Network-distributed Data Acquisition System for Photoproduction Experiments with LEPS2

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for the LEPS2 Collaboration

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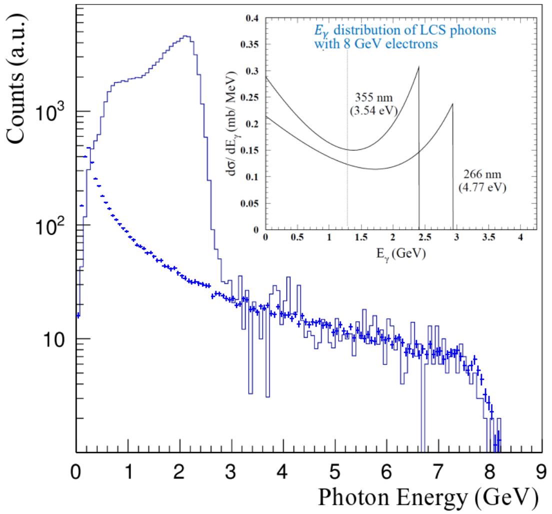
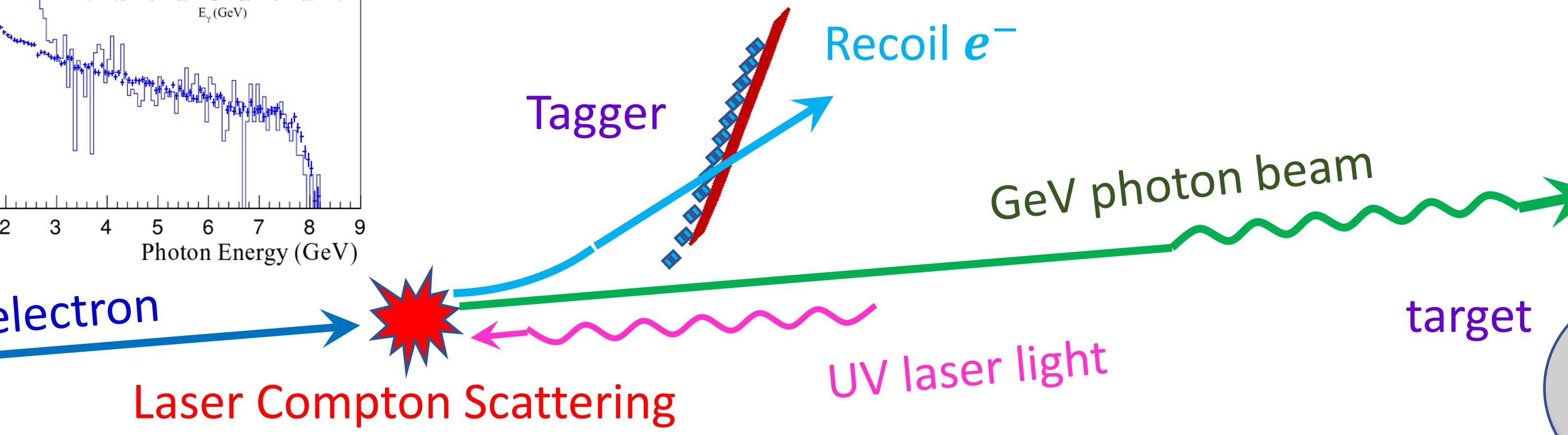
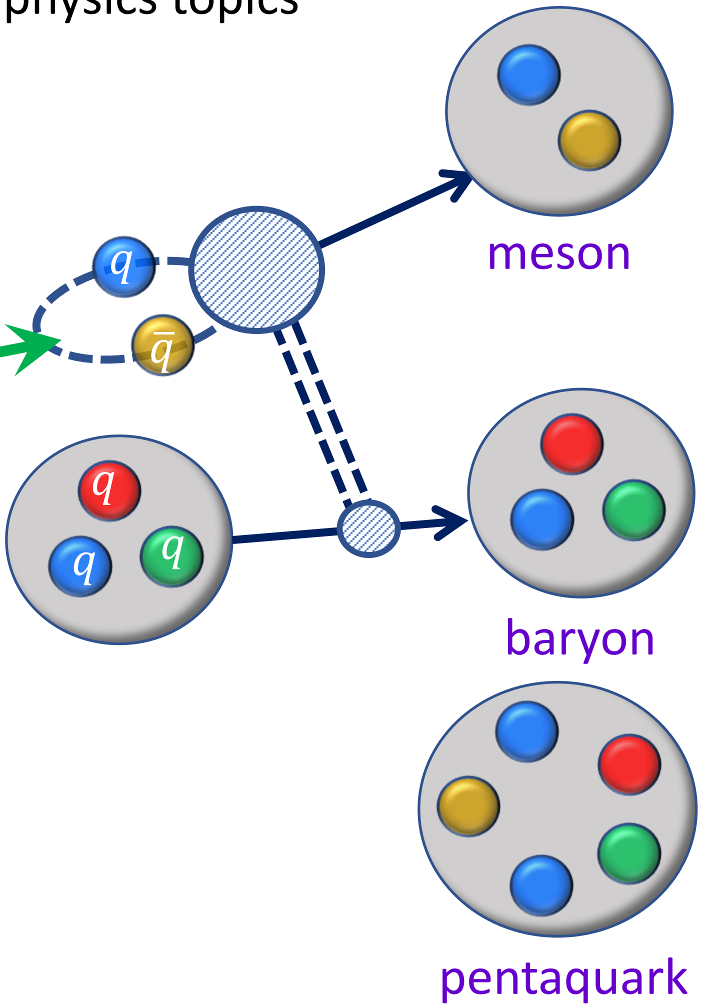
LEPS2 Experiment at SPring-8*

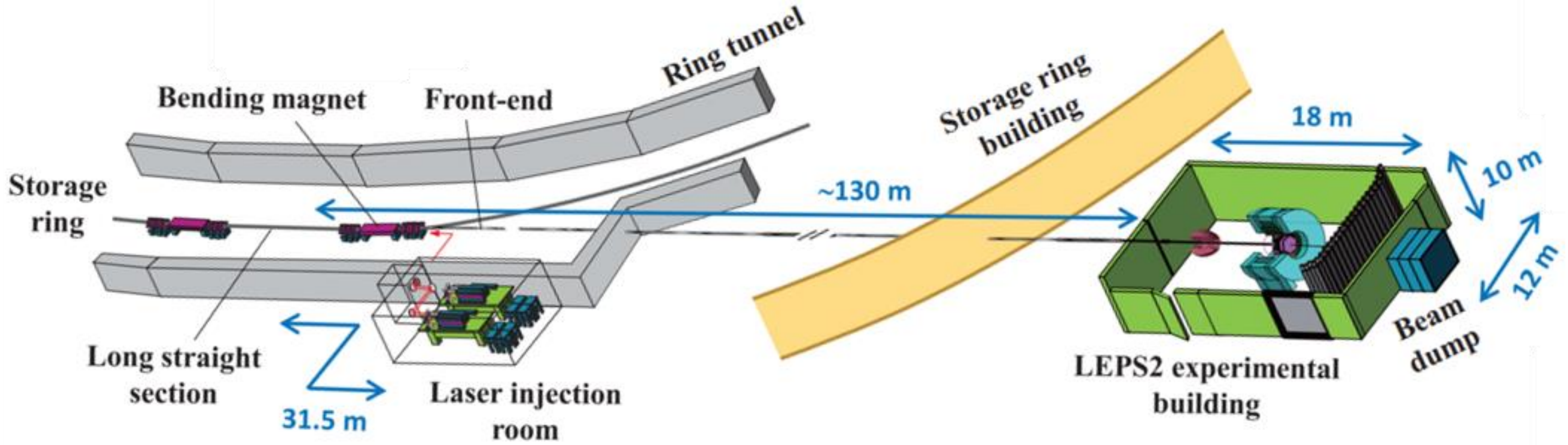
*Super Photon Ring 8 GeV

The LEPS2 program entails a broad range of hadronic physics topics with polarized photon beams.

