RICH 2022

XI International Workshop on Ring Imaging Cherenkov Detectors

Dedicated to the memory of Jacques Séguinot

Edinburgh, UK

12 – 16 September 2022

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Neutrino mass ordering determination through combined analysis with JUNO and KM3NeT/ORCA [1]

João Pedro A. M. de André[1*], Nhan Chau[2], Marcos Dracos[1], Leonidas N. Kalousis[1], Antoine Kouchner[2], Véronique Van Elewyck[2] for the KM3NeT Collaboration and members of the JUNO Collaboration

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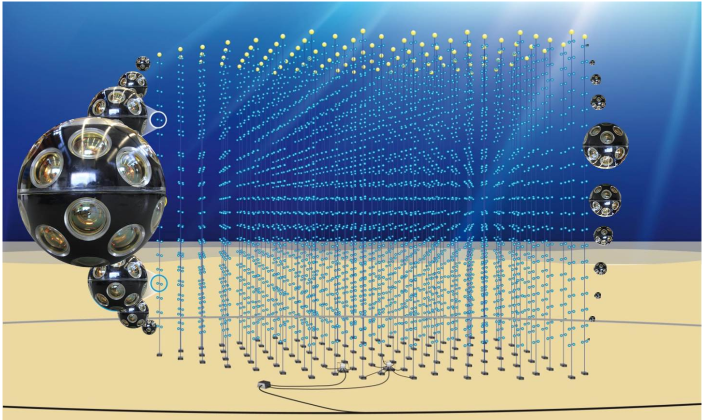
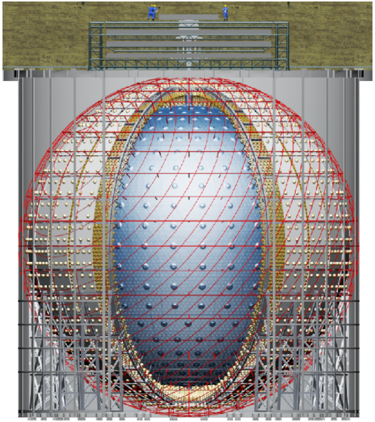
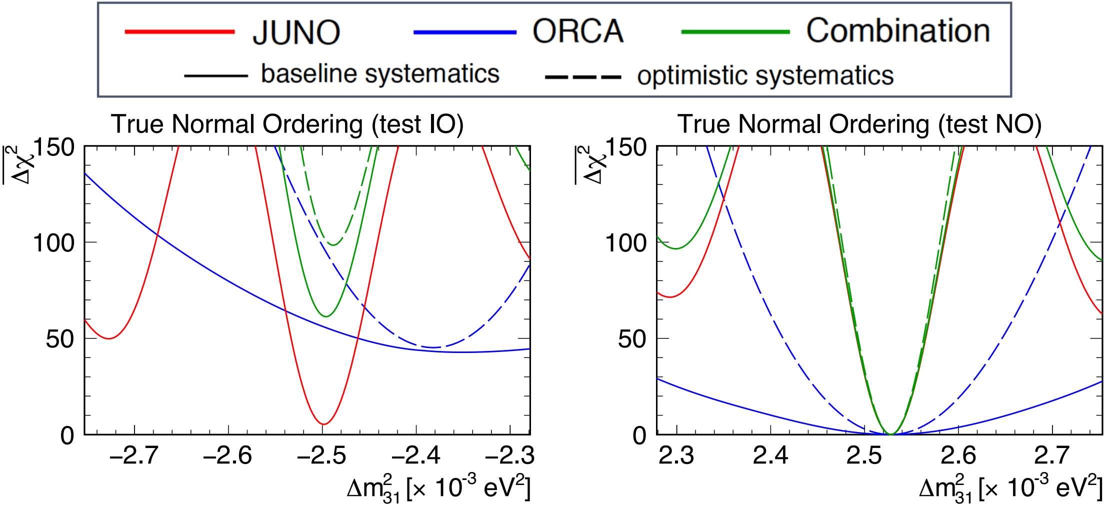
The detectors





- Very different detectors → no common detector/flux/...systematics
- Common oscillation parameters → most important Δm^2_{31} and θ_{13}

Combining JUNO and KM3NeT/ORCA – 6 years

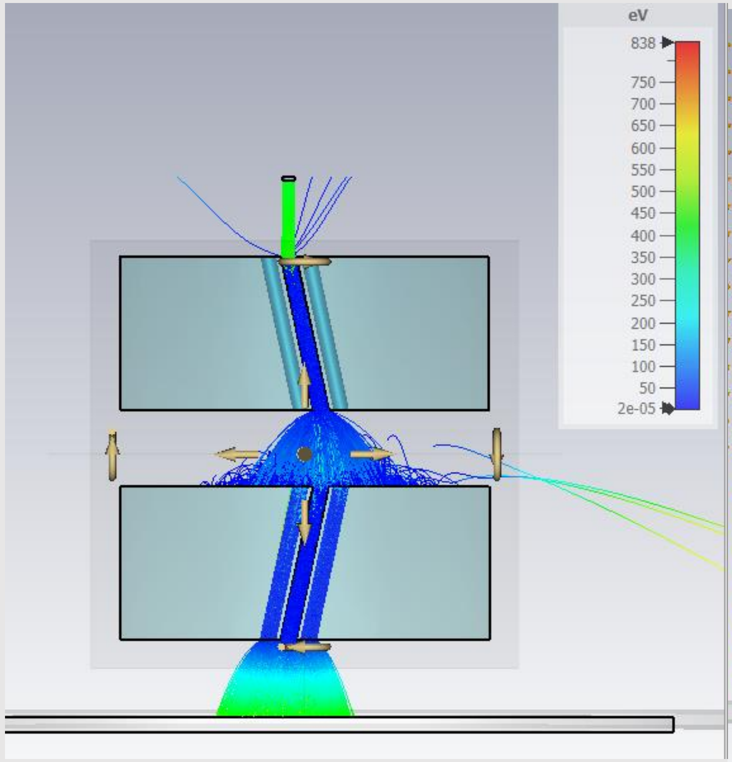


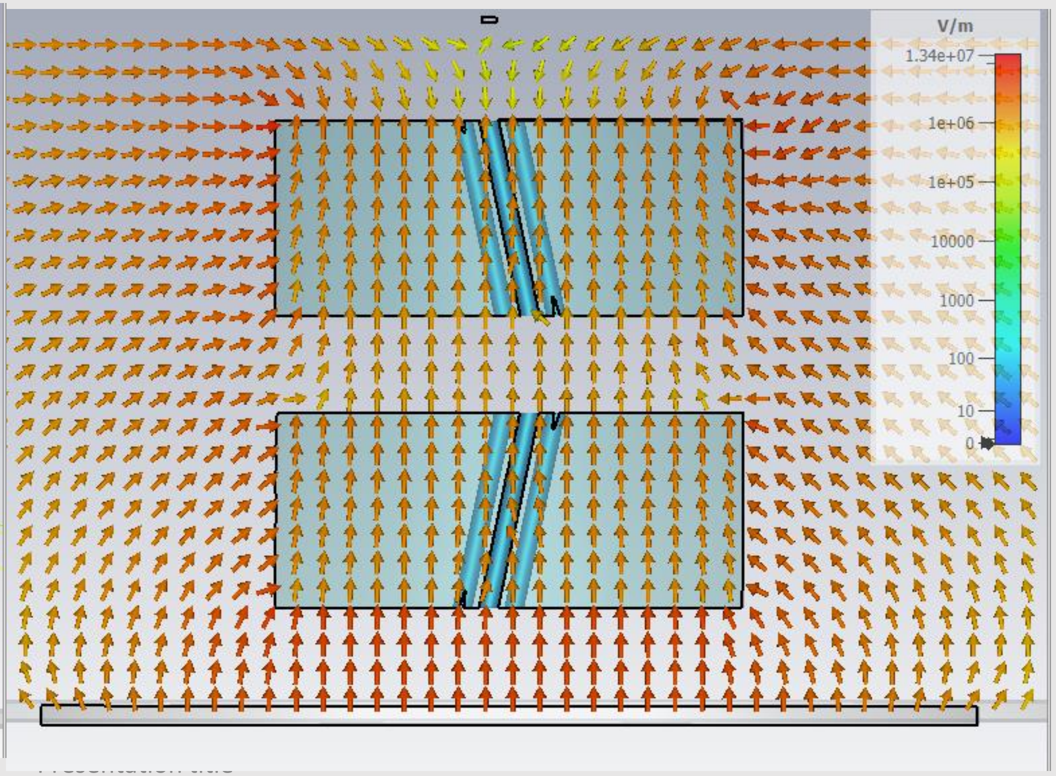
- JUNO: $\bar{\nu}_e \to \bar{\nu}_e$ KM3NeT/ORCA: $\nu_\mu \to \nu_e, \nu_\mu$ and $\bar{\nu}_\mu \to \bar{\nu}_e, \bar{\nu}_\mu$
- 5 σ NMO determination in $\leq$6 years once both detectors fully online

Simulating the Effect of External Magnetic Fields on Microchannel Plates

E J Baldwin, J S Lapington, S A Leach

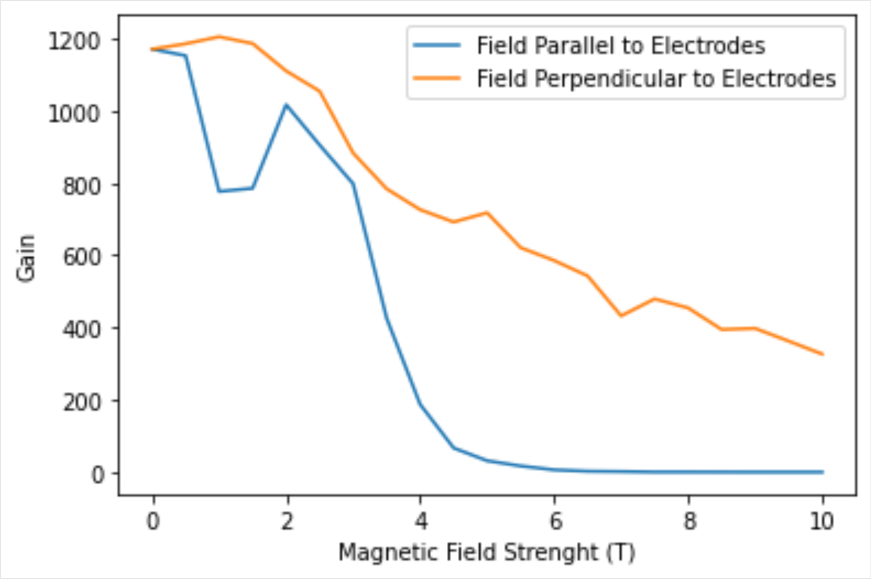
- CST Studio Suite can be used to simulate structures such as MCPs.
- More complex arrangements, such as the chevron arrangement can be modelled.
- Electron trajectories, electric field and other characteristics are simulated.
- Allows modelling of structures that are difficult/not yet possible to manufacture.

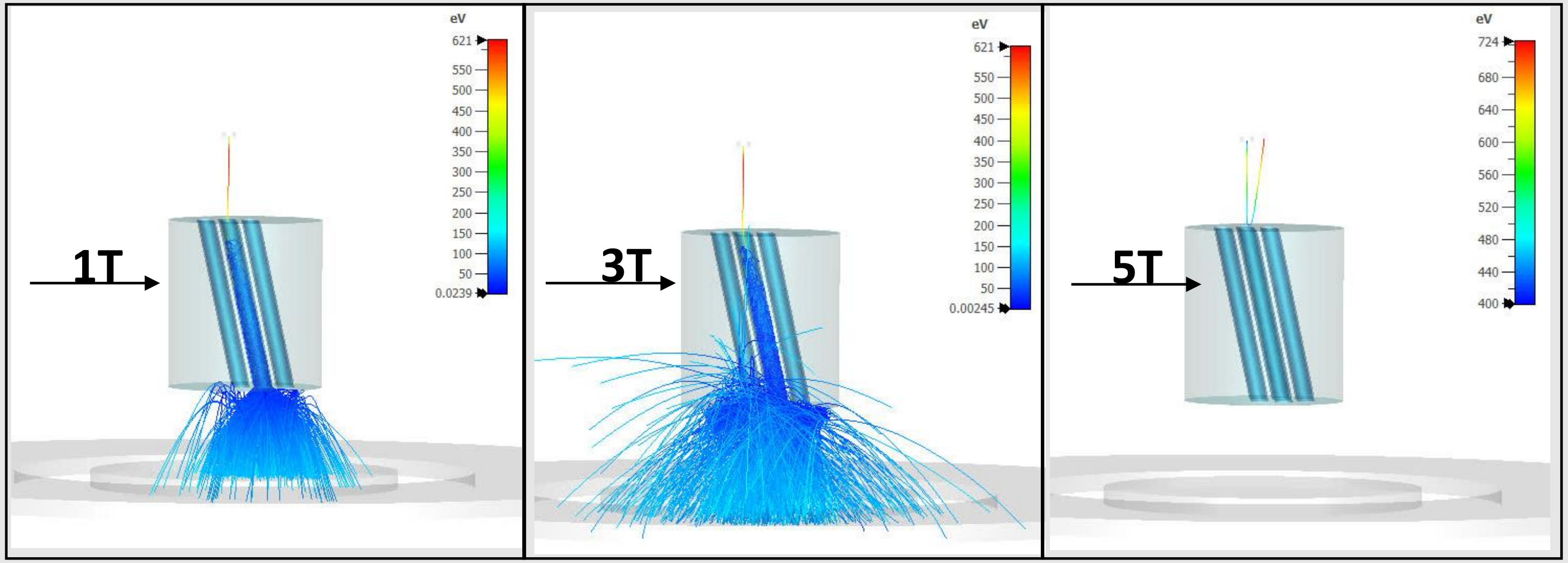




Simulating the Effect of External Magnetic Fields on Microchannel Plates
E J Baldwin, J S Lapington, S A Leach

- The effect of external magnetic fields are simulated for an L/D of 10:1.
- Different magnetic field magnitudes are simulated, both parallel and perpendicular to the electrodes.
- Both field directions result in a reduction of gain with an increase in magnetic field magnitude.
- Trajectories of electrons throughout the MCP are visualised to show why this gain degradation occurs for fields parallel to the electrode layers (field direction represented by arrow in images below).





Optical Systems For Future RICH detectors

R. Cardinale, A. Petrolini - on behalf of the LHCb/RICH collaboration.

University of Genova and INFN, Italy; CERN - European Laboratory for Particle Physics.

15 September 2022

- In $\approx$ 2012 the concept for what was called *RICH-2019* took shape, for an upgrade-1 of the RICH detectors of LHCb.
- Among many other things, the optics for RICH1 had margins for improvements: increased focal length (better angular granularity and reduced occupancy), longer path inside the radiator, reduction of the focusing uncertainty by optimization of the design.
- However, we had to work the improvements strictly inside the constraints, in order to avoid big changes outside the RICH.
- Some performance results are described in the poster
- For the upgrade-2, we can try to release some constraints: some more space available for increasing the focal length (however RICH1 needs to be rotated into the horizontal plane), mirror segmentation, to optimize the design in a different way for different angular regions, secondary mirror in acceptance, to improve focusing.
- The excellent performance results of a first design are described in the poster and compared with those of upgrade-1

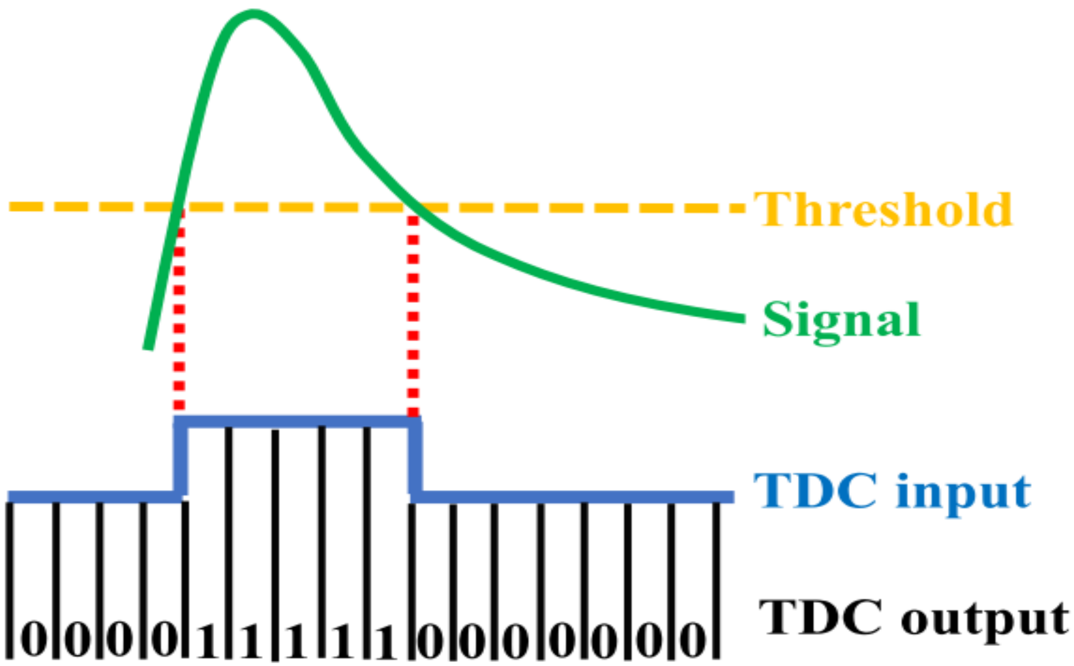
A multi-channel TDC-in-FPGA with 150 ps bins for time-resolved readout of Cherenkov photons

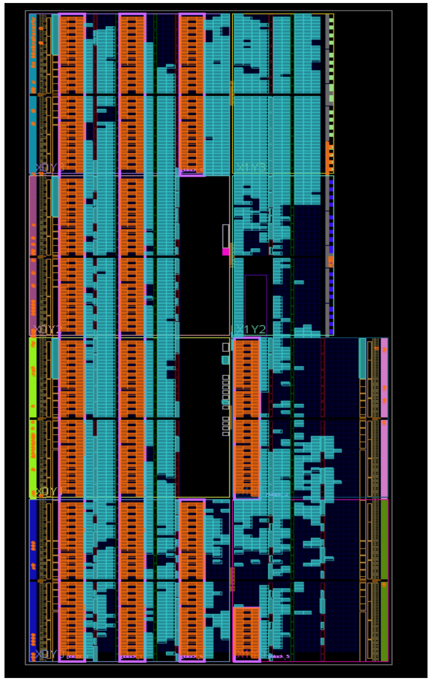
TDC-in-FPGA based on 16 phase-shifted clocks (420 MHz).

- Manual placement of TDC core.
- Relatively easy to implement and no drift with time, temperature or voltage.

Used to digitise Cherenkov photon signals from front-end ASIC.

- Time-and-arrival and Time-of-Threshold.

