# Seismic Control during Earthquakes: a Review of the proposed scheme

G1800399, March 20, 2018

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# Thinking about Controls

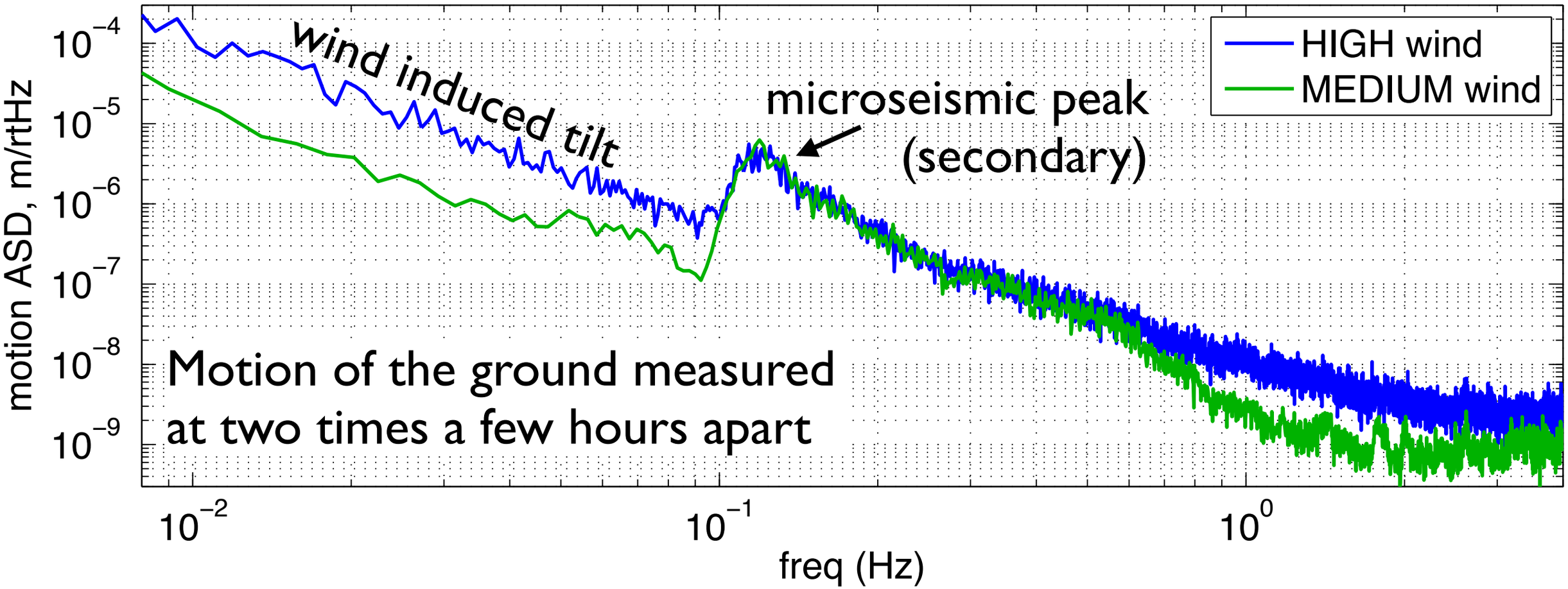
New control scheme for use during teleseismic earthquakes

Installation is very soon. (We've been talking about this for a while)

Discuss at CSWG because it uses several control choices not used before.

1. Routinely Change control based on predictions of the future. (done a few times in past)
2. Design for isolation below 100 mHz.
3. Do not isolate to minimize the inertial motion. Allow system to ride on the common-mode, and only isolate on the local differential.

# Recall - typical control condition



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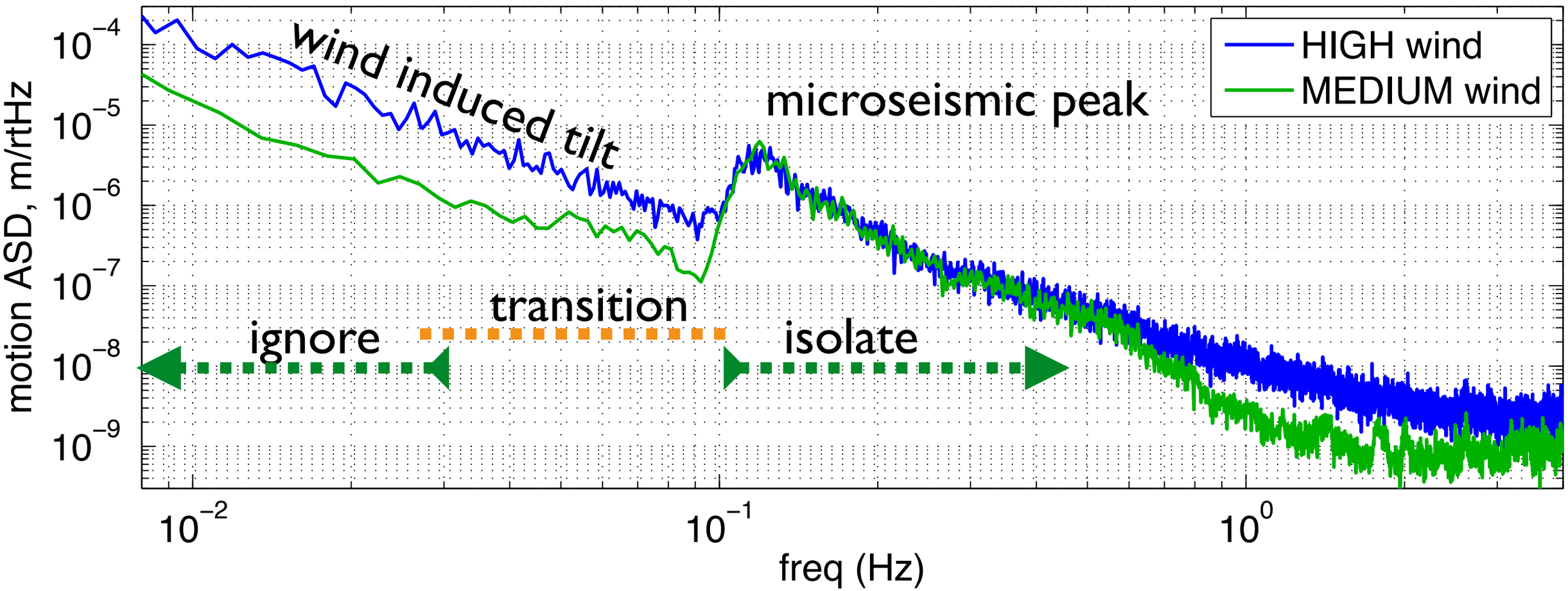
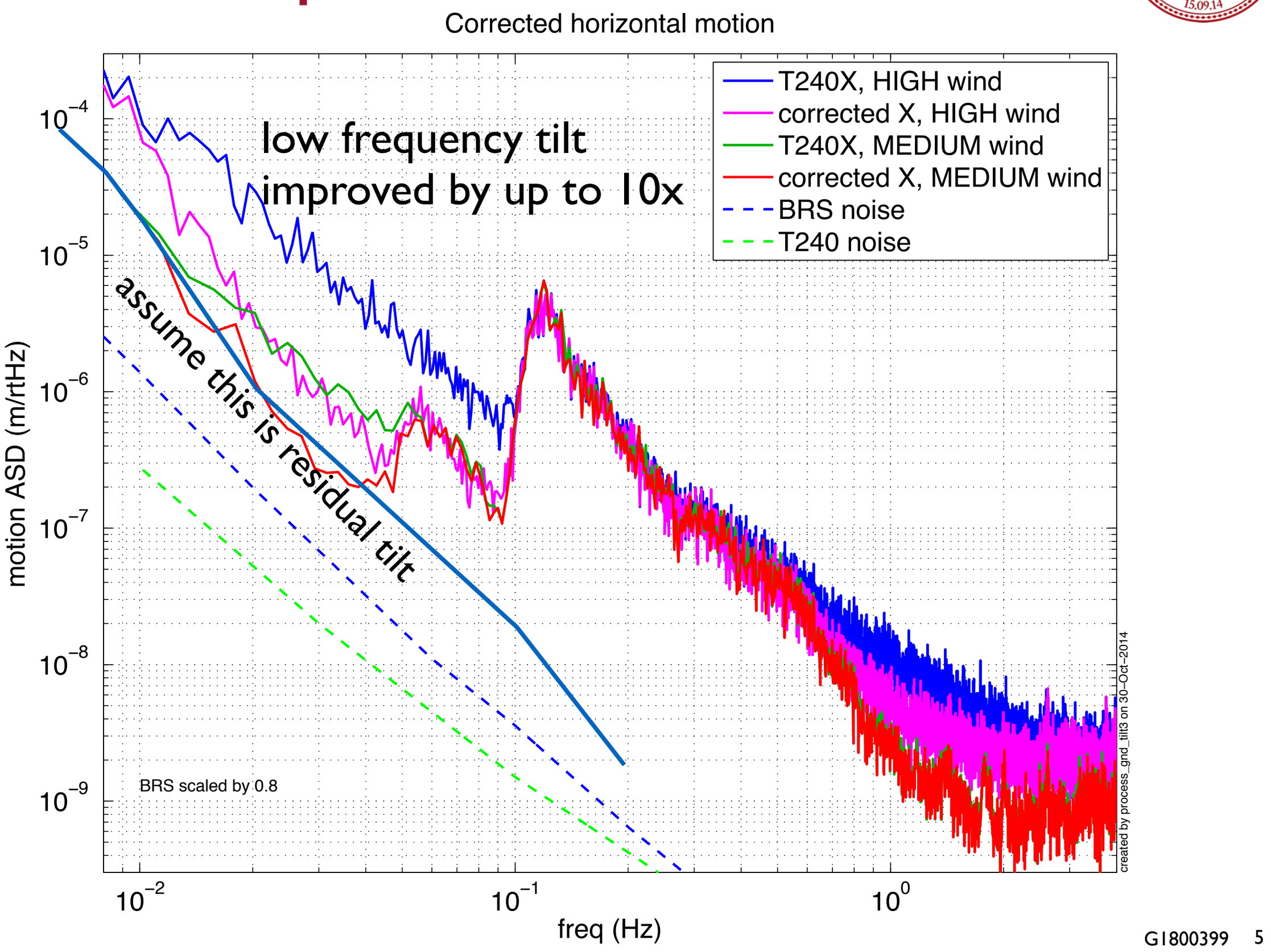



Use the ground motion signal for low freq. control (Sensor Correction)

- Use the signals above ~100 mHz to isolate against the microseism
- Filter out signals below ~30 mHz to not couple *measured* ground tilt.
- Transition band has amplification (waterbed effect). *OK if band is quiet*.

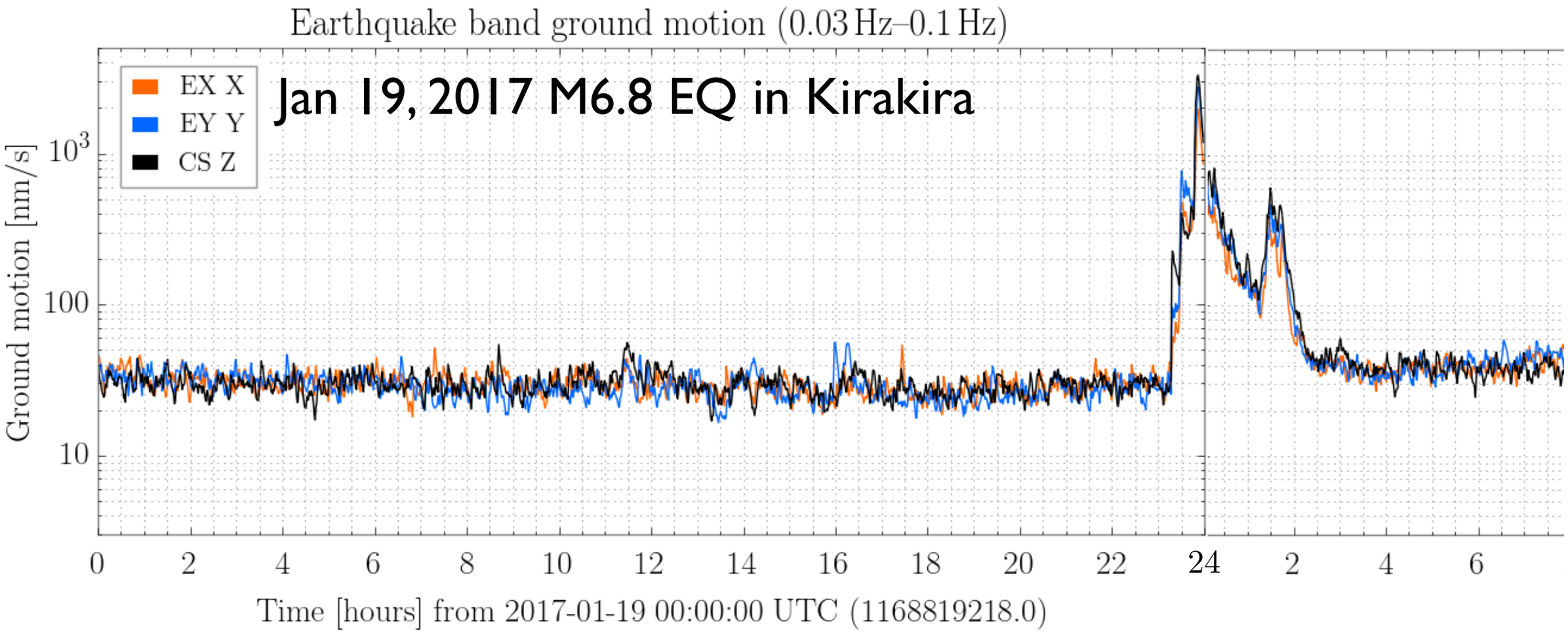
## *Difference #1*

# BRS Improves measured motion



*Difference #2*

# Earthquakes = motion at ~50 mHz

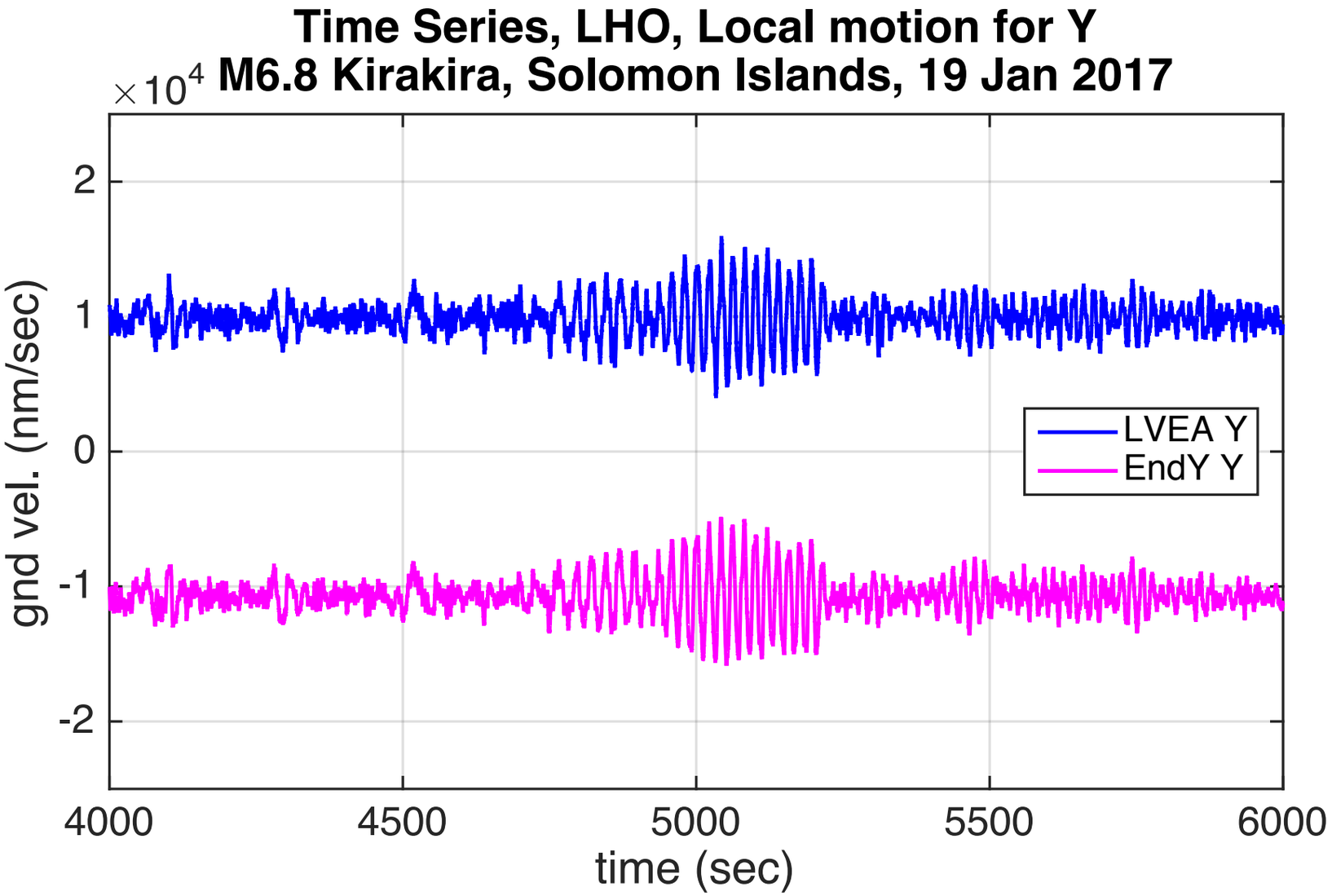



In this case, the BLRMS hits ~ 3 microns/sec

IFO loses ~ 4 hours of Observation time.

