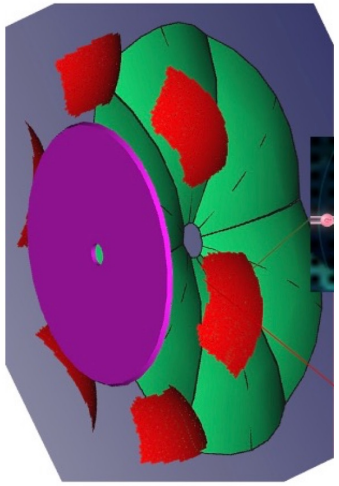
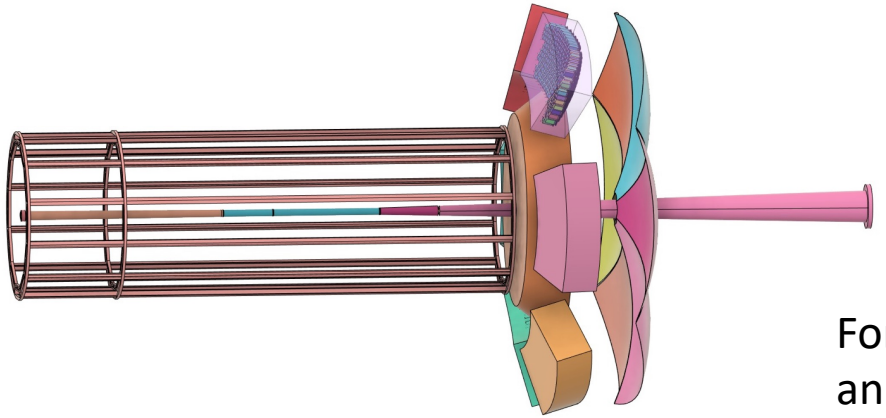
dRICH DAQ

- updates
- discuss DAQ scenarios for dRICH with the DAQ group (preparing discussion with GDI)

DISCLAIMER: talk very much oriented to DAQ design, no discussion on underlying results on ALCOR, radiation damage, annealing, etc





P. Antonioli, INFN – Bologna
on behalf of the dRICH group

For general progresses on dRICH see dRICH and photosensors talks at ePIC meeting

There is an obvious interest between DAQ and dRICH...

dRICH estimates of throughput (ATEHENA)

Table 2.5: Maximum data volume by detector.

Detector	Channels	DAQ Input (Gbps)	DAQ Output (Gbps)
B0 Si	400M	<1	<1
B0 AC-LGAD	500k	<1	<1
RP+OMD+ZDC	700k	<1	<1
FB Cal	4k	80	1
ECal	34k	5	5
HCal	39k	5.5	5.5
Imaging bECal	619M	4	4
Si Tracking	60B	5	5
Micromegas Tracking	66k	2.6	.6
GEM Tracking	28k	2.4	.5
uRWELL Tracking	50k	2.4	.5
dRICH	300k	1830	14
pfRICH	225k	1380	12
DIRC	100k	11	11
TOF	332k	3	.8
Total		3334	62.9

ASSUMPTIONS

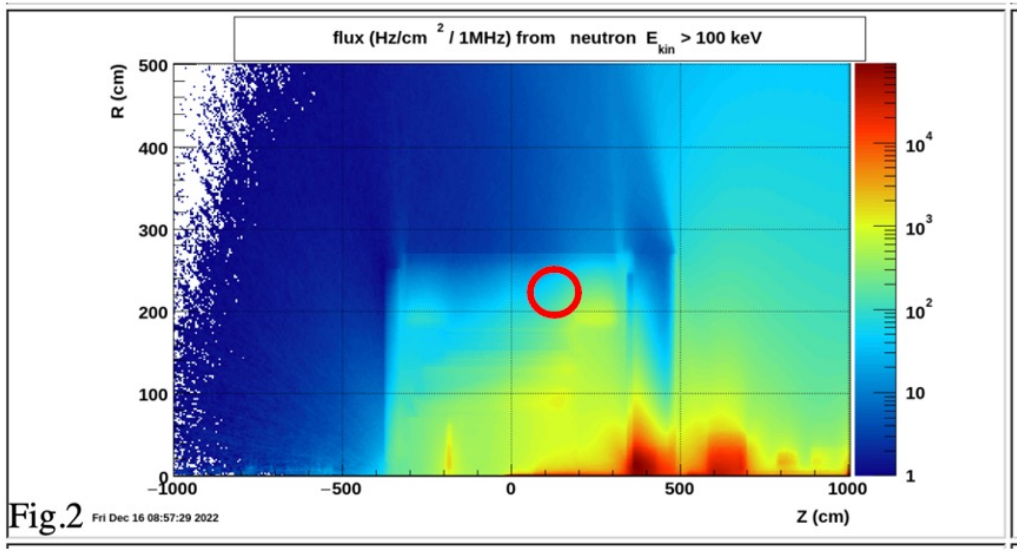
This was computed assuming an average 270 kHz DCR per pixel MAX before moving to annealing cycles given limitations on ALCOR and DAQ bandwidth

