Radiological Status and Trends of Injectors & Experimental Facilities

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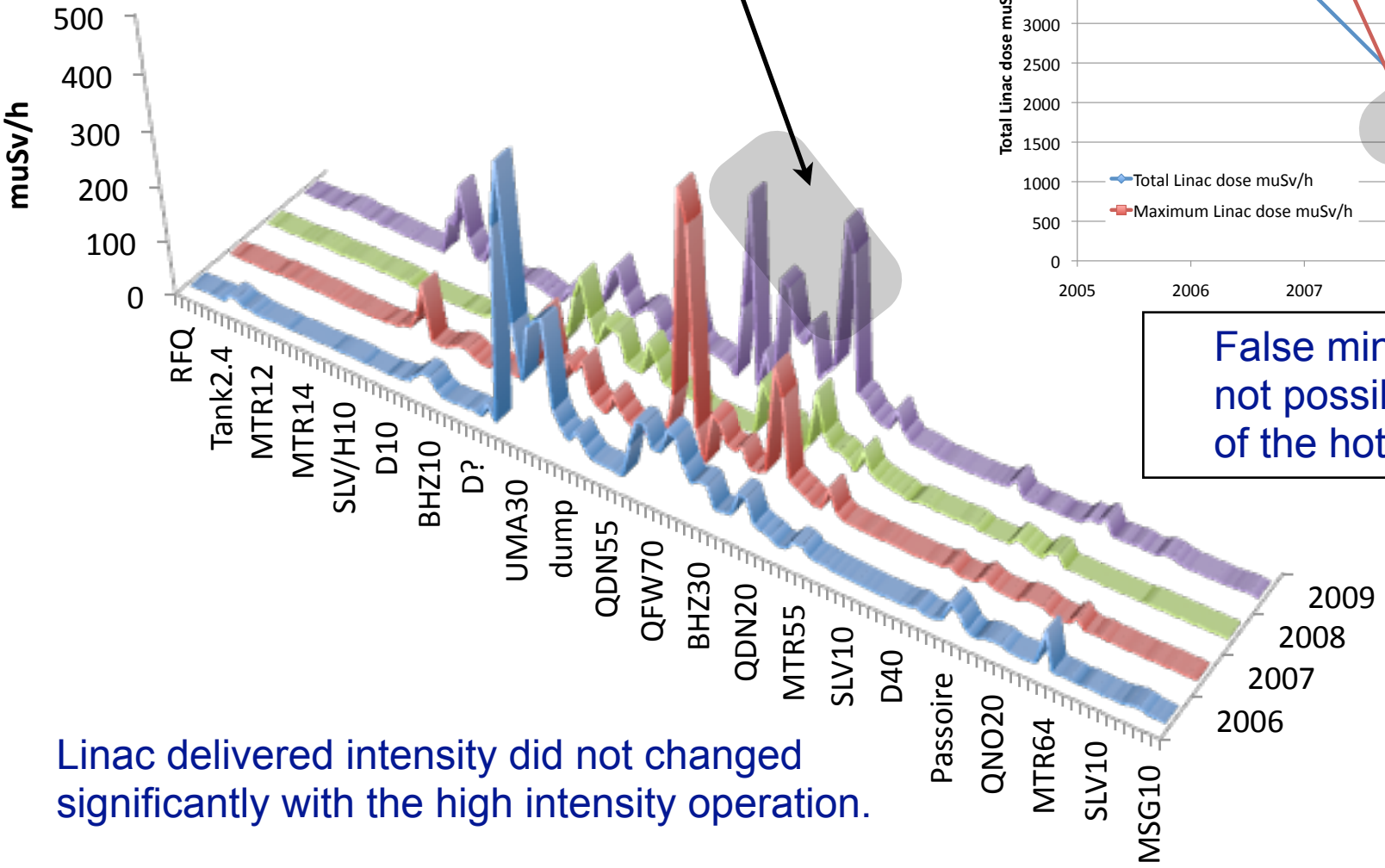
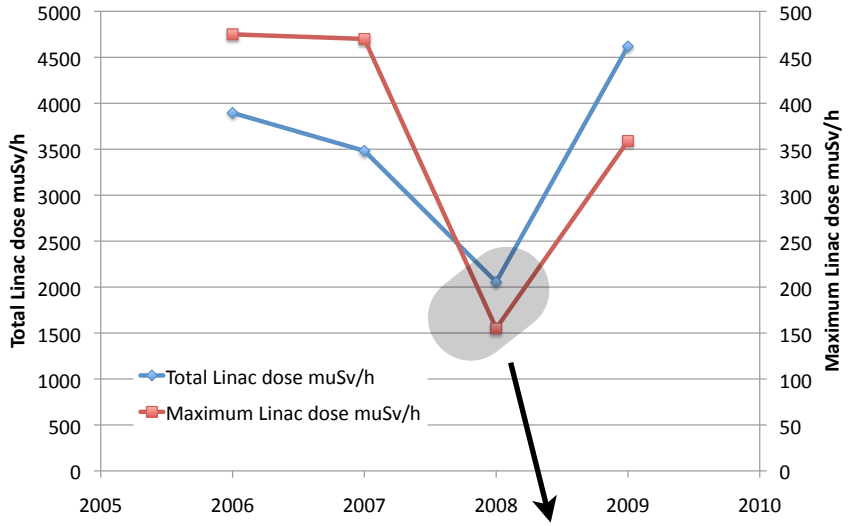
Data used to discuss the trends

- Goals of the presentation:
  - put together the data of the radiation surveys of different years for the injectors with the expected (measured) loss pattern to identify:
    - the trends for the machine irradiation vs losses or intensity
    - new hot spots not understood/expected or old hot spots that need to be studied to reduce the impact on the machines irradiation
    - propose an eventual solution (even not for the near future) and propose the next step
- Data:
  - BLMs and colleagues knowledge
  - Linac/PSB/PS radiation survey taken 32 hours after the machine stop at the end of the run and measured at 40 cm.
  - SPS radiation survey taken 30 hours after the machine stop at about 1 m. For the 2009 survey a new system to measure residual dose rate was implemented. This resulted in a better resolution of the measurement data.
- Anticipating the results:
  - I will concentrate a good fraction of the talk on the PS, since it is the source of the largest fraction of the concerns.

Trend of irradiation vs years in Linac2

Hot spot will be studied during the next run. Source not known yet.





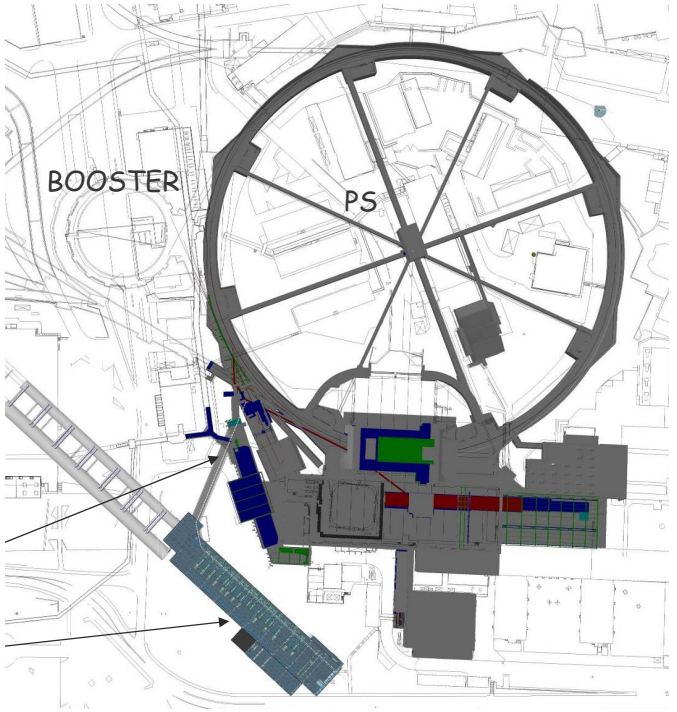
False minimum. In 2008 not possible to mesure one of the hot spot region.

Linac delivered intensity did not changed significantly with the high intensity operation.

ISOLDE shots were replaced by CNGS during the years.

A post-scriptum for the Linac2 run this year

- A lot of care has been put to reduce to the minimum the losses in the part of the Linac near the work site of the Linac4.

