MTE Status of commissioning with beam

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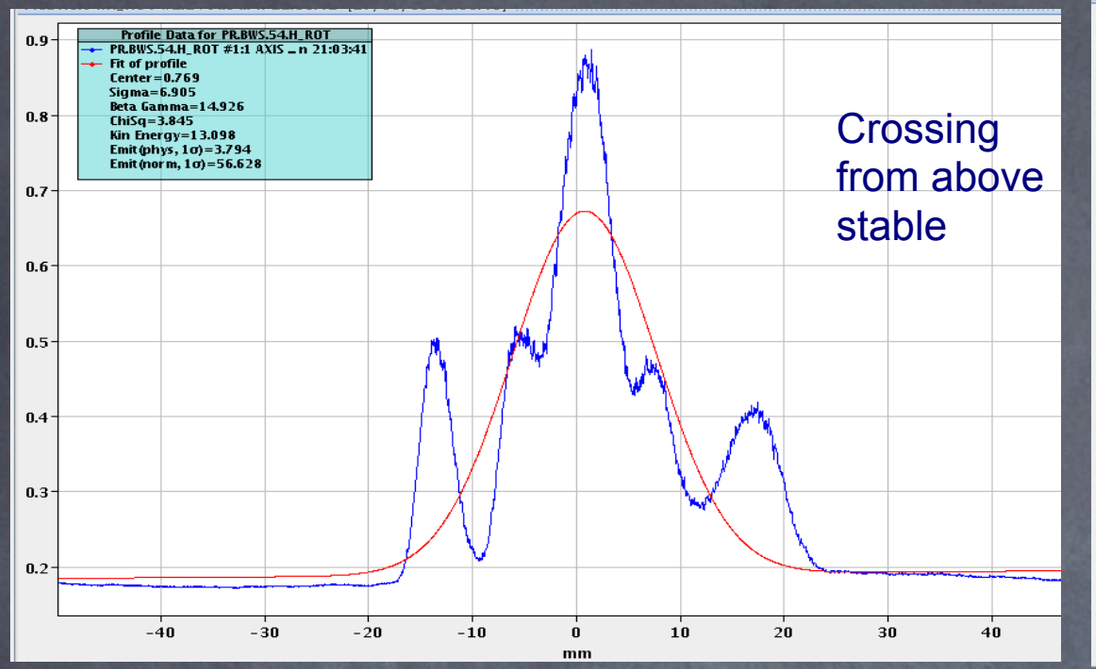
Acknowledgments: OP crews, BE/BI, BE/CO, DGS/RP,
TE/ABT, TE/MSC, ...

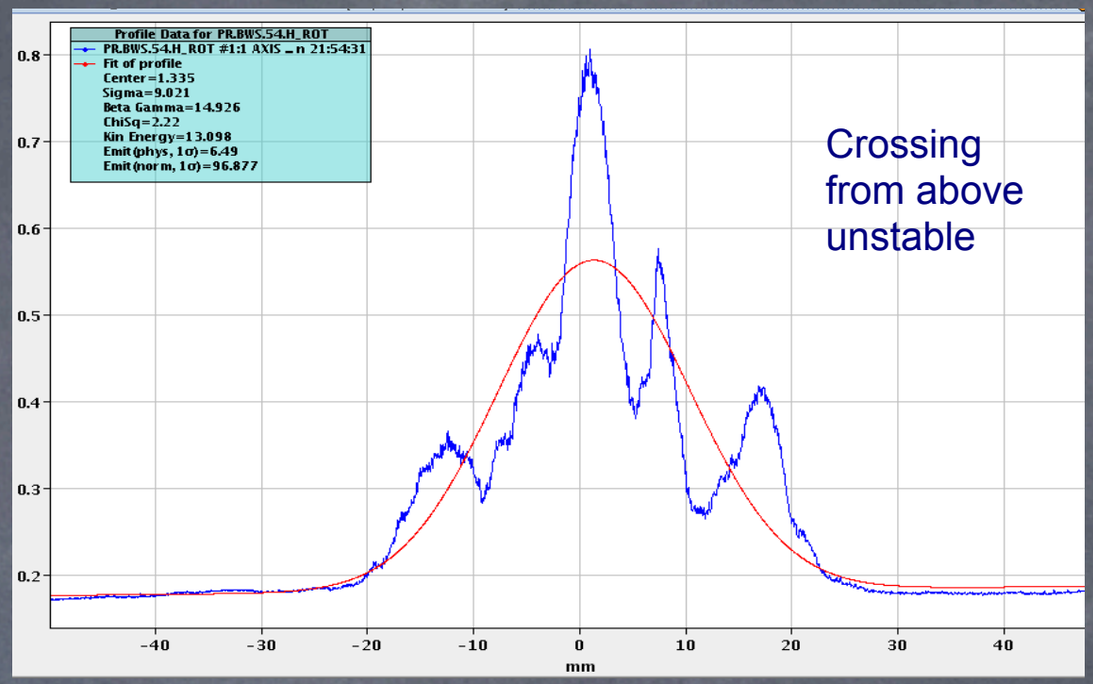
Main goals of 2011 studies

- Understand capture fluctuations
- Understand trajectory fluctuations observed in the SPS
- Study an alternative scheme to protect the SMH16 like:
  - hybrid-MTE, tests with beam
  - dummy septum, simulation studies

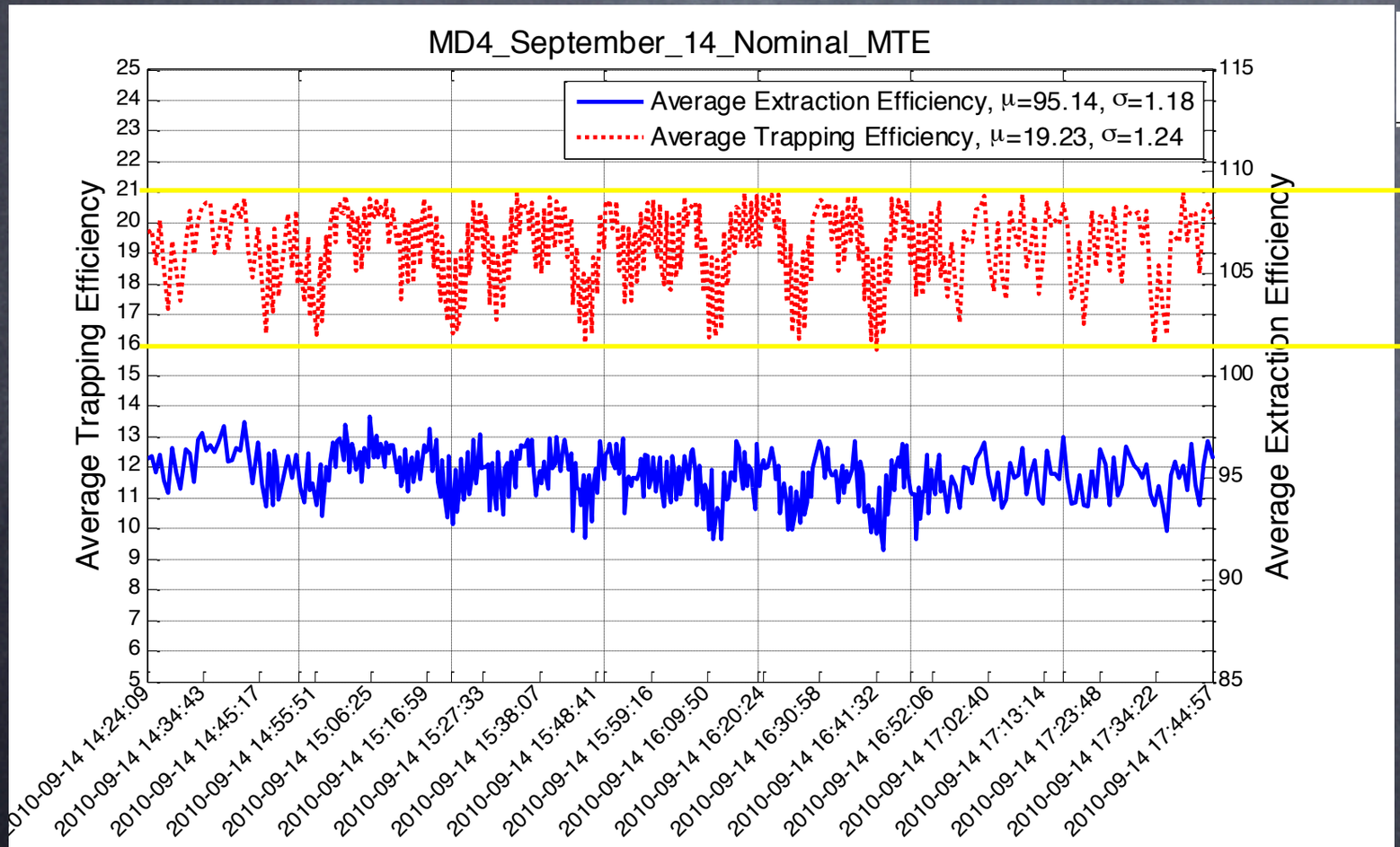
Capture instability



Crossing from above stable



Crossing from above unstable



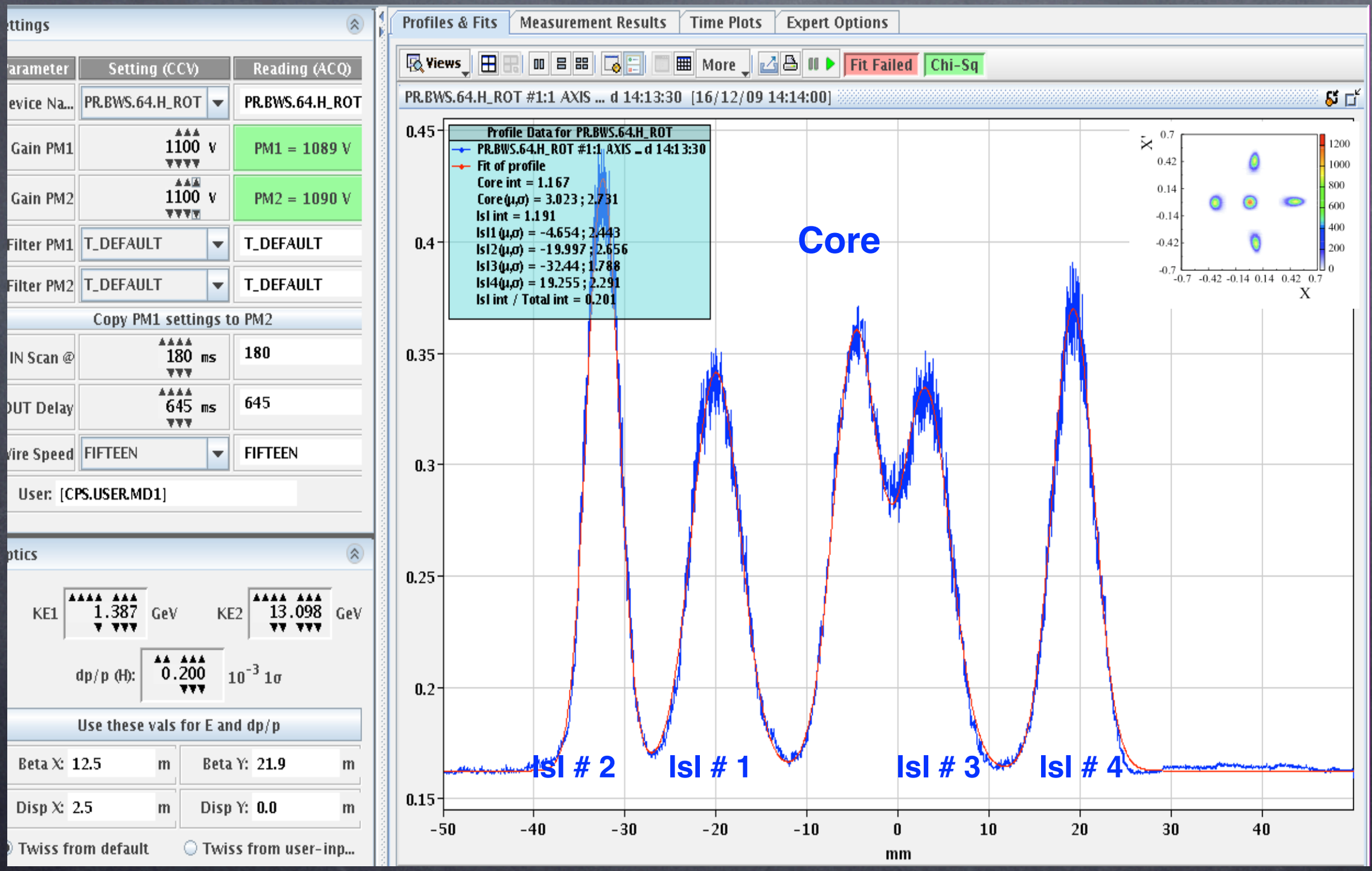
Average Extraction Efficiency, μ=95.14, σ=1.18
Average Trapping Efficiency, μ=19.23, σ=1.24

~ 21 %

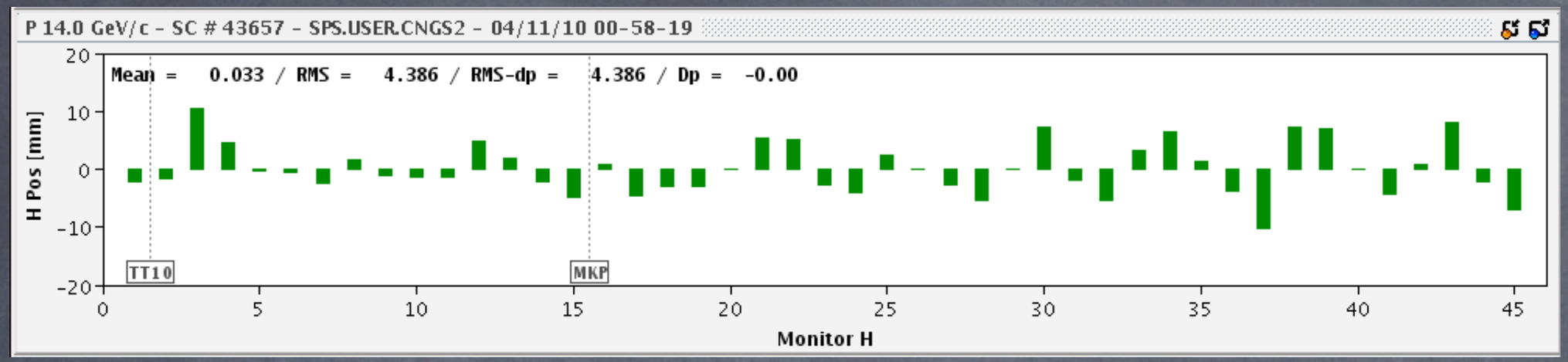
~ 16 %

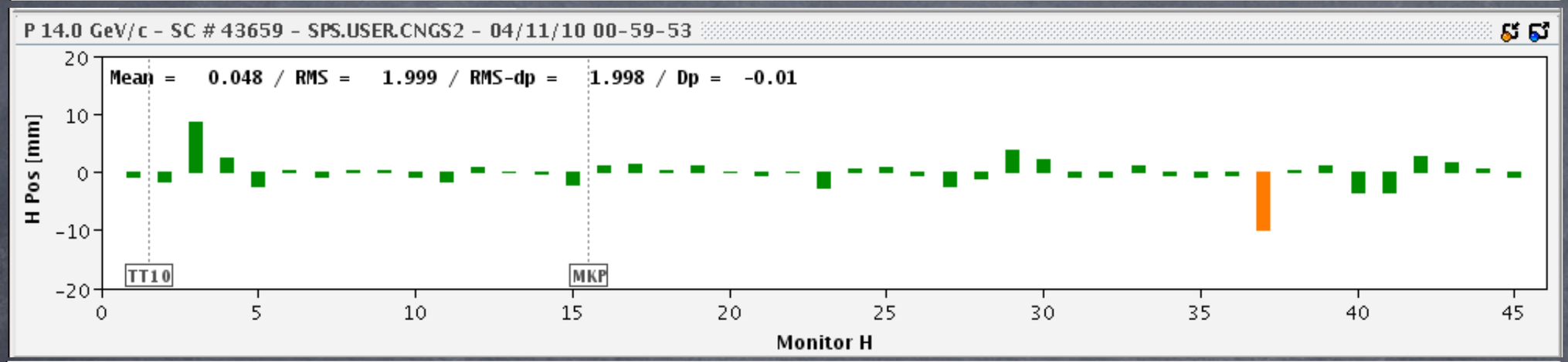
Capture data of 2010 shows a “regular” loss in capture efficiency vs time of about 4-5% with island profile degradation.

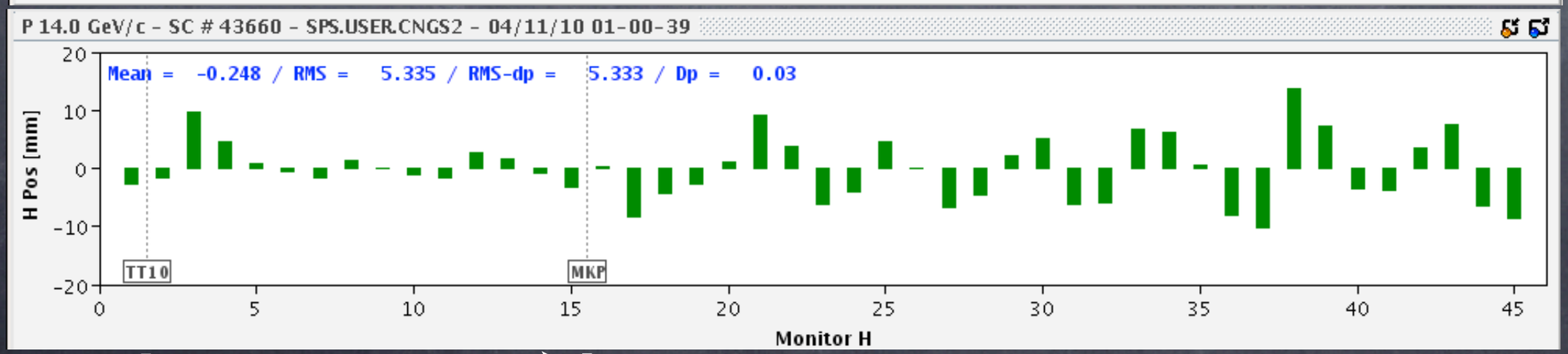
When the capture is perfect ...



