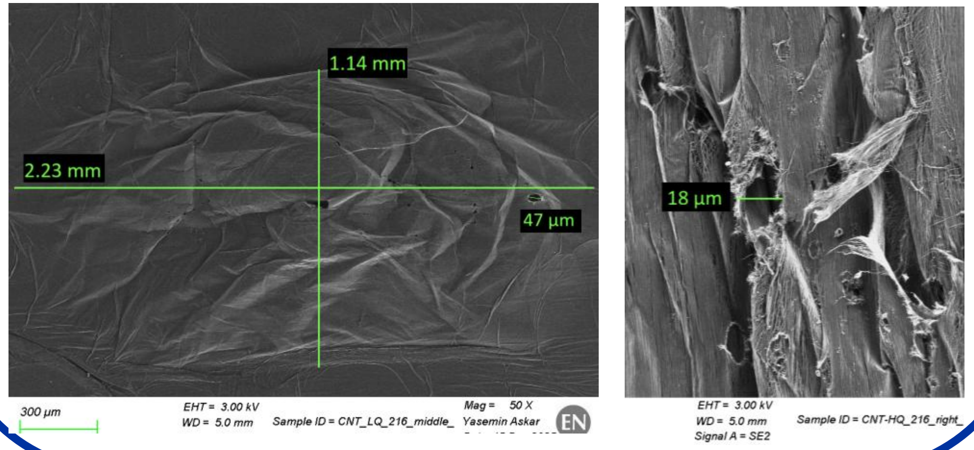
Experimental Observables

Light Yield production



Failure threshold





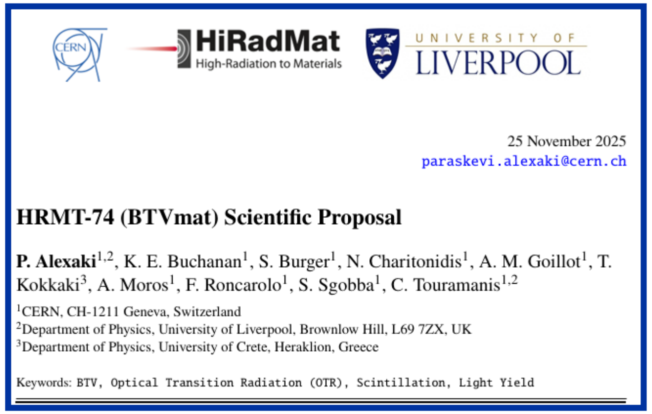
Materials under test

Material	Mechanism	Characteristics
Glassy Carbon	OTR	HiRadMat reference screen for high intensities, robust, unknown failure threshold
Chromox (Al_2O_3 (99.5%) + Cr_2O_3)	Scintillation	HiRadMat reference screen for low intensities, high light yield
YAG:Ce ($Y_3Al_5O_{12}$:Ce)	Scintillation	Fast response, high light yield
LuAG:Ce (Lu3Al5O12)	Scintillation	Alternative garnet scintillator
GAGG+	Scintillation	Similar to YAG:Ce & LuAG:Ce but higher light yield
Tungsten	OTR	High reflectivity, metal
Tantalum	OTR	High reflectivity, metal
CVD Diamond	OTR	High reflectivity, robust, exceptional thermal conductivity
BNNT	Scintillation	Low beam perturbation due to small thickness

First Year Progress

Experimental preparation

- Scientific proposal approved
- Technical Board approval
- Material procurement
- Frame manufacturing
- Laser cutting



25 November 2025
paraskevi.alexaki@cern.ch

HRMT-74 (BTVmat) Scientific Proposal

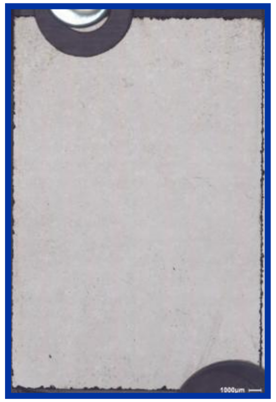
P. Alexaki[1,2], K. E. Buchanan[1], S. Burger[1], N. Charitonidis[1], A. M. Goillot[1], T. Kokkaki[3], A. Moros[1], F. Roncarolo[1], S. Sgobba[1], C. Touramanis[1,2]

[1]CERN, CH-1211 Geneva, Switzerland
[2]Department of Physics, University of Liverpool, Brownlow Hill, L69 7ZX, UK
[3]Department of Physics, University of Crete, Heraklion, Greece

Keywords: BTV, Optical Transition Radiation (OTR), Scintillation, Light Yield

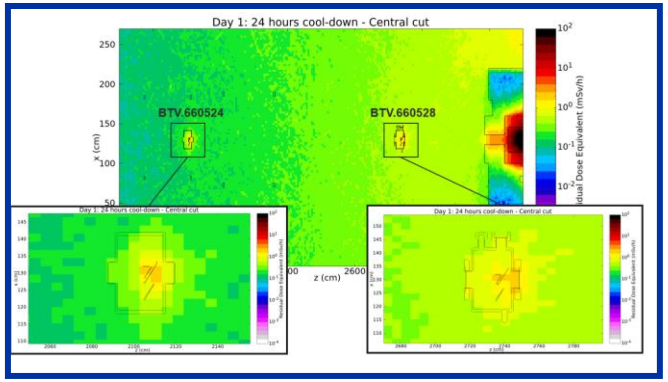
Characterization

- Measurements of the offset of the movement of the frame
- First irradiation of samples
- Optical microscopy
- SEM imaging



