

Detailed research report (See Annual Summary Document)

1. Project title;
2. List of deliverables covered in the present report
3. Summary (max. 1 page);
4. Detailed report, highlighting the results obtained during the reporting period and the objectives fulfilment, conclusions;
5. Publications list, conference presentations, list of attended meetings.

Annual Summary Document¹

Year: 2025

Months: 12

Project Title: Study of rare kaon decays at the CERN SPS/NA62

Project Work Plan (according to the contract)

Stage: II. HASC Maintenance & Operation, NA62 shifts, exotic, precision decays and dark matter studies, other software activities. DRD1 straw gas gain studies.

Activities:

- HASC maintenance & operation (MO);
- BR ($\pi^0 \rightarrow e^+ e^-$) - Run 2 selection criteria;
- BR ($K^+ \rightarrow \pi^+ e^+ e^-$) - Run 1&2 selection criteria;
- Dark matter studies - Produce a neutral particle MC sample for beam dump background studies; Develop biasing techniques for beam dump background studies;
- Coordination of Software and MC Validation WGs;
- DRD1 - Build the thermal enclosure and controls.

Allocated budget: 1,210,700.00 lei

Realized budget: 1,210,700.00 lei

¹ Please fill in all the required items and do not alter the template

Annual Summary Document

Summary / Cover Page

- Group list (physicists, staff, postdocs, students)

Name	Position
Alexandru-Mario BRAGADIREANU	Research scientist (CS III) – IFIN-HH
Stefan-Alexandru GHINESCU	Research scientist (CS III) – IFIN-HH
Ovidiu-Emanuel HUTANU	Engineer - IFIN-HH, <i>Master Student (Electronics)</i> ,
Petre-Constantin BOBOC	Research Assistant – IFIN-HH, <i>PhD Student (Physics)</i>
Ionut IONESCU	Assistant - IFIN-HH, <i>Student (Computing)</i>
Neagu IONEL	Engineer –IFIN-HH
Alina MOTORGA	Accountant- IFIN-HH

- Specific scientific focus of group (state physics of subfield of focus and group’s role)

Physics: Standard Model

Subfield: Flavor Changing Neutral Current decays with neutrinos in the final state with focus on the measurement of the very rare kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at the CERN SPS (NA62 Experiment).

Group role: Originally, to identify the π^+ coming from the $K^+ \rightarrow \pi^+ \pi^+ \pi^-$ decay (source of background in the $m_{miss}^2 := (p_K - p_{track})^2$ distribution) with a hadron sampling calorimeter (HASC). The HASC was shown to be efficient also as photon veto in the rejection of background coming from $K^+ \rightarrow \pi^+ \pi^0$ decay, the upgrade of HASC being proposed in 2018. Evaluation of NA62 sensitivity to various dark matter decays to visible particles. Coordination of the Software and MC Validation working groups. Precision measurement of the $\pi^0 \rightarrow e^+ e^-$ branching ratio.

- Highlights of accomplishments in the last year

We maintained the HASC continuous operation during the 2025 NA62 Physics Run. We also ensured availability of a HASC expert 24 h/ day during data taking.

In the autumn of 2021, NA62 collected a dataset in beam dump mode. In 10 days of data-taking, around 1.4×10^{17} protons on TAX were collected. This dataset made possible investigating physics case of a dark photon (A'), dark scalars (S) and axion-like particles – or ALPs (a), decaying to various final states. The investigation of Heavy Neutral Leptons production and decay in NA62 has started, using the 2021, 2023 and 2024 beam-dump datasets. Our tasks mainly concern the determination of the background for this scenario.

In June 2022, one of our group members started working in the Precision Measurements Working Group, on the measurement of the branching ratio of the process $K^+ \rightarrow \pi^+ \pi^0$; $\pi^0 \rightarrow e^+ e^-$. In the Chiral Perturbation Theory, the $\pi^0 \rightarrow e^+ e^-$ can be used to improve predictions of other pseudo-scalar meson decays to pairs of leptons. The analysis is close to finalization, and, once collaboration approval is obtained, a scientific paper is planned for submission in 2026. We also started working on the branching ratio determination of the $K^+ \rightarrow \pi^+ e^+ e^-$ decay using Run 2 data which was used as normalization channel for the branching ratio determination of the $\pi^0 \rightarrow e^+ e^-$ decay.