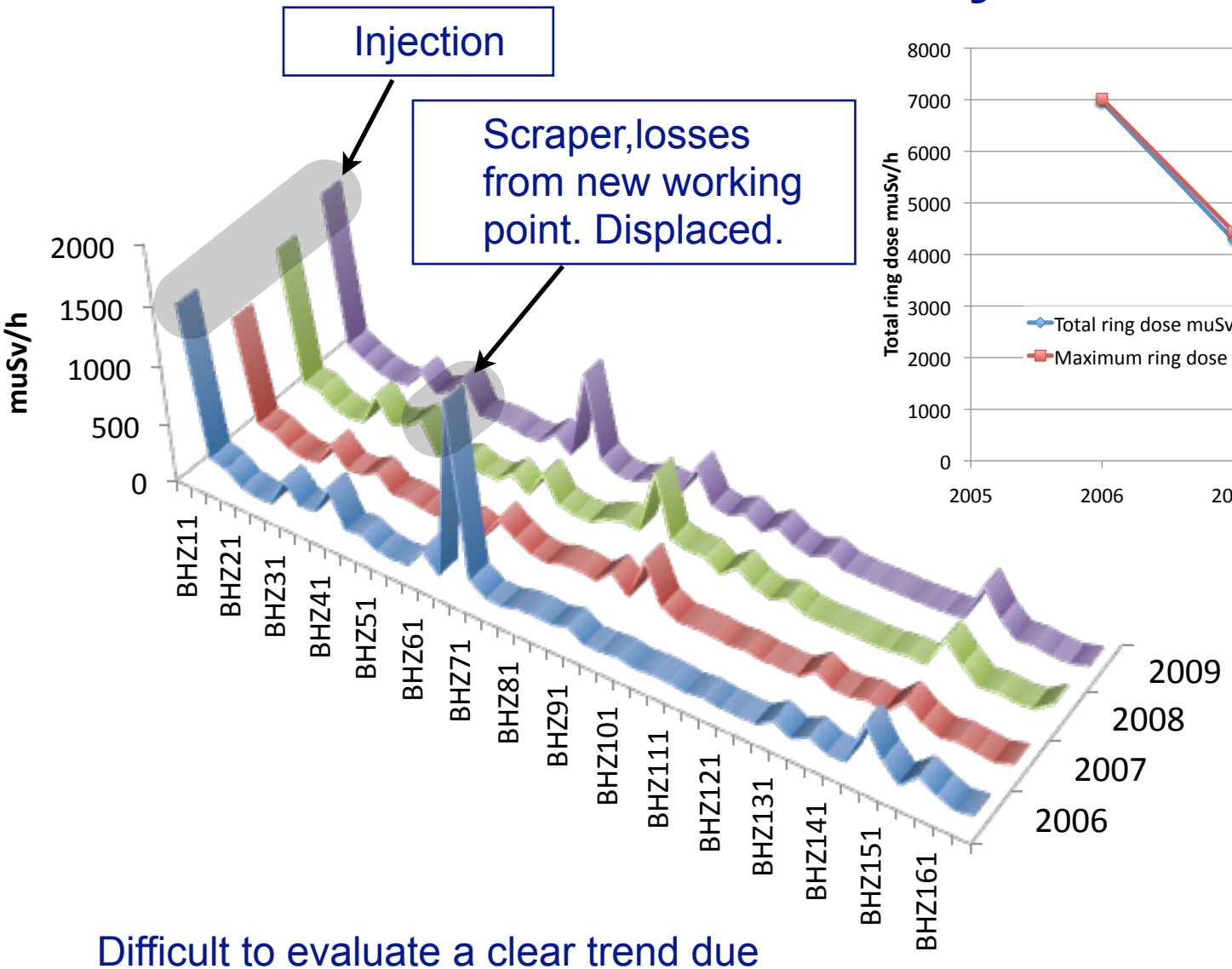


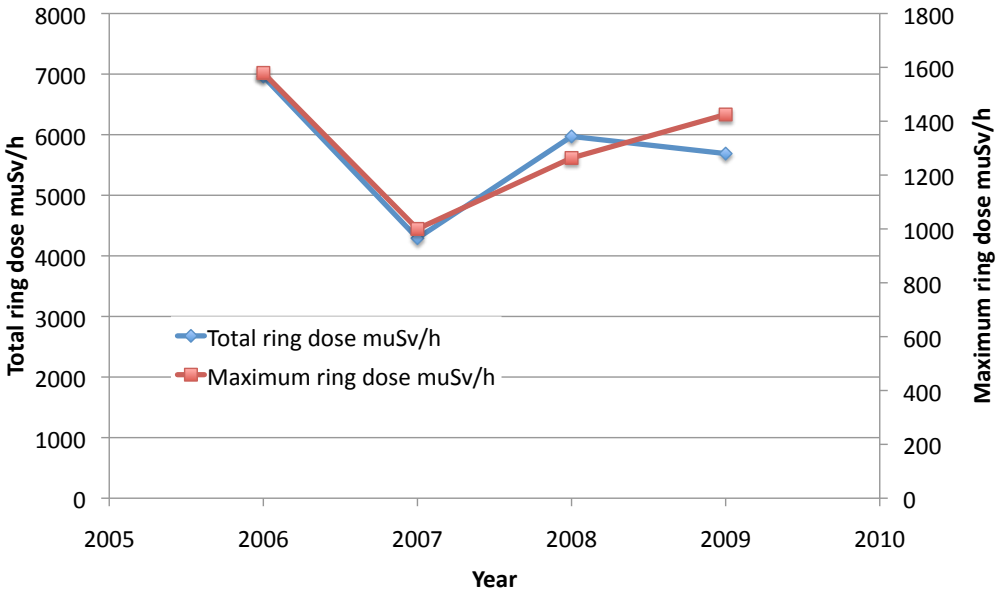
- During 2009, run with a radiation monitor interlocked to Linac2, at a level that will keep the Linac4 worksite with free access.

  With high intensity beams we will be closer to this interlock level this year.

- This interface of Linac2 to 4 will require more monitoring (radiation point of view), and possibly more evolution during the following years.

Trend of irradiation vs years in the PSB





Difficult to evaluate a clear trend due
to the mix operation of two high intensity beam types, i.e., ISOLDE and CNGS.

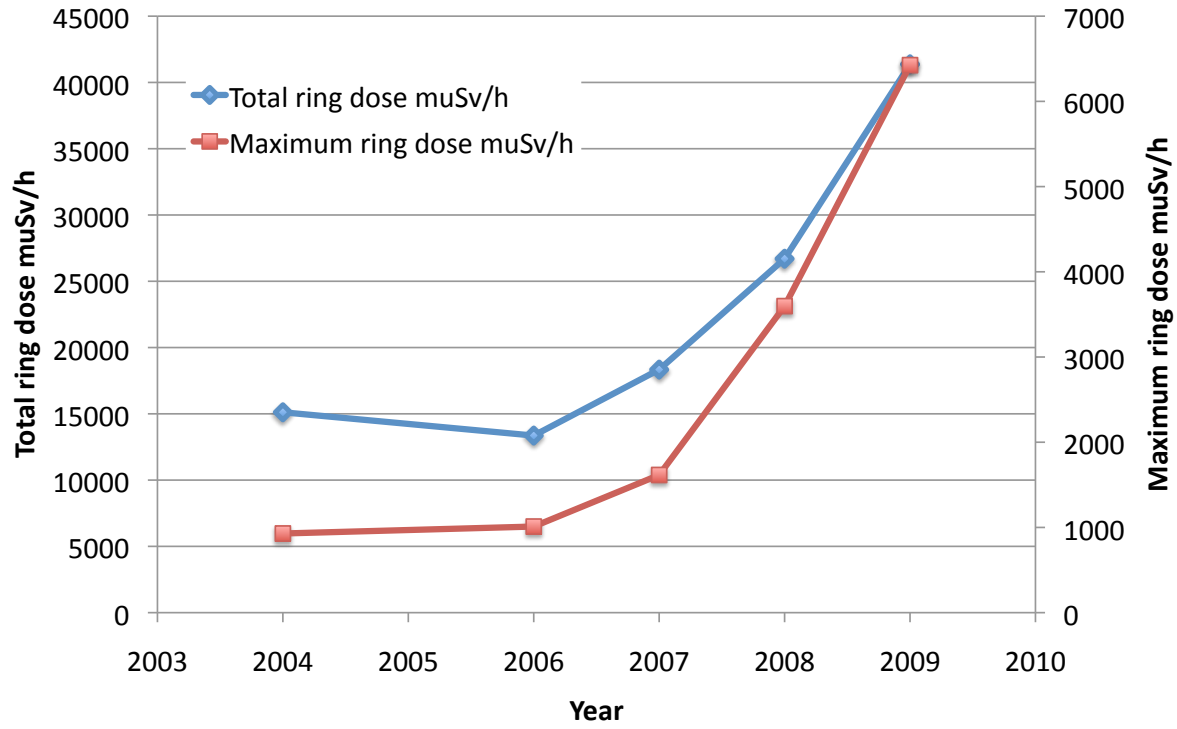
In 2007 and 2009, only moderate intensity requested by ISOLDE.

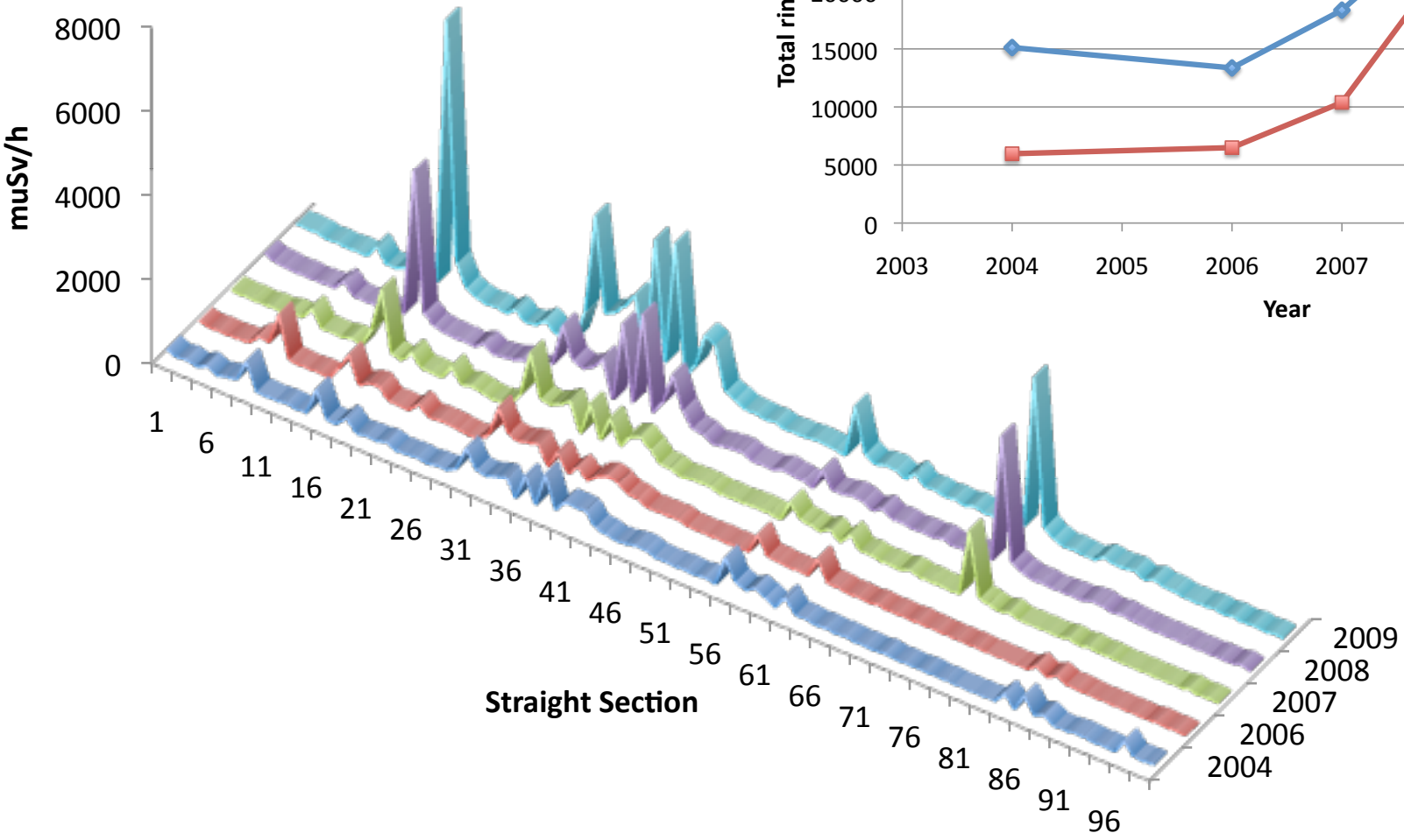
Trend of irradiation vs years in the PS

Net increase of the ring irradiation started in 2007, with the start of the CNGS.

