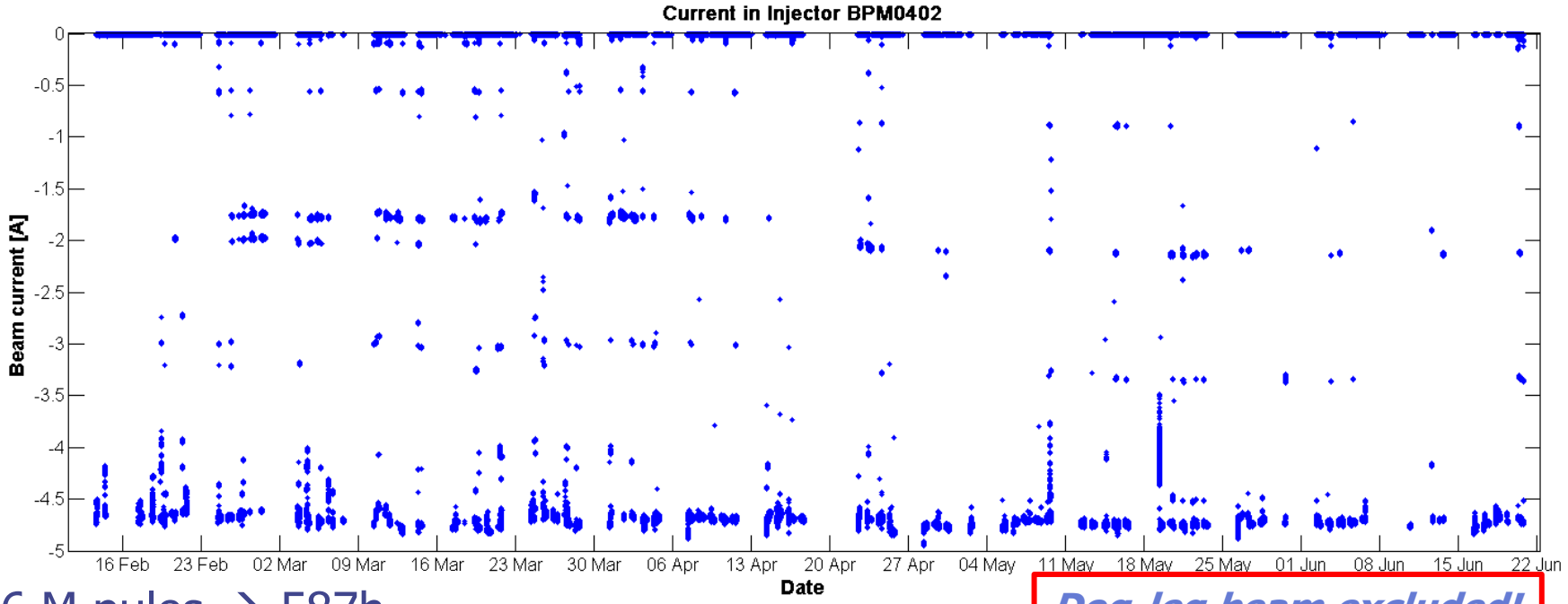
CTF3
2014 Operations & Plans

Piotr Skowroński for the CLIC Collaboration

CTF3 experimental program 2014-2016

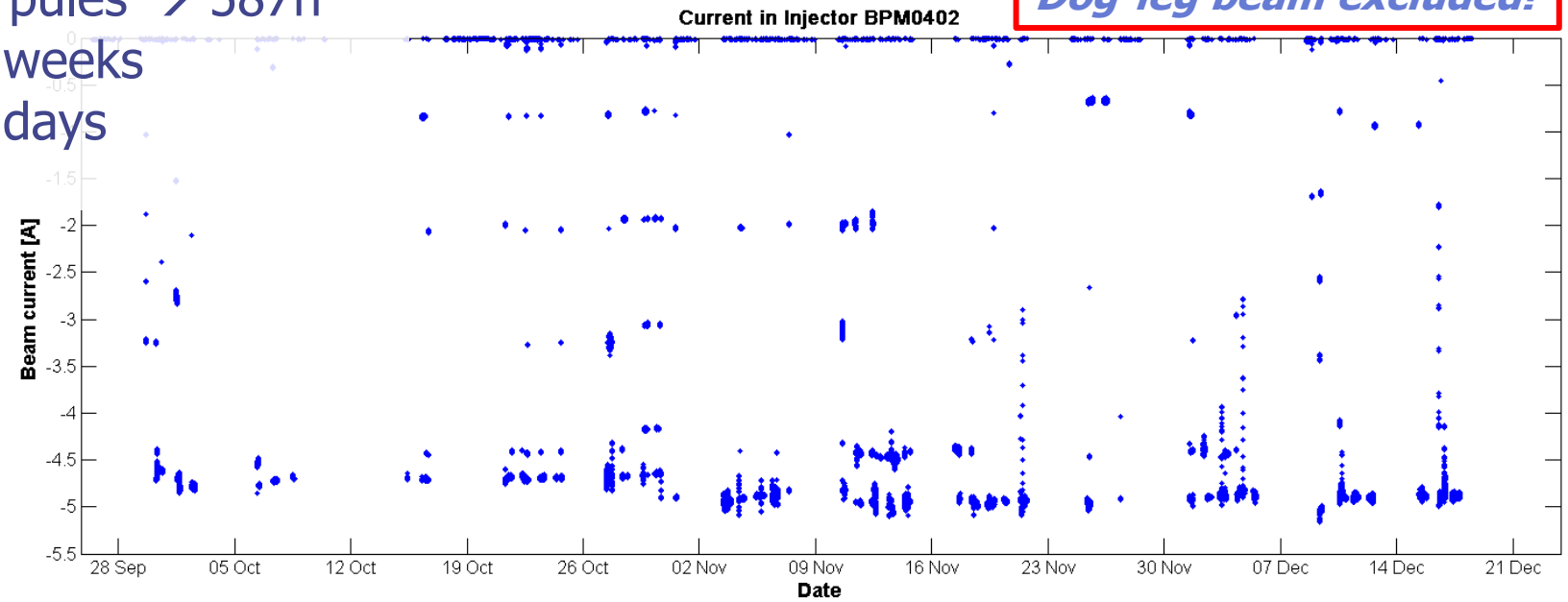
		Phase feed-forward & stability studies	Beam Loading / BDR experiment	Two-Beam Module	TBL Decelerator	Diagnostic Tests
2014	1	Commissioning	Beam tests (X-box n.a.)	TBTS program completion	Deceleration to 40% & RF shaping	Testing of EO bunch profile monitor, DB BPM, MB BPM
	2					
	3	Shut-down	RF Conditioning	Installation TBM	Installation of new tank	Installation
	4	Commissioning & tests	1st run	Commissioning	Deceleration to 50%	tests cont'd + OTR
2015	1	Shut-down + restart				
	2	Combined beams, femto-second timing	2nd run (shared with normal operation)	Complete commissioning & 1st run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					
2016	1	Shut-down + restart		Module upgrade?	Shut-down + restart	
	2	Transverse feed-forward	3rd run (shared with normal operation)	2nd run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					

2014 Running



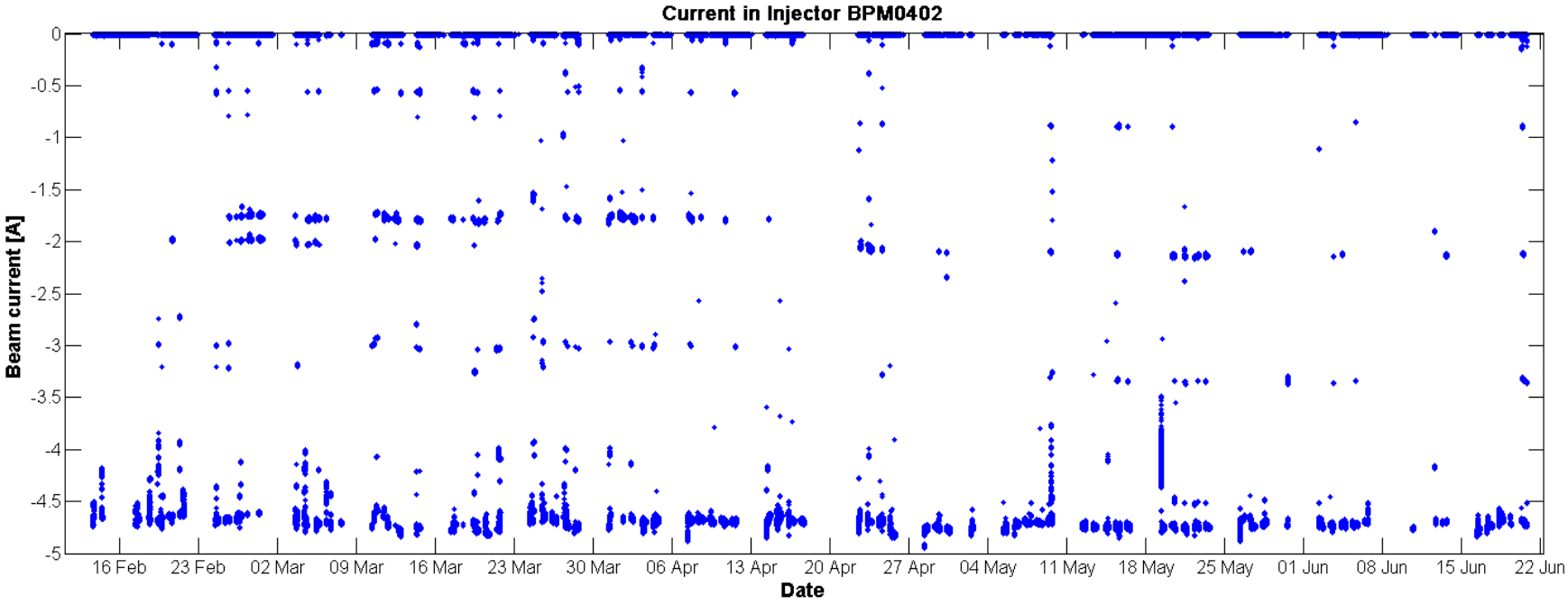
- 1.76 M pules → 587h
- 19+12 weeks
- 85+46 days

Dog-leg beam excluded!



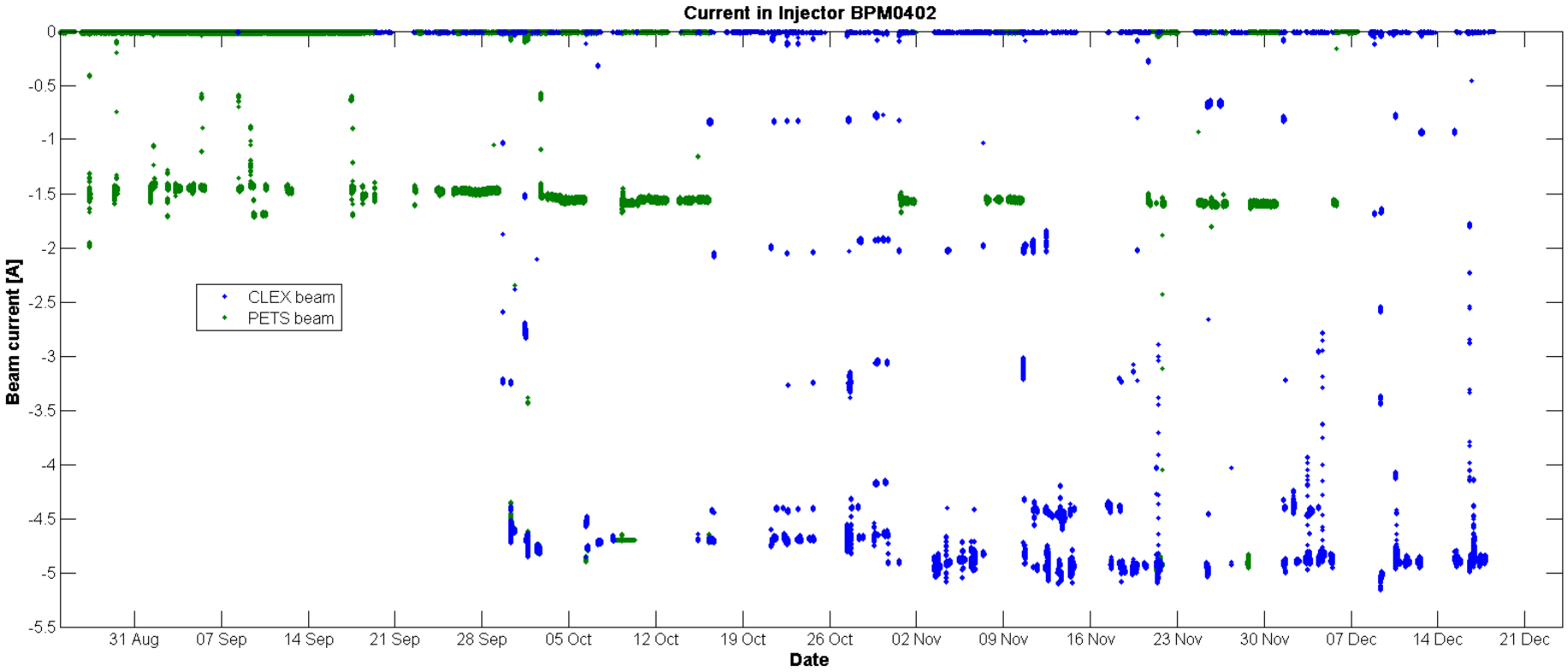
2014 Running

- The plotted data are the CTF3 monitor records of mean values
  Caveats: there are many reasons data is missing
  - Blocked control system communication (very often this year, up to 20%)
  - Short pulses outside the window where the mean is calculated
  - CTF3 monitor not running or hanging
- 1.76 M pules → 587h of beam
  - Dog-leg excluded