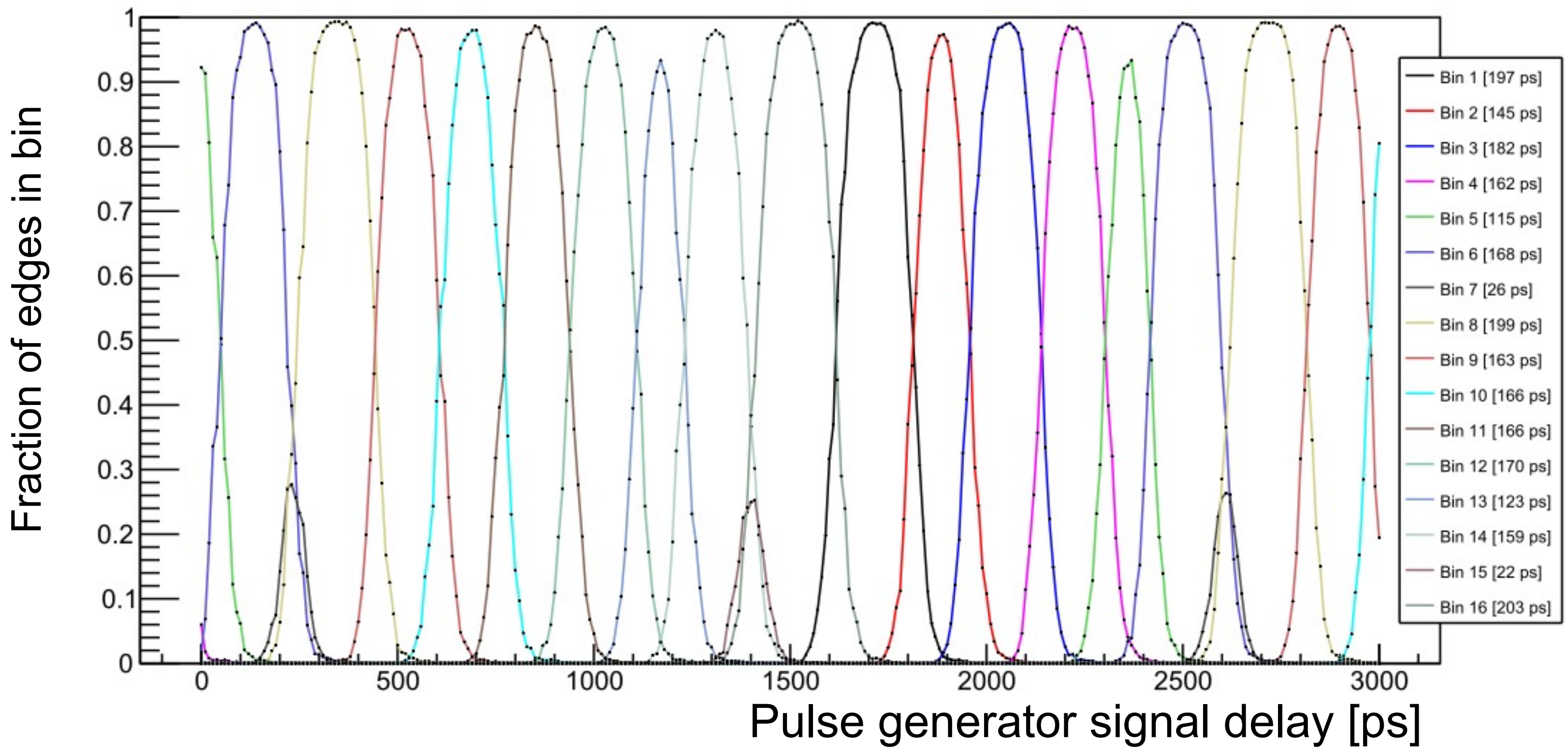




A multi-channel TDC-in-FPGA with 150 ps bins for time-resolved readout of Cherenkov photons

Calibration performed using injected pulse (10 ps steps, 25 ps jitter).

- Plot below shows variation in bin width for single TDC channel.
- Caused by signal path variations in the FPGA.
- Bin sizes vary from ~20 ps to ~200 ps.
- Calibration data is used to correct the obtained Cherenkov measurements.



Quality Assurance for the LHCb RICH Upgrade Photon-Detection chain

Carmen Giugliano[1]

[1] University and INFN Ferrara, on behalf of the LHCb RICH Collaboration

Istituto Nazionale di Fisica Nucleare SEZIONE DI FERRARA

11th International Workshop on Ring Imaging Cherenkov Detectors (RICH 2022)

Sep 12 – 16, 2022 University of Edinburgh

The LHCb RICH system Upgrade

LHCb relies on the Ring Imaging Cherenkov (RICH) detector system for the charged hadron identification in a wide momentum range (2 - 100 GeV/c). The RICH systems have been upgraded to sustain an increase of the read-out rate from 1 MHz to 40 MHz and the expected luminosity of $L = 2 \cdot 10^{33}\,\mathrm{cm^{-2}s^{-1}}$ foreseen during Run 3.

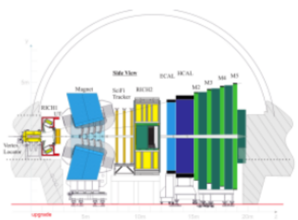


Figure 1: Side view of the Run 3 LHCb experiment.

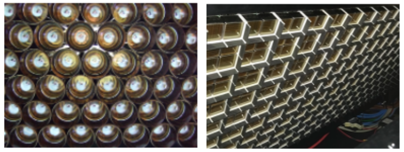


Figure 2: Left: HPD plane of the LHCb RICH 1 detector during RUN1 and RUN2. Right: MaPMT plane of the LHCb RICH 1 detector for Run 3.

In particular, the main change for the RICH was the replacement of the Hybrid Photon Detectors (HPDs) with Multi Anode Photomultiplier Tubes (MaPMTs), manufactured by Hamamatsu, with external read-out electronics [1, 2].

Photon-Detection chain

- **MaPMT**
  - –Hamamatsu R13742 MaPMTs for high occupancy region, Hamamatsu R13743 MaPMTs for low occupancy region
  - – 64 anodes with low dark count rate (< 1 kHz) and gain ~ 2×10^6 at 1kV
  - – high quantum efficiency (~ 40% at 300nm) super-bialkali photocathode
- **CLARO chip**
  - – 8-channel amplifier/discriminator ASIC
  - – adjustable threshold and attenuation for each channel
  - – radiation-hard by design and triple modular redundancy protection

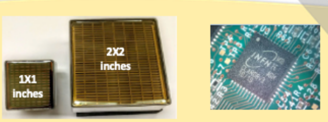


Figure 3: Left: Hamamatsu MaPMTs the R13742 (R-Type) on the left and R13743 (H-Type) on the right. Right: CLARO ASICS.

MaPMTs are integrated with Front End Boards and the CLARO chips in a compact device called Elementary Cell (EC) of type H and R (hosting a single H-Type MaPMT and four R-Type MaPMTs, respectively)

- 4 ECs constitute the Photon Detector Modules (PDM) which interface with the new LHCb readout through Photon Detector Module Digital Boards (PDMDB)
- PDMs are the fundamental modules of the RICH columns which form the photodetector planes

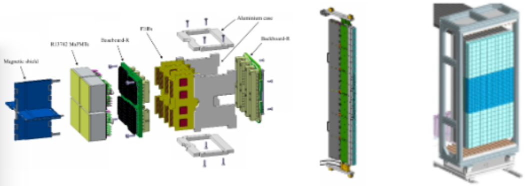


Figure 4: Left: R-type EC. Center: Column with 6 PDMs. Right: RICH2 Photodetector plane.

Quality Assurance and Commissioning

- Required more than 6 years
- Ensure minimum specifications
- Characterise the photon detectors and electronics
- Select components with similar characteristics to be installed in functionally related areas of the detector
- Calculate calibration parameters

Modular design to facilitate:
-maintenance
-operations
-**quality assurance campaigns**

Four major campaigns :

- Photodetector QA (PDQA) in Padova and Edinburgh
- CLARO chips and control system of Front-End Boards (FEB) and Back Board (BkB) in Ferrara and of Base Boards (BBs) in Genova and by Studioemme
- Elementary Cell QA (ECQA) in Ferrara and Edinburgh
- Column commissioning at CERN

PDQA

verify the specifications of the MaPMTs provided by Hamamatsu

System deployed on four stations

TEST STATION:
- Test box
- LED driver
- Slow control
- Power supplies
- Workstation computer

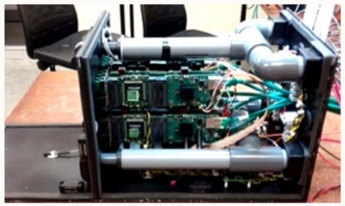


Figure 5: Test box with fully integrated Front-End readout, data acquisition, cooling and, environment monitoring.

The HV, light intensity, and the temperature and humidity sensors are controlled and monitored by a custom slow control based on the Arria-G25 FPGA

Automated procedure

The software implemented is a Finite State Machine (FSM) with C++ low-level language and graphical user interface in LabVIEW

The time required to test 16 R-Type or 4 H-type MaPMTs was one 1 day

Tested 3100 MaPMT R and 450 MaPMT H

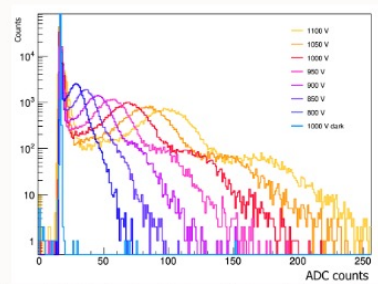


Figure 6: Typical signal amplitude spectra for a pixel as a function of the HV value.

QA of CLARO, FEBs, BkBs, and BBs

configure the CLARO chip register and read it back

verify the performances and the conformity of the BBs, FEBs and of the BKBs

System deployed on one station

The setup for the CLARO quality control:
- Pick&Place station
- interface board equipped with an Intel-ALTERA MAX10 FPGA
- computer running LabVIEW

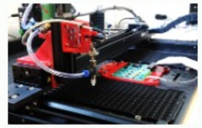


Figure 7: Pick&Place station used for the CLARO QA.

The time needed to perform the full test sequence was 160 seconds when no errors occur.

Tested more than 33000 CLARO then used in the upgraded RICH

The CLAROs passing the QA procedure have been assembled on the FEBs.

The test setup for the FEBs and BkBs:
- Test box
- custom boards based on Intel-ALTERA MAX10 FPGA
- system controller
- Workstation computer

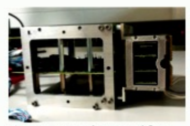


Figure 8: Test box used for the FEBs and BkBs QA.

The time required to test 4 BkBs was 15 mins.

A total of about 4200 FEBs were tested, together with 810 BkB-R and 460 BkB-H

The test setup for the BBs:
- Test station
- HV system controlled via WinCC-OA
- high precision multimeter for resistance measurement

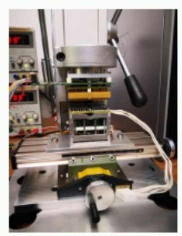


Figure 9: Test station used for the BBs QA .

Tested more than 1200 BBs

After the QA campaigns to validate all the components the ECs were assembled and the ECQA procedure started [3].

ECQA

verify the conformity of CLARO chips and MaPMTs

calibrate the CLARO channels and the MaPMTs anodes to optimise the single-photon detection efficiency

System deployed on four stations

TEST STATION:
- Dark box
- System controller
- LV power supply
- LED driver
- HV crate
- Raspberry Pi
- Workstation computer

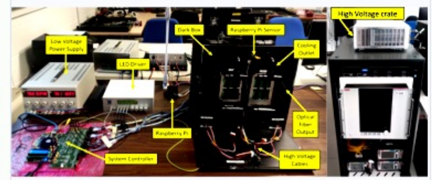


Figure 10: Test station used for the ECQA.

The core of the DAQ control software is given by low-level python functions while the upper hierarchy level is handled by the LabVIEW program.

Manual operation in case of critical errors and during the mounting procedures

ECs which successfully passed the QA tests were encapsulated in custom-designed jars to prevent any damage and then shipped to CERN to be assembled on columns.

The time needed to test 4 ECs was 18 hours

More than 1200 ECs have been characterised

Column Commissioning

characterise and calibrate the columns

All the components accepted by the QA procedure were assembled in the RICH columns during the commissioning performed at CERN. System deployed on one station

TEST STATION:
- Dark box
- Cooling system with Novec
- LV and HV power supplies
- Laser
- ELMB
- Server with LHCb Upgrade DAQ boards
- Workstation computer

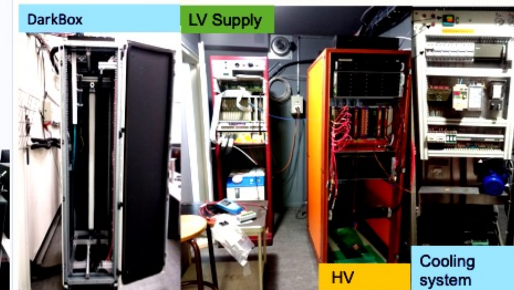


Figure 11: Test station used for the Column Commissioning.

Experiment Control System integrated in a FSM developed in WinCC-OA

Fully automated procedure

Large number of temperature and humidity sensors to ensure the safety of the detector hardware

The time needed to test 1 column was 18 hours

22 columns for RICH1 and 24 for RICH2 have been commissioned

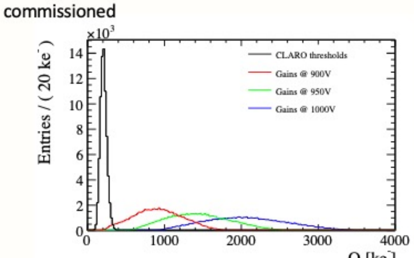


Figure 12: Distribution of RICH2 thresholds of the CLARO comparator converted into absolute charge (black). The threshold settings can be compared to the pixel gains at 900 V (red), 950 V (green) and 1000 V (blue) as determined from PDQA.

Conclusions

The extensive programme of QA, developed by the LHCb RICH group, tested and verified thousands of components enabling the installation of the photon detection subsystem in the LHCb cavern in a timely fashion, leading to the detection of Cherenkov rings in RICH2 during the pilot test beam of the LHC in October 2021.
The installation of both RICH detectors was completed successfully in March 2022 and are currently in full operation for the LHC Run 3.

References

[1] LHCb Collaboration, LHCb PID Upgrade Technical Design Report, CERN-LHCC-2013-022, LHCB-TDR-014

[2] S. Gambetta [LHCb RICH Collaboration], First results from quality assurance testing of MaPMTs for the LHCb RICH upgrade, Nucl. Instrum. Meth. A 876, 206 (2017). doi:10.1016/ j.nima.2017.02.079

[3] LHCb Collaboration, Experimental studies for the validation of the opto-electronic components for the LHCb RICH Upgrade,"2020", https://cds.cern.ch/record/2715879

From the FastIC ASIC to the FastRICH

A readout chip for the LS3 (2026) and LS4 upgrades of the LCHb RICH detector

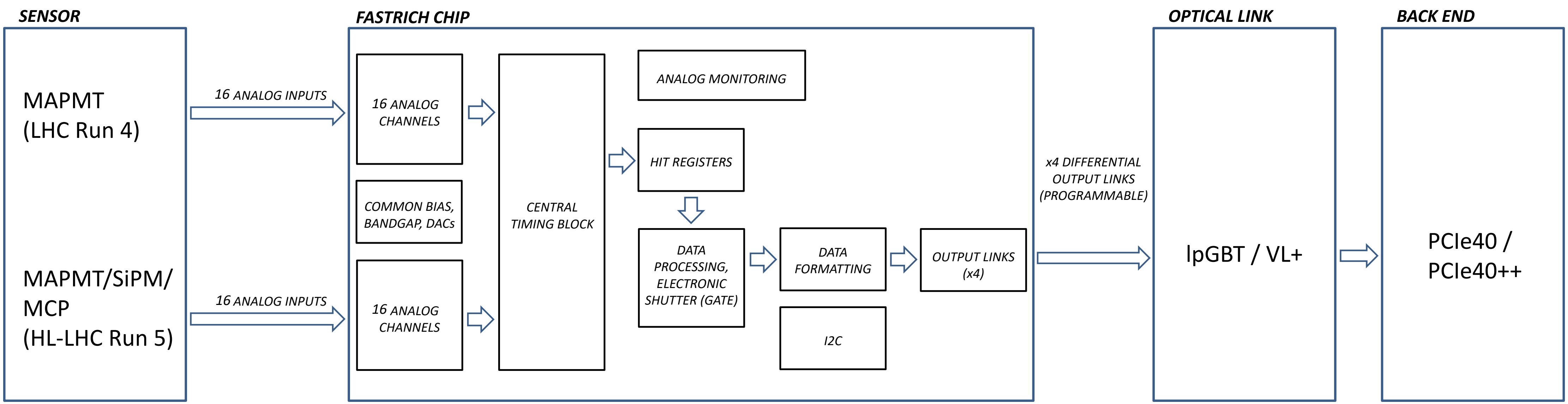
A radiation-hard ASIC for fast-timing single-photon detection at high data throughput.

FastRICH ASIC: **analog specifications**

- 16 channel.
- Constant Fraction Discrimination (CFD).
- Dynamic range from 5 μA to few mA for coupling to MAPMT / SiPM / MCP-PMT.

FastRICH ASIC: **digital specifications**

- TDC with 25 ps time bins.
- Data-compression: zero-suppression, 2 ns gate and CFD. 7 bits time and 4 bits channel ID.
- Compatibility with lpGBT / VTRX+ optical link chipset.
- Readout rate: 40 MHz (LHC); up to 4 links at 1.28Gbps.

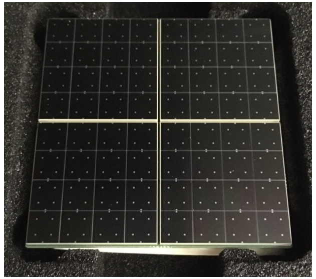


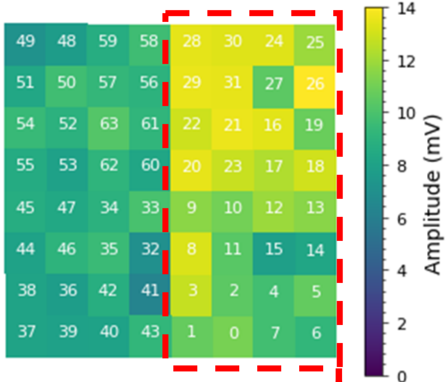
Analog part with CFD design completed, digital implementation started (ICCUB and CERN EP-ESE).

