Radiation Issues of the PS and SPS Accelerator Complex

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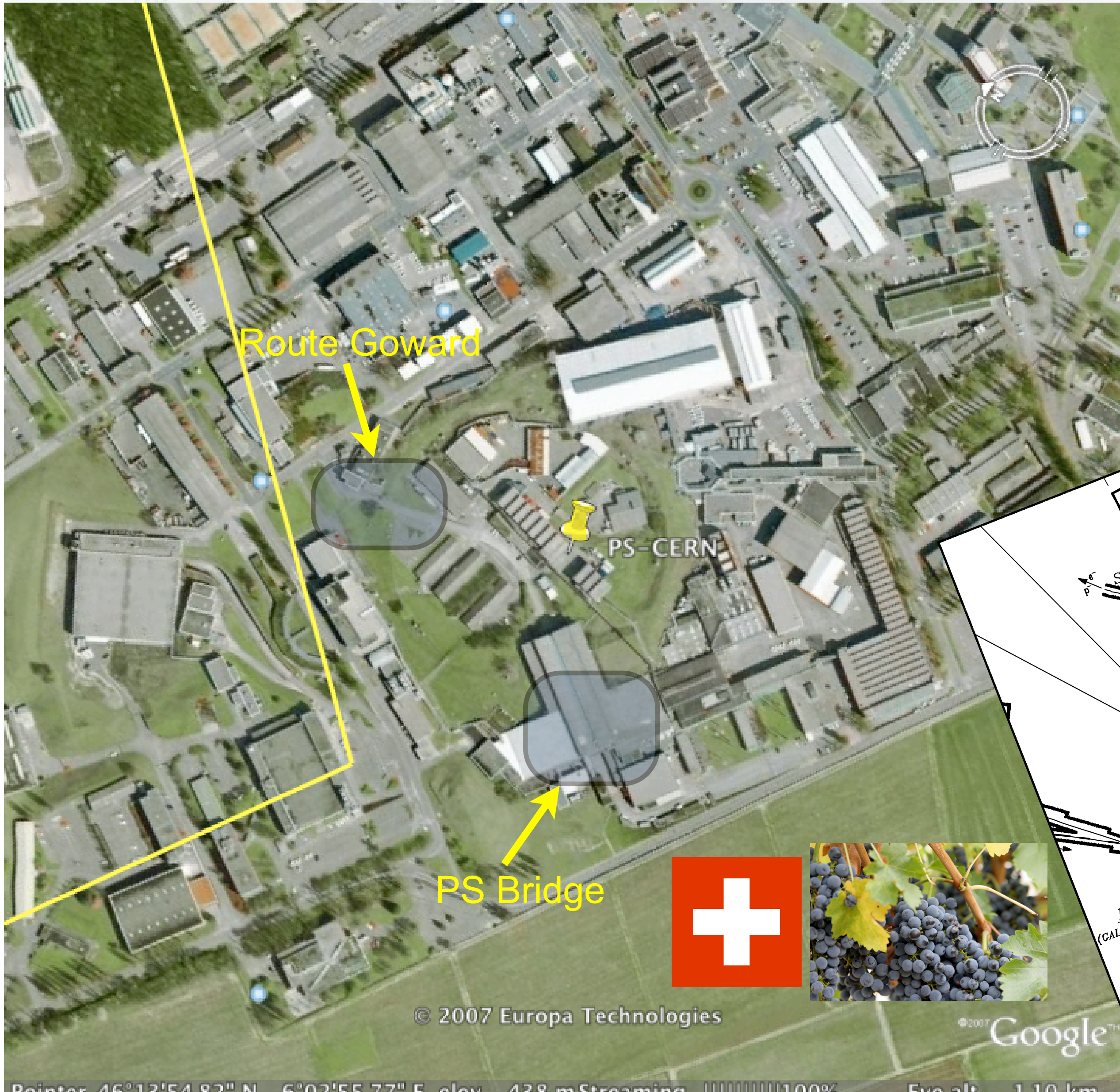
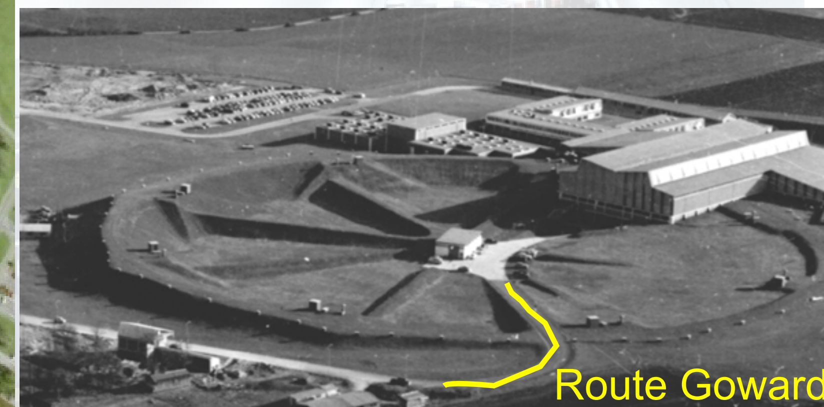
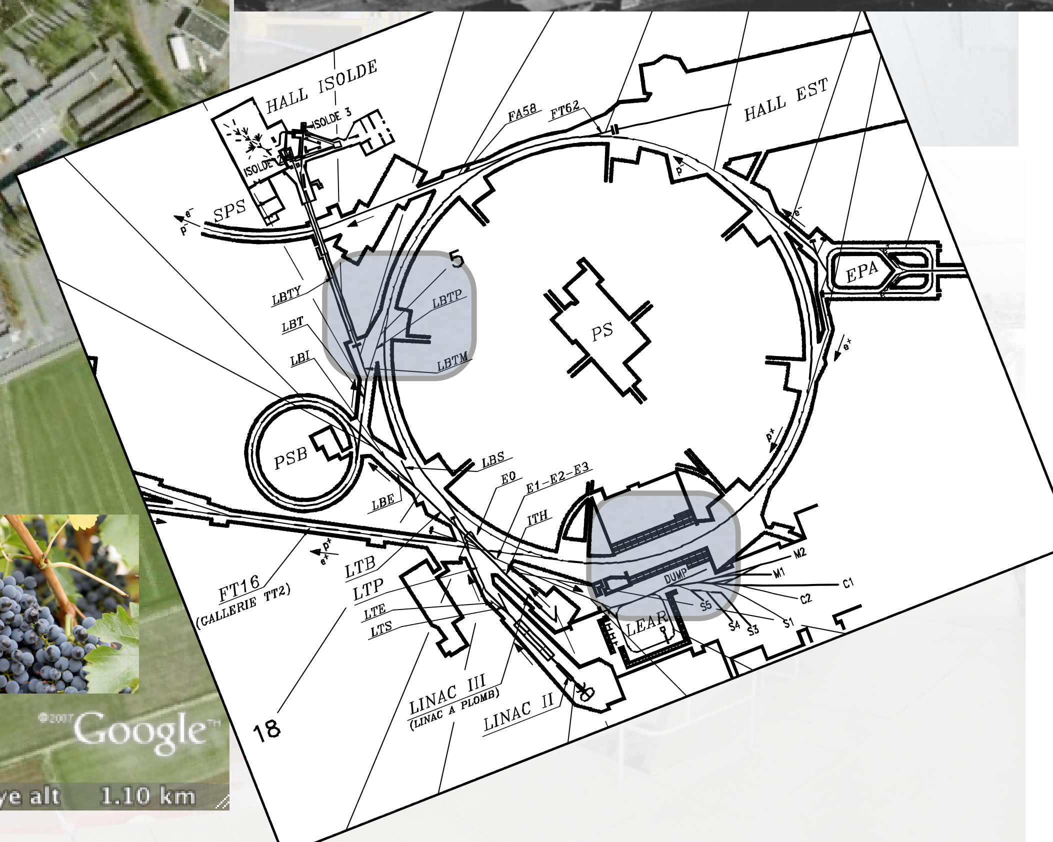
Thanks to AB/OP for the help/support
during machine running

PS radiation issue

Tunnel built at ground level, not enough shielding in some locations ....

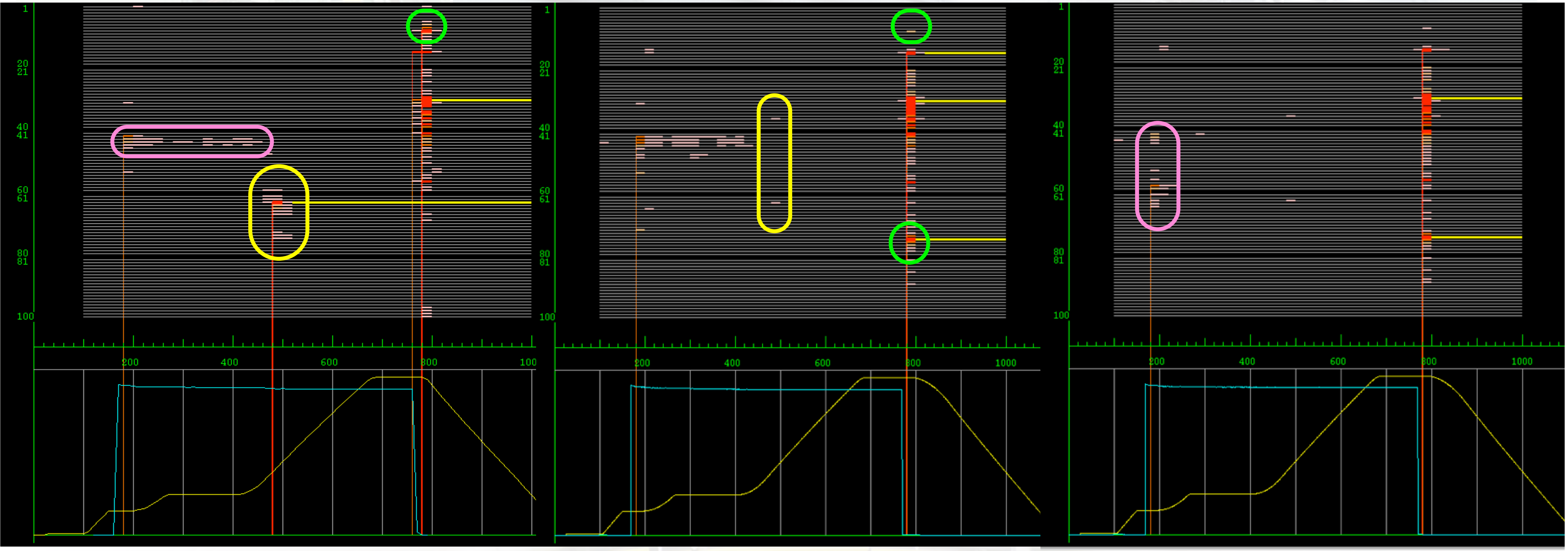






Injection & transition losses common to all beams, SFTPRO/CNGS CT extraction losses

