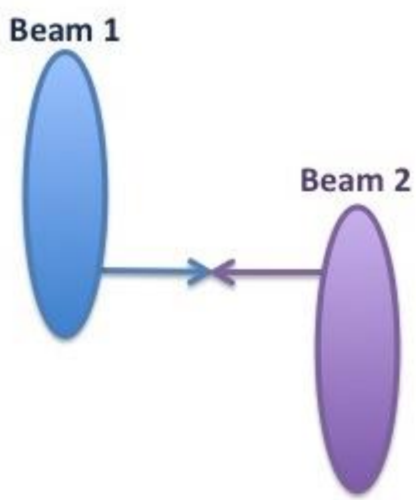
Implementation and experience with luminosity levelling with offset beams



Fabio Follin
Delphine Jacquet
For the LHC operation team

OUTLINE

- Motivation
- Implementation
- Operational experience
- Conclusion

MOTIVATIONS

Design luminosity for LHCb and Alice is much lower than CMS and Atlas

- High peak luminosity can cause detector HV trips for Alice
- For LHCb, high peak luminosity and high pile-up is not a protection issue but has an impact on data quality.
- High luminosity causes premature ageing of the detectors
- Optimization of β* and crossing angle at each interaction point not enough

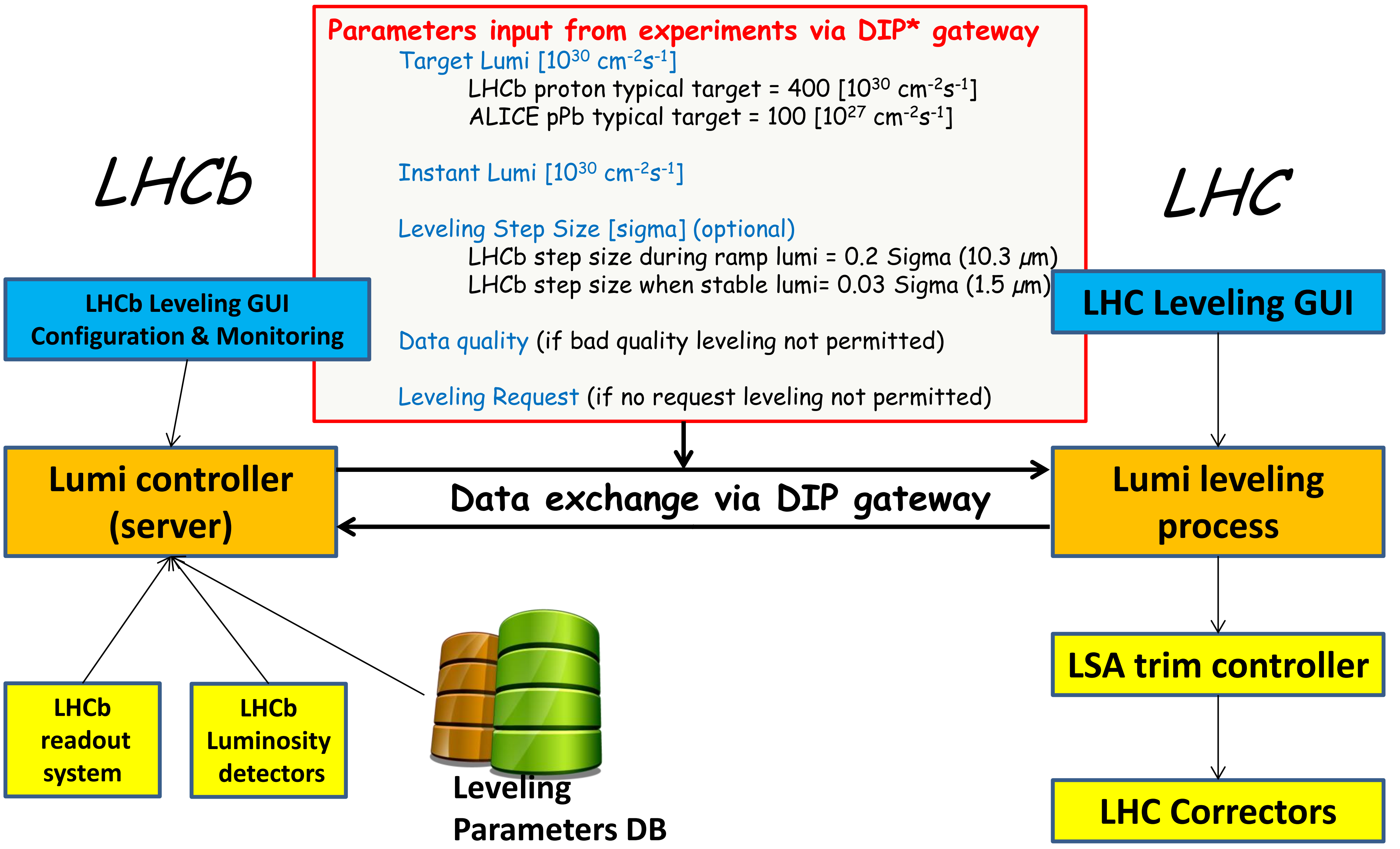
Integrated luminosity of Alice and LHCb can be maximized by delivering constant luminosity during the fill

Luminosity leveling

- β* leveling : complicated, implication on machine protection
- **Beam offset leveling**: relatively simple, large range

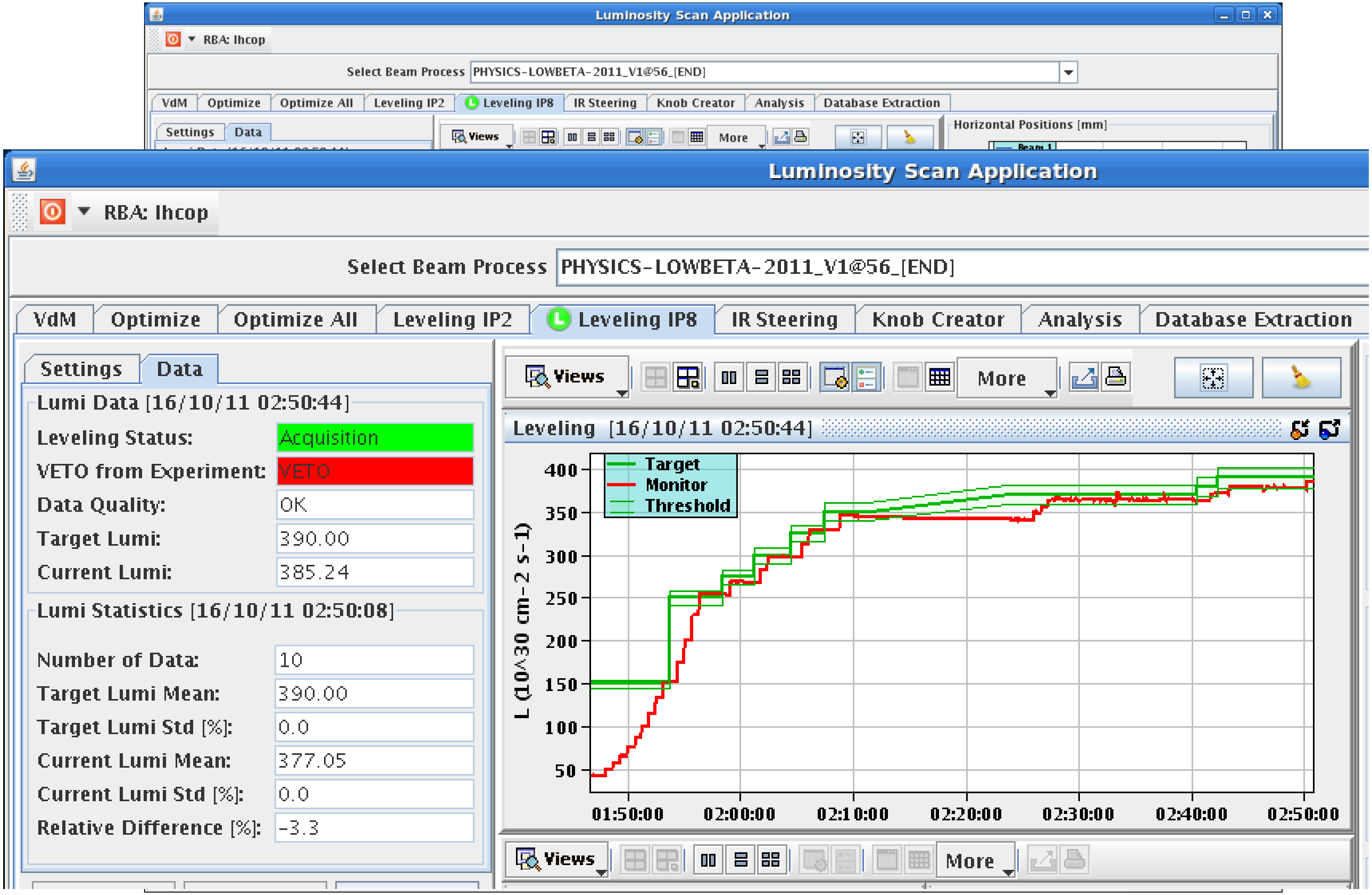
For details, see Richard Jacobsson presentation in this session : Future wishes and constraints from experiments

LEVELING IMPLEMENTATION

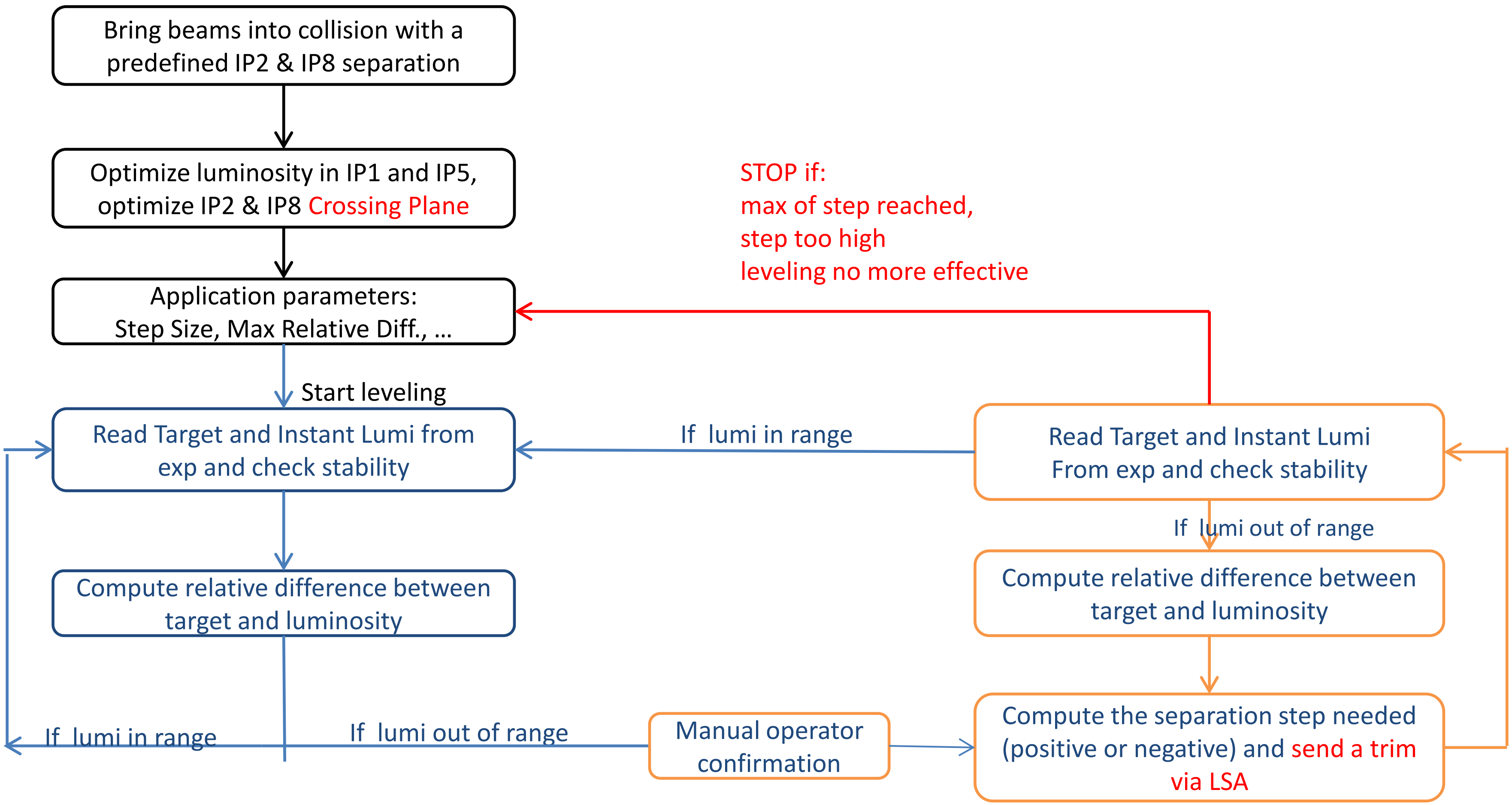


Courtesy Richard Jacobsson

LEVELING USER INTERFACE



LEVELING ALGORITHM



LSA PARAMETERS

Luminosity scan application

Request a change of position in mm for a given beam and plane

LSA TRIM package

High level knobs in mm

Compute Corresponding corrector settings

HW parameters in Amps

<u>LSA Database</u>
Settings and trim history

Send new settings to Hardware

Correctors

LSA is the software infrastructure for the CERN accelerator's control

LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

Lumi scan application

TRIM LSA HIGH LEVEL KNOBS

B1 sep scan X plane Knob [mm]

B2 sep scan X plane Knob [mm]