We have coordinated the activities of the SW and MC Validation working groups.

2. Scientific goals (2 pages)

The main goal of NA62 experiment [1] is to measure the branching ratio of the ultra- rare kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at the CERN SPS. The standard Model (SM) prediction for the branching ratio is calculated with high precision [2],

$$BR(K^+ \rightarrow \pi^+ \nu \bar{\nu})_{SM} = (0.84 \pm 0.10) \times 10^{-10}$$

while significant deviations from the SM value are predicted by new physics models [3,4,5]

In addition to the main objective, thanks to its high beam intensity and detectors performance, NA62 has a wide physics programme: precise measurements of lepton universality in $K^+ \rightarrow l^+ \nu$ decays, searches for Lepton Number (LNV) and Lepton Flavor Number Violating (LFNV) processes and searches for exotic particles such as Dark Photons, Heavy Neutral Leptons, axion-like particles (ALPs), etc. In the framework of Physics Beyond Collider initiative, prospects for data taking in beam dump mode have been addressed too.

To reach its main goal, NA62 needs to collect about 100 in-flight $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ events and to keep the total systematic uncertainty small. Assuming a 10% signal acceptance and a $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ branching ratio of 10^{-10} , at least 10^{13} K^+ decays are required.

Since the $\nu \bar{\nu}$ pair is undetectable, the technique adopted by NA62 is to match an upstream K^+ track with a downstream π^+ track and to use the squared missing mass distribution $m_{miss}^2 := (P_K - P_\pi)^2$ to discriminate the signal from background (Figure 1). The main background events are expected to come from the other K^+ decay channels and accidental matching of an upstream track with a K^+ .

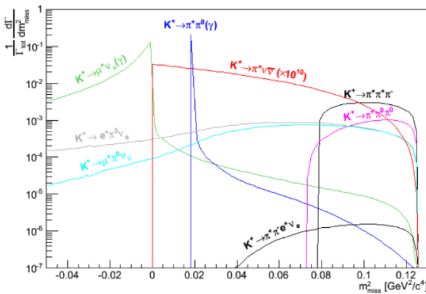


Figure 1: Squared missing mass distribution.

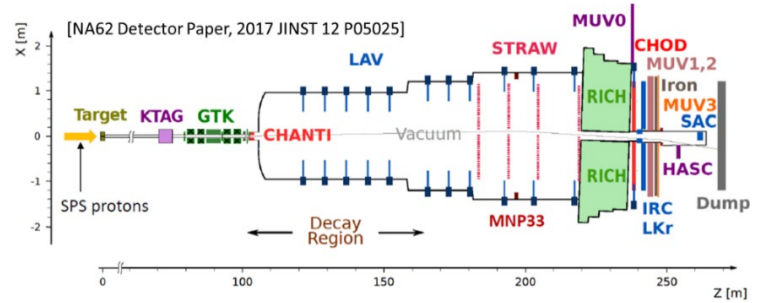


Figure 2 NA62 experimental setup.

2.1 NA62 Hadron Sampling Calorimeter (HASC)

The NA62 experimental setup proposed in the Technical Design Document [6] was improved, by the IFIN-HH team, with a new hadron calorimeter to veto the $K^+ \rightarrow \pi^+ \pi^+ \pi^-$ events in which the π^- undergoes hadronic interaction in the first STRAW chambers and the more energetic π^+ (≈ 40 GeV/c) which is traveling through the beam hole, not being detected by the IRC, then emerging at $Z > 253$ m. In these decays, the upstream detectors (Figure 2), namely the CEDAR and GTK, are used for K^+ identification, the STRAW together with RICH, CHOD and MUV are used to detect one of the π^+ s, while HASC has to detect the second π^+ traveling through the beam pipe and deflected by the bending magnet.

HASC has been demonstrated to be effective (2016-2018 $\pi^+ \nu \bar{\nu}$ dataset) as photon veto, complementary to LAV, LKr, IRC and SAC calorimeters, an additional 30 % reduction of $\pi^+ \pi^0 (\gamma)$ background being obtained with HASC. This fact, stimulated the idea of using a second calorimeter HASC-like in a position symmetrical with respect to the beam axis, to double the π^0 rejection.

Each HASC station is made up of 9 identical modules recovered from a prototype developed by NA61 Collaboration. Each module is a sandwich of 120 lead/scintillator alternating tiles, with a total volume of

10x10x120 cm³ (W x H x L). The sampling ratio is 4:1, the scintillator tiles having a dimension of 100 x 100 x 4 mm while the lead thickness is 16 mm.



