HiRadMat Facility Overview, Technical Details & Future Plans

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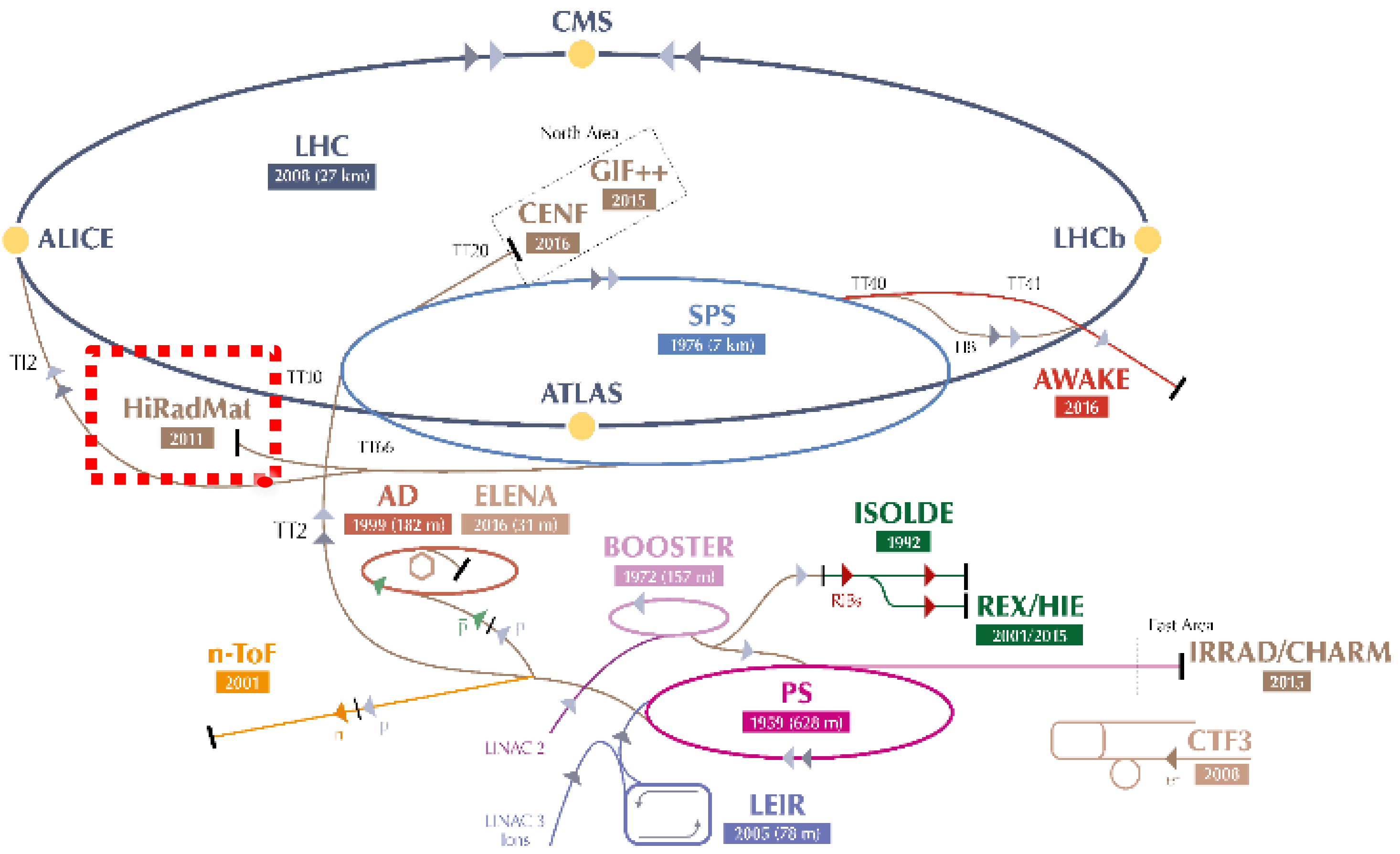
CERN, EN/EA

Brief history

- 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[3] and has continued to deliver pulsed, high intensity, LHC-type beam to over 40 experiments.



[1] http://lhc-collimation-project.web.cern.ch/lhc-collimation-project/HiRadMat.htm

[2] R. Assmann et al. 2009 "User Requirements for a Test Facility with High Power LHC Type Beam", EDMS No: 1130296

[3] I. Efthymiopoulos et al. 2011 "HiRadMat: A new irradiation facility for material testing at CERN", Proc. 2nd Int. Particle Accelerator Conf. (IPAC'11) paper TUPS058 1665-67.

Beam specifications

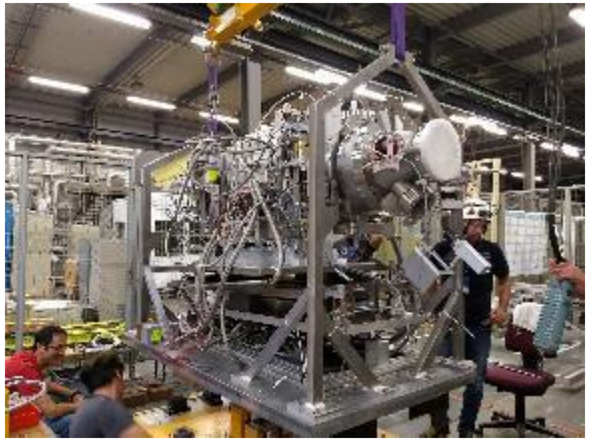
- Facility for R&D using pulsed high energy, high intensity, proton beams. Ion beams are also possible.
- Facility has, so far, completed experiments on **materials testing, prototype & novel designs validation, beam monitoring devices, investigations at cryogenic temperatures and pre-irradiation materials analysis**.

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)

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.

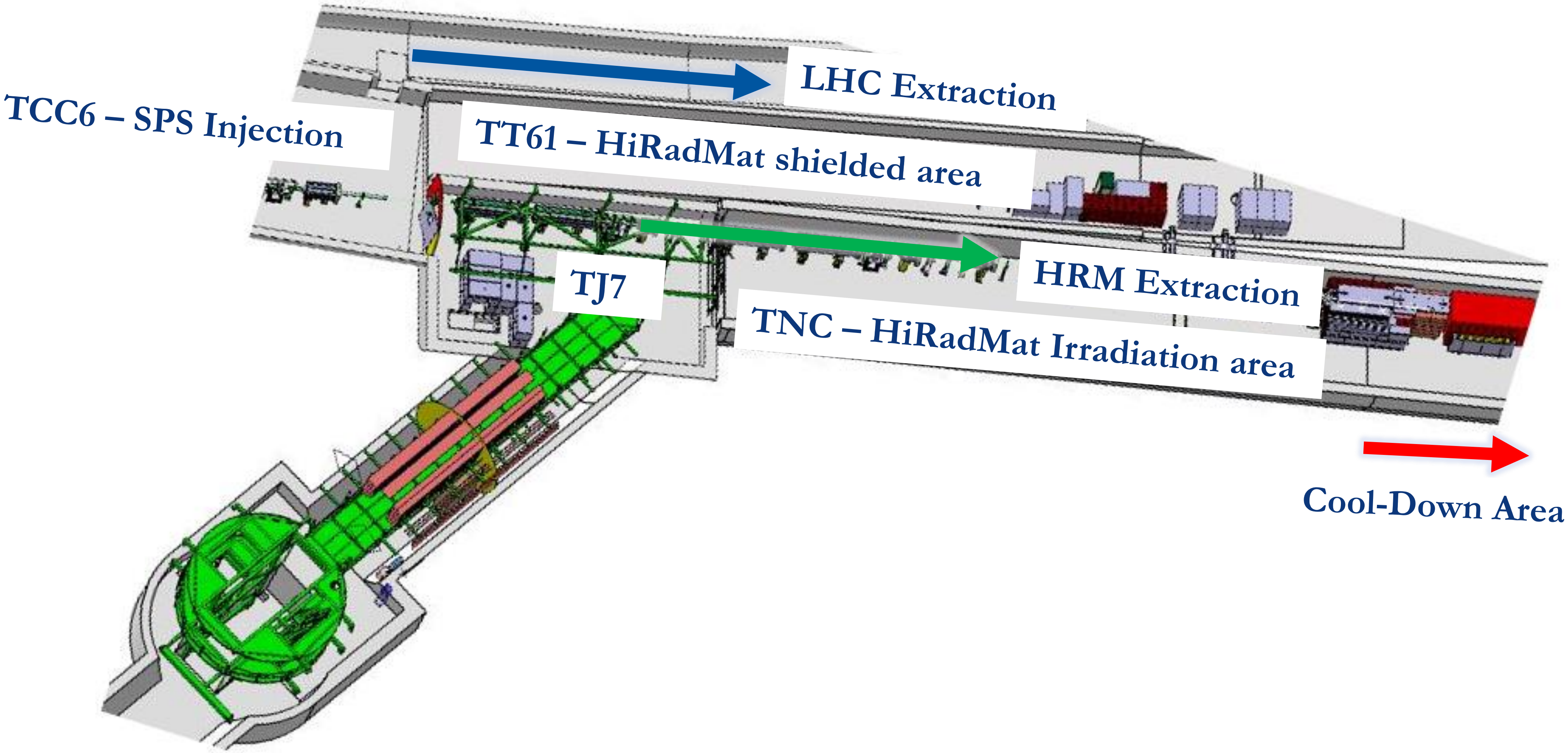


HRMT45 Transport

HiRadMat Control Room

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

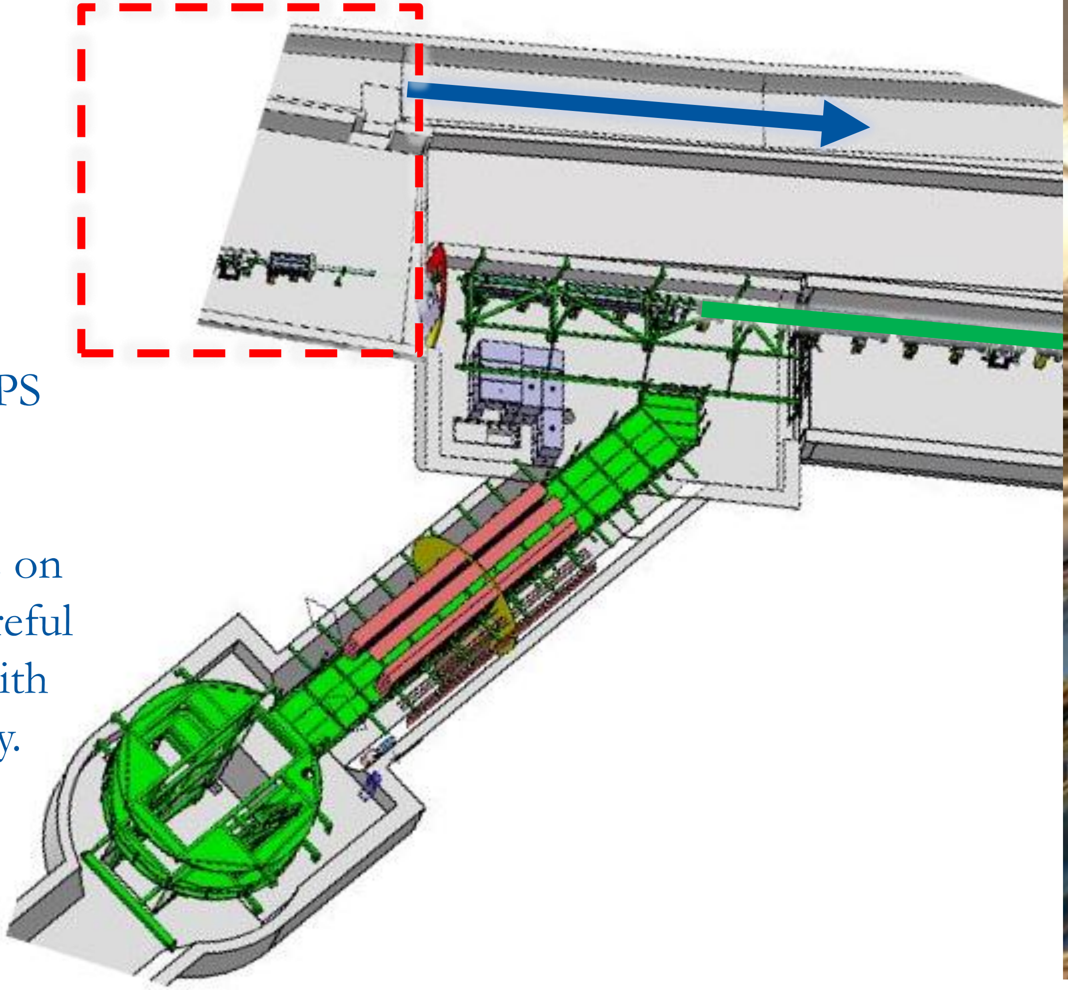
HiRadMat tunnel & surroundings

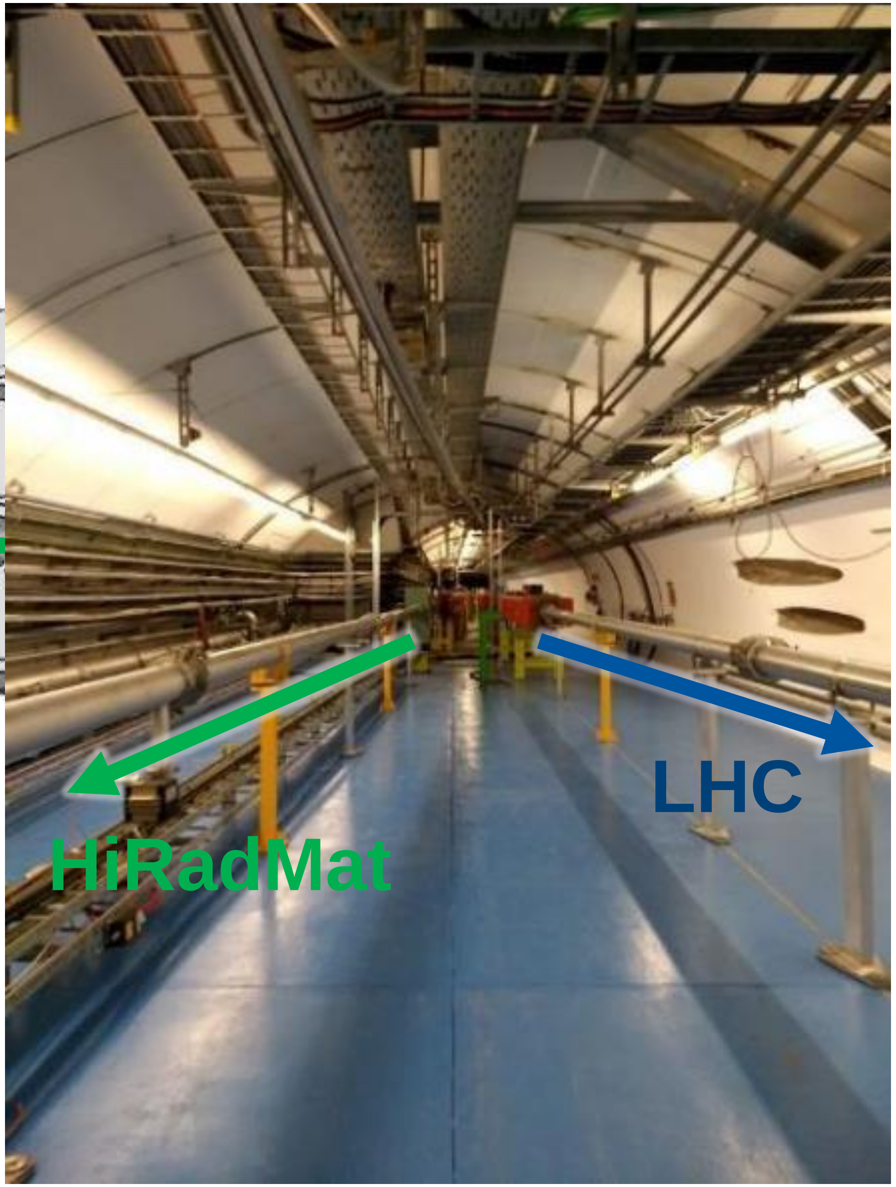


SPS extraction to HiRadMat

HiRadMat is adjacent to an SPS extraction point to LHC.

