Summer 2024 Joint EICUG/ePIC Collaboration Meeting

Jul 22 – 27, 2024
US/Eastern timezone

A proposal for a dRICH Interaction Tagger (dIT)

M.Battaglieri, S.Vallarino (INFN-GE)
on behalf of the dRICH group and ePIC Italy
July 26, 2024

The problem and the (possible) solution

The problem (w/o an interaction tagger)

- The dRICH is the ePIC sub-detector generating the highest FE data rate
- 1 p.e. background generated by SiPMs dominates the data rate
- the dRICH bg is not reducible at the channel level [Cherenkov light (signal) is expected in the same range (~ 1 p.e.)]
- an external 'trigger' that identifies high-momentum hadrons crossing is needed

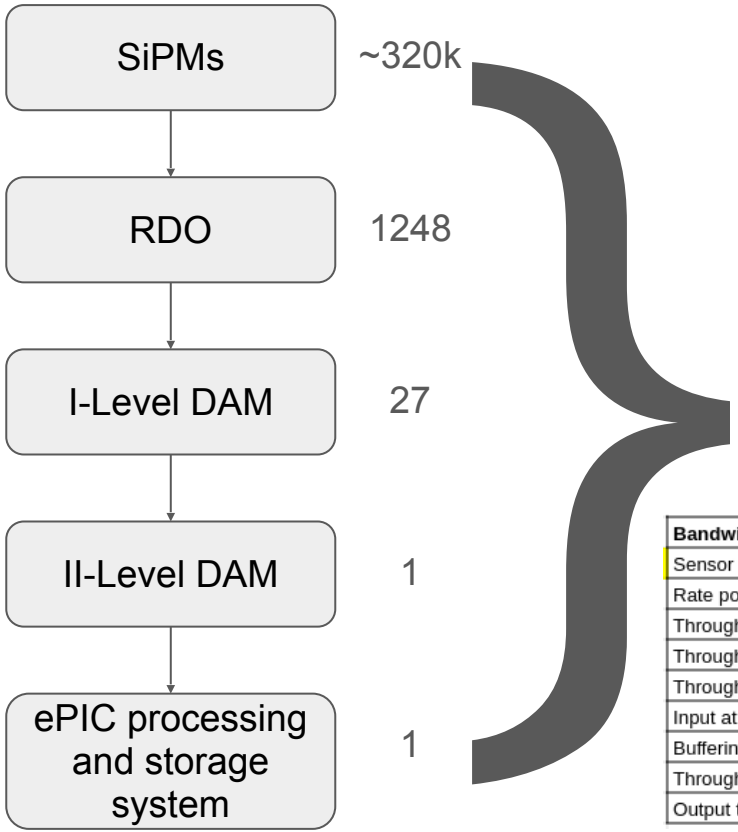
Requirements

- Trigger signal: generated by fast hadrons crossing the dRICH volume
- Prompt: the trigger signal should be fast to generate a narrow time coincidence window
- Local: the data rate should be reduced as closely as possible to the source
- dRICH-generated: to avoid uncontrolled delays and respect the ePIC SRO-DAQ concept
- Time and position: to veto noise and identify the dRICH region with hadron candidates

The solution

A dRICH Interaction Tagger (dIT) integrated into the dRICH based on plastic scintillators that provide a prompt and fast signal (position-sensitive) of hadrons crossing the dRICH volume