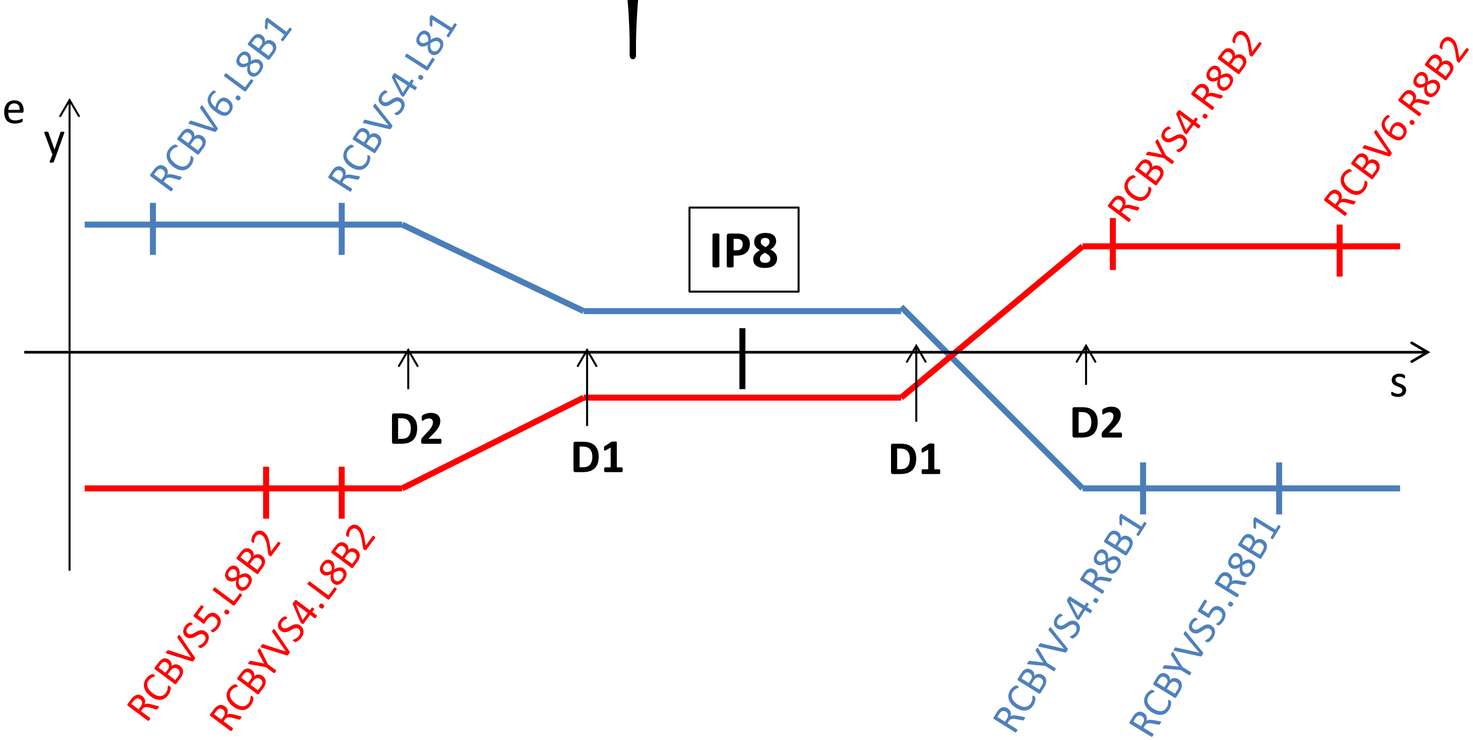
B1 sep scan Y plane Knob [mm]

B2 sep scan Y plane Knob[mm]

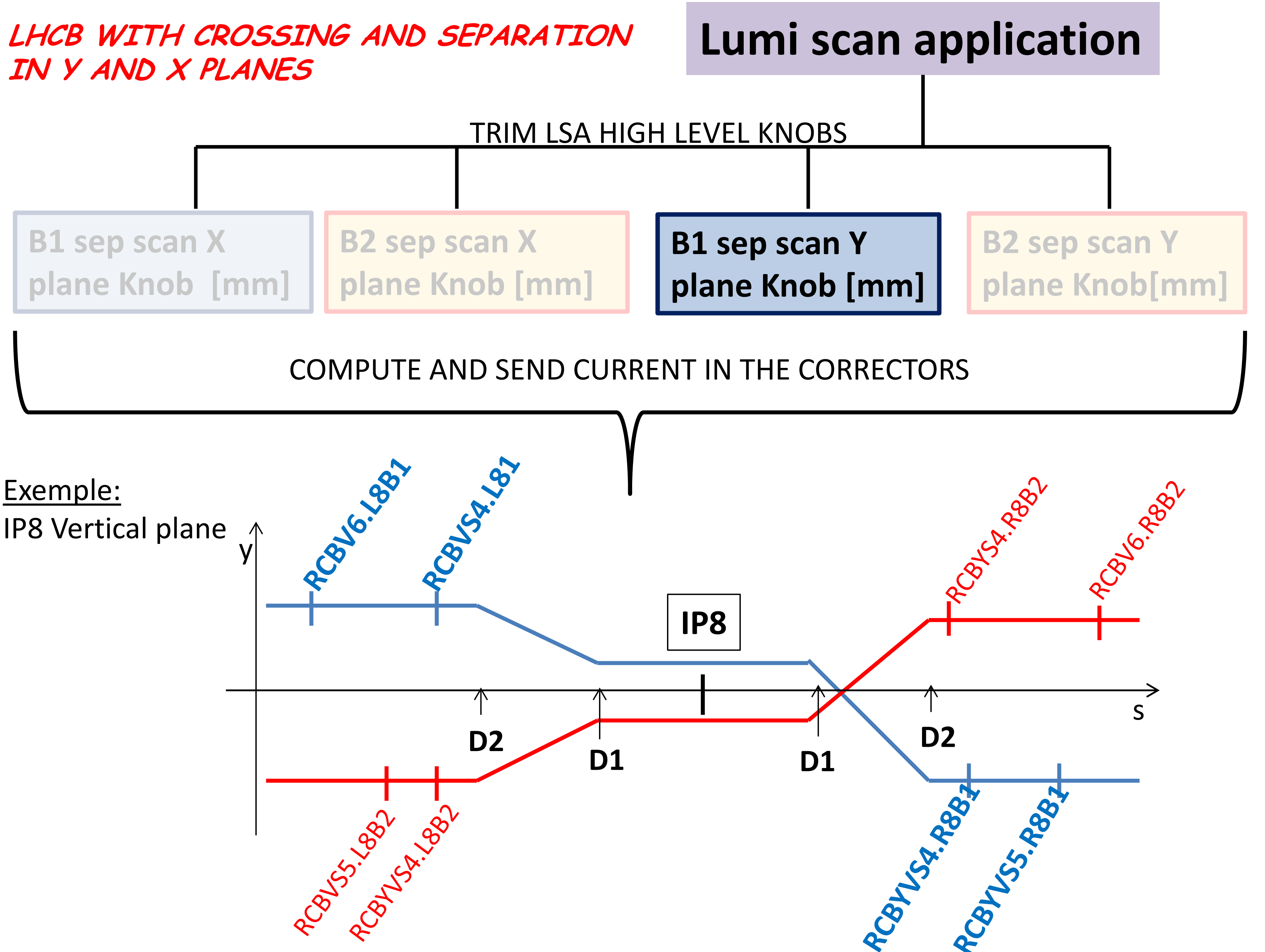
COMPUTE AND SEND CURRENT IN THE CORRECTORS

Exemple:

IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

Lumi scan application

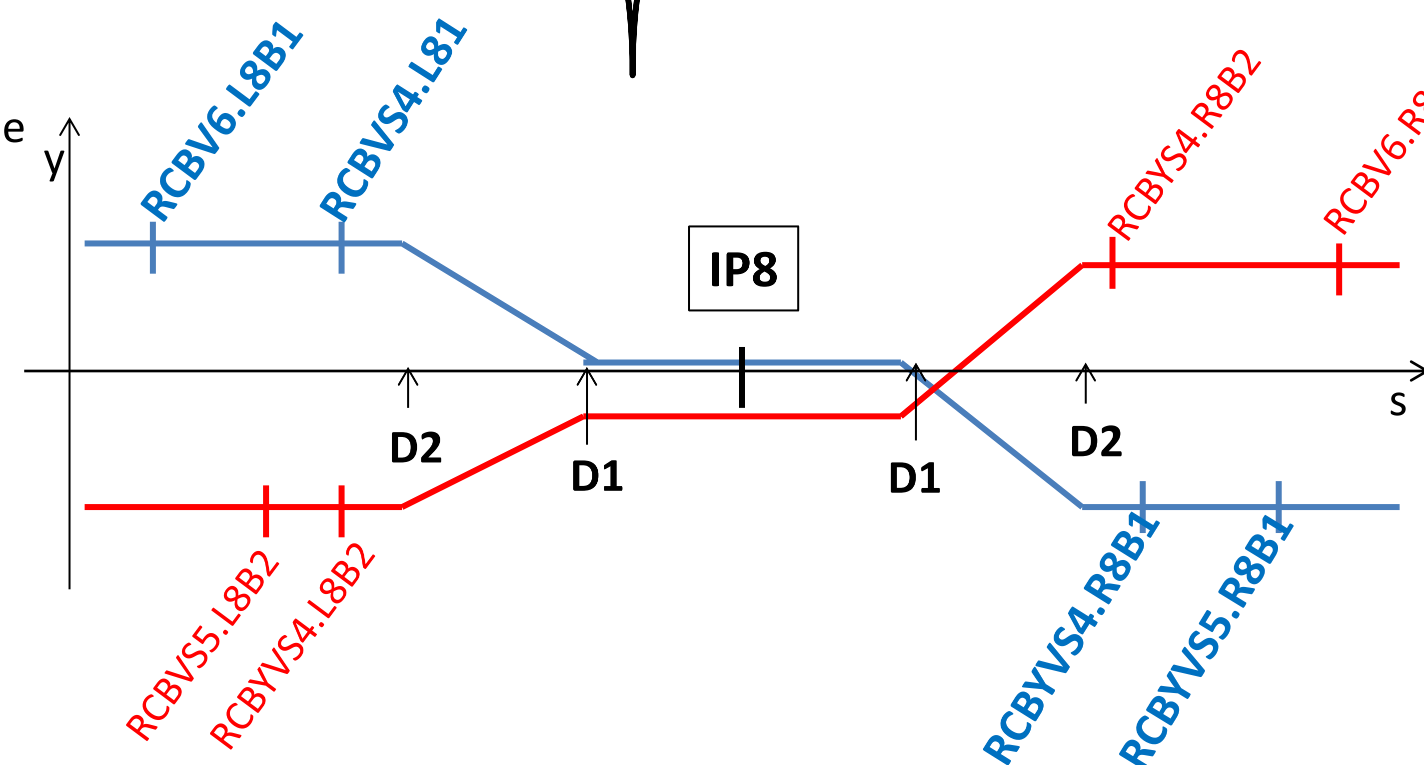
TRIM LSA HIGH LEVEL KNOBS

B1 sep scan X plane Knob [mm]	B2 sep scan X plane Knob [mm]	**B1 sep scan Y plane Knob [mm]**	B2 sep scan Y plane Knob[mm]

COMPUTE AND SEND CURRENT IN THE CORRECTORS

<u>Exemple:</u>

IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

Lumi scan application

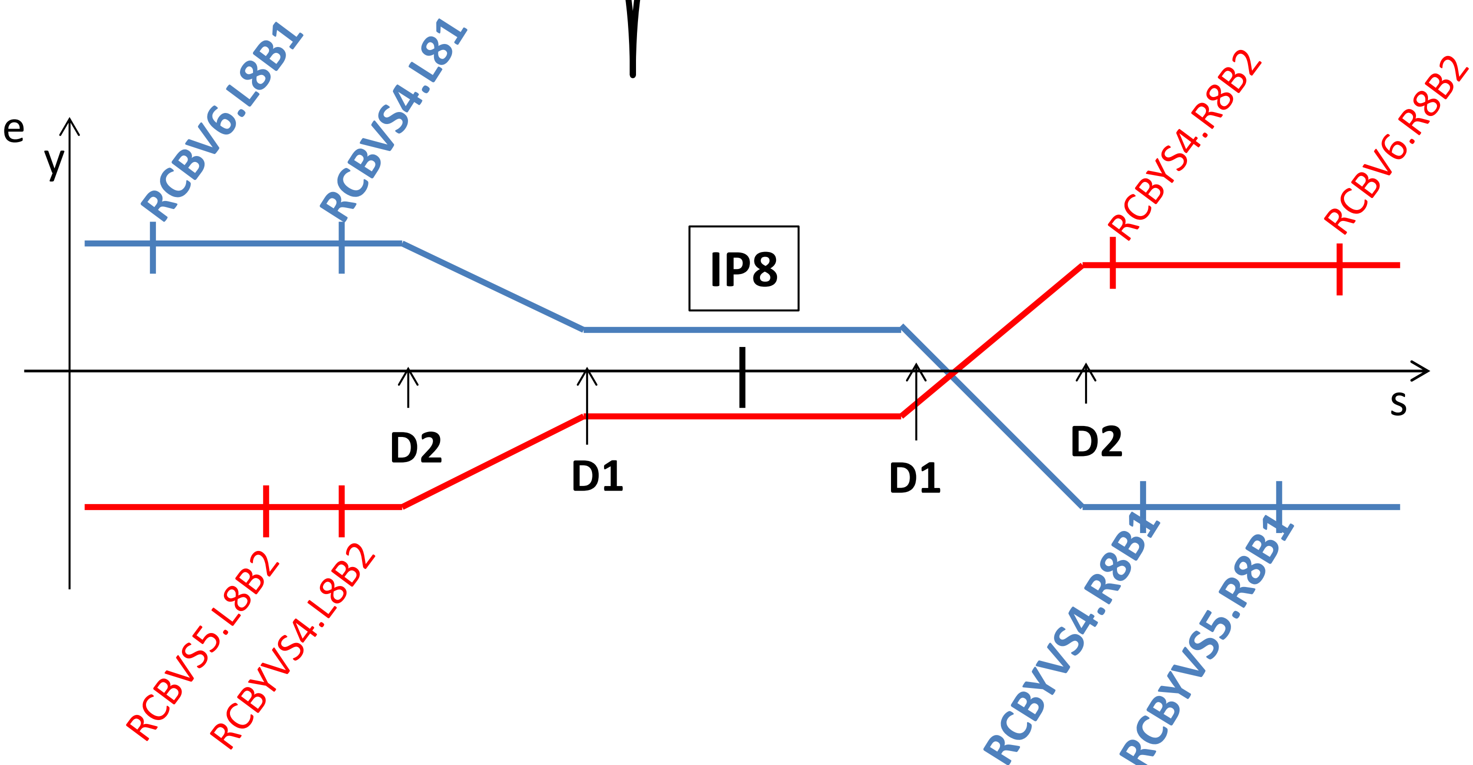
TRIM LSA HIGH LEVEL KNOBS

- B1 Lumi scan X plane Knob [mm]
- B2 Lumi scan X plane Knob [mm]
- **B1 Lumi scan Y plane Knob [mm]**
- B2 Lumi scan Y plane Knob[mm]

COMPUTE AND SEND CURRENT IN THE CORRECTORS

Exemple:

IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

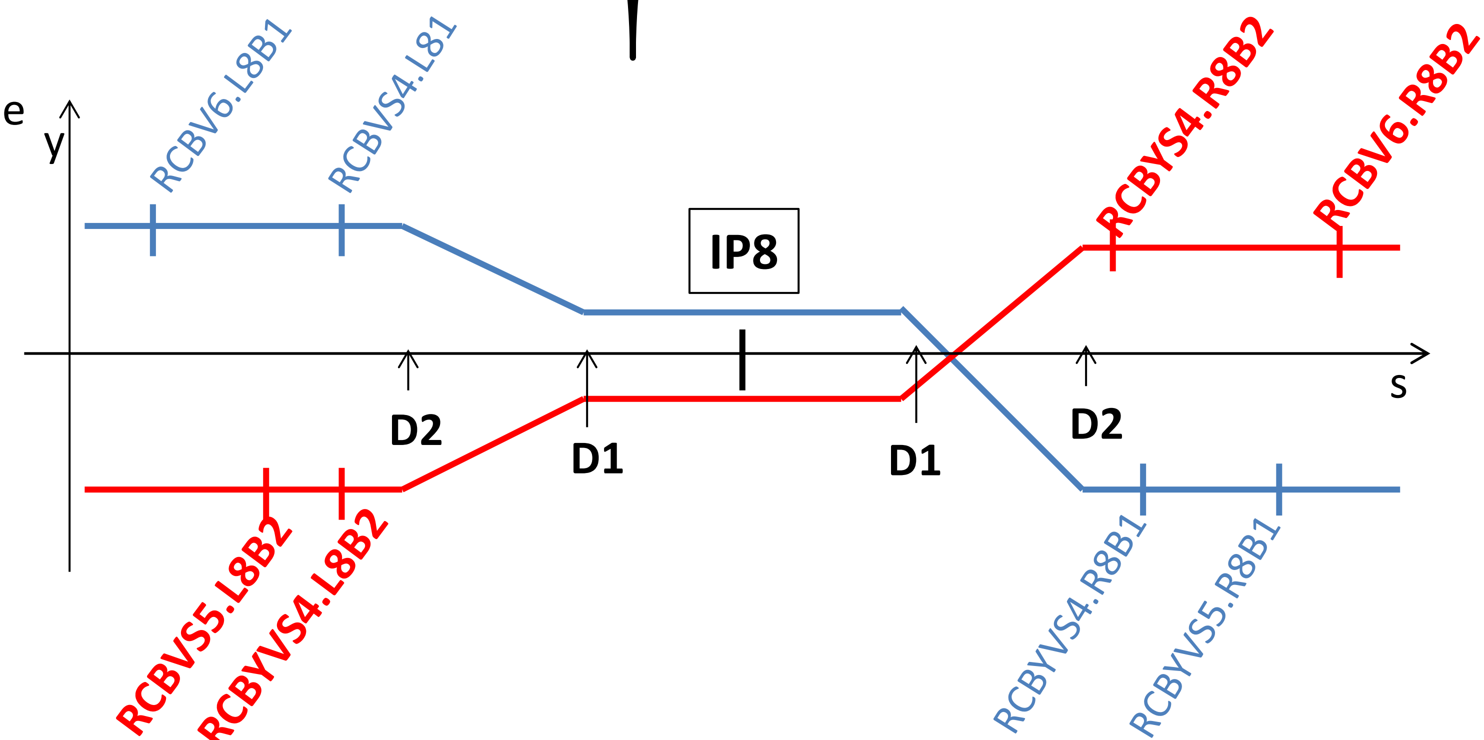
Lumi scan application

TRIM LSA HIGH LEVEL KNOBS

- B1 sep scan X plane Knob [mm]
- B2 sep scan X plane Knob [mm]
- B1 sep scan Y plane Knob [mm]
- **B2 sep scan Y plane Knob[mm]**

COMPUTE AND SEND CURRENT IN THE CORRECTORS

<u>Exemple:</u>
IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

Lumi scan application

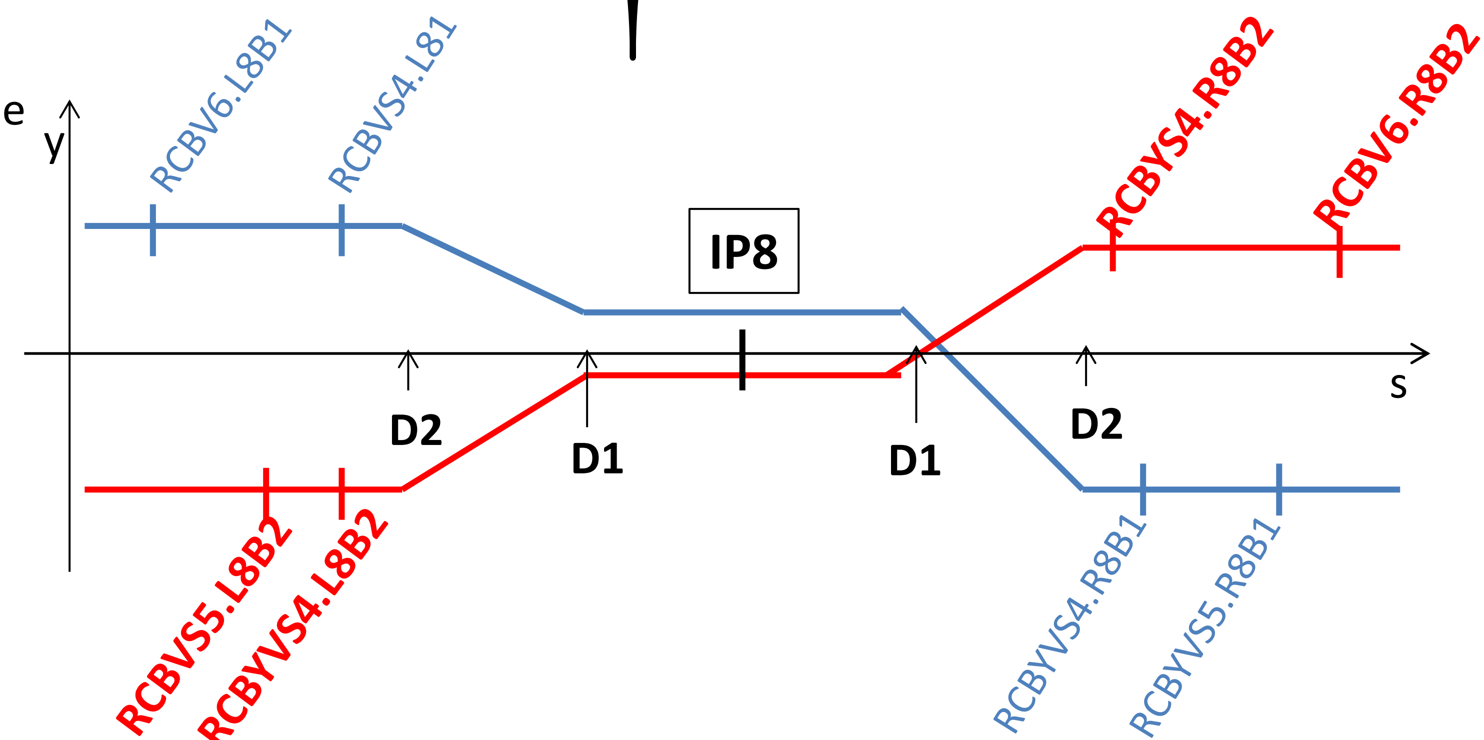
TRIM LSA HIGH LEVEL KNOBS

B1 sep scan X plane Knob [mm]	B2 sep scan X plane Knob [mm]	B1 sep scan Y plane Knob [mm]	**B2 sep scan Y plane Knob[mm]**

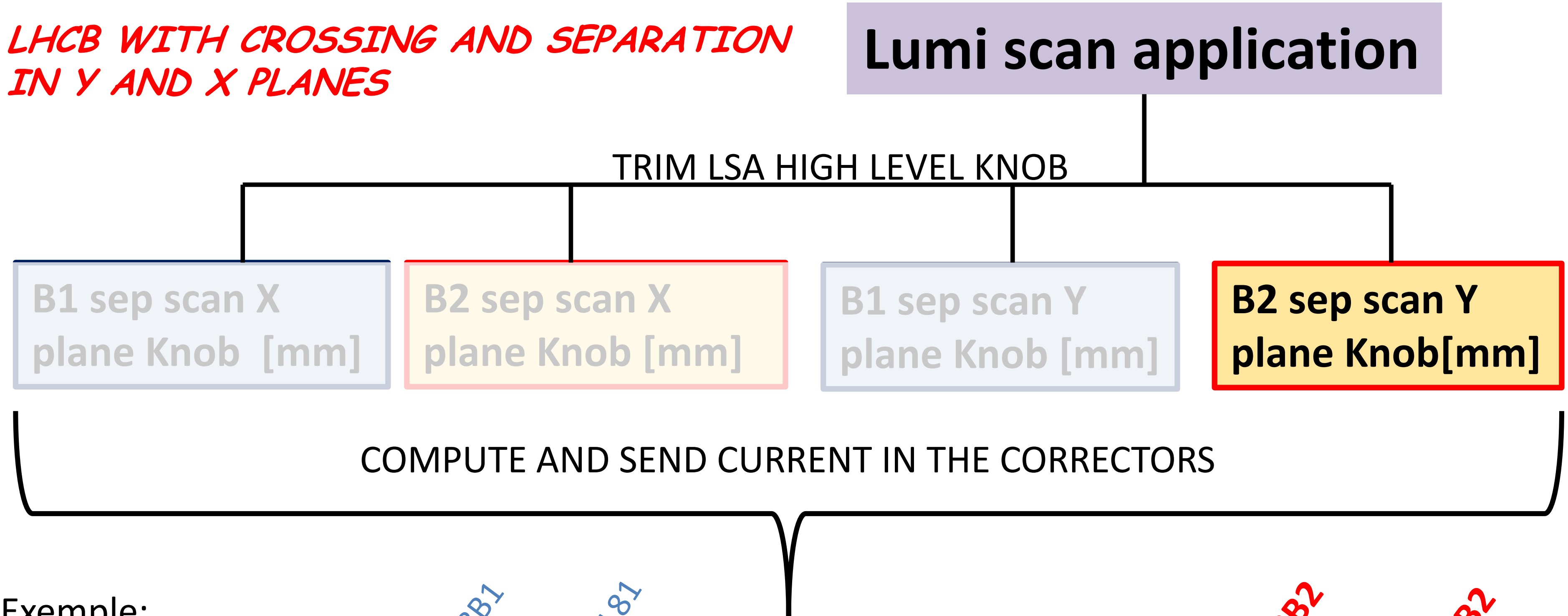
LSA COMPUTE AND SEND CURRENT IN THE CORRECTORS

Exemple:

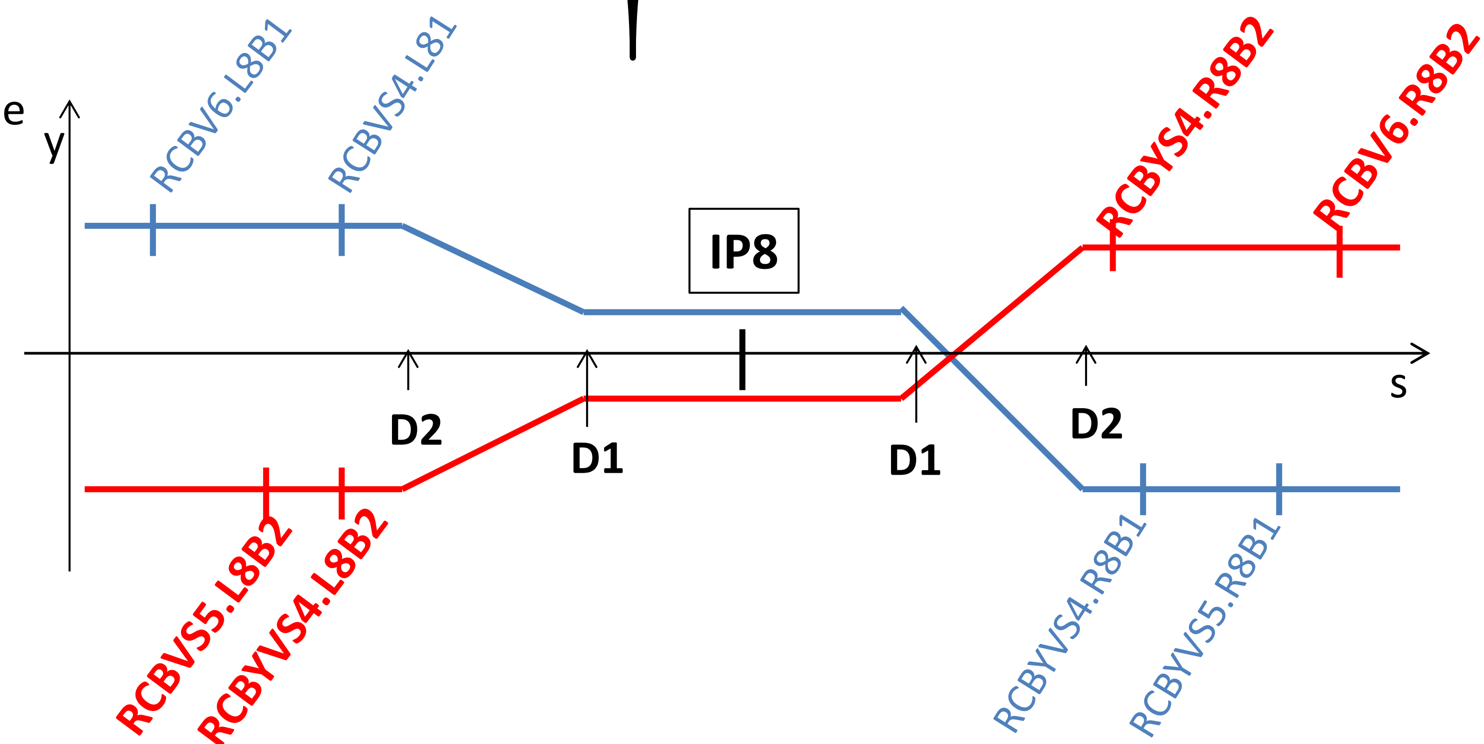
IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES



<u>Exemple:</u>
IP8 Vertical plane

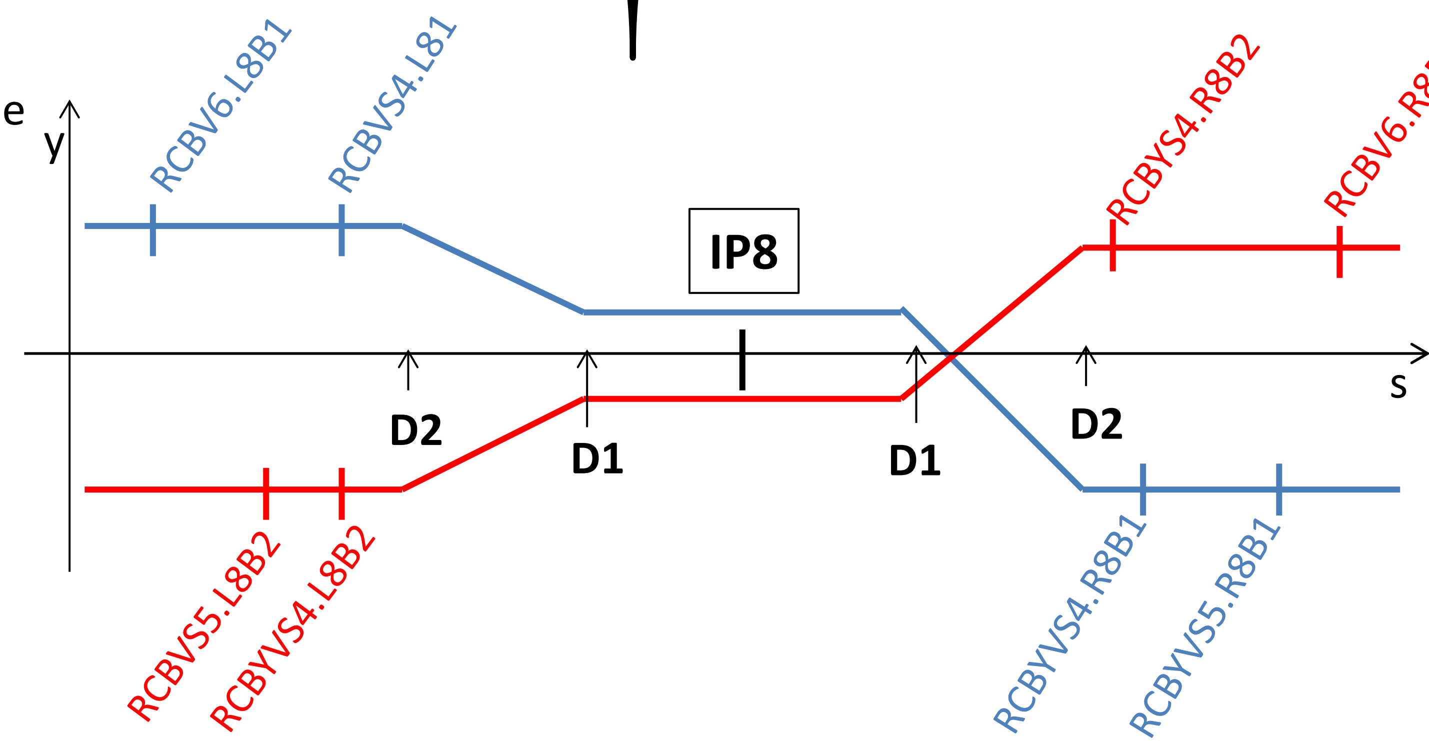


- KNOBS exist also in LSA to trim the angle at the IPs
- In operation the angle is kept to 0 for every IPs