We considered already a factor 3 reduction due to timing selection (it might be 5 or 10…) [at the time of proposal it was ambiguous if It was at ALCOR or FPGA level]

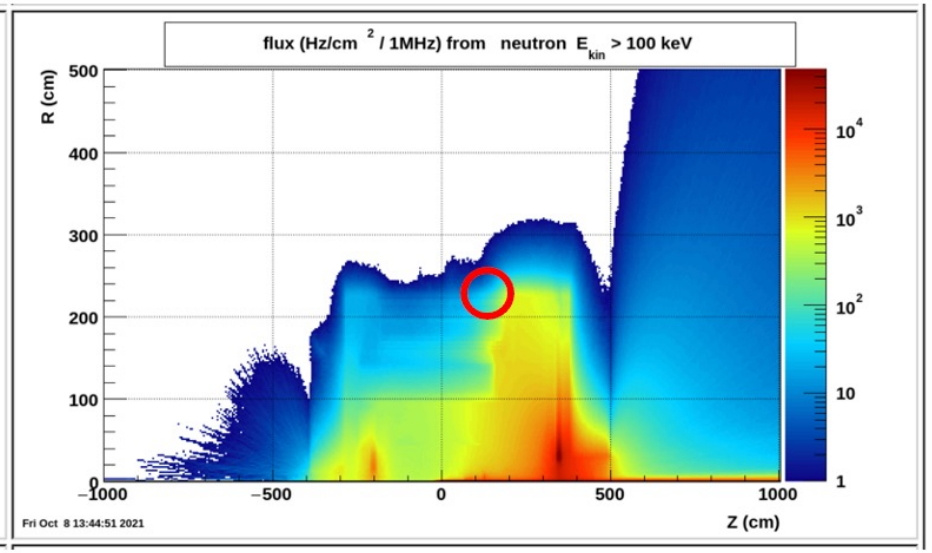
Throughput assumed 64 bit per hit (TOT)

What's new?: radiation levels: finally with ePIC geometry

Finally with ePIC geometry



Best thing we had in the past (ATHENA)



And we have to sum up protons to neutrons...

Results from (new) background task force

The esitimate of 1-5 10^9 n/cm^2 reached in 30 weeks @ 10^{34} lumi seems confirmed in ePIC geometry

Up to 2034, radiation levels will be much lower
When we start the sensor DCR rate is 2 kHz

10^{11} n/cm^2 1-MeV n_{eq} is a "true maximum"

- 30 weeks @ 10^{34} cm^{-2} s^{-1}= 100 fb^{-1} → 1-5 10^9 n/cm^2
- 10^{11} n/cm^2 would be reached in O(10+) years at full $\mathcal{L}$!

