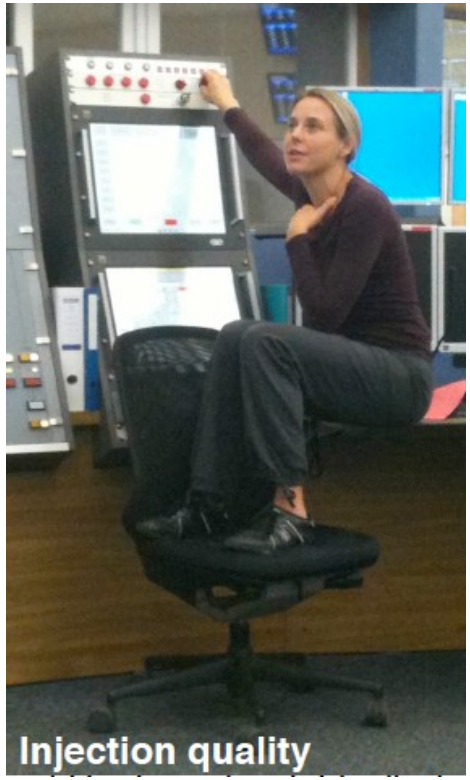
Evian wrap-up

Mike Lamont



Sessions 1 & 2

LHC BEAM OPERATIONS

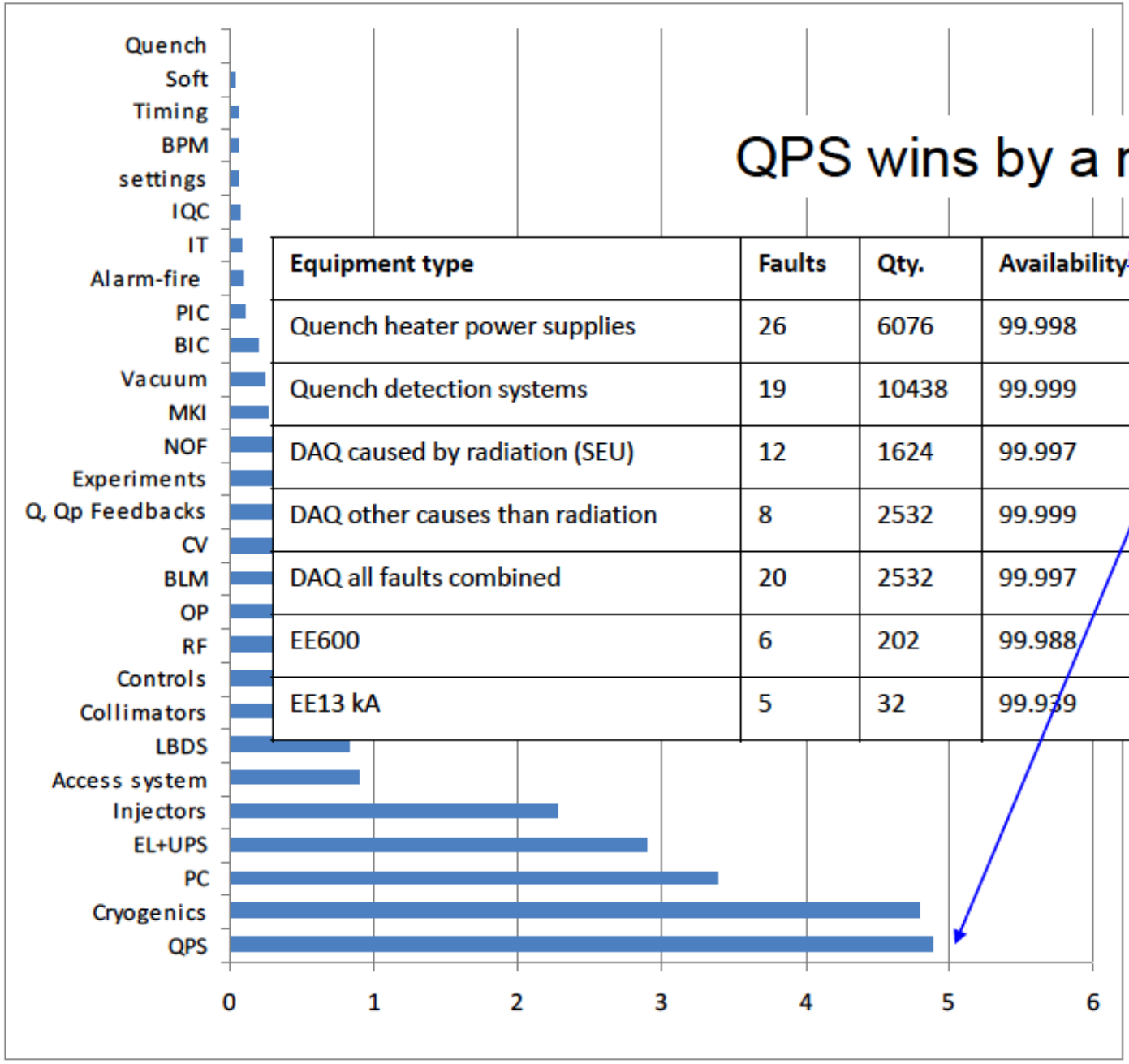
Very nice 2010 statistics summary

Walter Venturini

- 2010 run was driven by commissioning, not physics
- Equipment performs above expectations (MTBF etc)
- Equipment groups are aware of the weak points and are working to improve them

