ALICE electronics upgrade

Technical design report of the ALICE high rate detector upgrade

A. Kluge, 24 September 2013

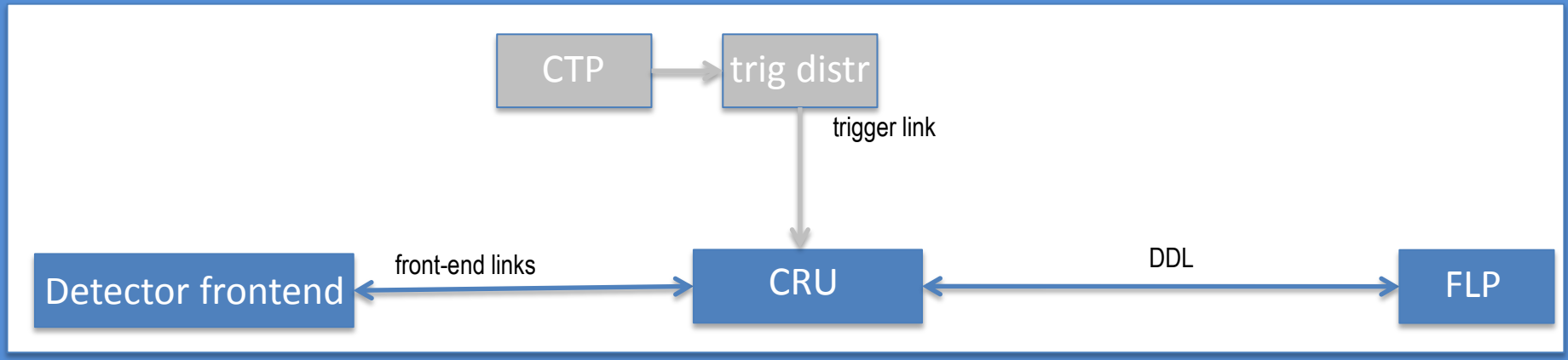
Upgrade Overview

- data taking & trigger strategy
- architecture
- detector overview
  - read-out capabilites
- upgrade developments
  - common developments
  - detector specific developments

Upgrade overview- RO and trigger

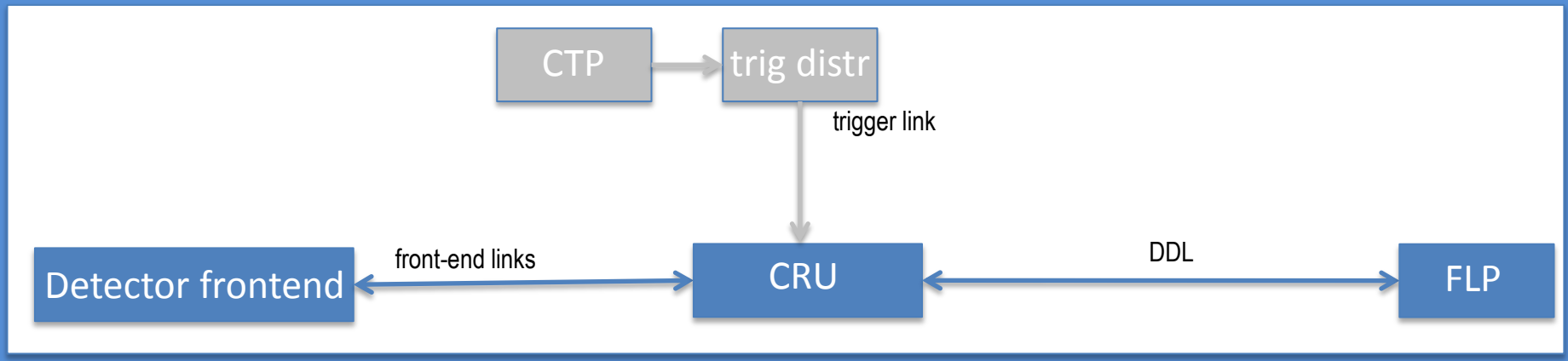
Upgrade overview- RO and trigger

- General principle:
  - store all information from interactions (if possible)
  - upgrade detectors to
    - trigger-less, data driven → continuous read-out



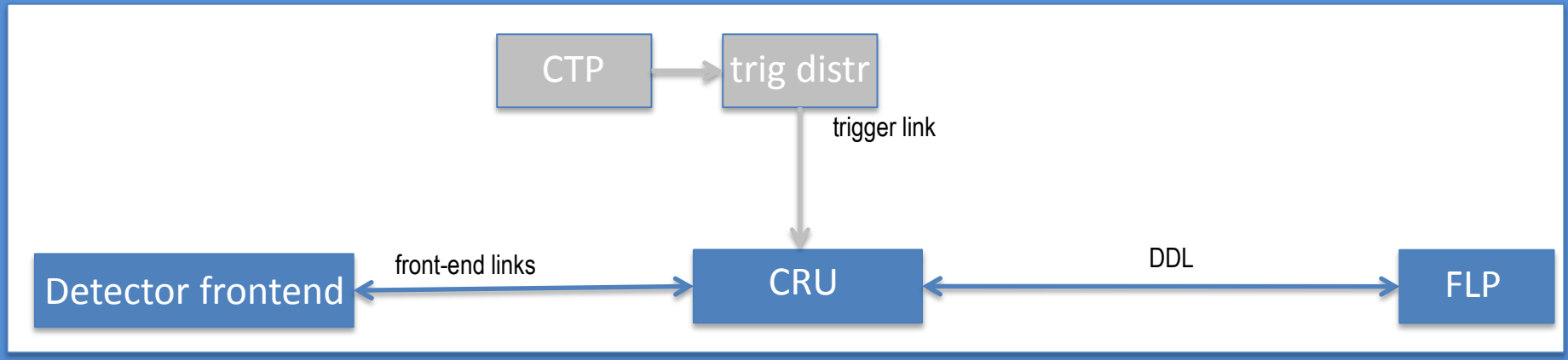
Upgrade overview- RO and trigger

- Upgrade to a continuous/trigger-less read-out of:
  - TPC
  - muon chamber (MCH)
  - inner tracking system (ITS)
- for an interaction rate of 50 kHz
  - with a design margin to 100 kHz for the read-out