2008 → 1.78e19 pot

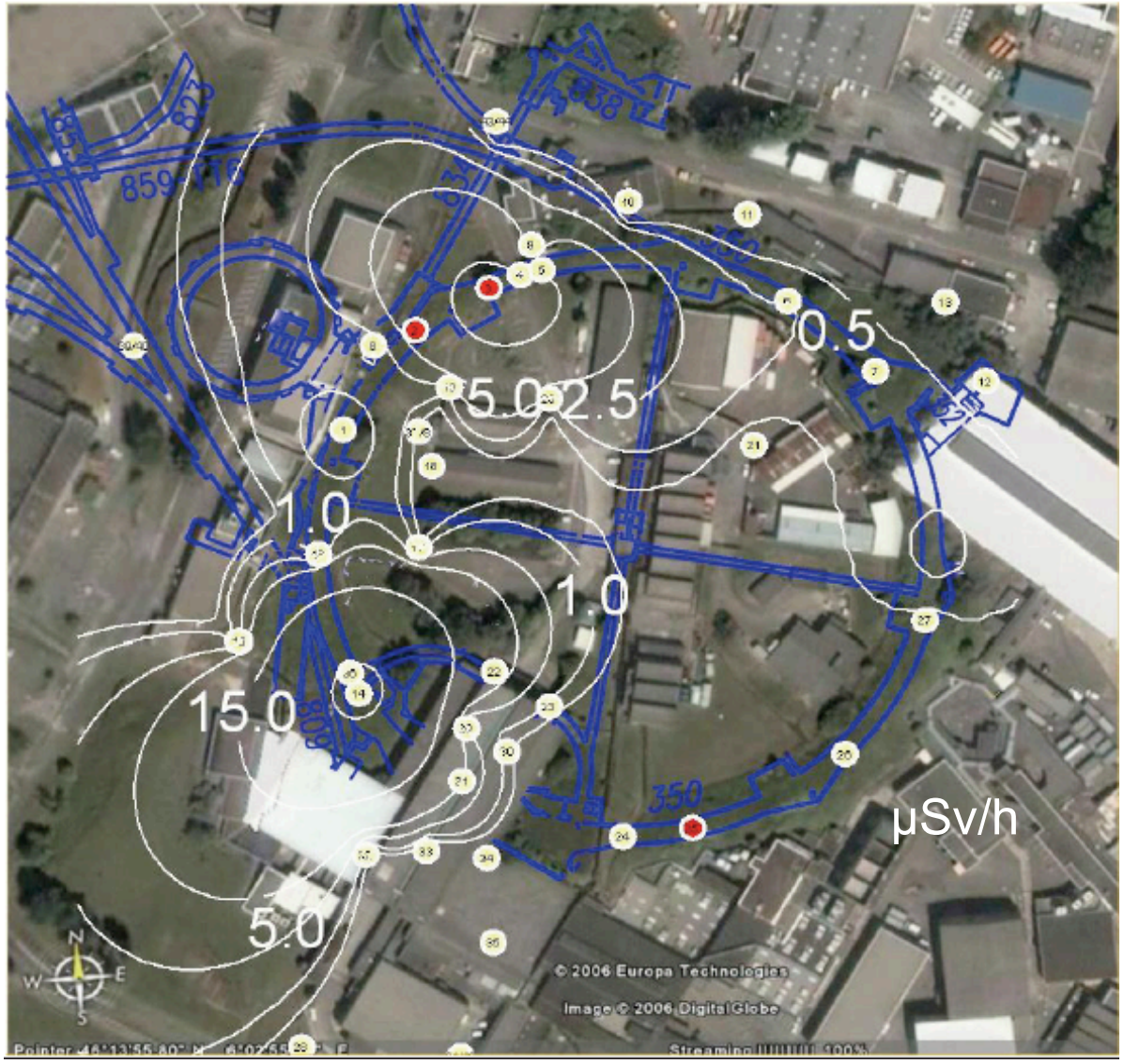
2009 → 3.5e19 pot





PS radiation survey overview outside the tunnel

Survey 2007 OUTSIDE the PS tunnel



2007 radiation survey outside the PS tunnel during CNGS operation at about 0.8 p/s.

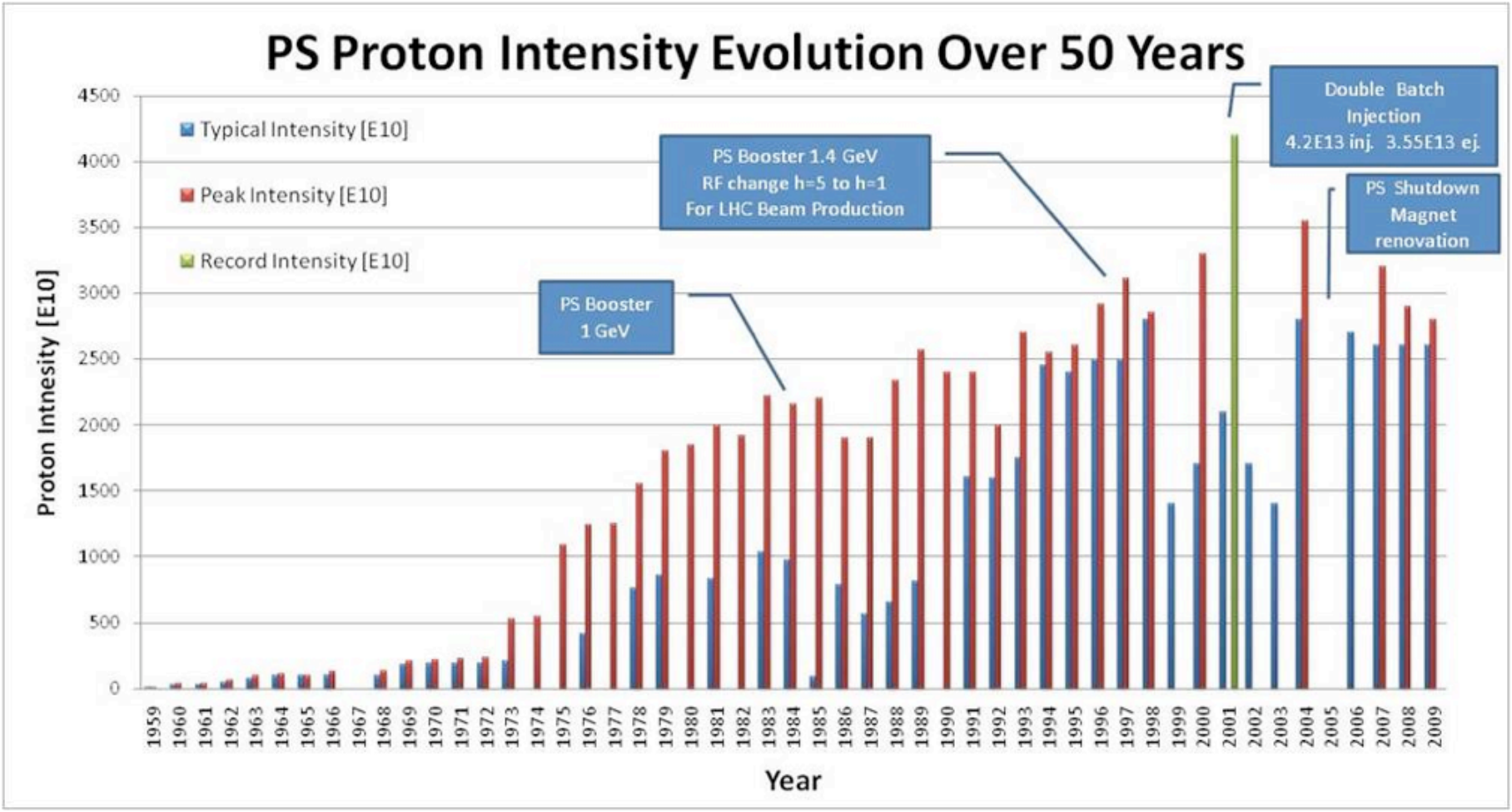
An increase of the dose inside the tunnel corresponds to an increase (not proportional) to the dose outside the tunnel.

Survey to be repeated once MTE will be operational (and probably also before) with full CNGS.

Image shall give an overview “at a glance” over the measured values at all points. Isodose curves are not valid in areas, where data was extrapolated and only of limited validity where interpolated due to inhomogeneities from shielding structures and a large radiation source.

M. Widorski

Increase dose distribution



Increase of machine irradiation is not produced by an increase of the maximum intensity but by the high repetition rate required by the CNGS operation.

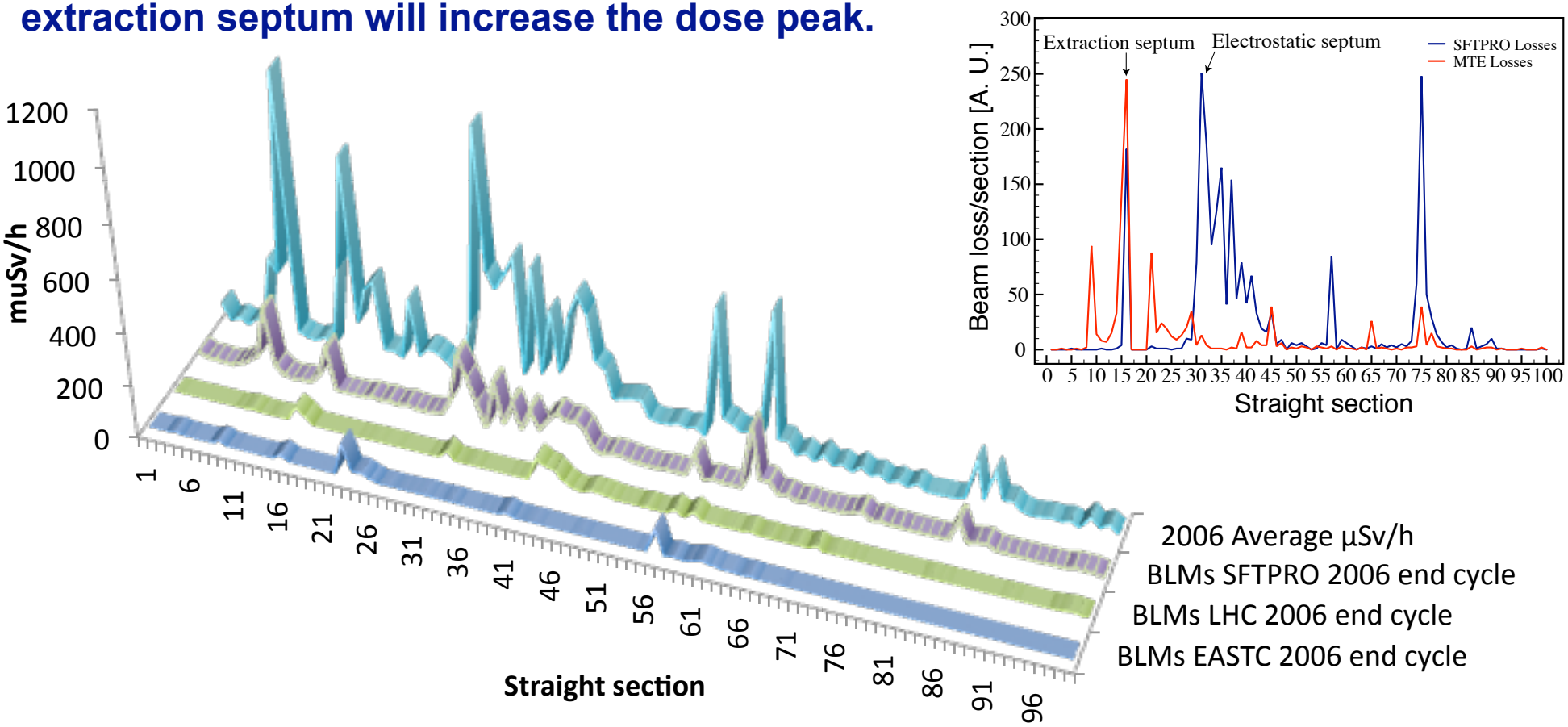
No new losses appeared between the years
→ losses reduced thanks to different optimisation

