
CERN

MKBH erratics and experience with MKB retrigger system

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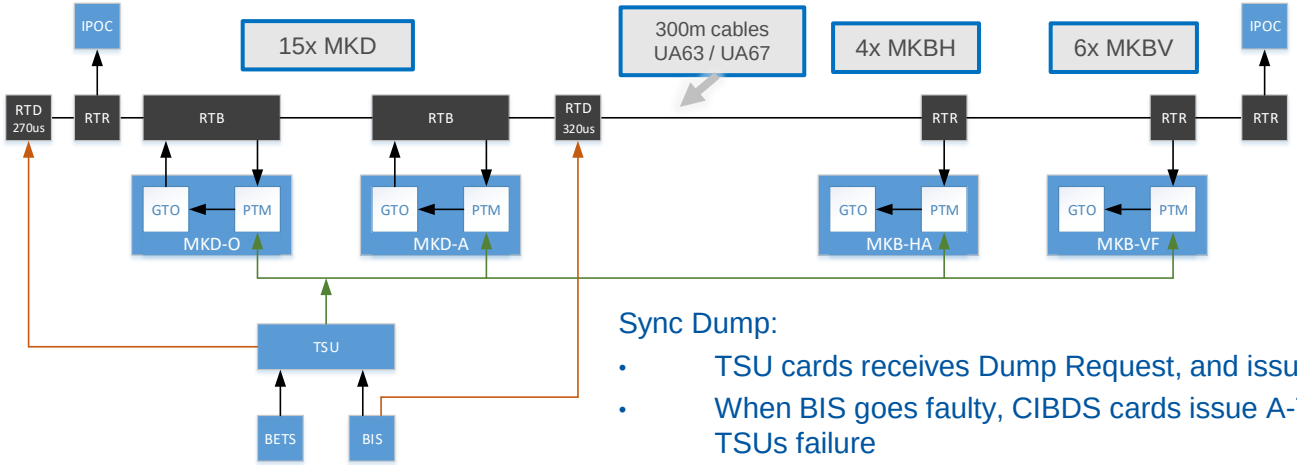
Outline

- Re-Triggering system before LS2 – Dilution issues
- New re-triggering system after LS2
- New IPOC channels for improved diagnosis
- New XPOC modules for validation of good shape of re-triggering system
- Re-trigger test sequence
- MKB erratic event in 2023

LBDS RTL upgrade

- New MKB re-triggering system study presented at MPP 27.04.2018:
  - https://indico.cern.ch/event/724736/contributions/2981141/attachments/1641036/2620626/2018-04-27_MPP_MKB_retriggering.pdf
- LS2 RTL upgrade presented at MPP Workshop 07.05.2019:
  - https://indico.cern.ch/event/803870/contributions/3398065/attachments/1839749/3015770/MPP_Workshop_05.2019_LBDS_Upgrades_v1.pdf

Former Re-Triggering System



Sync Dump:

- TSU cards receives Dump Request, and issue S-TRIG and A-TRIG (270us)
- When BIS goes faulty, CIBDS cards issue A-TRIG (320us) – In case of total TSUs failure

Async Dump – MKD erratic:

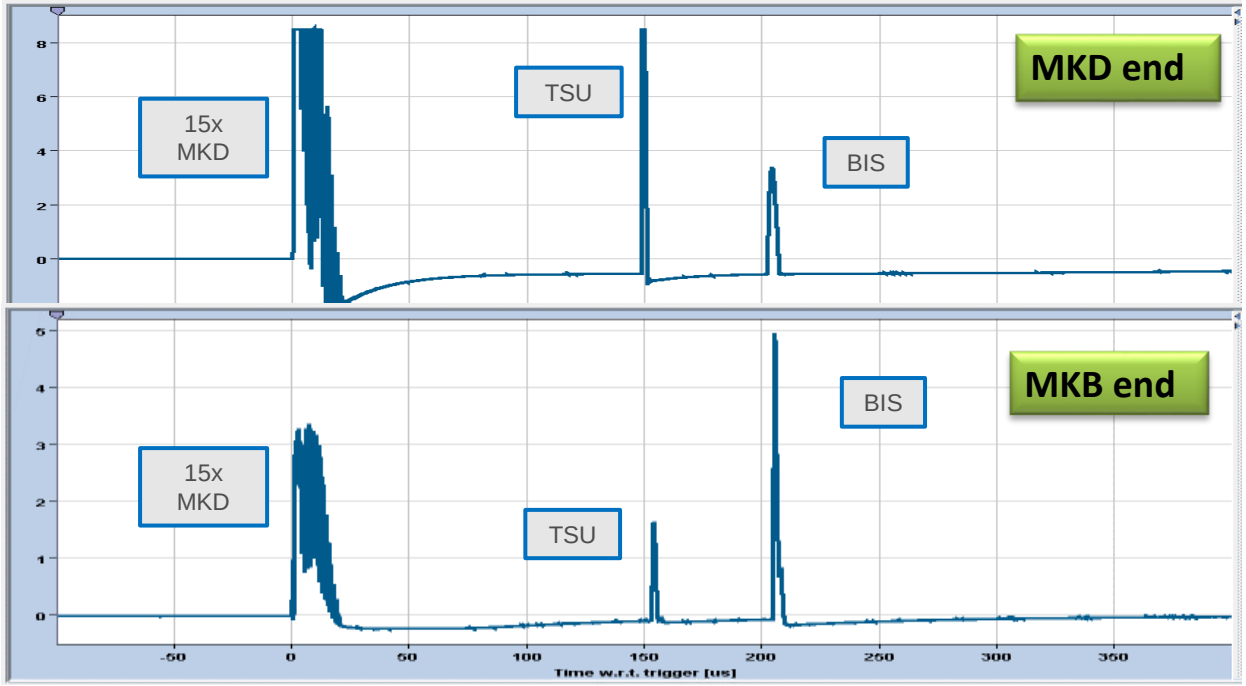
- MKD Re-Trigger boxes: Inject energy on the RTL in case of MKD erratic

Diagnosis: IPOC at both ends to the RTL Validation of RTL continuity

- Check TSU/BIS pulses presence (Redundant pulses not participating to normal dumps)

