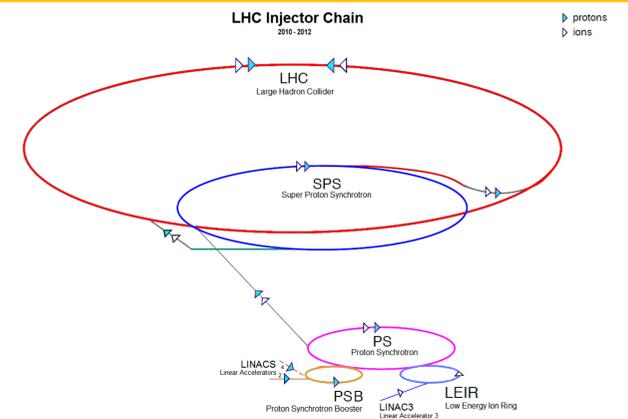


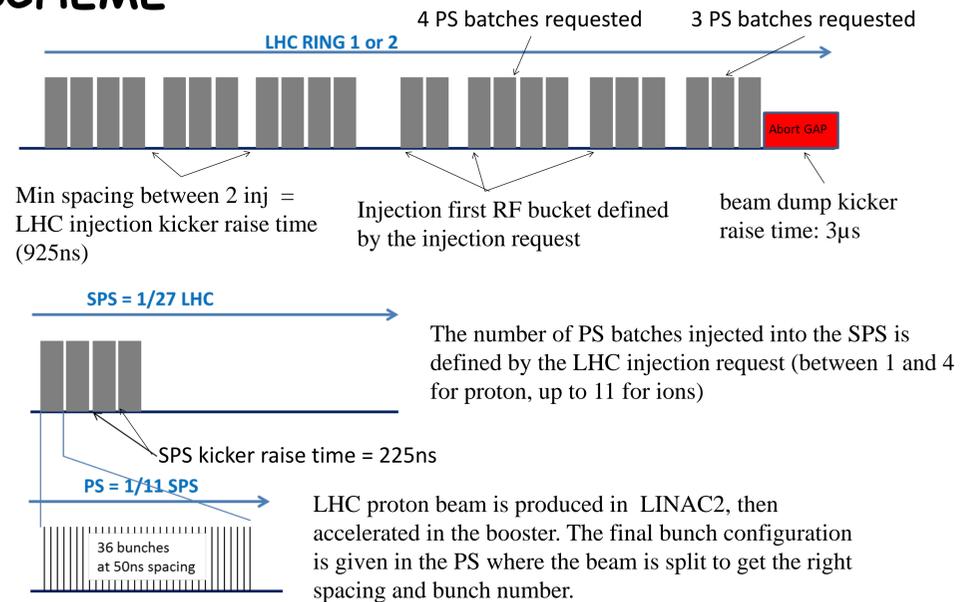
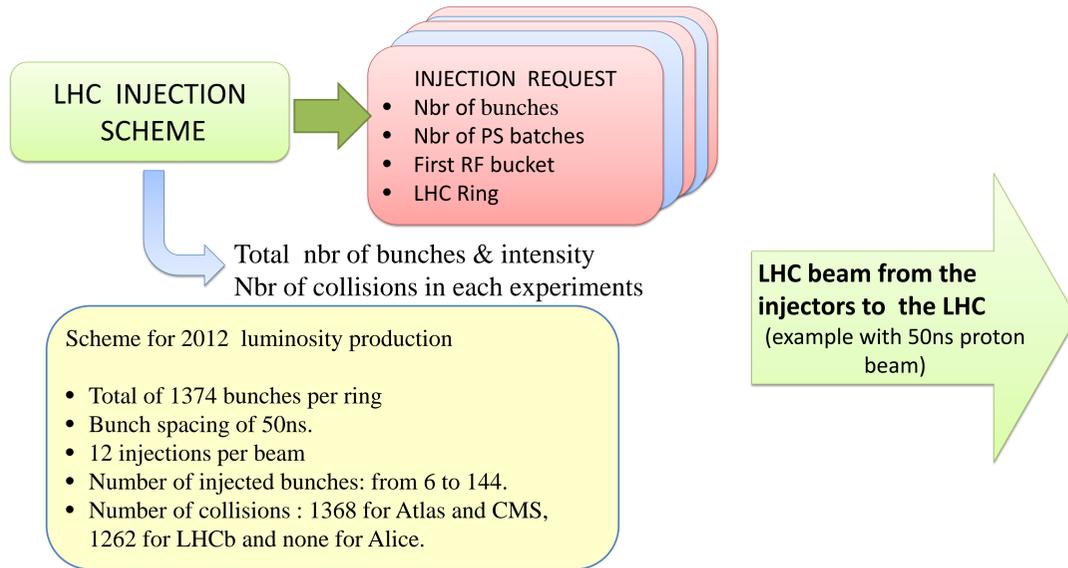
INTRODUCTION