B1 angle scan X plane Knob [urad]	B2 angle scan X plane Knob [urad]	B1 angle scan Y plane Knob [urad]	B2 angle scan Y plane Knob[urad]

COMPUTE AND SEND CURRENT IN THE CORRECTORS

<u>Exemple:</u>
IP8 Vertical plane

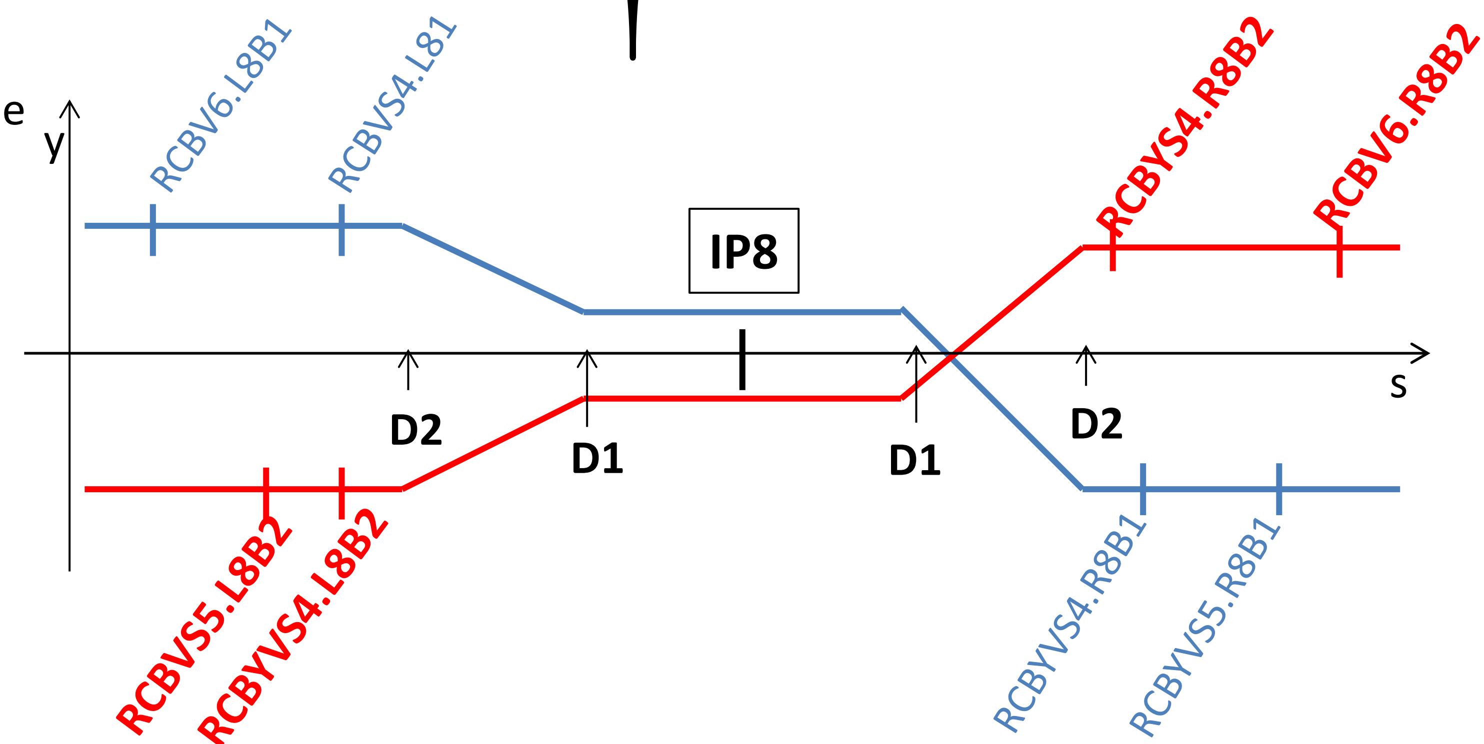


- KNOBS exist also in LSA to trim the angle at the IPs
- In operation the angle is kept to 0 for every IPs

B1 angle scan X plane Knob [urad]	B2 angle scan X plane Knob [urad]	B1 angle scan Y plane Knob [urad]	**B2 angle scan Y plane Knob[urad]**

COMPUTE AND SEND CURRENT IN THE CORRECTORS

Exemple:
IP8 Vertical plane



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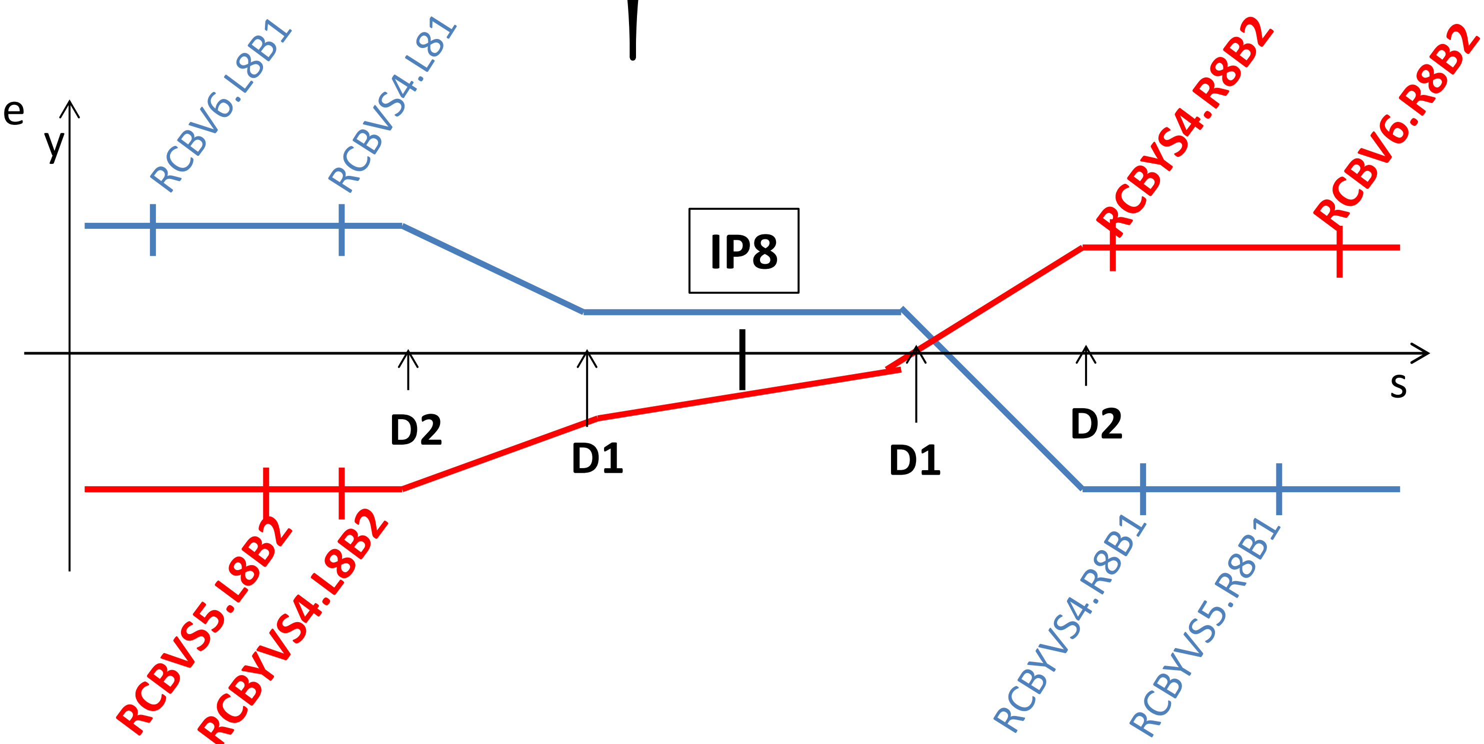
- In operation the angle is kept to 0 for every IPs

B1 angle scan X plane Knob [urad]	B2 angle scan X plane Knob [urad]	B1 angle scan Y plane Knob [urad]	**B2 angle scan Y plane Knob[urad]**

COMPUTE AND SEND CURRENT IN THE CORRECTORS

Exemple:

IP8 Vertical plane



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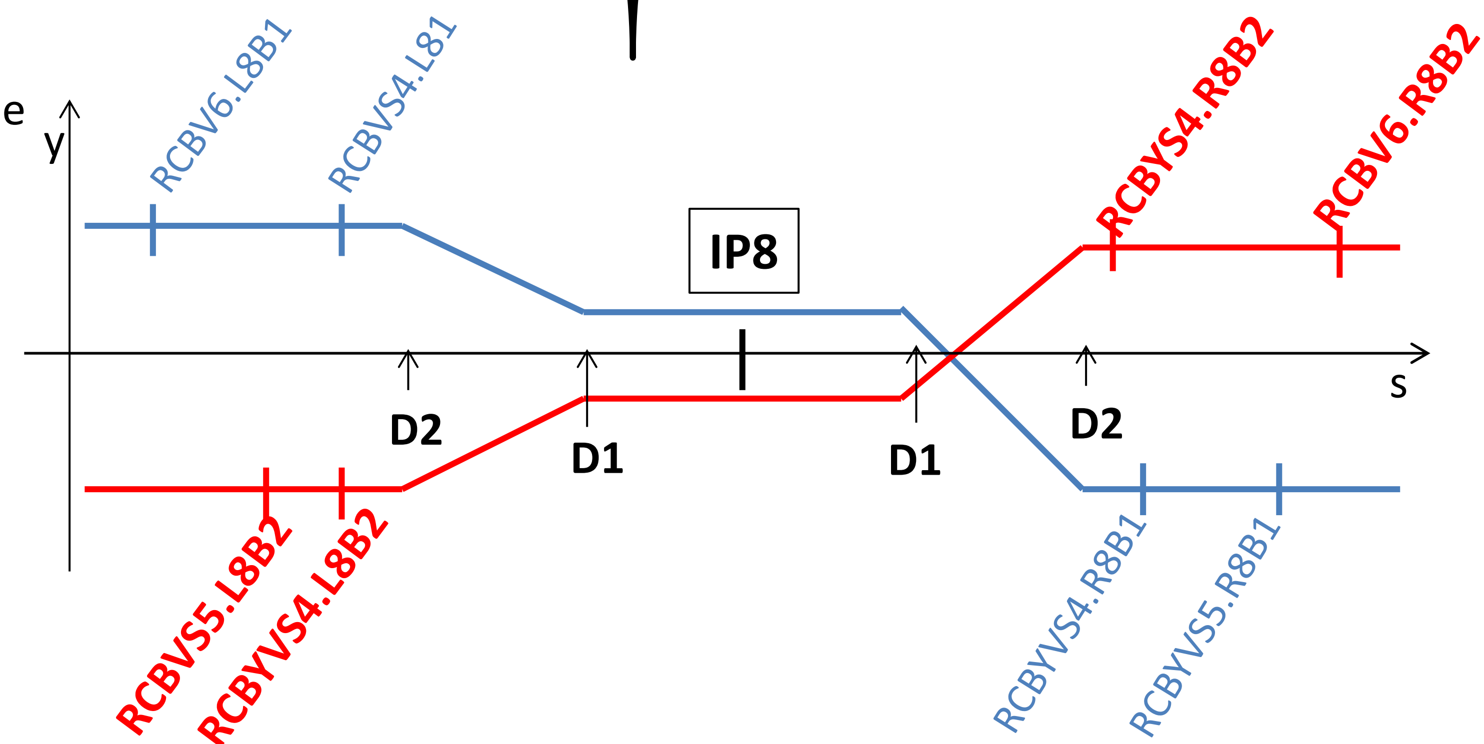
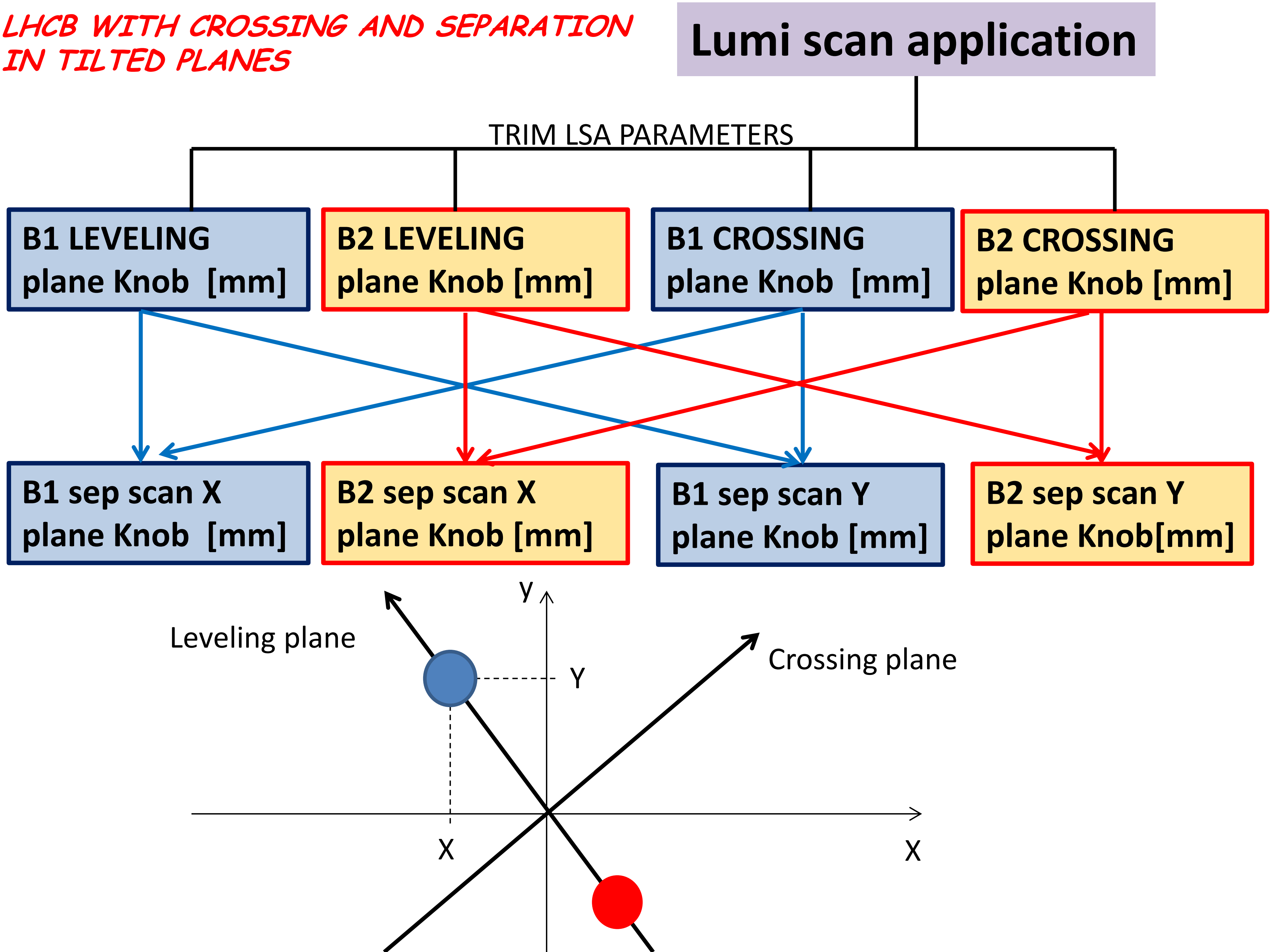
COMPUTE AND SEND CURRENT IN THE CORRECTORS

