LHC Consolidation after Beam Operation – Radiation Protection Constraints

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on behalf of DG-SC-SL

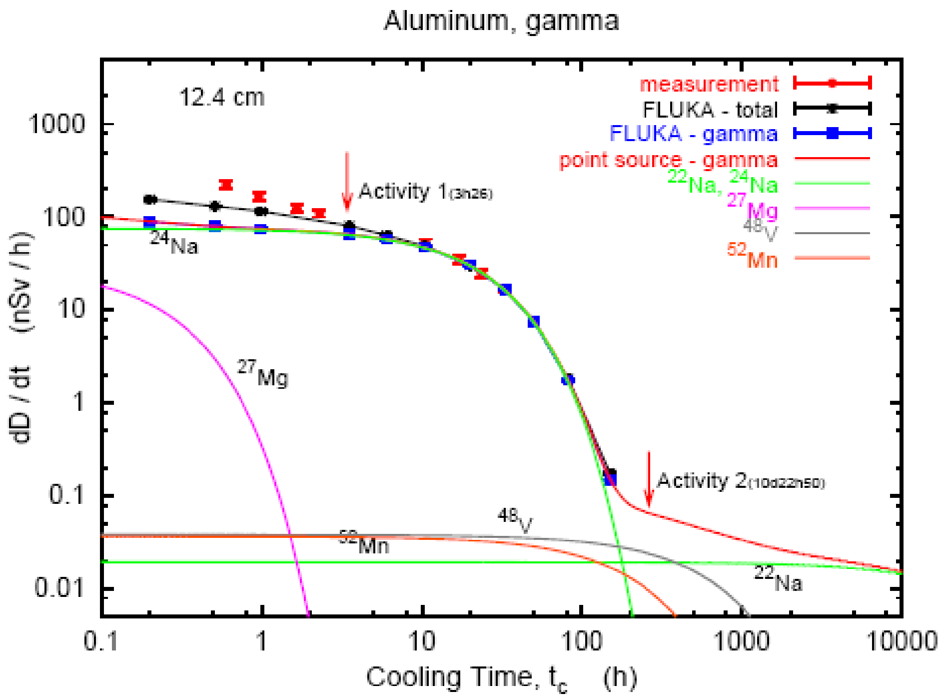
Chamonix , 3rd February 2009

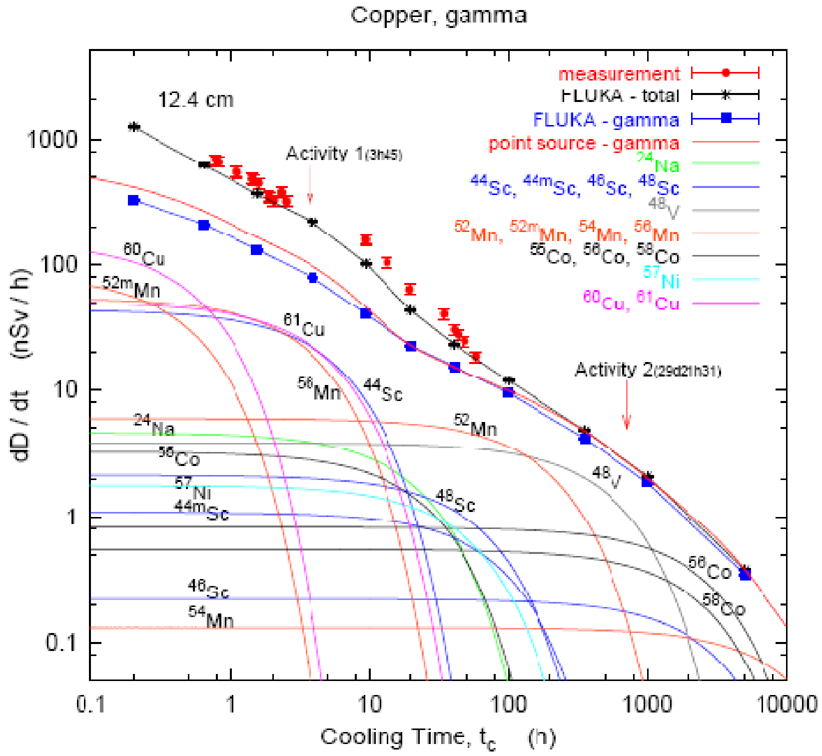
Table of Content

- Radiation risks at High Energy Accelerators – a short reminder
- LHC after the 19th of September 2008
- LHC after resuming operation
- RP's point of view on repair and maintenance scenarios

Activation of Material

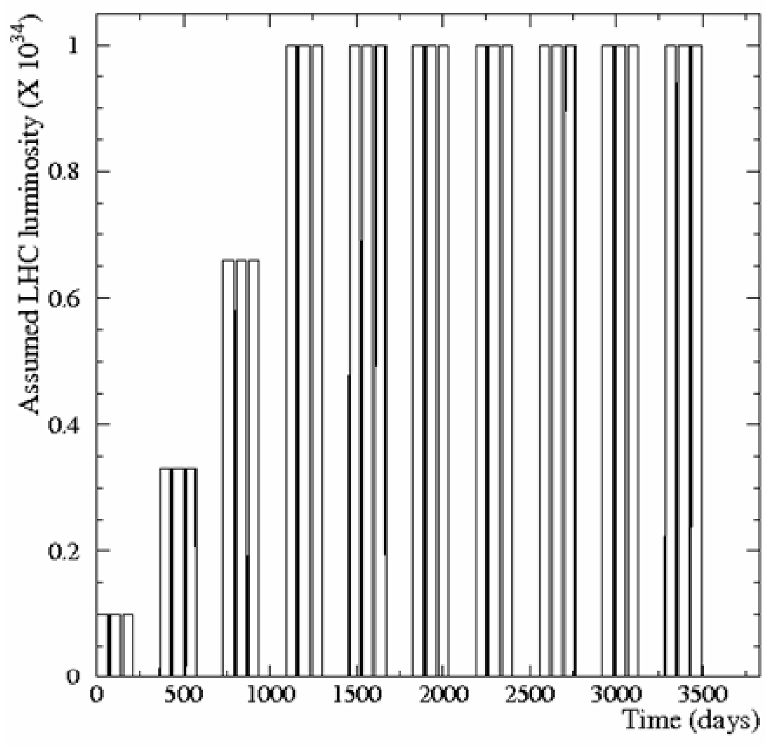
Beam losses result in the activation of material
(beam line components, tunnel structure, etc.)





