Investigation of silicon pixel sensors for the ALICE Inner Tracking System upgrade project

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OUTLOOK

- Motivation for upgrade of ALICE ITS
- Design objectives and layout of new ALICE ITS
- ALPIDE silicon sensors
- Tasks for diploma work
- First results

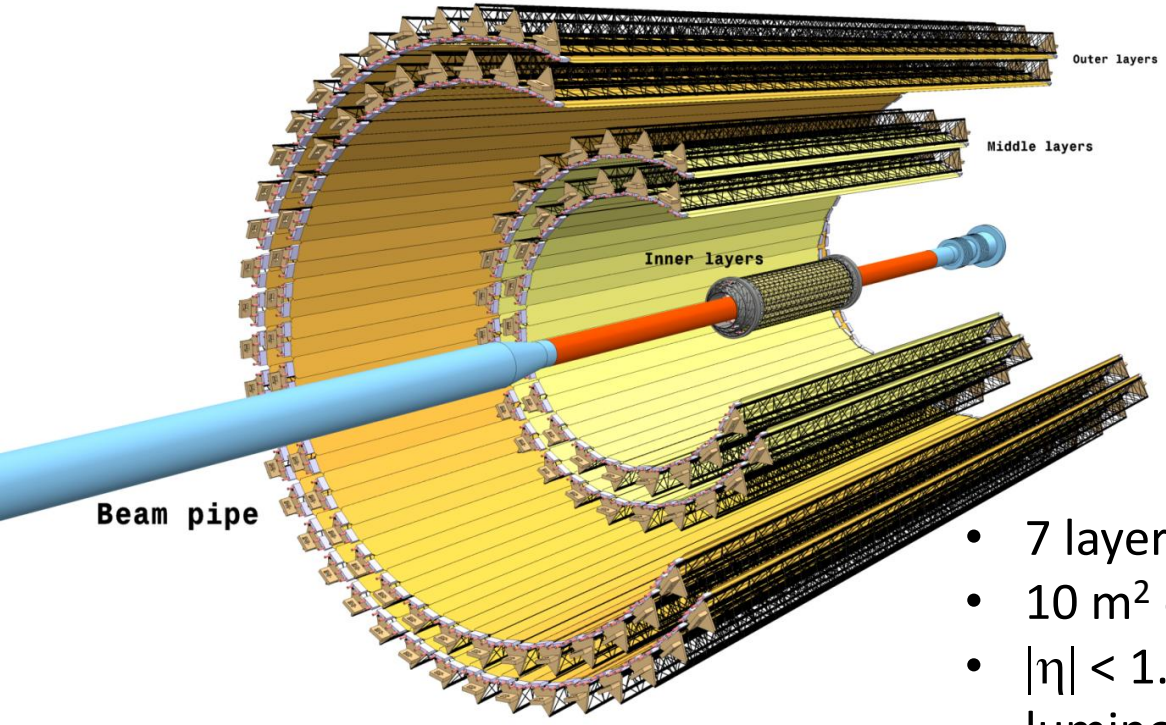
ALICE ITS Upgrade

By 2019-2020 ALICE plans to upgrade its Inner Tracking System detector, the purpose of this upgrade is:

- Improve impact parameter resolution of tracks by a factor of 3(5) in r-φ(z)
  - First layer closer to interaction point: 39 mm→23 mm
  - Material budget: 1.14% X_0 → 0.3% X_0 for the three innermost layers
  - Pixel size: 50μm × 425 μm → 29 μm × 27 μm
- Improve tracking efficiency and p_T resolution at low p_T (down to 50 MeV/c)
  - 6 layers → 7 layers
  - All layers pixel chips (instead of strip, drift and pixel layers)
- Fast readout (present ITS is limited to 1 kHz)
  - Pb-Pb: up to 50 kHz
  - pp: several 100 kHz
- Fast insertion/removal for yearly maintenance

Requirements for the upgrade of the ITS

	Inner Barrel	Middle and Outer Barrel
TID radiation in 4 years	2700 krad	100 krad
NIEL radiation in 4 years	1.7 $\times 10^{13}$ 1MeV n eq/cm^2	1 $\times 10^{12}$ 1MeV n eq/cm^2

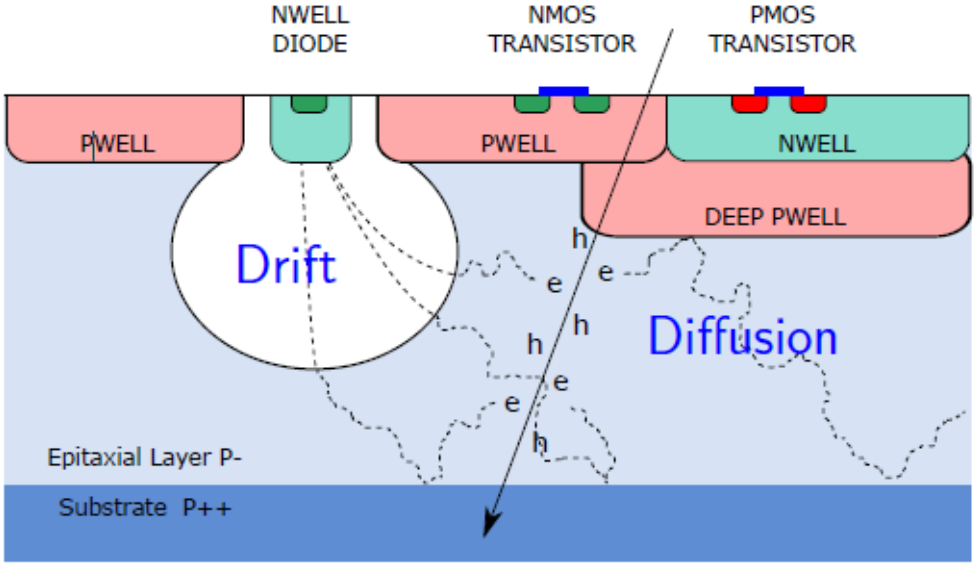


- 7 layers of pixel sensors (r = 23 - 400 mm)
- 10 m^2 of silicon with 12.5 Gpixels
- $|\eta| < 1.22$ for tracks from 90% of the most luminous region

Choice of sensor technology

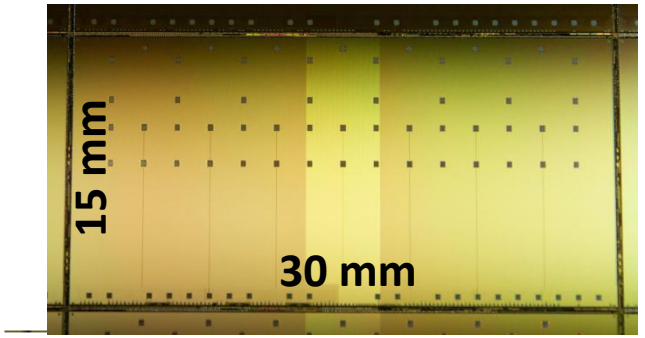
Monolithic Active Pixel Sensors (MAPS)

