XVII European Synchrotron Light Source Workshop 2009

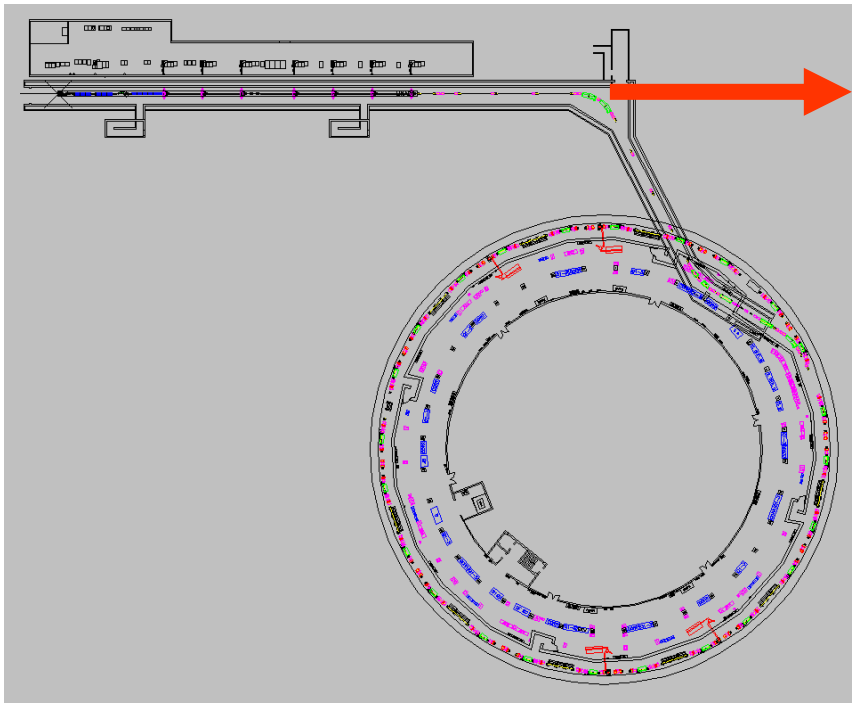
Hamburg, November 25-27, 2009

Developments at ELETTRA

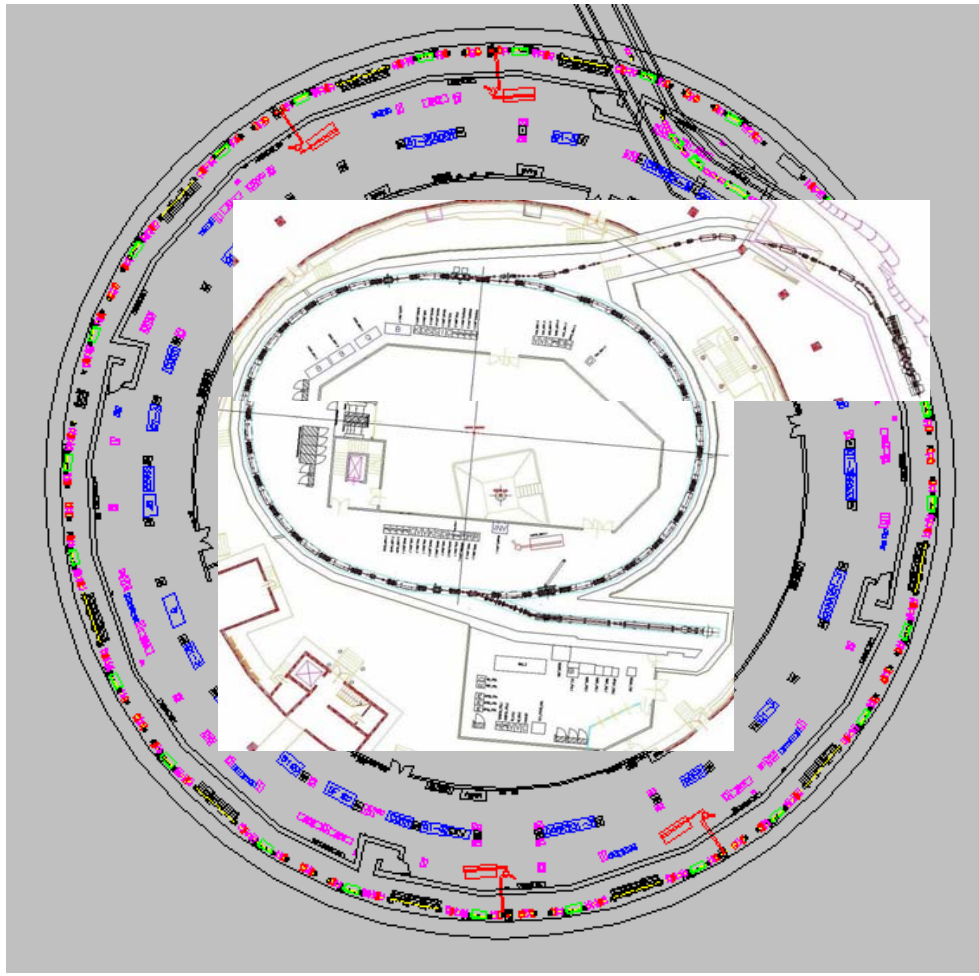
Emanuel Karantzoulis

Past and Present Configurations

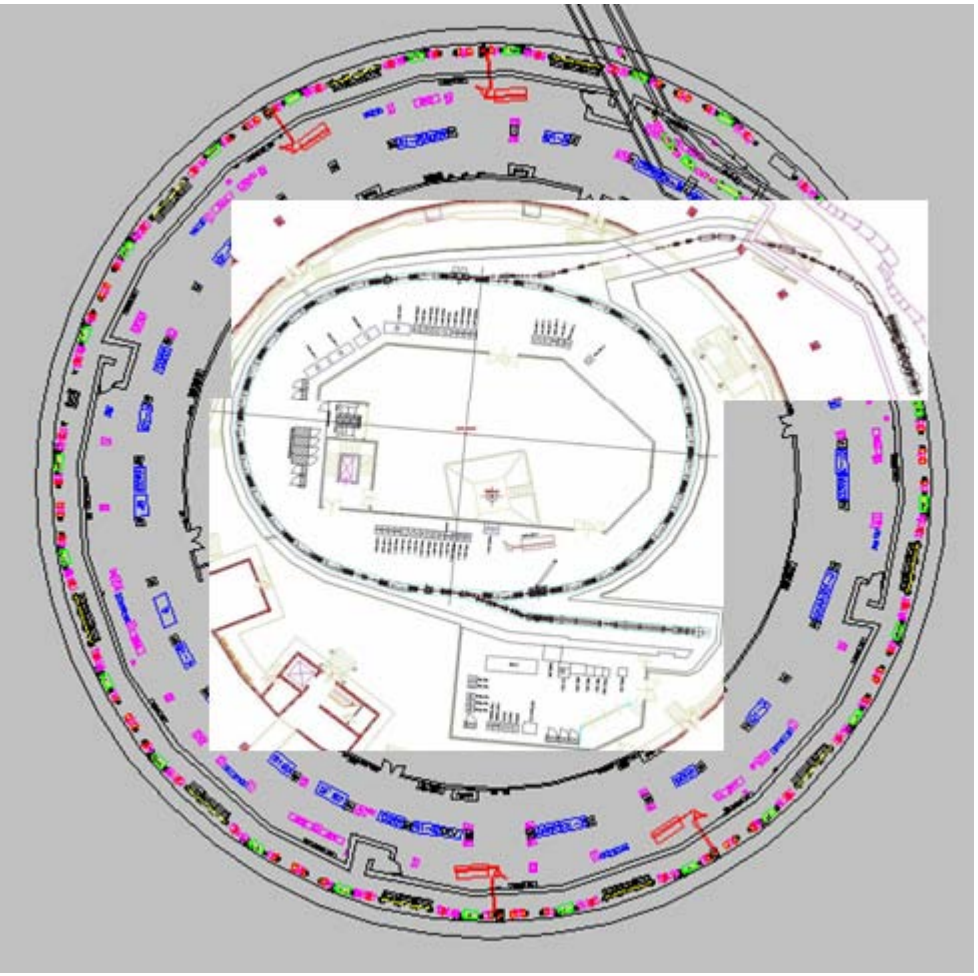
Up to 2007

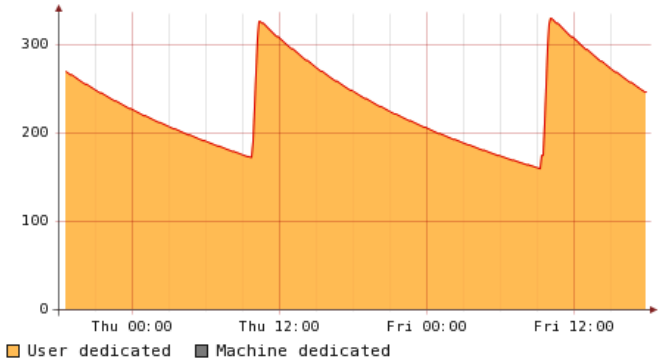


From 2008



Configuration and Operational summary





2009		
Injection energy	At any operating energy	
Final energy	2.0 GeV	2.4 GeV
Starting current	330 mA (τ ~ 22 hrs)	150 mA (τ ~ 35 hrs)
Filling pattern	multibunch, ~ 95 % contiguous	

0.9 GeV (accelerator physics time) for SR-FEL single bunch

Pre-injector 100 MeV

Redundancy

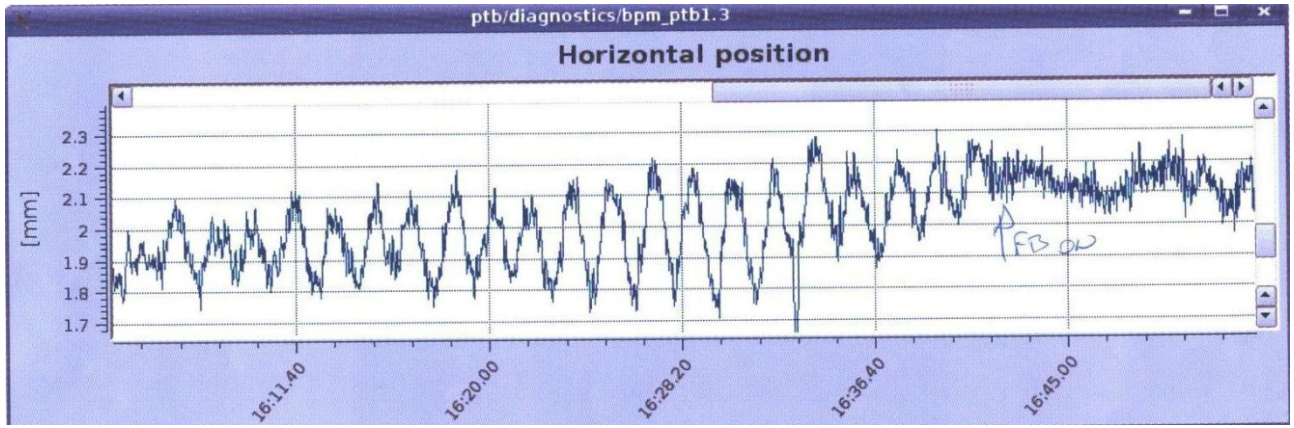
Spare modulator 1 completed, all partial tests done, waiting the timing for a full test.
Spare GUN completed and electronics tested

Mod 2: Replaced thyratron CX1536 X (over 20.000 working hours)

Mod 1: Replaced Klystron Thales TH132 A due to continuous internal arcs at “low” klystron voltage

Stability

Energy feedback to minimize energy oscillations (0.1 mm or 0.14 MeV) in operation



P. Borsi / A. Carniel / S. Krecic

Booster operational progress

- Acceptable operations established. Booster operates at full cycle (2.5 GeV) and up to 3 Hz
- Full energy injection to Elettra at any energy up to 2.4 GeV and any filling (multibunch , single bunch ,few bunch) up to 2.4 Hz rep. rate with efficiencies up to 95%

The Booster operates at full cycle (on-fly mode) i.e. to get a different energy the extraction time is changed

Booster PS refurbishing

Feb 09 : Sextupole power supplies in function; repairing modules DC/AC (change torroids in overheated) filters; studies on the spurious switching off and spurious alarms of the modules; stabilizing the DC-link and improving amplitude reproducibility

Jun 09: Improvements of the auxiliary electrical supply; Substitution of damaged contacts and problem fixing; low level software debugging; studies on the spurious switching off.

Sept 09: repairing some damaged modules DC/AC and software changes in the local control and a damaged sextupole one; verified that an electronic board of the filter of PSB_BTS must be changed, continue investigating the spurious switching off.

Still to do:

Change a board of the filter; tests on the new IGBT trigger boards and new modules DC/AC, understand the spurious story.

