How does NA61/SHINE work?

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November 22, 2024

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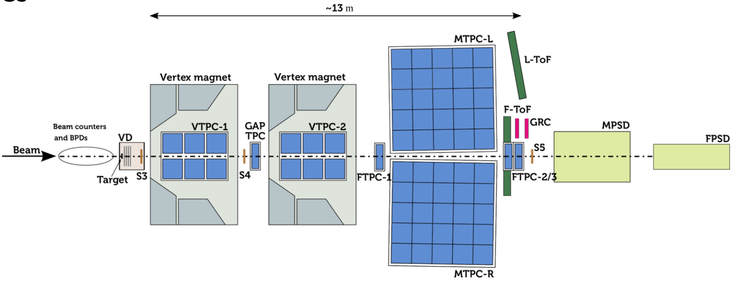
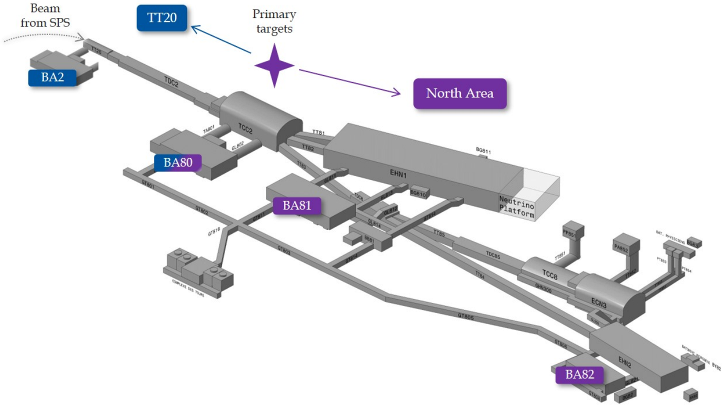


Beam

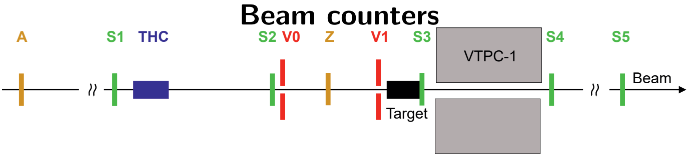
The beam for us is delivered from SPS. We are on H2 beamline.



Beam delivery to NA61/SHINE was presented in details in ▸ Kamil's presentation

For all problems related to beam delivery upstream of S1 – call CCC

Beam detectors



- Timing detectors (S1, S2)

  plastic/quartz start counters
- Veto detectors (V0, V1)

  plastic counters with a hole
- Interaction detectors (S3, S4, S5)

  plastic counters at special XYZ
- Secondary beam detectors (A, Z)

  plastic/quartz counters which are used to select fragments via ToF and amplitude(Z) measurements

- Hadron beam detectors (CEDAR, THC)

  CERN's old-fashioned and robust gaseous Cherenkov counters
- PSD

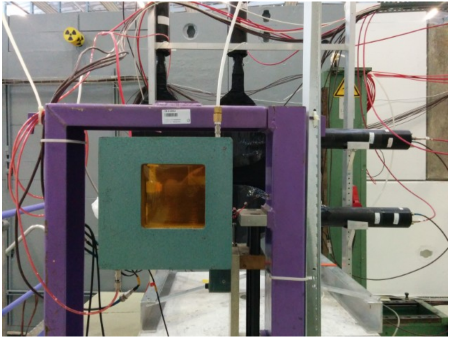
  energy deposit in central module(-s)

Beam position detectors

BPDs are used to measure trajectories of the incoming beam particles. We use two types of BPDs.

