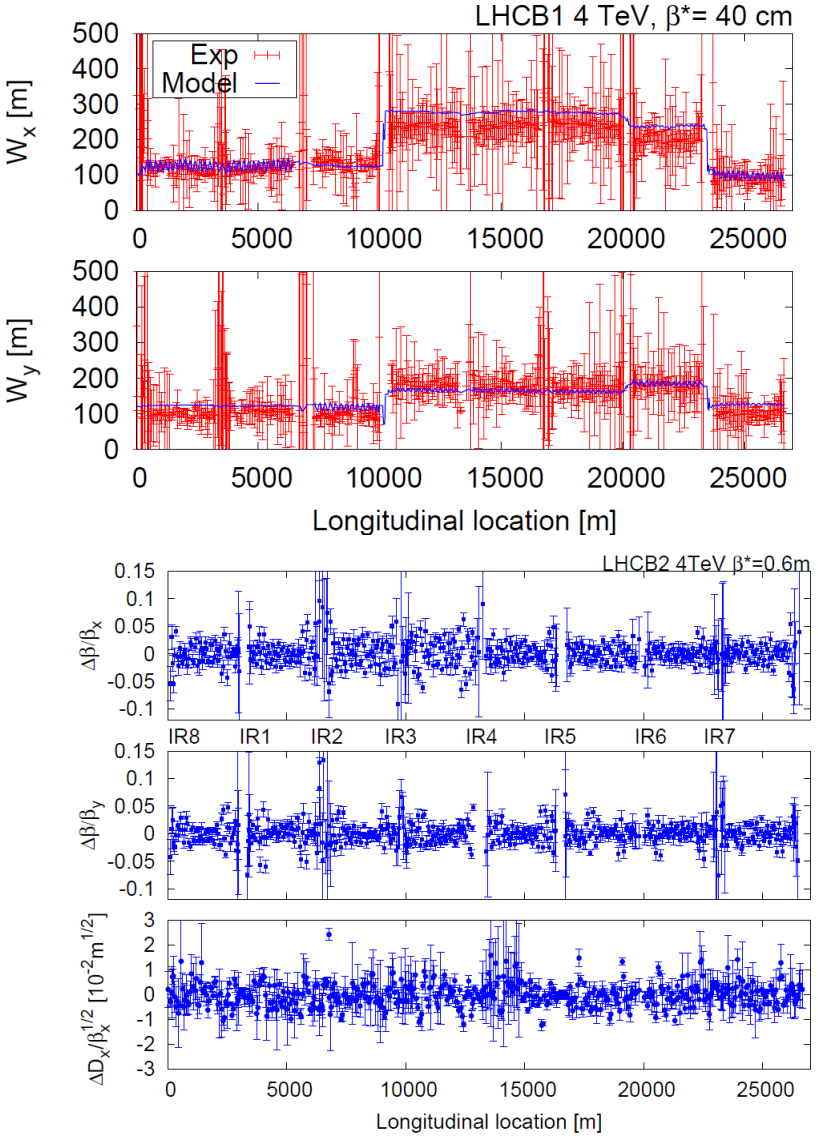
Closeout

G. Arduini, R. Tomàs

A success story…

P. Skowronski

- Optics as expected thanks to:
  - careful design
  - accurate magnetic measurements
  - Excellent tools and instrumentation to measure and correct optics errors
- Allowed us to operate safely the machine at high intensity with high luminosity



- Second Workshop: LHC Optics Measurement and Corrections review
- Why?