Booster PS Ripple and Stability

Required Tolerances	Dipole PS @800 A	Quad PS @400A
Ripple (±15ppm)	≤ ±12mA	≤ ±6mA
Stability and reproducibility (±50ppm)	≤ ±40mA	≤ ±20mA

X10 still

Better reproducibility but still not as in specs

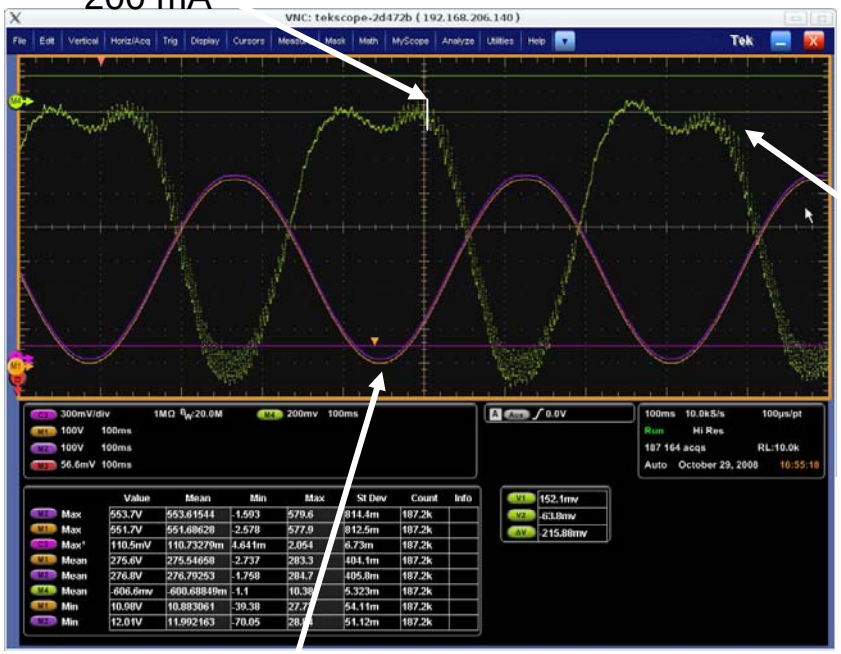
Ripple unchanged

2008 X3 above

2009 OK up to 2 Hz but then X2 up to 3 Hz **(operate at 2.4 Hz)**

PS Ripple and stability effects

200 mA



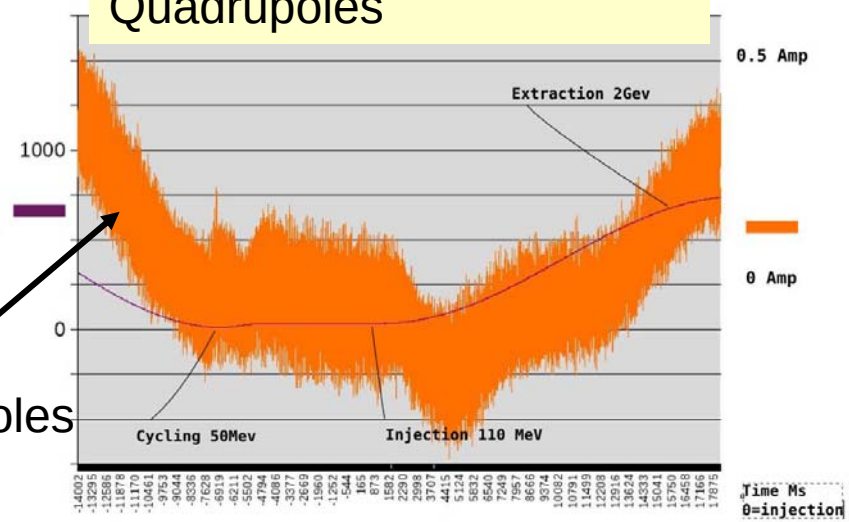
Current difference between the two ps of the booster dipoles

Stability and reproducibility improved but worsens at increasing the frequency (at 3 Hz is as large)

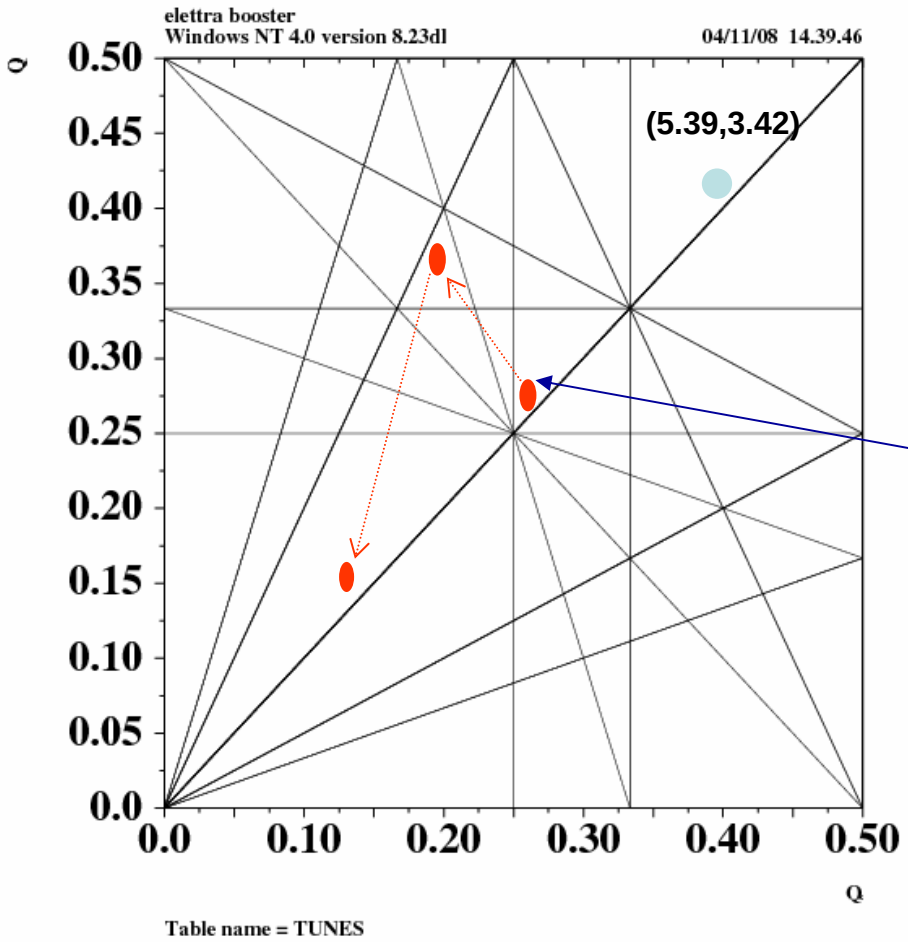
Injection point 110 MeV, after 10-20 ms large and pulsating distortion of the current difference were observed

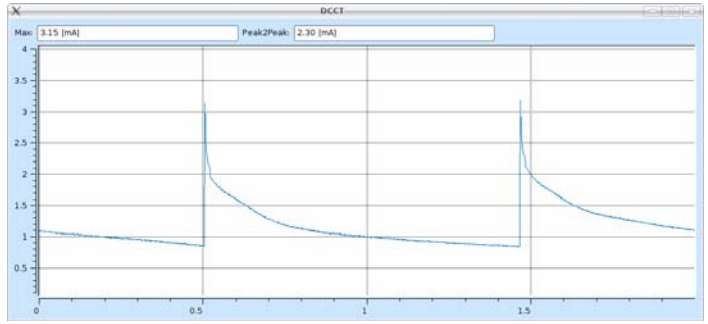
Normalized current difference between dipoles and quadrupoles

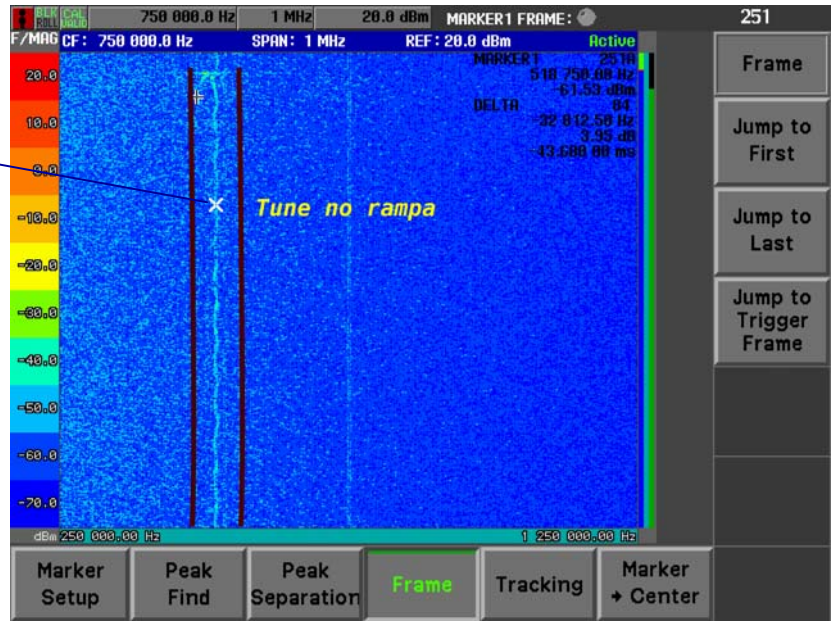
Ripple stays - Mainly Quadrupoles



Booster dynamic and static tune







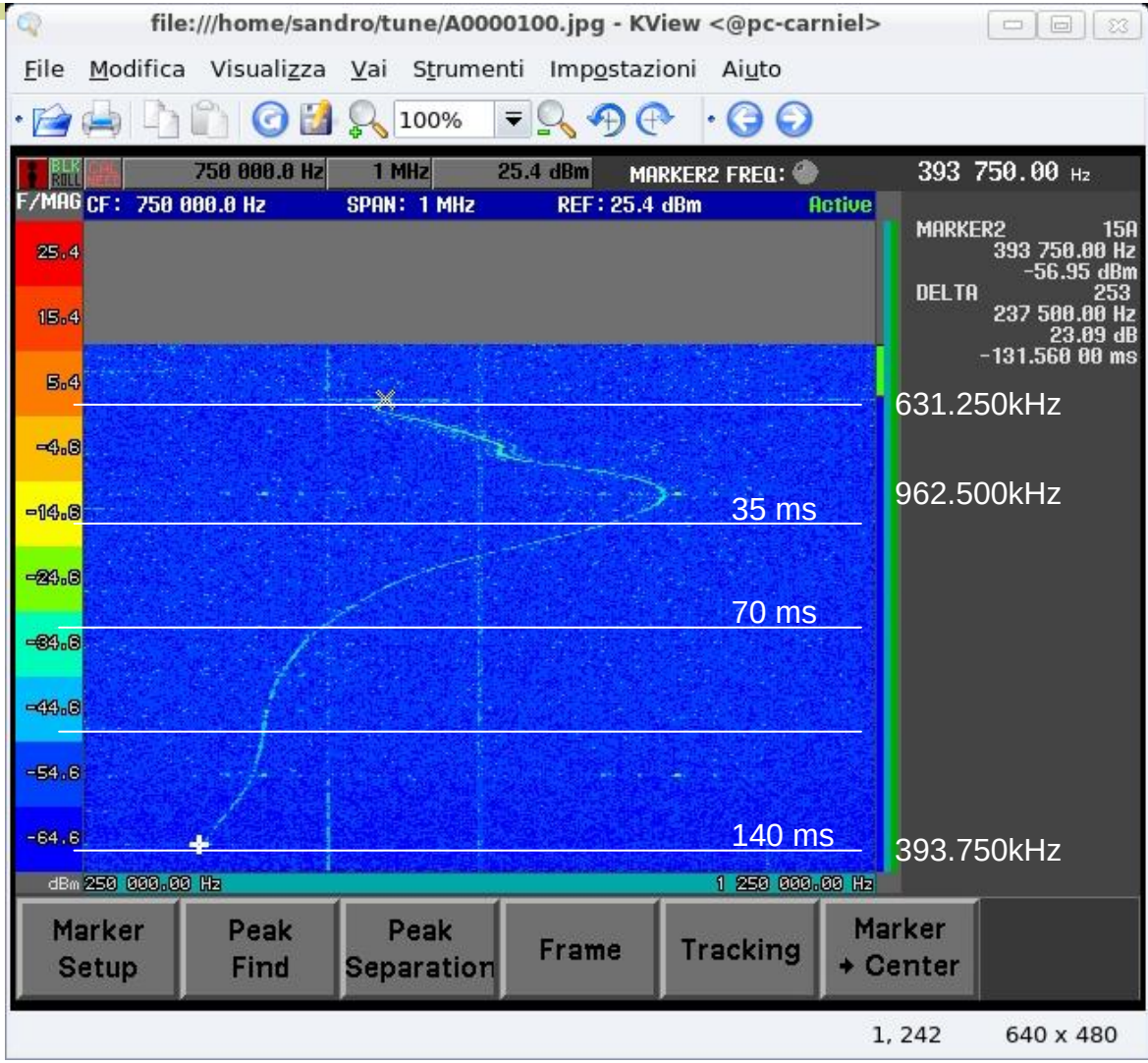
Booster tune measurements

Fast sweep from 250 to 1250 kHz in 1 ms -> 2 spectra/ms

Injection ⟶ qy=0.2498

qy=0.3808

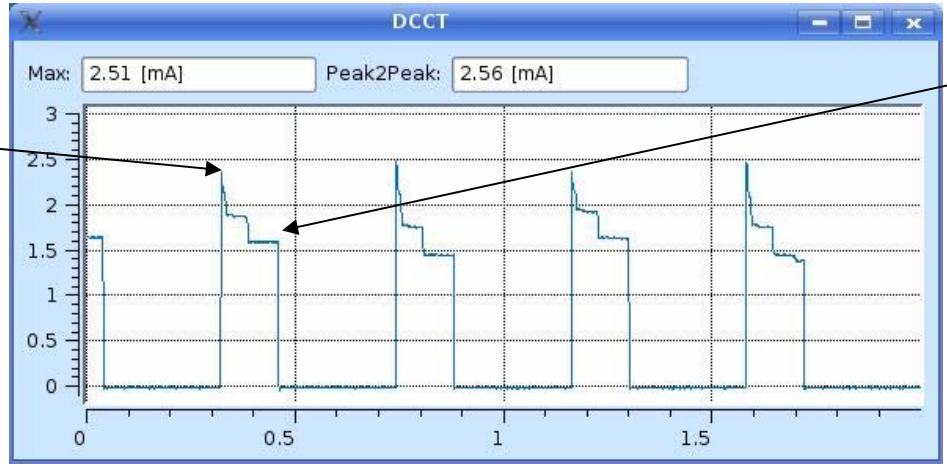
Extraction ⟶ qy=0.1558



S. Bassanese

A. Carniel

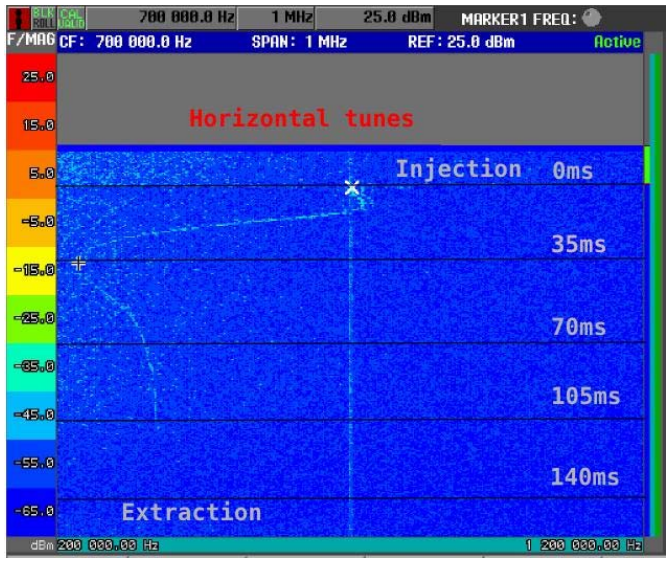
Before tune compensation 2008

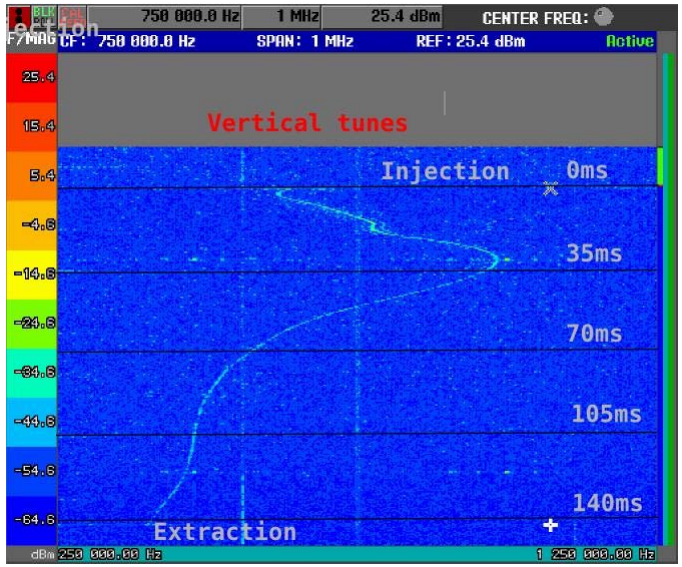


injected

extracted

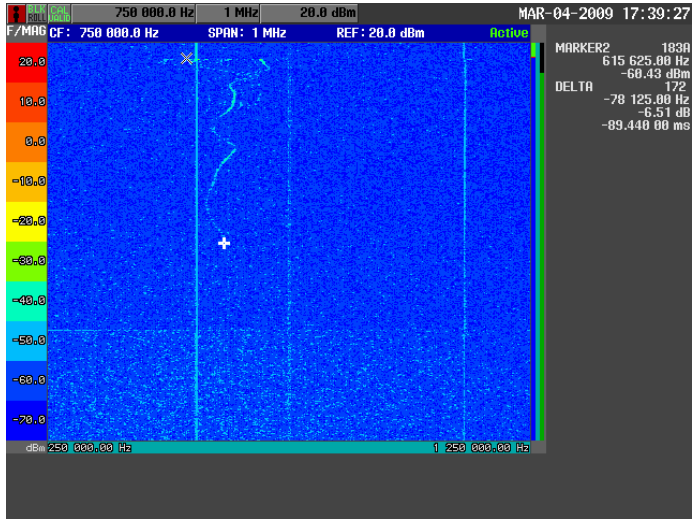
At full cycle (up to 2.5 GeV)