Nothing special about this event,
chosen because I had to time to follow up

# Most of the motion is Common-mode



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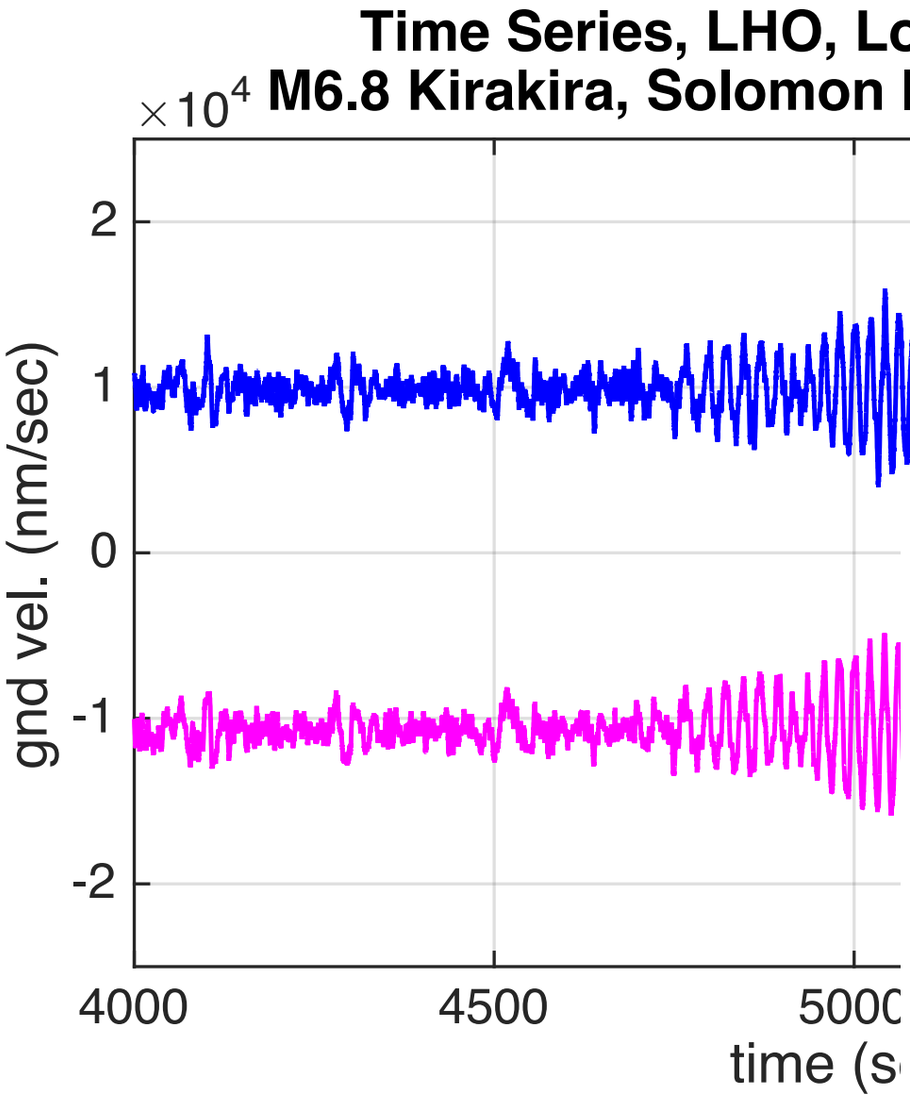


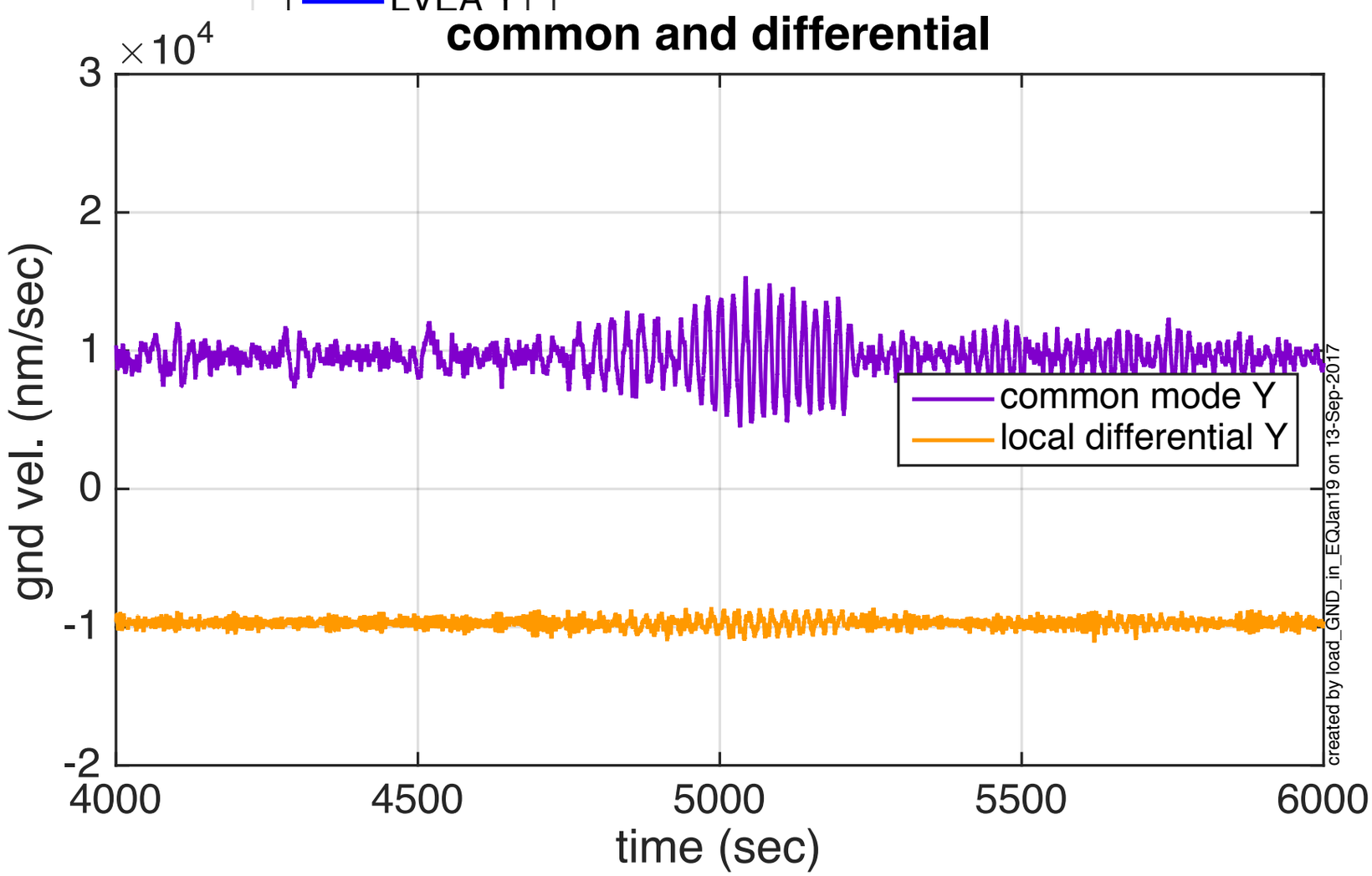

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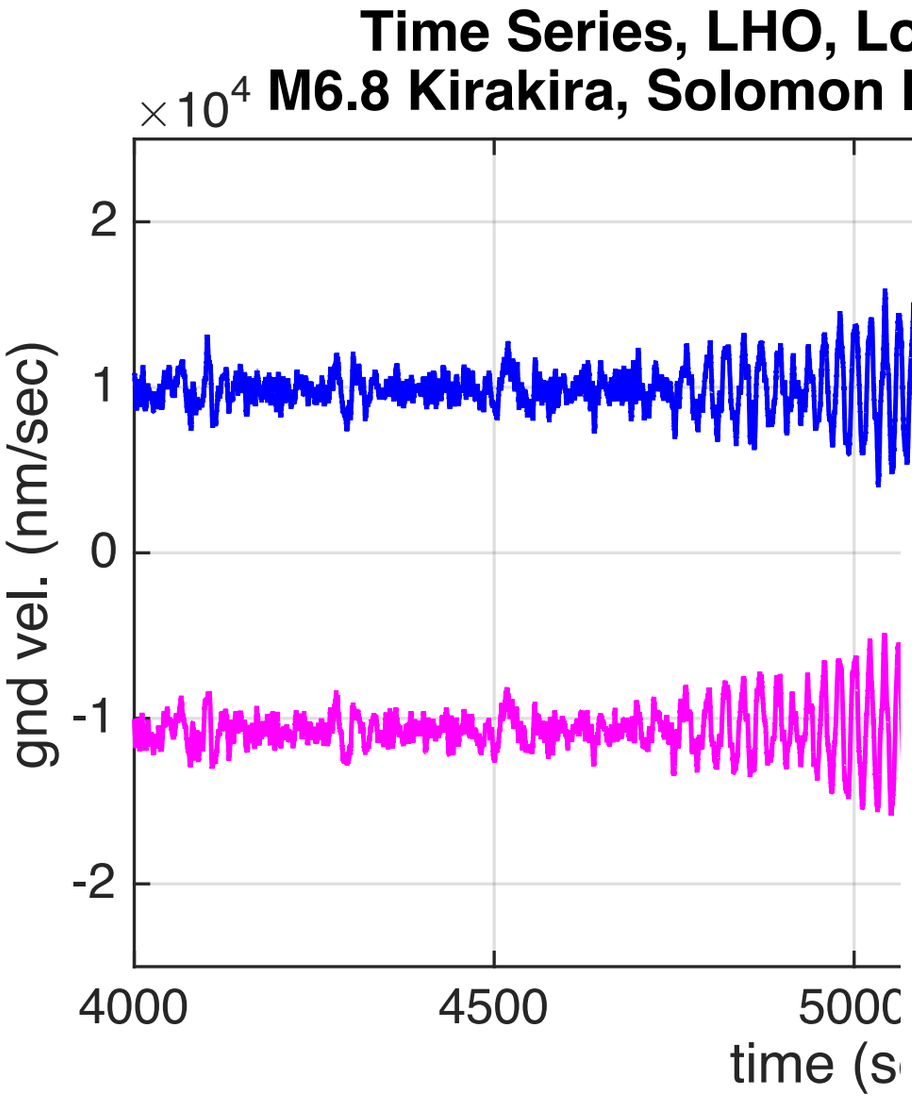
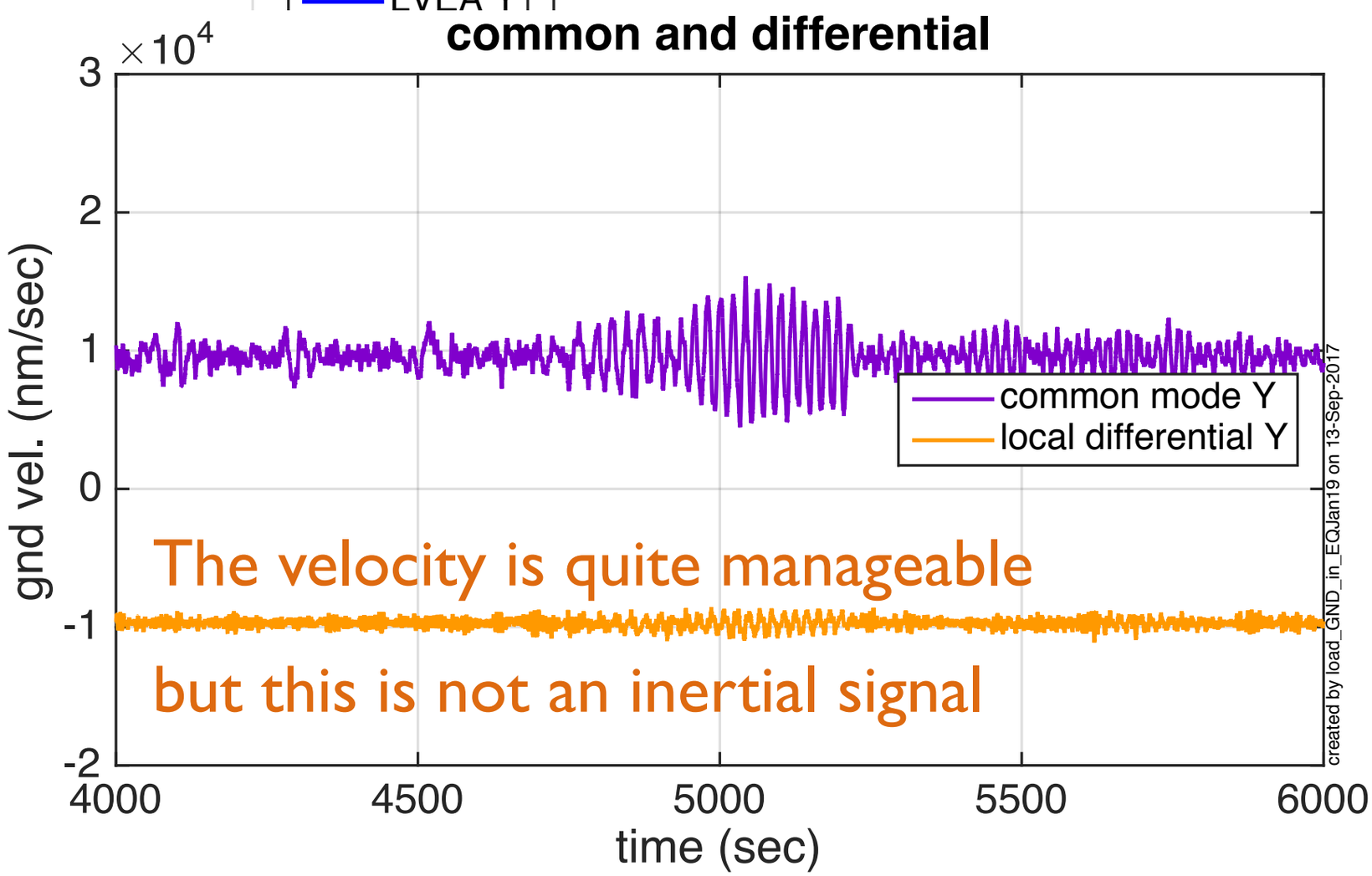
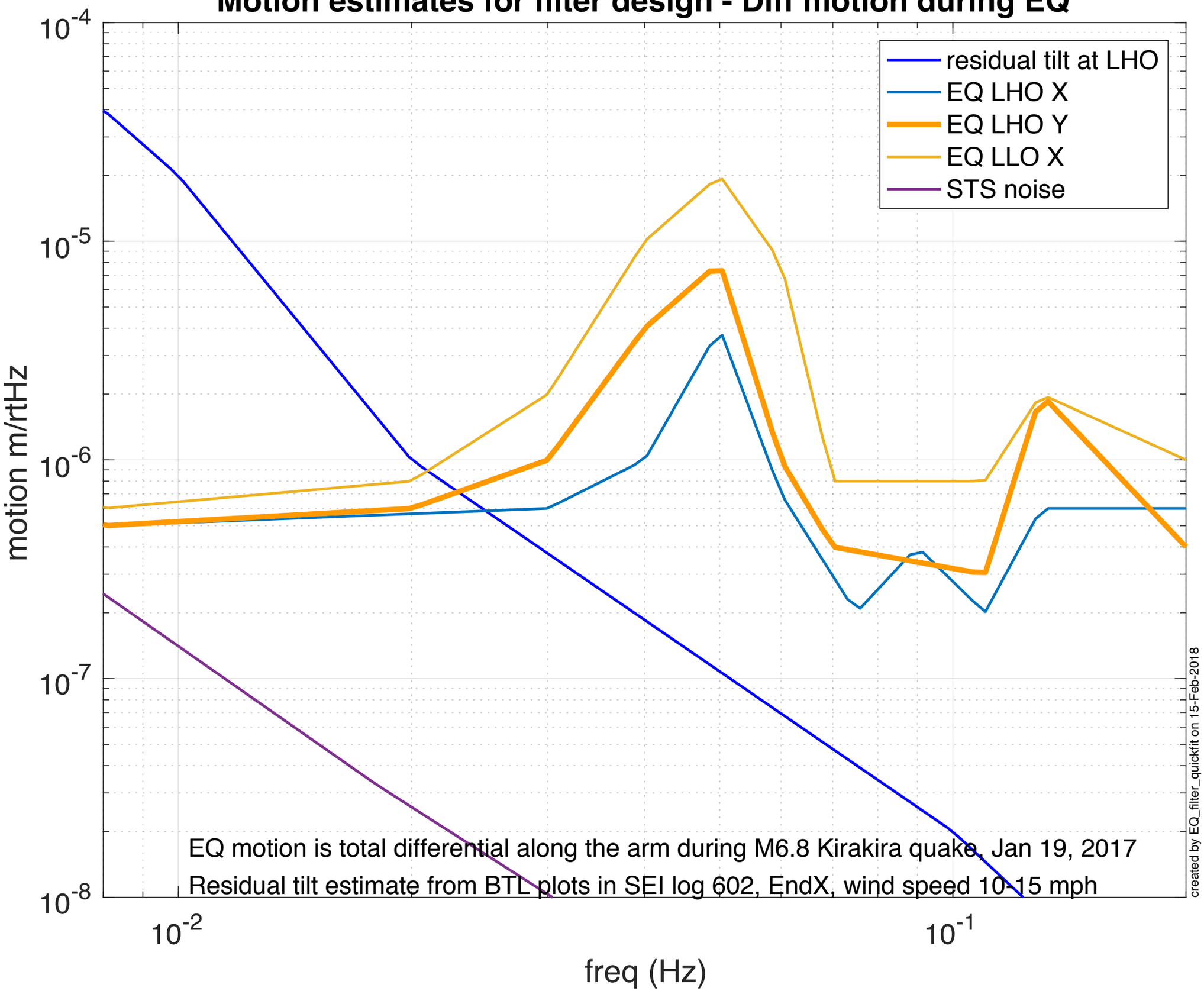


