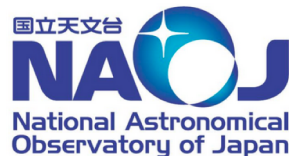# Development of the new Detchar tool GlitchPlot
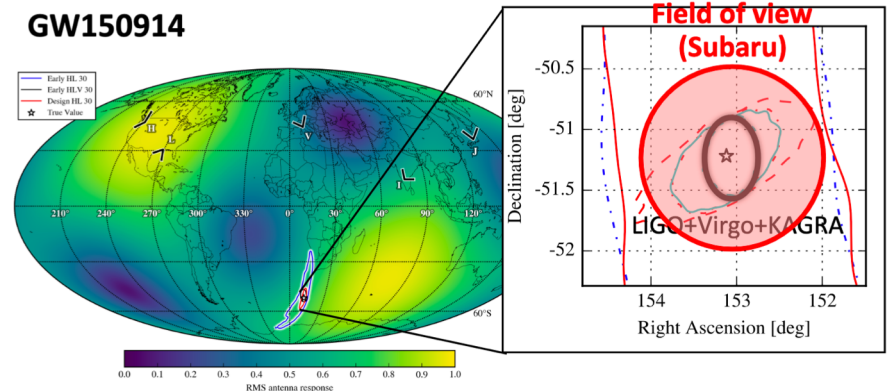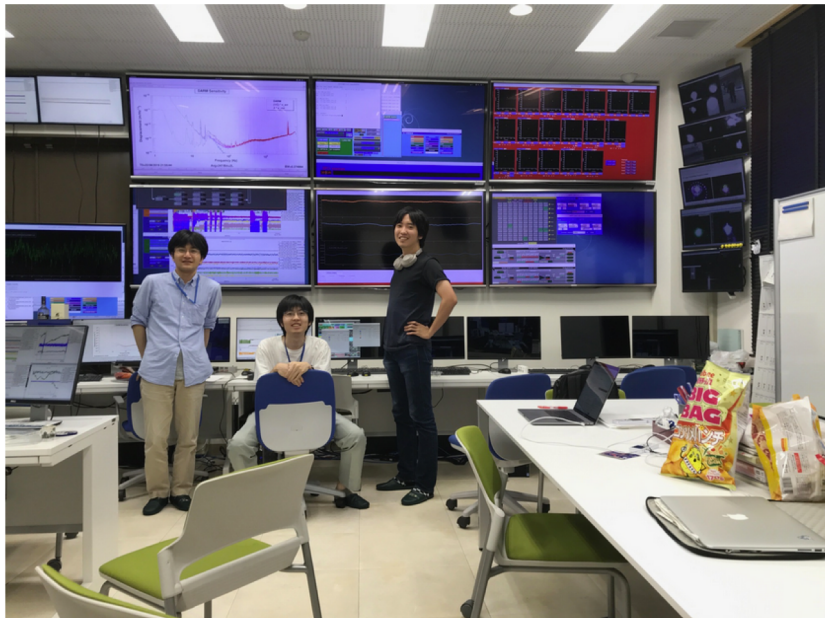
Chihiro Kozakai on behalf of the KAGRA collaboration

2019/10/14  GWPAW@RESCEU

# KAGRA

● We are on hard working to join the GW observation network within 2019 !

  ◦ FPMI lock is achieved in August. Sensitivity improvement is ongoing.

  ◦ When KAGRA joins the observation, significant improvement of GW source direction resolution is expected.



GW150914

Localization area (realtime analysis)
LIGO: 600 deg² => 300 deg²
LIGO + Virgo: 5.5 deg²
LIGO + Virgo + KAGRA: 1.2 deg²

