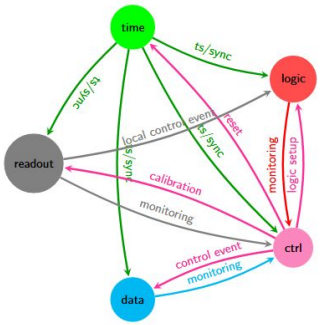
NUSTAR DAQ and slow control developments at GSI/FAIR

Mostly R3B and FRS…

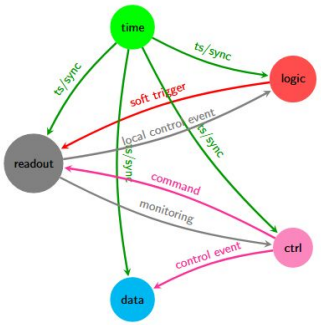
Hans Törnqvist, Chalmers University of Technology
On behalf of the NUSTAR collaboration

NDAQ (NUSTAR DAQ) TDR

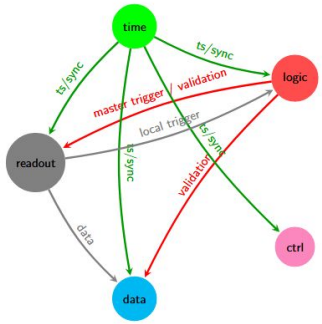
- Infrastructure concept
  - DAQ interfaces
  - Slow control interfaces

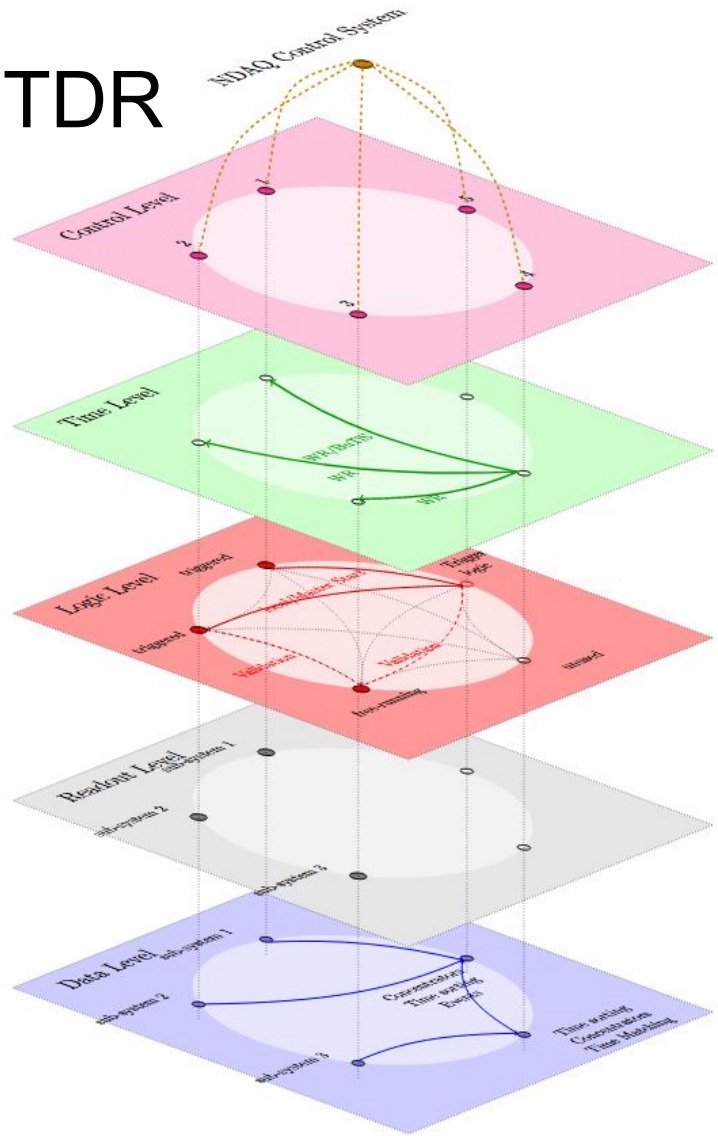


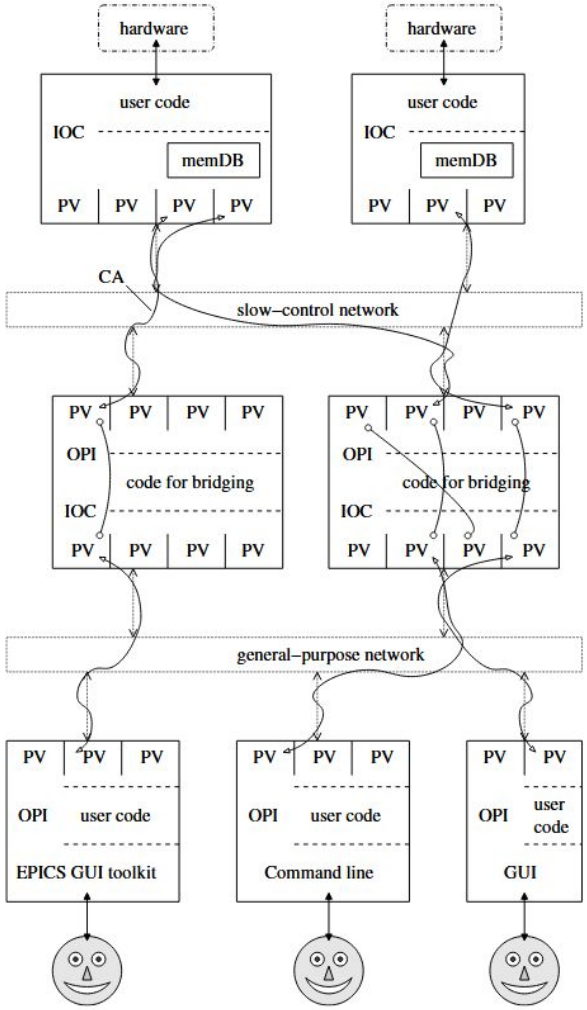
(a) Run Control.



(b) Slow Control.







https://fair-center.de/user/experiments/nustar/documents/technical-design-reports

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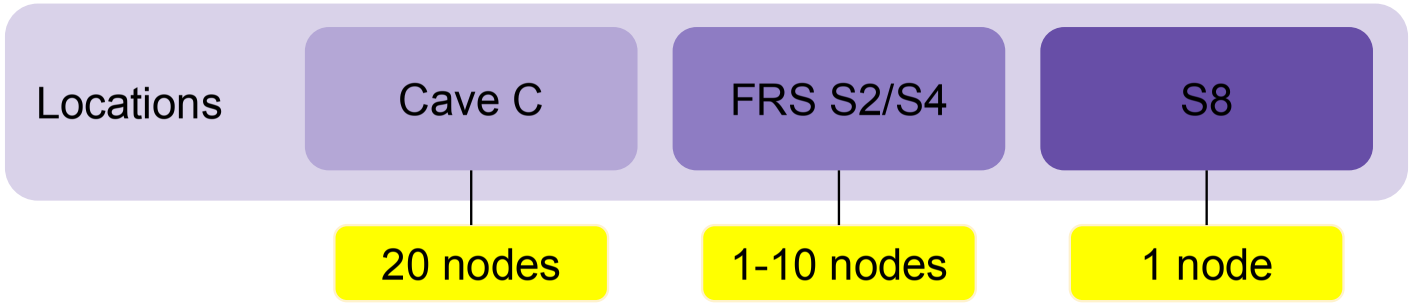
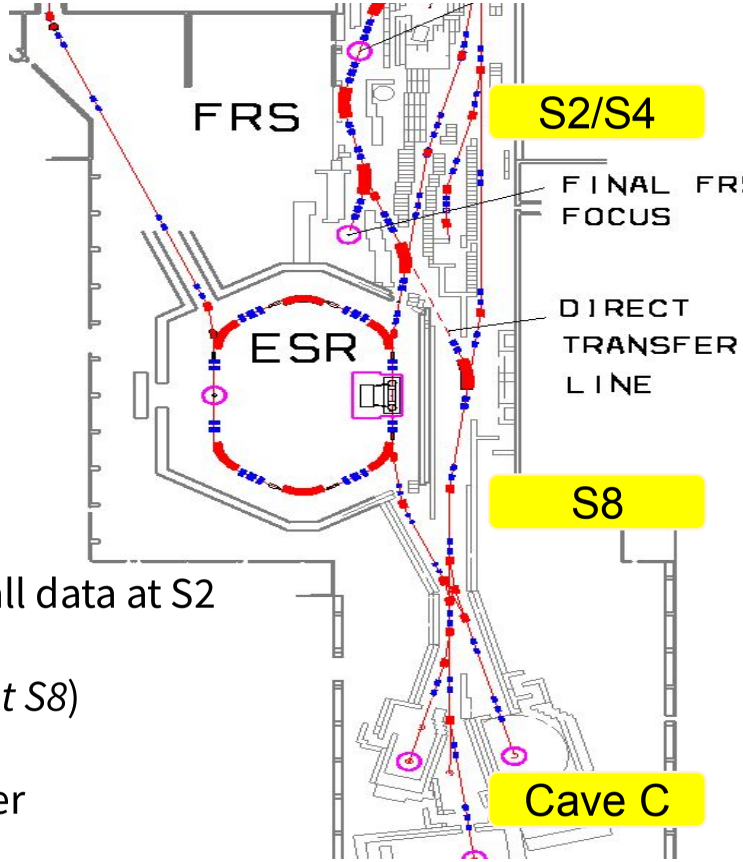
Locations





How do we combine?

- **Triggering**
  - Signals sent from Cave C to other locations → No need to collect all data at S2
- **Event synchronisation with timestamps**
  - White Rabbit time is used everywhere (*NEW: Now also available at S8*)
- **High resolution Time-of-Flight**
  - Derive phase-stable clock from White Rabbit or BuTiS → 30 ps jitter
- **Experiment data**
  - Central Timesorting

Who are the users?

- R3B
- FRS (FRS detectors)
- Gamma spectroscopy (FRS detectors)

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Common infrastructure

Common | Trigger | Clock | Time | Pulser

What's provided?

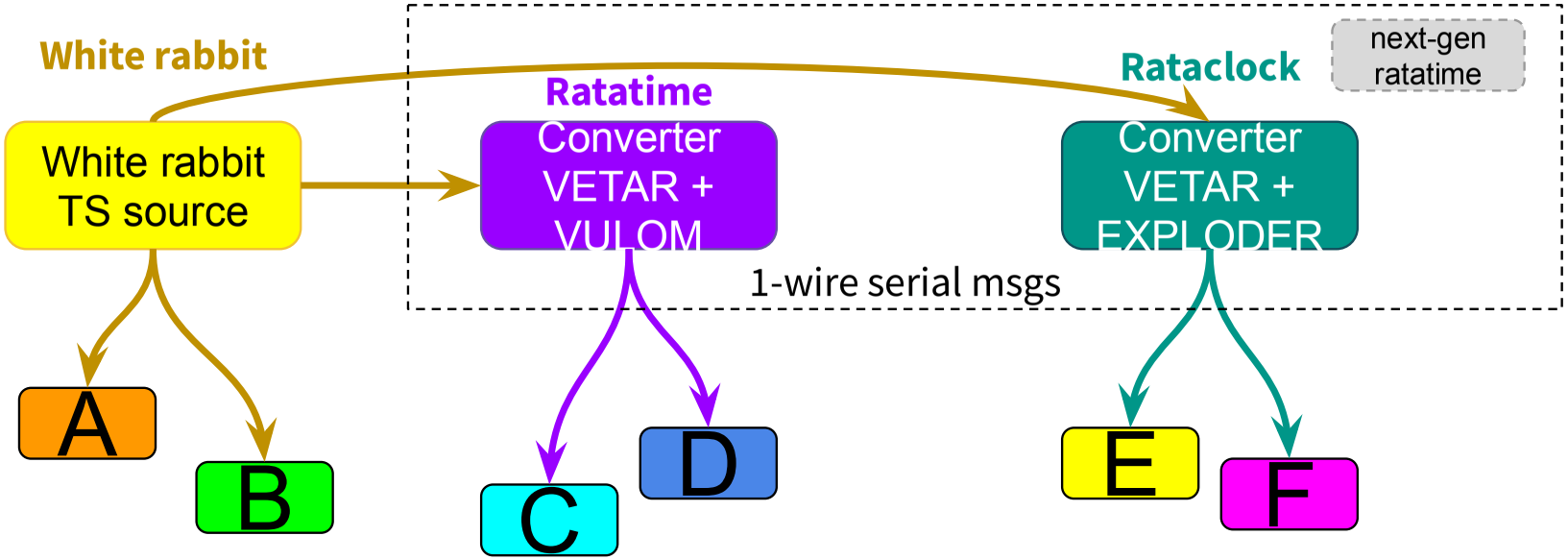
- Trigger and master start signal distribution from Cave C
- 200 MHz phase-stable synchronised clock in each location
- Connection to White Rabbit network in each location
- Logic pulser distribution from Cave C
- Analog signal simulator in Cave C, with recorded spill pattern (including micro spill structure)

How do we know it works?

