Protons, neutrons & mixed fields irradiation facilities in the CERN-PS East Hall "Irrad1….Irrad6"

Maurice Glaser
Michael Moll
Nicola Pacifico (5 Months 2008)

http://www.cern.ch/irradiation/

CERN- PH-DT - Geneva - Switzerland

OUTLINE

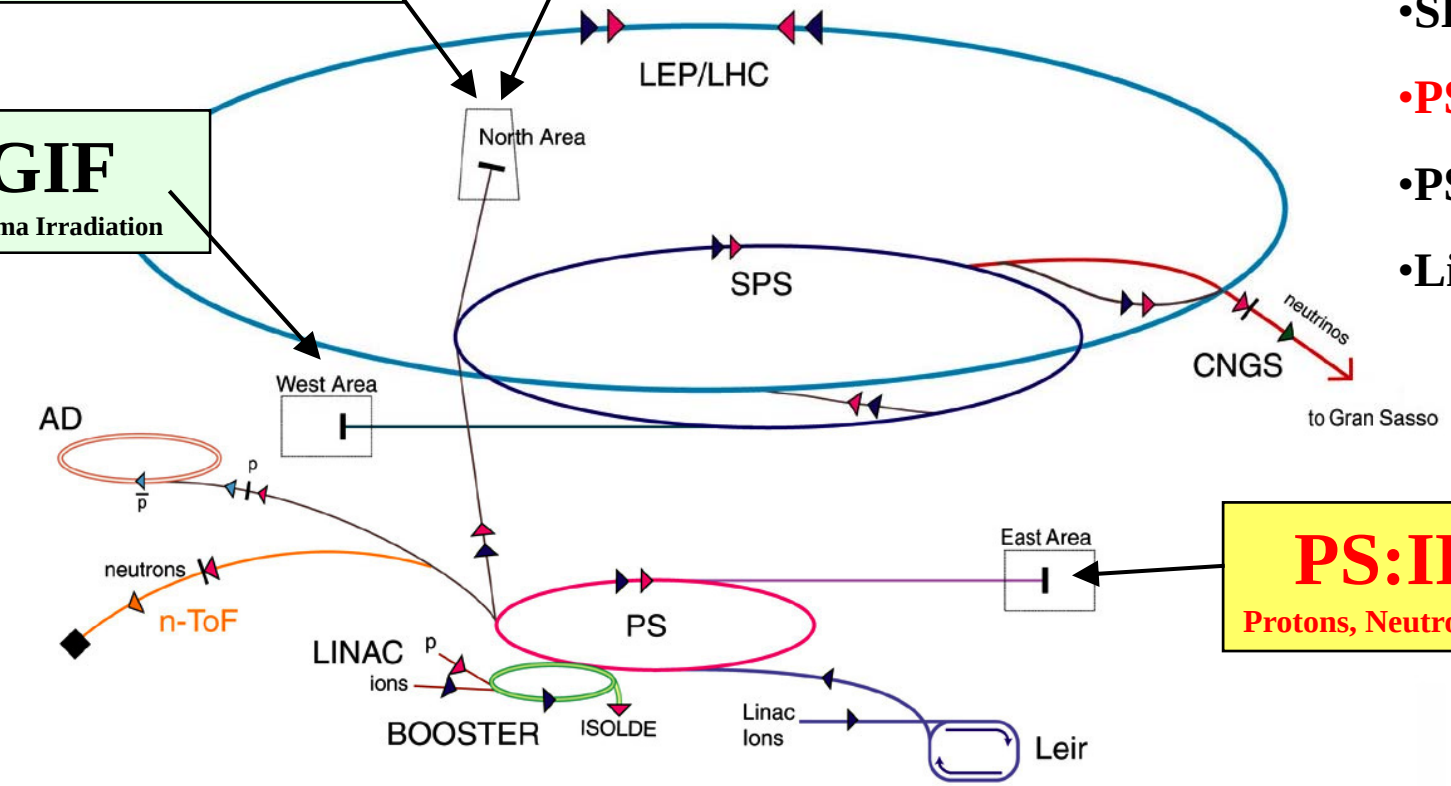
- **PS East Hall irradiation facilities**
- **Irradiation services**
- **Availability of facility and user statistics**
- **Future plans (possible facility upgrades)**

CERN Accelerators & Irradiation Facilities

SPS:CERF

SPS: Future GIF ?

GIF
Gamma Irradiation



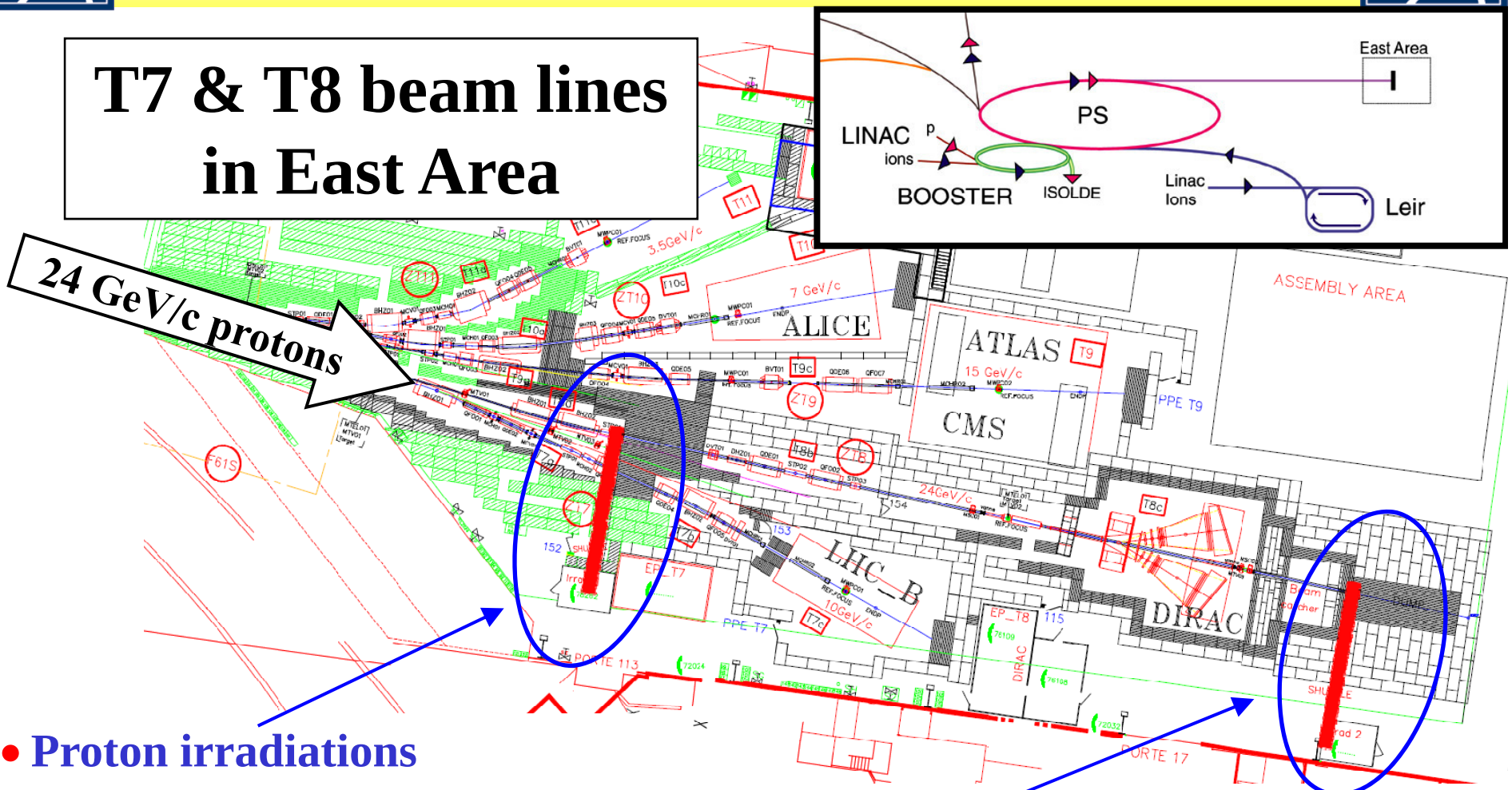
Proton energy

- **LHC 7 TeV**
- **SPS 450 GeV**
- **PS 28 GeV**
- **PSB 1.4 GeV**
- **Linac 50 MeV**

PS:IRRAD
Protons, Neutrons & Mixed fields

CERN PS East Hall - Irradiation Facilities

T7 & T8 beam lines in East Area



- **Proton irradiations**
  - **Direct exposure to 24 GeV/c protons** (IRRAD1, IRRAD3, IRRAD5)
  - **Low intensity radiation field of backscattered particles** (SEU and Dosimeter testing) (IRRAD6)
- **Neutron (mixed field) irradiations**
  - **Mixed field produced in cavity after carbon** (50cm) **iron** (30cm) **lead** (5cm) **'target'** (IRRAD2)

