ePIC TOF DAQ Update

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for the ePIC TOF WG

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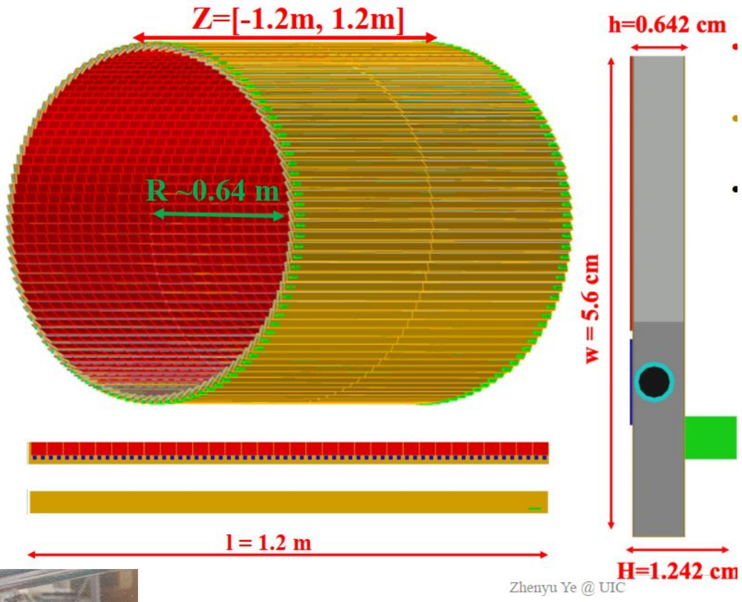
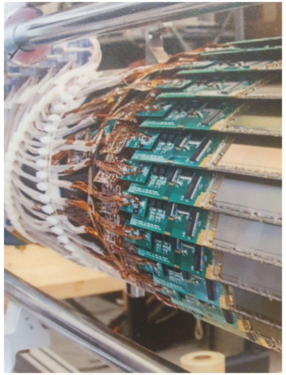
General Comment

- I propose we handle the Barrel TOF and the Forward Endcap TOF as two separate detectors for at least DAQ purposes
  - apart from technology they don’t share that many things:
    - one is part of the barrel detector structure with its own set of detectors before and after the TOF
    - the other is part of the forward detector structure with a completely different set of detectors before & after
    - particle tracks are disjoint: a particle doesn’t traverse both at the same time
    - so (likely) any sort of processing in either DAQ or Offline will <u>not</u> require e.g. both to be present either at the same time or at the same bunch Xing

Barrel

- 2 equal barrels/sides: East & West
- each side contains 144 staves
- each stave is (partially) tiled with 32 B-TOF AC-LGAD sensors of 1.6 x 1.6 cm2
  - each sensor has 256 strips of 0.5mm in phi X 10mm in z
- each sensor is wire-bonded to 2 EICROCb ASICs, 128 chs each
  - ⇒ stave holds 64 ASICs
- staves are overlapping for 100% coverage
- each stave has 1 RDO located at the edge (see green PCBs in photo →)
- Totals
  - 288 RDOs/fibers
    - 6 FELIX (of 48 fibers each)
  - 18432 ASICs
  - 2.36 M channels
- modelled on the STAR IST





Barrel Readout

- let's express the rates as "X Hz per channel"
  - 5 particles per DIS event in entire barrel (on average, from recent simulations)
  - each particle "lights up" 3 strips
  - DIS events @ 500 kHz
  - 5*3*500kHz divided by 2500000 M strips ⇒ 3 Hz per strip (channel) on average
- noise = 1 kHz per strip
  - my colleagues tell me this number is excessive but it hasn't yet been measured so I will keep this "pessimistic" rate
- physics data rate is negligible compared to the noise
- rates: per ASIC
  - 128 chs X 64bits (of ASIC hit data) X 1 kHz ⇒ 8.2 Mbs per ASIC (pretty low)
- rates: per fiber
  - 64 ASICs x 8.2 Mbs ⇒ 0.53 Gbs per fiber (still low)
- rates: per FELIX
  - 48 fibers x 0.53 Gbs ⇒ 25.4 Gbs per FELIX
  - or 400 Mchannels per FELIX (important number for the next slides)
- rates: entire B-TOF
  - 244 fibers x 0.53 Gbs ⇒ 130 Gbs for Barrel TOF

