IRRAD - The New CERN Proton Irradiation Facility

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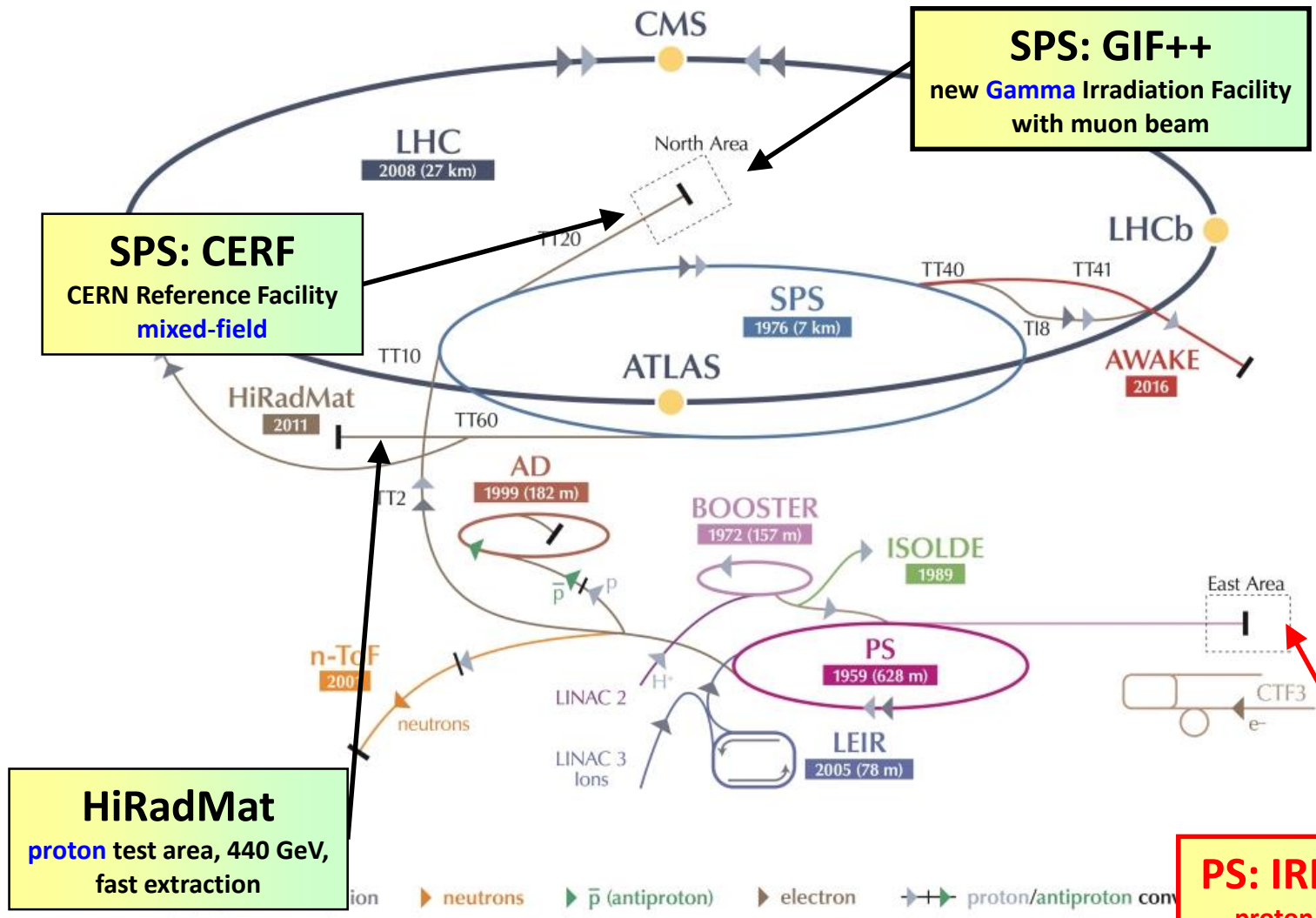
Outline

- PS East Area Irradiation Facilities until 2012
- New PS East Area Irradiation Facilities from 2014
- IRRAD Proton Facility Infrastructure & Equipment
- Proton Beam Parameters
- Beam Profile Monitor
- Radiation Background & Dosimetry Measurements
- Summary

Present CERN Irradiation Facilities



SPS: GIF++
new Gamma Irradiation Facility with muon beam

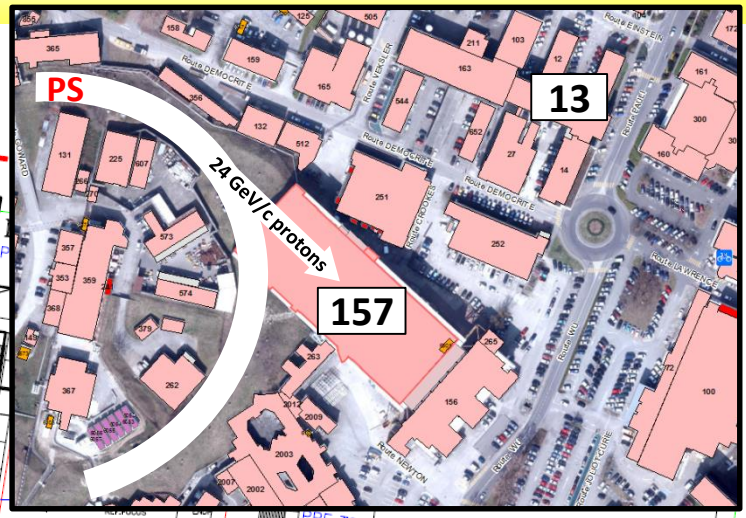
SPS: CERF
CERN Reference Facility
mixed-field

HiRadMat
proton test area, 440 GeV, fast extraction

PS: IRRAD & CHARM
proton facility & mixed-field
24 GeV/c, slow extraction

Proton Energy	
LHC	7 TeV
SPS	450 GeV
PS	23 GeV
PSB	1.4 GeV
Linac	50 MeV

PS-EA Irradiation Facilities until 2012



- **from 1992 - until 2012**
- **Proton irradiations (T7)**
  - **Primary 24 GeV/c proton beam** (IRRAD1, IRRAD3, IRRAD5, …)
- **Mixed-field irradiations (T8)**
  - **Mixed field produced in cavity** after **C** (50cm) - **Fe** (30cm) - **Pb** (5cm) **'target'** (IRRAD2)

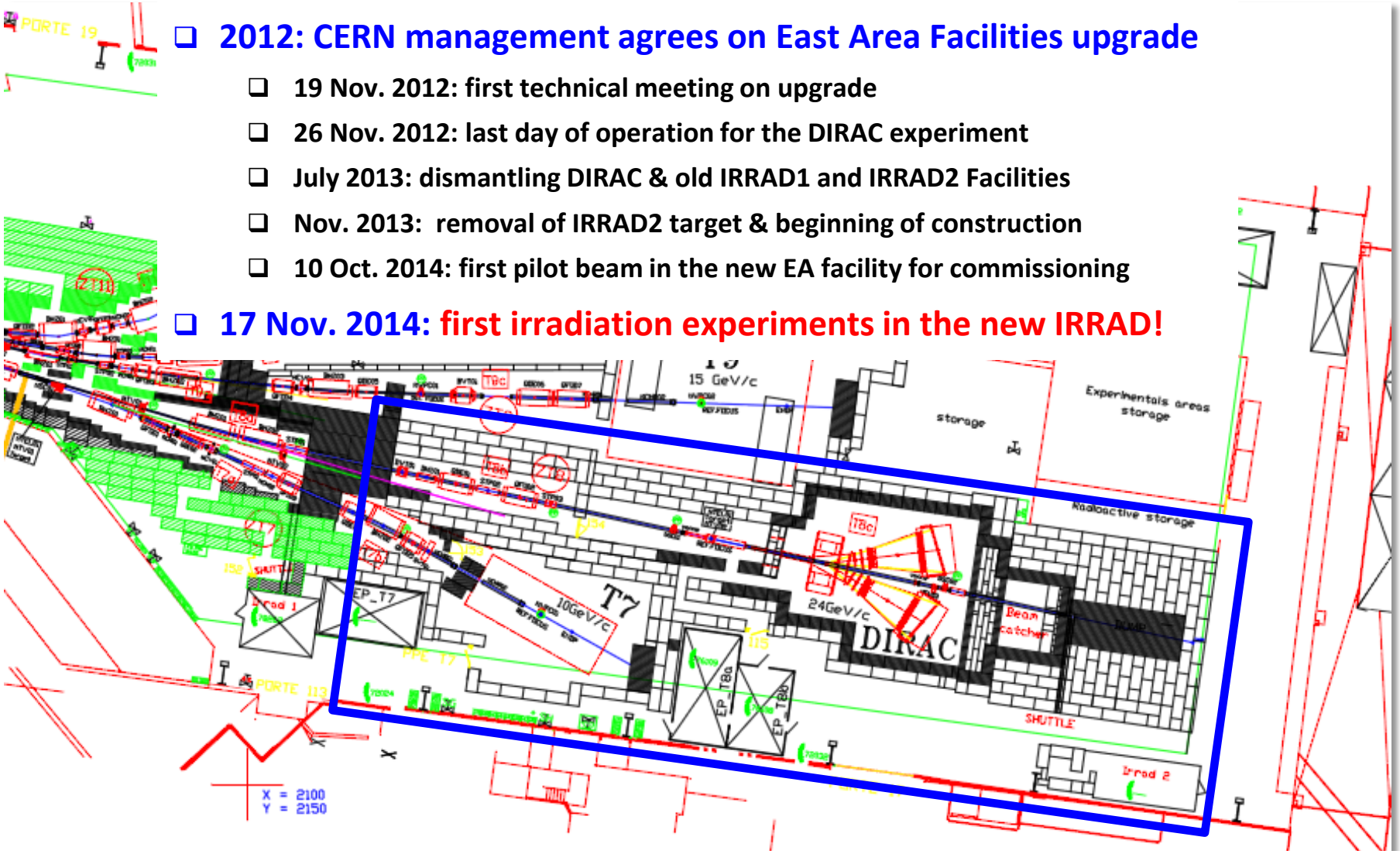
Irradiation Experiments

- **Former IRRAD facilities in numbers …**
  - from **1999** to **2012** (no beam in 2005)
  - more than **8300** “pieces” irradiated (**~650 per year**)!
  - about **5800** dosimeters (Al foils) measured!

