Multigap resistive plate chambers research

The work was created in frames of international project "Extreme Energy Events"

Science director - Dr. Vladimir Peskov

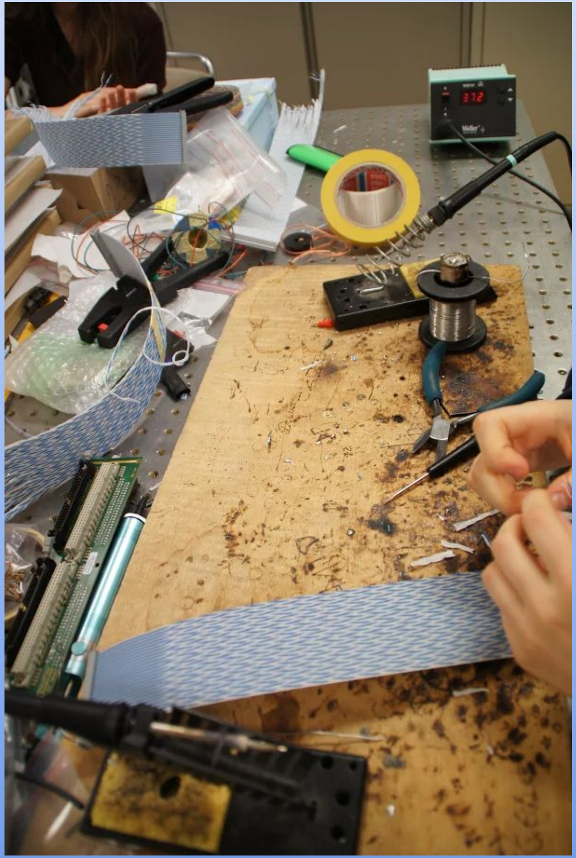
Speakers:
Makeev Vladislav
Shirshov Dmitry

Project participants:
Makeev Vladislav
Shirshov Dmitry
Dzebisashvili Alice
Nikolay Bragin

CERN

We were in CERN and have built a telescope with students from **Liceo Scientifico Gobetty** (the detector stands in their school). There we've met the inventor of MRPC -- Crispine Williams.

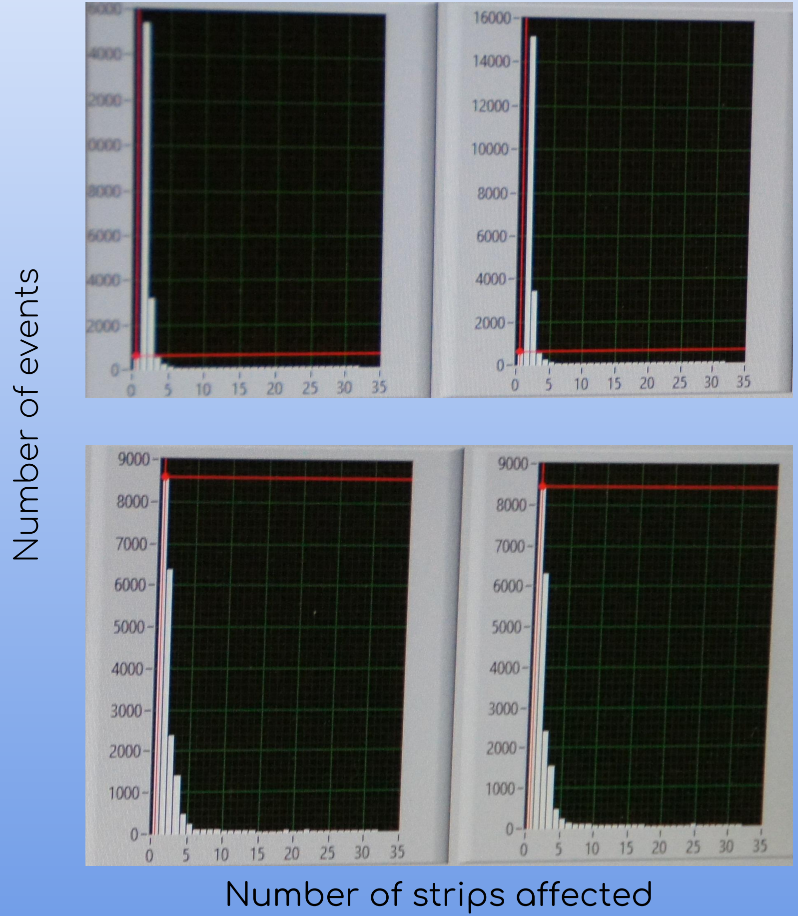
Assembly



Results and statistics

Chamber comparison

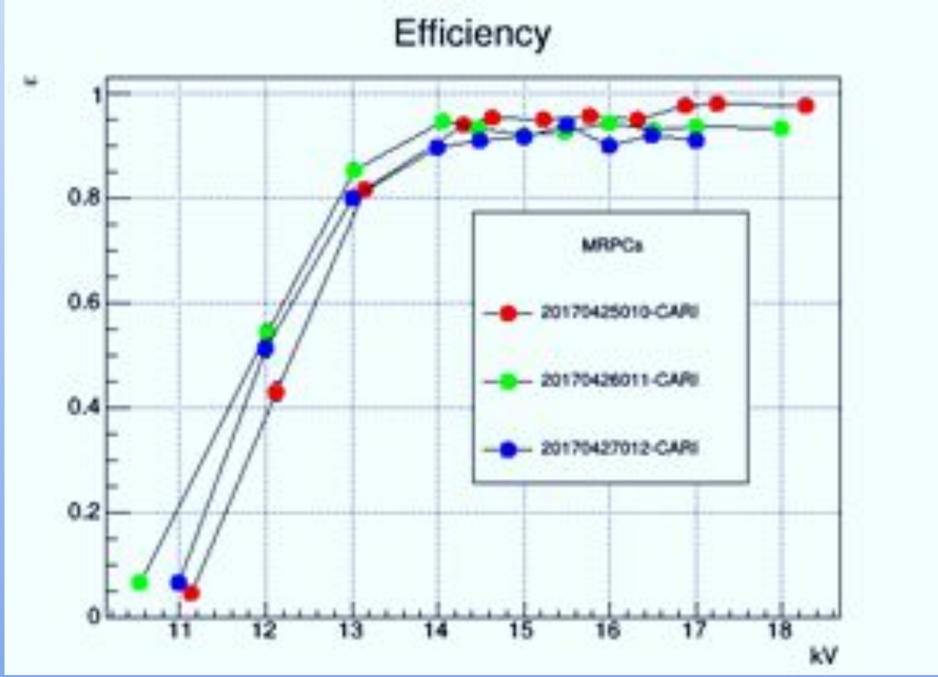
You can see the difference between normal and just-done chambers. The first one basically triggers on one-two-strip events whereas non-purged chamber skips a lot of events (0 strips).