End 2006 → Mid 2007 → End 2007



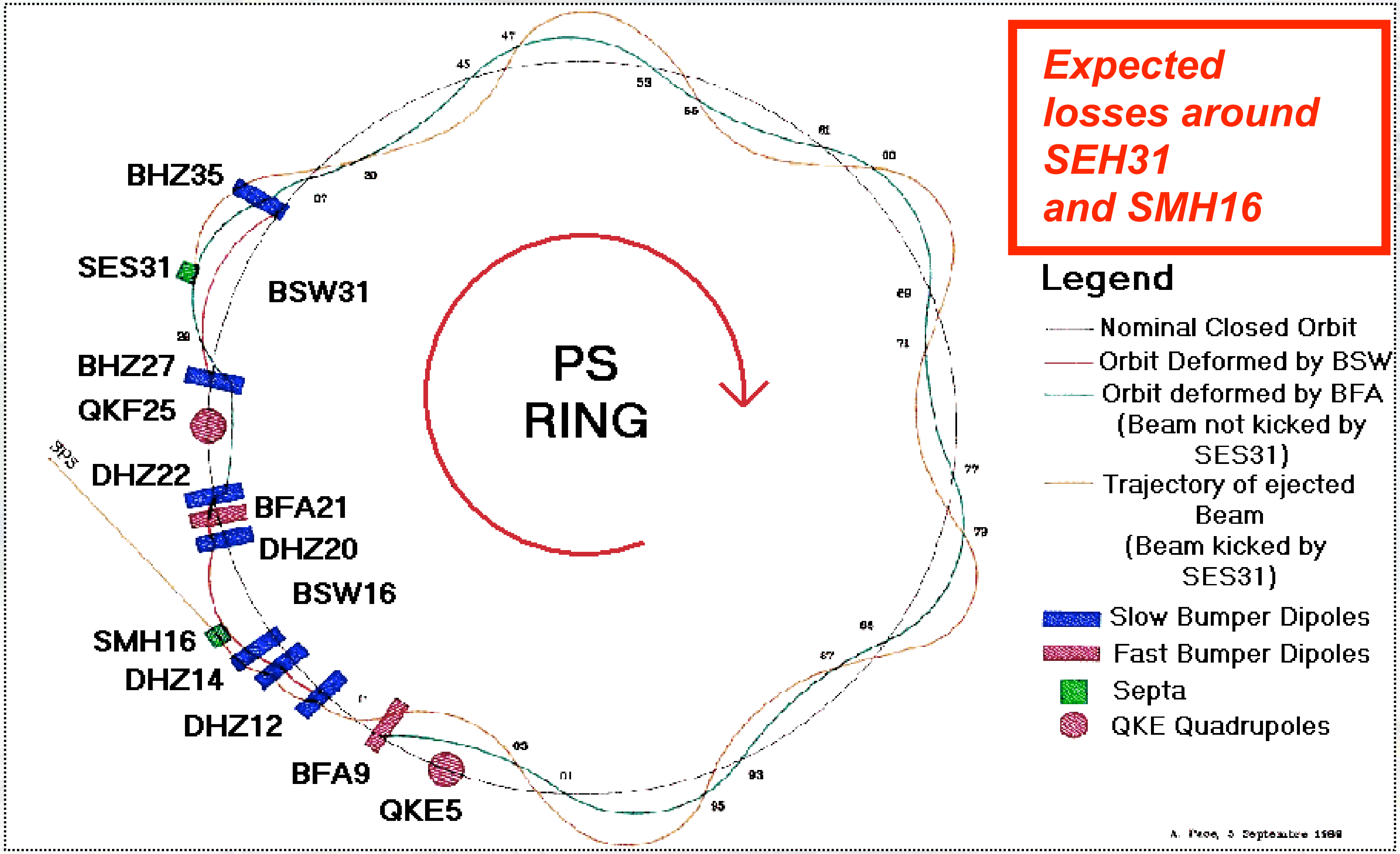
Goal of the study of ’07 at the PS (in order of impact on site irradiation):

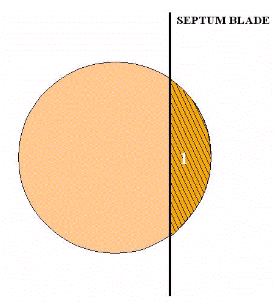
A) implement and evaluate the displacement of the losses during CT extraction (PS-BRIDGE radiation main limitation for CNGS operation)

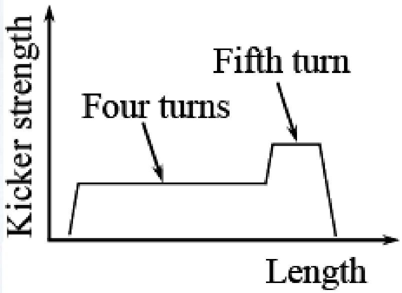
B) understand and reduce the losses in the injection region, namely under Goward Road

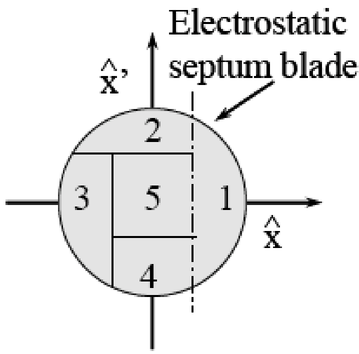
C) better understand and correct transition losses

Element used for CT extraction



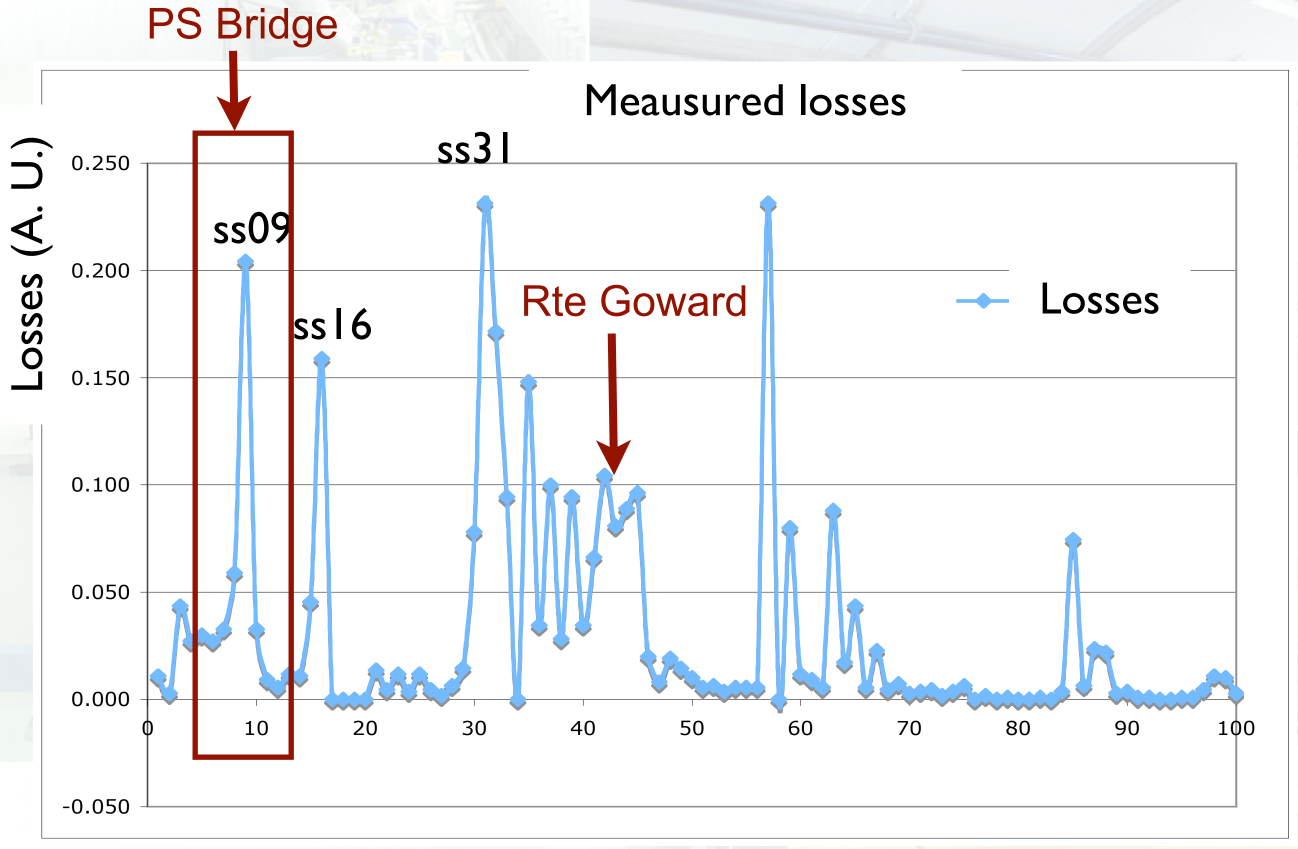


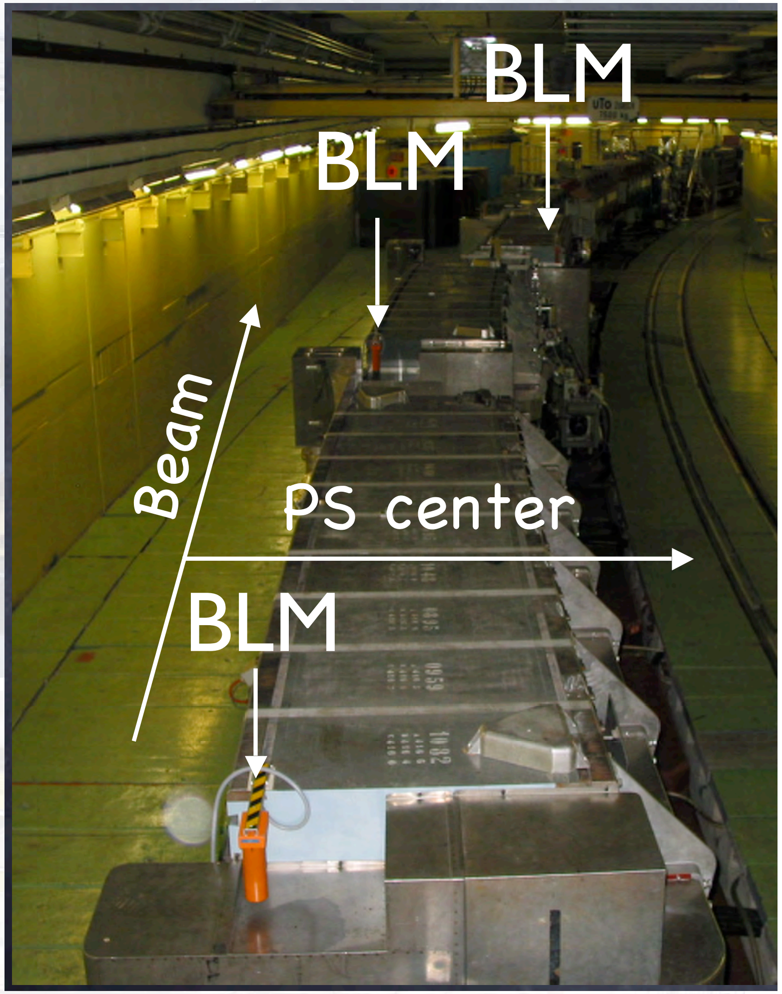




Bump31 (BSW31) to send the beam near the septum 31, about 2 m long
BFA9-BFA21 fast kickers (5 turns) to send the beam above the septum 31
Septum31 (SEH31) to slice the beam during the 5 turns
QKE16(5-25) to increase the beta and reduce the dispersion to zero at the SEH31
Bump16 (BSW16) to send the beam to SPS
Septum16 (SMH16) extraction septum

Observed loss pattern before run '07

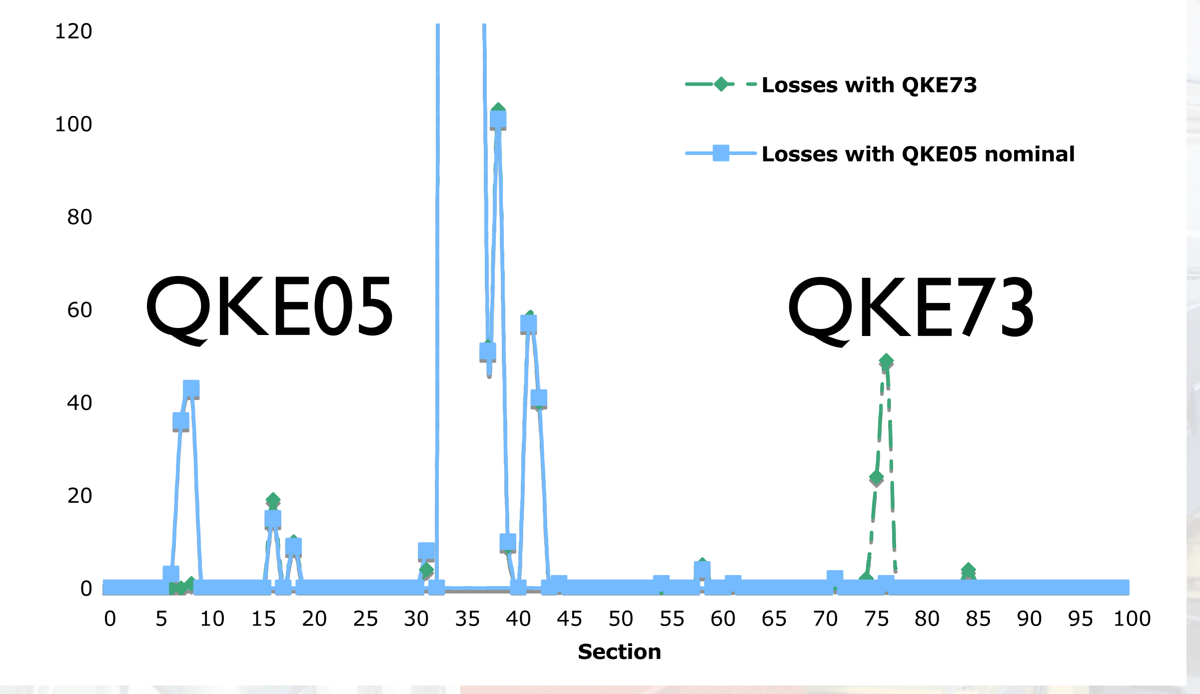


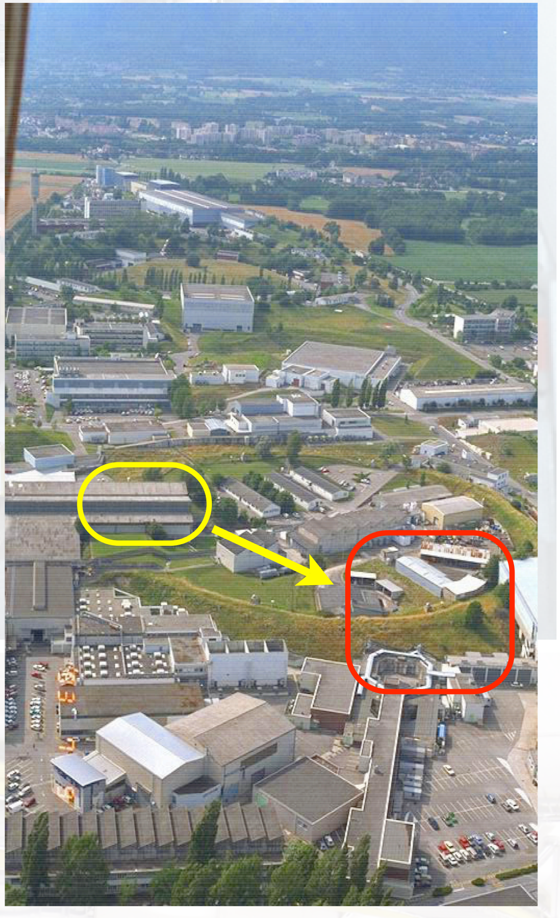


a) BLMs located at each main dipole, 100 BLMs
b) Not all the BLM have same installation location
c) Not possible to evaluate the ratio of losses between different straight section wrt the ratio of the BLM signals nor the relation between BLM signal and intensity lost.

