Streaming Computing Infrastructure WG
Electronics & DAQ Cross Cutting WG
Joint workfest on July 25, and WG report

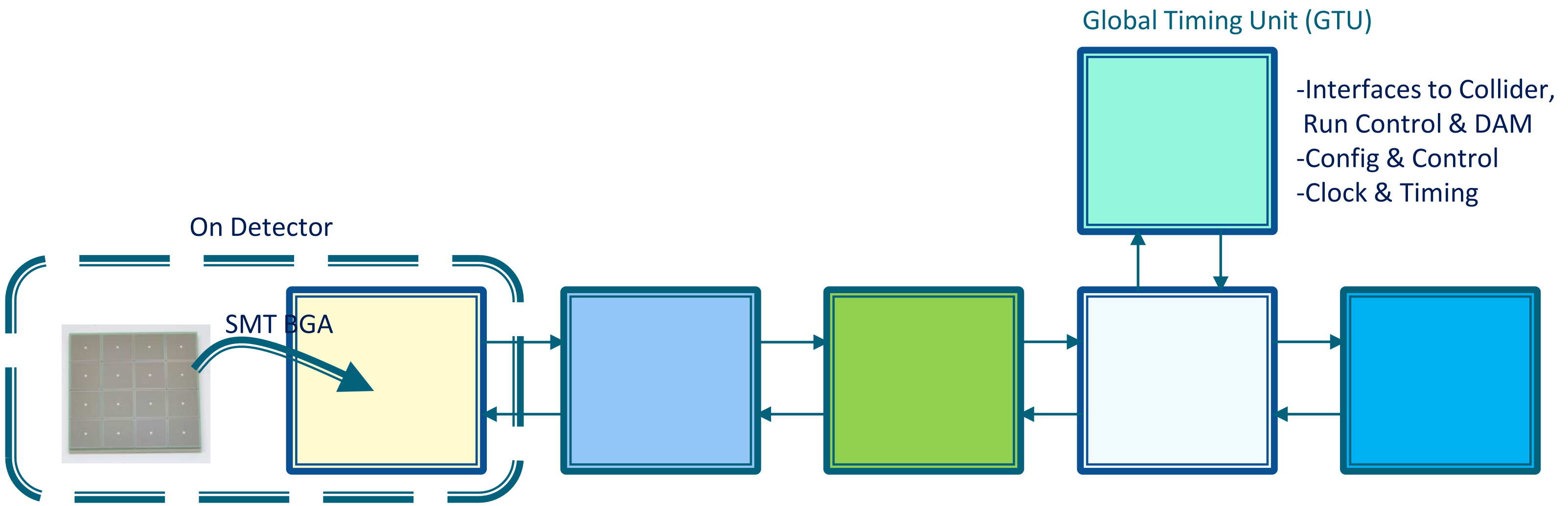
Fernando Barbosa (JLab)
Marco Battaglieri (JLab)
Jin Huang (BNL)
Jeff Landgraf (BNL)
David Lawrence (JLab)

ePIC

SRO and Electronics&DAQ WGs

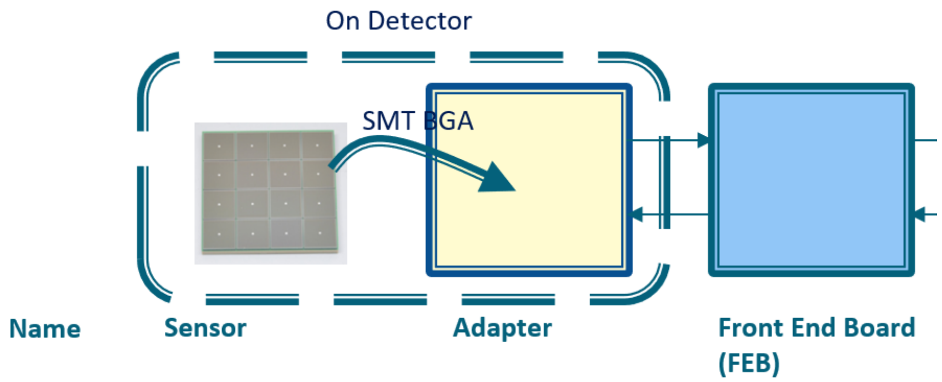
- Working closely to build an integrated data pipeline from detector → analyzers
  - Also, in close collaboration with detector and Software/Computing group, EIC project
- Meetings: Tue 9AM (SRO WG), Thu 9AM (E&DAQ WG);
  - Topic driven meetings, frequently joint between the two WGs.
  - Also, workfests: both in Jan and this CM, ePIC Computing meetings
- Email lists:
  - https://lists.bnl.gov/mailman/listinfo/eic-projdet-daq-l, eic-projdet-compsw-l
  - Also, focused topical discussions in ePIC mattermost for rapid progresses
- Conveners/Project CAMs:
  - David Abbott (JLab) : CAM (DAQ)
  - Fernando Barbosa (JLab) : E&DAQ WG, CAM (Elec.)
  - Marco Battaglieri (JLab) : SRO WG
  - Jin Huang (BNL) : both WGs
  - Jeff Landgraf (BNL) : both WGs, CAM (DAQ)

ePIC Readout Chain



Name	Sensor	Adapter	Front End Board (FEB)	Readout Board (RDO)	Data Aggregation Module (DAM)	Computing
Design	Detector Specific	Detector Specific	Detector Specific	Few Variants	Common	Common
Function	Multi-Channel Sensor	-HV/Bias Distribution -HV divider -Interconnect Routing	-Amplification -Shaping -Digitization -Zero Suppression -Bias Control & Monitoring	-Communication -Aggregation -Formatting -Data Readout -Config & Control -Clock & Timing	-Computing Interface -Aggregation -Software Trigger -Config & Control -Clock & Timing	-Data Buffering and Sinking -Calibration Support -QA/Scalers -Collider Feedback -Event ID/Building -Software Trigger -Monitoring
Attributes	MAPS, AC-LGAD MPGD, MCP-PMT SiPM, LAPPD	-Sensor Specific -Passive	-ASIC/ADC -Discrete -Serial Link	-FPGA -Fiber Link	-Large FPGA -PCIe -Ethernet	-COTS -Ethernet

Digitizer and ASIC choices



Detector System		Channels	SensorTechnology	Redout Technology
Si Tracking				
	3 vertex layers	7 m^2	MAPS	lpGBT, VTRX+
	2 sagitta layers	368 pixels	MAPS	lpGBT, VTRX+
	5 backward disks	5,200 MAPS sensors	MAPS	lpGBT, VTRX+
	5 forward disks		MAPS	lpGBT, VTRX+
MPGD Tracking				
	Barrel, e & H Endcaps	202 k	uRWELL, MicroMegas	SALSA
Forward Calorimeters				
	LFHCAL	63,280	SiPM	CALOROC
	HCAL Insert	8 k	SiPM	CALOROC
	pECAL W/SciFi	16,000	SiPM	Discrete
Barrel Calorimeters				
	HCAL	7,680	SiPM	CALOROC
	ECAL SciFi/Pb	5,760	SiPM	CALOROC
	ECAL Imaging Si ASTROPIX	500 M pixels	Astropix	
Backward Calorimeters				
	nHCAL	3,256	SiPM	CALOROC
	ECAL (PWO)	2,852	SiPM	Discrete
Far Forward				
	B0: 3 Crystal Calorimeter	135	SiPM/APD	Discrete
	B0: 4 AC-LGAD layers	688,128	AC-LGAD Pixel	EICROC
	2 Roman Pots (RP)	524,288	AC-LGAD Pixel	EICROC
	2 Off Momentum (OMD)	294,912	AC-LGAD Pixel	EICROC
	ZDC: Crystal Calorimeter	900	SiPM/APD	Discrete
	ZDC: HCAL	9,216	SiPM	CALOROC
Far Backward				
	Low Q Tagger 1	33,030,144	Timepix4	
	Low Q Tagger 2	33,030,144	Timepix4	
	Low Q Tagger 1+2 Cal	420 (2x210)	SiPM	CALOROC
	2 Lumi PS Calorimeter	3,360 (2x1680)	SiPM	Discrete
	2 Lumi PS Tracker	128,000 (2x64,000)	AC-LGAD Strip	FCFD/EICROCx
	Lumi Direct Photon Calorimeter	100	SiPM	Flash250
PID-TOF				
	Barrel bTOF	2,359,296	AC-LGAD Strip	FCFD/EICROCx
	Hadron Endcap fTOF	3,719,168	AC-LGAD Pixel	EICROC
PID-Cherenkov				
	dRICH	317,952	SiPM	ALCOR, VTRX+
	pfRICH	69,632	HRPPD	FCFD/EICROCx
	hpDIRC	73,728	MCP-PMT or HRPPD	FCFD/EICROCx

CERN

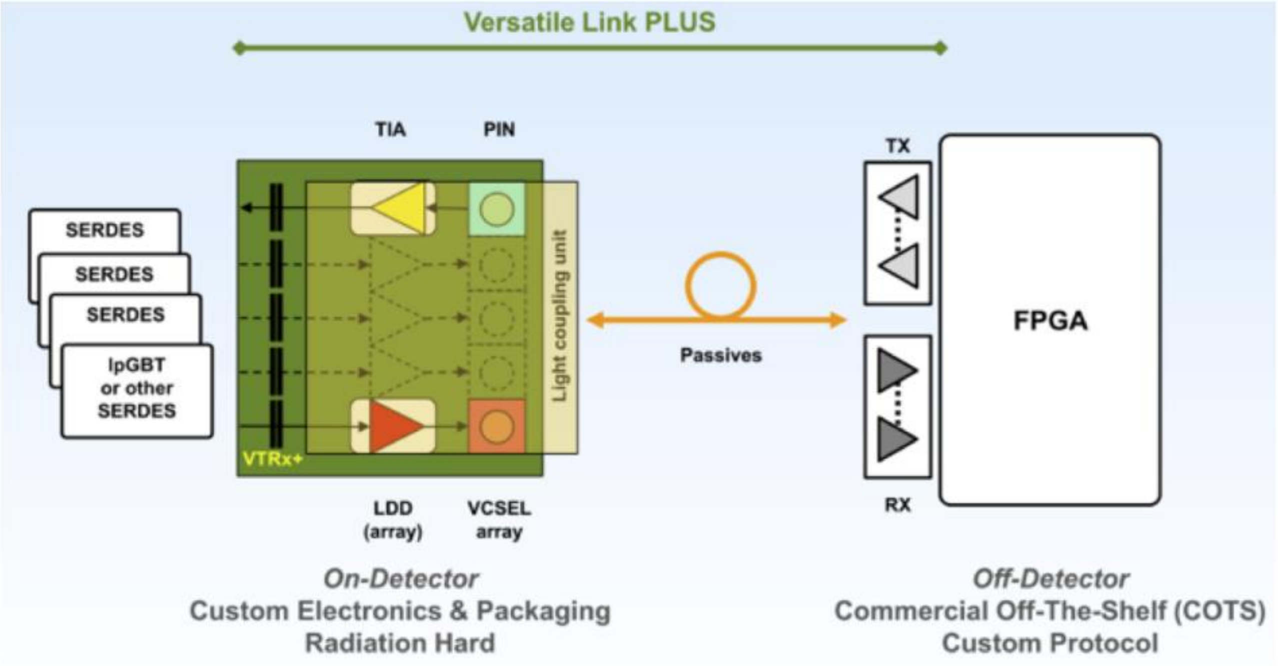
eRD109

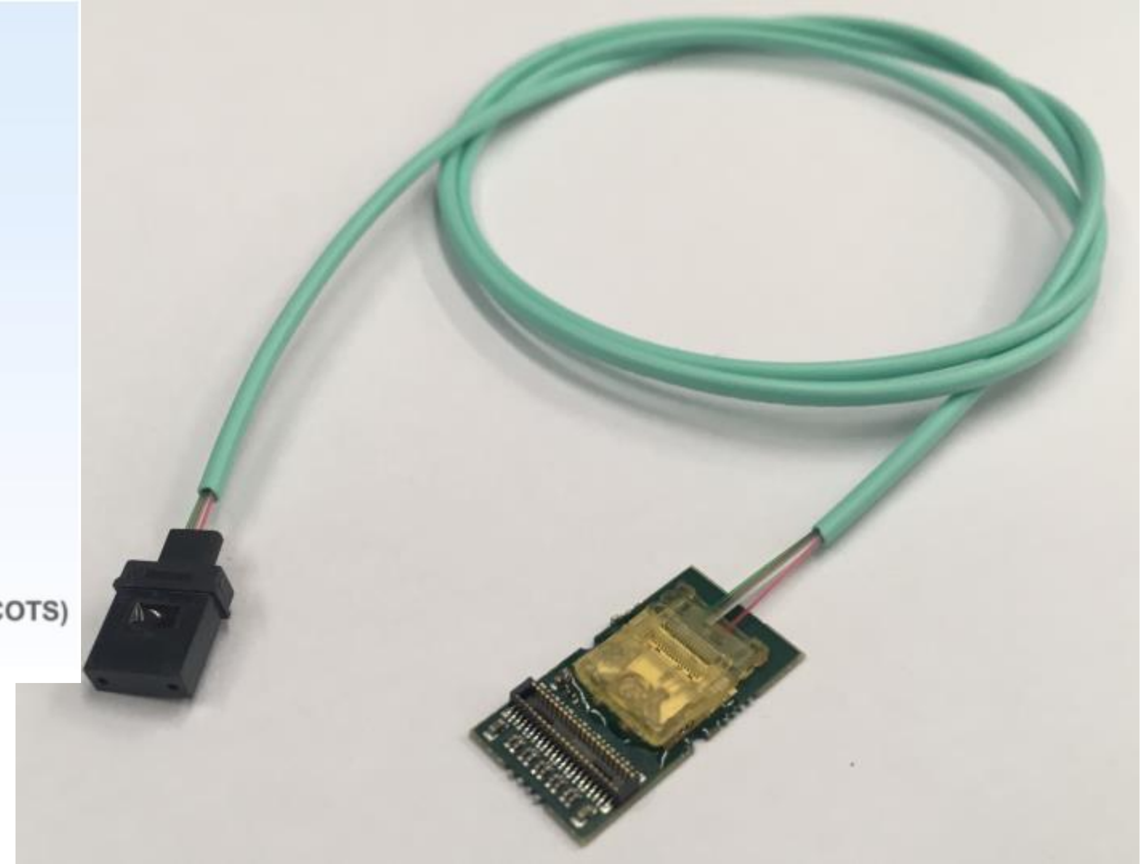
JLab

eRD109

Fernando, Marco, Jin, Jeff, David

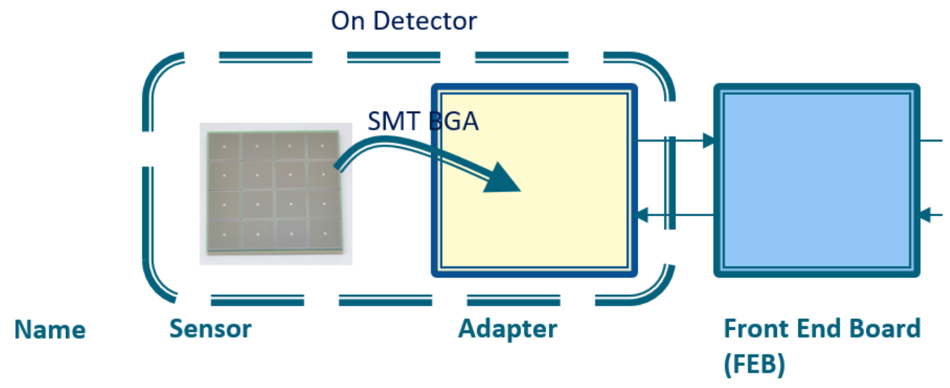
VTRX+ – Versatile Link+ Transceiver





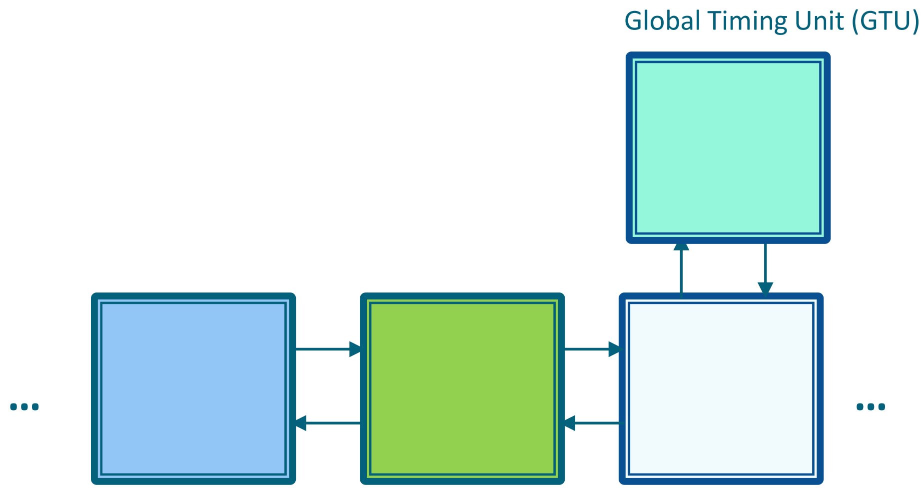
- Specialized optical module
  - Tx Data rate up to 10.24 Gbps.
  - Rx Data rate up to 5.12 Gbps.
  - Power consumption up to 320 mW.
- Plan to be used by SVT and dRICH for space and power reasons
- Produced by CERN, successful ePIC final design review in June 2024, procurement supported by project as part of early CD3 process

eRD109 Initiatives, monthly update in E&DAQ meeting



- Addresses ASIC and Electronics R&D needs.
  - FY23 Proposals submitted in October 2022
    - Contract awards took longer than expected.
  - FY24 Proposals submitted in July 2023
    - Contract awards should now be in synch with FY funding
    - Continuation of previous work.
  - FY25 Proposals due 1 July 2024
- R&D completion dates have been included in P6
  - Si-related R&D tends to have longest times to complete
  - ASIC completion is ~4 years, compatible with EIC detector schedule.
- ASIC & Electronics:
  - Discrete/COTS – Calorimeters, SiPMs, 12-14 bit
  - CALOROC – Calorimeters, SiPMs, 10 bit
  - EICROC - AC-LGAD, pixel *
  - FCFD – AC-LGAD, strip
  - ALCOR – dRICH, SiPM, 1 p.e.
  - SALSA – MPGD.

