

IRRAD

The New 24GeV/c Proton Irradiation Facility at CERN

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CERN EP/DT/DD, IRRAD Facility Team



- ❑ **Need for Proton Irradiation Facility & Phase II Requirements**
- ❑ **PS East Area Irradiation Facilities until 2012**
- ❑ **New PS East Area Irradiation Facilities from 2014**
 - ❑ **Proton Facility (IRRAD)**
 - ❑ **Mixed-Field Facility (CHARM)**
- ❑ **IRRAD Proton Facility Infrastructure & Equipment**
- ❑ **Beam Parameters / Characterization & Dosimetry Measurements**
- ❑ **Summary & Run 2016**

□ Radiation damage studies on:

- **materials** used around accelerators/experiments
 - structural materials, glues, pipes, insulations, thermal materials, ...
- **electronic components**
 - transistors, memories, COTS, ASIC, ...
- **semiconductor** and **calorimetry** devices
 - silicon diodes, detector structures, scintillating crystals ...
 - **equipment sitting in the inner/middle layers of HEP experiments**

□ Test of prototypes & final assemblies before installation:

- performance **degradation after long exposure**/ageing (TID, NIEL, ...)
 - *Irradiation experiments usually precede test-beams*
- functional **degradation of electronics** (SEU, latch-up, ...)

□ Test and calibration of components:

- **dosimeters**, radiation monitoring / measurement devices

❑ Radiation levels for LHC Experiments phase II upgrade (2025)

Max expected hit rates and integrated charges

Numbers refer to the hottest regions extrapolating the behavior of the present systems

	ATLAS				CMS			LHCb		ALICE	
Lumi	CSC	MDT	RPC	TGC	CSC	DT	RPC	Lumi	MWPC	Lumi Pb-Pb	RPC
$7 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ 25 fb ⁻¹	20	10	3	21	3	0.1	3	$4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ 3 fb ⁻¹			
	770	280	13	100	170	2	14				
$1 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ 100 fb ⁻¹	80	40	11	84	12	0.35	12	$4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$ 8 fb ⁻¹			
	1100	400	18	140	250	3	20				
$3 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ 350 fb ⁻¹	280	140	38	280	41	1.2	42	$1 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ 23 fb ⁻¹			
	3300	1200	54	430	750	9	60				
$7 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ 3000 fb ⁻¹	2400	1200	330	2450	350	10	360	$2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ 46 fb ⁻¹			
	7700	2800	130	1000	1700	20	140				

Additional tests needed on some detectors to assess their behavior during all HL-LHC

Common test facility

► 9

P. Iengo - Muon longevity - ECFA HL-

© P. Iengo (ECFA HL-LHC 2013)

inner detectors (trackers):
 $> 10^{16} \text{ 1MeV}_{\text{neq}}/\text{cm}^2$

outer (muon) detectors:

$\gamma\text{-BKGD} \sim \mathcal{O}(10)$ w.r.t. LHC

Crosscheck with ATLAS Phase II LOI

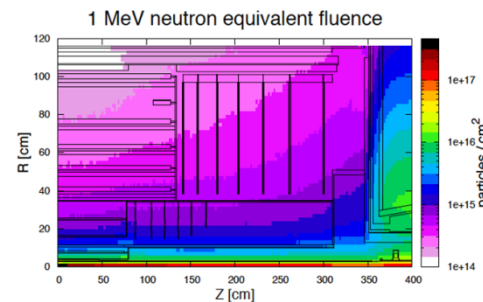


Figure 6.2: RZ-map of the 1 MeV neutron equivalent fluence in the Inner Tracker region, normalised to 3000 fb⁻¹ of 14 TeV minimum bias events generated using PYTHIA8.

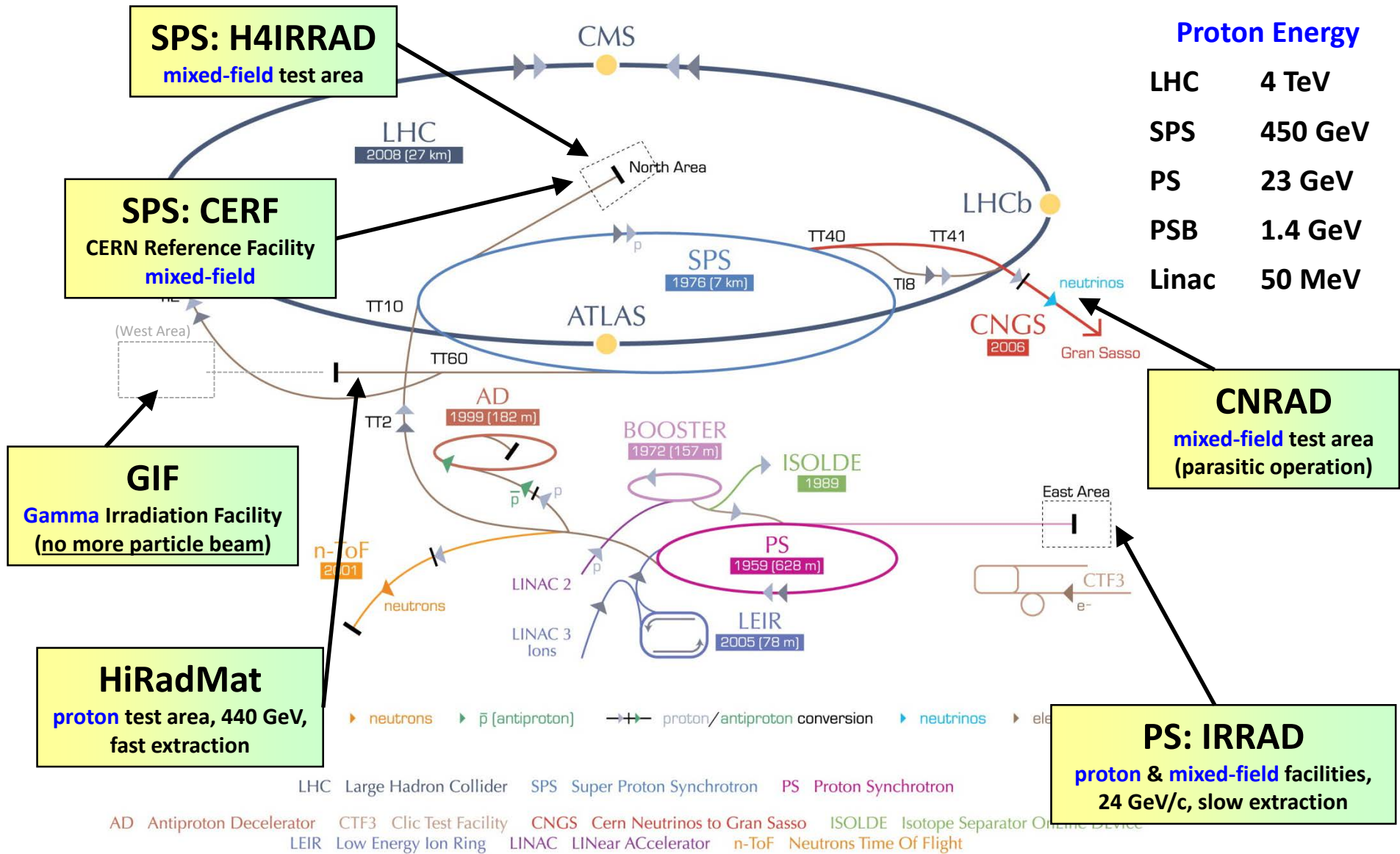
3000 fb⁻¹
80mb inelastic pp crosssection
 2.4×10^{17} events
 $dN/d\eta = N_0 = 5.4$ at 14 TeV
Pixel layer1 at $r=3.7\text{cm}$

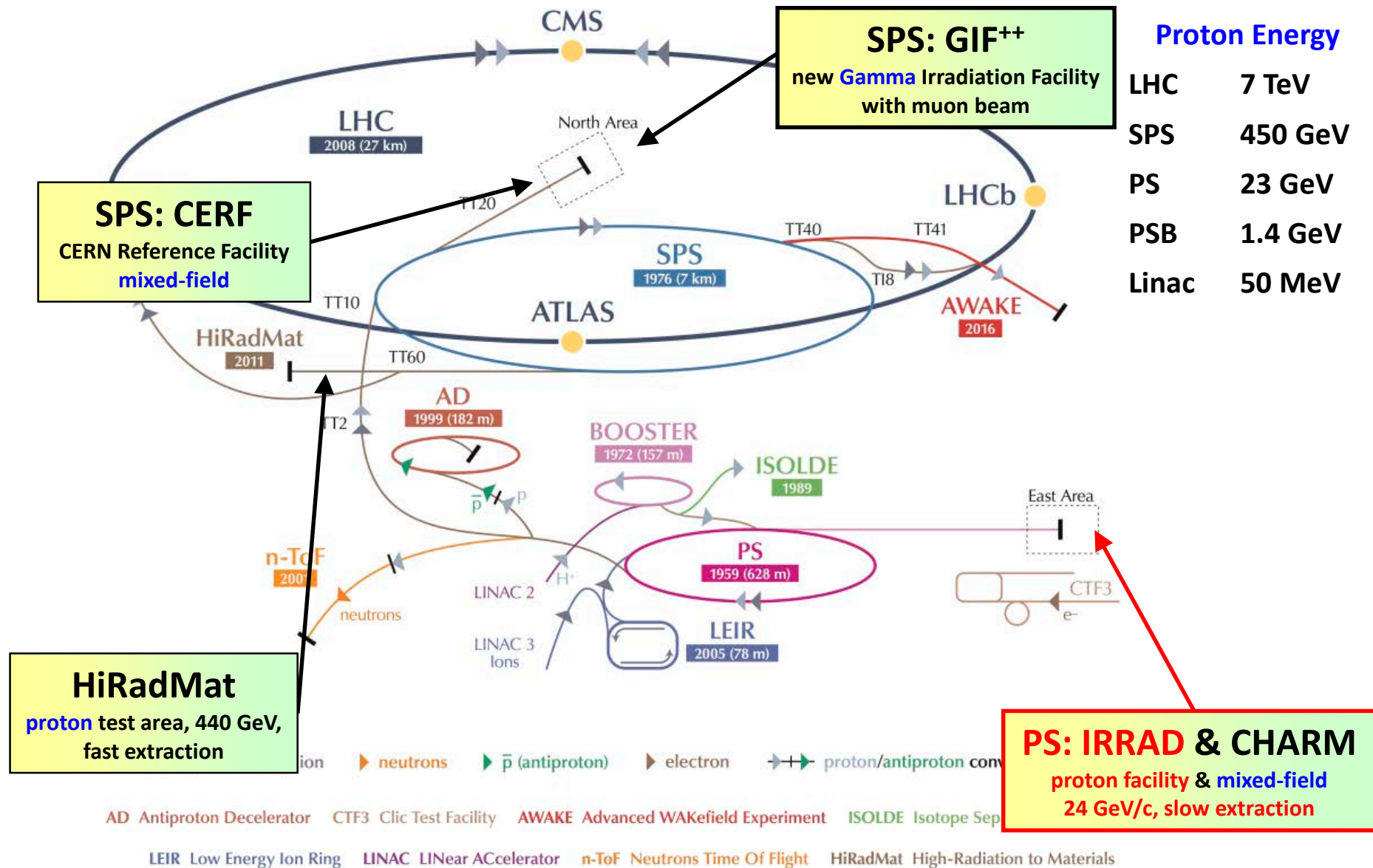
1MeV_{neq} Fluence =
 $2.4 \times 10^{17} \times 5.4 / (2 \times \pi \times 3.7^2) =$
 $1.5 \times 10^{16} \text{ cm}^{-2}$

