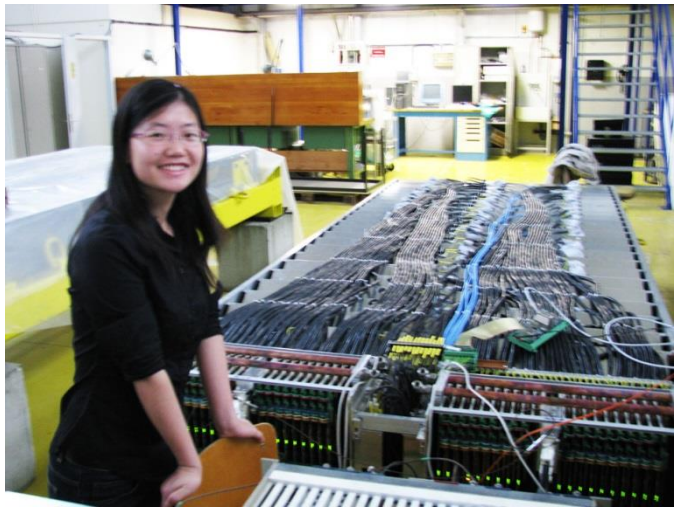
EMCal Readout Upgrade



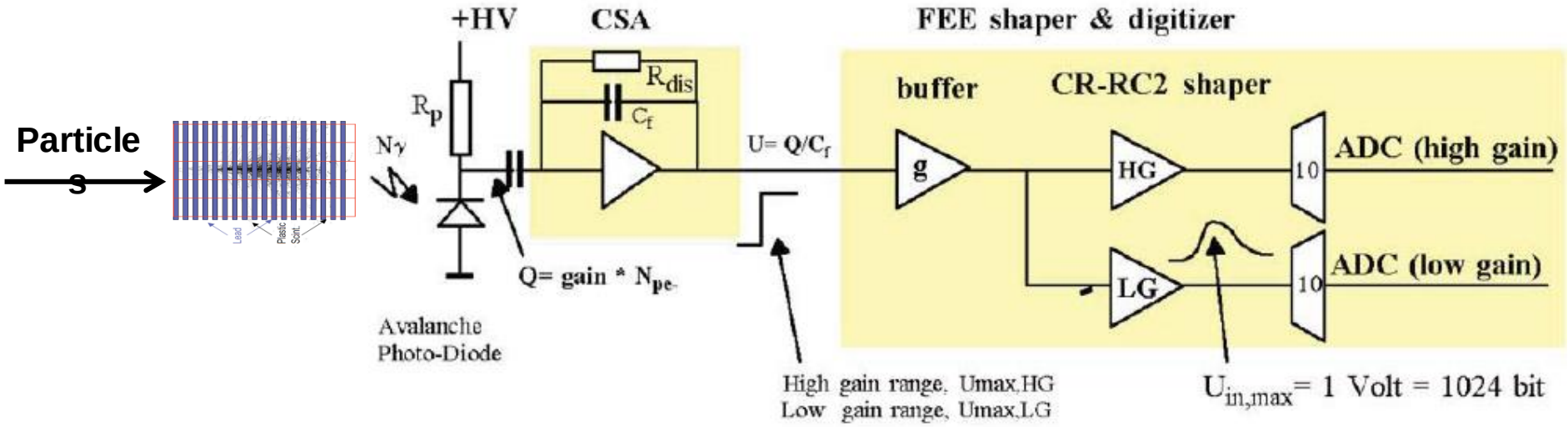
Acknowledgements to:

- Hans Muller on SRU system
- Fan Zhang (Wuhan) for EMCal SRU and FEE Firmware development (and many of the slides/figures shown here).

Summary for TDR

- EMCal Readout has now (May 2013) been upgraded to SRU readout – same to be used for DCal.
  - Using Point-to-point DTC (Data-Timing-Control, DTC) link.
    - **Minimum dead time: ~270 us → ~19 us.**
    - **Expect to reach ~50kHz Min bias Pb+Pb**
- Description of SRU application to EMCal has been submitted to NIM.
  - Can be condensed to 2 page writeup for TDR

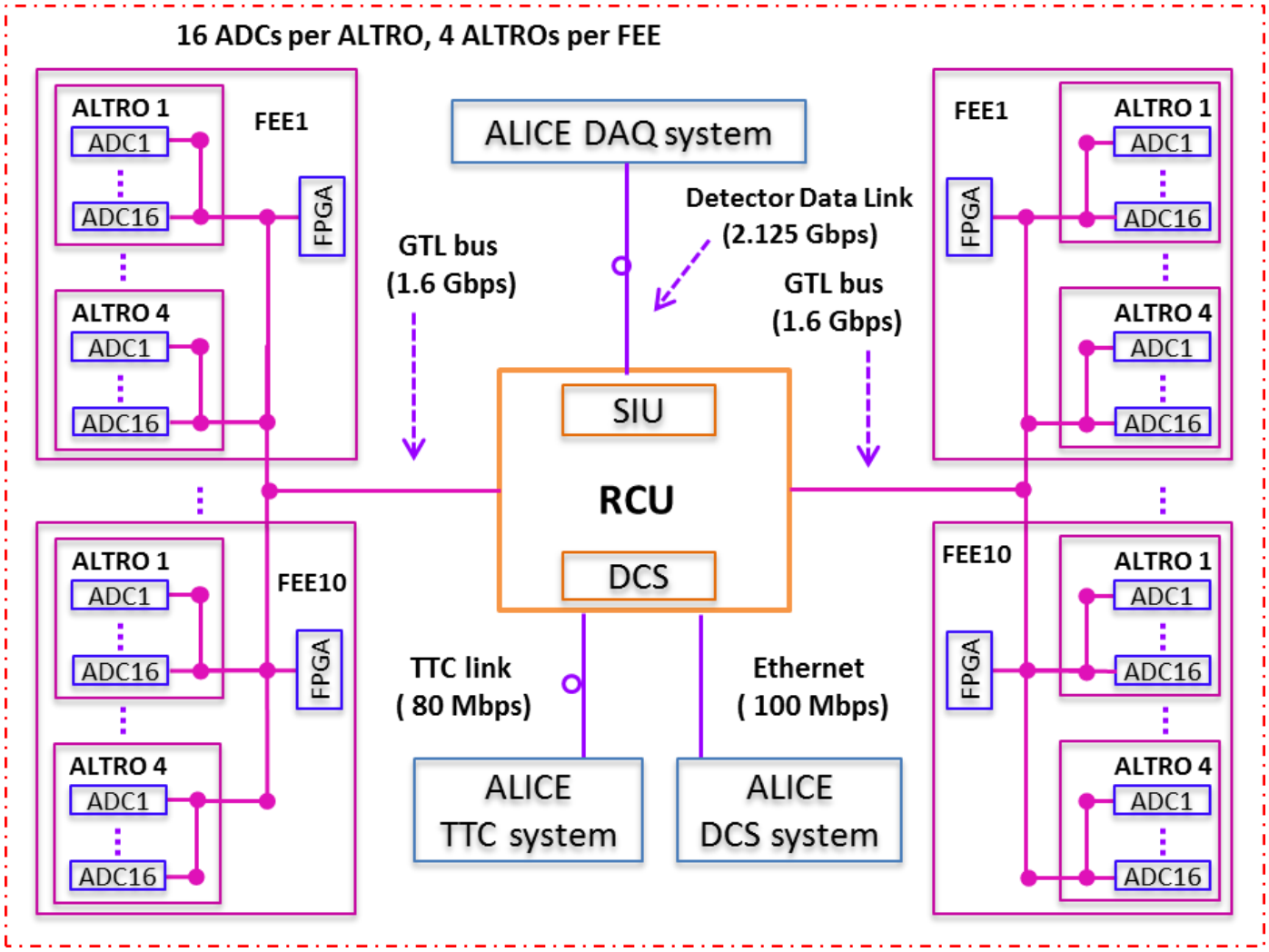
EMCal Signals



- EMCal(PHOS) : Dual gain range energy measurement
- EMCal peaking time = 200ns; typically 5 time samples (time also via peak fit with σ_t~1ns).
- PHOS peaking time = 2μs; (typically 50 time samples?)

