CERN-PH Irradiation Facilities

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… presenting the work of many contributors to the ***East Area Upgrade*** *and* ***GIF^{++}*** *construction projects at CERN*
EN holds the overall projects leadership

Core teams: ***EA Upgrade Project:*** *D. Brethoux, R. Froeschl, L. Gatignon, M. Lazzaroni, et al.*
R2E Project: *M. Brugger & J. Mekki, et al.*
GIF^{++} Project: *B. Biskup, I. Efthymiopoulos, A. Fabich, S. Girod, D. Pfeiffer, et al.*

CERN groups:
EN-MEF *and* ***EN-STI*** *(core teams),* ***HSE*** *and* ***EN-HDO*** *(Projects Safety),* ***DGS-RP*** *(op. RP and sources),* ***EN-CV*** *(EA-IRRAD ventilation),* ***EN-HE*** *(exp. areas transports),* ***GS-ASE*** *(access control),* ***BE-BI*** *and* ***TE-CRG*** *(EA-IRRAD cryogenic system), …*

Summary

- **Introduction**
  - definitions, history, requirements for LHC upgrade, type of facilities at CERN
- **Overview (and evolution) of Irradiation Facilities at CERN**
- **PS East Area Irradiation Facilities (EA-IRRAD)**
  - **New IRRAD Proton Facility**
  - **New CHARM Mixed-Field Facility**
- **Gamma Irradiation Facilities**
  - GIF
  - **New GIF at the SPS North Area (GIF^{++})**
- **Other Irradiation Facilities at CERN** (relevant for detectors/electronics)
  - **New CC60**
  - CERF
  - others on CERN site
- **Irradiation results data**
- **Summary**

Irradiation Facilities: what for ?

- **Radiation damage studies**
  - on **materials** used around accelerators/experiments (cables, glues, …)
  - on **semiconductor** devices (silicon diodes, detectors, …)
  - on **electronic components** (transistors, memories, COTS, ASIC, …)
  - on materials / accelerator **components exposed to high-intensity pulsed beams** (collimators, absorbers, …)

  CERN - specific

- **Test and development of prototypes / final assemblies / electronic equipment before installation**
  - performance **degradation after long exposure**/ageing (TID, NIEL, …)
  - functional **degradation of electronics** (SEU, latch-up, …)
  - performance **evaluation under background conditions** ("noise")

  CERN - specific

- **Test and calibration of components**
  - **dosimeters**, radiation monitoring / measurement devices
  - provide **benchmark data for Monte Carlo** particle transport codes

  CERN - specific

Irradiation Facility vs. Test Area

"A properly performed irradiation TEST is an EXPERIMENT in itself !"

What a FACILITY (should) provide to perform irradiation experiments:

- **Deliver the desired beam**
  - on-demand (not parasitic) with required intensity, beam spot, time structure, …
- **Knowledge and control the radiation environment**
  - well-defined and simulated spectra, in-situ dosimetry, proper shielding, …
- **Access conditions regulated**
  - pre-test documentation, preparation/optimization, dry-runs, logs, traceability of material, …
- **Services**
  - remote handling tools, storage area, qualified lab, flexible infrastructure (gas, cooling), …
- **Final product: make scientific results available to the community**
  - document and spread out the knowledge; results databases
- **Address RP issues from the beginning: radioactive waste, doses, … !**

Irradiation test locations which are not fulfilling the above requirements (ad-hoc tests, parasitic use of beam, …) are referred as TEST AREAs

Facilities at CERN (short history …)

- **'70-'80: irradiations mainly for damage studies on accelerator materials**
  - commercial sources, experimental reactor; **damage data compilations**
- **'90-'00: suitable locations (= "test areas") at CERN for LHC and its HEP Expt.**
  - examples: PSAIF, CERF, IRRAD1, IRRAD2, TCC2, TT40, …
- **'00-'12: some dismissed / consolidated "facilities" / fulfil temporary needs**
  - examples: TCC2, … / CERF, GIF, IRRAD, … / CNRAD, …
  - **'08-'10: WG on "Future irradiation facilities at CERN"**
    - CERN-wide coherent approach towards future upgrades (HL-LHC)
    - http://www.cern.ch/irradiation-facilities/
    - Conclusion: **need for 4 different types of facilities**
- **'11-'14: implementation phase**
  - **Before LS1:** HiRadMat
  - **During LS1:** EA-IRRAD (IRRAD + CHARM), GIF^{++}, …

end of 2012

this Talk …

today

Upgrade Requirements (Experiments)

Radiation levels on detectors/electronics for LHC phase II upgrade

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
$7\times10^{33}cm^{-2}s^{-1}$ 25 fb^{-1}	20	10	3	21	3	0.1	3	$4\times10^{32}cm^{-2}s^{-1}$ 3 fb^{-1}			
	770	280	13	100	170	2	14				
$1\times10^{34}cm^{-2}s^{-1}$ 100 fb^{-1}	80	40	11	84	12	0.35	12	$4\times10^{32} cm^{-2}s^{-1}$ 8 fb^{-1}			
	1100	400	18	140	250	3	20				
$3\times10^{34}cm^{-2}s^{-1}$ 350 fb^{-1}	280	140	38	280	41	1.2	42	$1\times10^{33} cm^{-2}s^{-1}$ 23 fb^{-1}			
	3300	1200	54	430	750	9	60				
$7\times10^{34}cm^{-2}s^{-1}$ 3000 fb^{-1}	2400	1200	330	2450	350	10	360	$2\times10^{33} cm^{-2}s^{-1}$ 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)

outer (muon) detectors:
γ–BKGD ~$\mathcal{O}$(10) w.r.t. LHC

Crosscheck with ATLAS Phase II LOI

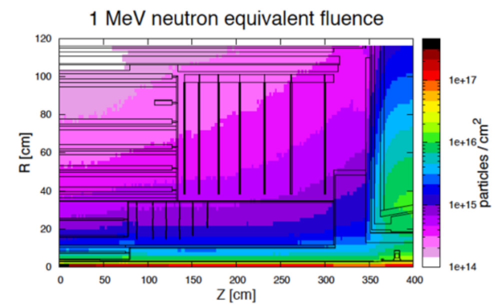


Figure 6.2: *RZ*-map of the 1 MeV neutron equivalent fluence in the Inner Tracker region, normalised to 3000 fb^{-1} of 14 TeV minimum bias events generated using PYTHIA8.

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

$1MeV_{neq}$ Fluence = $2.4\times10^{17}*5.4/(2*\pi*3.7^2)$ = 1.5×10^{16} cm^{-2}

Dose = $3.2\times10^{-8}*1.5\times10^{16}$ = 4.8MGy

Layer	Radius mm	Occupancy with 200 pile-up events (%) 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 $1.4\times10^{16}cm^{-2}$ and 7.7 MGy at the centre of the innermost barrel layer. For the

04/06/2014 W. Riegler, CERN 23

inner detectors (trackers):
> 10^{16} $1MeV_{neq}/cm^2$

© W. Riegler (TIPP 2014)

Upgrade Requirements (Accelerators)

PH DT

❑ **Testing of electronics equipment in "real" representative conditions**

Mixed-Beam Facilities

Advantages:

- **Particle/Energy spectrum** 'trimmed' to actual application
- **High-Energy tail of spectrum** (important for SEL, etc…)
- **Big volumes** (also many components at the same time!)
- Complete **system tests** "easily" possible
- **On-site (CERN)**, "easy" access
- **Combined effects:** parallel study of TID/DD/SEE
- All required **services can be pre-installed**
- **Detailed monitoring** adopted for mixed-field requirements

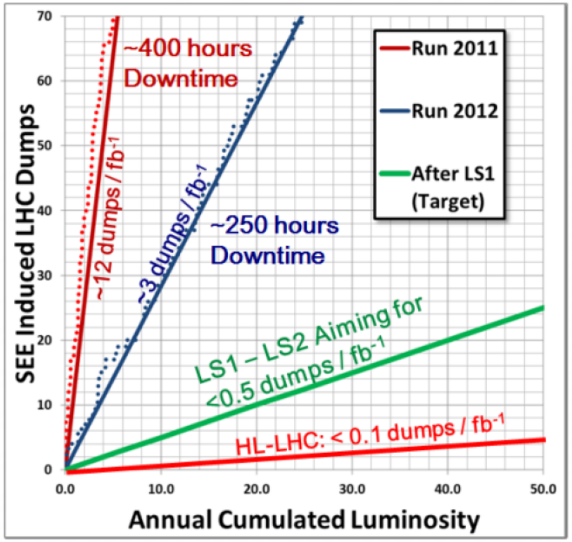
Reduce LHC downtime →

R2E Mitigation Project – Radiation Tests & Facilities 15 February 1st 2012

© M. Brugger (EA-Day, 1st February 2012)

Evaluate (mainly SEE) tolerance of commercial electronics:

- **broad ("ad-hoc") spectrum**
- **dedicated (large) space**
- **pre-installed services**
- **variable intensity**

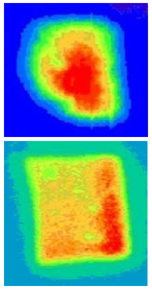


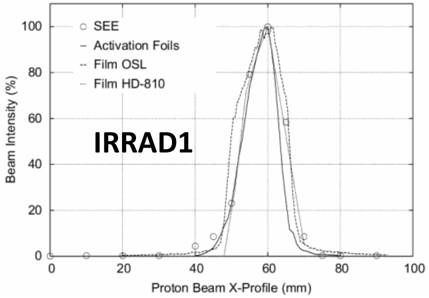
- Downstream of proton irradiation facility

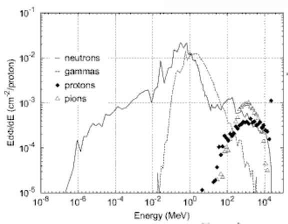
© R. Froeschl (SATIF 12 Conference)

R. Froeschl, M. Brugger, S. Roesler (CERN) – SATIF 12 CERN High Energy Accelerator Mixed Field (CHARM) 3

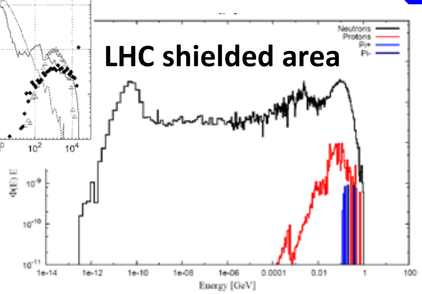
Facilities / Test Areas @ CERN







IRRAD2



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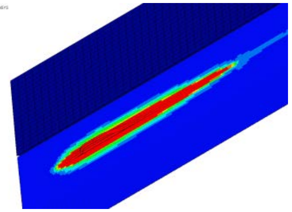


(^{137}Cs) GIF

- ❑ **Mono-En. charged hadron beams (slow extraction)**
  - radiation field similar to **experiments inner detectors** (π)
  - **study of basic mechanisms**; physics of damaging processes
- ❑ **Mixed-field radiation environments (slow extraction)**
  - mimic radiation field within experiments / **accelerators regions: tunnel & partially shielded areas** (n^0, γ, HEH)
  - **SEE studies**; calibration of radiation monitors
- ❑ **High-energy (-density) pulsed proton/ion beams**
  - **impact of intense pulsed beam on materials**
  - **study of LHC collimators** & absorbers
- ❑ **γ- (X-)photon "beams"**
  - accelerated **TID tests**; **simulate detectors background**
  - ageing studies; **detector tracking performance**

CERN Irradiation Facilities until 2012

SPS: H4IRRAD
mixed-field test area

SPS: CERF
CERN Reference Facility
mixed-field

GIF
Gamma Irradiation Facility
(no more particle beam)

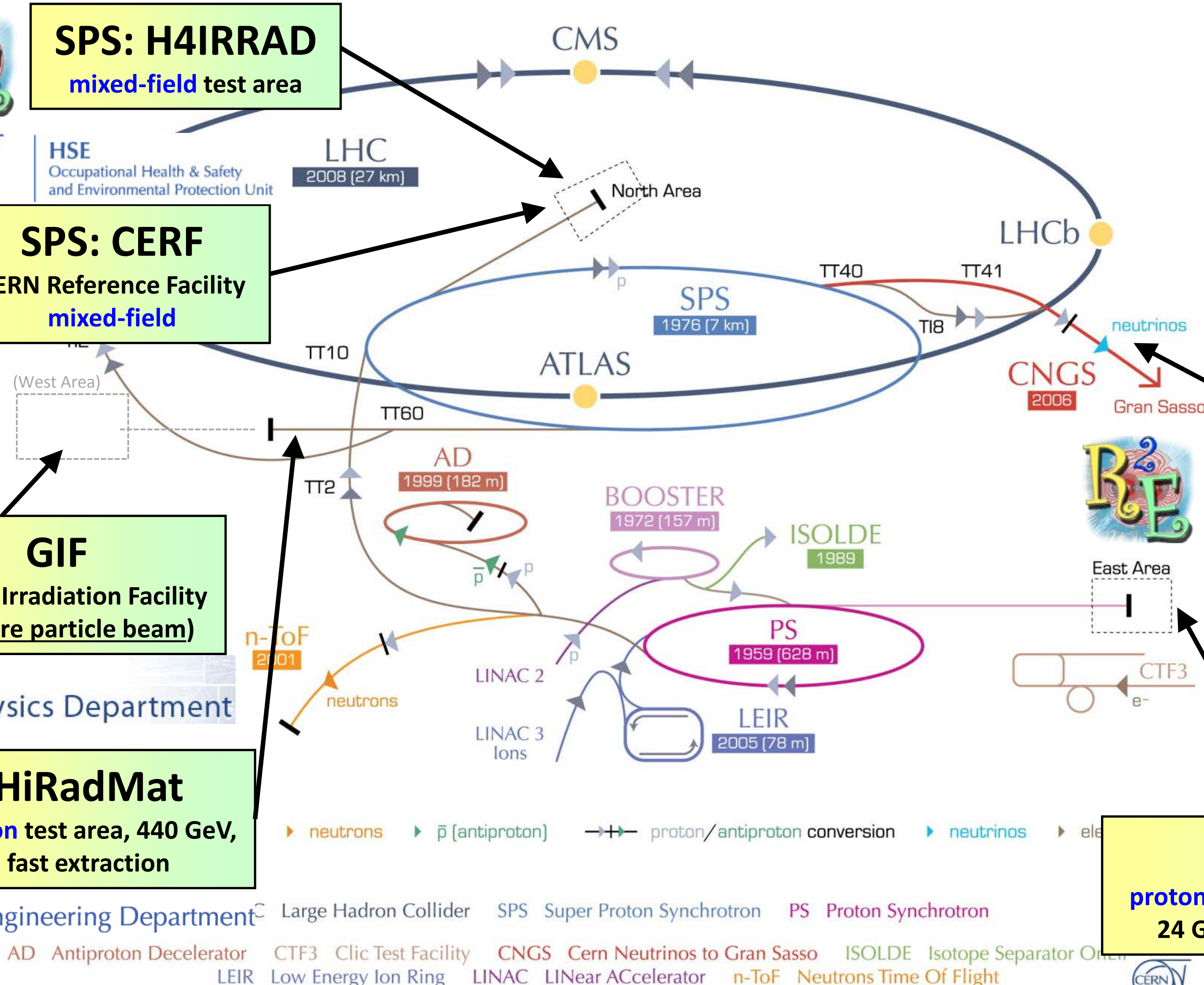
HiRadMat
proton test area, 440 GeV,
fast extraction

CNRAD
mixed-field test area
(parasitic operation)