Barrel: Data Compression & Processing 1

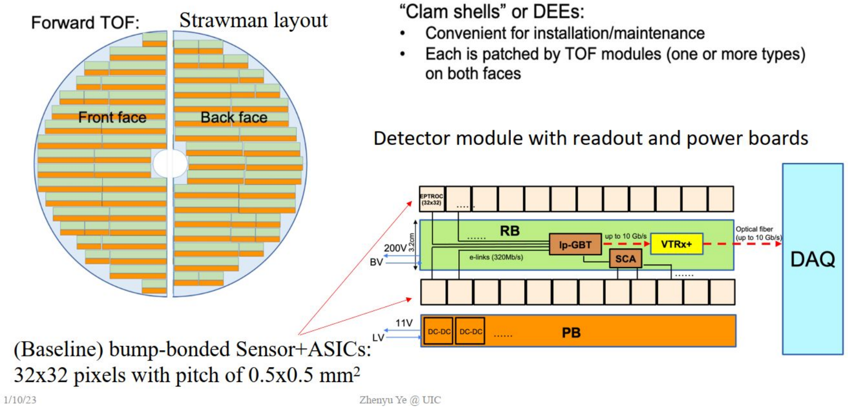
- each barrel stave is 128 strips in z and 64 strips in phi
  - the local stave coordinate system is thus a plane of 64 x 128 “pixels”
- per-channel processing
  - gain correction is applied to the ADC data
  - t0 correction is applied to the TDC data
  - slewing corrections is applied to TDC data
  - ⇒ obviously unphysical data is removed (cuts down the noise significantly)
- cluster finder runs on this (locally x-y) plane and looks for strip patterns
  - more than 1 adjacent strips with the same timing information form a valid particle (as opposed to random noise)
  - timing data should correspond to possible collisions, out-of-time hits are assumed to be noise
  - morphological cuts: e.g. middle pixels should be higher than neighbors, etc
  - we think this gives us at least x100 noise rejection
    - a better number needs a slow simulator & reconstruction
- hits are formed and saved with the following information
  - **coarse counter C** 17 bits (relative tick from the start of the timeframe ; 17 bits is up to 1.3 ms ⇒should be enough)
  - **local x-coordinate** as a fixed point number of 7.5 bits (relative coordinate system of the stave)
  - **local y-coordinate** as a fixed point number of 6.5 bits (relative coordinate system of the stave)
  - **fine hit time T** as a fixed point number in 10.5 bits (timing from TDC)
  - **summed up ADC** (charge) is 12 bits
  - **flags** 4 bits
  - total #bits per hit is 71 ⇒ but let’s call it 10 bytes

Processing (outgoing)

- 393 k-channels per FELIX
  - 393 MHz noise hits
  - 1.25 MHz physics
- assuming 1:100 noise rejection
  - 3.93 MHz noise remains
- total # hits ⇒ 1.73 MHz clusters
- 1.73 MHz X 10 bytes ⇒ 17.3 MB/s per FELIX/DAQ-PC (easy)
- 6 DAQ PCs ⇒ 105 MB/s “to tape”
  - but if we can to 1:1000 noise suppression (which I think is possible) ⇒ only 33 MB/s

Forward Endcap

- circle of radius ~65 cm
  - broken into 2 symmetric “D”s for ease of installation over the beampipe
- the surface of each “D” is tiled with modules which contain AC-LGAD sensors in a 32x32 matrix of 0.5mm X 0.5mm pixels
- EICROCe ASIC has 32x32 channels and is bump-bonded on top of the sensor
- Readout Boards come in 3 different lengths to efficiently tile the “D”
  - 48 ASICs
  - 40 ASICs
  - 24 ASICs
- there are 212 RDOs/fibers in total
  - 5 FELIX (@48 fibers/FELIX)
- there are 8704 ASICs in total ⇒ 8.9 M channels
- on average an RDO reads out ~41 ASICs
- modelled after the CMS ETL detector https://etl-rb.docs.cern.ch/
  -



