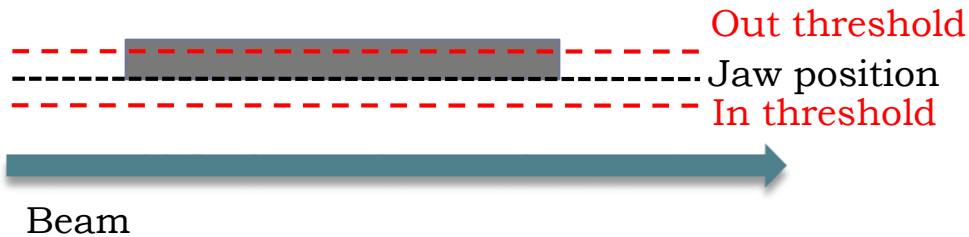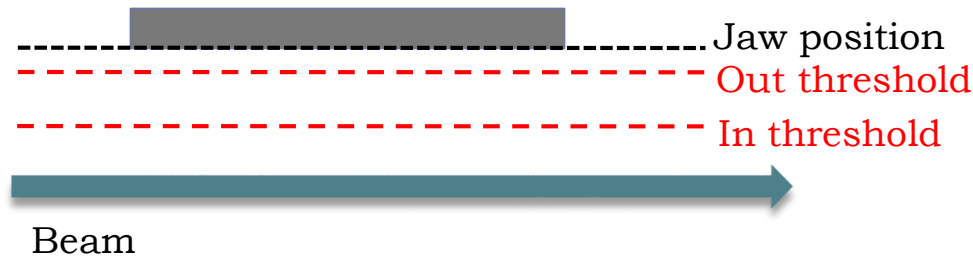# TDI interlocks

MPP, 27-April-12

W. Bartmann, C. Bracco, B. Goddard, V. Kain, J. Uythoven,
O. Aberle, R. Assmann, R. Losito, A. Masi, S. Redaelli

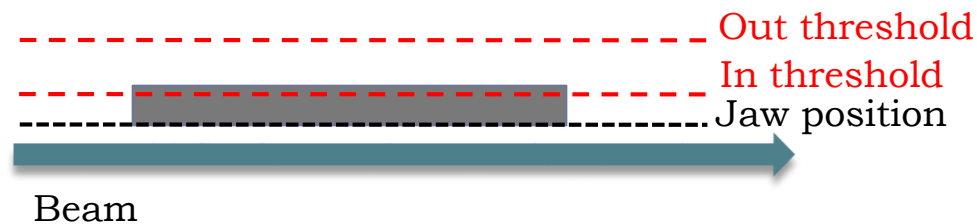# Logic for Injection Collimators Position Interlock

Out threshold

Jaw position

In threshold

Beam

▸ If:

Jaw position

Out threshold

In threshold

Beam

Out threshold

In threshold
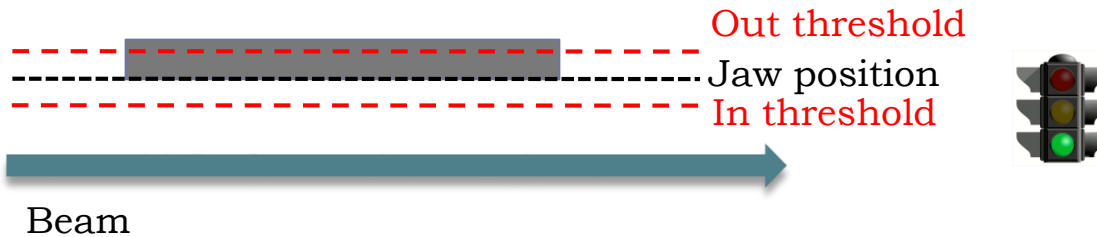
Jaw position

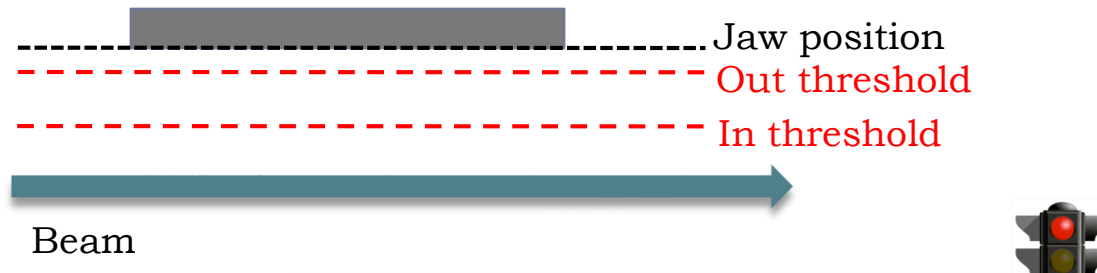Beam

TDI and TCLI:

Jaw movement is not blocked
+ Injection inhibit

Jaw movement is blocked
+ Injection inhibit + beam dump

Logic for Injection Collimators Position Interlock

Out threshold

Jaw position

In threshold

Beam

- ▸ If:

TDI and TCLI:

Jaw position

Out threshold

In threshold

Jaw movement is not blocked
+ Injection inhibit

Beam

Beam

✓ **Thresholds** do not have to be changed during operation to open injection collimators ➔ **always kept at injection setting**

