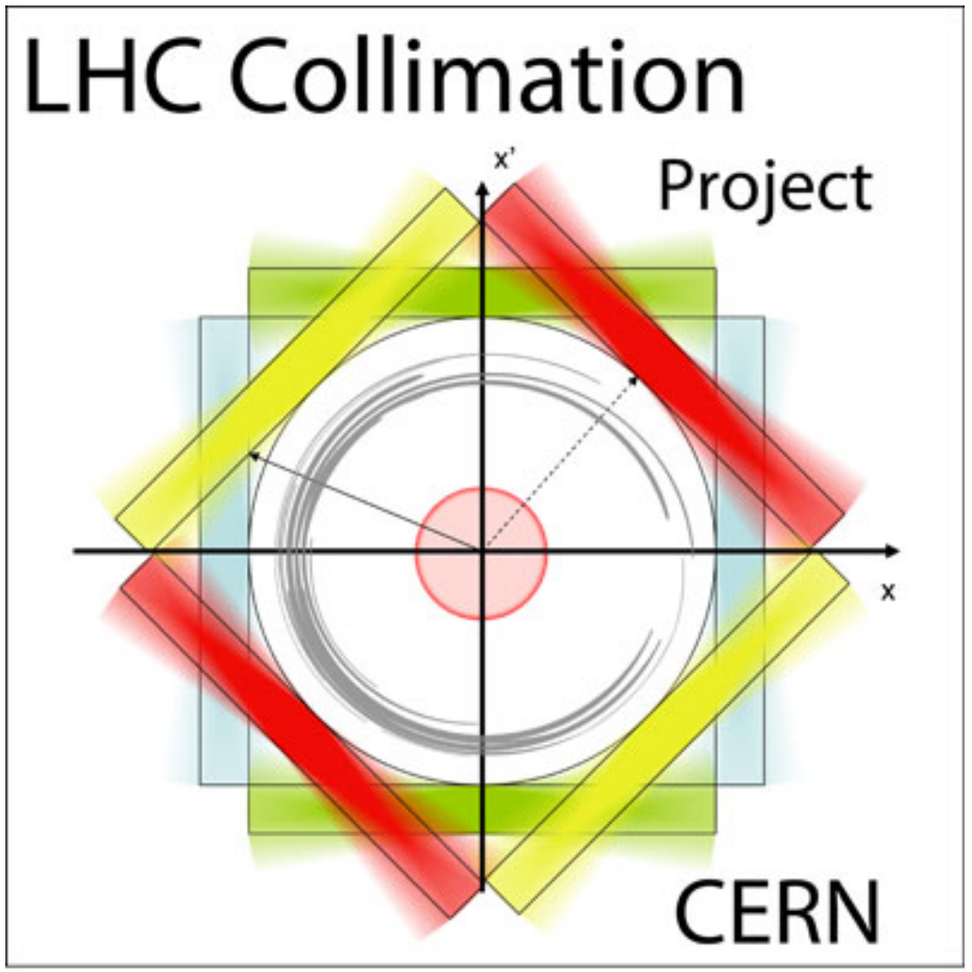
Beam-based validation of settings

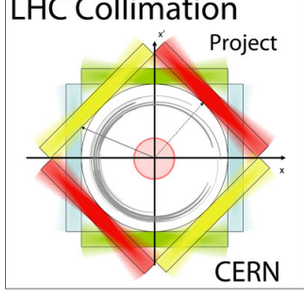


B.Salvachua, R.Bruce, M.Cauchi, D.Deboy, L.Lari, E.Quaranta, A.Marsili, D.Mirarchi, A.Rossi, S.Redaelli, G.Valentino and D.Wollmann
Collimation Team

ADT team: W.Hofle and D.Valuch
And many inputs from: M.Solfaroli and J.Wenninger

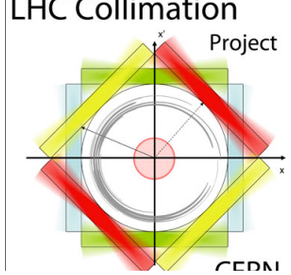
MPP Workshop, March 2013, Annecy

Outline

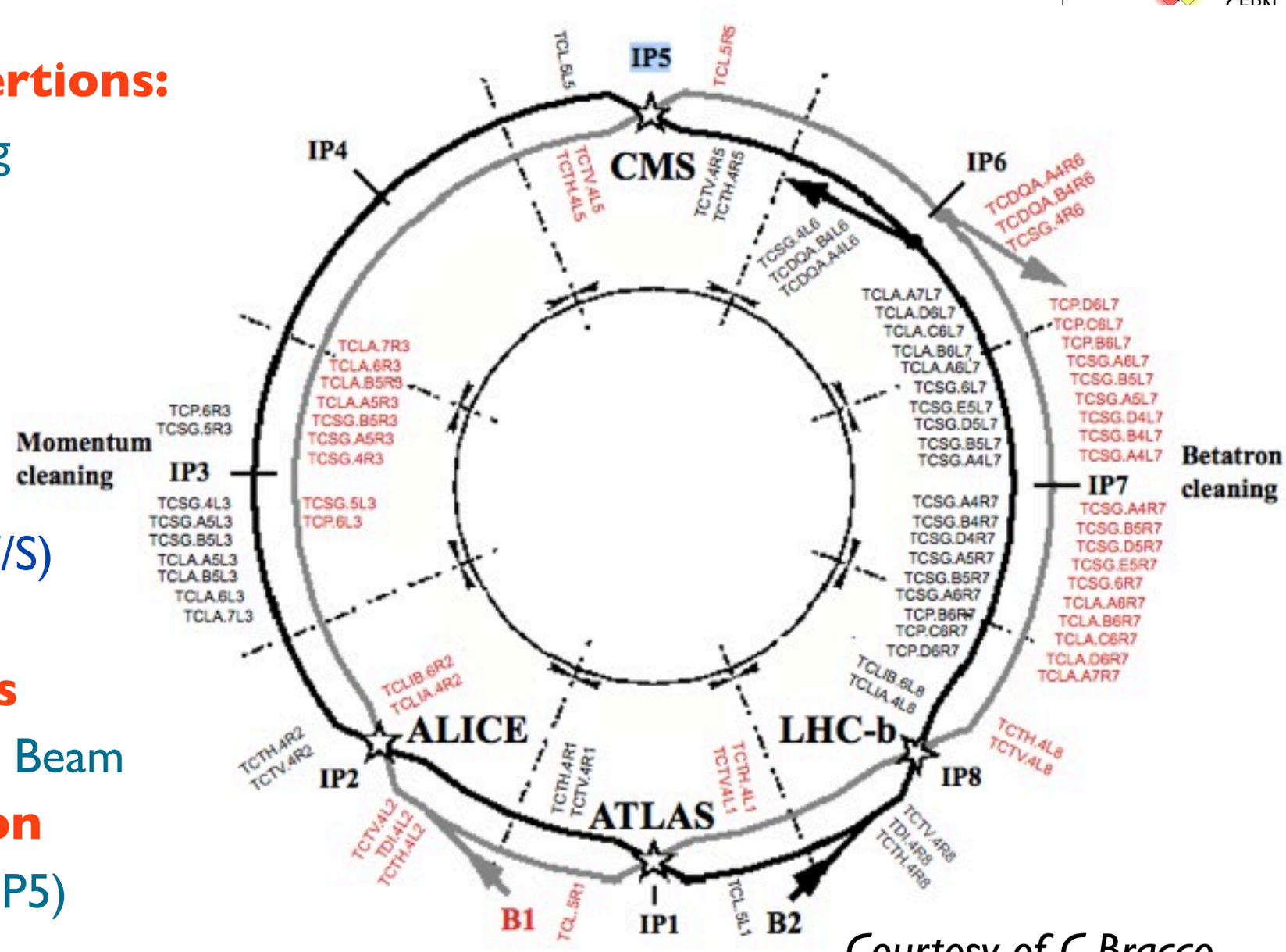


- Introduction and review of present loss map strategy
- Review betatron loss maps
  - Validation of settings
  - Minimum intensity required for loss maps
  - Can we control the intensity loss rate?
- Review off-momentum loss maps
  - What is the minimum frequency change required?
  - Can we get it without dumping?
- Prospects for improving loss maps:
  - Continuous loss maps: ramp-squeeze
  - Online monitoring of cleaning

LHC Collimation Layout



- **Two warm cleaning insertions:**
  - IR3: momentum cleaning
    - 1 Primary (H)
    - 4 Secondaries (H/S)
    - 4 Shower Abs. (H/V)
  - IR7: betatron cleaning
    - 3 Primaries (H/V/S)
    - 11 Secondaries (H/V/S)
    - 5 Shower Abs. (H/V)
- **Local cleaning at triplets**
  - 8 tertiaries: 2 per IP per Beam
- **Physics debris absorption**
  - 2 TCL (1 per beam IP1/IP5)



Courtesy of C.Bracco

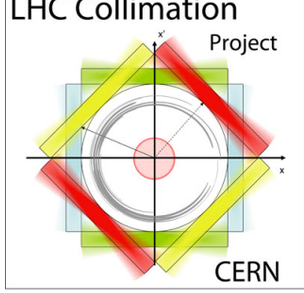
8 passive absorbers for warm magnets in IP3/IP7

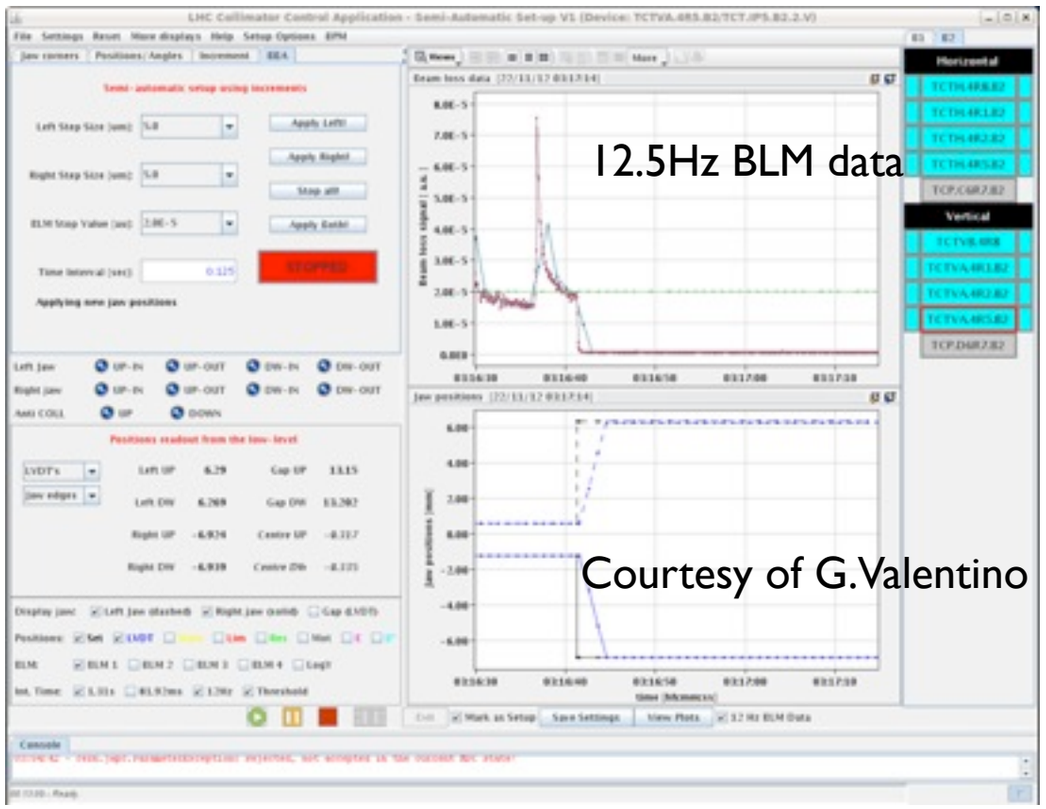
Transfer lines (13 collimators)

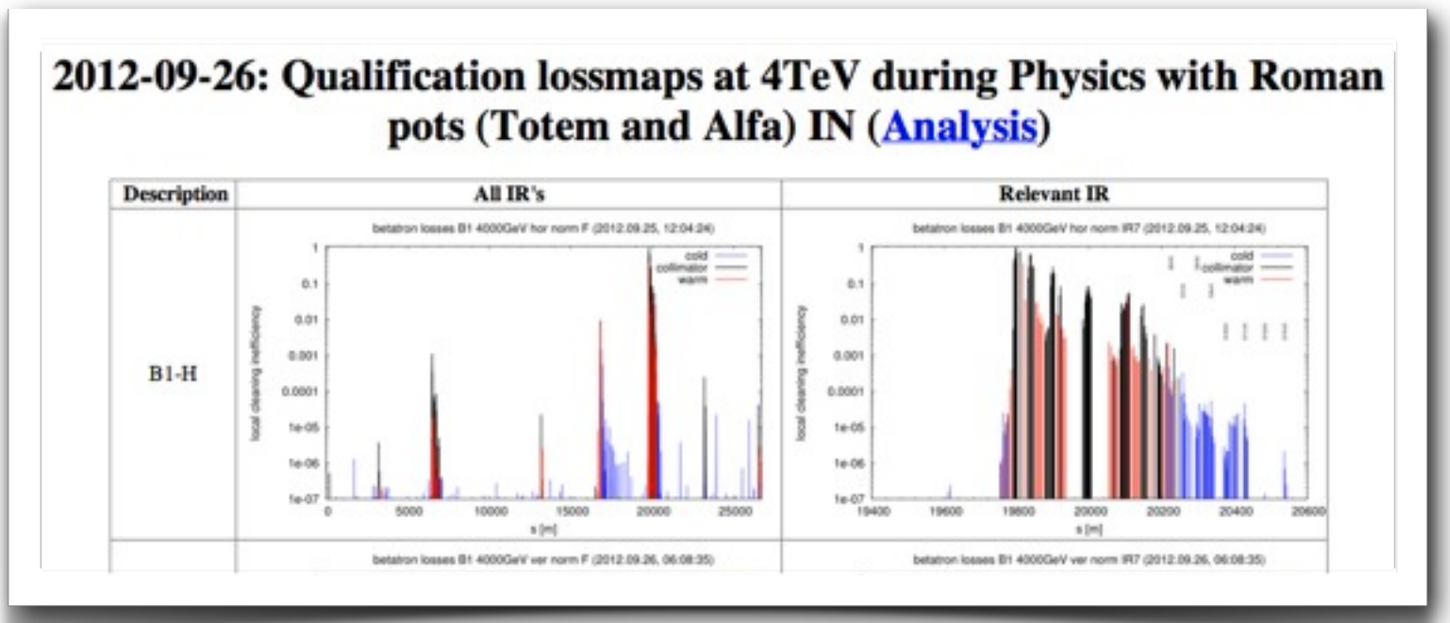
Injection and dump protection (10 collimators)

Total of 108 collimators (100 movable)

Collimation Setup Tools







see also previous presentations G.Valentino and S.Redaelli

Collimator alignment

↓

Generation of settings

↓

Validation

↙ ↘

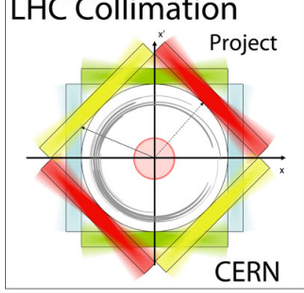
Betatron cleaning → Transverse blow up of the beam

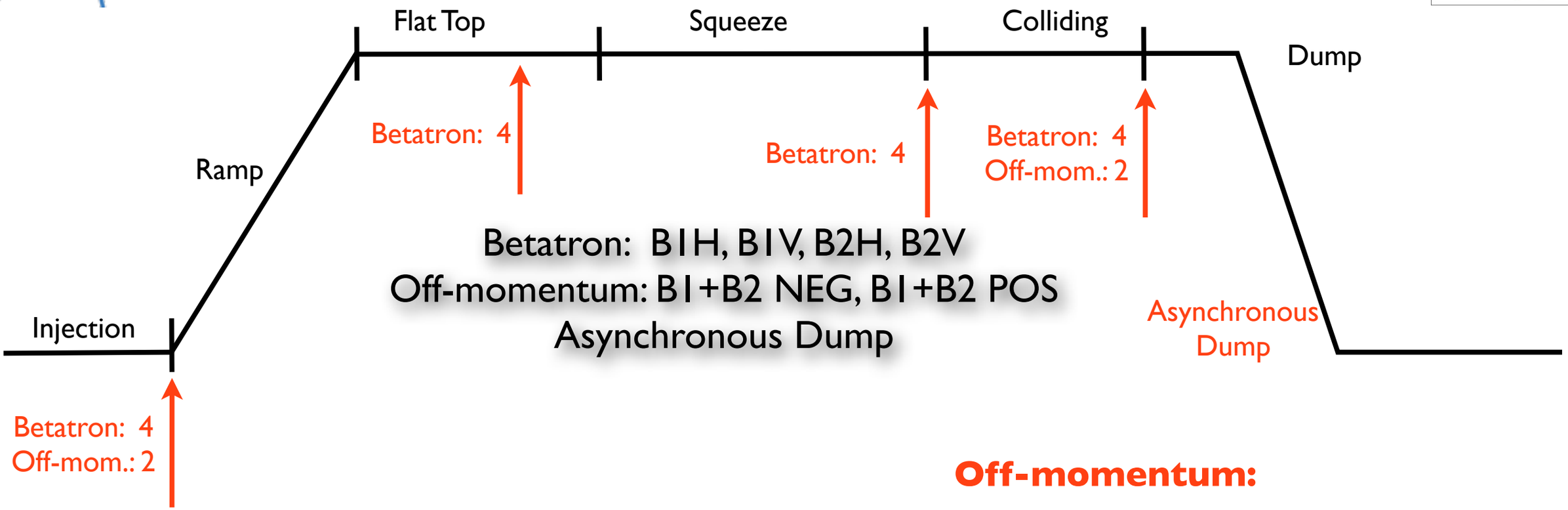
Momentum cleaning → Change of RF frequency

↘ ↙

Ready for operation!