Characterisation of Cherenkov Optimised Silicon Photomultipliers Following Long Duration Operation

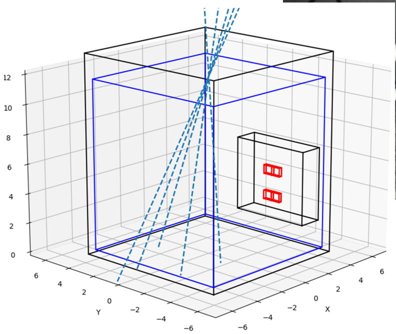
UNIVERSITY OF LEICESTER

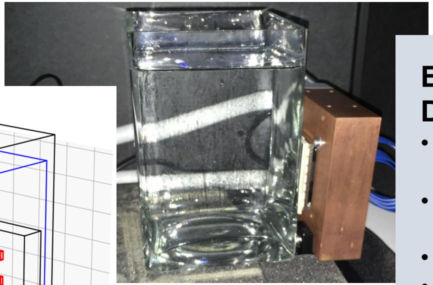
Step 1) Laser





Step 2) µ

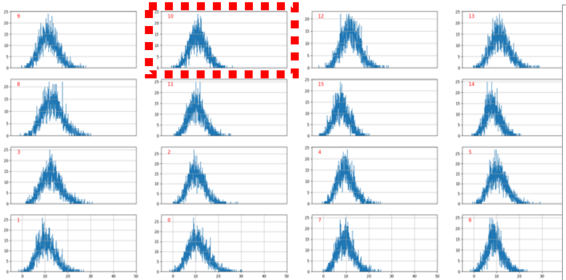




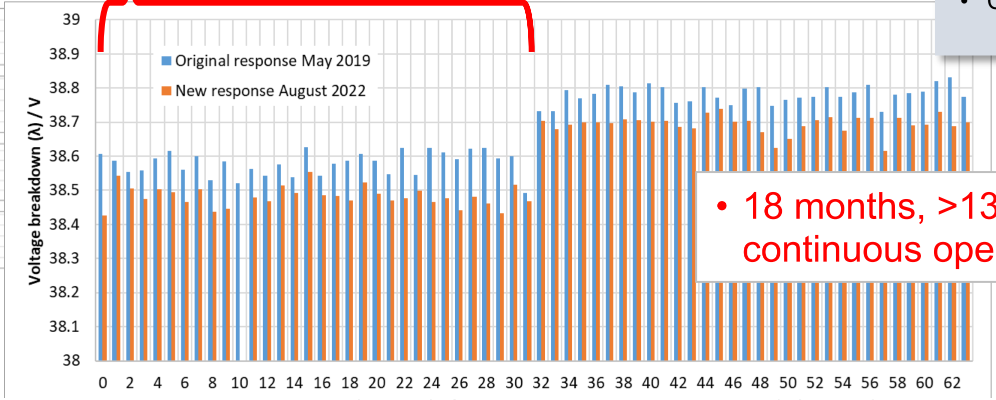
Extensive Air Shower Detection Unit:

- Four 6 mm LVR3 6075 SiPM pixels
- 75 µm Hamamatsu, peak sensitivity 465 nm
- Controlled 11 °C, <70% RH
- 89 x 89 x 112 mm (w-d-h) water tank
- 1.5 pe per channel (x4) <8 ns coincident threshold trigger
- Continuous 24/7 operation

Pixel 10



Pulse height distributions



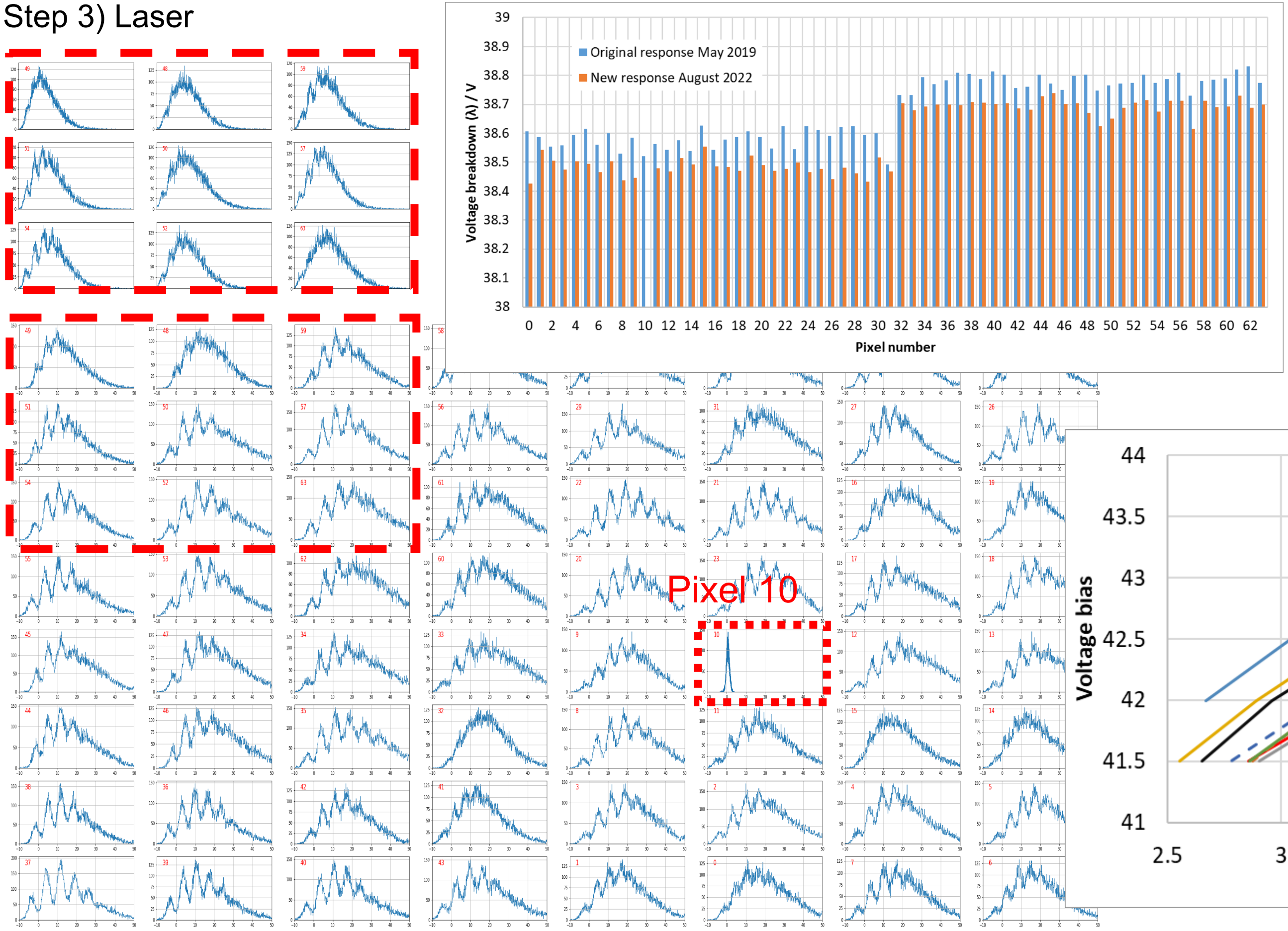
- 18 months, >13,100 hours continuous operation

Pixels 0 to 31 Pixels 32 to 64

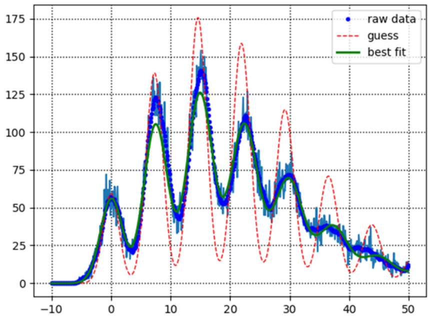
[1] Leach, S. A. and Lapington, J. S. : Extensive Air Shower Tracker using Cherenkov Detection. JINST (Sept 2022)

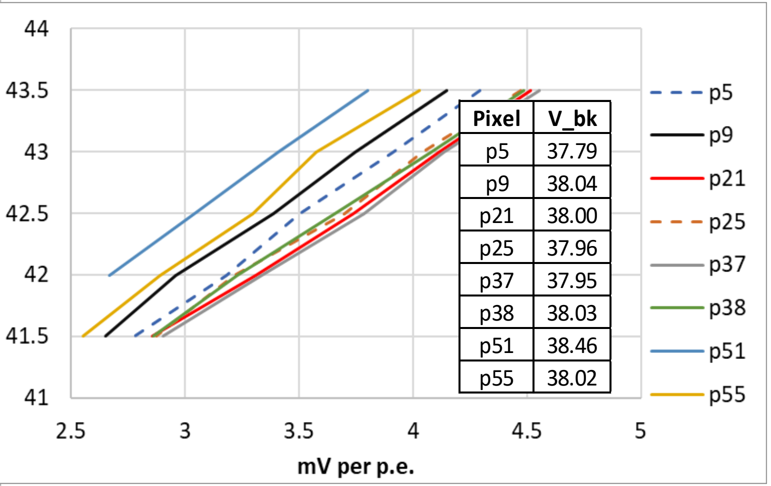
Contact: Dr Steve Leach, sal41@le.ac.uk
Space Research Centre, University of Leicester, UK

Step 3) Laser



Step 4) Further Analysis





Pixel	V_bk
p5	37.79
p9	38.04
p21	38.00
p25	37.96
p37	37.95
p38	38.03
p51	38.46
p55	38.02

[1] Leach, S. A. and Lapington, J. S. : Extensive Air Shower Tracker using Cherenkov Detection. JINST (Sept 2022)

Contact: Dr Steve Leach, sal41@le.ac.uk
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Study of new aerogel radiators for the LHCb RICH upgrade

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[1]Jožef Stefan Institute, Ljubljana, Slovenia, [2]CERN, Geneva, Switzerland, [3]INFN, Genova, Italy, [4]University of Ljubljana, Ljubljana, Slovenia

Introduction

Goal:

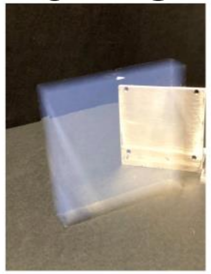
- Aerogel yield measurements
- Prepare setup for alternative radiators/sensors, readout electronics

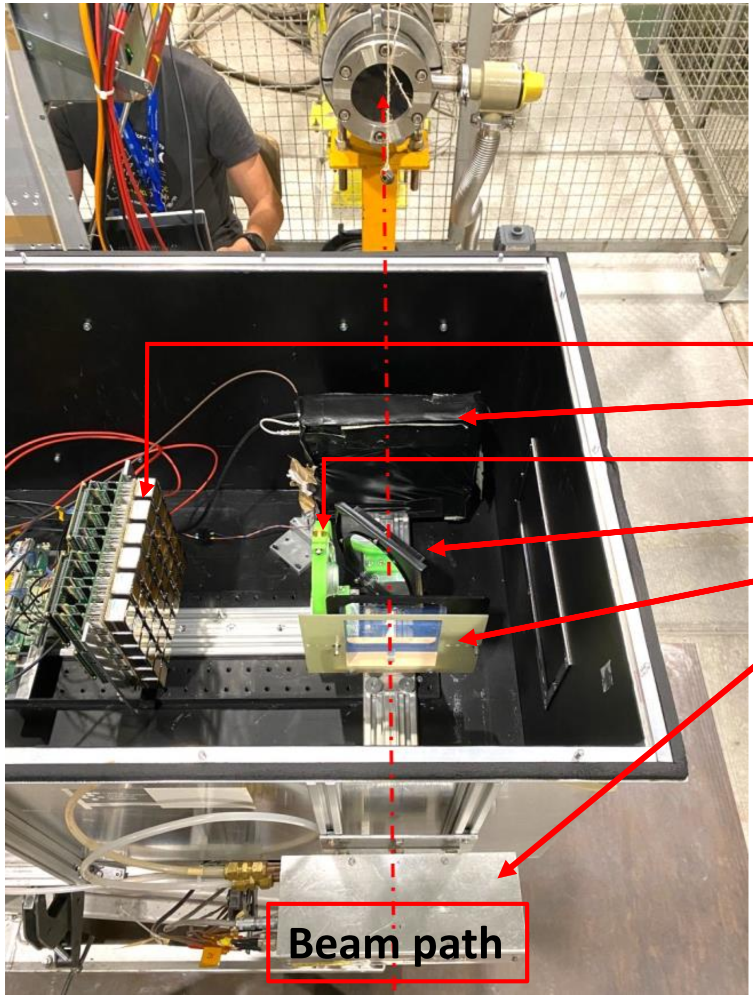
Experimental setup

Hydrophobic aerogel:

- Produced by Chiba University, Japan
- Tile size: 12 x 12 x 2 cm^3
- Refractive index: 1.03, 1.04, 1.05
- Average transmission lengths @ 400 nm:

1.03	63 mm
1.04	56 mm
1.05	37 mm



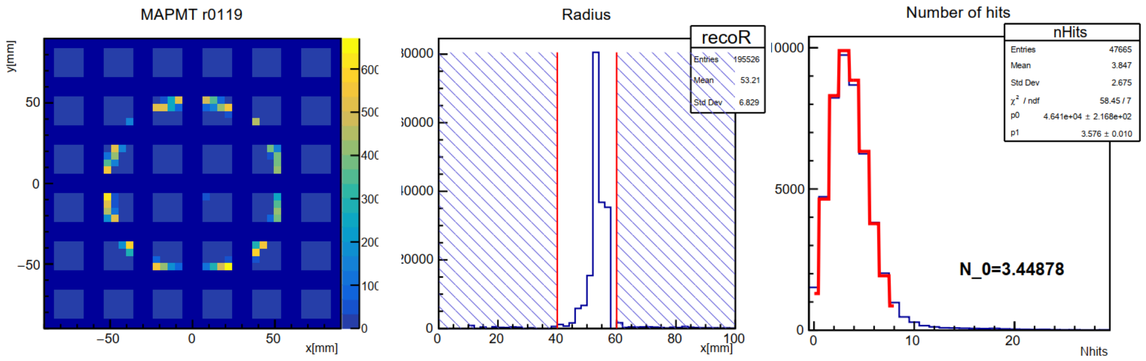


Components:

- Dark box on adjustable table
- 6x6 MAPMTs R5900-M16
- Scintillator + MWPCs for trigger
- Focusing lens
- Mirror
- Aerogel sample
- Beam tracking: MWPC

Measurements

- All three refractive indices
- Stack of tiles: from 1 (2 cm) to 4 (8 cm) for 1.03
- Number of detected photons per track ($N_{detected}$)
    - Estimate radius for each hit
    - Apply radius cut
    - Fit Poisson distribution
- Compare with simulation in Geant4-based software (GEARS)



Results

	$N_{detected}$	N_{mean}	$N_{detected}$	N_{mean}	Geo. eff.
Ref. ind.	Data		Simulation		
1.03	3.6	3.9±3.2	3.3	3.3±2.0	49%
1.04	4.0	4.2±2.8	3.8	3.8±2.2	50%
1.05	3.5	3.7±2.6	3.1	3.2±2.0	40%

Estimation of the yield:

- **Geometrical** efficiency: ~50%
- **Photon detection** efficiency: ~8%
- **Losses** in the optical components: 10-20%
- Total efficiency ~3.5% and 3.6 photons: ~ 50 photons / cm

Outlook

Next testbeam in October: measure detectors with fast timing readout

MUCH: an imaging Čerenkov telescope for volcano muography

Davide Mollica

INAF-IASF Palermo

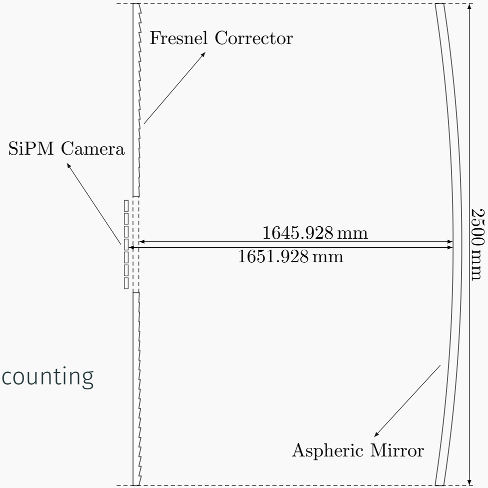
Optical system

Schmdit-like OS

- Compact optical system
- Flat focal plane

SiPM camera

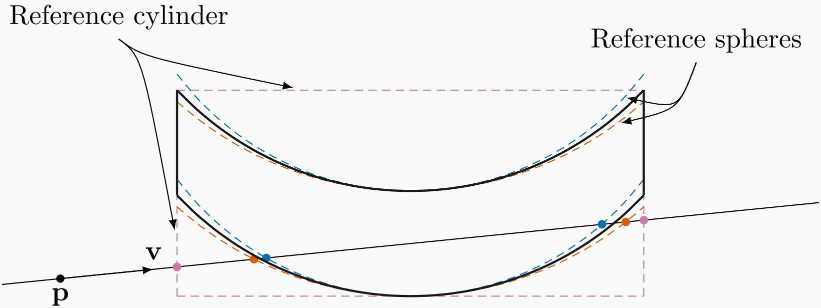
- 12° field of view
- Pixel size 7 mm (0.2°)
- RADIOROC ASIC
  - ↪ 200 MHz single photon counting



GEANT4 simulator: aspheric mirror

New GEANT4 CSG solid

- No analytic solution for intersections
  - ↪ Two reference spheres are used to restrict root-finding intervals



Optical performance: GEANT4 results

- Resolution better than 0.2° over the entire FoV
- Optical quality is uniform over the whole aperture

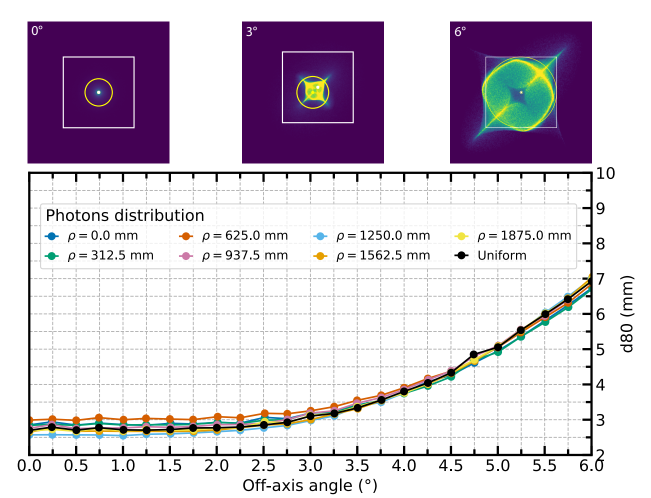


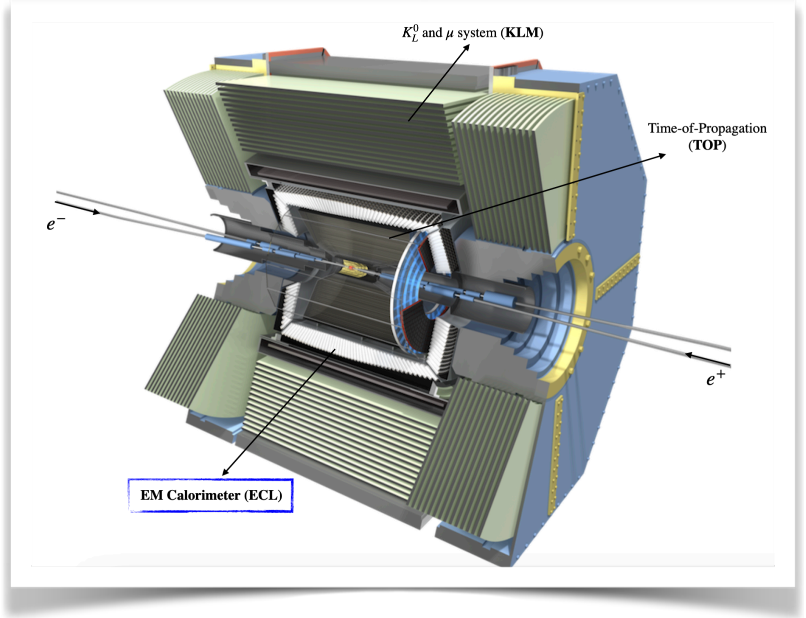
Image Based Particle Identification at Low Momenta