- Technical stops mess us up but it's getting better
- Impressive, impressive availability for a first full year
- Must consolidate fault statistics gathering
  - Walter – brain the size of a planet – he's got better things to do

All faults downtime distribution



QPS wins by a neck…

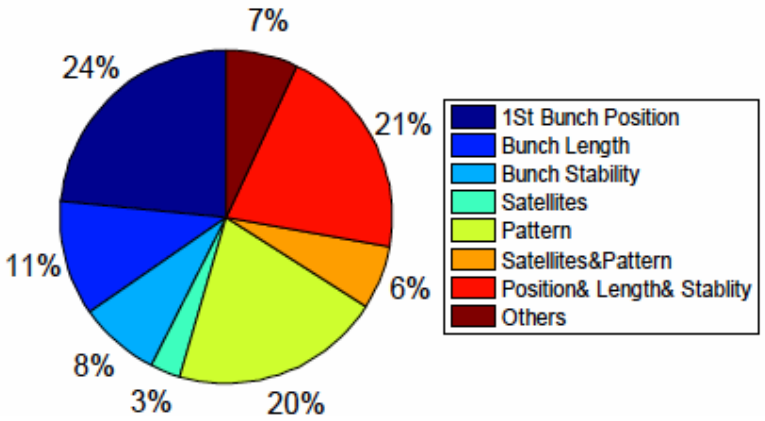
Equipment type	Faults	Qty.	Availability[1] [%]	MTBF [hours]
Quench heater power supplies	26	6076	99.998	1145760
Quench detection systems	19	10438	99.999	3362135
DAQ caused by radiation (SEU)	12	1624	99.997	828240
DAQ other causes than radiation	8	2532	99.999	1936980
DAQ all faults combined	20	2532	99.997	774792
EE600	6	202	99.988	206040
EE13 kA	5	32	99.939	39168

R. Denz

Beam quality and availability from the injectors

- Clear procedures needed (scraping, blow-up etc.)
  - Preparation in good time, check lists
- Must be able to track beam quality through the injectors
  - Emittances, intensities
- LHC request must be clearly communicated in good time
  - Talk to you suppliers
- Nice long list of RF improvements in the SPS
- Dedicated LHC filling to be pursued

Giulia Papotti



Turnaround optimization

Stefano Redaelli

- *Turnaround time dominated by the injection time: more than 2h lost!*
  - Nice set of proposals for improving length of time spent at injection
- **We hope to achieved turnaround time close to 2h**
  - *Requires significant improvement of the injection.*
  - *"Manual" changes should be reduced to a minimum.*
  - *Can gain probably 10-15 min with the squeeze. DON'T STOP.*
- **We do not seem to be yet in the position to gain from aggressive approaches**
  - *Continuous functions for ramp, squeeze and collision or combined*
  - *Ramp&Squeeze become interesting when present issues are solved.*

Mistakes are expensive – target eliminating these

Software & controls

Delphine Jacquet

- Long, well order list of improvements
  - Equipment control; Injection sequencer, state machine; LSA; Alarms; Diamon…
- Sequence need to be nailed down – team handed
- How are we going to organize tackling a lot of stuff in very little time?

We need: faults and overall efficiency:
fill summaries, automatic run and fault statistics

Can we improve the magnetic model/cycle and its effects?

- Ramp-down for access settings
  - (Check out differences between precycle and ramp-down-combo)
- There are instructions for what to do with cycle trips
- Go dynamic on b3 compensation at injection
  - ~20 units of decay, as expected by FiDeL, but on much longer time constant
  - Measure and implement
- Remove hysteresis handling
- Rollback decay driven trims before starting each injection
- Chromaticity during ramp
  - Tracked within ±7 units – we can improve the initial part

Ezio Todesco

The human factor

- Discipline
- Communicate
- Protect
- Document
- Ergonomics

- Machine protection envelope
- Experience can be a dangerous guide

Alick
Macpherson

RF

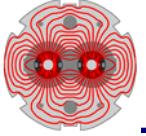
P. Baudrenghien

- Cogging works well
- 50 Hz is no problem in the ramp
- Blow-up in the ramp to avoid lost of Landau damping
  - Longitudinal blow-up has performed…perfectly
- September - reconfigured the RF for higher intensity and faster ramp
  - No more idling cavities. All klystrons ON
  - Counter phasing at 450 GeV
- Capture losses
  - the sensitivity of the BLM dump system to injection loss must be decreased by 2 orders of magnitude (x100)
- RF noise turned out to be a “no-problem” in 2010

- Need a clear strategy for cavity trips in physics
  - Don't panic: 3 out of 8 with 15% of nominal intensity was OK
  - But will have to dump with nominal intensity
- If you do fill the abort gap, wait.

