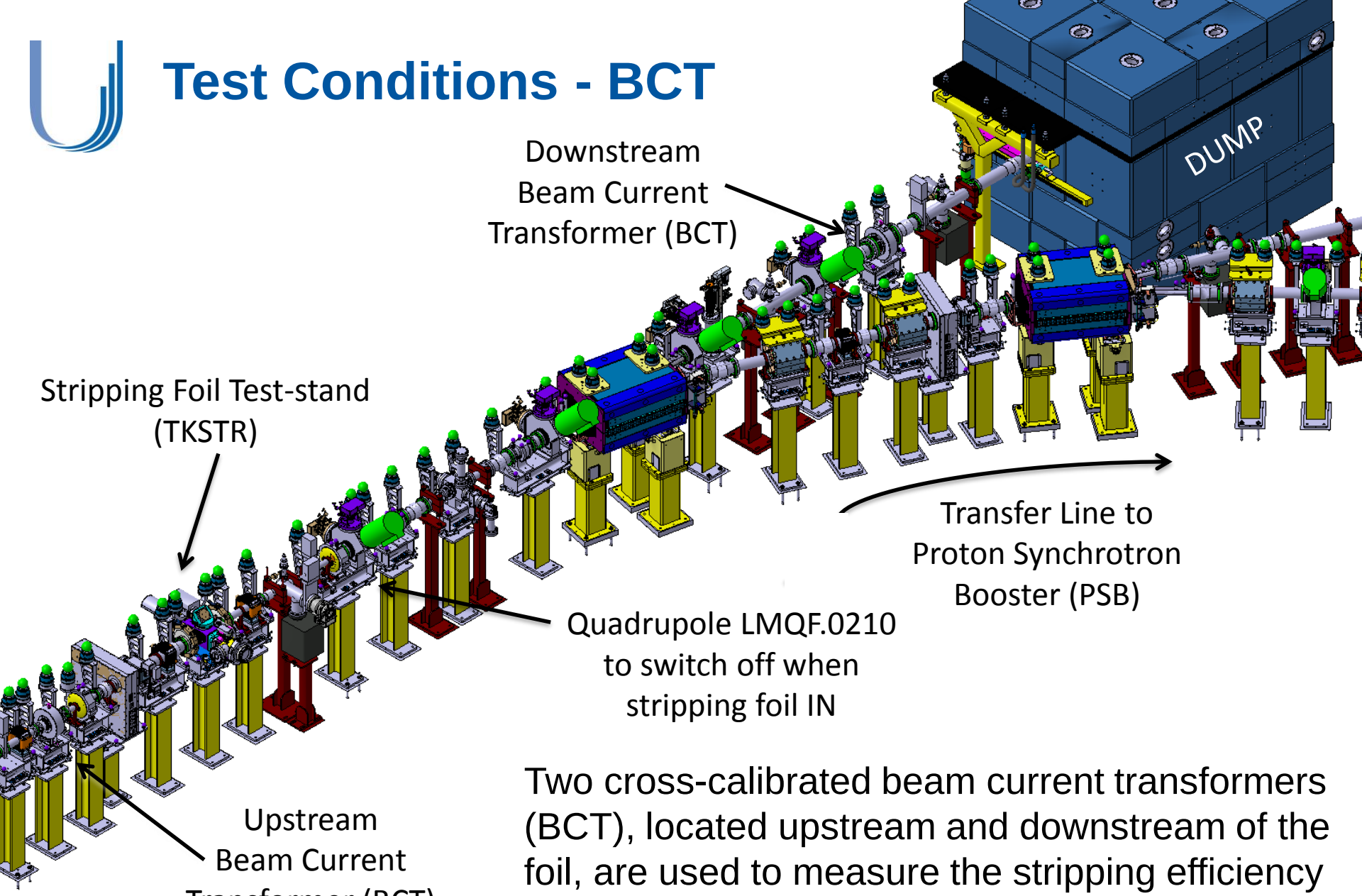
Results on Stripping Foil Tests

C. Bracco, L. Jorat, R. Noulibos, P. Van Trappen and **W. Weterings**

Acknowledgment: Linac4 and PSB-OP teams

Test Conditions - BCT



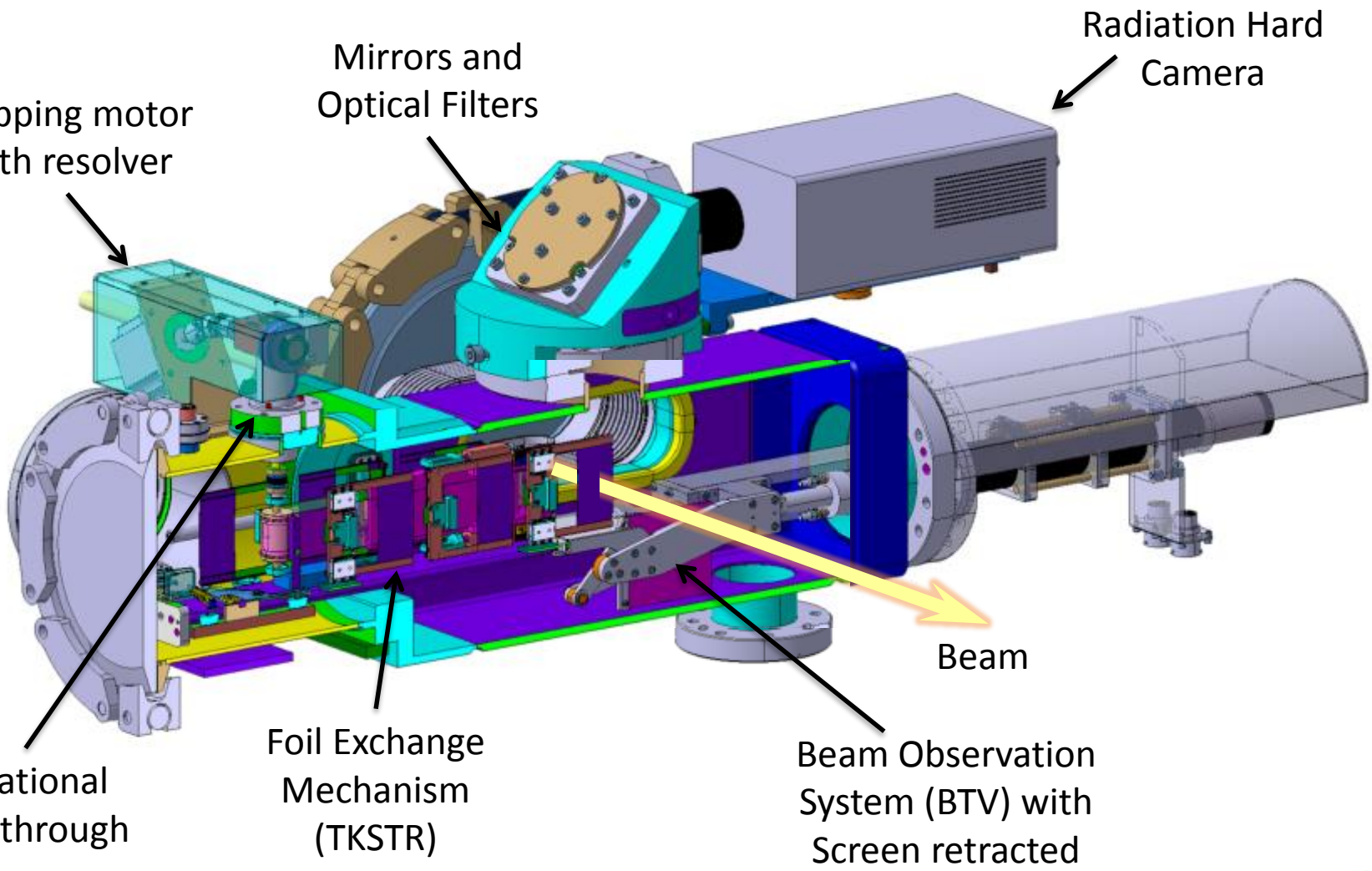
Two cross-calibrated beam current transformers (BCT), located upstream and downstream of the foil, are used to measure the stripping efficiency by looking at their relative current decrease.

