Beamline for Schools
Μια δέσμη για τα σχολεία

Τα αποτελέσματα του διαγωνισμού “*μια δέσμη για τα σχολεία*”

Ανακοινώθηκαν (13 Ιουνίου 2016) από το CERN οι νικήτριες ομάδες για τον διαγωνισμό “beamline for schools-2016” (μια δέσμη για τα σχολεία-2016). Οι ομάδες “Pyramid Hunters” από την Πολωνία και “Relativity Special” από το Ηνωμένο Βασίλειο επιλέχθηκαν να εκτελέσουν, τον Σεπτέμβριο του 2016, τα πειράματα που πρότειναν χρησιμοποιώντας δέσμες του CERN. Στον διαγωνισμό συμμετείχαν 151 ομάδες (1250 μαθητές) από 37 χώρες από όλο τον κόσμο.

Από τις 151 συμμετοχές, 29 θεωρήθηκαν υψηλού επιπέδου και τους απονεμήθηκε σχετική βεβαίωση καθώς και ένας ανιχνευτής μιονίων (Cospic Pi) για το σχολείο τους. Ανάμεσα σ' αυτές τις συμμετοχές συμπεριλαμβάνονται τρεις Ελληνικές ομάδες: από το 7ο ΓΕ.Λ. Ν. Σμύρνης, το Βαρβάκειο Πειραματικό Λύκειο και το Ζάννειο Πειραματικό Λύκειο Πειραιά.

Η Ελληνική παρουσία στο διαγωνισμό μετρά συνολικά οκτώ συμμετοχές. Εκτός από τις τρεις παραπάνω ομάδες, συμμετείχαν και οι ομάδες από το Πειραματικό Λύκειο του Αριστοτέλειου Πανεπιστημίου Θεσσαλονίκης, το ΓΕ.Λ. Γουβών, μια δεύτερη ομάδα του Ζάννειου Πειραματικού Λυκείου Πειραιά, τα Εκπαιδευτήρια Μαντουλίδη και την Εκπαιδευτική Αναγέννηση.

Παρακάτω, μπορείτε να βρείτε τις προτάσεις των τριών ομάδων που διακρίθηκαν.

Τα video που στείλανε οι τρεις ομάδες μπορείτε να τα βρείτε στο youtube

Βαρβάκειο
https://youtu.be/3iTzNj8WzMs

Ζάννειο
https://www.youtube.com/watch?v=C0snU_FTajc

7ο Ν. Σμύρνης
https://www.youtube.com/watch?v=I6LVpb6b50Y

A NEUTRINO MASS MEASUREMENT

Odysseus Comrades 2016

Varvakios Pilot School, Athens Greece

Neutrino is one of the fundamental particles which make up the Universe. It is also one of the least understood. It is similar to the more familiar electron, with one crucial difference: it does not carry electric charge. So it is not affected by the electromagnetic forces which act on electron. Neutrinos are affected only by a "weak" sub-atomic force and are therefore able to pass through great distances in matter, without being affected by it. And there are billions upon billions of them. At any given moment there are about 100 billion solar neutrinos streaming through every centimeter of our body.

But how much is their mass? The Standard Model of particle physics assumes that neutrinos are massless. However the Nobel prize in Physics 2015 was awarded to both Takaaki Kajita and Arthur B. McDonald for their experimental discovery of neutrino oscillations, which requires neutrinos to have nonzero masses. But the absolute neutrino mass scale is still not known. So a number of efforts are under way to directly determine it in laboratory experiments. The methods involve mainly nuclear beta decay. The research project for which we apply is an effort to measure neutrino mass through pion decay.

1 The Method

In Relativity the connection between the total energy (E) of a free particle, its momentum ($\vec{p}$) and its rest mass (m_0) is given by:

$$E^2 = (|\vec{p}|c)^2 + (m_0 c^2)^2, \tag{1}$$

which for neutrino takes the form:

$$E_\nu{}^2 = (|\vec{p}_\nu|c)^2 + (m_{\nu 0}c^2)^2. \tag{2}$$

We can use this equation to determine the neutrino mass ($m_{\nu 0}$), if we know its total energy (E_ν) and the magnitude ($|\vec{p}_\nu|$) of its momentum.