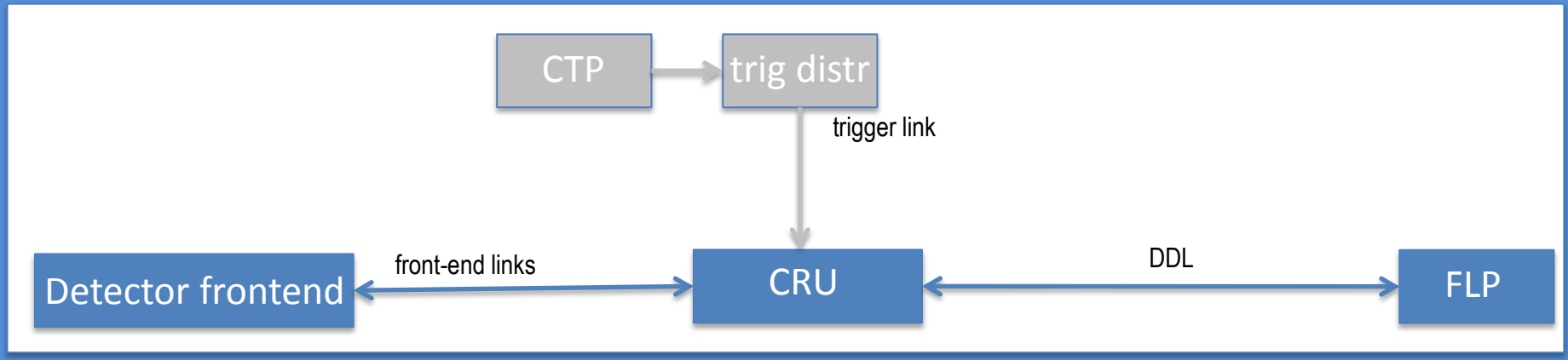
Upgrade overview- RO and trigger

- All other detectors have a triggered read-out



Upgrade overview- RO and trigger

- Two groups of detectors:
- continuous read-out and triggered detectors:
  - →ALICE still needs a trigger signal:
  - interaction trigger



Upgrade overview- RO and trigger

- Within triggered detector group:
  - Those with and without multi-event buffer
  - With different maximum read-out rate
    - with different live (not busy) time

Upgrade overview- RO and trigger

- Concept: Upon interaction trigger → read-out all detectors which are not busy

- Trigger scaling for specific combination of detectors optional.
  - Control by Central Trigger Processor (CTP)
  - trigger cluster

Upgrade overview- Summary trigger

- Interaction trigger for triggered detectors
- Suppression of trigger transmission to detectors already busy
- Possible beam or sensor induced noise rejection for ITS →
- Commissioning, cosmic runs →

- Consequence → continuous read-out detectors (TPC, MCH, ITS) need trigger capability

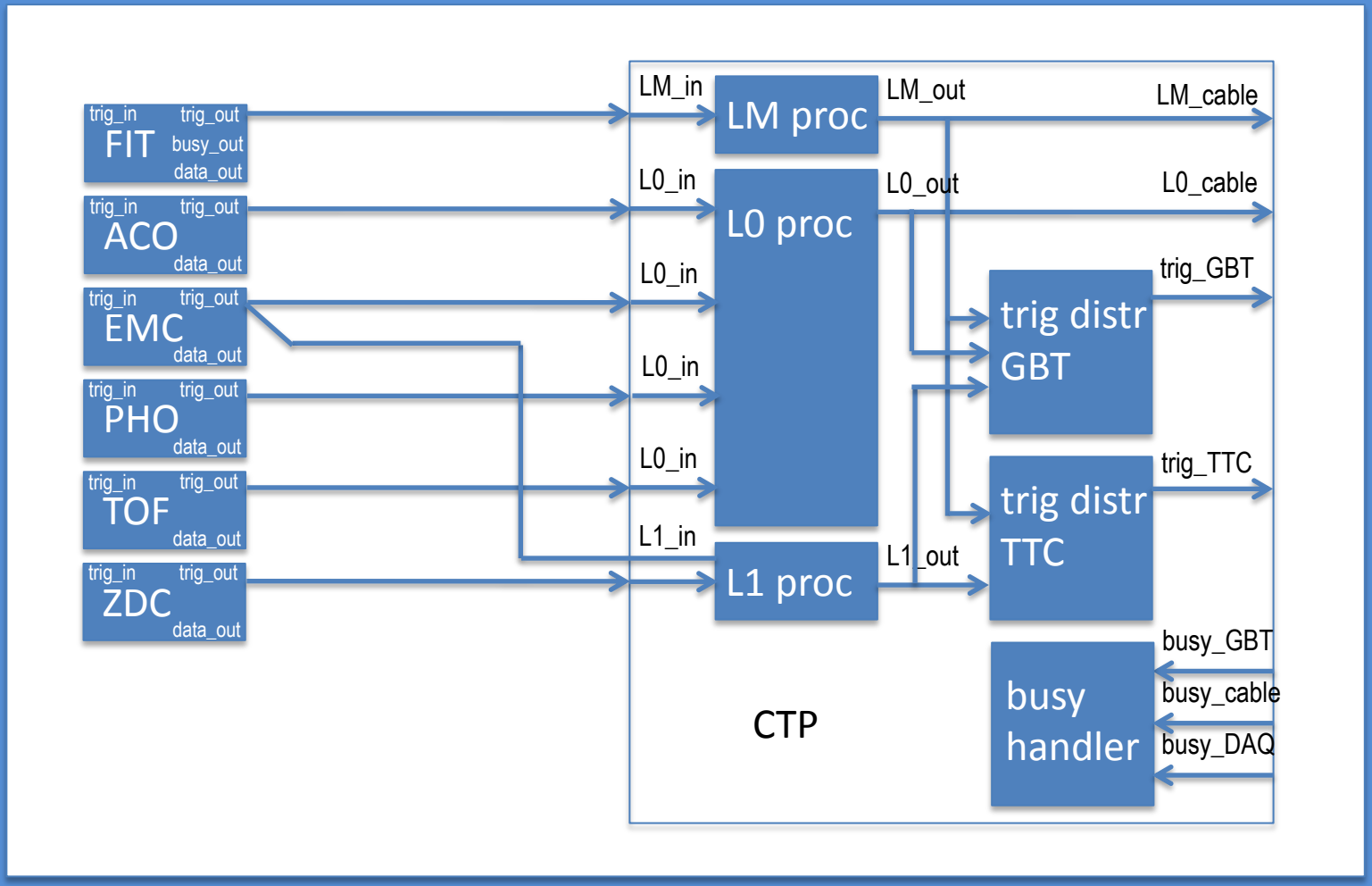
Upgrade overview- Summary trigger

- Option: Statistic scaling for detector combination with low read-out rate (EMC, PHO, HMP)
- Option: Interaction rate down scaling if DAQ is not fully active →

