RF-foil temperatures under various conditions

to answer the question

Do we observe heating of the RF-foils by the beams ?

- Introduction
- Conditions matrix:
  - LV on/off
  - DAQ running or not,
  - VELO OPEN/CLOSED,
  - Beam properties: intensity, energy, collisions
  - Characteristic times
- Observations and conclusions

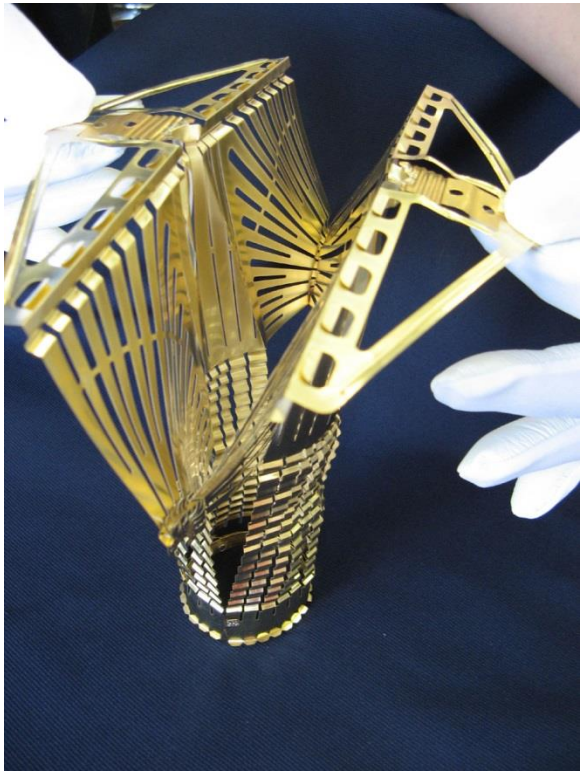
Design considerations

To minimize RF-coupling to the beams and to optimally guide the mirror currents special attention was given to:

- the wakefield suppressors,
- the shape and material choice of the RF-foil.

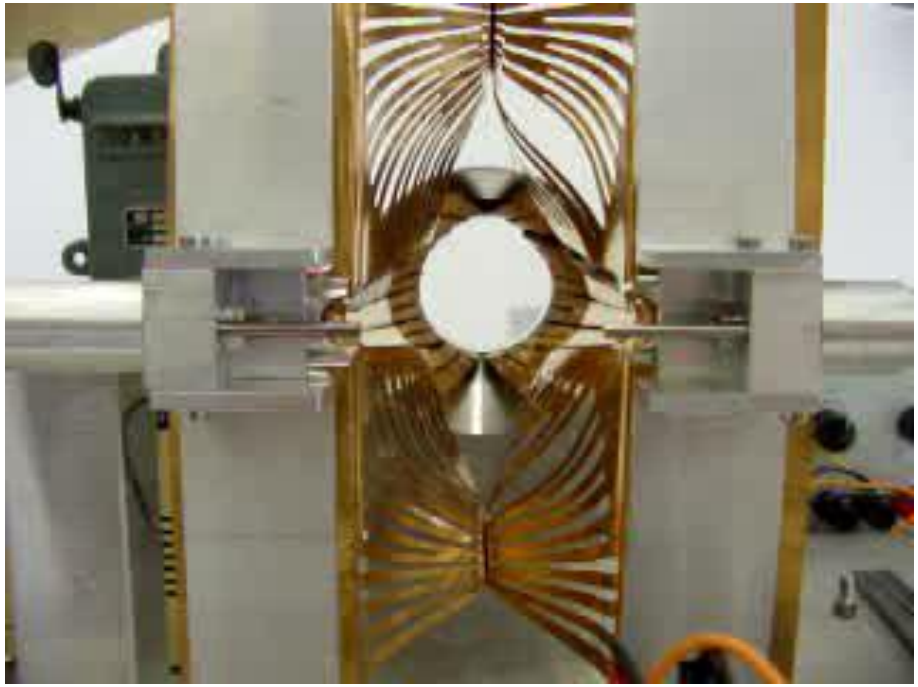
Wakefield suppressors

Connect the fixed beam pipes with the moveable RF-box to create a "smooth" transition for the electromagnetic waves induces by the bunches of the beams.
Made of 75 μm thick CuBe foils.



