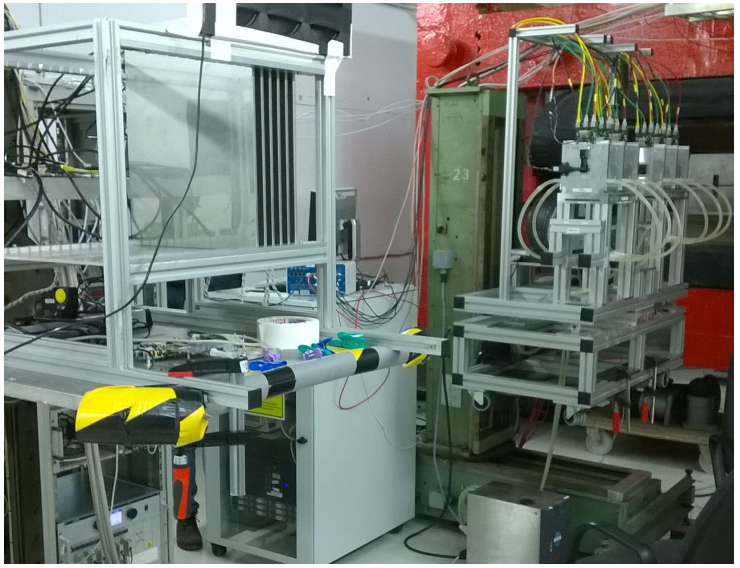
Combined testbeam: CALICE AHCAL & Beam telescope

- AHCAL introduction: timing
- Setup with Beam telescope + results
- Setup with Mini-TLU + results
- Plans
- Conclusion



Jiri Kvasnicka
BTTB 2017, Barcelona
jiri.kvasnicka@desy.de

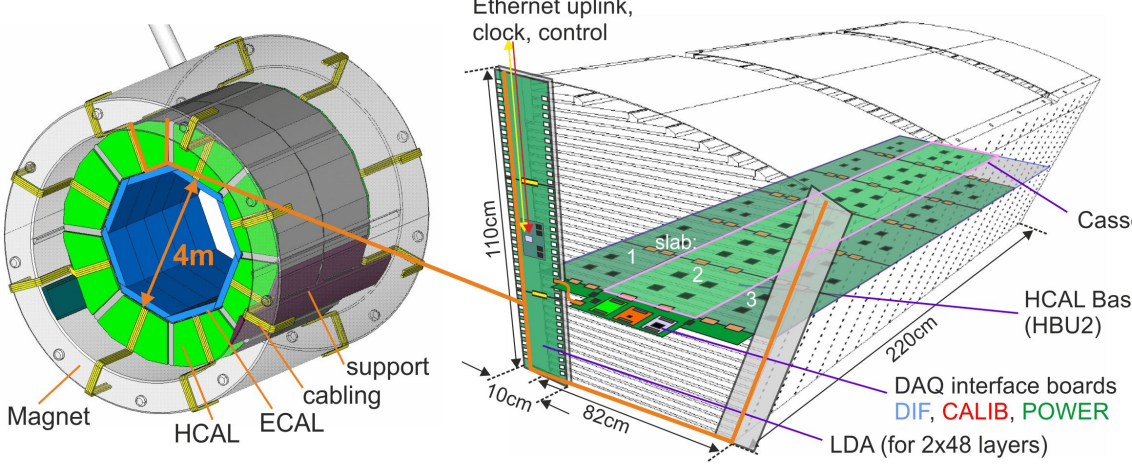
HELMHOLTZ ASSOCIATION

AIDA 2020

Fyzikální ústav Akademie věd ČR, v. v. i.

DESY

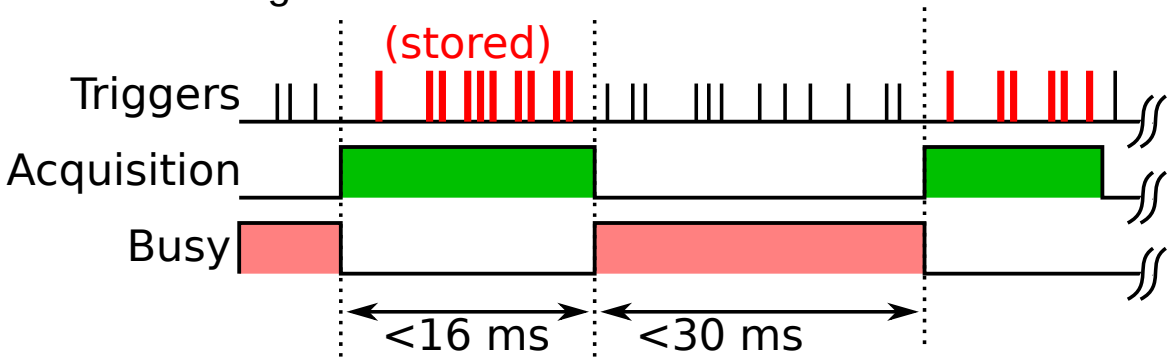
AHCAL introduction



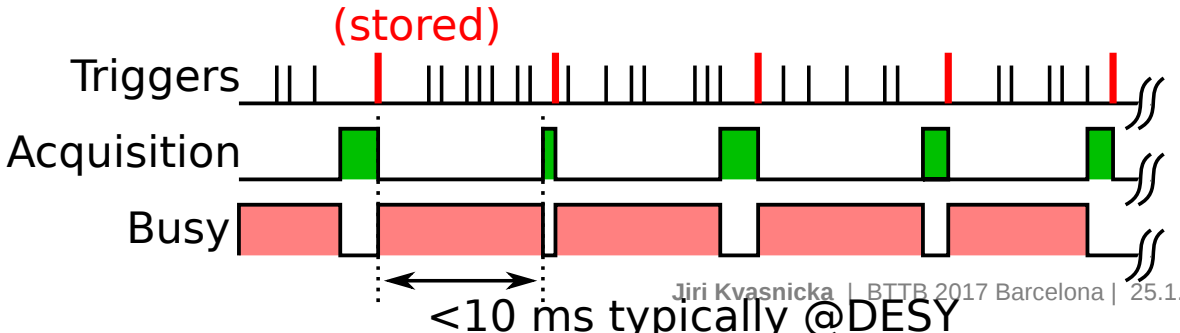
- A high-granular detector:
  - 3 x 3 x 0.3 cm^3 scintillator tiles
  - organized in 36x36 cm boards
  - Layer can reach up to 2m long slab
- **Designed for 1ms spills every 200ms** → 0.5% duty cycle!
- Bunch crossing clock period of 200 ns or 4 us (=> 1 or 16 ms spill)
- 36-channel ASIC: 16-deep analog memory for up to 16 triggers
  - Each ASIC **self-triggered independently** (start & stop are the only common events)
    - → ASICs can record different particles in different locations
  - Possibility of discarding event not validated by external trigger (only 4 us BX clock)
- Readout: **"Acquisition cycle" oriented** (up to 16 ms!)
  - Complete readout cycle from all ASICs (all event mixed)
- Integration challenge to match with EUDET TLU TriggerID
- Implemented for integration:
  - Timestamps (cycle start+stop) in the data stream => can restore absolute time
  - TLU TriggerID (with timestamp) added to the data stream