Trigger levels

Trigger mode/level	Max rate PbPb [kHz]	Latency @ CTP output [ns]	Detector contributor
continuous	-		
LM	50	800	FIT
L0	50	1200	option: ACO, EMC-sum, PHO-sum, TOF
L1	50	1200 – 6000	ZDC, (option: EMC-jet)

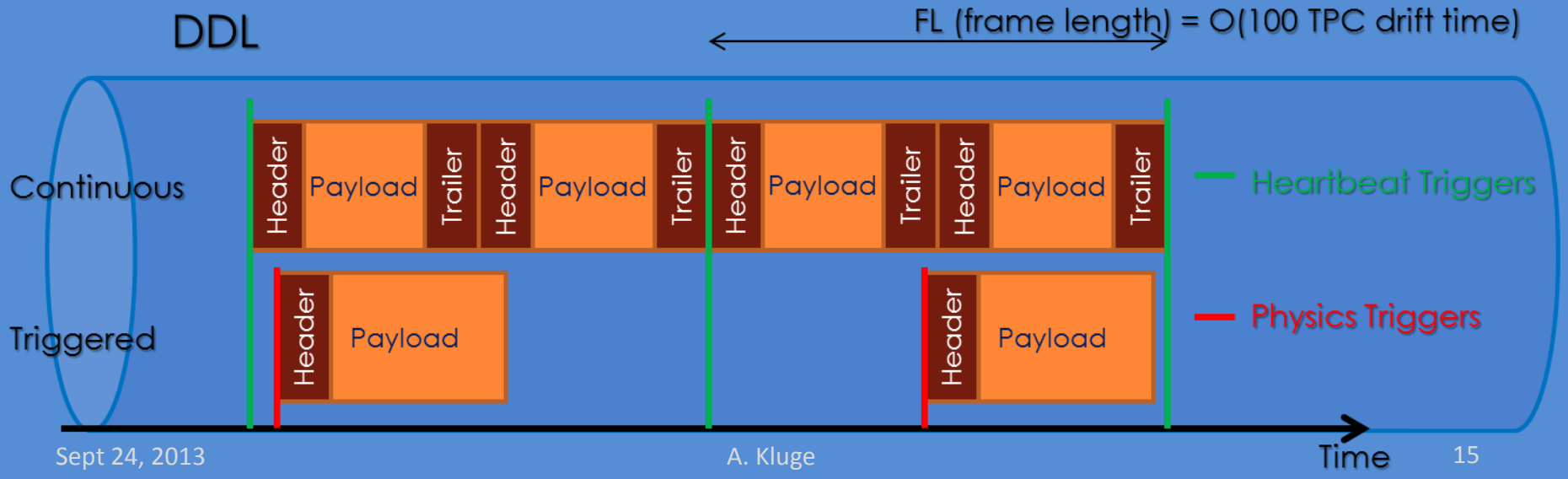
Central Trigger Processor



DAQ & heartbeat trigger

DAQ & heartbeat trigger

- Continuous & triggered read-out → collects (time) slices – time frames > 100 ms
- Continuous read-out detectors →
  - data stream separated in time frames
  - using heart beat triggers sent at time frame boundary



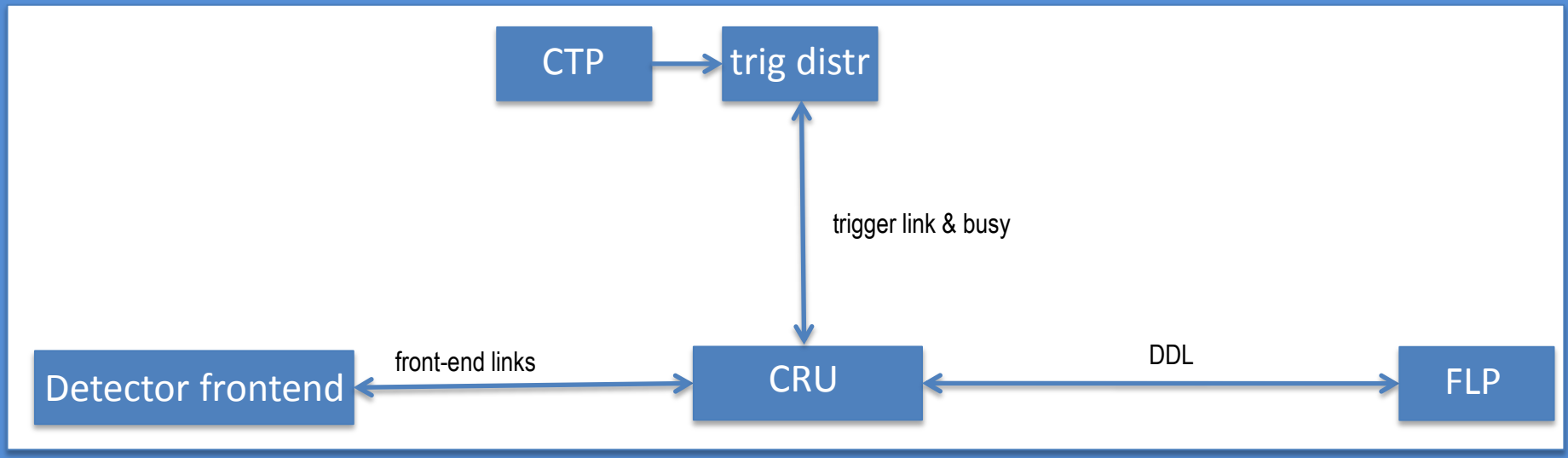
DAQ & heartbeat trigger

- Heart beat trigger (hb)
  - creates time frame boundary
  - sends bunch crossing (bxc) and orbit counters (oc)
    - FE re-synchronises
  - TTC system will not send full bxc & oc
    - bandwidth excess
  - also triggered detectors get hb trigger