Physics after LS1: standard model and beyond

- Outstanding achievements of RUN 1 define a rich set of physics goals
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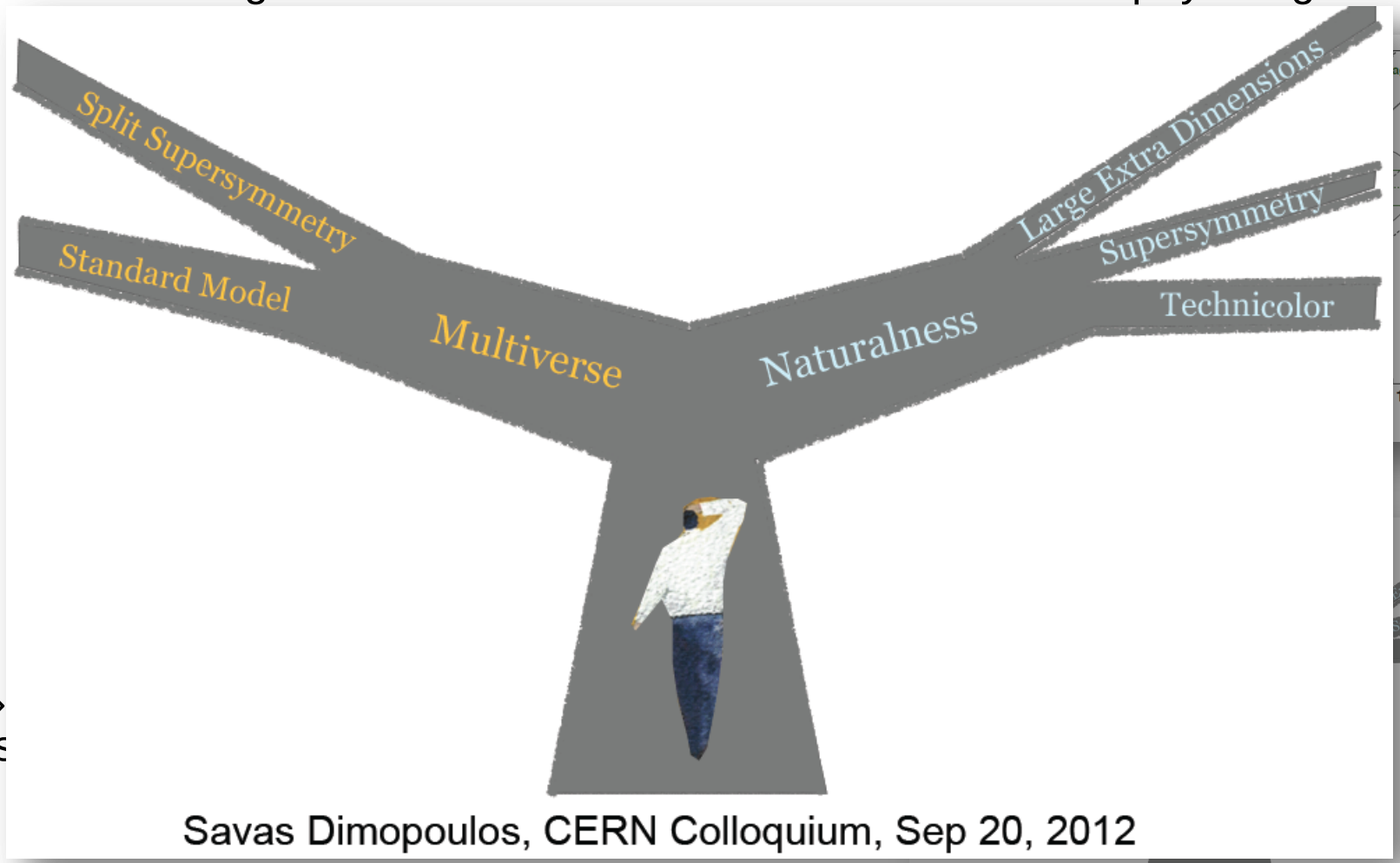
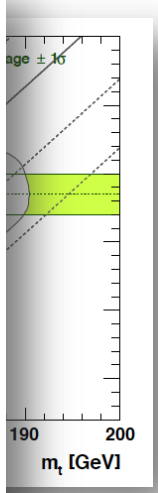
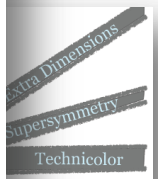
us

