LHC Performance Workshop - Chamonix 2012

Hotel "Les Aiglons", Chamonix, France

February 6th-10th, 2012

Turn-around improvements

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and

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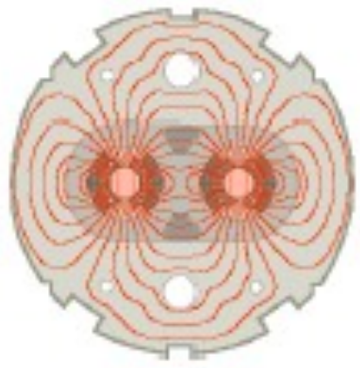


Acknowledgments

Talk based on inputs from:
LHC-OP team: EiC + operators
(Lasse, Markus, Verena, Laurette, Delphine, Rossano)

New cycle for 2012:
Mike Lamont, Gabriel Müller, Jörg Wenninger,
FiDeL (Ezio, Nicholas), optics and beta-beat (Rogelio) teams
Stéphane F.

Statistics on beam modes: Chris Roderick

References:

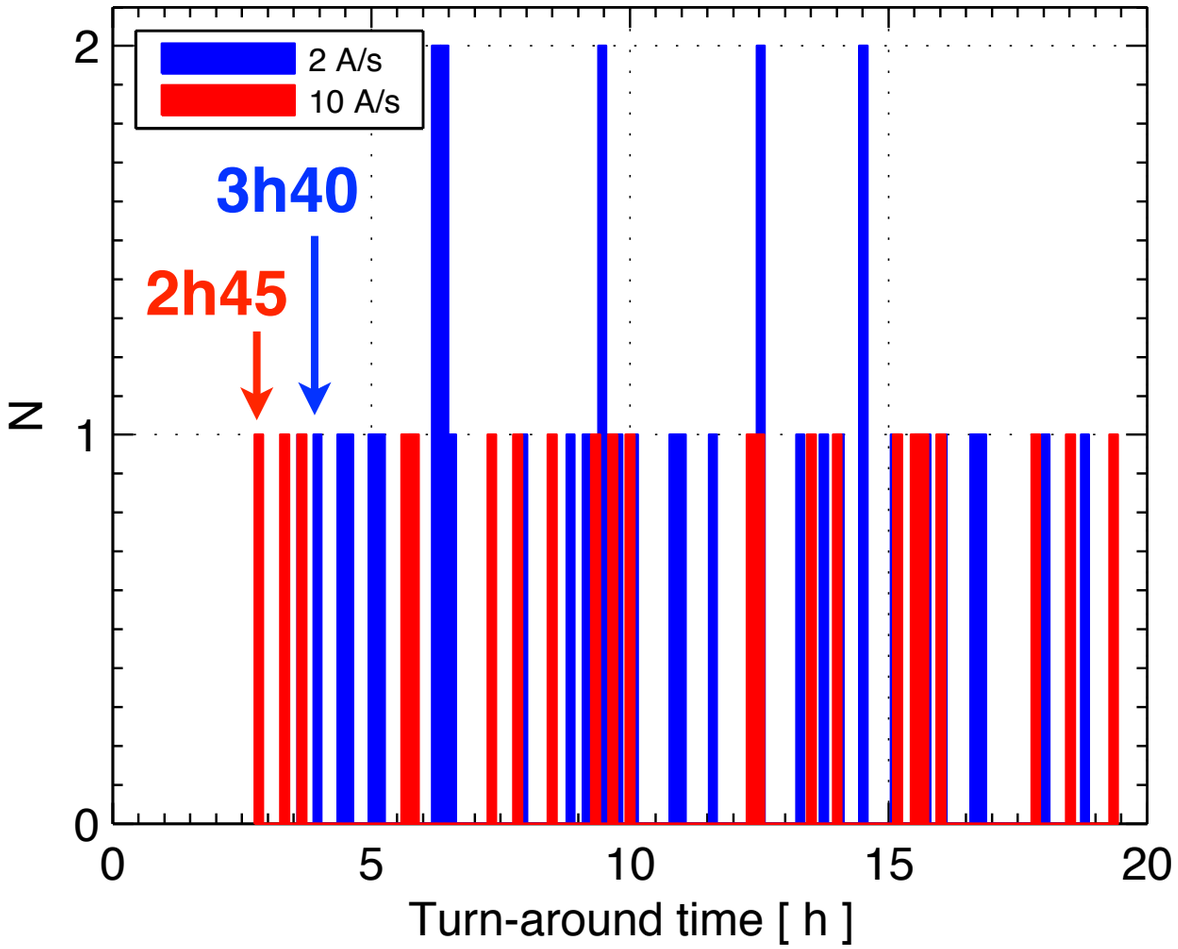
Evian2011 talks by W. Venturini, A. MacPherson
Proceedings of Evian 2010 and Chamonix 2011 by S. Redaelli
LBOC meetings on Feb. 8th, 2010 and Jan. 31st, 2011.

Outline

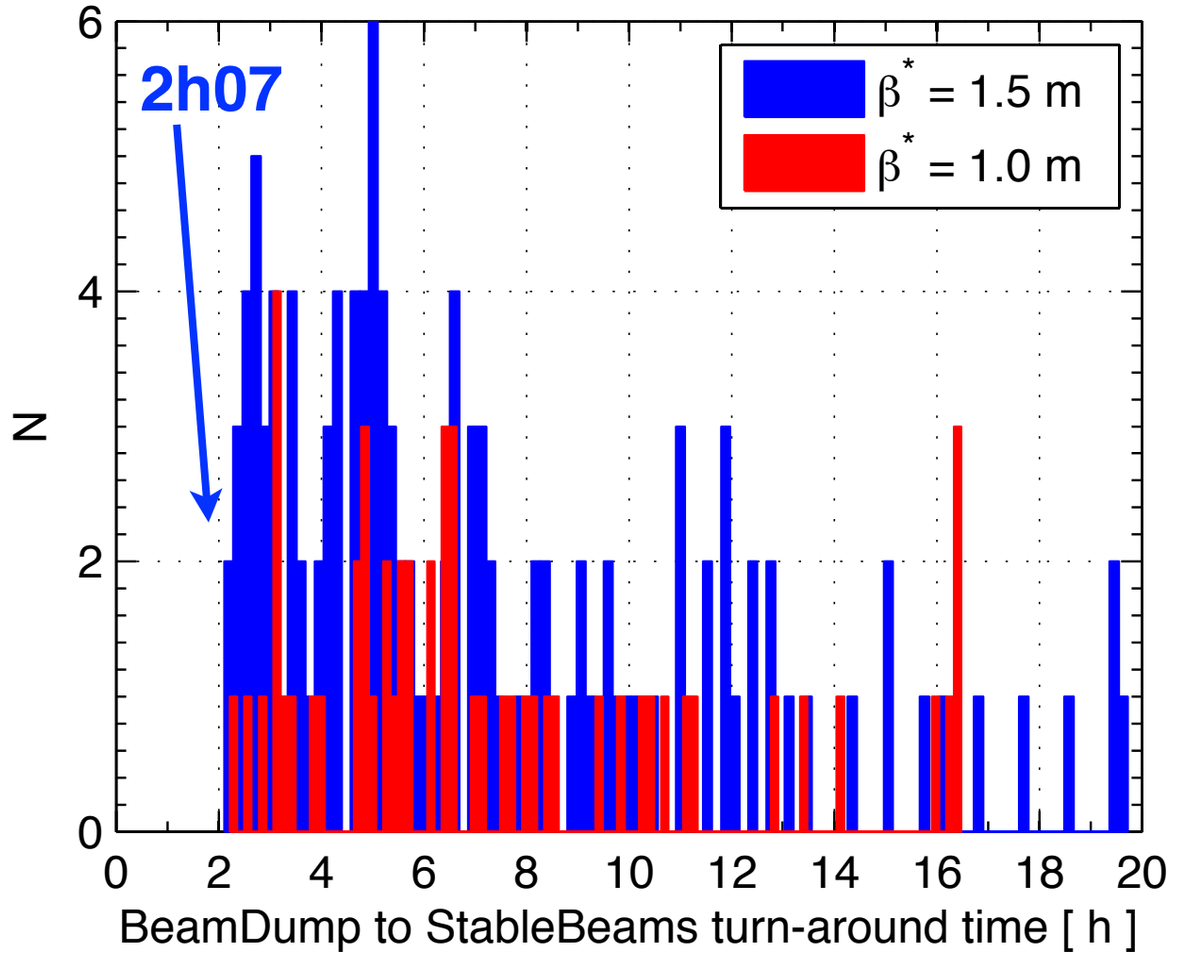
- ☑ Introduction
- ☑ Improvements in 2011
- ☑ 2012 operational cycle
- ☑ Miscellaneous
- ☑ Conclusions

Introduction

2010



2011



Overall yearly figures *(distribution cut: 20h)*

	Min_{Theory}	$Min_{Achieved}$	Average
2010 :	***2h01***	***2h45*** *(+44 min.)*	***> 10.8 h***
2011 :	***1h45***	***2h07*** *(+22 min.)*	***~ 7.2 h***

We are getting closer to the theoretical minimum, but the average is still 3 times longer (with larger n_b and smaller β^*)!