Hp: particles lost in not expected SS - (SS05 → SS10) are generated by the interaction of the circulating beam with the electrostatic septum

"Cleaning" by moving the QKE05 in SS73, simplified case

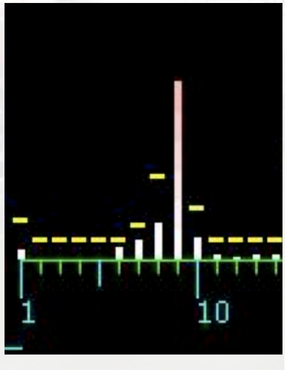




New simulations using same approach for LHC collimation study developed : MADX+K2+detailed aperture model
(J. Barranco - PhD - in the framework of the PS2 studies)

a) Different optics for each of 5 turns: different fast bumps
b) Septum element implemented both for material as for kick, multi-turn re-interaction taken into account
c) Detailed aperture model

<u>Simulated losses move with the position of the QKE</u>



Irradiate inside the CERN site since the losses cannot be avoided due to particle-matter interaction.

P.S.: **Real maximum of the losses could be different by one or two SS**

What we proposed, from ATC-ABOC days ‘07...

CT study program for 2007

(A) Test of the extraction efficiency with the new QKE configuration, two new quadrupoles and power supplies installed during the current SD ✓

(B) Understand the new loss pattern and measure the radiation levels after test runs. ✓

(C) Evaluation of doses in case of intervention on the irradiated equipment ✓

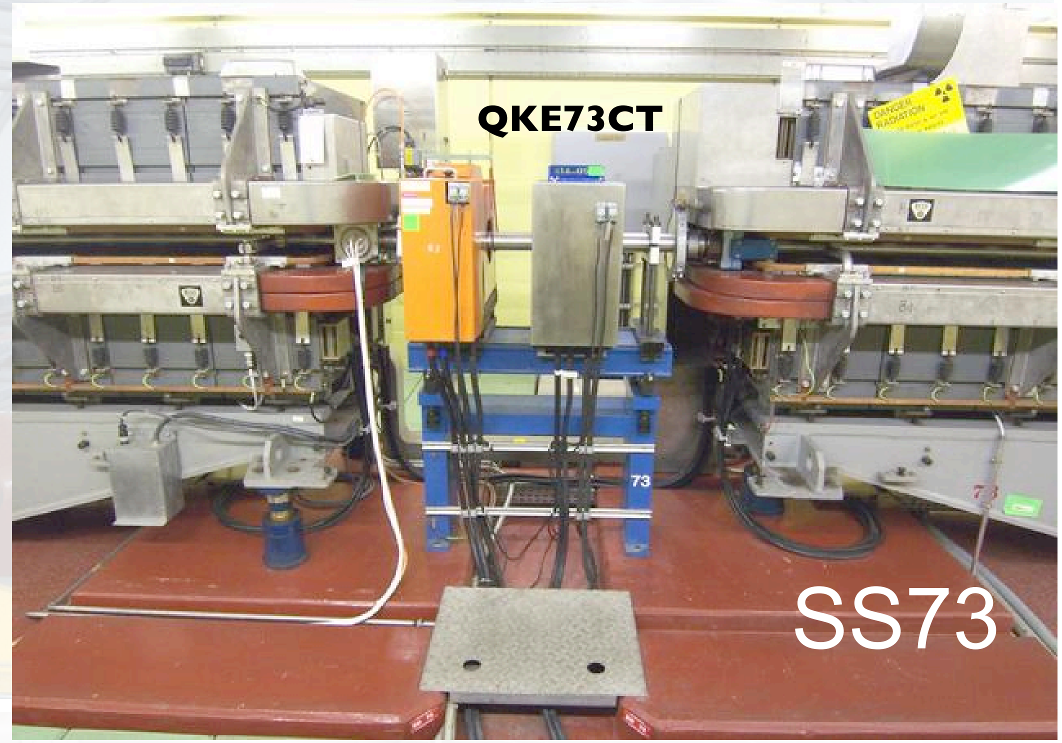
(A) Study of the estimated doses ongoing.

Decide on the basis of (B)+(C) if the new settings of the CT are acceptable or not. ✓

- Reducing the losses concentrated in specific sections (i.e. SS09 or/and SS77) which host delicate equipements (RFs, kickers, ...): ✓

- Pulsing all the 4 QKEs at half of nominal current. Optics at electrostatic septum in SS31 should be the correct one. In simulations, losses are equally shared between SS9 and SS77;
- Implement orbit distortion to clean the beam in non-critical sections

Two quadrupoles installed during SD'06

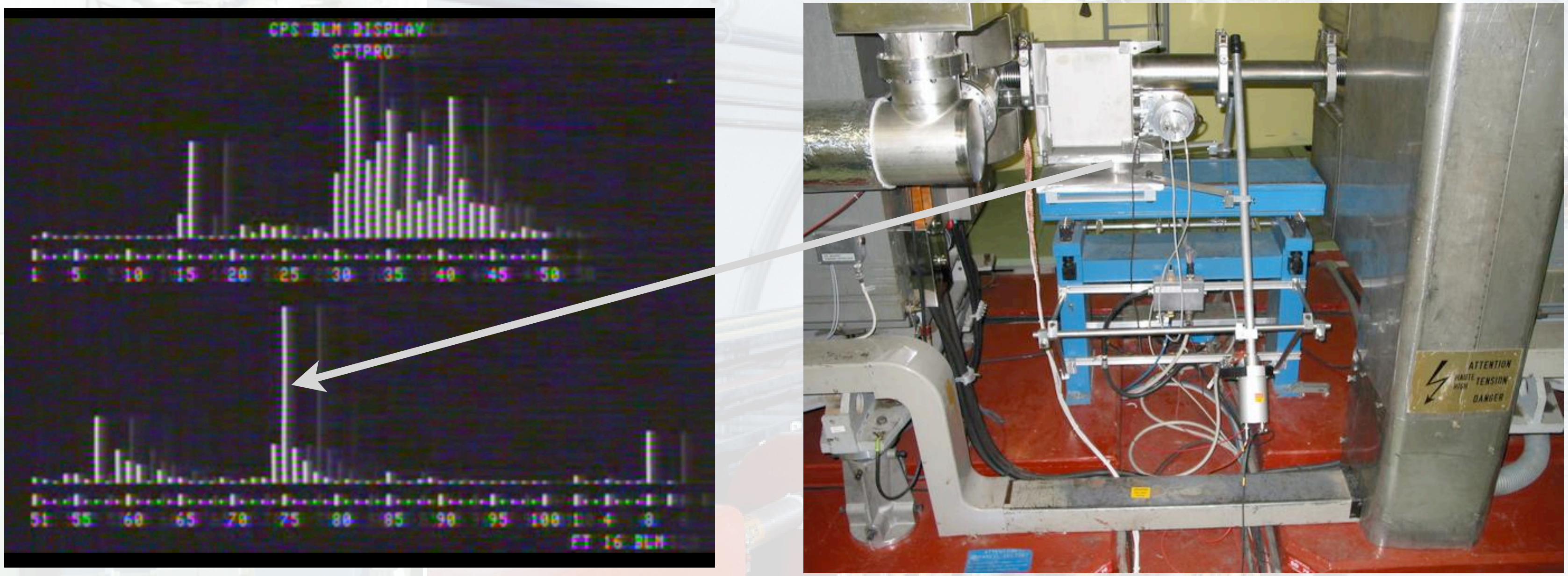


- Two quadrupoles installed with crash program (thanks to R. Brown and S. Baird)
- Three power converters borrowed from AD (thanks to AD and PO colleagues)
- New controls installed (thanks to CO)

➡ Two QKE16s available for operation since the start-up:

- QKE16 for fast extracted beams (LHC type beams, AD)
  needed because second module of KFA71 is after the QKE73CT
- QKE16CT for CT extracted beam (CNGS and SFTPRO) (QKE73CT and QKE25CT)

Irradiation/Loss peak on FWS75



Experimental Loss pattern as predicted by simulations without changing the extraction efficiency: high intensity CNGS run and normal SFTPRO operation with this configuration.

Viable solution to displace the losses in a better shielded area until MTE will become operational

Loss peak in SS75: Fast Wire Scanner, necessary to mesure vertical profiles.

During SD'07-08

- Phototubes, wire scanner mechanics removed and installed in SS65, reusing an existing tank
- *The displacement of the FWS and not the simple removal is needed to have always 2 operational FWS per plane in the PS, in particular during the LHC commissioning and operation.*

PS radiation measurements

Measurement conditions

Safety Commission

Aims:

- Verify the radiation situation with the new extraction scheme
- Compare the results with the measurements done on 6/11/06
- Verify permanently occupied workplaces in proximity of the accelerator

Measurement done: 4/10/2007 9:00h – 12:00h

Measurement time per point: ~ 10 min -> 180 min

Number of measurement points: 39

Beam conditions (stable over 3.5 hours):

- 1.5E13 p/SFTPRO, 2.0E13 p/CNGS
- 15 x CNGS + 2 x SFTPRO / 33 basic periods
- 0.8E13 p/sec

M. Widorski - SC/RP APC 12/10/07

Radiation survey of 39 measurement points outside the PS tunnel during stable beam condition reproducing the same proton per second expected during a normal CNGS run.

Test necessary to decide if the new CT extraction configuration is effectively reducing the dose of the PS bridge region without causing irradiation issues in other places.

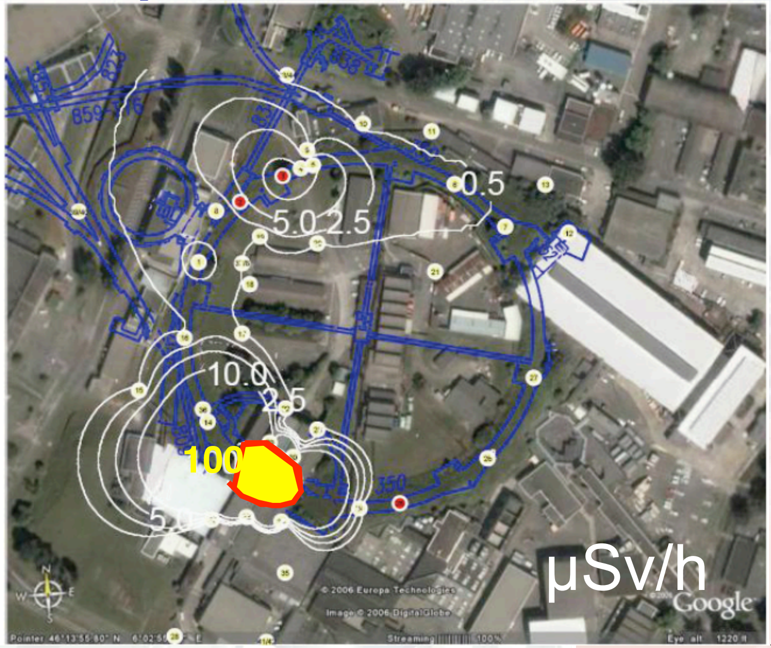
Results: **the dose in the B.151/150 (North and South halls) and on the PS Bridge have been reduced by a factor between 80 and 100.**

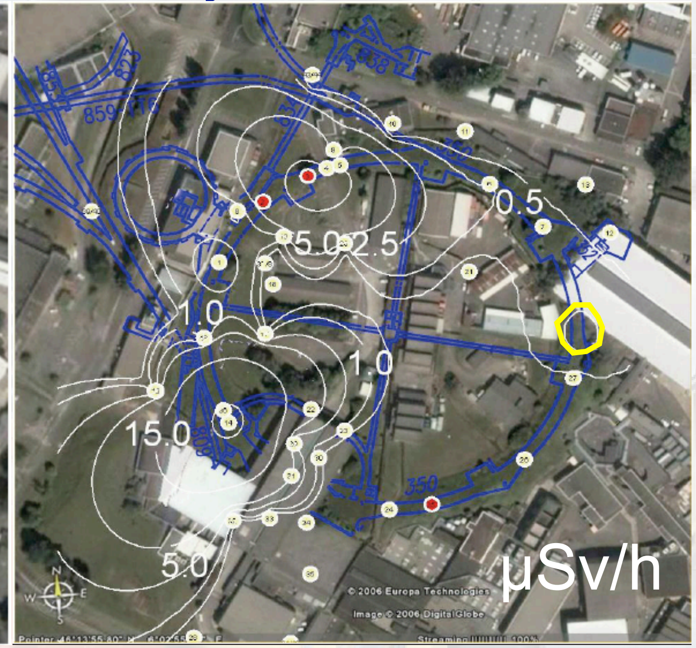
The new CT configuration has been retained for the CNGS nominal run.