Since neutrinos are hard to detect, we can infer the properties of neutrinos by studying the accompanying charged leptons produced simultaneously with them. Using the easily detectable leptons, together with energy-momentum conservation, we can determine the properties of the escaped neutrinos.

In the positive pion beam provided by PS at CERN the positron component is very small and decreases as a function of beam momentum. Therefore we shall use a positive pion beam, in order to detect the positrons that are produced only inside the experimental area.

The positive pions decay into antimuons or positrons and neutrinos as follows:

$$\pi^+ \rightarrow e^+ + \nu_e$$

$$\pi^+ \rightarrow \mu^+ + \nu_\mu.$$

We shall measure the energy and the momentum of the positrons produced and, using the equations of energy and momentum conservation, we shall calculate the energy and momenum of the neutrinos:

$$E_\pi = E_e + E_\nu \tag{3}$$

$$\vec{p}_\pi = \vec{p}_e + \vec{p}_\nu \tag{4}$$

2 The Experimental Setup

We shall measure the energy and the momentum of the positrons, since they deposit all their energy in calorimeter. Heavier particles (such as muons) produce a signal as well but they don't deposit all their energy in the calorimeter.

Figure (1) shows the setup to be used. In the entrance of the experimental area two Cherenkov counters (CH1 and CH2) are part of the fixed setup, each consisting of a Cherenkov threshold selector and a photomultiplier. We shall use them to identify pions and discriminate pions against other particles contaminating the beam. CH1 will give a signal only when pions, muons and electrons pass. CH2 will give signal only when muons and electrons

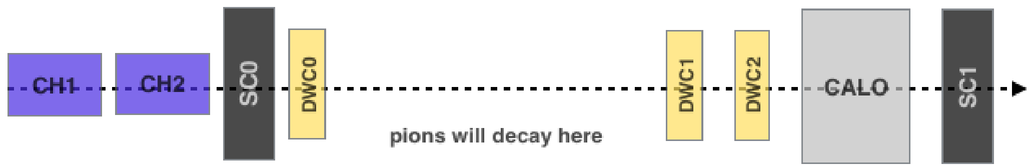

Figure 1: The experimental setup

pass. So we can use CH2 to veto muons and electrons that contaminate the beam. When the scintillator SC0 fires together with the pion identification information from the Cherenkov counters, it will signal that a pion enters the experimental area. A fraction of the identified pions that enter the experimental area will spontaneously decay before the calorimeter (CALO). A positron coming from the decay will be totally absorbed in the calorimeter, while a muon will just pass through. Therefore if the scintillator SC1, which is behind the calorimeter, has a signal, we categorize this event as a pion dacay into an antimuon and a neutrino. In contrast to this if the SC1 has not any signal, this event corresponds to a pion decay into a positron and a neutrino. Since this positron has been absorbed in the callorimeter, we can measure its energy.

Knowing E_π (the energy of the beam), having measured E_e and using equation (1) for pion and positron, we can calculate $|\vec{p}_\pi|$ and $|\vec{p}_e|$ respectively. So we can calculate $|\vec{p}_\nu|$, through the equation (4), from which we take:

$$|\vec{p}_\nu|^2 = |\vec{p}_\pi|^2 + |\vec{p}_e|^2 - 2|\vec{p}_\pi||\vec{p}_e|cos\theta, \tag{5}$$

where θ is the decay angle, when the pion decays into positron (Figure 2).

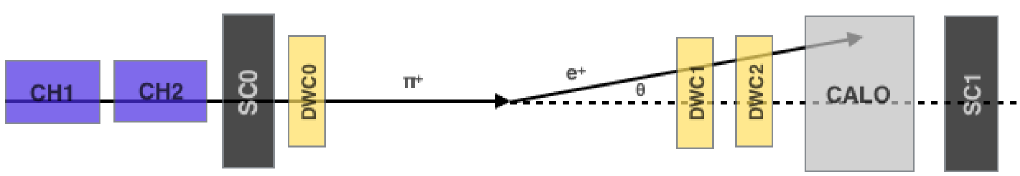

Figure 2: The decay angle θ

Using two delay wire chambers (DWC1 and DWC2) as tracking devices to reconstruct the track of the positron, we can compute the decay angle. Knowing θ and using the equation (5) we can compute $|\vec{p}_\nu|$. Finally having E_ν and $|\vec{p}_\nu|$ along with the equation (2) we compute the mass of electron neutrino.