- Problems listed
  - Noisy cavities: These problems are worrying. To be investigated during hardware re-start. We do not know what it is…

- Incoming
  - SPS-LHC phase energy matching
  - Longitudinal damper
  - Coupled bunch instabilities
  - …

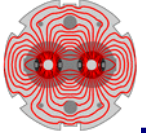


BEAM DIAGNOSTICS AND FEEDBACK SYSTEMS

Bunch by bunch everything

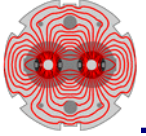
- Orbit
- Head-tail monitor
- BCT
- Longitudinal profile
- WCM
- LDM
- WS
- Sync light
- Experiments' data
- Tune?

- STORAGE, ACCESS & DISPLAY



Feedbacks: Status, Operational Dependencies and Outlook for 2011

- Feedbacks performed well and facilitated a fast commissioning
  - – de-facto required during every ramp and squeeze with nominal beam and expect the same also for next year
  - More than half of all ramps would have been definitely lost without them
  - additional safety margin to operation provided feed-forward is performed regularly
- Good overall performance with little transmission losses and minimal hick-ups related to Q/Q' instrumentation, diagnostics and Q/Q' & orbit feedbacks
  - – However: this year's 1% losses may become more criticial in 2011



Feedbacks: Status, Operational Dependencies and Outlook for 2011

- Tune peak-to-peak stability typically below 0.02 with margin to push it < 0.003
  - – little impact of residual tune error on transmission of
  - – Most RT-trims correlated with Q'(t) ↔ a feed-down effect?
- Q'(t) a bit neglected this year → some indication of trade-off: beam stability (low transmission losses) vs. beam size growth
  - – Could we further explore this via dedicated/controlled measurements?
- Effective ADT noise floor and observed bunch-to-bunch cross-talk hinders reliable operation of LHC's Q/Q'-Diagnostics and related feedbacks
  - Explored alternate BI diagnostic options → the ball is now on the RF group's side

Ralph Steinhagen

Note

- Energy FB@injection
- Got to feed-forward more regularly
- Tune tune to avoid 50 Hz
- Orbit FB should be discussed in a darkened room at some point

Transverse dampers

Wolfgang Hofle

- ✓ commissioned damper at 450 GeV, during ramp and with colliding beams
- ✓ nominal damping rate reached and surpased
- ✓ commissioned operation with bunch train
- ✓ commissioned damper for ions at 450 GeV and with colliding ion beams
- ✓ abort gap cleaning and injection slot cleaning successfully used
- ✓ diagnostics (logging, fixed display, multi-bunch acquisition) available

- (in)compatibility with tune measurement somewhat surprised

  - Lots incoming in 2011
  - Tune measurement options listed
  - Work on compatibility with tune feedback (witness bunches?) Strategy to be defined.

BPMs

- Number of improvements through the year
  - Looking good
- Temperature compensation
- Synchronous mode on IR BPMs
- Cables to be hit this shutdown
- Pre-flight checks with beam
  - After modifications, technical stops
  - Quickly done

- Frequency of calibration?
- Long term drifts?

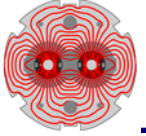
Eva Calvo

Transverse beam size

F. Roncarolo

- Wire scanners
  - Turn and bunch-to-bunch
  - Reference but take care
- BSRT
  - DC and pulsed mode
  - Resolution – optics;
  - accuracy via x-calibration with WS – correction factors not stable
  - Complicated in ramp – change of focusing etc.
  - Bunch by bunch, turn by turn incoming – fast camera
- AGM
- BGI
  - Commissioning phase
  - Calibration with bumps

