LHC transfer lines and injection

W. Bartmann

with many inputs from:

M. Barnes, C. Bracco, E. Carlier, S. Cettour Cave, B. Dehning, R. Folch, G. Le Godec, B. Goddard, S. Grishin, E.B. Holzer, V. Kain, A. Lechner, R. Losito, N. Magnin, A. Masi, M. Meddahi, A. Perillo Marcone, M. Taborelli, J. Uythoven, N. Voumard, C. Zamantzas, M. Zerlauth

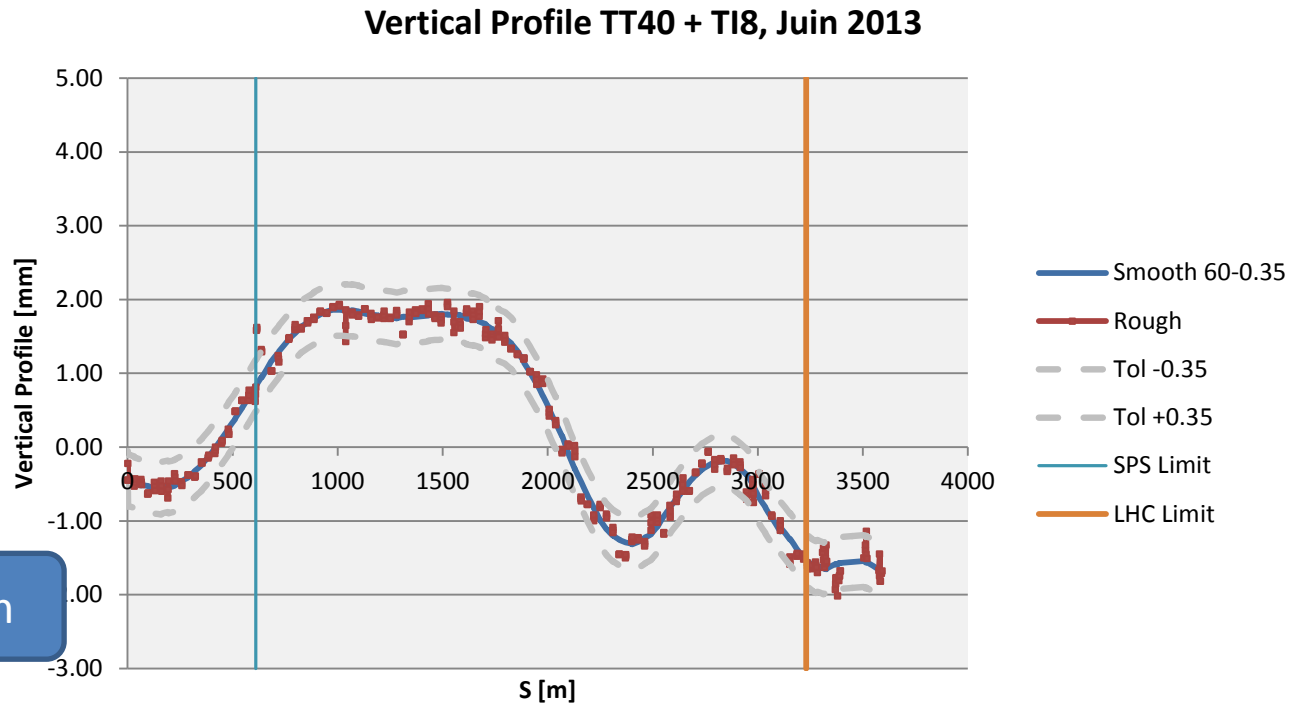
5th Evian Workshop, 2-4 June 2014

Outline

- TLs
  - Realignments
  - Expected transfer line stability
- Injection system
  - Final TDI
  - TDI gap interlock
  - MSI current interlock
  - Changes to MKI
  - BLM modifications
- Operational
  - Improved turnaround with optimised supercycle
  - Extra measurements

TL realignment

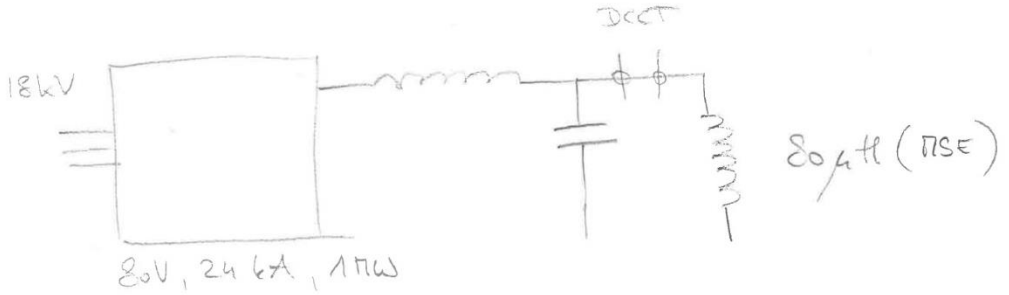
- Realignments in SPS and TLs
- Different trajectories to be expected already from SPS extraction