Timing schemes used in testbeams

- Optimally, AHCAL stores 16 events within 16 ms acquisition window
  - Used when AHCAL runs alone
  - ~200 events/s in this mode (@DESY)
  - Event building done offline

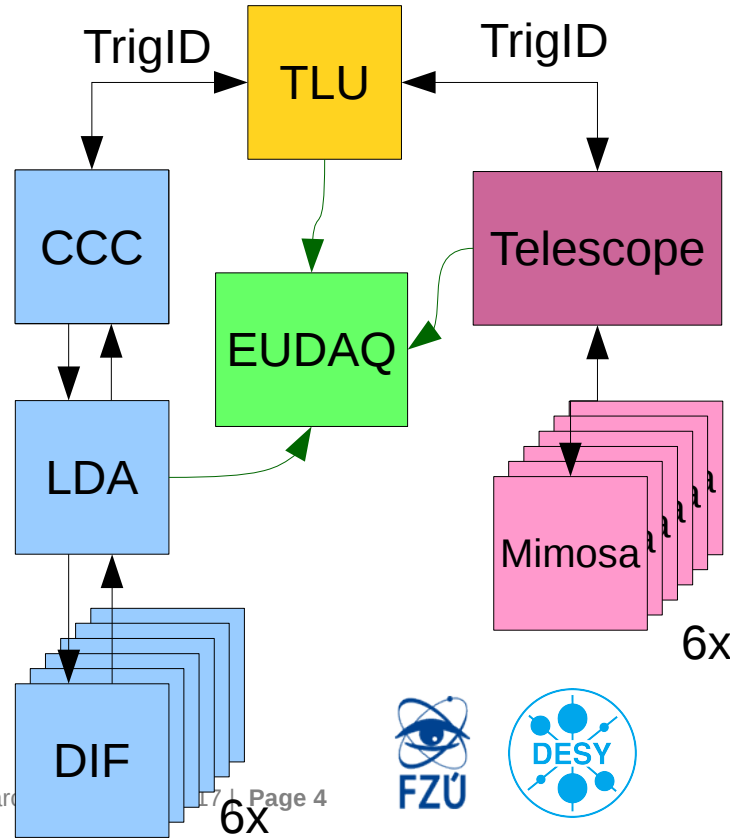


- Stop after 1st trigger
  - <90 events/s due to readout cycle overhead
  - Used with (old) TLU, which tags the trigger with the TriggerID
  - Assignment of AHCAL data to TriggerID is straightforward (and safe)



AHCAL + Telescope @DESY 2016

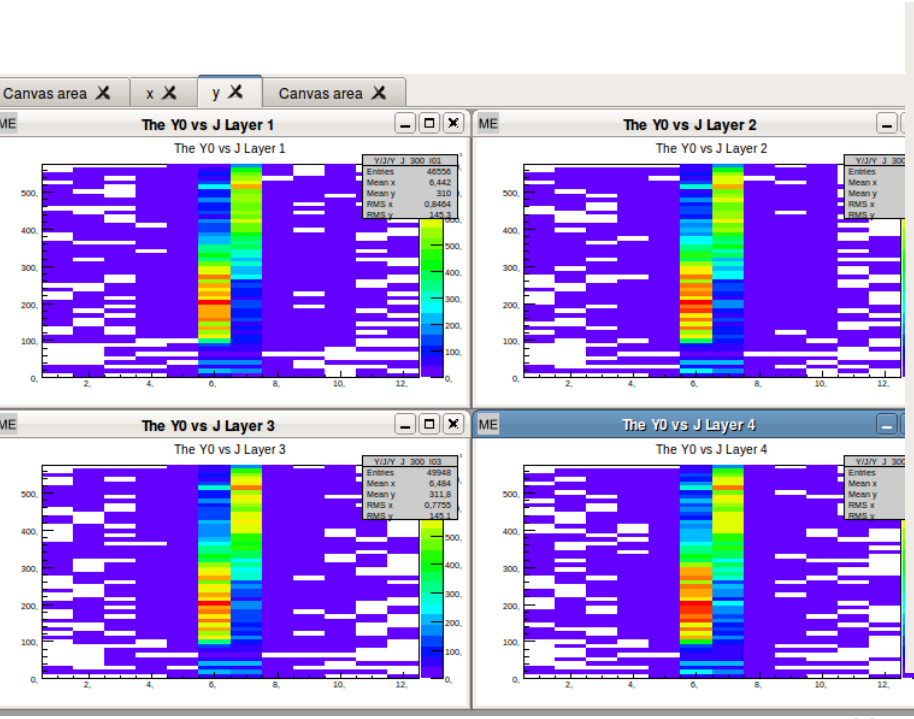
- Combined data taking of AHCAL, Mimosa beam telescope and (old) TLU
  - October 2016 + December 2016
  - External triggerID from TLU
    (TtriggerID clocked out from TLU)
  - All devices have **independent clocks** (!)
- Issues with TLU TriggerID handshake
  - TrigID clockout protocol (HW workaround: 50ns filter)
  - Triggers come even when AHCAL is busy (treated in software)
  - All fixed in the new mini-TLU
- Timing: AHCAL stops after TLU sends trigger
  - 20~90 particles/s (depending on beam conditions)
- Data combined in EUDAQ
  - Smooth integration
  - Events defined by Trigger ID
  - A Complete readout cycle assigned to TriggerID
  - All events numbers synchronized issues fixed
  - Can do a long runs without event number mismatch

