

LHC Status Report



Jan Uythoven
For the LHC Team

LPCC 08.10.2010

LPCC $(S^2 \times S^1) \times B(\theta, \phi)$
<http://cern.ch/lpcc>

LHC Physics Centre at CERN

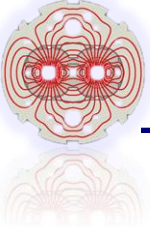




Outline



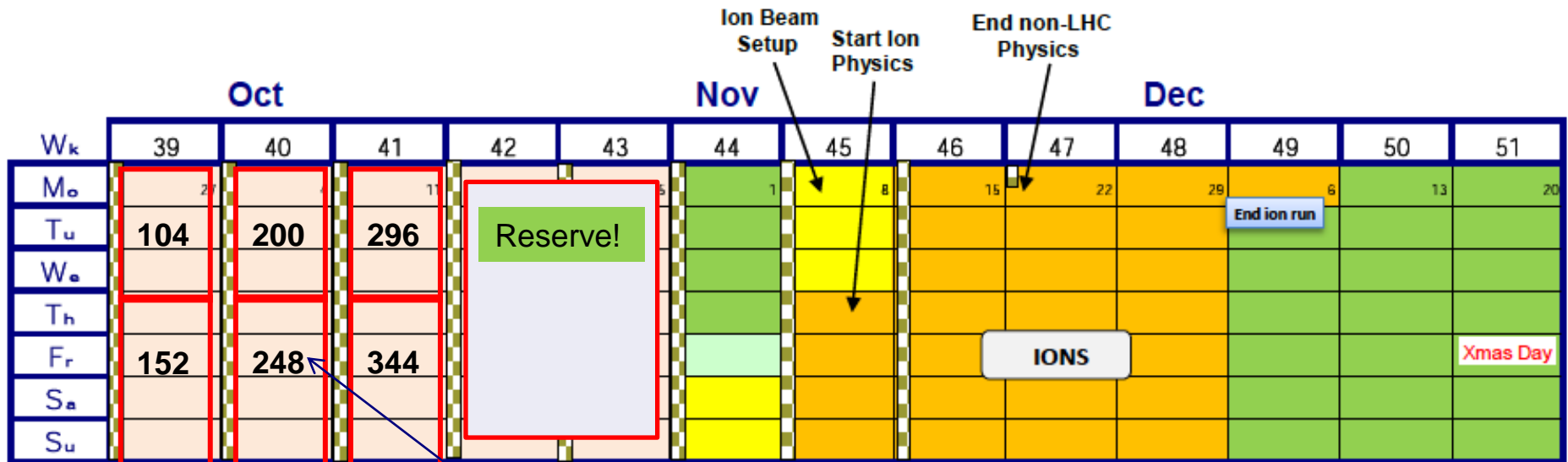
- Targets and beams
- Current issues
 - Bunch trains
 - Injection
 - UFOs
 - Vacuum
- Outlook for the coming weeks



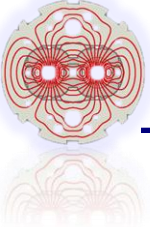
Targets



- Instantaneous **Luminosity of $>10^{32} \text{ cm}^{-2}\text{s}^{-1}$** by the end of 2010
- Run like this to obtain **$>1 \text{ fb}^{-1}$** by the end of 2011
- The plan: gradual increase of the number of bunches



248 Bunches
Indeed, where we are now !

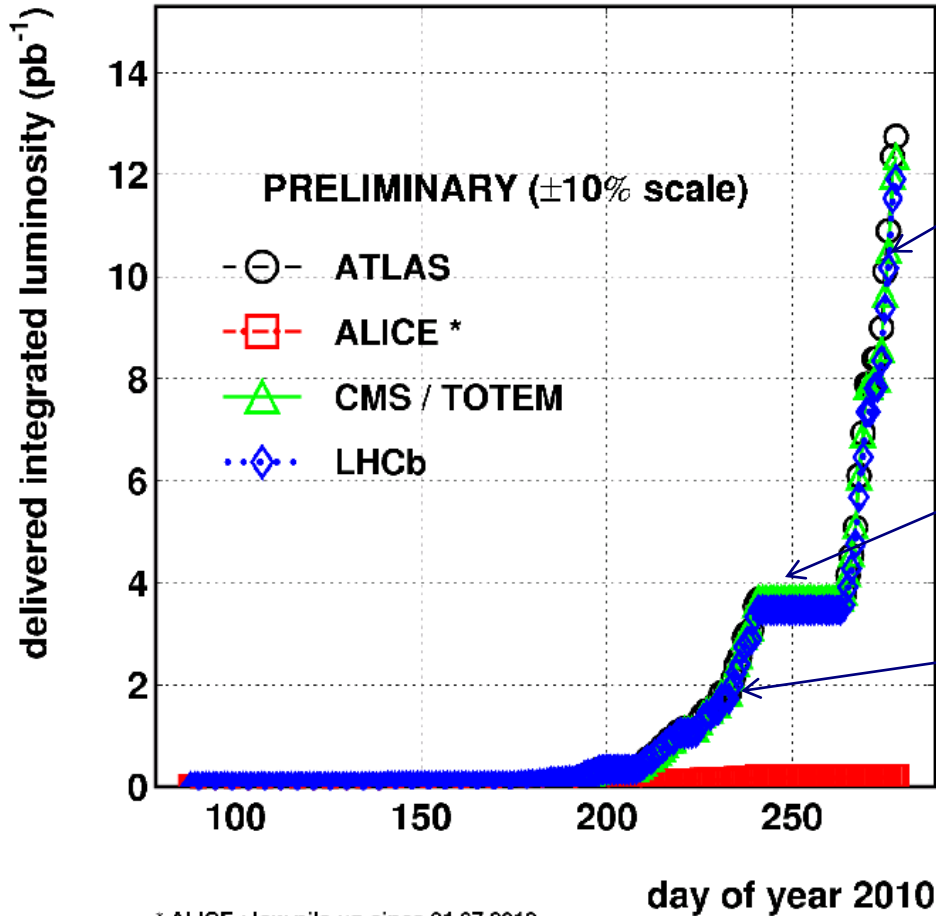


The road to our targets



2010/10/07 10.36

LHC 2010 RUN (3.5 TeV/beam)



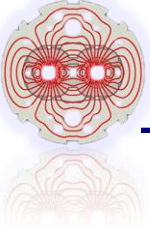
* ALICE : low pile-up since 01.07.2010

September/October:
2 Week s (!) of Bunch Trains

Development of
Bunch Trains

August: Stable running with about 1 μs bunch spacing

M. Ferro-Luzzi



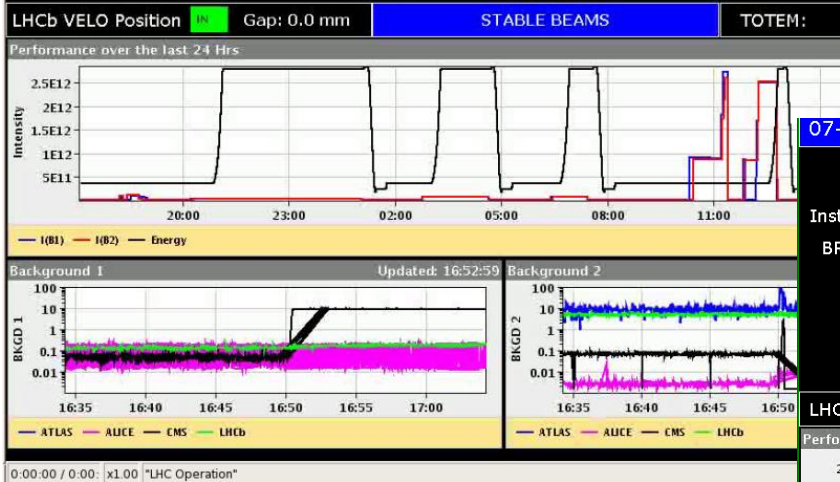
Progress with trains



22-Sep-2010:
24b_16_16_16 : 13.5 h – ~170 nb⁻¹

22-Sep-2010 17:04:45 Fill #: 1364 Energy: 3500 GeV I(B1): 2.45e+12 I(B2): 2.39e+12