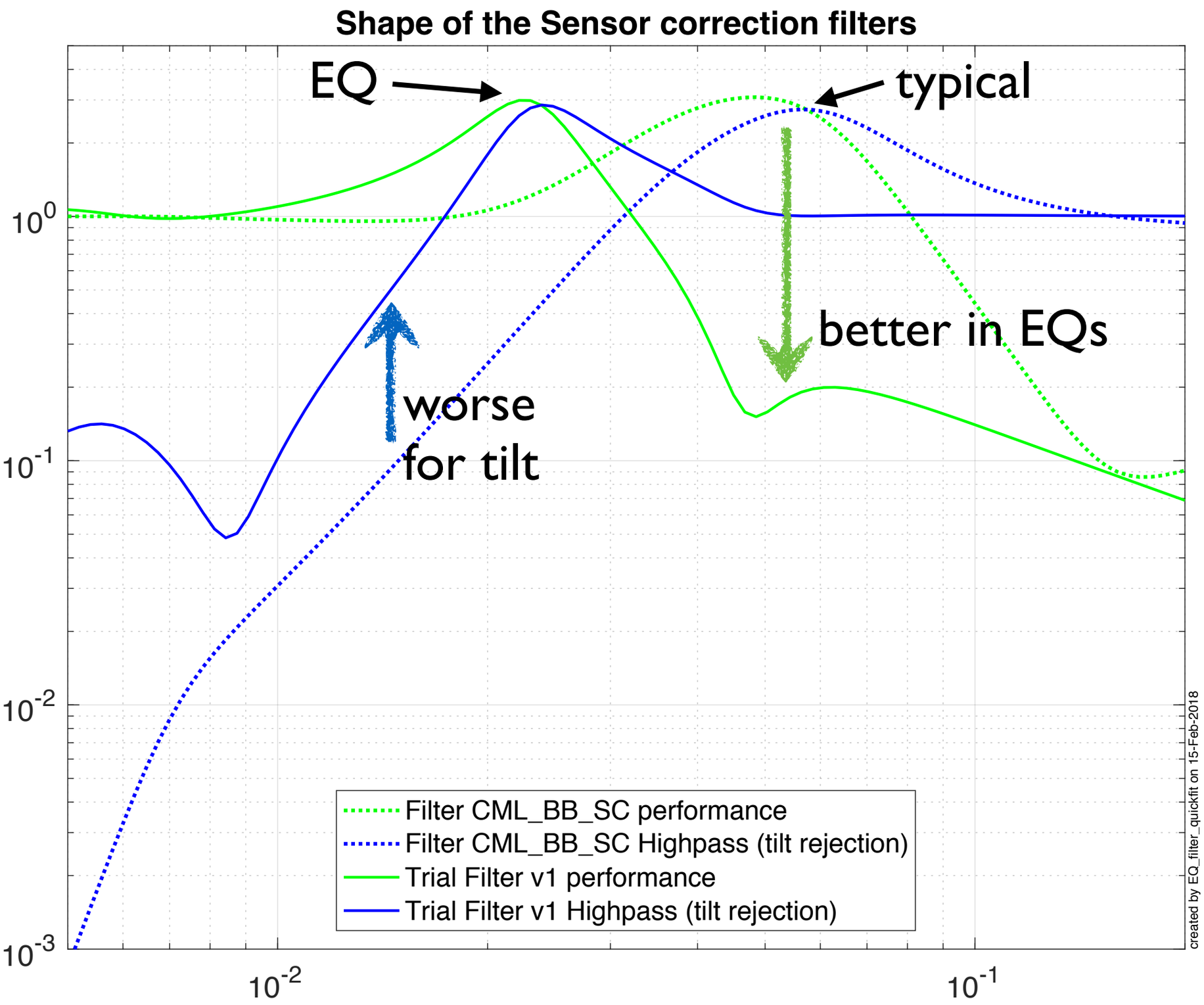



# Motion estimates



# New Sensor Correction

Pick a shape that works better for the EQ motion



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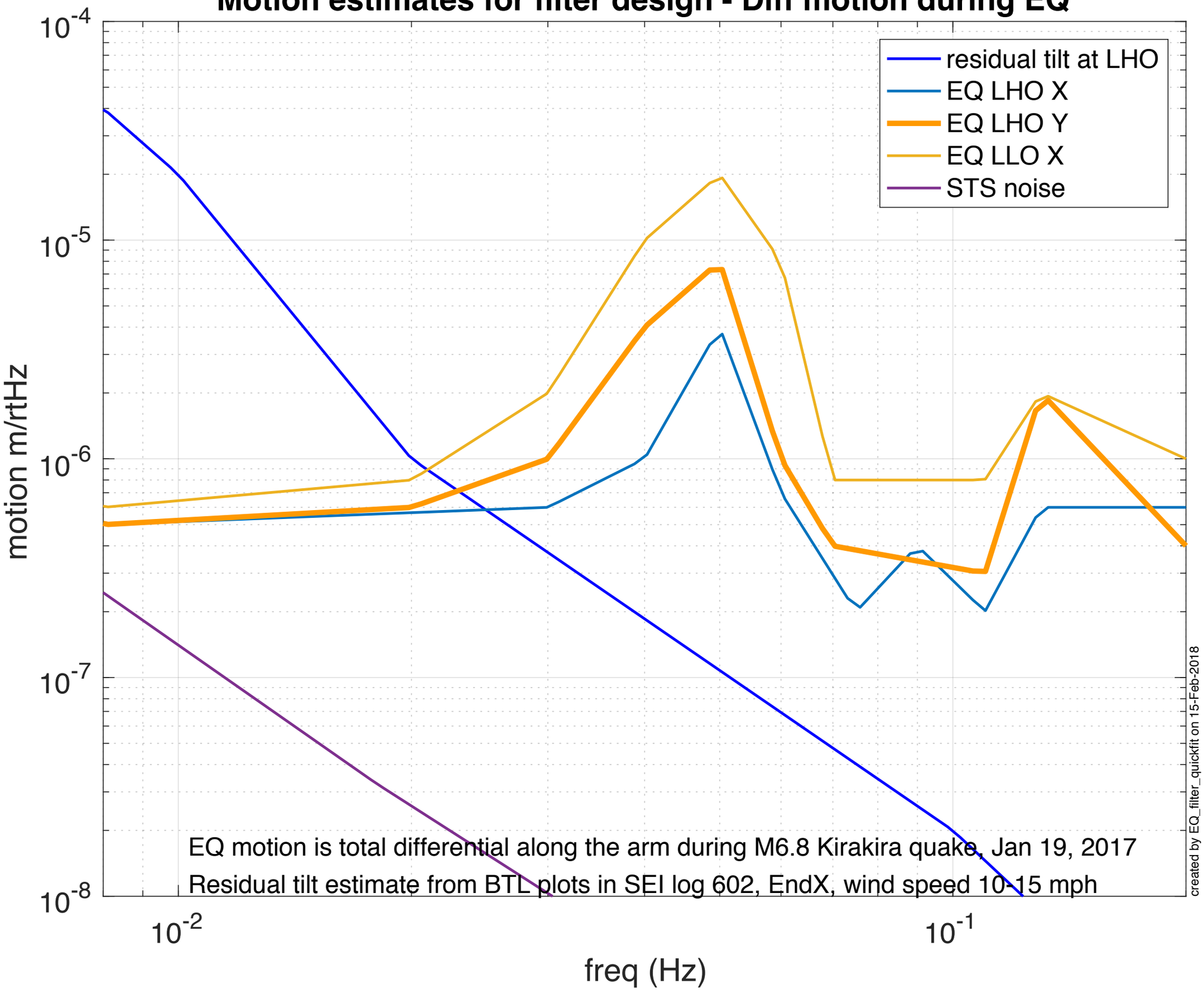
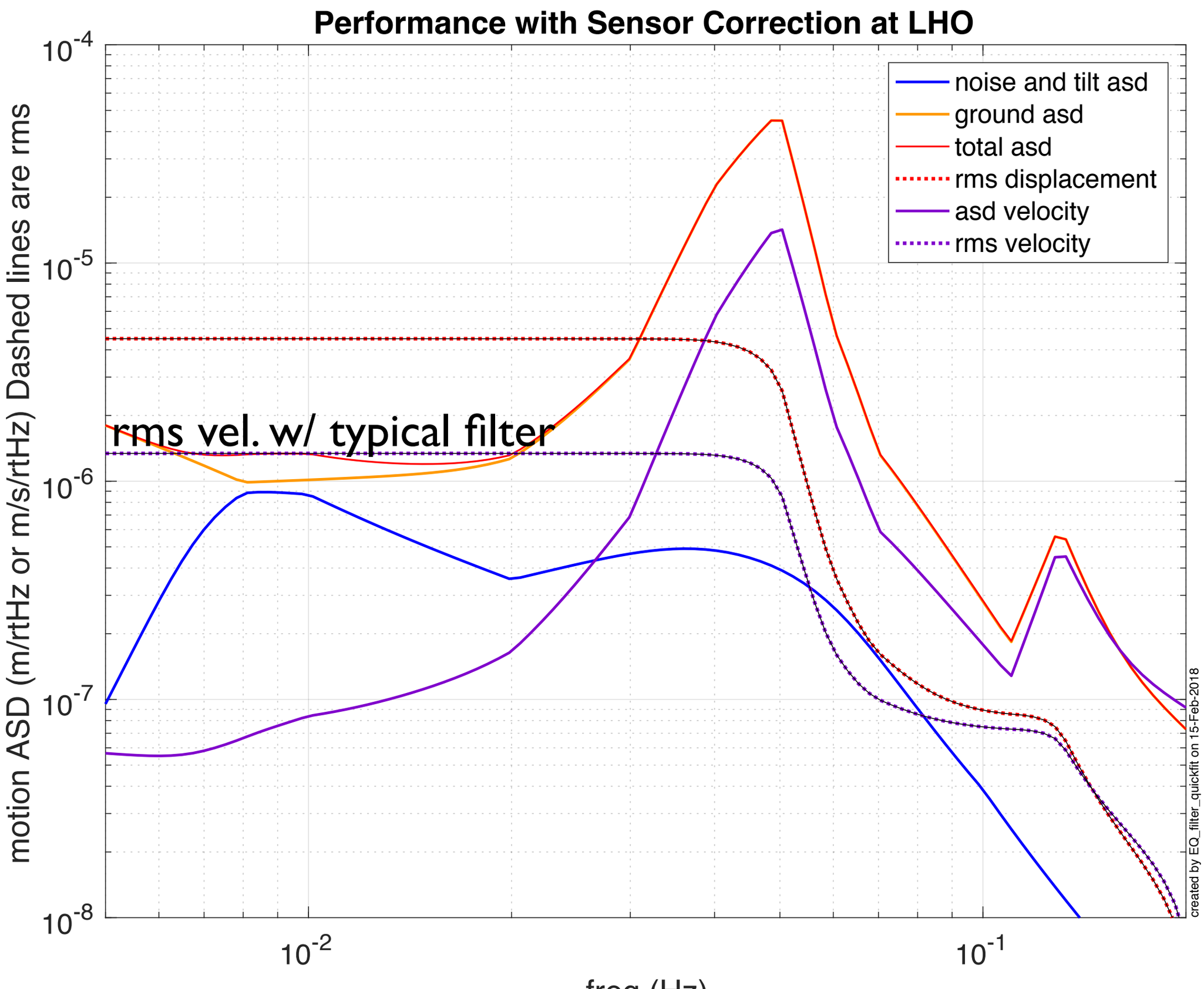
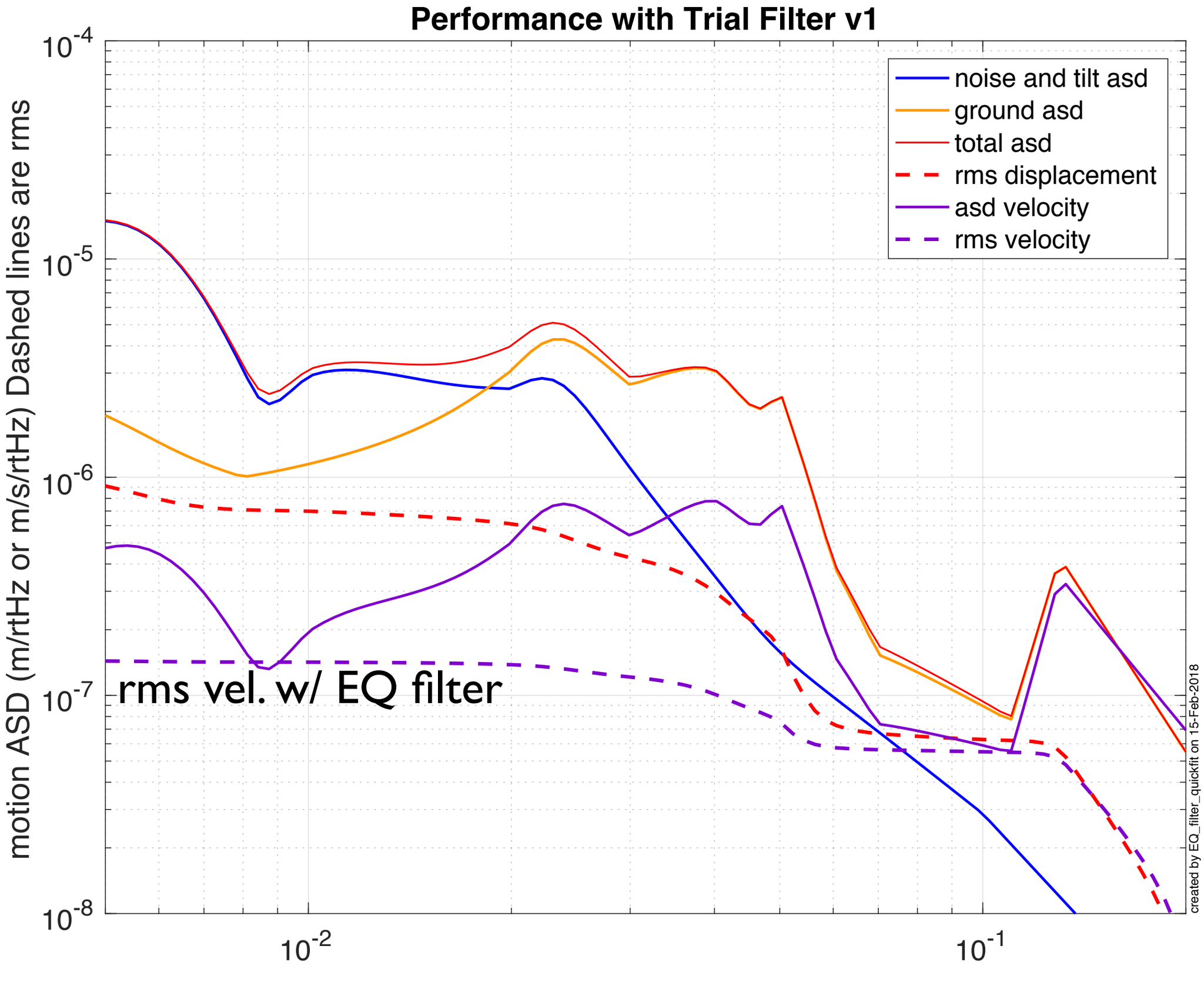


# Sensor Correction



# Sensor Correction



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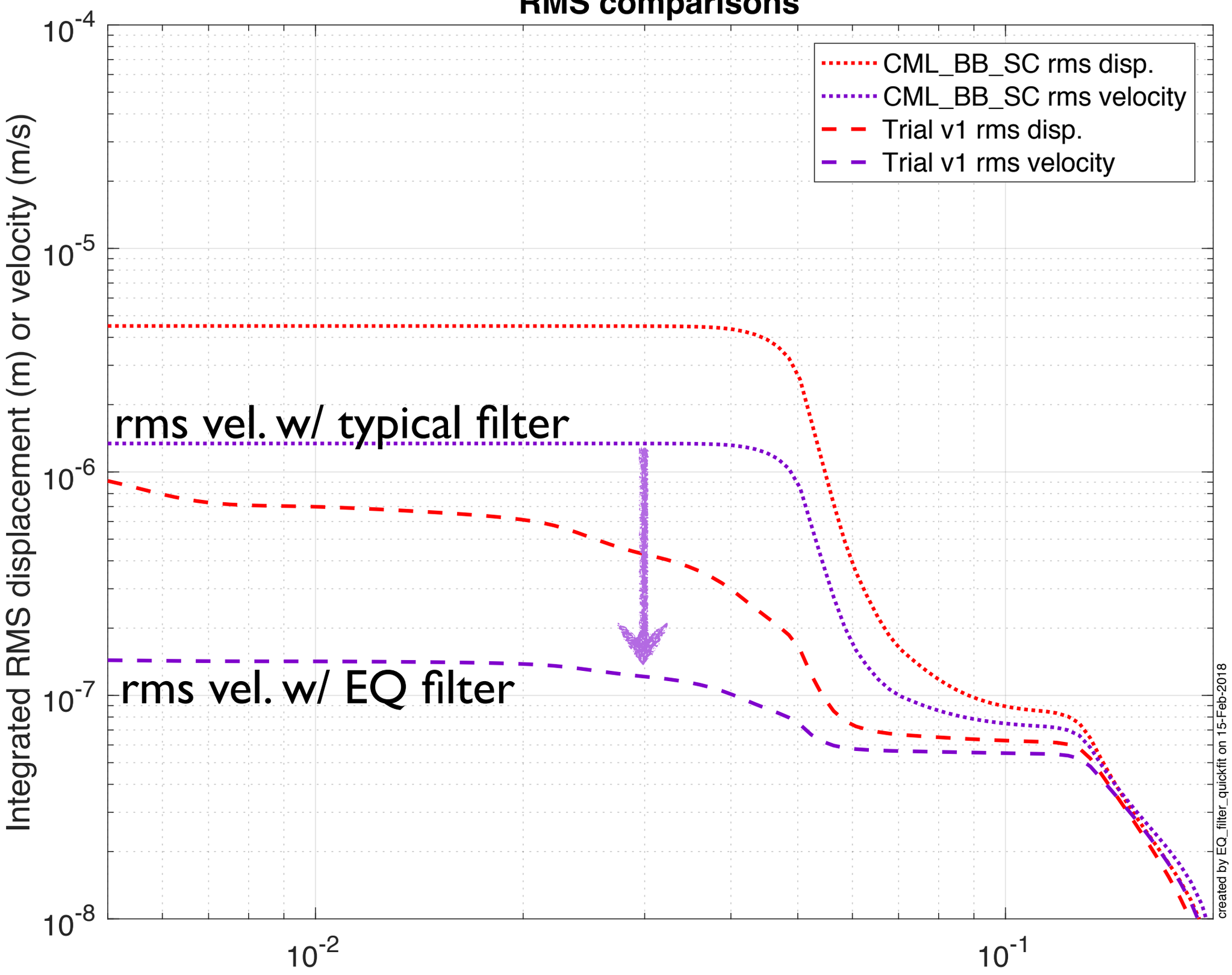
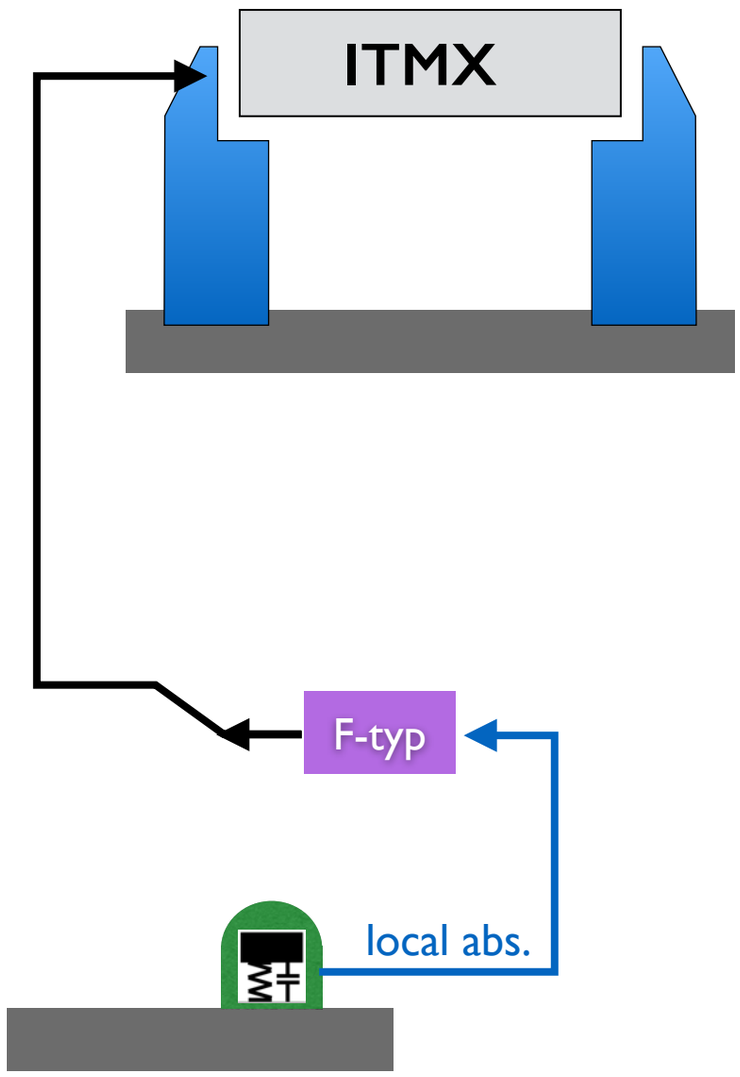
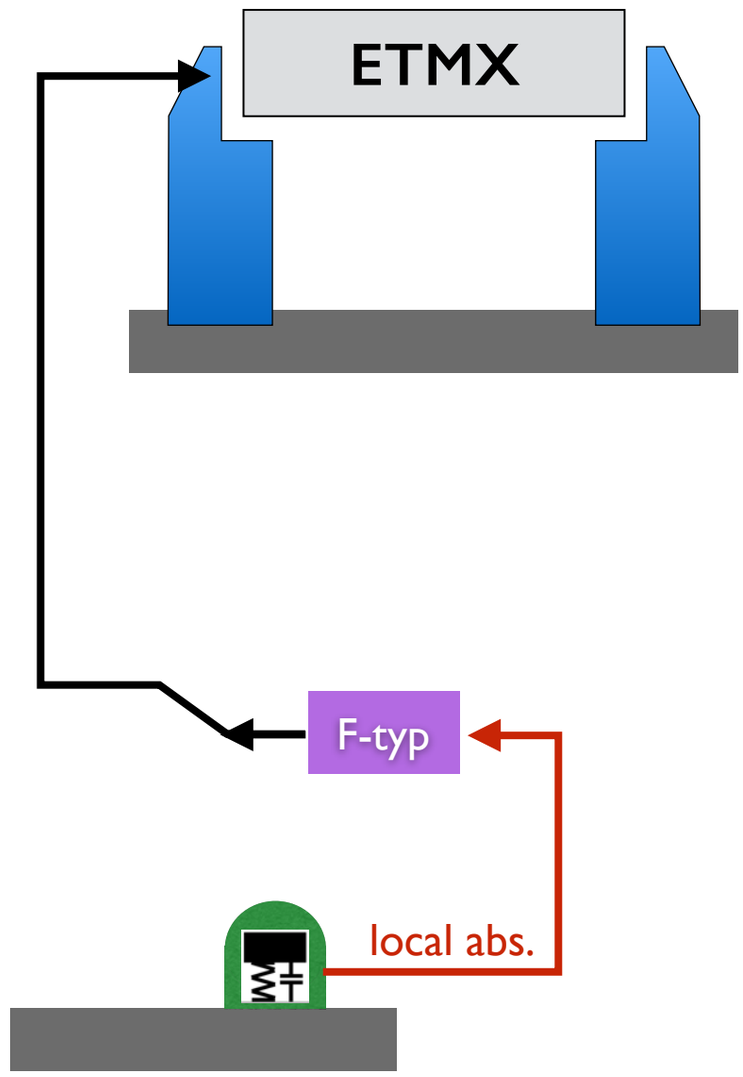