Want MD time



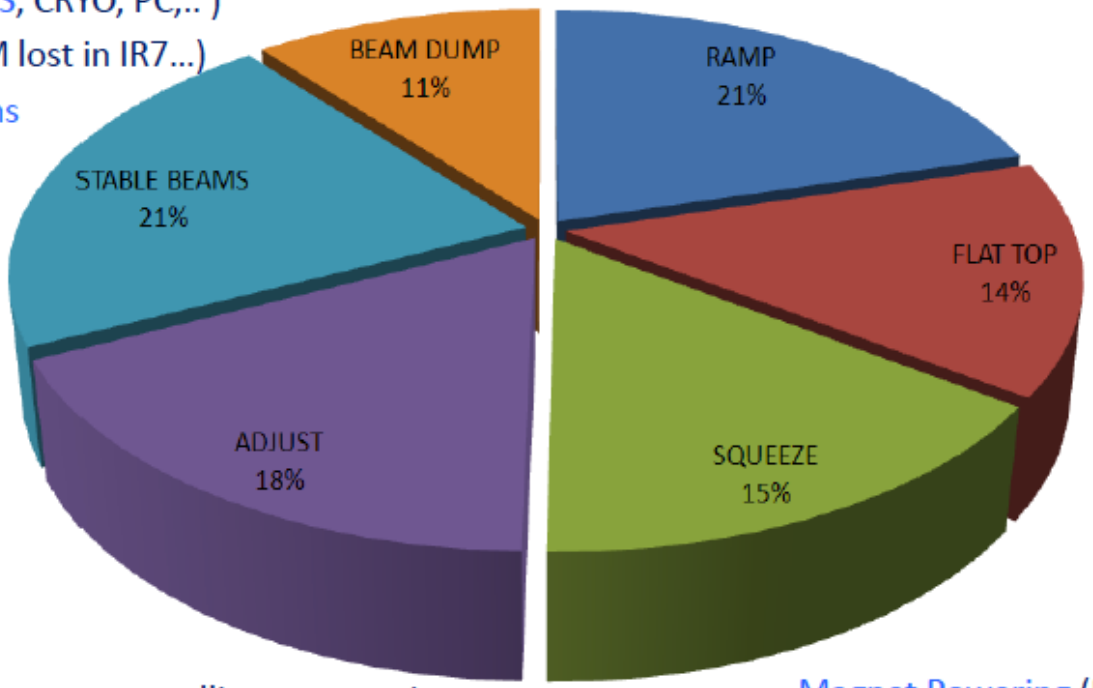
MACHINE PROTECTION

Do we understand everything about MP system response?

Beam dumps as a function of beam mode for fills where energy ramp started and main causes of loosing the beams…

SIS (TCDQ Position, missing energy)
Magnet Powering (Orbit Feedback, etc..)
Collimator interlocks during ramp

>> Fast Losses (UFOs)
Magnet Powering (QPS, CRYO, PC,..)
SW Permit (Orbit, BLM lost in IR7…)
Electrical Perturbations

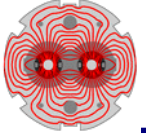


Magnet Powering (OFB/QFB, QPS sector trip, ..)
Loss Maps, Collimator setup, Fast losses
ATLAS

Loss maps, wire scanner tests, collimators moving…
SW Permits (TCDQ position,…)
Magnet Powering (Mostly PC issues, …)

Magnet Powering (Mostly PC issues + FB, CRYO,..)
Fast losses, loss maps,…
SW Permits (TCDQ position, trip of DOCs)

Markus Zerlauth



Do we understand everything about MP system response?

LHC Machine Protection Systems have been working extremely well during 2010 run thanks to a lot of commitment and rigor of operation crews and MPS experts

Most failures are captured before effects on beam are seen, still no quenches with circulating beam (with ~ 30MJ per beam and 10mJ for quenching a magnet)

Beam dumps above injection are rigorously analyzed, we can do better at injection (avoiding repetitive tries without identifying the cause)

Still a lot of room for improving tools for more efficient and automated analysis

No evidence of major loopholes or uncovered risks, but bypassing of protection layers was/is still possible -> Follow-up of MPS Review recommendations

Still we have to remain vigilant to maintain current level of dependability of MPS systems, especially when entering longer periods of 'stable running'

Long list of improvements for 2011 including SMP3

Enforcing a more rigorous approach at injection > 500 kJ?

LBDS and abort gap cleaning

Number of total dump system failures (unacceptable):1 every 1000000 years

- 1 energy tracking error at 3.5 TeV due to instabilities of 35 kV power supplies ➔ beam dump (30/03/2010: media day)
- Asynchronous beam dump, during energy scan without beam (due to spark on the outside of the gate turn-off GTO thyristor):
  - 1 at 5 TeV
  - 2 at 7 TeV

  } Safe margin for 3.5 TeV operation, isolators implemented during technical stops (starting in January 2011 → finished during 2012 TS)
- 4 internal triggers due to vacuum interlocks on the MKB for B2
  - FALSE vacuum pressure reading – logic now changed to use only VAC signal
- **1 Asynchronous beam dump with beam**
- **2 beam dumps induced by TCDQ faults**

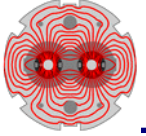
Chiara Braco

LBDS and abort gap cleaning

- LBDS failures occurrence in agreement and not worse than requirements and expectations
  - No damage or quench during synchronous and asynchronous beam dumps
  - Leakage to downstream elements within specifications
  - TCDQ needs TLC – long-term plans to define
- Logic for MKD triggering in case of spontaneous kicker pre-firing to change
  - Pre-trigger of 2 generators is much worse for TCDQ
- Machine protection validation tests, procedures and tests frequency:
  - Is this adequate? (too often, too rarely)
  - Could tests be improved?
  - Do they really insure machine safety?
- XPOC functionalities and upgrade:
  - Missing checks?
  - Different RBAC role needed for XPOC signoff from EiC?
- Abort gap cleaning
  - Always ON at 450 GeV
  - When operational at 3.5 TeV ➔ ON through the sequencer
  - Solution to connect the BSRA to SIS interlock system: how to implement redundancy?

How reliable is the AGM?

10 shifts and 10 ramps (TCQQ-TCT) during commissioning 2011

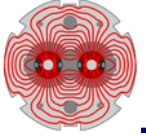


Injection protection:

Are we taking it seriously? How can we make it safer?

- TDIs came in handy
- Reducing limits on injection oscillations
- Improvements incoming
  - Safety, fixes, tightening
- What do we gain with intermediate settings?
  - Different SPS/TL cycles for probe/high intensity
  - Same supercycle?