The LHC is the largest accelerator at CERN. The 2 beams of the LHC are colliding in four experiments. Each beam can be composed of up to 2808 high intensity bunches. The LHC beam is generated at the source of the LINAC, and then accelerated in the Booster, PS and SPS accelerators, before being injected to the LHC through the 3km long transfer lines. The injected beam contains up to 288 high intensity bunches, corresponding to a stored energy of 2 MJ. This powerful beam could easily create damage, and many protections at different level are in place to prevent from any incident. To build for each LHC ring the complete bunch scheme that ensures a desired number of collision for each experiment, several injections are needed from the SPS to the LHC.

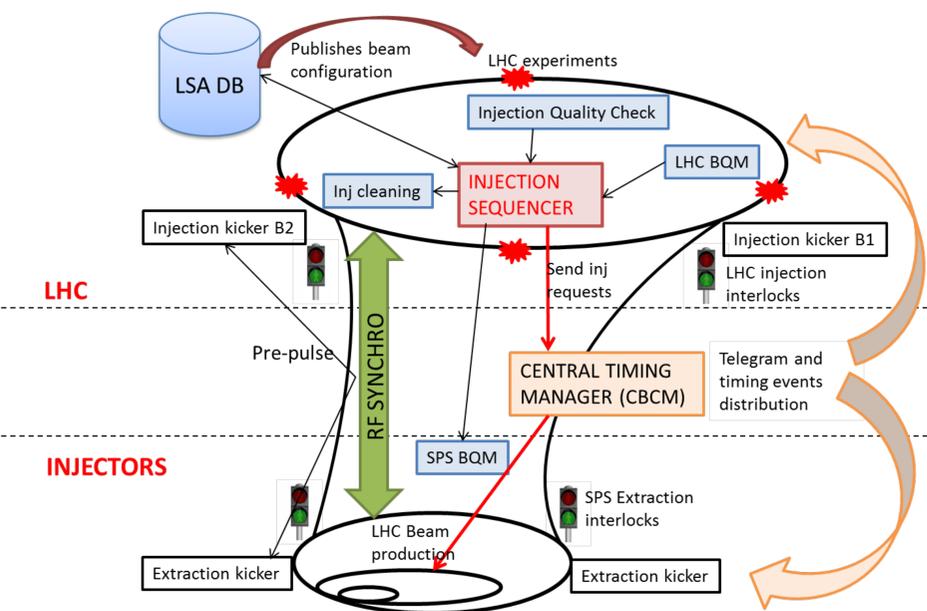
The LHC injection sequencer is the user interface that allows the LHC operator to request the beam to be injected into the LHC, following predefined schemes created for the purpose of different type of operation like physics production, beam studies or injection tests for example.



LHC INJECTION SCHEME



LHC INJECTION ACTORS



Central Timing Manager (CBCM) [1]

- Orchestrates the cycles that are played in each accelerators by sending telegram information and timing events to all accelerator's equipment.
- Gets the injection requests from the injection sequencer, manages beam production and destinations in the injectors.