2014 Running

- With Dog-Leg
  - 1.31 M Dog-Leg pulses → 436 hours of beam time



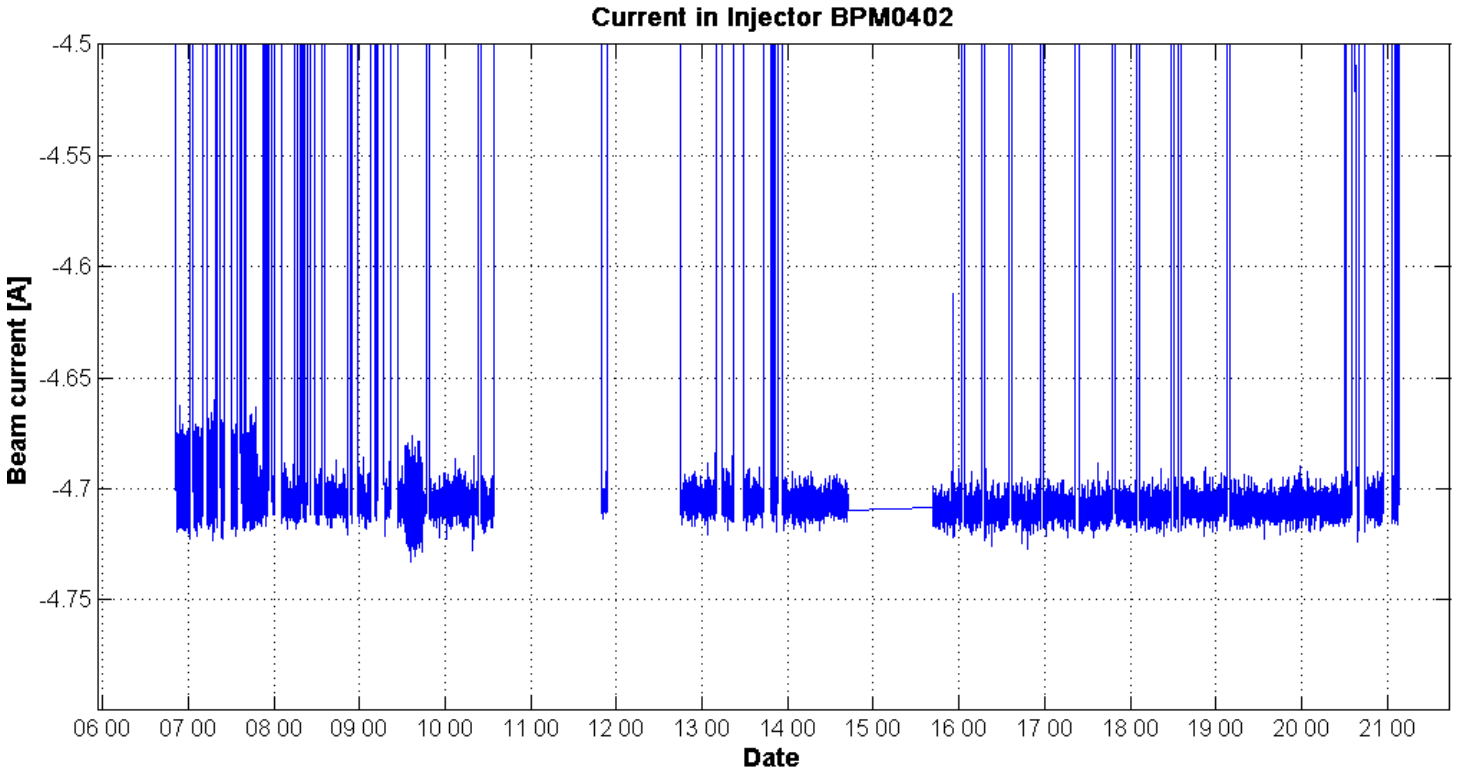
- CLEX Beam Efficiency
  - 85+46 days * 8 h/day = 1048h
    → 587 h of beam / 1048 h = 0.56
- Dog-Leg Beam Efficiency
  - 30d*24h/d + 13d*8h/d = 824h
    → 436h of beam / 1048 h = 0.53

Adding 20% margin: **~75% efficiency**

- For blocked CO communication, etc.

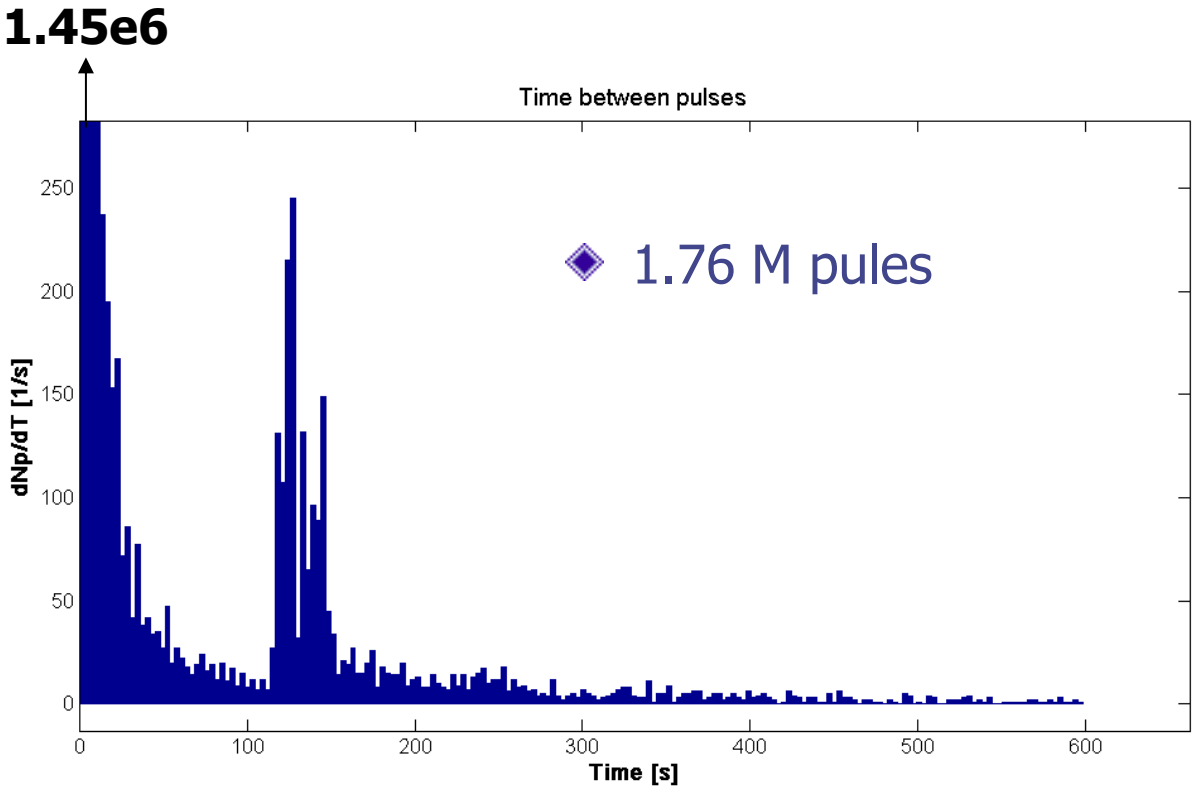
2014 Running

- One the biggest issues are the klystron trips and the 2-3 minutes recovery that it takes for the pulse compressors to stabilize

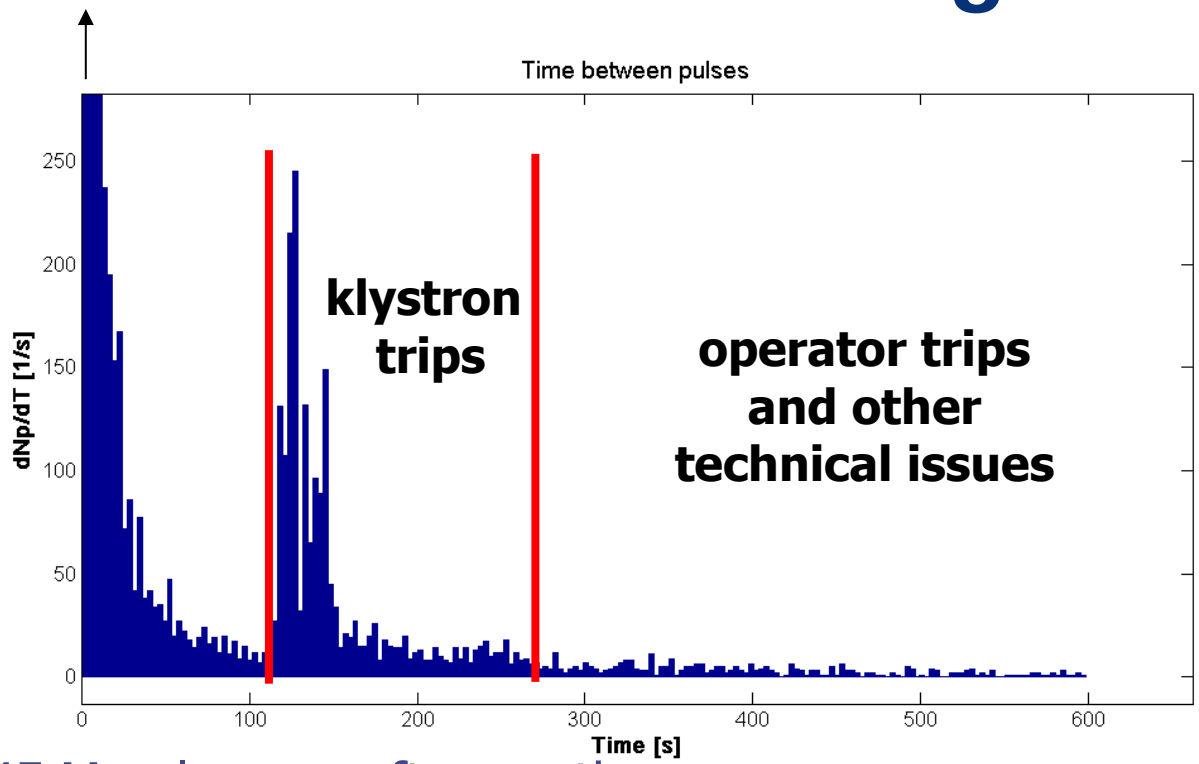


2014 Running

- One the biggest issues are the klystron trips and the 2-3 minutes recovery that it takes for the pulse compressors to stabilize
  - Distribution of the time between pulses (CLEX beam only)



2014 Running



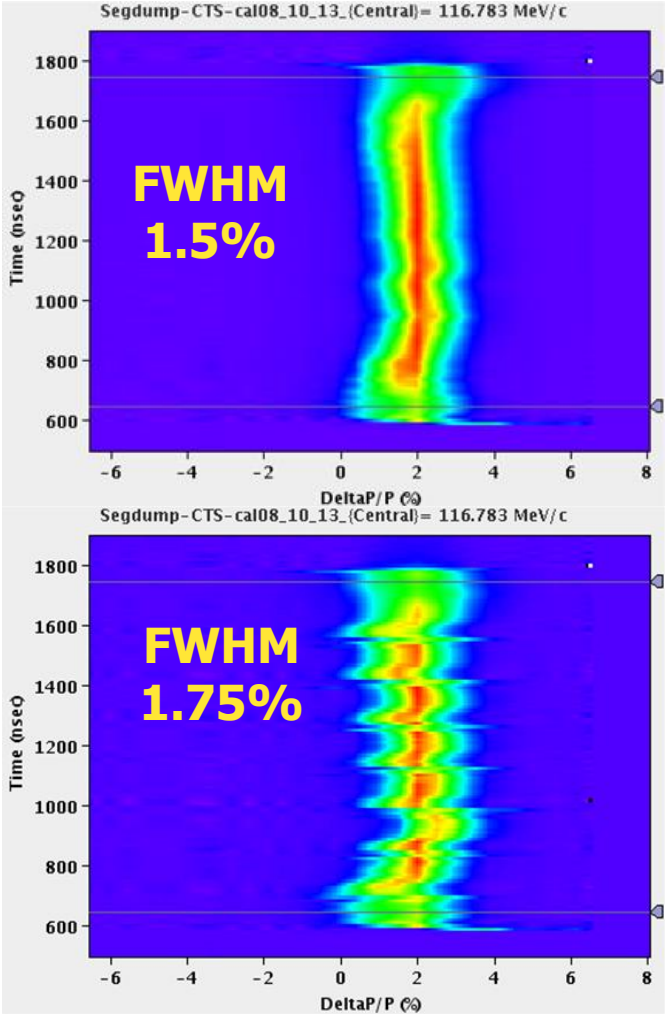
- 1.45 M pules one after another
- 1900 klystron trips
  - Pause between pulses in range of 111s - 270s
  - Avg. recovery time ~130s → Total: 130s*1900 = 68h
- 155 stops from 4.5 to 60 minutes
  - Includes all operator trips: discussions, meetings, coffees, cigarettes, lunches and other "I have to leave for 5 minutes"
  - Avg. recovery time ~600s → Total: 600s*155=26h

1.5 GHz beam setup

- Setup directly 1.5 GHz beam with switches

- The setup strategy during previous runs
  - Start with 3GHz beam, setup factor 4
    - Easy beam, comfortable for initial measurements
  - Setup 1.5 GHz, readjust the linac
  - Add the phase switches
    - However, it is not transparent as we expected
      - There is above 140 ns transient
      - Adjusting TWT and pre-buncher phases lets to recover the condition
      - However, the beam is different

  - We were ending up with 3 different setups



3 GHz Beam setup

- 3 GHz beam is still needed
  - Orbit setup, optics measurements, some experiments (PFF)
  - Some BPI's badly read 1.5 GHz beam
    - Still a puzzle why (I will come back to it)
  - 3 GHz beam is much easier to handle: more stable and smaller
    - Smaller dp/p
      - Smaller beam size in dispersive regions
      - Smaller non-linearities and emittance growth
  - For experiments where moderate power is sufficient
- Having 1.5 GHz going, the 3 GHz one is immediate to setup
  - Disable TWTs
  - Adjust phase of klystron 02
    - Defines bunching phase -> adjust to the LINAC bucket
  - Adjust the gun current