DAQ System Components



Front End Board (FEB)

Readout Board (RDO)

Few Variants

-Communication
-Aggregation
-Formatting
-Data Readout
-Config & Control
-Clock & Timing

-FPGA
-Fiber Link

Data Aggregation Module (DAM)

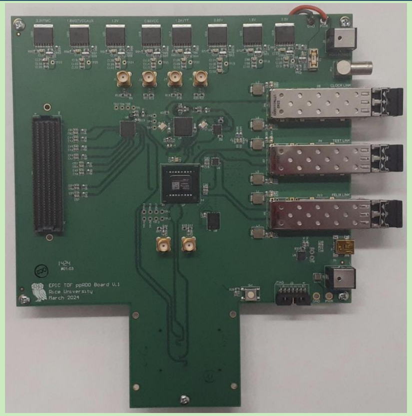
Common

-Computing Interface
-Aggregation
-Software Trigger
-Config & Control
-Clock & Timing

-Large FPGA
-PCIe
-Ethernet

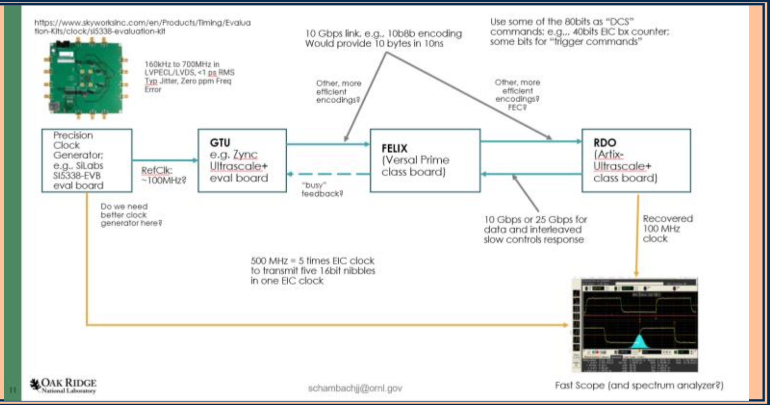
RDO Status:

- **Pre-prototype now available for timing studies and firmware development**
- Nominal 2.5” x 2.5” for common elements + connector space
- FPGA defined by price (Artix Ultrascale+ Class)
- Power 3-5 Watts. 2 LV +5V for optical interfaces, lower for FPGA/digital components
- Accept 2 or 3 fibers for potential very low jitter timing



GTU status:

- **Mocking up with dev-kits for initial studies**
- Interface to collider (Bunch crossing clock, Spin Patterns per bunch crossing)
- Distribution of timing to ~150 DAMs + ~220 RDOs for Hi-Res Timing Detectors
- User command interface & distribution
- Interface to Run Control



DAM Status:

- **2 FELIX engineering articles obtained (Model FLX-182)**
- **Input to FELIX design FLX-155, to be used in ePIC**
- Xilinx Versal Premium FPGA
- PCIe Gen4 x16 or 100Gb Ethernet output
- **28 Firefly links** up to 25Gb/s options

Fiber Protocol / DAQ operation

See workfest talk Jeff Landgraf

Synchronous Commands:

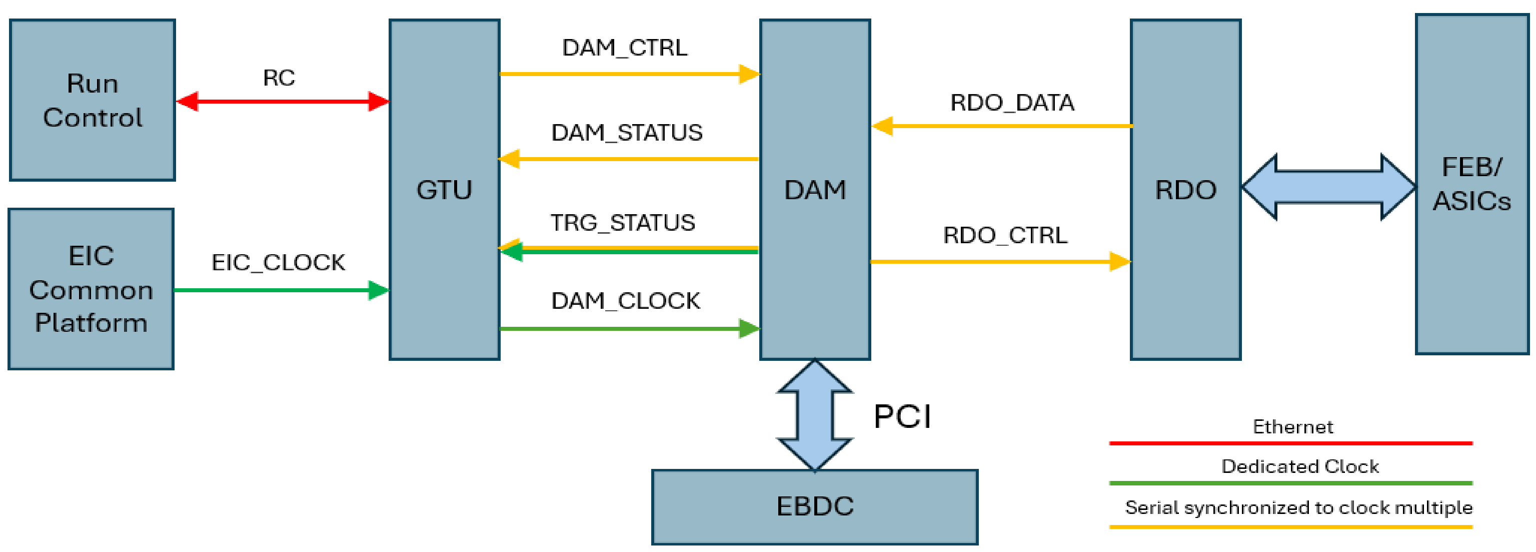
64 bits (80 bits 8b/10b encoded) per bunch

- Reconstructed clock
- Redundant BCO
- Distinct synchronous commands (eg)
  - RC
  - Time Frame Control & Definition
  - Flow Control
  - Trigger
    - Request special events
    - Data filter (firmware trigger)
  - Configuration (ASIC / RDO firmware)
  - Data Formatting
  - Data Transfer
    - Hits
    - Slow Controls

Trigger Operation:

- Support Max Data Volume to DAM / Readout computer Buffers
- Generate Trigger Signals in DAM
- Communicate triggered crossings via synchronous cmds through GTU

Information Layer



Time Frame Definition:

- 16 bits BCO (0.66ms -> 8MB @ 100Gbps)
- Flexible formatting
  - Filtered & Unfiltered data can coexist
- Time Frames are built, they contain the full set of detectors for the time period
- Tiered Data Format.
  - High level flexible, named navigation via banks (e.g. star SFS, sPHENIX DAQRC)
  - Low level supports direct, detector specific (eg ASIC) formats.

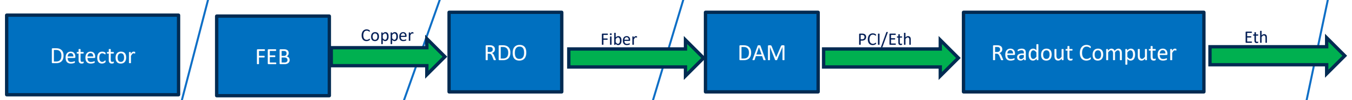
Particular highlight thoughts and prototyping work by **William Gu (JLab)** [WG talk]

Summary of Channel Counts and Data Flow

Detector Group	Channels					RDO	Fiber Pairs	DAM	Data Volume (RDO) (Gb/s)	Data Volume (To Tape) (Gb/s)
	MAPS	AC-LGAD	SiPM/PMT	MPGD	HRPPD/ MCP-PMT					
Tracking (MAPS)	16B					183	183 (6046 simplex To Detector)	7	15	15
Tracking (MPGD)				164k		160	160	5	27	5
Calorimeters	500M		100k			510	510	17	70	17
Far Forward		1.5M	10k(+201k*)			80(+218)	80(+218)	7(+6)	36	12
Far Backward	66M	128k	4k			60	82	14	301	16
PID (TOF)		6.1M				500	500	14	50	12
PID Cherenkov			318k		143k	1283	1283	32	1275	32
TOTAL	**16.6B**	**7.7M**	**432k(+201k)**	**164k**	**143k**	**2816(+218)**	**2798(+218)**	**96(+6)**	**1,774**	**109**

Data reduction solution required

Summary of Data Flow



100% Occupancy	27.5-1760 Pb/sec

Aggregate	**1.8 Tb/sec**
Noise	1.4 Tb /sec
Signal from Physics + Background	400 Gb / sec

Aggregate	**1.8 Tb/sec**
Per RDO (Avg)	0.6 Gb/sec

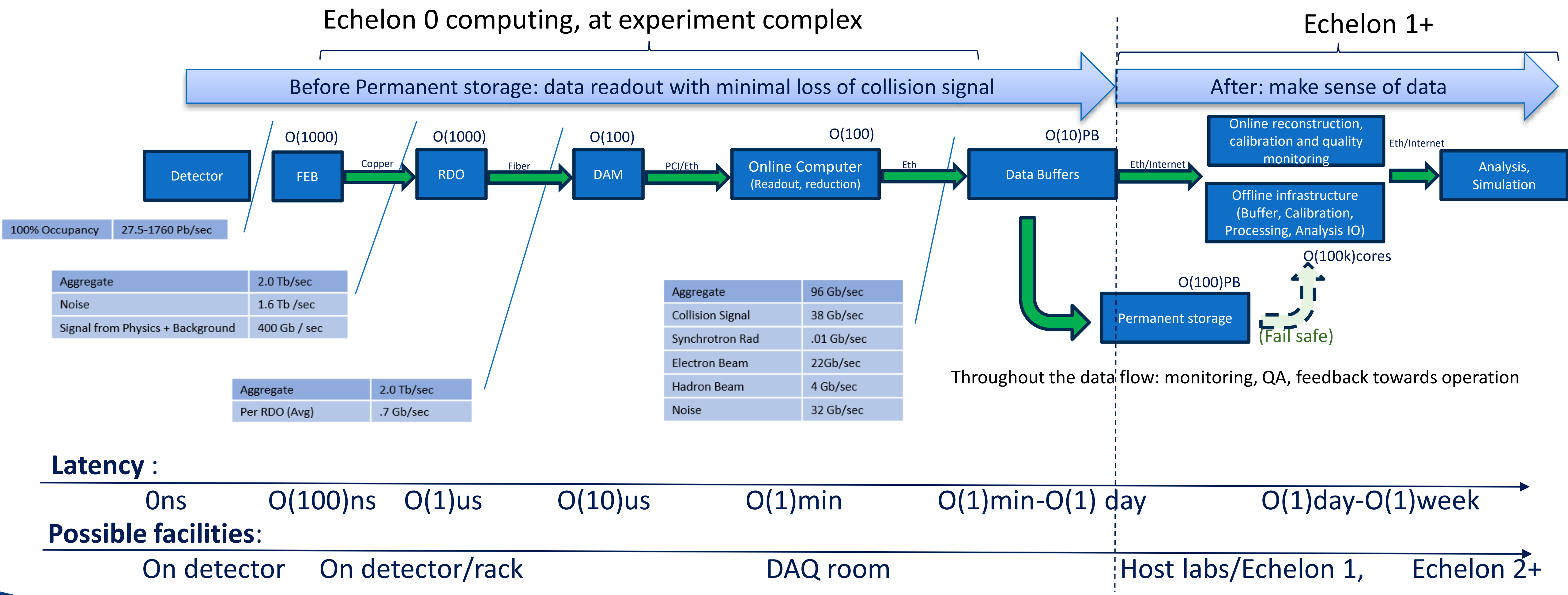
Aggregate	**109 Gb/sec**
Collision Signal	62 Gb/sec
Synchrotron Rad	Under design
Electron Beam	4.5 Gb/sec
Hadron Beam	1.0 Gb/sec
Noise	41 Gb/sec

Where needed:

- Computing based data reduction, e.g. clustering, pattern finding
- Data throttling via local trigger (tagger) See also: dRICH tagger Workfest and report

Streaming computing: online to offline

See also SCC talk:
Markus Diefenthaler



Aggregate	2.0 Tb/sec
Noise	1.6 Tb /sec
Signal from Physics + Background	400 Gb / sec

Aggregate	2.0 Tb/sec
Per RDO (Avg)	.7 Gb/sec

Aggregate	96 Gb/sec
Collision Signal	38 Gb/sec
Synchrotron Rad	.01 Gb/sec
Electron Beam	22Gb/sec
Hadron Beam	4 Gb/sec
Noise	32 Gb/sec

Reference:

- ePIC 2023 Computing plan and review [link]
- ePIC DAQ wiki: https://wiki.bnl.gov/EPIC/index.php?title=DAQ
- ECCE computing plan, *Nucl.Instrum.Meth.A* 1047 (2023) 167859

Joint Workfest

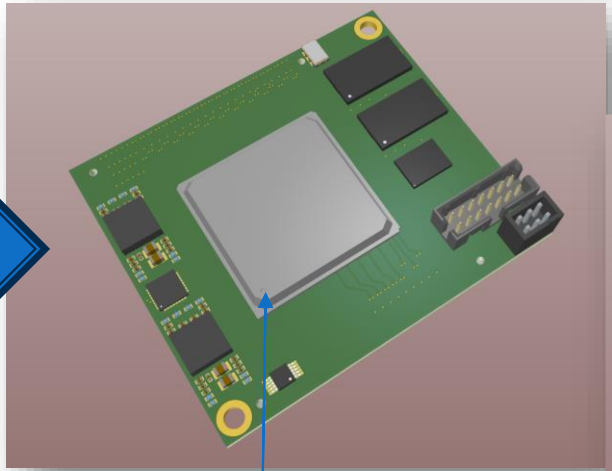
- Full day July 25: https://indico.bnl.gov/event/20727/sessions/7431/#20240725
  - Follow up to the joint workfest in Jan-24 CM
- Focus on making progress on four areas:
  - Prototyping and detector prototype support on (1) electronics (2) DAQ
  - First discussion of SC and meta data management
  - Streaming computing model
- About 20 participants both in room and over ZOOM. Plenty discussion in talks

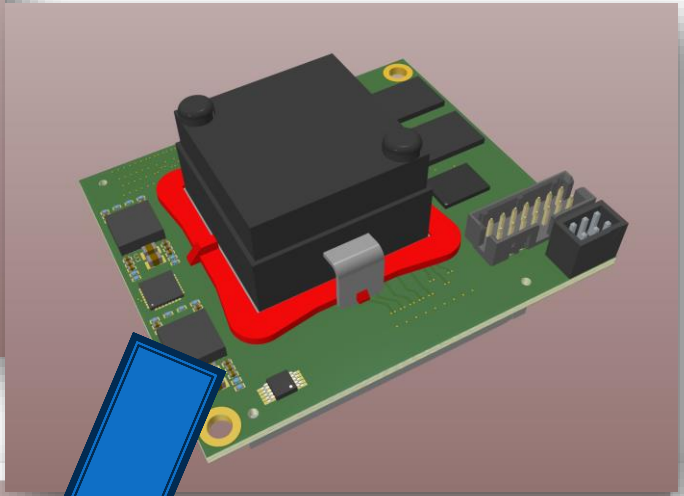
Fernando, Marco, Jin, Jeff, David

Electronics :
Prototyping and prototype support

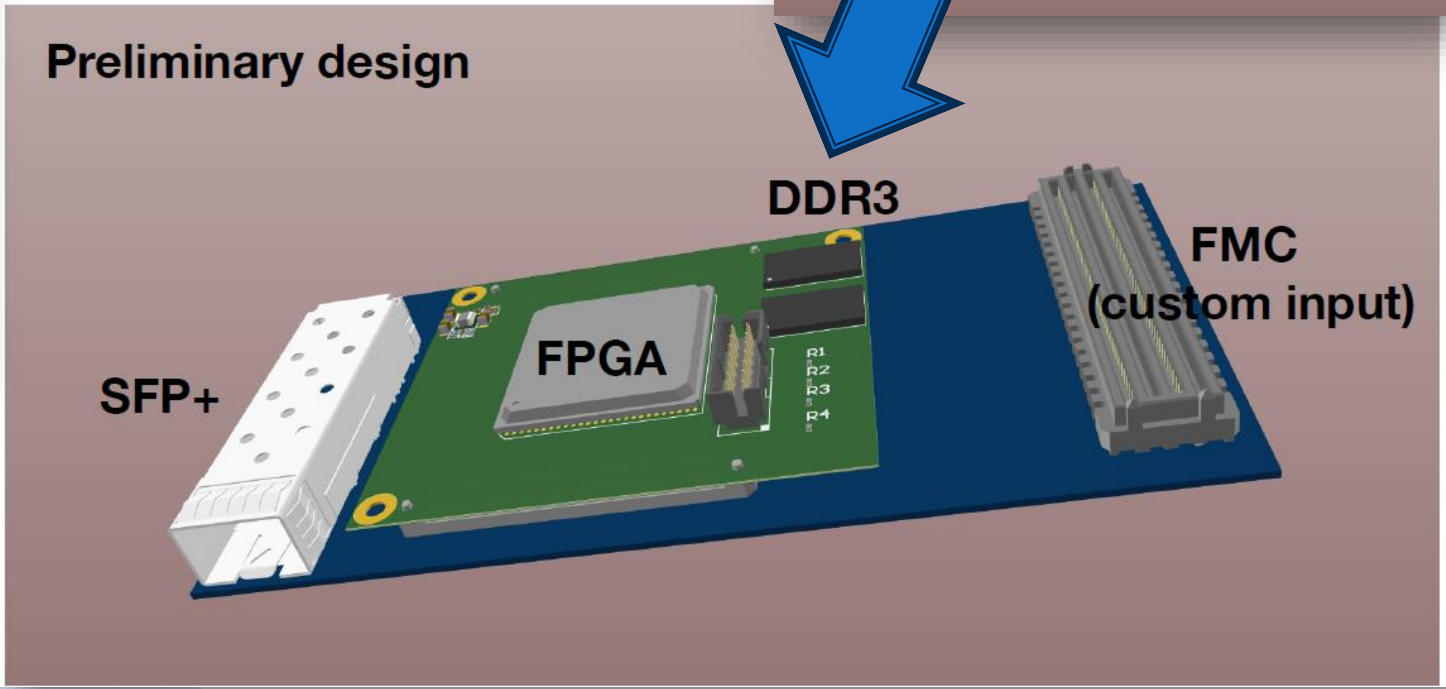
See work from Tonko, Norbert [talk]

RDO v1->v2





FPGA: Artix Ultrascale+



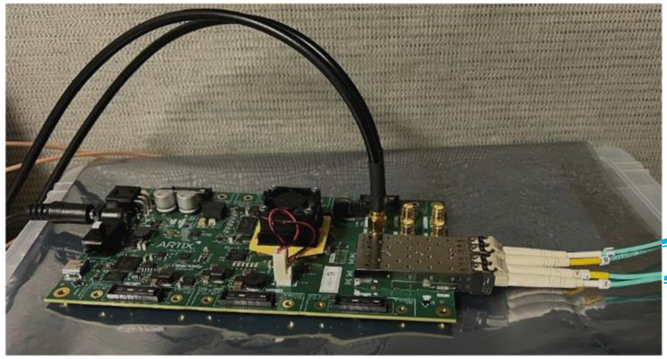
DAM/FELIX prototyping

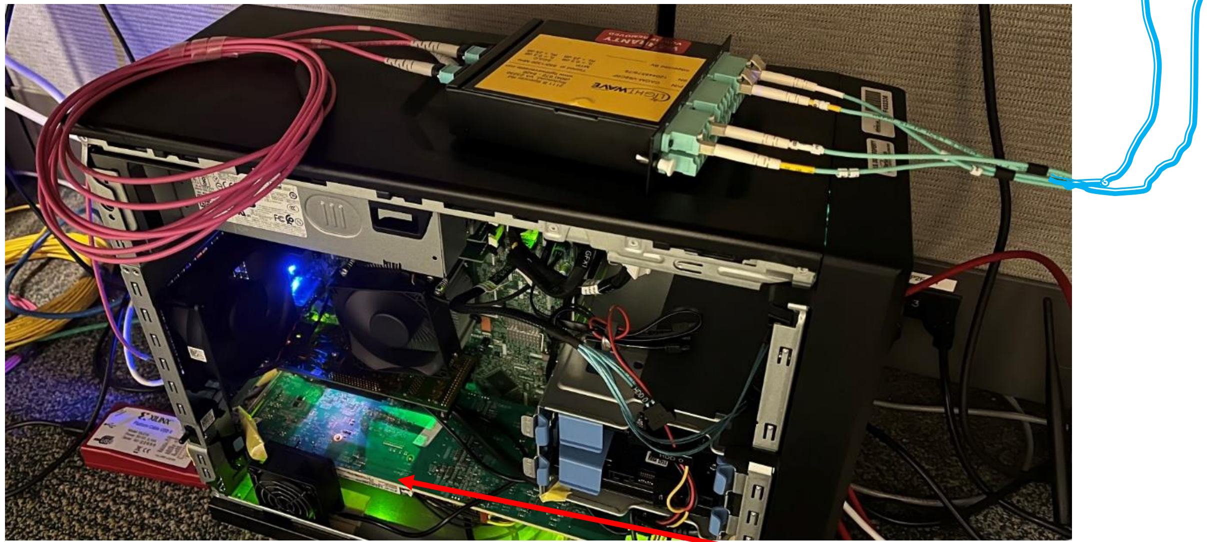
- Finishing timing studies
- Define clock/command distribution protocol
  (manage jitter and phase drift)
  - Refine requirements for the GTU
    (scale of the distribution, interface to DAM)

- Current in ePIC, 2x FELIX-182
- Finalize requirements for FELIX development to define EIC DAM Board: FELIX-155
  - Collaborating with ATLAS OMEGA group at BNL

- **All for development of the TDR and the CD2 baseline.**

XEM8320,
Artix Ultrascale+
(RDO)





FLX 182 board
Used for timing studies and DAM firm/software development

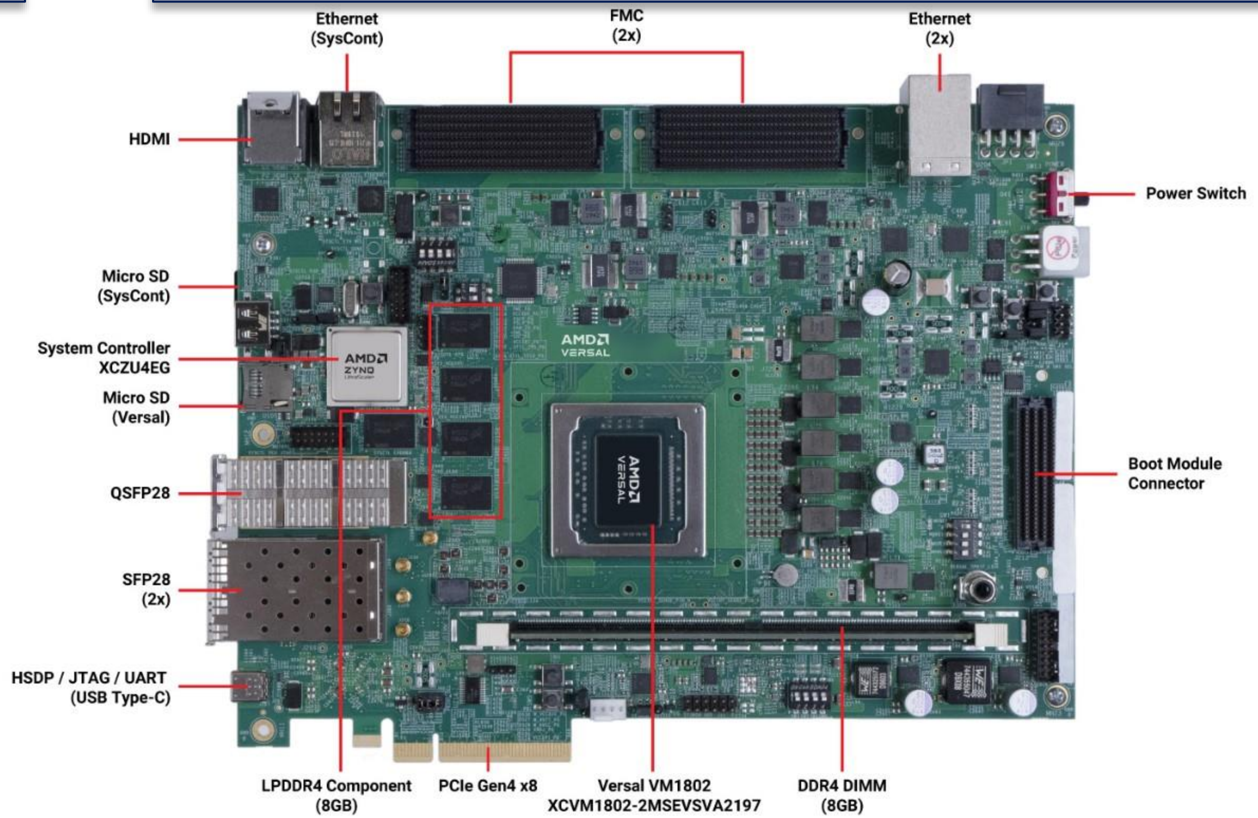
Pre-FELIX board prototyping strategy: COTS eval. boards

- Final FELIX card still in development by ATLAS, first engineering article end of CY 24
- It is difficult to obtain sufficient final FELIX boards in time for ePIC prototyping.