- Check clock synchronisation via coarse counter tracking (ucesb: unpacking and event-data processing tool)
- Check timestamp correlation in the time sorter, displayed in tree view (drasi)

High precision timestamp distribution system

- 1 ns granularity timestamps across GSI



Users:

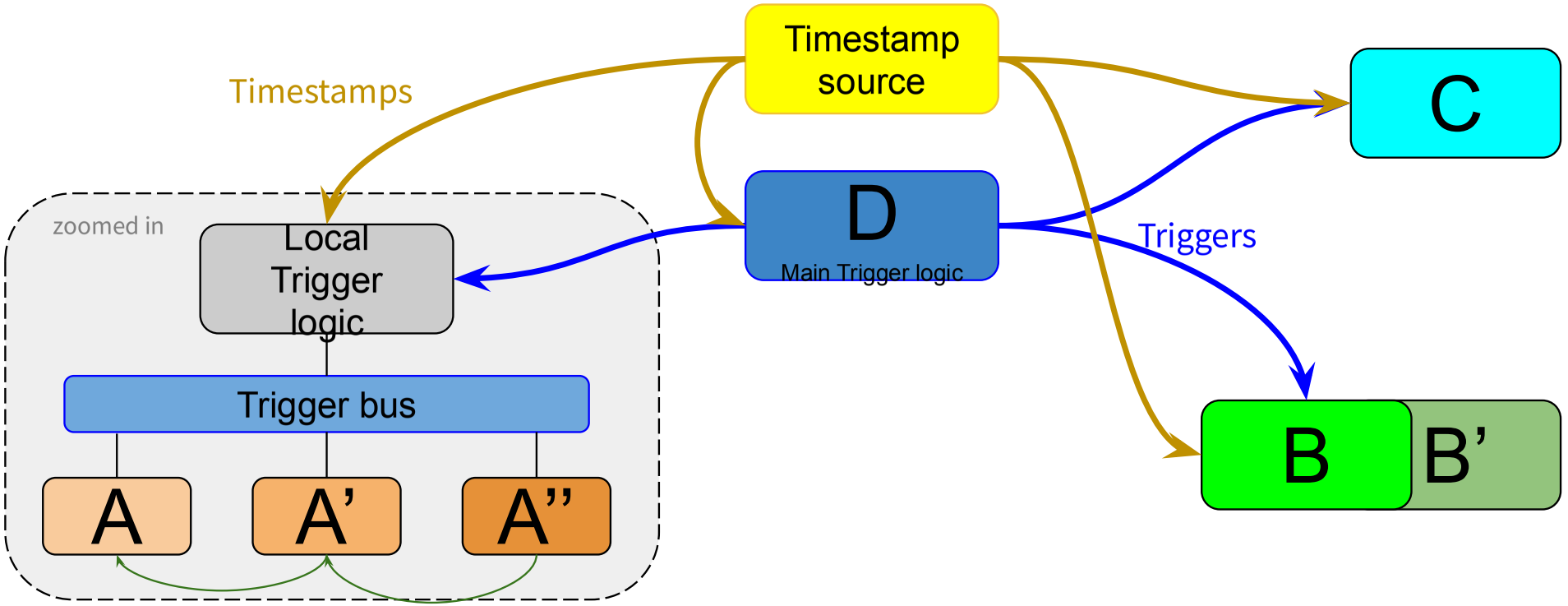
- CALIFA (local timestamp + interpolation)
- Neuland

- Master
- MUSIC
- S2

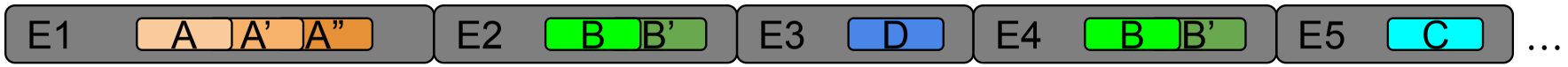
- FOOT
- RPC

Event synchronisation – Time distribution

Current R3B - relaxed coupling:



Data layout:



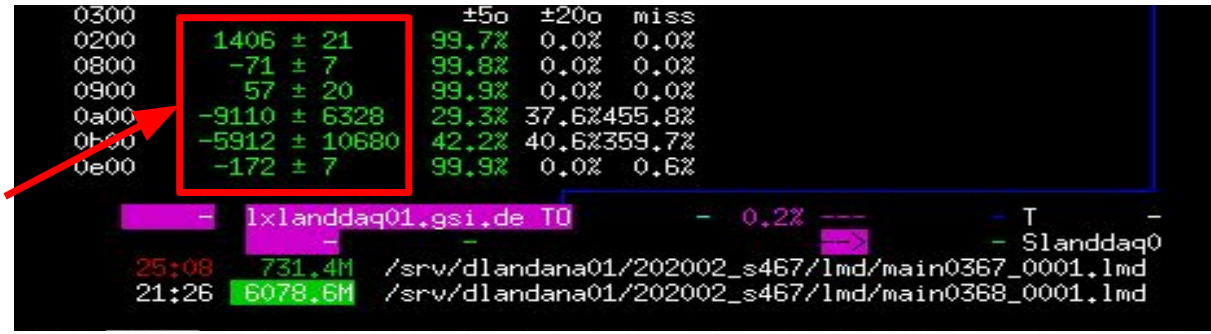
Timesort & Store

Timesort & Store

drasi timesorter LMD format

What's in the drasi timesorter?

- Timesorter sources can come and go at any time, **will not halt** the TS
- Timestamp differences / distribution relative to a reference
- Time tracking per system, correlation to CPU clock
  - Report offset of local clock to NTP time in tree view
  - Check WR timestamps for monotonic increase and alignment with local CPU clock scale
- Additional time sync trigger to check correlation and delay without beam down to +- 5 ns (currently trigger 7)



Alert user on error!

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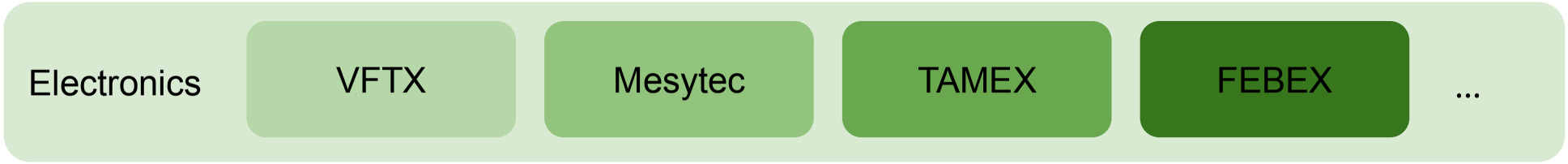
Electronics



Who uses what, and why?

PC

GSI FEBEX3	CALIFA, X5 PSP	digital processing / PID
GSI FQT + TAMEX3	NeuLAND, R3B ToF wall, LOS	high time res, density, ToT
MCFD + GSI TAMEX2	ToF wall tests	high time resolution, ToT
GSI PaDi + Clock-TDC	SiPM fiber, drift chambers	high channel density
GSI PaDi + KILOM	Fiber detectors	highest integration & density
GSI VULOM	ROLU, SEETRAM, ionisation chamber, TRLO II	low cost
Mesytec VMMR8	Sofia MWPC	custom front-end, high density
Mesytec MDPP16	Sofia Twin/Triple MUSIC, R3B MUSIC	digital processing
GSI VFTX	S2, S8, Sofia START, Sofia ToF wall, LOS	highest time resolution
GSI SIDEREM + SAM	AMS (alternative: INFN DAQ)	hardware constraint

VME

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Electronics

Electronics | VFTX | Mesytec | TAMEX | FEBEX | ...

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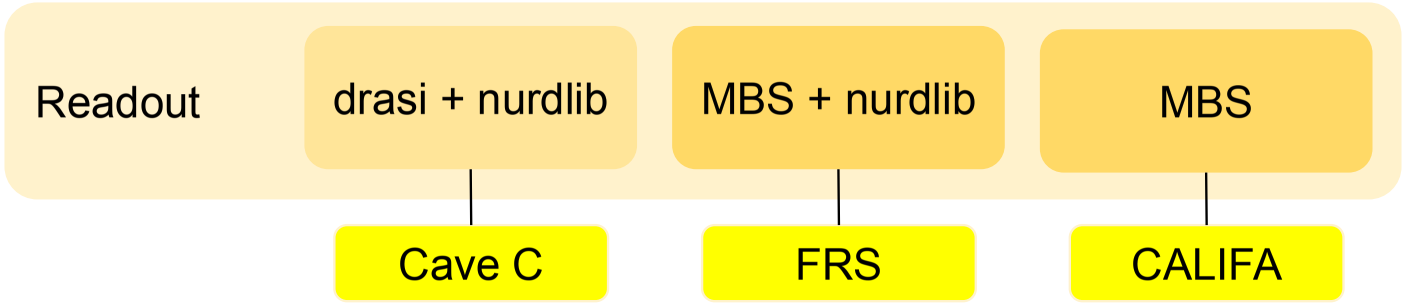
Mesytec MDPP16		essing
GSI VFTX		e resolution
GSI SIDEREM + SAM	AMS (alternative: INFN DAQ)	hardware constraint

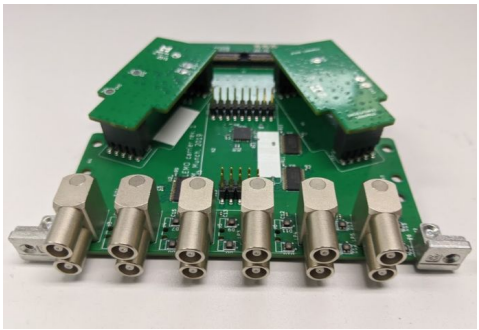
- GSI TRB3 – RPC – high time res, density, ToT

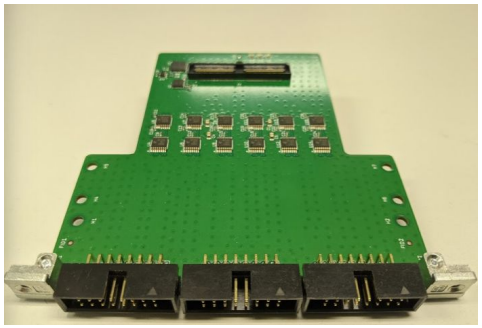
- FOOT – ADC-board + DE10 – microstrip charge readout
- ALPIDE – MOSAIC – 5µm pixel, tested at CERN now

VME

Readout







What's new?