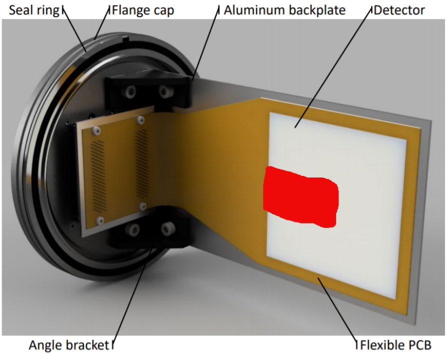
Silicon BPDs for ion beams

Delay Wire Chambers for hadron beams



Beam position detectors - SiBPDs

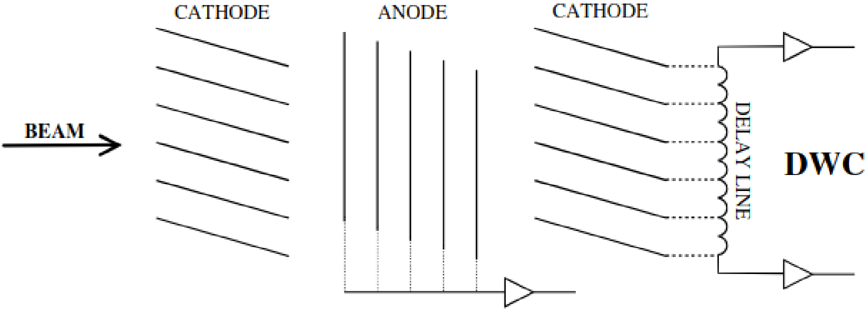
SiBPD is double layer (X and Y) detector positioned in vacuum and used for heavy ion beams. Each layer is a single-sided readout silicon strip detector with 1024 channels. But we are using only central 200 channels ($\approx 3.8 - 4$ cm).



Problems? Call BPD Expert.

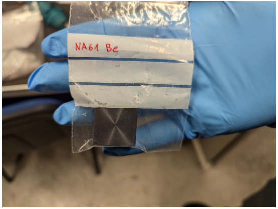
Beam position detectors - DWCs

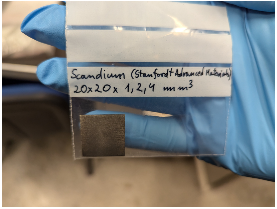
DWC is a MWPC-based detector with a delay line readout from cathode which we are using with hadron beams. The responsibility of installing and servicing them is by the side of SY-BI.

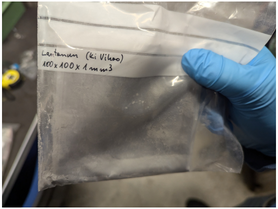


Problems? Call Detector Supervisor (who will call people from SY-BI).

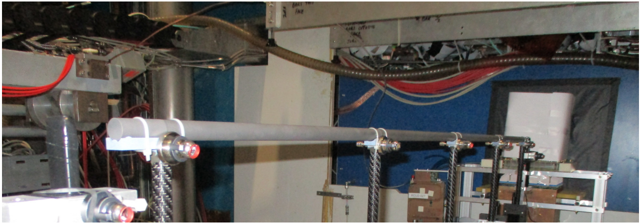
Targets


NA61 Be


Scandium (Stanford Advanced Materials)
20x20x 1,2,4 mm3


100x100x1 mm3


Pb target 1 mm
used in 2016 during
Pb Pb data taking

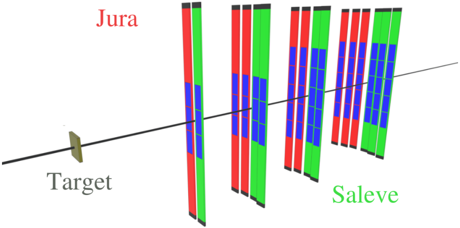


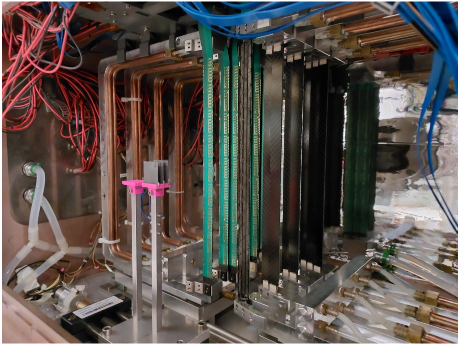
Trigger

Trigger system is responsible for gathering signals from beam counters and determining whether the collision qualifies as a good event.
For the Trigger system, see ▸ Jarek's presentation

Problems? Call Trigger Expert.