Anja Novosel[1], Abtin Narimani Charan[2], Luka Šantelj[1], Torben Ferber[3]

[1]Jožef Stefan Institute, [2]Deutsches Elektronen-Synchrotron DESY, [3]Karlsruhe Institute of Technology

Institut "Jožef Stefan" Ljubljana, Slovenija

Motivation

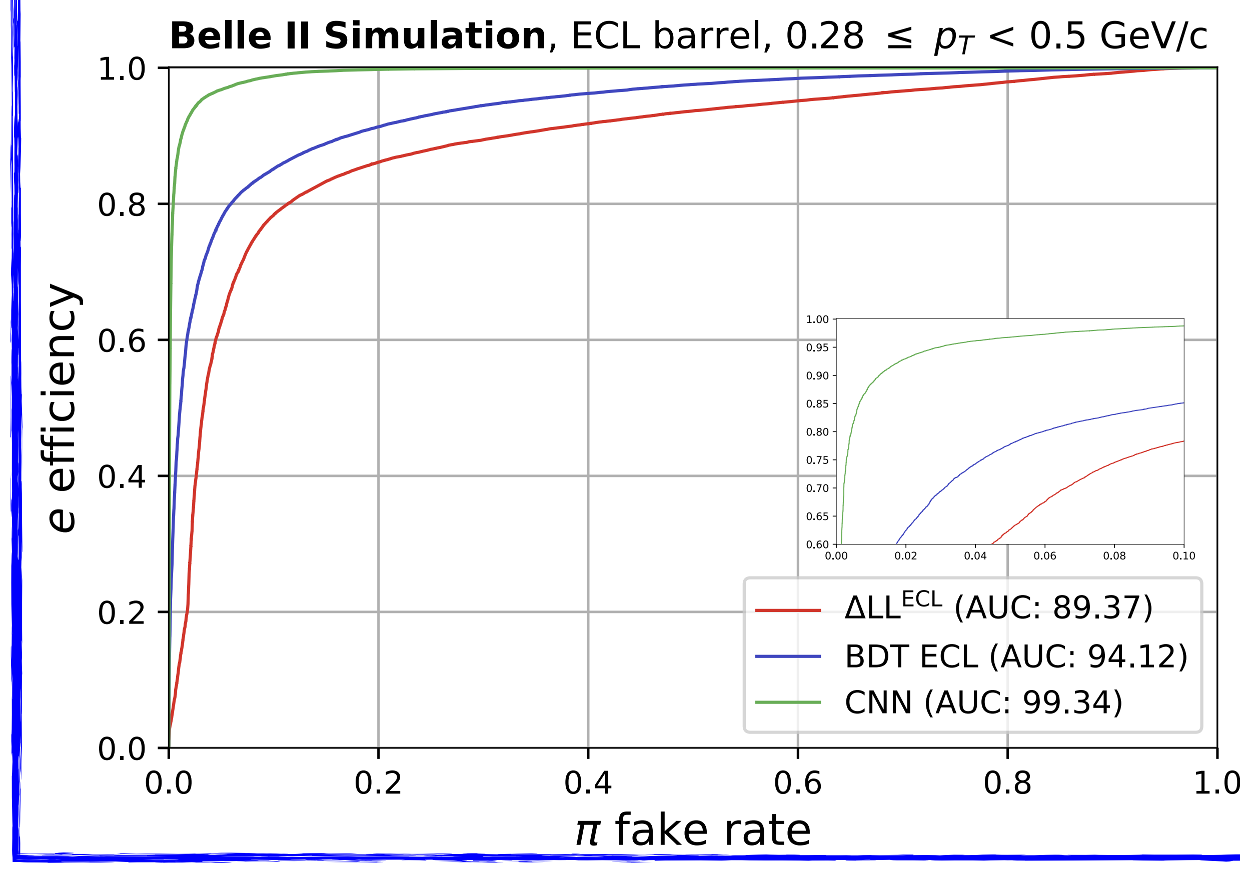


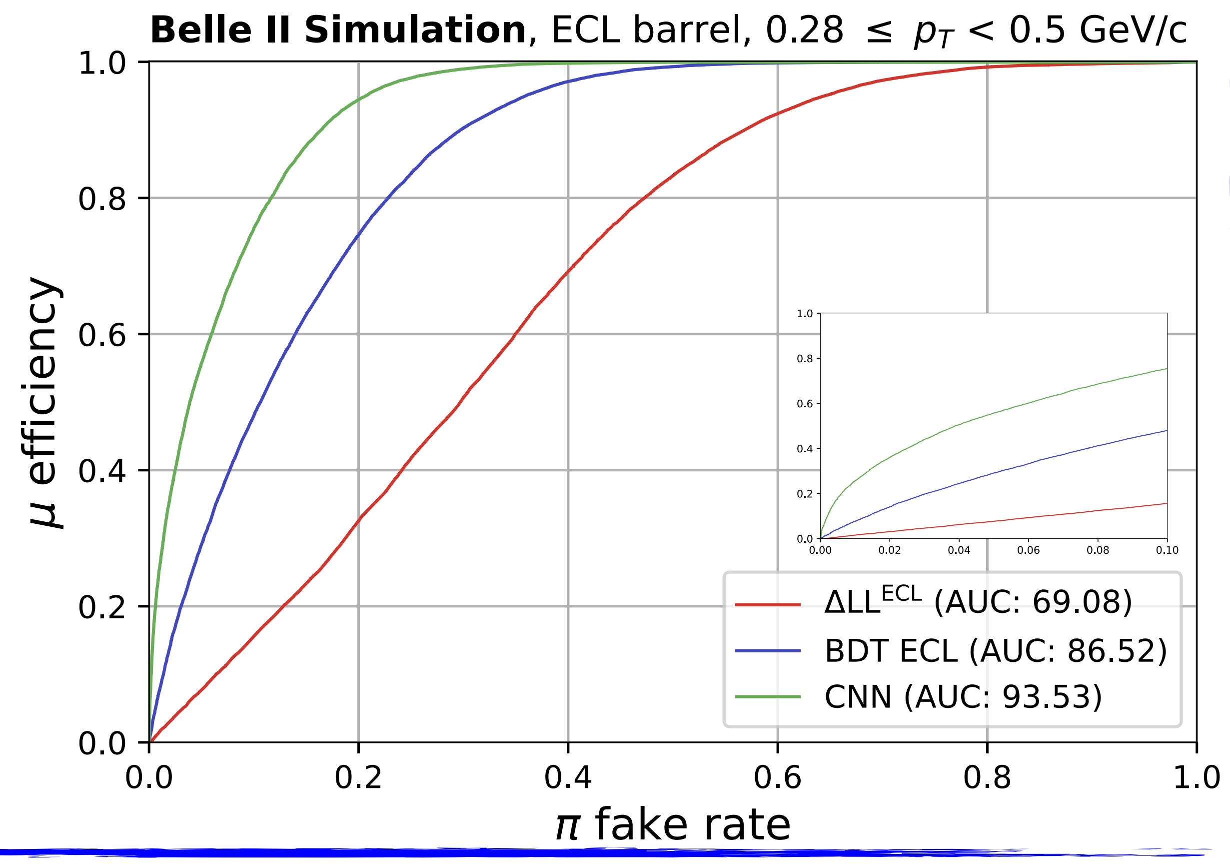
Interesting processes to search for New Physics are **semi-tauonic** decays of B meson. Charged decay products of τ lepton (e. g., **electrons** or **muons**) have **low momenta**.

- **low identification efficiency for** μ with $p_T < 0.6$ GeV/c (out the acceptance of the dedicated sub-detector KLM),
- low momentum e have increased energy losses from bremsstrahlung (**reduced separation from hadrons**)
- improve the separation of low momentum leptons from hadronic background (mainly pions) **using the information from the ECL** ($p_T > 0.28$ GeV/c)

e vs. π classification $\quad$ μ vs. π classification

The performance of 3 different binary classifiers based on ECL information only: log-likelihood difference (ΔLL^{ECL}), Boosted Decision Trees (BDT ECL), Convolutional Neural Network (CNN).



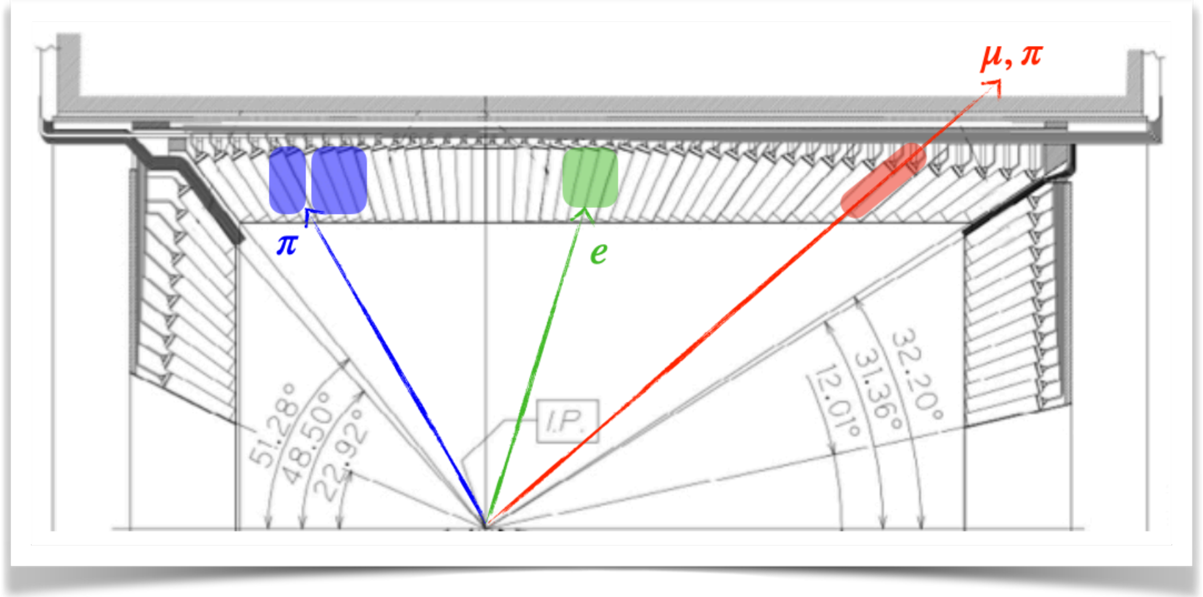


Electromagnetic Calorimeter

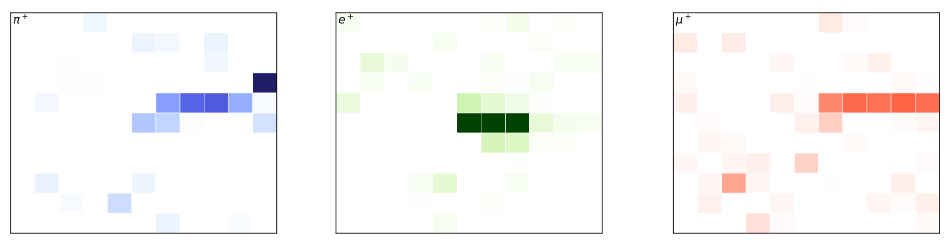
The dominant interaction in the ECL for μ and π in $p_T \in [0.28, 0.9]$ GeV/c is ionization. Additionally π can strongly interact with nuclei. Electrons generate EM showers depositing the majority of their energy in the ECL.

Are there some specific **patterns** in energy deposition?

Use low-level information from the ECL in form of **images** and **Convolutional Neural Network** a classifier.



pixel intensity = **energy deposited in the ECL crystal**



Conclusion

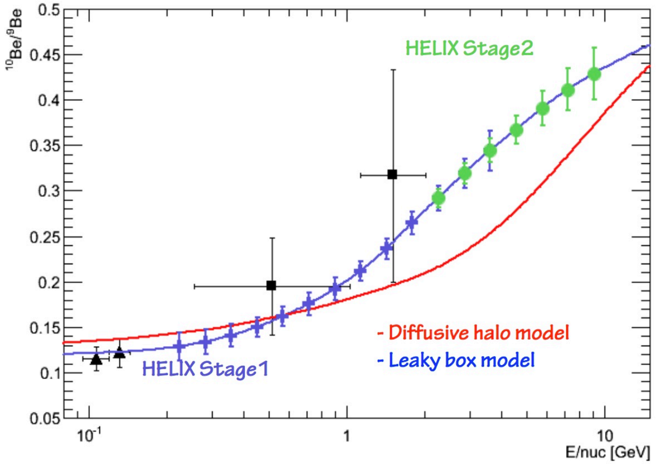
Separation between low momenta **leptons** and **pions** can be **improved by using CNN** on **ECL-based images**. The improvement is most significant in low momentum regions ($\mathbf{0.28 \leq p_T < 0.7}$ **GeV/c**), where most of the charged τ decay products are found.

Additionally, the CNN can provide also the separation for **tracks without clustering** information.

Calibration of Aerogel Tiles for the HELIX RICH Detector

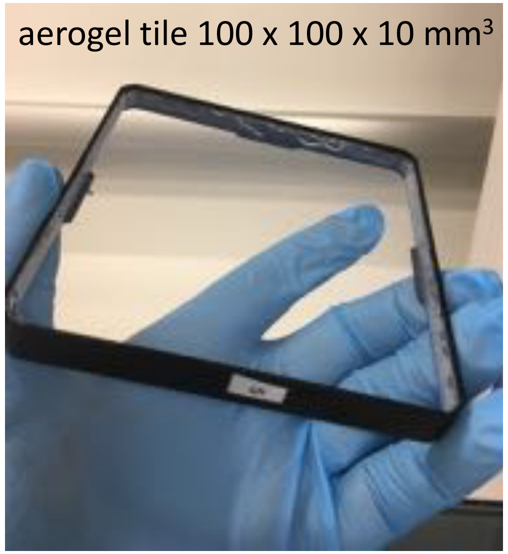
RICH-2022, Edinburgh

David Hanna
McGill University
(for the collaboration)

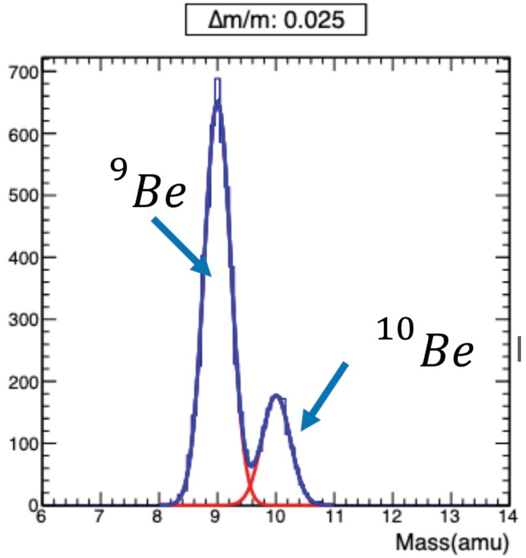


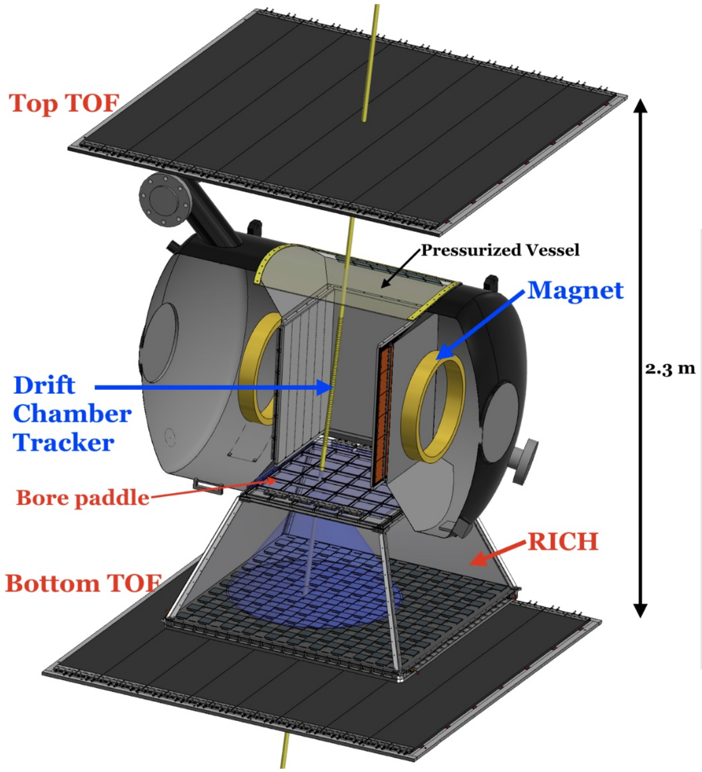
physics aim: measure the Be-10/Be-9 ratio to investigate local Galactic neighbourhood (see AMS-02 talk – F. Giovacchini)

aerogel tile 100 x 100 x 10 mm^3



Goal is to ***resolve*** the two isotopes





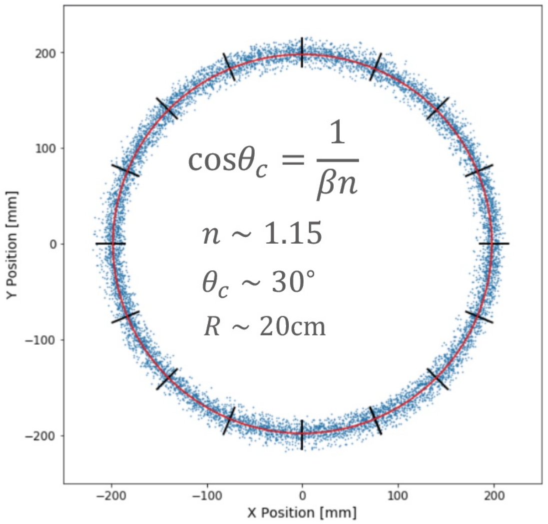
Balloon-borne (40 km asl) detector:
- 1 Tesla magnet
- drift-chamber tracker
- aerogel (n=1.15) RICH

Need to know n to 1/10000

Measuring *n* using electrons

Concept:

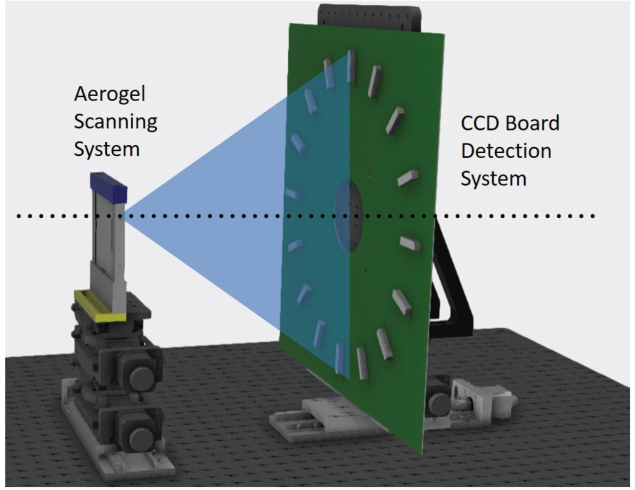
use a 35 MeV electron beam to make the ring and sample it using an array of one-dimensional CCDs.