Patrick Bestmann

Trajectory stability – MSE PC

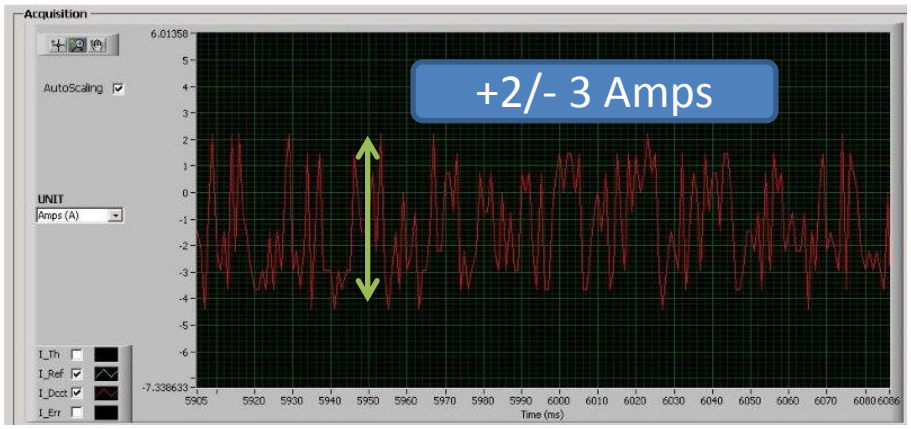
- General problem:
  - Low MSE inductance: almost no filtering effect from the load side on the current
  - Asymmetries in the PC: 100-200Hz
  - Measurement, stray fields: 50 Hz
  - Regulation: few Hz

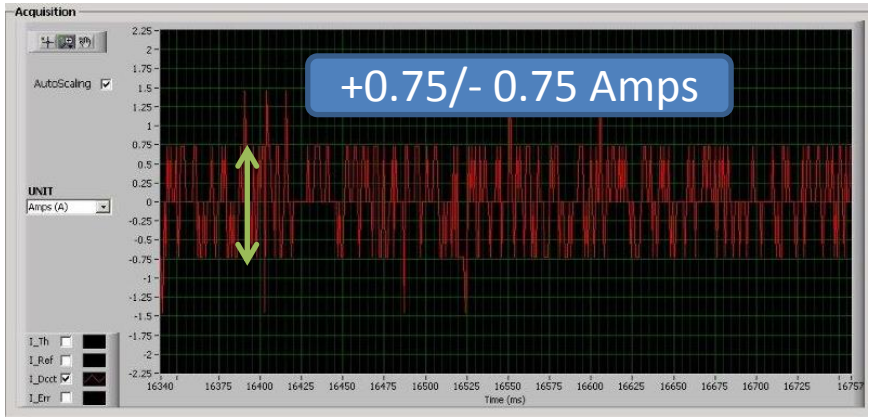


- MSE.BA6
  - Improvement of filter: expect reduction of peak-to-peak ripple from 9 →3.5 A (4 A is the aim)

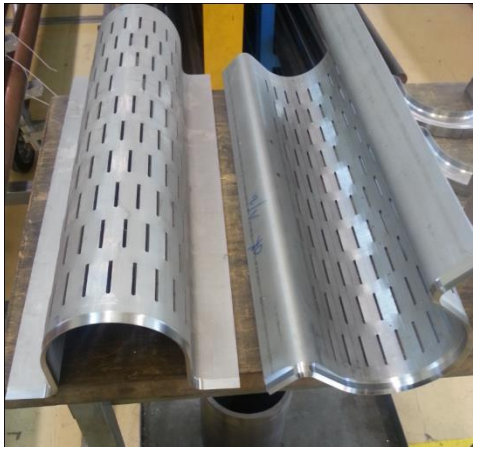
Trajectory stability – MSE PC

- MSE.BB4
  - PC topology better than in BA6 but asymmetric 18 kV ac distribution network
  - Found problem with DCCT
    - 5 A ptp oscillation for PC switched off – the closed FB loop tries to correct for this non-exisiting error
    - Repaired during LS1
    - DCCTs in BA6 were tested; no problems reported
  - Improvement of the filter: a total of 200 capacitors to be changed

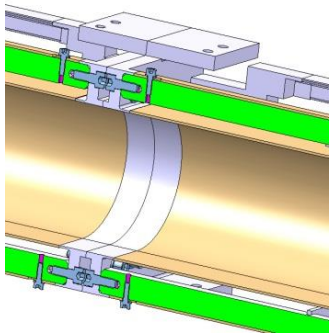


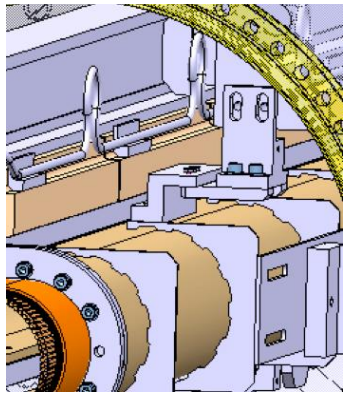


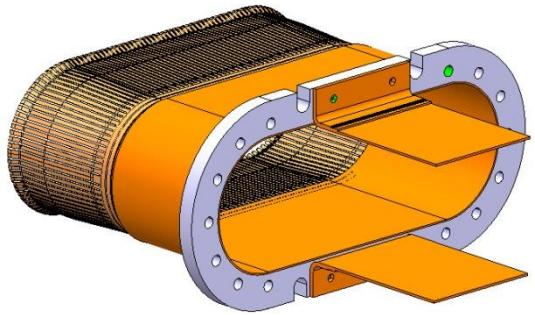
Final TDI hardware



- Final hardware
  - Beam screen:
    - New reinforced 6 mm stainless steel, ~~copper (200 um) and NEG (1 um) coated~~, new supporting frame
    - New sliding systems
    - Replacement of the central RF fingers by a mechanical connection
    - RF extremities bolted instead of EB welded
    - Addition of 8 temperature sensors
  - Replaced the gearbox by new greased ones
  - Keep cooling circuits