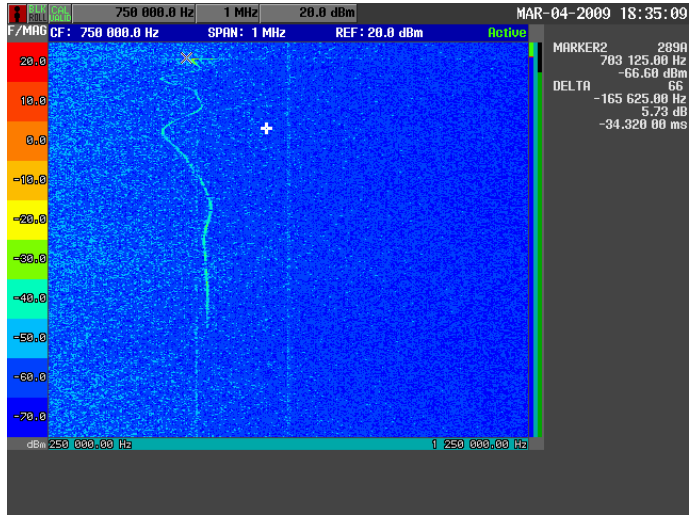




Compensating Tune 2009

By modifying the quadrupole driving curve i.e. feed forward

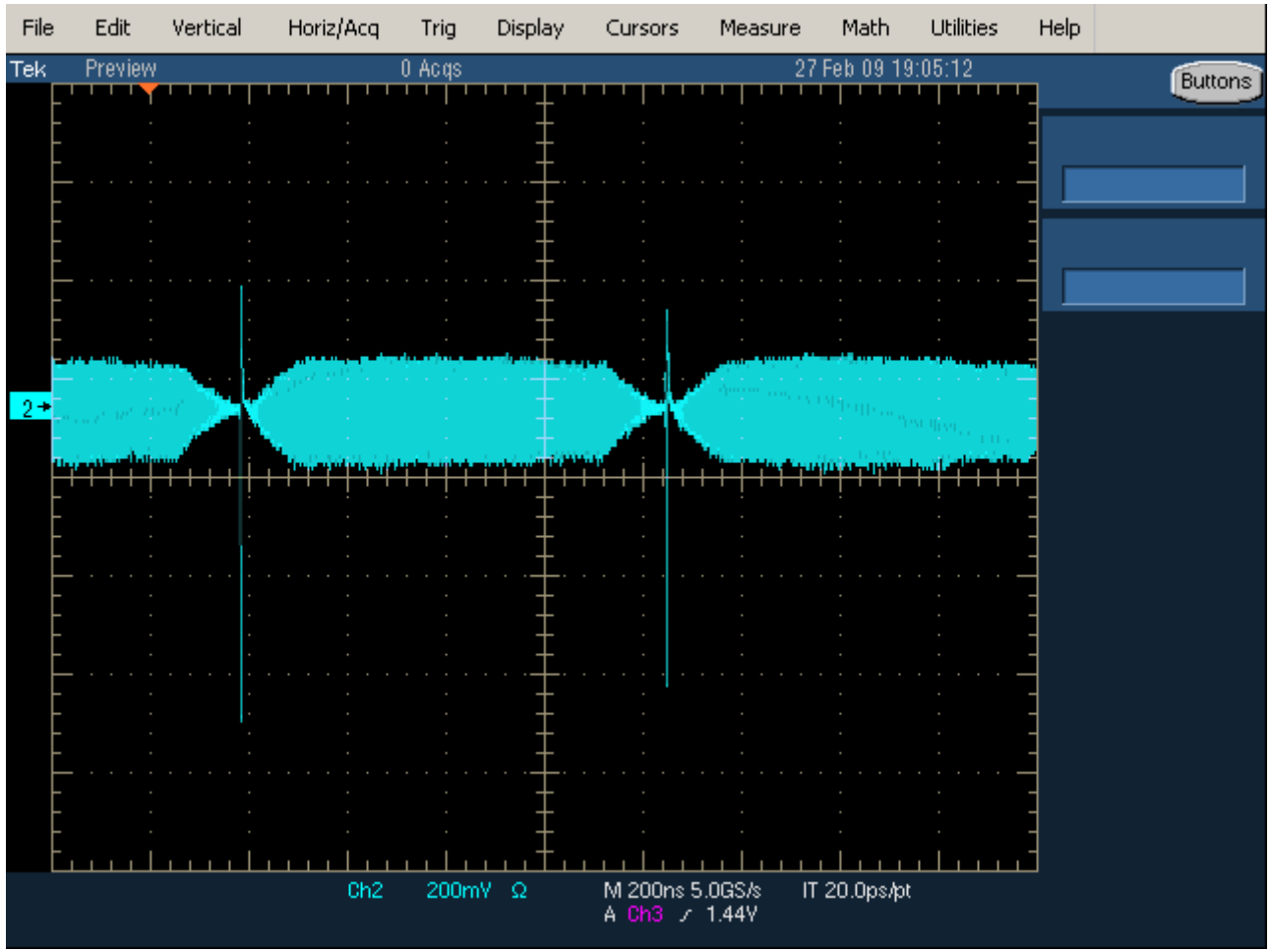




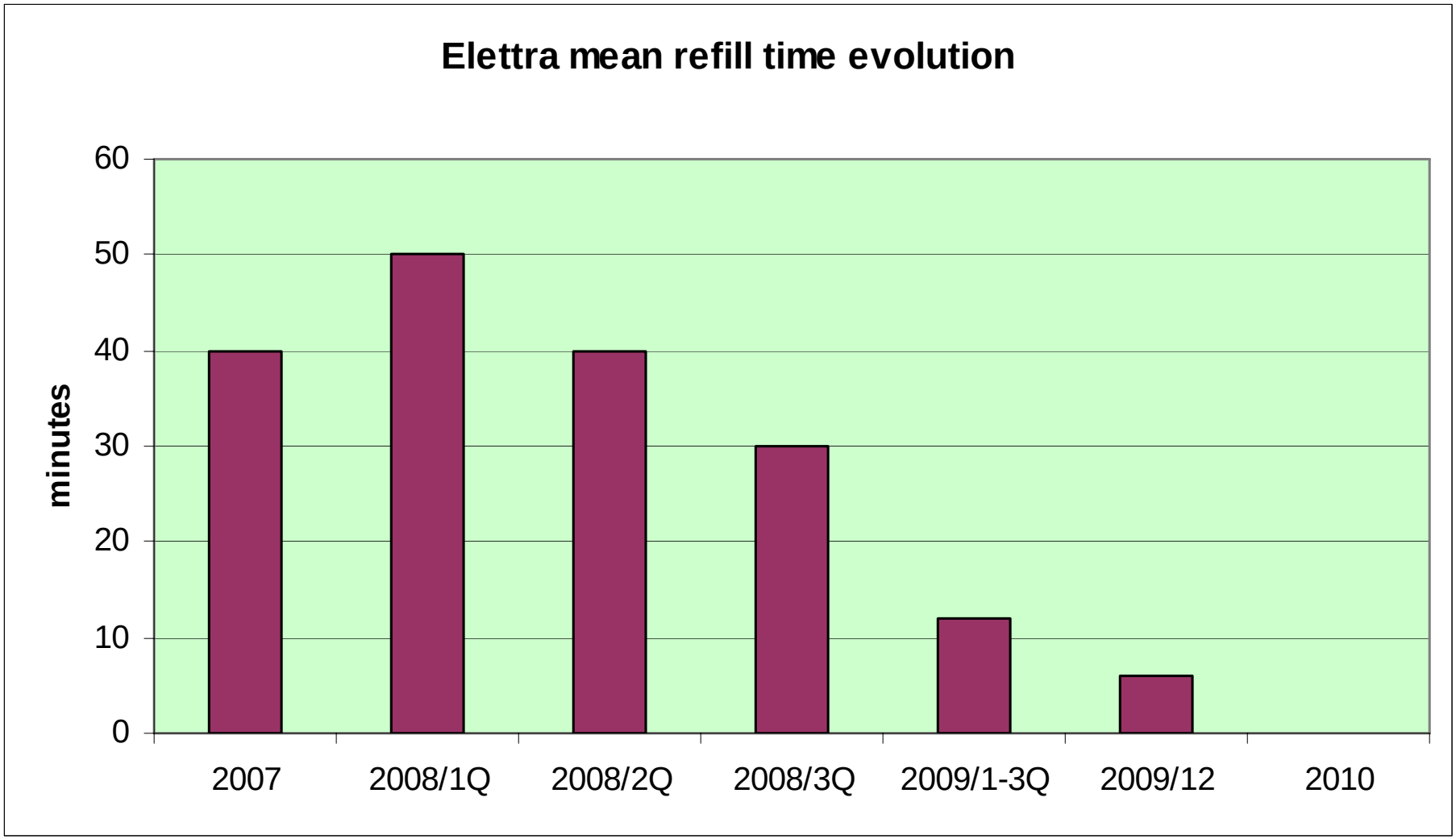
Occasionally up to 15% difference from pulse to pulse due to ps reproducibility and also to pre-injector

Hybrid filling in SR

Easy multi and single bunch operations or Hybrid that ***has been operational for users in May 2009***

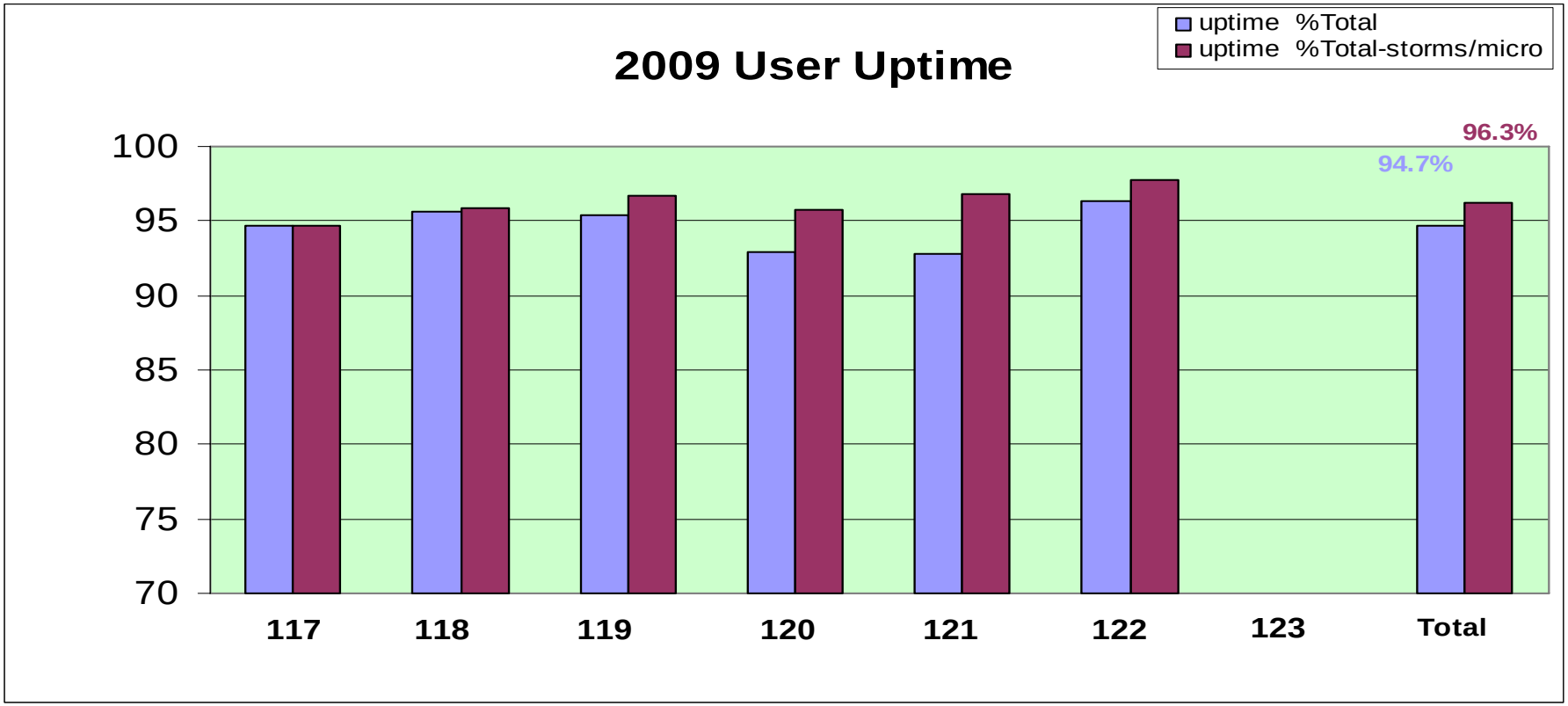


Refill time


Elettra mean refill time evolution
minutes
60
50
40
30
20
10
0
2007
2008/1Q
2008/2Q
2008/3Q
2009/1-3Q
2009/12
2010