Former Re-Trigger Line Diagnosis - IPOC

Voltage on RTL for a synchronous dump at **450 GeV**



Redundant pulses do not participate to normal dump

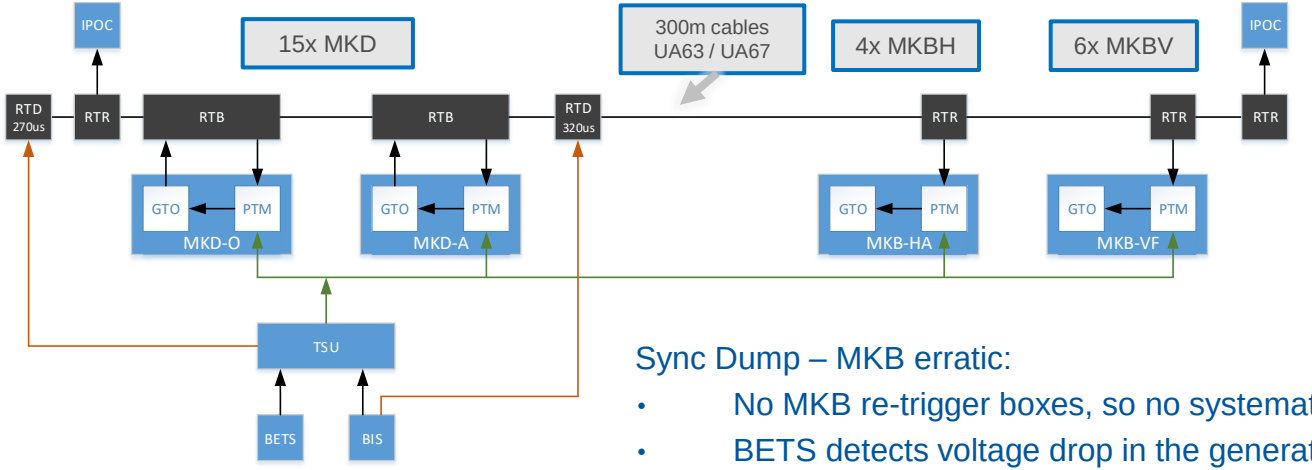
How do we know that they are OK ?

=> Checks continuity of RTL and presence of TSU/BIS pulses on RTL

Acquisition of waveforms of the two RTL.

- IPOC measure time and amplitude of two pulses on RTL
- XPOC check presence and correct delay of two pulses on RTL

Former Re-Triggering System – MKB Erratic



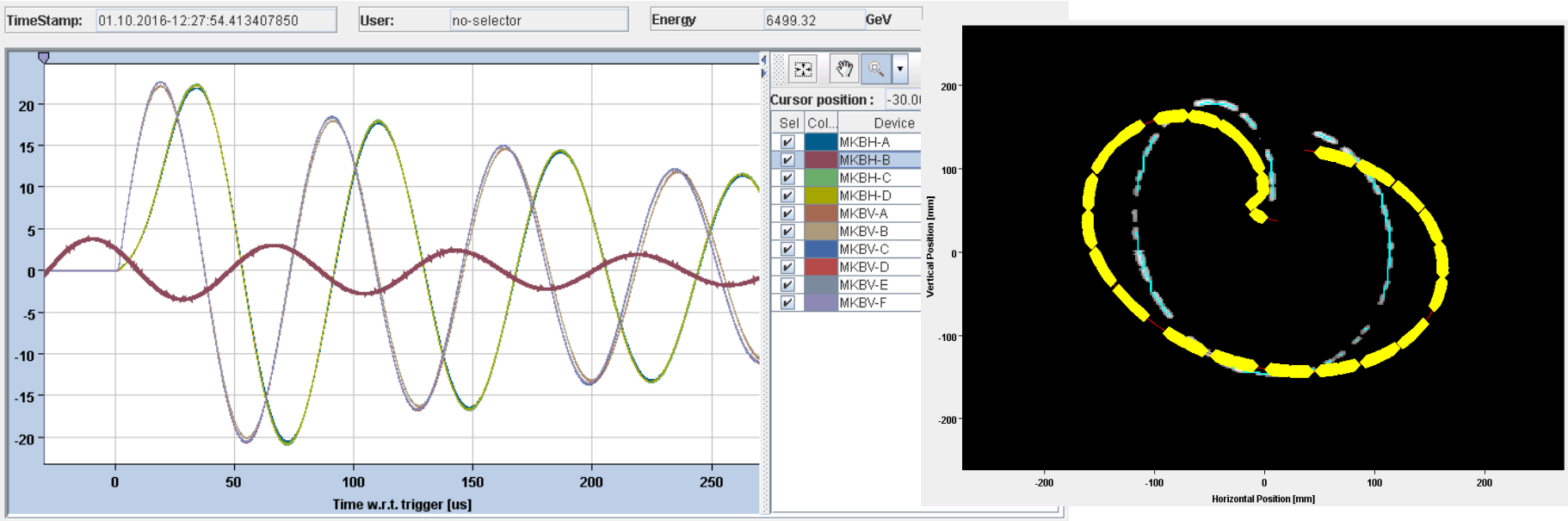
Sync Dump – MKB erratic:

- No MKB re-trigger boxes, so no systematic re-triggering of other kickers.
- BETS detects voltage drop in the generator triggered erratically (Slow detection, typ 1ms)
- BETS requests dump to TSU, then sync trigger all MKD / MKBs

⇒This could yield in phase opposition between MKB magnets !
⇒+ Problem of coupling between MKBH HV generators = loss of more than 2 MKBH !

