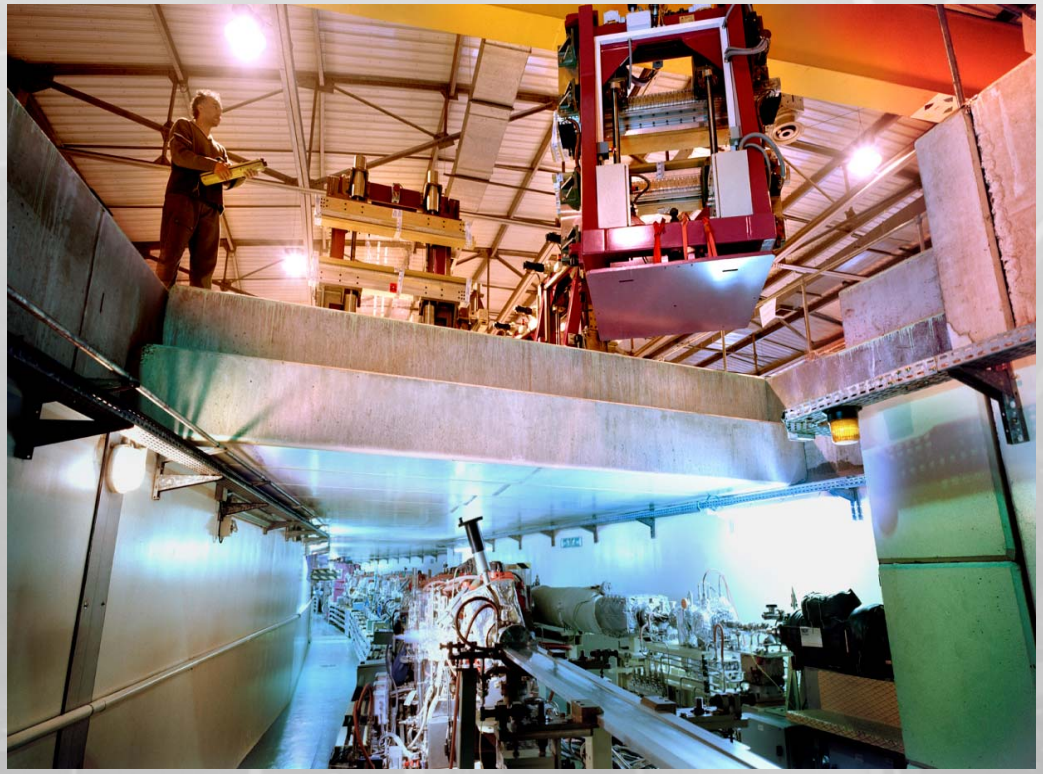


# ESRF: Accelerator Operation and Stability

Jean-Luc Revol

On behalf of the Accelerator and Source Division

**ESRF, SPring-8, APS Three-Way Meeting (3WM08)**
**Argonne National Laboratory**
***March 17-19, 2008***

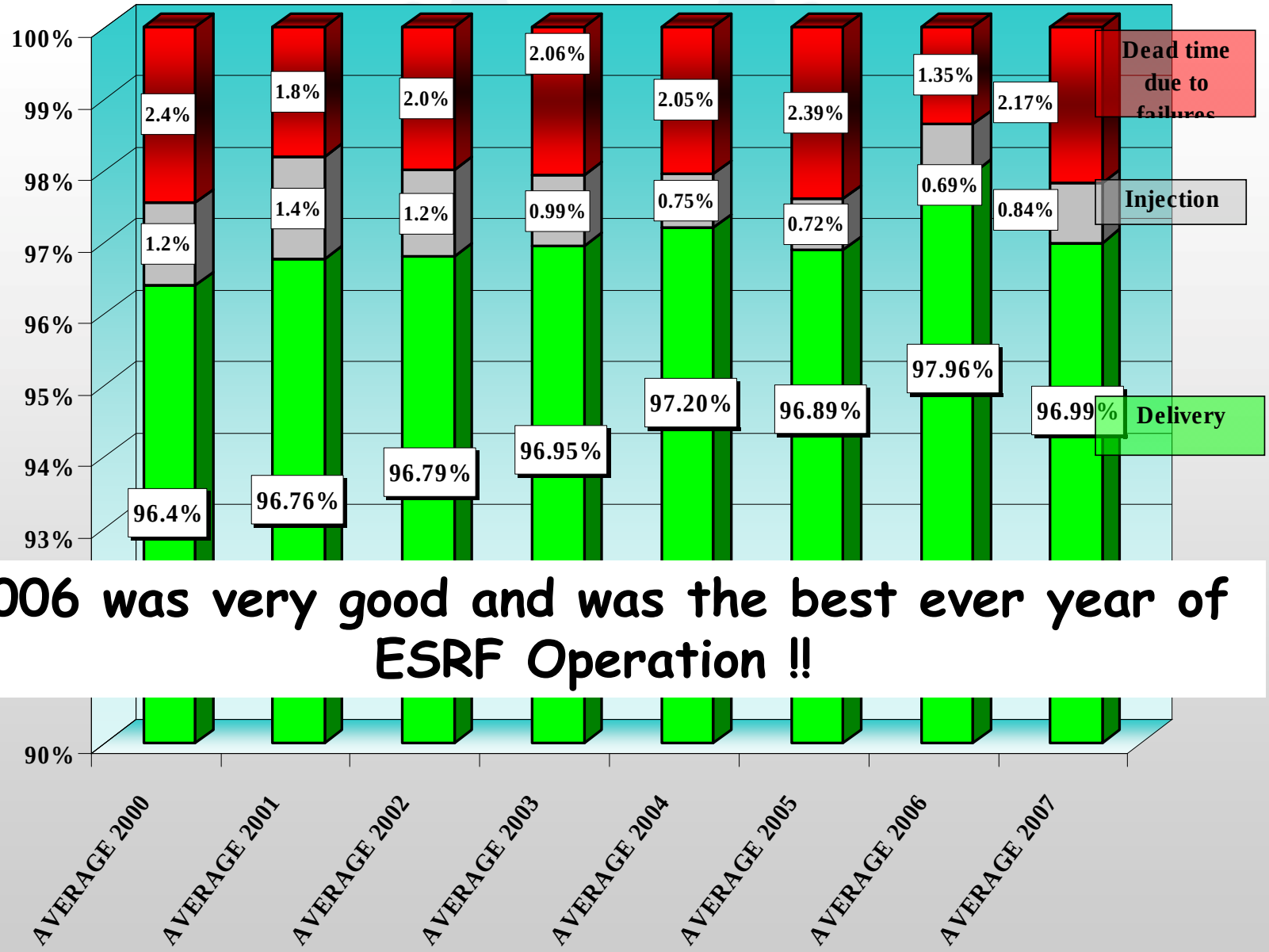
1. Statistics
2. Main difficulties in 2007
3. MDT developments linked to operation
4. Filling pattern evolution
5. Stability
6. Control system
7. Electronic Logbook

# Statistics for 2005-2007

| | 2005 | 2006 | 2007 |
|---|---|---|---|
| Xray source availability (%) | **97.6** | **98.7** | **97.8** |
| Mean time between failures (hrs) | **44.4** | **61.5** | **56.8** |
| Mean duration of a failure (hrs) | **1.1** | **0.8** | **1.24** |
| Number of failures | **123** | **85** | **96** |
| *Time lost in hours* | **131** | **71** | **114** |
| *Accelerator downtime* | **2.4%** | **1.3%** | **2.1%** |

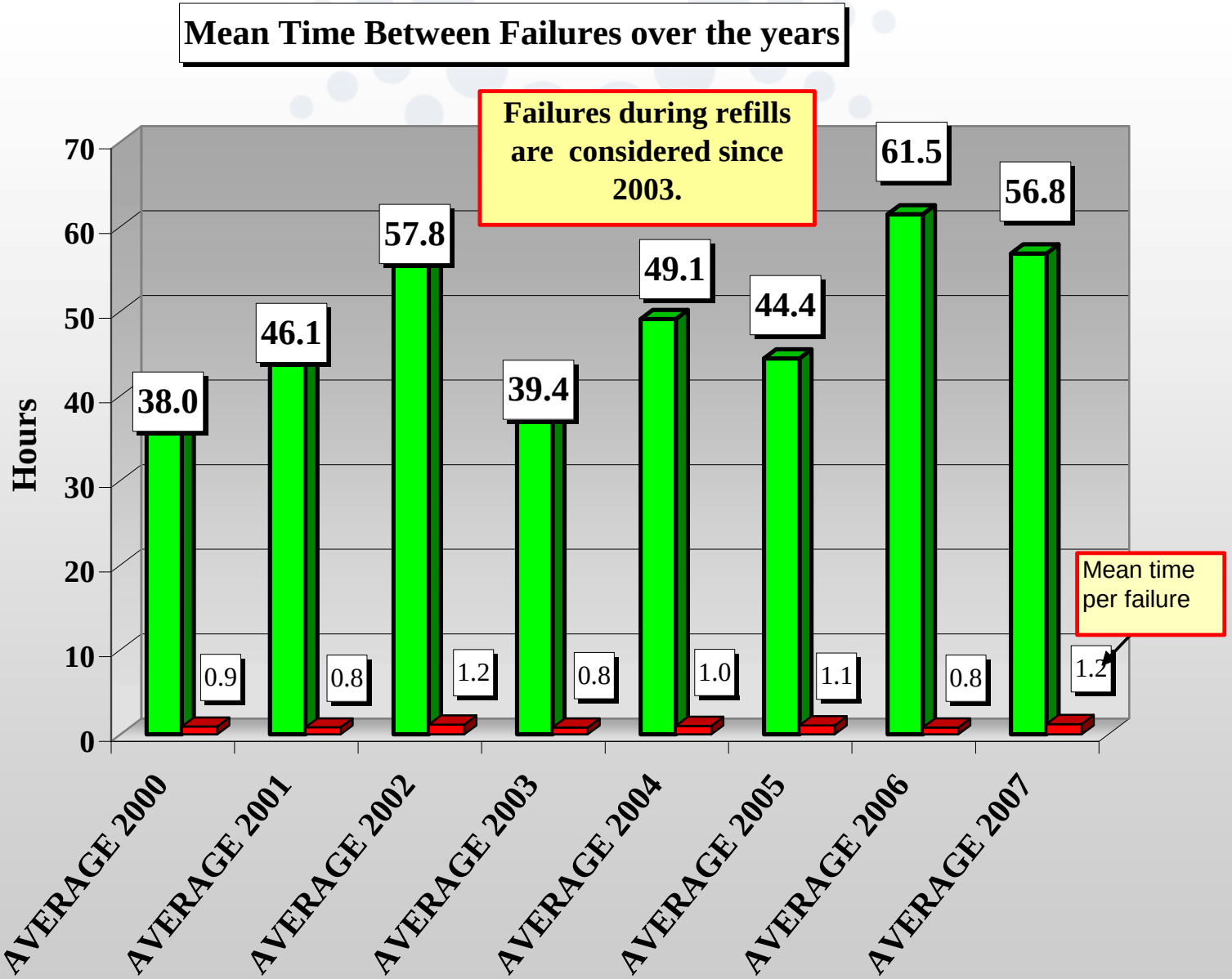
*Lowest figure achieved since the start of the ESRF*

# Statistics overview




**2006 was very good and was the best ever year of ESRF Operation !!**

# Statistics overview



# What affected 2007 ?

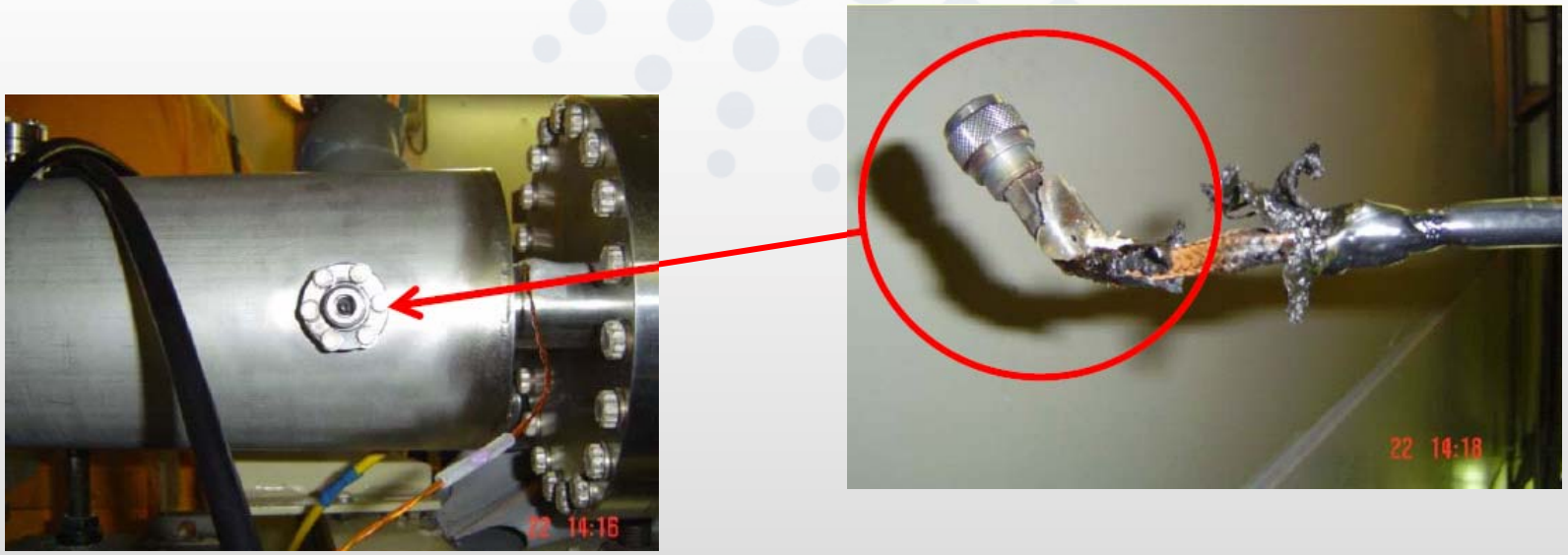
## The main reasons for downtime in 2007:

| | |
|---|---|
| Events influencing **AVAILABILITY**<br>**11 failures > 2 hours**<br><br>**- Stripline Cell 4 (July 2007) (27 USM hours)**<br><br>**- Default on 24 V PS on RF HIS inducing wrong interlocks (5 hrs)** | Events influencing **MTBF**<br>**97 failures < 1 hour**<br><br>**- SRRF : 21**<br><br>**- HQPS / Mains: 13**<br><br>**- Human Mistakes : 10 !** |
| Events influencing both<br>**MTBF and AVAILABILITY**<br><br>**- Absence of HQPS**<br>**→ Drops on electrical mains: 22.5 hours lost for 22 failures !!!** | Significant Events influencing **or not**<br>**Beam Quality Delivery**<br><br>**- Leak on SRRF cavity 5**<br><br>**- Defective RF finger cavity 3**<br>**→ reduced intensity in 16 bunch** |

# What affected 2007 ?

## Failure of the horizontal stripline

***End of run 3 in July***

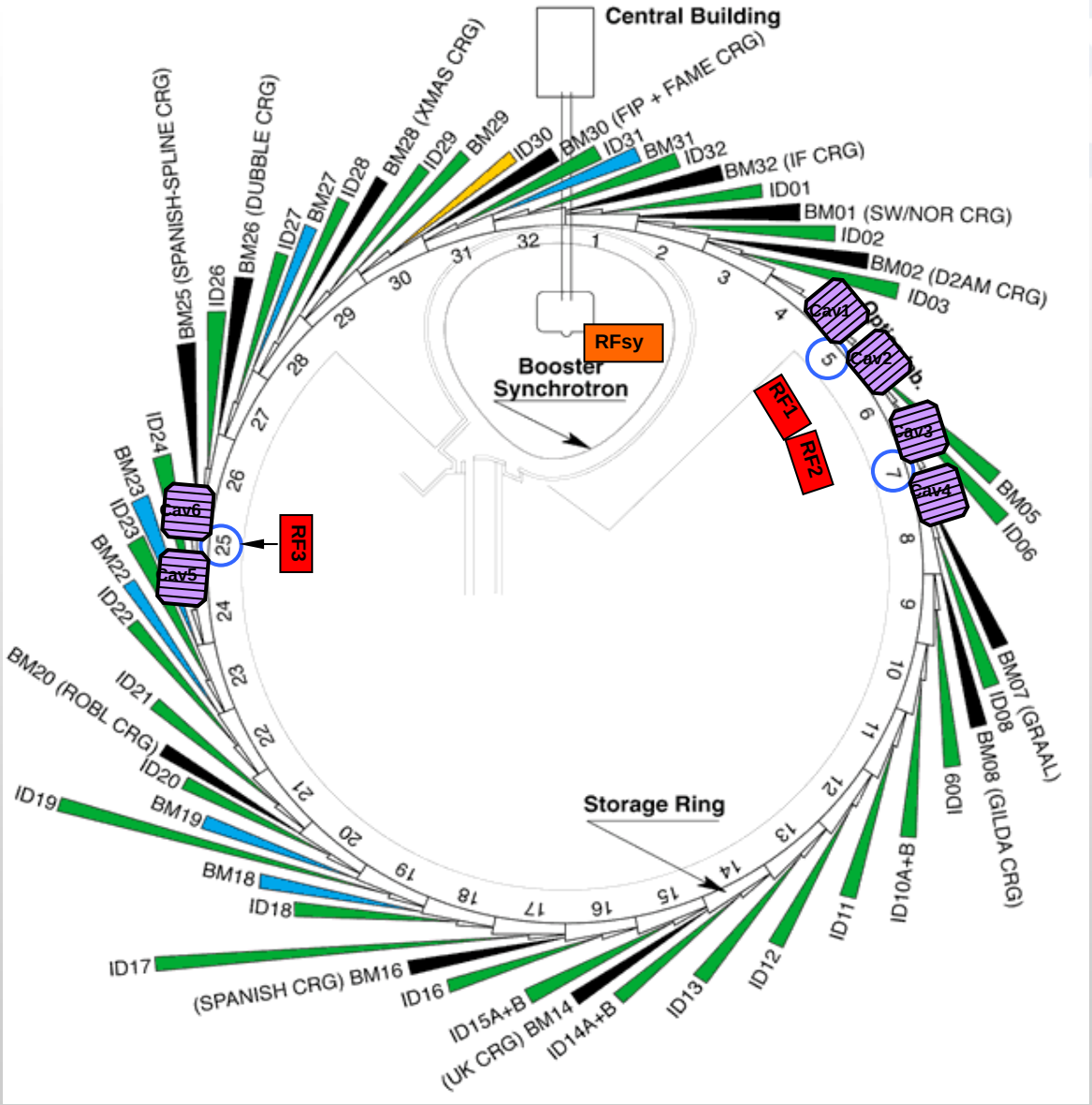



**Fire alarm and broken feed through on the horizontal stripline in cell4**

***Repaired but end of the run cancelled: a total of 75 hours lost but 27 hours "only" in USM since 2 USM days were given back to Users***