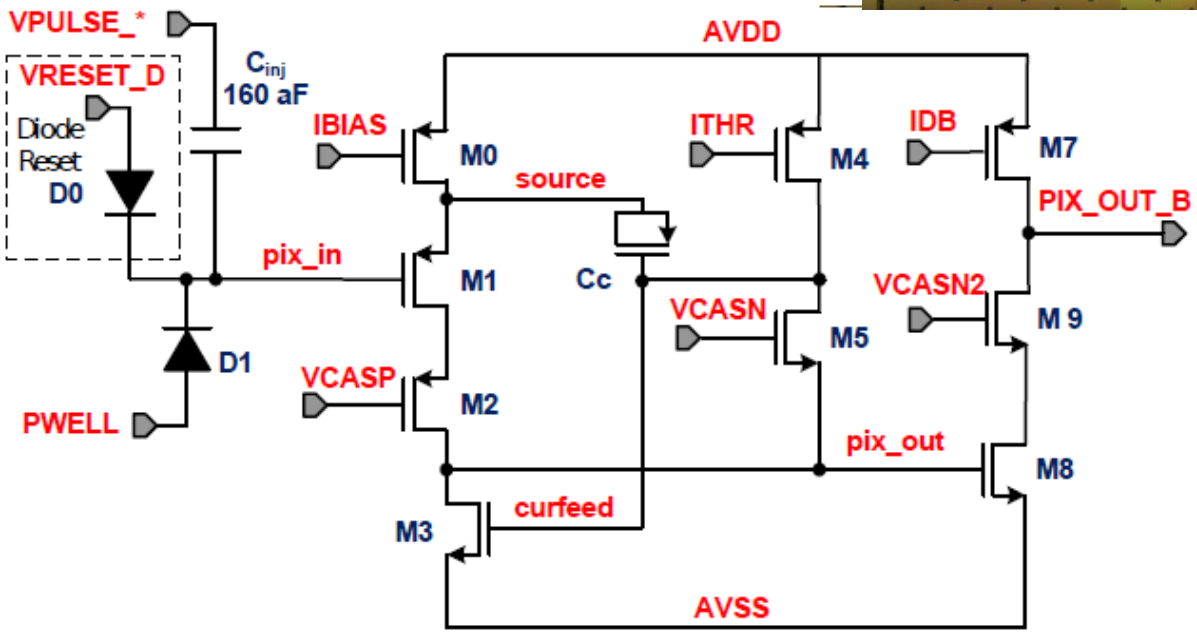
- Using TowerJazz 0.18 μm CMOS imaging process
- High-resistivity (> 1kΩ cm) epitaxial layer on p-type substrate
- Deep PWELL shields NWELL of PMOS transistors
  - Allows full CMOS circuitry in active area
- Moderate reverse substrate biasing possible -> Larger depletion volume



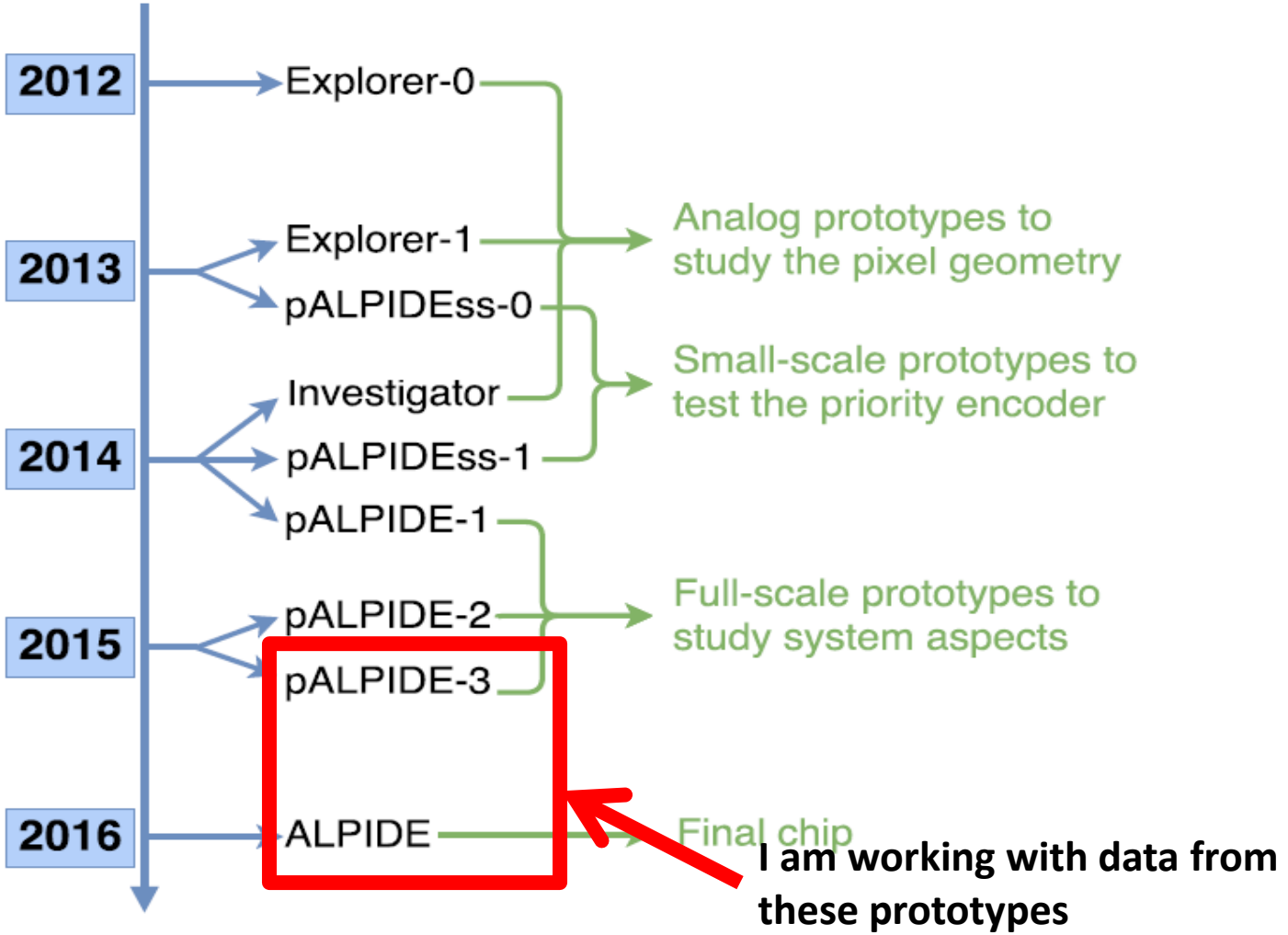
Specifications of ALPIDE

- Large silicon sensor (15 mm × 30 mm)
- 512 × 1024 pixels
- Pixels are 27 μm × 29 μm
- Digital readout with priority encoder





pALPIDE family



Tasks

1. Analysis of beam test data, taken from PS CERN facilities at inclined tracks:

a) Comparison of cluster size, cluster shape for different pion energies and inclination angles.

b) Development of EUTelescope code for study of cluster size vs. impinging point.