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

Proton Energy

LHC	4 TeV
SPS	450 GeV
PS	23 GeV
PSB	1.4 GeV
Linac	50 MeV

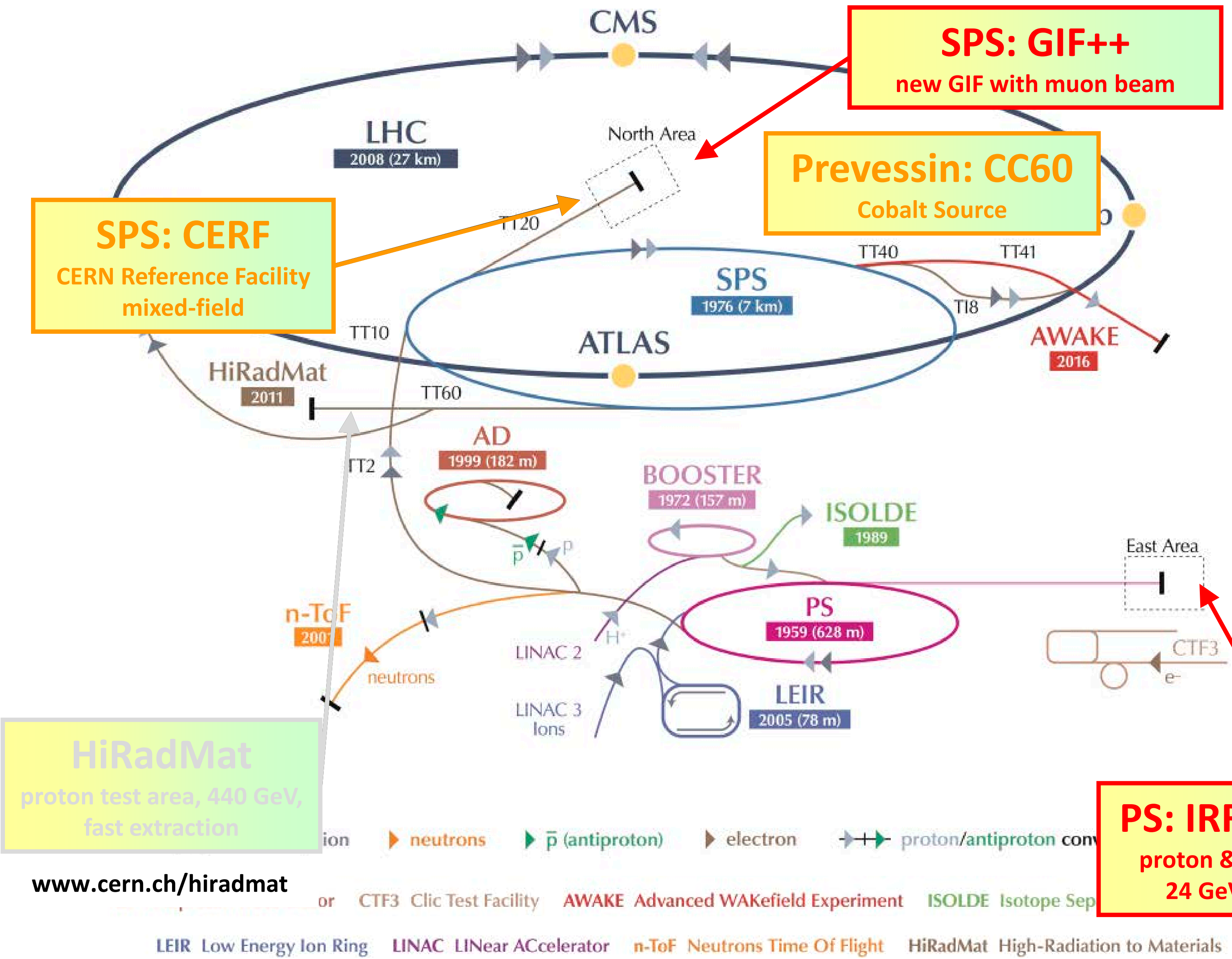


Physics Department

EN Engineering Department

Physics Department

CERN Irradiation Facilities from 2014

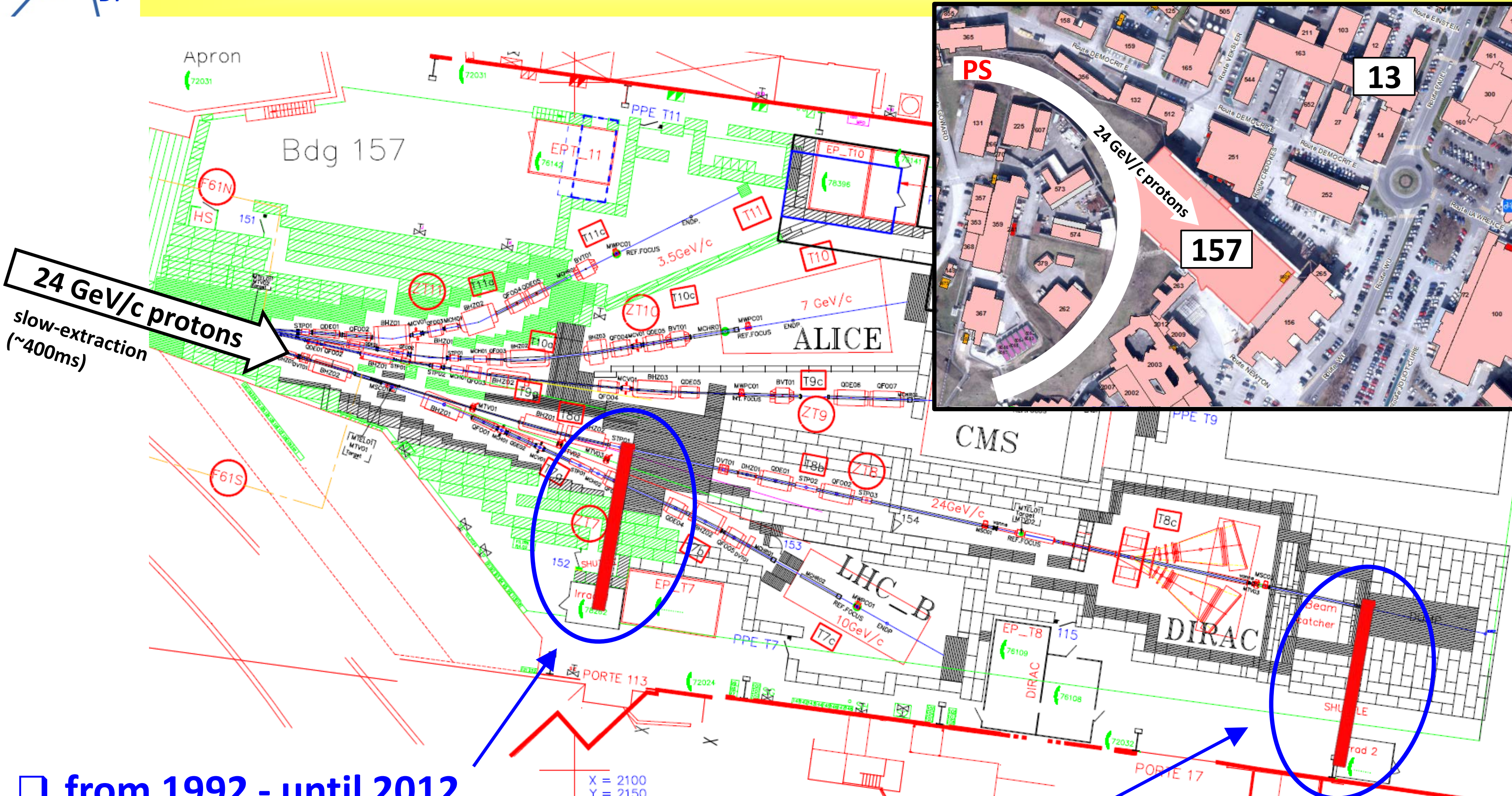


Proton Energy

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

New PS EA-IRRAD Facility

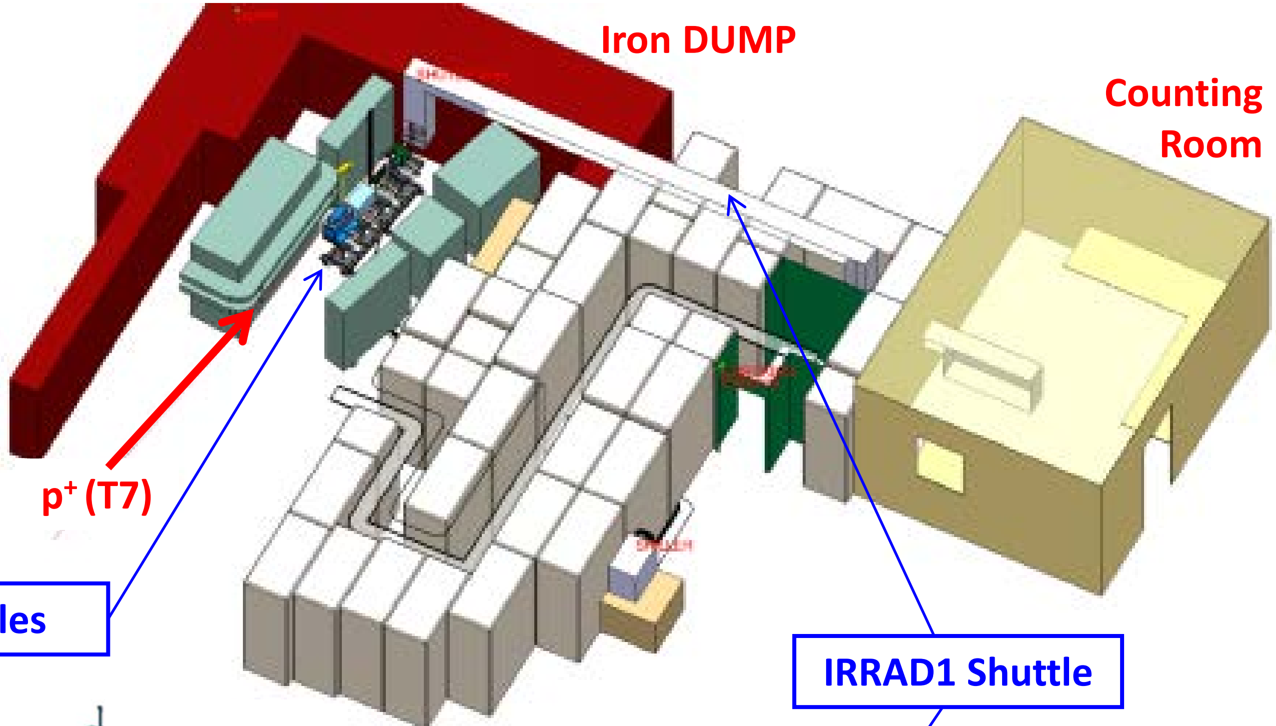
PS-EA Irradiation Facilities until 2012



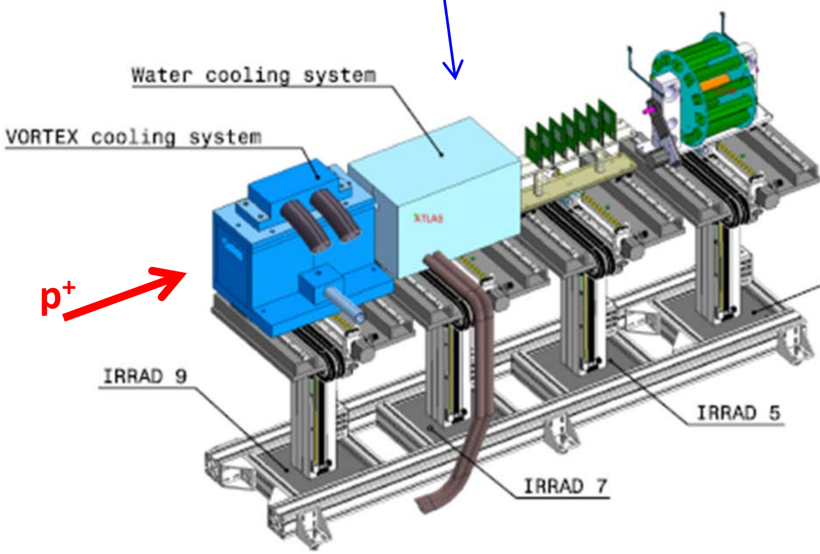
- from 1992 - until 2012
- Proton irradiations (T7)
  - **Primary 24 GeV/c proton beam** (IRRAD1, IRRAD3, IRRAD5, …)
- Mixed-field irradiations (T8)
  - **Mixed field produced in cavity** after **C** (50cm) - **Fe** (30cm) - **Pb** (5cm) **'target'** (IRRAD2)

Proton Irradiation Facility (2012)

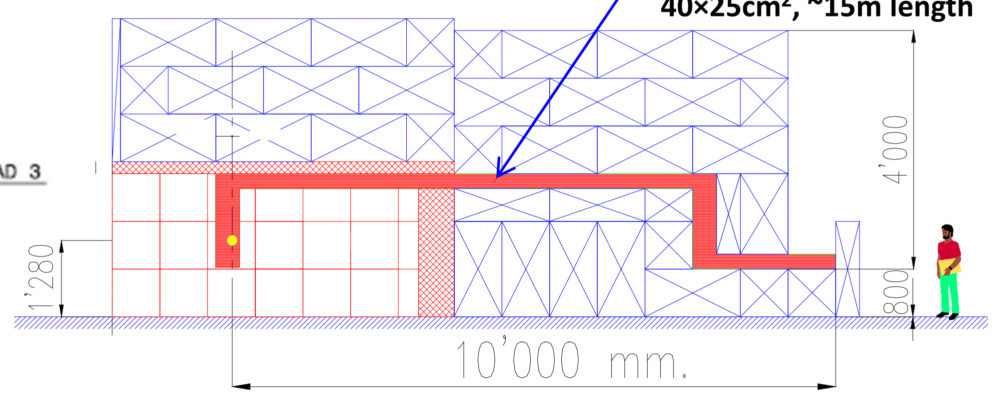
- **Beam spot**
  12×12 mm^2 (FWHM)
- **Beam momentum**
  24 GeV/c
- **Proton flux**
  $\sim 1\times10^{16}$ p · cm^{-2} $20days^{-1}$
  (year average)



IRRAD3, IRRAD5, … Tables



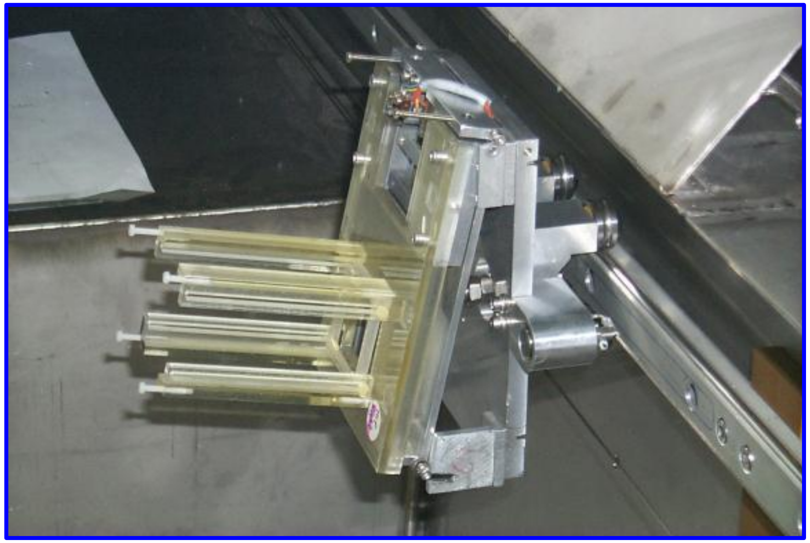
IRRAD1 Shuttle

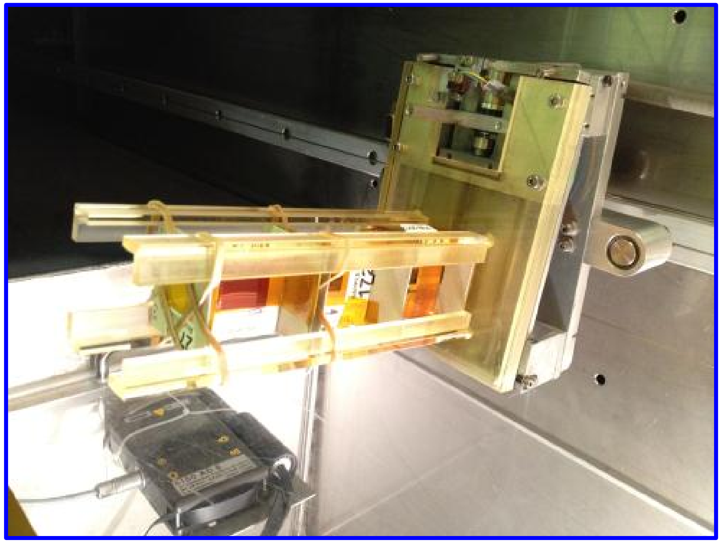


IRRAD1 Shuttle & IRRADx Tables

IRRAD1 Shuttle

V_{max}=5×5×15cm^3

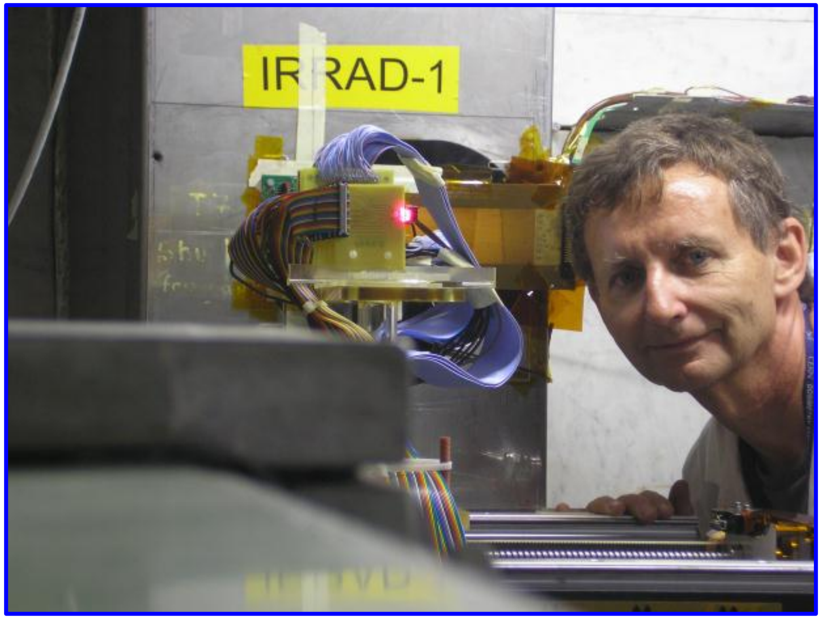


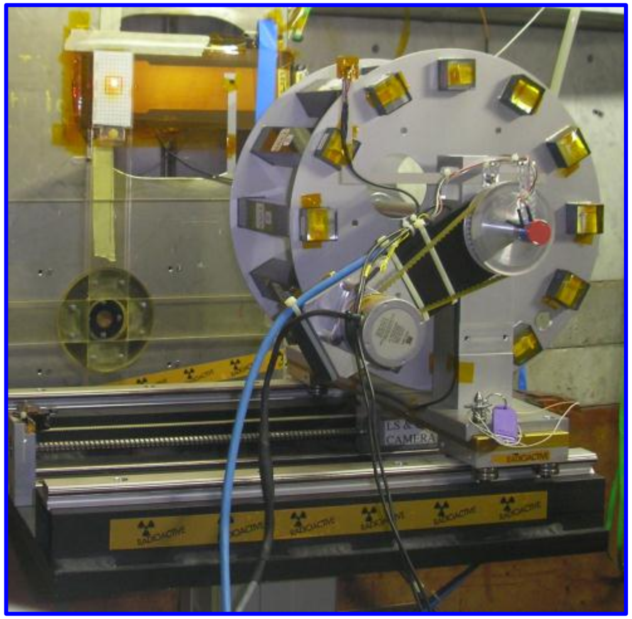


IRRAD3 & IRRAD7 Tables

V_{max}=20×20×50cm^3

scanning over surface

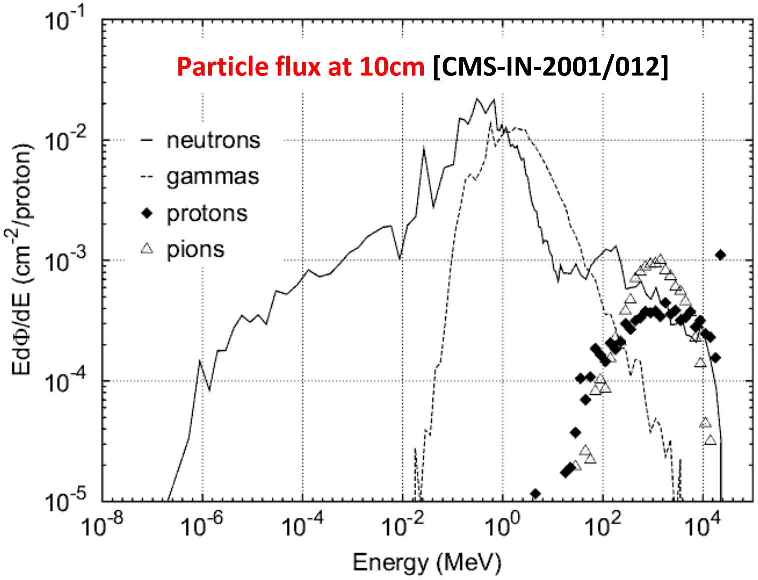


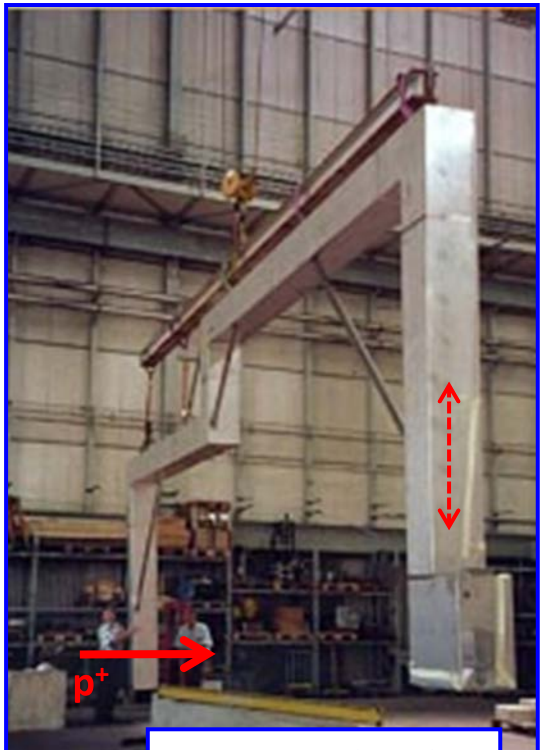


Mixed-field Irradiation Facility (2012)

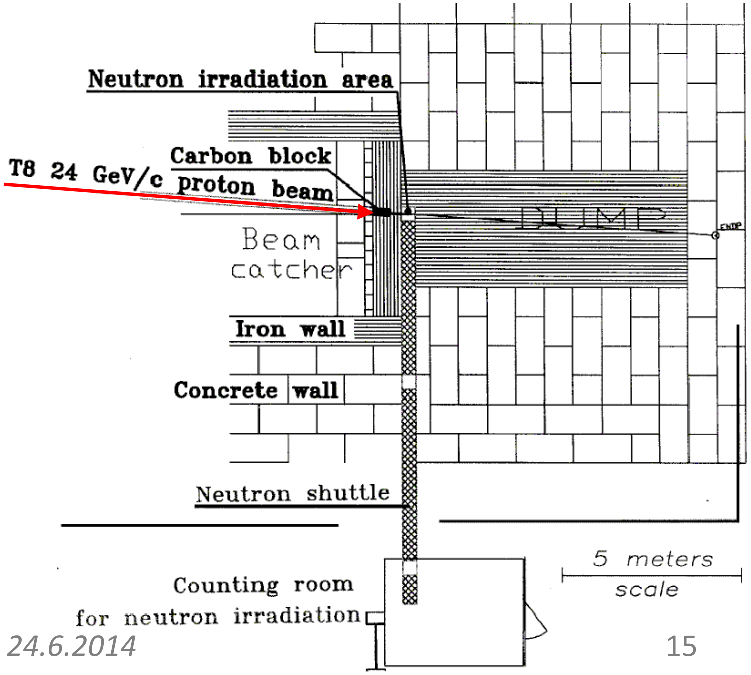
❑ Secondary particles in a cavity (IRRAD2)

- 24 GeV/c proton beam on a C/Fe/Pb target
- **Small volume** (max ~30×30×30cm³) behind DIRAC
- Spectrum & flux of ***n*, *p*⁺, π⁺, π⁻, γ** simulated & measured
- **~1×10¹³ n₍E>1MeV₎ cm⁻² 5d⁻¹** @ 50cm from beam axis

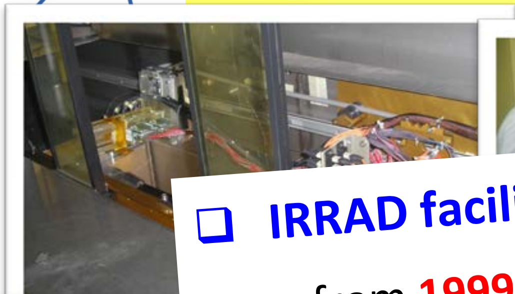




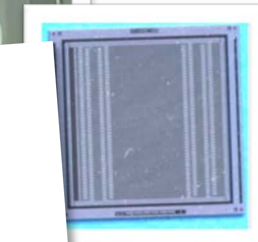
IRRAD2 Shuttle



Past Irradiation Experiments





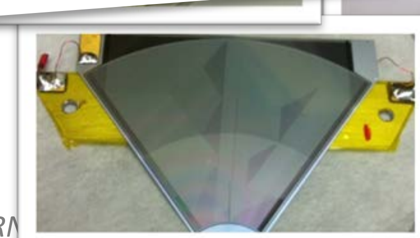



❑ IRRAD facilities in numbers …

- from **1999** to **2012** (no beam in 2005)
- more than **8300** "pieces" irradiated (**~650 per year**)!
- about **5800** dosimeters (Al foils) measured!

❑ Statistics for 2012 …

- **40** users
- from **20** institutes belonging to several experiments/projects
- main users: ATLAS, CMS, LHCb, ALICE, RD39, RD50, LHC (BE and TE)
- **649** objects irradiated
- **358** dosimeters measured
- **223** days of beam time (~8.5×10^{16} protons delivered to IRRAD)


© **IRRAD user community!**

Drawbacks & Shortcomings

(of the old facilities / test areas with respect to future needs)

❑ Proton IRRAD Facility

- **Located in primary radiation area** (limited access: stop all beam lines of East Area for access)
- **Limited space** (ALARA, difficult to scan beam over big objects, backscattered particles)
- **Limited flux of primary protons** (weakness of the shielding)
- **Safety standards to be improved!**

❑ Mixed-field IRRAD Facility (behind DIRAC)

- **No irradiation positions lateral to target** (missing an important 'particle mix' component)
- **Limited intensity** (present flux not interesting for inner detector community)
- **Too little space and limited accessibility** (access only via shuttle system!)
- **Parasitic to DIRAC operation**
  - ➢ **IRRAD Facilities were located in different beam lines: competing for beam!**

❑ Mixed-field H4IRRAD/CNRAD Test Areas

- CNRAD **not operational** after 2012
- **Limited accessibility** ("ad-hoc installations", lack of flexibility, access required **shielding removal**)
- **Limited** control on **beam intensity**

Towards a new EA Irradiation Facility

- **2012: CERN management agrees on EA facilities upgrade**
  - CERN-EN is charged and funded to design and construct the irradiation beam line in the framework of the **EA renovation plan during LS1** (PL: *Lau Gatignon*)
  - CERN-PH through AIDA EU FP7-founded project (Task 8.3)

Secondary Beams & Areas
EN Engineering Department

- **19 Nov. 2012: first technical meeting on upgrade**
  - **R2E project (LHC machine): Mixed-field facility & infrastructure design**
  - **CERN-PH & AIDA: Proton facility & infrastructure design**

EN STI
EN Engineering Department
PH-DT AIDA Detector Technologies

- **26 Nov. 2012: last day of operation for the DIRAC experiment**
- **2013: Dismantling (DIRAC & old IRRAD facilities); beginning of construction**
  - Involvement of **teams from EN, PH, DGS-RP, …**
- **2014: End of construction, equipment and commissioning of new facilities**
  - First irradiation experiments toward end of the year
    - **R2E project: Cern High-energy AcceleRator Mixed-field facility (CHARM)**
    - **CERN-PH & AIDA: proton IRRADiation facility (IRRAD)**

Decommissioning (2013)

T7b area dismounted

T7 roof open

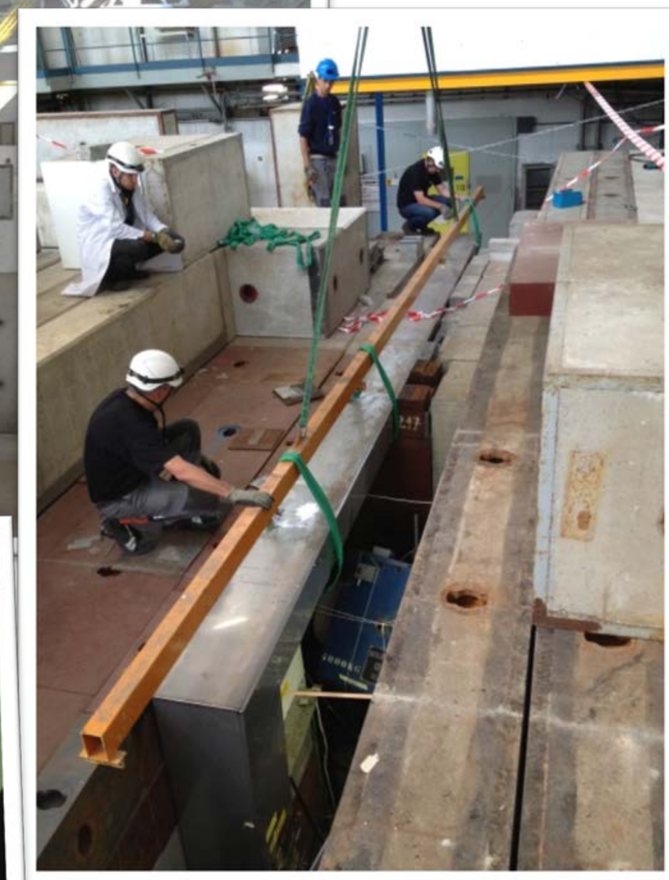
T8 roof open

Removal of DIRAC experimental equipment

Decommissioning (2013)