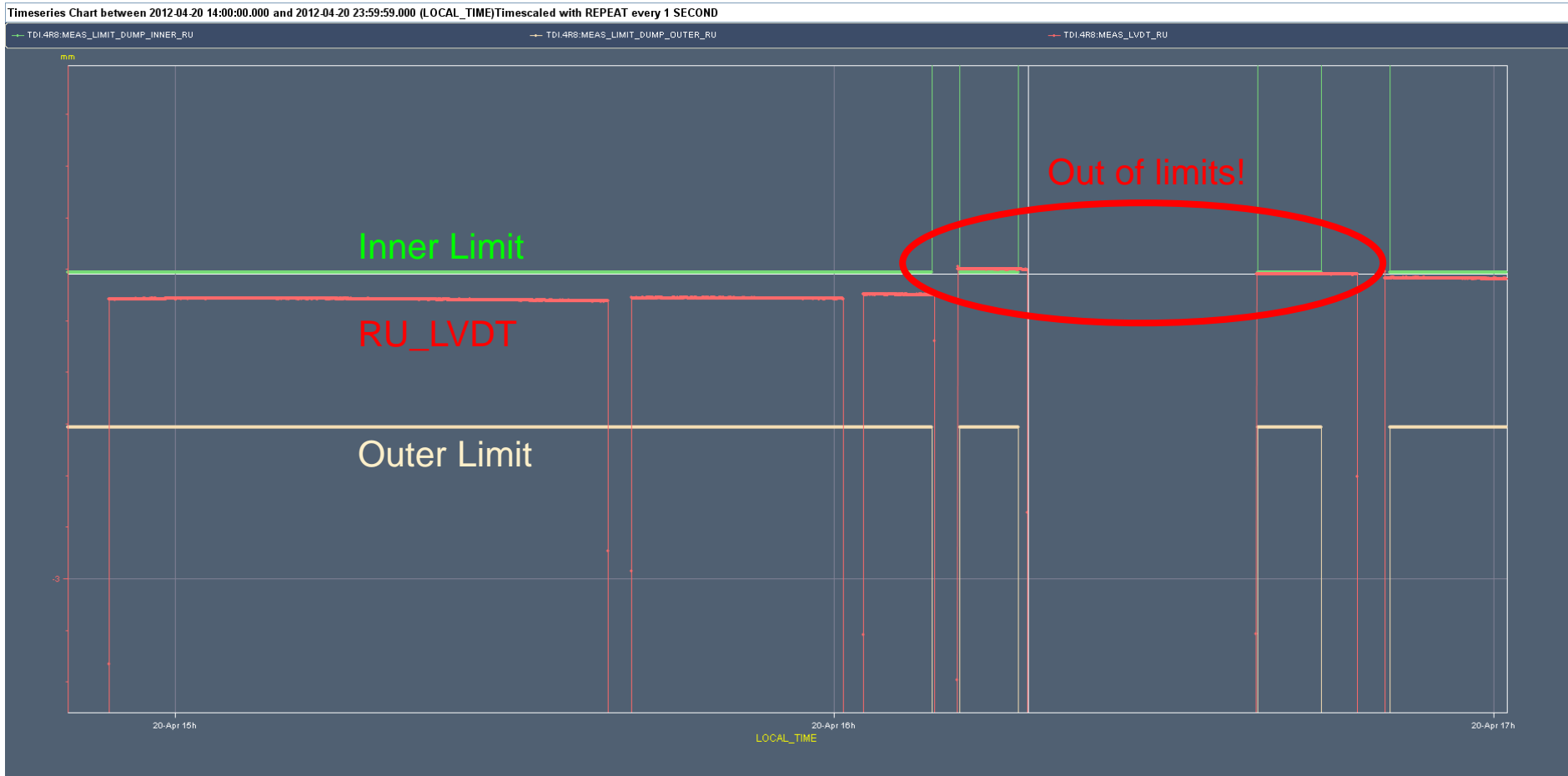✓ **Redundant energy interlock** for **TDI and TCLI** (injection inhibit if gap bigger than defined thresholds)

✓ **MKI set to standby** before opening TDI and TCLI (sequencer) ➔ beam dumped at TDI in case of erratic kicks

TDI Interlocks   27-April-12

Separated Beam Process for Injection

▸ Problem:
  ▸ Injection protection part of the injection beam process (daughter of the ramp beam process)
  ▸ Many different hyper cycles/ramp BPs/injection BPs through the year
  ▸ Collimator settings need to be copied each time – mistakes happened

▸ Separate beam process for injection protection: the same for all hyper cycles, no copies, no re-generation

TDI.IP8 for Beam 2 During 2012 Operation

Timeseries Chart between 2012-04-20 14:00:00.000 and 2012-04-20 23:59:59.000 (LOCAL_TIME)Timescaled with REPEAT every 1 SECOND

TDI.4R8:MEAS_LIMIT_DUMP_INNER_RU   TDI.4R8:MEAS_LIMIT_DUMP_OUTER_RU   TDI.4R8:MEAS_LVDT_RU

Out of limits!

Inner Limit

RU_LVDT

Outer Limit

20-Apr 15h   20-Apr 16h   20-Apr 17h
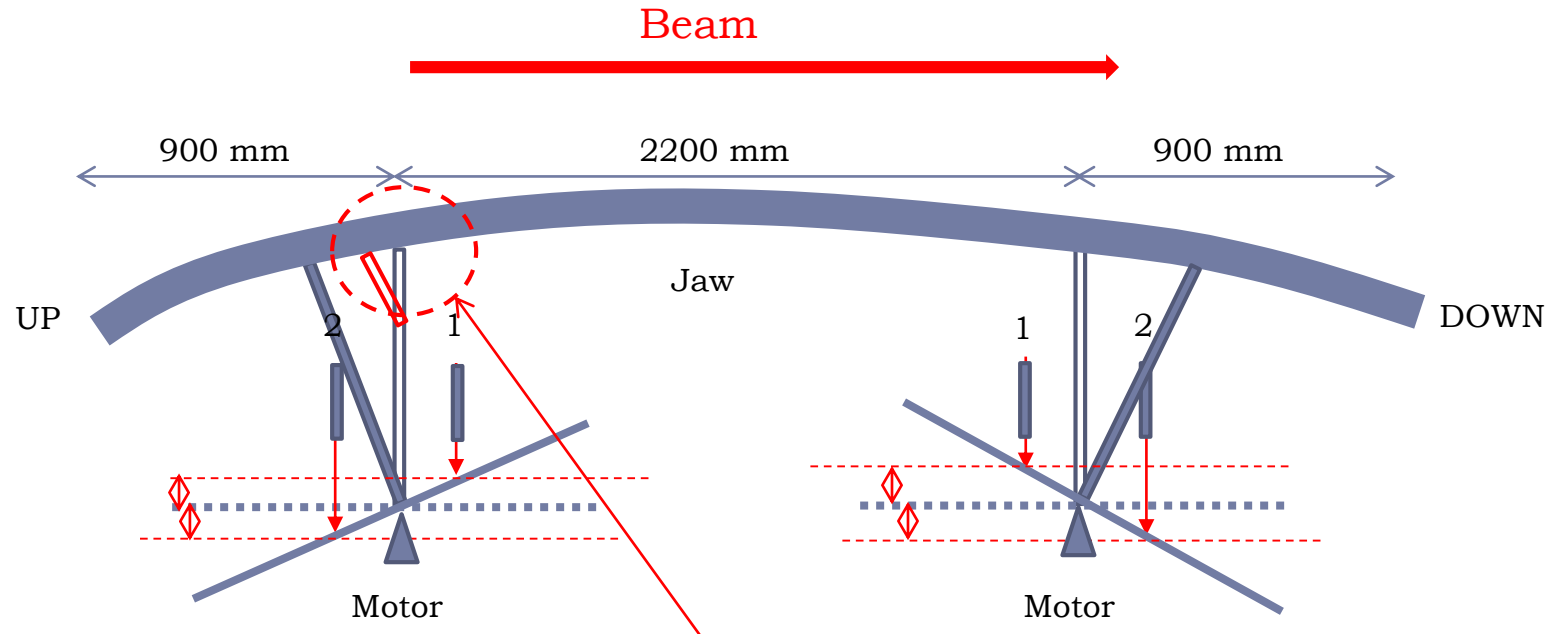
LOCAL_TIME

