Unified Communication Framework

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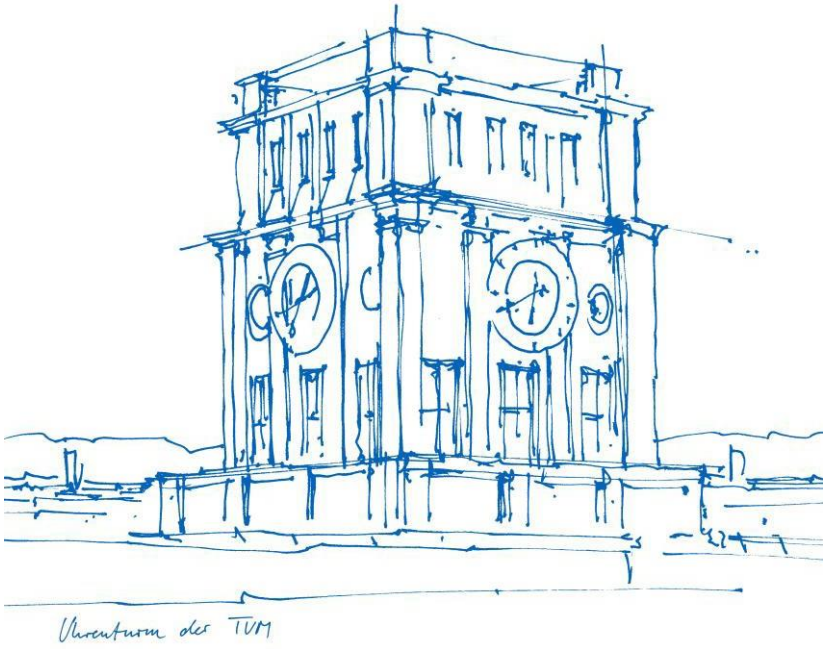
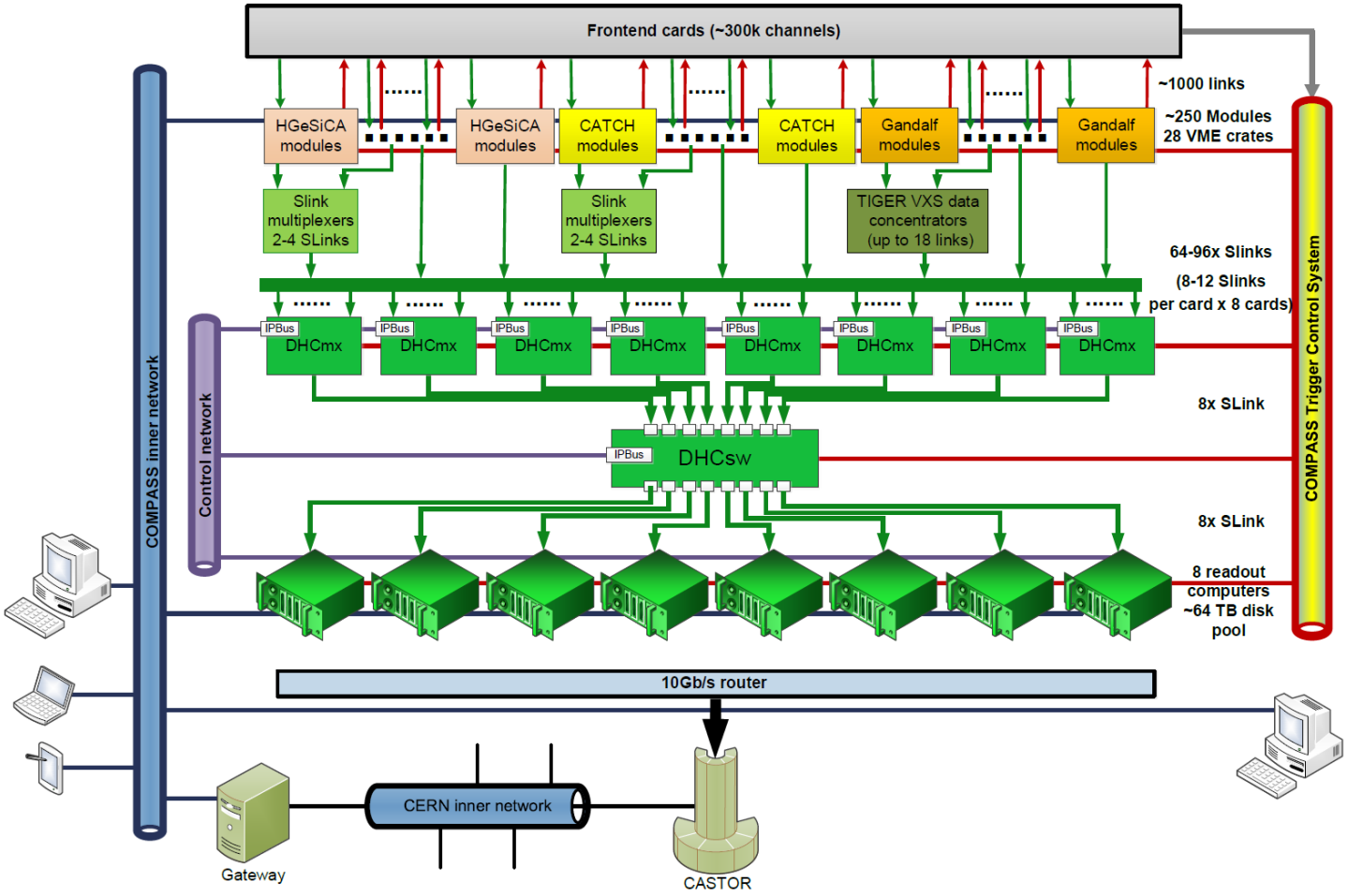