Simple teststands (low data load, timing test)
ALINX VD100 (~$1000) based on Versal Edge FPGA

Versal Edge AI SoM (dual core ARM)
2x SFP+ (12.5Gps)
2x 1Gb Ethernet
4GB DRAM
156MHz on board clock

Large test stand (multi channel, data processing):
Xilinx VME180 [link] (~$10k) based on Versal Prime FPGA



Coming fEMCal test at RHIC/STAR in 2025 [Oleg Tsai]

- Built upon eRD 2017 test at STAR
- ECal block with SiPM board, first version of FEB, along with RDO SEU tests

Questions / Discussion:

- Will it make sense to push for ePIC fEMCal test at STAR in Run25? - **Yes**
- Is it enough time and manpower to do this for upcoming Run25? - **I don't know.**

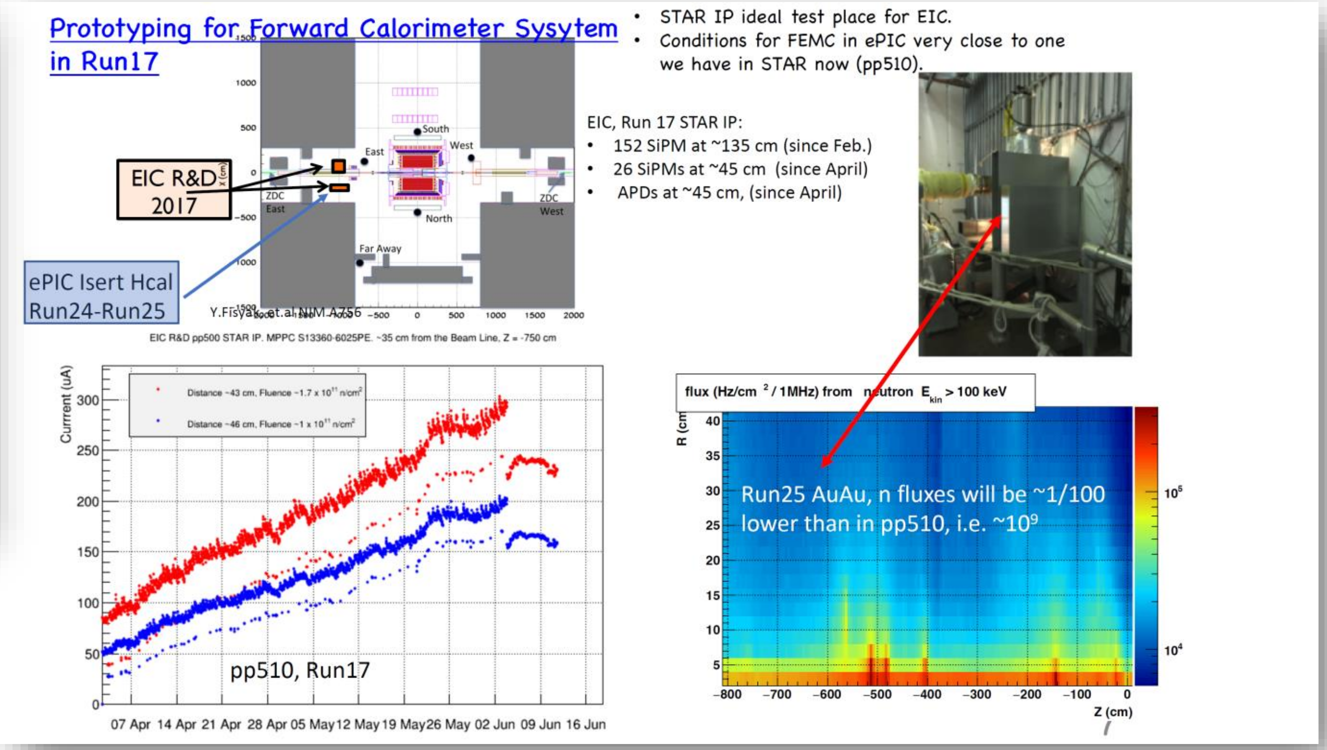
Projections:

Hardware:

- Two installation ECal blocks with SiPM boards will be available late fall.
  (64 channels, partially instrumented with SiPMs)
- First version of FEB in late fall? Gerard V.
- 'RDO' and DAQ – Tonko said he already have ppRDO board for SEU tests, but can it be used with Gerard's FEB?

Software?

A. Ogawa (BNL) ?



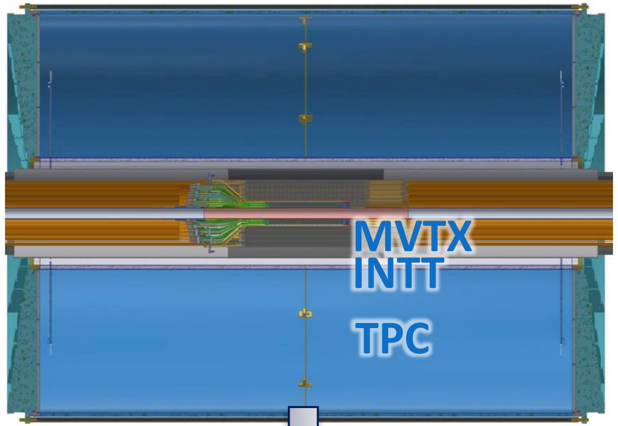
DAQ:
Prototyping and prototype support

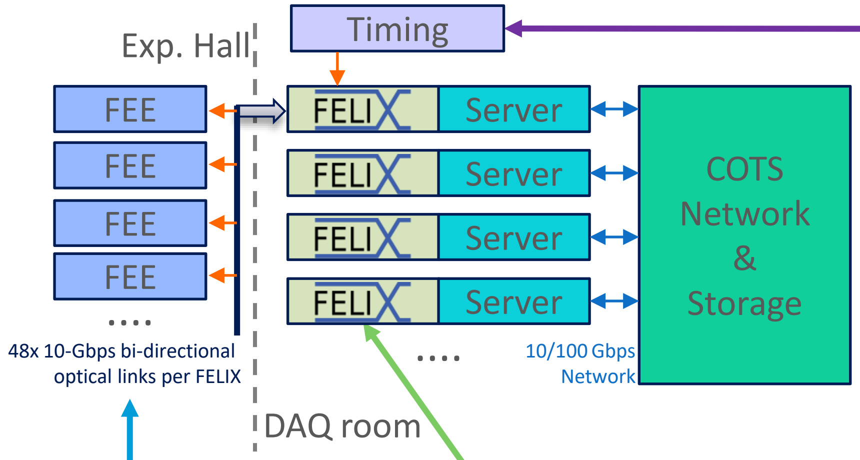
- Based on rich experience of ePIC collaboration members on high performance DAQ
- Three options for prototyping discussed : RCDAQ, CODA, nestDAQ (coming slides)
- Final ePIC DAQ would be built upon experience and components from these DAQ systems

RCDAQ use in sPHENIX

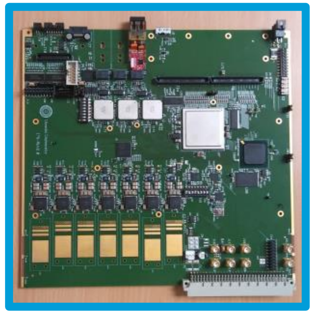
100% streaming operation in sPHENIX tracker in Run24

sPHENIX streaming DAQ for tracker





Global Timing Module (NSLS II/sPHENIX)
Receiving from RHIC RF low glitter clock source



MVTX RU, 200M ch INTT ROC, 400k ch
ALPIDE (ALICE/sPHENIX), FPHX (PHENIX)

TPC FEE, 160k ch
SAMPAv5 (ALICE/sPHENIX)

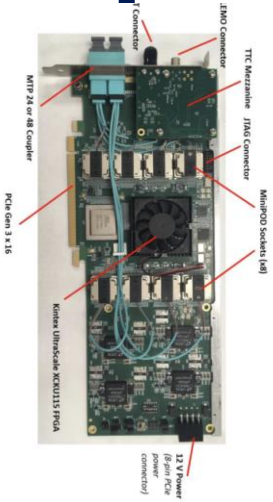
BNL-712 / FELIX v2 x38 (ATLAS/sPHENIX)
FELIX Ref: 10.1109/tim.2019.2947972

Some workhorse devices implemented in RCDAQ

RCDAQ

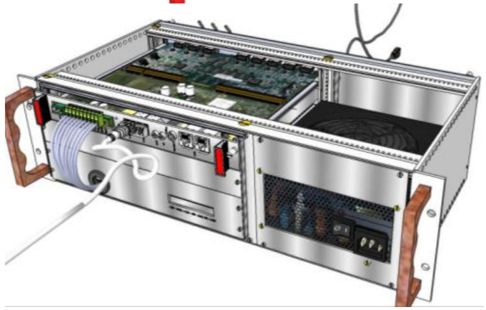
PCIe

PCIe

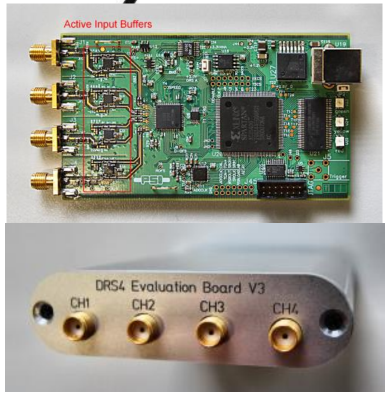


FELIX Card

The CAEN V1742 waveform digitizer



The CERN RD51 SRS System



DRS4 Eval board

"USB Oscilloscope"

There are *many* more not shown (all told, there are plugins for about 60)

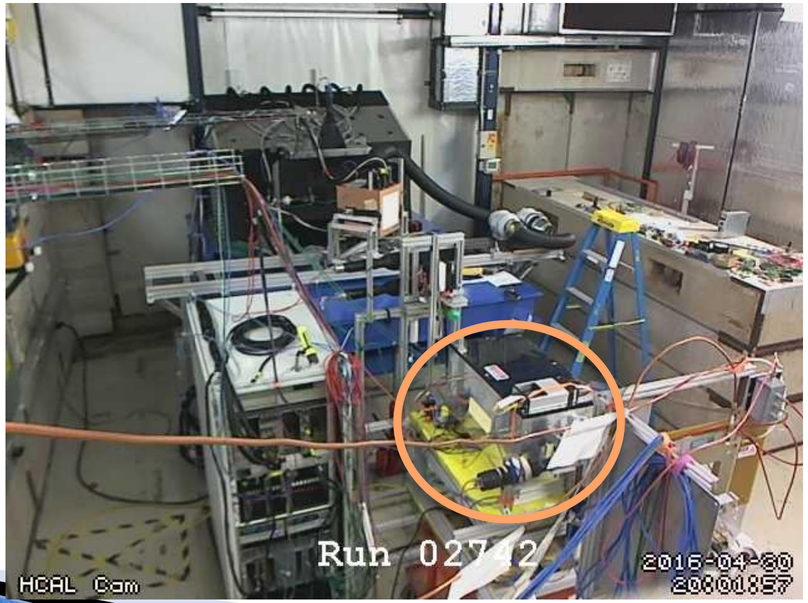
Many devices that you can often find in your institute already, or in the CAEN catalog

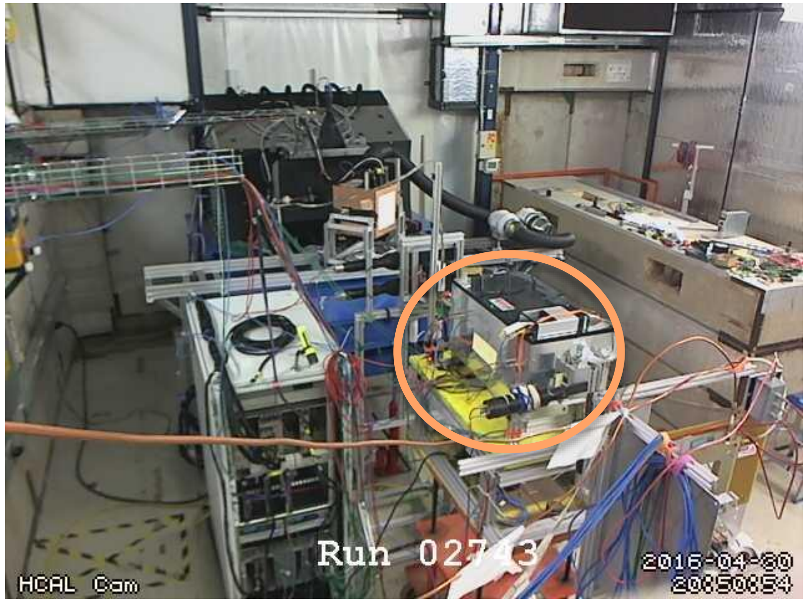
More Forensics (HCal at the Fermilab test beam again…)

“There is a strange effect starting in run 2743. There is a higher fraction of showering than before. I cannot see anything changed in the elog.”

Look at the cam pictures we automatically captured for each run:

```
$ ddump -t 9 -p 940 beam_00002742-0000.prdf > 2742.jpg
$ ddump -t 9 -p 940 beam_00002743-0000.prdf > 2743.jpg
```

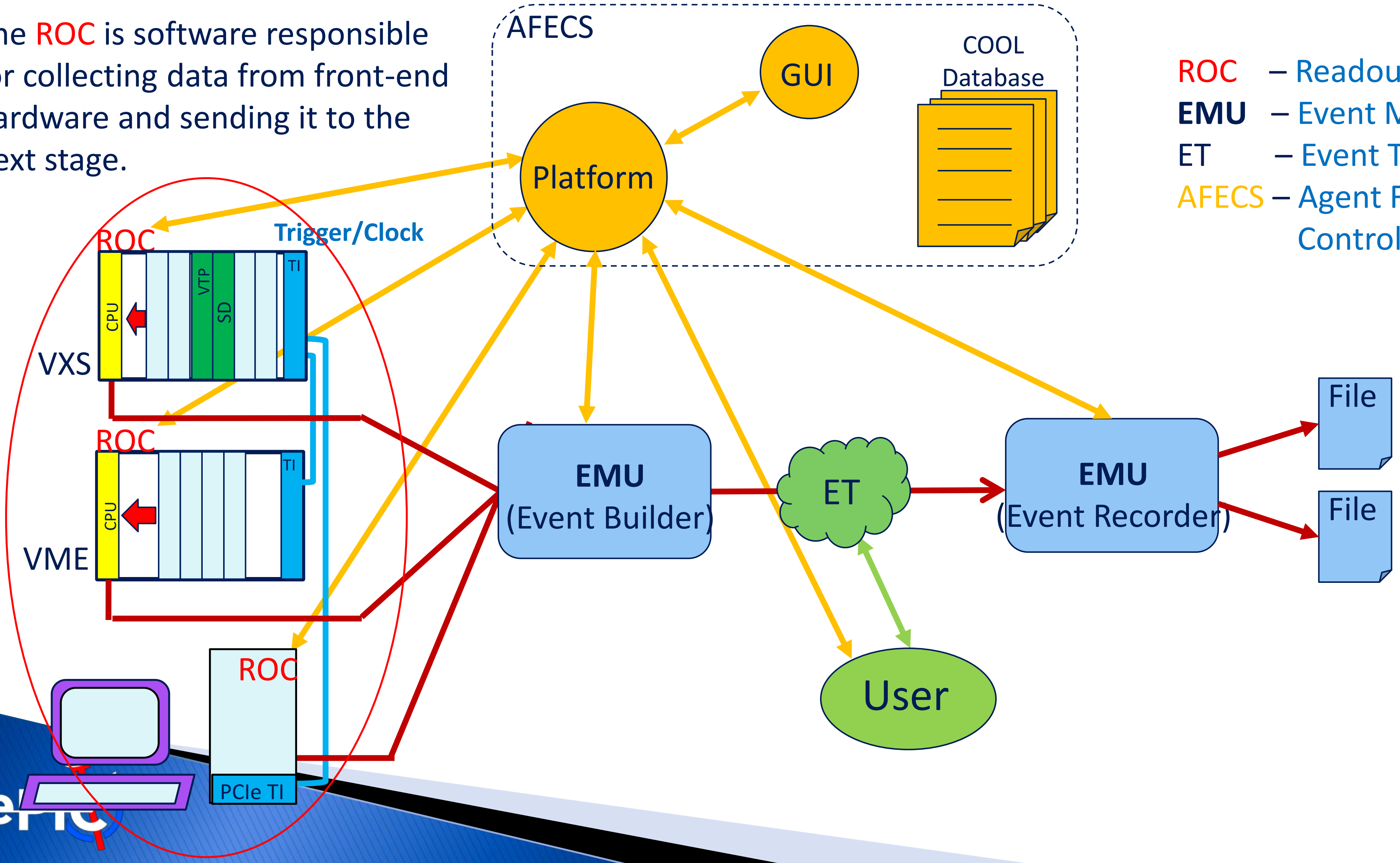




The CODA Data Acquisition (software) Toolkit

CODA [David Abbott]

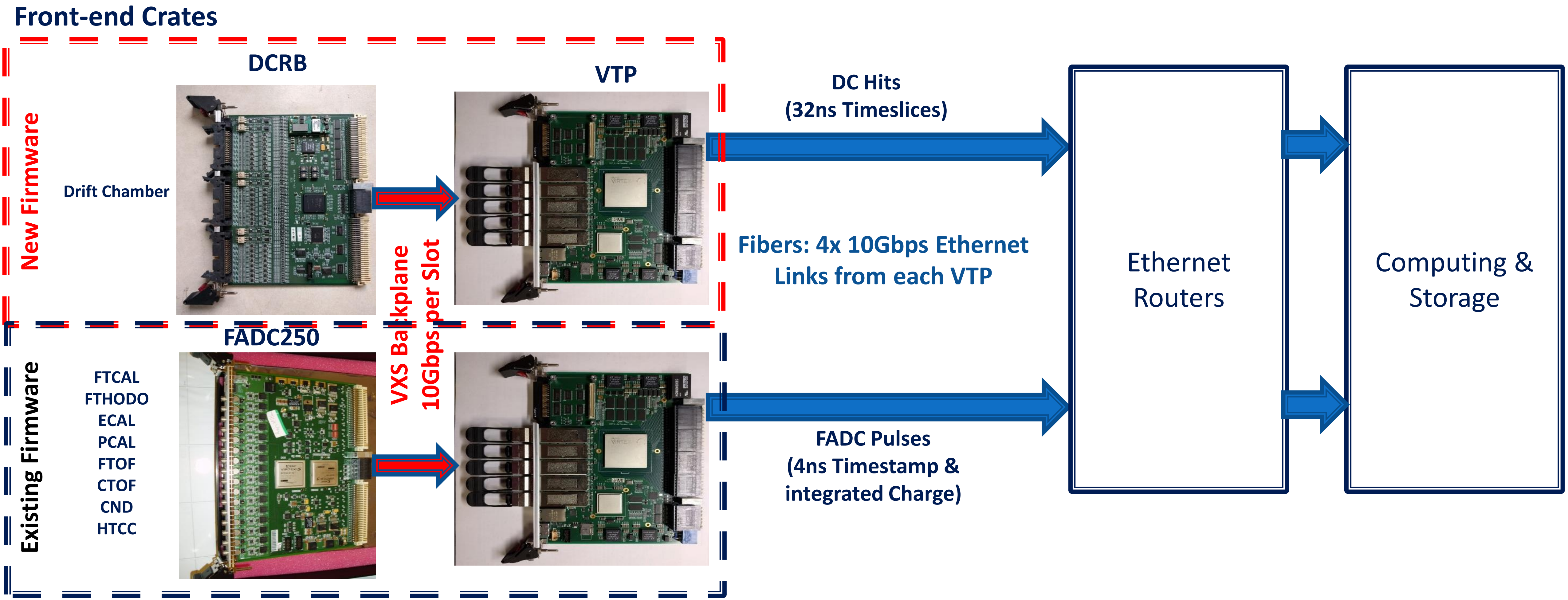
The ROC is software responsible for collecting data from front-end hardware and sending it to the next stage.