SPS instability: H trajectory reproducibility







Horizontal trajectory

Consecutive SPS injection

TT10

SPS ring

Follow-ups from 2010 workshop 1/3

Activity	When	Status @ 2011	Comments
Round corners of ODE/OMTs function	Short		PO eventual delay, no change in capture
Low energy quads: CO installation for 40 channels	Short		QLOW stable, ADC problem identified also for CTF3
Study source of spill fluctuation	**Short**		**No capture re-established since start of the run**
Take data/analysis of PC stability vs spill data	Short		No correlation found
Study correlation of PFW-N fluctuations with spill	Short		No correlation found
Check performance when crossing resonance from above	Short		No time to repeat the first tests
Check impact of longitudinal parameters on adiabaticity of process	Short		No correlation found
Repeat tests with different tune curves	**Short**		**To be repeated, not clear results**
Re-measure PC stability with better DCCT	Short		PFW/F8L stable
TT2 PU tests	Short		New electronics will be installed in 2011
YASP implementation of trajectory correction in TT2	Short		Not done but not urgent
Fix YASP problem with MTE optics in TT10	Short		
Determine which islands is measured in TT10	Short		It is the third
Correct overall trajectories in TT10	Short		Optics in TT10 corrected
Correct slice by slice	Short		Bug in SPS application found
Study trajectory stability problem	**Short**		**Ongoing without capture**
Study systematically fluctuations in SPS for the various injected turns and correlate with B-field at PS	**Short**		**Not possible yet to have systematic B-field meas.**
Finish tests of new BLMs	**Short**		**No suitable BLMs installed in extraction region**
Continue calibration of BCTs	**Short**		**Cross calibration done. Missing precision required**

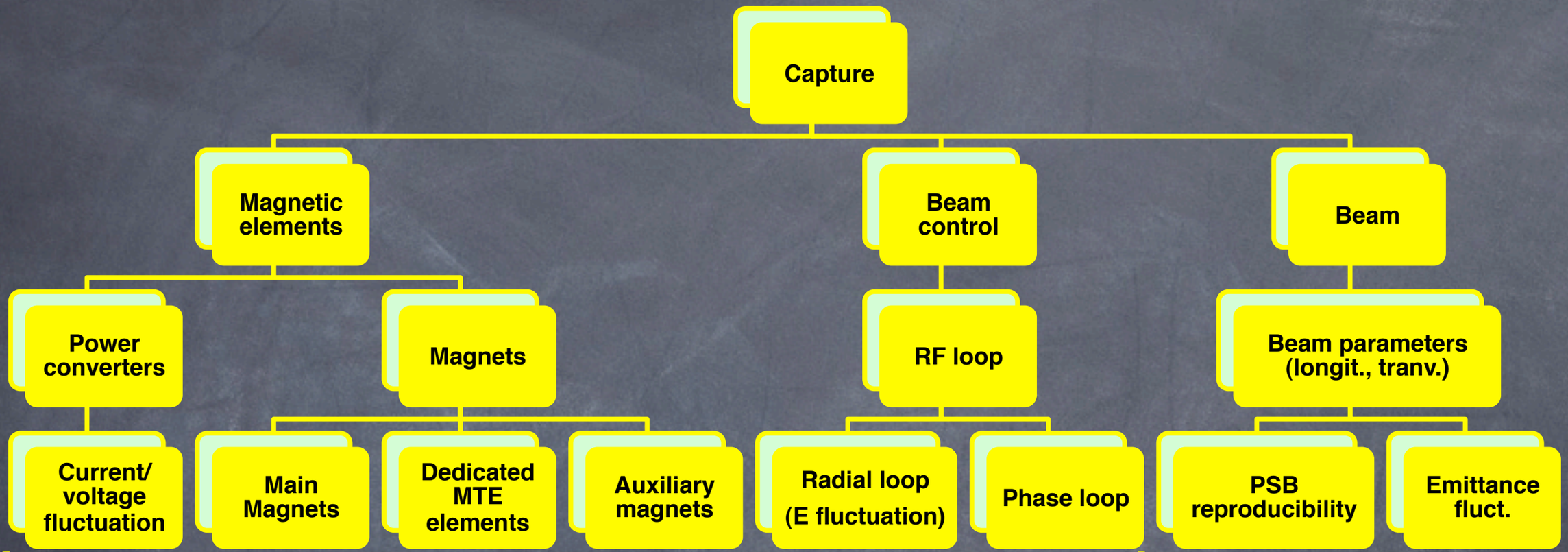
Follow-ups from last workshop 2/3

Activity	When	Status	Comments
Launch approval of new PS FWS documents	Short		New tank installed, new mechanics in production, see LIU
Orbit meas. at extraction for LHC-type single bunch beams for E fluct.	**Short**		**Ongoing with the traj. measurements**
Fluka simulation RP expert for dummy septum	Short		EDMS document available
Fluka simulation RP expert for spoiler for SMH16	Short		Renounced, no gain
Contact R. Losito for eventual septum design/studies with FLUKA	Short		Not done, decided to do with RP
Trajectory simulation to determine impact point on dummy septum	Short		
Fast polarity switch for KFA13/21	Short		
Improve OP application stability	Short		Improvements implemented
Propose increase shielding on top SS16 (eventually 31)	Short		Done, SMH16 will be done during LS1
Improve INCA stability	Short		Ongoing
Review the generation of the PS beam with the aim of reducing vertical emittance.	**Medium**		**NO IMPROVEMENT FOUND**
Full remote control over transverse blow up with Labview	Medium		
Full remote control over transverse blow up with CVORG	Medium		Not done but will be necessary soon
Make BFA and DFA fully ppm	**Medium**		**Important if hybrid-MTE with also period with CT**
YASP implementation of five-turn trajectory correction in TT2	Medium		Started
Study and integrate improved shielding at door 122	Medium		Shielding installed in the tunnel and in front of the door
Review usage of Linac 3 area and building 151	Medium		Remote control being implemented
Improve materials vs activation for next SMH16 spare built	Medium		Current material choice already optimised
Improve control for PC	Medium		Loop improved
Magnetic model for multipoles calculation with current error	Medium		Thesis ongoing in MCS group

Follow-ups from last workshop 3/3

Activity	When	Status	Comments
Change PS model to separate odd-even PFW	Medium		Not done but not urgent
Dose impact in the extraction zone with dummy septa	Medium		Study done available in EDMS
Design of spoiler in SMH16	Medium		Decided not useful
Study displacement of gj quadrupole and DHZ15	**Medium**		**Gamma jump done, DHZ15 to be done**
Study new extraction design CT+MTE	**Medium**		
Test with CT+MTE	**Medium**		**Tried but not conclusive**
Hardware change with installation of dummy septa	Long		Foreseen for LS1
Definitive split and installation of pickup electronics for TT2 line	Long		During next SD or LS1

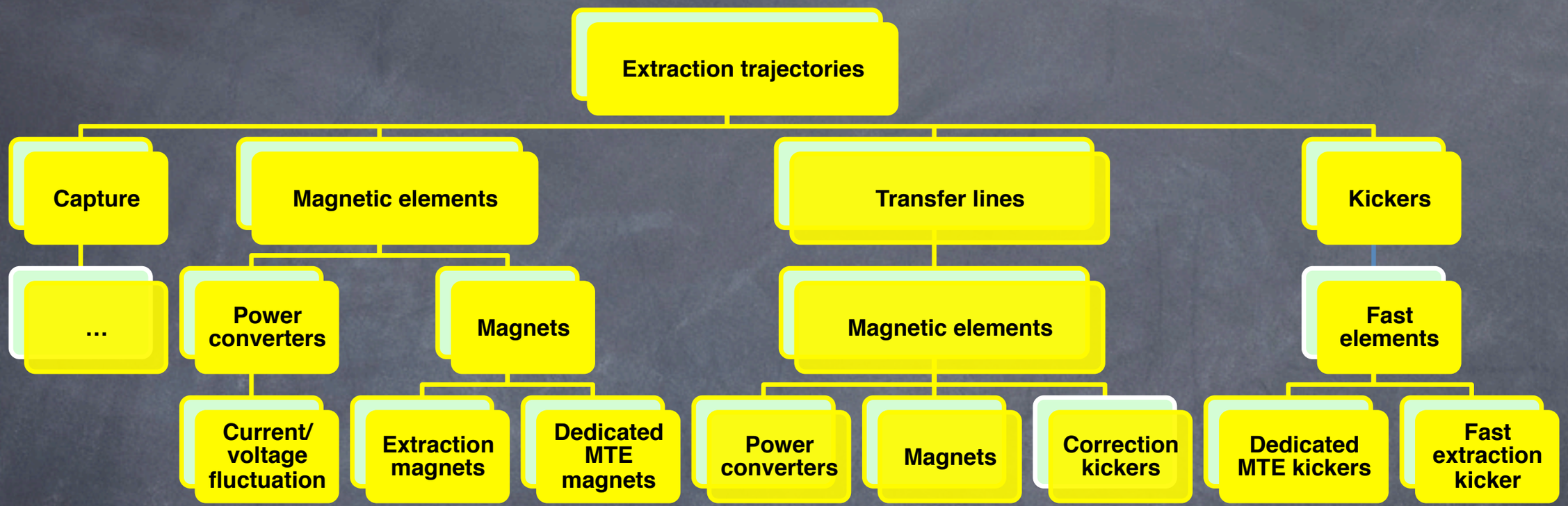
Fluctuation Searches: logic scheme 1/2



These can cause a variation of a parameter within a cycle during island formation and separation

These can vary from cycle-to-cycle

Fluctuation Searches: logic scheme 2/2



These can cause a variation of a parameter within a cycle during the slow part of the extraction process

These can cause a variation of a parameter within a cycle during the fast part of the extraction process

These can vary from cycle-to-cycle

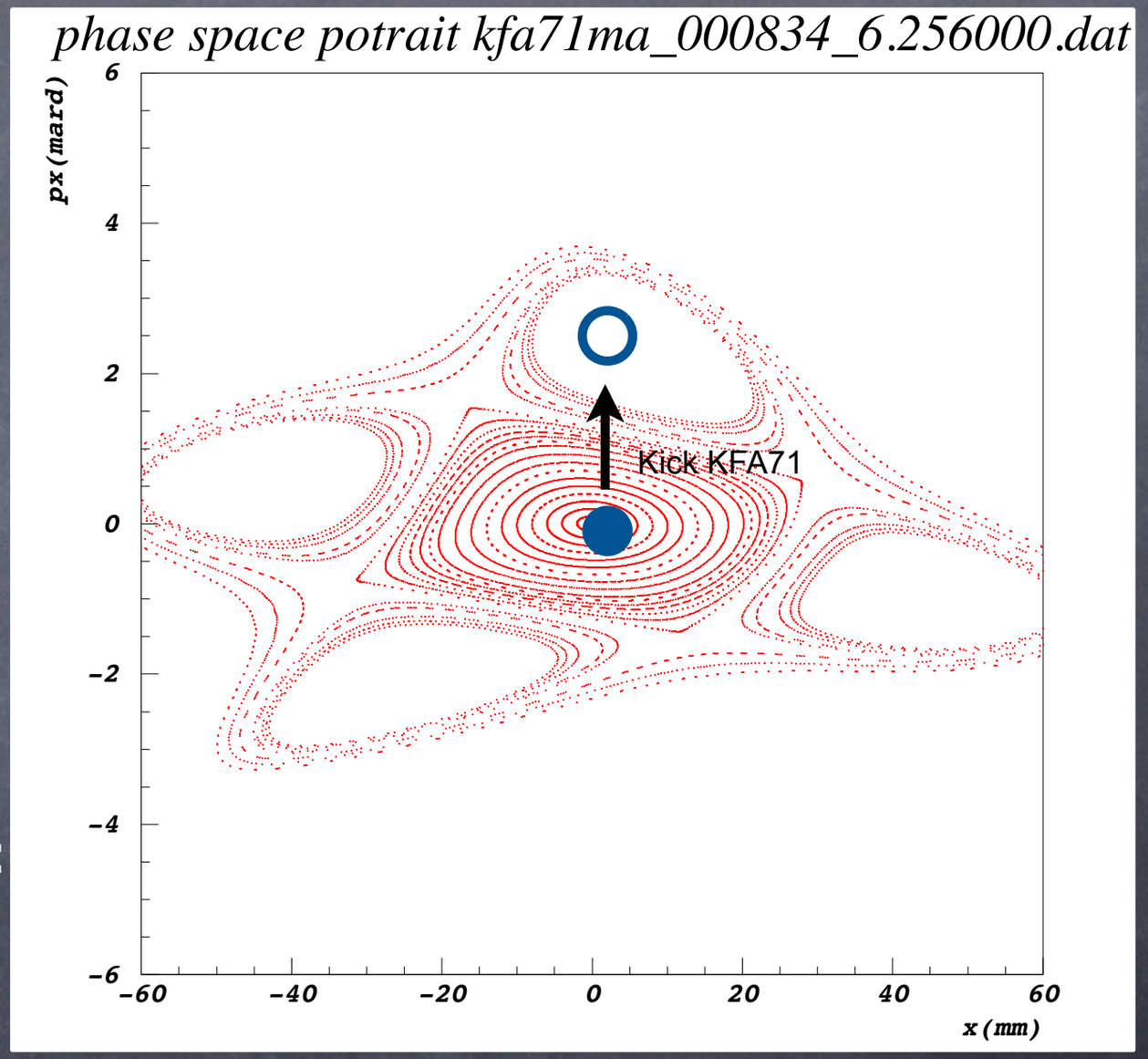
Single-bunch studies to probe fluctuations

Goal: probe the phase-space and the island stability by kicking with the extraction kicker a small-emittance single-bunch beam in an island.

Very simplified situation:

a) no capture process involved
b) static situation after filamentation
c) all the magnetic elements are working at fixed gradients, so static situation
d) constant main magnetic field

The trajectory system can be used measure the beam trajectory in the islands turn-by-turn since the beam is not split and bunched

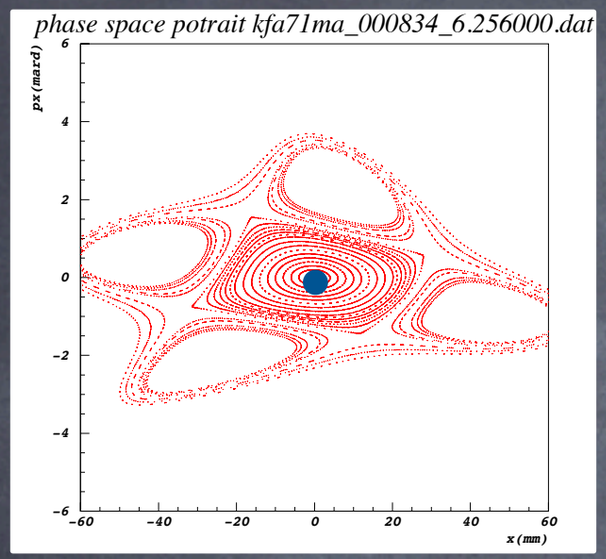


Tests to check time stability of fixed point trajectories by varying different parameters:
a) linear and non linear chromaticity
b) beam position
c) tune
.....