Read-out architecture

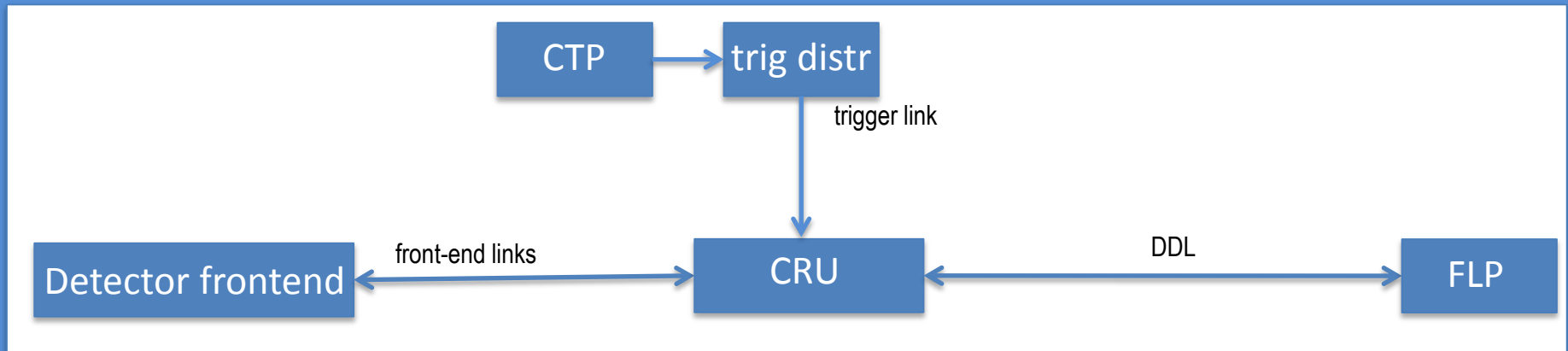
Read-out architecture

- General principle:
  - store all data from interactions (if possible)
  - includes a trigger processor



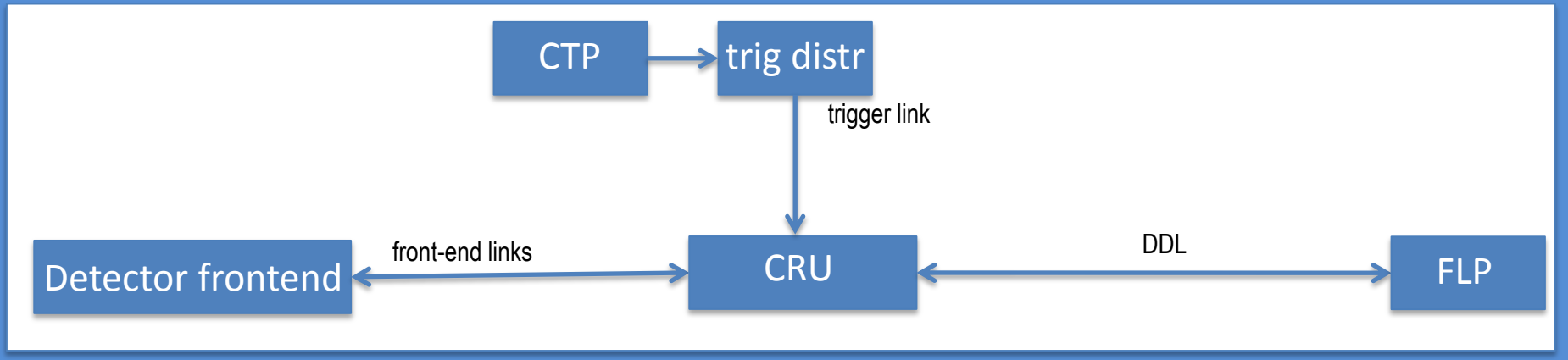
Read-out architecture

- Standard interface to DAQ/DCS
  - Detector Data Links DDL 1, 2 already developed
    - 2.125 and 4.25/5.3125 Gb/s
  - DDL3 still to be developed
    - ≤ 10 Gb/s GbE or PCIe over cable or PCIe plug-in cards
- Standard interface to Trigger
  - GBT links
  - TTC links for non-upgraded electronics