Figure 3: HASC module longitudinal section (left) and optical readout couplings (right).

Each HASC module is organized in 10 longitudinal read-out sections, each scintillator tile of every single section (Figure 3) being optically coupled with 1 mm² round Wave-Length Shifting (WLS) optical fibers. In the rear side of each module there are 10 optical connectors, originally designed to be coupled with 3x3 mm² green sensitive Micro-pixel Avalanche Photodiodes (MAPD), currently S12572-015C Hamamatsu SiPM sensors being used.

The FE electronics and SiPMs installed on the new HASC station, are cooled down to about 21 °C using a system designed by our group, which consists of 3 Peltier thermoelectric coolers / module and a water-air heat exchanger used to blow cold air in the modules endcap cases. The temperature is maintained constant by a temperature controller – MCU based – which regulates the Peltier supply voltage via a PID routine. Due to last moment mechanical incompatibilities, we were not able in June 2021 to upgrade the old HASC station with new mechanics and Peltier cooling, but we were able to accommodate the cooling with air, which lowered the nominal temperature of SiPMs from 36 °C to about 24 °C.

2.2 Study of dark matter

Thanks to its high beam intensity and detectors performance NA62 can achieve sensitivity to new-physics scenarios. Since 2018, IFIN-HH team is actively involved in the study of dark matter in various portals [7]. Our original goal, the study of the Higgs-coupled dark scalar, had to be postponed due to the urgency of finalizing the $ALP \rightarrow \gamma\gamma$ sensitivity evaluation. Significant efforts have been made during 2020-2021 to simulate the muon-induced background for this physics case. However, the analysis has been halted when NA62 collected another beam dump sample (1.4×10^{17} POT). The Exotics Working Group started investigating the physics case of a dark photon (A') [8,9]decaying into a pair of leptons. Our team was highly involved in several aspects of this analysis. The primary goal was to fully implement the analysis of the $A' \rightarrow e^+e^-$ analysis to derive new exclusion regions in the model parameter space [10]. Additionally, our team led the effort to combine the results of this analysis with the previous one, on the $A' \rightarrow \mu^+\mu^-$ analysis [11]. The analysis of $A' \rightarrow$ hadrons has also been finalized [12], with our team being responsible with the background from various channels. The results obtained for dark scalars can also be interpreted in terms of other exotic particles. We are currently involved in the searches for several exotic particles decaying into hadronic final states, using the same dataset.

2.3 Precision measurement of the $\pi^0 \rightarrow e^+e^-$ decay rate

In the framework of Chiral Perturbation Theory, the $\pi^0 \rightarrow e^+e^-$ decay rate measurement provides a tight experimental constraint on calculations. The process has negligible short-distance contributions and is the best-measured pseudo-scalar decay to a pair of leptons. Immediate benefits of the decay rate precision

measurement are improved predictions of rates for other pseudo-scalars decays to lepton pairs, such as $\eta \rightarrow \mu^+ \mu^-$ and the long-distance contribution of the $K_L^0 \rightarrow \mu^+ \mu^-$ decay. In the latter case, the short-distance contribution is a potential source of information on $|V_{td}|$.

Efforts to measure the $\pi^0 \rightarrow e^+ e^-$ decay rate within NA62 have been made in the past, but conclusions were never reached. The analysis was restarted by one of our Ph.D. students in June 2022, with the goal of measuring the branching ratio of the $K^+ \rightarrow \pi^+ \pi^0; \pi^0 \rightarrow e^+ e^-$. The analysis is almost done and a scientific paper is foreseen to be submitted in 2026.

We have also initiated a study to determine the branching ratio of the $K^+ \rightarrow \pi^+ e^+ e^-$ decay. This decay is of particular importance as it represents a flavor-changing neutral current (FCNC) process, which is strongly suppressed by the GIM mechanism. The decay provides valuable insight into the structure of the weak interaction at low energies. Moreover, since this decay serves as the normalization mode in the $\pi^0 \rightarrow e^+ e^-$ analysis, a new and more precise measurement based on Run 2 data will help reduce the external uncertainty on the $\pi^0 \rightarrow e^+ e^-$ branching ratio.