What can be gained in COMPASS



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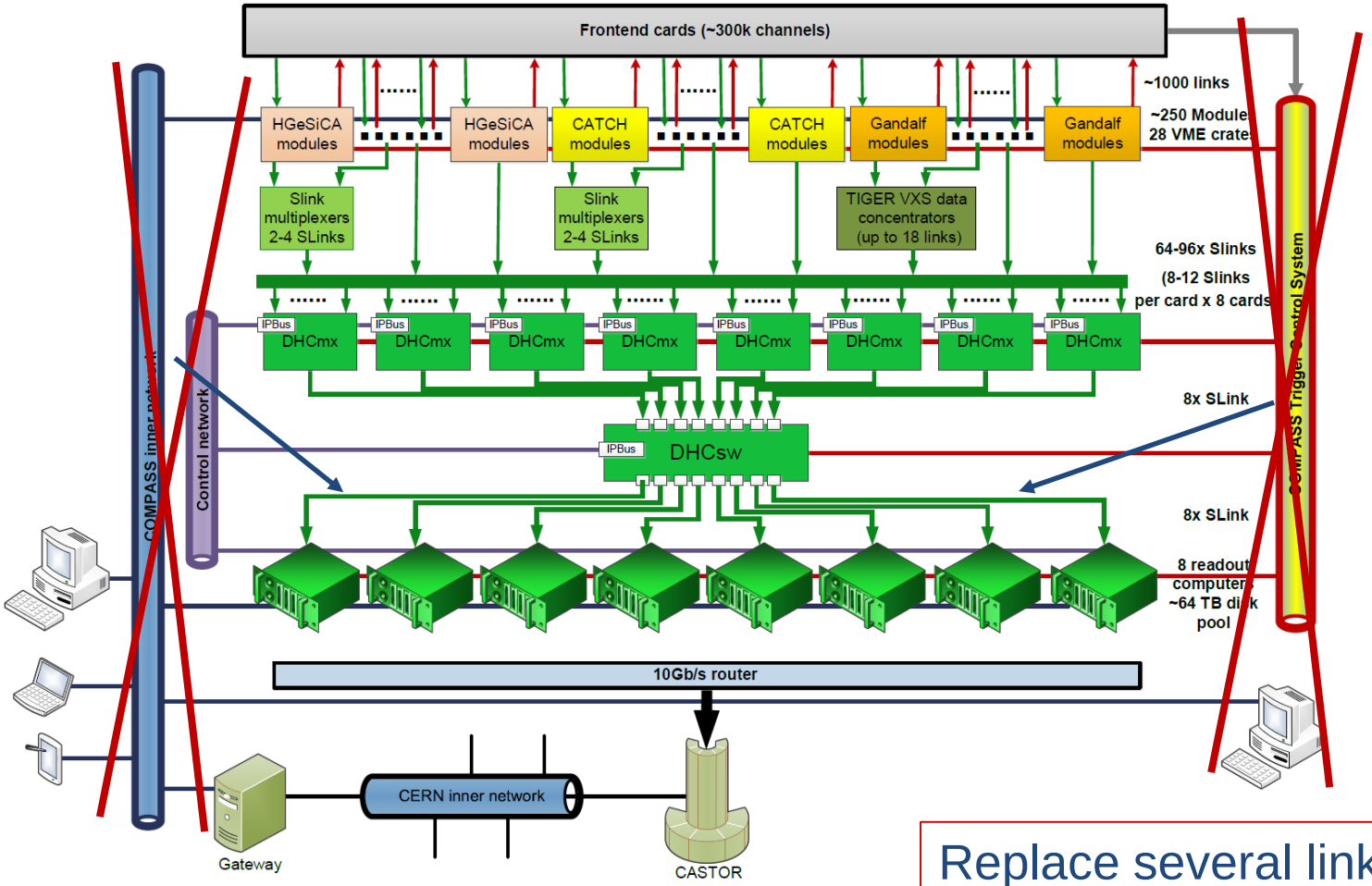
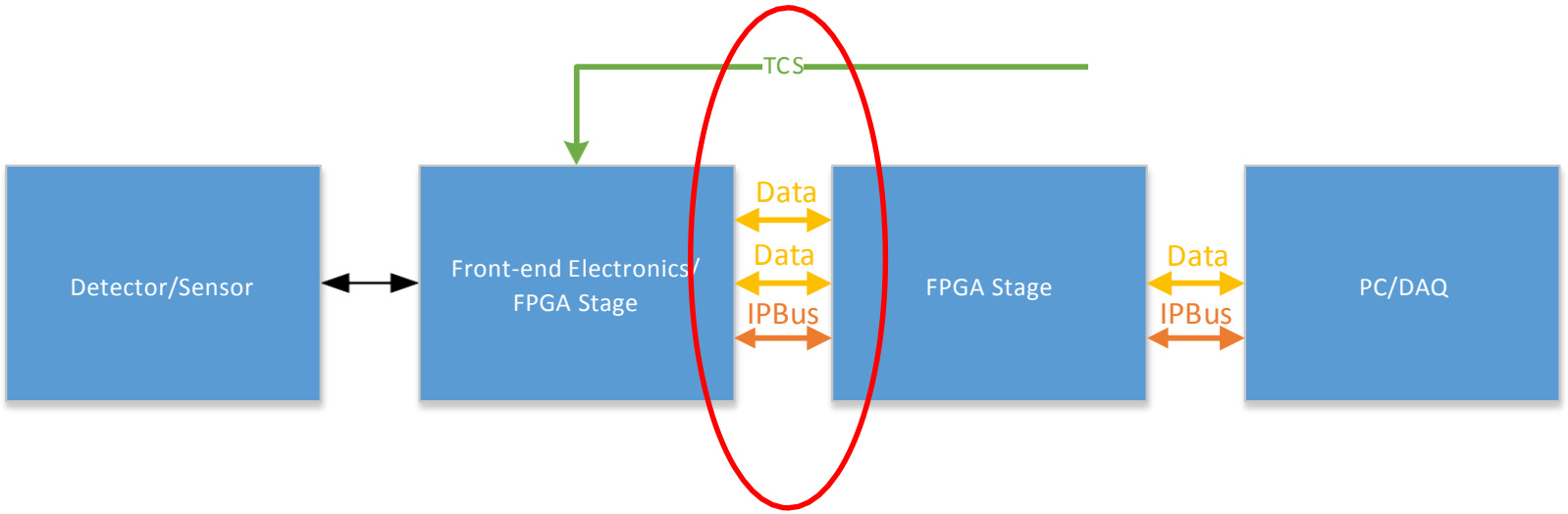