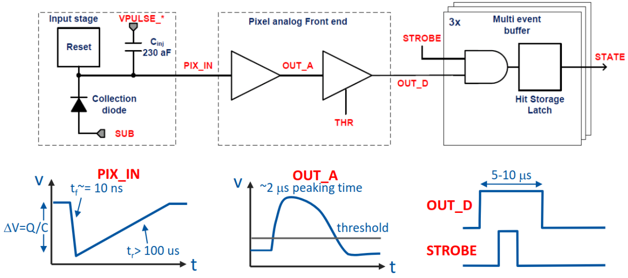
Vertex Detector

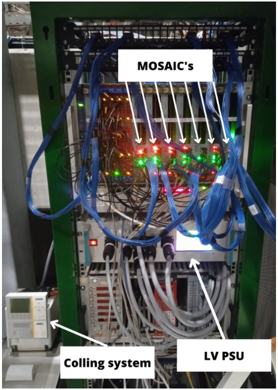




- ☐ Two(2) arms: Jura and Saleve
- ☐ Eight(8) staves in each arm
- ☐ Three(3) to five(5) ALPIDE sensors used in each stave
- ☐ About of 525k cells (pixels) in each ALPIDE sensor
- ☐ Pixel size 29.24 μm $\times$ 26.88 μm

Vertex Detector



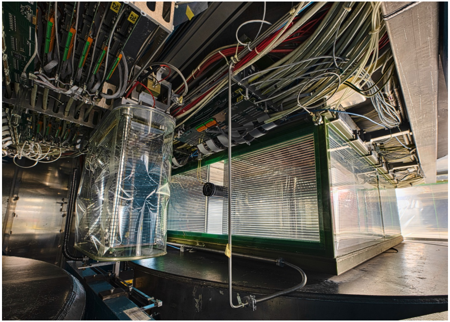


- ☐ Readout by "Firefly" cables and MOSAIC boards
- ☐ Cooling system for stable temperature inside of box
- ☐ LV system to supply ALPIDE sensors

Problems? Call VD Expert.

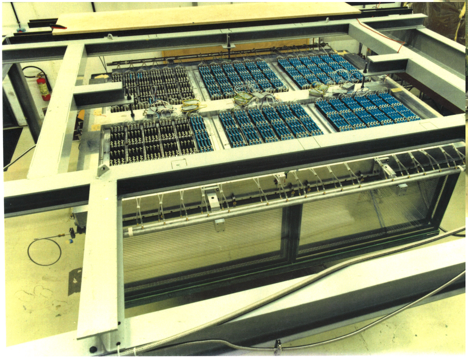
Magnet and cryo

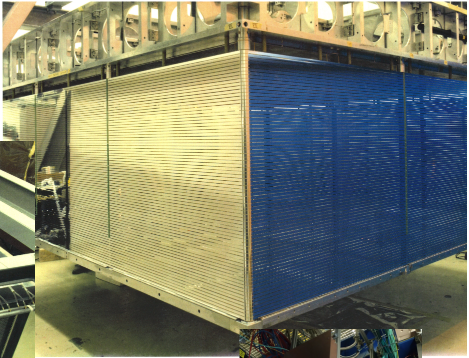
- Bending power of the 2 vertex magnets: 9 Tm at 1.5 T magnetic field (setting for 150 GeV/n).
- Field is scaled with the beam momentum.
- One week before ramping up magnets, we need "CRYO_OK" (i.e. approval for usage) from TE-CRG



Problems? Call Detector Supervisor (who will call people from TE-CRG).