In conclusion in a positive pion decay measuring the energy of positron and the angle between the direction of the pion and the positron produced we can calculate the mass of the electron neutrino. The more accurate these measurements would be, the more precise the value of neutrino mass.

Measuring the effect of cosmic rays on computer storage devices

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Abstract. We propose an experiment that measures how cosmic rays affect non-volatile computer storage devices (e.g., flash drives, SSDs, memory cards, e.t.c.). The T9 beamline is employed as a means to simulate the "primary" component of cosmic rays. The beam is directed towards a single storage device, whose contents are subsequently tested to determine possible degradation.

I. Introduction

Over the past two years our team has been involved with the Zero Robotics programming challenge, a competition organized jointly by M.I.T., N.A.S.A. and E.S.A. During our engagement with the programming of small satellites, we have often wondered about the effects of Cosmic Radiation (CR) on their electronics. As crazy as it sounds, any storage device can be harmed by cosmic radiation. If such an error occurs in space it may lead to loss of significant data, or (more importantly) it may compromise the operation of a critical spacecraft's system. Besides the fact that CERN is one of the few places on earth, where young students (who seek inspiration and excitement) can interact with top level scientists that unravel the laws of physics, it is also one of the few places where particles can be accelerated in order to simulate CR. Hence, naturally, when we found out about the BL4S competition we were excited! So please, let us bombard a flash drive, in the name of science, in order to see if our astronauts are indeed in danger.

II. Cosmic Radiation

Cosmic Rays (CRs) are immensely high-energy radiation that it is composed primarily of high-energy protons and atomic nuclei (99%). When they enter earth's atmosphere they produce showers of secondary particles (i.e. muons, neutrinos, e.t.c).

CRs have sufficient energy to alter the states of circuit components in electronic integrated circuits, causing transient errors to occur, such as corrupted data in electronic memory devices, often referred to as "soft errors". Studies by IBM in the 1990s suggest that computers typically experience about one CR-induced error per 256 megabytes of RAM per month. Although the related experiments were not very detailed (partially due the inability to create CR particles), the papers do refer to a change in the probability of encountering errors when we increase the altitude. This implies that primary (rather than secondary) nucleons, which are more commonly found in higher altitudes, are the main cause of soft errors. Their intensity at the top of the terrestrial atmosphere in the energy range from several GeV to somewhat beyond 100 TeV is given approximately by

$$I_N \approx 1.8 \cdot 10^4 \cdot E^{-2,7} \quad \frac{nucleons}{m^2\, s\, sr}, \quad \textbf{(1)}$$

where E is the nucleon's energy. The following table gives an approximation of the absolute numbers of primary nuclei per second and m^2, for some energy levels.

Energy (GeV)	≈ Number of nuclei
1	225000
2	35000
5	3000
10	450

III. The experiment

In order to measure the effect of CR on non-volatile computer memory, we propose to employ the T9 beam line (as a means to simulate the primary spectra of cosmic radiation) to bombard a typical flash storage device. We plan to expose the device to several T9 energy levels (e.g., 1, 2, 5 and 10 GeV) for various time frames (ranging from seconds to one or two minutes) and measure the number of memory errors (e.g., by comparing the contents of the device's memory to an original). Hopefully, this will allow us to build measurement tables (that relate the number of soft errors to the number of passing nuclei) and design models that approximate the error rate produced by primary rays at certain energy levels (see Figure 1). We note that the T9 beam is considerably denser that the typical cosmic radiation. Hence, a single burst is actually equal to several hours (or days – depending on the energy level) of exposure in standard CR levels. We can measure this time using a simple formula:

$$T = \frac{N_{nuclei}}{2 \cdot \pi \cdot R^2 \cdot A_{nuclei}}, \qquad \textbf{(2)}$$

where N_{nuclei} is the actual the number of protons in the beam, R is the radius of the beam's cross section, A_{nuclei} is the number of particles per second and per m^2 of CR which relates to a given situation (e.g., a specific energy level, a specific altitude inside earth's atmosphere, e.t.c.) and T is the total exposure time (in CR) which corresponds to one T9 burst. If the experiment is successful, we may be able to derive a general (simplistic) law that will relate the soft error rate to the rate of primary CR nuclei (A_{nuclei}) for certain energy levels (Figure 2).

IV. The set-up

We ‘ll employ the positive beam of the PS, whereas a set of bending magnets and a collimator will be used to set-up the desired energy level (Figure 3). In the following, Cherenkov detectors are used as triggers (the readout is initiated if a large ammount of protons pass through) and two scintillators are used to determine the velocity and the number of protons. Afterwards, two quadrupole magnets (one horrizontal and one vertical) focus the beam so that it has a specific radius R and the beam is directed towards the storage device (this can be a typical flash drive or an EPROM memory, e.t.c.). Finally, a scintillator measures the number of protons that do not interact with the storage device. We note that the storage device (i.e. a usb adapter that can have different types of computer memory) is connected through a long usb cable (10 m) to a desktop computer that will measure the errors in the device’s memory. We also note that we have succesfully tested the proposed configuration (i.e. the connection of the storage device with the long usb cables). Results will be published online in real time.

V. Conclusions - Dissemination

We believe that our experiment might unravel usefull information regarding the effects of CR on storage devices. If we are to be selected, we plan to share the knoweldge and experience that we will gain with the local community and perform additional experiments using the cosmic ray detector (that CERN provides) inside the premises of our school (collaborating with other schools in our area). We will also design a blog to make our experience (and the results of our experiments) available online.

1 GeV Energy Level	
# of passing nucleui (10^6)	# of soft errors
1	0
2	3
3	5
4	6
5	8
6	12

2 GeV Energy Level	
# of passing nucleui (10^6)	# of soft errors
1	0
2	2
3	6
4	7
5	9
6	14

5 GeV Energy Level	
# of passing nucleui (10^6)	# of soft errors
1	1
2	2
3	4
4	8
5	12
6	15

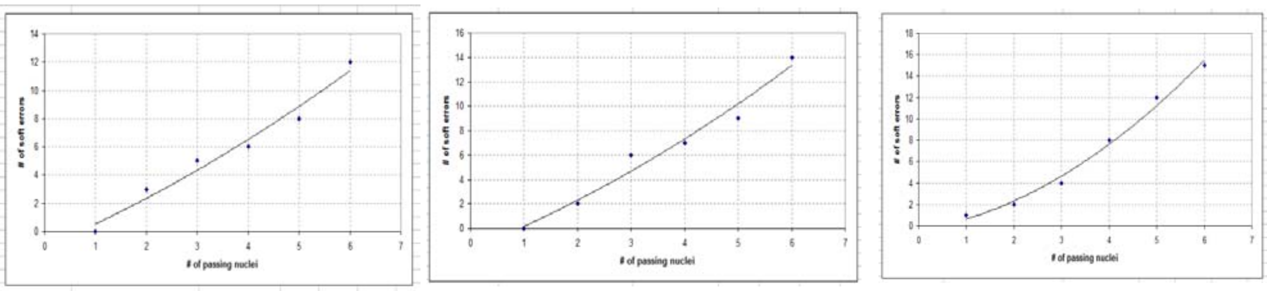


Figure 1. Examples of measurement tables (and corresponding figures with regression lines) with random entries.