Dose vs loss distribution

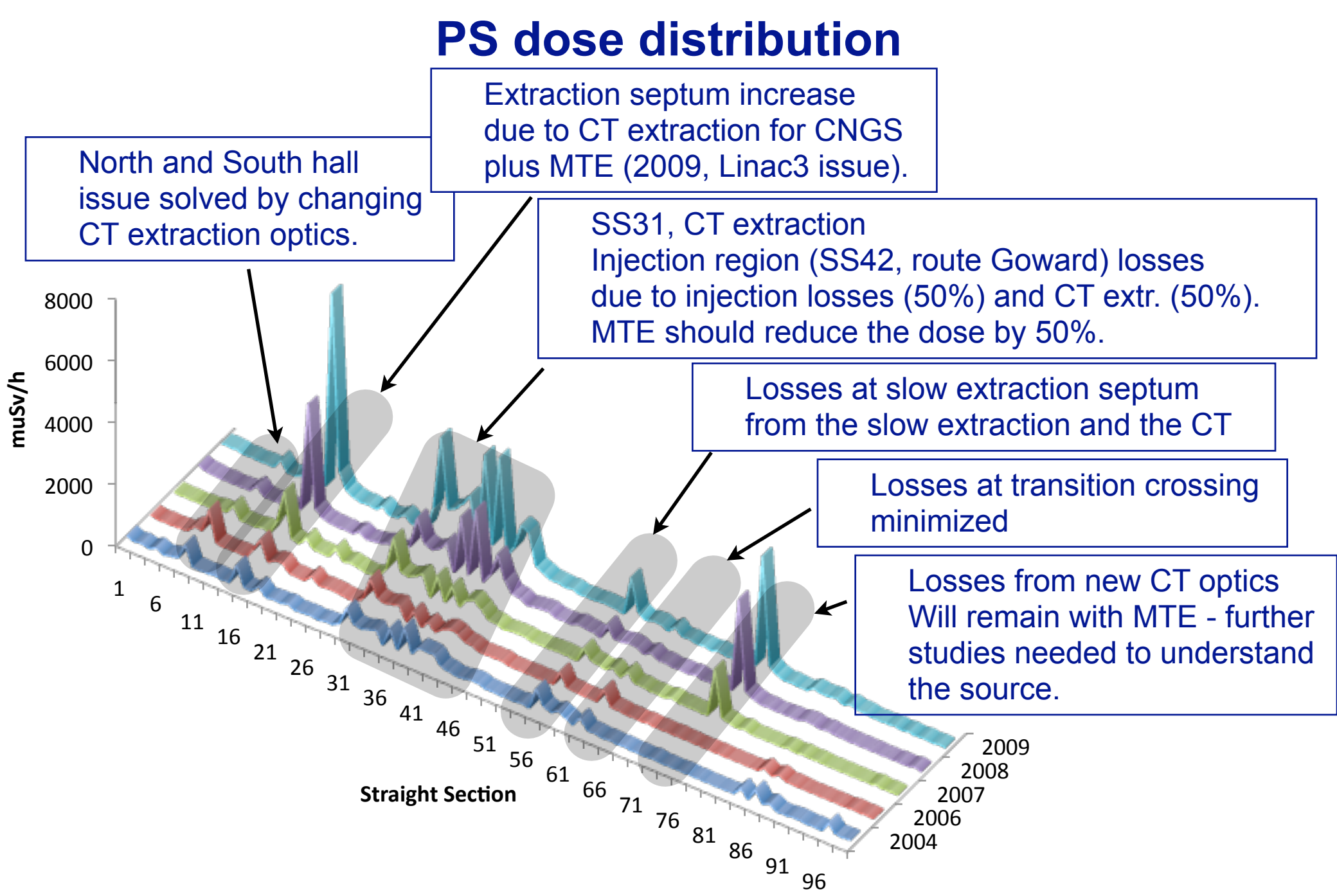
The largest contribution to the overall dose of the ring is produced at the extraction of the SFTPRO and the CNGS.

Extraction efficiency of the order of 10% for 2.4-2.6e13 protons

With MTE, the losses at the SS31 and in the injection should disappear. Integrated dose in the ring should be reduced, however losses concentrated on extraction septum will increase the dose peak.



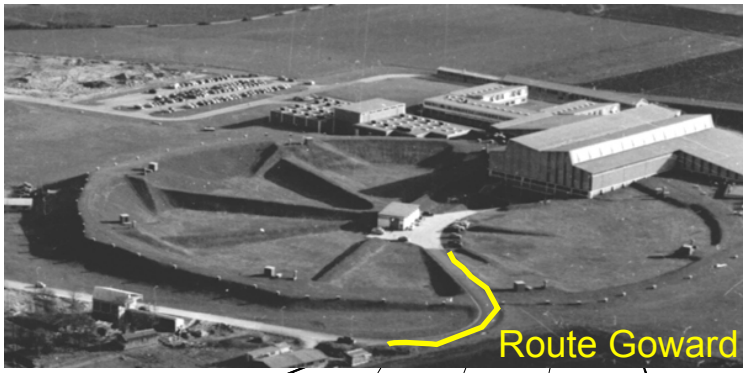
PS dose distribution



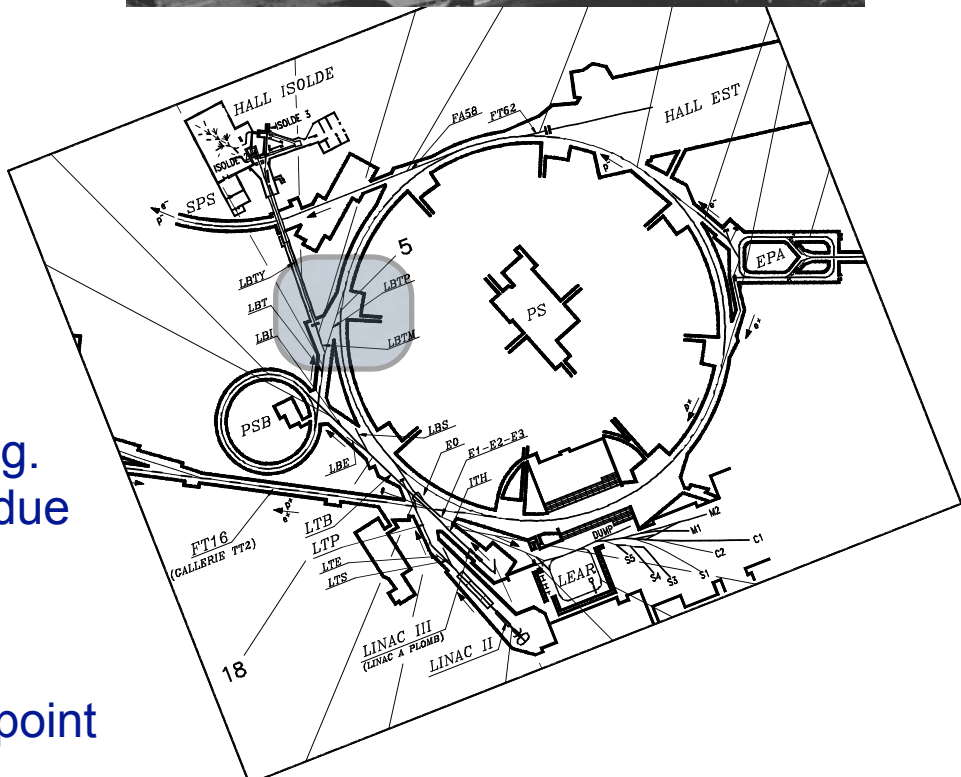
PS radiation issue of Route Goward

Situation not improved...15-10 μSv/h (allowed for a route → 2.5 μS/h)

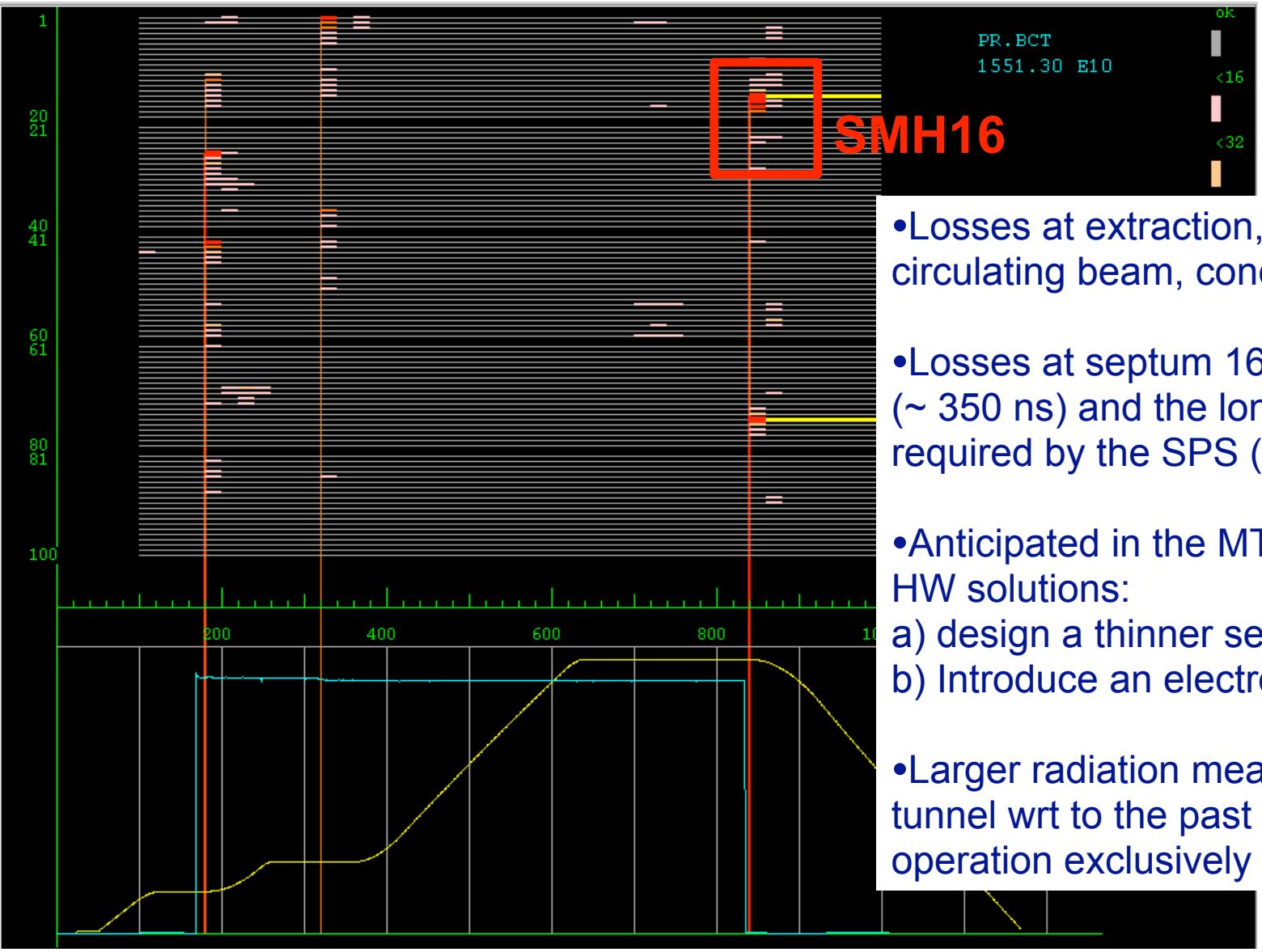
50% irradiation from CT extraction. ~ 0% with MTE
50% directly from beam injection