- Rimfaxe VME controller / trigger logic hybrid (Aarhus contribution)
  - First two prototypes at GSI, testing is ongoing
  - Single-cycle access up to 2x faster than RIO4
  - Native integration of TRLO II
  - Sequencing logic work in progress (Håkan)
  - I/O onboard: 24 ECL + 4 LEMO
  - I/O with expansion: additional 96 (ECL and/or LEMO, TTL or NIM)
  - RIO4 is reaching end of life (can not be purchased)

DAQ – readout library nurdlib

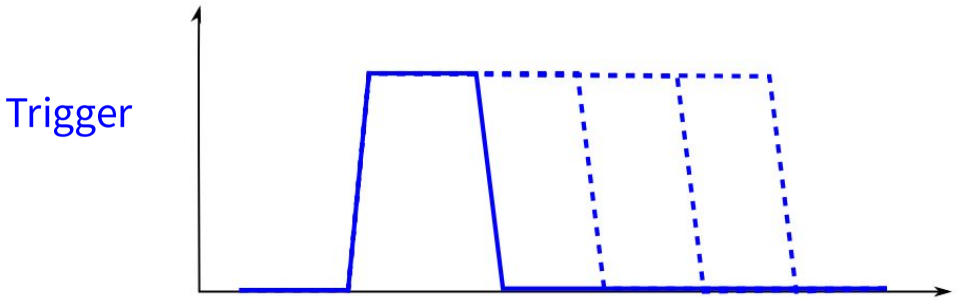
- 2014 January: copy-paste templates and scattered libraries
- 2014 April: **nurdlib** (NUstar ReaDout LIBrary) collected all readout into one library
  - Initially named **vmelib**, but VME only goes so far…
- Collects all support, all experiences, all tests, all fixes, all weird readout modes, in one place
- Has seen several core overhauls to support growing feature list, but rather stable in the last few years
  - Documentation and examples…

```
land@lxir123:r41-56 > cat main.cfg
#log_level = debug
CRATE("LOS_ROLU") {
        deadtime_release = true
        TAGS("1")
        # SMA connectors.
        GSI_VFTX2(16, 0x04000000) {
                GATE {
                        time_after_trigger = -4 us
                        width = 4.5 us
                }
                clock_input = external
        }
        BARRIER
        TAGS("1", "3", "10", "11", "12", "13")
        GSI_VULOM(0x03000000) {
                ecl = (0..7,12..15)
                pulser = (3)
                input_coinc = (0)
        }
}
```

```
land@lxir123:202205_s509 > cat x86l-101/main.cfg
#log_level = verbose
CRATE("NLR0_TAMEX3") {
        deadtime_release = true
        GSI_PEX() {
                include "$EXP_PATH/nl_pex.cfg"
        }
        TAGS("1", "3")
        # (SFP=0..3, version=2|3)
        GSI_TAMEX(0, TAMEX3) {
                data_reduction = true
                ref_ch0 = true
                clock_input = backplane
                long_range = true
                include "$EXP_PATH/nl_gate.cfg"
                GSI_TAMEX_CARD(0) {}
                GSI_TAMEX_CARD(1) {}
                GSI_TAMEX_CARD(2) {}
                GSI_TAMEX_CARD(3) {}
                GSI_TAMEX_CARD(4) {}
                GSI_TAMEX_CARD(5) {}
                GSI_TAMEX_CARD(6) {}
                GSI_TAMEX_CARD(7) {}
                GSI_TAMEX_CARD(8) {}
                GSI_TAMEX_CARD(9) {}
                GSI_TAMEX_CARD(10) {}
                GSI_TAMEX_CARD(11) {}
```

Anti-event-mixing - Sync check signal

- TRLO II generates trigger signal with known variable length



- Detectors measure length **for every trigger** and include in data stream
  - Directly via front-end (TDC or TAC/ADC) <- nice for testing full electronics chain
  - Via TRLO II <- if front-end does not support this
- User, DAQ and unpacker can analyse and check the measured values
  - Measured values should agree between all systems **for every trigger**

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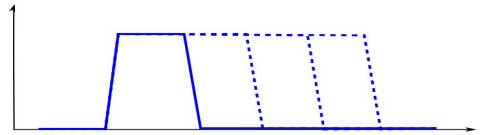
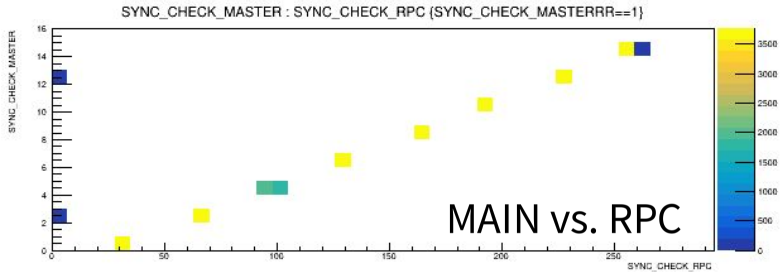
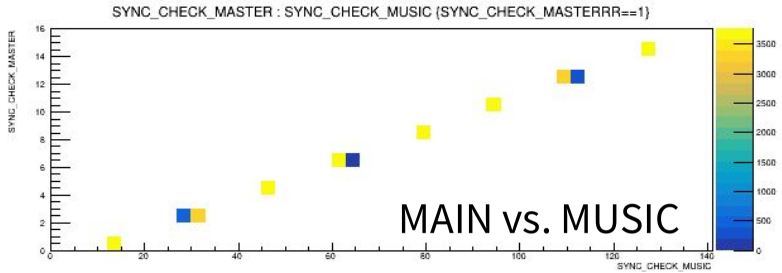
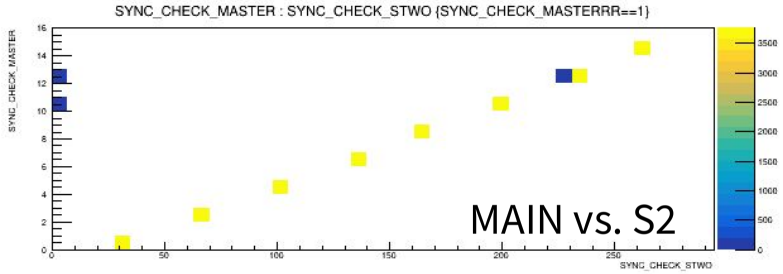
Sync check signal plots

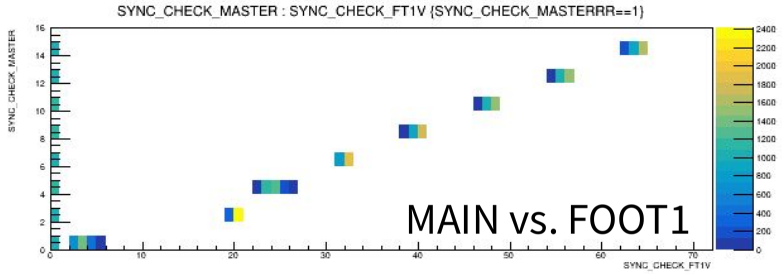


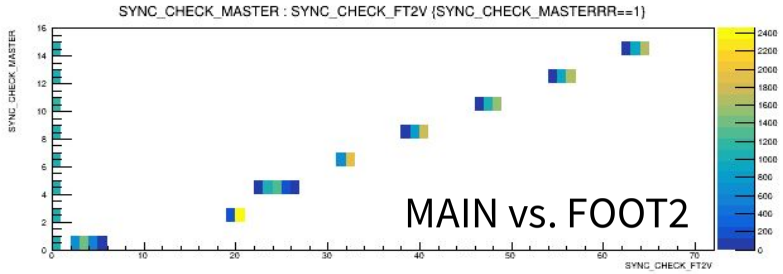
- Correlations (online, **nearline**, offline)

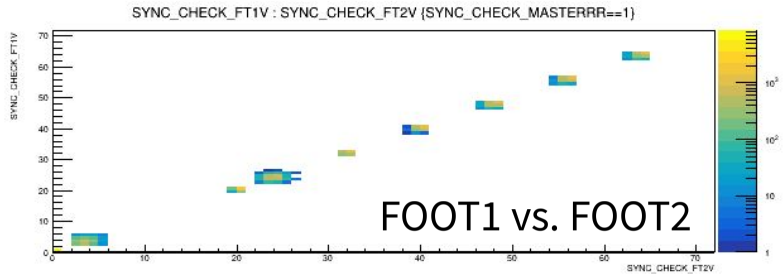












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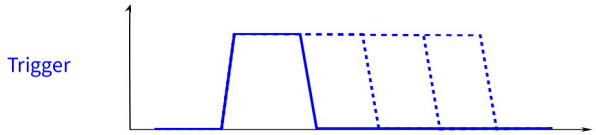
Sync check signal analysis



- DAQ monitoring (online):

10	Master	ncv	nrf	good	amb	bad	mis	spu	rel	#o
01	?	-	-	2815	-	-2785	-			13
02	S2	269	-	5327	-	-	-	-		60
03	RPC	6	-	5596	-	-	-	-		62
04	?	-	-	2815	-	-2783	-			13
06	?	-	-	2815	-	-2785	-			13
07	?	-	-	2817	-	-2785	-			13
09	?	-	-	2815	-	-2785	-			15
0a	CAL_M	101	-	-	-	-5496	-			-
0b	CAL_W	101	-	-	-	-5496	-			-
0c	?	-	-	2815	-	-2785	-			14
0d	?	-	-	2815	-	-2785	-			14
0e	Music	6	-	5596	-	-	-	-		32
0f	?	-	-	2815	-	-2785	-			13
12	?	-	-	2817	-	-2785	-			16
13	?	-	-	2815	-	-2785	-			14
14	?	-	-	2815	-	-2785	-			12
15	?	-	-	2815	-	-2785	-			11

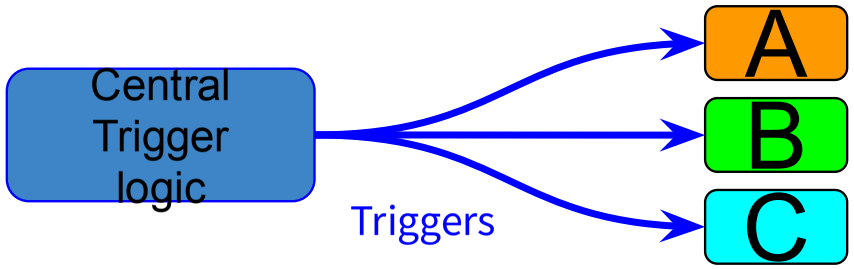
- UCESB output (**online**, **nearline**, offline):

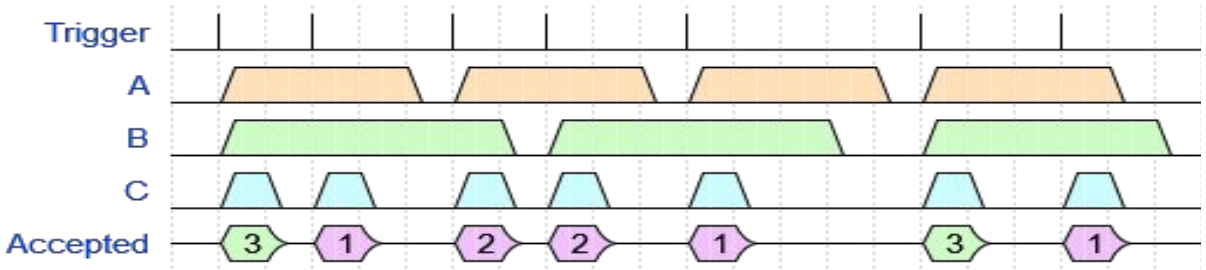
```
Reading mapping/calibration file '/u/htoernqv/toys/ucesb/empty/gen_empty/data_mapping.hh'...
Optional map/calib file '/u/htoernqv/toys/ucesb/empty/calibration.hh' does not exist, is ok.
Opened input from file '/d/land5/202205_s509/lmd/main0152_0001.lmd', process...
Events: 1000000   1000000            (0 errors)

          oooref       local       extra       nofit       ambig       mism
ID   ooo       noaref       spur       noval       outfit       noref       match
01     -     -     1     -   182     -     -     -     -     -     -     - 52801
02     -     -     2  3753     -     -     -     -     -     -     -     - 86236
03    15     -     2   259     -     -     -     -     -     -     -     - 89963
04     -     -     1     -   182     -     -     -     -     -     -     - 52801
06     -     -     2     -   182     -     -     -     -     -     -     - 52801
07     -     -     2     -   182     -     -     -     -     -     -     - 52801
09     -     -     1     -   182     -     -     -     -     -     -     - 52801
0a     -     -     -     -   253     -  1477     -     -     -     -     -     -
0b     -     -     -     -   254     -  1476     -     -     -     -     -     -
0c     -     -     1     -   182     -     -     -     -     -     -     - 52801
0d     -     -     -     -   182     -     -     -     -     -     -     - 52801
0e     -     -     2   270     -     -     -     -     -     -     -     - 89978
0f     -     -     2     -   182     -     -     -     -     -     -     - 52801
10     -     -     2   270     -     -     -     -     -     -     -     - 89978
12     -     -     1     -   182     -     -     -     -     -     -     - 52801
13     -     -     1     -   182     -     -     -     -     -     -     - 52801
14     -     -     1     -   182     -     -     -     -     -     -     - 52801
15     -     -     1     -   182     -     -     -     -     -     -     - 52801
```