Dose = $3.2 \times 10^{-8} \times 1.5 \times 10^{16} =$
 4.8 MGy

Layer	Occupancy with 200 pile-up events (%)			
	Radius mm	Barrel (z = 0 mm)	Z mm	Endcap
Pixel: layer 0	37	0.57	Disk 0 710	0.022–0.076

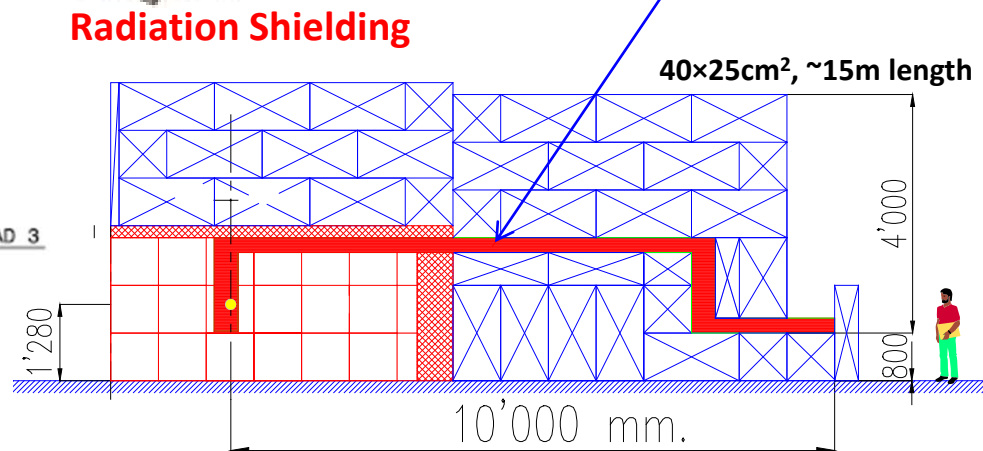
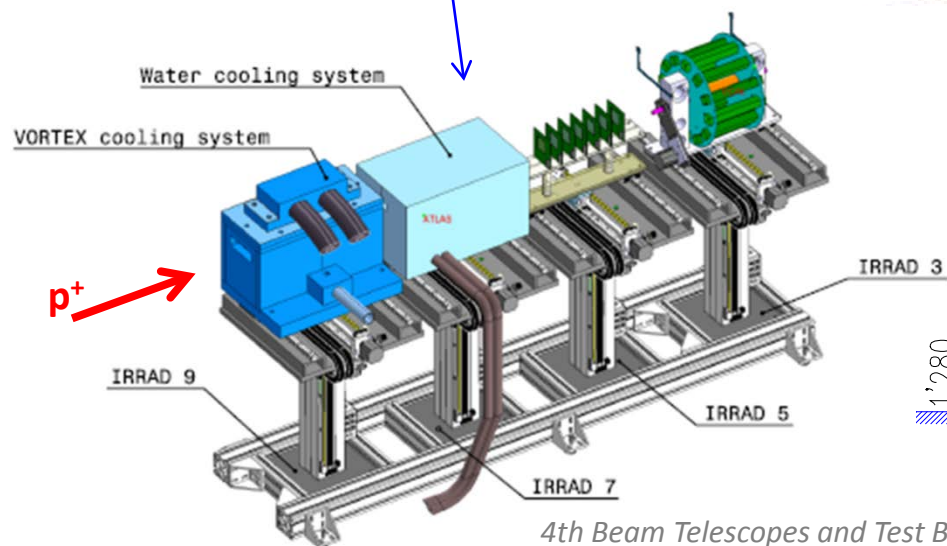
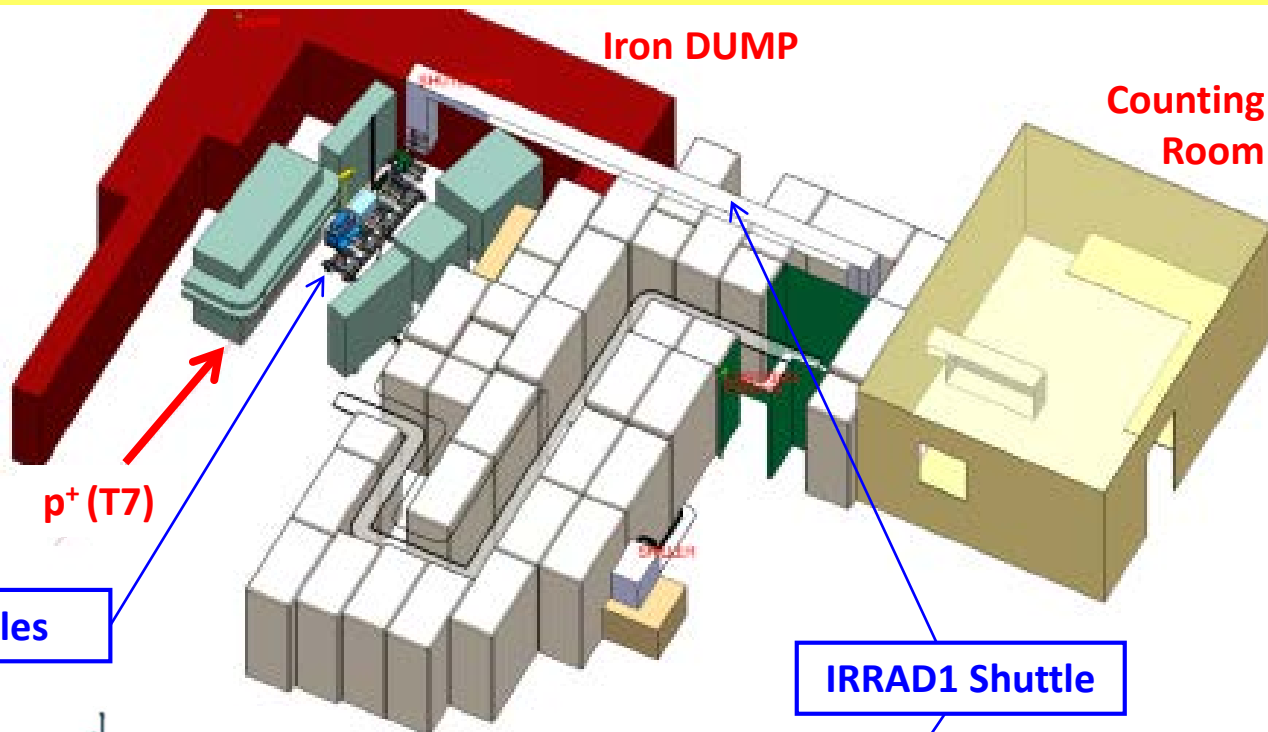
The predictions for the maximum 1MeV-neq fluence and ionising dose for 3000fb⁻¹ in the pixel system is $1.4 \times 10^{16} \text{ cm}^{-2}$ and 7.7 MGy at the centre of the innermost barrel layer. For the