Minimum required validation





For alignment: 1 Fill with 3 nominal bunches

- Betatron loss maps are done parasitically after alignment in each cycle

For validation Top Energy: 3 Fills with 3 nominal bunches

- After the alignment is completed the functions are prepared. All betatron are repeated to check the functions parasitically. Roman Pots IN and OUT at colliding.
- Both sides of off-momentum loss maps
- One asynchronous dump

For validation Injection Energy: 3 Injections

- Both sides of off-momentum loss maps
- One asynchronous dump
- Parasitically betatron with injection protection IN and OUT

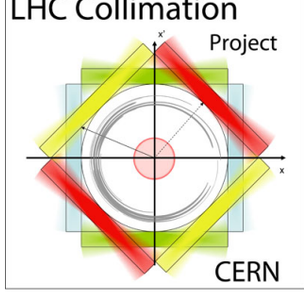
Off-momentum:

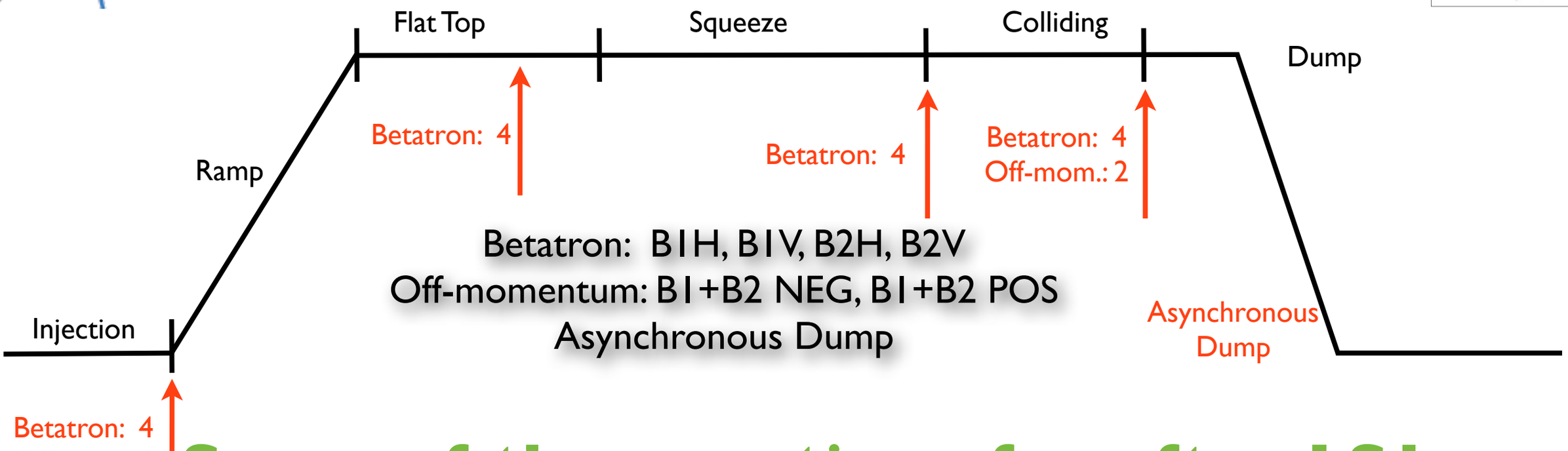
During commissioning for the initial alignment we require off-momentum loss maps everywhere.

For regular validation the off-momentum loss maps are only required at colliding and injection.

For smaller changes in the configuration like TCT alignment, the minimum validation at squeeze/colliding is required.

Minimum required validation II



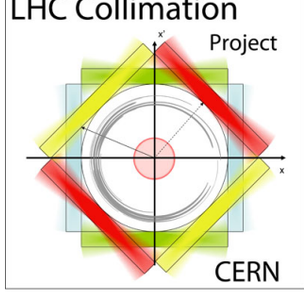


Some of the questions for after LS1...

The Setup Beam Flag (SBF) at 7TeV will allow less intensity, probably 10^{10} protons.
What is the minimum intensity for the loss maps? Could the alignment and the loss maps be done with "unsafe" beam (increased intensity)?

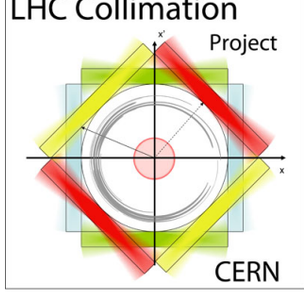
Currently, all betatron loss maps are done parasitically. We are limited by the number of fills needed for the asynchronous dump and the off-momentum loss maps (3 fills).
Could this be reduced? Could we do off-momentum loss maps without dumping?

How can we validate the collimation system during the cycle? Up to date, there is no indication that this is needed, but things may change: combine ramp-queeze, squeeze and collisions, moving of collimators during squeeze...



Betatron loss maps

Review Betatron loss maps



- They are done:
  - after a TS or every 8 weeks
  - when there is a change on the collimator settings or machine configuration
- How many?
  - horizontal losses
  - vertical losses
  - for each beam
  - for each cycle:
    - Injection (with Injection Protection IN / OUT)
    - Flat Top
    - After Squeeze
    - Physics (with Roman Pots IN / OU)

For long proton run the time spent on validation is small compared to the data taking time.

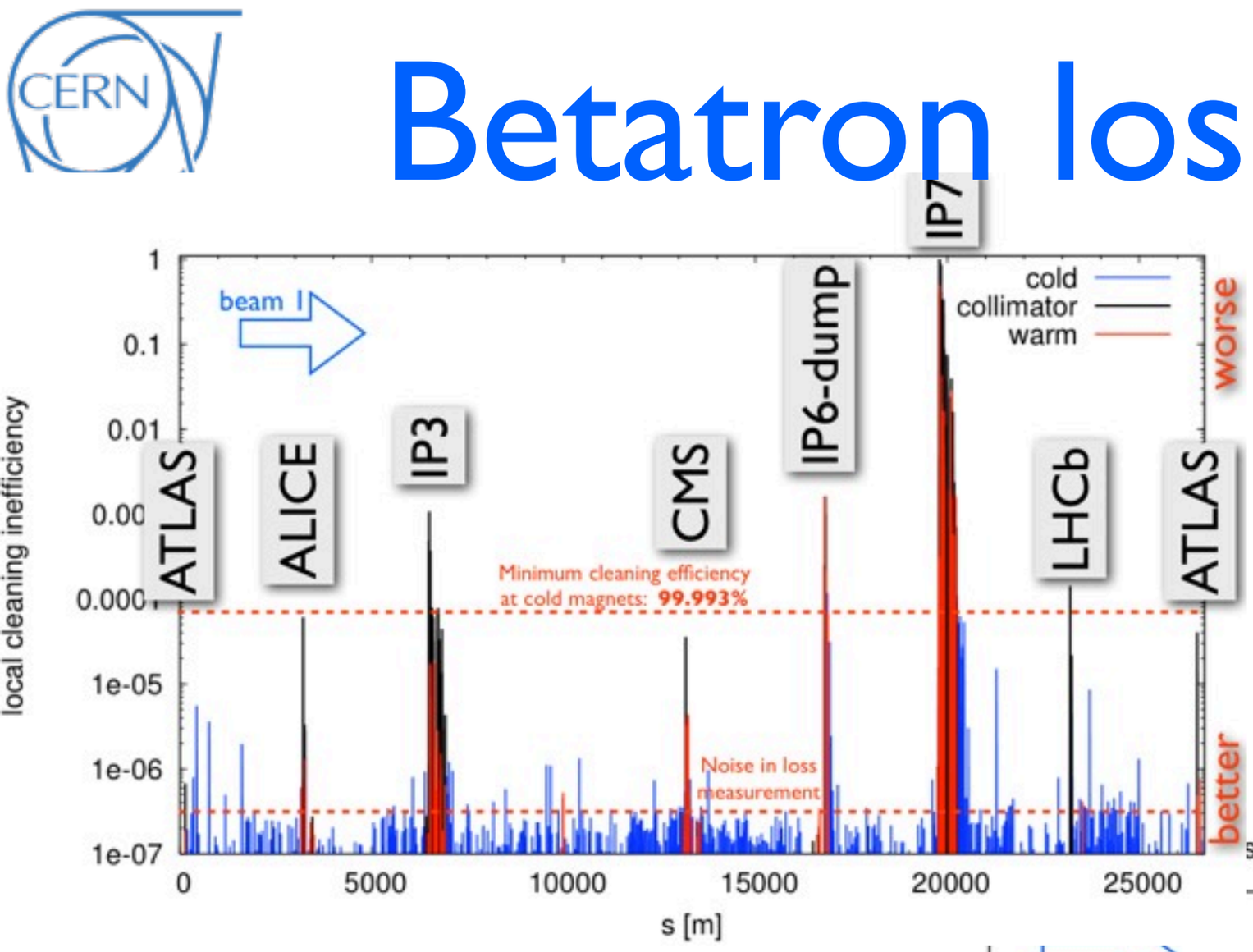
The agreed validations repetition rates were rarely achieved. The often changes of machine configuration were driving the number of loss maps

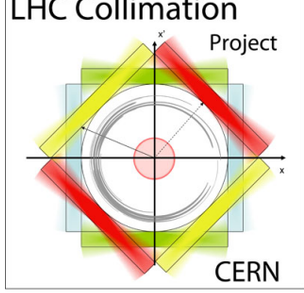
Many thanks to the ADT team: D.Valuch, W.Hofle

since the ADT is in place all these can be done in one fill
The limitation comes from the off-momentum loss maps and the asynchronous dumps

If change of physics configuration that requires TCT alignment (i.e. ALICE polarity change) only the ones at Physics are repeated

Betatron loss maps



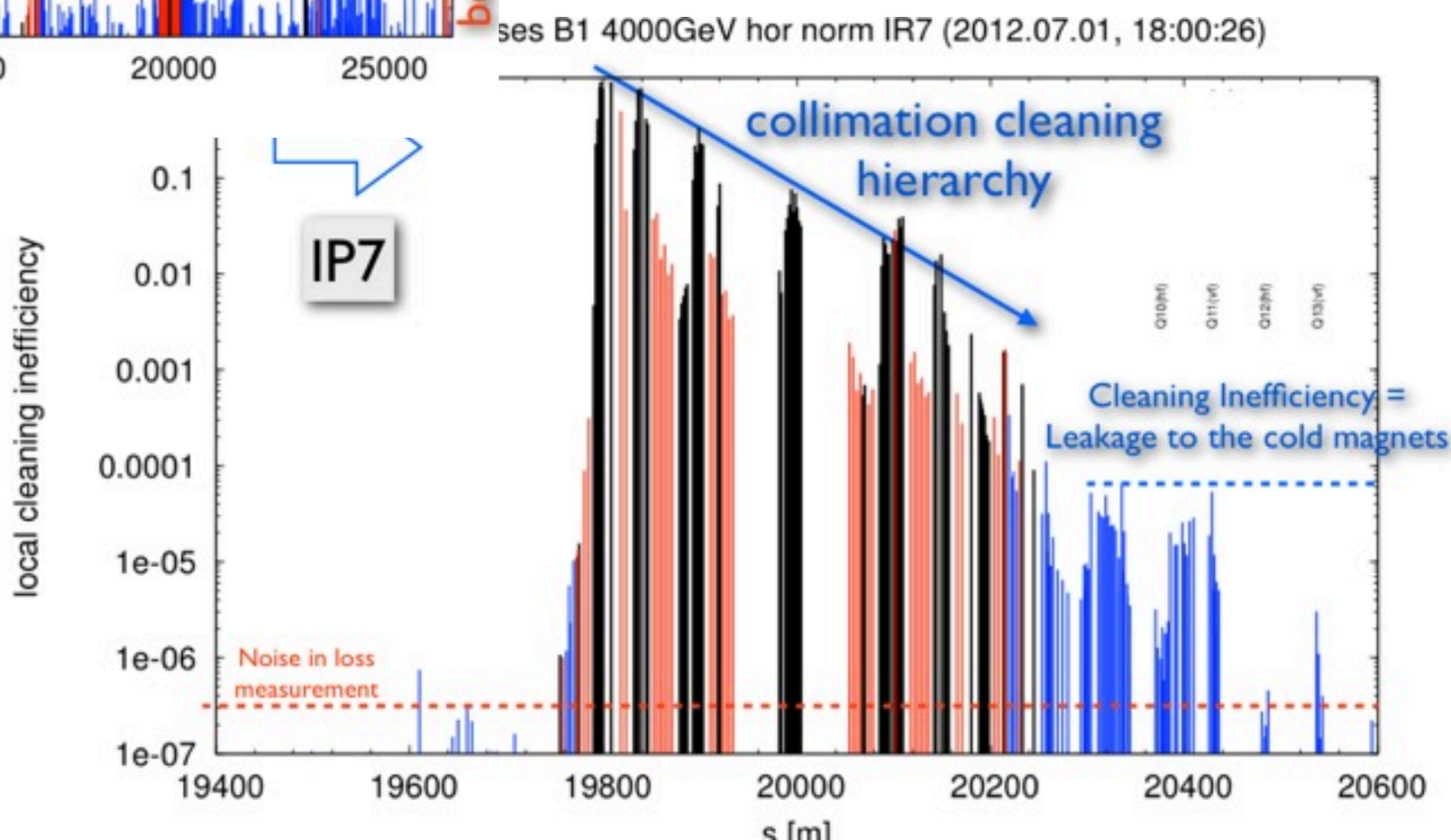


for every betatron loss maps we monitor the leakage from IP7 to the rest of the IPs. The cleaning hierarchy in IR7 and the leakage into the DS in IR7 (cleaning inefficiency in Q8).

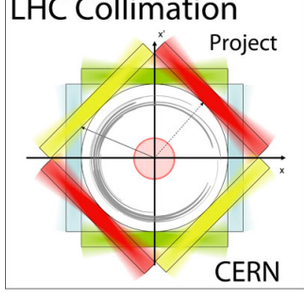
If there is something suspicious we ask for new los maps and in some cases we repeat the alignment i needed.

However, we need good references, it is hard to predict detailed distribution of the losses, it is important to get it right at the beginning.