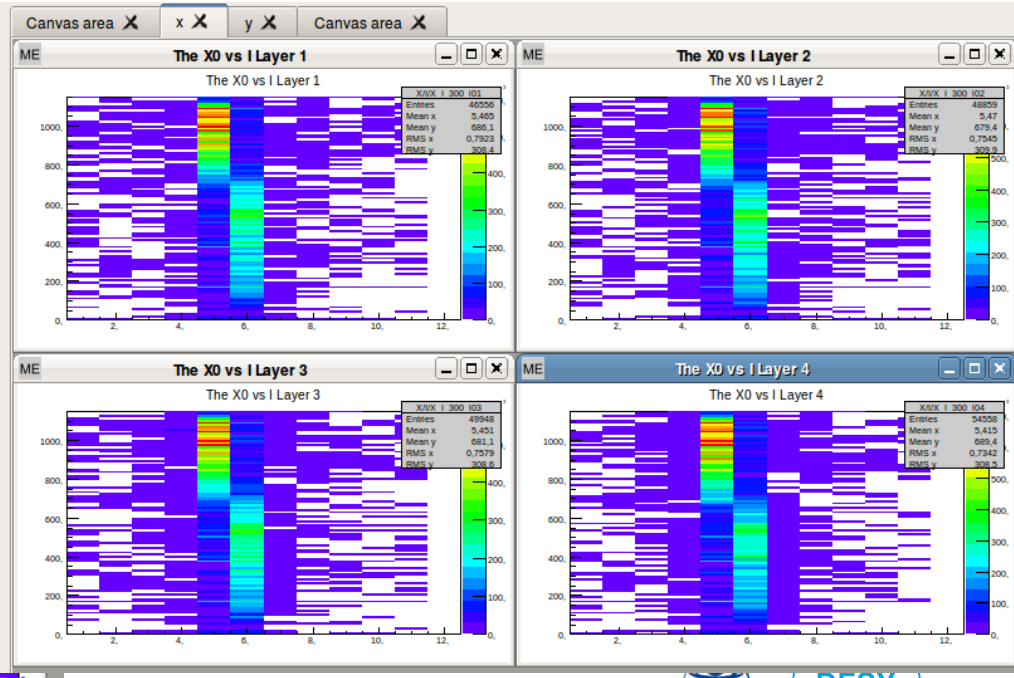


X & Y spatial correlations for 5.8 GeV e-

- Main excersize for AHCAL: get properly synchronized events
- Semi-online analysis with DQM4HEP
- Detectors ~2m apart => multiple scattering is an issue
- We squeezed 5.8 GeV energy out of DESY testbeam to see a reasonable correlation

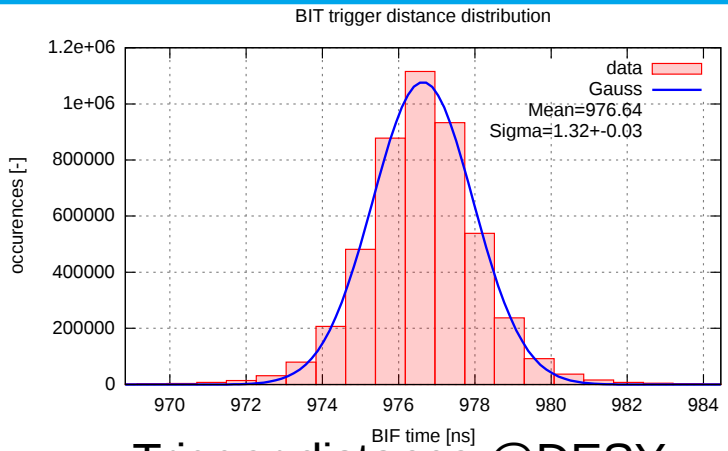
  => very low rate: can record only ~20 triggers / s



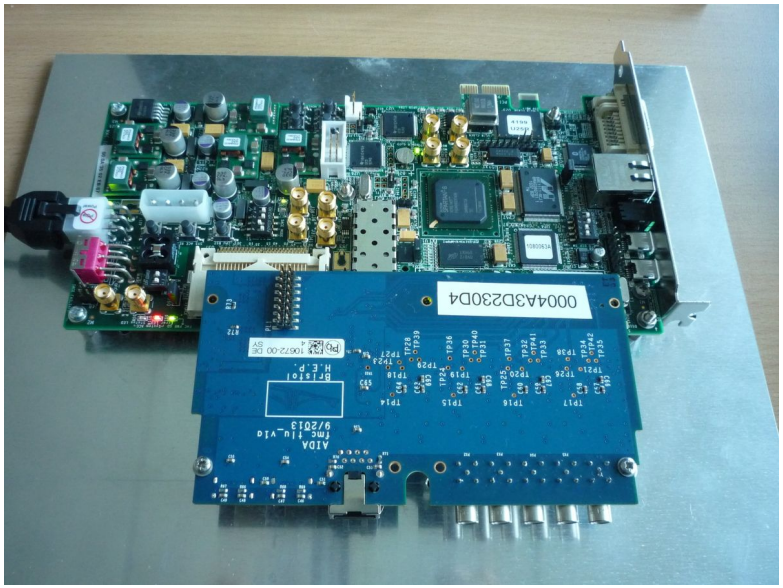


Combined beam test with a beam interface (mini-TLU)

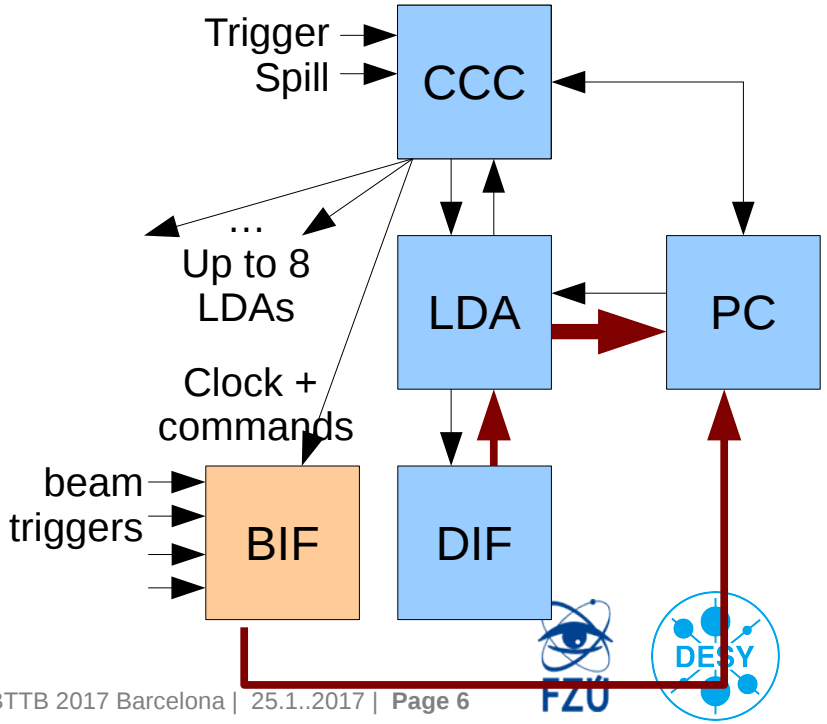
- Motivation: Callibrate AHCAL TDC
- BIF = **AIDA mini-TLU** with custom firmware
  - **Receives AHCAL clock** (40 MHz)
  - Operates in same readout cycles as AHCAL
  - Triggers outside AHCAL readout cycle ignored
- Records timestamps from 4 inputs (lemo) + start&stop of acquisition of AHCAL
  - Estimated jitter: 1 ns (measured on 1 MHz DESY beam)
- Data combined in EUDAQ



