HiRadMat
High-Radiation to Materials

The HiRadMat Facility Overview and Perspectives for Post LS2

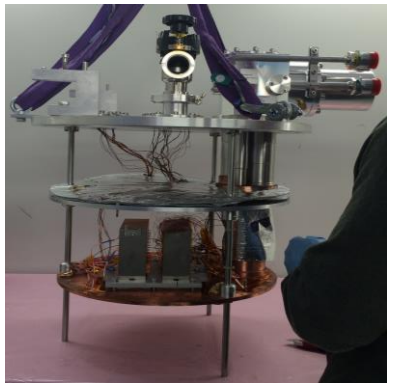
F. Harden (on behalf of the HiRadMat Team)
CERN

HiRadMat at a Glance

- Originated from the LHC Collimation Project, due to requirements for a facility capable for "testing accelerator equipment with beam shock impacts[1] using high power LHC type beams[2]".

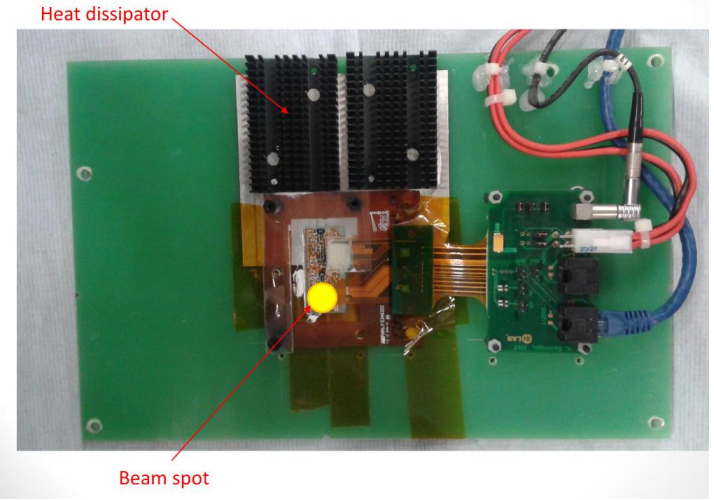
- The High Radiation to Materials (HiRadMat) testing facility took its first beam in 2012 and has continued to deliver pulsed, high intensity, LHC-type beam to over 40 experiments.

SextSc investigated damage limits of superconducting magnets, via use of cryostat to reach temperatures ~4K.



BLM2 studied the signal linearity and response, calibration, saturation and comparison of different types of Beam Loss Monitors

ATLAS investigated radiation hardness and damage threshold of pixel tracker detectors.



[1] http://lhc-collimation-project.web.cern.ch/lhc-collimation-project/HiRadMat.htm
[2] R. Assmann et al., "User Requirements for a Test Facility with High Power LHC Type Beam", 2009, EDMS No: 1130296

Fundamental Details

- Irradiation Facility for R&D using pulsed high energy, high intensity, proton (& ion beams).
- Facility has, so far, completed experiments on materials, equipment, prototype, detectors, instrumentation and cryogenic testing.

HiRadMat Proton Beam	
Beam Energy	440 GeV
Pulse Energy (max)	2.4 MJ
Bunch Intensity	5.0×10^{9} to 1.2×10^{11} protons
Number of Bunches	1 to 288
Minimum Pulse Intensity	5.0×10^{9} protons (1b at 5.0×10^{9} ppb)
Maximum Pulse Intensity	3.5×10^{13} protons (288b at 1.2×10^{11} ppb)
Pulse Length (max)	7.95 µs
1 σ r.m.s. beam radius	0.5 to 2.0 mm (standard) [0.25 to 4.0 mm currently upon request]
Total allocated protons/year into facility	1.0×10^{16} protons (equivalent to approx. 10 experiments per year)

ARIES – Transnational Access

- Provides funding as part of the European Union's Horizon 2020 Research and Innovation Programme.
- Part of WP10 (Materials Testing).
- Project started in 2017.
- 4000 Transnational Access hours completed (2700 during EuCARD-2).

2017

50% of 2017 experiments applied for TNA:

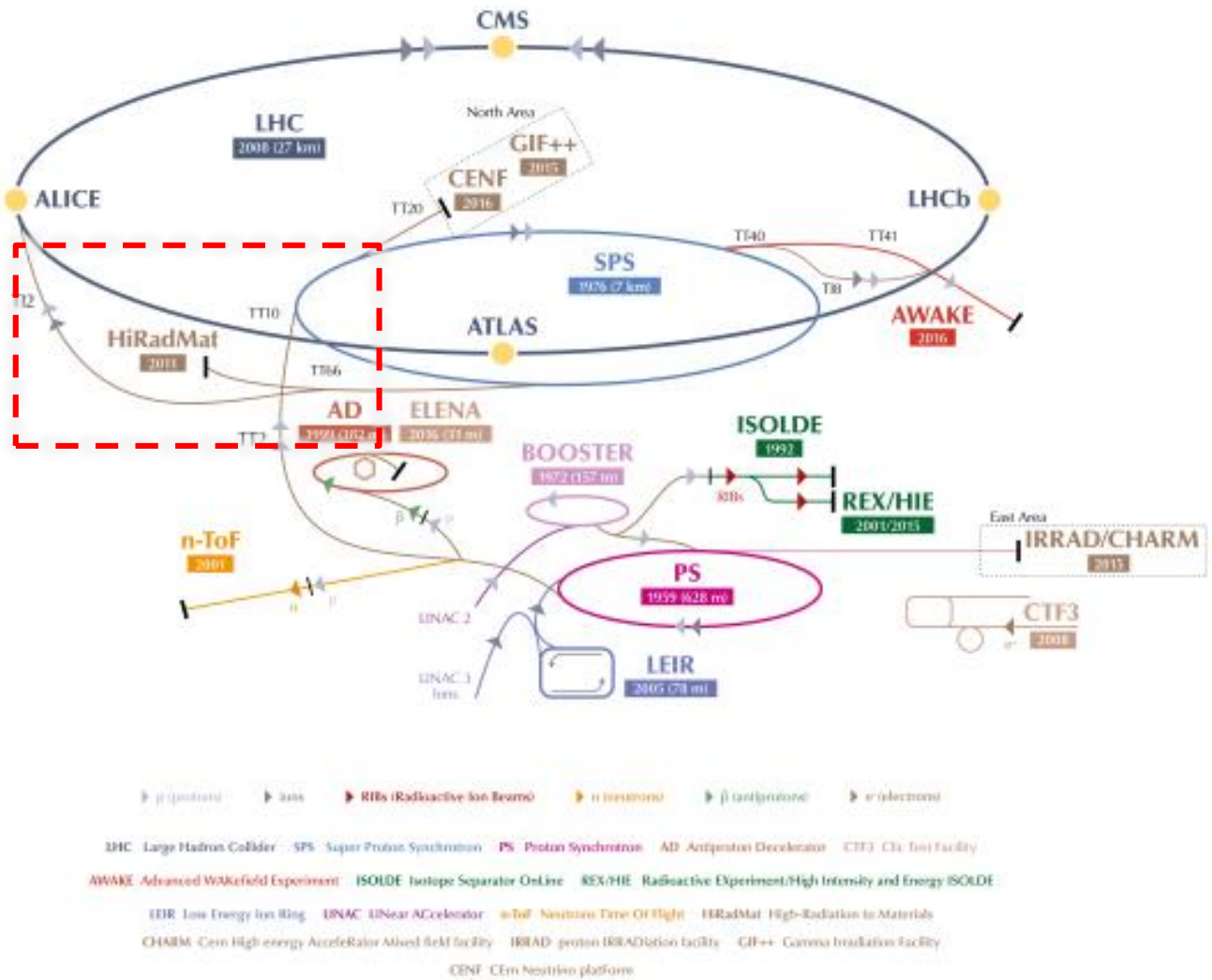
- HRMT19: BLM2 (ESS, Lund, Sweden).
- HRMT41: ATLAS pixel (INFN Genova, IFIC Valencia, CAS China, PNPI Russia).
- HRMT21: RotColl (SLAC USA, U. Malta).
- HRMT36: MultiMat (U. Malta, Brevetti-Bizz SME Italy).