Scope and assumptions

- Focus of this analysis: **improvements of operational aspects**
  - Statistics of fills that made it to physics to address OP efficiency
  - Aim to identify areas of improvement for turnaround time.
- **Methods:**
  - Look at the times spent in each machine mode for *physics fills*
  - Not consider special fills and MDs *(even though they also profit of a better turnaround!)*
  - Machine setups, system commissioning periods and EOFs disregarded.
- **Statistics based on the times of machine mode changes**
  - Uncertainty on the scale of some minutes.
  - Source: start/end times of modes from database (provided by Chris R.)
- **Same analysis tools used for 2010 analysis, for comparison**
- **Other important operational improvements not discussed here** (e.x.: automated handling of orbit references) [robustness]

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- **Improvements in 2011**
- 2012 operational cycle
- Miscellaneous
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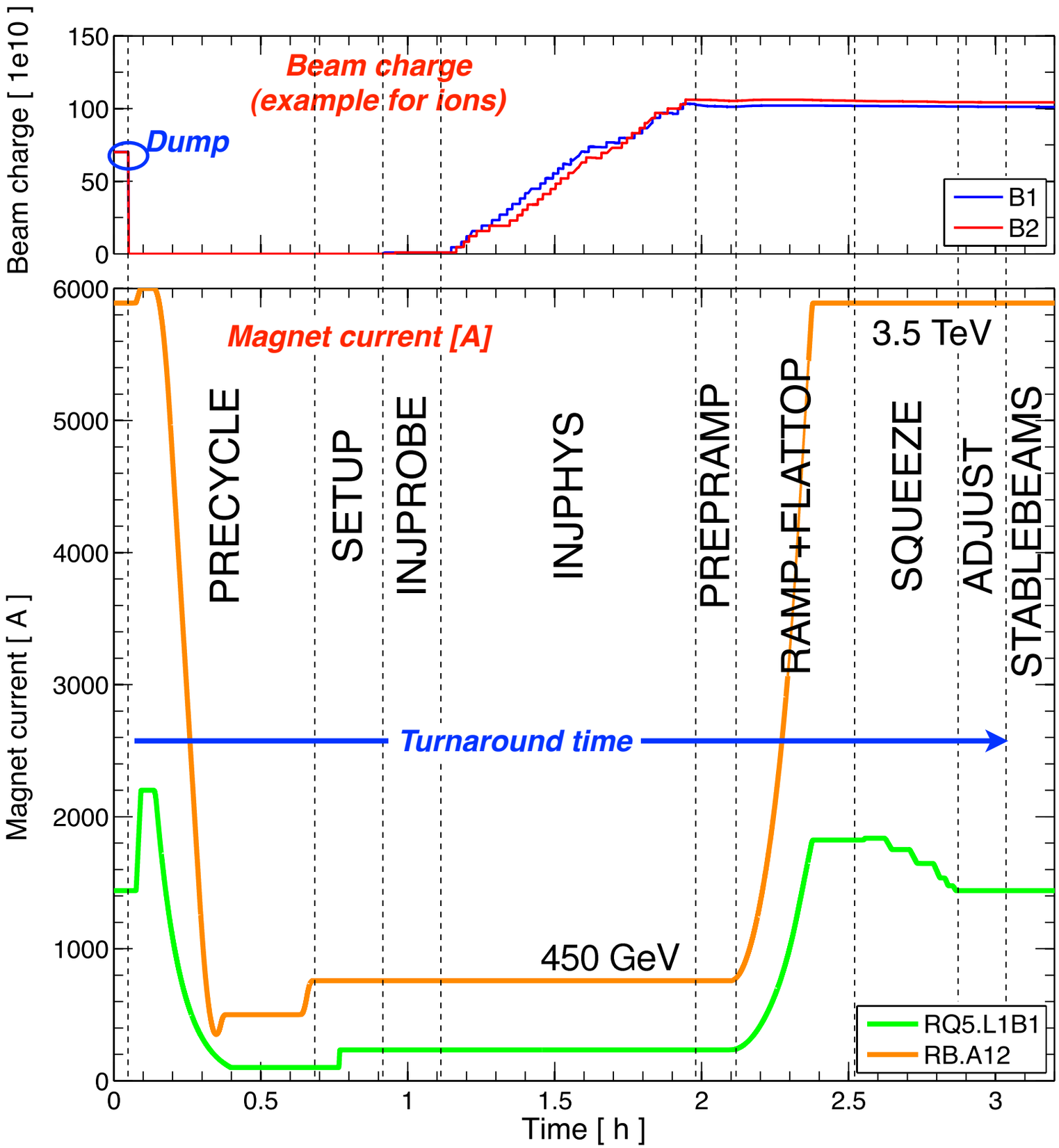
Recap.: operational cycle



Time-functions *for settings of*
(1) ramp,
(2) squeeze(s),
(3) collisions,
(4) pre-cycle (without beam).

Discrete *("actual") settings for:*
(1) injection,
(2) prepare ramp,
(3) flat-top,
(4) adjust (end of squeeze),
(5) stable beams.

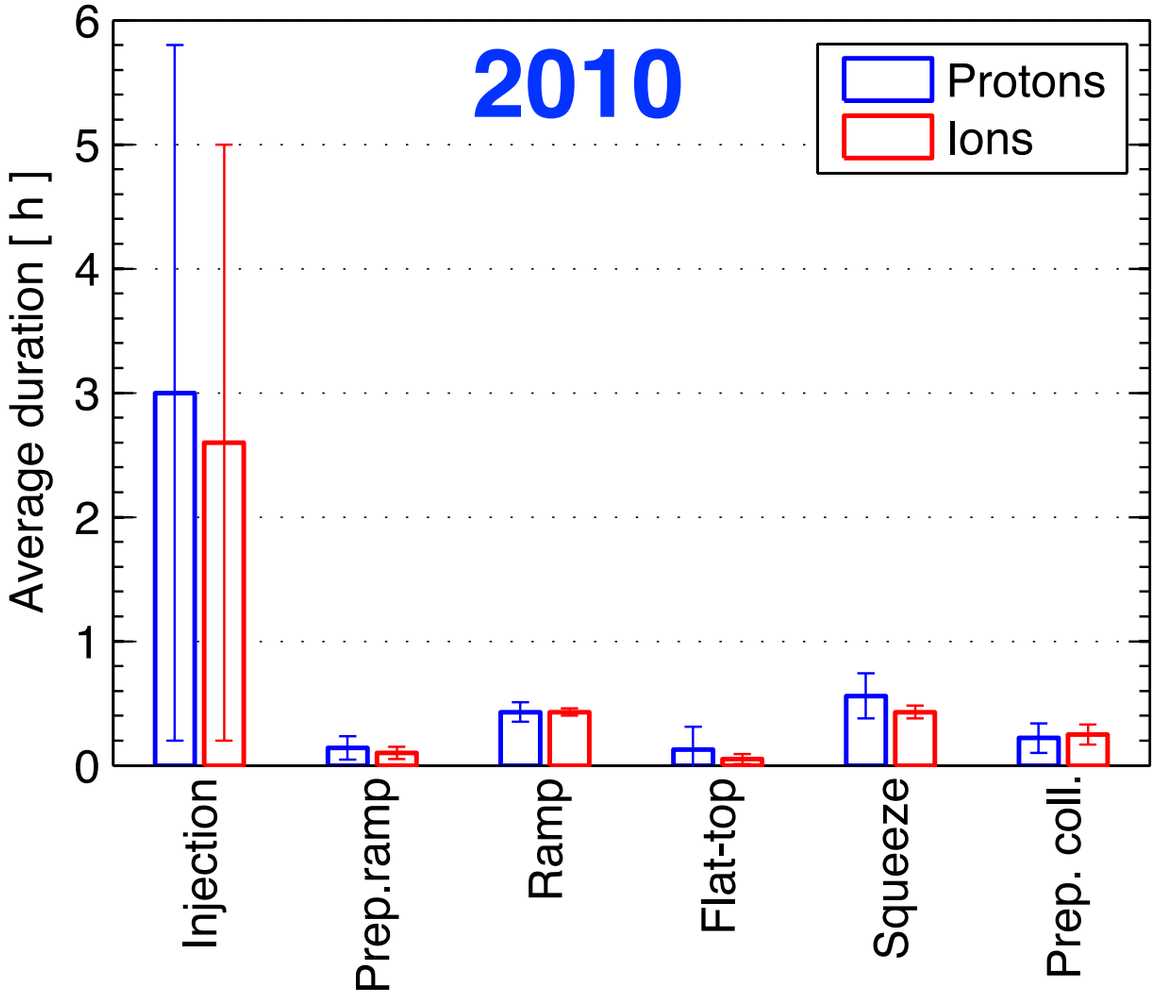
Remark:
Machine recovery after dump at top energy full yin the shade of the precycle → analysis starts from injection