Live time (de)synchronisation

- Unaligned local deadtimes leaves parts of the setup blind to certain triggers



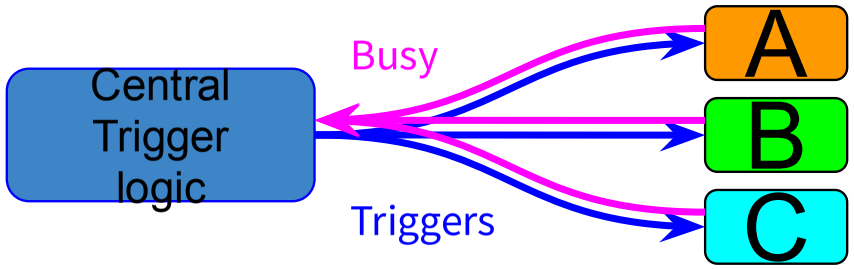


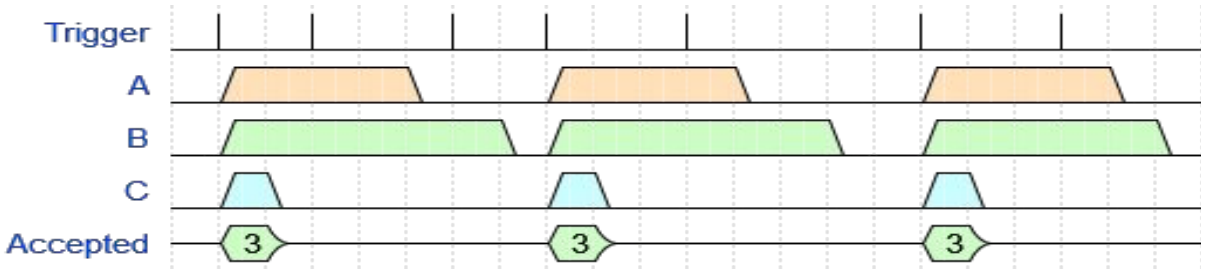
Incomplete events

Wave plots made with https://wavedrom.com

Live time (de)synchronisation

- Pay attention to busy signal of subsystems



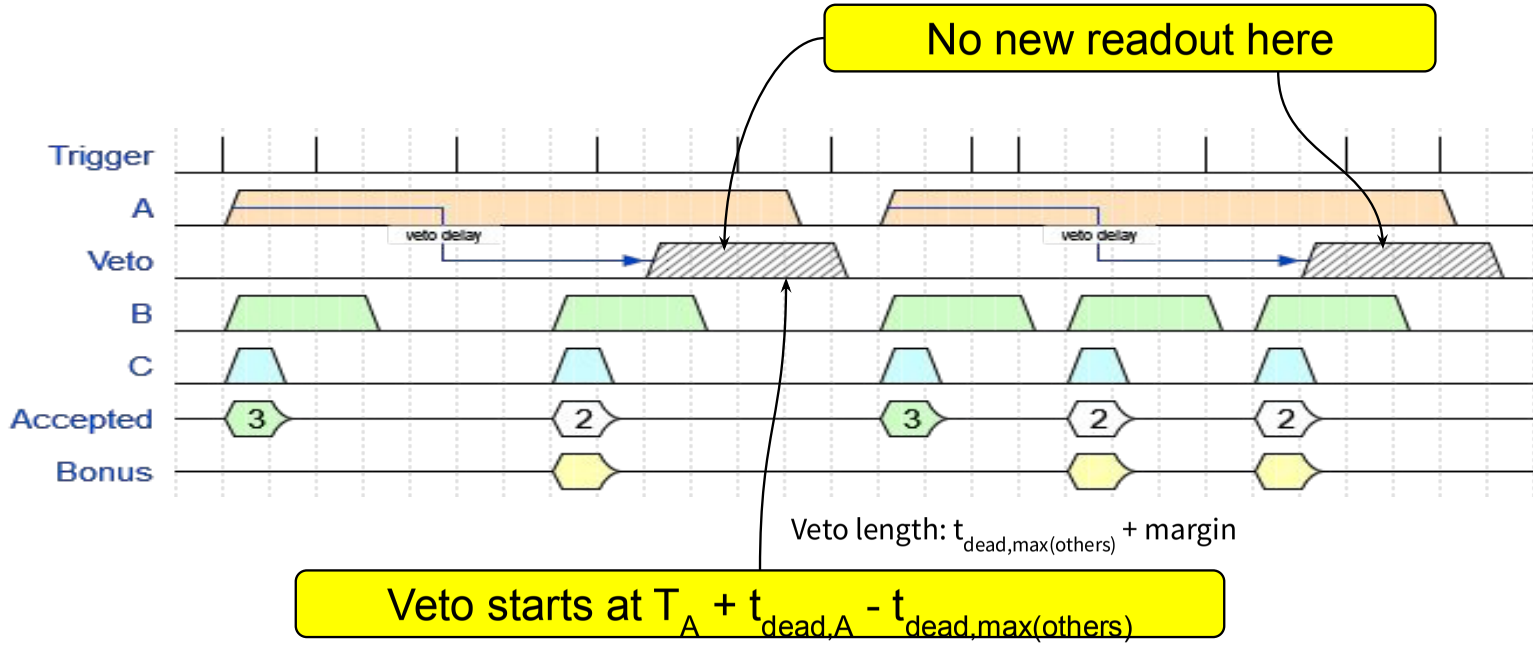


More complete events

Wave plots made with https://wavedrom.com

Live time (de)synchronisation

- Bonus events, while systems with long deadtime (here: A) are busy



Wave plots made with https://wavedrom.com

DT and rate

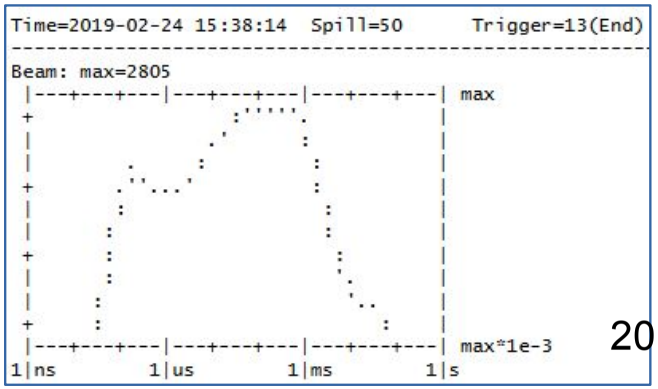
- Full readout DT per system type:
  - Master VME: **19 us**
    - LOS negligible
  - Tamex 1-6 cards (TOFD): **21 us**
  - CTDC 4 cards (Fibers): **21-23 us**
  - Febex 16 cards (PSPXs): **43 us**
  - Tamex ~50 cards (NeuLAND): **~60 us**
- **s444/s473** max uniform rate → **17 kHz**
- **s454** max uniform rate → **43 kHz**

General news

- DAQ scripts for many domains in parallel
  - E.g. main + LOS + NeuLAND with all event builders on one host
  - Structure ASCII-file based
- Nurdlib shadow readout
  - Original implementation and investigations by M. Munch at Aarhus
  - CAEN v775 32-ch -> **51.4 kHz**
  - Mesytec MDPP16 zero-suppressed -> **156 kHz**
    - With MBLT -> **220 kHz**, the setup physically screams, also a bit unstable
  - (Not useful for our current electronics, but imagine the things we could do…)
- Firmware updates
  - Less data from TAMEX, slow control auto-thresholding on CTDC
- 200 MHz clock from BUTIS and White Rabbit

Beam micro-structure and dead-time (DT)

- Incoming particles distributed in tight bunches average **10-100 us** apart → nearby particles lost during long DT
- TDC conversion **<3 us**, single event readout **20..60 us**
- But cannot release DT with GOSIP until token trip finished, i.e. **~17 us** dead (otherwise data garble)
- Considering s454-style DAQ:
  - Under controlled unsafe conditions, **48 kHz**, in real life **35 kHz**
  - VME headers and counters in DT (+misc) → **8 us**, buffers read out off DT **~10 us**
    - Use few modules to reduce in-DT readout, or more crates in parallel (Triva bus limits?)



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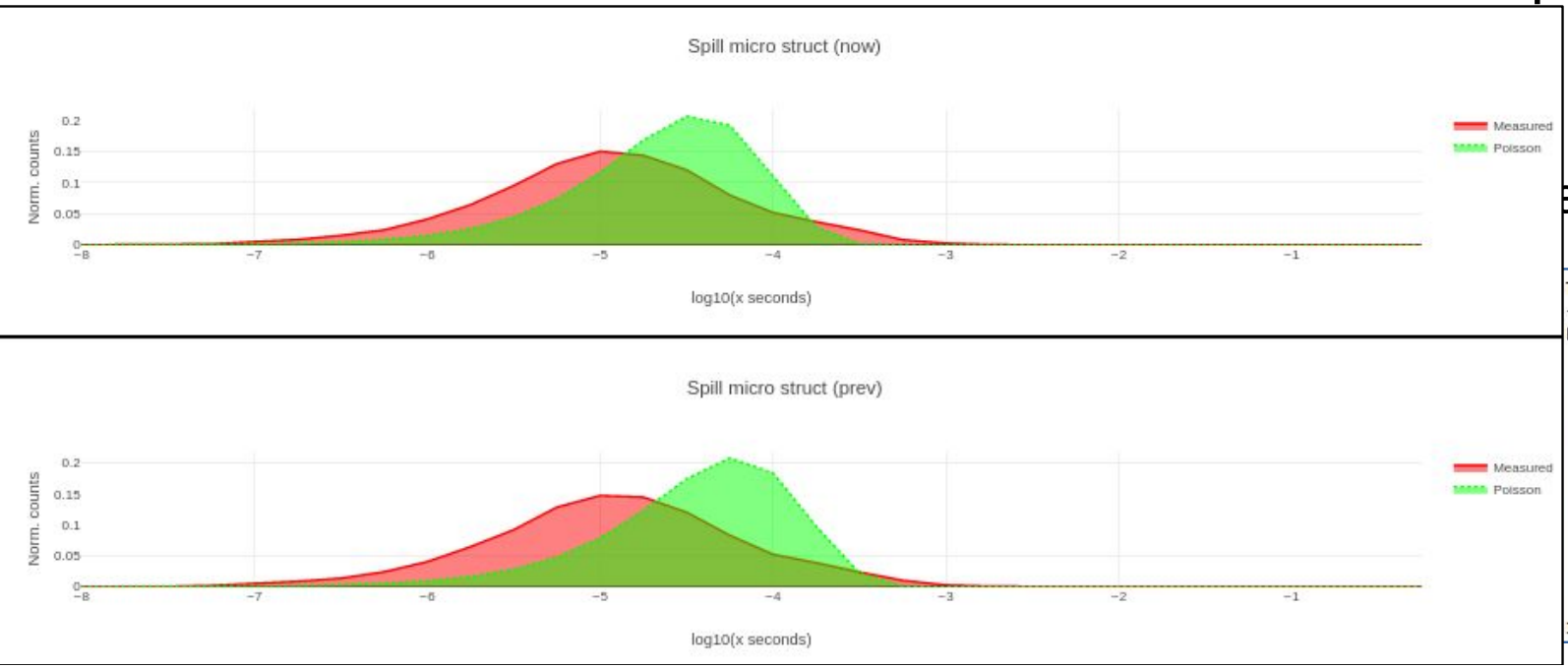
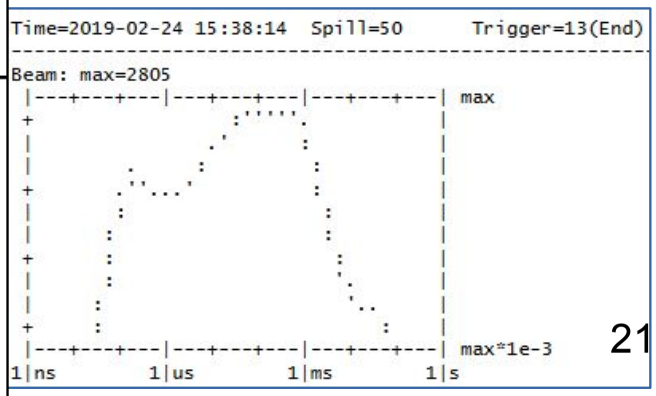
- TDC conversion **<3 us**, single event readout **20..60 us**
- But cannot release DT with GOSIP until token trip finished,