Verena Kain



BEAM LOSSES

Multi-turn losses and cleaning

D. Wollmann

- Phase-I LHC collimation system delivers expected collimation efficiency. Impact of imperfections factor 2 smaller than predicted (better orbit control in DS).
- Setup procedure has been refined and optimized (15-20mins per collimator needed)
- Validity of collimation setup around 5-6 months, then close to the edge (radiation profile not conform). Might require two setups in 10 months run in 2011.
- Instantaneous peak loss rate about factor 9 lower than specified: With this we should be good for nominal intensity at 3.5 and 4.0 TeV (in terms of cleaning efficiency – other issues like R2E not considered here). NB
- But: Instabilities can increase loss rate and therefore cause collimation induced intensity limitations (possible for higher intensities and energies).

Hierarchy problems noted

Injection/extraction losses

Wolfgang Bartmann

- Limits for 2011
  - 96 or 108b per injection for operation
    → looks OK
  - Injection Tests with higher intensity or 25 ns spacing
    → depending on TL shower/capture loss mitigation

  } Injection

  - Extraction losses on Q4/Q5
    → dominated by shower from TCDQ

  } Extraction

- Loss mitigation at injection
  - necessary to go beyond operational intensity scope
  - potential techniques to further reduce losses need to be
    - commissioned (eg Injection cleaning)
    - installed (eg TCDI and TDI shielding)
    - designed (eg BLM sunglasses)

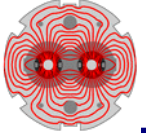
  } partly available in 2011

7-8 shifts for injection commissioning

Losses away from collimators: statistics and extrapolation

Barbara Holzer

- UFOs
  - Scaling with total intensity – extrapolations look worrying
  - Don't appear to get harder with intensity
  - Loss duration falls with intensity
  - Interestingly – hot and cold regions out there
  - Triplet, IRs and arcs
- BLM hardware failures
  - Acceptable!
- 2011
  - 6 days hardware tests without beam
  - 6 hours with beam



LUMINOSITY PERFORMANCE

Longitudinal and transverse emittance preservation

Verena Kain

- Injection
  - 3%
  - Want matching monitor, want it now!
- Until collision
  - ????
  - Luminous region – difficult to deconvolute
- IBS
  - Longitudinal OK
  - Transverse – not so obvious – see more – presumably hump
- Nominal optics
  - Instruments close together – so nominal quoted
  - For quoted emittances?

Beam-beam

Werner Herr

- Forget LEP – we have, we have
- Few problems with head-on beam-beam
- Collisions with separation standard
  - We have forgotten LEP
  - Offsets: S,M,L,XL
- Filling schemes
  - 3 on 3, pacman effects
  - Trains & crossing angles
    - Max. out beam-beam effects
- 150 ns. bbts 0.02
- Limits?
- Long range: effect of reducing crossing angle
  - Depends on beta*, kick in at 50 ns

Beam-beam

- Significant losses going into collisions
  - Get use to it
- Coherent beam-beam
  - …
- 2011
  - Find limits, push N, small emittances
  - Checkout full long range and then squeeze
  - Offset in LHCb should be OK
  - Equalize beam sizes
  - MD…

Strategy for luminosity optimization

Simon White

- Fully automated scans, optimization in parallel - excellent
- Fill-to-fill reproducibility
  - +/- 60 micron
- Alice
  - Optimize vertical plan as well
- Stability during a fill – excellent
- Declare stable beams while optimizing?
- Speed up collision BP?
  - Ramp down separation during ramp.
- Movement at TCTs
  - Tighter limits or move TCTs,
  - Orbit drift, low but fill2fill fluctuations
  - Should be within margins
- Software to be passed on

Move TCTs during large scans etc

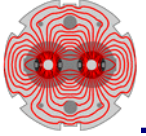
Implementation in LSA already

TEST!

Lumi leveling…?

Distance scale calibration

Dithering



Optics

Rogelio Tomas Garcia

- Beating at injection, during squeeze well corrected
- 2 m. mystery – 10% drift
- 3.5 m.
  - 10% achieved!
  - Slightly worse with LSA… not driving IR3,4,6 and 7
  - Hysteresis – 10% beating at 1.5 m.
- Excellent long-term stability!
- Non-negligible drift 8% observed at injection
- Beta* within 10%
- Beatings going to get worse, but correctable
- IR coupling correction mandatory below 2 m.
- Knock hysteresis handling on the head and knob it

Shopping list

The hump

- Is there all the time. Use the hump buster.
- Emittance blow-up at injection
- Faster decrease in beam intensity in collision
  - Tails, beam loss – nice plots
- Constant magnetic field effect – linear with energy
- Mitigation
  - Low noise TFB at maximum gain
- Incoming
  - On in squeeze next year
  - Optimization of gain in collision
  - More noise reduction
- The hunt continues