A moderately hostile environment:
10^9 1-MeV n_{eq}/cm^2 → most of the key physics topics
10^{10} 1-MeV n_{eq}/cm^2 → GPD and more statistically eager topics
10^{11} 1-MeV n_{eq}/cm^2 → may be we will never go here…

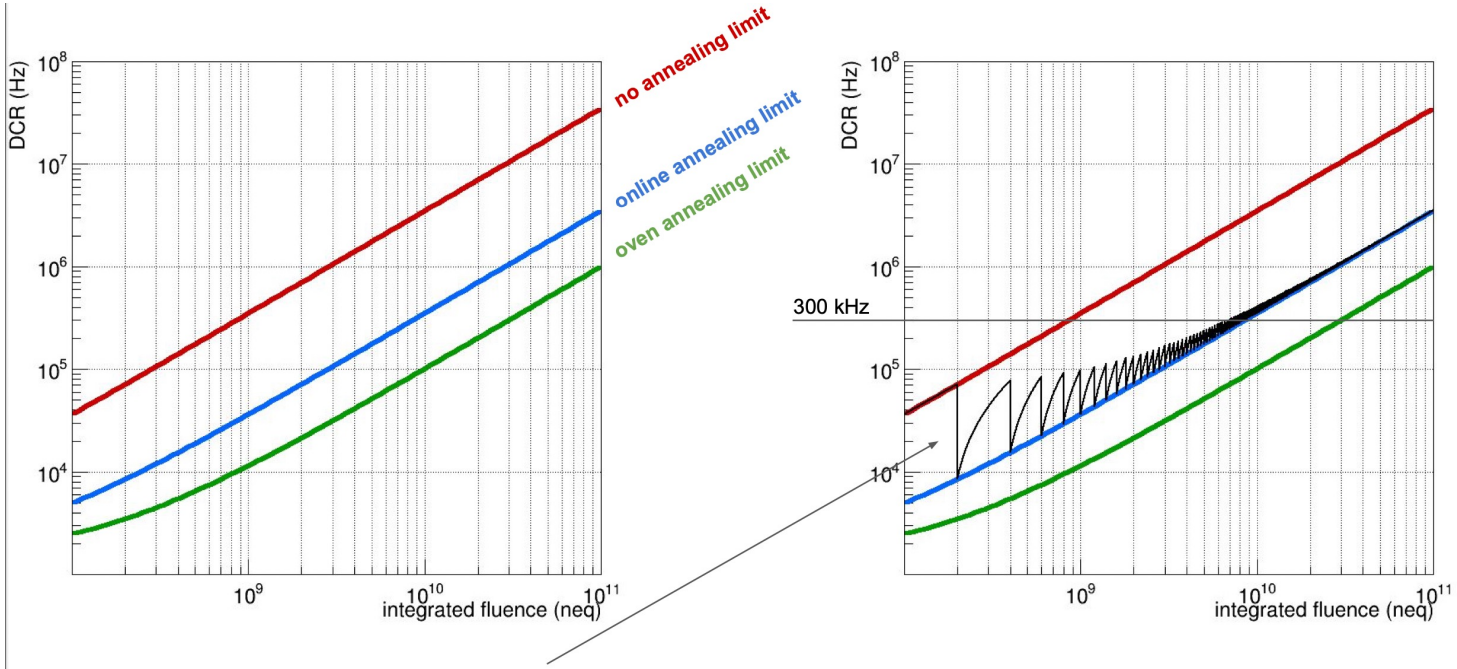
Memento: now we have a radiation damage model

Radiation damage model (HPK S13360-3050 @ Vover = 3 V)

- **reasonable assumptions**
  - radiation damage is additive
  - does not know and care of the past damage
  - annealing heals up to a certain fraction of damage, not more than that
- **numbers**
  - DCR when new = 1.5 kHz
  - DCR increase with radiation damage = 350 kHz / 10^9 neq
  - DCR increase with online annealing = 35 kHz / 10^9 neq
  - DCR residual after oven annealing = 3%
- **how it works?**
  - start with DCR as new → NEW
  - add DCR with increasing radiation → NEW + NIEL1
  - heal with annealing → NEW + x NIEL1
  - add DCR with increasing radiation → NEW + x NIEL1 + NIEL2
  - heal with annealing → NEW + x (NIEL1 + NIEL2)

Numbers in the parameterisation reflects measurements
However optimisation still on-going
You get however the idea.
Note that 10^{10} neq might be reached > 2040!