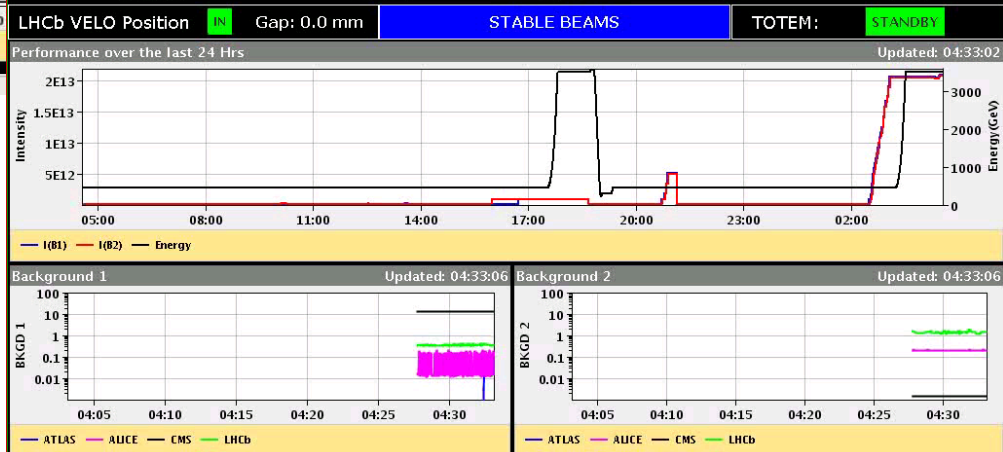
	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	PHYSICS
Instantaneous Lumi (ub.s) ⁻¹	4.656	0.002	4.601	4.295
BRAN Luminosity (ub.s) ⁻¹	4.414	0.003	3.437	4.023
Fill Luminosity (nb) ⁻¹	3.4	--	3.3	2.8
BKGD 1	0.032	0.016	10.030	
BKGD 2	12.000	0.009	0.002	
BKGD 3	20.000	0.007	0.003	

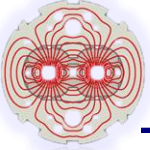


07-Oct-2010:
200b_186_8_186_8+8bpi17inj
6.5 h – ~1350 nb⁻¹

07-Oct-2010 04:33:06 Fill #: 1397 Energy: 3500 GeV I(B1): 2.09e+13 I(B2): 2.08e+13

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	STANDBY	PHYSICS	PHYSICS
Instantaneous Lumi (ub.s) ⁻¹	68.210	0.083	0.010	64.534
BRAN Luminosity (ub.s) ⁻¹	51.438	0.077	59.826	59.635
Fill Luminosity (nb) ⁻¹	37.6	--	0.0	35.5
BKGD 1	0.034	0.017	13.556	0.385
BKGD 2	337.000	0.212	0.002	1.460
BKGD 3	16.000	0.006	2.100	0.367

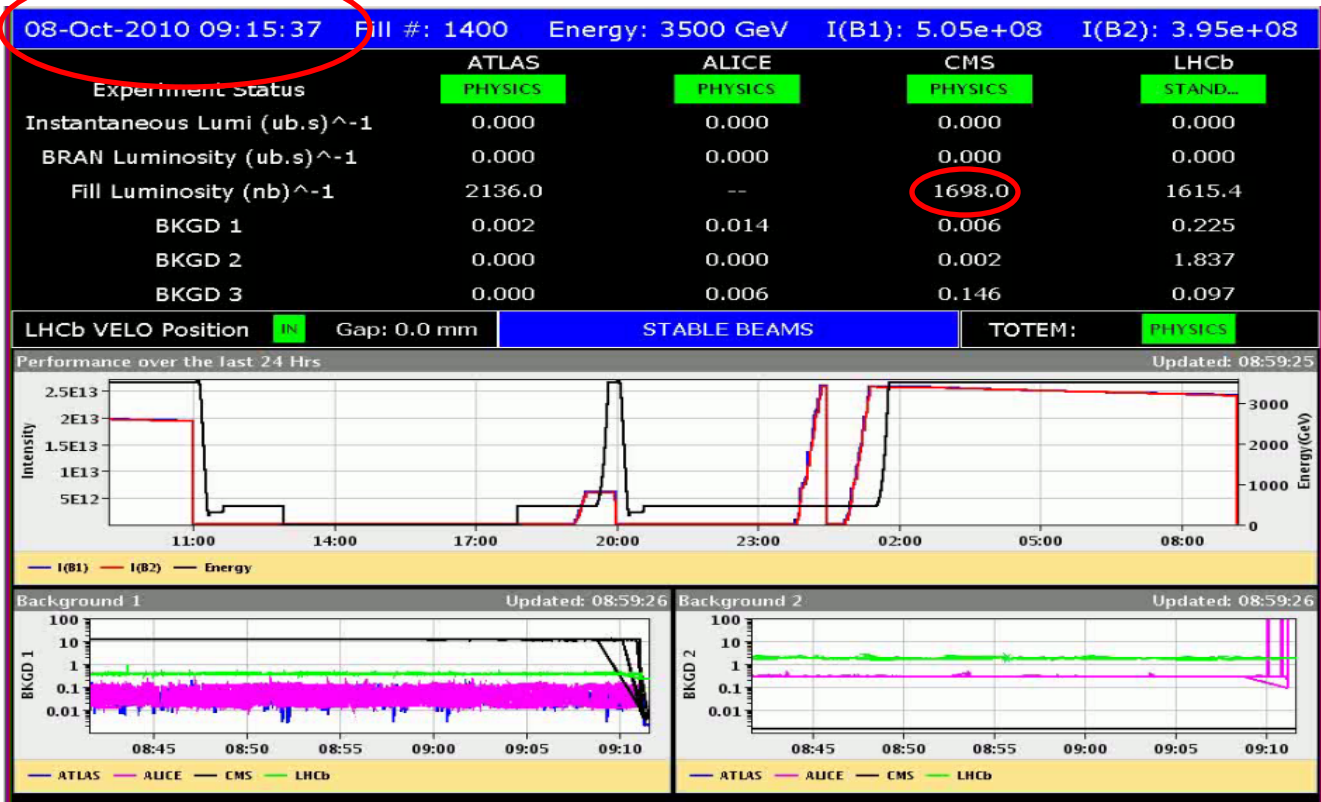




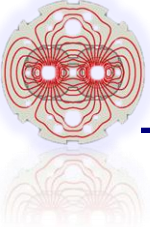
This morning's Fill with 2 x 248 bunches



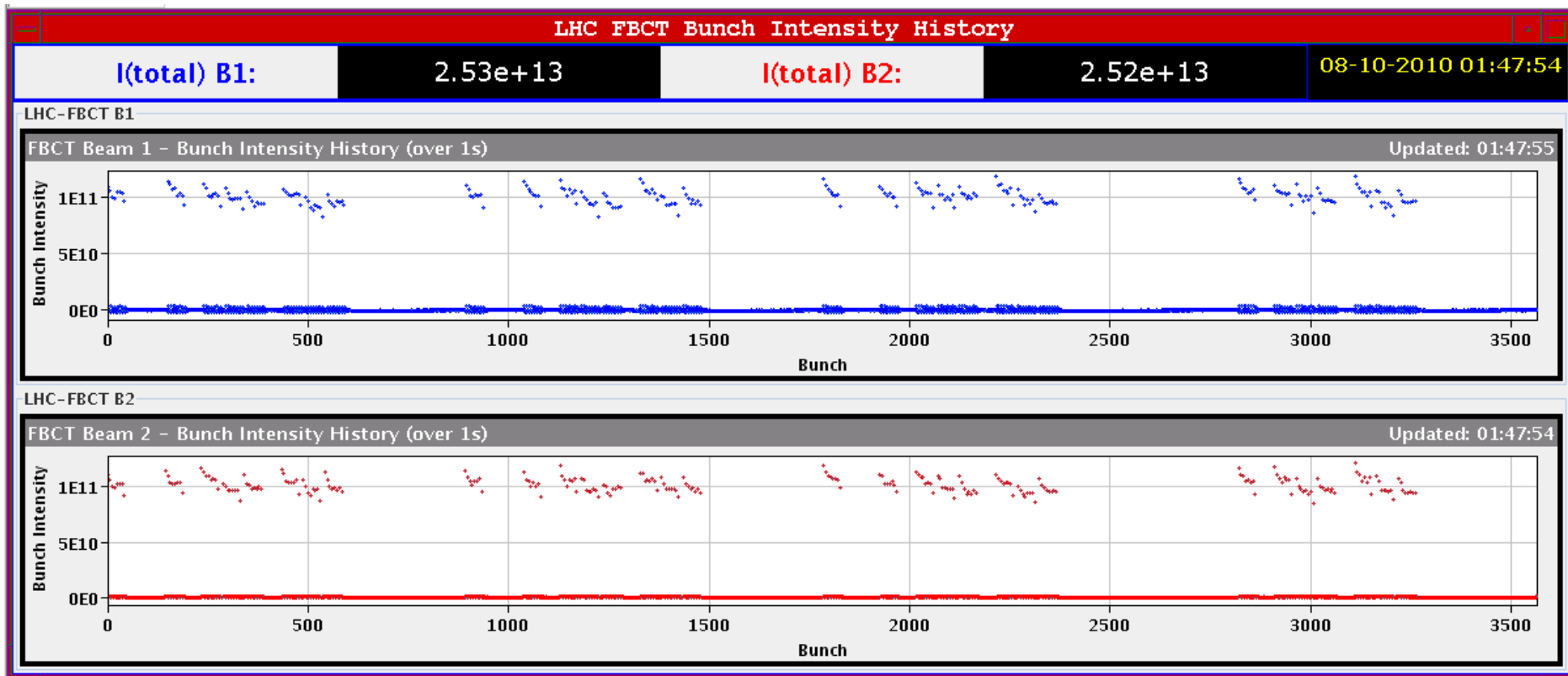
- Injection 24 bunches ok - first time for physics
- Tune Feedback stayed on through the ramp !!
- @ 2:36 declare Stable Beams – kept beams for 6:30 hours
 - Maximum Lumi $8.8e 10^{31}$: Very close to target of $10^{32} \text{ cm}^{-2}\text{s}^{-1}$
 - High Backgrounds at the various experiments