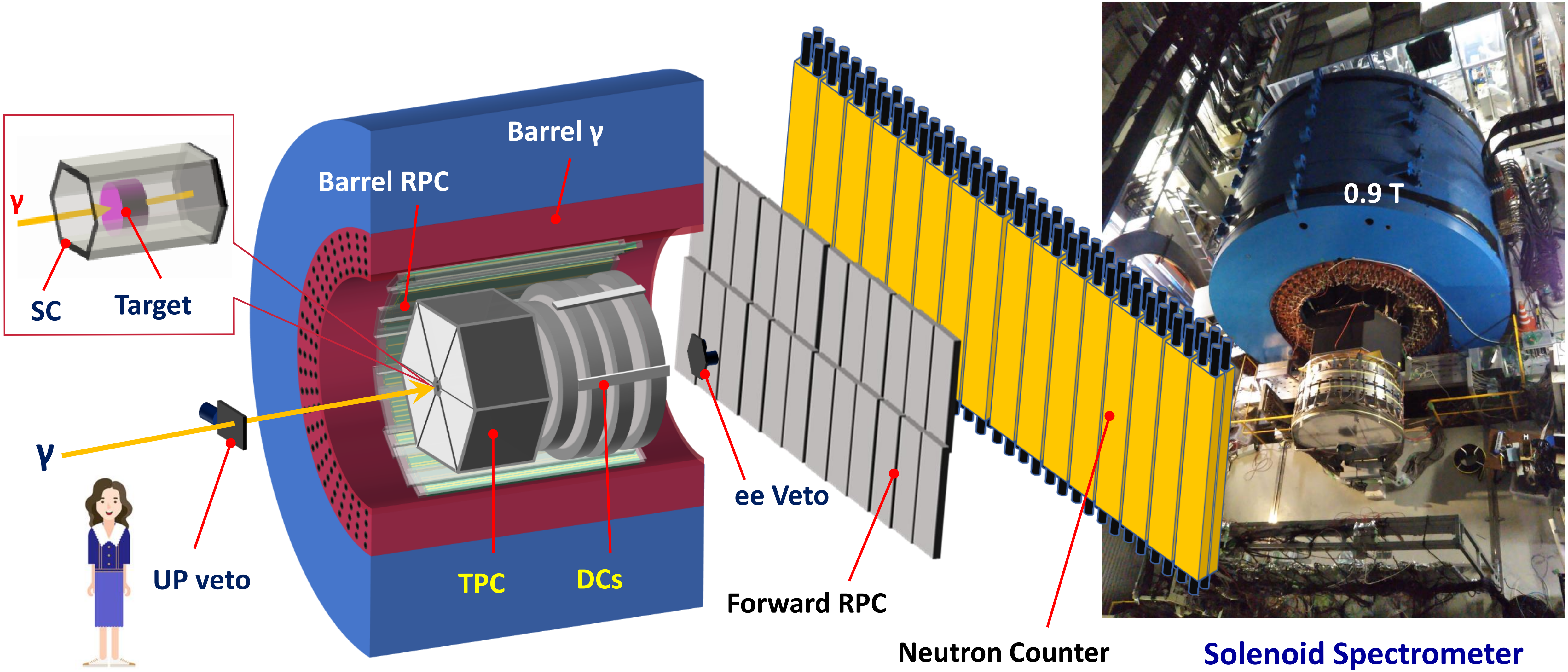






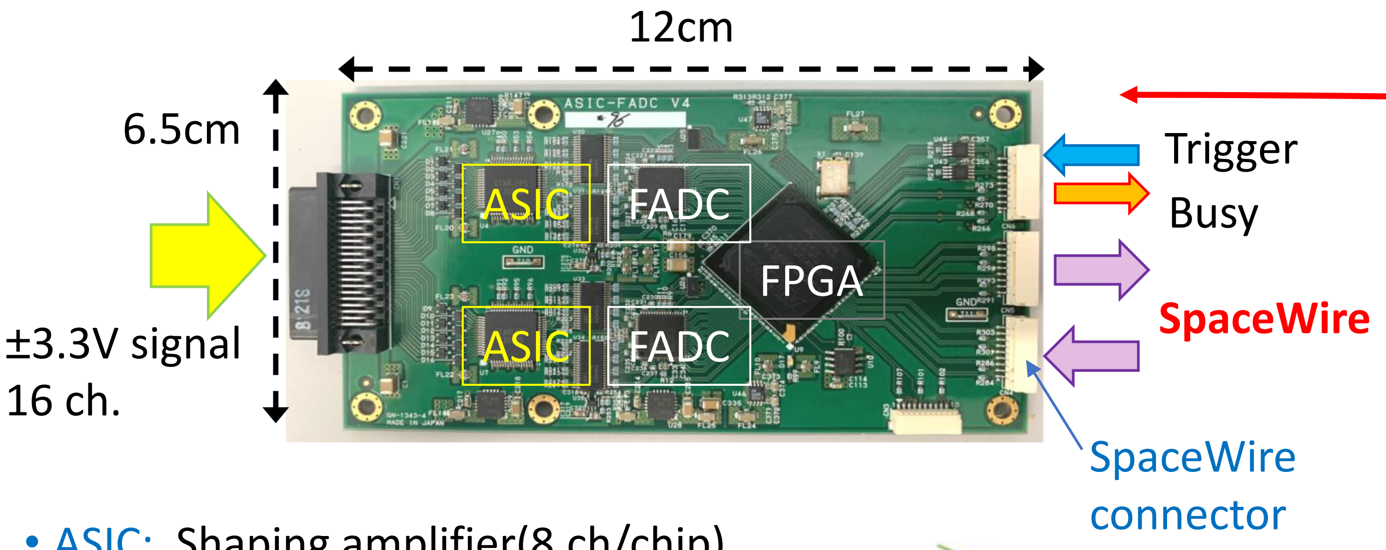


LEPS2 Detector



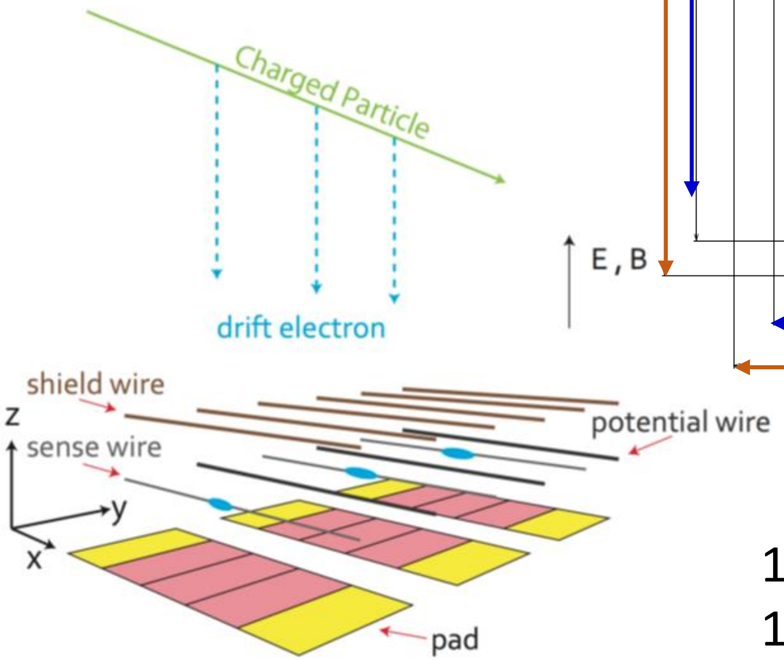
Solenoid Spectrometer
@ LEPS2/SPring-8

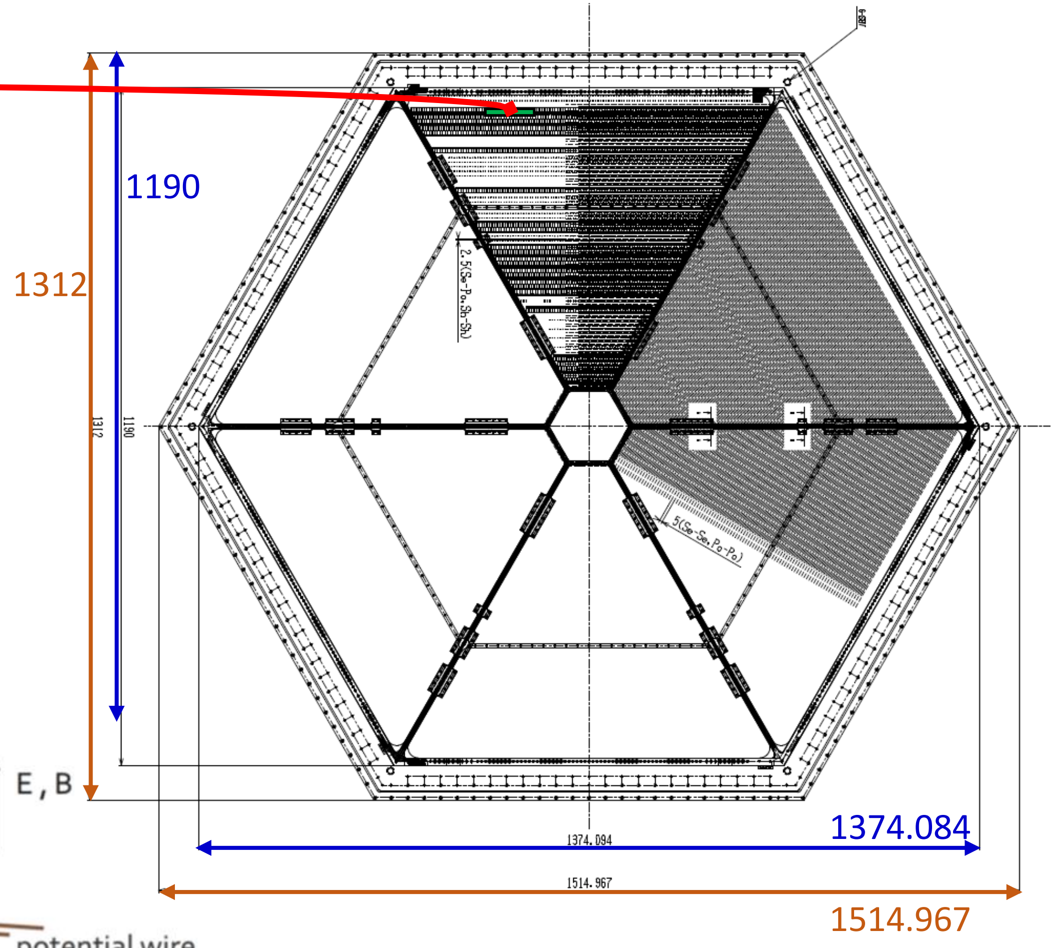
Time Projection Chamber (TPC)



- ASIC: Shaping amplifier(8 ch/chip),
  Gain: 1 V/pC ,
  Signal width: 200~400 ns
- FADC: AD9257(8 ch/chip)
  Precision: 14 bit
  Input voltage range: 2 V
  Sampling frequency: 40 MSPS
- Power consumption: ~230 mW/ch

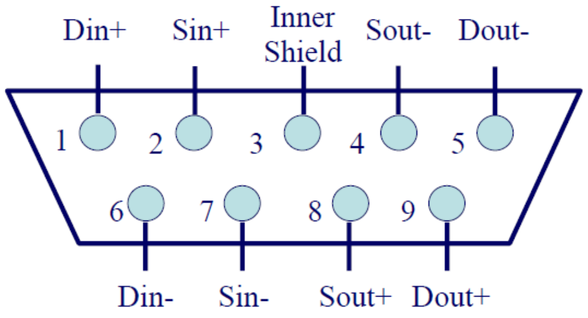
*Developed by KEK electronics group.and RCNP





10K pad signals are read out via 16-ch shaping amp + FADC boards.

SpaceWire



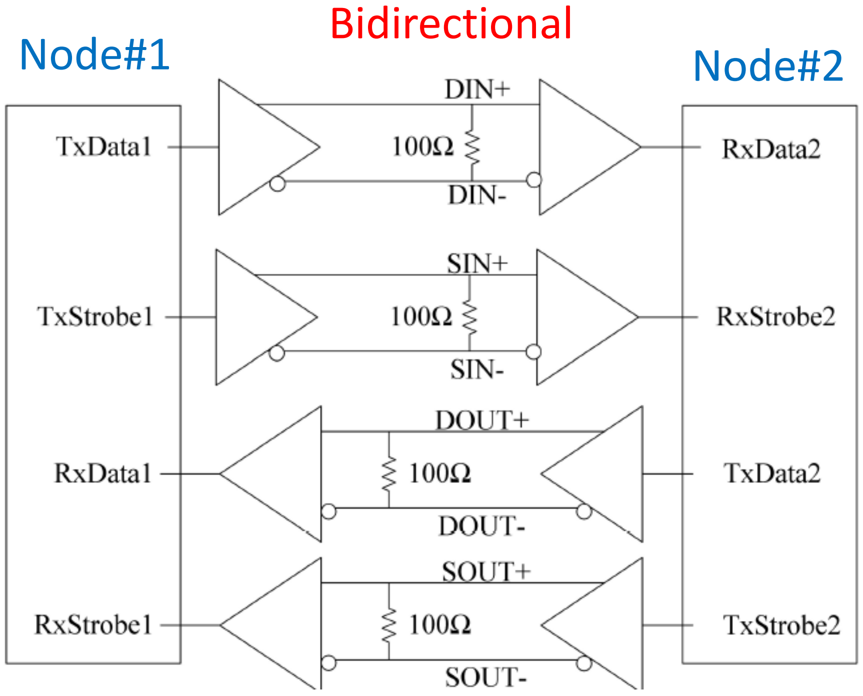
SpaceWire connector pin-out

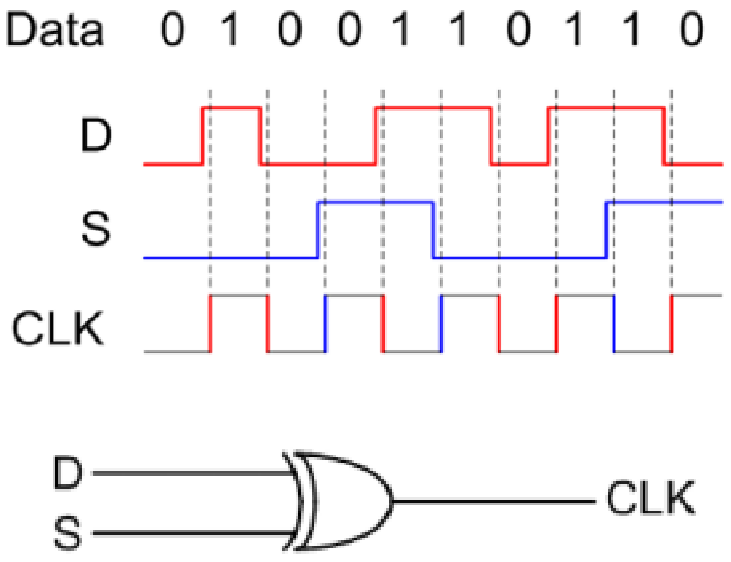
- 8 Signal wires
- 9-pin micro-miniature D-type

SpaceWire uses Data Strobe (DS) encoding to send information over the LVDS links Data values transmitted directly

- Clock encoded with data to form strobe
- XORing data and strobe recovers clock
- Provides improved jitter/skew tolerance compared to data/clock encoding

The data and strobe signals are transmitted differentially using **LVDS**.
A SpaceWire link contains two sets of differential signals, one set transmitting the D and S signals in one direction and the other set transmitting D and S in the opposite direction.





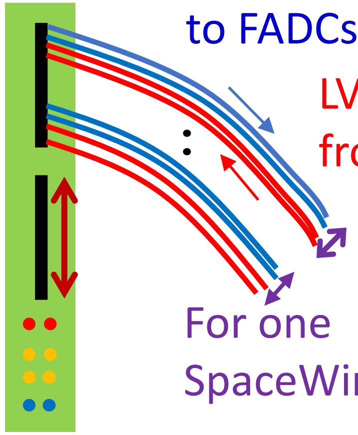
S. Parkes, Space OPS Conference 2004.

TPC Readout System (1) : SpaceWire Network

Trigger-IO module distributes the trigger signal to the FADC boards using its LVDS output and generates the NIM busy signal from its event-tag buffer busy + LVDS busy signal from FADCs

HSMC connector
: Configurable I/O Standards
1.5/1.8/2.5/3.3V

DE10 Stnadard board
Cyclone V Soc FPGA
SoC—5CSXFC6D6F31C6N



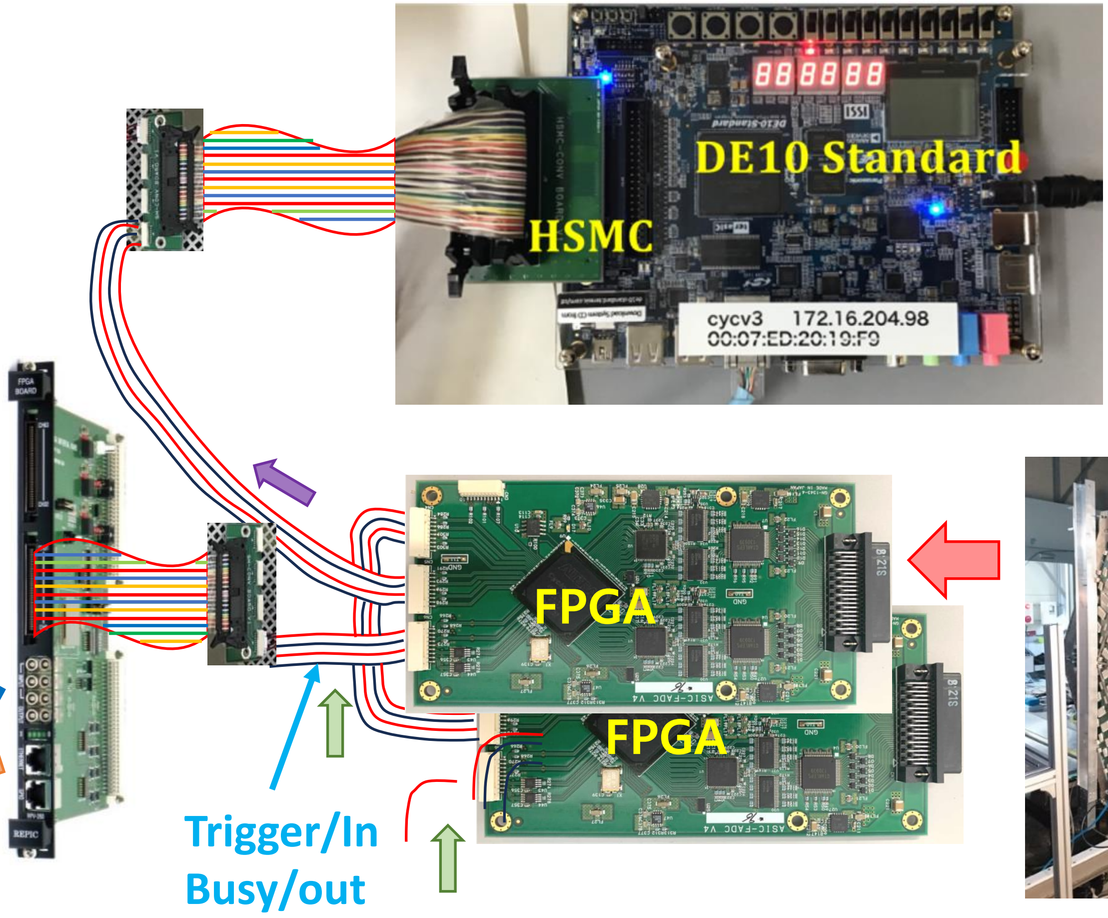
LVDS Output to FADCs

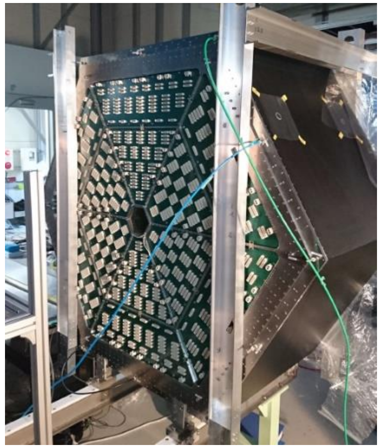
LVDS Input from FADCs

For one SpaceWire port

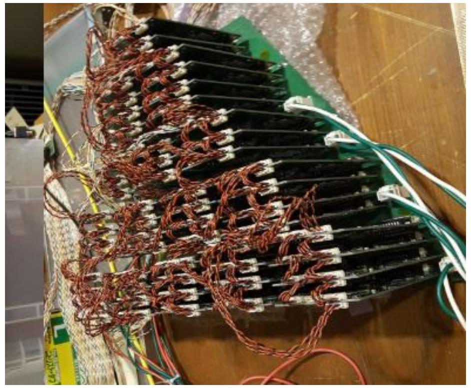
Trigger-IO

NIM Input
: Trigger
: 4 bit event tag
NIM Output
: Busy signal from connected all FADCs in series