Trigger distance @DESY



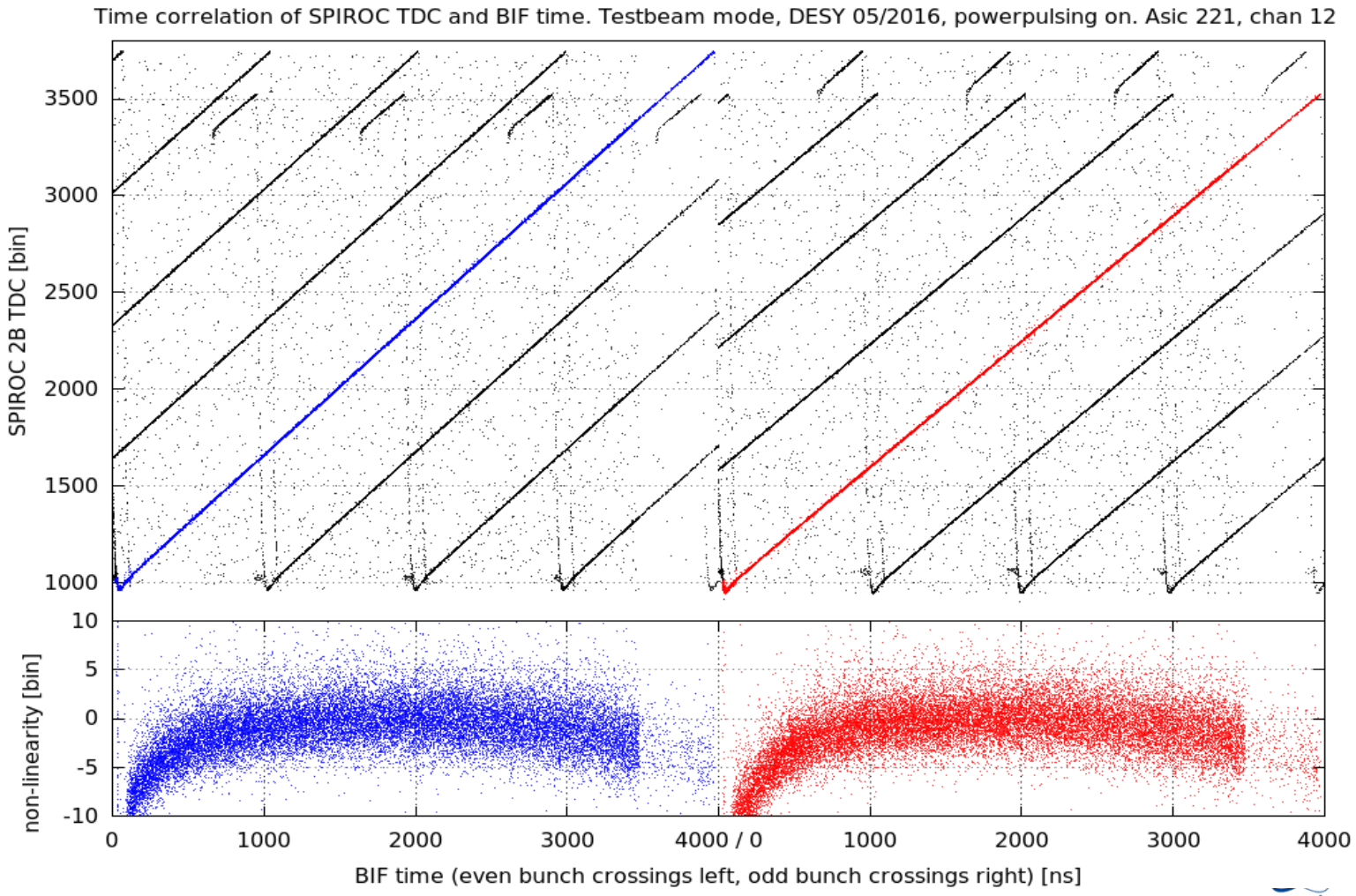
http://www.ohwr.org/projects/fmc-mtlu/



Correlation of BIF Time vs AHCAL TDC

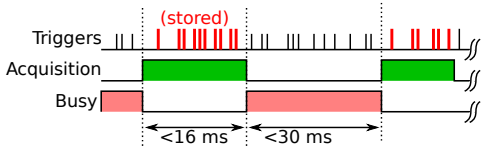
> Odd and even BX are treated separately (AHCAL specific feature)

> 4 us BX width => DESY beam structure (~1 us period) clearly visible

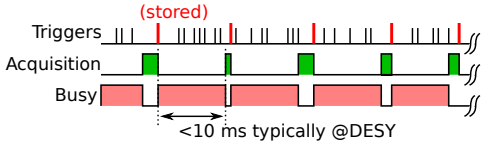


AHCAL EUDAQ Producer development strategy

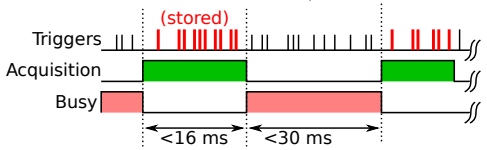
- Keeping the data as raw readout cycles is fairly limiting
- rewriting the producer to support different modes:
- ReadOutCycle (done & tested)
  - EUDAQ Event# = Readout cycle number
  - Full dump of the raw data from the cycle