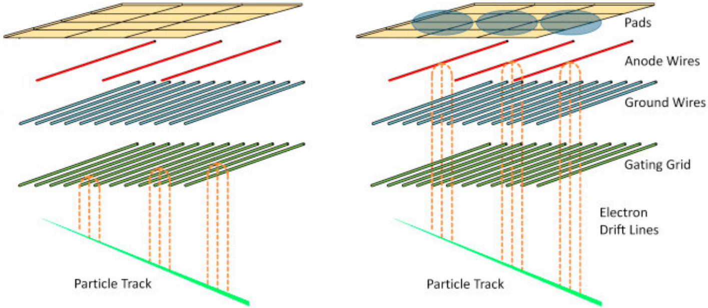
Time Projection Chambers and GRCs





Time Projection Chambers

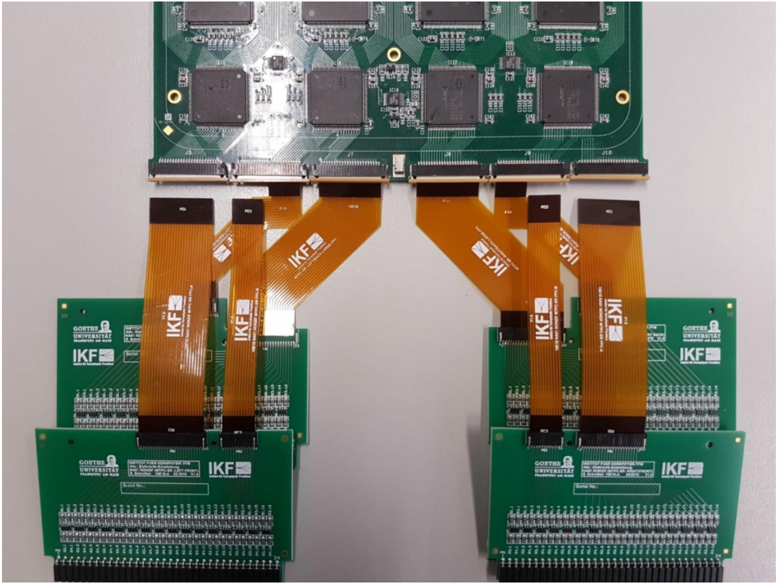
- ☐ Momentum resolution: $\sigma(p)/p^2 = 10^{-4}$ $(\text{GeV/c})^{-1}$
- ☐ Particle identification via dE/dx: $\frac{\sigma(dE/dx)}{dE/dx} = 3 - 4\%$ (p-p ... Pb-Pb)



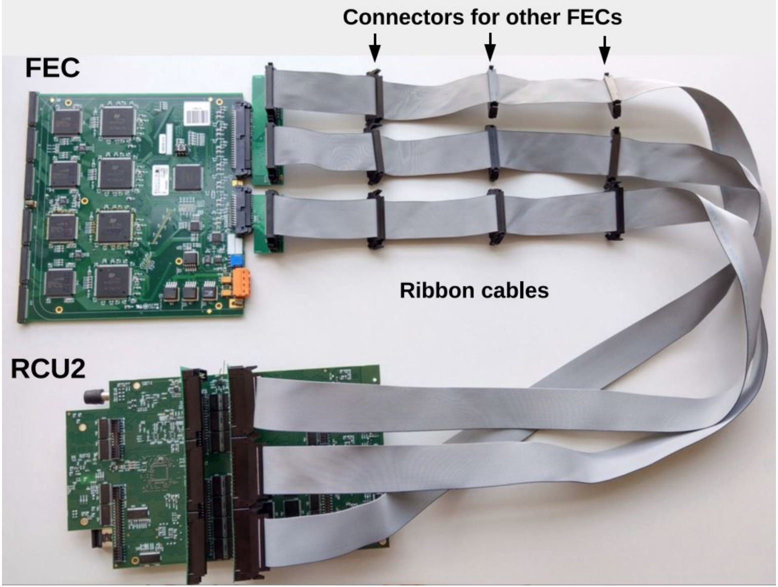
TPC - readout electronics

- Analog output of TPC chamber goes through adapter board to frontend. One adapter board reads one padrow.
- Four adapters are connected to one frontend. Since now data transfer is only digital.
- Four to six frontends are connected to one RCU.
- RCUs are connected through fibers to switches in TPC huts. They are steered by tpc-centipede.
- Data from switches in TPC huts go to tpc-XX machines in DAQ