Courtesy of W. Weterings

Stripping Foil Test Stand – from INTDS2014

Conceptual Design

J. Radioanal. Nucl. Chem. (2015) 305: 831.
doi:10.1007/s10967-014-3917-0



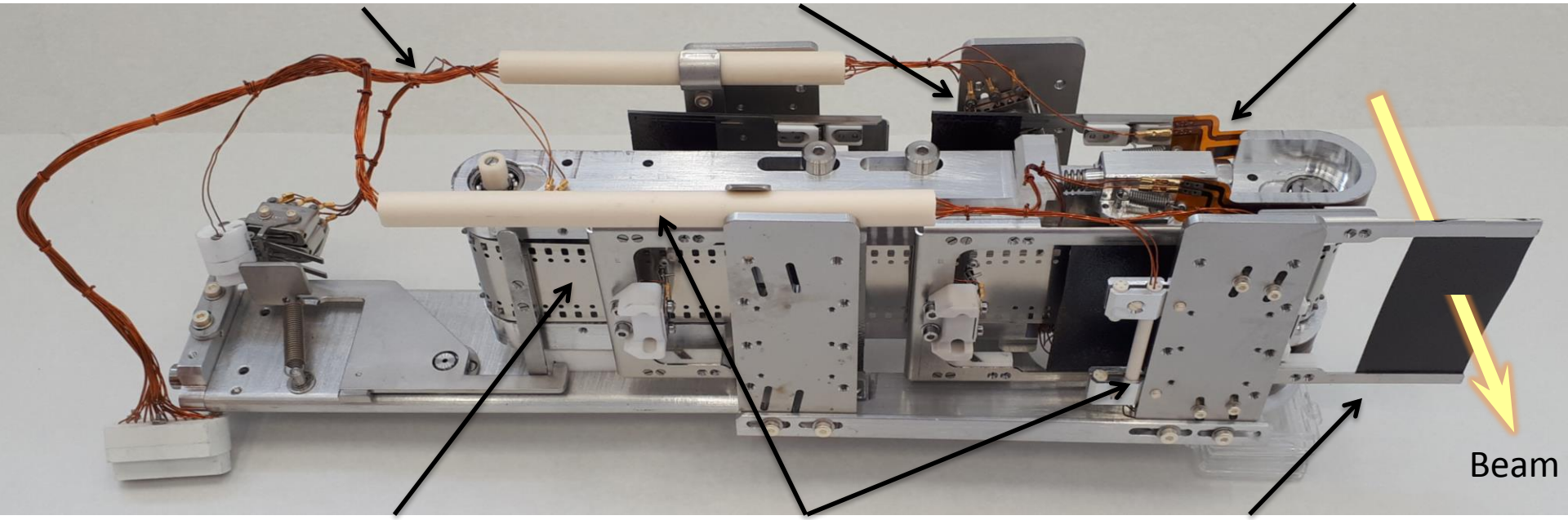
Courtesy of W. Weterings

Stripping Foil Exchange Mechanism (TKSTR)

UHV compatible Kapton® cabling

UHV compatible micro switches

membrane potentiometers



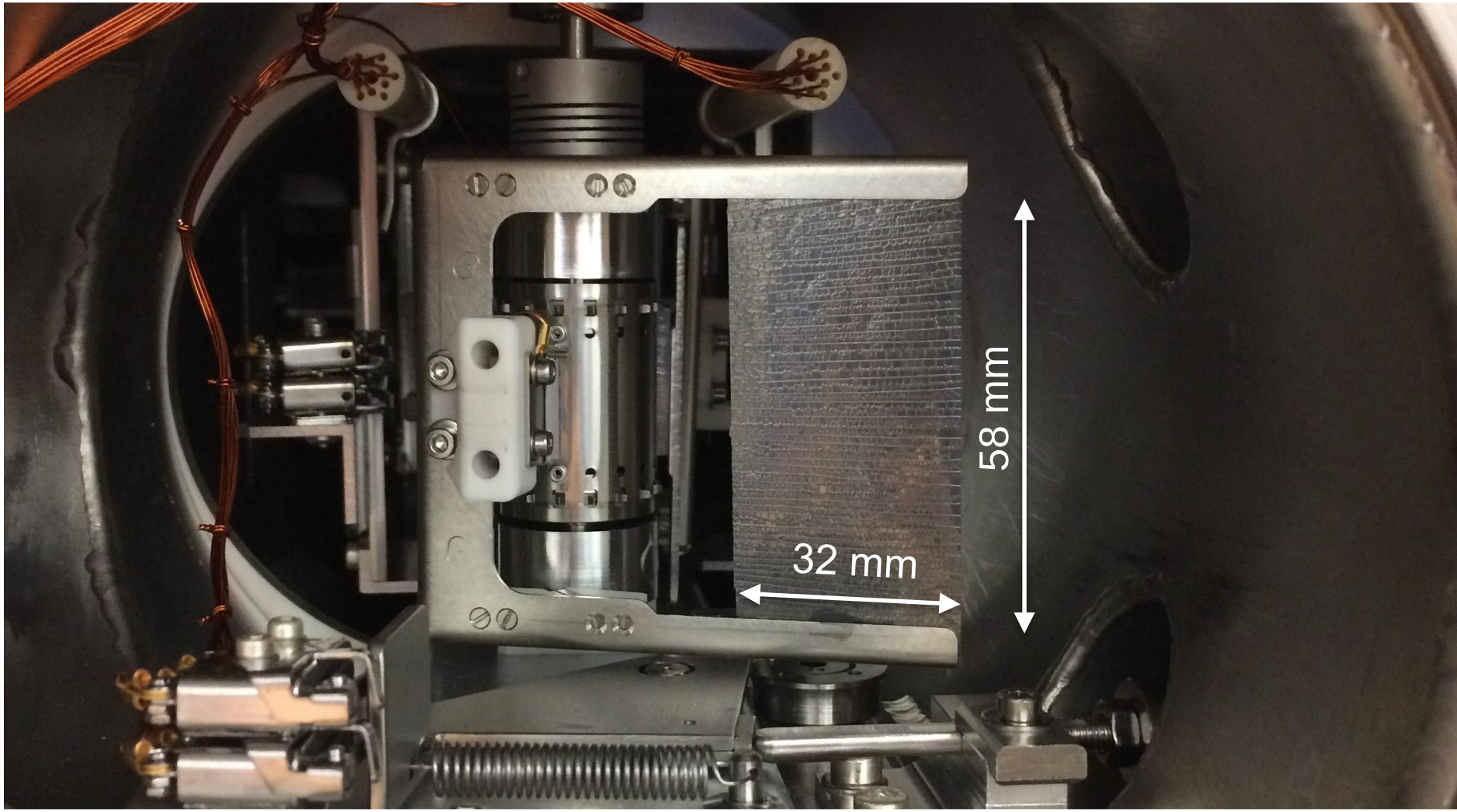
rotating stainless steel belt for 6 holders