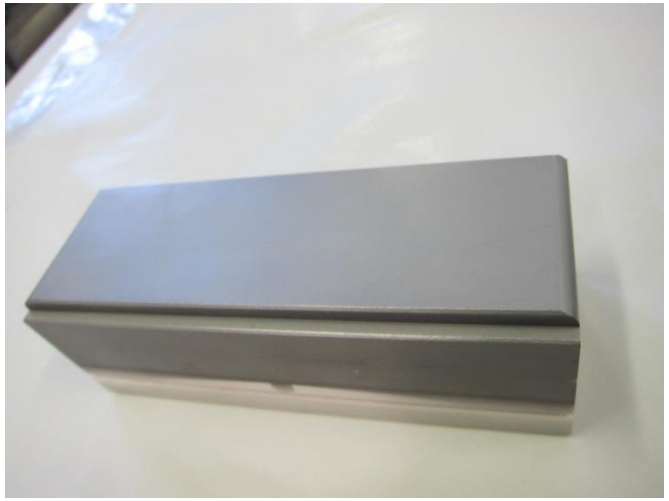




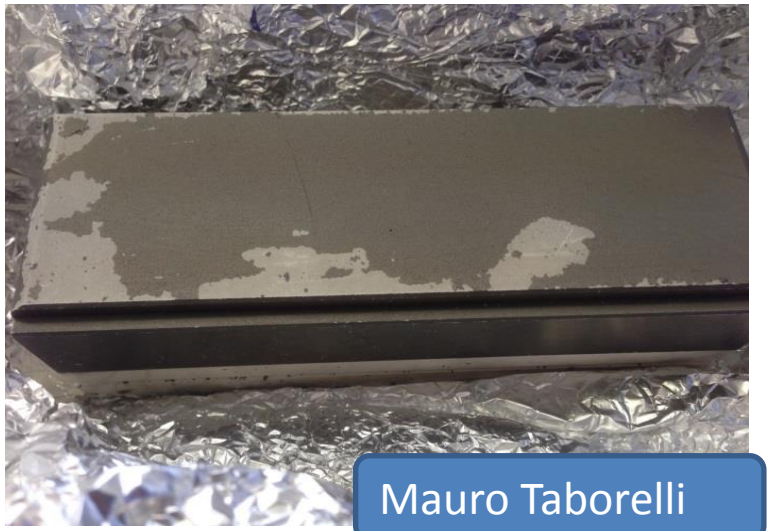
TDI coatings issues

Jan Uythoven, LMC
19-Mar-14

BN after coating (Ti 5um+NEG+Cu 2um+NEG)



BN after bake 300°C (pressure up to 1e-3 mbar)



Mauro Taborelli

NEG coating not compatible with the hBN outgassing during TDI bake-out

BN blocks, CuBe blocks, Al blocks, beam screens

Final TDI hardware

- Install 2 TDIs without any NEG

	Original proposal	New proposal
BN blocks	Ti + NEG + Cu+ NEG	Ti coating
Al blocks	NEG	Ti coating
CuBe blocks	NEG	No coating
Beam screens	Cu + NEG coated	No coating

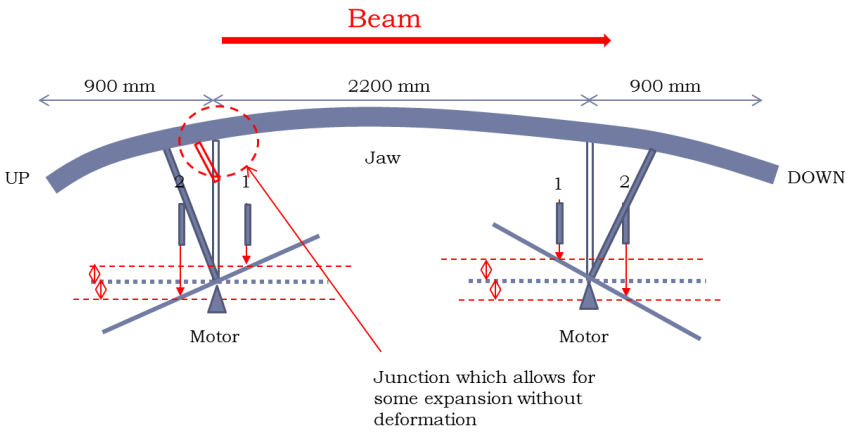
Jan Uythoven, LMC 19-Mar-14

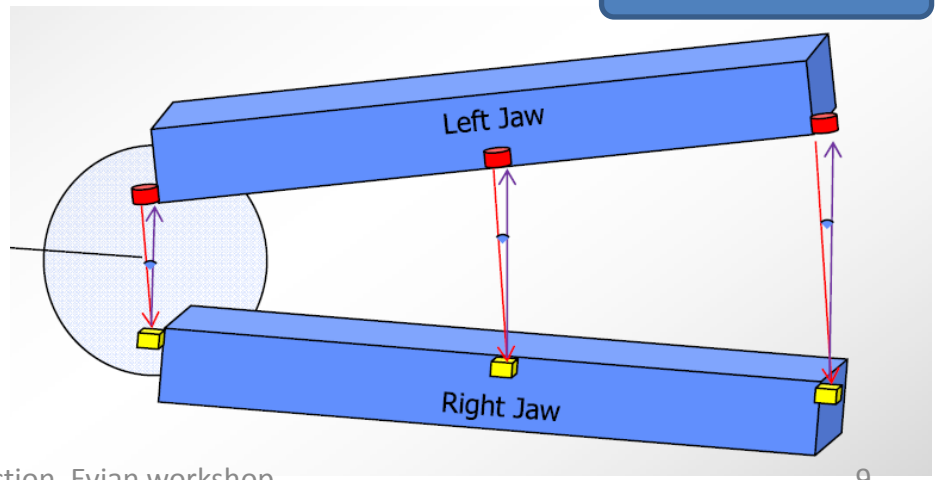
- Bake-out and NEG coating on adjacent chambers to improve vacuum and thus reduce experimental background
- Spare TDIs (Christmas stop 2015/16 ?):
  - Plan to add Cu on top of Ti for BN blocks to reduce beam impedance; to be validated by tests
  - This needs development time, so not done for initial installation