TDI Position Sensors: LVDT

➤ Originally 2 LVDTs per motor on the same side of the support bar motor/jaw

➤ During TS5 2 LVDTs have been moved on the other side of the support bar

Beam

900 mm   2200 mm   900 mm

UP   DOWN

Jaw

2   1   1   2
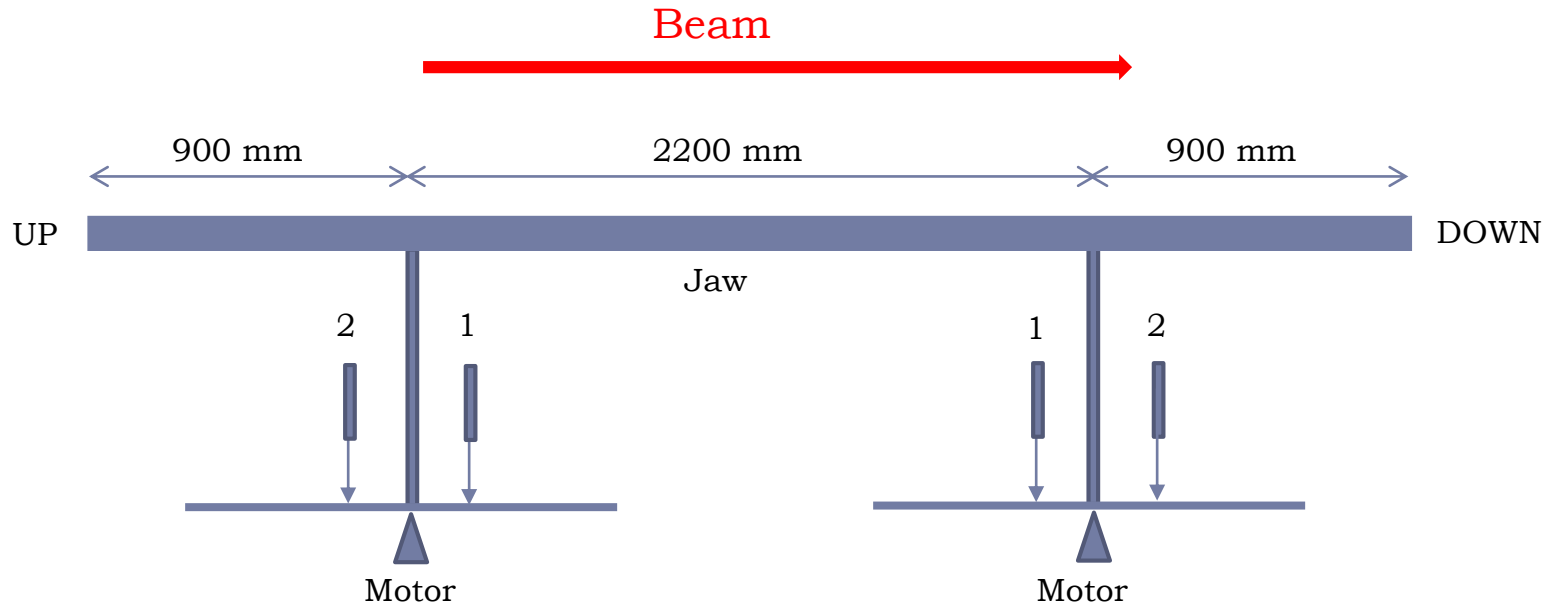
Motor   Motor

TDI Position Sensors: LVDT

➢ Originally 2 LVDTs per motor on the same side of the support bar motor/jaw

➢ During TS5 2 LVDTs have been moved on the other side of the support bar ➔ deformation detection

