FUTURE IRRADIATION FACILITIES AT CERN

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http://cern.ch/irradiation-facilities

Outline

- Introduction on irradiation facilities
- Present situation
- User survey
  - Future prospects
  - Possible implementations
- Summary

Irradiation facilities working group

Composition

CERN-wide working group:

- R. Assmann – BE/ABP
- J. Bauche – TE/MSC
- M. Brugger – EN/STI
- M. Capeans – PH/DT
- F. Corsanego – DG/SCG
- I. Efthymiopoulos – EN/MEF
- D. Kramer – EN/STI
- L. Linssen – PH/LCD (chair)
- R. Losito – EN/STI
- M. Moll – PH/DT
- C. Rembser – PH/ADE
- M. Silari – DG/SCR
- Y. Thurel – TE/PO
- R. Trant – DG/SCH
- E. Tsesmelis – DG/DG
- H. Vincke – DG/SCR
- T. Wijnands – EN/STI

Mandate:

- Collect requirements for future irradiation facilities at CERN, taking into account availability of facilities outside CERN
- Put these requirements in the context of presently available facilities/infrastructures at CERN.
- Propose cost-effective options for future facilities, aiming for a maximum of synergy.
- Produce a (yellow) report on the findings

Introduction

- Irradiation facilities – what for?
- Setup and operate an irradiation facility – what it really involves?

Irradiation facilities

What for?

- Test and development of prototypes or final assemblies before installation in a radiation environment
  - issues addressed (not exhaustive)
    - SEU, radiation damage, performance degradation of electronics
    - beam impact or radiation damage on materials
    - performance degradation after long exposure (ageing)
    - performance evaluation under background/”noise” conditions
  - passive or “hot” (i.e. online) irradiations

- Test or calibration of components
  - radiation measurement/monitoring devices
  - feedback data to simulation codes

Setup and operate an irradiation facility

What it really involves?

- Deliver the desired beam
  - intensity, beam spot, time structure (slow or fast extraction)
  - steering : beam and/or equipment (scanning table)
  - monitoring of beam intensity and radiation field
    - reference maps available to users

- Know and control the radiation environment
  - provide detailed Monte Carlo simulations in order to have well-defined spectra
  - in-situ dosimetry providing information on the actual doses accumulated
  - escaping radiation (by shielding) and internal activation (by design) must remain within limits
  - for high intensities:
    - closed ventilation loop, humidity control
    - Impact on infrastructure – optimized maintenance procedures

- Access conditions
  - pre-test documentation, preparation and optimization: materials, time
  - access authorization, training
  - traceability : in/out movements, logs, RP control

Setup and operate an irradiation facility

… what it really involves?

- **Auxiliary installations**
  - nearby **control room** for “hot” tests during exposure
  - **remote handling** of equipment and services
  - **storage area**
    - initial cool down just after exposure
    - medium/long term storage in view of future re-use
  - **qualified lab** to work on exposed materials
    - modify for re-use, analysis after irradiation
  - **flexible detector infrastructure**
    - E.g. gas systems, cooling

- Final product: make scientific results available to the community
    - document and spread out the knowledge
    - **results database**: materials, components, ..

  - .. and **radioactive waste**
    - must be considered from the beginning !

Present Irradiation Facilities

- PS
  - **Proton irradiation** facility in the East Area (since 1992)
- SPS
  - **GIF - G**amma **I**rradiation **F**acility in the West Area (since 1997)
  - **CERF - CE**RN **R**eference **F**acility in the North Area (since 1992)
  - (parasitic) irradiation of electronics in CNGS

… and ad-hoc tests – now decommissioned

  - (parasitic) irradiation of electronics in the SPS/TCC2 target area
  - material test (collimators, targets) in TT40 line
  - (parasitic) irradiation of materials or "target units" in ISOLDE

Due to limited time for this talk, please see spare slides for summary on the current/past facilities with their assets and shortfalls

User survey

- Survey results
  - Requirements, future prospects,
  - Possible implementations

User survey

Future needs for irradiation facilities

- Web-based questionnaire launched to a very wide community
  - Details in : http://cern.ch/irradiation-facilities
  - **145 replies**
    - extensive requests from LHC experiments and accelerator groups for **present** and in view of the **upgrade** program

- Questions asked on:
  - Beam type: gamma, proton, mixed field
    - particle energy, spill-type, …
  - Total dose, irradiation surface, exposure profile
  - Dimensions of experimental area, infrastructure
  - Access needs during exposure

- Thorough analysis of the replies to understand the user requirements.
- The WG investigated the possibilities to combine needs and minimize the proposed facilities. Diverse requirements make several facilities necessary.

User survey - conclusions

Identified needs

1. High-energy and high-density proton (ion) irradiations : 5 replies
   - impact of intense pulsed beams to materials
   - proposed facility : **HiRadMat**
   - primary use : LHC collimators & absorbers

2. Gamma irradiations with beam : 37 replies
   - study long-term exposure of equipment
   - proposed facility : GIF → **GIF++**
   - primary use : muon trackers of LHC experiments, detector or accelerator electronic components, beam diagnostic equipment

User survey - conclusions

Identified needs

3. High-intensity proton irradiation (slow, slow-fast extraction): 52 replies
   - study long-term exposure of equipment
   - primary use: inner trackers of LHC experiments, detector or accelerator electronic components, beam diagnostic equipment
   - proposed facility: continue with **PS East Area** → future facility at **PS2**

4. Mixed field irradiations : 39 replies
   - study impact on system components exposed in radiation fields
   - primary use: LHC accelerator and detector components (SEE studies), radiation monitoring calibration
   - proposed facility : **CNGS**, CERF → **CERF++**

5. Heavy ions: 12 replies
   - the feedback does not indicate the need for a construction of an exclusive Heavy Ion Irradiation Facility. If the availability of ions can be added at low cost to the plans for one of the future CERN irradiation facilities, it should definitely be included.