© IRRAD user community!

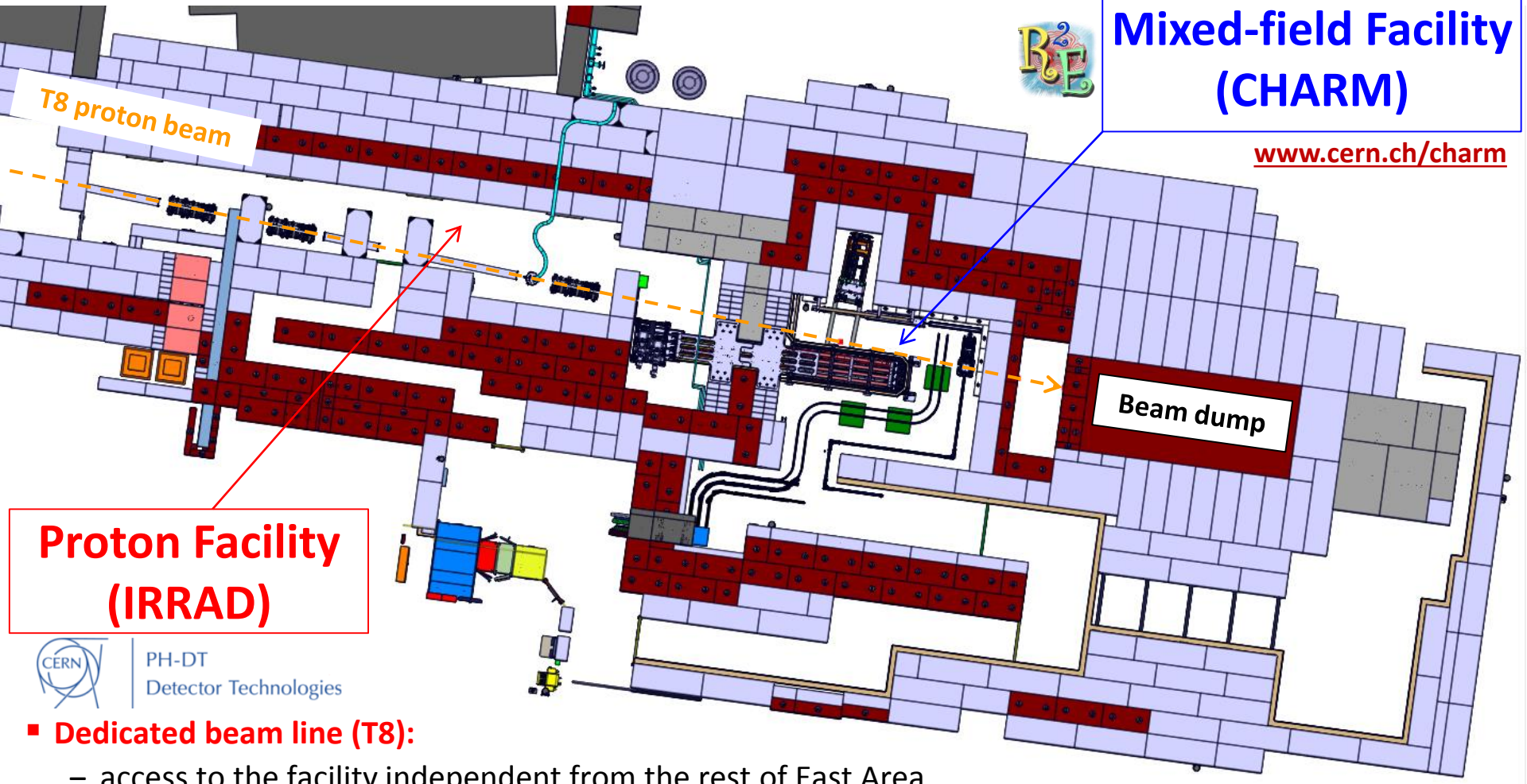
Towards a New Combined EA Facility

- **2012: CERN management agrees on East Area Facilities upgrade**
  - 19 Nov. 2012: first technical meeting on upgrade
  - 26 Nov. 2012: last day of operation for the DIRAC experiment
  - July 2013: dismantling DIRAC & old IRRAD1 and IRRAD2 Facilities
  - Nov. 2013: removal of IRRAD2 target & beginning of construction
  - 10 Oct. 2014: first pilot beam in the new EA facility for commissioning
- **17 Nov. 2014: first irradiation experiments in the new IRRAD!**



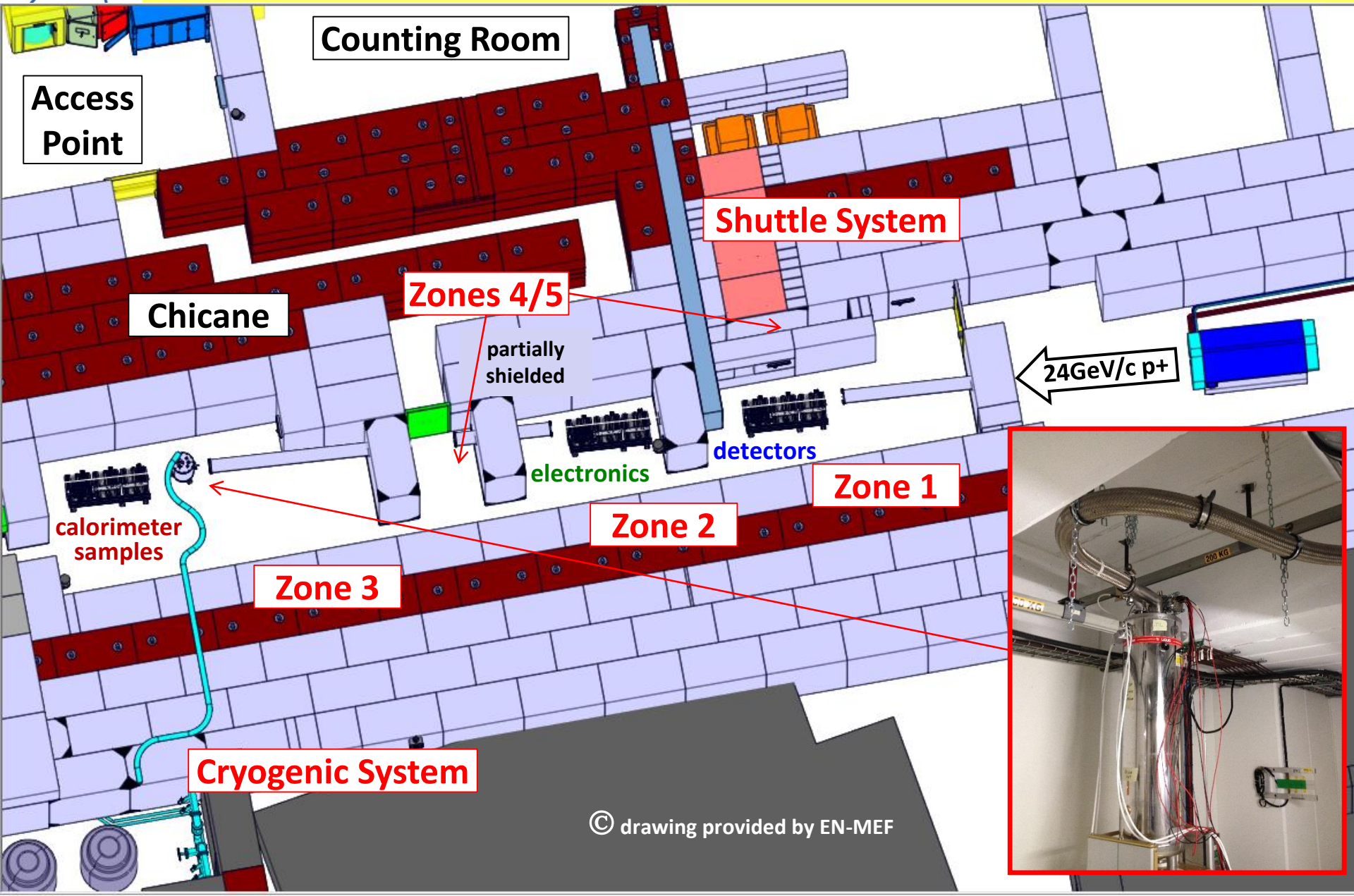
EA-IRRAD upgrade project: ***Joint effort of many CERN groups.*** ***PH-DT, EN-MEF, EN-STI*** *(core teams),* ***HSE*** *and* ***EN-HDO*** *(Project Safety),* ***DGS-RP, EN-CV*** *(ventilation),* ***EN-HE*** *(transports),* ***GS-ASE*** *(access control),* ***BE-BI*** *and* ***TE-CRG*** *(IRRAD cryogenic system), …*

New East Area Facilities Layout



- **Dedicated beam line (T8):**
  - access to the facility independent from the rest of East Area
  - serving two facilities → improved PS cycle economy **= increased beam availability!**
- **Optimised layout:**
  - shielding, ventilation, more space for installation and handling of samples, etc. (**= improved safety!**)

New IRRAD Proton Facility



IRRADx Remote-Controlled Tables

- DUTs powered and cooled
- V_{max} = 20×20×50cm³ (standard); «scanning» over surface