# Control schematic



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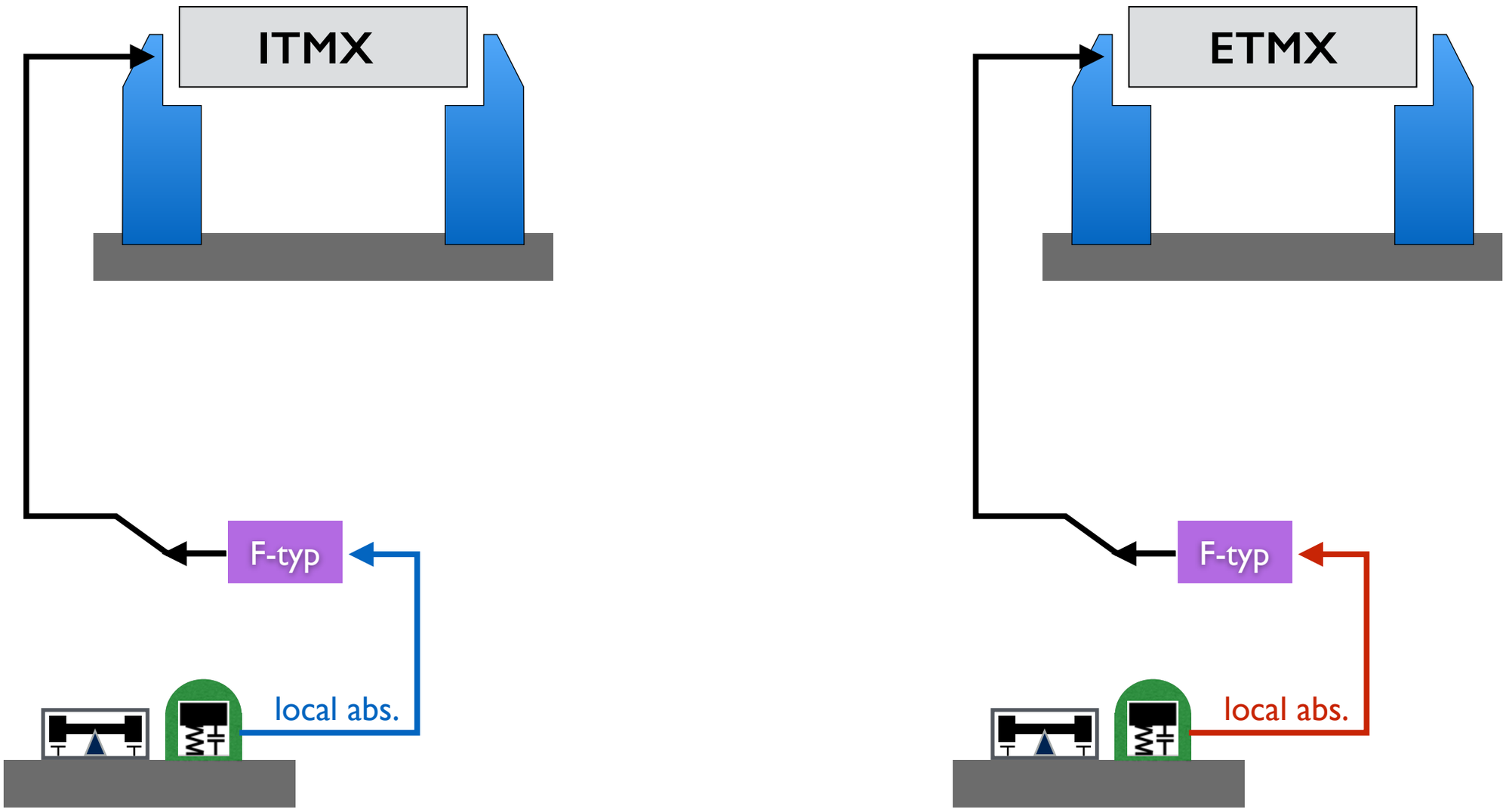

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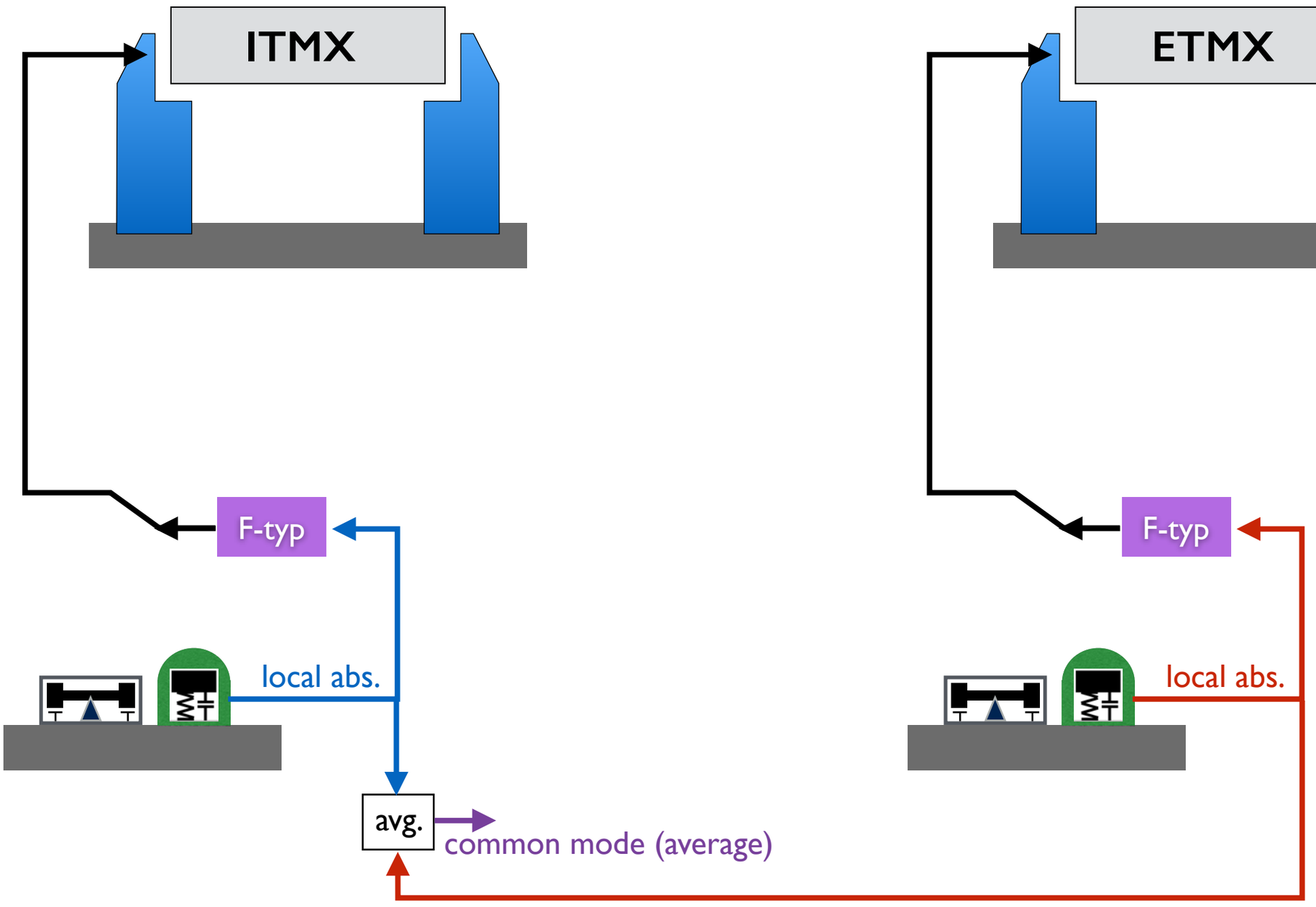
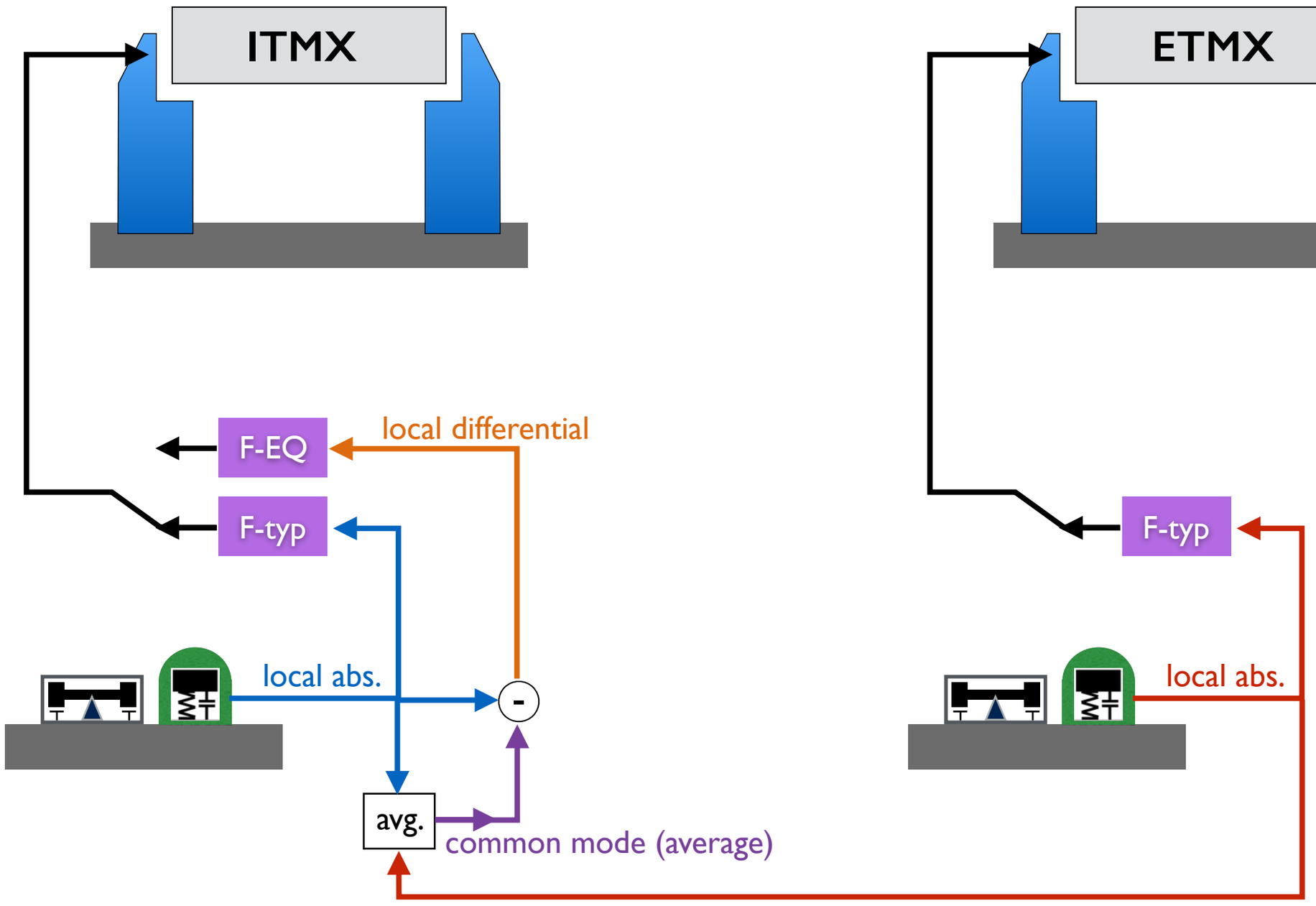
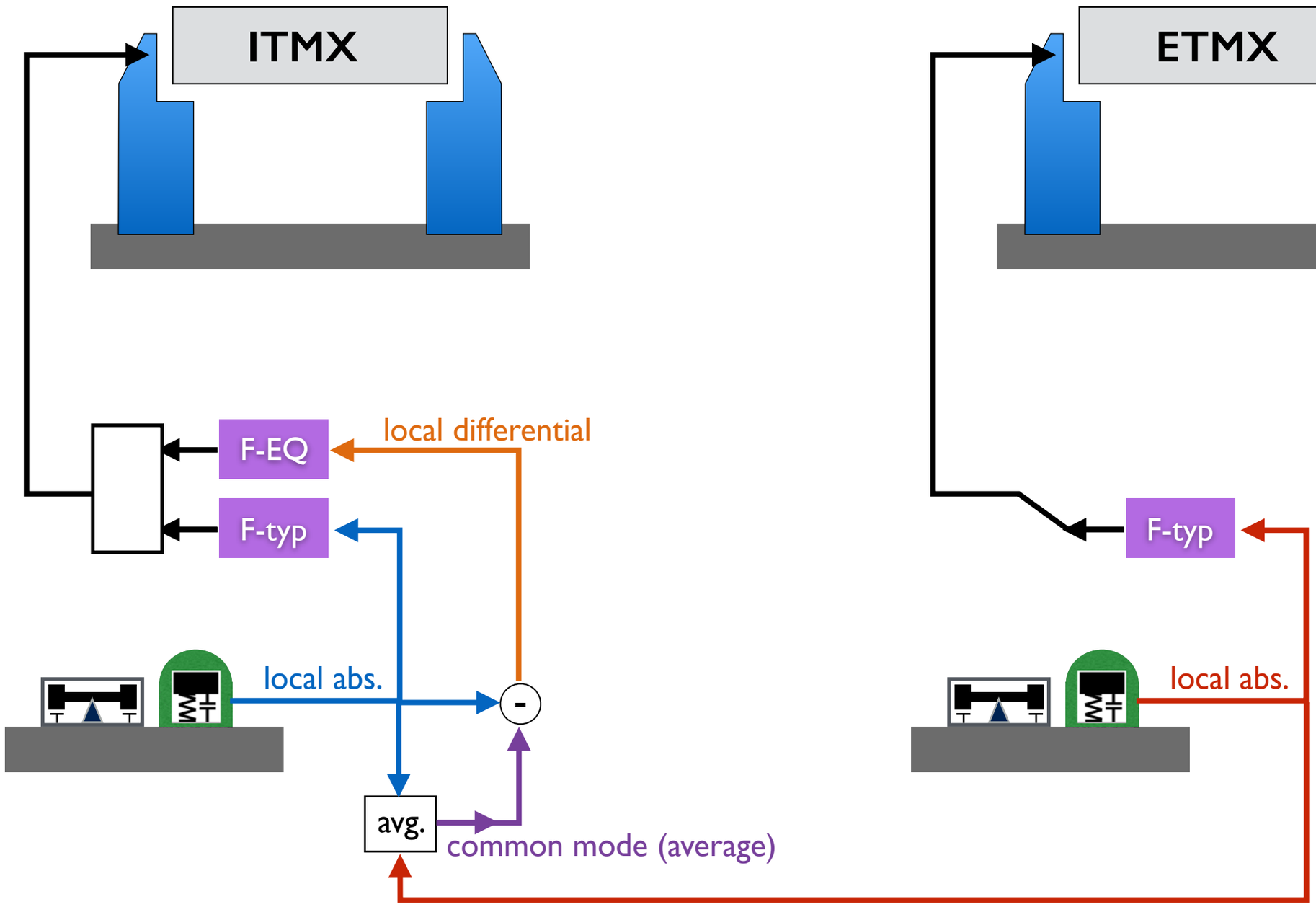