EMCal RCU based readout

For 1 EMCal Readout Partition = ½ EMCal SM readout:



EMCal SM with RCU

- Data volume/readout partition (per RCU = ½ EMCal SM)
  - Total channel number: 20(FEE) * 32(Towers)*2(Gains) = 1280
  - Minimum byte count for a hit channel: 12
  - Byte count of the event header: 32
  - Byte count of the event trailer: 36

EMCal Data Volume/Occupancy

- Data volume/readout partition (per RCU = ½ EMCal SM)
  - Total channel number: 2*32*20 = 1280
  - Minimum byte count for a hit channel: 12
  - Byte count of the event header: 32
  - Byte count of the event trailer: 36

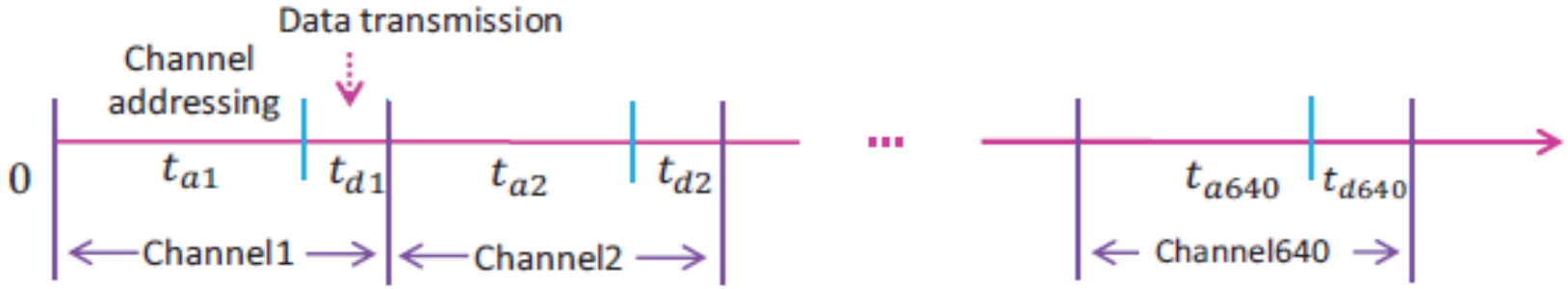
$$N_{ch} \approx (N_{event} - 68) \div 12$$

	Empty[a]	p+p	Min. Bias Pb+Pb	Central Pb+Pb	LED Calibration[b]	Full Readout[c]
N_{event}(Bytes)	750	1000	2.5k	5k	25k	35.9k
N_{ch}	60	80	220	420	1280[d]	1280

Low occupancy: Even for the highest occupancy central Pb+Pb collisions ~1/3 of channels have hits

System Limitation: Low Bandwidth Utilization

RCU reads out 640 ALTRO channels serially (64/FEC for 10 FEC)

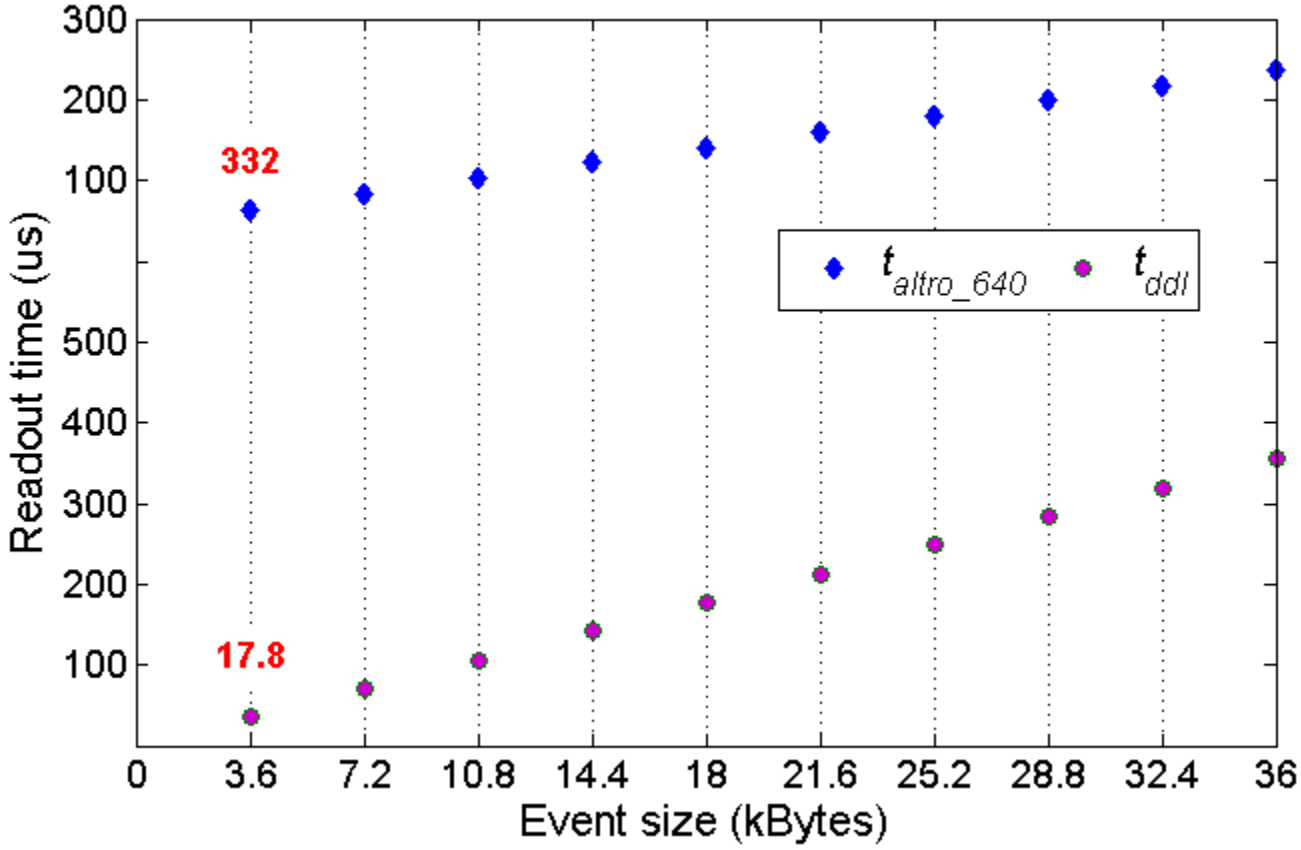


- ALTRO channel address time t_a = 0.5 μs
  - Minimal readout time of 320 μs for full readout with no data
- Maximum data transfer time t_d^{max} = 0.15 μs
- Plenty of ALTRO bus bandwidth (3.2 Gb/s), but
- Bandwidth utilization on ALTRO bus is less than 25% for EMCal