***Due to high peak power induced in 4 x 10 mA and 16 bunch operation***

***New design installed in October shutdown with low pass filter in the gap ➔ reduced voltage***




## 8 RF copper cavities

2 cavities in booster

6 cavities in the storage ring

*3 straight sections (5metres) occupied in the storage ring*

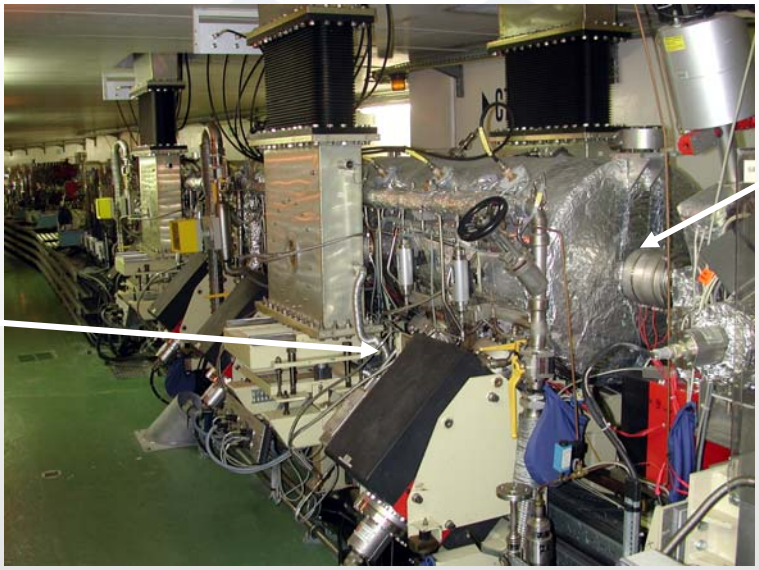
➔ *No major difficulties since 1992*

# What affected 2007 ?

***Restart of June 2007***

**Leak on <u>cavity 5</u> tuner port 2**

**Induced by a problem of welding on the port of the piston tuner during manufacturing in 1997 ➔ problem appeared 10 years later.**

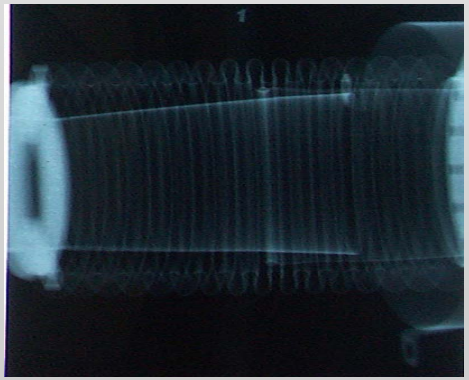


***September 2007***

**Strong outgassing in the <u>bellow</u> adjacent to cavity 3 from a defective RF finger in 16 Bunch**

**Current limited to 70 mA**

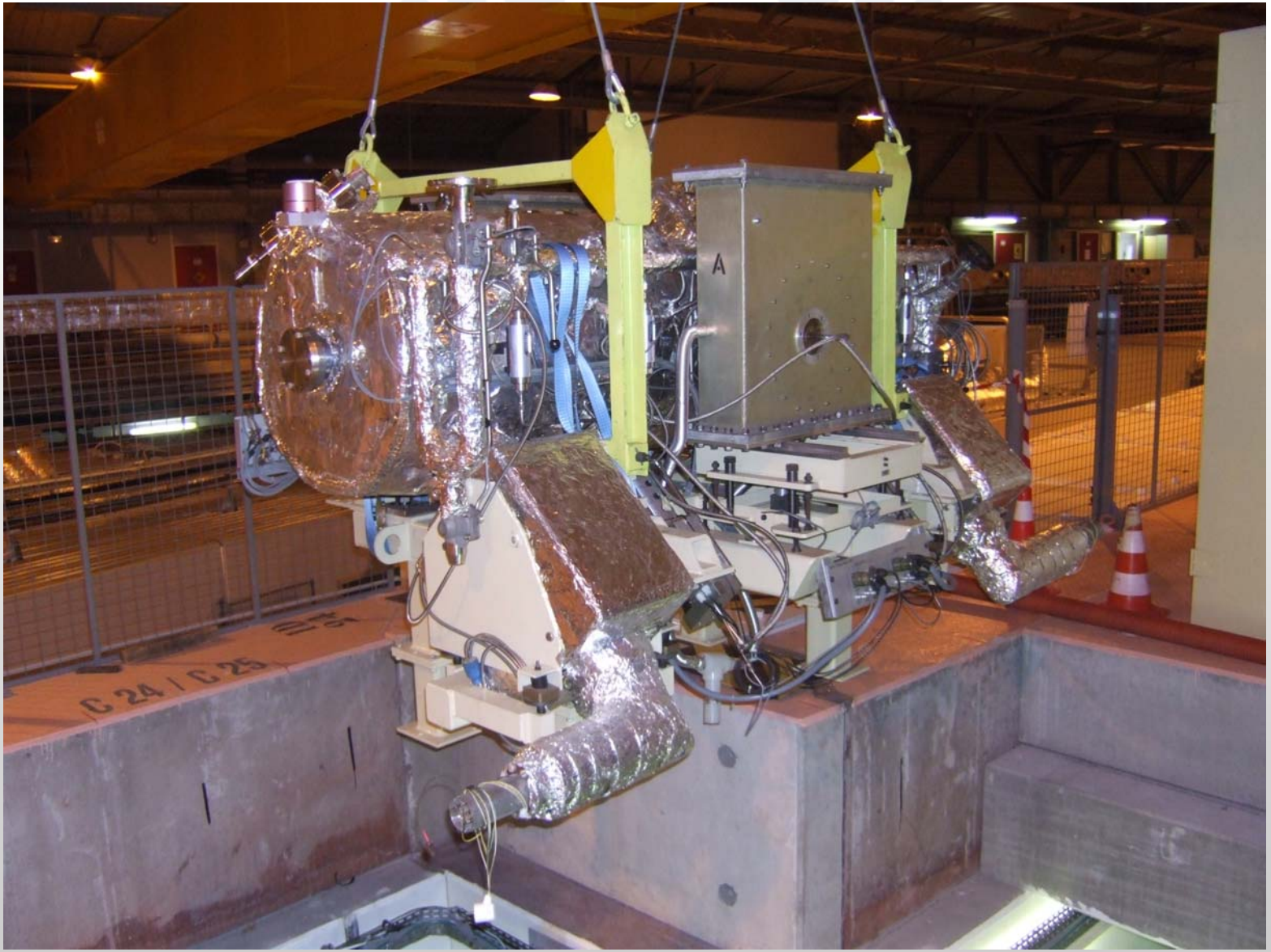
**Operation without cavity 5 for 6 months**



# Operation without cavity #5

- **DECISION**: no further risk for operation → stop powering Cavity 5
- **11th June:** start of the run without TRA3 / Cav 5&6
  - Fall back RF working point for 200 mA:
  - HOM detuning not perfectly reliable ⇒ 2/3 filling for Landau damping
- **19th June MDT:** Implement operation with 5 cavities
  - Disconnect leaky cavity 5, tuners on parking position
  - Setup operation at 200 mA including HOM detuning
  - Successfully applied at 200 mA until Christmas shut down
- Existing **spare Cavity prepared** to replace Cavity 5 during Christmas shut down
  - Baked * RF conditioned on RF power teststand using TRA2
- **Winter shutdown:**
  - Replace RF fingers upstream and downstream pair cavity3&4
    Cavities carefully vented, baked out
  - Replace cavity5 and baked out
  - Winter shutdown shortened by 3 days for RF conditioning and beam restart
- **January restart:**
  - No major difficulties to restart beam
  - But slow vacuum conditioning
  - After restart, still strong vacuum out gassing depending of the working points
    ➔ need more RF conditioning

# Replacement cavity 5



# Hard time with SY cavities

**Fall 2007**, air leak appears on a small pick up feed through used for measurement

- Cavity 1&2 put to atmospheric pressure during winter shutdown

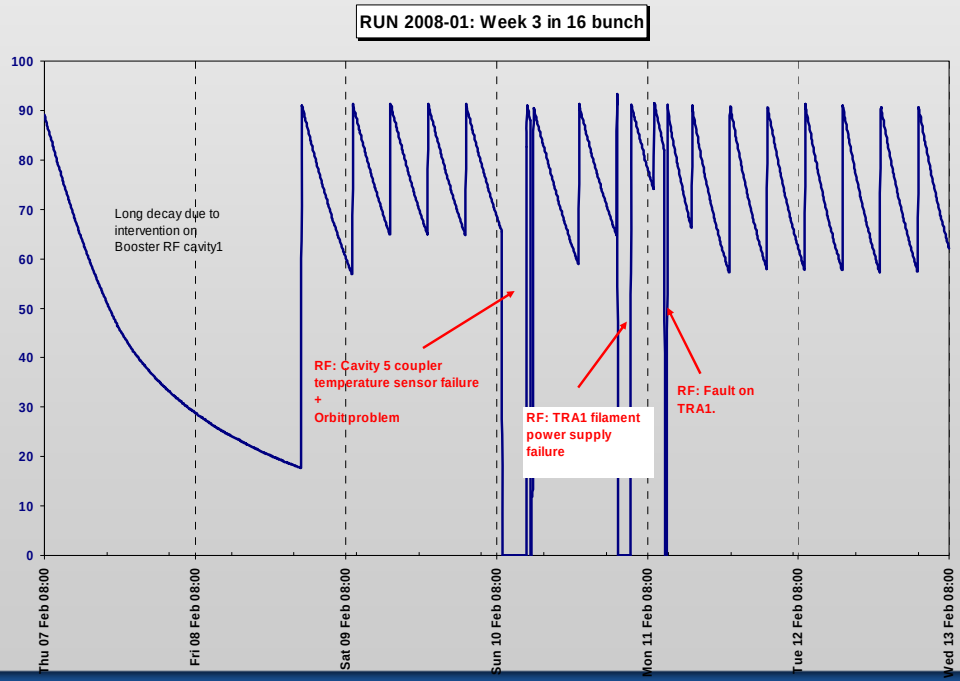
  ➔ *Feed through replaced and cavity reconditioned*

- Then a leak took place in the RF coupler

  ➔ *Coupler changed at the end of the shutdown and reconditioned*

- 2 weeks after the restart again a leak on the exchanged coupler

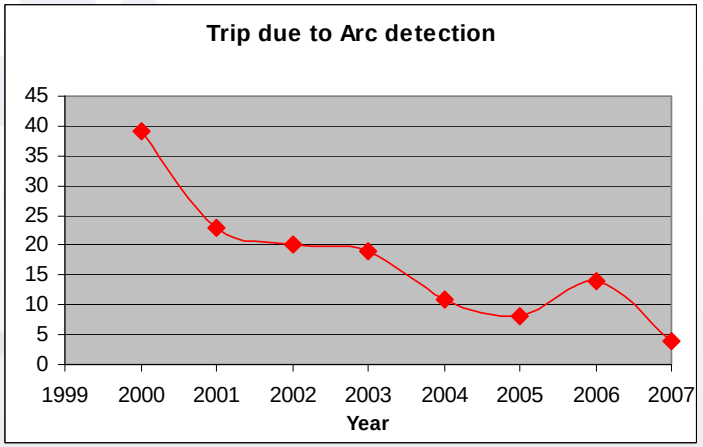
  ➔ *Coupler changed in emergency during user service and reconditioned*

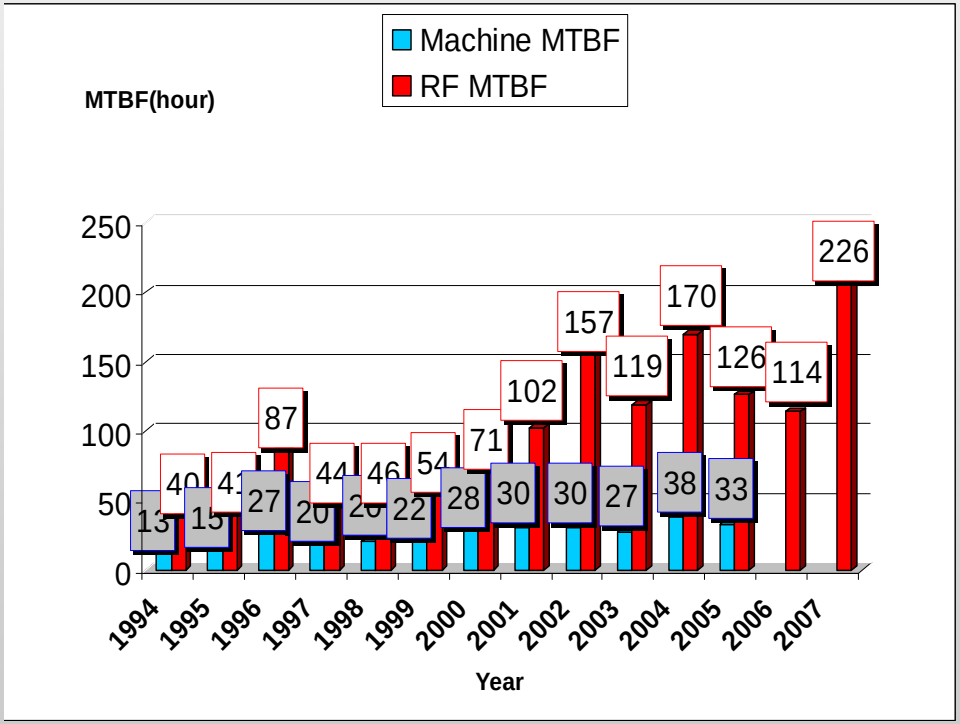


## Record RF-MTBF in 2007:

**Only 24 RF trips,**
**despite severe cavity vacuum problems**

- **Low Level RF: 0 trip** ☞ benefit from preventive maintenance
- **Klystrons: 4 trips** ☞ instabilities &Vacuum interlocks
- **Klystron auxiliaries: 2 trips**
- **HVPS: 1 trip** ☞ crowbar due to thunderstorm
- **Arcs: only 4 trips**
  ☞ noise floor
- **Control: 2 trips** ☞ 1 unexplained driver disable by PLC, 1 circ. Load interlock wrongly cabled on cavity interlock chain
- **Cavity 5: 1 break down**
- **Other cavities: 10 trips** ☞ breakdowns (Cav 1 & 3), overvoltage (Cav 4)



# Storm activity

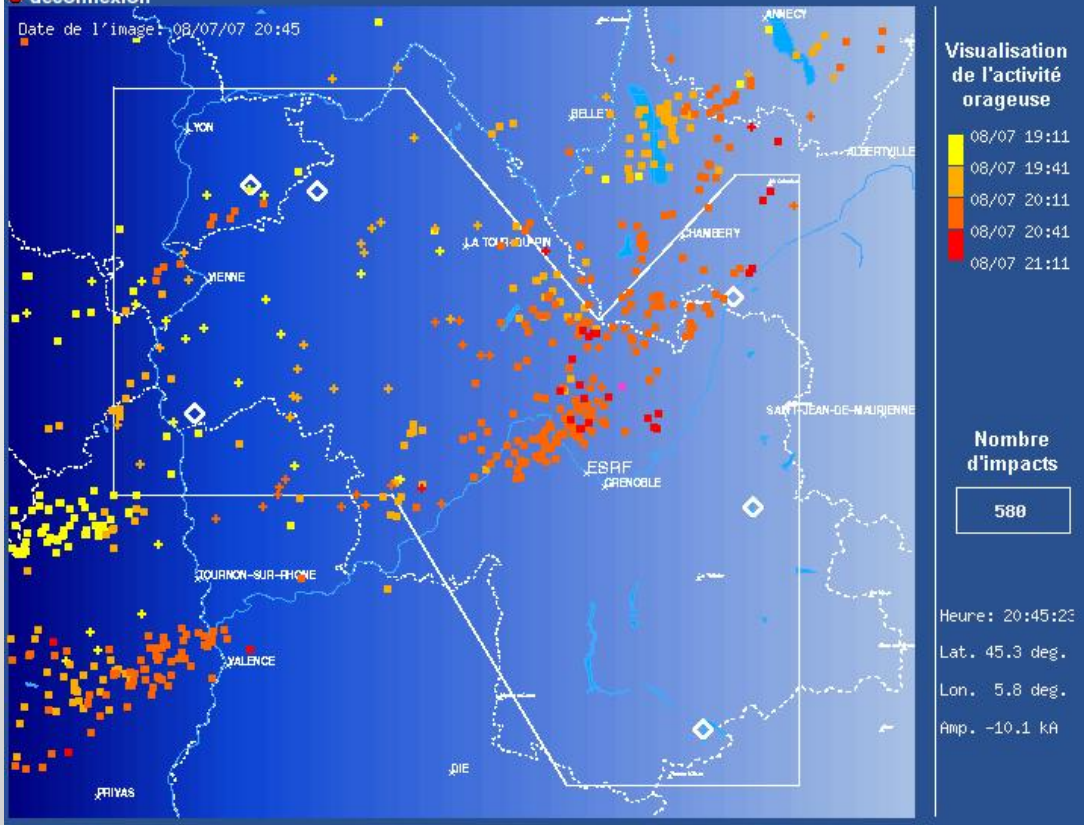
File Edit View Go Bookmarks Tools Help

http://www.meteorage.fr/cgi-bin/catsweb/obsweb/obsweb.pl?sid=38cf5d7caf3dde

ESRF Trouble Ticket | JLOGBOOK | Operator's main WEB ...