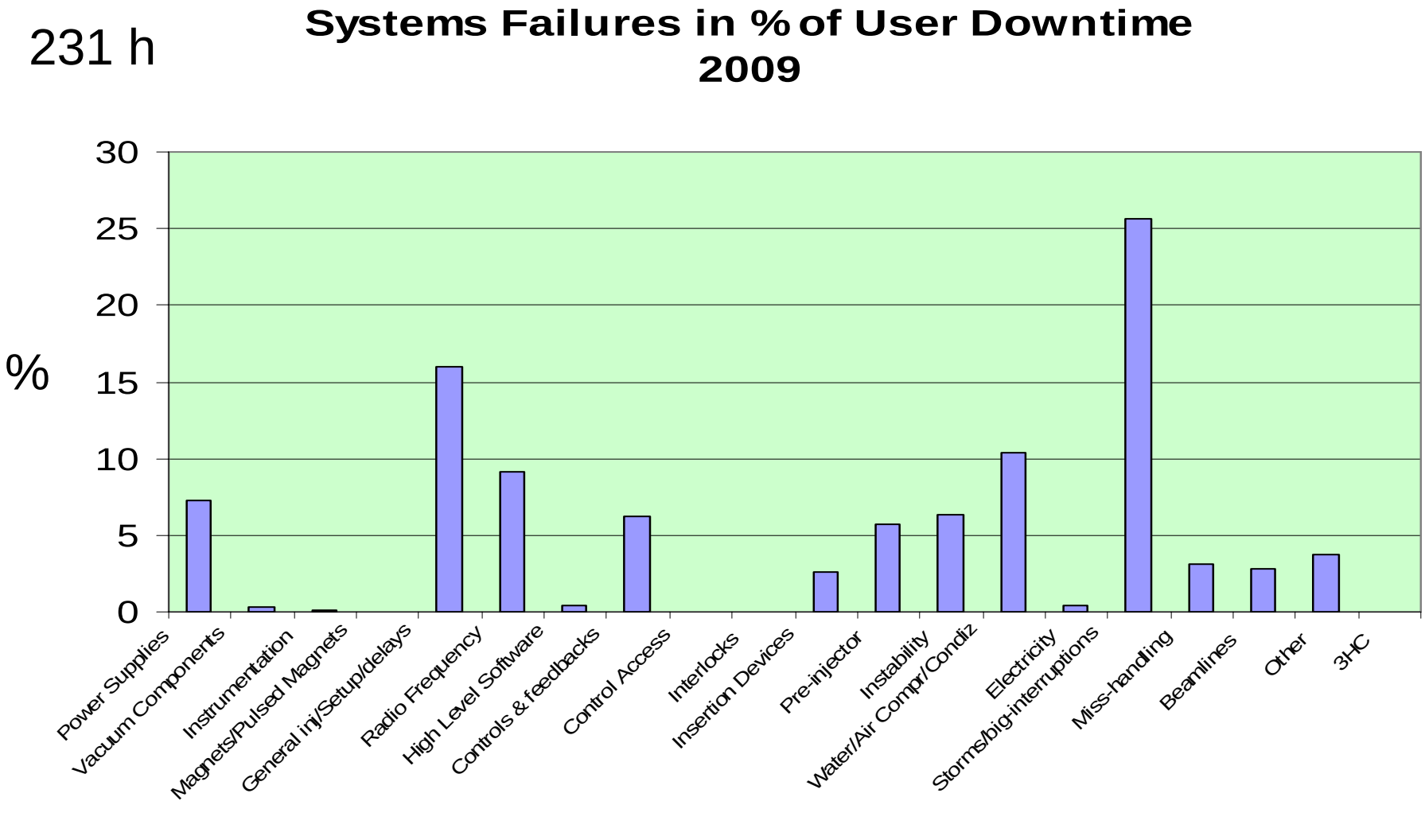
2009 Up-Time

for **4368** scheduled hours of user operation (87.1% of total user)

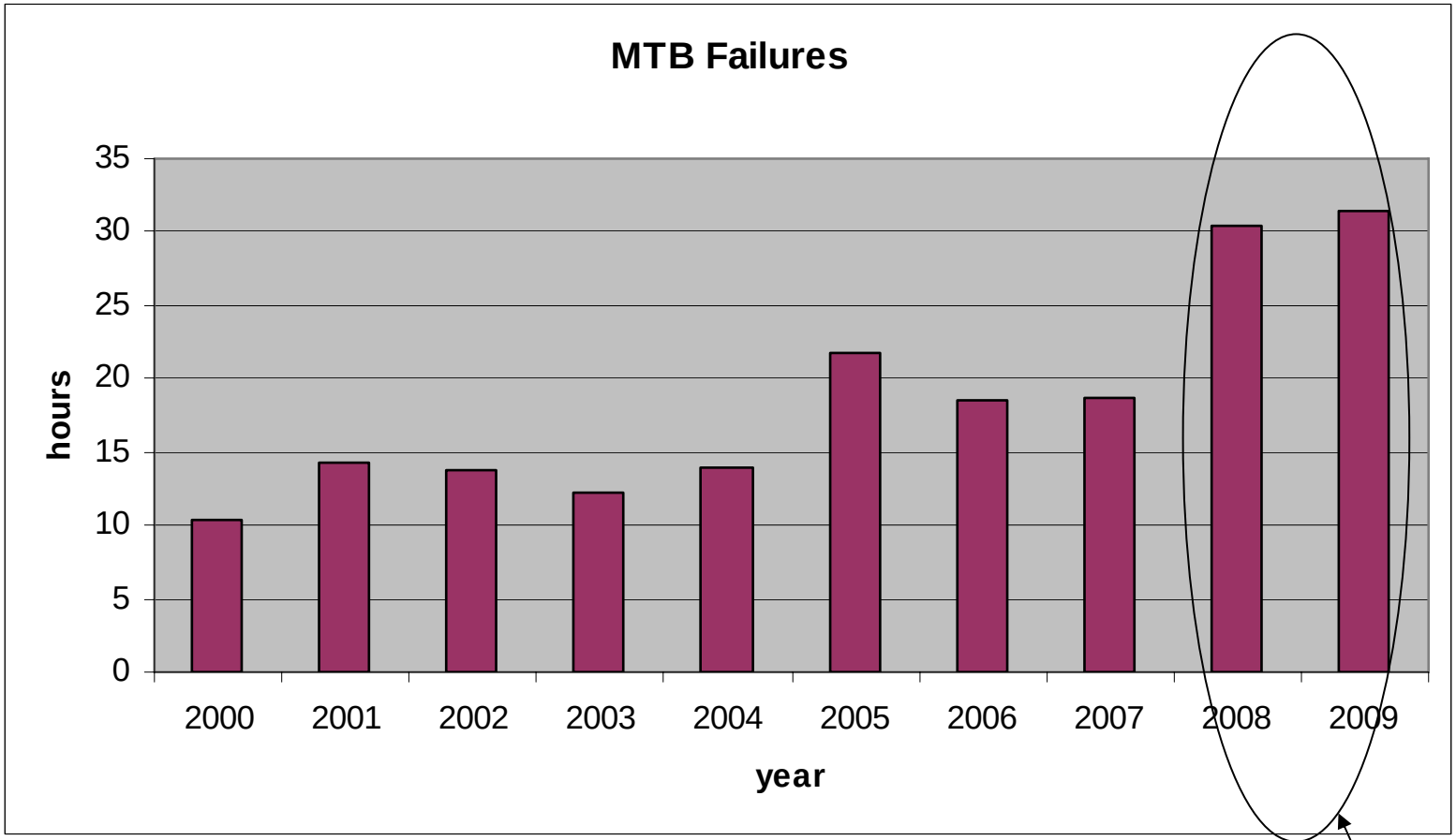


statistics including history are on-line on elog (operations server)

Systems failures



Mean time between failures



Booster beneficial influence

Elettra operations in 2010

FERMI @elettra

2010 Elettra beam-time Schedule

	Gennaio January (date M L N)	W	Febbraio February (date M L N)	W	Marzo March (date M L N)	W	Aprile April (date M L N)	W	Maggio May (date M L N)	W	Giugno June (date M L N)	W	Luglio July (date M L N)	W	Agosto August (date M L N)	W	Settembre September (date M L N)	W	Ottobre October (date M L N)	W	Novembre November (date M L N)	W	Dicembre December (date M L N)	W	
L			1 u2 u2 u2		1 u4 u4 u4																1 sd sd sd				L
M			2 u2 u2 u2		2 u4 u4 u4						1 u2 u2 u2										2 sd sd sd				M
M			3 u2 u2 u2		3 u4 u4 u4						2 u2 u2 u2						1 u2 u2 u2				3 sd sd sd	44	1 u2 u2 u2		M
G			4 u2 u2 u2	5	4 u4 u4 u4	9	1 u2 u2 u2	13			3 u2 u2 u2	22	1 af af af	26		30	2 u2 u2 u2	35		39	4 sd sd sd		2 u2 u2 u2	48	G
V	1 sd sd sd		5 u2 u2 u2		5 u4 u4 u4		2 sd sd sd				4 u2 u2 u2		2 af af af				3 u2 u2 u2		1 af af af		5 sd sd sd		3 u2 u2 u2		V
S	2 sd sd sd		6 af af af		6 af af af		3 sd sd sd		1 af af af	17	5 u2 u2 u2		3 af af af				4 u2 u2 u2		2 af af af		6 sd sd sd		4 af af af		S
D	3 sd sd sd		7 af af af		7 af af af		4 sd sd sd		2 af af af		6 u2 u2 u2		4 u2 u2 u2		1 u2 u2 u2		5 af af af		3 af af af		7 sd sd sd		5 af af af		D
L	4 sd sd sd		8 sy u2 u2		8 u2 u2 u2		5 sd sd sd		3 u2 u2 u2		7 sd sd sd		5 u2 u2 u2		2 u2 u2 u2		6 u4 u4 u4		4 u4 u4 u4		8 sd sd sd		6 u2 u2 u2		L
M	5 sd sd sd		9 u2 u2 u2		9 u2 u2 u2		6 sd sd sd		4 u2 u2 u2		8 sd sd sd		6 u2 u2 u2		3 sd sd sd		7 u4 u4 u4		5 u4 u4 u4		9 sd sd sd		7 u2 u2 u2		M
M	6 sd sd sd	1	10 u2 u2 u2	6	10 u2 u2 u2	10	7 sd sd sd	14	5 u2 u2 u2	18	9 sd sd sd	23	7 u2 u2 u2	27	4 sd sd sd	31	8 u4 u4 u4	36	6 u4 u4 u4 129	40	10 sd sd sd	45	8 u2 u2 u2	49	M
G	7 sd sd sd		11 u2 u2 u2		11 u2 u2 u2		8 sd sd sd		6 u2 u2 u2		10 sd sd sd		8 u2 u2 u2		5 sd sd sd		9 u4 u4 u4		7 u4 u4 u4		11 af af af		9 u2 u2 u2		G
V	8 af af af		12 u2 u2 u2		12 u2 u2 u2		9 sd sd sd		7 u2 u2 u2		11 sd sd sd		9 u2 u2 u2		6 sd sd sd		10 u4 u4 u4		8 u4 u4 u4		12 af af af		10 u2 u2 u2		V
S	9 af af af		13 u2 u2 u2		13 u2 u2 u2		10 sd sd sd		8 u2 u2 u2		12 sd sd sd		10 u2 u2 u2		7 sd sd sd		11 af af af		9 u4 u4 u4		13 af af af		11 u2 u2 u2		S
D	10 af af af		14 u2 u2 sd		14 af af af		11 sd sd sd		9 af af af		13 sd sd sd		11 af af af		8 sd sd sd		12 af af af		10 af af af		14 af af af		12 af af af		D
L	11 af af af		15 sd sd sd		15 af af af		12 sd sd sd		10 af af af		14 sd sd sd		12 af af af		9 sd sd sd		13 u2 u2 u2		11 u2 u2 u2		15 u4 u4 u4		13 sy u2 u2		L
M	12 af af af		16 sd sd sd		16 u2 u2 u2		13 sd sd sd		11 u2 u2 u2		15 sd sd sd		13 u2 u2 u2		10 sd sd sd		14 u2 u2 u2		12 u2 u2 u2		16 u4 u4 u4		14 u2 u2 u2		M
M	13 u4 u4 u4	2	17 sd sd sd	7	17 u2 u2 u2	11	14 sd sd sd	15	12 u2 u2 u2	19	16 sd sd sd	24	14 u2 u2 u2	28	11 sd sd sd	32	15 u2 u2 u2	37	13 u2 u2 u2	41	17 u4 u4 u4	46	15 u2 u2 u2	50	M
G	14 u4 u4 u4		18 sd sd sd		18 u2 u2 u2 125		15 sd sd sd		13 u2 u2 u2		17 sd sd sd		15 u2 u2 u2		12 sd sd sd		16 u2 u2 u2		14 u2 u2 u2		18 u4 u4 u4 130		16 u2 u2 u2		G
V	15 u4 u4 u4		19 sd sd sd		19 u2 u2 u2		16 sd sd sd		14 u2 u2 u2		18 af af af		16 u2 u2 u2		13 sd sd sd		17 u2 u2 u2		15 u2 u2 u2		19 u4 u4 u4		17 u2 u2 u2		V
S	16 u4 u4 u4		20 sd sd sd		20 u2 u2 u2		17 sd sd sd		15 u2 u2 u2		19 af af af		17 af af af		14 sd sd sd		18 u2 u2 u2		16 u2 u2 u2		20 u4 u4 u4		18 u2 u2 u2		S
D	17 u4 u4 u4		21 sd sd sd		21 af af af		18 sd sd sd		16 af af af		20 af af af		18 af af af		15 sd sd sd		19 u2 u2 sd		17 af af af		21 u4 u4 u4		19 u2 u2 u2		D
L	18 u4 u4 u4		22 af af af		22 af af af		19 sd sd sd		17 af af af		21 u4 u4 u4		19 u2 u2 u2		16 sd sd sd		20 sd sd sd		18 u2 u2 u2		22 u4 u4 u4		20 u2 u2 u2		L
M	19 af af af		23 af af af		23 sy u2 u2		20 af af af		18 sy u2 u2		22 u4 u4 u4		20 u2 u2 u2		17 af af af		21 sd sd sd		19 u2 u2 u2		23 u4 u4 u4		21 u2 u2 u2		M
M	20 u2 u2 u2		24 af af af	8	24 u2 u2 u2		21 af af af		19 u2 u2 u2	20	23 u4 u4 u4	25	21 u2 u2 u2	29	18 af af af	33	22 sd sd sd	38	20 u2 u2 u2	42	24 u4 u4 u4	47	22 u2 u2 u2	51	M
G	21 u2 u2 u2	3	25 u4 u4 u4		25 u2 u2 u2	12	22 af af af	16	20 u2 u2 u2		24 u4 u4 u4		22 u2 u2 u2		19 af af af		23 sd sd sd		21 u2 u2 u2		25 u4 u4 u4		23 af af sd		G
V	22 u2 u2 u2		26 u4 u4 u4		26 u2 u2 u2		23 u4 u4 u4		21 u2 u2 u2		25 u4 u4 u4		23 u2 u2 u2		20 u2 u2 u2		24 sd sd sd		22 u2 u2 u2		26 af af af		24 sd sd sd		V
S	23 u2 u2 u2		27 u4 u4 u4		27 u2 u2 u2		24 u4 u4 u4		22 u2 u2 u2		26 u4 u4 u4 127		24 u2 u2 u2		21 u2 u2 u2		25 sd sd sd		23 u2 u2 u2		27 af af af		25 sd sd sd		S
D	24 u2 u2 u2		28 u4 u4 u4		28 u2 u2 u2		25 u4 u4 u4		23 af af af		27 u4 u4 u4		25 af af af		22 u2 u2 u2		26 sd sd sd		24 af af af		28 u2 u2 u2		26 sd sd sd		D
L	25 u2 u2 u2				29 u2 u2 u2		26 u4 u4 u4		24 af af af		28 u4 u4 u4		26 af af af		23 u2 u2 u2		27 sd sd sd		25 af af af		29 u2 u2 u2		27 sd sd sd		L
M	26 u2 u2 u2 124				30 u2 u2 u2		27 u4 u4 u4 126		25 u2 u2 u2		29 u4 u4 u4		27 u2 u2 u2		24 u2 u2 u2 128		28 sd sd sd		26 sy u2 u2		30 u2 u2 u2		28 sd sd sd		M
M	27 u2 u2 u2				31 u2 u2 u2	13	28 u4 u4 u4	17	26 u2 u2 u2	21	30 u4 u4 u4	26	28 u2 u2 u2	30	25 u2 u2 u2	34	29 sd sd sd	39	27 u2 u2 u2	43		48	29 sd sd sd	52	M
G	28 u2 u2 u2	4					29 u4 u4 u4		27 u2 u2 u2				29 u2 u2 u2		26 u2 u2 u2		30 sd sd sd		28 u2 u2 u2				30 sd sd sd		G
V	29 u2 u2 u2						30 u4 u4 u4		28 u2 u2 u2				30 u2 u2 u2		27 u2 u2 u2				29 u2 u2 u2				31 sd sd sd		V
S	30 af af af								29 af af af				31 u2 u2 u2		28 u2 u2 u2				30 af af af						S
D	31 af af af								30 af af af						29 af af af				31 af af af						D
L									31 u2 u2 u2						30 u2 u2 u2	35									L
M															31 u2 u2 u2										M