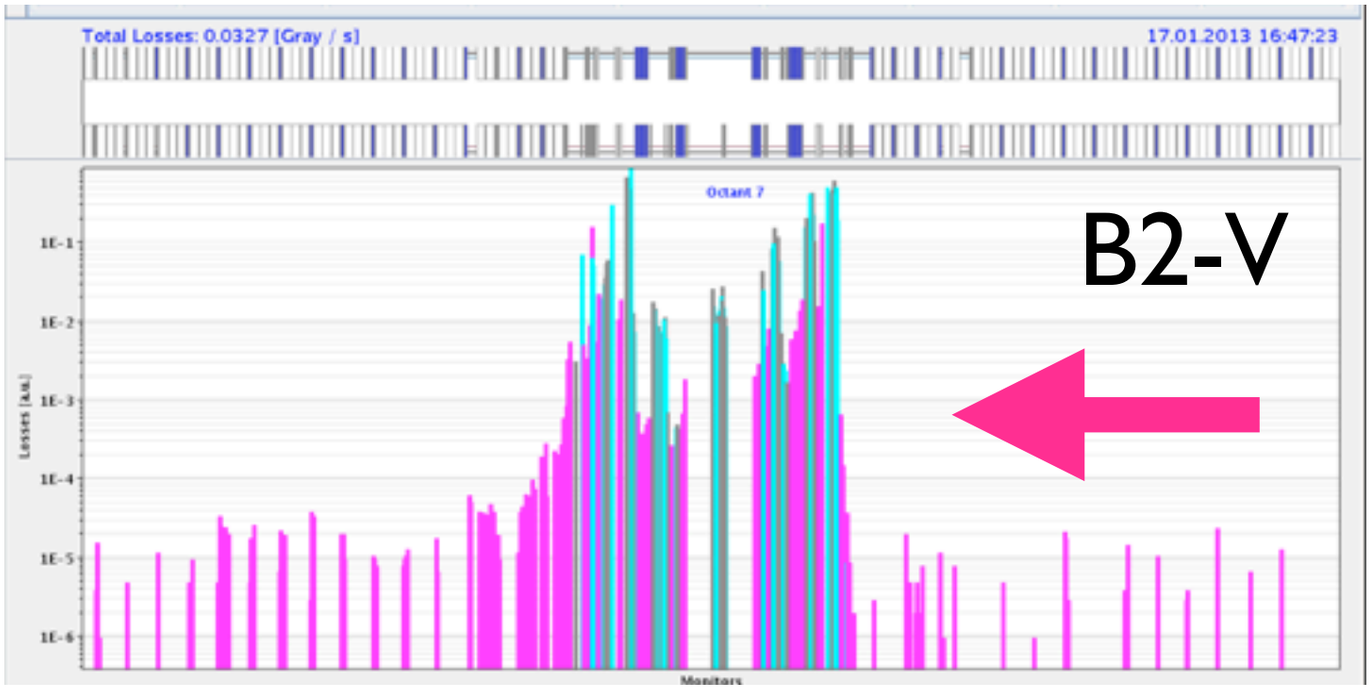
For example, we had wrong TCT settings in IR2 at beginning of 2012 that could not be spotted on the loss maps because of lack of good references.



Example of usefulness of loss maps



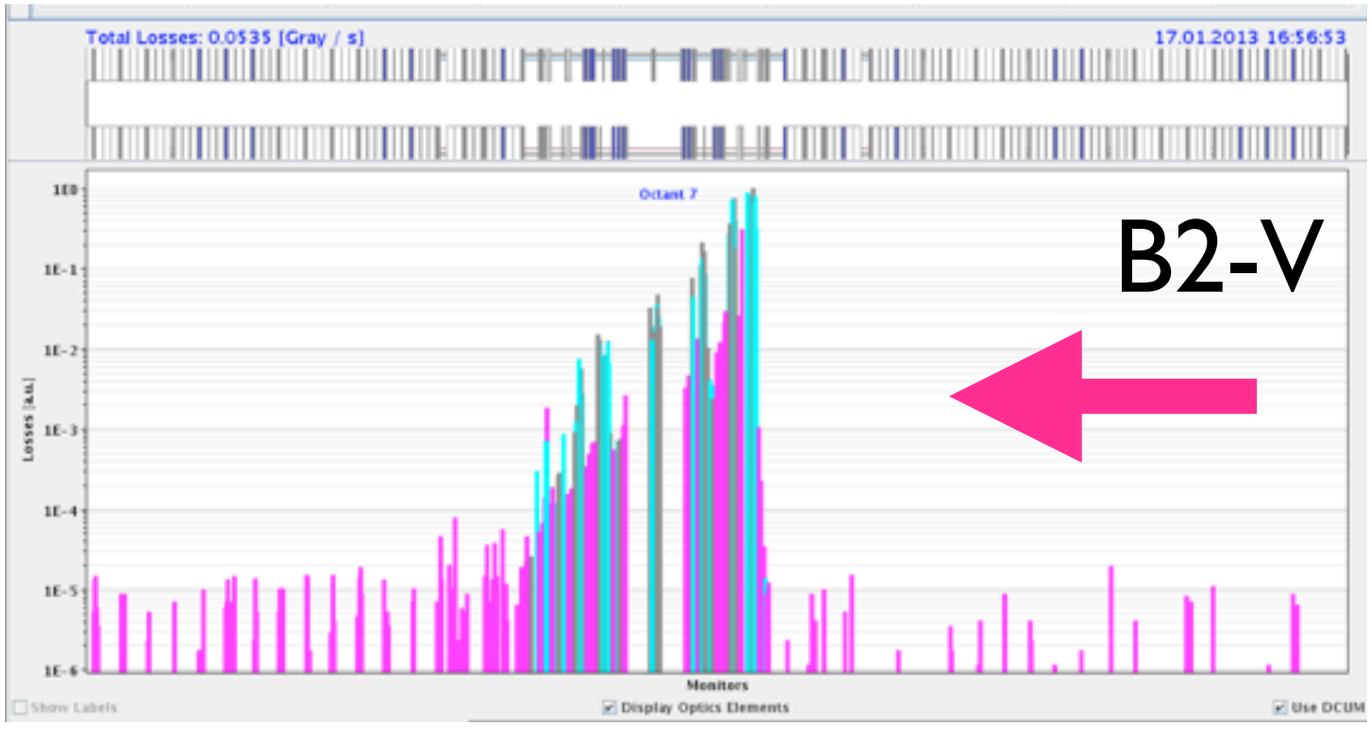
However, in other cases (p-Pb alignment), loss maps done during alignment were extremely useful to spot problems BEFORE releasing new settings for operation



17.01.2013 16:47:23

Broken hierarchy in IR7 for B2 after alignment

TCLA.A6L7.B2: error of 700um in the measured center! Caught in loss maps right after alignment. Re-aligned and checked again in the same fill.



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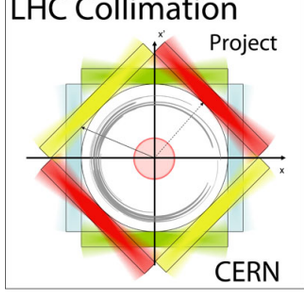
Cleaning Hierarchy for B2 restored

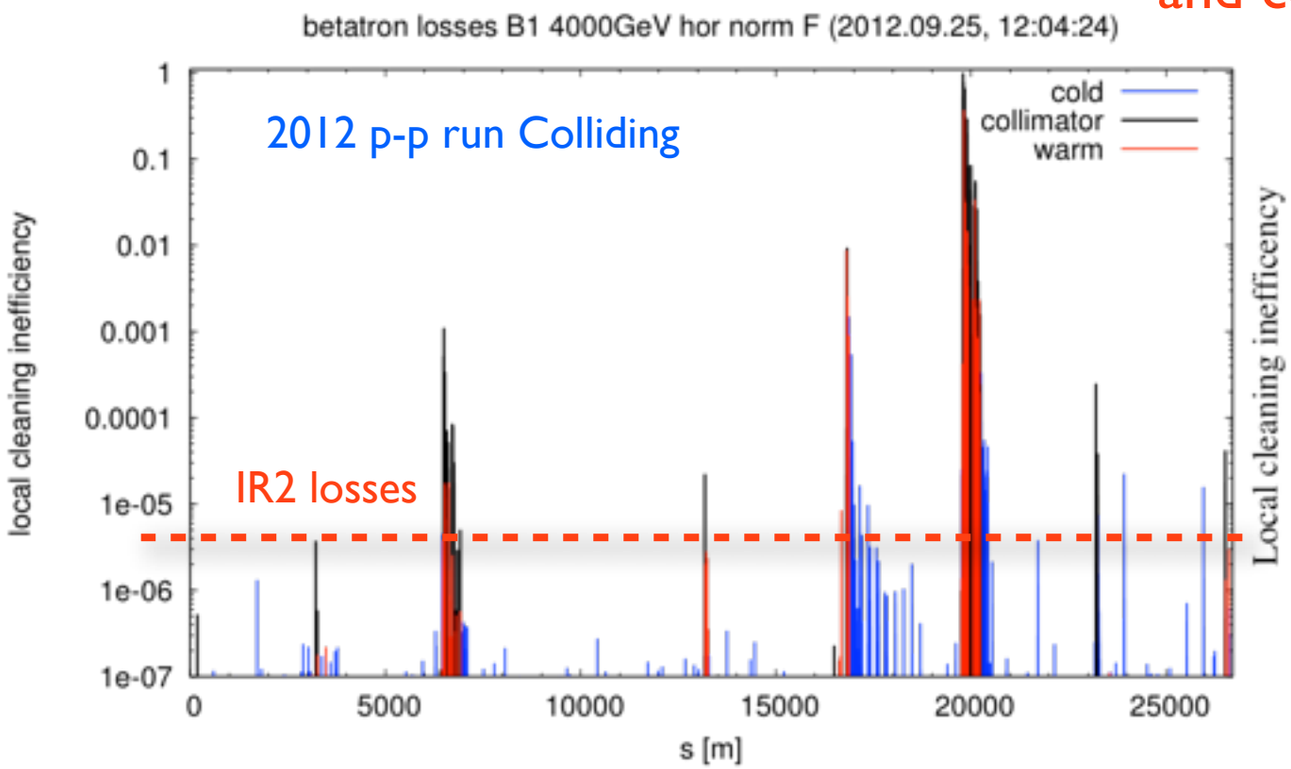
And the correct settings release for operation

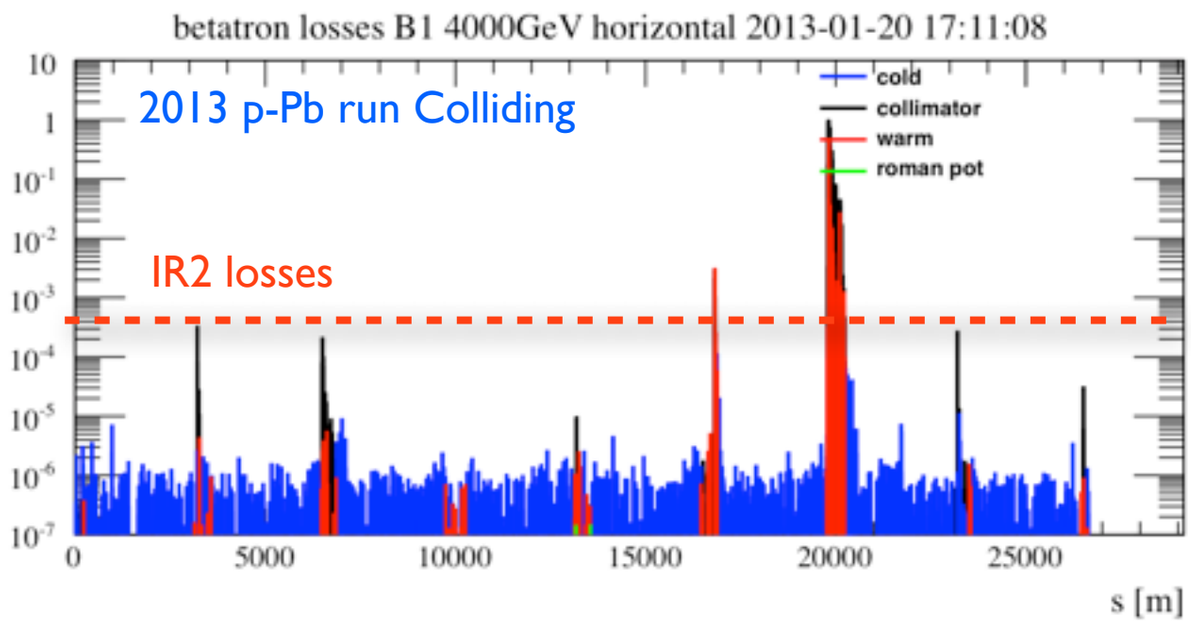
The need of good references

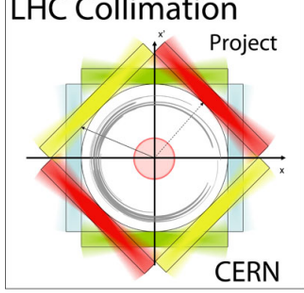


- We cannot always spot misalignment problems, in the previous case it was very evident. But loss maps do not have sometimes enough resolution to spot smaller misalignments.
- It is very important to have reference loss maps. It's difficult to predict the leakage to the IRs when we don't have any reference case.

Losses in IR2 higher, we repeat the alignment and did not find significant differences. In this case we think it is due to the change of beta* (first time IR2 is squeezed) and collimator settings TCT was at 12sigmas and now is at 10sigmas.







- **Addressing some of the questions…**

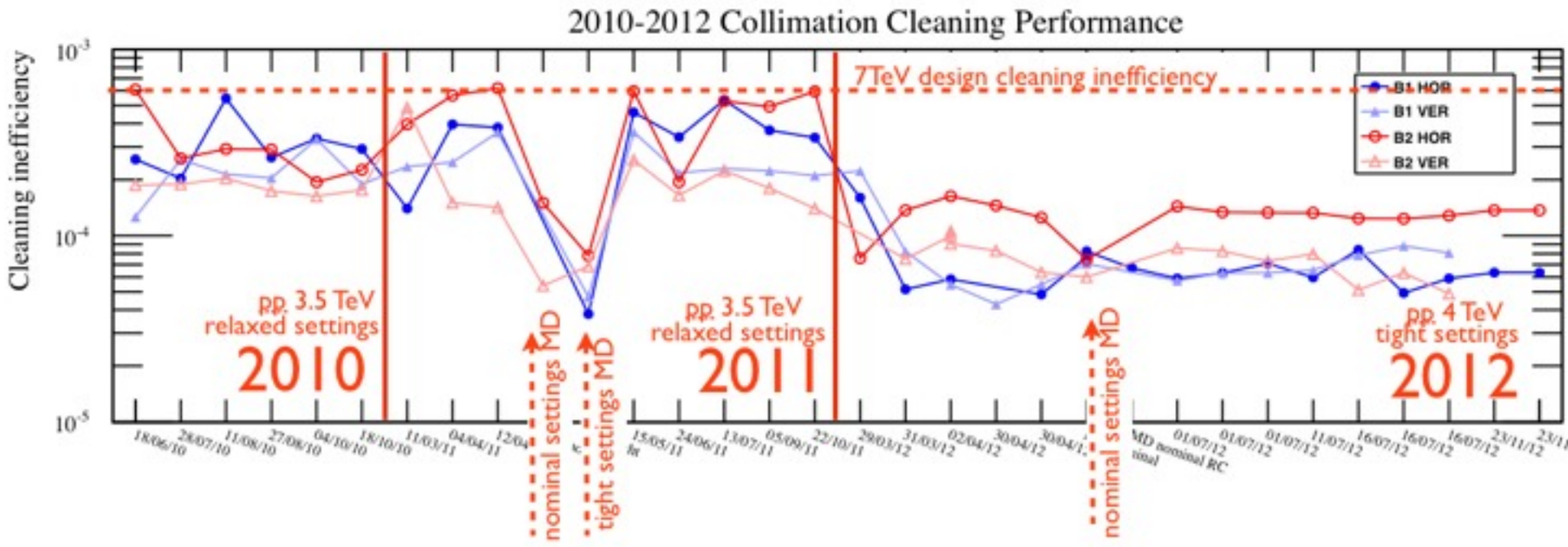
- What is the minimum intensity needed for the betatron loss maps?
- Can we do them with “unsafe” beam?
- How well can we control de losses?