IRRAD2 Shuttle (April)

IRRAD1
Counting Rooms
(May)

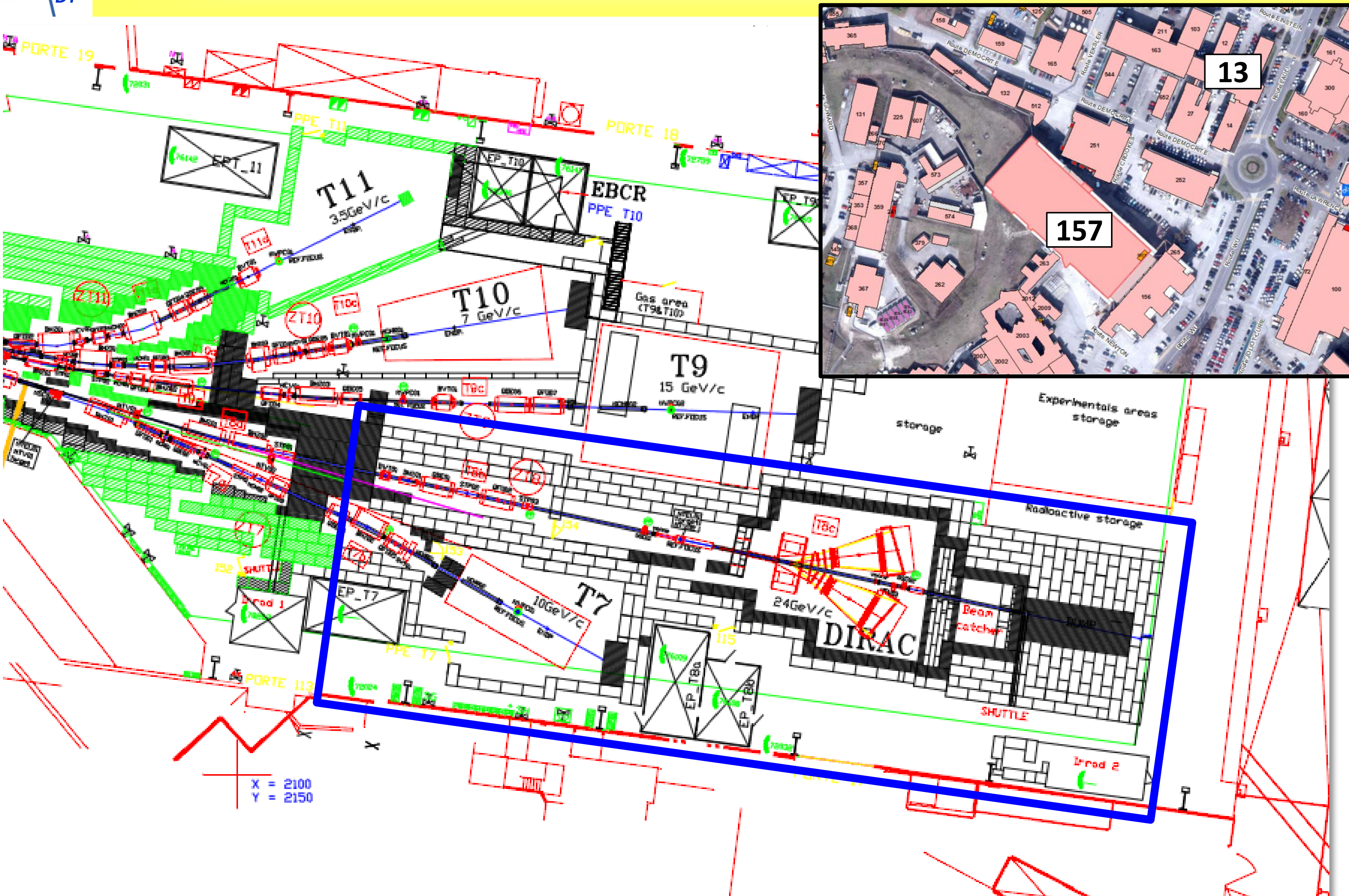


IRRAD1 Shuttle (June)

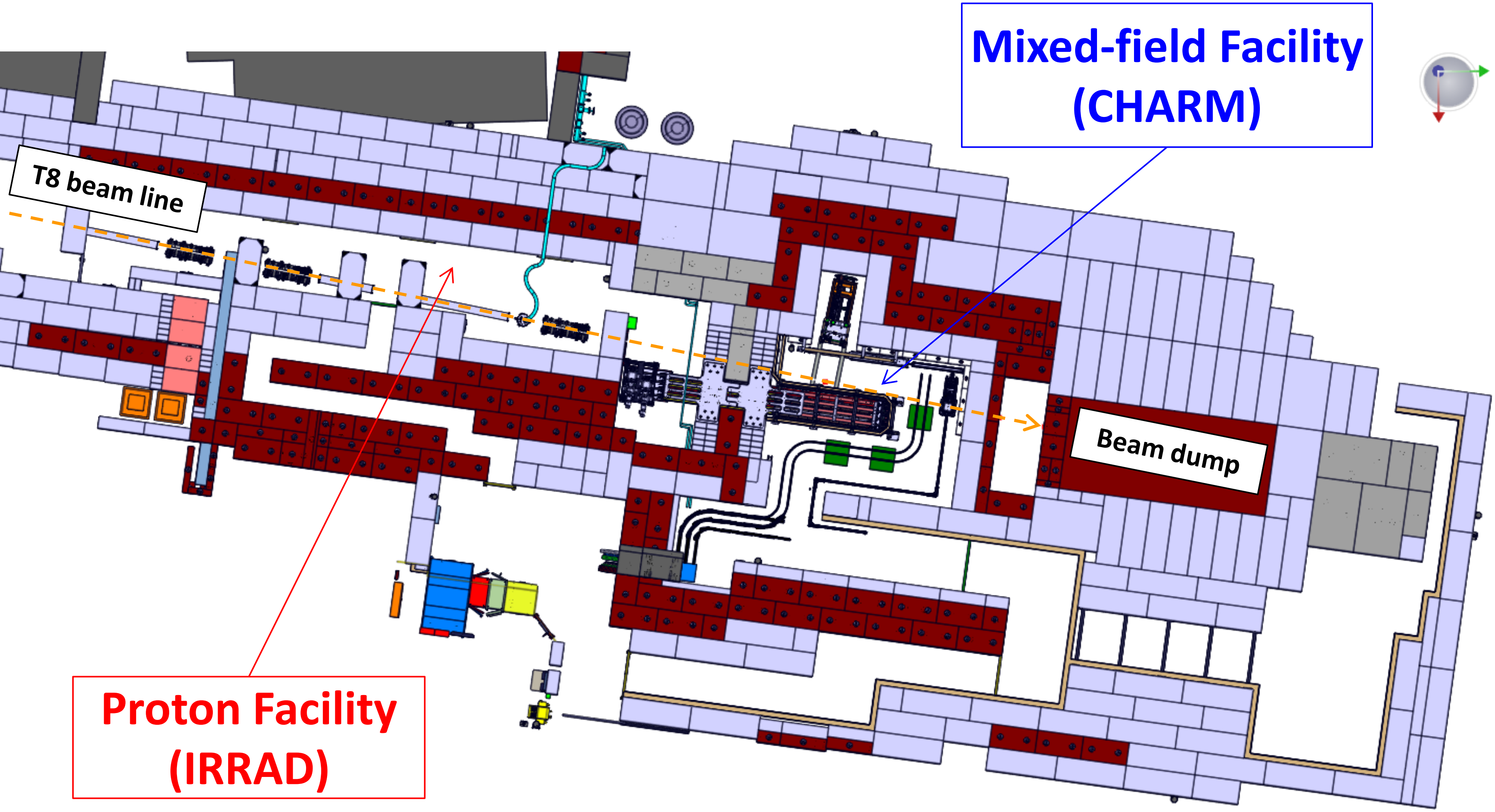
“Goodbye IRRAD1/2” (July)

Decommissioning (2013)

OLD East Area Layout



NEW East Area IRRAD Layout



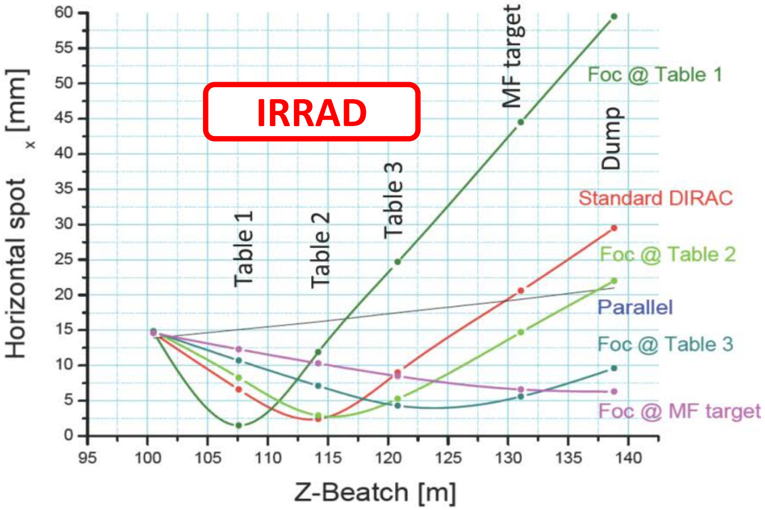
24 GeV/c Proton Beam Parameters

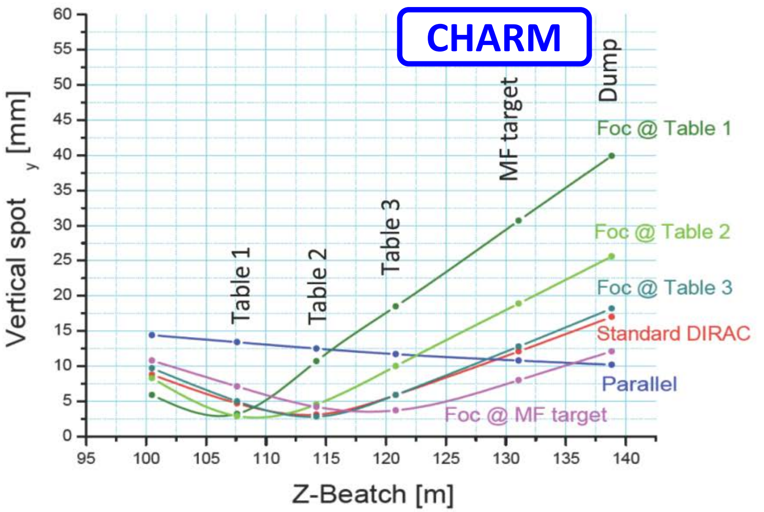
❑ Beam dimensions

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

❑ Beam intensity (estimations)

- p^+ are delivered in "spills" of ~5×10^{11} p
- number of spills/frequency depends on CPS
- **Typical CPS from 2014: 30s**
- **Typical figures (High Intensity)**: 3 spills per CPS
  - **~1×10^{16} p cm^{-2} 5days^{-1}** (12x12 mm² FWHM)
  - **~4x more than the old facilities**
- **Design figures (maximum):** 6 spills per CPS
  - **~1×10^{17} p cm^{-2} 4days^{-1}** (5x5 mm² FWHM)

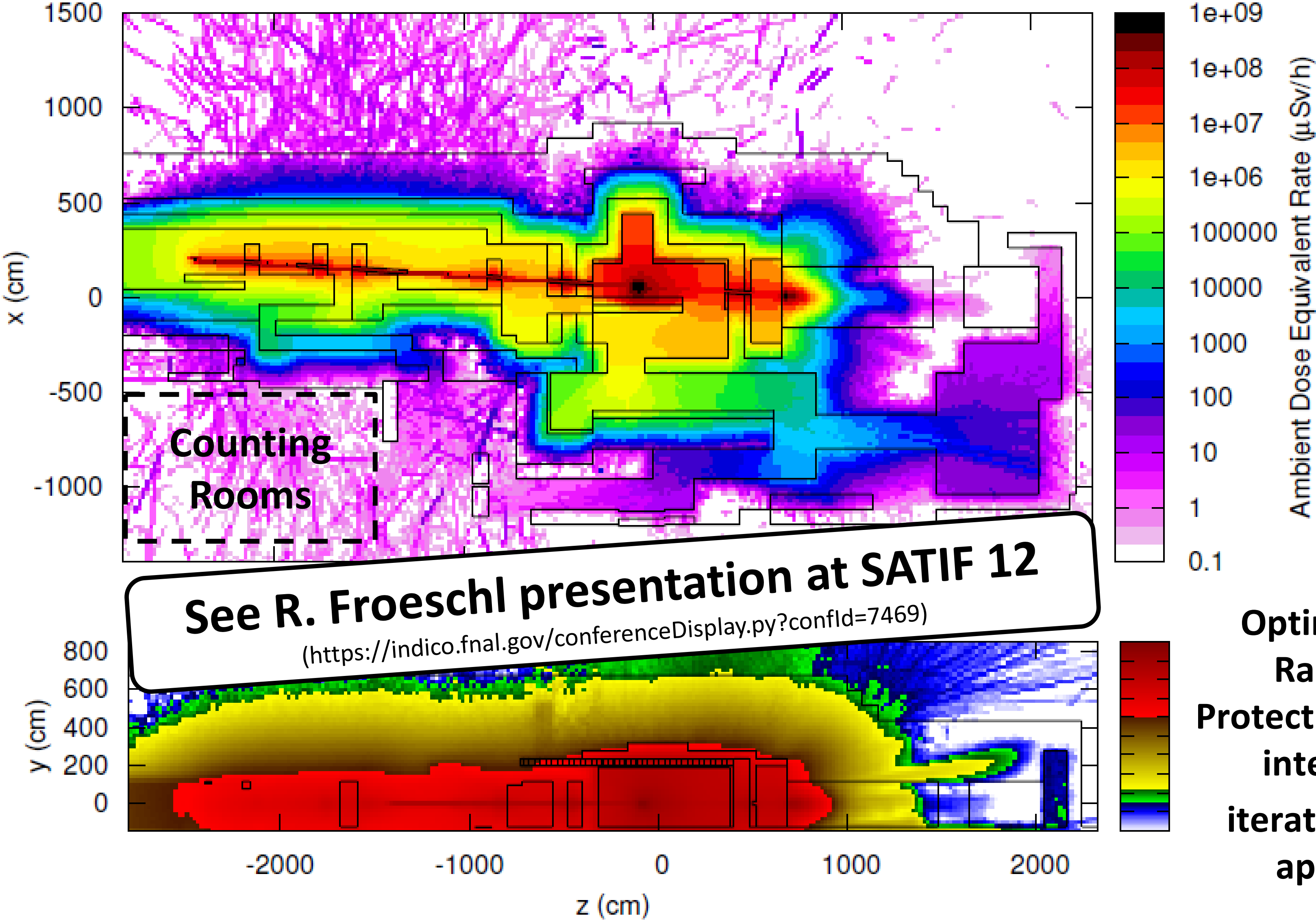




© **L. Gatignon, preliminary calculations (EDMS 1270807)**
Here dimensions are mm (RMS)

IRRAD Facility Design

© FLUKA Simulations, R. Froeschl (DGS-RP)



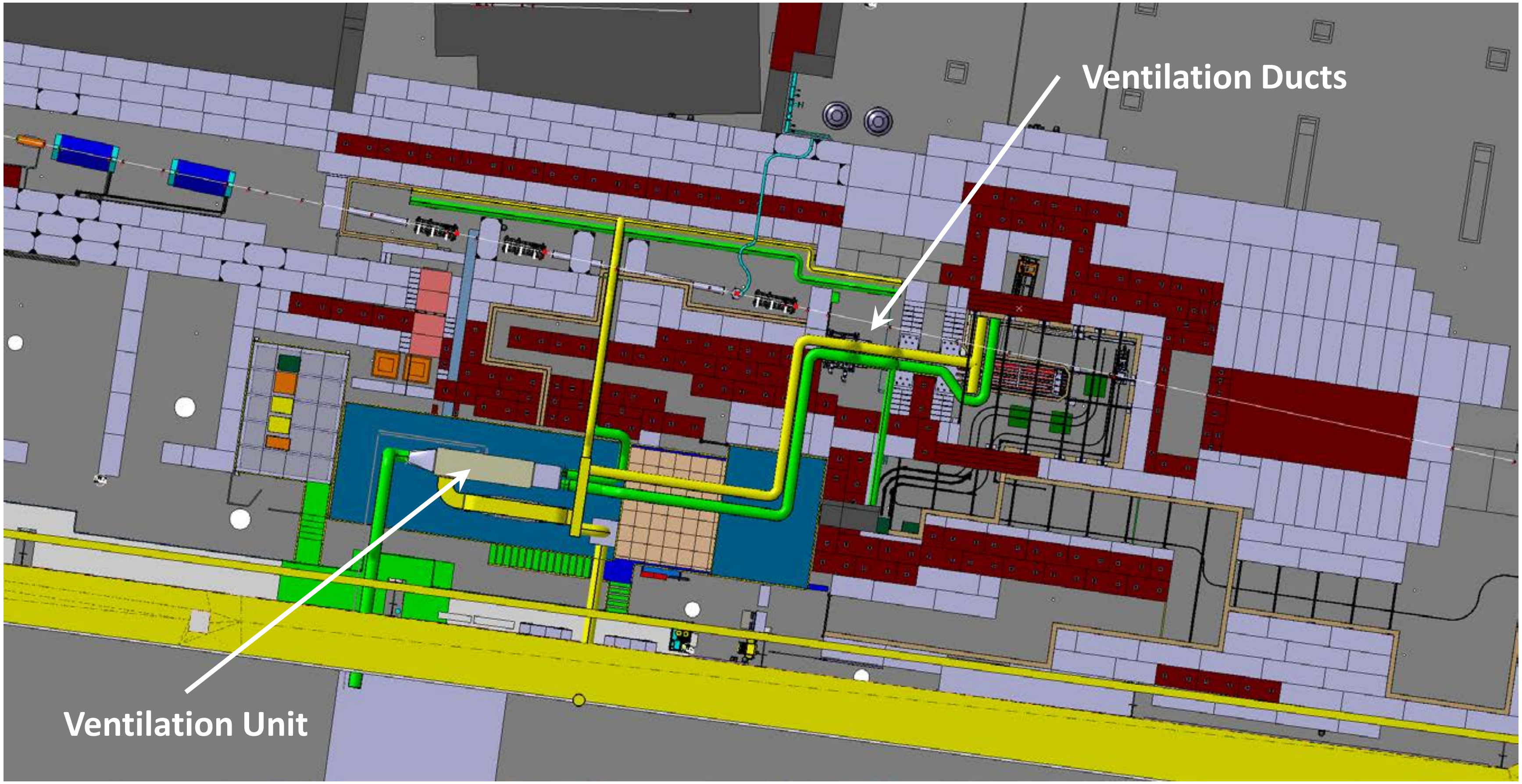
See R. Froeschl presentation at SATIF 12
(https://indico.fnal.gov/conferenceDisplay.py?confId=7469)

Optimized for Radiation Protection using an integrated, iterative design approach

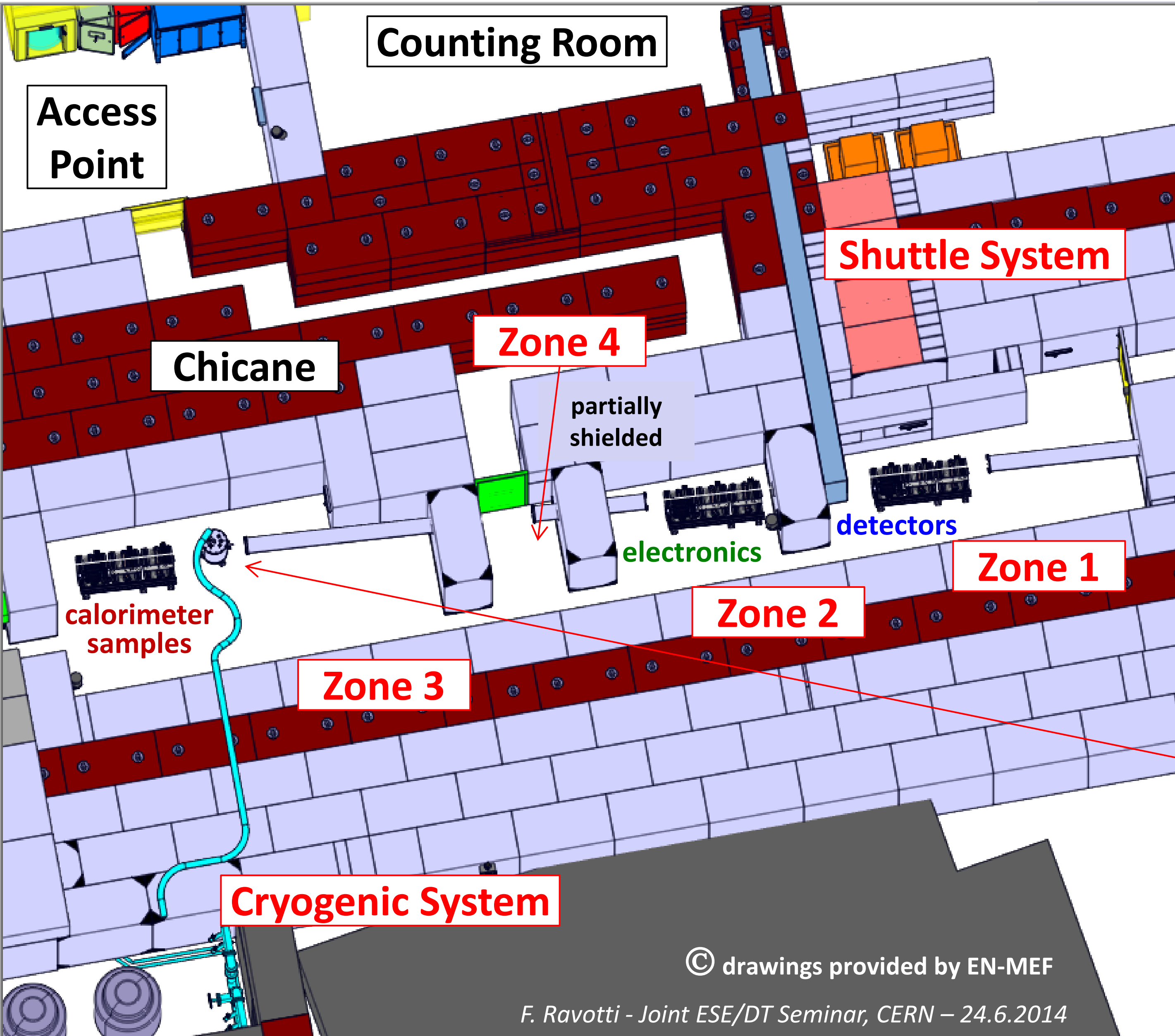
Ventilation System

❑ Ventilation system (CERN EN/CV)