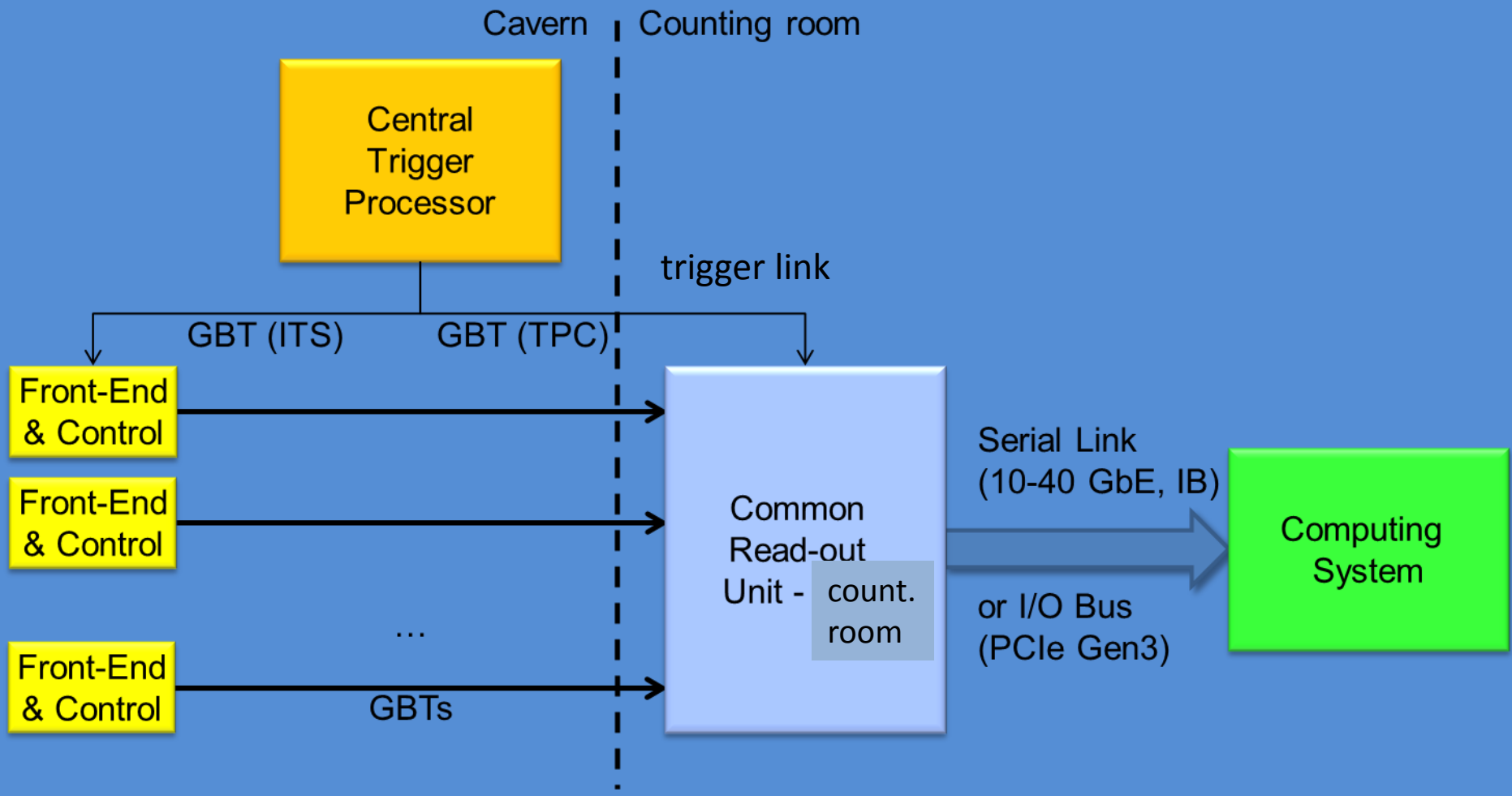


Architecture – common read-out unit CRU

- ALICE standard common read-out unit CRU used by new detectors & those who upgrade
  - TPC, MCH, ITS, TRD, ZDC, MID

