Free Running intelligent DAQ Data Flow

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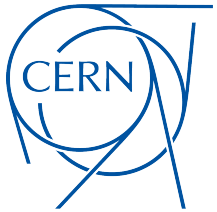
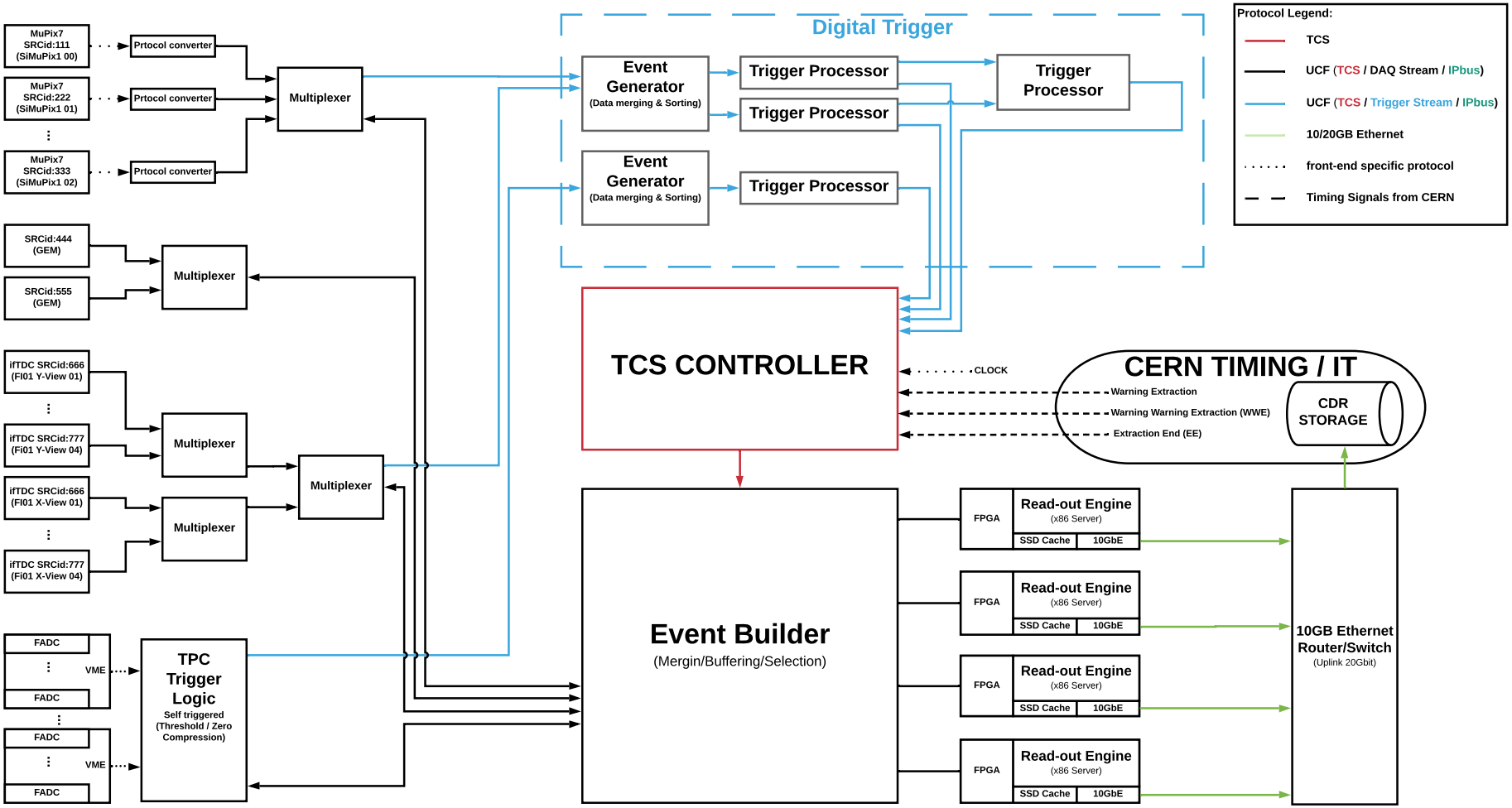