The HiRadMat Facility

Key assets

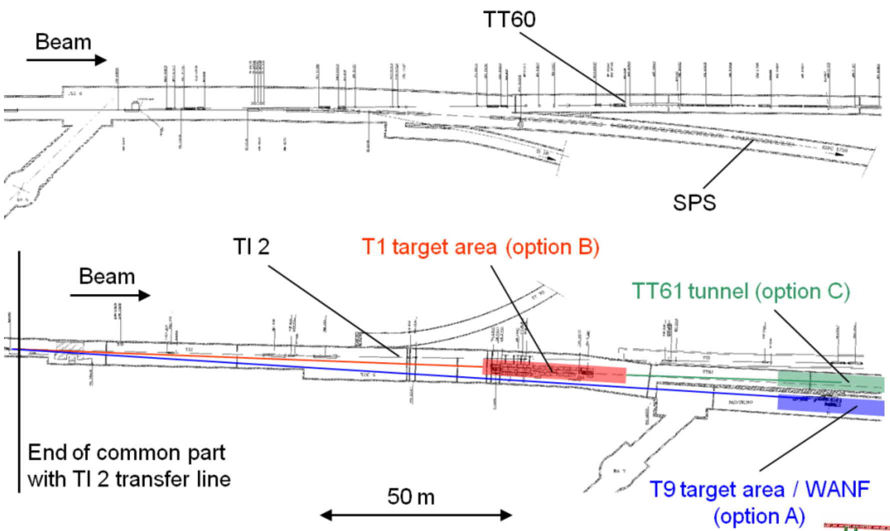
- Study the impact of intense pulsed beams on materials
  - Thermal management (heating)
    - material damage even below melting point
    - material vaporization (extreme conditions)
  - Radiation damage to materials – change of properties
  - Thermal shock - beam induced pressure waves

- Test bed, important for the design validation of LHC near-beam components before installation in the machine

- Requires **LHC-type** beam from **pilot to 288 nominal bunches**

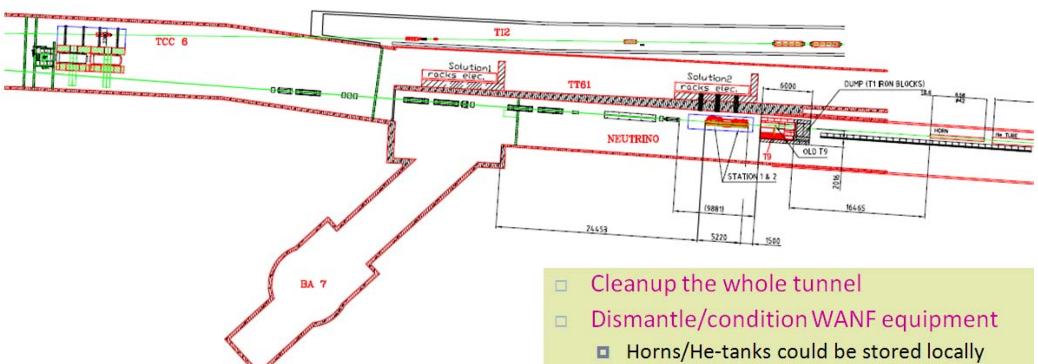
The HiRadMat Facility

13 Possible implementation in the TT60/WANF tunnel



- modify the TI2 extraction line to deflect an LHC-type beam towards the old WANF area tunnel
- max intensity: 1×10^{16} prot/year
  - 10 experiments, 1×10^{15} prot/exp
- foreseen start of operation: 2011
  - to be adapted to the new LHC schedule and long 09/10 shutdown

Parameter	Unit	Value (proton beam)	Value (lead ion beam)
Beam energy	GeV	**450**	36.9×10^3 (177.4 GeV/n)
Bunch intensity	particles	5×10^9 to **1.15×10^{11}**	5×10^9 to 4.1×10^{10}
Bunch length	cm	11.2	11.2
Number of bunches	-	1 – **288**	1 – 592
Bunch spacing	ns	25	≥ 25
Pulse energy	MJ	2.4	28×10^{-3}
Pulse length	µs	7.2	7.2
Peak power	GW	340	2.3
Normalized emittance (1σ)	µm	3.5	1.4
$\sigma_x \times \sigma_y$ at exp. (baseline)	mm²	1.0	1.0
$\sigma_x \times \sigma_y$ at exp. (request)	mm²	**0.25 – 4.0**	0.25 – 4.0



- Test area upstream the T9 target
- Convert T9 to a beam dump
  - Remove target head and replace with special blocks like in CNGS hadron stop: Graphite core, Al plates with cooling
  - Add lateral shielding (concrete)
  - Reuse blocks from T1 (TAX area) to add downstream shielding

- Cleanup the whole tunnel
- Dismantle/condition WANF equipment
  - Horns/He-tanks could be stored locally until disposal path (and budget) agreed
  - Move the rest to waste
- Maintain escape passage from tunnel end