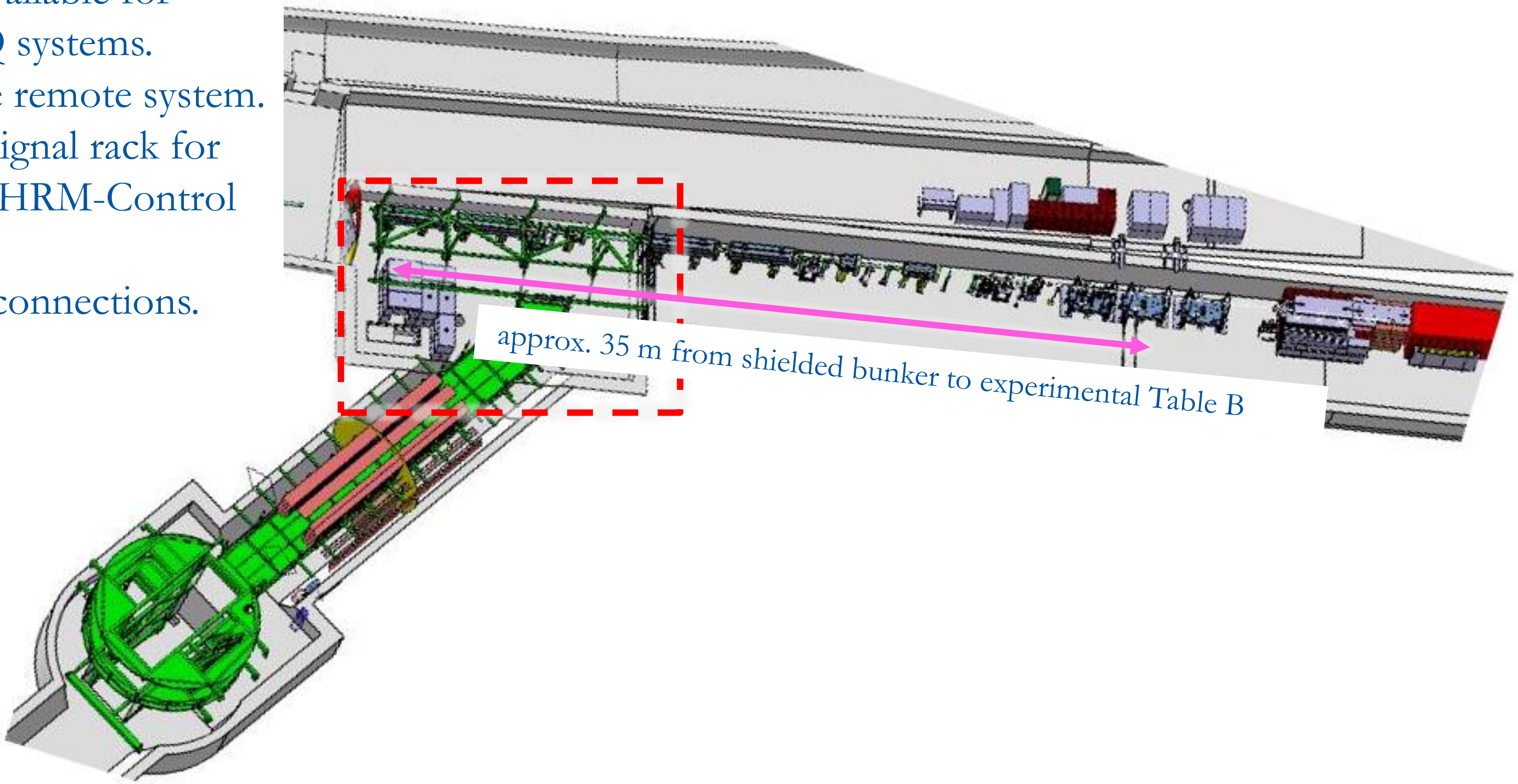
Access to HiRadMat depends on the LHC filling: therefore careful planning and co-ordination with the LHC schedule is necessary.





Preparation area and remote bunker (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.



Experimental area (TNC)

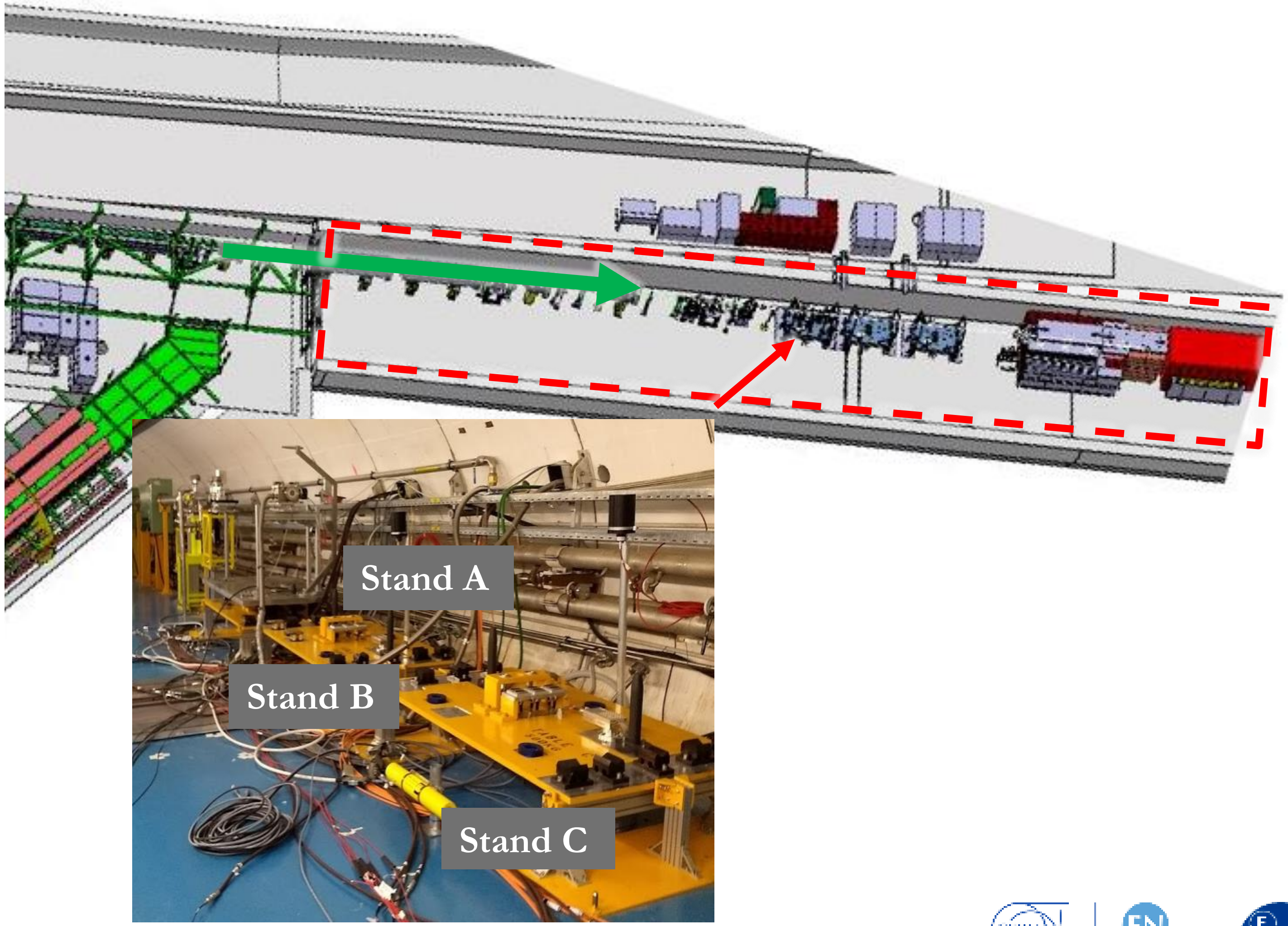
3 Experimental Stands in HiRadMat Experimental Area

- **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)

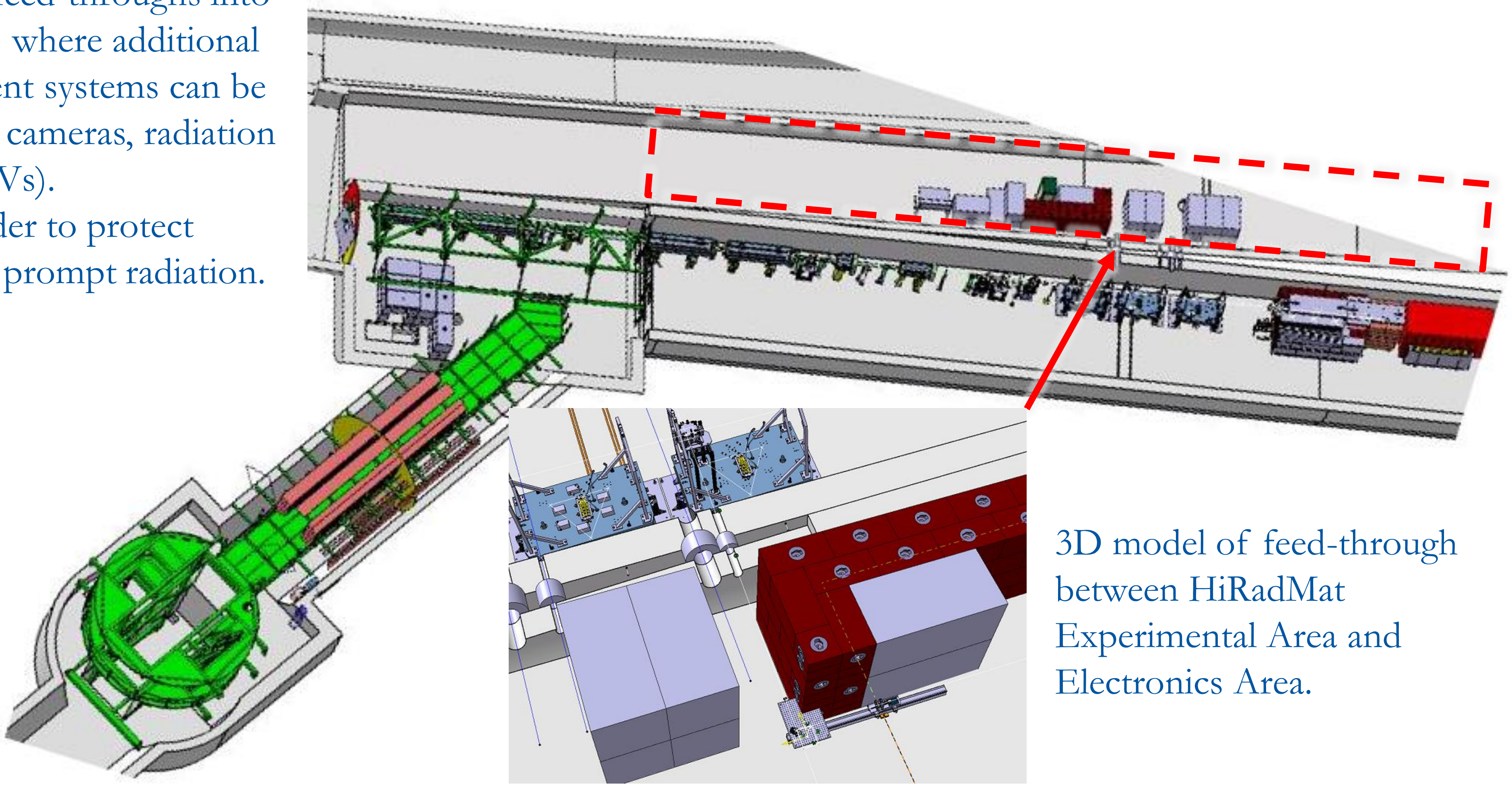
- Power provided (4kV / 2.5 kA)

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



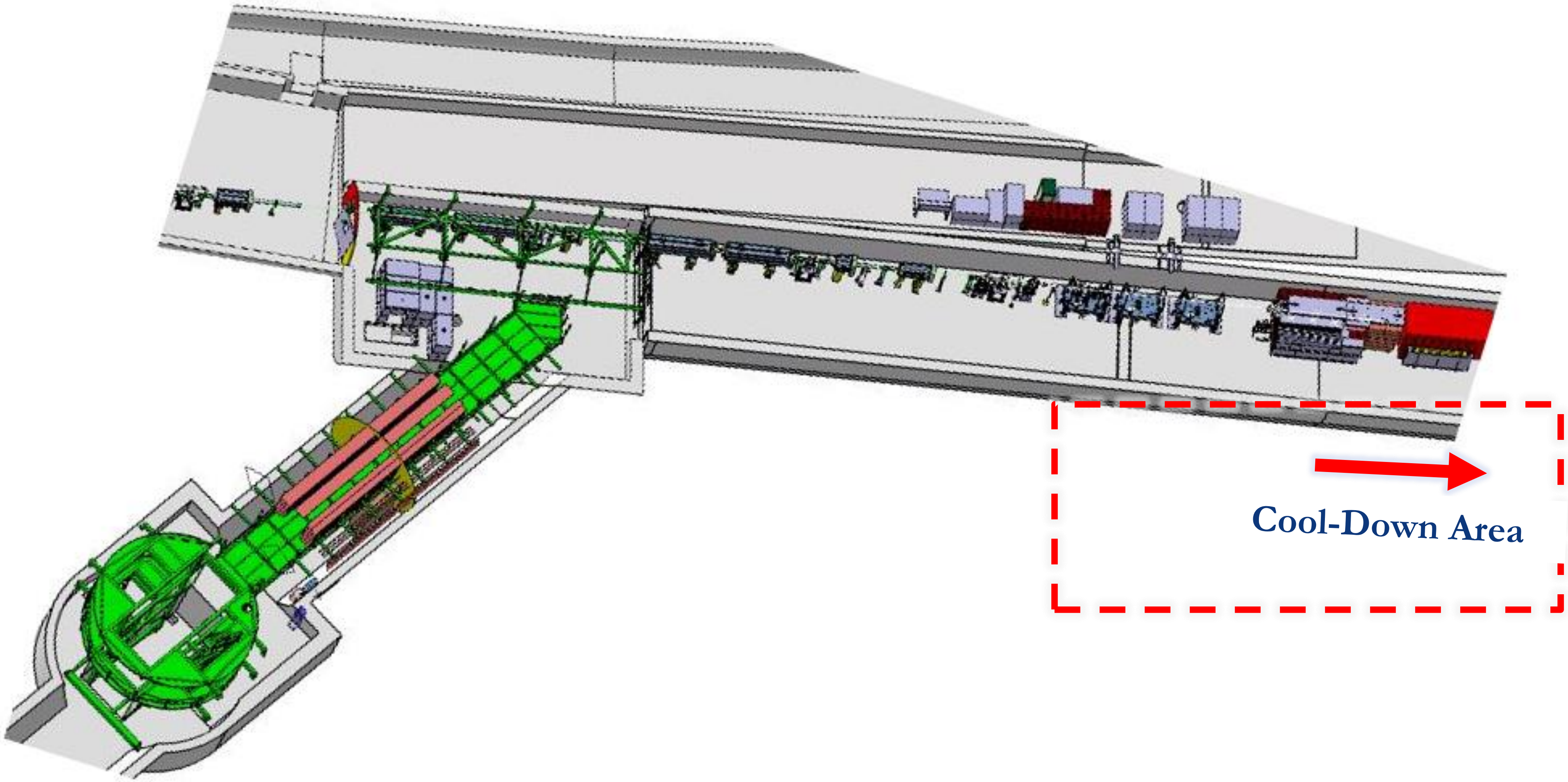
Shielded area (TT61)

HiRadMat has dedicated feed-throughs into an adjacent tunnel (TT61) where additional electronic and measurement systems can be added (e.g. equipment for cameras, radiation sensitive cameras and LDVs).
Shielding optimised in order to protect sensitive equipment from prompt radiation.