Replace several links to Fes by one optical fibre

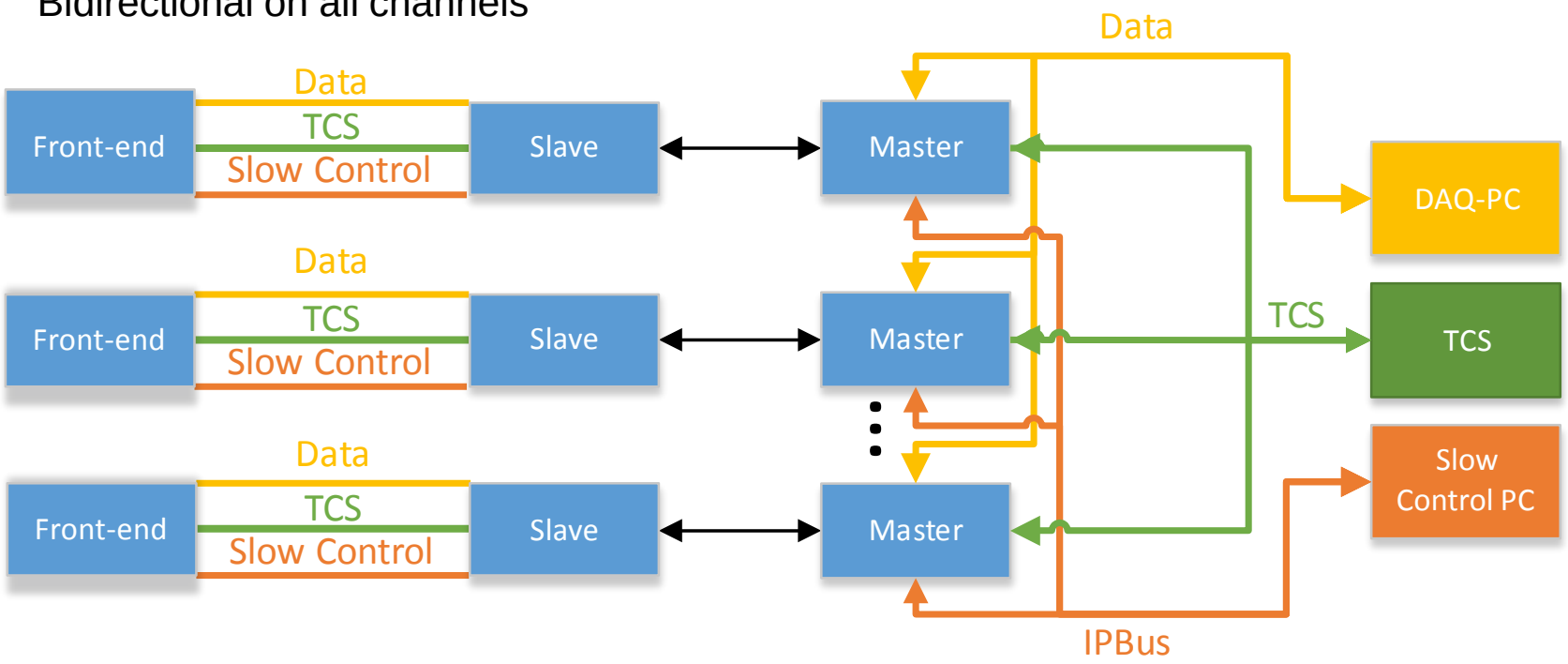
Unified Communication Framework (UCF)