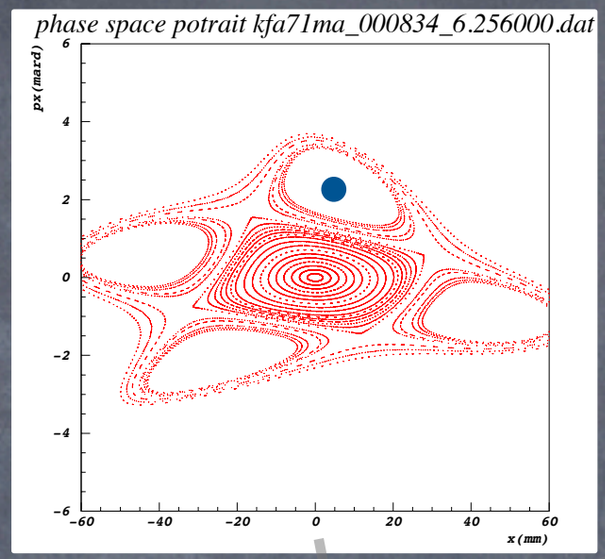
Eventually "simulate" capture process by displacing the island

Single-bunch studies: the method

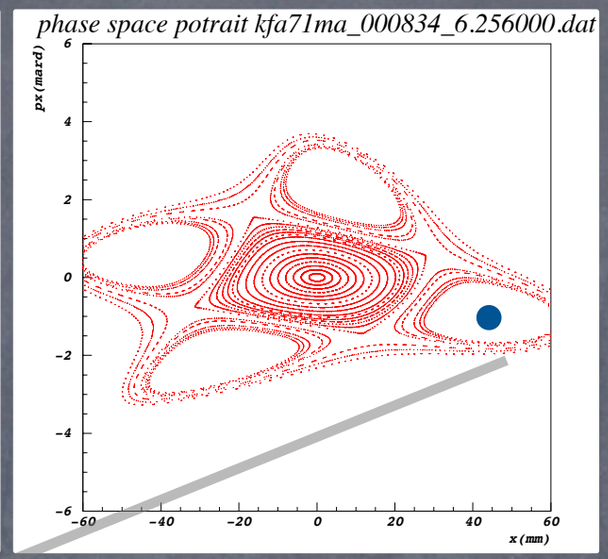
before kick



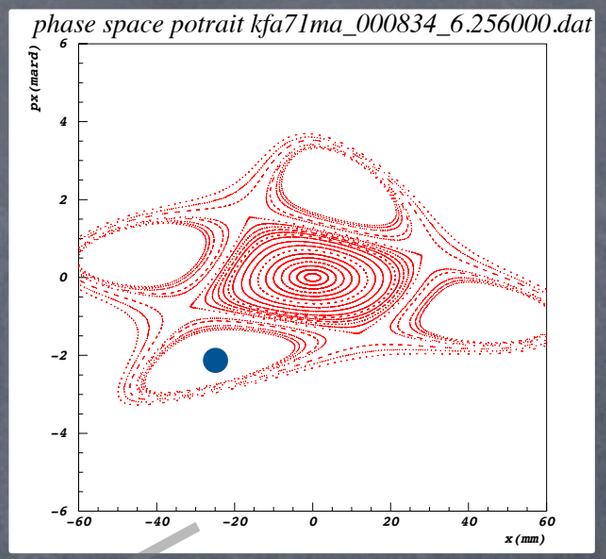
1st turn

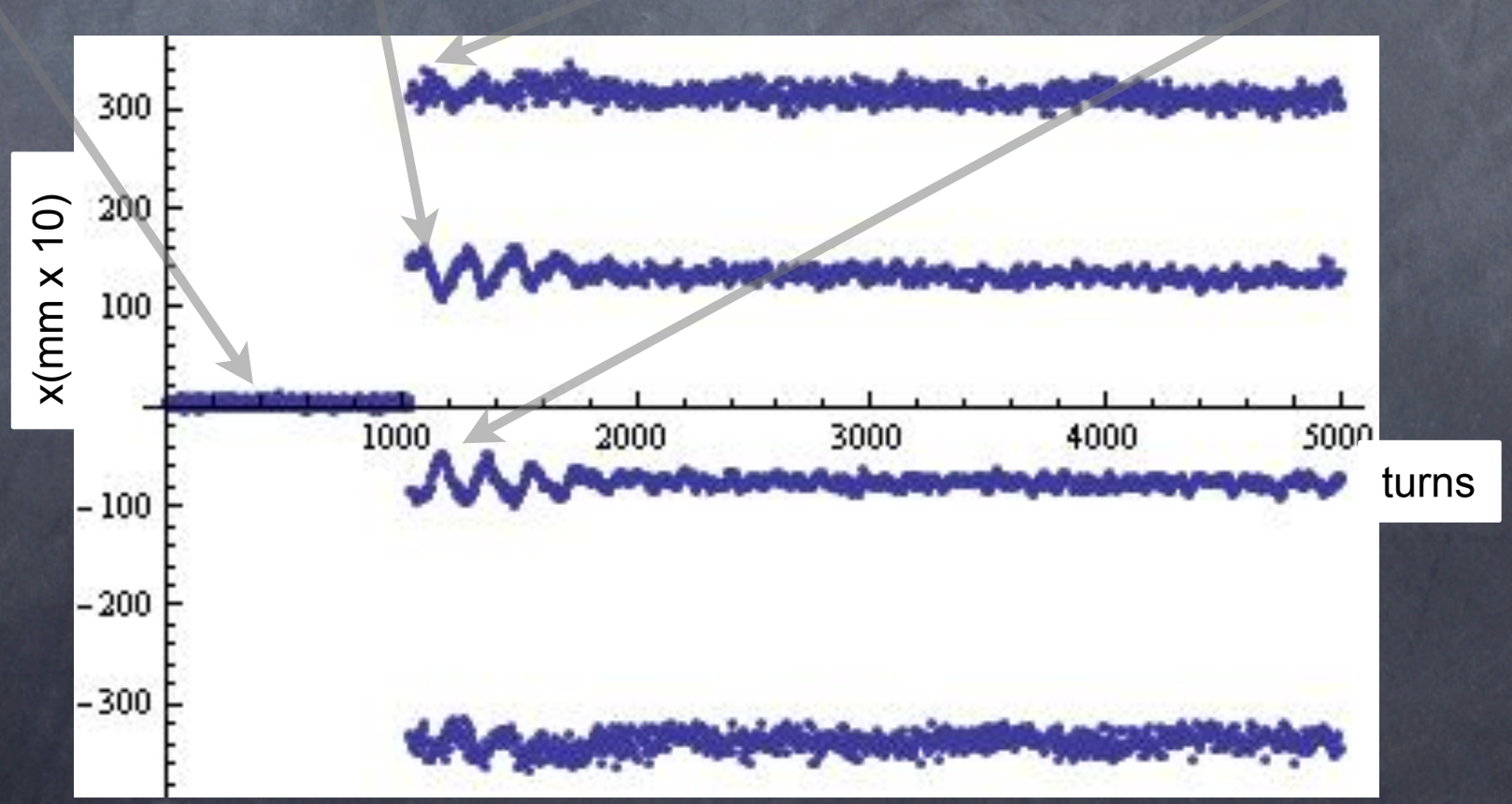


2nd turn

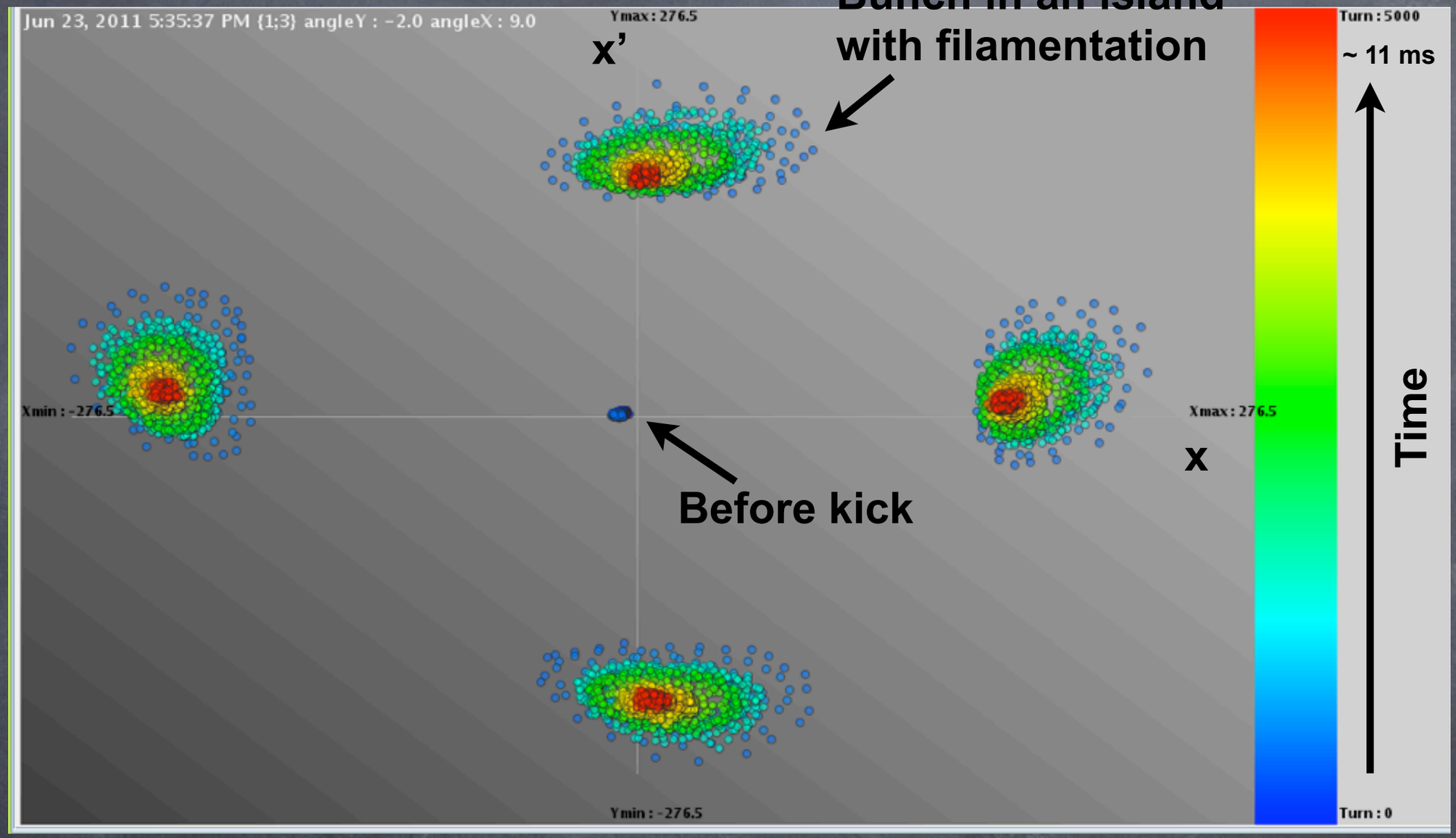


3rd turn





“Poor man” xx’ reconstruction



Turn-by-turn data used to “reconstruct” xx’ at a given PU.

Not real reconstruction but actually plotting the amplitude data of a PU versus the amplitude data of a PU at ~ 90 degrees phase advance.

New software version taking into account optics in between selected pick-ups is under tests

First results.... or what we repeated....

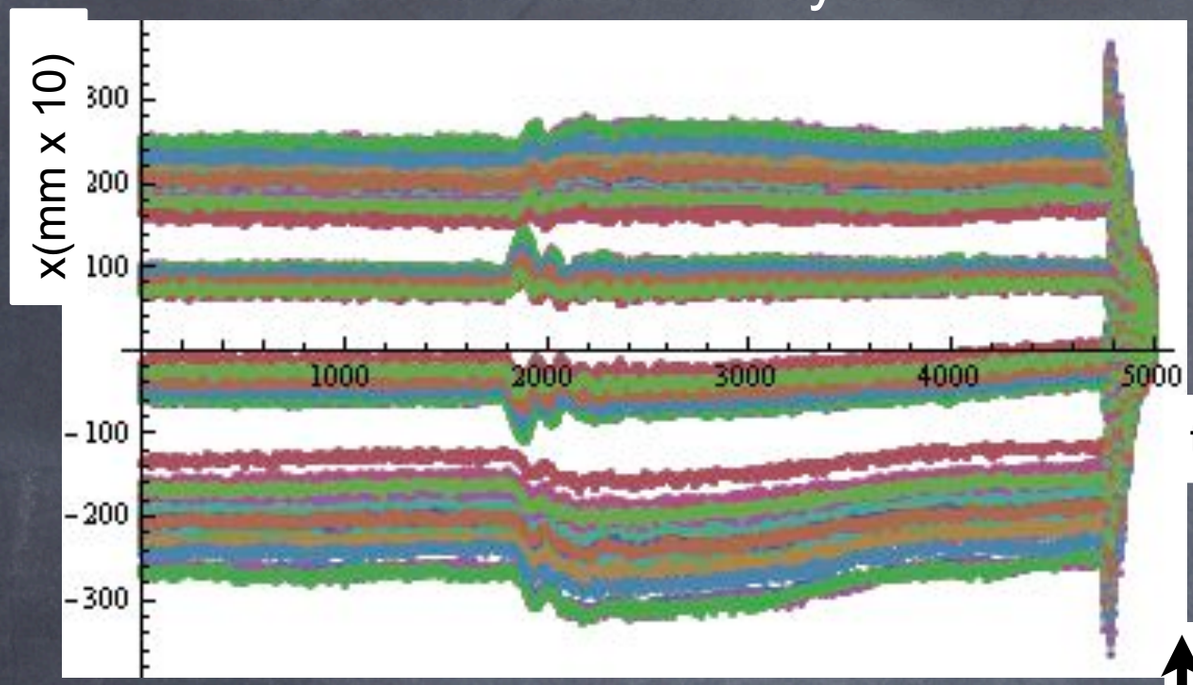
- Parameter variations studied by scans (about > 2 months):
  - change in linear chromaticity
  - linear chromaticity produced by one sextupole only or by different sextupole combinations
  - different values of the octupoles and different combination of the octupoles
  - working point in 3 and 4 current mode (PFW)
  - working point without PFW and F8L

Found: for some combinations, it seems that there were islands fluctuations as observed in the capture and in the trajectories.... even for the nominal case...

***Found finally in May**: fluctuations were a "feature" produced by different issues of the trajectory measurements.*
Found How? we calibrated the kick of the extraction kicker... and found variations of the amplitude after the kick from shot-to-shot implying a variation of the kicker strength not compatible with the injection into the SPS of the LHC beams....

An example of the fake results

Each line a different cycle

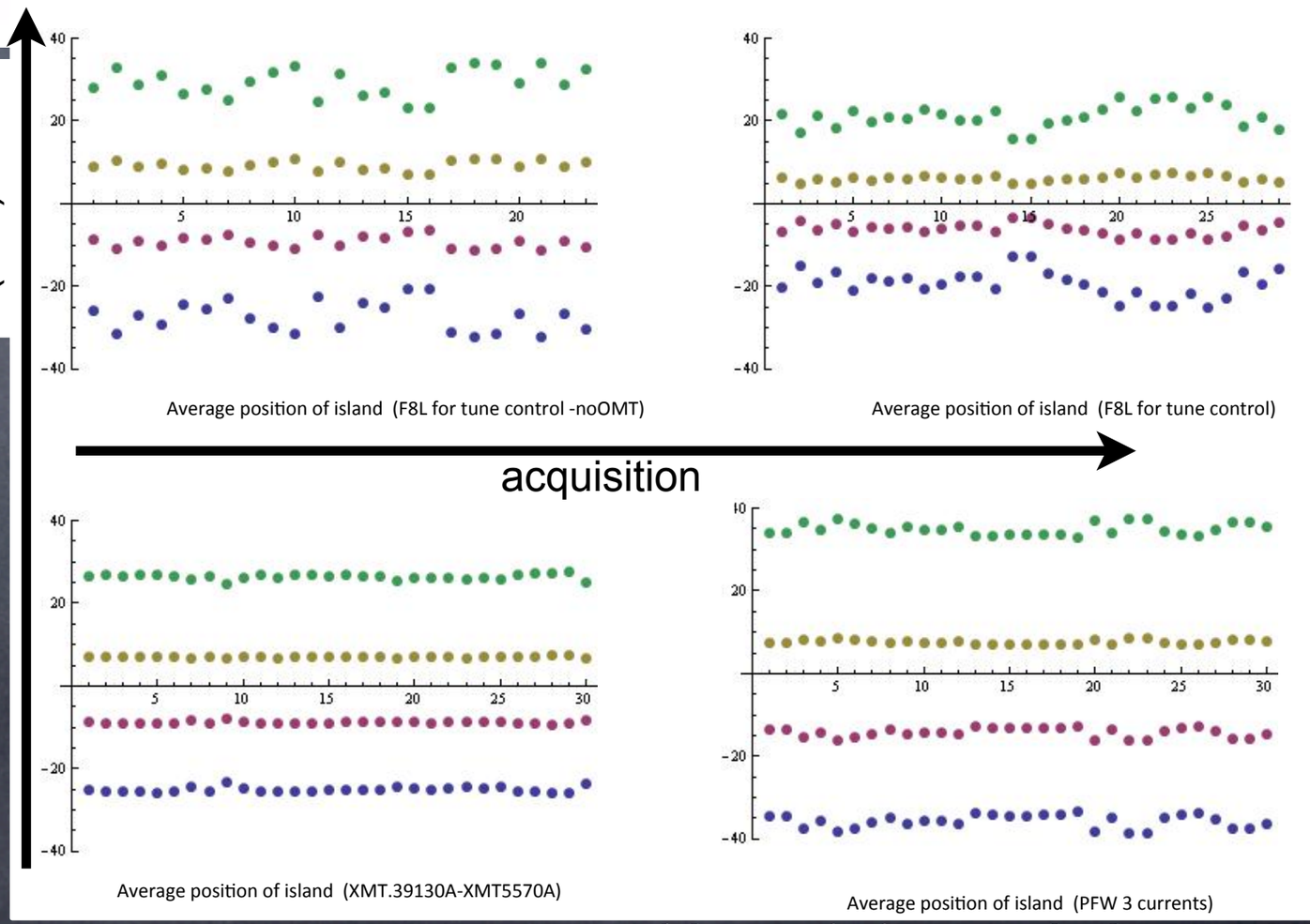


One would imagine large fluctuations of island positions from cycle-to-cycle

Different setting of sextupoles and tune control

One would imagine that the fluctuations could be minimized by the proper choice of the working point.

