A radiation hard and direction sensitive **sapphire detector** for charged particles

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DPG Frühjahrstagung, 3.04 Halbleiterdetektoren
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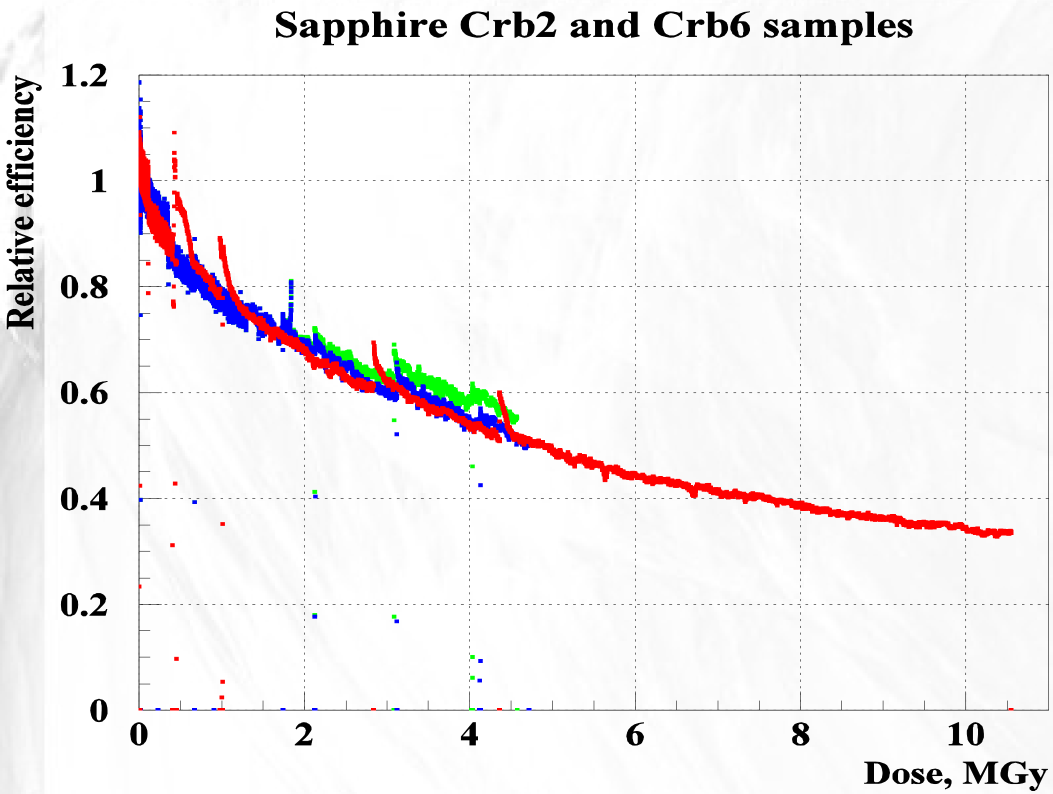
Sapphire is a very promising material for sensors.

- For experiments at accelerators beam halo and beam loss monitoring needs very radiation hard detectors.
- Currently used detectors:
  - ionisation chambers →

    cheap and wide-bandgap, but slow;
  - diamond sensors →

    fast, but limited in size and expensive;
- Single crystal sapphire is considered as a promising alternative →
  - *it is available in size up to 40 cm, cheaper in comparison to diamond, fast and radiation hard.*

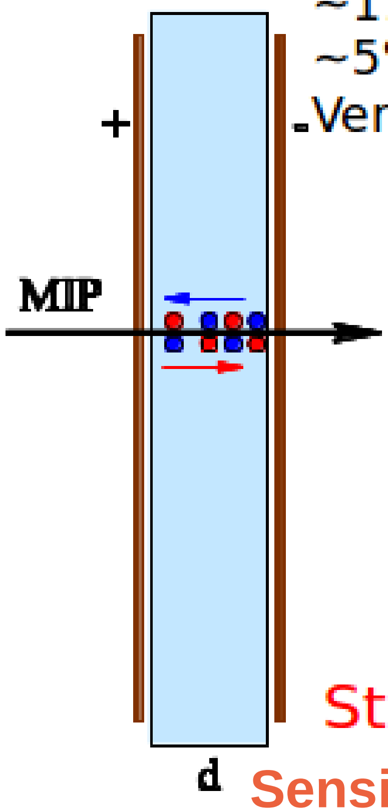
Radiation hardness study and current application