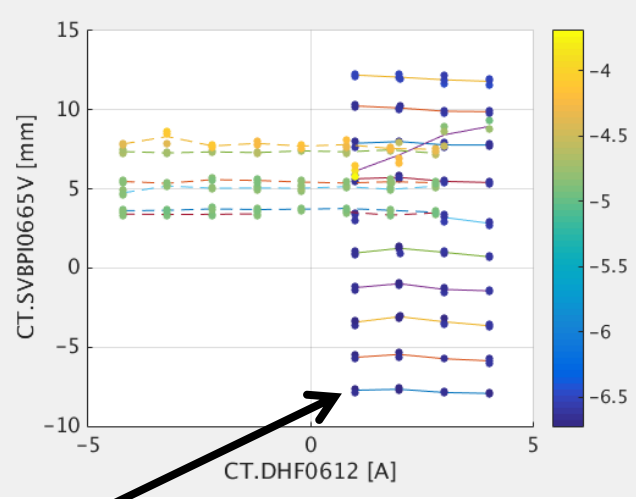
BPI response to 1.5 & 3 GHz beam

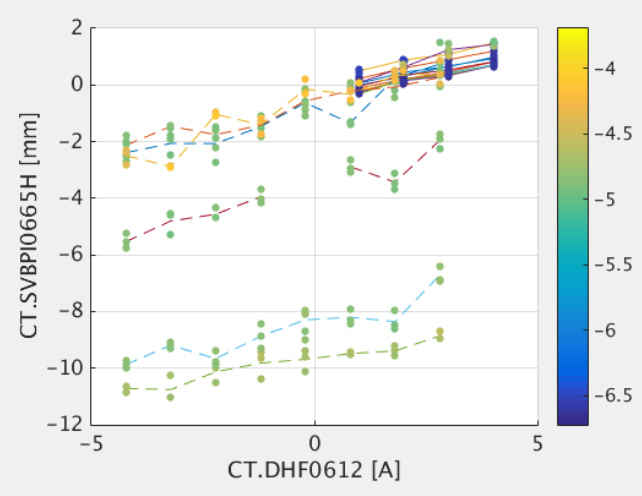
- 2D scans (h/v) with a corrector magnet

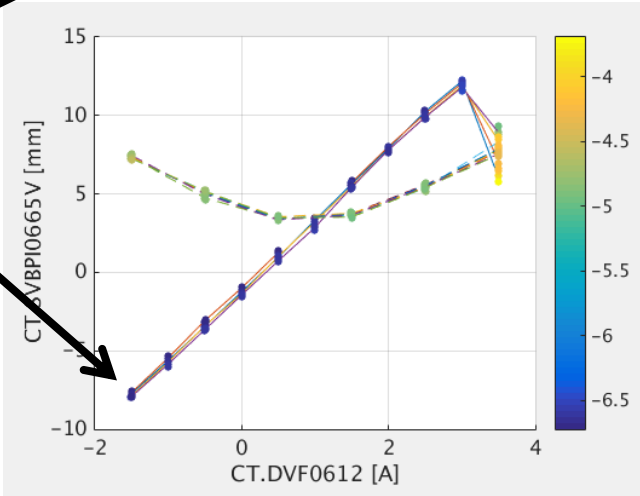
example:
CC.BPI0665

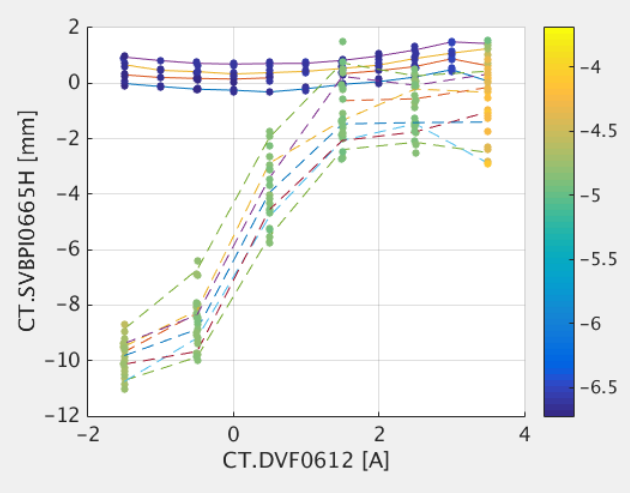
Solid 3GHz
Dashed 1.5GHz

All should be like this









Timeline

- Very short winter break
- No shutdown, restarted the beam in January (Jan 30)
- Initial problems with the gun
  - Very slow "heating" process, up to 4 hours
- Problems with timing, controls (large "LS1 upgrade"), cooling stations
- Vacuum problems in Linac girder 15 after a power cut
  - Took more than a week
- Problem with MKS14
- CLIC Workshop 2014

Timeline

30 Jan first beam from the gun

CLIC Workshop 2014

13 Feb first beam in the injector

Injector setup
3rd TWT (the brand new one) added

17 Feb first beam in spectrometer 10 (3 GHz)

Linac rematch

18 Feb first 3 GHz beam in CR, first 1.5 GHz beam in linac

19 Feb first CALIFES beam

20 Feb first 1.5 GHz beam to CR

Optimization of dp/p in CTS,
Transverse rematch after the Stretcher

24 Feb first combination 4 beam (1.5 GHz with phase switches)

26 Feb 14 A (factor 4) extracted from CR

27 Feb first drive beam in CLEX (uncombined)

4 Mar first beam (3 GHz) to – and through – DL

5 Mar full combination factor 2 in DL (7 A)

Dispersion, closure, emittance, ring length optimizations

13 Mar beam (uncombined) end of TBL / 3 GHz factor 4 optimized, 16 A

Timeline

19 Mar	first drive beam to TBTS for Uppsala beam tests (factors 1 to 4)
20 Mar	conditioning of the new TBL tank
21 Mar	first factor 8 recombination ~ 20 A
25 Mar	good factor 8, ~ 25 A ~1% stability
	CALIFES, start of EOS tests
1 Apr	start of BLM tests in CALIFES
9 Apr	transport to TBTS, > 20 A
	Tuning of Factor 8: closure, dispersion emittance
25 Apr	lossless factor 8, 28 A ~ 0.7% stability after CR, 28 A end of TL2, 25A in CLEX
28 Mar	streak camera measurements of CALIFES beam for EOS crosscheck
29 Apr	26 A in CLEX, measured emittance 550/120
30 Apr	leak in TBL, RF load, new one outgassing for very long time (weeks)
7 May	23 A end of TBTS
8 May	24 A end of TBTS
	Tuning of Factor 8: closure of Twiss parameters, 2nd order corrections
13 May	EOS experiment on the CALIFES beam
20 May	TBL conditioning after the vacuum issue

Timeline

6 Jun	MKS15 died, one week reparation
15 Jun	Wake Field Monitor Tests on CALIFES
17 Jun	PFF the first tests of a complete system
	slow phase correction tests (Phase Feed-Back)
20 Jun	Shutdown
Jun-Sep	TBM installation
	Alignment

Timeline

26 Aug Dog-Leg run start

30 Sep First DB of run 2

- Until Oct 16 running DB Mon-Wedn, Dog-Leg Thu-Sun
- 7 Oct Linac rematch
- 16 Oct Dispersion Tuning in CT

17 Oct Power Cut causing many problems

- MKS14
- Many power converters
- Coil Temperature probes on CR bends to be changed

21 Oct Recovered the power cut

- 21-22 Oct dp/p optimization in CTS (RF phase tuning)
- 22 Oct Dispersion Tuning in CT
- 29 Oct Beam through DL
- 30 Oct Increase the gun current and lower the beam energy
- 31 Oct-10 Nov Re-tuning optics, dispersion, dp/p

10 Nov First beam in CALIFES, probe beam goes through TBM

11 Nov First beam in the Combiner Ring

12 Nov Straight beam through TBL

13 Nov First beam through DL

- 14 Nov CT quad scans and re-matching

19 Nov First drive beam through TBM (uncobined)

Timeline

17 Nov DL recombination

19 Nov DB in TBM, some acceleration seen on the probe

Record beam charge in CALIFES 1.4 nC for single bunch

21 Nov Start of PFF beam

- 25 Nov PFF beam through, start of PFF commissioning
- 26 Nov Varying TL1 R56, very easy (surprise)
- 1 Dec Back to recombination factor 2
- 2-3 Dec Combiner Ring closure,

28 Nov CALIFES beam for OTRI commissioned

- Dec OTRI tests

3 Dec Factor 8 combination re-established

- 4-5 Dec PFF
- 8 Dec Factor 2 Circulating in CR, ring length measurements
- 9 Dec Recombination 8, Straight beam to TBM

9 Dec Problem with TBM phasing confirmed

- 10-18 Dec PFF

11 Dec Start of WFM commissioning in TBM

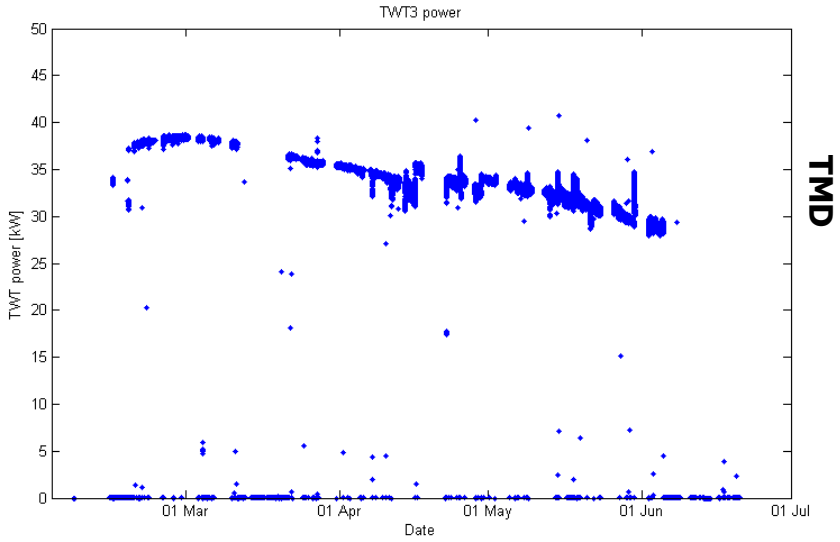
- 12 Dec Half a day for TBM

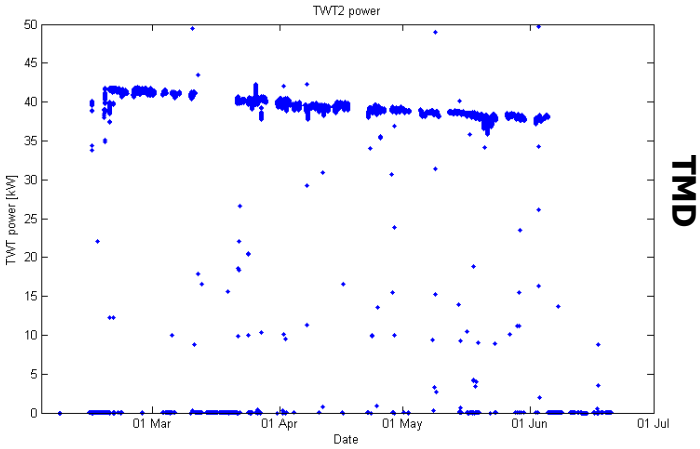
17 Dec Beam based alignment checks in TBM and CALIFES

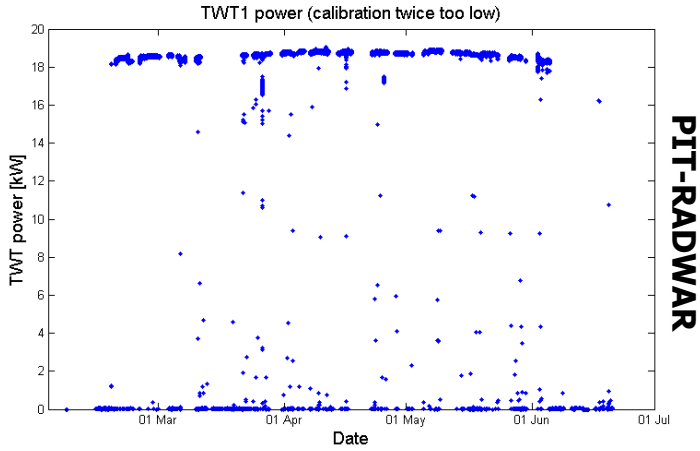
18 Dec Shutdown

1.5 GHz sources

- End of 2013 got brand new amplifier from PIT-RADWAR (former Bumar Electronika) that works flawlessly (almost)
  - Next one is expected to arrive in 2 week
- This gave us finally 3 TWTs + 1 spare
- However
  - One of TMD's broke again
  - Another one started dropping in power, which made factor 8 operation difficult again