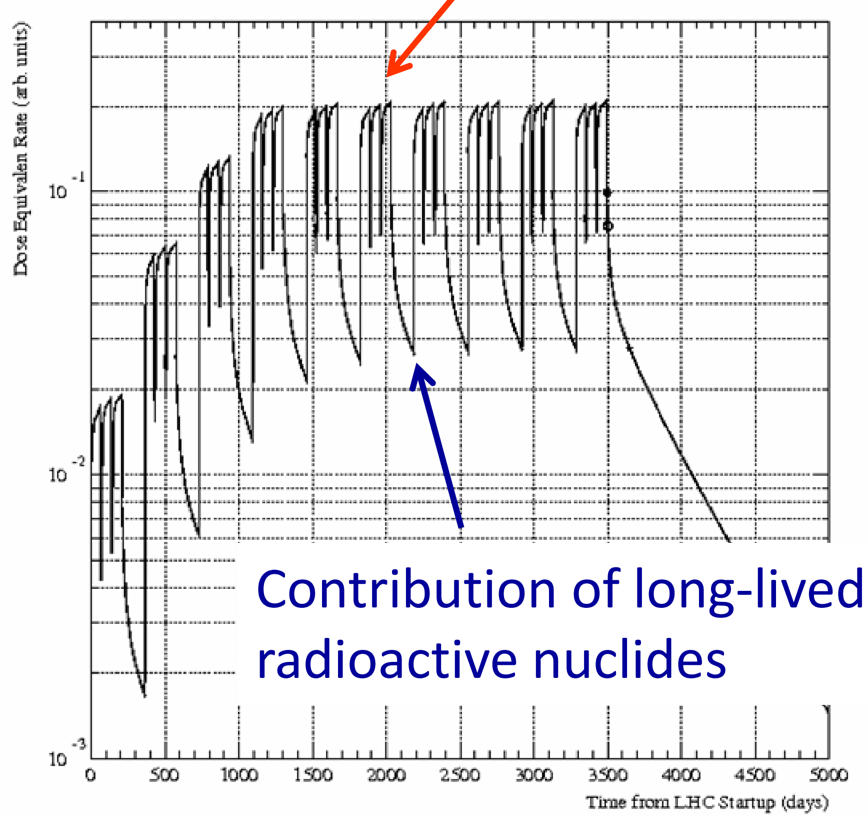
Risk of external (all work) and internal exposure (destructive work)

Ambient Dose Equivalent Rate as Function of LHC Operation

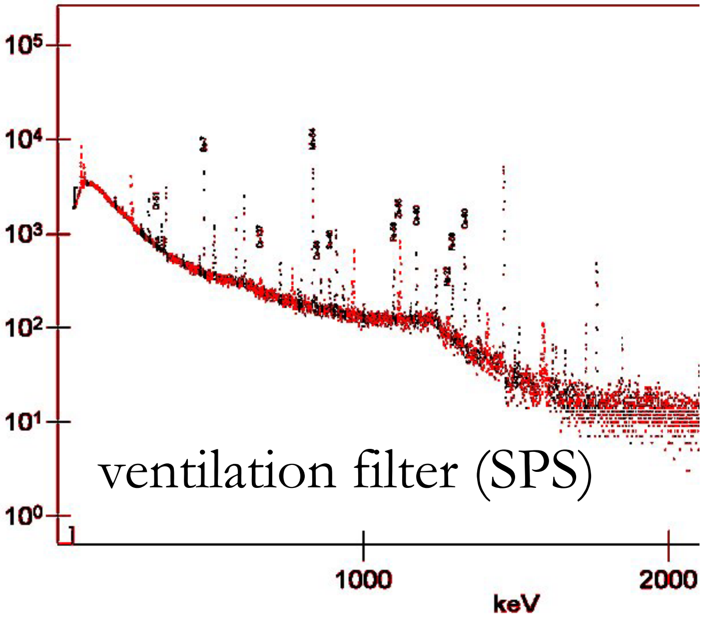


M. Huhtinen, RPC/2003/XXXVIII/138

Contribution of short-lived radioactive nuclides



Contribution of long-lived radioactive nuclides



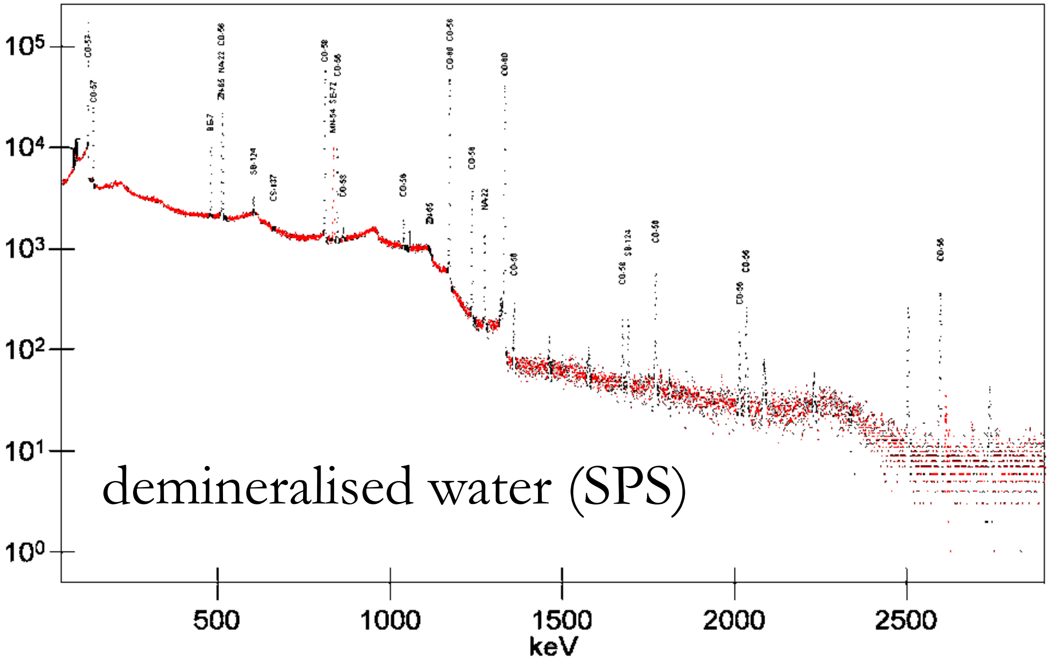
Nuclide	Halflife
Be-7	53 D
Na-22	3 Y
Sc-46	84 D
Cr-51	28 D
Mn-54	312 D
Co-56	77 D
Fe-59	45 D
Co-60	5 Y
Zn-65	244 D