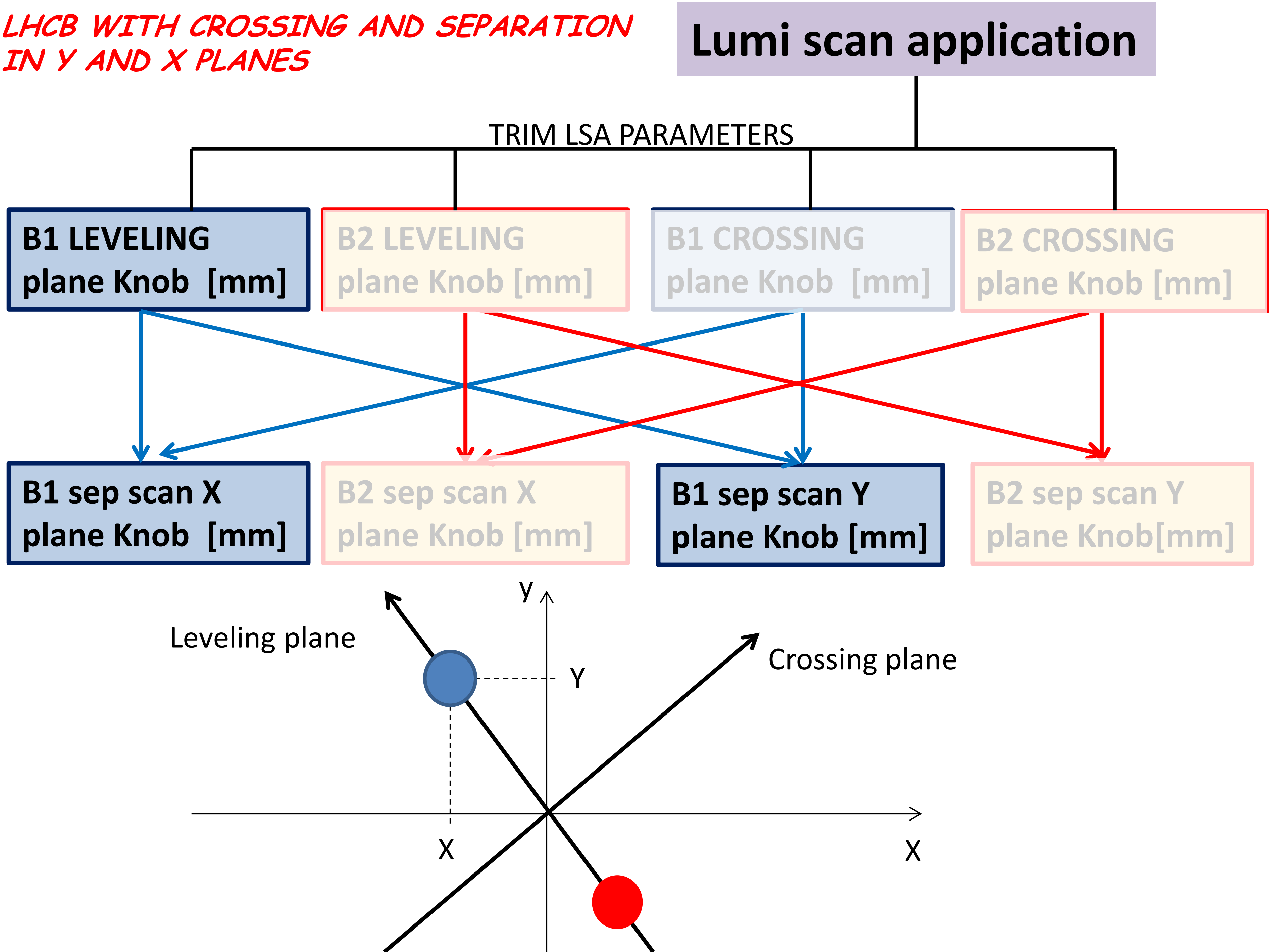
<u>Exemple:</u>
IP8 Vertical plane



LHCB WITH CROSSING AND SEPARATION IN TILTED PLANES

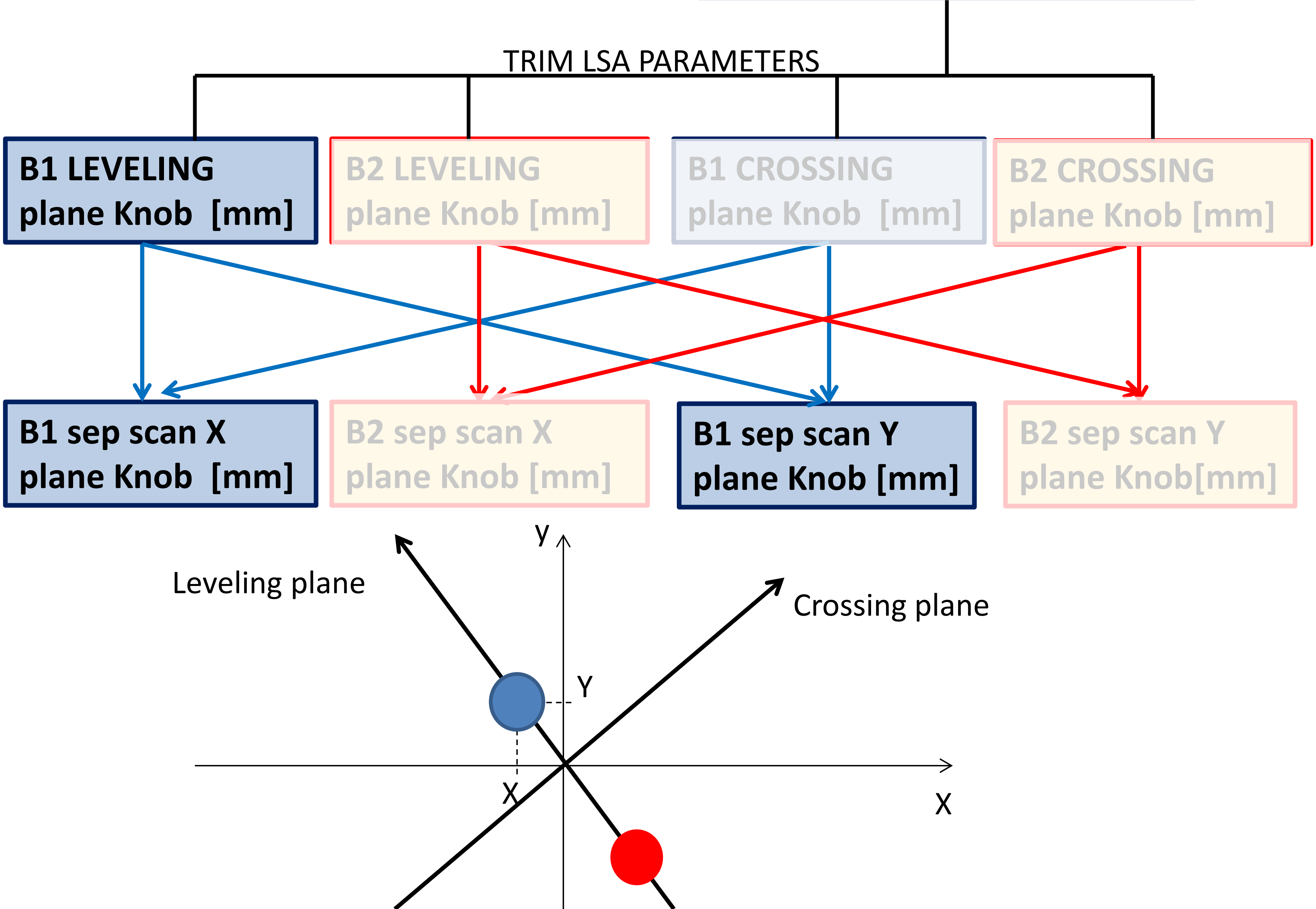


LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

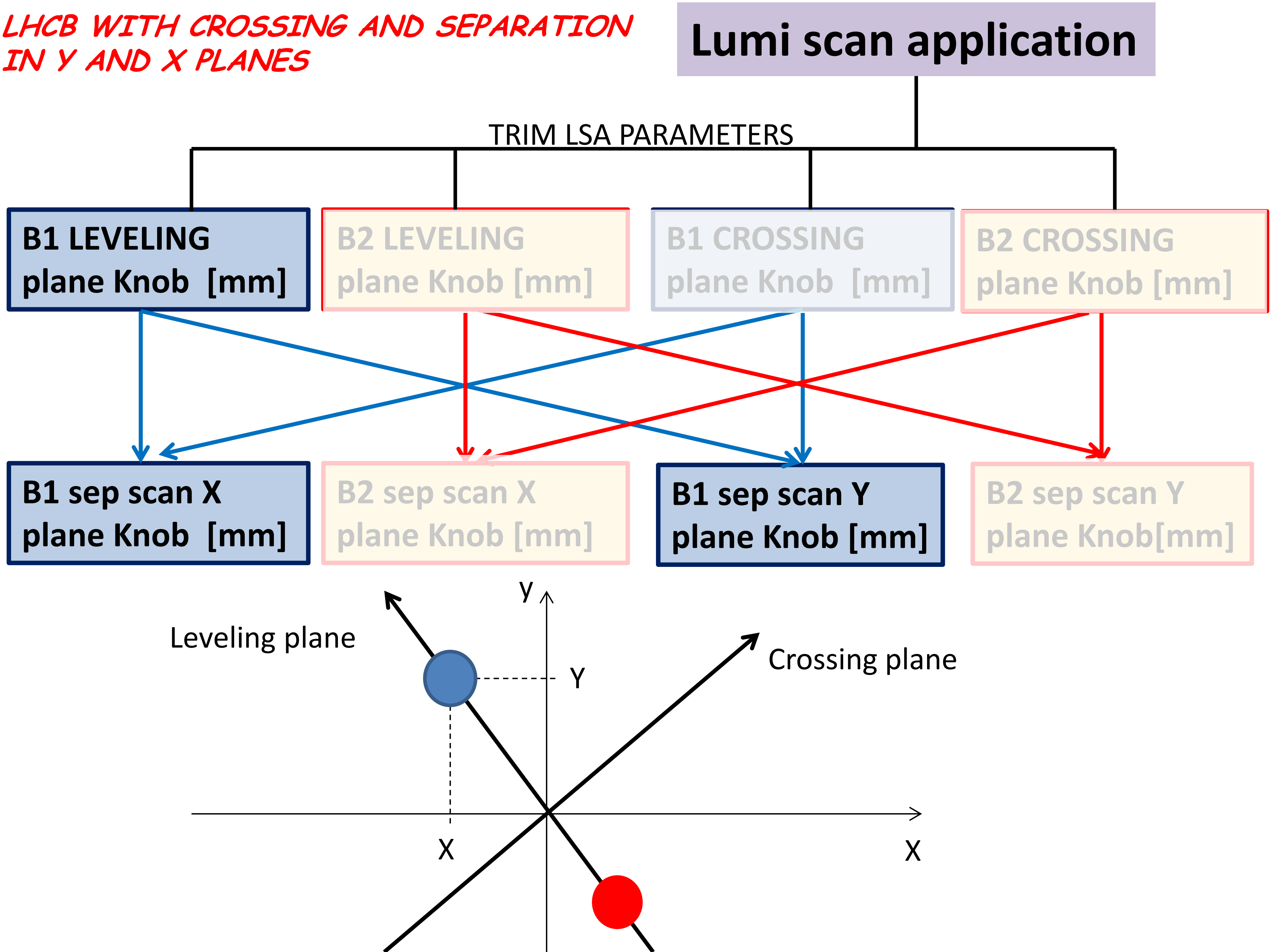


LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

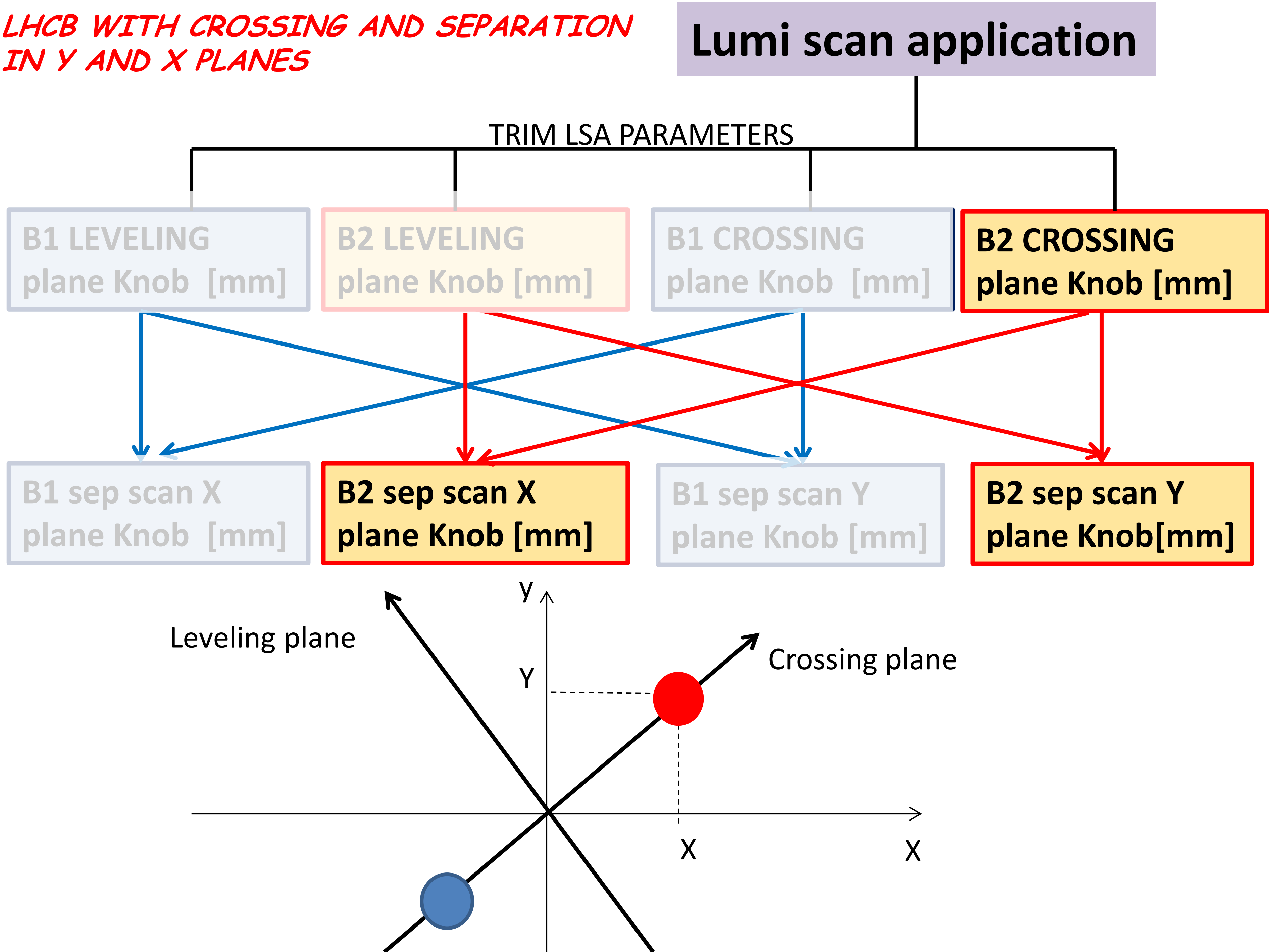
Lumi scan application



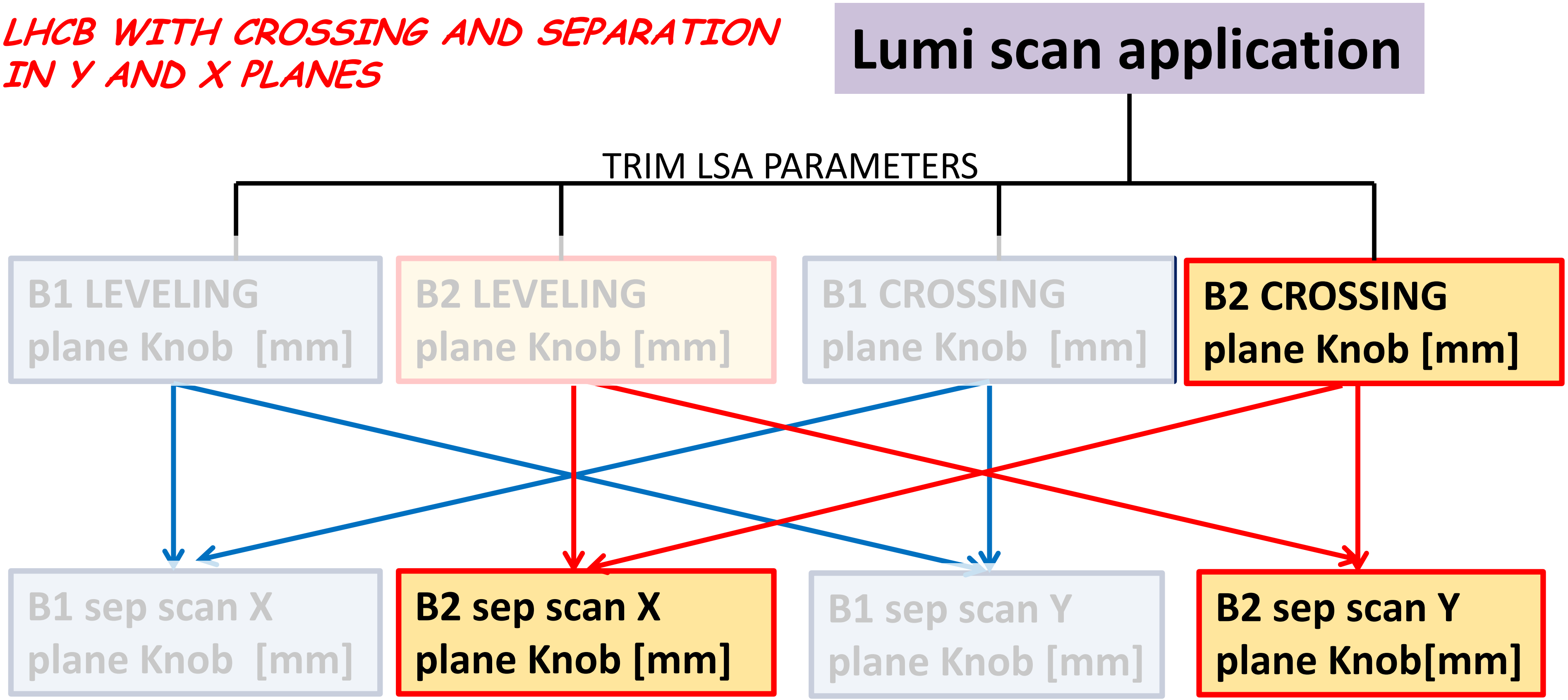
LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