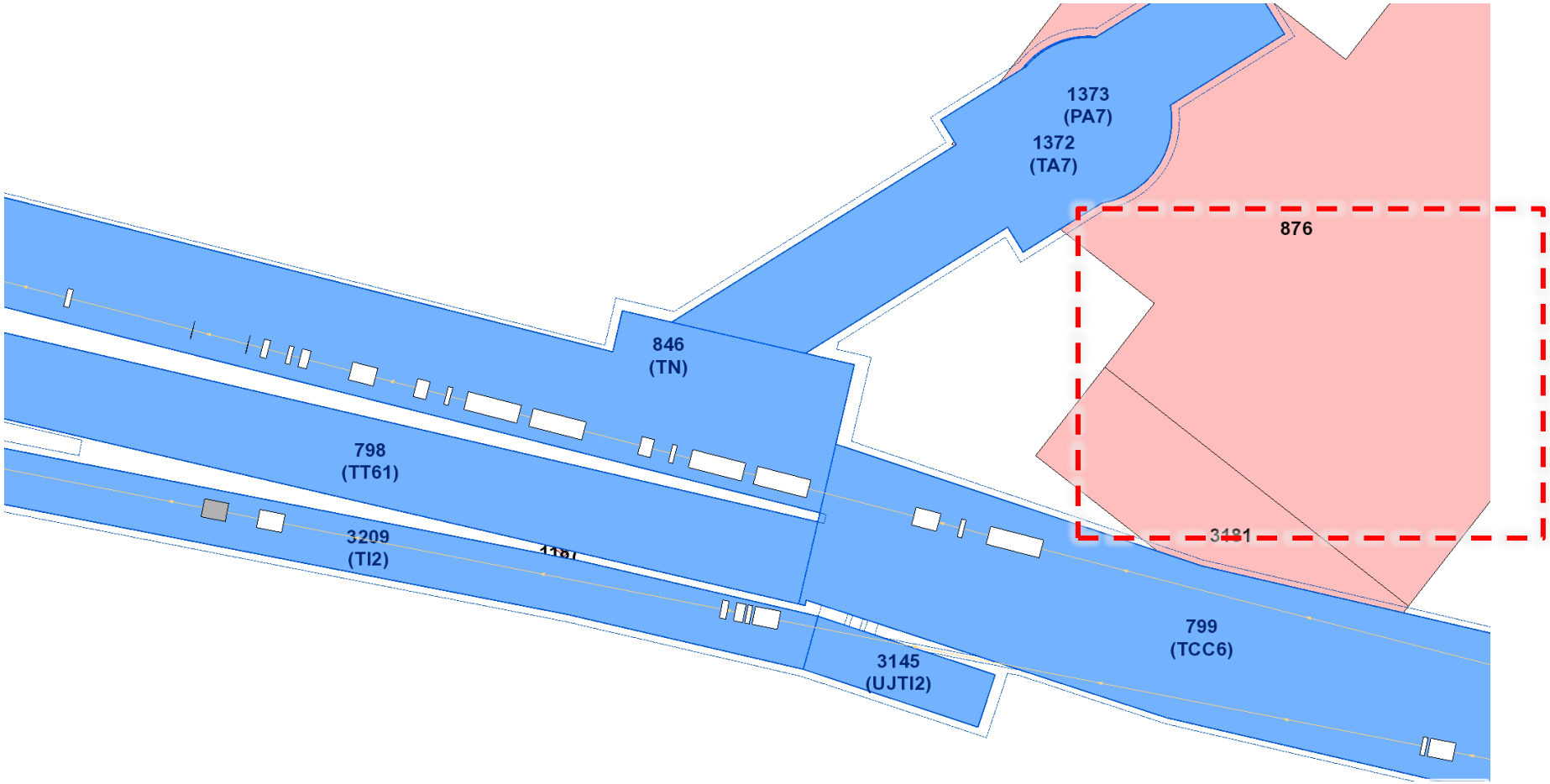
2018

40% of experiments applied for TNA:

- HRMT19: BLM2 (ESS, Lund, Sweden).
- HRMT47: ATLAS PixRad (INFN Genova, IFIC Valencia, CAS China, PNPI Russia). Linked with HRMT41.
- HRMT38: FlexMat (GSI Germany).
- HRMT43: BeGrid2 (FNAL USA, STFC UK, KEK/JAEA Japan).

How does HiRadMat fit into the CERN Acc

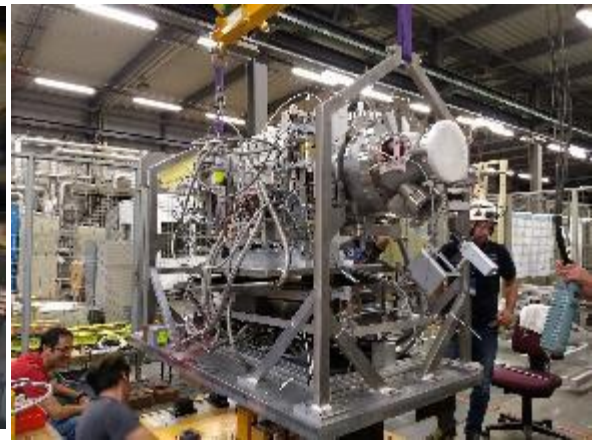



1373
(PA7)
1372
(TA7)
876
846
(TN)
798
(TT61)
3209
(TI2)
3181
799
(TCC6)
3145
(UJTI2)

Surface Infrastructure

HiRadMat Surface Lab

- Located in bldg. 876/R-017.
- Supervised Radiation Area.
- Contains laboratory fixed tables enabling pre-commissioning tests on experiments before final installation in experimental area.



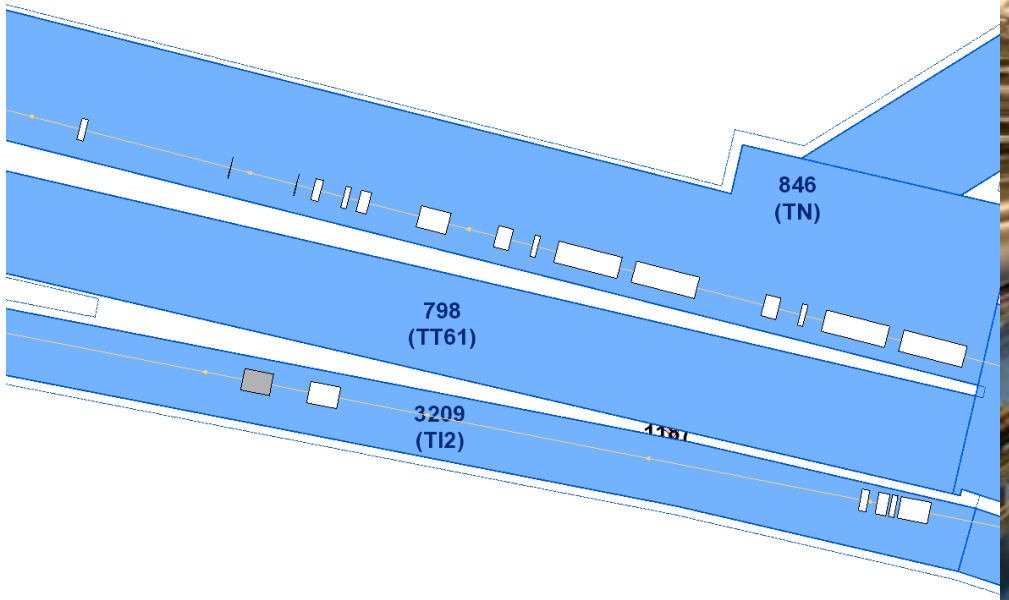
HiRadMat Control Room

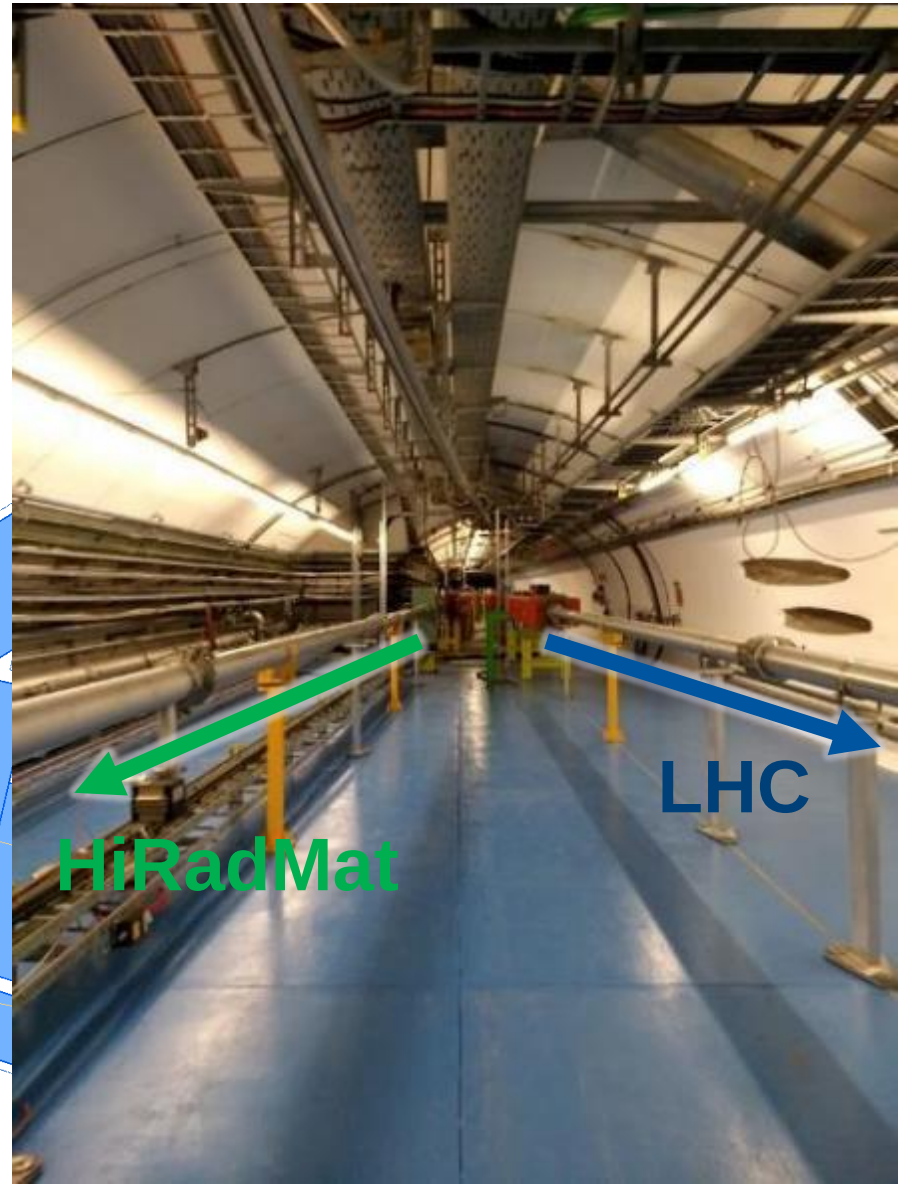
- Located in bldg. 876/R-003.
- DAQ and offline monitoring systems can be set-up for each experiment.