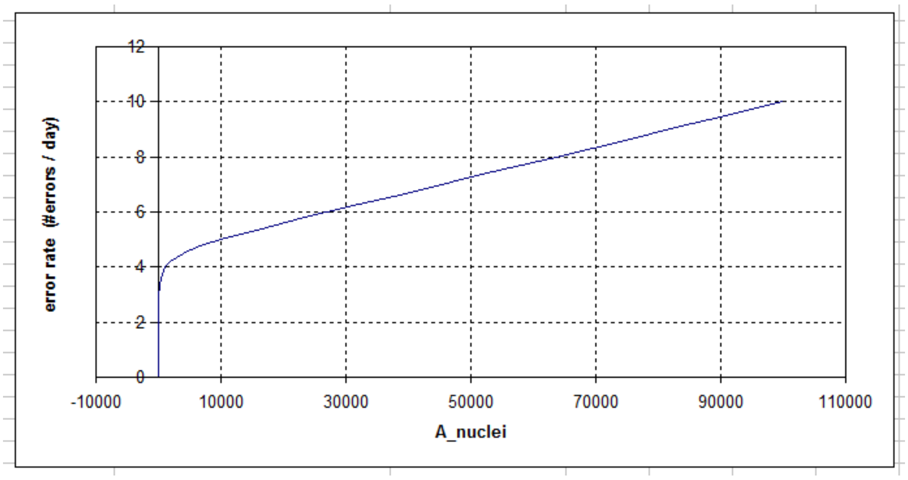


Figure 2. A close study of the results of the experiment may reveal a simple relation between the error rate and the rate of primary nuclei of CR. In this hypothetical example the relation is a linear one.

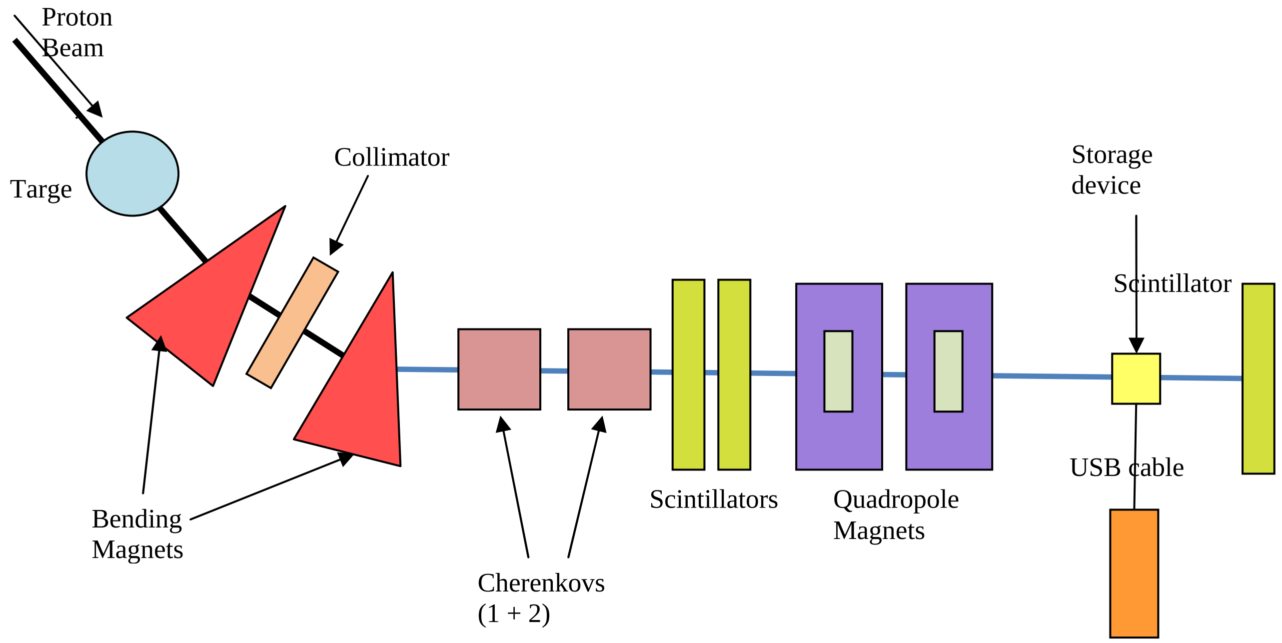


Figure 3. The experimental set-up for the PS.

Acknowledgements
We are grateful to Dr. Andromachi Tsirou for her valuable suggestions.