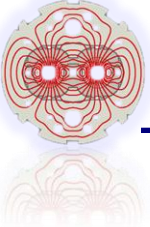
End of fill this morning



Bunch intensities for fill $\approx 1.0e11$ /bunch



2 x 248 bunches

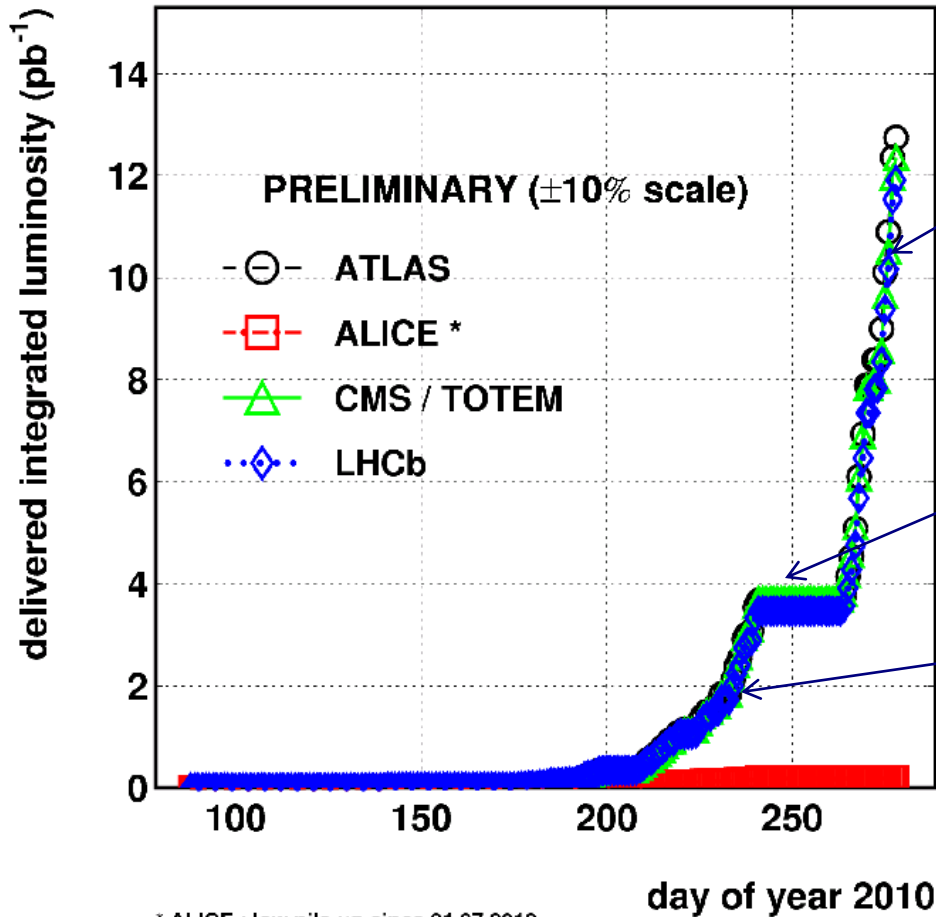


The road to our targets



2010/10/07 10.36

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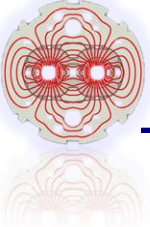
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2 Weeks (!) of Bunch Trains

Development of
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August: Stable running with about 1 μs bunch spacing

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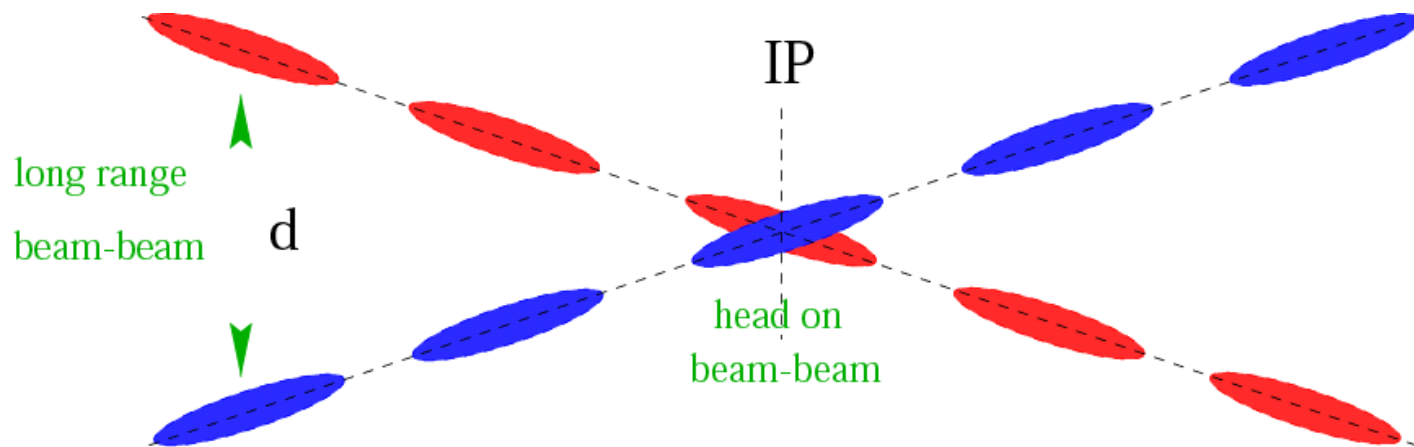


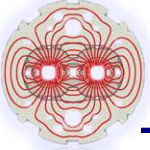
Bunch Trains



- < September: bunch separation between 1 μs and 2 μs
- Nominal bunch separation for 2808 bunches is 25 ns
- In September moved to **150 ns bunch separation**
 - Bunches start to 'see' each other at the Interaction Point
 - Need to put in **Crossing Angle** to reduce the effect of 'Parasitic Collisions' and Beam-Beam effects
 - 170 μrad at injection, as the beams are larger at injection
 - 110/100 μrad at physics energy

For 150 ns spacing, the first encounter is at ± 22.5 m from the IP





Crossing angles at injection

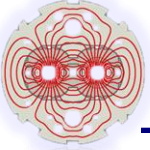


B1 Hor
±10 mm

B1 Vert

B2 Hor

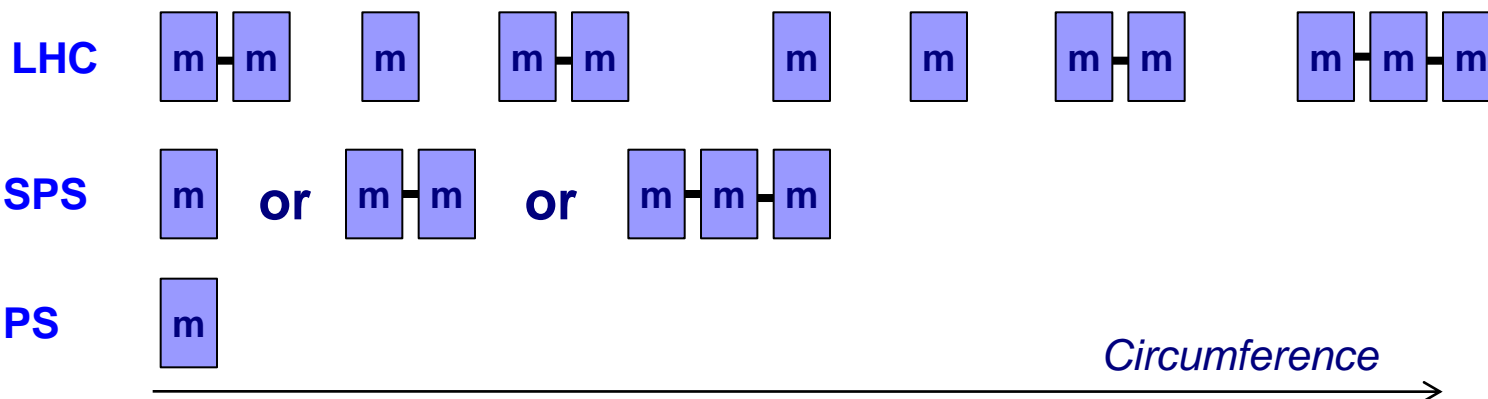
B2 Vert

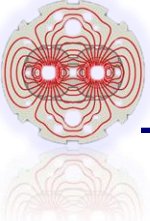


Generation of bunches



- ❑ **PS** produces trains of **m** bunches (spacing 150 ns).
 - **m** = 8 or ~~12~~.
 - **m** is fixed for a given filling sequence.
- ❑ **SPS** assembles **n PS** trains of **m** bunches
 - **n** = 1,2,3 or 4. Yesterday injected with $3 * 8 = 24$ bunches
 - train spacing defined at injection to SPS, presently 300 ns.
 - **n** may change for each cycle.
- ❑ **LHC** requests **p SPS** train groups
 - **n** may vary from one injection to the next.