https://arxiv.org/pdf/1703.08988.pdf
TAUP2019 talk by M. Tanaka

# GW Interferometer noise

● Noise can be classified in 2 categories.
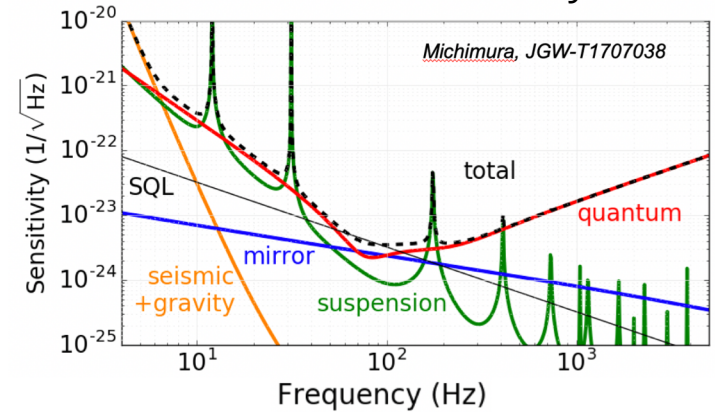
1. Stationary noise
   ◦ Noise which is not local in time.
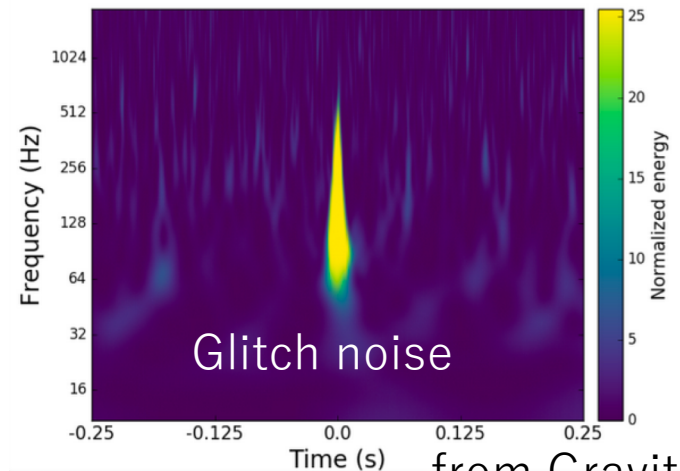   ◦ It affects how small $h(t)$ is detectable.

2. Glitch noise
   ◦ Due to problem in hardware side or external disturbance like earthquake, the GW signal is sometimes contaminated by large signal.
   ◦ It affects false alarm rate.
   ◦ **It is important to distinguish glitch from true GW events like CBC and burst events.**

Stationary noise



Glitch noise

from Gravity Spy (LIGO)

# Investigation of the glitch noise

- **By investigating the cause of noise and eliminating them, we want to lower the threshold to detect the GW signal and improve the reliability to identify the event as GW origin.**
  → It is necessary to check if the detector is working well.

- As a simple method, a tool for easy visual inspection of the detector state, "GlitchPlot" was developed.
  1. To search glitch noise, external tool is used.
     ◦ Omicron (Q-transform based search, developed by F.Robinet)
     ◦ Preparation for combination with data analysis pipeline is ongoing.
  2. According to the result of 1, plots of each auxiliary channels are provided.
  3. With the cooperation of Yuzurihara-san(ICRR), the result is easily accessible on website and collaborators can vote their opinion about the glitch origin.

✓ It is also useful for detector sanity check for GW event candidate.

✓ It can be applied to lock loss event investigation too.

# Search for glitch noise

● Software library developed by F. Robinet ：Omicron is used.

  ◦ **Search for time-frequency bin with large SNR using Q-transform.**

  ◦ Q-transform : Spectrogram with variable time window depending on frequency.

$$X(\tau, \phi, Q) = \int_{-\infty}^{+\infty} x(t)w(t - \tau, \phi, Q)e^{-2i\pi\phi t}dt.$$

$$w(t - \tau, \phi, Q) = \frac{W_g}{\sigma_t\sqrt{2\pi}} \exp\left[-\frac{1}{2\sigma_t^2}(t - \tau)^2\right], \quad \sigma_t^2 = \frac{Q^2}{8\pi^2\phi^2}$$

  ◦ It is performed for several Q value. The list of large SNR bin in each Q is output.

● Omicron provides time, frequency, band width, duration, SNR and so on.