=> We need a MKB Re-Triggering System

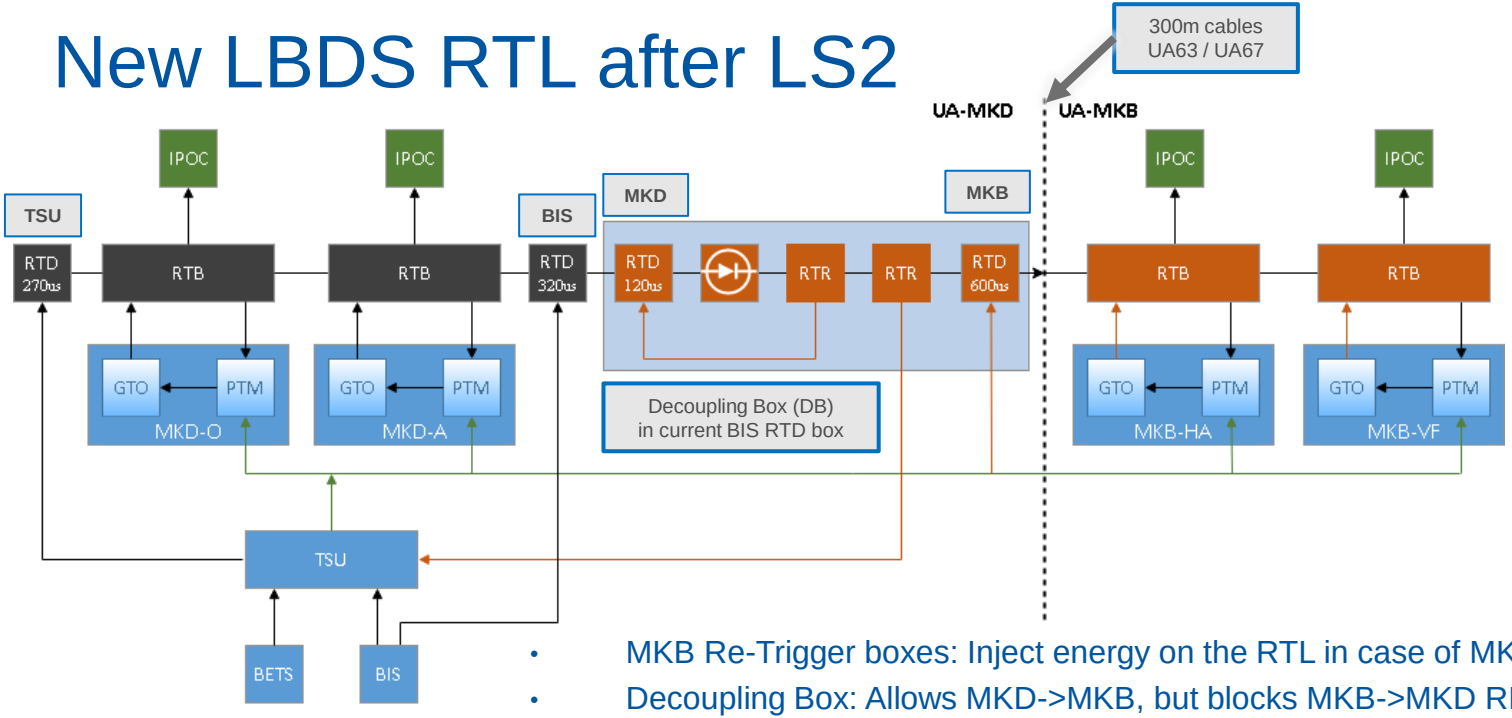
MKB erratic – phase opposition



Erratic detected by BETS, Sync Trigger after ~ 1ms.

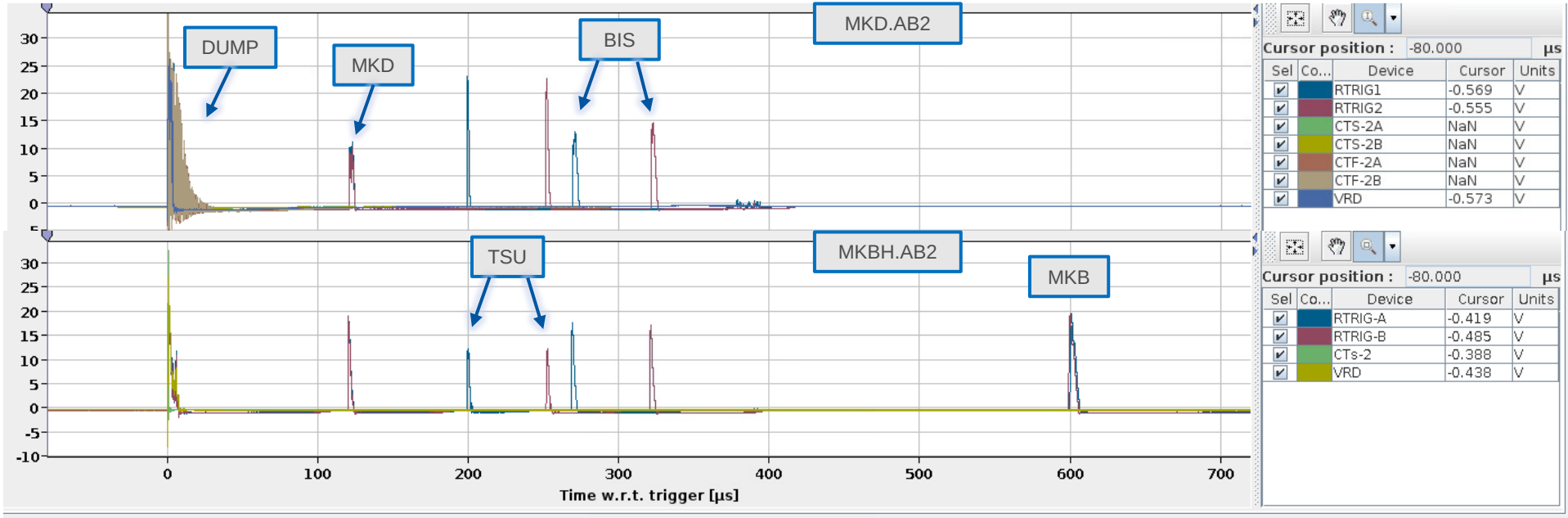
MKBH.BB1 not completely discharged, and in phase opposition with other MKBs.
=> Lost more than 1 MKBH (~1.2 in this case)

New LBDS RTL after LS2



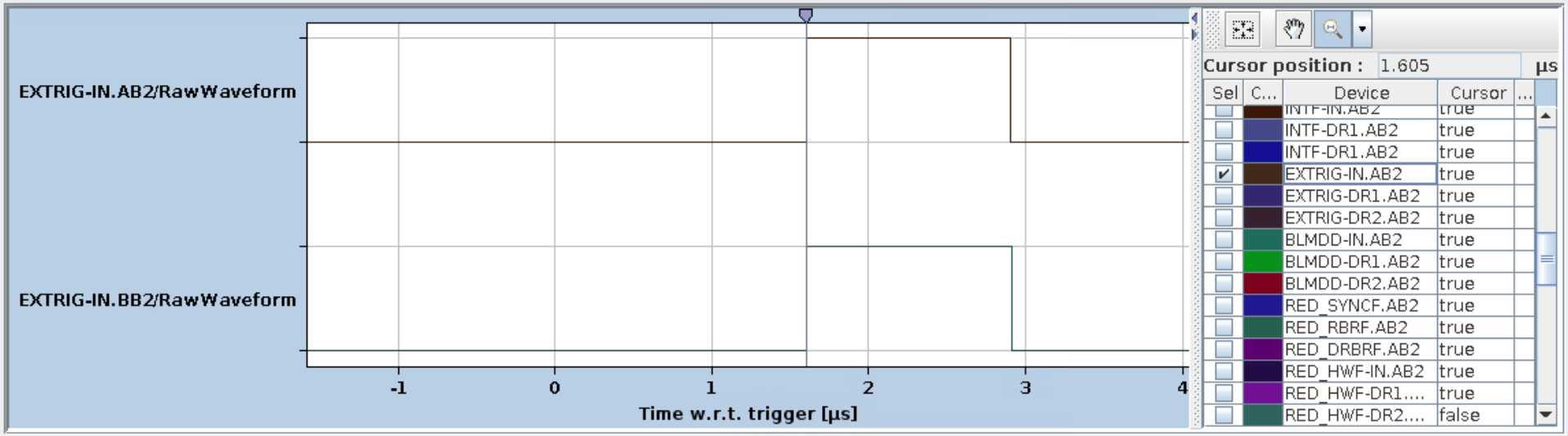
- MKB Re-Trigger boxes: Inject energy on the RTL in case of MKB erratic
- Decoupling Box: Allows MKD->MKB, but blocks MKB->MKD RLT pulses
- New RTR to detect MKB erratic, and request a dump to TSUs (EXTRIG)
- New RTD 120 us to do async dump in case TSU do not react in <1 revolution
- New RTD 600 us to check decoupling diodes are blocking MKB erratic.
- New PTC card allows access to one RTB signals for IPOC on each HV generator