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

Experiment cool-down area



Post-Irradiation cool-down time

- After irradiation, experiments are moved to the HiRadMat cool-down area (usually 1-2 weeks after beam) to allow for an activation cool-down of the irradiated samples.
- After a sufficient cool-down period, and in coordination with CERNs Radiation Protection group and the experimental team, the experiments is moved to an appropriate lab for post irradiation examination.

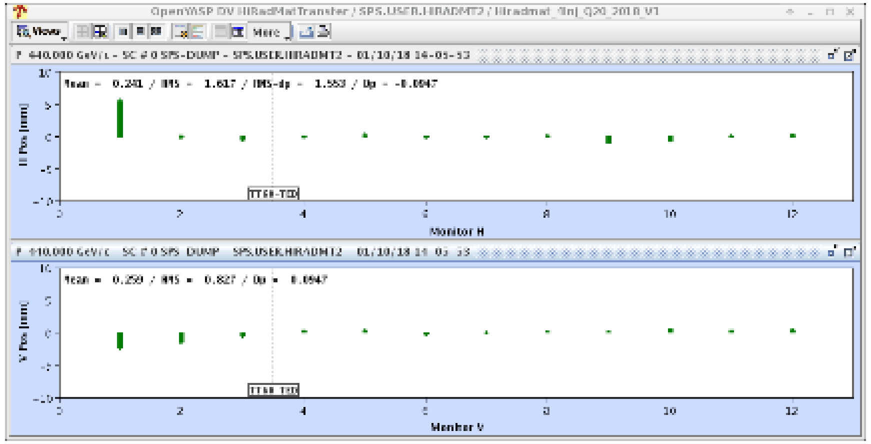
HiRadMat Beam Dump

HiRadMat Cool-Down Area

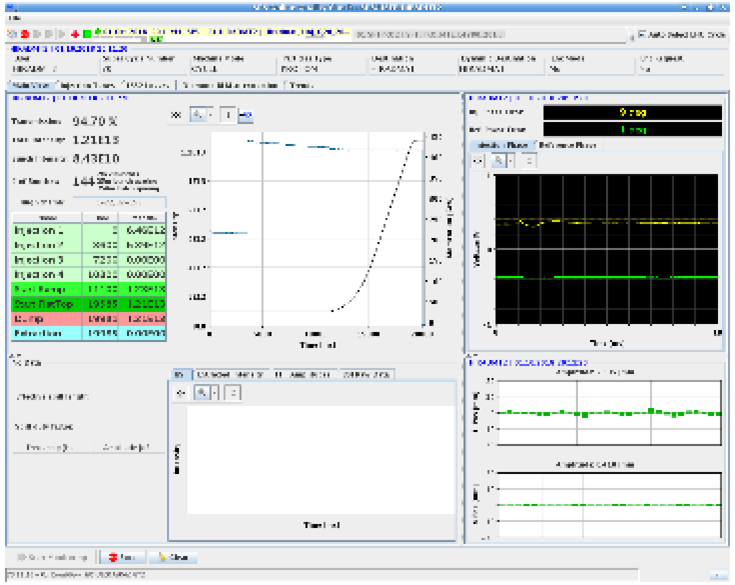
Support for users

SPS Operation

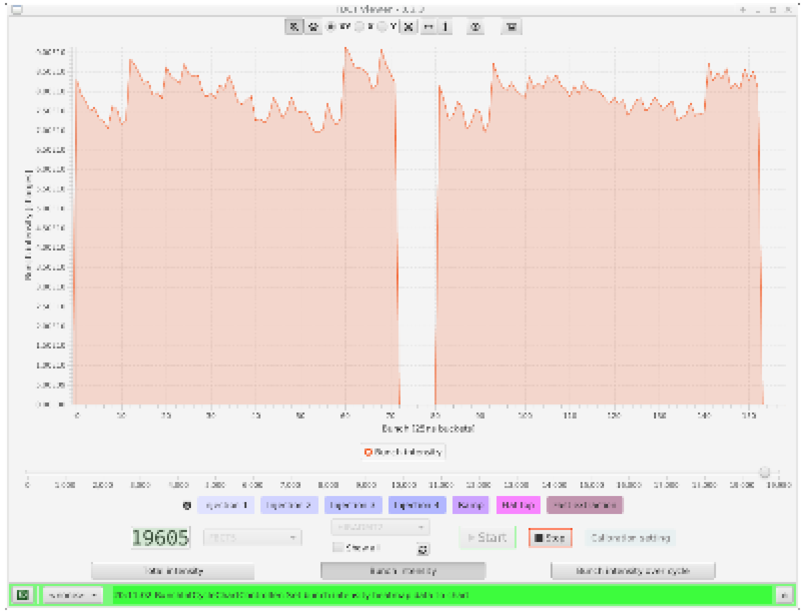
Colleagues from SPS Operations provides high quality proton (or ion) beam to the HiRadMat experiment. Standard procedures relating to beam trajectory, beam emittance, beam spot size, proton bunch sets, etc. are all completed by the experts during the dedicated HiRadMat beam time.



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



Example of the extracted intensity for delivered 144 protons.

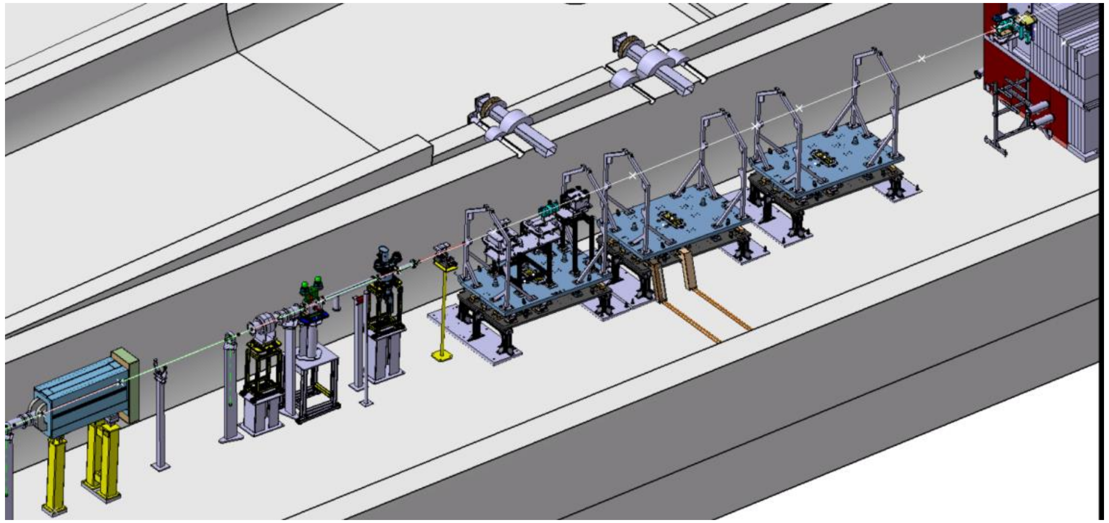


Example of quality of bunch-bunch intensity for 144 bunches (2×72 bunches)

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

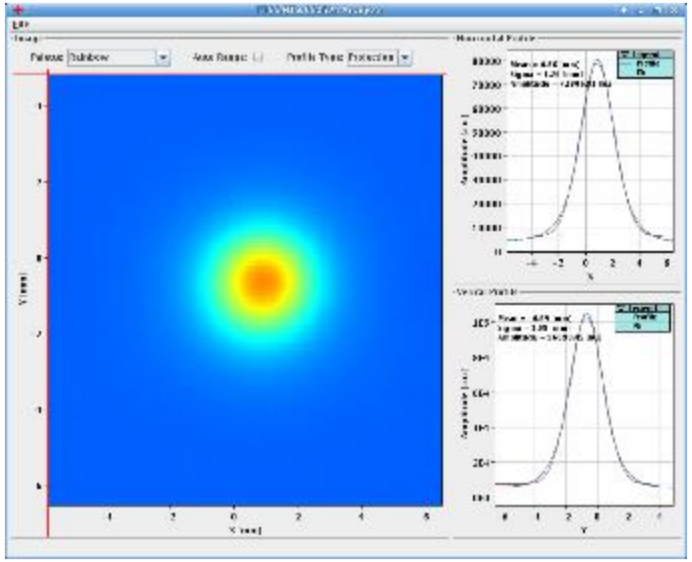
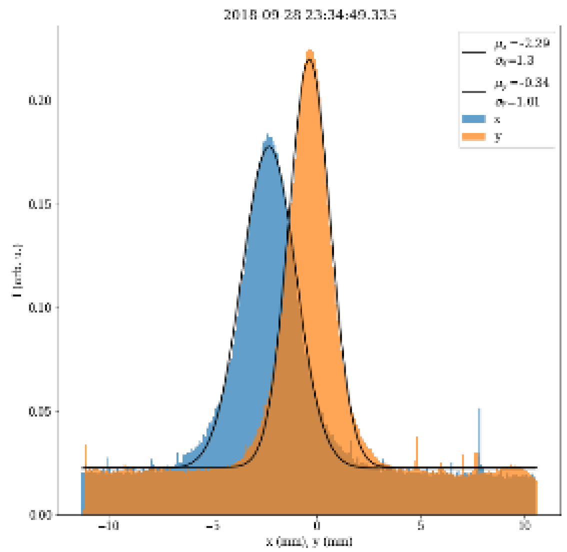


Image obtained from HRM-BTV



Experiment Timeline (to beam time)

T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11

Experiment Timeline

Discussion with HiRadMat Management

Contact the HiRadMat management team for all enquires (feasibility, beam parameter, timeframes, etc.)
hiradmat.sps@cern.ch

T1

Experiment Timeline

T1

T2

Proposal submission to HiRadMat Management

A beam request is submitted


HiRadMat - Experiment Proposal
EDMS No: 1213282
Version 2.0

HiRadMat High-Radiation to Materials

HiRadMat Beam Time Request Form

Designation		
Experiment Name		#completed by HRM
Acronym		#completed by HRM

Date

General	
Responsible/primary contact	
Name	
Home institute	
E-mail	
Phone	
Participating institutes	
Number of team members	
Interested in Transnational Access	

Person completing this beam request

Scientific description	
Executive summary	
Scientific motivation	
Measurement methods	
Additional comments	

HiRadMat - Experiment Proposal
EDMS No: 1213282 — V2.0

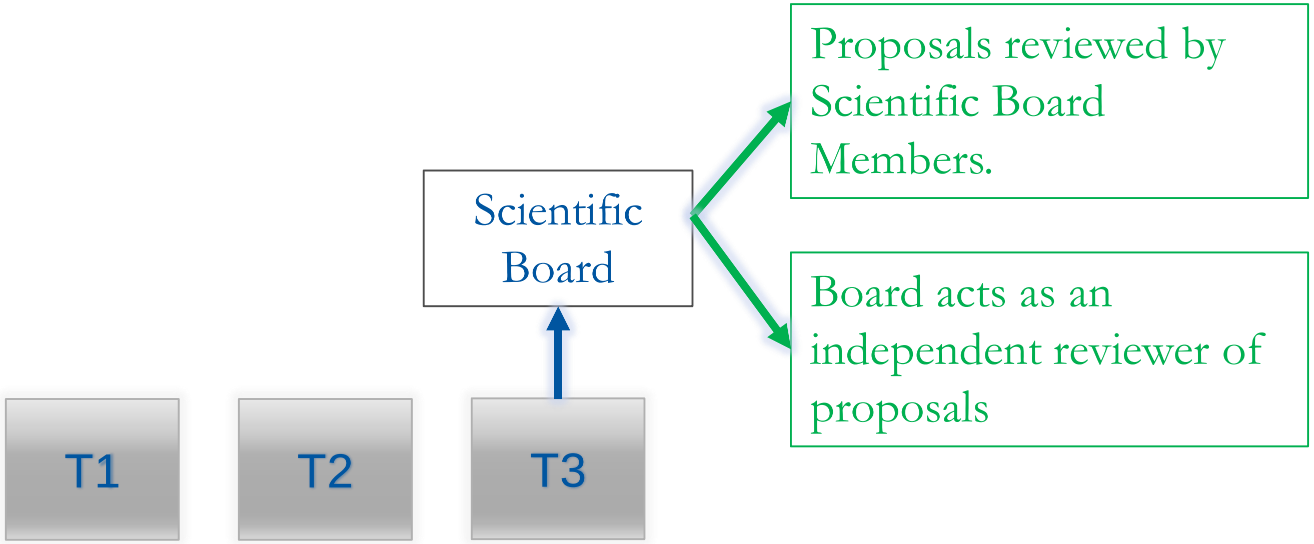
Experimental Setup	
Equipment to be installed	
Dimensions	
Weight (total)	
Target	
Support	
Measurement/observation tools	
Online monitoring	
Post-irradiation analysis and decommissioning	
Additional comments	

Beam parameters		
Particle type	Protons	Ions (type)
Pulse intensity (range)		
No. bunches		
Intensity/bunch		

Page 2 of 4

Template available (**EDMS 1213282**)

Experiment Timeline



Mandate:

- The scientific case of each experiment and the importance/contribution towards the advancement of the state-of-the-art knowledge on materials, components and systems associated with particle accelerators.
- The feasibility of the proposed experiment based on HiRadMat beam parameters and availability.
- The completeness of the proposed experimental process from concept to in-situ experimental configuration.
- The thoroughness of the pre-experiment assessment, parameter envelope and the clarity of the experimental goals.
- The clarity and the detailed description of the post-irradiation analysis and the identification of the key scientific and technical questions/answers that are to be deduced following from the experiment.
- Publication of experimental results and their utilisation by the accelerator community.

Experiment Timeline

<u>More details provided in presentations today:</u>

- Beam instrumentation developments at HiRadMat (T. Lefevre) (TODAY at 11:20 – 11:50)
- Lessons learned about mechanical instrumentation in HiRadMat facility and possible future developments (M. Guinchard) (TODAY at 11:50 – 12:20)

Support teams include:
BE/BI (Beam Instrumentation),
EN/HE (Handling Engineering),
EN/EA (Experimental Areas)
EN/MME (Mechanicals and Materials Engineering),
EN/SMM (Survey, Mechatronics and Measurements).