γ-emitter only

Activation

of air, gas, water, cooling liquids,

risk of external and internal exposure



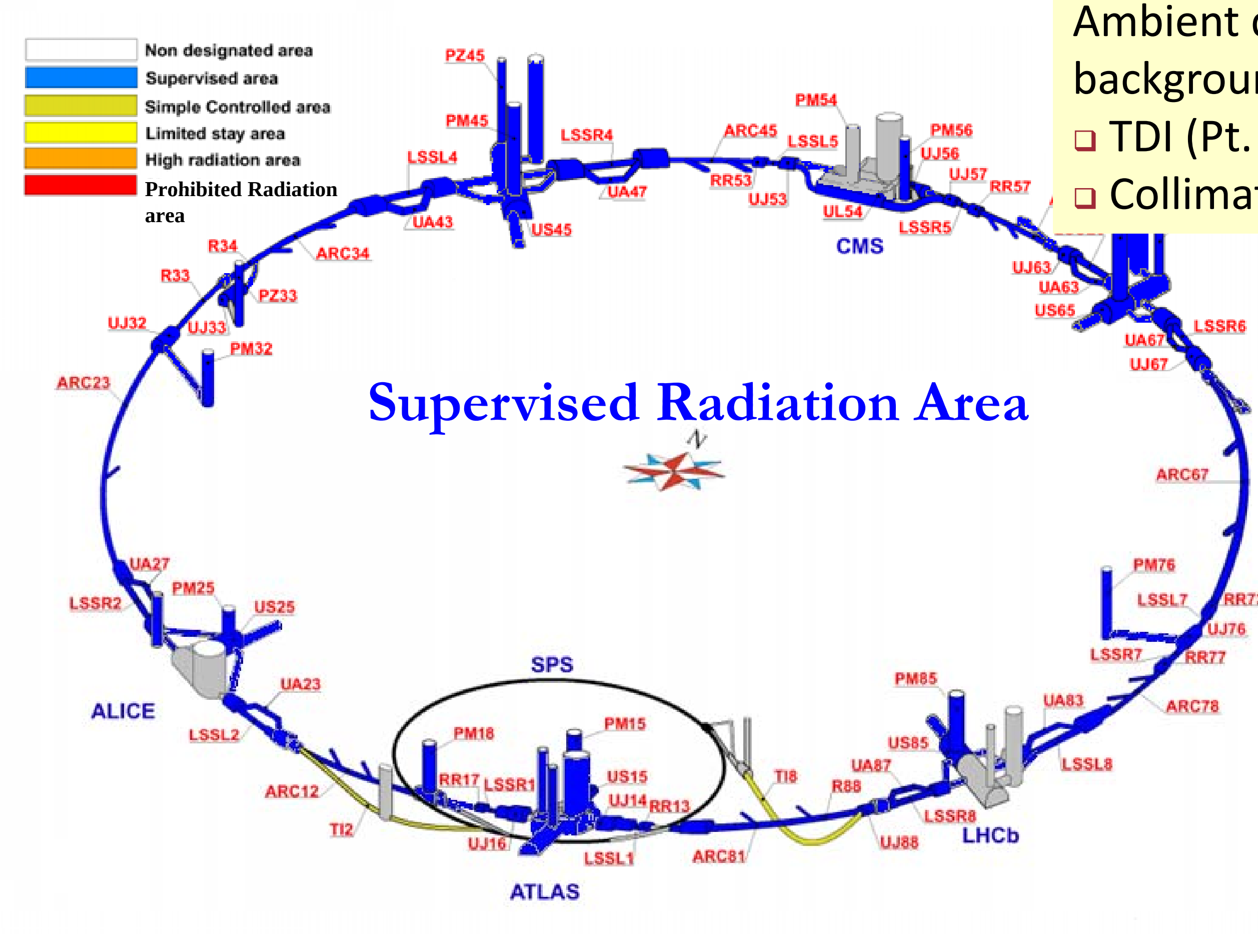
Nuclide	Halflife
BE-7	53 D
NA-22	3 Y
CO-56	77 D
CO-57	271 D
CO-58	71 D
CO-60	5 Y
ZN-65	244 D
SB-124	60 D

γ-emitter only

LHC since 19th September 2008

Ambient dose equivalent rate is background with exception of

- TDI (Pt. 2 + 8)
- Collimators and absorbers (Pt. 3 + 7)



Cooling liquids and gases not radioactive

Survey collimateurs Point 3 LHC le 21/11/08	
N° CERCA	Mesures en µSv/h
TCS031	‹ 0.1
TCS014	‹ 0.1
TCS051	1.4
TCT023	5.2
TCT035	1.5
TCT047	‹ 0.1
TCSG 5R3S	‹ 0.1
TCAPA 6R3 B2	‹ 0.1
TCT074	‹ 0.1
TCT065	‹ 0.1
TCP 6L3 B1	‹ 0.1
TCSG A5R3 B1	‹ 0.1
TCSG B5R3 B1	‹ 0.1
TCP 6R3 B2	‹ 0.1

LHC since 19th September

LHC is Supervised Radiation Area:

- Only radiation workers are allowed to access this area (DIS dosimeter required)
- Any destructive work (machining, grinding, etc.) on beam line components has to be announced to SC-RP, work procedures to be discussed with and approved by SC-RP prior to the start of the work
- Risk of contamination for any non-destructive work can be excluded
- All material that had been in the LHC tunnel during beam operation and that will leave the LHC needs to be controlled by SC-RP

LHC since 19th September

However:

- Negligible dose to personnel during maintenance
- Information on beam losses from beam operation (M. Lamont) in combination with RP Monte Carlo calculations eases the radiological classification of material by RP.
- A considerable amount of LHC accelerator equipment can be declared as non-radioactive *(after control by RP).* Consequently, simplified repair procedures and repair techniques inside the tunnel can be authorized by RP.
- Equipment *(declared as non-radioactive by RP)* can be repaired in ordinary work shops
- Equipment *(declared as non-radioactive by RP)* can be sent to any company for repair or modifications

Resuming LHC Operation

Scenario until 20th December 2009 (M. Lamont):

1) 30 days commissioning

pilot beam up to few 10^{10} protons / bunch, 450 GeV - 5TeV

2) 65 days pilot physics

up to 156 × 156 bunches with 9 × 10^{10} protons / bunch
(=1.4 ×10^{13} protons/beam, *i.e.*, factor ~20 below nominal)
luminosity: 5 ×10^{31} /cm^2/s

RP studies:

1) Arc magnets

single bunch losses:

2.82 × 10^9 protons / bunch, 450 GeV and 7 TeV

beam gas interactions:

2.4 × 10^4 protons/m/s (both beams, *nominal* machine), 7TeV, 180 days op.

2) Inner triplets

particle cascade from *pp*-collisions: 1 month operation at 10^{32} /cm^2/s

RP results can be scaled with energy, intensity and luminosity

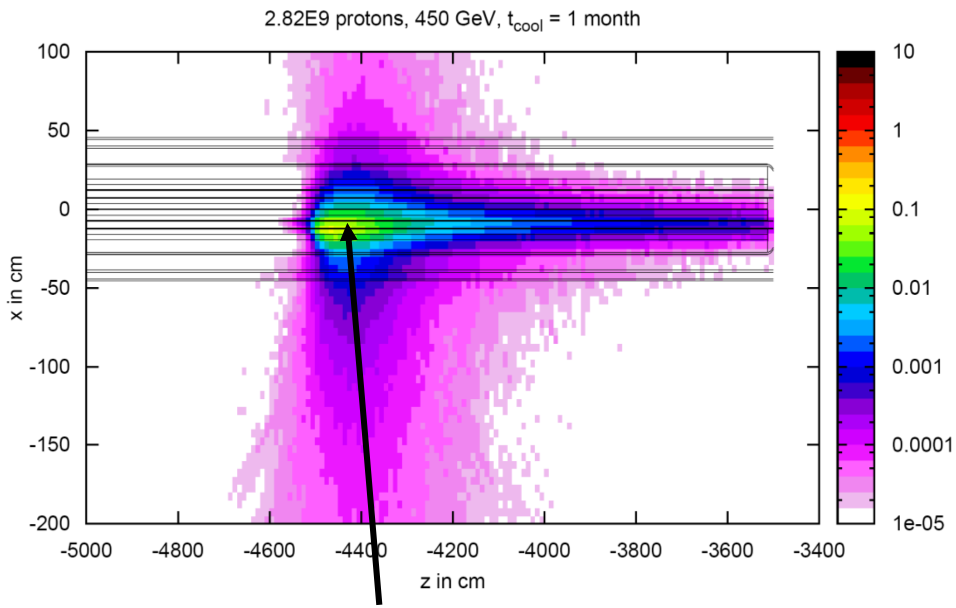
Arc: Loss of Single Bunch (2.82 x 10^9 protons)