e **35 kHz**

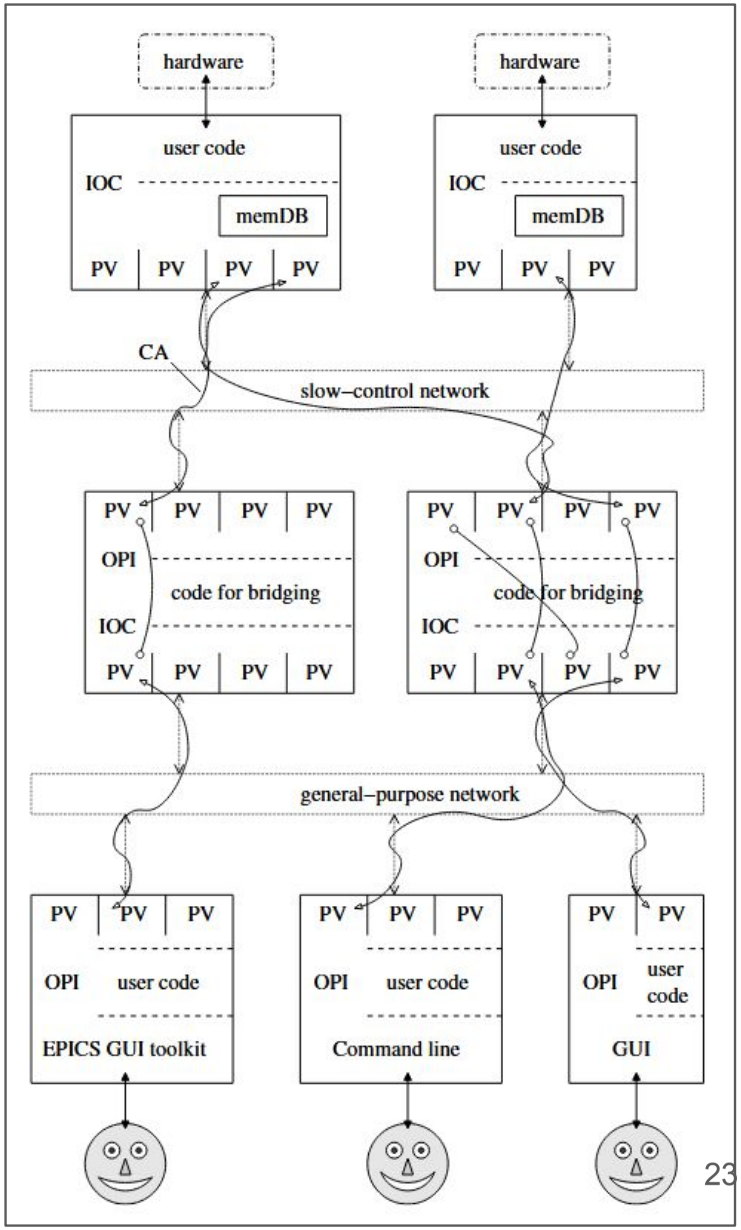


Slow control - EPICS

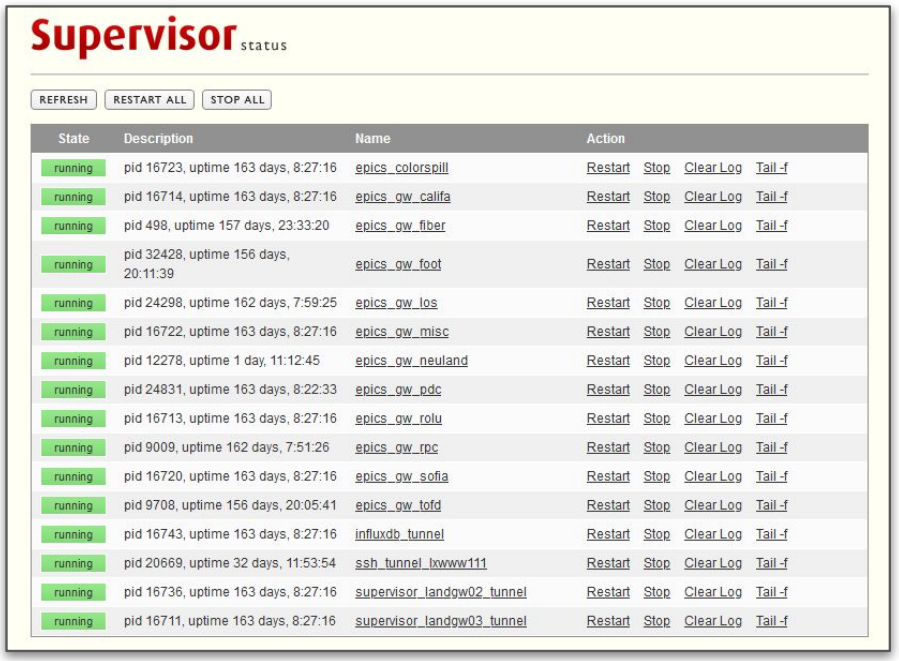
- EPICS is the common slow control software infrastructure
  - Sub-systems can easily convert local system to EPICS
- Old
  - Can be a good thing!
  - Very well-tested, lots of support
  - It’s fast on old machines -> it’s fast on new machines (well, mostly)
  - Also fast on new simple machines, we still use lots of them!
  - Less creep of features, libraries, and “bling”
- Command line tools make “anything” possible
  - If there’s a keyboard, network, and scripting, we’ll make it happen
  - Click-and-play is fine for users, but not the experts! And not for great experiments!

Slow control hierarchy

- IOC - Input/Output controller
  - Speaks with hardware/service
  - Transforms to/from EPICS Process Variables (PV:s)
- Gateway
  - Network and naming segmentation/isolation
  - Access control
  - Technical IOC names switched to logical human names
    - As human as we can…
- Archiving, snapshotting, restoring
  - Log everything!
- Presentation and controls
  - Graphical tools
- Network infrastructure + services built in cave C with backup hardware



Gateway



- Official gateway not quite enough
  - R3B has >100,000 PV:s!
- **r3bcagw**!
  - Written from scratch with EPICS base PV comm libs
  - No more regexps, every single PV directly aliased
    - Move CPU from runtime to setup
  - “Splitter” chops and groups PV:s by prefix (host?) in separate gateway processes
    - Lib/process caring about fewer nodes seems more stable?
    - The ultimate tech power – “Did you try turning it off and on again?”
- EPICS PV comm library not 100%
  - Huge beast, let’s leave it for now…

Archiving, snapshotting, restoring

- *Archiving:* store changes in **fluxdb**, visualised online with eg. **Chronograf**
- *Snapshotting:* record PV set values
  - Mass *“caget”* invocations with stdout -> text file
  - Text file add + commit to params git repo
  - Can run anywhere
- *Restoring:* read and write PV set values
  - git selection of file version
  - Output is written with “caput”
    - Slow, but unsafe fast writes not an option
    - Need to implement “verified” fast writes

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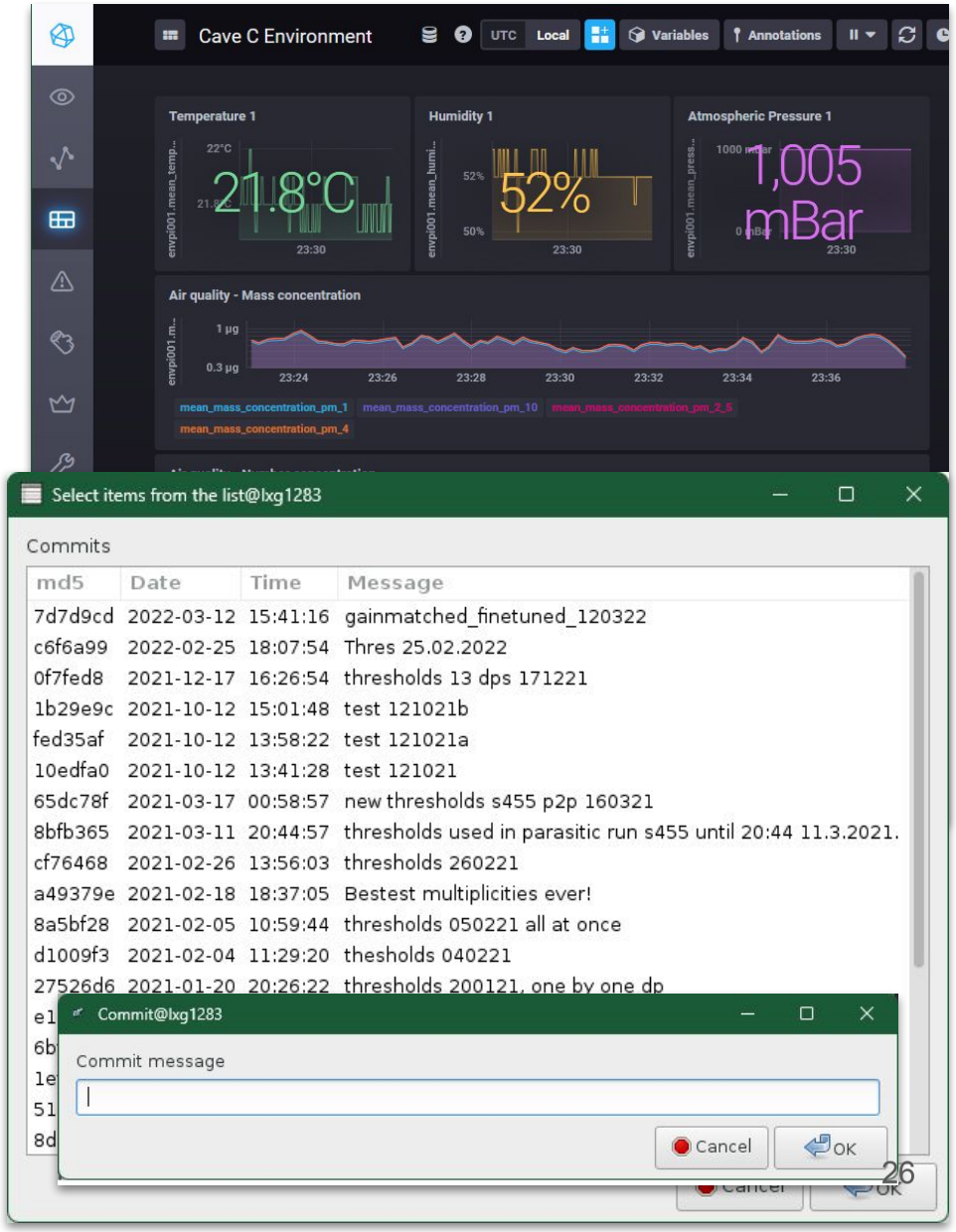
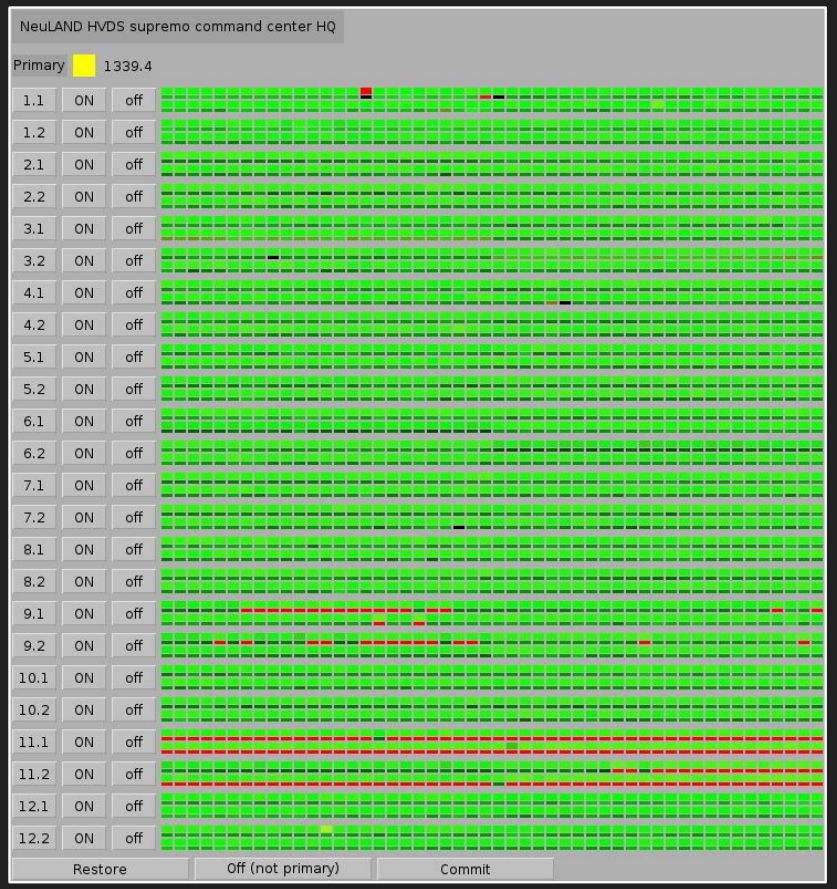


EPICS – Visualisation

- Most detectors still manageable with eg MEDM
  - Text-based file to setup GUI with controls and monitors
- NeuLAND currently has 2,600 channels
  - General-purpose tools can not handle this!
- **r3bcavalcade**!
  - SDL-based renderer
  - Much simplified version of MEDM, but expensive operations gone
  - EPICS expression support
  - Can handle NeuLAND many times over on a single host
    - NeuLAND will eventually have 6,000 channels, don’t get lazy!