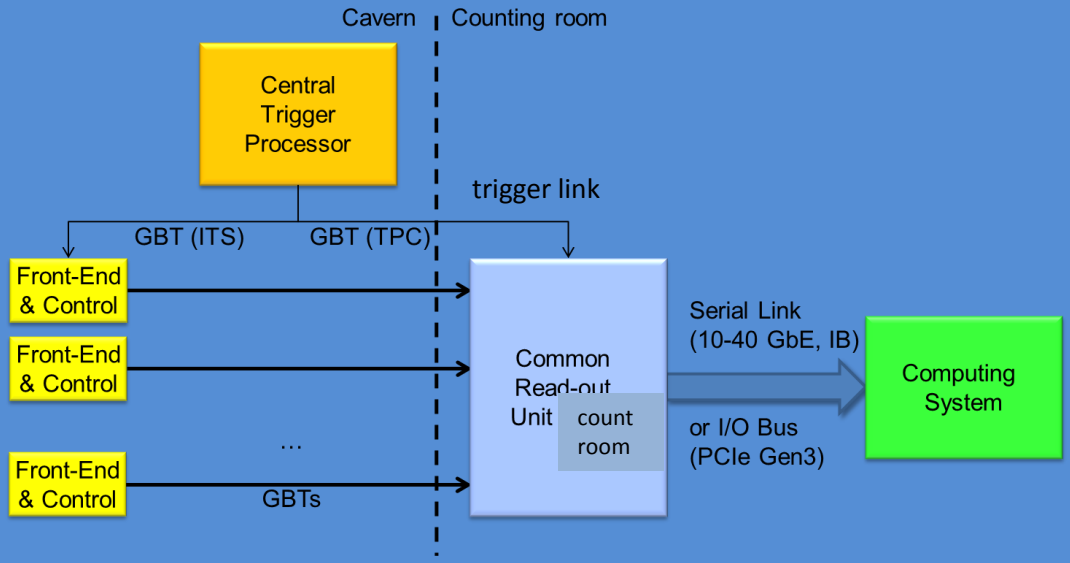


Architecture – CRU – counting room

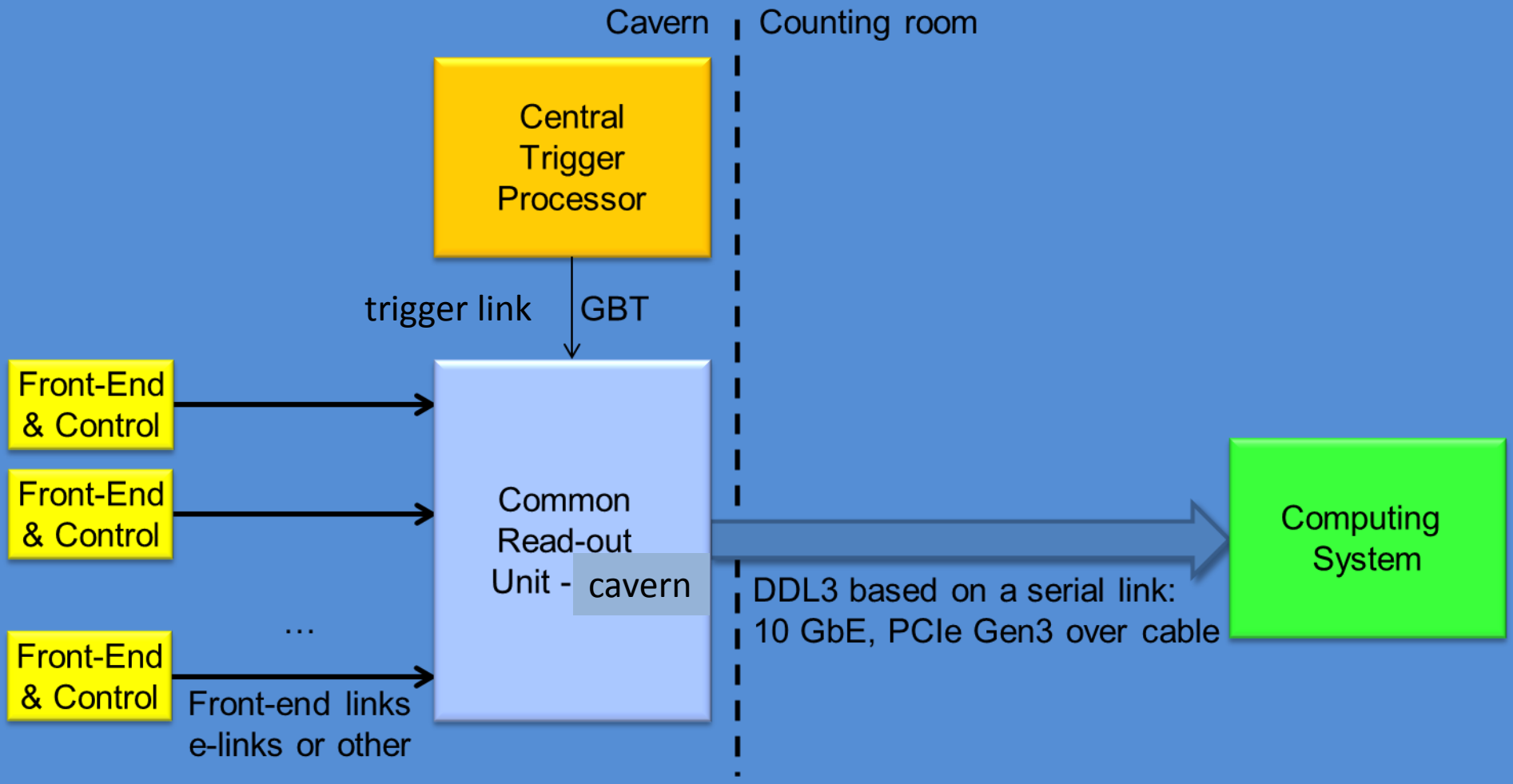


Architecture – CRU – counting room

- TPC is cost defining factor for optical fibers:
  - CRU – counting room study
    based on the LHCb read-out board AMC40
- 6300 TPC front-end links with SEU correction
- 4700 TPC front-end links without SEU correction
  - TPC front-end links only partly bi-directional

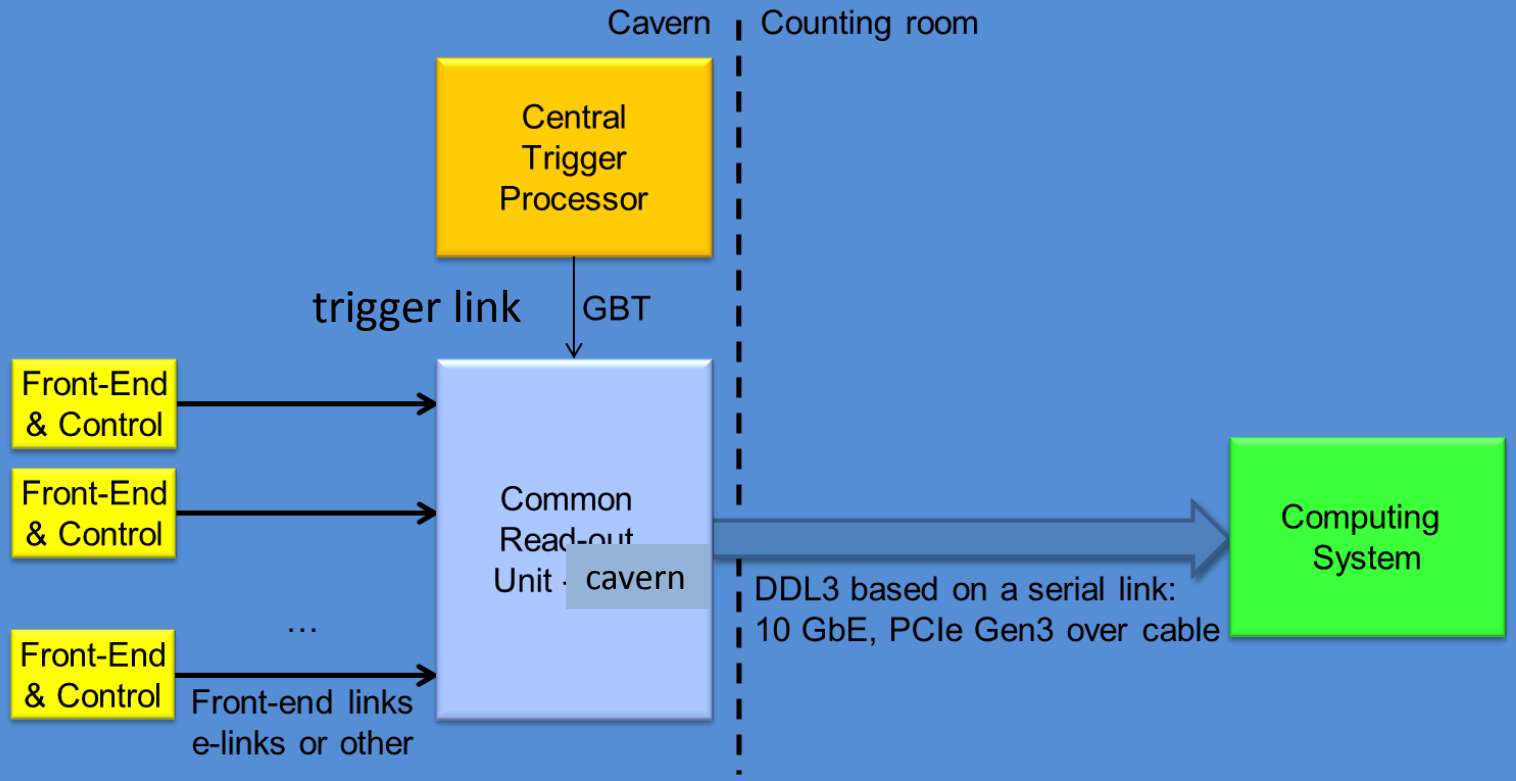


Architecture – CRU – cavern



Architecture – CRU – counting room

- TPC is cost defining factor for optical fibers:
- 1836 DDL fibers, all bi-directional
- up to 1836 trigger fibers