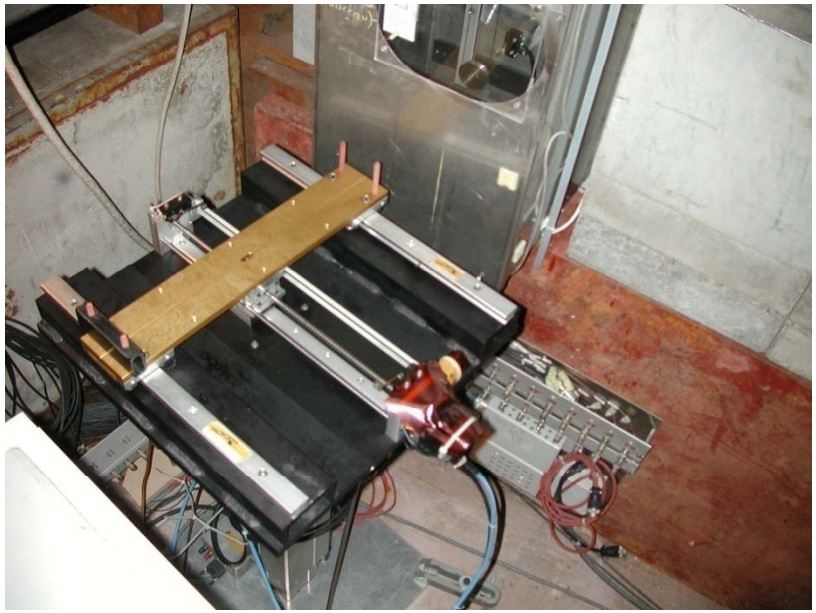
Proton irradiation facilities

Beam specifications:

- **Primary PS proton beam**
  - **Beam line:** PS-T7
  - **Beam energy:** 24 GeV/c
- **Slow extraction**
  - **Spills of protons (~ 2×10^{11} p, 400 ms)**
  - **Beam spot:** 1x1 to 5 x 5 cm^2
- **Proton flux**
  - **~ $1 - 9 \times 10^{13}$ p cm^{-2} h^{-1}**
  - **~ 5×10^{14} p cm^{-2} day^{-1}**
  - **~ 1×10^{17} p cm^{-2} 150$days^{-1}$**

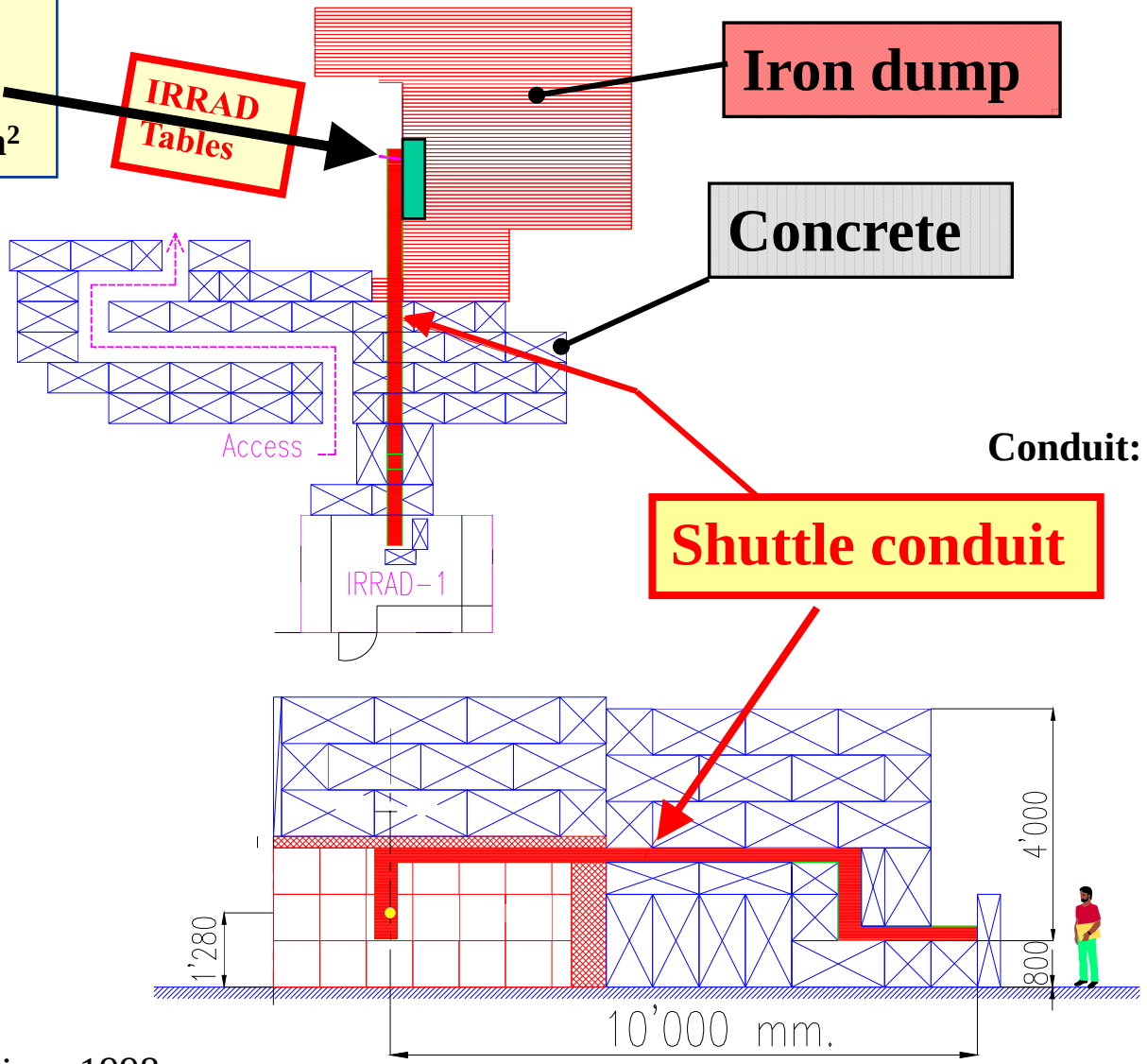
Irradiation tables and boxes (IRRAD3 & IRRAD5)

- **Located in primary beam area**
  - **access only on request**
  - **no beam for East Hall during access**
- **Irradiation on x-y-z movable tables (max 100 Kg)**
- **Irradiation inside cooled** (-20°C) **and atmosphere controlled** (e.g. N_2) **boxes** (max volume:20 x 20 x 50 cm^3)
- **Scanning over surfaces up to 20 x 20 cm^2**
  (according reduction in flux/cm^2!)



Shuttle System for Proton Irradiations

Beam line T7
24 GeV/c protons
Beam spot = 2x2 cm²



Top view

Side view

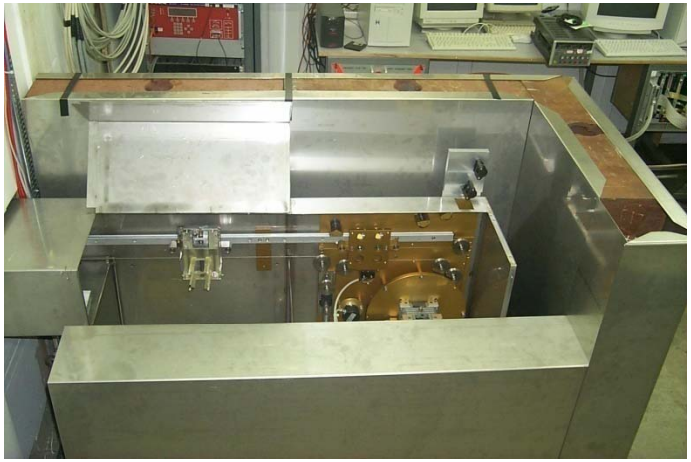
Conduit: 40 x 25 cm², 15 m length

shuttle operational since 1998

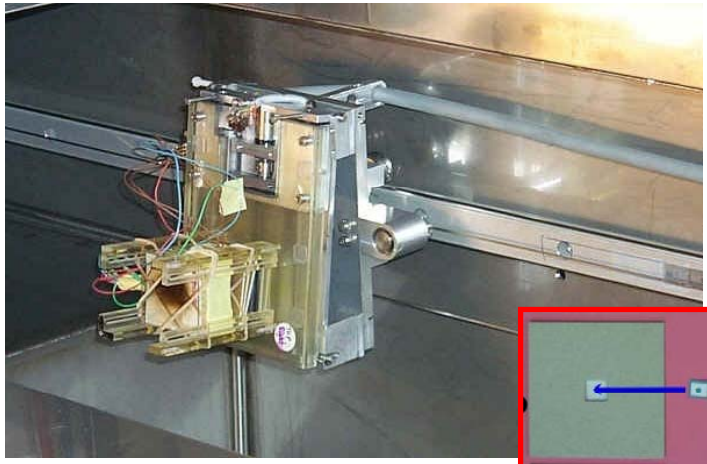
Proton irradiation facility - Shuttle

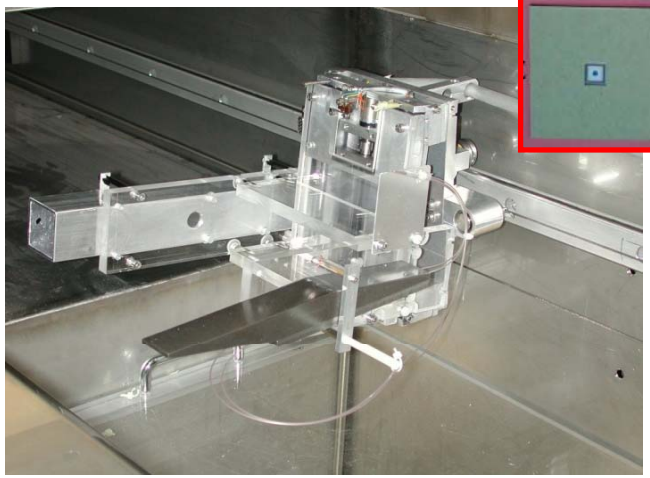
- **Standard volume: 5 x 5 x 15 cm^3**
- **Max. volume (on request) 10 x 10 x 20 cm^3**
- **Electrical connections**
- **Cooling box (on request)**