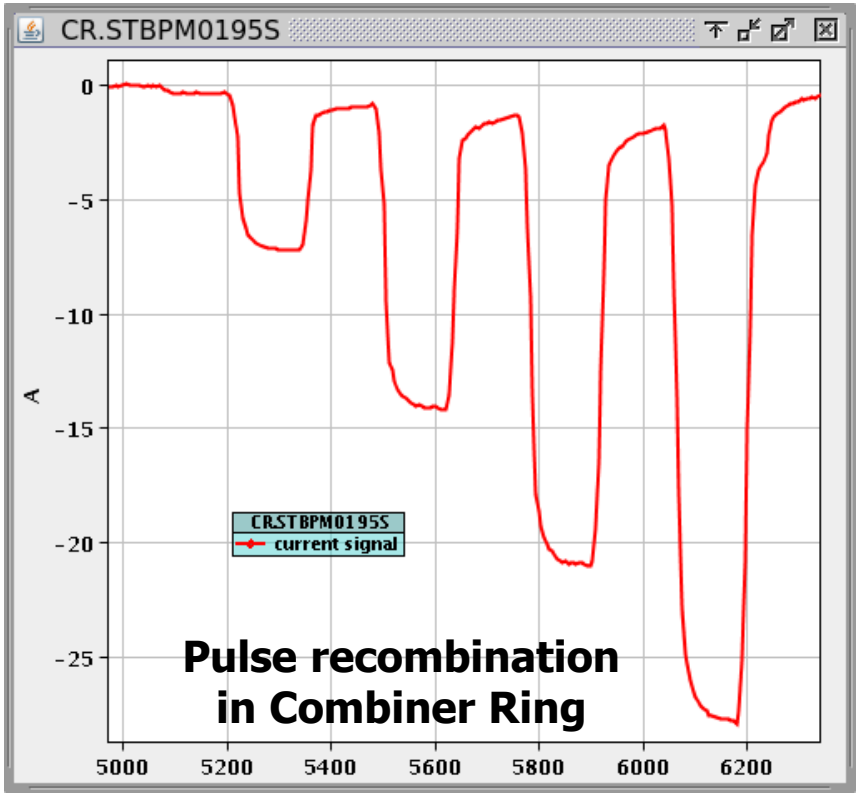






Drive Beam Generation Factor 8

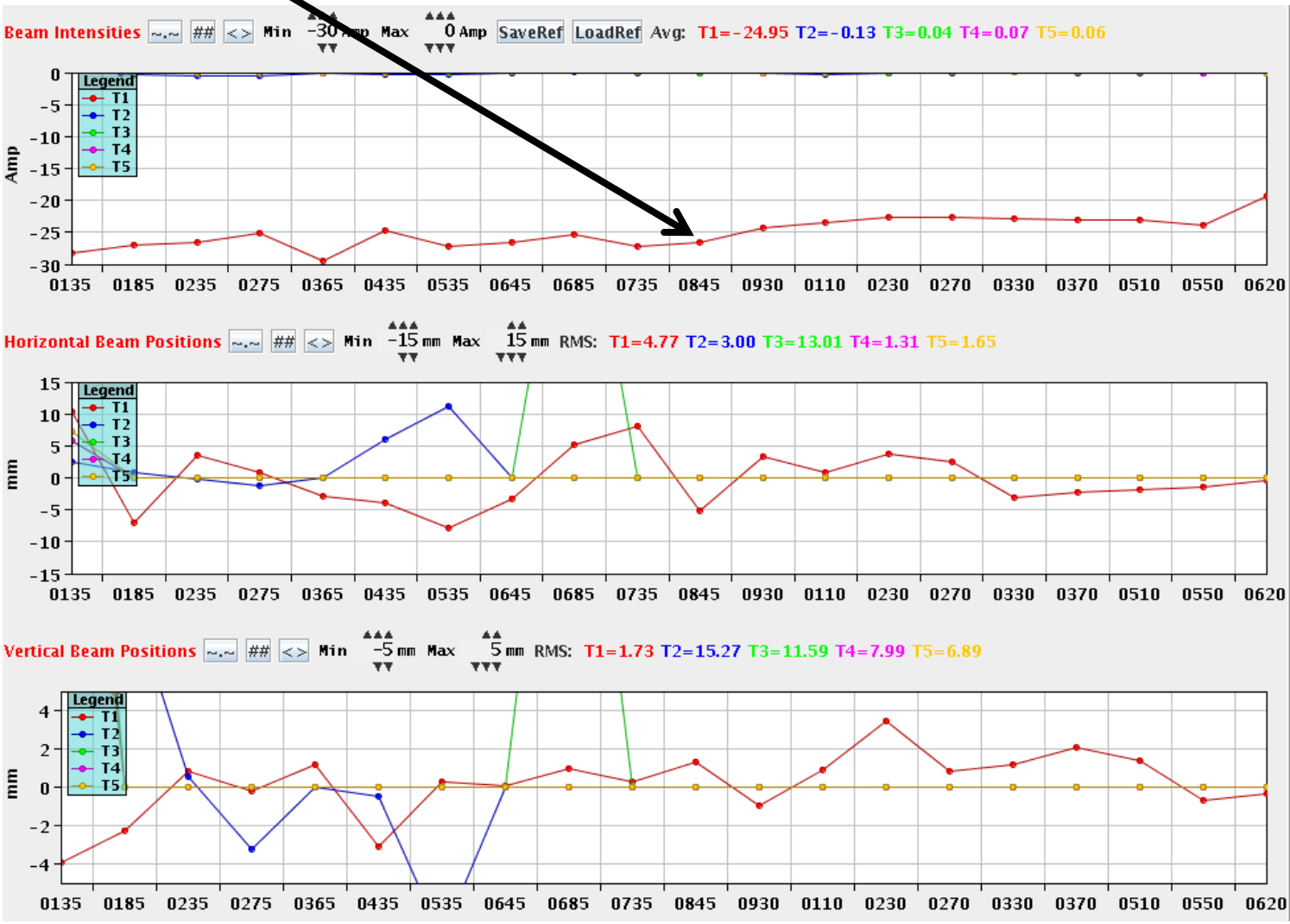
- Finally reached lossless full recombination
  - 0.4 – 0.5 A in satellites
  - Still need some improvement
    - Emittance: ε_H= 350 µm ε_V= 120 µm, target < 150 µm
    - Stability: 1%, target < 0.1%



Combined beam transport

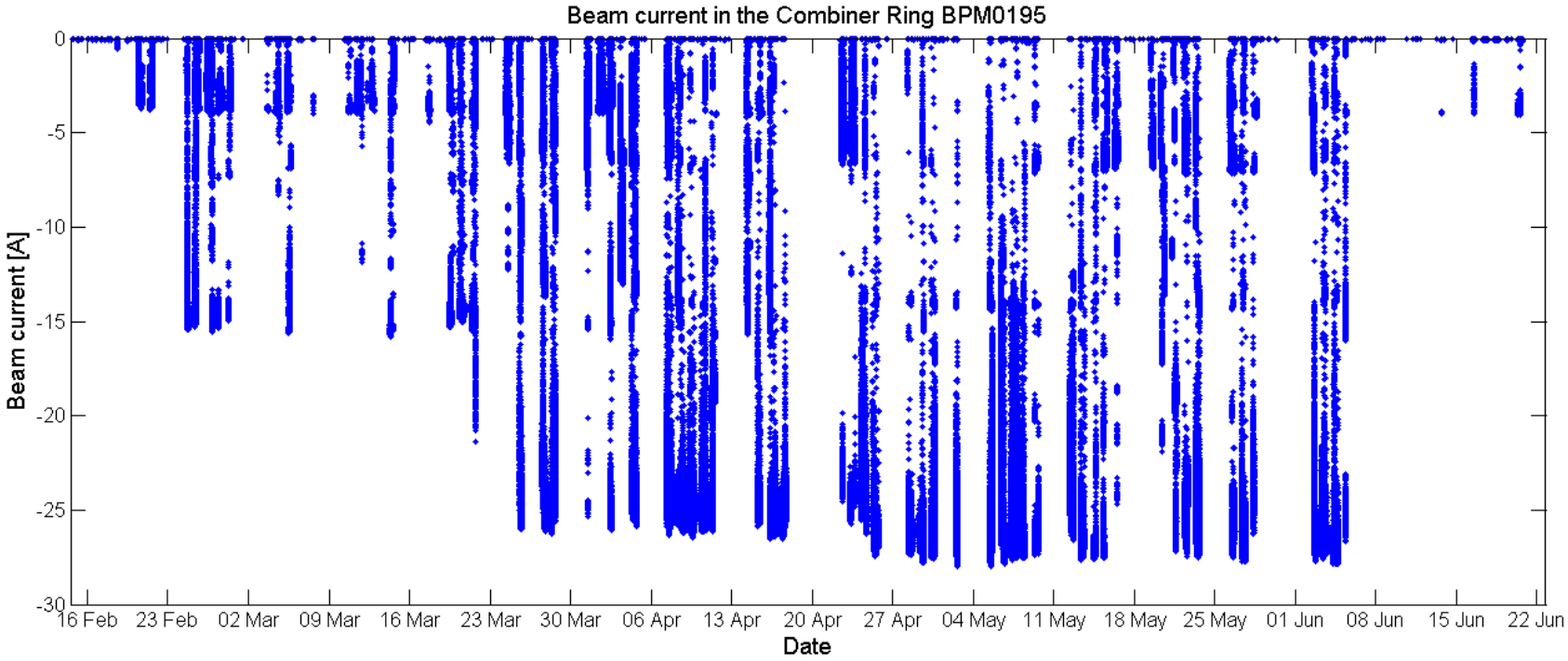
- 28 A at the CLEX wall
- Issue with BPMs calibration

- 25 A in CLEX

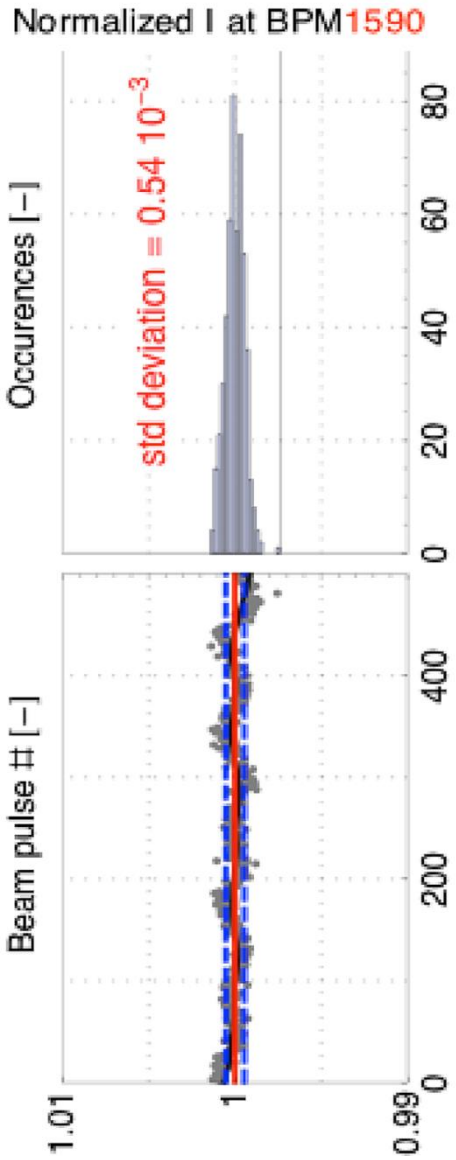


Reproducibility

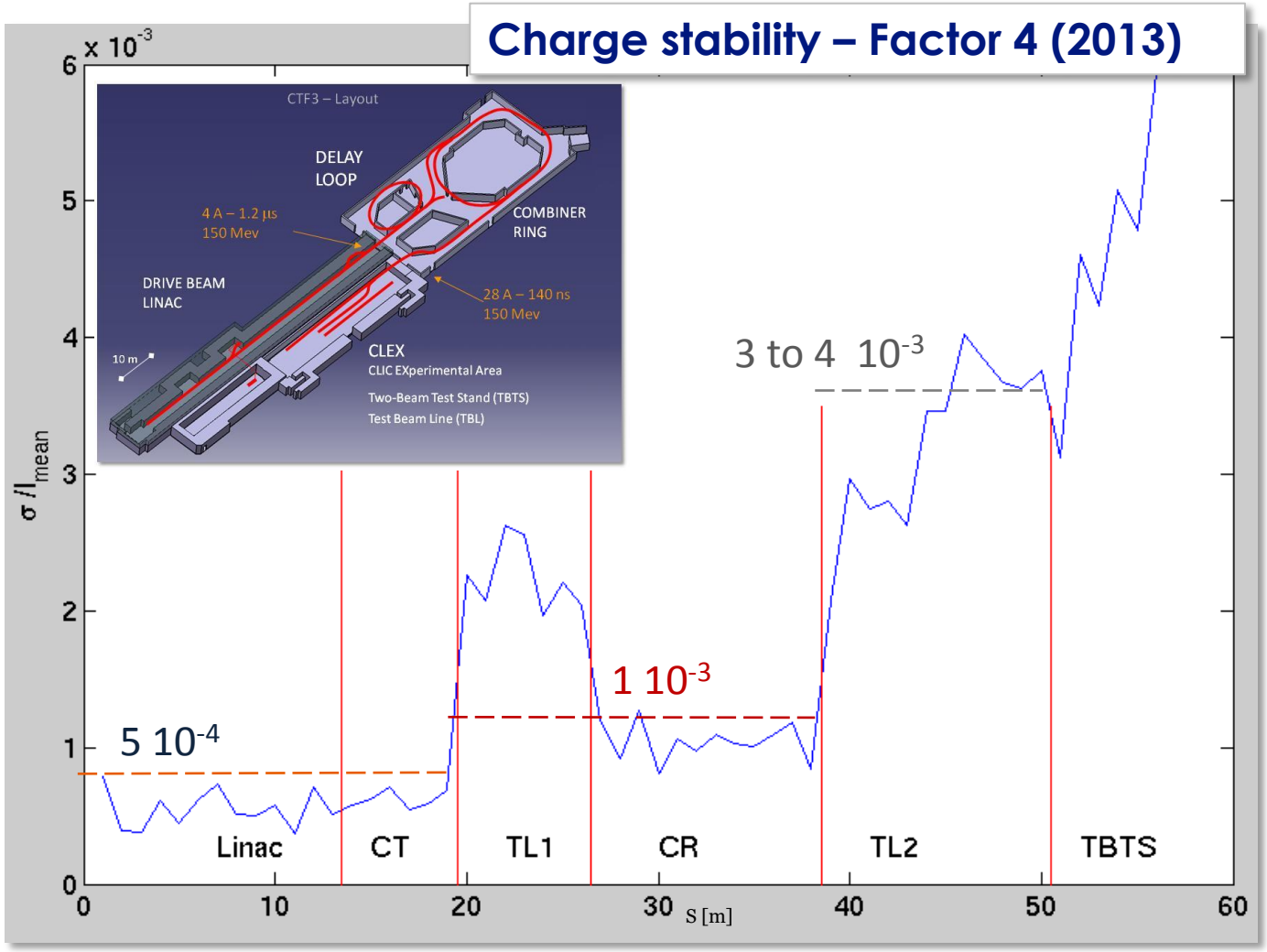
- We were able to maintain the current, I think, quite well taking into account a TWT that was continuously dropping in power
  - Although other parameters were forfeited
  - Naturally, continuous readjustments took quite a lot of beam time from the experiments and fine tuning procedures