TDI gap interlock - BETS

- Redundant interferometric measurement of TDI gap (wrt LVDT)
  - Instead of mirror reflecting tubes to increase angular acceptance
  - Want to keep position at all times to avoid reinitialisation
  - Radiation tests for all items up to 10 MGy
  - Feedthrough to be tested for vacuum tightness
  - Will be installed on spare and tested for 6 months
  - Should be ready for XmasStop 2015/16 – installation tight due to bake out

A. Masi





TDI gap interlock - BETS

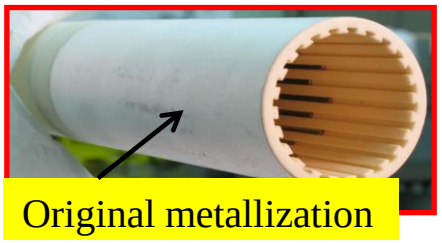
- Until interferometric measurement ready use gap calculated from LVDT as BETS input
- Change from LVDT gap to interferometric gap transparent for BETS
- BETS connection
  - 3 positions
  - Dump: TDI to stop beam, BETS on maskable input to allow for injection setup
  - Injection: ~10 mm gap, interlock only if gap outside tolerance or internal failure
  - Parking: BETS interlocks SPS extraction

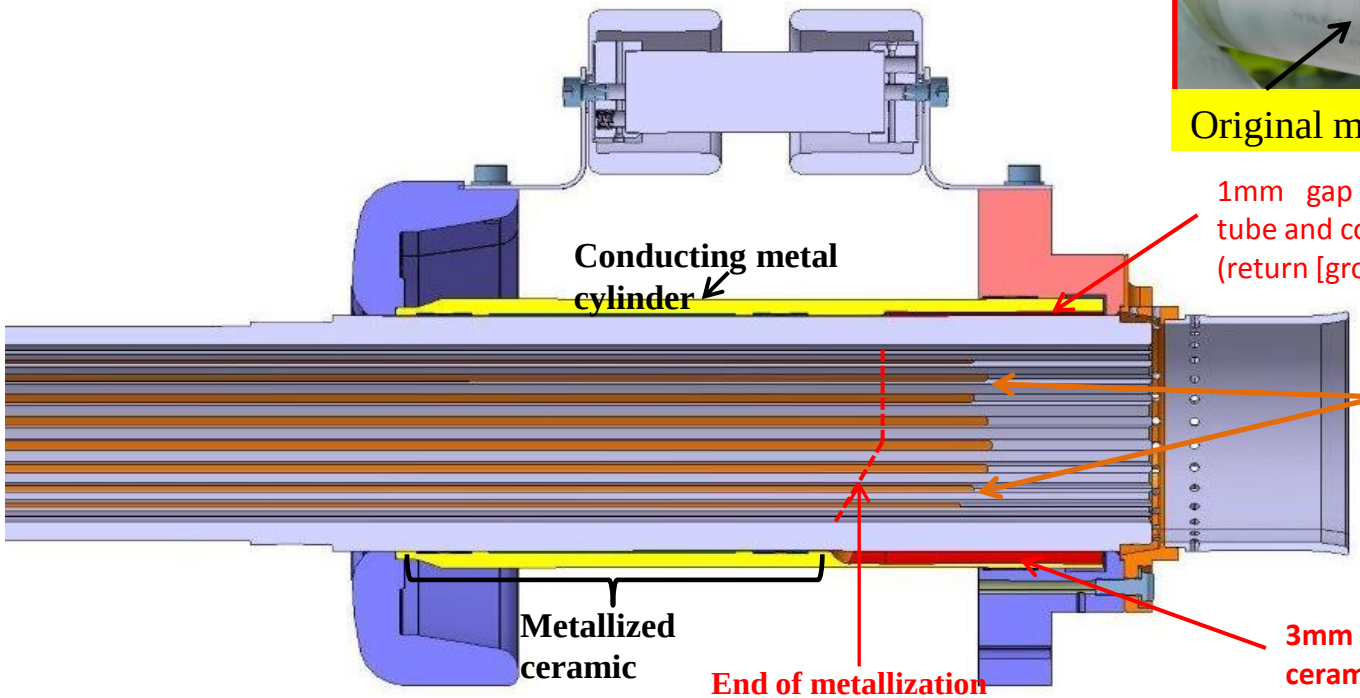
MSI current interlock - BETS

- No horizontal protection element → redundancy to FMCM in HW protection
- Measured current from EPC (main and feedback)
- Set limit on measured current corresponding to 1 sigma trajectory oscillation
- Fiber optics link between MSI and BETS
- With upgrade to FGC electronics no additional link between MSI power converter and BETS acquistion card needed
- BETS transfer function translates current into energy – can be changed only locally in the UA
- If current within limits and LHC energy within 450 ± 1 GeV → OK