N.B.: Half of the dose on the Rt. Goward is produced by extraction losses which should disappear with the MTE extraction.

PS radiation survey overview

Survey 2006 - Old extraction → Survey 2007 - New Extraction





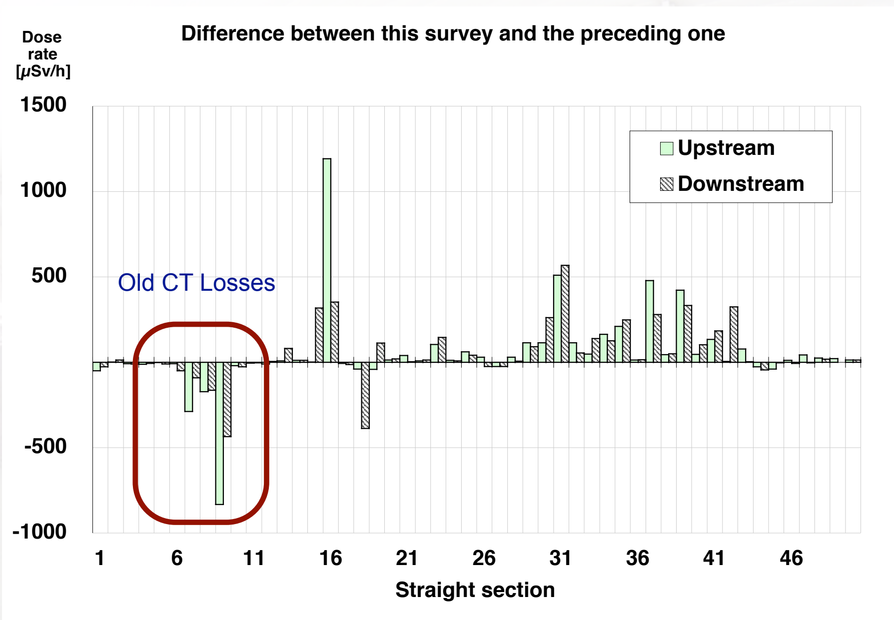
Radiation survey shows the expected reduction in the PS Bridge zone, both outside as inside the machine.

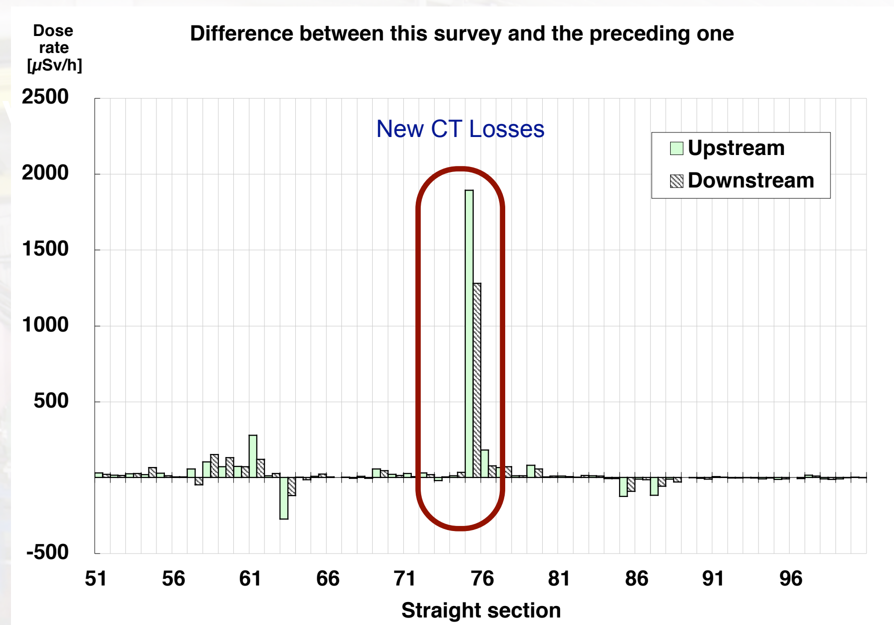
A new hot spot appear in the SS75, as expected.

The CT losses under the Rte Goward are unchanged as the injection losses

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.

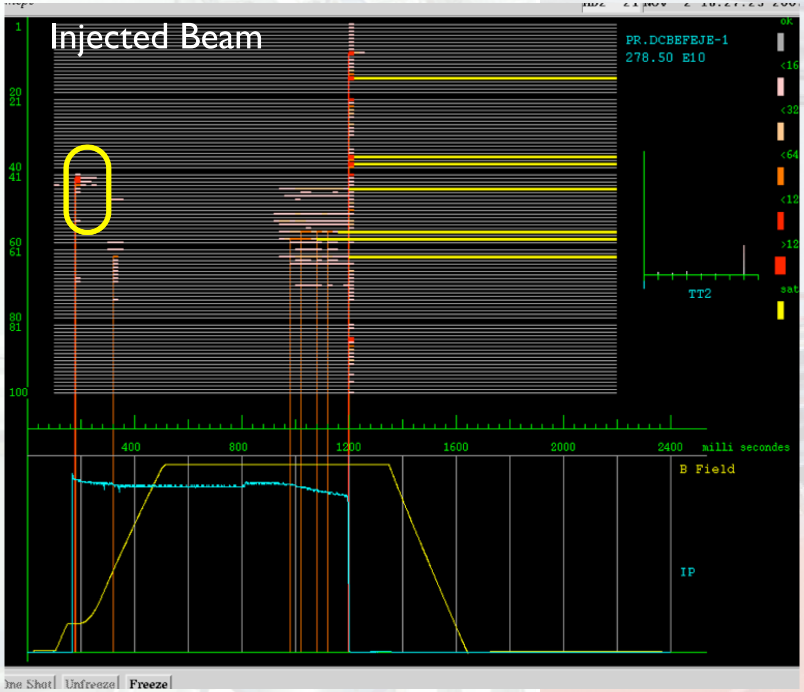
EDMS ID: 882770 M. Widorski

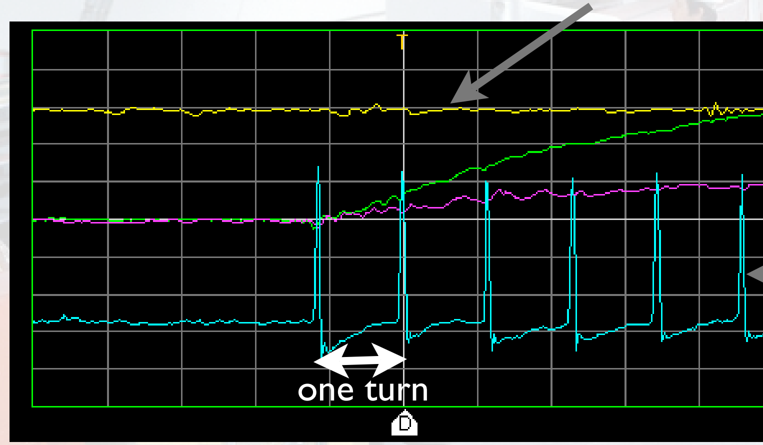


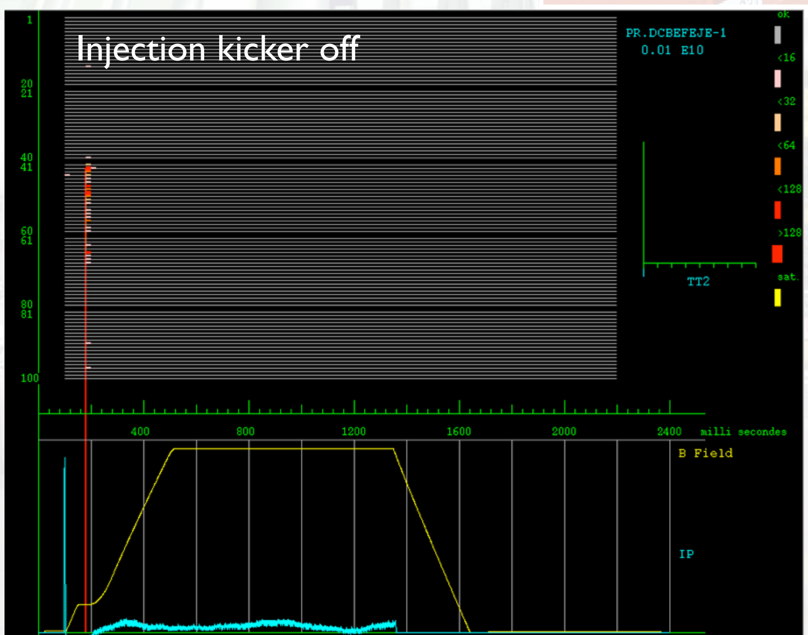


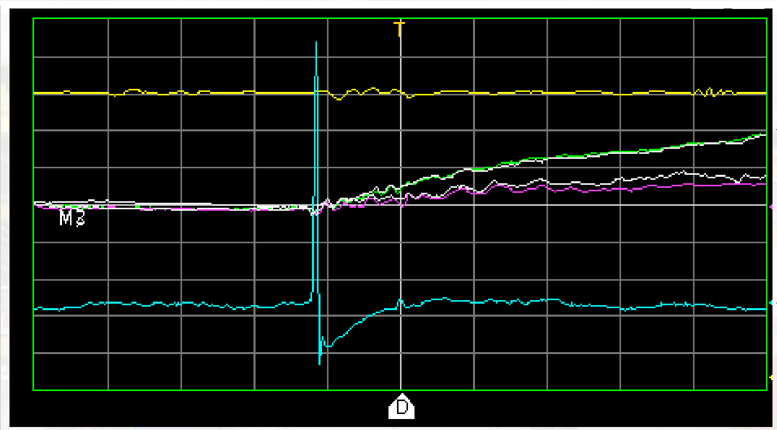
Losses at injection (under Rte Goward), example on MD2- TOF like

MD to understand if losses at injection produced by the circulating or by the injected beam: injection kicker disabled to loose the beam during the first turn.





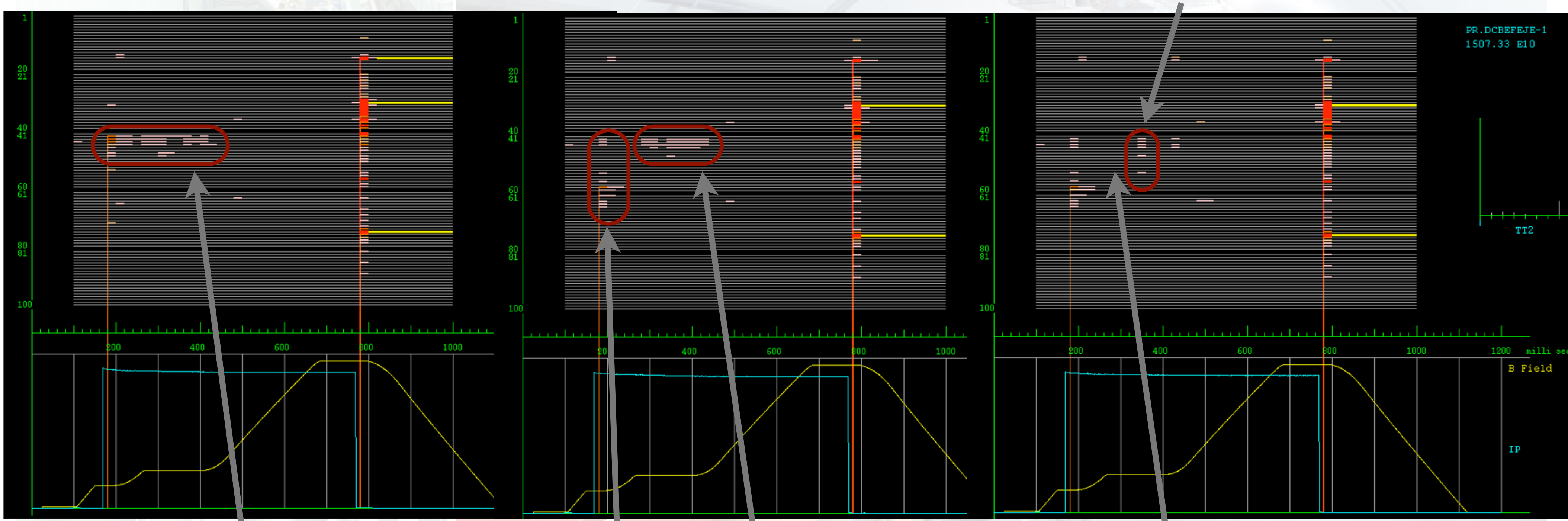




Losses are produced mainly by the beam entering in the machine, either in the BTP injection line on at the injection septum.

