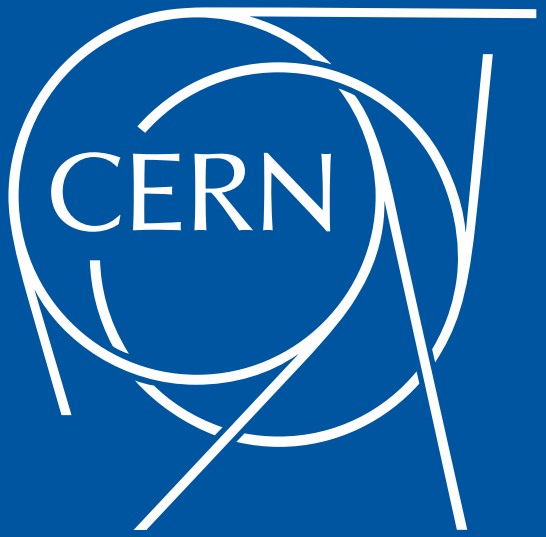
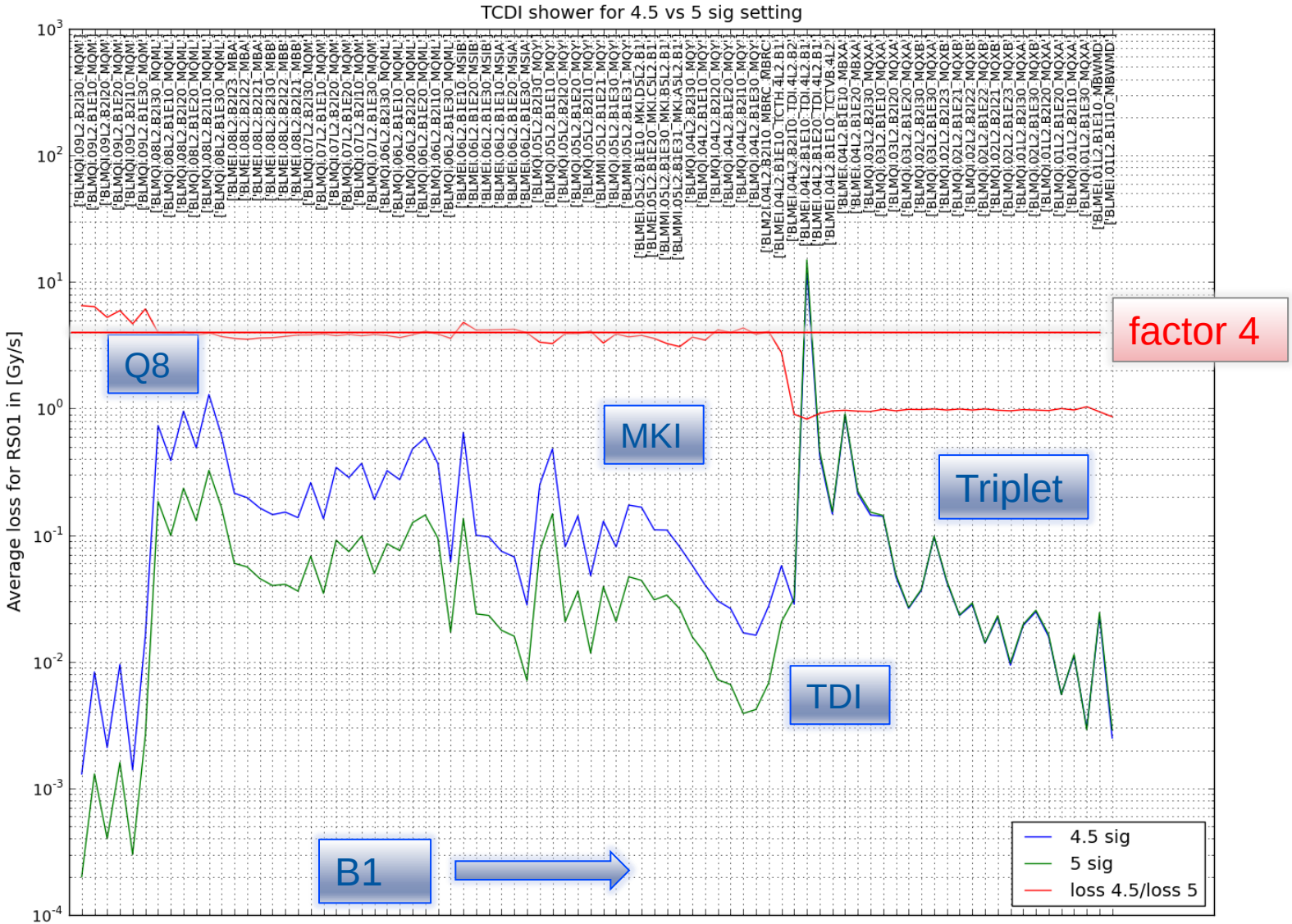