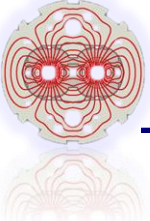




Injection set-up with more bunches



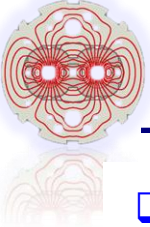
- ❑ Injection is becoming more critical:
 - *Injected beams have now a real damage potential.*
 - *Losses at injection collimators become more critical – also shower into the machine and the experiments*
 - ***Debunching of the already circulating beam can lead to beam dump during injection.***
 - **Abort gap cleaning by exciting particles in the gap (→ collimators) may soon become mandatory.**
- ❑ Overall - injection is going rather well: injection 24 bunches this morning
- ❑ Injected emittance can be less than 2 μm – almost a factor 2 below nominal value (3.5 μm).
 - *Emittance increase to collisions under control (transverse damper) – routinely start collisions with emittances below nominal (better for B1 than for B2).*
 - ***Direct gain of luminosity, up ~30%.***



Strategy to Increase Intensity



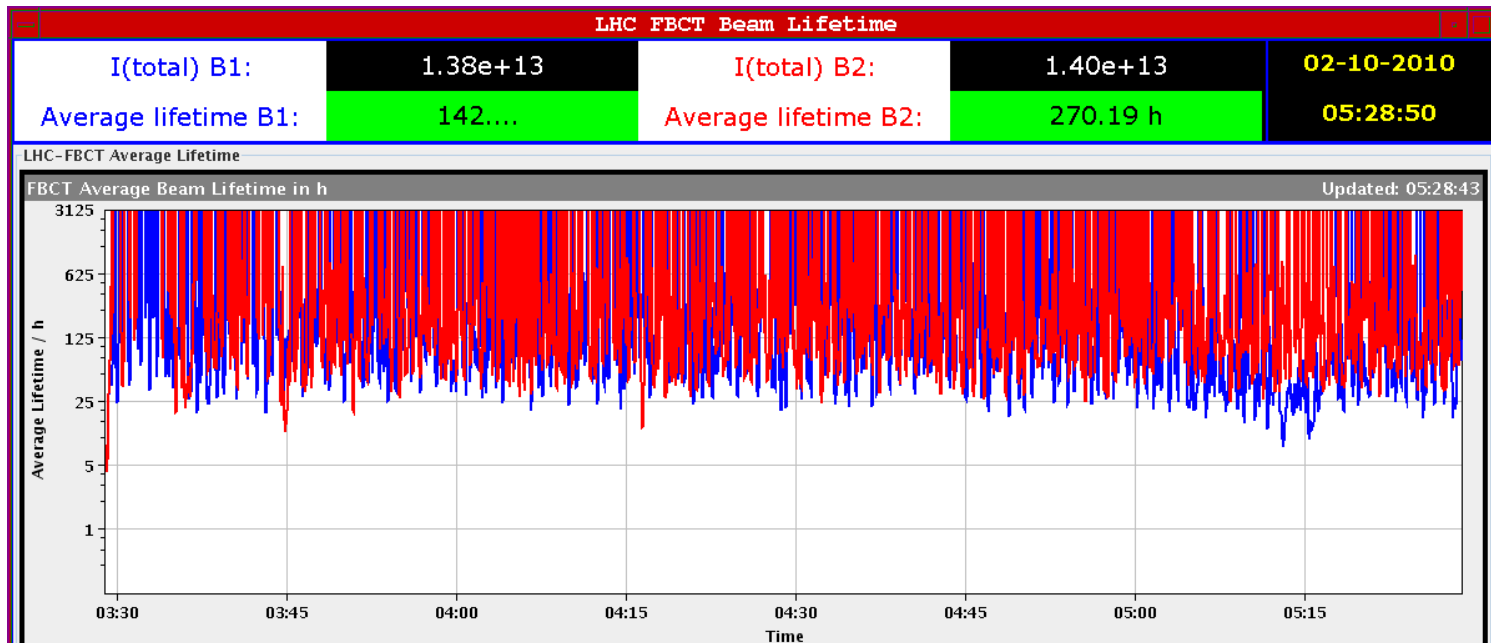
- Machine Protection driven
- rMPP with check list before increasing intensity
- Need at least
 - 3 Successful fills brought into Physics
 - At least 20 h in physics
 - No Accidents, measurable within tolerance
 - Everything understood
- Not more than about 20 injection
 - Inject bunch trains of 8 + 8 + 8 bunches from the PS into the SPS in one batch into the LHC

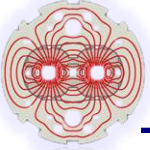


Collisions with Bunch Trains



- Beam current lifetimes in collisions now ≥ 25 hours.
 - *No more lifetime dips when bringing beams into collisions.*
 - ***Excellent news is that the beam-beam effects (both head-on and long-long range) seem much less critical than anticipated.***
 - ***>> Can think of more bunch current, smaller emittance !***
- Luminosity decay dominated by emittance growth,
 - *Current decay ~30-40%*
 - *Emittance growth ~60-70%*

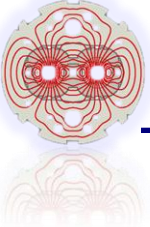




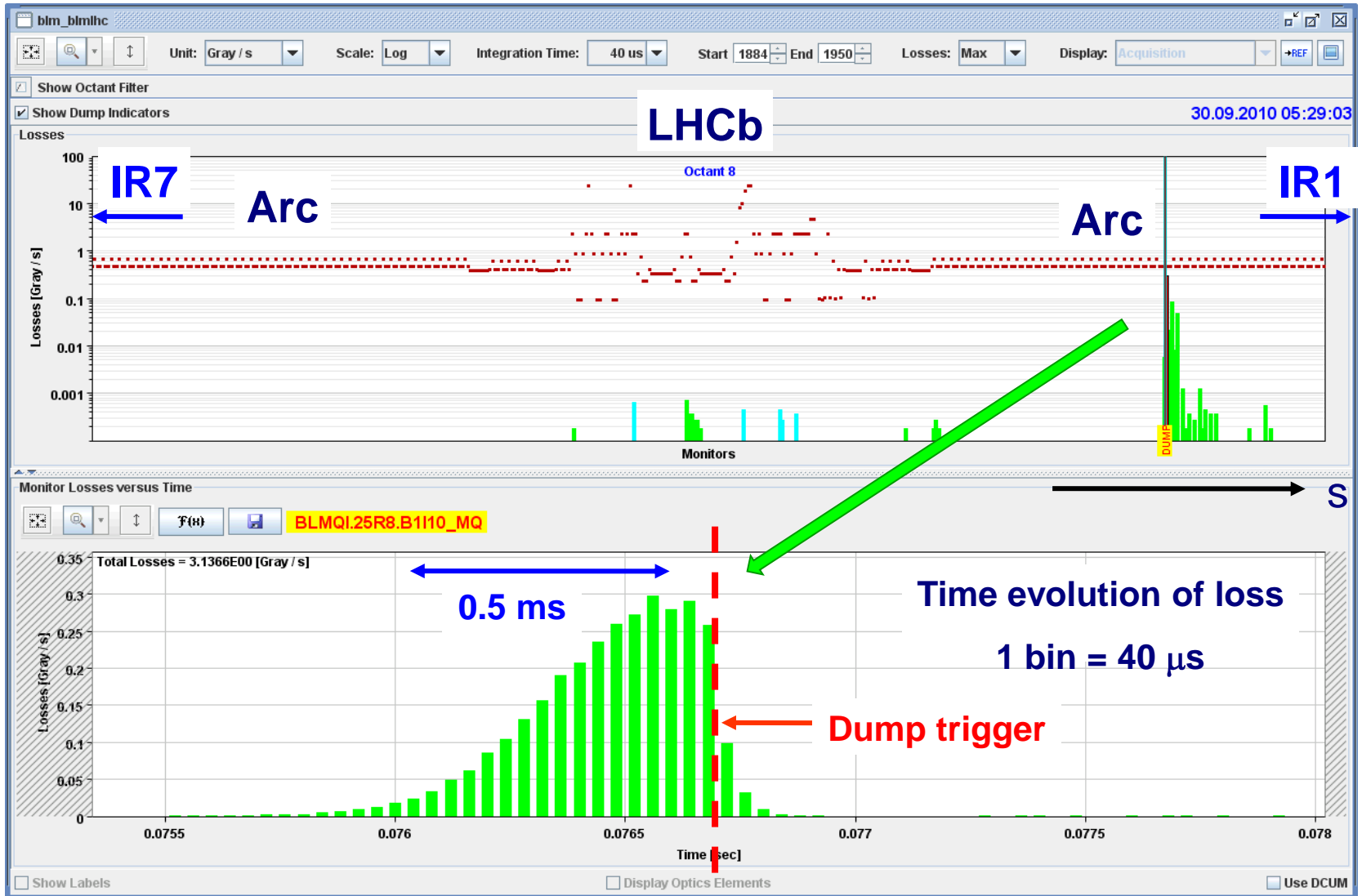
Unexplained Beam Dumps: UFOs

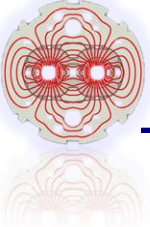


- On 7th July we observed the first occurrence of fast beam loss events in the super-conducting regions of the ring:
 - *Beam loss at a SC magnet.*
 - *Fast loss over ~0.5-2 ms.*
 - *Most events during stable beams: no power converter changes, orbit rock-stable, no lifetime issue before the event...*
 - *Loss at regions of very large aperture > 40 beam sigma (collimators between 6 and 15 sigma).*
- The hypothesis quickly emerged that it is not the beam that moves to the aperture, but rather the opposite !
 - *'Dust' particles 'falling' into the beam, estimated size ~100 μm think Carbon-type object.*
 - *Two events in perfect coincidence (time & space) with TOTEM roman pot movements make this hypothesis rather convincing.*
 - *However, Totem moved in without problems over last 2 fills.*



Beam loss monitor post-mortem



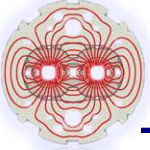


Dump on integrated loss



About 50% of the UFOs lead to dumps while the loss is decaying...