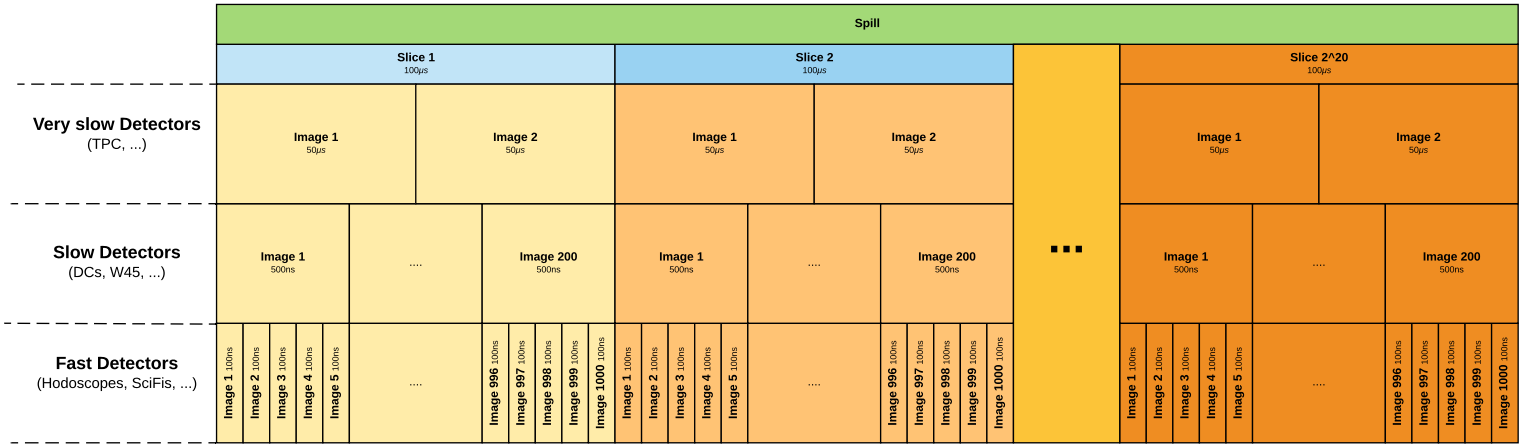
New DAQ Structure

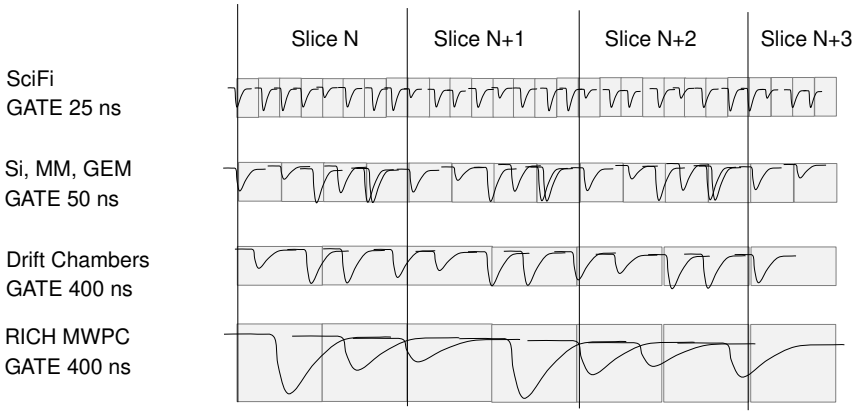


Time Slices vs Images

Time Slices are generated by a synchronous signal which is distributed to all front-ends.

Additional partition in **images** according to detector resolution.





Protocol Considerations

The data word length is 32 bit. The first three bits are reserved as control word, the last 29 bits can be used for data.

Naming Convention:

- A **Spill/Epoch** is made out of **Slices**.
- A **Slice** is made out of **Images**.
- A **Image** contains **Groups**.
- A **Group** contains **Data Words** which comes from one source, it represents a functional unit which could be an Detector Station, Plane or a Processor Unit...