CERN

Proposal for deployment strategy of BLM interlock inhibit at injection

MPP, 15-Aug-14

Open TCDI gap: loss shower on LHC BLMs for B1



W.Bartmann – MPP Oct'11

Possible Mitigation techniques

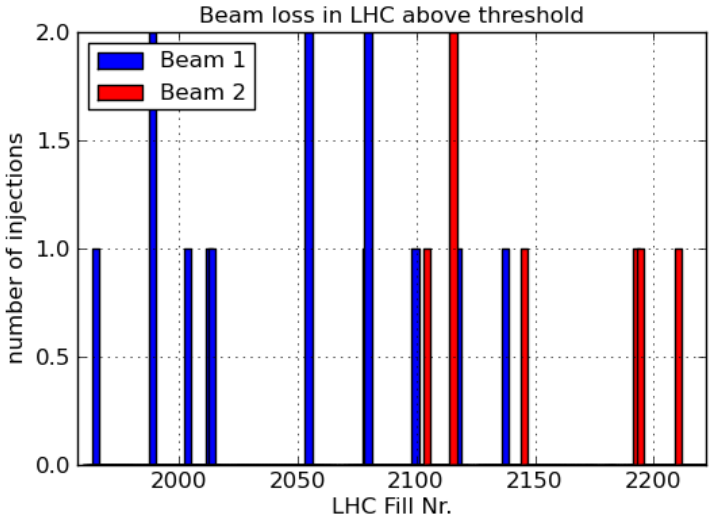
- Overinjection and MKI failure
  - Interlocking and good procedure ✔
- TL showers:
  - Local shielding between TCDIs and LHC ✔
  - Beam scraping in SPS ✔
  - Opening TCDIs ✔
  - BLM interlock inhibit at injection ✔
  - Moving/adding TCDIs ✖
  - Improve stability of MSE ✔
- Uncaptured beam
  - Local shielding after TDI ✔
  - Minimisation of capture losses ✔ (depends on RF voltage/phase adj)
  - Injection and abort gap cleaning ✔
  - Carefully monitoring beam quality in injectors (bunch length, satellites) ✔
  - BLM interlock inhibit at injection ✔

Mitigation techniques with expected future gain

	MITIGATION	POTENTIAL FUTURE GAIN
TL Shower	Local shielding between TCDIs and LHC	Presently less gain than expected from simulations; difficult to increase shielding, in particular for TI 8
	Beam scraping in SPS	No gain with present emittances, for future bigger emittances probably worse;
	Opening TCDIs	No gain for TI 2 (already at 5 sig), but possible gain for TI 8 (at 4.5 sig), Machine Protection!
	BLM interlock inhibit at injection	With LICs at certain positions and removed filters gain of factor 5 possible, Machine Protection!
	Moving/adding TCDIs	Potentially significant gain, under study
	Improve stability of MSE	Ripple improvement and phase stabilisation in place since 3 days, effect to be checked
Uncaptured beam	Local shielding after TDI	No gain: on hold
	Minimisation of capture losses	No gain: trade-off with mismatch and resulting bunch length reduction
	Injection and abort gap cleaning	No gain: trade off with luminosity
	Carefully monitoring beam quality in injectors	No gain in losses but better detection of bad beam quality early in the chain
	BLM interlock inhibit at injection	With LICs at certain positions and removed filters gain of factor 5 possible, Machine Protection!

Dumps due to injection losses end of 2011

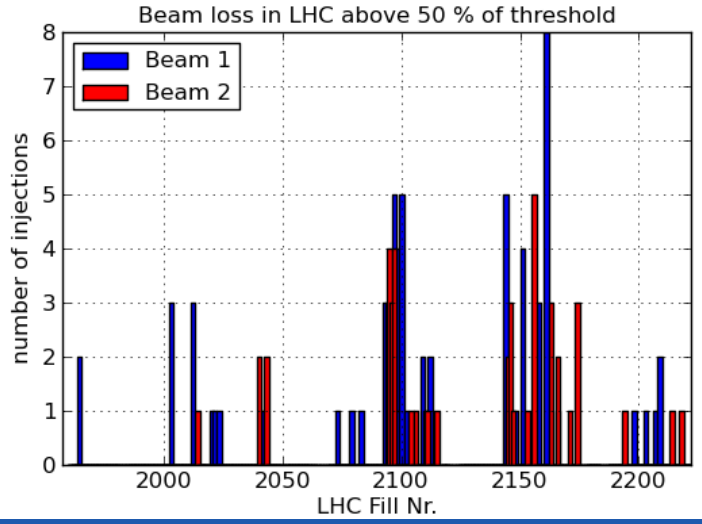
- Number of dumps due to injection losses since middle of July



14 dumps for beam 1

6 dumps for beam 2

- Try to avoid dumps, start steering before we reach dump level



Steering frequency:

Beginning of year: ~ once a week
September: every 2 – 3 fills
Now: every couple of days

Steering mainly triggered by losses

Dumps due to injection losses in 2012/13

All dumps in 2012/13	**1236**
Dumps at injection	528
Dumps at injection with at least a pilot in either beam	355
Dumps at injection with at least a pilot in either beam and BLM as dump cause	58
Dumps at injection with at least pilot in either beam and dump triggered by injection losses	14

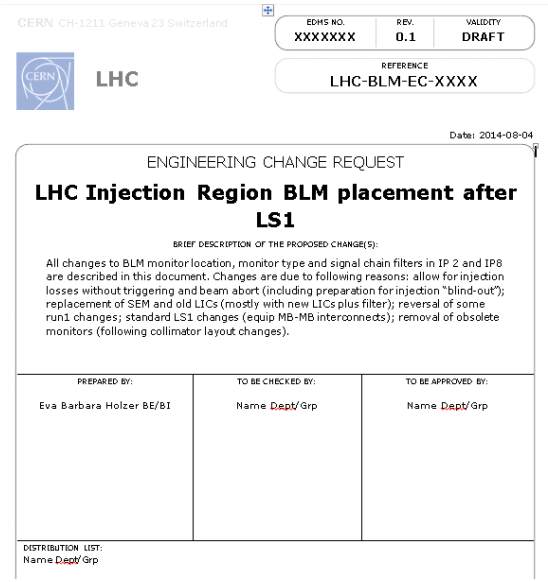
- **~5%** of already circulating beams @injection been dumped by losses.
- Not full figure of merit as **transfer lines were re-steered** before dumping to reduce the losses ….