Minimum intensity loss for loss maps

The minimum bunch intensity is defined by the minimum BLM signal that we need to measure the cleaning inefficiently at Q8 IR7.

$$\mathrm{BLM}^{\mathrm{Q8}} = \eta_c \times \mathrm{BLM}^{\mathrm{TCP}}_{\mathrm{min}} > \mathrm{BLM}^{\mathrm{noise}}$$

$$\mathrm{BLM}^{\mathrm{TCP}}_{\mathrm{min}} > \frac{3 \cdot 10^{-7}[\mathrm{Gy/s}]}{5 \cdot 10^{-5}} = 6 \cdot 10^{-3}[\mathrm{Gy/s}]$$



Minimum Intensity lost to measure the cleaning inefficiency at Q8 IR7

$$\mathrm{BLM}^{\mathrm{TCP}}_{\mathrm{min}} > 6 \cdot 10^{-3}\ [\mathrm{Gy/s}] \rightarrow \approx 8 \cdot 10^{9}\ [\mathrm{protons/s}]$$

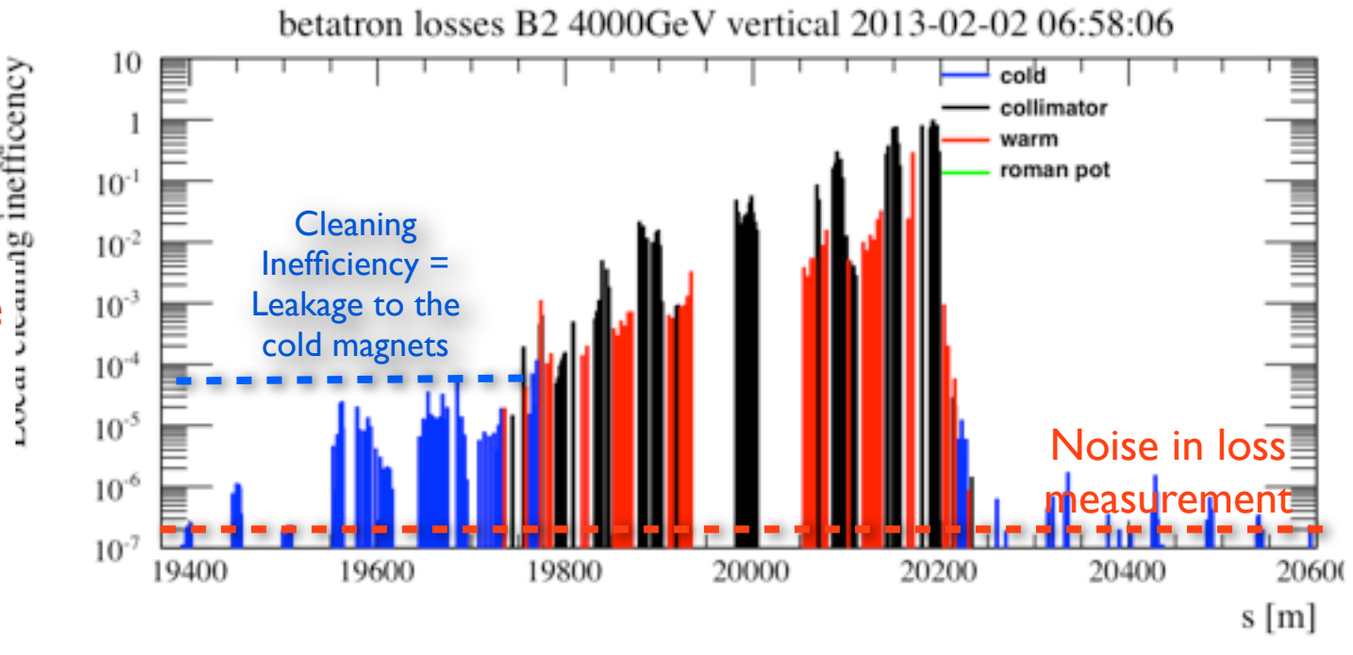
This was tested during the p-Pb run, the loss maps were done by exciting single bunches of few 10^{10} protons/bunch. The plot shows that with 1 pilot bunch we got enough resolution to measure the cleaning in IR7 at 4TeV.

We could excite smoothly the bunch keeping the losses below the dump threshold

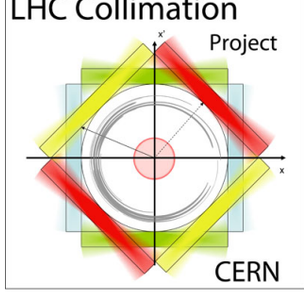
→ No need to mask BLMs

→ Loss maps could be done with "unsafe" intensities

see M.Solfaroli presentation



Control of intensity loss



Can we control the loss rate?

During the proton collimation quench test we have created controlled peak loss rates of up to 1MW over few seconds.

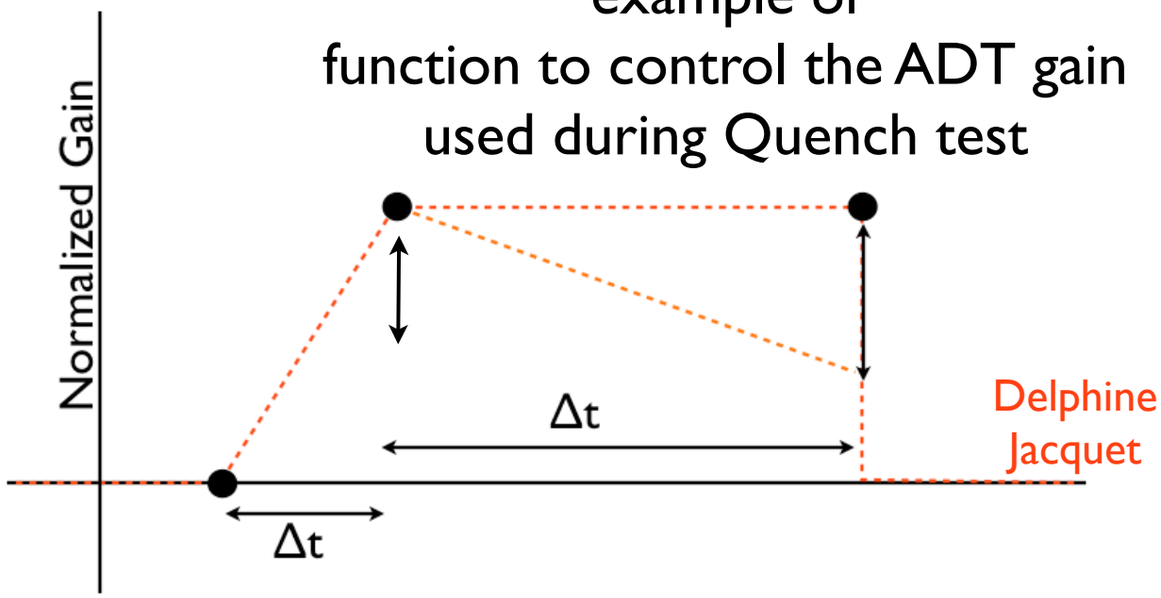
The ADT gain was controlled by a function, were the rise time of the loss, the maximum gain and the duration of the excitation could be setup.

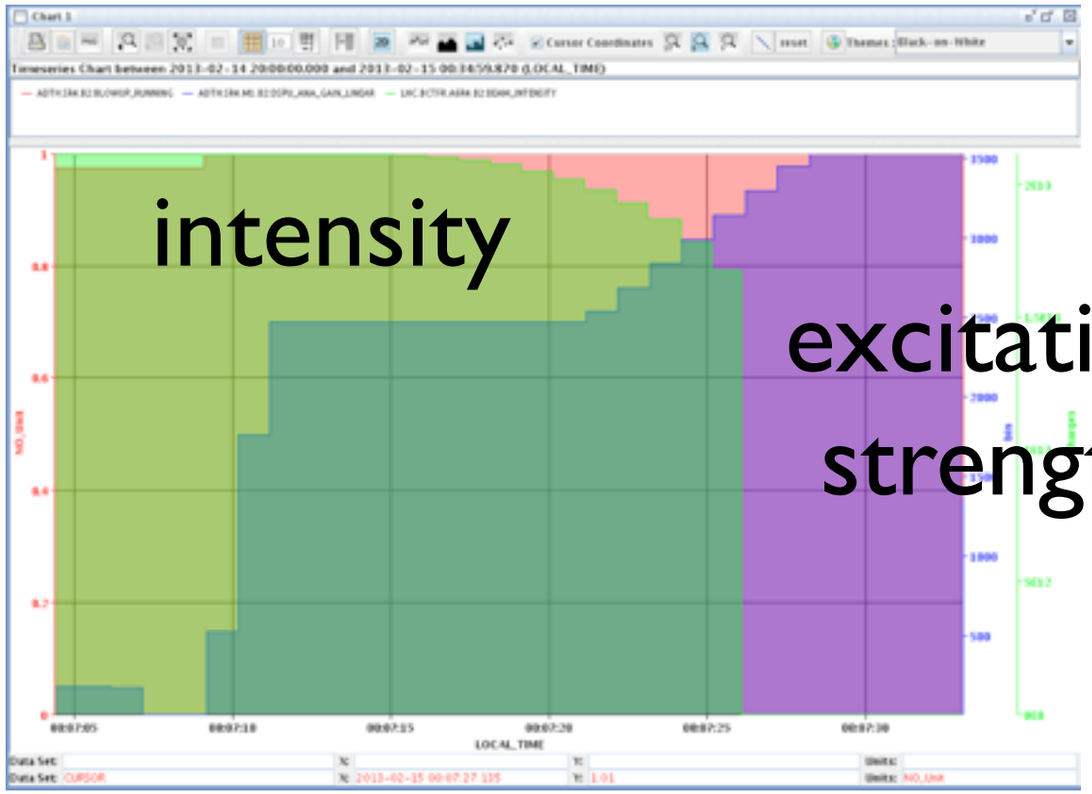
The setup of the ADT was done in individual bunches and worked as well as for exciting several bunches together.

We tried same ADT settings in different fills and the result was consistent

Answer: YES, we can control the maximum loss rate and the duration in individual bunches

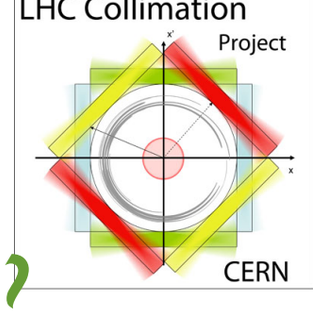
example of
function to control the ADT gain
used during Quench test





Excitation of individual bunches

Can we excite individual bunches also at 25 ns?

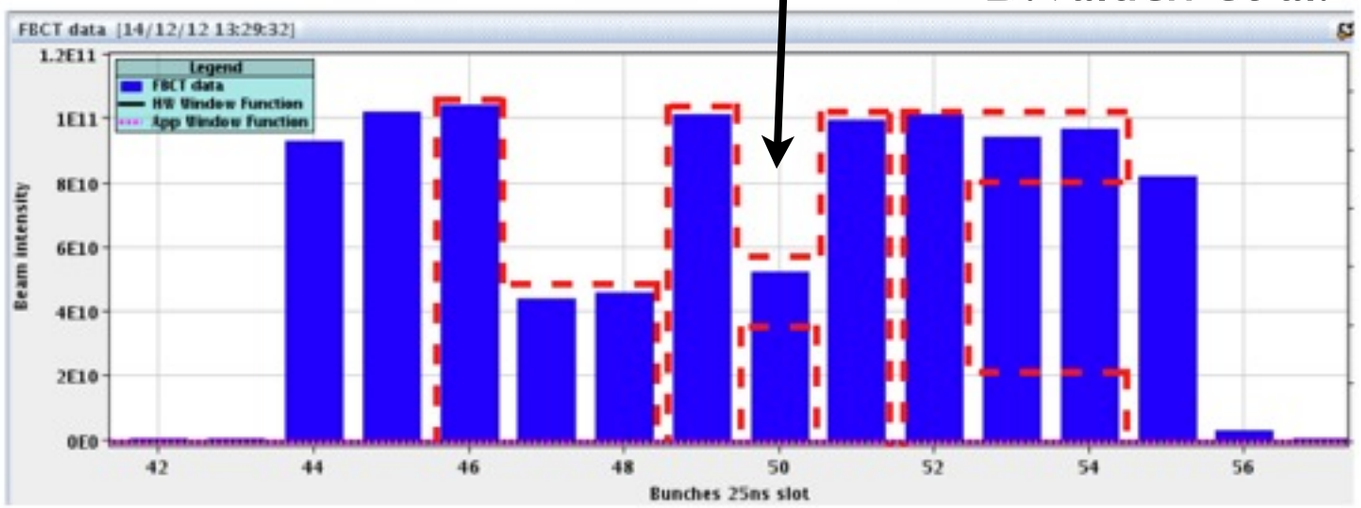


- During 2012-2013 we have used the ADT to excite individual bunches separated by 50 ns. It worked well.

- In December 2012 we also tested the excitation of individual bunches separated by 25 ns.

- Loss maps were taken in the first and last bunch of a 12b train, and afterward single bunch excitation of bunches inside the train was also tested.
  - example of #50, the neighbor bunches are note affected.

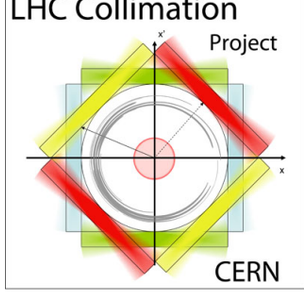
D.Valuch et al.



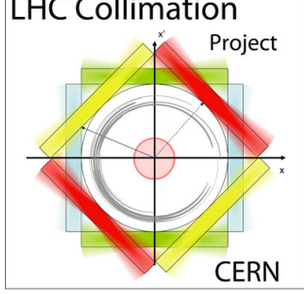
Loss maps done with "unsafe" beam and the losses were kept below the BLM dump thresholds.

ANSWER: YES, we can excite individual bunches also at 25 ns.
Opens the possibility of performing regular checks for all fills (if needed) at the end of the fill, provided that we leave non-colliding bunches.

Betatron summary

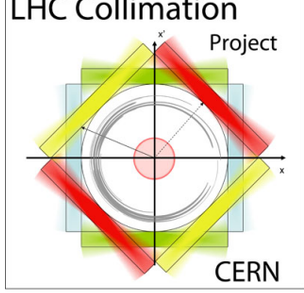


- Since the ADT is used to perform the betatron loss maps, this has become essentially transparent for operation.
  - They can be done several times within the same alignment campaign which helped to spot on-the-fly errors that otherwise would have been caught in later fills.
- During the past years there were important studies to keep improving this situations:
  - Continuous loss maps over few seconds.
  - Loss maps with low intensity (expect to be ok for 7TeV).
  - Achieved loss maps with "unsafe" beam:
    - possibility of regular loss maps before dumping
    - regular post mortem analysis



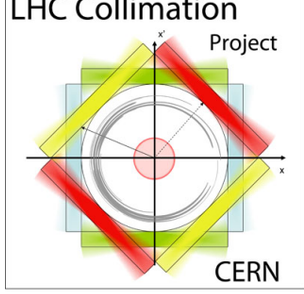
Off-momentum loss maps

Review off-momentum



- How many?
  - Negative off-momentum, RF frequency change of +500Hz, B1 and B2 together
  - Positive off-momentum, RF frequency change of -500Hz, B1 and B2 together
  - After the first alignment these are done for every cycle case (Flat Top, Squeeze, Colliding)
  - For minor changes and regular validations, only done at injection and during physics
    - Sometimes only 1 side, NEG off-momentum.
- "Problem": the beam is dump, typically by losses at the unmaskable BLMs
- What should be investigate if we want to make them with "unsafe" beam and no dump:
  - Minimum RF frequency change required to have off-momentum losses in IR3.
  - What is the maximum orbit change?
  - Where is going to be the dump, BLMs, BPMs, RF?