Solutions

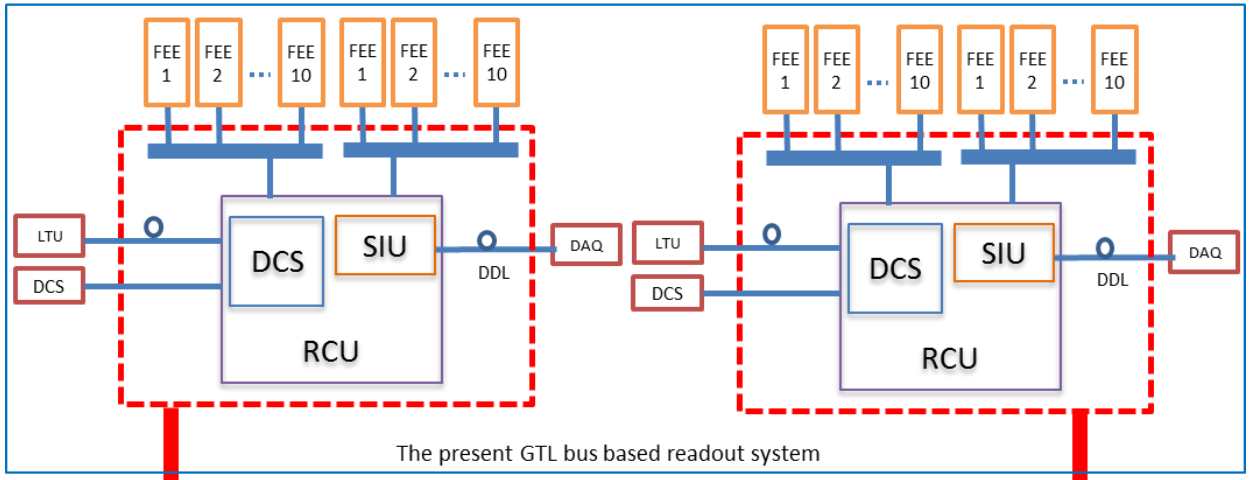
- Implement the Sparse Readout with the old EMCal/DCal readout system.
  - **Minimum dead time: ~400 μs → ~270 μs.**
- Apply RD51 Scalable Readout System (SRS)
  - Using Point-to-point DTC (Data-Timing-Control, DTC) link.
    - **Minimum dead time: ~270 μs → ~36 μs.**
  - Using LG Readout Suppression
    - **Minimum dead time: ~36 μs → ~19 μs.**
  - Using 10 GbE transmission (possible for future)
    - **Decrease dead time by 50% for very large events.**

Limitation of RCU-based readout

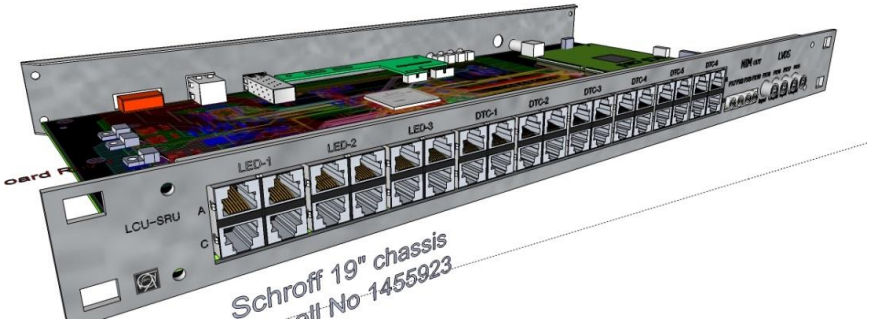


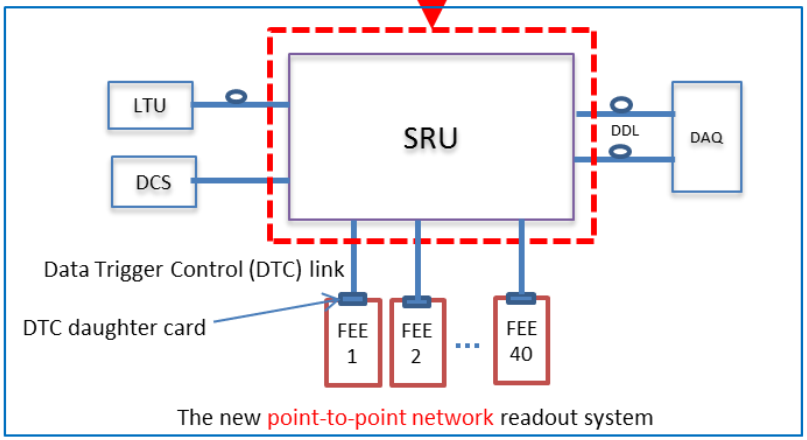
Readout time spent on the ALTRO bus is bottleneck.