Message:
Max “tolerable” rate per channel determines frequency of annealing

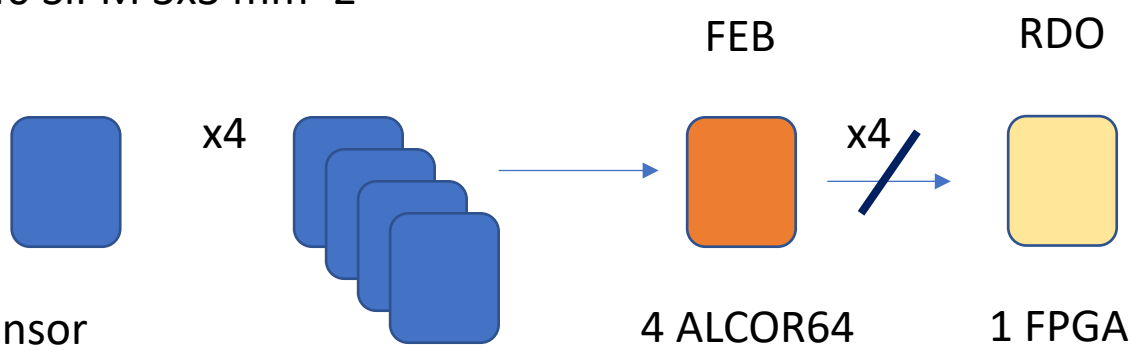


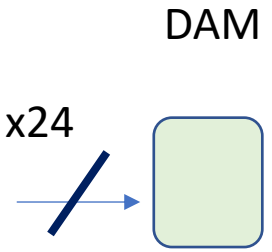
R. Preghenella

dRICH baseline scenario (”A”)

“current” scheme (elaborated at the time of ATHENA design)

317440 SiPM 3x3 mm^2





4960 1240 1240 310

310 optical links

13/14
Note: if 48 links (FELIX2)
we might have 1 DAM for
dRICH sector which would be nice…

Scenario	RDO	Fibers	DAM	DAQ link throughput	Total trhoughput	Notes
A	310	310	14	3.3 Gbps	1.8 Tbps	Assumed 270 kHz max sesnsor + timing reduction factor = 3

Let’s add some information

- We assume conservatively 500 kHz sensor max now (damage at 10^9 neq without annealing and V_{over}=4 V)
- We assume we can implement in ALCOR a shutter at 1 ns (timing reduction factor = 10, instead of 3) → ALCOR v3 [eRD109]
- We take into account 8% reduction due to machine cycle / bunch gap (1.015 us/12.789 us)
- We now know (not a surprise) we need TOT → 1 hit = 64 bit

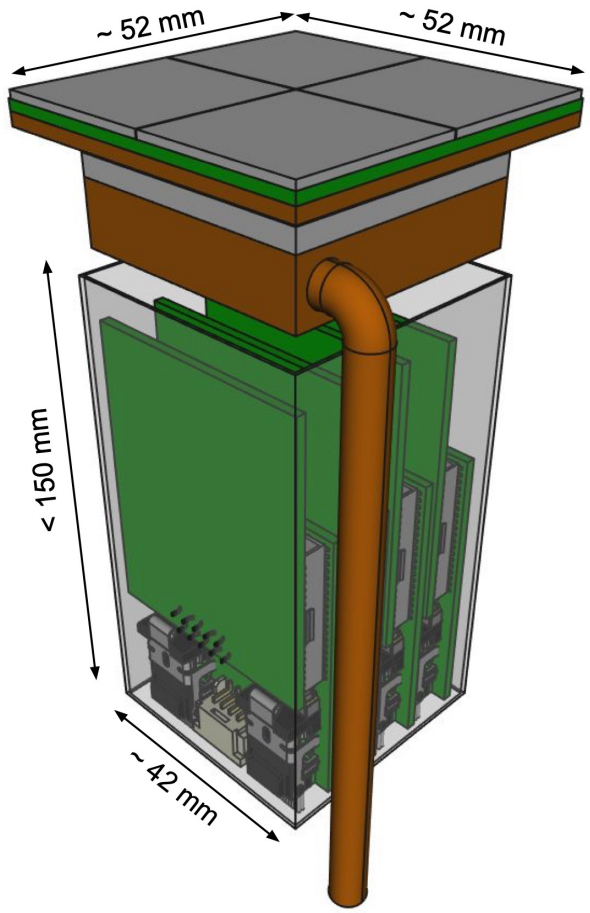
Scenario	DCR rate	RDO	Fibers	DAM	DAQ link throughput	Total trhoughput	Notes
A	270	310	310	14	5.8 Gbps	1830 Gbps	timing reduction factor = 3
B	500	310	310	14	2.94 Gbps	935 Gbps	Timing reduction factor – 10 / machine cycle accounted