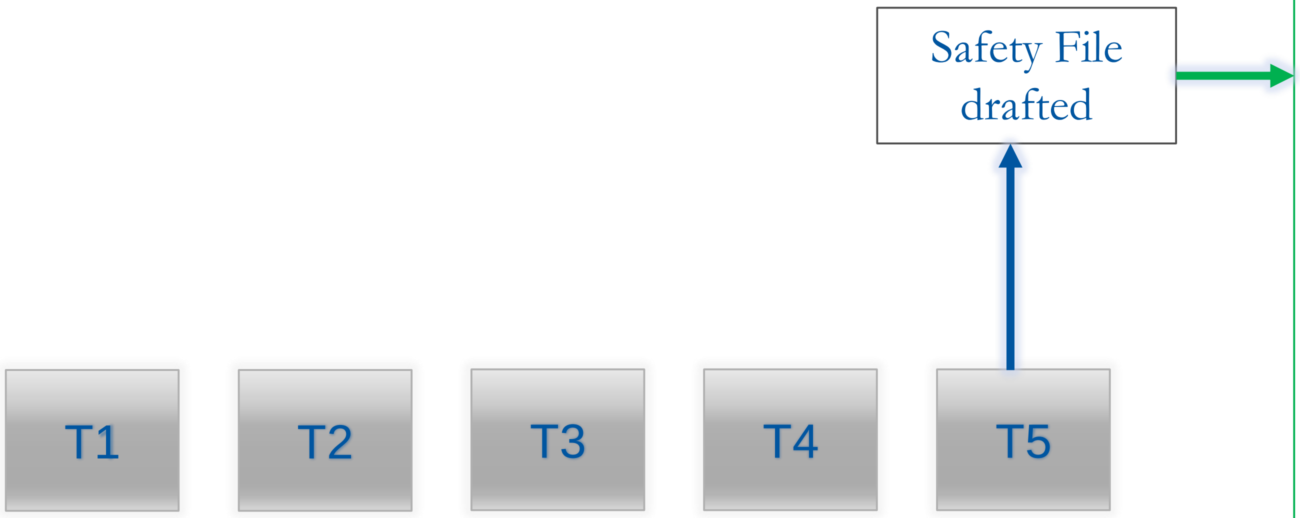
T1 T2 T3 T4

Collaboration with design, metrology, survey & support teams

Design includes CAD models and cross-checks of compliance with HiRadMat standards (e.g. size, weight).

Metrology & Survey to ensure alignment of beam to experiment.

Experiment Timeline



File enables an assessment to be made of all safety aspects and includes the following:

- Experiment aims & goals
- Technical description (design, support systems, diagnostics, etc.)
- Preparation (timeframes, expectations)
- Installation details (e.g. extras equipment, monitoring devices, connections etc.)
- Operational aspects (beam alignment protocol, beam parameters)
- Post irradiation phase (plans after experiment)
- Removal timeframes and disposal (if relevant)
- Hazard inventory (including radioactive isotope information, radiation risks, etc.)
- Risks & mitigations.

Template available **EDMS 1224448**

Experiment Timeline

Mandate:

Review technical aspects of proposal including:

- Design & production (integration models, timelines for production/builds etc.).
- Survey & alignment.
- Installation (including details on connections, data acquisition systems etc.).
- Radiological aspects (hazards/risks/mitigations).
- Full support required (beam monitoring, mechanical integration, software).
- Operation & beam time planning.
- Beam Parameters.
- Post-beam information (cool-down time estimates (FLUKA, WDP), transferral, PIE).

T1 | T2 | T3 | T4 | T5 | T6

↓

Technical Board → Made up of experts from HiRadMat, Radiation Protection, Metrology & Survey, Support Teams, Safety, Transport, Operations.

Experiment Timeline

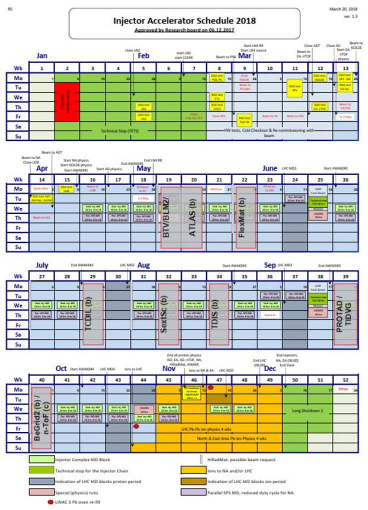
T1 | T2 | T3 | T4 | T5 | T6 | T7

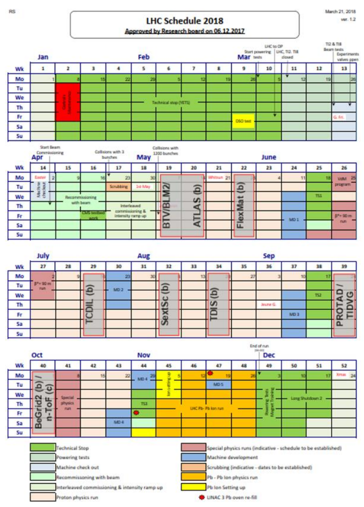
Safety File corrected & approved

Safety file is reviewed after the Technical Board, and comments reflected in new document(s).

The safety file **MUST** be approved prior to experiment installation in HiRadMat and subsequently beam time.

Experiment Timeline





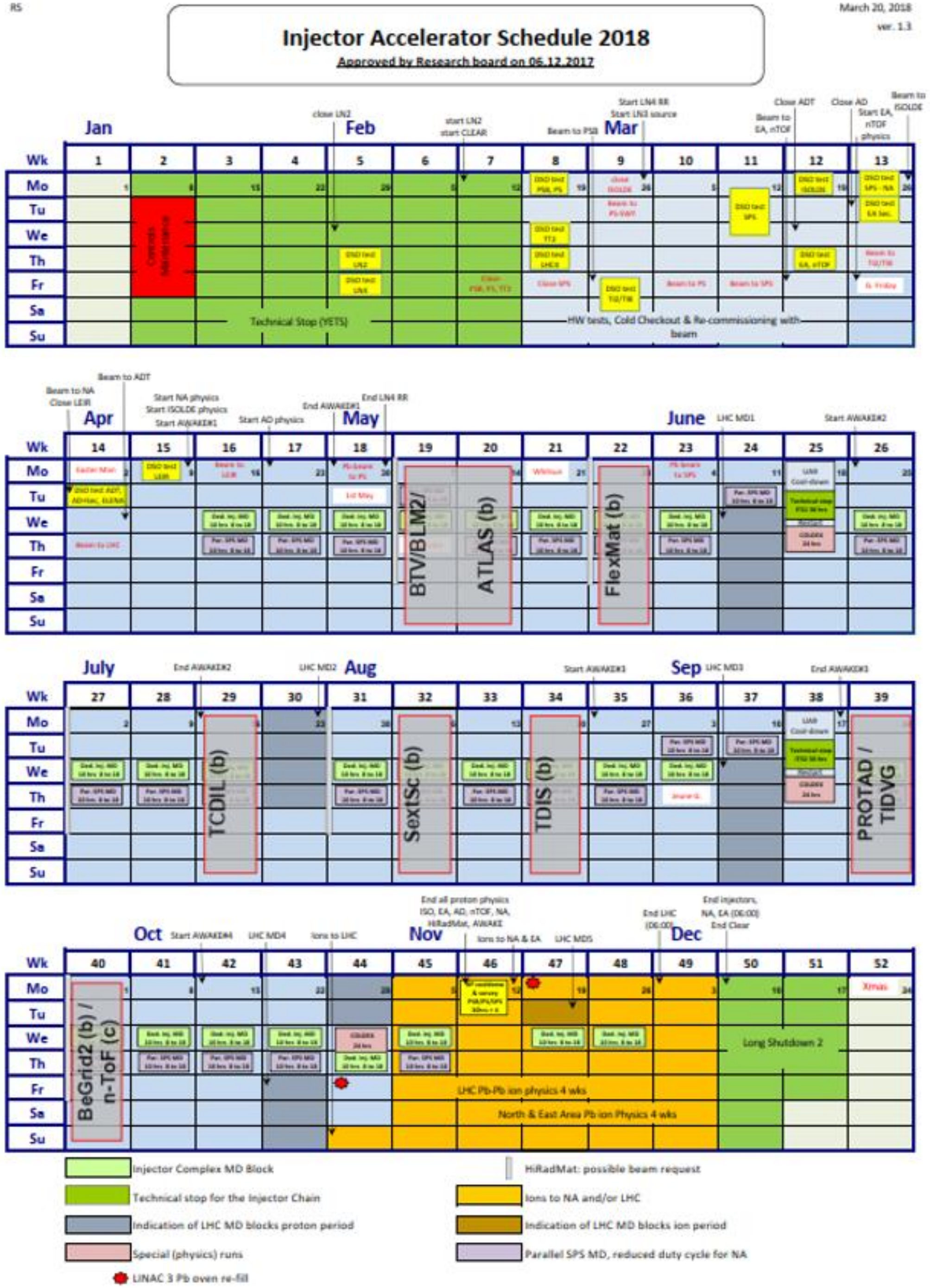
T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8

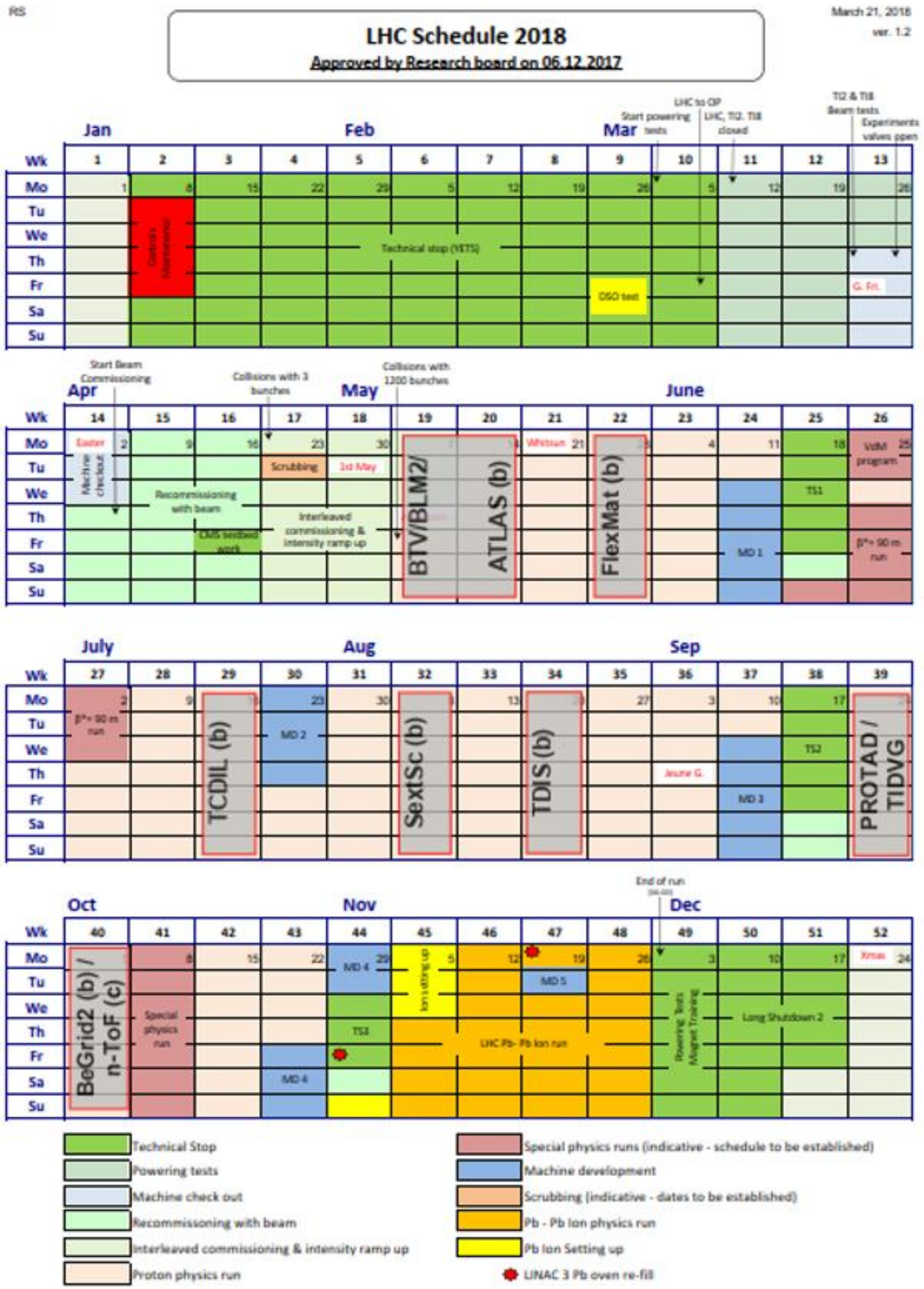
Beam Time scheduled

HiRadMat can accommodate up to 10 experiments/year (in general). Max. of 2 experiments can be performed per month but flexibility is required from all involved.

Beam time depends on:

1. LHC schedule
2. Machine schedules
3. Experiment schedules
4. User schedules


RS
March 20, 2018
ver. 1.3
Injector Accelerator Schedule 2018
Approved by Research board on 06.12.2017
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Wk
Mo
Tu
We
Th
Fr
Sa
Su
Technical Stop (YETS)
HW tests, Cold Checkout & Re-commissioning with beam
BTV/BLM2/
ATLAS (b)
FlexMat (b)
TCDIL (b)
SextSc (b)
TDIS (b)
PROTAD / TIDVG
BeGrid2 (b) / n-ToF (c)
LHC Pb-Pb ion physics 4 wks
North & East Area Pb ion Physics 4 wks
Long Shutdown 2
Xmas
Injector Complex MD Block
Technical stop for the Injector Chain
Indication of LHC MD blocks proton period
Special (physics) runs
LINAC 3 Pb oven re-fill
HiRadMat: possible beam request
Ions to NA and/or LHC
Indication of LHC MD blocks ion period
Parallel SPS MD, reduced duty cycle for NA


RS
March 21, 2018
ver. 1.2
LHC Schedule 2018
Approved by Research board on 06.12.2017
Jan
Feb
Mar
Apr
May
June
July
Aug
Sep
Oct
Nov
Dec
Wk
Mo
Tu
We
Th
Fr
Sa
Su
Technical stop (YETS)
DSO test
Recommissioning with beam
Scrubbing
Interleaved commissioning & intensity ramp up
BTV/BLM2/
ATLAS (b)
FlexMat (b)
MD 1
TS1
MD 2
TCDIL (b)
SextSc (b)
TDIS (b)
MD 3
TS2
PROTAD / TIDVG
BeGrid2 (b) / n-ToF (c)
Special physics run
MD 4
TS3
MD 5
LHC Pb- Pb ion run
Long Shutdown 2
Technical Stop
Powering tests
Machine check out
Recommissioning with beam
Interleaved commissioning & intensity ramp up
Proton physics run
Special physics runs (indicative - schedule to be established)
Machine development
Scrubbing (indicative - dates to be established)
Pb - Pb ion physics run
Pb Ion Setting up
LINAC 3 Pb oven re-fill

Experiment Timeline

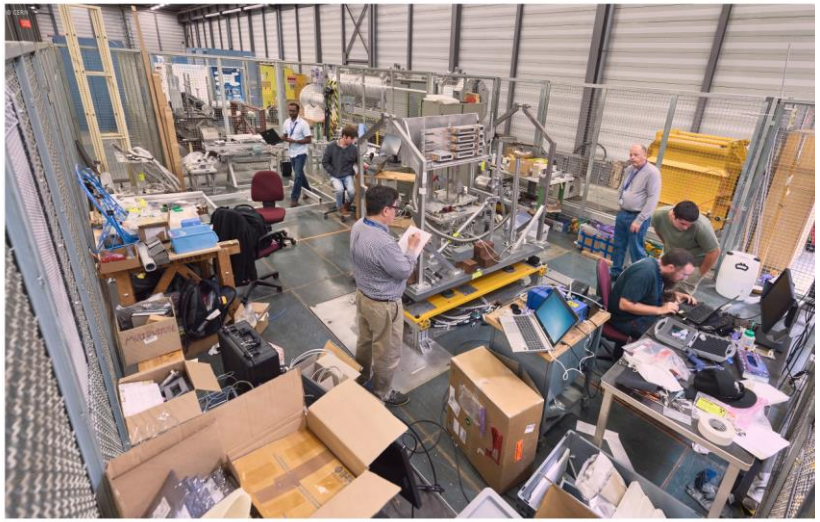
How will samples/materials be aligned?
How will experiment be aligned in HiRadMat tunnel?
How will experiments be aligned during beam time?