Water cooling system

Temp. Control down to -25 ºC

VORTEX cooling system

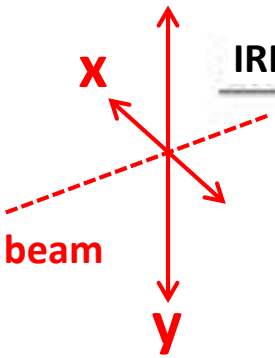
Temp. Control down to -20 ºC

Control Unit

IRRAD9

IRRAD13

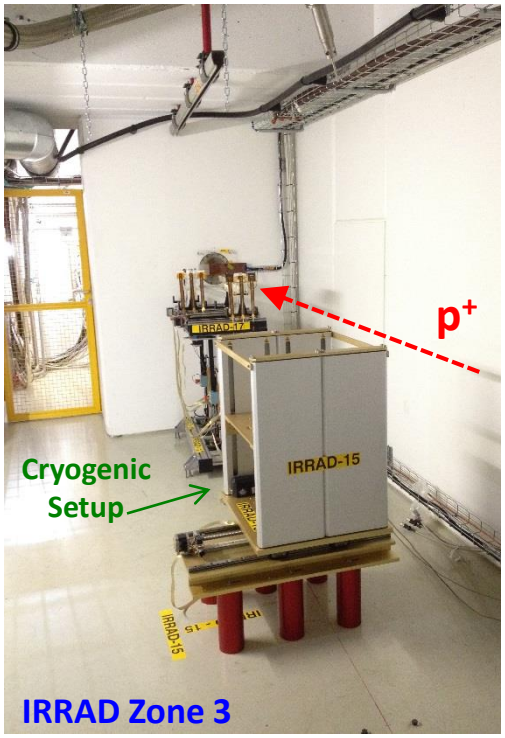
IRRAD11

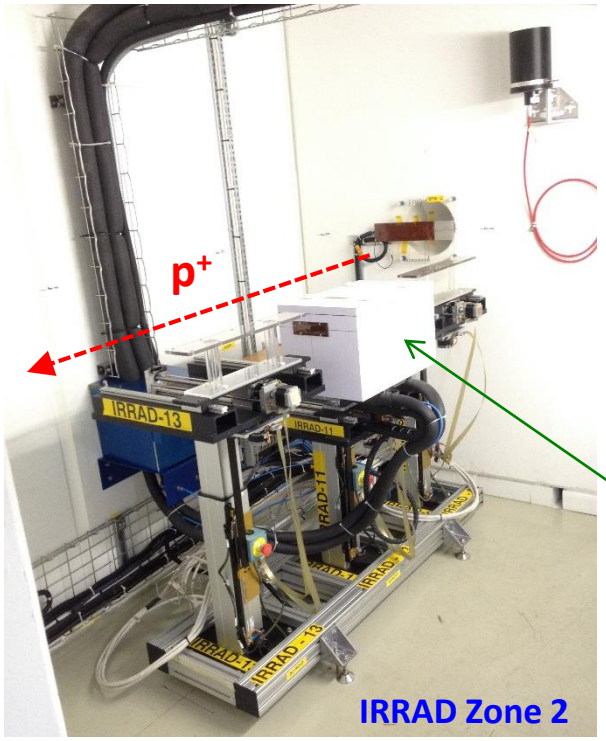


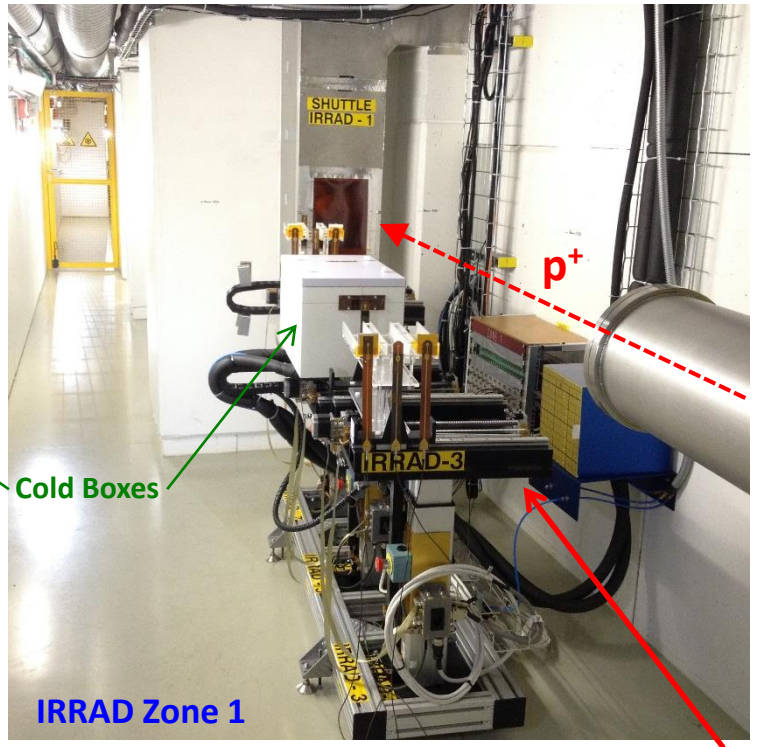
Irradiation Table

- stand-alone control unit (users) + software applications

IRRAD Zones Equipment

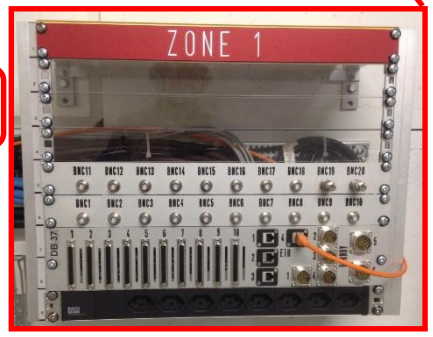






- **3 tables per IRRAD zone**
  - **9 irradiation tables operational from Oct. 1st 2015**
    - 6x RT irradiation (*IRRAD 3,7,9,13,17,19*)
    - 2x water-cooled cold boxes down to -25°C (*IRRAD 5,11*)
    - 1x dedicated to the cryogenic setup (*IRRAD 15*)
- **Pre-installed cabling infrastructure**

Cables length from ~13m to ~20m

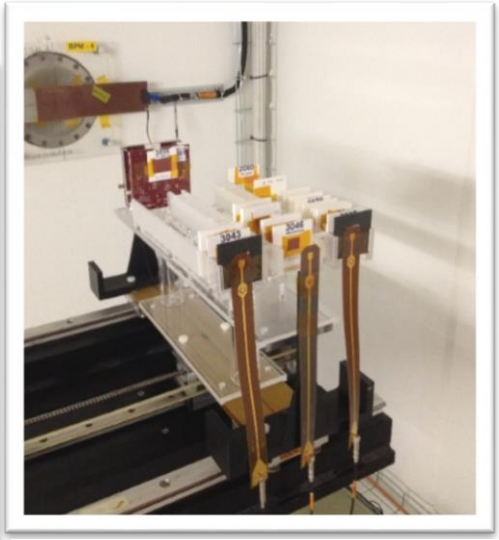


- **4 Patch-Panels** installed along IRRAD
  - twisted-pairs, coaxial, power HV/LV, …
- space for **custom user-cabling**
  - optical fibers, etc..

Cold & RT Irradiation Experiments

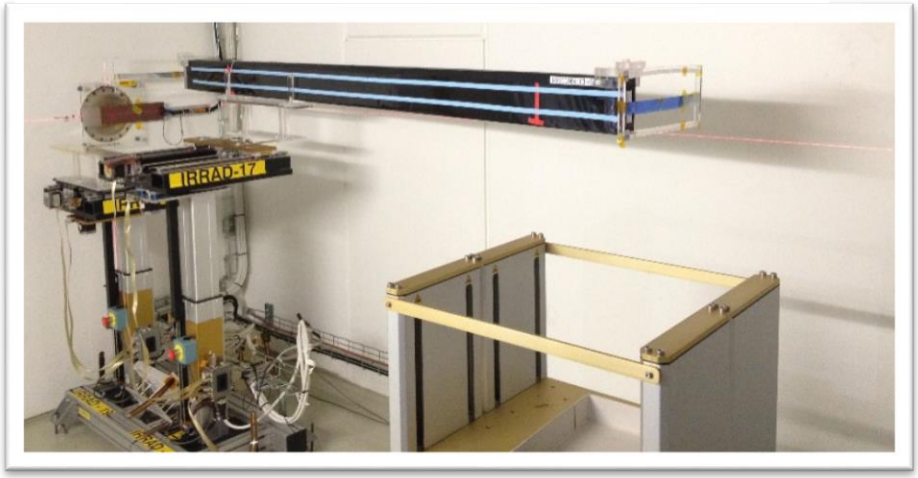
❑ RT Irradiation Setup

Users-made supports



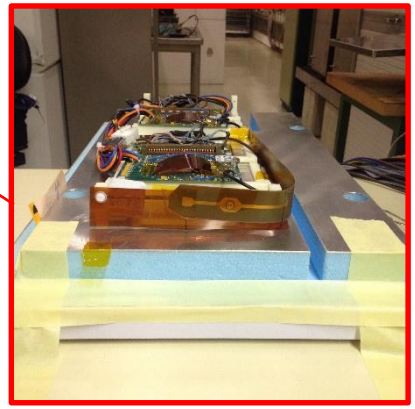
Small samples support (cardboards)

Complex Irradiation experiment (*LHCb SciFi prototype*)

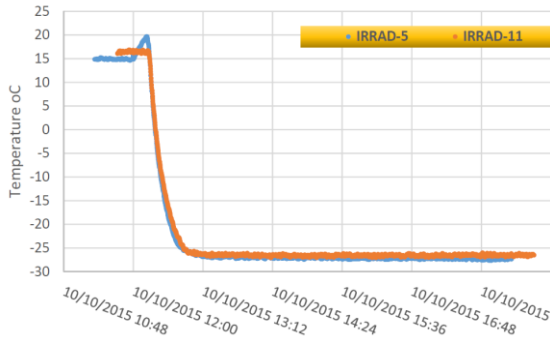


❑ Cold boxes from AIDA (QMUL/Sheffield, UK)