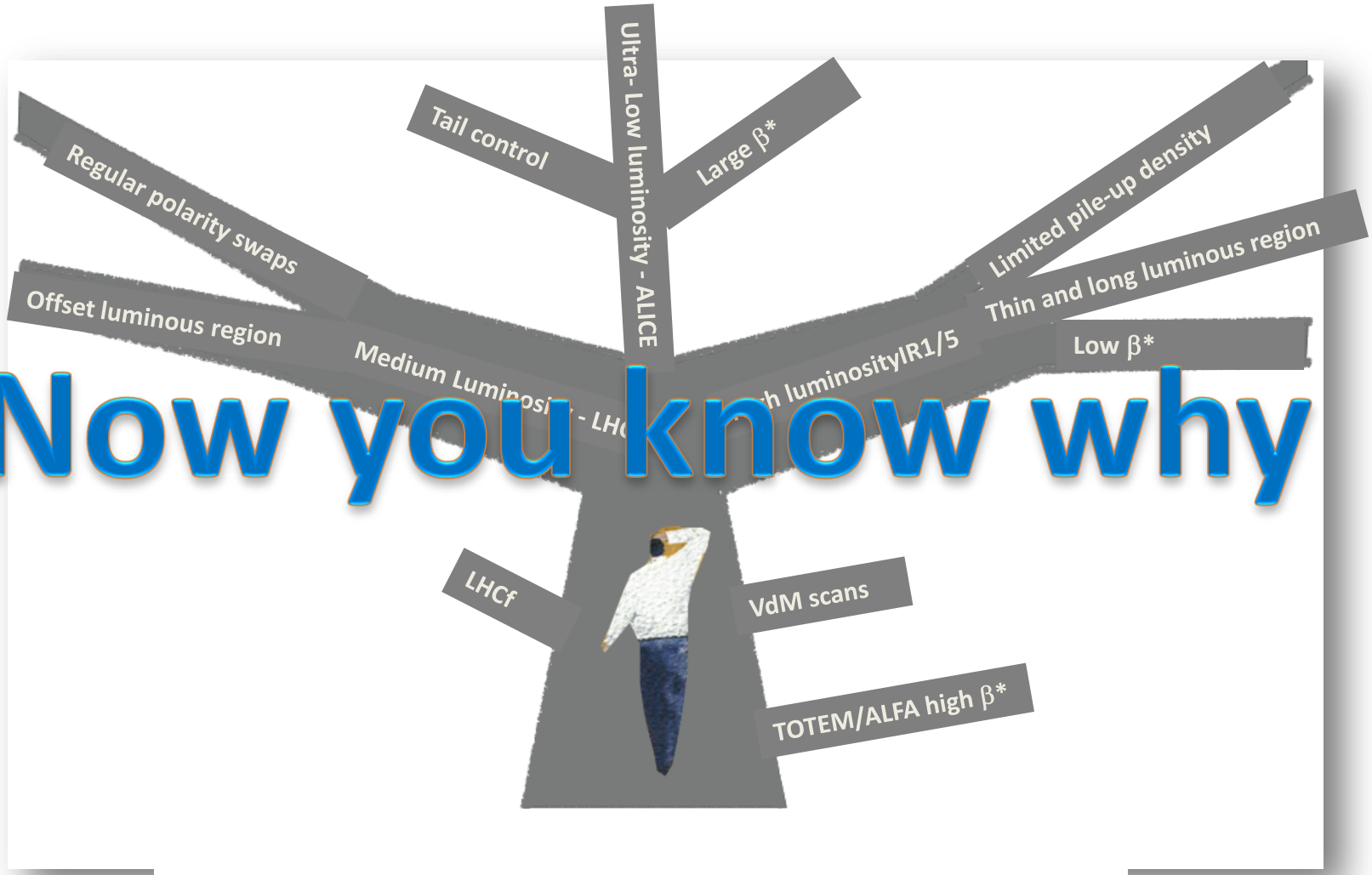






Savas Dimopoulos, CERN Colloquium, Sep 20, 2012

B. Gorini



Now you know why

- **Opening**
- **Operational scenarios**
  - ***Review the requests from the experiments and the options from the machine point of view with implications in commissioning time and performance.***
- **Beam Instrumentation**
  - ***Requirements for emittance and optics measurements together with system upgrades***
- **Optics measurements and corrections**
  - ***Improvements and developments in optics measurement and correction algorithms and applications.***
- **Early commissioning stage**
  - ***Are we ready to face a commissioning coming out of a long shut down with major machine modifications? Will there be sector tests?***
- **Closeout**

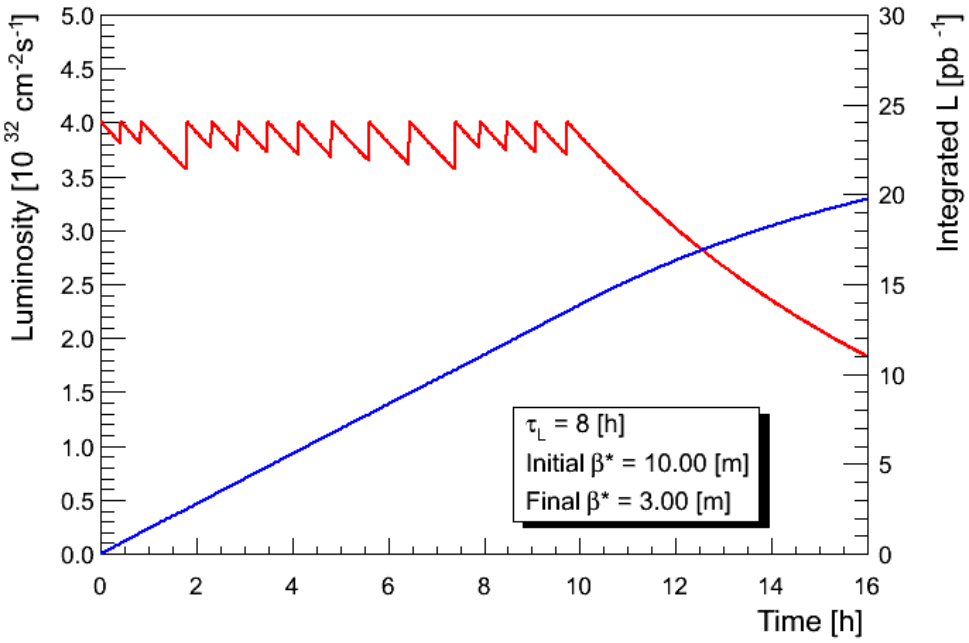
2015 scenarios

- Operation at 50 ns would require levelling in all experiments and likely colliding squeeze due to the high bunch intensity:
  - IR2 could be used as IP to provide head-on collisions and Landau damping during the squeeze of the high luminosity experiments
  - β^* levelling would be applied in IP1 and 5
  - IP8 levelling by separation

- Operation at 25 ns might not require levelling in IP1/5 and might not require colliding squeeze due to lower bunch intensity:
  - In that case IP8 could be used as test bed for β^* levelling

2015 scenarios

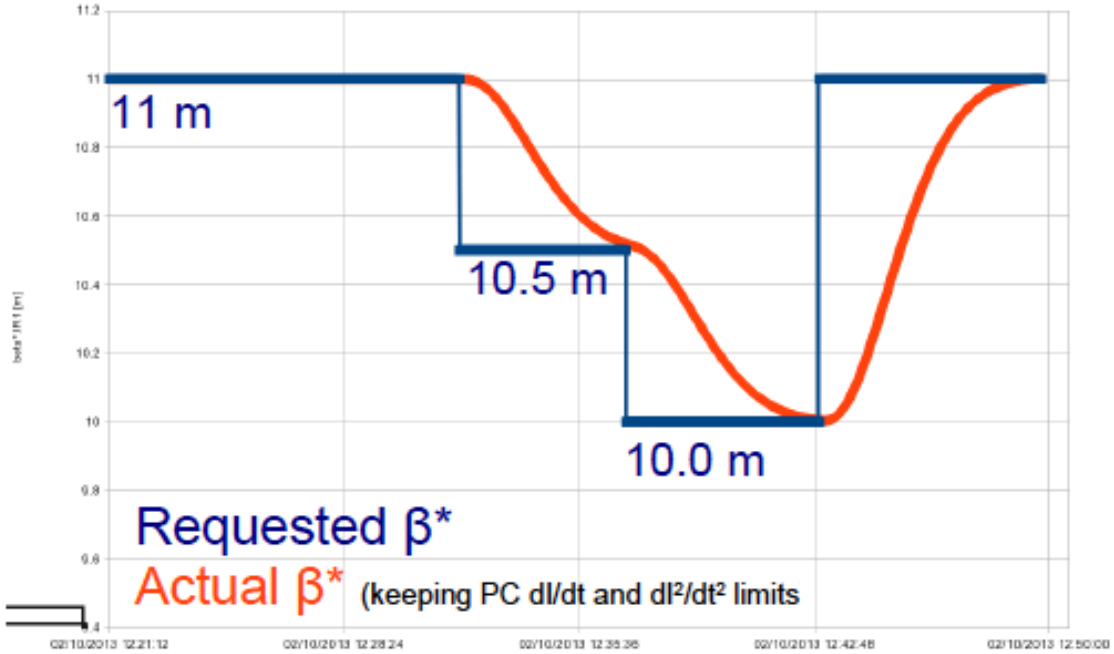
- In all cases we need to learn to handle β* levelling
- In order to guarantee felxibility for “Ultimate levelling” make correction local. ➔ Challenge: localize precisely the sources of errors