Architecture: CRU considerations

- access of location during operation
- electronics in radiation
- installation direct on detector
- possibility to share development
- bandwidth GBT – 10 GbE → number of fibers

- Base-line is CRU-counting room
  - Feasibility studies on-going

Detector Overview

Detector Overview

	trigger needed	max RO rate (kHz)	busy > 0%
– TPC		50	
– MCH		100	
– ITS:		100	
– TOF:	Y	100	
– MUONID:	Y	>100	
– FIT:	Y	200	
– ZDC:	Y	>100	
– PHOS:	Y	46	Y
– TRD:	Y	50	Y
– EMCAL:	Y	46	Y
– HMPID:	Y	2	Y

Detector Overview: new components

	FE ASIC	FEC	MUX
– TPC	17k SAMPA	3400	CRU
– MCH	33k SAMPA	550	CRU
– ITS:	25k pixel ASIC	200	CRU/other
– TOF:			72 DRM
– MUONID:	FEERIC	234	CRU
– FIT:		upgrade	DRM(TOF)
– ZDC:		commercial	CRU
– PHOS:			
– TRD:			CRU
– EMCAL:			
– HMPID:			

Detector developments: common

- common read-out ASIC – SAMPA
- TPC & muon chambers (MCH)

Detector developments: SAMPA

- common read-out ASIC – SAMPA
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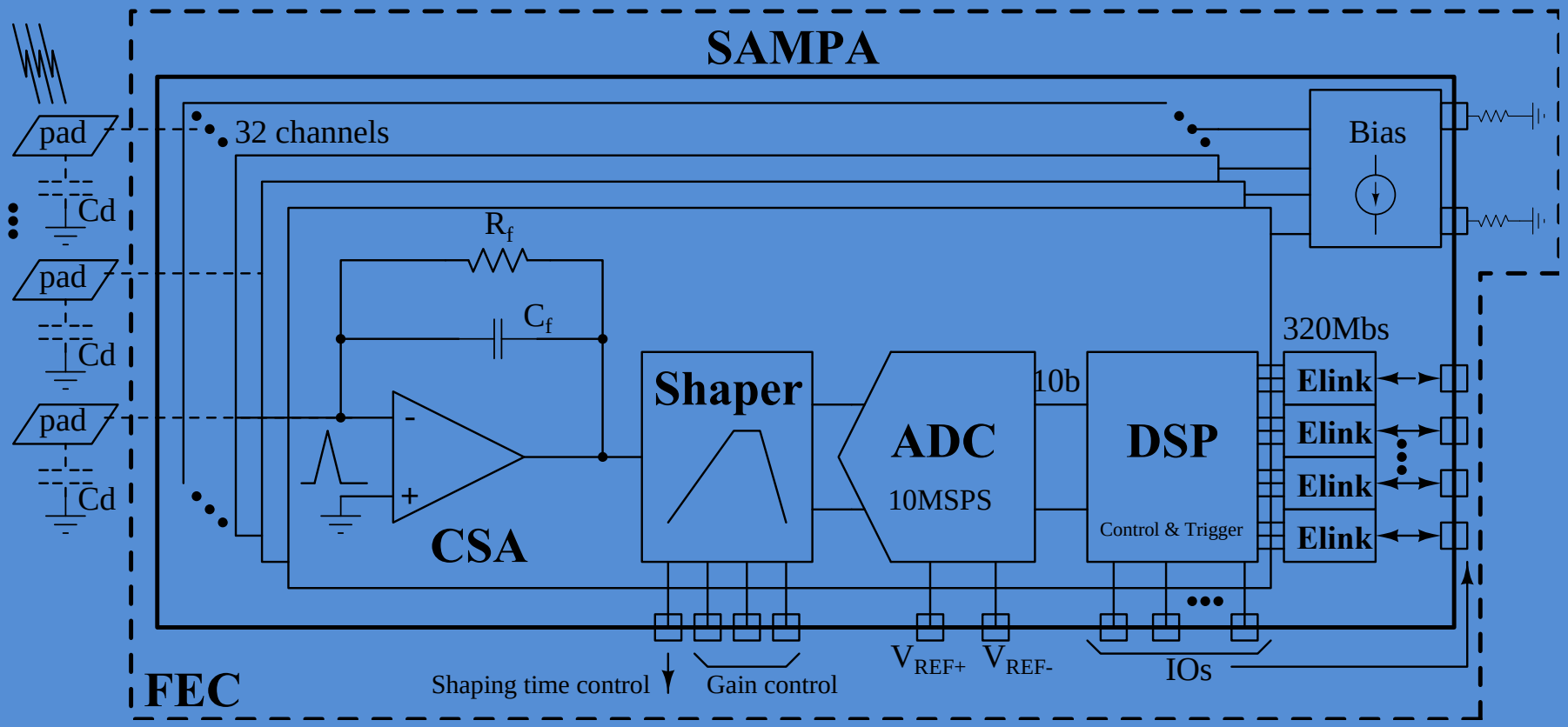
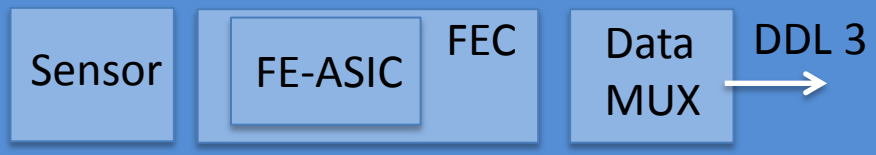


Detector developments: common

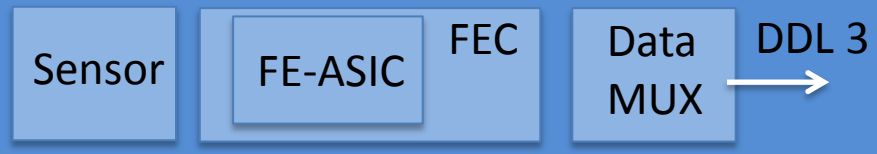
- common read-out ASIC – SAMPA
- TPC & muon chambers (MCH)
  - 32 channel amplifier-shaper-ADC-DSP
  - trigger less or continuous read-out
  - <600 e @ 25 pF (TPC), < 750 e @ 40 p (MCH)
  - bi-polarity input
  - 10 bit ADC – 10 Msamples/s
  - on ASIC base-line correction and zero suppression
  - 4 x 320 Mbit/s serial outputs
  - 130 nm TSMC CMOS process