What to expect in 2015+?

- Replacement of most affected ICs with less sensitive LICs
  - Should allow already **gaining factor 5** without BLM interlock inhibit.
- Re-arrangement of BLMs onto 2 mask-able crates / injection region.

- In 2015 we will have
  - **Less losses** because of 25ns, shielding, better MSE ripple,… .
  - **More losses** because of 288b, scrubbing with doublets, higher capture losses.

- Answer whether we have to rely on the BLM interlock inhibit only **after initial experience with (25ns) injection** in 2015.



CERN CH-1211 Geneva 23 Switzerland

EDMS NO.	REV.	VALIDITY
XXXXXXX	0.1	DRAFT

LHC

REFERENCE: LHC-BLM-EC-XXXX

Date: 2014-08-04

ENGINEERING CHANGE REQUEST

LHC Injection Region BLM placement after LS1

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):

All changes to BLM monitor location, monitor type and signal chain filters in IP 2 and IP8 are described in this document. Changes are due to following reasons: allow for injection losses without triggerng and beam abort (including preparation for injection "blind-out"); replacement of SEM and old LICs (mostly with new LICs plus filter); reversal of some run1 changes; standard LS1 changes (equip MB-MB interconnects); removal of obsolete monitors (following collimator layout changes).

PREPARED BY:	TO BE CHECKED BY:	TO BE APPROVED BY:
Eva Barbara Holzer BE/BI	Name Dept/Grp	Name Dept/Grp

DISTRIBUTION LIST:
Name Dept/Grp

Pro / Cons of deployment of BLM interlock inhibit at injection

- **PRO**
  - **Less time lost** at injection / re-steering the TL.
  - Can **close the injection protection** elements more.
  - Can set **lower thresholds for circulating beam** (always at least a close-by BLM which is not blind-able).
  - **Less requirements** on other mitigation techniques (injection/AG cleaning,…).
- **CON**
  - Consistent masking may make us **run with degraded conditions** for longer time (activation, reduced margins to quench/damage…). Losses are measured but the dump trigger will be inhibited for a certain time.
    - **Masking these BLMs** also for circulating beam.
    - Still have **IQC for monitoring**.
  - Will most likely imply **two code versions to start with** → Additional commissioning time, increased maintenance.
  - If deployed in all BLM crates masking function a priori present in ALL crates → **erroneous activation** of inhibit functionality in one crate means, that **1/3 of a sector would be unprotected**.
  - Might impact implementation of other new features (limited development resources).

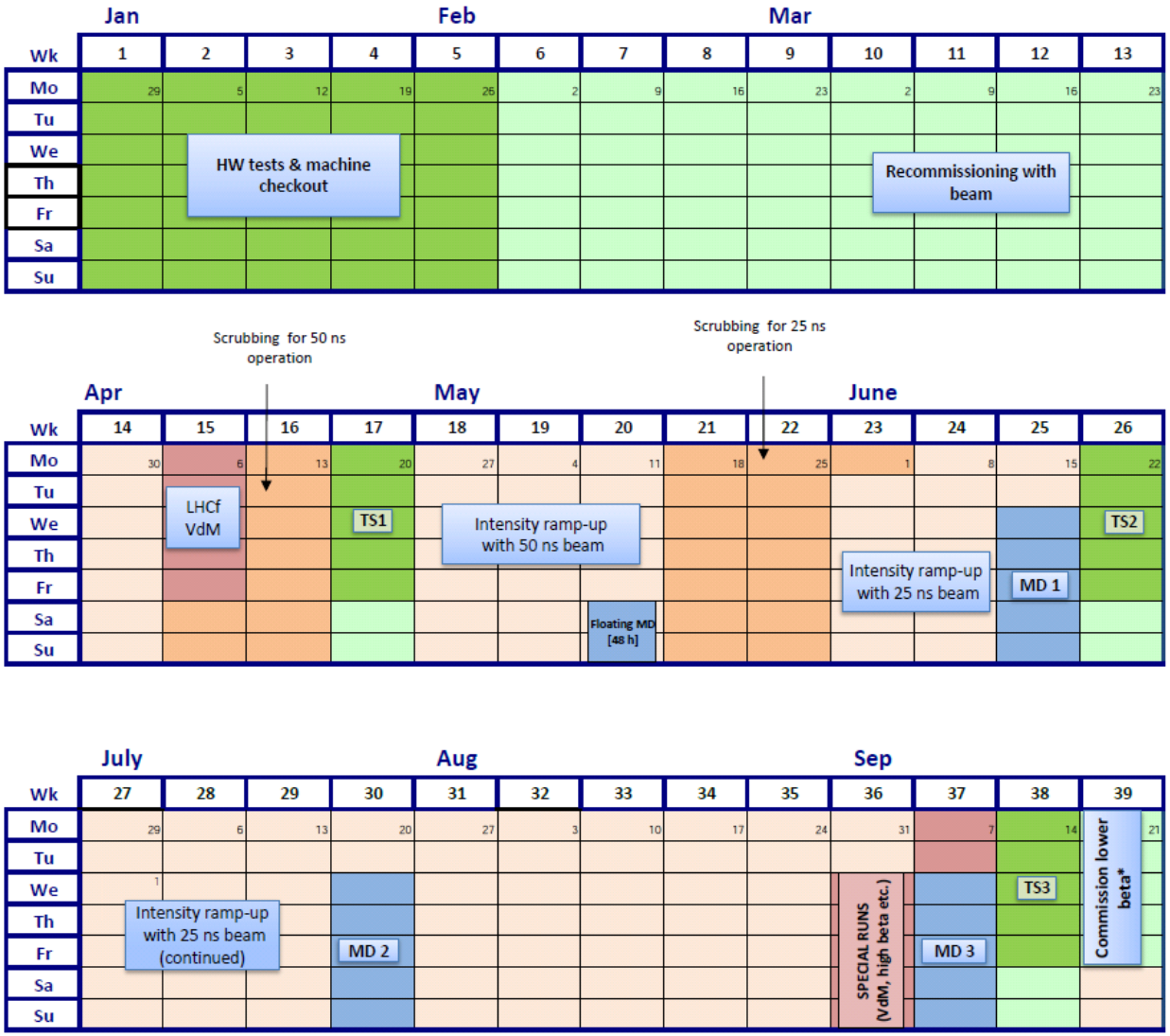
Constraints for deployment of BLM interlock inhibit at injection