New IPOC channels for RTB signals



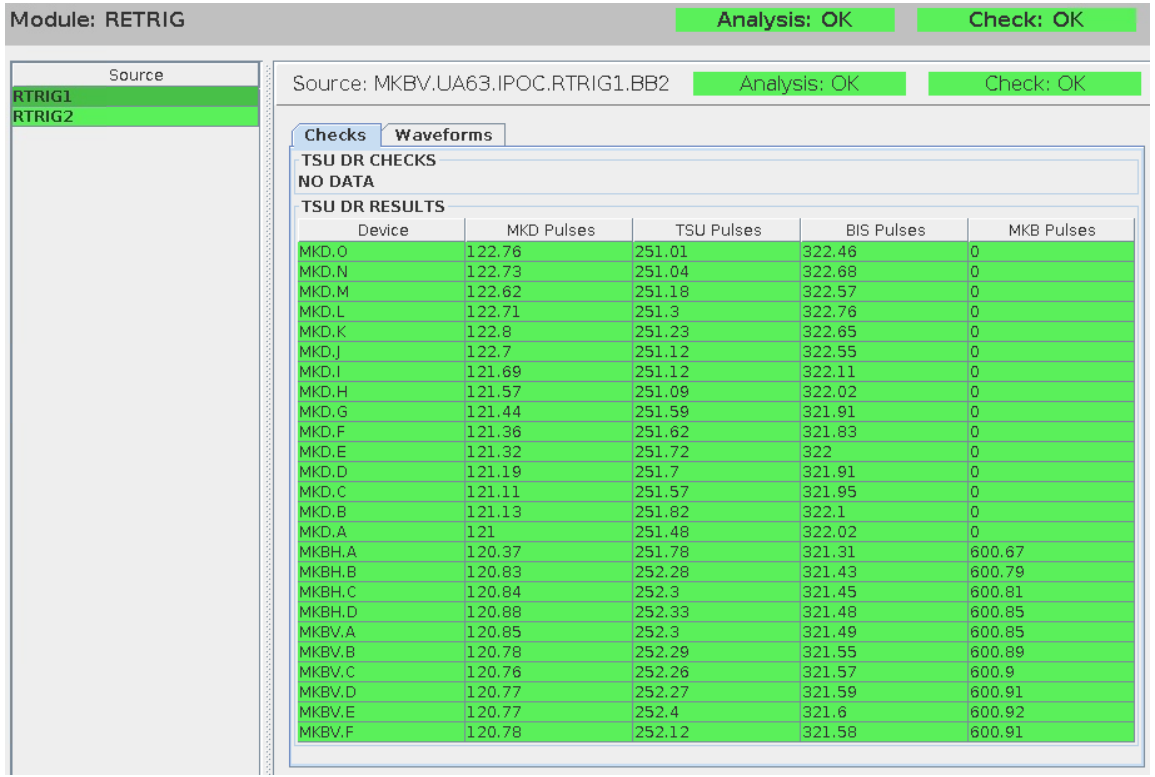
- Acquisition of waveforms of two RTLs and inputs of one RTB (coming from HV generators)
- IPOC measures the amplitude and time of the four pulses on both RTL (MKD, TSU, BIS, MKB)
- MKB pulse not present on MKD side (blocked by diode)

IPOC acquisition of TSU EXTRIG from MKB RTL



- Acquisition of waveforms of EXTRIG at input of the two TSUs (coming from MKB RTL)
- IPOC measures the delay and width of the pulses.
- Delay ~1.6 us after dump (300m cable from MKBs to TSUs) and width 1.3 us