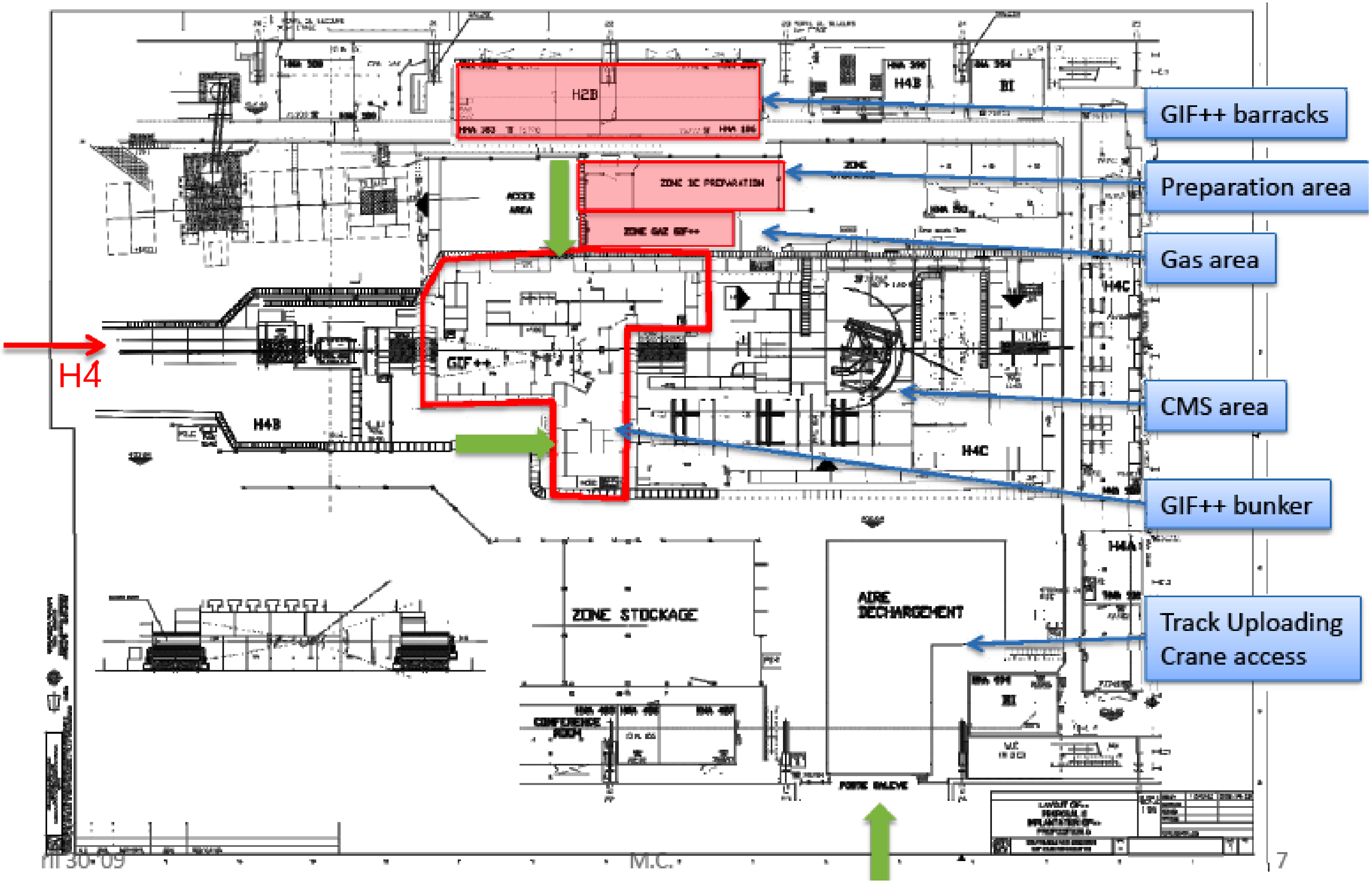
GIF++ facility

New GIF++ facility in the SPS North Area – H4 beam line

- Source
  - **Cs^{137} (662 keV) 10TBq** (GIF in West-area: 740GBq)
  - movable filters, as present source
    - attenuation down to $F=10^5$
  - second irradiation facility (pointing upstream)
- Secondary beam – H4 line
  - muon beam
    - 100GeV/c, ~10^4 μ/spill, 10x10cm^2
  - electron beam
- Shielding
  - Cs^{137}: 2 Gy/h at 50 cm for a 10 TBq source
  - radiation limits for supervised area -> requires 1.6m concrete
- Requested start of operation : 2010

GIF++ facility

New GIF++ facility in the SPS North Area – H4 beam line



Proton irradiation

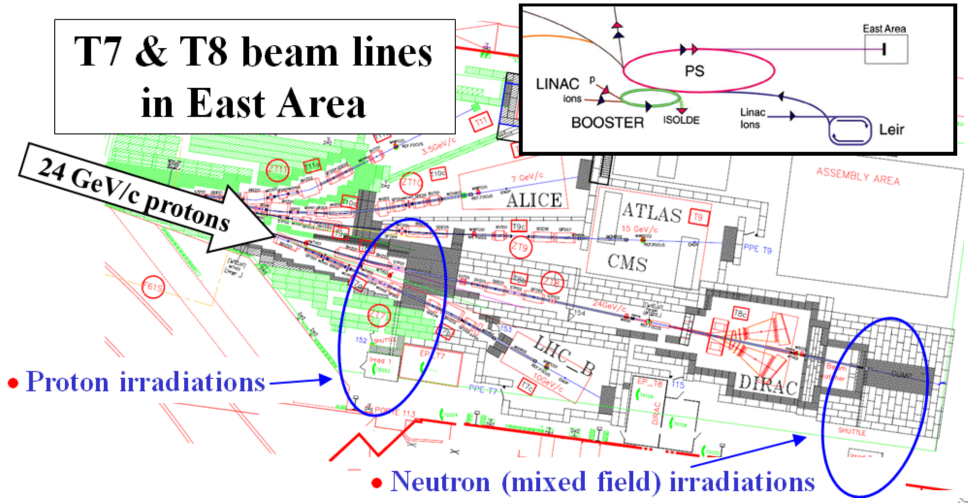
Proposal

- Maintain with minimal investment the **PS East Area facility**
  - improved duty time to gain x2 in integrated rate (scheduling?)
  - upgrade in the beam monitoring systems
  - upgrade in the mobile trolley and cabling