Begin of Slice / End of Slice

Begin of Slice:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	# of Images in Slice [29:20] 10bit										Slice Number in Epoch [19:0]																		
0	0	0	Start Time of Slice in Epoch in 25ns Ticks [28:0]																												

- **#of Images in Slice:**
  A 10 bit value to indicate the number of Images in on Slice (max. 1024).
- **Slice Number in Epoch:**
  A 20 bit value to identify the number of the current slice in the current Epoch.
- **Start Time of Slice in Epoch:**
  The start time of Slice in epoch as 29 bit counter which indicates the global time of the slice in TCS ticks (25 ns steps). The maximum value is 13.42 s ($2^{29} \cdot 25$ ns) [Maximum duration of Epoch].

End of Slice:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	1	CRC [28:3]																										Flags [2:0]		

Begin of Image / End of Image

The **Begin of Image** data word contains the start time of the Image relative as absolute time in the current epoch as a 29 bit counter in 25 ns TCS ticks.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	1	0	Start Time of Image in Epoch in 25ns Ticks [28:0]																												

The start time of image in epoch (send by every front-end) can be used to verify the consistency of data at the level of the multiplexer while merging data.

End of Image (EOI) → Not for-seen at the moment!

Begin of Group / End of Group

A Group contains data from the front-ends/trigger processor SRCids.

Begin of Group:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	0	SRCid [28:19] 10bit										ViewID 5bit					First HitTime in Group 14bit [13:0]													

- **SRCid:** A 10 bit value which contains the source id of the data
- **ViewID:** A 5bit value to group data in according to views or sub-region of detectors. ViewID 0 is reserved for the whole detector station where ViewID 1-31 describes the different views or sub-regions.
- **First Hit-time in Group:** A 14 bit value which contains the time of the first hit in the group. In case of an Trigger Group header this is the calculated trigger time.

End of Group:

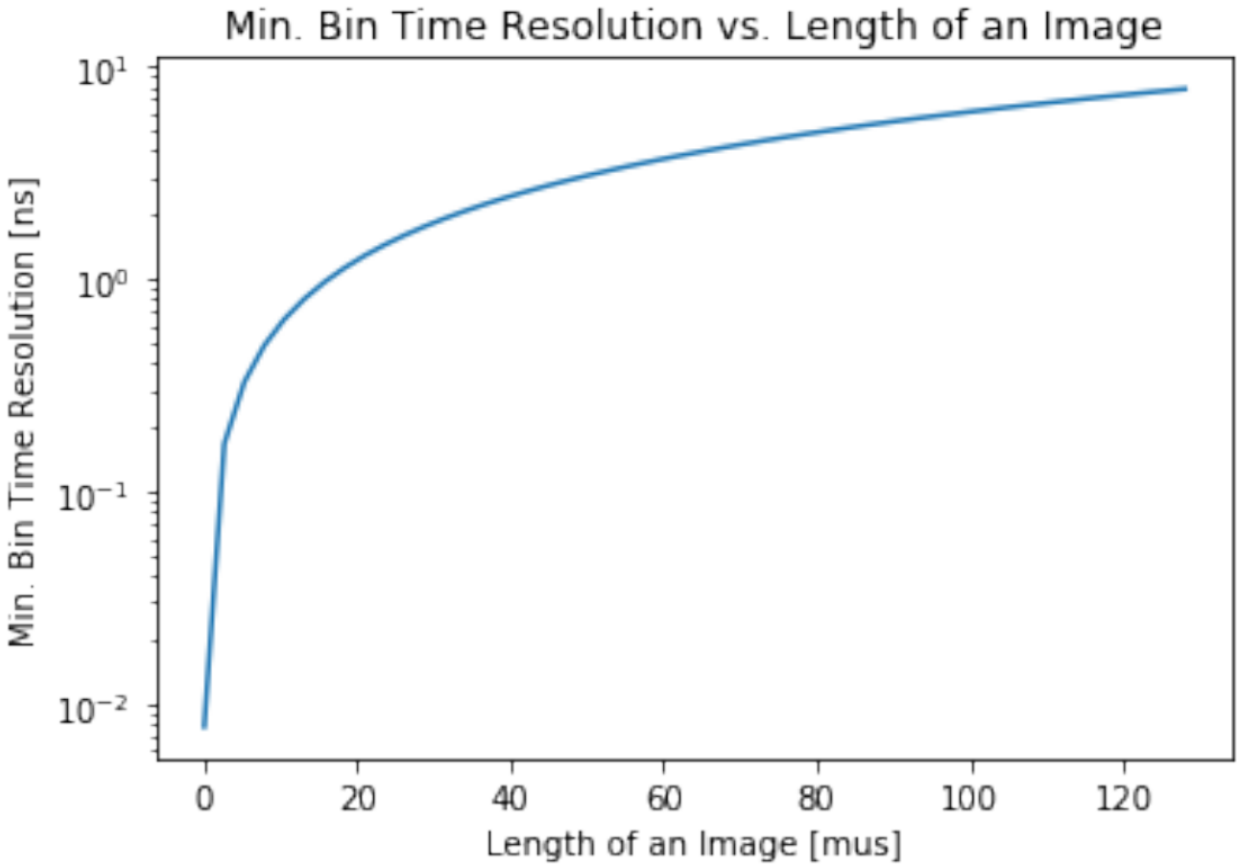
31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	0	1	CRC [28:3]																										Flags [2:0]		