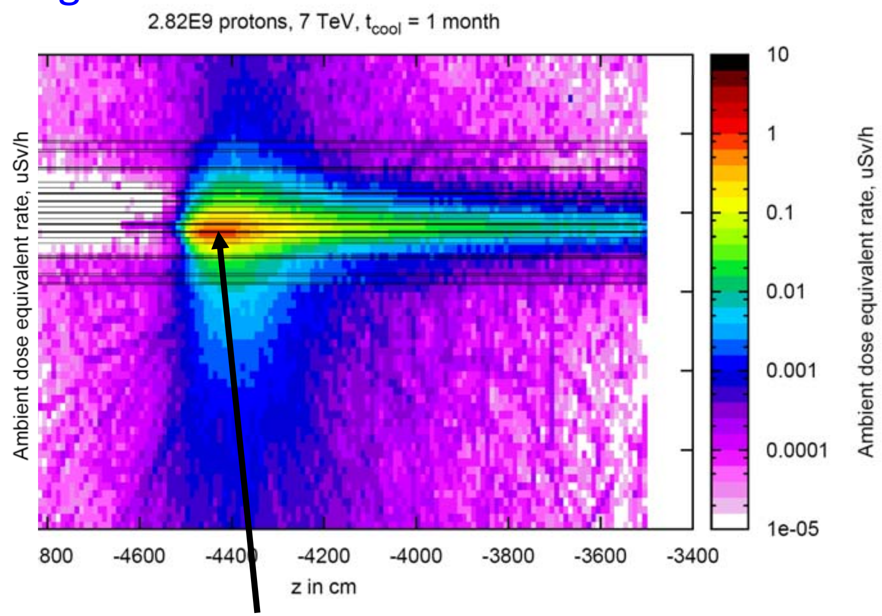
Ambient dose equivalent rate

450 GeV

1 month cooling

7 TeV





<150 nSv/h (contact)

~1 μSv/h (contact)

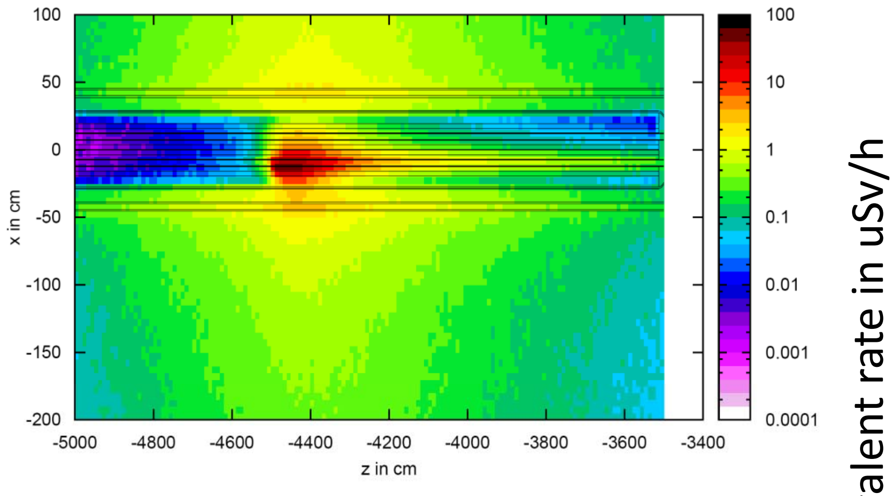
Residual dose rates scale with beam energy approximately like ***$E^{0.8}$***

$(7000 \text{ GeV} / 450 \text{ GeV})^{0.8} = 9.0$

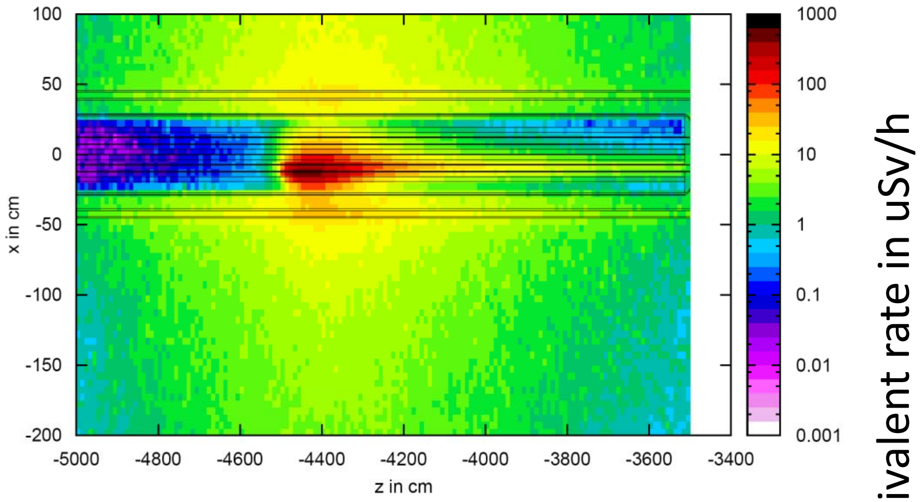
$(5000 \text{ GeV} / 450 \text{ GeV})^{0.8} = 6.8$

Arc: Loss of Single Bunch (2.82 x 10^9 Protons)