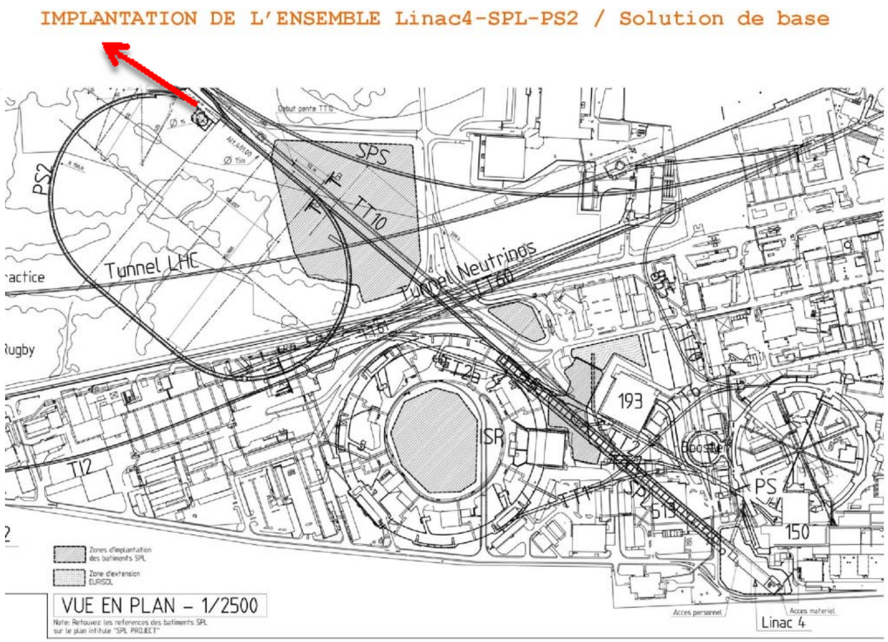
- Plan for a **high-intensity proton irradiation facility** coupled to the future **PS2**
  - PS2 facility at 20 GeV is preferred
    - 20 GeV is already conveniently used at the PS
    - allows placing several samples in the beam at the same time
  - Flux: 1.1×10^{12} protons/pulse (16.8 s interval)
  - Fluence: $2\text{x}10^{16}$ p/cm^2 over ~5 cm^2 to be reached in two weeks
  - Future PS2 proton and mixed field irradiations could co-exist

Proton irradiation

Current facility and proposed solution for the future



Current PS east hall facility



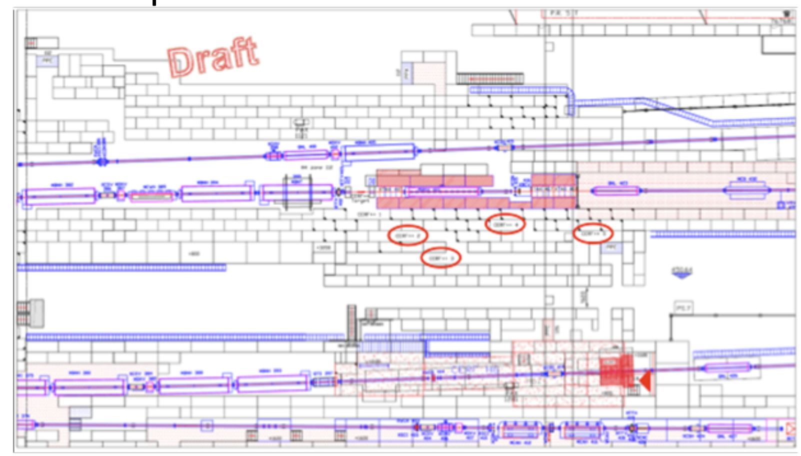
Requested future PS2 facility

- 20 GeV
- >10^{12} protons per spill

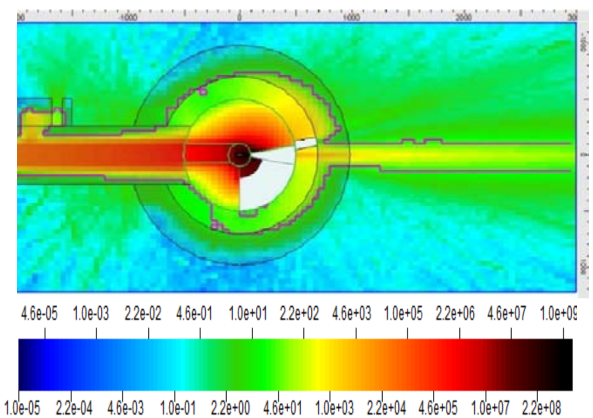
CERF++ mixed field irradiation facility

Possible CERF++ implementation in the H4 beam line

- Transport an attenuated proton beam in the H4 beam line up to the entrance of EHN1 hall
  - Feature last used for NA31 in 1986
- Beam intensity : <1×10^{11} p/spill
- measurement locations around the thick target

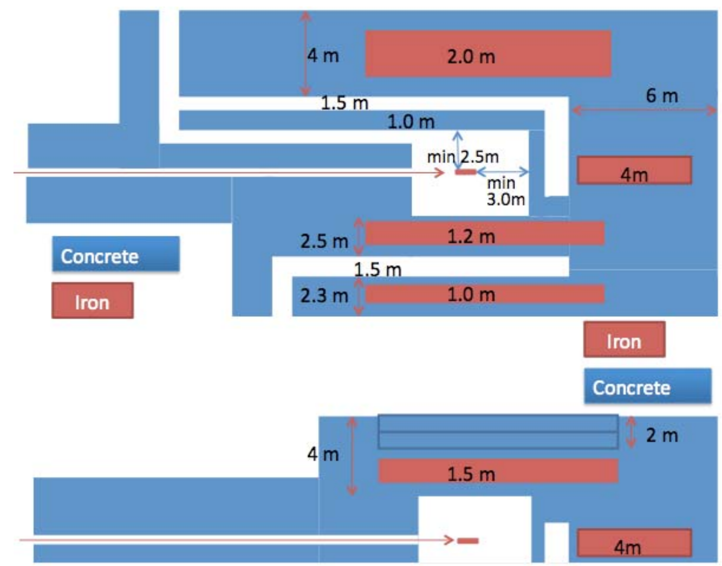


- FLUKA Simulation
- 10^{10} particles/spill @ 450 GeV/c
- Contour = 15 μSv/h



Eduard.Felbaumer@cern.ch

Implementation studies for this facility are just starting



Requested start of operation : 2010

Summary of required facilities

The WG investigated the possibilities to combine needs and minimize the proposed facilities. Diverse requirements make several facilities necessary:

- **Proton and ion irradiations at high energy and high density (fast extraction)**
  - HiRadMat at WANF (implementation plans)
- **Gamma irradiations in the presence of a muon beam**
  - GIF++ at SPS north area H4 (implementation plans)
- **Proton irradiations at high intensity (slow extraction)**
  - Continuation of PS east hall facility with minor upgrading
  - Future PS2 proton irradiation facility
- **Mixed field irradiations, slow extraction**
  - CERF++, SPS location currently under study

Summary

- The WG was a good opportunity to bring together experts from various departments to promote collaboration and common solutions
- A complete survey of the needs of the whole community for irradiation facilities was made. A summary report is under preparation
- Short and long term needs identified, supporting the request for improved facilities in view of the current LHC (machine and detectors) and the upgrades
- Next steps: advance from the feasibility studies to implementation and technical designs for all 4 facilities
- Survey shows that facilities (GIF++, CERF++, HiRadMat) are needed "as soon as possible" (by 2010/2011)

Spare slides

Present Irradiation Facilities

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  - (parasitic) irradiation of electronics in CNGS

… and ad-hoc tests – now decommissioned

  - (parasitic) irradiation of electronics in the SPS/TCC2 target area
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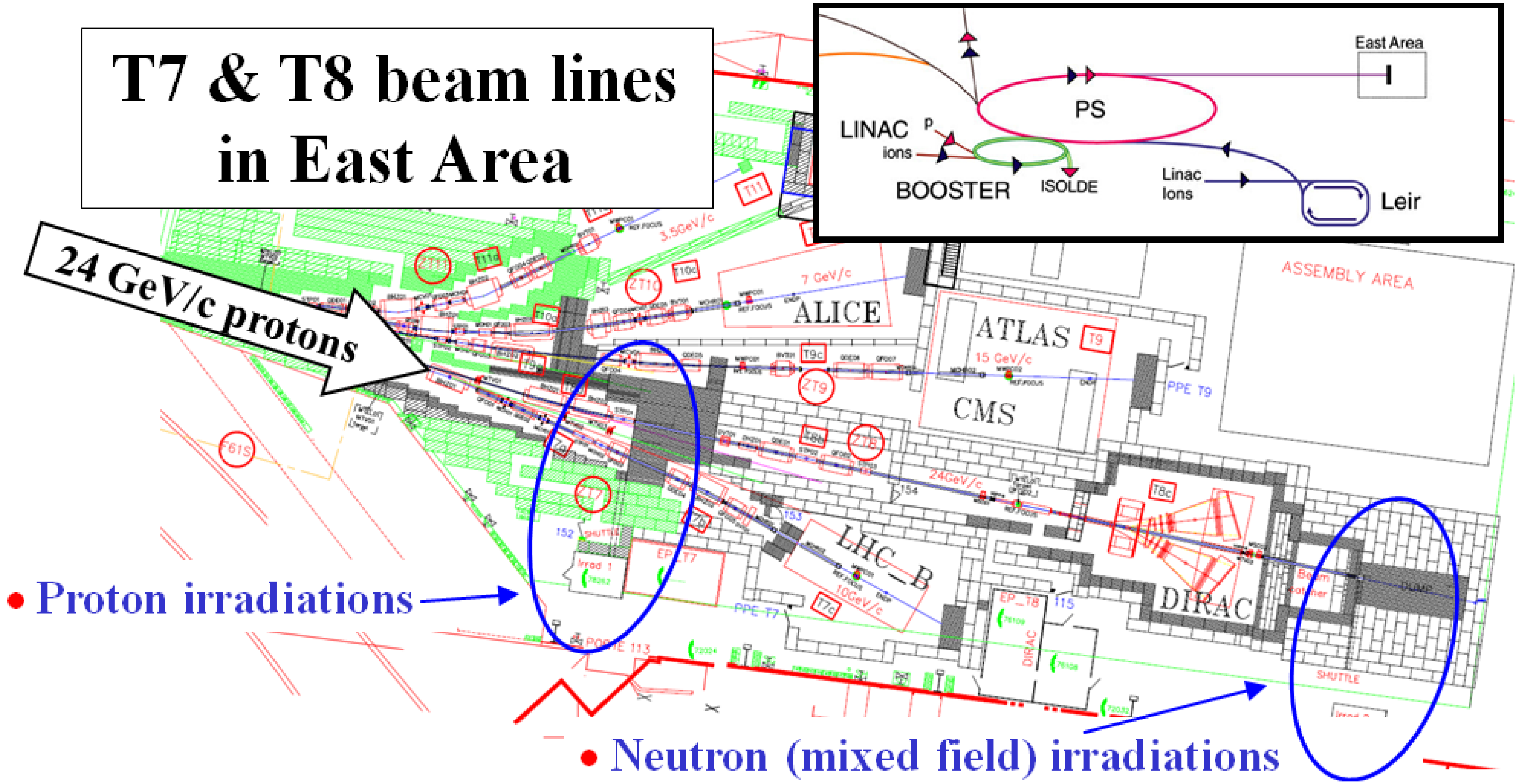
  - (parasitic) irradiation of materials or "target units" in ISOLDE

Summary of current/past facilities with their assets and shortfalls

Proton irradiation in the **PS East Area**

Layout



Proton irradiation in the **PS East Area**

Characteristics

- Protons and mixed field irradiations

- Intensities
  - **max 10^{11} protons/extraction** (slow or fast-slow extraction)
  - up to 10^{14} protons/(cm^2hr) on a 2×2 cm^2 surface
  - up to 10^{12} neutrons/(cm^2hr) on a 30×30 cm^2 surface (1 MeV equiv.)