Intermezzo: remember dRICH@startup

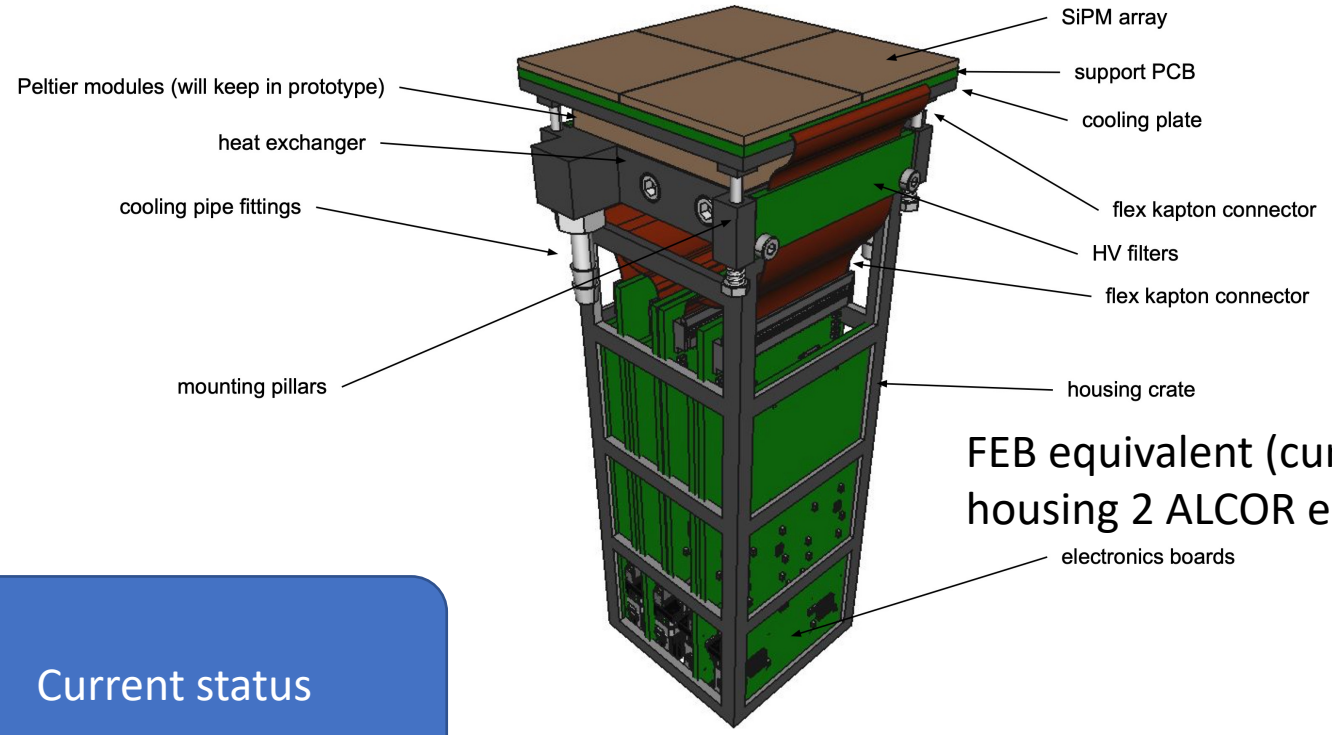
Scenario	DCR rate	RDO	Fibers	DAM	Link/ DAM	DAQ link throughput	Total trhoughput	Notes
B	**2**	310	310	14	24	**12 Mbps**	**3.7 Gbps**	Timing reduction factor – 10 / machine cycle accounted

During first years, and especially during commissioning in 2030-2031 dRICH trhoughput will be "easy" allowing for calibration, optimization of shutter etc.