15 seconds movie of production (with sound):

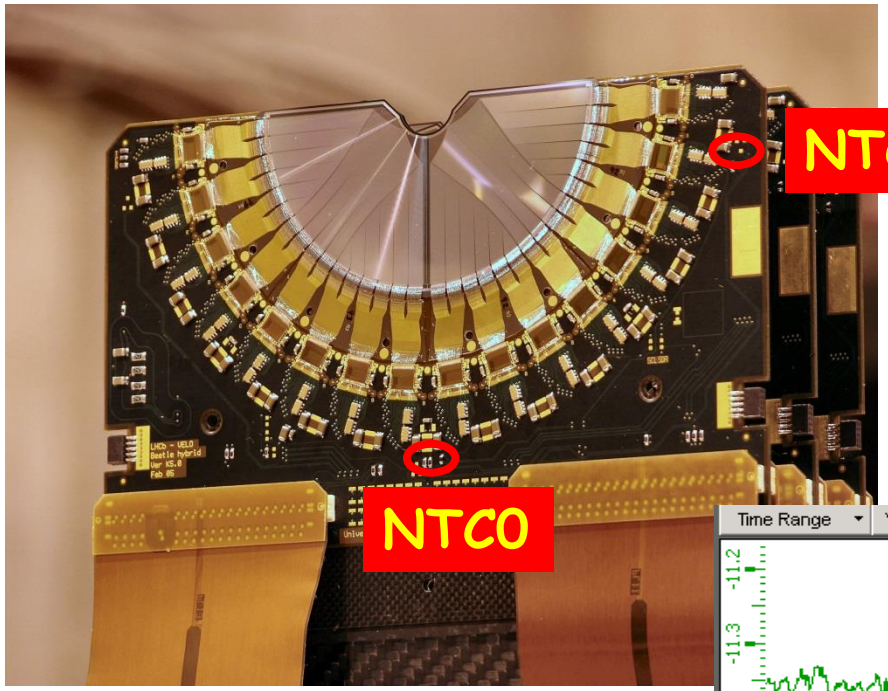
http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/production/wakefieldsuppressor/video.mpg

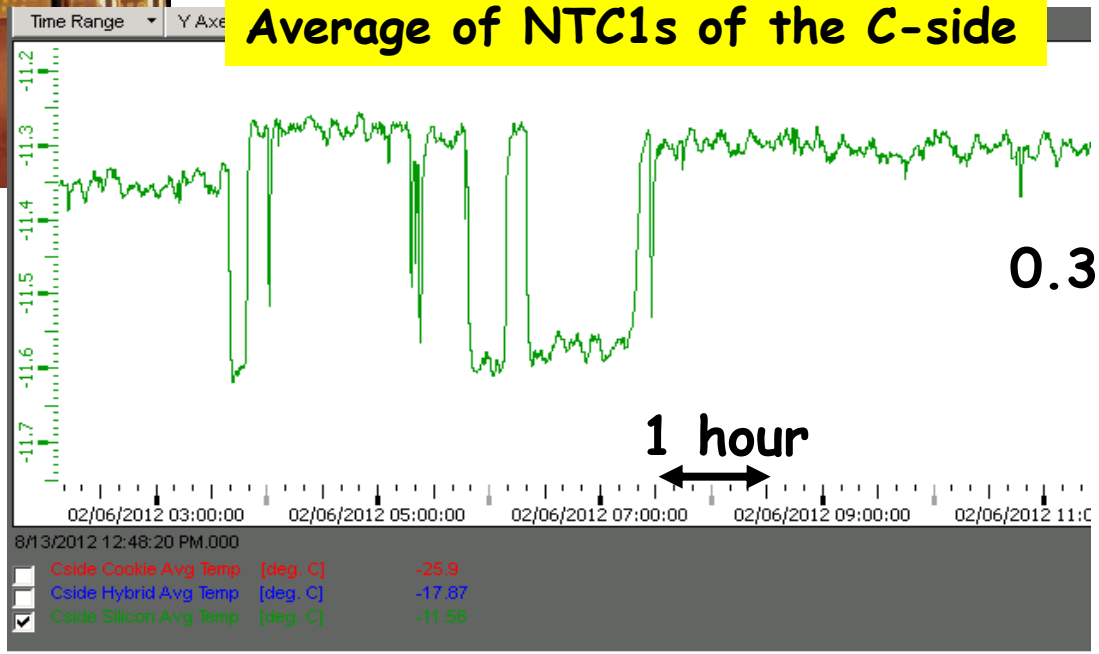


15 seconds movies of steadiness tests with sound:

http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/test/wakefield/VIDEO1.MPG
http://www.nikhef.nl/pub/departments/mt/projects/lhcb-vertex/test/wakefield/VIDEO2.MPG