The dRICH DAQ chain in ePIC → the throughput issue



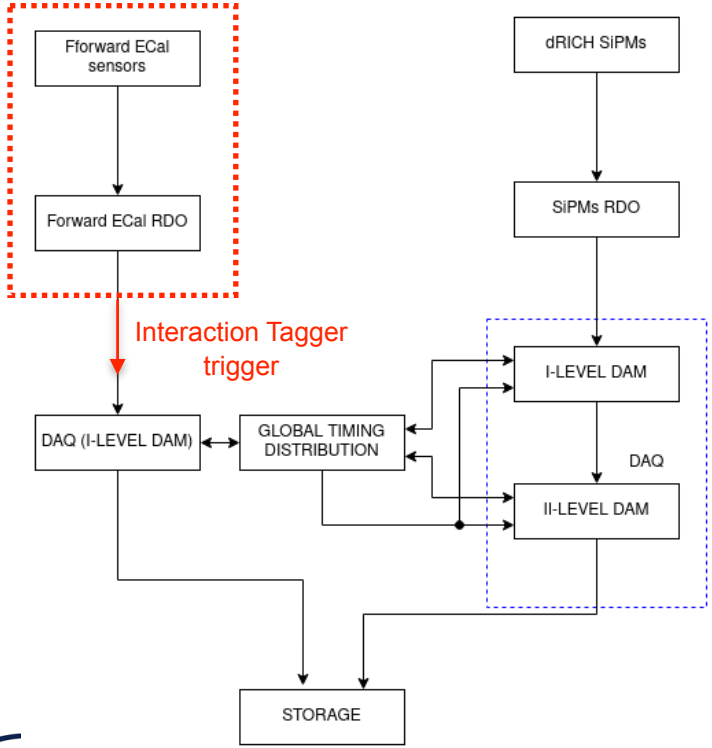
dRICH DAQ parameters	
RDO boards	1248
ALCOR64 x RDO	4
dRICH channels (total)	319488
Number of DAM L1	27
Input link in DAM L1	47
Output links in DAM L1	1
Number of DAM L2	1
Input link to DAM L2	27
Link bandwidth [Gb/s] (assumes VTRX+)	10
Interaction tagger reduction factor	1
Interaction tagger latency [s]	2,00E-03
EIC parameters	
EIC Clock [MHz]	98,522
Orbit efficiency (takes into account gap)	0,92

Bandwidth analysis		Limit
Sensor rate per channel [kHz]	300,00	4.000,00
Rate post-shutter [kHz]	55,20	800,00
Throughput to serializer [Mb/s]	34,50	788,16
Throughput from ALCOR64 [Mb/s]	276,00	
Throughput from RDO [Gb/s]	1,08	10,00
Input at each DAM I [Gbps]	50,67	470,00
Buffering capacity at DAM I [MB]	12,97	
Throughput from DAM I to DAM II [Gbps]	50,67	10,00
Output to each DAM II [Gbps]	1.368,14	270,00

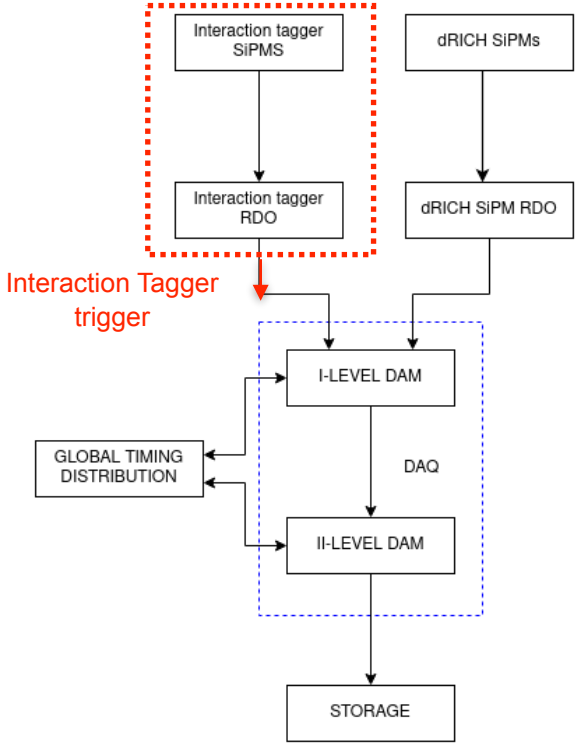
- Sensors DCR:
  3 - 300 kHZ (increasing with radiation damage → with experiment lifetime).
- Full detector throughput (FE):
  14 - 1400 Gbps
- A reduction >1/5 is needed
- EIC beams bunch spacing:
  10 ns → bunch crossing rate of 100 MHz.
- For the low interaction cross-section (DIS) → one interaction every ~ 100 bunches → interaction rate of ~1MHz
- A system tagging the (DIS) interacting bunches can solve the throughput issue (reducing to ~1/100 the data throughput)

The dRICH Interaction Tagger (dIT) possibilities

Based on information provided by other sub-detectors through the Global Timing Unit board.