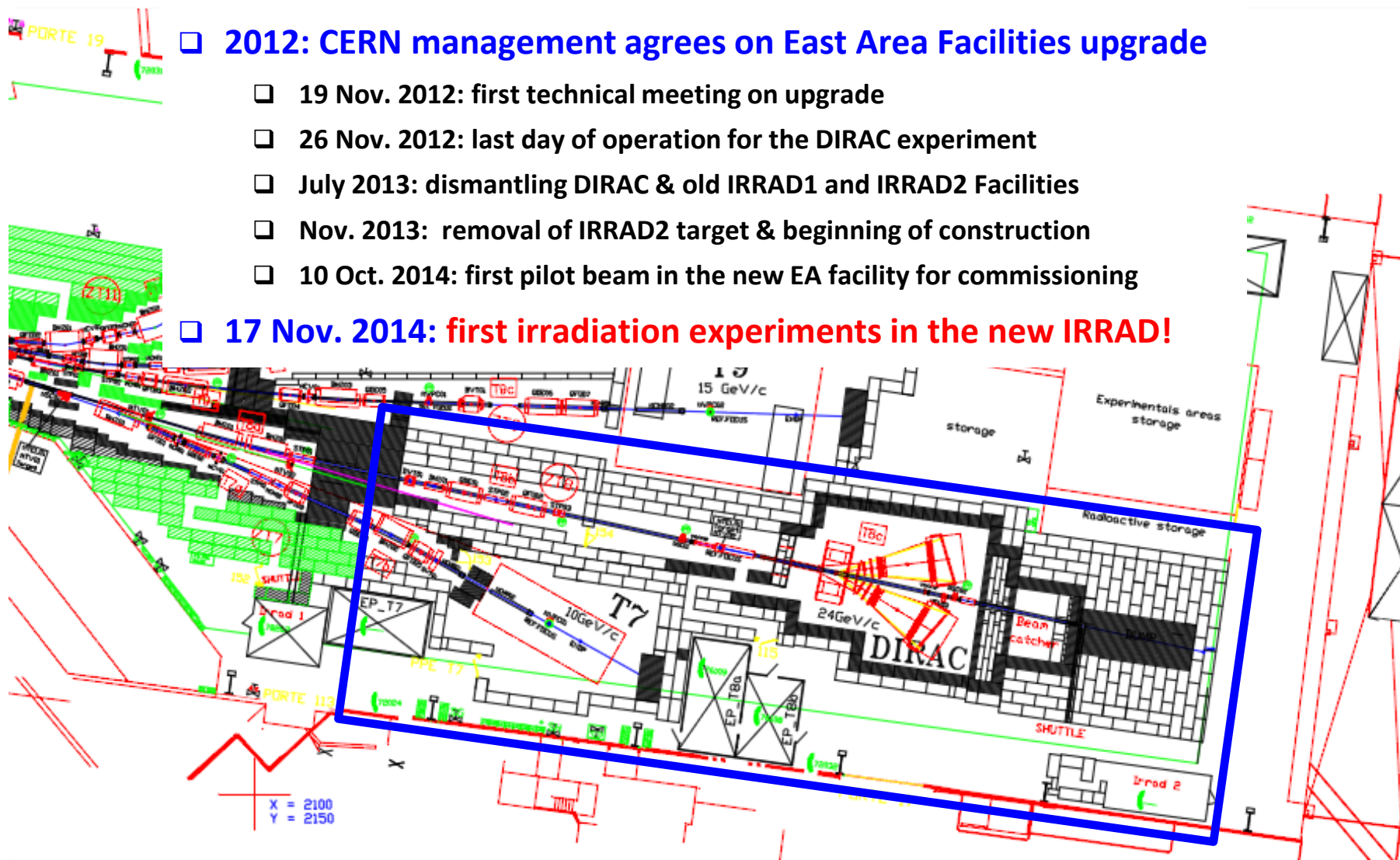
- ❑ **Beam spot**
12×12 mm² (FWHM)
- ❑ **Beam momentum**
24 GeV/c
- ❑ **Proton flux**
 $\sim 1 \times 10^{16} \text{ p cm}^{-2} \text{ 20days}^{-1}$
(year average)



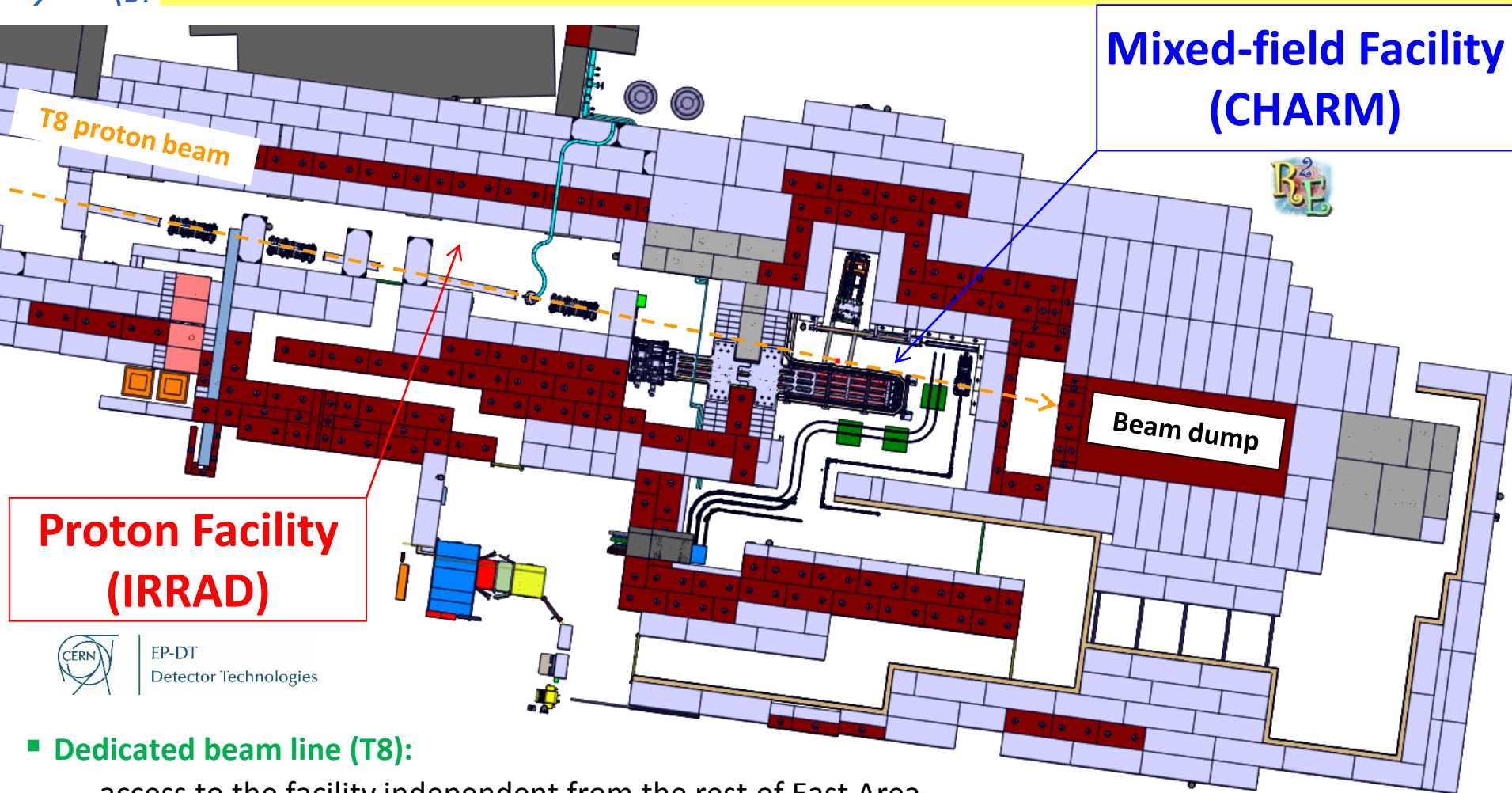
2012: CERN management agrees on East Area Facilities upgrade

- ❑ 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), ...



**Proton Facility
(IRRAD)**

**Mixed-field Facility
(CHARM)**

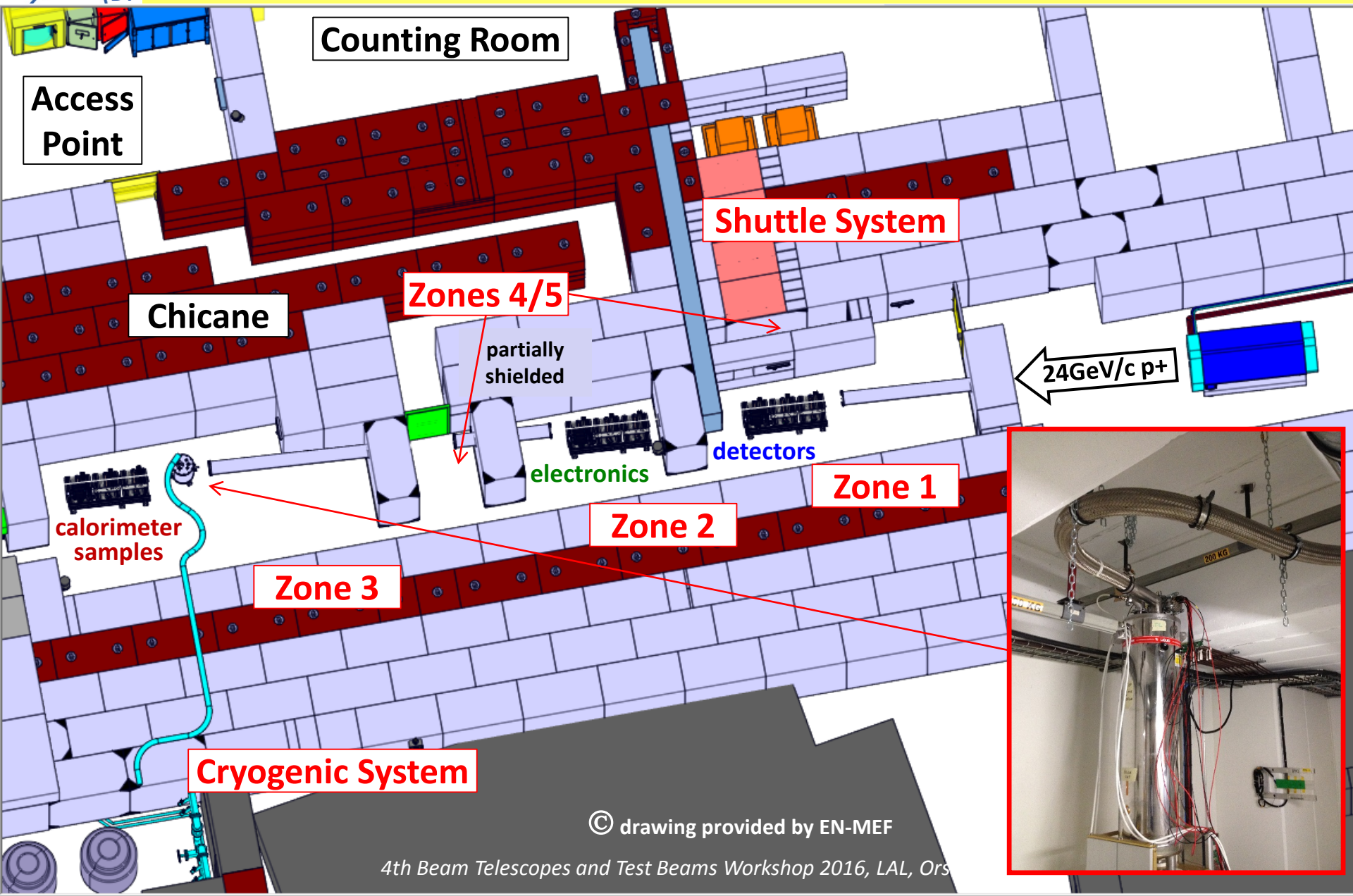
Beam dump

■ 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!**)