New XPOC RETRIG module

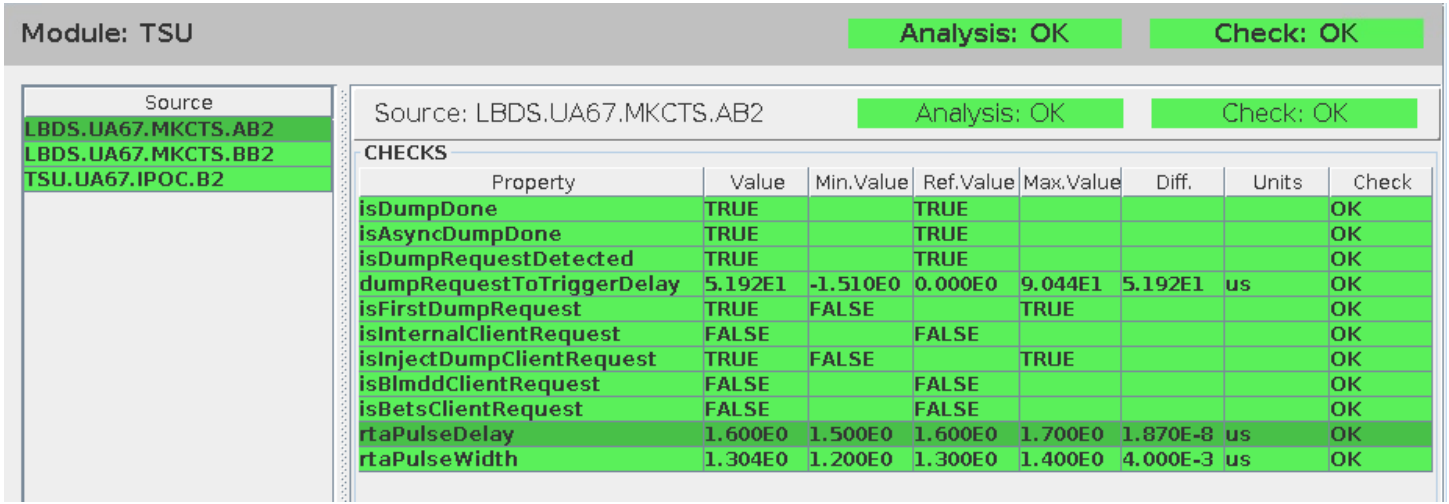


Device	MKD Pulses	TSU Pulses	BIS Pulses	MKB Pulses
MKD.O	122.76	251.01	322.46	0
MKD.N	122.73	251.04	322.68	0
MKD.M	122.62	251.18	322.57	0
MKD.L	122.71	251.3	322.76	0
MKD.K	122.8	251.23	322.65	0
MKD.J	122.7	251.12	322.55	0
MKD.I	121.69	251.12	322.11	0
MKD.H	121.57	251.09	322.02	0
MKD.G	121.44	251.59	321.91	0
MKD.F	121.36	251.62	321.83	0
MKD.E	121.32	251.72	322	0
MKD.D	121.19	251.7	321.91	0
MKD.C	121.11	251.57	321.95	0
MKD.B	121.13	251.82	322.1	0
MKD.A	121	251.48	322.02	0
MKBH.A	120.37	251.78	321.31	600.67
MKBH.B	120.83	252.28	321.43	600.79
MKBH.C	120.84	252.3	321.45	600.81
MKBH.D	120.88	252.33	321.48	600.85
MKBV.A	120.85	252.3	321.49	600.85
MKBV.B	120.78	252.29	321.55	600.89
MKBV.C	120.76	252.26	321.57	600.9
MKBV.D	120.77	252.27	321.59	600.91
MKBV.E	120.77	252.4	321.6	600.92
MKBV.F	120.78	252.12	321.58	600.91

Check presence of four pulses on RTL

- XPOC get the IPOC measures of the four pulses on RTL on every HV generator
- XPOC RETRIG module checks the presence and correct delay of the four pulses on the two RTL
- Check at the level of every MKD and MKB HV generators
- On MKB side all four pulses should be present
- On MKD side the ‘MKB’ pulse 600 us after dump should **NOT** be present (diode blocking)

Upgrade of XPOC TSU module



Module: TSU — Analysis: OK — Check: OK

Source
LBDS.UA67.MKCTS.AB2
LBDS.UA67.MKCTS.BB2
TSU.UA67.IPOC.B2

Source: LBDS.UA67.MKCTS.AB2 — Analysis: OK — Check: OK

CHECKS

Property	Value	Min.Value	Ref.Value	Max.Value	Diff.	Units	Check
isDumpDone	TRUE		TRUE				OK
isAsyncDumpDone	TRUE		TRUE				OK
isDumpRequestDetected	TRUE		TRUE				OK
dumpRequestToTriggerDelay	5.192E1	-1.510E0	0.000E0	9.044E1	5.192E1	us	OK
isFirstDumpRequest	TRUE	FALSE		TRUE			OK
isInternalClientRequest	FALSE		FALSE				OK
isInjectDumpClientRequest	TRUE	FALSE		TRUE			OK
isBlmddClientRequest	FALSE		FALSE				OK
isBetsClientRequest	FALSE		FALSE				OK
rtaPulseDelay	1.600E0	1.500E0	1.600E0	1.700E0	1.870E-8	us	OK
rtaPulseWidth	1.304E0	1.200E0	1.300E0	1.400E0	4.000E-3	us	OK

Check connection between MKB RTL and TSU cards

- XPOC gets the IPOC measure of TSU ‘EXTRIG’ dump request coming from MKB RTL
- XPOC TSU module checks the presence, correct delay and width of pulse, to validate connection between TSU and MKB RTL

Re-Trigger Line Validation Tests

Performed minimum at the end of every YETS:

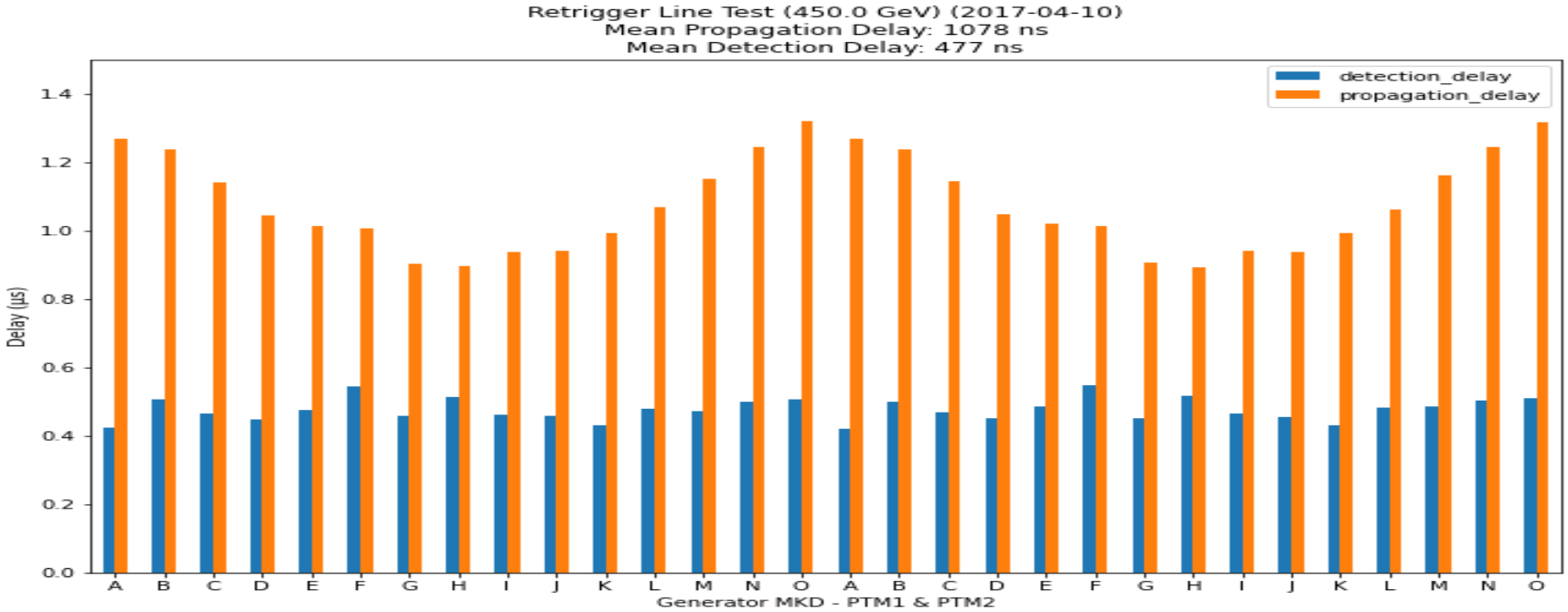
LOCAL Re-Trigger Line Test sequence:

- Simulation of self-trigger of all MKDs and MKBs (inject trigger in PTMs directly without using trigger distribution)
- For MKDs erratics, validate that all MKDs and MKBs are triggered
- For MKBs erratics, validate that only all MKBs are triggered, no MKDs (diode blocking)
- Measurement of re-trigger detection and propagation times

During Remote Reliability Run (with local BIS loops and TSUs armed in REMOTE):

- Simulation of self-trigger of few MKBs (inject trigger in PTMs directly without using trigger distribution)
- Check that all MKDs are triggered by the TSU in less than one LHC revolution
- Validation of all XPOC checks during normal dump

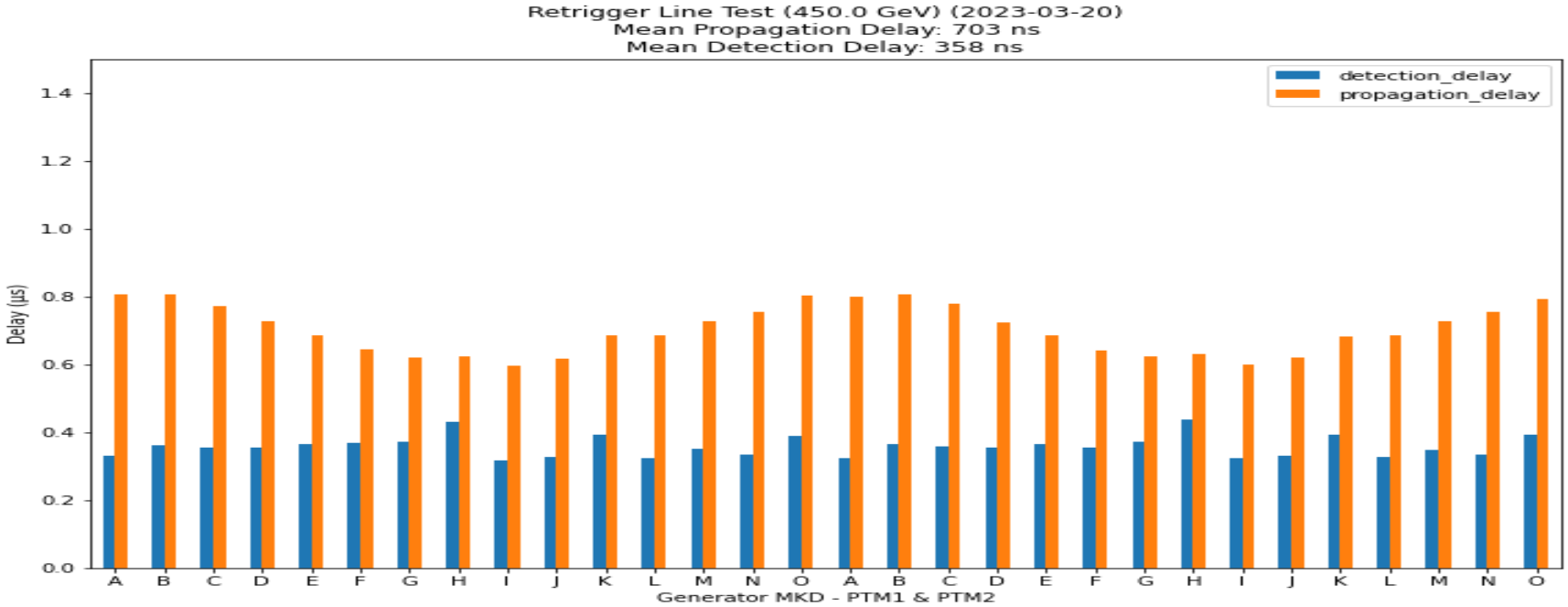
Re-Trigger test sequence – Before LS2



Long cables between each MKD generators, with weak pulses on re-trigger line

=> Up to 1.3 us needed to re-trigger all MKDs

Re-Trigger test sequence – After LS2



Shorten cables between each MKD generators with stronger pulses on re-trigger line

=> less than 0.8 us needed to re-trigger all MKDs

MKB erratic events

Two MKB erratics occurred in 2023:

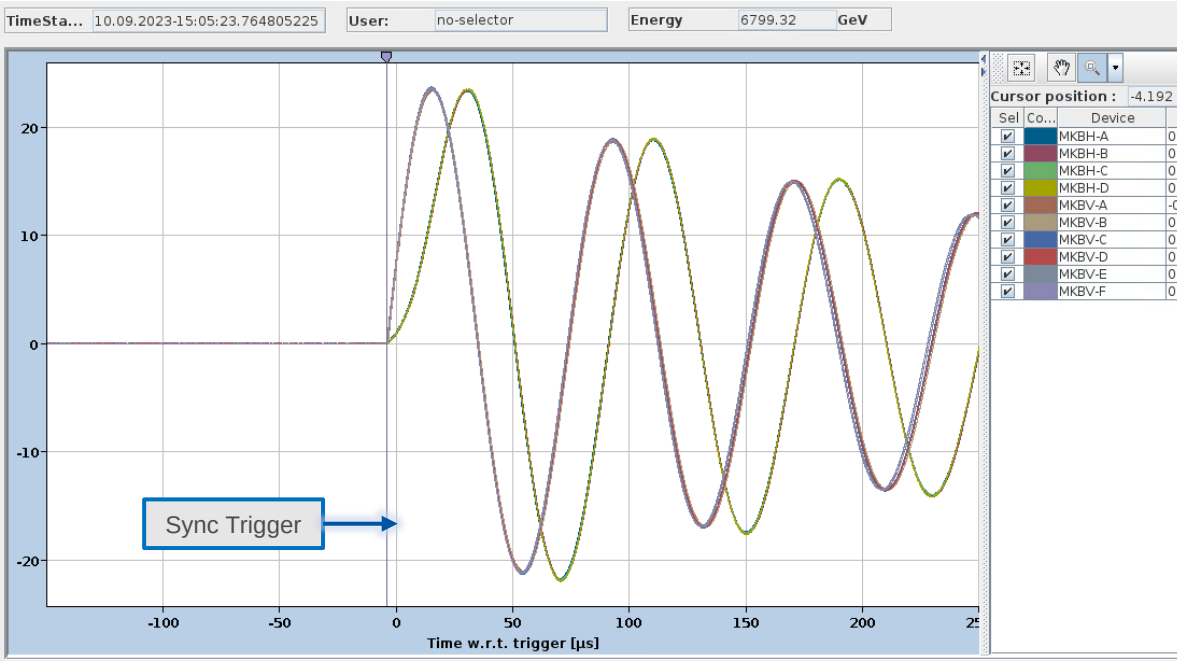
- MKBH.CB2 erratic on 10.09.2023
  - https://logbook.cern.ch/elogbook-server/GET/showEventInLogbook/3827812
- MKBH.CB2 erratic on 15.09.2023
  - https://logbook.cern.ch/elogbook-server/GET/showEventInLogbook/3830675