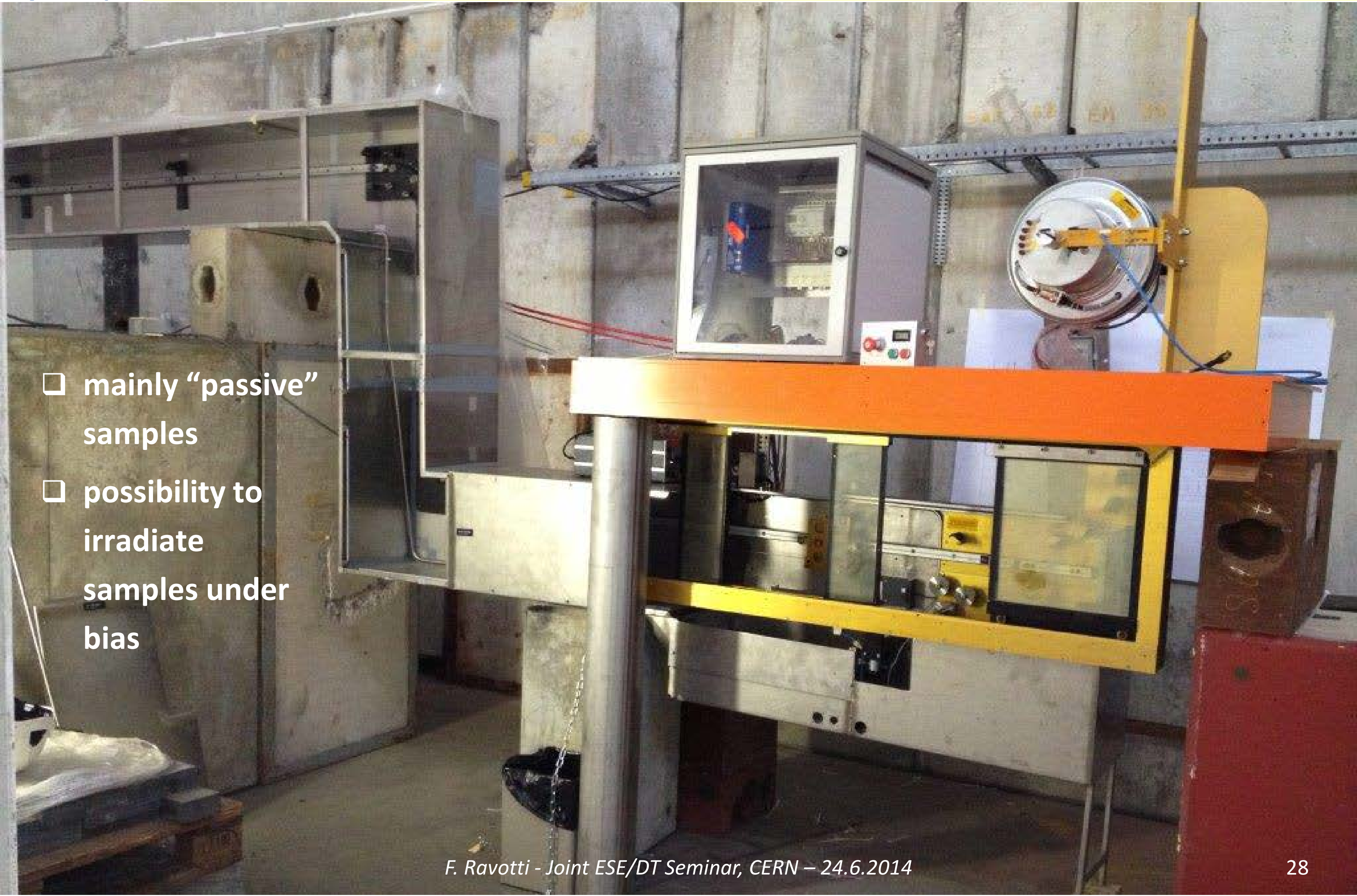
- area confinement (under-pressure) for air activation, ozone formation, temp. control, etc.
- air **re-circulated during operation** (through filters) and **flushed before access**
- integration of ducts through the shielding:



Proton IRRAD Facility (PH)



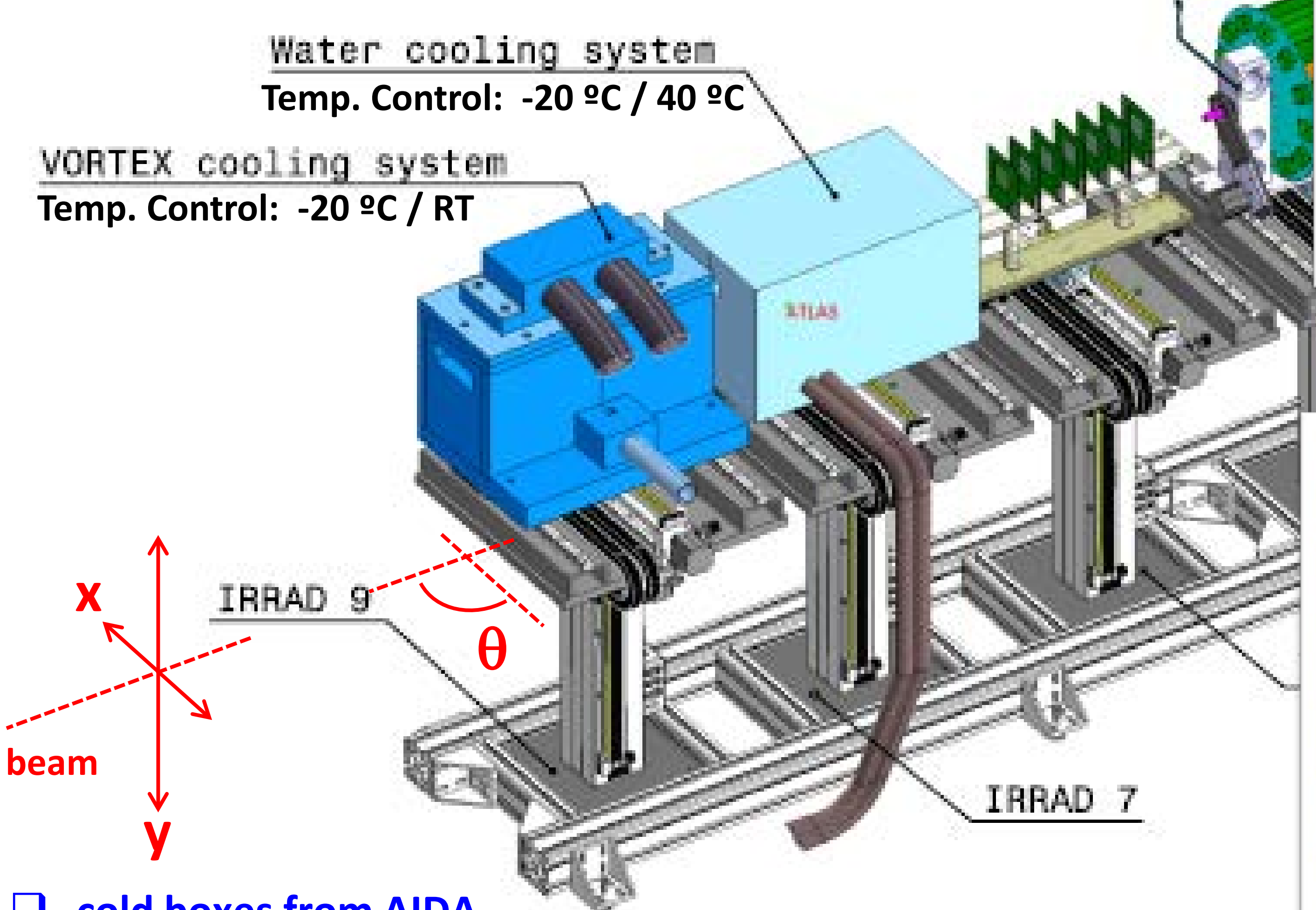
Proton IRRAD Shuttle System



- mainly "passive" samples
- possibility to irradiate samples under bias

IRRAD Remote-controlled Tables

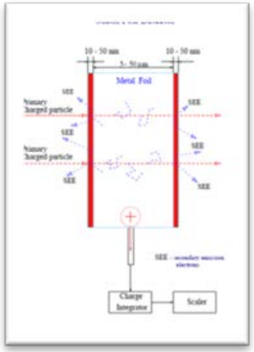
- 3 tables per IRRAD zone; DUTs powered and cooled
- 1 stand-alone control unit per table (on UPS)

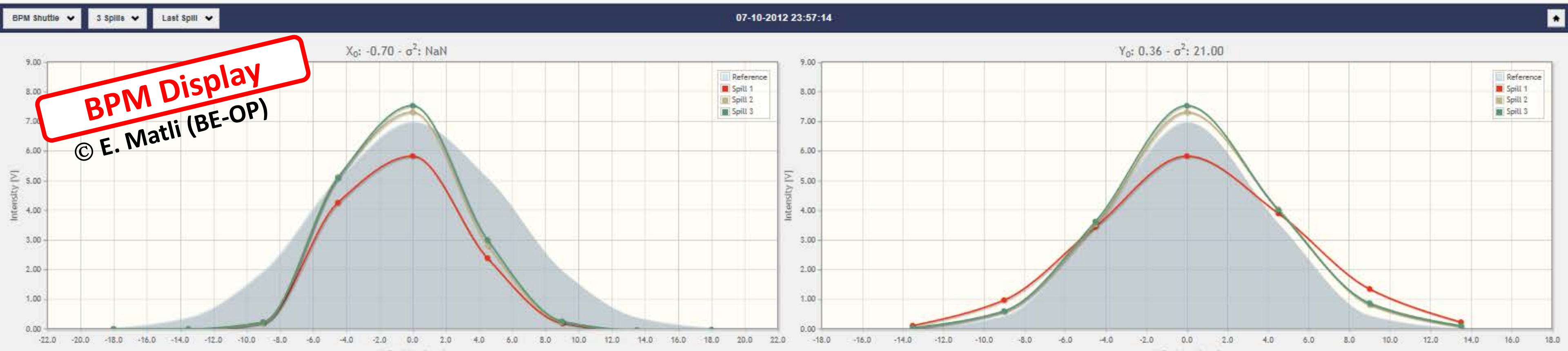


- cold boxes from AIDA (WP8.3.2 QMUL/Sheffield)
- prototype (AIDA MS31)

IRRAD Beam Instrumentation & DAQ

- **New Beam Position Monitors (Metal Foil Detectors)**
- **New Web-application**
  - display **Beam Profile Monitor** data (for IRRAD users and CERN CCC)
  - new database for data storage (ORACLE); can display multiple BPM devices
  - flexible display also for other IRRAD data: **SEC counters**, **table/shuttle positions**, **T.**, …





“CryoBLM” Setup

- **Setup for irradiation in cryogenic conditions (1.8K/4.2K)**
  - clone of the system used for “*CryoBLM*” (BE-BI) experiment in 2012
  - cryogenic line “embedded” in the shielding; bigger cryostat
- **Cryogenic system operated by TE-CRG**
  - manual refilling; dewar outside rad. area
  - installed on a **movable irradiation table**

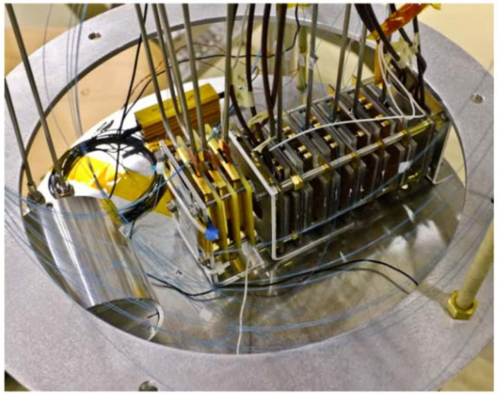
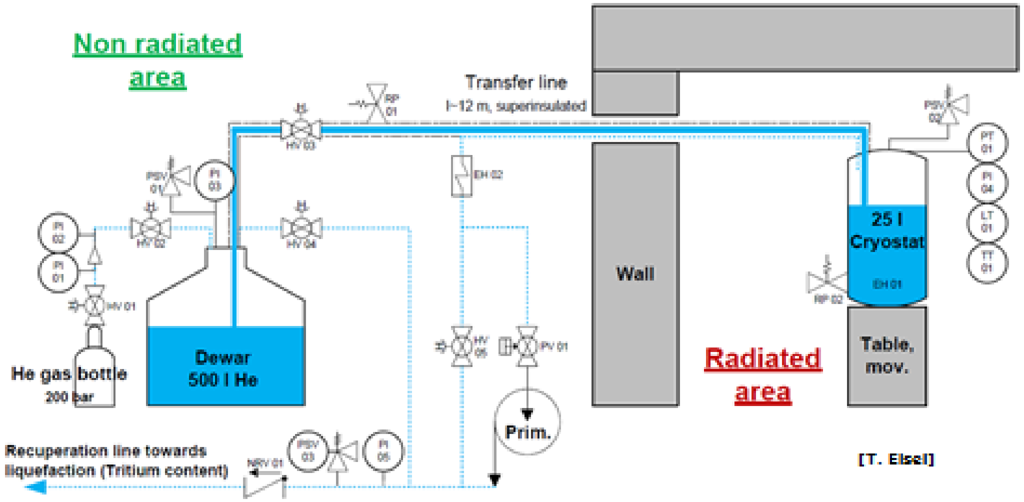


Figure 6.16: Detector modules mounted on the support plate and ready for cooling down and irradiating.

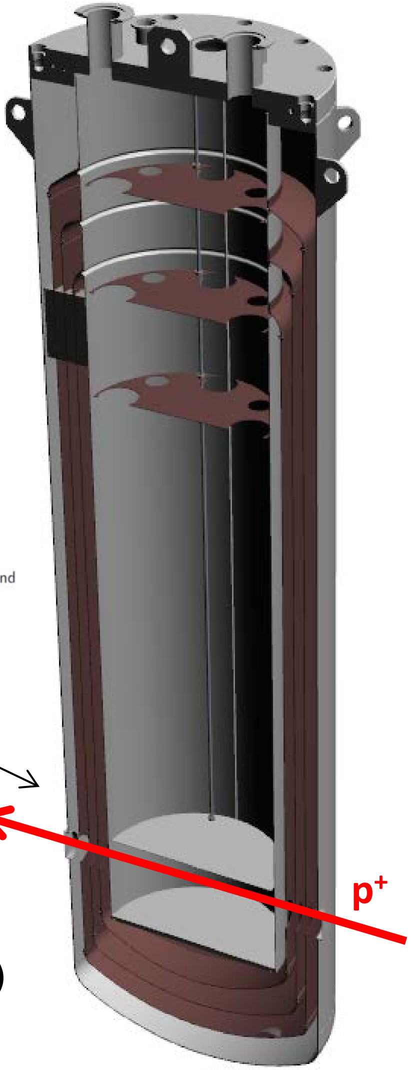
Past installation - overview

Cryolab

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



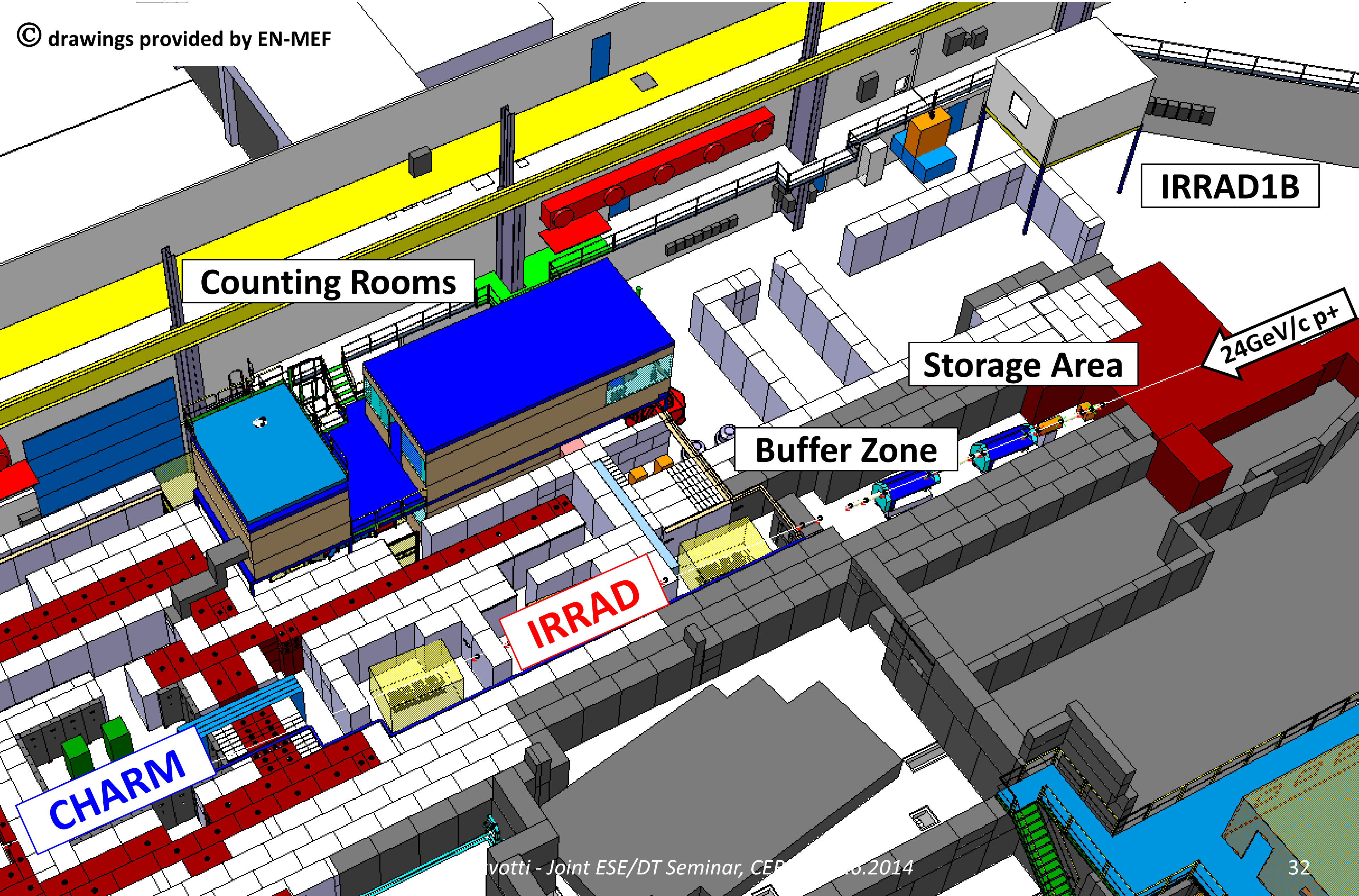
February 19th, 2013, Page 4 — Cryogenic installation for LS1 East area upgrade — T. Eisel, CERN TE-CRG-CI



© **Bernd Dehning (BE-BI)**
Marcin Ryszard Bartosik (BE-BI)
Christoph Kurfuerst
Thomas Eisel and TE-CRG

wessington cryogenics

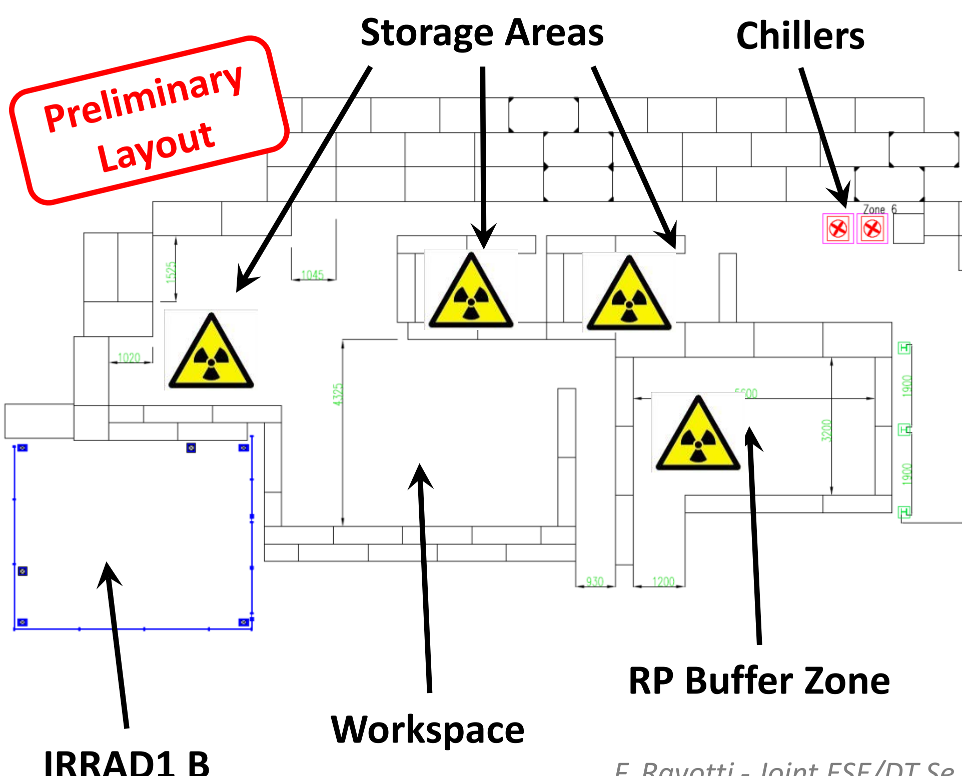
East Area EA-IRRAD Infrastructure



Proton IRRAD Infrastructure

❑ Storage area

- shielded zones for **cool-down** and **storage at room and low temperature** of IRRAD (and CHARM) irradiated equipment
- workspace to handle and **perform (setup) measurements** on irradiated equipment