ROC – Readout Controller
EMU – Event Management Unit
ET – Event Transport (Shared memory)
AFECS – Agent Framework Experiment Control System (JAVA)

VTP Streaming Readout Testing in CLAS/Hall B – with recent DCRB support

CODA [David Abbott]



- FADC250 streaming support (pulse charge & time) already supported
- DCRB streaming support added for CLAS12 beam tests (2 sectors -> 6 crates)
- First streaming test in CLAS12 with calorimeters, Cherenkov, and Drift Chambers for large triggerless DAQ

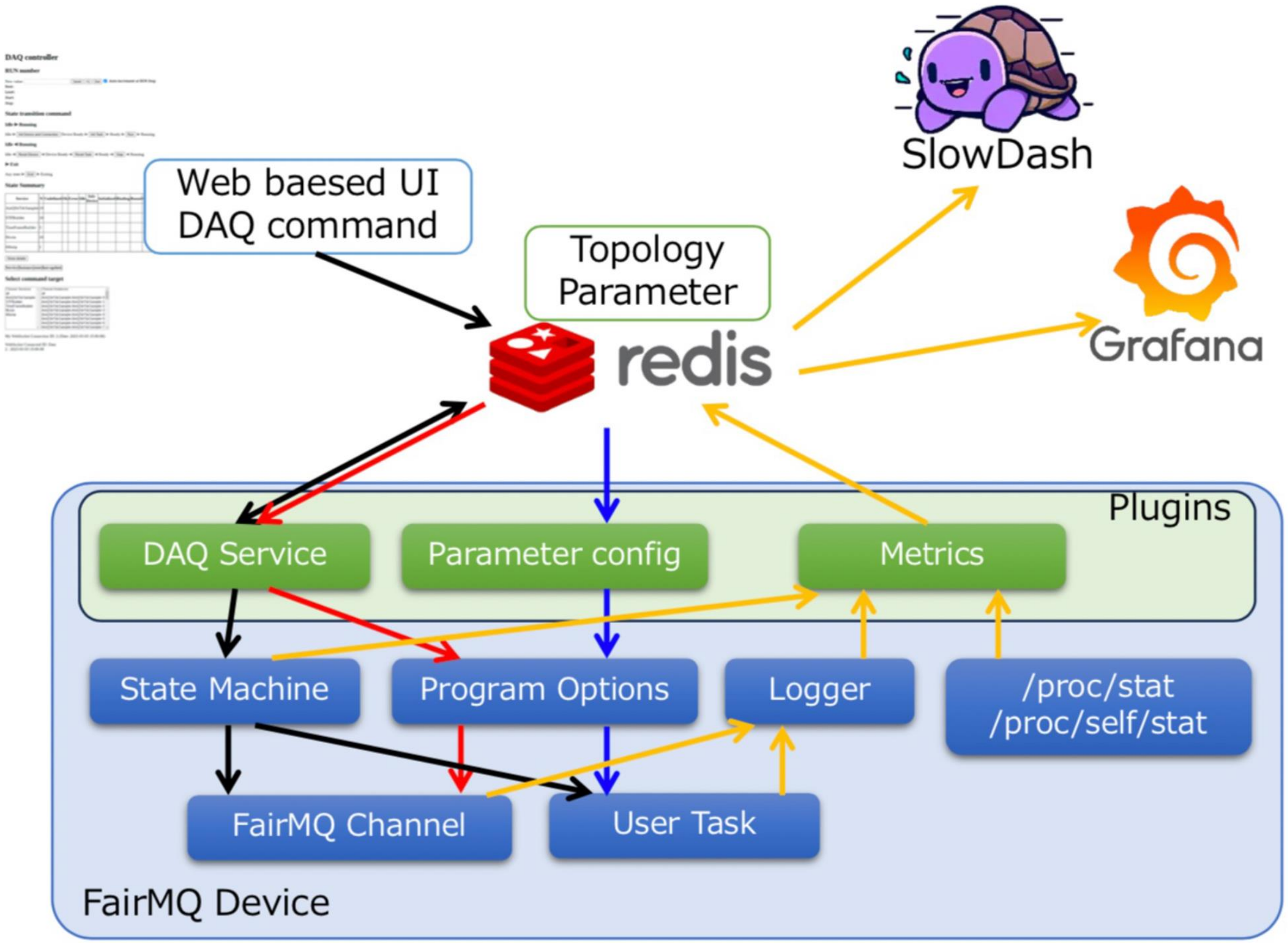
WG3: nestDAQ

SPADI Alliance
Signal processing and data acquisition infrastructure alliance

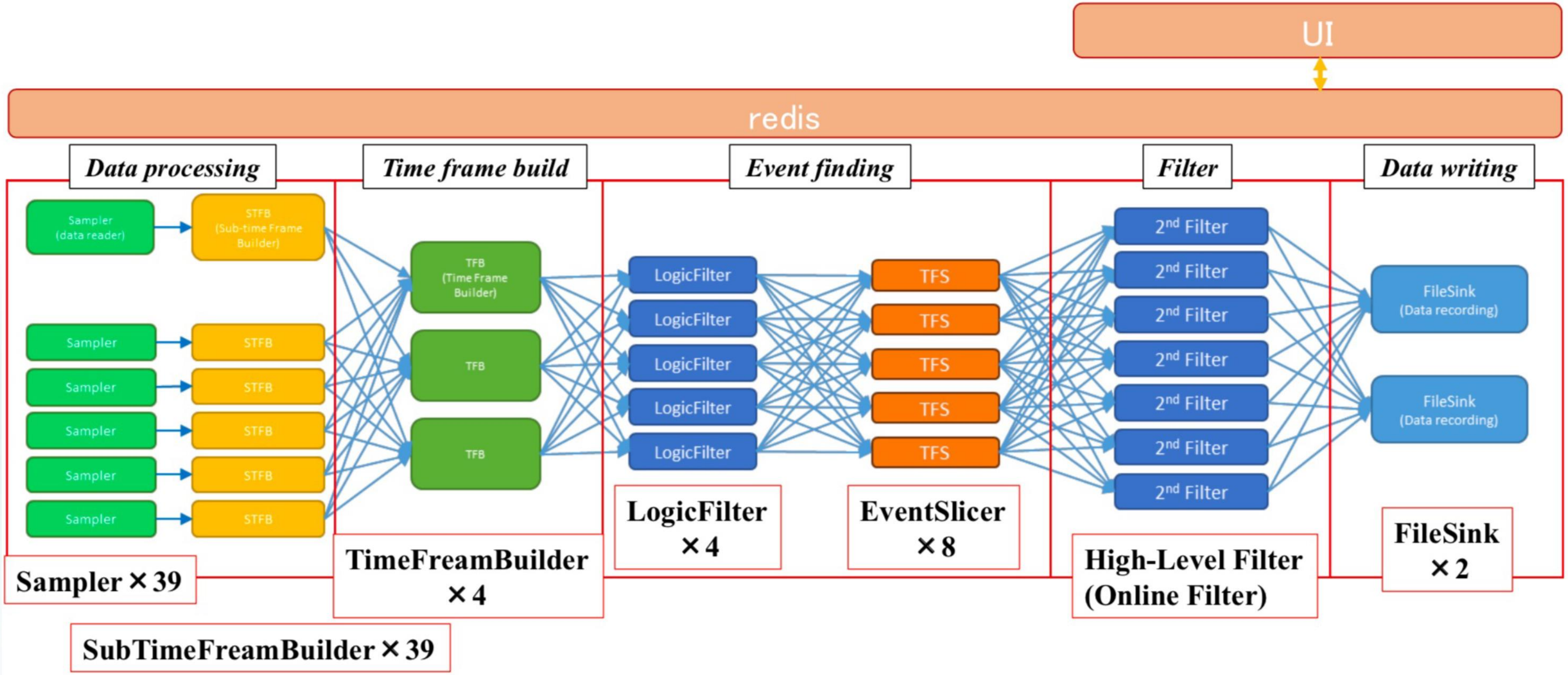
7

- **nestDAQ process structure**
- **FairMQ Plugins**

- DAQ Service Plugin
  - Run control
    - Control the state machine
    - Set the run number
  - Service discovery
    - Semi-automatic connection configuration
- Metrics Plugin
  - Grasping the processes statuses
- Parameter config Plugin
  - Read program option from the command line or the database.
  - Read device initialization parameters from the database.



nestDAQ Configuration

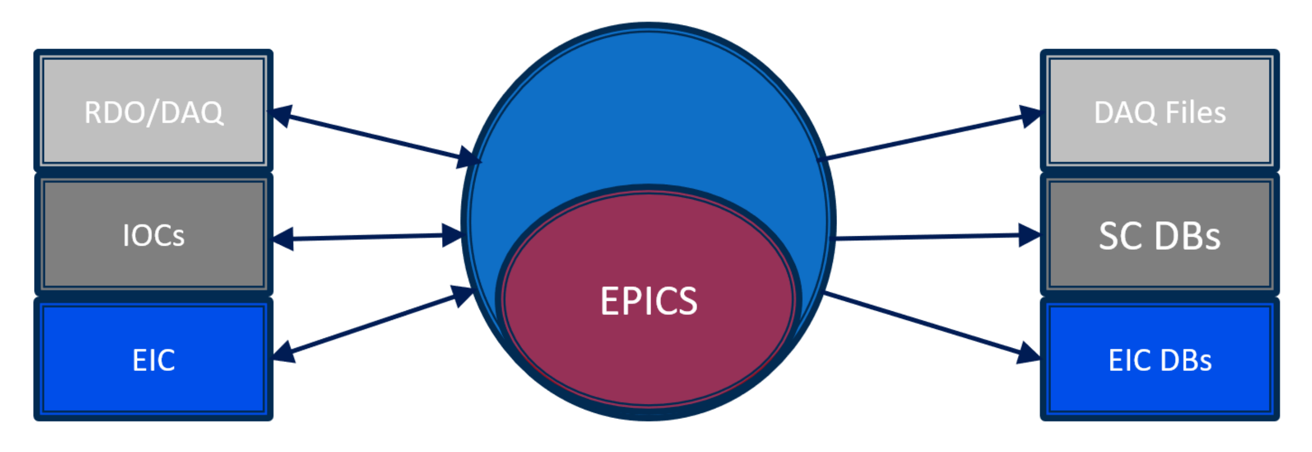


- **No Filter**: Sampler → STFB → TFB → FileSink
- **Filtered**: TFB → LogicFilter → EventSlicer → High-level Filter → FileSink

Next plans for ePIC

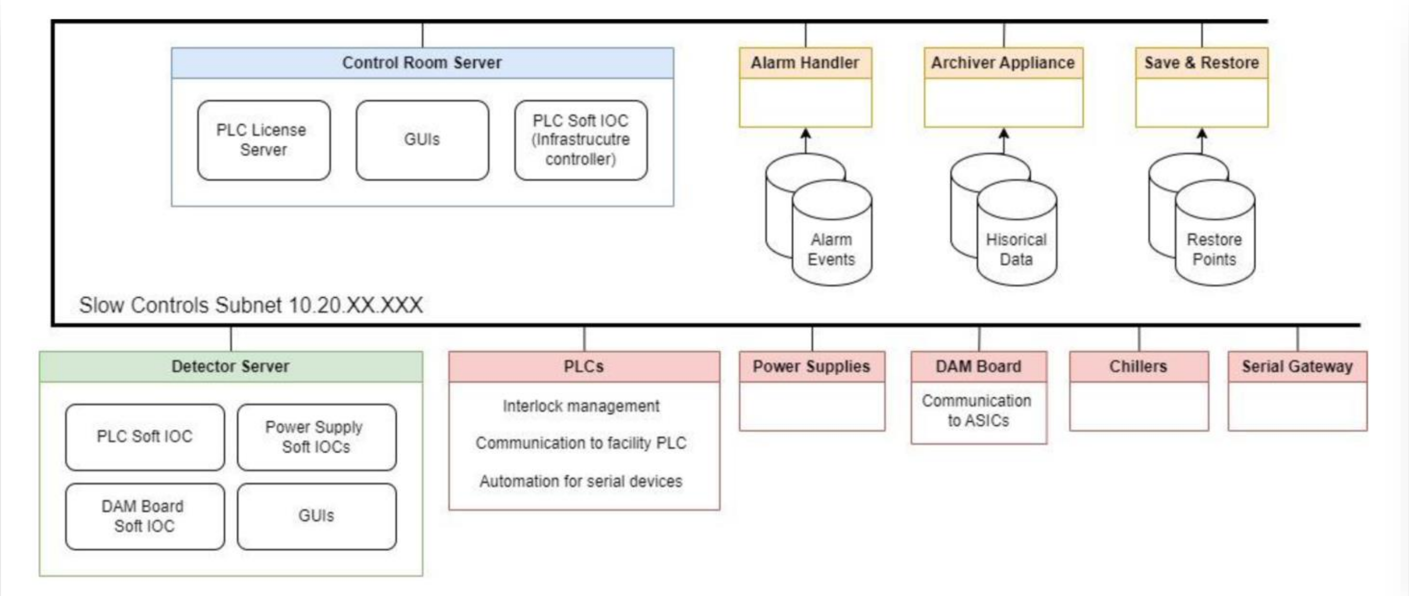
- Development of nestDAQ for ePIC
  - + Interface with DAM and GTM
  - + Interface with SC system and DB
  - + Interface with Calibration and EICRecon framework
- Japan is making budgetary requests to MEXT. If all goes well,
  - Increase human resources to work on streaming DAQ and computing for ePIC.
  - Purchase some computing nodes behaving as echelon0, echelon1, and echelon2, install them in BNL, and build vertical-slice setups to test full chains.
  - ~5 persons will be in BNL (or JLab) and work on developing and implementing streaming DAQ framework with BNL and JLab teams and work on testing full chains using vertical-slice setup.
  - In Japan, we will start working on echelon2.
    - Distributed online computing system (RIKEN-Tokyo-Osaka)

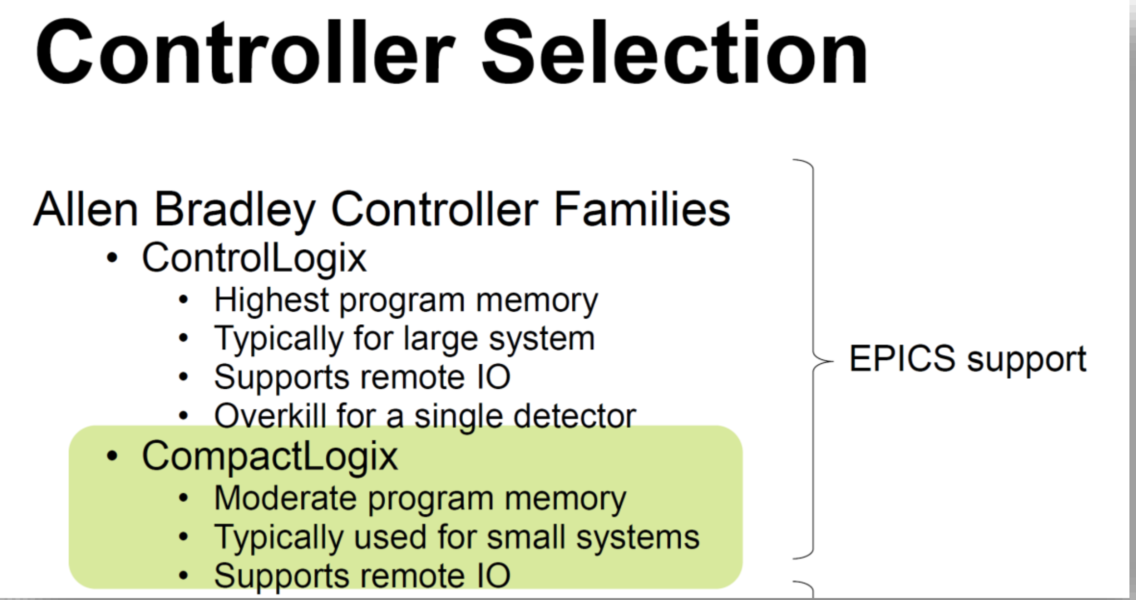
SC, monitoring, and meta data management



Experiment control slow control hardware

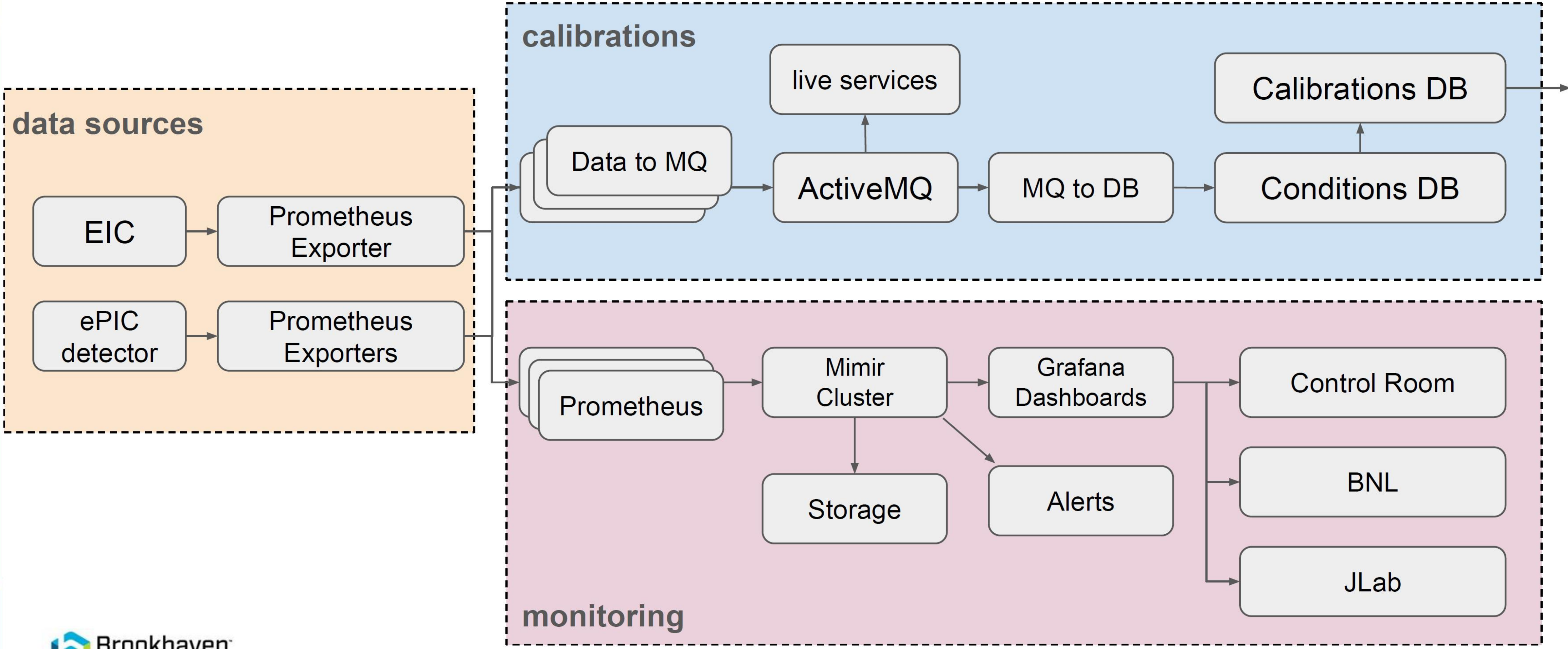
- Lee Flader overviewed the SC controller options
- https://indico.bnl.gov/event/20727/contributions/94189/