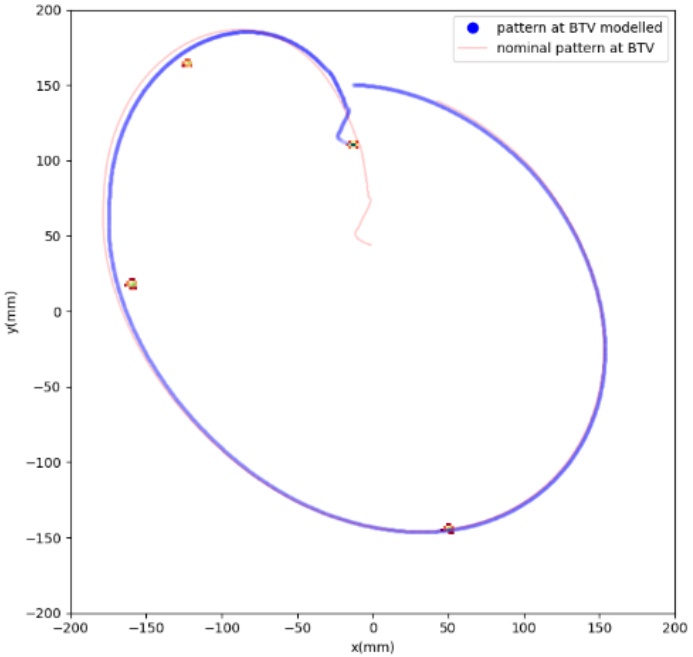
Both events resulted in synchronous beam extraction. No specific loss pattern.

Reduced dilution due to MKB erratic. But new retrigger system is accounted for the TDE specification.
=> All possible dilution patterns will not cause a failure of the TDE even with the full HL beam.

We are planning to review the procedure we established in case of MKB erratic, as now it is less critical for TDE (https://edms.cern.ch/document/1728268/1)