SPS Extraction to HiRadMat

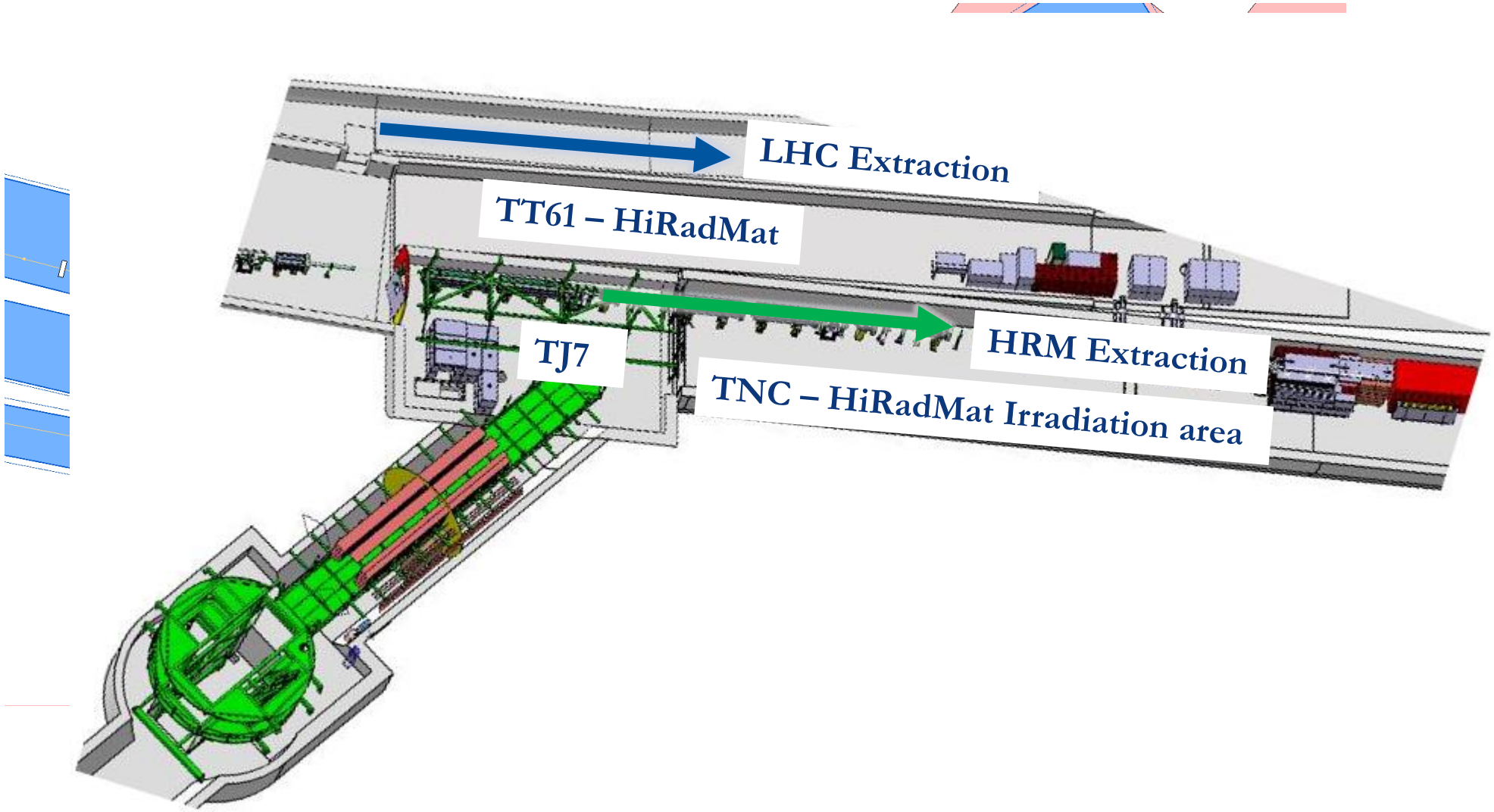
HiRadMat is adjacent to an SPS extraction point to LHC.

All interventions to HiRadMat are dependent upon the LHC schedule resulting in all access being planned, flexible and executed efficiently.





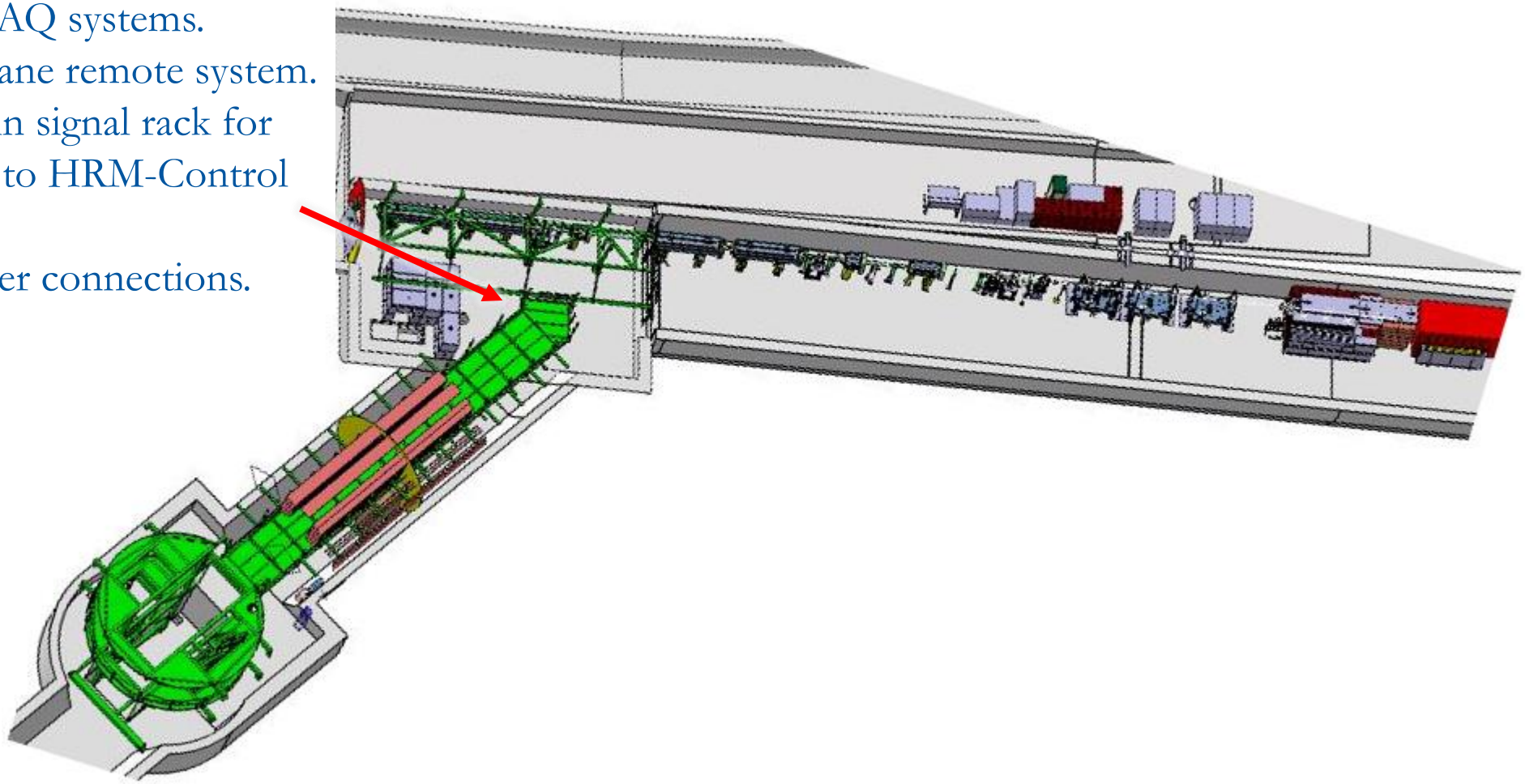
Irradiation Area



Irradiation Area

TJ7

- Shielded area available for additional DAQ systems.
- Overhead crane remote system.
- Patch panel in signal rack for connections to HRM-Control Room.
- Cooling Water connections.



Irradiation Area

TNC

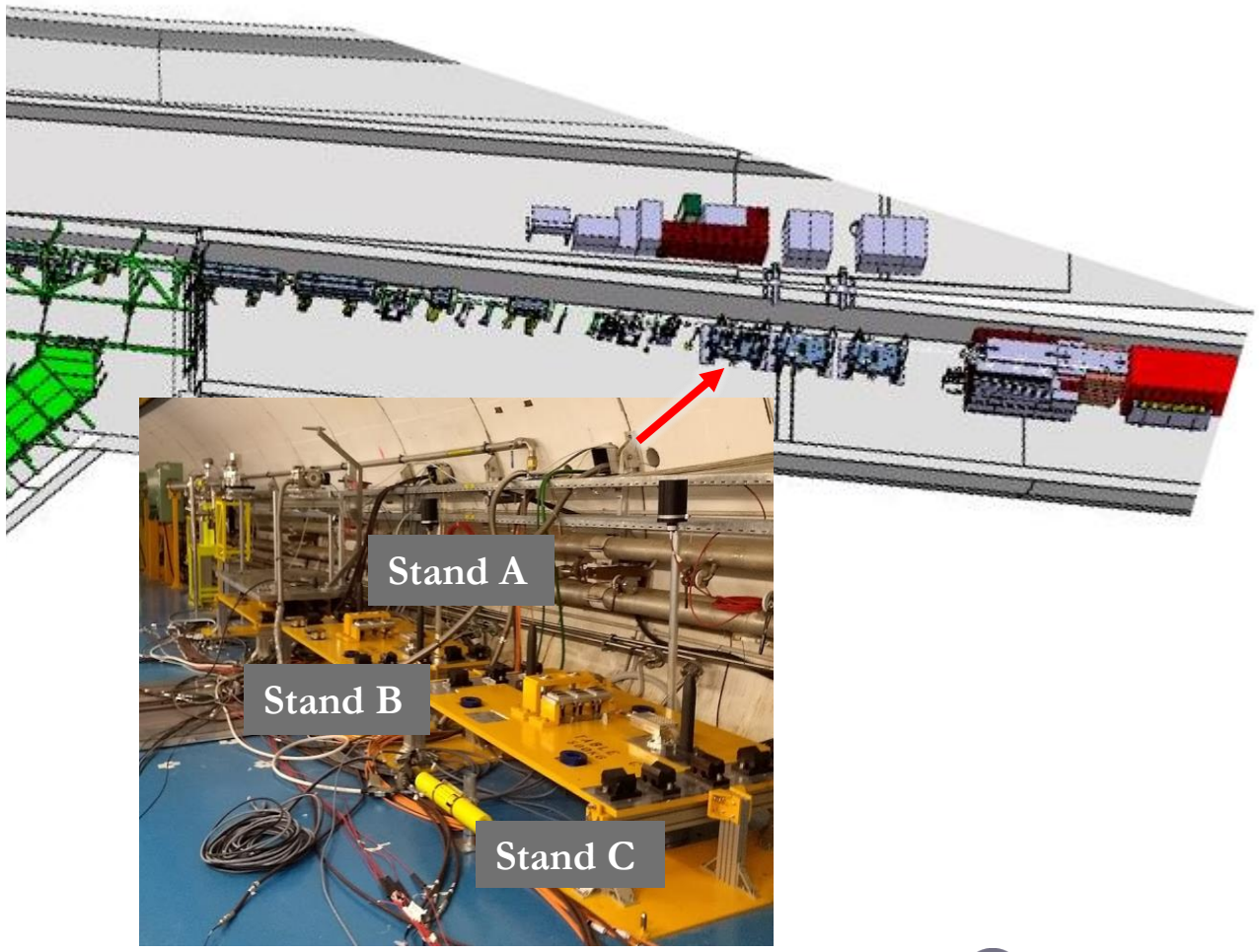
3 Experimental Stands in HiRadMat Experimental Area

- **Stand A:** Dedicated Beam Instrumentation Stand providing beam diagnostics and monitoring systems.
- **Stand B & C:** Dedicated Experimental Stands enabling different optics to be achieved.

