



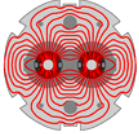
*LHC Performance Workshop  
Chamonix 23 September 2014*

## Machine Development Priorities

Jan Uythoven

Gianluigi Arduini, Giulia Papotti

Participants of the LSWG Day

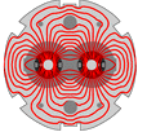


# Machine Development Priorities

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- Isn't 2015 just an MD year with a little bit of physics?
  - What is MD and what is Operational Development
- Some statistics of MDs during Run 1
- What is foreseen for Run2
  - MD blocks in the LHC Schedule
  - Summary from the LHC Studies Working Group day on 2 September 2014
    - Split between Commissioning and MDs
- Organisation of MDs
  - Strict to be successful and efficient

*Longer term: see presentation on Wednesday in **HL-LHC session:**  
"Down Selection Criteria and MDs Prior to LS3"  
by Gianluigi Arduini*



# Definition of Machine Development

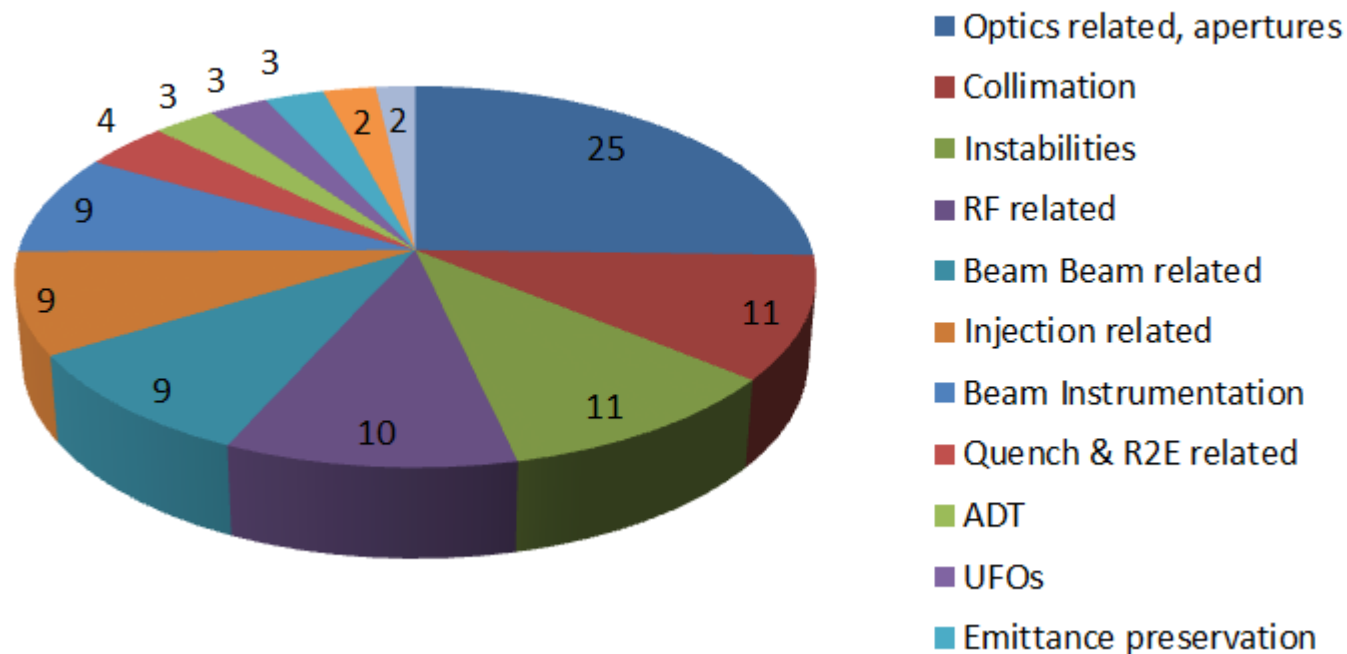
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- **Machine Development** aims at improving the understanding of the LHC, its equipment and beam physics in general which should result in the improvement of machine performance (= integrated luminosity) on the longer term
  - Performed during designated periods on the LHC Schedule
- **Operational Development** and **Commissioning** of the LHC has a direct and immediate impact on the machine performance
  - Performed during foreseen commissioning period, intensity ramp-up period or physics time.
- Electron cloud scrubbing and related beam tests are not part of Machine Development
- *We need to find the correct balance between measurements to be done as Machine Development and work to be done during “physics hours”*