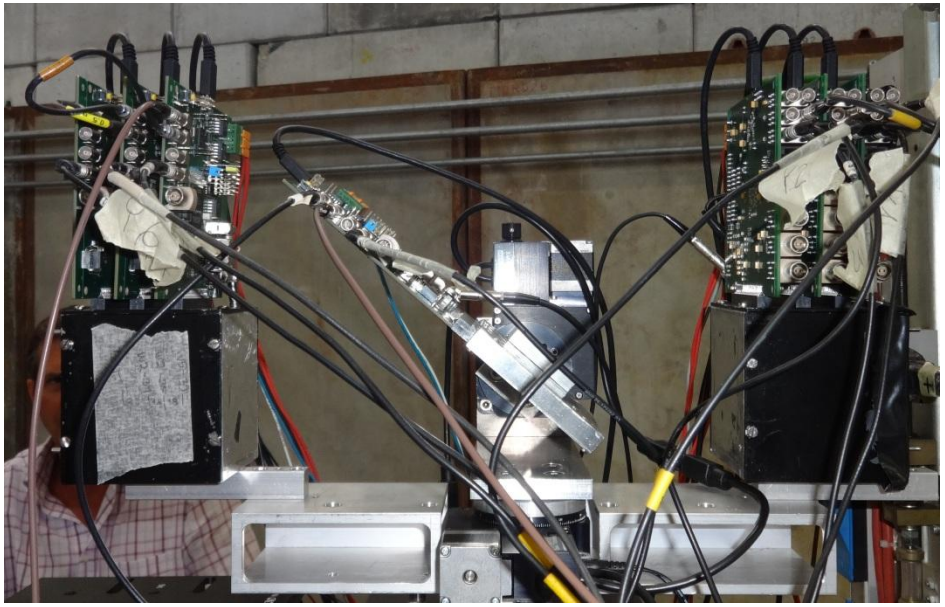
c) Application of this new code for available sets of data from pALPIDE v3 and for final ALPIDE (May 2017)

2. Characterization of irradiated ALPIDE chips

3. Development of driver for XY positioning stage for measurements at cyclotron U-120M, Rez

1. Beam test setup at PS CERN

- Several pion beam campaigns with energies 250 MeV - 6 GeV for inclined tracks studies
- Tracking is done by telescope consisting of 3+DUT+3 layers
- Readout and analysis is done using the Eudaq+EUTelescope framework
- Data for analyzing was provided by ALICE ITS group in .ROOT format



Results of beam data analyzing

Results:

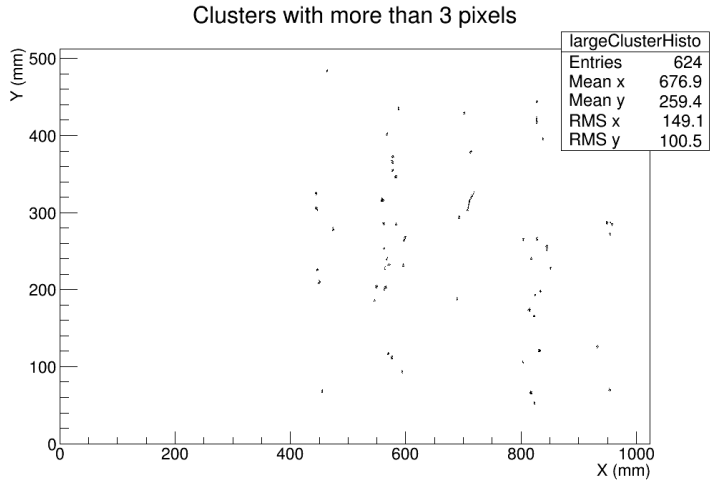
- I have already prepared ROOT macros:
  - Comparing cluster size at different energy vs. inclination angle
  - Comparing cluster shape at different energy vs. inclination angle

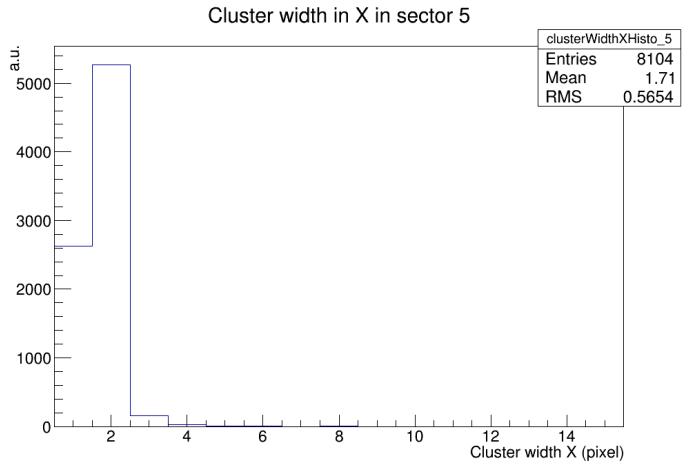
Application of soft Root v6.07 on Ubuntu.

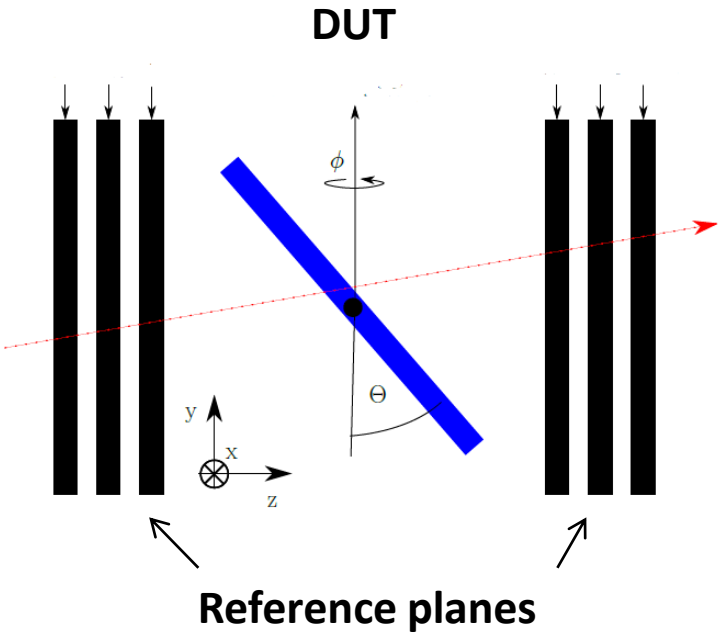
Future task in this direction:

- EUTelescope new version was installed on my personal directory at CERN server (lxplus).
- Tests of RAW data processing are going on.