- Single high-speed serial link for data, slow control, trigger, and timing information
- Up to 64 different communication channels (Trigger, Data, Ethernet)
- Fixed latency for one channel
- Priority handling for all channels
- Self recoverable after connection losses
- Independent from physical layer



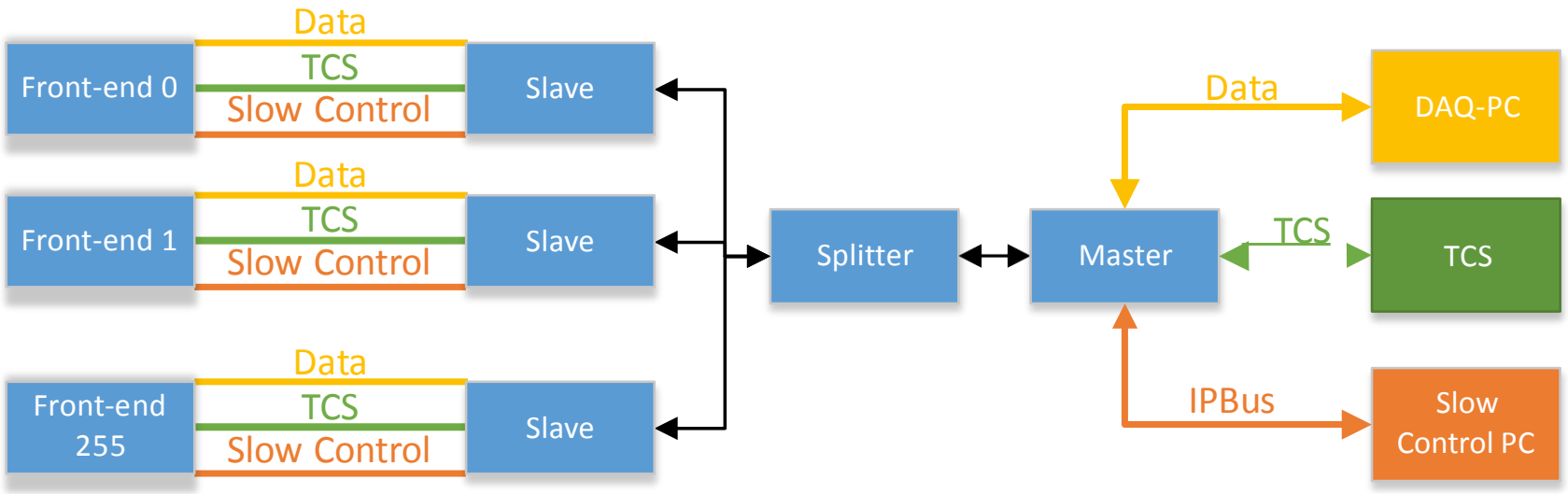
UCF – Example Topologies

- Point-to-Point topology:
  - Multiple or single 1:1 connections
  - Experiments with high data rates, …
  - Bidirectional on all channels