J. Wnninger

RT squeeze

- Allows arbitrary changes (test on 2013-02-10, RS & ML):



- N.B. naked squeeze in IR1 only with no prior orbit, Q/Q' corrections included. 2nd-order feed-down effects on tune and orbit clearly observed. Beam lifetime OK throughout test → to be further studied/explored for after LS-1

M. Lamont

Ramp and Squeeze

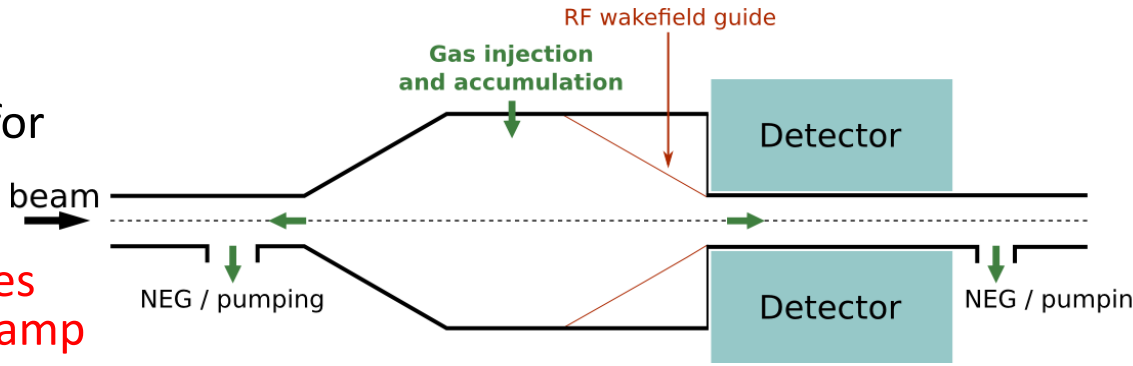
- It will be needed in any case in IP2 and IP8 above 6.2 TeV due to limitation in the triplet strength (to be confirmed)
- Not considered a bold option (Mike)
- “Why do you worry about changing the optics during the ramp?” (Mei Bai): More a psychological problem…
- We could squeeze to ~5 m in IR1/5 at the same time:
  - This could be the value of β^* in which we close the collimators to tight settings (after going in collision if colliding squeeze is needed for stability reasons)
  - Compatible with LHCf requirements
- I would start form the beginning with this option…

ATS – no ATS

- ATS potential will not be used it totally if we remain at 40 cm ➔ pre-squeeze:
  - Better chromatic behaviour but might not be sufficient to justify its use except for flat beam option that could improve “use of the luminous region” (particularly interesting for long bunches and 50 ns) ➔ Decision to be taken based in the most likely scenario

Other optics changes

- A series of modifications are proposed:
  - Mandatory:
    - New crossing scheme in IR8
  - To be evaluated
    - LSS3 and 7 to get spares for MQWs
    - IR4 optics at injection for instrumentation ➔ implies optics change along the ramp
    - IR6 optics for improved protection at the dump area
    - Injection at lower beta* (might not be interesting if we go for combined ramp and squeeze)



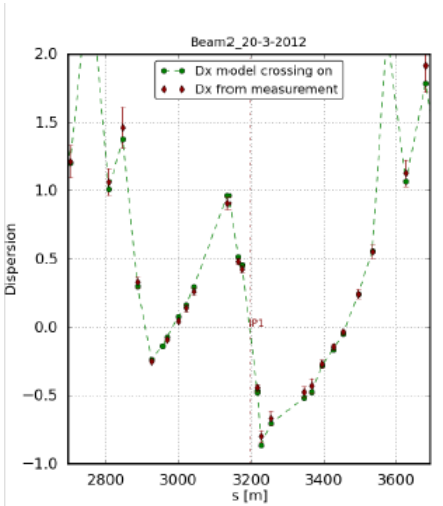
6.5 TEV

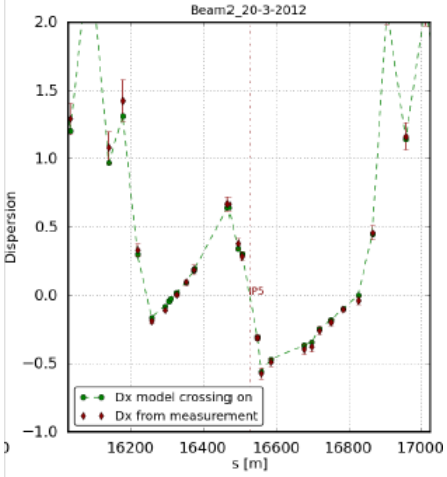
Saturation and hysteresis is going to be an issue for 6.5 TeV (IR magnets)
Careful optics measurements and localization of the errors will become even more important
Decay and snapback will be 50% larger