What we know more from test-beam prototype design now? (I)



initial design concept



FEB equivalent (currently housing 2 ALCOR each)

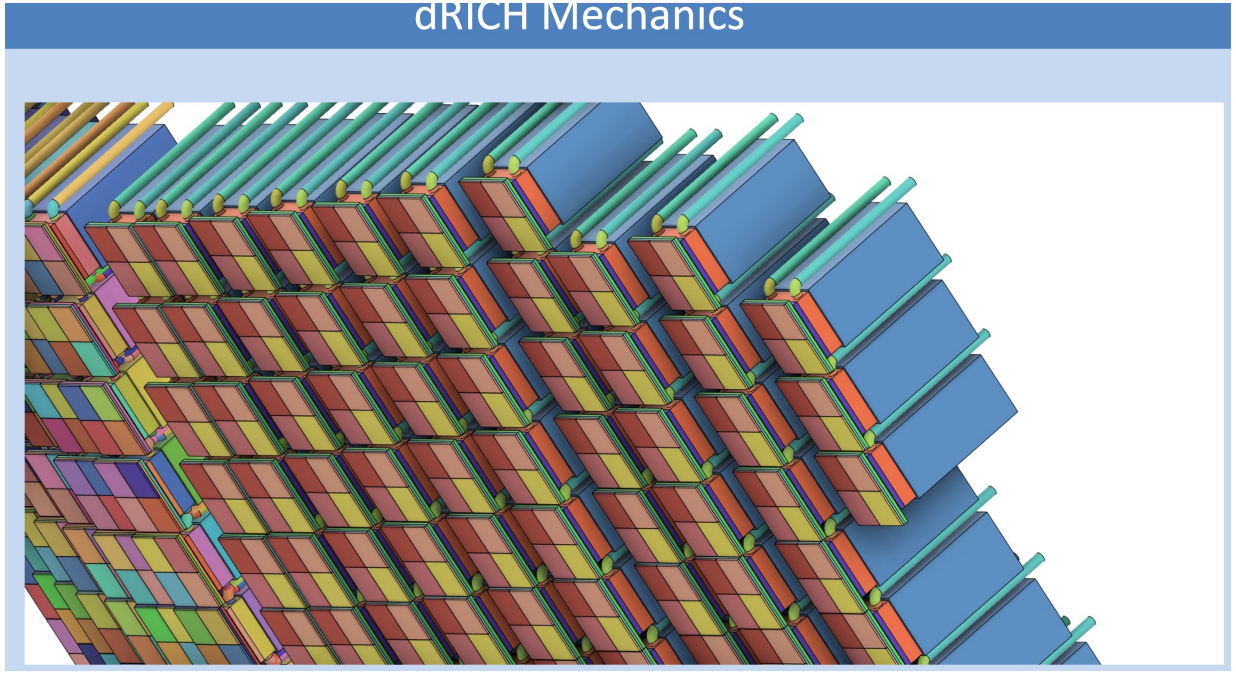
Current status

We will likley have FEB orthogonal to RDO

RDO not yet designed because:

- For test beam we continue to use FPGA evaluation boards (Xilinx KC705)
- Lack of specifications so far

What we know more from test-beam prototype design now? (II)



It might be challenging having a RDO matching “four dRICH tiles” as originally planned
→ possibility: RDO reads 4 ALCOR64 (instead of 16 as planned in Scenario A)
→ This would simplify some design, maintenance and some choice in terms of modularity
→ Also the number of I/O pins requirement for the FPGA will decrease → cheaper FPGA selected for RDO