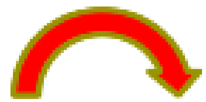
- **During TB in Darmstadt it was shown, that after 10 MGy dose sapphire still have 30% relative efficiency.**
- **Leakage current even after irradiation stays in pA range.**

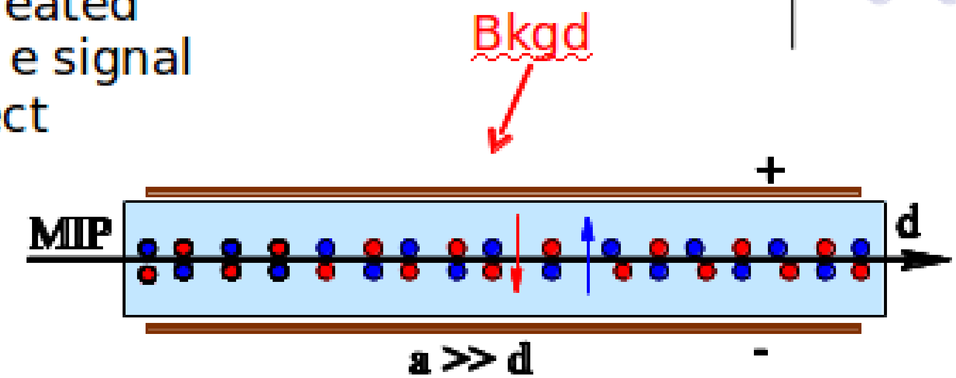
- Sapphire sensors are applied for beam-loss monitoring at FLASH. Signal current measurements for relatively large particle flux.
- System for XFEL is proposed.

MIP detection with sapphire sensors



Typical thickness ~0.5 mm
~11K e-h pairs created
~5% CCE -> 550 e signal
Very hard to detect





a=10 mm => 220K e-h pairs produced
~5% CCE -> ~11000 e signal, similar to scCVD diamond detectors.

Signal size can be increased by larger track length!

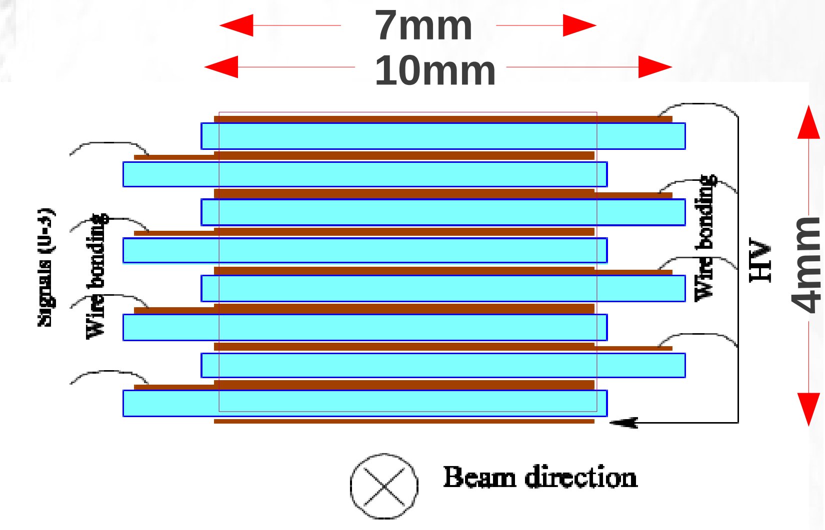
Strongly reduced sensitivity to background!