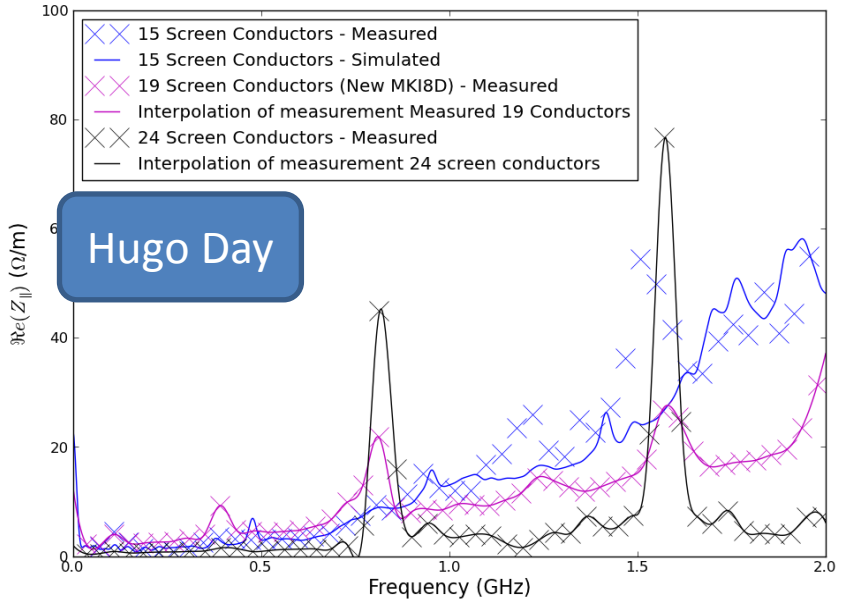
MKI upgrades for LS1 (I)

- Improved Beam Screen for the 8 upgraded MKIs is being implemented
- Outside metallization removed from ceramic tube starting ~20mm before end of screen conductors
- Conducting metal cylinder with a (vacuum) gap of between 1mm and 3mm to ceramic tube
- Electric-field on the surface of the ceramic reduced by a factor of ~3
- 24 screen conductors installed without flashover at 56 kV PFN.





MKI upgrades for LS1 (II)



- In 2012 with 15 conductors:
  - most MKIs: **~70 W/m** (did not limit injection);
  - old MKI8D: ~160 W/m !!
- Expected power deposition, post-LS1: **~50 W/m**

MKI heating is not expected to limit injection

MKI upgrades for LS1 (III)

Upgrades to (and nearby) MKIs, during LS1, include:

- **Higher emissivity** of clamps and corona shields for damping resistor of toroidal ferrites;
- Improved cleaning of the ceramic tube giving a substantial reduction of dust particles relative to the MKI8D installed during TS3, 2012 – which itself was a lot better than the pre-TS3 MKI8D;
- Installation of V2b RF fingers;
- NEG coated by-pass tubes;
- BTVSIs and BPTXs have been NEG coated during LS1;
- NEG cartridges will be installed, on the cold-warm transition, to supplement existing ion pumps;
- MKI interconnects: ion pump with NEG cartridge