qplane_5.98140
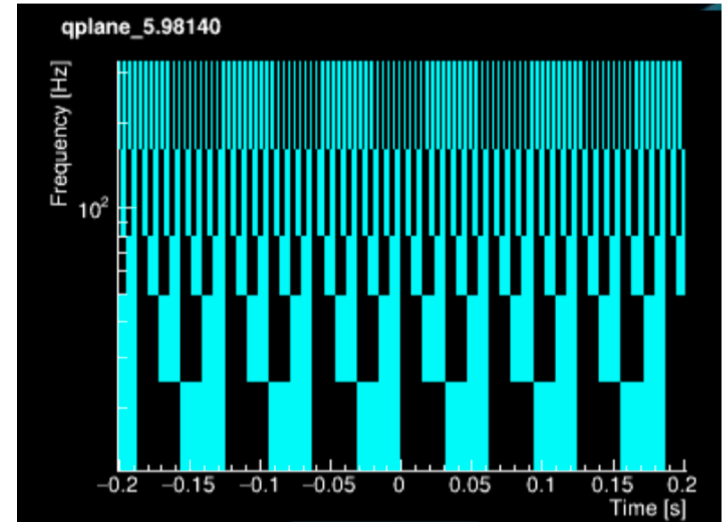
● Omicron usually provides multiple output for 1 event from several Q value or several frequency/time. In GlitchPlot, continuous or overlapping time output is counted as 1 event.

# Making plots

● Several basic plots are provided for all channels which may affect to the main channel.

- Time series
- Spectrum
- Spectrogram
- Q-transform
- Coherencegram

- Main (trigger) channel
- Upstream channels
- Channels used for interferometer control
- Suspension channels
- Physical environmental monitor channels etc.

● There is many types of glitches with various wave form. The parameters for plot should be optimized depending on the property of each glitch.

→ In GlitchPlot, using Omicron information, the plot parameter is automatically determined.
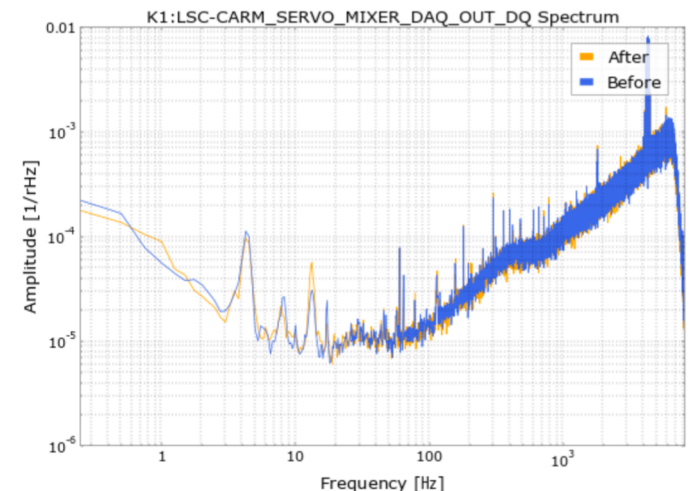
# Plot parameter determination

- Time series
  - To see immediately before and after the event, 10 times long time as event duration is plotted before and after the event. If too short, the time is extended to 2 sec.
    - ✓ The glitch event comes to the center of the plot.
    - ✓ Fine tuning according to the spectrogram setting (described later)
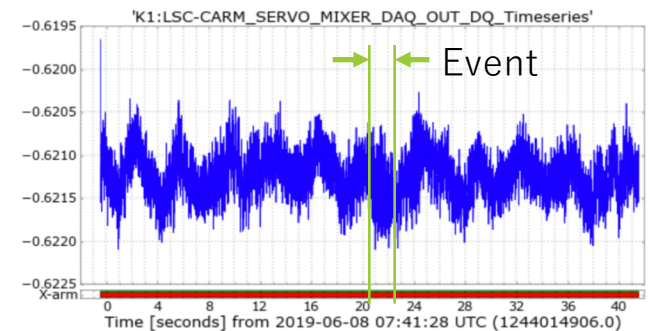
- Spectrum
  - Taking 2 sec margin, check spectra of immediately before and after the glitch. (Spectrum of the event itself will be provided in spectrogram.)
    - ✓ Check if glitch causes state change.
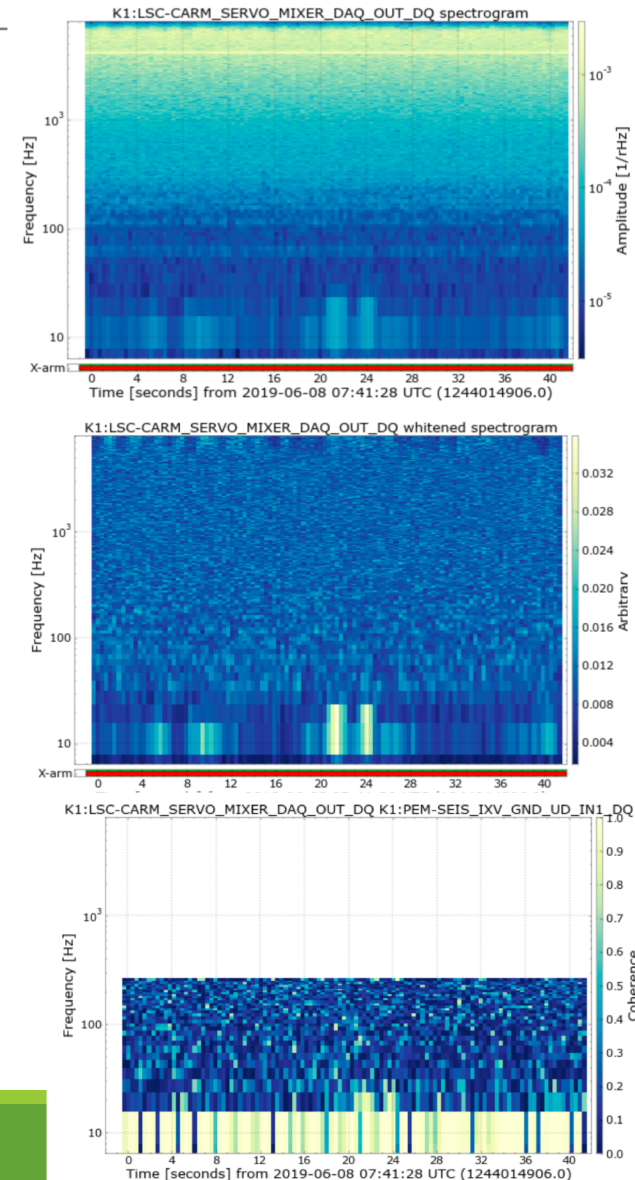  - Enough frequency resolution is given according to the band width of the event.