Cables length from ~13m to ~20m

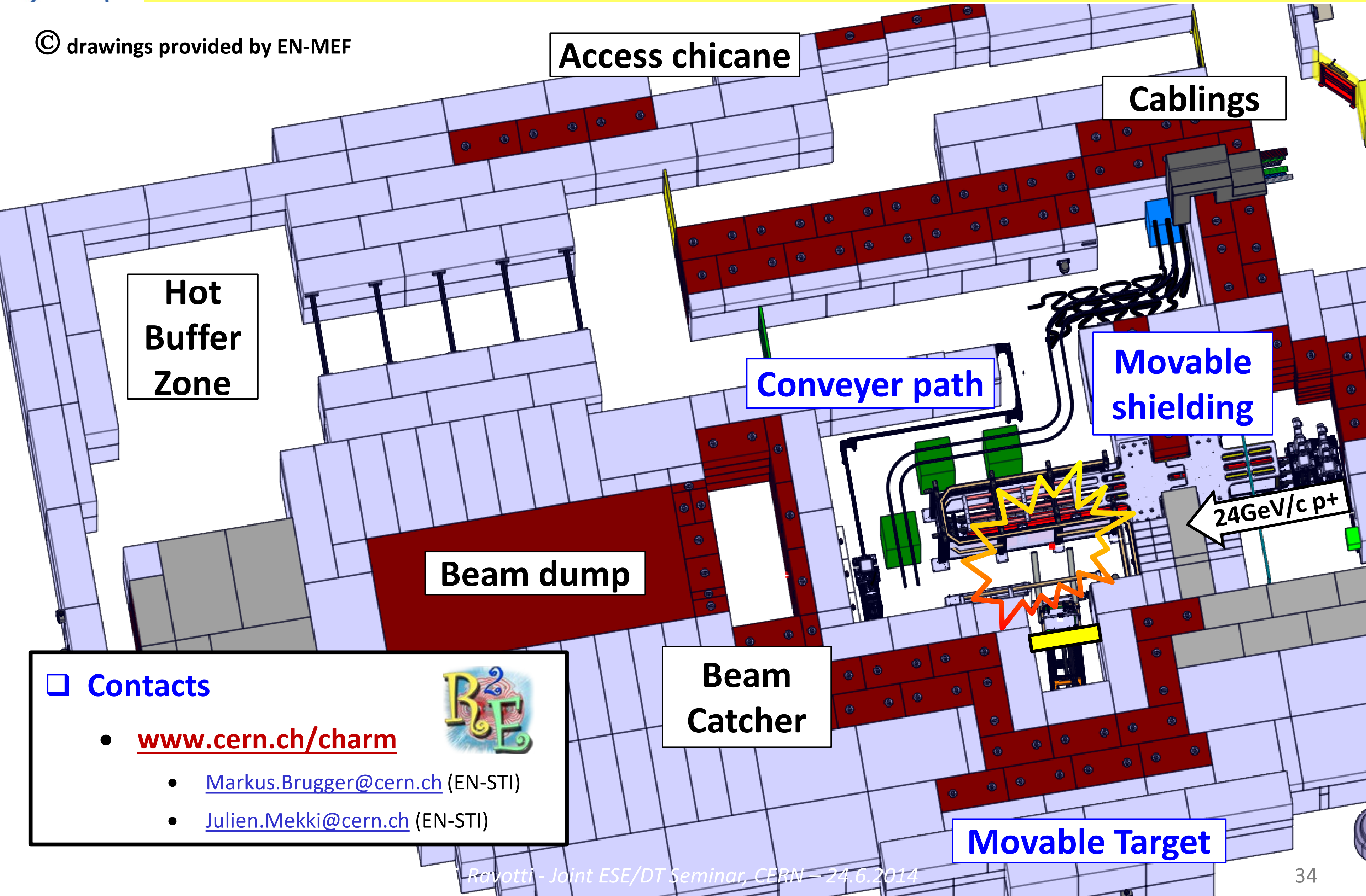
Function	Number	From	To	PP	Type of cable/pipe (CERN SCEM)	Diameter (mm)	Length (m)	Connector Beam	Connector Counting Room	Comments
Cooling Pipes (water)	2x2 pipes	Z.6	→IRR.3/5/7 →IRR.9/11/13	No	water pipe in EPDM Angst+Pfister (06.5332.2018) page 5.1.20	inner Ø 18 outer Ø 24 Ø 100 (PE isolation)	→16 →20	Raccord Laiton : douille cannelée/ MALE G ¾ A+P (06.5030.2349) Page 5.1.117	Raccord Laiton : douille cannelée/ MALE G ¾ A+P (06.5030.2349) Page 5.1.117	Paper Catalogue
Irradiation Table (2 tab... 6					**Power stepper-motors** Multi-condu... scre...	...2	→14 →17 →20	DB15 - FEMALE Socket (09.21.21.050.4)	DB15 - MALE Plug (09.21.21.060.2)	24V/1A In stock: 2x40m + 2 irradiated
								DB50 - MALE Plug 3M 8250 for IDC (RS 121-0090)	DB50 - MALE Plug 3M 8250 for IDC (RS 121-0090)	**For Chassis:** DB50 – FEMALE Crimped type (09.21.21.170.7) DB50 – FEMALE Socket IDC 3M 8350 (RS 121-0157)
					...ower 220V Flexible multi-core power cable 7×1.5mm² (RS 141-255) 137euros/50m	outer Ø 8.9		7-Poles Connectors FEMALE 618-7SNVDEX-AC (09.31.49.040.7)	7-Poles Connectors MALE 618-7PNVDEX-AC (09.31.49.030.9)	In stock: 4x40m (2 are irradiated)
SHORT TWISTED PAIRS CABLES (through shielding)	3	B.3	→Zone 2	Yes	Loose Pair Round Twist cable for IDC 2×34 type MA68 0.09mm² (AWG 28) (04.21.51.568.2)	outer Ø 11.2	→ 12 (13.2)	68poles FEMALE 3M MDR10268-0210EL (Farnell 2216932)	68poles FEMALE 3M MDR10268-0210EL (Farnell 2216932)	Male from RS 770-9022 197-2999
STANDARD TWISTED PAIRS CABLES	5 5 7 5 10 (32)	B.1 B.2 B.2 B.3 B.3	→Zone 1 →Zone 5 →Zone 2 →Zone 4 →Zone 3	Yes	Loose Pair Round Twist cable for IDC 2×34 type MA68 0.09mm² (AWG 28) (04.21.51.568.2)	outer Ø 11.2	→ 14 → ? → 17 → 16 → 20	68poles FEMALE 3M MDR10268-0210EL (Farnell 2216932)	68poles FEMALE 3M MDR10268-0210EL (Farnell 2216932)	Male from RS 770-9022 197-2999
IRRAD Beam Profile Monitor	3	B.1 B.1 B.3	→BPM1 →BPM2 →BPM3	No	Micro-Coax Samtec EQCD-020-1181.00-SBL-SBL-1-B	Ø 20-30 "Gaine" FORCH	→ 26 → 18 → 25	MALE (with cable)	MALE (with cable)	Cable in PET 30m length In stock: 4x new
COAX LEMO (5ns/m – Type C-50-2-1 <200MHz)	4x 20 (80)	B.1 B.2 B.3 B.3	→Zone 1 →Zone 2 →Zone 3 →Zone 4	Yes	50Ω Coaxial Cable Type Fitted Plugs (04.69.11.A)	outer Ø 2.85 (in bundle)	→ 14 → 17 → 20 → 16	LEMO 00 FEMALE CHASIS PFS.00.250.NTME52 (09.46.11.124.4)	LEMO 00 FEMALE CHASIS PFS.00.250.NTME52 (09.46.11.124.4)	Type of connectors!!
COAX BNC (4ns/m Type C-50-3-1 <800MHz)	4x 10 (40)	B.1 B.2 B.3 B.3	→Zone 1 →Zone 2 →Zone 3 →Zone 4	Yes	50Ω Coaxial Cable Type CB50 (04.69.11.A)	outer Ø 5 (in bundle)	→ 14 → 17 → 20 → 16	CRIMP.CAB.PLUG.C-50-3-1-BNC 50 MALE (09.46.11.700.4)	CRIMP.CAB.PLUG. C-50-3-1-BNC 50 MALE (09.46.11.700.4)	Female-Female UNION for chassis (09.46.11.254.5)
POWER (LV)	4x 4 (16)	B.1 B.2 B.3 B.3	→Zone 1 →Zone 2 →Zone 3 →Zone 4	Yes	Control Cable LSZH (12×1.5mm²) not screened (RS 141-176) (or 04.08.61.562.7)	outer Ø 12	→ 14 → 17 → 20 → 16	MOLEX Micro-FIT MALE CHASSIS 43020-1200 (RS 233-2854)	MOLEX Micro-FIT MALE CHASSIS 43020-1200 (RS 233-2854)	*Prise Female* 43025-1200 RS 233-2797
TRIAXIAL	10	B.3	→Zone 3	No (tbc)	DRAKA S-02YS(St)C(mS)CH 2.6/7.3 - CKC50	outer Ø 11.6	→ 20	Triax plug connector POLAMCO (PC90055-P-1-C)	Triax plug connector POLAMCO (PC90055-P-1-C)	BLM
TWISTED PAIRS CABLES	3x 2 (6)	B.1 B.2 B.3	→Zone 1 →Zone 2 →Zone 3	Yes	Multi-conductor screened, twisted pairs, 0,25mm², 9x2 type ND18 (04.21.52.010.3)	outer Ø 12	→ 14 → 17 → 20	BURNDY connector Chassis mounting 19pins MALE PLUG (09.31.05.148.2)	BURNDY connector Chassis mounting 19pins FEMALE SOCKET (09.31.05.152.6)	BLM
POWER (HV)	10 10 (20)	B.3	→Zone 3 →Zone 4	Yes	HV COAX.CABLE HTC-50-1-1, 5kV, RED (04.31.51.750.1)	outer Ø 3.3	→ 20 → 16	5 kV FEMALE SHV crimping connectors (09.41.25.130.5)	5 kV FEMALE SHV crimping connectors (09.41.25.130.5)	BLM M-M SHV UNION (09.41.25.170.7)

❑ Fixed cabling/piping infrastructure

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

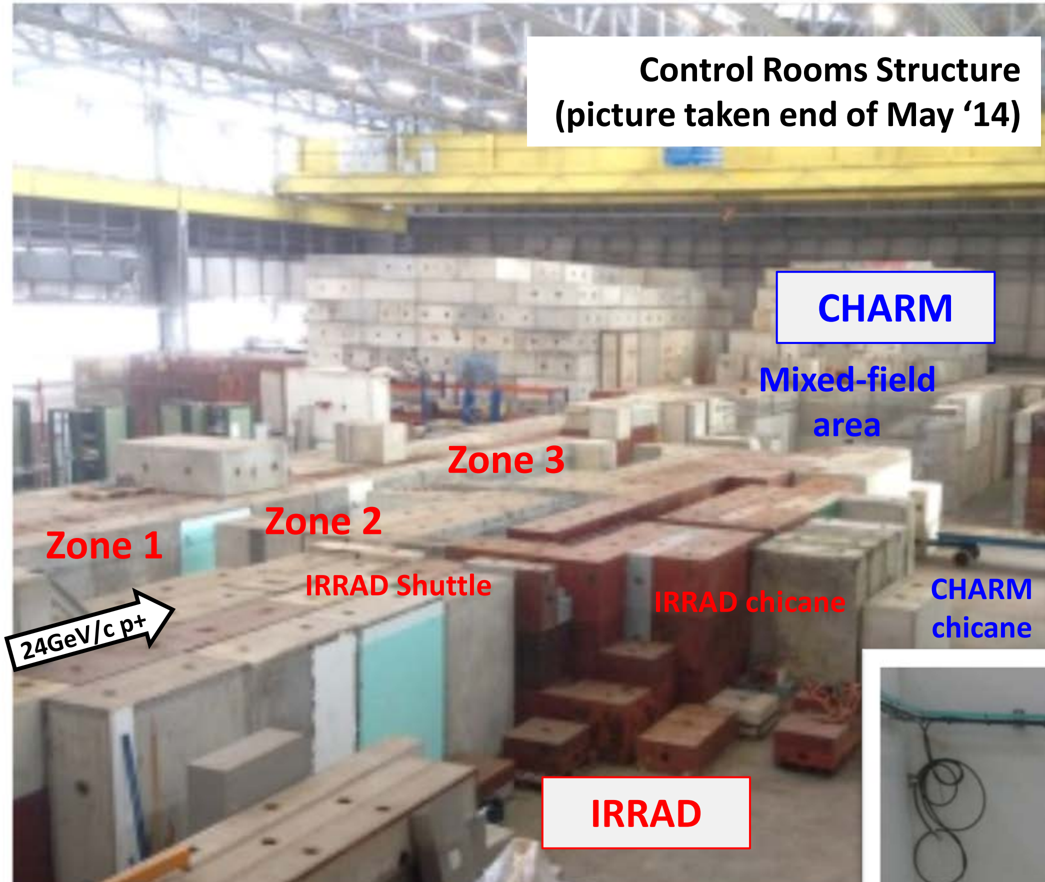
Mixed-field CHARM Facility (EN)

© drawings provided by EN-MEF



- **Contacts**
  - www.cern.ch/charm
    - Markus.Brugger@cern.ch (EN-STI)
    - Julien.Mekki@cern.ch (EN-STI)

Under construction ….

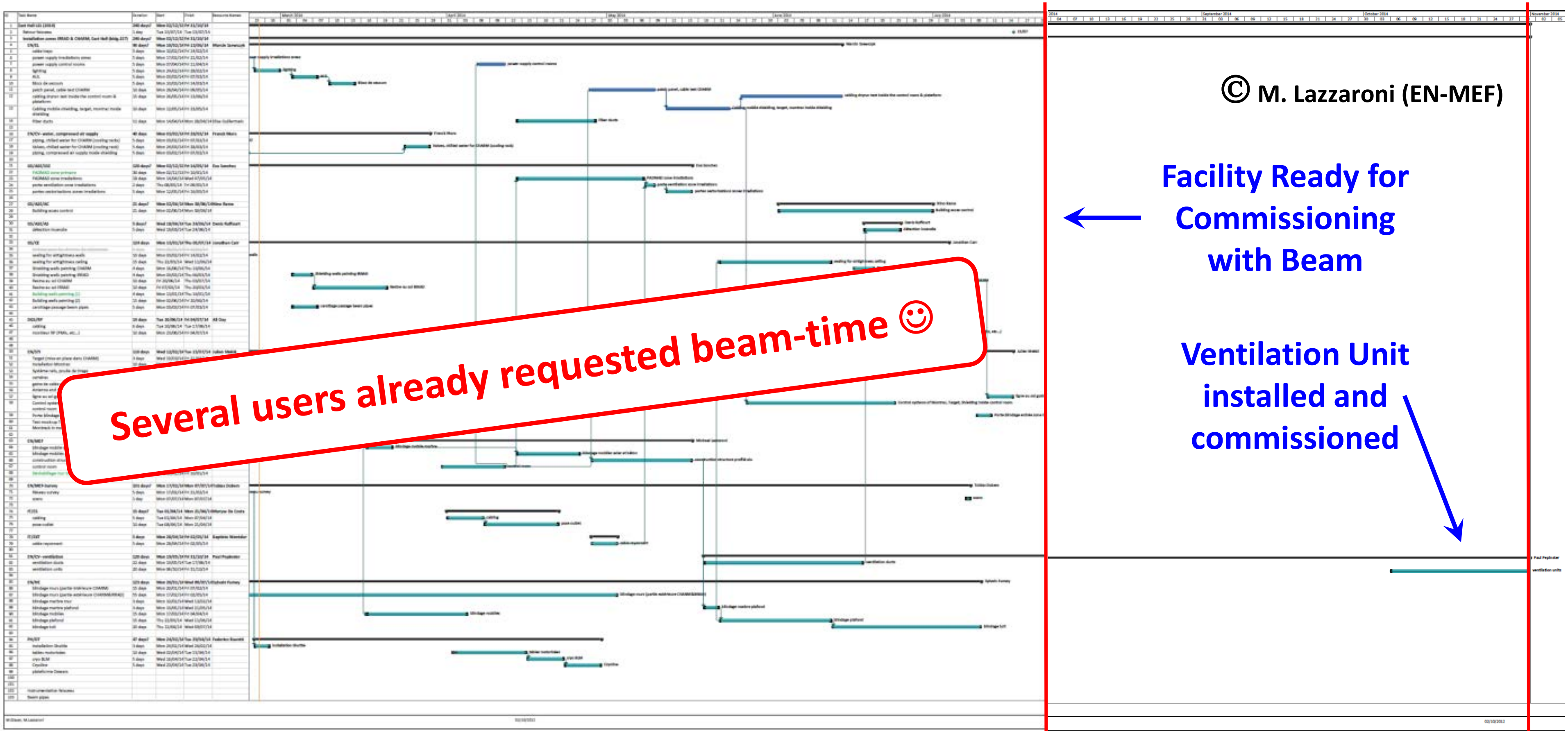


Lateral Shielding (picture: March '14)

Control Rooms Structure
(picture taken end of May '14)

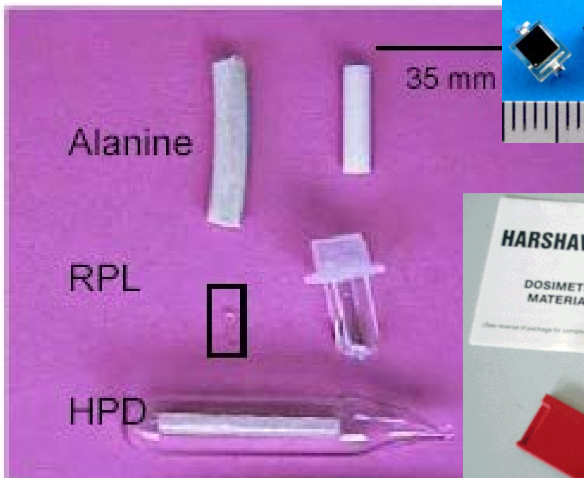
IRRAD Zone 3
(picture: end of May '14)

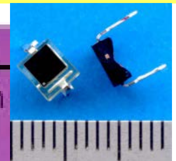
Schedule To Completion



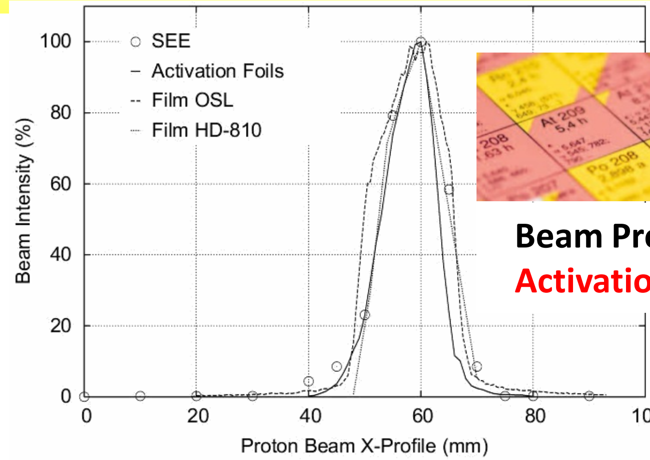
- **Current planning**
  - goal: EA-IRRAD facility ready for beam from the beginning of the EA exploitation in 2014
  - **commissioning with low intensity beam from summer 2014**
  - goal to start **first irradiation experiments in IRRAD before Winter TS (Nov. – Dec. 2014)**

Dosimetry & RadMon





Passive Dosimetry



Beam Profile / Intensity from
Activation of Aluminium foils

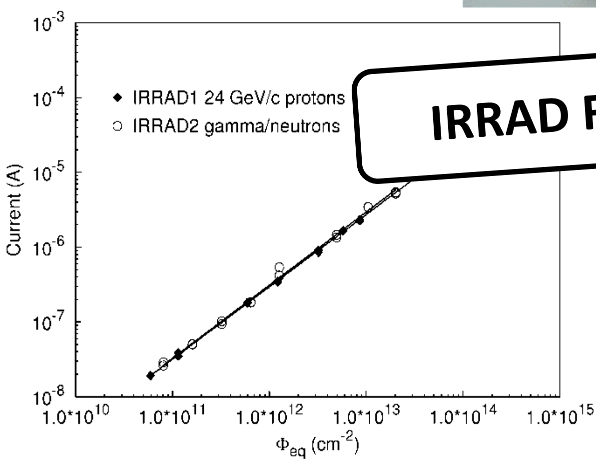
(^{27}Al(p,3pn)^{24}**Na**, ^{27}Al(p,3p3n)^{22}**Na**)

1x NaI spectrometer (+/- 6%)

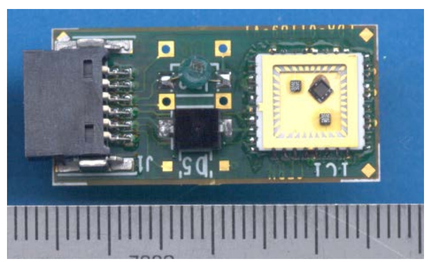
^{24} **Na**, half-life 15h, Eγ = 1368.53 keV

2x HpGe spectrometer (+/- 2%)

^{24} Na, ^{22} **Na**, half-life 2.6y, Eγ = 1274.54 keV

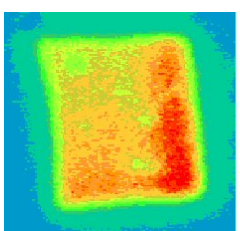


IRRAD Facility Laboratory 14-R-12

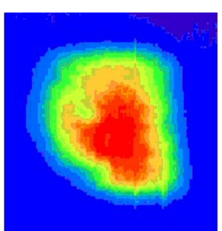


radmon.experiments@cern.ch

Active Sensors



4.5x4.5 cm²



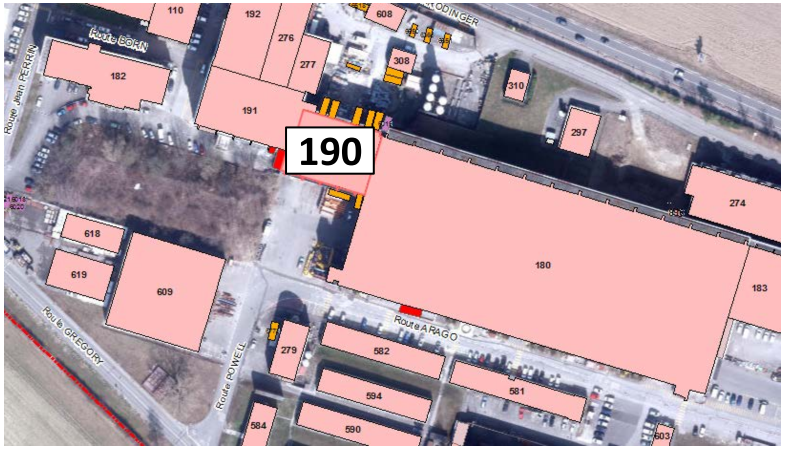
2x2 cm²

Proton beam spot characterized with GAF films

New Gamma Irradiation Facility (GIF^{++})

Gamma Irradiation Facility (GIF)

Among other clients, most LHC gas detector technologies have been validated at the GIF: CMS (RPC, CSC); ATLAS (MDT, RPC, TGC, CSC); ALICE (TOF, AMS, CPC, RPC); LHCb (MWPC); COMPASS detectors....