Main Data Word

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	FrontendID 8bit [28:21]								ChannelID 7bit [20:14]							HitTime relative to Image start time 14bit [13:0]													

- **FrontendID:**
  A 8 bit value to address up to 256 front-ends per SRCid.
- **ChannelID:**
  A 7 bit value to address up to 128 channels for each front-end.
- **HitTime:**
  The HitTime is an 14 bit value which is relative to the start time of the image defined by the last BOI data word.

Variable Hit Time Bin Resolution



- 128 ns Image $\rightarrow$ 7.8 ps minimum bin resolution
- 64 μs Image $\rightarrow$ 3.9 ns minimum bin resolution

Additional Data Word

In case of sampling-ADC readout we need more then one data word per hit in channel (e.g. for TPC). An hit with additional information is started by an MainData word (110) which contains the FrontendID, ChannelID and a 14 bit timestamp and then an number of additional data words (111) until the next main data word is sent.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	1	0	FrontendID 8bit [28:21]								ChannelID 7bit [20:14]							HitTime relative to Image start time 14bit [13:0]														
1	1	1	ADC Sample 1 [28:16] 14bit															ADC Sample 0 [15:1] 14bit														
...																															

The additional data word has 29bits for user information. As an example we can transfer two samples a 14 bit for sampling-adc-read-out or used it for the trailing edge time information for an iFTDC in ToT mode per additional data word.