All information will have been detailed in the safety file to ensure efficient preparation for beam time.

Survey performed in HiRadMat surface lab.

Experiment ready for metrology & survey

T1 T2 T3 T4 T5 T6 T7 T8 T9



Photographers: Julien Marius Ordan, Maximilien Brice
HRMT43 Survey

Experiment Timeline

Photographer: Julien Marius Ordan
HRMT45 Installation



Photographer: Maximilien Brice
HRMT27 Installation

T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10

T10 → Installation

Huge team effort.
Transport, HiRadMat, Radiation Protection & support teams all involved in installation.
Procedures outlined in the safety file will be followed.
Time in HiRadMat tunnel should be as short as possible to minimise radioactive dose received by all.

Experiment Timeline

Users must be flexible during beam time - ready to take beam when available. Shifts recommended.

Beam time usually spreads across 1 week (even if only 1 day is anticipated).

Support provided from HiRadMat, BE/BI, BE/OP, EN/EA, EN/MME, EN/SMM

Beam Time

T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 | T9 | T10 | T11

Photographer: Julien Marius Ordan

CERN Control Centre (CCC)

Experiment Timeline (to beam time)

- T1 → Discussion with HiRadMat Management
- T2 → Proposal submission to HiRadMat Management
- T3 → Scientific Board
- T4 → Collaboration with design, metrology, survey & support teams
- T5 → Safety File drafted
- T6 → Technical Board
- T7 → Safety File corrected & approved
- T8 → Beam Time scheduled
- T9 → Experiment ready for metrology & survey
- T10 → Installation
- T11 → Beam Time

Experiment Timeline (post beam time)

T12 T13 T14 T15 T16 T17

Experiment Timeline

Post-beam cool down time

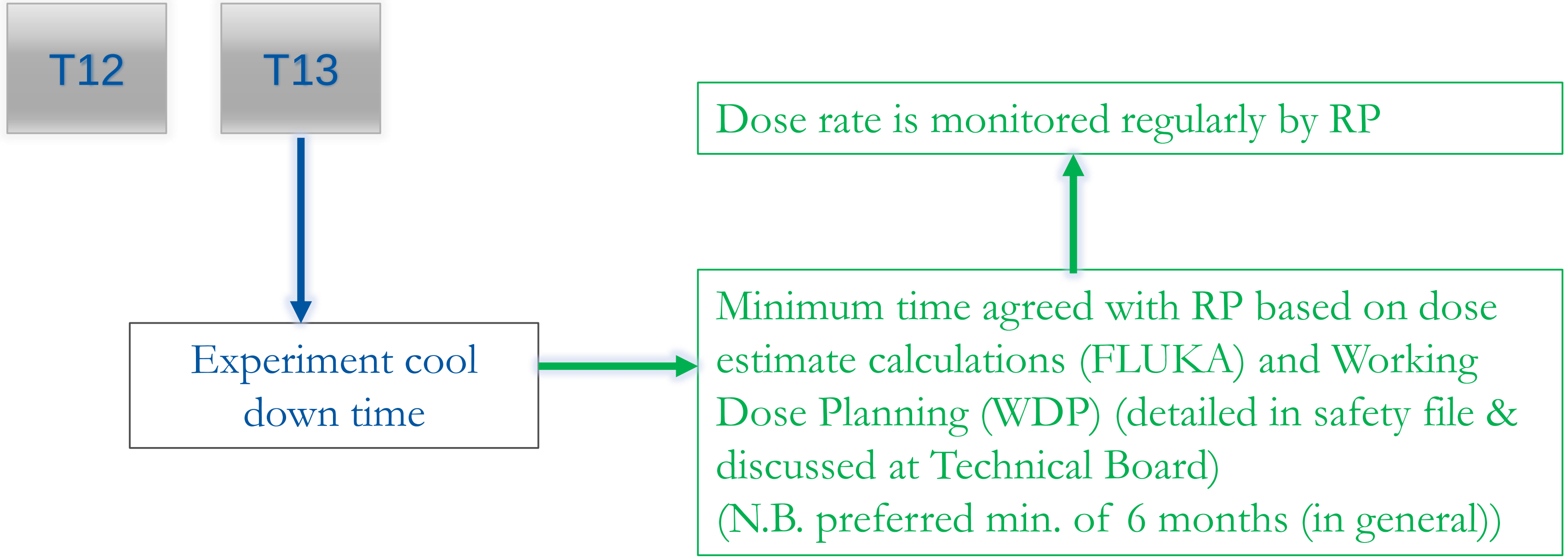
T12

After beam time, an experiment must wait approx. 1-4 weeks before being moved to the cool down area.

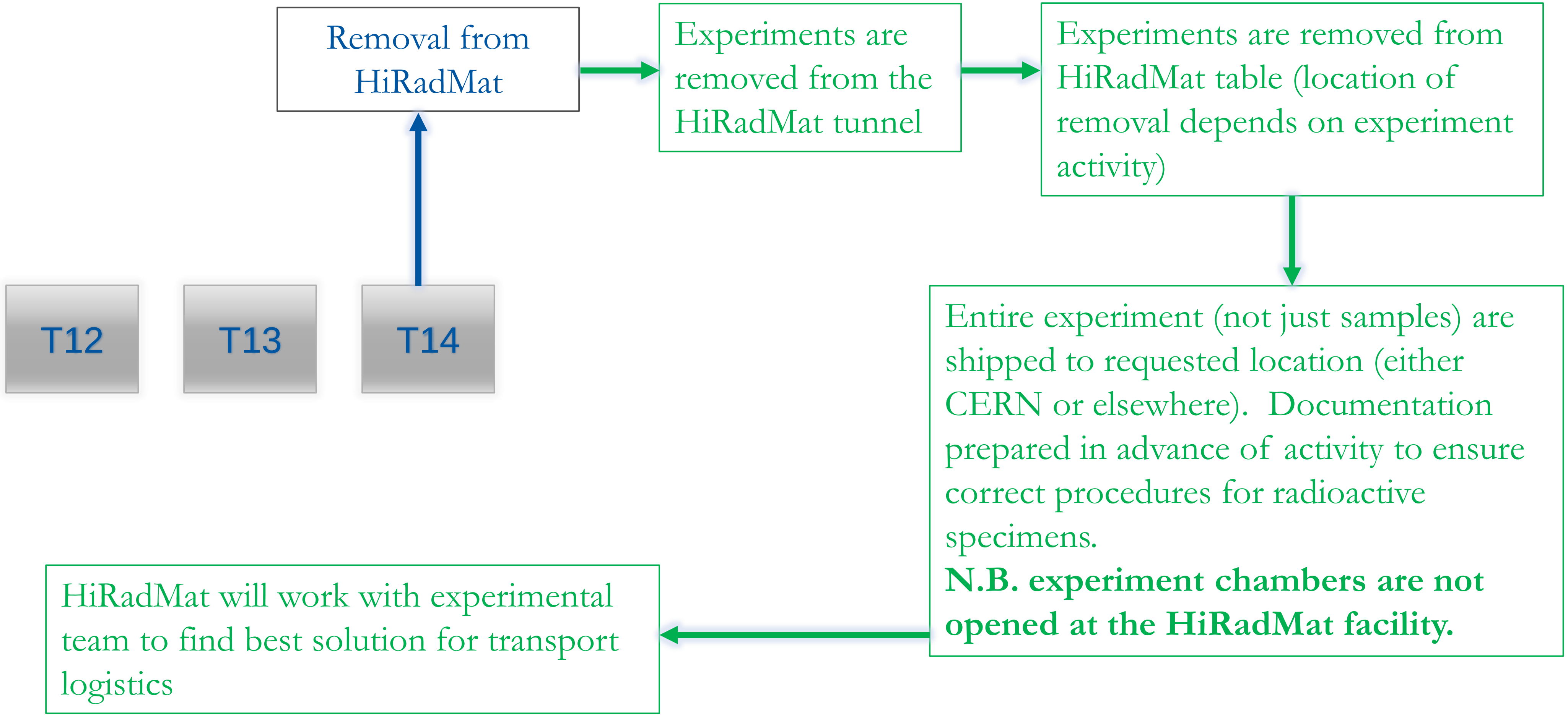
Dose rate at experiment is monitored regular by RP

If dose rate levels are low enough the experiments are moved to the cool down area.

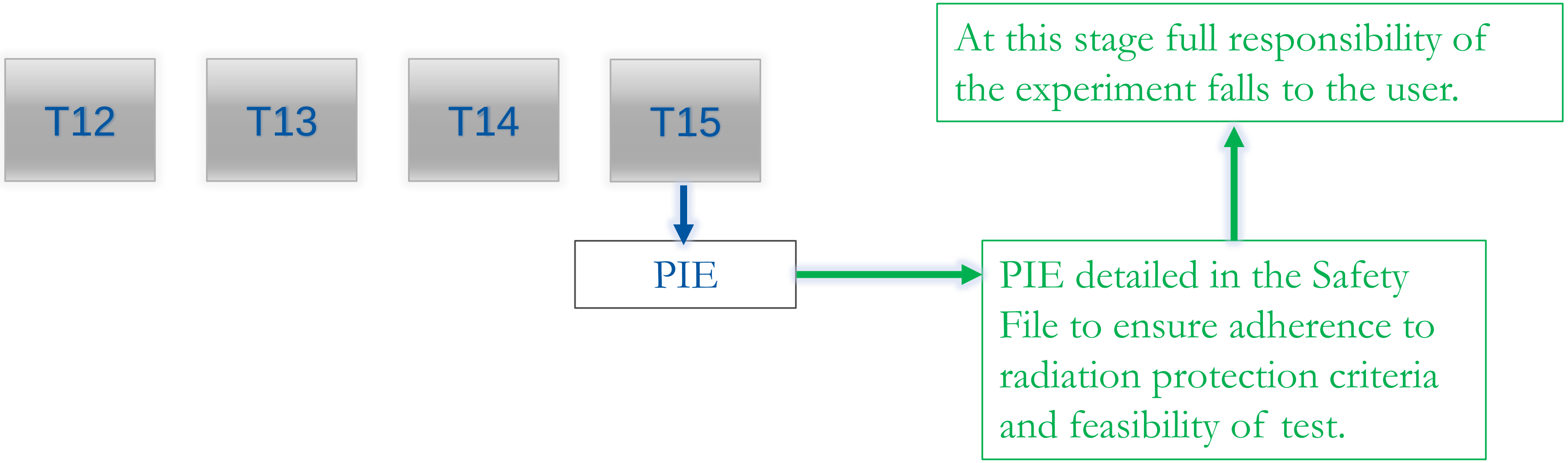
Experiment Timeline



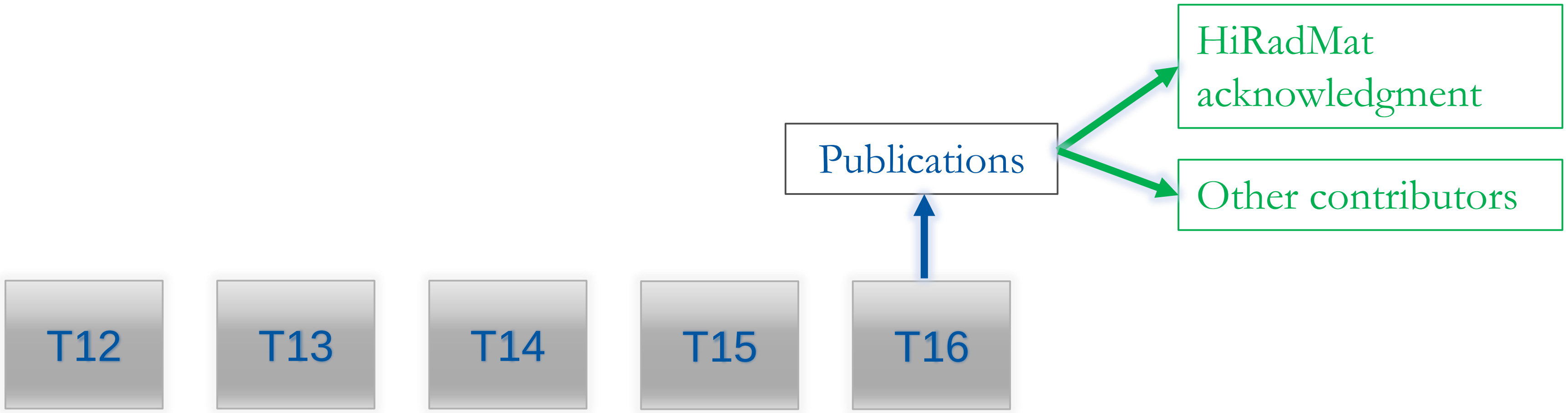
Experiment Timeline



Experiment Timeline



Experiment Timeline



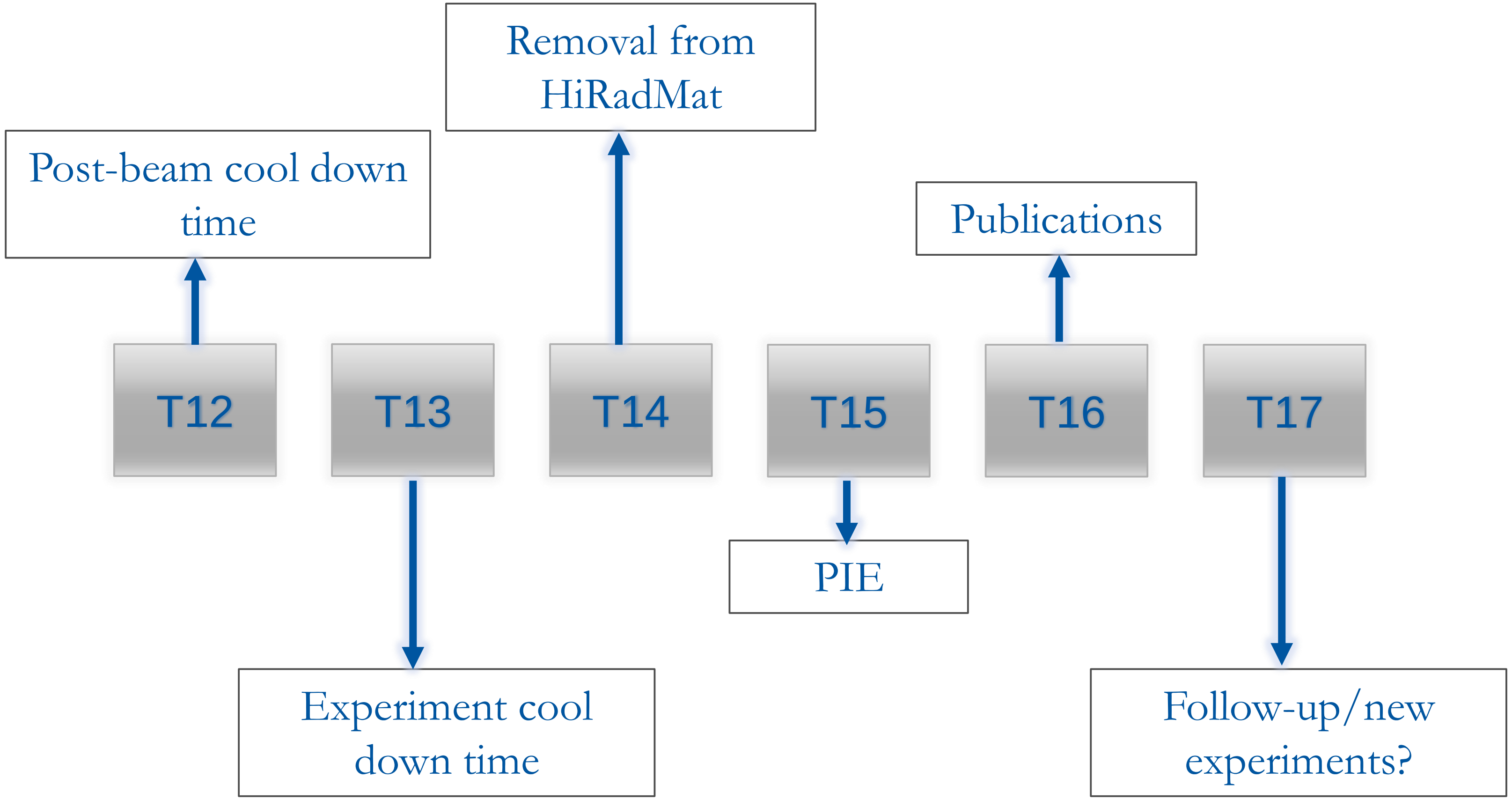
Experiment Timeline (post beam time)

T12 T13 T14 T15 T16 T17

Follow-up/new experiments?