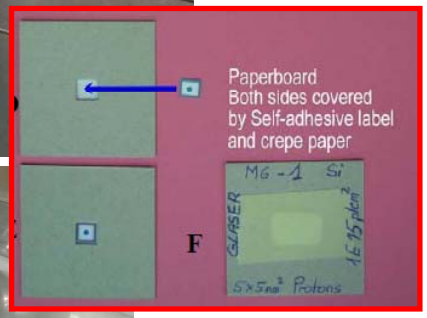
Load station



Sample holder

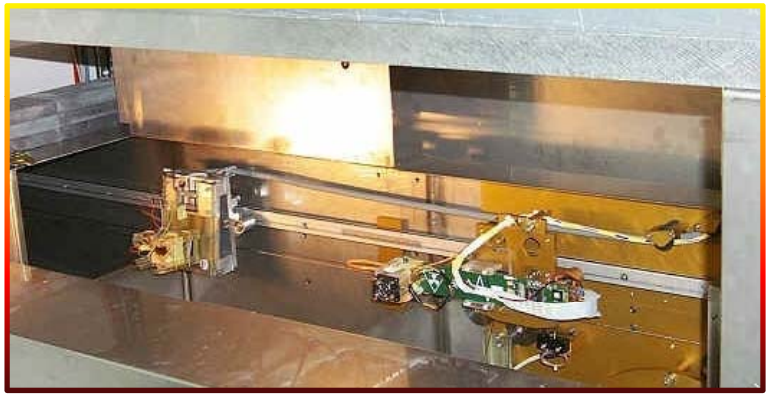


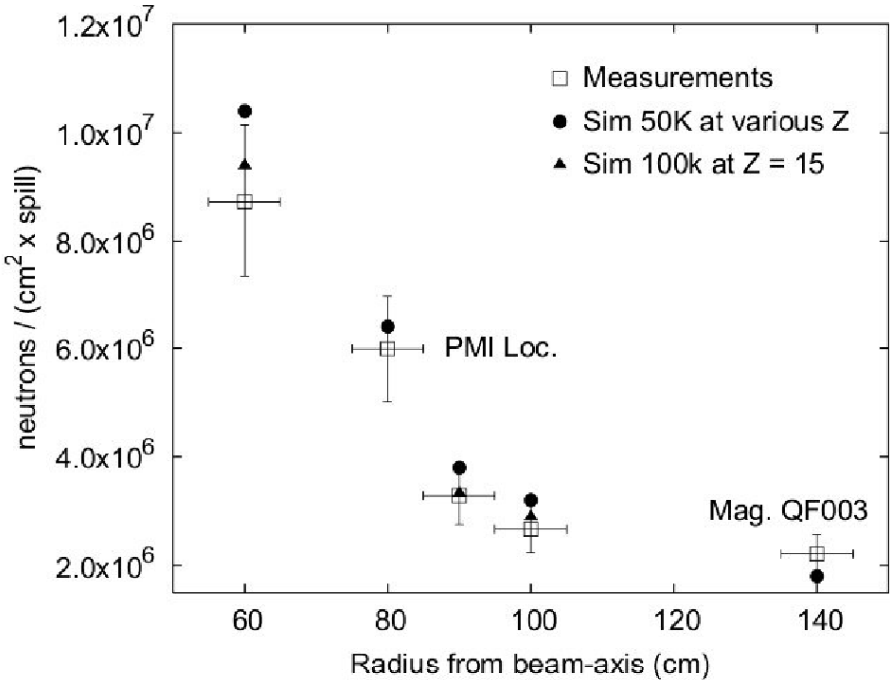




Irradiations with low flux of hadrons

- **Exposure in radiation field of backscattered particles**
  - **Low flux of high energetic particles (~ 1 x 10^7 cm^{-2}/spill)**
- **test of SEU in electronic components and high sensitivity dosimeters**
- second platform on shuttle system is also used for readout electronics needed in proximity of objects in primary beam (within a distance of 50 cm) (Irrad6)





[F.Ravotti et al., CERN PH-EP/2006-024]

Neutron irradiation facility (IRRAD2)

- **Irradiations performed with a shuttle system very similar to proton shuttle**
  - **Conduit:** 40x40 cm^2, 15 m long
  - **Standard volume for irradiations 20 x 20 x 20 cm^3 (**on demand up to ~ 30 x 30 x 35 cm^3)

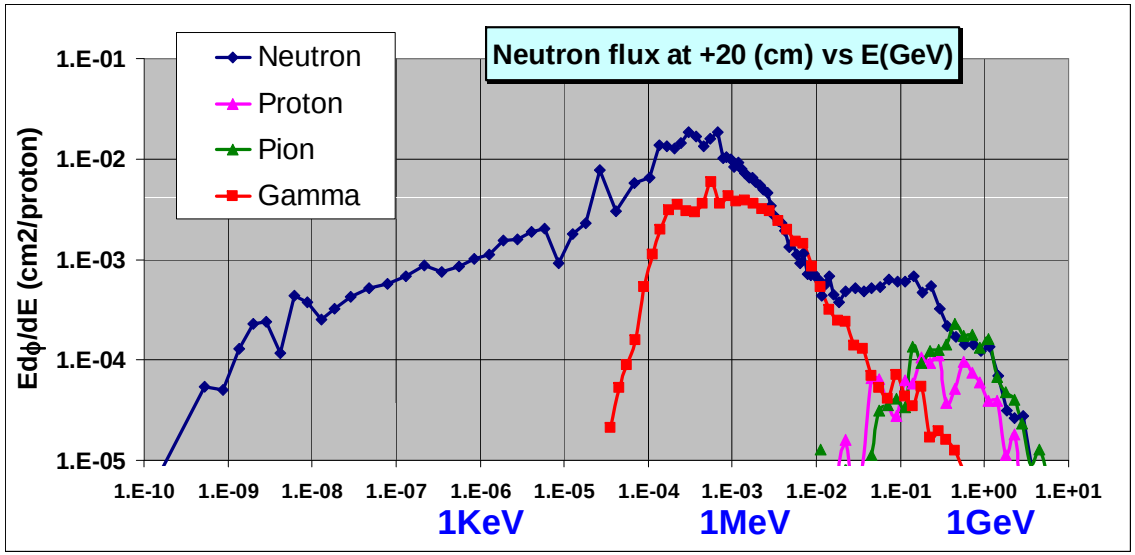


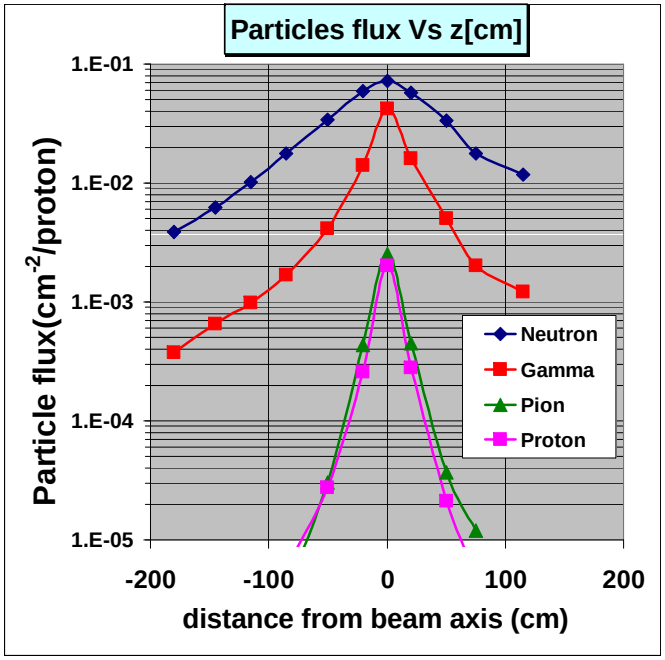
Neutron irradiation facility (IRRAD2)