Observation WEB | Meteo France - Carte de prévisions ... | Calepin Montagne, Ephémérides, P...

déconnexion




Visualisation de l'activité orageuse

08/07 19:11
08/07 19:41
08/07 20:11
08/07 20:41
08/07 21:11

Nombre d'impacts

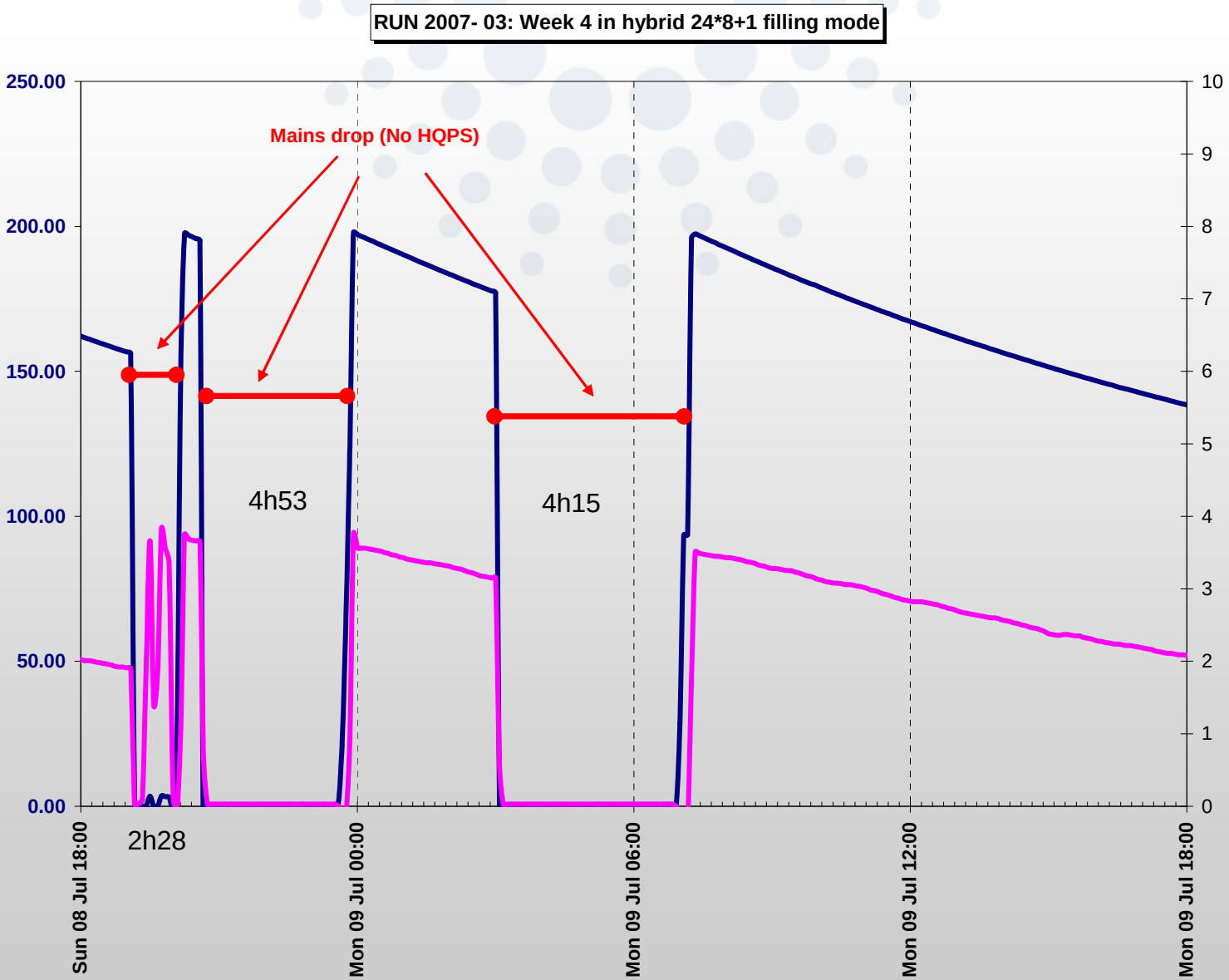
580

Heure: 20:45:23
Lat. 45.3 deg.
Lon. 5.8 deg.
Amp. -10.1 kA

Done

**Sunday 08/07/2007 evening**
**500 impacts in 2 hours**

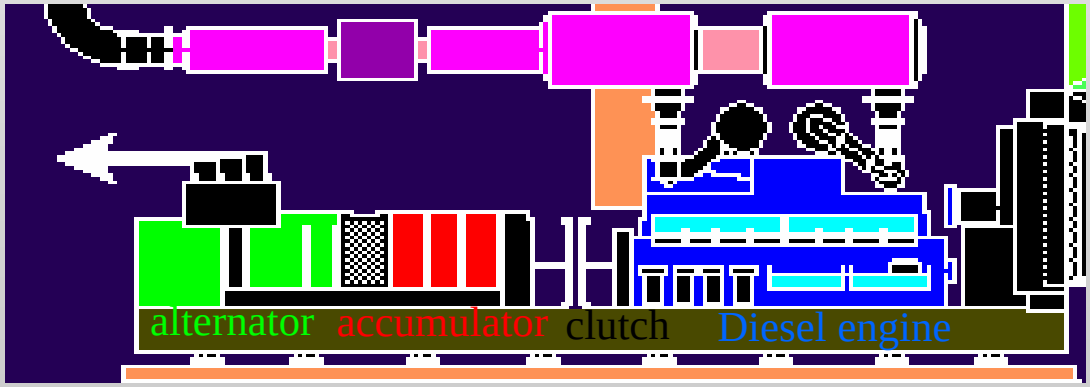
# Storm activity



# HQPS 1 is stopped

- The **HQPS1 system** run with difficulties its last months of operation.
  ➔ The stop took place in September 2007.
- *The arrangement of an accumulator with a diesel engine through an electro-magnetic clutch is the origin of our problems. Suppressing the clutches and the diesel engines is the way to resolve this situation safely*
- ➔ 8 units over 10 were sold
  ➔ Unit 2 kept to avoid any lack of evidence in the damages for the legal case.
  ➔ Unit 1 refurbished to protect ESRF accelerators during long cuts linked to the HQPS2 system

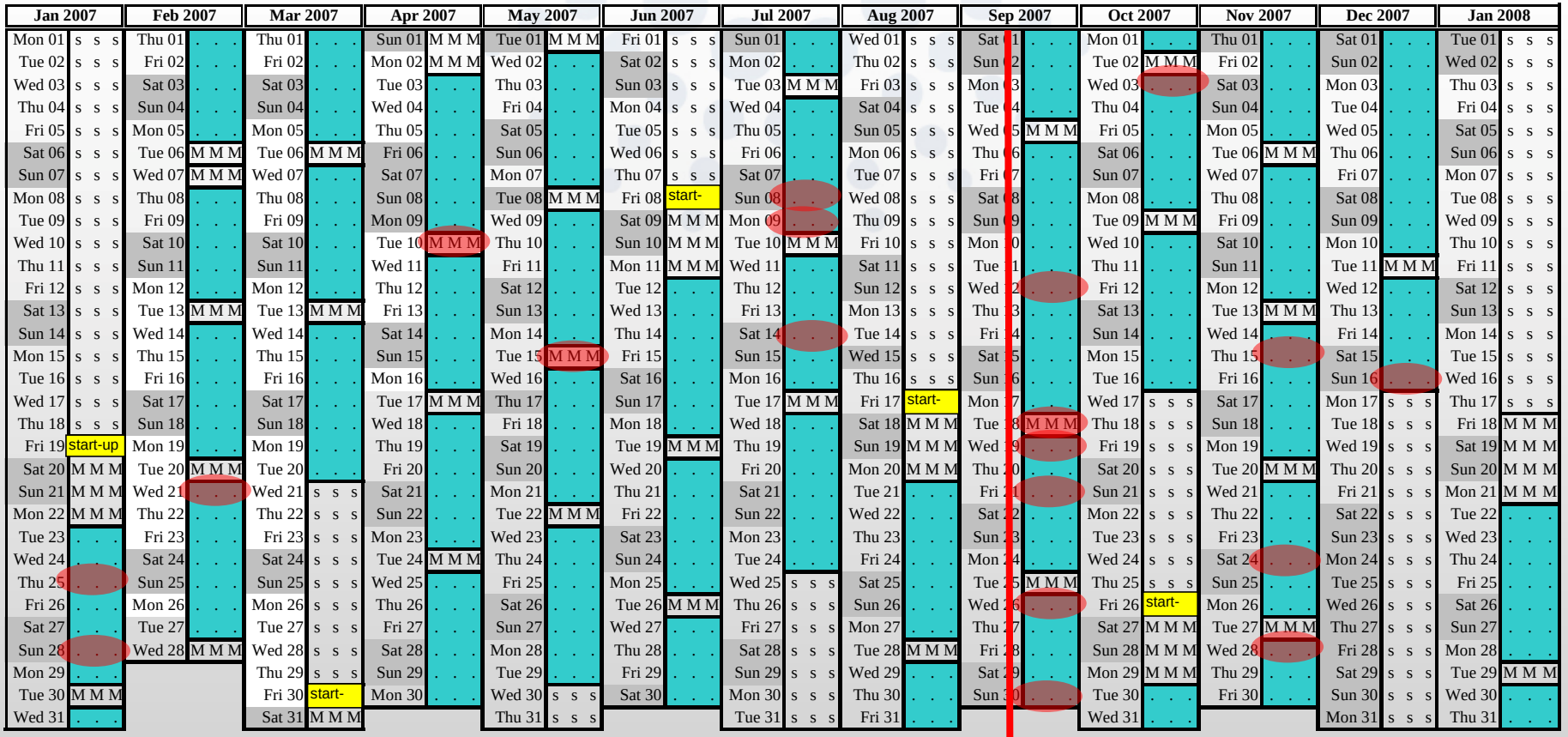
*Origin of the problem:*
Magnetic field leakage at the clutch location inducing eddy currents in the crankshaft and in bearings




*HQPS1 was divided into 10 units of ~ 1 MVA*

# What affected 2007 ?

## The Beam Losses due to the absence of HQPS + Mains drop



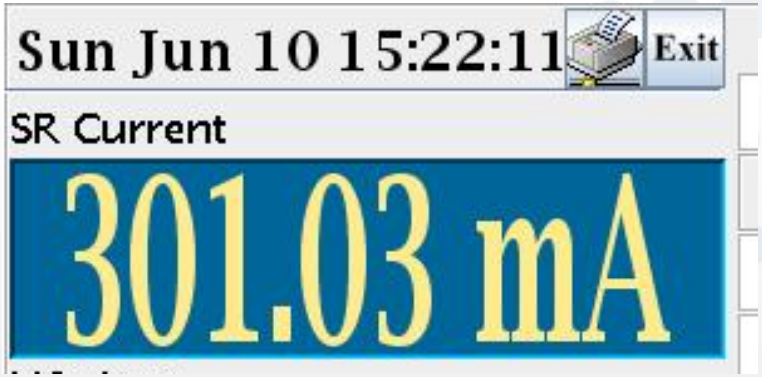
# HQPS 2 is starting

- Build a system of 14 units able to sustain 9.3MW during 12 seconds
- Reduced coverage of the protection (no permanent protection of the beam).
  The electrical part will have to cover 3 multiple drops of less than 3 seconds.
- “Long cuts” above 3 sec are guarantied by the public body not to append more than twice a year.
  - ➔ critical equipment powered by a genset (the old KS1 from HQPS1 refurbished 1MW power is needed after a beam dump).
- Installation finished mars 2008.
- Individual tests unit by unit: April 2008
- Site acceptance tests : May and June 2008.
- HQPS2 ready : summer 2008

# Good weeks !!

| Year 2007 | | |
|---|---|---|
| **Run number** | **Week number** | **Hours of beam delivery without a single failure** |
| **Run 2007-01** | Week 2 | 100 |
| | Week 3 | 96 |
| | Week 4 | 92 |
| | Week 6 | 97 |
| | Week 8 | 144 |
| **Run 2007-02** | Week 1 | 126 |
| | Week 2 | 74 |
| | Week 3 | 131 |
| | Week 5 | 144 |
| | Week 6 | 125 |
| | Week 8 | 108 |
| **Run 2007-03** | Week 1 | 168 |
| | Week 2 | 102 |
| | Week 3 | 144 |
| | Week 4 | 90 |
| | Week 6 | 92 |
| **Run 2007-04** | Week 2 | 168 |
| | Week 3 | 114 |
| | Week 4 | 89 |
| | Week 7 | 94 |
| **Run 2007-05** | Week 3 | 109 |
| | Week 6 | 86 |

# 300 mA operation

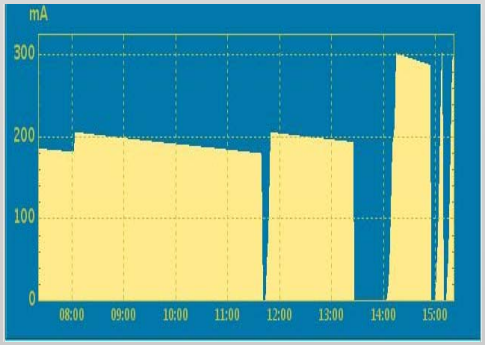



- Longitudinal feedback is operational
- 300 mA reached during MDTs in June 2007 in uniform filling mode with the longitudinal & transverse feedback
- Further test postponed due to the failure of cav5

- Ramping to 300mA will resume next run during machine time
- Machine time will later be dedicated to qualify the beamlines concerning radioprotection

***With the present policy of pre-conditioning an ID chamber before installing it on a beamline, bremsstrahlung produced in the narrow aperture ID chambers and the in-vacuum undulators (level multiplied by 9/4) will remain compatible with the maximum dose rate of 0.5 microSv/h around the hutches that corresponds to unexposed personnel within the European legislation.***

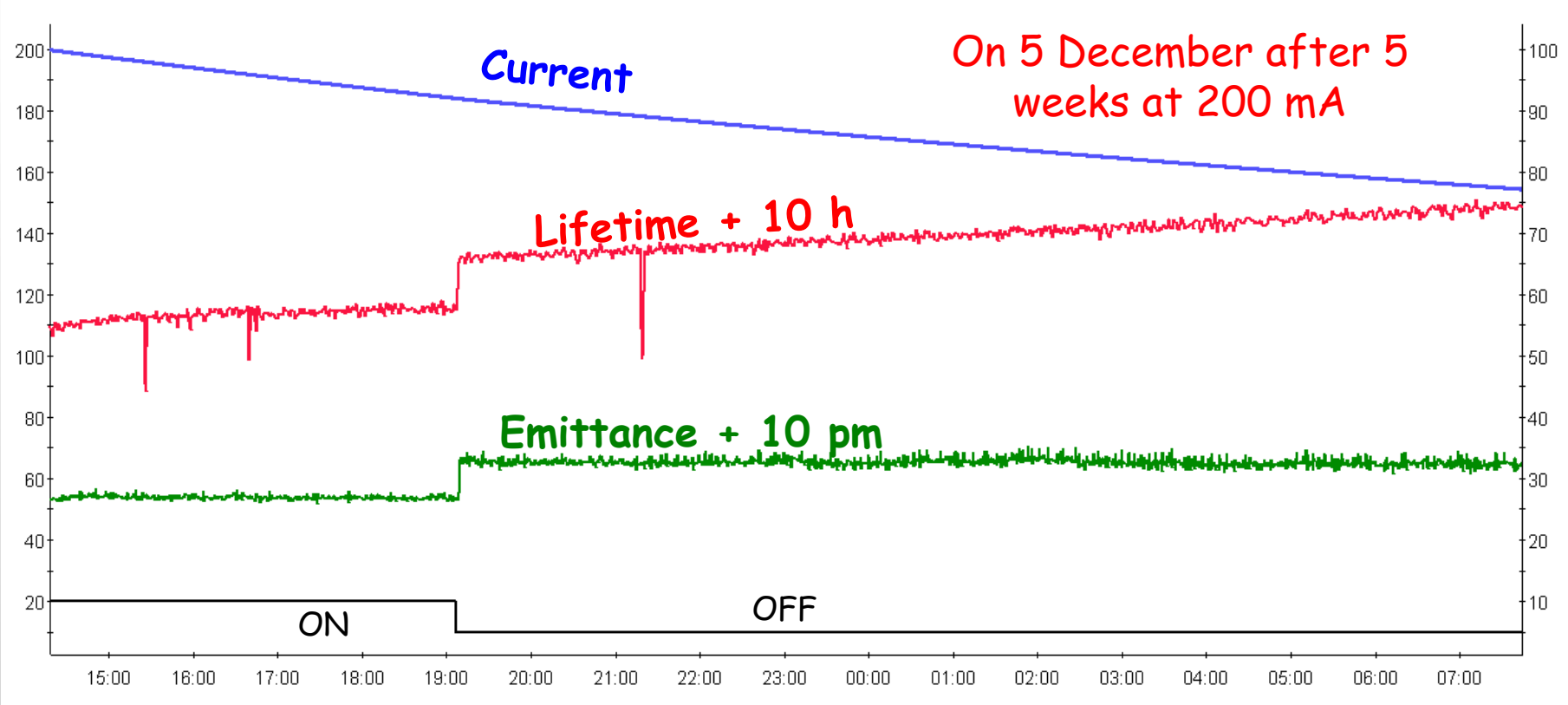
- Machine time will then be dedicated to qualify the beamlines for optics and instrumentation




***No redundancy for RF power source without RF upgrade***

# Transverse feedback is operational

Transverse Multibunch Feedback was experimentally used during Run 2007-05 in USM in uniform to stabilize beam ion instabilities.