- ❑ DUTs powered and cooled
- ❑ $V_{\max} = 20 \times 20 \times 50 \text{ cm}^3$ (standard); «scanning» over surface

Water cooling system

Temp. Control down to -25°C

VORTEX cooling system

Temp. Control down to -20°C



Control Unit

IRRAD9

IRRAD11

IRRAD13

θ

x

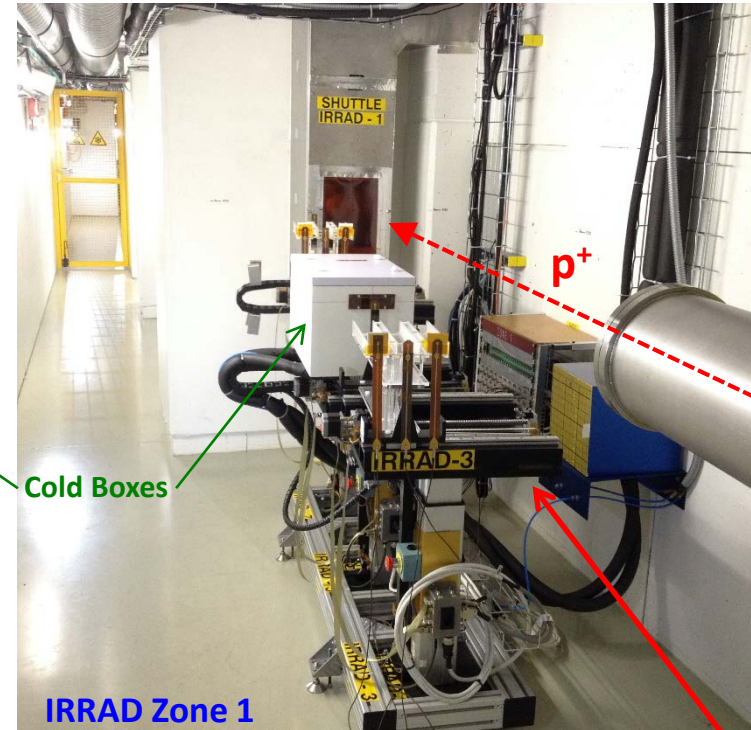
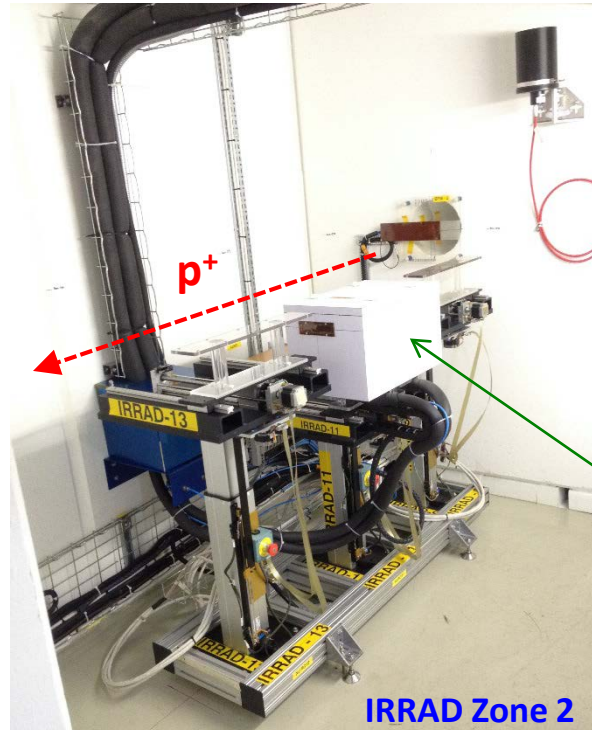
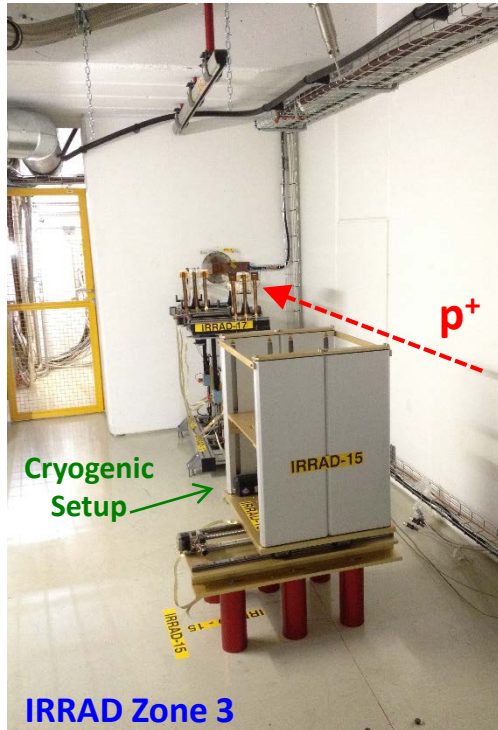
beam

y



Irradiation Table

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



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

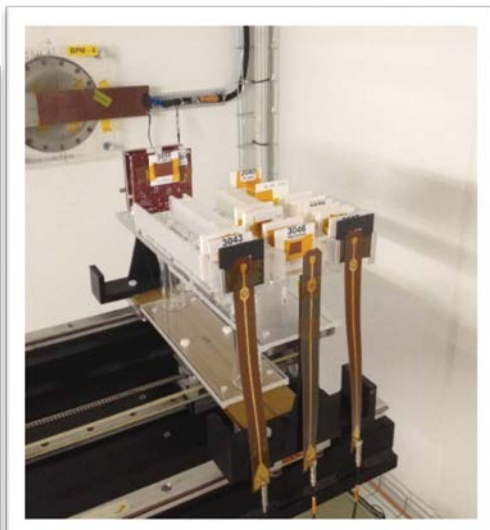
Cables length from
~13m to ~20m



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

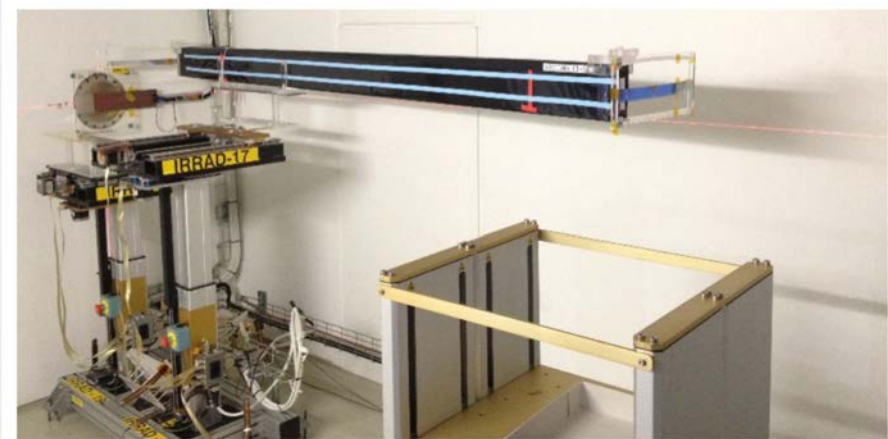
RT Irradiation Setup

Users-made supports



Small samples support (cardboards)

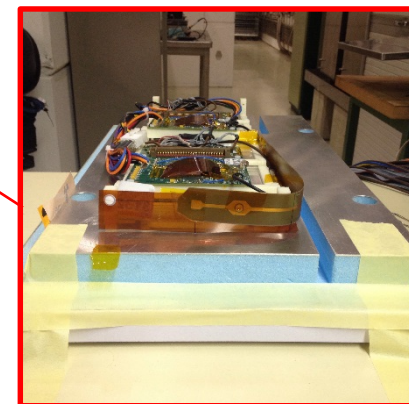
Complex Irradiation experiment (*LHCb SciFi prototype*)



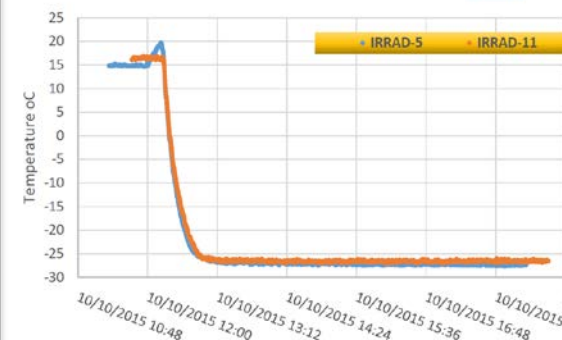
Cold boxes from AIDA (QMUL/Sheffield, UK)