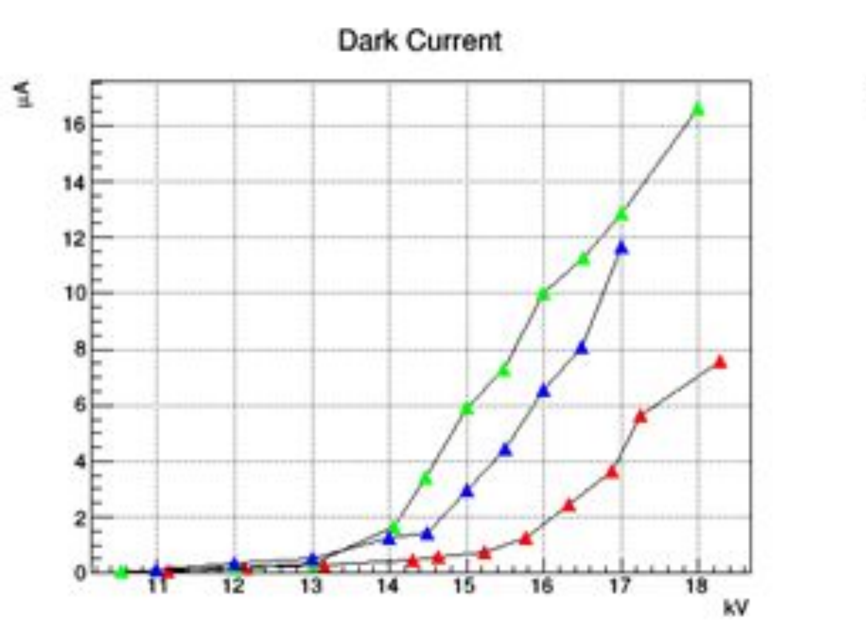
Chamber’s efficiency

Efficiency grows fast at low voltages till some threshold then it becomes a constant, because the avalanche saturates.

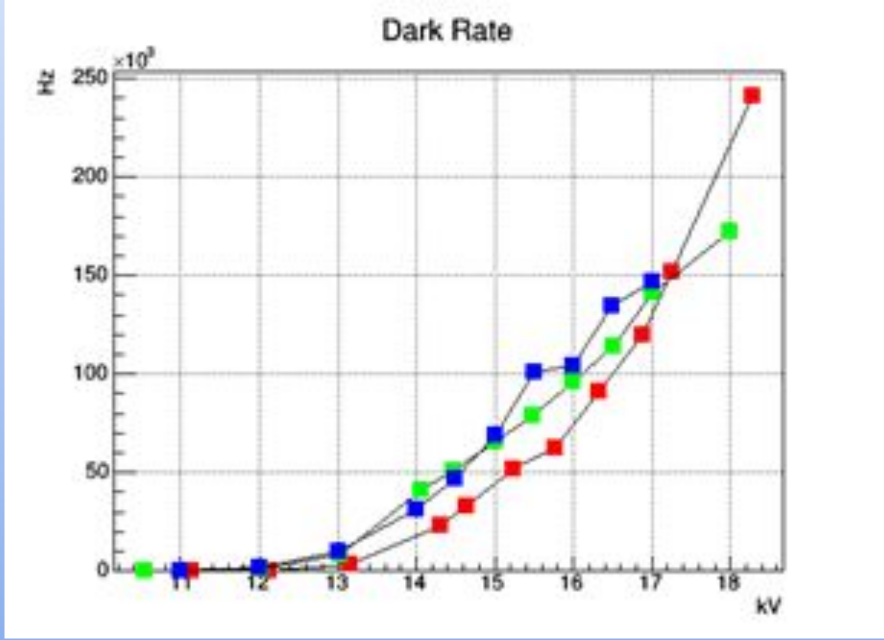
Primary clusters influence on the signal, because distance to anode is maximum and fluctuation of this distance is a main reason of maximum efficiency value decreased.



Dark current



Dark current – is a sum of linear (non-ideal resistive dividers between electrodes) and exponential currents. By our hypothesize exponential growth of the dark current is result of the Malter Effect.