Beam

900 mm   2200 mm   900 mm

UP   Jaw   DOWN

2   1   1   2

Motor   Motor

Junction which allows for some expansion without deformation

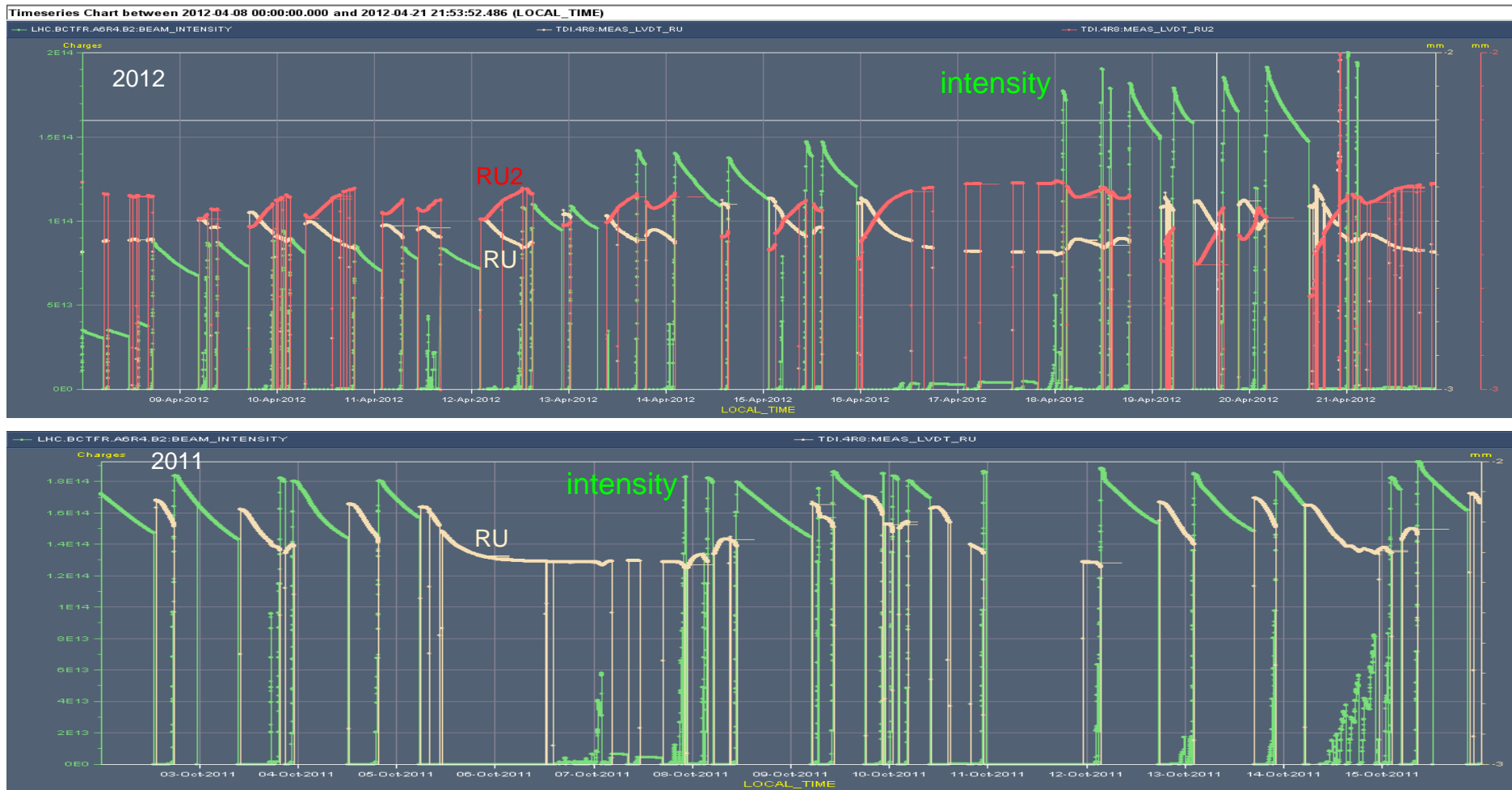100 um drift per LVDT corresponds to 450 um sagitta

Looking at the 2 LVDTs (RU-RU2)
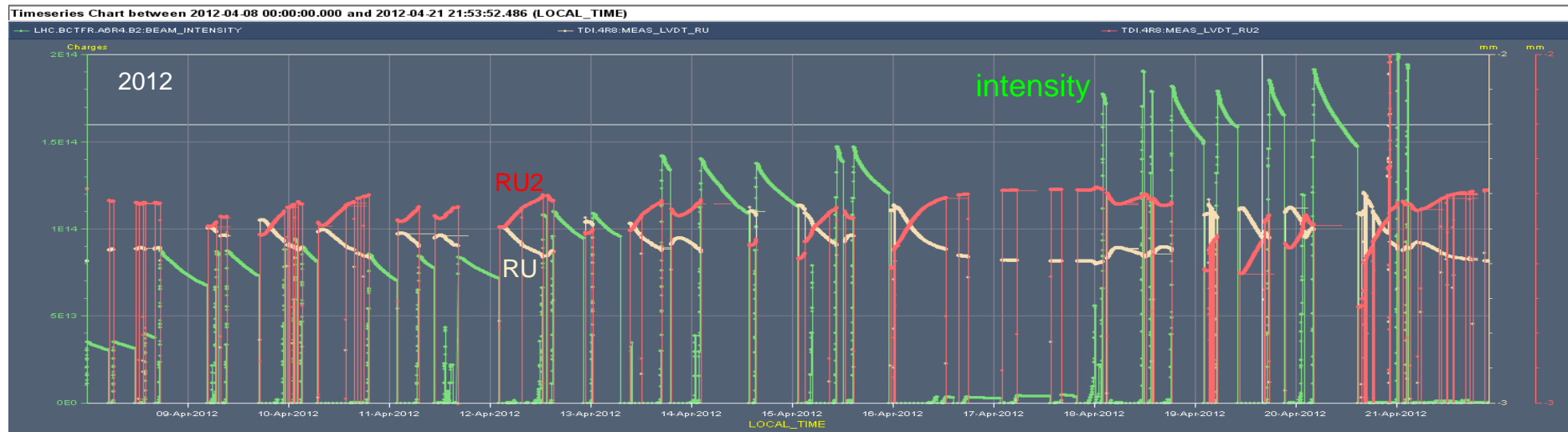
Clear symmetric drift of the 2 LVDTs indicating a possible deformation of the right jaw of TDI in point 8.

Looking at the 2 LVDTs (RU-RU2)

→ Same LVDT feature in 2011 and 2012. However, not seen in 2011, as limits were twice larger (0.5σ) than in 2012 (0.25σ).

TDI Interlocks   27-April-12

Real Jaw Deformation?