- Introducing a masking functionality in the (generic) BLM firmware bears risks and has to be **carefully implemented and tested**
  - **Lower protection/failure can be accepted** from these crates (redundancy in monitoring).
  - Two versions/branches in use for start-up implies that a modification/bug will need to be corrected in both → **Increased maintenance effort.**
  - **Early version** will **not have all safety features** if we don't have the time for proper development. e.g. if enough time, we could add Triple Mode Redundancy (TMR).

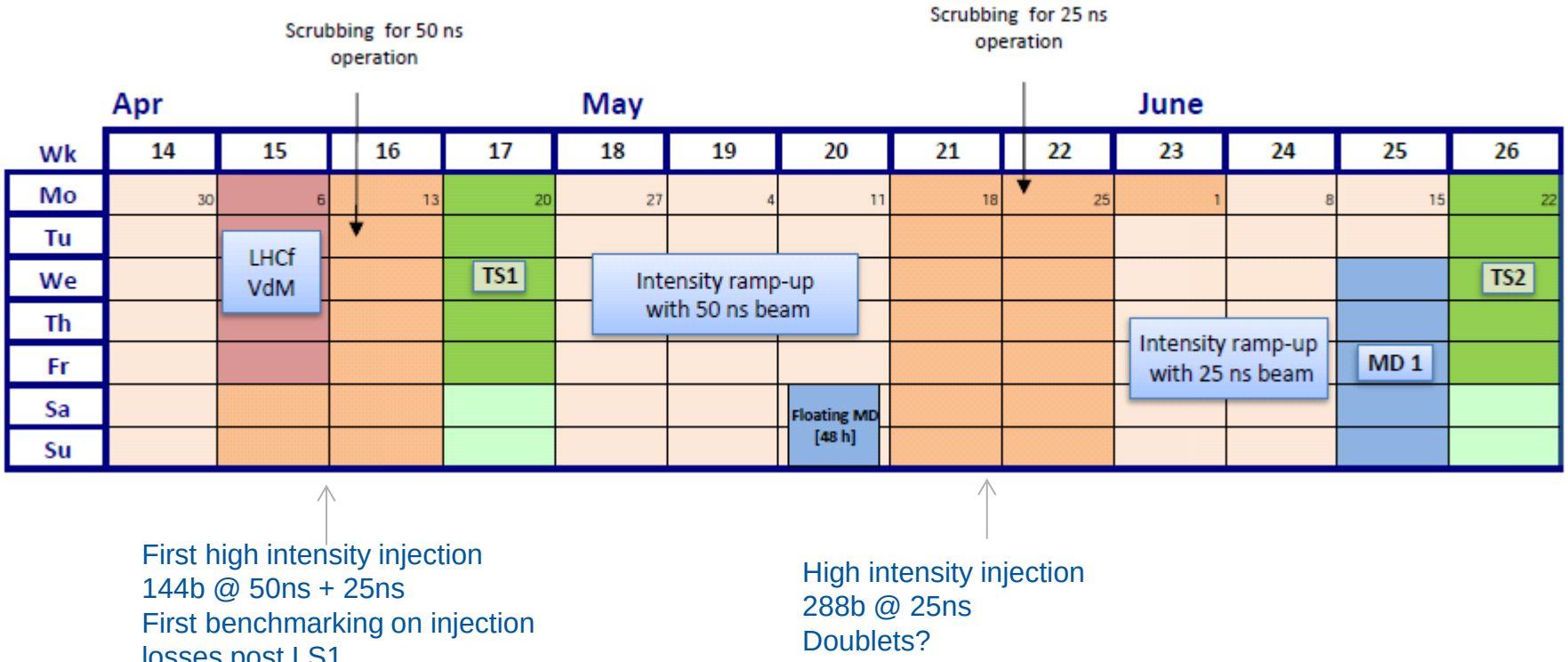
- Interlock inhibit vs other commitments during LS1
  - Development/Deployment should be **done after the completion of the core system** (LS1 improvements, PM , XPOC,…).
  - Christos asked for a written statement that the system needs to be changed (recommendation by auditors).
  - Christos asked for agreement in the prioritisation of the tasks.