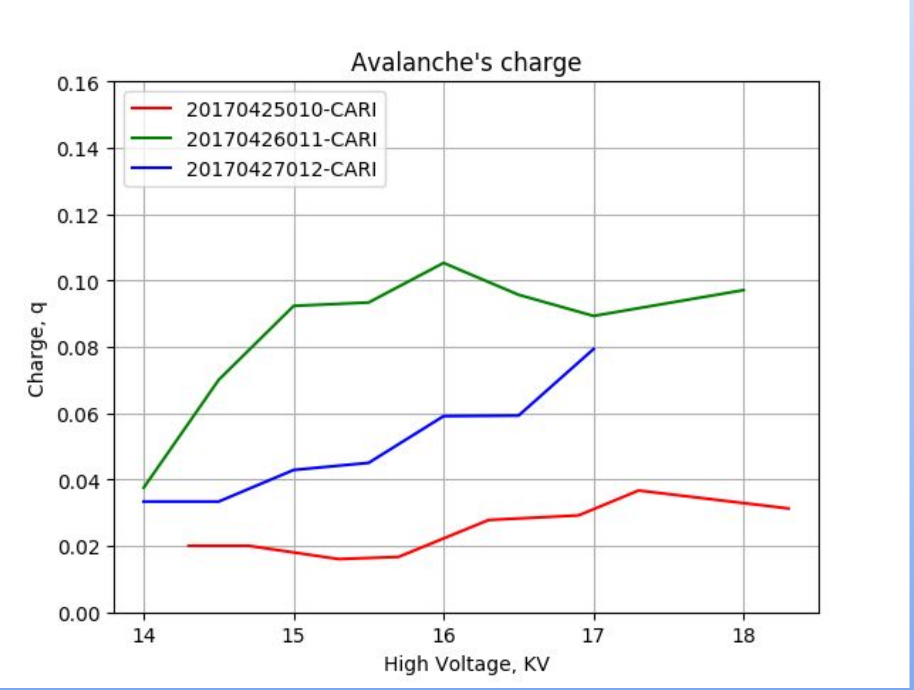
Dark rate – frequency of random electric impulses on the electrode, that does not linked with with incoming particles

Avalanche’s charge

$q = I / v$

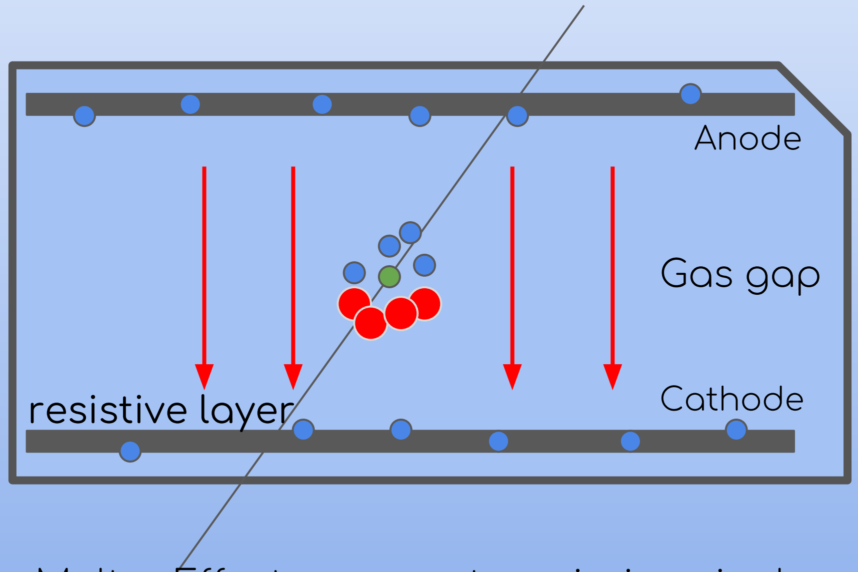
Where v – frequency of dark current, and I – dark current. Therefore, approximated quantity of electrons may be found by trivial formula :