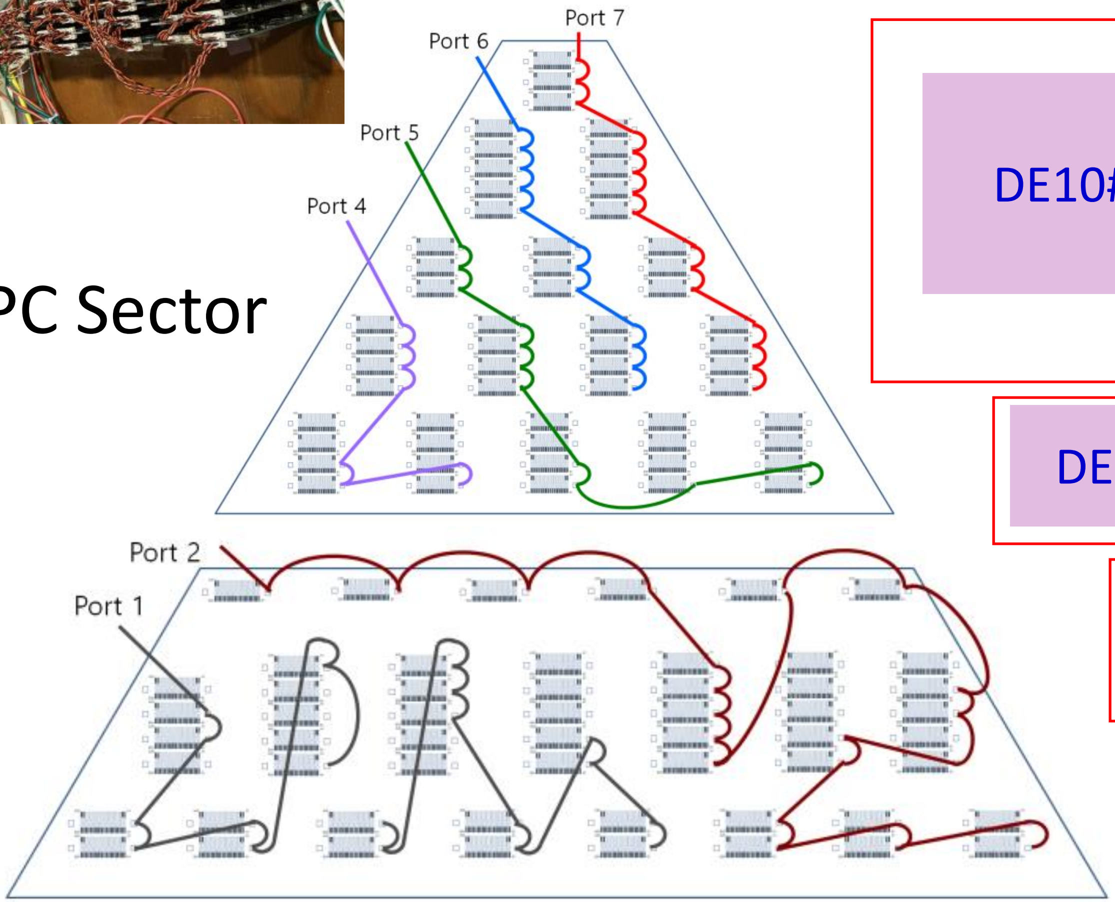
TPC Readout System (2) : SpaceWire Network

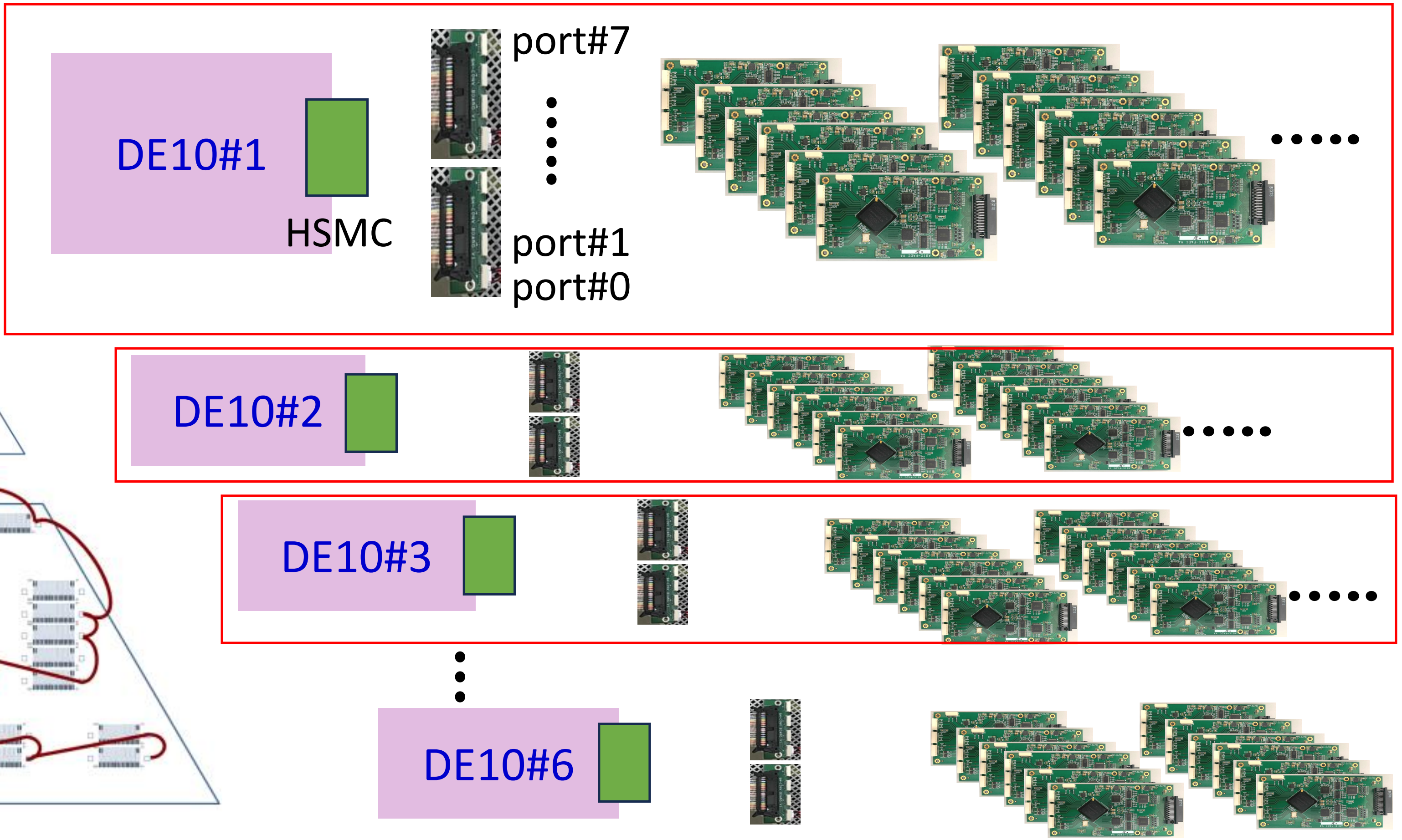


We are using 6 SpaceWire ports per DE10 board and 6 DE10s.

port#1	port#2	port#4	port#5	port#6	port#7	total
19	22	8	12	12	15	88

TPC Sector





TPC Readout System (3) : SpaceWire RMAP Protocol

RMAP Command

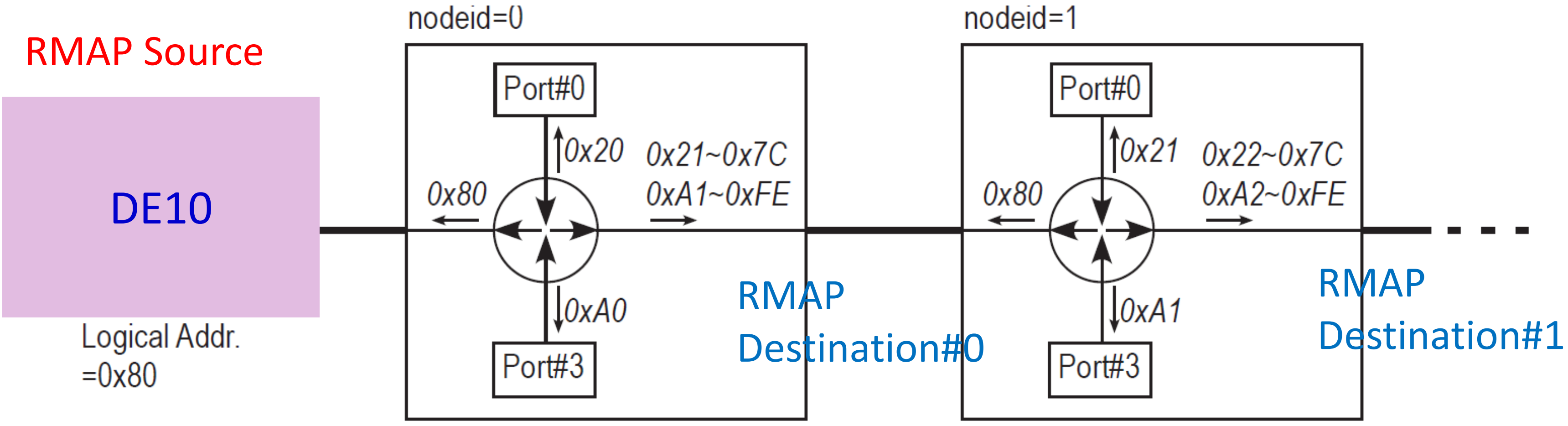
Destination Path Address	Destination Logical Address	Protocol ID		Frame Packet	EOP