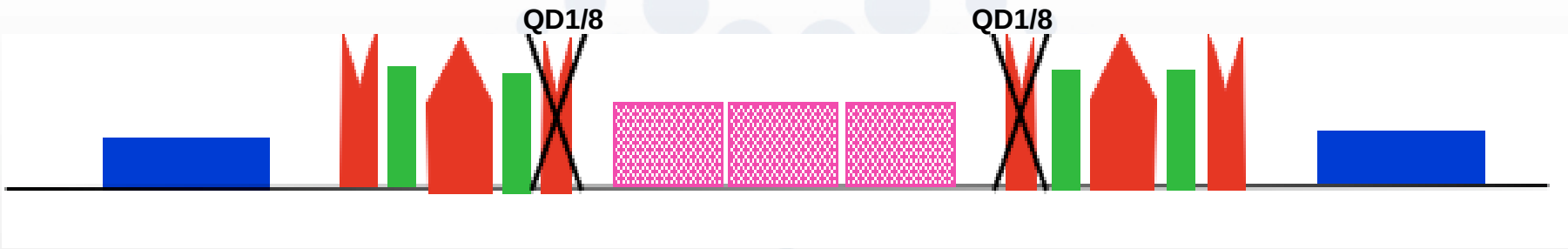



Transverse multibunch will from now on be permanently used during USM in uniform filling to guarantee a lower vertical emittance

*(but still a reduction in lifetime observed due to ions which do not escape, increase of local pressure ➔observation of even worse lifetime in uniform than 2*1/3 with MDT conditions).*

# A new lattice is operational

- **Goal: Increase ID length from 5 to 6 metres**



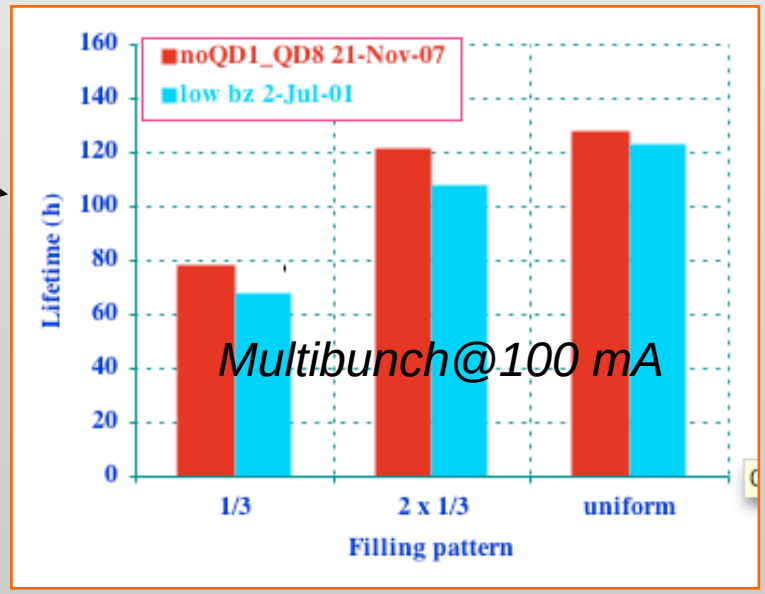

- First step: the 2 quadrupoles (QD1 and QD8) on each side of the IDs are not powered for all cells

New lattice implemented in USM fall 2006

**The first version of the lattice with βz = 3.5 m υz = 12.39 suffered from a moderate lifetime**
**In 2007, a lot of efforts were dedicated to improving the lifetime**

- **Reduce βz = 3 m**
- **Increase of the vertical tune by one integer**
- **Re-optimisation of sextupole settings**

➔ **Now back to nominal lifetime**

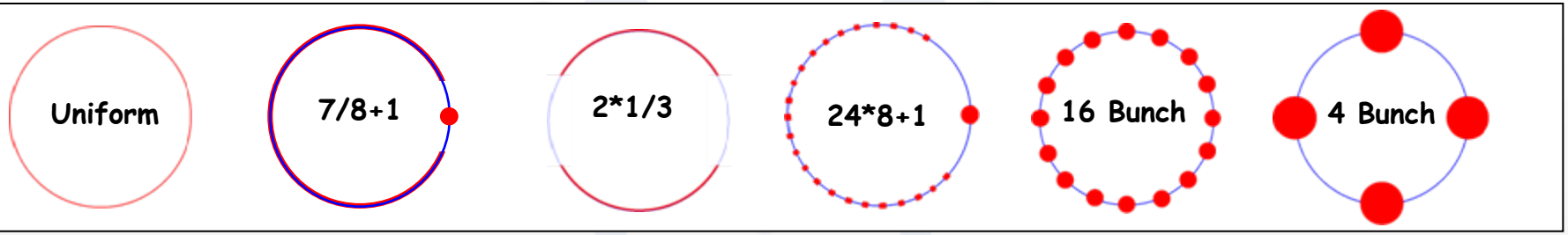



- Next step:

Design of a CV6000 vessel (initiated)
QD1 and QD8 removed
6 m long IDs installed

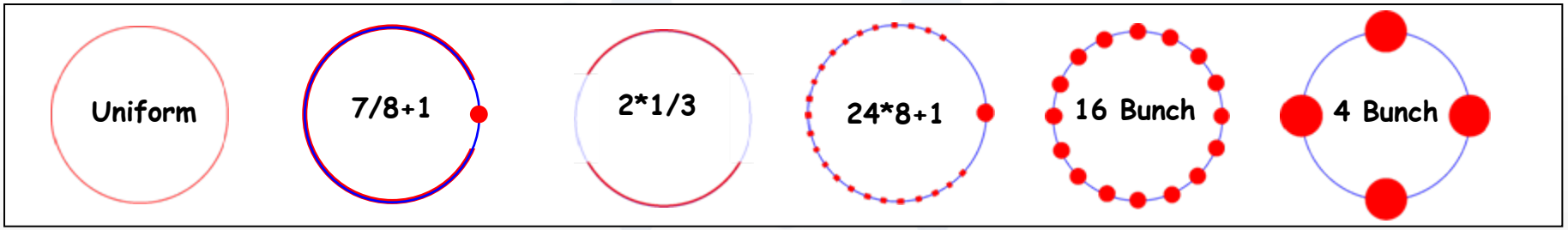
*Test will be done for the machine straight section*

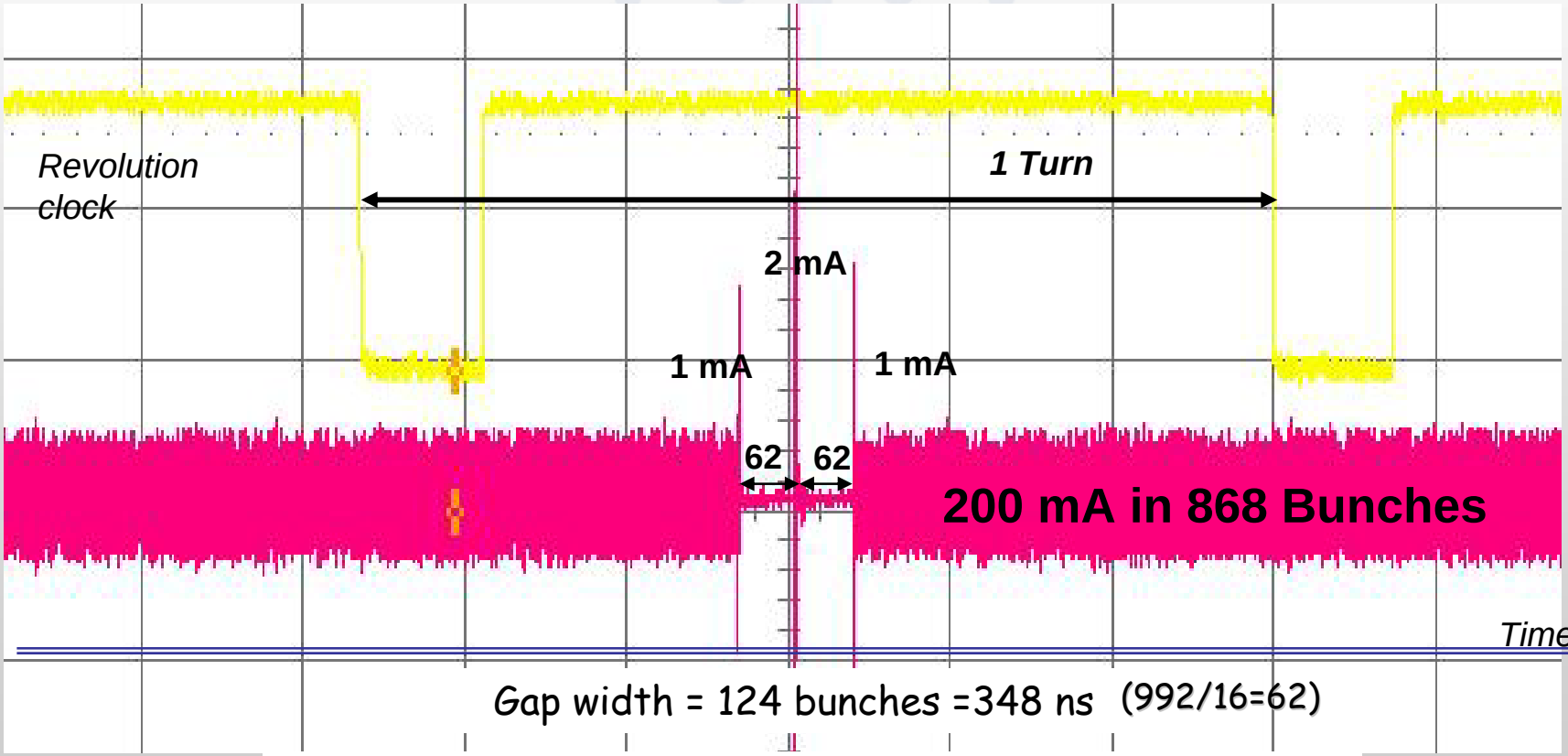
# Filling modes




| | Current (mA) | Lifetime (Hours) | Refill Number | Current per bunch |
|---|---|---|---|---|
| **Multibunch** | | | | |
| **Uniform (992 bunches)** | **200** | **80** | **2/day** | ***0.2 mA*** |
| *7/8+1* **(868 bunches)** | *200* | *72* | *2/day* | *0.23 mA & 2 mA* |
| *2*1/3* **(704 bunches)** | *200* | *65* | *2/day* | *0.28 mA* |
| **Time structure** | | | | |
| 24*8+1 Hybrid | 200 | 30 | 2/day | 1 mA & 4 mA |
| 16 Bunch | 90 | 12 | 4/day | 5.62 mA |
| 4 Bunch | 40 | 6 | 6/day | **10 mA** |

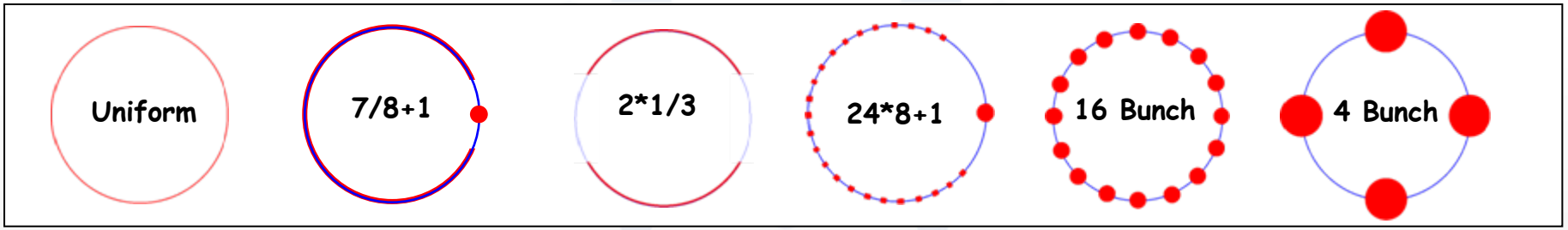
# 7/8+1: A fine compromise




Single bunch centred in the middle of the gap

# 7/8+1: A fine compromise




Chromaticity identical to multibunch:

➔Lifetime intermediate between uniform and 2*1/3 for the multibunch part

➔ Maximum single bunch current = 2.5 mA

➔ Refill current = 2 mA, Lifetime = 15 hours

Small vertical emittance: 25 pm

No emittance growth due to ion trapping thanks to the presence of a gap

Injection time slightly longer than multibunch
(injection speed reduced by a factor 2 and cleaning process)

Cleaning performance identical to other timing modes
(for Moss Bauer experiments)

# Benefit for ID9

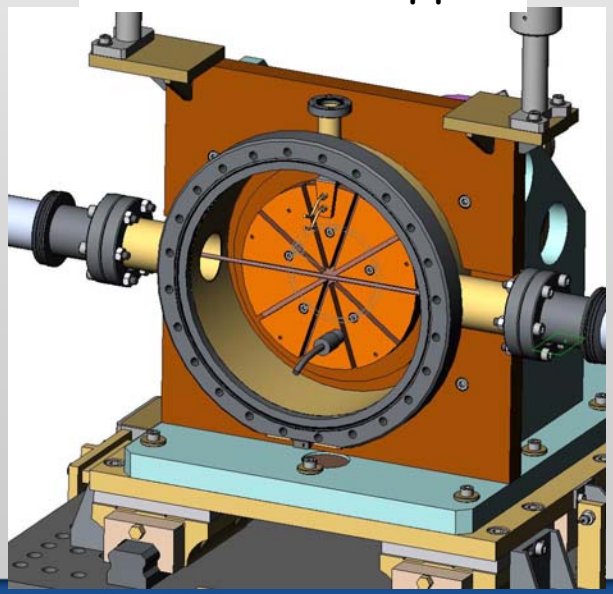
1) Pump probe experiments could be done with a filling pattern which does not penalise multibunch users.

2/ lower emittance than in other timing modes (smaller and more stable focus)

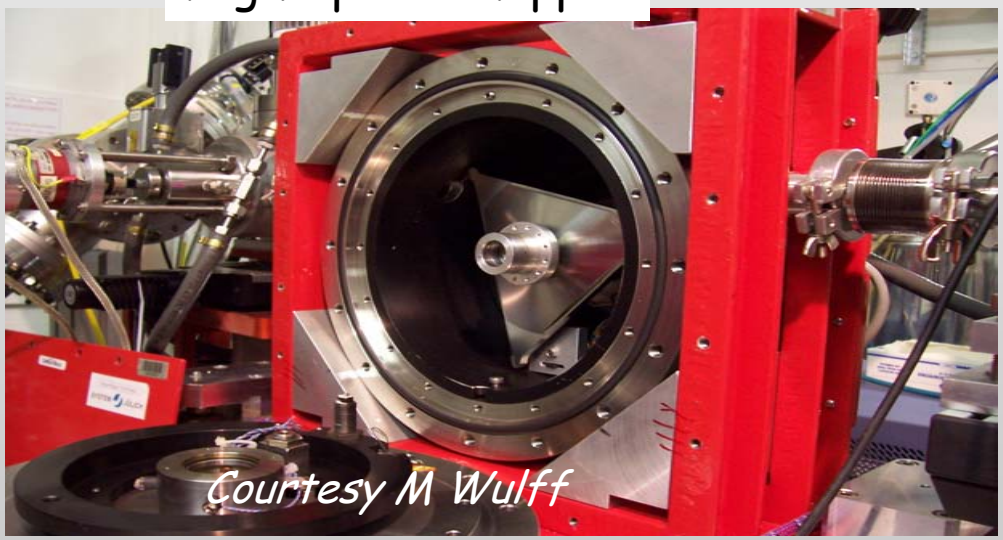
3/ shorter X-ray pulse, 60-80 ps instead of 90-110 ps (16 bunch mode)

The lower bunch charge, 2 mA compensated by running some experiments at 3 kHz instead of 1 kHz.
Higher heat load at 200 mA for a timing experiment reduced by the heat load chopper.

Heat load chopper

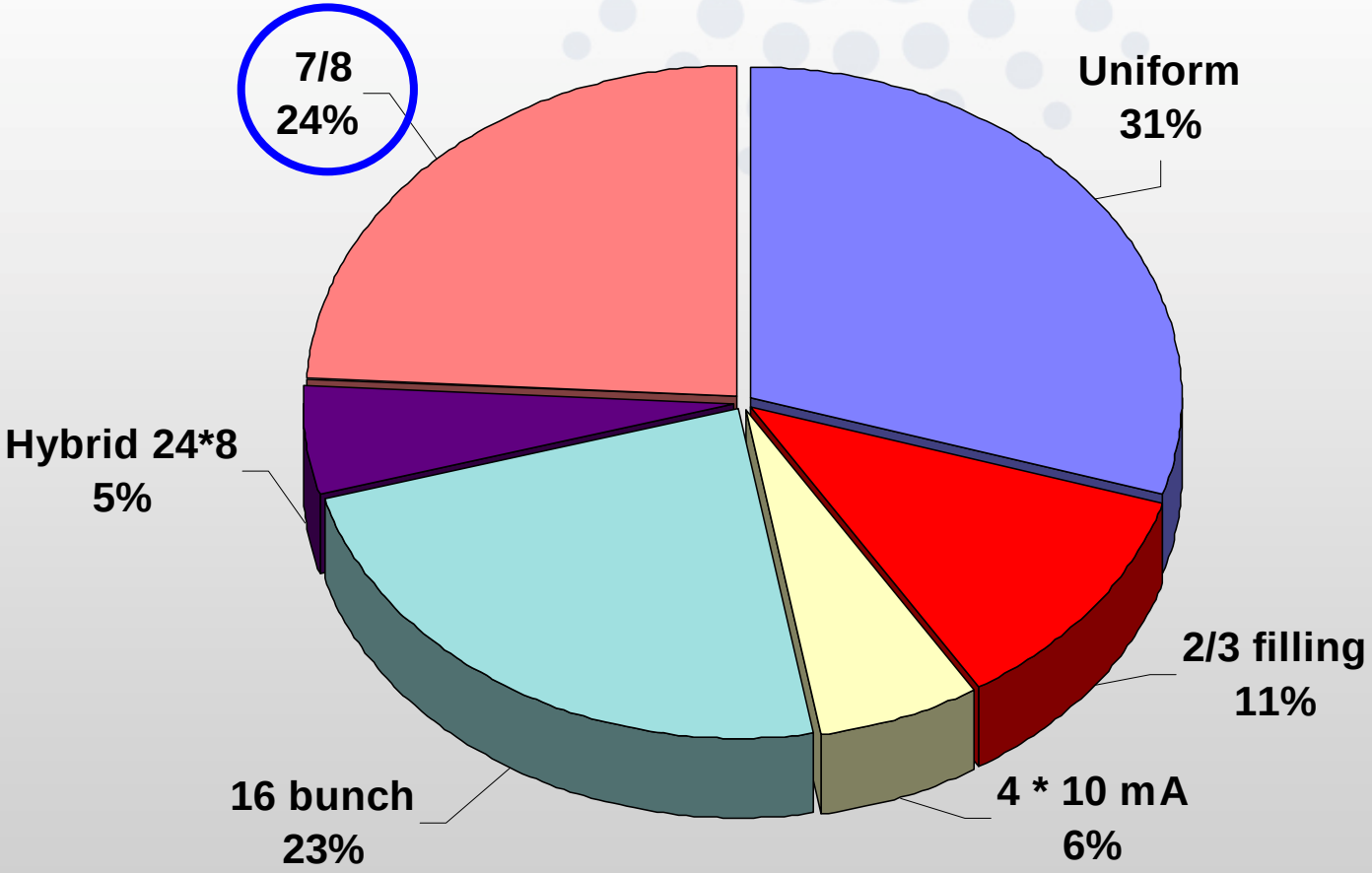


High-speed chopper



# Filling modes in 2007

*Newcomer in 2007*



# Beam stability and filling patterns

| | Current (mA) | Lifetime (Hours) | Refill Number | Current variation between refill |
|---|---|---|---|---|
| **Multibunch** | | | | |
| **Uniform** | **200** | **80** | **2/day** | **13%** |
| *2*1/3* | *200* | *65* | *2/day* | *18%* |
| **Time structure** | | | | |
| 24*8+1 Hybrid | 200 | 30 | 2/day | 30% |
| 16 Bunch | 90 | 12 | 4/day | 44% |
| 4 Bunch | 40 | 6 | 6/day | **50%** |