DUTs installed under the box cover lid

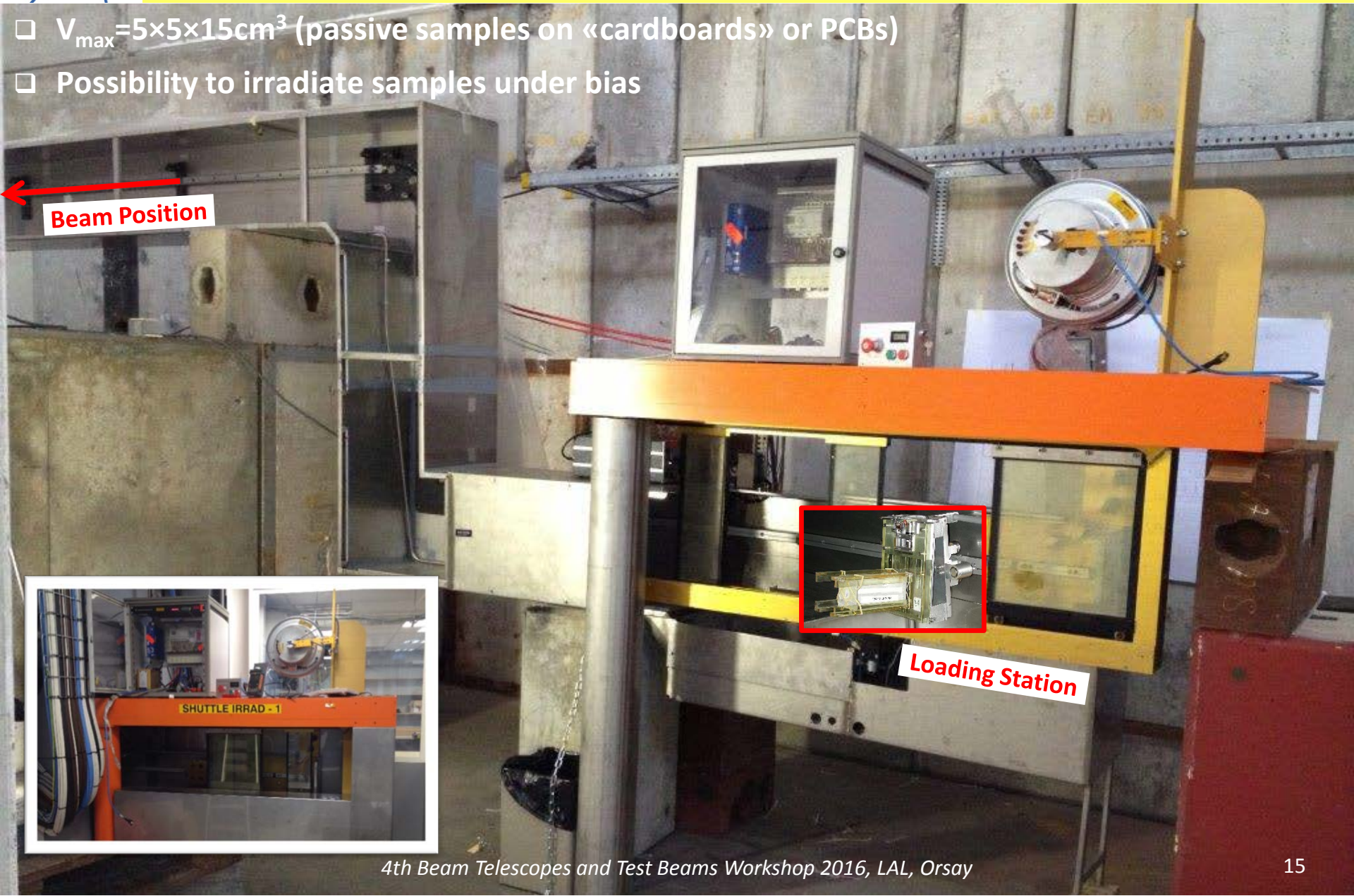


Cold Boxes Performance



Chiller Units
Thermo-fluid: *Si/Oil*

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



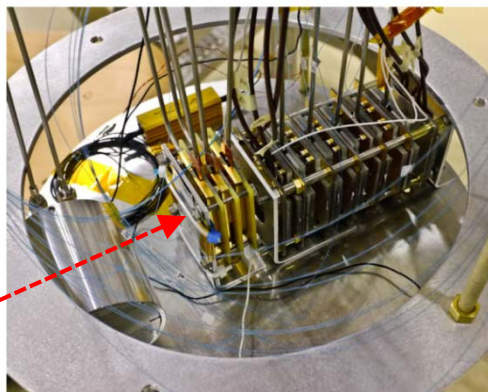
Cryogenic Setup IRRAD15



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

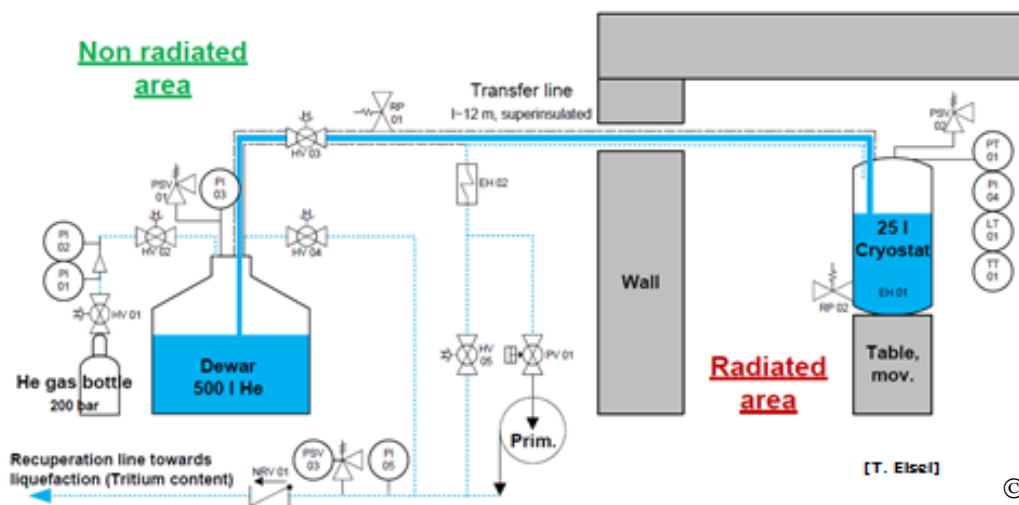


Picture:
Nov. 2015

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

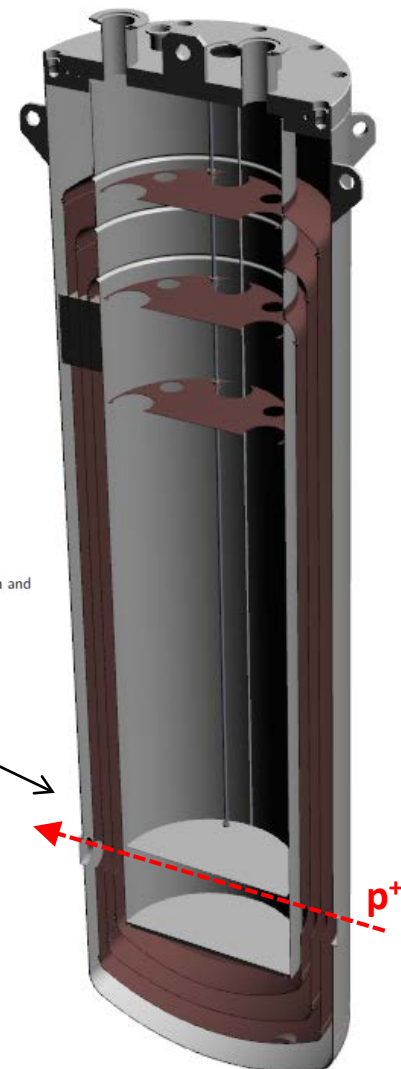


[T. Elser]