Ceramic cable guides

holder with stripping foils attached

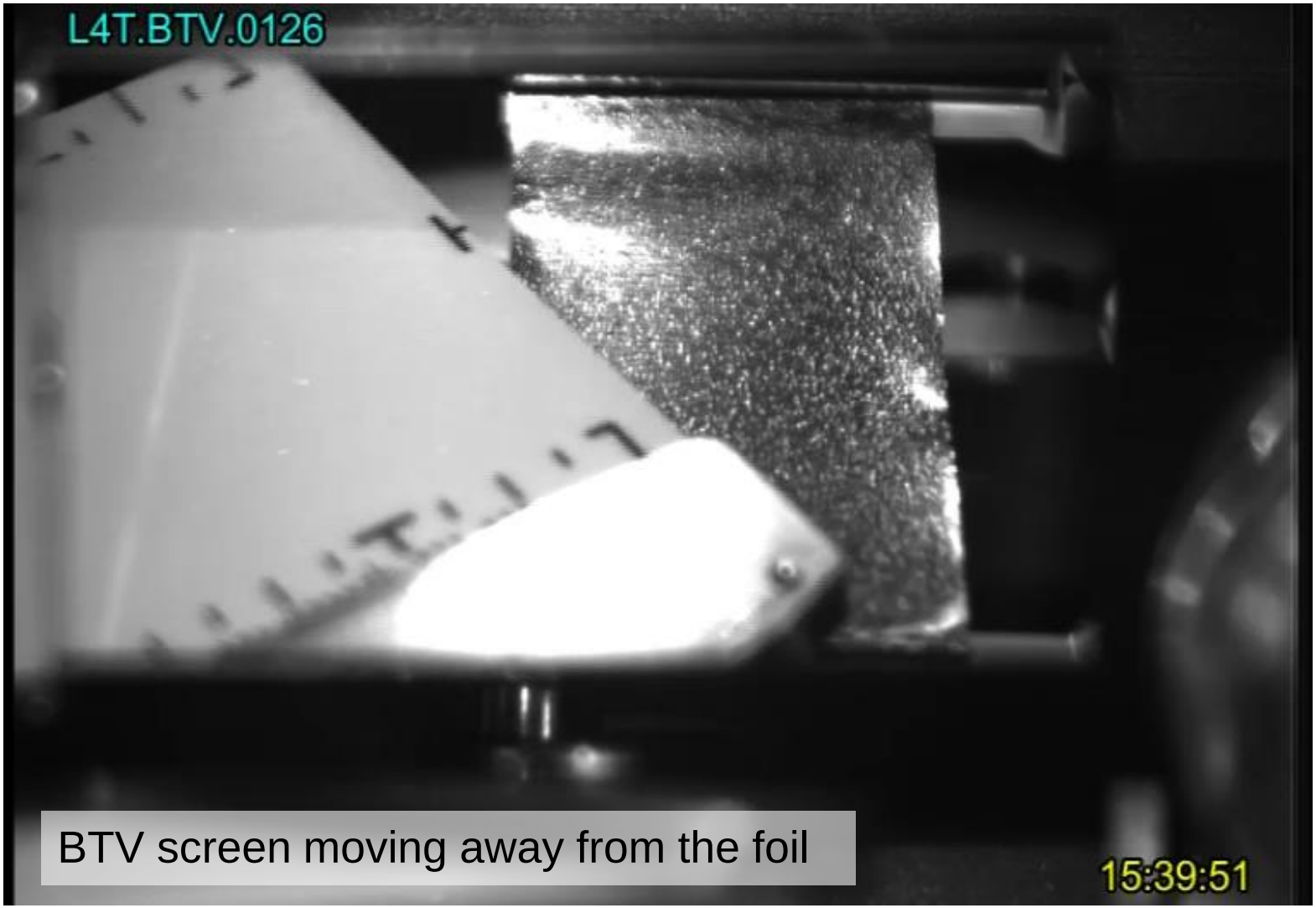
Courtesy of W. Weterings

Stripping foil Test stand (TKSTR Inside tank)