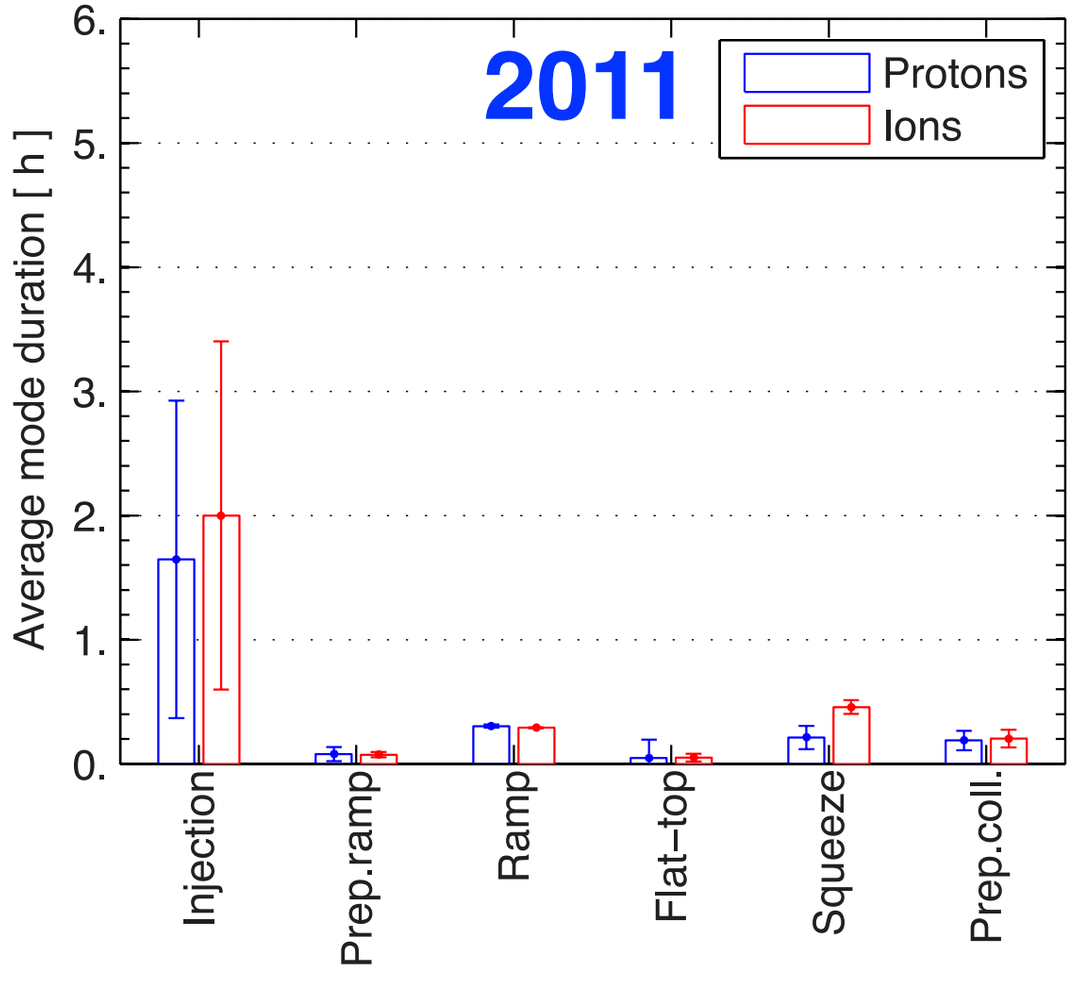
Theoretical* times in 2011

Beam mode	Theoretical (s)	Min. achieved (s)
BEAMDUMP + RAMPDOWN+ SETUP	2490	2490
INJPRO 1092	300	336
INJPRO 1380	300	206
INPHYS 1092	1574	1249
INPHYS 1380	1574	1599
PRERAMP	120	126
RAMP	1020	1026
FLATTOP	0	13
SQUEEZE 1.5 m	475	558
SQUEEZE 1 m	548	663
ADJUST	270	270
TOTAL (1380b, 1m)	1h 45’	2h 07’

**Theoretical* for typical 2011 SPS supercycle (without dedicated filling for the LHC!)*

Comparison 2010-2011 by mode (I)





(1) Injection still drives the time to go back in physics

(2) Nevertheless, the process was improved in 2011!

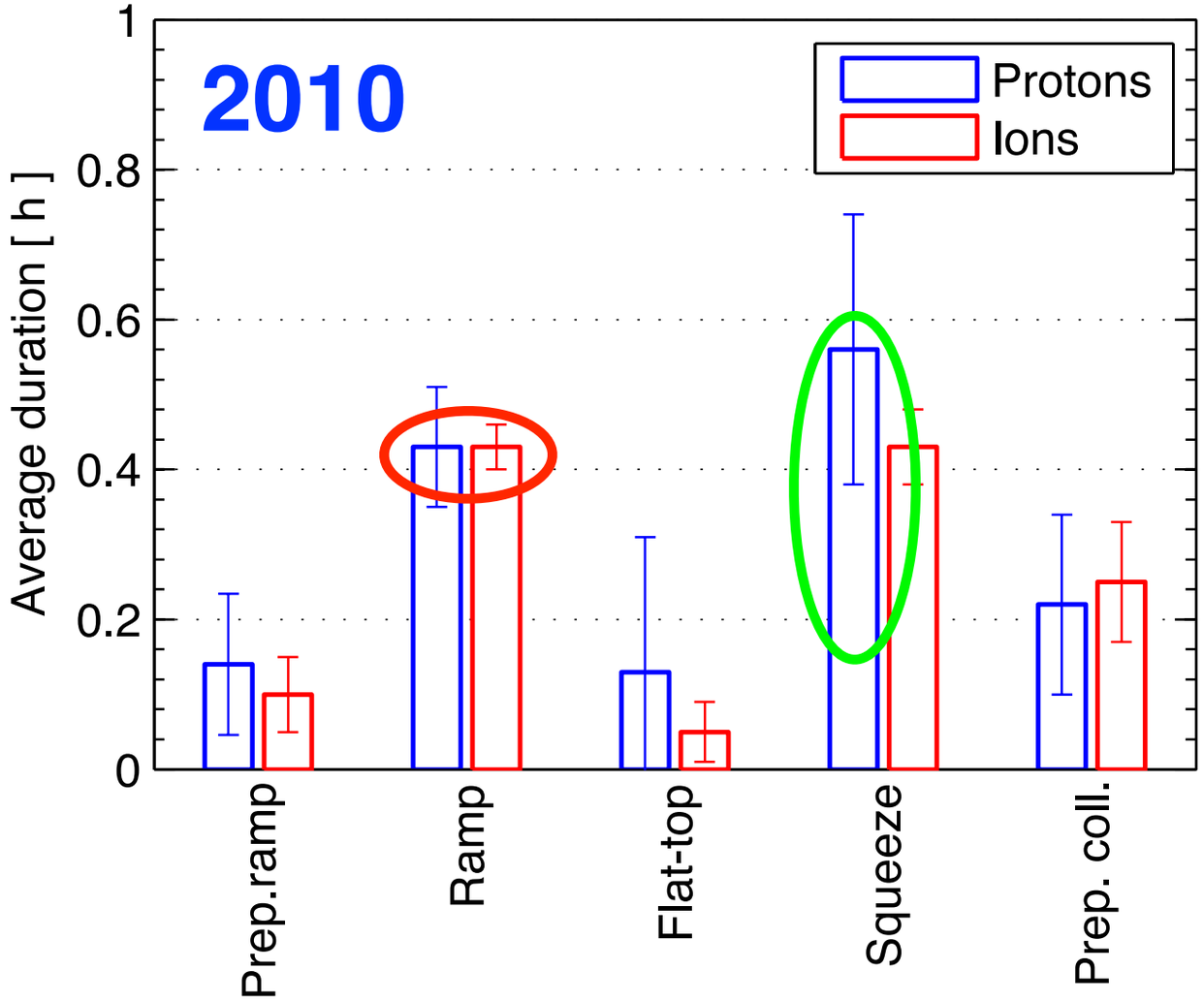
On average we gained 1.4h with respect to 2010 (larger n_b)!