Endcap Readout

- E-TOF DIS physics particle rates are 2 particles/event
  - rates on the fiber (and ignored below) are negligible compared to the 1 kHz of noise/channel!
- rates: per ASIC
  - 1024 chs x 64bits x 1 kHz ⇒ 65.5 Mbs per ASIC
- rates: per fiber – 3 different sizes
  - 48 ASICs: 48 * 65.5 Mbs ⇒ 3.1 Gbs (worst)
  - 24 ASICs: 24 * 65.5 Mbs ⇒ 1.5 Gbs (lowest)
  - average 41 ASICs * 65.5 Mbs ⇒ 2.7 Gbs (average)
- rates: per FELIX
  - 48 x 2.7 Gbs ⇒ 130 Gbs per FELIX
- rates: entire E-TOF ⇒
  - 212 x 2.7 ⇒ 572 Gbs per E-TOF
- same processing as for the Barrel ⇒ see the summary in the next table

Summary Table

	chs/ASIC	rate/ch	bits/ch	rate/ASIC	#ASICs/RDO	rate/fiber Gbs	#RDOs	#chs total	#ASICs total
B-TOF	128	1 kHz[a]	64[b]	8.2 Mbs	64	0.53	288	2.36 M	18432
E-TOF	1024	1 kHz[a]	64[b]	65.5 Mbs	24-48 (41 ave)	1.5-3.1 (2.7 ave)	212	8.9 M	8704

a) almost all is noise and just a guess at this time
b) likely somewhat smaller

	#FLX[a]	rate/ FLX	rate/ all	noise suppress.	bytes/ particle	to EVB noise/FLX	to EVB phys/FLX	to EVB noise	to EVB phys	to EVB all	to EVB with 1:1000 noise suppr.
B-TOF	6	25.4 Gbs	130 Gbs	1:100	10	4 MHz (13.3 MB/s)	1.25 MHz (4.2 MB/s)	80 MB/s	25.2 MB/s	105 MB/s	33 MB/s
E-TOF	5	130 Gbs	572 Gbs	1:100	10	17.8 MHz (60 MB/s)	0.6 MHz (2 MB/s)	300 MB/s	10 MB/s	310 MB/s	40 MB/s

a) assuming 48 fibers

Final Remarks

- 1 kHz/ch noise is possibly (hopefully) a ~10x exaggeration
  - needs a real measurement
- 1:100 noise suppression can be possibly (hopefully) better, perhaps 1:1000
  - needs at least a rough slow simulator and cluster finder
- physics particle rates are reasonably well simulated
  - but only for top energy ep – we need eA and all energies
- BUT, we have no collision related background yet

Thank you for listening!

Backup Slide for the TOF WG only

- we really need a noise number expressed in Hz/channel
  - I don’t think my 1 kHz is unrealistic but it is out-of-the-hat
  - this is an essential number for readout & DAQ planning and it makes a lot of difference
    - and it is required for the TDR, IMHO
  - [Alessandro] noise is mostly on the ASIC’s preamp section?
    - can we have a number here, preferably from a measurement with EICROC0?
- we need to make a clarification regarding the ASIC for B-TOF vs E-TOF
  - B-TOF: 128 channels, wire-bonded
  - E-TOF: 1024 channels, bump-bonded
  - **Options**
    - **option a) those are 2 different ASICs; exactly the same functions just differentially packed on the Si real estate**
    - option b) we finagle the 1024 channel one and have only 128 chs wire-bonded to the sensor, somehow??
      - will add a significant capacitance
- I would like to see the plot showing the distribution of the number of strips (and pixels) hit per particle
  - people claim 2, some claim 3, some think 9 (for 0.5 mm case)
- we should not forget simulations for the eA case as well as all the energies
- it would be great (and not that hard) if someone can do a quick-and dirty slow-simulator
  - followed by reconstruction with noise-suppression heuristics
  - we _need_ to know how much noise we can suppress with a simple scheme
  - this is another very important number for DAQ (determines MBs to tape)
    - it is required for the TDR, IMHO