- Tables are cooled by a cooling circuit (30 kW, 3m^3/h, 9bar)

- Power provided (4kV / 2.5 kA)

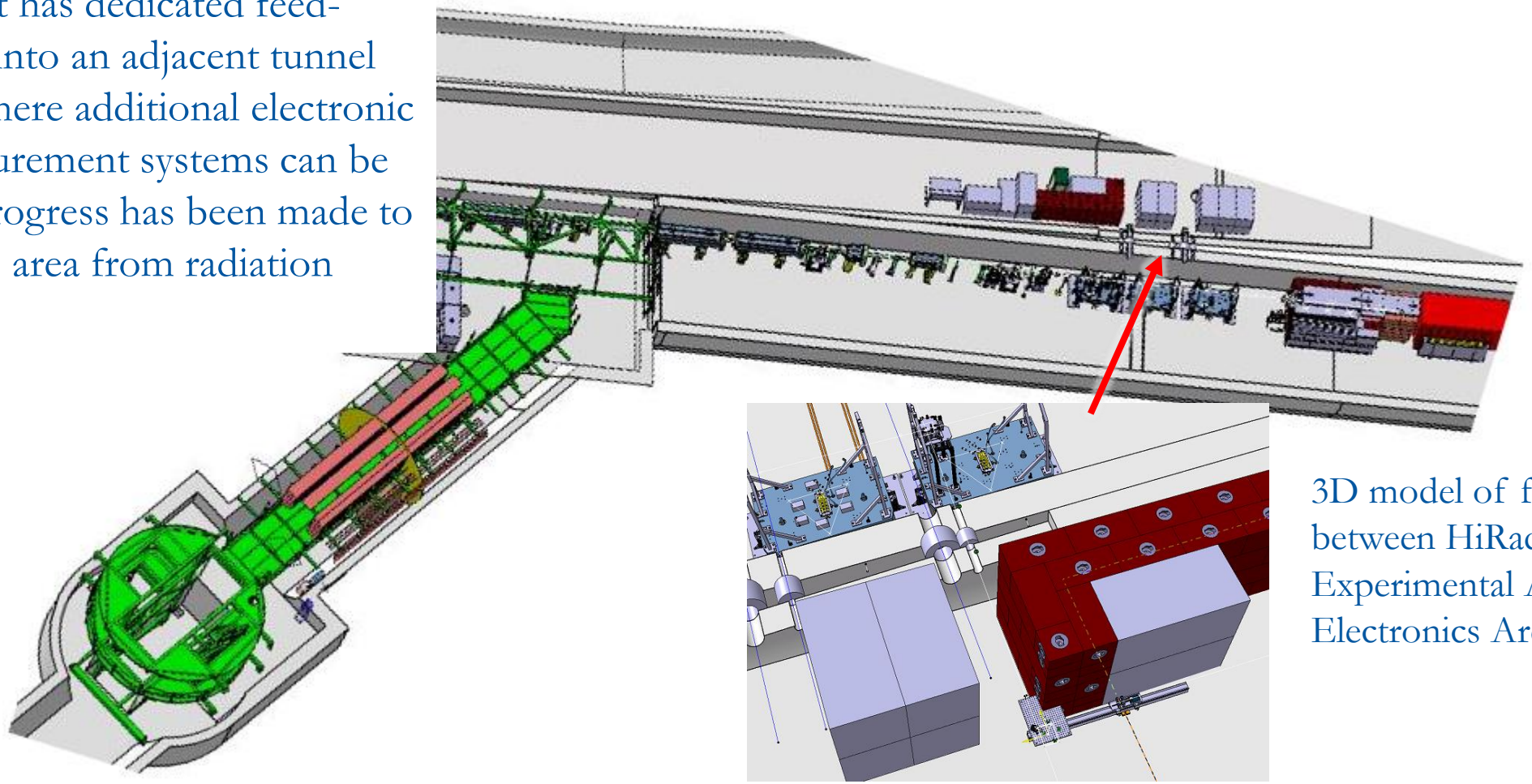
- Signal cables (50 V / 2 A) for motorization stages, cameras, etc.



Irradiation Area

TT61

HiRadMat has dedicated feed-throughs into an adjacent tunnel (TT61) where additional electronic and measurement systems can be added. Progress has been made to shield this area from radiation effects.



3D model of feed-through between HiRadMat Experimental Area and Electronics Area.

Support for Users

Preparation Phase

- All experimental proposals are reviewed for their scientific merit and feasibility by the HiRadMat Scientific Board.
- Accepted proposals are then reviewed by the HiRadMat Technical Board where technical aspects, safety files and beam operations are evaluated.

Design Phase

- Design and Integration Checks.
- Technical Discussions, including safety requirements, on-line monitoring requirements, etc.
- Design assistance/production available.

Installation Phase

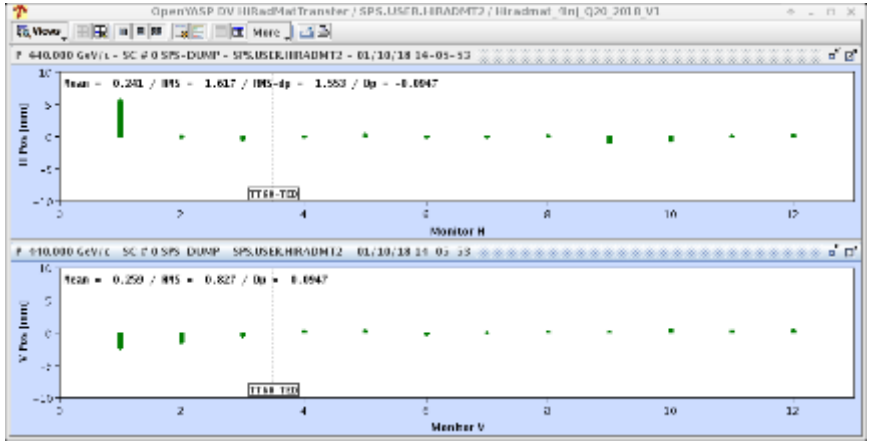
Access to CERN services from collaborating teams, including, Survey, Mechatronics and Measurements, Mechanical and Materials Engineering, Beam Instrumentation, Handling, Radiation Protection.

Installations into HiRadMat Irradiation Area

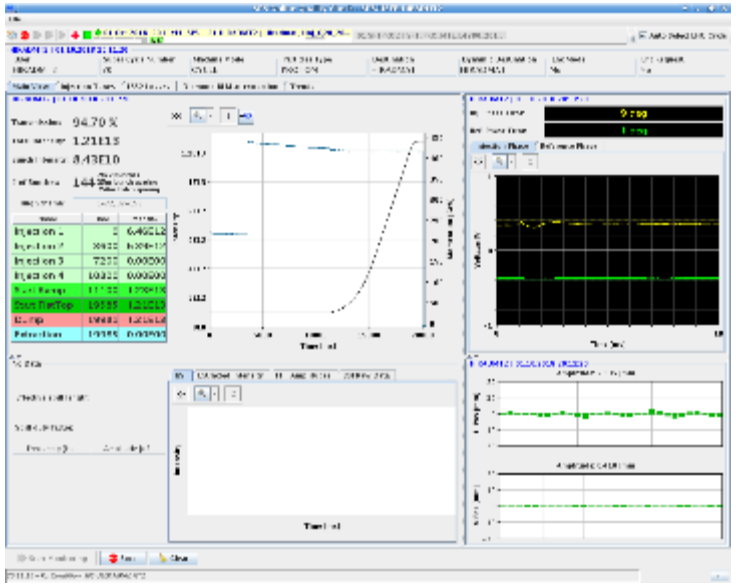
Support for Users

SPS Operation

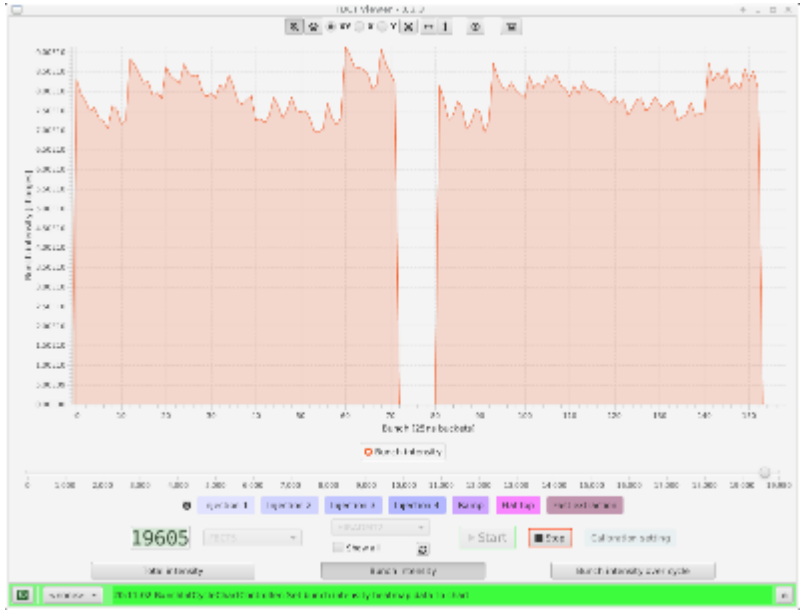
- Colleagues from SPS Operations provides high quality proton (or ion) beam to the HiRadMat experiment. Standard procedures relating to beam trajectory, beam emittance, beam spot size, proton bunch sets, etc. are all completed by the experts during the dedicated HiRadMat beam time.



Example of the HiRadMat proton beam trajectory for 12 bunches delivered to experiment.



Example of the extracted intensity for delivered 144 protons.