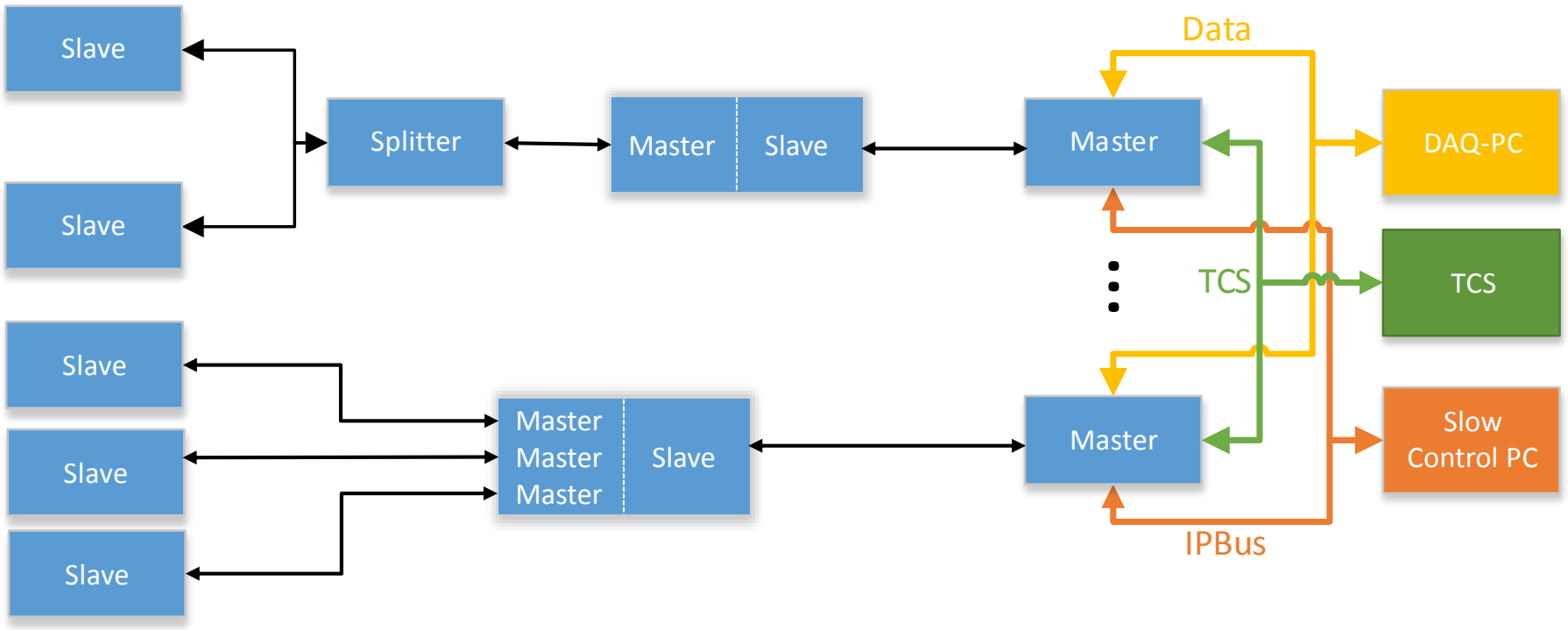
UCF – Example Topologies

- Star-like topology:
  - Single 1:n connections
  - Experiments with low data rates, time distribution systems …
  - Slaves share link in time division manner
  - Bidirectional on all channels



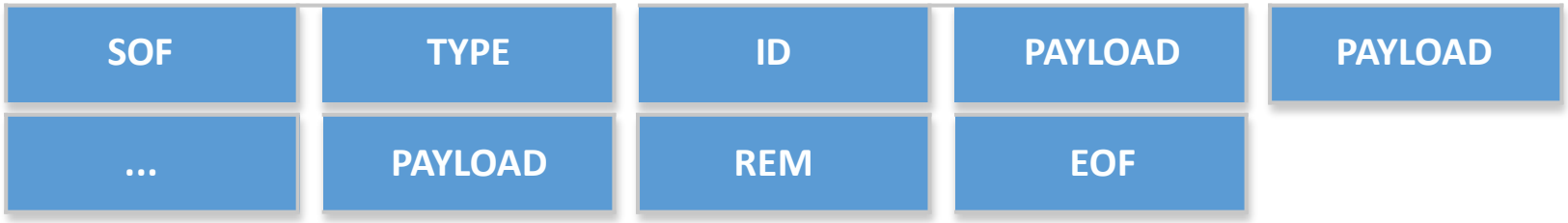
UCF – Example Topologies

- Hybrid topology:
  - Example for a full experiment
  - Several stages
  - Different topologies dependent on the FE requirements



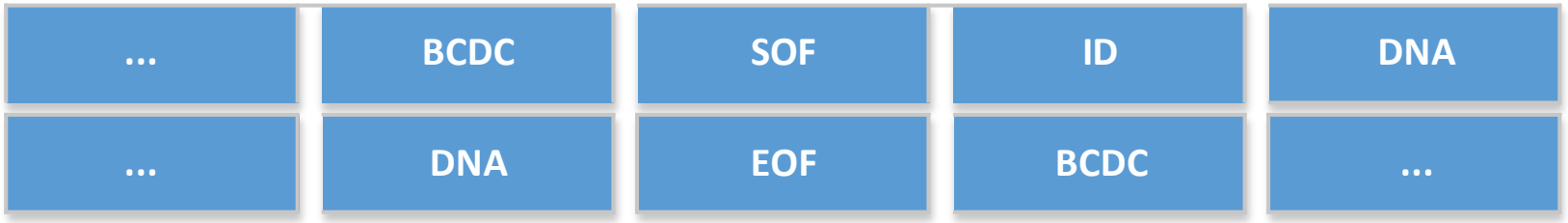
UCF – Low Layer Protocol

- Backbone of UCF
- Handles communication and initialization
- 8b/10b encoding scheme
- 10b K-characters for control and synchronization
- Protocol frames consist always of several character sequence:
  - Start of frame
  - Type of the message (either specific destination or broadcast)
  - Protocol identifier
  - Payload
  - Remainder defining the valid bytes in the last transmission
  - End of frame