Interlock systems [2][3]

- Ensure injection process safety. In case of problem detected with the equipment it can
 - Prevent beam extraction from SPS
 - Prevent beam injection into the LHC

Injection Quality Check (IQC) [4]

- Analyses the quality of the injection (beam really injected, losses, trajectories)
- Interlock of next injection in case of poor injection quality

SPS/LHC Beam Quality Monitor (BQM)

- Check SPS beam longitudinal characteristics against requested pattern, can block beam extraction
- Check beam longitudinal characteristics in LHC

LHC RF synchronisation system [5]

- Revolution frequency, kicker prepulses
- SPS frequency rephasing to LHC frequency
- RF bucket selector (delay of the inj freq to align SPS bucket 1 with LHV requested bucket)

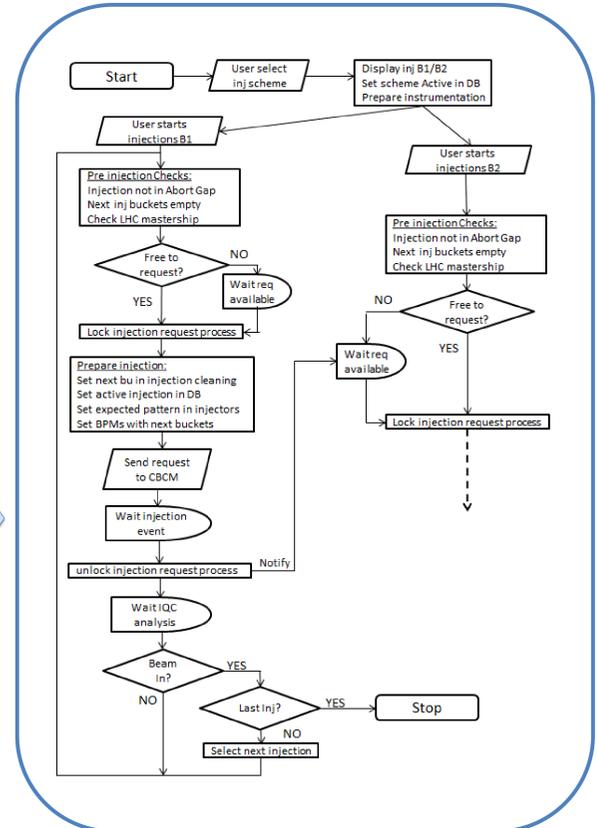
Injection cleaning system [6]

- Transvers damper system kicks out the unbunched beam in the injection area before each injection request

INJECTION PROCESS

- LHC beams dumped, prepare for next injection
- Beam parameter optimization in the injectors (bunch intensity & distribution, bunch spacing)
- The LHC gets the control over the LHC cycles in the injectors
- Pilot beam request (intensity $1E10$), for machine checks.
- Beam parameters measured and corrected with the pilot.
- Send physics beam requests

Simplified flow chart of injection request process



CONCLUSIONS

The LHC injection process requires the intervention of many equipment and systems in the entire accelerator complex from which the injection sequencer application is one of the main actors. Its role is to synchronise the beam request sent to the CBCM, but during 3 years of operation many functionalities have been incorporated to improve the injection process efficiency, distribute information on next injection request to different systems, guarantee coherency between database information and beam measurement and help the LHC operator to keep track of the injection quality along the process.

REFERENCES

- [1] J. Lewis "Timing", indico event : LTC extended meeting, Mar 2008, CERN, Geneva, Switzerland.
- [2] J. Wenninger "Software Interlock System", indico event: MPS internal review, Jun 2012, CERN, Geneva, Switzerland.
- [3] B. Puccio "The Beam interlock system", indico event: external review of the beam interlock system, Sep 2009, CERN, Geneva, Switzerland.
- [4] V. Kain, V. Baggiolini, W. Bartmann, C. Bracco, L. Norderhaug Drosdal, B. Goddard, E. B. Holzer, D. Khasbulatov, N. Magnin, M. Meddahi, A. Nordt, M. Sapinski, M. Vogt, "Injection Beam Loss and Beam Quality Checks for the LHC", IPAC 2010, Kyoto, Japan.
- [5] Ph. Baudrenghien "Commissioning the LHC LLRF", indico event : LTC extended meeting, Mar 2008, CERN, Geneva, Switzerland.
- [6] D. Valuch "Transverse feedback: high intensity operation, abort gap cleaning, injection gap cleaning and lessons for 2012", indico event: LHC Beam operation workshop, Dec 2011, Evian, France.