Simulations

- FLUKA Radiation Protection Studies
- ANSYS thermo-mechanical analysis
- Temperature increase calculations

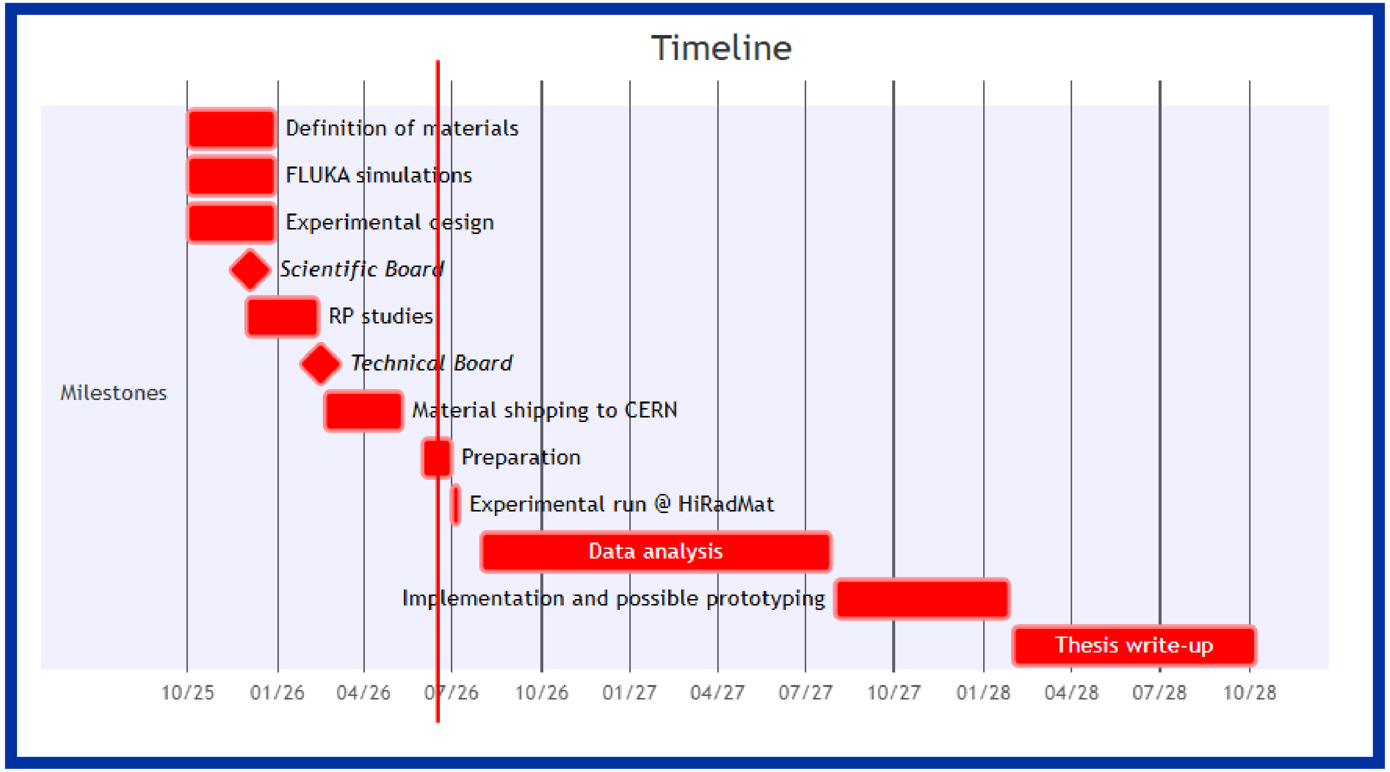


Timeline & next steps

Next 2 Months

- Complete reflectivity measurements of materials
- Characterize camera response and gain calibration
- **Validate beam optics (16 July pre-commissioning)**

HRMT-74 experimental run, Week 31



Presentations, Notes & publications

Talks

- **HiRadMat: A High-Power Beam Facility at CERN**, Presentation at the CERN Beams Seminar, January 2026, https://indico.cern.ch/event/1620665/
- **Performing Experiments in HiRadMat – A High-Power Beam Facility**, Presentation at the CERN BE-EA 63rd Coffee Meeting, https://indico.cern.ch/event/1598057/
- **HiRadMat: A High-Power Beam Facility at CERN – EURO-LABS Task Force 3.1**, Presentation at the EURO-LABS Fourth Annual Meeting, https://indico.cern.ch/event/1572254/

Notes & Publications

- **HRMT-74 (BTVmat) Scientific Proposal**, https://edms.cern.ch/document/3465788/
- **HRMT-74 Experiment Safety File**, https://edms.cern.ch/document/3380862/1/
- **Gerard Aliana-Cervera, ..., P. Alexaki et al.**, "Radiation tolerance of carbon nanotube wires: role of chemical treatment and wire structure", Submitted to *Radiation Physics and Chemistry*.
- **D.K. Manousou, ..., P. Alexaki et al.**, "Measurement of the failure probability of digital cameras in high-energy mixed radiation fields", Submitted to *NIM-A*.

Thank you!
☺
Questions?

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