- ❑ **GIF: former SPS West Area**
  - ^{137}Cs, 650 GBq installed in `90s
    - Set of movable filters to attenuate γ flux
  - secondary (μ) **beam de-commissioned** (2004)
- ❑ **Since then: limited use for physics!**
  - limited photon yield
  - limited space for increasing number of users
  - … but always fully booked !

GIF Irradiator

GIF^{++} - A New Irradiation Facility

- **HL-LHC: new challenge for particle detector technologies**
  - test detectors reliability
- **GIF^{++} focuses on the long-term behavior of large GAS DETECTORS**
  - **increase in luminosity** will produce a **higher particle background**
  - measure particle **signal under harsh background** (photon) radiation conditions
    - asses **performance of detectors** under high particle fluxes
    - understanding of possible **aging of detector materials** under irradiation

❶ New radiation source

- at least **10x higher source activity** needed to produce a γ background equivalent to the one expected at the HL-LHC in a reasonable time

❷ Again access to secondary beam from the SPS

- **100 GeV muons**, 10^4 particles per spill traversing 10x10 cm^2

GIF^{++} - A Joint Project

❑ The CERN EN-department (EN-MEF)

- provides the infrastructure for housing the irradiator and detectors: **civil engineering** components (shielding, false floor …), **beam line elements**, **control room** and the **supply of general infrastructure** (electricity, gas …)
- provides the **gas distribution lines inside the facility** (about 5 km) (PL: *I. Efthymiopoulos, A. Fabich*)

EN Engineering Department

❑ The CERN PH-department (PH-DT)

- provides the **irradiator & attenuator**, the **facility controls** (GIF control system), the **gas systems**, as well as the **user management**

PH-DT
Detector Technologies

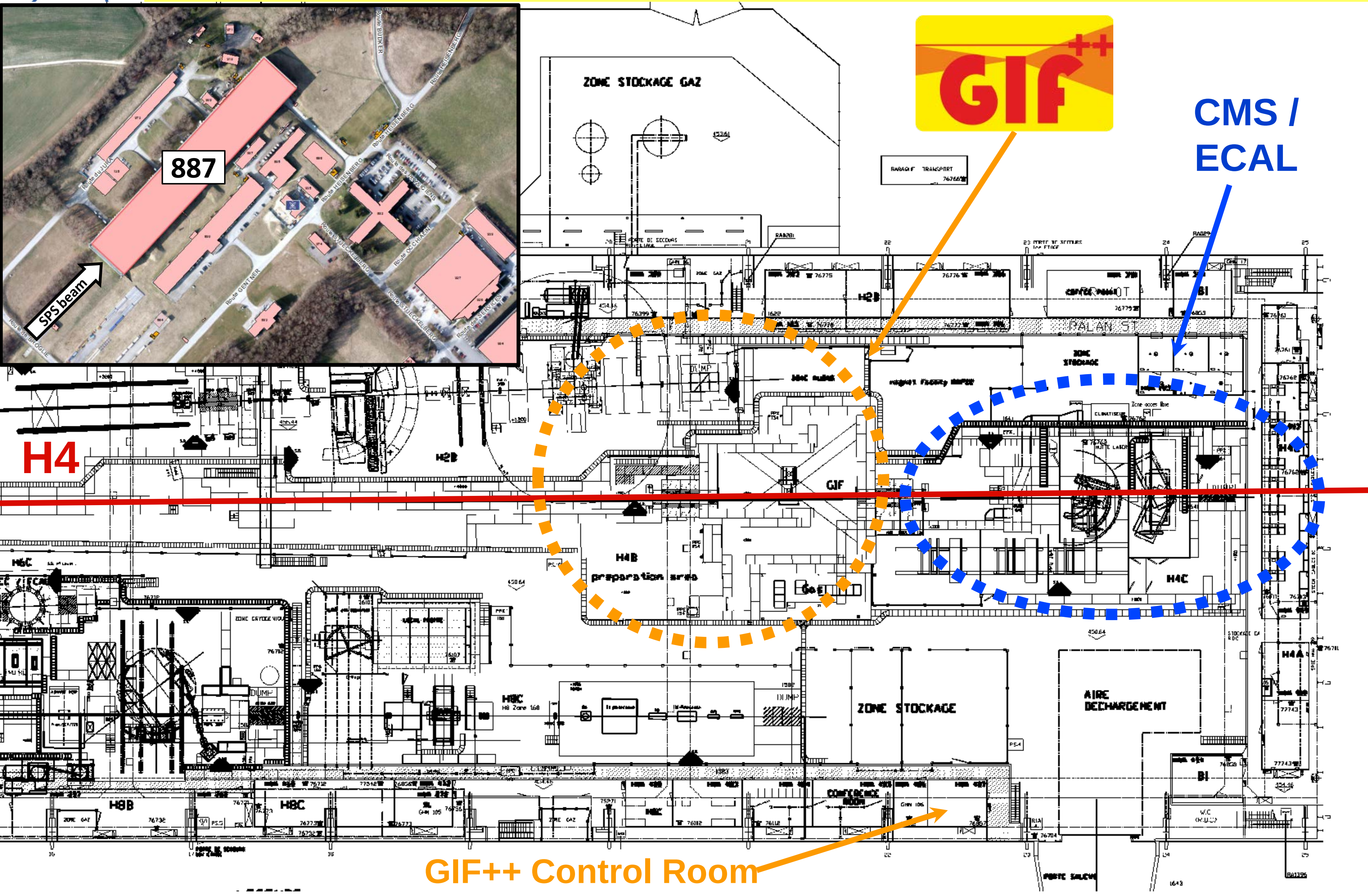
❑ The user community

- providing the **detector specific infrastructures** (beam trigger, cosmic trigger, …)
- within the framework of the FP7 **AIDA project**

GIF^{++} - Highlights

- **Unique features**
  - high-energy **μ beam combined with a ^{137}Cs source** (14 TBq)
  - **~30x higher intensity** than that at current GIF
- **High energy muon beam from T2 target, on H4 beam line**
  - **6-8 weeks dedicated beam** & around ≈ 30% of the SPS operation time halo μ beam
- **100m^2 Irradiation Bunker**
  - **two** independent **irradiation zones**
  - **real size detectors**, (several m^2), smaller prototypes, electronic components, …
- **Irradiation fields (±37°)**
  - equipped with independent **attenuator systems** up to a reduction of 50.000
  - equipped with **angular correction filters** (exchangeable).
- **Fixed installed beam-trigger & cosmic-trigger**
- **Central Control System**
  - **record of parameters** (environmental, beam, filter settings, gas, ...)
  - **provides interlocks** (e.g. for wrong gas mixtures)
- **Wide range of available gases (+ custom gases)**
  - gas patch panels in bunker & service zone

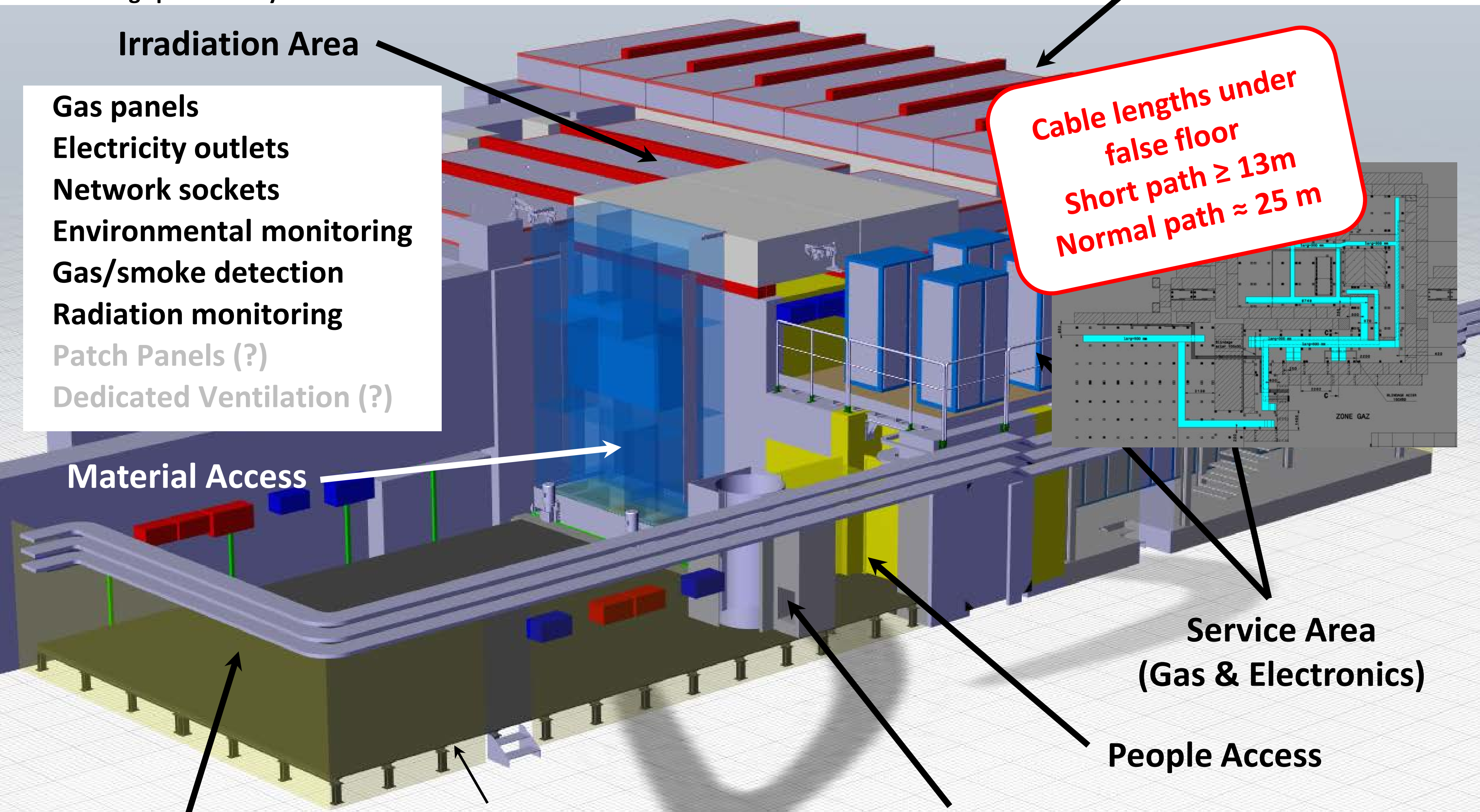
New CERN Gamma Irradiation Facility



GIF++ Irradiation Bunker

© drawings provided by EN-MEF

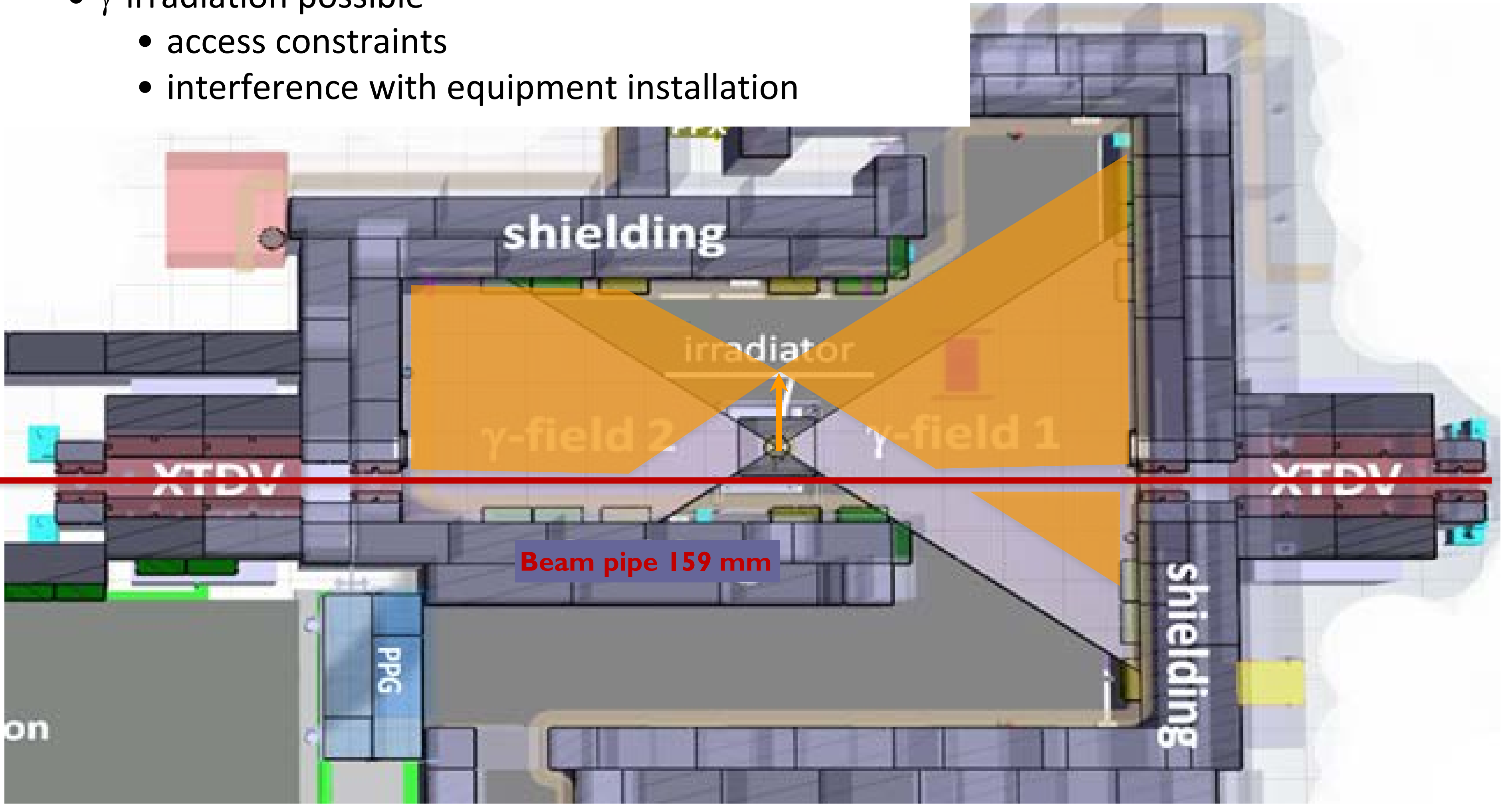
- Gas panels
- Electricity outlets
- Network sockets
- Environmental monitoring
- Gas/smoke detection
- Radiation monitoring
- Patch Panels (?)
- Dedicated Ventilation (?)



GIF^{++} - Irradiation Fields

GIF^{++} - Irradiation Fields + beam pipe

- **CMS ECAL requires e$^-$ beam for ≈ 3 weeks per year**
  - installation of beam pipe necessary
  - γ-irradiation possible
    - access constraints
    - interference with equipment installation



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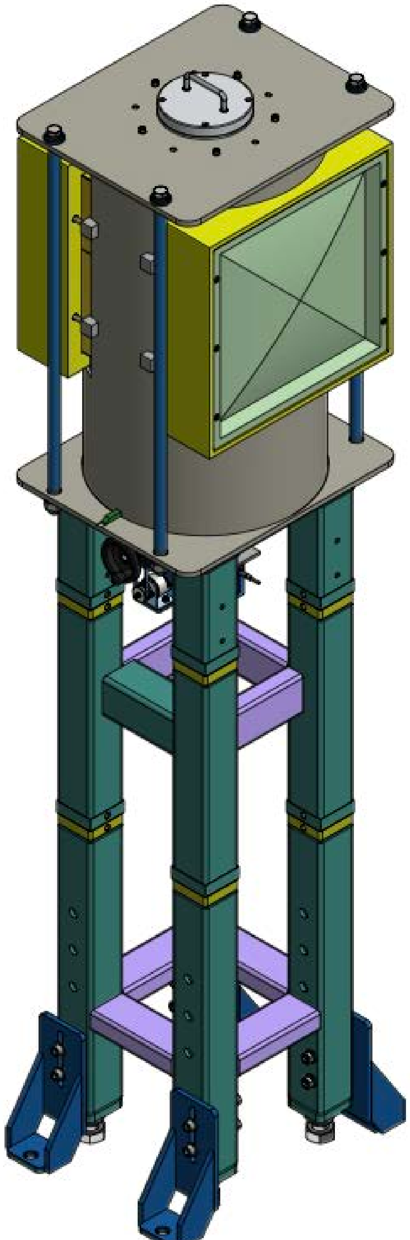
GIF++ Source

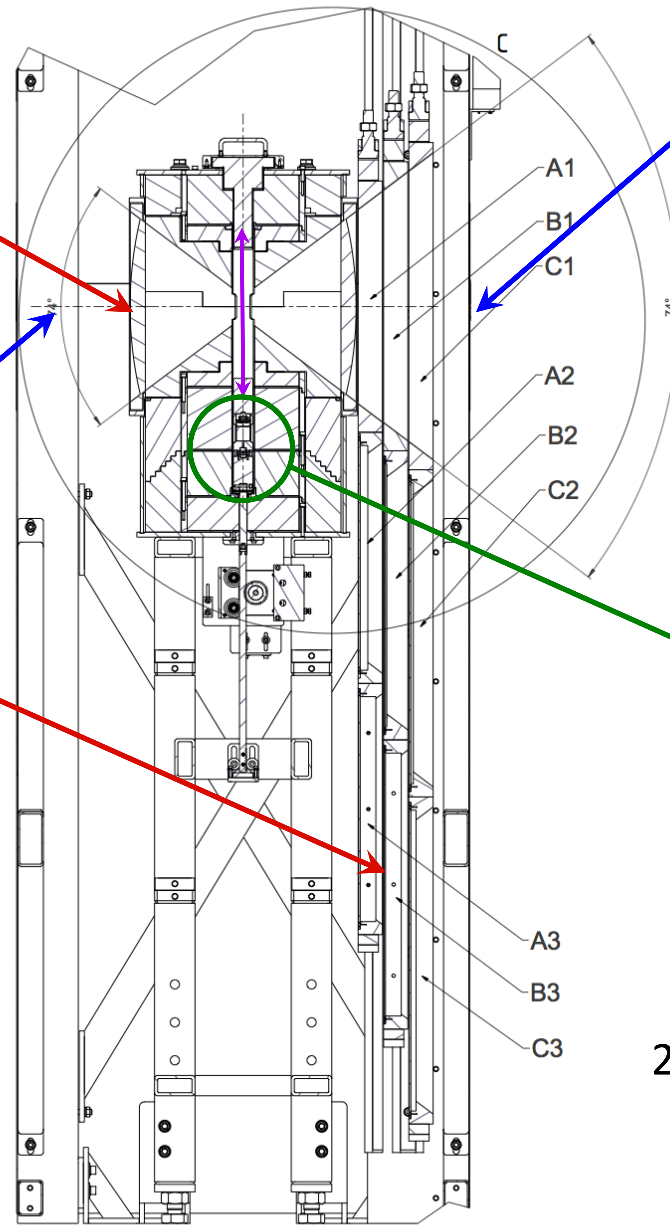


Angular correction filter

Secondary field

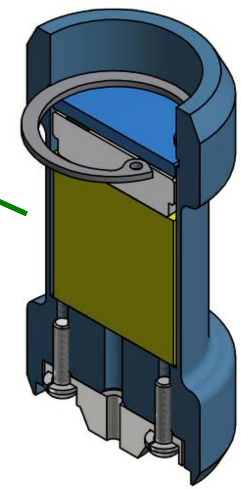
Radiation Attenuator

3 planes of Pb (Fe) plates, reduction factor up to 50.000



Main field

Source



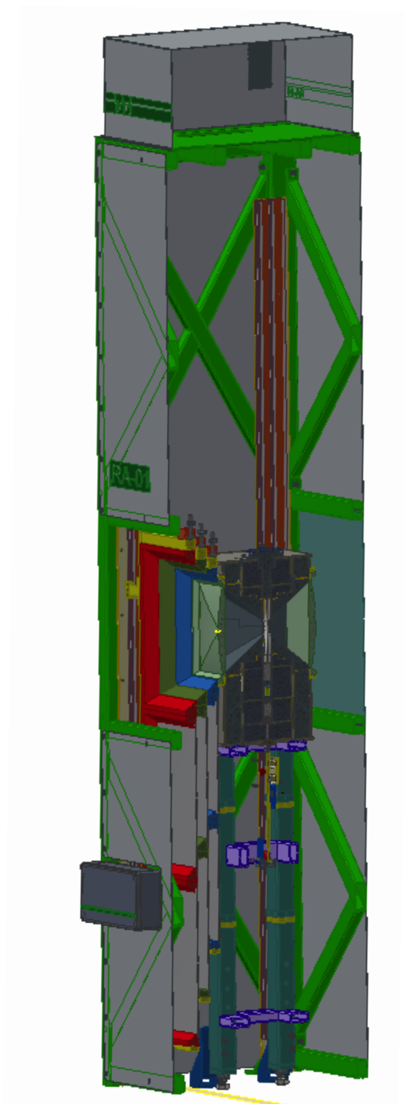
14 TBq ^{137}Cs

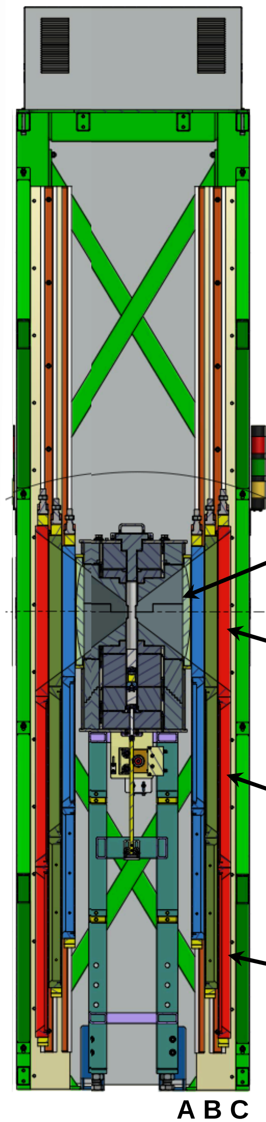
260 µGy/s at 1m.

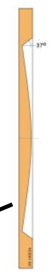
~1 Gy/h at 1m.