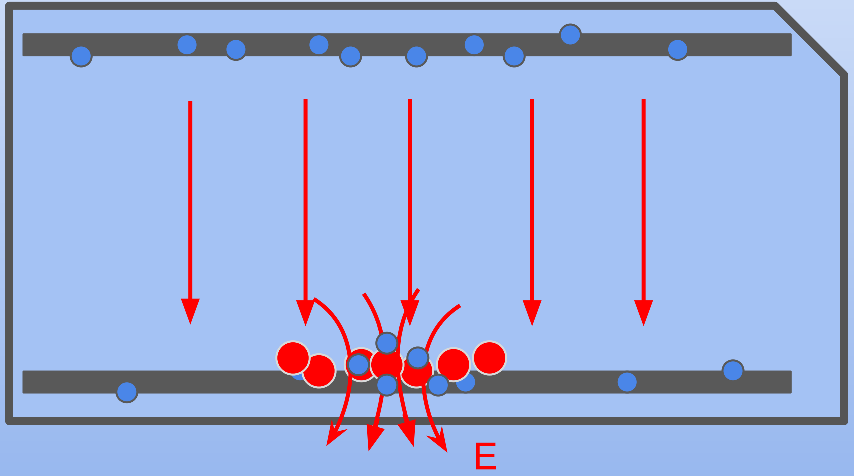
$N = q / q_e = I / (q_e * v)$



Muon
Electron
Ion of $C_2H_2F_4$

More about the Malter Effect



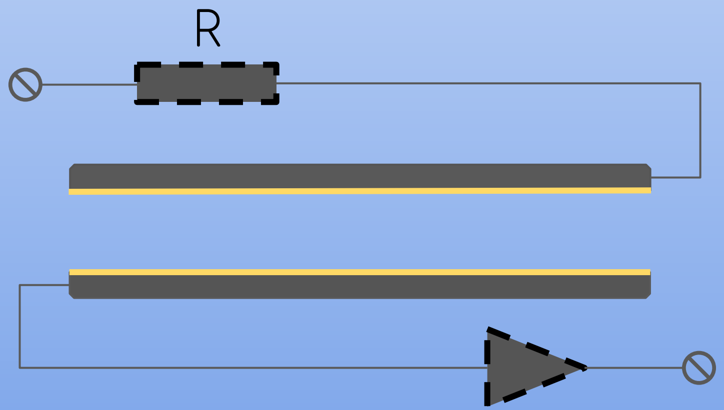


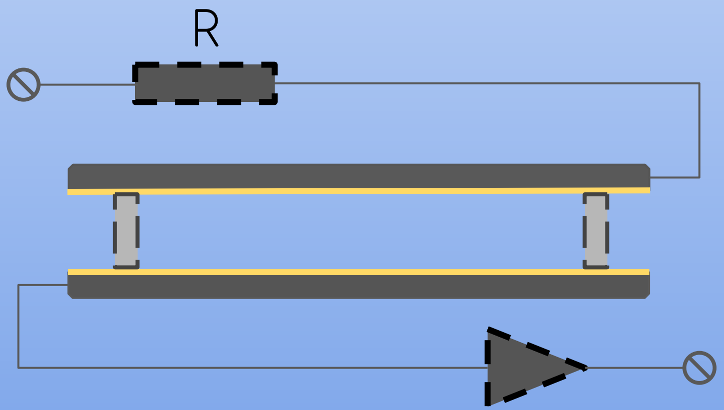
Malter Effect represents emission single electrons from cathode. Published mathematical model of those effect was based on Zimerfiled theory of field emission. Because of, the classical Malter Effect predicts single electron emission, one can speculate that it can not be observed in RPC due to the small avalanche charge.

Our hypothesis: after positive ions accumulated on the dielectric surface they create a strong double-layer electric field which cause emission of electrons, but not single, but in form of electron busts , Such bust were first observed in vacuum breakdowns and then also observed in the case of gaseous detectors

How to prove

We can take primary RPC -- two metallic electrodes, preferably gold plated, turn it on in standard MRPC mode and measure the current between them. Then we can add the same spacers as on MRPC and observe the linear growth.