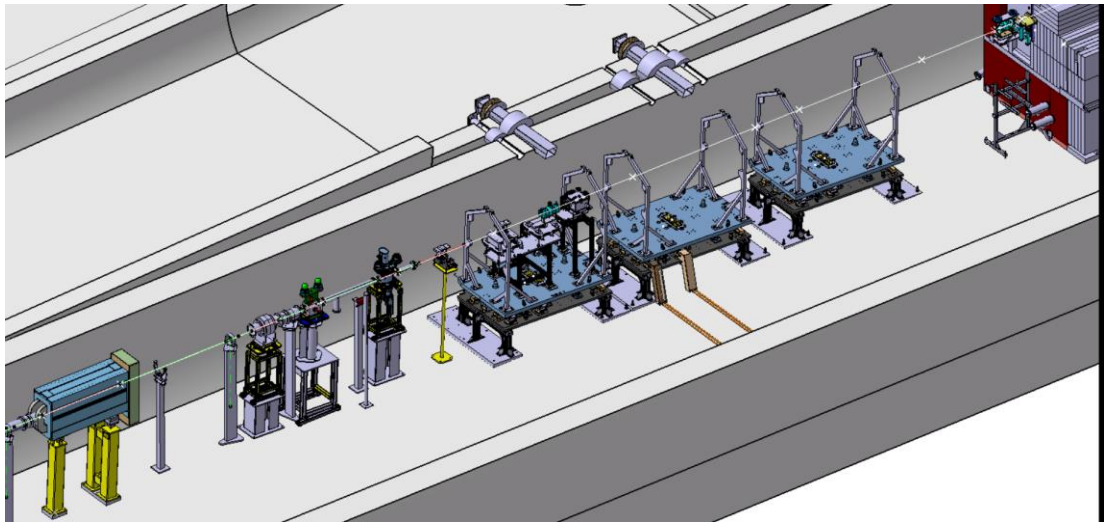


Example of quality of bunch-bunch intensity for 144 bunches (2×72 bunches)

Support for Users

HiRadMat Operation

- CERN colleagues available to assist with in situ measurements and monitoring, e.g. LDV, strain gauges, radiation hard camera, experiment motorisation.
- Beam diagnostic systems provided through collaboration with HiRadMat and Beam Instrumentation Group.
- Data stored and available for analysis after beam time.



Fixed Beam Instrumentation Table, currently includes a Diamond Detector, BPKG and BTV

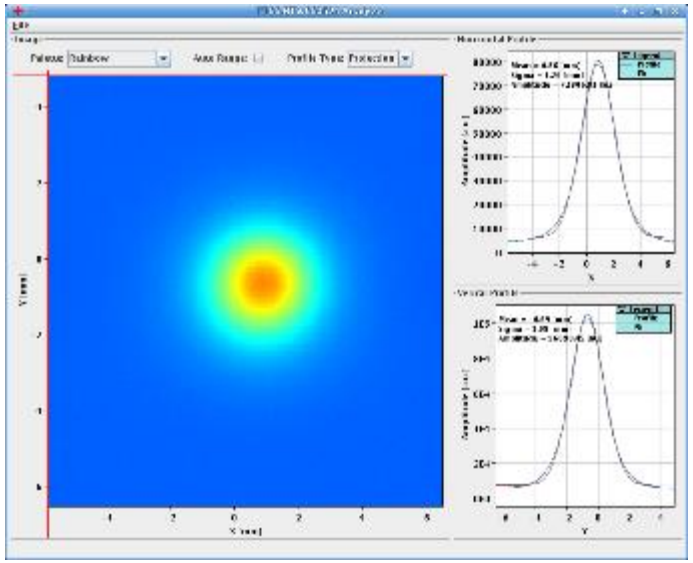
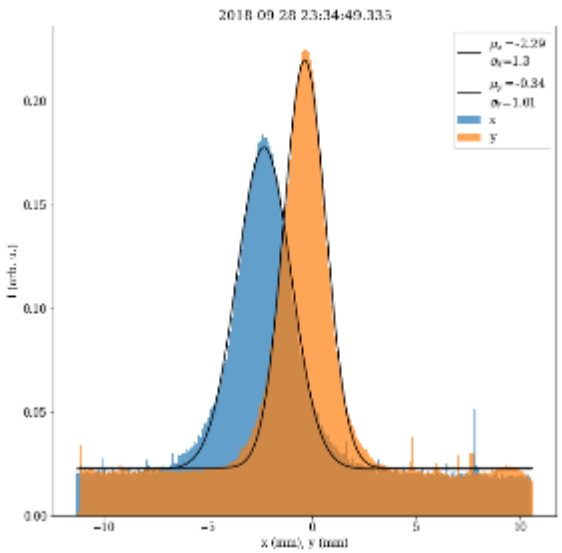


Image obtained from HRM-BTV



Post-Irradiation/Cool-Down Time

- After irradiation, experiments are moved to the HiRadMat cool-down area (usually 1-2 weeks after beam) to enable the integral dose of the experiment to decrease.
- After a sufficient cool-down period, Radiation Protection release the experimental container from HiRadMat. It is then transported to an appropriate irradiation facility (as arranged by experimental team) for post-irradiation analysis by the users.

HiRadMat Beam Dump

HiRadMat Cool-Down Area

Proven Track Record and Future Planning

- Since its commissioning in 2012, HiRadMat has proven its state-of-the-art facilities can be used outside its design remit, with a multitude of novel experiments completed.

- The facility has continued to advance to meet user requirements and to provide its facilities to global researchers.

- During LS2, HiRadMat will continue to develop with improvements to the following areas:
  - Renovation of TNC/TJ7/TT61.
  - Electrical Patch Panel installation and cabling checks.
  - Renovation of Surface Lab and HRM-Control Room.
  - Modifications to HiRadMat Operations Support for better user experience.

Facility Expectations and Requirements

- HiRadMat is a unique irradiation facility.
- Feedback from users regarding requirements, for example:
  - HL-LHC type beams?
  - Data Acquisition Upgrades?
  - Proton/Ion requests?
  - Interest beyond accelerator physics?
- Goal: To make HiRadMat a world-renowned facility.

BUT.....

WE NEED YOU!

Request for Letters of Intent

- Request deadline **28th February 2019**.

- LOI to include:
  - Scientific Description (executive summary, scientific motivation).
  - Technical Description (measurement methods, materials inventory).
  - Requests for HiRadMat Support (DAQ systems, in situ monitoring requirements).
  - Operational Description (protons/ions, intensity, spot size, etc.)

HiRadMat
High-Radiation to Materials

Purpose

- Determine interest in HiRadMat for post-LS2 experiments.
- Extend collaboration beyond Accelerator Physics Community.
- Determine what necessary upgrades are needed to reach out to different communities.
- Potential upgrades of the facility if deemed appropriate.

https://indico.cern.ch/event/767689/

Further Discussion

	HiRadMat facility experience and perspectives for post LS2	*Fiona Jacqueline Harden et al.*
	503-1-001 - Council Chamber, CERN	13:15 - 13:40
	Overview of HRMT24 & HRMT43 experiment	*Kavin Ammigan*
14:00	*503-1-001 - Council Chamber, CERN*	13:40 - 14:15
	HRMT48-PROTAD Experiment and Relevance for BIDs	*Dr Claudio Torregrosa*
	503-1-001 - Council Chamber, CERN	14:15 - 14:40
	DPA cross-section measurements and potential for HiRadMat	*Shin-ichiro Meigo*
	503-1-001 - Council Chamber, CERN	14:40 - 15:05
15:00	**Overview of some CERN High Radiation to Materials experiments and focus on Post Irradiation Examinations**	*Francois-Xavier Nuiry*
	Coffee break	
	503-1-001 - Council Chamber, CERN	15:30 - 16:00
16:00	**Working meeting - Collaboration by-laws and Future MOU considerations**	*Patrick Hurh*
	503-1-001 - Council Chamber, CERN	16:00 - 17:00
17:00	**Working Meeting - Future HiRadMat Planning Satellite meeting**	*Fiona Jacqueline Harden*
	503-1-001 - Council Chamber, CERN	17:00 - 18:00
18:00		

Thank you to all teams & groups involved with the HiRadMat operation:

BE/BI, BE/OP, EN/CV, EN/EA, EN/HE,

EN/MME, EN/SMM, EN/STI, HSE/RP, TE/MPE

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement No 730871.