3. Scientific achievements in the last three years corresponding to the actual program funding

Having in mind that HASC has to be operated also in 2026, we evaluated the degradation of HASC' SIPMs due to radiation through the evolution of the hit time resolution in both stations in the period 2021-2025. As shown in Figure 4, each station's time resolution remained within 100 ps of the value at the beginning of 2021.

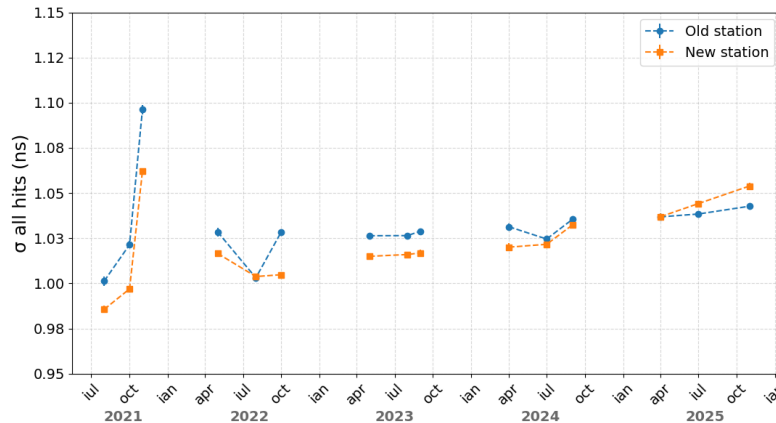


Figure 4: Evolution of HASC' time resolution in the 2021-2024 period.

At the end of 2021, NA62 collected a beam dump sample, approximately 10 times larger (1.4×10^{17} POT) than the one collected in 2017-2018. The focus of the Exotics Working Group shifted from the $ALP \rightarrow \gamma\gamma$ search to another interesting physics case, that of a dark photon decaying to a pair of leptons. The IFIN-HH group contributed significantly to this analysis by: developing tools to assess the data quality; studying the efficiency of various cuts used in the selection algorithm; simulating the background induced by halo muons. The analysis has been finalized in March 2023, this time our team having the leading role in across all aspects of the analysis. The results of this analysis extend the exclusion region significantly at low dark photon masses with some contributions also in the large mass range in previously unexplored domains. The internal note and the scientific paper have been published [10]. In addition to the above, our team had the role of providing a suitable method for the statistical combination of the $A' \rightarrow e^+ e^-$ search result with the previous NA62 search result $A' \rightarrow \mu^+ \mu^-$ [11]. The exclusions region obtained by the combined $A' \rightarrow e^+ e^-$ and $A' \rightarrow \mu^+ \mu^-$ searches is shown in in Figure 5.

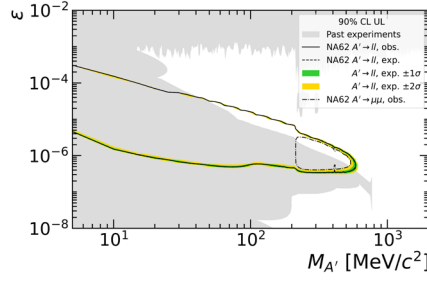


Figure 5: Exclusion contour obtained by the combined $A' \rightarrow e^+e^-$ and $A' \rightarrow \mu^+\mu^-$ searches. Grey areas indicate regions excluded by past experiments. The continuous line represents the observed exclusion contour obtained at 90% CL. The dashed line is the median expected exclusion contour. The $\pm 1\sigma$ and $\pm 2\sigma$ bands are shown in green and yellow, respectively. The dot-dashed contour is the one obtained by NA62 in the $A' \rightarrow \mu^+\mu^-$ search.

At the end of 2023/beginning of 2024 the analysis of other decay channels and other exotic particles started with the same dataset. The focus is on the production dark photons, dark scalars or ALPs which subsequently decay into hadrons. Our team led the efforts on the production of MC samples for the various background sources. We were also involved in the statistical combination of the $A' \rightarrow ll$ with the $A' \rightarrow$ hadrons results. The exclusion contours obtained in by the combined search is shown in Figure 6. Also shown are the interpretations of the $A' \rightarrow$ hadrons result in terms of dark scalars and ALPs.