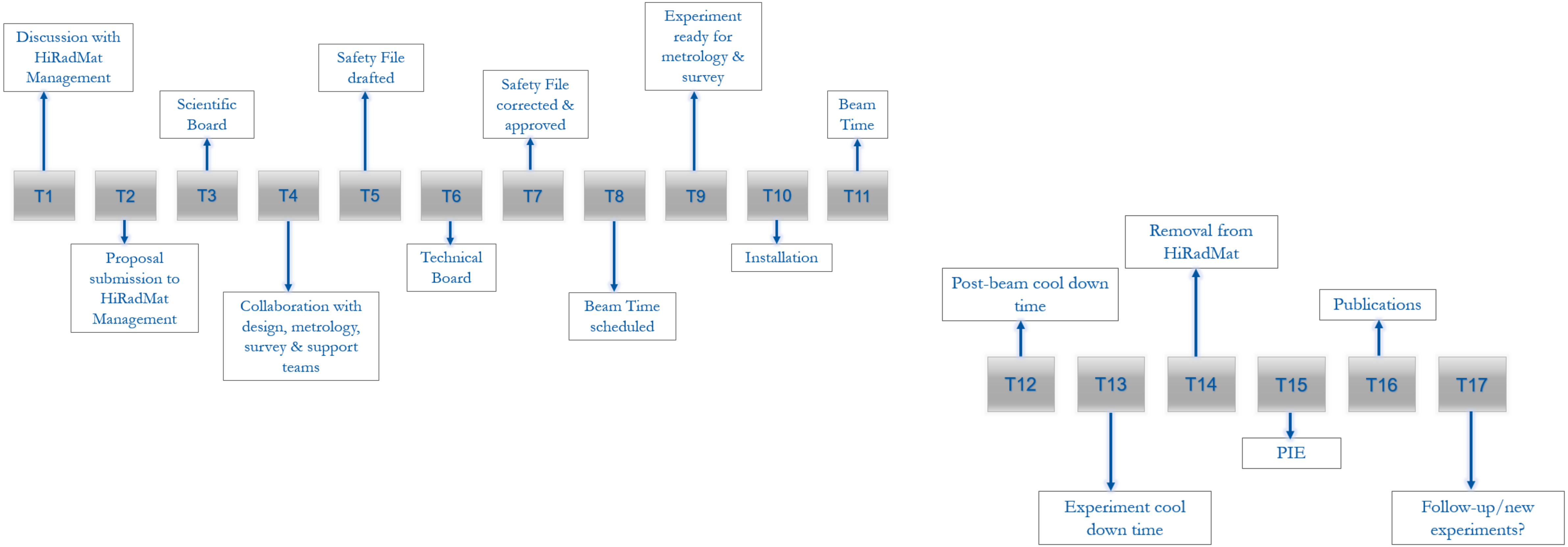
Get in touch with the HiRadMat Management

Experiment Timeline (post beam-time)



Experiment Timeline

Completion of experiment can take 1+ years from T1.



ARIES – transnational access

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

2017

50% of 2017 experiments applied for TNA:

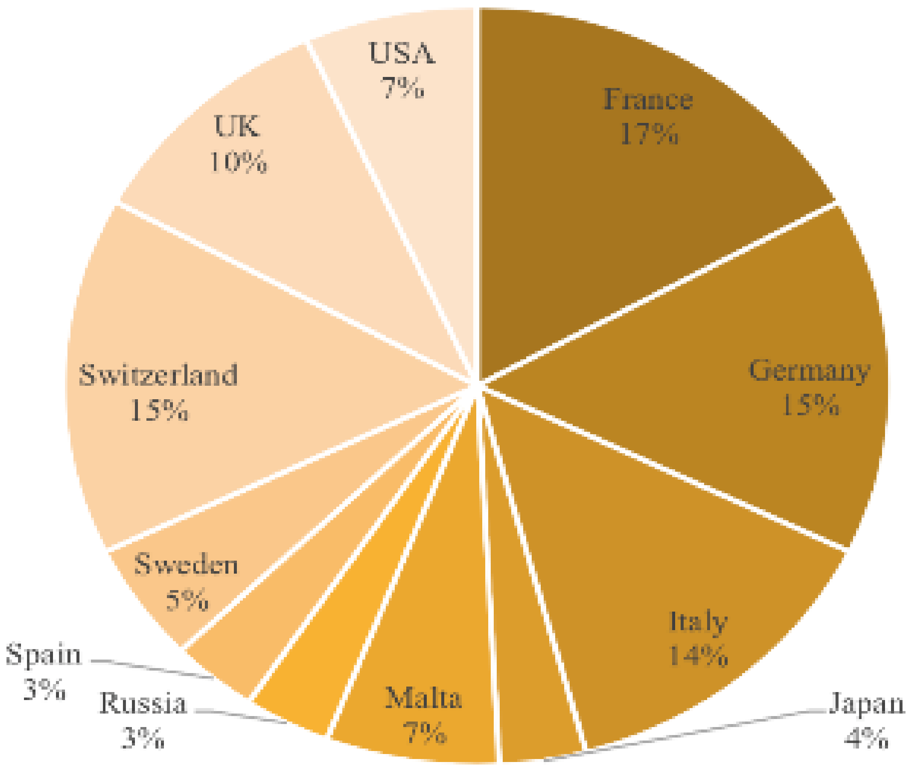
- HRMT19: BLM2 (ESS, Lund, Sweden).
- HRMT41: ATLAS pixel (INFN Genova, IFIC Valencia, CAS China, PNPI Russia).
- HRMT21: RotColl (SLAC USA, U. Malta).
- HRMT36: MultiMat (U. Malta, Brevetti-Bizz SME Italy).

2018

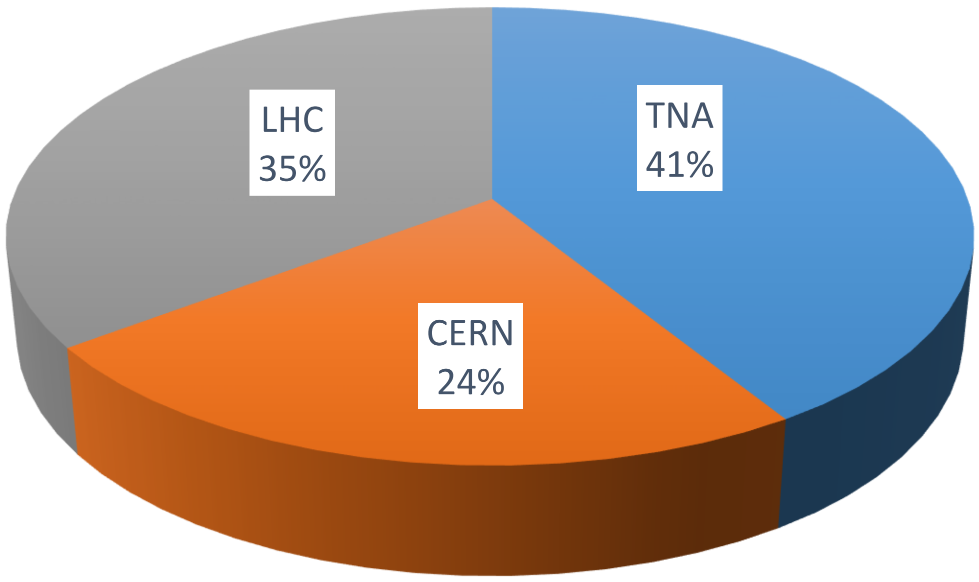
40% of experiments applied for TNA:

- 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).

User statistics (2017, 2018)



Distribution of Transnational Access users with respect to their home institute



Distribution of HiRadMat users

Future proposals

- Upgrade current surface lab proposal:
  - Increase size of lab area to accommodate increased number of users.
  - Increase surface space meaning 2 experiments can be fully accommodated at one time.
  - More storage, tools, working areas for users
  - Improve survey conditions
  - Improve space for transport logistics.

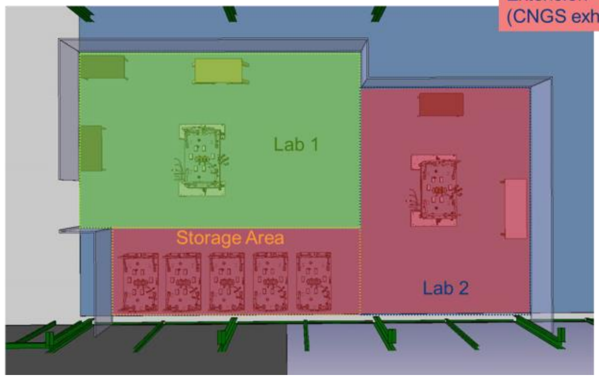
- New surface lab proposal
  - Better accommodate array of different experiments entering HiRadMat.
  - Possibility to temporally increase radiation protection classification to accommodate pre-irradiated experiments.
  - Lab design relevant for current (and anticipated future) needs – size, storage, table integrations, electronics, survey etc.)
  - Improved transport logistics (entering surface lab, installing in experimental area and exiting experimental area post-irradiation).

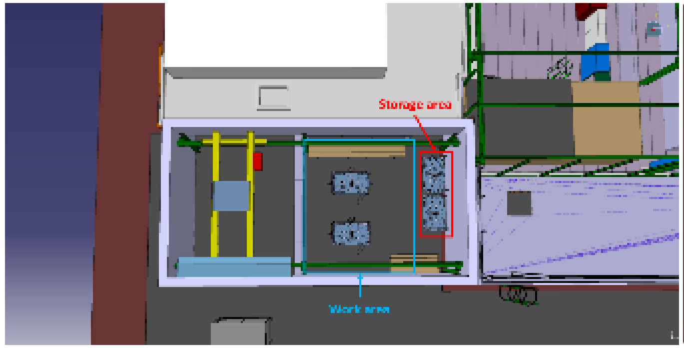
- Upgrade experimental area to enable HL-LHC type beams (**if significant need is justified**)
  - Beam windows & dump studies required.

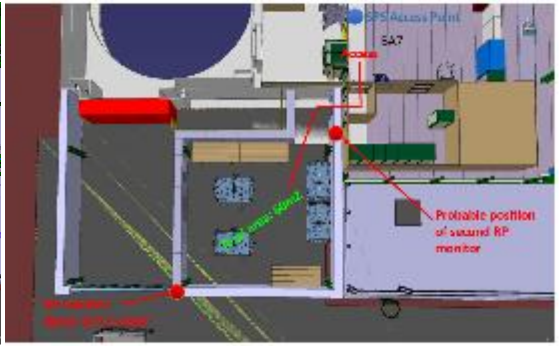
- HiRadMat control room upgrades to meet user requirements – more user friendly.

Current Laboratory

Extension (CNGS exhibition)







The future is bright

On behalf of the HiRadMat team, we look forward to working with past, current and new experimental teams in the future.

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

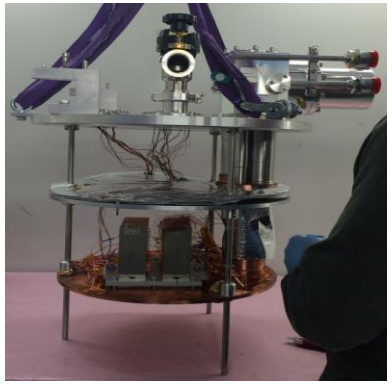
Back-up slides

HiRadMat 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]".

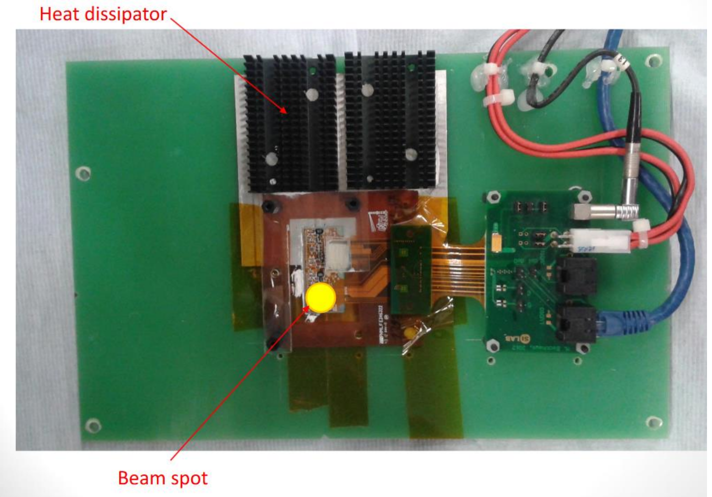
- The High Radiation to Materials (HiRadMat) testing facility took its first beam in 2012 and has continued to deliver pulsed, high intensity, LHC-type beam to over 40 experiments.