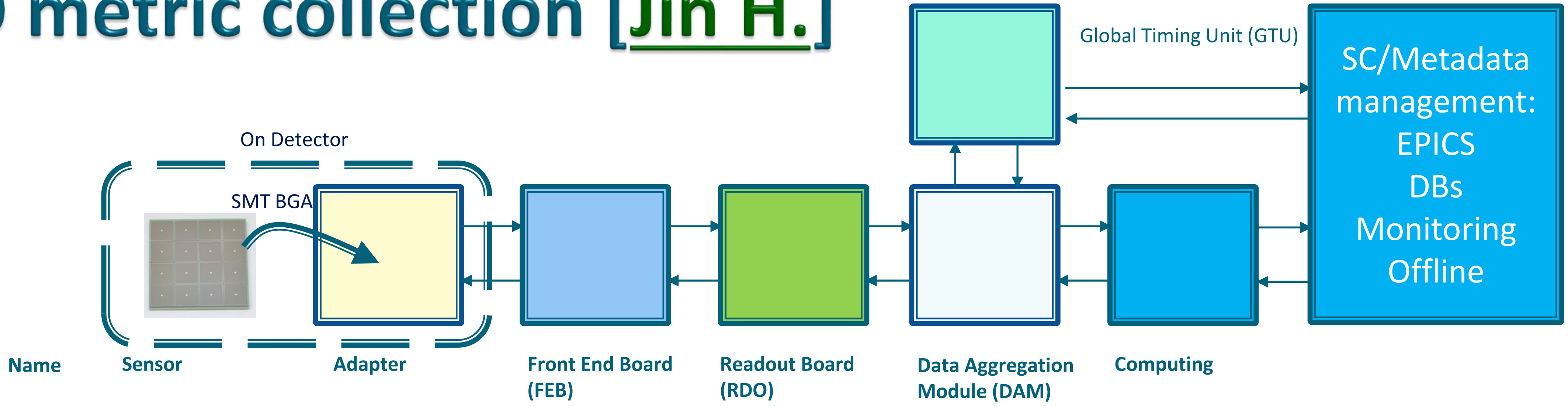


Slow control and meta data database, from online to offline [Dmitry Arkhipkin]

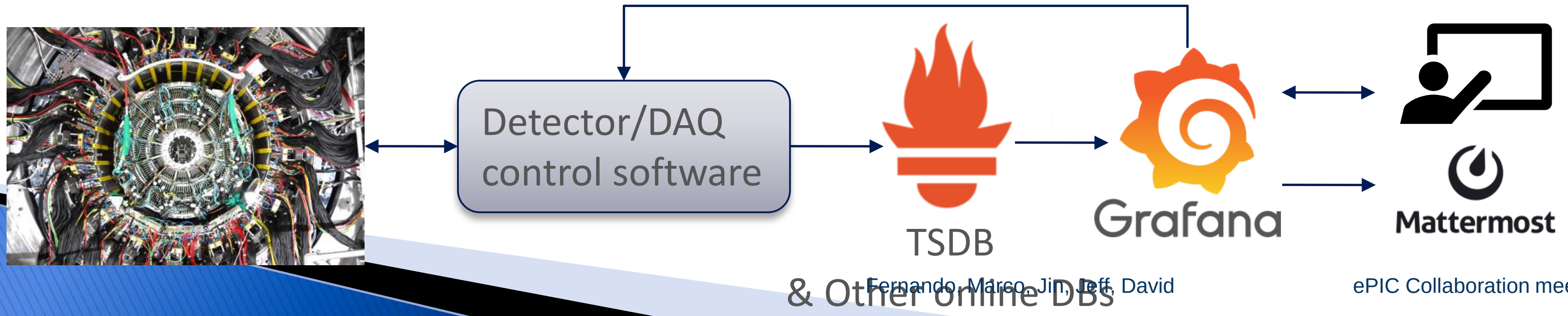
Solution for ePIC: DB + Prometheus?



SRO metric collection [Jin H.]



- SRO Readout collect continuous detector response → detector/accelerator feedback
- Readout pipeline health monitoring: critical for maintain a stable SRO pipeline
- I am big fan of using open-sourced monitoring stack, such as Time-Series DB+Grafana
  - High rate, O(second), metrics collection for online control; digestion for offline reco. DBs
  - 300k time series collected so far on sPHENIX



SRO metric collection [Jin H.]

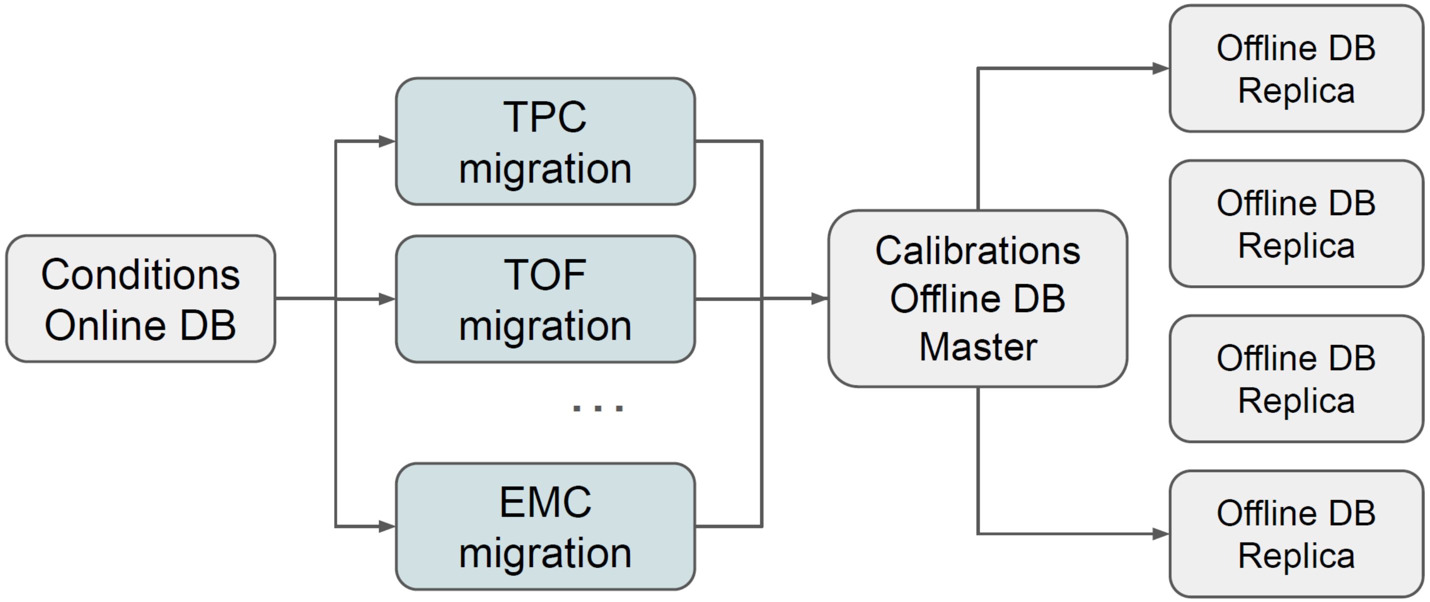
Fernando, Marco, Jin, Jeff, David

Slow control and meta data database, from online to offline [Dmitry Arkhipkin]

Online to Offline migration

(Raw recording to processed DB data)

- Online Databases: Conditions
  - raw detector conditions data: V, I, state
  - minimal grouping/structuring
  - “high” granularity, O(1s)
  - large data volume, O(1TB) / yr
- Offline Databases: Calibrations
  - processed data: ready to be applied
  - highly structured, schema-based
  - multiple conditions combined
  - “low” granularity, O(5m…1hr)
  - small data volume, O(10GB) / yr
  - optimized for fast data downloads
- Migration Codes:
  - dedicated set of scripts processing per-subsystem data
  - data filtering, smoothing, transformation
  - handle data gaps and issues graciously



ETL: extract, transform, load
ROOT macros, cron-based

+monitoring

Stream computing model development

Calibration in ePIC computing

See also SCC talk: Markus Diefenthaler

- ePIC aim to prompt reconstruction of experiment data at Echelon-1 facilities: aim to have latency of days, and < 3 weeks in steady state running
- The latency is driven by calibration
  - Collision/Calib data statistics required
  - Interdependency of detector calib.
- Concerted effort in SRO WG mapping out the calibration workflow

2023 Computing plan

4.5 First Pass Reconstruction

It is expected that the Echelon 1 facilities will have insufficient compute resources to perform the complete first pass reconstruction for incoming data. The prompt reconstruction workflow at Echelon 1 will process, at a minimum, the sample necessary for monitoring, diagnostics, quick-turnaround calibration and so on. The remaining first pass reconstruction processing will be shared with Echelon 2 facilities. The maximum acceptable completion time is about 2-3 weeks. This timescale is driven by calibrations. Given the expectation of relatively low data rates during commissioning and early running, and the need to commission, validate and stabilize the use of Echelon 2s for first pass reconstruction, it is likely that Echelon 2s will be integrated after the first pass reconstruction workflow at Echelon 1 is operating smoothly and Echelon 2s are validated as ready.

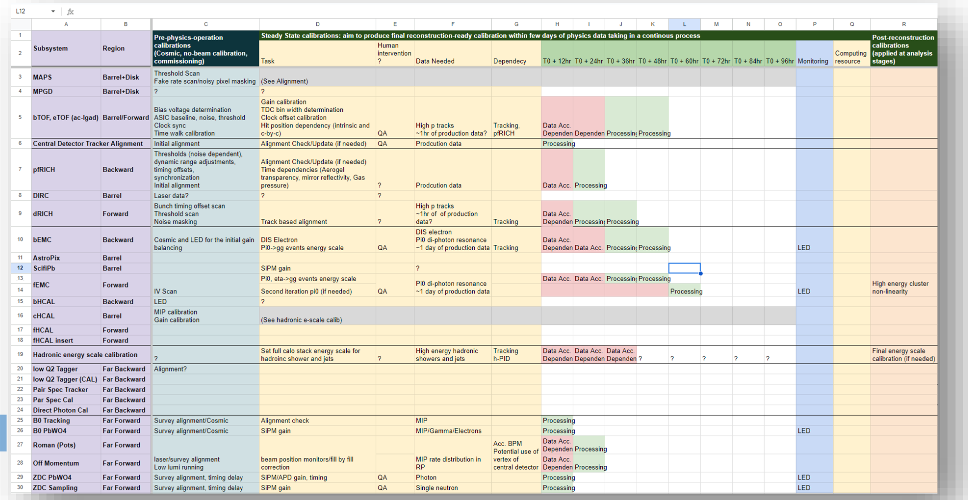
Concerned effort building calibration workflow

- Alignment, TOF: Dec 19 https://indico.bnl.gov/event/21619/
- SVT sensor, Barrel Hcal: Jan 23 https://indico.bnl.gov/event/21785/
- dRICH: Jan 30 https://indico.bnl.gov/event/22114/
- Backward, Forward EMCal: Feb 27 https://indico.bnl.gov/event/22412/
- Far forward: Mar 12 https://indico.bnl.gov/event/22676/
- AI driven calibration: Apr 16 https://indico.bnl.gov/event/23034/

Subsystem	Region	Pre-physics-operation calibrations (Cosmic, no-beam calibration, commissioning)	Steady State calibrations: aim to produce final reconstruction-ready calibration within few days of physics data taking in a continous process														Post-reconstruction calibrations (applied at analysis stages)
			Task	Human intervention ?	Data Needed	Dependecy	T0 + 12hr	T0 + 24hr	T0 + 36hr	T0 + 48hr	T0 + 60hr	T0 + 72hr	T0 + 84hr	T0 + 96hr	Monitoring	Computing resource	
MAPS	Barrel+Disk	Threshold Scan Fake rate scan/noisy pixel masking	(See Alignment)														
MPGD	Barrel+Disk	?	?														
bTOF, eTOF (ac-lgad)	Barrel/Forward	Bias voltage determination ASIC baseline, noise, threshold Clock sync Time walk calibration	Gain calibration TDC bin width determination Clock offset calibration Hit position dependency (intrinsic and c-by-c)	QA	High p tracks ~1hr of production data?	Tracking, pfRICH	Data Acc. Dependen	Dependen	Processing	Processing							
Central Detector Tracker Alignment		Initial alignment	Alignment Check/Update (if needed)	QA	Prodcution data		Processing										
pfRICH	Backward	Thresholds (noise dependent), dynamic range adjustments, timing offsets, synchronization Initial alignment	Alignment Check/Update (if needed) Time dependencies (Aerogel transparency, mirror reflectivity, Gas pressure)	?	Prodcution data		Data Acc.	Processing									
DIRC	Barrel	Laser data?	?	?													
dRICH	Forward	Bunch timing offset scan Threshold scan Noise masking	Track based alignment	?	High p tracks ~1hr of of production data?	Tracking	Data Acc. Dependen	Processing	Processing								
bEMC	Backward	Cosmic and LED for the initial gain balancing	DIS Electron Pi0->gg events energy scale	QA	DIS electron Pi0 di-photon resonance ~1 day of production data	Tracking	Data Acc. Dependen	Data Acc.	Processing	Processing					LED		
AstroPix	Barrel																
ScifiPb	Barrel		SiPM gain		?												
fEMC	Forward		Pi0, eta->gg events energy scale				Data Acc.	Data Acc.	Processing	Processing							
		IV Scan	Second iteration pi0 (if needed)	QA	Pi0 di-photon resonance ~1 day of production data						Processing				LED		High energy cluster non-linearity
bHCAL	Backward	LED	?														
cHCAL	Barrel	MIP calibration Gain calibration	(See hadronic e-scale calib)														
fHCAL	Forward																
fHCAL insert	Forward																
Hadronic energy scale calibration		?	Set full calo stack energy scale for hadroinc shower and jets	?	High energy hadronic showers and jets	Tracking h-PID	Data Acc. Dependen	Data Acc. Dependen	Data Acc. Dependen	?	?	?	?	?			Final energy scale calibration (if needed)
low Q2 Tagger	Far Backward	Alignment?															
low Q2 Tagger (CAL)	Far Backward																
Pair Spec Tracker	Far Backward																
Par Spec Cal	Far Backward																
Direct Photon Cal	Far Backward																
B0 Tracking	Far Forward	Survey alignment/Cosmic	Alignment check		MIP		Processing										
B0 PbWO4	Far Forward	Survey alignment/Cosmic	SiPM gain		MIP/Gamma/Electrons		Processing								LED		
Roman (Pots)	Far Forward						Data Acc. Dependen	Processing									
Off Momentum	Far Forward	laser/survey alignment Low lumi running	beam position monitors/fill by fill correction		MIP rate distribution in RP	Acc. BPM Potential use of vertex of central detector	Data Acc. Dependen	Processing									
ZDC PbWO4	Far Forward	Survey alignment, timing delay	SiPM/APD gain, timing	QA	Photon		Processing								LED		
ZDC Sampling	Far Forward	Survey alignment, timing delay	SiPM gain	QA	Single neutron		Processing								LED		

Calibration workflow

[Working document for calibration workflow]



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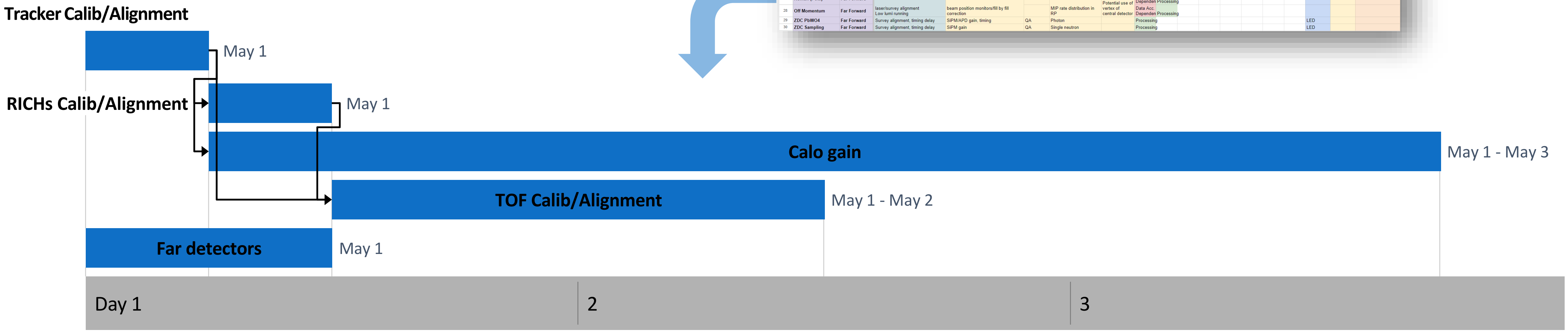
ZDC Sampling	Far Forward	Survey alignment, timing delay	SiPM gain	QA	Single neutron		Processing								LED		

- Calibration workflow seems fits into the prompt reconstruction computing model. Inputs welcomed.
- High level summary plot:

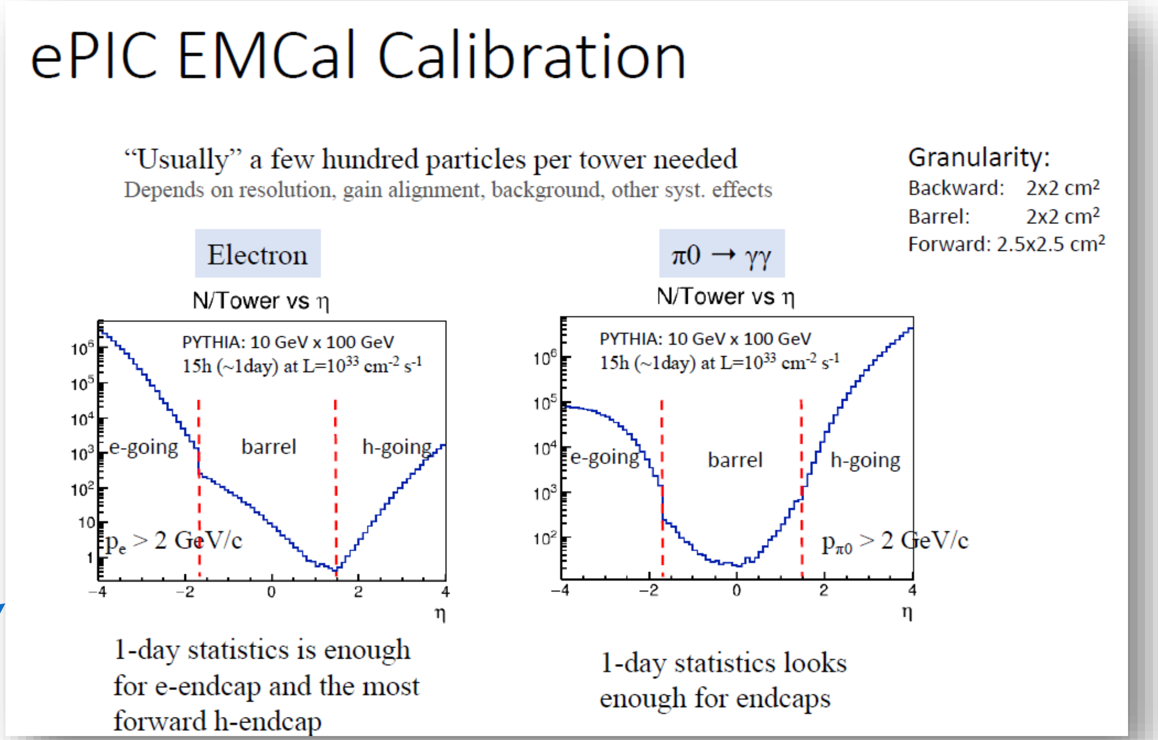


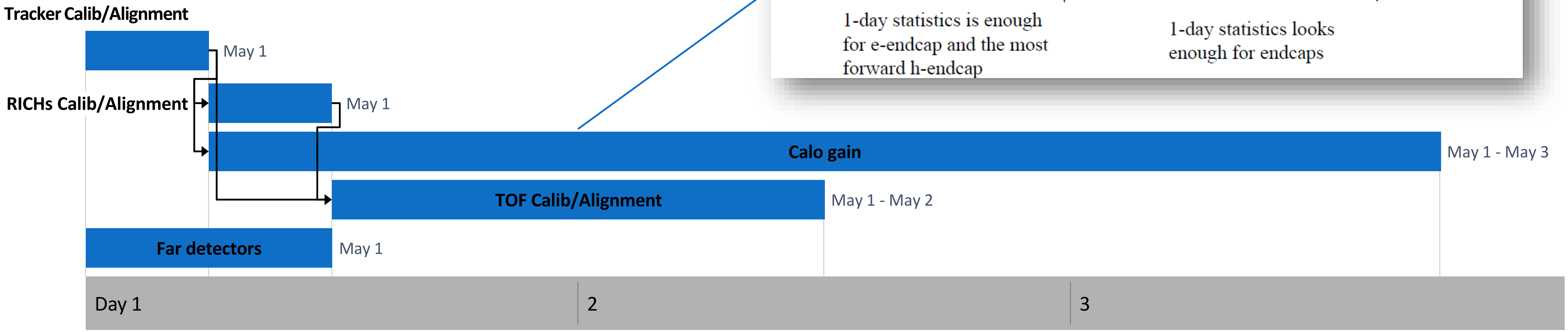
- So far, the calibration workflow seems fit well into reconstruction latency goal; Suggestions always welcomed.
- To summarize into next update of computing model and computing review