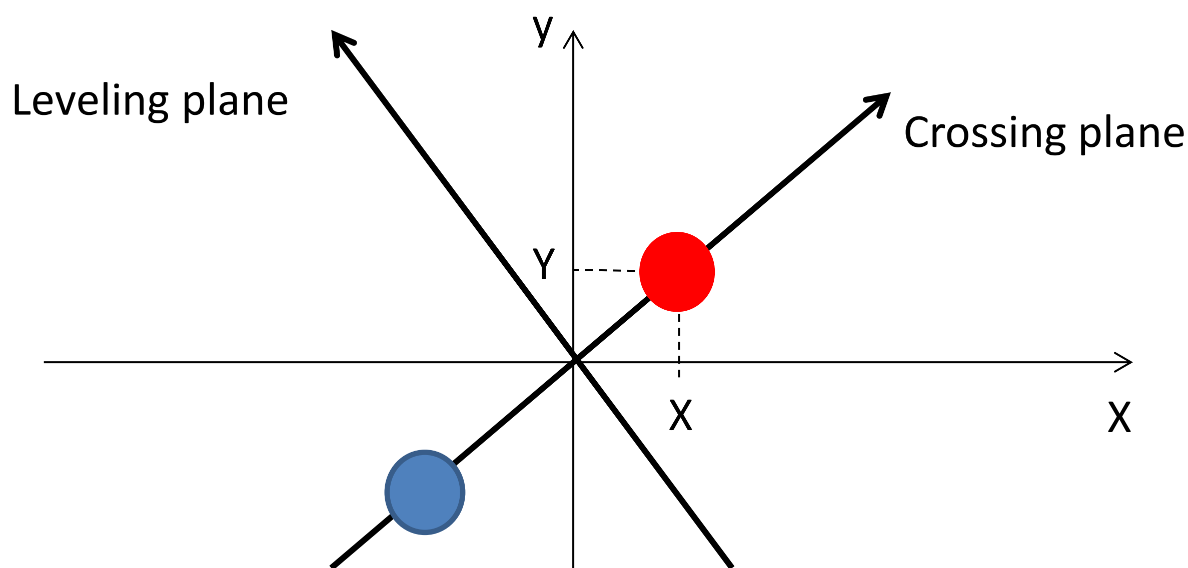


LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES

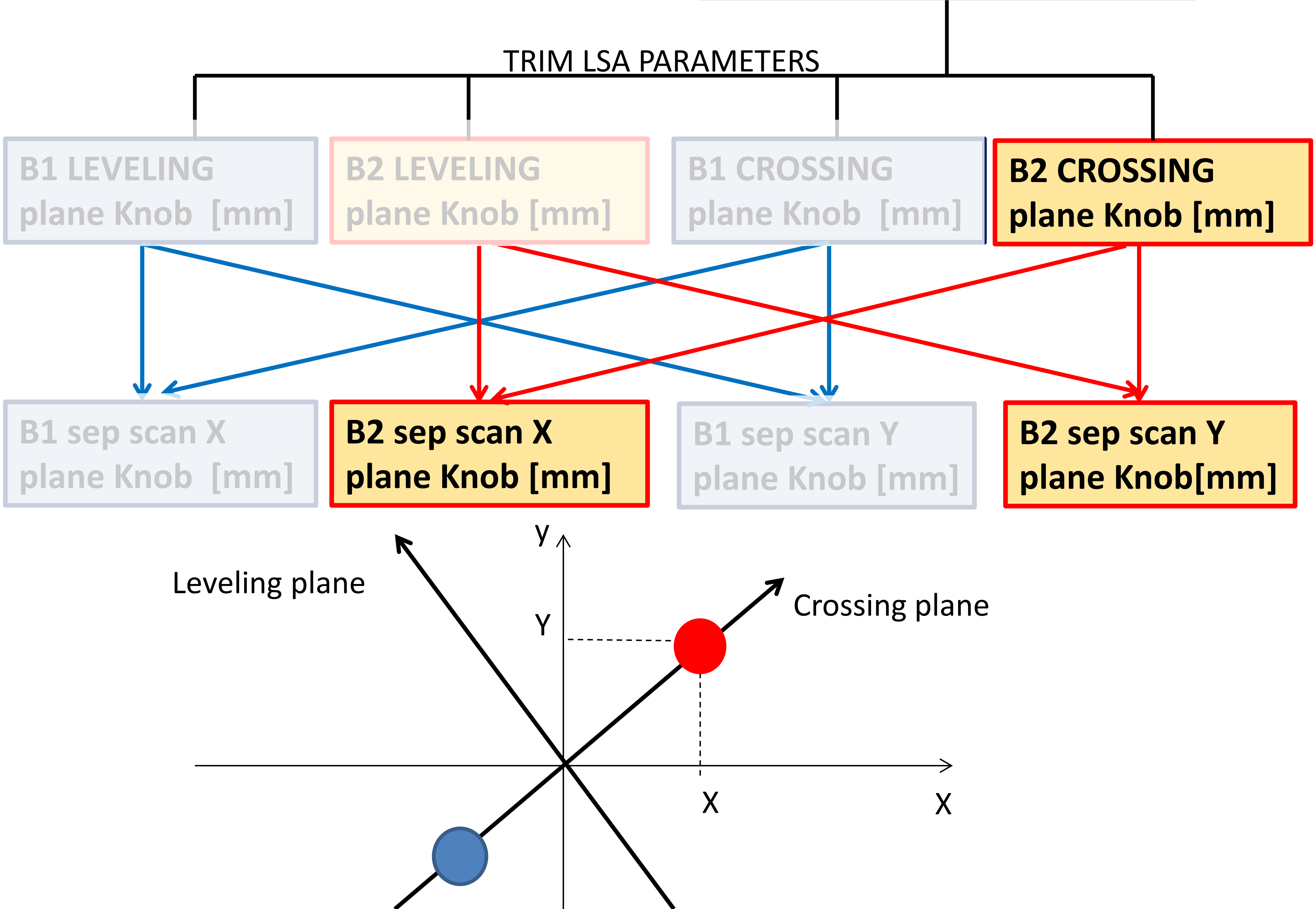


LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES



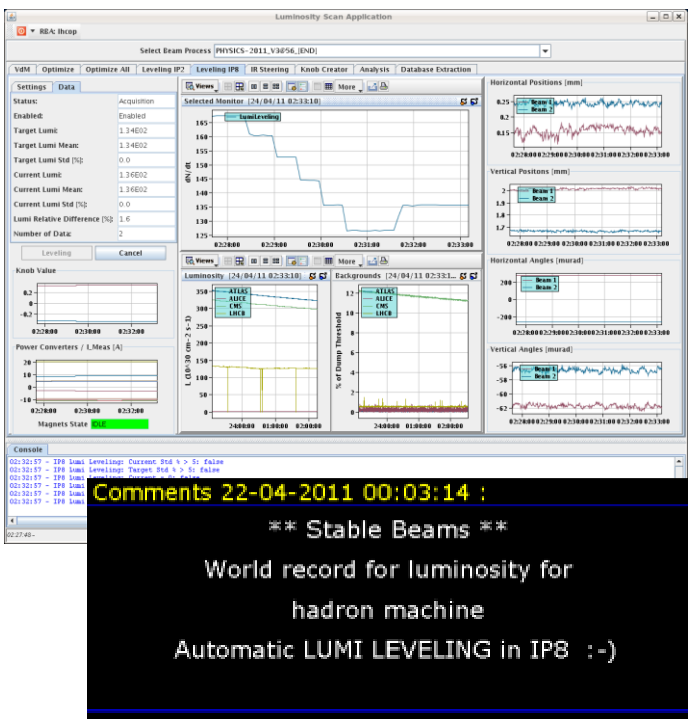


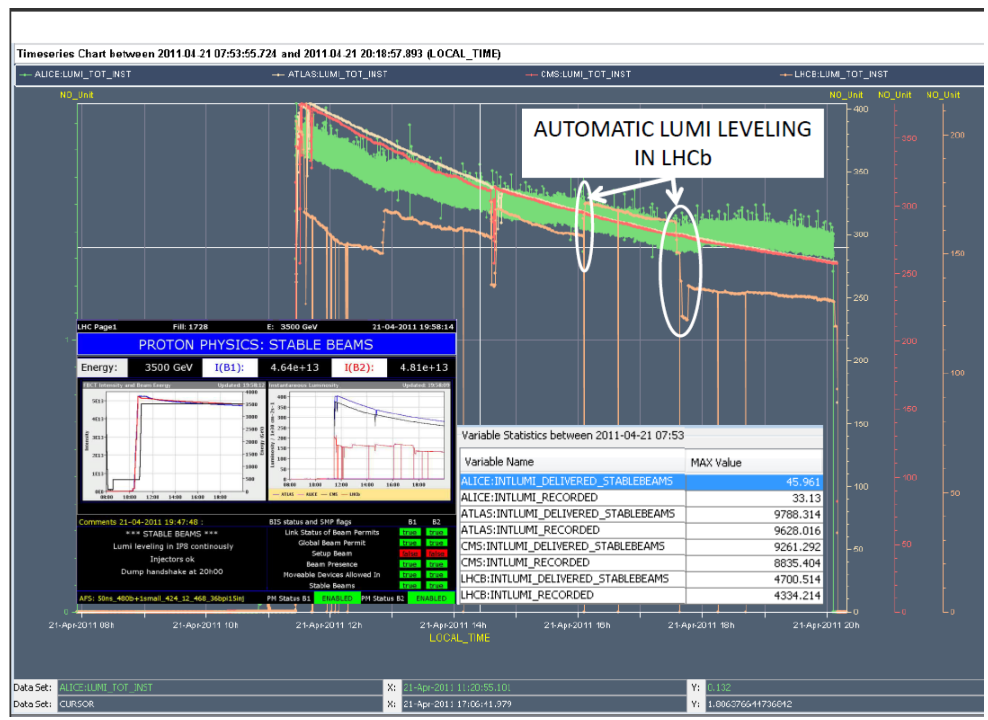
LHCB WITH CROSSING AND SEPARATION IN Y AND X PLANES



OPERATIONAL EXPERIENCE WITH BEAM OFFSET LEVELING

21-04-2011: First automatic luminosity leveling in LHCb

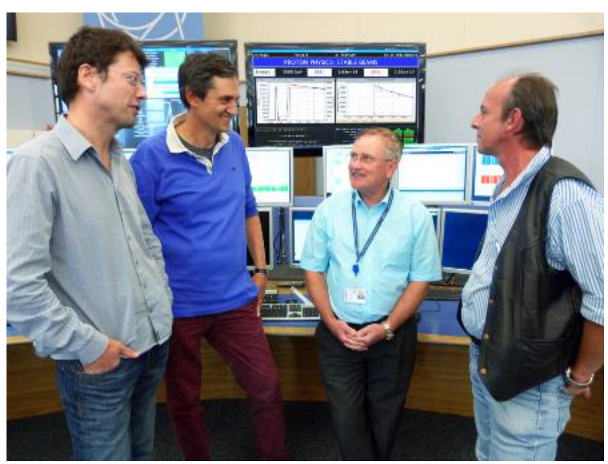


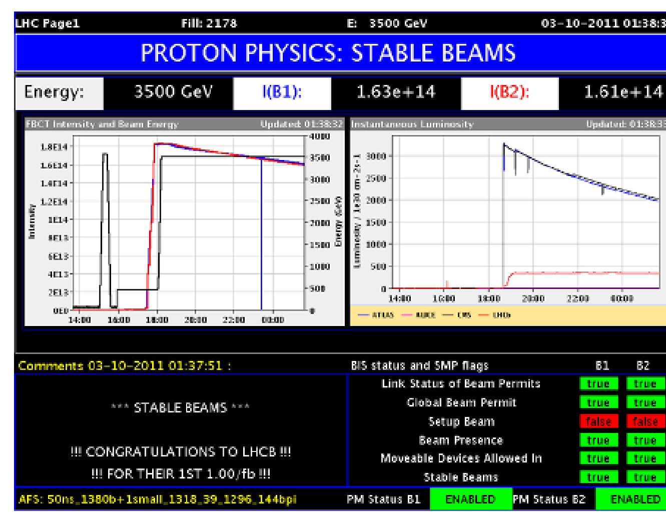


OPERATIONAL EXPERIENCE WITH BEAM OFFSET LEVELING

- 24-05-2011: First automatic lumi leveling in ALICE

- 03-10-2011: 1 fb-1 of luminosity has been delivered to LHCb





OPERATIONAL EXPERIENCE WITH BEAM OFFSET LEVELING

- 2012 Proton run
  - LHCb tilted plane for collisions : leveling application adapted.
  - Alice used collisions with satellites to reduce its luminosity, leveling was needed only in case of higher satellites
  - Leveling prepared for Atlas and CMS in case of too high pile-up. Was not needed in operation.

- 2013 Proton-Lead run
  - Used to limit the luminosity of Alice during the few days of low luminosity run
  - Used at beginning of each pPb fill to ensure the luminosity below requested limit of 1E5 ub/s

OPERATIONAL EXPERIENCE WITH BEAM OFFSET LEVELING

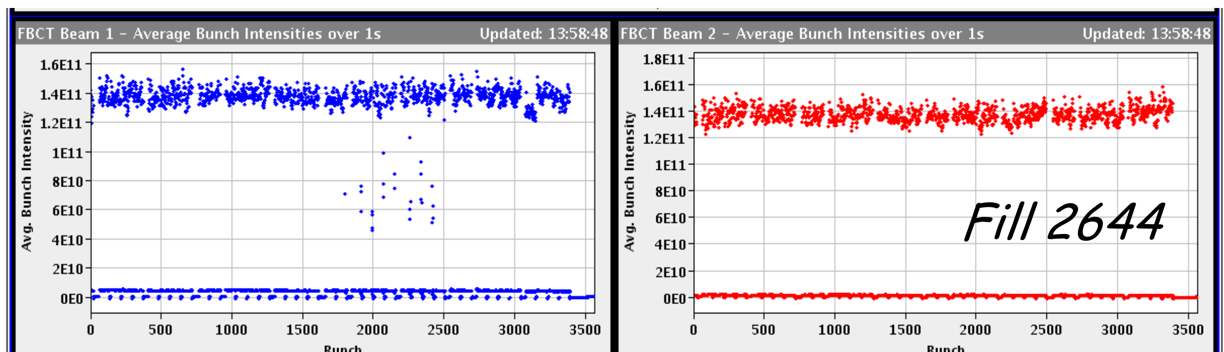
Weakness

- DIP communication not always reliable and failed to publish experiments parameters -> leveling stopped.