Integrate it directly on the dRICH, adding few RDO and scintillating fibers layers.



Some general considerations

- The EIC bunch crossing rate is ~100 MHz
- The EIC DIS interaction rate is expected to be ~ 1 MHz
- The dIT reduction factor is roughly provided by the ratio of the dIT rate and the EIC bunch crossing rate
- The max data throughput is ~1.4 Tbsp and the DAQ limit ~270 Gbps: the minimal reduction factor is ~ 5
- **A reduction factor in the order of 10 can be achieved with dIT rate lower than 10 MHz**
- A dIT based on plastic Scintillating Fibers (SciFi) or small tiles of plastic scintillators should work
- The dIT reduction factor shall be determined by simulations (signal, background, and dIT response)

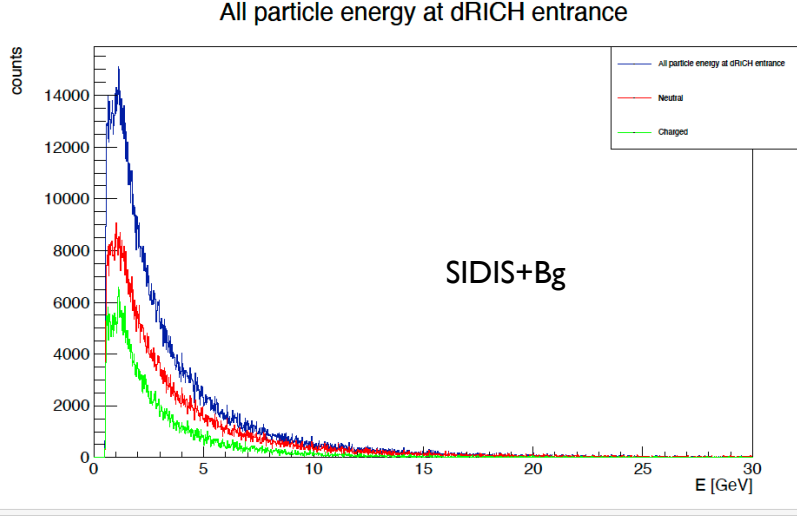
- (If possible) the **dRICH Interaction Tagger** could act as as a fast/low-resolution **Tracker** providing prompt/minimal information on particle track to be used in the fast AI-supported data reduction algorithm running on I Level DAM (under development by INFN-RM group)