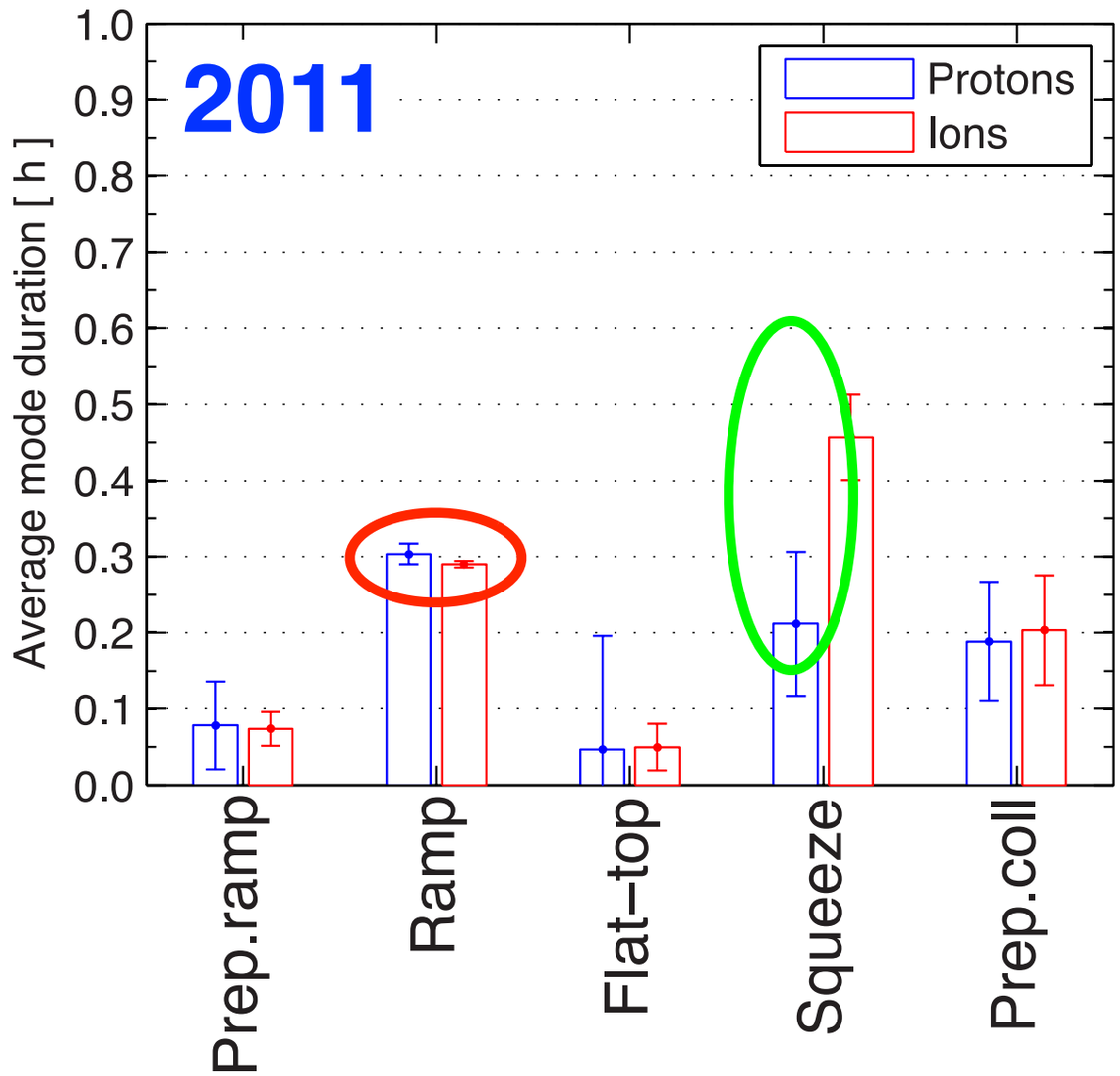
(3) Ions: gain is smaller

(more injections + longer squeeze than 2010)

2010: averages over last ~30 fills; 2011: all proton fills since mid-May

Comparison 2010-2011 by mode (II)





(1) Squeeze for protons almost *x3 faster*! (and β*=1m vs. 3.5m)

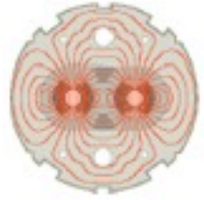
Ions: choice to make squeezes in series → 771s longer!

(2) Gained 6-7 minutes in the ramp functions

(3) Average gain of 10-15 minutes in manual phases

Prepare ramp, flat top, adjust: still room for improvements!

Operational improvements in 2011



(1) Various improvements of the injection

- Separated injection requests for B1/B2
- Improved threshold settings for injection quality checks (mainly, BLMs)
- Dynamic compensation of Q and Q' decay at flat bottom

(2) Optimizing ramp setting functions

- 6 min gain from improved dipole settings generation
- Dynamic orbit reference while energy changes: Xing/sep set to final values

(3) Squeeze much improved

- Optimized distributions of intermediate optics: **halved duration** for β^* 3.5 times smaller, without compromising optics quality and beam transmission!
- Sequencer handling of orbit references (JW, LP): no need to stop!
- Smooth collimation functions instead than step movements

(4) Improved operational sequences and GUI

- All setup in the shade of the precycle; minimum manual actions.

(5) Reduced to a minimum "manual" phases

(6) Reminder: new dump handshake with 5 min timeout → ok

Operational improvements in 2011

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What can still be improved?

(don't expect the same improvement in 2012)

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Working assumptions for 2012

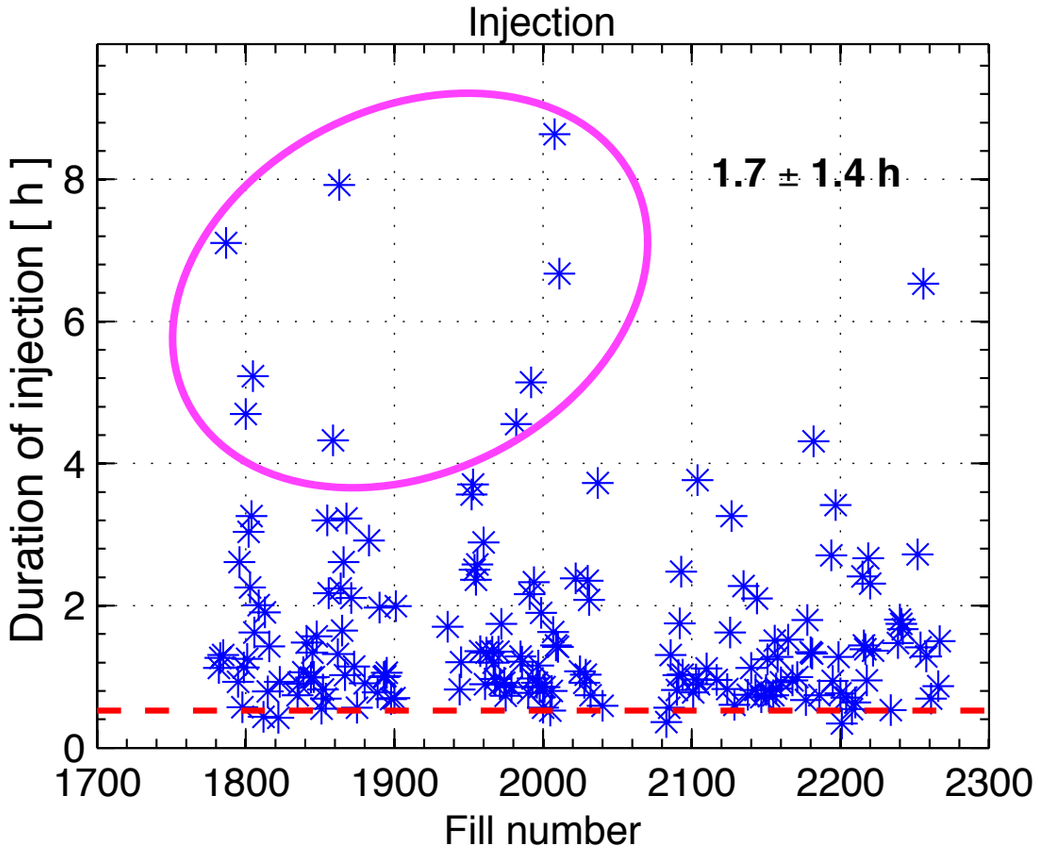
- ☑ **Operation energy = 4 TeV**
- ☑ **Target β^* = 60 cm in IP1 and IP5**
  - At the limit of 2011 aperture: need to address early on in 2012 the aperture!
  - Plan a detailed commissioning in the β^* range 1.0 m to 0.6 m (intermediate points) to allow “easy” fall-back to larger β^*
- ☑ **Partial squeeze of IP2 to 3 m, in parallel to other IPs**
  - Improve rates for main-satellite collisions
  - Will speed-up squeeze for ions
- ☑ **Vertical crossing in IP8** *- see dedicated LBOC meeting 24/01/2012*
- ☑ **Straightforward to go back to 3.5 TeV configuration if proposal of 4 TeV not endorsed...**