- In operation since 1992
  - up to **1500** irradiated samples per year
  - mainly used by detector communities: trackers, electronics

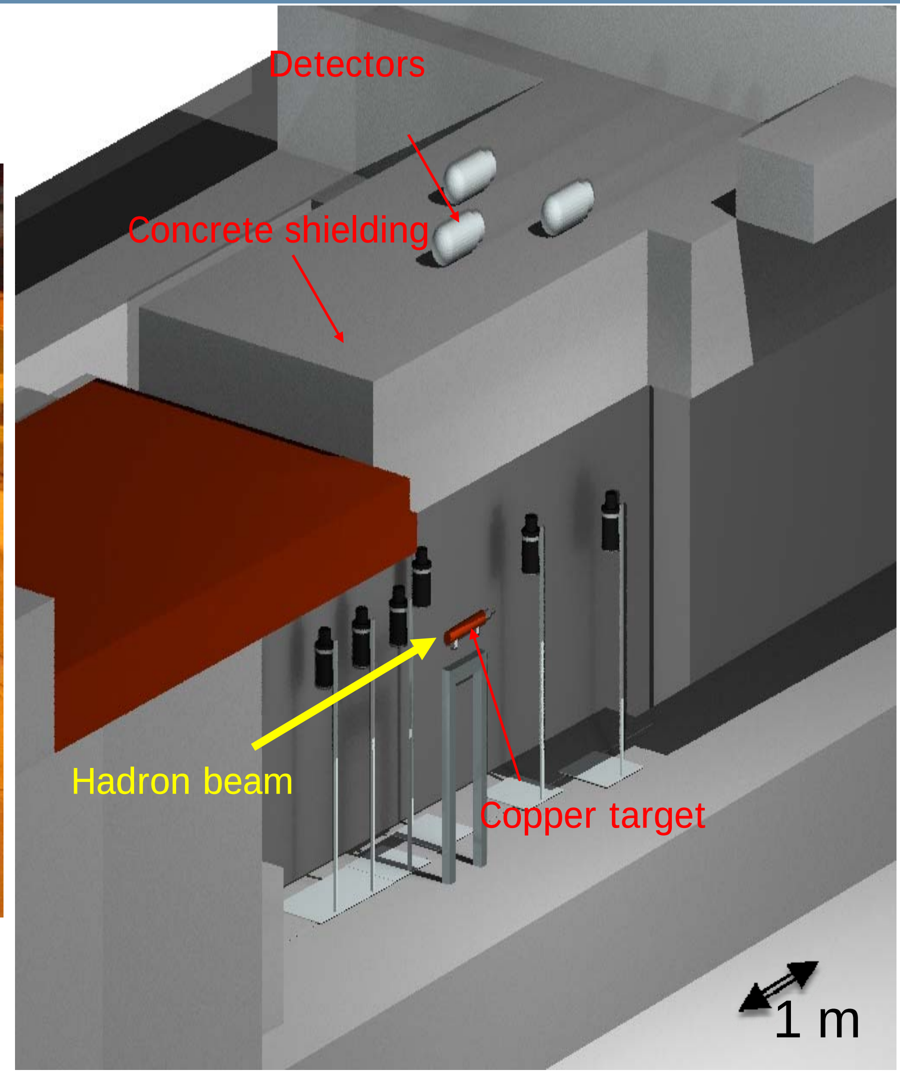
- Drawback:☹
  - parasitic operation to DIRAC, access via primary beam area, personnel exposure, limited space, limited rate

CERN Reference Facility – SPS NA

H6 beam in the SPS North Area EHN1 experimental hall

reference locations

H6 beam



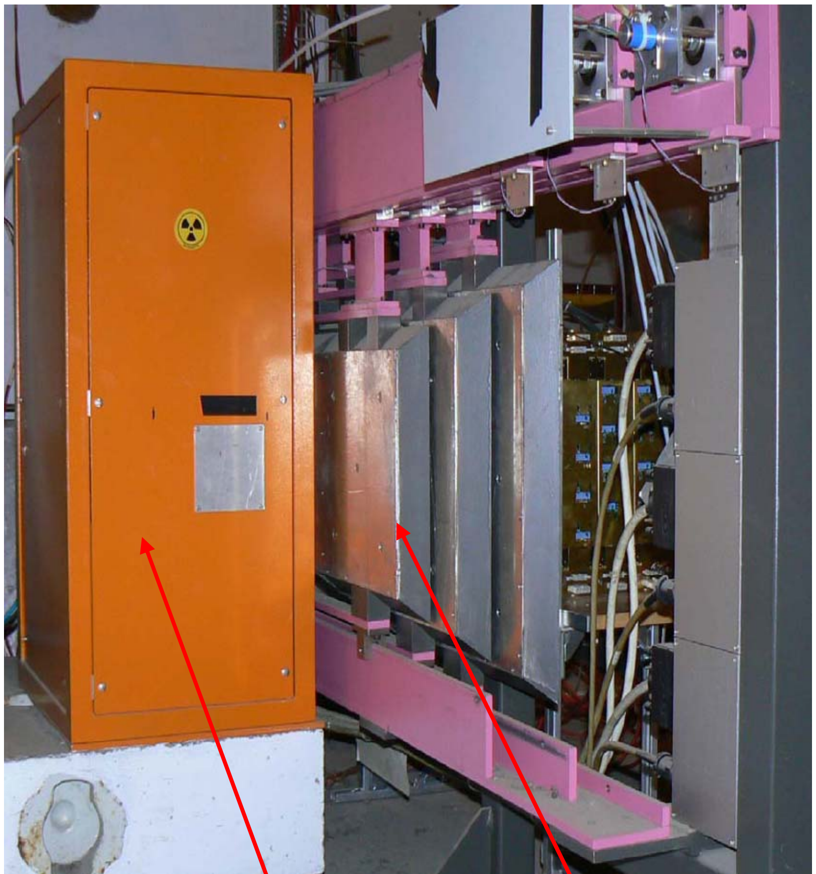
CERN Reference Facility – SPS NA

Characteristics

- SPS H6 secondary beam, **120 GeV/c hadrons**
  - 56% protons, 39% pions + 5% Kaons
  - well defined and simulated mixed radiation fields
- Intensities
  - **max 10^8 protons/pulse** (5s) (slow extraction)
- In operation since 1992, 1-2 weeks/year
  - mainly used for test/calibration of passive and active detectors for dosimetry or radiation monitoring
  - ~20 teams/week, internal and external users
  - FLUKA benchmarking, beam loss monitor studies
- Drawback: ☹
  - limited dose rates, muon background from TCC2 (reduced since 2006)