# MD Statistics Run 1

Main MD users in % of total MD time



- ABP group clearly 'leading', including collimation
  - Optics *feasibility* should be in MD, setting up should be in physics

*Based on a total of 657 MD hours during run 1,  
raw data by Giulia P.*

# LHC Schedule - 2015

Draft for approval

September 4, 2014  
V0.4

	Jan			Feb				Mar						
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13	
Mo		29	5	12	19	26	2	9	16	23	2	9	16	23
Tu														
We														
Th														
Fr														
Sa														
Su														

Annotations: HW tests (Feb 4-7), Sector test (523) (Feb 6), Sector test (578) (Mar 8), Machine checkout (Mar 10), Recommissioning with beam (Mar 11-12)

	Apr			May						June				
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26	
Mo		30	6	13	20	27	4	11	18	25	1	8	15	22
Tu														
We														
Th														
Fr														
Sa														
Su														

Annotations: Recommissioning with beam (Apr 15-16), Special physic run (May 20), Scrubbing for 50 ns operation (May 21), TS1 (May 22), Intensity ramp-up with 50 ns beam (May 23-24), Scrubbing for 25 ns operation (June 25)

	July			Aug						Sep				
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														

Annotations: MD 1 (July 28-29), Intensity ramp-up with 25 ns beam (Aug 30-31), TS2 (Aug 35), Special physic run (Sep 36), MD 2 (Sep 37), Lower beta\* (Sep 37)

	Oct			Nov				Dec						
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														

Annotations: Floating MD (Oct 41-42), MD 3 (Nov 46), Technical stop (Nov 46), Ions setup (Nov 47), IONS (Dec 49), Technical stop (Dec 51), Xmas (Dec 52), End physics (Dec 51)

## ■ For approval

- No MD periods during re-commissioning period
  - “Continuous MD”
- Due to initial delay:
  - 3 MD blocks 5 days
  - 1 floating 4 days
- **First MD late, July**
  - Urgent MD like measurement to be done during ‘commissioning’
  - No high intensity 25 ns
- Second MD *just* before possible change to lower beta\*
  - Too late to be used for beta\*
- MDs combined with other interruptions of ‘Main Physics’ programme
  - Good to reduce the overall impact on the physics programme
  - Heavy load on the machine teams → floating better



# LSWG Day 2 September 2014

## LHC Studies Working Group Day

Tuesday, 2 September 2014 from 09:00 to 17:00 (Europe/Zurich)  
at CERN ( 864-1-D02 - BE Auditorium Prevezin )

**Description** A one-day review to:  
- recall the main results of the Machine Developments carried out during the LHC Run 1,  
- have a first look at the requests for Run 2.  
Note that the presence of at least one person per MD team would be appreciated for the discussion.

**Material:** [Minutes](#) [Presence Sheet](#)

### Tuesday, 2 September 2014

- 09:00 - 09:20 **Introduction and scope 20'**  
Speaker: Dr. Jan Uythoven (CERN)  
Material: [Slides](#)
- 09:20 - 09:35 **Linear and non-linear optics, measurements and corrections 15'**  
Speaker: Ewen Hamish Maclean (University of Oxford (GB))  
Material: [Slides](#)
- 09:35 - 09:45 **Questions**
- 09:45 - 10:00 **ATS MD experience for run I and perspective for run II 15'**  
Speaker: Stephane Fartoukh (CERN)  
Material: [Slides](#)
- 10:00 - 10:10 **Questions**
- 10:10 - 10:30 **Collimation, crystals, halo control 20'**  
Speaker: Dr. Stefano Redaelli (CERN)  
Material: [Slides](#)
- 10:30 - 10:40 **Questions**
- 10:40 - 11:00 **Coffee break**
- 11:00 - 11:15 **Single and two beam stability 15'**