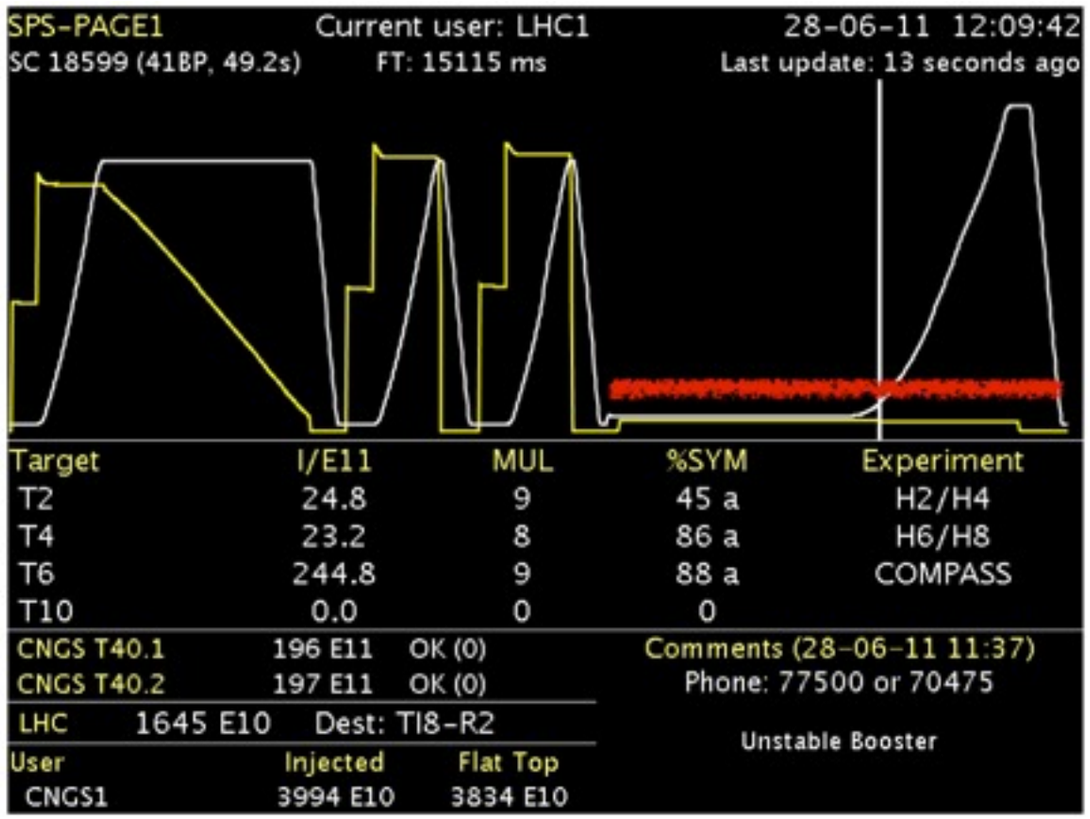
2012 parameter table (protons)

Parameter	Value at 450 GeV	Value at top energy
Energy [GeV]	450	**4000**
$\beta^*_{IP1/5}$ [m]	11.0	**0.6**
β^*_{IP2} [m]	10.0	**3.0**
β^*_{IP8} [m]	10.0	3.0
Parallel separation [mm]	2.0	**0.67**
Crossing angle IP1/5 [μrad]	170	**145**
Crossing angle IP2 [μrad]	170	**90+**
Crossing angle IP8 [μrad]	170	**100#**
Ramp duration [s]	2010: 1020	→ **770**
Squeeze duration [s]	2010: 548 (1.0 m)	→ **819** (0.6 m)
Collision BP duration [s]	2010: 56	→ **56**

+: Preliminary estimate by J. Jowett, R. Versteegen, assuming 2.5 micron emittance
#: assumed crossing in V plane (W. Herr)

Injection - operation's view points





(1) Improved communication with injectors

Prepare the LHC beams during precycle (PS RF drifts + SPS parameters)

(2) Dedicated filling with a minimum of CNGS cycles (1?)

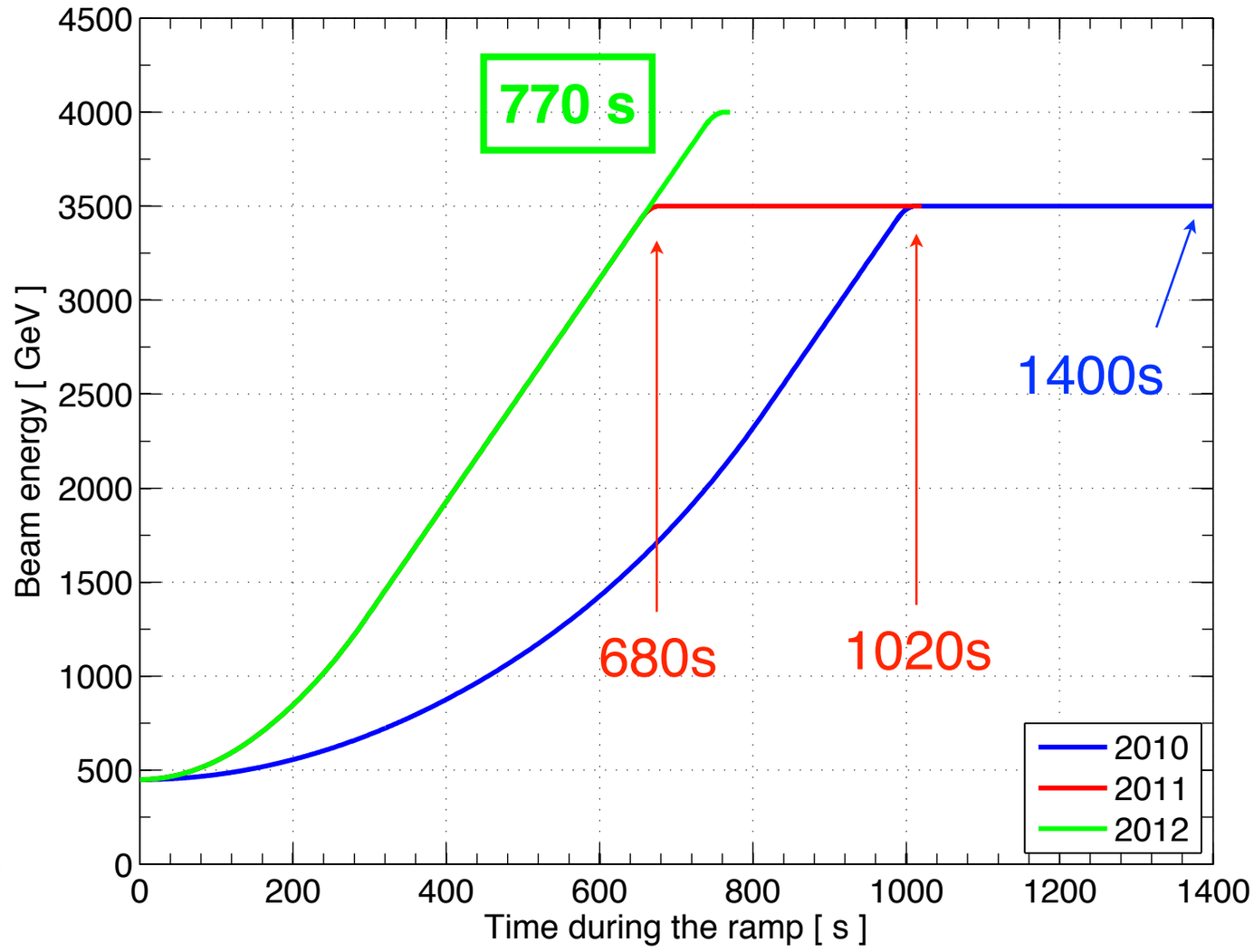
(3) Permit injection requests before completion of analysis of previous injection

Would allow injection at every cycle - being followed up by inj team

(4) Beams on TEDs during LHC pre-cycle to check/steer lines?