Drive Beam stability

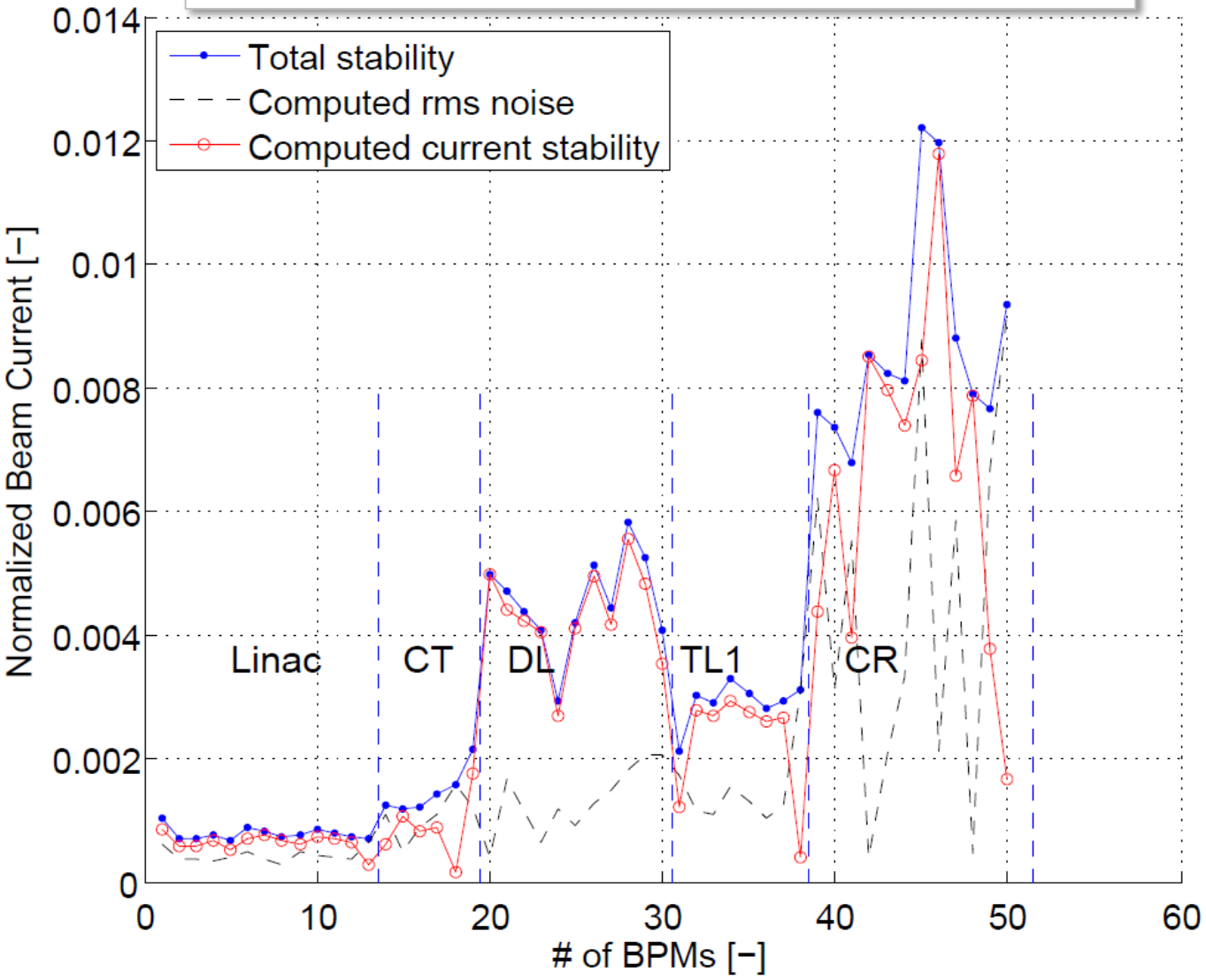


Charge stability at end of the LINAC better than CLIC requirements



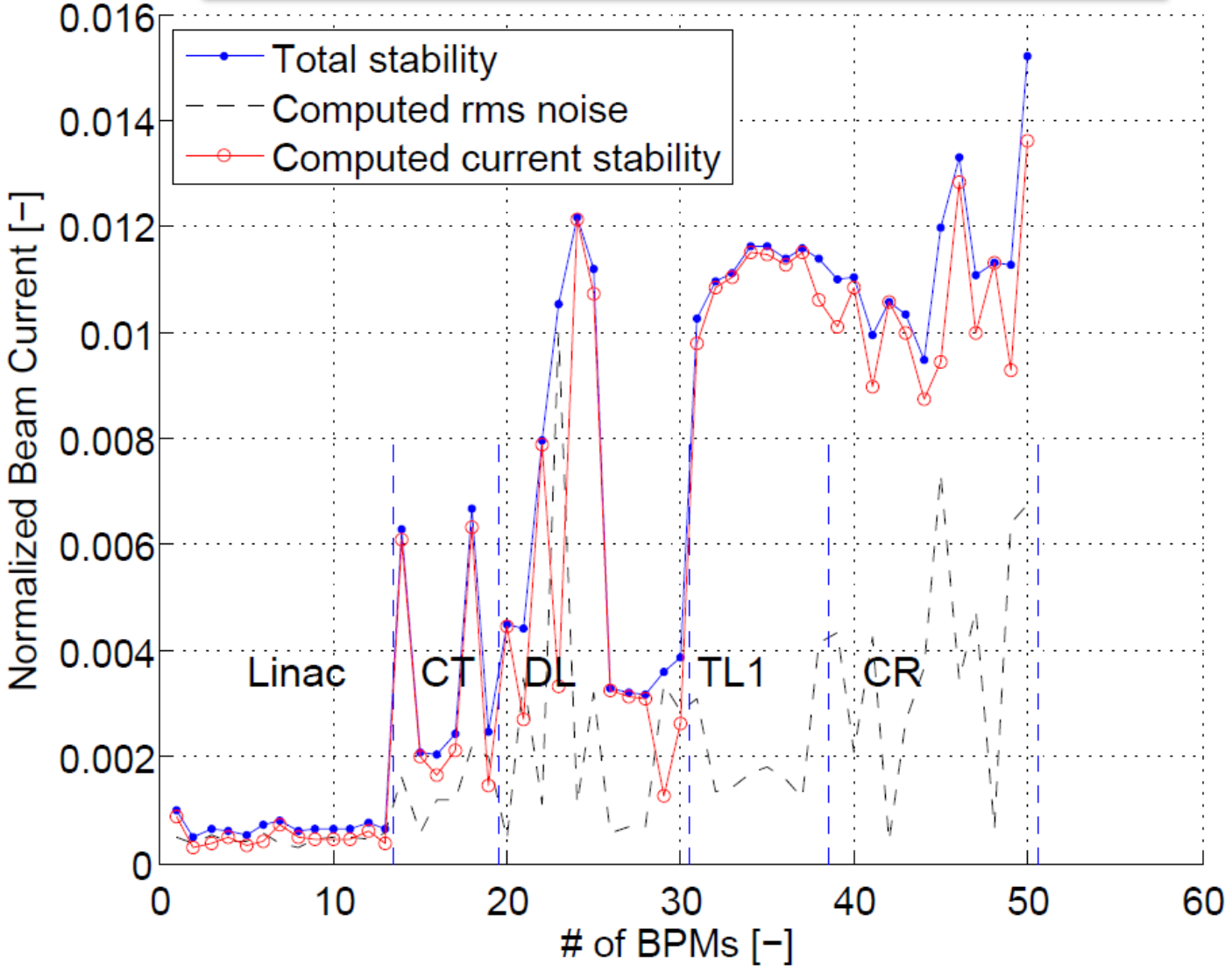
Drive Beam stability

Charge stability – Factor 8 (on a good day)



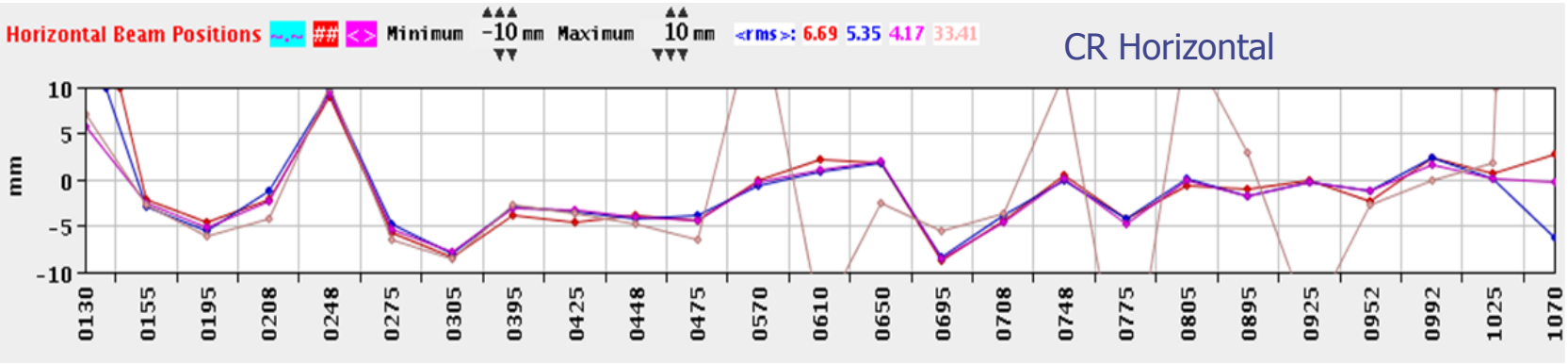
Drive Beam stability

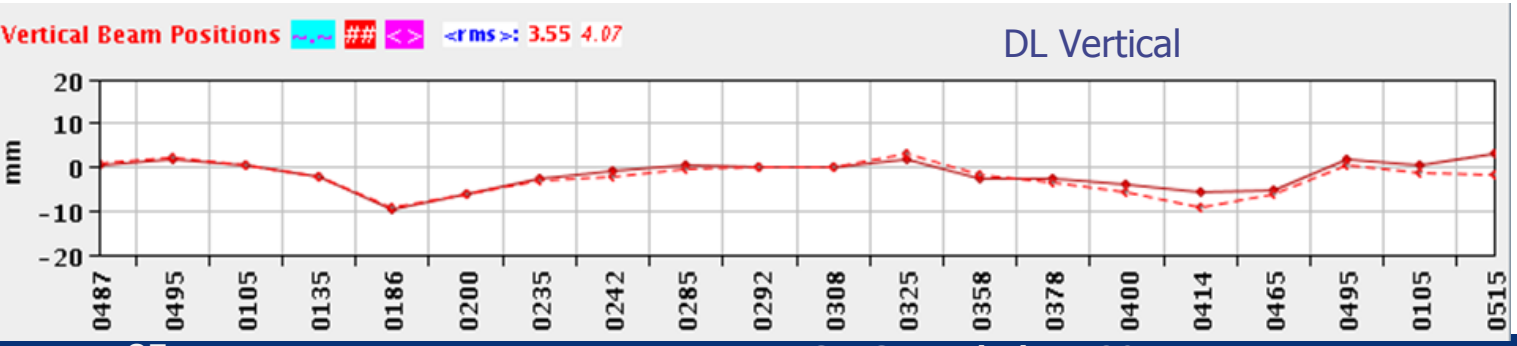
Charge stability – Factor 8 (a usual day)



Beam control
Orbit

- Fully automatic tools for steering and orbit closure of the combined beams (see Devide talk after the following one)
  - Automatic response matrix learning, including "correct and learn" mode
- The improvement is huge, both in resulting quality and correction speed
- However, even this did not help to get orbit of a required quality
  - Large feed-down effects leading to large spurious dispersion and big difficulties in chromatic corrections

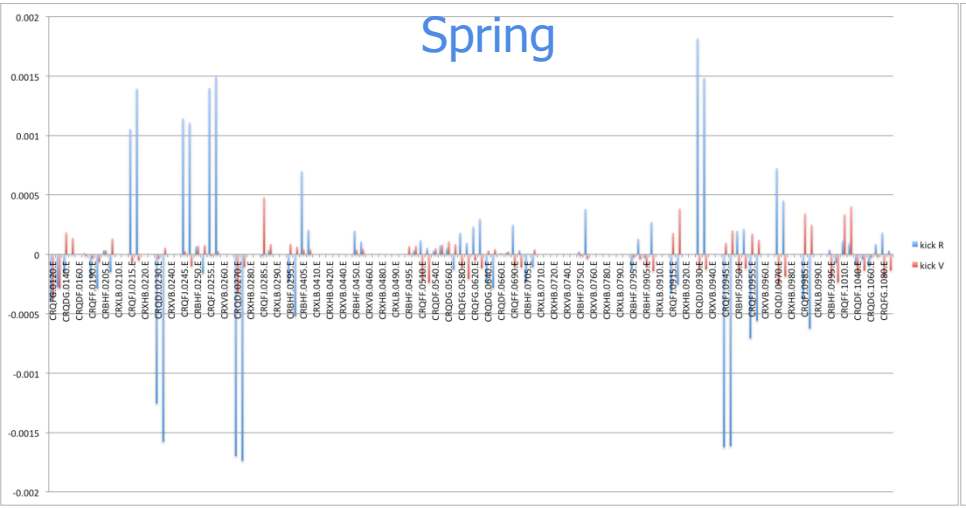


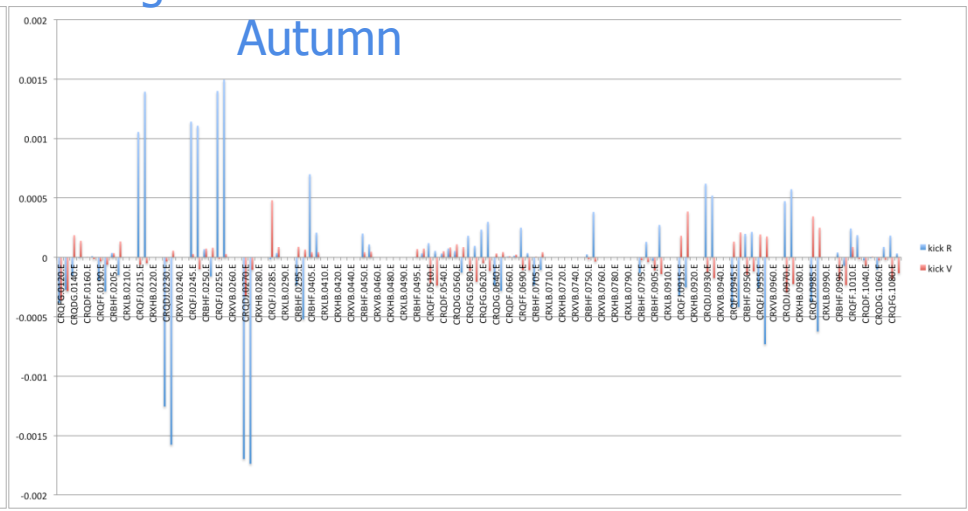


Alignment

- Complete alignment campaign started during summer stop
  - Started with measurements
  - Only few magnets could have been realigned right away
    - Availability of surveyors during LS1 combined with finite length of shutdown
  - It is being completed during this shutdown
  - Measured BPM offsets set in the control system