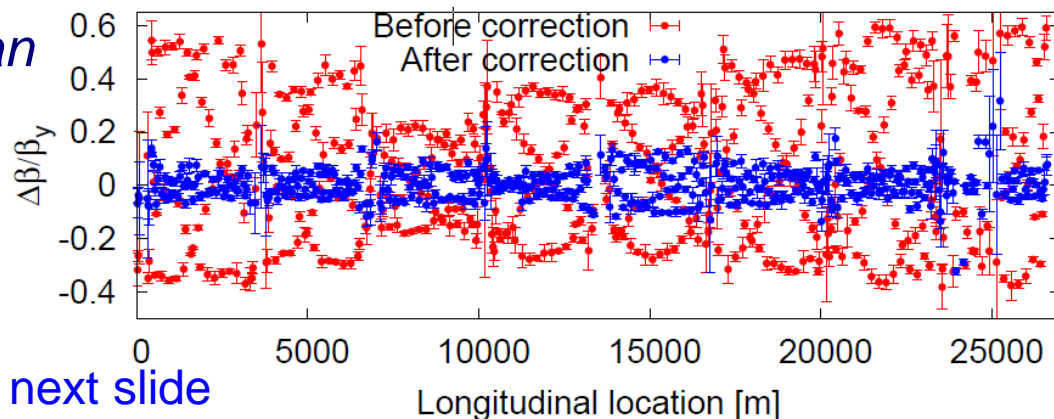
- <https://indico.cern.ch/event/331020/>
- ¾ day. 58 people present
- Presentation by the different stake holders
  - Recall main MD results during LHC Run 1
  - First look at requests for LHC Run 2
- Below: Summary per interest group



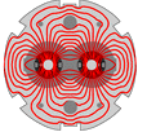


# Optics Measurements and Corrections (OMC)

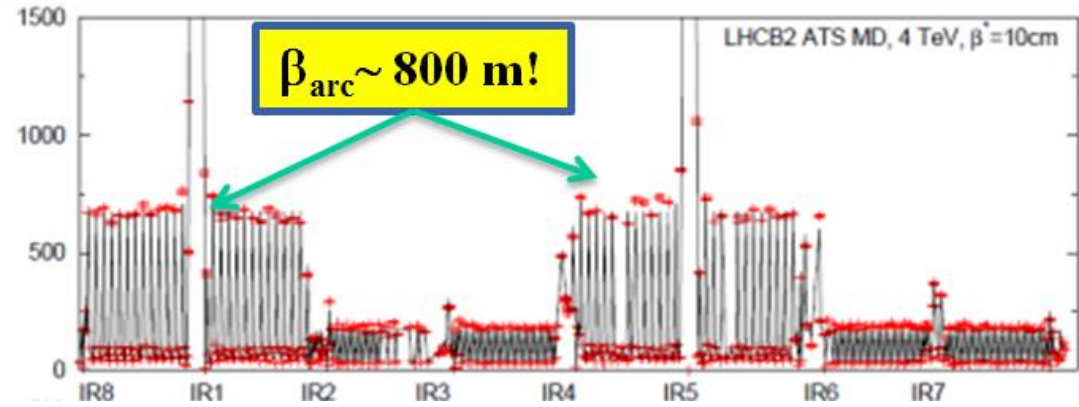
*Ewen Hamish Maclean*



- Run 1: 10 MD blocks
  - 3 x linear, 3 x non-linear
  - 4 x MDs on ATS optics → next slide
- Run 2 commissioning
  - Polarity checks, chromatic coupling, coupling feedback, beam based correction of b4, amplitude detuning throughout cycle
- Run 2 MD request
  - Linear
    - Stability of nominal optics, modular corrections for dynamical beta\*
    - Study off-momentum optics corrections especially at half integer tunes
    - Choice of working point at injection / through the cycle / tune jump with MQT
  - Non-linear optics – **most important**
    - Q' and Q'' discrepancy, natural chromaticity measurement, Q'' in ramp
    - Q''' and chromatic amplitude detuning
    - Improve non-linear model of the LHC esp. at IR5 & corrections