GIF^{++} - Irradiator & Filter Setup

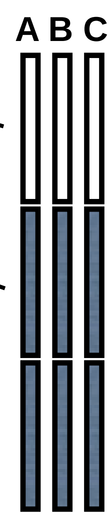
Two identical attenuation systems each consisting of one angular correction filter (Fe) and 6 absorption filters - a total of 14 custom shaped filters





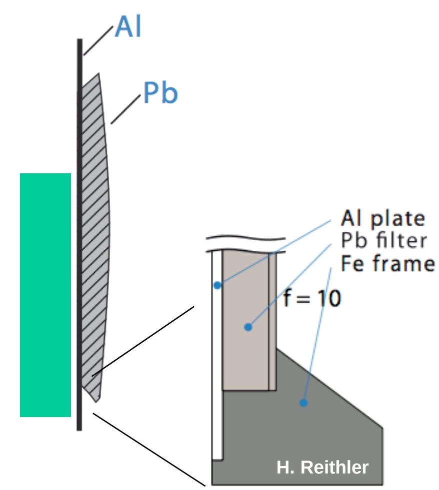


Angular correction filter provides uniform photon distribution for large area detectors



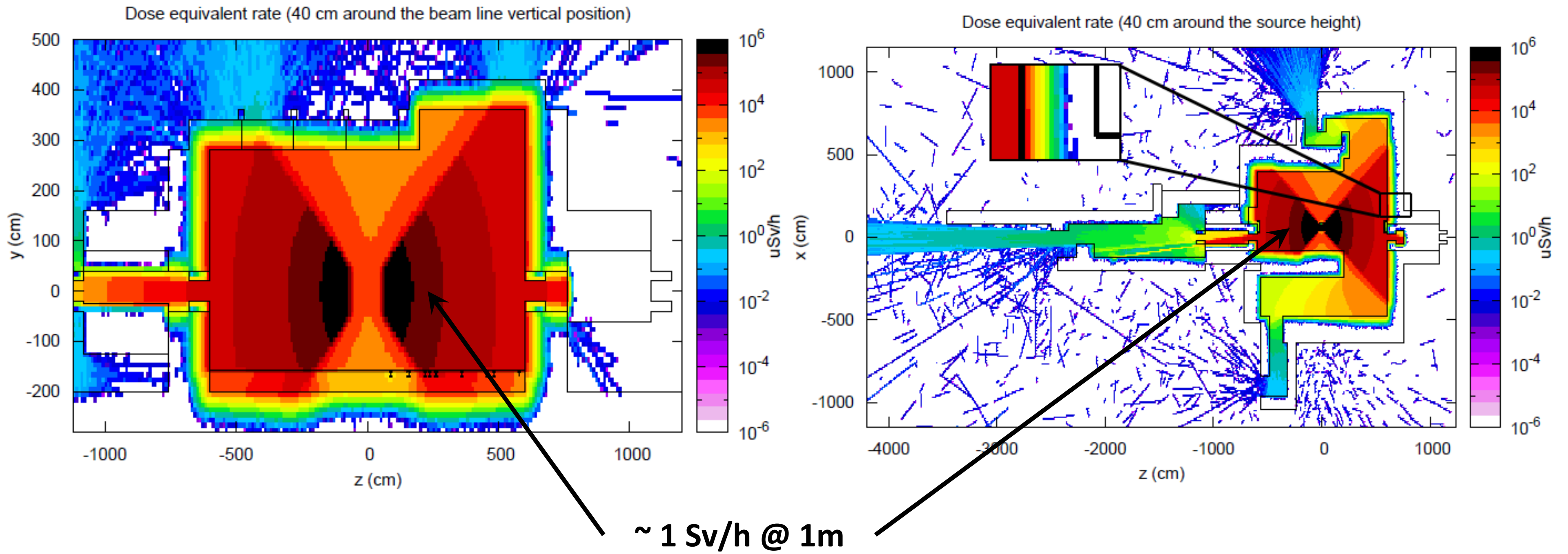
Filter System :

Absorption factor		
0	0	0
10	1.47	2.15
100	100	4.64



GIF++- Radiation Simulation

© **B. Biskup (EN-MEF), D. Pfeifer**

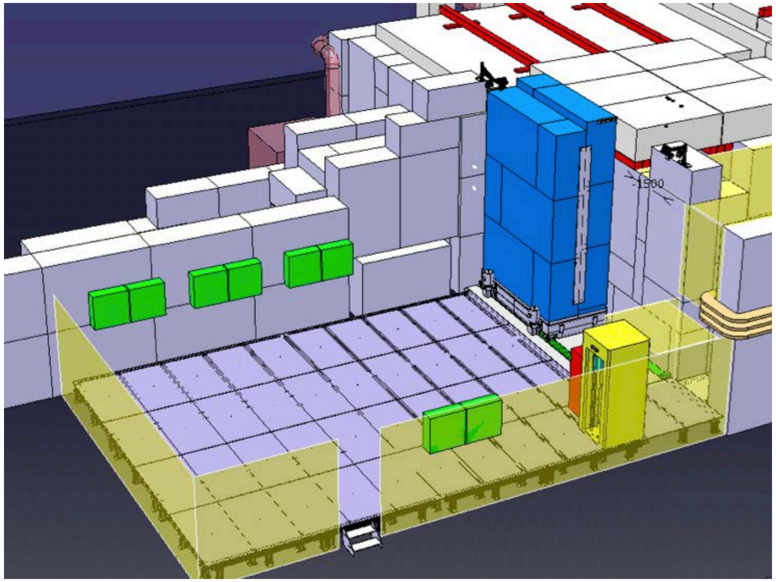


Max. expected doses at HL-LHC	Equivalent time at GIF++ (~ 50 cm from source)
Si-trackers: ~ MGy/y	>> years
Calorimeters: ~ tens kGy/y	< 1 year
Muon systems: ~< Gy/y	**~ minutes/hours**

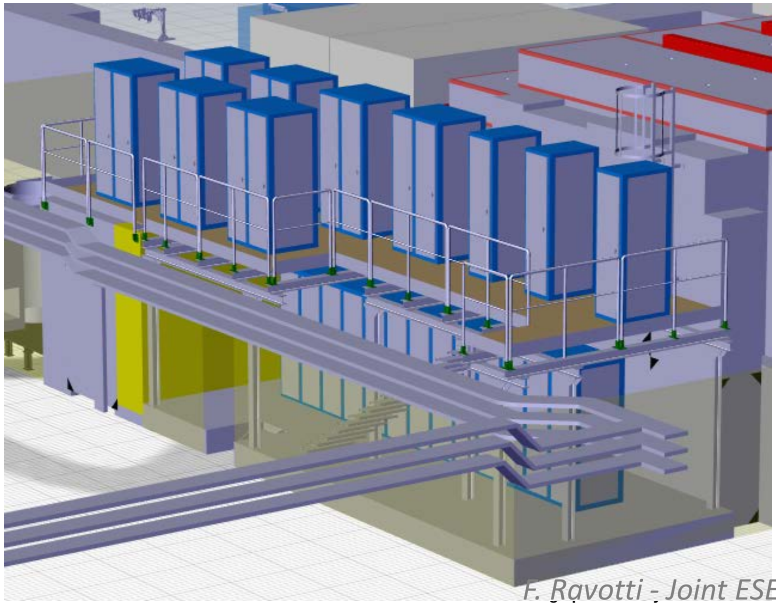
Layout Optimized for Radiation Safety

(FLUKA Simulations)

GIF^{++} - Preparation & Service Zone

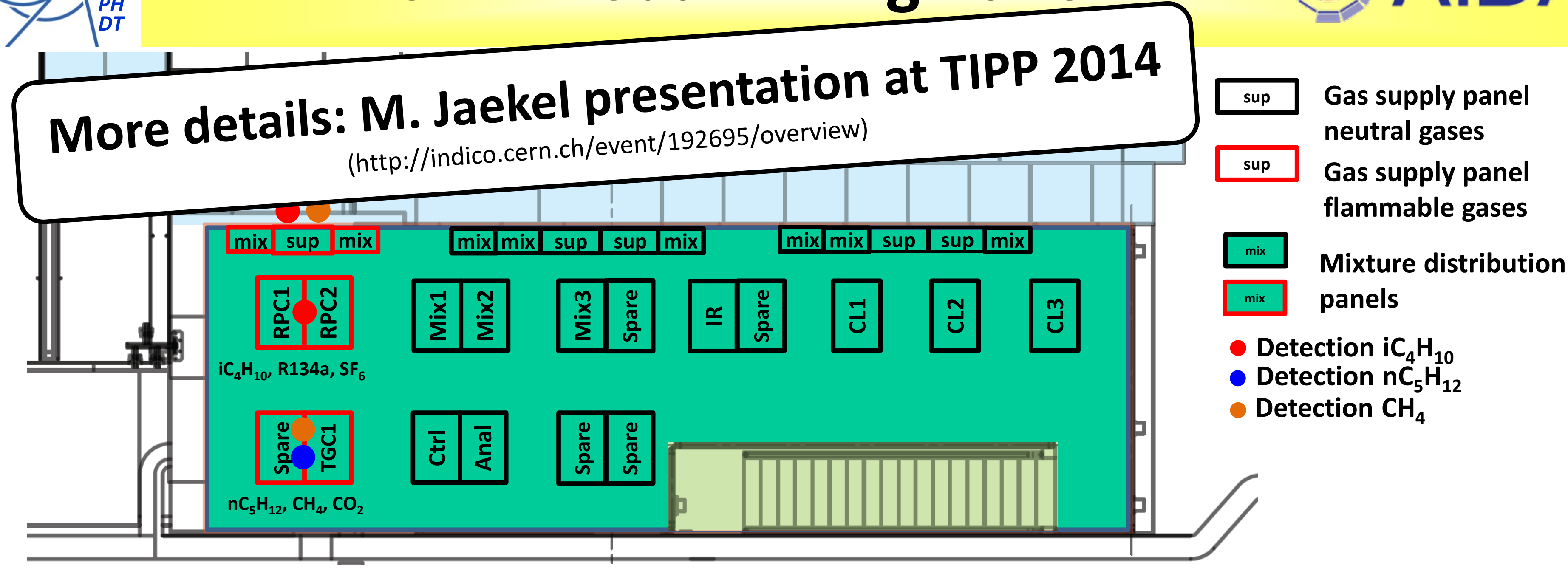


- **Large Preparation Zone (≈ 80m^2)**
  - equipped with gas lines, electricity & network. Signal cables and HV/LV patch panels will be added during a first upgrade
  - **full-size detectors can be setup and commissioned before moved to the radiation zone**, already connected to the final DAQ



- **Ground floor**
  - **17 electronic racks** hosting the irradiator controls, DCS, user equipment, fire detection, ...
- **Top floor**
  - **17 gas racks** and distribution panels (40m^2 net area)

GIF^{++} - Gas Mixing Zone



❑ Gas-mixing zone

- 9 lines for **neutral gases**: Ar, CO_2, N_2, He, SF_6, CF_4
- 6 lines for **flammable gases** or with very low vapour pressure:

  iC_4H_{10}, CH4, Ar/H_2 (optional), $C_2H_2F_4$ + 2 spares
- 3 spare pipes; 2 exhaust lines
- lines & room heated
- several supply panels

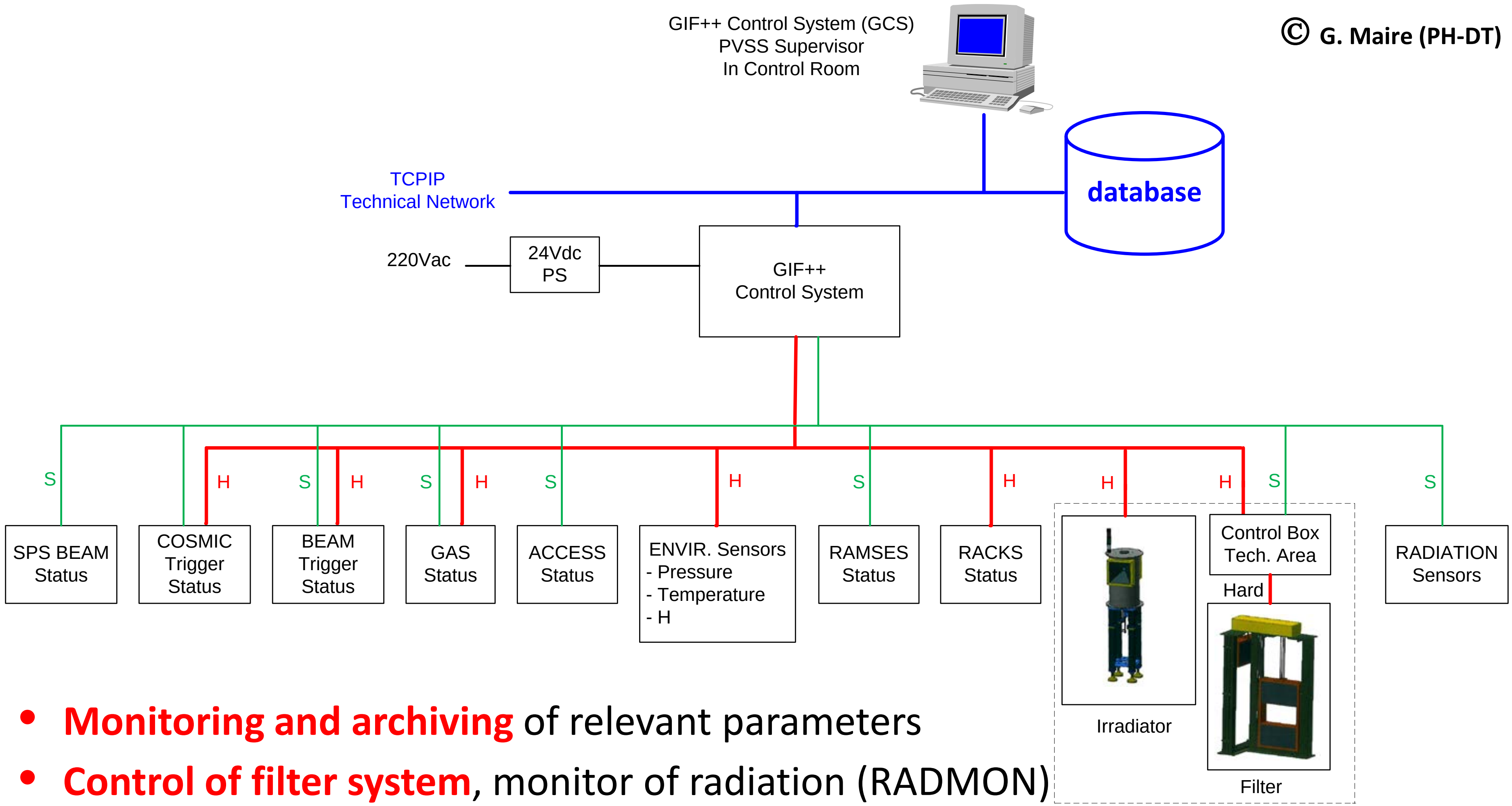
❑ At full capacity

- 6 mixing racks
- 3 closed loop gas systems
- 2 analysis racks
- 1 control rack
- 5 spare racks

❑ Gas analysis capabilities

GIF++ - Control System

© G. Maire (PH-DT)



- **Monitoring and archiving** of relevant parameters
- **Control of filter system**, monitor of radiation (RADMON)
- **Providing interlocks** (e.g. on gas system faults)
- **Remote monitoring**, web display, ...

GIF^{++} User Infrastructure

TIPP 2014
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User infrastructure

WP-8.5.3: GIF++ User Infrastructure

- *Bulgaria:* INRNE
- *Greece:* NTUA, AUTh, Demokritos, NCUA
- *Israel:* Weizmann, Technion, Tel-Aviv U.
- *Italy:* INFN-Bari, -Bologna, -LNF, -Rome2

- **Beam tracker**
- **Cosmic tracker**
- **Gas + Environmental monitoring**
- **Radiation monitoring**
- **Detector Control System**
- **DAQ system**

1 deliverable:

GIF++ Infrastructure commissioning and utilization → 30/09/2014

More details: M. Jaekel presentation at TIPP 2014 (http://indico.cern.ch/event/192695/overview)

TIPP 2014
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Cosmic tracker

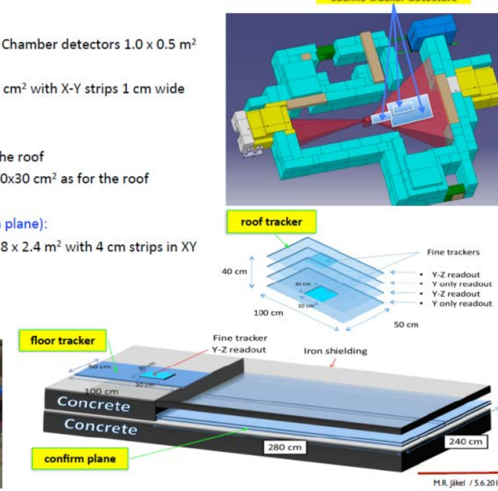
expected location of the cosmic-tracker detectors

Roof tracker:
- 4 independent Resistive Plate Chamber detectors 1.0 x 0.5 m^2
- readout strips 3 cm wide
- 1 or 2 fine tracking RPC 30x30 cm^2 with X-Y strips 1 cm wide

Floor tracker:
- 1.0 x 0.5 m^2 chambers as for the roof
- 1 fine tracking RPC chamber 30x30 cm^2 as for the roof

Underground detector (confirm plane):
- Double layer RPC chambers 2.8 x 2.4 m^2 with 4 cm strips in XY

RPC chamber very similar to the confirm plane recently installed in ATLAS



M.R. Jäkel / 5.6.2014

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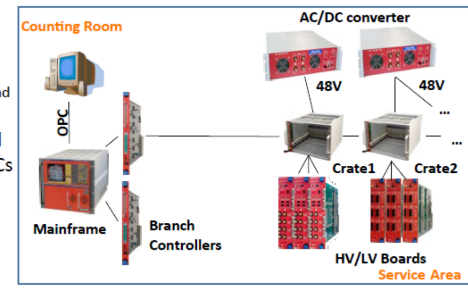
Detector Control System + sensors

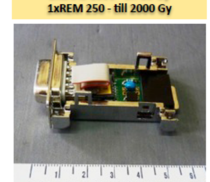
- Use PVSS/WinCC OA (as in LHC experiments)
- CAEN Easy Power System [1 mainframe, 1 Power Generator, 1-2 crates + with HV and LV boards and 1 ADC A-3801 board for monitoring (128 channels), also for ENV and gas monitoring]
- Mainframe and PC in proximity of the control room (radiation-free area) along with DAQ PCs and equipment
- EASY crates and other equipment closer to detector area



Radiation sensors

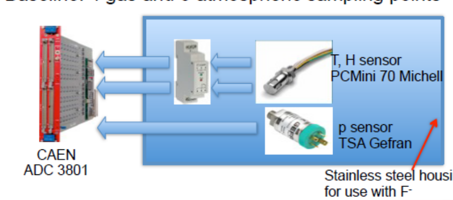
Basic configuration:
4 + 4 dosimeters,
(controlled by a
PC→RS485→μCU)

RADMON PCB BASED WITH 2 RadFETS DETECTORS
1xLAAS 1600 - till 10 Gy
1xREM 250 - till 2000 Gy



Gas and Environmental sensors

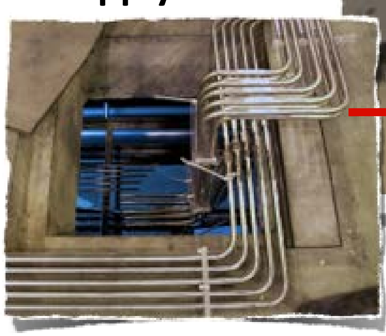
Monitoring (for both atmospheric and gases): **p, T, rH**
Baseline: 4 gas and 6 atmospheric sampling points



M.R. Jäkel / 5.6.2014

GIF^{++} - Construction Overview

Supply lines



© M. Jaekel (PH-DT), picture taken 28/5/2014

GIF^{++} - Construction Overview

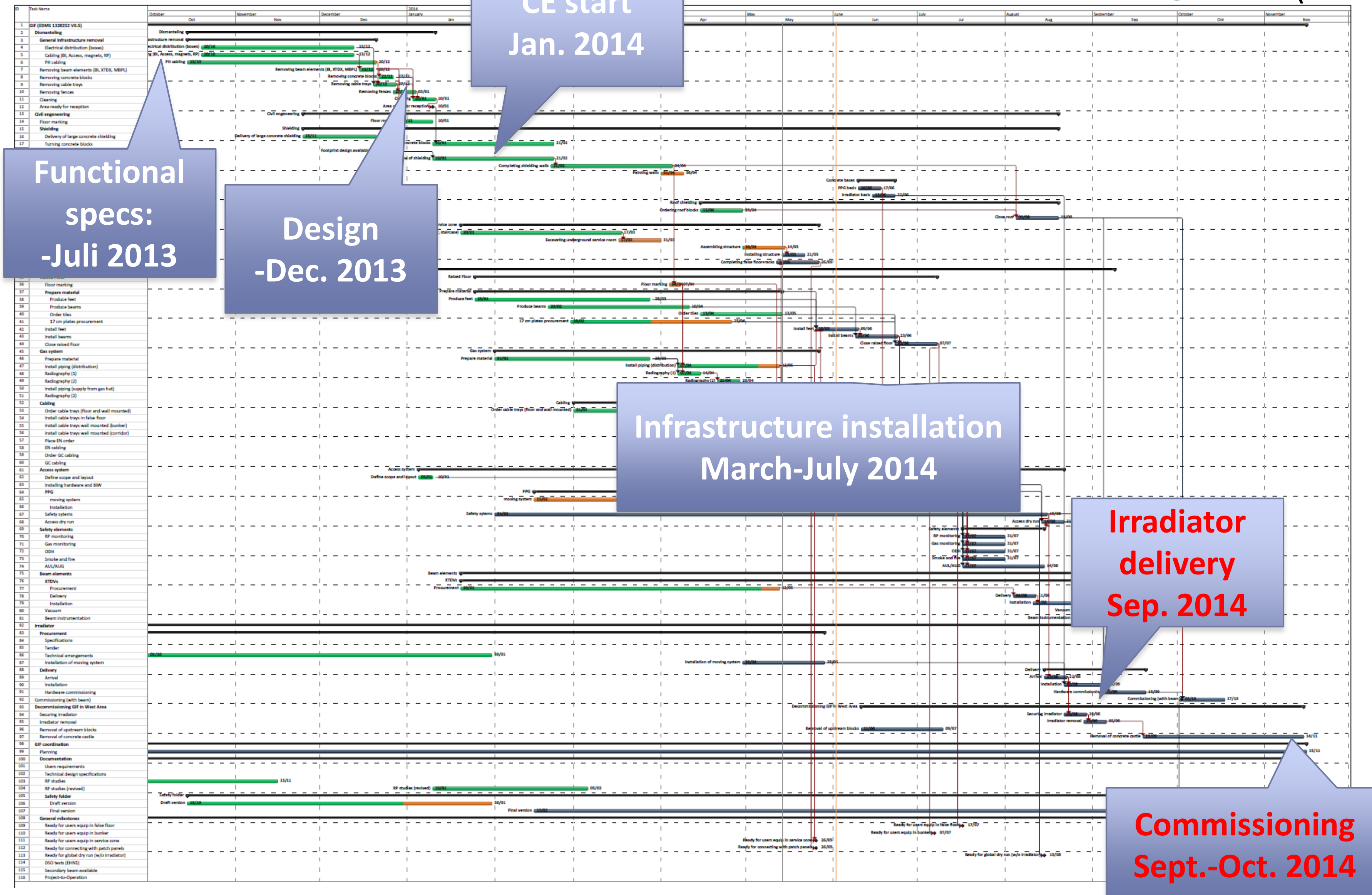
© M. Jaekel (PH-DT), picture taken 28/5/2014