Those would have been the kind of fluctuations we are looking for



Solutions implemented by BE/BI

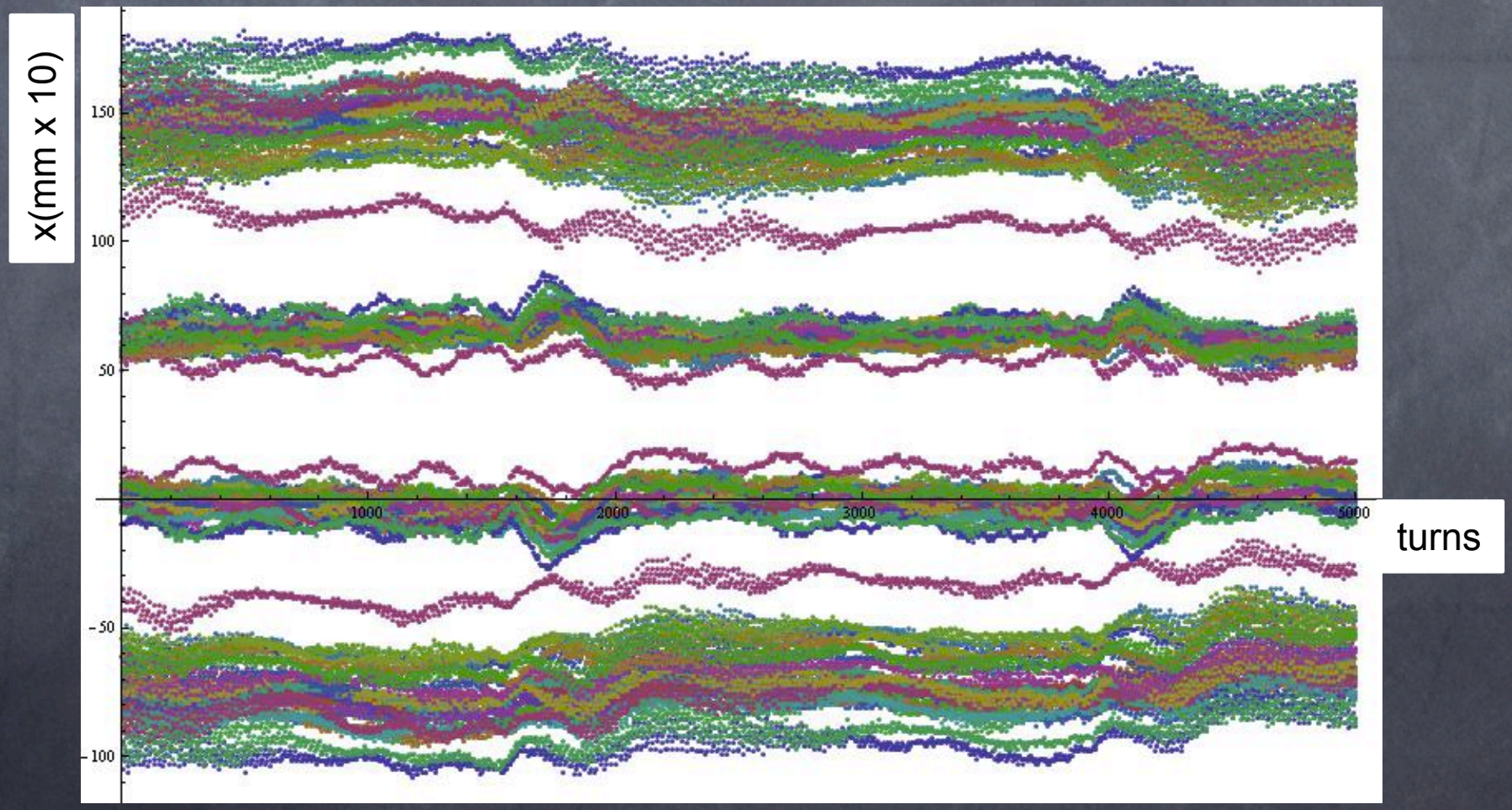
- Special settings of gate/noise rejection found for this type of beam
  - which is, btw, an LHCPROBE type, so problem common to all the LHC low intensity beams
  - saturation and not good ratio signal/noise were producing a part of the fake oscillations
- Synchronisation improved
  - the gate sometimes moved and cut a part of the bunch.
    1% bunch cut is enough to produce fake beam oscillations
  - common to all the other beams
  - de-synchronisation of some pick-ups during the cycle still remain to be solved

After the system upgrade in early July

Optimized trajectory measurement settings lost by BE/BI for an unclear reason. Acquisition went automatically on default settings creating again fake oscillations.

Unfortunately this was noticed after a new measurement campaign:
again few weeks of data lost....

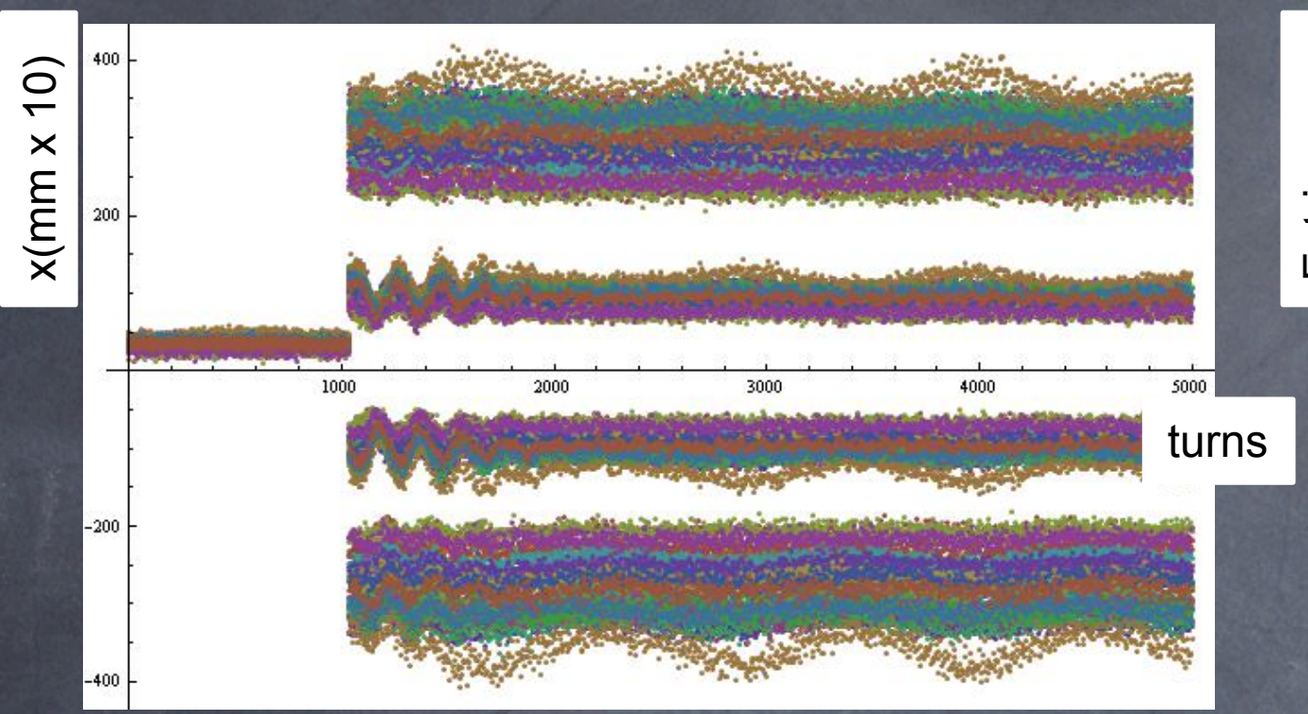
Upgrade of the system early July... unfortunately at first not too effective for MTE

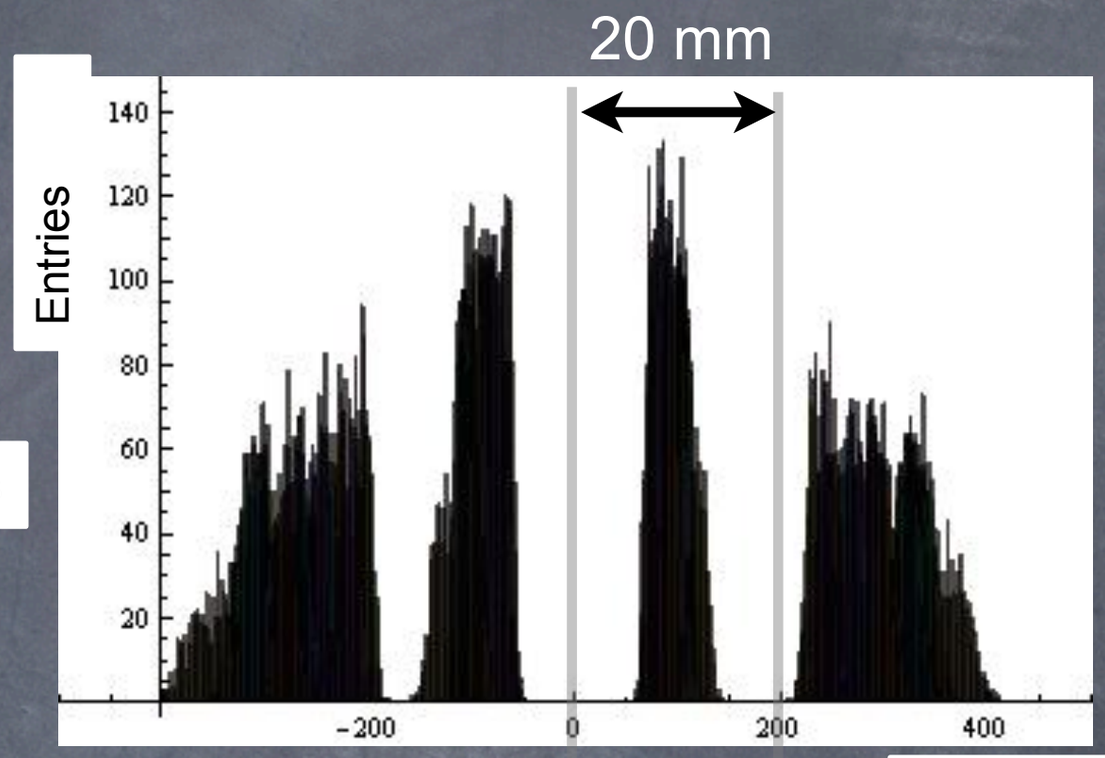


Final settings found ... measurement campaign re-started

Current situation, there are no fluctuations...

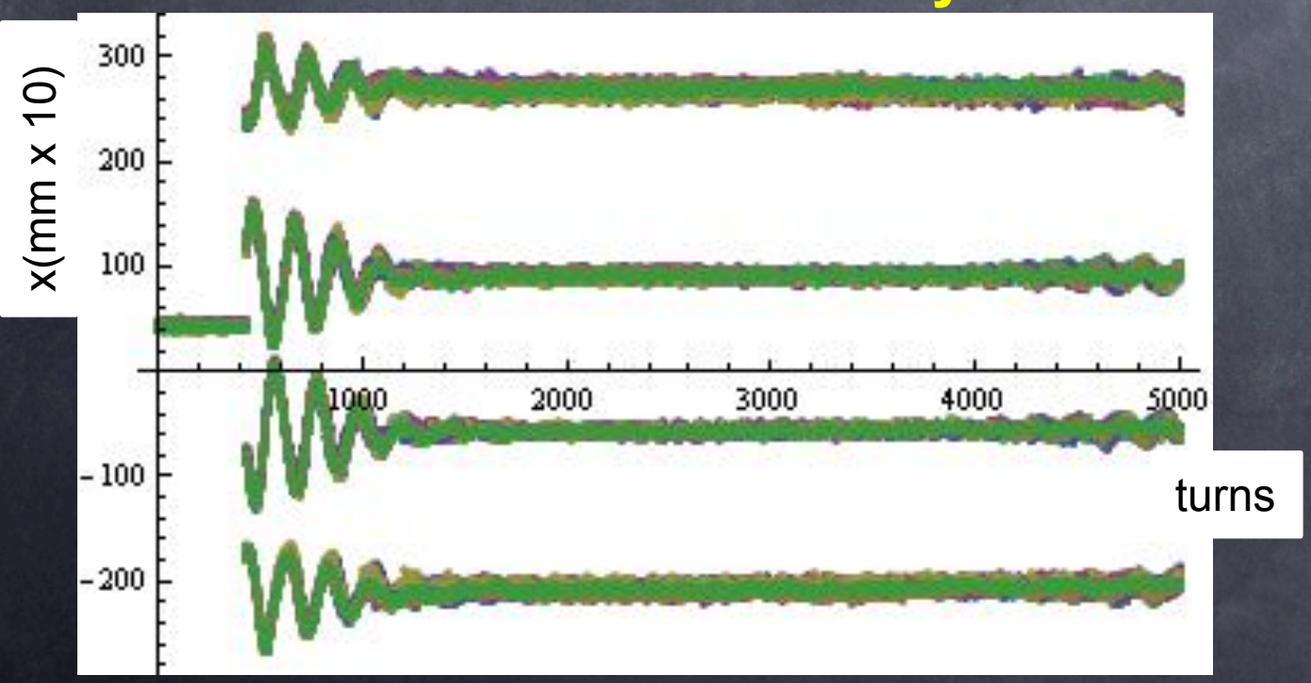
Each line a different cycle



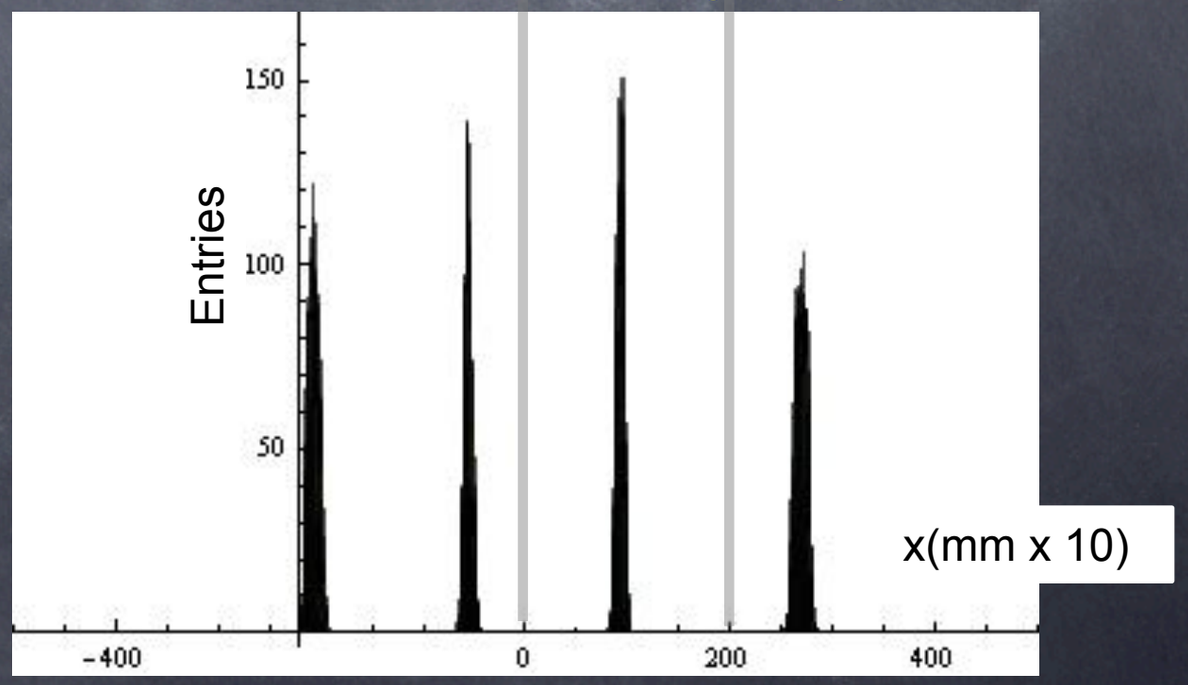


Before correction of the trajectory measurement

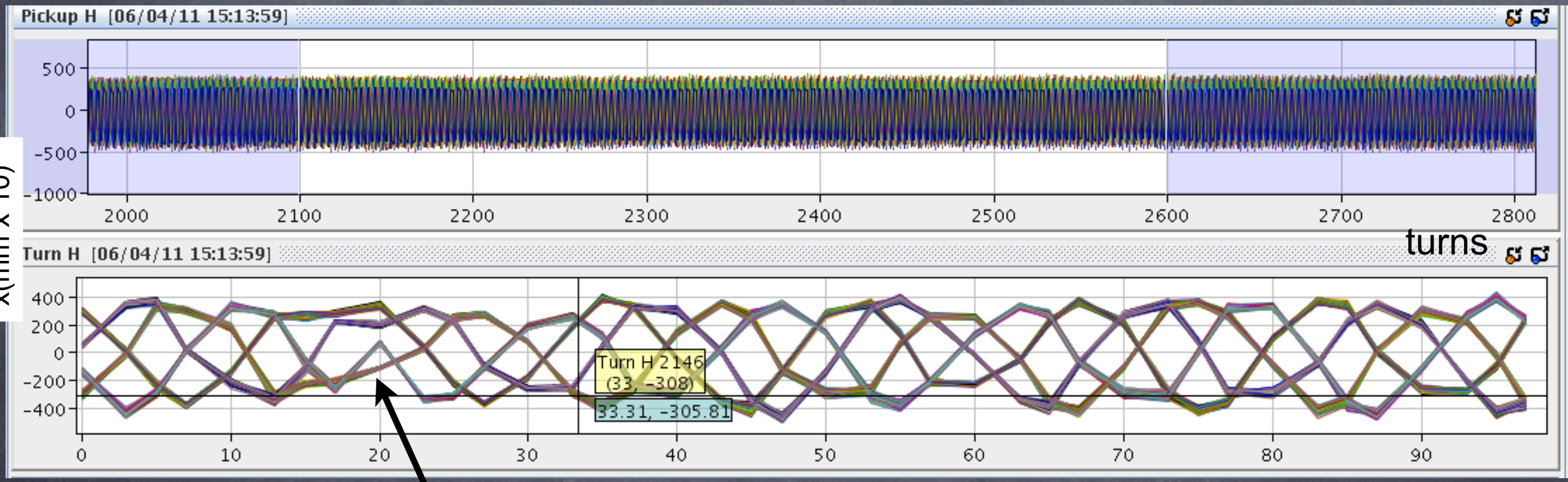
!!! Each line a different cycle !!!