Losses during SFTPRO(CNGS) after injection in the injection region

Losses during bunch splitting



Total losses in the injection region

Losses displaced by vertical bump

Losses during 3.5 GeV/c plateau

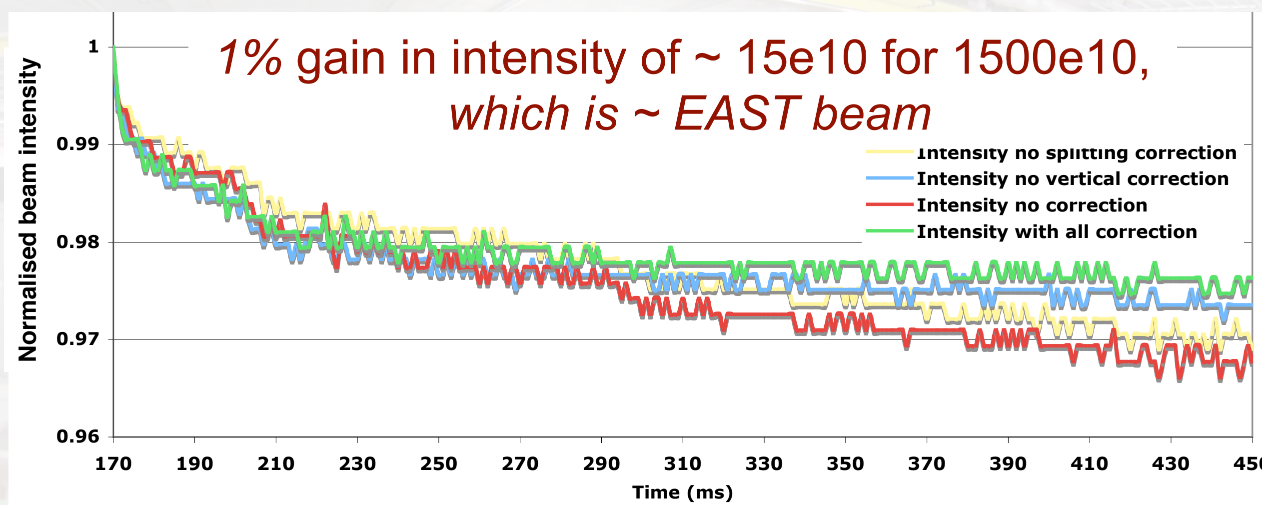
Losses *before* bunch splitting reduced by radial steering

Other losses in the injection region studied and minimised:

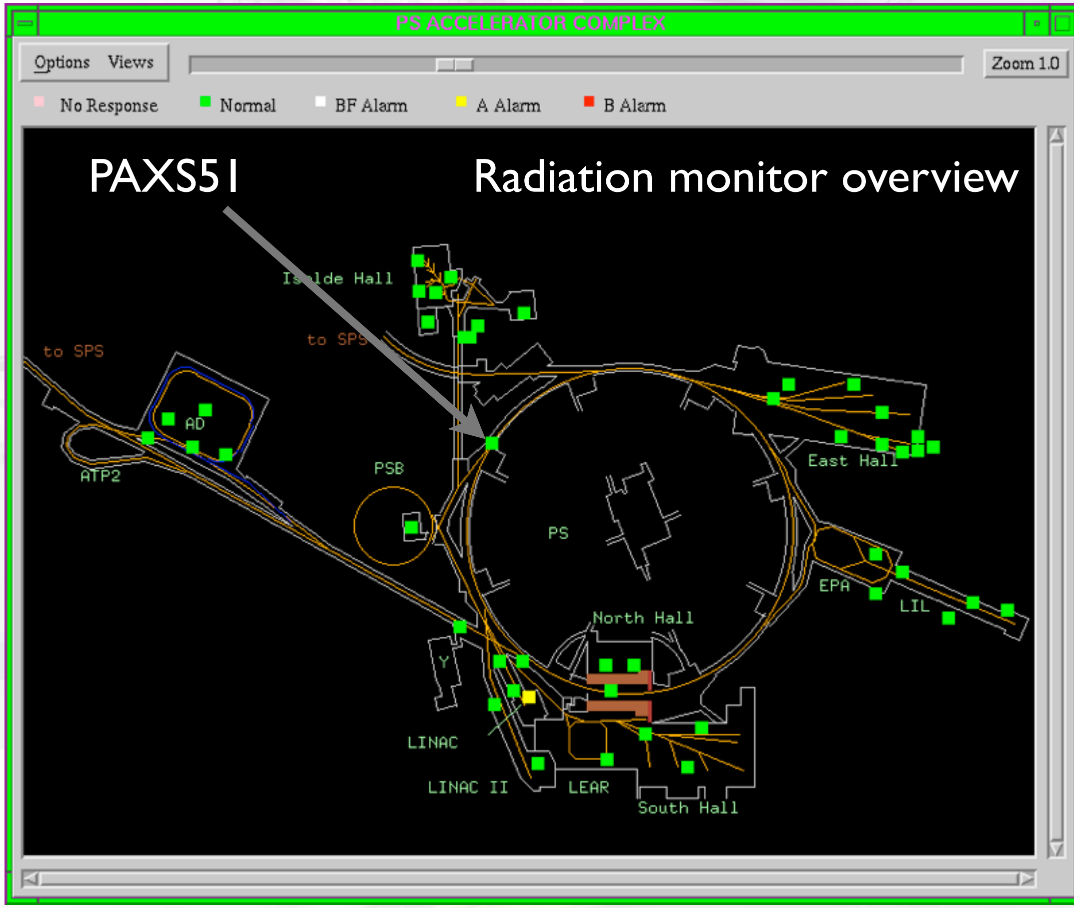
1. losses displaced by vertical bump
possible sign of bad vertical alignement

2. losses on the 3.5 GeV/c plateau
cured but source not clear yet

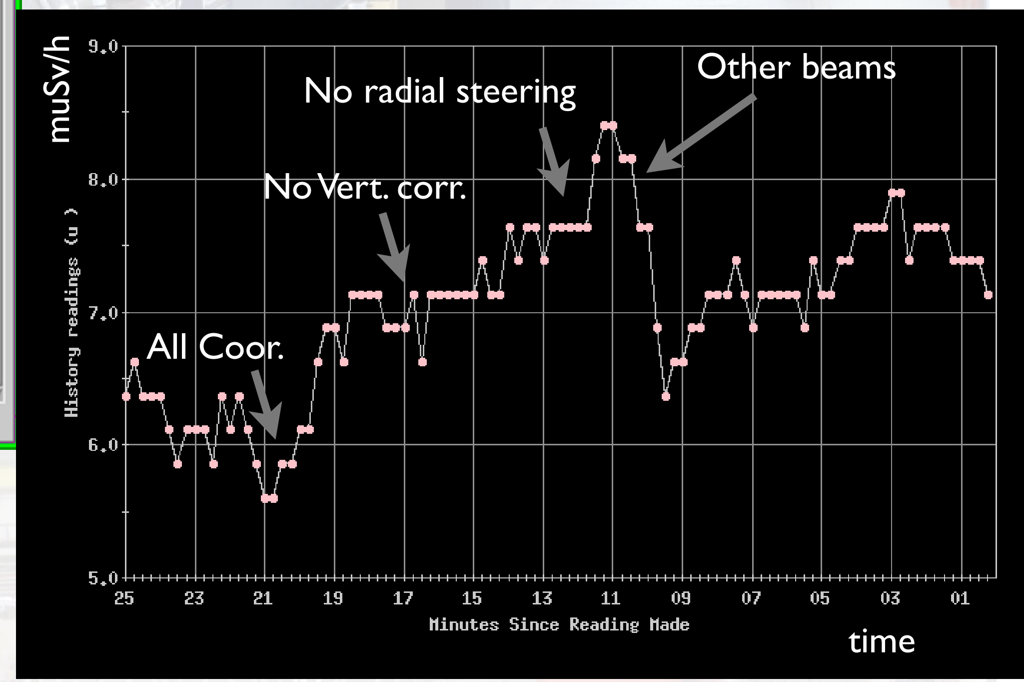
3. losses during h8-h16 bunch splitting
appearing when the splitting is not perfectly adjusted



Radiation monitor on Route Goward: PAXS51



Influence of different corrections tested wrt beam losses but also wrt the dose measured outside the tunnel on the Route Goward by the PAXS51



Net gain observed
(starting from the dose level of that particular day and related to the particular supercycle):

1. removal of vertical correction: *from about 6 muSv/h to about 7 muSv/h* *≈ 15 %*
2. removal of radial steering: *from 7 muSv/h to about 7.6 muSv/h* *≈ 10%*

Proposals for SD 07-08 and run 2008

Different sources of losses in the injection region has been identified, and whenever possible, fixed.

This lead to a 40-70% loss reduction in the injection region. Still to understand the relation between losses and PAXS51.

Losses are produced from:

1. The beam entering in the machine before or during the first turn. Possible reasons and cure adopted:

   (a) Losses are in the BTP line due to beam trajectory and are seen by the ring BLMS and by the PAXS51

   ⇒ LHC BLMS will be installed in the BTP line
   ⇒ Study of the beam trajectory wrt to BTP aperture
   ⇒ Relative alignement of BT+BTP+PS will be checked during the current SD
   ⇒ Orbit/trajectory study, simulation and next year measurements

   (b) Losses are mainly at the septum due to the different aperture reductions either at the last part of BTP, or/and at the BSM42 or/and at the septum:

   ⇒ Modelling of the Septum region (BSM42, SMH42 and relative aperture restrictions) in a Monte-Carlo simulation.

2. Losses are produced during the 3.5 GeV/c magnetic plateau for the h8-h16 bunch splitting:

   (a) Losses at 330 ms are generated by a sudden change in the radial position when the radial loop is disabled during the splitting when the bunch splitting is not perfectly tuned

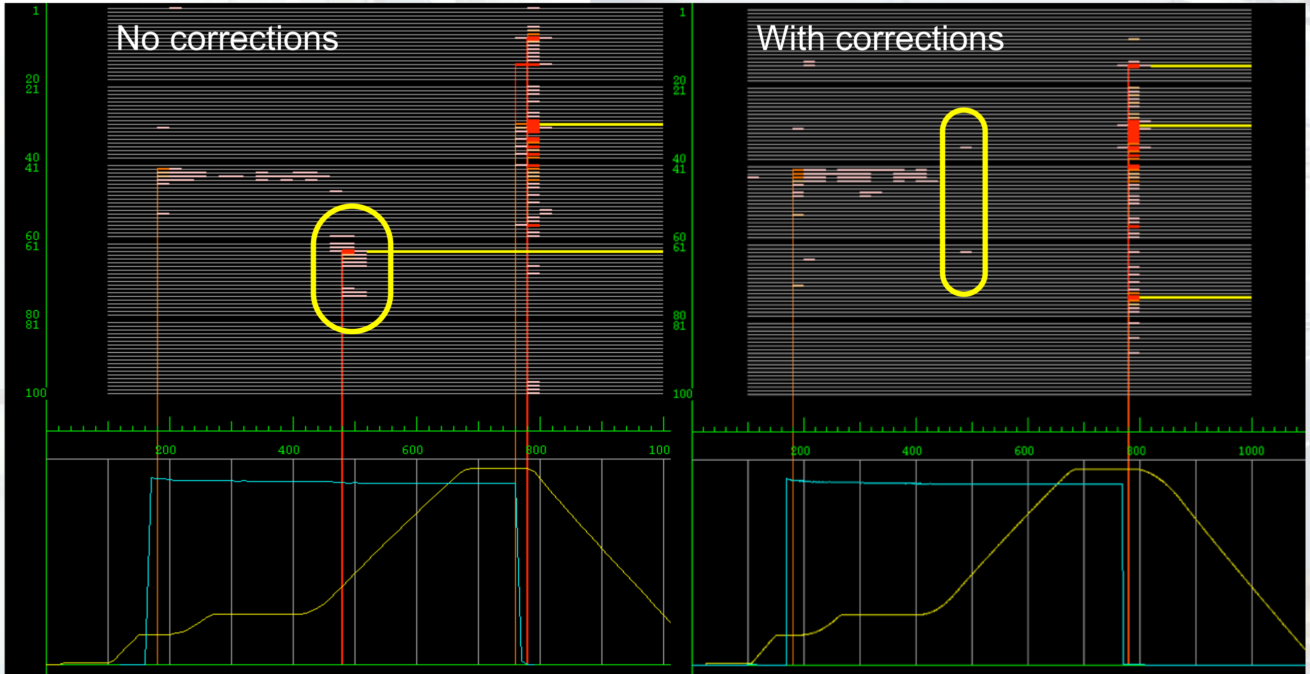
   ⇒ New frequency program implemented next year might solve the problem