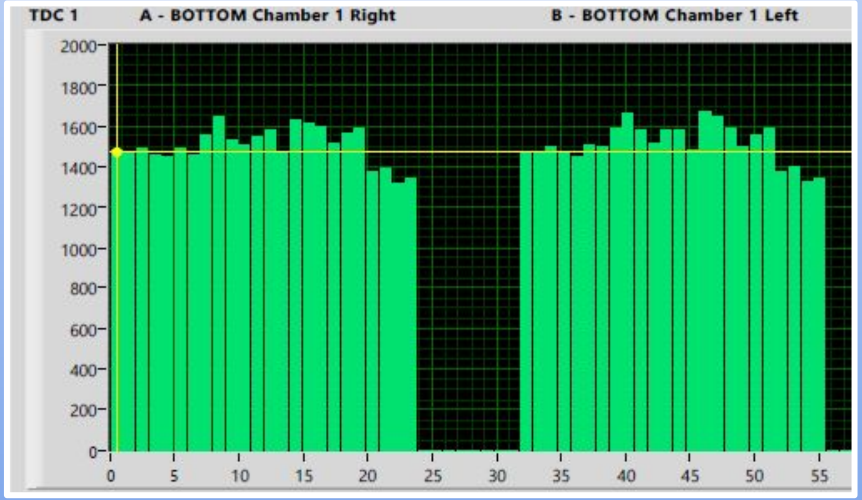




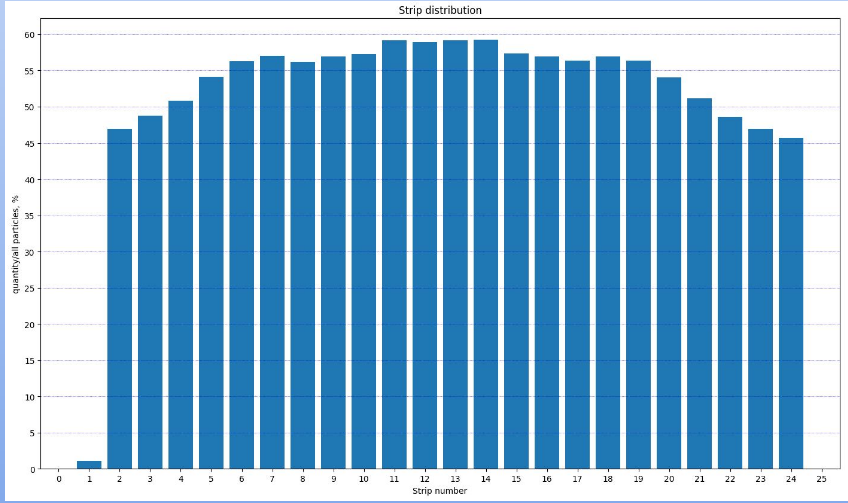
Simulations

Computer simulations are similar to a real data

Reality



Simulation



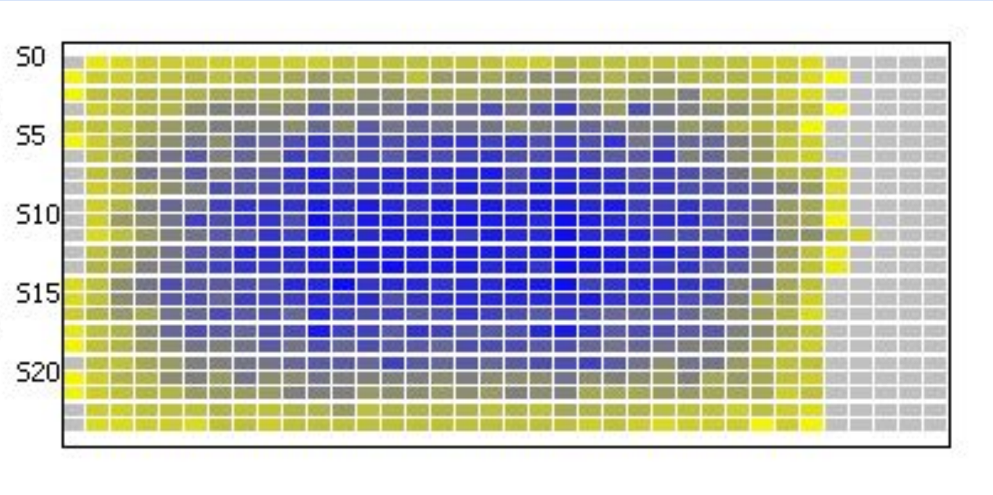
Efficiency distribution on strips

Simulations

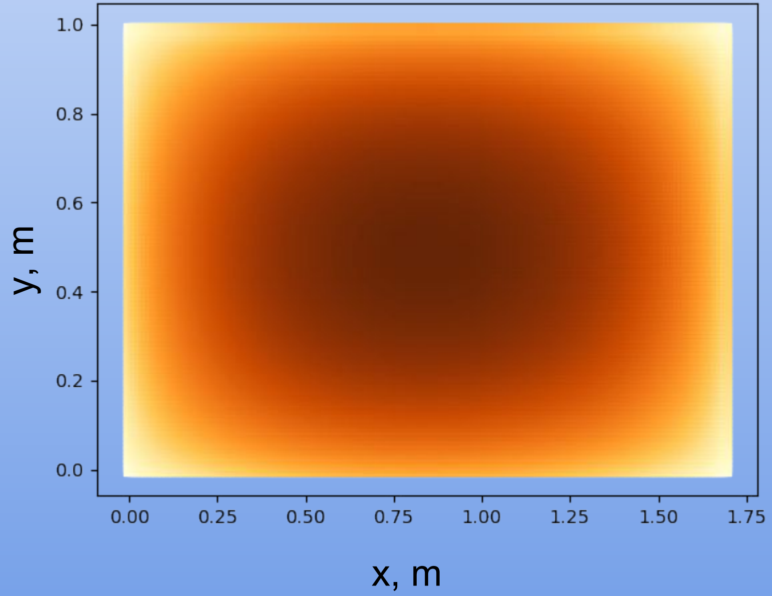
Computer simulations are similar to a real data

Efficiency distribution on plain

Reality



Simulation

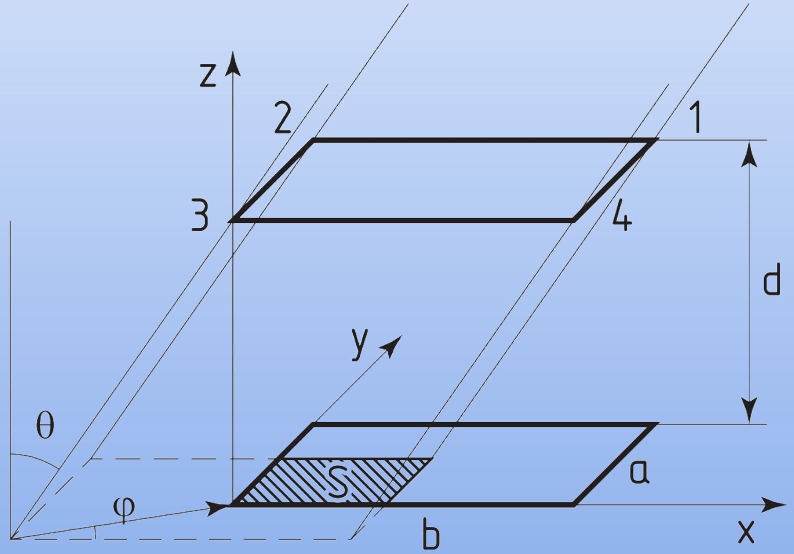


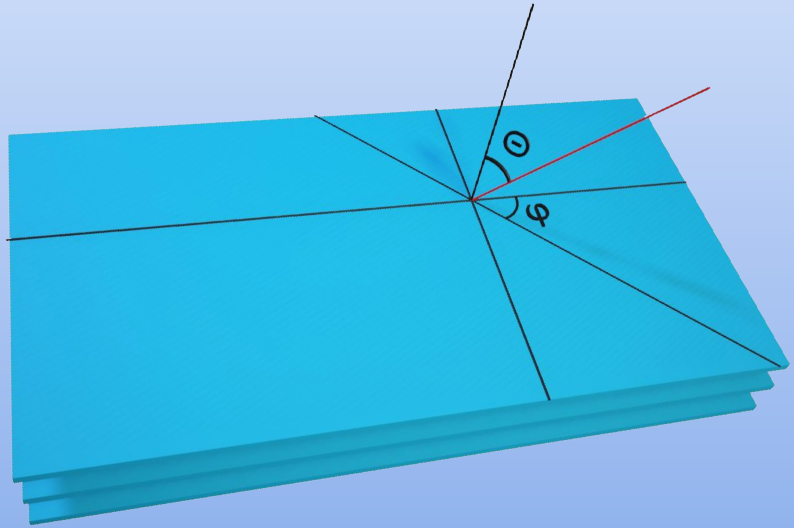
We have written a program, which goes through all possible tracks directions, generating parametric quantity of random dots on the imaginary layer (which is bigger than a chamber and located above the telescope) and counting differential geometric efficiency.

```cpp
#include <fstream>
#include <ctime>

#include "UTILS.h"

int main() {
    double ptick = 0.01, ttick = 0.01,
        w = 1.7, h = 1, mar = 0.1, D = 0.9;
    double iw = w + mar, ih = h + mar;

    size_t counter = 0;
    size_t oks = 0, dots = 5000;

    std::ofstream output { "genoutput.bin", std::ios::binary };

    srand((unsigned)time(0));

    for(double phi = 0; phi < twopi; phi += ptick) {
        for(double theta = 0; theta < halfpi; theta += ttick) {
            oks = 0;
            double tgth = tan(theta);