- Check position of the TDI jaws with respect to the beam (nominally at 6.8 sigma) with pilot bunch
  - Opened vertical TCSG in point 7 in order not to intercept the beam
  - Used the transverse damper to blow up the beam until seeing losses at the vertical TCP in point 7
  - Moved the TCP away from the beam with 0.1 σ steps
  - Monitored losses at the TCP and TDI
  - Position of the TDI in σ corresponds to the TCP position (in σ) when losses start decreasing at the TCP and increasing at the TDI
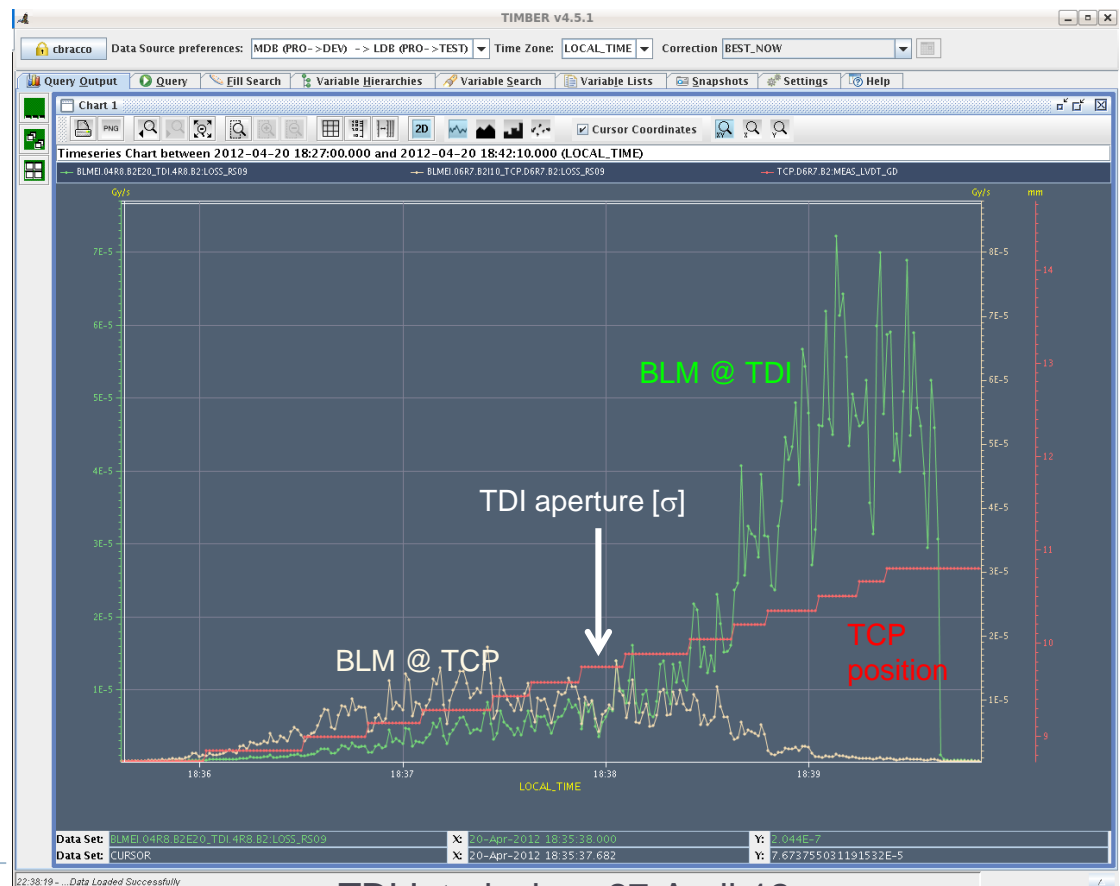
TDI Interlocks   27-April-12

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  - Moved the TCP away from the beam with 0.1 σ steps
  - Monitored losses at the TCP and TDI
  - Position of the T corresponds to position (in σ) w start decreasing and increasing a
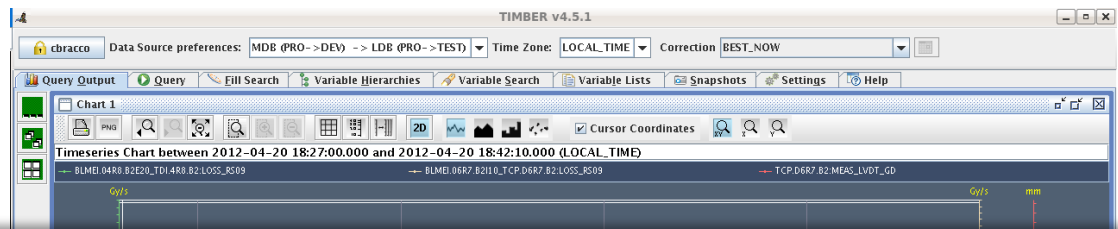
We found:
  - B2 both jaws at 6.4 σ instead of 6.8 σ
 - B1 left (upper jaw) at 6.2 σ and right (lower) jaw at 6.8 σ

Small difference can possibly be explained by using a different method than used for the original set-up.

Calculated sagitta based on LVDT drifts does not correspond to these measured positions of beam intercepting.

→ **repeat measurements with "cold" jaw for reference (and again for "warm" jaw)**

TDI Interlocks   27-April-12

Change in the Angle?