Detector developments: TPC



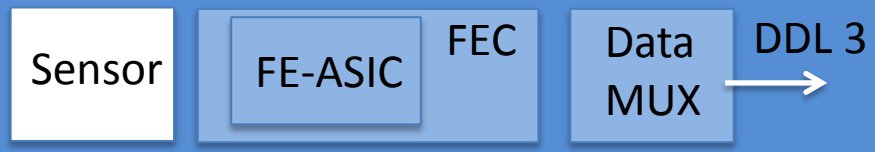
- ~ 500.000 pads
- MWPCs replaced by GEMs for 50 kHz read-out rate
- upgrade to continuous read-out @ 50 kHz interaction rate
- 4320 Front-end cards are replaced
- ~ 17.000 SAMPA ASICs
  - baseline specifications:
    - input charge: < 100 fC,
    - 160 ns shaping time,
    - 10 MHz ADC sampling,
    - 10 bit resolution
- RCUs are replaced by CRUs allowing continuous read-out
- Trigger optional

Detector developments: ITS



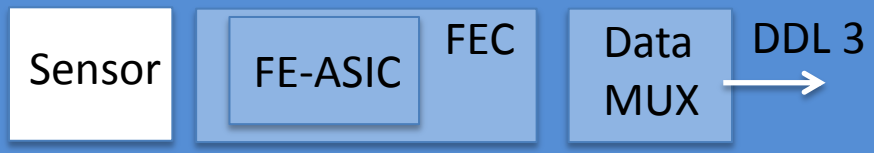
- 25 G pixels
- complete new detector
  - ASIC, sensor, read-out, mechanics cooling
- continuous read-out @ 100 kHz hit rate
- trigger option
  - to decrease effects to due possible beam/sensor effects
- Detector module sends data 1 Gb/s links
  - base-line electrical
  - close to detector link interface needed
- Baseline read-out concentrator CRU

Detector developments: muon chamber



- ~1.000.000 MWPC
- upgrade to continuous read-out @ 100 kHz hit rate
- Replacement of the front-end by ~ 33.000 SAMPA ASIC
  - baseline specifications:
  - input charge: < 400 fC,
  - 330 ns shaping time,
  - 10 MHz ADC sampling,
  - 10 bit resolution
- Replacement of active patch panels (first level of data concentration)
  - based on GBTs or electrical e-links
- Replacement of data concentrator by CRUs

Detector developments: muon identifier



- 21.000 RPC
- replacement of front-end electronics to slow down aging speed of RPCs
  - by operation in avalanche mode reducing charge produced in the gas
- Front-end ASIC is replaced by FEERIC ASIC
  - with amplification
- Read-out out at 100 kHz @ 0 % busy
- Suppression of muon trigger capability

Detector developments: muon identifier

- Replacement of 2 levels of data concentrators by 234 new front-end cards and CRUs
- Small scale system with FEERIC will be tested already in run 2

Detector developments: TOF

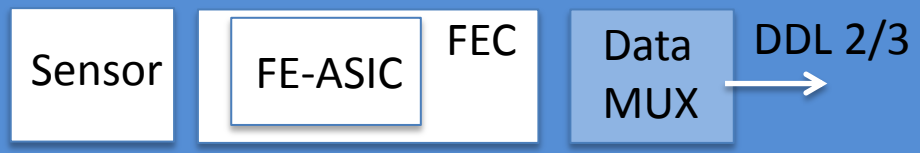
- ~160.000 MRPC pads

- rate upgrade from 10s of kHz to 100 kHz PbPb without dead time
  - max limit by HPTDC in FEC is 440 kHz
  - rate limit comes from VME based read-out and data format
- upgrade firmware for data format and VME protocol
- replace 72 2nd level data concentrator boards (DRM)

Detector developments: TRD

- 1.151.000 channels
- rate upgrade from 8 kHz to 50 kHz with 23 % busy
- triggered operation (LM & L1)
- FE electronics unchanged, but data load reduced with firmware change
  - pre-processed data (tracklets) are transferred only or
  - partial read-out based on electron region candidates
- Data MUX is CRU

Detector developments: FIT



- 160 MCP-PMT +
- 64 Scintillators
- Provides interaction trigger
- timing reference for TOF
- multiplicity measurement
- New detector implementation
  - new front-end
  - RO based on TOF read-out scheme

Detector developments: ZDC

- 22 channels
- outside of radiation zone
- use NIM, VME and commercial electronics
- provides timing trigger
- upgrade from 8 kHz to 16 kHz by introduction of multi-event buffers in firmware (run 2)
- to 100 kHz without dead time
  - commercial digitizers with on board FPGAs
  - TDC model firmware upgrade
  - replacement of data concentrator card (ZRC) and
  - use CRU

Detector developments: EMCal

- ~ 18.000 channels

- provides trigger
  - L0 input: sum
  - L1 input: shower and jet
- has already been upgraded to 46 kHz @ 15 % busy
  - front end (ALTRO) limits to 50 kHz
  - data reduction by on-line data evaluation
  - replacement of data concentrators by SRU (Scalable Read-out Unit, RD51)

Detector developments: PHOS

- ~ 17.000 channels
- provides trigger
  - L0 input: sum
- taking same approach as EMCAL to 45 kHz @ with busy time
  - front end (ALTRO) limits to 50 kHz
  - data reduction sample number reduction
  - replacement of data concentrators by SRU (Scalable Read-out Unit, RD51)
  - replacement of trigger region units (TRU)

Detector developments: HMPID

- ~160.000 channels MWPC
- RO rate to 2,5 kHz
- No detector/electronics change

Summary

- Continuous RO of TPC, MCH, ITS
- Other detectors triggered RO for interaction at 50 kHz
- CTP simplified, but still required
- Common read-out architecture for new systems - CRU
- Common TPC/MCH read-out ASIC - SAMPA