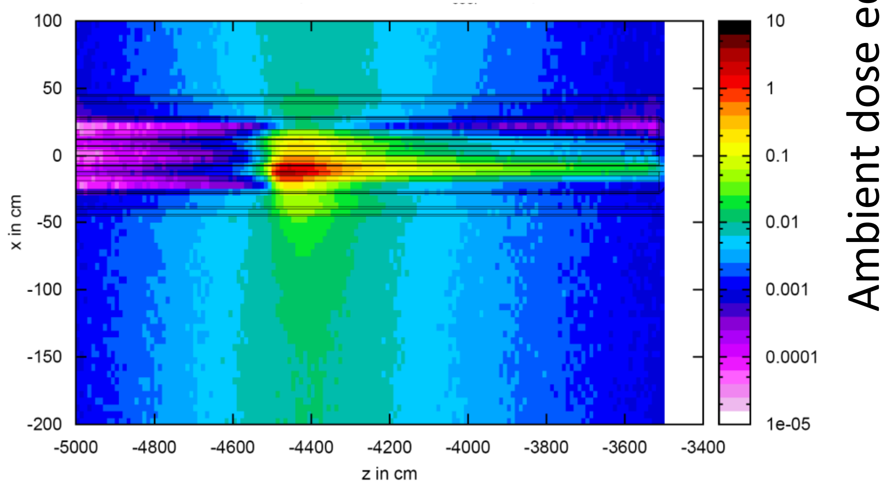
2.82 E9, 450 GeV, tcool = 1 hour



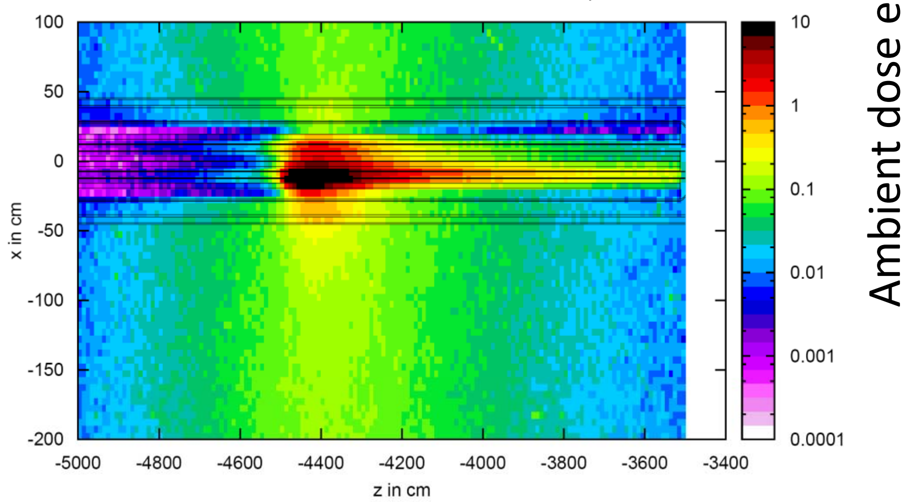
2.82 E9, 7 TeV, tcool = 1 hour



2.82 E9, 450 GeV, tcool = 1 day

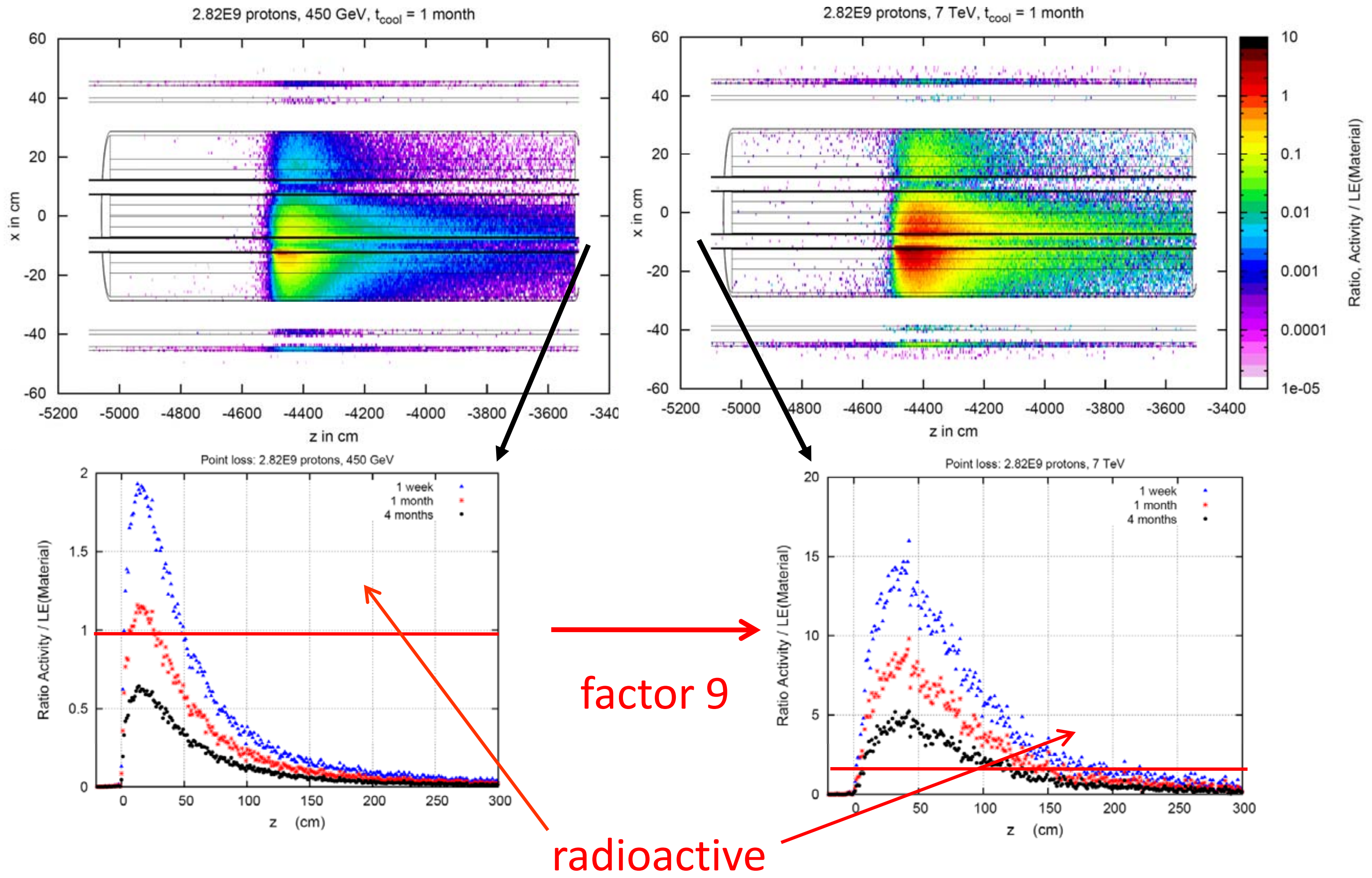


2.82 E9, 7 TeV, tcool = 1 day