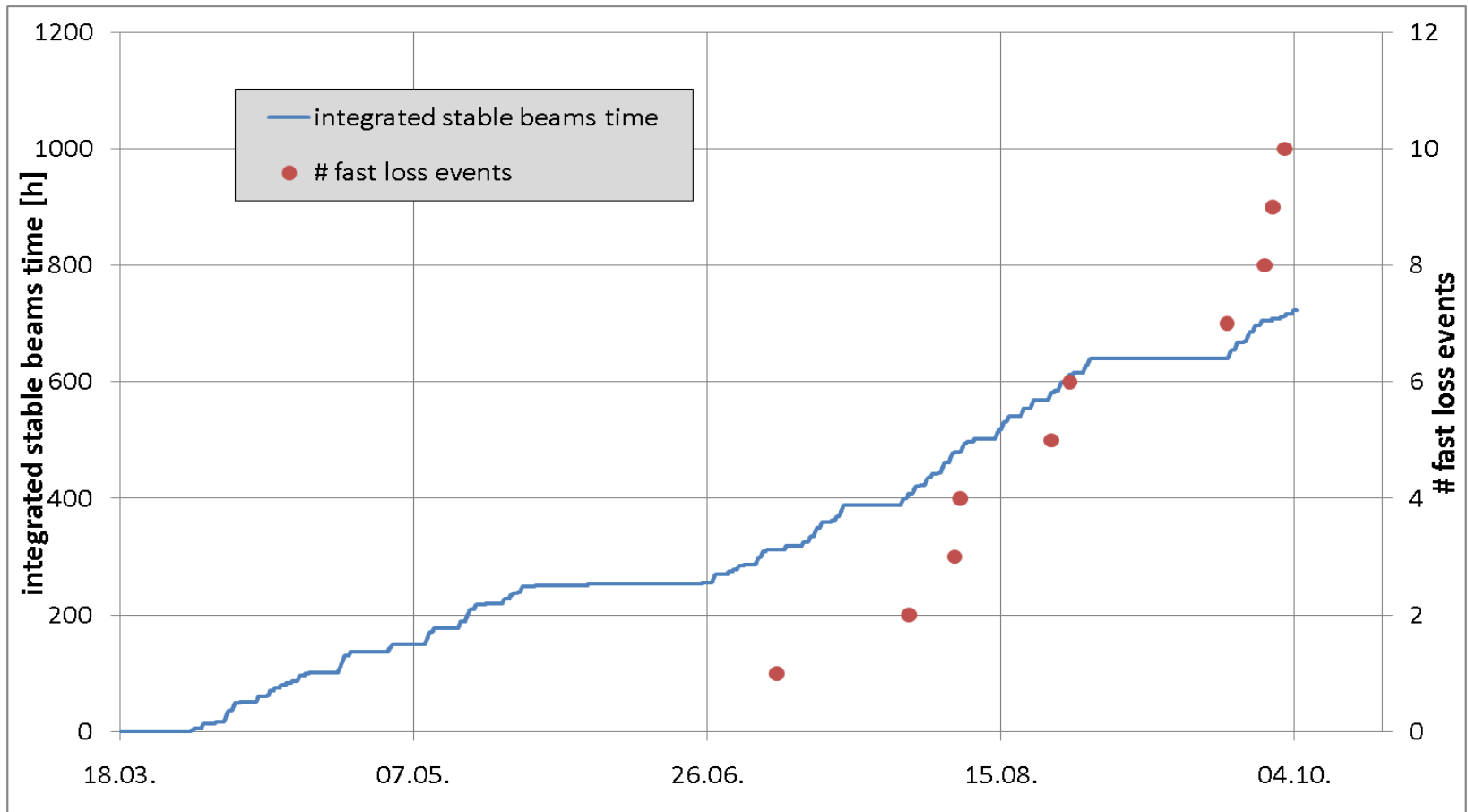




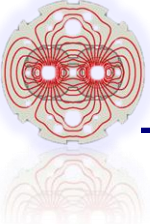
UFOs – Unidentified Beam Losses



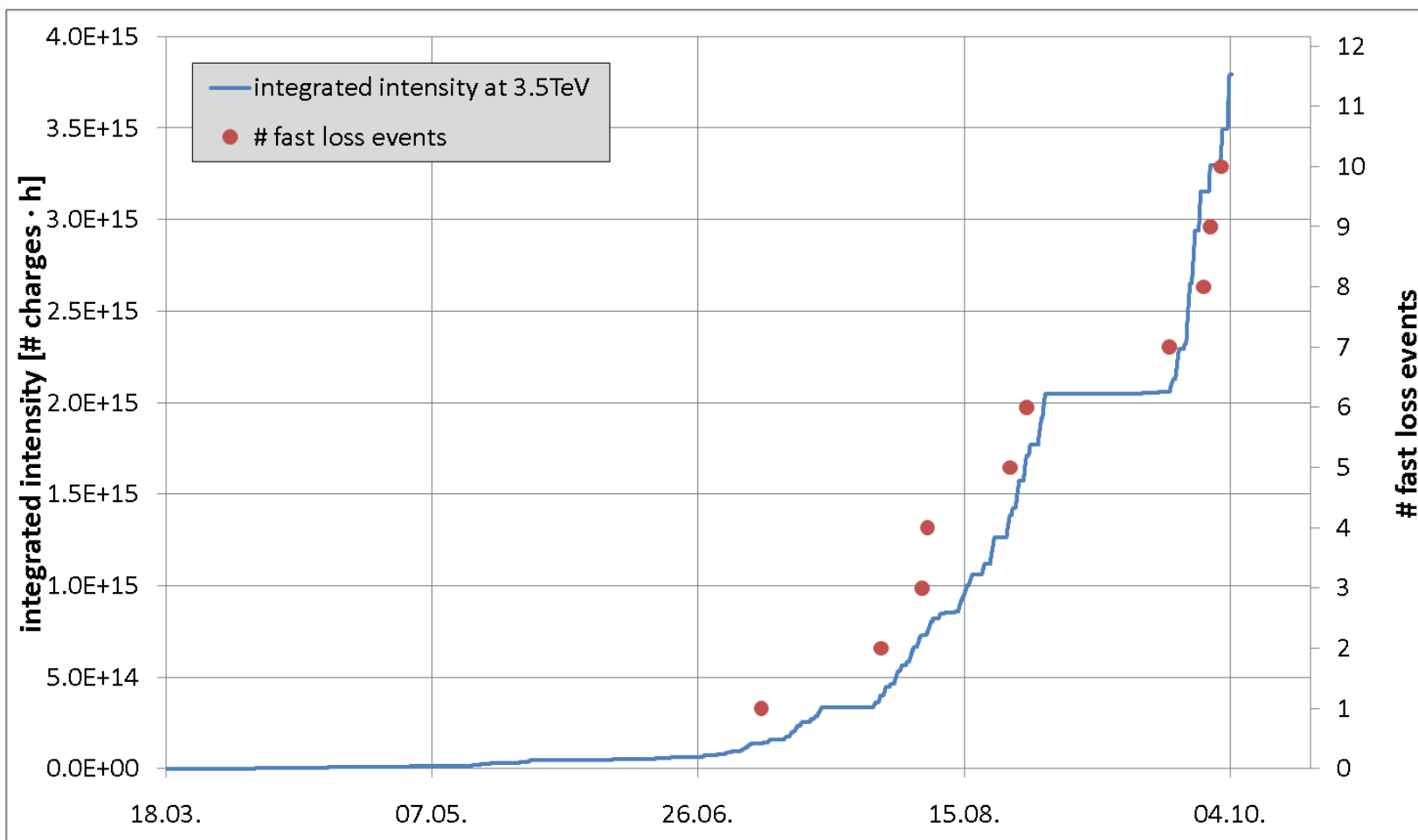
- The number of UFOs is not only correlated to the time in stable beams
 - Many more UFOs observed in the last months with high intensity