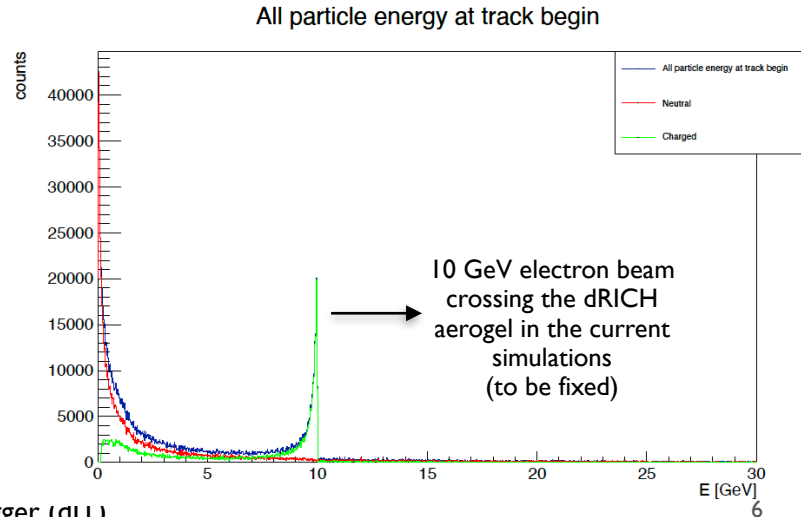
Preliminary dIT response and rates

- A plastic scintillator-based dIT is sensitive to MIPs (not only high momentum hadrons)
- Mitigation:
  - The high magnetic field will shield the dRICH from low-momentum particles
  - (Large) fibers' light quenching cuts off very low-energy particles
  - dIT neutral detection efficiency is <<10%
  - A few cm of plastic scintillator/SciFI will efficiently tag particles with energy deposition larger than 10 MeV

- Preliminary ePIC simulations include particle tracks crossing the dRICH front face
  - ~ 0.3 MHz background
  - ~ 1.8 MHz SIDIS events

- Simulations includes low-momentum and neutral particles
- dRICH geometry needs to be refined (asymmetric and beam position)
- 10 GeV electron beam crosses the aerogel
- Low energy bg needs to be checked



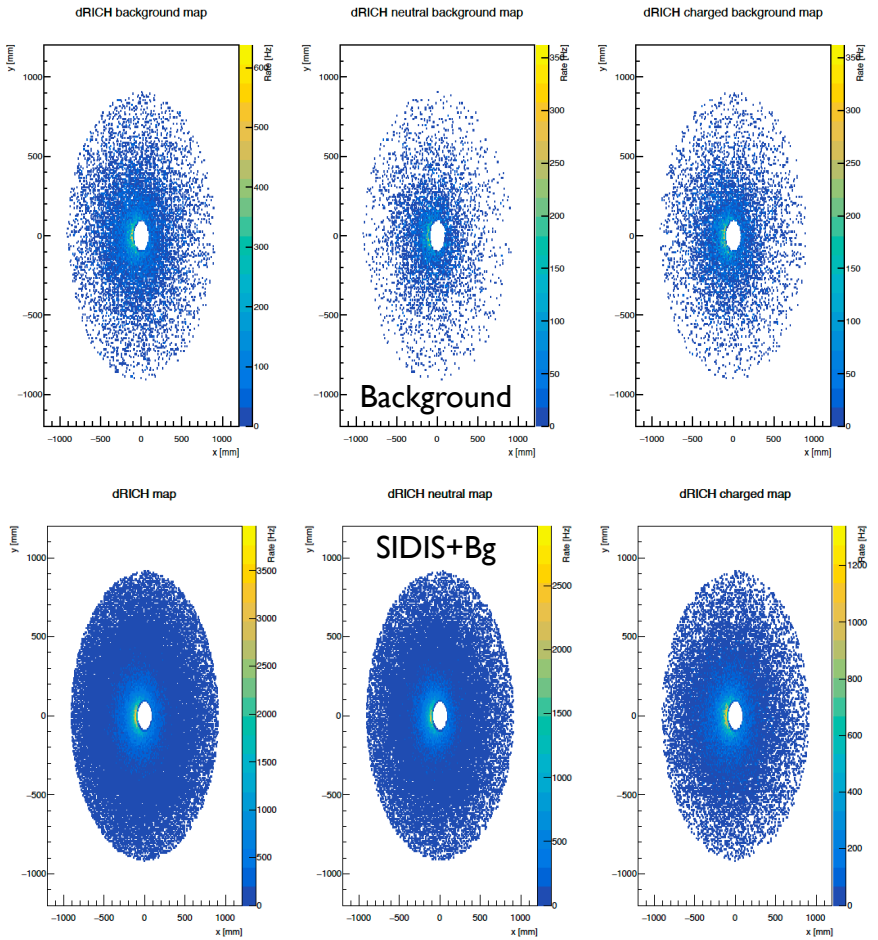


Signal/BG rates (dRICH front face)