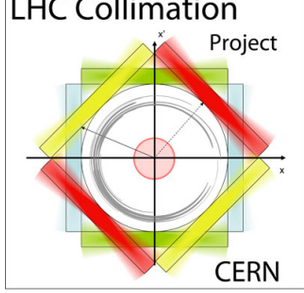
Cases analyzed

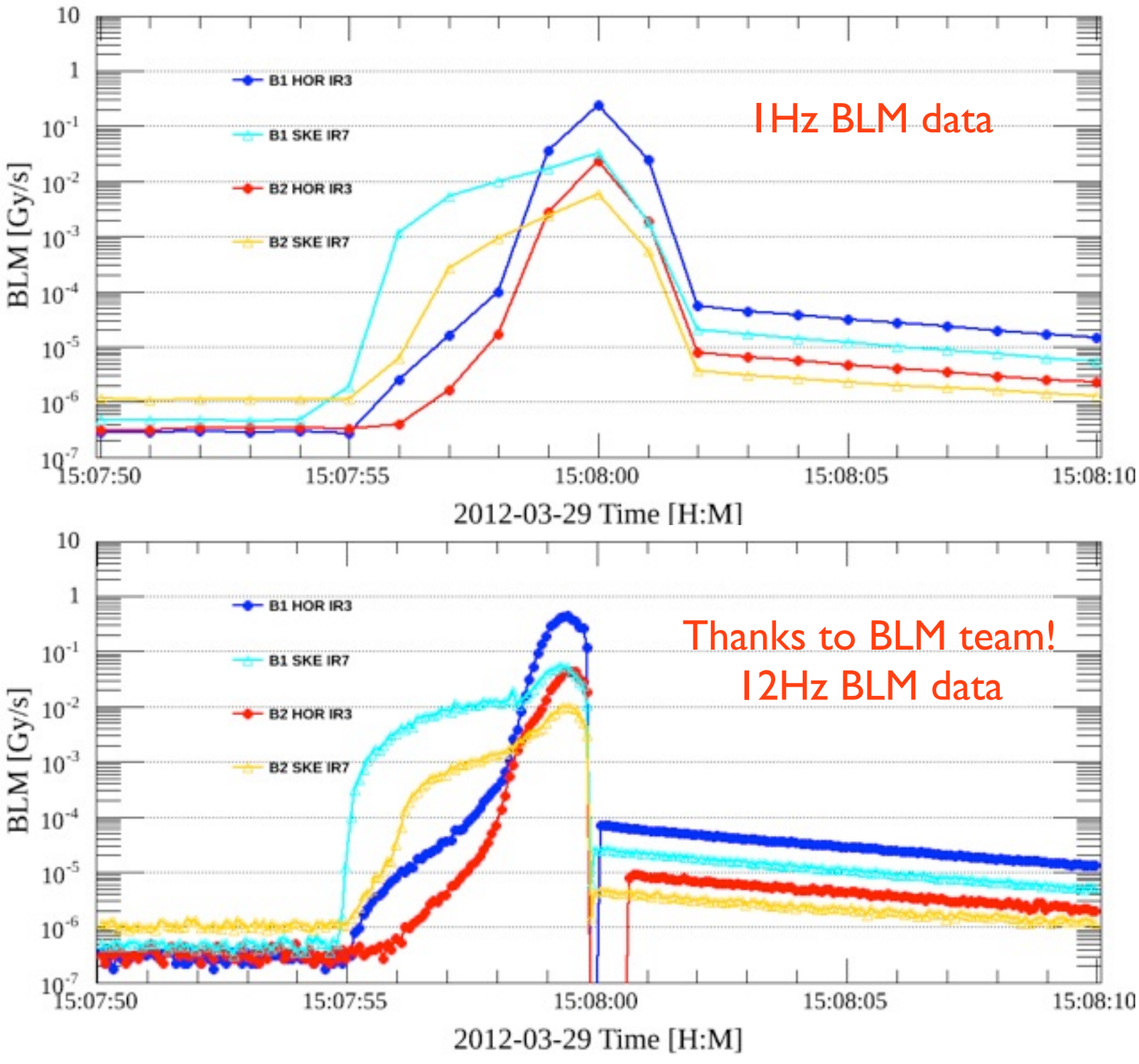


- 4 cases checked:
  - case 1 : NEG FLAT TOP 2012-03-29
  - case 2 : NEG COLLIDING 2012-04-02
  - case 3 : POS COLLIDING 2012-04-03
  - case 4 : NEG PHYSICS 2012-07-01
- We look at:
  - BLM signal of TCP in IP3 and skew TCP in IP7
  - Beam Intensity
  - RF frequency change
  - close orbit change from BPMs in mm and sigma

Trying to find a set of these parameters that will allow for both off-momentum sides in one single fill.

BLM 1 Hz vs 12 Hz

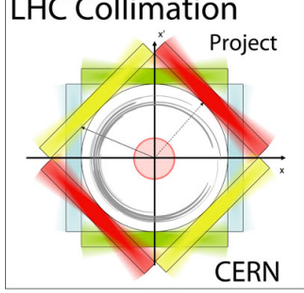


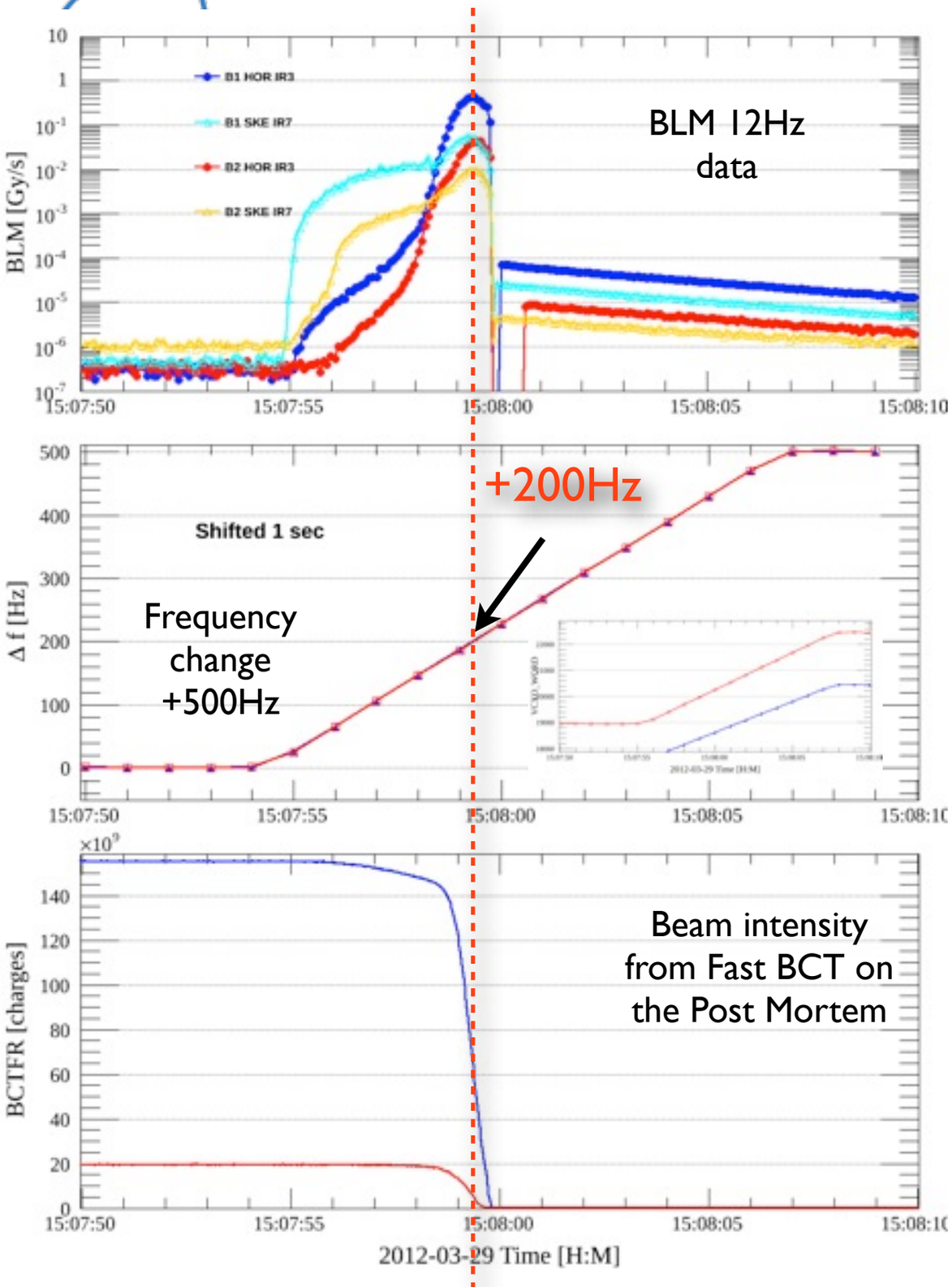


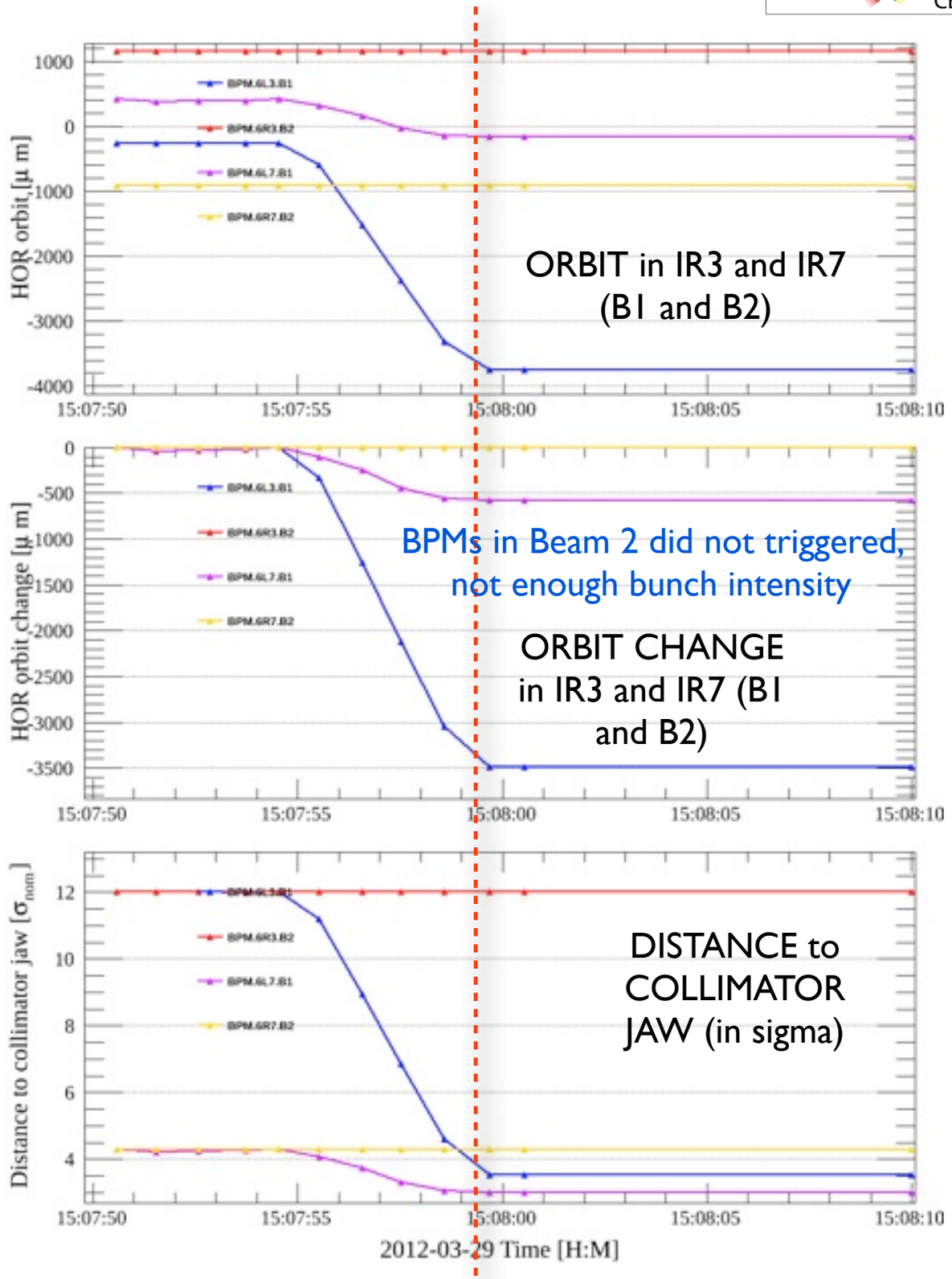
example:
case 1
NEG off-momentum
FLAT TOP

With the 12 Hz data we can identify more precisely when off-momentum losses take over the betatron losses.