Energy ramp to 4 TeV in 2012

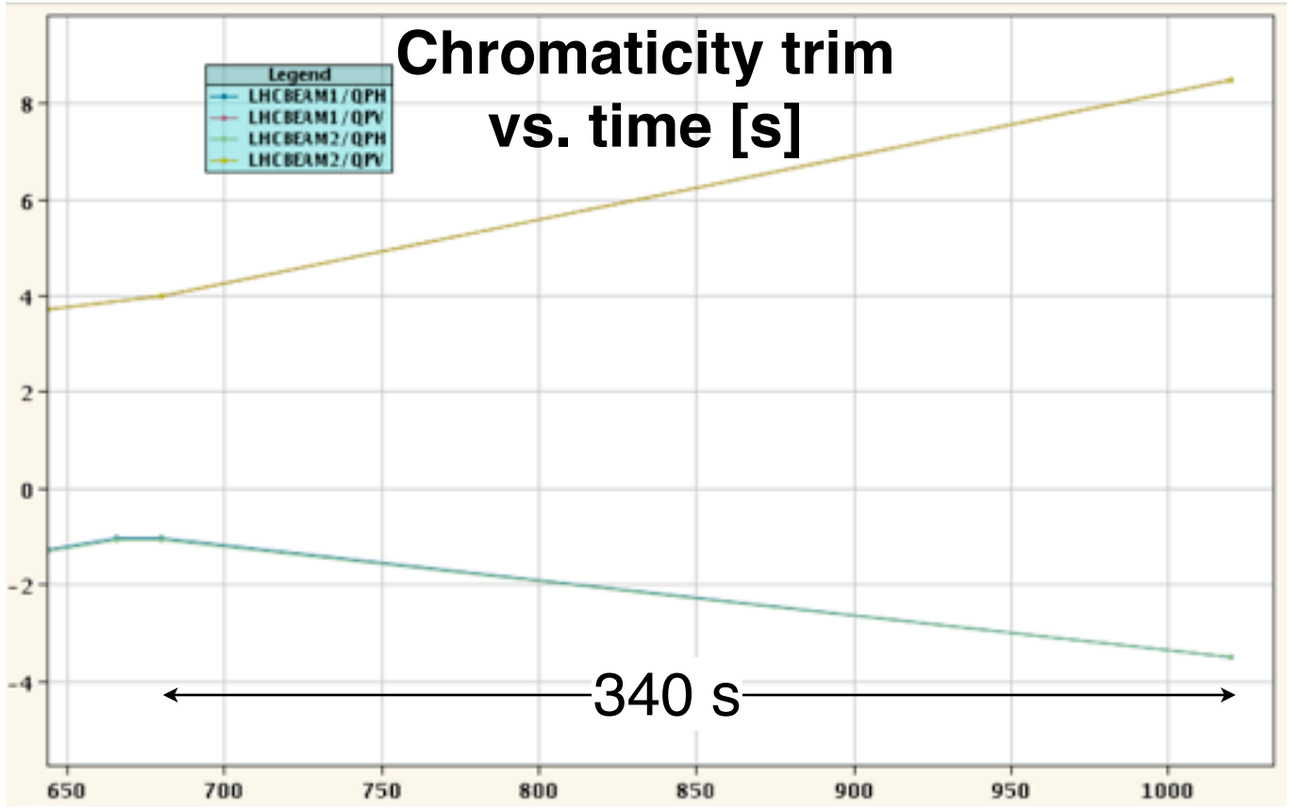
- Same optics and dipole parameters as 2011 give a duration of 770 s (4 TeV)
- For 2011, Mike improved parabolic/exponential branches before linear part
- Linear variation in t of Sep/Xing during energy change
- Same strategy as in 2011 for decay/snapback handling
- Remove decay *plateau* at top energy



Can we remove the decay *plateau*?

Decay at flat-top

- **We observed a decay of tune and chromaticity at 3.5 TeV**
  Source: field decay in dipoles (Q': b_3)
- **Operation in 2010 and 2011:**
  Decay corrected with Q and Q' knobs:
  → machine frozen because these knobs are needed in the squeeze
  → global correction for local error source, hence the idea to use b_3 spool pieces (RCS's)
- **Proposal for 2012:**
  Measure systematically the effect!
  Quantify how much we can compensate with RCS's only (we could be left with some residual Q' - same for x,y - of ~ 1)
- **Technical implementation**
  Feasible with reshuffling of sequences and separated beam processes for longer setting functions of RCS's



LSA trims in 2012:

$\Delta Q'_x = -2.5$
$\Delta Q'_y = +4.5$

$\Delta Q_{x,y} = 1.0\text{-}2.0 \times 10^{-3}$

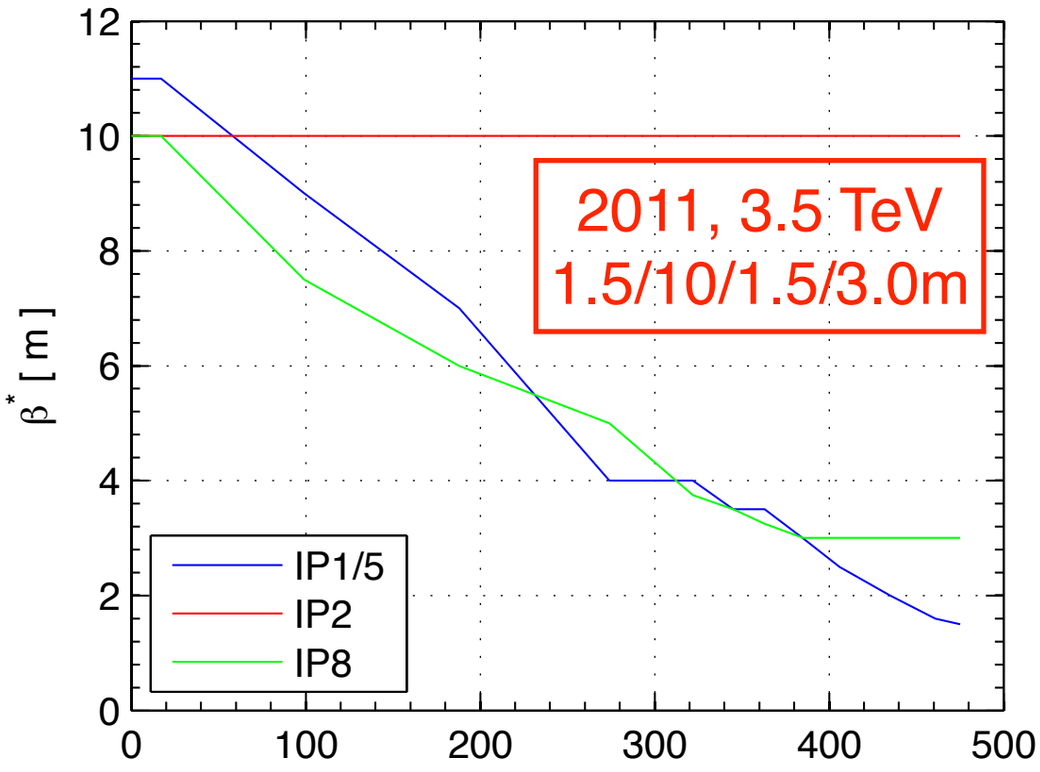
New squeeze

Recap of strategy for 2011:

1. *Optimized duration down to 3m (based on 2010)*
2. *No optimization in new territory below 3m*
3. *Keep ~same β* in all IPs (better for protection)*

Strategy for 2012:

1. *Optimized duration in known range above 1.5m*
2. *Keep the same optics below 1.5m*
3. *Allow different β* values in IPs (ok in 2011!!)*
   Ex.: no repeated points in IP1/5; IP2 slower...
4. *Keep all matched points in IP8*



Achieved parameters:

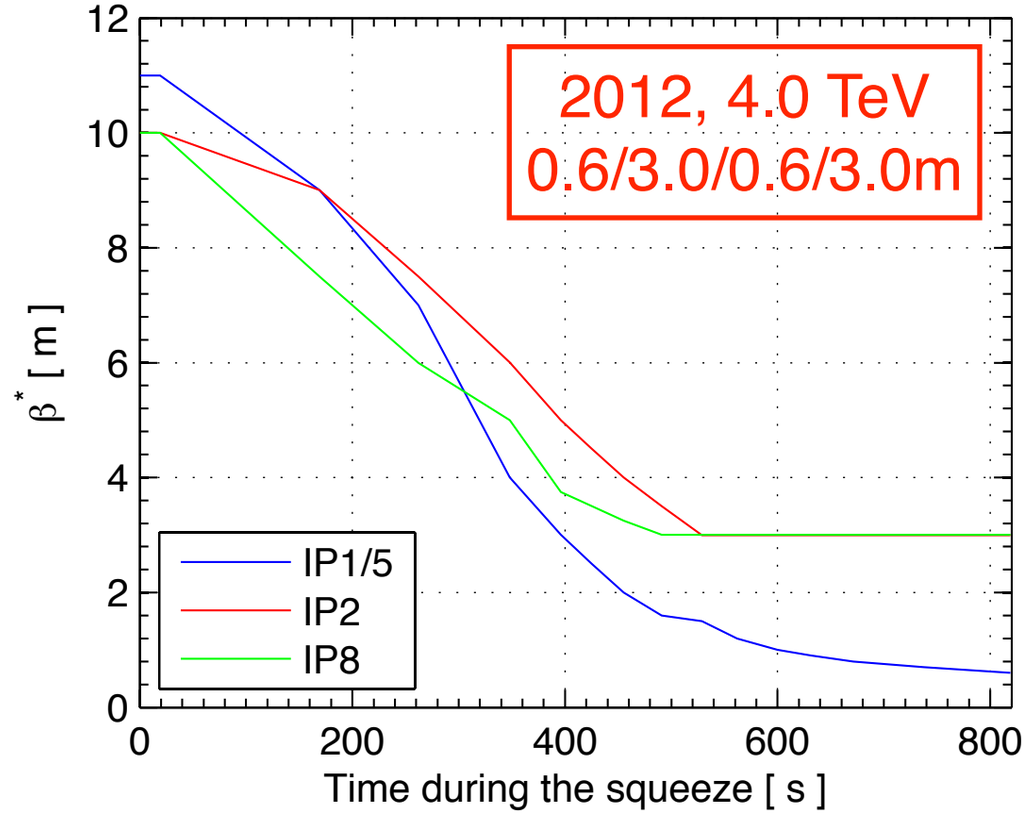
*Duration = **819 s** (lost 48s due to IP2)*
Settings preparation/validation ongoing (M. Solfaroli)

Improved feed-forward strategies

Q, Q', beta-beat and orbit based on simulations!

Some software improvements

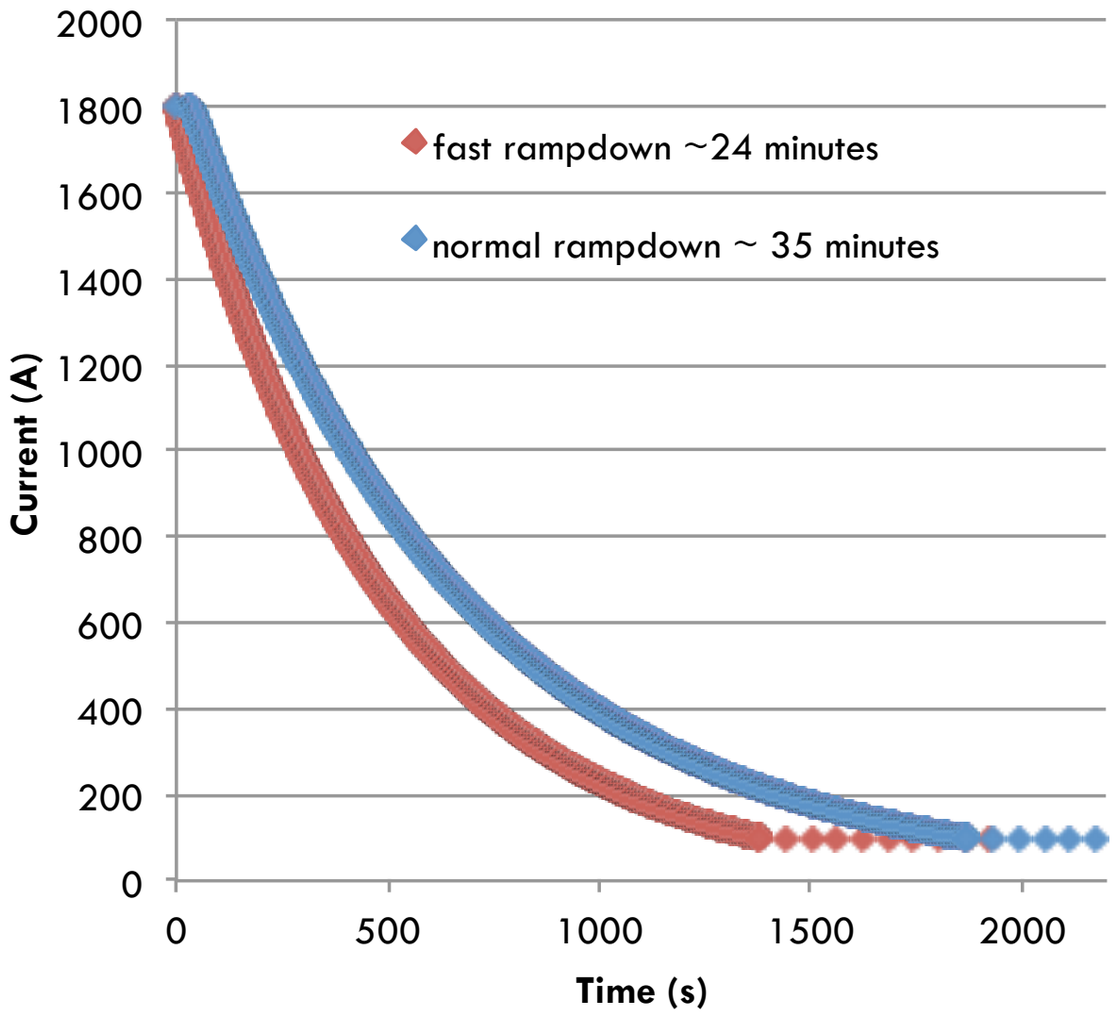
Better strategy for knobs current round-offs
Improved generation for slow unipolar quads