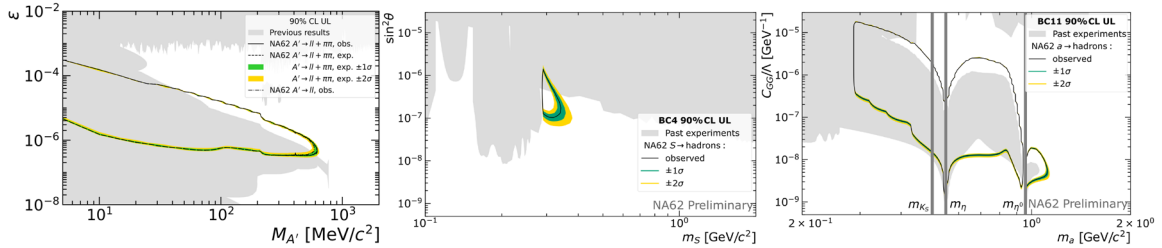


Figure 6: Exclusion contours obtained in the $A' \rightarrow l^+l^-$ and $A' \rightarrow \pi^+\pi^-$ combined search (left), the $S \rightarrow$ hadrons search (middle) and the $a \rightarrow$ hadrons search (right). The same color conventions as in Figure 5 is used.

Following the success of the 2021 BD dataset analyses, NA62 has collected data in the same setup in 2023, 2024 and 2025. The 2021-2024 dataset, consisting of 6.2×10^{17} POT, is currently being used for a new analysis – that of the production and decay of a Heavy Neutral Lepton (HNL) in the NA62 apparatus. Details on the model can be found under BC7 and BC8 in [8] and references therein. In November 2024, we started working on the simulation from first principles of a charged hadrons MC sample for beam dump background studies that is expected to play a significant role in understanding the background for the HNL search. In normal simulations of our beamline, one primary proton interacting in the TAX has a chance of 2.5×10^{-6} of producing a hadron that protrudes in the NA62 sensitive volume. One of our important accomplishments in this direction was the development of a biasing algorithm capable of enhancing the hadron halo component production by a factor $\simeq 4 \times 10^5$ with respect to the yield obtained from normal simulation. We have benchmarked our algorithm against data by comparing the yield of $K_S \rightarrow \pi^+\pi^-$ and $\Lambda \rightarrow p\pi^-$ observed in a selected dataset. The results are summarized in Table 1. It is noteworthy that the MC expectation agrees to the data observation within a factor of two. Moreover, the Data-MC agreement is highlighted by the momentum distributions of the two hadron species, shown in Figure 7.

	Data	MC
$K_S \rightarrow \pi^+\pi^-$	142 ± 12	76 ± 14
$\Lambda \rightarrow p\pi^-$	91 ± 10	73 ± 15

Table 1: Estimated number of K_S and Λ decays at 2×10^{16} POT. Table extracted from [cite pres]

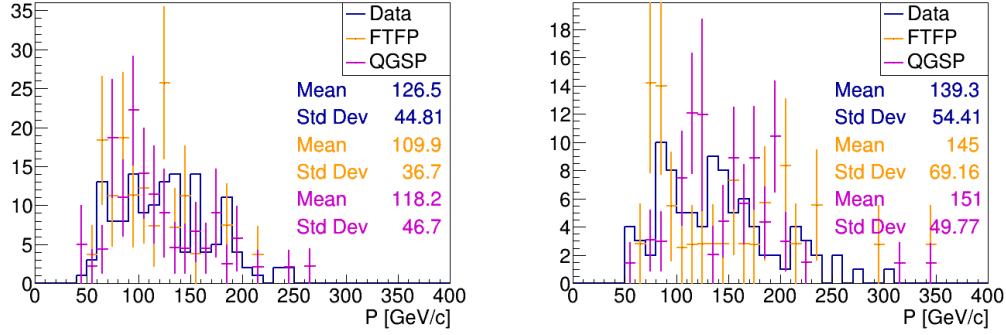


Figure 7: Momentum distribution of K_S (left) and Λ (right) at their decay point in data and two versions of MC.

In 2022, one of our PhD students started working in the Precision Measurement Group, on the measurement of the branching ratio of the $\pi^0 \rightarrow e^+ e^-$ decay. The 2017 and 2018 datasets are used with about 500 reconstructed $K^+ \rightarrow \pi^+ \pi^0; \pi^0 \rightarrow e^+ e^-$. The analysis is based on the reconstructed invariant mass of the electron and positron tracks (m_{ee}) forming a vertex in the fiducial volume ($105 \text{ m} < z_{vtx} < 180 \text{ m}$). Contributions were focused on the selection algorithm, resulting in increased signal acceptance and higher particle identification (PID) efficiency with respect to previous studies.