# ATS MDs – *Stéphane Fartoukh*



- Run 1: 4 MDs dedicated to ATS
  - Beta\* of about 12 cm demonstrated with pilot bunches
- Run 2 commissioning
  - ATS not part of the initial commissioning, to be decided when to be put in operation or tested
  - Full commissioning pre-squeezed ATS with high intensity beams – when?
- Run 2 MDs
  - Telescopic FLAT optics, validate with few nominal bunches
  - Develop and validate special telescopic round optics for maximising the MO efficiency
  - Anti-ATS optics for very large beta\*





# Collimation, Crystals and Halo Control

- Run 1: *Stefano Redaelli*
  - Fast alignment, quench tests, tight settings, impedance etc.
- Run 2 commissioning
  - Commissioning of new collimators, incl. those with BPMs
  - Effectiveness of new TCLs
  - Measurement of collimation impedance
  - Improved loss maps for 6.5 TeV beams & other loss maps
- Run 2 MDs → will need to be prioritised
  - Collimation quench tests at 6.5 TeV
  - Tighter collimation hierarchy, linked to impedance limits
  - Faster collimator alignment with BLMs and BPMs & BPM tests
  - Passive abort gap cleaning in IR3
  - Halo population scans at 6.5 TeV
  - **Crystal collimation experiment**: ambitious programme
  - Halo control





# Single and Two beam Stability – *Tatiana Pieloni*

## ■ Run 1:

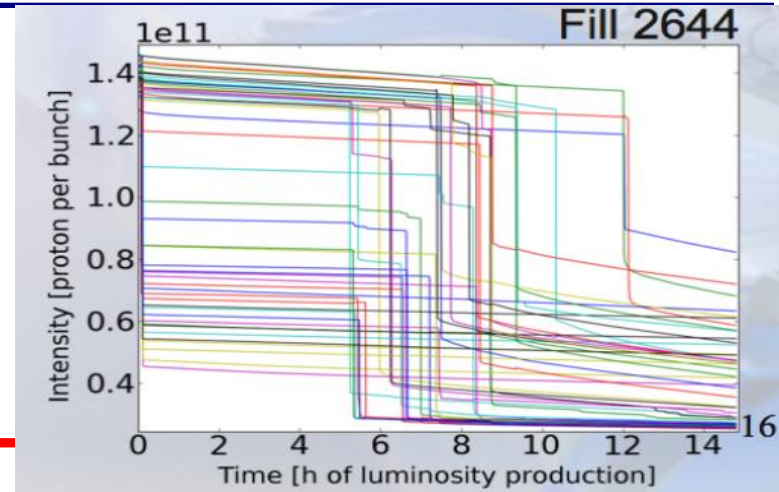
- Growth rate of instabilities, octupole thresholds, chromaticity, damper gain
- Stability diagrams and coherent Beam-Beam Impedance
- No good data Beam 1

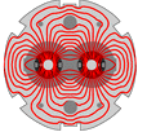
## ■ Run 2 commissioning

- Will need to work with certain MO polarity and current, chromaticity and damper gain....
- Knowledge and control of machine parameters ( $Q$ ,  $Q'$ , Oct feed-down)
- **Profit from set-up of trains during commissioning period**

## ■ Run 2 MDs

- Combine single and two beam stability studies possible
- Instability growth vs. Chromaticity / Damper gain / Octupole polarity → remaining
- Diffusion mechanism and impact on distribution profiles
- Collide and squeeze development → see later
- Bunch by bunch and turn-by-turn measurements
- BBLR with 25 ns, noise on colliding beams, flat beams, half-integer tune