Execution:

mount the aerogel tile on an x-y scanner upstream of a custom-made circuit board with 16 CCDs.

integrate 100 beam pulses per scan point for a 19x19 5mm grid to map out the tile.

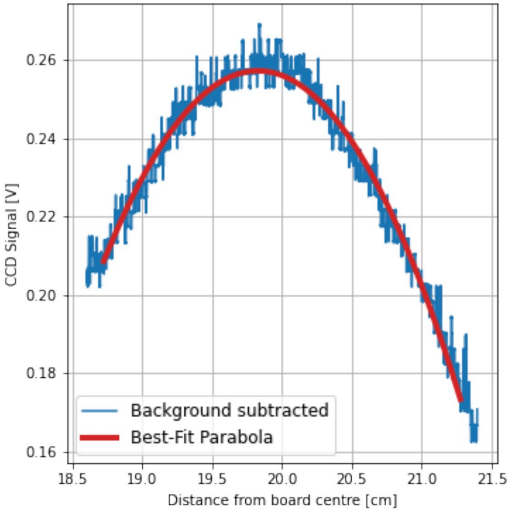


Analysis:

for each CCD reduce the 3600 pixels to 400 using medians-of-nine.

Fit a parabola and use the maximum as estimator of average ring position. (Width is mostly due to beam divergence).

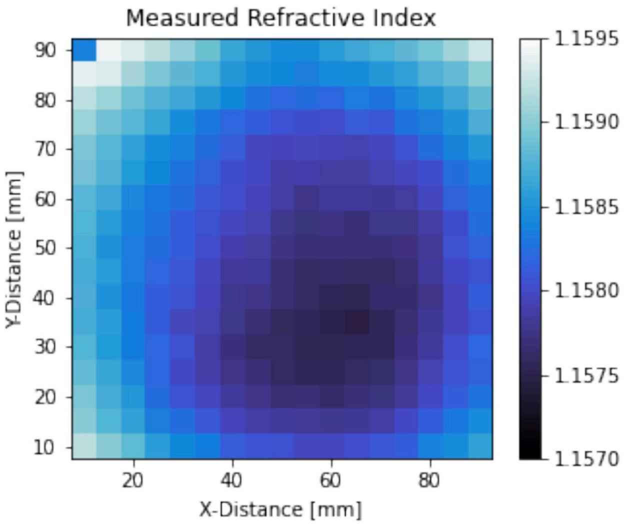
Fit a circle and compute Cherenkov angle and ***n***.



Results:

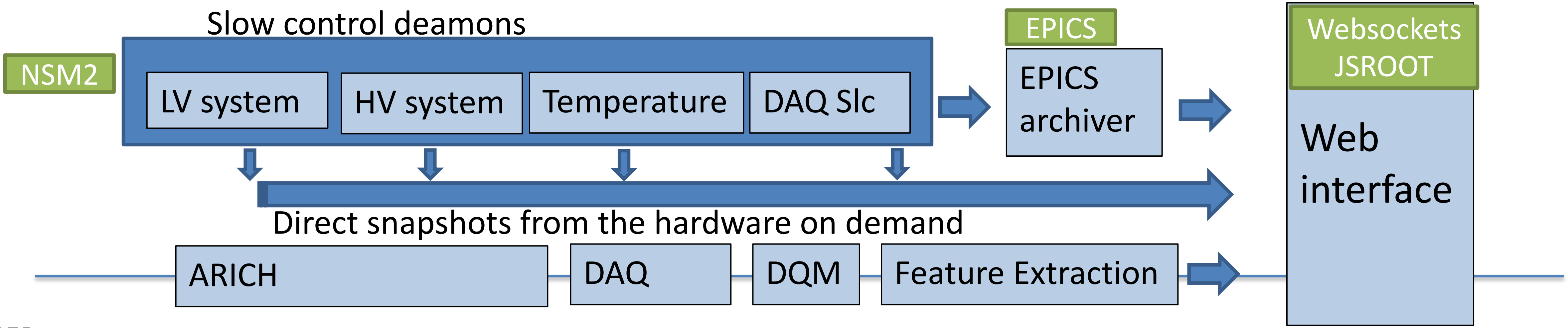
example map of a typical tile.

lateral variation of ***n*** is significant but smooth and is well-described by a two-dimensional parabola.



Slow control of the Belle II Aerogel Ring Imaging detector

Rok Pestotnik, on behalf of the Belle II ARICH group



LV system:

- 2 Wiener MPODs + 12x 8V MPV8008LI
- supply of +3.8V, +2V, and -2V 420 FEBS
- +1.5V and +3.8V to the 72 merger boards
- 24 multiwire cables 25 m long
- The voltage drop on the wire is about 1V.
- LV deamon communicating with the hardware using SNMP protocol

HV system for 420 HAPDs:

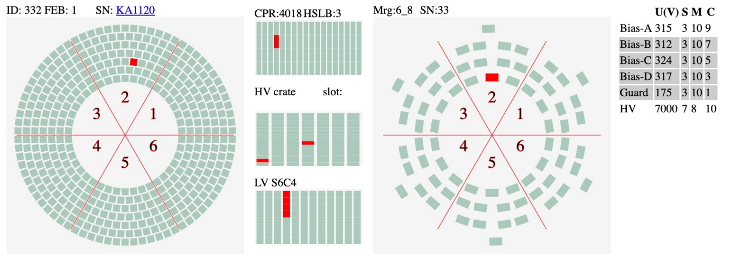
- 4 bias and one guard voltage: 8 CAEN SY4527 crates, 45 CAEN A7042P 48 Channel 500 V Common Floating Return
- High voltage: 28 CAEN A1590 - AG590 16ch 9kV boards used to supply 420 high voltages.
- HV daemons using the CAEN HV wrapper library.
- the operation of all 6 HV channels synchronous. and should

Slow control of the Belle II Aerogel Ring Imaging detector II

Institut "Jožef Stefan", Ljubljana, Slovenija

DAQ - controls the parameter settings of the 420 FEBs

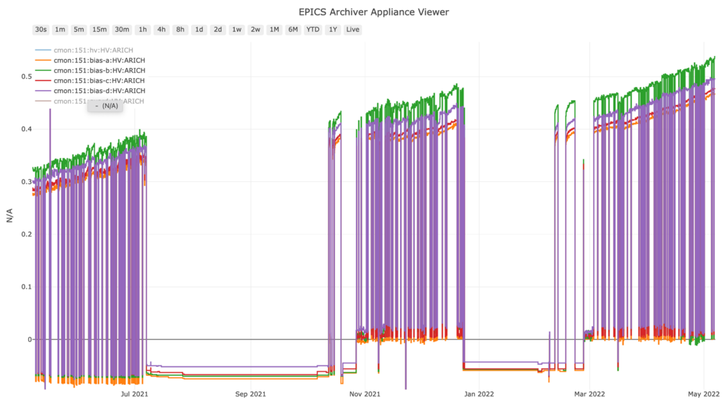
- Monitor the measured values of the supply voltages, temperatures,
- temperature sensors – efficiency of the cooling system

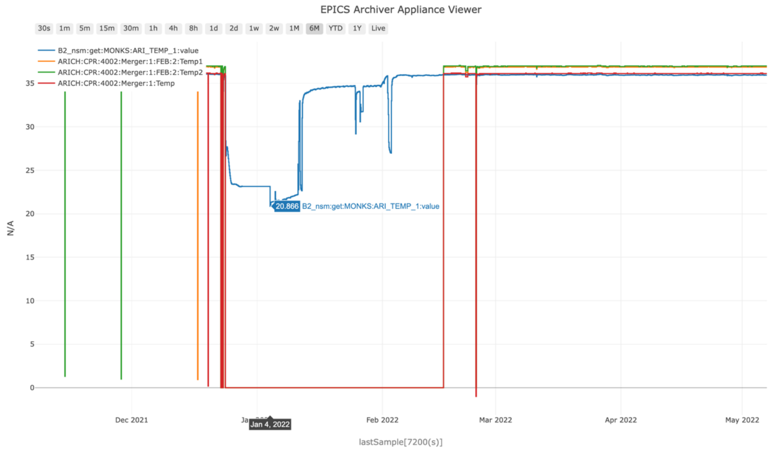


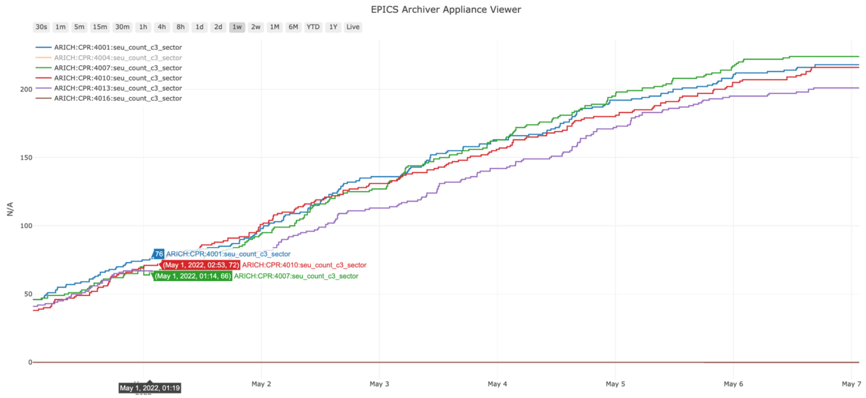
Monitoring of the bias currents: Due to the irradiation of the sensors, the bias currents increase. The time evolution allows to estimate and project the operation usability of the sensors.

Time variation of temperature

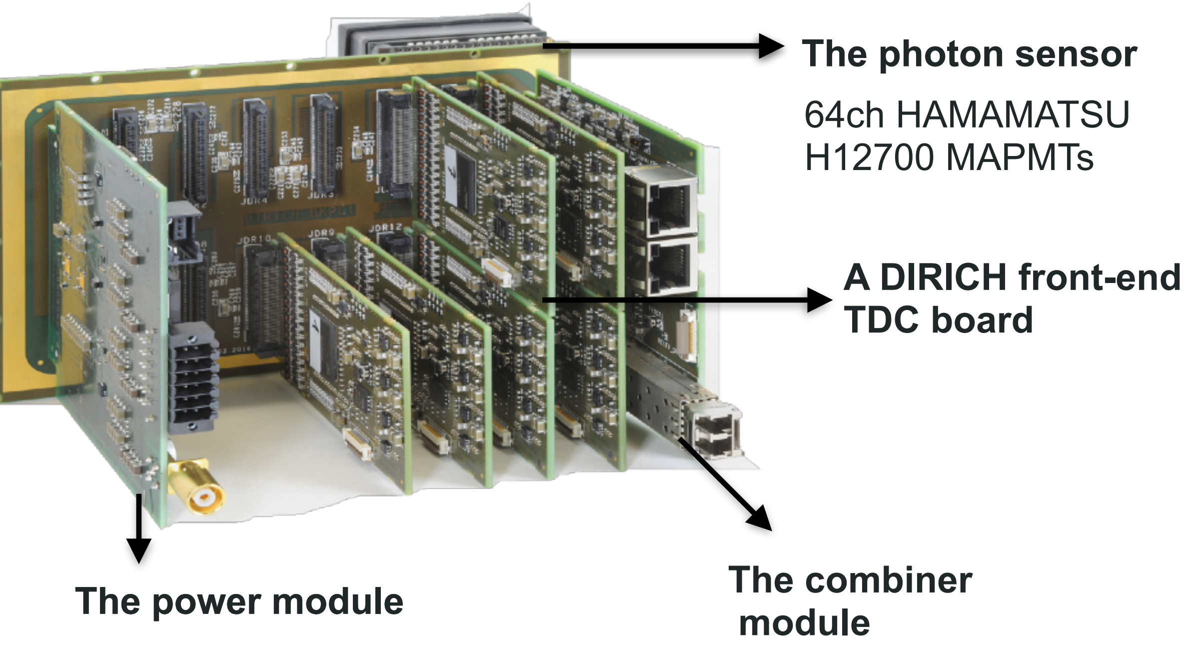
Cumulative number of SEUs - custom SEU mitigation controller.





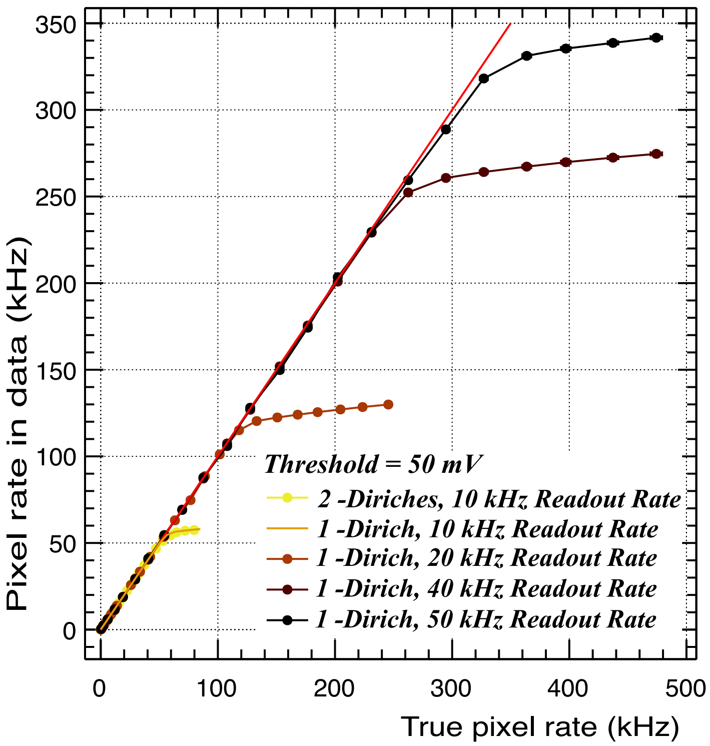


Qualification of DIRICH readout chain

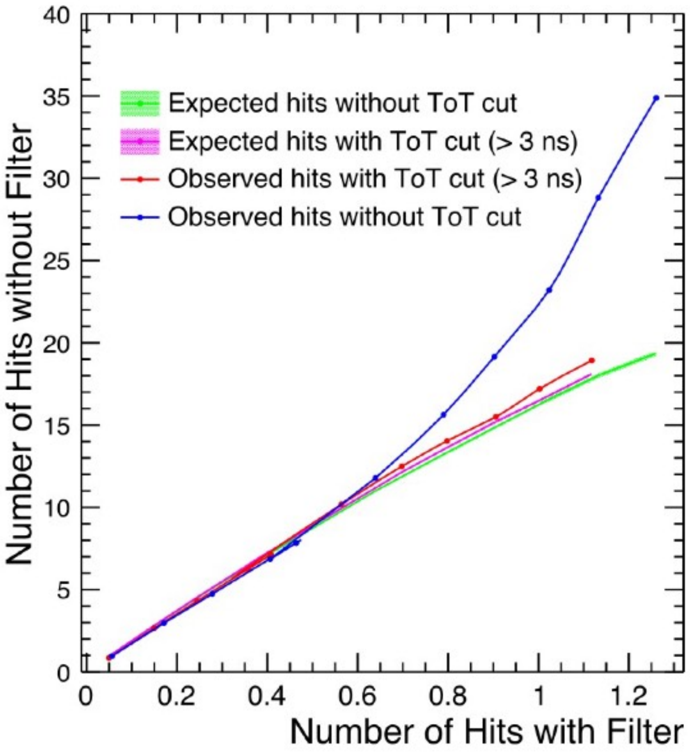


- Low power modular FPGA based readout chain.
- Leading and trailing edge measurement -> Time over Threshold.
- Leading edge timing precision ~ 20ps.

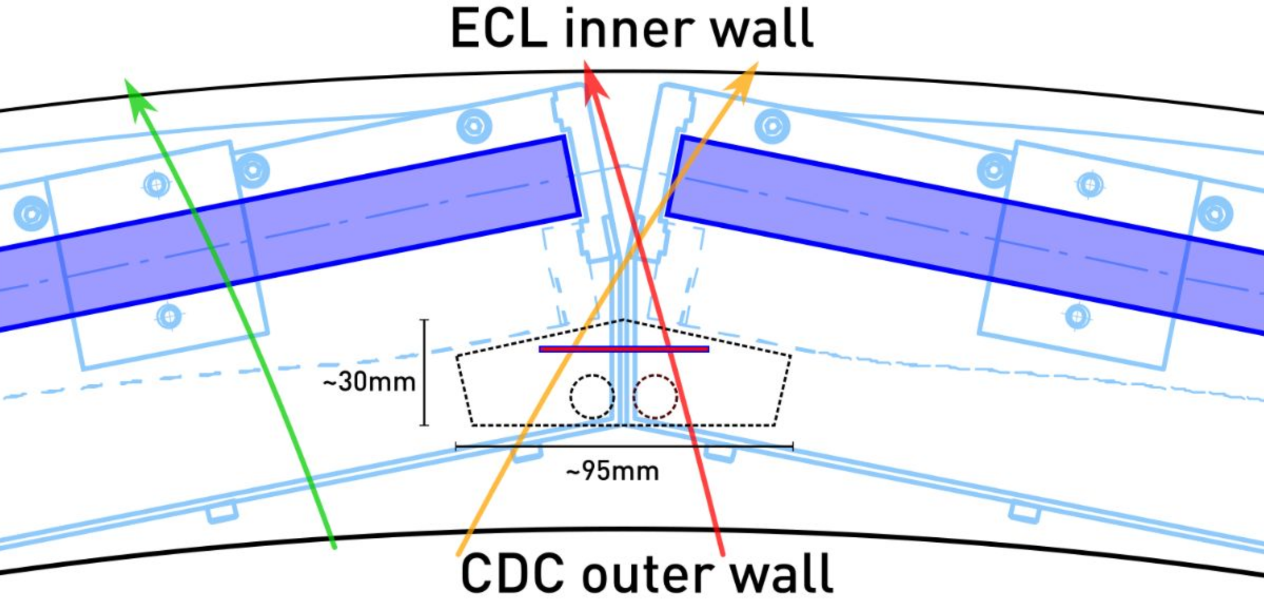
High rate test

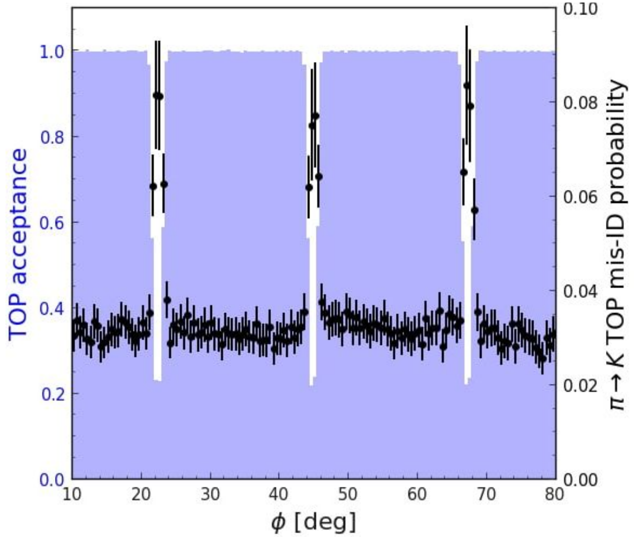


Crosstalk suppression using ToT



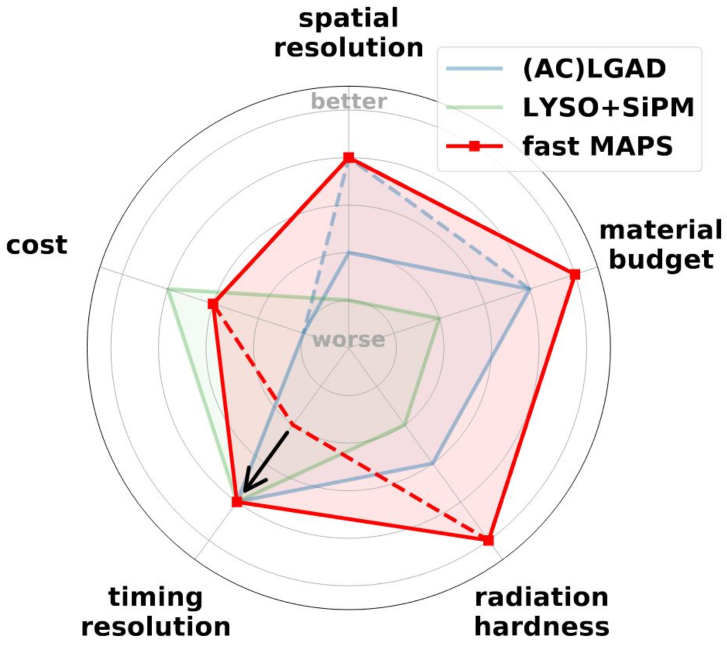
The Belle II Barrel PID has holes...