# Plot parameter determination

● Spectrogram：

$$X(\omega, t) = \int_{-T}^{T} x(\tau) w(t - \tau) e^{-i\omega t} \mathrm{d}\tau$$

○ Time bin width is determined to be shorter than event duration.
  • Trade off with frequency resolution. If event duration is short, the time bin width is half of the event duration. Else it is determined according to the Omicron information.
  • Fine tuning to contain $2^n$ data point.
○ Whitened plot is also provided.
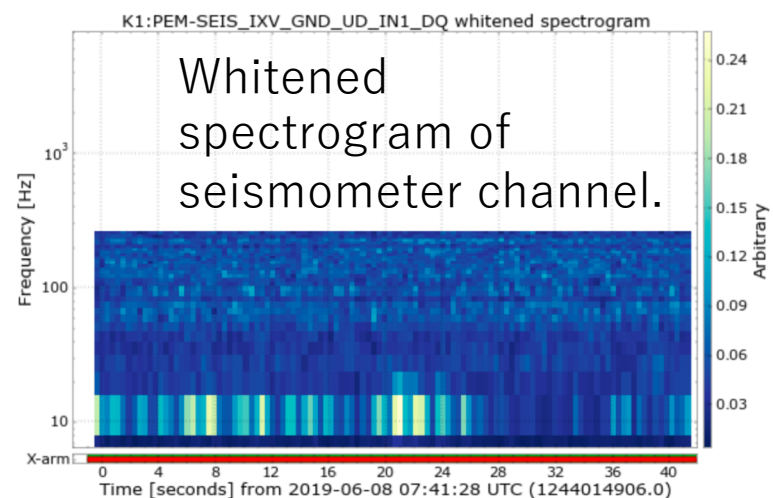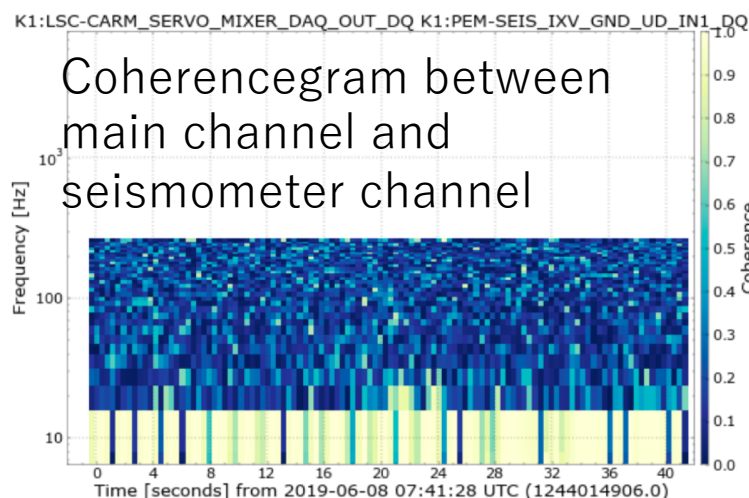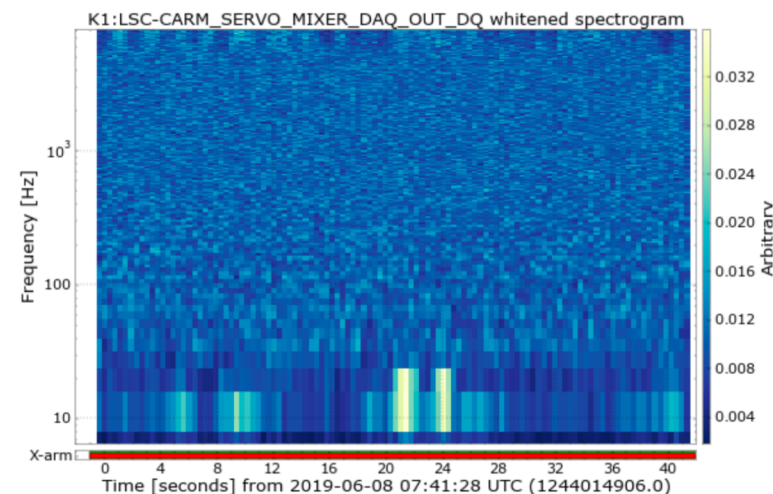  • Whitening：By normalizing the amplitude of each frequency, time depending component is clarified.