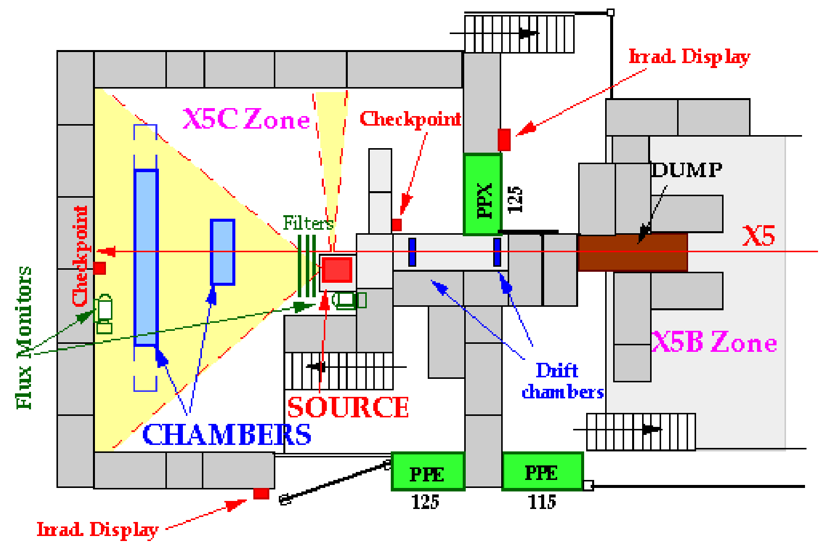
Gamma Irradiation Facility – West Area

Area layout



The Cs^{137} source container

The external screens and collimators



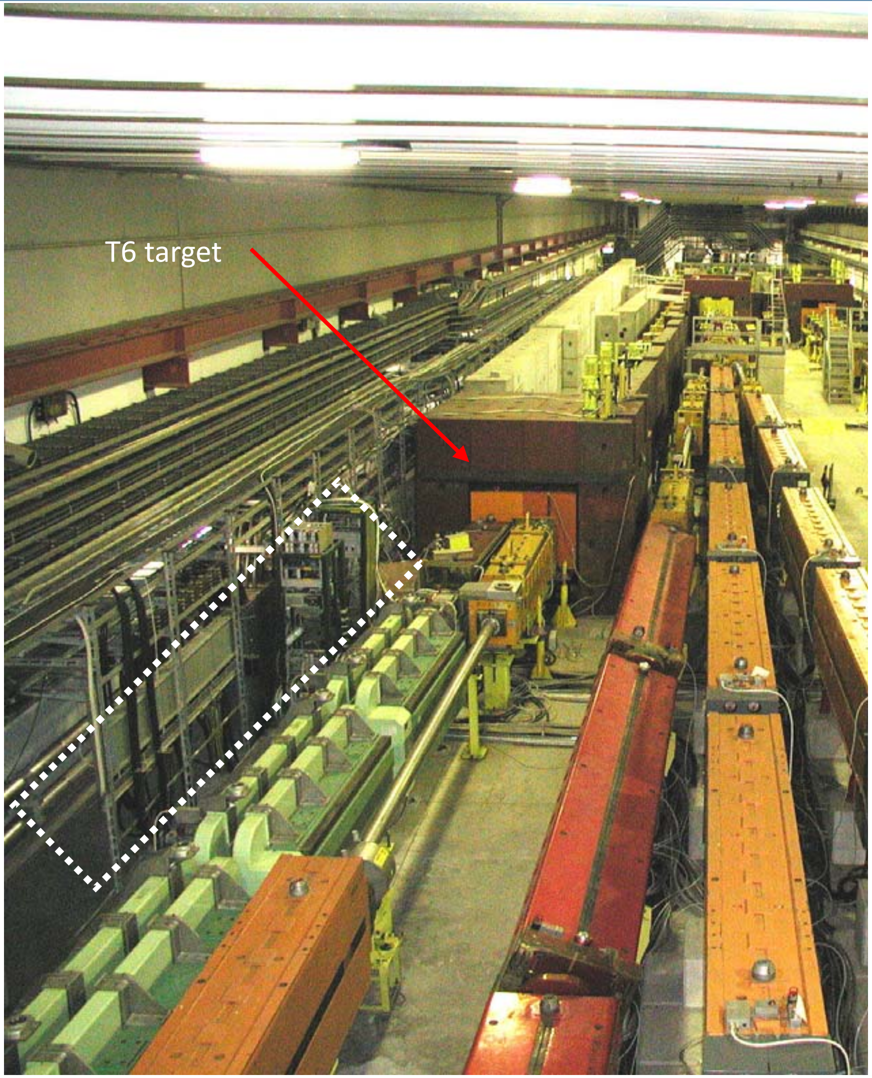
Gamma Irradiation Facility – West Area

Characteristics

- **740 GBq Cs^{137}** source, irradiation over large surfaces
- Combined with (muon) beam from X5 line
- In operation since 1997
  - all year (source), some weeks (beam)
  - mainly used for tests of muon detectors for LHC experiments
    - ageing tests, performance under "background" conditions (photons from the source)
- Drawback: ☹
  - more intensity would be desirable (accelerated ageing) , combined with higher muon beam energy
  - space issue in bat.190 → space needed for LHC magnet lab