After correction of the trajectory measurement

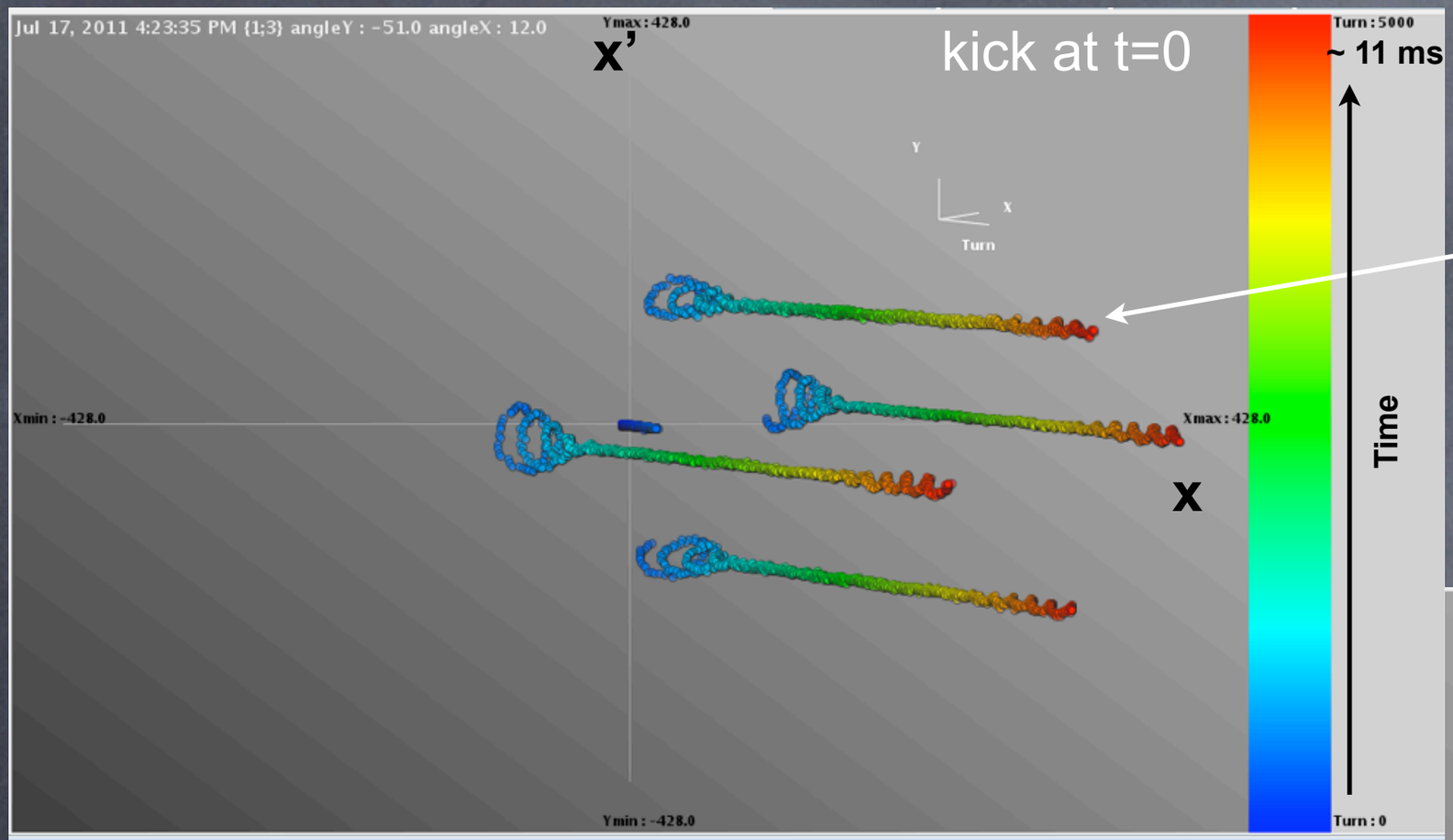


Remaining issue with trajectory measurement

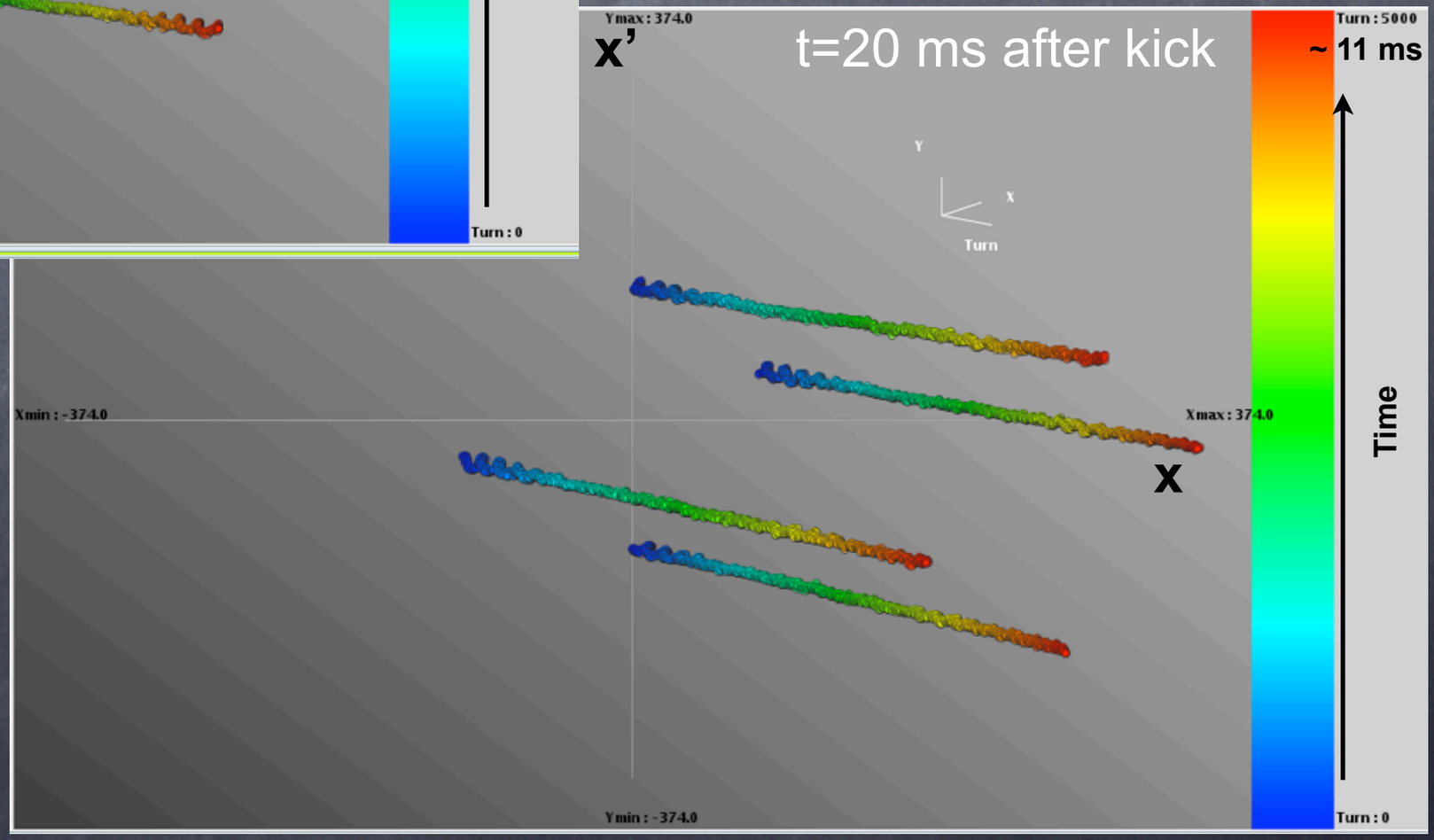


Synchronization turn-by-turn lost for at least one pickup

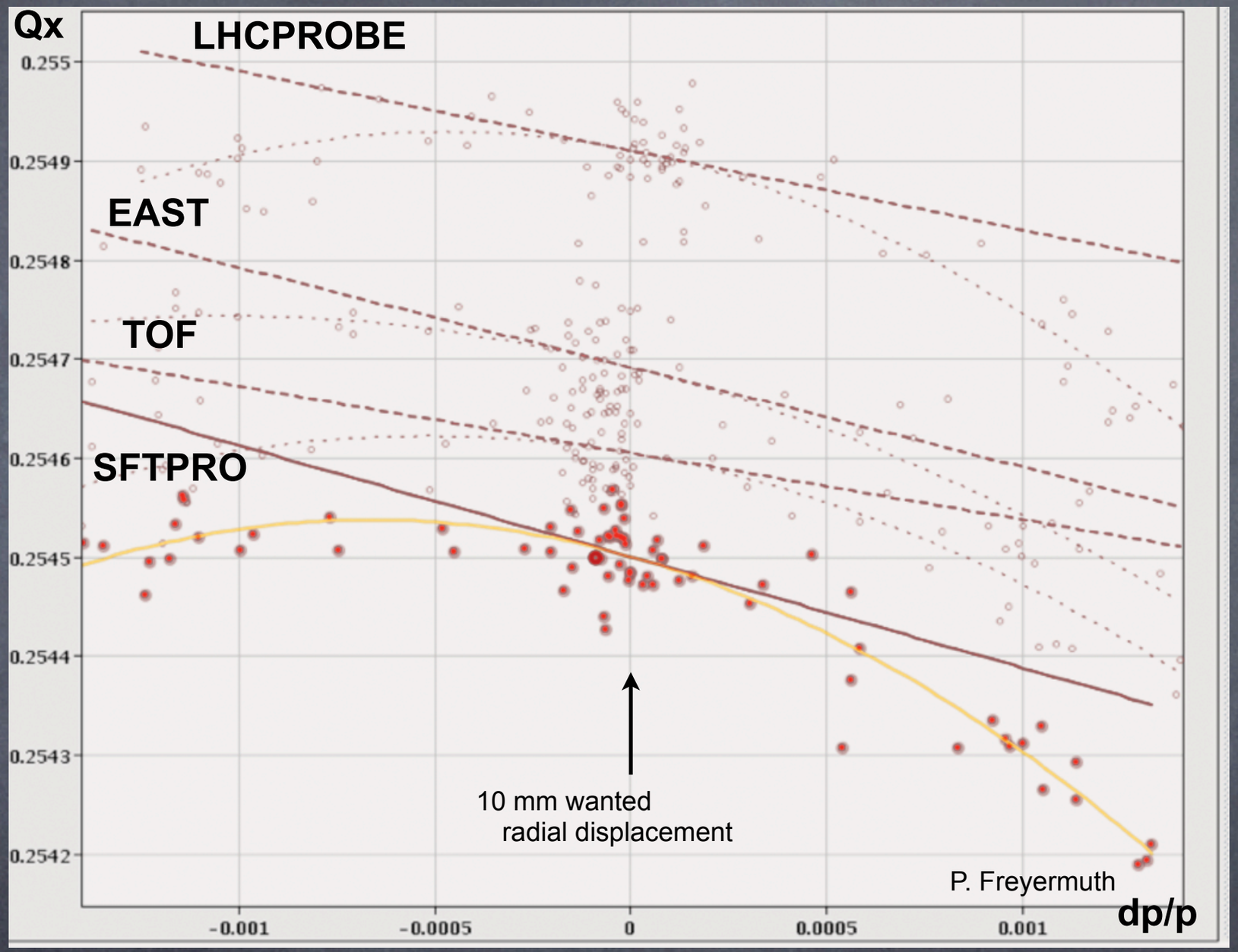
Study restarted ...



Re-coherence visible after few thousands turns



Machine stability: influence of preceding user



Test on machine stability: changed the magnetic cycle **preceding** the MTE one and measure the tune with a radial displacement of 10 mm and also non-linear chromaticity.

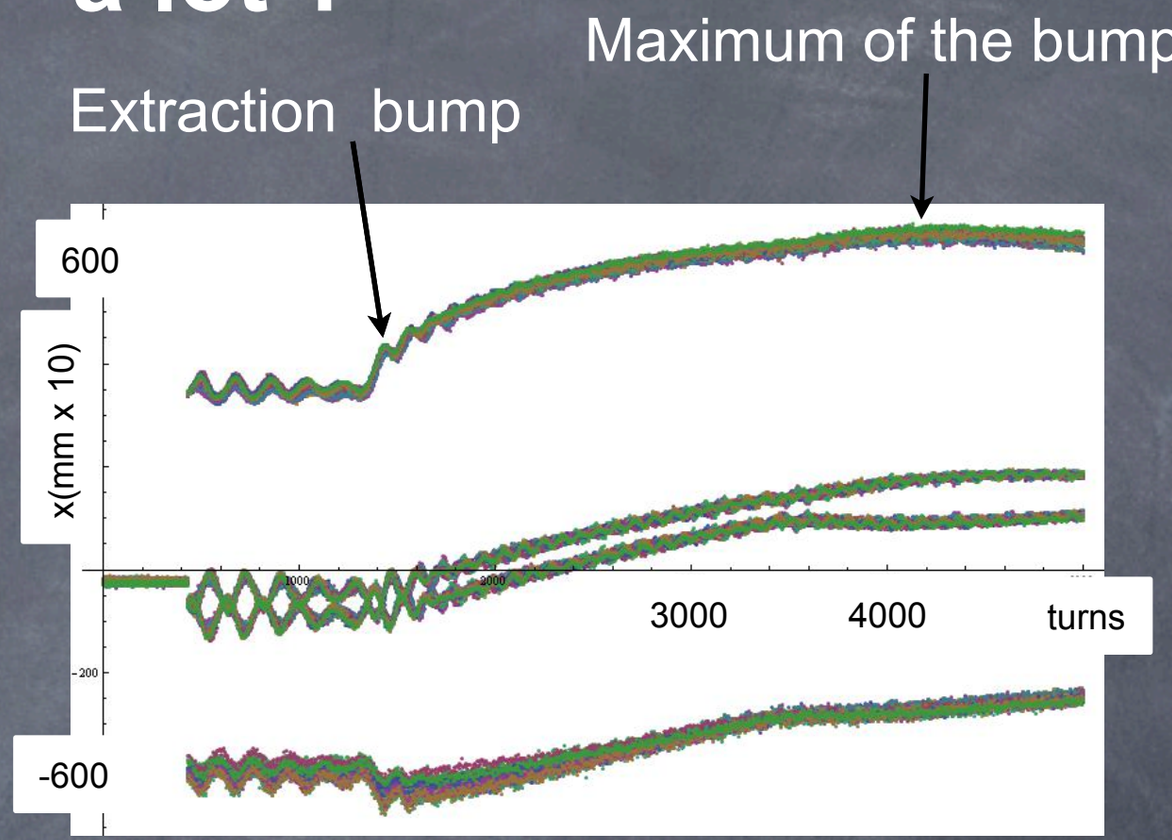
Found: there is a systematic Q and Q'' shift, *with a minor modulation from cycle-to-cycle,* depending on the preceding user, with a ΔQ_x up to $5\ 10^{-4}$.

Is ΔQx~5 10^{-4} a lot ?

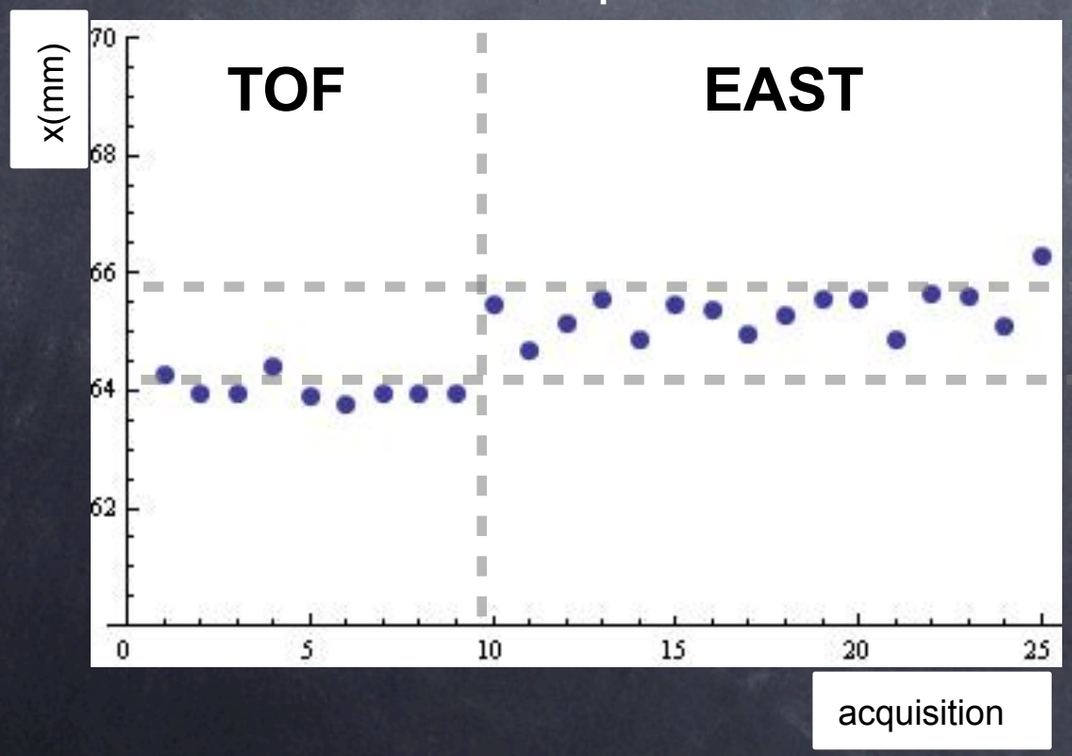
The effect of the ΔQx induced by a different supercycle composition is visible on island trajectory at extraction.

The difference is **systematic and reproducible** even after a second supercycle change.

Discussion with TE/MSC to understand the source of the effect.