dIT rates from ePIC SIDIS/BG simulations

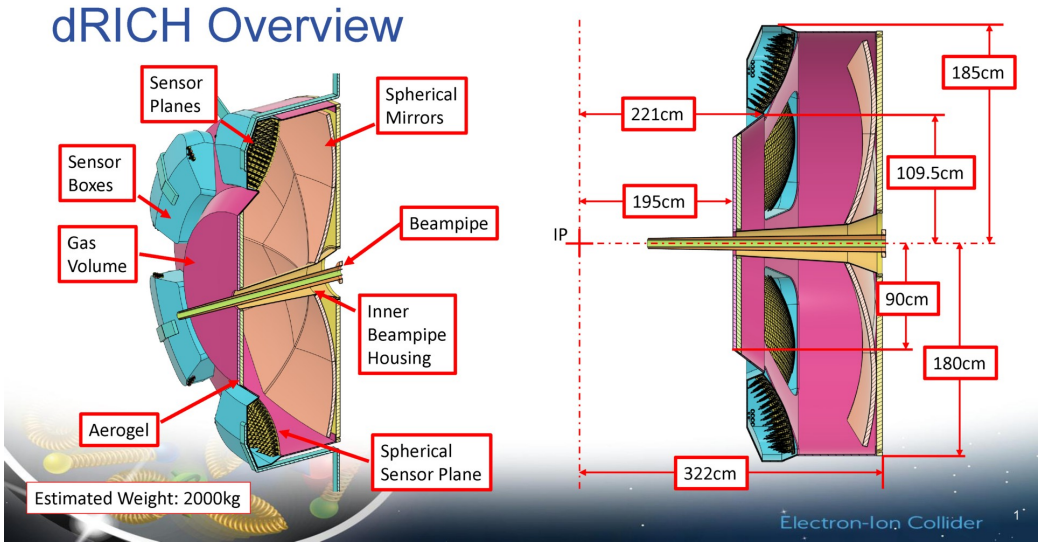
- background + SIDIS → total:
  - 0.3 MHz + 1.8 MHz = 2.1 MHz;
- x5 extra safety factor
  - dRICH front face expected rate <10 MHz

A tight time coincidence with hits in a detector located in upstream of the dRICH (dIT) could reduce the dRICH data rate by > x10



dIT preliminary design

- The signal/bg rate is not uniform on dRICH front face (larger in the central region)
- Preliminary ideas include:
  - a grid of V and H SciFi at 90°
  - a grid of diagonal 60 ° SciFi
  - small (~1x1 cm^2) in the central region and large (~10x10 cm^2) in the peripheral region plastic scintillator tiles