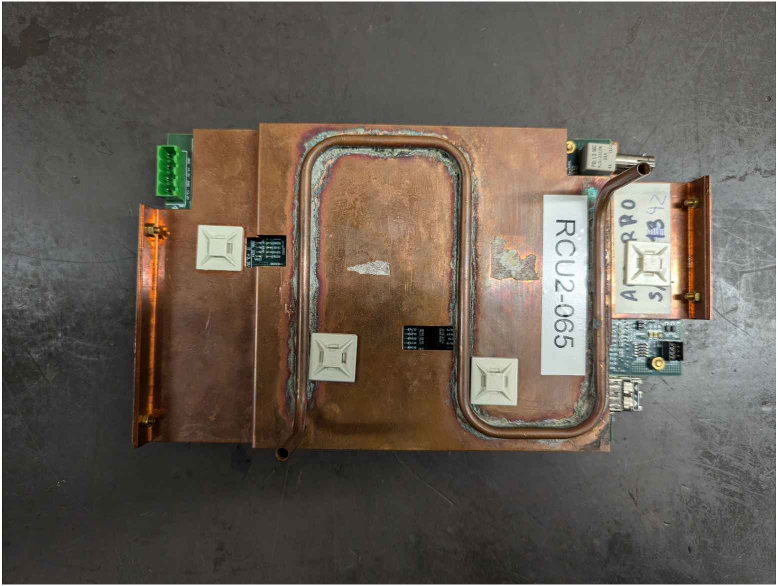
TPC readout electronics - adapters and frontends



TPC readout electronics - frontends and RCU

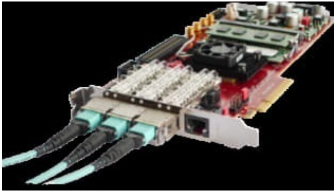


TPC readout electronics - RCU



TPC readout

- Data from switches in TPC huts go to one of three slots of a CRORC card
- One CRORC is installed in PCI-Express x16 slot of every TPC readout machine
- One CRORC has three QSFP connectors (i.e. three RCUs can be connected to one CRORC)
- There are 11 TPC readout machines



TPC Low Voltage

- Readout electronics require Low Voltage power supplies in order to run
- The electronics of each sector consumes up to 100 A
- VTPCs - 6 sectors, MTPCs - 25 sectors, GTPC and FTPCs - 1 sector

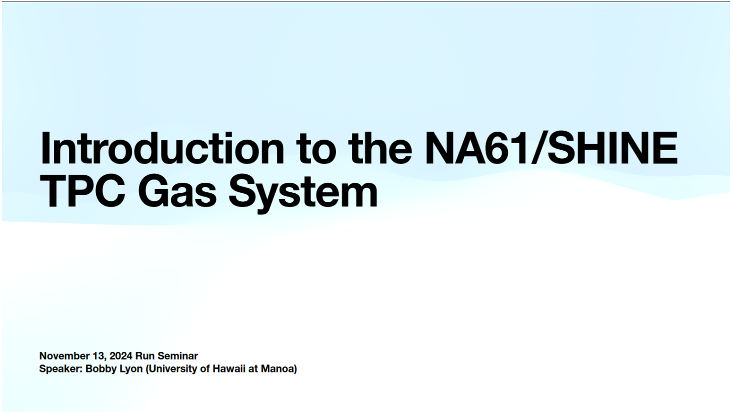
TPC electronics cooling

- TPC readout electronics produced large amount of heat that should be dissipated through metal plates cooled with water cooling.
- There are two water cooling setpoints used: 20.5°C and 15.5°C. 20.5°C when TPC electronics is not used for at least several hours. 15.5°C during operation.
- Photo shows control panel of TPC electronics cooling.

Gas in TPCs

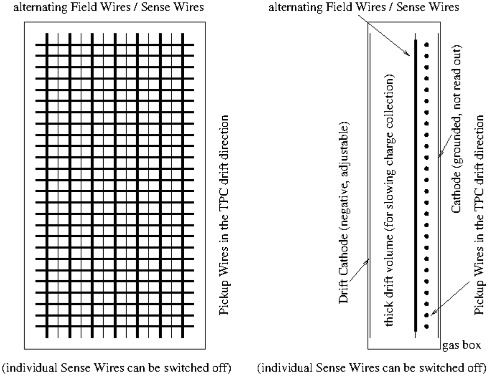
TPC gas system and not only

For the TPC/GRC/He gas and TPC HV systems, see ▸ Bobby's presentation



GRCs

- ☐ Geometry Reference Chamber - NA61/SHINE naming
- ☐ MWPC with cartesian readout (X,Y) - detector naming