● Coherencegram： $\mathrm{coh}^2(\omega) = \dfrac{|S_{xy}(\omega)|^2}{S_{xx}(\omega) S_{yy}(\omega)}$

○ Use same parameters as spectrogram.



K1:LSC-CARM_SERVO_MIXER_DAQ_OUT_DQ spectrogram

K1:LSC-CARM_SERVO_MIXER_DAQ_OUT_DQ whitened spectrogram

K1:LSC-CARM_SERVO_MIXER_DAQ_OUT_DQ K1:PEM-SEIS_IXV_GND_UD_IN1_DQ

# Example of the glitch noise in KAGRA

Main channel

- In this event, main channel and seismometer shows significantly large amplitude in the same time-frequency bin. The correlation is also confirmed by coherencegram.



K1:LSC-CARM_SERVO_MIXER_DAQ_OUT_DQ whitened spectrogram



K1:LSC-CARM_SERVO_MIXER_DAQ_OUT_DQ K1:PEM-SEIS_IXV_GND_UD_IN1_DQ

Coherencegram between main channel and seismometer channel



K1:PEM-SEIS_IXV_GND_UD_IN1_DQ whitened spectrogram

Whitened spectrogram of seismometer channel.

# Conclusion

● Interferometer noise can be categorized into stationary noise and glitch noise. Glitch noise has to be distinguished from true GW event and we need to understand them well.

● To investigate glitch noise, a new tool "GlitchPlot" is developed.

● GlitchPlot is a tool which provides glitch related plots with optimized parameter using event information given by external tool.

● By investigating various information related to the interferometer using GlitchPlot, it will be easy to identify glitch noise from instrumental cause.