- Further injection optics study:
  - losses due to vertical restriction at injection. Would need a new septum with larger aperture.
  - slow losses, about 200 turns, to be understood. Instrumentation to study the losses available only since the middle of the run.
  - new optics computed and implemented but not enough time to evaluate the losses. Pb for the MDs due to lack of dedicated time and problem with beam instrumentation.
- Slow losses during the SFTPRO-CNGS bunch splitting at 3.5 GeV/c eliminated by keeping the radial loop enabled during the splitting. Before small losses but eventually very frequent due to the CNGS.
- Re-design of injection line ongoing trying to build a sort of insertion with small beta at the injection point



MTE losses at extraction



•Losses at extraction, about 2-3% of circulating beam, concentrated in 2 points.

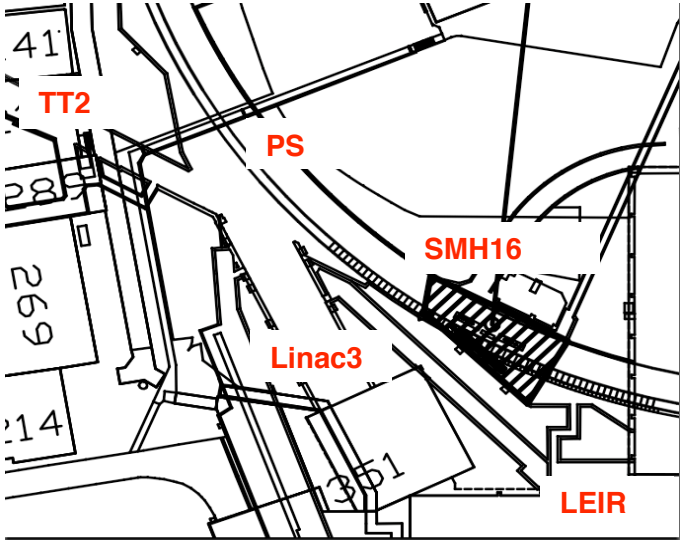
•Losses at septum 16 due to kicker rise time (~ 350 ns) and the longitudinal structure required by the SPS (de-bunched beam).

•Anticipated in the MTE Design Report.
HW solutions:
a) design a thinner septum
b) Introduce an electrostatic septum in SS11

•Larger radiation measured in the Linac3 tunnel wrt to the past even during the operation exclusively with the CT extraction.

Linac3 issue

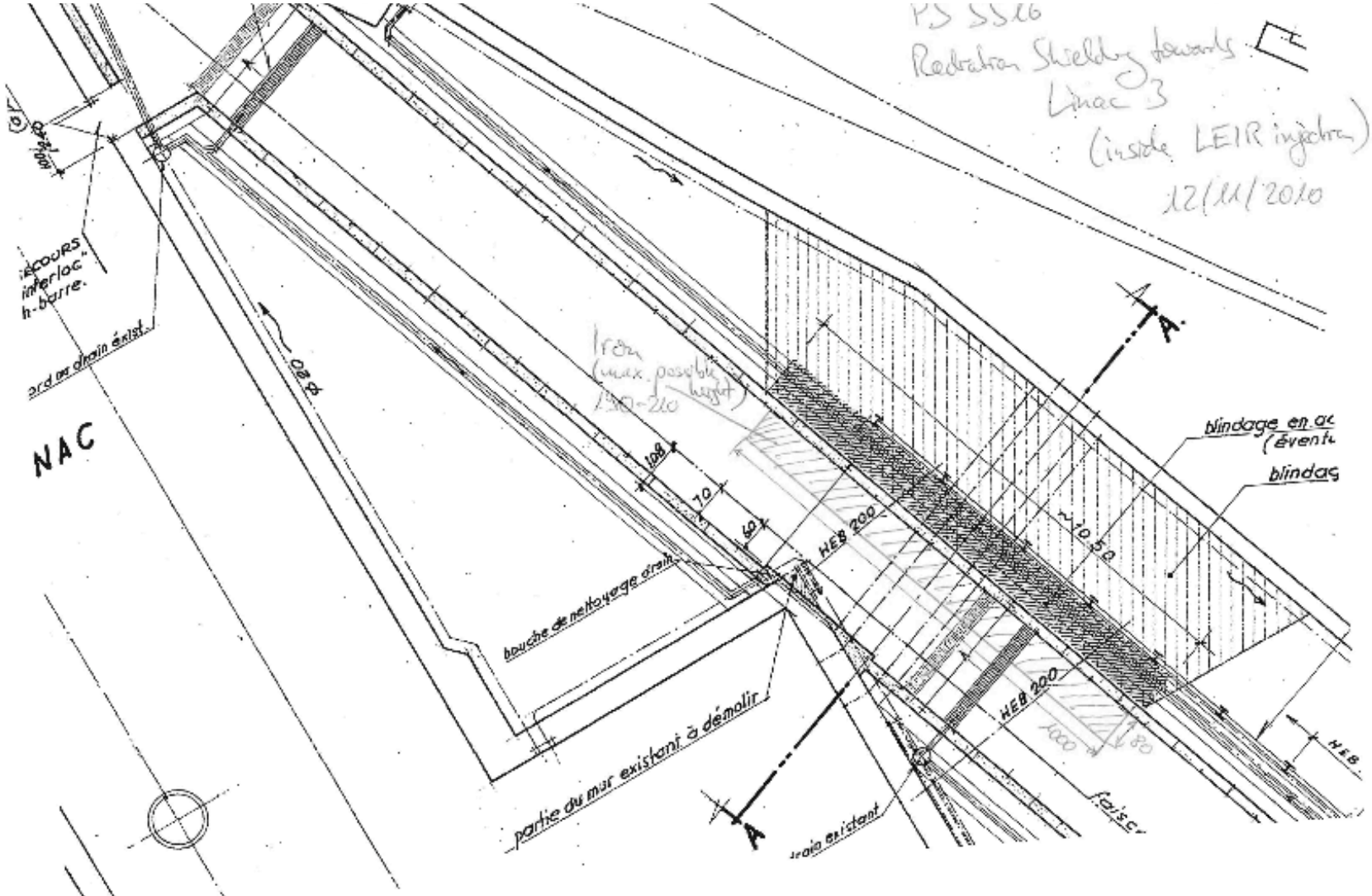
- Due to the (weak) existing shielding, the dose in the Linac3 tunnel increased during the CNGS run and the MTE commissioning
  - dose would exceed the current area classification during exclusively MTE operation with 0.85×10^{13} p/s (typical CNGS operation).
- This result is based on a series of measurements performed in November 2009.
- The dose will be about 13 μSv/h using MTE, whereas the limit is 10 μSv/h.
- With the CNGS based on the CT extraction it was measured about 4 μSv/h.



NB: access to the Linac3 is required for continuous tuning of the Lead source and in particular during the next run for the commissioning of the new source

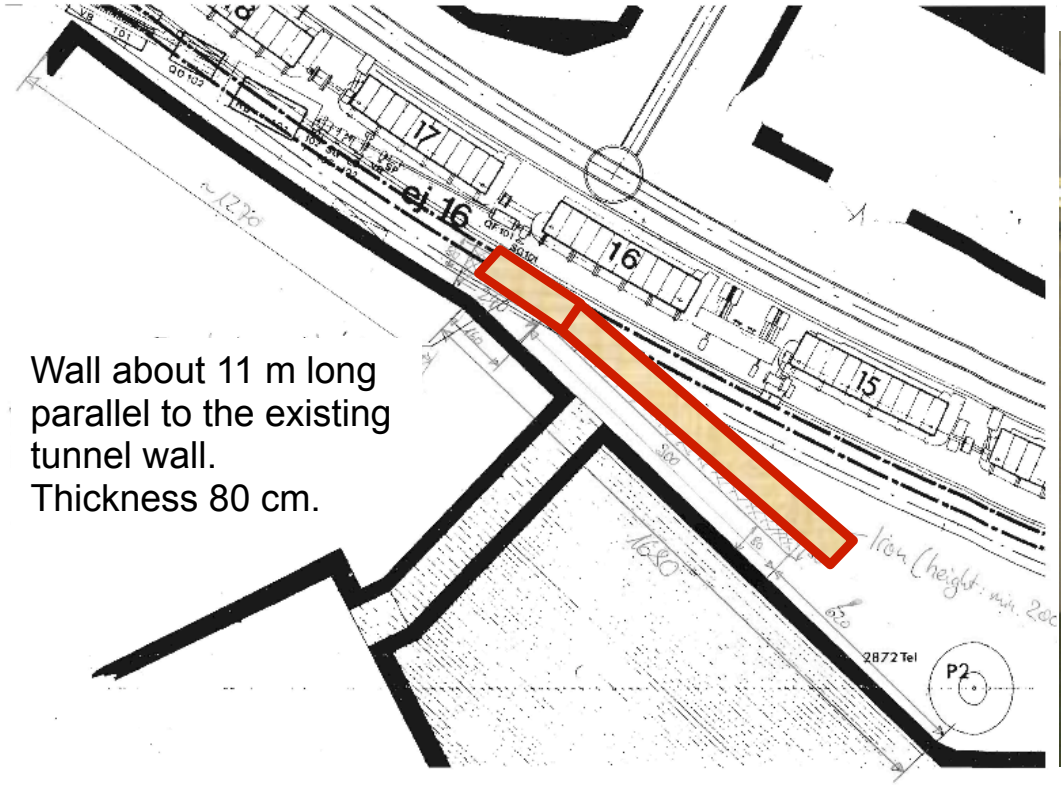
Shielding foreseen during LEAR construction

During LEAR construction, to accommodate injection/extraction line about 2 m of earth shielding removed. Reinforcement of remaining shielding proposed but not realised.