- **Irradiation with secondary particles in irradiation cavity**

[NIMA 426(1999)72; CMS IN 2001/012]

  - **Field created by 24 GeV/c proton beam on carbon/iron/lead 'target'**
  - **Spectrum and flux of neutrons, protons, π+, π- and, gammas simulated and measured**
    (In collaboration with PH/CMG (M.Huhtinen) and SC/RP)

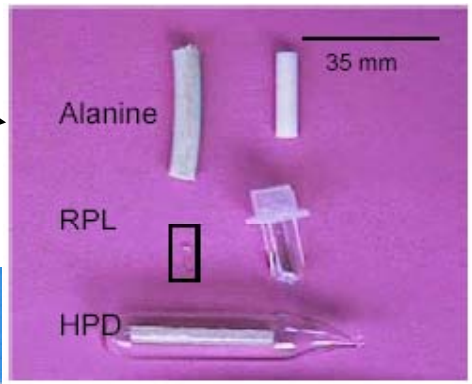


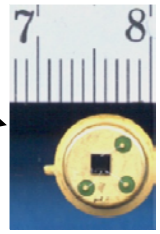


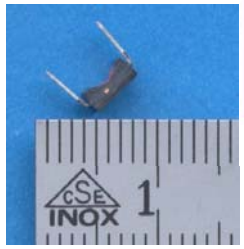
- **Neutron flux**
  - **$1 - 3 \times 10^7$ n cm^{-2} s^{-1} (E > 1 MeV) at 50 cm from beam axis** (6 days for 10^{13} n cm^{-2})
  - **Tabulated fluxes for different energy cuts and irradiation positions available for users**

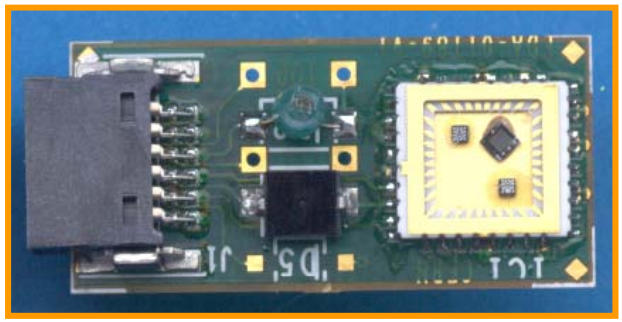
Dosimetry

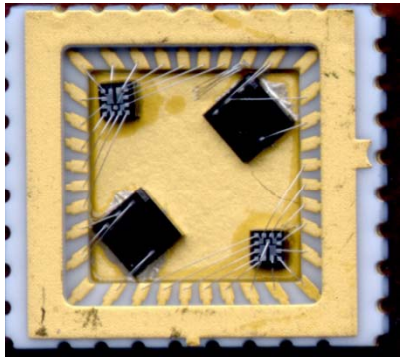
- **Passive Dosimeters (integrating)**
  - **PAD, RPL, TLD, HPD, Activation foils , Dye films, ……**
- **Active Dosimeters (integrating)**
  - **RadFETs (TID), silicon diodes (NIEL)**
- **Active Dosimeters (dose/fluence rate)**
  - **semiconductor diodes ('photocurrent'), OSL**
- **PH-RADMON project**

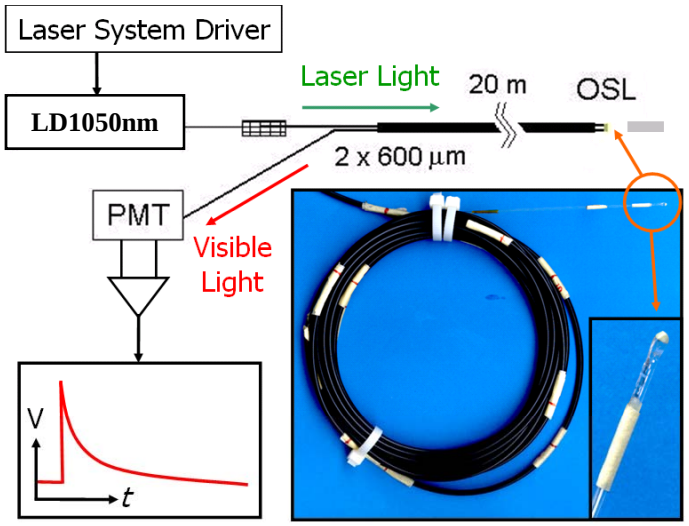












Beam instrumentation

- **Secondary Emission Chamber (SEC)**
  - **20 protons → 1 SEE (Secondary Emission Electron),**
    - **One SEC chamber has 20 Aluminum foils →1 proton = 1 SEE**
  - **We use the SEC to estimate the total protons per extraction (Spill)**

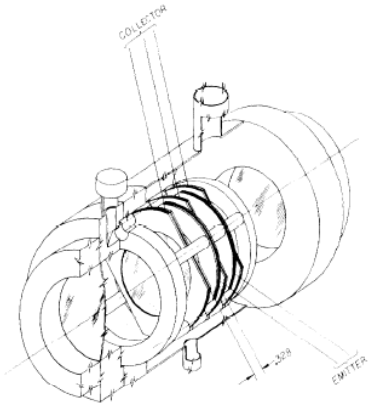
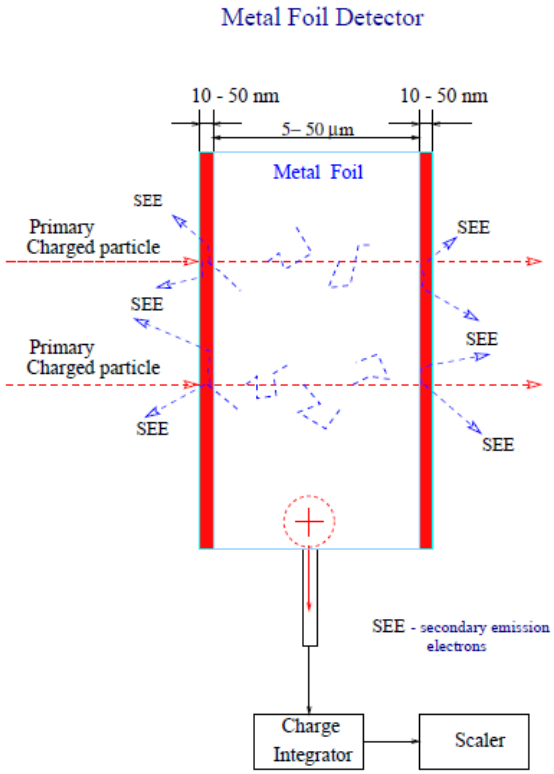


Fig. 2 SEC assembly



Beam instrumentation

•Beam Profile Monitor (BPM) (M. Glaser, N. Pacifico, D.S. Smith (Ohio University)

- **Same operating principle as the SEC**

IN: integrator
OUT: Gate, Reset, Addr.