Umberto Tamponi, *Oskar Hartbrich, Gary Varner*

STOPGAP- A ToF for Belle II as Fast MAPS Demonstrator



Requirements

- Pixels can be large (mm-cm)
- $< 0.2\ X_0$
- Time resolution 50-70 ps
- Fill factor > 99%

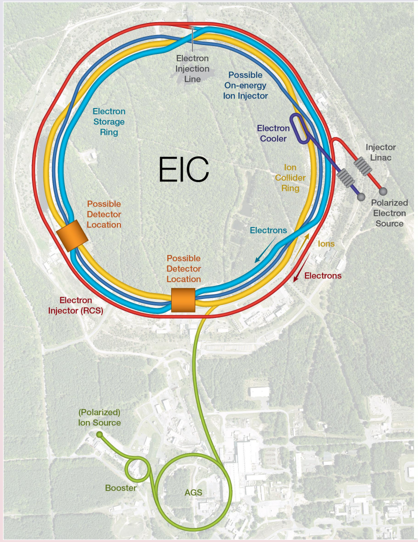
STOPGAP a great demonstrator for Fast MAPS

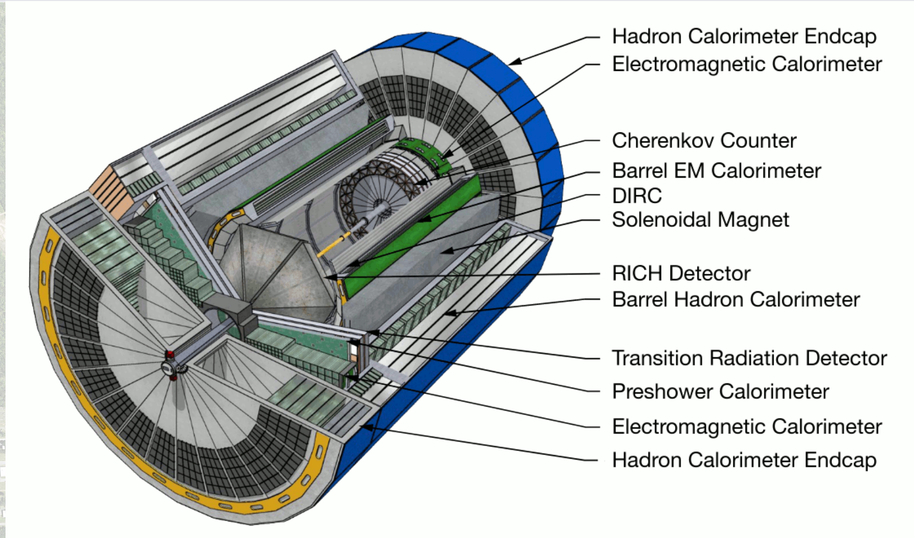
- Low background
- Low occupancy
- Limited area (1-3 m^2)
- Real detector environment

***Umberto Tamponi**, Oskar Hartbrich, Gary Varner*

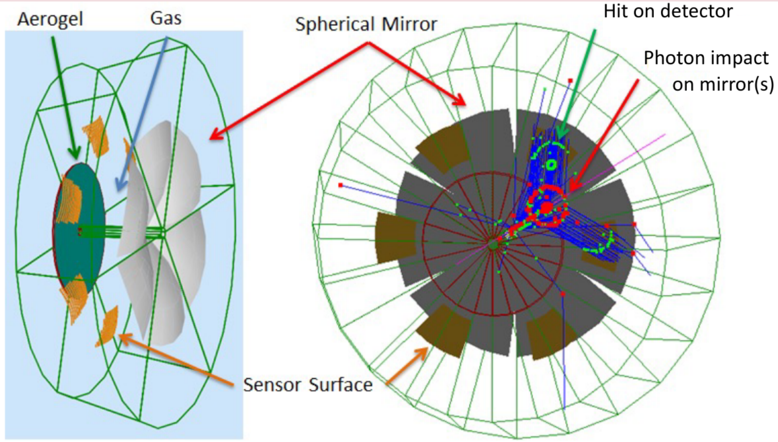
The dual RICH for the Electron Ion Collider

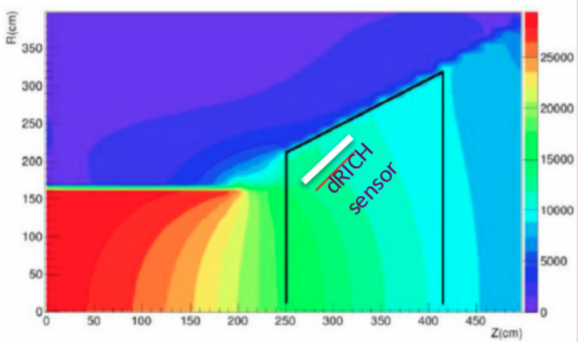
EIC @ Brookhaven National Lab

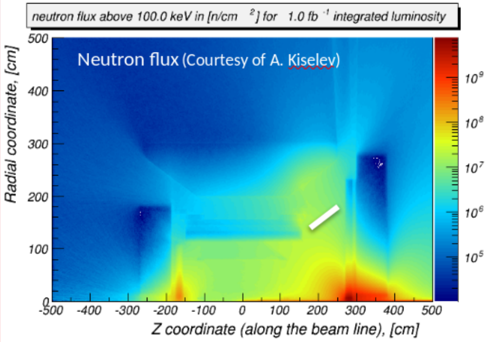




- A dual RICH to cover the full momentum range 3-50 GeV/c
- The photon detectors will be placed inside a strong magnetic field $O(1T) \rightarrow$ SiPM
- A study is on going on the recovery of radiation damage through the annealing process (see R. Preghenella talk this afternoon).



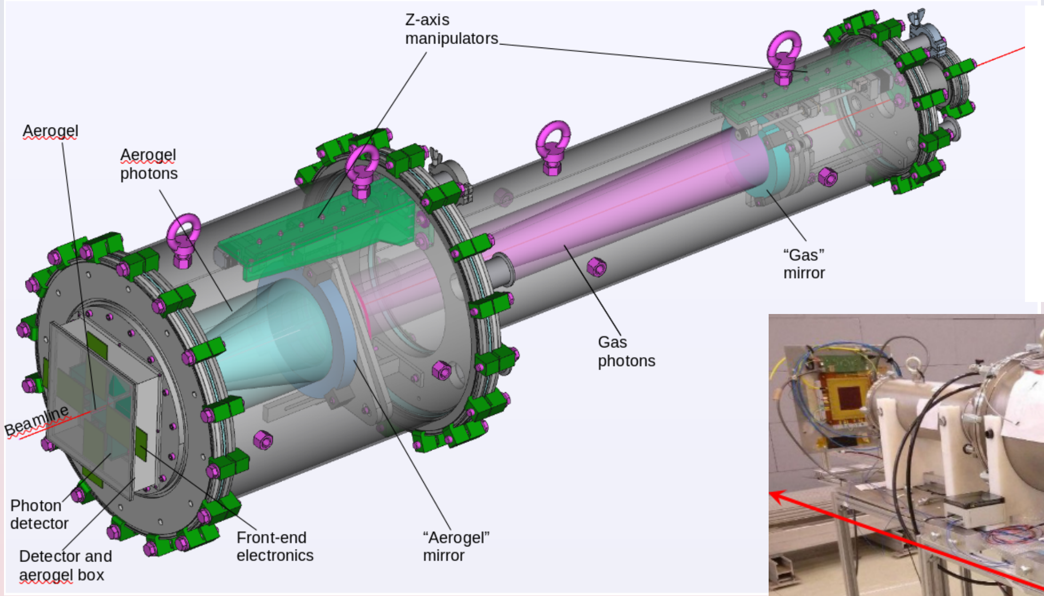


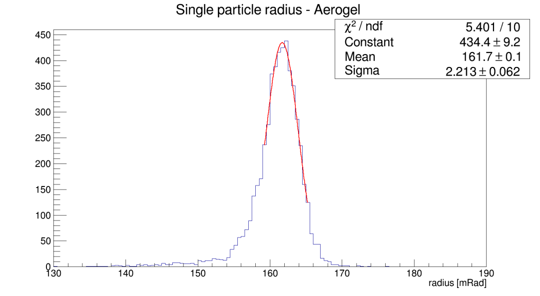


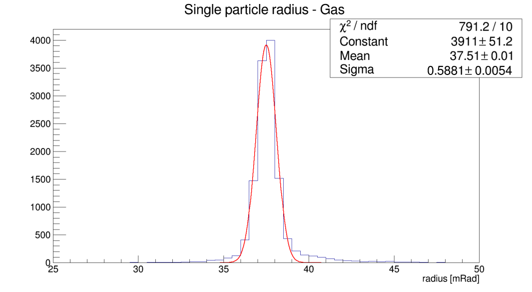
Simone Vallarino – RICH2022
University and INFN Ferrara

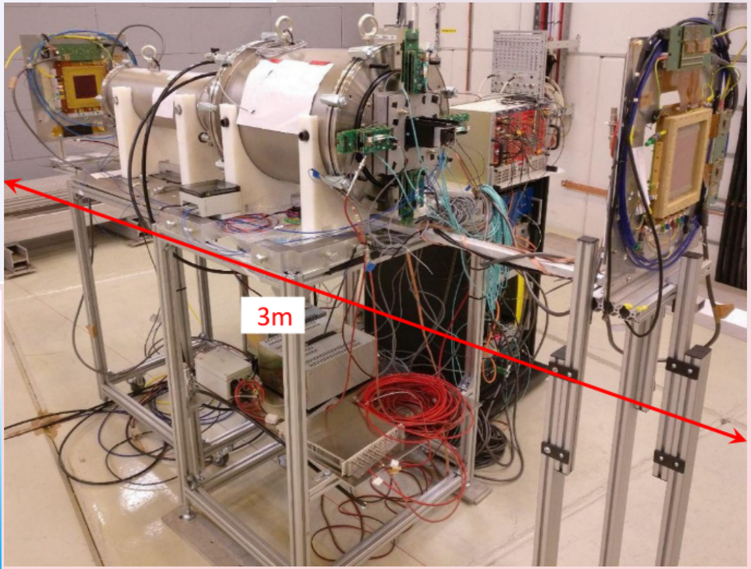
INFN Istituto Nazionale di Fisica Nucleare
Università degli Studi di Ferrara

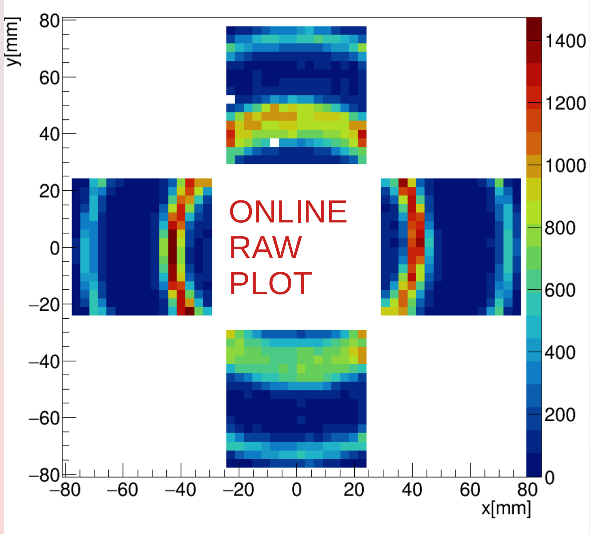
The dRICH prototype of EIC_NET

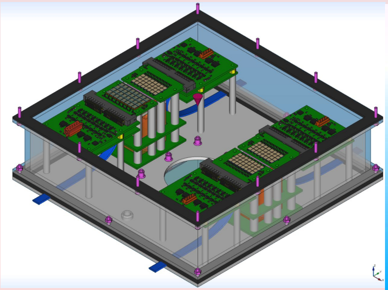


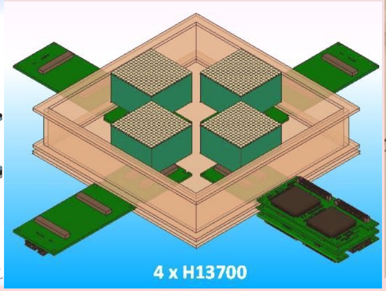












2 test beams in 2021, the goal of making all subsystems works has been achieved.
2 new test beams will occur in fall 2022.

Remote Contributions

ARICH performance study in the Belle II experiment

Gayane Ghevondyan

(on behalf of the Belle II ARICH group)

09.09.2022

Belle II experiment and data selection

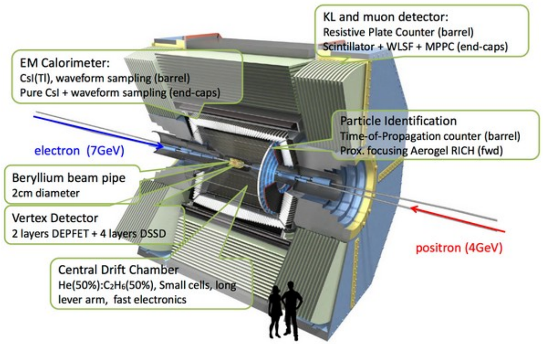


Fig.1 Schematic view of the Belle II spectrometer.

The Belle II experiment at the SuperKEKB asymmetric e+e- collider in High Energy Accelerator Research Organization (KEK, Tsukuba, Japan) is searching for CP asymmetries in different rare decays. The ARICH counter is located in the forward end-cap of the Belle II spectrometer as shown in Fig. 1. This is a novel type of particle identification device that has been developed for the Belle II experiment which is capable of identifying pions and kaons with momenta up to 4 GeV/c by detecting Cherenkov photons emitted in the silica aerogel radiator.

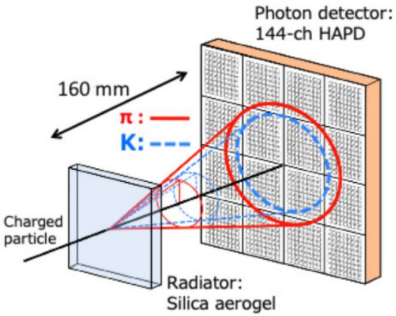


Fig. 2. The principle of the particle Identification of the ARICH counter.

We study the ARICH performance using a clean sample of pions and kaons from the ***$D^{*\pm} \rightarrow D0\ (K^{\mp}\pi^{\pm}) + \pi^{\pm}$ decay.***

<u>Data selection</u>

- pValue of the track fit pValue > 0.001
- two oppositely charge tracks
- transverse momentum of a track pt > 0.1 [GeV/c]
- momentum of a track p > 0.5 [GeV/c]
- energy released in the decay 0.0 < Q < 0.01 [GeV]

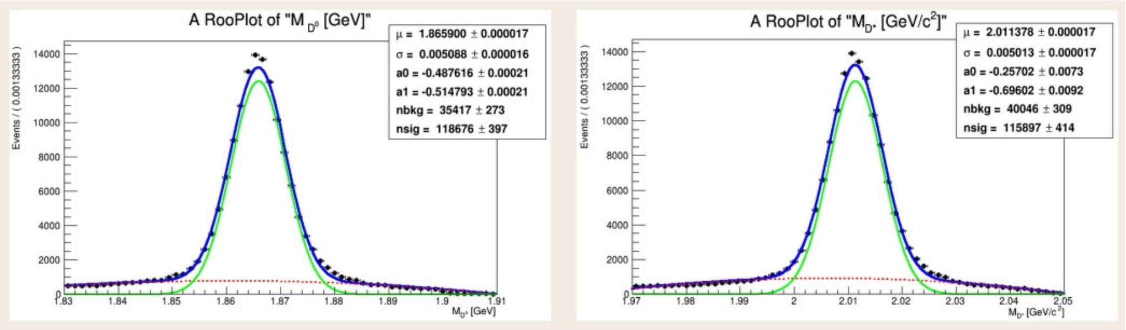


Fig 3. Invariant mass distributions of D^0 (left) and D (right) decay samples.*

Results and conclusion

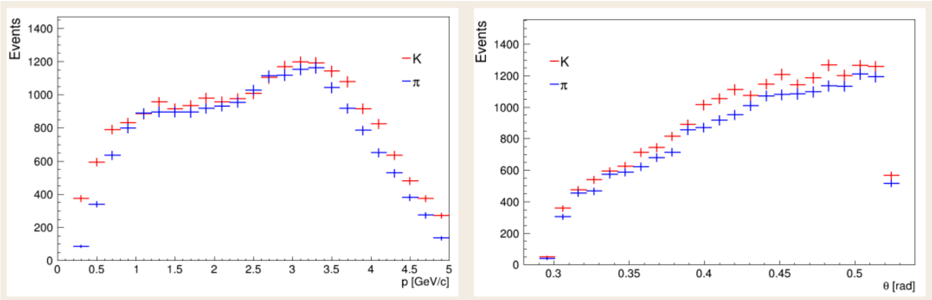


Fig.4 Momentum (left) and polar angle (right) distributions for kaons and pions from D^0 ($\bar{D}^0$) decays in ARICH acceptance.