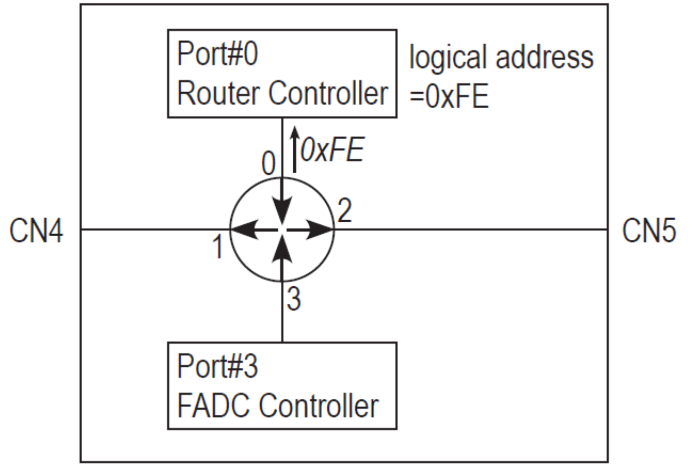
Reply

Source Path Address	Source Logical Address	Protocol ID		Frame Packet	EOP

12 bit 8 bit

Packet Type 8 bit
Command (Write, Read) / Source Path Address Length

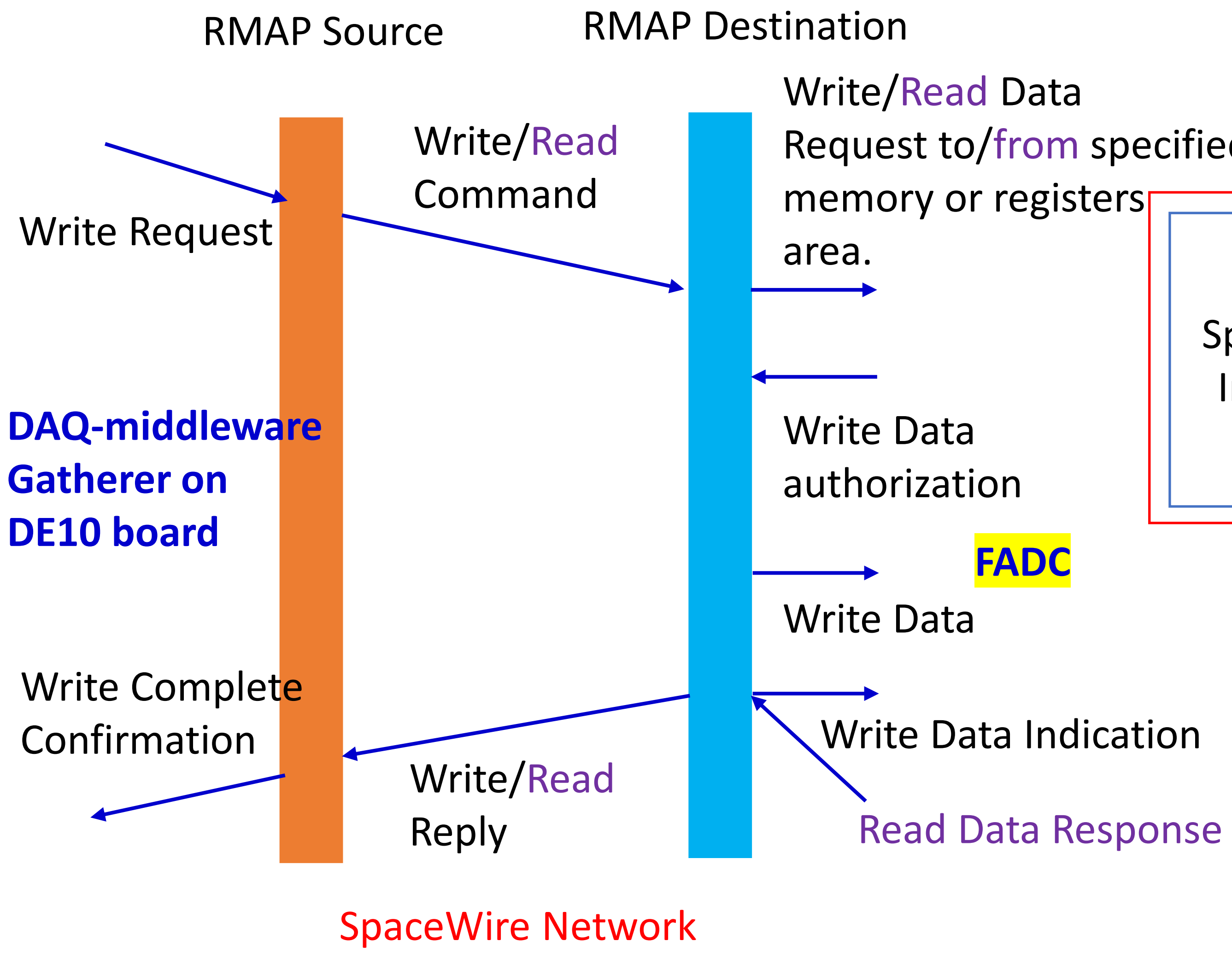


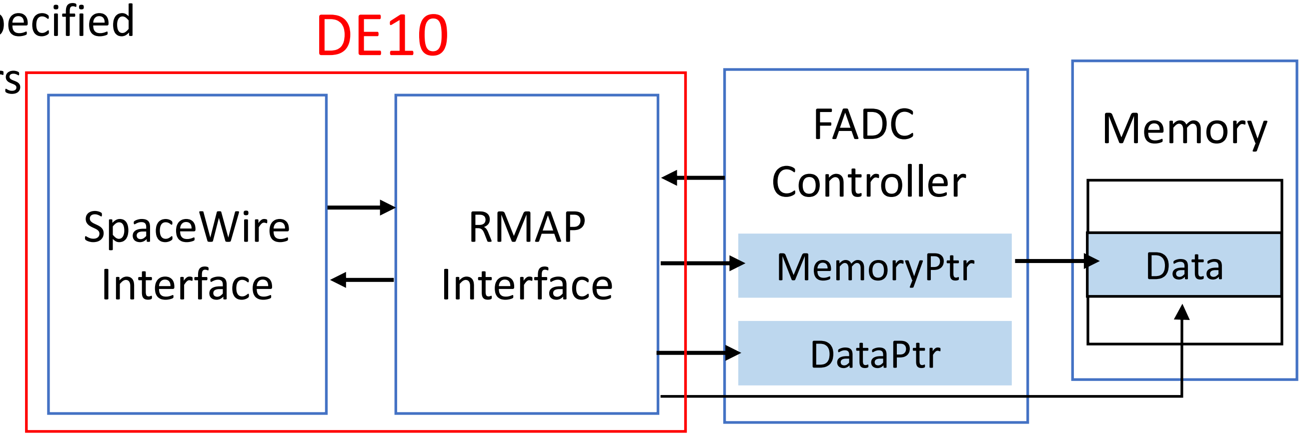


- RMAP access is available via DE10 board with 8 bits logical address.
- The maximum number for cascade connection is 93.
- We read out 88 FADC boards per DE10.

Initial logical address 0xFE is assigned when FADC is powered on

TPC Readout System (4) : SpaceWire RMAP Protocol



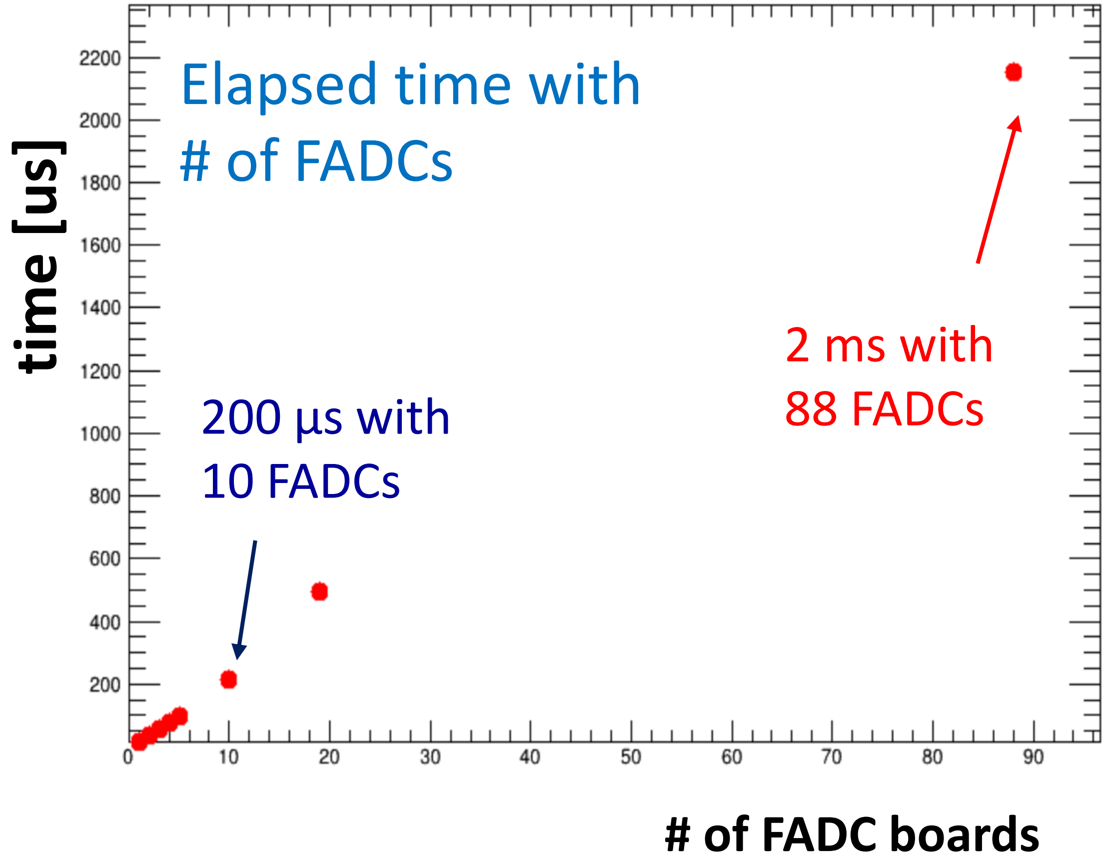


- Remote memory access protocol.
- Provide a means of writing/reading to/from registers or memory on the SpaceWire node over the SpaceWire network.
- It is simple and effective.
- It is flexible to encompass diverse applications.

Command and data are both checked with CRCs before data are written and sent.

TPC Readout System (5) : Performance

Time to access 88 FADCs with a single command → ~2ms

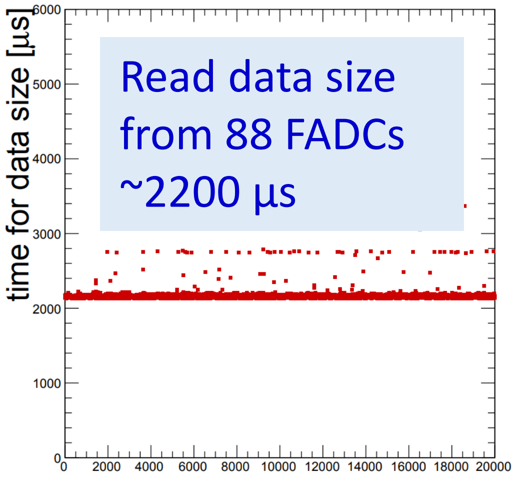


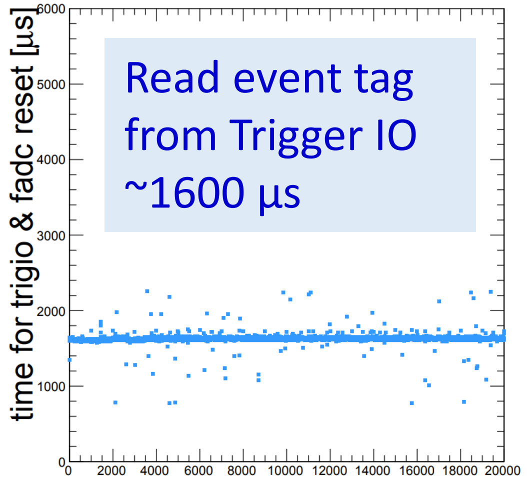
SpaceWire network

3 commands for 88 FADCs → up to 6ms

1. Read trigger status from a FADC register
2. Read data size
3. Read data from only FADCs with non-zero data size.

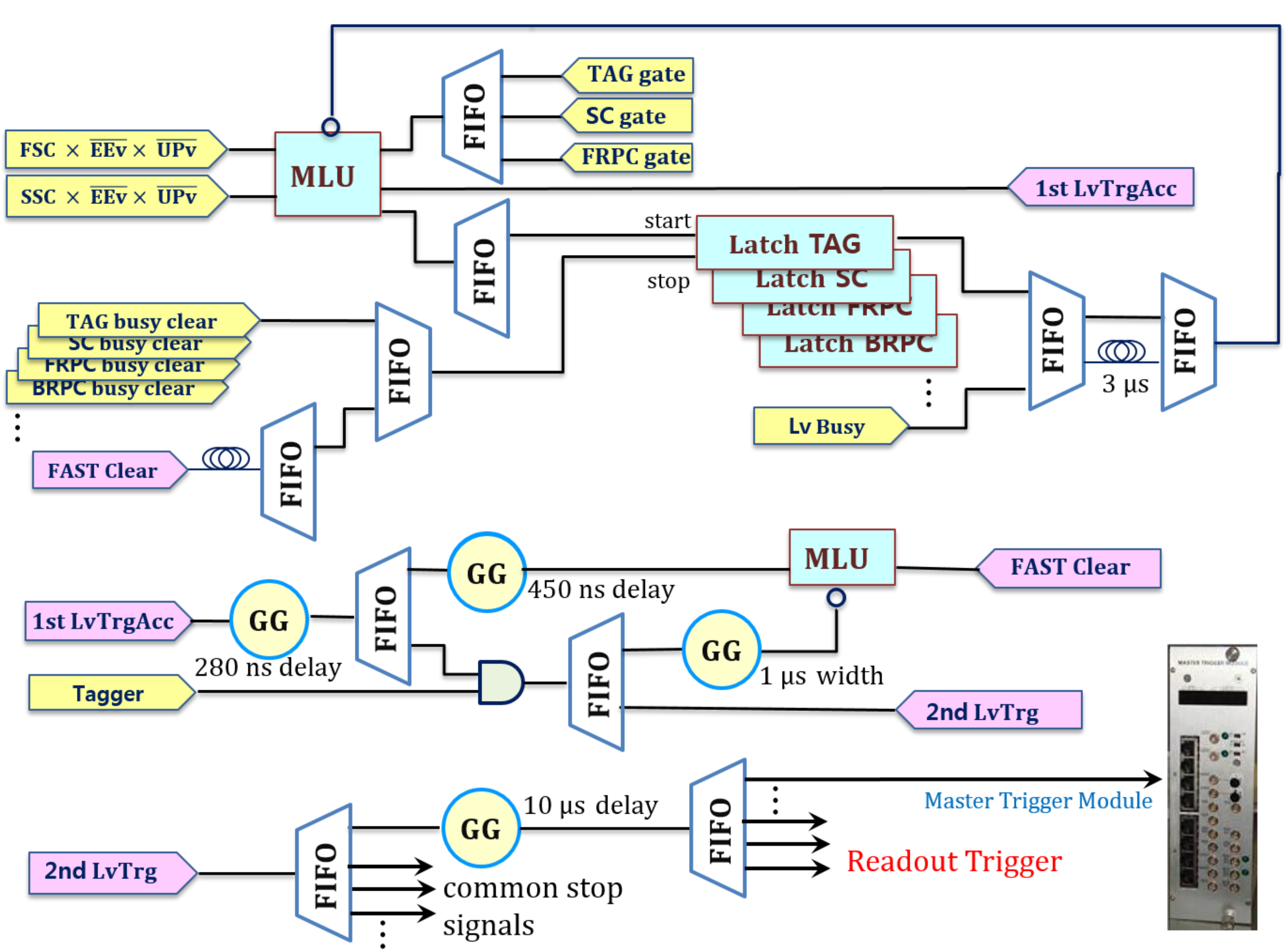
Getting the event tag from Trigger IO module →~1.6 ms