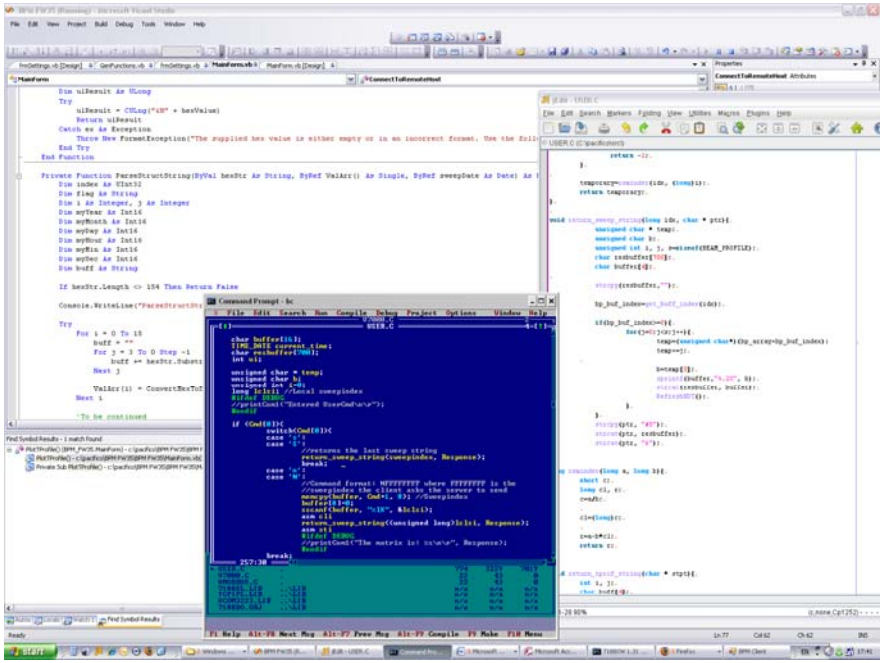
PLC ICPcon

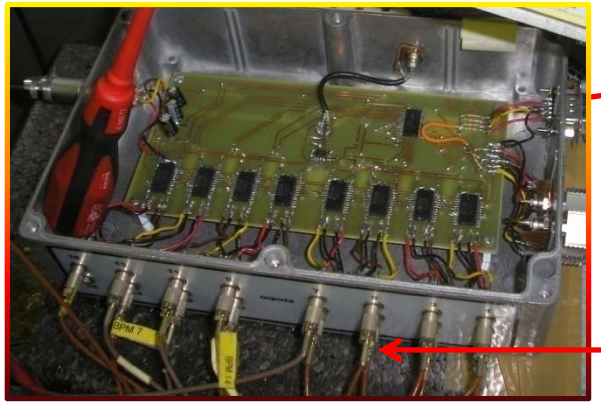
CPS Trigger

SPILL Trigger

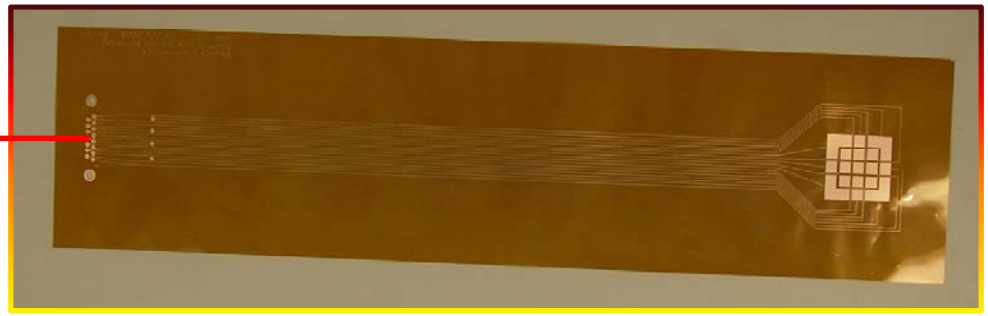
Ethernet

24V



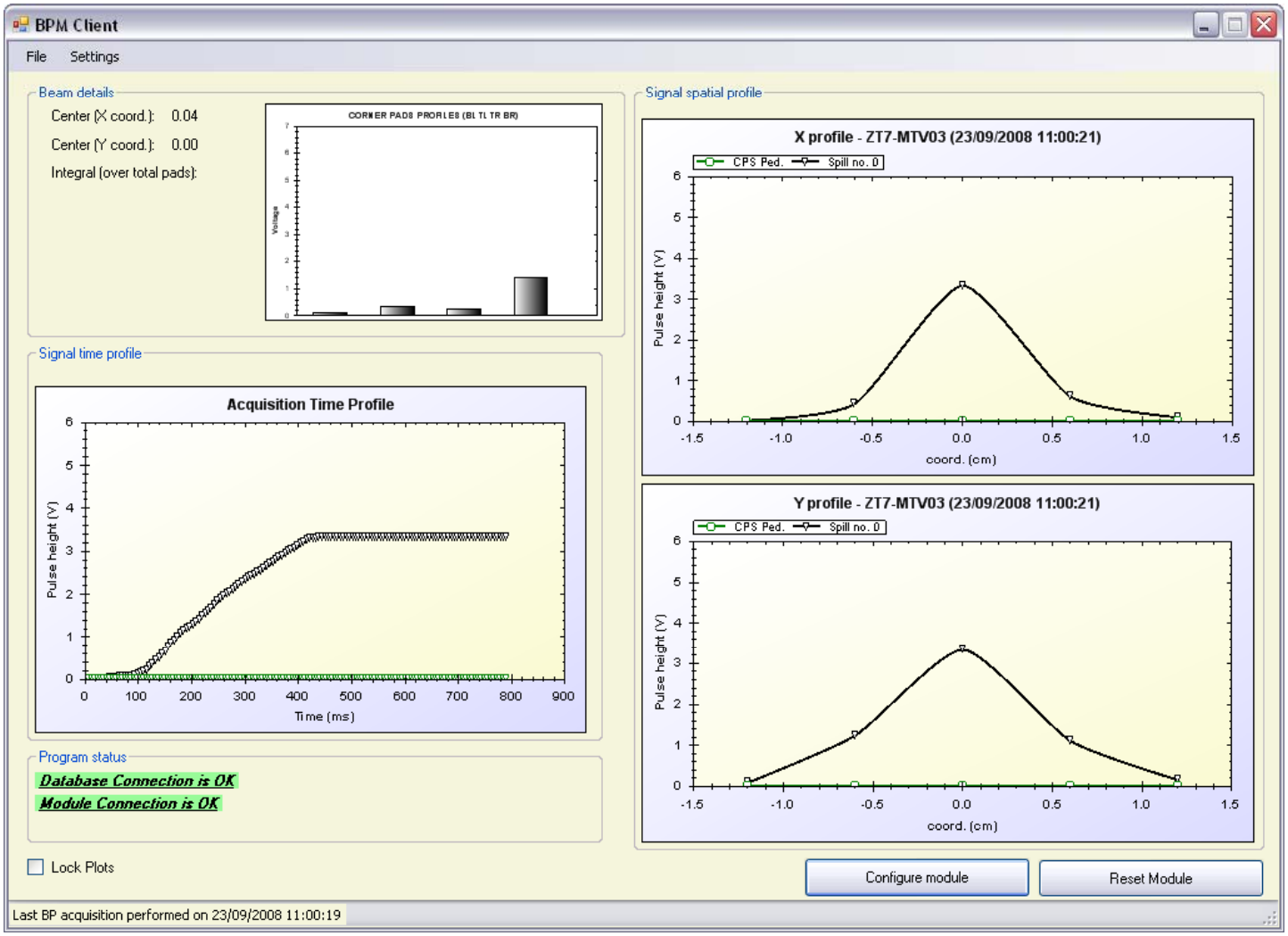


16 Channels integrator (BB-ACF2101).



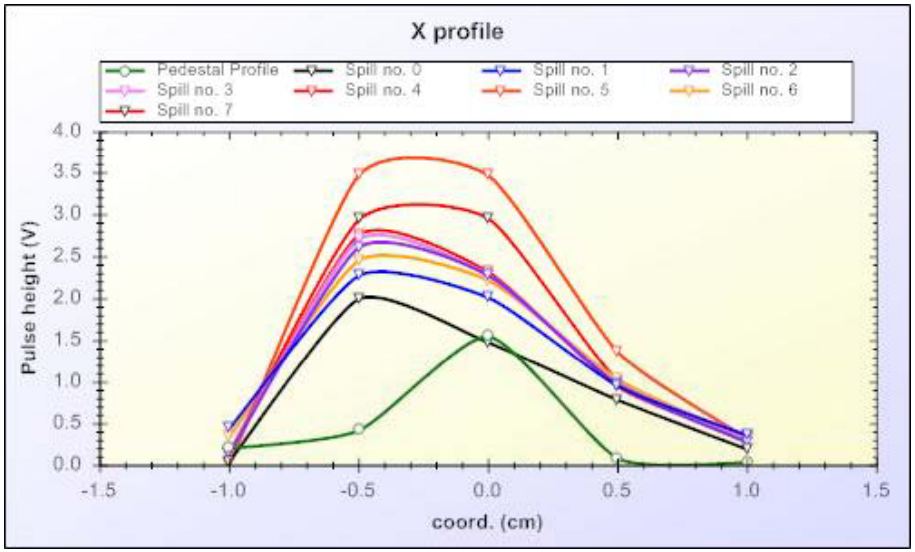
Beam instrumentation

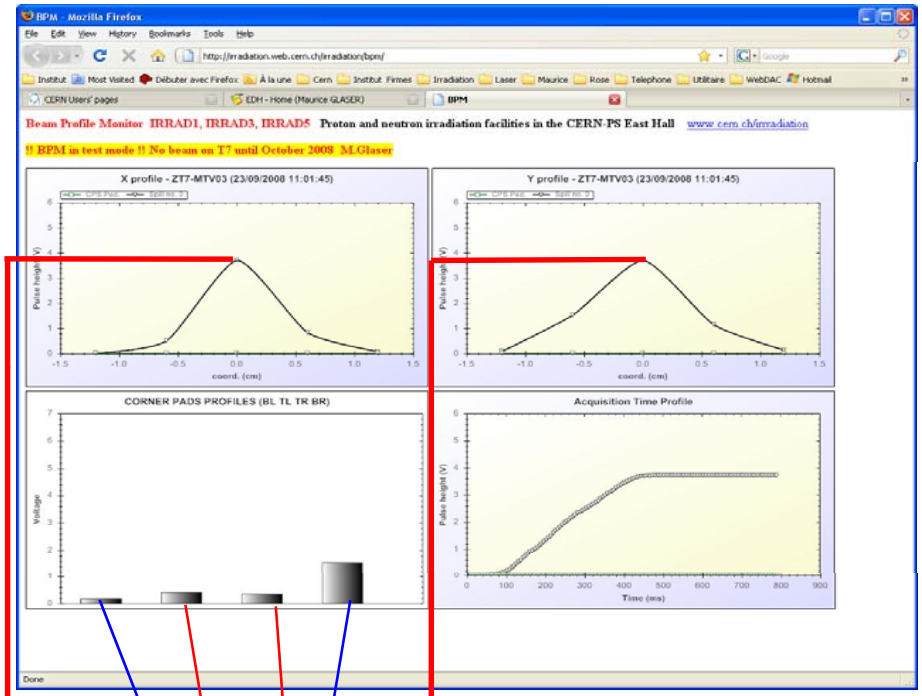
•Beam Profile Monitor (BPM), client running on a PC, read data on the PLC through Ethernet, store them onto a Database and produce a WEB page after each spill.