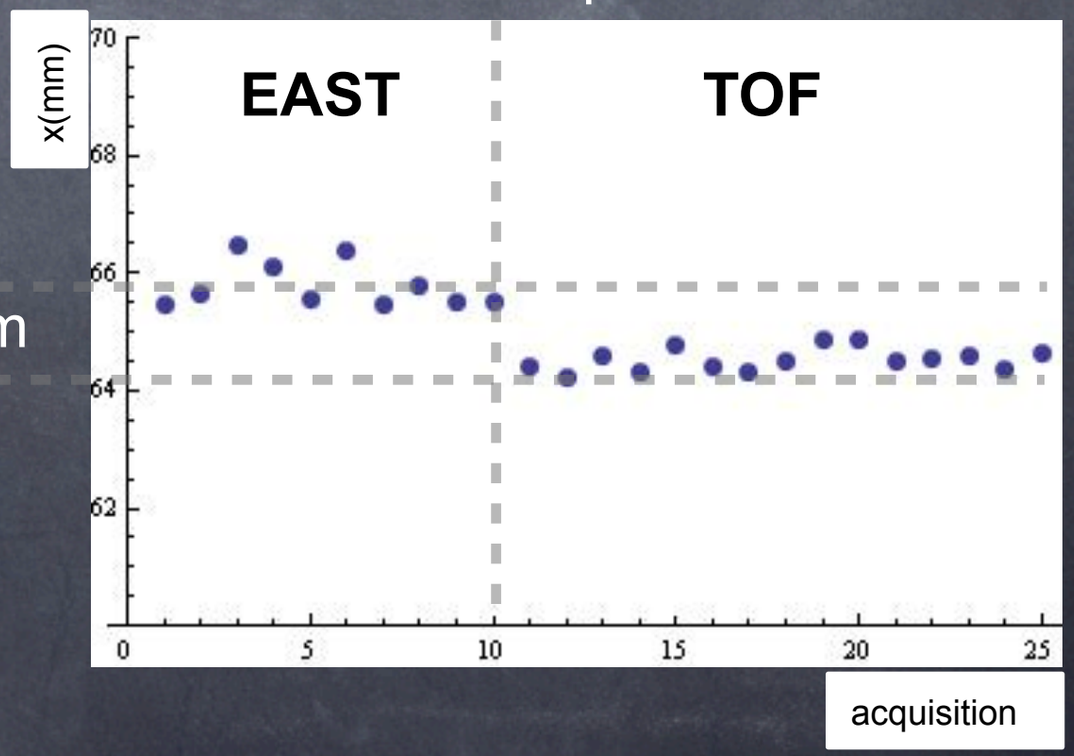


Maximum of the bump for external island



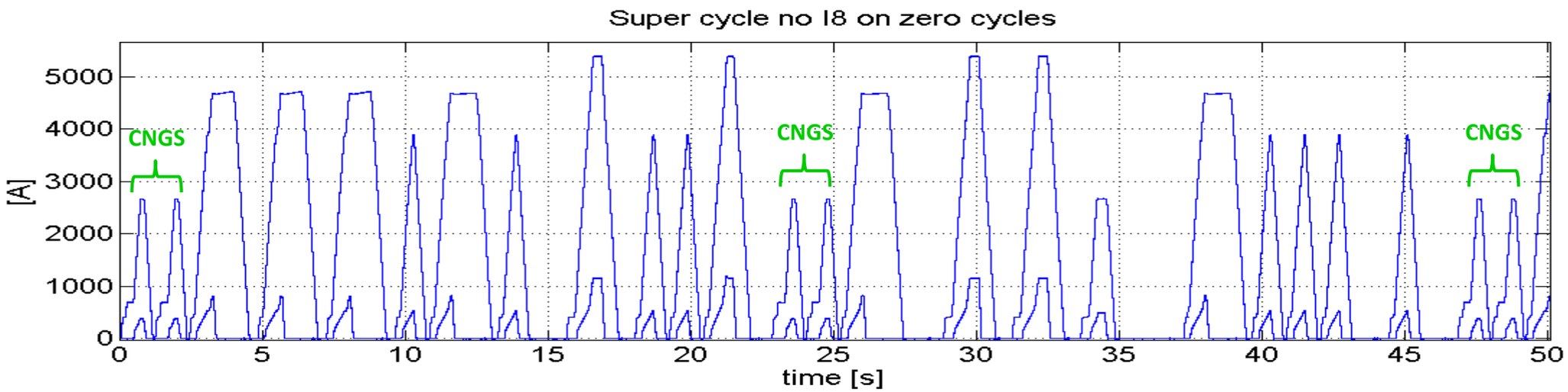
~ 1-2 mm

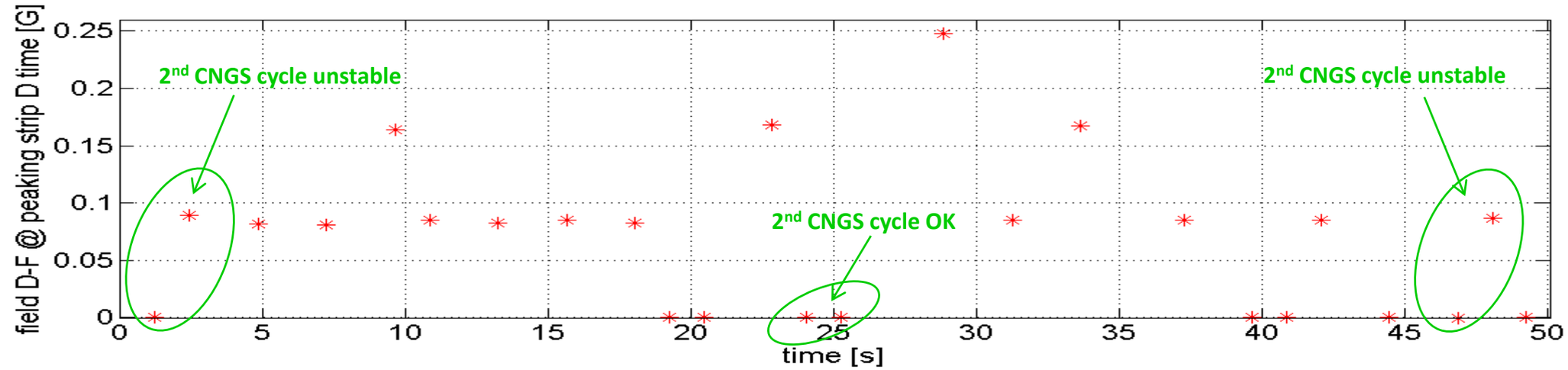
Maximum of the bump for external island



Machine magnetic stability

PS beam stability test @ injection – June 2011





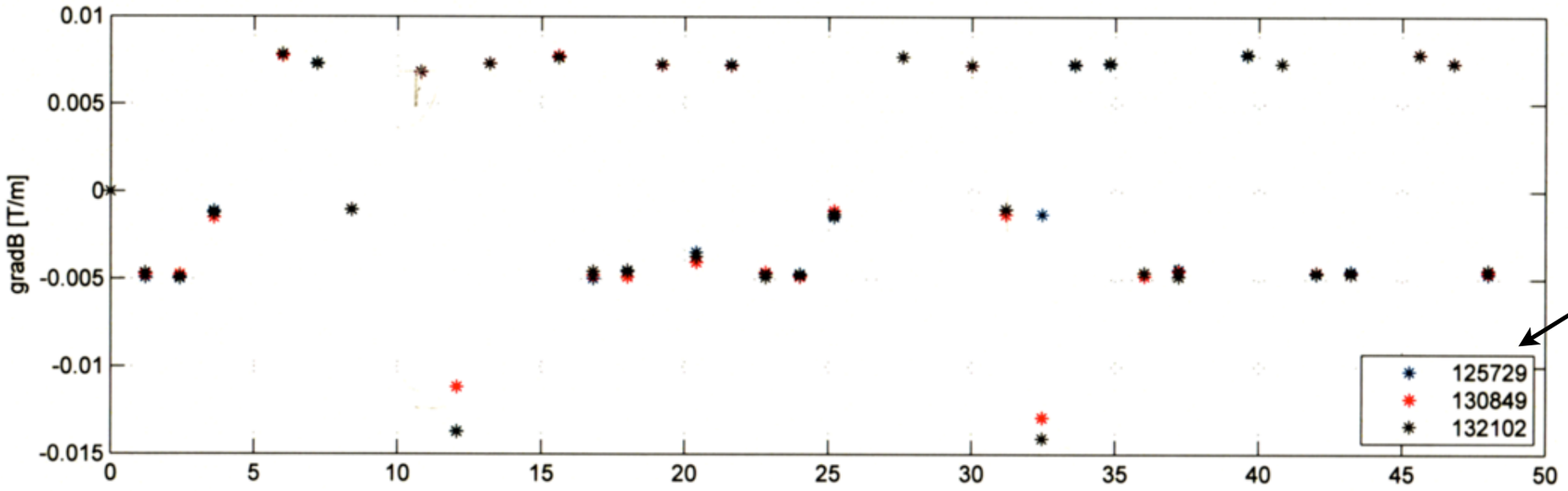
specific powering cycle sequences lead to reproducible MRP errors
now we can observe correlation with reproducible magnetic errors

Field error from the picking strip (48.9 G field marker) observed on the CNGS cycle.

Different MRP observed at injection for different CNGS or TOF cycles

Machine magnetic stability

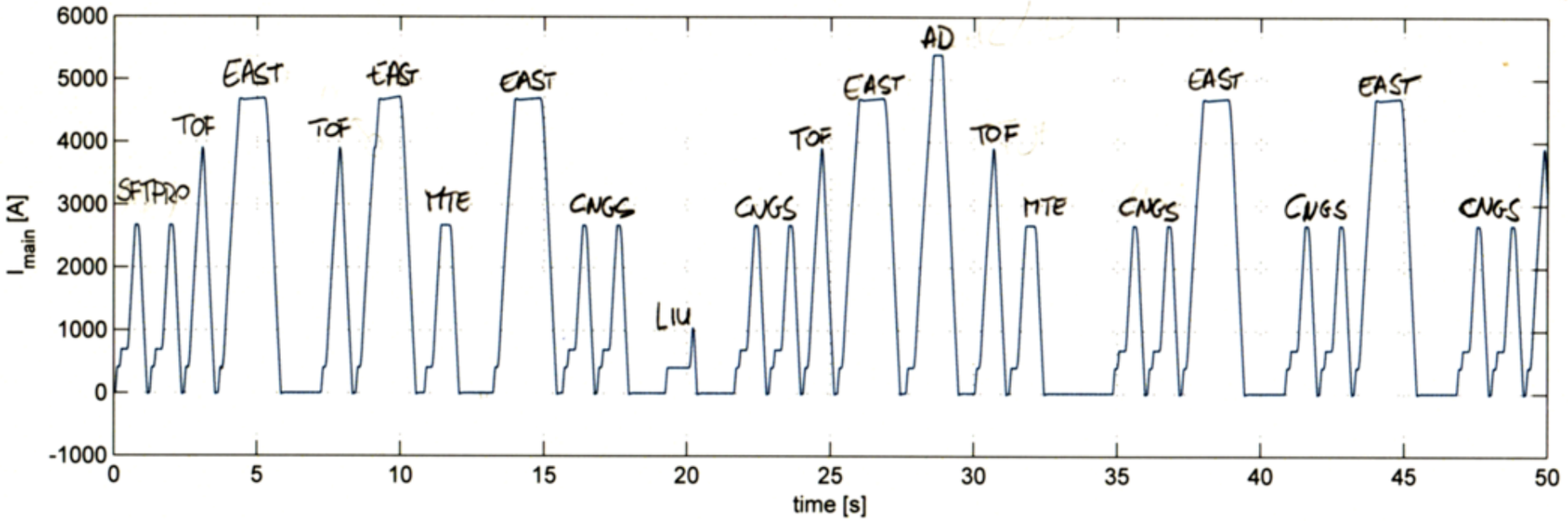
Main dipole quadrupolar error



Different supercycle

Courtesy of M. Buzio. PRELIMINARY

Current in the main coil



Remnant magnetic field due to hysteresis induce a reproducible remnant quadrupolar field @ injection depending on the previous cycle.

Not clear the effect of this error at 14 GeV/c

Considerations about machine fluctuation

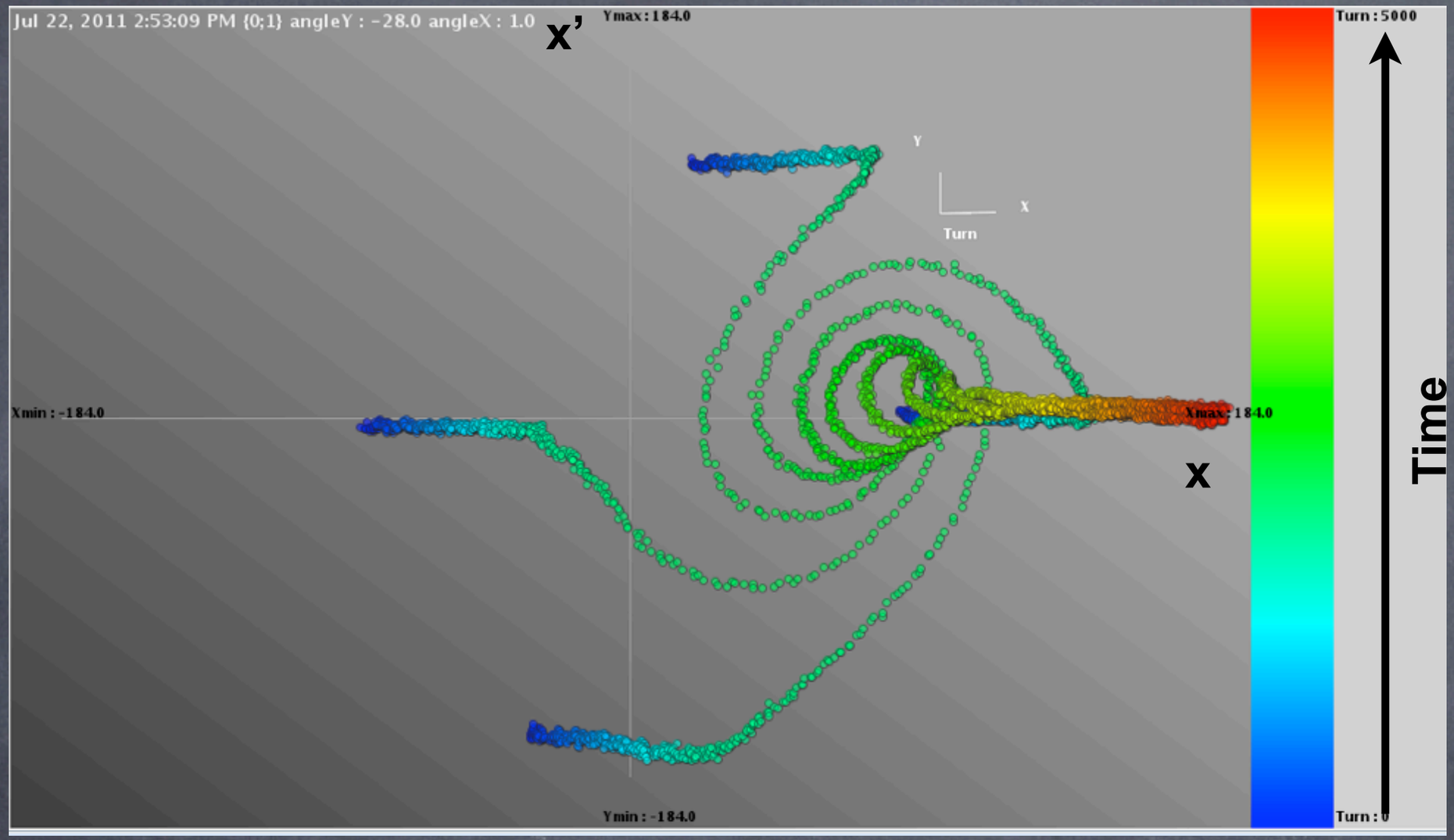
- Found different observables indicating the non-reproducibility of the machine **at injection**
  - TOF losses at injection depends on the previous cycle
  - CNGS cycles trajectories different at injection depending on the previous cycle
  - Losses during working point scans (LIU-PS MDs) depend on the previous cycle
- All these indicates that for a fixed super-cycle the machine is reproducible but with different behavior for the same cycle depending on the magnetic history of the machine within a given super-cycle
- **These do not explain the fluctuations observed for the same cycle for a fixed super-cycle composition**
- **It is not clear how to extrapolate these observations to 14 GeV/c**
- **Trajectory tests done without MTE-Octupoles**
  - Everything seems to indicate that the main magnets are the source of fluctuations

Hybrid-MTE tests

Hybrid-MTE: use the SEH31 of the classical CT to jump to minimize the effect of the slow rise time of the MTE kickers and to reduce the radiation on the SMH16

- First tests on the machine not conclusive due to the mentioned issues with the trajectory measurements
  - tests resumed, measurement now seems to be correct.