Data Flow

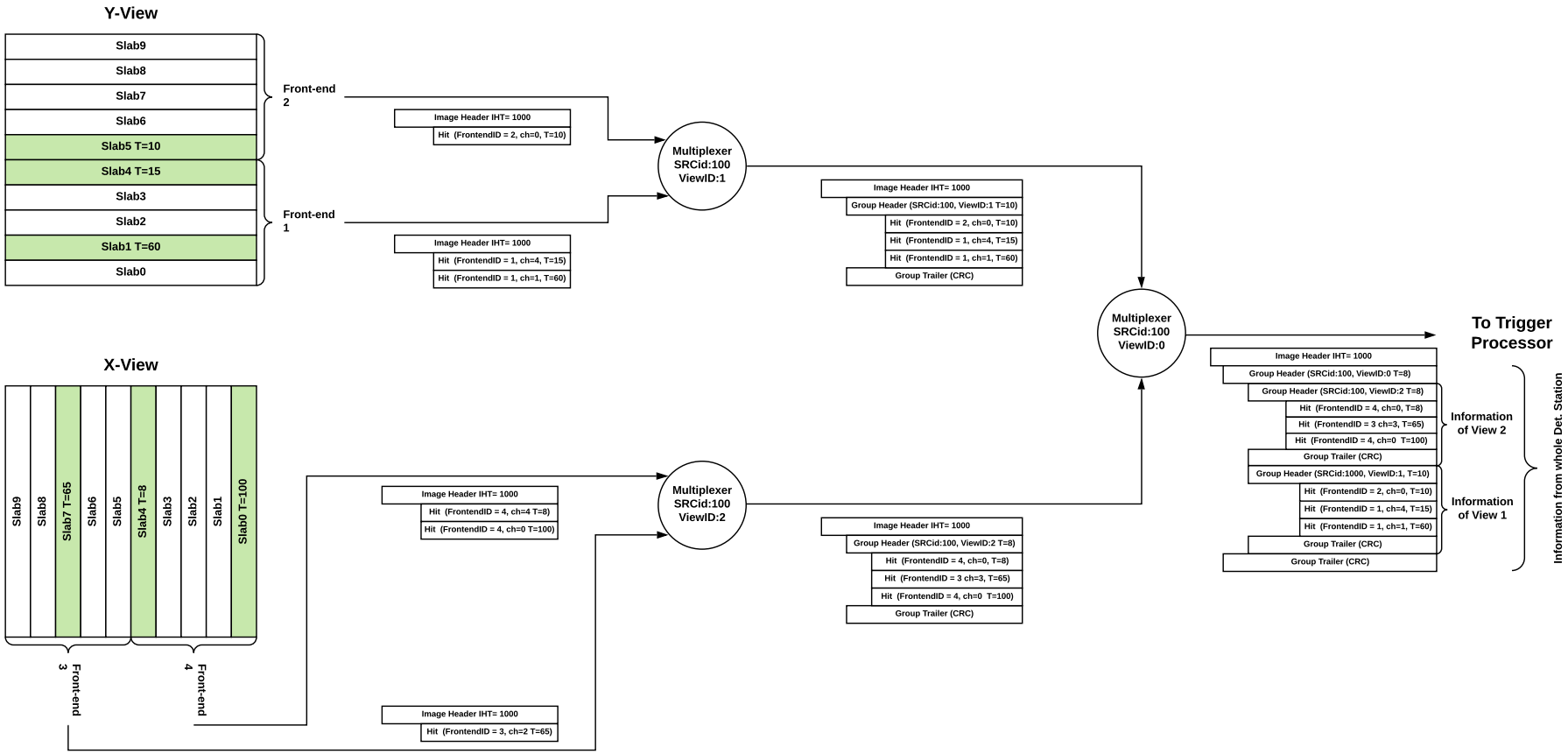
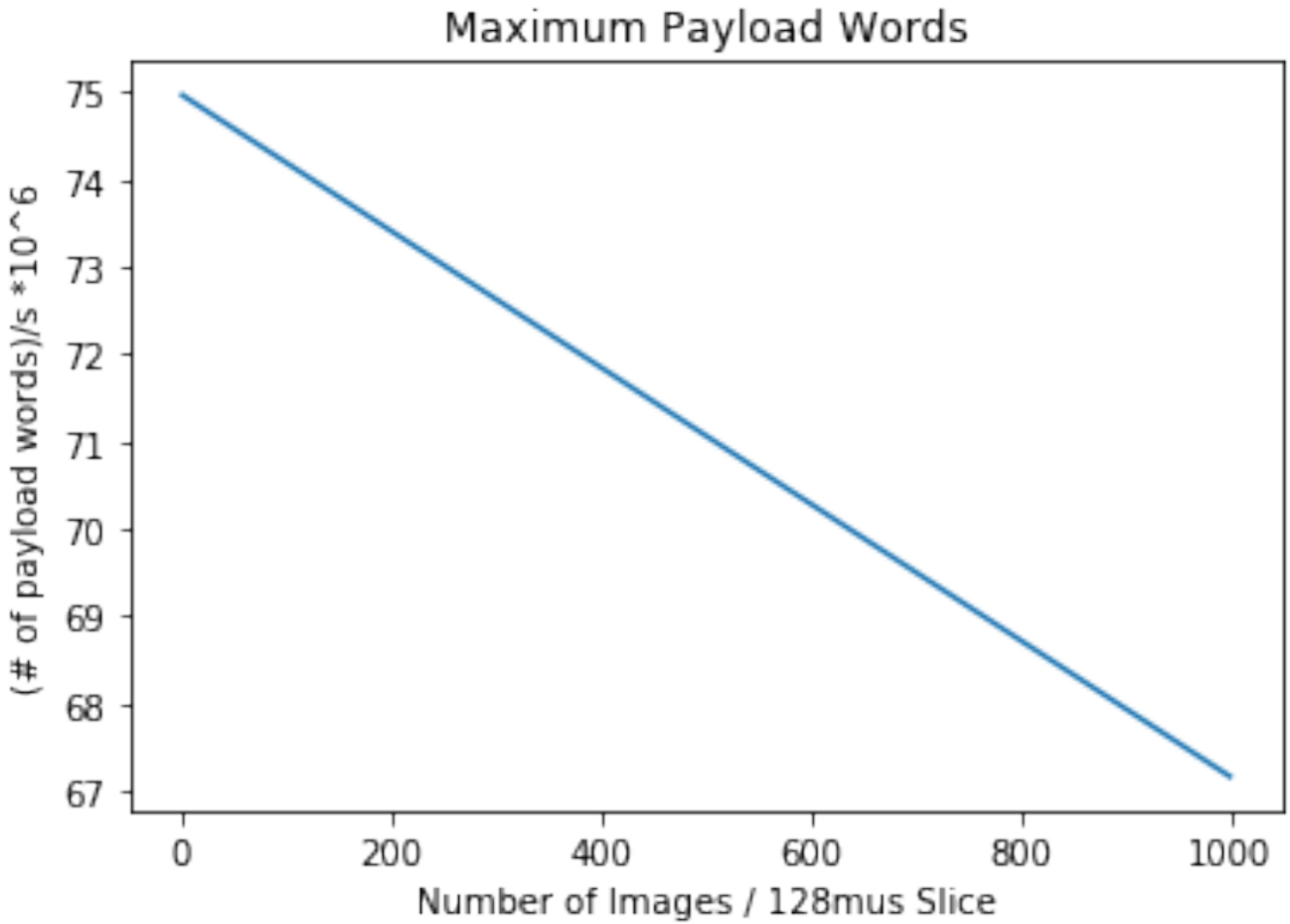