Using SRU on the EMCal/DCal: Replace GTL bus with point-to-point Links

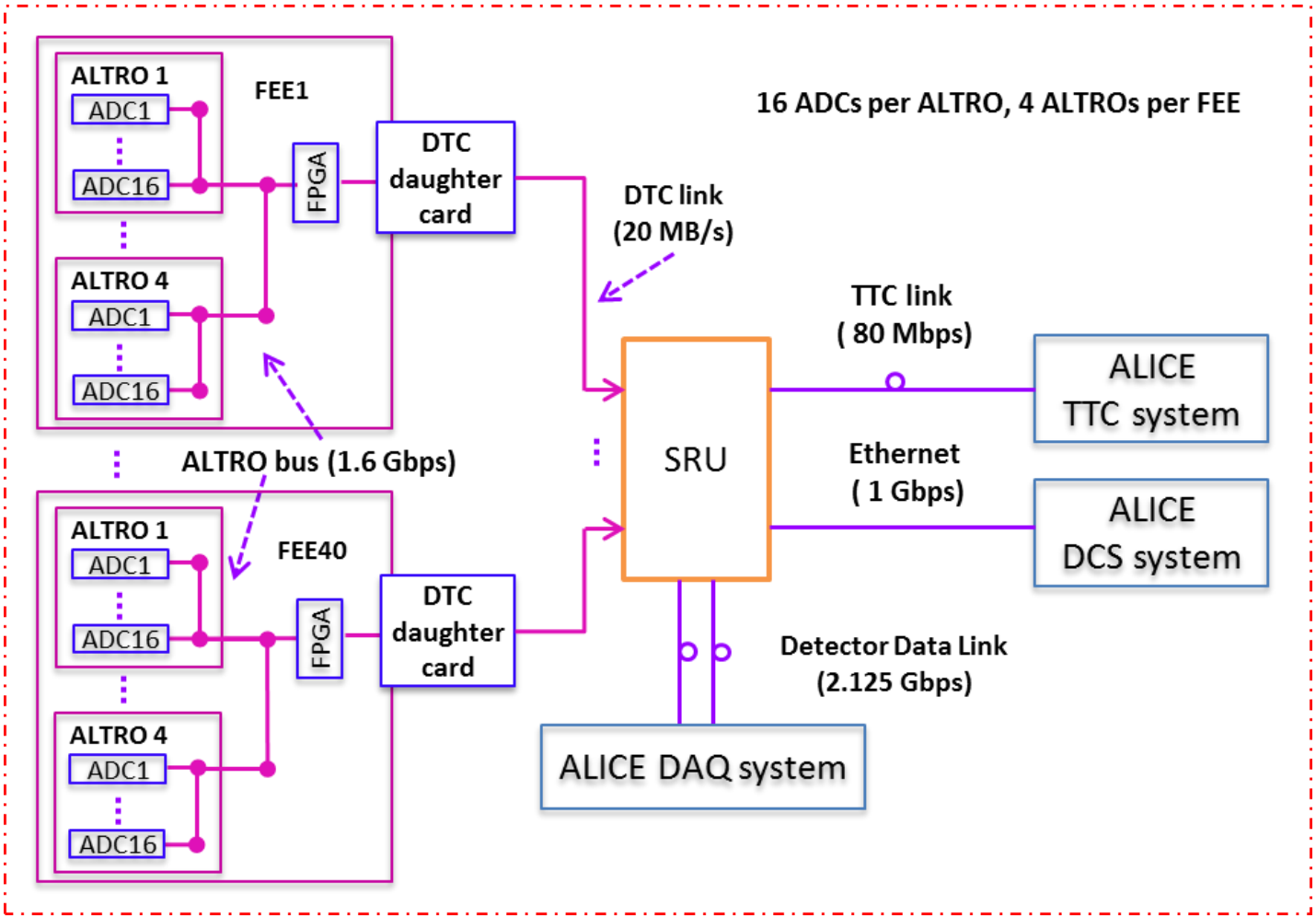


Hardware Replacement



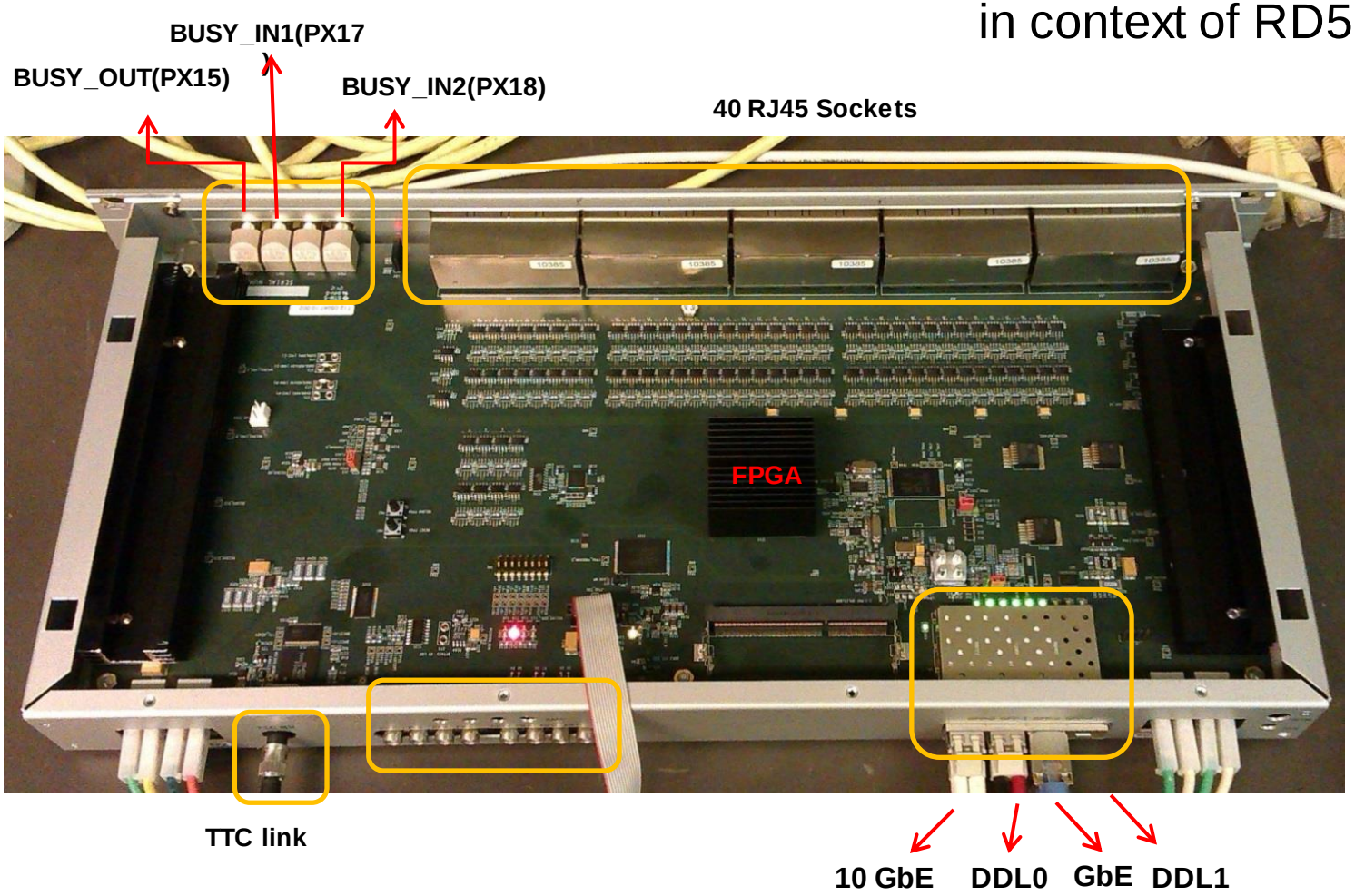


Apply SRS to the EMCal\DCal: Using Point-to-point Links



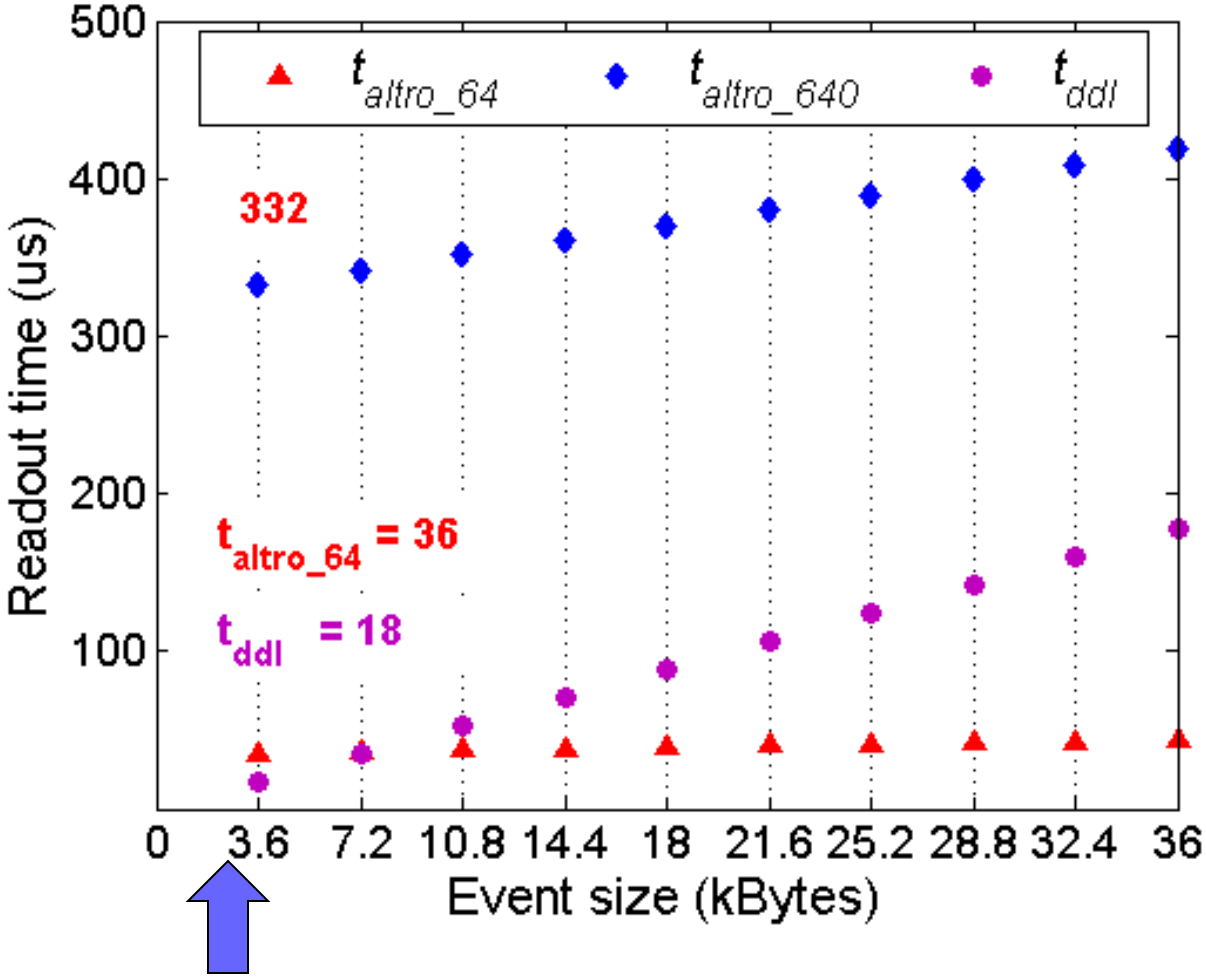
Scalable Readout Unit (SRU): Provide readout concentration.