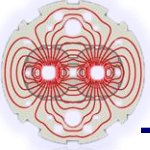
T. Baer



UFO: related to Intensity * time



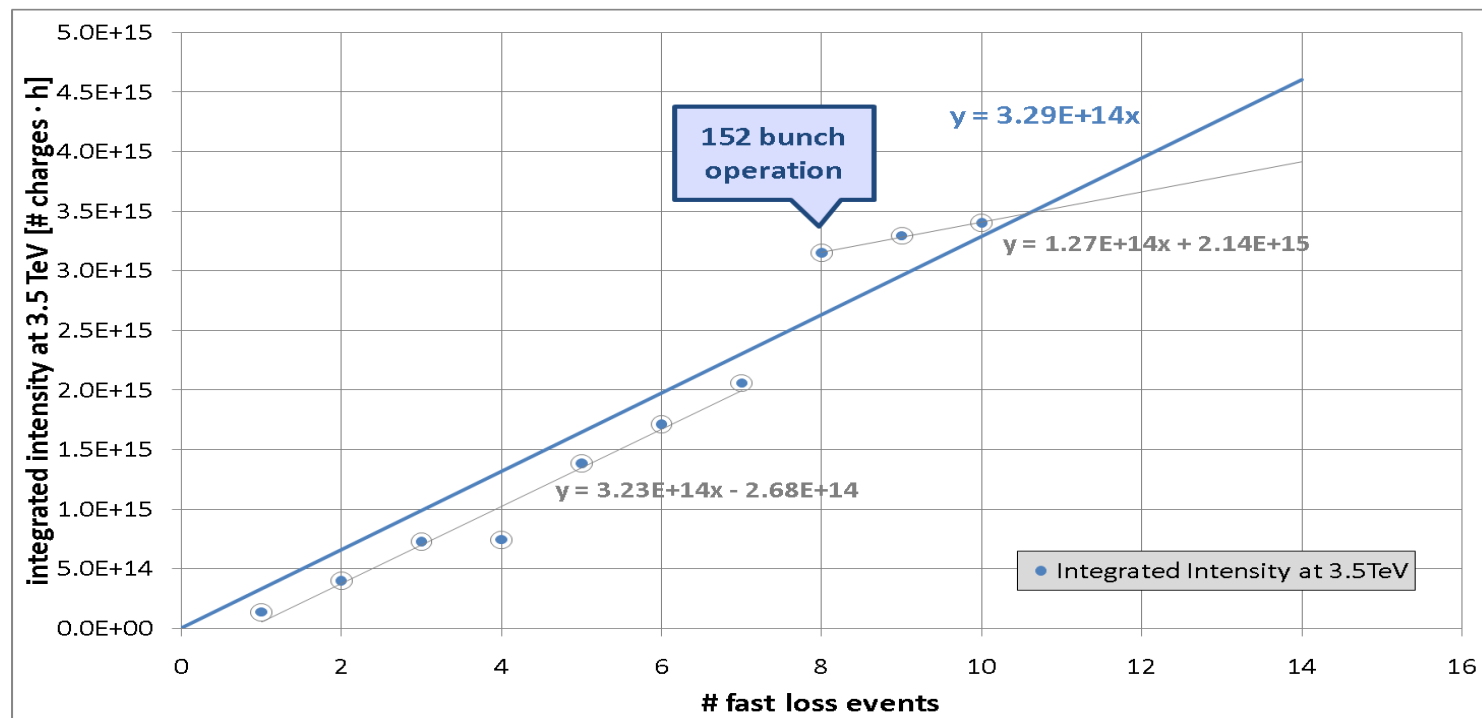
Excluded Totem UFOs



Latest news on UFOs



- Last fills didn't see any UFO
- Seems to flatten out
- No UFO's over the last days with record intensities
 - But we also increased the BLM threshold





UFO – Increase of BLM thresholds



- ❑ We have accumulated 12 UFO events (→ beams dump).
- ❑ Strong hints that things become worse with intensity.
- ❑ So far there was no quench – the BLMs triggered first.
 - *In many cases the signal was just above threshold of the BLMs...*
- ❑ Last weekend (2/3 October) **we have increased the dump thresholds of almost all BLMs at super-conducting elements by a factor 3**.
 - *Since then no new UFOs were observed !*
 - *Initial thresholds were set to 30% of quench level – we are now essentially at the estimated quench level.*
 - *New models of the magnet cooling indicate more margin than initially estimated, and the BLM response is tuned on a different loss scenario (beam on the beam screen).*
- **Cross Fingers !**

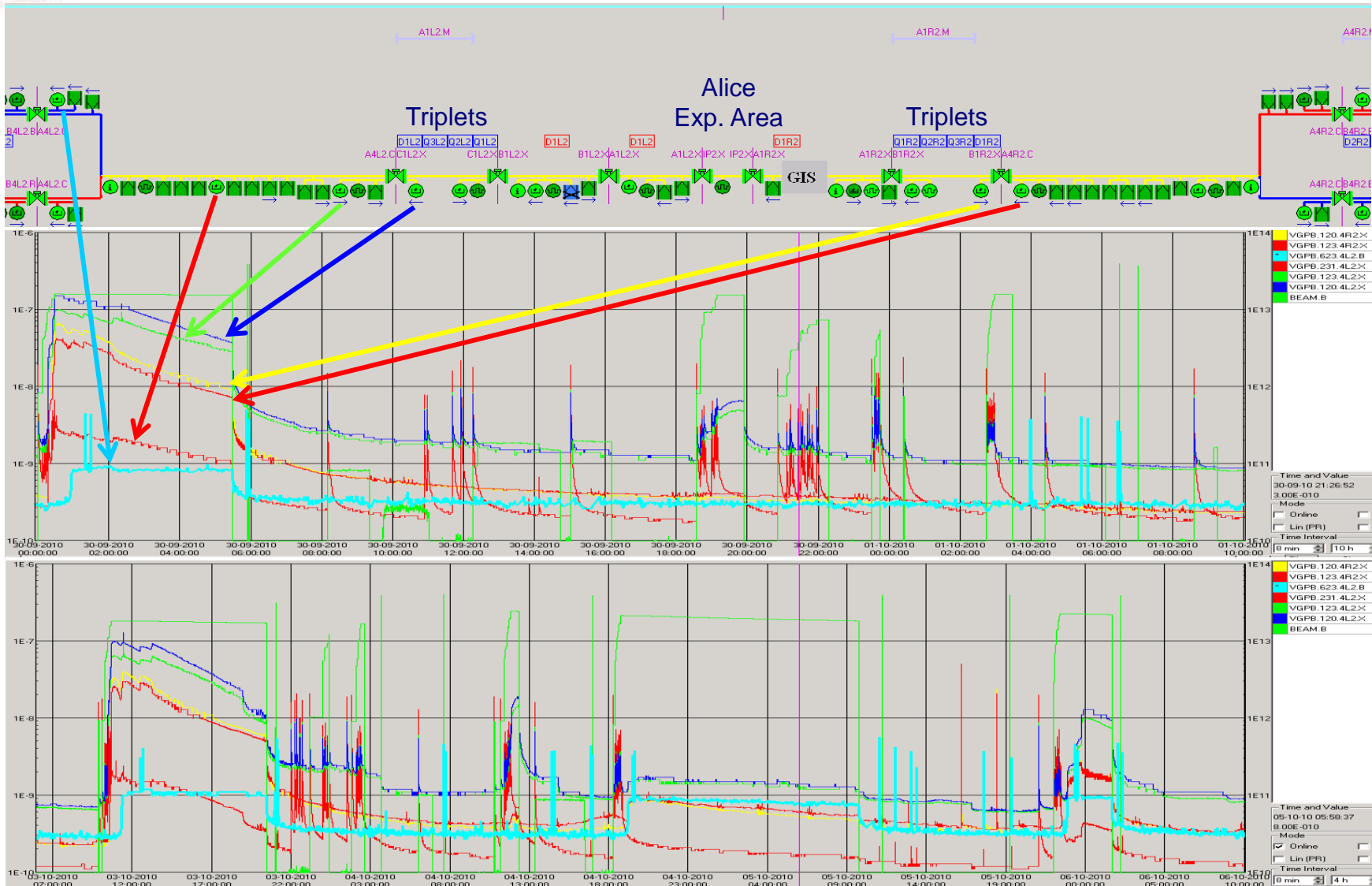


Vacuum near the Experiments

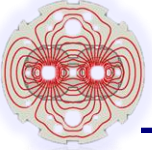


- ❑ Vacuum activity in the common beam chamber of all experiments.
- ❑ Local pressure bump around ± 60 m from the IP.
 - ❑ Uncoated segment of vacuum chamber at the warm-cold transition of inner triplets
- ❑ Pressure rise driven by the presence of both beams
 - *Higher backgrounds.*
 - *Driven by beam and bunch intensity*
 - *Possibly higher order mode heating from the beam.*
 - *Possibly due to synchrotron light heating desorption D1/D2 and Quads*
 - *Possibly Electron Cloud*
 - *NOT due to some beam losses as nothing on BLMs*
 - *Same order of magnitude everywhere (towards 10^{-7} mbar).*
 - *Gets worse when beam intensity goes up*
 - *Improves when running at same beam intensity*
 - *Cleaning effect*
 - *Valves will close if $p > 4 \cdot 10^{-7}$ mbar in 2 out of 3 gauges. Still ok.*