Faster HV status display

- **Problem:** Neuland HV status display has lots (thousands!) of little lights
- **Limitation:** MEDM is not made for this and uses a lot of CPU
- **Solution:** Replace HV MEDM display with custom GUI based on efficient SDL library, actually a mini-MEDM with configurable layout
- **Outcome:** MEDM used 100% CPU on landgw01, r3bcavalcade < 10% CPU on lxg1290
- **Side effect:** More colors, more information, faster update rate possible, easier to add requested features



Most of the red stuff is fine...

Bulk mapping – r3bmap

- Huge number of channels and crazy detector mappings
  - *NeuLAND* - 13x double planes, split among 13 TAMEX cards in different sequential chains on different DAQ PC:s, and 4 HV modules split between two HVDS system (with sub-chains…)
  - *Fibers* - Fiber swizzling, mask rotation, MAPMT rotation, for thousands of fibers
  - Ever-changing host-names for LV supplies, motor controllers, failing raspberries etc
- **r3bmap**!
  - Scripts/programs that made life easier eventually collected
  - One place to generate all mapping (unpacking, slow-control, GUI:s…) for all detectors, no need to hunt in someone's temp working dir
  - git of course…
  - Super pre-alpha and sheltered so far
    - (General point, we need courses in computing hygiene)

r3bbm2 – Fast web-based 100% uptime beam monitor

R3B Beam Monitor (V2)

Last update: Tue Jul 13 2021 07:06:47 GMT+0200 (Central European Summer Time)
Server status: Connected

Beam quality

Overkill: **1.17** Evaluation: **17% bad** Transmission: 3.0e-7 Acq rate: 21384

Last max: 113277
Last sum: 120156950

ROLU (Hz)

	13734	
54038	9582	55232
	4605	

19408 103 5354

ROLU1 W: 30 mm
ROLU1 H: 30 mm
ROLU2 W: 30 mm
ROLU2 H: 30 mm

Spill

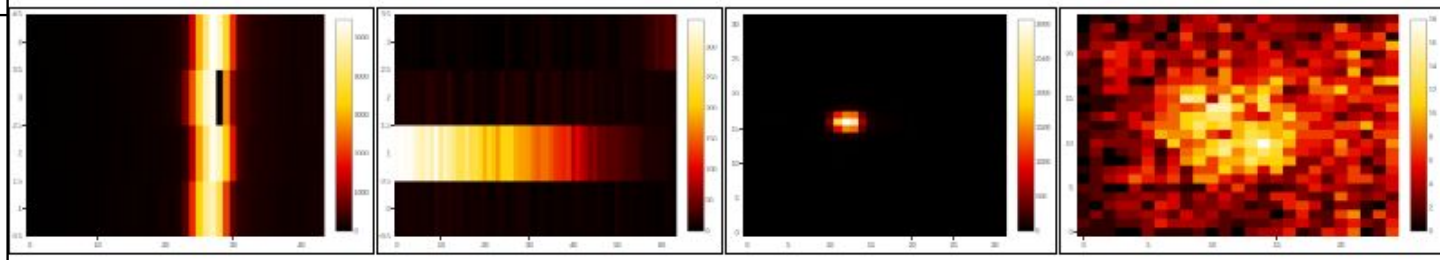
ROLU (Hz)

	215	
180		121
	85	

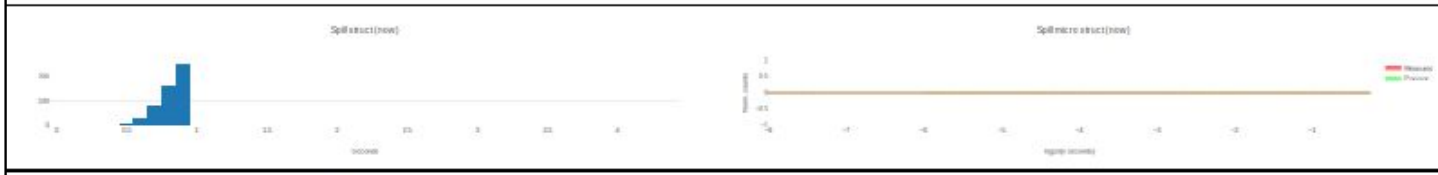
LOS (Hz)

LOS: 28532
LOS 0: 28560 LOS 4: 28556

TOFD Fib3x FOOT in-beam NeuLAND dp1



Spill



TRLOII scalers (average over spill in counts per second)

Onspill (Hz)	19.05.22, 04:58:14					Offspill	19.05.22, 04:58:15				
Input	Before LMU	TPAT	Before DT	After DT	Downscaled	Input	Before LMU	TPAT	Before DT	After DT	Downscaled
LOS!ROLU	28066.3	+MinBias	6171.9	5624.6	1406.3	LOS!ROLU	1.2	+MinBias	0	0	0
Clf-And	615.3	+Frag	5866.9	5342.8	1335.6	Clf-And	0.6	+Frag	0	0	0
Clf-Or	2100.5	+P2P	106.4	97.7	97.7	Clf-Or	34.7	+P2P	0	0	0
RPC	199.1	+P2Pv	62	55.5	55.5	RPC	26	+P2Pv	0	0	0
NeuLAND	31771.7	+OR	321.8	289.3	289.3	NeuLAND	8564	+OR	0	0	0
ToFD	51573.3	+ORv	223.3	200.4	200.4	ToFD	540.6	+ORv	0	0	0
Fi32	28787.5	-MinBias	14766.9	4205.3	1051.5	Fi32	1447.1	-MinBias	0	0	0
Fi30	50995.7	-Frag	13544.7	3967.5	991.8	Fi30	14475.8	-Frag	0	0	0
Fi33	6295.8	-P2P	293.3	73.7	73.7	Fi33	3508.6	-P2P	0	0	0

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Beam quality

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Last max: 113277
Last sum: 120156950

Fiber temperatures (threshold = 90 deg)

Fib23	57.3	50.8	45.2	80.4	80.4	81.0	51.7	57.2
Fib30	81.9	83.5	75.5	74.4	76.0	73.3	74.1	77.8
Fib31	82.1	83.1	92.2	88.6	81.6	78.6	75.2	79.9
Fib32	85.9	86.9	79.2	82.1	77.3	78.0	75.8	78.9
Fib33	83.6	79.2	81.3	79.2	72.1	77.9	72.6	80.3

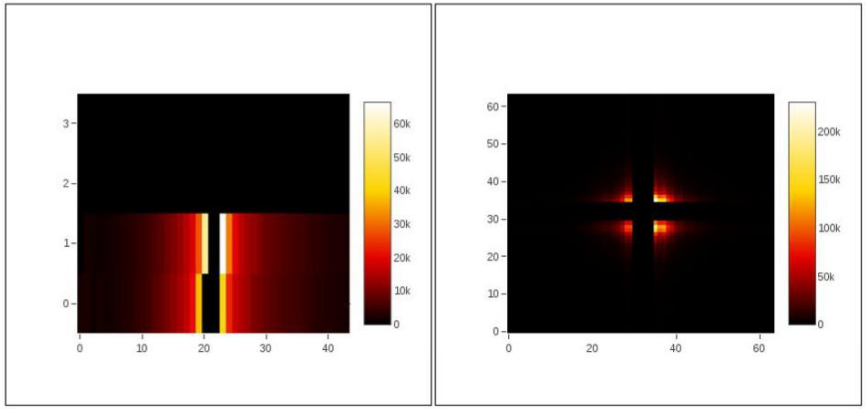
ROLU (Hz)

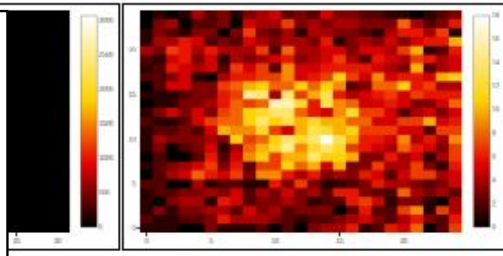
	13734	
54038	9582	55232
	4605	

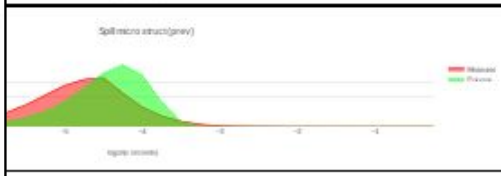
	19408	
	10309	
	5354	

ROLU1 W: 30 mm
ROLU1 H: 30 mm
ROLU2 W: 30 mm
ROLU2 H: 30 mm

TOFD **Fib23a/b**







58:15

TPAT	Before DT	After DT	Downscaled
+MinBias	0	0	0
+Frag	0	0	0
+P2P	0	0	0
+P2Pv	0	0	0
+OR	0	0	0
+ORv	0	0	0
-MinBias	0	0	0
-Frag	0	0	0
-P2P	0	0	0

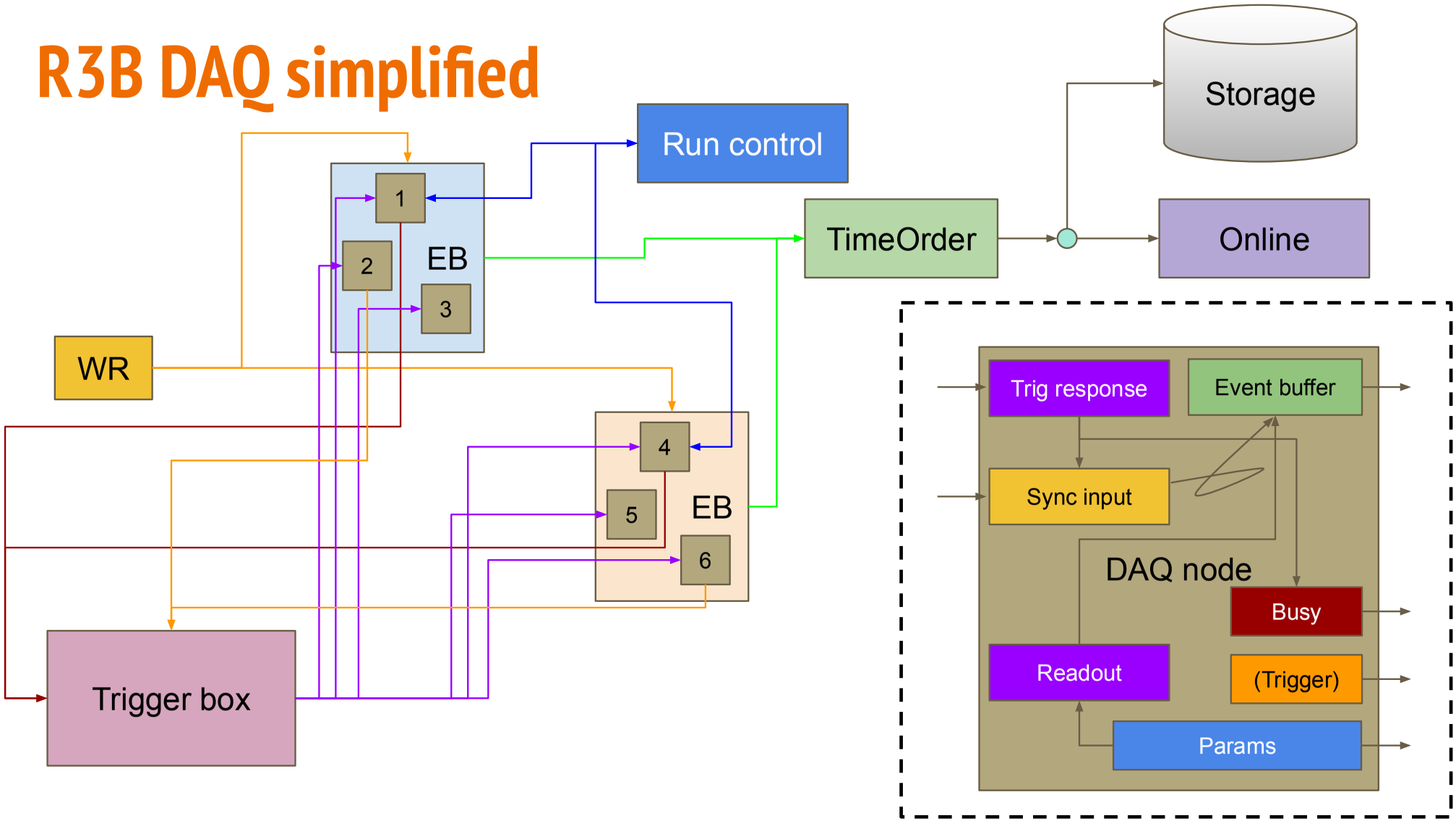
THE END

Thanks for listening!