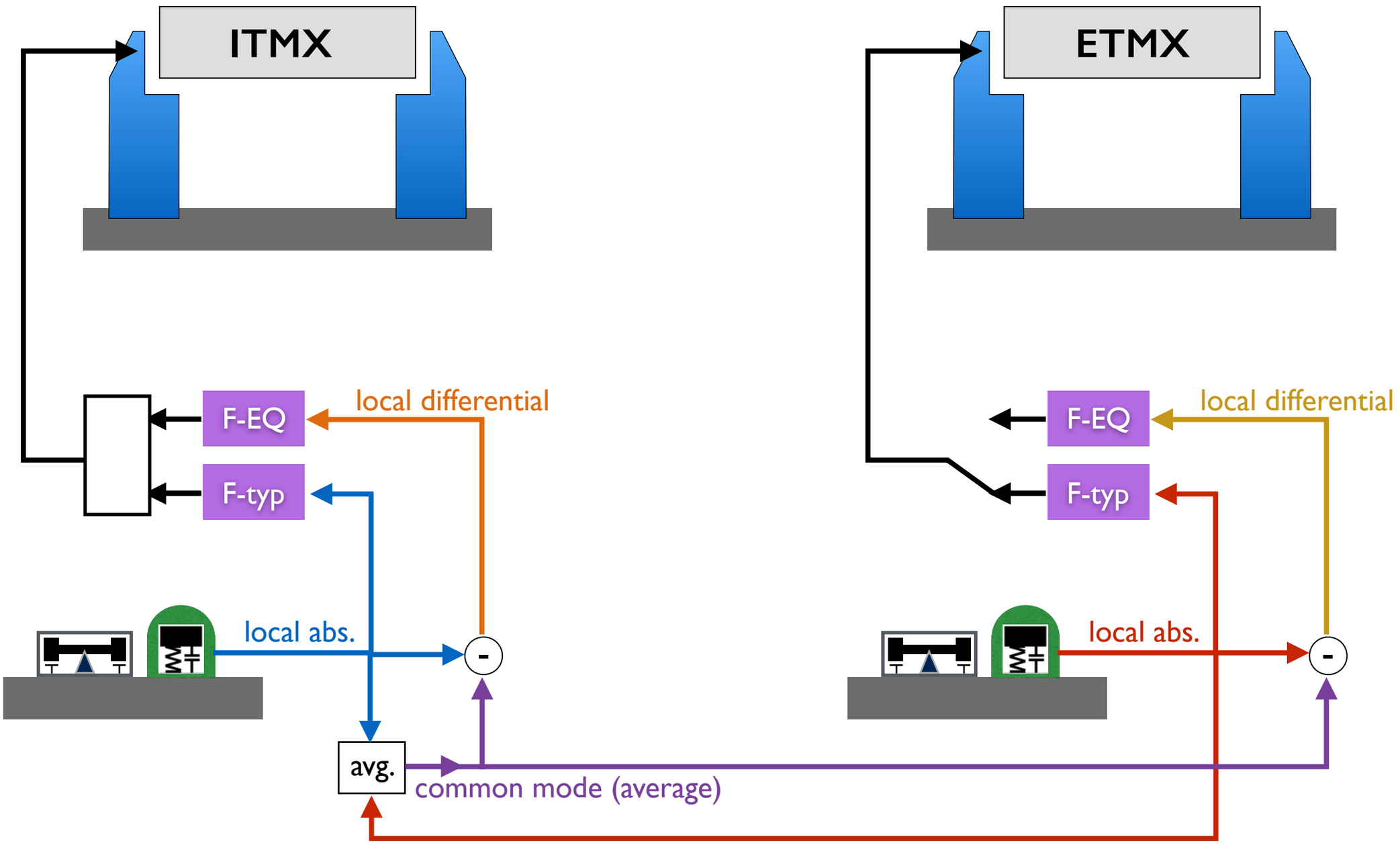
# Control schematic



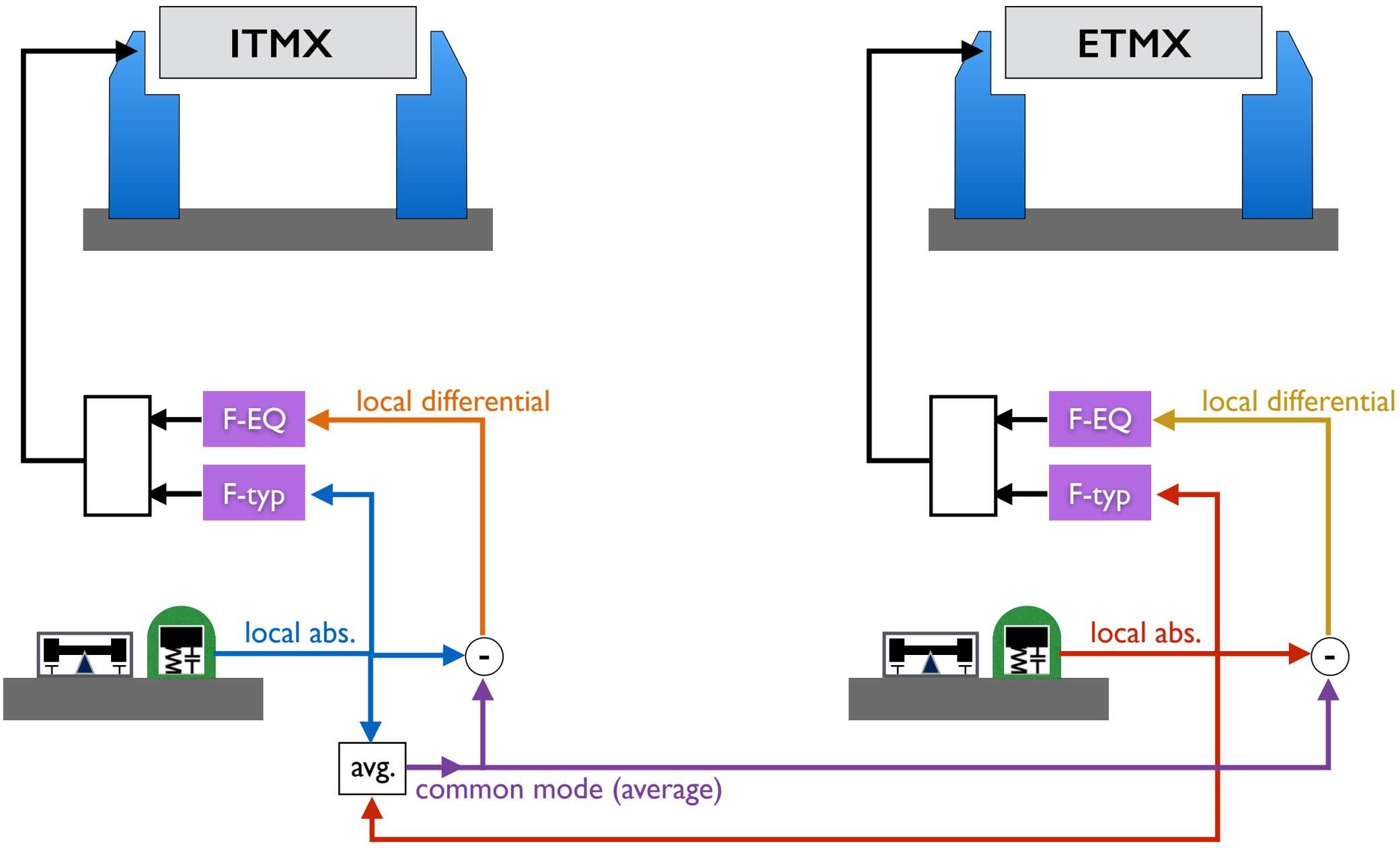
# Control schematic



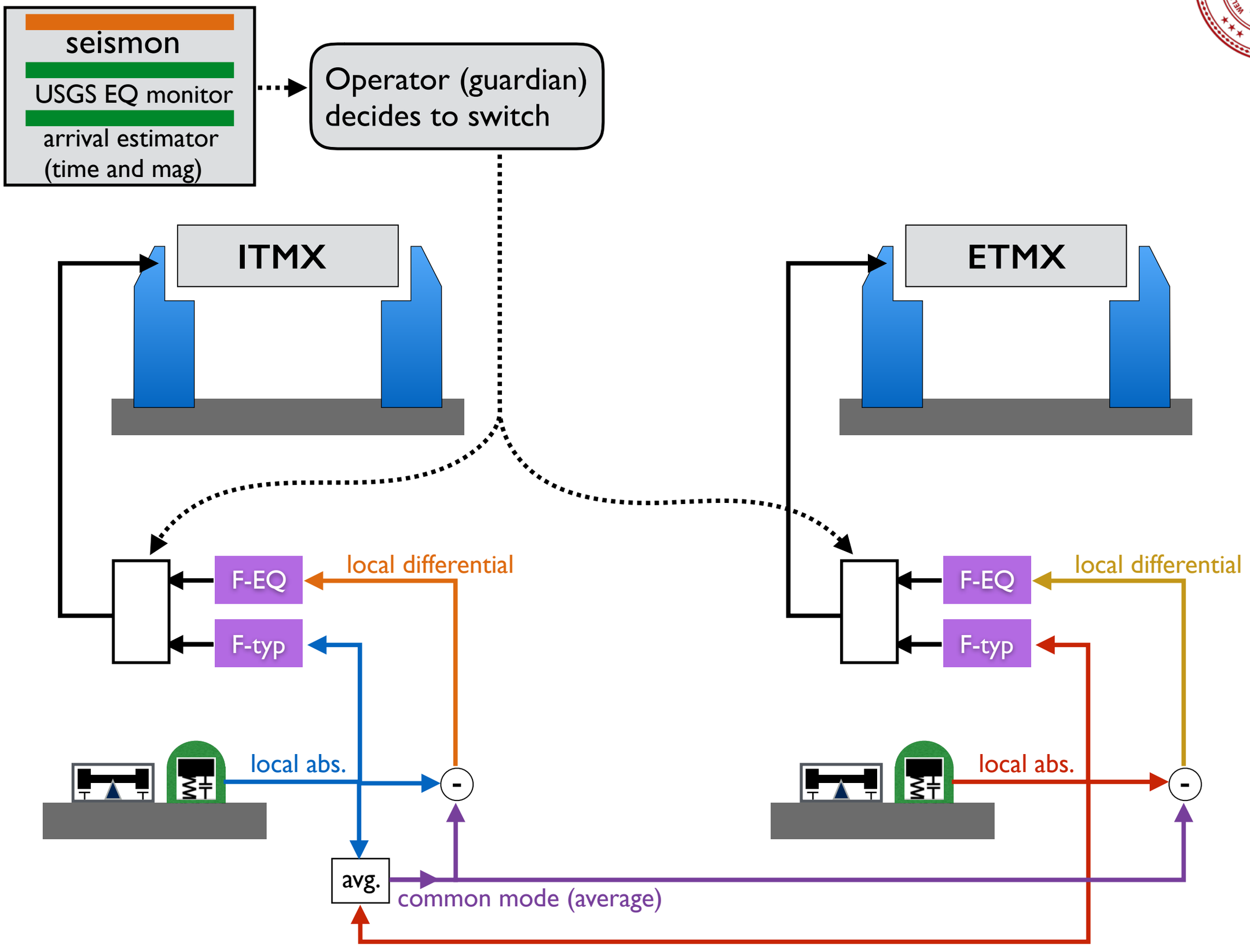
# Control schematic



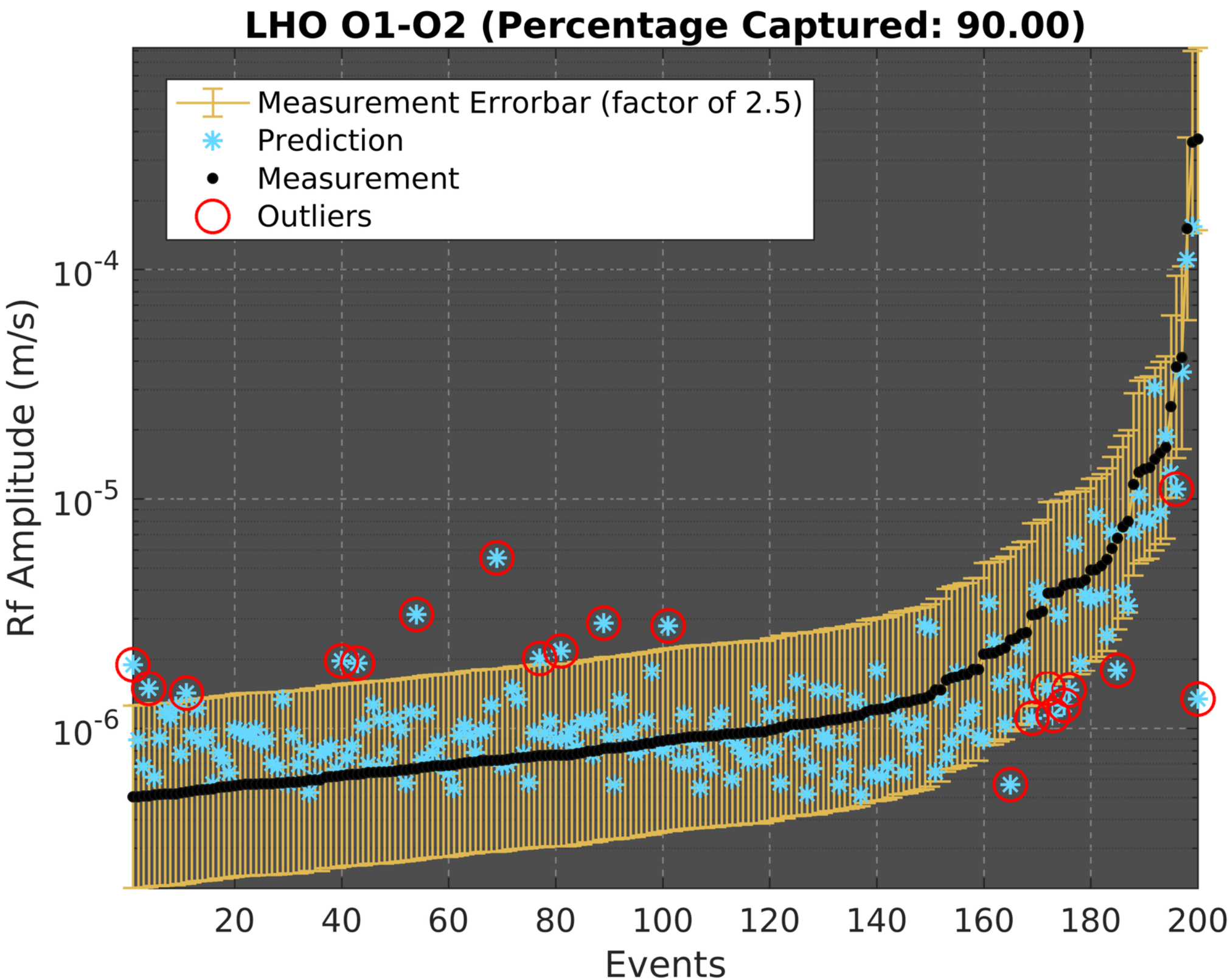
# Control schematic



# Control schematic

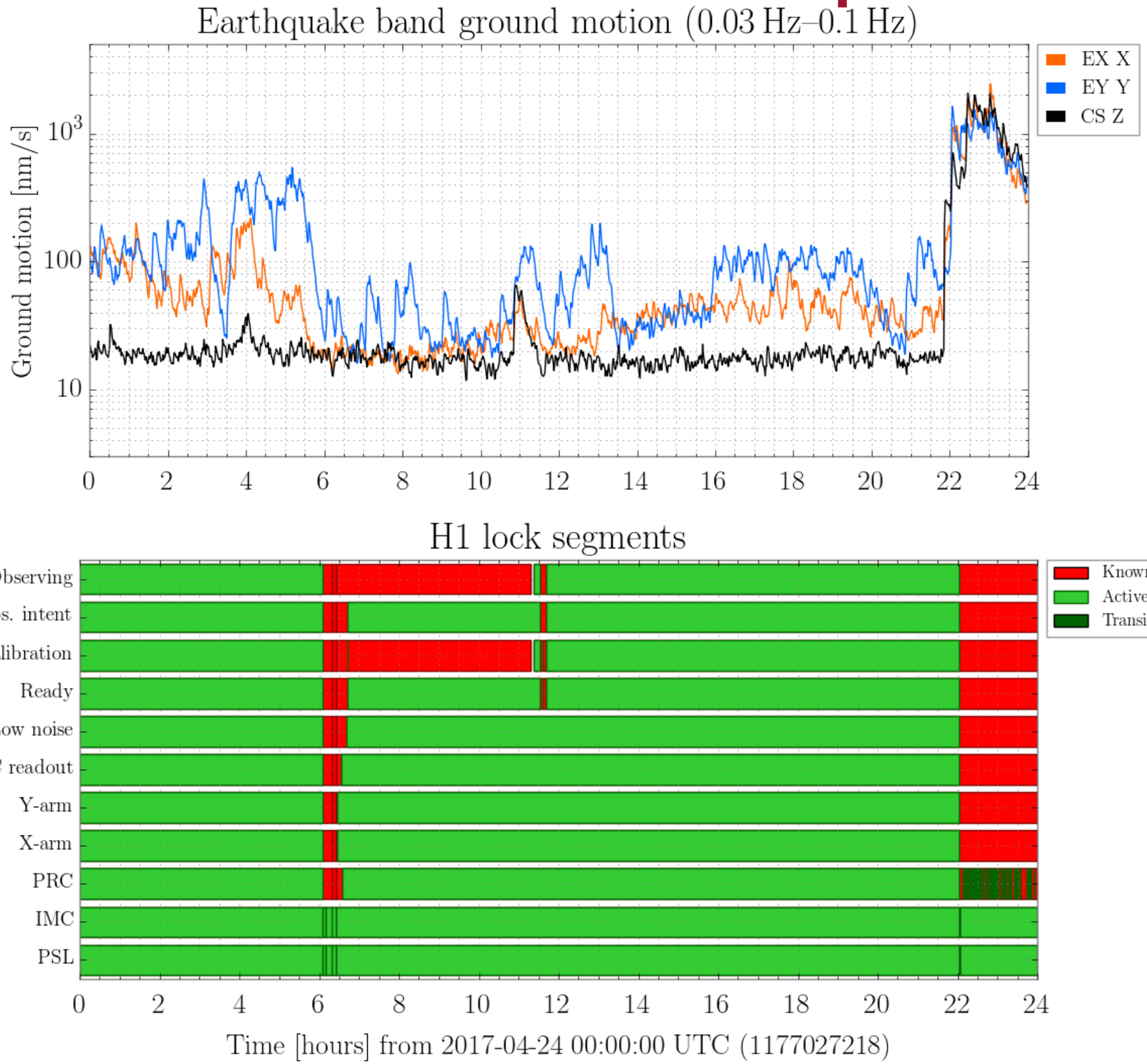


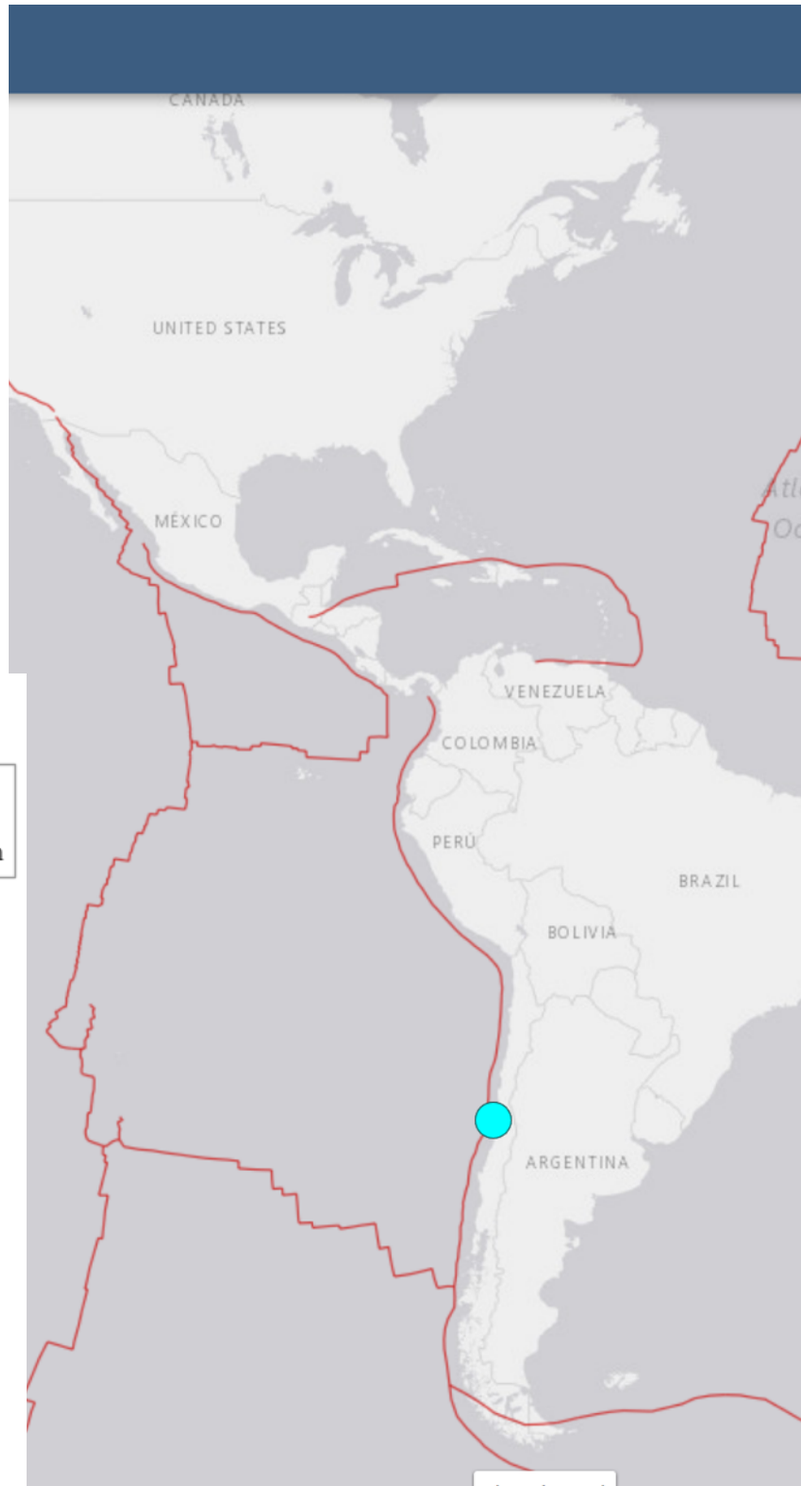