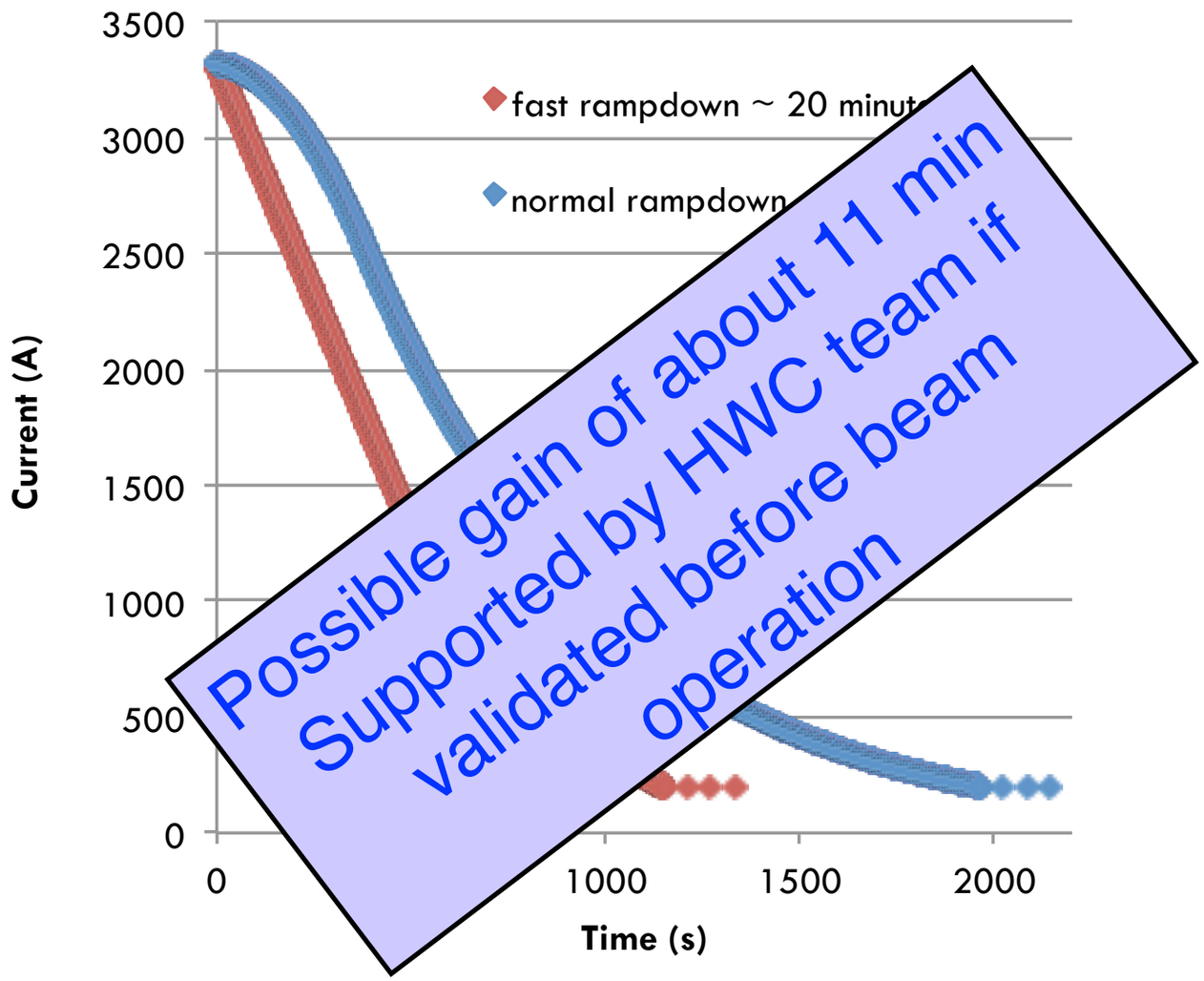


Faster LHC pre-cycle

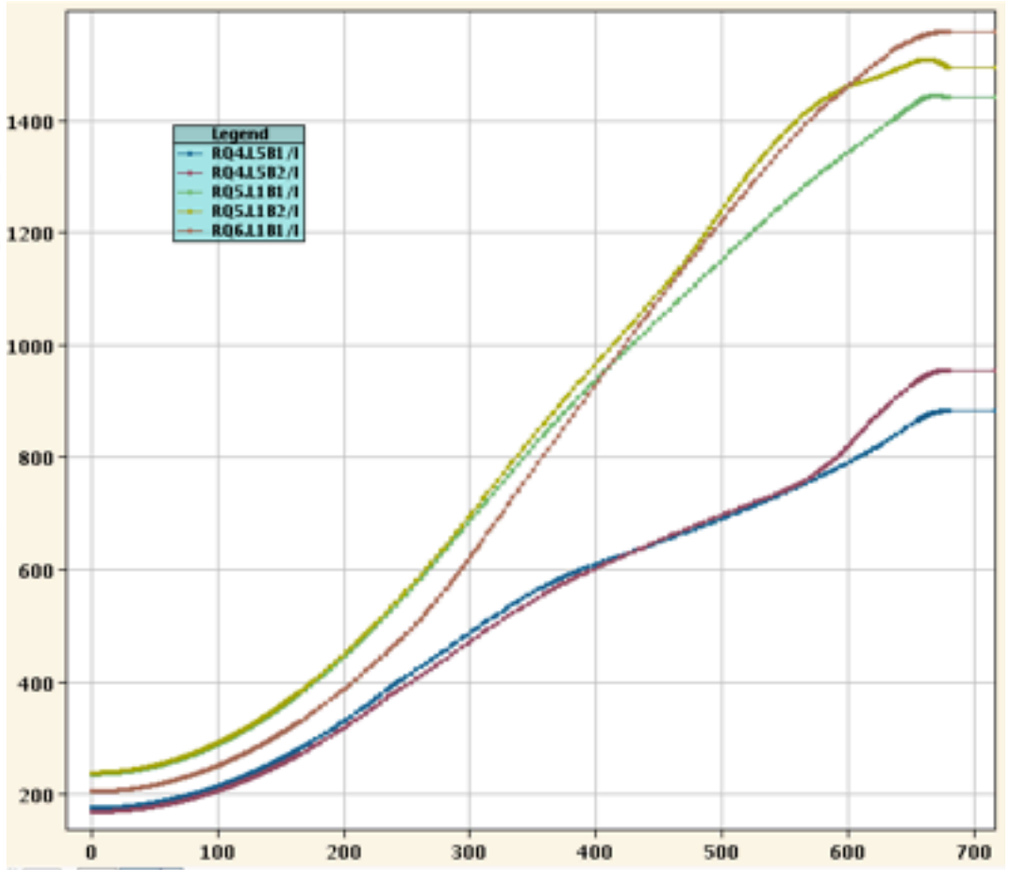
RQ4.R2 (slowest magnet in the machine).
Achieved ramp down from 1900A to 100 A in about 24 minutes (open loop).
During 2010 run, ramping from 1800 A down to 100 A took about 43 minutes (9 minutes to control the last 300 A!)
2011: took 35 minutes

RQX were the next bottleneck, but can ramp faster by tuning the di/dt of the nested circuits to remain in the shade of the Q4





Postponed: combined Ramp&Squeeze



Studies systematically several options for MD beam tests in 2011 for *(as requested in Chamonix2011)*

Converged on two options:

3.5 TeV: **3.5/10.0/3.5/3.0 m**

4.0 TeV: **3.0/10.0/3.0/3.0 m**

Overall gain **~ 400s per fill**!

Status:

- *Settings ready for beam tests at 3.5 and 4 TeV*
- *Dry-run of full machine done with PC's (3.5 TeV)*
- *Established strategy for tune/beta-beat feedforward correction*

Unfortunately, no MD time given for that - decided to postponed it > LS1

Diploma thesis by N. Ryckx, EPFL

Miscellaneous

(1) OP sequences can be improved further to parallelize tasks

Preparation of ramp can be improved

Advance incorporation tasks (tested ok for ion run!)

Goal: all EiC should run sequences in the same way!

(2) We can improve the time lost in case of accesses

Often not in statistics but quoted as in the "shade" of the faults...

Start precycle as soon as people are out, then short for EiS

"Short access procedure" costed ~20min if done at injection

Could have a set of sequences to cover different cases

Access after top energy dump; at injection current; at pre-cycle end

(3) Establish a homogeneous procedure to go in collision

Parallel optimization of different IPs; when to start levelling, ...

(4) Working on new coupling knob (R. Tomas)

(5) Launch pre-cycle immediately after the dump *(there's plenty of time to understand the details of the dump during the precycle...)*

Conclusions

☑ The 2011 experience on turnaround was reviewed

*Average turnaround improved by ~3h. Still dominated by **injection**.*

*Fastest turnaround was **2h07**, but on average we are well above.*

☑ Many improvements put in place in 2011

Improved significantly time spent at injection

Squeeze and ramp much faster than in 2010

Improved and automated handling of orbit references

Much more robust operation through OP sequencer

☑ Operational cycle in 2012:

*Ramp and squeeze will be **longer** if we operate at **4 TeV** and **β*=60cm***

*But we can maintain the **same cycle duration** with various improvements:*

Ramp without decay plateau, optimized squeeze, faster precycle

Hopefully, even more optimized OP sequences and faster injection

☑ How will the turnaround look like in 2012?

Forecast for 2012

2011 estimates

Machine phase	Ideal [s]	2010 [s]	2011 [s]
Pre-cycle combo	2100+300	n. a.	2100+300
Inject probe	300	5603 ± 8264	300
Inject physics	1900 (=50x38)	4409 ± 3869	1900
Prepare Ramp	120	495 ± 338	120+300
Ramp	1400	1565 ± 289	1400
Flat top	0	473 ± 655	0+300
Squeeze	1041	2000 ± 651	550*
Adjust	108	1524 ± 4080	60+300
TOTAL	**2h00**	4h27 + 0h40	**2h07**

Only gain if injection is faster!

S. Redaelli, LHC Beam WS, 08-12-2010 30

This is what we achieved!

My estimate at Evian 2010

Forecast for 2012

2011 estimates

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Pre-cycle combo	2100+300		
Inject probe	300		
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Prepare Ramp	120		
Ramp	1400		
Flat top	0		
Squeeze	1041		
Adjust	108		
TOTAL	**2h00**		

Only

S. Redaelli, LHC Beam WS, 08-12-2010

My estimate at E

Yearly average will be significantly better only with improved injection!

Machine phase	Ideal [s]	2012 [s]
Pre-cycle combo	1440+300	1440+300
Inject probe	300	300
Inject physics	1574	1574
Prepare Ramp	120	120+300
Ramp	770	770
Flat top	0	0+300
Squeeze	819	880
Adjust	56	56+300
TOTAL	**1h30**	**1h46**