TOTAL SHIFTS	6672	Hours		76.2%	of the year
Users shifts	5000	Hours		74.9%	of total
Users at 2.0 GeV	3640	Hours		72.8%	of users
Users at 2.4 GeV	1320	Hours		26.4%	of users
SYRMEP dedicated shifts at 2.4 GeV	40	Hours		0.8%	of users
Accelerator Physics shifts	1672	Hours		25.1%	of total
Shutdown	2088	Hours		23.8%	of the year
TOTAL shifts and shutdown	8760	Hours			

versione V2 del 16/7/2009 ok da tutti 9/9/09 approvato da CE e CS 22.9.09

	Sabati	Domeniche	
	20	9.33	
	6	5	
Tot	26	14.3	Users
	15	26	Acc.Phys.

Total 6672 h

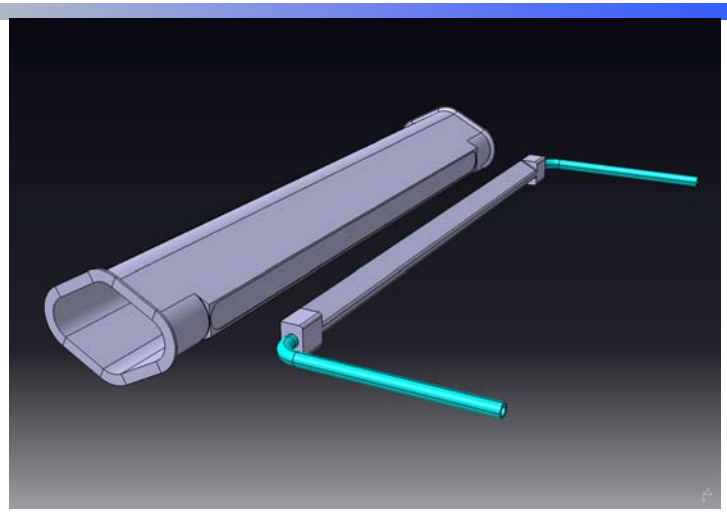
Users 5000 h

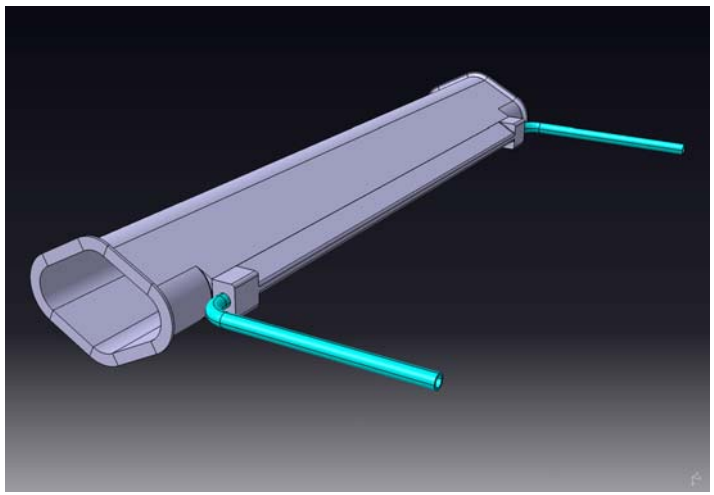
Some upgrades

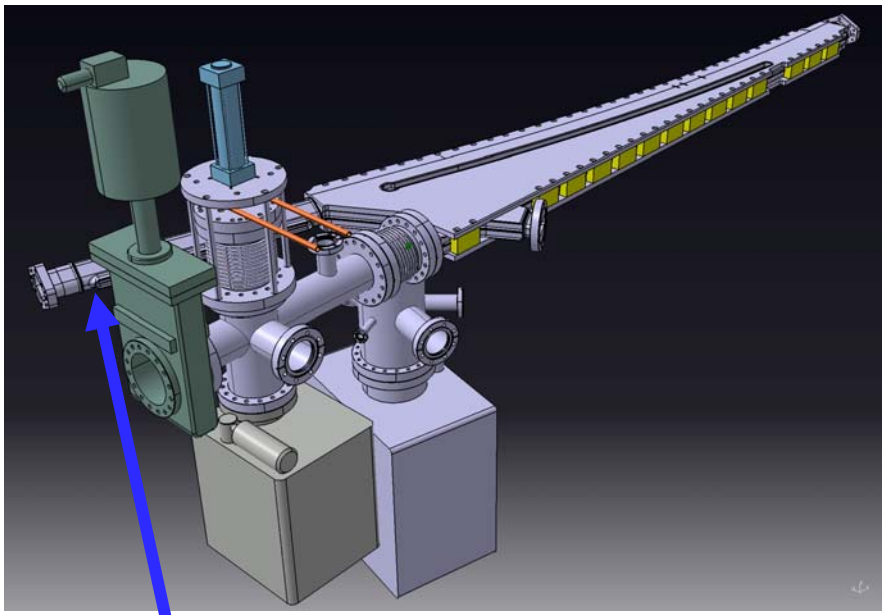
Aluminum Dipole light exits ->gradually replaced/repaired

2 low gap chambers (9.0 mm internal 11 external) -> start installing in January

Replacing 2 Elettra photon shutters





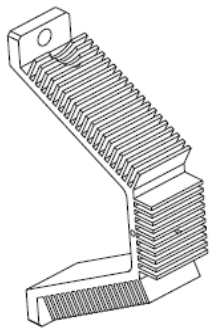


Front part damaged **(all of them!)**

Trying to increase the intensity -> rf power and stability/intensity ->heat load

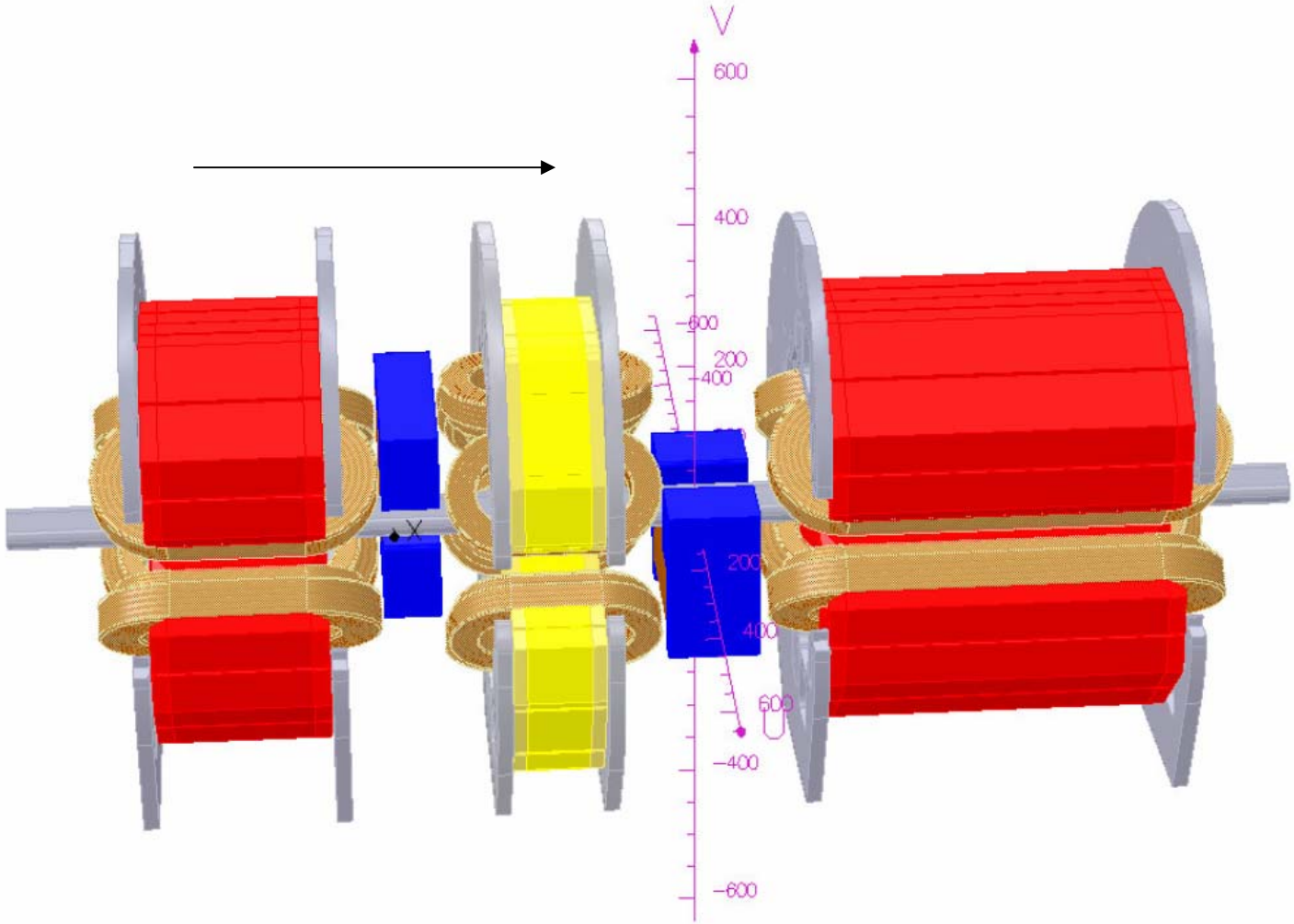
RF power –> 2 IOTs total 150 kW but still problems with the tubes

Heat load: radiators at the bpm after every bending and fans. Instead of 90 C down to 60 C and with air to 40



For general diagnostic “synchrobot” in collaboration with R. Pugliese and the scientific calculus

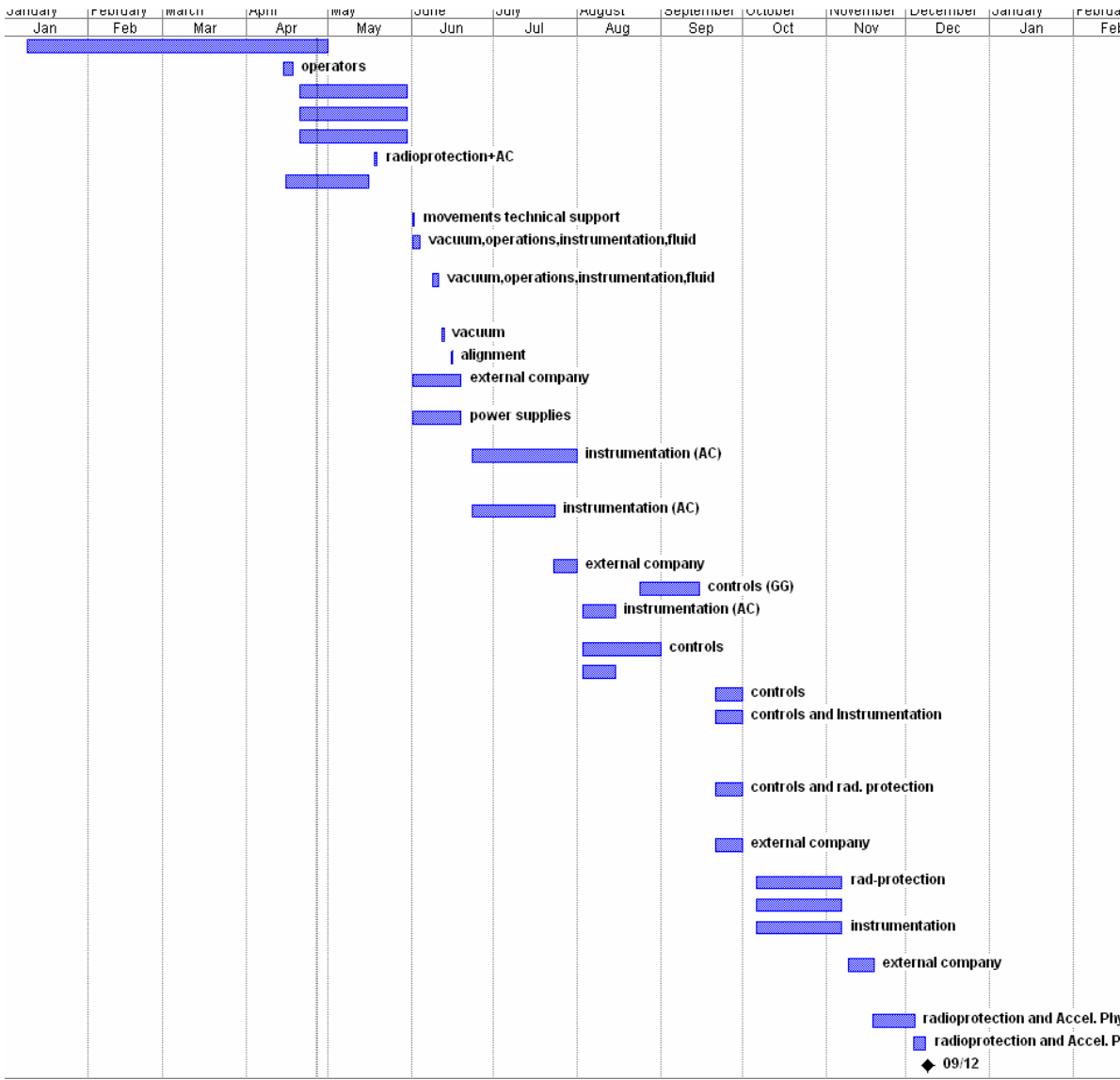
8th corrector



Elettra is having 7 correctors per section, not enough also due to their distribution to locally control 3 source points