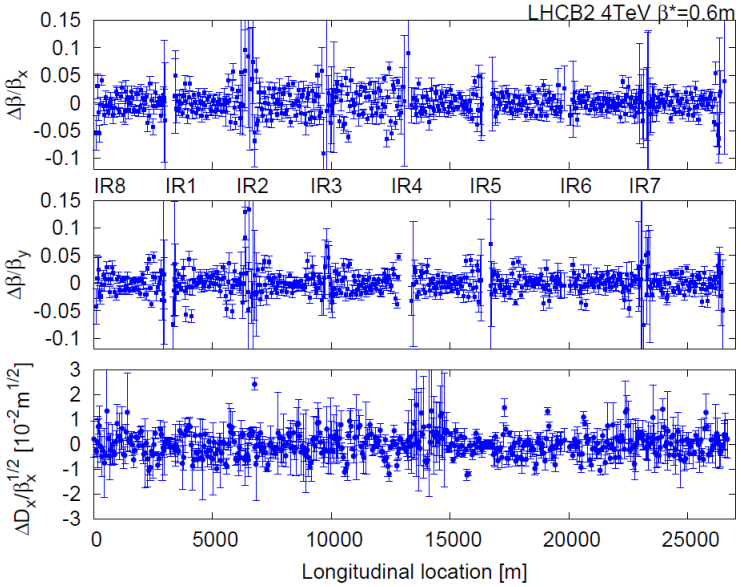
Ezio (Fidel) Todesco

Linear model

- We know and model VERY WELL linear optics.
- Beta beating, dispersion
- Do we understand all the corrections? Mostly (e.g. transfer functions) but not eveything
- Target dispersion?







P. Skowronski

K. Li

S. White, Y. Levinsen, E. Maclean, P. Skowronski

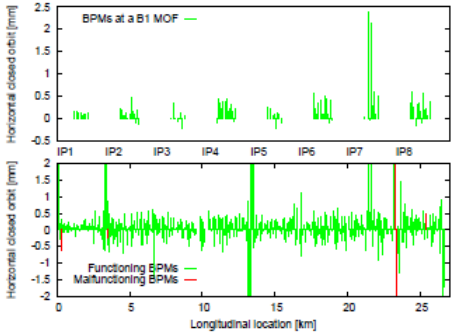
Non linear model

- Next challenge will be to improve non-linear model.
- Although we can reproduce well chromatic coupling and beta-beating we need to improve our understanding of:
  - Chromaticity
  - Detuning with amplitude
  - IT model (in particular IR5. Why so different from IR1?)
- Some ingredients are still missing
- Need careful measurement campaign on top of linear optics measurements during start-up to disentangle various contributions (e.g. decay and snapback, MCO v.s. MO, etc.) and apply proper corrections
- Tools are there:
  - Based on non linear chromaticity
  - Local bumps
  - Off-momentum beta beating and coupling
  - Recent tool using AC dipole excitation
- It will pay off for flexibility given the amount of gymnastics we are thinking of and going.

Effect of non conformities

- Even the unavailability of an “innocent” orbit corrector might have implications for our model and indirect implications when mode of operation is changes
- On line model (based on installed machine) is important to pick-up potential issues during regular operation

- Feed-down due to closed orbit (CO) is another possible source



- $dp/p \sim 0.05 \times 10^{-3}$
- Similar orbits for MOF / MOD
- Similar orbits for both beams

- Observe substantial systematic CO in the MOF and MOD
- Observe minority of MO with dramatic excursions
- **BPM.29R7.B1→2.40mm!**
- **BPM.33R7.B1→2.15mm!**
- These 2 MO explain $\sim 30\%$ of the Beam 1 $\Delta Q'_x$
- Results from broken orbit corrector

Ewen Maclean

Emittance measurements

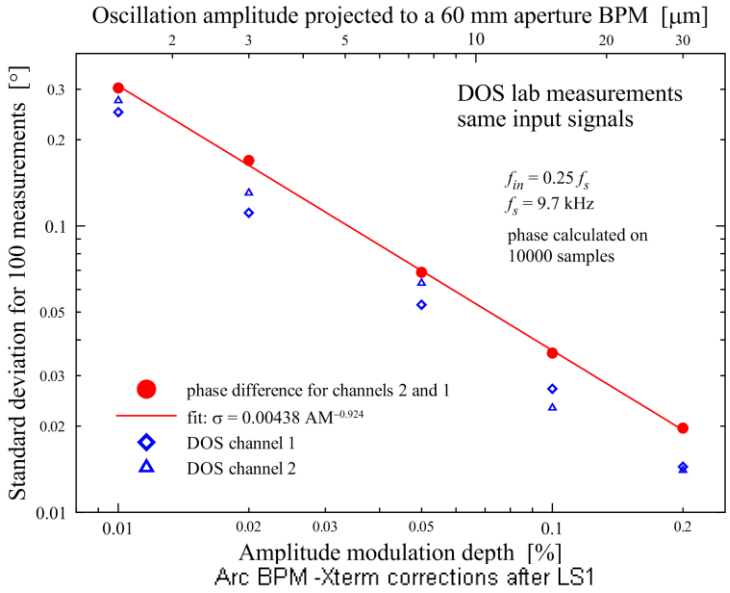
- Measurement of emittance evolution along the cycle is crucial for assessing and optimizing performance. Even more in the future (HL-LHC)
- Accurate optics functions values are required all through the accelerator cycle for determining emittances form beam profile measurements
- Effort ongoing to improve our measurement accuracy:
  - Improving algorithms
  - With additional instrumentation