Cluster size beam data analyzing

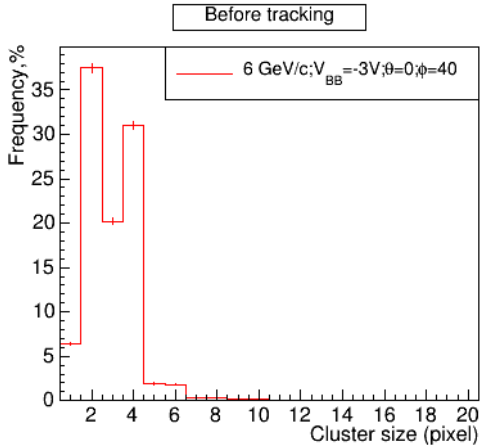


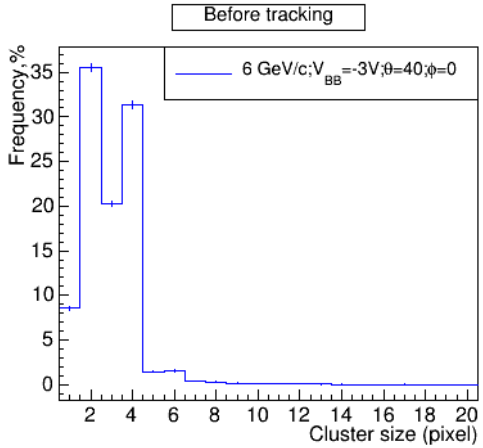


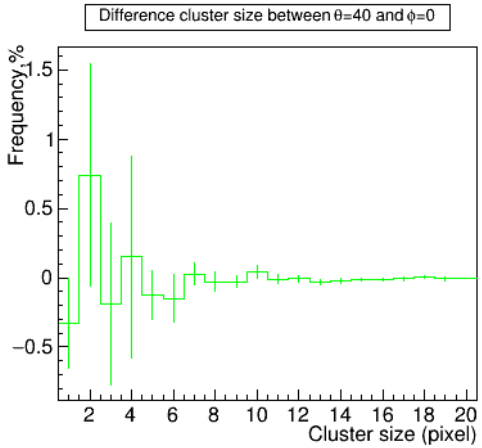


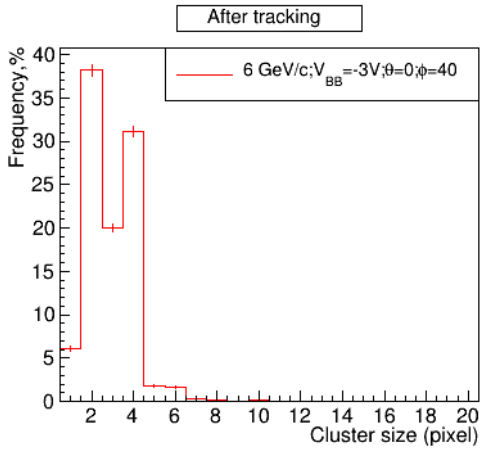
Results of beam data analyzing

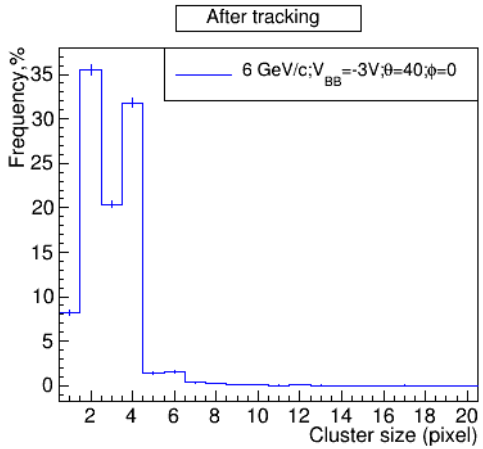
Comparison histograms of cluster size for runs with different symmetrical inclined angles

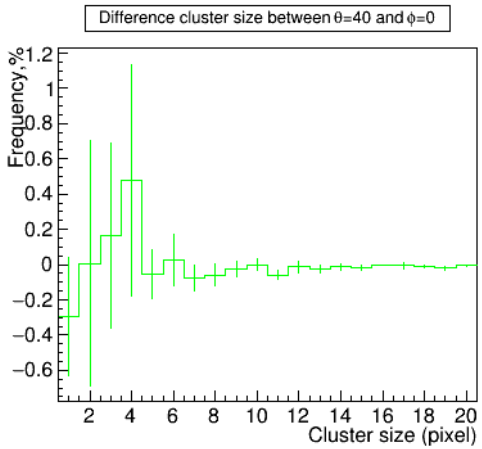












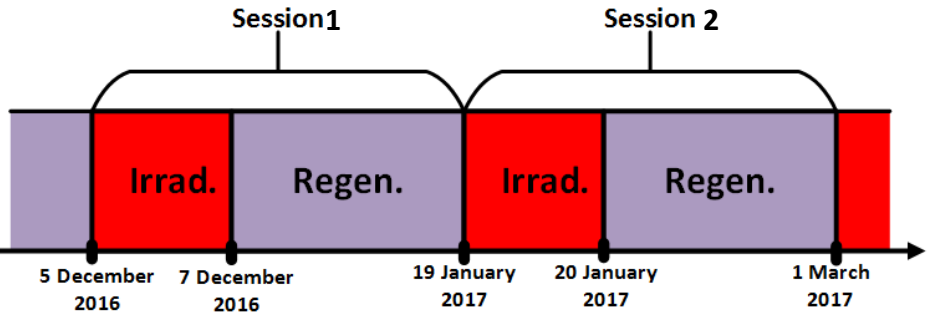
2. Study of laboratory characteristics

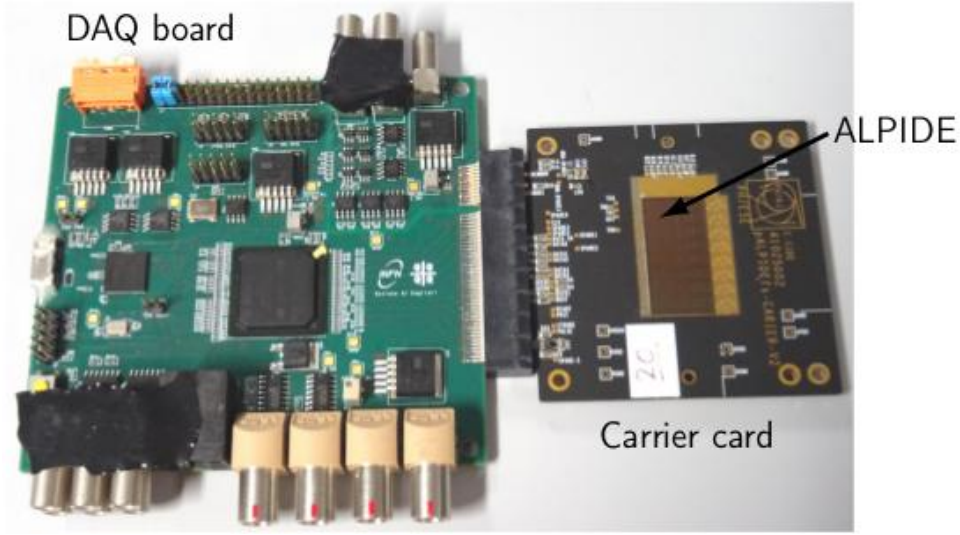
1. ALPIDE is irradiated on cyclotron U-120M to study how properties of the chip change, when it irradiated by given radiation dose (~115 krad).