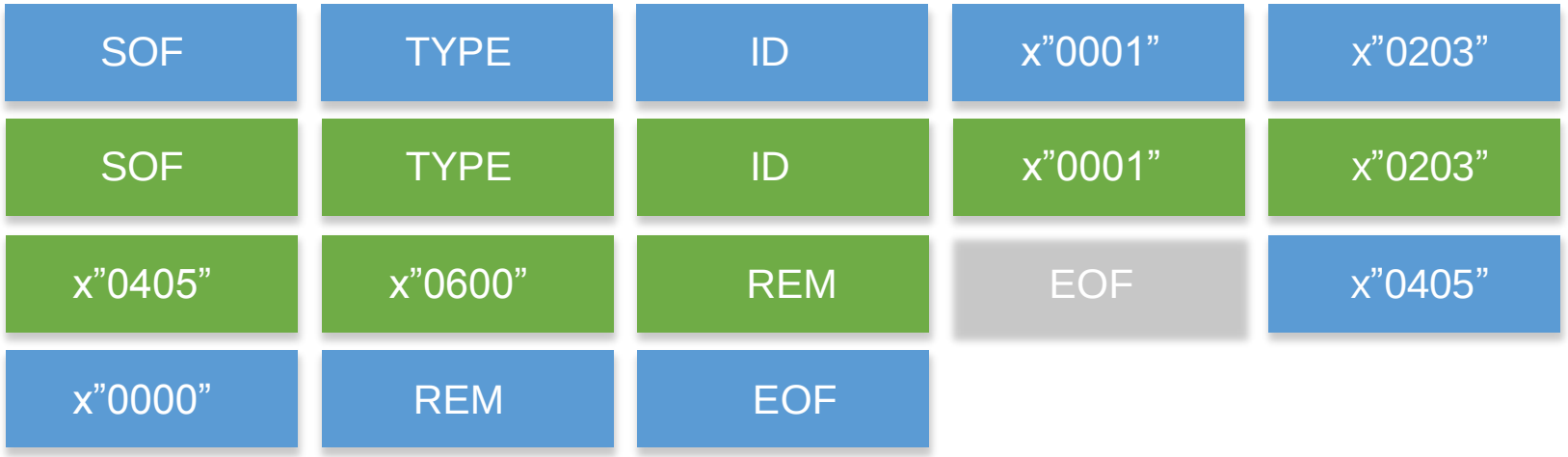
UCF – Initialization

- Fixed phase synchronization by sequence of two defined K-characters (x”BCDC”)
- Link polarity detection
- Synchronization character will be send for specific time to let the slaves synchronize
- Unique ID and IP assignment for all connection parties



UCF – Priority Handling

- All 64 communication channels have different priorities
- Protocol 0 has the highest and then it cascades down to the protocol 64 which has the lowest priority
- Frames with higher priority can always interrupt lower priority frames
- Maintains fixed latency for the timing channel



UCF – User Interface and Configuration

- UCF consists of a Logic block
- And a Hardware specific block
  to be adapted to new FPGA architectures
- Interface to user protocols via AXI-Stream
- Configuration parameters:
  - Link speed
  - Topology
  - Device type ….

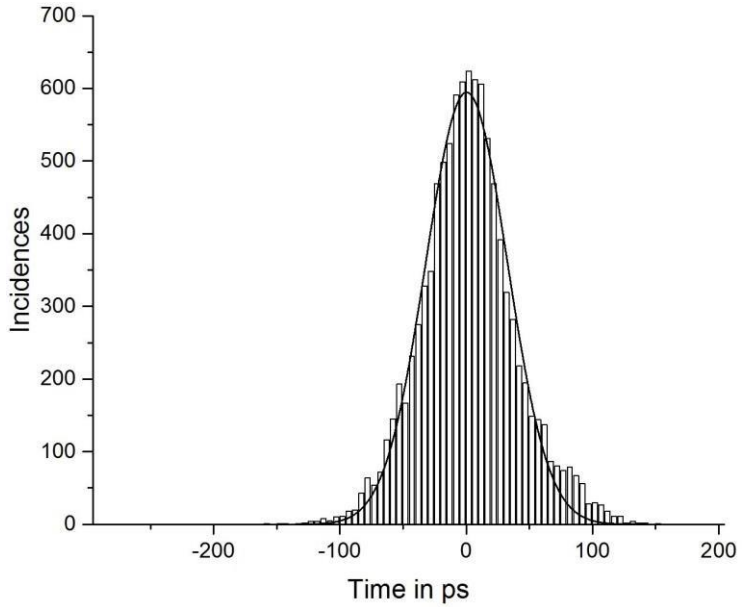
```
Inst_UCF_Wrapper : entity work.ucf_wrapper_ucf
generic map(
    recg.intInterfaces                  => intInterfaces,
    recg.intTransceivers                => intTransceivers,
    recg.intCyclesMin                   => intCyclesMin,
    recg.intSerials                     => intSerials,
    recg.intMaxTries                    => intMaxTries,
    recg.slP2PActivation                => slP2PActivation,
    recg.slCardPurpose                  => slCardPurpose,
    recg.slActivateSim                  => slActivateSim,
    recg.strDeviceType                  => strDeviceType,
    recg.PLL_DIVSEL_FB                  => PLL_DIVSEL_FB,
    recg.PLL_DIVSEL_OUT                 => PLL_DIVSEL_OUT,
    recg.PLL_DIVSEL_REF                 => PLL_DIVSEL_REF,
    recg.PLL_DIVSEL45_FB                => PLL_DIVSEL45_FB,
    recg.CLK25_DIVIDER                  => CLK25_DIVIDER,
    recg.RX_Polarity                    => RX_Polarity,
    recg.TX_Polarity                    => TX_Polarity
)port map(
  clk                                   => refclk125_bufg,
  reci                                  => reci(0),
  reco                                  => reco(0)
);
SFP_TX12_N                              <= reco(0).slTXN;
SFP_TX12_P                              <= reco(0).slTXP;
reci(0).slRXP                           <= SFP_RX12_P;
reci(0).slRXN                           <= SFP_RX12_N;
reci(0).slReferenceClk                  <= refclk127;
reci(0).slLinkReset                     <= '0';
reci(0).slLinkReinit                    <= '0';
reci(0).slvDNAList(0)                   <= x"00C0426EBA540890";
reci(0).slvDNA                          <= x"00C0426EBA540890";
reci(0).DIFFCTRL_IN                     <= DEF_DIFFCTRL;
reci(0).PRECTRL_IN                      <= DEF_PRECTRL;
reci(0).POSTCTRL_IN                     <= DEF_POSTCTRL;
```