CR: orbit kicks due to misalignments



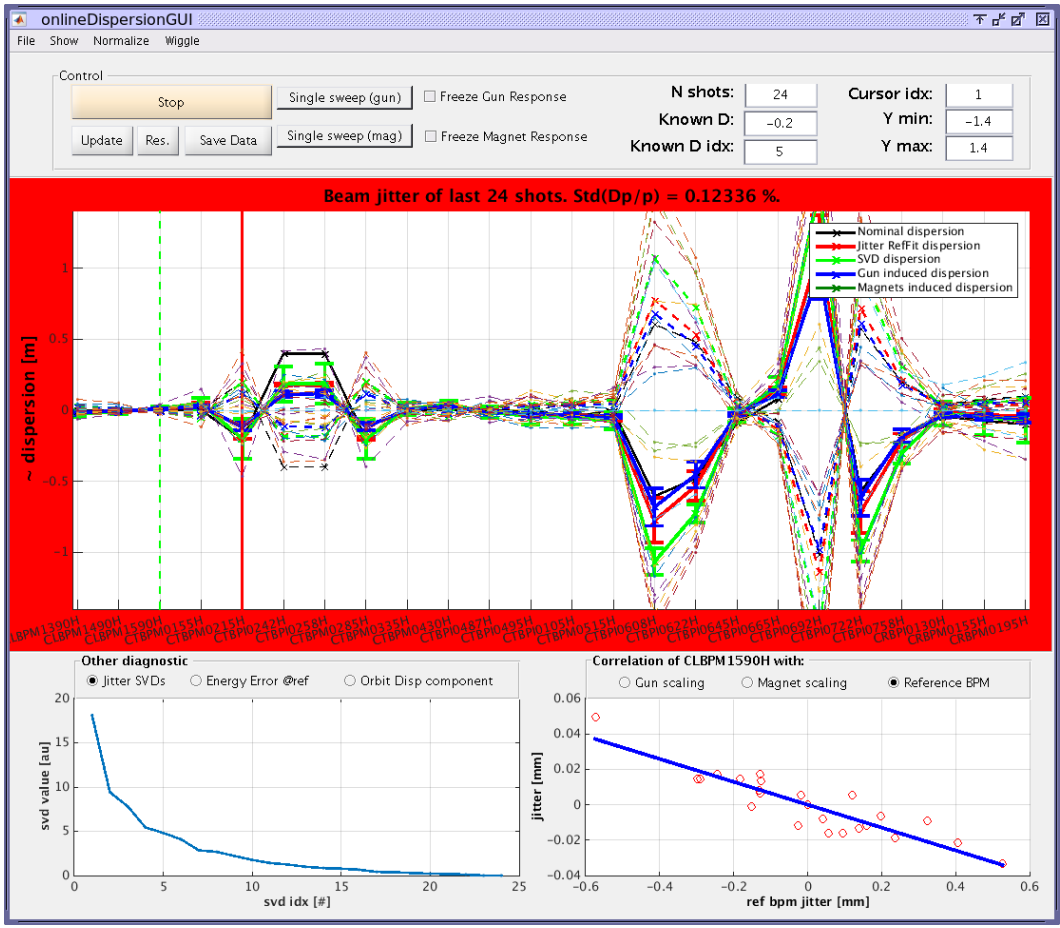


Alignment

- Beam chamber alignment
  - Up to +/- 1cm on a 4 cm chamber
  - There is no proper alignment system provisioned
  - Tremendous help from surveyors who did ad-hoc measurements such that OP team could correct the misalignments
  - Several locations still to be fixed
- Alignment is also an issue for the probe beam

Beam control
Dispersion

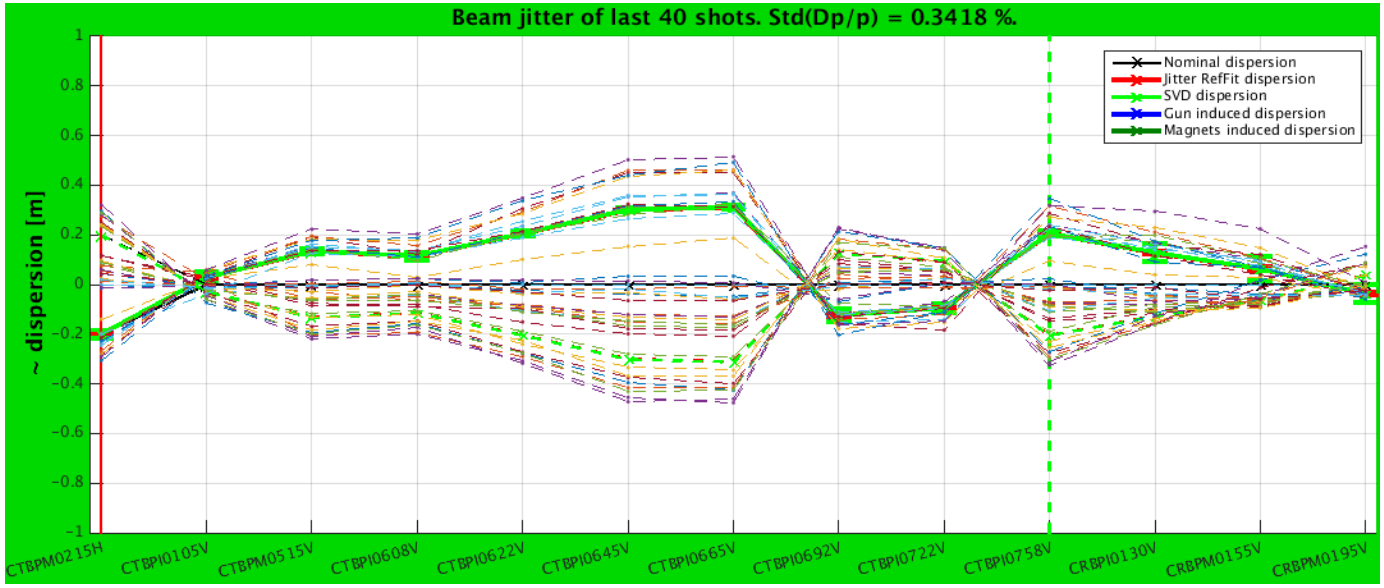
- Large progress in dispersion control
  - Fully automatic tool for fast and precise dispersion measurements by Davide (*)
  - A key instrument for quick dispersion corrections
- It enabled Dispersion Free and Dispersion Target Steering
  - Fully automatic tool (prepared also by Davide (*))
- Satisfactory control of horizontal dispersion
  - Despite of the large misalignments present



(*) see the one after following talk by Davide

Beam control
Dispersion

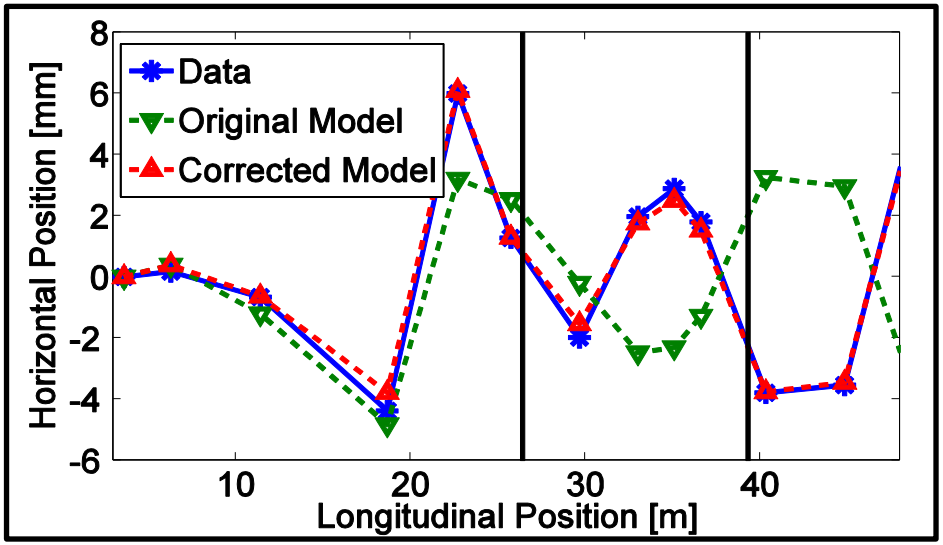
- This year we discovered problem with vertical dispersion in TL1
  - Dispersion Free Steering did not manage to take it out
    - Not enough correctors
  - Alignment in the suspicious region is being checked
  - It seems that it plays important role in issues with TL2 transport
    - Only a small change in vertical orbit leads to losses, while the vertical should be "easy"



Beam control
Model

- Improved model of TL2
  - Much easier setup of beams this
    - Plus magnets and chamber alignment helped
    - Still, can be much improved
- There is a large error in TL2', both TBTS and TBL lines affected
  - Optics Measurements using phase space painting were planned, but finally did not find any time slot for this

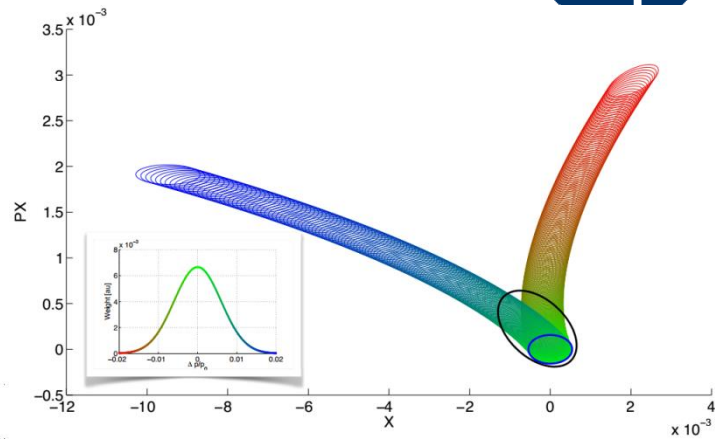
TL2 model vs measured Response Matrix

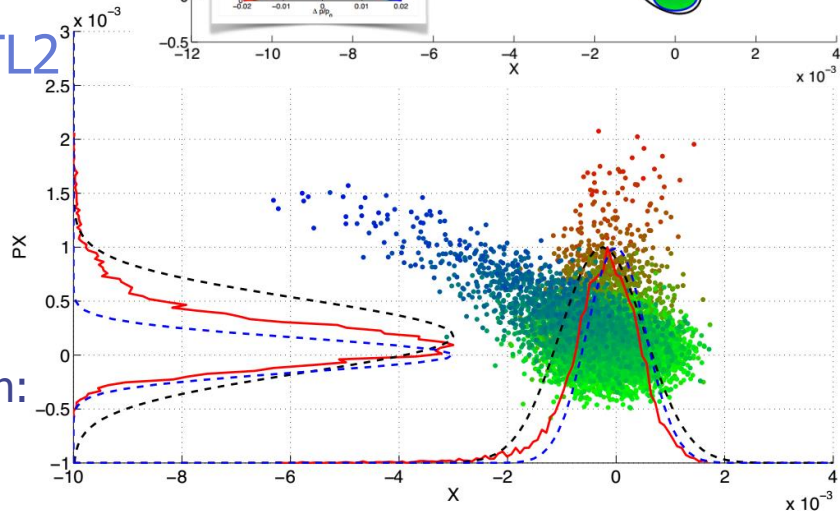


Beam control
Non-linearities

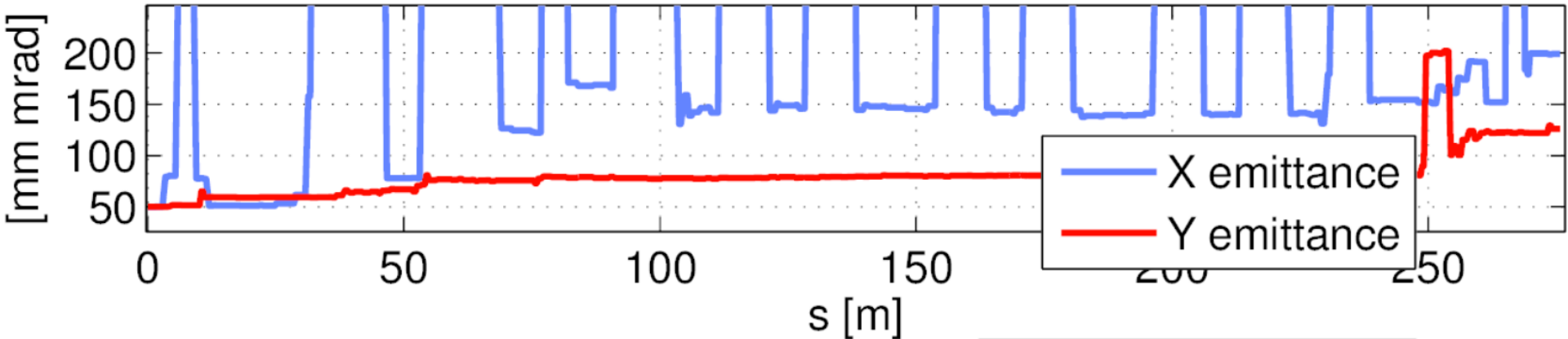
Delay Loop and TL2 dog-leg optics shows large emittance growth due to induced higher order dispersion

- Need of sextupole corrections
  - Tricky, see next slide
- Need for a smoother optics in DL and TL2
  - And always isochronous and achromatic
  - Not straight forward to get, needs some deeper study
    - And not sure that it can be found