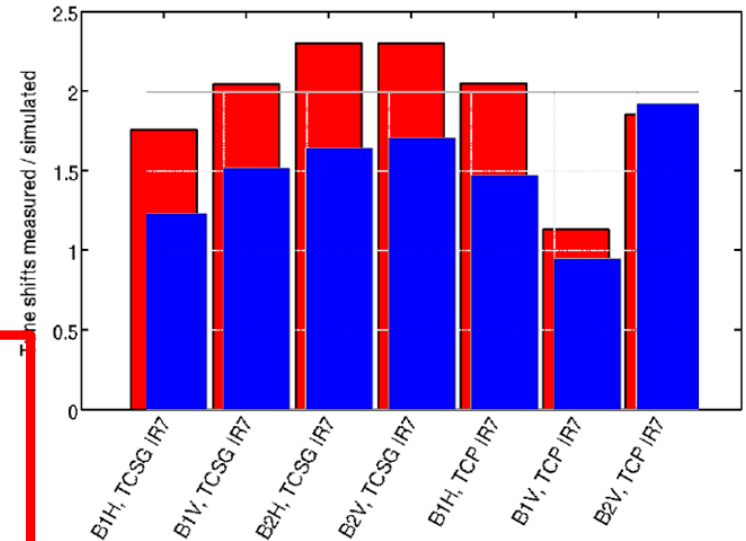


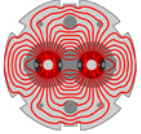
# Impedance and Beam Induced Heating

- Run 1 *Benoit Salvant*
  - Tune shift measurements, discrepancy with model up to factor 2
  - Impedance / heating of devices
  - Bunch length reduction

- Run 2 commissioning
  - **Parasitic / end of fill MDs very useful**
  - Impedance of modified equipment (TDI, TCDQ, TCTP, Roman Pots)

- Run 2 MDs
  - Obligatory
    - Asses if intensity limits have changed during LS1
  - Nice to have
    - Localize (other) impedance sources, impedance and heating of non-modified devices
    - Effect of changing bunch length and/or profile
    - Impedance with changing gaps vs. number of bunches
    - Feasibility to optimize beta function to reduce transverse impedance





# Beta\* levelling and Collide and Squeeze

*Arkadiusz Gorzawski*

## ■ Run 1: 3 MDs

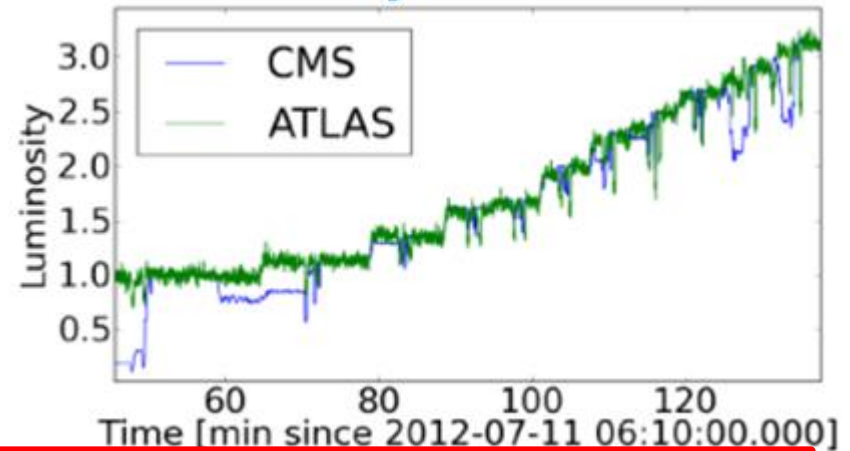
- Feasibility proven, beta\* from 3 m to 0.6 m → 9 m to 3 m
- TCTs kept at 0.6 m settings

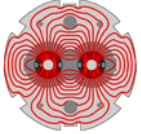
## ■ Run 2 commissioning

- No Beta\* and collide and squeeze from the start
- When put into operation, will need operational experience