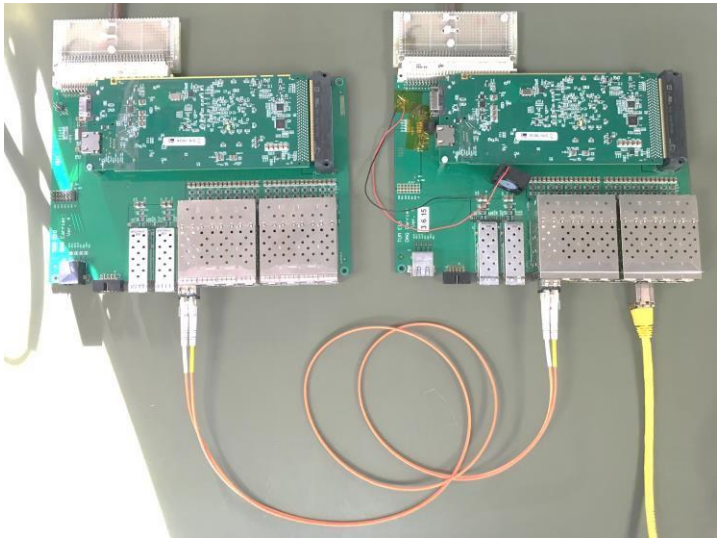
UCF Versions

- Version 1
  - 2Byte AXI-Stream interface
  - Version currently used in Belle II
  - Implemented for Virtex6, Artix7
- Version 2
  - 4Byte AXI-Stream interface
  - Supports backpressure
  - Link polarity detection
  - Transmission of 32bit parameters during startup
  - Implemented for Virtex6, Artix7, KintexUltraScale

UCF – Tests and Measurements

- Point-to-Point topology with 1 slave and 1 master
- 2.5 Gbit/s link speed
- Virtex 6 as slave and master
- Recovered clock jitter (σ) of 23 ps
- Requires 2 % slice register and 4 % slice LUT utilization on a Virtex 6 LX130T