Developed by H.Muller in context of RD51



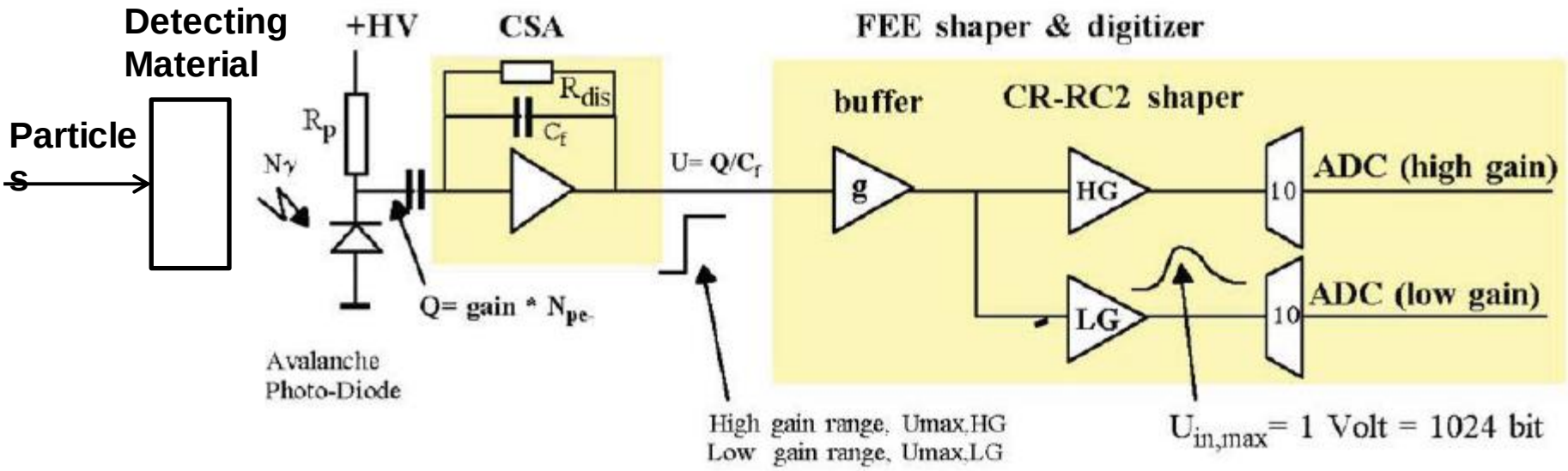
Performance Estimation

Readout time on the ALTRO bus is x10 lower.



Pb+Pb Min Bias data volume/DDL (2.5kB)

Solution 2B: Low Gain Readout Suppression

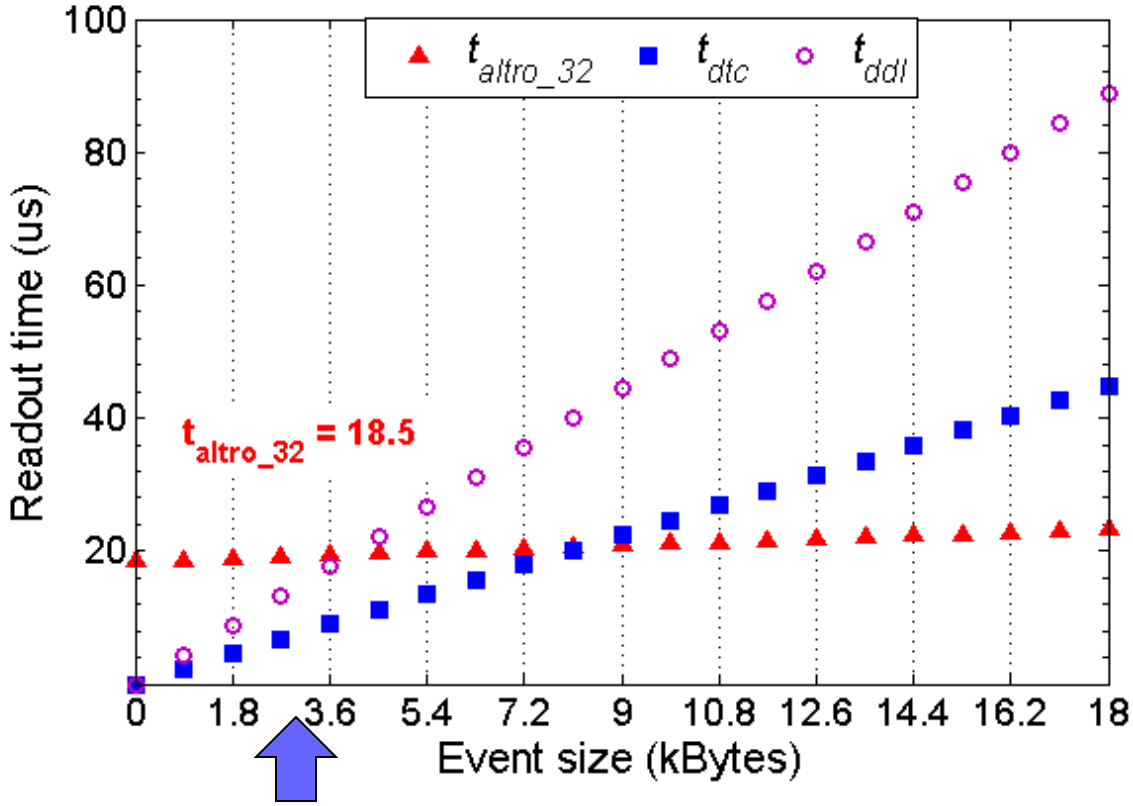


	Empty[a]	p+p	Min. Bias Pb+Pb	Central Pb+Pb	LED Calibration[b]	Full Readout[c]
N_{event} (Bytes)	750	1000	2.5k	5k	25k	35.9k
N_{ch}	60	80	220	420	1280[d]	1280

Low Gain channels are occupied as frequently as High Gain channels, but LG data is used in offline analysis only when HG is saturated (~16GeV for EMCal). Read LG only when HG near saturation reduces occupancy x2.

LG Readout Suppression

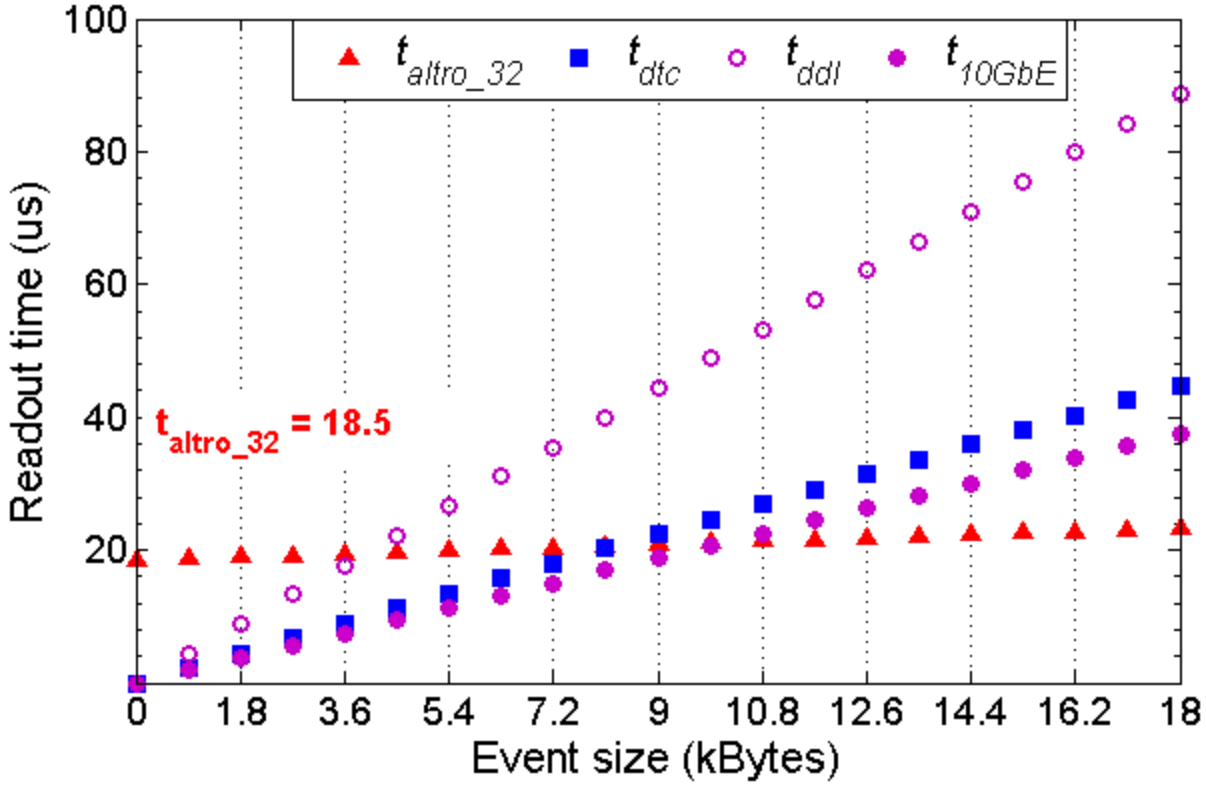
Check (readout) LG channel only if HG of tower is near saturation



Pb+Pb Min Bias data volume/DDL (2.5kB)

Minimum Readout time spent on the ALTRO bus is decreased from 36→18.5 us.