Calibration workflow

Critical path goes through calo calibration
which requires 1-day of data +
two iteration of calibration processing

Work from A.Bazilevsky
Cited in calo calib meeting [ref]





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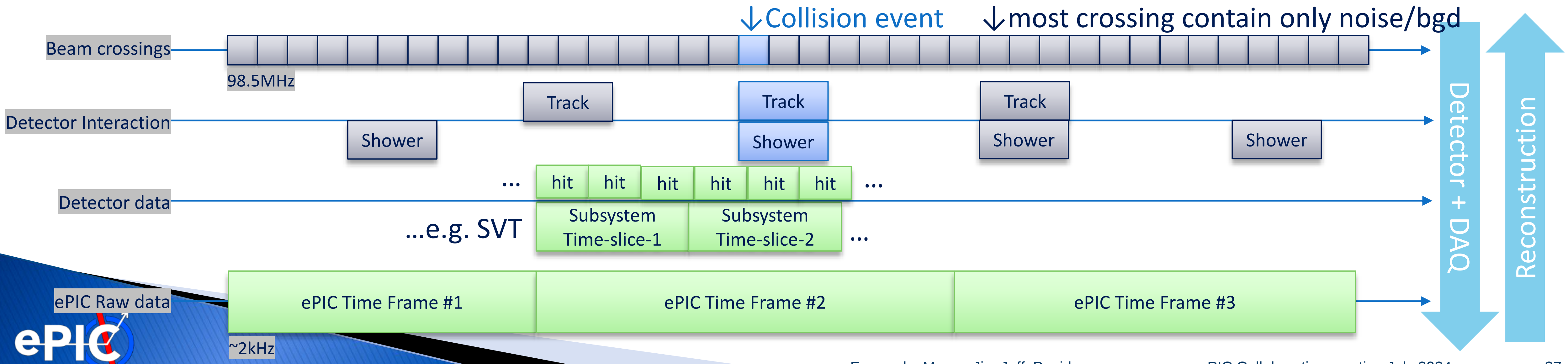
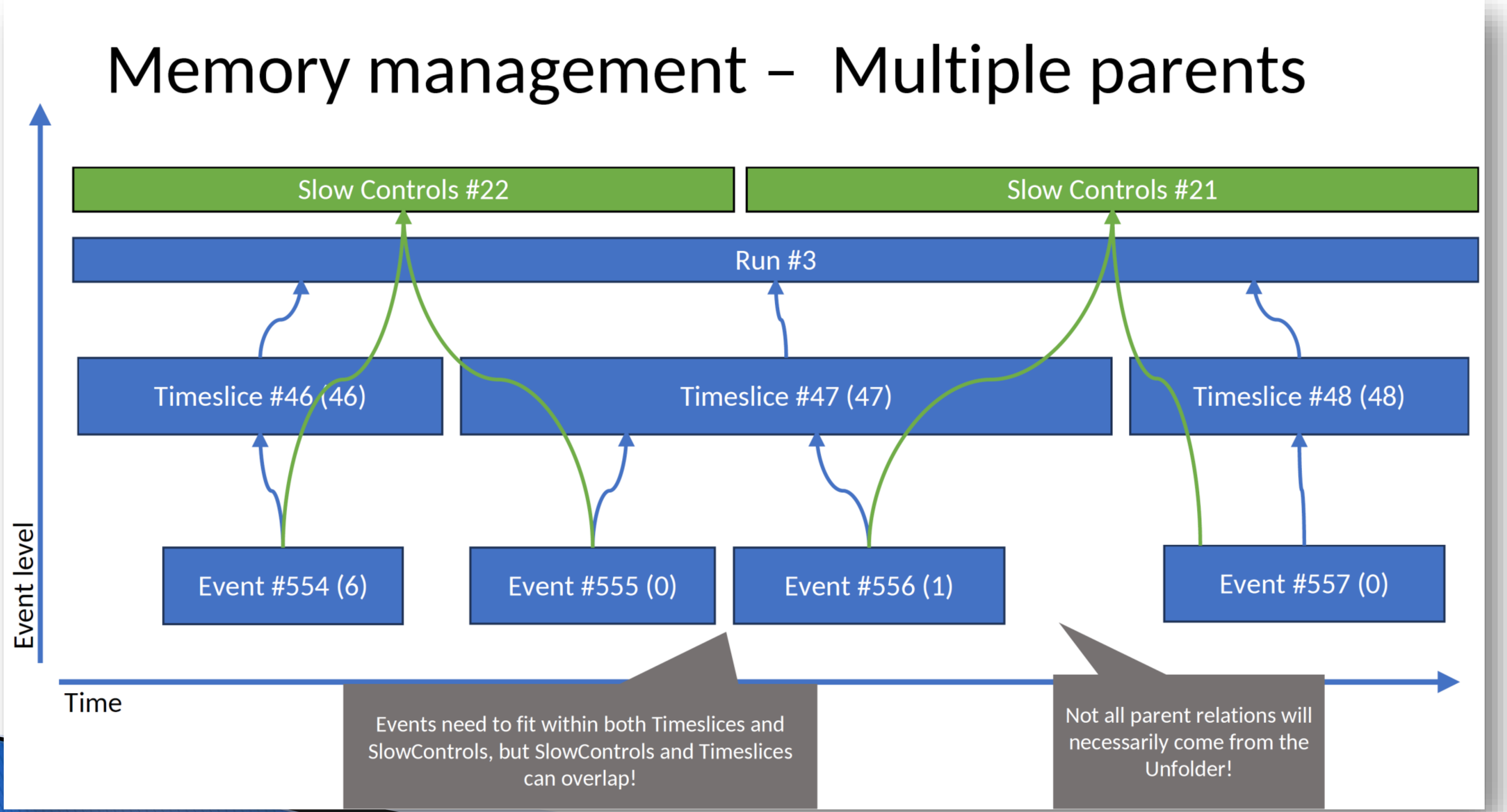
ePIC Time Frames [Apr-9 SRO WG meeting]

- Preference not to align time frame length with respect to the EIC beam rotation.
- Event keying: primary key is 64-bit beam clock (BCO) counter; secondary convenient key is tuple run-timeframe-BCOInTimeFrame; reconstruction will generate event counter tagging
- Run structure will be used, driven by configuration changes; plus continuous readout information on beam/detector monitoring
- Redundant information in storing slow control data: database and raw data file embedding. Need to follow up on the implementation of SC data flow from online to offline.

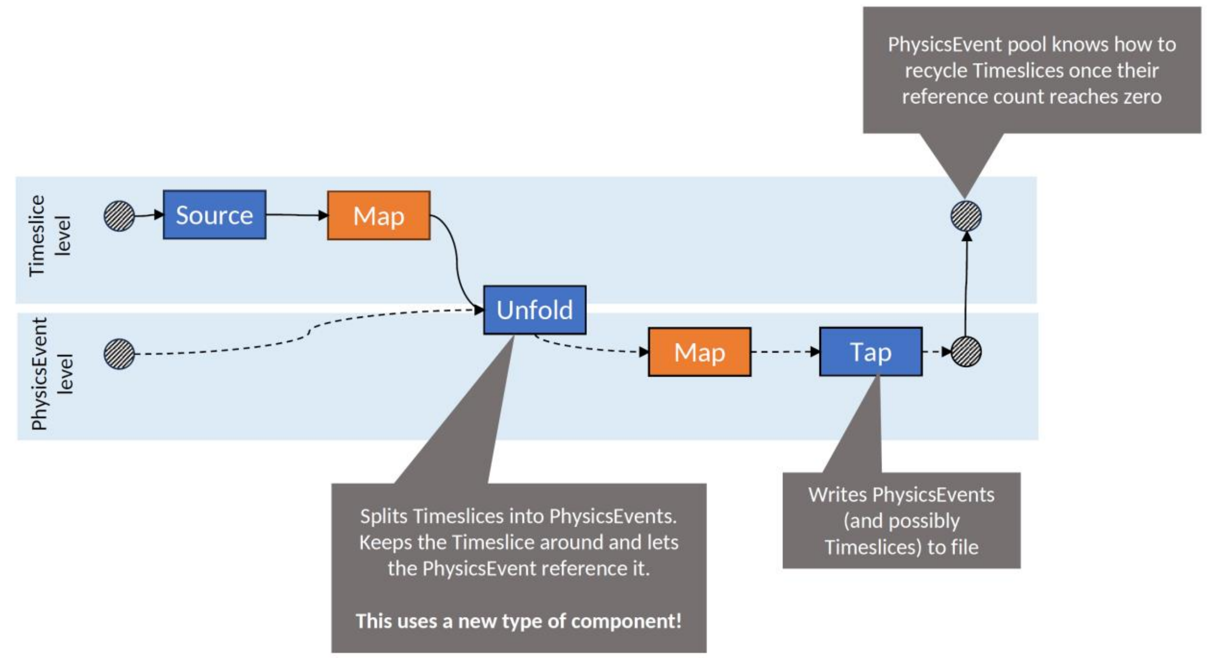


Timeframe in EICRecon [Nathan Brei]



Timeframe in EICRecon [Nathan Brei]

See also SCC talk: Markus Diefenthaler

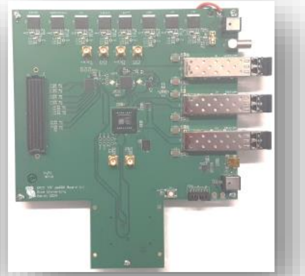


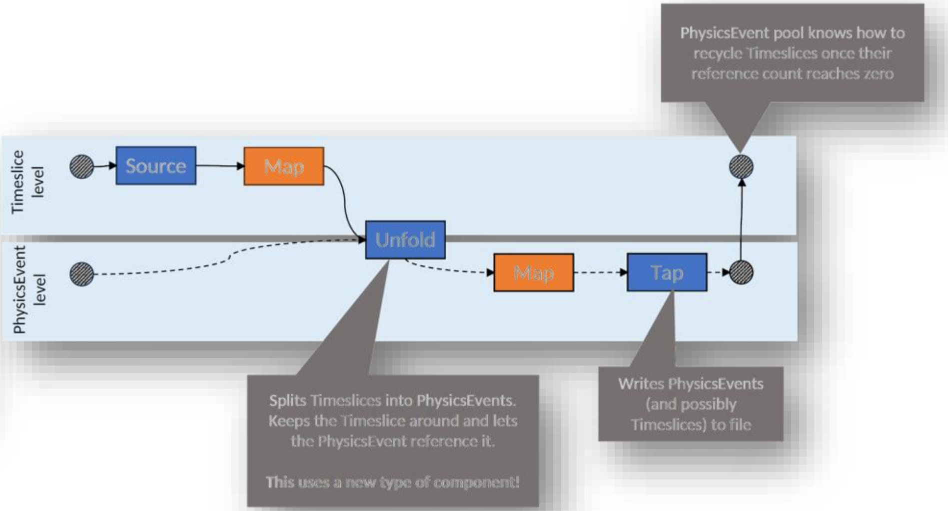
Current status

- An end-to-end working example of timeframe splitting is already present in JANA2's master branch
  - src/examples/TimesliceExample
  - https://github.com/JeffersonLab/JANA2/
- EICrecon has a skeleton for timeframe splitting as a WIP PR
  - https://github.com/eic/EICrecon/pull/1510
  - Proof-of-concept for TDR: Kolja, Shuji, Barak
  - Generated data files containing "wide events" with background
  - Goal: test tracking accuracy without requiring realistic timeframe splitting logic
  - Developing realistic timeframe splitting logic is non-trivial

Summary

- Two working groups work closely: E&DAQ + SRO
  → data pipeline from detector to analysis
  - Also in close collaboration with detector and Software/Computing group, EIC project
- Tremendous progress in reaching consensus on ePIC data pipeline from detector to analyzable data
- June 2024: Successful Incremental Preliminary Design and Safety Review of the DAQ and Electronics, Final Design Review for lpGBT/VTRX+
- Join us! Much work & fun ahead!





Extra Information

- Feel free to share your views

  Live note on indico [link]

Why streaming DAQ/computing?

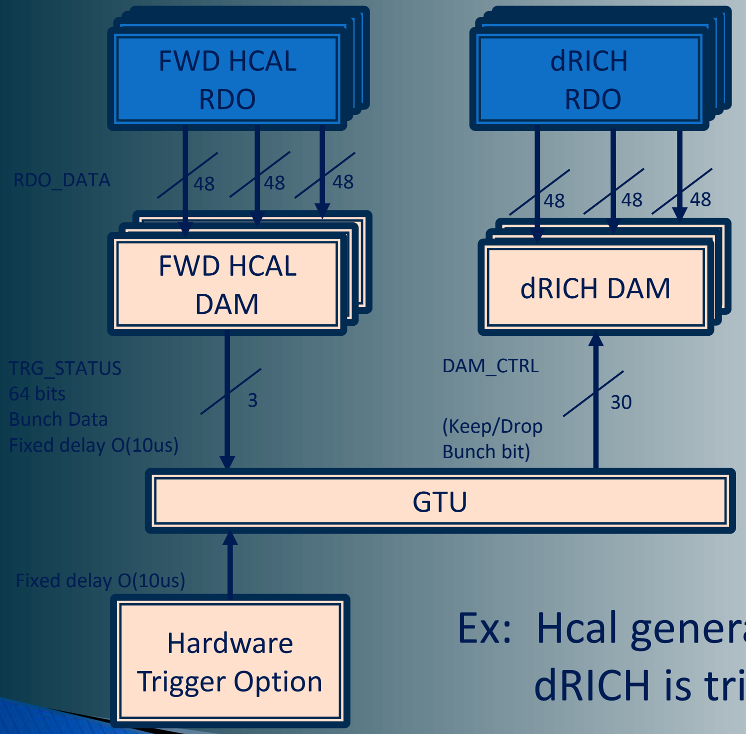
	EIC	RHIC	LHC → HL-LHC
Collision species	$\vec{e}+\vec{p}, \vec{e}+A$	$\vec{p}+\vec{p}/A, A+A$	$p+p/A, A+A$
Top x-N C.M. energy	140 GeV	510 GeV	13 TeV
Bunch spacing	10 ns	100 ns	25 ns
Peak x-N luminosity	10^{34} cm^{-2} s^{-1}	10^{32} cm^{-2} s^{-1}	$10^{34} \rightarrow 10^{35}$ cm^{-2} s^{-1}
x-N cross section	**50 μb**	**40 mb**	**80 mb**
Top collision rate	500 kHz	10 MHz	1-6 GHz
$dN_{ch}/d\eta$ in p+p/e+p	0.1-Few	~3	~6
Charged particle rate	**4M N_{ch}/s**	**60M N_{ch}/s**	**30G+ N_{ch}/s**

- Events are precious and have diverse topology → hard to trigger on all process
- Signal data rate is moderate → possible to streaming recording all collision signal, event selection in offline reconstruction using all detector information after calibration
- Background and systematic control is crucial → avoiding a trigger bias; reliable data reduction

Example: (dRICH tag based on external detector)

- *Given the requirement for a backup triggered readout for RICH, it is necessary to carefully define the physics trigger rate, trigger conditions, and trigger latency in order to facilitate design of the RICH front-end.*

ePIC depends upon a flexible scheme in which sufficient bandwidth is available for data to the dRICH DAM in the worst case. (> 4x safety). The selecting detectors (ex FWD HCAL) generate information characterizing beam in O(10us). The decision is made by the GTU and returned to DAM boards with fixed latency. The maximum latency is orders of magnitudes less than available buffering in DAM board memory. A hardware trigger is supported by the GTU but uses the same dRICH buffering scheme and delays as the firmware trigger option.



Ex: Hcal generates trigger
dRICH is triggered

Activitiy	Notes
Data Arrives at DAMs	<=10us from Bunch Crossing
Data Evaluation in HCAL DAMs	100ns
TRG_STATUS to GTU	Data transmitted to GTU after fixed delay from source crossing O(10us)
Trigger Evaluation on GTU	Fixed Latency O(100ns)
Keep/Drop Bit to (dRICH) DAMs	Fixed Latency O(40ns)
Drop data / forward data	Drop/Forward after fixed time O(11us)
DAM Buffer	16GB
Buffer Time available	2.6 seconds

Relevant WG meetings

- Alignment, TOF: Dec 19 https://indico.bnl.gov/event/21619/
- SVT sensor, Barrel Hcal: Jan 23 https://indico.bnl.gov/event/21785/
- dRICH: Jan 30 https://indico.bnl.gov/event/22114/
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- Far forward: Mar 12 https://indico.bnl.gov/event/22676/
- AI driven calibration: Apr 16 https://indico.bnl.gov/event/23034/

Summary of consensus in SRO WG Apr-9 meeting

- Preference not to align time frame length with respect to the EIC beam rotation.
- Event keying: primary key is 64-bit beam clock (BCO) counter; secondary convenient key is tuple run-timeframe-BCOInTimeFrame; reconstruction will generate event counter tagging
- Run structure will be used, driven by configuration changes; plus continuous readout information on beam/detector monitoring
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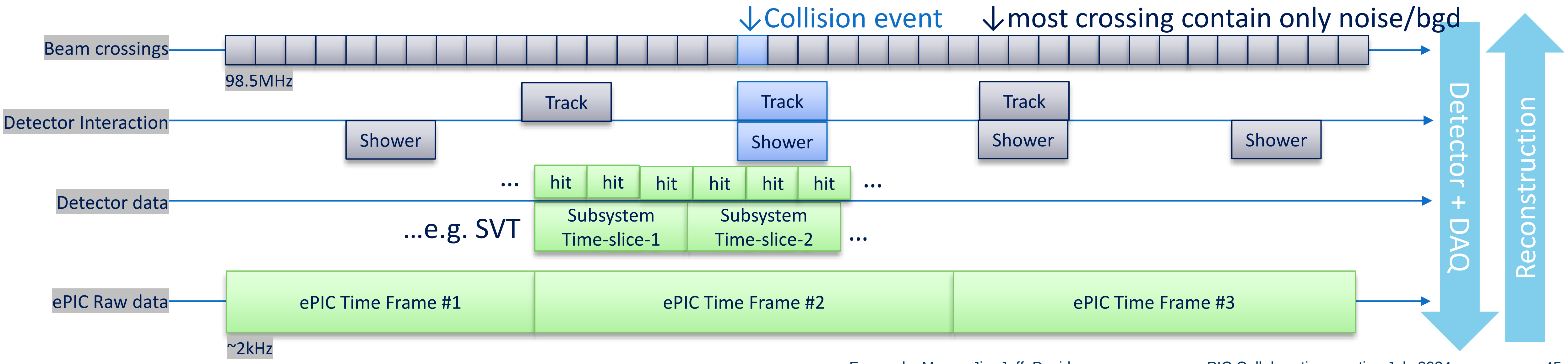
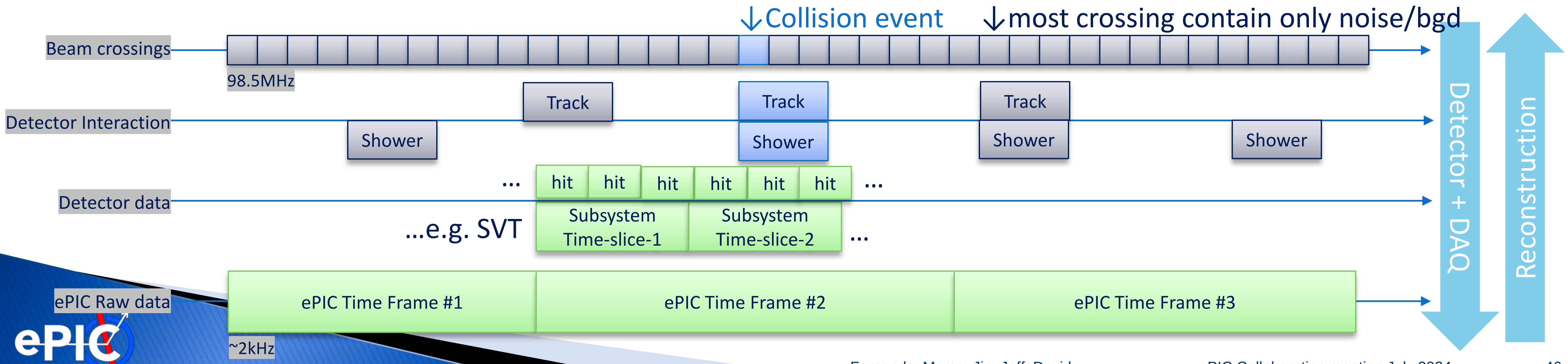