Instrumentation

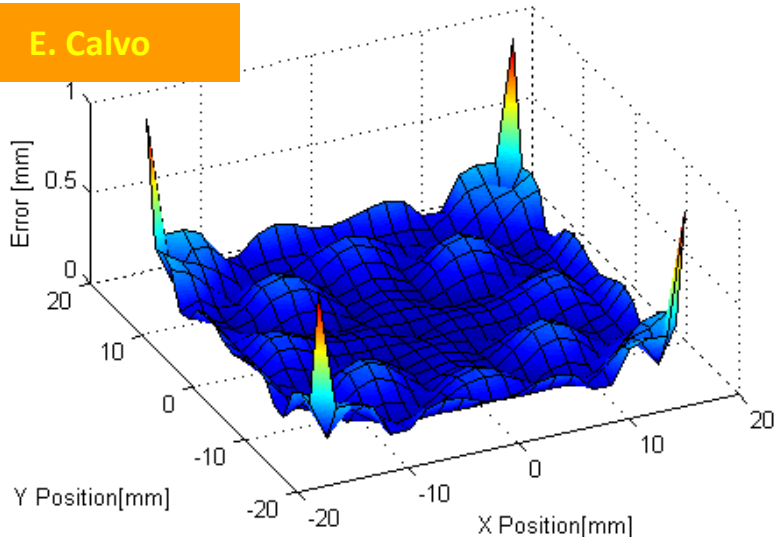
M. Gasior

- Rely on excellent insturmentation that we had from day one:
  - BPMs
  - Excitation devices (MKA, AC dipoles)

  ….and on the continuous improvements
- Will profit of:
  - DOROS (new collimators, IR4 – BGI and possibly in the IRs)
  - additional features in the BPM turns (10000) and longer excitation intervals for the AC dipole
  - New and more accurate BPM calibration



E. Calvo



E. Calvo, M. Gasior, L. Jensen, N. Magnin, J. Uythoven

Measurement tools

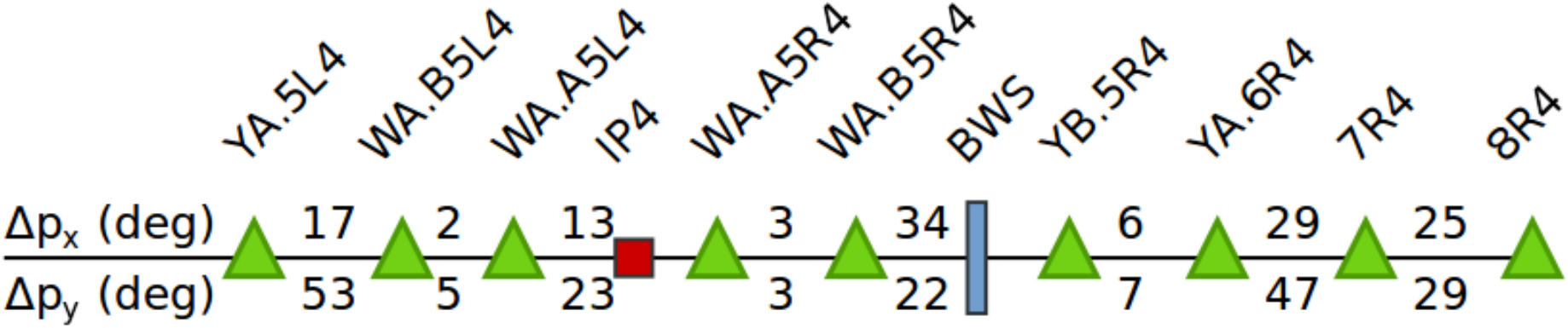
- Additional analysis tools available
  - Coupling measurement at injection (at least)
  - Segment by segment analysis
- Continuous effort to improve resolution and error reconstruction:
  - BPM selection. So far using combination of 3 BPMs could be extended to larger number.
  - b2 dipole error inclusion from magnetic measurements
  - K-modulation for local beta measurements
- Coding discipline, maintainability, use supported (by BE/CO) practices

M. Kuhn, A. Langner, T. Persson, P. Skowronski

Measurement tools

- This is required to improve our accuracy of the optical functions at the beam instrumentation and at the experiments
- K-modulation provide an optimum complement but only for some specific locations (see above):
  - Need modulation to reduce noise (Compatible with power supply?)
  - Compatibility with QPS?
  - Can we profit of PLL?

Improvements for IR4.



BPMWA B5R4	Current Algorithm	Optimized BPM sets
β_x (m)	183.1	190.2
$\sigma_1\beta_x$ (m)	23.7	2.1
$\sigma_2\beta_x$ (m)	2.4	0.2
β_y (m)	174.0	167.1
$\sigma_1\beta_y$ (m)	21.5	1.9
$\sigma_2\beta_y$ (m)	4.6	0.2

BPMYB B5R4	Current Algorithm	Optimized BPM sets
β_x (m)	197.6	191.8
$\sigma_1\beta_x$ (m)	15.6	3.0
$\sigma_2\beta_x$ (m)	1.7	0.7
β_y (m)	405.1	407.7
$\sigma_1\beta_y$ (m)	32.9	4.6
$\sigma_2\beta_y$ (m)	9.1	3.3

$\sigma_1 =$ error propagation from ϕ
$\sigma_2 =$ standard deviation of using 3 BPM sets