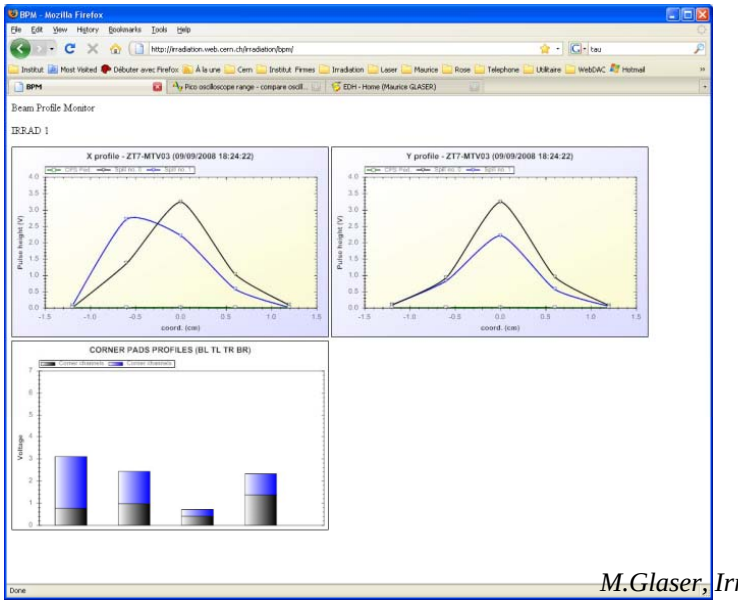


Beam instrumentation

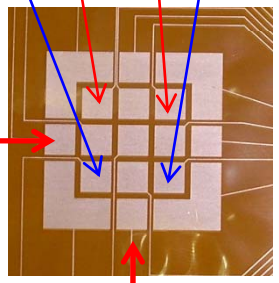
- **Beam Profile Monitor (BPM)**







Send SMS to all users registered inside the database

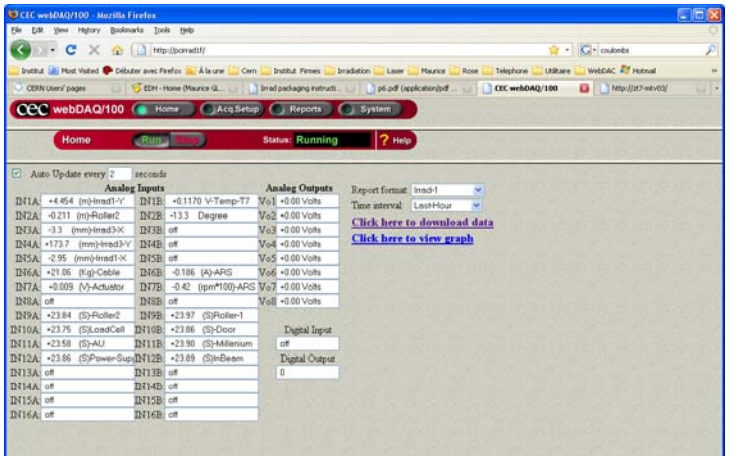


~200pC

M.Glaser, Irradiation facilities protons, neutrons & mixed fields (IRRAD1...IRRAD6) 24/09/2008

IRRAD Information system

- **WEBDac**



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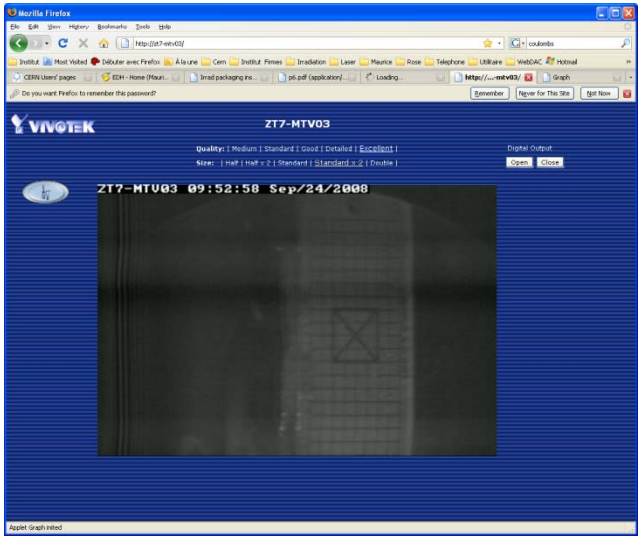
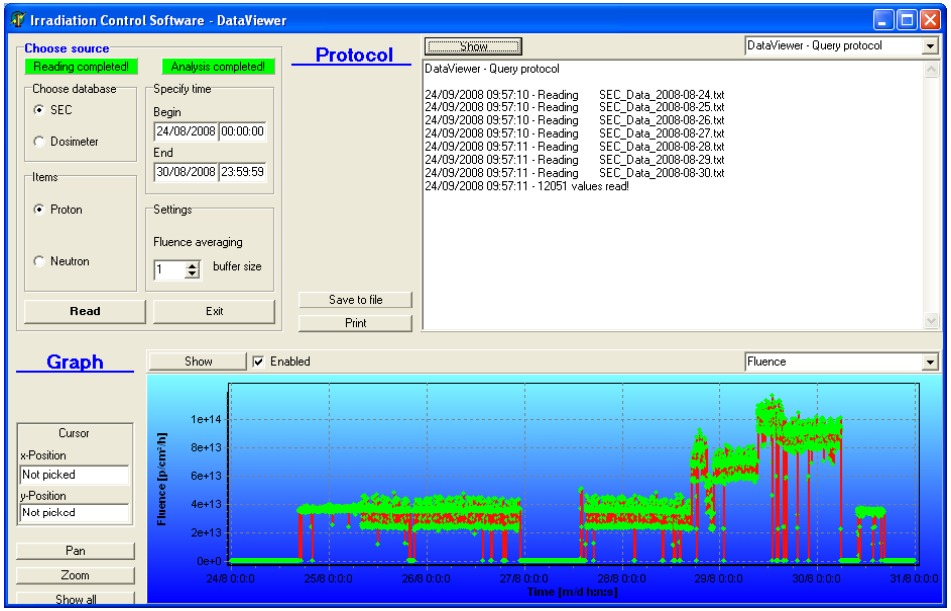
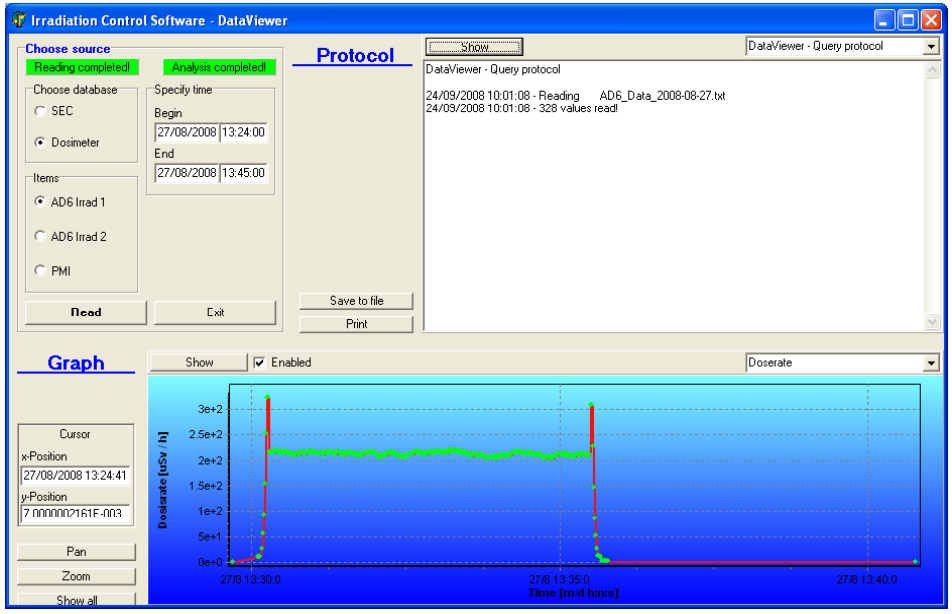






Irradiation service

- **Irradiations**
  - **Consulting -** (15 years of experience in performing irradiations in the PS East Hall)
  - **Planning of irradiation experiment**
  - **Support in producing specialized sample holders**
    e.g.: CNC machine dedicated to produce sample holders from plexiglas (perspex)
  - **Clients are asked to register on our web-site and submit irradiation requests**
  - **Irradiation usually free of charge** (We are a CERN-PH common project)
  - **Low volume, passive irradiations are performed by us - Clients are requested to participate in extensive or complicated irradiations or in case of on-line measurements**
  - **Bench tests for electrical characterizations available** (e.g. CV and IV measurements)