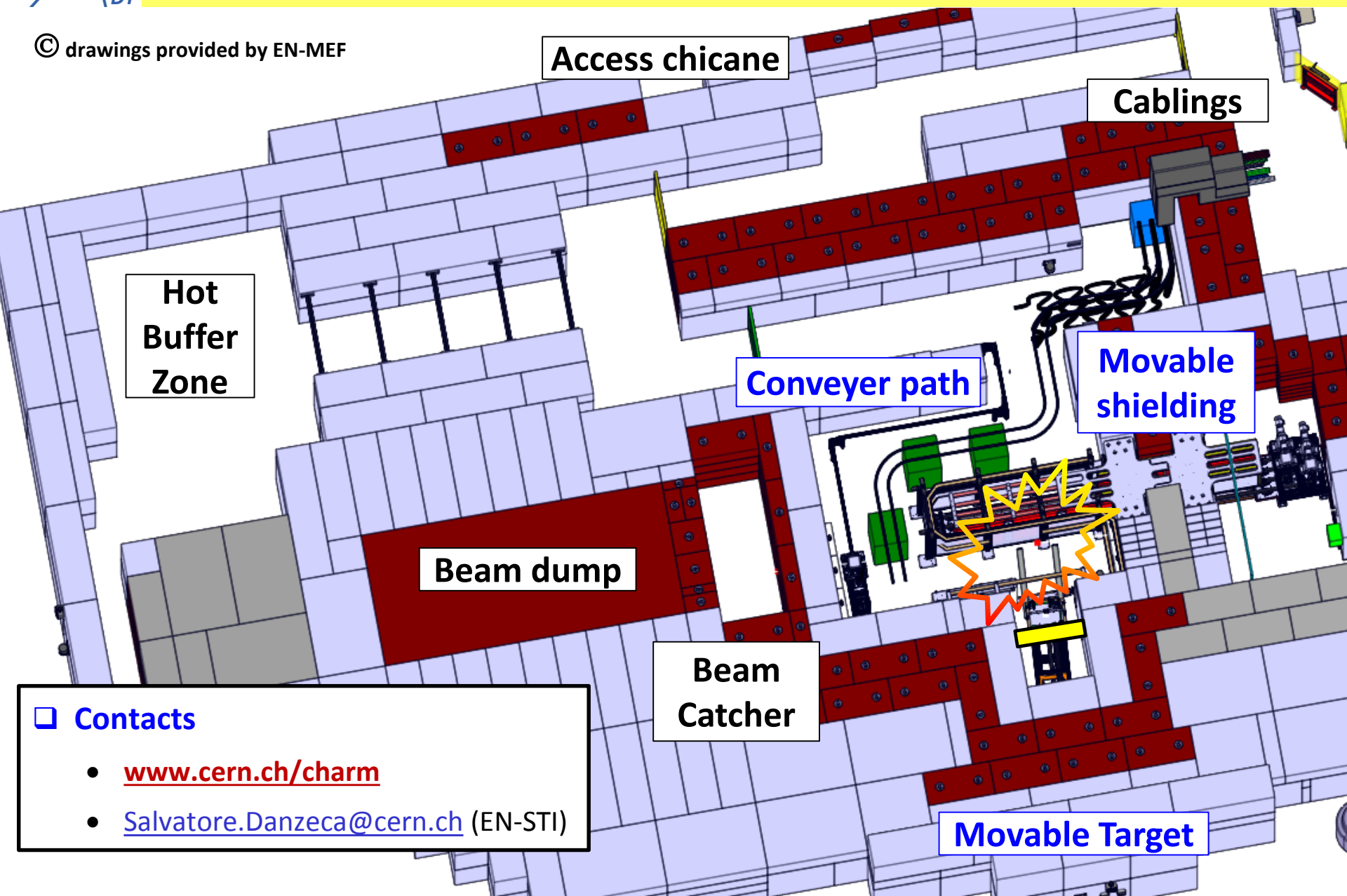
© CERN BE/BI and TE/CRG groups

4th Beam Telescopes and Test Beams Workshop 2016, LAL, Orsay

Samples
position



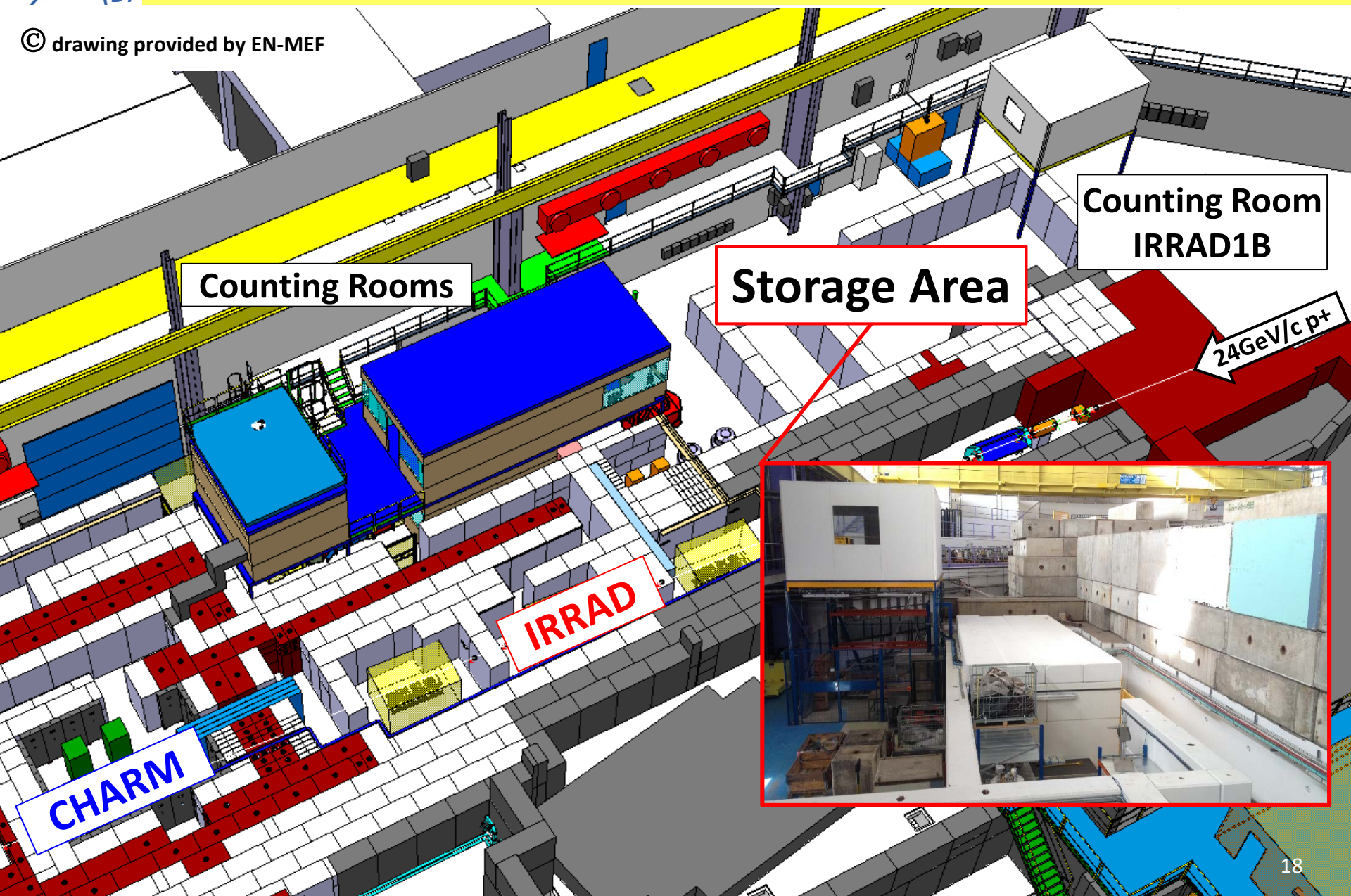
© drawings provided by EN-MEF



□ Contacts

- www.cern.ch/charm
- Salvatore.Danzeca@cern.ch (EN-STI)