   ⇒ Study to understand why the losses are in particular in the injection zone

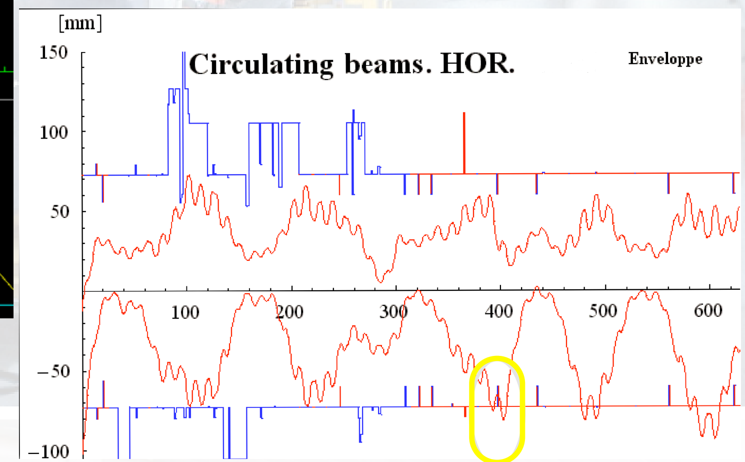
   (b) Losses all along the plateau

   ⇒ A radial steering seems to correct completely for those losses
   ⇒ Not clear from where the losses are coming from (transverse or longitudinal)
   ⇒ Study to understand why the losses are in particular in the injection zone and what is the source.

PS - Transition losses reduction

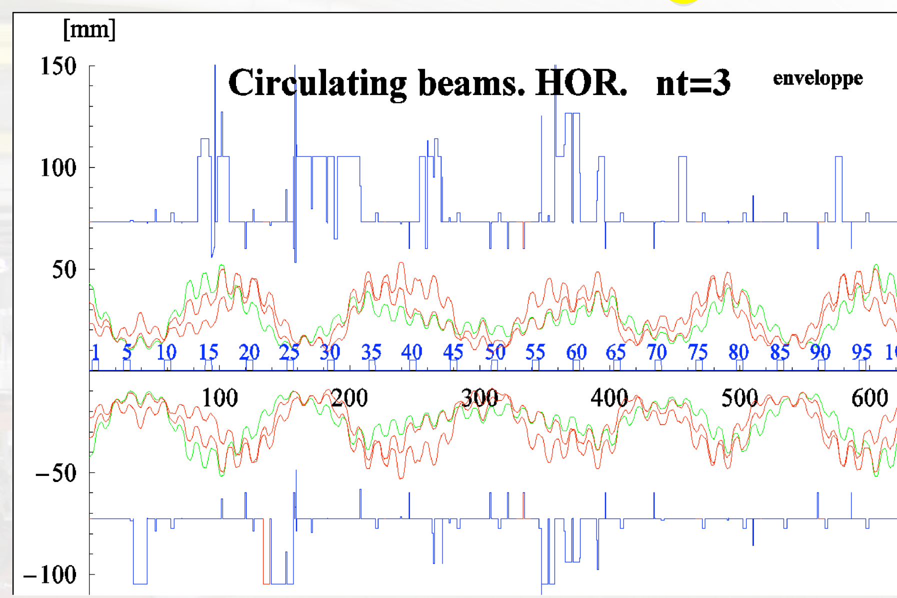


γ-jump scheme at transition induces an optics distortion by pulsing 14 quadrupoles separated in 2 triplets and 4 doublets.
Losses observed in SS with large enveloppe with also large orbit distortion.



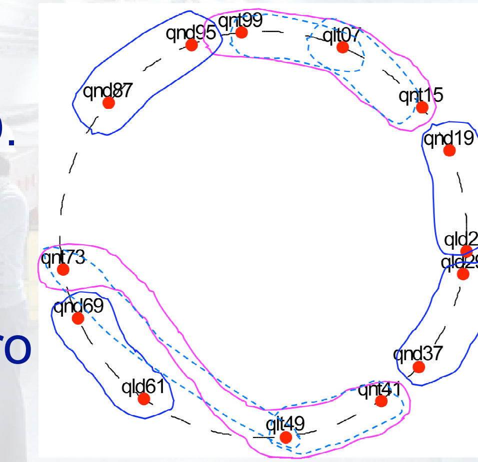
What is going to be done in 2007

- Two new power supplies for triplets with max current of 250 A
  - Test of moving of the envelope to larger aperture SS without decreasing the gamma jump efficiency
  - Test of orbit variation with respect to magnet powering, both for the doublets as for the triplets
- Doublet and Triplet quadrupoles aligned to smooth curve
  - Test if the alignment precision is enough for the orbit distortions, theoretical and experimental study
- Other possible knobs:
  - Implement local bump in SS63 with BSW57 to avoid radial steering which interferes also with the transition longitudinal fine tuning
  - DHZ15-DHZ60 (correctors for the non-closure of BSW16) with bipolar power supply can be used for global orbit correction.

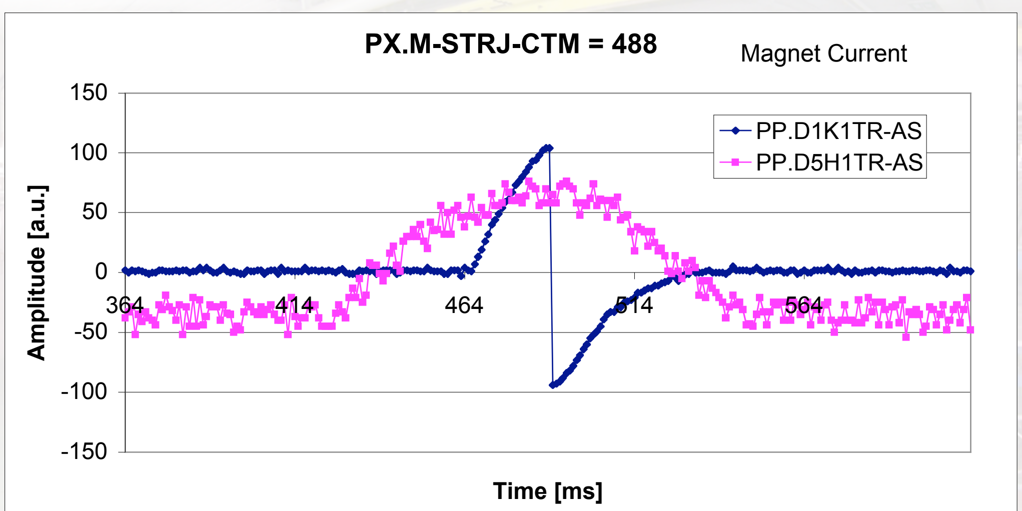


Outcome of the study

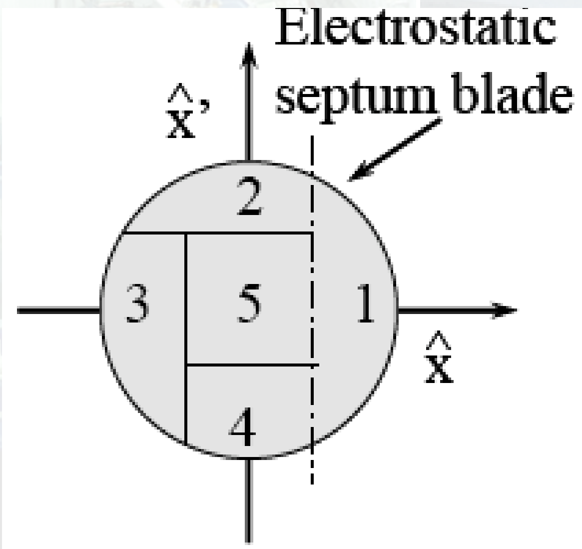
- Overall losses reduced by de-balancing the triplets power converted in the machine
  - New power converters for the doublets installed during this SD.

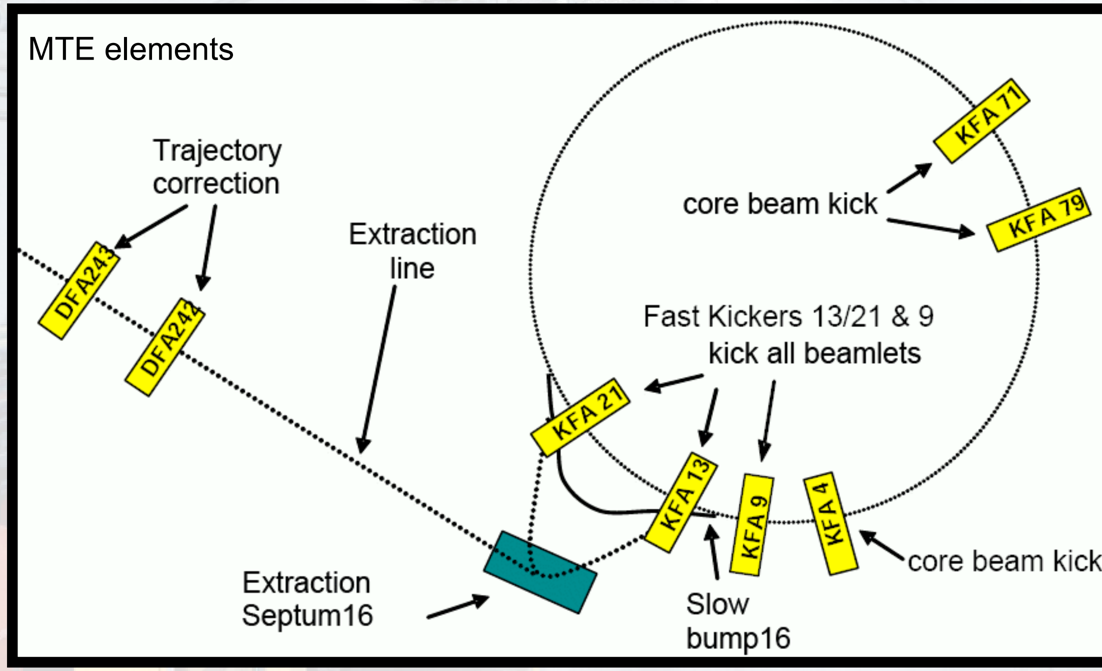


- Radial position of the beam at transition found to be not zero
  - Beam is not centered due to, probably, a lack or feedback
  - More study with the new frequency program
  - Losses furthermore reduced by a radial steering which moves the peak of the distorted orbit in region with larger apertures.