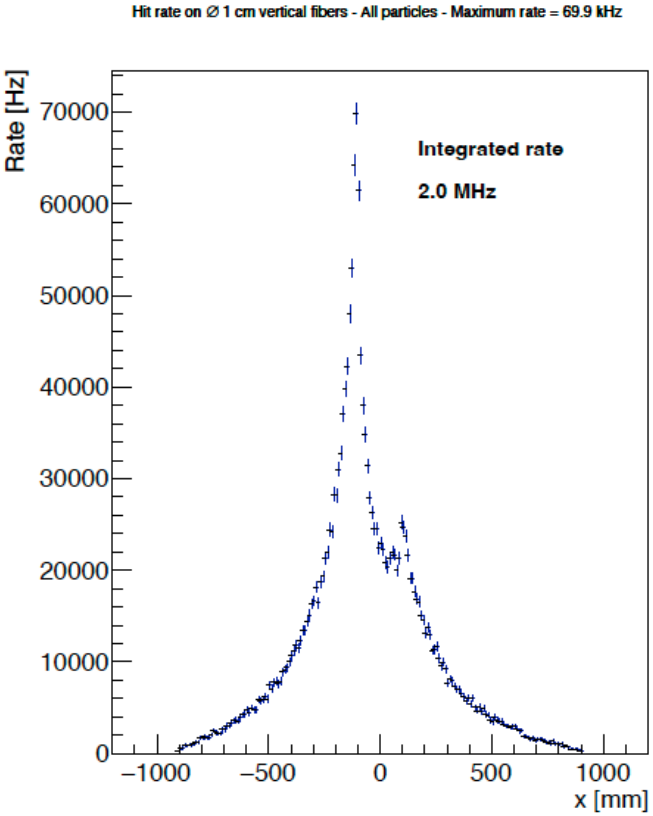


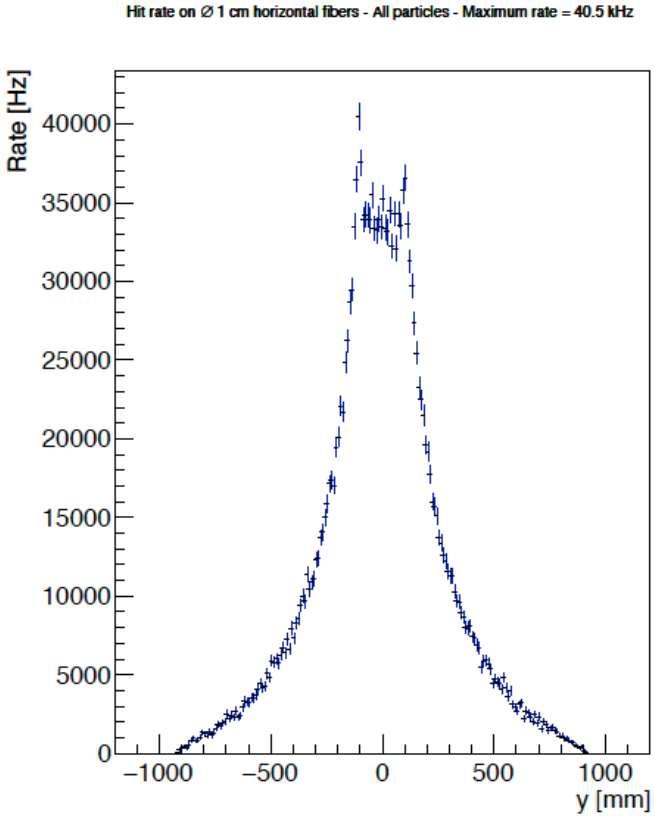
E.g:

- 2 layers, 1000 SciFi, 2 m long, and 0.5 cm ∅;
- SciFi:
  - attenuation length ~ 4 m
  - time rising edge ~ 100 ps
  - hit duration ~ 10-20 ns
- SciFi optical coupled with SiPMs cabled to RDOs;
- Two-sides readout → 4k SiPMs & 4k channels (dRICH 320k channels)
- 256 channels for RDO →need to add 16 RDOs
- Cost estimate: ~ $150k