CERN

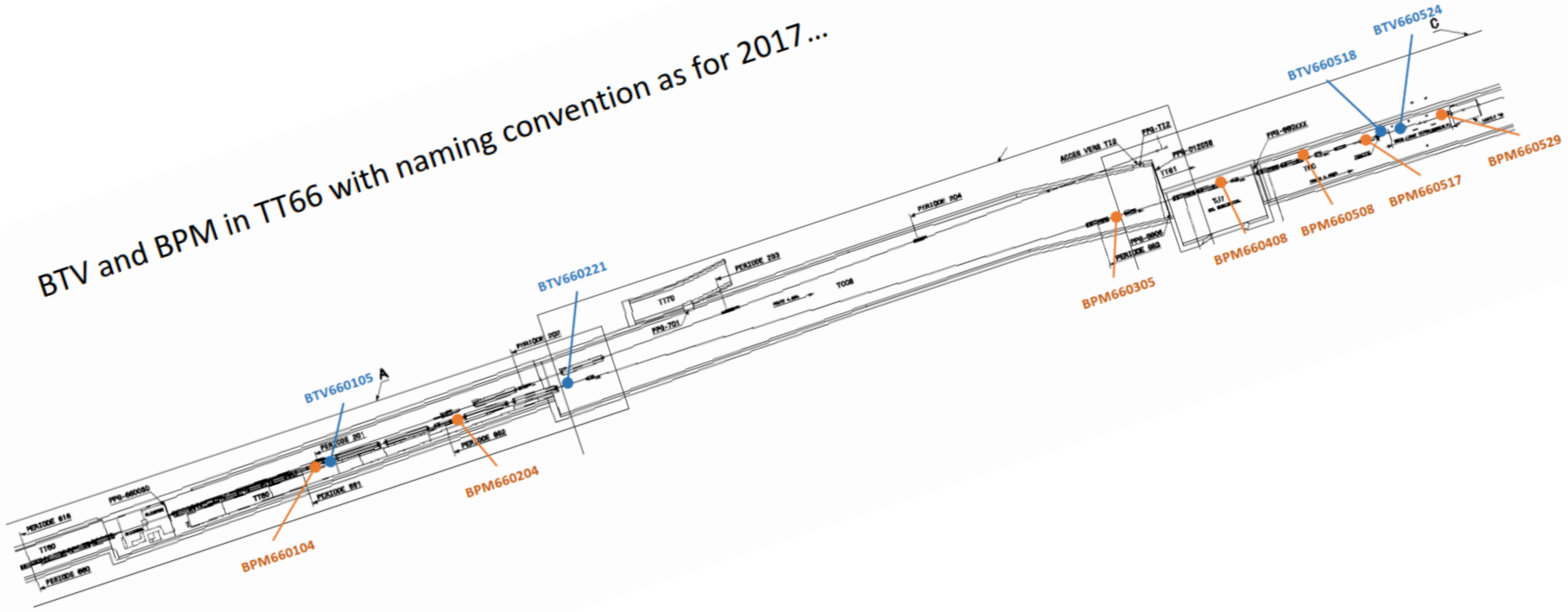
Back-Up Slides

HiRadMat Super Cycle Information

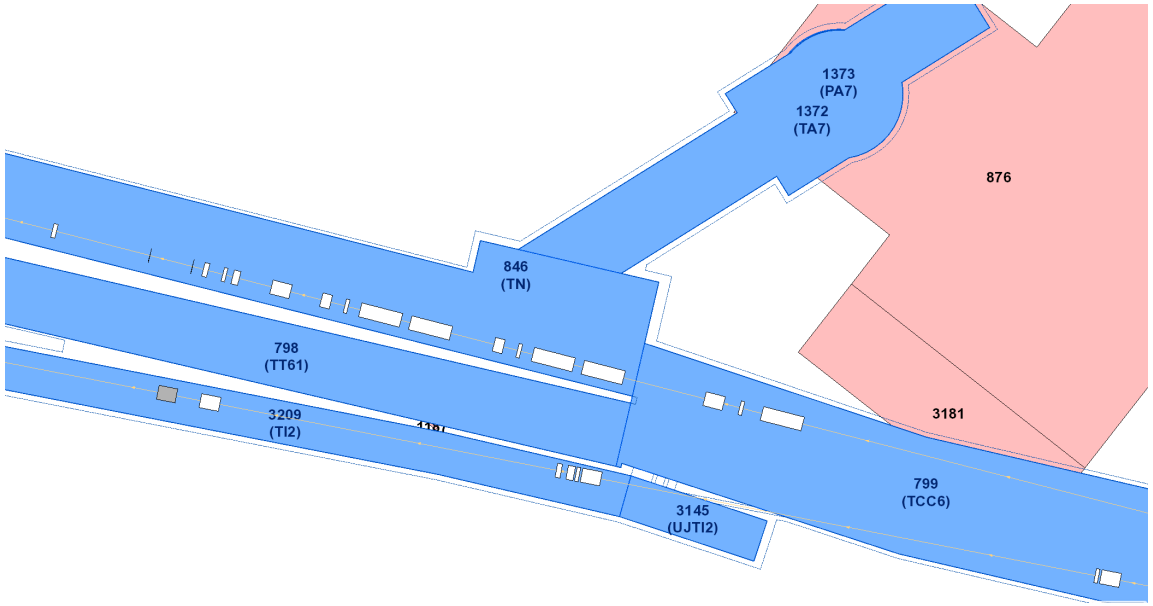
- HiRadMat 'Long' Super Cycle:
  - HRM_LS = 22.8 s, SFTPRO = 10.8 s, MD cycle = 7.2 s (3.6 s potentially depending on planning).
  - TOTAL = 40.8 s (or 37.2 s).

- HiRadMat 'Short' Super Cycle:
  - HRM_SS = 8.4 s, SFTPRO = 10.8 s, MD cycle = 7.2 s (3.6 s potentially depending on planning).
  - TOTAL = 26.4 s (or 22.8 s).

BTV-BLM-TT66 Line



HRM facility layout and access

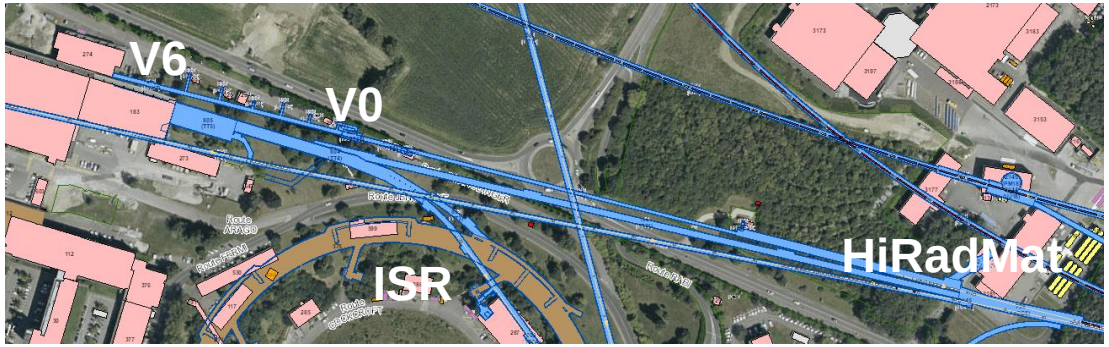


- Access to HiRadMat
  - Only without extraction to TCC6 (=TI2 and HRM)
  - SPS can continue cycling.
- Since 2014: TT61 is used for placing DAQ equipment only 10 m from the impact centre
- Access coordinated with BE/OP, particularly in view of LHC operation
  - Often stand-by for access during several days
  - Great flexibility by RP and TRANSPORT (HE) is highly appreciated.

Access to V0-V7

Muon pits of former WANF

- Exposed to muon beam in forward direction of HiRadMat target area
- Access to be restricted upon RP request
- Access to VO needed about twice a year for intervention by CV



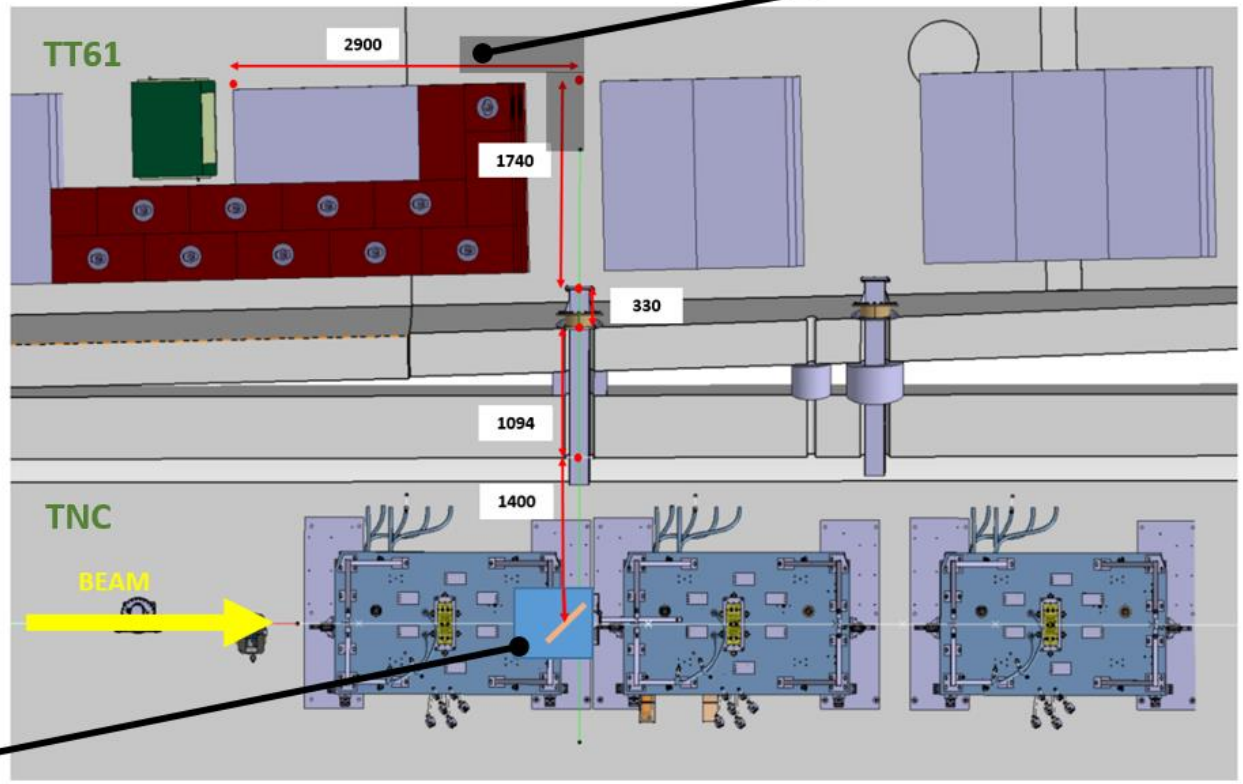
- Skipping installation of full-fletched access control system (SPS)
- Padlocks with manual veto system like in the North Area
  - Agreed by EN, BE and RP (EDMS 1578411)
  - Installed by BE/ICS
  - Manual veto held by EN/EA

- Installation completed, operational from 2016

BTV Optical Path

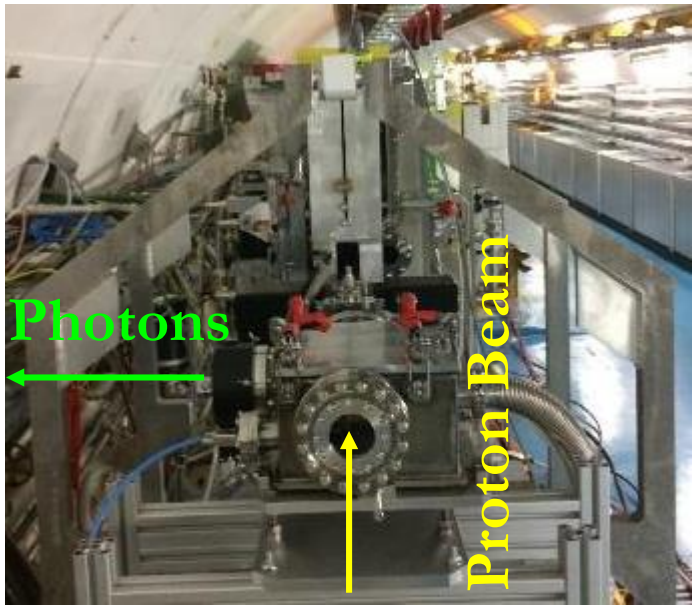
Installation of camera in TT61 to move away from the irradiated zone
→ Optical line up to TT61, behind shielding