2. During processes of irradiation and regeneration of the chip following tests are done with help of C++ macros:

- Noise and threshold measurements
- Noise occupancy measurements
- Radioactive source measurements

3. Data for analyzing was provided by ALICE ITS group in .ROOT, txt format





Results of this task

Results:

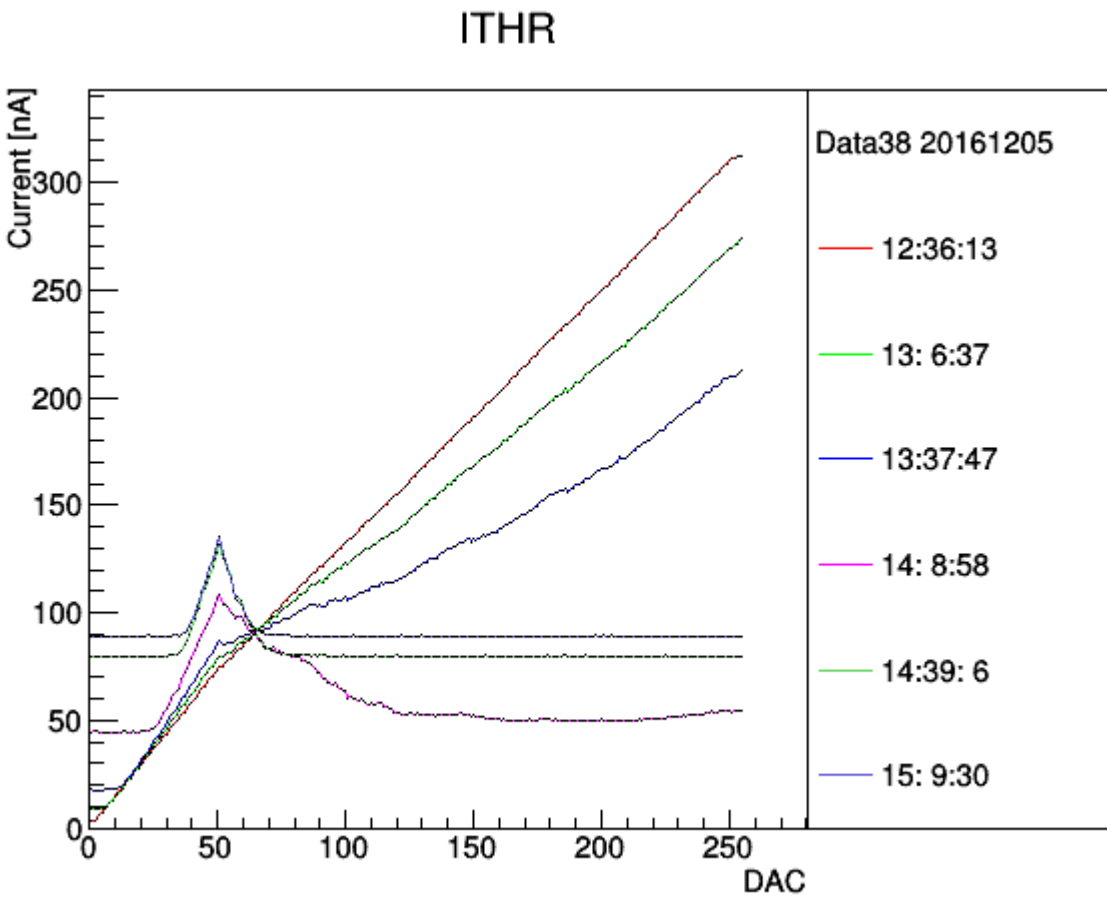
- I have already prepared ROOT macros for three investigations.
    1. DACscan test
    2. Threshold test
    3. Analog current test

Future task in this direction:

- Macros will applied to data from upcoming irradiation test (1.March) and older campaigns.

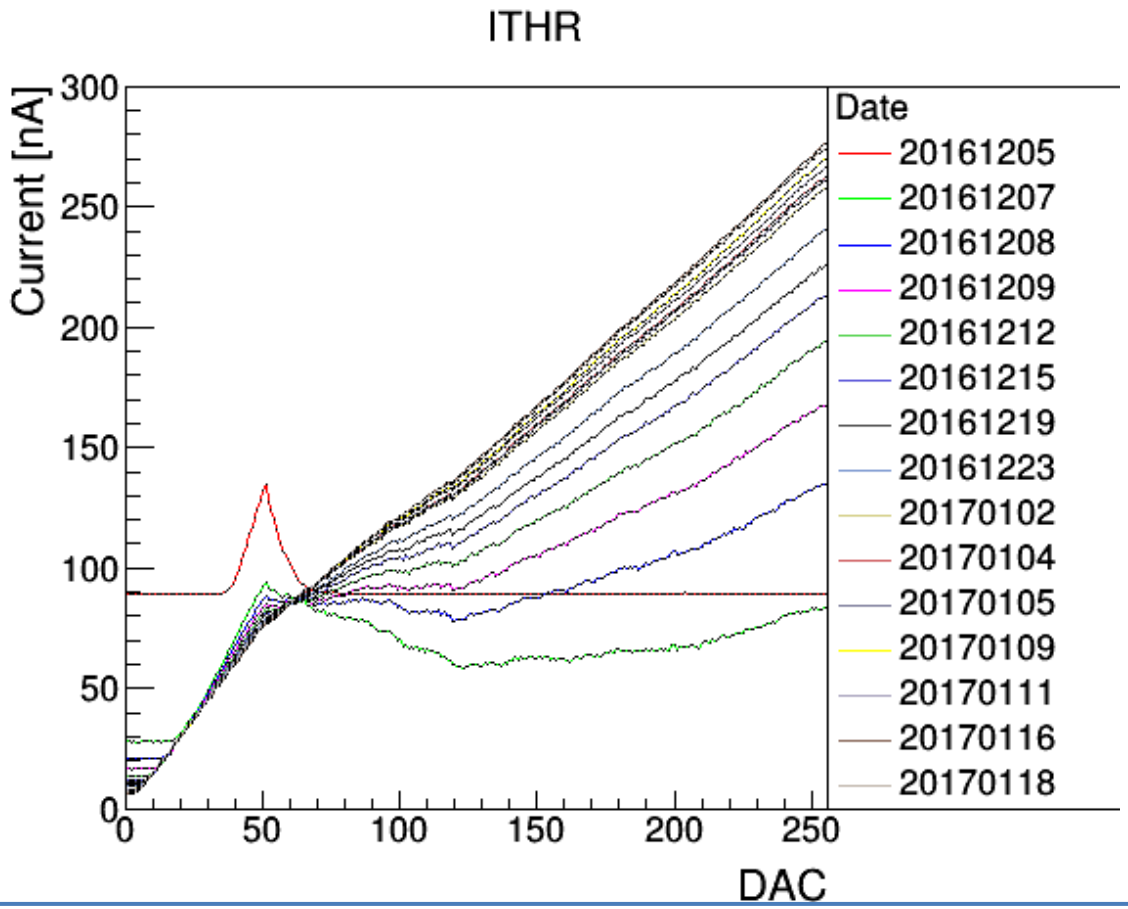
Results of **DAC scan** while irradiation

