Design, Performance and Perspective of NA62-RICH at CERN

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on behalf of NA62-Collaboration

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About NA62 experiment

NA62 is a fixed target experiment located in the North Area of CERN

dedicated to the study of charged kaon decays

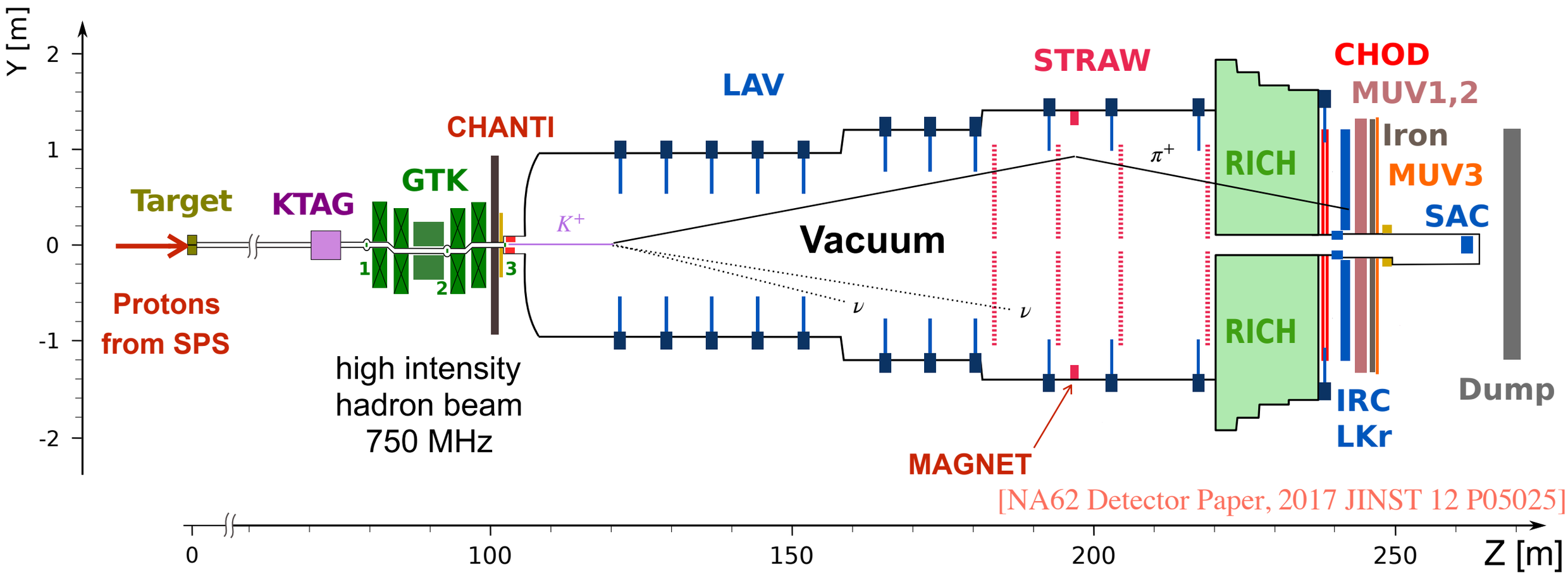
in particular the very rare decay $K^+ \to \pi^+\nu\nu$

2016 →2018 Physics run
2015 RICH commissioned
2009 NA62 approved

Beam characteristics

- 400 GeV/c protons from SPS on beryllium target produce secondary **hadron beam**
- 3.5 seconds spill
- **75 GeV/c** momentum positive particle selected (1% rms)
- **750 MHz** nominal rate
- **6%** are kaons

Experimental strategy for $K^+ \to \pi^+\nu\nu$



[NA62 Detector Paper, 2017 JINST 12 P05025]

signal probability is 10 order of magnitude smaller than background!

Background rejection

$$K^+ \to \mu^+\nu$$

$$K^+ \to \pi^+\pi^0$$

TRIGGER

Level 0 : RICH, CHOD, ~~MUV3~~, <20 GeV in Lkr

Level 1 : ~~PHOTON~~, Kinematic

CONTROL: minimum bias and downscale

RICH specialities in NA62

★ NA62-RICH was built to provide an **extra factor 100** to $\pi - \mu$ separation on top of kinematics and calorimetry

★ With sub-ns precision it was used as random veto free **fast hodoscope** for $K - \pi$ matching