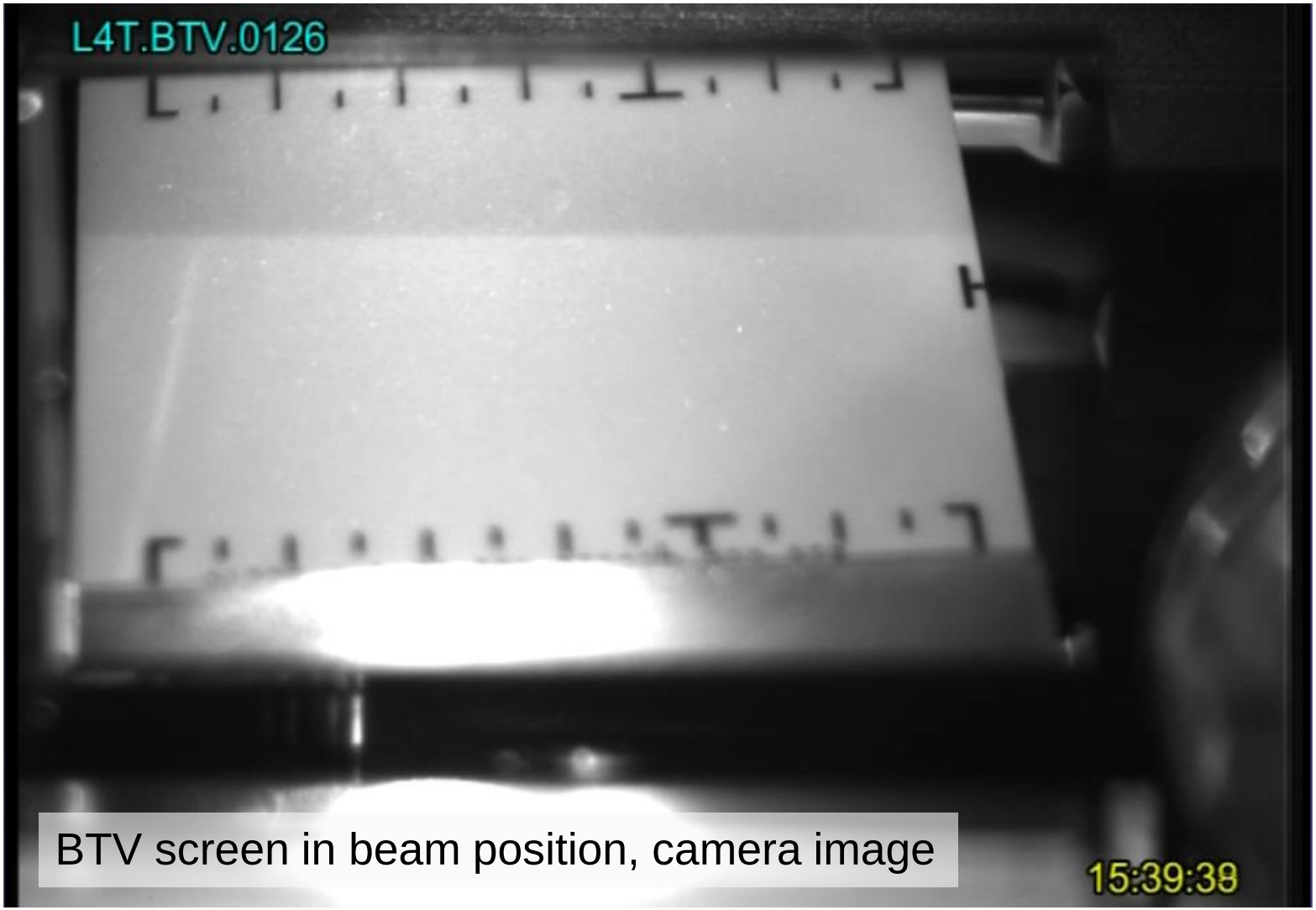
Courtesy of W. Weterings

Test Conditions – Setting up with BTV



Courtesy of W. Weterings

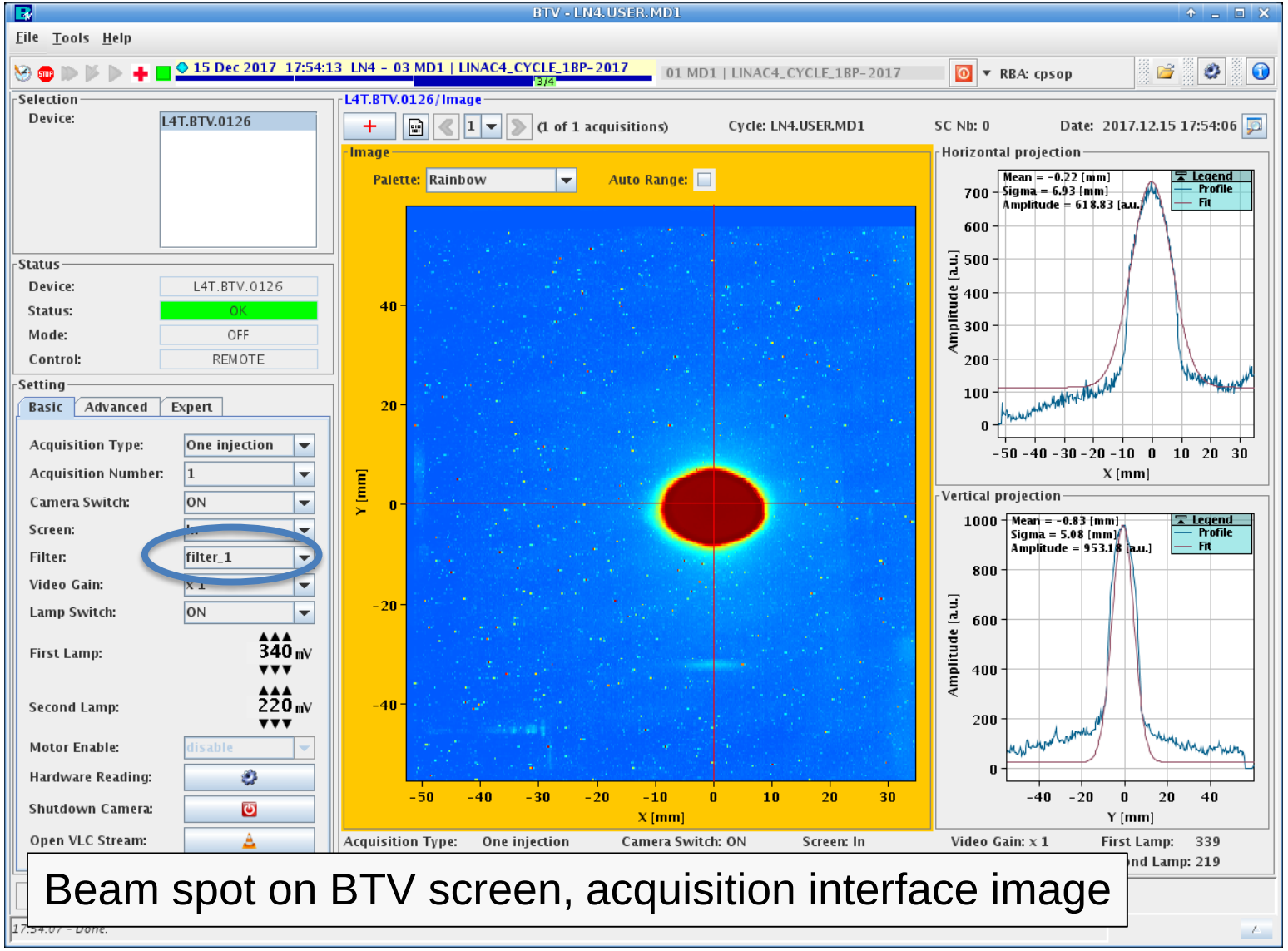
Test Conditions – Setting up with BTV



BTV screen in beam position, camera image

Courtesy of W. Weterings

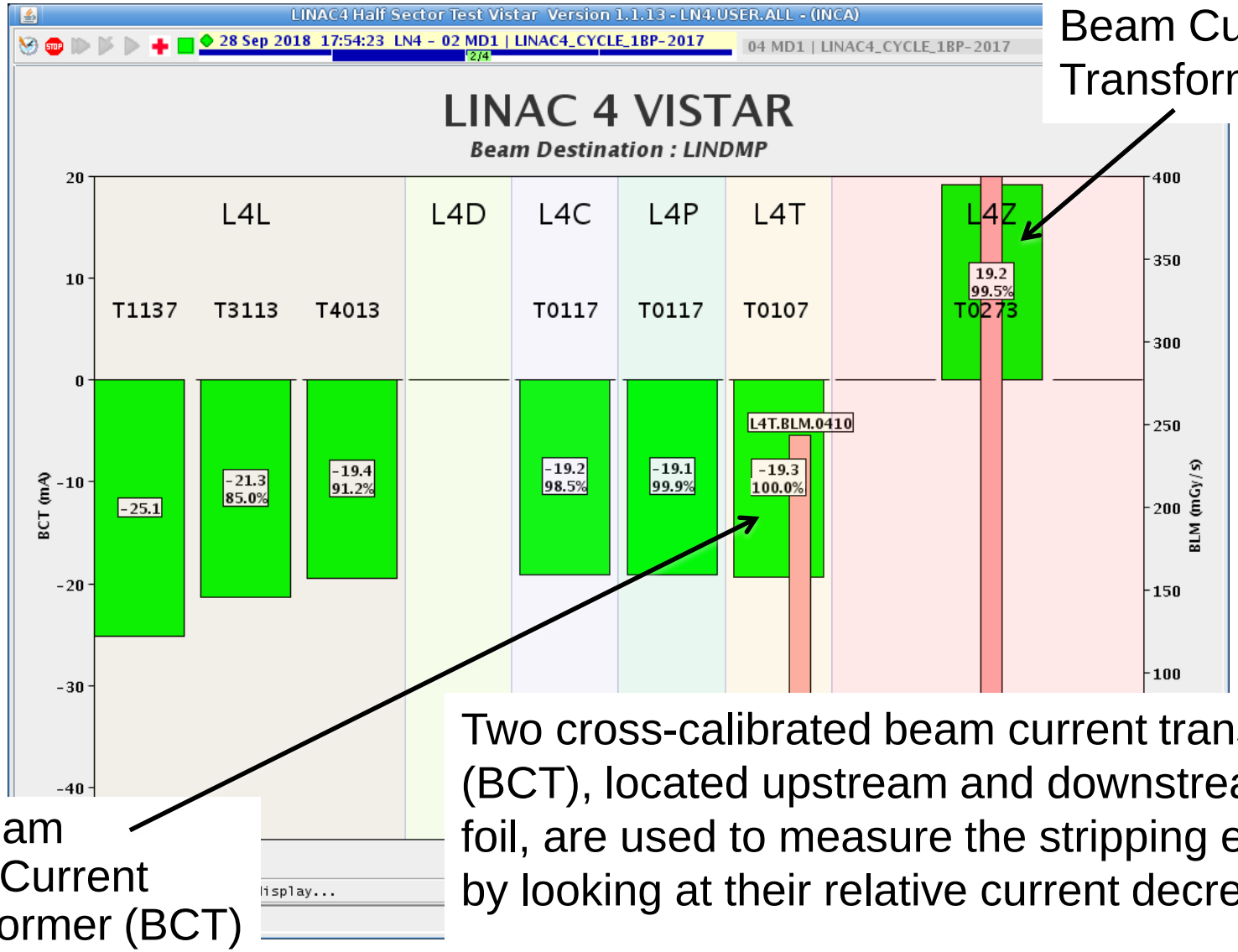
Test Conditions – Setting up with BTV



Beam spot on BTV screen, acquisition interface image

Courtesy of W. Weterings

Test Conditions - BCT



Downstream Beam Current Transformer (BCT)