Gianluigi Arduini

2011
INCOMING

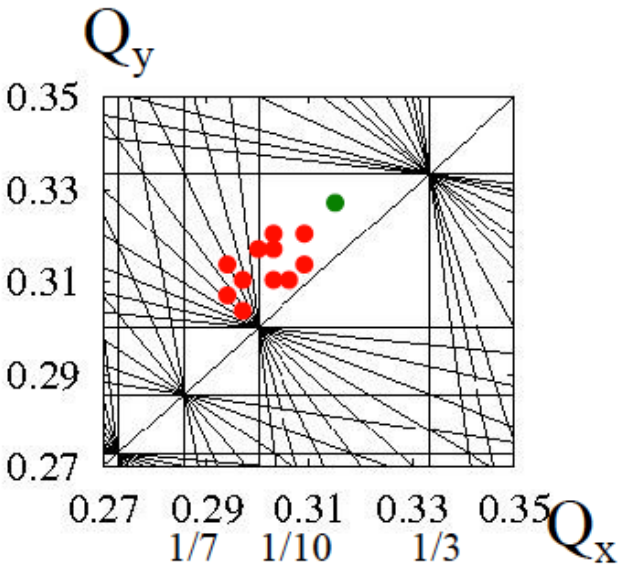
Experiments

Massi

- Seamless injection
- Flip and go polarity reversal
- Van der Meer scans a la go-go
- Luminosity leveling for LHCb
  - Max 3e32, max mu 2.5
- Many fb^{-1} for Atlas and CMS
- Max 4e30 for Alice (beta*, separation)
- Accurate BCTs
- Plus intermediate energy, 90 m. etc.
- 2 months of ions agreed with Alice rep.

Limitations

- Electron cloud
- UFOs
- Beam-beam
- (R2E)



- Need
  - Bunch-by-bunch everything
  - Heat load, RF, vacuum, scrubbing monitoring
  - UFO display
  - Tune scans, tune diagram and spread
  - DA scans
  - Automatic Giulia plots

Oliver Bruning

50 & 75 ns

- Really kicked off with 50 ns
- But saw it in single beam warm sections with 75 ns
- Scrubbing time constant around 8 hours with 50 ns
- Scrubbing at tighter bunch spacing buys margin
- Scrub with your expt. solenoids off
- Scrubbing in arcs with 50 ns but not 75 ns
- Scrubbing at 450 GeV is good for the arcs
- 50 ns: see instabilities developing along the trains – curable with high chromaticity
- Possible coupled bunch modes with 75 ns
  - Plus head-tail
  - Feedback, low chromaticity as cures

50 & 75 ns

- 75 ns: incoherent effects with low e-cloud density
  - 30-40% emittance blow-up
  - (with high chromaticity)

This would imply having a period of 1 week for scrubbing at 50 ns (based on extrapolations from experimental data ➔ to be corroborated by simulations - ongoing -) with ~1.3-1.5x10^{11} p/bunch in order to run with 1.3x10^{11} p/bunch (maximum possible in the PS at present) with 75 ns later

- RF also needs to be conditioned for high intensity

Gianluigi Arduini

Ramping up in intensity

- "Just because we have a check-list doesn't mean we're safe"
- Reviews and staged increase served us well in 2010
- Similar in 2011
  - Back-up to 300b in 50 bunch steps
    - Would imagine starting with 75 ns
    - In 2010 took around 4 days (minimum) per 50 bunch step
      - Machine availability, lost fills (UFOs…)
    - 50 – 100 – 150 – 200 – 250 – 300
    - Around 3 weeks to get back to 300 bunches
  - 100 bunch steps thereafter.
    - 400 – 500 – 600 – 700 – 800 – 900
    - Around 3 weeks

β* - how low can we go?

Roderick Bruce

- Aperture larger than expected
- Scaling to 3.5 TeV (orbit uncertainty 3 mm, measured beam size…)
  - Could go to 2.5 m without reducing present margins
- Decrease margins
  - TCT/triplet: 1.5 σ
  - Reduce margin TCT-dump protection from 5.7 to 3.4 σ

VdM – TCTs must follow

- Assume
  - Nominal 0.7 mm separation – should bring down in ramp
  - Using measured beating at injection and top energy with 5% reproducibility, 10% beating in n1 calculation
  - 3mm orbit shift in pessimistic direction between measurement at injection and top energy
  - 12 sigma beam-beam separation (larger than nominal)
  - Triplet aperture at injection 2 sigma larger than global limit

How low can we go?

Three sets of margins evaluated. Possibilities at 4 TeV:

- Keeping 2010 margins: $\beta^*=2.5$ m with scaling
- Moderate, reducing margins to feasibility level observed in 2010 operation: $\beta^*=1.5$ m with scaling
- Nominal: not possible with present orbit stability

Proposal for 2011 running: $\beta^*=1.5$ m, intermediate settings, margins: 1.5 σ aperture–TCT, 2.1 σ TCT–TCDQ. n1 gives slightly more pessimistic results but we have seen that aperture is larger than predicted

Any β^* and collimator settings will be qualified through provoked losses before being used during runs!