Courtesy: BLM team

The planning



Possible strategy



- Deploy BLM interlock inhibit at injection for potential use in in TS1 in order not to slow down scrubbing and initial intensity ramp-up.
  - Special version ONLY on blind-able crates.
  - Commission blinding with timing signal but **INITIALLY DO NOT BLIND** in order to allow assessment of post LS1 situation.
- Prepare **for full deployment** if need confirmed in **TS2**.

Conclusion

- Many **mitigations deployed to decrease injection losses** during LS1, one of which are BLM re-arrangements and BLM interlock inhibit at injection.
- Interlock inhibit helps to **mitigate dumps at injection (but not losses!)** but adds a **new (potentially very dangerous) failure mode** into the BLM firmware.
- Need for BLM interlock inhibit at injection can only be **confirmed during beam commissioning**.
- BLM team to prepare **for initial deployment in TS1** (beg. of April 2015) a 'light' firmware (only to be **used in blind-able crates**, where less dependability can be accepted for short-term).
- Decision for ultimate (and **full) deployment** after first **scrubbing run** (mid April 2015) for eventual deployment in TS2.

Spare Slides

Comments from Christos (13.08.2014)

- We have commented several times in the past to please avoid the “sunglasses” name. The change request is not to filter the signal, as the name implies, but to completely ignore the interlock trigger the card creates when there is an injection. Therefore, a more accurate name have been requested and proposed “BLM blinding at Injection” or better “BLM Interlock Inhibit at Injection”.
- The most feared failure, if this feature is deployed everywhere, is what is referred in reliability analysis as silent or sleeping failure. Meaning the inhibit function erroneously activates, e.g. from SEU or FPGA’s logic element error, during beam operation. This cannot be detected until it is too late and the consequence is that 1/3 of a sector is unprotected. The probability is low but not zero.
- In the architecture we have in mind, the measurements stream will not be modified at all. That is, during the blinding periods of the interlock signal, you will continue to have the ability to see measurements over thresholds if those happen from all channels as usual. In my opinion, this is the safest way to implement this, because an external check (online or offline in a software layer) could indicate that something is going wrong.

LBOC

- M. Lamont asked what is expected in term of capture losses when operating with 25 ns beams.
- P. Baudrenghien answered that these losses will clearly increase and it is not excluded that BLM sunglasses will be needed to avoid unwanted beam dumps at injection.
- V. Kain commented that it might be possible to perform the injection and abort gap cleaning even closer to the beam edge and mitigate these losses. She added that, in some sense, blinding the BLMs in the injection region could prevent from detecting drifts in the TLs.
- C. Bracco commented that the BLM signal would still be recorded and checked by the IQC so that misbehaviors in the TL will be detectable. She reminded that if the TCDIs will have to be closed to 4.5 sigma the cross-talks from the line are expected to increase by a factor of 4. Operation without sunglasses requires using RC filters (delayed loss signals) and increasing the thresholds at some BLMs for full operation at 450 GeV. With sunglasses the filters could be removed and thresholds kept safer.
- V. Kain commented that shot-to-shot TL variations should be less important after LS1 due to the improvement of the MSE current ripples. This should reduce the losses from the lines.
- D. Wollmann reminded that the main issues with the blindable BLMs is that, for maintenance and safety reasons, BI wants to have just one code running on all the crates. It cannot be guaranteed that, in case of failure, the modification of this code will not cause the blinding of the full BLM system.
- S. Redaelli asked if this means that the BLM sunglasses are then completely excluded.
- W. Bartmann answered that this is not the case and BI people are working on the new code. Due to lack of resources, it is not guaranteed that the code will be ready to be tested during the commissioning time. The present strategy is anyhow to have it checked and available in order to use it in case of major issues at injection.

TCDI Shielding

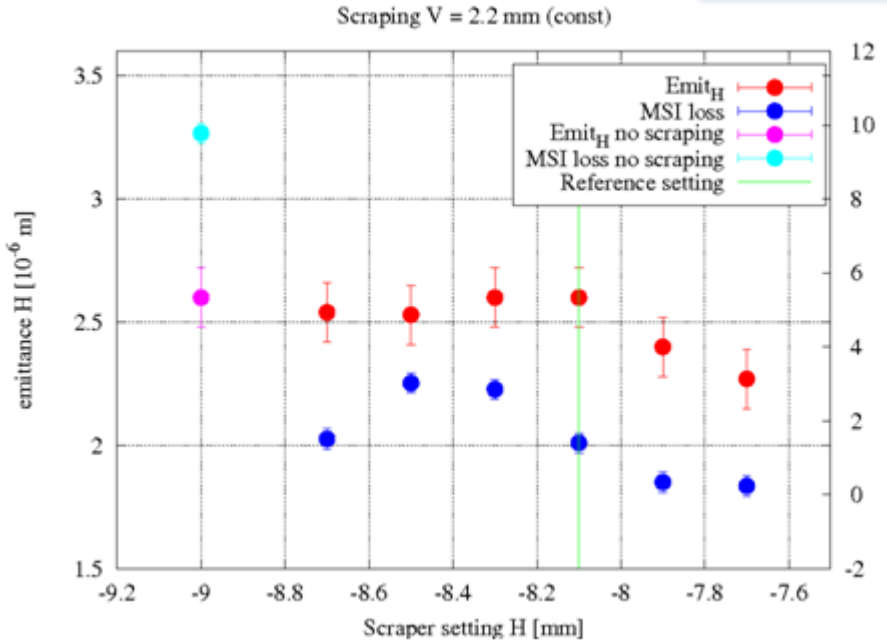
Simulations by Vittorio Boccone: factor 4-5 loss reduction expected