GIF^{++} - Control Room

© M. Jaekel (PH-DT), picture taken 28/5/2014

Schedule To Completion

© A. Fabich (EN-MEF)



EDMS 1328252 V0.3

Other CERN Irradiation Facilities

CC60 - CERN Cobalt 60 Test Facility

© M. Brugger (EN-STI)

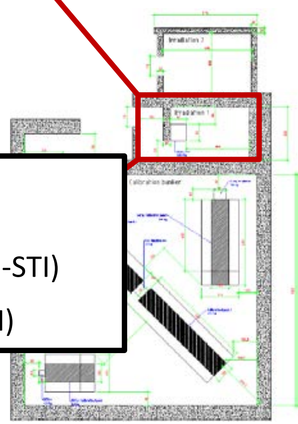
❑ New CERN Co-60 Test Facility

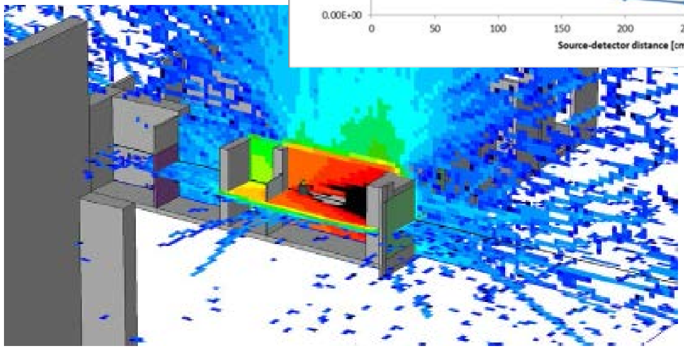
- **Location:** new DGS-RP calibration hall on Prevessin site
- **Available:** > Nov. 2014

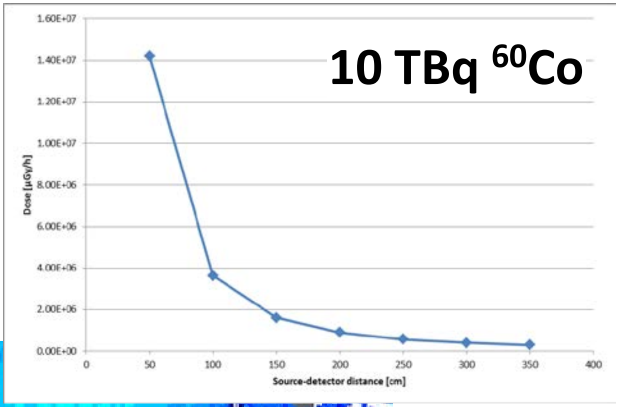
NEW!

❑ Target users (main)

- electronic component/system qualifications including batch testing, …
- dose range from ELDRS to applications in the **1-10kGy** range (for **larger volumes**)
- higher doses (up to the **range of 100kGy**) can be reached for **smaller samples**





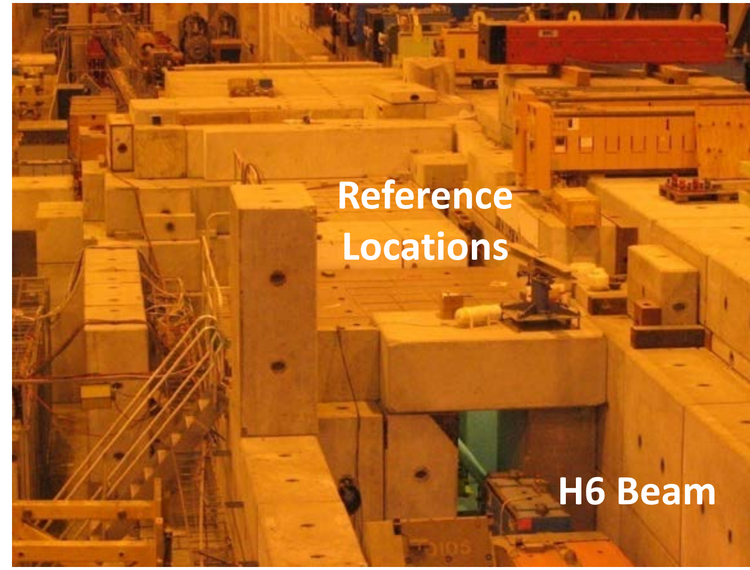


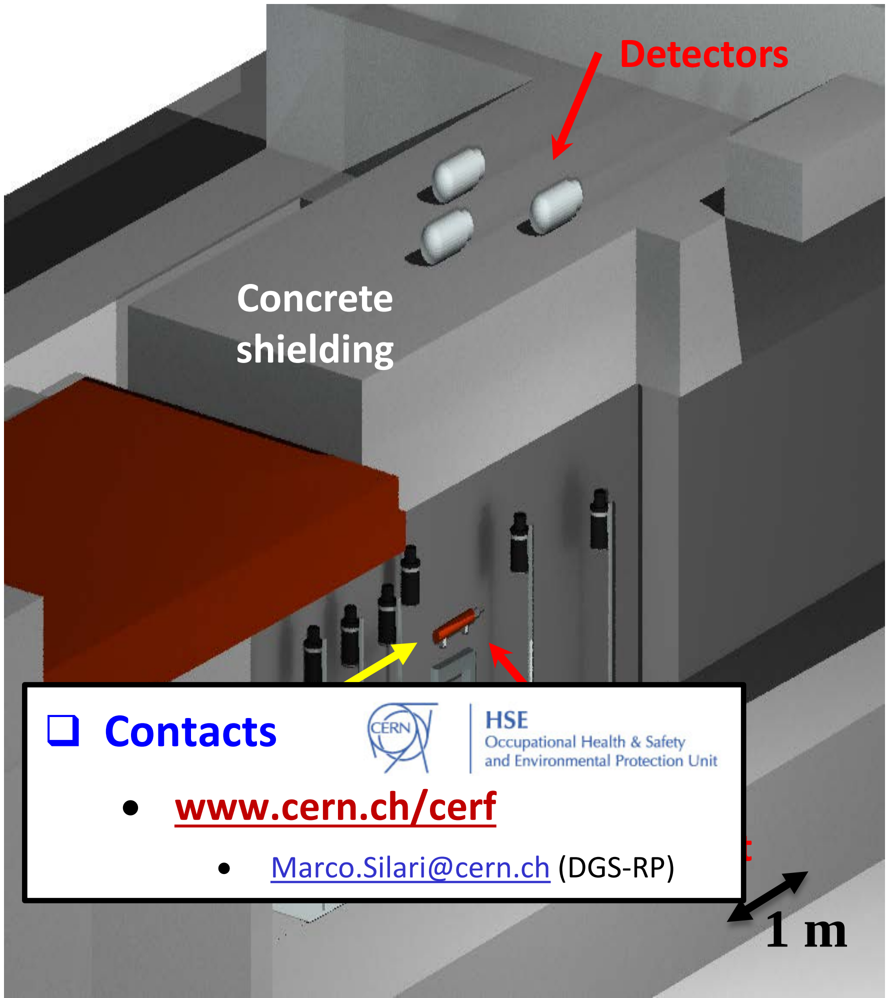
❑ Contacts

- Markus.Brugger@cern.ch (EN-STI)
- Julien.Mekki@cern.ch (EN-STI)

CERF - CERN Reference Facility

- **SPS (H6) secondary beam, 120 GeV/c hadrons**
  - SPS North Area; H6 beam-line
  - HEH beam (61% π^+, 35% p^+, 4% *k*) on Cu target





- **Contacts**
  - **www.cern.ch/cerf**
    - Marco.Silari@cern.ch (DGS-RP)

HSE
Occupational Health & Safety
and Environmental Protection Unit

- **Well defined & simulated mixed-field**
- **Intensity**
  - max 10^8 particles/pulse (slow extraction)
  - resulting in **up to few Gy/h**
- **In operation since 1992 (few weeks/y)**
- **Users (mainly)**
  - test/calibration of passive/active detectors for **dosimetry** or **rad. monitoring**
  - internal and external users

CERN “small” Irradiation Facilities

❑ Irradiation equipment on CERN site

- **X-ray generators/sources** belonging to CERN groups / institutes
- specific use (e.g. calibration); **sometimes** open for “public” use
- **not covered in this talk …**

X-ray generator (PH-ESE), up to 9Mrad/h
Contact: Federico.Faccio@cern.ch

Many others on CERN site:
bld. 14,
bld. 15,
bld. 27,
bld. 154,
…

Irradiation Results Data

Radiation Damage CERN Reports

© compiled after M. Tavlet (EIROWorkshop RadHard2010, Lisbon, 2010)

Radiation test results DATA COMPILATION

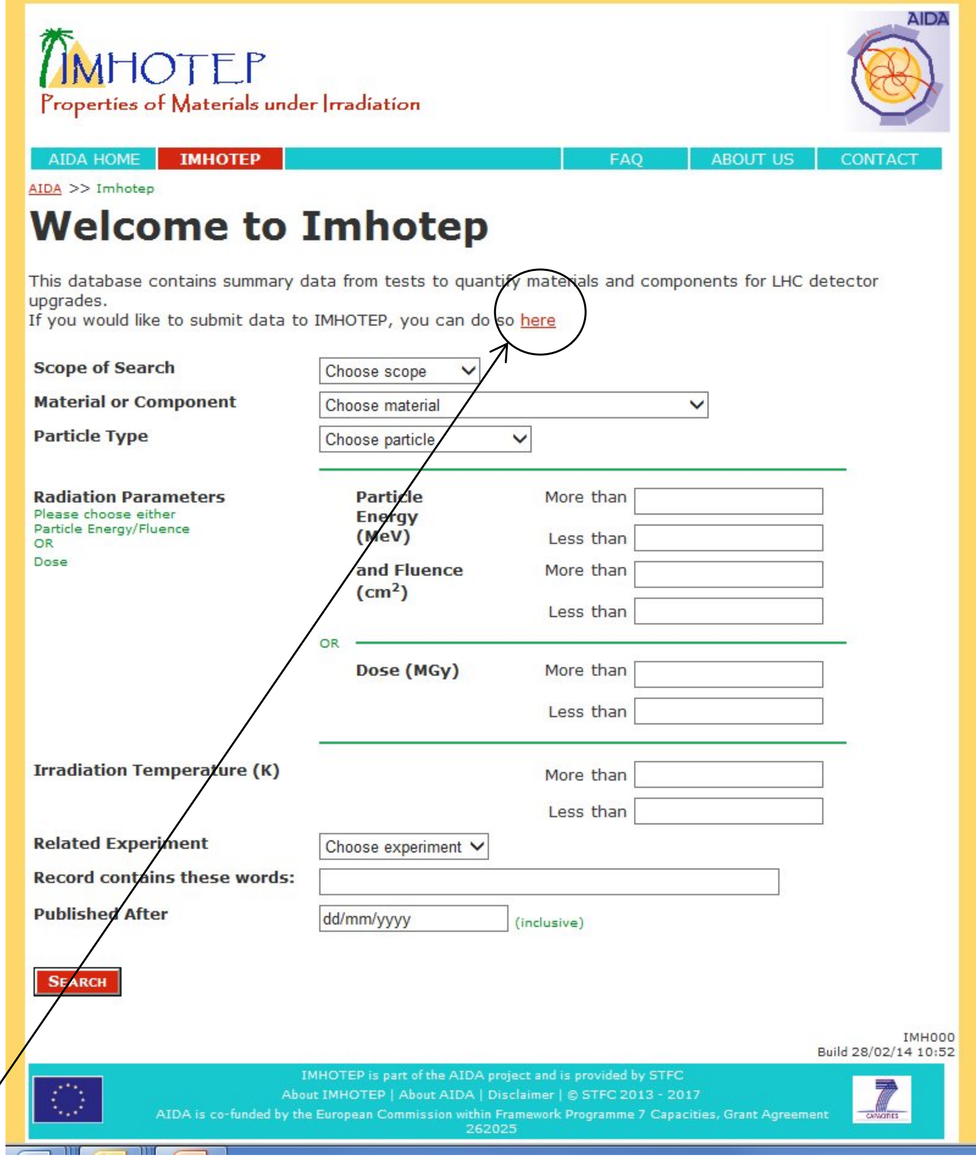
- Systematic results "catalogues" published as CERN Yellow Reports (http://cds.cern.ch/):
  - 79-04 + 89-12 / **cable insulating materials**
  - 79-08 + 98-01 / **resins and rigid plastics**
  - 82-10 / **miscellaneous materials and components**
  - 85-02 / **resins for HV applications**
  - 2001-006 / **adhesives**

Other interesting CERN reports on Radiation Damage/Effects on Materials:

- 68-13 / The effect of nuclear radiation on the electrical properties of epoxy resins
- 70-05 / Effects of radiation on materials and components
- 75-10 / Action des radiations ionisantes sur les résines époxydes
- 72-07 / **Selection guide to organic materials for nuclear engineering**
- 75-03 / Radiation and fire resistance of cable-insulating materials used in accelerator engineering
- 81-05 / The selection and properties of epoxide resins used for the insulation of magnet systems (…)
- 83-08 / **Long-term radiation effects on commercial cable-insulating materials irradiated at CERN**
- 85-08 / **Radiation damage to organic scintillation materials**
- 96-05 / **Results of radiation tests at cryogenic temperature on some selected organic materials for the LHC**

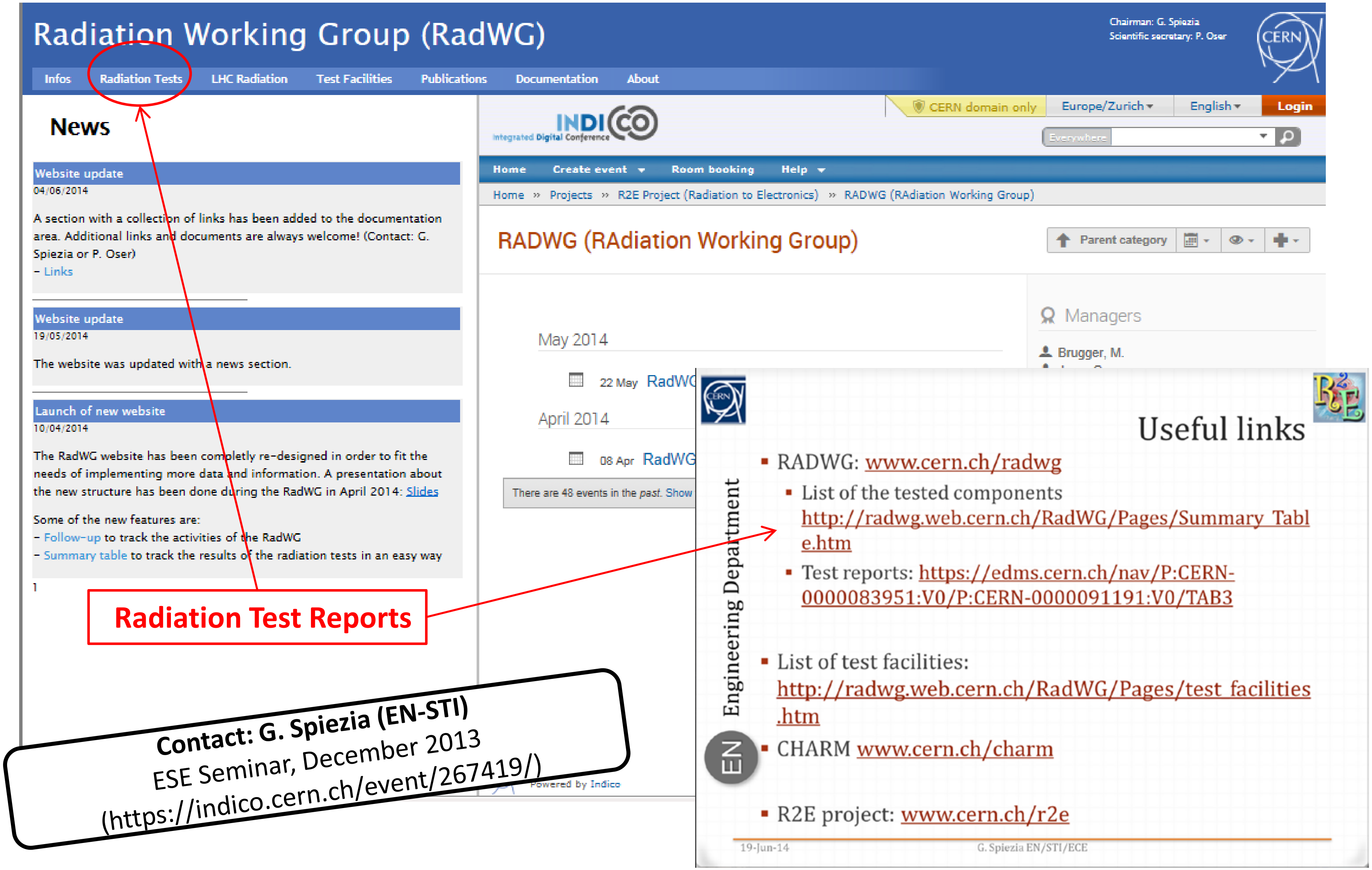
AIDA Database (Experiments)

- **Qualification of selected components in the framework of AIDA**
- **Participants**
  - INFN (MI, PG), STFC-RAL, UNIGE, ETHZ
  - on-line since March 2014
- **http://tinyurl.com/aidaimhotep**
- **Material tested so far:**
  - inorganic scintillating crystals, electronics, APS, epoxies, …
  - 17 entries (March 2014)
- **Characteristics**
  - ready to take data,
  - rely on the users!
  - possibility to upload pdf
  - robust implementation
    4 servers (backup, firewalled)



Link to data entry page

Electronics Equipment (Accelerators)



Summary

- **Unique set of Irradiation Facilities available at CERN**
  - from **TEST-AREA “locations”** in the ‘90 …
  - … to **fully dedicated (and equipped) FACILITIES** after LS1
  - upgrade of **detectors**, **electronics** and **accelerator equipment** toward HL-LHC
- **Upgrade projects (fully operational in 2015)**
  - Experimental community (PH):
    - **Proton** facility (**IRRAD**) and “detector” **gamma** facility (**GIF++**)
  - Accelerator community (EN):
    - **Mixed-field** facility (**CHARM**) and **gamma** facility (**CC60**)
- **Existent infrastructures**
  - **back after LS1:** **HiRadMat** and **CERF**
  - **“always” running:** **X-rays generators/sources** in laboratories within CERN
- **Irradiation results data**
  - “historical” CERN reports (data collections)
  - efforts ongoing to create dedicated “collections” for accelerator/experiments

Summary

Facility	Particle Type	En. / Mom.	Intensity	Beam Spot	Beam structure	Availability
IRRAD	p^+	24 GeV/c	~ 1-3×10^{10} p/cm^2/s	12×12mm^2 (FWHM)	1-3 spill/CPS (30s) spill = 0.4s	May-November (PS operation)
CHARM	mixed-field (24 GeV/c p^+)	n^0 (thermal - HE) + HEH > few 100MeV	Lateral: 10^7-10^{10} HEH/cm^2/h Long.: 10^8-10^{11} HEH/cm^2/h TID: 0.01-100 Gy/h	secondary environment from target	1-3 spill/CPS (30s) spill = 0.4s	May-November (PS operation)
GIF^{++}	$\gamma + \mu$	0.662 MeV + 100 GeV muons	14TBq (~1Gy/h at 1m.) + 10^4 particles/spill	panoramic (±37°) + 100×100mm^2	continuous + spills/SPS cycle	all year + 6-8 weeks/year
CC60	γ	1.17 MeV, 1.33 MeV	10TBq (~3Gy/h at 1m.)	standard	continuous	all year
CERF	mixed-field (120 GeV/c HEH)	n^0 (10-100 MeV or lower) + HEH	max: 10^8 particles/spill (on the target)	tertiary environment from target	spills/SPS cycle spill of few sec.	few weeks/year (SPS operation)
HiRadMat	p^+ or HI	440 GeV or 173GeV/u	3×10^9 to 1.7×10^{11} (p^+)	~1 mm^2	1 pulse/ SPS cycle pulse = 7.2μs	May-November (SPS operation)

- **…. many EXTERNAL FACILITIES used by CERN people**
  - **complementary to CERN facilities** (> intensities and/or < E); **study of basic mechanisms**
  - RADECS 2011: **Compendium of International Irradiation Test Facilities** (link)
- **Contacts for Irradiation Experiments**
  - IRRAD: www.cern.ch/irradiation (Maurice.Glaser@cern.ch - Federico.Ravotti@cern.ch)
  - GIF/GIF^{++}: IMPACT-GIF-Coordination@cern.ch (Martin.Jaekel@cern.ch - Roberto.Guida@cern.ch)
  - CHARM/CC60: www.cern.ch/charm (Markus.Brugger@cern.ch - Julien.Mekki@cern.ch)

Questions ?

References

- H. Vincke, 2008, *Status report of the working group on future irradiation facilities at CERN*, presentation at SPSC (www.cern.ch/irradiation-facilities)
- A. Fabich, 2013, *HiRadMat facility at the CERN SPS*, WAMAS at CERN (https://indico.cern.ch/event/229108/)
- M. Jaekel, 2014, *The new Gamma Irradiation Facility at CERN* (https://indico.cern.ch/event/282487/)
- M. Brugger, 2014, *CHARM: a new high-energy mixed beam test facility for various radiation environments*, presentation at RADSOL … and (many) private communications!

Some other interesting links

- GIF^{++} facility: https://espace.cern.ch/sba-workspace/gifpp/SitePages/Home.aspx
- Irradiation facilities around the world: http://www.cern.ch/rd50 and http://radwg.web.cern.ch/
- L. Linssen, 2009, Future Irradiation Facilities at CERN (http://indico.cern.ch/event/51128/)
- G. Spiezia, 2013, Radiation Tests A&T sector (https://indico.cern.ch/event/267419/)
- M. Brugger, 2012, Irradiation facilities - R2E requirements at East Area Day (https://indico.cern.ch/event/167761/)