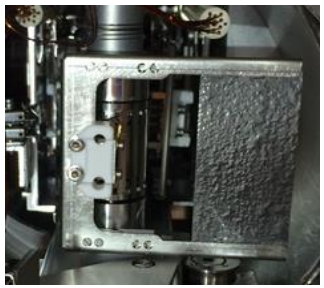
Upstream Beam Current Transformer (BCT)

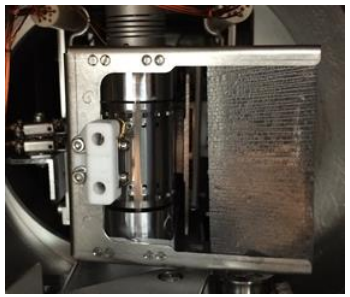
Two cross-calibrated beam current transformers (BCT), located upstream and downstream of the foil, are used to measure the stripping efficiency by looking at their relative current decrease.

Courtesy of W. Weterings

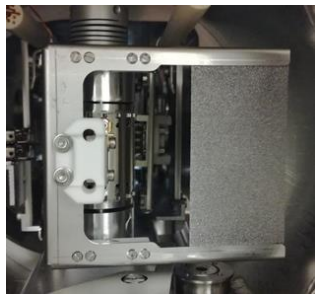
Stripping Foils Tested with Beam

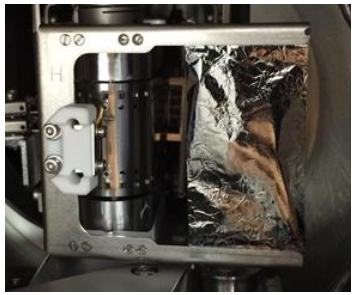
Foil #	Description	Thickness	Reference	Beam Time
1	Arc evaporated amorphous Carbon	200 µg/cm^2	XCF-200	Autumn 2017 ➔ Spring 2018
2	Arc evaporated amorphous Carbon	199 µg/cm^2	GSI-199	Autumn 2018
3	Multilayer Graphene	233 µg/cm^2	MLG-233	Autumn 2018
4	Arc evaporated amorphous Carbon	200 µg/cm^2	XCF-200	Autumn 2018
5	Diamond-like Carbon	200 µg/cm^2	DLC-23-1000-S	Autumn 2017 ➔ Autumn 2018
6.1	Multilayer Graphene	200 µg/cm^2	MLG-200	Autumn 2017 ➔ Spring 2018
6.2	Multilayer Graphene	251 µg/cm^2	MLG-251	Autumn 2018


XCF-200


XCF-200


GSI-199


MLG-233

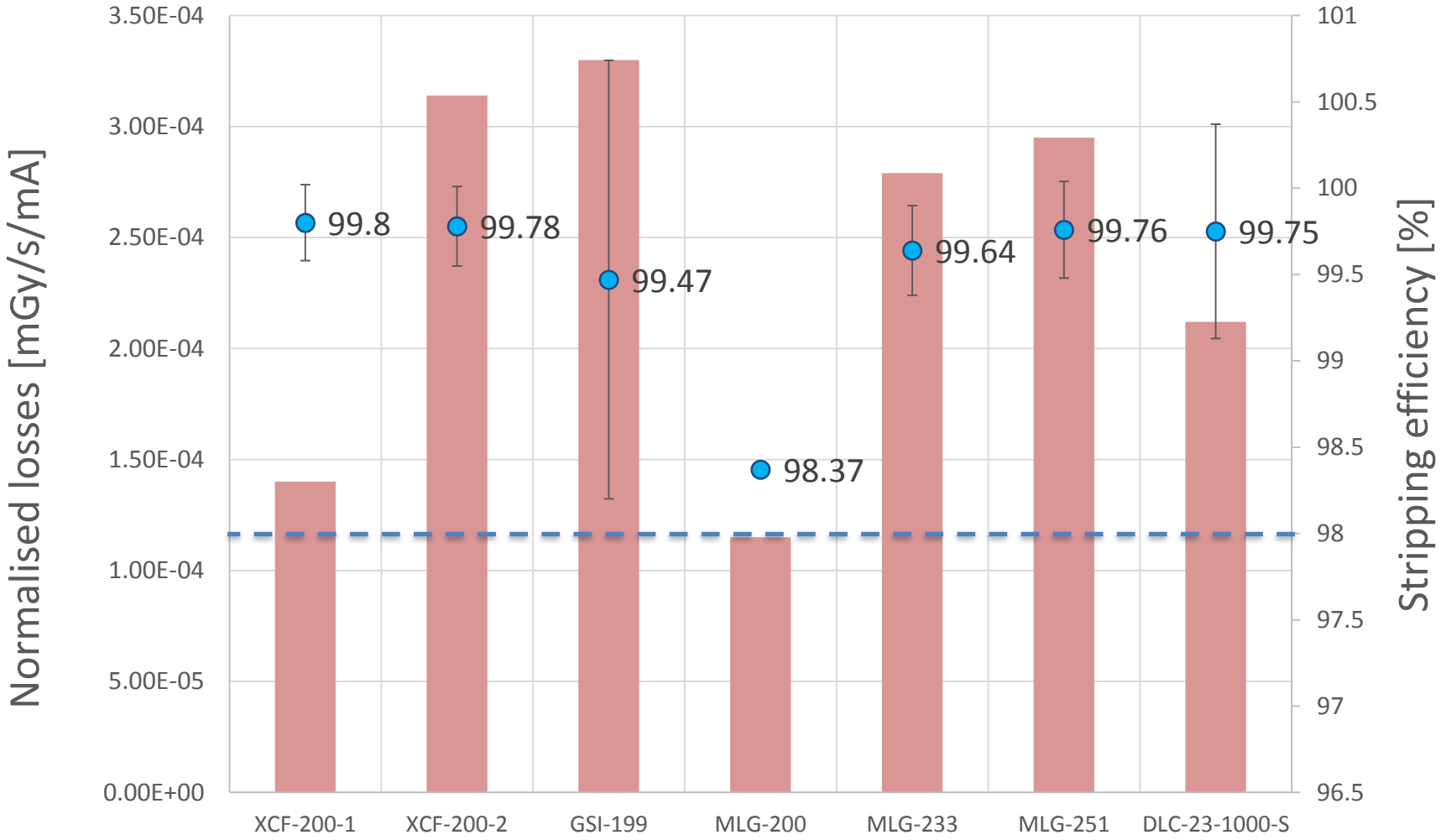

DLC-23-1000-S

Test Conditions – Beam Characteristics

	Autumn 2017	Spring 2018	Autumn 2018
Repetition rate [s]	1.2	1.2	1.2
Beam pulse length [μs]	150-600	150-600	600*
Average pulse current [mA]	~15	5-20	15*