- TriggerID (done& tested)
  - EUDAQ Event# = TriggerID
  - Full dump of readout cycle, that was intercepted by TLU trigger (or empty block if no data was recorded for that particular TLU trigger)
  - Inefficient for AHCAL

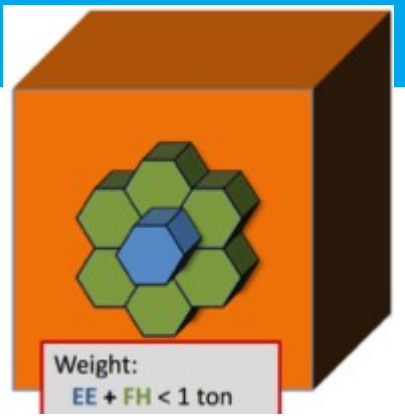


- More TriggerIDs in ROC (work in progress)
  - EUDAQ Event# = TriggerID
  - Motivated by **AHCAL efficiency**
  - **Online event building**: All AHCAL hits from same BX window (4us/200ns) and same ROC stored in one EUDAQ Event

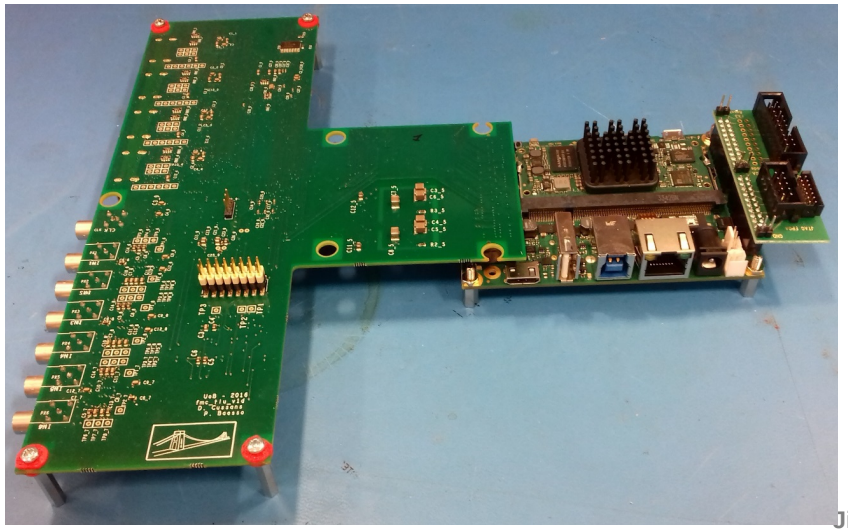


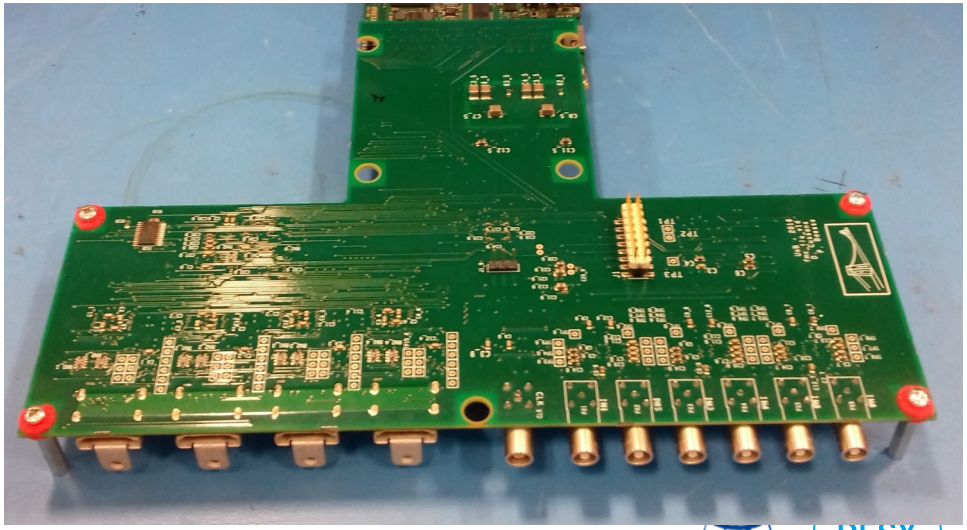
- Timestamp oriented Event building (work in progress)
  - EUDAQ Event# = (arbitrary sequence number) + **TIMESTAMP**
  - 48-bit 40 MHz counter (unique within 2 months)
  - **For test of EUDAQ 2**

Plans



- Test of EUDAQ 2: February 2017
  - Verify functionality before EUDAQ 2 is released
  - Improved data rate expected
- Test of AHCAL in magnetic field (CERN SPS, 5/2017)
- Combined beam test with CMS HGCAL (CERN SPS, 6/2017)
- Test of AHCAL with a **new TLU** (DESY TB, Q1-Q2/2017)
  - 6 lemo inputs, 4 full-size HDMI connectors for DUT
  - New clocking chip with advanced jitter filtering
  - Firmware to be finished soon