Beam parameters @ injection (SPS)

From E. Metral

75 ns	N_b [10^{11} p/b]	ε_n [μm]
1-batch	1.2	2

OK in terms of density

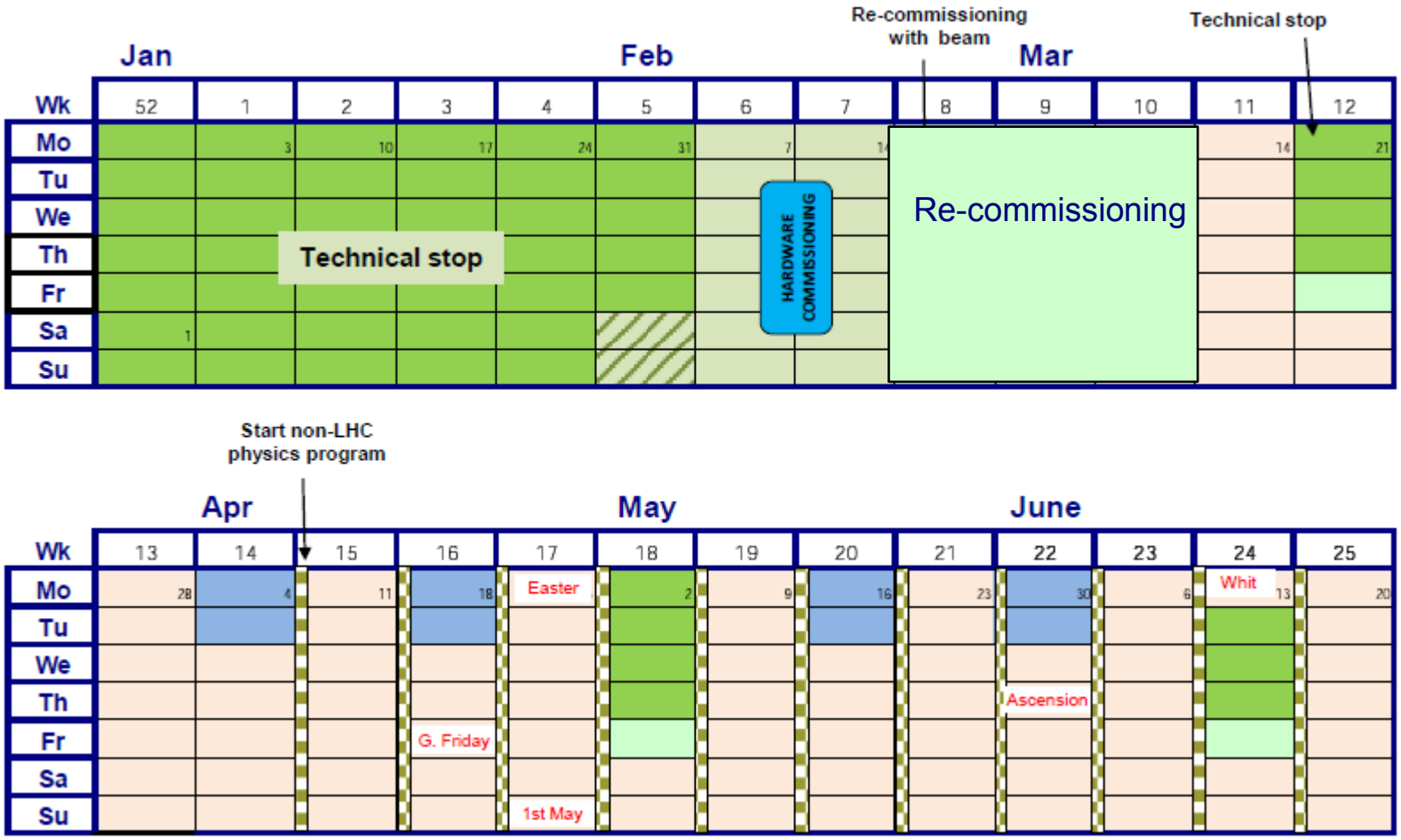
50 ns	N_b [10^{11} p/b]	ε_n [μm]
1-batch	1.15	2.5
1-batch	1.6	3.5
2-batch	1.15	1.5