# Nikhil amplitude updates



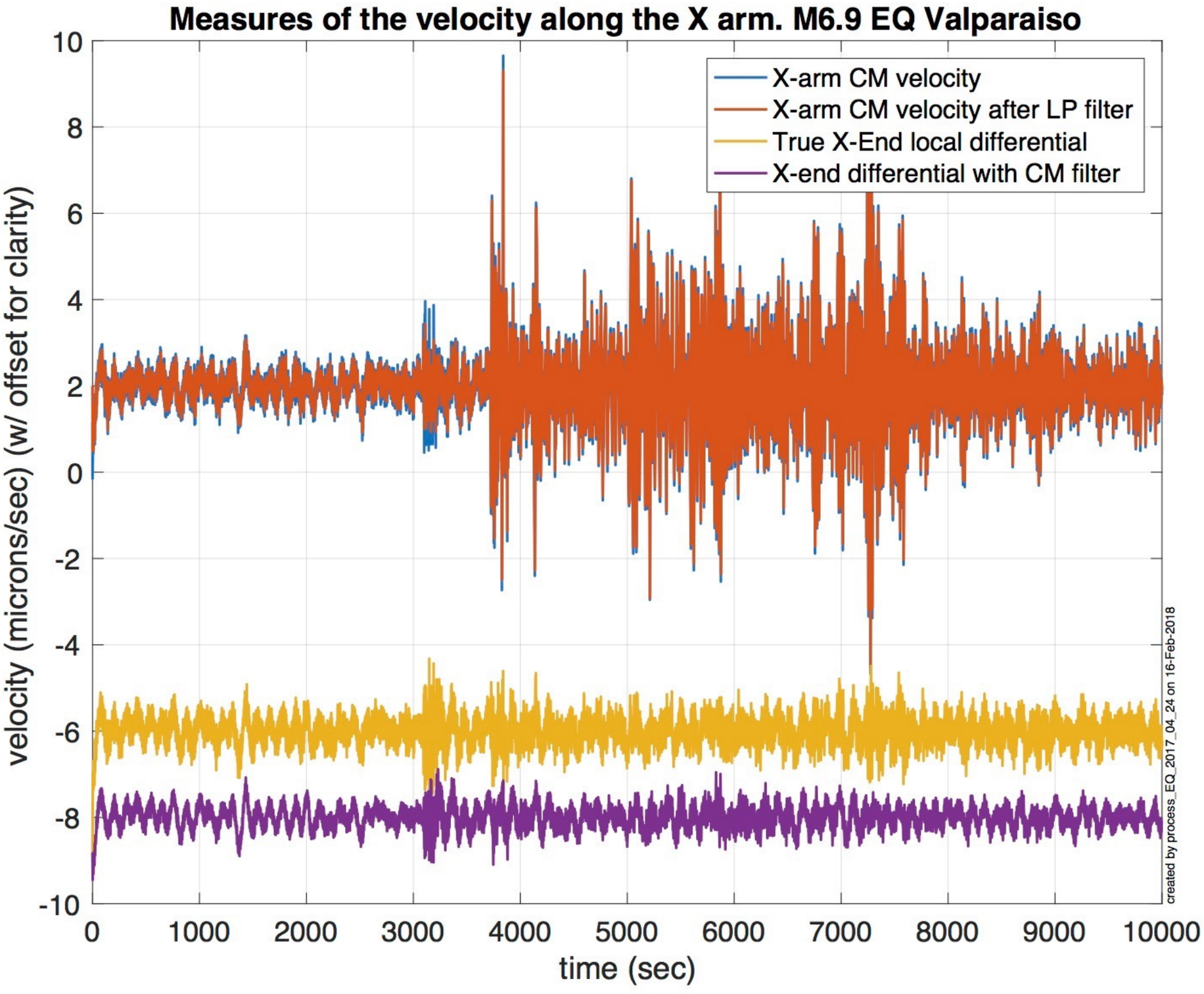
# Est. perf with a different event

# M6.9 Valparaiso



# EQ traces, M6.9 Valparaiso



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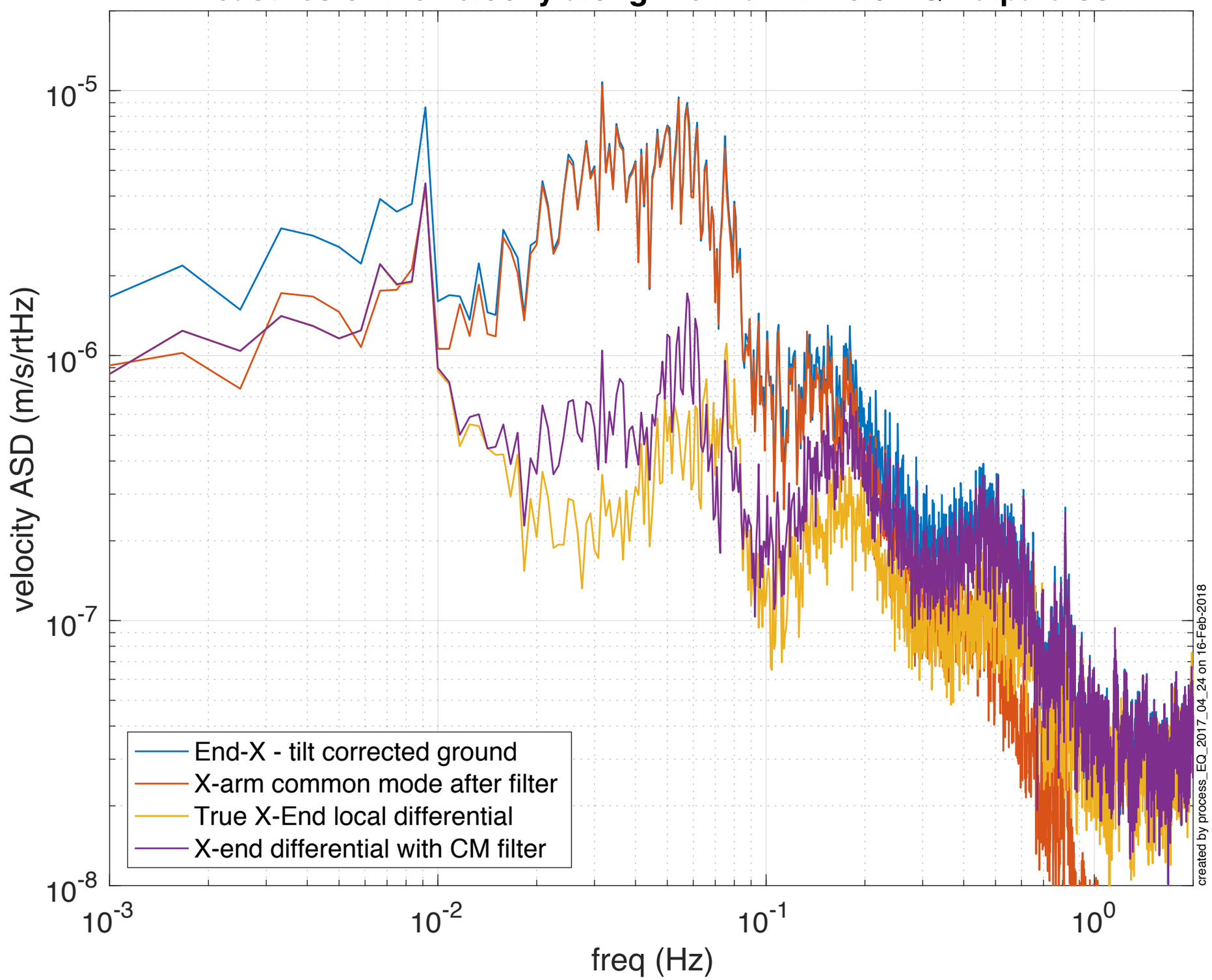
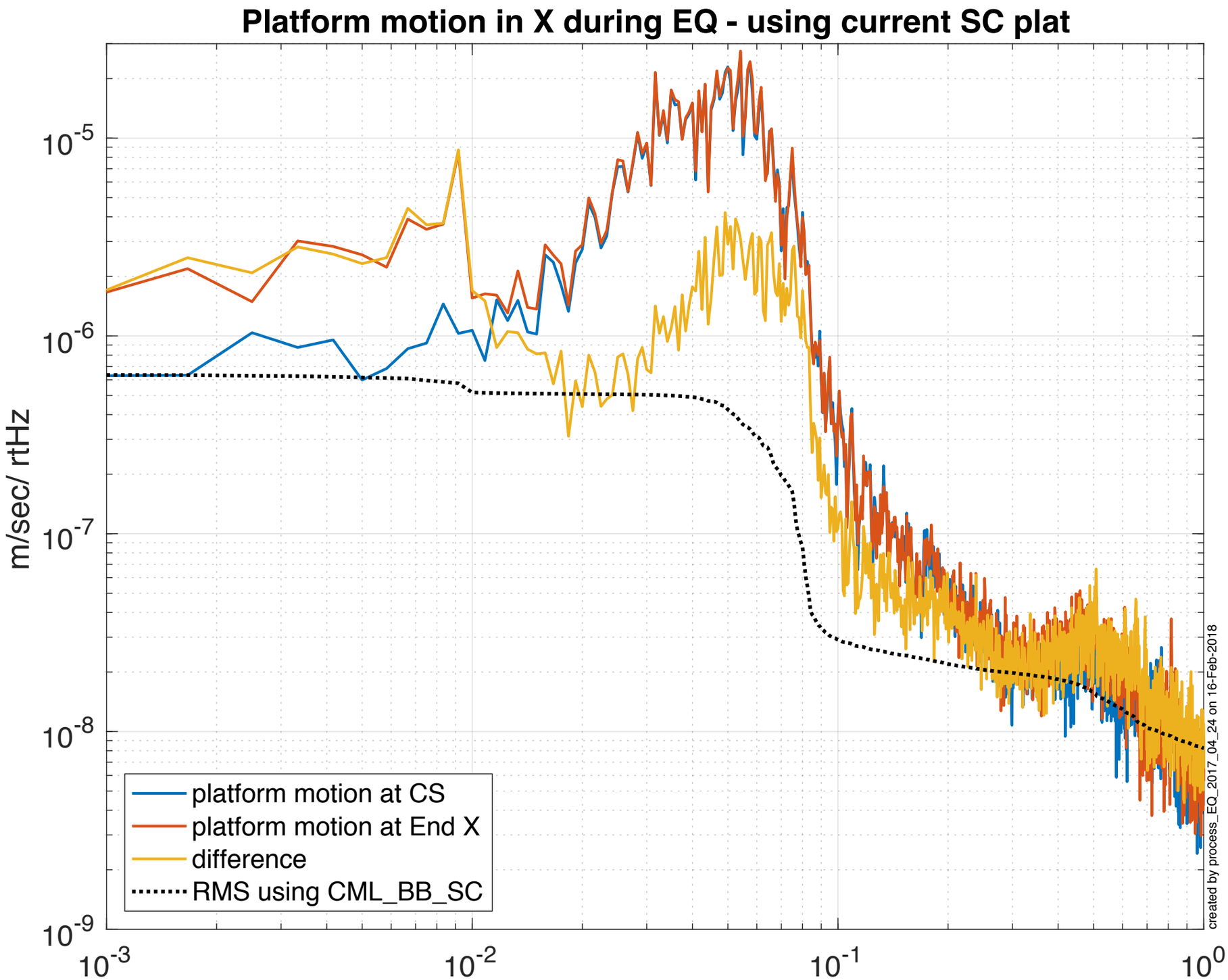
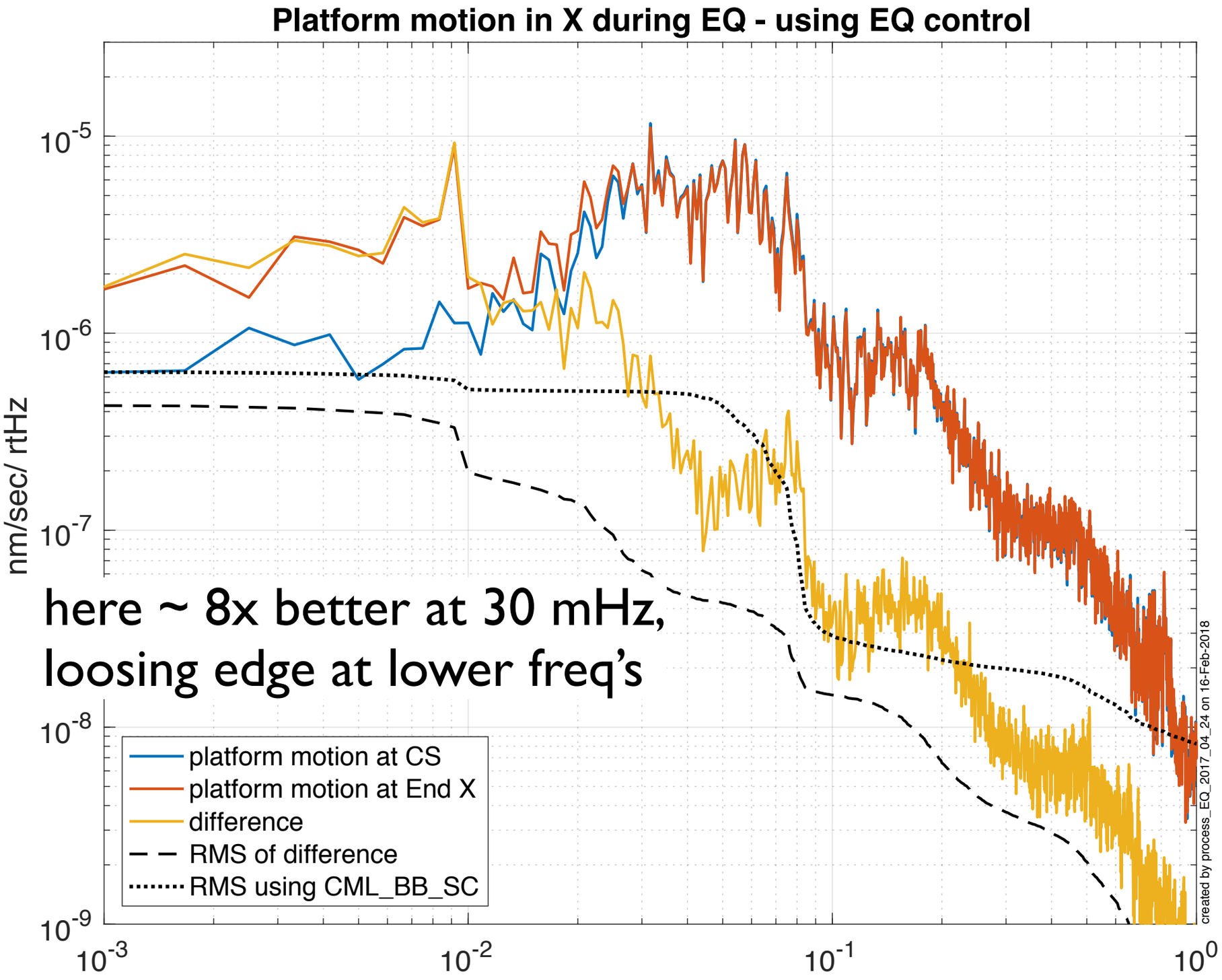