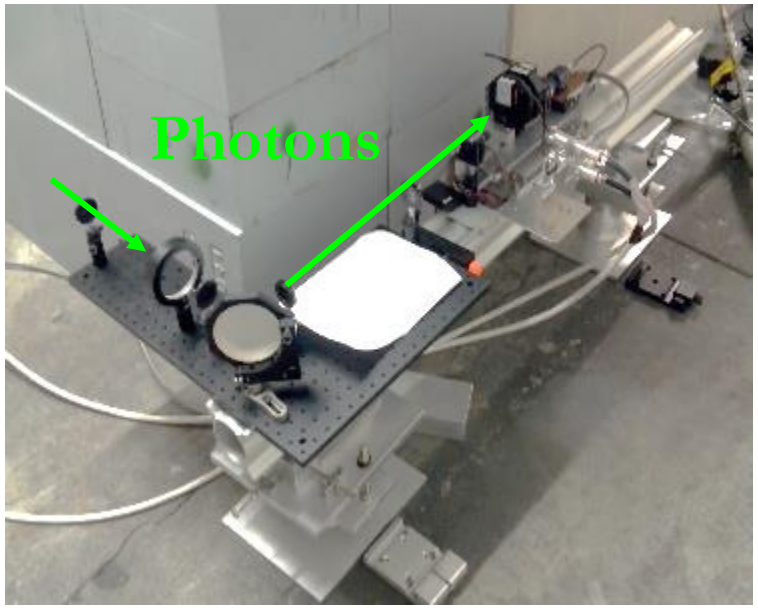
Location for camera

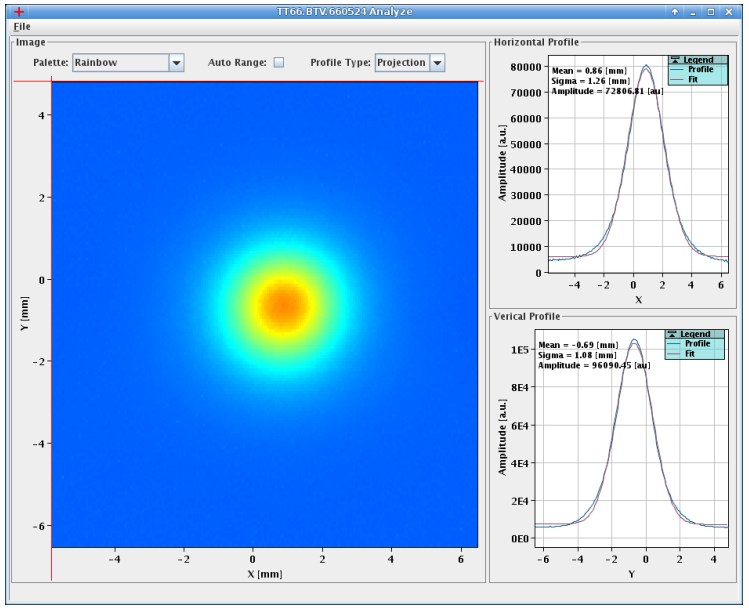


New BTV

Beam Diagnostic Instrumentation







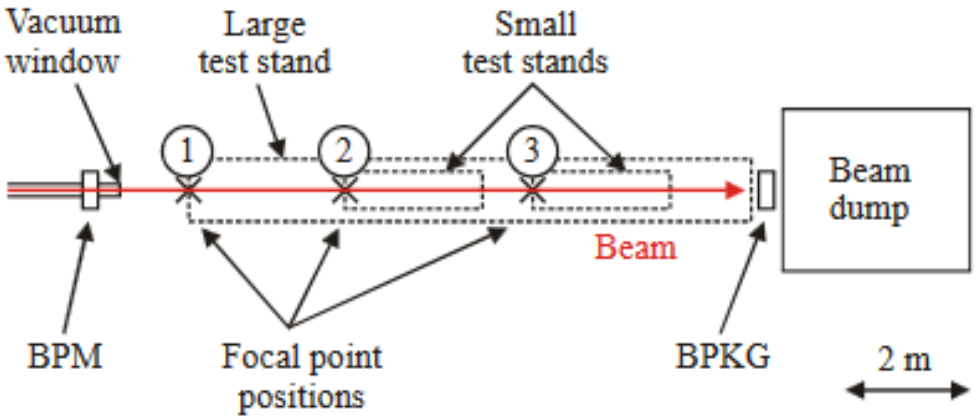
Beam diagnostic & monitoring equipment

Optical path relating to beam profile capture in adjacent tunnel

Image/Data acquired from the HiRadMat beam diagnostic and monitoring system

Variable Beam Optics

- Optics updated.

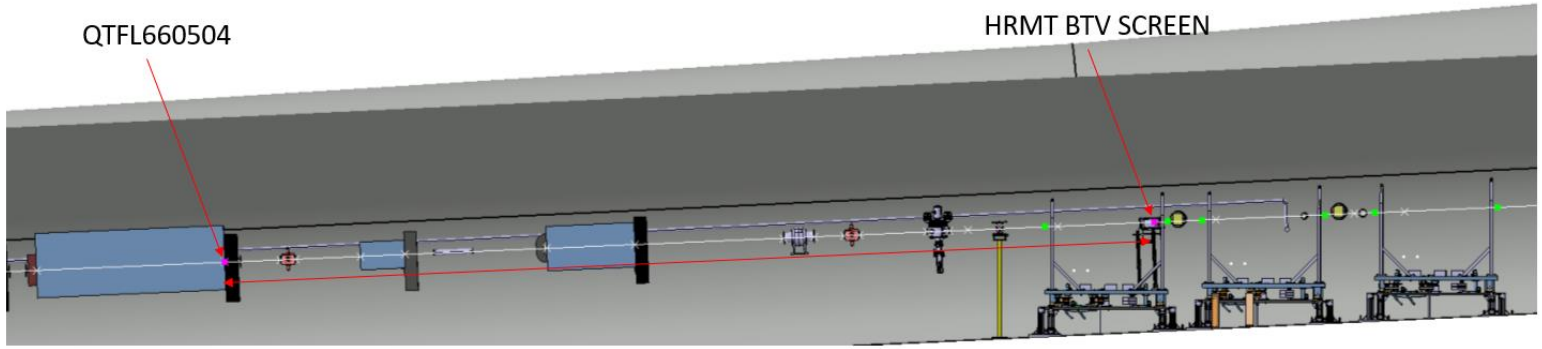


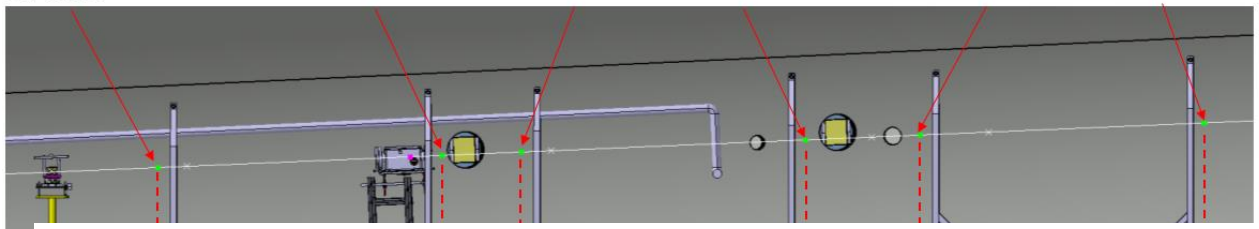
C. Hessler et al. "The Final Beam Line Design for the HiRadMat Test Facility", IPAC'10, Kyoto (2010)

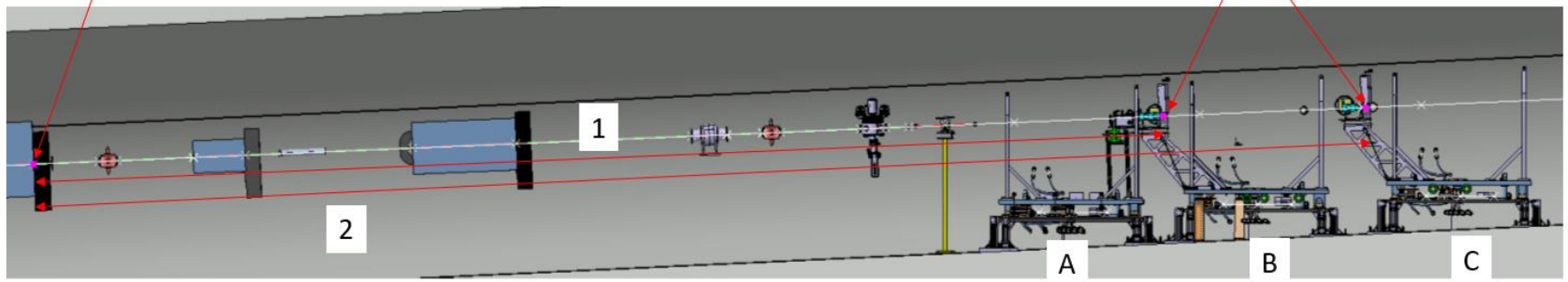
- Optics currently calculated for beam radii of $\sigma = 0.25 – 4$ mm.
- HRM beam optics standards 0.5 – 2 mm Table B and Table C (FP2 and FP3 respectively).
- Table B (FP2) can achieve optics to as low as $\sigma = 0.25$ mm.