DUTs installed under the box cover lid



Cold Boxes Performance



Chiller Units
Thermo-fluid: *SilOil*

IRRAD1 Shuttle System

- V_{max}=5×5×15cm^3 (passive samples on «cardboards» or PCBs)
- Possibility to irradiate samples under bias

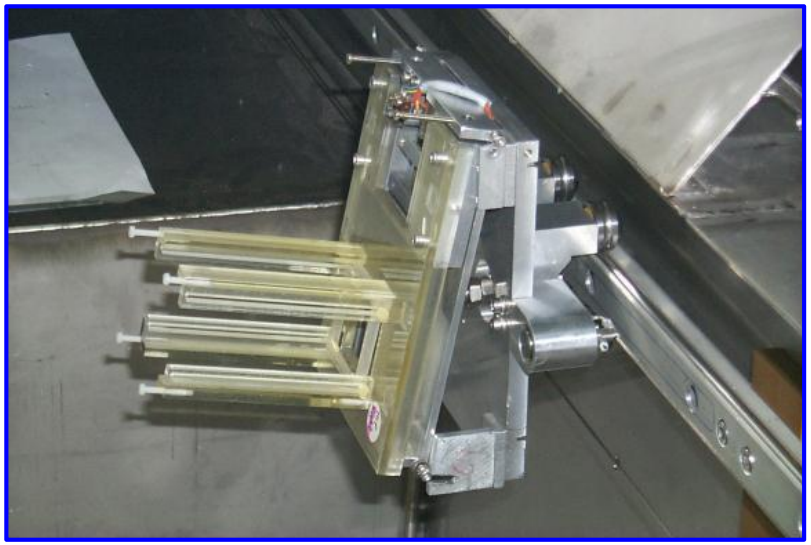
Beam Position

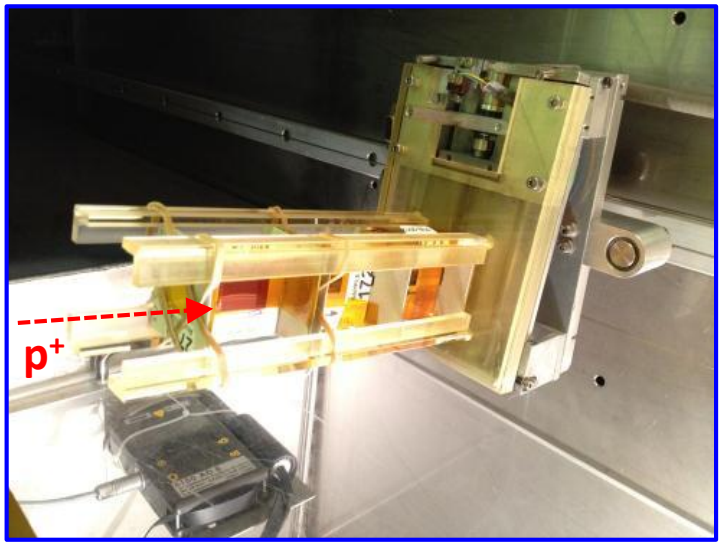
Loading Station

IRRAD1 Shuttle & IRRADx Tables

IRRAD1 Shuttle

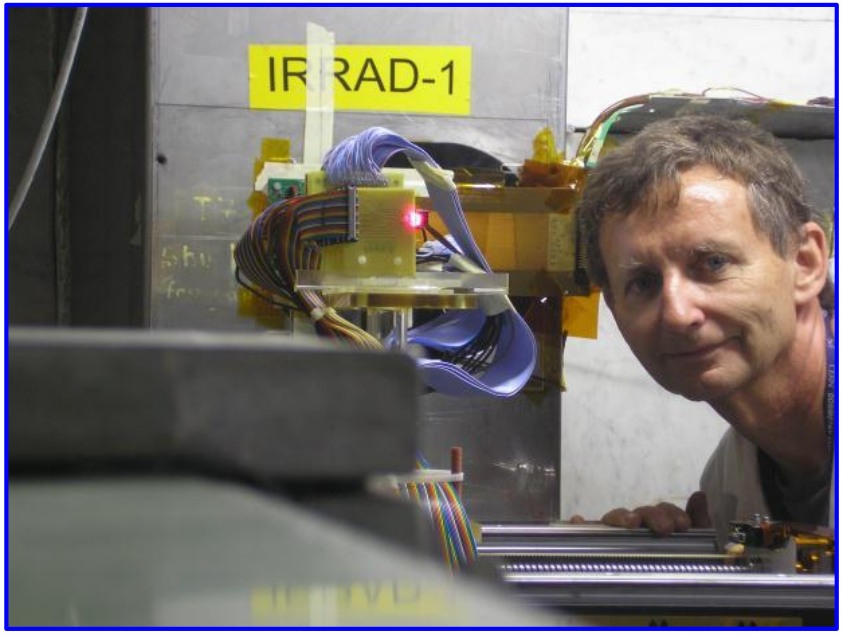
«small» samples

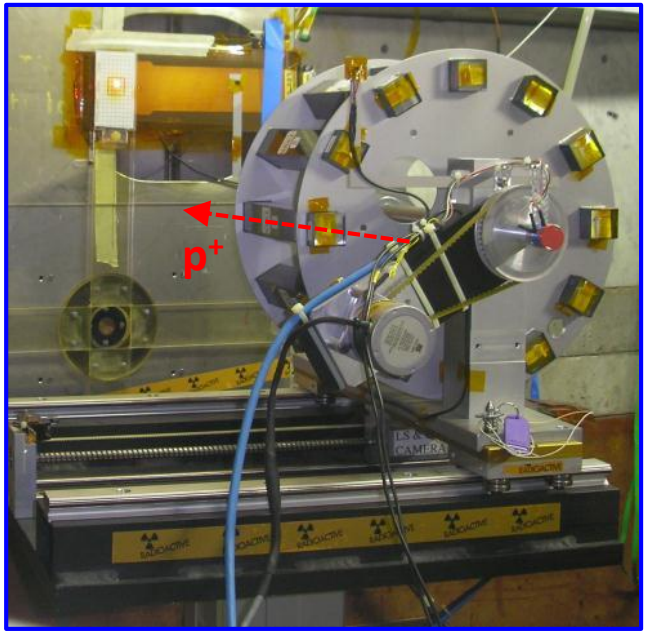




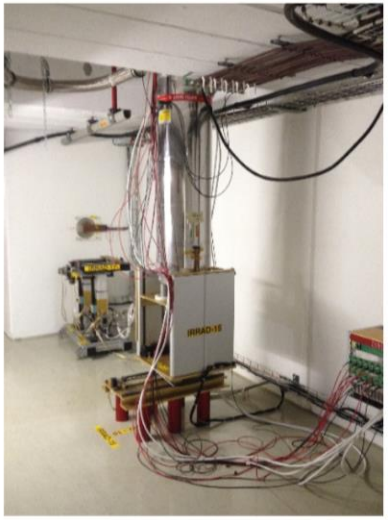
IRRAD3 & IRRAD7 Tables

«big» experimental setups





Cryogenic Setup IRRAD15



Picture: Nov. 2015

- **Setup for irradiation in cryogenic conditions (1.8K/4.2K) with L-He**
  - Main user "*CryoBLM experiment*" (BE-BI)
  - Transfer line "embedded" in IRRAD shielding

Samples Holder

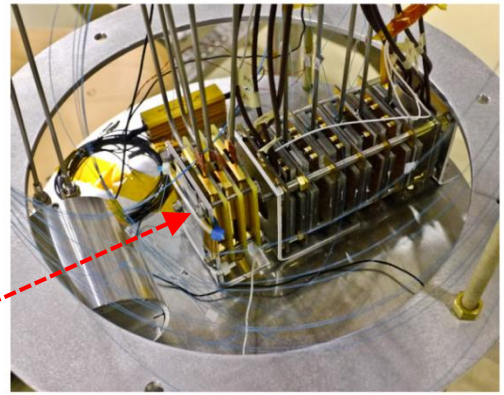
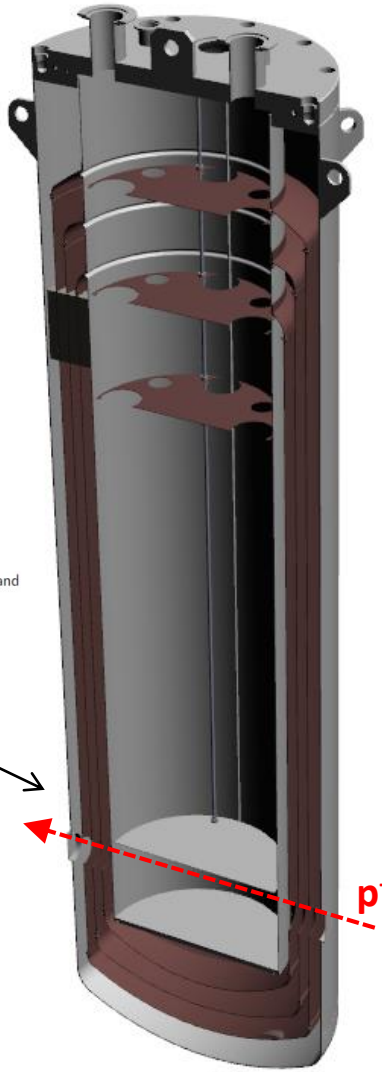
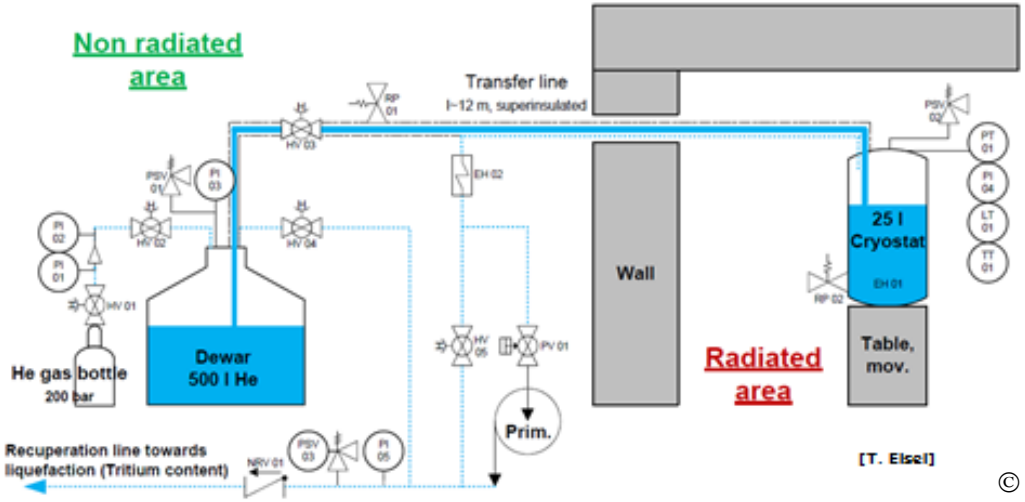


Figure 6.16: Detector modules mounted on the support plate and ready for cooling down and irradiating.