Installation of new shielding

- Install concrete wall shielding in the PS nearby the zone of the septum 16
  - Heavy charge on the floor (about 50 t): impact on structural stability verified.
  - No impact on repairing activities in the area (septum 16, QFO105).
  - High shielding efficiency, studied by FLUKA simulations.
    - Expected dose reduction > factor of 4-5. (desired factor of < 2).



Linac3 radiation issue summary

- Linac3 radiation levels turned out to increase due to the MTE losses concentrated at the septum 16. During CNGS operation with exclusively CT extraction larger doses than past years observed. The problem was generated by the choice of not consolidating the shielding between the PS and the LEAR injection/extraction line during the LEAR construction → a concrete wall has been installed as compensatory measure.

- In case the shielding would turn out to be not sufficient for reasons unknown at the moment, CNGS could be delivered during the day (work ongoing in Linac3) with CT extraction, and during the night with MTE.

- The installation of the wall should be considered as a temporary solution. The current run should be used to look for a better one, for example:

  - Revise the current installation of the Linac3 equipments (radiation mapping of the Linac3 area needed -> detailed measurements to be performed this year)

  - Install shielding on the Linac3 side (if possible)

  - Change the extraction septum (longer time scale)

  - … etc...

- Hopefully the use of MTE in normal operation should also bring a better extraction efficiency thanks to optimisation.

  - further study on the longitudinal structure will be done once MTE will be fully operational.

SPS

- The CNGS is the beam with the highest repetition rate.
  Optimised setting up with losses reduced to the minimum.
- Continuous check of eventual aperture restrictions.
- With MTE in operation in the, no changes are expected in the SPS.

CNGS Larger
Former teletext 111

User: CNGS1

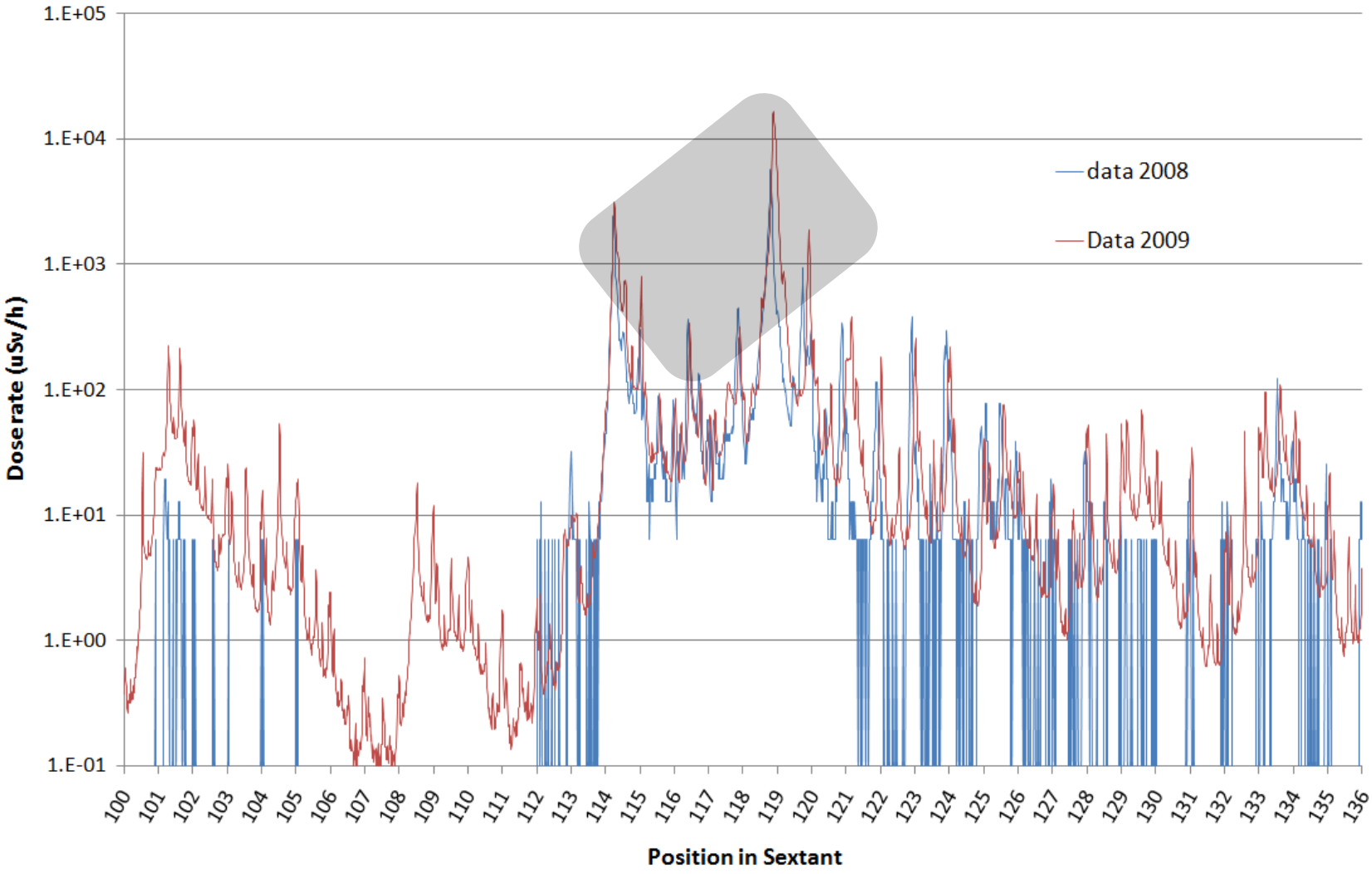
28-Aug-2009 09:35:07
Last update: 3 secs ago

TT2	TT10	%LOSS	INJ	%LOSS
2319	2298	0.9	2122	7.6
2339	2320	0.8	2216	4.5

	I/E10	%LOSS	%TRNS	TIME/ms
INJECT	4338	6.1	94	1210
END FB	4300	0.9	99	1260
20 GeV/c	4255	1.0	98	1470
27 GeV/c	4200	1.3	97	1530
50 GeV/c	4173	0.6	96	1740
400 GeV/c	4146	0.6	96	4200