Arc: Specific Activity after Single Bunch Loss

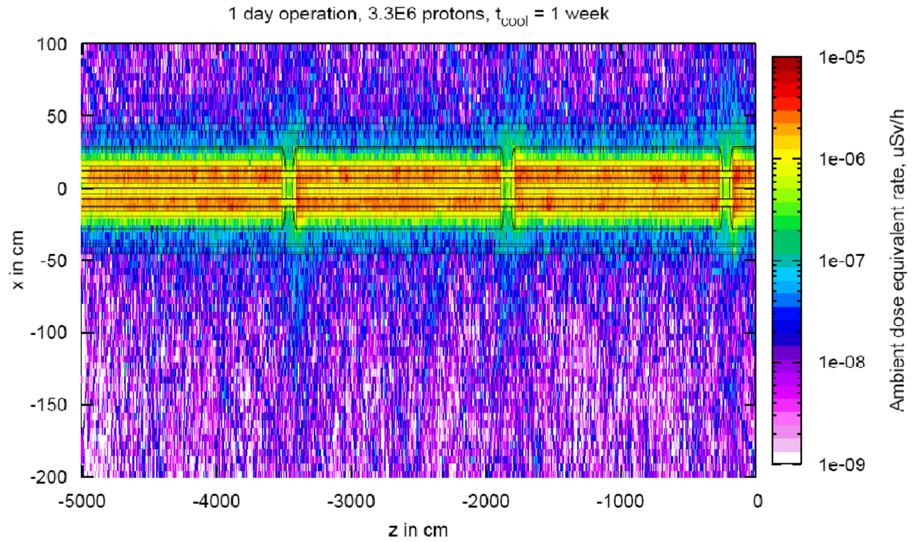
450 GeV 1 month cooling 7 TeV

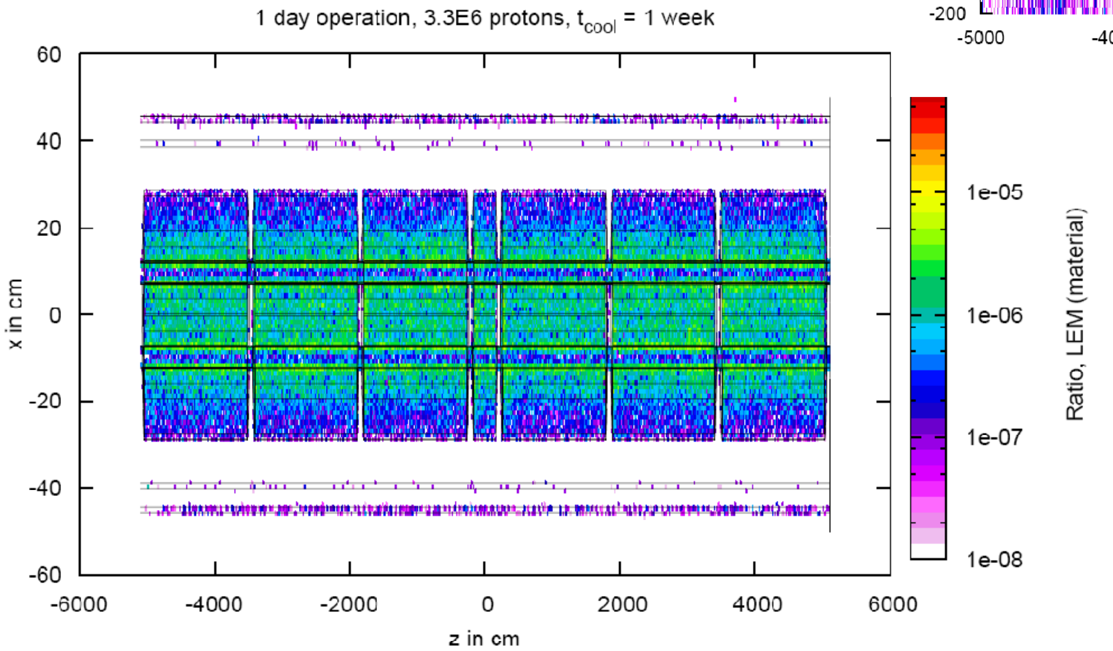


Arc: Beam Gas Interactions (2008)

Ambient dose equivalent rate

< 10^{-5} uSv/h (contact)