Also thanks to B. Löher, H. Johansson, M.Munch, H. Simon, A. Heinz, S. Petri,
the R3B@GSI group, the GSI EE dept., and many many more!

H. Törnqvist, R3B collab. meet. 2021

R3B DAQ simplified

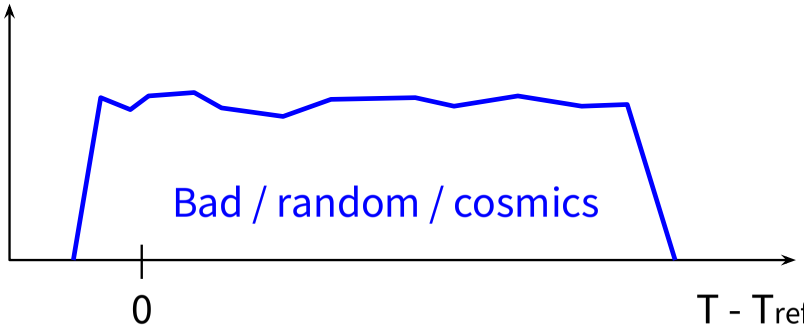


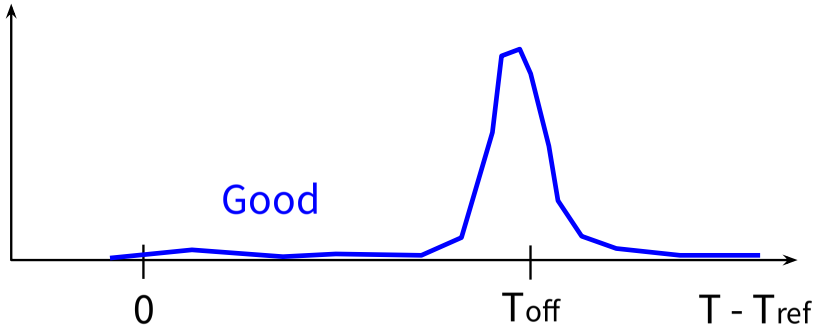
Why timestamped+triggered?

- Flexibility - systems can come and go, broken systems don’t harm everyone
  - Pro: Local failure has no effect on the rest, especially helpful during preparations
  - Con: Local failure can go undetected -> Shift crew must be vigilant!
- Integrity - trigger is a common reference point
  - Pro: Common reference time available everywhere
  - Con: Different cabling required -> Prepared in advance
- Sparse data - only data of interest is recorded
  - Pro: Unrelated data (cosmic / noise) is dropped from unrelated systems, moderate storage/computing requirements
  - Con: Region of interest needs to be correct -> Requires monitoring
- Event-wise data in single file
  - Pro: Simplifies analysis
  - Con: Time sorting and time stitching is required for correlations -> Part of DAQ software + UCESB

Monitoring - Timestamp differences

- Timestamp difference histograms (part of DAQ monitoring)

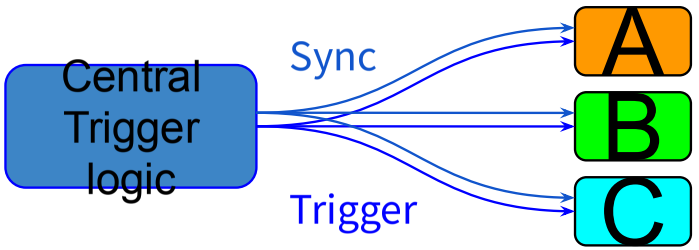




		all-trig	◆5σ	◆20σ	miss	sync-trig	>20σ
10	Master	-65 ◆ 12	50.9%	0.0%	0.4%	-9 ◆ 27	0%
01	?	318 ◆ 6	100.0%	0.0%	0.0%	- -	-
02	S2	-91 ◆ 7	99.9%	0.0%	0.0%	-46 ◆ 21	0%
03	RPC	-59 ◆ 12	50.9%	0.0%	0.4%	-8 ◆ 26	0%
04	?	-56 ◆ 12	50.9%	0.0%	0.4%	-14 ◆ 30	0%
06	?	-54 ◆ 12	50.9%	0.0%	0.4%	-13 ◆ 30	0%
07	?	-56 ◆ 12	50.9%	0.0%	0.4%	-18 ◆ 30	0%
09	?	-56 ◆ 12	50.9%	0.0%	0.4%	-18 ◆ 30	0%
0a	CAL_M	1239 ◆ 18	1.6%	0.0%	0.0%	472 ◆ 21	0%
0b	CAL_W	1257 ◆ 18	1.6%	0.0%	0.0%	502 ◆ 21	0%
0c	?	-53 ◆ 12	50.9%	0.0%	0.4%	-13 ◆ 31	0%
0d	?	-61 ◆ 12	50.9%	0.0%	0.4%	-12 ◆ 28	0%
0e	Music	231 ◆ 6	100.0%	0.0%	0.0%	233 ◆ 7	0%
0f	?	-58 ◆ 12	50.9%	0.0%	0.4%	-15 ◆ 28	0%
12	?	-51 ◆ 11	50.9%	0.0%	0.4%	-15 ◆ 30	0%
13	?	-62 ◆ 12	50.9%	0.0%	0.4%	-11 ◆ 30	0%
14	?	-67 ◆ 12	50.9%	0.0%	0.4%	-11 ◆ 29	0%
15	?	-69 ◆ 12	50.9%	0.0%	0.4%	-11 ◆ 28	0%

Peak offset / width

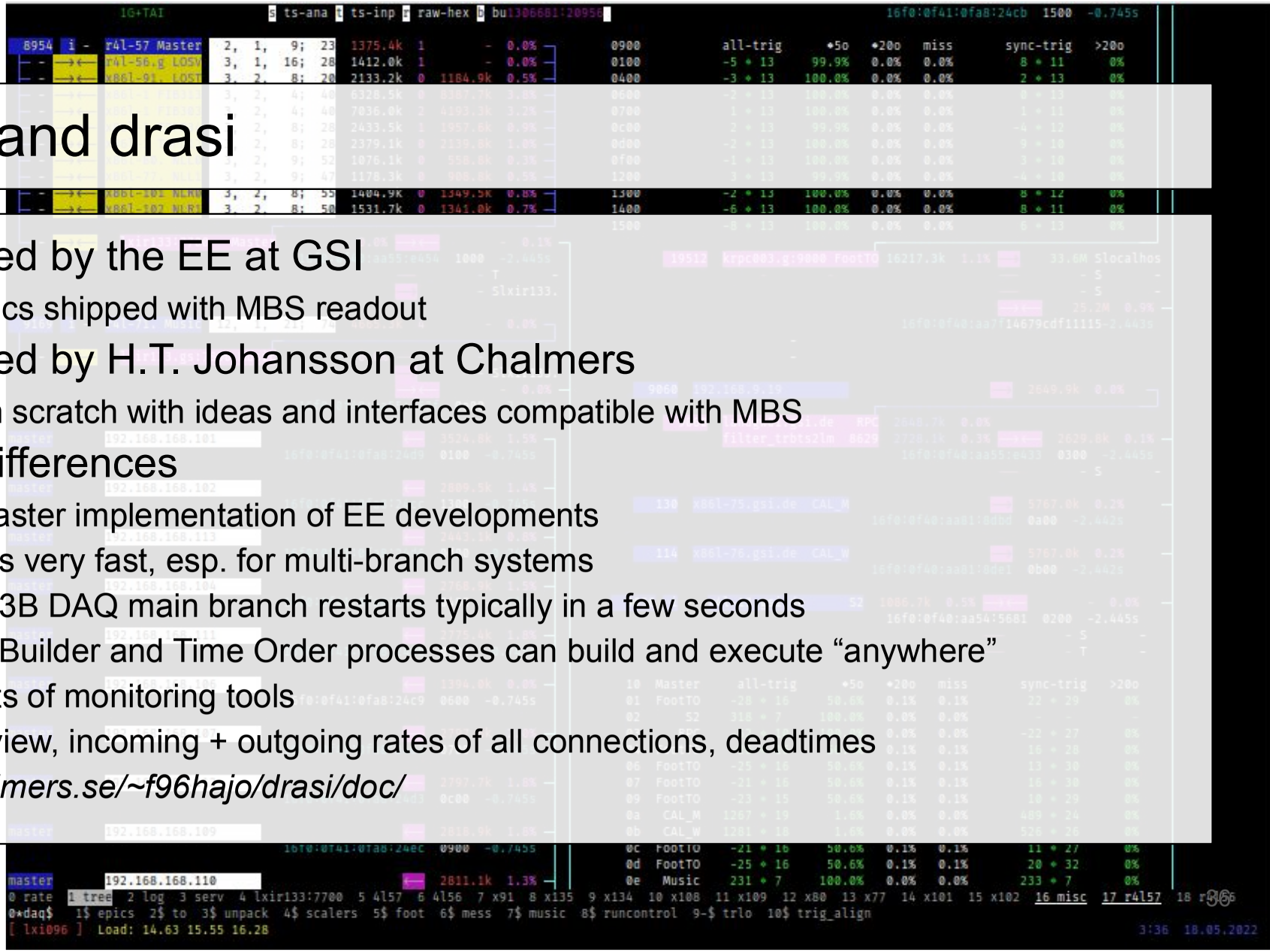
Sync trigger



Sync trigger: Periodic, low rate

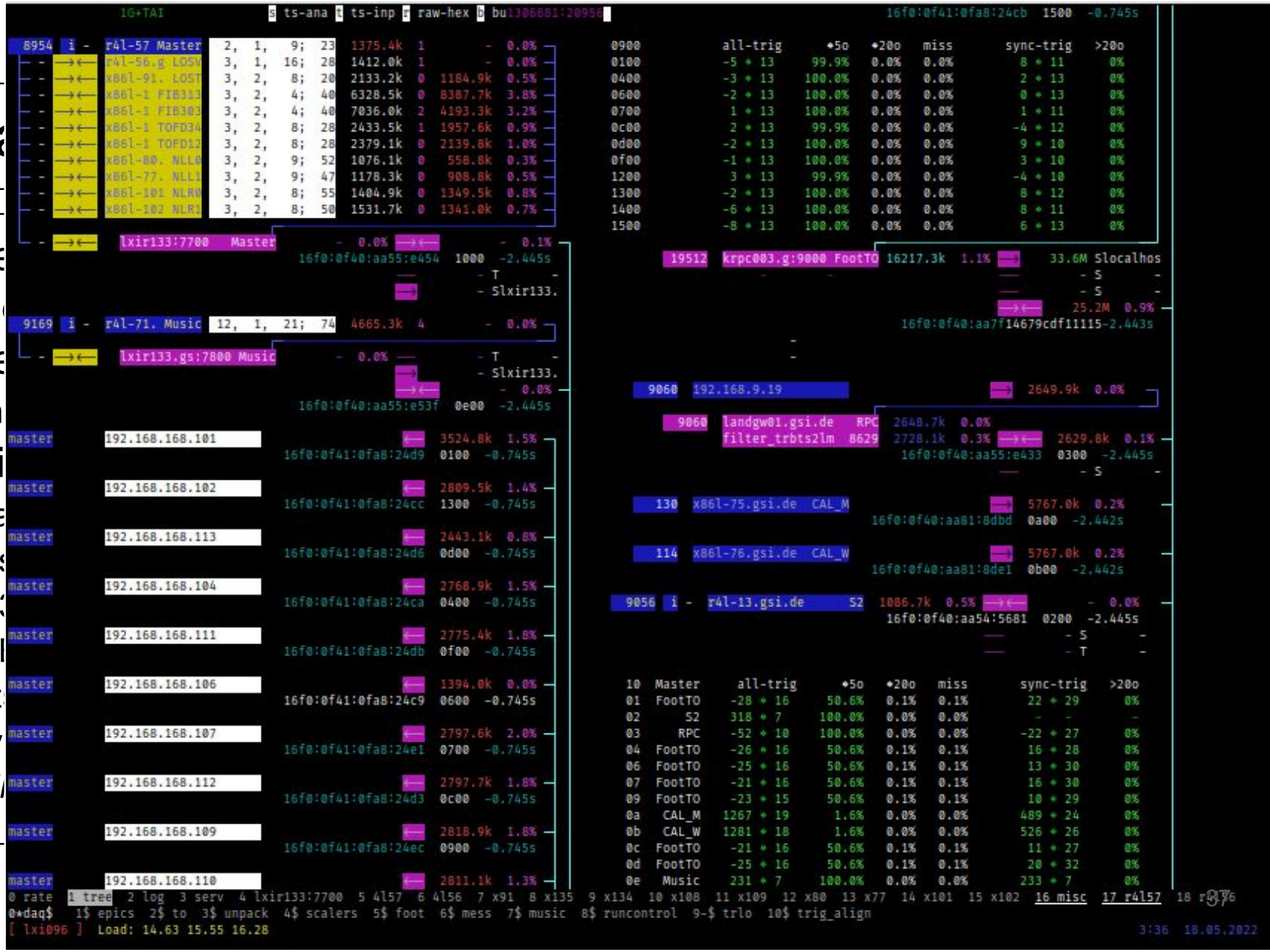
DAQ – MBS and drasi

- MBS developed by the EE at GSI
  - EE electronics shipped with MBS readout
- drasi developed by H.T. Johansson at Chalmers
  - Written from scratch with ideas and interfaces compatible with MBS
- Selection of differences
  - MBS sees faster implementation of EE developments
  - drasi restarts very fast, esp. for multi-branch systems
    - The R3B DAQ main branch restarts typically in a few seconds
  - drasi Event Builder and Time Order processes can build and execute “anywhere”
  - drasi has lots of monitoring tools
    - Tree-view, incoming + outgoing rates of all connections, deadtimes
  - *http://fy.chalmers.se/~f96hajo/drasi/doc/*