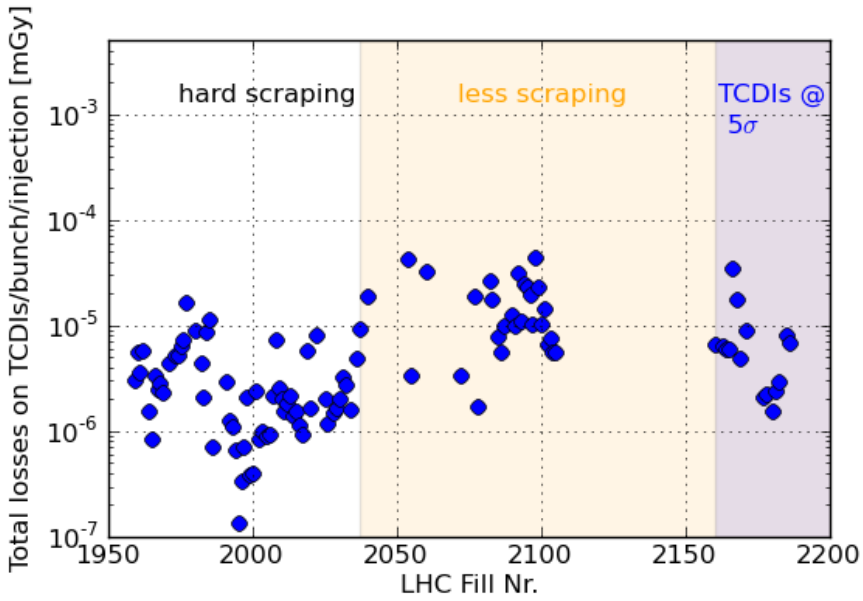
- TI 2 shielding: factor ~2 reduction measured
- TI 8 shielding: factor 2.5 – 3 reduction measured

SPS scraping: Losses on TCDI BLMs in TI 2

- Scraping the tails has strong effect on injection losses
- In optimum position without touching beam core
- Currently reduced scraping due to activation of SPS equipment

V. Kain, L. Norderhaug Drosdal



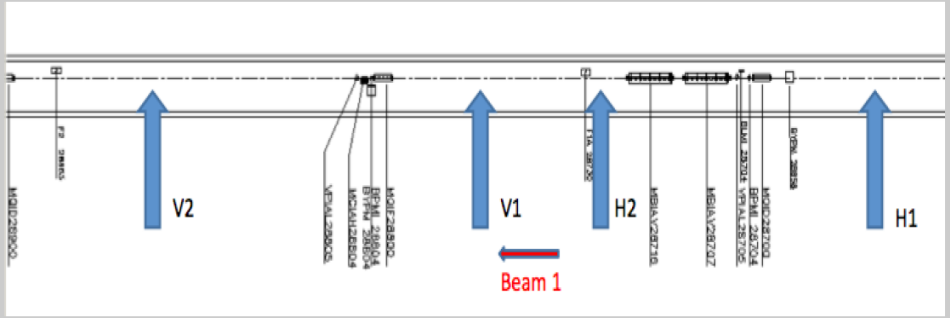


Move/add TCDIs

Results of studies by Eliana Gianfelice:

- New locations for TCDIs in TI 2 and TI 8
- FLUKA simulations started
- impact of Q20 optics to be checked
- MD desirable to distinguish loss patterns

New collimator positions (schematic).



Proposed TI2 collimators, re-matched

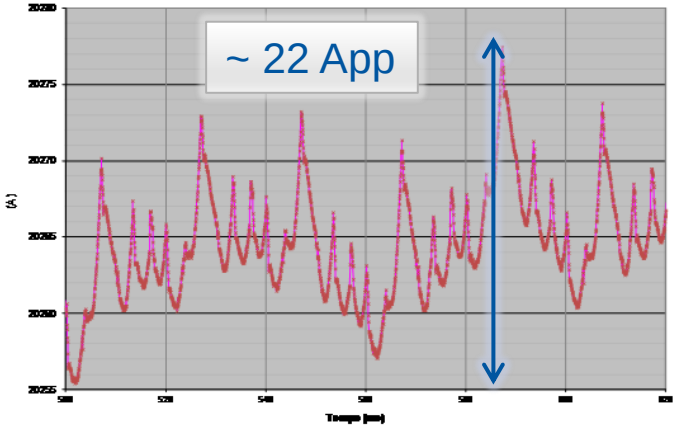
	position(m)	β_x(m)	D_x(m)	σ_x^β (μm)	σ_x^p (μm)	$\Delta\mu_x$ (deg)
TCDIH.NEW1	2846.230	26.2	1.121	437	482	0
TCDIH.NEW2	2867.631	35.0	-0. 006	506	3	62.6
TCDIH.29050	2971.0	83.8	-1.986	782	854	60.9