- ☐ Sense and Pick-up wires are readout by the same readout as all TPCs
- ☐ Sense wires can be turn off to mitigate fake hits with high multiplicity events

TPC problems

- Problems related to gas conditions - Gas Expert
- Problems related to electronics temperatures - Technical Coordinator (who calls EN-CV)
- Problems related to readout electronics (missing pixels/sectors on Event Browser) - TPC Readout Expert
- Problems related to GRC - GRC Experts

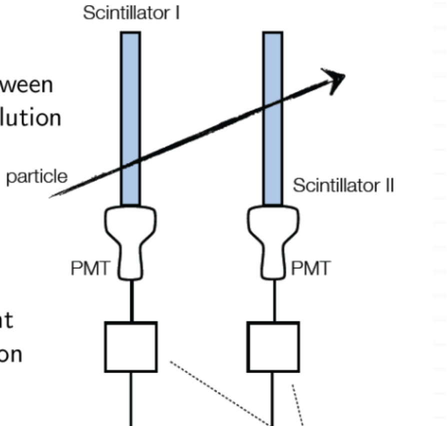
Very detailed presentation made by ▸ Rainer

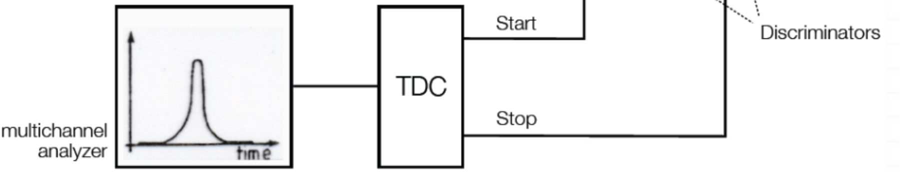
Time of Flight walls

Basic idea

- ☐ Measure signal time difference between two detectors with good time resolution
- ☐ Typical detectors:
  - ■ Scintillation counters
  - ■ Resistive plate chambers
  - ■ *Cherenkov counters optional*

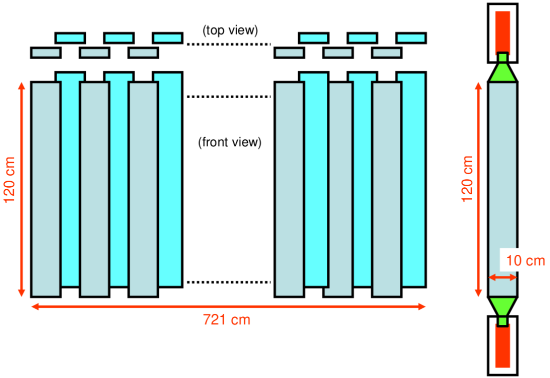
Coincidence setup or TDC measurement with common start/stop from interaction time

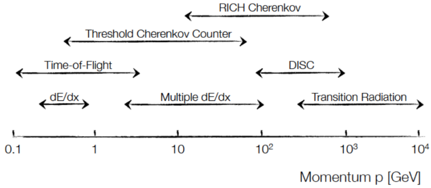




Time of Flight walls

Time of Flight walls - ToF-F (32 counters)

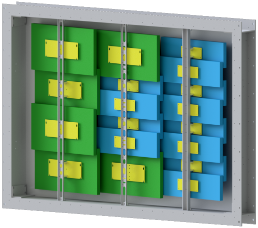




Time of Flight walls

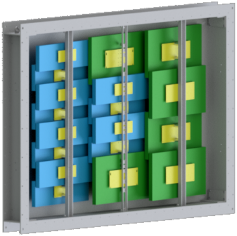
Time of Flight walls - ToF-LR (MRPC)

MRPC-R



beam

MRPC-L



MRPC sybSystems

- MRPCs with gas module (12+6 detectors)
- modification of HV and gas systems
- LV system
- Front-end electronics (∼2000 ch)
- DRS4 or **picoTDC** readout

- **MRPCs with gas module (12+6 detectors)**
- **Closed-loop gas system for two modules**
- **HV & LV systems**
- **Front-end electronics (1728 ch)**
- **DRS4 readout (54 boards)**

Time of Flight walls - ToF-LR (MRPC)