The preliminary obtained branching ratio is [13] $B_{NA62}(\pi^0 \rightarrow e^+ e^-, x > 0.95) = (5.86 \pm 0.30_{stat.} \pm 0.11_{syst.} \pm 0.19_{ext.}) \times 10^{-8}$. Extrapolated to the full kinematic range, the obtained branching ratio is $B_{NA62}(\pi^0 \rightarrow e^+ e^-, no - rad) = (6.22 \pm 0.39) \times 10^{-8}$.

In the last two months of 2024 we developed an emulator for the Liquid Krypton (LKr) calorimeter response to electrons, positrons, and pions to address a long-standing discrepancy between data and MC in the reconstructed energy deposit (E) and momentum (p) for charged tracks traversing the LKr. Using a sample of 7×10^6 $K^+ \rightarrow \pi^+ \pi^0; \pi^0 \rightarrow e^+ e^- \gamma$ decays reconstructed in data we mapped electron and positron positions on a 10×10 grid (each ‘‘cell’’ covering a surface of 40 cm^2) and recorded E/p distributions for each cell. For pions, only a single E/p distribution was stored. During analysis, each track’s energy deposit was sampled based on its momentum, position, and particle type. This approach improved data/MC agreement for pions (Figure 8), and the emulated response is now used as the default MC.

We redid the systematic studies with the new reprocessing and the new LKr Energy Emulator. The total systematic uncertainty on the branching ratio is 0.12×10^{-8} . The largest contribution comes from the trigger efficiency (0.09×10^{-8}), followed by background simulation (0.05×10^{-8}). Signal simulation, reconstruction, and particle identification contribute by (0.04×10^{-8}) while the beam simulation has a negligible effect ($< 0.01 \times 10^{-8}$). Overall, the total systematic uncertainty is 0.12×10^{-8} . The implementation of the LKr Energy Emulator shifts the central value of the branching ratio closer to the updated theoretical prediction [14,15], $B_{Th.}(\pi^0 \rightarrow e^+ e^-, x > 0.95) = (5.87 \pm 0.04) \times 10^{-8}$ and $B_{Th.}(\pi^0 \rightarrow e^+ e^-, no - rad) = (6.25 \pm 0.03) \times 10^{-8}$. After the new reprocessing using the improved LKr Energy Emulator, the obtained result is $B_{NA62}(\pi^0 \rightarrow e^+ e^-, x > 0.95) = (5.88 \pm 0.28_{stat.} \pm 0.12_{syst.} \pm 0.19_{ext.}) \times 10^{-8}$. Extrapolated to the full kinematic range, the obtained branching ratio is $B_{NA62}(\pi^0 \rightarrow e^+ e^-, no - rad.) = (6.26 \pm 0.38) \times 10^{-8}$.

An updated analysis based on Run 2 data is planned, aiming to reduce the statistical uncertainty by employing an improved multi-track electron trigger line with a lower downscaling factor. Furthermore, to mitigate the external uncertainty associated with the branching ratio of the $K^+ \rightarrow \pi^+ e^+ e^-$ decay channel—used as the normalization mode in our study—a dedicated reanalysis of this decay has been initiated. This effort will provide an improved measurement of the $K^+ \rightarrow \pi^+ e^+ e^-$ branching ratio.

Although our analysis includes fewer expected signal events than the KTeV sample, the precision of our measurement is comparable to that of KTeV-E799-II, and the two results are consistent. However, our central value shows better agreement with theoretical predictions [14,15].

Using the Run 1 data set, approximately 10^4 $K^+ \rightarrow \pi^+ e^+ e^-$ candidates were observed, applying the requirement $m_{ee} > 140$ MeV/c². The reconstructed $m_{\pi ee}$ distribution is shown in Figure 9.

Using the Run 2 data collected so far, over 10^5 $K^+ \rightarrow \pi^+ e^+ e^-$ candidates were observed [16]. Measuring the branching ratio of this decay will allow us to improve the current world averages of both the $\pi^0 \rightarrow e^+ e^-$ and $K^+ \rightarrow \pi^+ e^+ e^-$ decay.