★ Being fast and simple the RICH was used as **trigger** detector for NA62

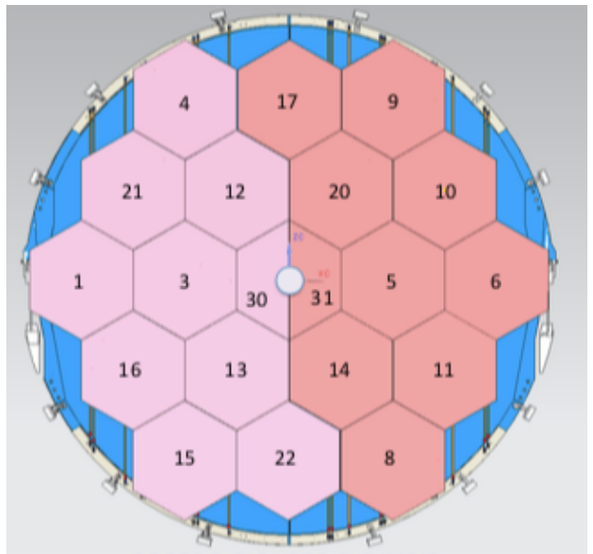
Light production and focusing

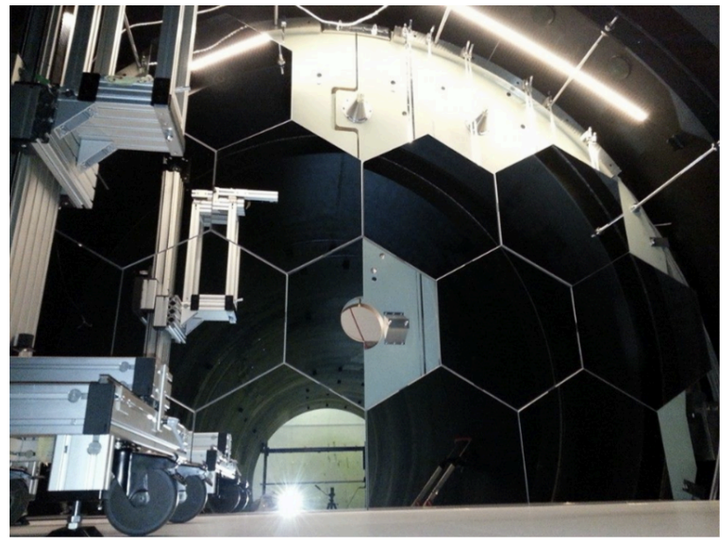
Radiator: Neon gas at 1 atm

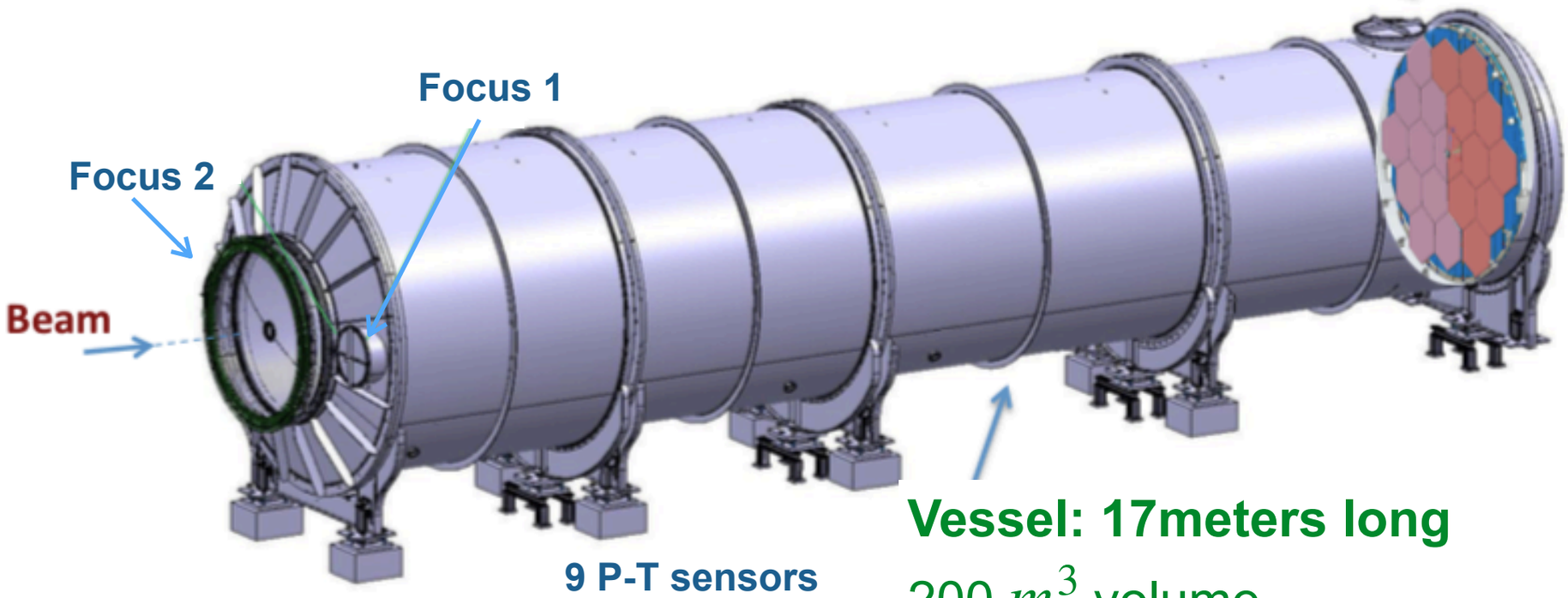
$(n-1) = 62.8 \times 10^{-6}$ at 300 nm

Optics: mirror mosaic

- Aluminized glass, MgF_2 coating
- Reflectivity 90% in 195 - 650 nm
- Alignment precision 1 mm (30 μrad)







Vessel: 17meters long

200 m^3 volume

Beam pipe ∅168 mm for undecayed particles

Alignment method

Single track extrapolation from spectrometer and comparison with fitted ring center.

Adjust mirror orientation and iterate

[Mirror alignment Paper, 2018 JINST 13 P07012]