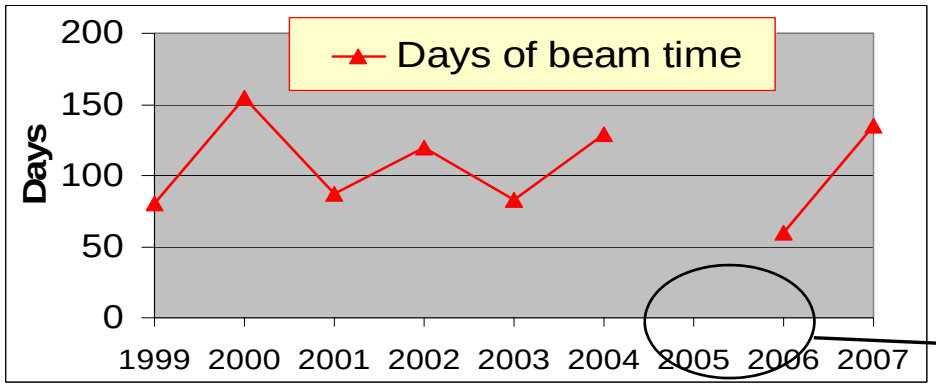
- **Dosimetry** (typical accuracy about 7-10%)
  - **Activation of Al-foils** (^{24}Na, $\tau_{1/2}$= 15h, ^{22}Na, $\tau_{1/2}$= 2.6y)
  - **Silicon p-i-n diodes, RADFETs, Alanine, Radiachromic Dosimeters**
  - **Expertise in Dosimetry and Fluence measurements** (see list of publications on web-site)

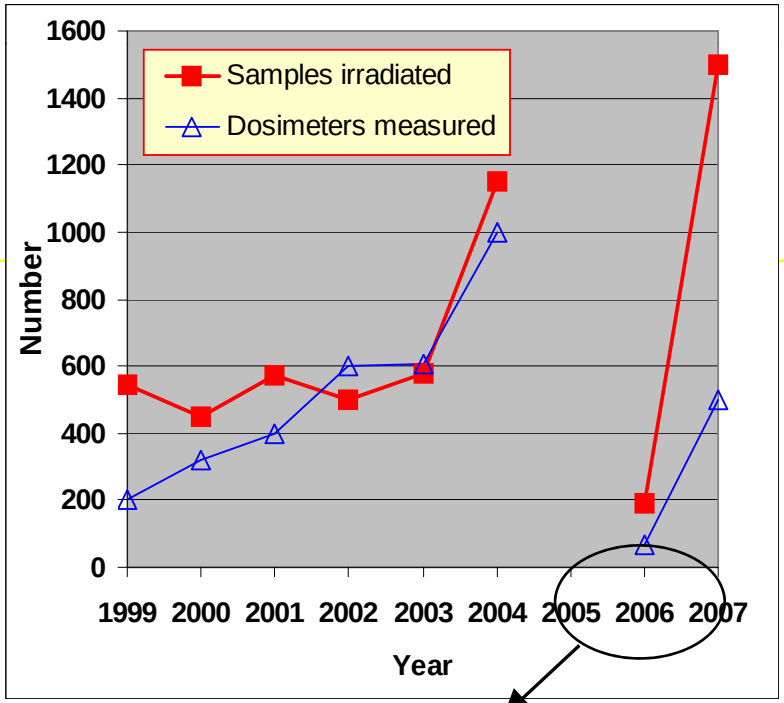
- **Handling of activated samples, material storage and Shipping**
  - **All material handled, packaged and shipped following strictly CERN Safety Regulations** (this includes tracing of all irradiated material!)
  - **Shipping in containers that allow to keep samples cold for several days**

- **Irradiations outside of CERN**
  - e.g.: pion irradiations at the PSI

Users & Statistics

- **Main users:**
  - **LHC Experiments** (in particular innermost detector components – silicon tracking detectors)
  - increasing requests linked to detector developments for LHC-upgrade (up to $2x10^{16}$ p/cm^2)
- **since 2000: 130 registered users working for 32 different physics experiments,**
  - **More than 5500 samples have been irradiated for the LHC community!**
- **Irradiations in 2007** (Main users: ATLAS, CMS, TOTEM, RD50, RD42, RD39)
  - **1500 objects irradiated**
  - **500 dosimeters measured**
  - **135 days of beam time**
- **Irradiations in 2008 (115/150 Days)**
  - **5 complex irradiations , 220 irradiated samples and 65 dosimeters measured until today**