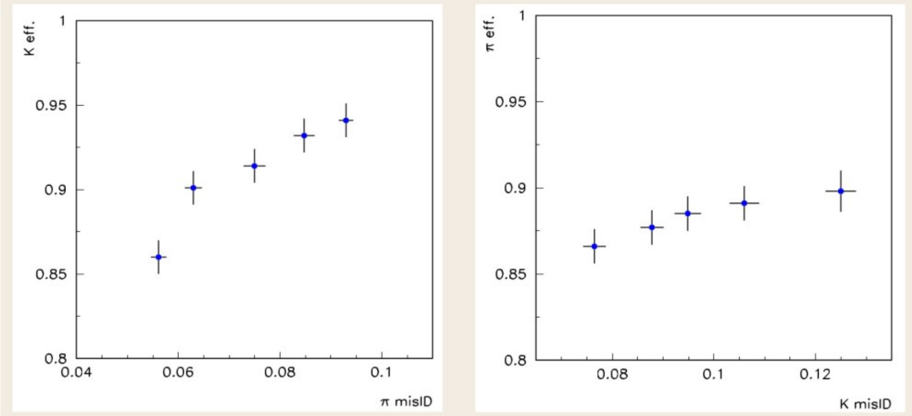


Fig 5. ROC curve for the K efficiency versus the π misidentification probability (left) and the π efficiency versus the K misidentification probability (right)

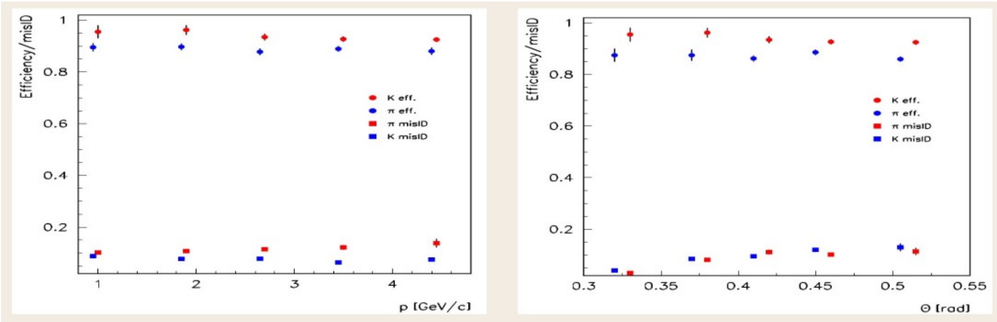


Fig 6. Efficiency and misID dependencies in 1D momentum (left) and polar angle (right) bins.

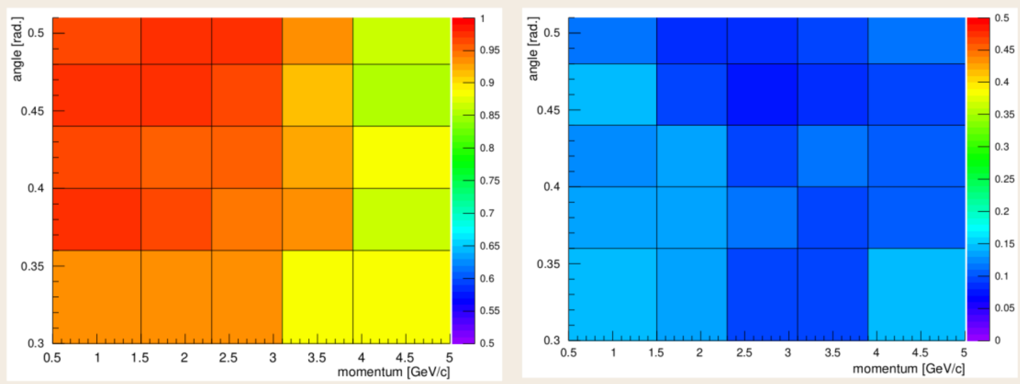


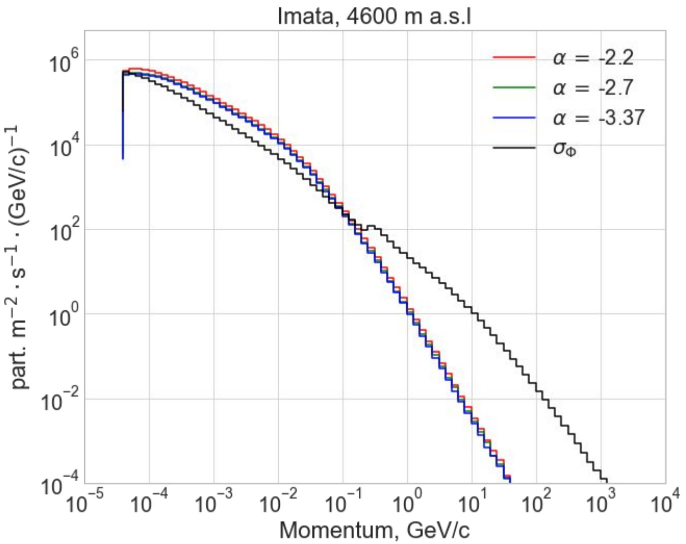
Fig 7. Kaon efficiencies (left) and pion misID's (right) in 2D (p-θ) plane.

Conclusion

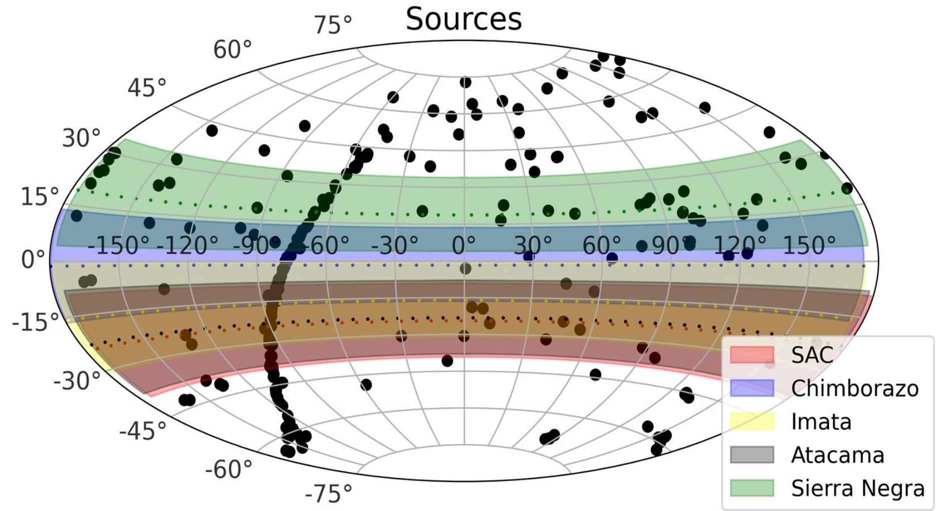
The overall K(π) efficiency and π(K) misidentification probability are estimated to be 93.2 ± 0.59 % (88.7 ± 0.69 %) and 11.1 ± 0.38 % (7.38 ± 0.25 %), respectively.

The capability of water Cherenkov detectors arrays of the LAGO project to detect Gamma-Ray Burst and High-Energy Steady Gamma sources

I. Sidelnik[1,*], L. Otiniano[2], C. Sarmiento-Cano[3], J. Sacahui-Reyes[4], R. Mayo-Garcia[5], A. Rubio-Montero[5] and H. Asorey[1,6]
for the LAGO Collaboration[7]

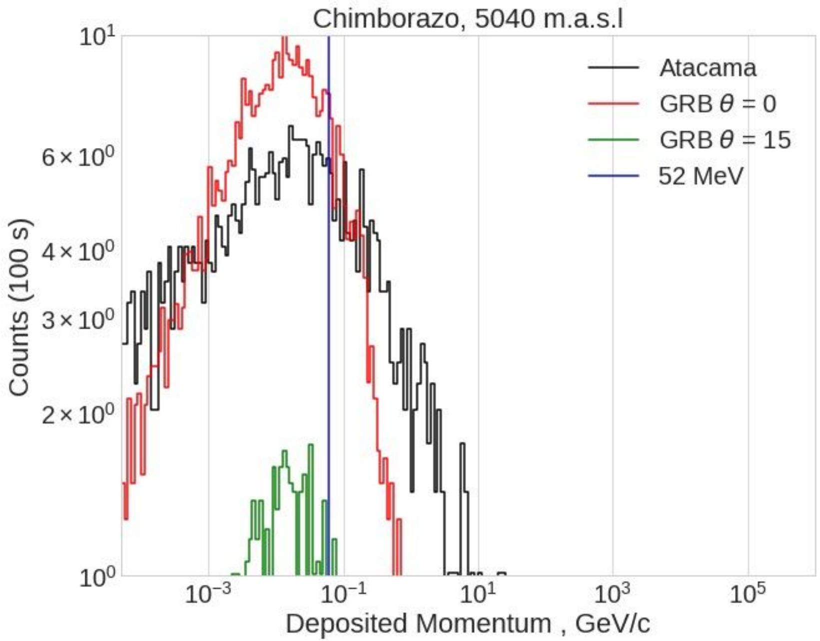


Flux of secondaries at ground level for a high-energy GRB with three possible spectral indices. The black line is the total secondary radiation background at 4600 m asl in Imata

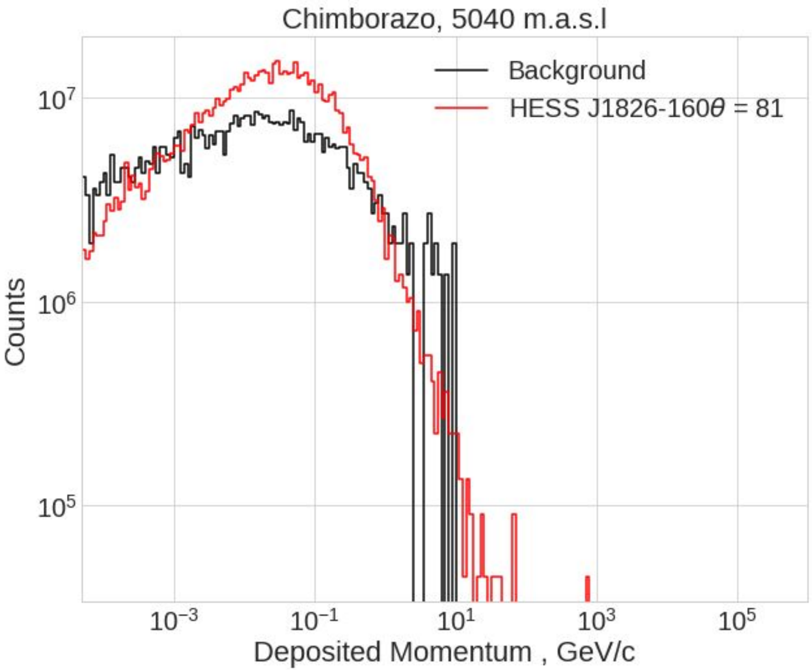


TeV steady gamma sources detected by 2022 (black dots) reported in the TeVCat catalogue. Colored bands represents the overlapping FOV of five of the high-altitude LAGO sites.

GRB and Gamma Source Simulations



Response of a single WCD from an array of 3 detectors operating in coincidence to the EM component of the expected background (black) and GRB (color) fluxes of secondary particles.



Response of a single WCD fom an array of 3 detectors operating in coincidence to the simulated expected flux of the HESS J1826-160 TeV-emitter steady gamma source

11th International Workshop on Ring Imaging Cherenkov Detectors

Sep 12 – 16, 2022

Particle Classification in the LAGO Water Cherenkov Detectors using Clustering Algorithms

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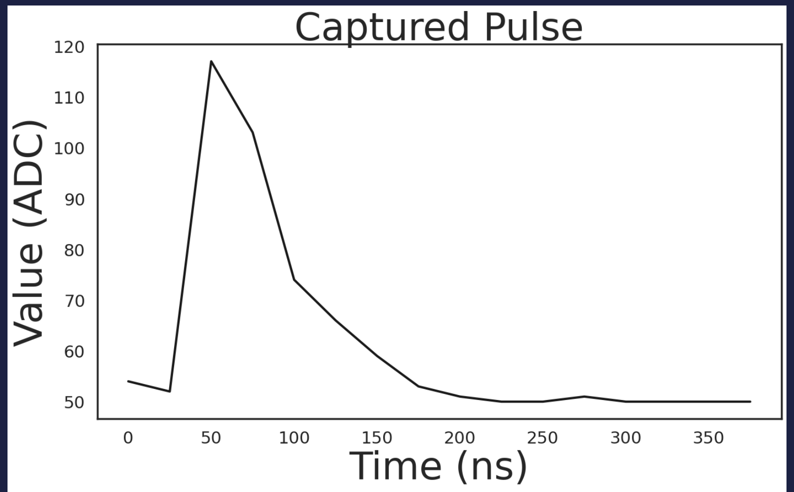
11 The LAGO Collaboration, see the complete list of authors and institutions at https://lagoproject.net/collab.html

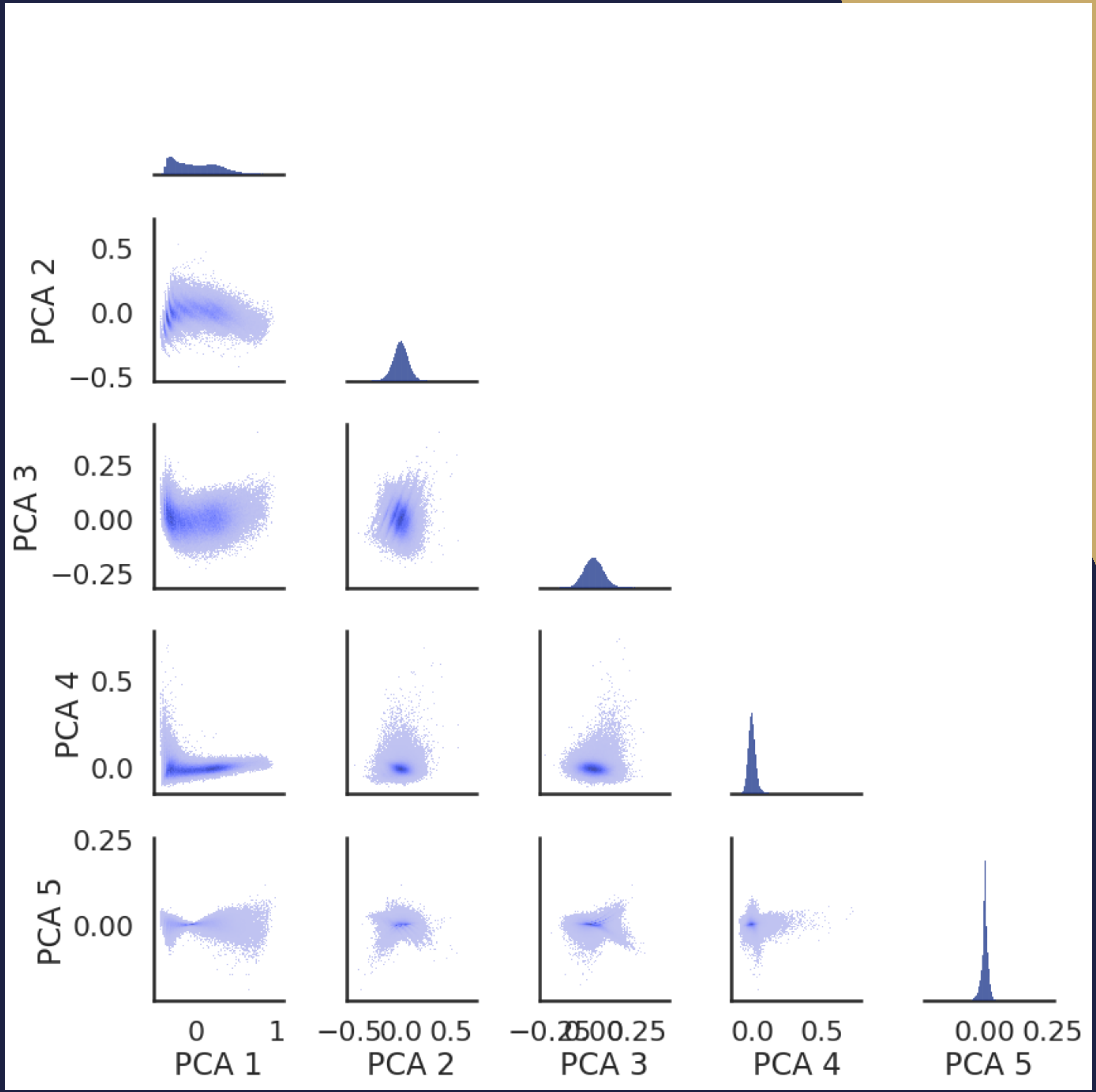
1. PROBLEM DESCRIPTION

- Captured pulses by Water Cherenkov Detector has limited resolution and provide no direct way to discriminate between secondary particles.
- We proposed a Machine Learning method for clustering pulses based on similarity patterns.



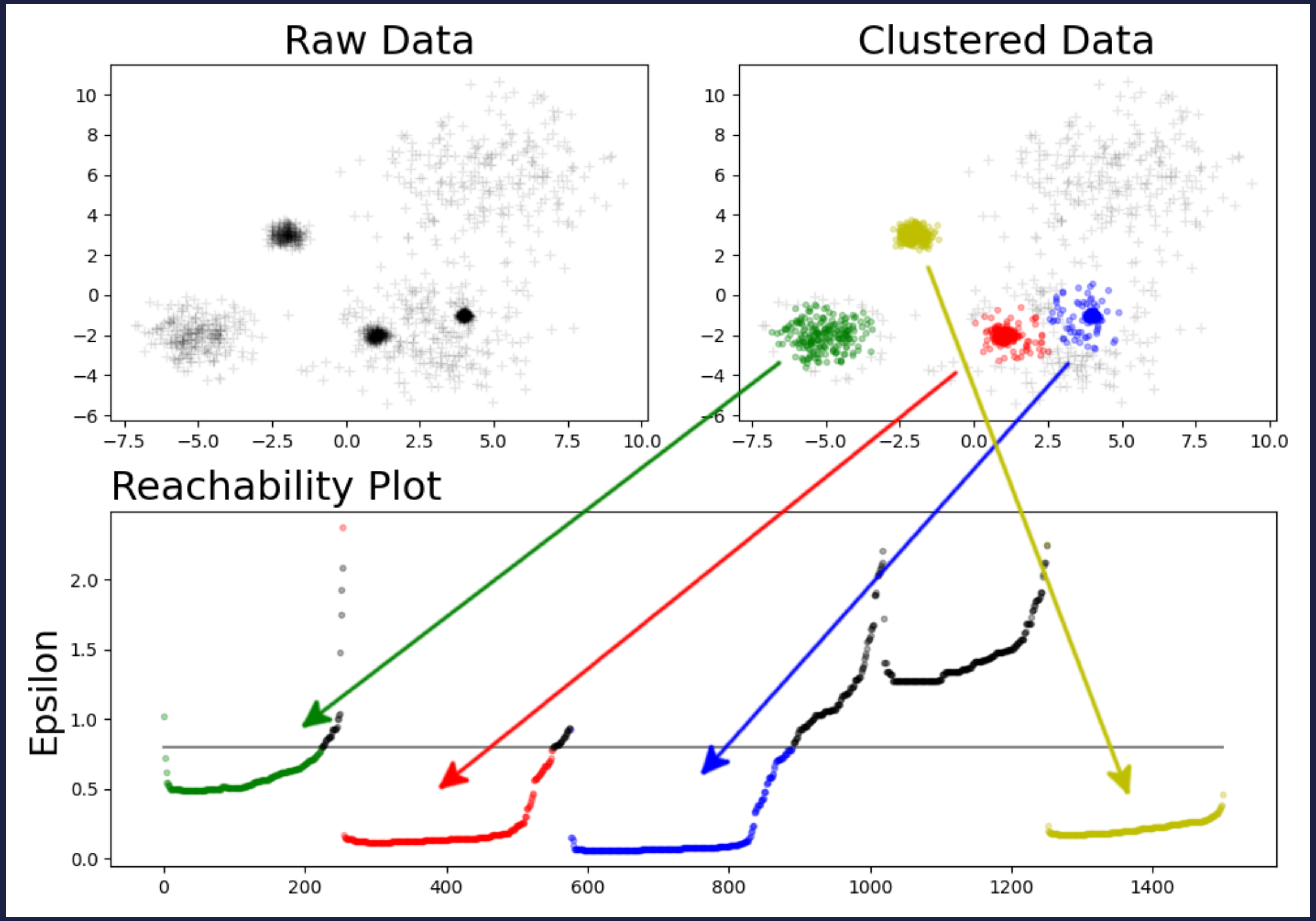
2. DATA PREPARATION AND FEATURE SELECTION

- Raw data from "Nahuelito" WCD site at Bariloche, Argentina. Total of 24hs of data between 13:00, 01 of March of 2012 and 12:00, 2 of March of 2012.
- Pulses have 12 bits - 25 ns resolution.
- ~39 millions preserved after preprocessing (~ 40%).
- Multidimenisonal feature space was very noisy. Applied Normalization and Principal Component Analysis to improve separability of feature space.