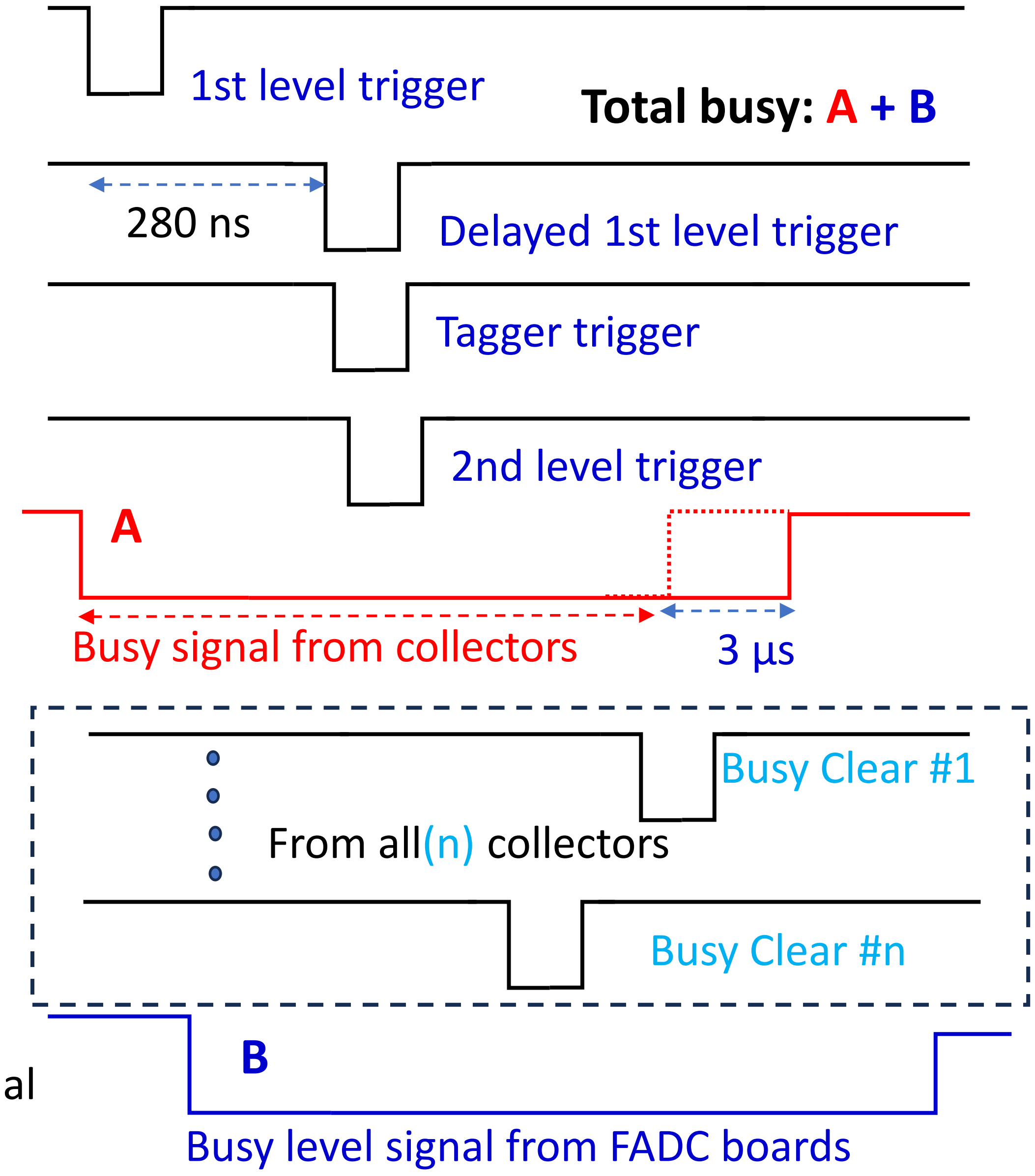




In order to improve the speed of the DAQ, we need to reduce # of FADC boards per DE10 and to have DE10 directly read the event tag through its own GPIO. → Current DAQ accept rate is 100~150Hz

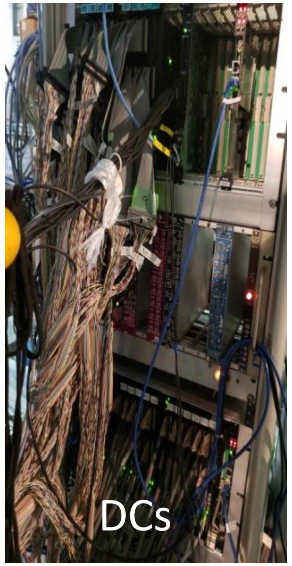
LEPS2 Trigger System

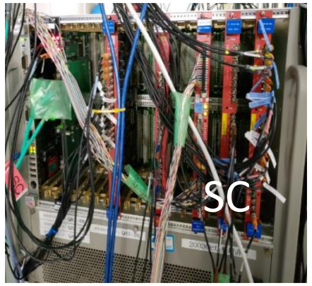


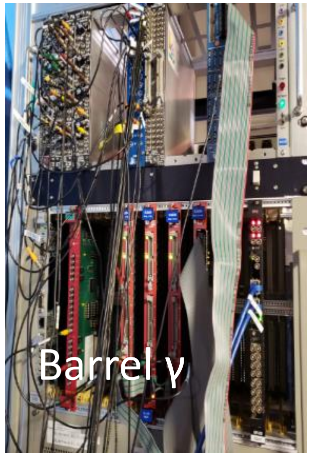


GNN-570 generates the event-tag signal and distribute it to all FEE system.

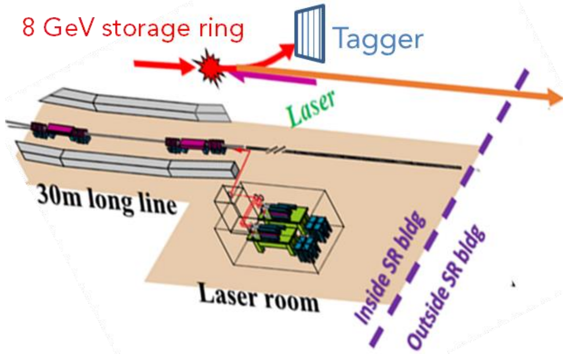
LEPS2 Front-end Electronics

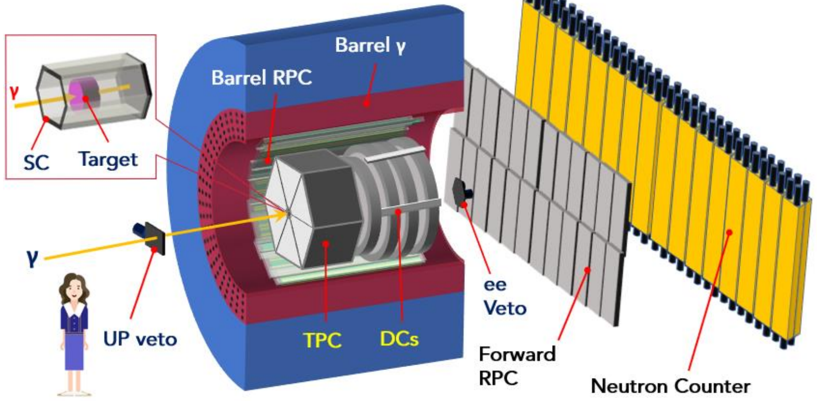




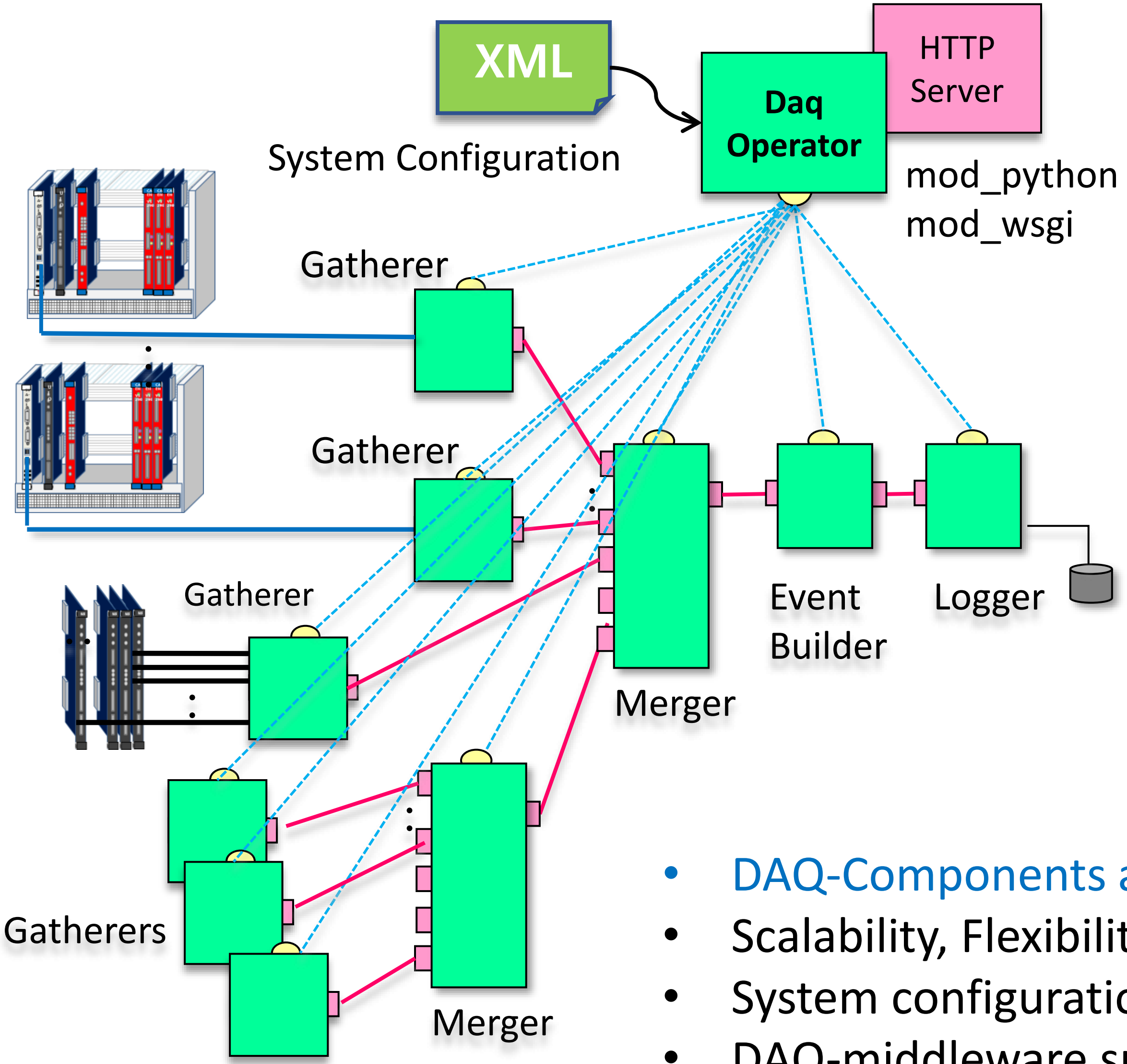


Detector	# of channels	TDC module	ADC module	Controller
Tagger	184	V1190A x 2	V792 x 2	SVA041 x 2
Start Counter	25	V1290A x 1	V965 x 2	SVA041 x 1
DC	1824	RPV260 x 29		
Forward RPC	288	V1290A x 9	FERA System	SVA051 x 2
Barrel Gamma	192 (TDC) 288 (ADC)	V1190A x 2	V792 x 9	SVA051 x 2 SVA061 x 1
Barrel RPC	480 (TDC) 240 (ADC)	MTDC32 x 15	DRS4 QDC x 16	SVA051 x 2
TPC	8928	16ch-FADC x 558		DE10 x 6
AC2	36	V1190A for BG	V792 x 2	
Neutron Counter	96	V1190A	V792 x 3	SVA061 x 1

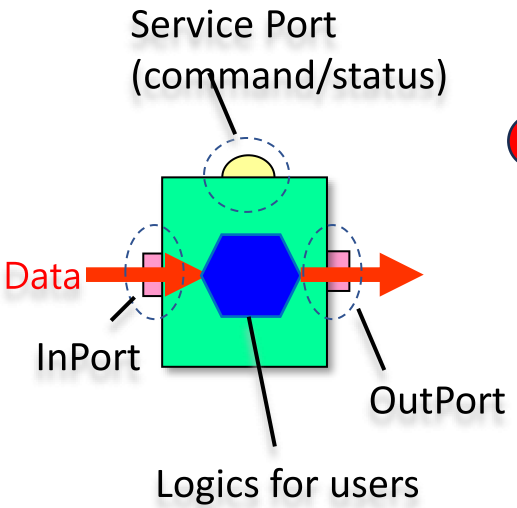


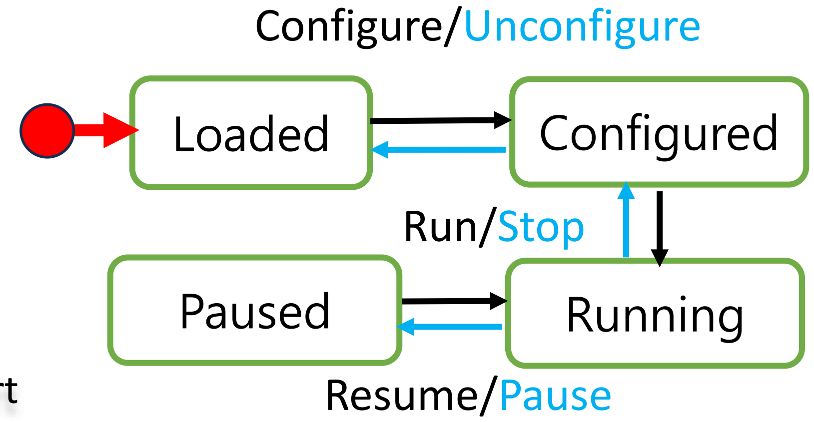


DAQ Middleware



- General-purpose framework for network-based DAQ software based on RT-Middleware
  (Robot Technology Middleware)