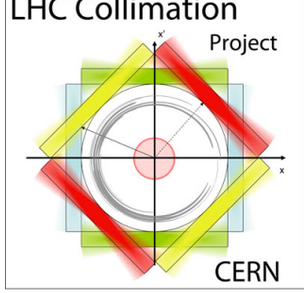
case 1: NEG dp, Flat Top

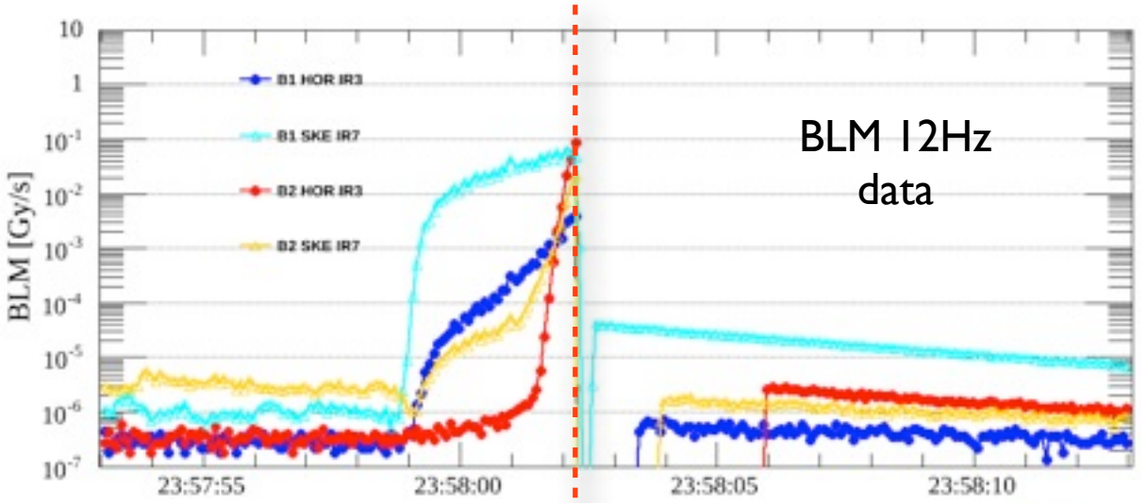




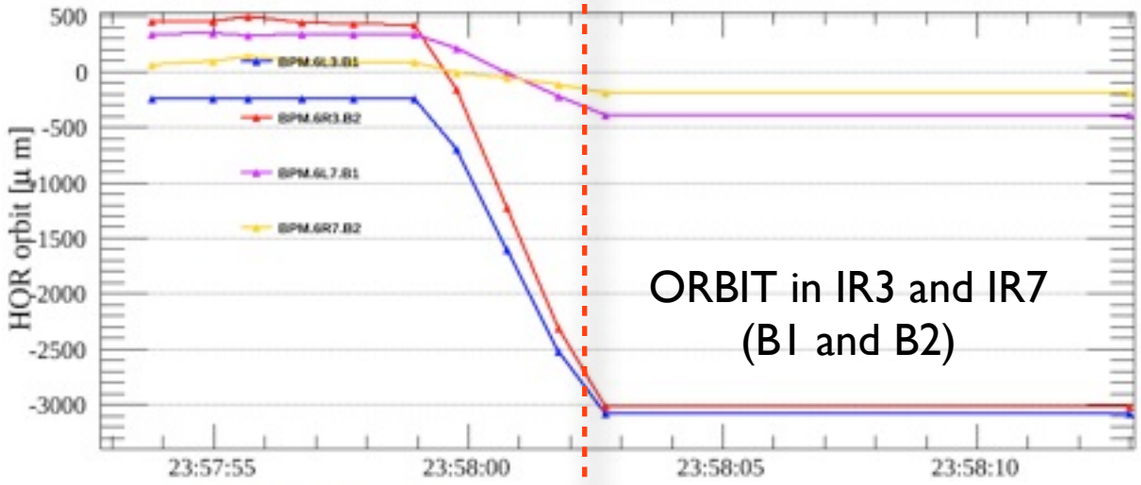


case 2: NEG dp, COLLIDING

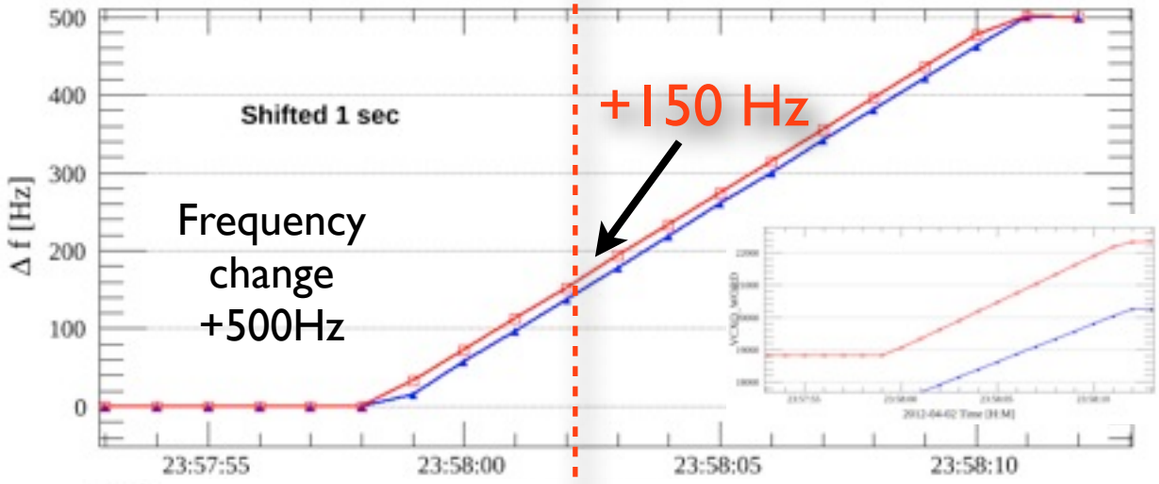


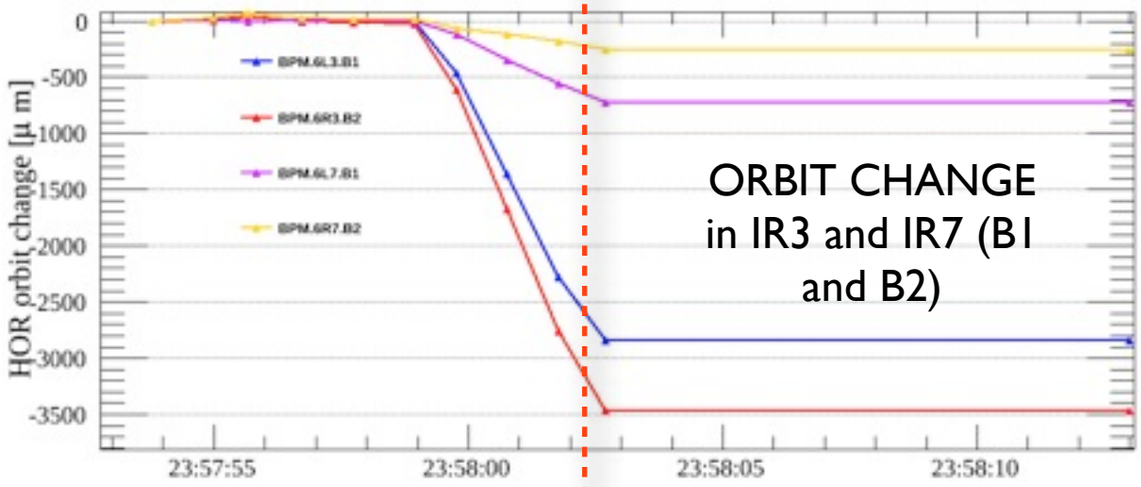


BLM 12Hz data

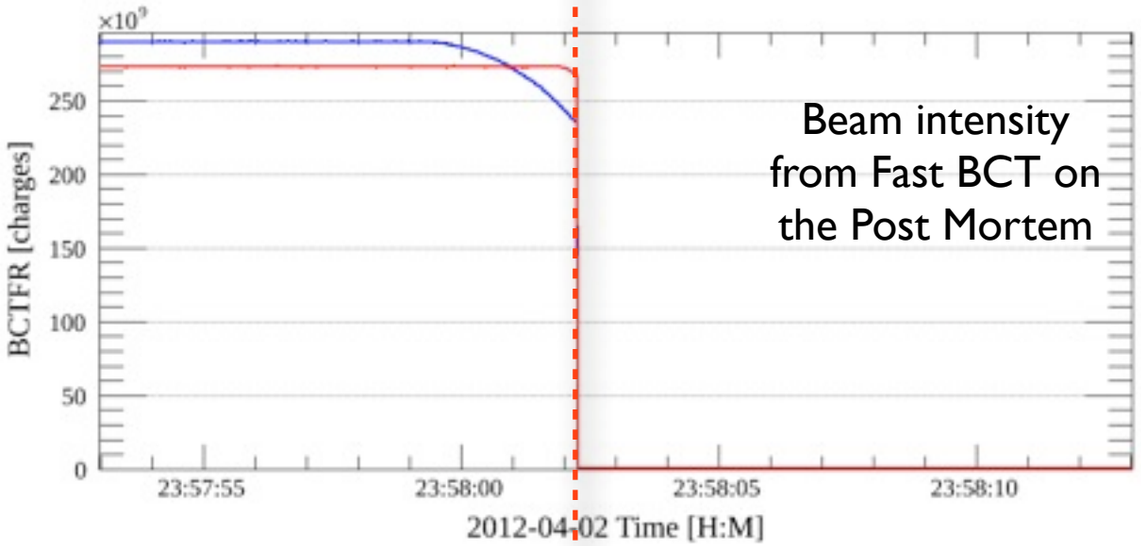


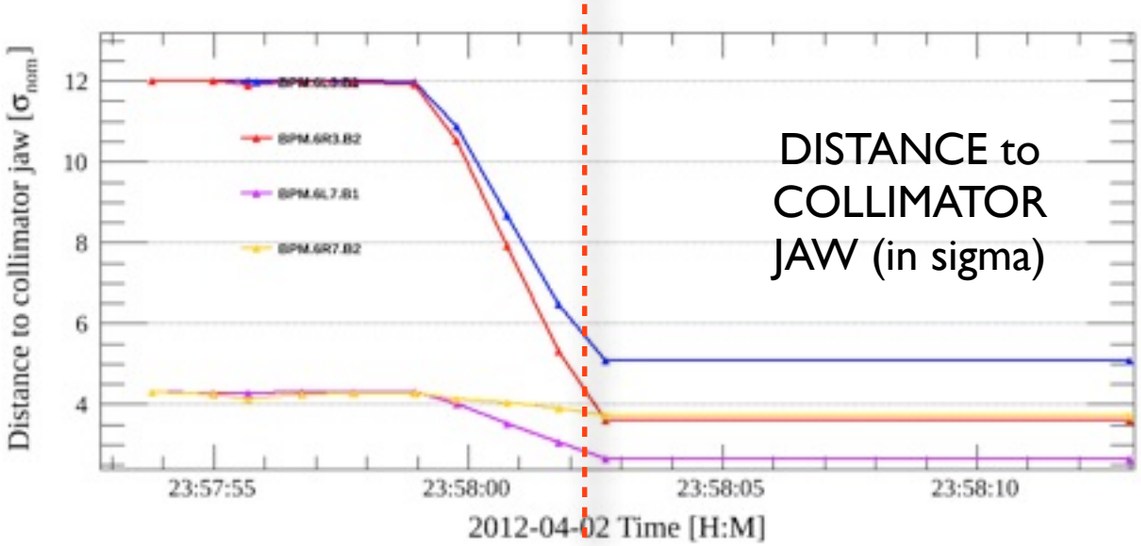
ORBIT in IR3 and IR7 (B1 and B2)



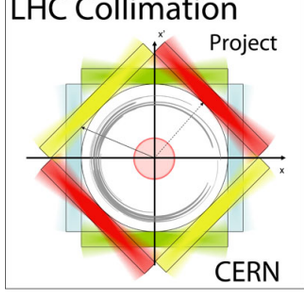


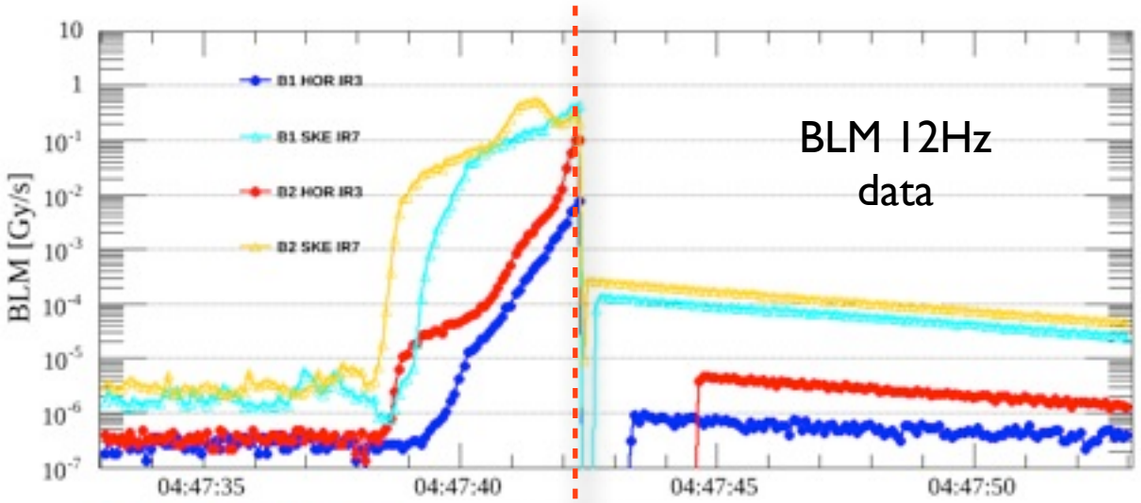
ORBIT CHANGE in IR3 and IR7 (B1 and B2)