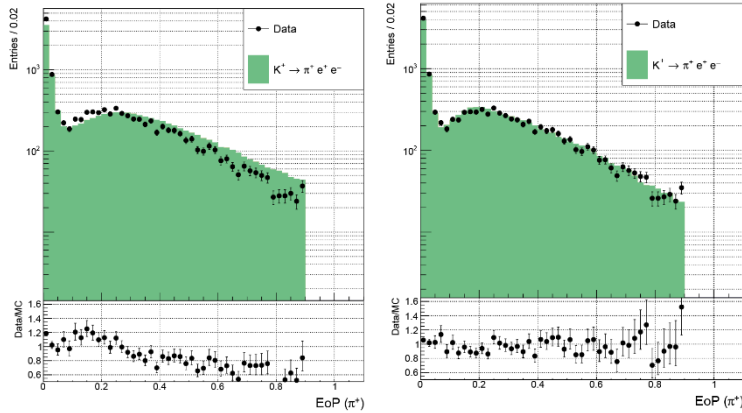


Figure 8: The E/p distributions of the pion track for the default MC response (left) and the emulated MC response (right).

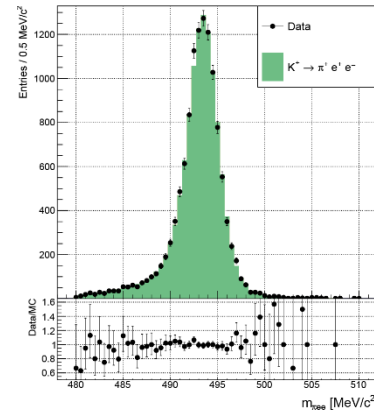


Figure 9: Reconstructed $m_{\pi ee}$ distribution for the $K^+ \rightarrow \pi^+ e^+ e^-$ where $m_{ee} > 140$ MeV/c².

In the framework of CERN Detector Research & Development Collaboration devoted to gaseous detector technologies (DRD1) we've build a thermal enclosure (Figure 10) for the study of straw gas gain vs. gas temperature and the proactive correction of the gain variation by high voltage automatic tuning via straw control system. The controls are planned to be implemented in 2026.



Figure 10: Straw thermal enclosure.

4. Group members (table)

- List each member, their role in project(s) and the % time on each project (analysis, R&D, detector operation, detector construction, etc.);

Name	Role	FTE
Alexandru-Mario BRAGADIREANU	HASC upgrade, maintenance, and operation; detector control system; reconstruction software.	0.60
Stefan-Alexandru GHINESCU	Data analysis, MC simulation and reconstruction software	0.51
Ovidiu-Emanuel HUTANU	HASC upgrade, maintenance, and operation;	0.62
Petre-Constantin BOBOC	Data analysis	0.52
Ionut IONESCU	HASC, maintenance, and operation;	0.25
Neagu IONEL	HASC upgrade and maintenance	0.40
Alina MOTORGA	Project accountant	0.27
TOTAL		3.17

- List former students (in last 5 years) and current position/job and institution.

Publications list, conference presentations, list of attended meetings and list of deliverables covered in the present report

5. Papers and talks in last year

- List papers (journal or conference proceeding or note) with role of group member(s) – split on categories, do not mix journal papers with conference notes etc.;
 - E. Cortina Gil et al. NA62 Collaboration, *First detection of a tagged neutrino in the NA62 experiment*, Phys. Lett. B 863 (2025) 139345;
 - E. Cortina Gil et al., NA62 Collaboration, *Observation of the $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ decay and measurement of its branching ratio*, JHEP 2025, 02, 191;
 - E. Cortina Gil et al., NA62 Collaboration, *Search for hadronic decays of feebly-interacting particles at NA62*, Eur. Phys. J. C 85, 571 (2025);
- List talks of group members (title, conference or meeting, date);
 - [SW/MC status](#), NA62 Software & MC Validation WG, 12 March 2025.
 - [Pi0ee analysis](#), NA62 Precision Measurements WG, 13 March 2025.
 - [MC production of background samples](#), NA62 Exotics WG, 13 March 2025.
 - [SW/MC status](#), NA62 Software & MC Validation WG, 16 April 2025.
 - [Exotics background MC](#), NA62 Exotics WG, 17 April 2025.
 - [SW/MC status](#), NA62 Software & MC Validation WG, 04 June 2025.
 - [Exotics background MC](#), NA62 Exotics WG, 05 June 2025.
 - [SW/MC status](#), NA62 Software & MC Validation WG, 09 July 2025.
 - [SW/MC status](#), NA62 Software & MC Validation WG, 02 September 2025.
 - [Updates on upstream MC](#), NA62 Exotics WG, 04 September 2025.
 - [SW/MC status](#), NA62 Software & MC Validation WG, 14 October 2025.
 - [Techniques for the prompt-background MC simulation for 2023 – beam-dump data sets](#), NA62 Exotics WG, 16 October 2025.
- Other deliverables (patents, books etc.).