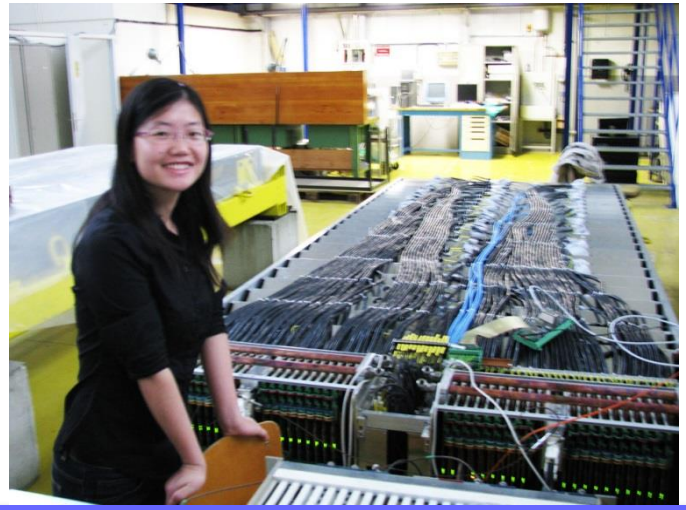
Solution 2 C: Using 10 GbE



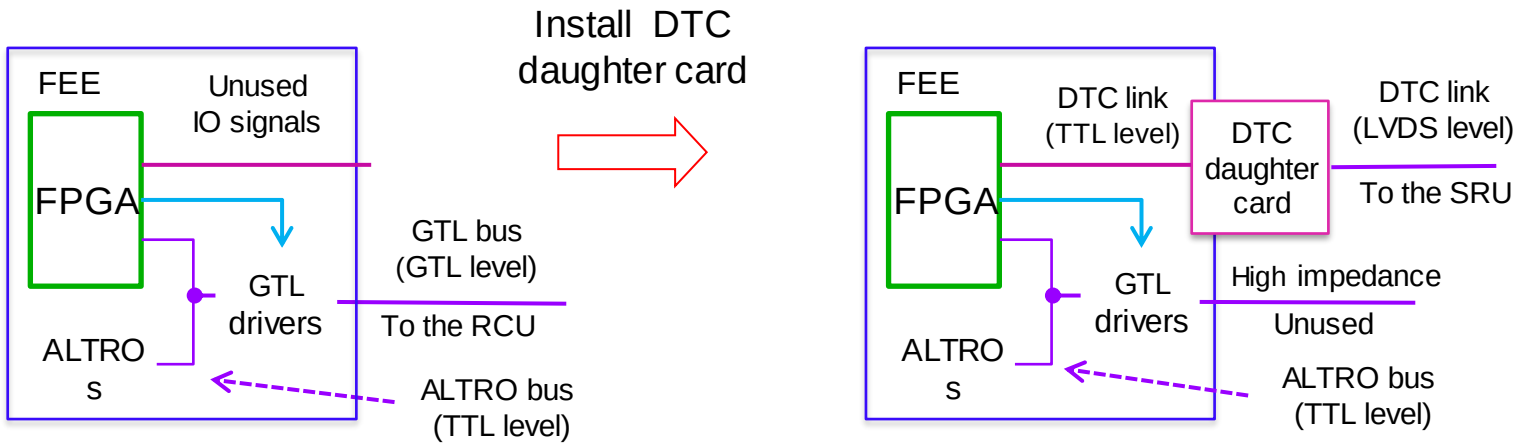
The dead time of large events (>3.6 kBytes) is decreased by ~50%. Ready to be implemented, but not apparently necessary.

Hardware and Firmware development

- DTC daughter card to be mounted on FEC
- Upgrade FEE firmware
- SRU module
- Custom SRU firmware for EMCal

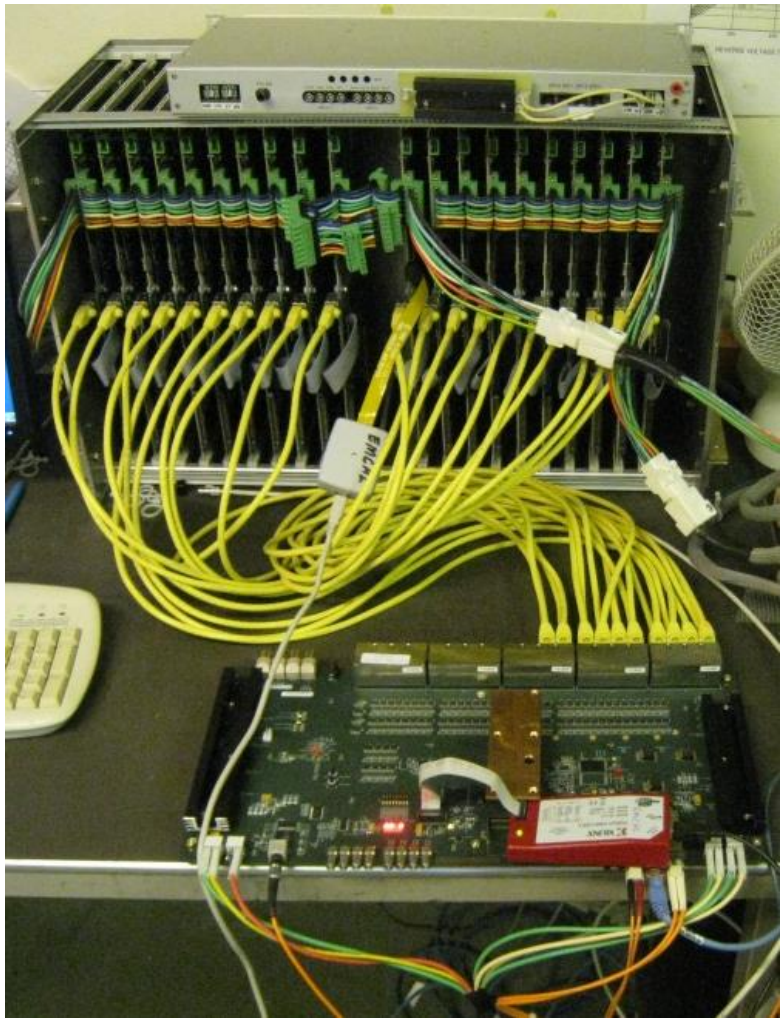


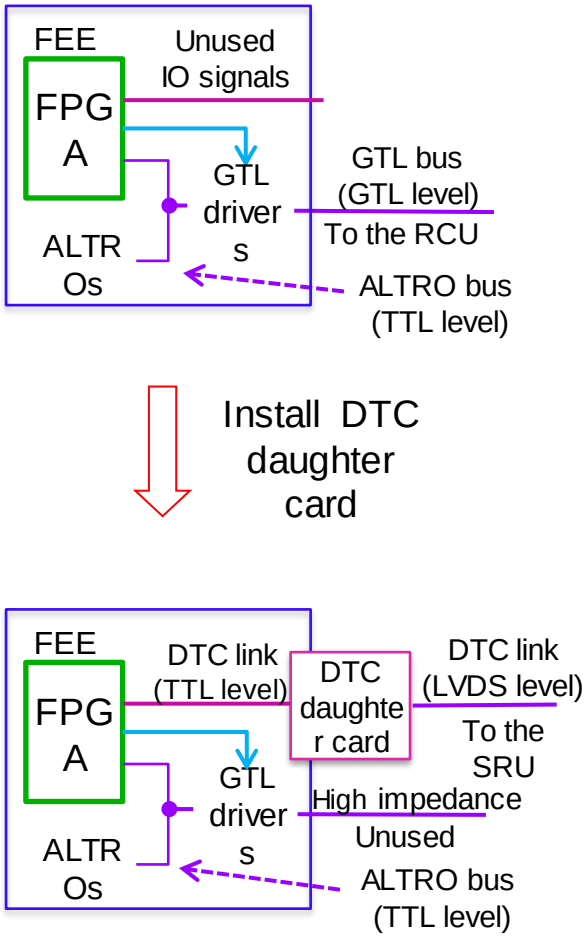
DTC daughter card: Provide interface compatibility



- Provide interface compatibility between existing FEE with both old and new system topologies.
- Avoid to produce more than 600 new FEE boards
- DTC daughter cards have been installed on all the FEE boards, and SRU-FEC communication has been verified for all FEC on EMCal.