**Beam current variation**

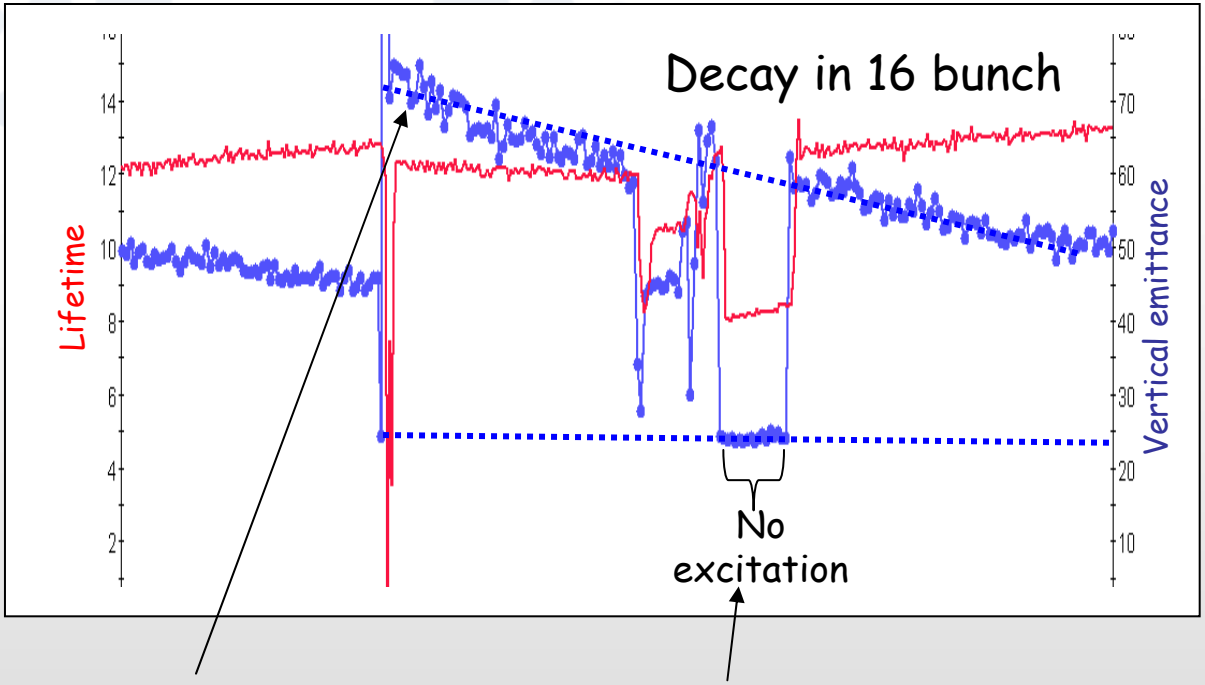
➔ Variation of thermal load on the beamline optics

➔ Variation of beam characteristics

(Position, emittances, energy spread, bunch length and **position stability**)

# Increasing lifetime

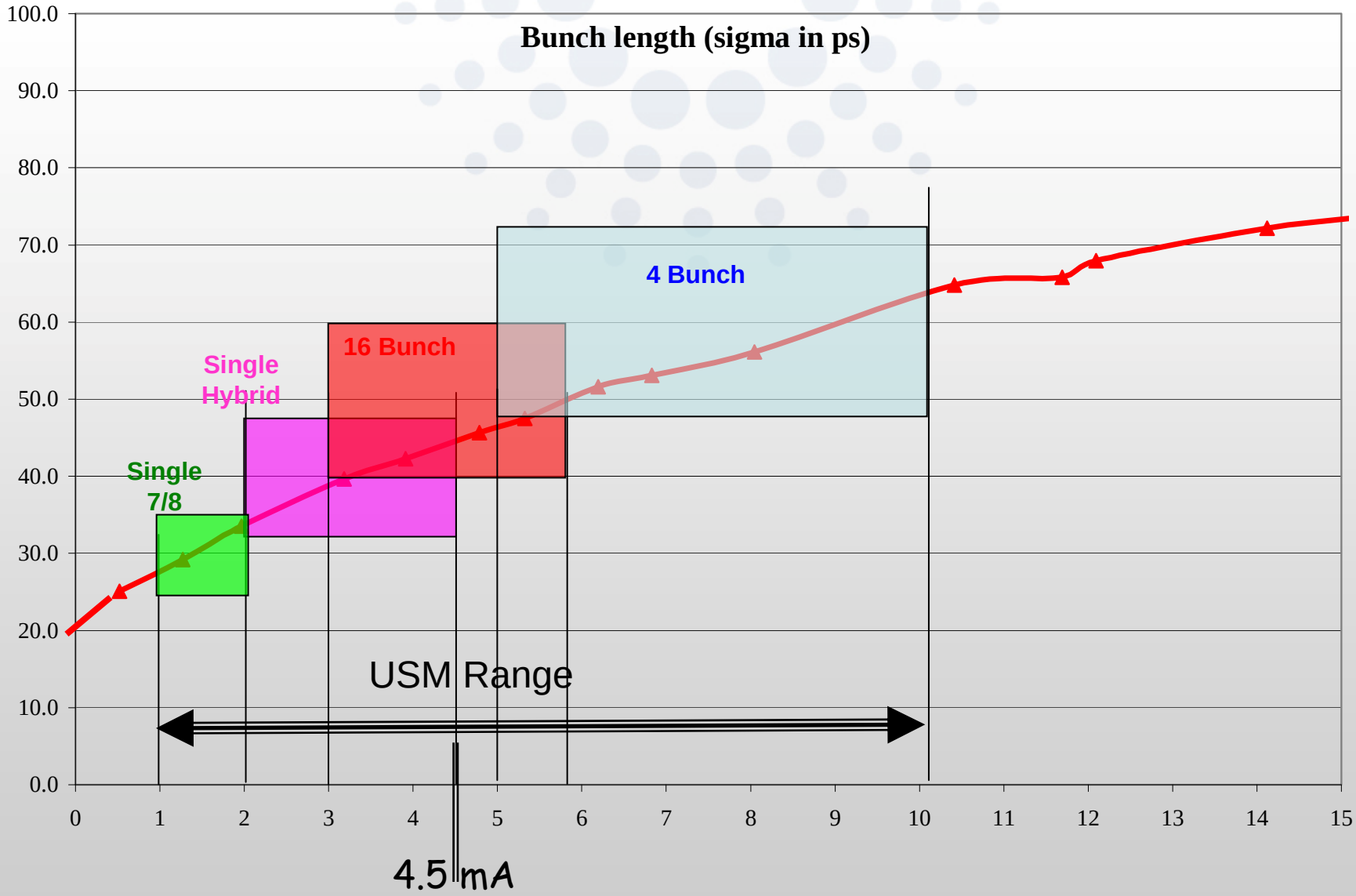
**In order to increase the lifetime (factor 2) the vertical emittance is blown up using vertical transverse excitation.**



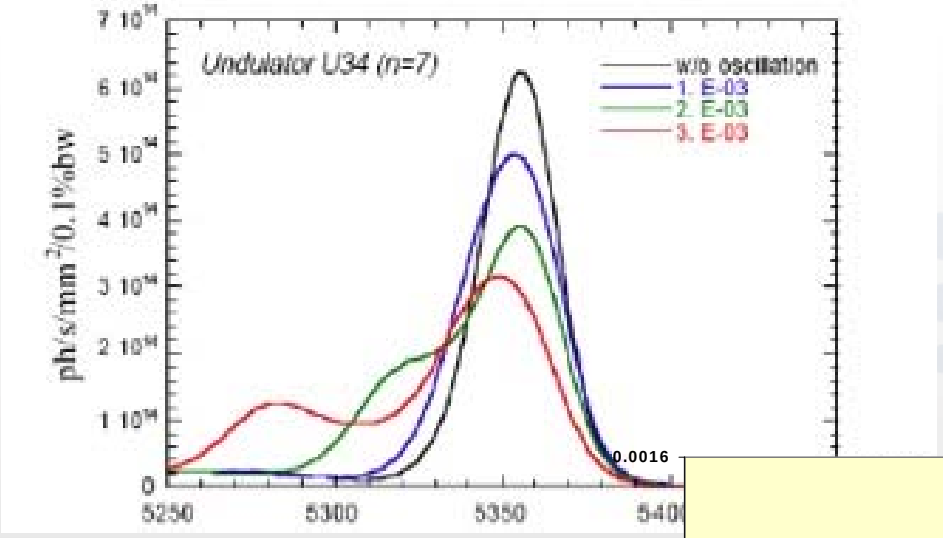

Vertical emittance: 70 pm *(with excitation)* ➔ 20 pm

| | | | |
|---|---|---|---|
| 4 Bunch | 3h30 | ➔ | 6h |
| 16 Bunch | 6h30 | ➔ | 12 h |
| Hybrid: | 18h | ➔ | 30 h |

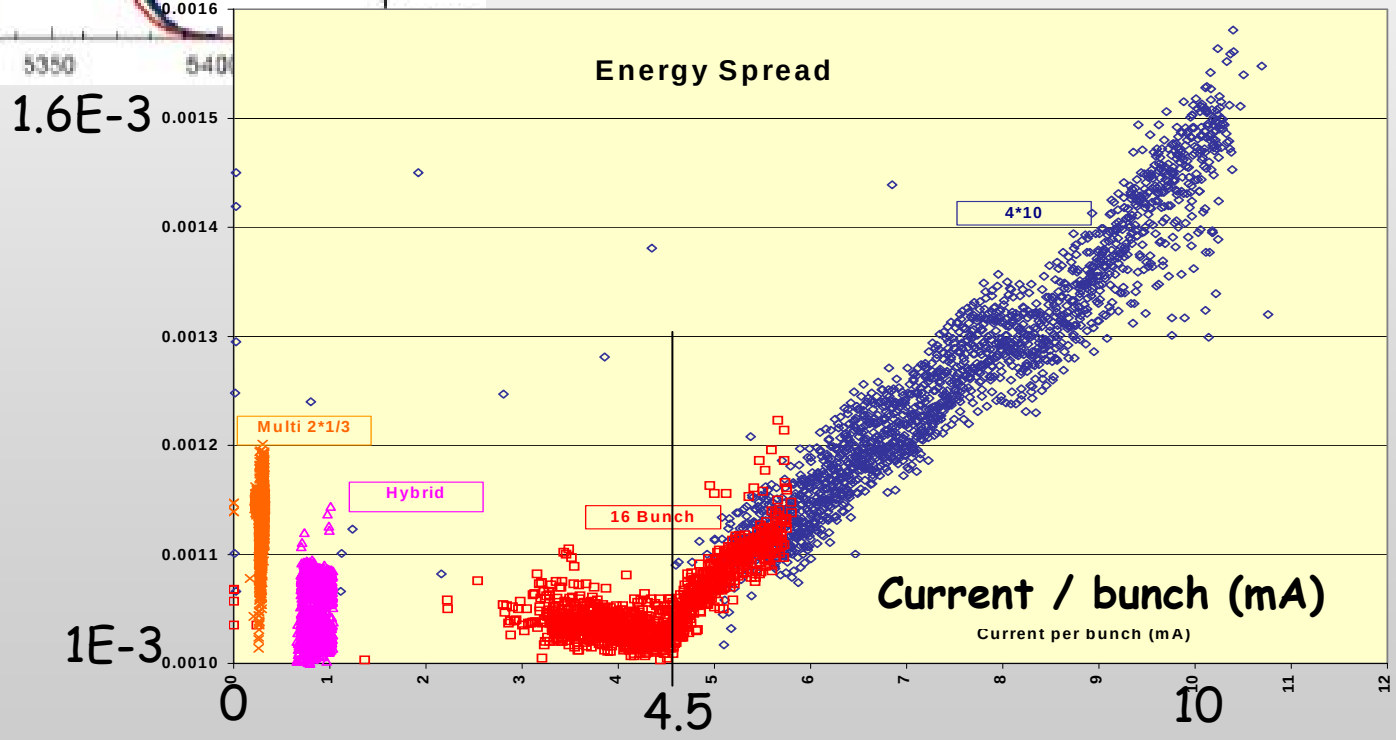
# Bunch Lengthening with current



# Energy spread variation




Energy spread increase induced by longitudinal instability in single bunch



# Position stability and filling patterns

**Electron beam position stability is affected by the varying heat-load resulting from the beam decay:**

✓Quadrupoles are displaced by a few tenths of μm due to thermal deformations of the vacuum chamber:

➔ 35μm rms beam motion *(from 0 to 200 mA),* corrected by slow orbit feedback.

✓Beam Position Monitors (BPMs) are also displaced by the same effect:

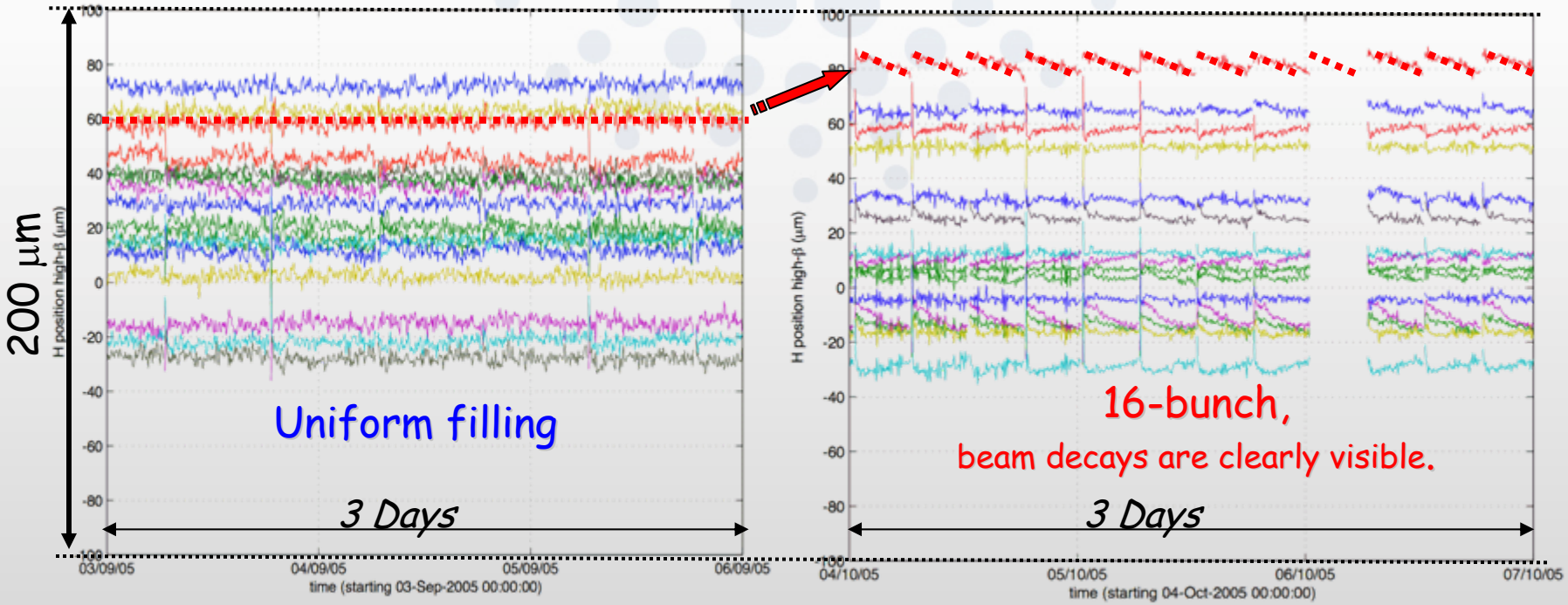
➔Identical to quadrupole motion but 0.5 μm ➔ negligible.

✓BPM readings are sensitive to the beam intensity:

➔ Compensated using a feed forward calibration.

# Position stability and filling patterns

**Horizontal absolute position in all straight sections over 3 days: the real picture**




The correction has limits: it evolves with time,
it depends on the filling pattern (worse in 16 bunch), on BPM maintenance…

<u>Better stability with reduced current variation from an operational point of view *(correction, calibration…)*.</u>

*However the final figure will not differ from today's in multibunch.*

# Topping up

We are already operating in topping up mode……with a repetition rate of a few times per day .

Improvement in progress for all modes :

1) The in-vacuum gap will not be open during topping up.

2) Position perturbation during topping up has to be reduced.

For multibunch:

3)The frequency of topping up could be increased if needed.

For time structure modes:

5) Topping up frequency must be increased to compensate for the short lifetime and to stabilize the beam parameters (Better stability and no beam blow up necessary for a decent lifetime) ➔ Refill every 5 minutes is envisaged

6) Cleaning in the injector is still under development.

7) Machine physics studies on the injector are in progress.