Effect on NTC1 of triggering Beetle readout

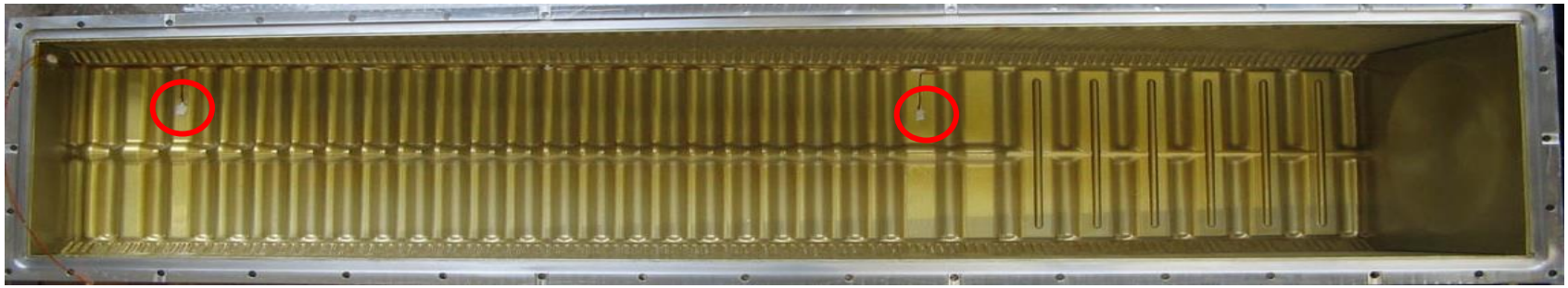




ΔT of NTC1 between DAQ on/off is 0.3 °C.
This time constant is very short.

Each RF-foil (nominal 0.3 mm thick AlMg3) has two temperature sensors on the detector side.

RF-box on the C-side

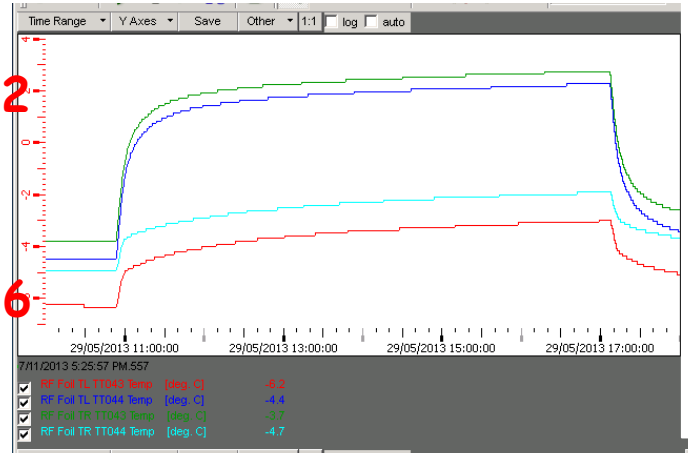


Caveat: these temperatures stabilize rather slowly with various time constants for changing experimental conditions, like VELO open/close, Injection, beam intensities, Ramp, LV on/off, DAQ on, etc.
So the effects mix and are therefore difficult to disentangle.