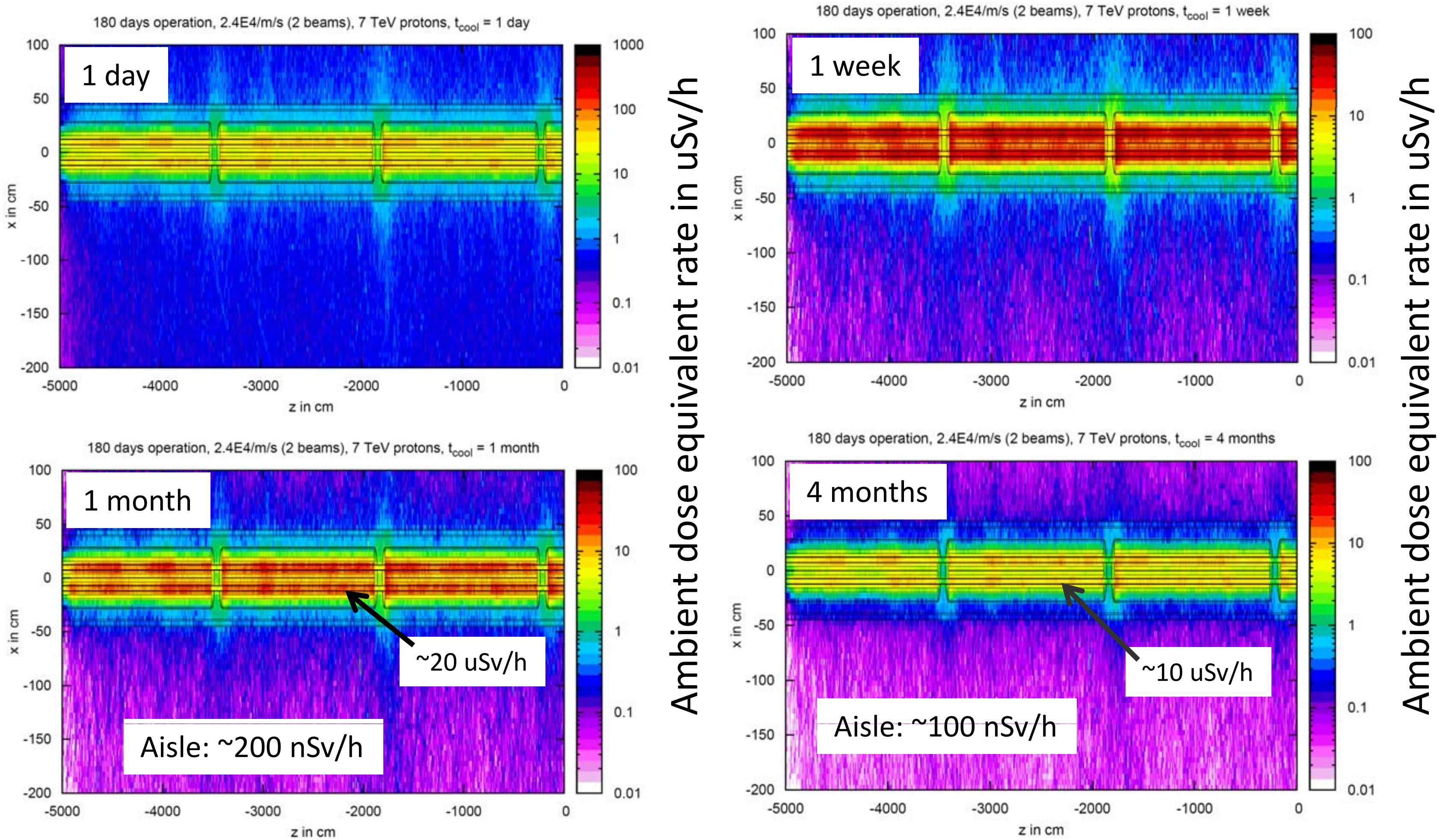


Radioactivity

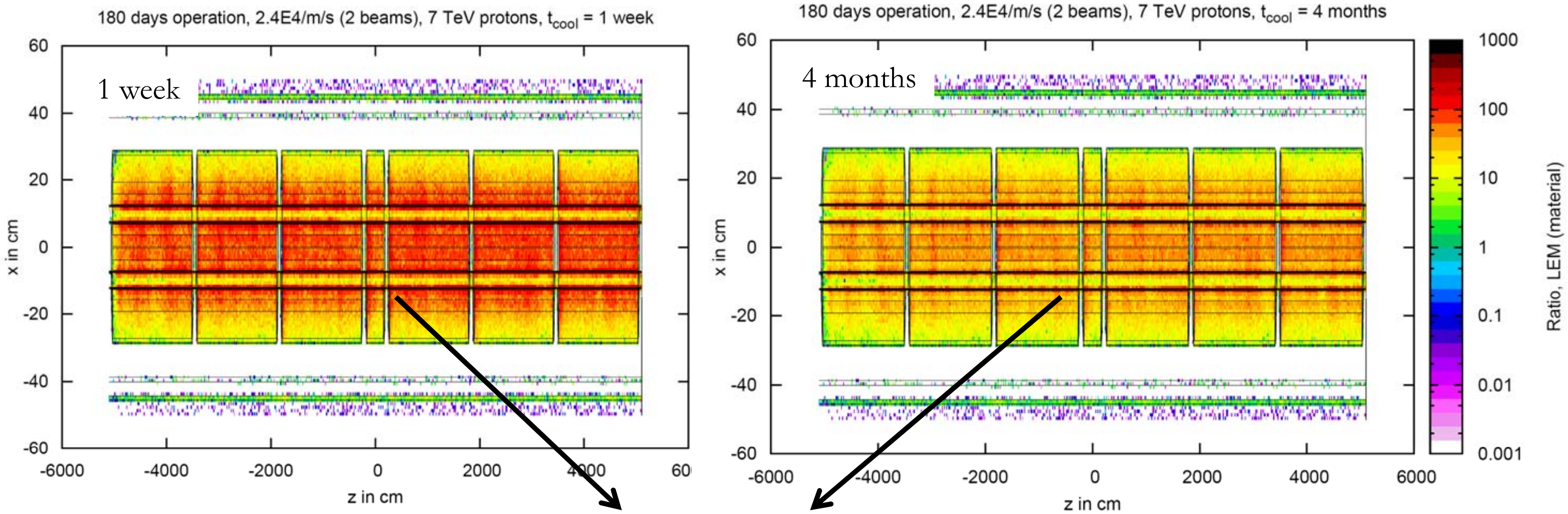
< 10^{-5} below limit

Arc: Beam Gas Interaction (nominal)

Assumption :2.4 × 10^4 protons/m/s (both beams), 7TeV, lost for 180 days continuously
(corresponds to an H_2-equivalent beam gas density of 4.5 × 10^{14} /m^3)



Arc: Beam Gas Interaction (nominal)

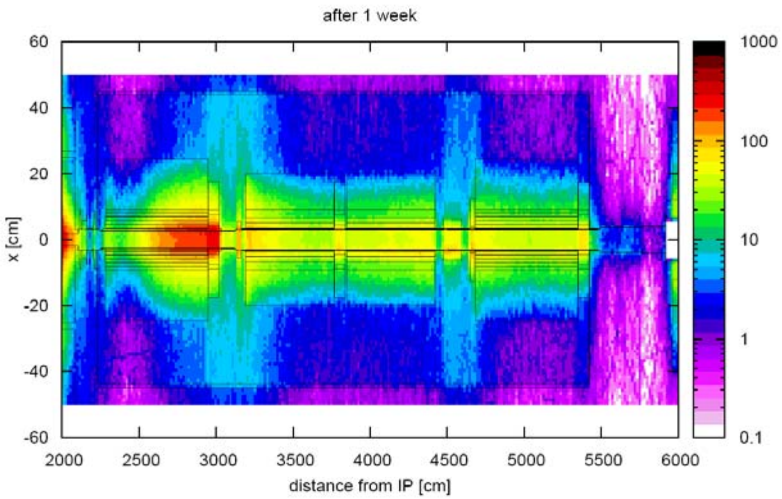


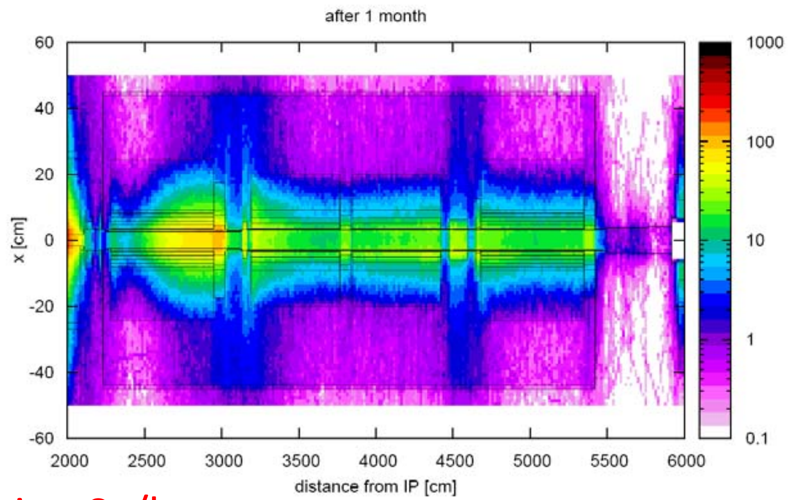
Level of radioactivity 2:1 for 1 week to 4 month cooling

→ even for 1/100 of nominal beam intensity beam gas interactions cause at least the inner parts of the magnet to be radioactive