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

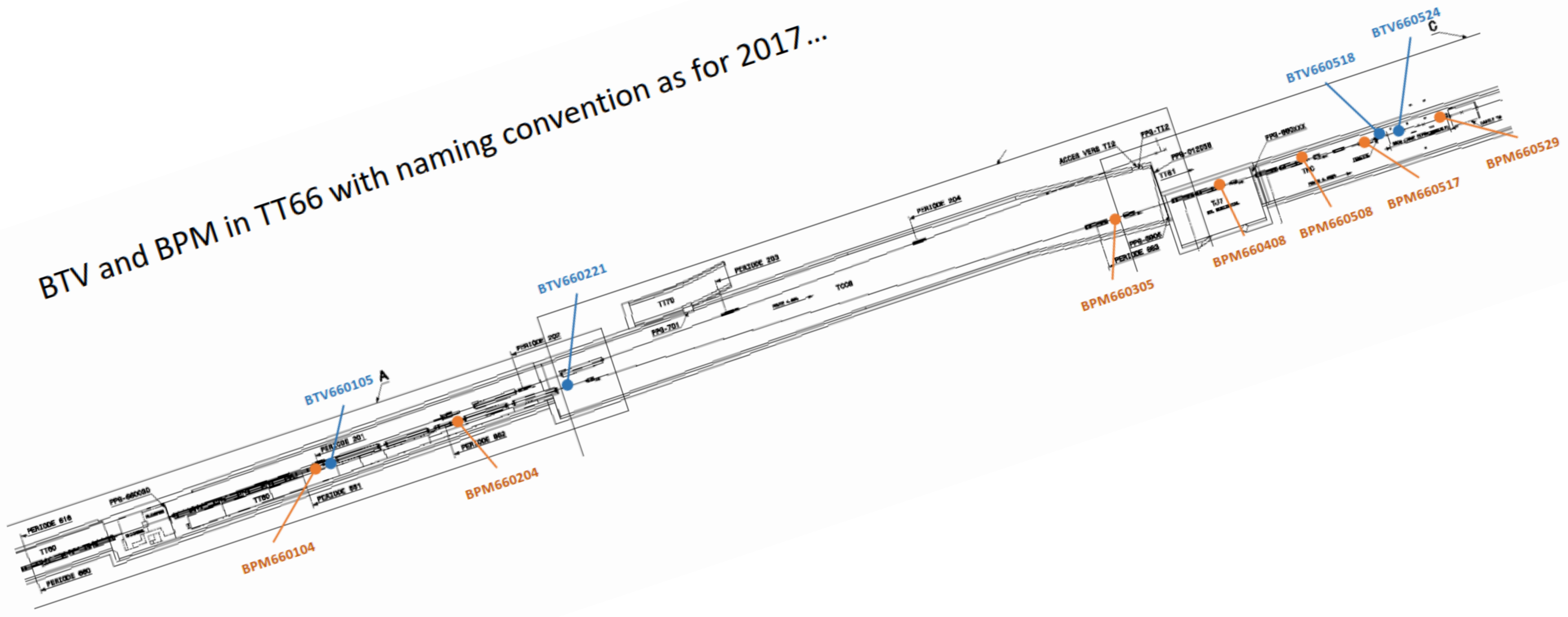
[2] R. Assmann et al., "User Requirements for a Test Facility with High Power LHC Type Beam", 2009, EDMS No: 1130296

HiRadMat Super Cycle Information

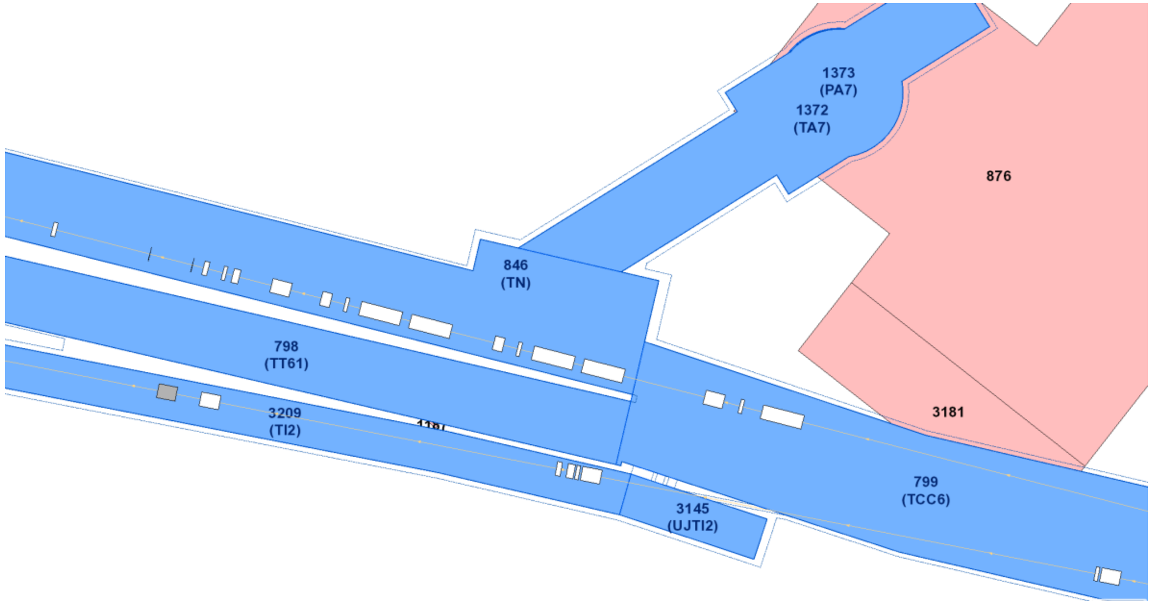
- HiRadMat ‘Long’ Super Cycle:
  - HRM_LS = 22.8 s, SFTPRO = 10.8 s, MD cycle = 7.2 s (3.6 s potentially depending on planning).
  - TOTAL = 40.8 s (or 37.2 s).

- 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

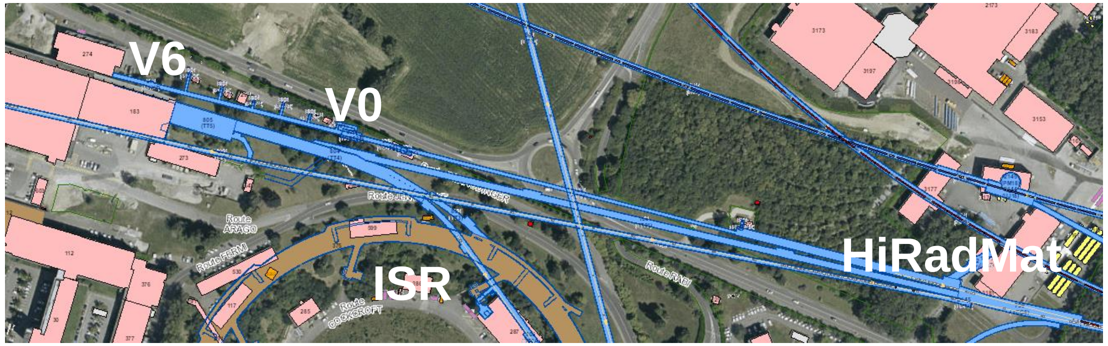


- Access to HiRadMat
  - Only without extraction to TCC6 (=TI2 and HRM)
  - SPS can continue cycling.
- Since 2014: TT61 is used for placing DAQ equipment only 10 m from the impact centre
- Access coordinated with BE/OP, particularly in view of LHC operation
  - Often stand-by for access during several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

Access to V0-V7

Muon pits of former WANF

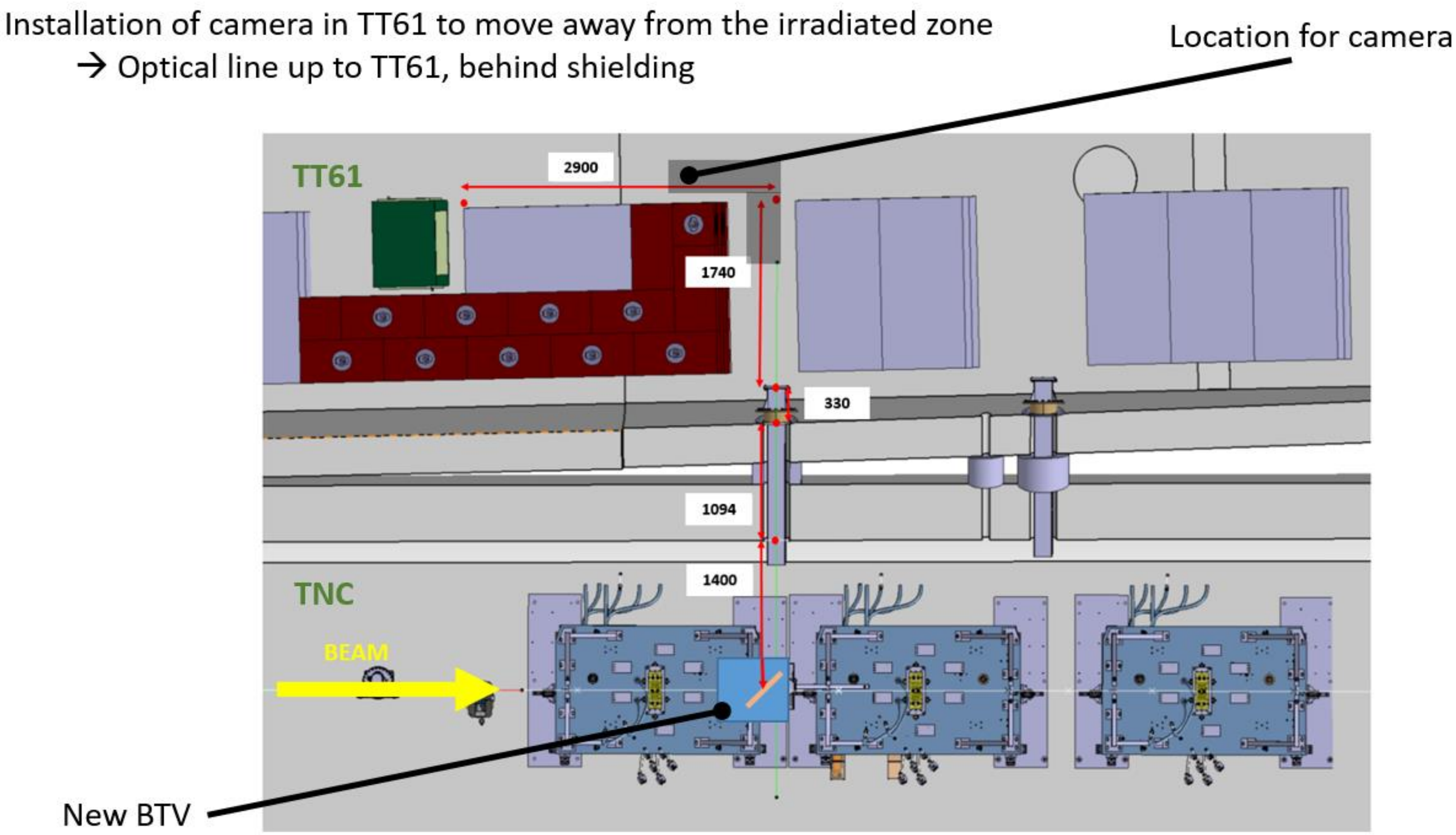
- Exposed to muon beam in forward direction of HiRadMat target area
- Access to be restricted upon RP request
- Access to VO needed about twice a year for intervention by CV



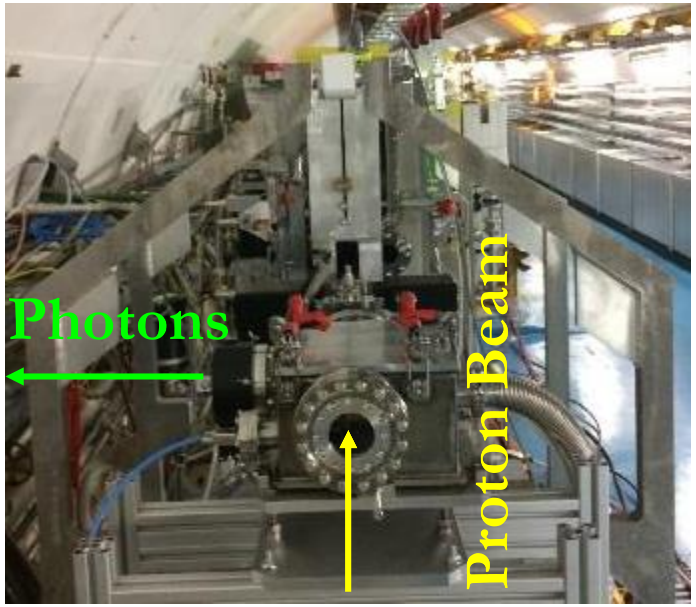
- Skipping installation of full-fletched access control system (SPS)
- Padlocks with manual veto system like in the North Area
  - Agreed by EN, BE and RP (EDMS 1578411)
  - Installed by BE/ICS
  - Manual veto held by EN/EA

- Installation completed, operational from 2016

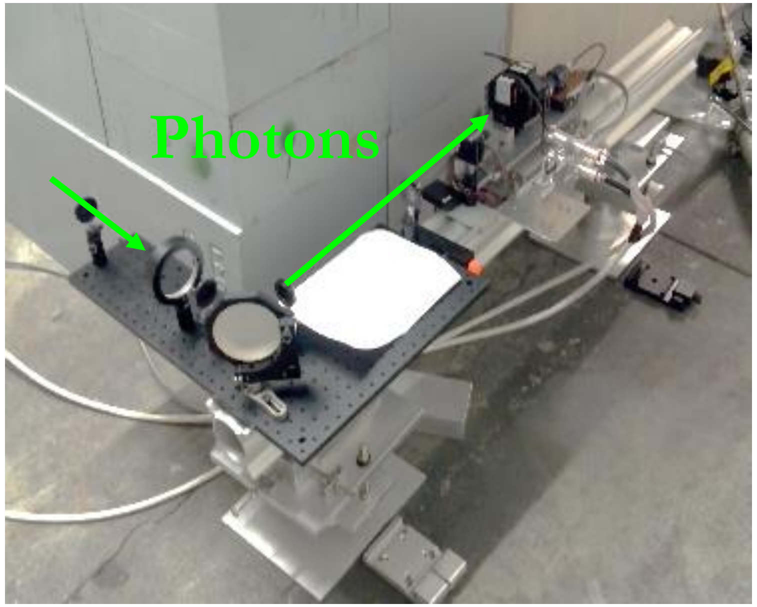
BTV Optical Path



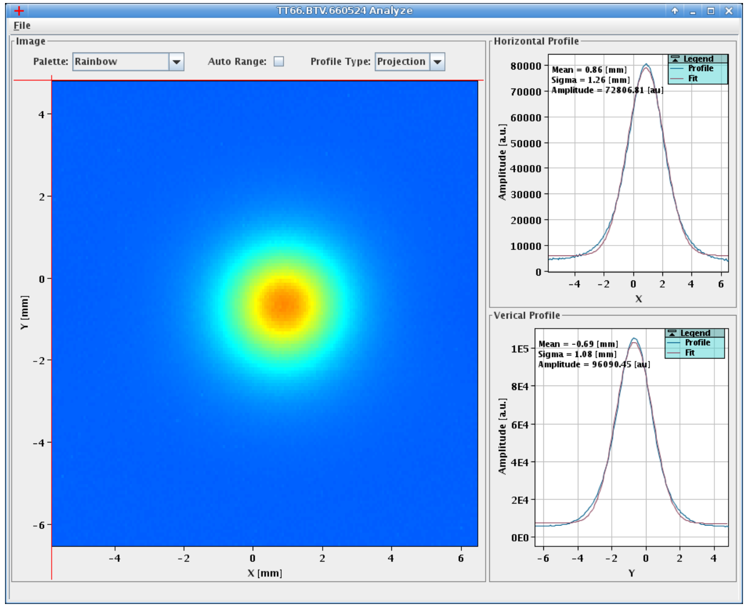
Beam Diagnostic Instrumentation



Beam diagnostic & monitoring equipment



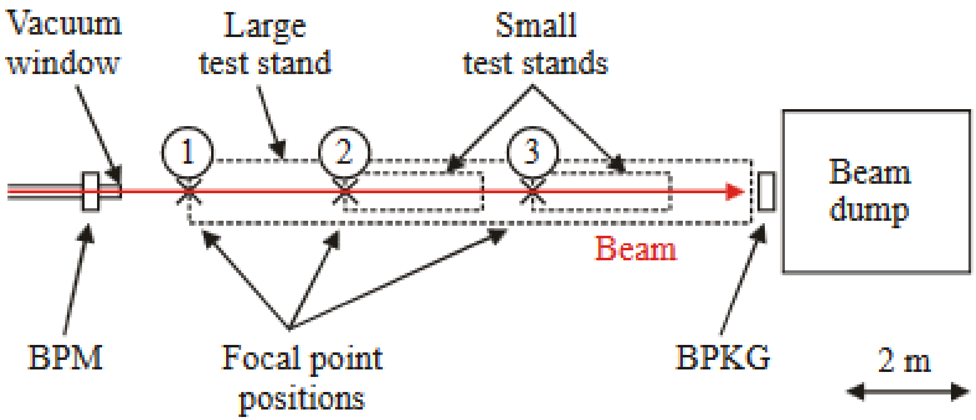
Optical path relating to beam profile capture in adjacent tunnel



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

Variable Beam Optics

- Optics updated.