Options for 2011

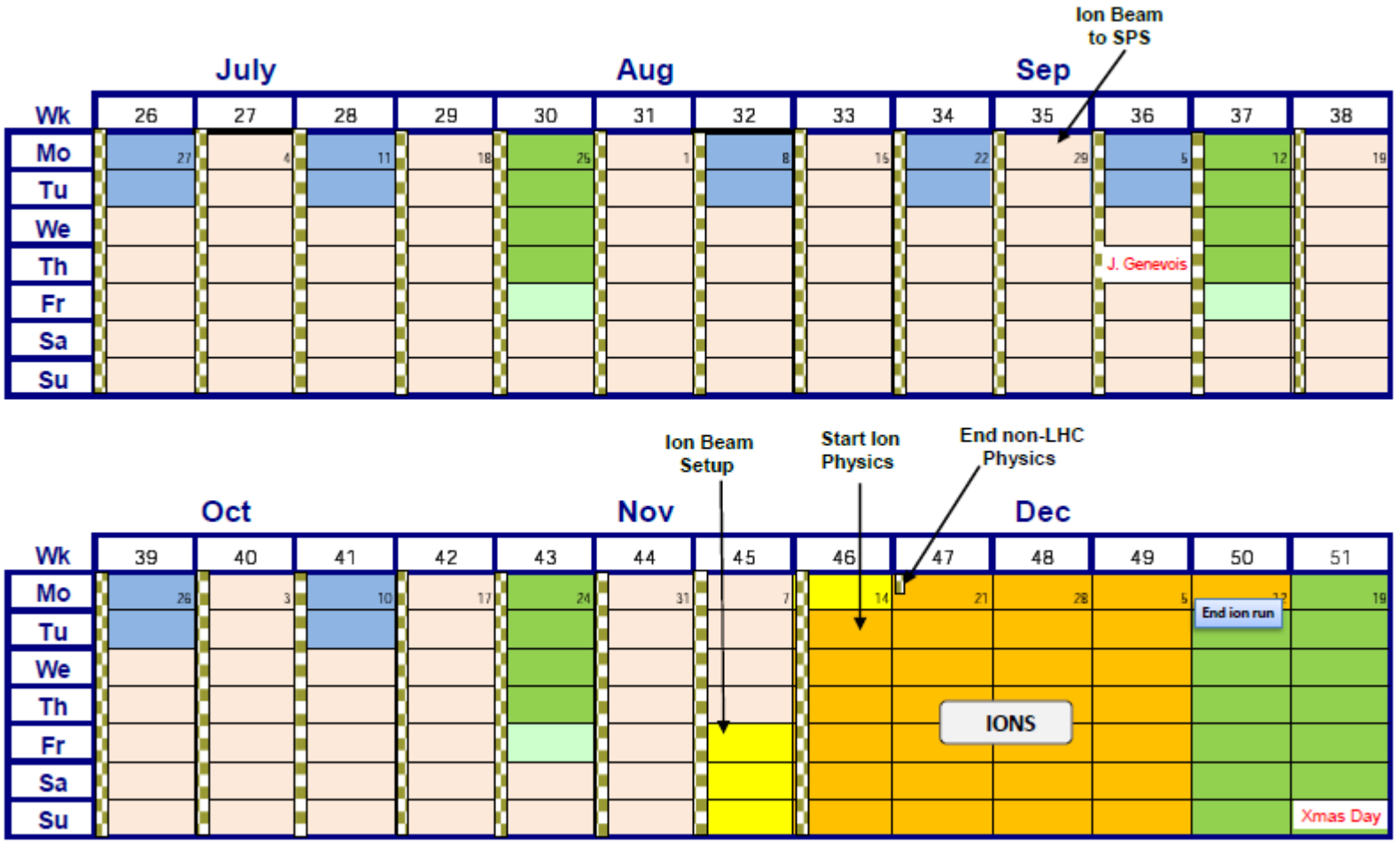
Goal: 1 fb^{-1}

- Energy to 4 TeV under consideration
  - Not yet given
- No limit on beam intensity from collimation
- Reduction of beta* to a minimum of 1.5 m
  - Collimation, aperture, orbit look OK
  - Alice and LHCb (max. lumi 1e32) to be decided
  - Between 2.5 to 1.5 m certainly possible
- Bunch intensity at least nominal
  - 1.2e11 with emittance of 2 micron – 75 ns – single batch
- beta* Alice and LHCb to be defined
  - LHCb: 5 to 3.5 m (semi-dynamic squeeze?)
  - Alice 10 m and accepted overhead of commissioning squeeze for ion run?

Draft LHC schedule 2011 Q1 & Q2



2011 Q3 & Q4


Ion Beam to SPS
July
Aug
Sep
Wk
26 27 28 29 30 31 32 33 34 35 36 37 38
Mo
Tu
We
Th
Fr
Sa
Su
J. Genevois
Ion Beam Setup
Start Ion Physics
End non-LHC Physics
Oct
Nov
Dec
Wk
39 40 41 42 43 44 45 46 47 48 49 50 51
Mo
Tu
We
Th
Fr
Sa
Su
End ion run
IONS
Xmas Day
Technical Stop
Recommisssoning with beam
Machine development
Ion run
Ion setup

2011 schedule

First beam: 21st February

End proton run: 10th November

	Days
Re-commissioning	21
Machine development	22
Technical stops	30
(Scrubbing run)	(7)
Special physics runs	10
Ramp-up to peak luminosity	40
Peak luminosity	133
Total	263

2011: conservative-ish numbers

- 3.5 or 4 TeV
- 930 bunches (75 ns)
- 3 micron emittance
- 1.2 x 10^{11} protons/bunch
- beta* = 2.0 m, nominal crossing angle
- Hubner factor 0.2

Peak luminosity	~7 x 10^{32}
Integrated per day	12 pb^{-1}
~170 days	~2 fb^{-1}
Stored energy	63 MJ

Lot of variations possible (see Steve and Jorg):
1 to 3 fb^{-1} looks reasonable
1 x 10^{33} $cm^{-2}s^{-1}$ not out of reach – usual caveats

Conclusions

- Come a phenomenally long way in 9 months
- Notable feature - remarkable maturity of some key systems after just a year
  - It hasn't come for free
  - It's been years in the preparation
  - Devil is, as always, in the details, lots to follow-up
- Possible improvements, consolidation detailed for all systems
- 2011 clearly aims to leverage off of what's been learnt this year
- With some known problems incoming:
  - UFOs, electron cloud, R2E…
- We'll be pushing up Ralph's stored energy plot
  - LET'S TRY NOT TO BREAK IT!