8) An upgrade of the booster power supply is part of the upgrade programme

*(No current increase foreseen in time structure, limited by heat load induced in the RF fingers*).

## Stability Criteria:

Emittance growth < 20%

➔ 10% on beam size and 10% on beam divergence

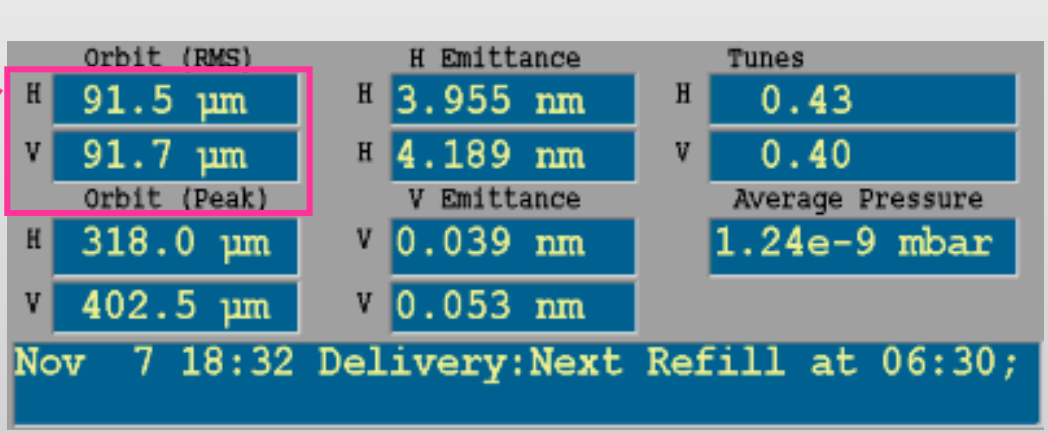
| | *Horizontal* | *Vertical* |
|---|---|---|
| Emittances | 4 nm | 30 pm |
| β function | 35 m | 3 m |
| Beam size | 380 μm | 9 μm |
| **Required stability** | **38 μm** | **0.9 μm** |

# Slow motion

*The electron beam position is continuously measured at 224 positions around the ring with a resolution of 1 µm with averaging.*

This deviation from the reference orbit is minimized by a *global correction by SVD method, which is computed every 30 sec.*

*The correction is applied at 96 positions in each plane using steerer magnets.*

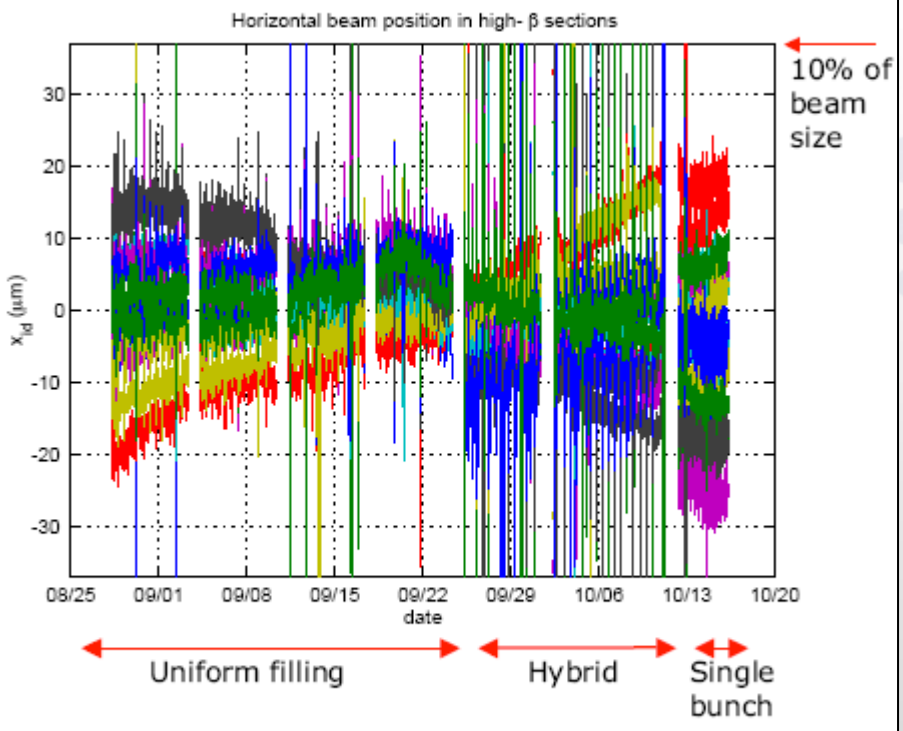



*The offset of the BPM and the calibration of drifts with beam intensity are periodically updated*

# Long term electron beam stability

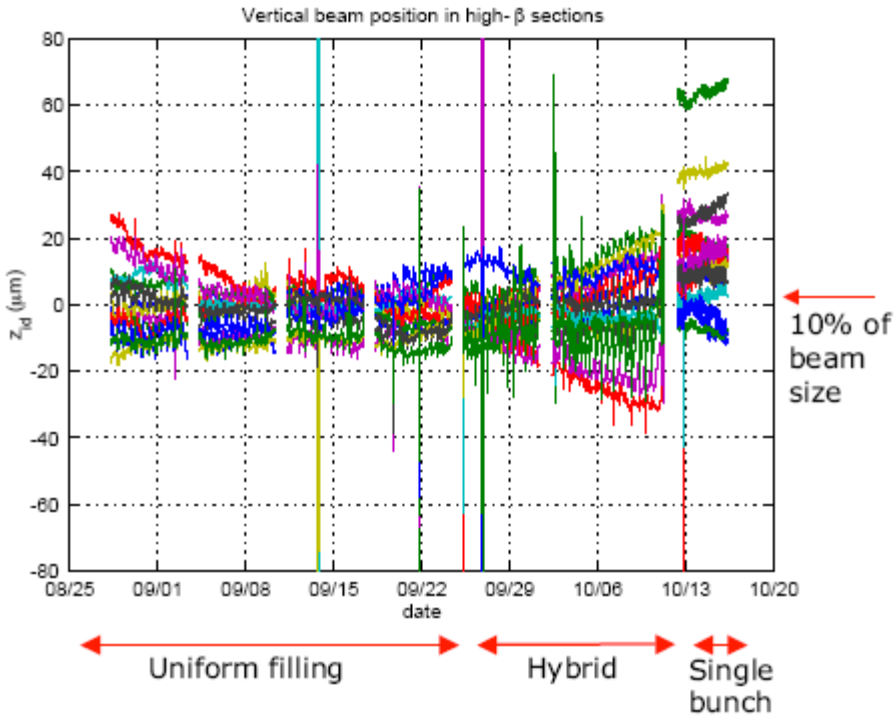
*(7 weeks)*

**Horizontal**




**Horizontal beam motion in the middle of high-β straight sections ($\beta_x$ = 35.1 m, $\sigma_x$ = 380 μm)**

**Vertical**




**Vertical beam motion in the middle of high-β straight sections ($\beta_z$ = 2.5 m, $\sigma_z$ = 9 μm)**

➔Within 10% of horizontal beam size for more than 6 weeks

➔ Visible influence of the filling pattern

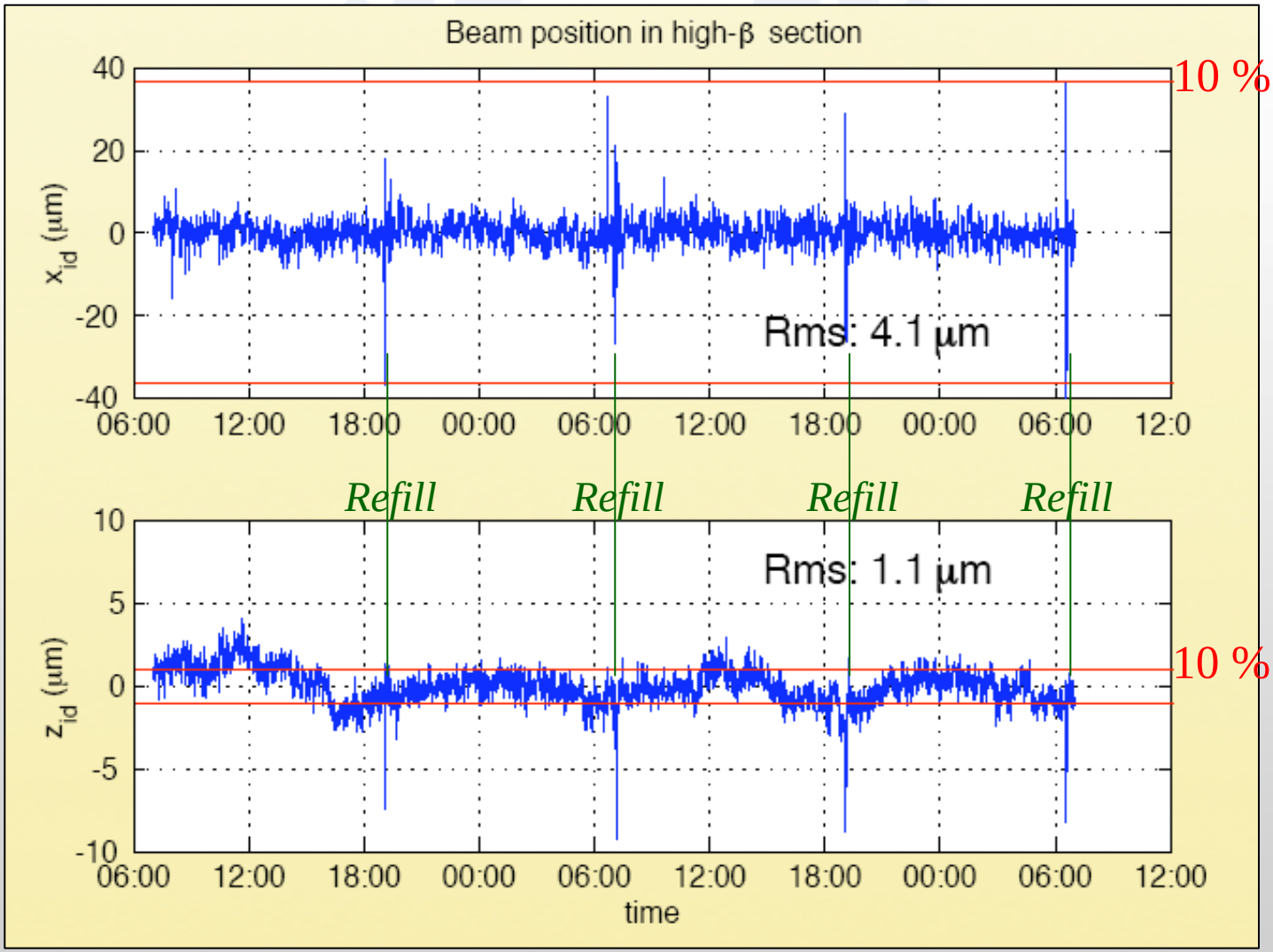
➔Exceed 10% of beam size over long term

➔Influence of the filling pattern

➔Problem of referential: the ground itself is not an absolute reference in that range.

# Medium term electron beam stability

(2 days, uniform fill)




The stability is corrected by the permanent closed orbit correction.

# Fast beam motion

Fast horizontal and vertical global feedback reduce the noise in a bandwidth from 0.1 to 150 Hz:

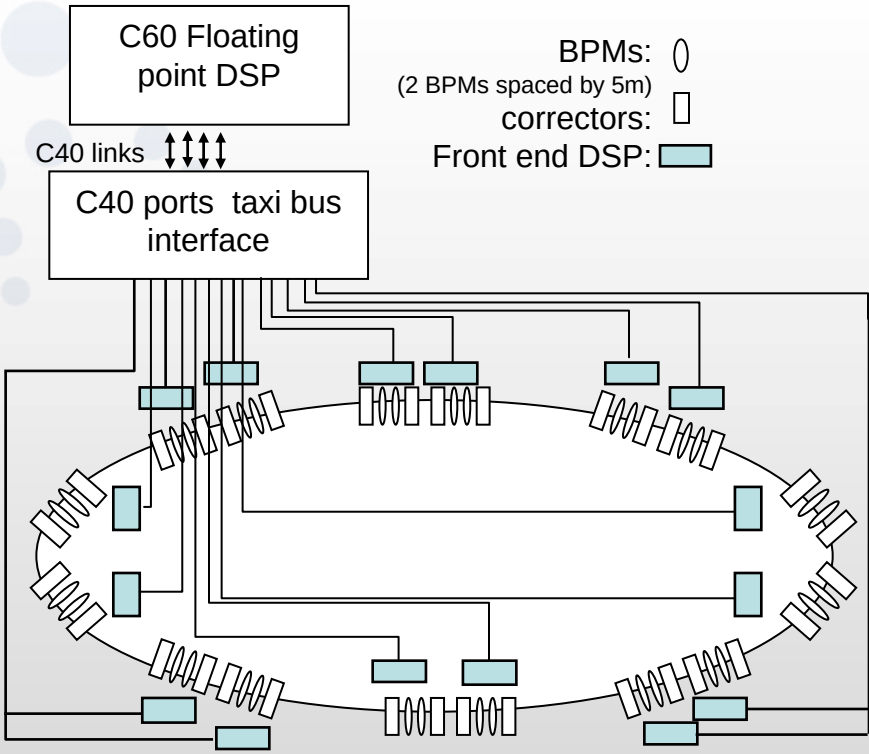
H: 32BPMs and 32 correctors

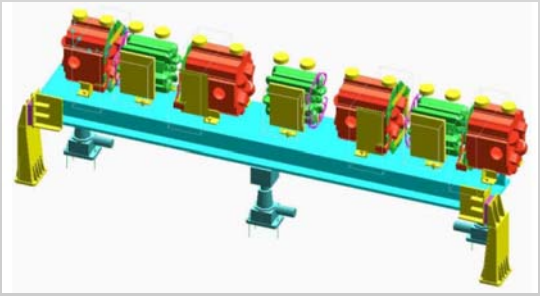
V: 16BPMs and 16 correctors,

4.4 kHz correction rate

Gain = 4 in horizontal

Gain = 2 in vertical



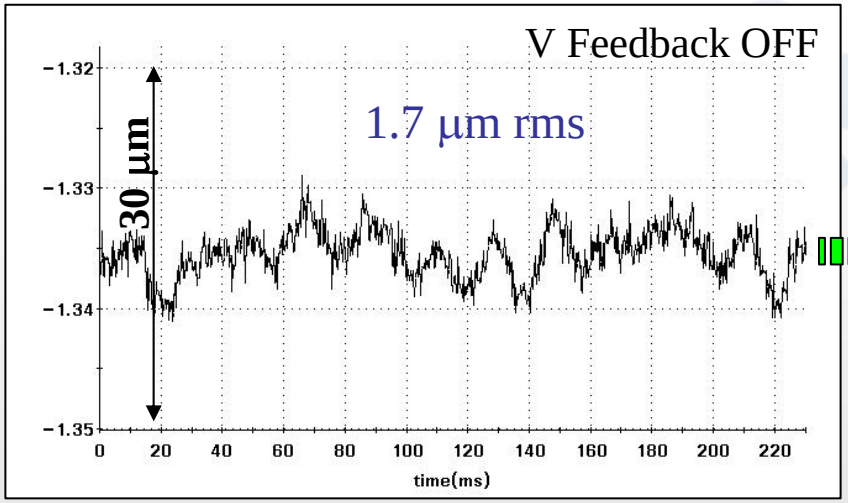



*Damping material are located on each side of the girders to reduce vibration effects*