LV off→on

Temps of RF-foil

VELO open



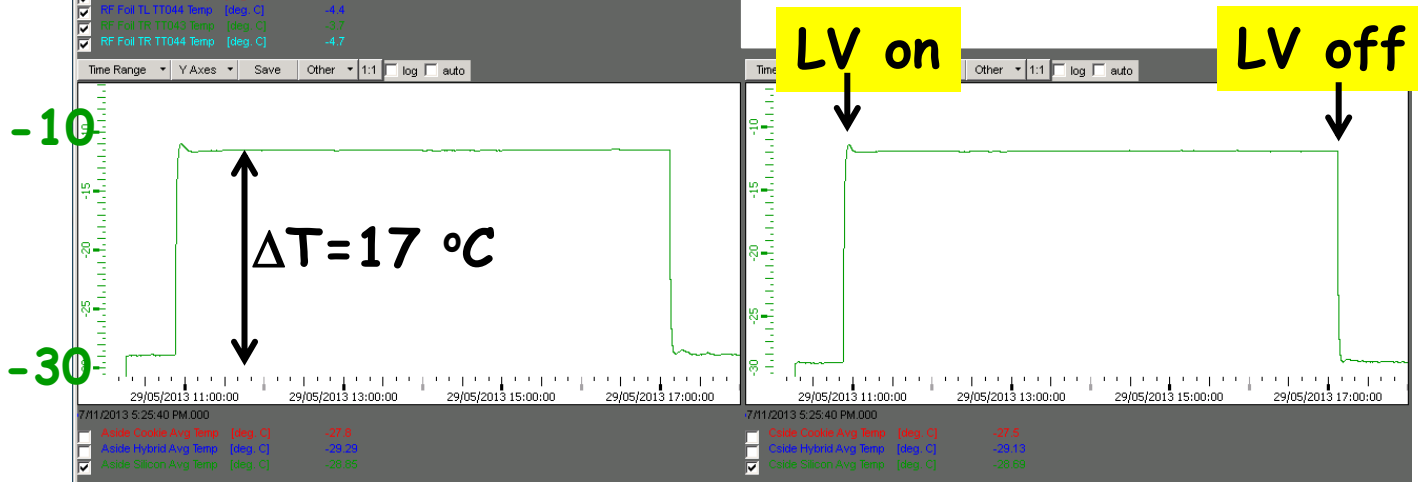
C: ΔT=6.5 °C

A: ΔT=6.8 °C

C: ΔT=3.0 °C

A: ΔT=3.2 °C

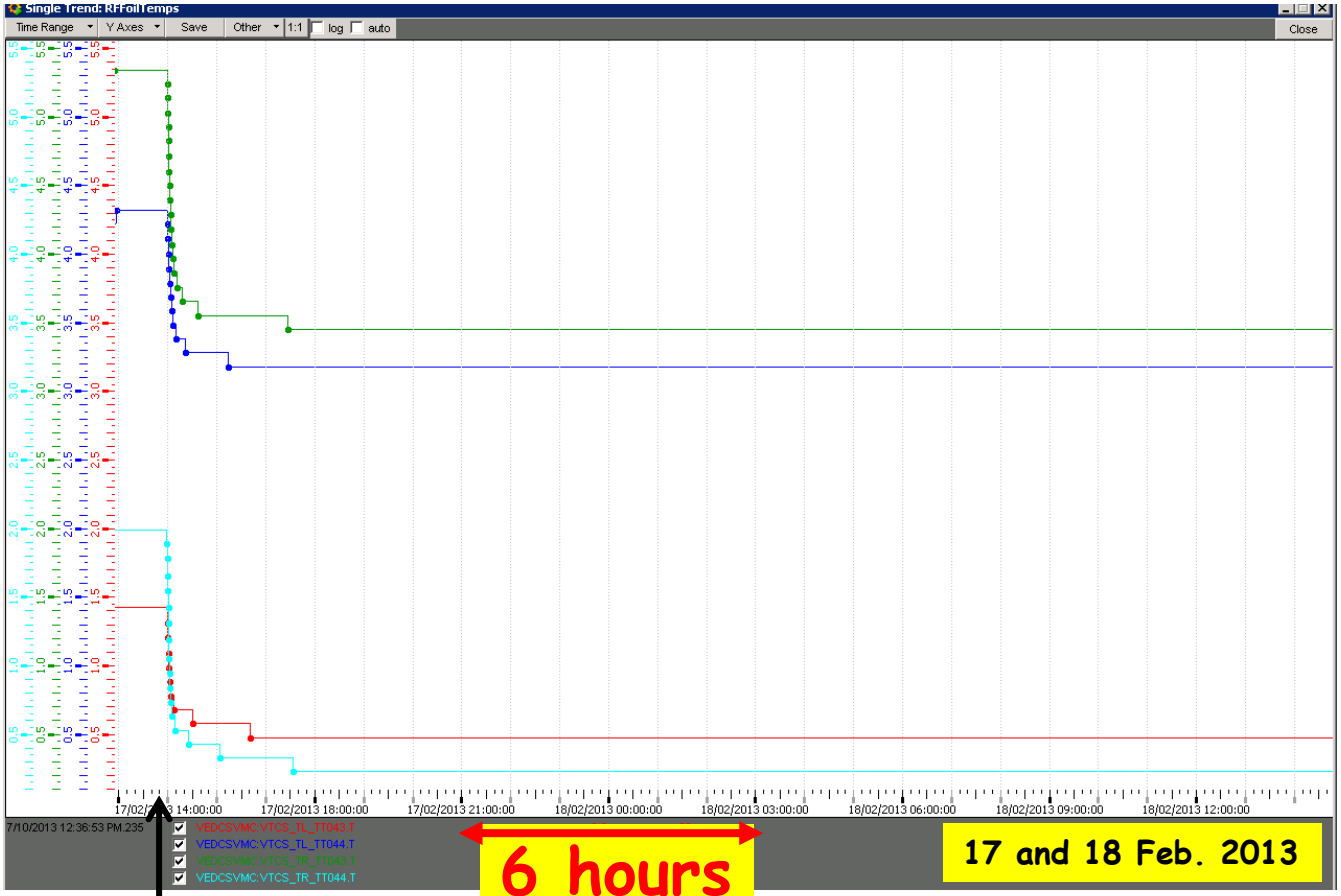
NTC1



6 hours