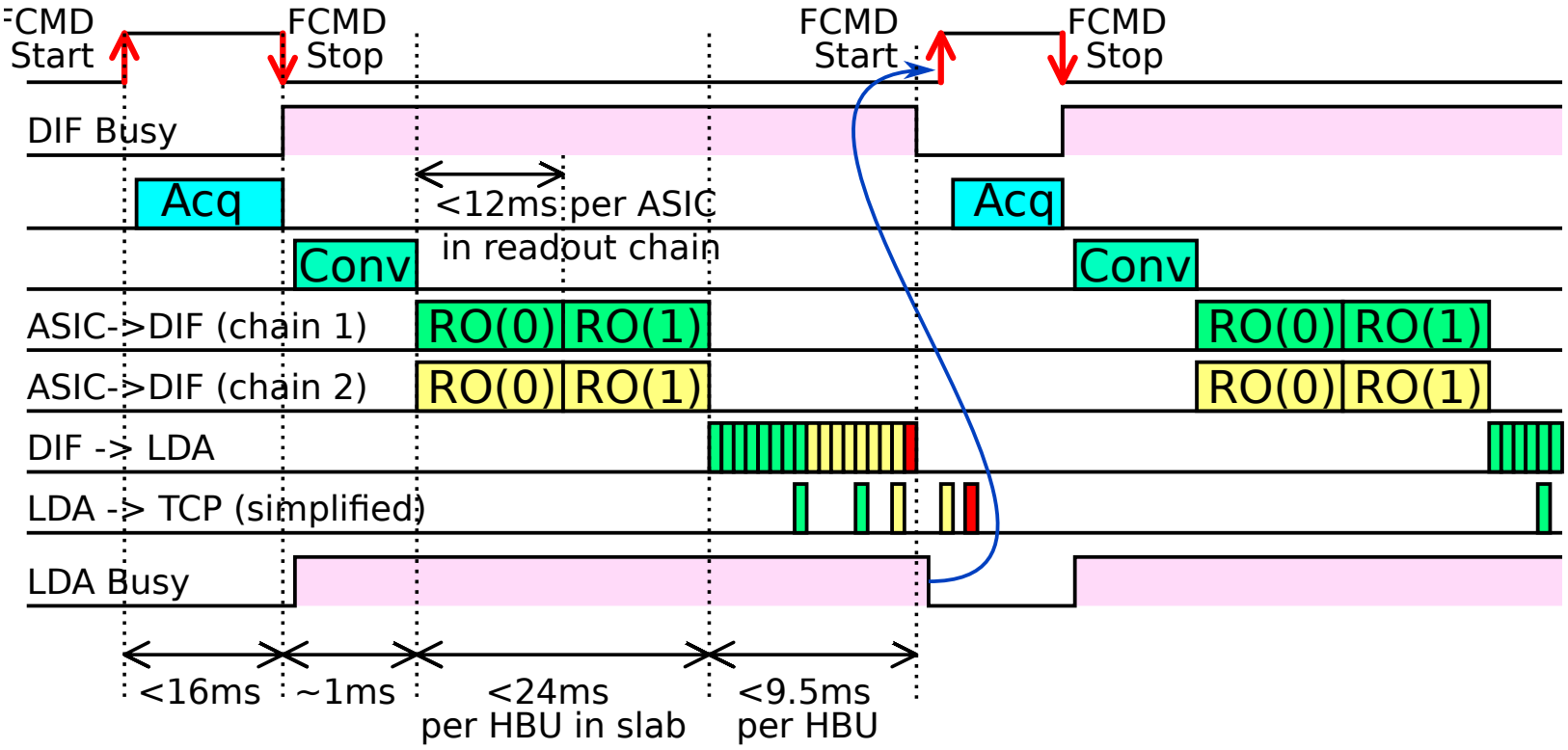


Conclusion

- Combined testbeams with AHCAL
- Externally triggered and a self-triggered devices working togetger(!)
- AHCAL & MIMOSA beam telescope @DESY
  - “safe” mode: only 1 triggerID per acquisition cycle at the moment
  - More efficient solution soon
- AHCAL & Mini-TLU (a.k.a. AHCAL BIF)
- Good correlation observed in both setups
- Moving on towards basic event building in AHCAL EUDAQ producer
  - Necessary to record more than 1 TriggerIDs within a 16 ms AHCAL Acquisition cycle
- Plenty of combined tests of AHCAL foreseen this year
- First test user of EUDAQ 2
  - Adding Timestamp to the EUDAQ Events → for further event building in EUDAQ2

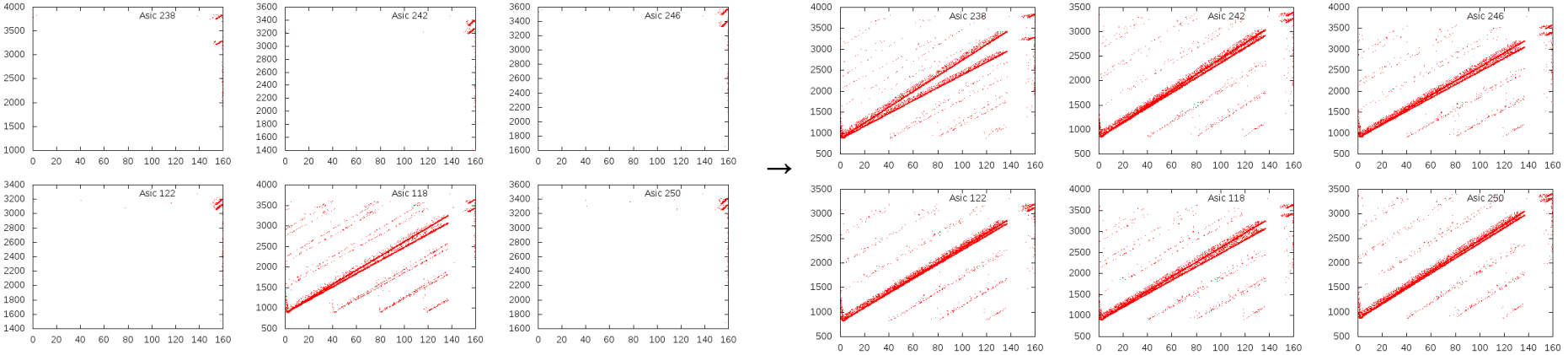
Spare

Typical timing (details)



Results

> Trigger validation fixed (correlations of TLU trigger time and AHCAL TDC)



Testbeam performance

> Chip design duty cycle: 0.5% Operated at 30%

> Different conditions at CERN PS, CERN SPS and DESY beam line

- spill structure, beam intensity, particle rate stability, SiPM noise

	CERN PS TB 2014 USB	CERN SPS TB 2015 HDMI	DESY TB 2016 HDMI[1]		TB 2016 1ms spill	TB 2016 Triggered
Max asics in layer	16	16	16	4	4	4
ROC/s (calib=full asics)	1-2	6.2	~15	29	-	?
ROC/s (autotrig)	2-3	~17	17	*25-30	99	90~100
Duty cycle	(?)	(?)	10%	*20-30%	9.2%	?
Events/s	<30 (?)	<165 (?)	135	<200	41	90~100