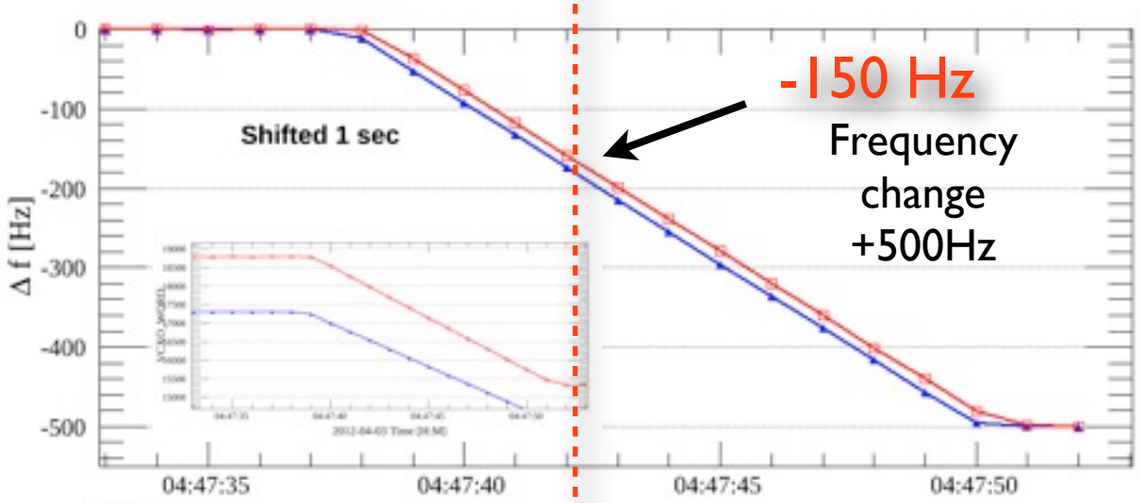


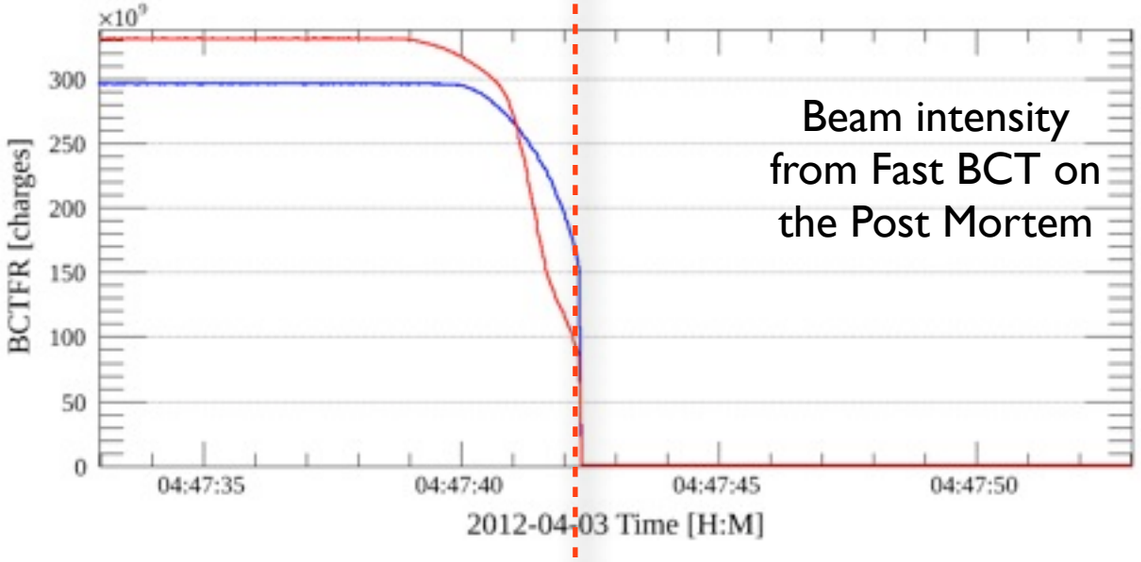


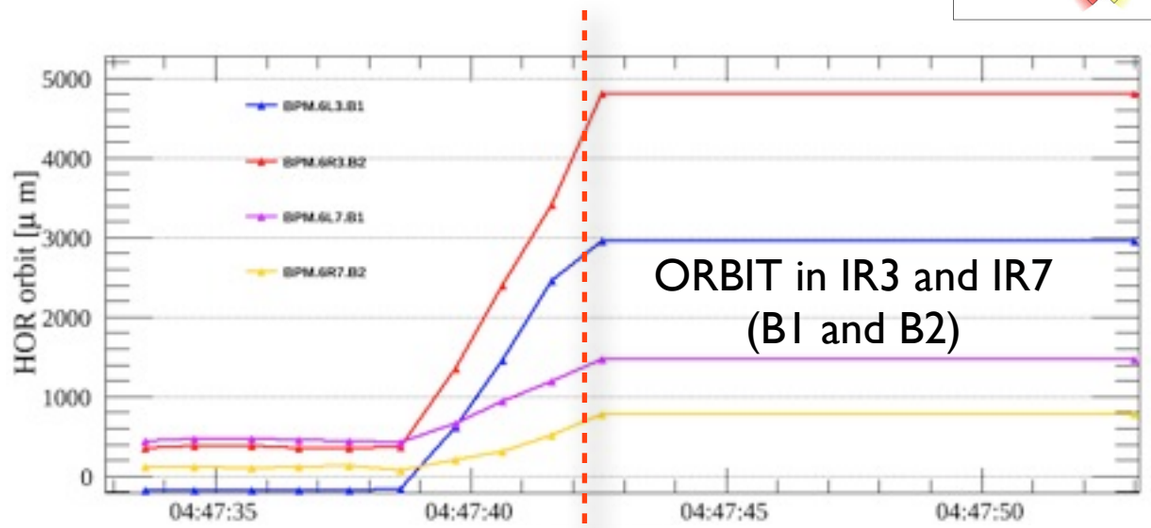
case 3: POS dp, COLLIDING

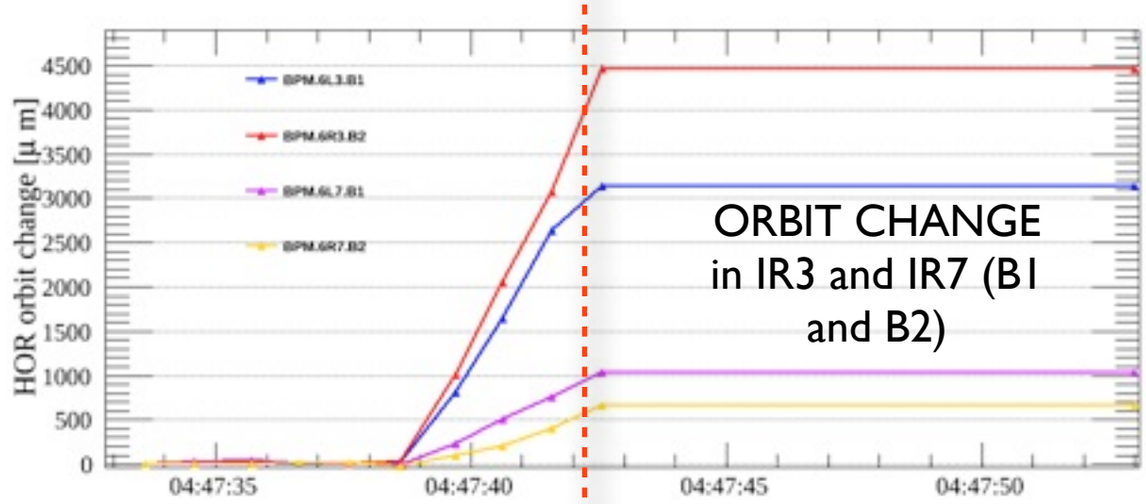


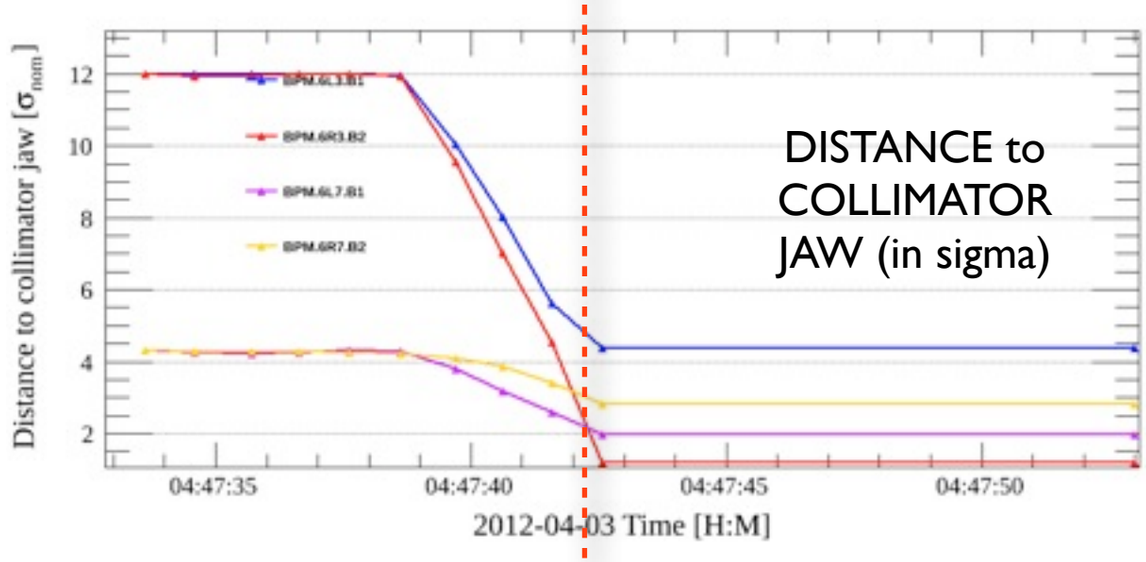




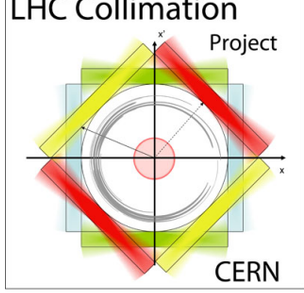


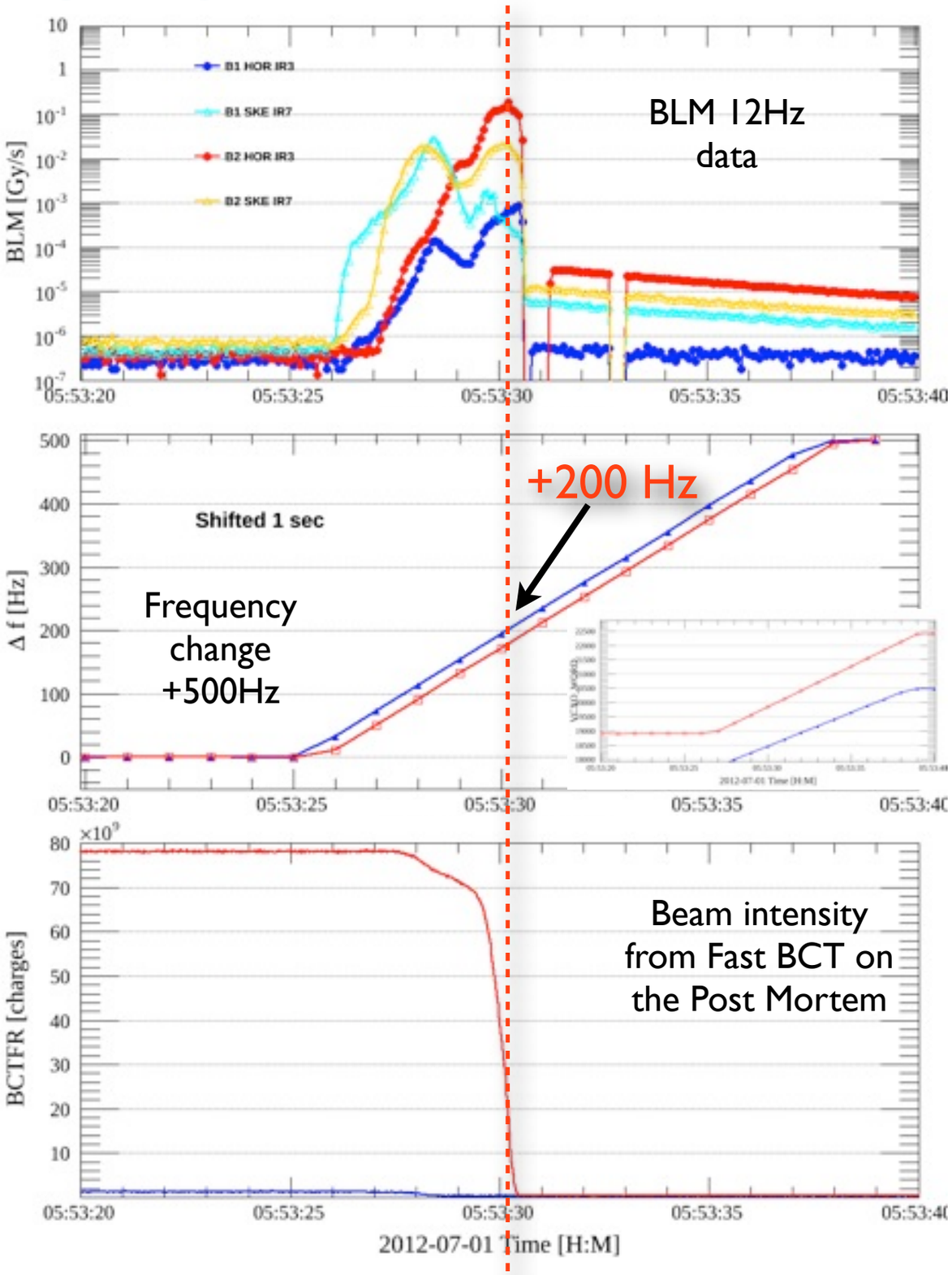


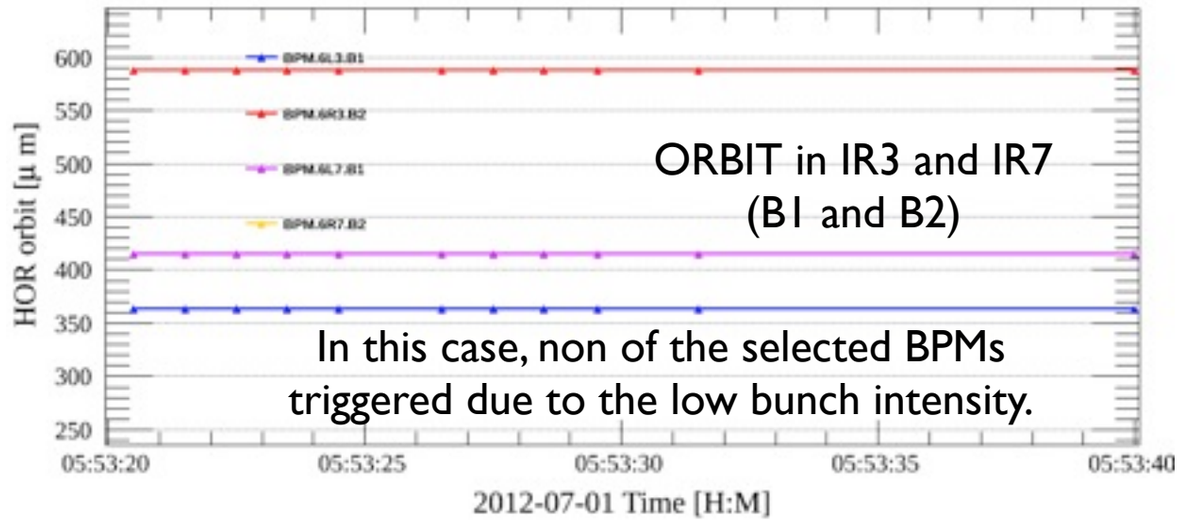




case 4: NEG dp, PHYSICS







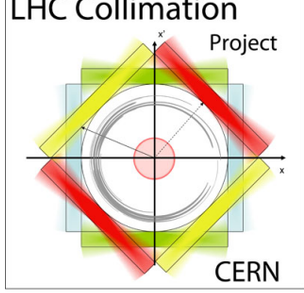
Conclusion from the 4 cases analyzed:

The maximum loss at the TCP in IR3 occurs when we reach around +/-150 to 200Hz frequency change.

Orbit drift at the TCP IR3 of about 3-4 mm.

off-momentum losses appear when the beam is at 4-5 nominal sigmas of the collimator jaw. (TCP IR3)

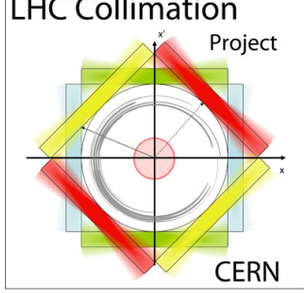
We cannot promise now (beam tests are needed) but it seems possible to find a frequency with higher losses in IR3 before dumping.



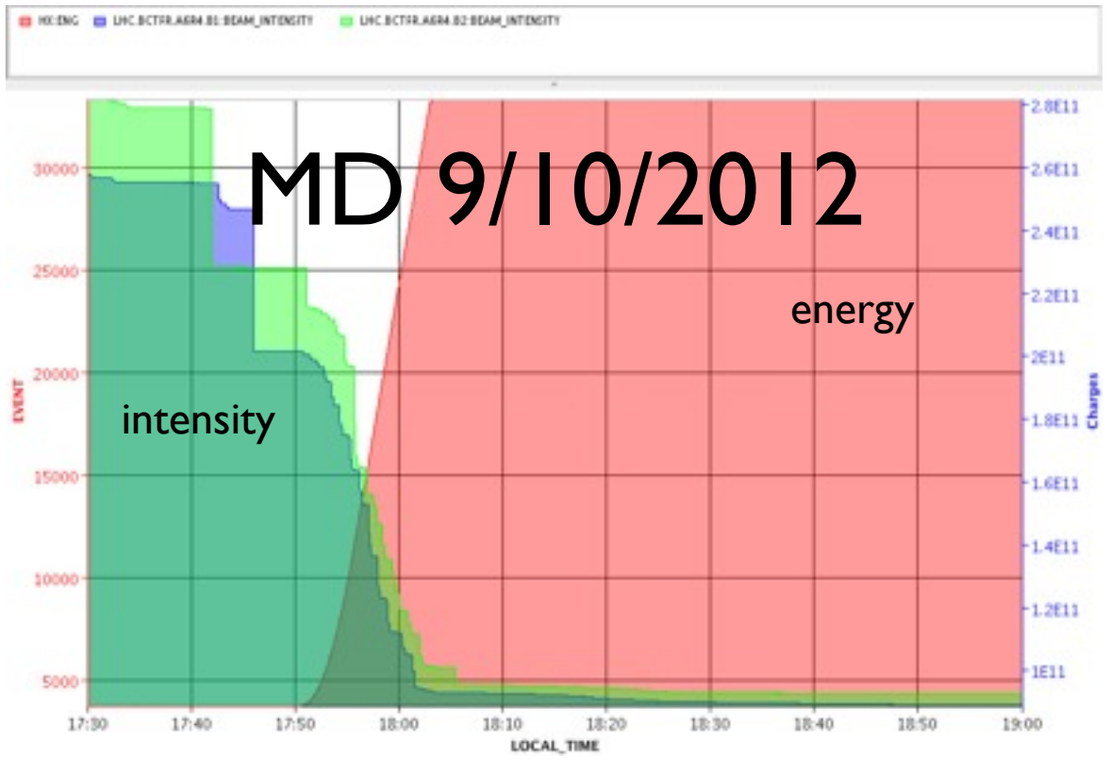
Continuous loss maps during a cycle.

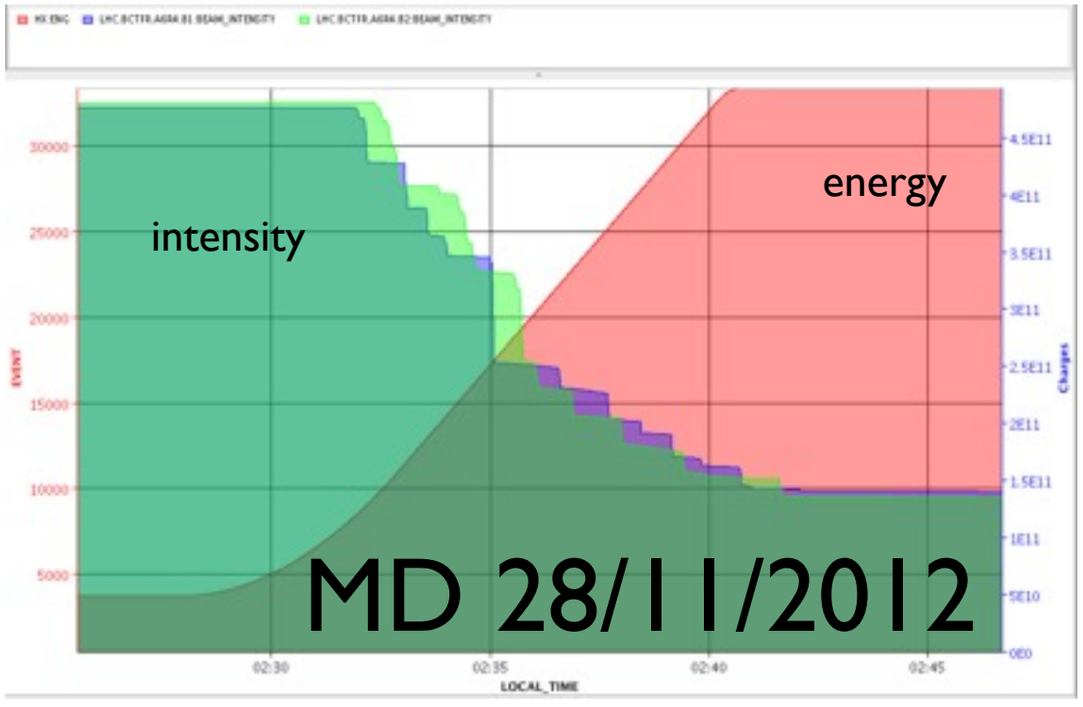
Example: combined Ramp-Squeeze

Continuous loss maps



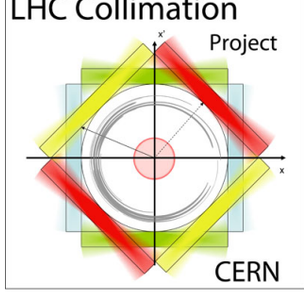
- Now we just measure the cleaning at start and end of the cycle. But in particular for squeeze or ramp-squeeze at 6.5 TeV it would be important to check the cleaning during the cycle.





We performed 2 MDs in 2012 to check the possibility of making continuous betatron loss maps in B1 and B2 (H,V) during the energy ramp

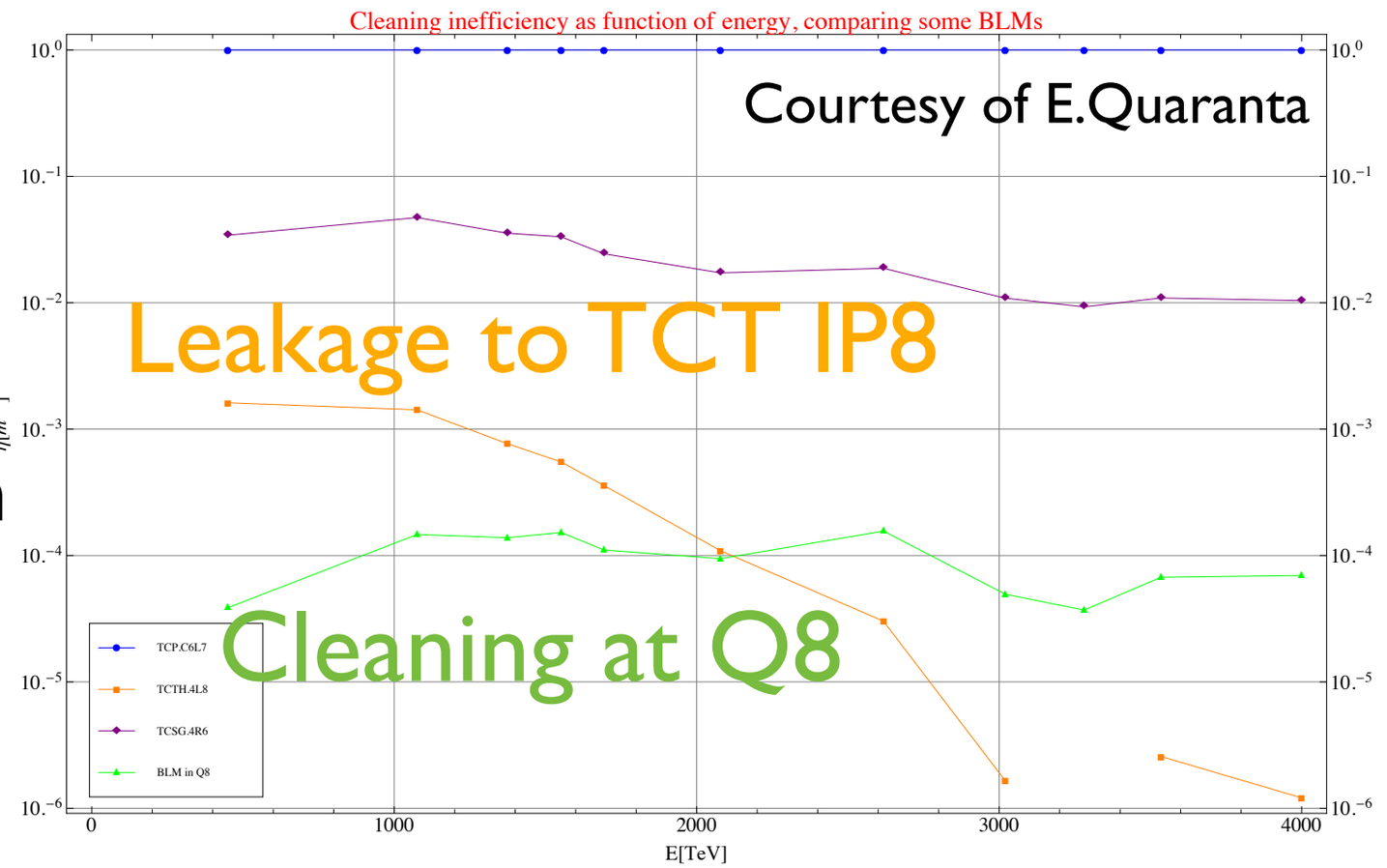
Result MD continuous loss maps



Cleaning to Q8 and leakage to all collimators was measured during the 2 MDs versus beam energy while the collimators were moving from injection settings to tight settings.