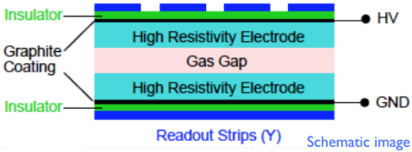
- Use parallel plate chamber with high field
- Electrons of ionization clusters start to produce an avalanche immediately
- Induced signal = sum of all simultaneously produced avalanches
- But: Electron avalanche develops according to Townsend:

$$n = n_0 e^{\alpha x}$$

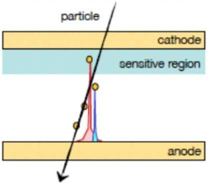
$$G = \frac{n}{n_0} = e^{\alpha x}$$

α : Townsend coefficient
x : traversed path length
G : amplification (gain)

- Raether limit: G = 10^8 ($\alpha x = 20$), then sparking sets in ...



Schematic image of typical RPC geometry

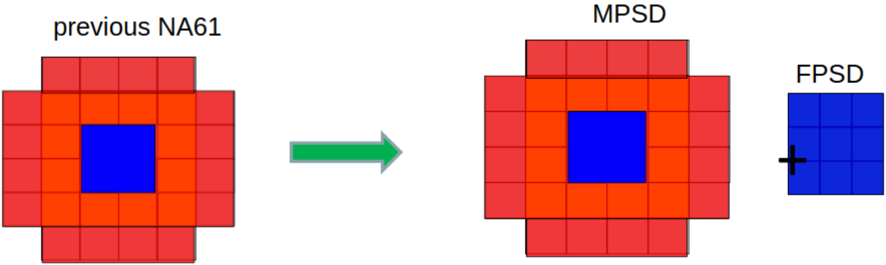


Schematic view of the avalanche process

Gap size matters!
[the smaller the better]

Time jitter: time to cross sensitive region

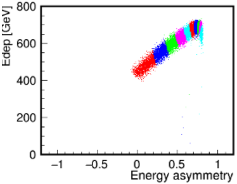
Projectile Spectator Detectors



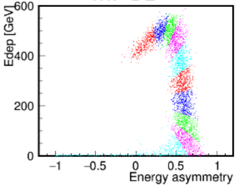
Energy asymmetry = (Eblue-Ered) / (Eblue+Ered)

Deposited energy vs asymmetry

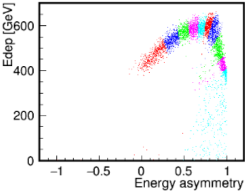
old PSD



MPSD



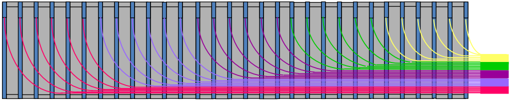
MPSD+FPSD



Projectile Spectator Detectors

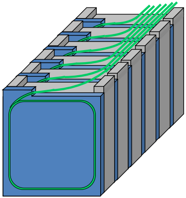
PSD: light readout with WLS-fibers from scintillators

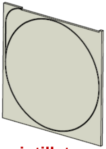
Projectile Spectator Detector is a lead/scintillator sampling compensating hadron calorimeter with light readout by WLS-fibers and signal readout by silicon photomultipliers.



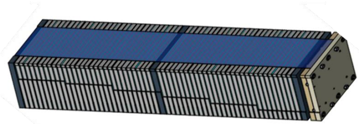
6 fiber/SiPM
10 SiPMs/module

Half of module.





scintillator



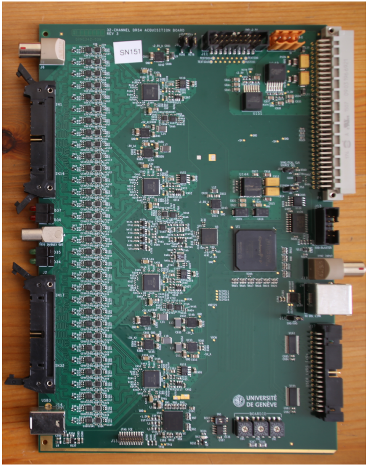
60 lead/scintillator sandwiches.

Compensating ratio:
Lead/Scintillator 4:1.
Lead- 16 mm; scintillator – 4 mm

11

Problems? Call PSD Expert.