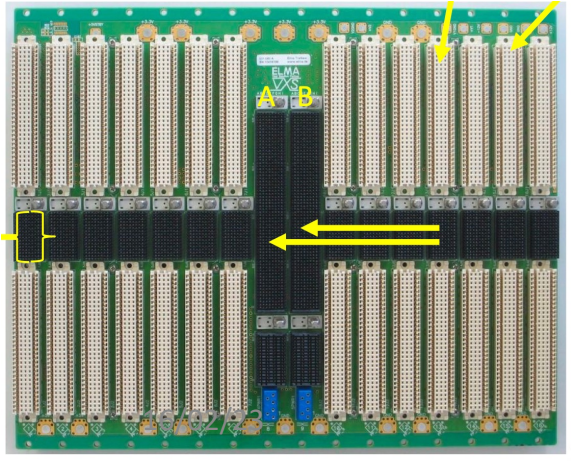
Scenario	DCR rate	RDO	Fibers	DAM	DAQ link throughput	Total trhoughput	Notes
A	270	310	310	14	5.8 Gbps	1830 Gbps	timing reduction factor = 3
B	500	310	310	14	2.94 Gbps	935 Gbps	Timing reduction factor – 10 / machine cycle accounted
C	500	1240	1240	56	0.75 Gbps	935 Gbps	**Costs up:** more fibers, more FPGA, more DAM

Scenario	DCR rate	RDO	Fibers	DAM	Link/ DAM	DAQ link throughput	Total trhoughput	Notes
A	270	310	310	14	24	5.8 Gbps	1830 Gbps	timing reduction factor = 3
B	500	310	310	14	24	2.94 Gbps	935 Gbps	Timing reduction factor – 10 / machine cycle accounted
C	500	1240	1240	56	24	0.75 Gbps	935 Gbps	**Costs up:** more fibers, more PCB, more FPGA, more DAM
D	500	1240	1240	28	48	0.75 Gbps	935 Gbps	Assuming FELIX2 can reach 48 links per DAM

However the costs of DAM can be curbed, **if it is confirmed FELIX2 has 48 links** (scenario D)

Observation: the foreseen bandwidth of the DAQ link (RDO-DAM) in C and D would be seriously unused (14 Gbps available)

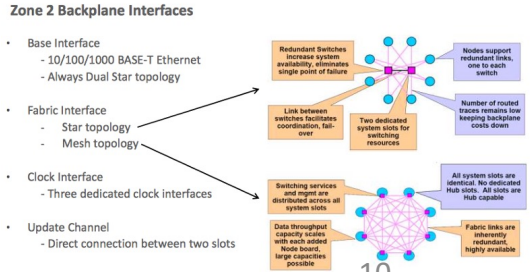
At this point we could decide to curb the cost of DAM making a **private dRICH-DAM system**, à la JLab concentrating data first in a crate using mesh topology (µTCA or VXS), moving then data to DAM. There are also potentially COTS options



David @[DAQ group 2 Feb]

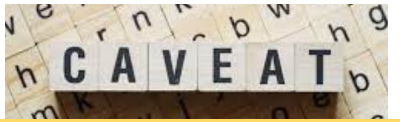
CAEN FERS concentrator DT5215
https://www.caen.it/products/dt5215/

µTCA®



A private dRICH-DAM

- For dRICH in general it could make sense quickly concentrate data in sector (total/6) *because it is where in a sector the 20 hits of Cerenkov photons are focused (the "signal" is **mainly** a the sector level)*
- 1240/6 approx 200 link (1 Gbps)
- A dRICH-DAM VXS card could get (let's say) 20 links from RDO
- A 10 cards mini crate (VXS/uTCA) could:
  1) sum all hits in a sector
  2) check for time hit clustering in 10 ns window
     → In a 10 ns window (after shutter reduction) we expect(*) 25 hits from DCR and 40 hits (from DCR + signal)
     → It would therefore output data not at 100 MHz but at 500 kHz (interaction rate) → factor 200
  3) Bring to DAM (FELIX2) only the selected time windows (1 DAQ link to to DAM every 20 links)



this is not strictly true. Especially for aerogel rings

Scenario	DCR rate	RDO	Fibers	DAM	Link/ DAM	DAQ link throughput	Total trhoughput	Notes
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C	500	1240	1240	56	24	0.75 Gbps	935 Gbps	**Costs up:** more fibers, more PCB, more FPGA, more DAM
D	500	1240	1240	28	48	0.75 Gbps	935 Gbps	Assuming FELIX2 can reach 48 links per DAM
E	500	1240	1240 → 62	2	48	0.075 Gbps	4.65 Gbps	**Costs up**: minicrates, cards, fibers, FPGA… **Costs down:** from 28 to 2 FELIX2 **Throughput down**

(*) 50000 ch/sector x 500 kHz x 10 ns / 10 (shutter) = 25

Scenario F: let's be not politically correct!