Issue with bump 31 now solved



~ 11 ms

0 ms

- Fake acquisition of the trajectory system lead to a wrong setting-up of the bump 31.
- A bump 31 too high causes the islands recombining during the rise of the bump
- Still not clearly implemented the possibility to observe the last turn trajectory

Program for the near future

- On the experimental side
  - conclude the measurements for the machine stability
  - close the extraction bump for the island and the core
  - change the sign of the Q'' or Q''=0 at 14 GeV/c and re-do trajectory measurements
  - test with PFWs/F8L in three current mode
  - test of MTE at 2 GeV
  - test of the hybrid-MTE
  - resume capture
- On the simulation side
  - evaluate the effect of the non-closure of the bump on the trajectories in TT2
  - close the extraction bump for island and core
  - finish the simulations for the hybrid-MTE
  - finish simulation for the dummy septum
  - understand the effect of the magnetic remnant field at injection at 14 GeV/c

Data analysis

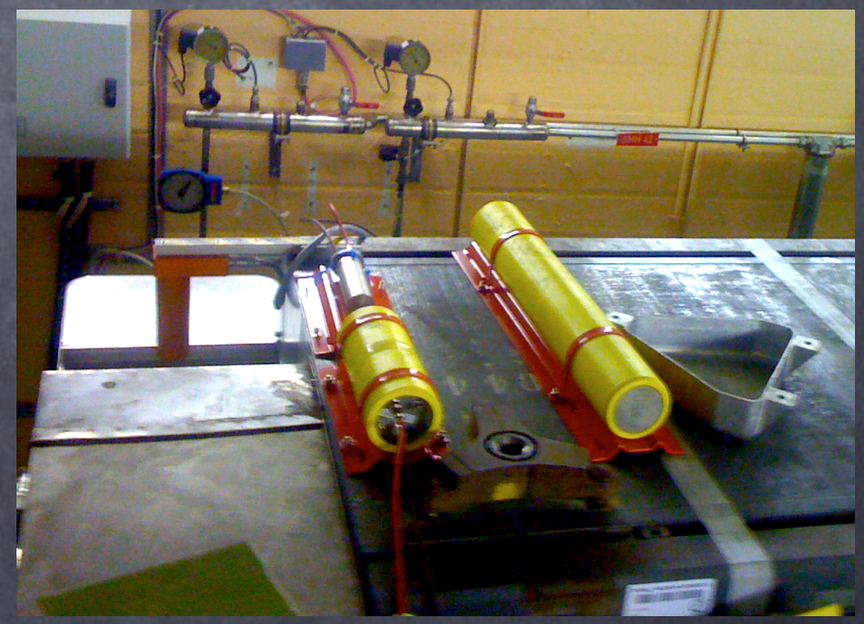
What we would need

Activity	Orbit/ Trajectory	Q-meter	BWS	BCTs (DCCT/BCTs)	BLMs	Magnet meas.	PO meas.
Machine stability							
Improve closures of extraction bumps							
Q'' optimisation							
Three current mode tests							
Tests at 2 GeV							
Tests hybrid-MTE							
Resume capture and extraction							
Issues or future needs	Keep correct settings	Solve problem of timing jitter of acquisition	Use should be limited	Cross calibration and precision not better than 5%	Fast BLMs not installed yet	Install new system and new FMR for main B field measure	Install trigger in PO buildings and improve OASIS signal quality

BLMs available

Fast BLMs necessary to determine loss dynamics during extraction process, i.e. to distinguish turn-by-turn losses

- Tests done in collaboration with BI proved that (done in SS42):
  - ACEM would saturate for such large losses (the detector itself)
    New tests foreseen soon
  - LHC-IC not fast enough
  - LIC (Small Ionization chamber) did not work for a cable problem
  - SEM not sensible enough
  - **PEP-II detectors seems to be fast enough**
  - Diamond could not be tested yet



Due to unfortunate mis-understanding with BI, it was not possible to install a fast BLMs on the SMH16 during the last technical stop.

The installation will be done during the next one in November

Conclusions

- Studies are progressing ... but ...
  - lost about 3 months of data due to the issues with the trajectory measurements. Thanks to BI for the support, but we cannot relax now the attention.
  - hybrid-MTE tests delayed due to different issues
  - **not found yet a source of the capture instabilities for the same cycle with fixed supercycle**
- Found for the first time the effect of the supercycle composition on the island position
  - this might explain a part of the trajectory behavior in the SPS
  - **Fluctuations are for different supercycle compositions**
- Found that the extraction bump should be better closed to avoid fluctuations at extraction

... and resources as usual are limited....

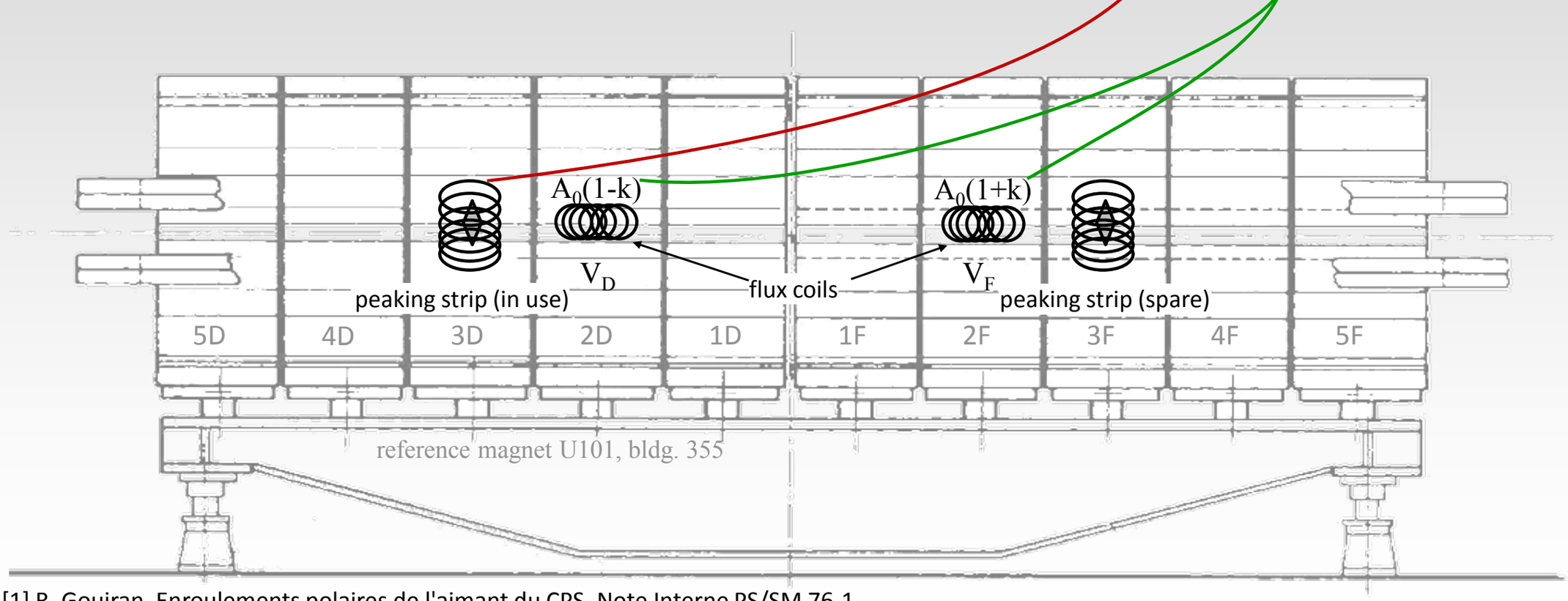
SPARES

Magnetic meas. configuration in ref. magnet

PS B-train - current configuration

- 3 sensor sets (1 in operation, 1 hot spare, 1 reserve) dating from 1976
- electronics renovated in 2000 (same as in PSB, AD, LEIR)
- $B_{avg}(t)$ is generated under in-built assumptions: $B_D(t_0)=B_F(t_0)=49.8$ G, $k=0.091$ [1]

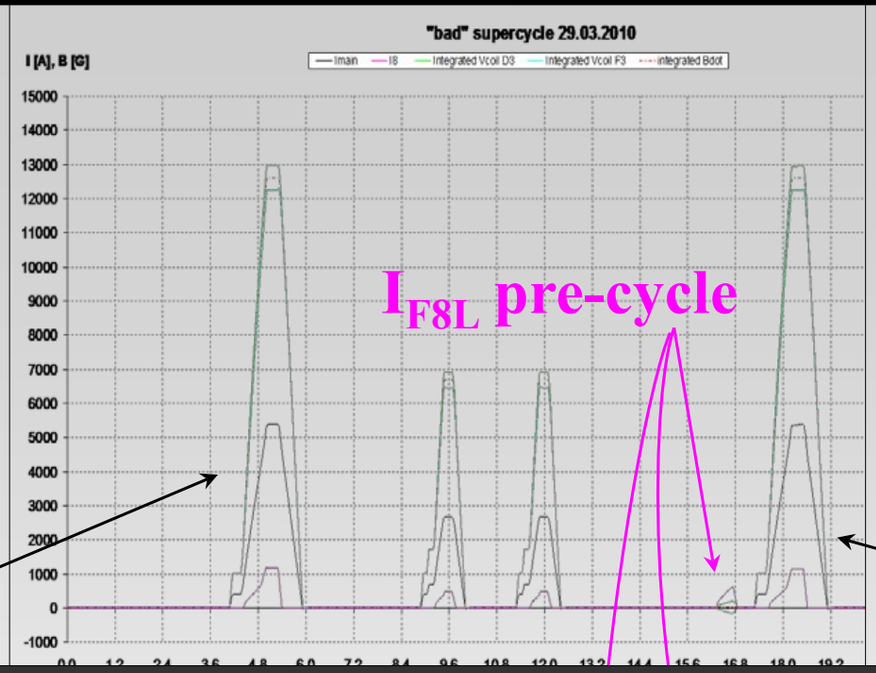
$$B_{avg} = \frac{1}{2}\left((1-k)B_D + (1+k)B_F\right) = 49.8\,G + \frac{1}{2A_0}\int_{t_0}^{t}\left(V_D + V_F\right)dt$$

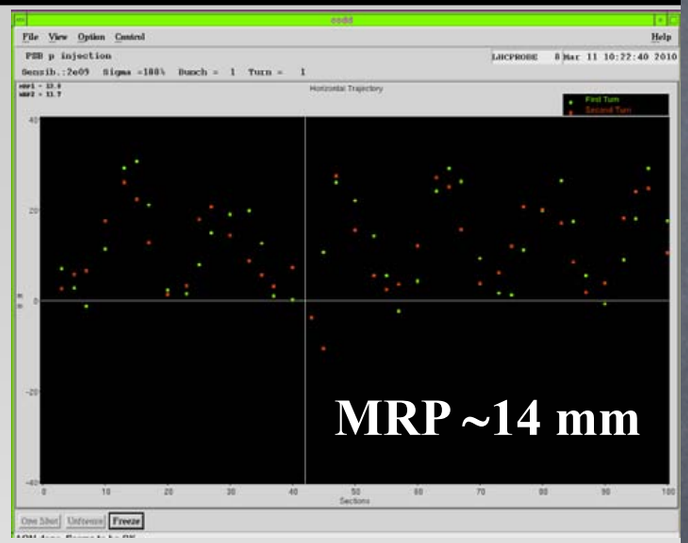


[1] R. Gouiran, Enroulements polaires de l'aimant du CPS, Note Interne PS/SM 76-1