*Nominal chopping pattern (650/350)

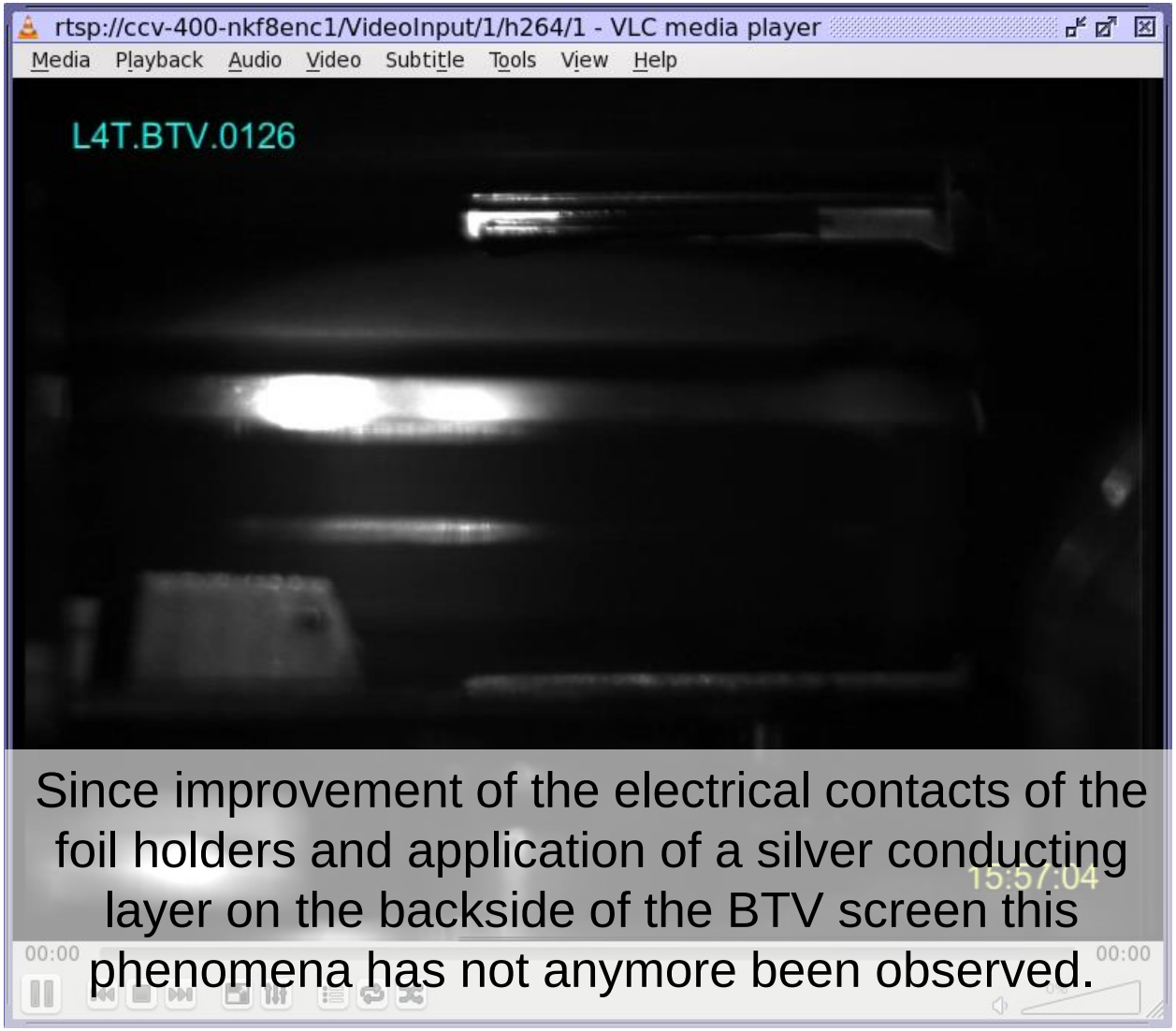
Test Results – Stripping Efficiency



Beam time:	261 h	14 h	165 h	25 h	10 h	36 h	240 h

Test Results – Observation #1

INTDS2016; AIP Conference Proceedings 1962, 030003 (2018)



Since improvement of the electrical contacts of the foil holders and application of a silver conducting layer on the backside of the BTV screen this phenomena has not anymore been observed.

01/11/2016 14:36h
Seems foil got broken - due to radiant heat from BTV screen? - right after putting the BTV screen in for ~2min with beam. Efficiency not affected since rupture is rather at the right-hand side.

03/11/2016 15:56h
Foil #5 broken! It has disappeared completely. Also some vacuum activity visible.

It happened while we moved OUT the BTV screen (beam was kept ON).