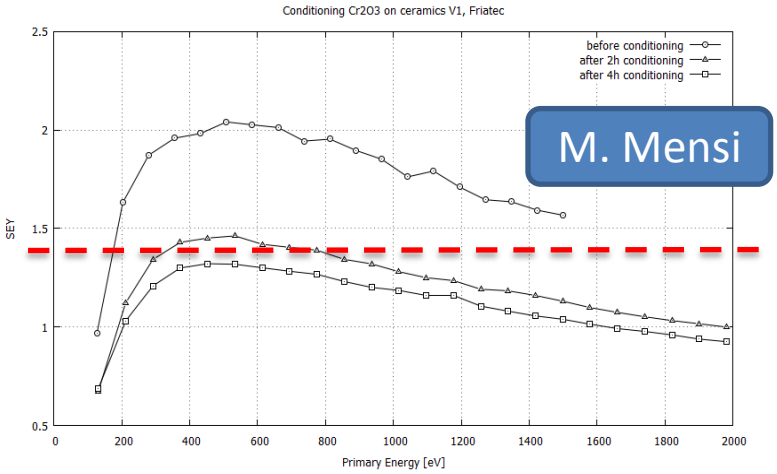
Heat transfer

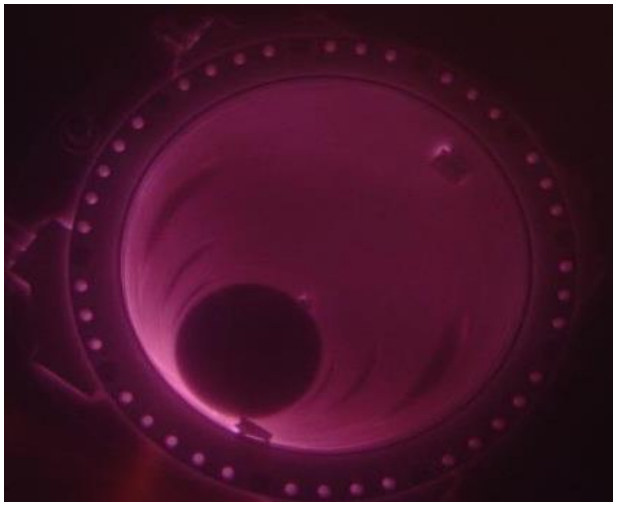
UFOs

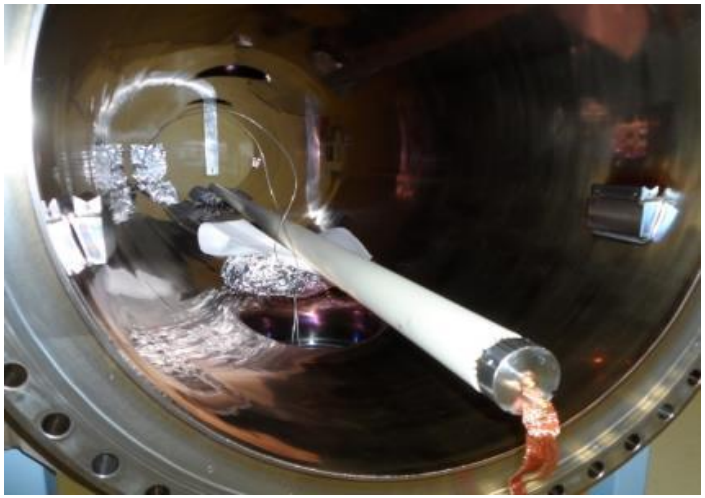
Vacuum

MKI ongoing studies

- Cr_2O_3 coating: examples from industry obtained; SEY < 1.4; develop for long ceramic tubes
- aC coating (200 nm): SEY between 1.25-1.5 due to uncoated parts in the measurement area; needs HV testing
- Ion bombardment of tank:





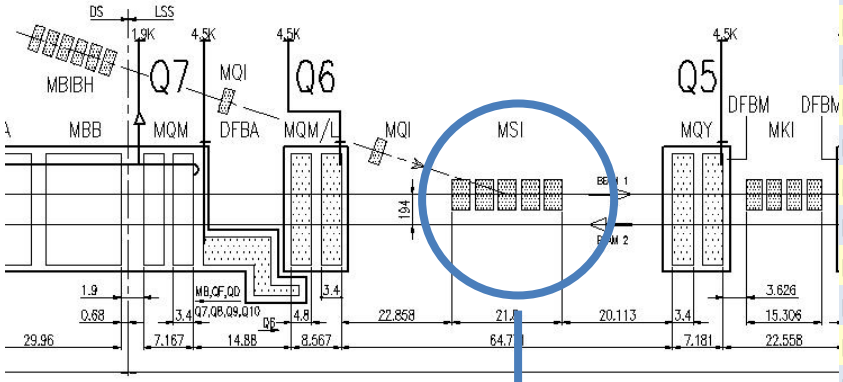


Modification of BLM system

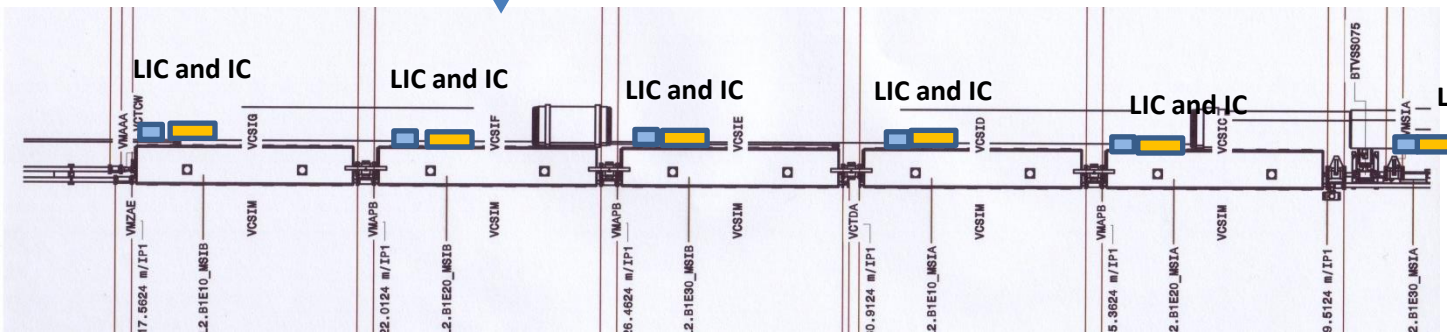
- Logic behind
  - Deploy LICs: upper dynamic range limit factor 10 higher than IC
  - Increasing thresholds for LICs keeps increased value always at 450 GeV higher – not only during injection
  - Provide/ keep redundancy between ICs and LICs
  - Connect only ICs+filter to blindable crates
  - Criterion to choose monitor location to be blindable:

    Operational loss levels should have factor 5 margin to dump threshold AND be high enough to give still readable signals in the monitor
- Changes to crates
  - Installed two new processing crates
  - Modified cabling to route all blindable monitors to those crates
- Deployment strategy of blindable BLMs
  - FPGA development
  - Create test bench and verify in lab
  - MP tests to validate system