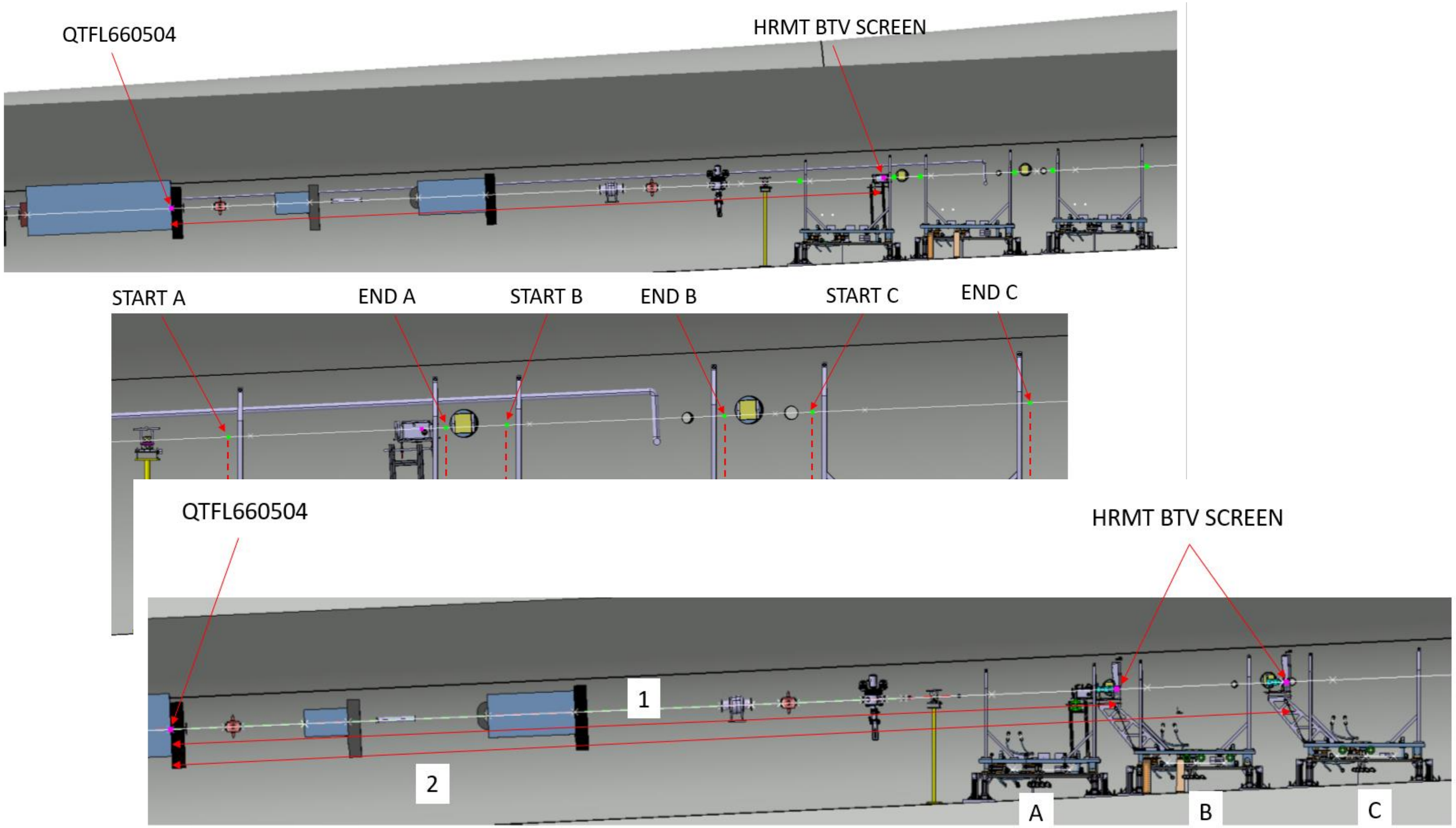


C. Hessler et al. “The Final Beam Line Design for the HiRadMat Test Facility”, IPAC’10, Kyoto (2010)

- 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

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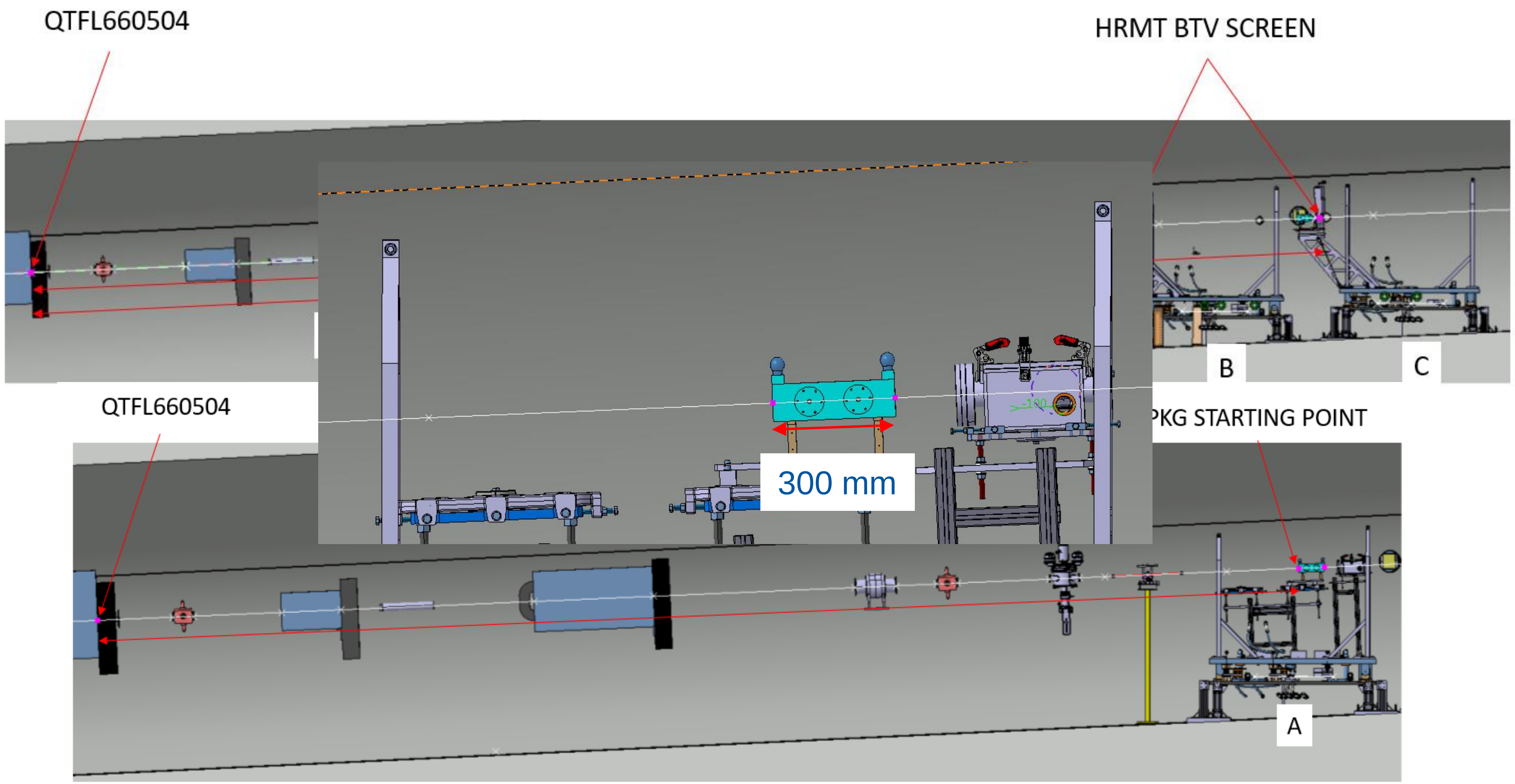

HRM Optics Distance Info

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

Brief history

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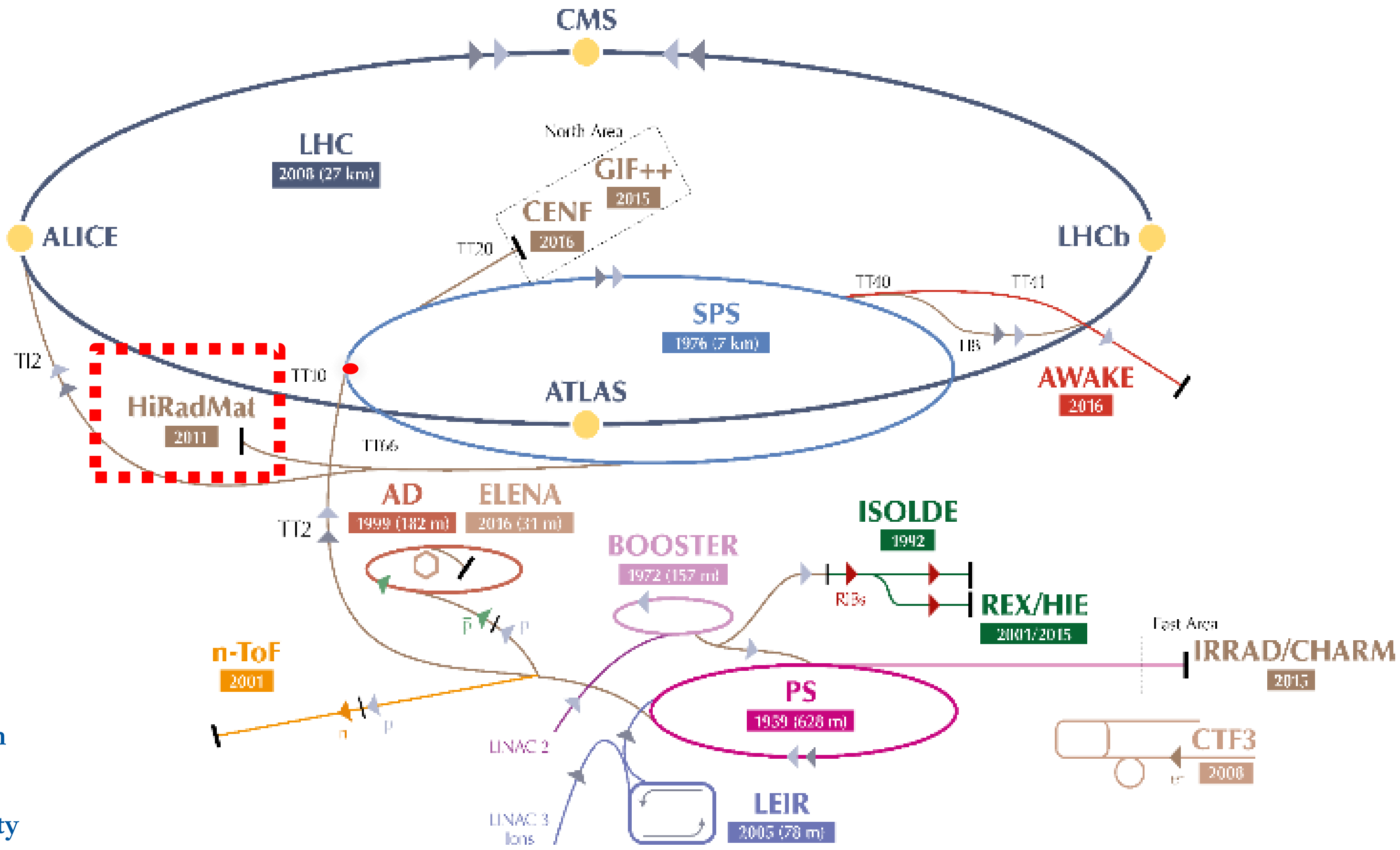

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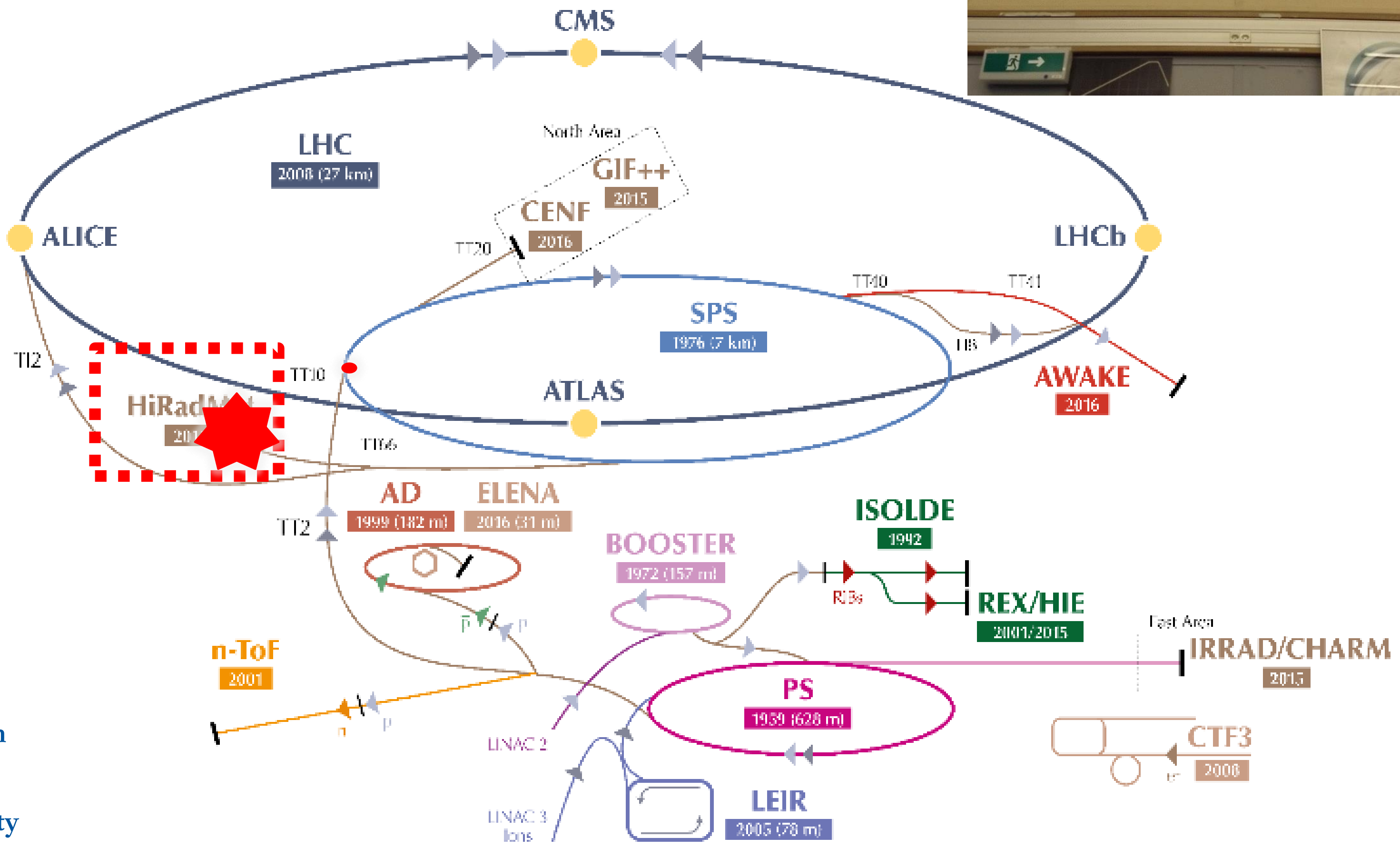

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Experimental approval process and user support

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.

Installation Phase

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

Design Phase

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

Beam Time Phase

Support provided from CERN teams, including HiRadMat, Survey, Mechatronics and Measurements, Mechanical and Materials Engineering, Beam Instrumentation, Operations.