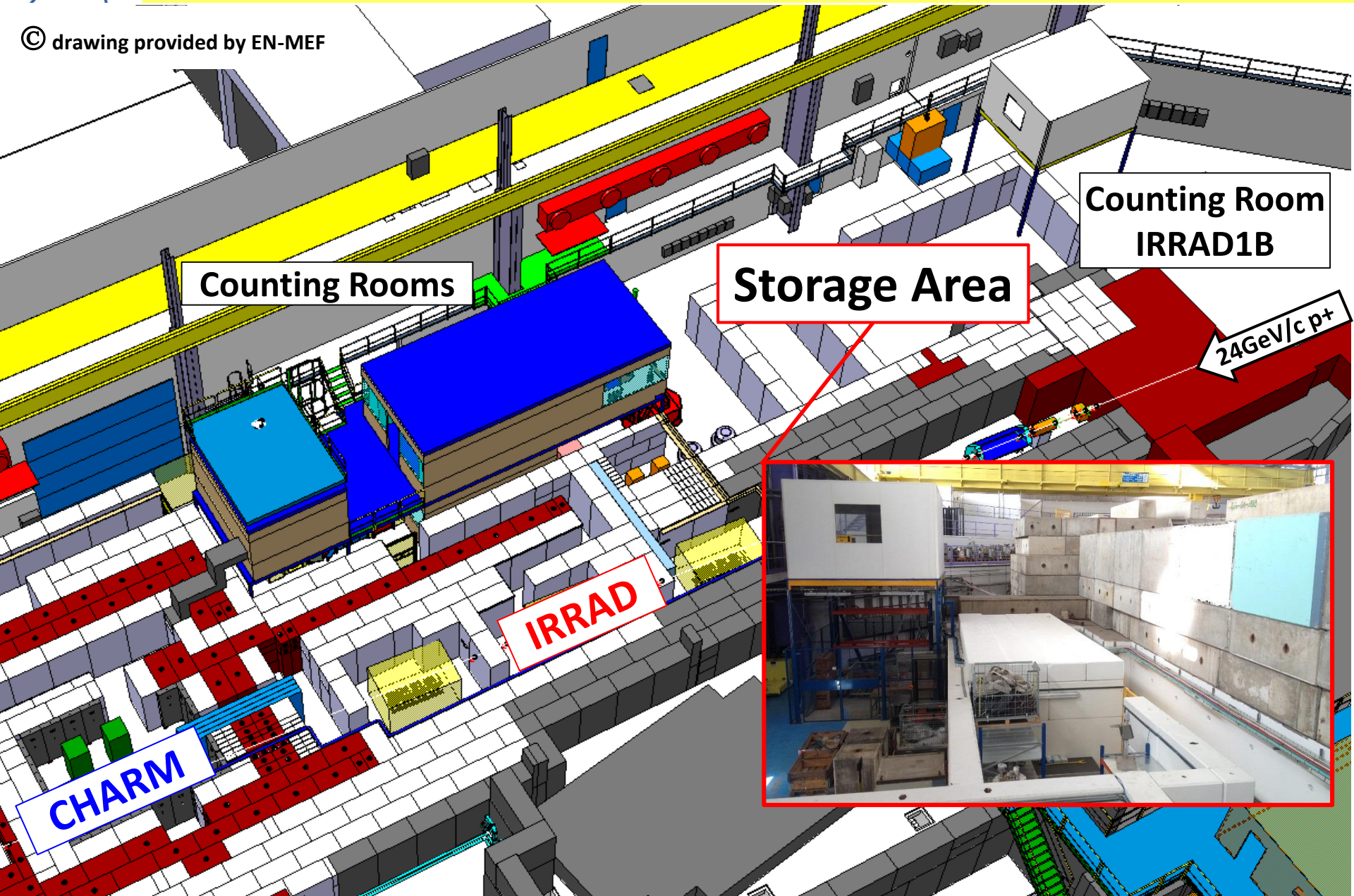


- P&I Diagram
  - Manual refilling
  - Temperatures between 1.8 K and 4.2 K



[T. Eisel]

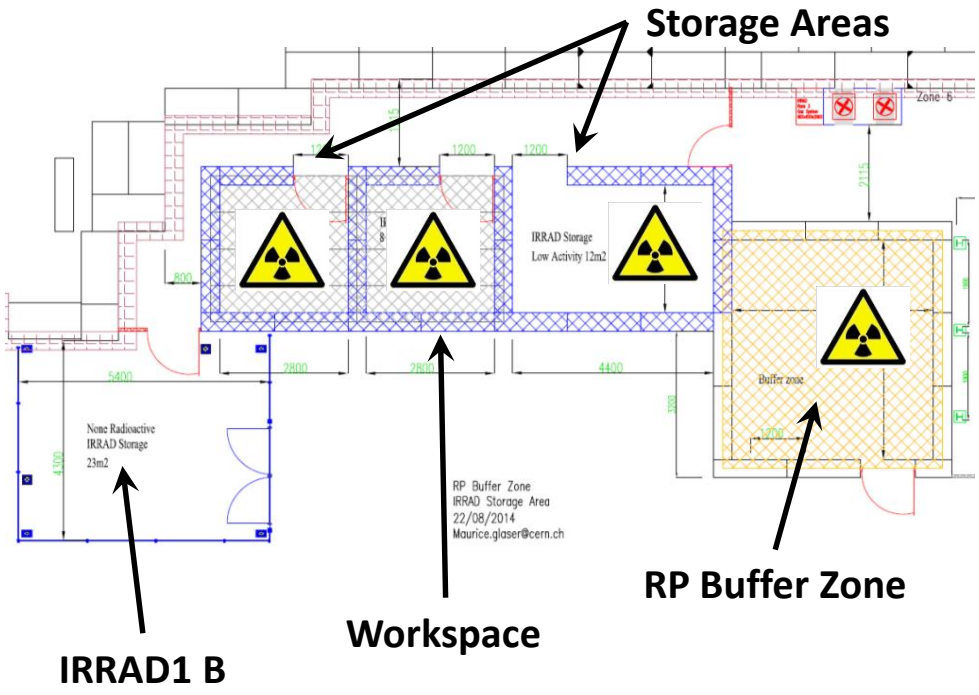
East Area EA-IRRAD Infrastructure



Proton IRRAD Infrastructure

❑ Storage Area

- 2x shielded zones for **cool-down** and **storage** at **room and low temperature**
- 1x **workspace** equipped to handle and characterize irradiated equipment
- dedicated **cabling infrastructure** from workspace to counting room IRRAD1B



Proton Beam Parameters

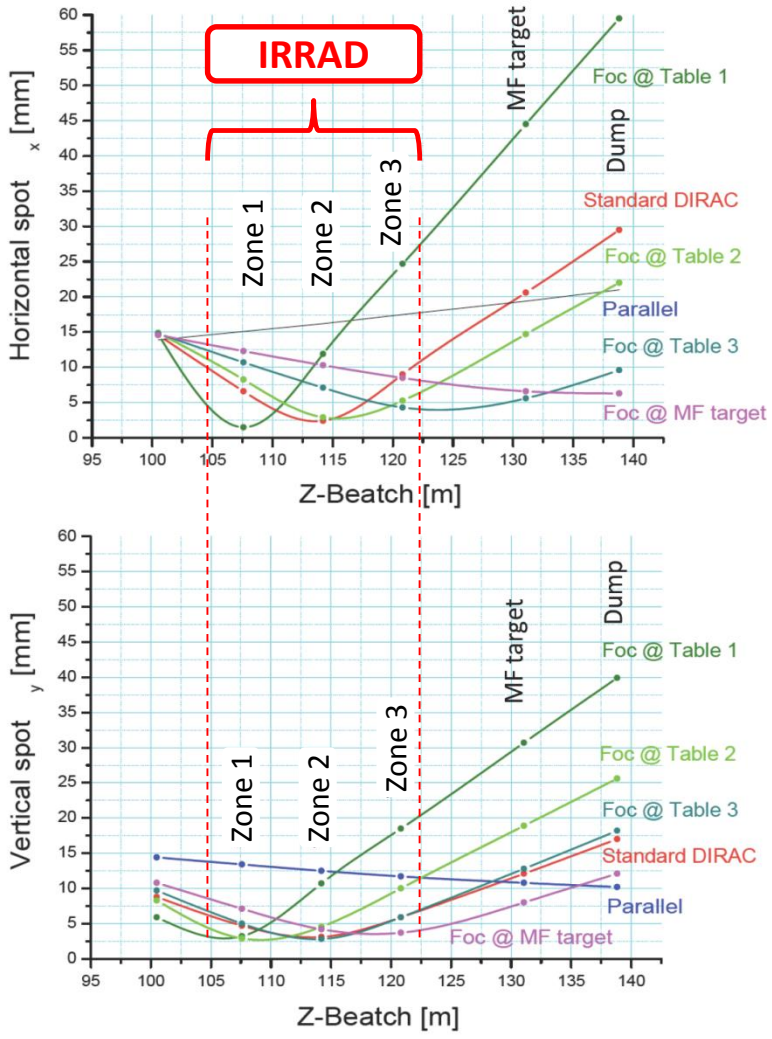
Beam dimension

- **several optic variants possible on T8**
- standard **Gaussian**: **12x12 mm²** (FWHM)
- from **5x5 mm²** to **20x20 mm²** (FWHM)