Time schedule for top up - 2009

Task Name	Duration	Start	Finish
Top up studies with IDs closed	80 days?	Fri 09/01/0	Thu 30/04/0
Installation of cable for provisional current limitation interlok	4 days?	Tue 14/04/0	Fri 17/04/0
Prebuncher stability study (8 hours)	30 days?	Mon 20/04/0	Fri 29/05/0
Preinjector energy stability study (20 hours)	30 days?	Mon 20/04/0	Fri 29/05/0
Injection magnets distubance study (8-16 hours)	30 days?	Mon 20/04/0	Fri 29/05/0
Radio protection injection measurements at 2.4 GeV	1 day?	Mon 18/05/0	Mon 18/05/0
Meet with BLs for specs for eletrical and mechanical standa of Beam line Gate/trigger	23 days?	Wed 15/04/0	Fri 15/05/0
Open SR shielding/roof (1/2 day)	1 day?	Mon 01/06/0	Mon 01/06/0
scraper dismantlement (2 persons vacuum,1 operator,1 instrumentation,1 fluid.)	3 days?	Mon 01/06/0	Wed 03/06/0
Fast Current Transformer installation in SR (2 working days vacuum persons,1 operator,1 instrumentation, 1 movement technical)	3 days?	Mon 08/06/0	Wed 10/06/0
leak tests (1/2 day, 2 persons)	1 day?	Fri 12/06/0	Fri 12/06/0
alignment control (2 persons)	1 day?	Mon 15/06/0	Mon 15/06/0
First part of cable -fiber installation for Interlock and BTS,SR energy reading (external company 2-3 days)	14 days?	Mon 01/06/0	Thu 18/06/0
Installation of DCCT in magnets for reading BTS and SR en (16 hours)	14 days?	Mon 01/06/0	Thu 18/06/0
Study of FCT response with beam using high frequency sco (20-30 hours 70% can be done also in passive mode durin user run)	29 days?	Tue 23/06/0	Fri 31/07/0
Start Development of Digitizer for bucket by bucket current accquisition (1 month for internal development)	23 days?	Tue 23/06/0	Thu 23/07/0
Mounting PCB board	7 days?	Thu 23/07/0	Fri 31/07/0
HLS for top-up (2 weeks one person)	16 days?	Mon 24/08/0	Mon 14/09/0
Installation of timing board for top-up (trigger and gate for interlock, 8 hours)	10 days?	Mon 03/08/0	Fri 14/08/0
Control panel for timing board (16 hours)	21 days?	Mon 03/08/0	Mon 31/08/0
Check of cable and signal in section 5 (8 hours)	10 days?	Mon 03/08/0	Fri 14/08/0
Installation of final interlock system board addendum	8 days?	Mon 21/09/0	Wed 30/09/0
Installation of ADC 20 bit in section 5 and substitution of old CPU of SR DCCT system with Motorola CPU and real time system (1 week control group + 1 week strumentation)	8 days?	Mon 21/09/0	Wed 30/09/0
Integratio of interlock and Access control with actual system (2 week 2 person control group + 1 week test Radio protection)	8 days?	Mon 21/09/0	Wed 30/09/0
Installation of fiber for Beam line (external company 1 wee	8 days?	Mon 21/09/0	Wed 30/09/0
Control access tests	24 days?	Tue 06/10/0	Fri 06/11/0
Finalization of HLS sosftware for top up and top up tests	24 days?	Tue 06/10/0	Fri 06/11/0
First test of Digitizer for bucket by bucket current accquisitio with HLS software(24-32 hours Machine shift)	24 days?	Tue 06/10/0	Fri 06/11/0
Mounting Timing receiver for beam line and Gate for Top-up (1-2 week 70% can be done during machine user shift)	8 days?	Mon 09/11/0	Wed 18/11/0
Top up and further tests	12 days?	Wed 18/11/0	Thu 03/12/0
Top up final test	3 days?	Thu 03/12/0	Mon 07/12/0
Top up ready for users	0 days	Wed 09/12/0	Wed 09/12/0

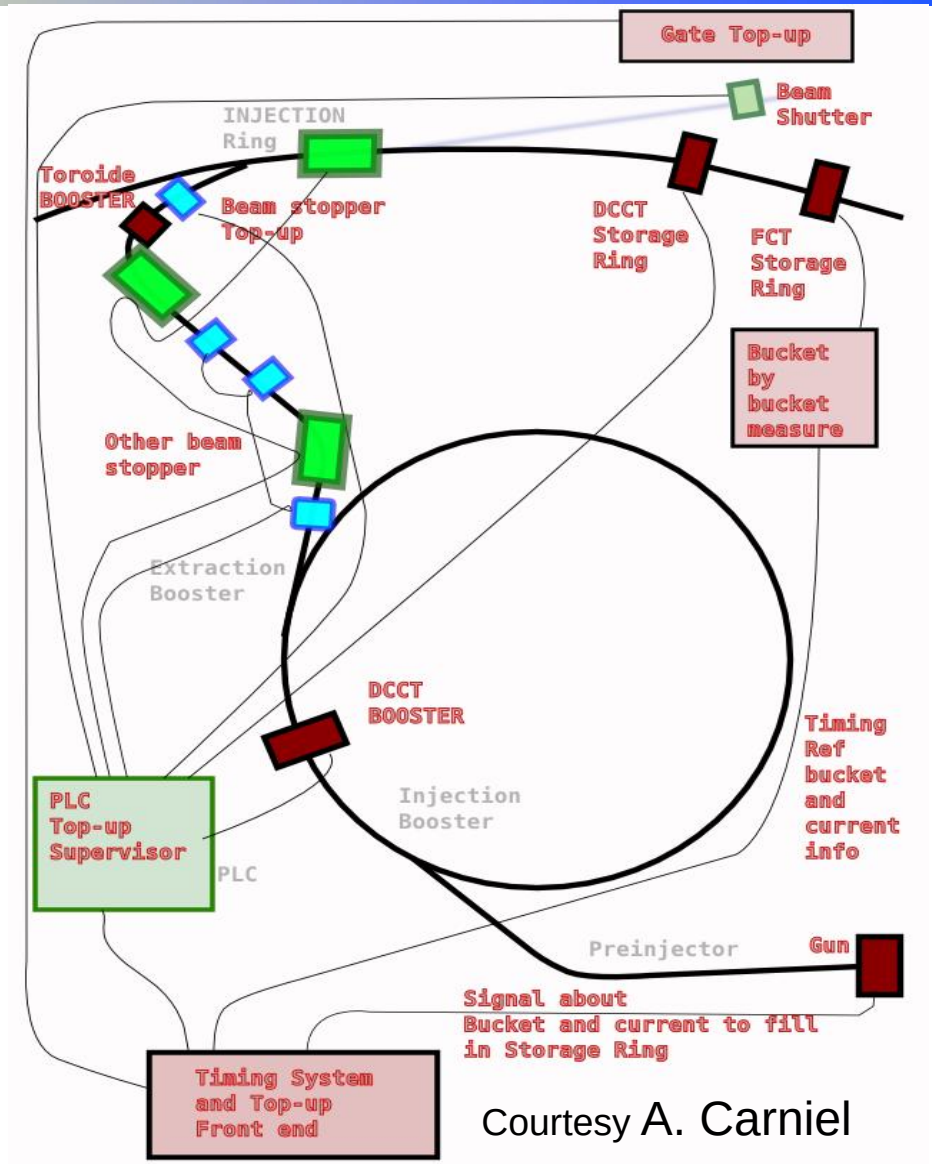


Top-up logic diagram

- Fill to the requested intensity with IDs open and BL shutters closed
- Close Ids and open shutters
- Inject 1 mA every certain time with less than 0.2 mA/s – (preferably in sb choosing less filled buckets) - otherwise topup TL beam stopper does not open

Block TU procedure if:

- efficiency less than certain value and/or radiation/ budget above defined level
- TL/SR magnets current reading vary/ fail / not matched with SR/TL
- No current in booster



Courtesy A. Carniel

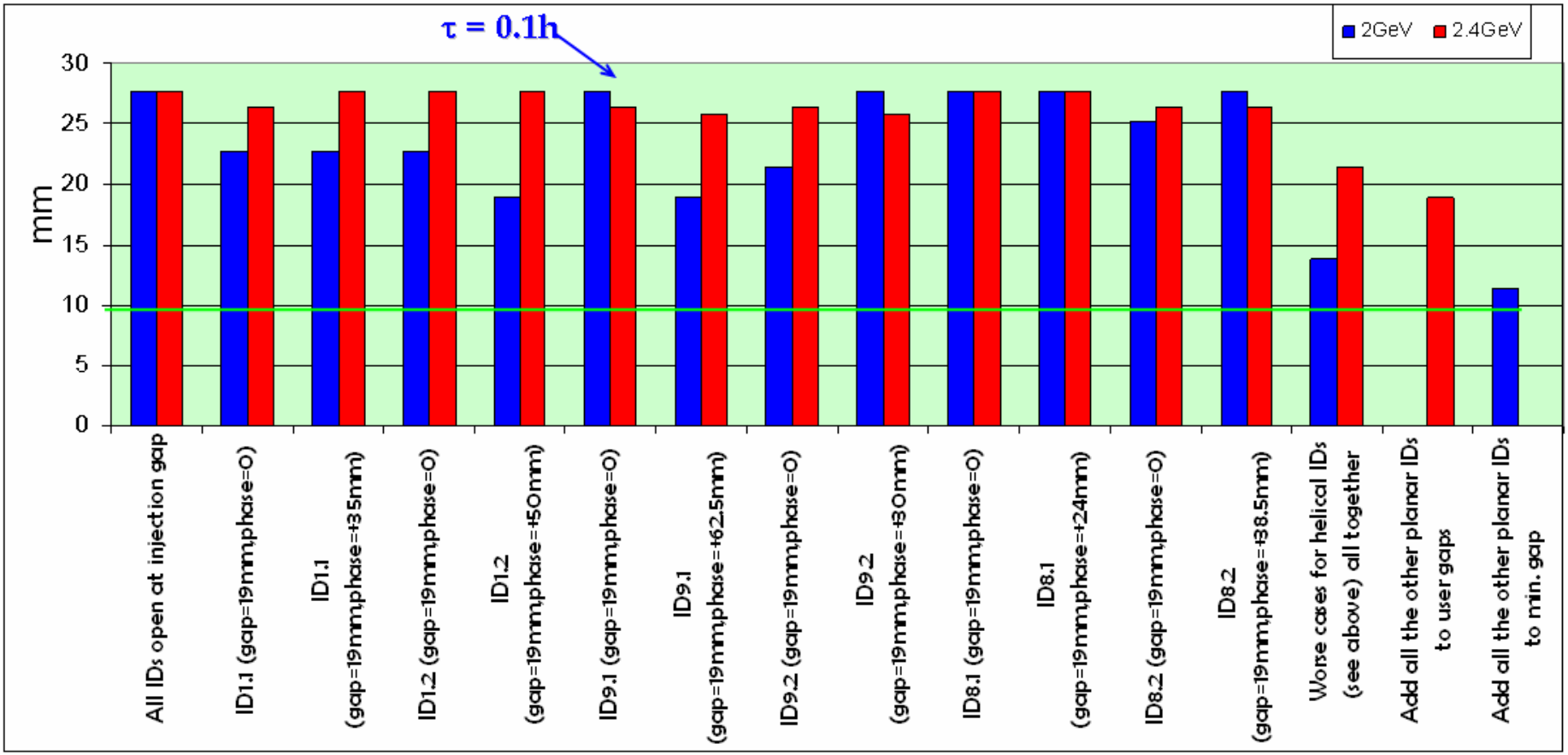
Work done

- Injected at both 2 and 2.4 GeV with ids closed and with efficiencies above 80% √
- Calibrated the injection system to minimize disturbance due to pulsing √ in any case a gating signal will be provided
- Simulations of worst case scenarios performed √
- Upgraded instrumentation, interlocks and radiation safety system √
- Started Series of radiation / interlock tests √

Actually commissioning the whole system at real conditions i.e. beam line shutters open