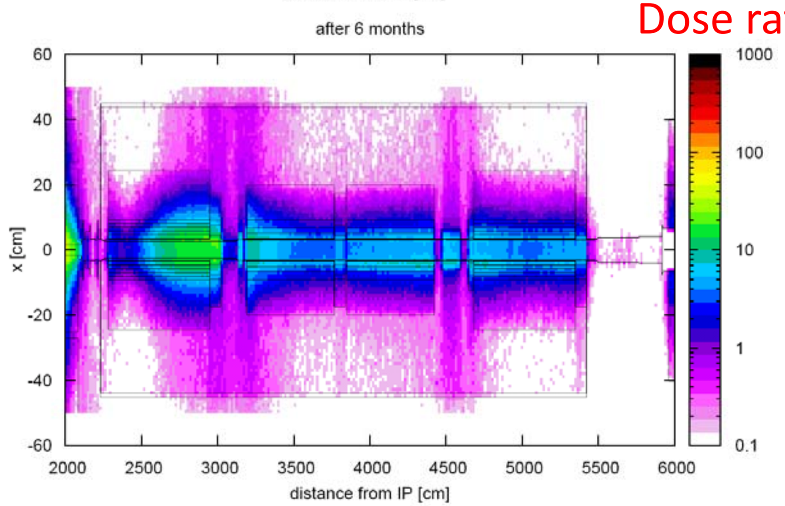
Inner Triplet and pp-Collisions

Assumption: 1 month operation at 10^{32} /cm^2/s





Dose rates in uSv/h



on the cryostat surface

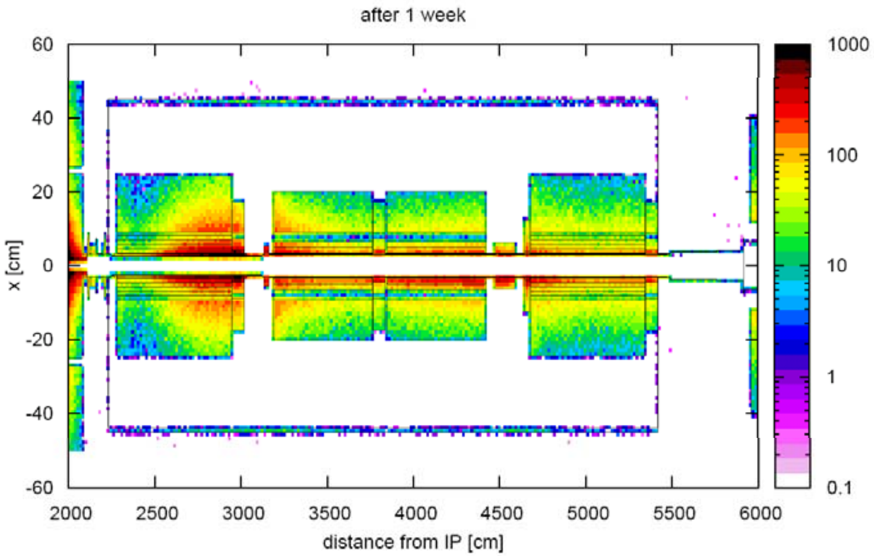
~ 10 uSv/h after 1 week

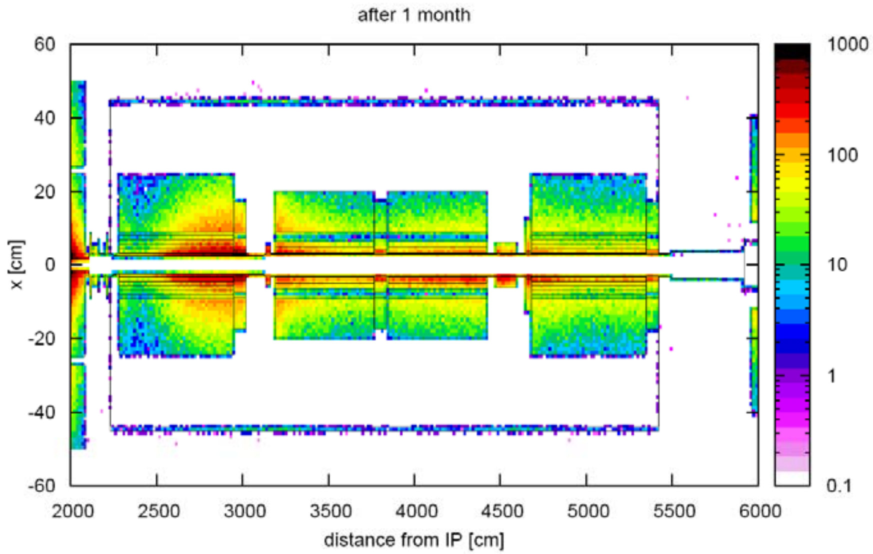
few uSv/h after 1 month

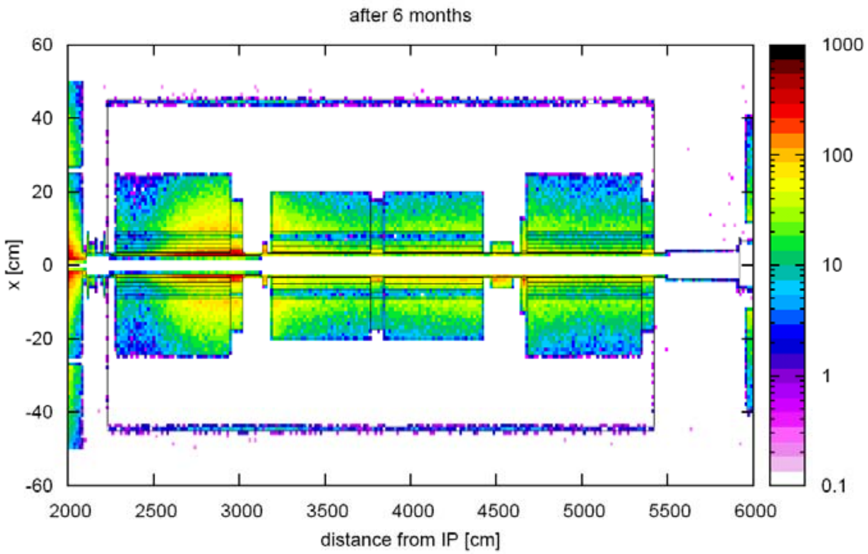
~ 1 uSv/h after 6 months

Courtesy of F.Cerutti, EN-STI

Inner Triplet and pp-Collisions







Specific activity:

in the magnet yokes values up to 100 above limits - even after 6 months of cooling

material is radioactive

Courtesy of F.Cerutti, EN-STI

Roadmap for Repair and Maintenance

Inner Triplet Collimator regions TAS, TAN regions	Recommendation: maintenance and new installation before start-up

Arcs: maintenance after restart
Arc magnets slightly radioactive
Ambient dose equivalent rates in the order of few uSv/h inside and some few 100 nSv/h outside the cryostat
-> Radiological risk involved in repair and maintenance is tolerable – but procedures and tooling (e.g. no grinder!) need to be qualified for work on radioactive items. Radioactive workshop is required.

Conclusion

- Repair and maintenance work before start-up has advantages:
  - RP can declare most of the equipment as non-radioactive
  - Non-radioactive items can be repaired in ordinary workshops and sent to any company
  - Waste zonage is waved

- RP constraints for repair, maintenance and installation will become severe after restart of the machine
  - Special procedures including use of special tooling to be respected
  - Radioactive workshops required
  - Radioactive equipment can be only sent to few, specialised companies
  - Waste zonage applicable

Conclusion

The development of one specific read-out tool for various radiation monitoring systems (Beam Loss Monitors, RADMON and RAMSES) would increase the efficiency of operational radiation protection:

The information obtained by radiation monitoring on beam losses, in combination with Monte Carlo calculations and screening measurements would allow a simplified RP approach to the radiological classification of material.

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