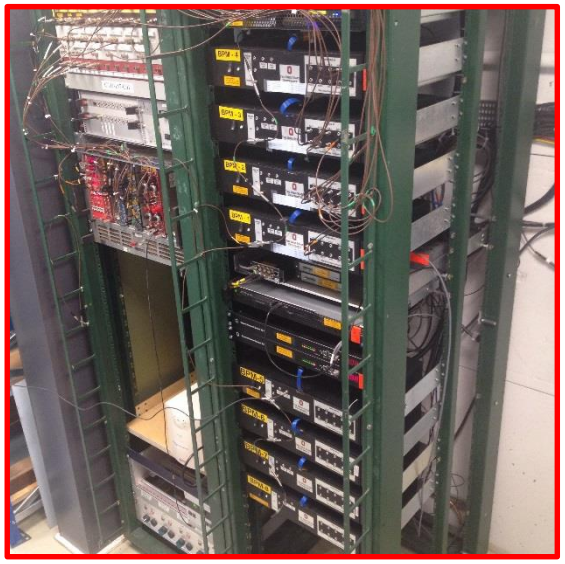
Beam intensity (Zone 1 & 2)

- p^+ are delivered in "spills" of ~3.5×10^{11} p
- number of spills/frequency depends on CPS
- **Typical figure (high intensity)**
  - 3 spills per CPS of 36s.
  - **~1×10^{16} p cm^{-2} 5days^{-1}** (12x12 mm²)
  - **~4x more than the old facilities**
- **Maximum figure (design):** 6 spills per CPS
  - **~1×10^{17} p cm^{-2} 4days^{-1}** (5x5 mm²)
- **Year 2015 (average):** variable CPS + PS efficiency
  - **~>1×10^{16} p cm^{-2} 10days^{-1}** (12x12 mm²)

Here dimensions are mm (RMS)



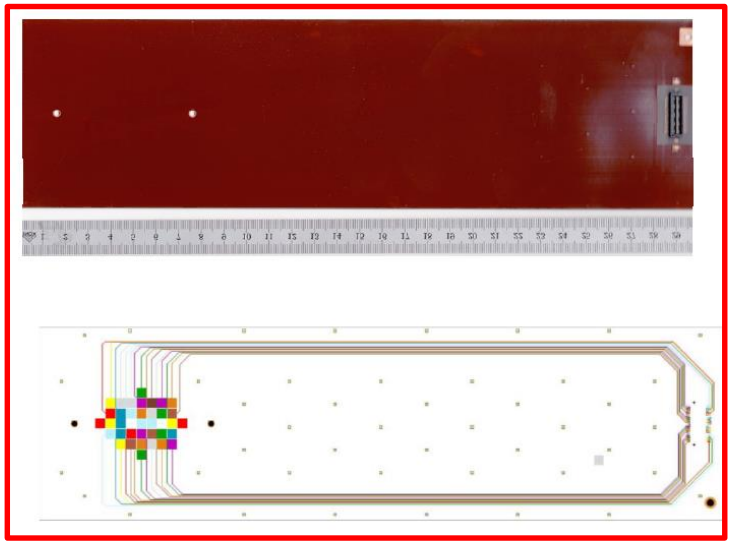
Beam Profile Monitor System



PS timing distribution & BPM rack IRRAD

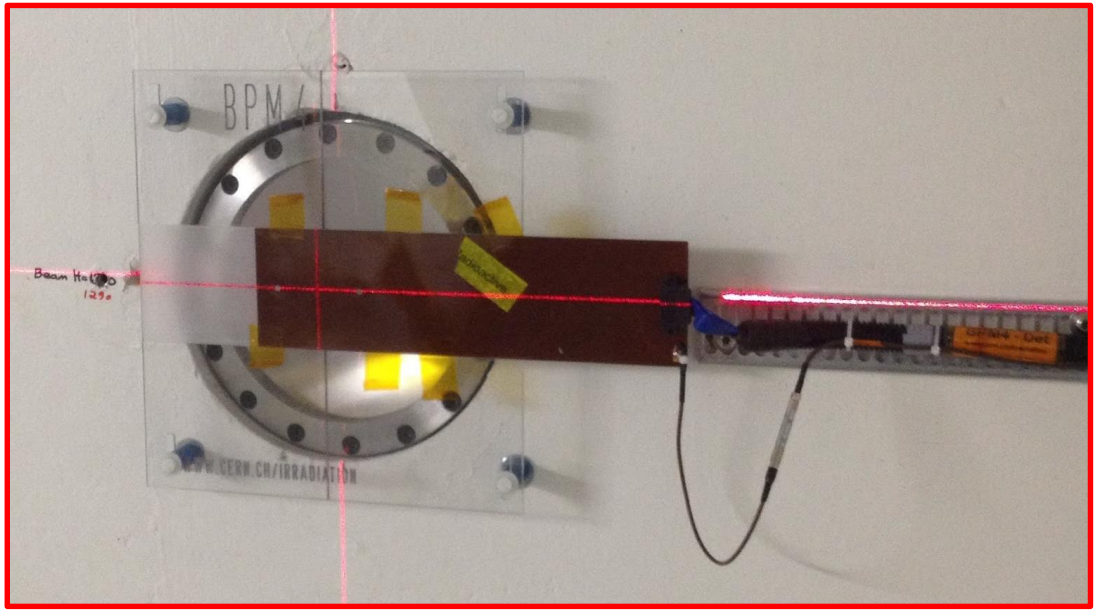
- Metal Foil Detector: pixelated (40 channels) + single PAD
- DAQ: Digitizes BPM detector signals in the 10pA to 500pA range
- Local Server collect and send data to ORACLE Database
  - Beam positions are recorded for later analysis
- Real time information displayed on a web-page and used by:
  - IRRAD OP team and IRRAD Users
  - PS operation team at CERN Control Center (CCC)

Single PAD & 40 channels BPM detector (picture)

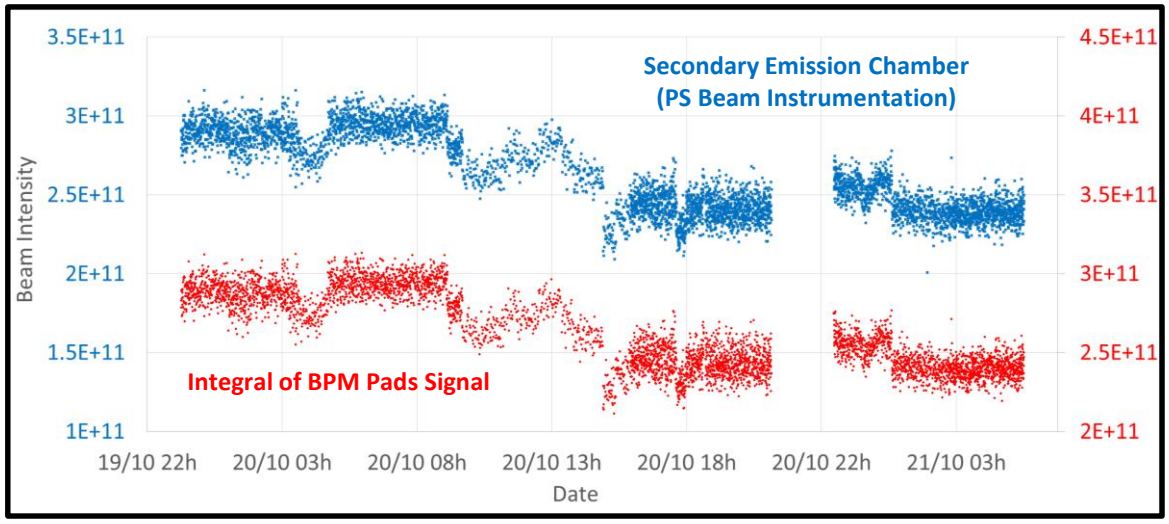


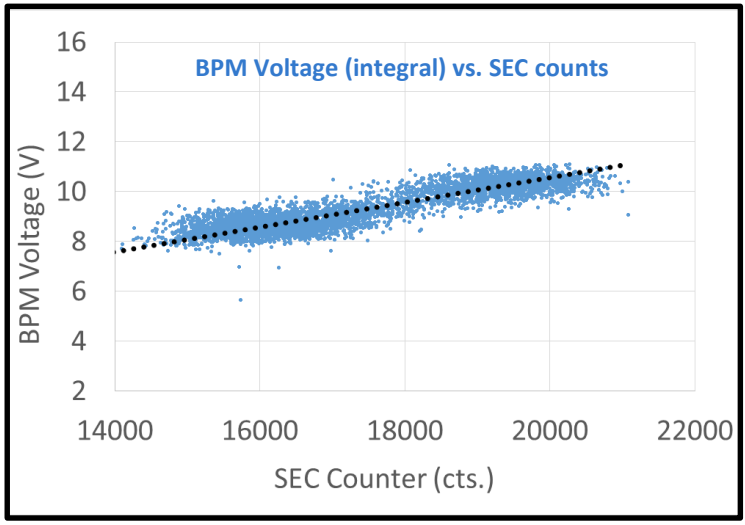
40 channels BPM detector (layout)