## ■ Run 2 MDs

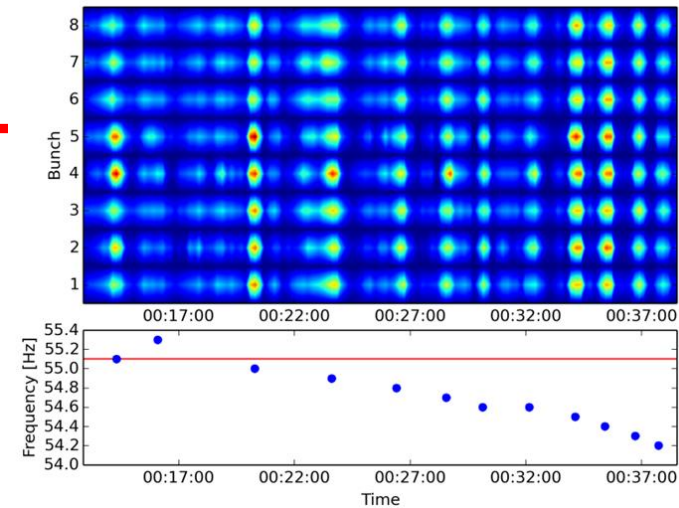
- In IR8 as end of fill – more efficient if not MD
  - Loss maps and asynch dump tests to be made as well
- In IR1/5
  - 11 m down to 0.4 m
  - Set-up and validation time required





# RF studies in the LHC, *Elena Shaposhnikova*

- Run 1: 16 MD notes
- Run 2 commissioning
  - Optimisation of RF parameters
    - Main RF voltage
    - Phase modulation
    - Longitudinal emittance
    - Bunch length and profile (related to heating)
  - RF specific beam diagnostics (Shottky, LHC BQM)
- Run 2 MDs
  - Minimal RF-Voltage to maintain Landau damping at 6.5 TeV
  - Longitudinal bunch profile (shape and length) evolution during coast without and with collision
  - Controlled RF phase noise (continuation of commissioning)
  - Longitudinal single bunch stability & coupled bunch instabilities
  - Bunch blow-up/shaping at 6.5 TeV, effect of the SR
  - Longitudinal impedance evaluation – factor 2-3 discrepancy with model
  - Etc. etc.



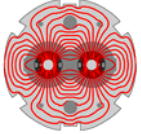


# Transverse Damper, Wolfgang Höfle

- Run 1:
  - Combination operational development and MDs
  - Active in many MDs of other groups →
- Run 2 commissioning
  - Injection oscillation and instability diagnostics via Observation Box
  - Abort Gap Cleaning improvements, bipolar pulse (as needed) *Usine à gaz*
  - Damping of Scrubbing Beam, optimization of 25 ns running
  - Tune Measurement with ADT: active excitation of leading bunch train
    - Tune loop using ADT can be envisaged, but decision from the start on this
  - Tune measurement with observation box w/o excitation
  - Loss maps with full beam / during ramp and end of fill
- Run 2 MDs
  - Halo Cleaning using Transverse Damper (S.R.)
  - Bench mark of blow-up equation with injected noise (W.H.)



*Usine à gaz*



# Beam Instrumentation, *Thibaut Lefevre*

## ■ Run 1

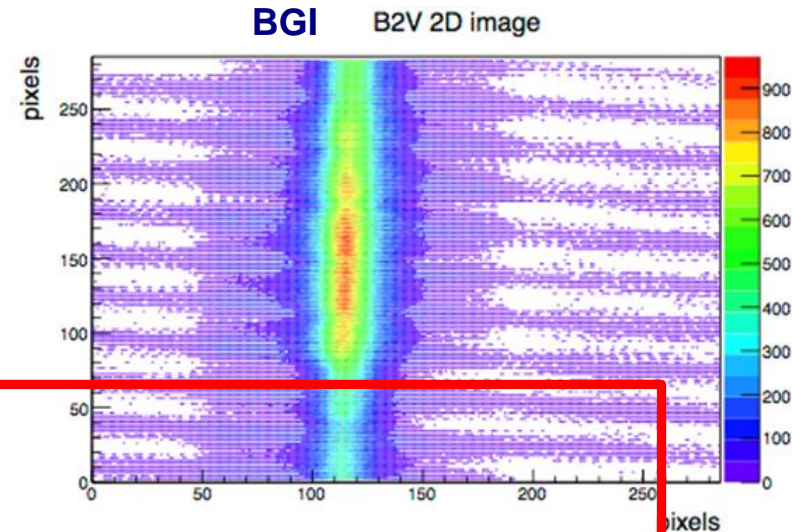
- Each MD period one BI shift with 4 – 5 different activities
- Performance and limitations of operational devices
- Test and develop new or modified instruments

## ■ Run 2 commissioning

- All instrumentation has been modified in one way or another & new equipment
- “What is done in MDs is what cannot be done parasitically during normal beam operation and initial beam commissioning”

## ■ Run 2 MDs – **request to keep one shift per MD period**

- dl/dt commissioning, directional strip-line BPMs in LSSs
- Bunch intensity scraping nominal bunches, bunch length dependency
- Instability monitoring triggering system, closed orbit bumps
- Emittance blow-up, cross calibration using BTV in dump line, BGV commissioning
- Etc.