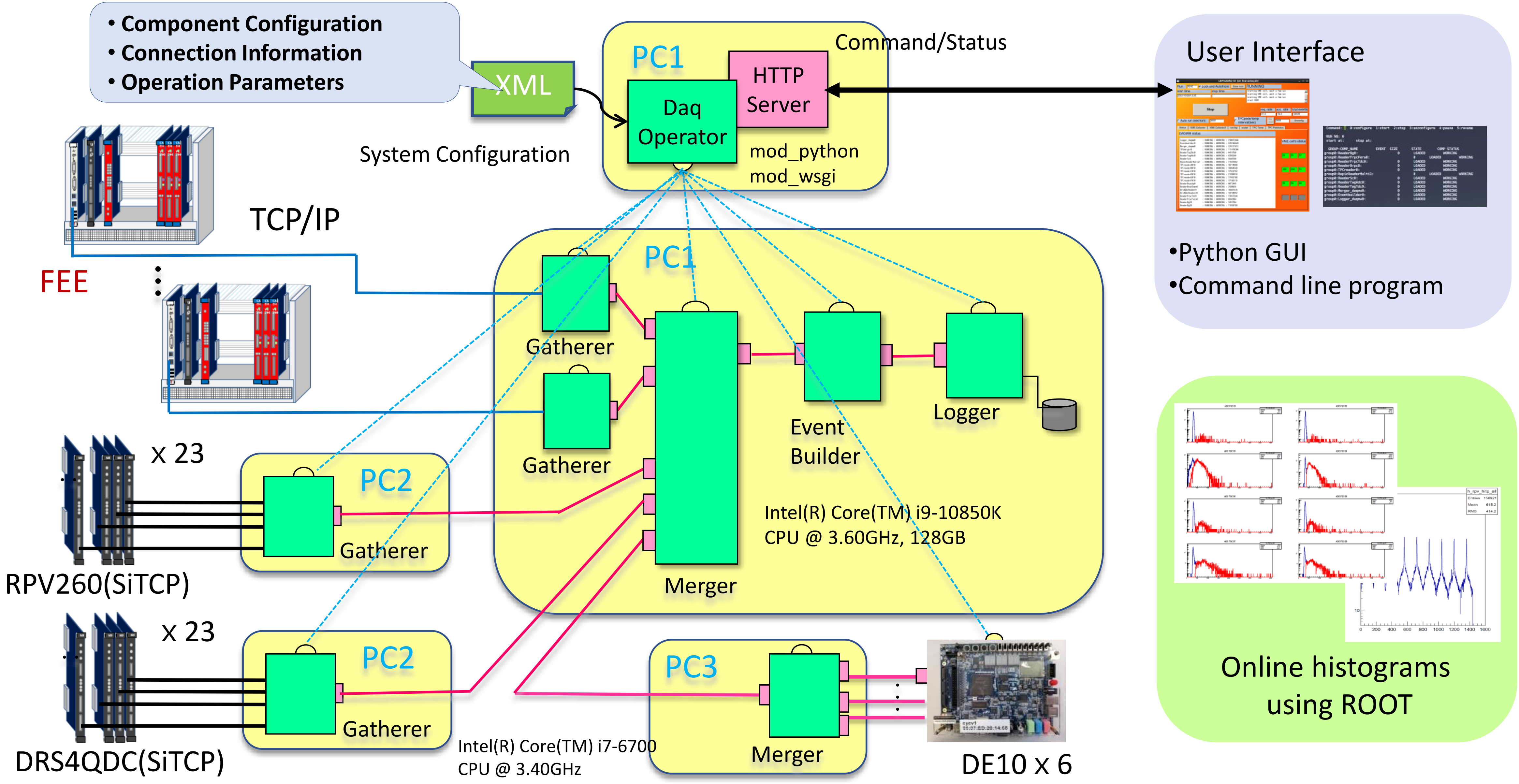


State transition diagram of the DAQ-Middleware system

- DAQ-Components are assigned to single processes independently
- Scalability, Flexibility, Location-transparency, and Reusability
- System configurations are expressed in XML.
- DAQ-middleware supports a data transfer between DAQ components.
- Users write core logics and implement them into DAQ components.

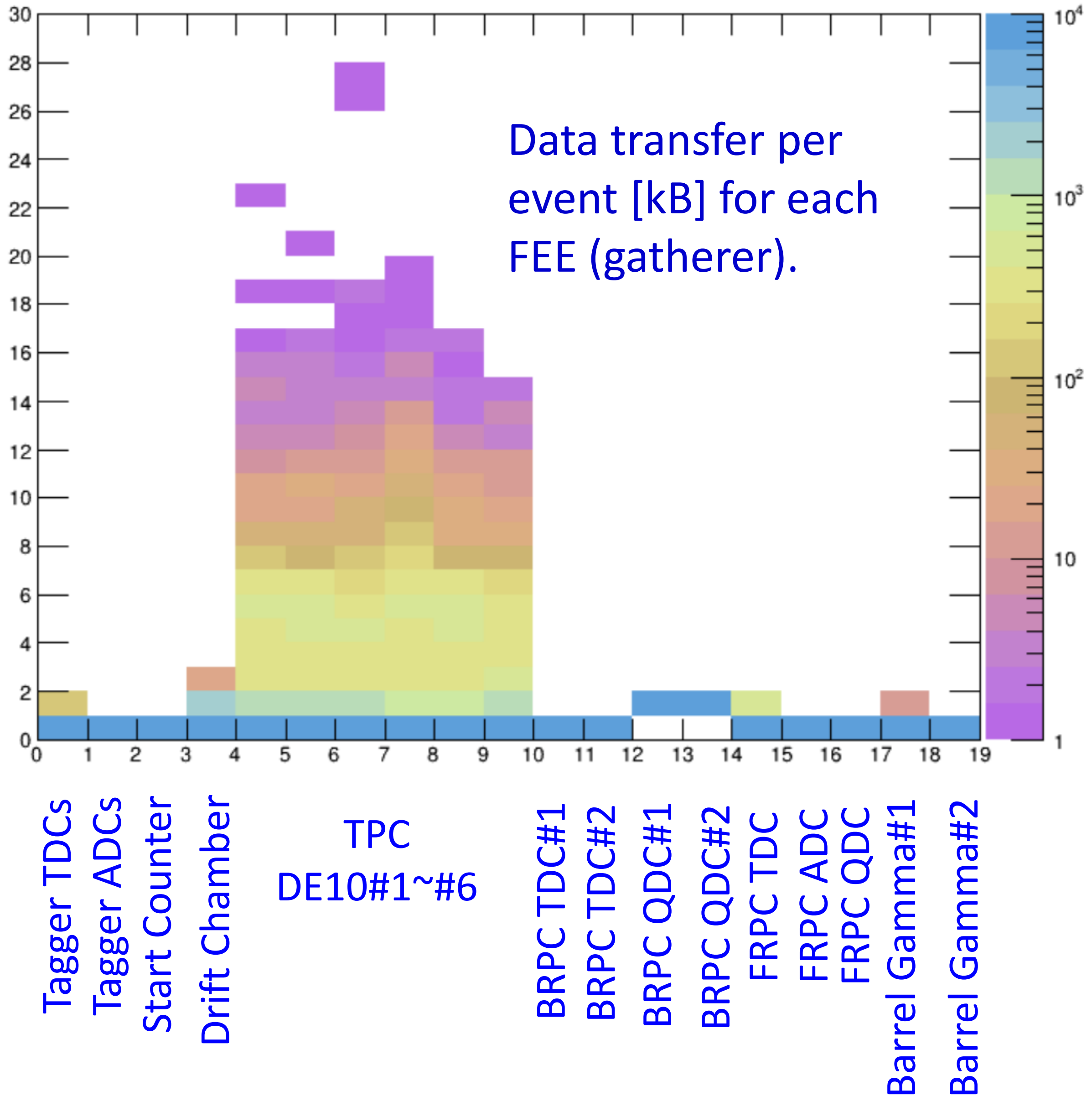
https://daqmw.kek.jp/

LEPS2 DAQ System

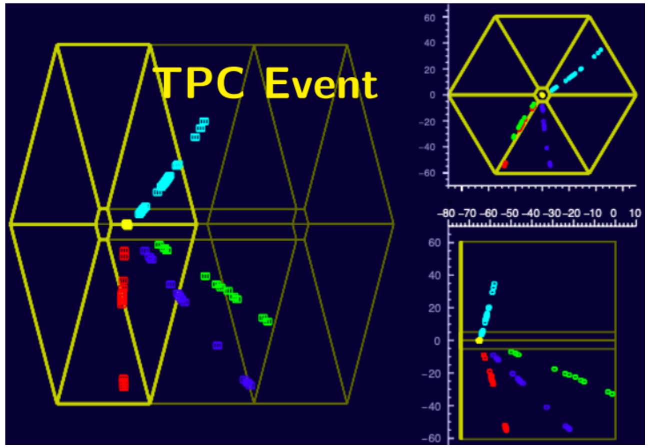


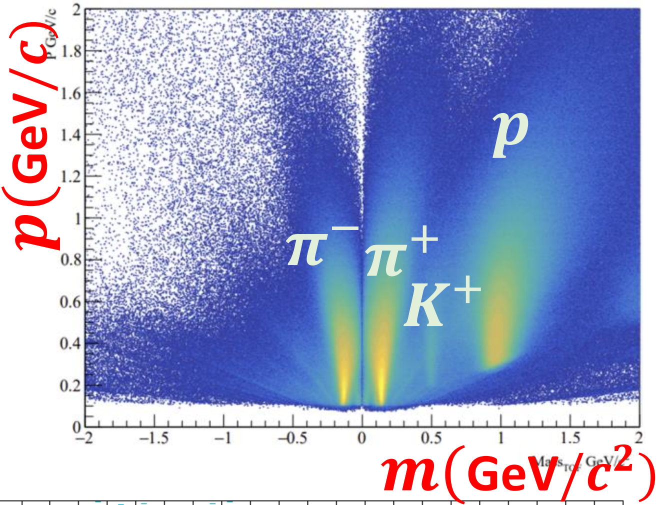
LEPS2 DAQ Performance 2022AB, 2023A Physics Run

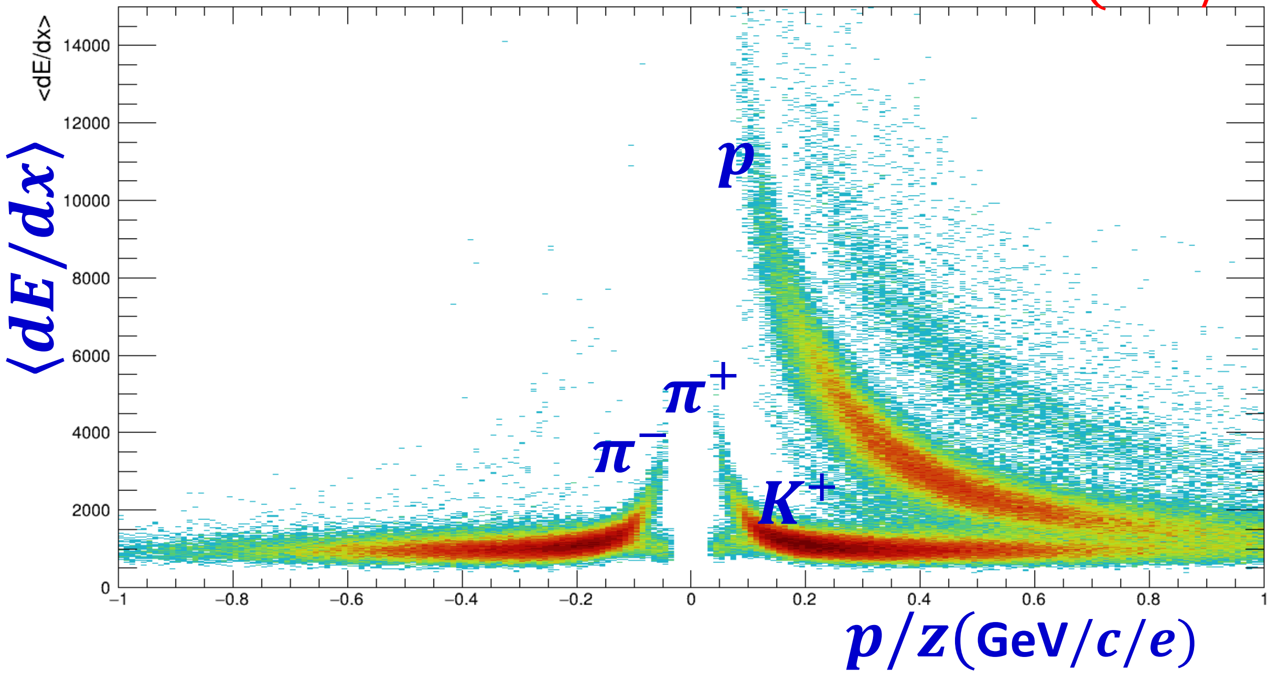
- We have collected physics data throughout 2022A/B and 2023A periods.
- The data was obtained at a trigger accept (request) rate of 100-150 Hz (120-200 Hz), resulting in a data throughput of a few tens of MB/s.
- The data size is primarily due to TPC data transferred through GbE from DE10 boards. The TPC data size is around 90-120 kB/event, while the size of other data is approximately 10-20 kB/event.



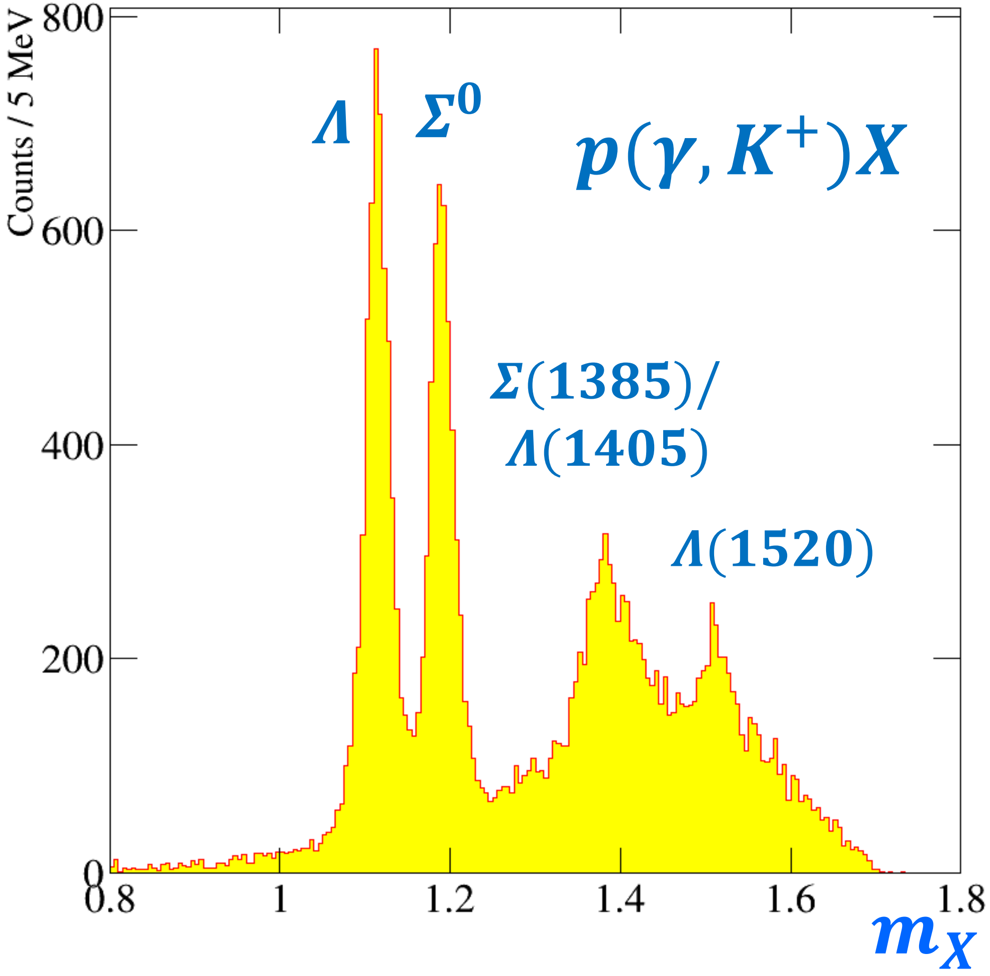
Preliminary Result from LEPS2







- LEPS2 has a good PID performance using the energy-loss information from the TPC and time-of-flight information from Barrel RPCs.