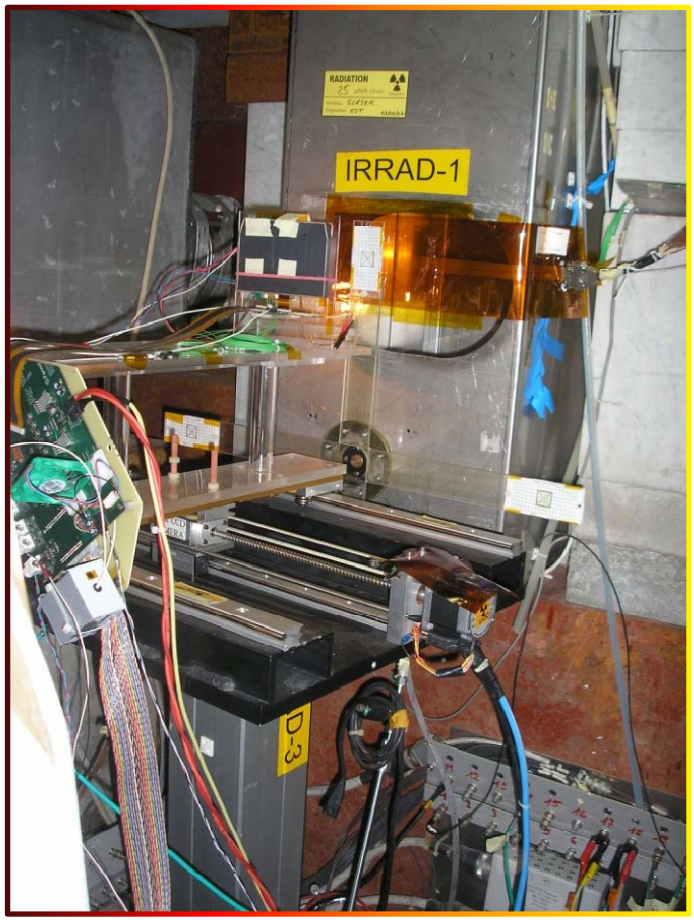


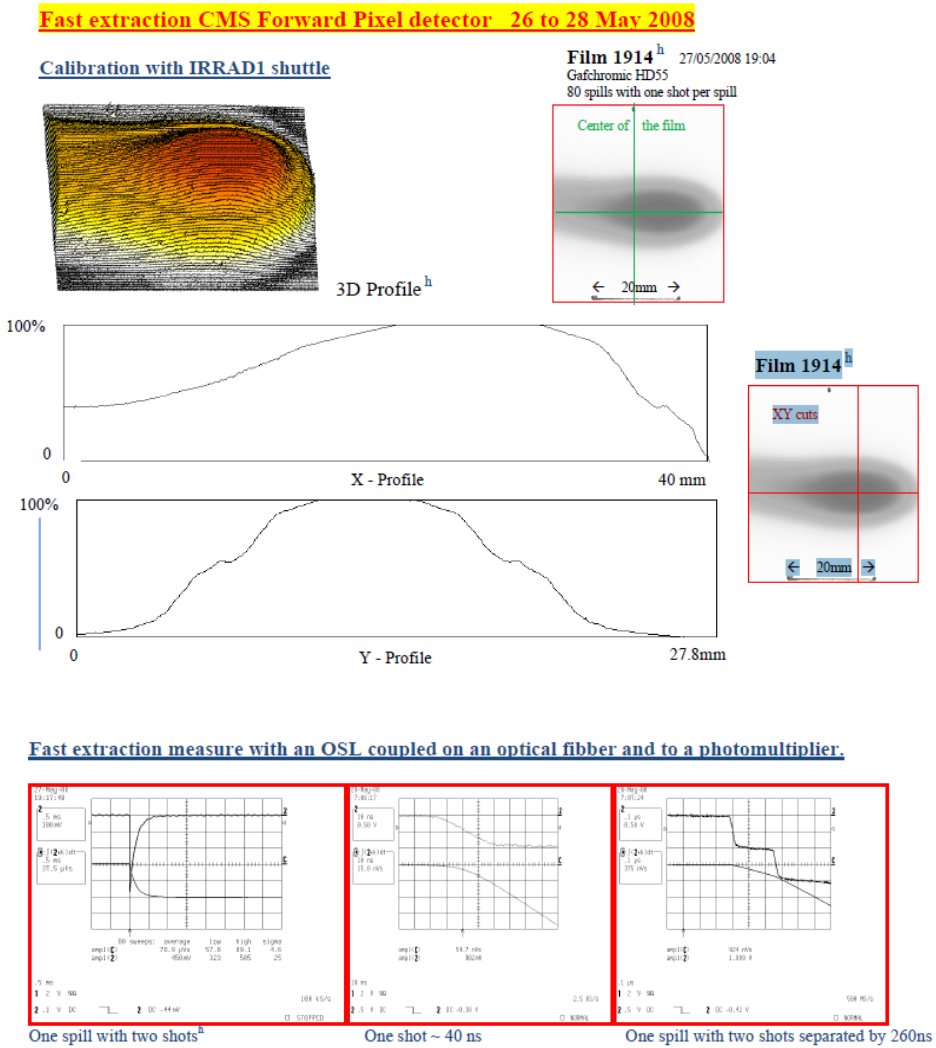


2005: no beams at CERN
2006: PS problems, magnet failure

Complex irradiations

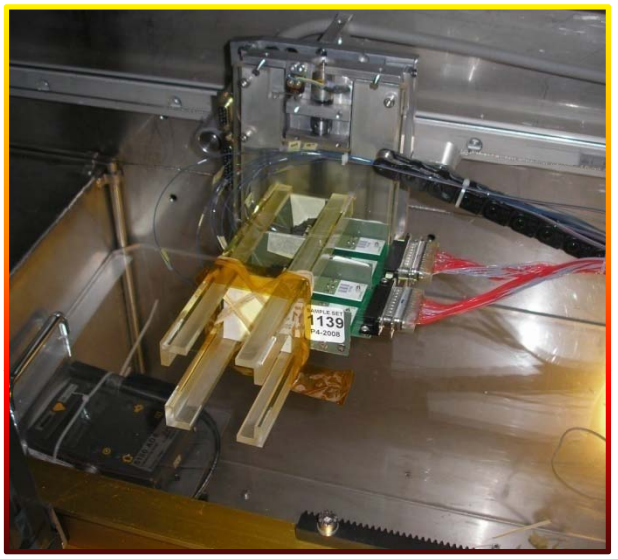
- **CMS Forward Pixel detector, Fast extraction 40 ms**





Complex irradiations

- **ATLAS Pixel team on IRRAD1** (KK Gan, Shane Smith, Babak Abi)
  - **Ohio & Oklahoma State University**
  - **Optical link for ATLAS Pixel detector > 50 MRad**
  - **Radiation-hardness and single-event-upset (SEU) probability of VCSEL and PIN arrays and ASICs as part of the detector, R&D for the SLHC**
  - **Si PIN diodes Hamamatsu S9055-01 $ S5973-01**
  - **GaAs PIN diode G8522-XX**
  - **GaAs PiN array G8921-01**



Complex irradiations

- **ATLAS Pixel team on IRRAD3** (KK Gan, Shane Smith, Mohsine Menouni, Alexandre Rozanov)
  - **Ohio State University, Marseille University**
  - **Irradiation of ASICs fabricated with IBM 130 nm technology**
  - **VCSEL driver chips with two flavors, 640 Mb/s and 3.2 Gb/s**
  - **DORIC chips (PIN receiver, BPM data/clock decoder, LVDS outputs) operating at 40, 160, or 320 Mb/s**

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Proposal for facility upgrade

• Present limitations and drawbacks

- **Irradiation tables are located inside the beam line complex (primary zone)**
  → Access to primary zone needed to enter
  → Very restricted space, Backscattered particles superimpose primary beam
  → Personnel exposed to radiation (activated material around irradiation tables – e.g. magnets)
- **Neutron facility parasitic to DIRAC**
  → Parasitic operation strongly limits flexibility
- **Proton & Neutron facilities located in different beam lines**
  → Parallel operation of two facilities difficult
  → Proton and Neutron facility 'competing' for beam

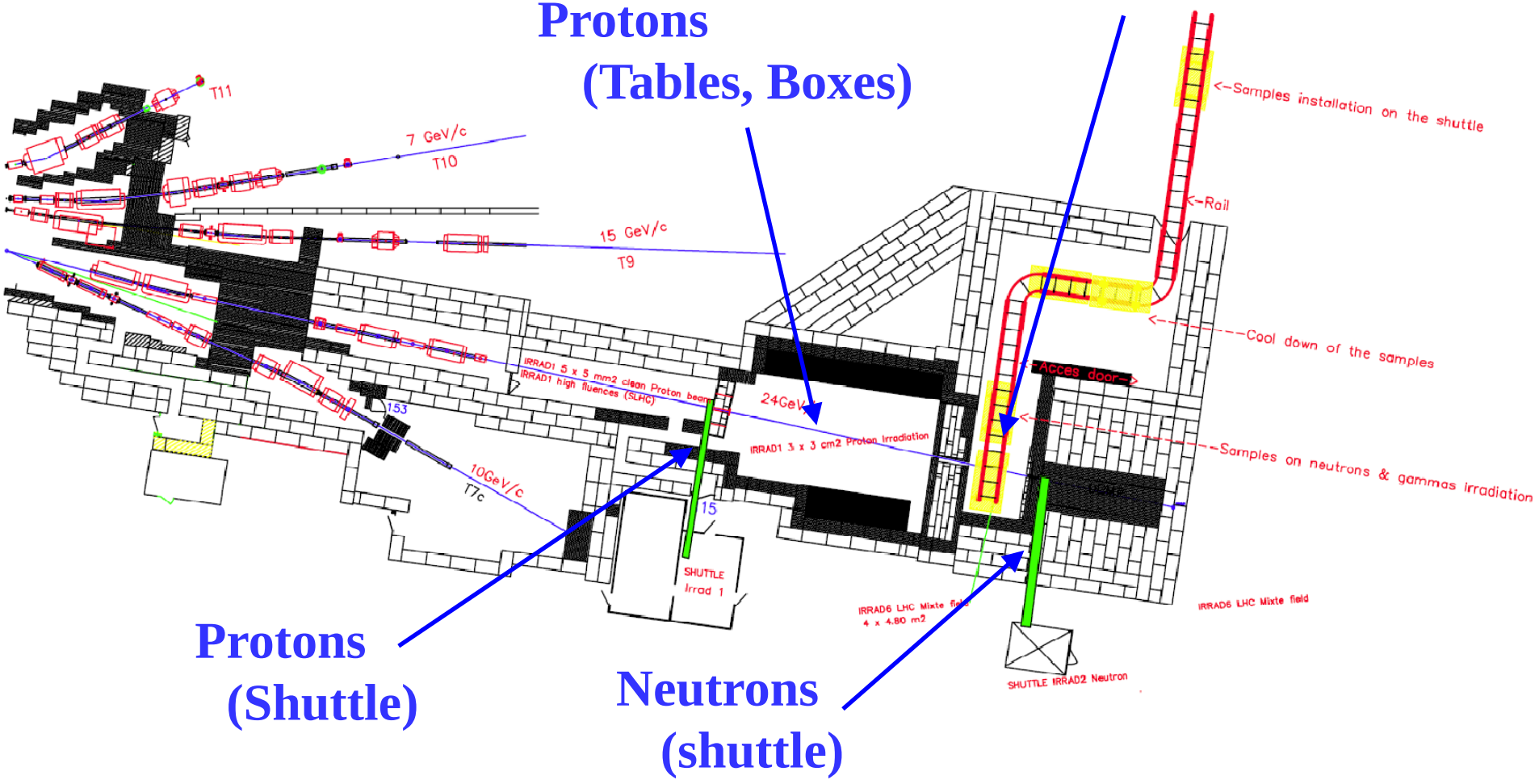
• Proposal: Proprietary beam line for irradiations

- **Combine proton and neutron irradiation facilities in one beam line**
- **Increase space for irradiation areas** (less background, less exposure to radiation of personnel)
- **Place facility in secondary zone** (outside beam line complex)
- **Allow access with big objects to the neutron irradiation facility**
- **Requires termination of DIRAC experiment in T8 beam line**

PS East Hall – Proposal for facility upgrade

Neutron field with rail system for heavy objects and remote access

Protons (Tables, Boxes)



Protons (Shuttle)

Neutrons (shuttle)

Summary

- **Proton irradiation facility**
  - **24 GeV/c protons** (in spills of ~ 2×10^{11} p over 400 ms), **~ 2 x 2 cm^2 beam spot, flux: ~ 1 - 5 × 10^{13} p cm^{-2} h^{-1}**
  - **Shuttle system** (10x10x20 cm^3) **and irradiation tables/boxes for bigger objects**
- **Neutron irradiation field**
  - **complex irradiation field dominated by neutrons, flux: ~ 2 10^7 n cm^{-2} s^{-1} (E_n > 1 MeV) at 50 cm position**
- **Proposal for upgrade of facility presented**
- **What we did not show** (see **http://www.cern.ch/irradiation**)
  - **Radiation control system**
    (online radiation monitoring, electronic logbook, data logging, etc..)
  - **Details about dosimetry**
  - **User & Material database systems**
  - **Irradiations performed outside of CERN (e.g. pion irradiations at PSI)**