            double vecd[] = { -cos(phi) * tgth, -sin(phi) * tgth, -1 };
            mulvec(vecd, D);
            for(size_t i = 0; i < dots; ++i) {
                double vecp[] = { doublerand(-mar, iw), doublerand(-mar, ih), D };
                sumvecs(vecp, vecd);
                if(vecp[0] >= 0 && vecp[0] <= w && vecp[1] >= 0 && vecp[1] <= h) ++oks;
            }
            writeFile(output, phi, cos(theta), (double)oks / dots);
        }
        ++counter;
        if(counter % 6 == 0) {
            std::cerr << '#';
            counter = 0;
        }
    }

    return 0;
}
```

```python
import struct
from ctypes import c_double, sizeof
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D

inp = open('genoutput.bin', 'rb')

double_size = sizeof(c_double)

def getDouble():
    a = inp.read(double_size)
    if len(a) < double_size: raise EOFError
    a = struct.unpack('d', a)[0]
    return a

x, y, z = [], [], []

while True:
    try:
        x.append(getDouble())
        y.append(getDouble())
        z.append(getDouble())
    except EOFError:
        break

inp.close()

fig = plt.figure()
ax = fig.add_subplot(111, projection = '3d')
ax.set_xlabel("Phi")
ax.set_ylabel("Cos Theta")
ax.set_title("Efficiency")
ax.scatter(x, y, z, marker=',', c=z, cmap='jet')
plt.savefig('genpic.png', transparent=True, dpi=500)
```