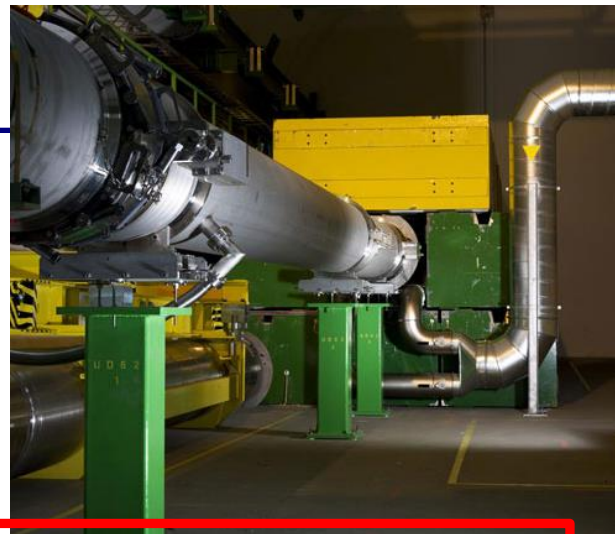




# Injection and Dump, *JU*

## ■ Run 1

- Injection studies: Tails, shielding, alignment TDI, quench margins
- UFO studies at MKI and MKQs
- Beam Dump studies: Quench margins, TCDQ alignment, abort gap cleaning



## ■ Run 2 commissioning

- Nominal injection 50 ns and 25 ns, beam dump, injection gap and abort gap cleaning
- Set-up of protection devices
- New BETS on TDI, MSI and TCDQ
- Effective MKD rise time measurement with AGK set-up
- Beam induced heating of modified TDIs

## ■ Run 2 MDs

- Injection stability (MKE), Steering, Injection losses, blindable BLMs, matching monitors, set-up of TCDIs and TDIs → special tests
- Simulation of MKI failure losses and measurements.
- Abort gap cleaning with ADT, automatic cleaning with new BSRA hard- and software
- Modified interlocked BPMs
- TCDQ – TCT retraction and losses, TCDQ impedance (ATS optics)
- Q4 IP6 quench level





# Quench Tests, *Bernhard Auchmann*

## ■ Run 1: about 8 tests incl. end-of-run tests

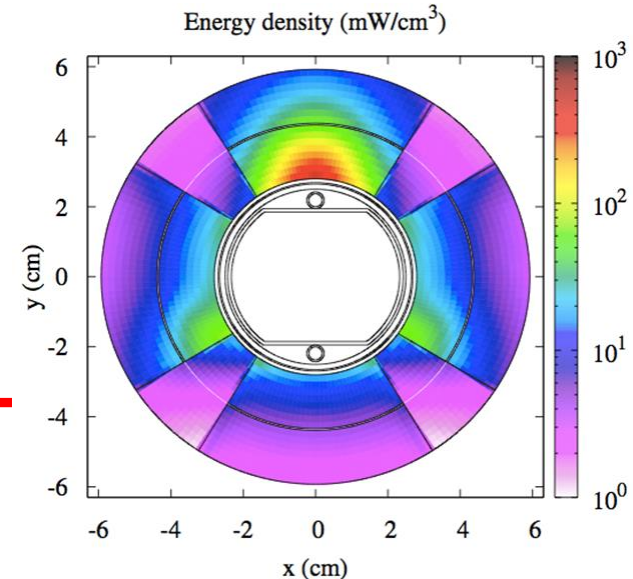
- Single turn losses – LIBD
- UFO time scale losses
- Steady-state losses