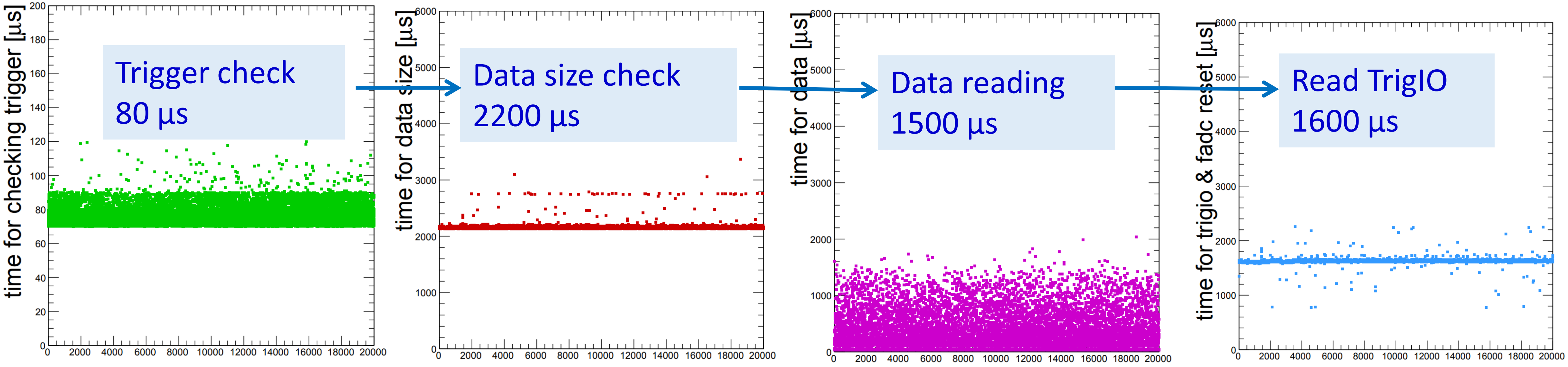
Summary

- The LEPS2 utilizes a network-distributed DAQ-middleware framework and forms the basis for the DAQ system.
- This framework underpins the LEPS2 DAQ system and is crucial for data acquisition and control, enabling efficient and reliable operation of the detector.
- The LEPS2 DAQ system has demonstrated its robust capabilities, successfully reading approximately 10K channels from TPC and 5K from other detector components.
- Our plan to speed up the readout process involves reducing the number of FADC boards per SpaceWire port. We will also use the DE10 GPIO for a faster event-tag readout, since the TPC readout speed is currently limited.

Special thanks to Prof. S. Ajimura (RCNP, Osaka) for developing the TPC readout system.

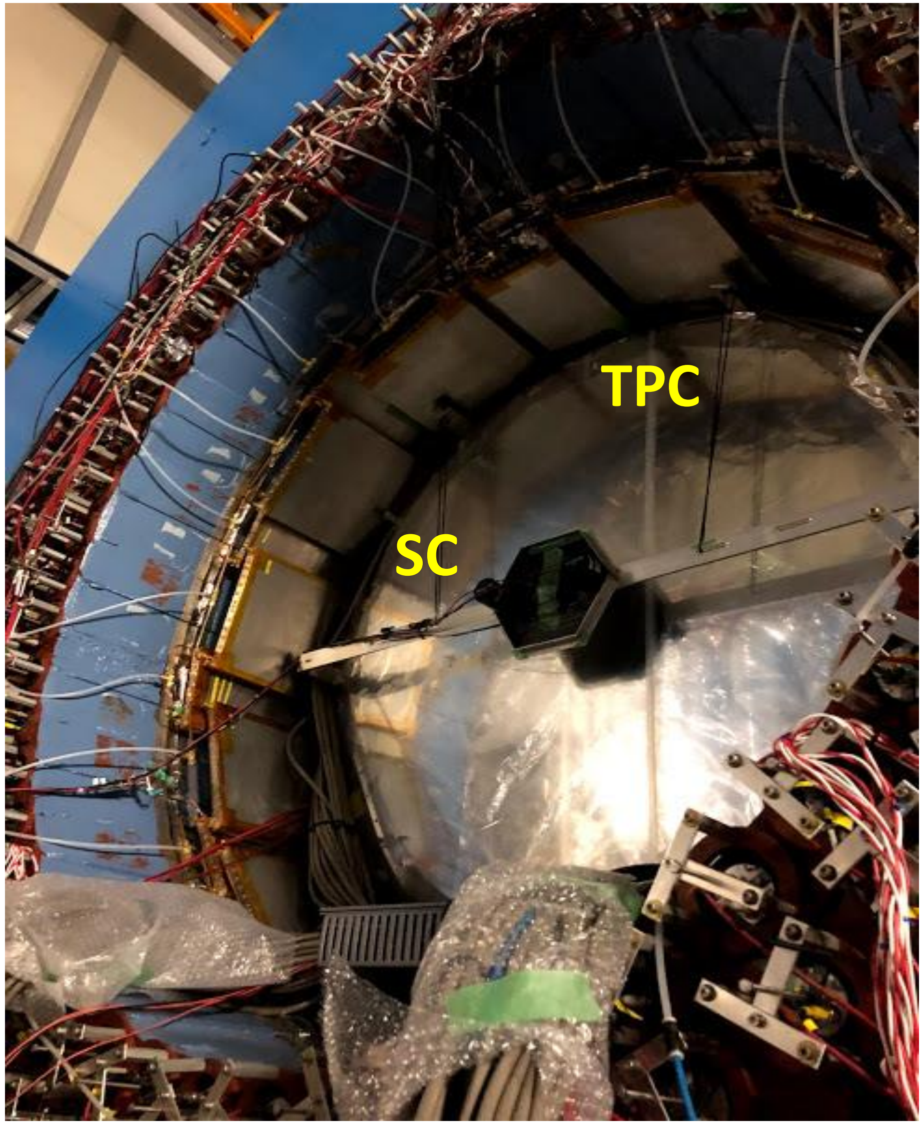
Back-up

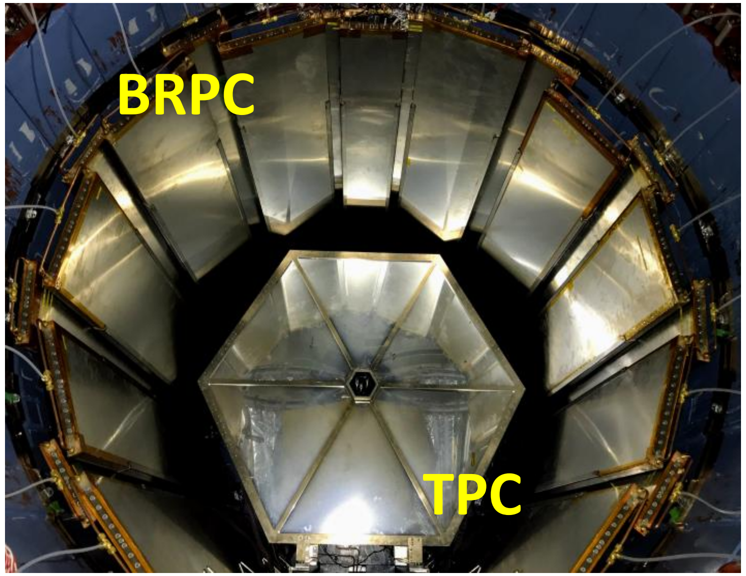
LEPS2 TPC Readout Sequence

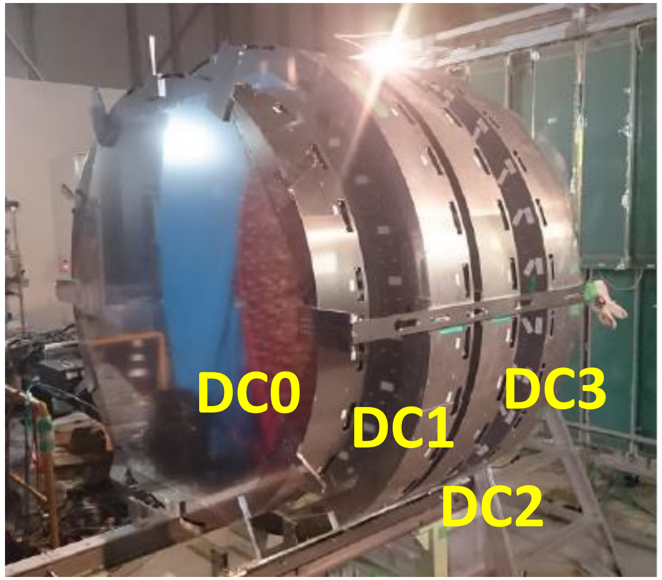


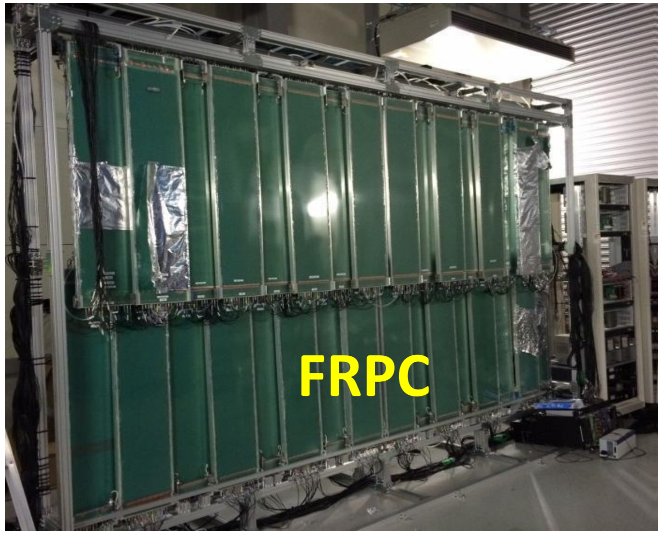
- DAQ quickly checks if FADC begins reading TPC signals from 6 boards (80 µs).
- DAQ reads the data size for each FADC board (2200 µs).
- DAQ starts reading pedestal-suppressed TPC data (1500 µs).
- DAQ clear buffers in TrigIO (RPV260 with TPC firmware) and reset FADC boards (1600 µs).
- A single sequence takes approximately 5.4 ms