© drawing provided by EN-MEF

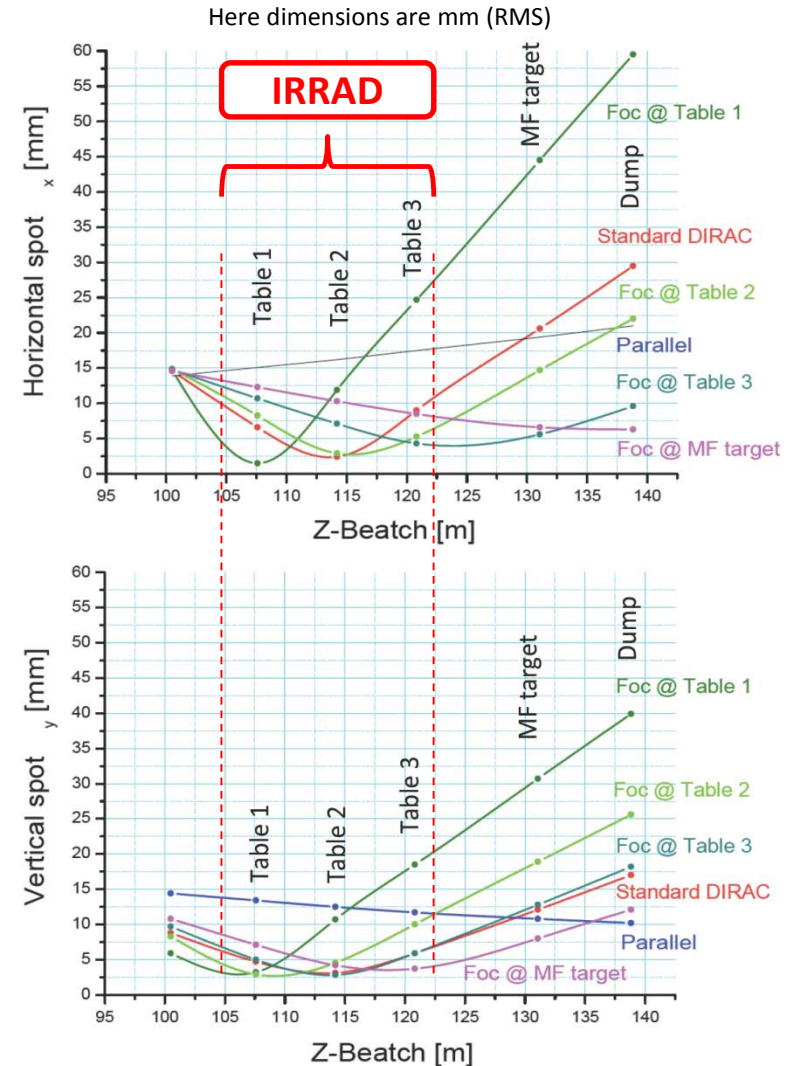


□ Beam dimension

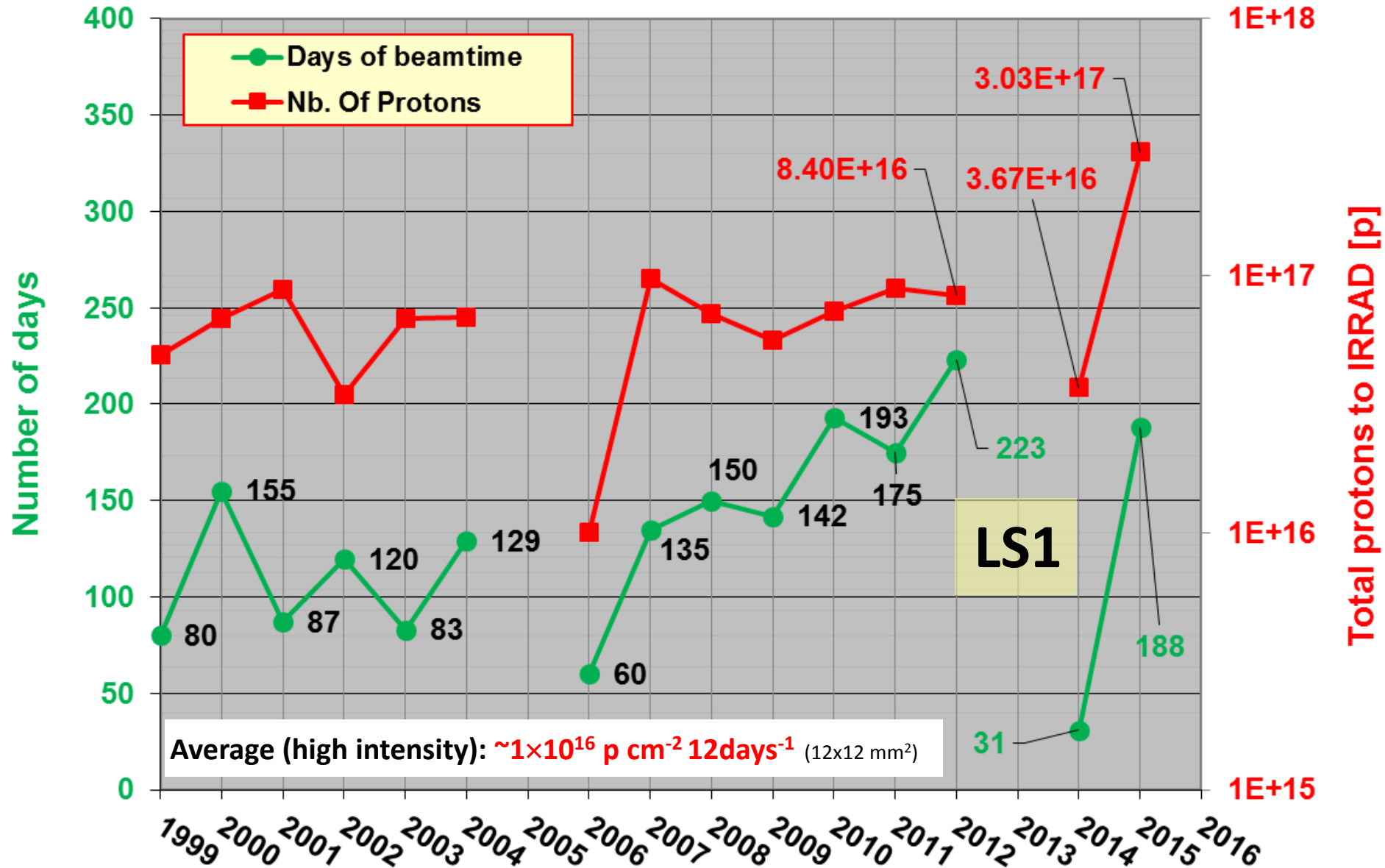
- **several optic variants possible on T8**
- standard **Gaussian**: 12x12 mm² (FWHM)
- from 5x5 mm² to 20x20 mm² (FWHM)

□ Beam intensity

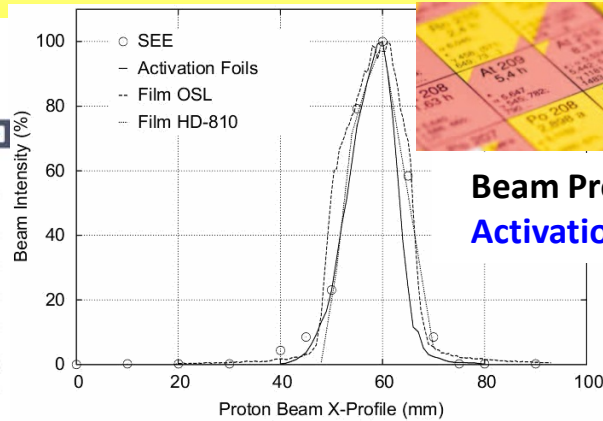
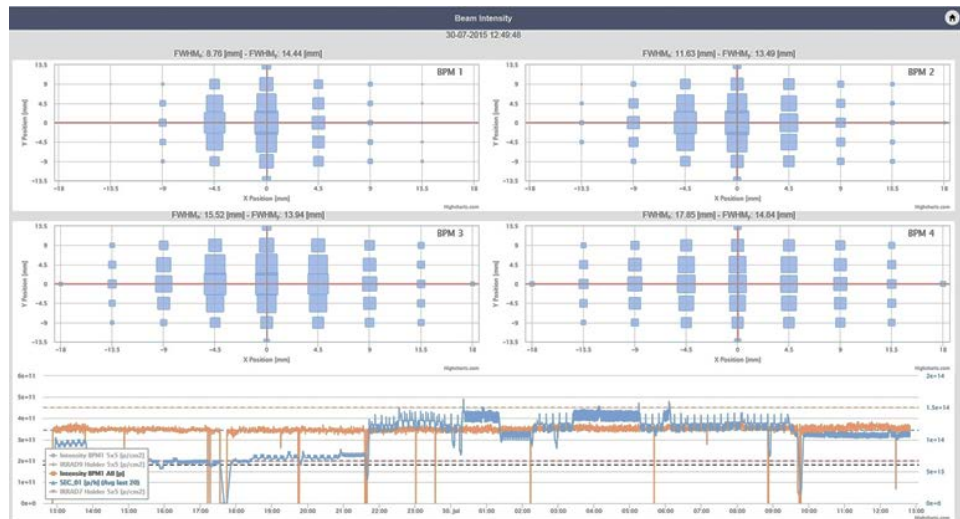
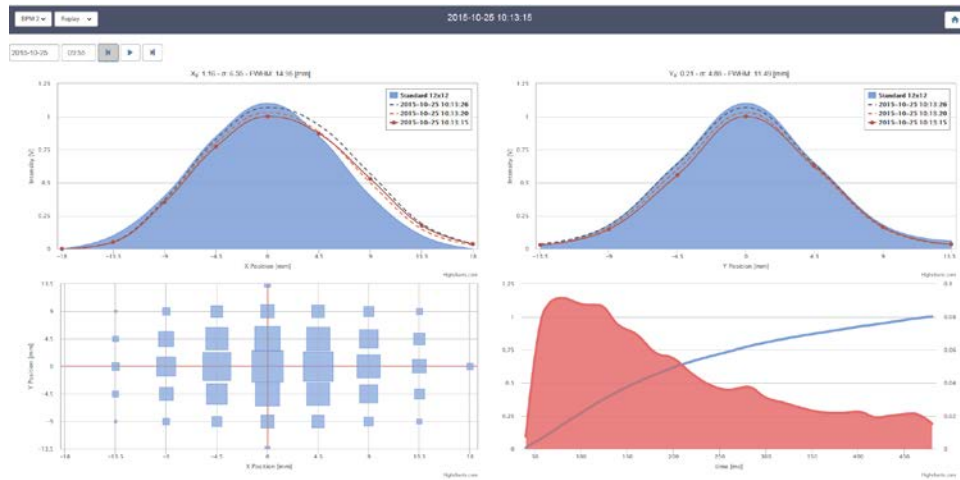
- p⁺ are delivered in “spills” of $\sim 3.5 \times 10^{11}$ p
- number of spills/frequency depends on CPS
- **Typical figure (high intensity)**
 - 3 spills per CPS of 36s.
 - **$\sim 1 \times 10^{16}$ p cm⁻² 5days⁻¹ (12x12 mm²)**
 - **~ 4 x more than the old facilities**
- **Maximum figure (design): 6 spills per CPS**
 - **$\sim 1 \times 10^{17}$ p cm⁻² 4days⁻¹ (5x5 mm²)**



Proton Beam in run 2015



Beam Profile Monitors (BPM)



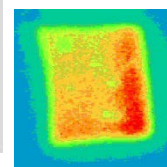
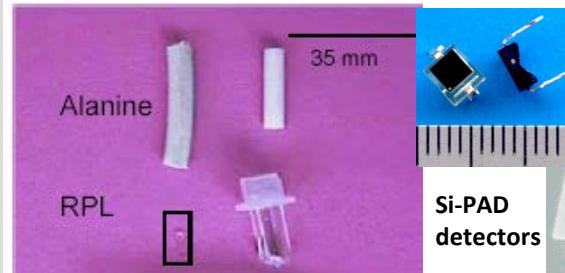
Beam Profile / Intensity from
Activation of Aluminium foils

$^{27}\text{Al}(p,3p)^{24}\text{Na}$ $^{27}\text{Al}(p,3p3n)^{22}\text{Na}$
1x NaI spectrometer (+/- 6%)

^{24}Na , half-life 15h, $E_\gamma = 1368.53$ keV

2x HpGe spectrometer (+/- 2%)

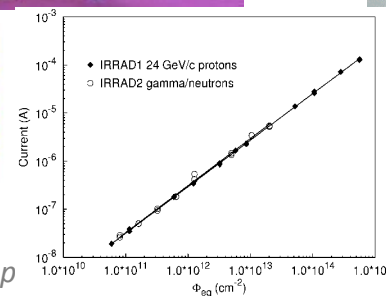
^{22}Na , half-life 2.6y, $E_\gamma = 1274.54$ keV