We repeated angular alignment that we did on March 26th to verify if any change in the angle occurred as a consequence of the warm-up
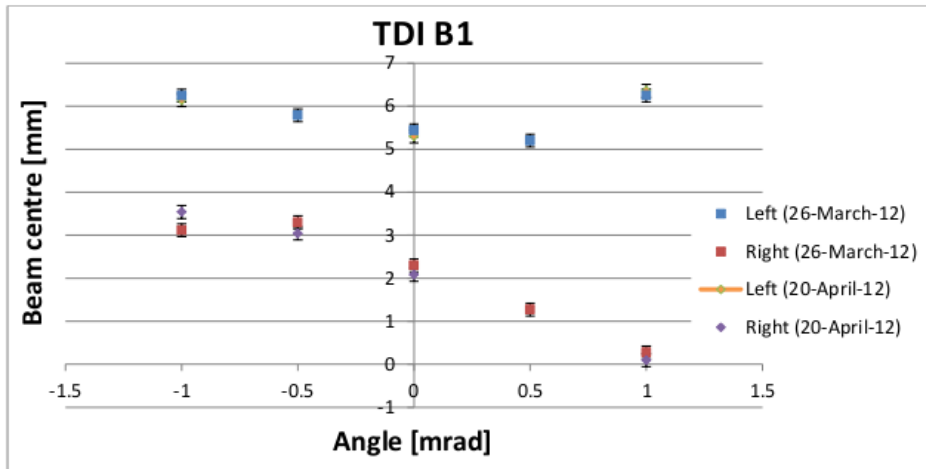
We found the same values within the measurement error.
By time of measurements jaws cooled down again??
Repeat measurements with "warm" jaw

TDI Interlocks   27-April-12
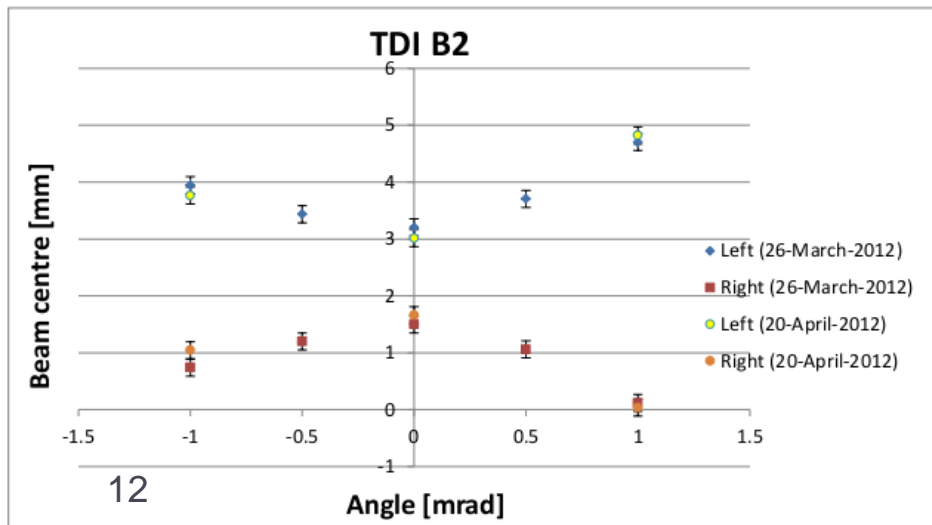
Position interlock tolerance

	Mis-kick of injected beam	Mis-kick of circulating beam
	sigma	sigma
Aperture to protect vertical	**12.5**	**12.5**
Orbit bumps	1.5	1.5
Injection oscillations	1.5	0
Beta beat	0.5	0.5
Energy	0	0
Position setup accuracy	0.2	0.2
Angle setup accuracy	0.8	0.8
What aperture is left	**8.0**	**9.5**
Protected aperture	**7.5**	**7.5**
TDI setting	6.8	
Upper limit for position interlock	**0.5**	**2.0**

No deformation included!
→ measurements on Saturday

Potential interlocks for future

- TDI on BETS
  - inhibit injection via the injection BIC
  - not inhibit only the MKI kick (could give a non-kicked beam onto the TDI with the wrong gap!)
  - BIC entry needs to be maskable for set-up
  - only on gap interlock not on position to allow for ALICE polarity flip without HW intervention; also the gap remains the same
  - TDI has no independent gap measurement (as all the other collimators) → required for TDI-BETS interlock
  - Having the BETS interlock would also avoid to injecting high intensity without properly set gap interlock

- "Deformation" interlock
  - Average LVDT1 and LVDT2 as input for position interlock could increase operational availability
  - **AND**
  - Interlock on LVDT1 and LVDT2 difference as limit for jaw deformation (LVDT calibration required)
 - Keeps safety and gives information on deformation

Conclusion

- We see a **drift** of the **TDI LVDTs** mainly during **physics** ➔ jaw position outside interlocks (±0.25 σ) when back at injection setting

- Different phenomena can lead to this behaviour: Particle impact, RF heating,...

- Same drift already observed last year but tolerances more relaxed (±0.5 σ)

- **Symmetric drift** for the 2 LVDTs located at the 2 sides of the motors ➔ jaw **deformation?**

- **Measurements with beam** indicate a **possible deformation** towards the beam ("safe" side) of the order of 0.5 σ

- **Angular scan** did not show any evident change (jaw already cold?)

- Not always clear correlation between **LVDT drift** and **beam condition** ➔ need more statistics (look also at existing data)

- No clear correlation between **LVDT drift** and **jaw deformation**
  - Tomorrow right after TS: reference measurements in different conditions
  - if correlation is understood ➔ setup thresholds accordingly

- Not taking into account the deformation we can allow for an interlock limit of 0.5 sigma to protect the LHC aperture
  - 0.5 sigma limit would allow for a theoretical worst case deformation of 2.1 sigma sagitta – but this is not even in qualitative agreement with measurements!