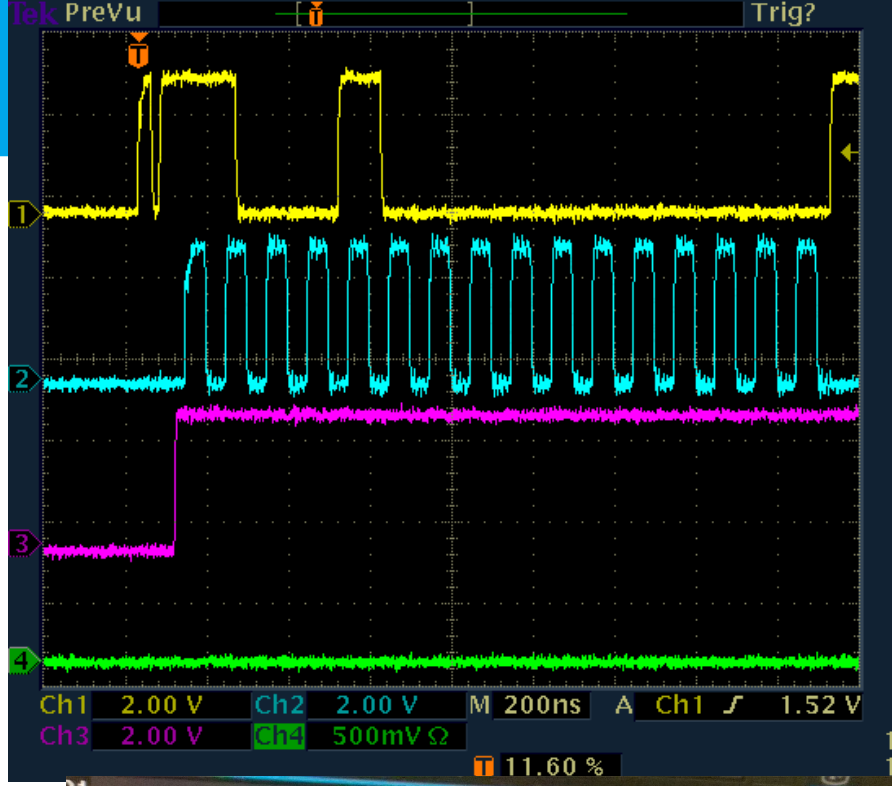
> DESY accelerator: not continuous → many empty cycles

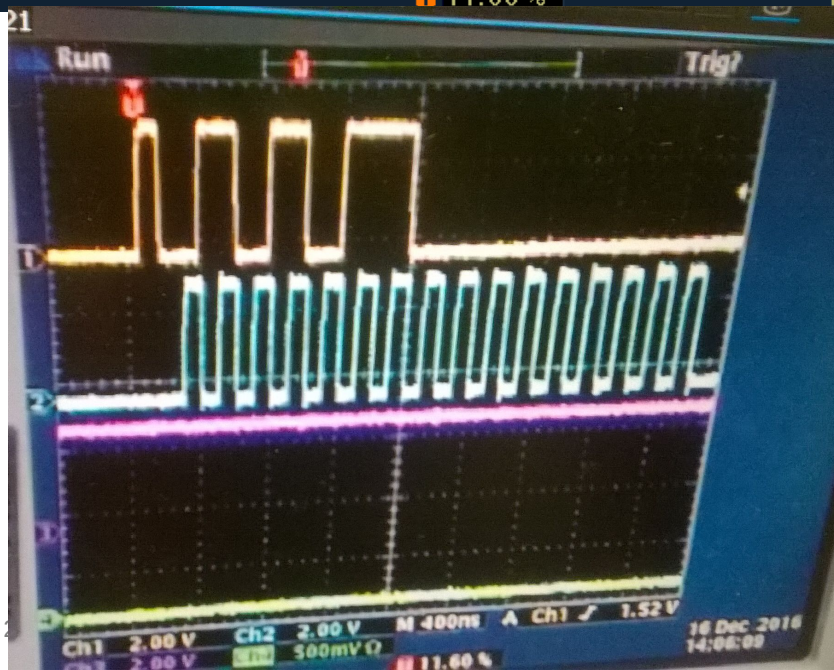
→ Didn't reach theoretical 450 events/s in TB