## ■ Run 2 commissioning

- Not really, but a lot of data might come for free
  - UFOs....
- Need to set the BLM thresholds

## ■ Run 2 MDs

- Single turn losses
  - Q4 point 6 – improved diagnostics with LICs
- UFO time scale losses**
  - Repeat ADT quench tests with improvements on experimental set-up and model
  - Losses induced by fast current changes in RD1.L/R1
- Steady-state losses
  - Repeat ADT quench tests with improvements





# Putting this all together

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- The *indicative* list of MD requests is at least as large as for Run I
  - Written, official requests to be collected early 2015
  - Most MDs are correctly justified and are valid requests
  - Priorities have not been decided yet → LSWG meetings
    - 11 interest groups \* 2 shifts =  
22 shifts / MD block. 15 shift available / block .....
- Anything which is vital for running the machine in the short term should not be MD but operation
- *The MD programme will also be affected by problems encountered during the Run*
- However, sneak preview of what we can expect
  - To be done in commissioning
  - To be done during first MDs, considering
    - We have a new machine
    - Keeping in mind beta\* step around September
    - No start-up with ATS optics

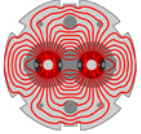


# Commissioning / High Priority MDs

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- Commissioning
  - Aperture measurements
  - Measurement of impedance of modified elements close to the beam, especially collimators
  - Stabilise the beam with Octupoles, Chromaticity and ADT, can't wait for MDs
  - ADT tune measurement and Observation Box
  - UFO quench tests (parasitically)
- High priority / early MDs
  - Change in beam intensity limits compared to pre LS1 (impedance)
  - More studies on beam stability – Octupoles, Chromaticity and ADT
  - Long range beam-beam 25 ns and variation of crossing angle
  - Collimation hierarchy / tight settings (impedance) & collimator buttons
  - Collide and squeeze to stabilise the beam
  - Beta\* levelling

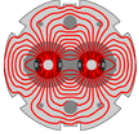
*Will also need operational hours on the clock*
- ATS optics related
  - Loss studies for validation
  - Asynch dump behaviour – TCDQ/TCT losses



# Reduction of $\beta^*$ - when decided to go for it

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- What should be there from operation
  - Aperture measurements
  - Orbit stability
  - Optics
  - Collimator impedance
- **What is needed from (first) MD block**
  - Collimator hierarchy linked to collimator impedance
  - Beam stability – do we need to go to collide and squeeze to stabilise?
  - Instability growth vs. Chromaticity / Damper gain / Octupole polarity for multiple bunches
  - Long range beam-beam related to crossing angle (no 25 ns trains first MD block)
- To be done during commissioning of any lower  $\beta^*$ 
  - Collimation set-up
  - RF set-up
  - Etc.
- Lower  $\beta^*$  can profit from flexibility of ATS optics (2016)



# We will be tough

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- Certain MD rules will be tightened for Run 2 to have a more efficient use of the MD time
- A written procedure for **EACH MD** has to be handed in at least two weeks ahead of the MD (approval one week before MD by LMC)
  - In the past this was only required for rMPP approval for 'dangerous MDs' (categories A, B and C). However, it was noted that good procedures made the MD a lot more efficient
  - If no procedures → move up MDs from 'spare list'
- Each MD linked to a **contact person within the OP group** (EiC or other), not necessarily the person on shift during the MD, who should help in the preparation of the MD and the procedures, follow-up on preparations of settings when necessary
- Each MD to result in an **MD note**, to be published within one → four weeks after the MD
  - Can be short and without complete analysis of all data, but should refer to all measurements made
  - Helps in planning any further studies – no next MD on same topic before at least a short write-up



# Conclusions

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- A preliminary inventory of MD requests has been made
  - No lack of ideas !
  - Some of them indicated as high priority, early on
  - Others important for longer term investment
  - Stay flexible to react on upcoming machine issues
- For an efficient start-up many MD-like measurements will need to be done during the commissioning period
  - To check on any bad surprises early on
  - To prepare a beta\* step later in the year
  - To be more efficient
- MDs will be more successful and efficient if well prepared and well written up