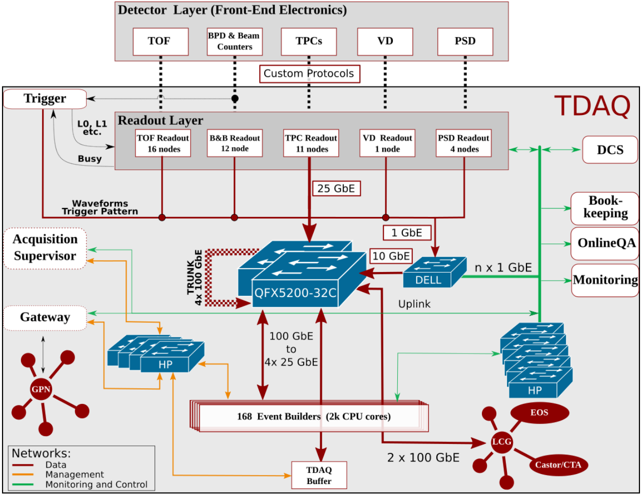
DRS4 Readout



- One channel samples waveforms to 1024 time bins (with adjustable sampling frequency)
- Each DRS board has 32 data channels and 4 timing channels
- One BPD needs 14 boards, counters: 2, TOF-L: 54, TOF-F: 2, PSD: 14
- Data from boards collected by readout machines (up to 4 boards can be connected to one)

Problems? Call DRS Expert

Data Acquisition System



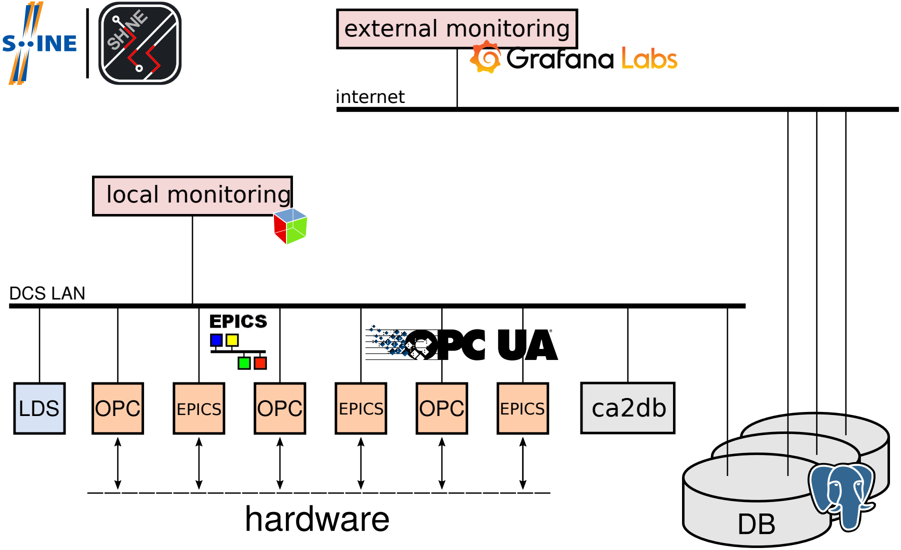
Problems with DAQ Control? Call DAQ Expert

Detector Control System

Detector Control System

Whet it does not - call DCS Expert

Detector Control System



List of Experts

- **Detector Supervisors**
  ≈ Technical Coordinators
  Piotrek, Bartek, Sasha D.
- **Beam/BPD Experts**
  Kamil, Yuliia
- **Trigger Experts**
  Jarek, Eric
- **Vertex Detector Experts**
  Paweł, Mateusz
- **Gas and TPC HV Experts**
  Bobby, Sasha D., Vitalii
- **TOF-L Experts**
  Sasha D., Andrey
- **TOF-F Experts**
  Eric, Amelia
- **PSD Experts**
  Sergey, Nikolay, Vadim, Marcin, Łukasz
- **TPC Readout Electronics Experts**
  Dominik, Bartek
- **DRS Experts**
  Dominik, Yuliia, Bartek
- **DAQ Experts**
  - Network - Bartek
  - DAQ Interfaces - Ivan
- **DCS Experts**
  Tobiasz, Valeria

Thank you!