- Luminosity sensible to orbit correction
  - Orbit correction can push luminosity beyond limits and trip detectors
  - Nothing to prevent it in reliable way
- Experiments have to define and publish clearly the parameters they need : perfect for LHCb , but often missing for Alice.
- Should we fully automate the process?
  - Avoid manual action from the control room
  - But OP need to check that the machine conditions are compatible with leveling.

OBSERVED BUNCH BY BUNCH INSTABILITIES

- At the beginning of the 2012 run, bunch by bunch instabilities were observed in the process of putting beams into collision or once already in stable beam.
- This instabilities affected the bunches that were colliding only in IP8

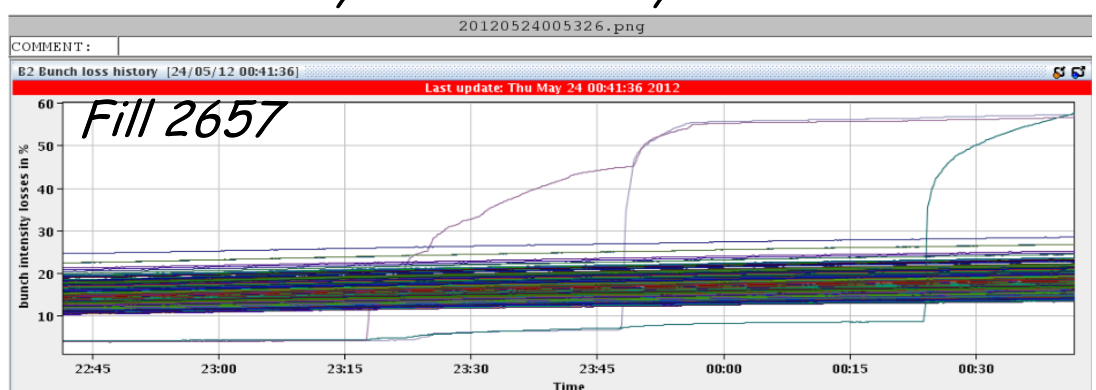
- Single bunch instabilities observed at the beginning of a stable beam for LHCb private bunches



Bunch by bunch intensity B1 and B2

- Filling Scheme with only 3 private bunches for LHCb

- Effect of instabilities clearly observed for B2, bunches lost one after the other.



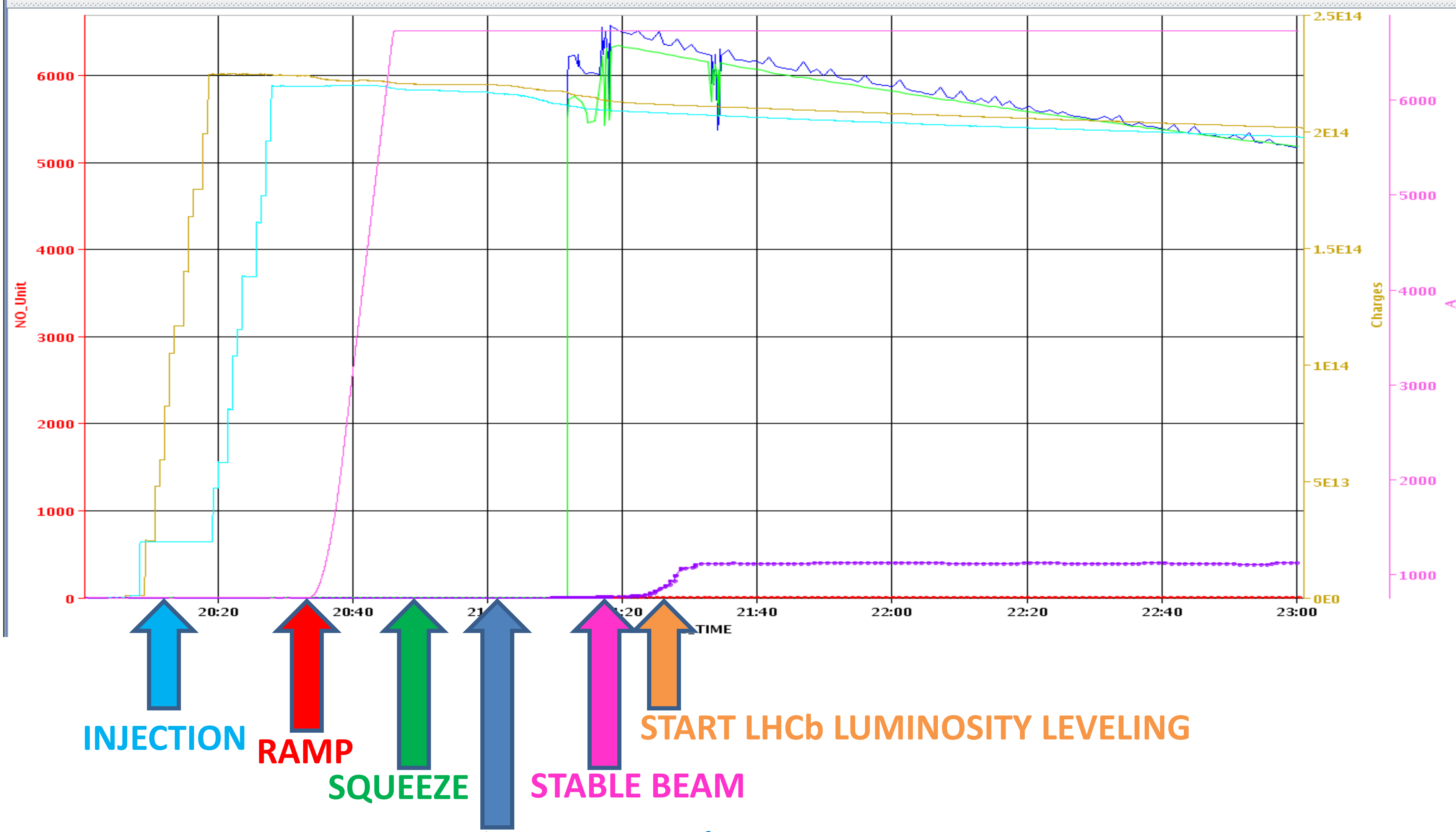
Bunch by bunch losses B2

OBSERVED BUNCH BY BUNCH INSTABILITIES

- **Cure**
  - Use only filling schemes were bunches colliding in LHCb also collided in IP1 and IP5 -> stabilized by head-on landau damping.
  - To reduce instabilities when beams get into collision, operation process adapted
    - First collide in Ip1 and 5 to stabilize the bunches
    - Then tilt LHCb planes and reduce separation in IP8