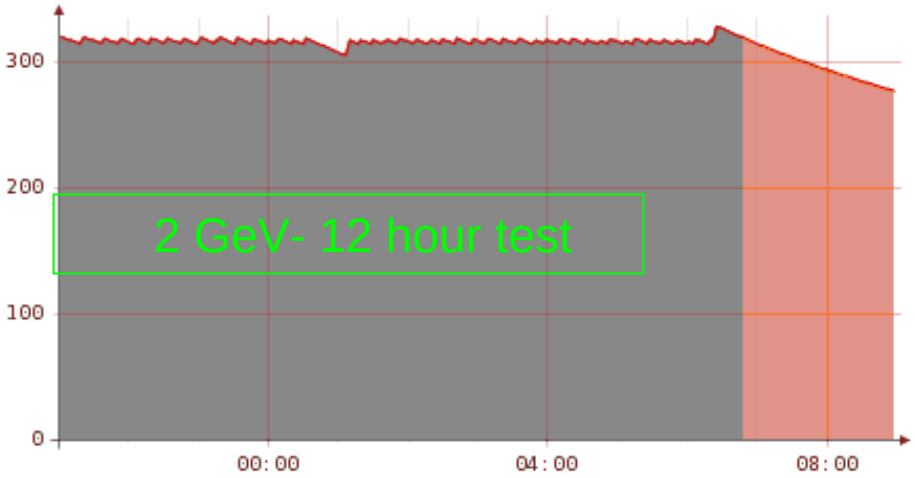
Exploring dynamic aperture limits

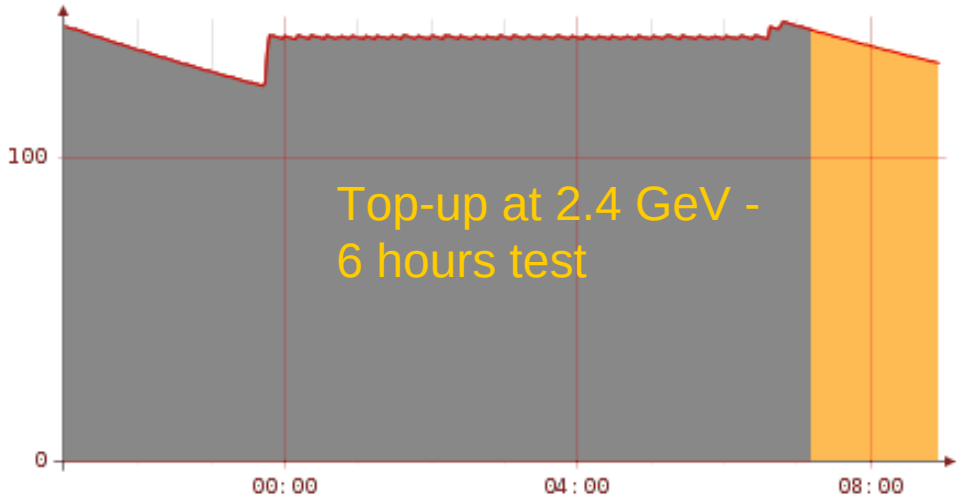
Dynamic aperture measurements in 2007 shown that top-up was possible at both operating energies of Elettra (our primary concern)

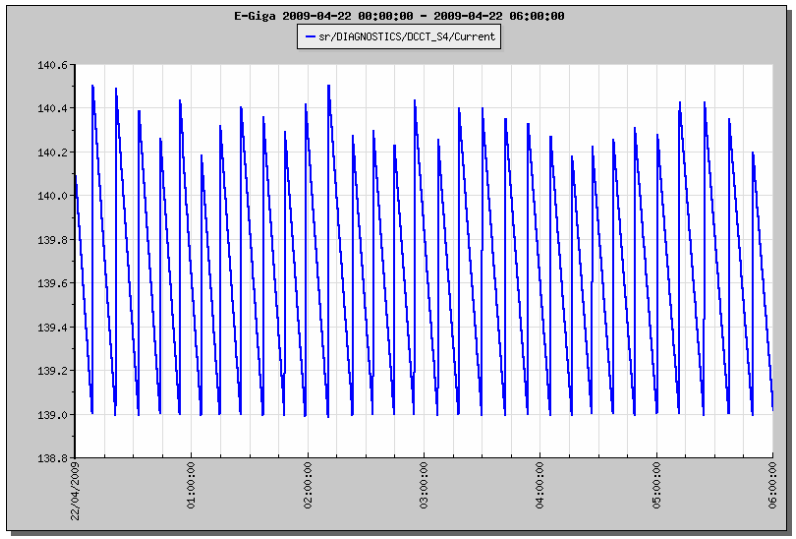


Top-up tests (Ids closed)

Confirmed that top up is possible at both energies, more critical at 2 GeV. Series of tests also for the stability of the injector.

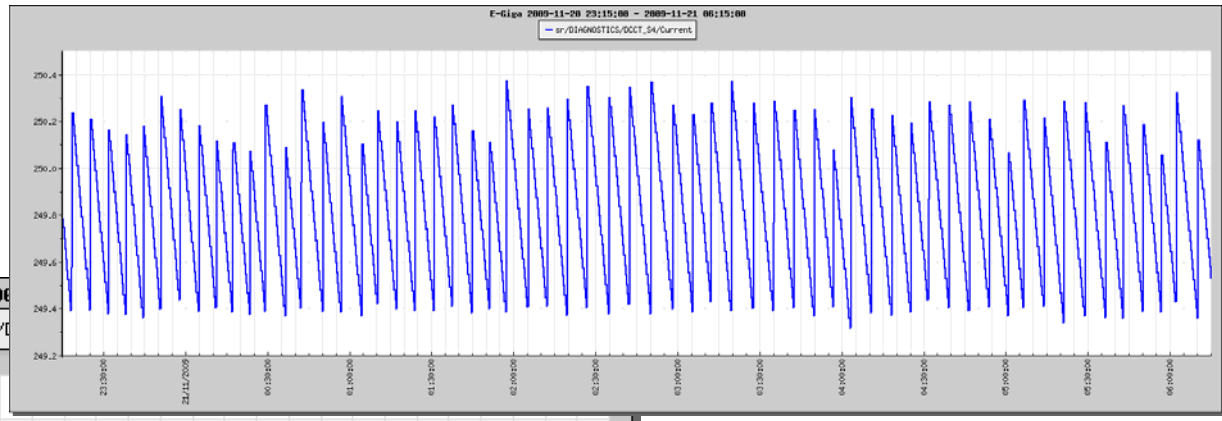


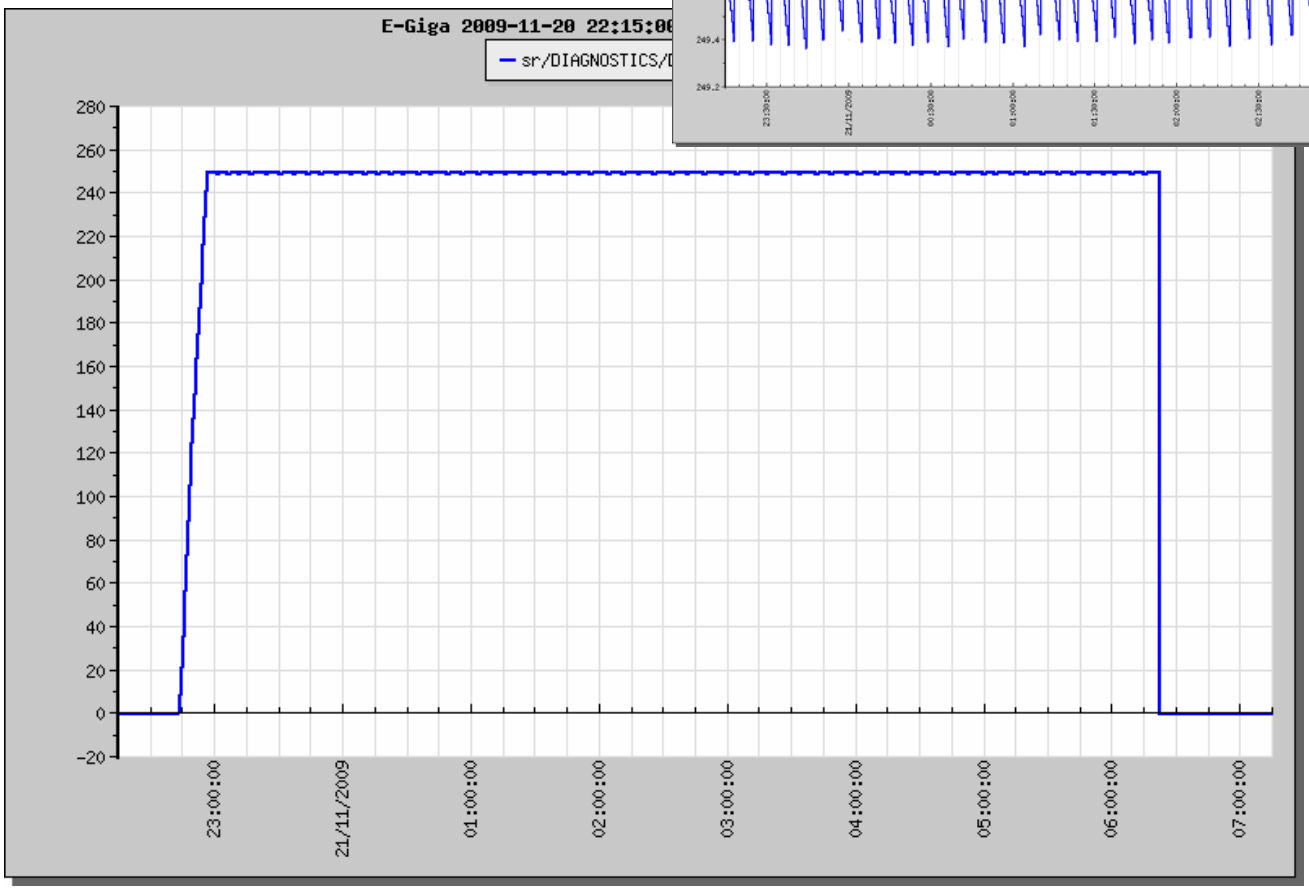




Stability during top-up

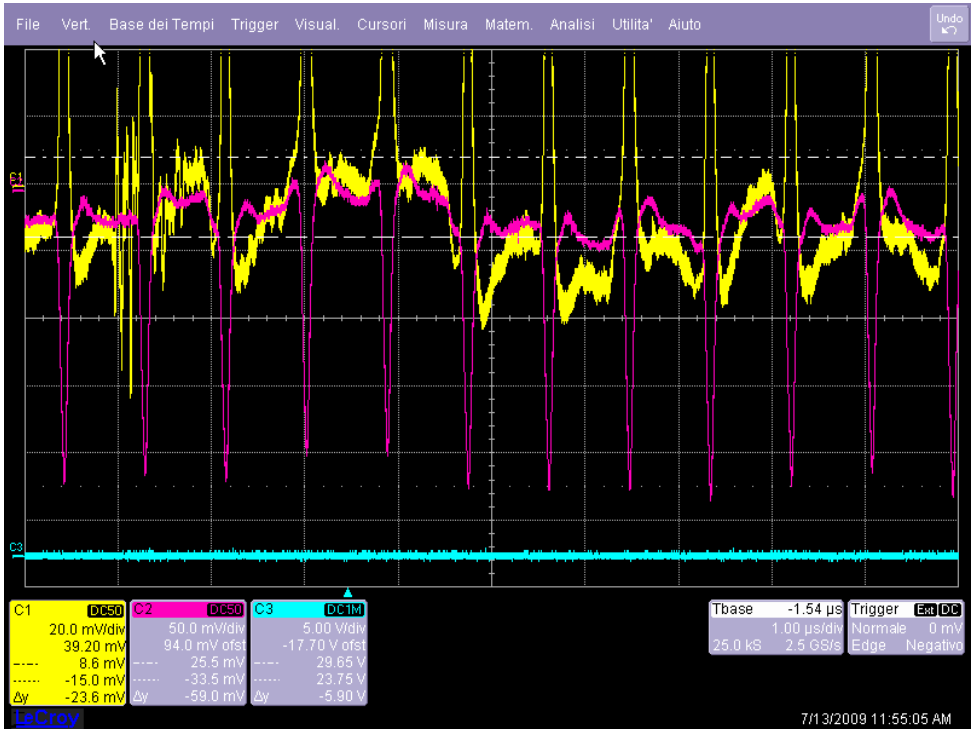
Set at 250 to 249 mA
2 GeV





75% homogeneity within 1 mA in 7 hours

Kicker optimization



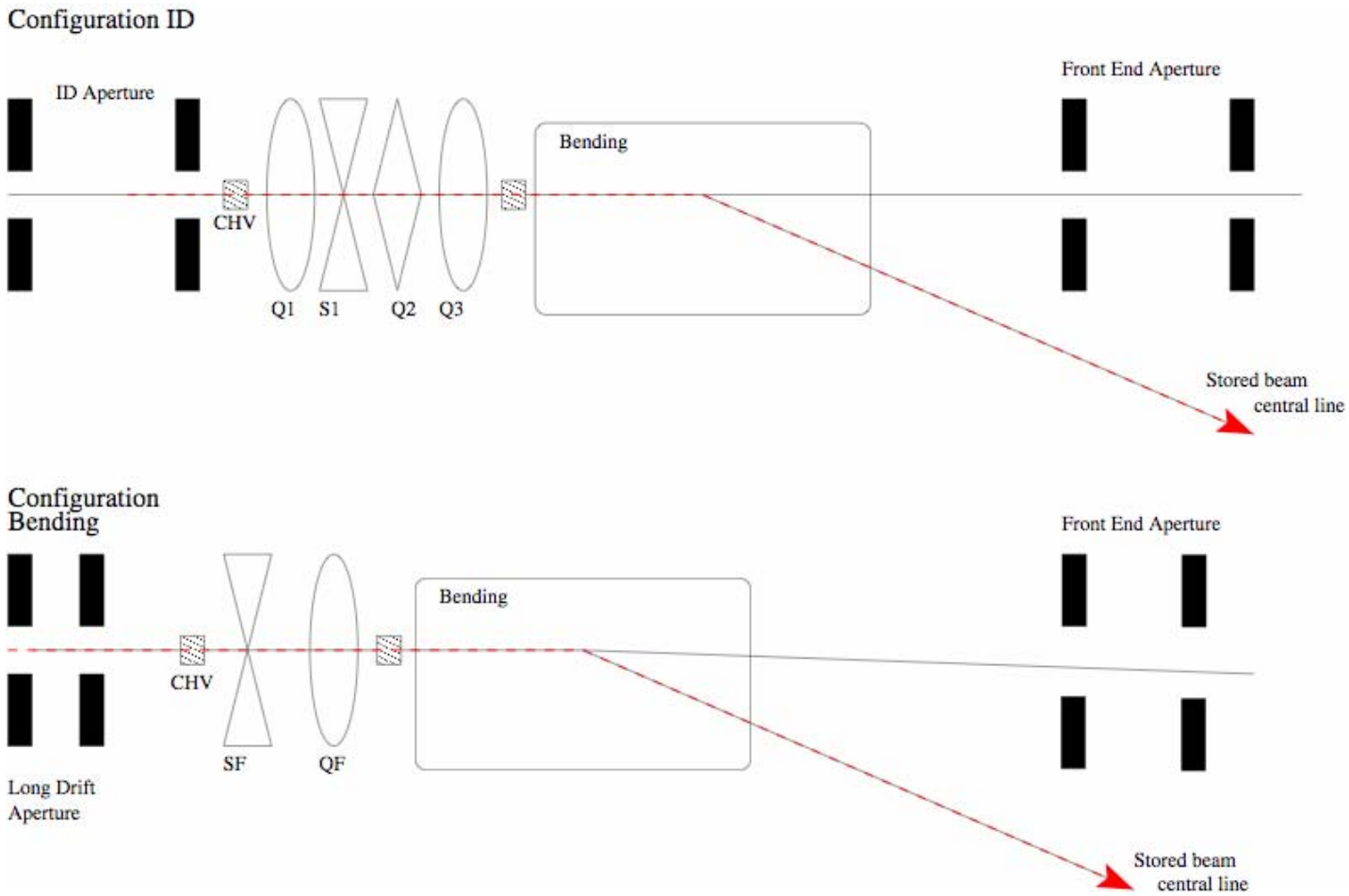
First trials of amplitude and synchronization optimization of the injection elements gave good results: a 0.5 mm orbit distortion was measured immediately after the last kicker that was reduced down to 20 μm after 32 ms.