Y-View
Slab9
Slab8
Slab7
Slab6
Slab5 T=10
Slab4 T=15
Slab3
Slab2
Slab1 T=60
Slab0
Front-end 2
Front-end 1
Image Header IHT= 1000
Hit (FrontendID = 2, ch=0, T=10)
Image Header IHT= 1000
Hit (FrontendID = 1, ch=4, T=15)
Hit (FrontendID = 1, ch=1, T=60)
Multiplexer SRCid:100 ViewID:1
Image Header IHT= 1000
Group Header (SRCid:100, ViewID:1 T=10)
Hit (FrontendID = 2, ch=0, T=10)
Hit (FrontendID = 1, ch=4, T=15)
Hit (FrontendID = 1, ch=1, T=60)
Group Trailer (CRC)
X-View
Slab9
Slab8
Slab7 T=65
Slab6
Slab5
Slab4 T=8
Slab3
Slab2
Slab1
Slab0 T=100
Front-end 3
Front-end 4
Image Header IHT= 1000
Hit (FrontendID = 4, ch=4 T=8)
Hit (FrontendID = 4, ch=0 T=100)
Image Header IHT= 1000
Hit (FrontendID = 3, ch=2 T=65)
Multiplexer SRCid:100 ViewID:2
Image Header IHT= 1000
Group Header (SRCid:100, ViewID:2 T=8)
Hit (FrontendID = 4, ch=0, T=8)
Hit (FrontendID = 3 ch=3, T=65)
Hit (FrontendID = 4, ch=0 T=100)
Group Trailer (CRC)
Multiplexer SRCid:100 ViewID:0
To Trigger Processor
Image Header IHT= 1000
Group Header (SRCid:100, ViewID:0 T=8)
Group Header (SRCid:100, ViewID:2 T=8)
Hit (FrontendID = 4, ch=0, T=8)
Hit (FrontendID = 3 ch=3, T=65)
Hit (FrontendID = 4, ch=0 T=100)
Group Trailer (CRC)
Group Header (SRCid:1000, ViewID:1, T=10)
Hit (FrontendID = 2, ch=0, T=10)
Hit (FrontendID = 1, ch=4, T=15)
Hit (FrontendID = 1, ch=1, T=60)
Group Trailer (CRC)
Group Trailer (CRC)
Information of View 2
Information of View 1
Information from whole Det. Station

Image Length vs. Payload Size



Dependency between number of images per 128 μs long slice and number of 32 bit payload words for suggested protocol (3Gbit/s per link).