DACscan test during irradiation for I_{THR} transistor for A4W7GR38 wafer



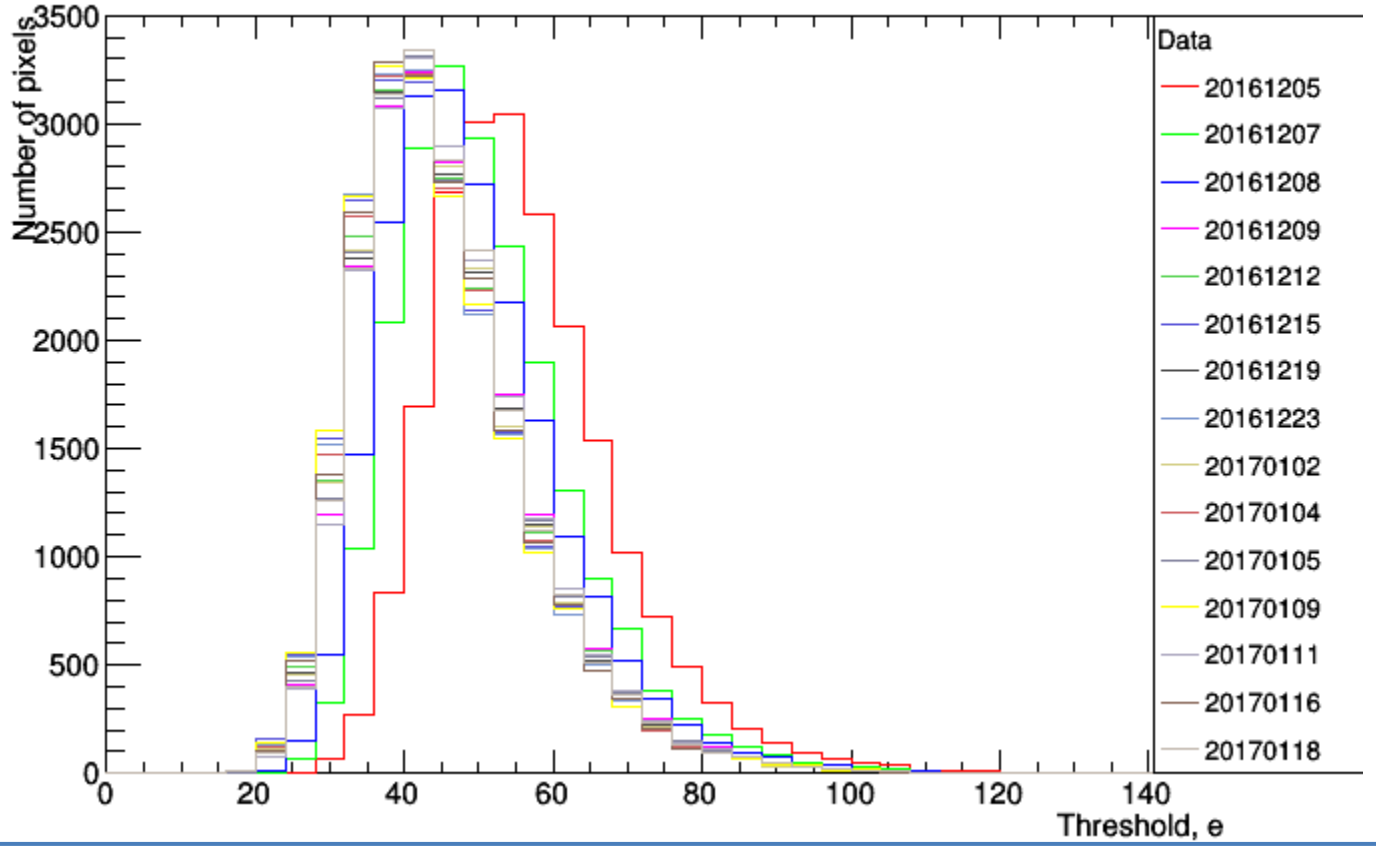
Results of **DAC scan** in recovery period