Improvement of one order of magnitude on the error bar

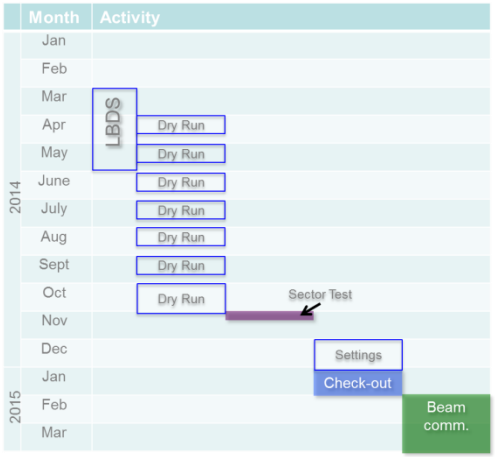
A. Langner

RHIC experience

- New ideas coming from TLC industry for signal processing (listening to different voices of the beam): Independent component analysis (ICA)
- Optics measurements along the ramp. Particularly important when operating the machine close to the integer
- Important beta beating in particular in the V-plane. Mostly for $\beta^*<2$ m. Can be corrected (errors mostly coming from IRs) down to 10 % level
- Beta beating correction applying displacements in the arc sextupoles. Do we understand the physics?

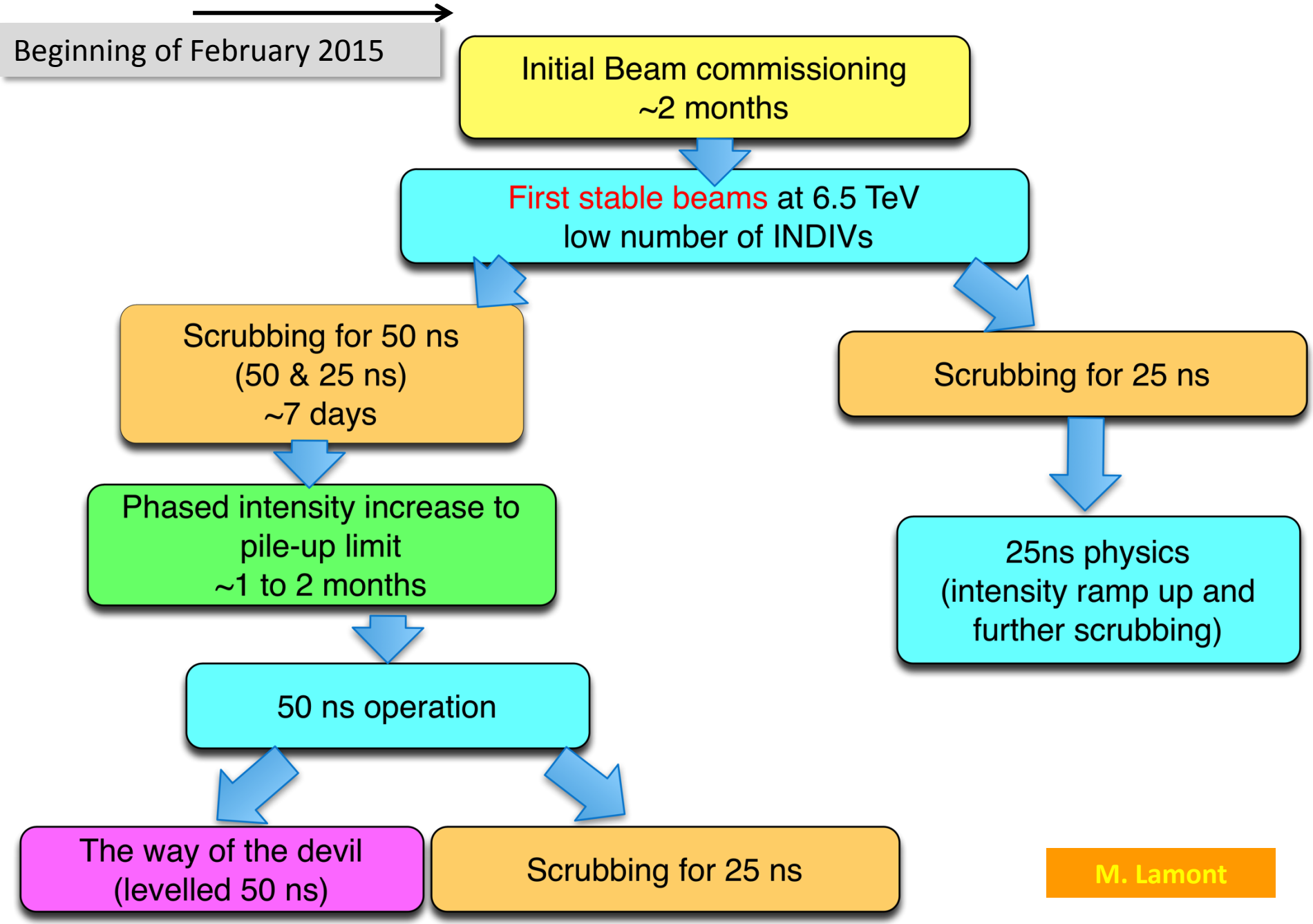
Are we ready?