Modifications of BLMs in IP2: 06L2

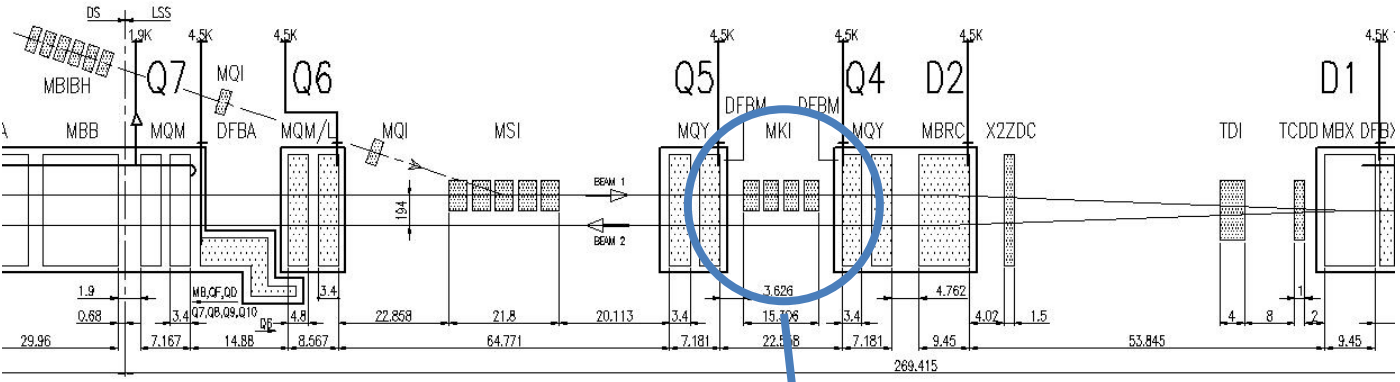


Expert names	blindable	connected to BIS	Monitor Type	DCUM
BLMEL.06L2.B1E10_MSIB	no	0	LIC+BF	3118.237
BLMEI.06L2.B1E10_MSIB	blind	1	IC+SF	3118.887
BLMEL.06L2.B1E20_MSIB	no	0	LIC+BF	3122.687
BLMEI.06L2.B1E20_MSIB	blind	1	IC+SF	3123.337
BLMEL.06L2.B1E30_MSIB	no	0	LIC+BF	3127.137
BLMEI.06L2.B1E30_MSIB	blind	1	IC+SF	3127.787
BLMEL.06L2.B1E10_MSIA	no	0	LIC+BF	3131.587
BLMEI.06L2.B1E10_MSIA	blind	1	IC+SF	3132.237
BLMEL.06L2.B1E20_MSIA	no	0	LIC+BF	3136.037
BLMEI.06L2.B1E20_MSIA	blind	1	IC+SF	3136.687
BLMEL.06L2.B1E30_MSIA	no	0	LIC+BF	3140.412
BLMEI.06L2.B1E30_MSIA	no	1	IC+SF	3141.062