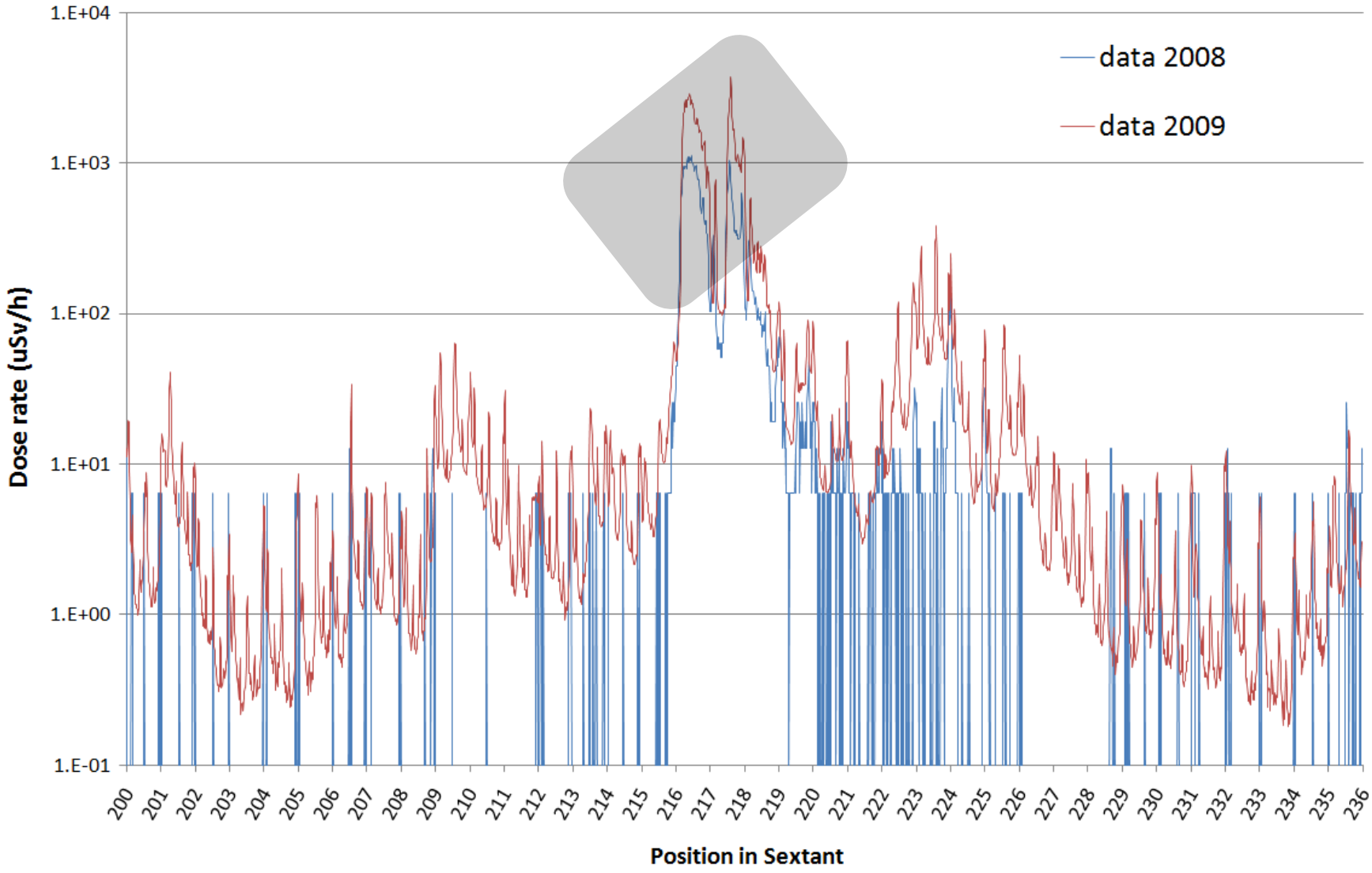
LOSS @ FB: 0.9%

Survey SPS-Sextant 1



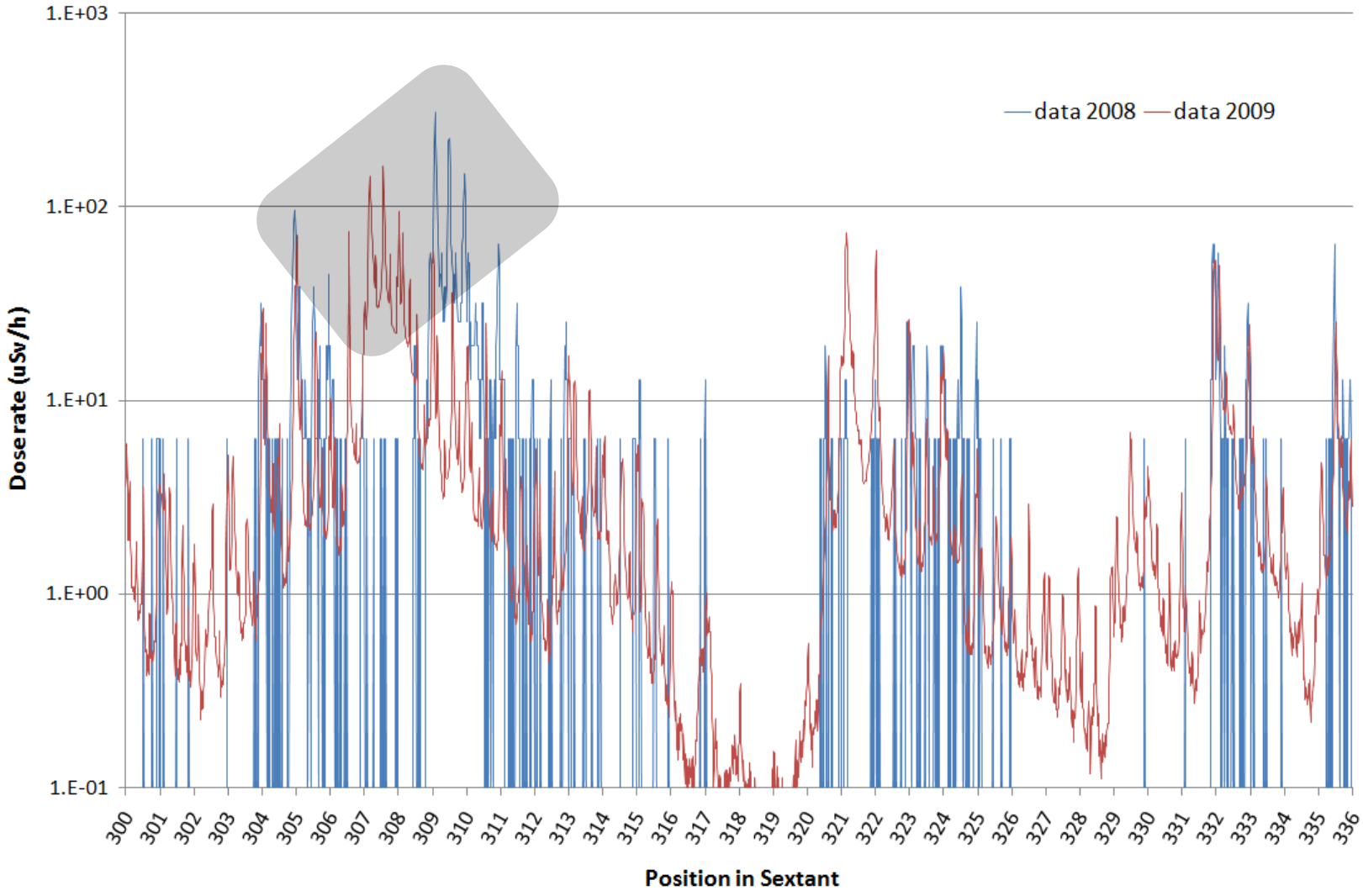
Higher peak at high-energy dump → higher intensities in 2009

Survey SPS-Sextant 2



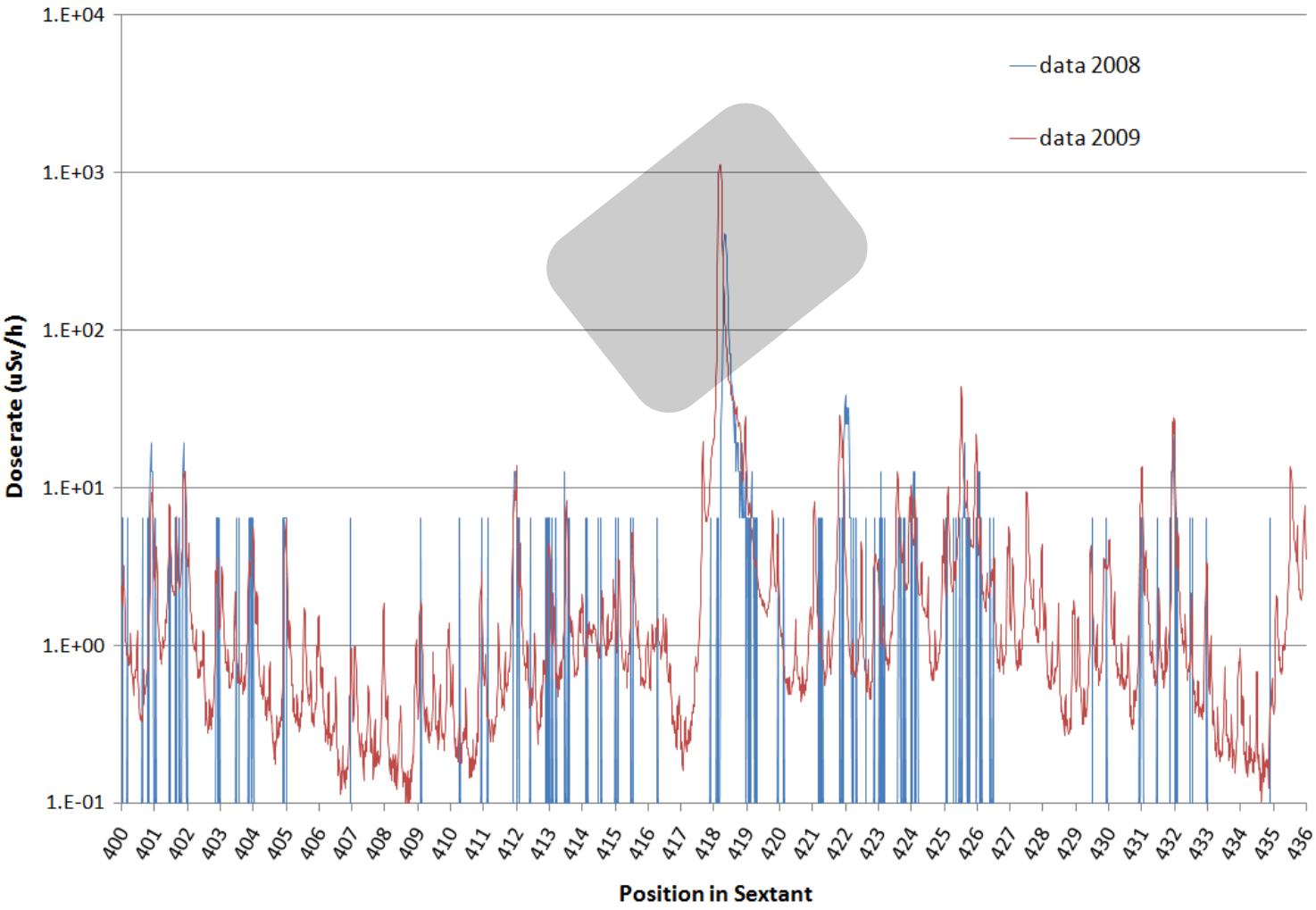
Higher peak at extraction to North Area → COMPASS received higher intensities than in 2008

Survey SPS-Sextant 3



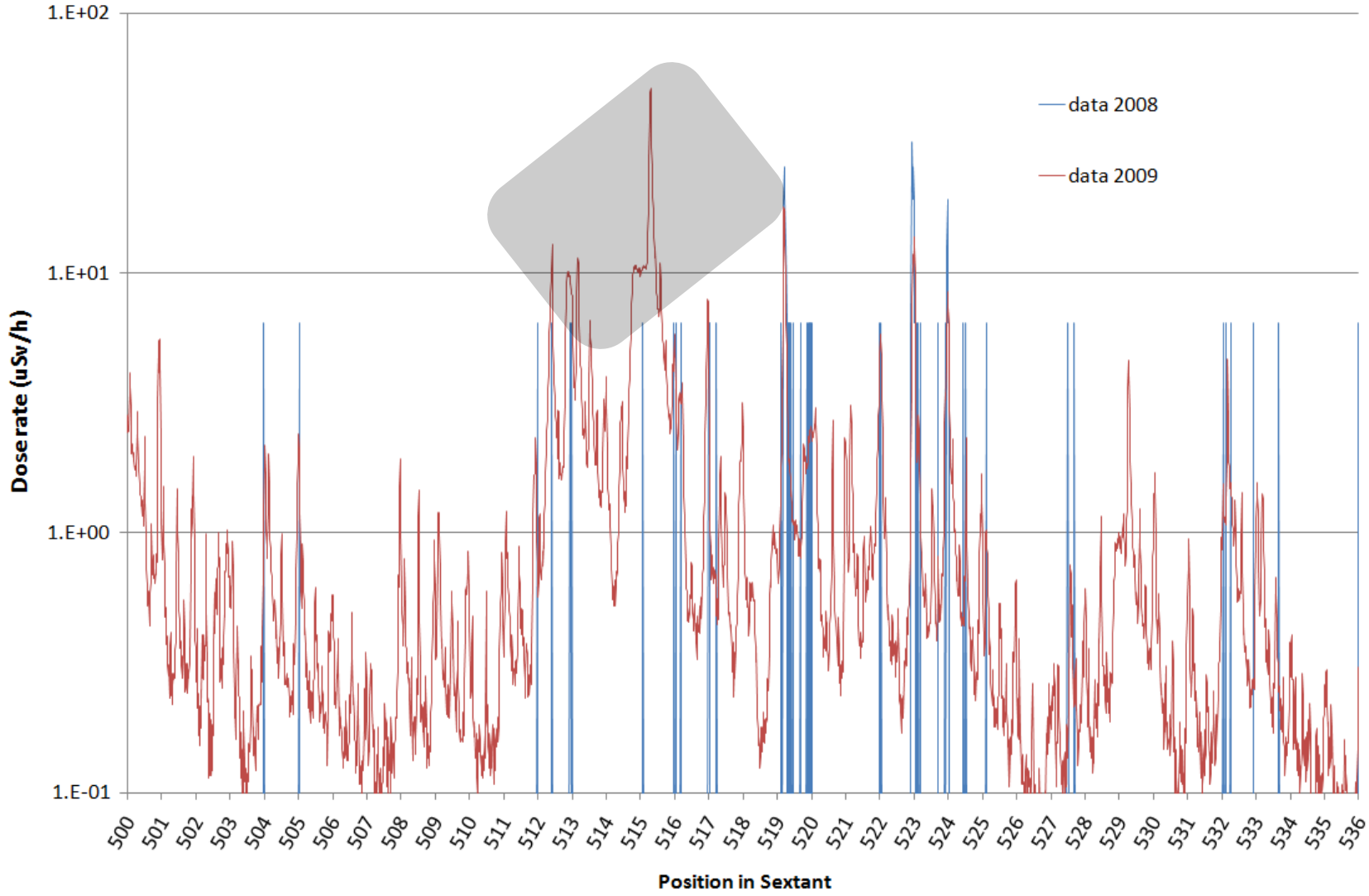
Losses in BA3 are shifted in comparison to 2008 → considered as normal