Efficiency

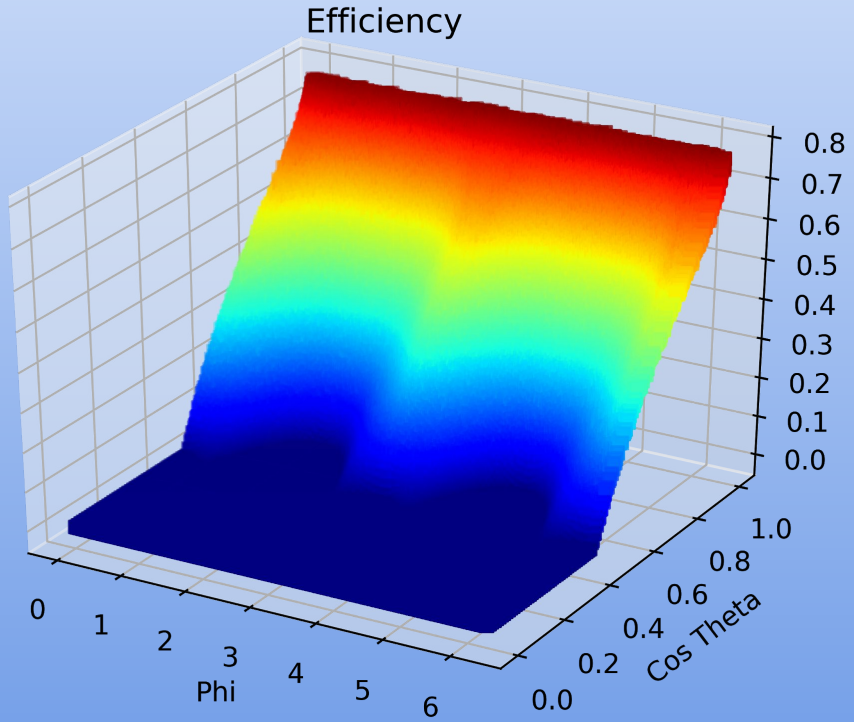


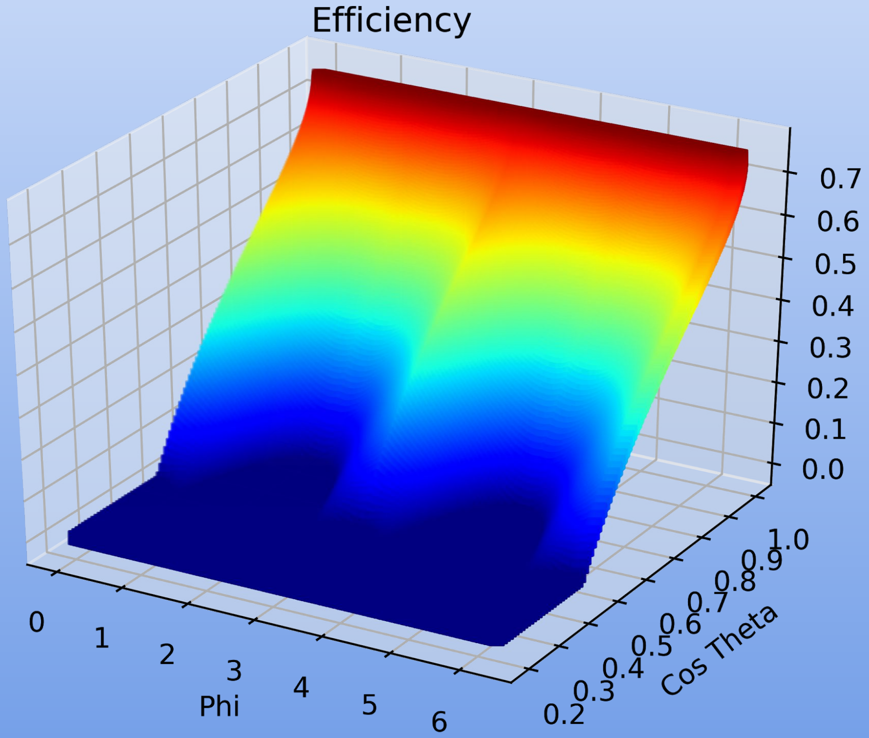


$$\eta = N / N_0 = S / (ab) = (1 - d / a * \tan(\Theta) * |\sin\phi|) * (1 - d / b * \tan(\Theta) * |\cos\phi|)$$