Light detection and digitization

2 x 976 (1952) Photomultipliers

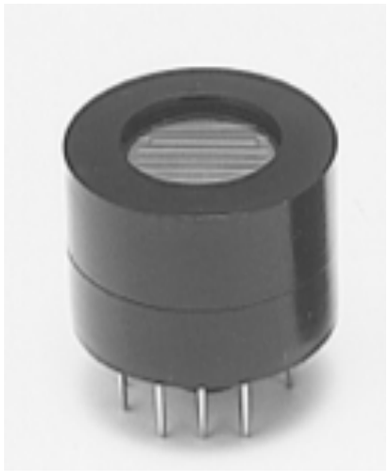
18 mm pitch

185-650 nm

QE 20% @ peak

280 ps FWHM

Custom voltage divider



R7400U-03

Possible replacement R9880U with QE 30% @ peak under study

Custom Frontend

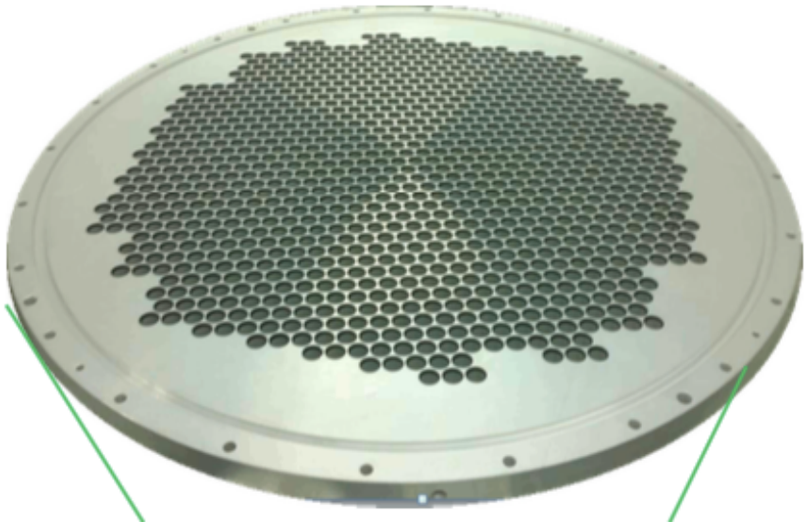
based on 8 channel NINO ASIC

fast discriminator amplifier

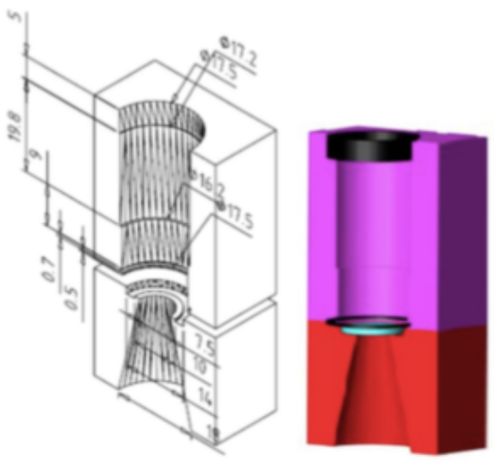
jitter < 25 ps @ 200 fC

LVDS output

analog sum output for trigger



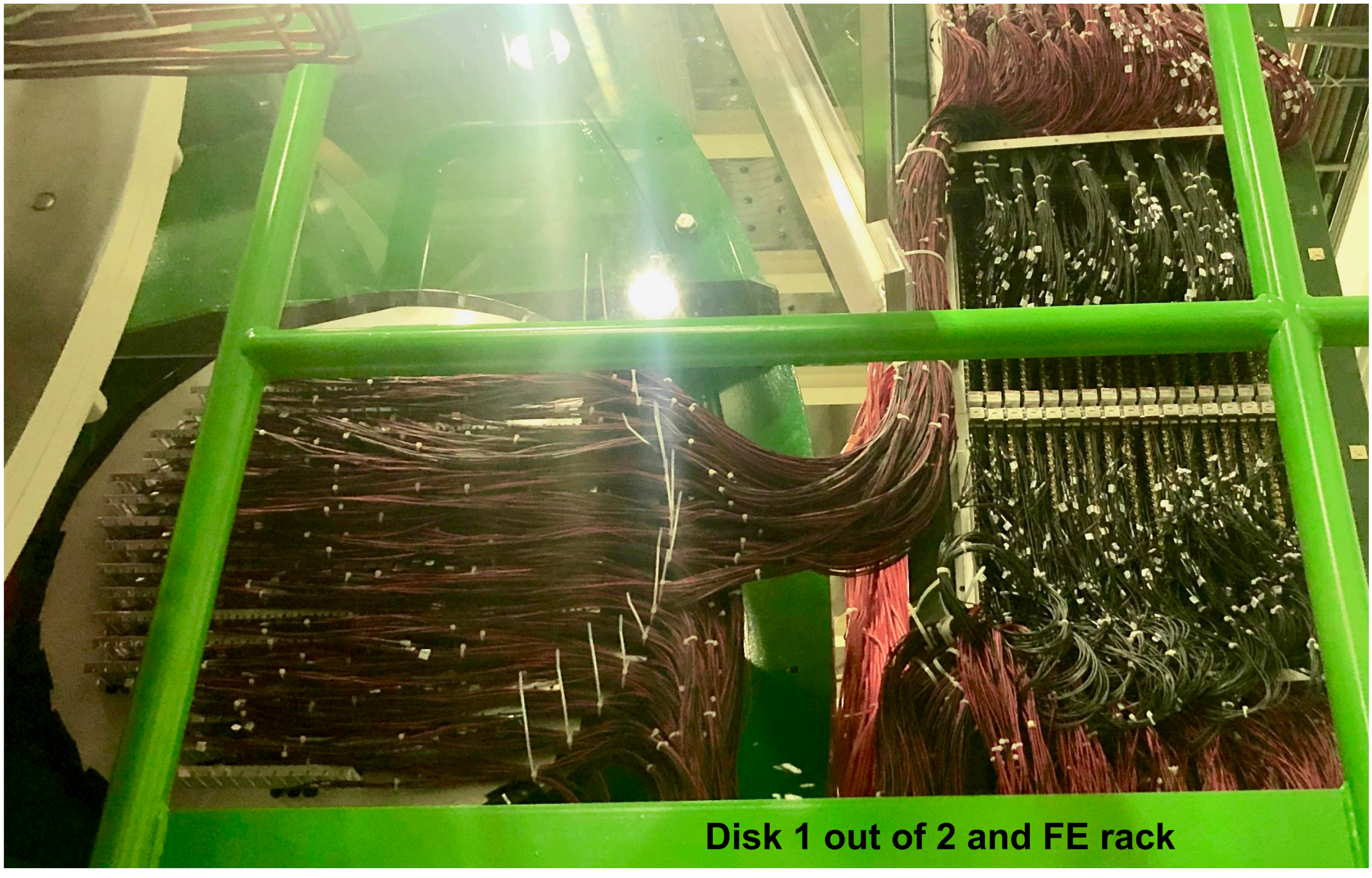
A quartz window decouples PM from gas (not in picture)