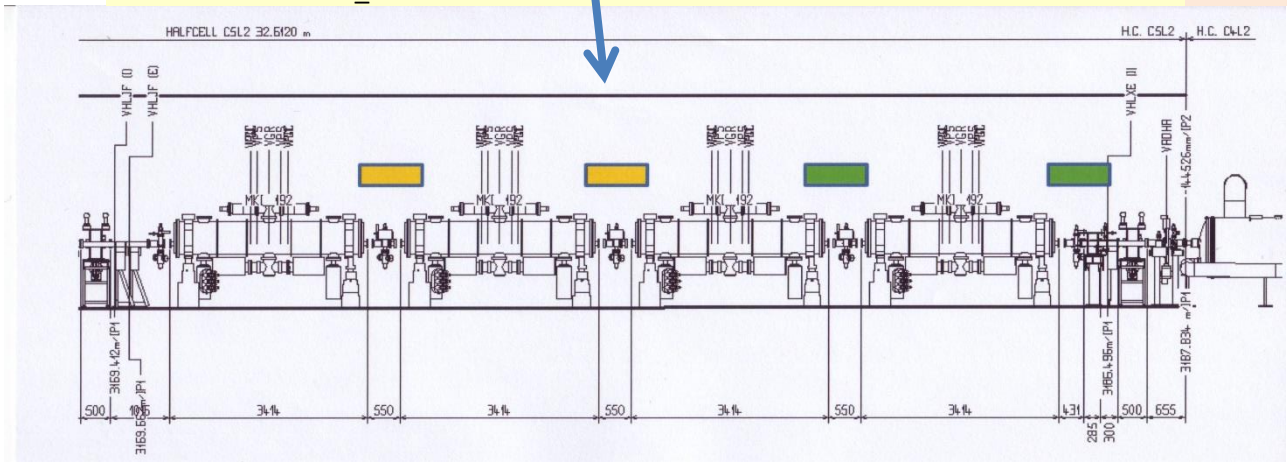


Slava Grishin

Modifications of BLMs in IP2: 05L2

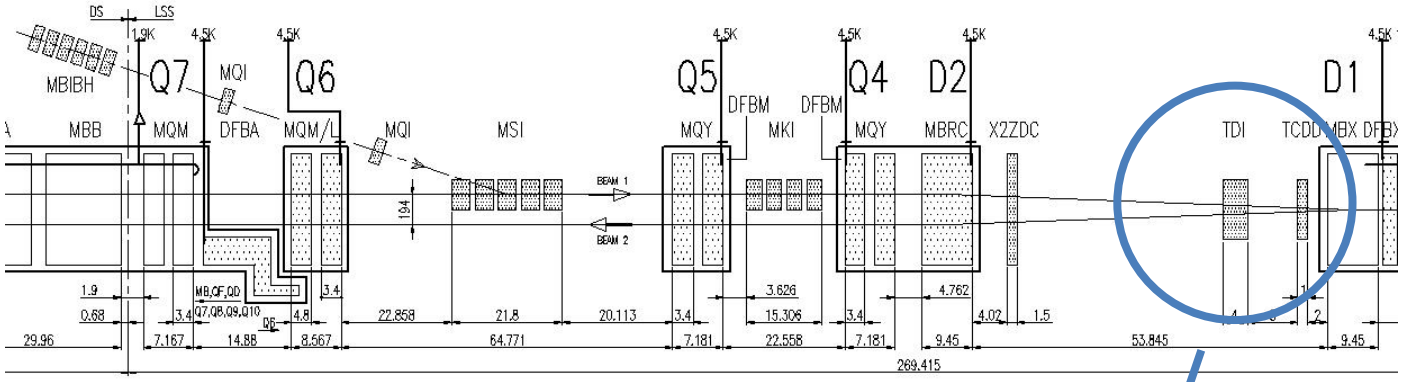


Expert name	connected to BIS	Monitor Type	DCUM	
BLMEI.05L2.B1E10_MKI.D5L2.B1	1	IC	3173.99	
BLMEI.05L2.B1E20_MKI.C5L2.B1	1	IC	3177.96	
BLMMI.05L2.B1E30_MKI.B5L2.B1	1	IC	3181.42	BLMEI.05L2.B1E30_MKI.B5L2.B1
BLMMI.05L2.B1E20_MKI.A5L2.B1	1	IC	3185.33	BLMEI.05L2.B1E20_MKI.A5L2.B1



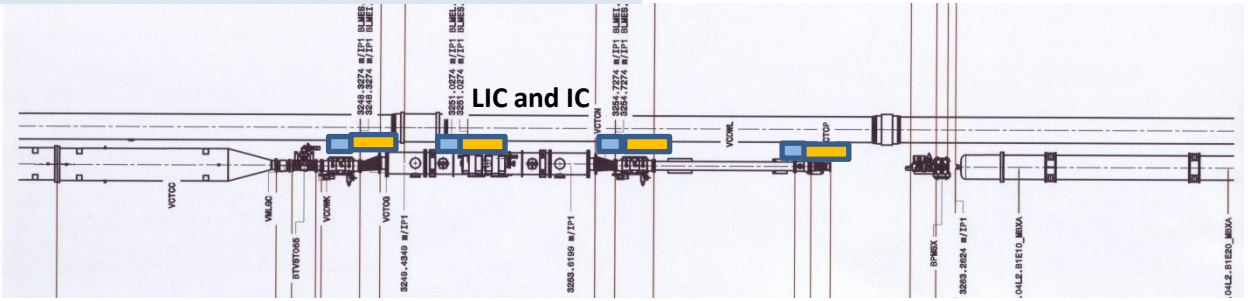
Slava Grishin

Modifications of BLMs in IP2: 04L2



	blindable	connected to BIS	Monitor Type	DCUM
BLMEI.04L2.B2I10_TDI.4L2.B2	blind	1	IC+SF	3248.3274
BLMEL.04L2.B2I10_TDI.4L2.B2	no	0	LIC+BF	3248.3274
BLMEI.04L2.B1E10_TDI.4L2.B1	blind	1	IC+SF	3251.0274
BLMEL.04L2.B1E10_TDI.4L2.B1	no	0	LIC+BF	3251.037
BLMEI.04L2.B1E20_TDI.4L2.B1	blind	1	IC+BF	3254.7274
BLMEL.04L2.B1E20_TDI.4L2.B1	no	0	LIC+BF	3254.727
BLMEI.04L2.B1E10_TCDD.4L2	no	1	IC	3262.26
BLMEL.04L2.B1E10_TCDD.4L2	blind	0	LIC+BF	3262.26

Slava Grishin



Blindable BLMs

- Machine protection commissioning in case of new firmware deployment:
  - A few pilot injections per beam
  - Interlock inhibit check:
    - Close injection protection collimator
    - Inject pilot
    - Check that the interlock of dedicated crates is inhibited and only that
  - Energy check
    - Disconnect timing cable from CISV on BLM crates of P2 and P8 surface (i.e. energy level fall to 7 TeV)
    - Inject again pilot
    - Check that dedicated crates' interlock request is not inhibited

Operational – dedicated LHC filling

Verena Kain, Stephane Cettour Cave

- Presently 43200 ms supercycle of which 21600 ms LHC cycle
- For beam production and IQC add 5 BPs = 6000 ms
- 21600 + 6000 ms = 27600 ms → minimum dedicated filling super cycle length
- Difference in 2015 not so big due to deprecated CNGS, shorter SFTPRO (36 s)
- Problem:
  - LHC filling ~ 1h, can be several hours in case of problems
  - Issue with injector physics

Measurements in addition to ‘standard’ commissioning

- SPS extraction apertures
- MKE waveforms
- Kick response in TLs+adjacent sectors for BPM/corrs and dispersion matching
- Injection apertures
- MKI waveforms
- MSI current and TDI gap BETS interlock
- BLM blindable crates commissioning

Summary I

- Realignments → start from scratch trajectory
- Trajectory stability due to MSE:
  - expect gentle improvements for TI 2 due to filter gain and in TI 8 due to repaired DCCT
- Final TDI:
  - major changes to beam screen
  - foreseen coatings need further investigation (Ti or no coating)
- TDI gap interlock:
  - Redundancy to calculated gap from LVDT as input to BETS (maskable)
  - Interferometric measurement designed and ready for 6 month testing on spare
  - Can be installed in WS 2015/16
  - Use LVDT as BETS input for the moment, change to interferometry transparent for BETS

Summary II

- MSI current interlock
  - No passive protection in horizontal plane
  - Change electronics to FGC then direct link to BETS
- MKI
  - Heating problem in MKI8D solved
  - Many upgrades for better heat transfer, cleaning and vacuum
  - Ongoing studies on tank emissivity, indirect ferrite cooling and coating
- Blindable BLMs
  - Installed HW
  - Deployment strategy to be defined
- Dedicated LHC filling: 36 → 28 s gain vs Injector physics
- Due to many HW upgrades during LS1 several additional measurements needed for this startup