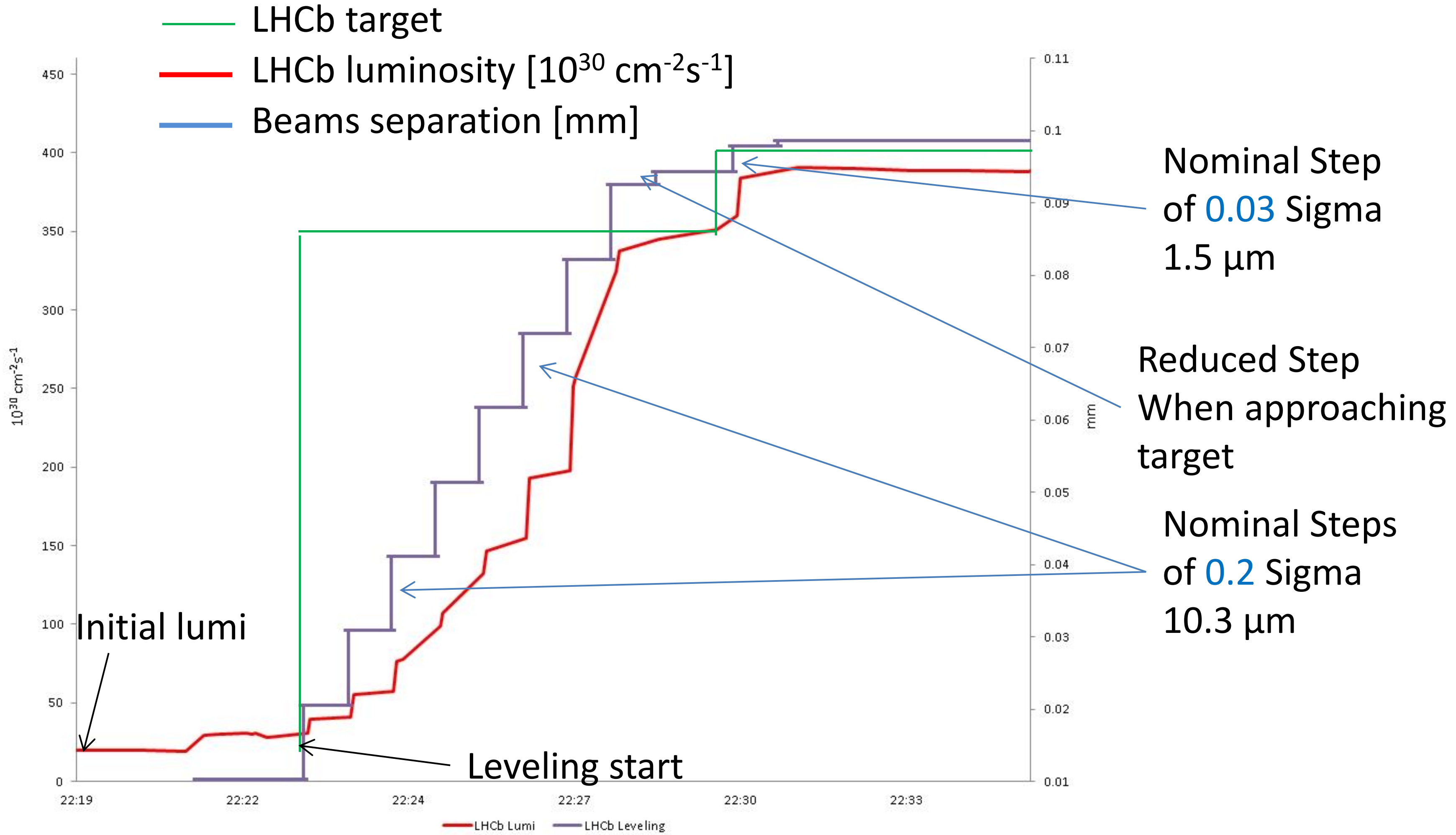
OPERATIONAL LHC PROTON-PROTON CYCLE

Fill 3266

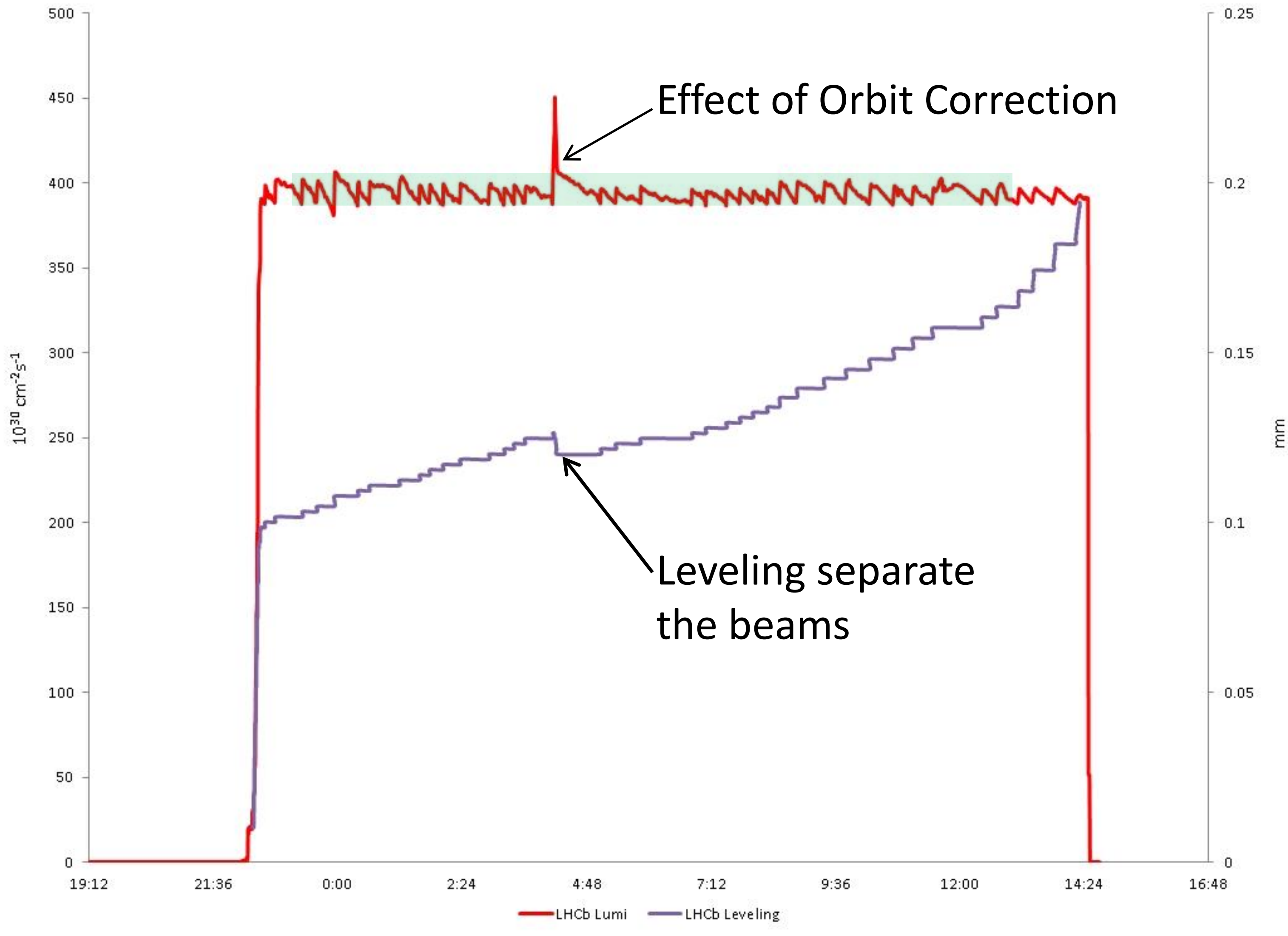


- Collide IP1/5
- Optimize IP1/5
- IP8 : Tilted planes - Reduce separation(keep lumi very low)
- Optimize IP8 crossing plane – optimize IP1/5

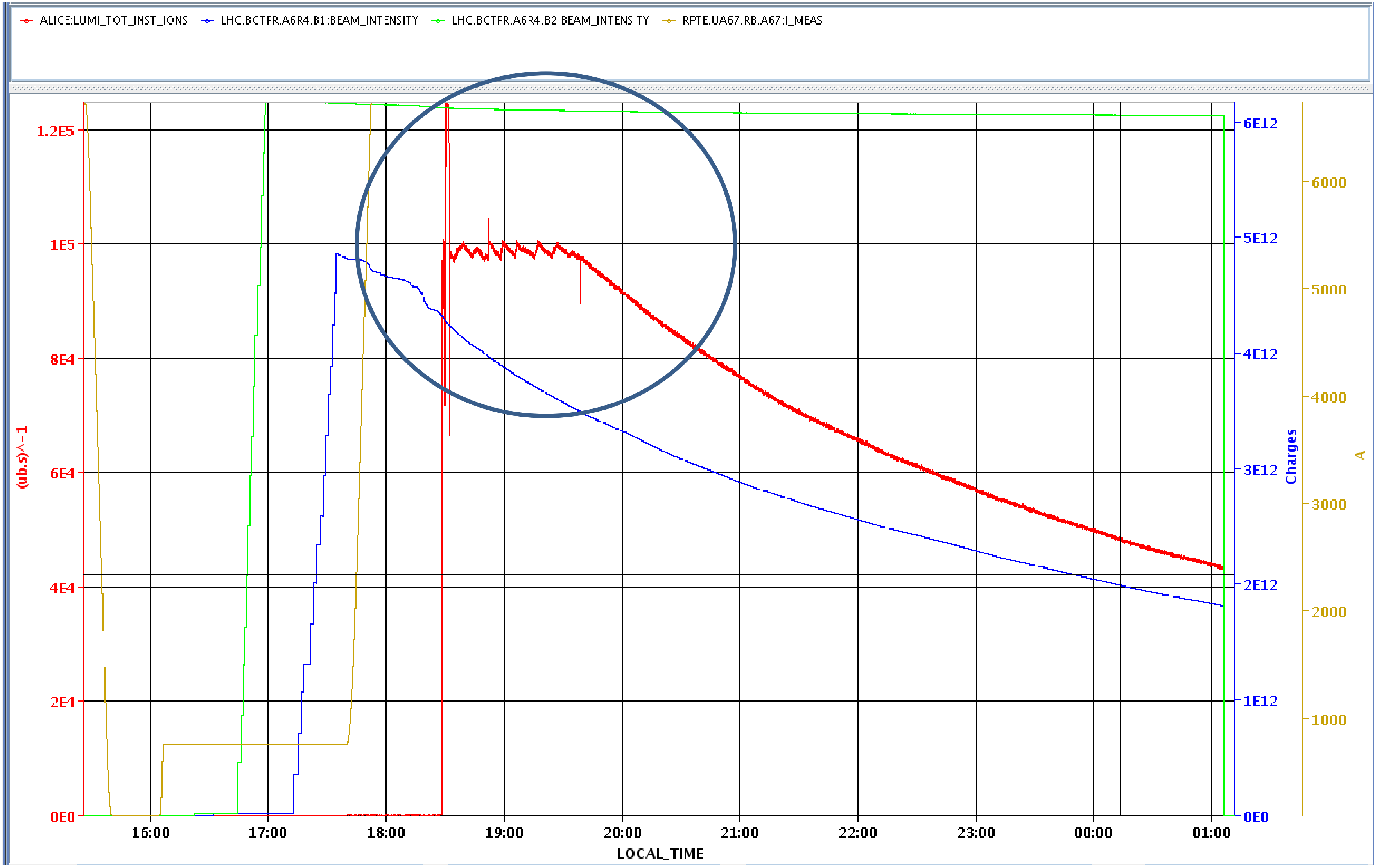
DETAILS OF LHCb LEVELING FOR FILL 3266



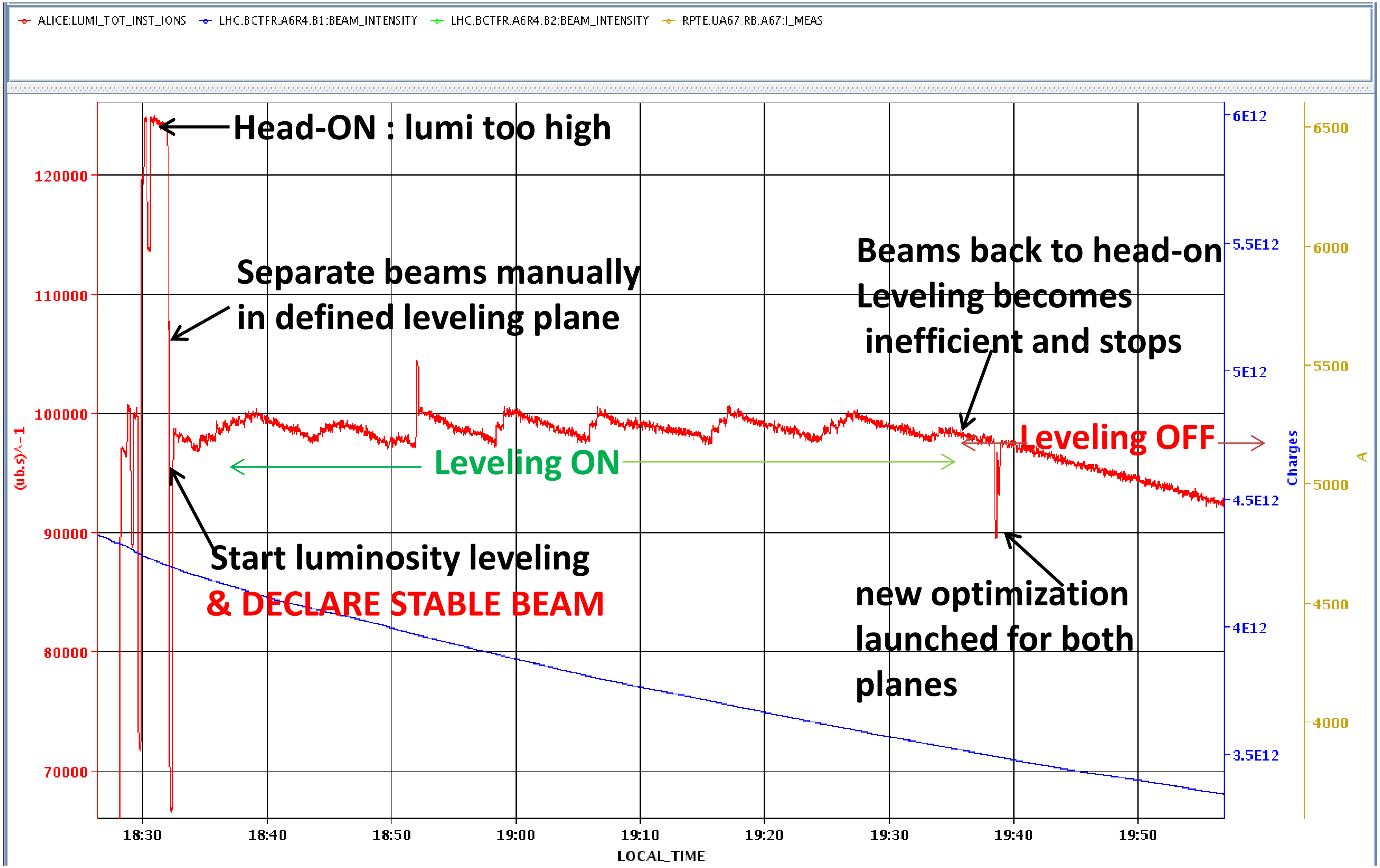
DETAILS OF LEVELING FOR FILL 3266



Alice run with pPb

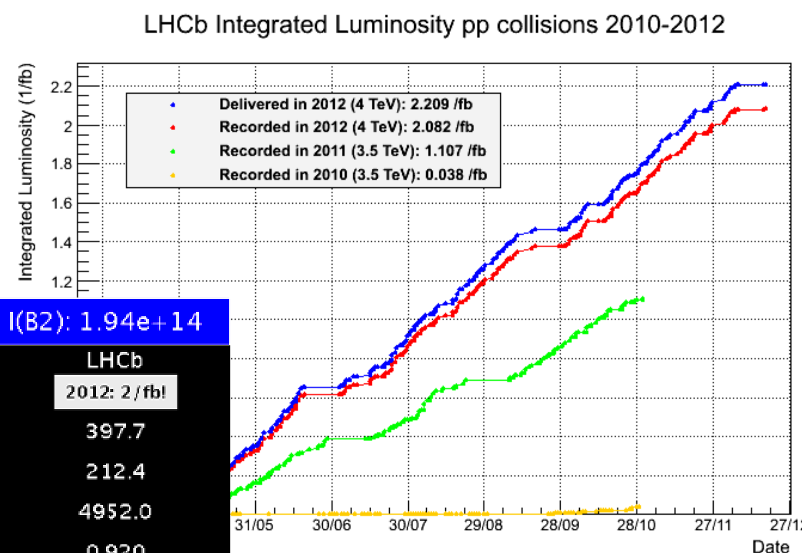


Alice high luminosity run with pPb



CONCLUSION

- Luminosity levelling part of the routine LHC operation for LHCb and Alice
- Luminosity levelling allows to maximize the integrated luminosity while keeping low luminosity peak and low pile-up



15-Nov-2012 10:31:27   Fill #: 3288   Energy: 4000 GeV   I(B1): 1.94e+14   I(B2): 1.94e+14

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	2012: 2/fb!
Instantaneous Lumi [(ub.s)^-1]	4427.0	2.925	4454.5	397.7
BRAN Luminosity [(ub.s)^-1]	4440.9	1.890	4478.6	212.4
Fill Luminosity (nb)^-1	67536.4	48.1	69245.1	4952.0
BKGD 1	0.616	0.589	2.528	0.920
BKGD 2	91.294	0.000	3.628	4.232
BKGD 3	1.615	8.334	16.074	1.293

LHCb VELO Position IN   Gap: -0.0 mm   STABLE BEAMS   TOTEM: STANDBY

More than 2fb-1 of exploitable data delivered for LHCb in 2012!!

CONCLUSION

- Beam beam effect under control in 2012 if no private bunches for LHCb.
- After LS1 : levelling may be needed in all experiments: β* levelling and beam offset levelling will probably be used in some combination.

➡ VERY CHALLENGING FOR OPERATION