Test setup




FEE
FPGA
Unused IO signals
GTL drivers
ALTROs
GTL bus (GTL level)
To the RCU
ALTRO bus (TTL level)
Install DTC daughter card
FEE
FPGA
DTC link (TTL level)
DTC daughter card
DTC link (LVDS level)
To the SRU
GTL drivers
High impedance
Unused
ALTROs
ALTRO bus (TTL level)

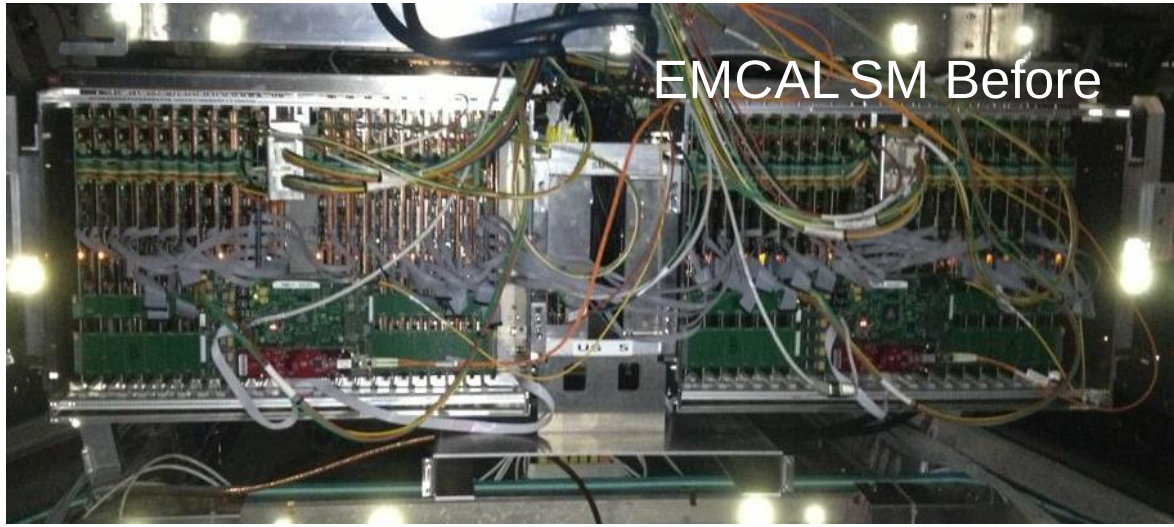
Dead Time Lab Test Result

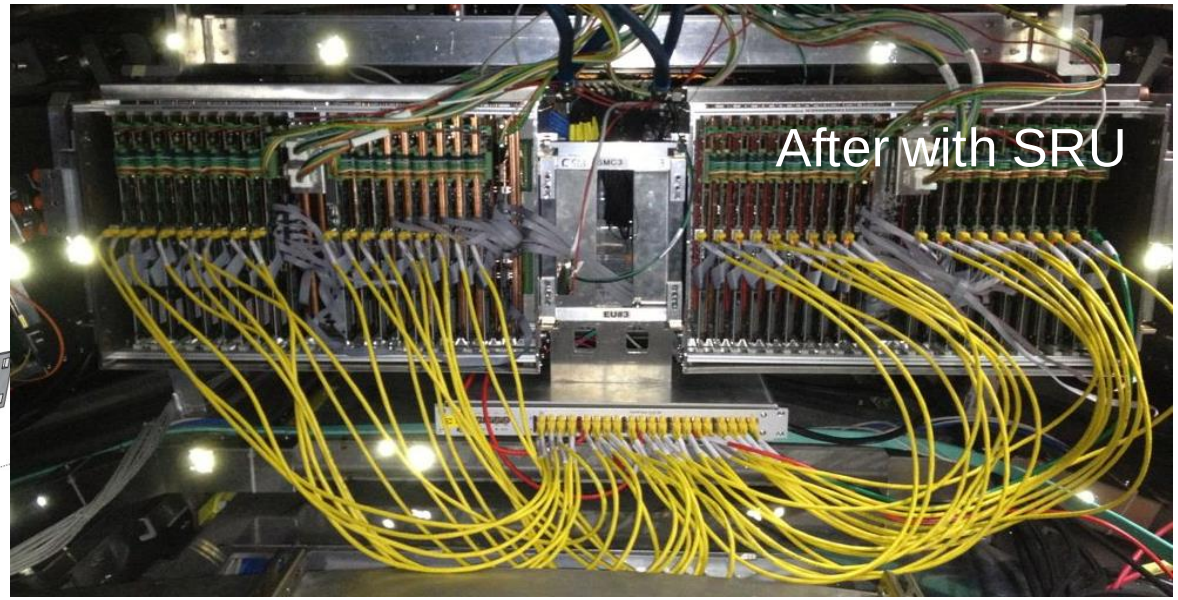
	Empty[a]	p+p	Min. Bias Pb+Pb	Central Pb+Pb
N_s^{chan}(bytes)	12	12	12	12
N_{chan}^{fee}	3	4	11	21
N_s^{fee}(bytes)	36	48	132	252
N_{chan}^{part}	60	80	220	420
N_s^{part}(bytes)	788	1028	2708	5108
$R_{est.}^{full}$(kHz)	29.0	28.9	28.3	27.7
$R_{meas.}^{full}$(kHz)	27.8	27.8	27.8	23.7
$R_{est.}^{lgs}$(kHz)	53.4	53.2	51.7	39.1
$R_{meas.}^{lgm}$(kHz)	45.1	44.7	43.2	33.6

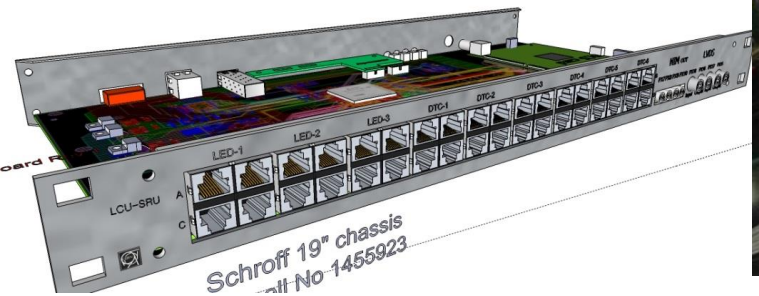
Busy time a bit higher than expected – Firmware optimization still underway

EMCal RCU-> SRU

- Changeover from RCU to SRU complete (May)
- Firmware work still underway:
  - TRU trigger modules
  - SRU firmware optimization & robustness