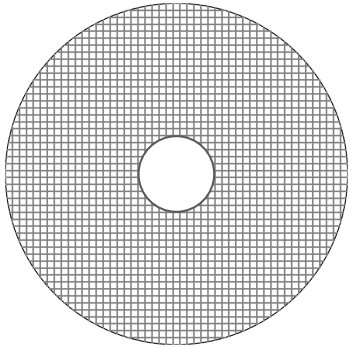
Signal+BG rates on SciFi fibers

- Signal rate (SIDIS events): d=1 cm fibers. Maximum = 70 kHz



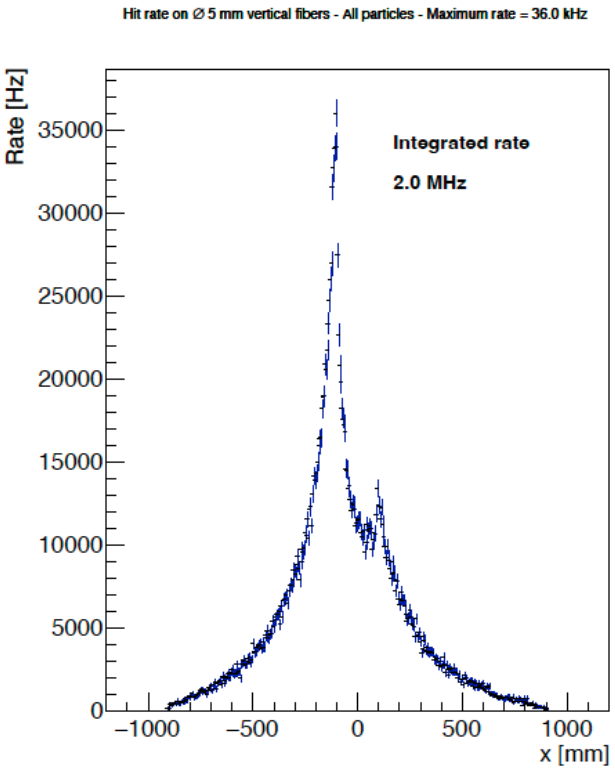


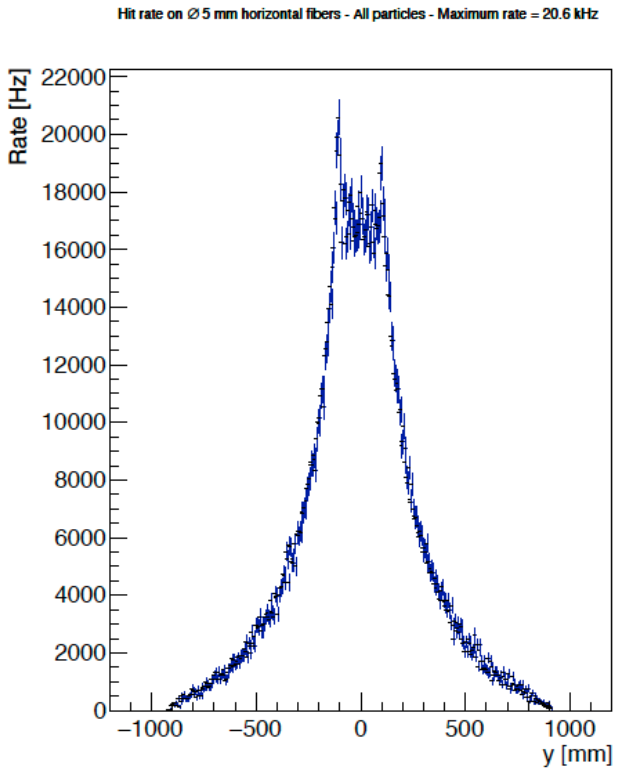
H-V fibers at 90°



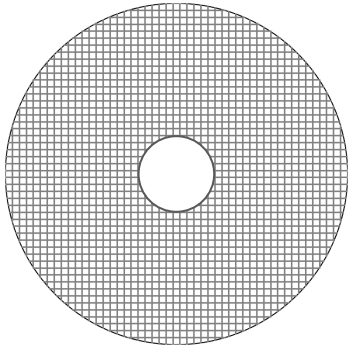
Signal+BG rates on SciFi fibers

- Signal rate (SIDIS events): d= 5 mm fibers. Maximum = 35 kHz





H-V fibers at 90°

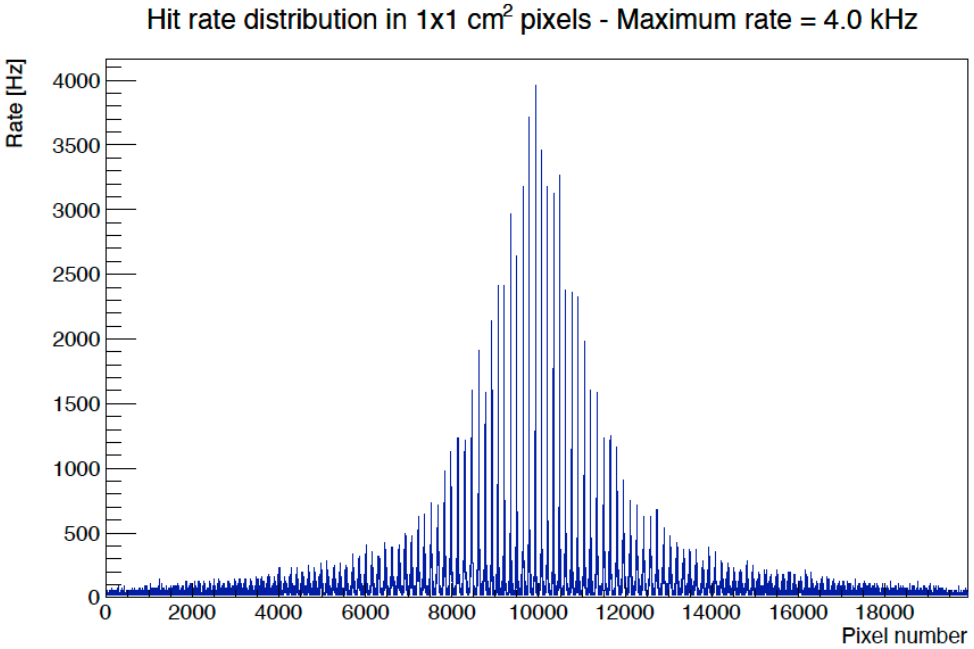


Smaller dimeter fibers requires more channels (~4k), increasing cost and complexity

dRICH Interaction Tagger (dIT)

Signal/BG rates on tiles

- Signal rate (SIDIS+Bg events): 1x1 cm2 and 2x2 cm2 tiles



- Maximum rates: 4 kHz
- Number of channels grows up to ~ 45k (1x1 cm^2)
- Hybrid design with different tile sizes (1x1, 2x2, 5x5, and 10x10 cm^2) to keep the number of channels low and sustainable rates

Work plan

- 2024
  - discuss the dIT concept at the ePIC Collaboration Meeting
  - Simulate full low-energy particle spectrum on the dRICH front face
  - Learning and practicing the DAQ chain based on dRICH RDO

- 2025
  - Procure different SciFi size samples and SiPMs for testing/prototyping
  - Implement the readout chain at INFN-GE
  - Testing the SciFi/SiPM coupling
  - Testing the dIT prototype response to low-energy particles