CP Violation in Kaon Decay

Proposed by 7th High School of N. Smyrni, Athens,Greece

Prologue

When our Physics teacher announced us that we could take part in CERN's competition, we were enthusiastic. Our school at CERN? Our school at the greatest research center of the planet? Our happiness was indescribable.

But very soon we began to get discouraged. How could we propose an experiment? We are all students in a school, which doesn't even have a Physics laboratory. Our Physics classroom turns into a swimming pool, when it rains! And the sorrow began to fill our hearts.

After having read the examples at Beamline website we were completely disappointed. We realized that other high schools had collaborated with Universities and research centers. How could we compete with other schools which are in close collaboration with Universities? We thought that we would be inadequate.

However our teacher insisted. He reminded us how Marie Curie had discovered polonium and radium by working hard at a shanty and in adverse circumstances. Besides, he explained us that we could gain the theoretical background by studying by ourselves a little harder than usually. Furthermore, he would give us lectures on Particle Physics every Sunday evening.

At the end he convinced us to take part at the competition and here we are!

Introduction

We have always been impressed by the case of anti-matter and the domination of matter after the Big Bang, although both of them were produced in equal quantities.

From the early stages of the universe one might expect equal numbers of baryons and antibaryons. However today the universe is matter dominated (there is no evidence for anti-galaxies, anti-stars, etc.) and, as we know from "Big Bang Nucleosynthesis" the matter/anti-matter asymmetry is:

$\xi = \frac{n_B - n_{\bar{B}}}{n_\gamma} \approx \frac{n_B}{n_\gamma} \approx 10^{-9}$, i.e. for every baryon in the universe today there are 10^9 photons.

How did this happen? Which mechanism of asymmetry between baryons and anti-baryons caused the disappearance of anti-matter and prevented the annihilation that would lead to a universe just full of energy (radiation)?

According to the CP invariance, for a reaction which generates a net number of baryons over anti-baryons there would be a CP conjugate reaction generating a net number of anti-baryons. Perhaps the CP violation is needed to explain matter/anti-matter asymmetry in the universe.

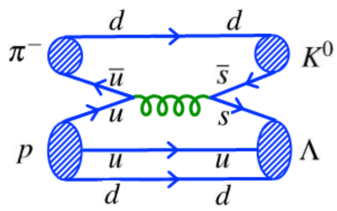
So we thought to propose an experiment where the CP invariance is violated while the weak force decays the neutral Kaon K_L^0 (ds).

Theoretical considerations

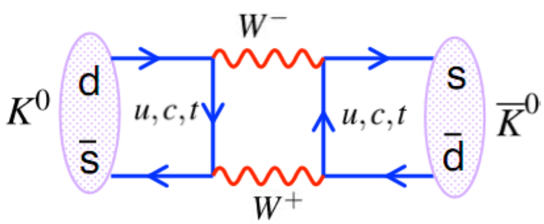
There are four Kaons which belong to the category of mesons. Two of them are charged and two are neutral. The charged Kaons are $K^+(u\bar{s})$, $K^+(u\bar{s})$ and they have the same lifetime $\tau(K^+) = \tau(K^-) = 1.24x10^{-8}s$.

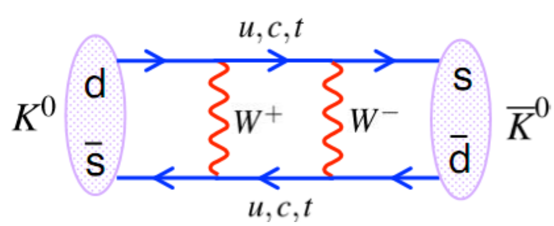
The neutral Kaons are $K^0(d\bar{s})$, $\overline{K^0}(s\bar{d})$ and they are produced during strong interactions :

$$\pi^-(d\bar{u}) + p(uud) \rightarrow \Lambda(uds) + K^0(d\bar{s})$$
$$\pi^+(u\bar{d}) + p(uud) \rightarrow K^+(u\bar{s}) + \overline{K}^0(s\bar{d}) + p(uud)$$



The Weak Interaction decays the neutral kaons and also allows them to mix.