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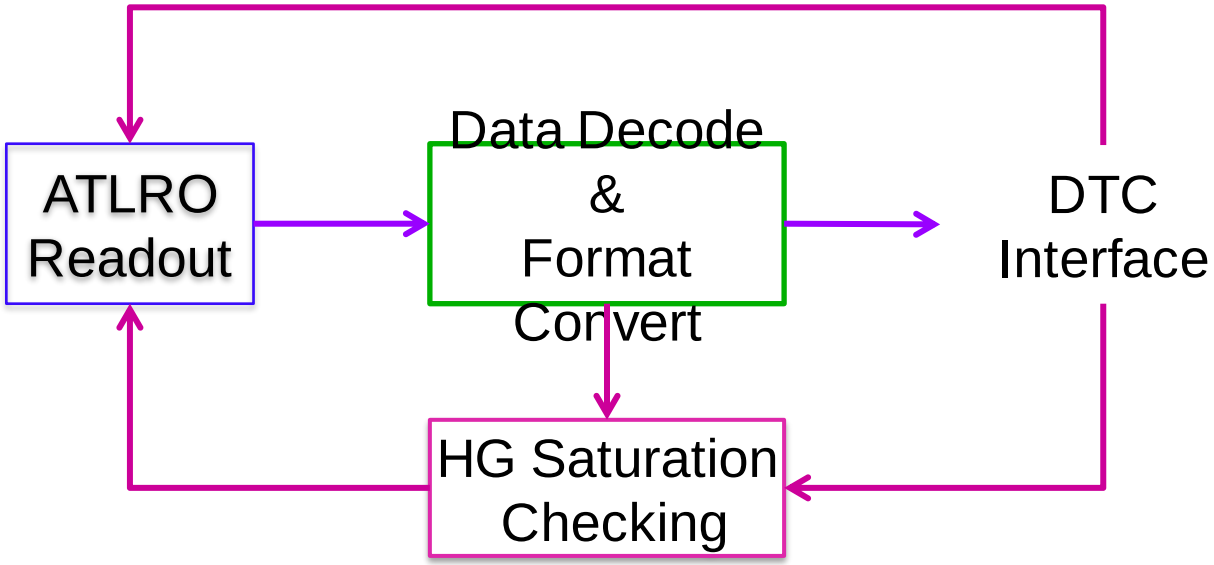
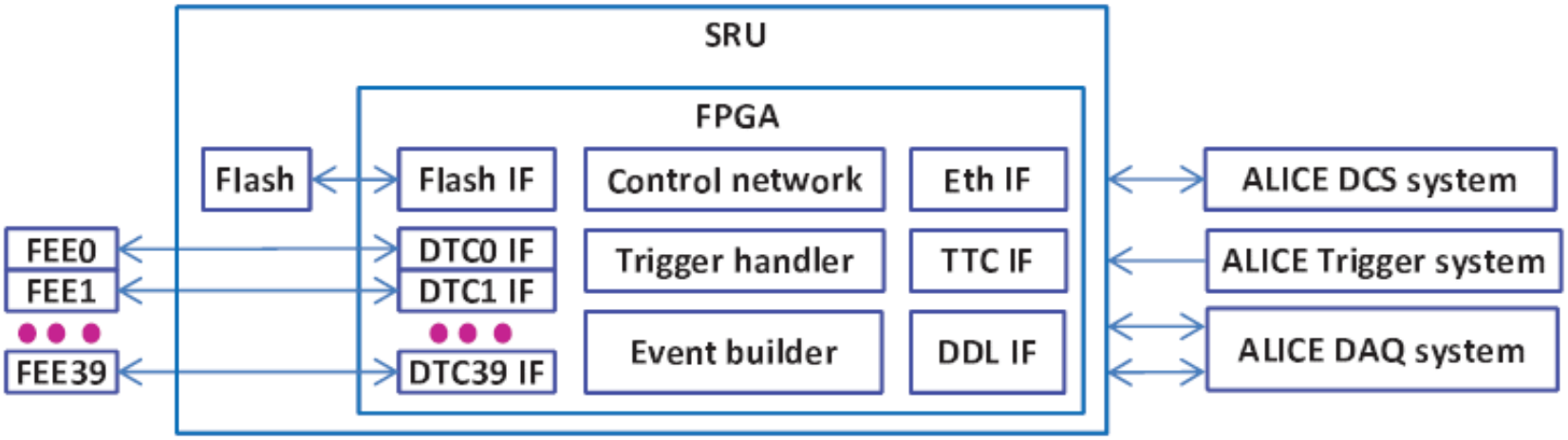
Extras

FEE Firmware Upgrade



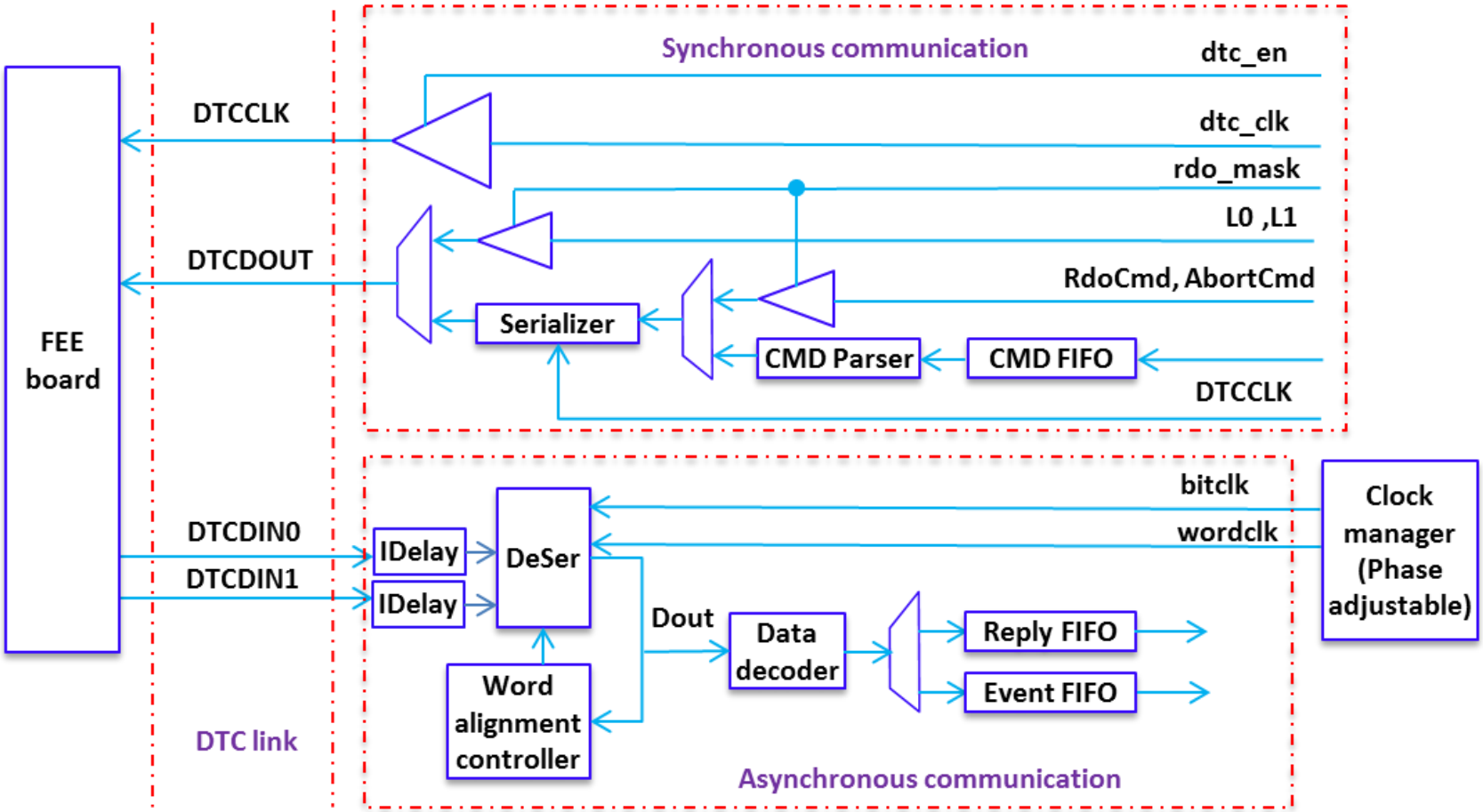
- Memory resource usage: ~90%
  - Logic element: 95%
  - Block memory: 72%

SRU Firmware Development



- **Resource Usage:**
  - Block Memory: 140*36Kb Block RAM (54%)
  - Lookup Table (LUT): 53 K (66%)
  - Registers: 46 K (29%)

DTC link protocol



Data Transferring and Multi-event buffer