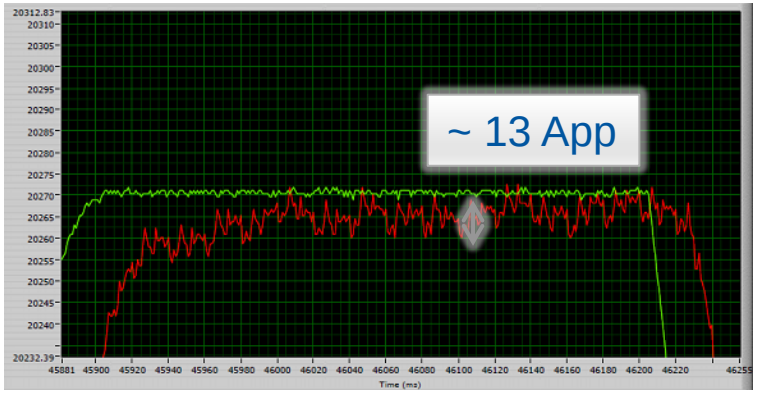
	position(m)	β_y(m)	D_y(m)	σ_y^β (μm)	σ_y^p (μm)	$\Delta\mu_y$(deg)
TCDIV.NEW1	2879.4	24.1	0.089	420	38	0
TCDIV.NEW2	2905.0	46.1	0.277	580	119	64.5
TCDIV.29012	2952.0	32.5	0.100	487	43	63.5

MSE stability

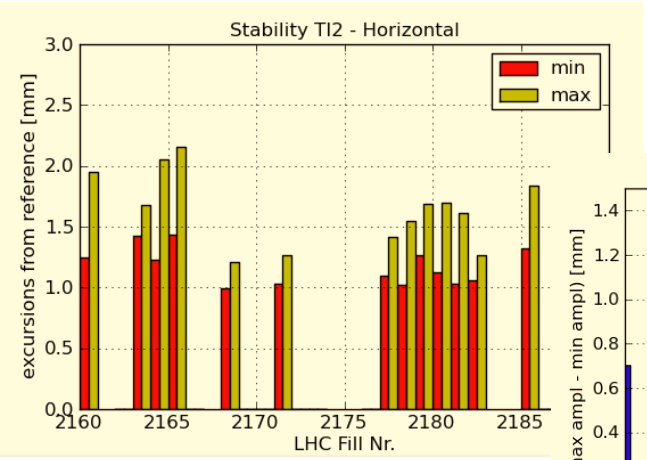
Gilles Le Godec for EPC:

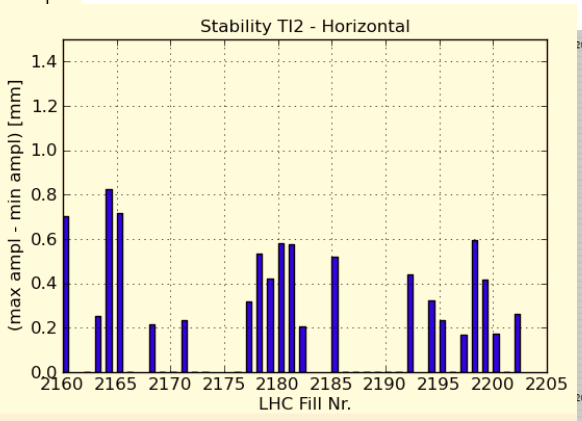
- Peak-to-peak ripple improved by factor 2.4
- Cycle to cycle reproducibility measured and improved by 38% on LHCION2 cycle
- Should be measured on LHC1 cycle