Winston cone

[NA62 Internal note, 2020, 20-01

A picture from experimental room



Disk 1 out of 2 and FE rack

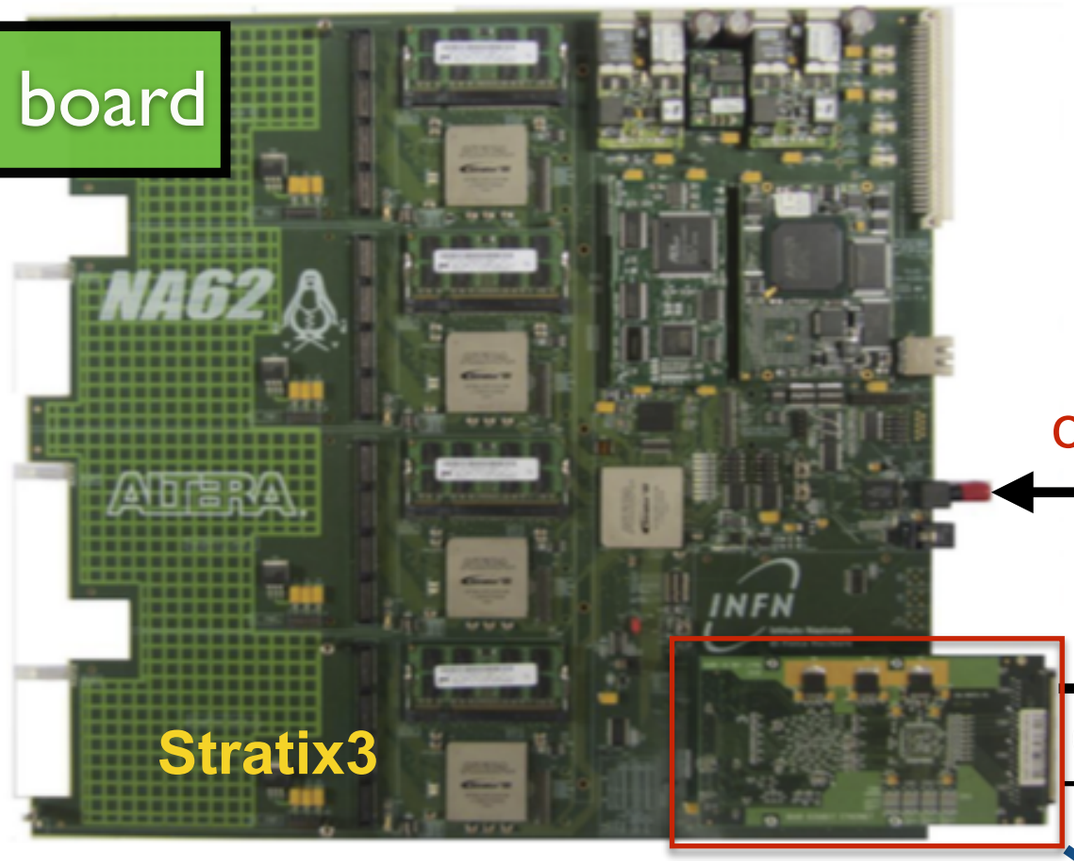
Trigger and readout

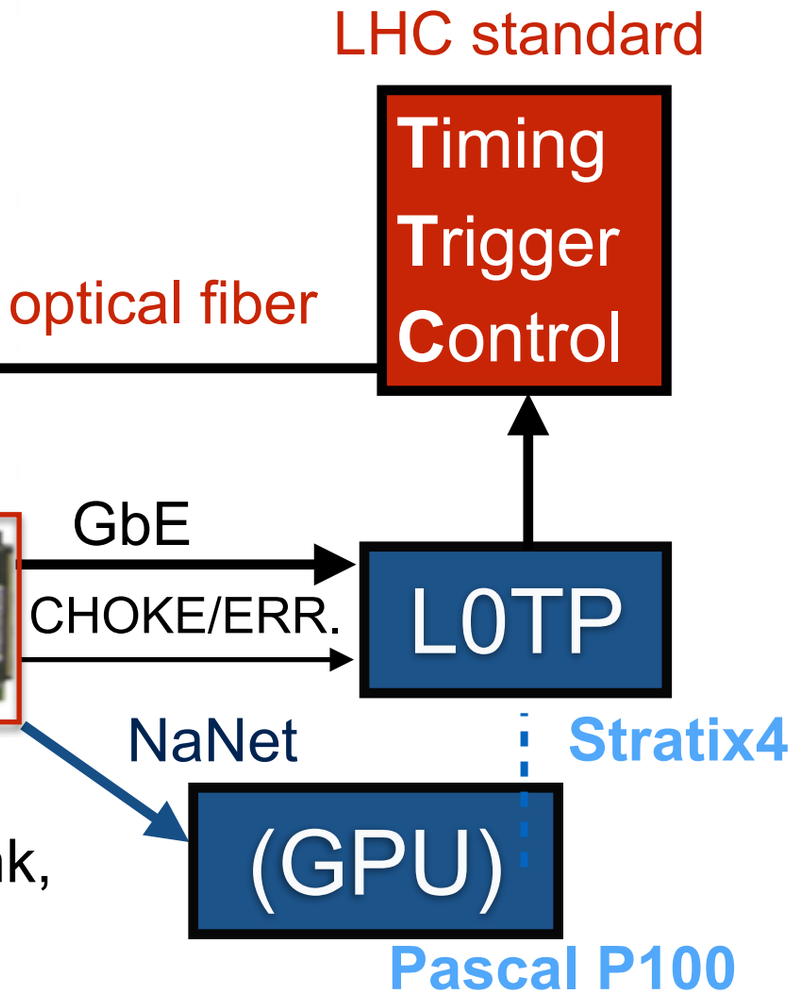
TEL62 board common NA62 TDAQ module, 512 channels, 2GB DDR2, max L0 latency **1 ms**, backpressure handling,

Frontend

TDC board

- **generates trigger primitives**
- **manages data transfer**





RICH in L0 trigger:

Current solution: Multiplicity based on low granularity data

Alternative (proven): All hits to GPU using NaNet custom link, dedicated algorithms to reconstruct complex quantities e.g. ring center and radius

[L0 trigger and readout Paper, 2019 ArXiv:1903.10200]

[NaNet Paper, 2015, JINST 10 C04011]