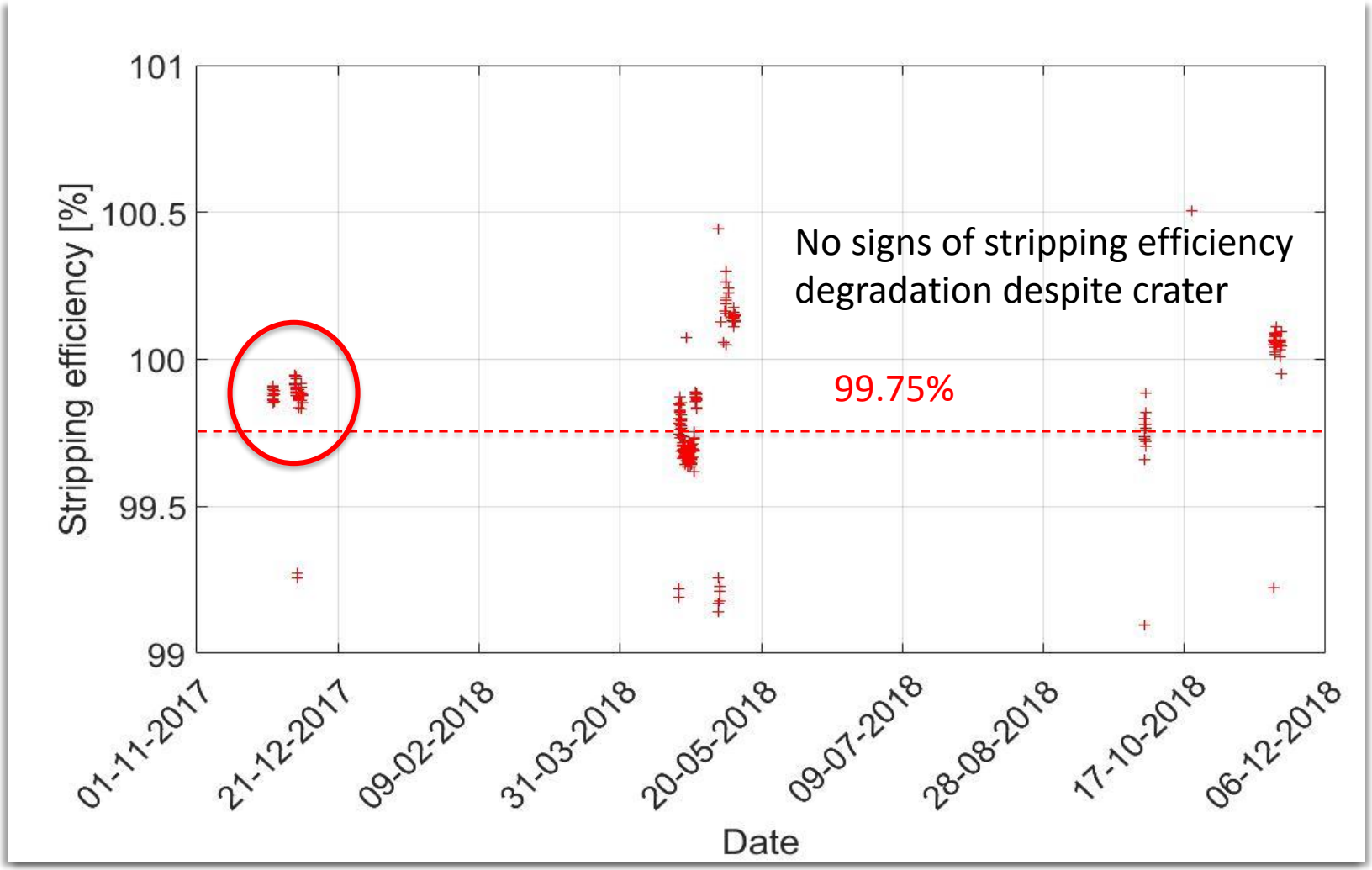
Courtesy of W. Weterings

Test Results – Observation #2

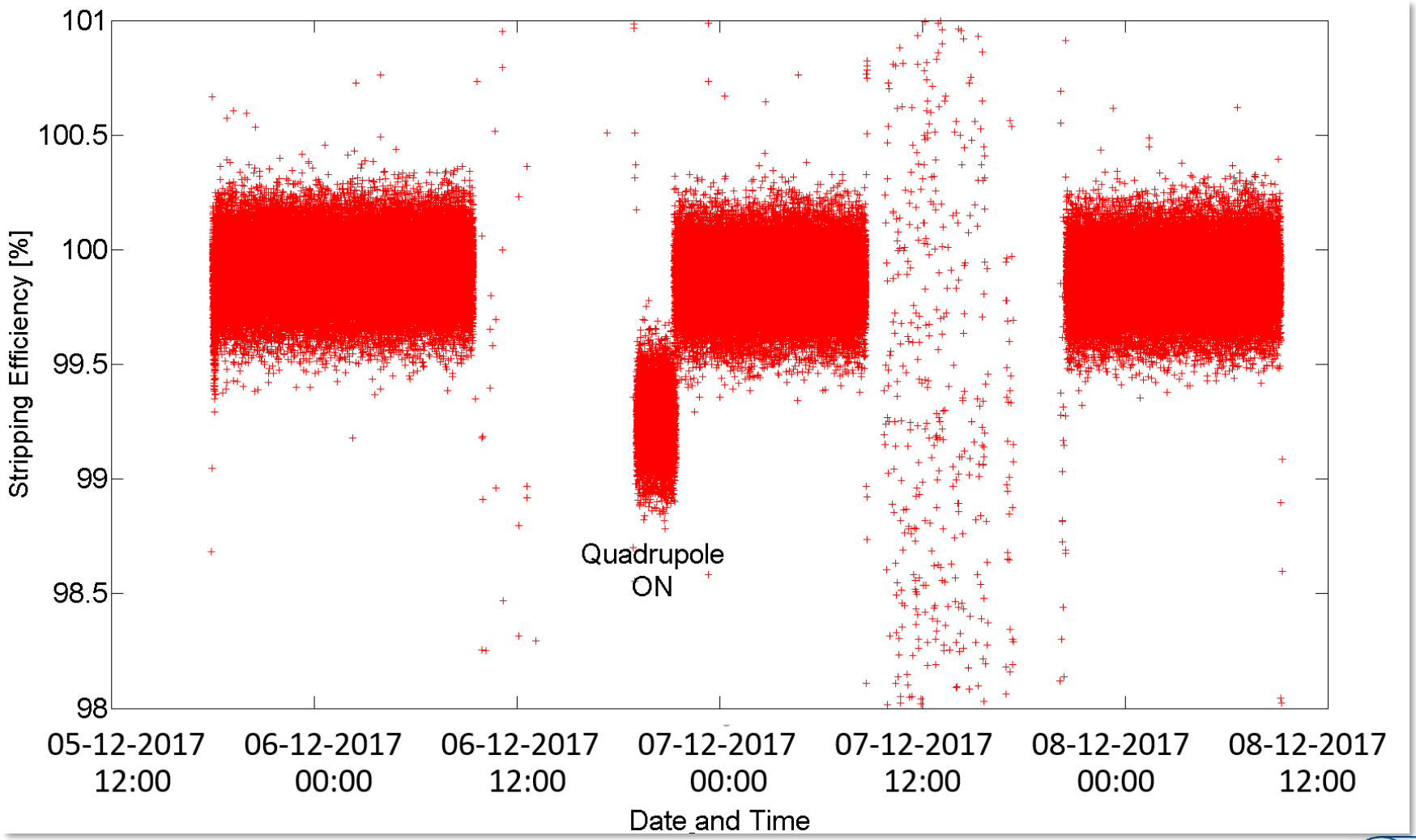
10/11/2017 15:58h
Foil #5, DLC-23-1000-S, movement of the foil is observed at every beam shot (like a heartbeat).
Foil in for ~ 5 minutes.
BCT.L4Z value 100%

Courtesy of W. Weterings

Stripping efficiency evolution – DLC-23-1000-S



Stripping efficiency evolution – DLC-23-1000-S



Test Results – Observation #3

24/04/2018 08:05h
Removed foil #5 from beam, foil visually in same condition as last night. [WW], Inspection of other foils, foil #2, DLC-23-1000-S, has disappeared from frame....

This foil has not been in the beam position, nevertheless it was completely removed from the foil holder.

Courtesy of W. Weterings

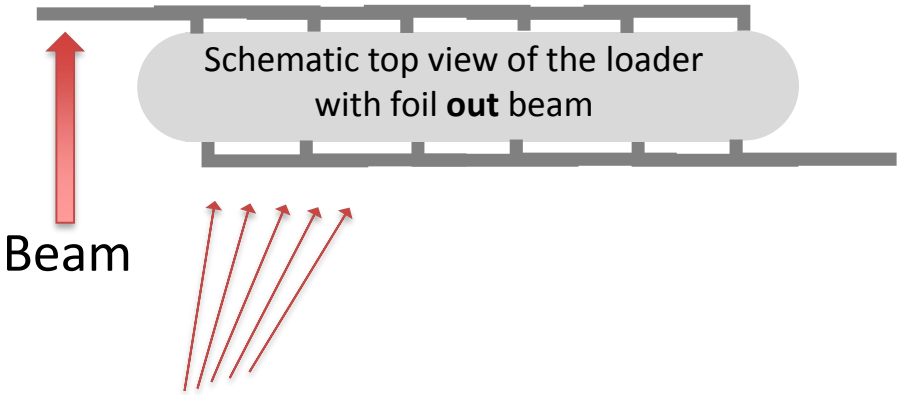
Test Results – Observation #3

It was found lying inside the vacuum tank and looked completely burnt. We notice delamination of the foil layers at the edge of the foil. The foil holder of this particular foil was very activated, > 38 µSv at contact, compared to 0.1 µSv of all other frames.