Location of 'Bad Vac' at Alice



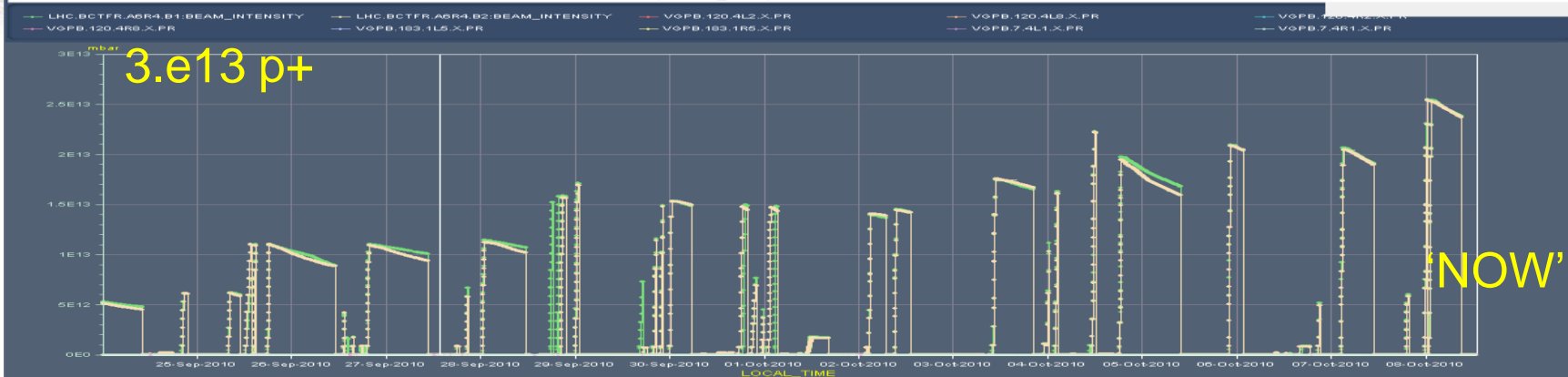
M. Jimenez



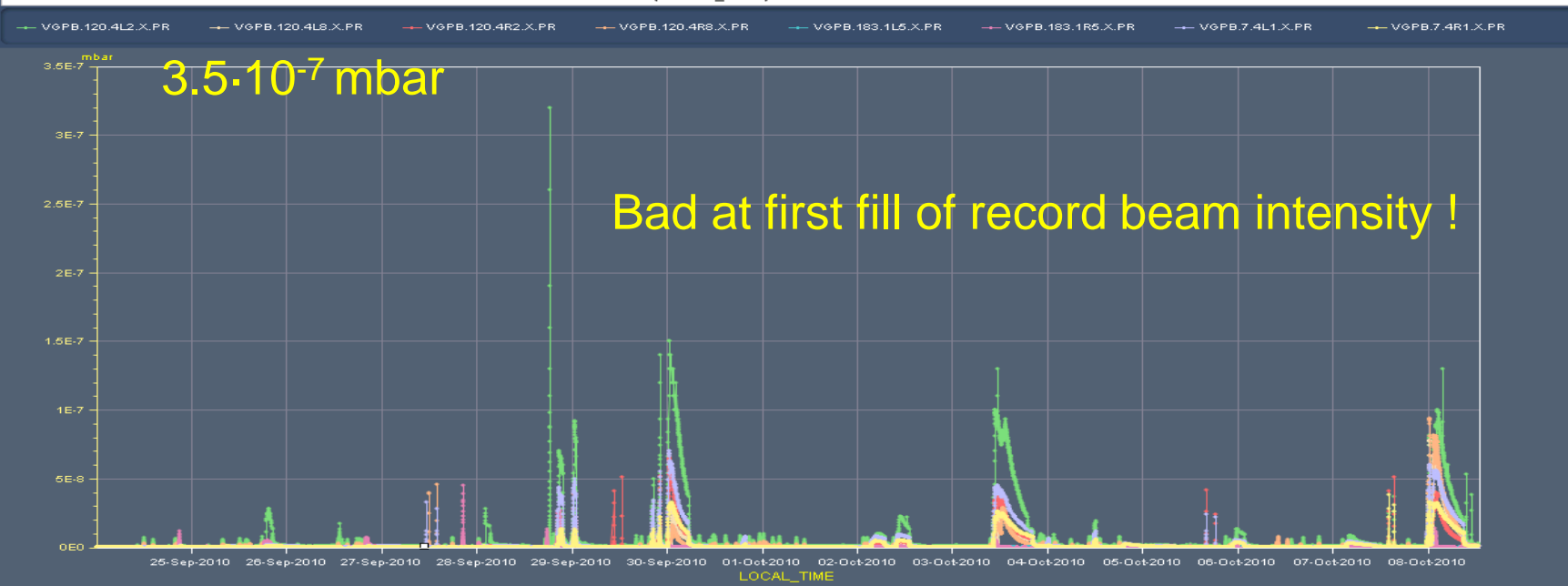
Bunch Current & Vac last 2 weeks



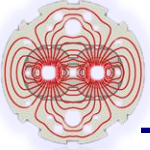
Timeseries Chart between 2010-09-24 00:00:00.000 and 2010-10-08 12:52:53.881 (LOCAL_TIME)



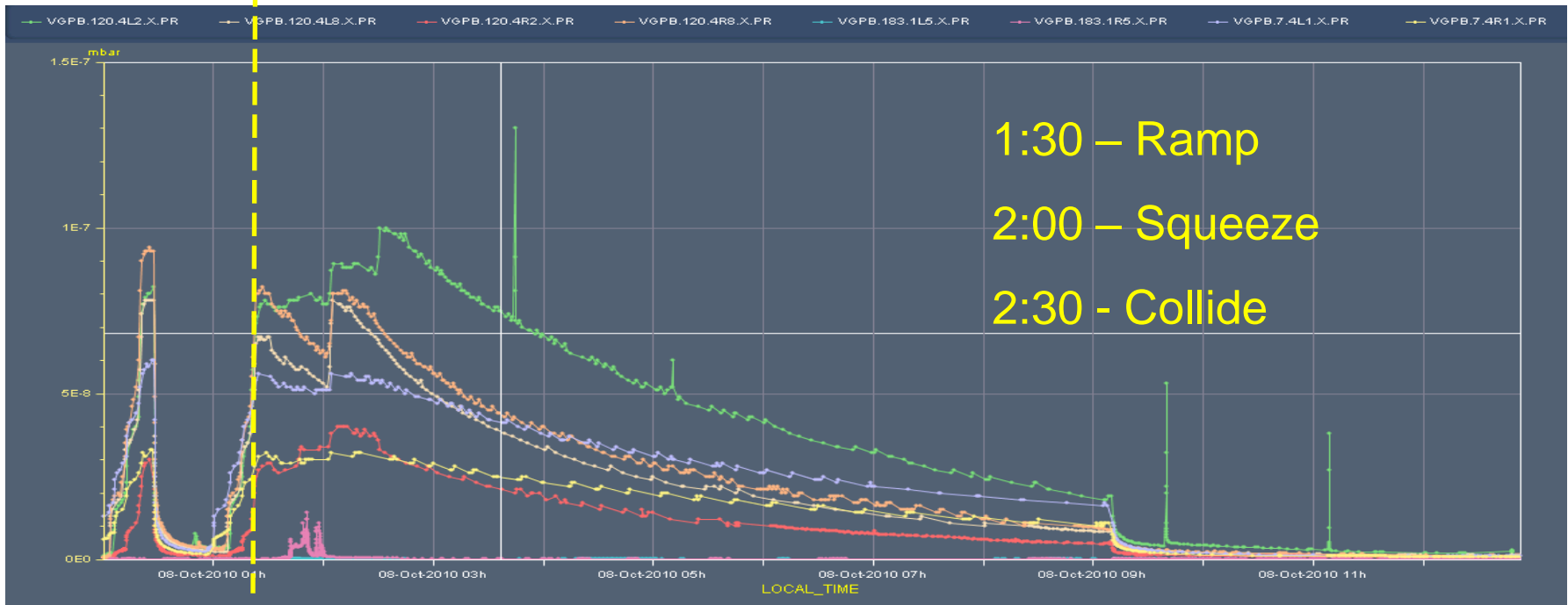
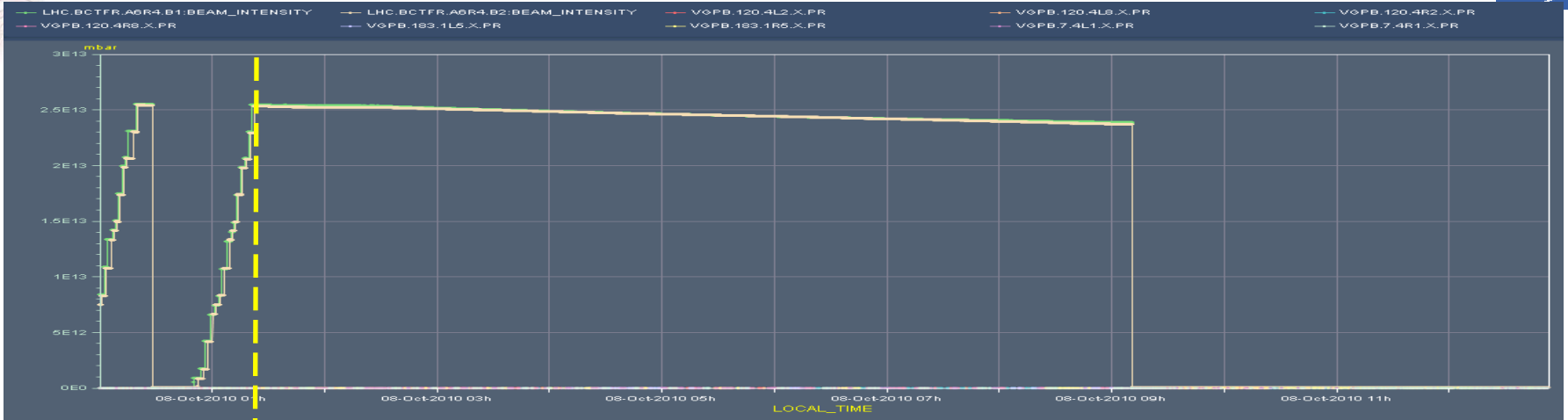
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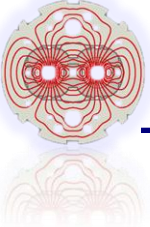
— VGPB.120.4L2.X.PR
 — VGPB.120.4L8.X.PR
 — VGPB.120.4R2.X.PR
 — VGPB.120.4R8.X.PR
 — VGPB.183.1L5.X.PR
 — VGPB.183.1R5.X.PR