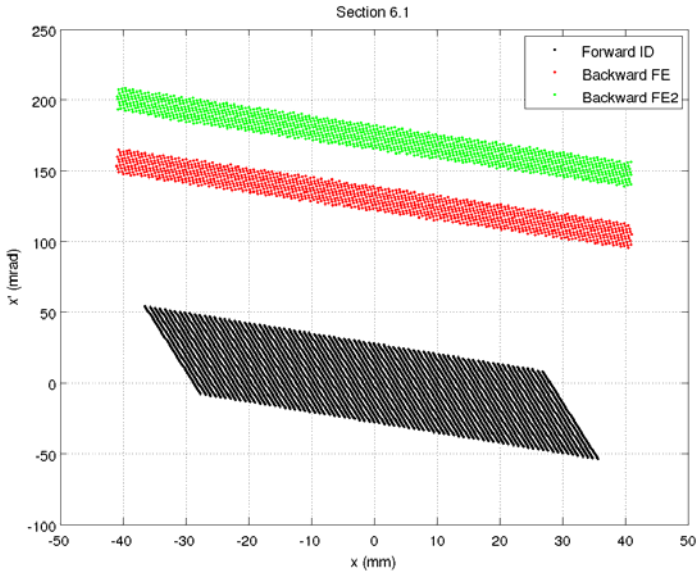
Letting the injection system on for 4 hours during a user shift (with feedbacks running) no photon beam deterioration has been reported

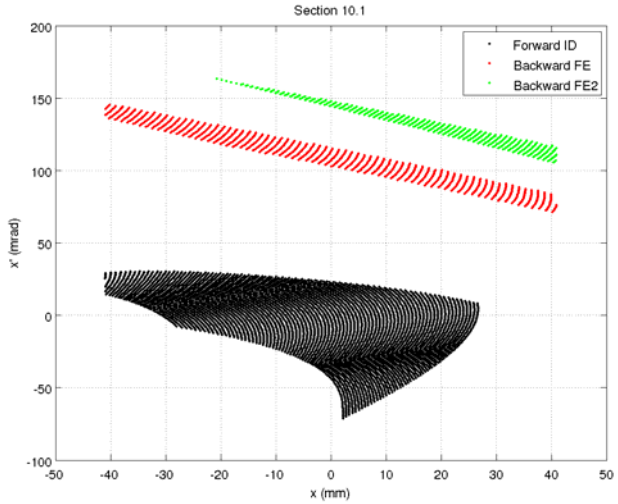
Peace of mind

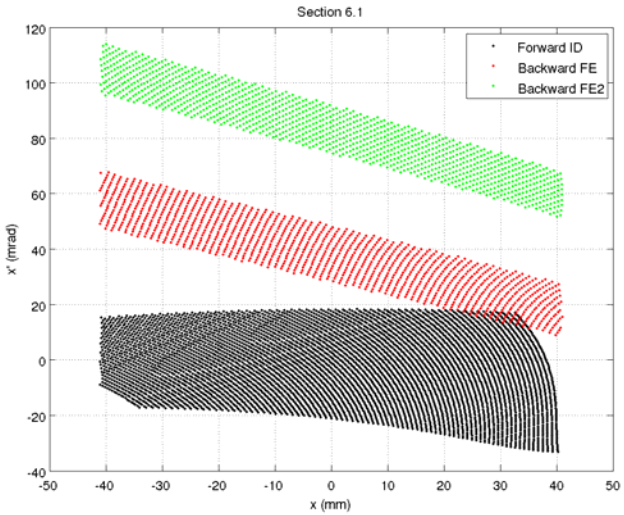
Worst case scenario investigated

(S. Ferry - *Top up Safety Simulation for Elettra, ST/M-TN-09/13*)

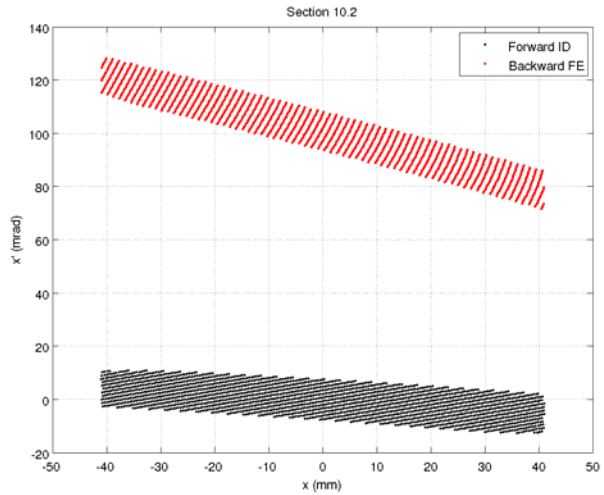


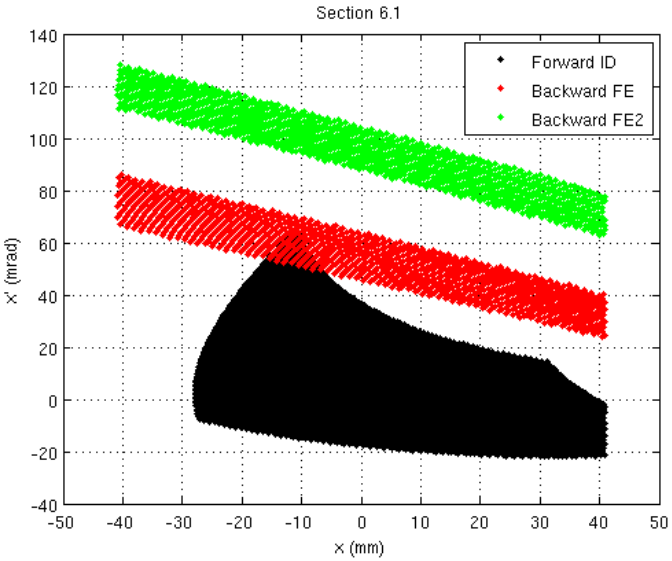

Section 6.1
Forward ID
Backward FE
Backward FE2
x' (mrad)
x (mm)

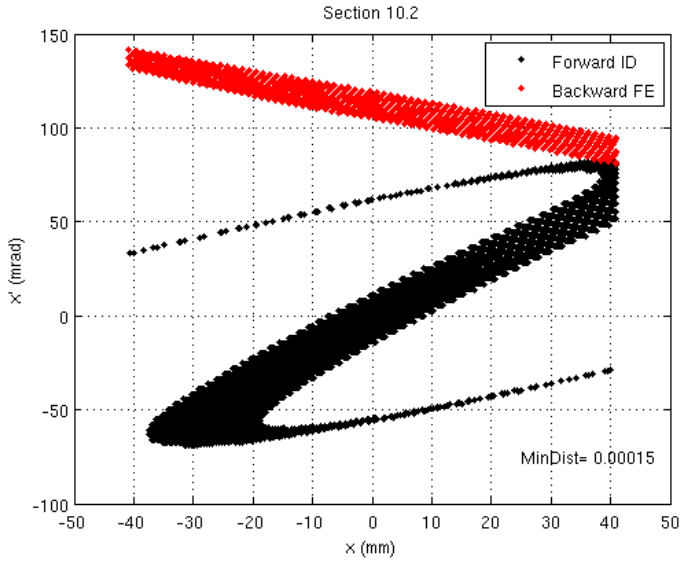

Section 10.1
Forward ID
Backward FE
Backward FE2
x' (mrad)
x (mm)


Section 6.1
Forward ID
Backward FE
Backward FE2
x' (mrad)
x (mm)

All PS
at
50%


Section 10.2
Forward ID
Backward FE
x' (mrad)
x (mm)





Line 6.1

- SF inverse polarity
- QF nominal
- Corrector 2mrad
- Einj = 2.4GeV
- 70% bending PS

Line 10.2

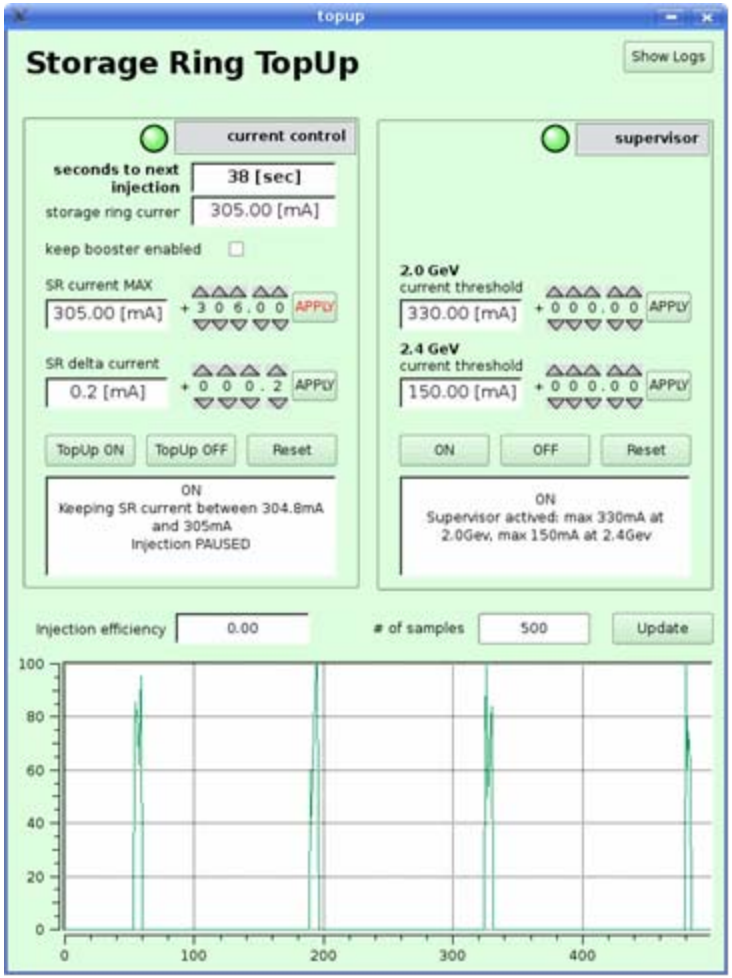
- Q3 off
- Q2 max power
- Q1+S1 inverse polarity
- Corrector 2mrad
- Einj = 2.4GeV
- 70% bending PS

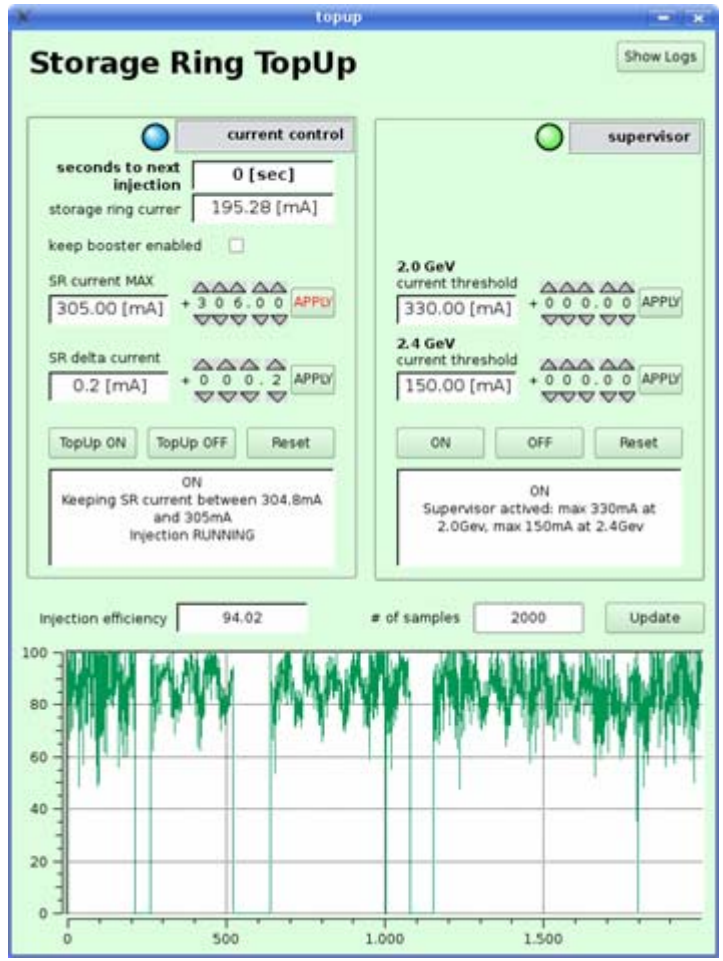
But applying to the whole SR these conditions do not give even an optics solution

Top up tests at real conditions

20-21/11/2009

Refill / Top-up controller





Conclusions

The Top up is functioning – as scheduled. There is still some work to be done especially with the gating signals for the beam lines, but the main job is finished. Hope to obtain soon the radiation protection license and start top up in normal operations early next year.

Many thanks to my collaborators :

A. Carniel, S. Krecic for the technical supervision

M. Vento and the operators

G. Gaio, F. Giacuzzo, S. Fontanini, C. Scafuri and the controls

K. Casarin, E. Quai, A. Vascotto and the radioprotection

S. Ferry for the worst case scenario simulations

…and certainly all members of the ODAC project

2010 outlook –> a busy year!

- Top up operations -> stability
- Increase reliability of injectors
- Install scrapers to create a preferential point of beam loss
- Realign-> reproducibility
- Increase intensity-> radiators + rf power
- Commission two low gap (9 mm) chambers and a new ID

- Reproducibility / submicron stability