Radiochromic
Films

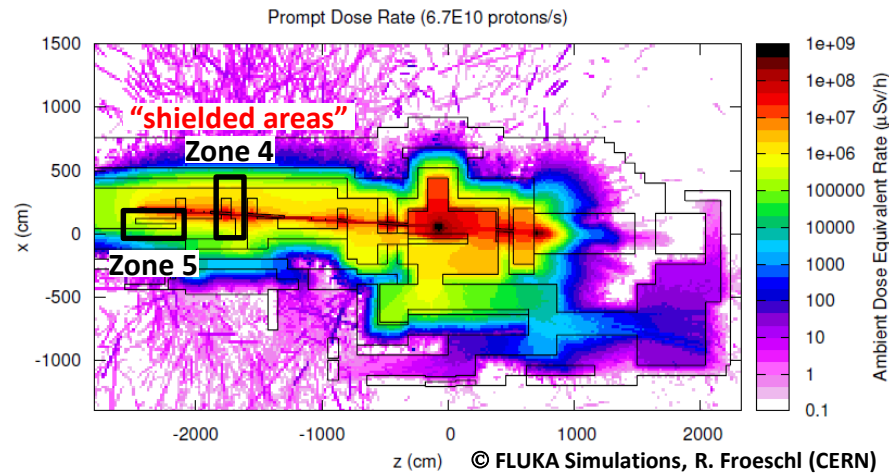


Passive Dosimetry



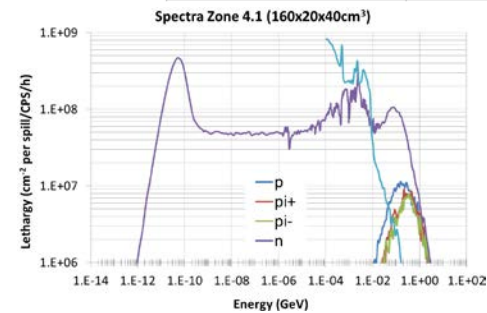
Monte Carlo Simulations (FLUKA)

- 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)
- $\Phi_{eq} \sim 3.8 \times 10^8$ n_(1MeV)/cm²/h (Si diodes)

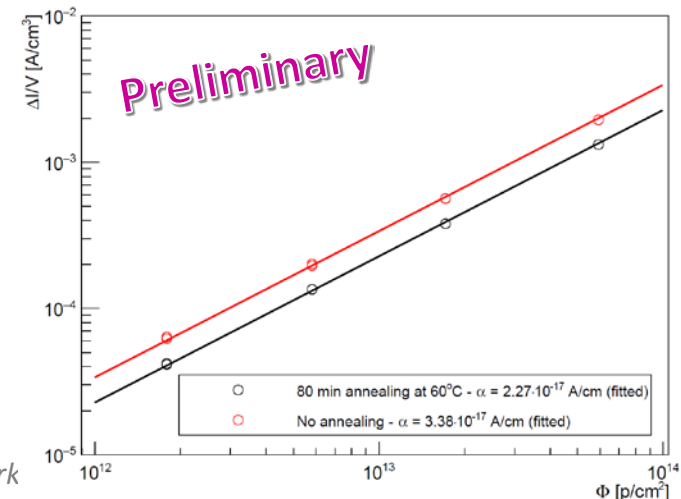
Zone 5

- Total Dose: about x2 lower
- good agreement with simulations

Non-Ionizing Energy Loss (NIEL)

Experimental determination of hardness factor

- Silicon PAD detector samples
- k = 0.57-0.58 (theoretical k = 0.51)



❑ IRRAD Facility completed successfully its first year of operation

- Infrastructure fully operational for run 2016
- Constantly improving beam intensity/conditions (OP team & PS/SPS users coordinator)

❑ IRRAD Proton Facility in 2015

- **341 objects** (127 SETs) at RT, low T, Cryogenic T
- **348 dosimetry measurements**
- **25 teams** of users from **20 institutes**
- belonging to 16 different
 - experiments / sub detectors
 - projects / R&D's
 - CERN groups

EA-IRRAD: aerial view of radiation shielding

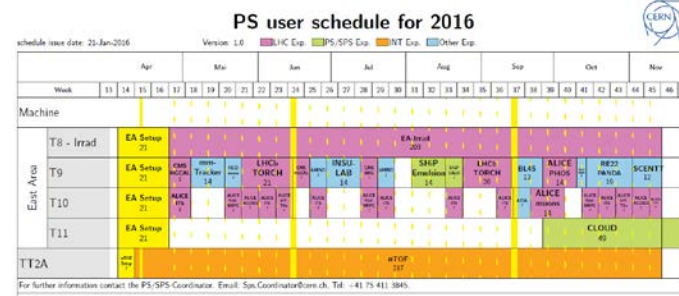


❑ Contacts:

- URL: www.cern.ch/ps-irrad
- e-mail: irradiation.facilities@cern.ch

❑ Registrations opened on February 1st

- We expect registration of complex experiments before the end of February
 - complex on-line setup
 - low temperature irradiations
 - heavy (high Z) materials, etc.
- Beam to T8-Irrad from second half of April
 - ~4w of setup (beam + facility)
 - **May to November for users** with weekly access to the IRRAD area on Wed. morning
- Users may be required to build specific samples holders/frames
- Complex experiments may require the preparation of a formal PRP17



Contacts

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Maurice Glaser	164276
Irradiation.Facilities@cern.ch	
<hr/>	
IRRAD Control Room	63344
CCC PS	76677

Useful Links

Vistar CPS
Vistar EAST Area
Beam Profile Monitor (BPM)
CHARM MWPC
ELOG PS OP
SCHEDULE EA-IRRAD
TREC (usage of Buffer Zones)

Irradiation run 2016

The registration of the irradiation experiments for the run 2016 is open (01/02/2016)

- Call for Irradiation Experiments 2016 ([download here](#))
- Click here to register samples or experiments

- Click here for details about the IRRAD Cabling Infrastructure
- How to package the samples for the IRRAD3 and IRRAD7 tables: [download here](#) (please replace crepe-paper tape with kapton tape in the packaging assembly)
- Standardized support for the IRRAD9 and IRRAD13 table: [download drawing here](#)
- Standardized support for the IRRAD5 and IRRAD11 cold boxes:

AIDA-2020 Transnational Access

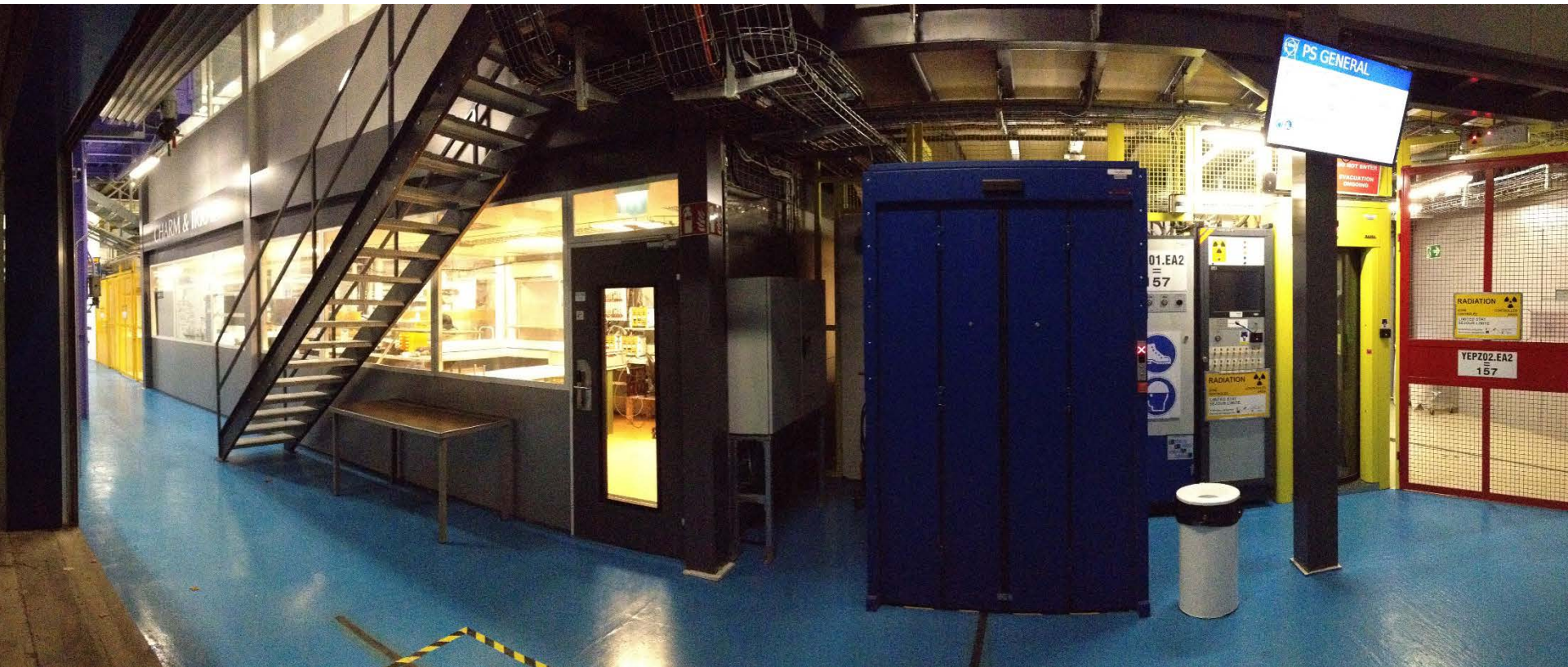


INFORMATION AND APPLICATION PROCEDURE FOR AIDA-2020 TRANSNATIONAL ACCESS ARE AVAILABLE [HERE](#)

www.cern.ch/ps-irrad

www.cern.ch/aida2020

AIDA-2020 Transnational Access supports teams to carry out irradiation tests in IRRAD !



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