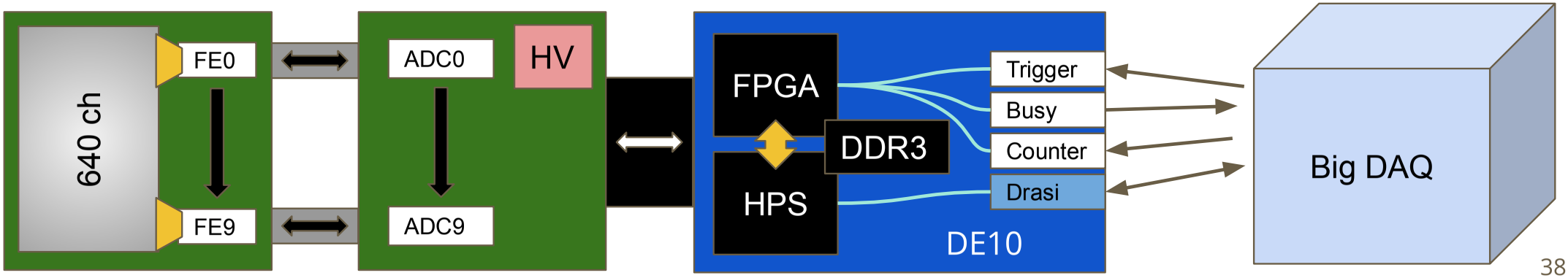
DAQ – MBS a

- MBS develope
  - EE electroni
- drasi develope
  - Written from
- Selection of di
  - MBS sees fa
  - drasi restarts
    - The R3
  - drasi Event I
  - drasi has lot
    - Tree-v
  - *http://fy.chal*



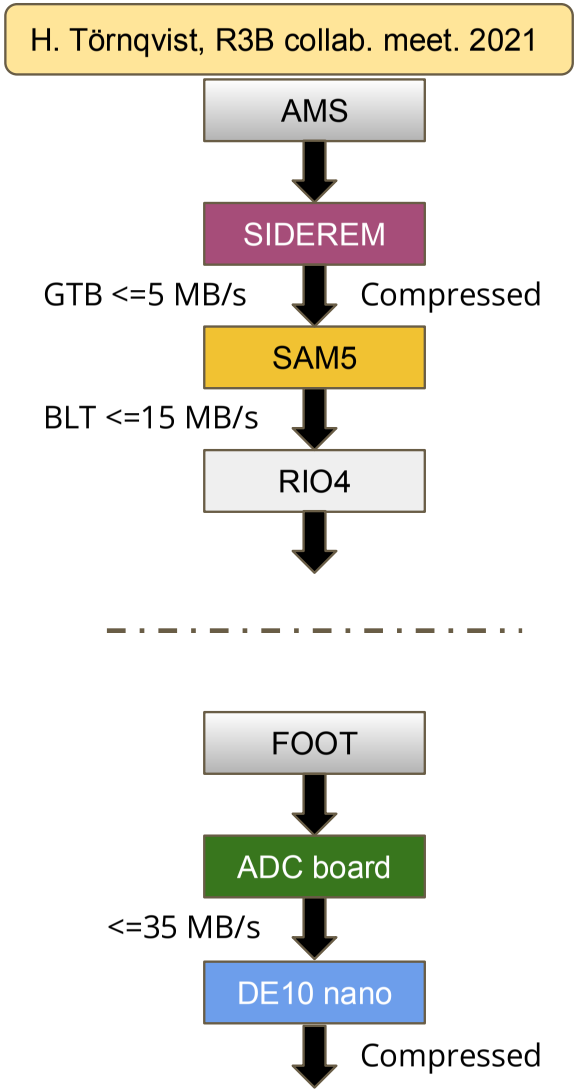
FOOT building blocks

- Detector – 640 ch
- Front-end (FE) – IDE1140, charge + hold muxing 10 MHz ASIC, 64 ch/chip, 10/detector
- ADC – AD7276, single-channel 12-bit 48 MHz ADC, 1/FE
  - FE and ADC actually clocked at 1.25 & 25 MHz
- DE10-FPGA – busy locking, trigs and clks FE:s + ADC:s, creates events, fills DDR3
- DE10-HPS ("CPU") – Init + config, LMD-event building, unique ID, networking
- Syncing – FPGA 50 MHz counter, can be driven externally
- Merging – defiled ucesb



FOOT data rate & compression

- FE <-> ADC <-> FPGA <-> HPS – max xfer rate ~35 MB/s
  - Makes **3 TB/day**!
  - Sometimes just 16 MB/s until restart, don't know why yet
- That is 1 detector, 10 detectors… Just no
- **AMS** had only 5 MB/s over GTB, slower than FE
  - Compress already in SIDEREM
- **FOOT** xfer lines much faster than FE, compress later
  - **dptc** by H.T. Johansson, G. Bruni et al (http://fy.chalmers.se/subatom/dptc/)
  - Fast "smooth" lossless trace compression
  - Due to ADC swizzling and endianness, reshuffle data before
  - ~5.5 MB/s
- Upexps can do unpacking and decompression of compressed / raw data



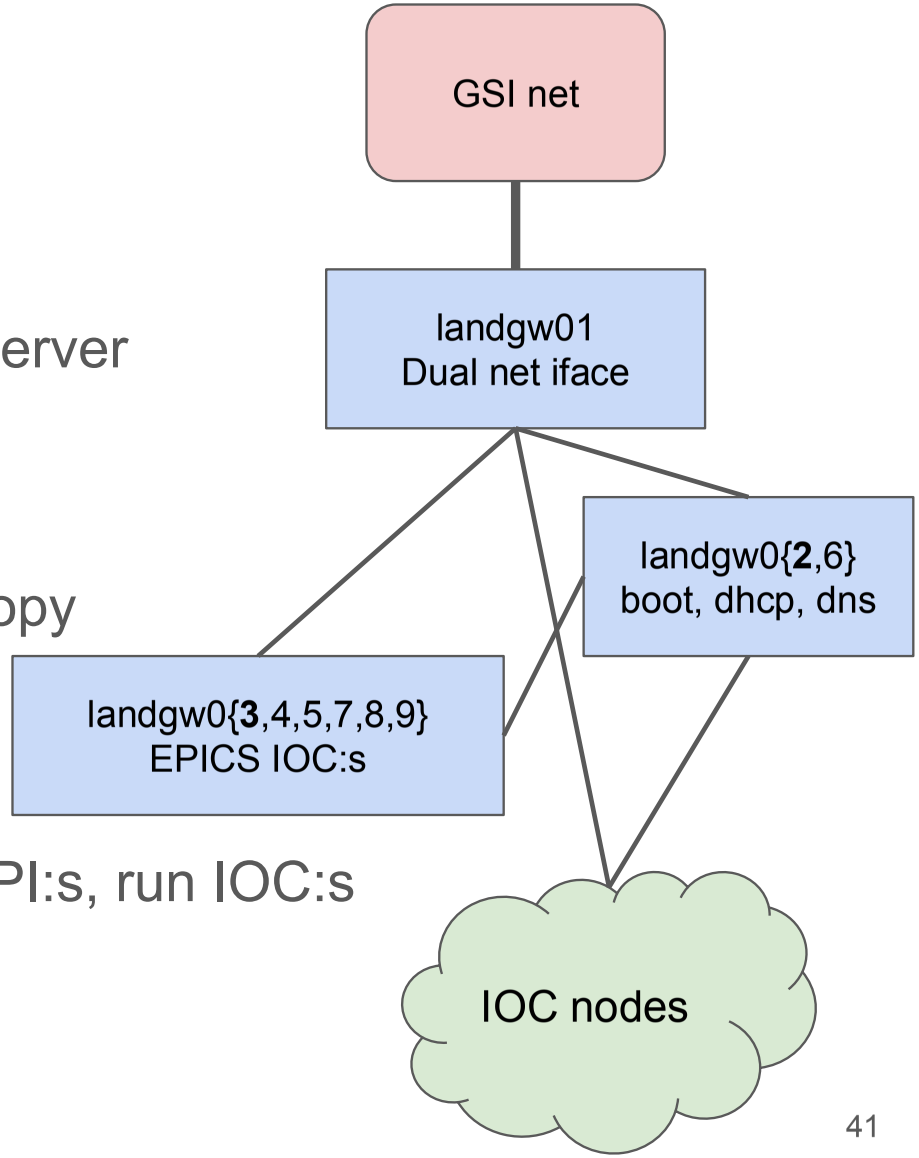
H. Törnqvist, R3B collab. meet. 2021

FOOT single system stability

- The original FPGA comm / readout code was very unstable
- Event corruption beyond a few kHz incoming triggers, not accepted
  - Also seen by FOOT collab during several tests with two DAQ:s
- An interplay of two sources:
  - **New FW**, have no idea what the original DE10 FW was
  - **Simpler DDR3 buffering code**, the original tests were incorrect
    - Now fills 10 MB buffer, extracts events, shifts, repeat, no exaggerated tests needed
- Went from initial unstable 2 kHz incoming + accepted to rock-solid 1 MHz incoming + 14 kHz accepted
  - Recorded more than a billion events without a single corruption
  - (Again, we don't really have 14 kHz... But the readout works *thumbs up*)

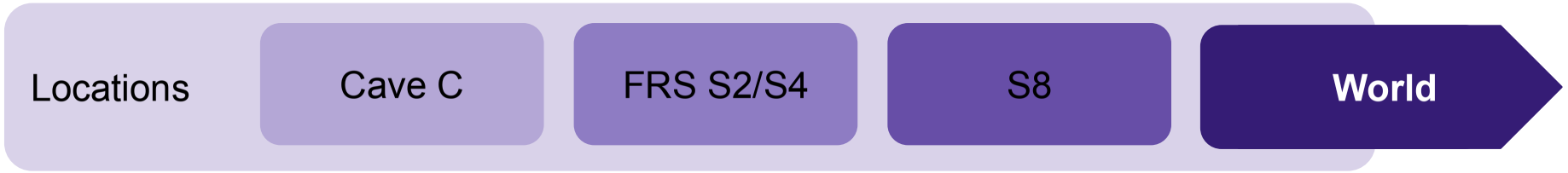
Network in Cave C

- “Private net”, “slow control net”
- Current gateway is an old repurposed boot server
  - Struggled badly with many IOC:s + GUI:s
  - Was too easy, security and efficient practices nil
  - Currently only EPICS gateway
- 1x gateway and network server + identical copy
  - Boot server, dhcp server, DNS etc
- 1x IOC server + identical copy
  - Runs IOC:s for “dumb” devices
- Computers, including loooads of Raspberry PI:s, run IOC:s
- No slow-downs or crashes since



B. Löher, R3B collab. meet. 2020

Outside R3B



We are not developing inside our R3B bubble:

- **GSI**
  - nurdlib used by FRS
  - nurdlib + drasi used by AP
  - parts of control system soon used by DESPEC
- **Aarhus University**
  - nurdlib / drasi
- **CERN**
  - nurdlib / drasi used at ISOLDE (developed in Aarhus)
- **IKP / TU Darmstadt**
  - nurdlib / drasi used at NEPTUN tagger & DHIPS NRF setup
- **Jena**
  - nurdlib / drasi used by microcalorimeter readout for FAIR
- **Duke University**
  - nurdlib / drasi used by HIGS setup at TUNL