Beam Profile Monitor Performance



BPM installed inside the new IRRAD facility





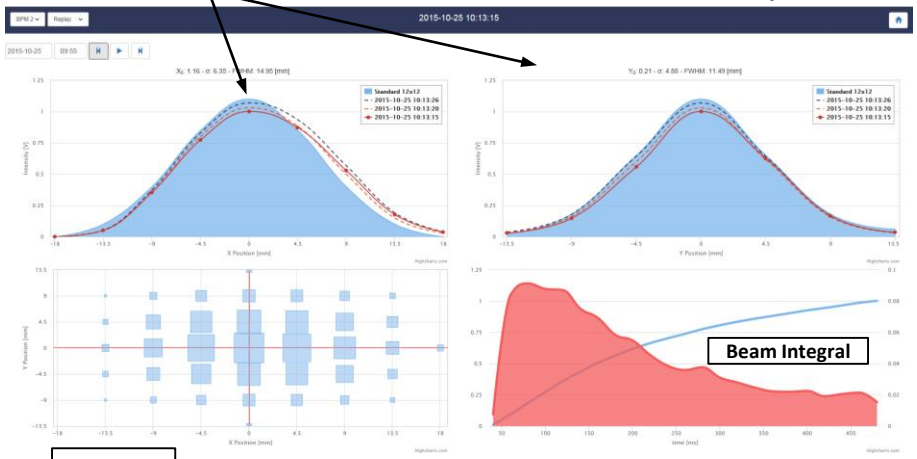
linear behaviour BPM signal vs. beam intensity

Beam Profile Monitor Display

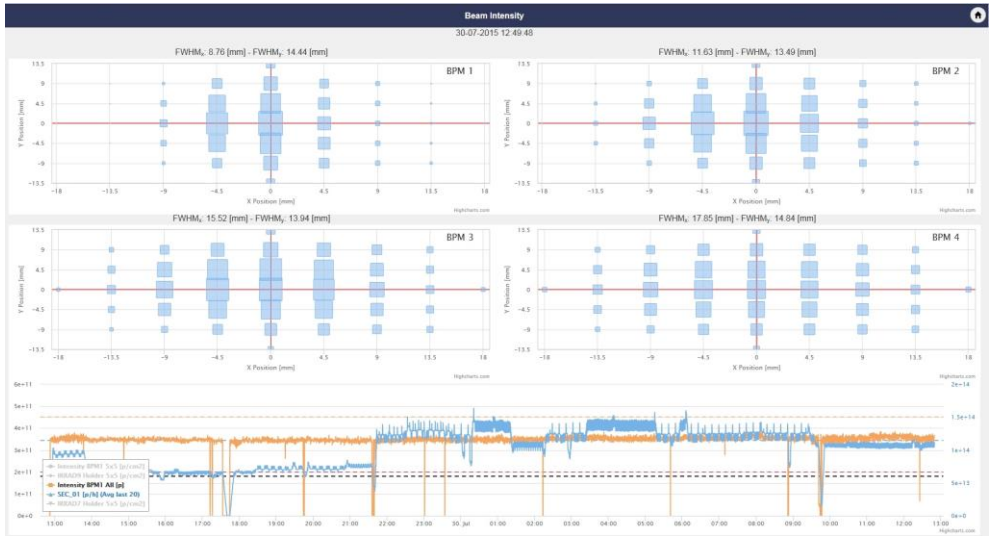
BPM "all" Page

Horizontal and Vertical Beam Profiles

"reply" function to display the archived beam profile data

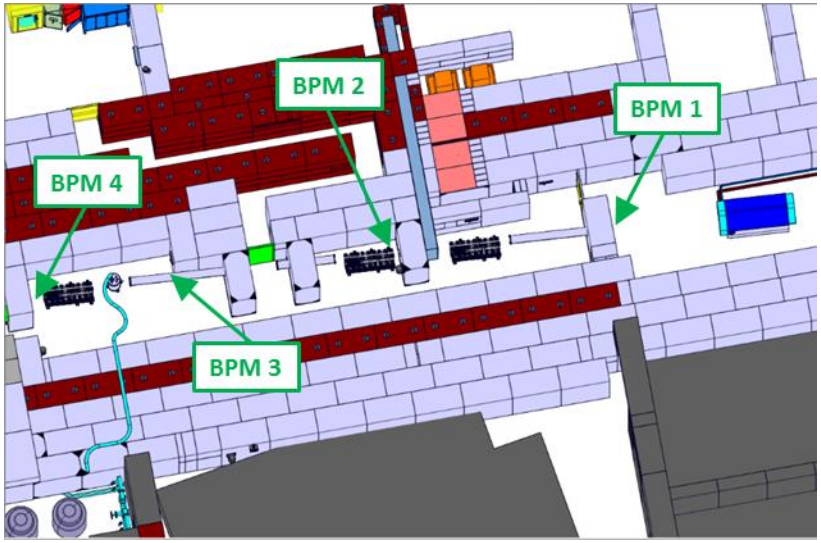


BPM PADs



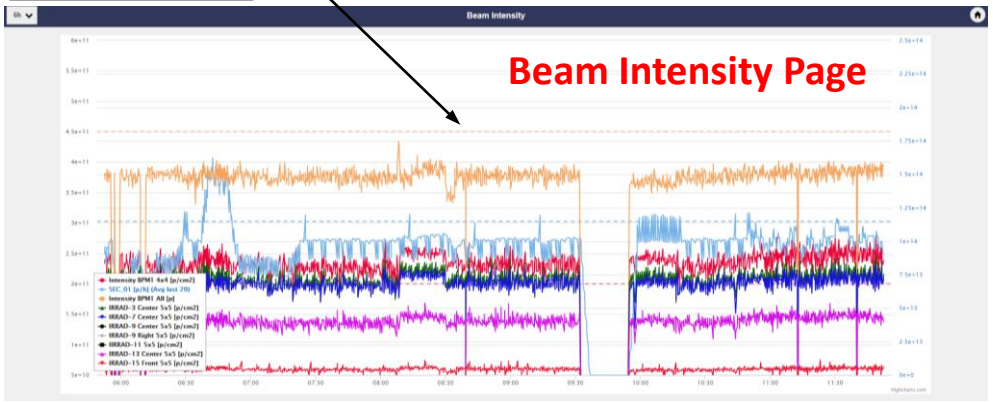
The summary page allows the simultaneous monitoring of the beam position along the IRRAD facility (beam steering)

BPM Display Page



Beam Intensities from both multi-pads and single pad BPM detectors

Beam Intensity Page



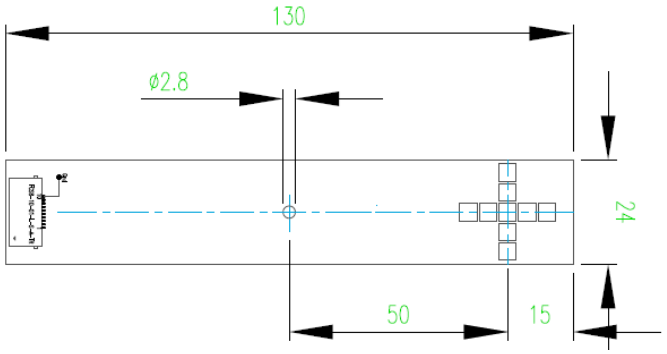
The single pad BPM detectors are used during IRRAD operation to monitor on-line the position of the irradiation equipment

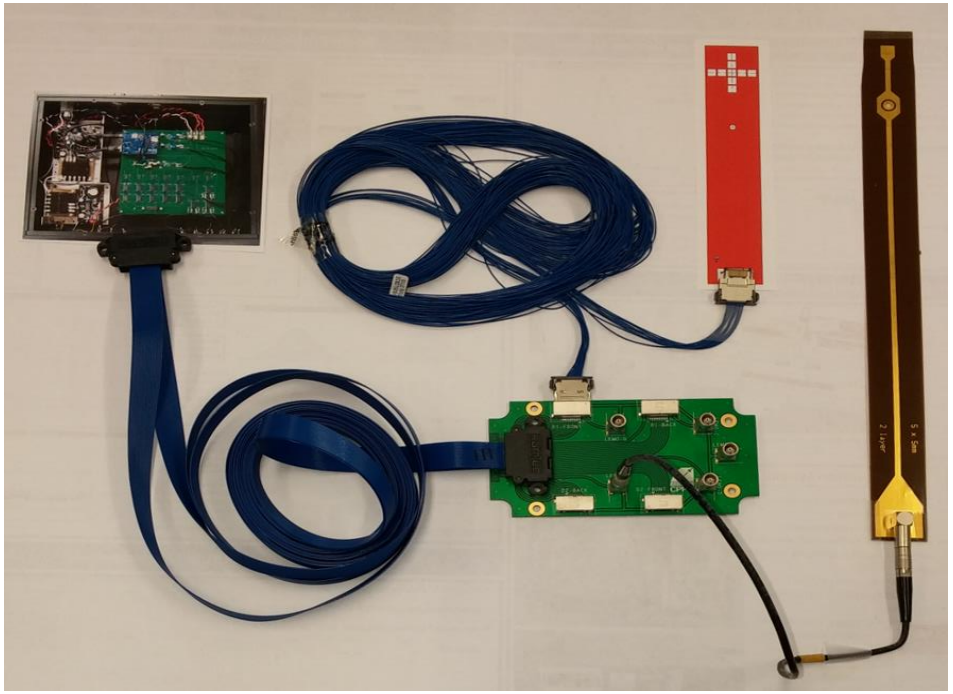
www.cern.ch/opwt/irrad

Beam Profile Monitor Upgrade

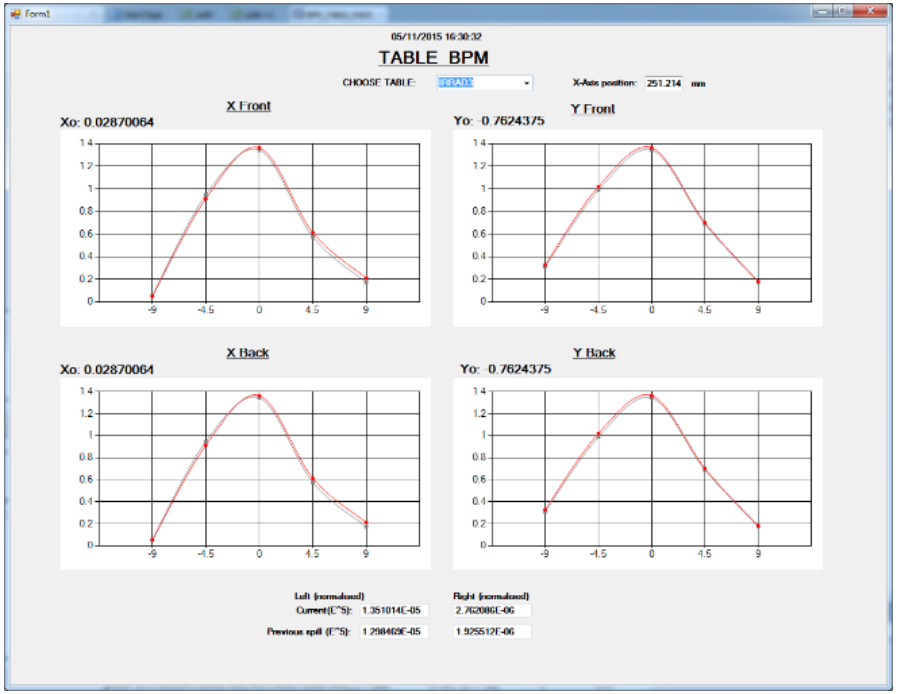
Future Upgrade

- **Mini-BPM device** for precise alignment of irradiation equipment and or “big” samples
- **Increased space resolution** w.r.t. single BPM devices