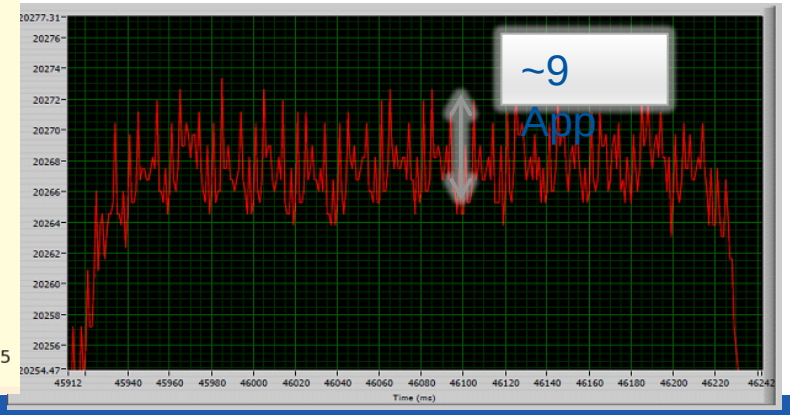




V. Kain







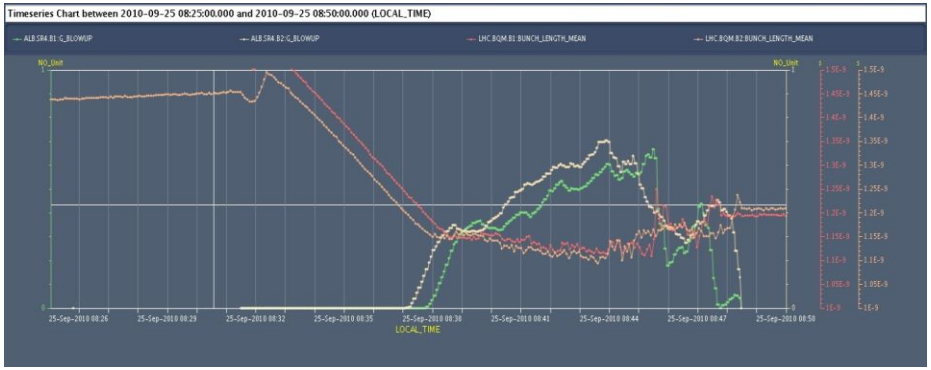
Capture

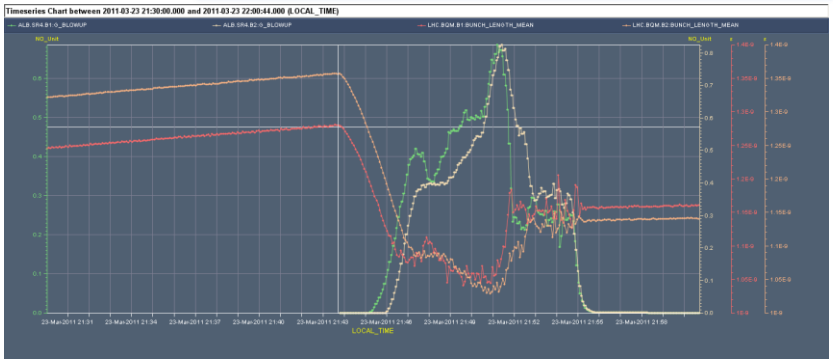
P. Baudrenghien for the RF team:

- SPS bucket length is double of LHC bucket due to RF frequency ratio 200/400 MHz
- MD on reducing injection losses by increasing nominal matched voltage of 3.5 MV to 6 MV (currently in operation)
- Running with mismatched voltage causes bunch length shrinking after capture → long. emittance blow up needed to reach the aim of 1.2 ns long bunches

Bunch Length Mean and Noise Amplitude during Ramp

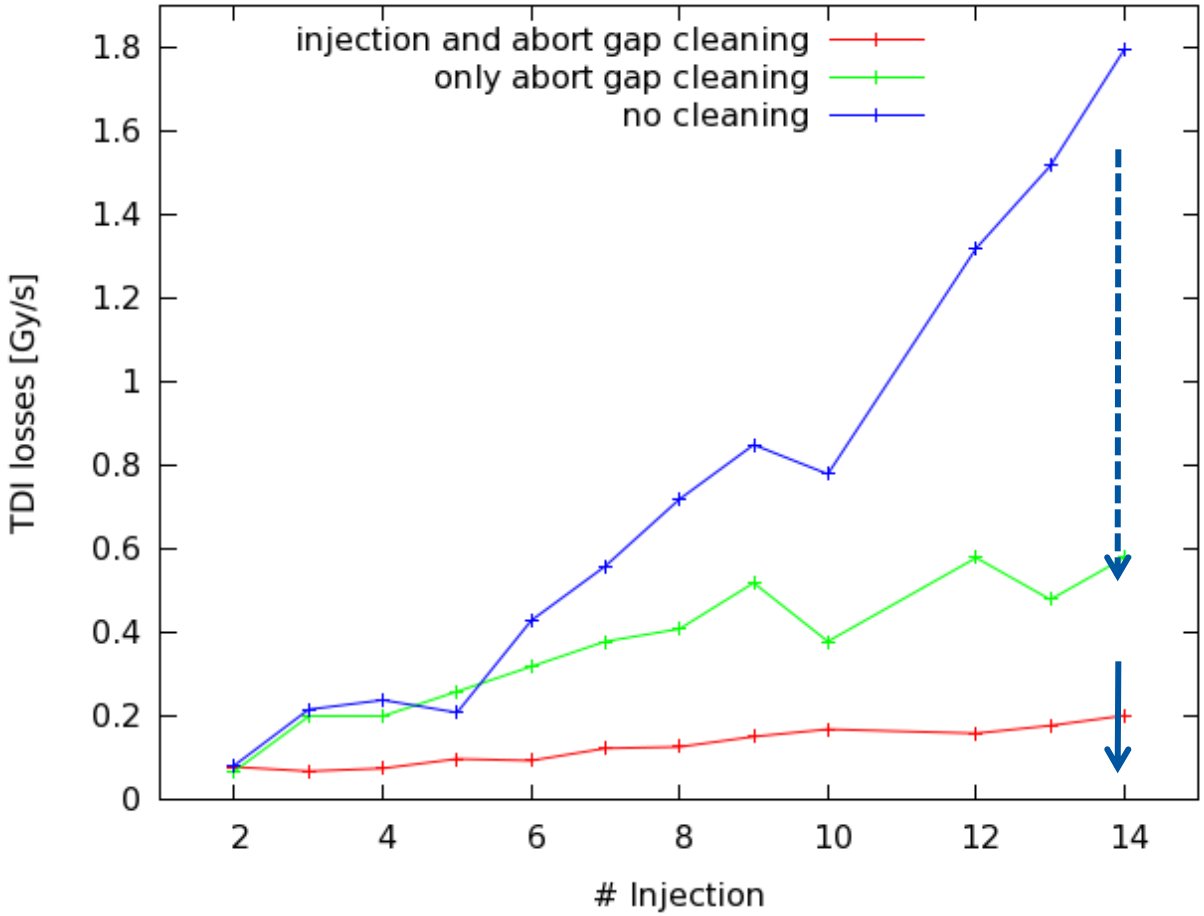
P. Baudrenghien for RF team





Injection and abort gap cleaning

E. Gianfelice, B. Goddard, W. Hoefle, V. Kain, M. Meddahi, J. Uythoven, D. Valuch,...



For later injections losses decreased by:

a factor 3 for AGC only

a factor 9 for injection and AG cleaning

Both operational

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