Example of Slice

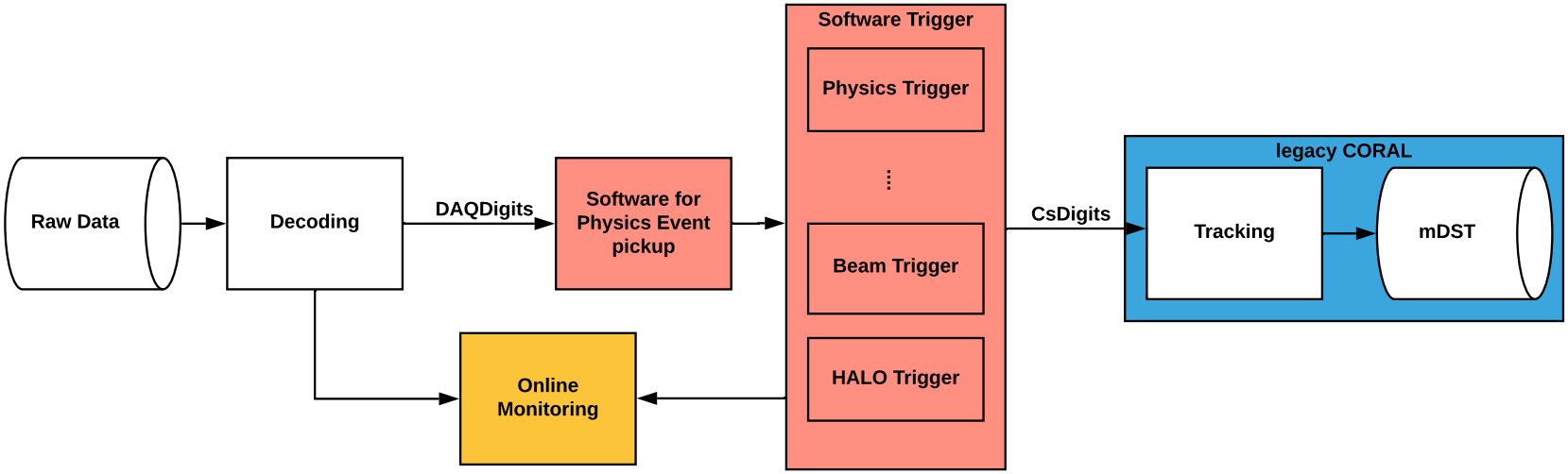
31	30	29	28 27 26 25 24 23 22 21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0			Abbreviation	Description
0	0	0	# of Images in Slice [29:20] 10bit	Slice Number in Epoch [19:0]		BOS	Begin of Slice #1
0	0	0	Time of Slice in Epoch in 25ns Ticks [28:0]			BOS	Begin of Slice #1
0	1	0	Start Time of Image in Epoch in 25ns Ticks [28:0]			BOI	Begin of Image #1 in Slice #1
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #3
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #1
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #1
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #2
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #2
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #3
0	1	0	Start Time of Image in Epoch in 25ns Ticks [28:0]			BOI	Begin of Image #2 in Slice #1
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #3
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #1
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #1
1	0	0	SRCid [28:19] 10bit	ViewID 5bit	First HitTime in Group 14bit [13:0]	BOG	Begin of Group #2
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	1	0	FrontendID 8bit [28:21]	ChannelID 7bit [20:14]	HitTime relative to Image start time 14bit [13:0]	DATA	
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #2
1	0	1	CRC [28:3]		Flags [2:0]	EOG	End of Group #3
0	0	1	CRC [28:3]		Flags [2:0]	EOS	End of Slice #1

Software related Projects

How to handle “event-less” data?

Reconstruction of continuous Data Stream

For the **Free Running Mode** we have to define the "Events" and timing after the recording in software:

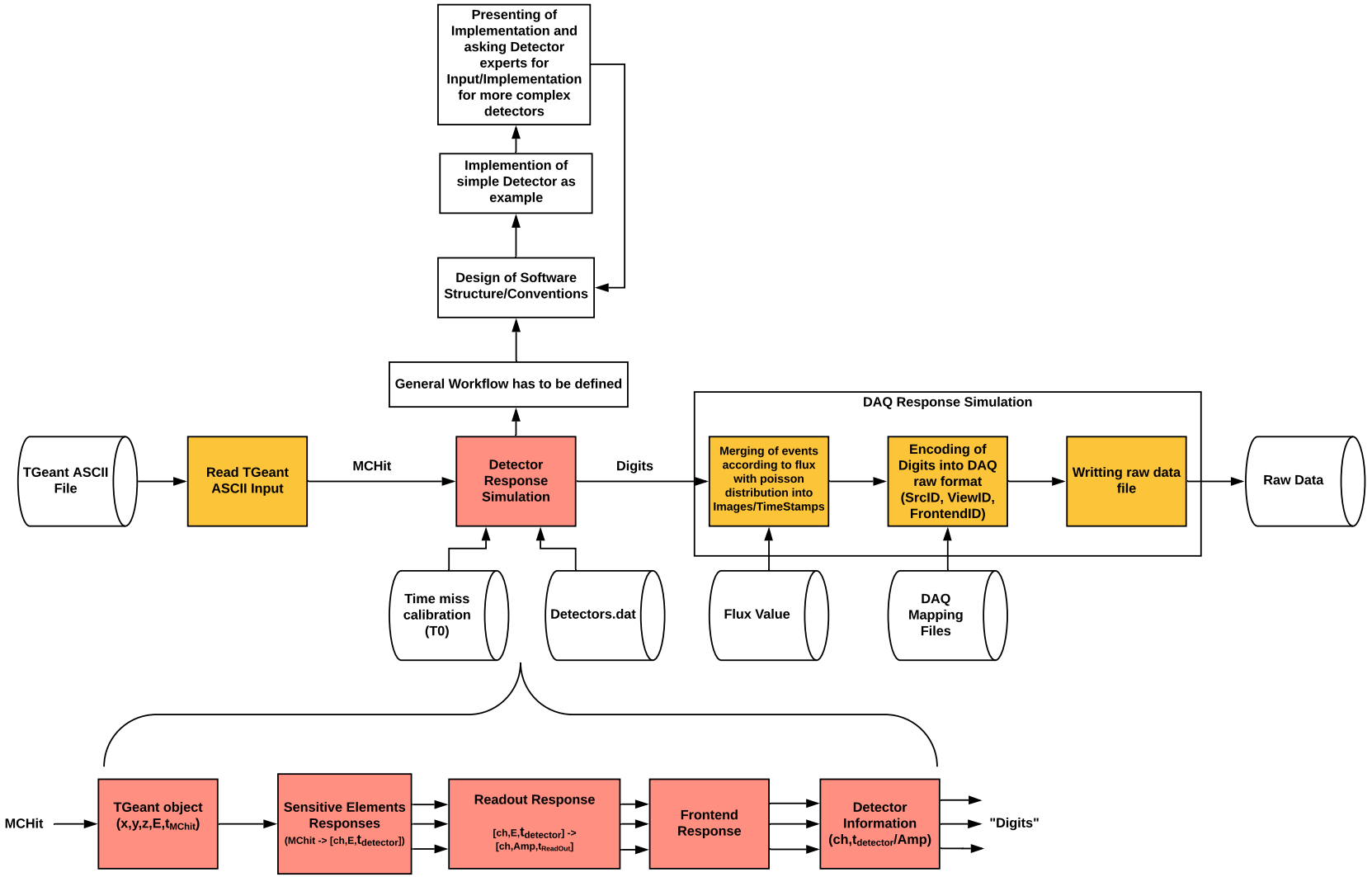


Two Options:

- Short Term: Application to convert continuous data to event data to reuse CORAL (red boxes).
- Long Term: Rewrite CORAL in the scope of the new scheme.

(lot of Man-power will be needed!)

Generating RAW data from MC Simulation



Conclusion for Software

The new free running DAQ scheme also have challenges on the "physics" software side. Some work packages are already defined:

- **MC Chain** has to be extended by an application which creates an continuous raw data stream out of the MC truth.
  → Needed for validation and testing of the new DAQ scheme.
  → Mandatory for development of the new reconstruction
- **Decoding** of data has to be adapted to the new read-outs and time corrections
- **Reconstruction** (CORAL) has to be adapted to deal with the free-running data → Physics Event "pickup" and Software Trigger (at least)
- New **Monitoring tools**

Interesting projects but lot of man power needed!