HRM Optics

Courtesy of V. Clerc (EN/EA)

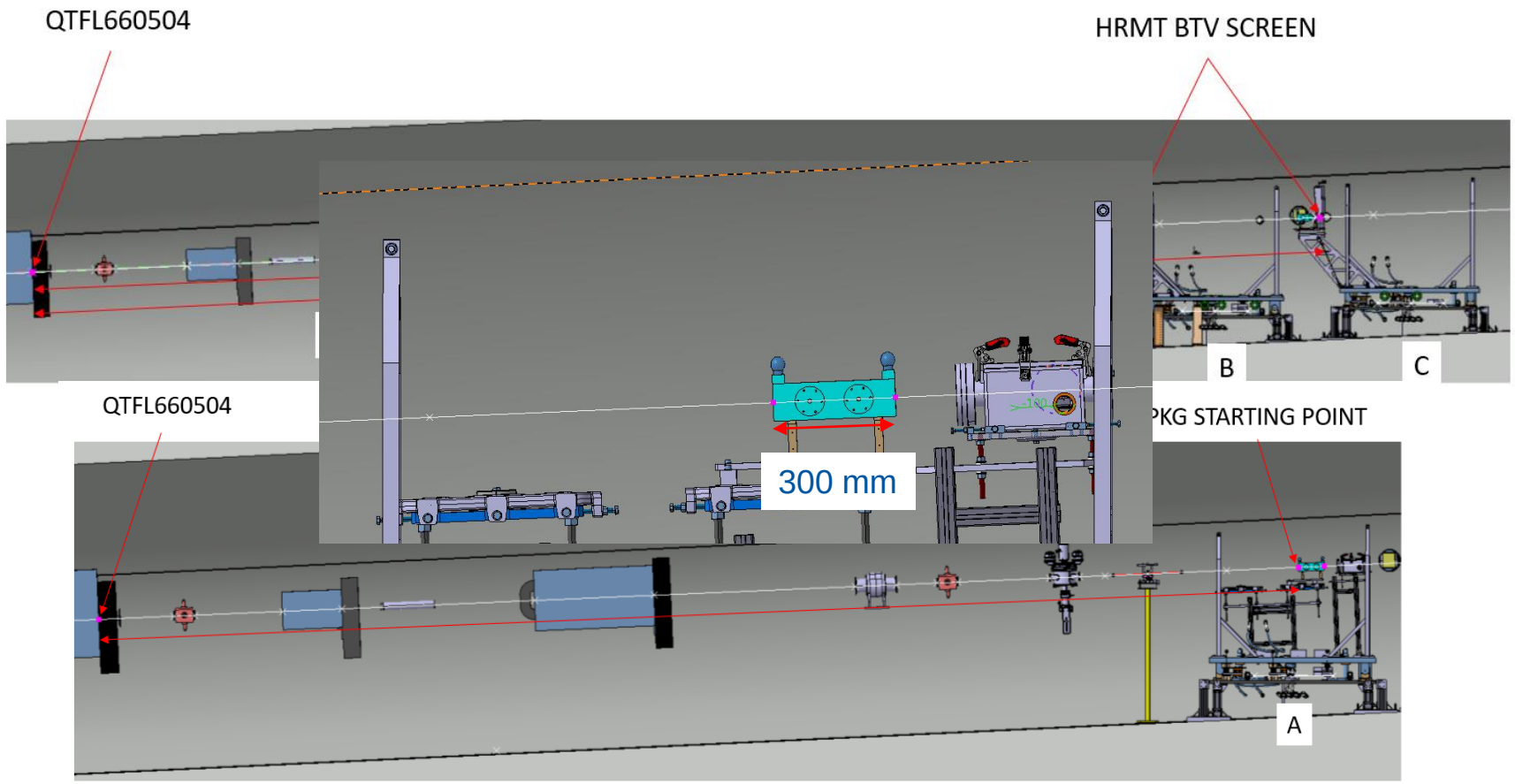






HRM Optics

Courtesy of V. Clerc (EN/EA)



HRM Optics Distance Info

Courtesy of V. Clerc (EN/EA)

- 1 - Exit point of QTLF660504 to start point of table A with respect to an experimental table being installed => 13028.081 mm
- 2 - Exit point of QTLF660504 to end point of table A with respect to an experimental table being installed => 14979.85 mm
- 3 - Exit point of QTLF660504 to start point of table B with respect to an experimental table being installed => 15523.081 mm
- 4 - Exit point of QTLF660504 to end point of table B with respect to an experimental table being installed => 17474.85 mm
- 5 - Exit point of QTLF660504 to start point of table C with respect to an experimental table being installed => 18259.082 mm
- 6 - Exit point of QTLF660504 to end point of table C with respect to an experimental table being installed => 20210.85 mm
- 7 - Exit point of QTLF660504 to the BPKG STARTING POINT on table A => 14072.544 mm
- 8 - Exit point of QTLF660504 to the HRM-BTV screen on table A => 14762 mm
- 9 - Exit point of QTLF660504 to the HRM-BTV screen on table B => 15238.427 mm
- 10 - Exit point of QTLF660504 to the HRM-BTV screen on table C => 17974.402 mm

Ions

HiRadMat Ion Beam (data from 2015)	
Beam Energy	173.5 GeV/nucleon (36.1 TeV per ion)
Pulse Energy (max)	21 kJ
Bunch Intensity	3.0×10^{7} to 7.0×10^{7} ions
Number of Bunches	52
Minimum Pulse Intensity	3.0×10^{7} ions (1b at 3.0×10^{7} ions)
Maximum Pulse Intensity	3.64×10^{9} ions (52b at 7.0×10^{7} ions)
Pulse Length (max)	5.2 µs
Beam size at target	Variable around 1 mm^2

Courtesy of A. Will

HiRadMat
High-Radiation to Materials

Superconducting wires/ tapes

- Nb-Ti strand (LHC)
- Nb_3Sn strand (HL-LHC)
- HTS tapes (future acc. magnets..?)

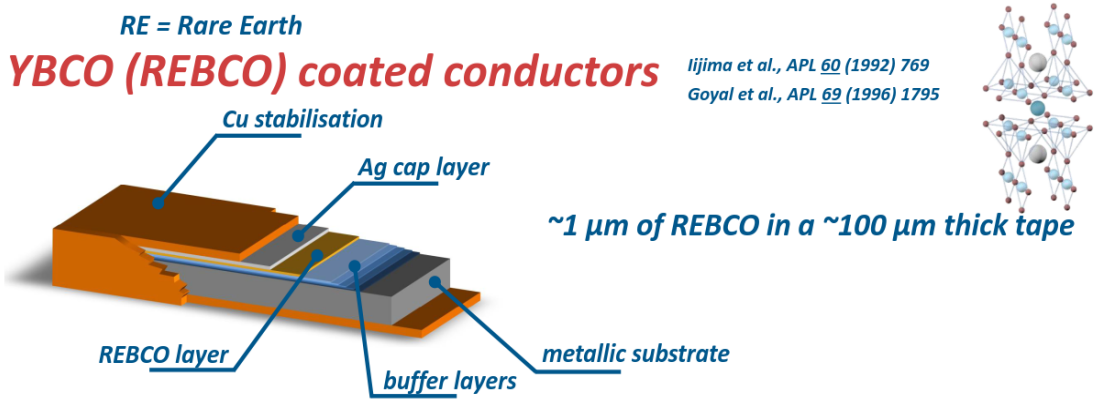


Image from C. Senatore, CAS Zuerich 2018

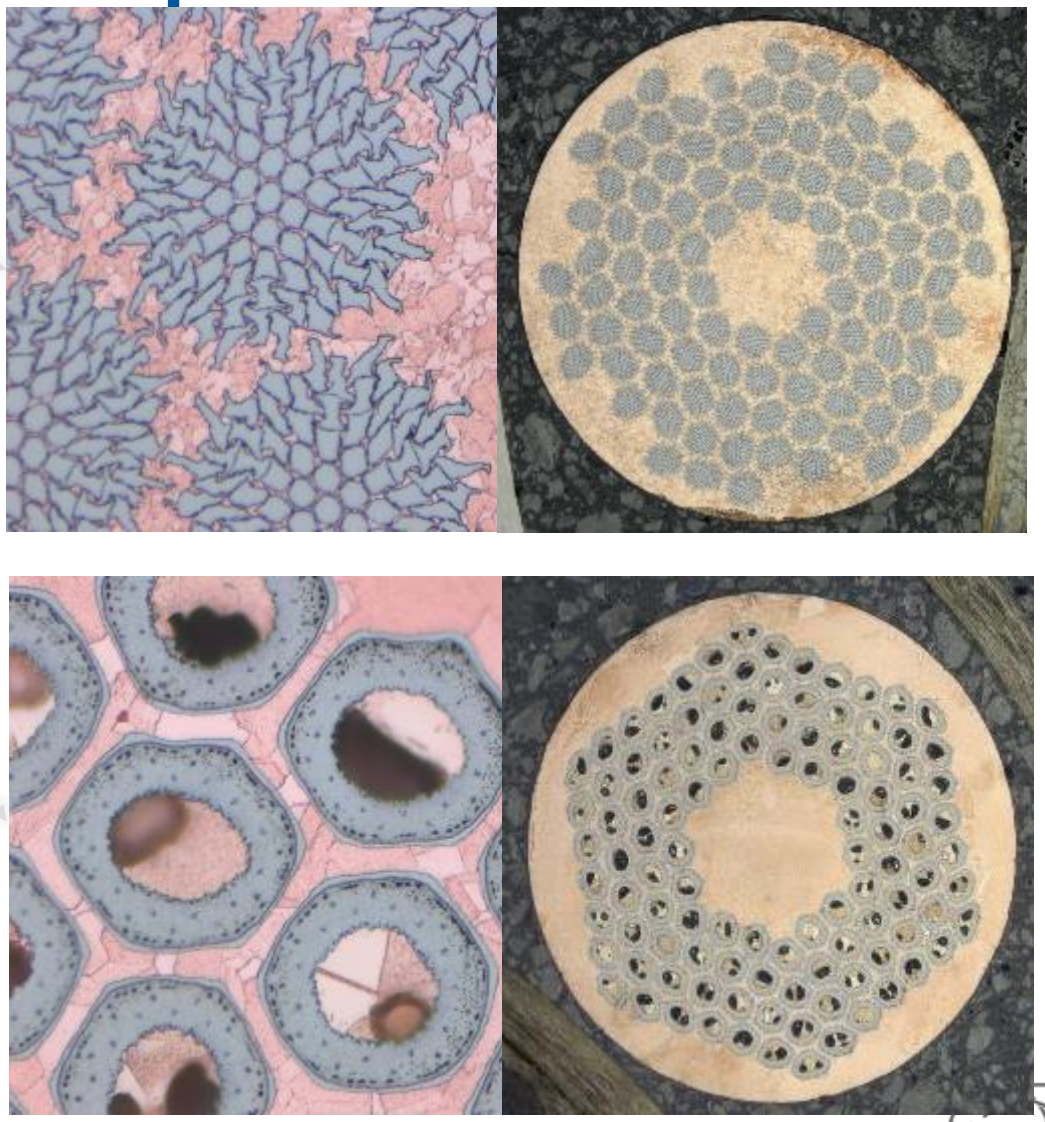


Image courtesy M. Meyer, CERN

Courtesy of A. Will

Sample Holders

- Nb-Ti: 20 short strand samples
  - 50 mm, Ø 0.825 mm
- Nb_3Sn: 30 short strand samples
  - 50 mm, Ø 0.85 mm
- YBCO tapes: 40 samples
  - 60 mm x 4 mm x 0.2 mm