# Modeled perf. now

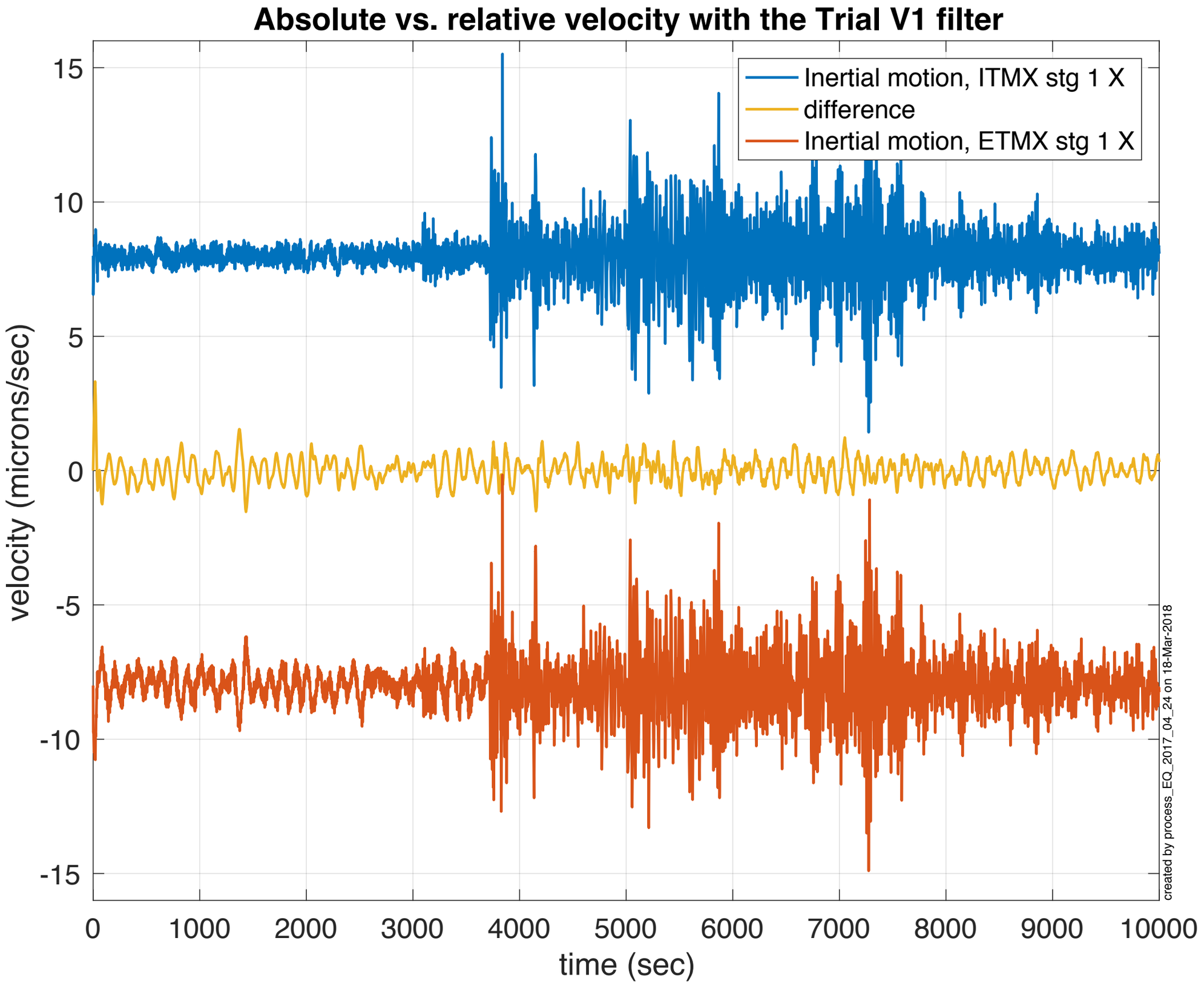


# Modeled perf with new SC

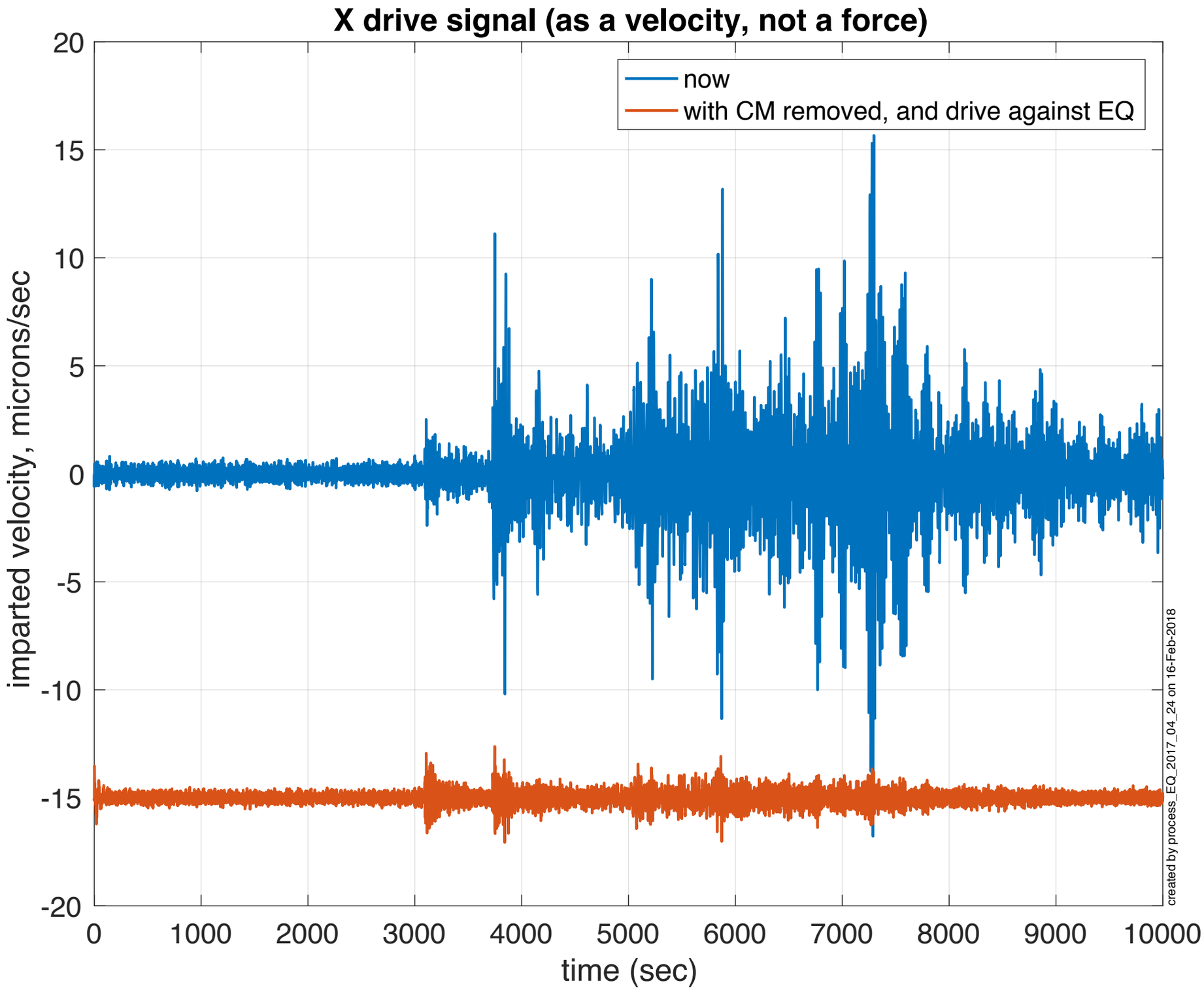



here ~ 8x better at 30 mHz,
loosing edge at lower freq's

# Perf. looks odd in local basis



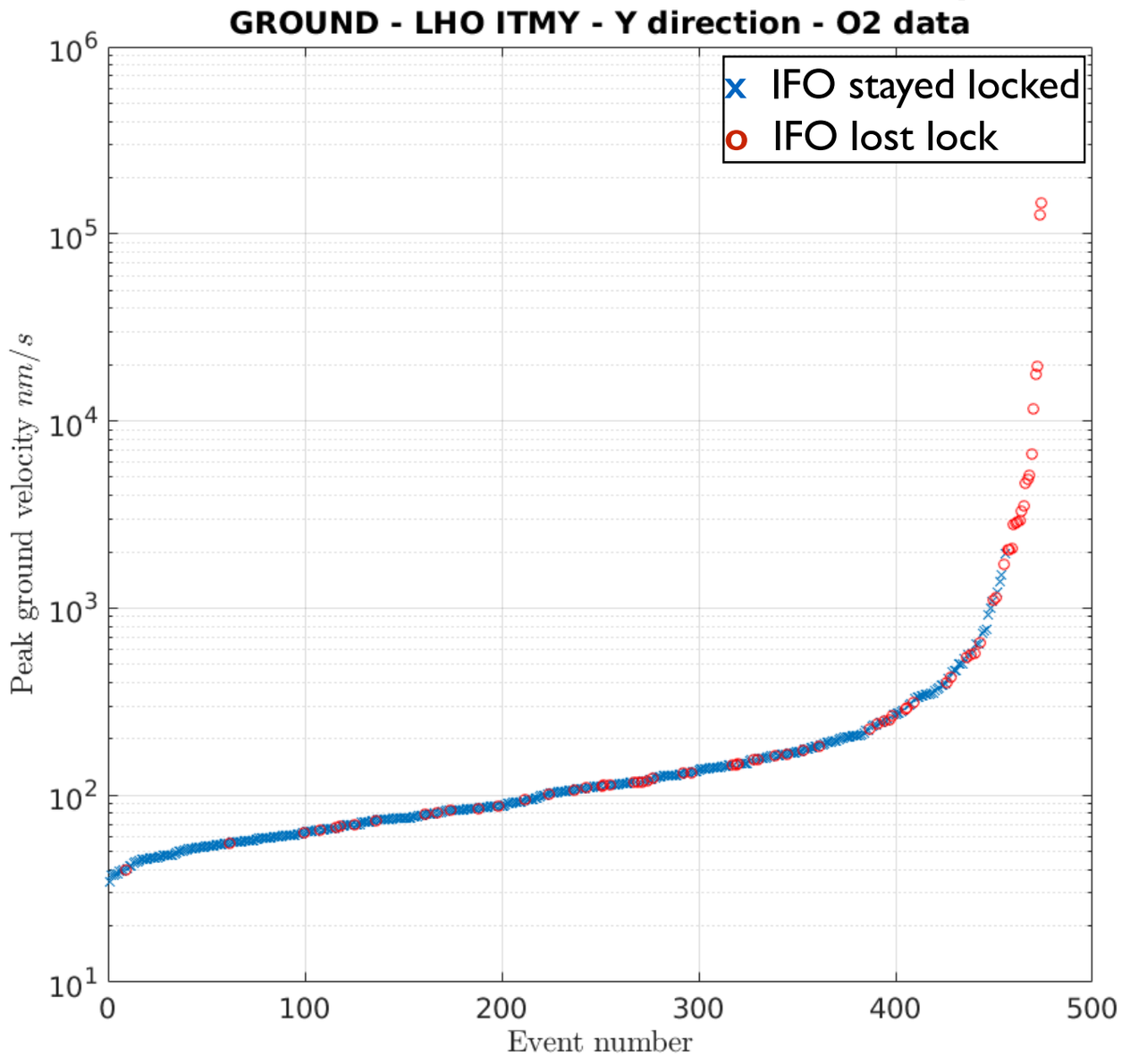
# Removing CM reduces drive lev

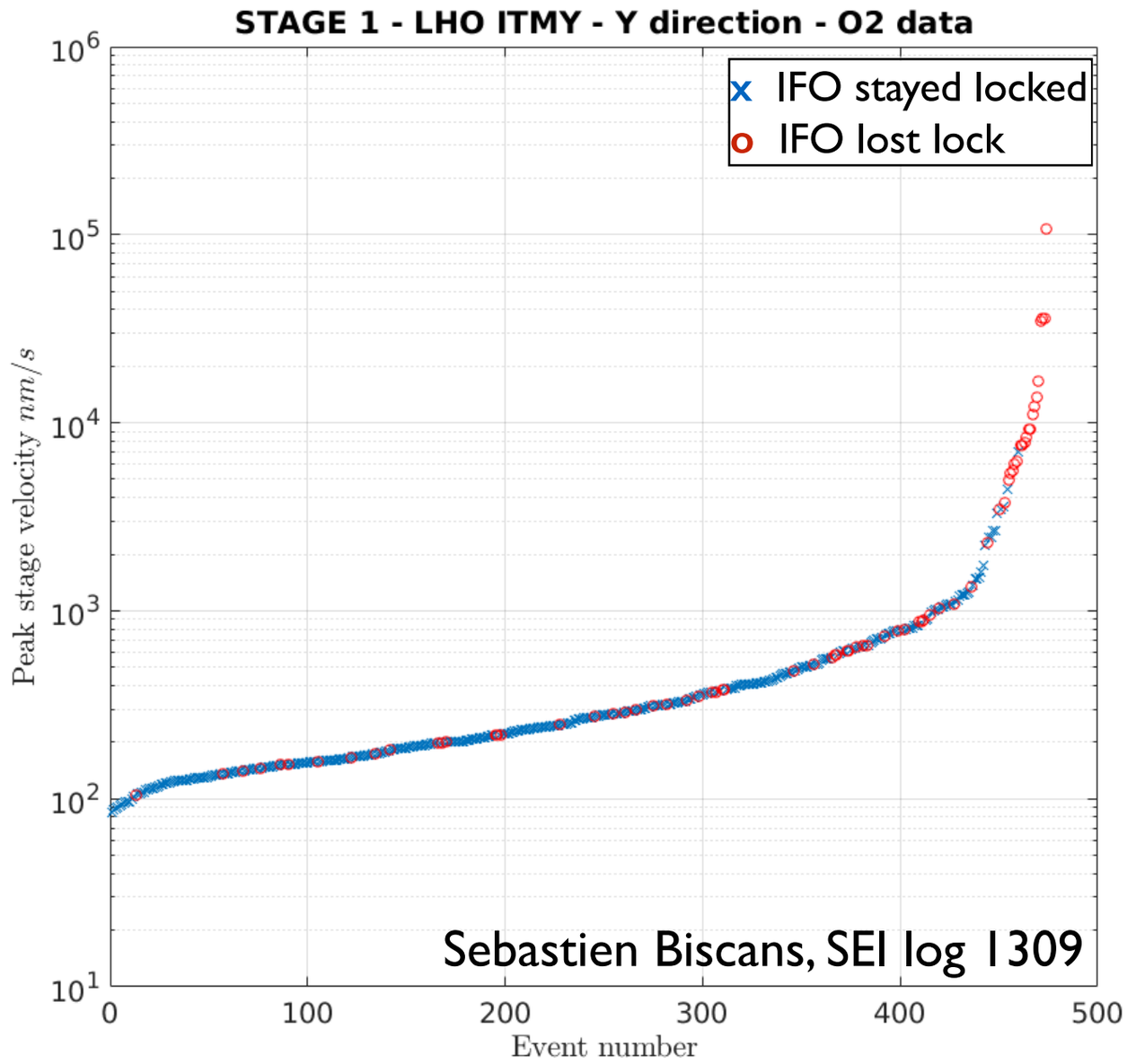


# Earthquake impact for O2

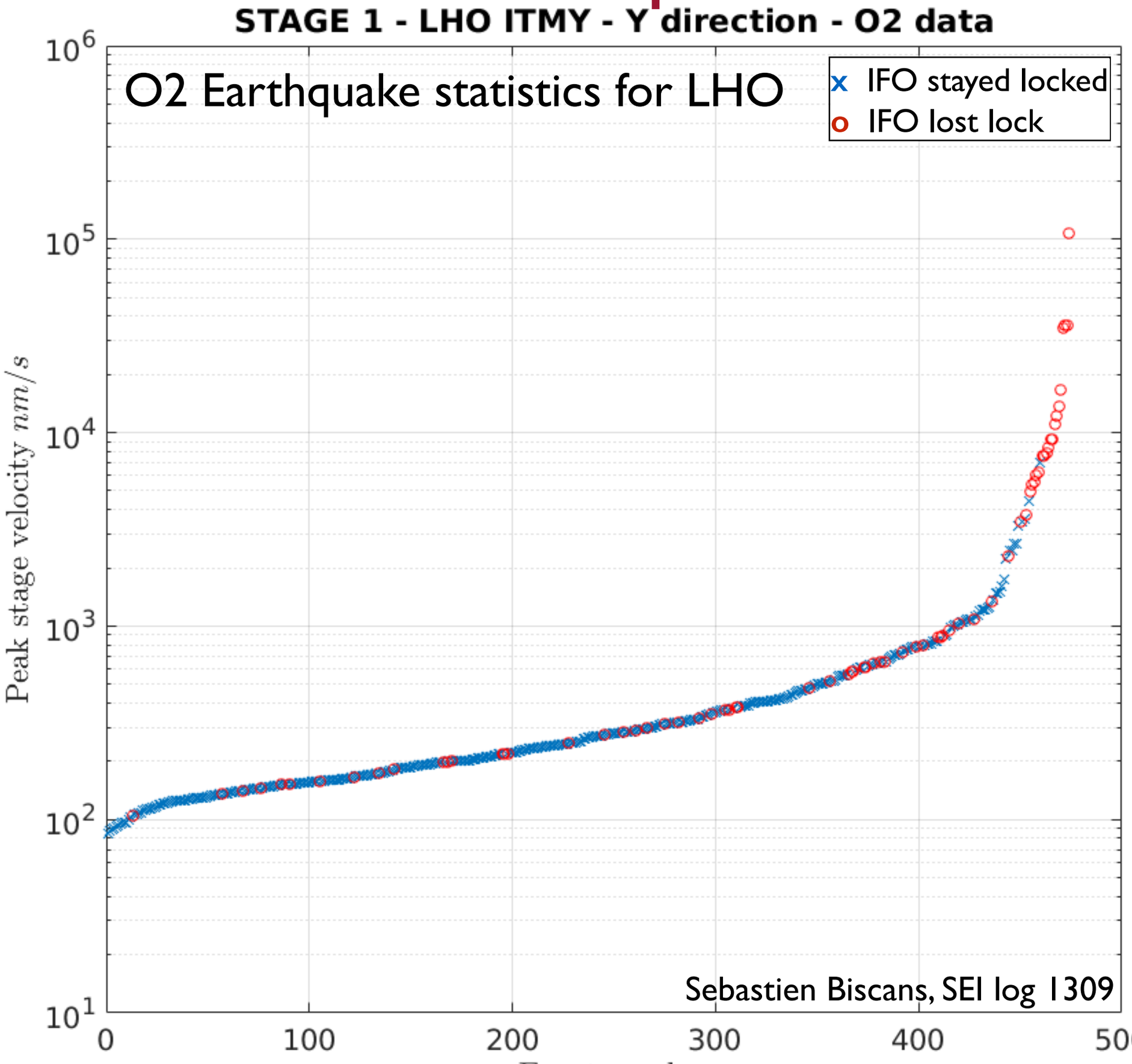
| | IFO not lock at the time | IFO stayed lock | IFO lost lock | Total |
|---|---|---|---|---|
| Number of events | 51 | 403 | 71 | 525 |

## O2 Earthquake statistics for LHO



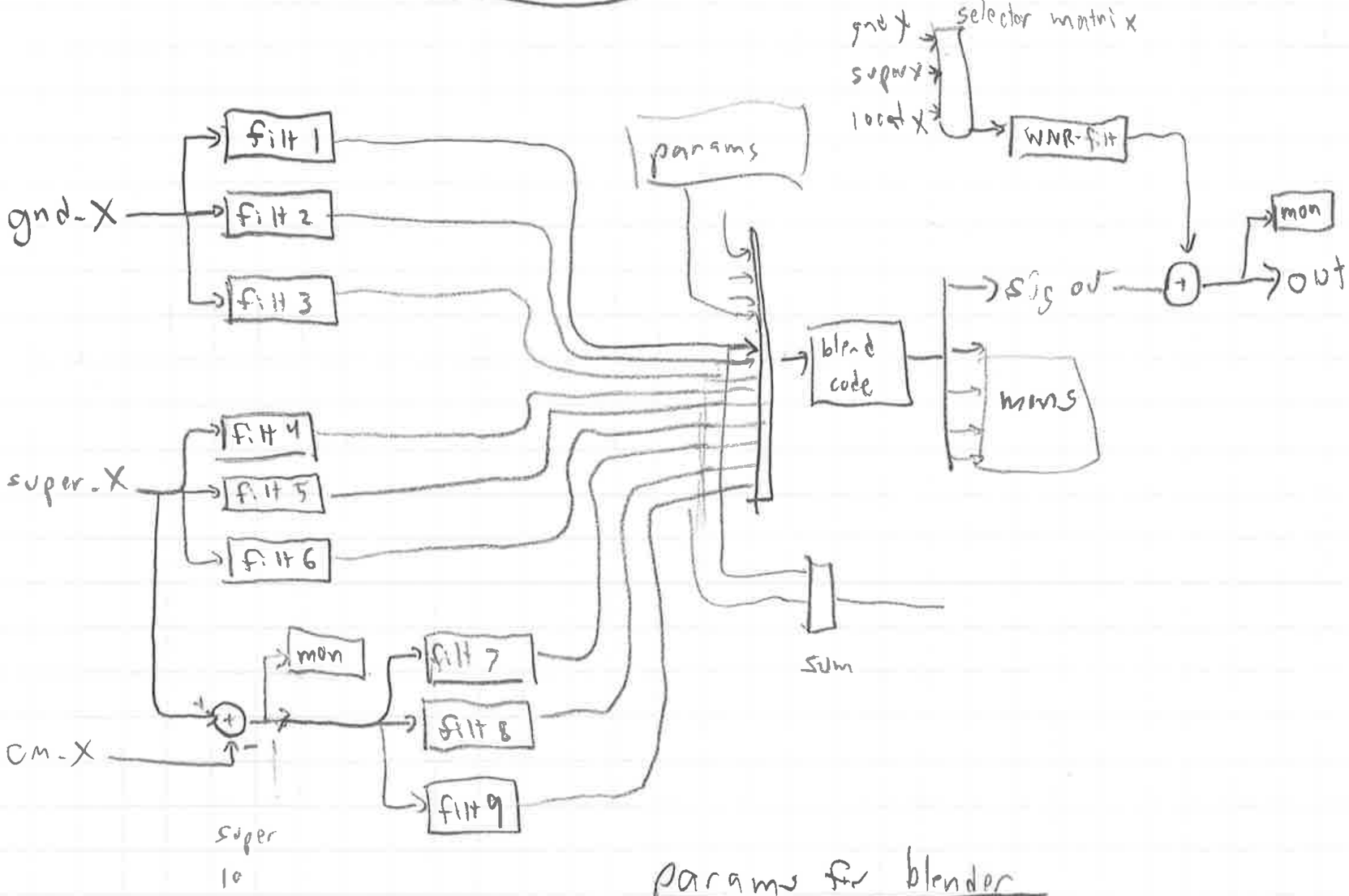
# Potential for improvement



# Final thoughts

- We should be able to significantly improve robustness against Earthquakes.
- Part the benefit comes from having new tools (BRS, Seismon)
- Part of the benefit comes from changing the control flow/ isolation performance during observing time based on changing environmental conditions.
- Part of the benefit comes from controlling the seismic system in a non-local way, controlling relative motion instead of controlling the absolute motion.
- Implementation should be complete at LHO by ~~April~~ May.

# Senscor — X




how many filter banks?