3. METHOD: OPTICS ALGORITHM

- Hierarchical density-based clustering algorithm Ordering Points To Identify Clustering Structure (OPTICS).
- OPTICS defines the reachability-distance, a minimum distance that helps describe cluster structure, and creates a reachability plot.

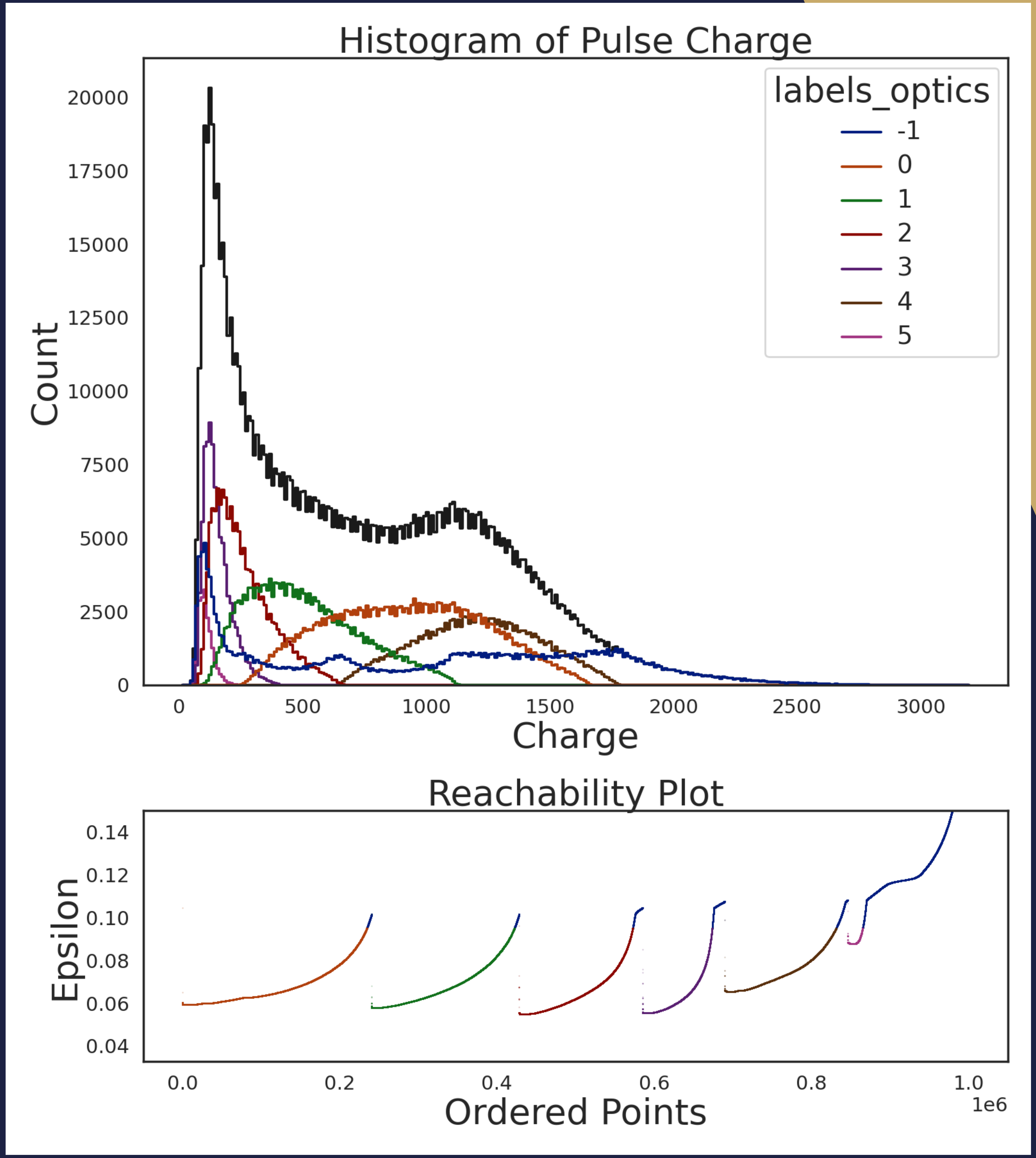


5. CONCLUSION AND FUTURE STEPS

- Cluster groups where located where secondary particle contributions are primarily expected to appear.
- Even with a highly noisy feature space, the reachability plot to shows clear cluster structures.
- Future steps:
    1) Further cleaning and study of the feature space.
    2) Additional validation using simulated data and using actual labeled data (for specific cases).

4. RESULTS

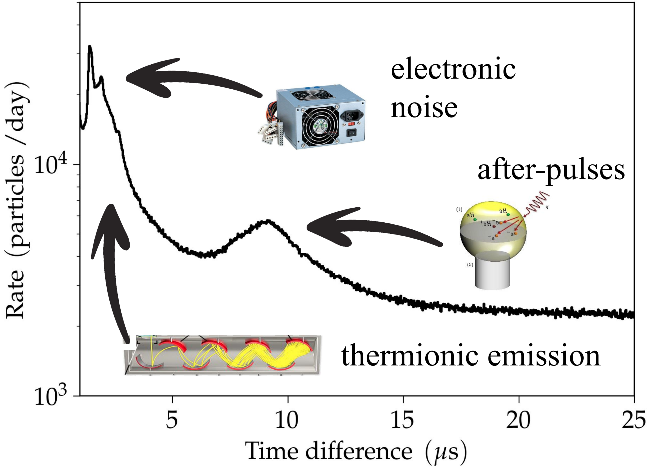
- Reachability-distance of 0.095 was chosen for cutoff.



Measurement of the Muon Lifetime and the Michel Spectrum in the LAGO Water Cherenkov Detectors as a tool to improve energy calibration and to enhance the signal-to-noise ratio

L. Otiniano[1,2], A. Taboada[3,4], H. Asorey[3,5], I. Sidelnik[4,5], C. Castromonte[1], A. Campos-Fauth[6]
for the LAGO Collaboration[7]

Time difference between two consecutive pulses histogram

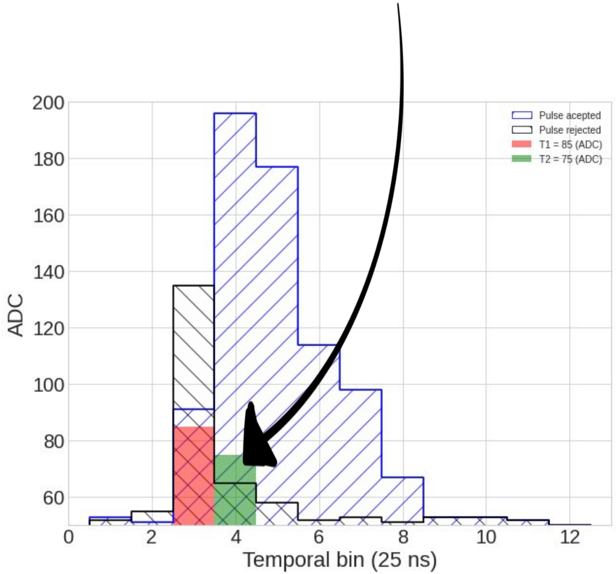


Noises in WCD are clearly visible

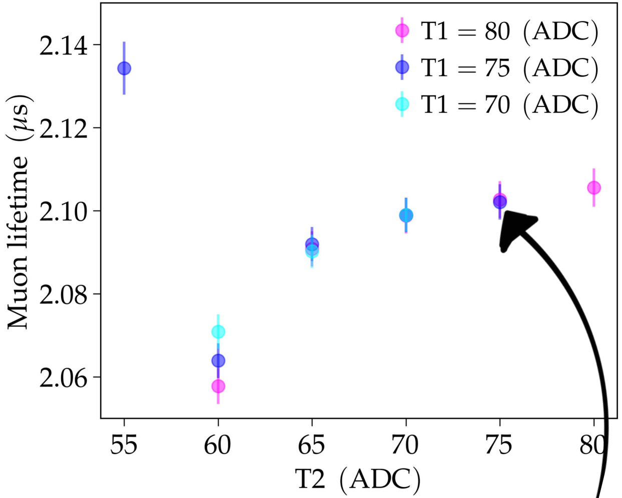
Short pulse width ~ ns

Noise Rejecting strategy

Impose a secondary trigger

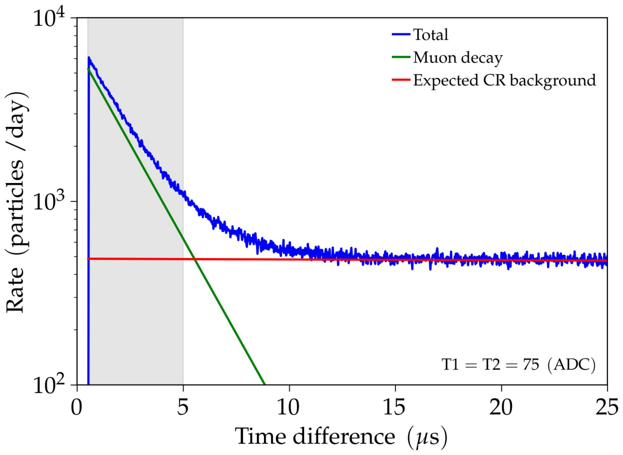


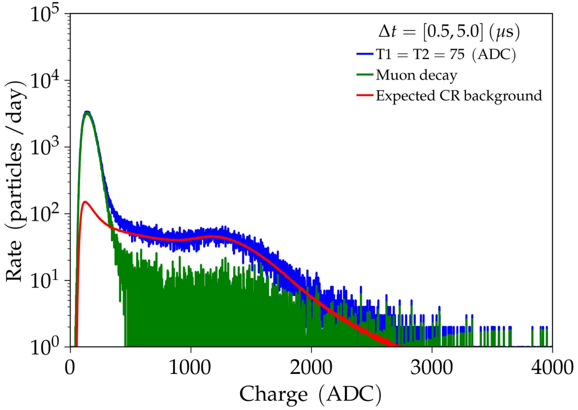
Measurement of the Muon Lifetime and the Michel Spectrum in the LAGO Water Cherenkov Detectors as a tool to improve energy calibration and to enhance the signal-to-noise ratio



We look for stable value of muon lifetime measure from time spectrum

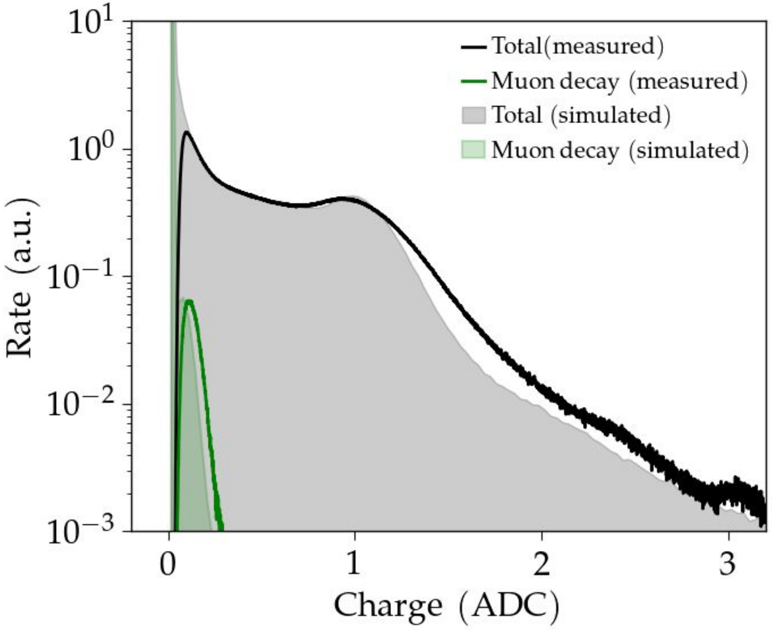
>90% of muon decay events are present in the 0.5-5 μs band of the time between consecutive pulses histogram





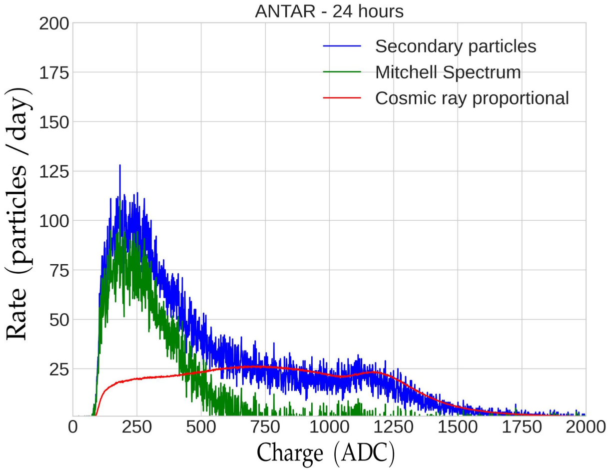
Michel spectrum is obtained from this band after background correction

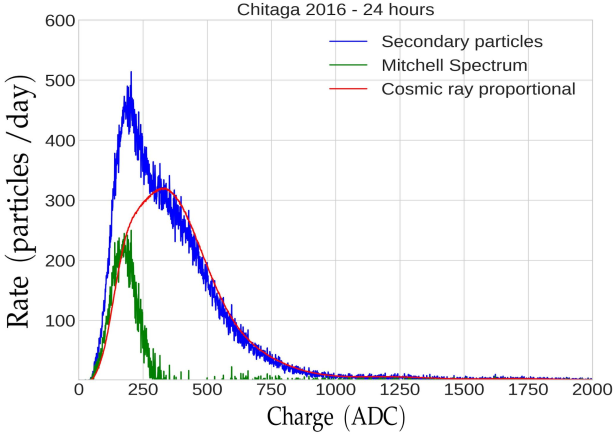
Measurement of the Muon Lifetime and the Michel Spectrum in the LAGO Water Cherenkov Detectors as a tool to improve energy calibration and to enhance the signal-to-noise ratio



Good agreement with simulations

This process is being used for correcting operative datasets of LAGO WCDs





Special Mention

Poster of E. P. Cherenkova available on indico

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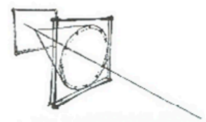
Российской академии наук
ФИАН

ABOUT THE DETAILS OF THE SUPERLIGHT PARTICLE OPENING



E.P. Cherenkova

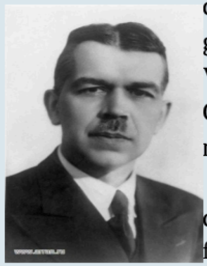
Pavel Alekseevich Cherenkov conducted his historical studies of the blue glow in 1933-1940. Let me clarify some of its details.

About the nascency of the theme

Research began when completing a candidate dissertation. Its leader was Academician Sergei Ivanovich Vavilov. What semantic connotation can you see in the words from the Russian scientific literature: "Vaviliov immediately determined the importance of the topic and proposed the topic of the dissertation to Cherenkov" [1] ?.

It is known that the topic of the work of Cherenkov "Investigation of electrons moving in matter with the superluminal speed" surfaced as a result of an unexpected discovery in his experiments on his candidate dissertation (or Ph.D.-1). In the course of experiments with γ- luminescence of solutions of uranyl salts, graduate student Cherenkov realized that there was a weak blue background, which, apparently, should be corrected. However, in previous works by Vavilov, when liquids were excited by ultraviolet radiation, a blue glow was also observed if the liquids were not sufficiently purified [2]. Sergei Ivanovich did not want to agree with the graduate student, suggesting that his observations depended on the fact that the liquids contained foreign impurities or that the dishes had not been washed thoroughly.

About the struggle for the cleanliness of dishes, L.V. Levshin, son of Vavilov's colleague V.L. Levshina, wrote: “Vavilov was convinced of the negligence of his ward, which one, despite of all the recommended measures, pure solvents continued to glow.



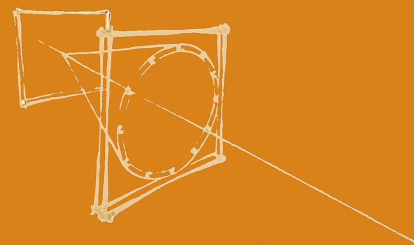
Vavilov became irritated and told Cherenkov that there would be no progress until he learnt to purify solvent properly [3]. Cherenkov, in spite of Vavilov's strict admonitions, did not want to give up his observations. He was convinced that he was right about the existence of the additional light. To resist the academician required firmness of mind and the character of a scientific experimenter.

In order to include the measurement of corrections for the additional radiation in the work on the luminescence, it was necessary for Vavilov to be convinced that the observed light was not due to the presence of foreign impurities in liquids, but had any another cause. Pavel Alekseevich later wrote that the full set of data obtained in his experiments made it possible to establish that the luminescence of a solvent and other pure liquids has an amazing constancy and universality [4] and, therefore, it exists as an independent physical phenomenon. When Sergei Ivanovich, although not immediately, but nevertheless convinced of the correctness of the student, he told the graduate student that the blue glow should be given the special attention later.

But the study of an luminescence began during Cherenkov's candidates work. Although it was devoted to the study of luminescence, its content already included a section "Visible gamma-luminescence of liquids" where he discussed the universal property of liquids discovered by him - the ability to glow under the action of γ-rays, which differs from the observations of S.I. Vavilov and L.A. Tumerman [2]. In the dissertation, for example, the discovered degree of polarization of the luminescence, the effect of temperature and the presence of solutions on its intensity, the spectrum and brightness were noted. This study became part of the first, candidat-Ph.D. thesis, because it was necessary to determine the corrections for the γ-glow.

RICH 2022

XI International Workshop on Ring Imaging Cherenkov Detectors



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Thank you all!

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