Temperature of RF-boxes stabilizes very slowly (>6 hours) after switching on the LV. So DAQ on/off influences the temperature of the RF-foils by at most 0.3*7/17= 0.1 °C.

LV on for >24 hrs, No beam, VELO OPEN→CLOSE



C: ΔT= -1.9 °C
A: ΔT= -1.1 °C

A: ΔT= -1.0 °C
C: ΔT= -1.8 °C

Close VELO

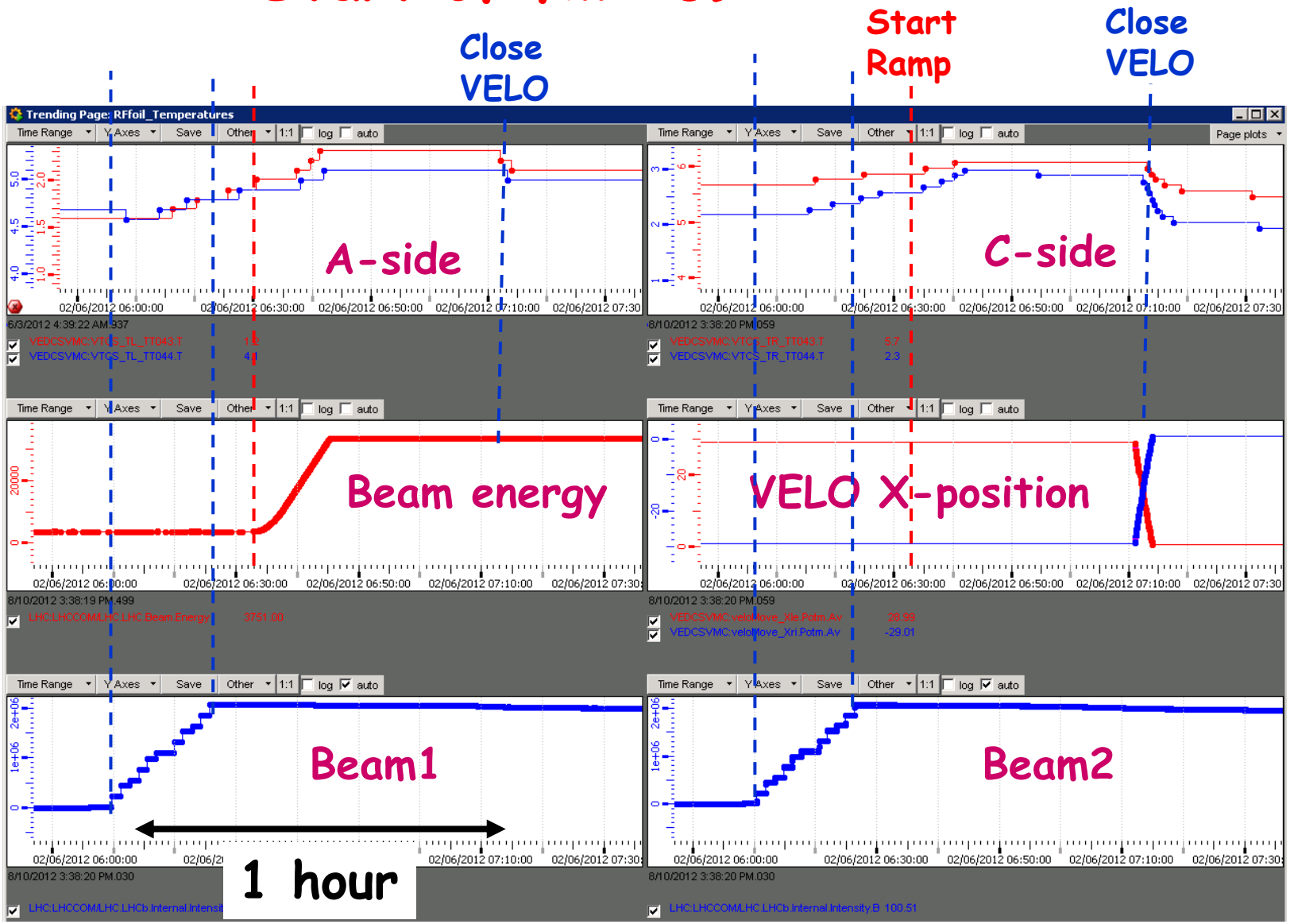
Bulk of the drop in ~1 hour
Stable after ~3 hours:

$\Delta T_{A\text{-side}}$ = -1.1 °C
$\Delta T_{C\text{-side}}$ = -1.9 °C

Next slide shows the two temperatures of each RF-box for fill 2692 (with 23 hours of Stable Beams) together with:

- # protons in Beam1
- # protons in Beam2
- Beam energy
- VELO-position

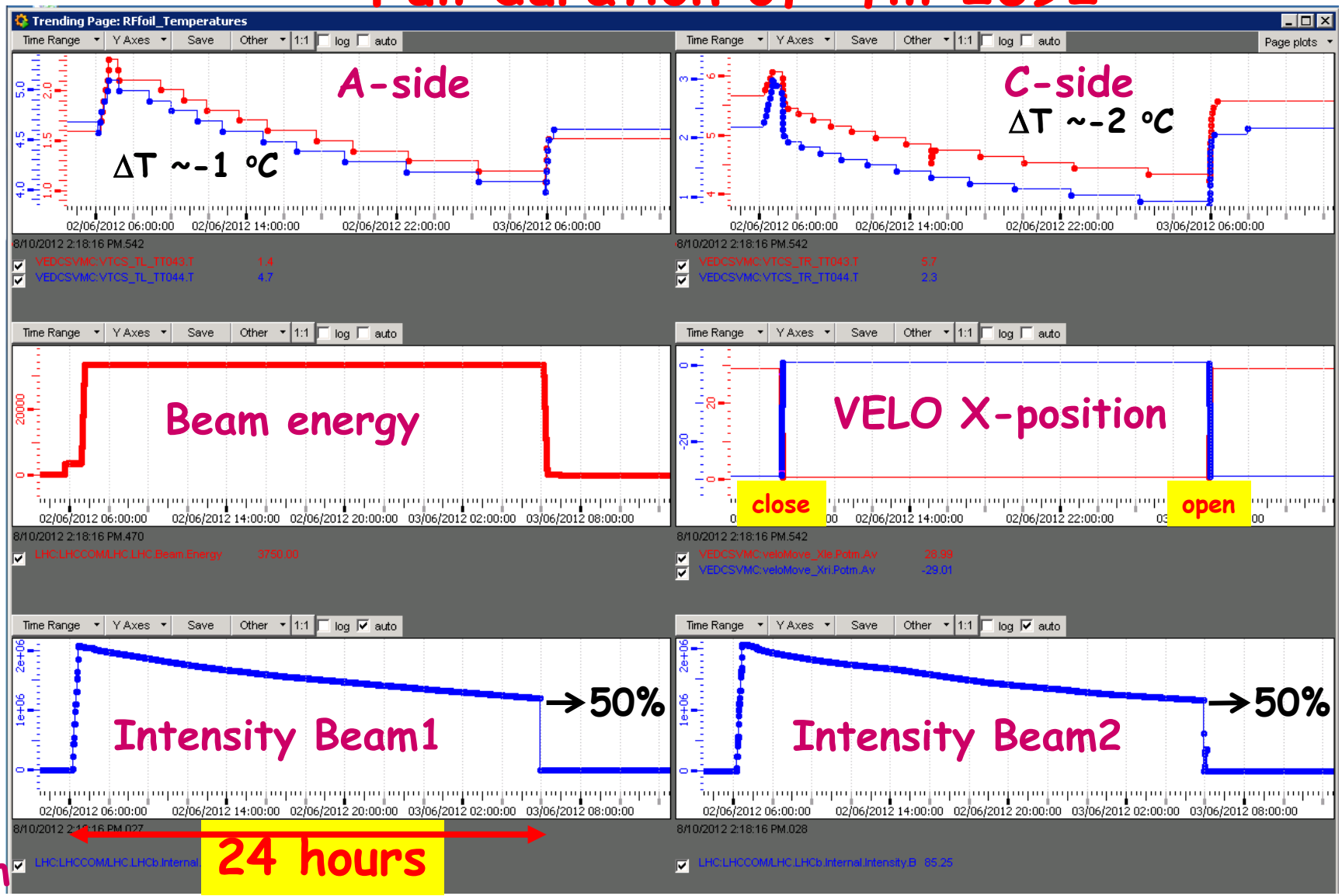
Start of fill 2692



Inject + Ramp: $0.7 > \Delta T_{A\text{-side}} > 0.5$ °C

$0.8 > \Delta T_{C\text{-side}} > 0.4$ °C

Full duration of fill 2692



from Stable Beams till Dump

$\Delta T_{A\text{-side}}$ ~-1 °C

$\Delta T_{C\text{-side}}$ ~-2 °C

Summary

	$\Delta T_{A\text{-side}}$	$\Delta T_{C\text{-side}}$
1 hr after closing **without** beam:	~-0.9	~-1.7
3 hrs after closing **without** beam:	~-1.0	~-1.8
24 hrs after closing **without** beam:	-1.1	-1.9
3 hrs after closing **with** beam:	~0.3	~-1.1
24 hrs after closing **with** beam:	~-1	~-2

The temperature drops shortly after closing **with beam** are less than the **bare 'closing effect' without beam**.

During the fill a temperature trend is visible which is similar to the decreasing beam intensities. However, the absolute scales don't match completely:
without beam: drop of -1.1 / -1.9 degree for A/C side
with beam: first a 0.6 degree rise and then a more gradual drop of -1 / -2 degree.

Conclusions

- A heating effect of ~0.7 °C in the RF-foils due to Injection of the beams of is observed, when the average current per beam amounts to 0.35 A.
- Possibly additional heating due to energy Ramp.
- After closing the VELO the temperatures of the RF-foils continue to decrease during the duration of the fill. Presumably due to the decreasing beam intensities.
- The absolute numbers of closing with/without beam don't fully match, but the effects are small: a few tenths of a degree.

Backup slides

Observations

- Closing the VELO without beam and LV on results in a ΔT of -1.1 and -1.9 °C for the A and C-side, resp.
- At Injection of the beams an increase of 0.7 and 0.5 °C is observed for TT043 and TT044 on the A-side. For the C-side these values are: 0.4 and 0.8 °C.
- During Ramp there seems to be an additional increase, although hard to disentangle from Injection.
- While closing the VELO with beam the C-side cools down more quickly than the A-side, and in 3 hours by ~ -0.3 °C. Temperature of the A-side drops more gradually and in 3 hours by ~ -1 °C.
- Temperatures continue to drop during the fill of 24 hours, similar to the decrease of the currents in the ring.
- After opening the VELO the temperatures rise quickly to their original values.