● GlitchPlot will be used for noise hunting in KAGRA and it will contribute to identify the cause of glitch noise.
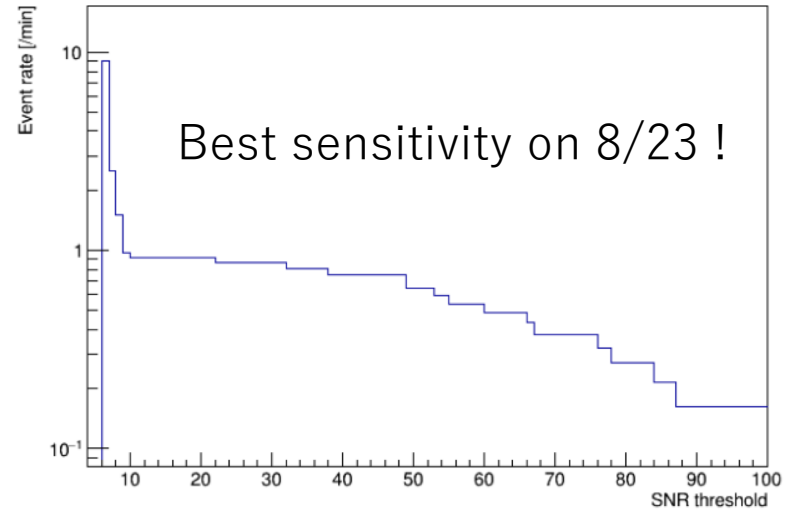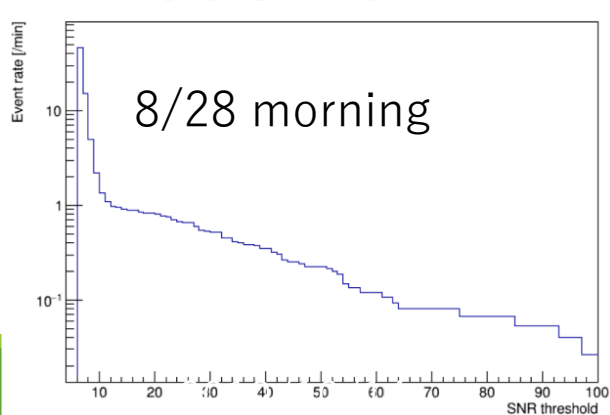
# Backup

# Trigger rate quick report
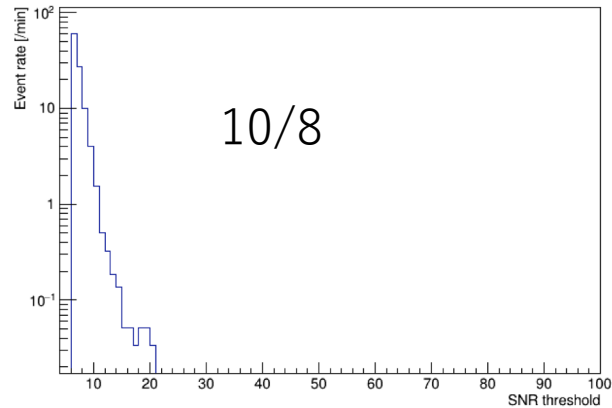
CAL-CS_PROC_DARM_DISPLACEMENT_DQ1250549061-1250550189

First FPMI lock !
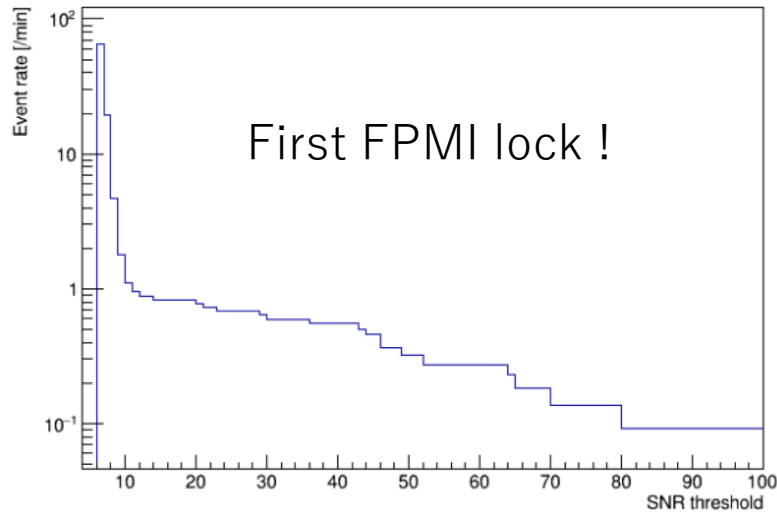
CAL-CS_PROC_DARM_DISPLACEMENT_DQ1250586584-1250587554

Best sensitivity on 8/23 !

CAL-CS_PROC_DARM_DISPLACEMENT_DQ1250981718-1250985978

8/28 morning

CAL-CS_PROC_DARM_DISPLACEMENT_DQ1254510018-1254513378

10/8

CAL-CS_PROC_DARM_DISPLACEMENT_DQ1254593718-1254595818

10/9