Same plots for last fill



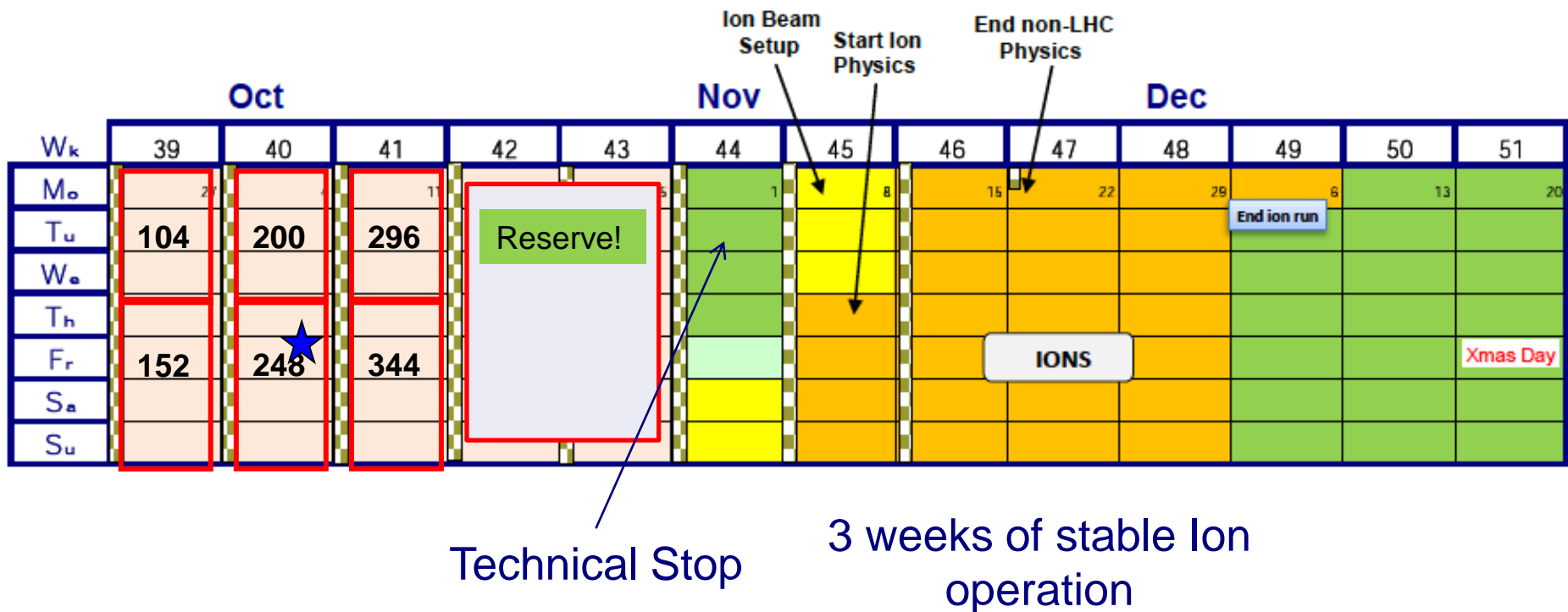
1:30 – Ramp
 2:00 – Squeeze
 2:30 - Collide

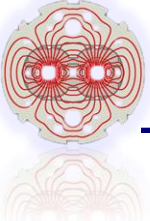


Outlook for the coming weeks



- Increase to 344 bunches
- Assuming we manage to follow this plan, by end of W41 we should collect **another ~20-25 pb⁻¹**.
- If the reserve is used for physics, with 6 fills per week it is possible to collect **~40 pb⁻¹** more since for 350 bunches fills deliver **~3-4 pb⁻¹ per 12 hours**.

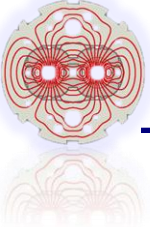




Things to do instead of Physics (3 wks)



- Further Increase Number of bunches – 400 bunches
 - Inject 32 bunches at a time
- Change parameters
 - Try bunch trains of 50 ns to prepare for operation with more bunches
 - Very interesting to check effect on vacuum!
 - Long range beam-beam
 - RF capture
 - Beam Instrumentation
 - Commissioning of Abort Gap Cleaning
 - Quench tests at 3.5 TeV
 - Commissioning of PLL system to measure tune
 - Not limiting transverse feedback strength
 - Increase of bunch intensity
 - Determine limits on β^* for 2011 - Check aperture at full energy



		Early (2010/11)	Nominal
$\sqrt{s_{NN}}$ (per colliding nucleon pair)	TeV	2.76	5.5
Number of bunches		62	592
Bunch spacing	ns	1350	99.8
β^*	m	2 → 3.5	0.5
Pb ions/bunch		7×10^7	7×10^7
Transverse norm. emittance	μm	1.5	1.5
Initial Luminosity (L_0)	$\text{cm}^{-2}\text{s}^{-1}$	$(1.25 \rightarrow 0.7) \times 10^{25}$	10^{27}
Stored energy (W)	MJ	0.2	3.8
Luminosity half life (1,2,3 expts.)	h	$\tau_{\text{IBS}}=7-30$	8, 4.5, 3

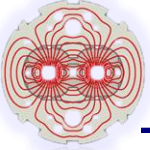
- ❑ Peak luminosity $\sim 10^{25} \text{ cm}^{-2}\text{s}^{-1}$, integrated L \sim few μb .
- ❑ Bunch charge corresponds $\sim 6\text{E}9$ – equivalent to a pilot proton bunch.
 - Visible on beam position system only down to $\sim 2-3\text{E}9$ (with good quality !)



Operation with Ions



- ❑ At the LHC the difference between Pb ions and protons is very small because of the high energy.
 - *Same orbit, tunes, optics, geometrical emittance...*
- ❑ Main difference between ions and protons is the RF frequency (revolution frequency):
 - *RF frequency swing 5 kHz instead of 800 Hz (wrt 400 MHz).*
 - *Difference in frequency is vanishing at 3.5 TeV : ~ 10 Hz.*
- ❑ It is possible to reuse almost all proton settings for ions !
- Some changes wrt protons:
 - ❑ We may remove the crossing angle – partly your choice.
 - ❑ Collimation does not work well for ions due to fragmentation.
 - *Basically a single stage system. Details of settings not finalized yet.*
- ❑ MPS issues are minor – no special setup.
 - *But we will keep our eyes open !*



Conclusions



- Things are going very well
 - Only had two weeks of bunch train operation
 - Today with 2 x 248 bunches, following aggressive schedule
- Almost reaching this year's target of $L = 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
 - Fill of this morning peaks at $0.88 \cdot 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- 'Challenges' – things not really understood
 - UFOs : fewer & increased BLM thresholds
 - Vacuum around Experiments: conditions with constant beam intensities, but goes up when intensity goes up
- Another 3 weeks of proton running
 - Further increase number of bunches
 - Collect Luminosity
 - Tests to prepare for next year
 - 50 ns bunch train operation & others
- Followed by Technical Stop and Ion operation