Up to 4 mini-BPM and 4 pad readout with one system

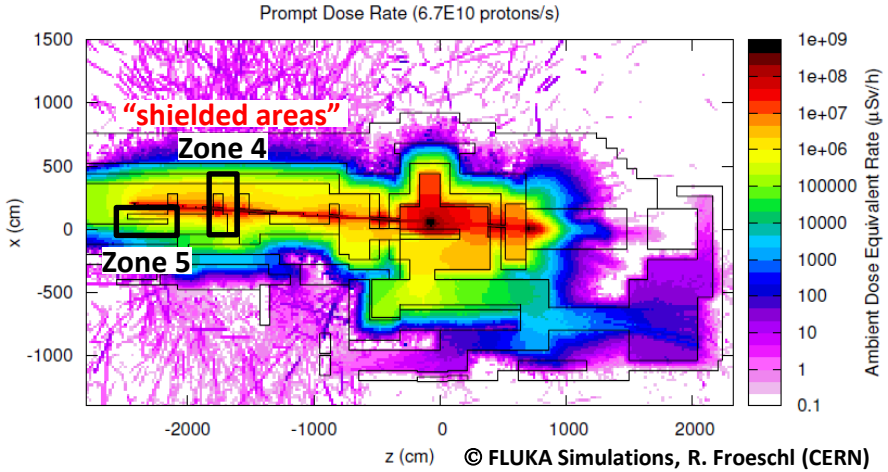


Mini-BPM profiles for alignment

Radiation Background & Proton NIEL

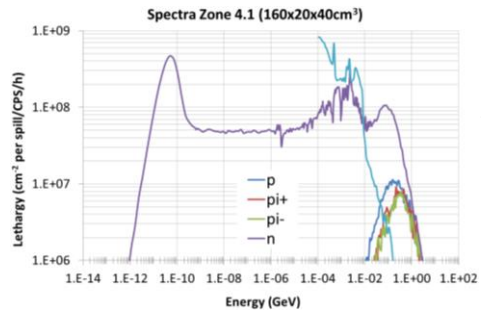
Monte Carlo Simulations (FLUKA)

- Radiation Protection Optimization
- Evaluation of IRRAD Facility background



Zone 4

Radiation Type	Energy	Intensity (cm^{-2} h^{-1})
protons	~ 200 MeV (peak)	~ 5×10^{7}
pions (+)	~ 300 MeV (peak)	~ 3×10^{7}
pions (-)	~ 300 MeV (peak)	~ 3×10^{7}
neutrons (all)	thermal – few GeV	~ 2.5×10^{9}
neutrons	> 20 MeV	~ 3×10^{8}



for **4×10^{13} p/cm²/h** (std. spot size)

Total Dose in Zone 4:

~0.13-0.15 Gy/h (air KERMA)

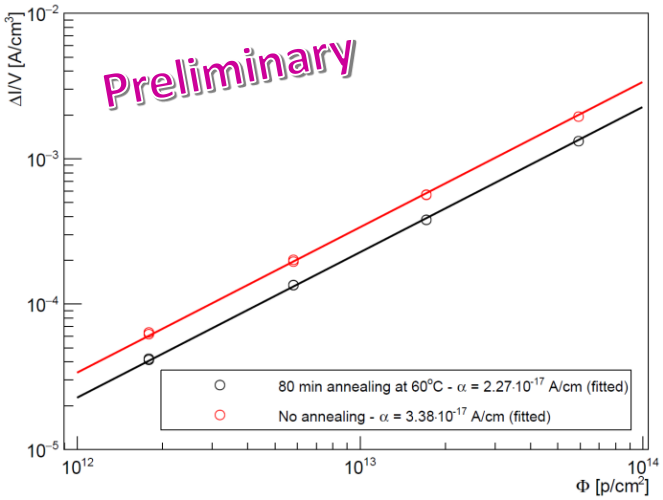
Dosimetric Measurements

Preliminary

- **Zone 4**
  - Total Dose **~0.10 Gy/h** (Film HD-810)
  - Φ_{eq} **~3.8×10^{8} $n_{(1MeV)}/cm^2/h$** (Si diodes)
- **Zone 5**
  - Total Dose: **about x2 lower**
  - good agreement with simulations

Non-Ionizing Energy Loss (NIEL)

- **Experimental determination of <u>hardness factor</u>**
  - Silicon PAD detector samples
  - ***k* = 0.57-0.58** (theoretical *k* = 0.51)

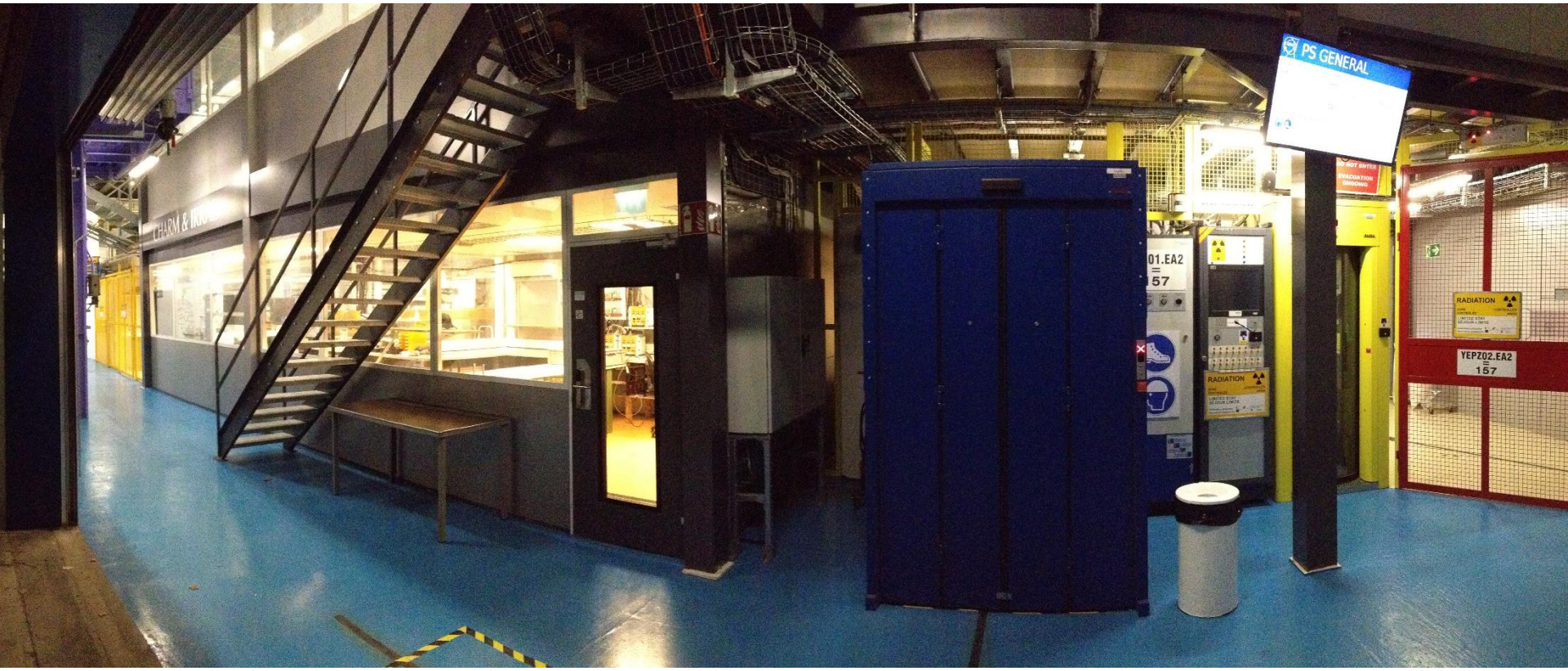


Summary

- **New IRRAD Proton Facility is fully operational**
  - Extensive description of the new infrastructure and irradiation equipment
    - **8 irradiation tables** for room- & low-temperature experiments (up to 24 users installed)
    - **1 shuttle system**
    - **1 cryogenic setup**
  - Future Upgrade
    - BPM devices
- **IRRAD Proton Facility in 2015**
  - **30** weeks of beam time
  - **28** user teams
  - from **18** institutes/experiments/R&D's
    - **>300 samples** (active/passive)
    - **>250 dosimeters** measured (Al foils)
- **Contacts:**
  - URL: www.cern.ch/ps-irrad
  - e-mail: irradiation.facilities@cern.ch

EA-IRRAD: aerial view of radiation shielding

Thank you for your attention!



IRRAD Facility Control Room (left-hand side) and access point to the irradiation area (right-hand side)