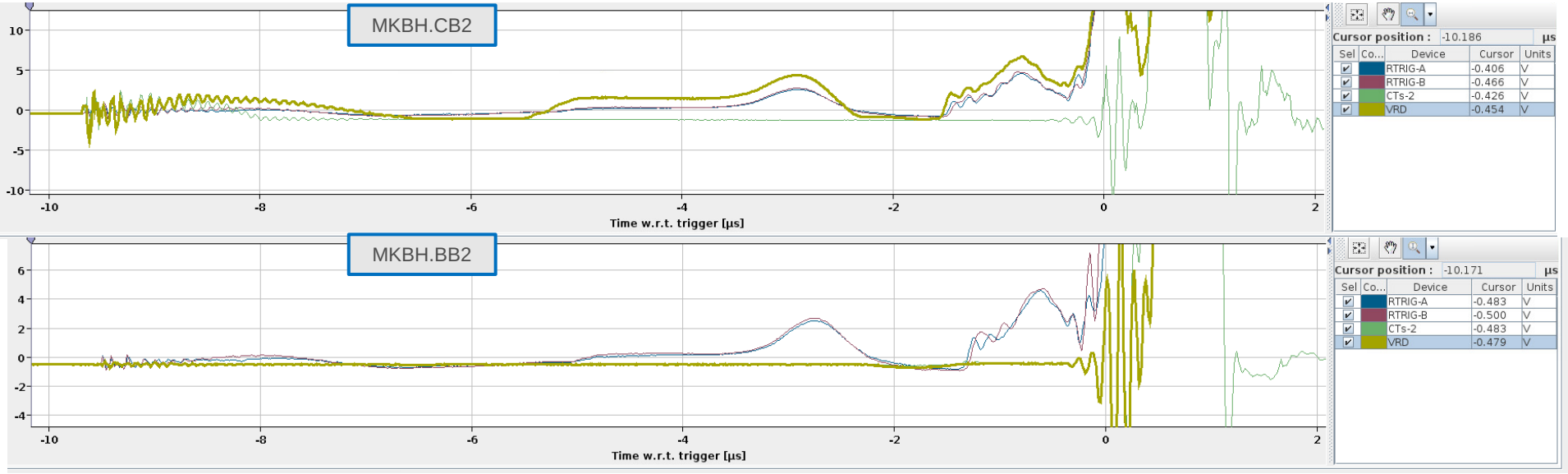
MKB erratic event on 10.09.2023





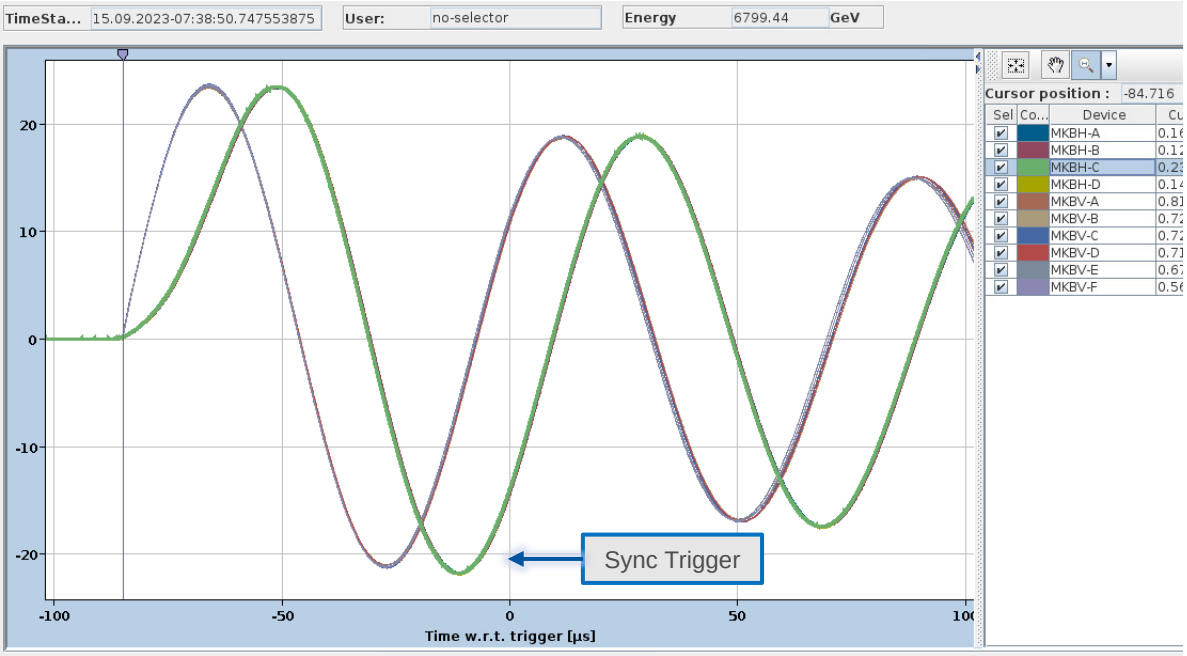
- All MKBs re-triggered after MKBH.CB2 erratic
- All MKDs synchronously triggered by TSU ~4 us later

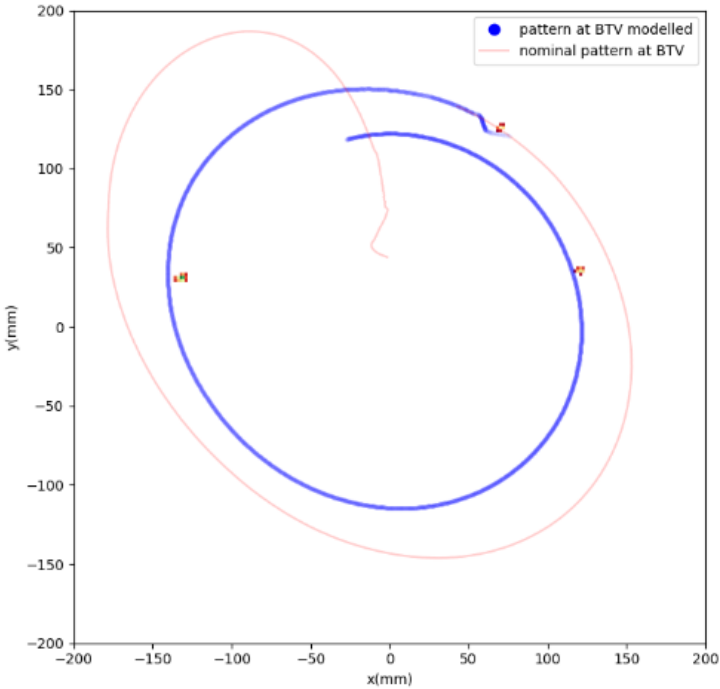
MKB erratic event on 10.09.2023



- Signal visible on input of RTB for MKBH.CB2 = source of signal on RTL
- No signal visible on input of RTB on other MKB generators (ex. MKBH.BB2), only signal on RTL
  => Clear identification of self-trigger of MKBH.CB2

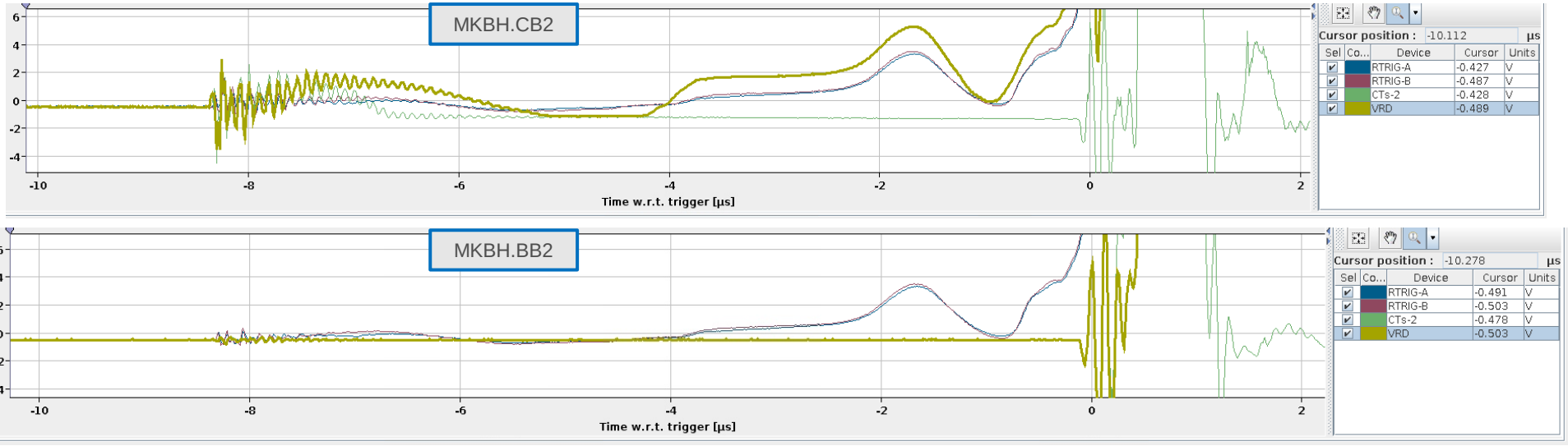
MKB erratic event on 15.09.2023





- All MKBs re-triggered after MKBH.CB2 erratic
- All MKDs synchronously triggered by TSU ~84 us later

MKB erratic event on 15.09.2023



- Signal visible on input of RTB for MKBH.CB2 = source of signal on RTL
- No signal visible on input of RTB on other MKB generators (ex. MKBH.BB2), only signal on RTL
  => Clear identification of self-trigger of MKBH.CB2

Summary

- New re-triggering system deployed during LS2
- Increased complexity in controls systems
- More post-operation checks needed to guarantee the good shape of re-triggering system

- New IPOC channels for acquisition of re-trigger line signals
- New XPOC modules to check correct behavior of re-triggering system

- New IPOC channels for acquisition of re-trigger signals improves diagnosis

- Improved MKD re-trigger line propagation delay (shorter cables and stronger re-trigger pulses)

- Correct behavior demonstrated with synchronous dump for two MKB erratics in 2023