  - Optimize thresholds to reduce low-energy particle background
  - Implement SciFi measured response in ePIC simulation
  - Finalize IdT design (pre-CDR)
  - Integrate the dIT into the dRICH mechanical design
  - present results to Summer ePIC Collaboration Meeting

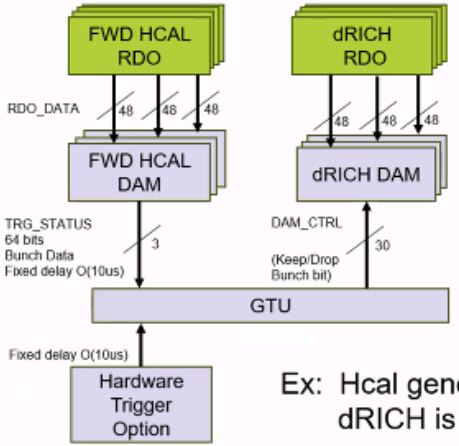
Conclusions

- The dRICH throughput can reach a warning level of 1.4 Tbps during its lifetime
- A dRICH Interaction Tagger (dIT) integrated into the dRICH, with a cost-effective design, can be an efficient solution with minimal impact on cost and ePIC detector design
- Preliminary simulations provided a rough estimate of dIT signal and background rates
- A thorough estimate, including low energy particles reaching the dRICH front face, is necessary to finalise the dIT design
- A SciFi-based IT can provide prompt information on particle track location to AI-based selection algorithms running on DAM-I and DAM-II FPGAs
- At the EIC start, the dRICH throughput is expected to be ~ 14 Gbps (low) allowing a complete characterization and optimization of the dIT performance

Backup slides

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.*



Ex: Hcal generates trigger dRICH is triggered

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.

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