- **Keep 0.25 sigma thresholds until we understand the situation**

- **New TDI design to be considered?!?**

Extra slides

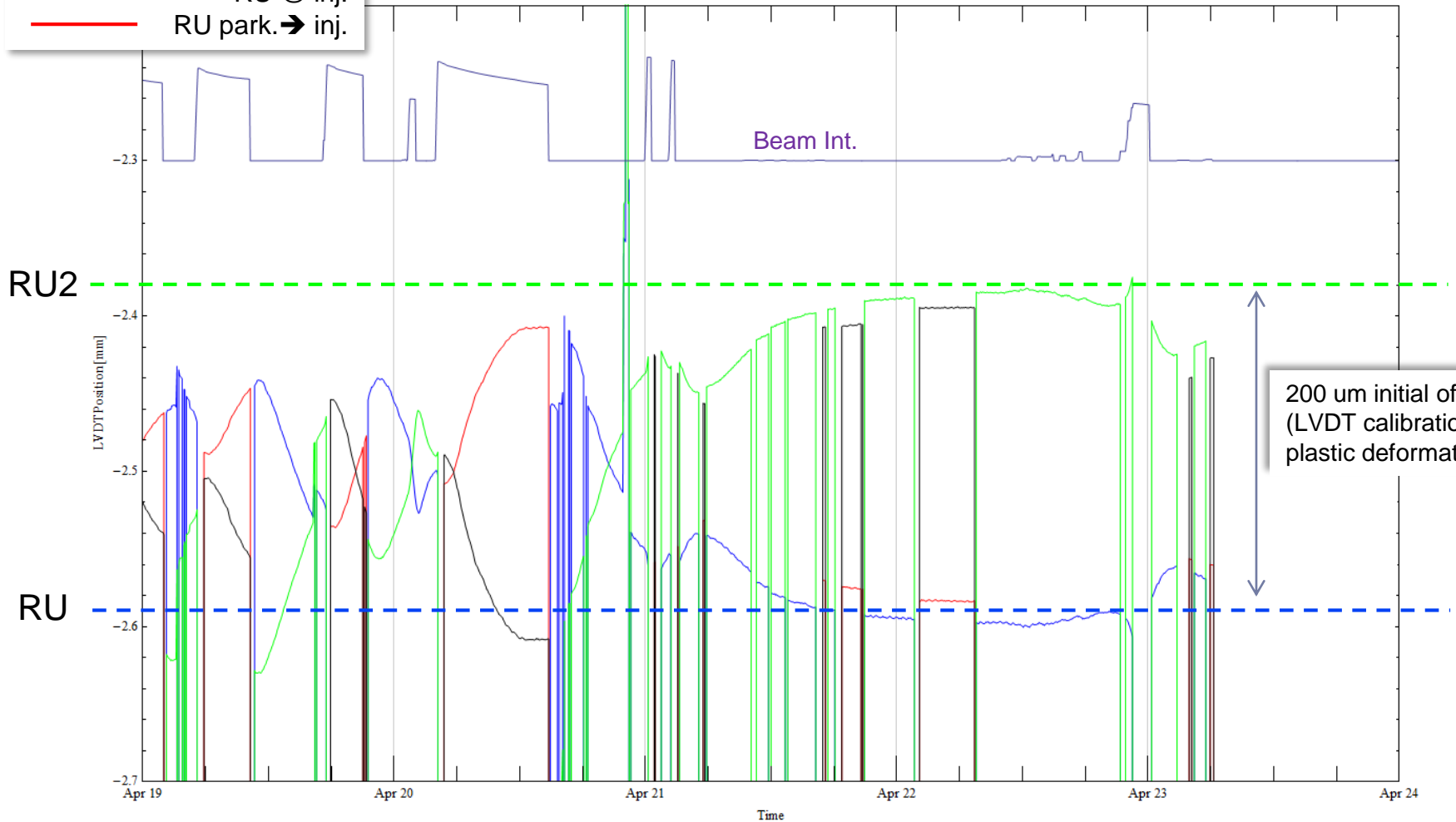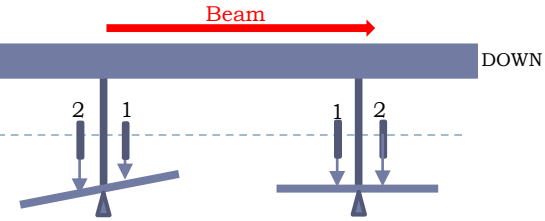# Correlation with Beam RU
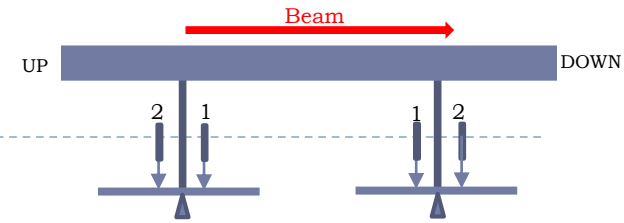
Legend:
- RU2 @ inj.
- RU2 park. ➔ inj.
- RU @ inj.
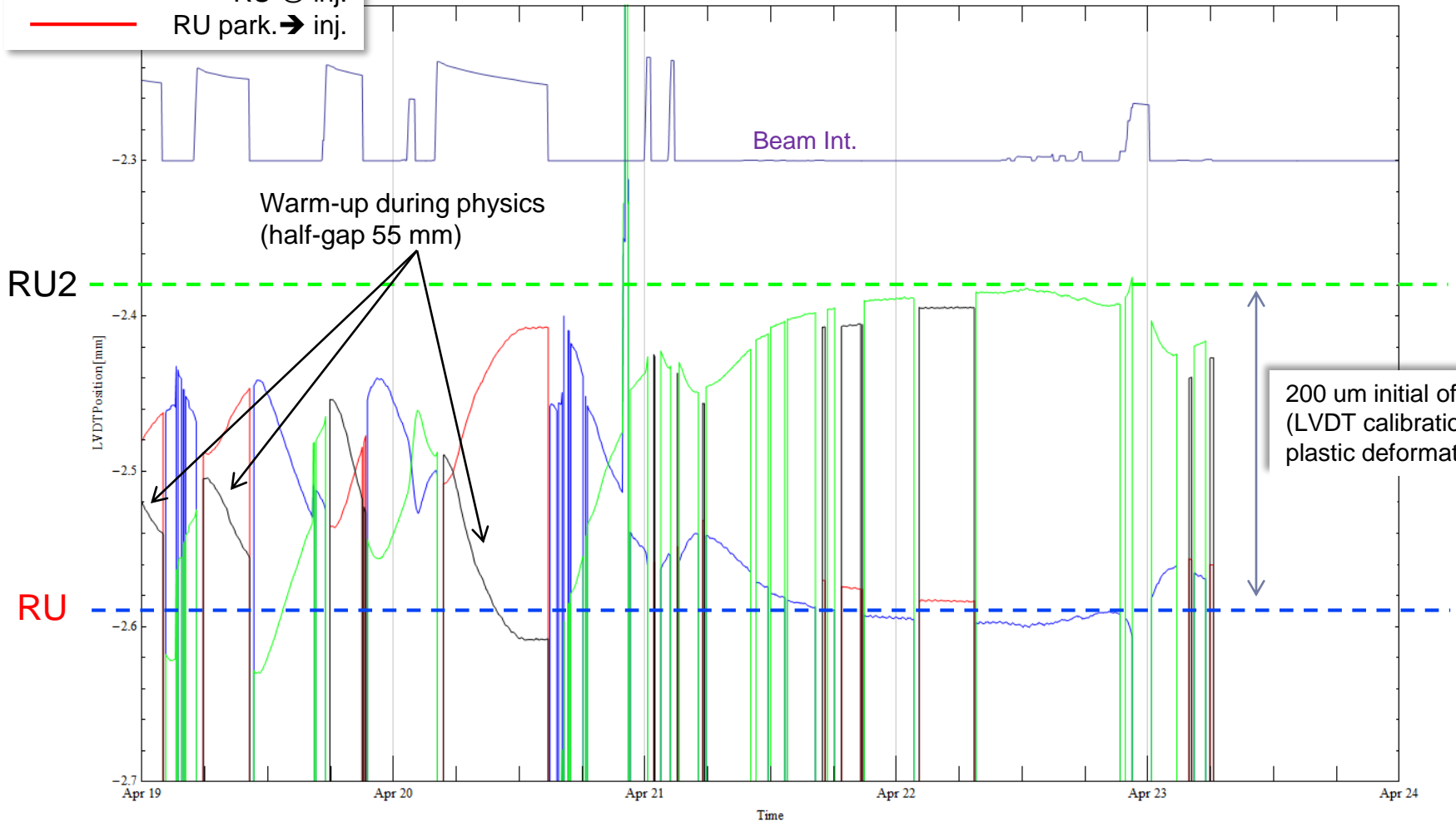- RU park. ➔ inj.