Other activities and Budget

6. Further group activities (1 page)

- Collaborations, local synergies, education, outreach

The multifunction rack control unit (MRCU) hardware was developed and built in the framework of NUCLEU 16 42 01 03 Project. The MRCU firmware and the high-level software were developed in the framework of the present project, the MRCU unit being operated at CERN ECN3 since July 2016 being part of the HASC Control system.

7. Realized budget

		lei
Type of expenditures		2025
1	PERSONNEL EXPENDITURES, from which:	676,957.00
	1.1. wages and similar income, according to the law	662,061.00
	1.2. contributions related to salaries and assimilated incomes	14,896.00
2	LOGISTICS EXPENDITURES, from which:	112,270.05
	2.1. capital expenditures	0.00
	2.2. stocks expenditures	33,955.05
	2.3. expenditure on services performed by third parties (including the contribution to CERN)	78,315.00
3	TRAVEL EXPENDITURES	44,011.75
4	INDIRECT EXPENDITURES – (OVERHEADS) *	377,461.20
TOTAL EXPENDITURES (1+2+3+4)		1,210,700.00
Indirect Expenditures = General IFIN-HH Overheads (35% from 1+ 2.2 +3) + Particle Physics Department Overheads (15 % from 1 + 2.2 +3)		

[1] NA62 Collaboration, *Proposal to Measure the Rare Decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ at the CERN SPS*, CERN-SPSC-2005-013, 2005.

[2] A.J. Buras, D. Buttazzo, J. Girrbach-Noe and R. Knegjens, *$K^+ \rightarrow \pi^+ \nu \bar{\nu}$ and $K_L \rightarrow \pi^0 \nu \bar{\nu}$ in the Standard Model: status and perspectives*, J. High Energy Phys. 1511 (2015),33.

[3] M. Bordone, D. Buttazzo, G. Isidori and J. Monnard, Eur. Phys. J. C 77 (2017) 618

[4] C. Bobeth and A. J. Buras, J. High Energy Phys. 1802 (2018) 101.

[5] M. Tanabashi et al. (Particle Data Group), Phys. Rev. D 98 (2018) 030001.

[6] NA62 Collaboration, *NA62: Technical Design Document*, NA62-10-07, 2010.

[7] M. Pospelov, *Notes on benchmark models for the PBC evaluation*.

[8] J. Becham, et al, *Physics Beyond Colliders at CERN: Beyond the Standard Model Working Group Report*, J. Phys. G 47 (2020), no. 1, 010501.

[9] T. Spadaro and M. Raggi, *Search for visible decays of long-lived dark photons at the NA62 experiment: a feasibility study*, NA62-16-01, 2016.

[10] E. Cortina Gil et al, NA62 Collaboration, *Search for leptonic decays of dark photons at NA62*, Phys. Rev. Lett. **133**, 111802, 2024.

[11] E. Cortina Gil et al, NA62 Collaboration, *Search for dark photon decay to $\mu^+ \mu^-$ at NA62*, JHEP 2023 (09) 035, 2023.

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- [12] E. Cortina Gil et al., NA62 Collaboration, *Search for hadronic decays of feebly-interacting particles at NA62*, Eur. Phys. J. C 85, 571 (2025);
- [13] P. C. Boboc, on behalf of the NA62 Collaboration, *Latest results from precision measurements at the NA62 experiment*, Proceedings of Science (DIS2024)123 (2024).
- [14] T. Husek, *Neutral-pion decay into an electron-positron pair: A review and update*, Phys. Rev. D 110, 033004 (2024).
- [15] M. Hoferichter, et. al, Improved Standard-Model prediction for $\pi^0 \rightarrow e^+e^-$, Phys. Rev. Lett. 128 no. 17, (2022) 172004.
- [16] K. Massri, *Unleashing NA62's full physics potential: status and prospects*, KAON 2025 Conference.