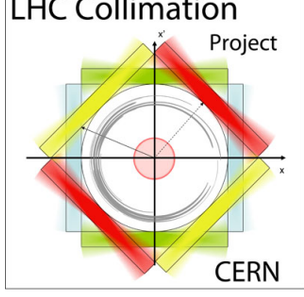
Cleaning at Q8 proved to be stable during the cycle.

Leakage to TCTs decreasing with the cycle.



Reminder:

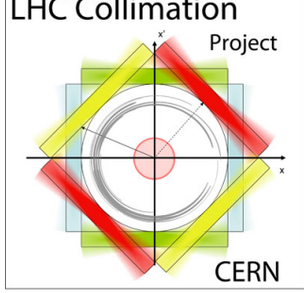
Although there is no indication that this is needed during the energy ramp, things may change after LS1 with a combine ramp-squeeze, squeeze and collisions, move of collimators during squeeze...

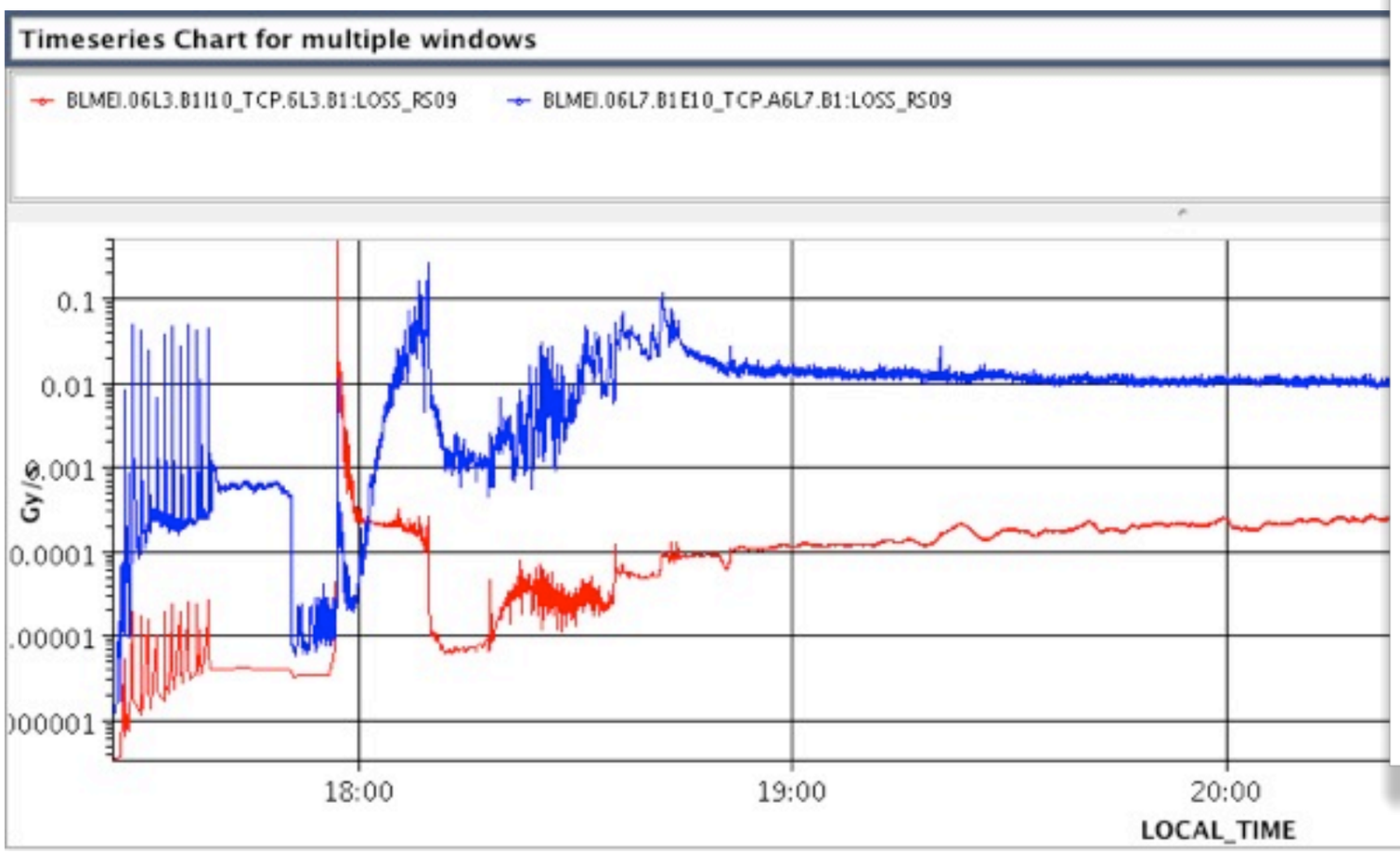


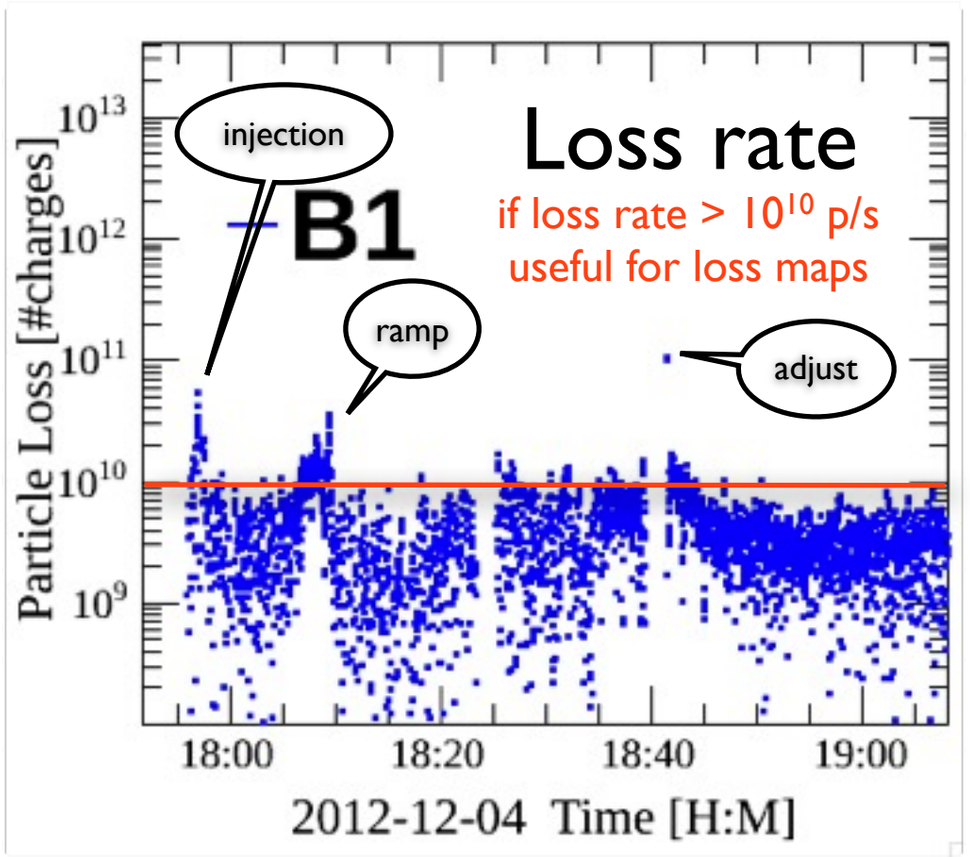
Some ideas on:

Online monitoring of the cleaning

Losses during the fill



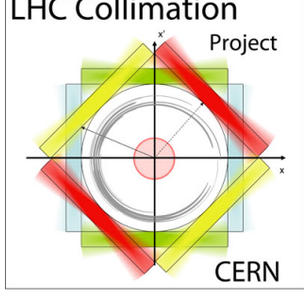


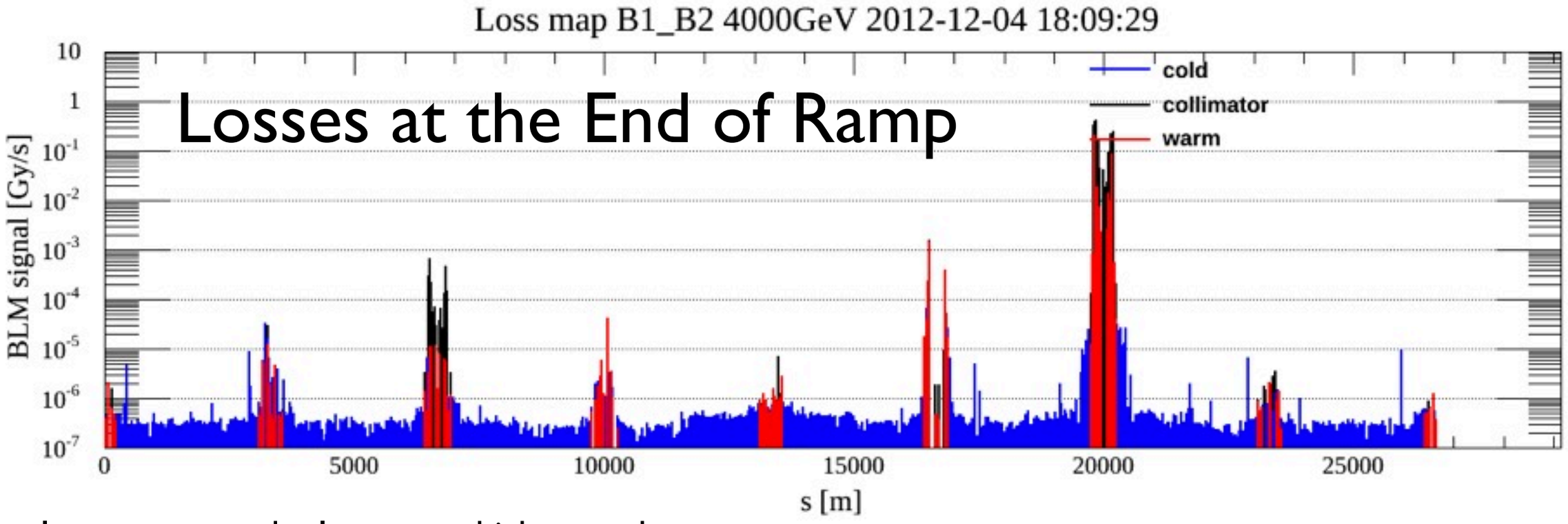


- IR3 losses at injection (injection settings)
- IR7 losses during ramp (collimators move to tight settings), so the settings are not the final ones.
- Losses at squeeze
- Losses at adjust

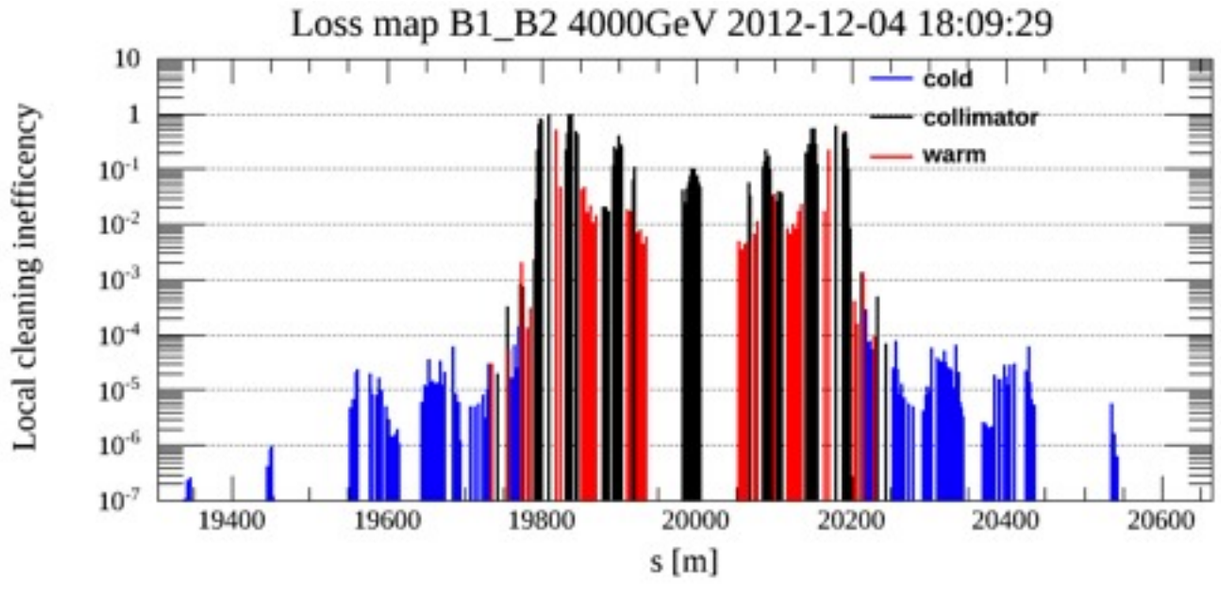
Online Monitoring

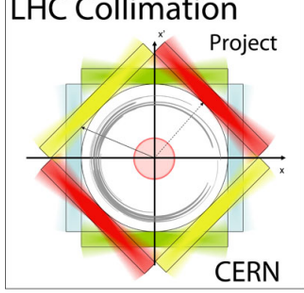
Cleaning and leakage during the fill





- In some cases the losses are high enough to measured the cleaning and the leakage.
- However:
  - it's hard to distinguish between the 2 beam
  - it's hard to disentangle the plane of the losses
- For the plane, there is a possibility which is to get the instability plan by analyzing the BBQ raw data. But in order to use it for this purpose needs further investigation.





Summary and Conclusions

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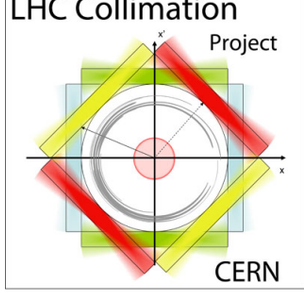

- Betatron:
  - The ADT was shown to be extremely useful for the loss maps (among other things)
    - Loss rate can be controlled to keep losses below dump thresholds
    - Possible to excite individual bunches with 25ns bunch spacing
    - Transparent for the cycle
  - Minimum intensity for loss maps of about a pilot (10^{10} protons/bunch)
  - Possibility of performing loss maps during the cycle if needed (i.e. combine ramp-squeeze, squeeze and collisions, etc.)

We'll keep using it after LS1!

- Off-momentum:
  - During 2012 we kept the standard philosophy and this together with the asynchronous dump were the limiting factor, requiring 3 fills.
  - No promises, but it might be possible to find an intermediate point on the frequency change that allows to have higher losses in IR3 before dumping:
    - Aim is to make several off-momentum loss maps in the same fill
    - Needs beam test
- Additional monitoring of cleaning:
  - Online:
    - Cannot substitute the standard validation, since it relies on having instabilities in the 2 planes in different cycles, but can give extra information between validation loss maps.
  - Post mortem:
    - Regular loss maps at the end of the fill, provided that there are non-colliding bunches, which will imply to perform the loss maps with intensities above the SBF, but controlling the losses.