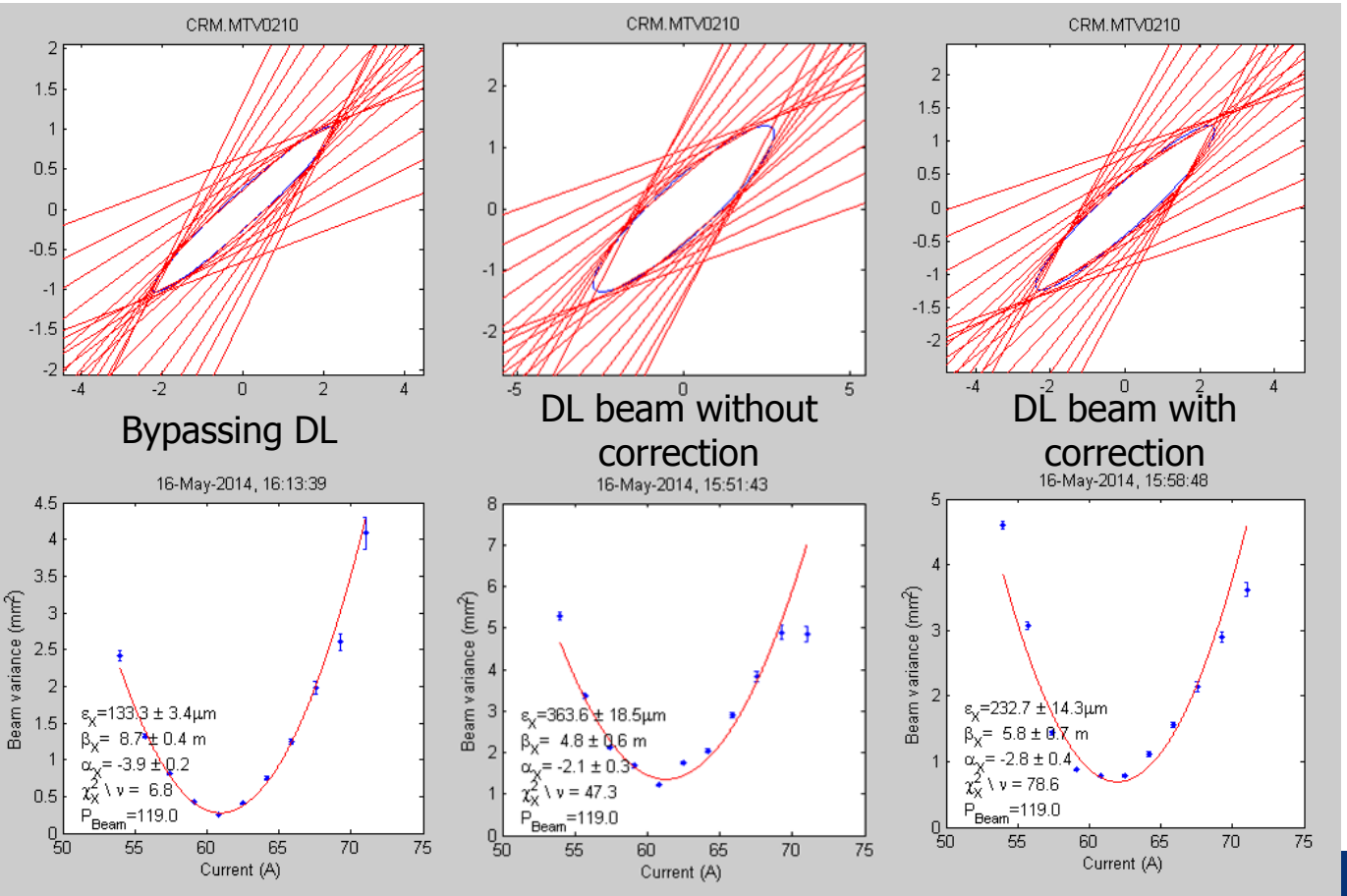


See Davide's presentation today & LCWS'15 presentation:
http://agenda.linearcollider.org/event/6389/session/10/contribution/111/material/slides/0.pdf



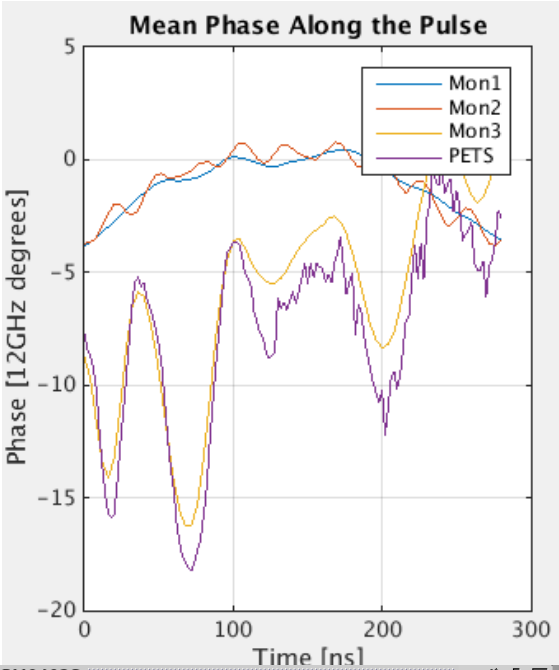
Sextupolar corrections

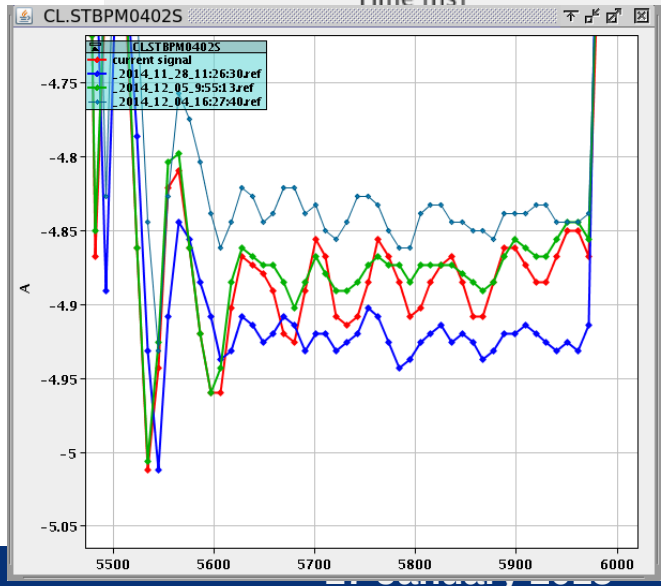
- Tried to correct the 2nd and 3rd order dispersion in the Delay Loop
- It helped to reduce the emittance
- On the other hand, it spoiled the combined beam transport
  - Not being able to recover recombination in time, correction was dropped



Beam control
Beam phase propagation

- The drive beam phase measured in CLEX was never good
  - However, the measurement with IQ demodulators of the RF produced in PETS was never fully trusted
- In August the 12 GHz PFF monitor was installed, and it agrees well with the PETS measurements
- The wiggling of the phase was traced to the imperfect gun pulse flattening Wave Form Generator
  - There is a static wiggle from the gun pulser
  - It is corrected by WFG
  - 10MHz only, the correction is imperfect
  - Not synchronized with CTF clock → changes pulse to pulse
  - New 120MHz WFG acquired



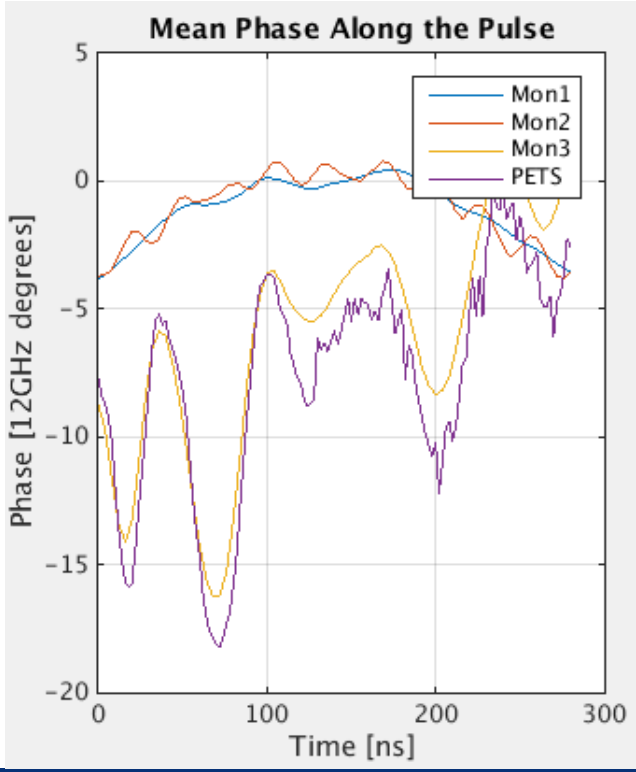


Beam control
Beam phase propagation

- During the Feed-Forward tests it was found that the phase jitter increases more than twice between CT and CLEX
  - The part related to energy was removed by tuning R_{56} of TL1
  - Correlation ~50% → additional source of phase jitter
  - The gun current ripple strongly reflected on the phase

- Launch of dedicated study
  - Correlation plots with beam current, position and RF signals

- Modified read-out of the phase monitor in the combiner ring
  - Its measurements were useless because the signal level was too small
    - It was setup to measure the fully recombined beam of 30 A

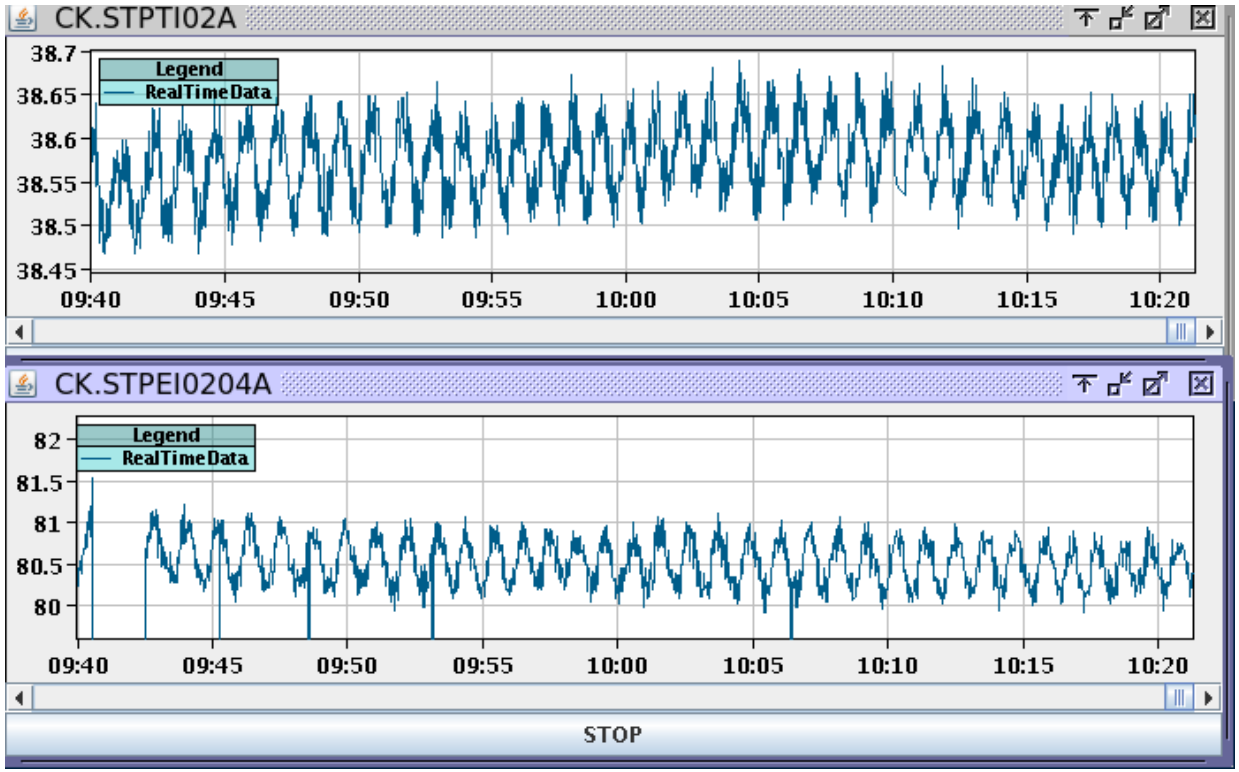


Controls

- During LS1 the Control System infrastructure was upgraded
- CTF3 served as the guinea-pig – it was the only operating acc.
- Renovated the crates for RF that made operation much easier
  - Modulators control
  - Amplitude and phase measurements
  - Wave-form generators and their read-back
- The new driver had a bug which triggered additional klystrons trips
  - Took a month until realized the reason for this large increase
  - And another month to fix it
    - Reloading waveform during beam pulse → no waveform → no pulse compression → produced RF in phase with the beam
- Troubles with Xeneric Sampler driver (BPMs and RF measurements) after upgrade to FESA 3
  - Server dying very often, for some crates every 2-3 hours
  - Should be fixed after the shutdown

Disturbing AD cycle

- Certain RF signals showed regular oscillation
- It was traced to the anti-proton decelerator cycle
  - It creates fluctuations on 230V line, which influences, e.g. TWTs
- Fortunately, the net effect on the beam was not big
- Stabilization 230V is being installed for the most important devices