Irradiation of electronics – SPS/TCC2

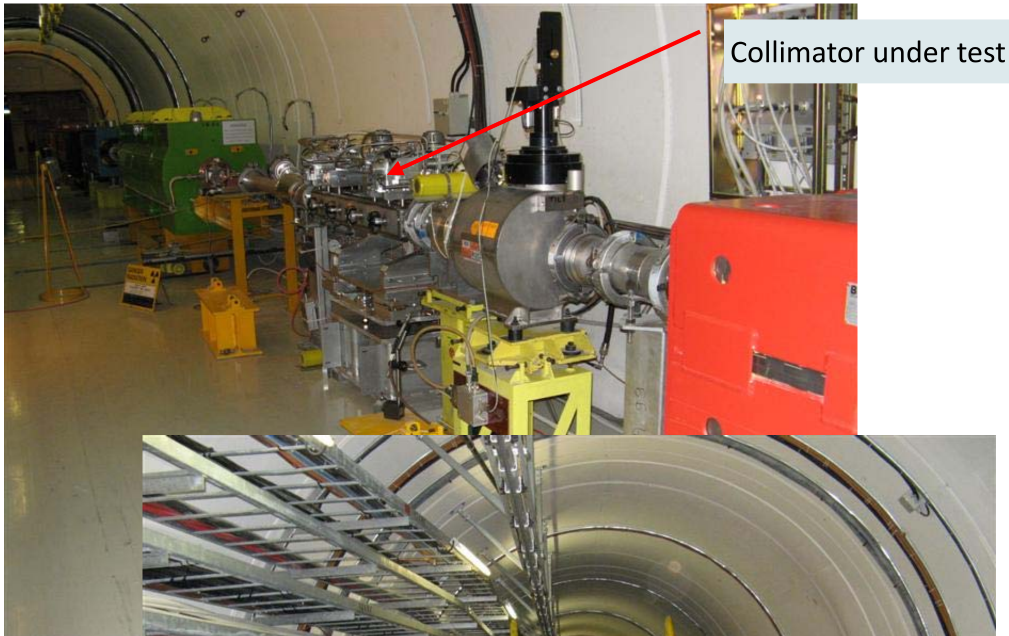
Parasitic mixed field irradiations – layout



- Mixed field irradiation, high doses within reasonable time
- Clients: LHC accelerator groups, testing components and electronics
  - up to 25 experiments/year
  - sufficient space to test complete systems
- Drawback: ☹
  - Parasitic ad-hoc test
    - no reproducible radiation conditions
    - high residual dose rate in the area (access, safety)

Pulsed proton irradiation – **TT40 line**

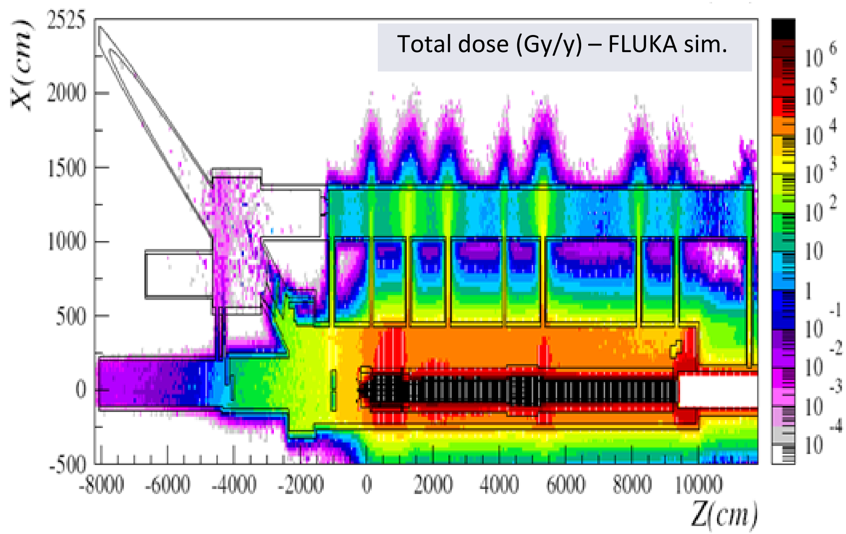
Intense proton beam irradiation - layout

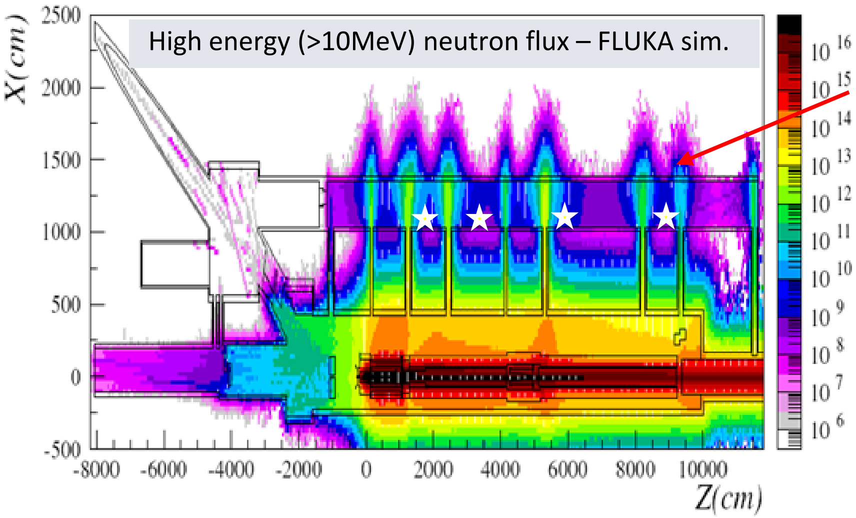


- Used for LHC collimator studies and material tests in 2004 and 2006
- Short pulses at 450 GeV/c
  - up to 3.3×10^{13}ppp (approx. 2 MJ)
- Drawback: ☹
  - limited space
  - interference with CNGS operation and LHC fill
  - area not ideal in terms RP aspects
    - production of radioactivity close to beam line elements
    - access conditions

CNRAD electronics irradiation - CNGS

Parasitic mixed field irradiations CNGS service gallery - layout





Test stations in the service gallery

CNRAD electronics irradiation - CNGS

Characteristics

- Exposure to mixed high-energy radiation fields, well-known field thanks to extensive FLUKA simulations

- Mainly focused for SEE on installed LHC electronics
  - four stations fully equipped for remote control and readout of components
  - possible to test complete systems (crates)

- Dose rates :
  - CNGS : 1 to 150 Gy per week
  - LHC ARC-DS : 1 to 200 Gy per year

- Drawback: ☹

  Parasitic to CNGS, access conditions, long access tunnel, safety