This allows transitions between the strong eigenstates K^0 and $\overline{K^0}$ (quantum oscillations).

These neutral mixing kaon states are called the K-short K_s and the K-long K_L and they have approximately the same mass: $m(K_s) \approx m(K_L) \approx 498MeV$, but very different lifetimes: $\tau(K_s) = 0.9x10^{-10}s$ and $\tau(K_L) = 0.5x10^{-7}s$, because the first decays to two mesons ($\pi^+ \pi^-$) and the second to three π mesons.

Actually the two different lifetimes belong not to K^0 and $\overline{K^0}$, but to a linear combinations of them:

$$K_s = \frac{K^0 + \overline{K^0}}{\sqrt{2}} \quad \text{and} \quad K_L = \frac{K^0 - \overline{K^0}}{\sqrt{2}}$$

Neutral kaons can also decay to leptons. The leptonic decays are more likely for the K-long because the three pion decay modes have a lower decay rate than the two pion modes of the K-short.

The main decay modes/branching fractions for the K-long are:

$$K_L^{\ 0} \rightarrow \begin{cases} \pi^+\pi^-\pi^0 (BR = 12.6\%) \\ \pi^0\pi^0\pi^0 (BR = 19.6\%) \\ \pi^- e^+ \nu_e (BR = 20.2\%) \\ \pi^+ e^- \overline{\nu_e} (BR = 20.2\%) \\ \pi^- \mu^+ \nu_\mu (BR = 13.5\%) \\ \pi^+ \mu^- \overline{\nu_\mu} (BR = 13.5\%) \end{cases}$$

In our experiment we consider the following processes of decay:

i) $K_L^{\ 0} \rightarrow \pi^+ + e^- + \overline{\nu_e}$ (electron decay pattern)

ii) $K_L^{\ 0} \rightarrow \pi^- + e^+ + \nu_e$ (positron decay pattern)

These decays are called semileptonic decays, producing one meson (π) and two leptons.

Using the CP operations we have:

$$CP\left[\pi^+ + e^- + \overline{\nu_e}\right] = \pi^- + e^+ + \nu_e$$

We see that the CP transforms one set of decay products into the other. CP invariance would then suggest an identical probability for the two sets.

If in our experiment we find that the positron decay pattern happens more or less than the electron decay, then we'll have CP violation in Kaon decay. So the kaon could have had played a significant role in the discussions of these symmetries since that time.

Experimental Considerations

We will use the primary particle beam provided by CERN to create kaons by hitting the target and we also use the rest equipment to identify these mesons.

Then, we will measure the quantity of the positron decays, divided by the quantity of the electron decays. Specifically:

$$R = \frac{N\left(\pi^+ + e^- + \overline{\nu_e}\right)}{N\left(\pi^- + e^+ + \nu_e\right)}$$

If the ratio above equals 1, the CP symmetry is not violated, but if it differs from 1, then the symmetry is violated.

Such a violation could be linked to the mystery of the antimatter's disappearance, since it would justify the series of the particle decays which led to this result.

Experimental setup

We'll work with both beams, positive and negative, since we need negative and positive particles.

With the Cherenkof detectors we can identify the Kaons by the light emitted that is converted into electrical pulses. With the scintillation detectors we can identify the charged particles, such as pions (π^+, π^-), electrons (e^-), and positrons (e^+). Neutrinos are hard to detect because of their weak interaction with matter but we can estimate the number of them by measuring the energy of the beam, before and after the hitting with the target, by using the calorimeters.

Acknowledgements

No matter if our proposal will be accepted or rejected, we feel grateful to CERN at first, for the opportunity it gave us, and to our Physics teacher Christos Tsamis, for his invaluable support and encouragement during all the preparation period. It's sure that, by being involved in this competition, we have learned a lot of new things, from tiny quarks, leptons, bosons and gluons to huge accelerators and enormous particle detectors.

For all the aforementioned we say a big "Thank you" and we wish, we could do our experiment at CERN's premises next September.

The beamline team of the 7th High School of N. Smyrni, Athens, Greece