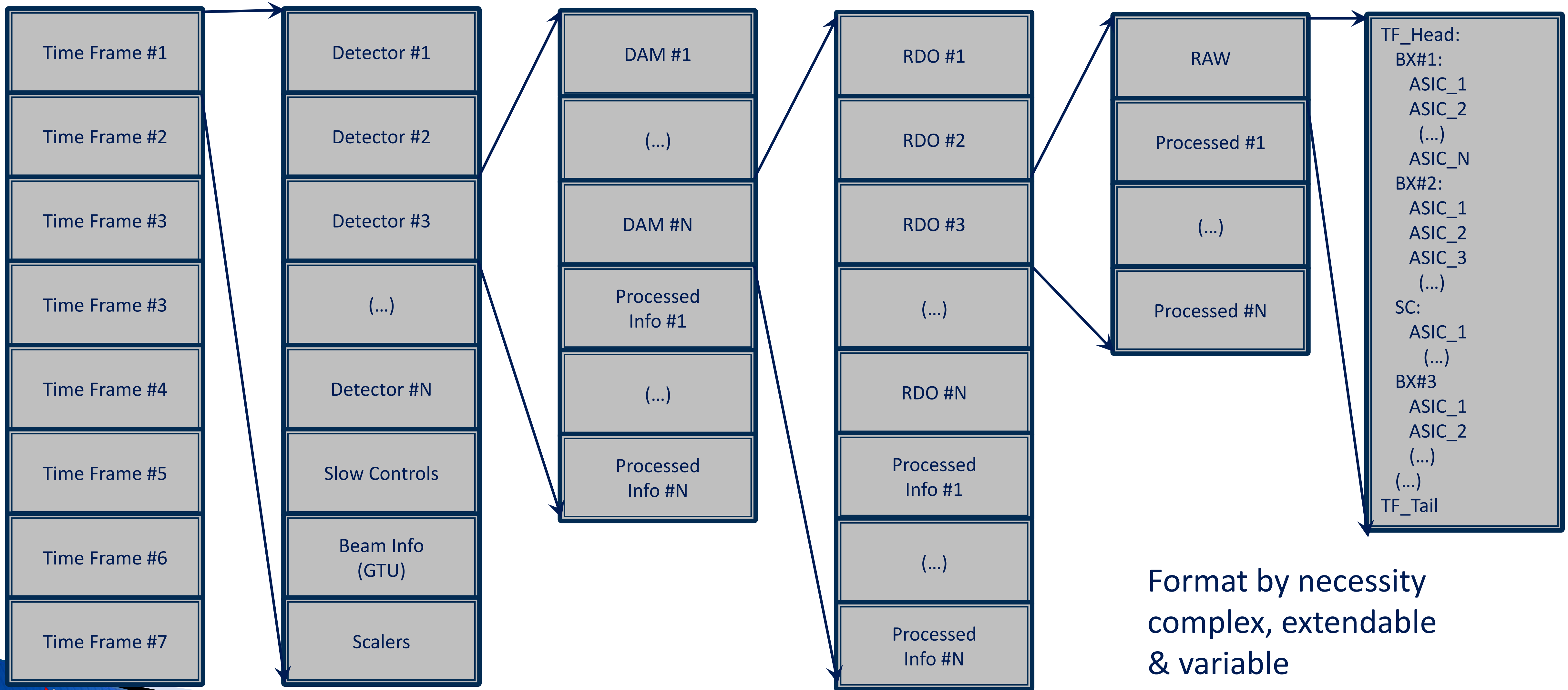
Time-Frames Introduction

- We plan to use this meeting to follow up on Nathan's talk on time-frame-based reconstruction, solidify a few open concept in our WG and make progress on their implementation in EICRecon
- ePIC Time Frame concept is developing towards a spec doc in DAQ and SAR WGs;
  - Update discussion on Apr 11 DAQ meeting , please join: https://indico.bnl.gov/event/22945/
  - <=2^16 crossing: 16-bit integer sufficient to locate hit's BX in Time Frame; <=665us/300 events/10MB
  - Exact length defined by GTU sync signal: most flexible
  - We could choose to align with EIC beam evolution (1260BX,): simpler to locate abort gap and spin states
- Time Frames will be order in data files, internally carry header-payload (a.k.a data bank/packets) data chunks from each detector component.



DAQ File Organization (Example…)

From Mar-21 meeting, Jeff's talk on Time Frame Organization and Data Volumes [link]



Format by necessity complex, extendable & variable

Readers

From Mar-21 meeting, Jeff's talk on Time Frame Organization and Data Volumes [link]

Two distinct sets of readers needed

- Data Bank Navigation

  rdr = getBank("NameOfBank") or
  rdr = getBank(TimeFrame, "lfhcal/dam_3/rdo_6/raw")

- Detector Bank specific readers (presumably implemented as plugins)

  hit = rdr->nextHit()
  hit.bx
  hit.highResTOA
  hit.channel
  hit.adc

- Could, of course have multiple readers instantiated at a time for simultaneous decoding
- One likely needs to fill intermediate data structure for processing, so time frame for DAQ and time frame for tracking need not be tied together!

Discussion 1: event keying

- One way to view information provided by streaming DAQ is clock triggered events at *each* beam bunch crossing; offline reconstruction/analysis apply event selections to select the interesting set of events for physics measurements
- Option 1 for event key is the beam crossing counter
  - GTU counting 98.5MHz beam crossing clock with a 64bit counter
  - DAQ/electronics will broadcast EIC beam crossing counter to indexing all detector hits
- Option 2 for event key could be a tuple
  (run, time-frame, crossing counter in time-frame)
- Either is sufficient. Could use both too

Event key

- Generalizes the concept of event number and possibly run number to streaming scenarios
- Event number: For each level in the event hierarchy, have:
  - Absolute number: Starts at 0, increments by 1 monotonically
  - Relative number: Starts at 0 for each parent, increments by 1 monotonically
  - User key: Could be anything
- Run number:
  - Key for reloading resources such as calibrations
  - Helps to be a number, not an interval

Reference to last meeting,
Nathan's talk [link]

Discussion 2: what is an (DAQ) run for ePIC?

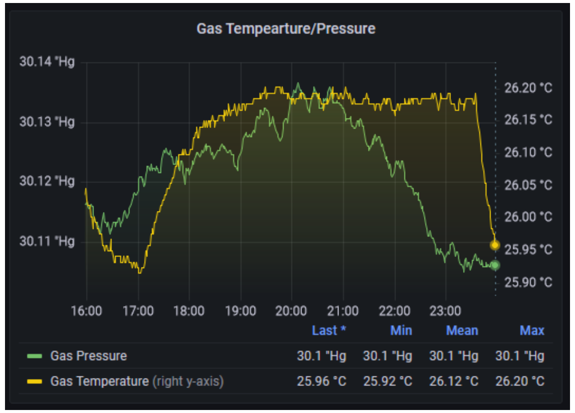
This is a discussion. Scenarios for a “DAQ run” could be:

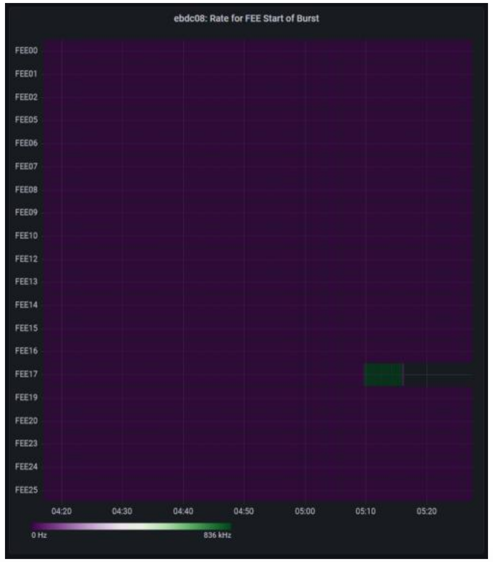
- Electron bunch replacement at O(1)Hz
  - Restarted automatically driven by accelerator bunch replacement control
  - Effectively a *luminosity block*, O(1000) ePIC time frames, require lumi/polarization measurement, scalar reading synchronized to the edge of the lumi window
- Data taking period between human-driven configuration changes (~1hr)
  - Commonly used by many experiment, neatly mapped in configuration DB storage
- Entire hadron ring fill (few hours)
- Not using a DAQ run concept, just luminosity blocks/time frames

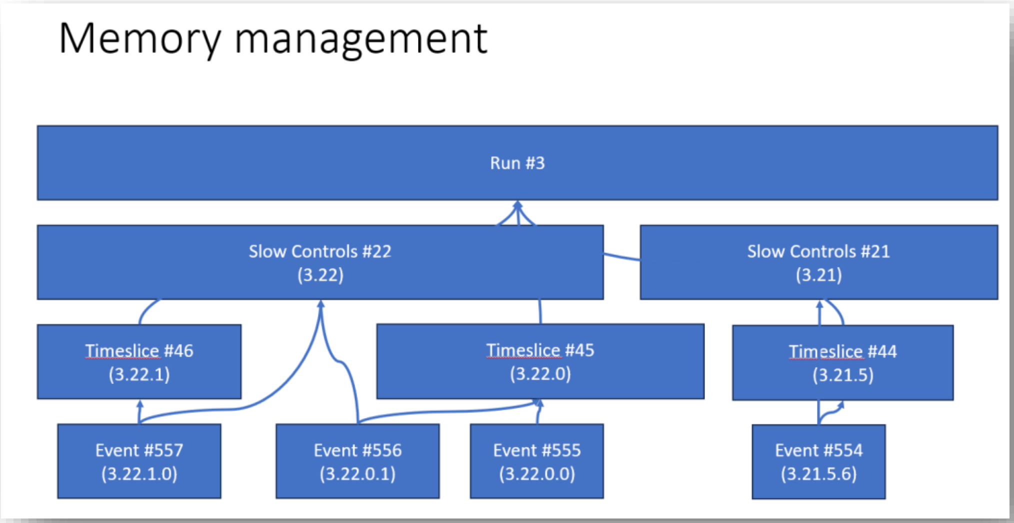
In any case, run start/end will be marked with beam crossing counter at GTU

Discussion 3: slow control (SC) data

- It is good practice to embed slow control data in raw data, but embedded data are hard to use
  - Some periodic reading require interpolation between readings (e.g. temperature); some requires future slow control reading (masking unstable FEEs in deadmap)
- Slow control data will be recorded to online DBs
  - Slow control recording persists regardless data taking
  - A mirror of online DB will be available for offline use
- *Suggest* detach slow control data access from reconstruction pass
  - Instead, use online database sources to produce calibration files (gain map, deadmap, etc.) as input to reconstruction, with validity marked with beam counter ranges
  - Use (automated) calibration job to process slow control data to form calibration input to reconstruction jobs, fits well in the multi-pass calibration computing plan
- Calibration access require scalable calibration database in offline world







Reference to last meeting, Nathan's talk [link]

Experiment Clock

- Clock will be distributed from GTU to FEB to synchronize digitizers and tag time of the hits
- For collider experiment, it is common to synchronize FEB clock to a harmonics of the beam collision clock
  - Absolute time of hit is not useful
  - But relative time to bunch crossing is critical for T0, spin, and luminosity tagging
  - EIC Clock frequency: 98.5MHz (no ramp variation), 1260 RF bunches, 12.8us/revolution
- SVT is a special case: fixed to LHC clock by lpGBT [40.078 MHz], slow [few -10us integrated], and synced to fast detectors offline [sPHENIX implementation]
- ePIC design specification discussion
  - We have multiple ASICs of various digitization frequency
    - E.g. ~40MHz (EICROC), ~50MHz (SALSA), ~200MHz (AstroPix)
  - Shall we distribute clock at 9.85MHz (1/10 harmonic of EIC crossing clock, 126*revolution frequency)?
    - Then FEB/DAM of each subsystem can generate their own synchronized clock at multiples of 9.85MHz
    - Existing example is sPHENIX 9.4MHz clock x 6*16bit per clock @ 1.1Gbps; W Gu tested to 7.9Gbps
  - Beam clock counter and sync signal broadcasted from GTU->DAM->FEE, and embedded in data stream

Example: sPHENIX clock data embedding at 6x 9.4MHz beam clock, 12Byte/beam clock [sPHENIX TDR]

clock count		0	1	2	3	4	5
bits 0-7	mode bits/BCO	mode bits	BCO bits 0-7	BCO bits 8-15	BCO bits 16-23	BCO bits 24-31	BCO bits 32-39
bit 8	beam clock	1	0	0	0	0	0
bit 9	LVL1 accept	X	0	0	0	0	0
bit 10	endat0	X	X	X	X	X	X
bit 11	endat1	X	X	X	X	X	X
bit 12	modebit en.	1	0	0	0	0	0
bits 13-15		3 user bits	0	1	2	3	4

Echelon 0 computing at streaming readout DAQ

- Readout routing, time frame building [see Discussion 1]
- Primary function: data reduction
  - Traditional DAQ: triggering was the main method of data reduction, assisted by high level triggering/reconstruction, compression
  - Streaming DAQ need to reduce data computationally: zero-suppression, feature building, lossless/lossy compression
- Challenge: any information loss is permanent; observe full DAQ rate with less than O(1min) of latency
  - Reliable data reduction methods; Sized to peak data rate + contingency; More expensive (than offline) to develop and maintain
  - → Application, only if needed; three subsystem need identified below
- Other critical roles:
  - Slow control; Monitoring (in coordination with monitoring via prompt reconstruction); Meta data collection, database service

Detector Group	Channels					RDO	Fiber	DAM	Data Volume (RDO) (Gb/s)	Data Volume (To Tape) (Gb/s)
	MAPS	AC-LGAD	SiPM/PMT	MPGD	HRPPD					
Tracking (MAPS)	36B					400	800	17	26	26
Tracking (MPGD)				202k		118	236	5	1	1
Calorimeters	500M		104k			451	1132	19	502	28
Far Forward	300M	2.6M	170k			178	492	8	15	8
Far Backward	82M		2k			50	100	4	150	1
PID (TOF)		7.8M				500	1500	17	31	1
PID Cherenkov			320k		140k	1283	2566	30	1275	32
TOTAL	36.9B	10.4M	596k	202k	140k	2980	6826	100	2,000	96

3 subsystem data reduction need beyond FEB/RDO zero-suppression

Calorimeter cluster building (CPU/GPU?)

FB high-rate tracker: Tracklet building (CPU/GPU?)

dRICH: Collision throttling (2 tier DAM FPGA)

EPIC Detector Scale and Technology Summary:

Detector System	Channels	RDO	Gb/s (RDO)	Gb/s (Tape)	DAM Boards	Readout Technology	Notes
Si Tracking: 3 vertex layers, 2 sagitta layers, 5 backward disks, 5 forward disks	7 m^2 36B pixels 5,200 MAPS sensors	400	26	26	17	MAPS: Several flavors: curved its-3 sensors for vertex Its-2 staves / w improvements	Fiber count limited by Artix Transceivers
MPGD tracking: Electron Endcap Hadron Endcap Inner Barrel Outer Barrel	16k 16k 30k 140k	8 8 30 72	1	.2	5	uRWELL / SALSA uRWELL / SALSA MicroMegas / SALSA uRWELL / SALSA	64 Channels/Salsa, up to 8 Salsa / FEB&RDO 256 ch/FEB for MM 512 ch/FEB for uRWELL
Forward Calorimeters: LFHCAL HCAL insert* ECAL W/SciFi Barrel Calorimeters: HCAL ECAL SciFi/PB ECAL ASTROPIX Backward Calorimeters: NHCAL ECAL (PWO)	63,280 8k 16,000 7680 5,760 500M pixels 3,256 2852	74 9 64 9 32 230 18 12	502	28	19	SiPM / HG2CROC SiPM / HG2CROC SiPM / Discrete SiPM / HG2CROC SiPM / HG2CROC Astropix SiPM / HG2CROC SiPM / Discrete	Assume HGCROC 56 ch * 16 ASIC/RDO = 896 ch/RDO 32 ch/FEB, 16 FEB/RDO estimate, 8 FEB/RDO conserve. HCAL 1536x5 *HCAL insert not in baseline Assume similar structure to its-2 but with sensors with 250k pixels for RDO calculation. 24 ch/feb, 8 RDO estimate, 23 RDO conservative
Far Forward: B0: 3 MAPS layers 1 or 2 AC-LGAD layer 2 Roman Pots 2 Off Momentum ZDC: Crystal Calorimeter 32 Silicon pad layer 4 silicon pixel layers 2 boxes scintillator	300M pixel 1M 1M (4 x 135k layers x 2 dets) 640k (4 x 80k layers x 2 dets) 400 11,520 160k 72	10 30 64 42 10 10 10 2	15	8	8	MAPS AC-LGAG / EICROC AC-LGAD / EICROC AC-LGAD / EICROC APD HGCROC as per ALICE FoCal-E	3x20cmx20cm 600^cm layers (1 or 2 layers) 13 x 26cm layers 9.6 x 22.4cm layers There are alternatives for AC-LGAD using MAPS and low channel count DC-LGAD timing layers
Far Backward: Low Q Tagger 1 Low Q Tagger 2 Low Q Tagger 1+2 Cal 2 x Lumi PS Calorimeter Lumi PS tracker	1.3M pixels 480k pixels 700 1425/75 80M pixels	12 12 1 1 24	150	1	4	Timepix4 Timepix4 (SiPM/HG2CROC) / (PMT/FLASH) Timepix4	
PID-TOF: Barrel Endcap	2.2M 5.6 M	288 212	31	1	17	AC-LGAD / EICROC (strip) AC-LGAD / EICROC (pixel)	bTOF 128 ch/ASIC, 64 ASIC/RDO eTOF 1024 pixel/ASIC, 24-48 ASIC/RDO (41 ave)
PID-Cherenkov: dRICH pfRICH DIRC	317,952 69,632 69,632	1242 17 24	1240 24 11	13.5 12.5 6	28 1 1	SiPM / ALCOR HRPPD / EICROC (strip or pixel) HRPPD / EICROC (strip or pixel)	Worse case after radiation. Includes 30% timing window. Requires further data volume reduction software trigger

By Jeff Landgraf, presented on Aug 22 WG meeting [link], Updated Sept 19

Summary of Channel Counts

Detector Group	Channels					RDO	Fiber	DAM	Data Volume (RDO) (Gb/s)	Data Volume (To Tape) (Gb/s)
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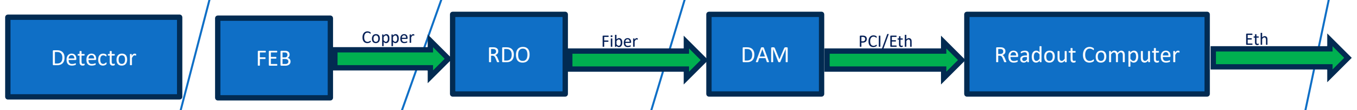
TOTAL	36.9B	10.4M	596k	202k	140k	2980	6826	100	2,000	96

Summary of Data Flow



100% Occupancy	27.5-1760 Pb/sec

Aggregate	2.0 Tb/sec
Noise	1.6 Tb /sec
Signal from Physics + Background	400 Gb / sec

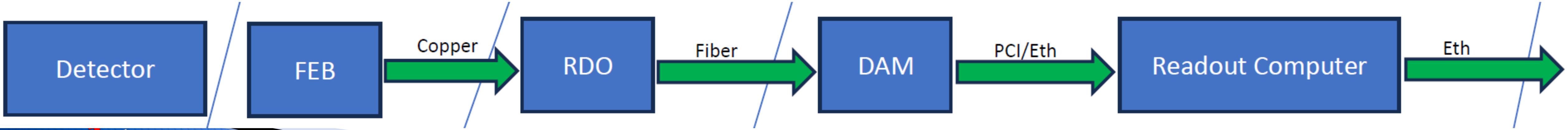
Aggregate	2.0 Tb/sec
Per RDO (Avg)	.7 Gb/sec