Let's suppose at the DAQ undergraduate course where you are teaching you ask a student for the exam the following question:

You have a sensor with a high DCR rate (500 kHz) and a detector of 300000 channels, with 64 bits payload/hit. Your bunch crossing rate (the machine) is 100 MHz, but your interaction rate (the physics) is 500 kHz. Assume you can reduce your data anyway by a factor 3 with a time selection around each bunch crossing.

How would you design your DAQ/trigger system? Which would be then the data throughput?

Answer A: I would design a streaming readout system reading everything always and taking a decision only later after inspecting my data with chatGPT. The DAQ should therefore be designed to sustain a 3.4 Tbps throughput.

Answer B: I would design a loose mimimum-bias trigger to select inclusively the interactions providing a factor 200 reduction. The DAQ should therefore be designed to sustain a 17 Gbps throughput and to have memory buffers close to the Front-End.

A student of mine:

- Would get F if he/she answers A
- Would get B if he/she answers B

Scenario	DCR rate	RDO	Fibers	DAM	Link/ DAM	DAQ link throughput	Total trhoughput	Notes
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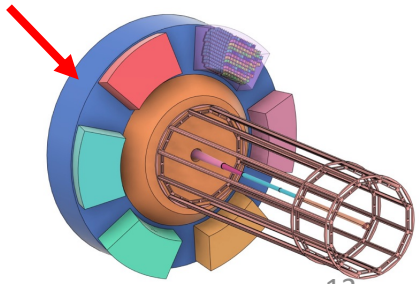
E	500	1240	1240 → 62	2	48	75 Mbps	4.65 Gbps	**Costs up**: minicrates, cards, fibers, FPGA… **Costs down:** from 28 to 2 FELIX2 **Throughput down**
F	500	1240	1240	28	48	3.75 Mbps	4.65 Gbps	**Requires an external trigger** (latency 10 υs to say). **Costs up but how much?** Internal buffers implemented at ALCORv3 level or at RDO level

- A trigger should reach RDO within 10 us (may be less is doable)
- We would have some extracost in memory (at RDO level) or in ALCORv3 (internal buffers)
- Intrinsically **more robust** than scenario E (costs aside)
- Given the very small bandwidth of the RDO link we might think about a private DAM-dRICH system much cheaper than scenario E and closer to the detector, but still reducing by a factor 10 the number of DAM/FELIX2 cards (note that with a trigger scenario each sector would have a modest throughput: 48 links == 1 DAM would be certainly enough). This would be “Scenario F+”



Summary

DAQ design is now starting to be impacted by the usual boundaries designing a real detector: sensor specs, front-end, mechanics, dimensions, etc.

Scenarios presented here are part of the work we will undertake this year (towards draft-TDR, with serious costing etc). They are brainstorming scenarios. Please comment on them.

Intermediate scenarios of course exist: we might have some “private” concentrators close to the Front-End and having then 6 sectors routed in 6 DAM/FELIX2. In 1 DAM=dRICH sector we might then implement scenario E…. (not paying for a μTCA crate ecc.) or even go just to one DAM/FELIX2 (Scenario F+)

Questions:

- Is an increase of fibers / DAM a problem?
- When we need to decide if having a private dRICH-DAM ? (space in crates close to the detector)
- DAM cost? (FELIX2) (needed for assess trade off). When you can confirm 48 links will be a reality?
- Should we assume 14 Gbps /DAQ link?
- Detectors able to provide a trigger? → discuss with GDI/opinion from DAQ group
- Could the trigger fly over RDO-DAM link? → I would add this to spec, but latencies are also critical