LEPS2 Detector

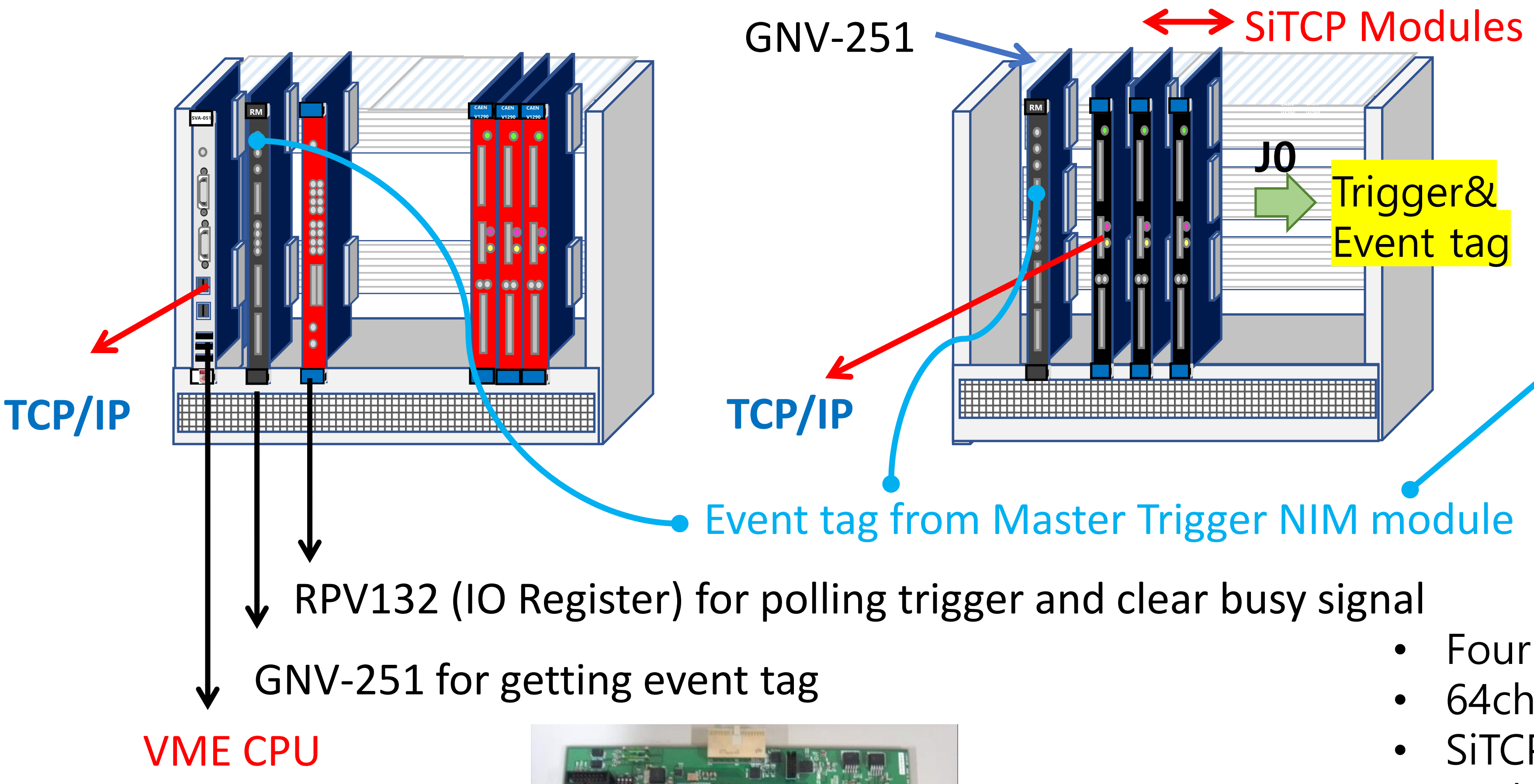








Readout System for Other Detectors



GNN-570

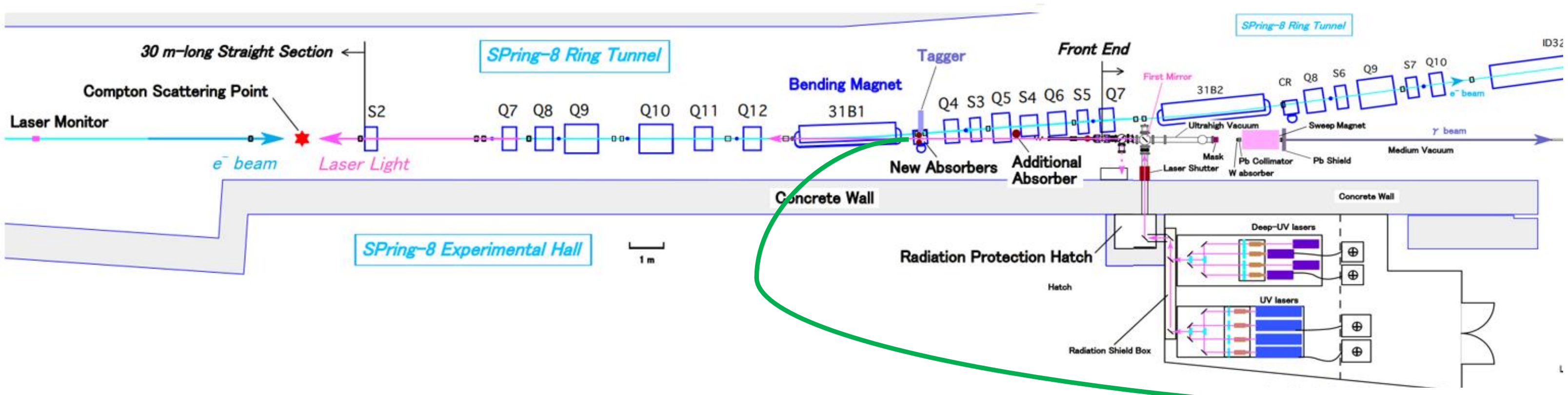
- Four DCs with 1920 channels
- 64ch RPV-260 TOT/TDC board
- SiTCP protocol via Ethernet
- 64ch 1-ns TDC firmware

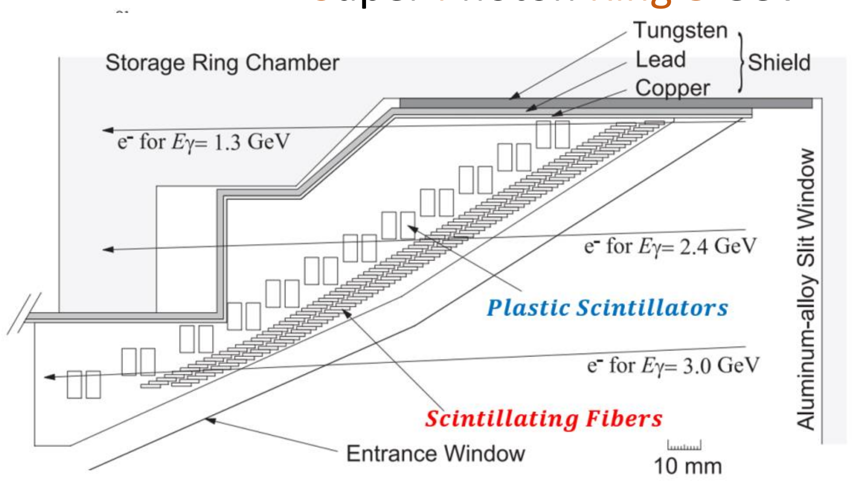
RPV-260

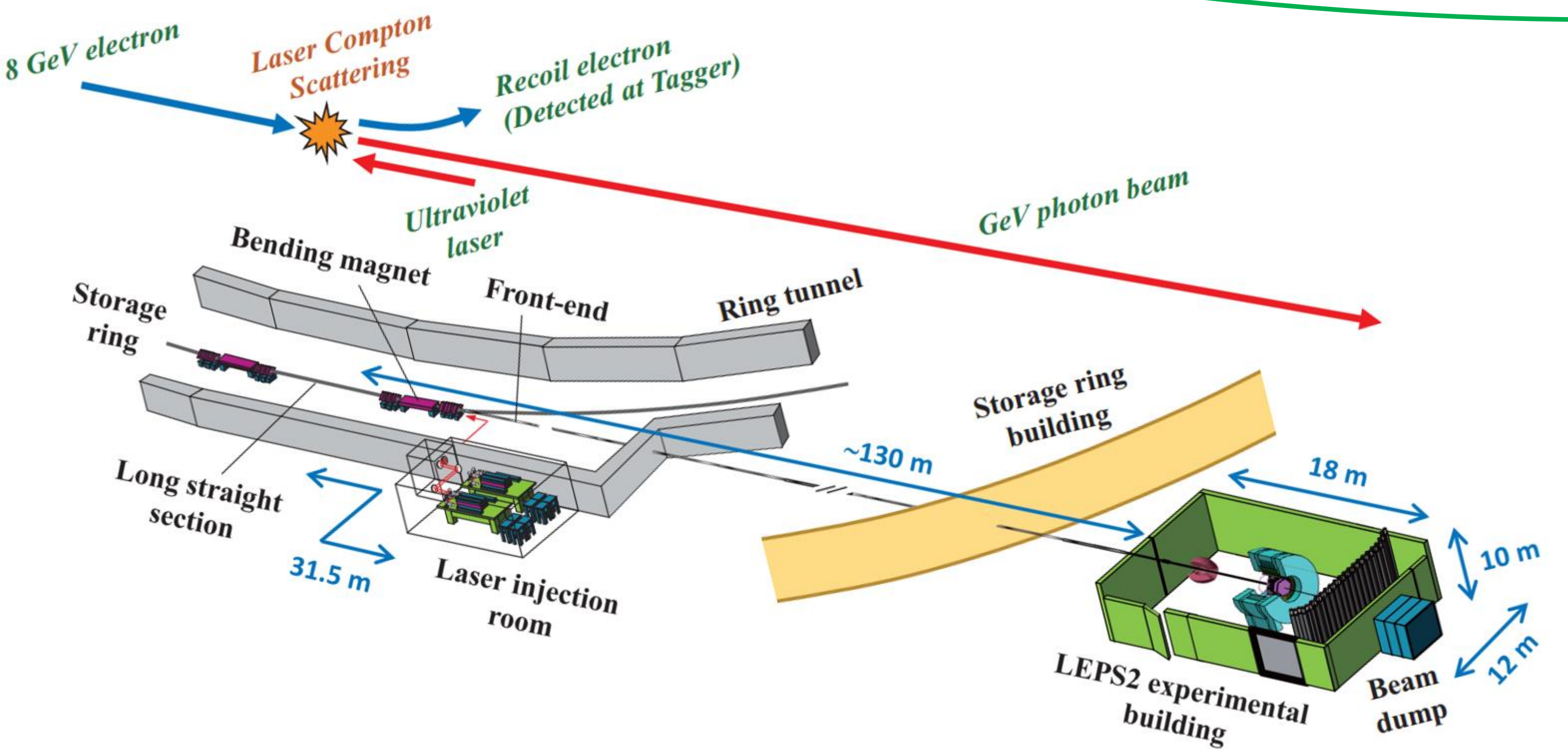
- DRS4 Digitizer board
- SiTCP protocol via Ethernet
- ADC for Barrel RPC

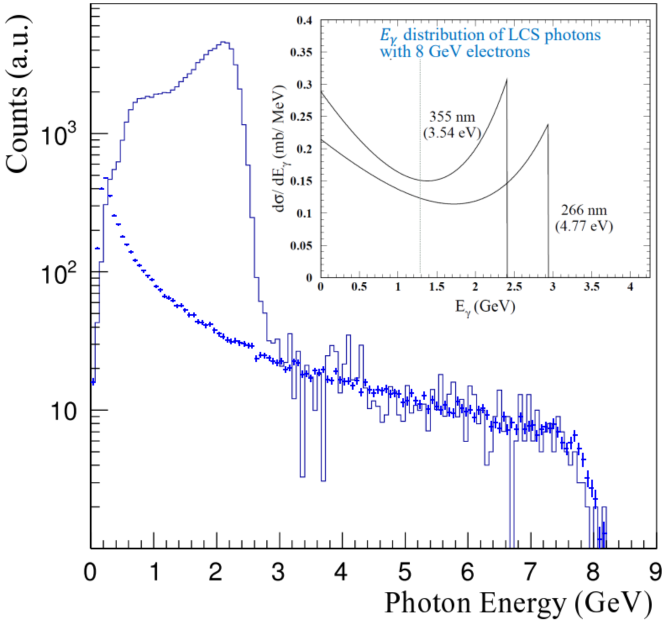
Polarized Photon Beam at LEPS2 / SPring-8*

*Super Photon Ring 8 GeV

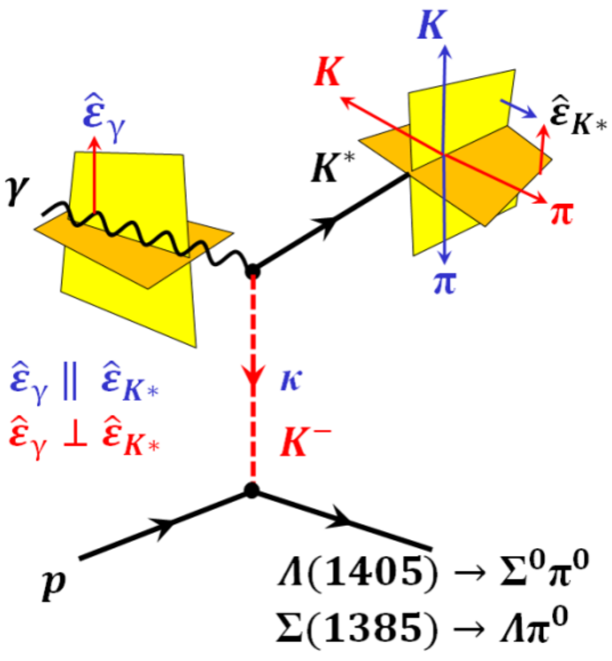


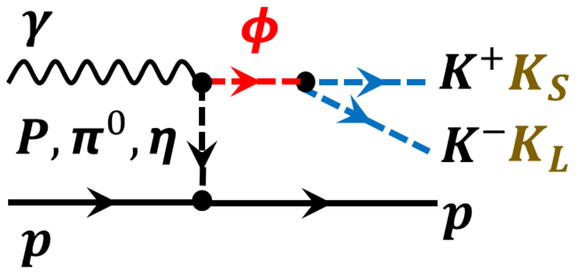


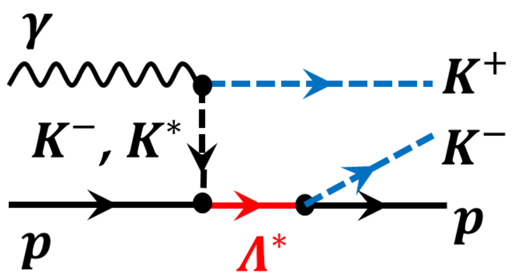


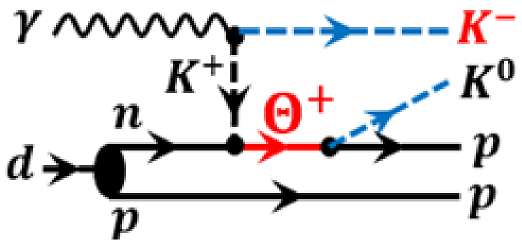


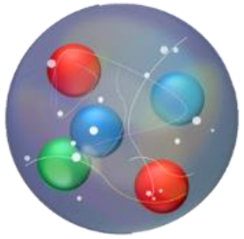
The LEPS2 Experiment

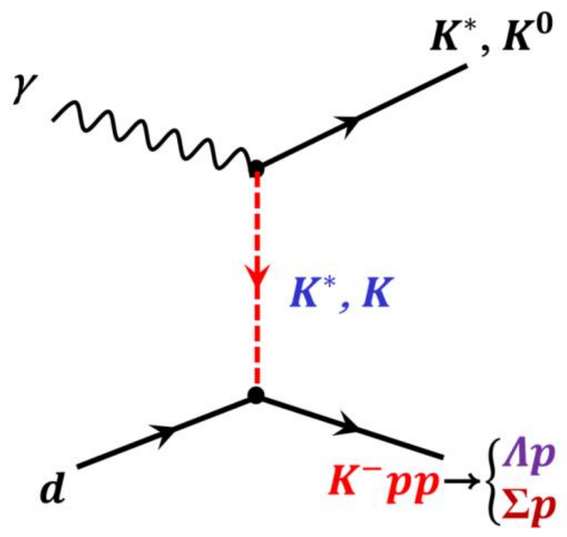












- The LEPS2 program entails a wide range of hadronic physics topics with polarized photon beams.
- One of the primary objectives is to study the spectrum of the hyperon resonances and the hadron mechanism of hadron production.
- There is a significant focus on searching for the exotic hadronic systems like pentaquark states (Θ^+ and P_s) and kaonic nuclei (K^-pp).