Remant B-field @ injection from hysteresis

PS beam stability test @ injection – March 2010





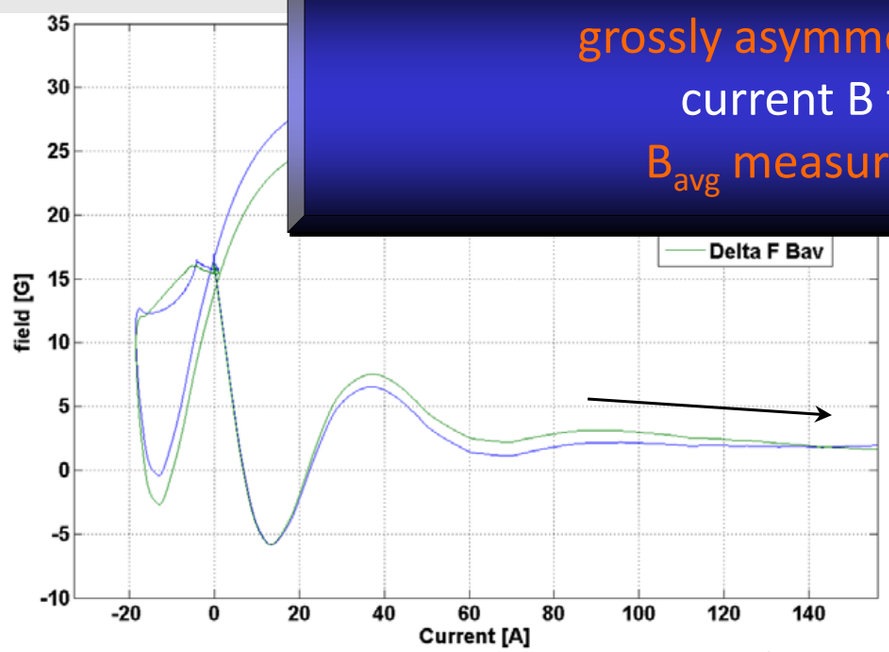
"good" cycle

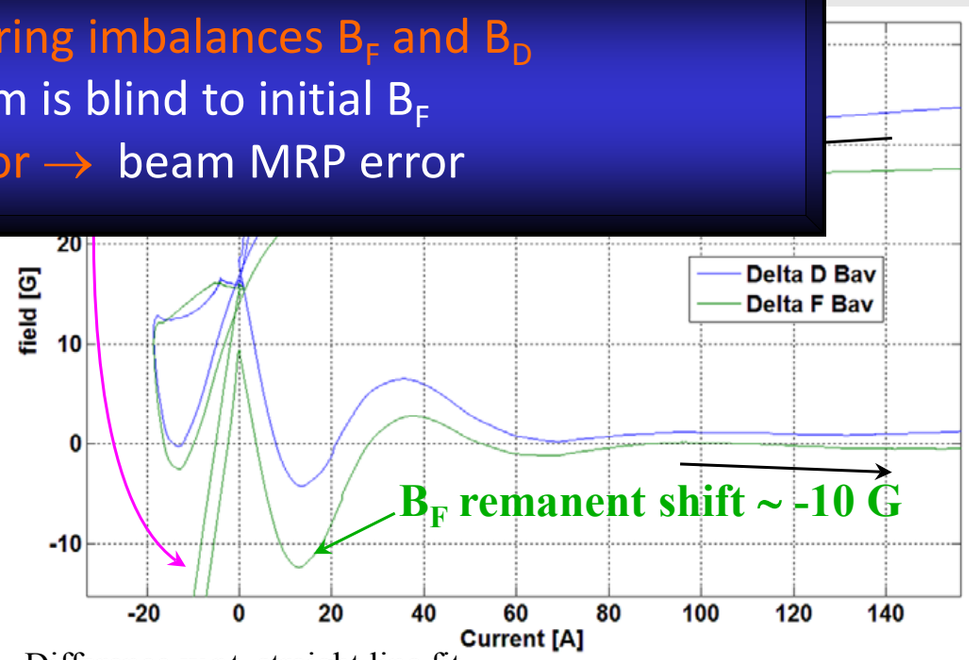
"bad" cycle

grossly asymmetric powering imbalances B_F and B_D

current B train system is blind to initial B_F

B_{avg} measurement error → beam MRP error

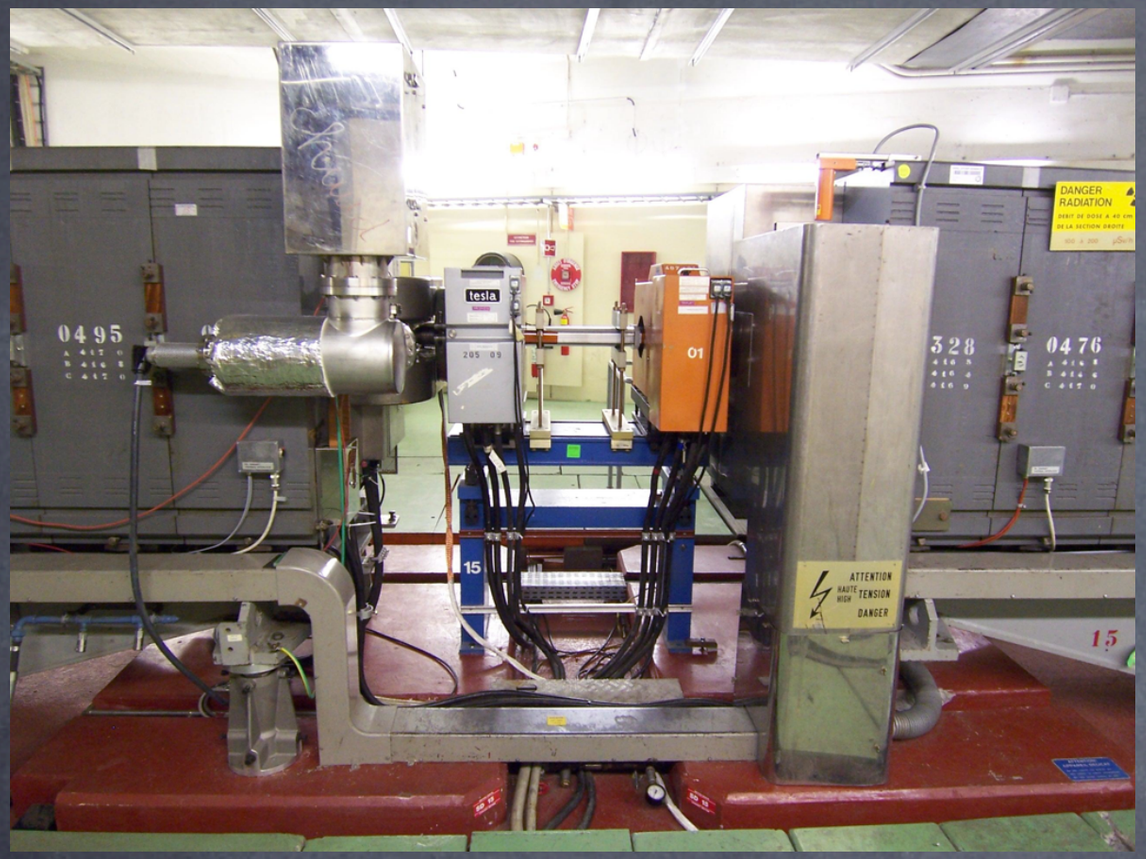




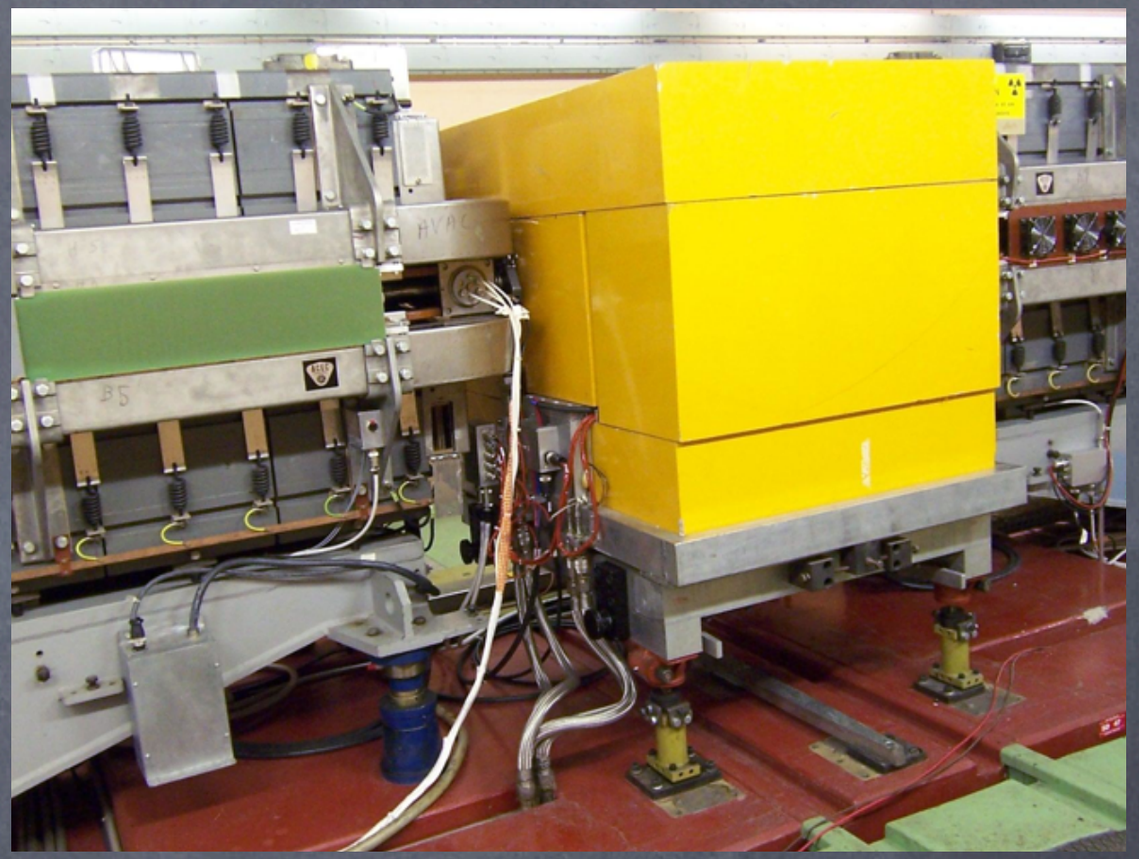
Hysteresis curves $B_F(I)$ and $B_F(I)$ – Difference w.r.t. straight line fit

SS15 magnetic elements displacement

SS15 today



future SS15 with dummy septum (as SS47)



Two magnetic elements in SS15 today:

- Quadrupoles for the Gamma Jump (triplet)

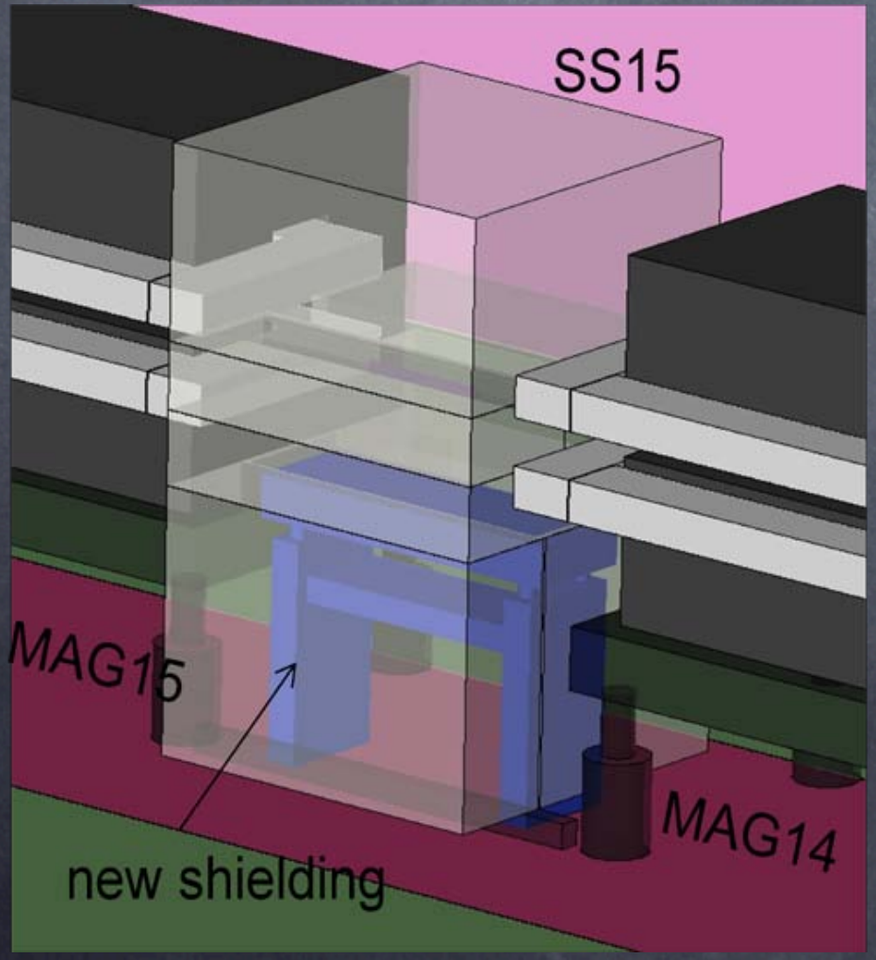
- high energy dipole for orbit correction and MTE extraction bump (displacement still to be studied).

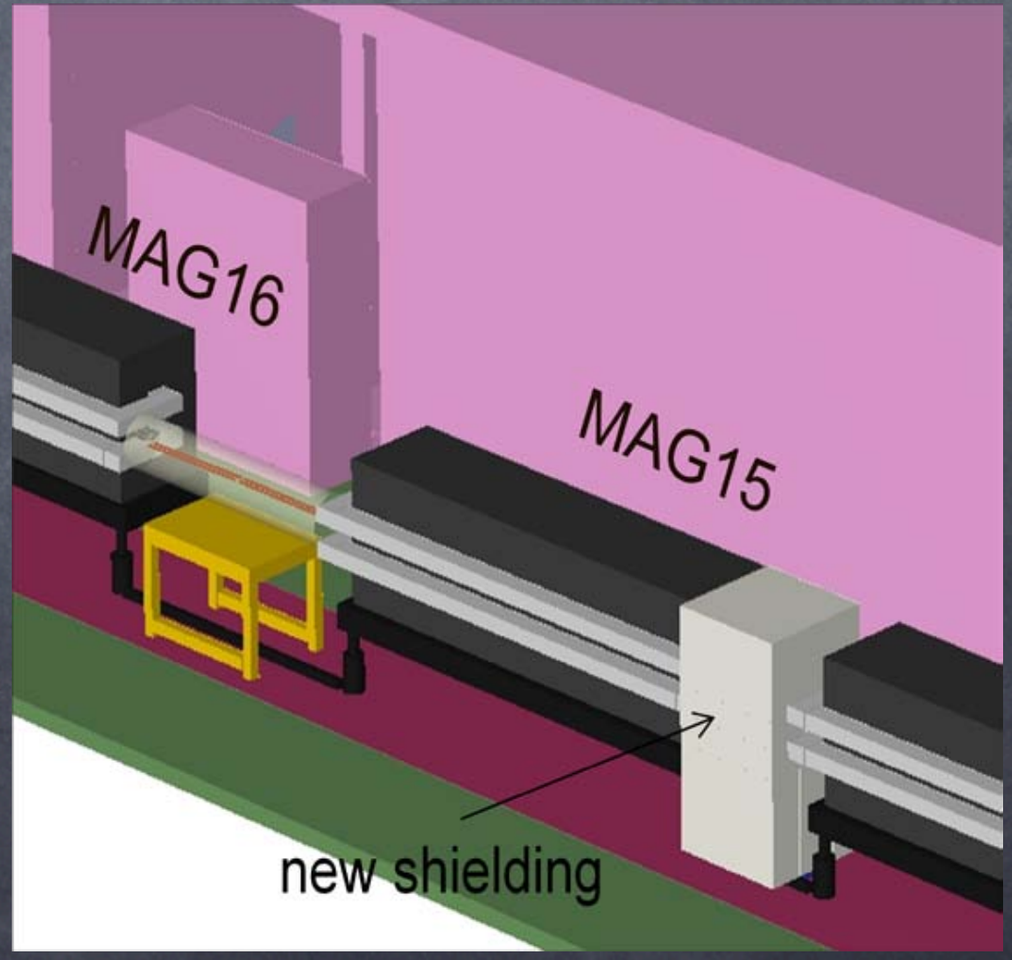
Dummy septum studies status

Dummy septum: passive device to be installed in SS15 to intercept the beam during the kicker rise time and protect the SMH16 blade.

Effectiveness of the device studied with RP/ABP/ABT published:
S. Damjanovic et al. "Radiological impact study of a protective device for the septum PE.SMH16", CERN-DGS-2011-003-RP-TN, March 2011

Dummy septum simulation (Fluka geometry)

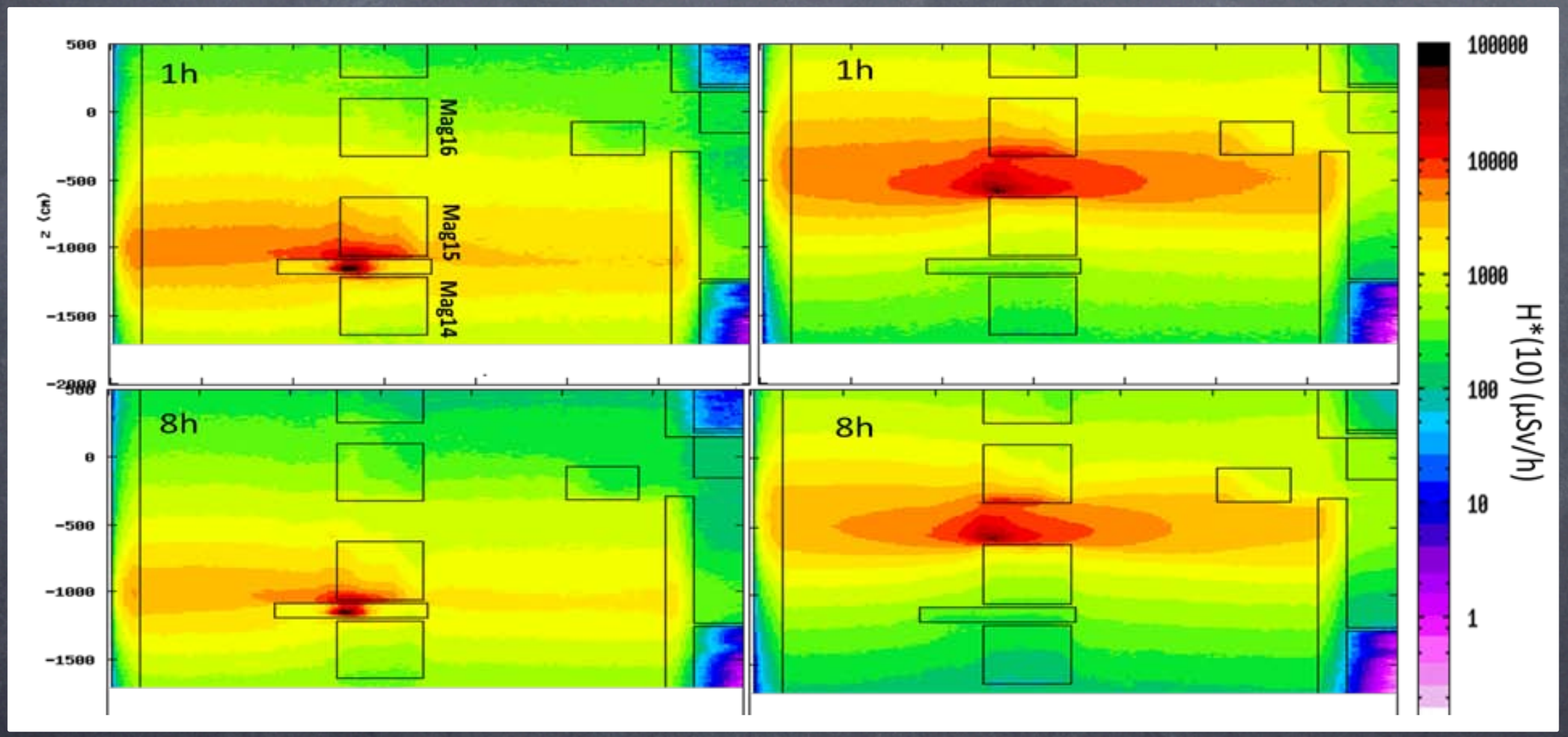




Dummy septum simulation results

Dose at the septum reduced, as wanted, by at least by a factor of 10 since primary proton interacting on the blade of the dummy septum.

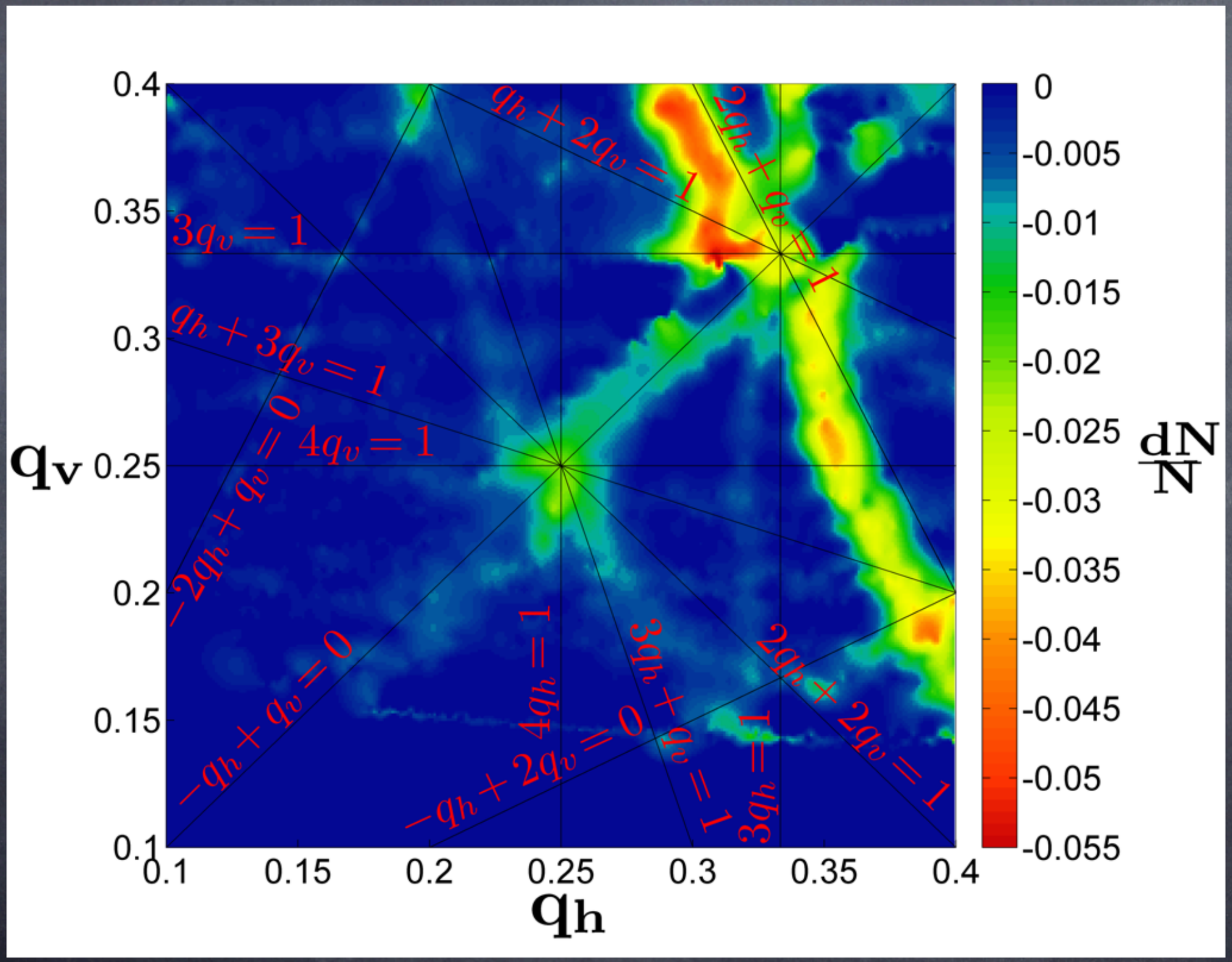
with dummy septum *w/o dummy septum*



180 days of irradiation followed by 1 or 8 hours radiation cooling

Still to be studied: a) impact of radiation on the main magnet 15; b) gain on radiation outside the tunnel; c) real trajectory simulation; d) impact for other beams. Some optimisation done: blade material, shielding material...

Tune scans


$q_h + 2q_v = 1$
$2q_h + q_v = 1$
$3q_v = 1$
$q_h + 3q_v = 1$
$4q_v = 1$
$-2q_h + q_v = 0$
$-q_h + q_v = 0$
$-q_h + 2q_v = 0$
$4q_h = 1$
$3q_h + q_v = 1$
$3q_h = 1$
$2q_h + 2q_v = 1$
q_v
q_h
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
-0.04
-0.045
-0.05
-0.055
$\frac{dN}{N}$

Traj. meas. settings