- WE have a (detailed) plan for all the steps (ring, injection,)!!!
  - At least now we have some experience
  - Some questions to be sorted out for SPS



- A lot will depend on the success of 25 ns
- But initially we should aim for 25 ns

C. Bracco, V. Kain,


Beginning of February 2015
Initial Beam commissioning
~2 months
First stable beams at 6.5 TeV
low number of INDIVs
Scrubbing for 50 ns
(50 & 25 ns)
~7 days
Scrubbing for 25 ns
Phased intensity increase to
pile-up limit
~1 to 2 months
25ns physics
(intensity ramp up and
further scrubbing)
50 ns operation
The way of the devil
(levelled 50 ns)
Scrubbing for 25 ns
M. Lamont

Are we ready?

- Sector/“Synchronization” tests – proved to be very valuable in 2008. need this in
  - in identifying possible errors after major intervention on the machine circuits:
    - Polarities (linear optics)
    - BPM calibrations
    - Calibration curves
    - SW errors
- Tools are there for optics measurements
- Need tool for commissioning tests procedure tracking and sequencing ➔ Proposal to do it in a similar fashion as HWC. End of 2013.
- Automatization & procedures

K. Fuchsberger

S. Redaelli, M. McAteer

Are we ready?

- Early commissioning steps. Needed verifications after major interventions. Necessary pre-condition to operate at low beta* and high intensity:
  - Aperture.
    - Deterioration with time? Important to know for long term operation….
    - Re-centering around aperture bottle-necks could give us 1 σ more
  - Polarities of non-linear circuits (some of them checked only in 2012 – no pressure at the beginning)
- Tools are there but automation (e.g. automatic aperture scans) and procedures would certainly benefit the commissioning
- Aperture meter is presently orphan

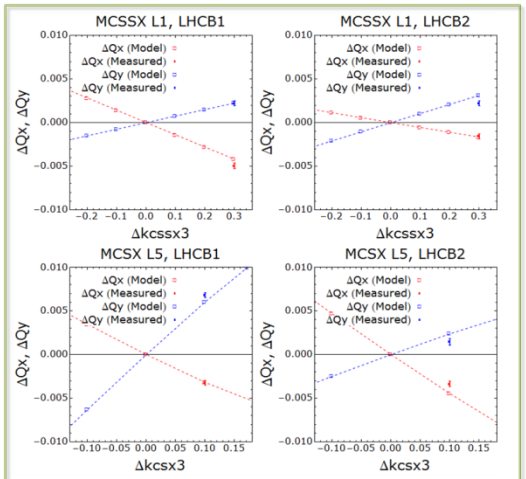
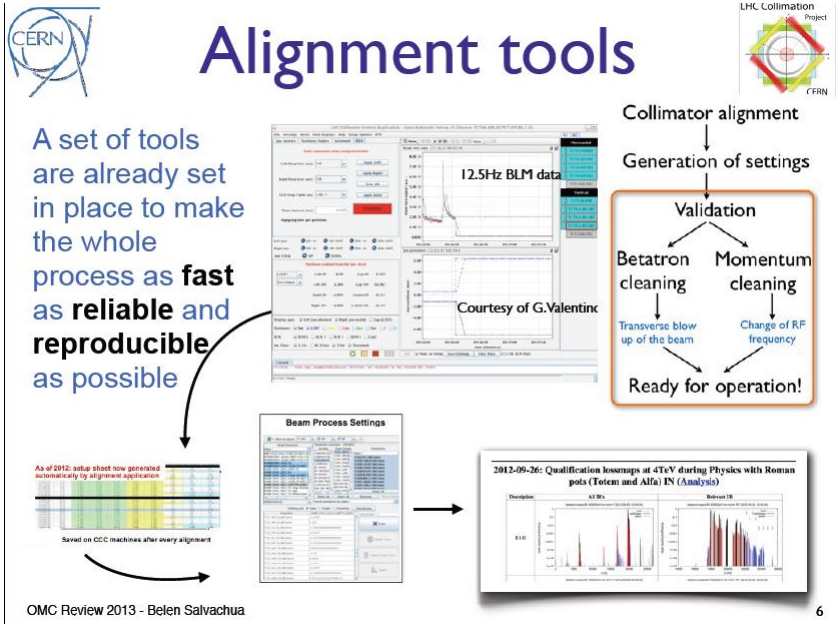


Figure: Measured and model tune shifts resulting from MCSSX trim in IP 1 and from MCSX trim in IP5 .

Are we ready?

- Collimator alignment, even more critical at 6.5 TeV:
  - Significant reduction of the alignment time and proven longevity of the settings, but any optics re-configuration requires setting-up (special physics runs….)
  - Well tested procedures
  - Need to learn how to profit of BPM collimators
- In general tools are ready but we should resist to the attempt of taking short-cuts given the higher energy and the less tolerant mode of operation (low beta*).



The many lives of the on-line model…

The LHC Online Model is a tool providing in the CCC a physical and mathematical model which can track and mirror the beam operation in the LHC in close-to-real-time, and which is implemented with the features to detect and address deviations from the model or degradation over time.

- Not only nominal machine
- As installed machine (Fidel, unavailable circuits, apertures, etc..)
- Continuous update of the model from measurements

- A lot of interesting ideas:
  - Two beam operation, p-ion, …
  - How tight the connection to the control system
  - Non-linear (bent) knobs
  - Too ambitious?
  - We (users/providers) need to agree on the requirements and the possible steps to that

G. Roy

A success story…to be continued

- Based on the pro-active attitude of Instrumentation, operation, optics teams

  have more and more users
  - Collimation Team
  - Experiments
  - Instrumentation
  - Operation
  - Optics team

- And we are testing the machine in more extreme cases and we are asked to enhance flexibility
- Absolute need to improve our understanding of the optics model

Many thanks to Organizers, Chairs, Speakers