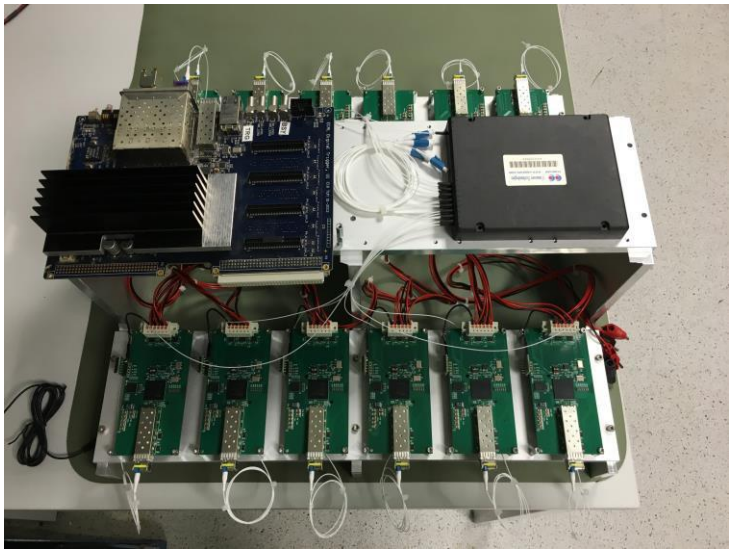




UCF – Tests and Measurements

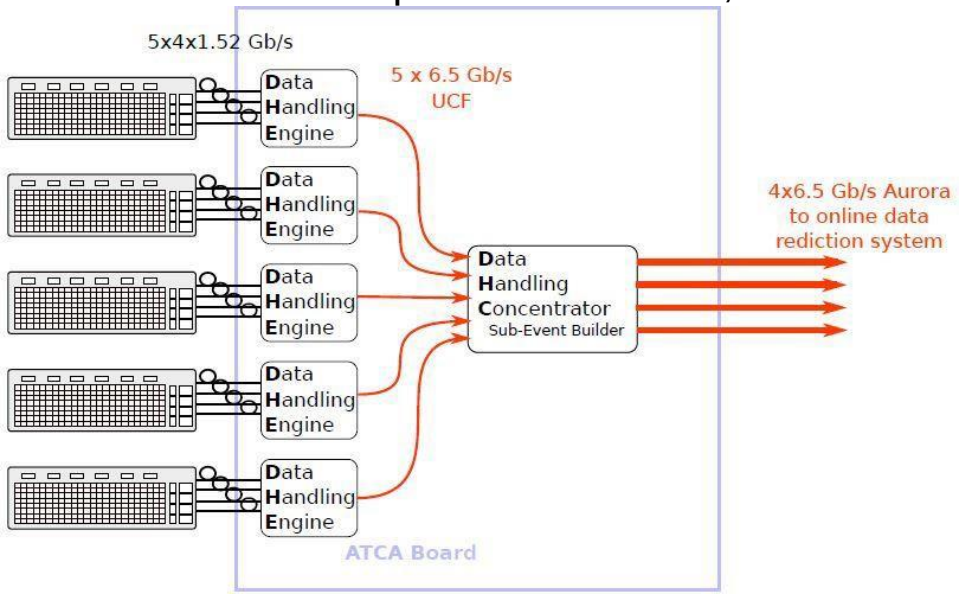
- Star-like topology with 12 slaves and 1 master
- 1.25 Gbit/s link speed
- Spartan 6 FPGA as slave and Virtex 6 as master
- Switching time of 16 µs (includes character transmission and synchronization)
- Long term stability test with 99 % link utilization over two weeks
- IPBus over UCF

Transmission Time [µs]	Efficiency [%]
25000	99,93
10000	99,84
1000	98,42
500	96,90
100	86,20



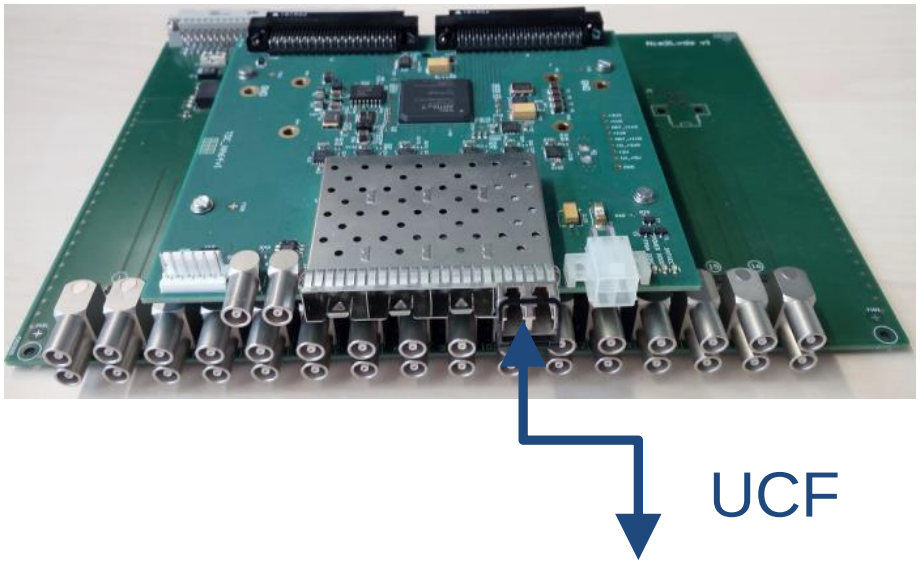
UCF – Belle II Pixel Detector

- Point-to-Point topology with 1 DHC and 5 DHE
- 22 GB/s data rate of the detector
- 127.21 MHz reference clock
- ~30ps clock jitter of the recovered clock
- 6.5 Gbit/s link speed, currently 2.5 Gbit/s
- IPBus, data and trigger distribution
- Communication via copper lines on ATCA carrier
- Four modules operational at KEK, UCF reliable for about a year



UCF – COMPASS iFTDC

- In 2018
  - UCF with 2Byte interface
  - 155.52MHz reference clock
  - 2.5Gbit/s to TDC multiplexer
  - 3 Protocols
    - TCS
    - IPBus
    - Data
- Future
  - Two UCF links
    - TDC multiplexer
    - Trigger processor



UCF – Conclusion

- UCF can be used as an interface between electronics modules in COMPASS
- Fixed latency for one channel
- Standardized ACI-Stream interface for user data
- Multiple 1:n and 1:1 connections possible
- IPBus over UCF
- Tested setups
    - Belle II
    - iFTDC
    - Starlike => LabTests

Plans

- Switch to 4 Byte version
- Deploy it as standard interface for all Fes
- Get feedback from other institutes about missing features and possible improvements

Thank you for your attention