Aggregate	96 Gb/sec
Collision Signal	38 Gb/sec
Synchrotron Rad	.01 Gb/sec
Electron Beam	22Gb/sec
Hadron Beam	4 Gb/sec
Noise	32 Gb/sec

Streaming DAQ – Computing : consideration 1

For kickstart the discussion, please interrupt to discuss at any moment

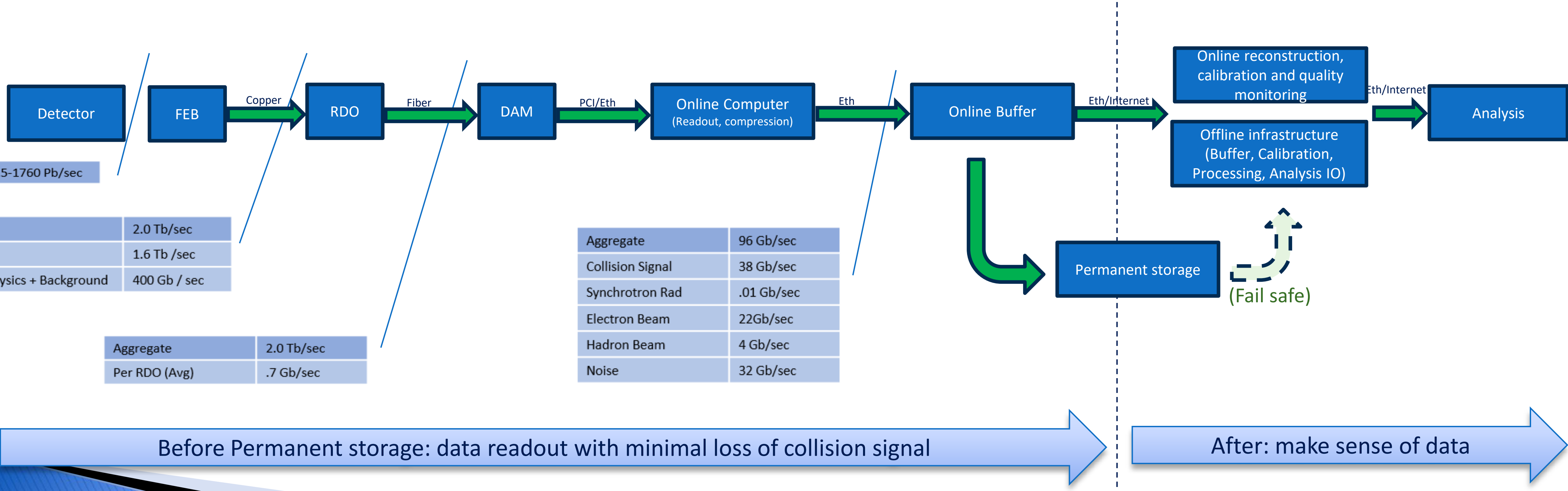
- Streaming DAQ naturally leads to no clear separation of streaming DAQ and computing
  - Streaming DAQ relies on data reduction computationally (i.e. no real-time triggering) → Any data reduction in streaming DAQ is a computing job
  - Which could be done at ASIC, FPGA, online-computers
  - Example could be zero-suppression (simple or sophisticated), feature extraction (e.g. amplitude in calo and tracklet in FB tracker)
  - Require minimal loss of collision signal; any data reduction require stringent bias control/study
- Citing ePIC software principles https://eic.github.io/activities/principles.html :
  We will have an unprecedented compute-detector integration:
  - We will have a common software stack for online and offline software, including the processing of streamed data and its time-ordered structure.
  - We aim for autonomous alignment and calibration.
  - We aim for a rapid, near-real-time turnaround of the raw data to online and offline productions.



Streaming DAQ – Computing : consideration 2

For kickstart the discussion, please interrupt to discuss at any moment

- Sooner or later, a copy of data is stored and saved for permanent storage
- This stage of first permanent storage could be viewed as a DAQ – computing boundary



100% Occupancy	27.5-1760 Pb/sec

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Collision Signal	38 Gb/sec
Synchrotron Rad	.01 Gb/sec
Electron Beam	22Gb/sec
Hadron Beam	4 Gb/sec
Noise	32 Gb/sec

Streaming DAQ – Computing : consideration 2

For kickstart the discussion, please interrupt to discuss at any moment

- Paid by project
- Has a hard archival limit (O(100Gbps)) from both throughput and tape cost
- Main goal on "online-computing" is data reduction to fit output pipeline
- Stringent quality and bias control for any lossydata reduction
- As minimal reduction as affordable to
  - (1) reduce unrecoverable systematic uncertainty
  - (2) reduce complexity, cost, failure modes.
  - Any processing beyond minimal need a physics motivation to justify project cost/schedule reviews (and possible descope reviews)
- High availability: any down time cost \$O(0.1)M/day → usually on host lab

Before permanent archival: DAQ

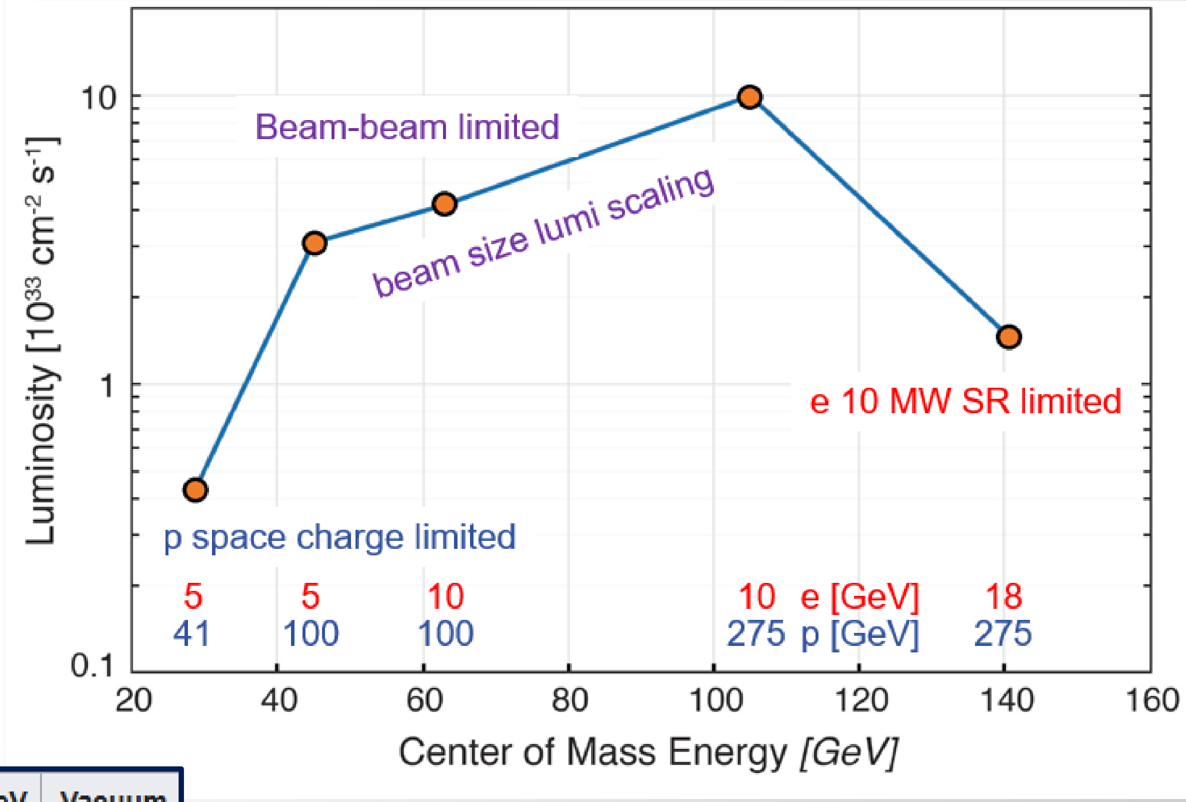
- Driven by collaboration, operation fund
- We would like to complete within a small latency (<O(1)week)
  - Usually driven by calibration and debugs
- Main goal on "offline-computing" is to bring out physics objects for analysis
- Quality control for reconstruction
- Can afford to redo reconstruction if new algorithm or with new physics insights (at cost of time, effort and computing)
- Can wait for short interruptions and can be distributed

After permanent archival: Computing

EIC Collider DAQ Environment

Charge 1&3

- 1260 Bunches arriving at 98.5Mhz (10.15ns bunch separation)
- 1.015us abort gaps (100 bunches)
- $\sqrt{s} \Rightarrow$ 20 – 141 GeV
- $\mathcal{L}_{max} \Rightarrow 10^{34}\ cm^{-2}\ s^{-1}$
- Electron, proton, and light nuclei beams can be polarized.
  - DAQ must tag data to specific bunch crossings
  - Need to track luminosity for each bunch crossing



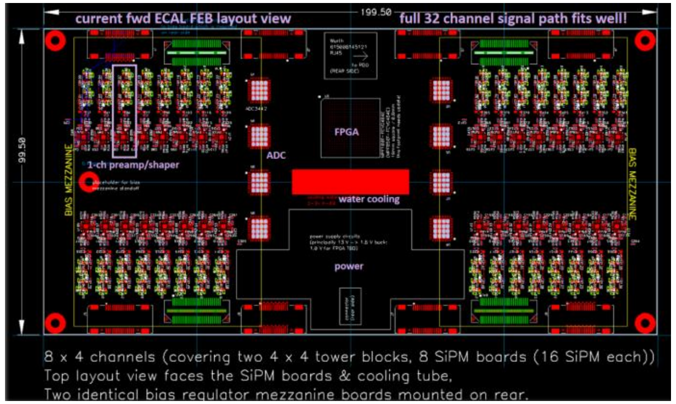
rates in kHz	5x41 GeV	5x100 GeV	10x100 GeV	10x275 GeV	18x275 GeV	Vacuum
Total ep	12.5 kHz	129 kHz	184 kHz	500 kHz	83 kHz	
hadron beam gas	12.2kHz	22.0kHz	31.9kHz	32.6kHz	22.5kHz	10000Ahr
	131.1kHz	236.4kHz	342.8kHz	350.3kHz	241.8kHz	100Ahr
electron beam gas	2181.97 kHz	2826.38 kHz	3177.25 kHz	3177.25 kHz	316.94 kHz	10000Ahr

eRD109 Initiatives – Synopsis

Charge 1, 2, 3, 4

Calorimeters – SiPMs – Discrete/COTS (IU)

- 32 ch Waveform Digitizer
- 12/14-bit TI ADC3422
- Microsemi MPF100T-FCVG484E Polarfire (radiation hard FPGA)
- CERN DC/DC converter bPOL12V, bPOL48V or COTS
- Cabling, Power, Cooling, Packaging.



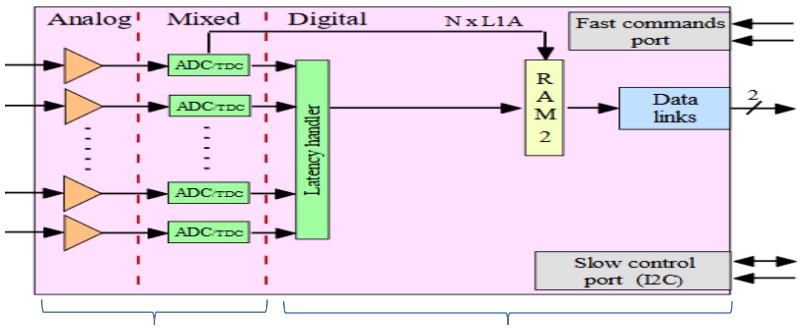
- Refer to talk by G. Visser

- Design, Fab: FY23 –FY24
- Tests + Beam: FY24 – FY25
- Engineering Article: FY26
- Production: FY27

Calorimeters – SiPMs – CALOROC (OMEGA/IN2P3/ORNL)

- 1D, 64 ch.
- 130 nm CMOS
- Charge (ADC+TOT) + Time (TOA)
- Cdin: 500 pF-10 nF
- Dynamic Range: up to 12 nC
- Timing: <500 ps (1 MIP)
- ADC: 10b; TOT: 15b
- 39.4 MHz operation from BX 98.5 MHz
- Links: 1260.8 Mbps @ 39.4 MHz, multiple
- Power: 10 mW/ch
- Radiation tolerant

Based on H2GCROC



No Change

Modify trig, mem, CLK dist.

- Refer to talk by F. Dulucq

- Design Backend: FY23 - FY24
- CALOROC1: FY24 – FY25
- CALOROC2: FY25 – FY26
- CALOROC3: FY27

ePIC

Fernando, Marco, Jin, Jeff, David

eRD109 Initiatives – Synopsis cont.

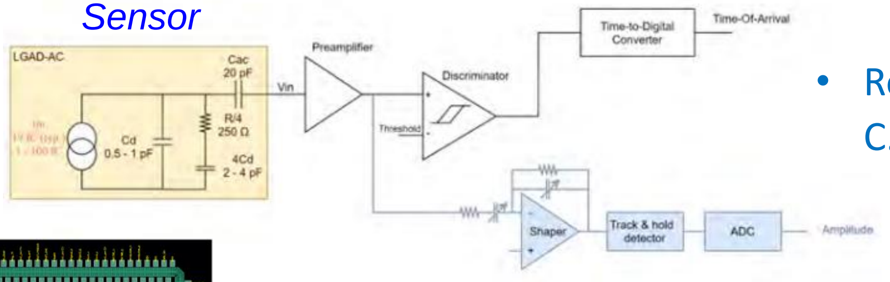
Charge 1, 2, 3, 4

AC-LGAD pixel – EICROC (OMEGA/IN2P3/IJCLab/CEA-IRFU/AGH)

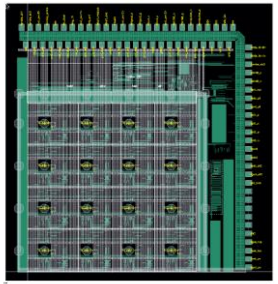
- 2D, 32x32 pixel readout
- 130 nm CMOS
- Preamp, Discriminator, TOA, ADC, TDC
- Cdin: 1-5 pF; Dynamic Range: 1-50 fC
- Timing: 30 ps; ADC: 8b; TDC: 10b
- 39.4 MHz operation from BX 98.5 MHz
- Links: 1260.8 Mbps @ 39.4 MHz, multiple
- Power: <2 mW/ch
- Packaging: Bump+Wire bonds
- Radiation tolerant

One pixel – EICROC0

Sensor



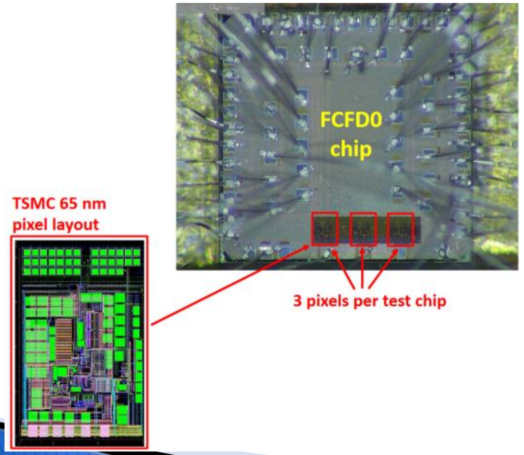
- Refer to talk by C. de la Taille



4x4 500 um pixels

- EICROC0: FY23
- EICROC0_v1 (4x4): FY23 – FY24
- EICROC1 (8x32): FY24 – FY26
- EICROC2 (32x32): FY27 – FY28

AC-LGAD strip – FCFD (FNAL)



- 128 ch strip readout
- 65 nm CMOS
- Constant Fraction Discriminator
- Plus TDC, ADC, interfaces
- Cdin: <15 pF
- Dynamic Range: 5-40 fC
- Timing: 10-30 ps
- Links: ~Gbps, multiple

- Considerable synergy with FNAL need for FCFD.

- Refer to talk by A. Apresyan

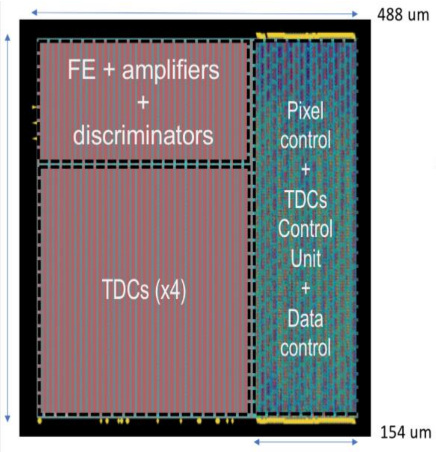
- FCFDv0: FY21 –FY22
- FCFDv1 (6 ch): FY23 – FY24
- FCFDv2: FY24 – FY25
- FCFDv3: FY25

eRD109 Initiatives – Synopsis cont.

Charge 1, 2, 3, 4

dRICH – SiPM – ALCOR (INFN – BO, TO)

- 2D 8x8 pixel readout
- 110 nm CMOS
- Dual polarity, RCG Amplification, conditioning, inhibit , digitization.
- Modes of operation: single-photon tagging or time and charge.
- Triggerless and triggered operation; Digital Shutter; Timing: <100 ps
- 25 ps TDCs, TOA+TOT
- 5 MHz input
- 4 or 8x 640 Mbps LVDS links.
- Power: 12 mW/Ch; Radiation Tolerant.

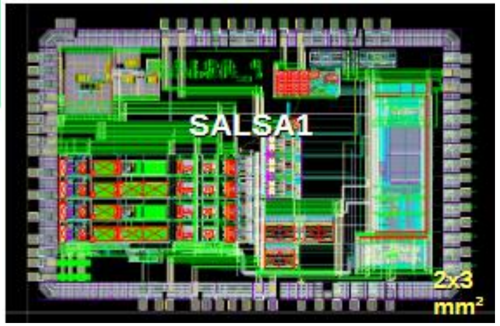


- Refer to talk by F. Cossio

- ALCOR v2 (32 pixel): FY23
- ALCOR v3: FY24 – FY26
- ALCOR: FY26 – FY27

MPGD – SALSA (CEA-Saclay, U. Sao Paulo)

- 64 Ch
- 65 nm CMOS
- Peaking time: 50 – 500 ns;
- Inputs: Cdin<200 pF; Dual polarity; Q: 3 – 250 fC
- ADC: 12 bits, 5 – 50 MSPS.
- Extensive data processing capabilities
- I2C configuration.
- Triggerless and triggered operation;
- Several 1 Gbps links.
- Power: 15 mW/Ch; Radiation Tolerant.



- Refer to talk by D. Neyret

- SALSA0 (IP blocks): FY23
- SALSA1: FY23 – FY24
- SALSA2: FY23 – FY25
- SALSA3: FY25 – FY26
- SALSA: FY27 – FY28

Scope of the Effort

Charge 2, 3

- Approximate quantities and costs.
- Costs include mask sets, fabrication and packaging, wrt quantities needed.

	#Ch	#Ch/Unit	#ASICs/ Wafer	#Wafers	Node (nm)	Packaging	Cost/ch ($)
Discrete/COTS	24 k	32	NA	740 Digitizers	COTS	NA	91*
CALOROC	97 k	64	480	5	130	BGA	3.2
EICROC	5.2 M	1,024	160	42	130	Wafer Bump	0.1
FCFD	2.6 M	128	180	149	65	Wire Bond	0.5
ALCOR	318 k	64	800	8	110	BGA	0.9
SALSA	202 k	64	500	9	65	BGA	4.1

* Includes FE

- Production
  - 65 nm: $750 k masks + $3.5 k per wafer
  - 110 nm: $190 k masks + $4 k per wafer
  - 130 nm: $250 k masks + $4 k per wafer
- Packaging BGA: $3-$7.5 per chip.
- ASIC Costs Total: ~$3.3 M
  - Masks: ~$2.2 M; Chips: ~$1.1 M

Timeline cont. - Installation

Charge 3

eRD102	eRD109	R&D Milestones	FEB QC Complete
Calorimeters	Discrete, CALOROC	30 September 2025	Mar 2028 – Jan 2030
AC-LGAD	EICROC, FCFD	30 September 2025	Nov 2027 – Jan 2029
dRICH	ALCOR	2 January 2026	Nov 2028
MPGD	SALSA	31 March 2026	Sep 2028 – Jun 2029
LAPPD/MCPMT	FCFD/EICROCx	23 December 2026	Sep 2028 – Jan 2029

- eRD102 – Electronics for detectors R&D.
- eRD109 – Readout R&D.
- R&D Milestones – ASICs ready for production.
- ASIC Production FY25 – FY28.
- FEB QA/QC Complete – Ready for integration.

FY23 – FY26

R&D (eRD109)

FY25 – FY28

ASIC Production

FY26 – FY29

Readout Production & QC

11/2027 – 1/2030

QC Complete

Installation

Jan 2029 – Jan 2031