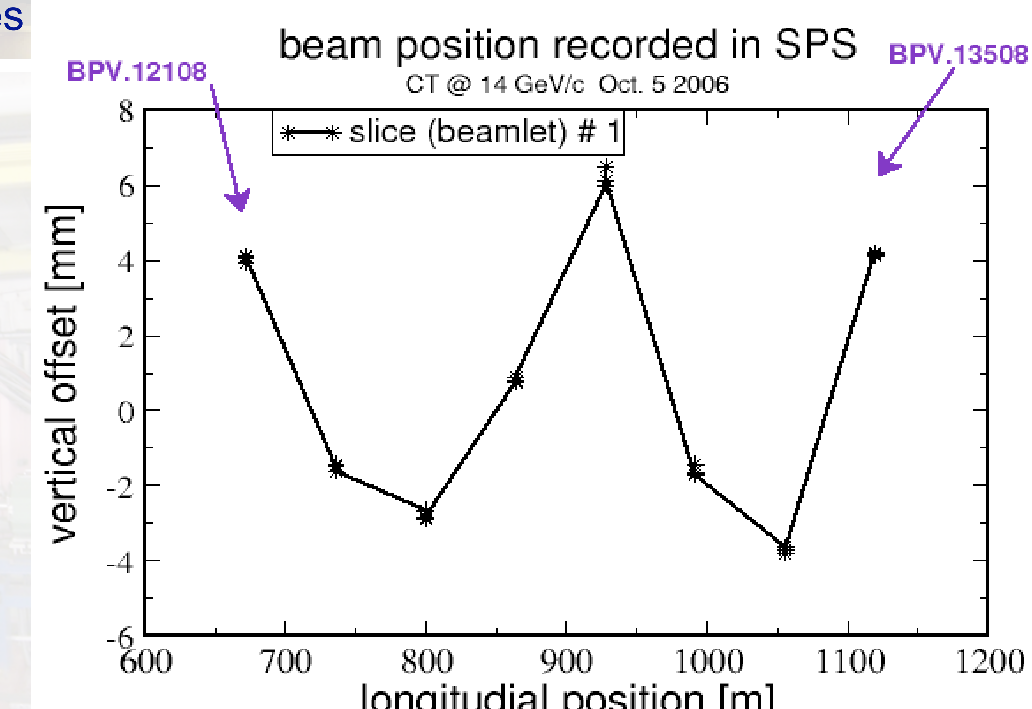


CT (and future MTE) slice correction in TT2



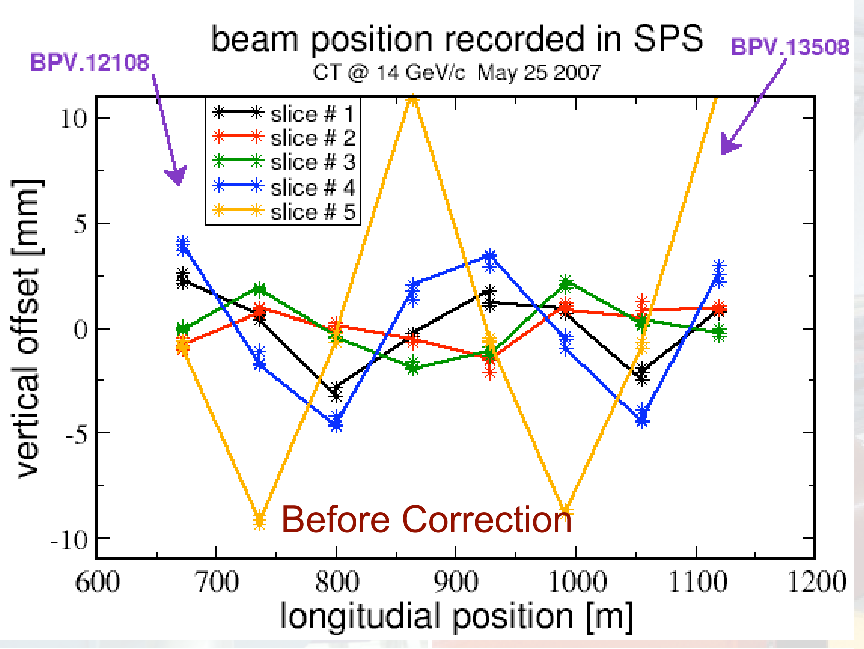


- *The centroids* in (X,X') of the PS ejected slices *are not the same.*
- Exchange of transverse emittances in TT2
  →Horiz. in PS becomes Vert. in SPS
- Result:
  → slices injected with a **vertical offset**
  → **vertical emittance blow up**
  → **Losses at injection in the SPS**
- **Automatic correction procedure developed to compute slice-by-slice correction to minimise vertical oscillation**



Losses reduction: results from 2007

1



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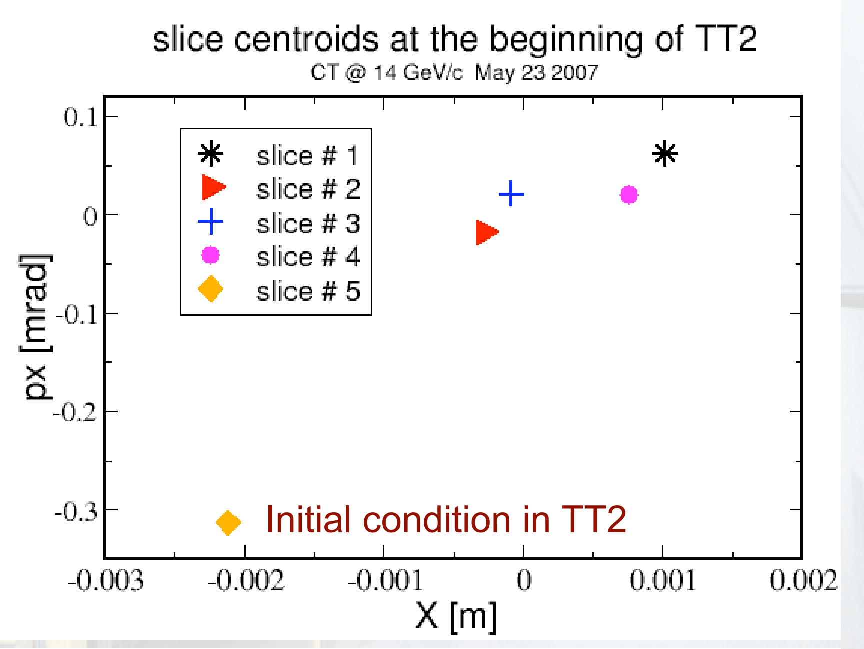

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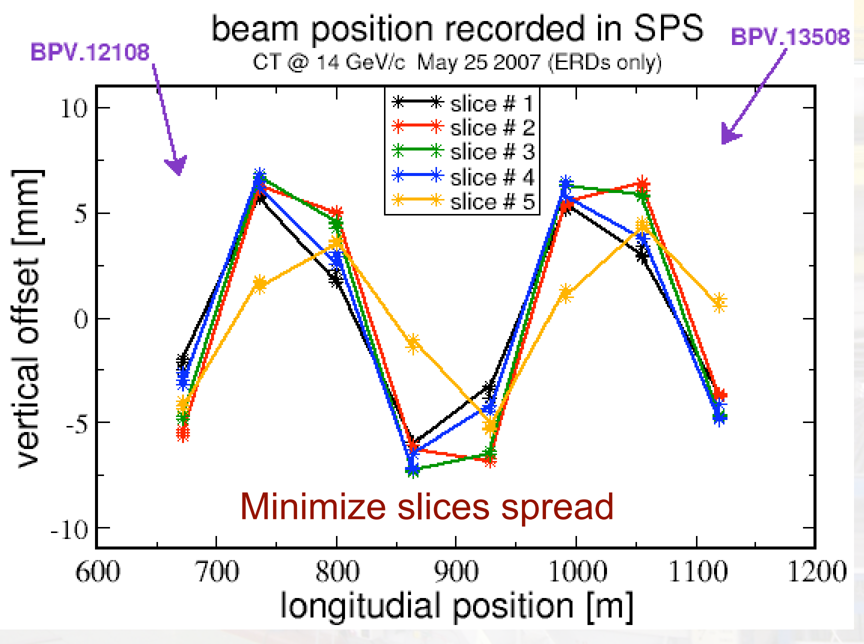

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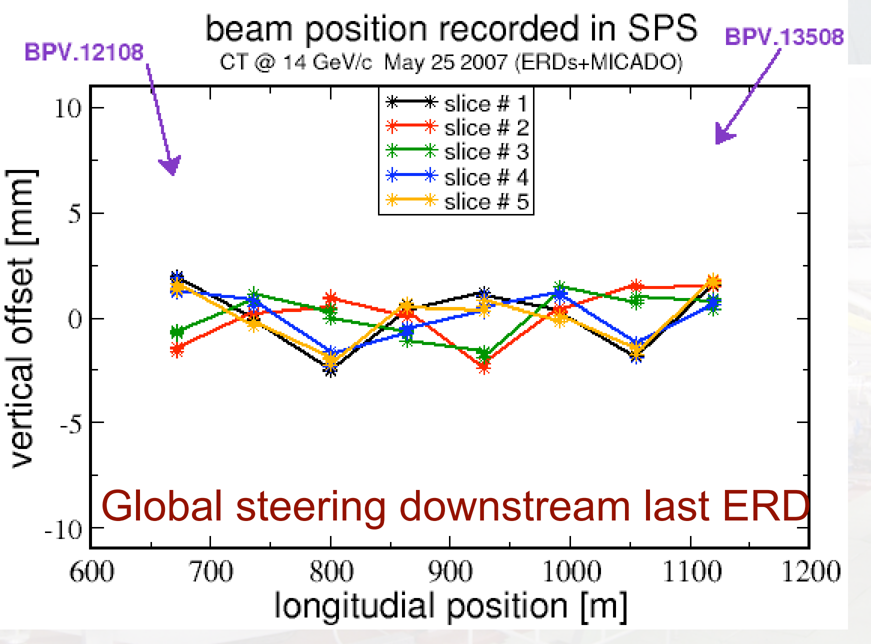


Losses @SPS injection → **2007 new scheme → loss reduction by a factor > 2**

BLRWG recommendations (PS). Where do we stand?

- **PS Bridge:**
  - ☑ Controlled access (2004-6 SD)
  - ☑ Understanding of the losses (loss displacement 2007)
  - ☑ Additional shielding ⇒ no more necessary
  - ☑ Additional monitoring & measurements in the PS area ⇒ done (2006-7) ⇒

    Goward Road problem (partial gain in 2007, expect reduction with MTE, more studies SD and run 2008)
- **SS31:**
  - ☑ Minimization of the CT extraction losses (done ⇒ running at ~95% eff.)
  - MTE implementation (during run 2008)
- **Air release points (PS and SPS):**
  - Monitoring of air activation in the PS area (to be extended)
  - Machine studies to identify contributions of the activated air release in the TT10 stack (data collected in 2006, need a second iteration in 2008)

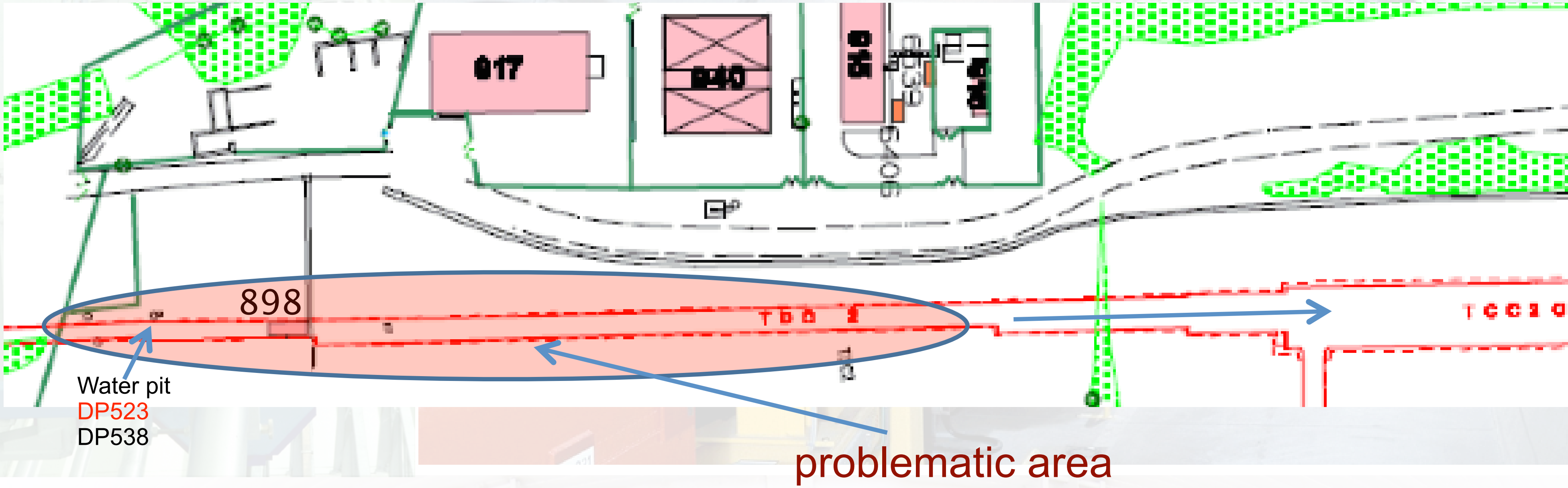
BLRWG recommendations (SPS). Where do we stand?