hardware upgrade foreseen for 2021 both for L0TP and GPU

Basic performance

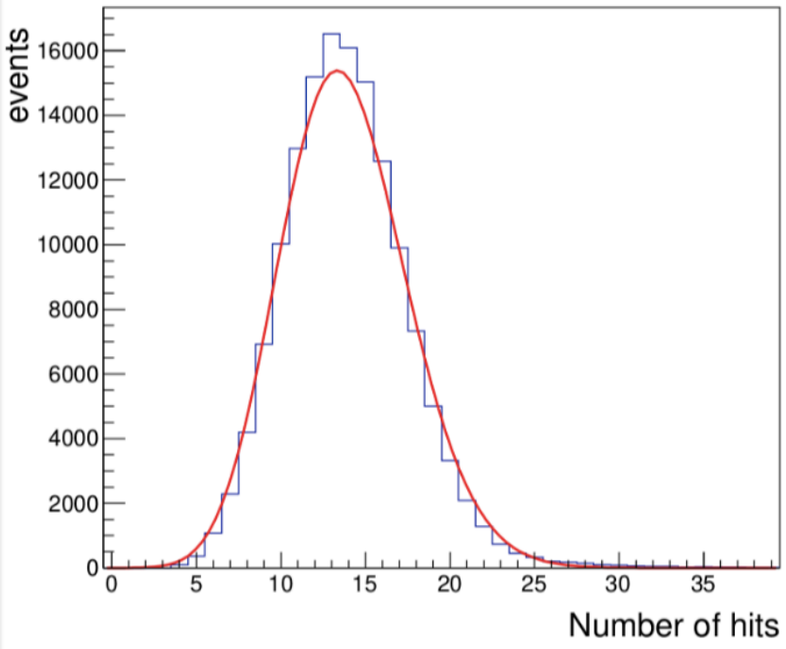
Hit multiplicity and spatial resoution

Clean positron from $K^+ \to \pi^0 e^+ \nu$

Single rings fully contained in RICH acceptance

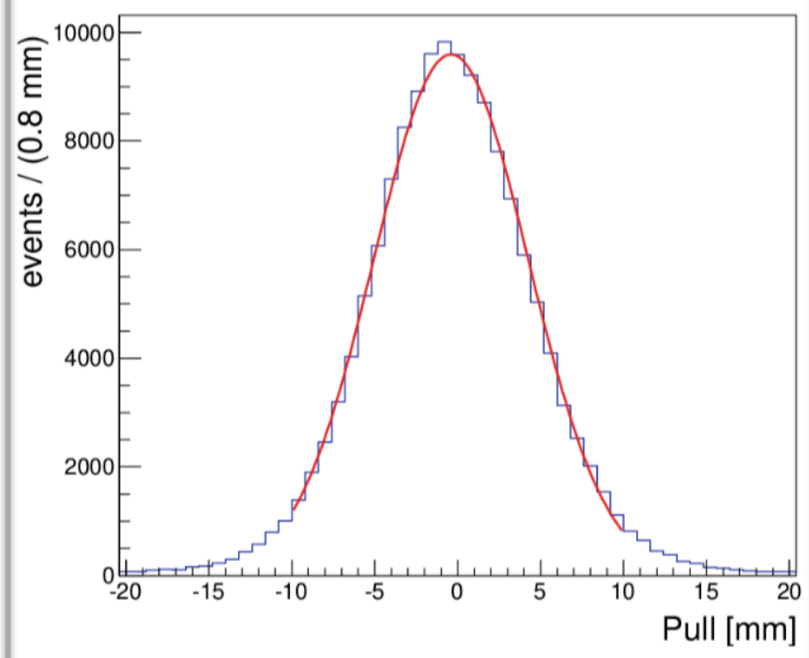
2016 data

Number of hits per ring



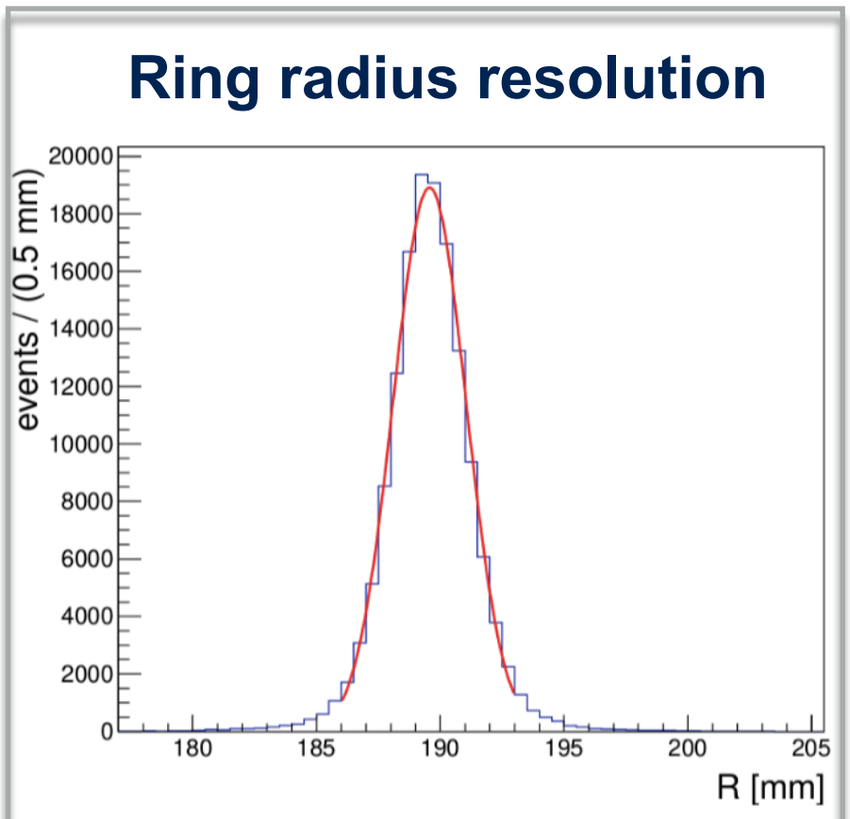
$< N_{hit} > = 13.8$

Single hit spatial res.