Courtesy of W. Weterings

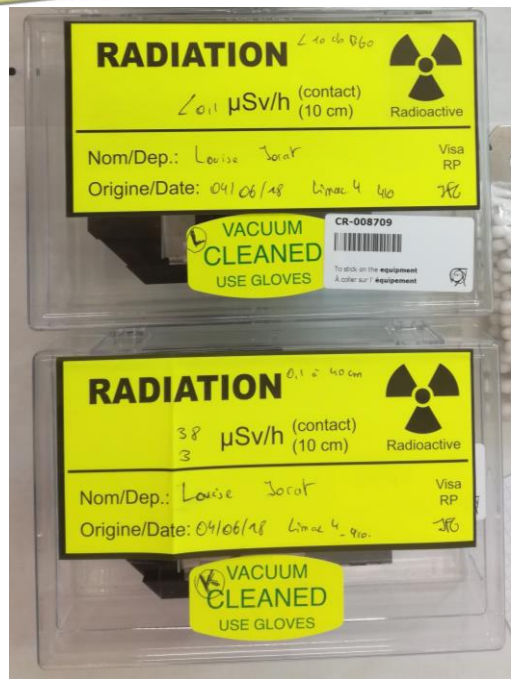
Test Results – Observation #3

Hypotheses



Showers on frame.

24/04/2018 08:05h
Removed foil #5 from beam, foil visually in same condition as last night. [WW], Inspection of other foils, foil #2, DLC-23-1000-S, has disappeared from frame....



Standard frame
0.1 µSv contact
0.1 µSv @ 10cm

Impacted frame
38 µSv contact
3 µSv @ 10cm

Logbook entries show that during the low energy tuning @ 3MeV, the beam was not properly steered and was lost just upstream of the TKSTR, causing showers on the foil holder. This was confirmed by damage to downstream electronics.

Courtesy of W. Weterings

Test Results – Observation #4

26/09//2018 19:03h
Preparing stripping foil tests. L4T.RQF.021 disabled. Image of beam on screen.
Unfortunately the screen is BROKEN!
Re-enable L4T.RQF.021

Probably due to high stress during tests to check that improved grounding solved issues with broken foils due to BTV charging/movements (~5 minutes with high intensity beams, BTV and foil IN)

Courtesy of W. Weterings

Test Results – Observation #5

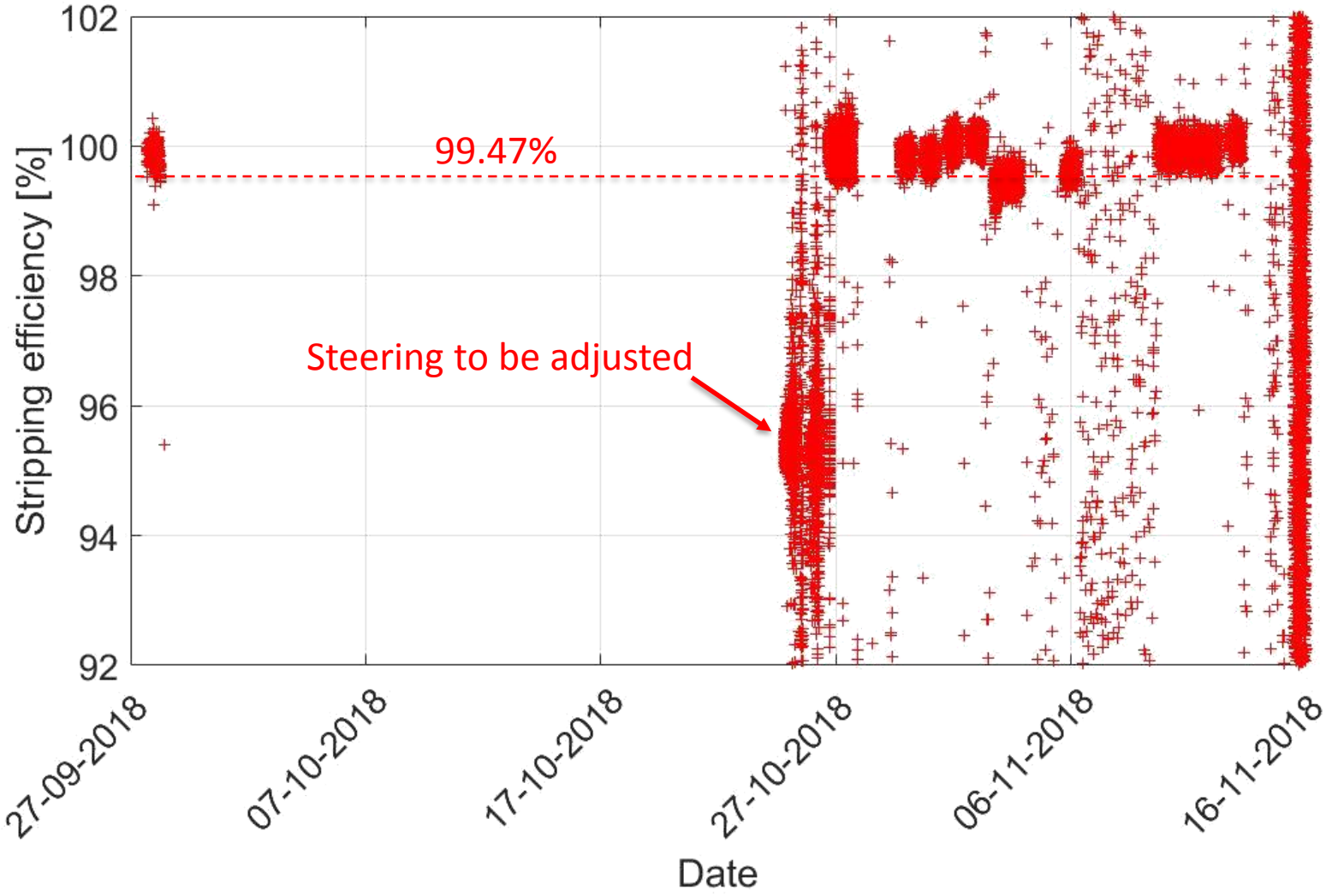
27/09//2018 19:05h Foil_2, GSI_199. After 1 beam pulse the foil completely changed aspect. It looks like the foil shrunk, or stressed towards the centre. Nevertheless, no changes in efficiency.

After only one 600µs pulse, 4x150µs @19.7mA, the foil completely deformed. No influence on performance, the foil remained in beam for 12 hours with stripping efficiency of ~99.8%.

Courtesy of W. Weterings

Stripping efficiency evolution – GSI-199

No signs of stripping efficiency degradation despite crater



Summary

- The test stand proved to be extremely useful in providing operational experience and knowledge with the stripping foils and the related diagnostics
  - Beam and foil setup using BTV screen
  - BTV interlock logic + grounding to prevent foil breakage
  - Cross-calibrated BCTs
- All foils are characterized by a stripping efficiency better than 98%
  - Also foils presenting evident deformation did not show any worsening in performance
  - Multi-layer graphene foils reach 99% stripping efficiency when thickness ≥ 233 μg/cm^2 ➔ very easy to mount! Emittance blow up?
  - Stripping efficiency mainly affected by steering and quad on/off
  - No clear correlation between stripping efficiency and beam losses
- Damages:
  - Foils mainly broken due to mechanical movements or BTV charging
  - Burnt foil probably due to radiation during energy tuning
  - BTV broken probably as a consequence as too high energy deposition during tests to evaluate effectiveness of grounding
- Preliminary conclusions: presently not clear preference for one type of foils (equivalent performance for different advantages in terms of cost, handling, etc.) ➔ different foils in the PSB injection region ➔ evaluate effect on beam emittance, beam losses and life time in real operational conditions ➔ final decision