*Gain of 3 in the horizontal plane.*

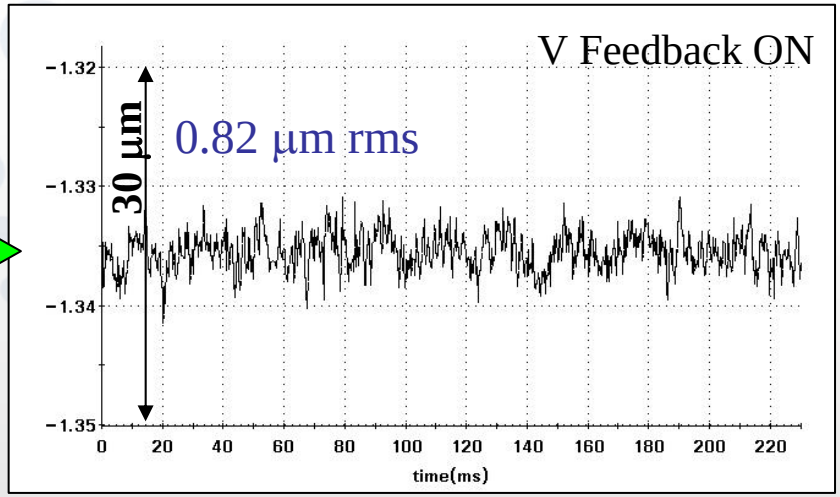
# Fast beam motion

Vertical electron fast beam motion

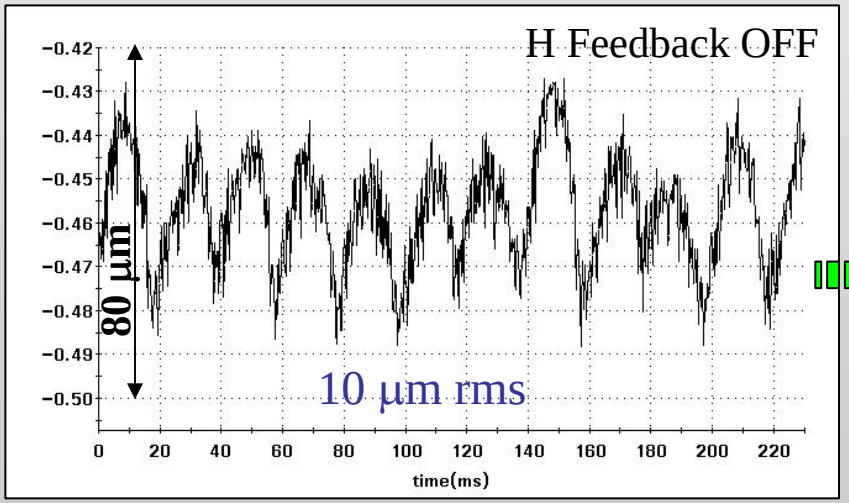



Gain 2

Vertical electron fast beam motion

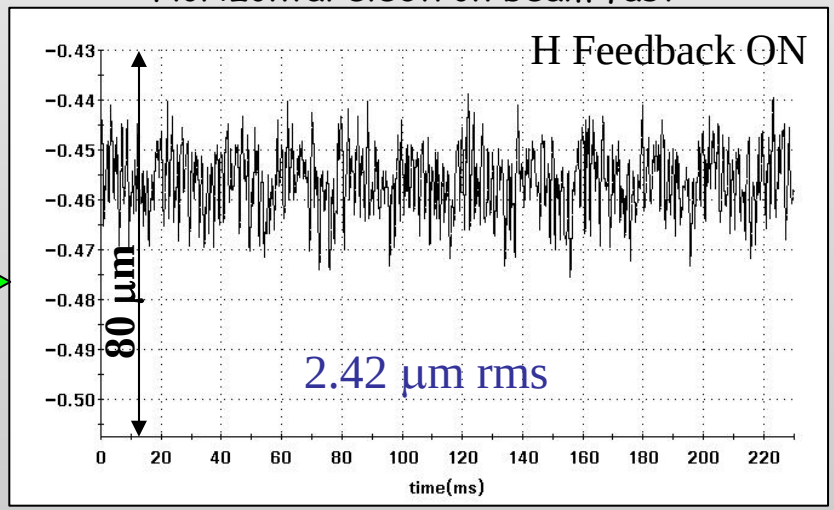



Horizontal electron fast beam motion




Gain 4

Horizontal electron beam fast



# Typical stability

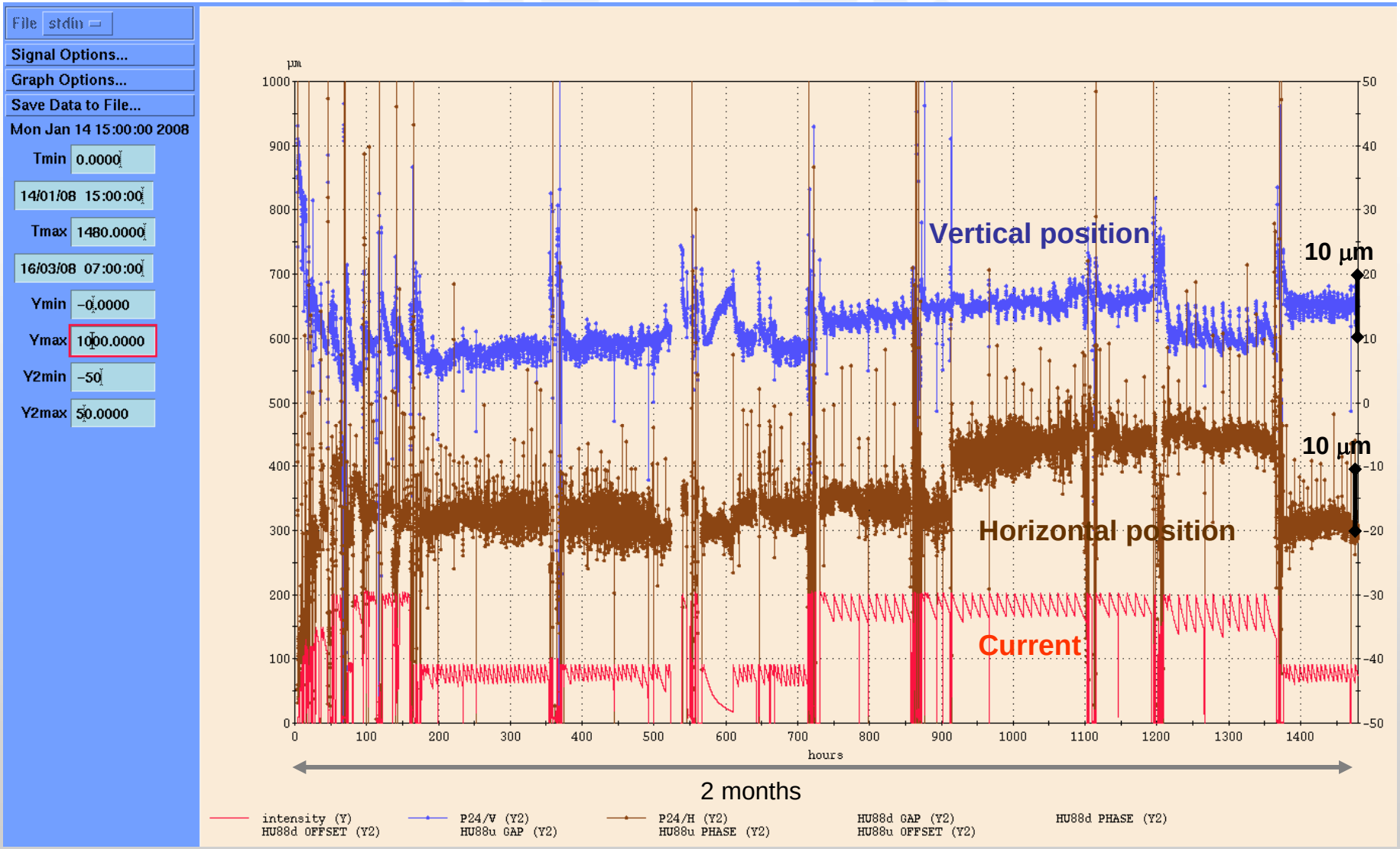
## Typical RMS beam motion in high beta straight sections

| | *Horizontal* | *Vertical* |
|---|---|---|
| ***10% of Beam size*** | **38 μm** | **0.9 μm** |
| | | |
| *One week* | **11 μm** | **8 μm** |
| *One day* | **5 μm** | **2 μm** |
| *One hour* | **5 μm** | **2 μm** |
| *One minute* | **5 μm** | **2 μm** |
| *One second* | **2 μm** | **1 μm** |

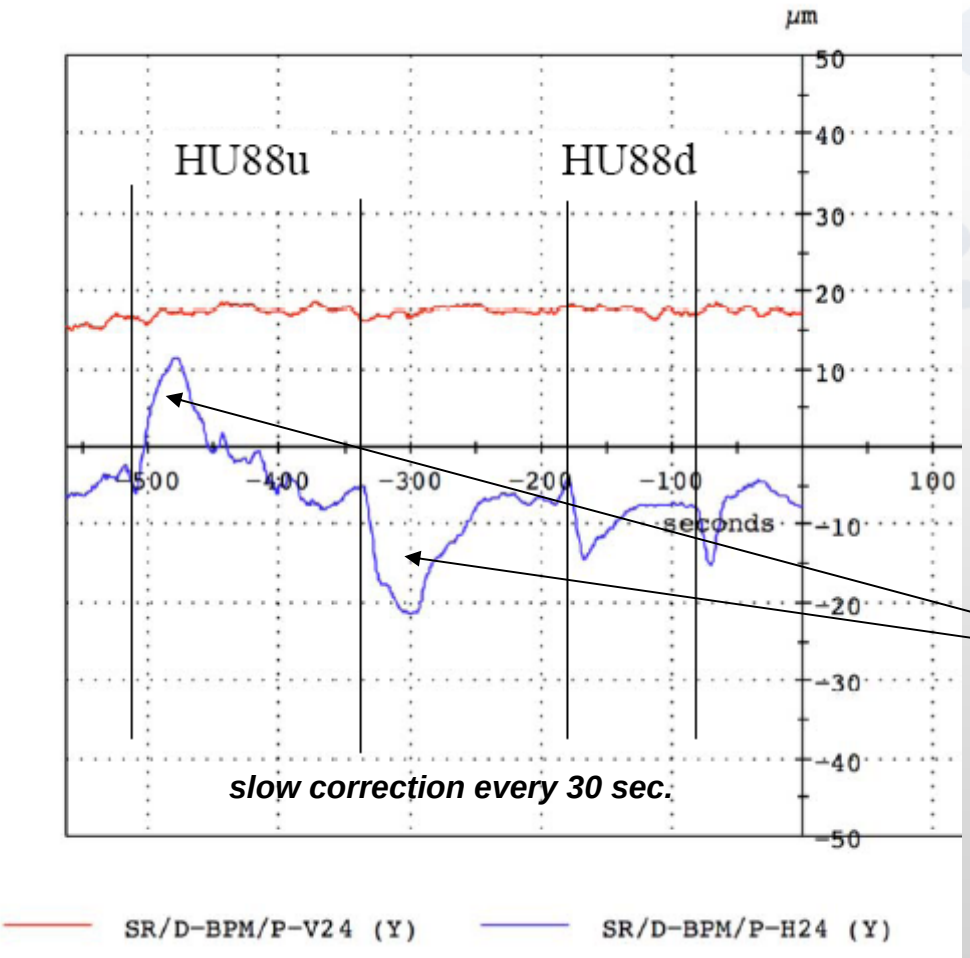
A combination of slow control, mechanical damping links and fast global feedback brings the vibration and the slow motion to an acceptable level.

The amplitude of very slow motion is still dominant.

# Typical beam position in cell 24



# Gap motion and feedback




Vertical and horizontal orbit perturbation in straight section 24

when the phases of the undulators in straight section 8.

*(Extreme conditions and feed forward corrections of the undulators are switched OFF)*

The orbit perturbations are due to the dead band between the slow and the fast correction systems.

**<u>Solution under investigations:</u>**

**Single position feedback system**

**from DC to 150 Hz**

# New BPM electronics

BPM electronics, the existing system :

Still works properly & reliably, after > 15 years of loyal service . .

➔ but first turn mode needs 4*5 mA from the injector, which may caused too high level of radiation and will block the instigations *(safety regulation has drastically evolve since 1992).*

➔ Need of a low current , pure single shot BPMs electronics

➔ Solution:

Libera system which now equiped :

Diamond, Soleil, Elettra, Alba, Petra-3, Delta and some other major Accelerators outside Europe


with a Turn-Key BPM system for both Slow & Fast orbit measurement

# New BPM electronics

The "**Libera**" :

•Fully integrated turn-key solution for signal acquisition & treatment of BPM signals.

•Measures weak signals with high quality RF electronics & Digital Signal Processing techniques to calculate the electron beam position with high precision, resolution and stability.

•Maintain an un-precedented stability of this position measurement over a large dynamic range (= 0.1 to 300mA beam current in the ESRF Storage Ring)

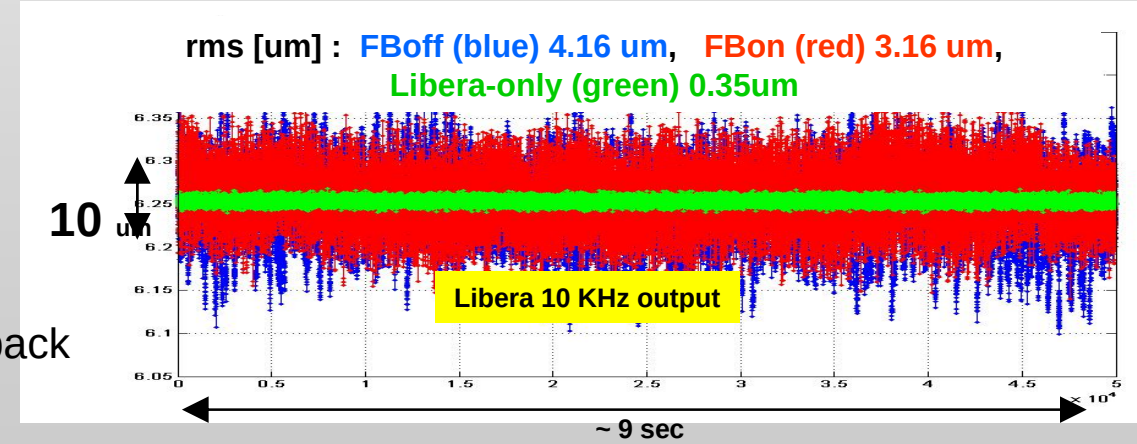
•In addition to measure the slow beam position (10Hz) it also provides :

- First-Turn and Turn-by-Turn outputs (355KHz)
- high-resolution 10KHz output for use in Fast-Orbit-Feedback schemes

*Status:* 8 electronics installed for qualification and later to be used for beam position interlocks.

The 224 existing electronics will be upgraded to Liberas within the upgrade programme

➔ 224 signals for the fast orbit feedback instead of the existing 32 inputs

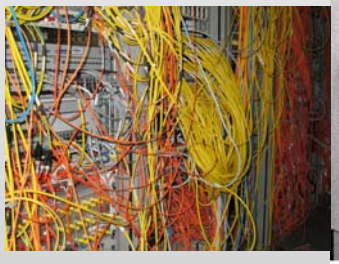


# News from Control system

- The ESRF accelerator control system has evolved to an object oriented distributed control system TANGO from 2000
  *(Old system TACO and new system still cohabit)*

http://www.tango-controls.org/

- Evolution of computing market
  ➔obligation to be more heterogenic to fulfil the technical requirements
- The compromise between standardisation and modernity is today extremely difficult.
  ➔ Evolution is mandatory in order
  not to be rapidly obsolete
- Embedded control system is today
  the direction of evolution



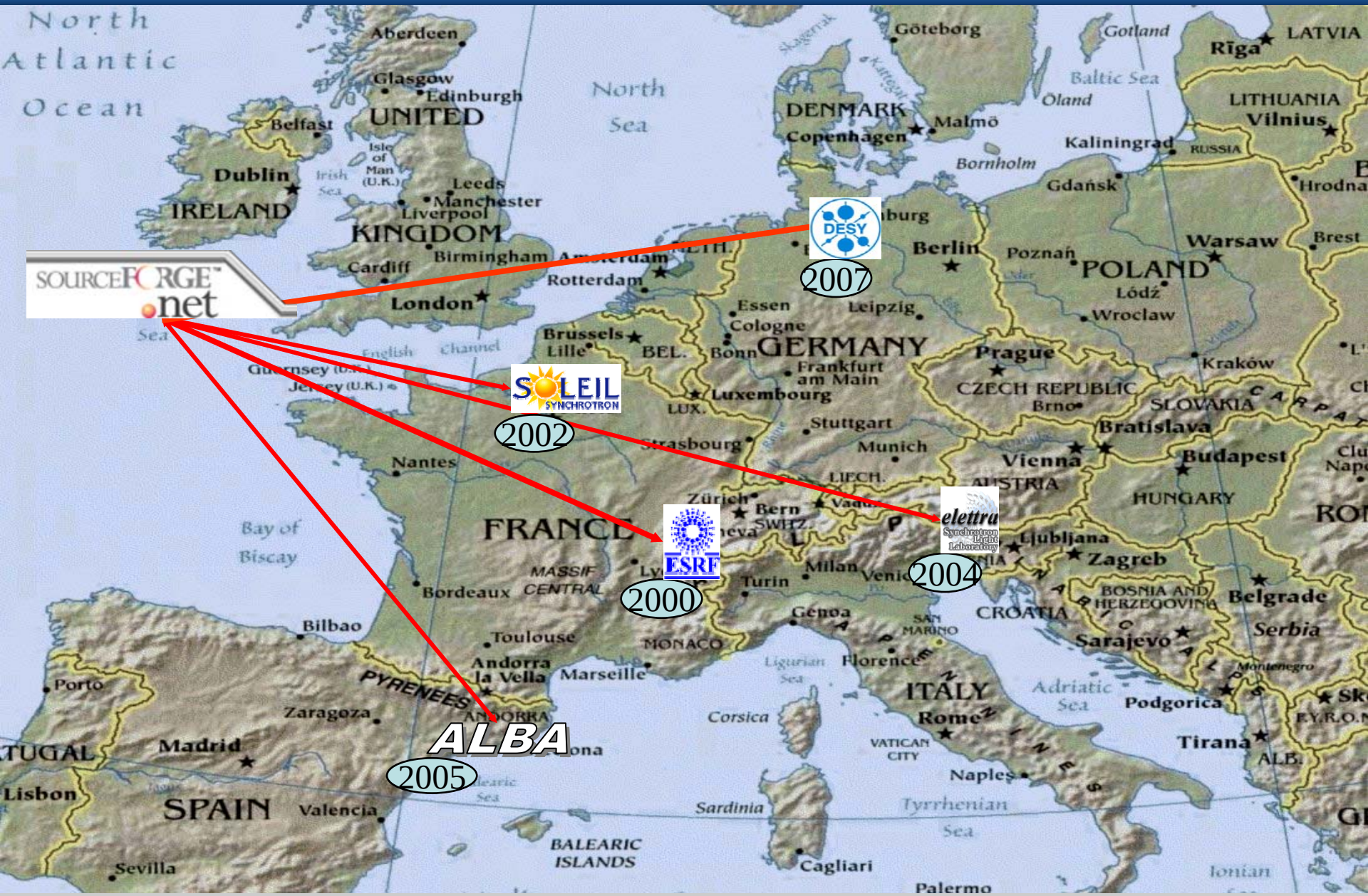
Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the

Despite its complexity the machine control system is extremely reliable thank to the close collaboration between the ASD and CS