$\sigma_{hit} = 4.66$ mm

Ring radius resolution



$< R > = 189.6$ mm

$\sigma_R = 1.5$ mm

Time performance

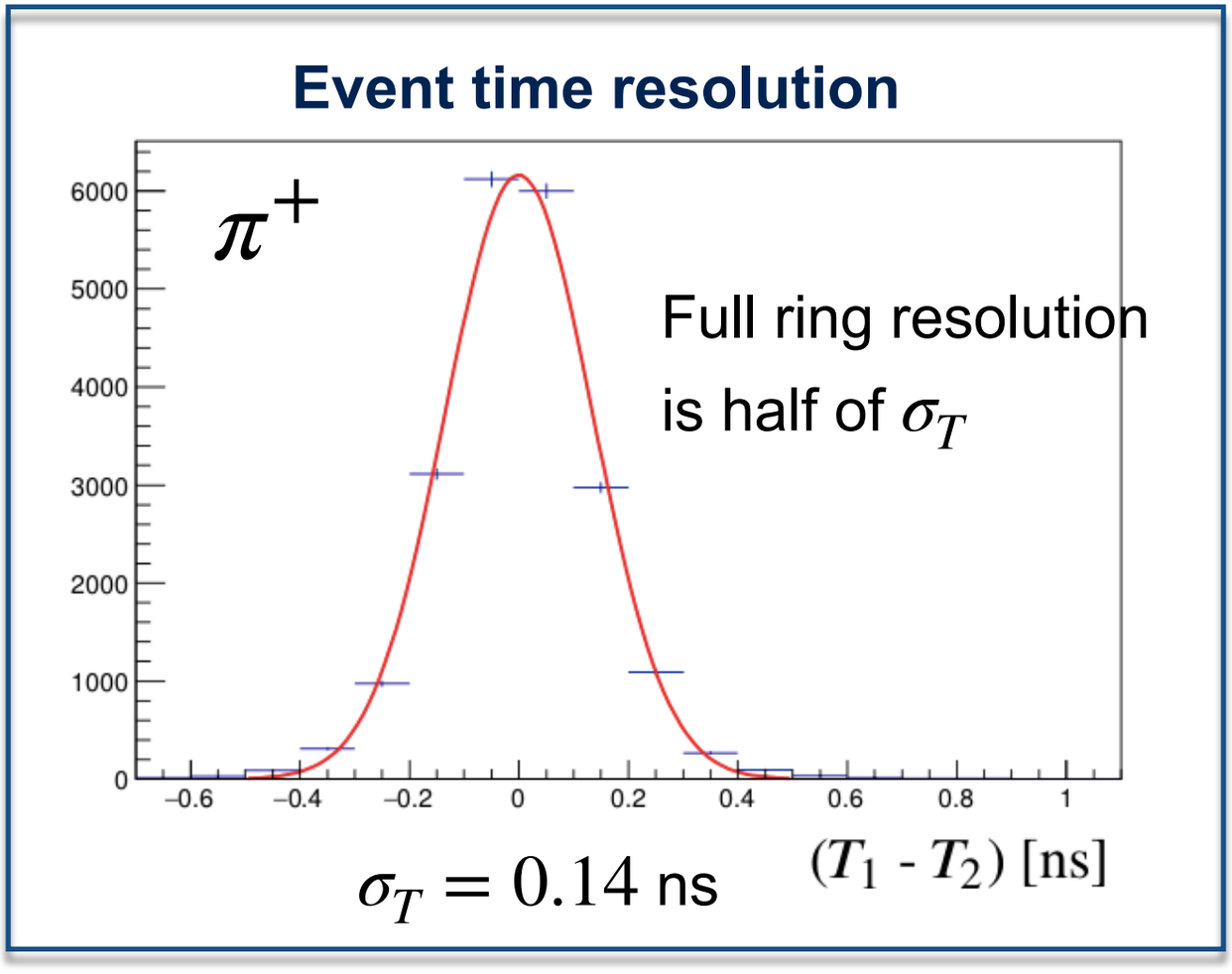
2017 data

Intrinsic time resolution

For each ring two groups of hits are formed, randomly assigned

Calculate time average of each group

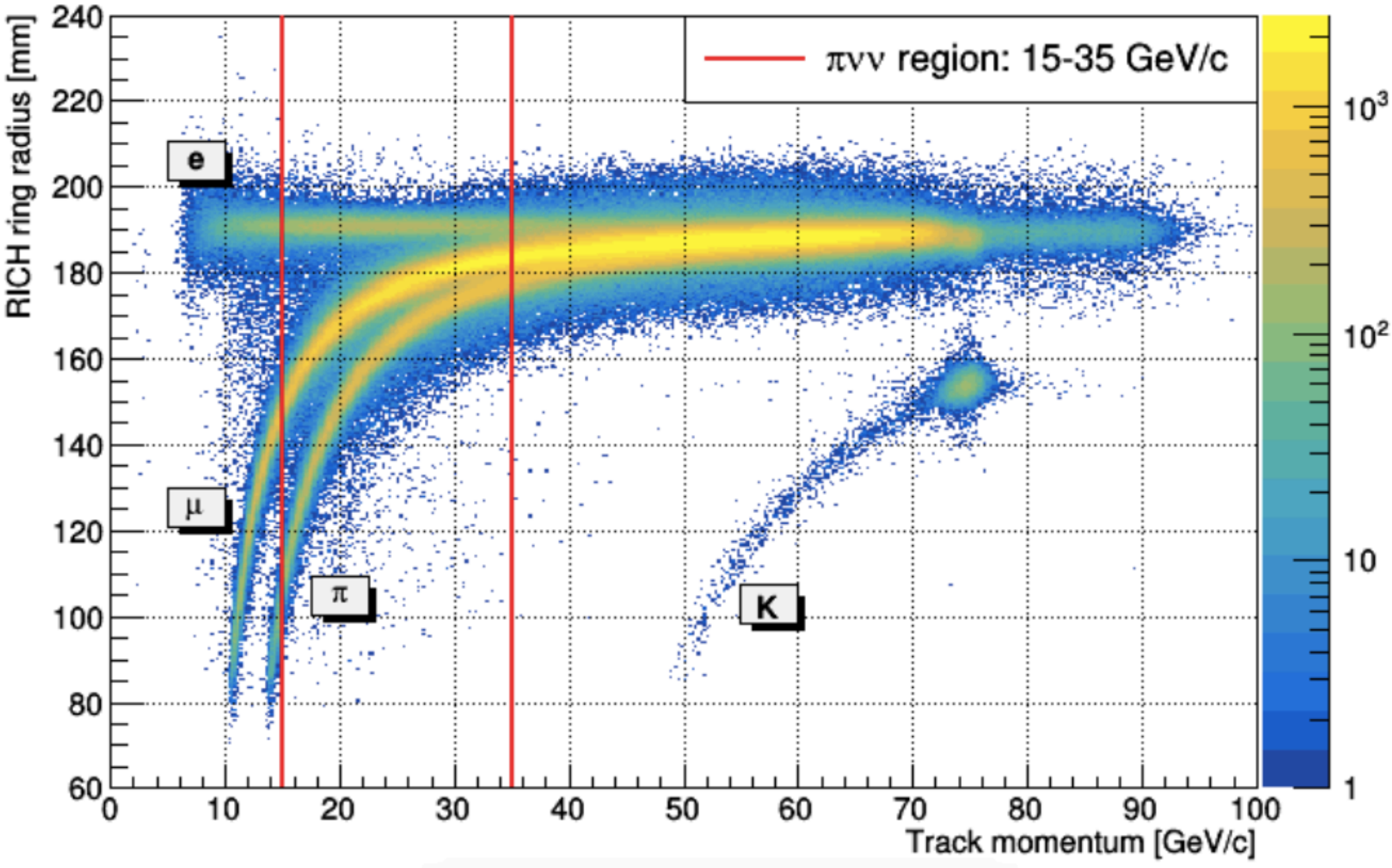
Plot the difference



RICH time resolution = 0.07 ns

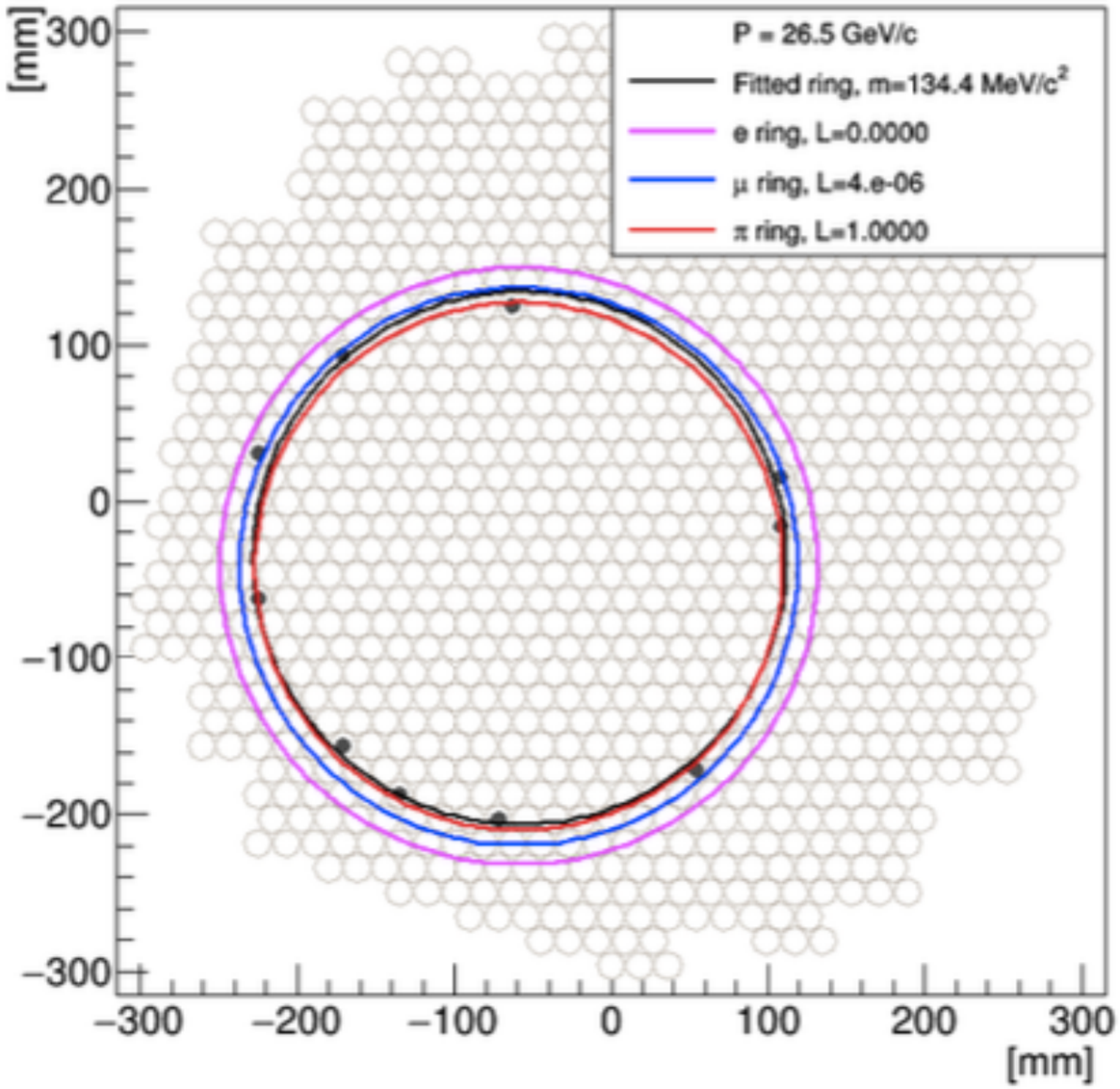
PID performance

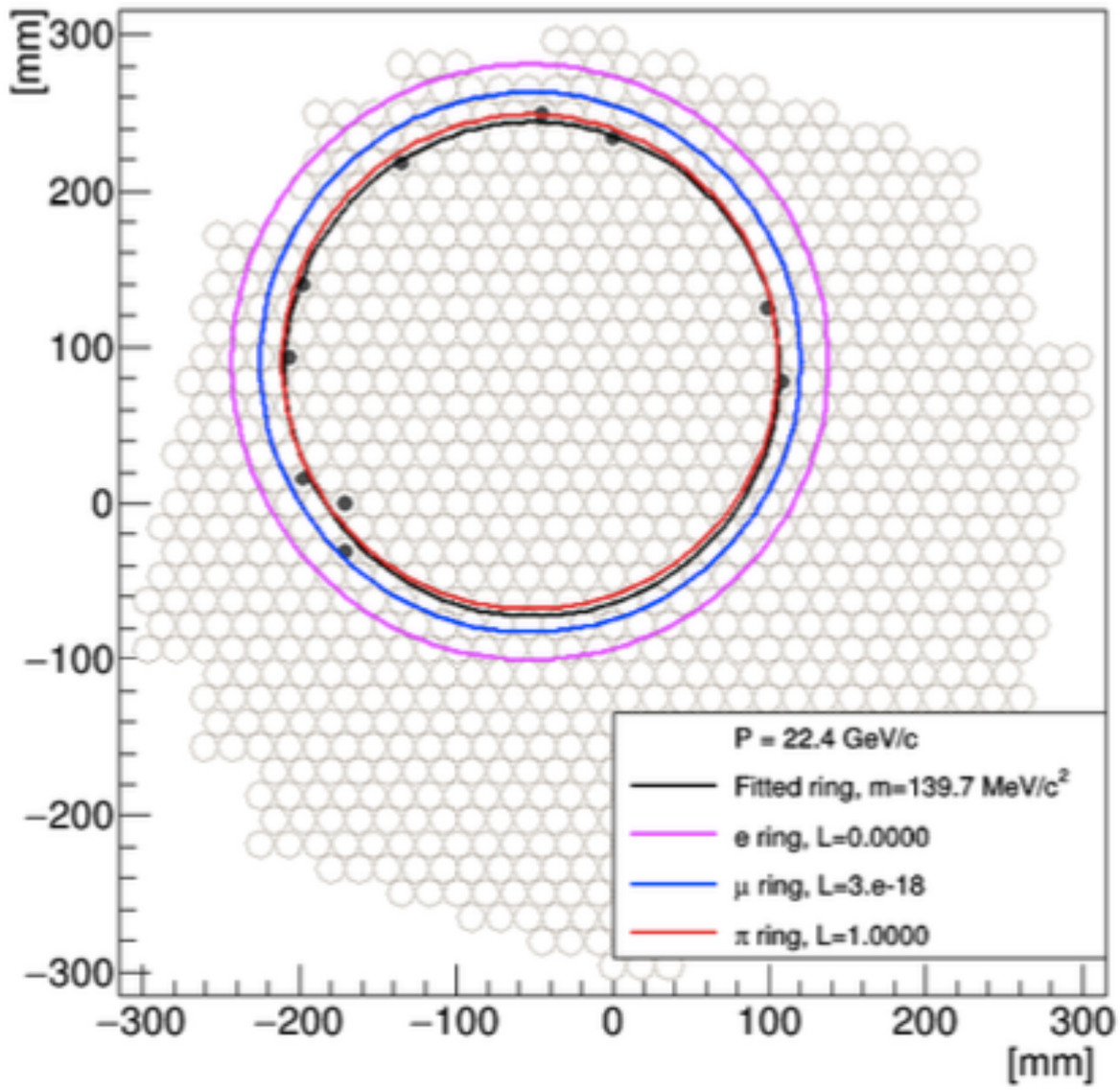
2017 data



The two signal candidates in 2017 data

Cherenkov ring for the two events observed in the signal region