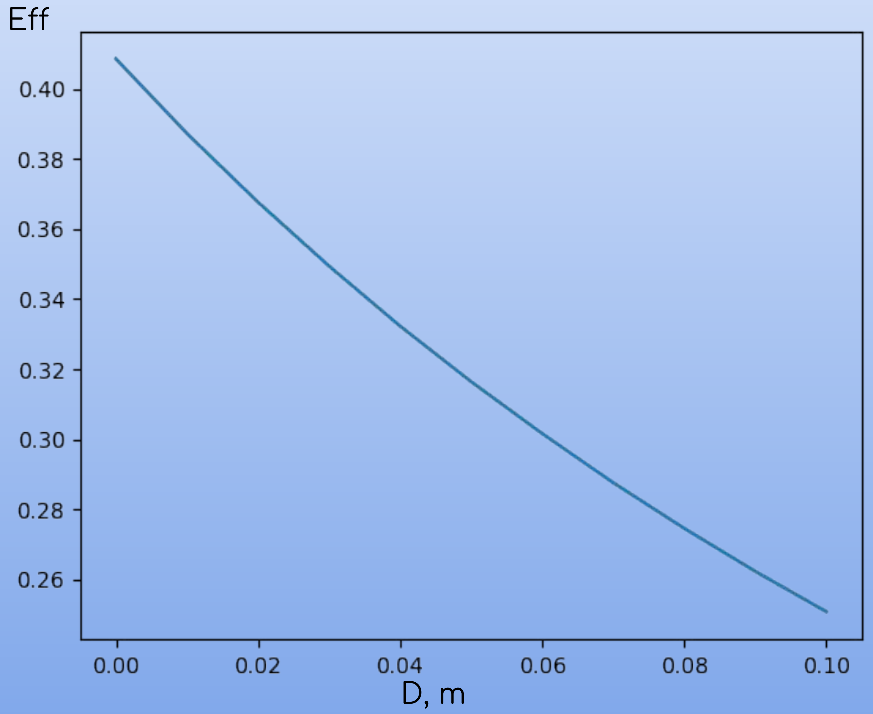
Simulation results

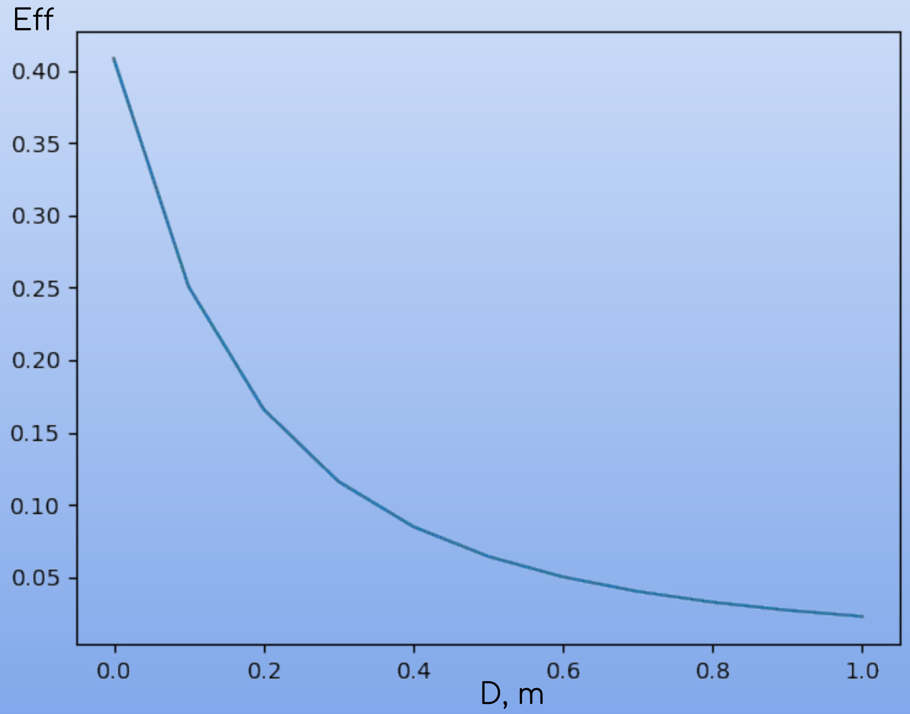
Simulation and Math Model





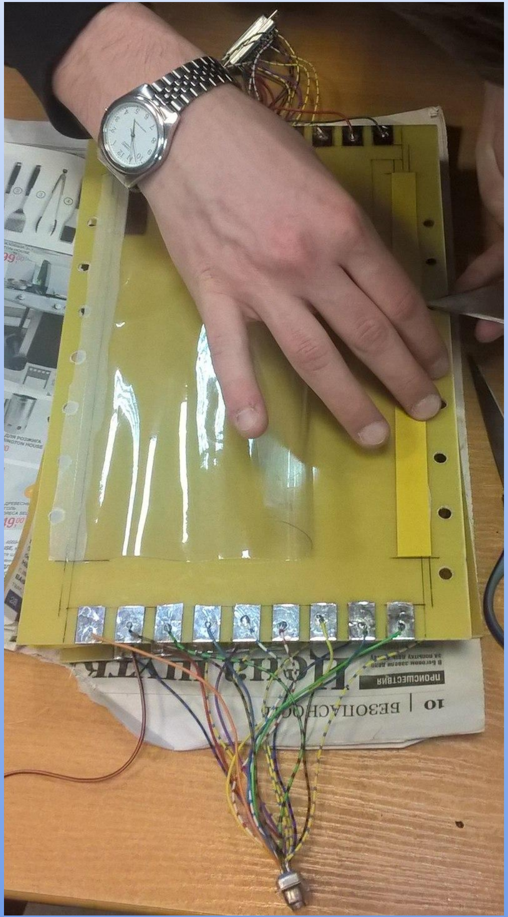
Total geometric efficiency

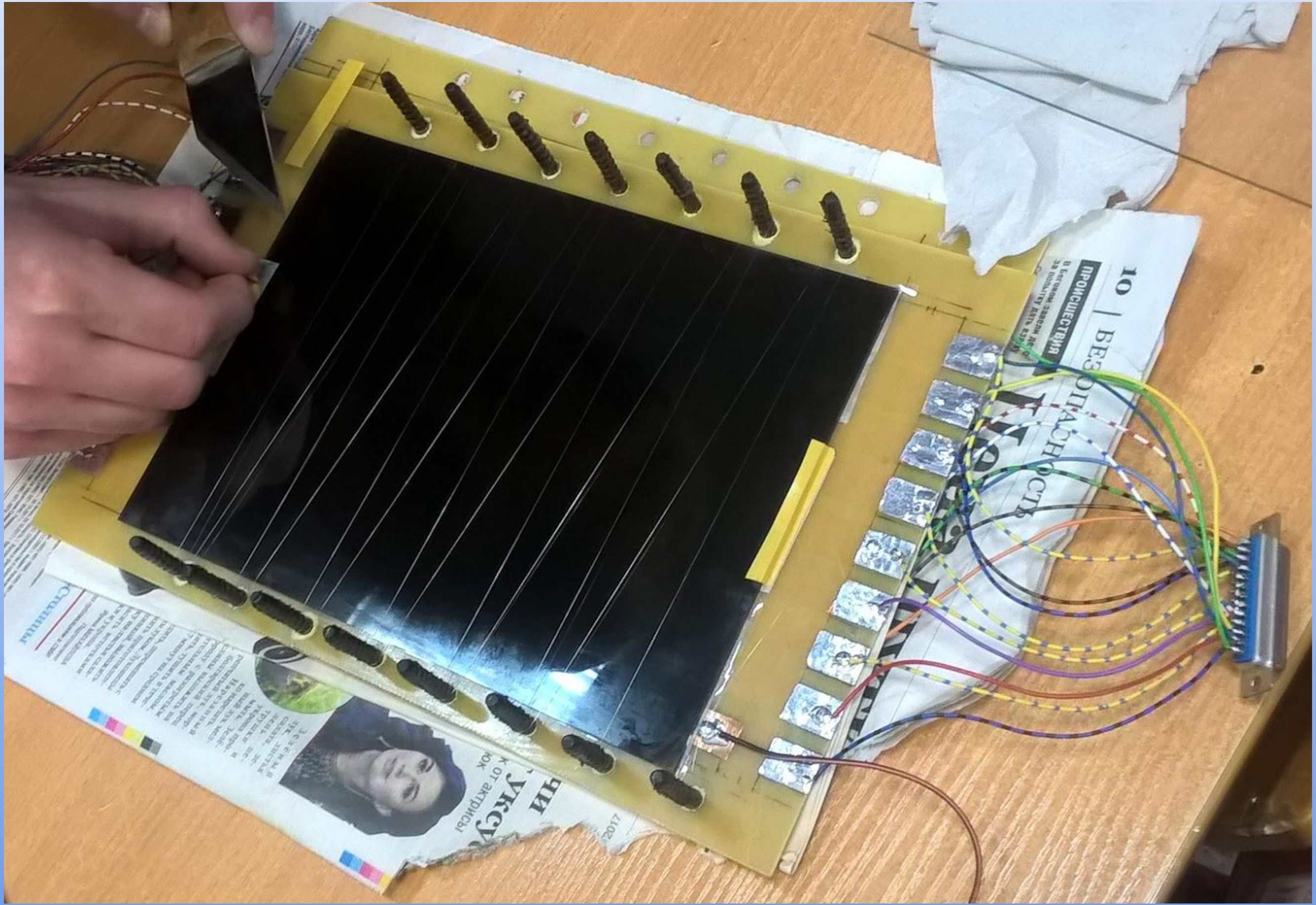




where D is a distance between chambers

Miniature RPC





Results

In total, we:

- Learned how *RPC* and *MRPC* works
- Mastered the *MRPC* technology and built a telescope
- Conducted a measurements of the main *MRPC* parameters: efficiency, dark current, dark rate
- Proposed explanations for the obtained dependencies
- Made a simulation of the triggered events number on each strip and compared it with the real data
- Measured the summary geometrical efficiency of a telescope
- Created the demo miniature of *MRPC*

Perspectives:

Participation of russian students in EEE project can be divided into four phases:

1) Public data analysis
2) Joining the EEE Project and creating our own telescope
3) Data collection, processing and interpretation
4) Involvement of other schools in order to establish a Russian network of telescopes
5) Dark current study

Literature list

1. The ALICE time of flight, http://aliceinfo.cern.ch/Public/en/Chapter2/Chap2_TOF.html
2. P-La Rossaet al., The EEE Project: a sparse array of telescopes for the measurement of cosmic ray muons, http://iopscience.iop.org/article/10.1088/1748-0221/11/12/C12056/pdf
3. Космическое излучение на уровне моря Анохина А. М., Ильина Н. П., Подгрудков Д. А., Силаев А. А., Силаев А. А. (мл
4. Latham, R. High –voltage vacuum insulation, new York, Acad. Press, 1995, R.
5. Yu Ivaniouchenkov et al., Breakdown limit studies in high-rate gaseous detectors, NIM A422, 1999, 300

Thanks for attention

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