- TDC2/TCC2 area:
  - ☑ Installation of a RAMSES ventilation station to monitor airborne radioactivity released to the environment (done SD 2006/7)
  - ☑ Interlocking of the ventilation unit to the access system ⇒ solution in place – access regulated by DIMR
  - Installation of air sniffing system to measure air activation during and after operation. Used to decide which safety measures are required for access to TDC2/TCC2 (pipe BA80⇒TCC2 installed, need to install monitoring station)

- ECA4:
  - ☑ Controlled access to the two highest gangways (SD 2004-2006)
  - ☑ Verification of the dose rates in ECA4 during CNGS operation to benchmark simulations (done, confirmed simulations ⇒ ECA4 floor level and barracks = supervised radiation area (safety code 2006 F))
  - ☑ Interlocks to prevent sustained losses at the extraction elements in LSS4 (done during CNGS commissioning)
  - ☑ Cleaning of the abort ⇒ not deemed to be necessary on the basis of the operational experience

- Restore and extend the use of BLMs to measure SPS wide the residual dose rate during beam-off periods:
  - ☑ BLM calibration in terms of H*(10)
  - Change of electronics gain, adaptation of integration timing, implementation of data logging system
  - Online display of the BLM residual dose rate function

Shielding weaknesses in the area of the building 898 located above the TT20 line (SPS extraction to TCC2)



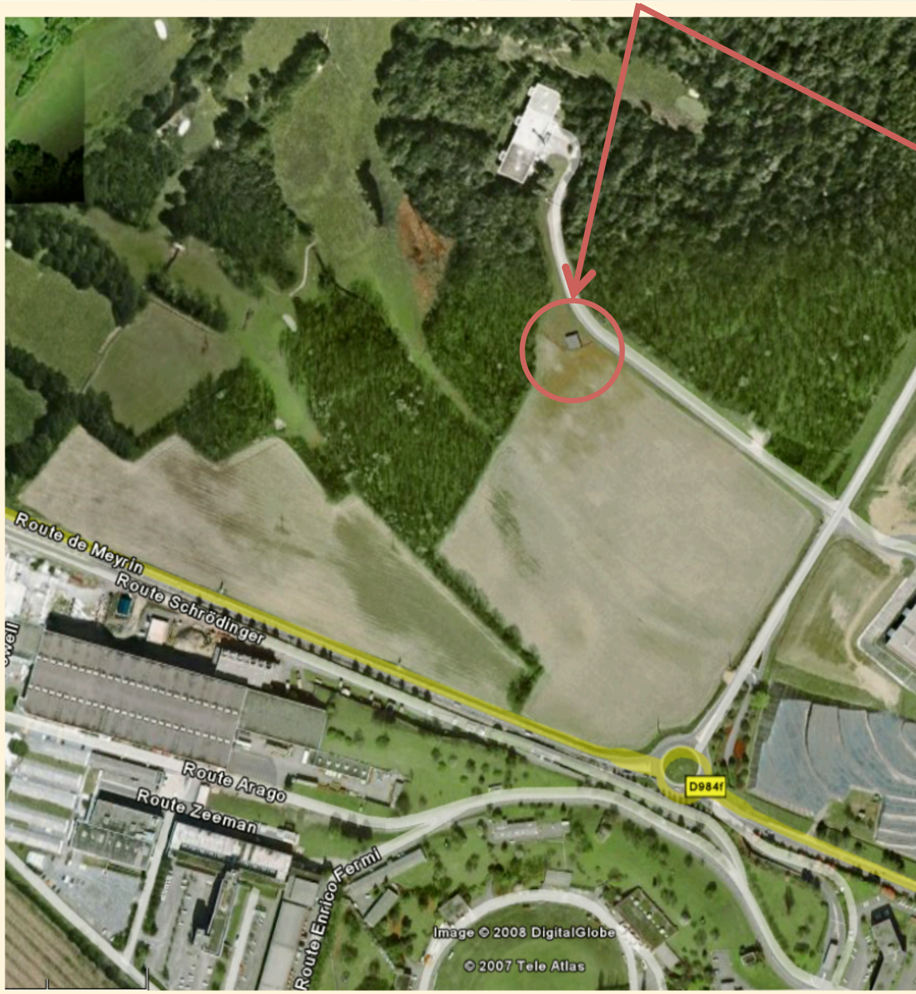
Observation:
radiation levels along TT20 exceeding the limit for non designated areas.

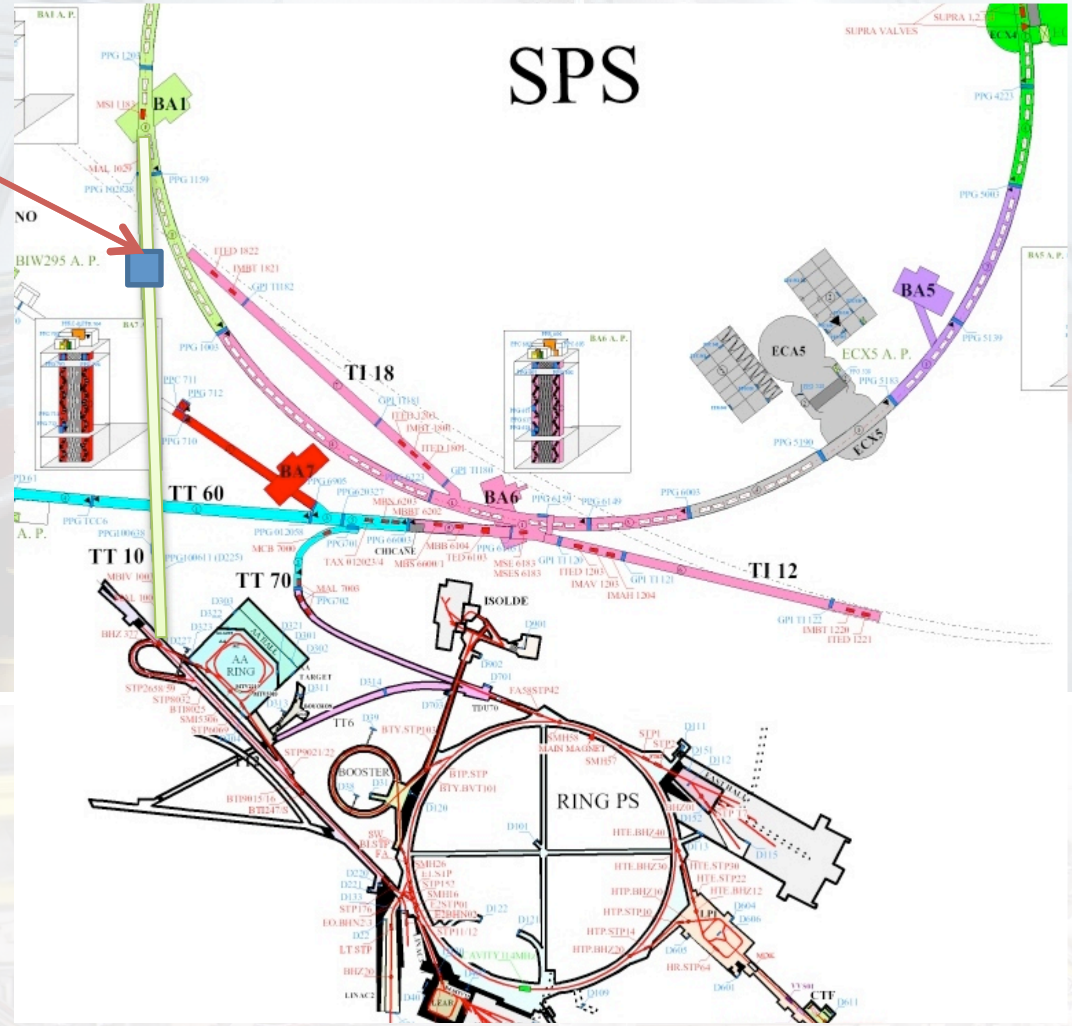
Classification as radiation area required.

- During the SD 2007-8 the area will be fenced
- Machine experiments in 2008 to better understand loss origin and to try to minimize them
- Need of an additional RAMSES station in building 898 (ventilation service building)

Reinforcement of the shielding of the PGC1 shaft of the PS – SPS transfer tunnel (TT10)

Shielding of PGC1 pit (r =4.5 m)

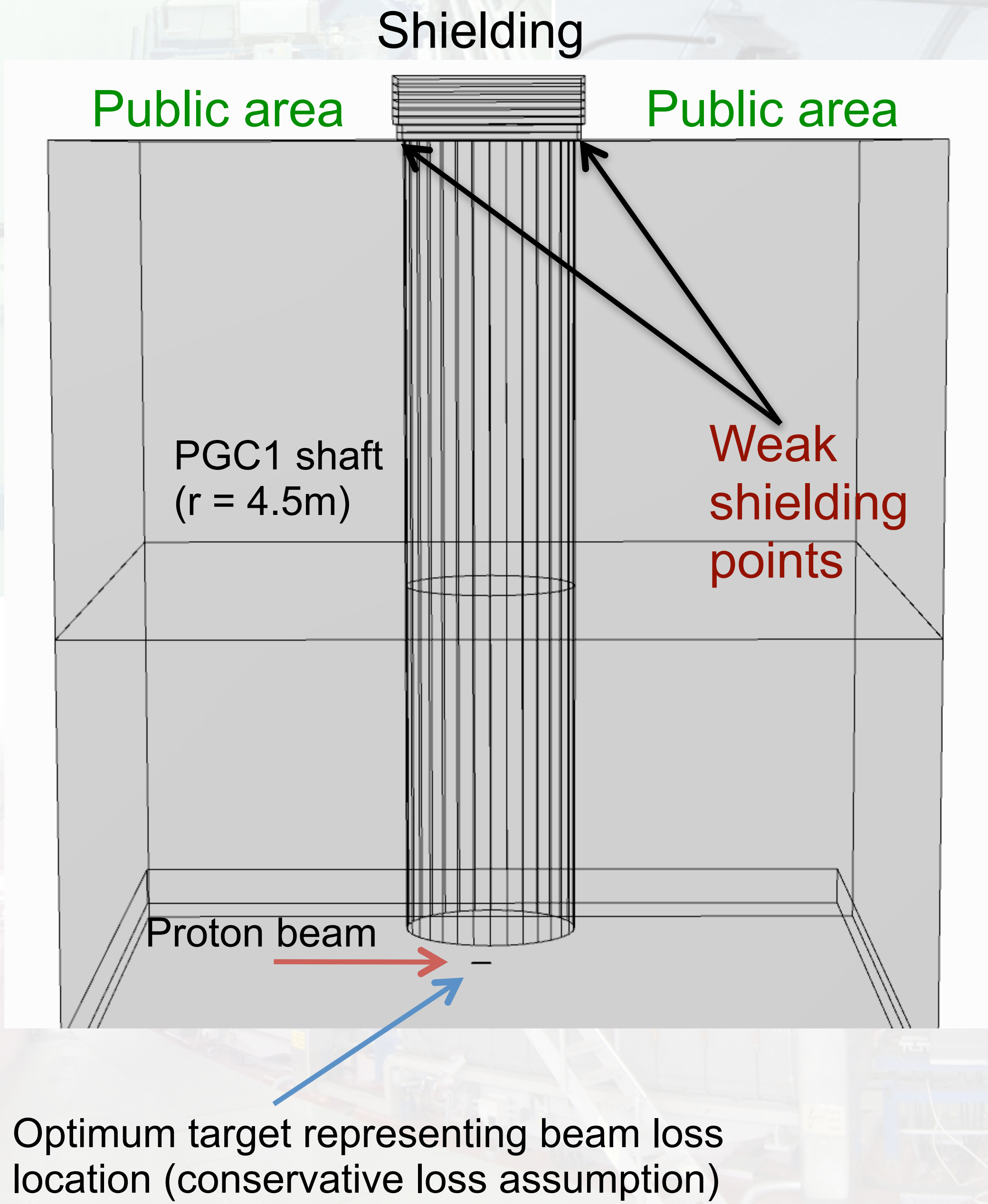




Future operations: *6E19 protons/year* will be sent through TT10.
→ CNGS + Fix Target + LHC nominal operation

Beginning 2008 increase of shielding planned during refurbishment work of the PGC1 pit
→ More measurements during 2008 run

Details of the study



Weak shielding points: Pit and shielding overlap at weak points by only 20 cm.

FLUKA simulations (CERN-SC-2007-030-RP-TN) for the current shielding and for shielding improvements were conducted.

+

First set of TLD measurements at weak points were carried out.

Annual dose at the weak points outside the shielding will be in the range of 5 mSv/y for future high-intensity operations.

With reinforcement reduced to 100 μSv/y

Conclusions

- Most of the recommendations from BLRWG have been or are being pursued. Detailed and systematic radiation measurements have allowed to identify some additional weak points and solutions are being implemented

- PS radiation issues:

  - CT losses under PS Bridge: new extraction optics displaced the losses in a better shielded region of the machine. Issues of south and north hall, MCR (new CMS control room) and radiation at the CERN fence solved.

  - Goward Road (injection losses) beam studies started with some actions taken for this SD. Some sources of losses has been identified and losses have been minimised. However, it could turn out that even with the best injection and minimum losses the shielding is not sufficient. Not yet clear whether it will be possible to reduce radiation below level required for non-designated area (< 2.5 µSv/h)

  - Transition losses minimised. Still some work to do for 2008.

  - With MTE losses related to CT extraction (SS31/PS Bridge/a part of Goward Road) will disappear.

- SPS radiation issues:

  - Automatic procedure to correct CNGS-SFTPRO SPS injection trajectory implemented and losses reduced by about a factor of 2.

  - The zone above the TDC2 (TT20) area and buiding 898 will be fenced and converted into radiation area.

  - Increase of the PGC1 shielding will be done during current shutdown.