DAC scan test during regeneration for I_{THR} transistor for A4W7GR38 wafer



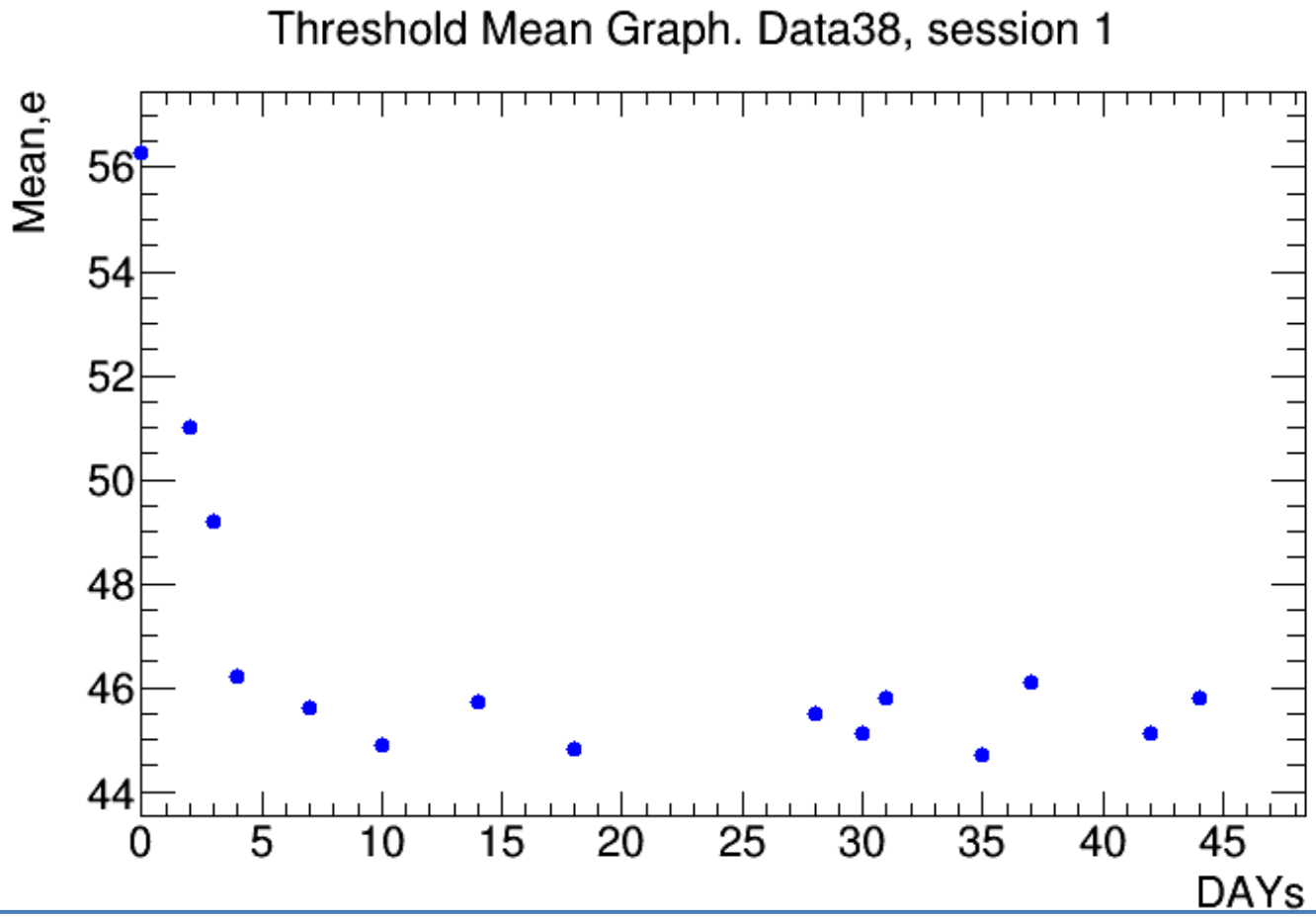
Results of Threshold test

Histogram of mean of threshold during regeneration for A4W7GR38 wafer



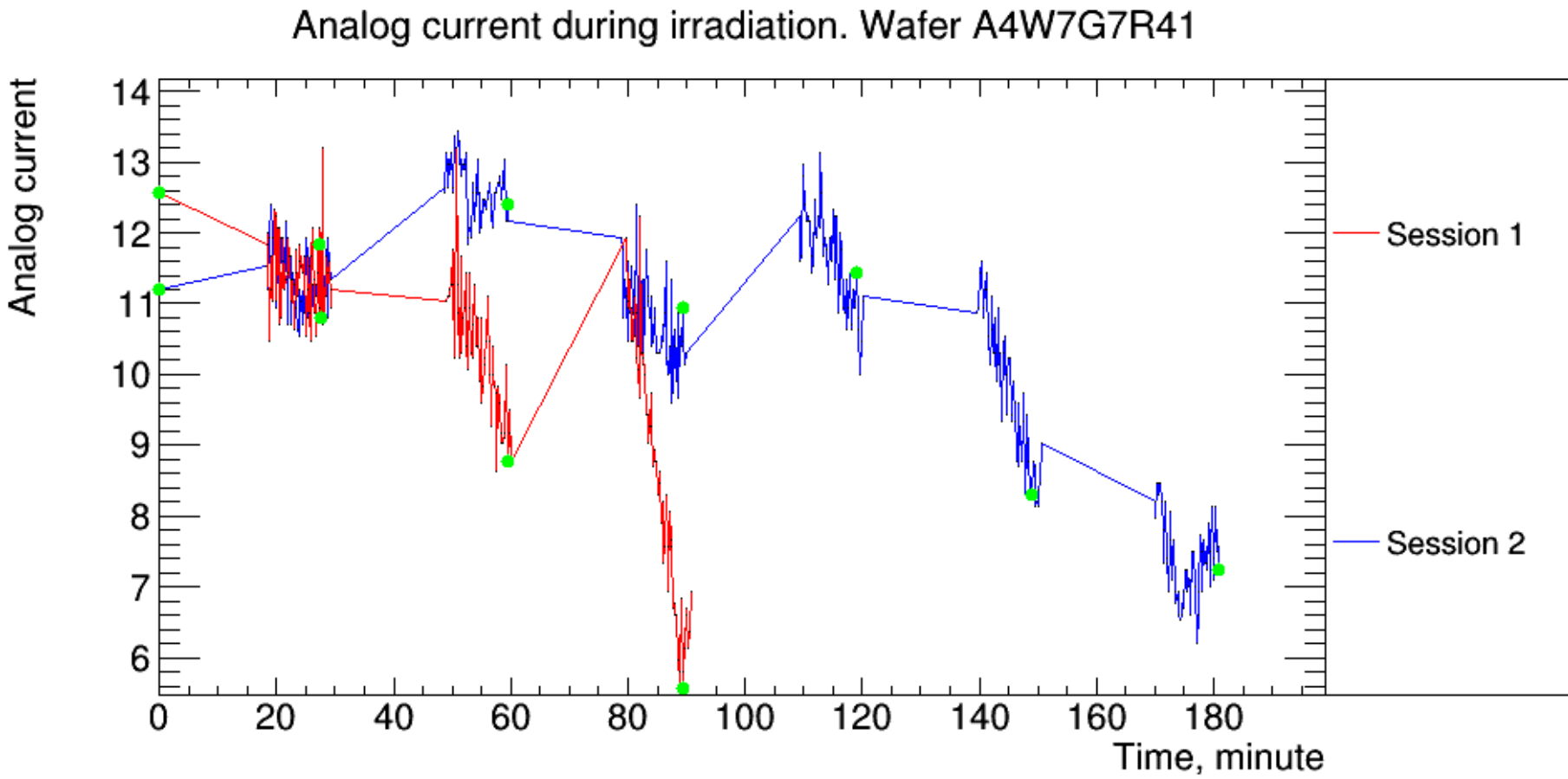
Results of Threshold test

Graph of mean of threshold vs. time during regeneration for A4W7GR38 wafer



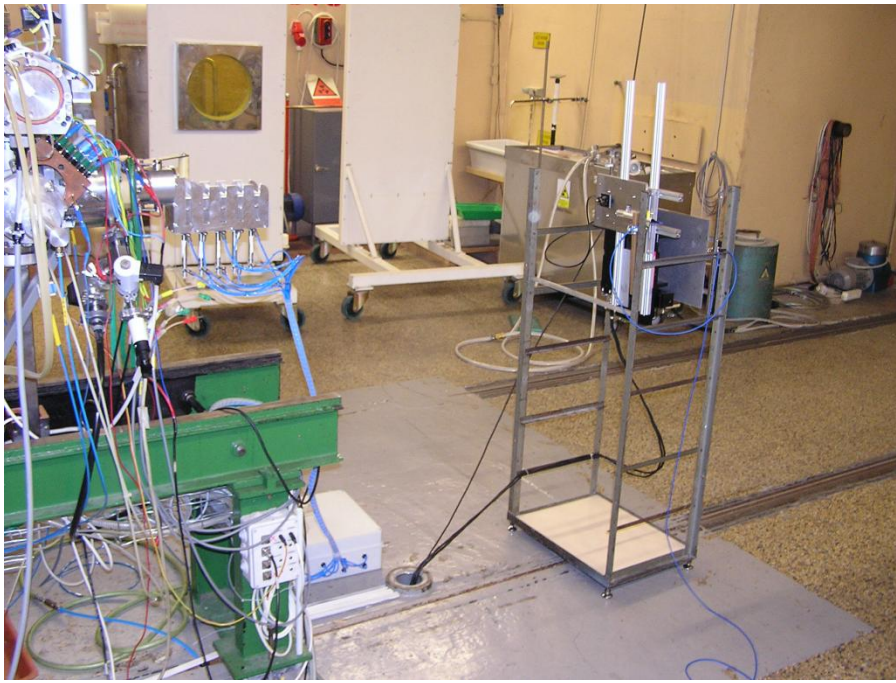
Results of Analog current test

Graph of mean analog current vs. time during irradiation for A4W7GR41 wafer



3. Development of driver for the XY positioning stage

1. XY cross table is used in radiation hardness test at cyclotron for positioning of electronics components to the beam (cables, FPGA, silicon chips (pALPIDE)) .
2. In order to extend the flexibility of the current control , new LabView based driver for XY stage is required.



Results of this task

Results:

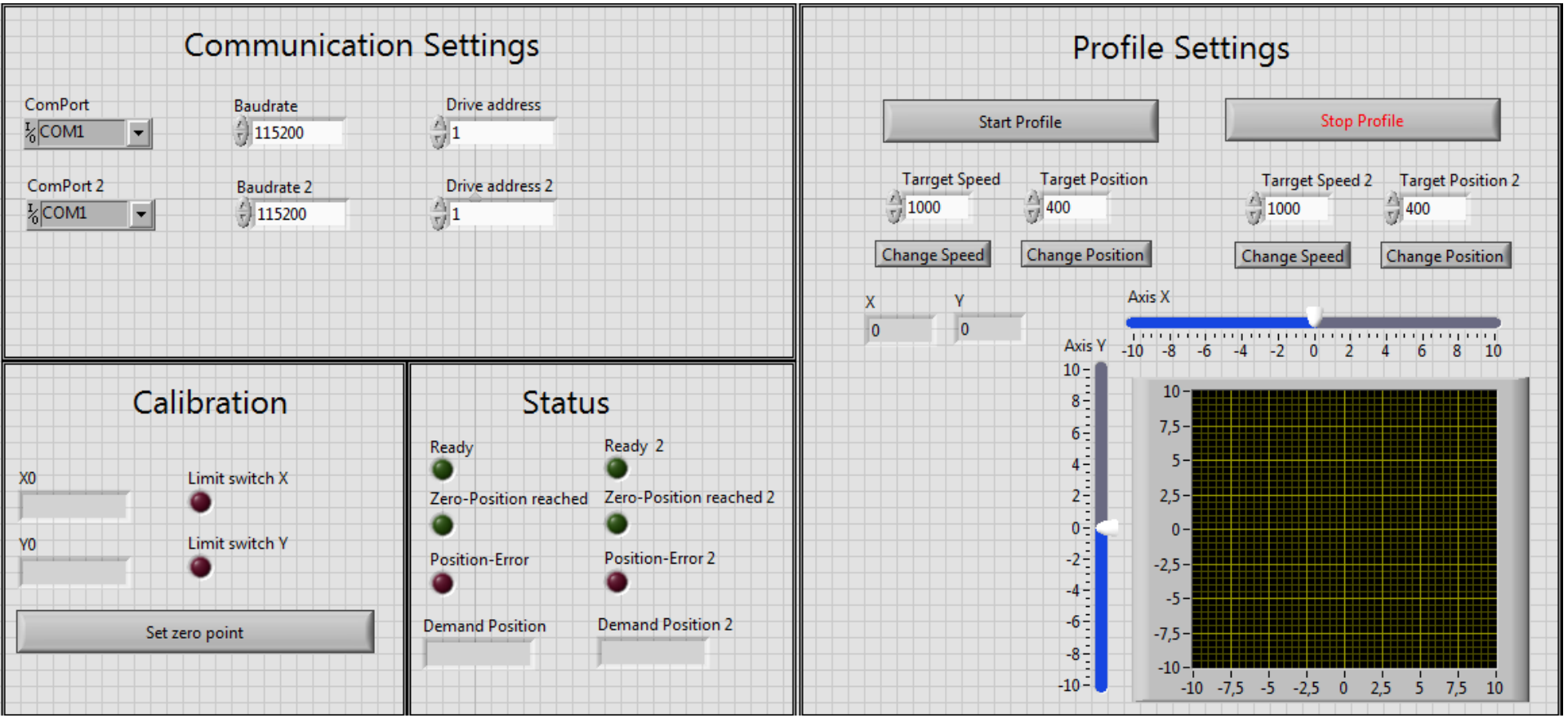
- First version of driver of XY positioning stage was designed in LabView software. This driver performs following function:
  - Provide user UI for setting position point, parameters of connection and other motor settings.
  - Find possible ranges defined by limit switches
  - Send device to given position

Future task in this direction:

- Debugging and testing of software:
  1) Use evaluation board in echo mode to check connection
  2) Test on real device
- Modification software

Results for driver of XY positioning stage

Screenshot of user UI



Conclusion

1. From 2 – 27 Feb my progress is :

- I am learning huge material of ALICE documentation (publications and tutorial for soft and hardware)
- I have installed new OS and new package (ROOT, EUTelescope, LabView)
- I prepared and tested macros for real experimental and laboratory data
- I am in close contact with ITS ALICE group, sending and discussing my first results.
- I am involved in video meeting at CERN, ITS.

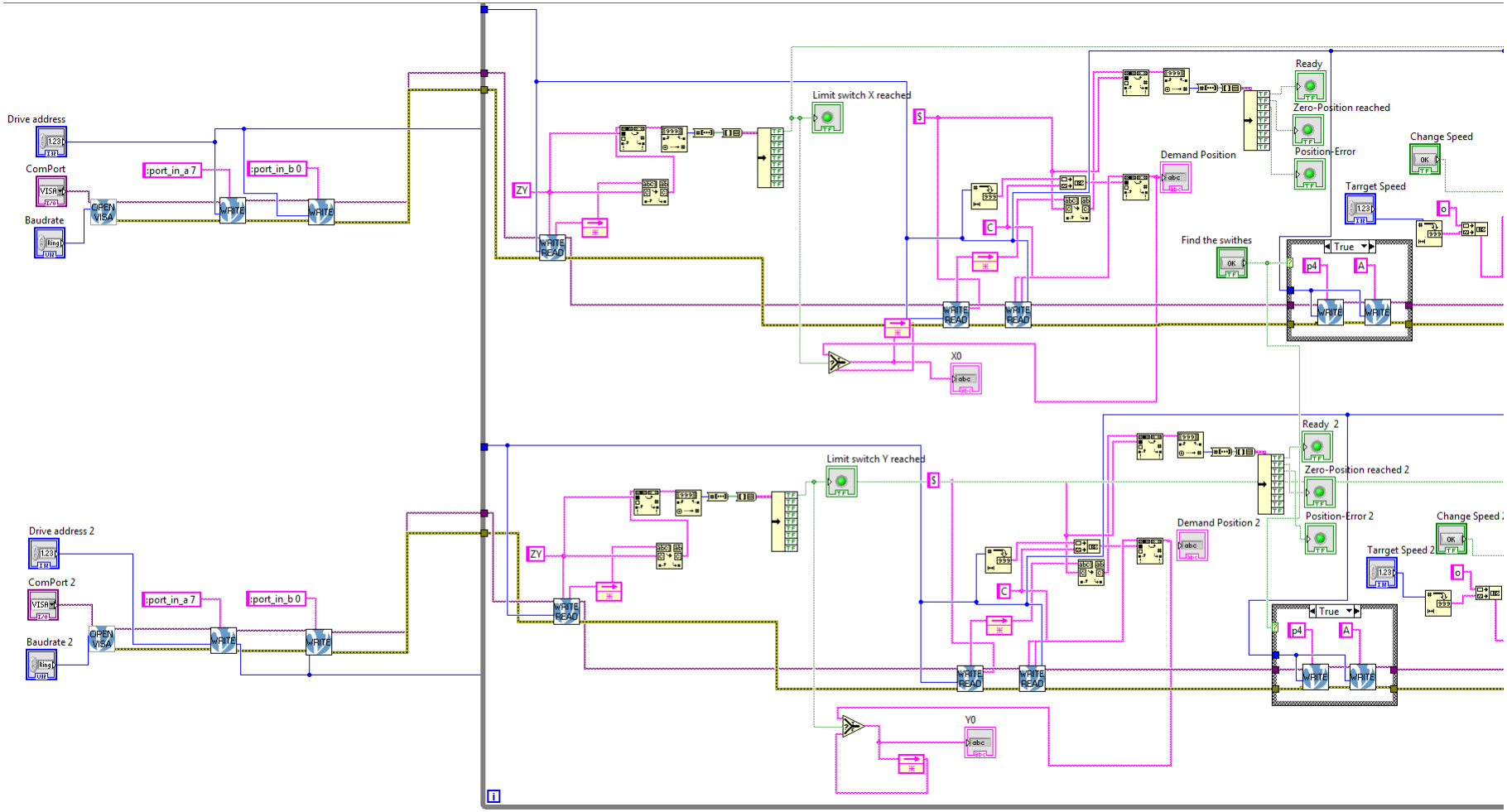
2. Next Steps

- Testing of new soft
- Learning EUTelescope
- Taking part in measurements in cyclotron
- Testing driver for XY positioning stage

Thank you for your attention

Results for driver of XY positioning stage

Screenshot of code of driver in LabView



Results for driver of XY positioning stage

Screenshot of code of driver in LabView