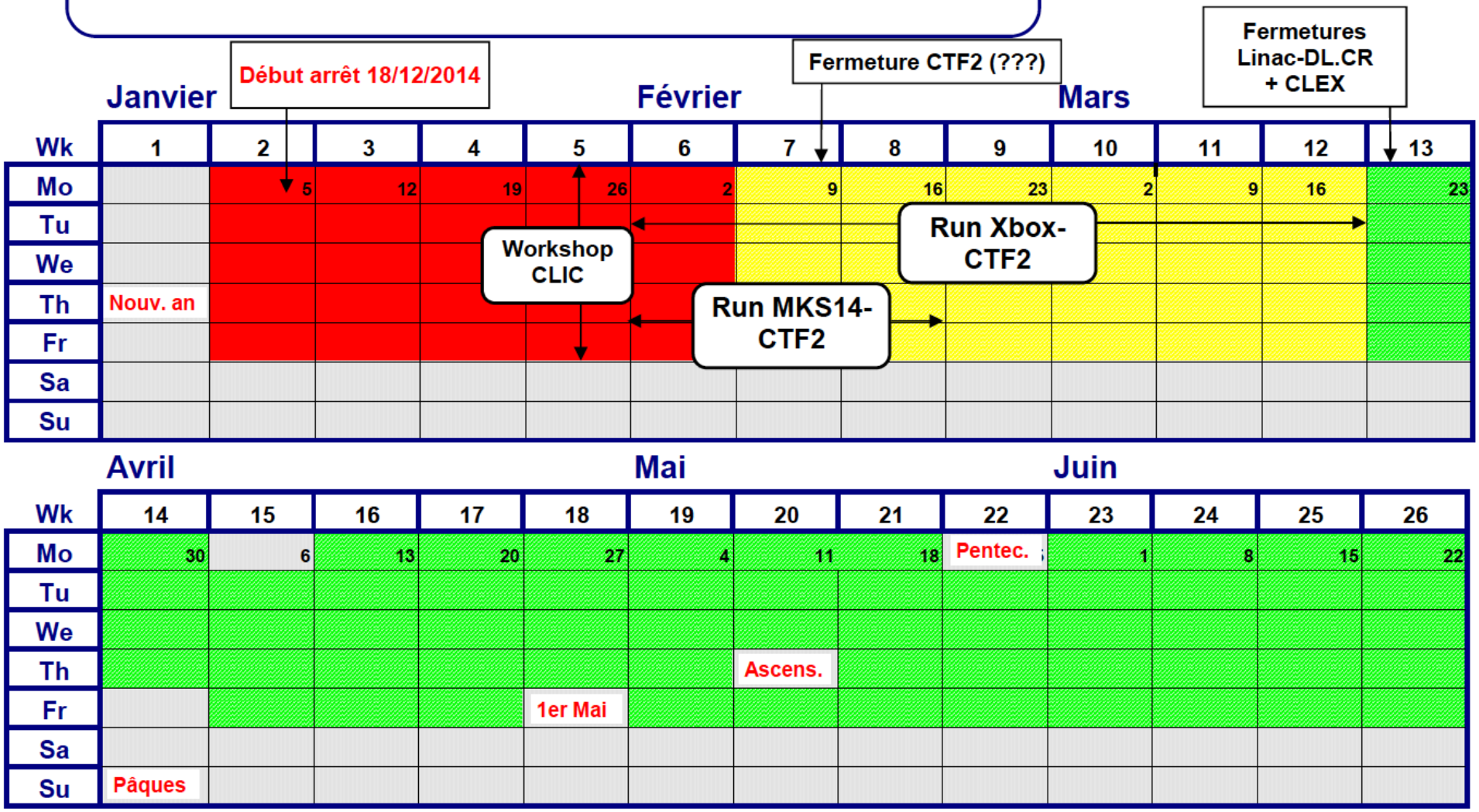


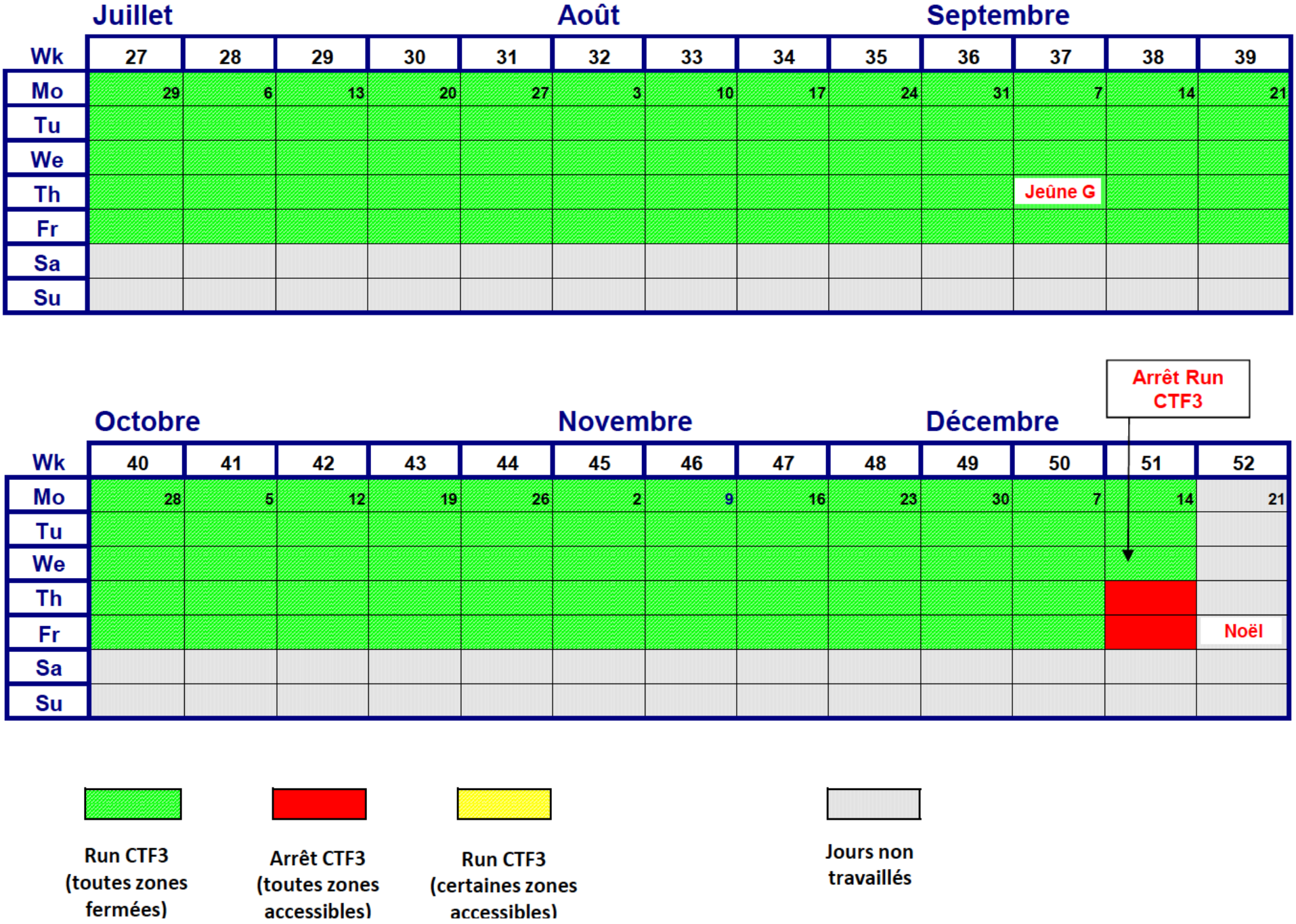
Conclusions

- Very good Run1, at least its first part
- Good Run 2
- Big improvement in control of dispersion and orbit
- Stability – large improvement, still a lot of space for more
  - And it is a must if we want to complete all the challenging program
- Reproducibility – improving every year, but we have to do better
  - More discipline in sticking to the reference
    - Computer program supporting it
  - Optimize the setup procedures
- Improved model, easier and faster beam setup

2015 - CTF 3 - Planning

07 Novembre 2014




Juillet
Août
Septembre
Wk
27 28 29 30 31 32 33 34 35 36 37 38 39
Mo 29 6 13 20 27 3 10 17 24 31 7 14 21
Tu
We
Th
Fr
Sa
Su
Jeûne G
Arrêt Run CTF3
Octobre
Novembre
Décembre
Wk
40 41 42 43 44 45 46 47 48 49 50 51 52
Mo 28 5 12 19 26 2 9 16 23 30 7 14 21
Tu
We
Th
Fr
Sa
Su
Noël
Run CTF3 (toutes zones fermées)
Arrêt CTF3 (toutes zones accessibles)
Run CTF3 (certaines zones accessibles)
Jours non travaillés

CTF3 experimental program 2015-2016

		Phase feed-forward & stability studies	Beam Loading / BDR experiment	Two-Beam Module	TBL Decelerator	Diagnostic Tests
2015	1	Shut-down + restart				
	2	tests with 32 & 64kW phase propagation tuning	2nd run (shared with normal operation)	Complete commissioning & 1st run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					
2016	1	Shut-down + restart		Module upgrade?	Shut-down + restart	
	2	combined beams	3rd run (shared with normal operation)	2nd run	RF conditioning & testing with drive beam	Available beam time
	3					
	4					

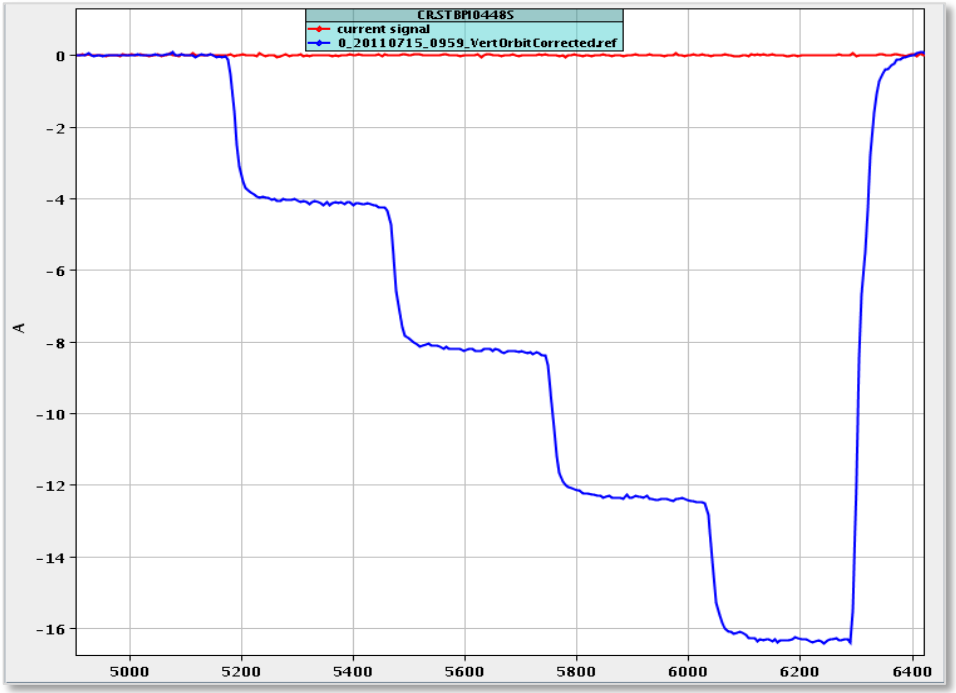
Still many things to achieve **!!!**

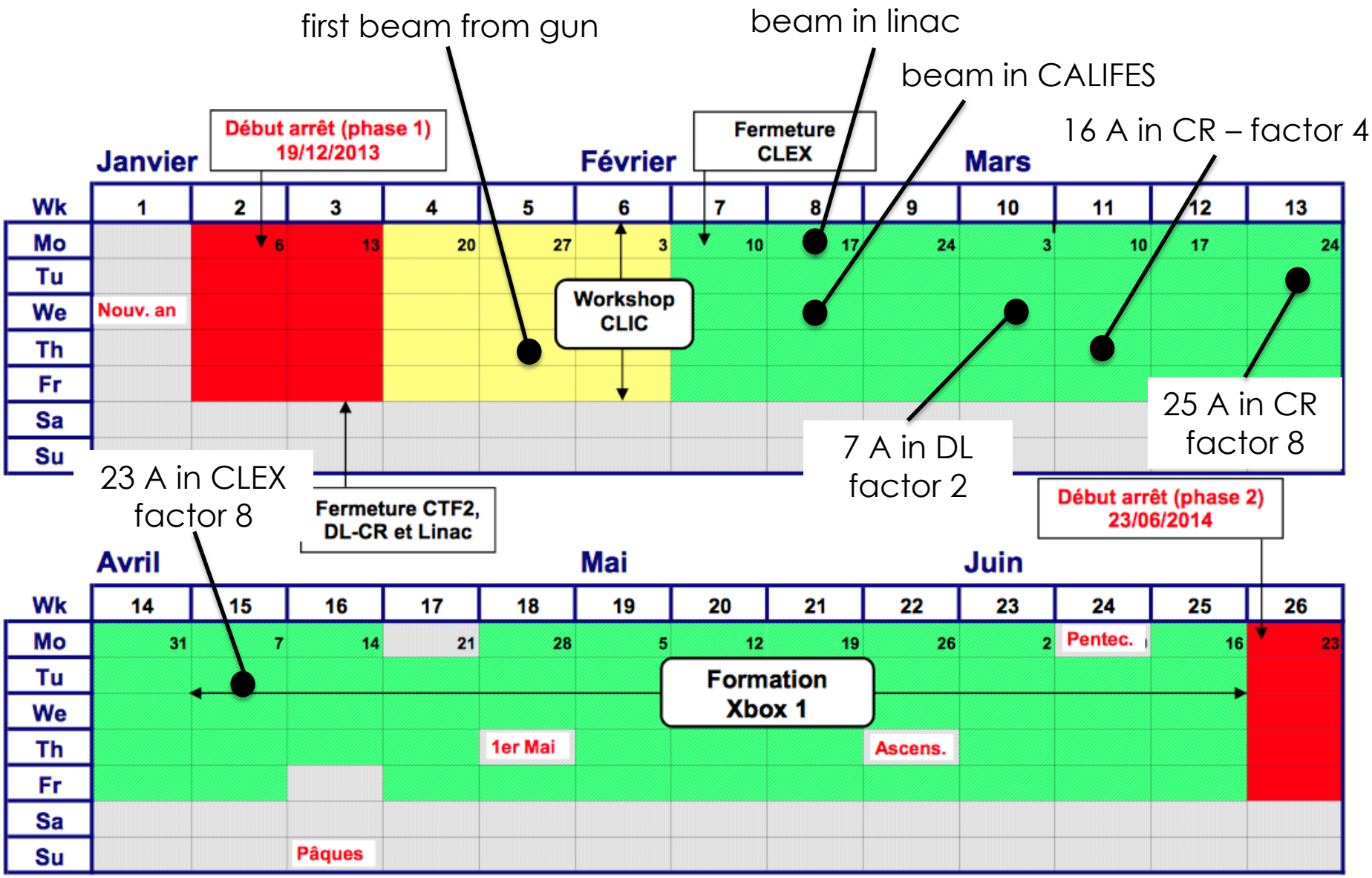
Backup slides

- ClicWS'14 Presentation
  - https://indico.cern.ch/event/275412/contribution/29
- Davides presentation LCWS'14
  - Automatic closure, dispersion measuremens https://indico.cern.ch/event/275412/session/3/contribution/93/material/slides/

Drive Beam Generation 2013 Factor 4

- Routine, well controlled, with nominal specs
  - Lossless: 4 A from the linac combined to 16A
    - Allows for higher repletion rate where needed
  - Emittance: ε_H= 170 μm ε_V= 120 μm
  - Stability around 0.1%
    - Stable enough to have machine running over-night with remote supervision only by PS operators from CCC




first beam from gun
beam in linac
beam in CALIFES
16 A in CR – factor 4
Début arrêt (phase 1)
19/12/2013
Fermeture
CLEX
Janvier
Février
Mars
Wk
1 2 3 4 5 6 7 8 9 10 11 12 13
Mo
Tu
We
Th
Fr
Sa
Su
6 13 20 27 3 10 17 24 3 10 17 24
Nouv. an
Workshop
CLIC
25 A in CR
factor 8
7 A in DL
factor 2
23 A in CLEX
factor 8
Fermeture CTF2,
DL-CR et Linac
Début arrêt (phase 2)
23/06/2014
Avril
Mai
Juin
14 15 16 17 18 19 20 21 22 23 24 25 26
31 7 14 21 28 5 12 19 26 2 16 23
Pentec.
Formation
Xbox 1
1er Mai
Ascens.
Pâques

•CTF3 Schedule 2014