Survey SPS-Sextant 4



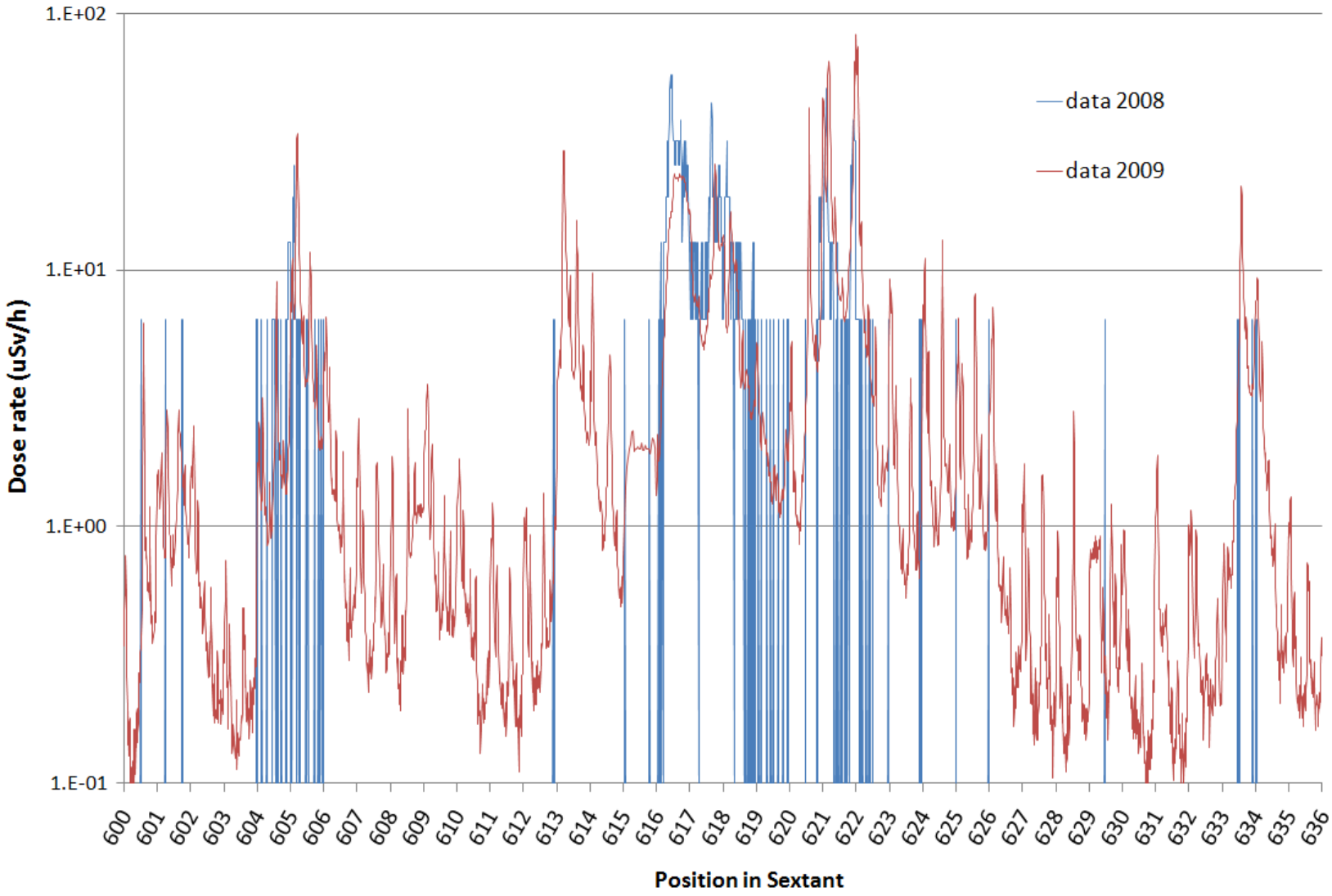
Higher peak at CNGS/LHC beam extraction area
→ higher CNGS integrated intensity in 2009

Survey SPS-Sextant 5



New peak around position 515 → UA9 collimator experiments in 2009

Survey SPS-Sextant 6

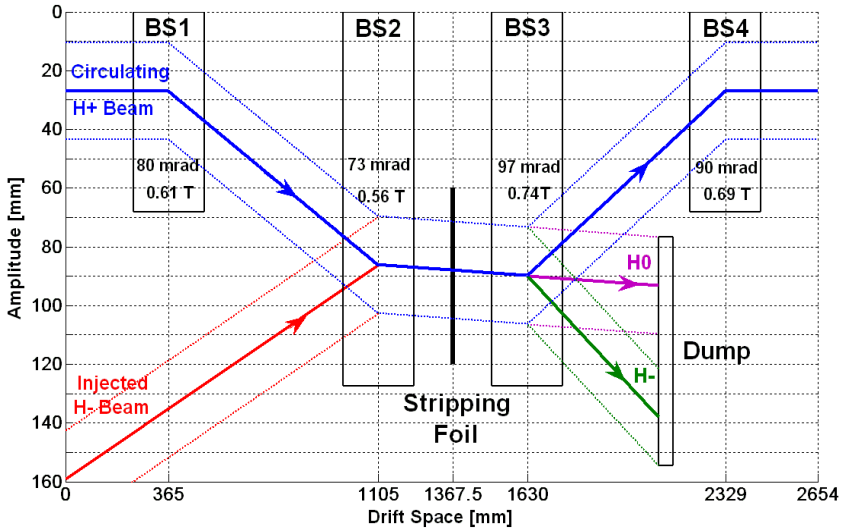


The Experimental area

- nTOF
  - alignement of the FTN line
  - problem encountered with the air irradiation solved by a better sealing of the tunnel
- EAST area
  - no particular problem, talk of L. Gatignon for the upgrade of the area
- CNGS
  - doses in the zone as expected
  - after the increase of the shielding and the re-arranging of the electronic racks, no more problems
  - Tritium issue not discussed here.
- NA
  - no particular problem in the area

For the future: Linac4-PSB transfer

- Less losses from H^- injection expected compared to the current proton injection
  - losses however will be at higher energy
- Impact on machine activation should be studied/estimated
- Possible collimation system in the ring should be studied:
  - Losses expected at injection plus during the first part of the acceleration (transverse blow up due to direct space charge + uncaptured beam)
  - Less losses but at higher energy (160 MeV compared to 50 MeV)
- New internal dump for unstripped H^- in a region already quite hot today
  - activation should reduce thanks to better injection efficiency
- Current status:
  - Lack of resources. One Phd student in ABP will start soon a first investigation.



For the future:PSB-PS transfer

- Losses at PS injection (route Goward) due to different reasons (see before):
  - redesign of the existing injection, either to move the losses in another place or to reduce them, by changing the injection optics → work ongoing.
  - increase the shielding of the injection area, inside or outside the ring. TS/CE, on request of the BLRWG, commissioned a study to an external consultant to verify the possibility of adding extra shielding on top of the existing tunnel. The outcome was that the tunnel has to be reinforced to increase the shielding.
  - the proposed upgrade of the extraction energy to 2 GeV should help but not in the near future. Reduction of the physical beam size should help. Losses however will be at higher energy.
  - in case of injection energy upgrade to 2 GeV, study should be done to see if possible to move the PS injection region to a better shielded zone (move it by one or two SS).
  - with Linac4, probably more intensity transfer per shot. Some margin has to be found.

For the future: PS-SPS transfer

- Losses in the PS from the CT extraction (short term)
  - replacement by MTE should reduce considerably the losses
- Identify the next source of problems
  - repeat the radiation survey outside the tunnel
  - new survey system (RAMSES)
- Losses with MTE extraction in the PS (long term)
  - reduce the thickness of the septum extraction blade
  - further study of the longitudinal structure at extraction, which require new HW
    - barrier bucket to create a gap in the spill
    - bunched extraction with new synchronization at low voltage
    - new RF system in the SPS (in the view of the SPS) to capture a bunched beam
  - reduce the rise time of the extraction kickers
- Losses in the SPS at injection for fixed target physics (very long term)
  - increase the PS extraction energy above transition but keeping the cycle length to 1 bp
    - new PS kickers
    - POPS in operation, higher dB/dt→ risk for the PS magnets lamination stability to be studied

What can be done in general

- Understand if the high repetition rate of the machines required by the CGNS increases the exceptional losses due to an increase of equipment faults.
- Continue the alignement campaign/check in the different machines:
  - optimise the mechanical aperture necessary for the high intensity beams
  - facilitate the setting up of the beams, less time required → losses for a shorter time
- Improve the loss detection capability
  - renovate the BLM system of the PS and PSB
  - add BLMs to the FTA and FTN line
- Improve even more the beam instrumentation
  - Doubts about cross calibration between beam transformer make difficult to evaluate the beam transfer efficiency.
- Improve even more (if possible) the reaction time of the control system, in particular for the PS and the PSB
- Understand if it is still possible to reduce even more the losses in the machines and what is the “dose budget” for the machine operation.
  - machines already operating on the basis of the minimum achievable losses for a given operation.

Conclusions

- The trend of the machine irradiation shows an increase of the irradiation in the PS and in the SPS, due to the high intensity beams (CNGS in particular).
  - Linac2 and PSB normal situation
- The PS is the machine that gives the more concerns in term of integrated dose (for the current losses)
  - MTE should decrease the extraction losses, i.e., the total dose received by the ring
  - Studies on the injection showed that the losses are quite optimised. The route Goward issue is more related to a lack of shielding.
  - The Linac3 irradiation problem should have been solved by the installation of a concrete wall near the septum 16.
- We are not yet at the limit by which we cannot intervene on an equipment in case of failure however, optimisation should continue to avoid reaching this limit.
  - should put targets for integrated intensity for every user, but may be also targets for transmission efficiencies.