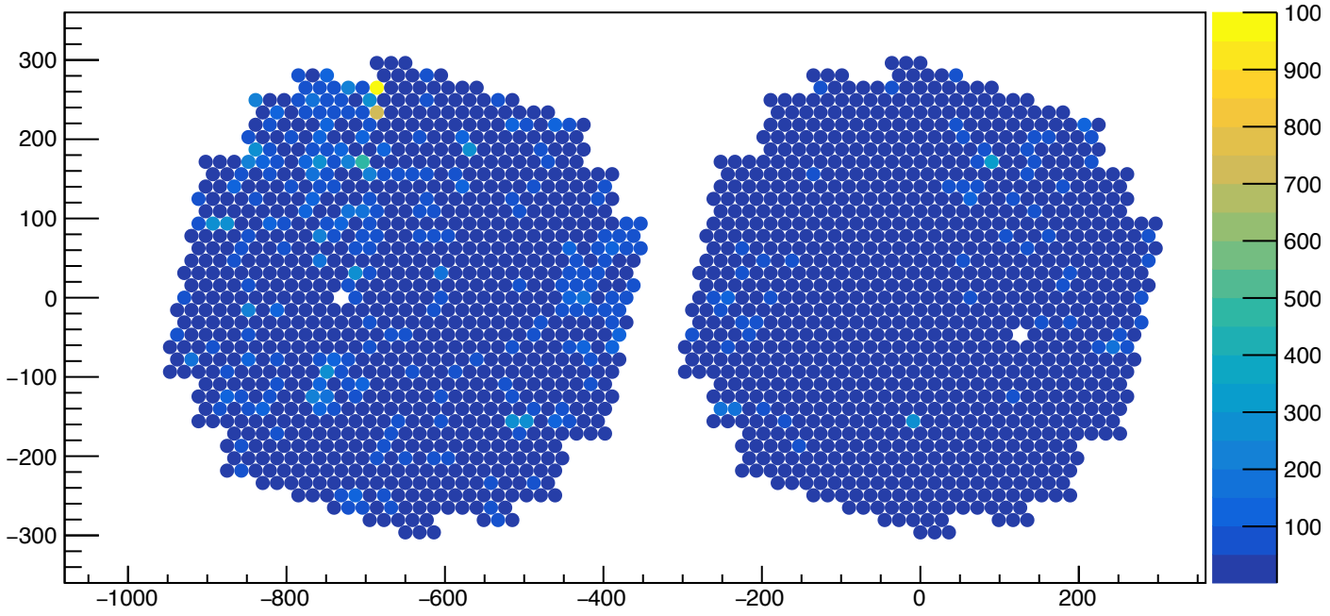


2016+2017 NA62 result $BR(K^+ \to \pi^+ \nu\nu) = 1.85 \times 10^{-10} @ 90\,\%\, CL$

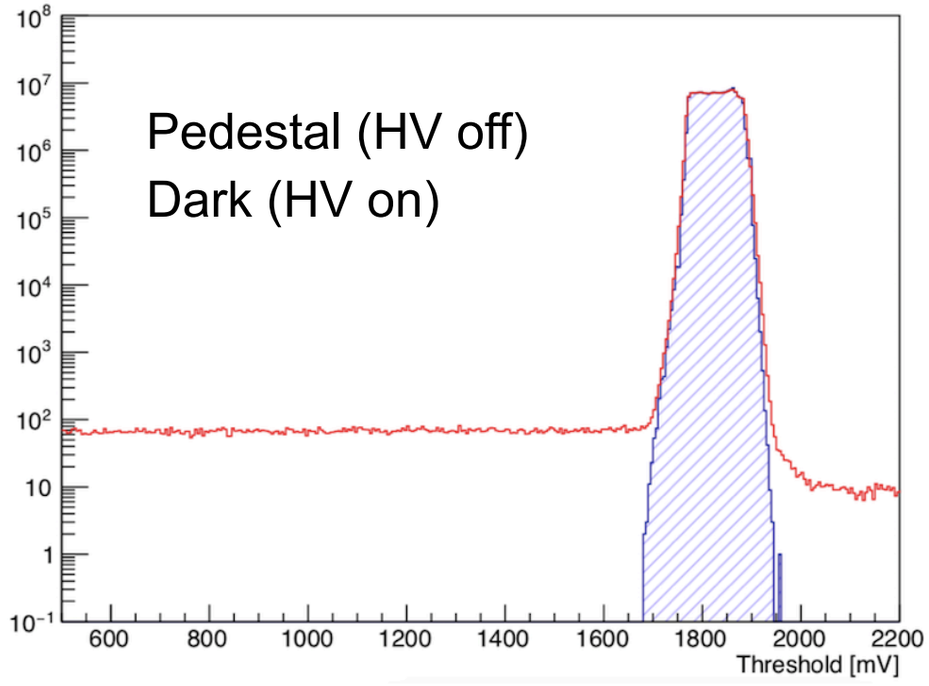
[Ruggiero.G, Kaon 2019]

Monitoring tools

Optimize single photoelectron response using thermal noise



Scaler data display
no beam, fixed threshold
typical value 10 cps



Single channel
count rate vs threshold

2019 data

Conclusion

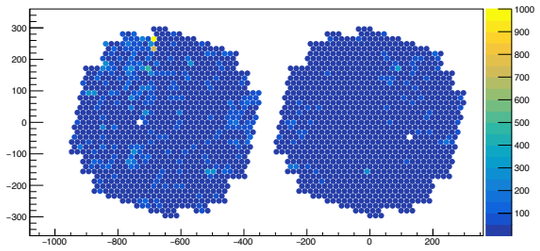
NA62 took $K^+ \to \pi^+\nu\nu$ data in 2016-2018 with RICH as crucial sub-detector

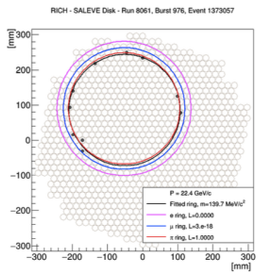
- providing additional muon rejection to calorimetry based PID
- participating in L0 trigger with hit multiplicity algorithm
- giving to the experiment a 70 ps time reference for charged particles

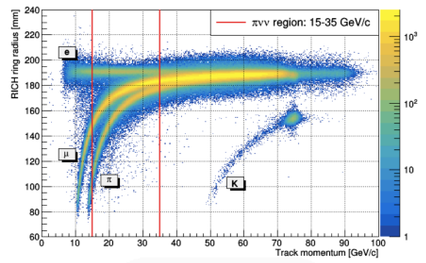
NA62-RICH has been a good test environment for GPU based online selection
In particular to reconstruct complex quantities at lowest trigger level L0

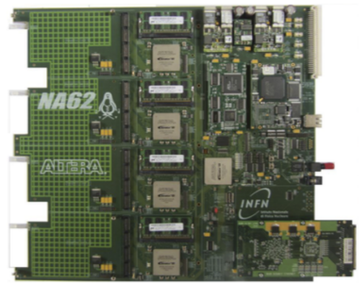
NA62-RICH, completed with monitoring tools, is ready for data taking restart in 2021 with upgraded L0TP and GPU

INSTR20 Instrumentation for Colliding Beam Physics









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