Current performance @ DESY beam

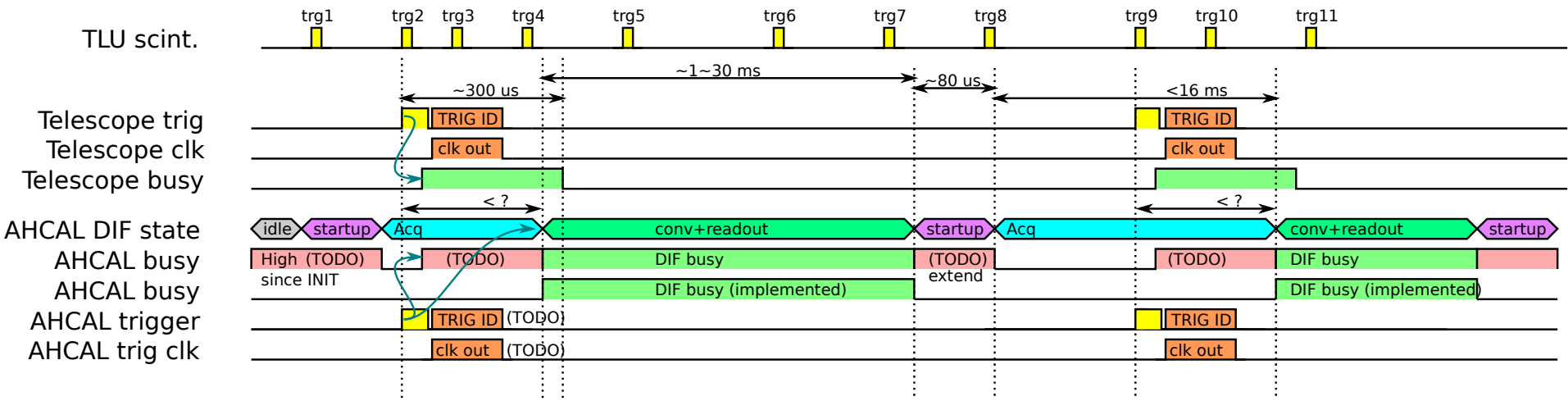
Problems

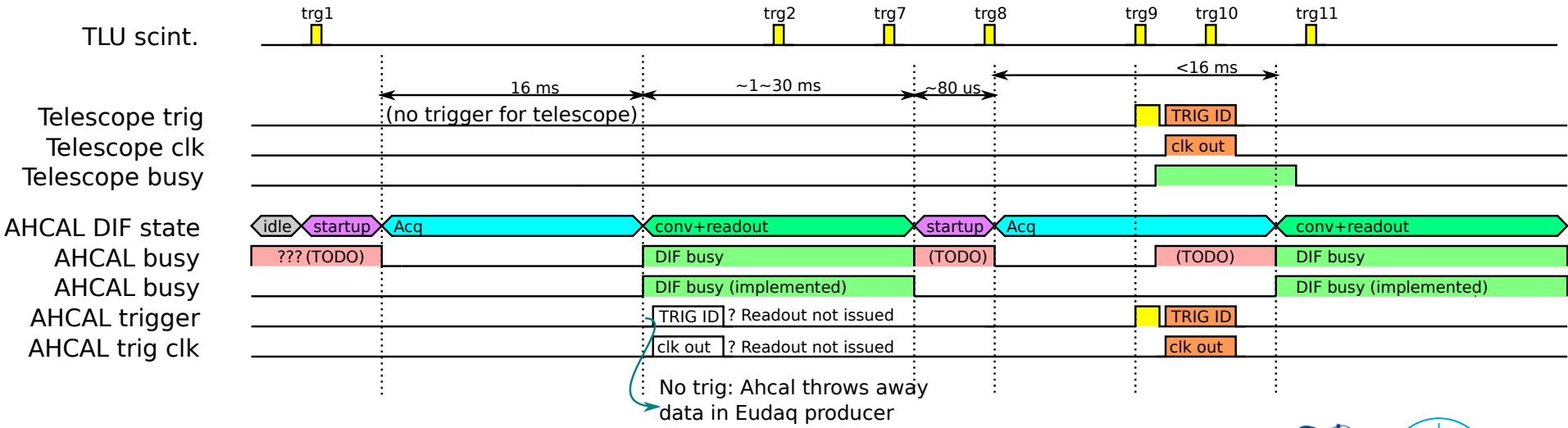
- DIF2 LVDS receivers started in wrong state => DIF2 did not see the validation
  - Fixed in CCC by new command for a manual long trigger pulse
  - Once long trigger sent, LVDS receivers are recovered until poweroff
- 20 ns glitch in the trigger pulse
  - could not run more than 16384 cycles
  - Results in the trigger count mismatch
- Triggers come even when busy is set
  - Producer was not designed for that
  - Trigger ID shift by ~50 events in 1000 events
- 2 triggers in the same ROC
  - Fixed in EUDAQ producer



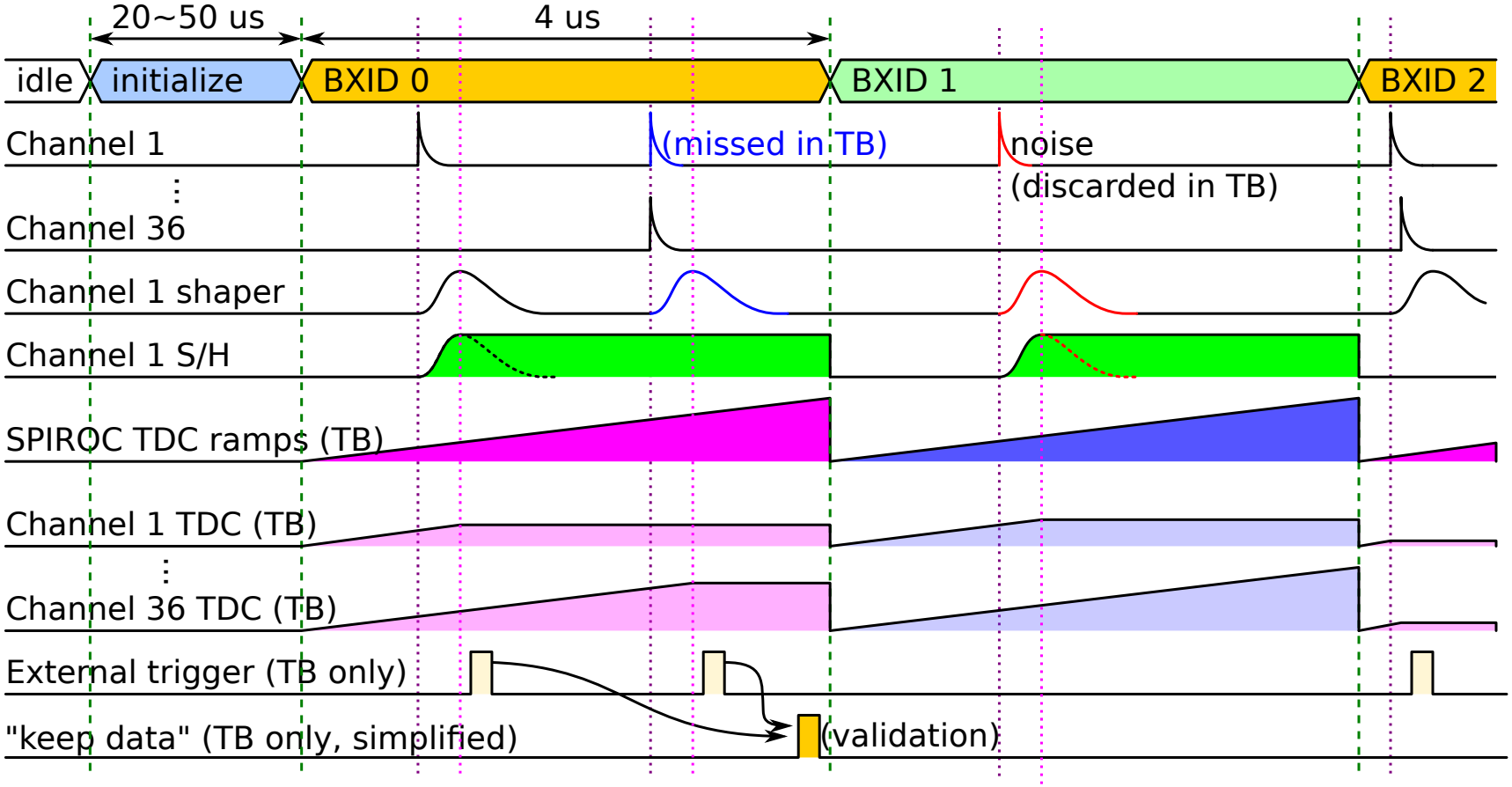


TLU ↔ CCC handshake





Spiroc operation: ADC & TDC (Testbeam case)



> ADC signal is stored after a programmable delay from internal trigger

> TDC value is stored at the moment of internal trigger

> In testbeam mode: possibility to validate trigger (else throw away)

Common running @ CERN PS 2014

- AHCAL + SiW ECAL layer
- ECAL System differences
  - 50 MHz clock (vs. 40 MHz)
  - No busy / Memory full
  - Only Spill input
  - 2.5 MHz BXID (vs. 250 kHz)
  - No TDC
- EUDAQ as common DAQ SW
  - AHCAL communication from Labview
  - Raw data forwarded to EUDAQ, stored in LCIO
- Common events properly timed found!