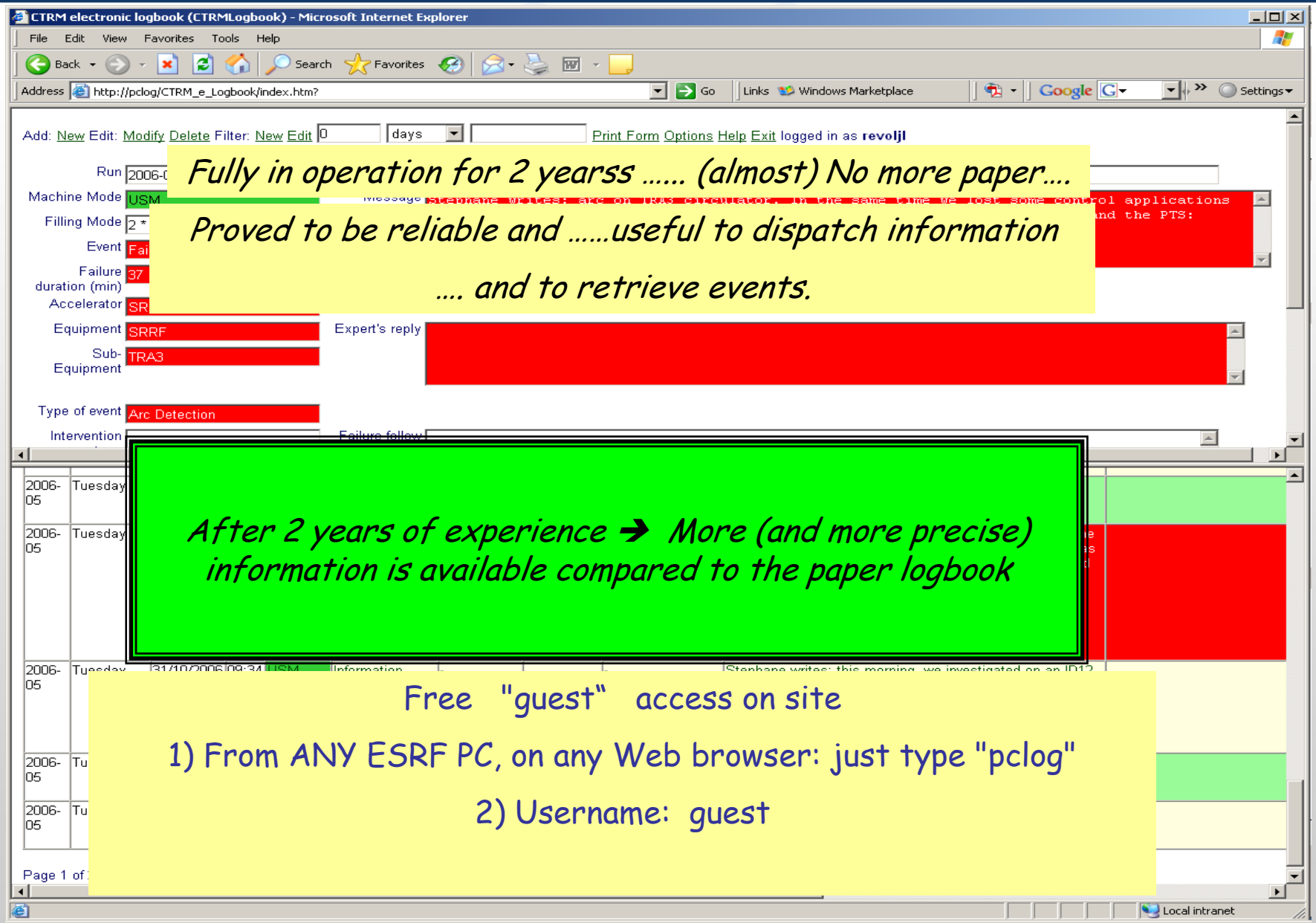
**Four hours of machine time with beam are purely dedicated each run to control activities**

# Who use and collaborate to tango?





# Electronic Logbook




*Fully in operation for 2 yearss …… (almost) No more paper….*

*Proved to be reliable and ……useful to dispatch information*

*…. and to retrieve events.*

*After 2 years of experience ➔ More (and more precise) information is available compared to the paper logbook*

Free "guest" access on site

1) From ANY ESRF PC, on any Web browser: just type "pclog"

2) Username: guest

# Electronic Logbook

**Present situation:**

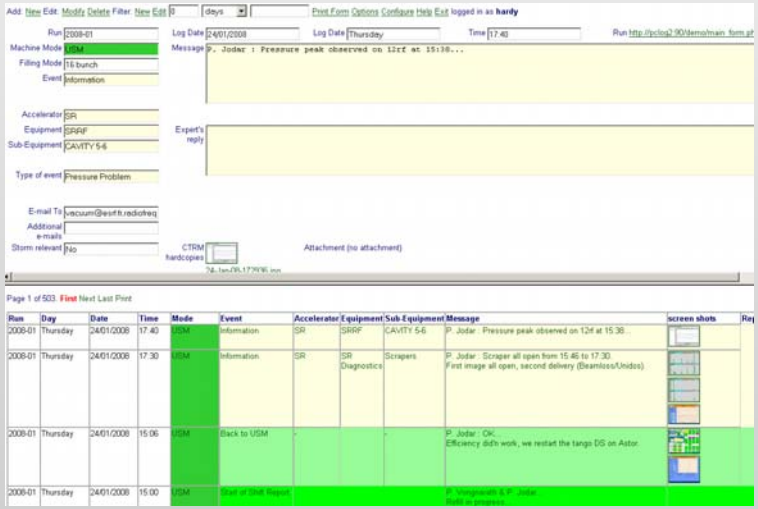
- 13 different logbooks are being routinely used (including the MX macromolecular Group)
- On 23/01/2008: 10 000 records entered in the CTRM electronic Logbook
  2560 documents entered in the AS Division
  Extensively used by many groups (within and outside the ASD)
- VERY strong request from several beamlines to have the same logbook

**In about 2-3 months:**

A new version will be installed with

a link to the ESRF Tango control System

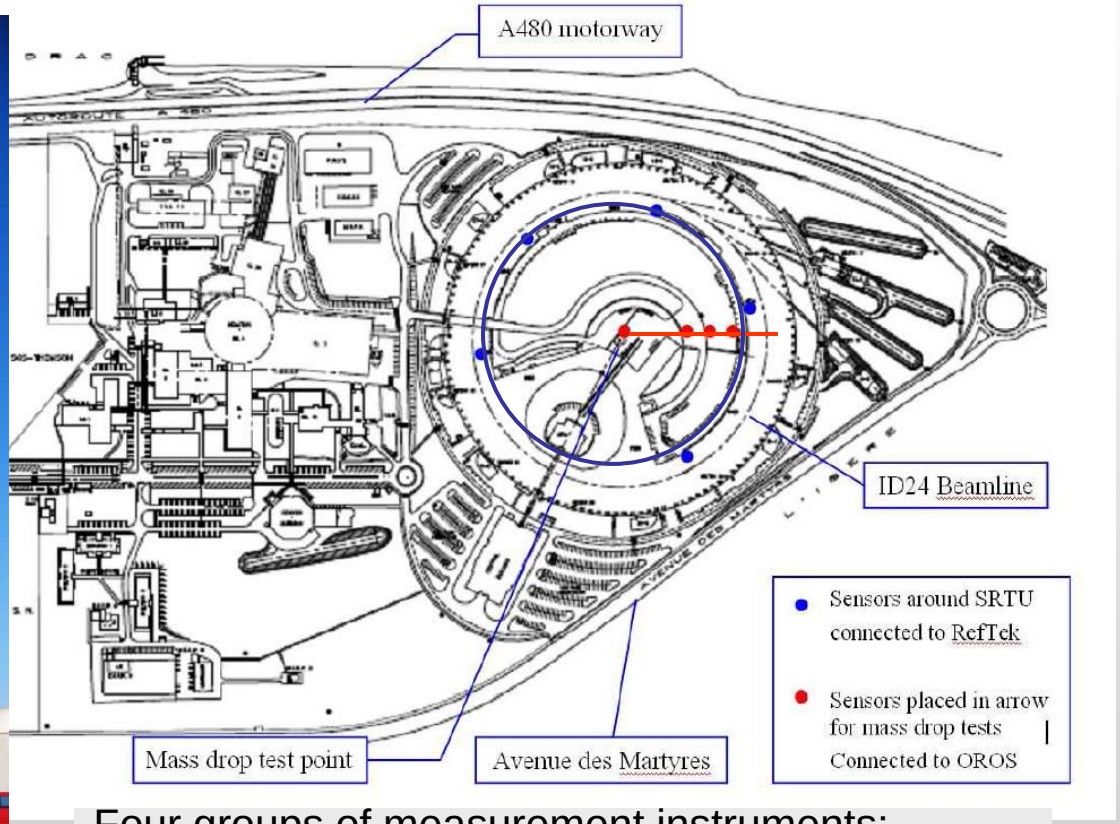
➔ Possibility to import automatic data on Operator's request and possibility to generate automatically records « on events » triggered by predefined criteria




MANY thanks
for your attention

# Mass drop induced vibration study

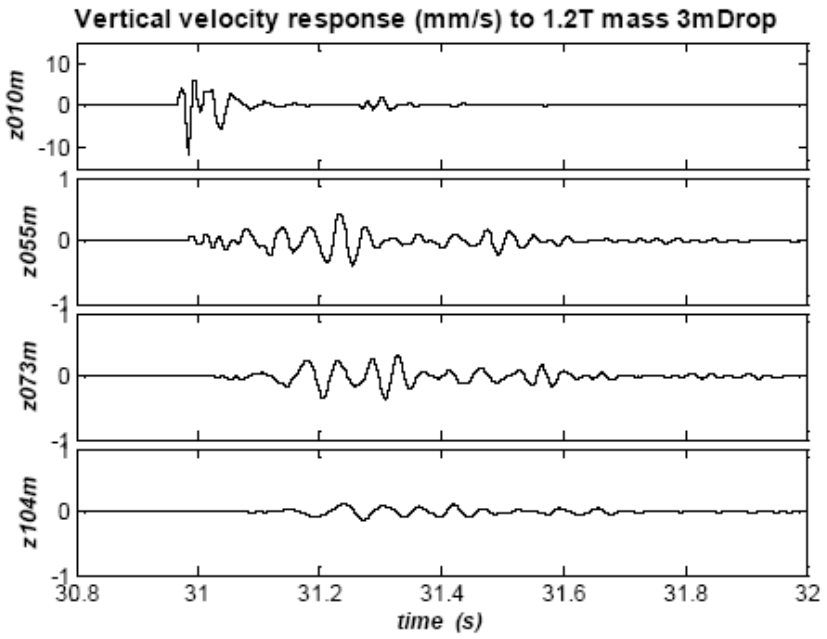
Common experiment on vibrations with technical service, beamlines and ASD in Feb08 to prepare the call for tender for the building extension.




Four groups of measurement instruments:

- Sensors around SRTU
- Sensors in an arrow from impact
- Sensors in ID24
- Electrons and X BPMs in ID24

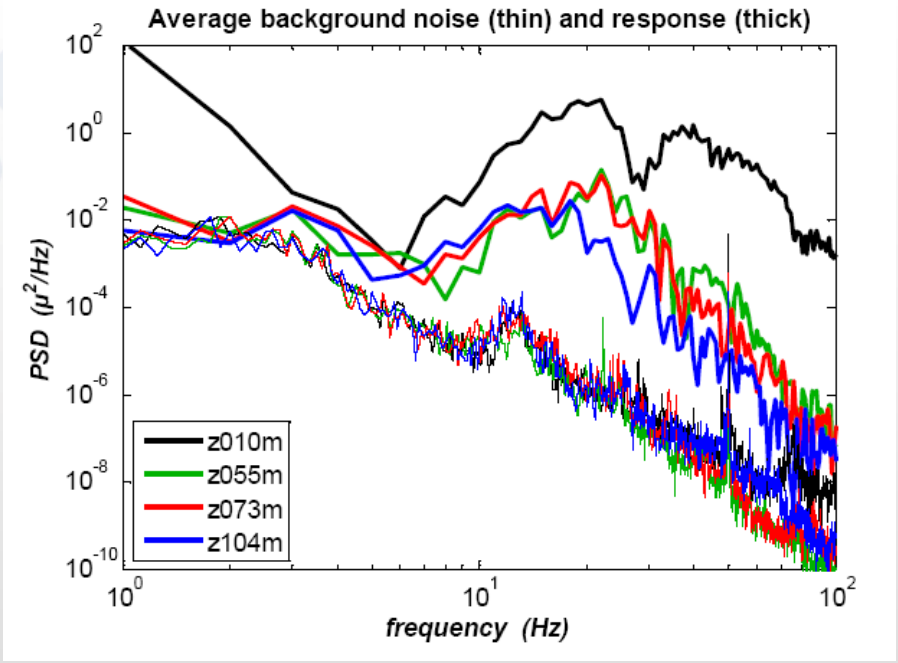
# Mass drop induced vibration study




**Vibration attenuation with distance and time**

**Vertical vibration velocity response to the 1200 kg steel mass drop from 3 m height.**

**Measurement points are at 10, 55, 73 and 104 meters from the impact point.**

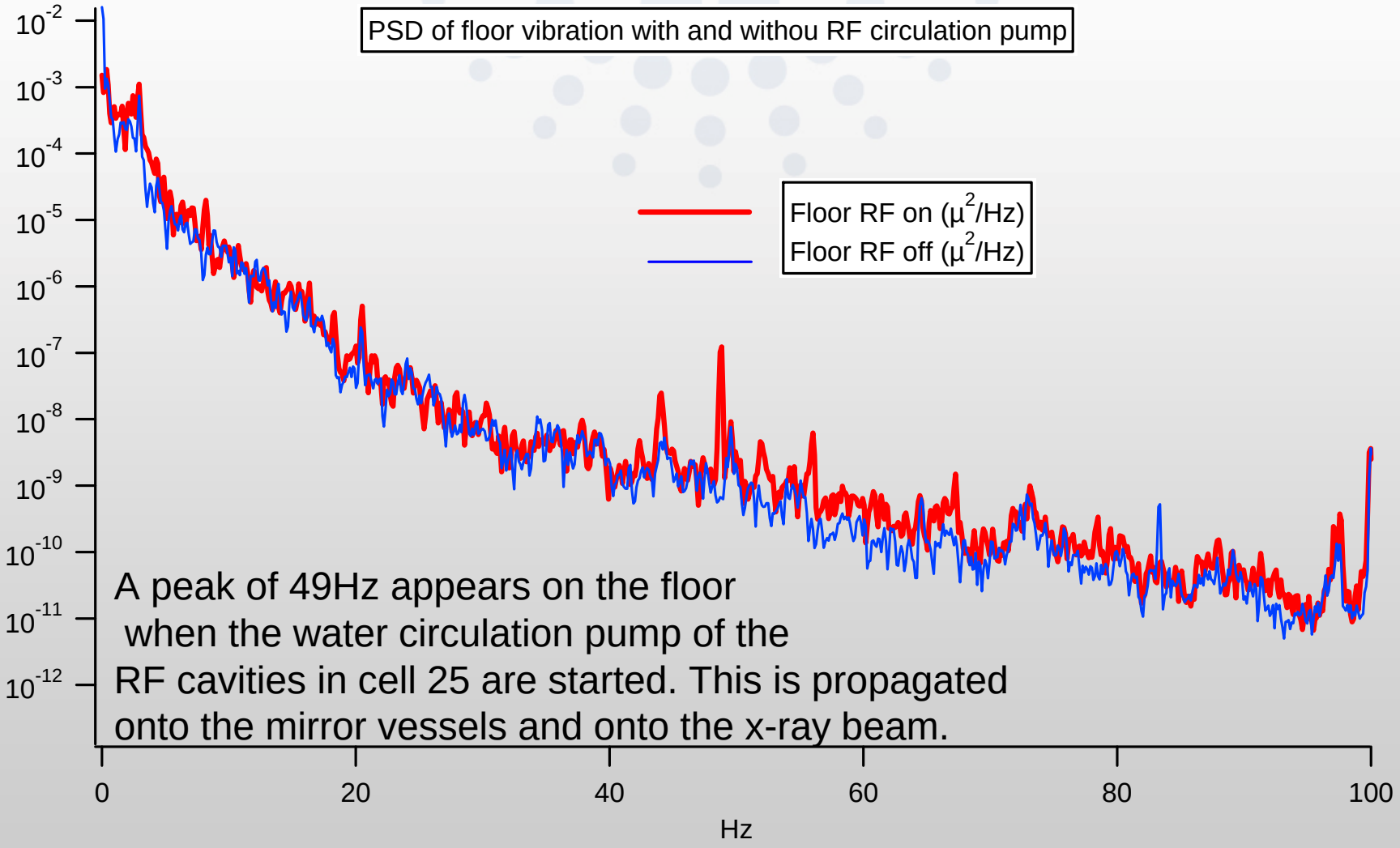



**Vibration attenuation with distance : spectral analysis**

**Vertical displacement PSD of the mass drop responses (thick lines) compared with the PSD of the background vibration noise (thin lines).**

*Data under processing*

# Floor vibration on ID24 beamline




A peak of 49Hz appears on the floor when the water circulation pump of the RF cavities in cell 25 are started. This is propagated onto the mirror vessels and onto the x-ray beam.

## THE PTS SYSTEM FOR STAFFING SHIFTS

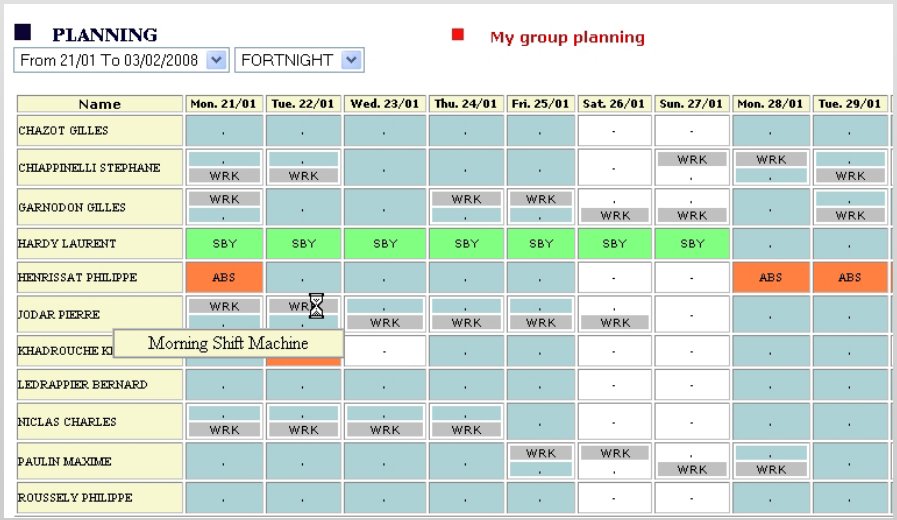
In **2007**:

**720** USM and USM-like shifts were covered by **81** PTS.

Since the start of the PTS system, on average 80 staff members participate every year in the continuous functioning of the installation as second member of the shift crew. The "typical" PTS is either a technician or engineer working in the Accelerator and Source Division, Technical or Computing Services.

Three members of the Administrative staff have joined the PTS pool and now participate on a regular basis.

*CTRM activity (shift, standby, intervention) is represented on the group planning in the same way as other activities (absences, RTT, training, missions).*




MANY thanks
for your attention