IP8, Right up 2012

Beam Int.

RU2

RU

200 um initial offset
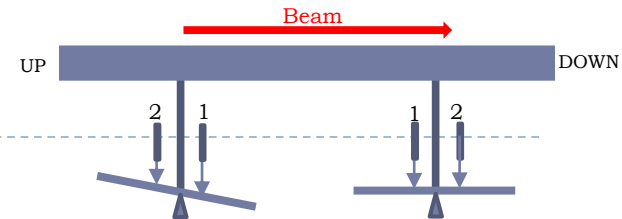(LVDT calibration or
plastic deformation??)

B2 Correlation with Beam RU

TDI Interlocks   27-April-12

Correlation with Beam RU

Legend:
- RU2 @ inj. (green)
- RU2 park. ➔ inj. (black)
- RU @ inj. (blue)
- RU park. ➔ inj. (red)

IP8, Right up 2012

Beam Int.

Warm-up during physics (half-gap 55 mm)

Warm-up at injection **but** different deformation!! (half-gap ~5 mm)

RU2

RU

200 um initial offset (LVDT calibration or plastic deformation??)

Correlation with Beam RU

Beam

UP   DOWN
2   1   1   2

Legend:
- RU2 @ inj. (green)
- RU2 park. → inj. (black)
- RU @ inj. (blue)
- RU park. → inj. (red)

IP8, Right up 2012

Beam Int.

Warm-up during physics
(half-gap 55 mm)

Warm-up at injection
(half-gap ~5 mm)

RU2

RU

200 um initial offset
(LVDT calibration or

Warming → deformation in opposite
direction when in physics or at
injection (to be analyzed in detail →
need more statistic to see if
systematic)

LVDTPosition[mm]

Apr 19   Apr 20   Apr 21   Apr 22   Apr 23   Apr 24

Time

Correlation with Beam RD

TDI Interlocks   27-April-12

Correlation with Beam LU

IP8, Left up 2012

Legend:
- LU2 @ inj.
- LU2 park. ➔ inj.
- LU @ inj.
- LU park. ➔ inj.

LU2

LU

60 um initial offset

Warm-up at
(half-gap ~5 mm)

Warm-up during physics
(half-gap 55 mm)

Beam Int.

Correlation with Beam LD

TDI Interlocks   27-April-12
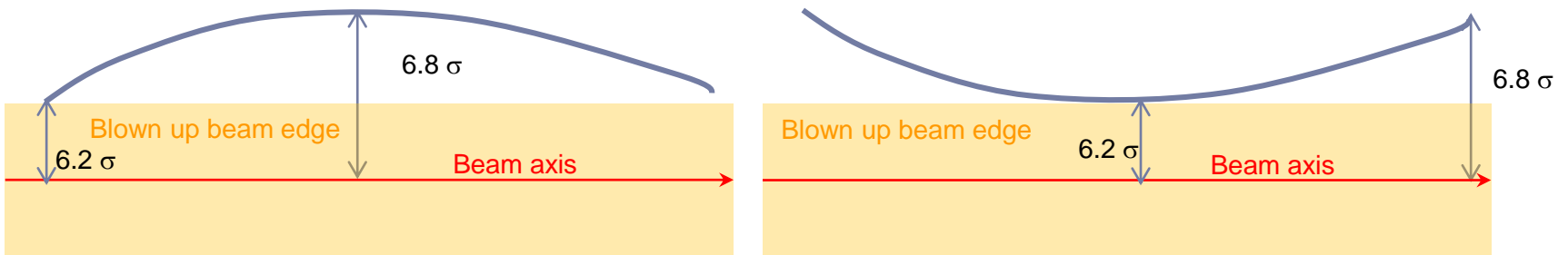
Do we have a Real Jaw Deformation?

- We found:
  - B2 both jaws at 6.4 σ instead of 6.8 σ
  - B1 left (upper jaw) at 6.2 σ and right (lower) jaw at 6.8 σ
  - We cannot say how the jaws are deformed

6.8 σ

Blown up beam edge

6.2 σ

Beam axis

Blown up beam edge

6.2 σ

Beam axis

6.8 σ

BLM @ TCP