## params for blender

startup_channel → epics #

next_channel → epics #

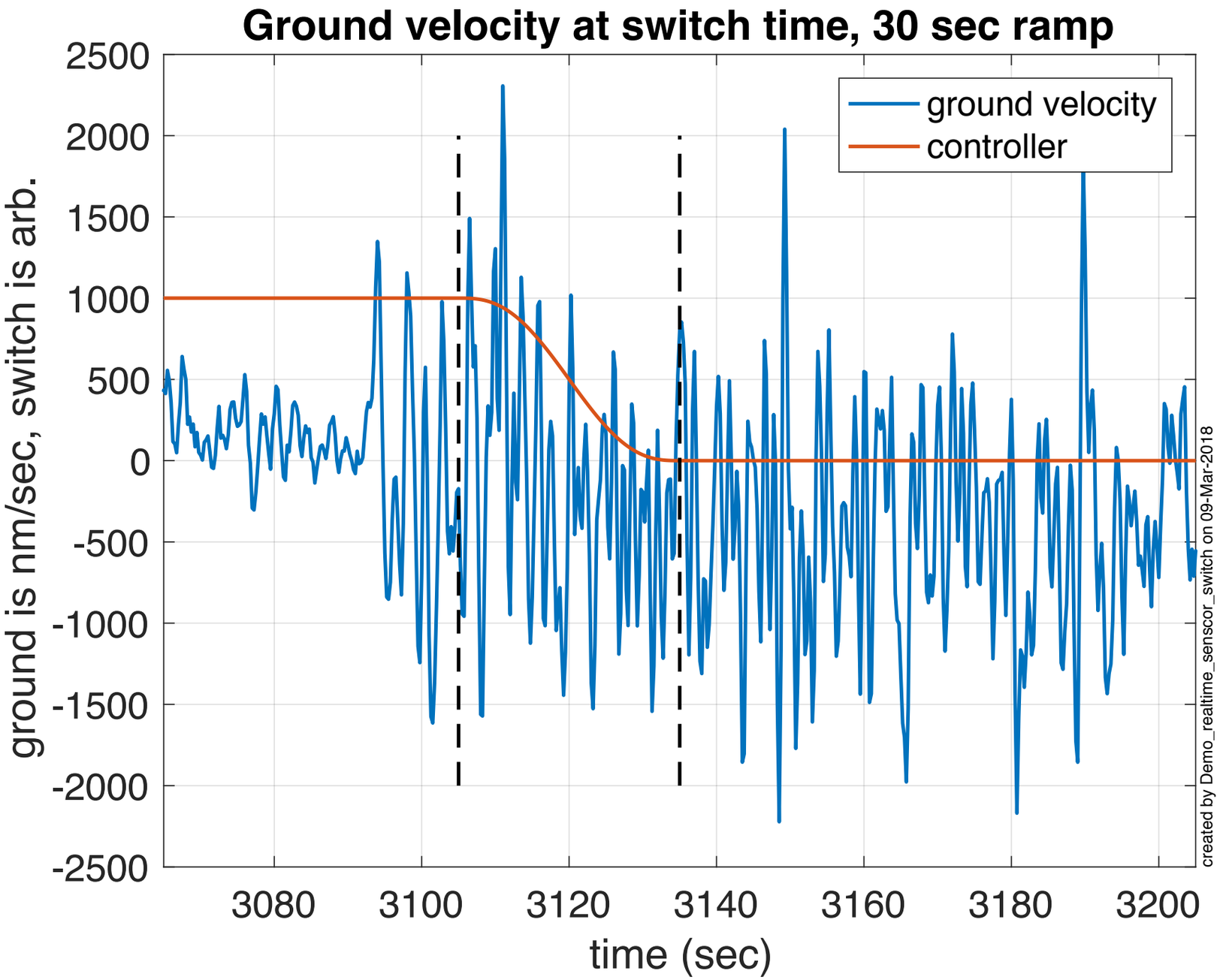
blend_time → epics #

start now → epics momentary

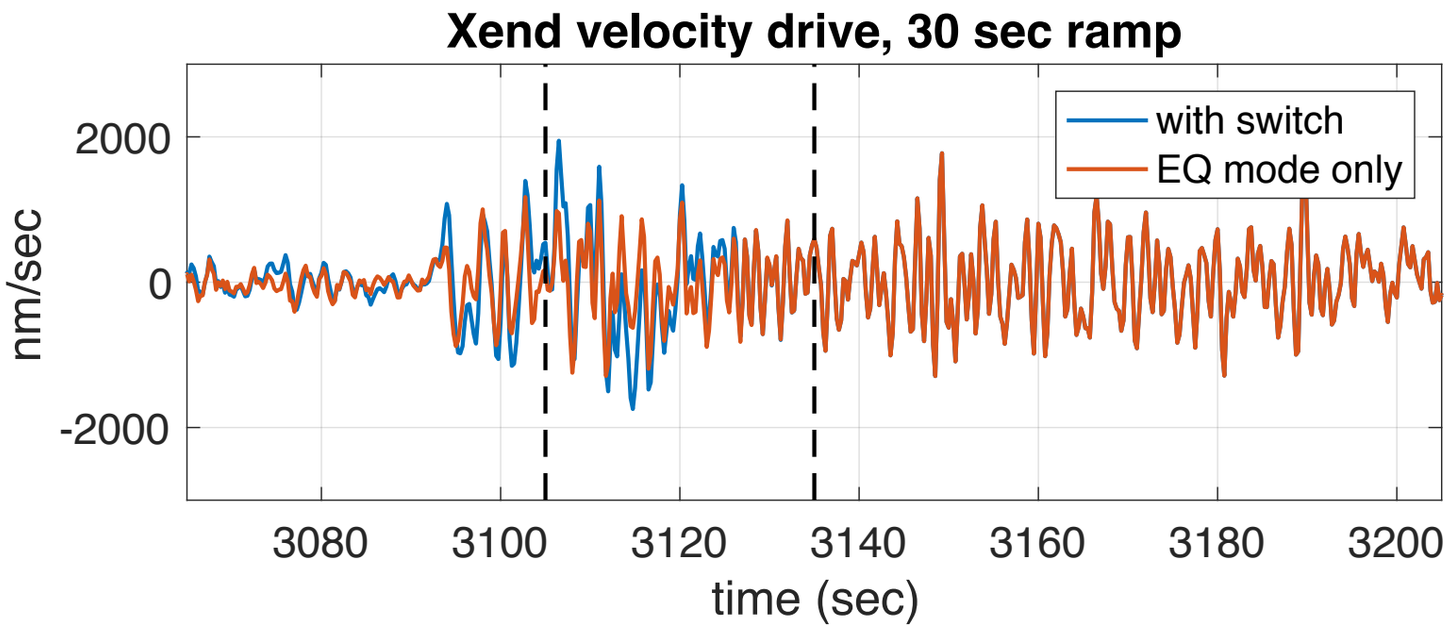
jump to end → epics momentary

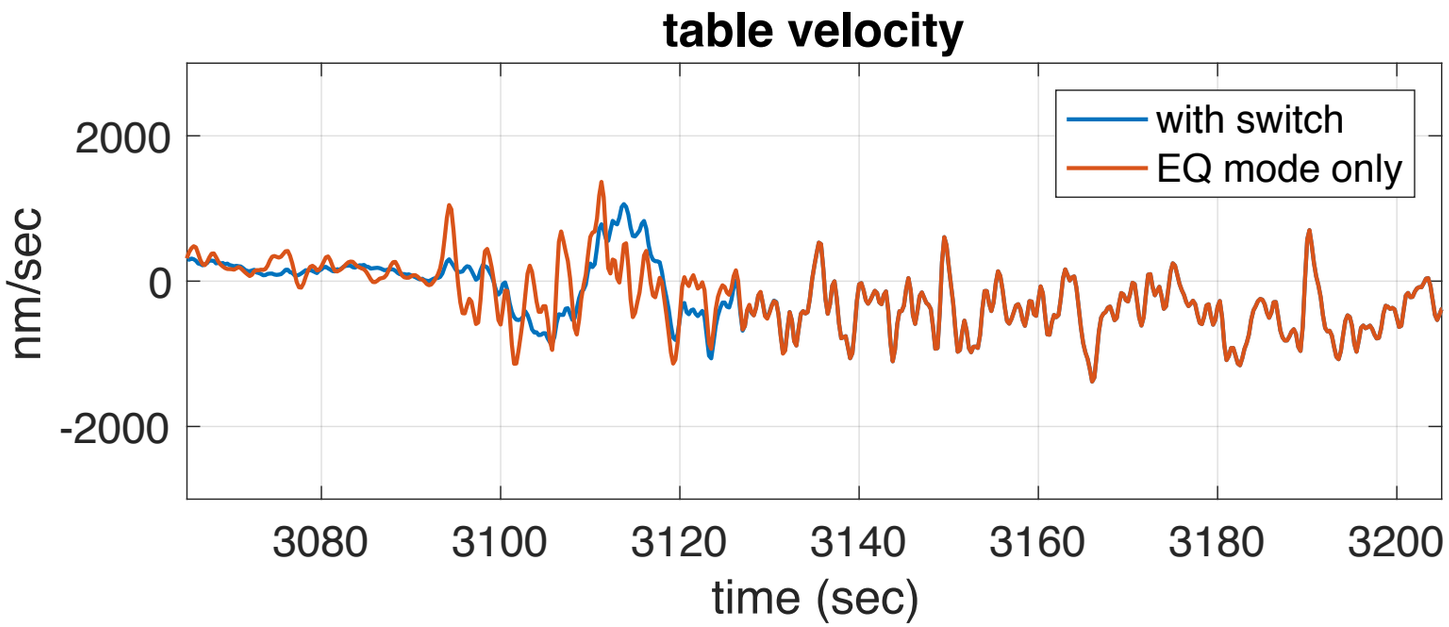
# Mode-switch transients

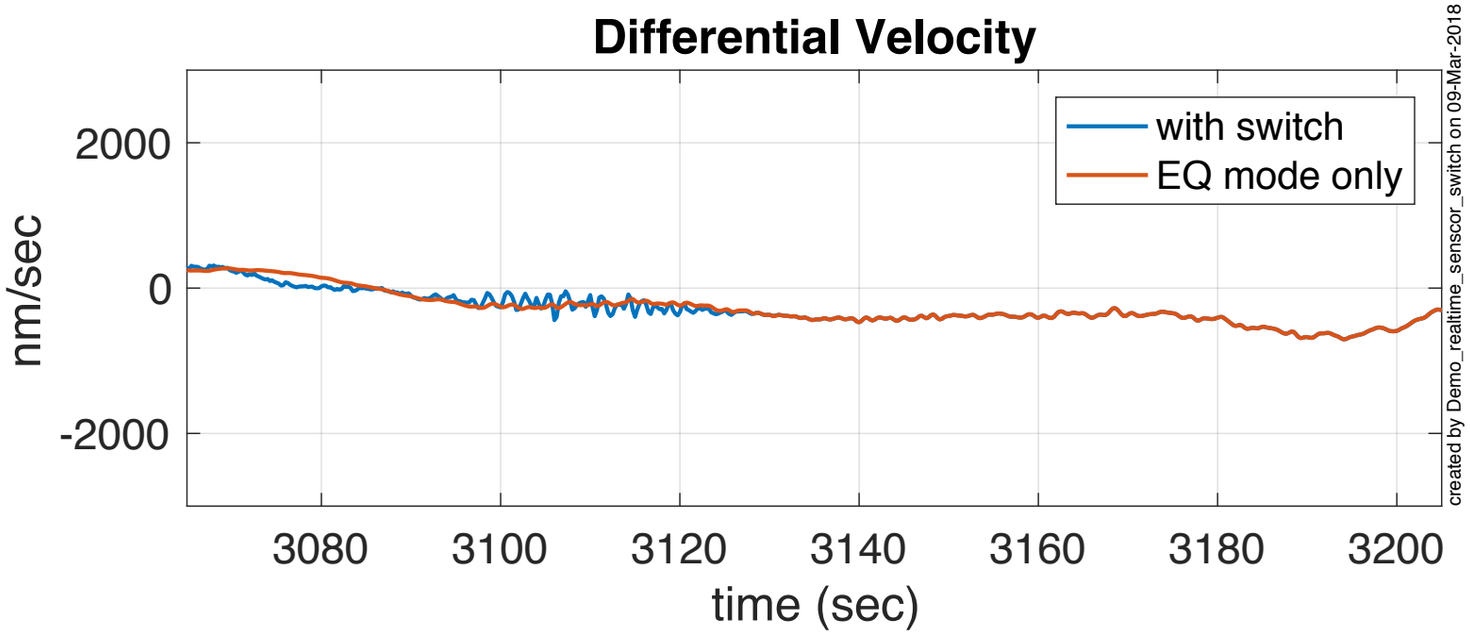
What happens if you switch control modes late, and the EQ has already arrived?



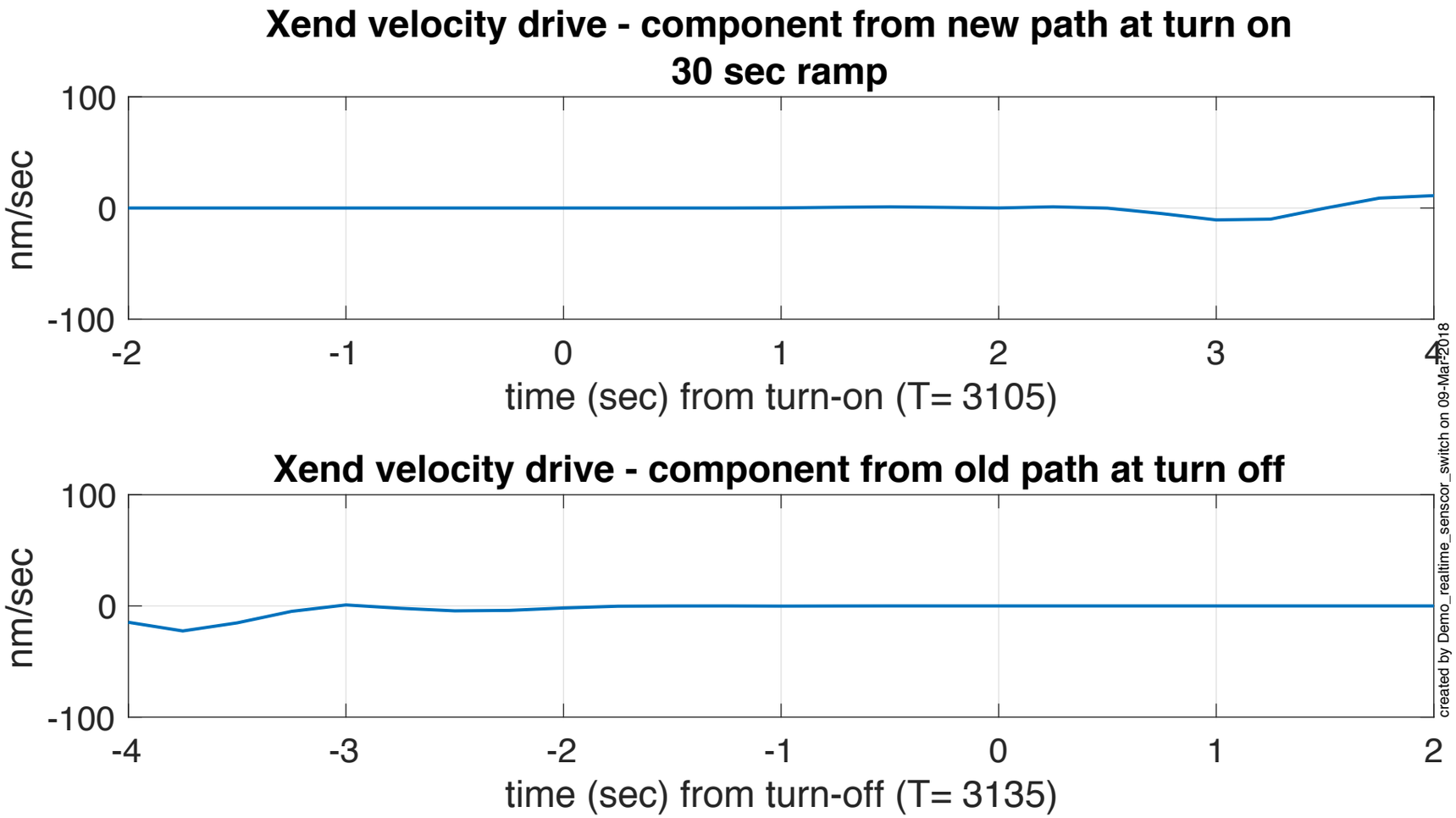
# Mode-switch transients



# mode switch transients



# Nikhil amplitude updates

USGS science for a changing world

Earthquake Hazards Program


↩ Earthquakes

Latest Earthquakes

Earthquake Lists, Maps & Statistics

Search Earthquake Catalog

Real-time Notifications, Feeds & Web Services

Information by Region

ANSS ComCat Documentation

Errata for Latest Earthquakes

Earthquakes

Hazards

Data & Products

Learn

Monitoring

Research


## Earthquake Statistics

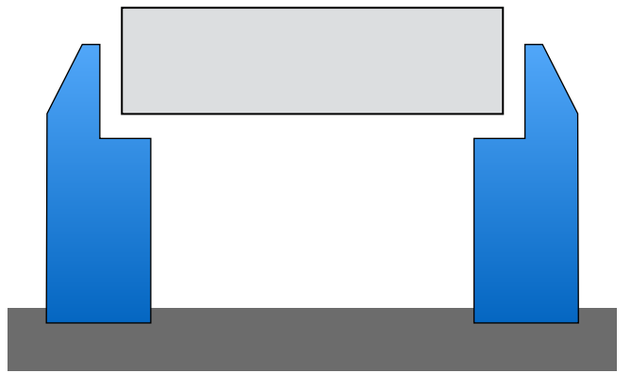
### Worldwide Earthquakes 2000–2016

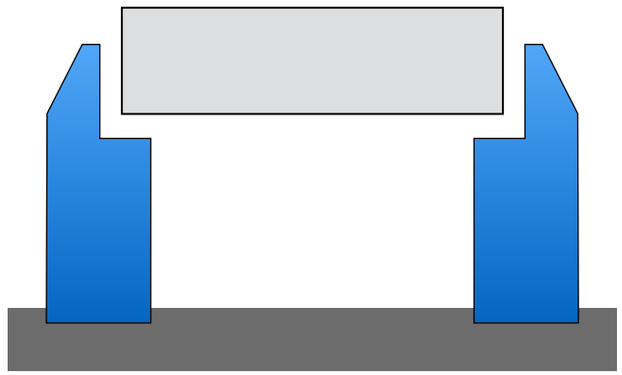
td>6

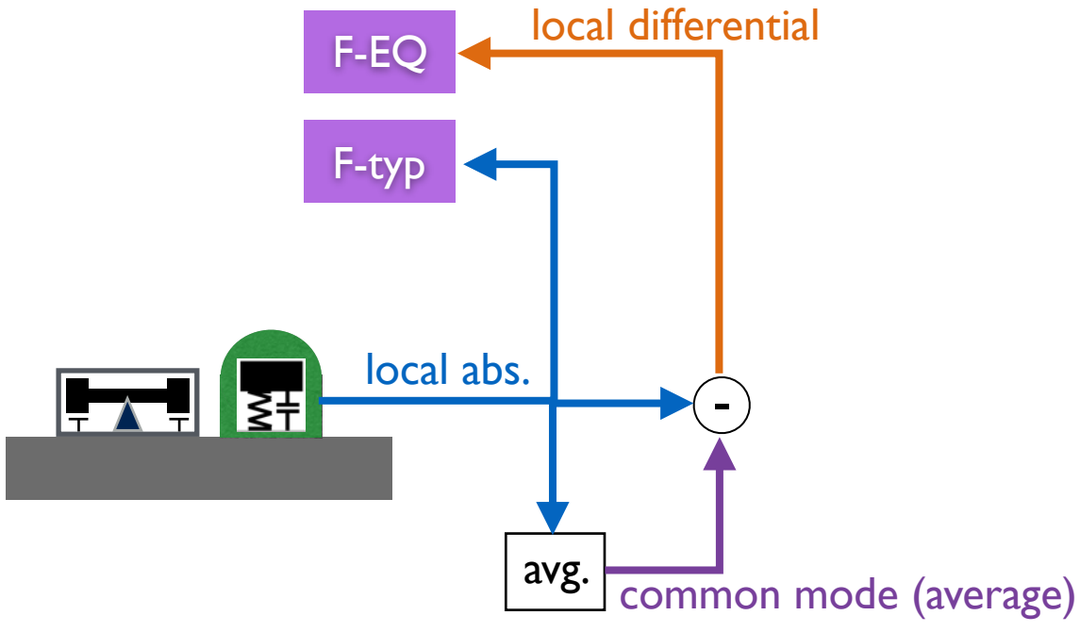
| Magnitude | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8.0+** | 1 | 1 | 0 | 1 | 2 | 1 | 2 | 4 | 0 | 1 | 1 | 1 | 2 | 2 | 1 | 1 | 0 | 1 |
| **7–7.9** | 14 | 15 | 13 | 14 | 14 | 10 | 9 | 14 | 12 | 16 | 23 | 19 | 12 | 17 | 11 | 18 | 16 | |
| **6–6.9** | 146 | 121 | 127 | 140 | 141 | 140 | 142 | 178 | 168 | 144 | 150 | 185 | 108 | 123 | 143 | 127 | 130 | 104 |
| **5–5.9** | 1344 | 1224 | 1201 | 1203 | 1515 | 1693 | 1712 | 2074 | 1768 | 1896 | 2209 | 2276 | 1401 | 1453 | 1574 | 1419 | 1550 | 1455 |
| **Estimated Deaths** | 231 | 21357 | 1685 | 33819 | 298101 | 87992 | 6605 | 708 | 88708 | 1790 | 226050 | 21942 | 689 | 1572 | 756 | 9624 | | |

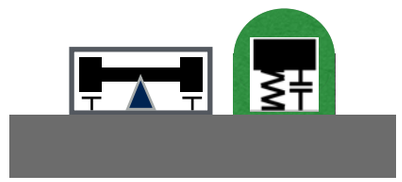
### United States Earthquakes 2000–2012

| Magnitude | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **8+** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **7–7.9** | 0 | 1 | 1 | 2 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 1 | 0 |
| **6–6.9** | 6 | 5 | 4 | 7 | 2 | 4 | 7 | 9 | 9 | 4 | 8 | 3 | 5 |
| **5–5.9** | 63 | 41 | 63 | 54 | 25 | 47 | 51 | 72 | 85 | 58 | 89 | 51 | 27 |






F-EQ
local differential
F-typ
local abs.
-
avg.
common mode (average)



SEISMON_V2_CUST.adl

SEISMON System Time (GPS): 1186379290 System Uptime (S): 116578 Keep Alive:

## EARTHQUAKE 1

TIME (UTC): 2017-08-10 03:44:06 UTC

LOCATION: Prince_of_Wales-Hyder,Alaska,United_Sta

MAGNITUDE: 4.200 DEPTH (KM): 1.000 LAT(DEG): 54.500 LONG(DEG): -134.100 DISTANCE(KM): 1.339e+06

| | TIME(GPS) | MIN | SEC | Velocity |
|---|---|---|---|---|
| P-Wave Arrival: | 1186372036.700 | -120 | -54 | |
| S-Wave Arrival: | 1186372172.900 | -118 | 0 | |
| R35-Wave Arrival: | 1186372246.700 | -117 | -24 | 7.7407e-07 |

## EARTHQUAKE 2

TIME (UTC): 2017-08-10 00:43:18 UTC

LOCATION: Lila,Bohol,Central_Visayas,Philippines

MAGNITUDE: 5.000 DEPTH (KM): 528.100 LAT(DEG): 9.500 LONG(DEG): 124.100 DISTANCE(KM): 1.117e+07

| | TIME(GPS) | MIN | SEC | Velocity |
|---|---|---|---|---|
| P-Wave Arrival: | 1186361831.900 | -290 | -59 | |
| S-Wave Arrival: | 1186362461.300 | -280 | 0 | |
| R35-Wave Arrival: | 1186364208.700 | -251 | -22 | 5.1483e-07 |

## EARTHQUAKE 3

TIME (UTC): 2017-08-10 00:36:29 UTC

LOCATION: Yachoyo_Bypass,Yachiyo,Chiba,Japan

MAGNITUDE: 5.000 DEPTH (KM): 59.600 LAT(DEG): 35.700 LONG(DEG): 140.100 DISTANCE(KM): 7.915e+06

| | TIME(GPS) | MIN | SEC | Velocity |
|---|---|---|---|---|
| P-Wave Arrival: | 1186361279.900 | -300 | -11 | |
| S-Wave Arrival: | 1186361832.900 | -290 | 0 | |
| R35-Wave Arrival: | 1186362868.900 | -273 | -42 | 4.3241e-07 |

## EARTHQUAKE 4

TIME (UTC): 2017-08-09 22:56:19 UTC

LOCATION: Ã¼kurgÃ¶l,Ã¼iftlikkÃ¶y,Bodrum,MuÃ¼la,A

MAGNITUDE: 4.100 DEPTH (KM): 10.000 LAT(DEG): 36.900 LONG(DEG): 27.600 DISTANCE(KM): 1.019e+07

| | TIME(GPS) | MIN | SEC | Velocity |
|---|---|---|---|---|
| P-Wave Arrival: | 1186355384.400 | -310 | -34 | |
| S-Wave Arrival: | 1186356016.600 | -300 | 0 | |
| R35-Wave Arrival: | 1186357508.100 | -275 | -10 | 3.1190e-07 |

## EARTHQUAKE 5

TIME (UTC): 2017-08-09 21:05:56 UTC

LOCATION: S301,Longkang,Jiuzhaigou_County,Ngawa_T

MAGNITUDE: 4.600 DEPTH (KM): 10.000 LAT(DEG): 33.300 LONG(DEG): 104.000 DISTANCE(KM): 1.013e+07

| | TIME(GPS) | MIN | SEC | Velocity |
|---|---|---|---|---|
| P-Wave Arrival: | 1186348759.600 | -331 | 0 | |
| S-Wave Arrival: | 1186349391.200 | -320 | 0 | |
| R35-Wave Arrival: | 1186350869.300 | -295 | -50 | 3.5304e-07 |