Sensitive to particle direction.

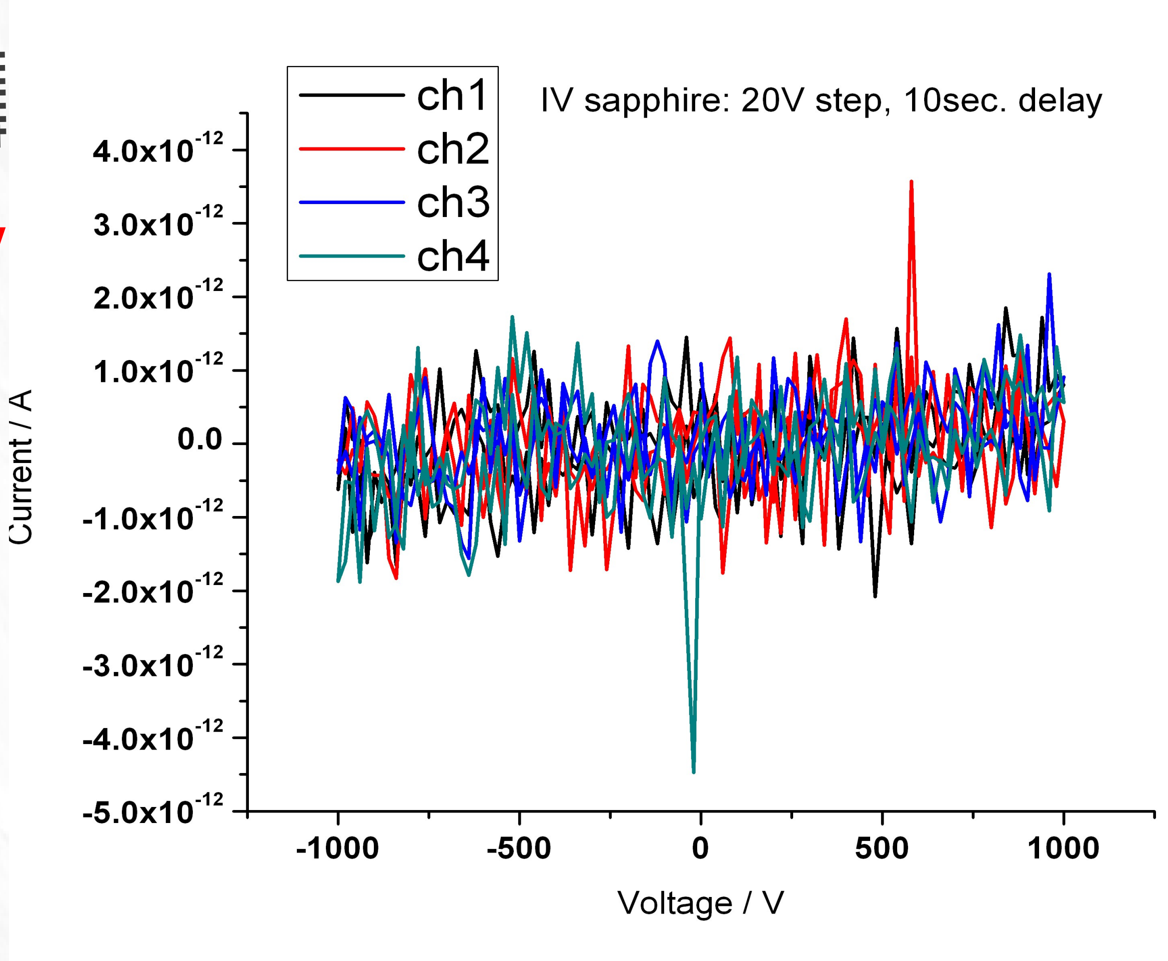
By S. Schuwalow,
Instrumentation Seminar,
DESY, Hamburg

We built sapphire detector prototype for MIP detection!

Sapphire detector (Al_2O_3) design



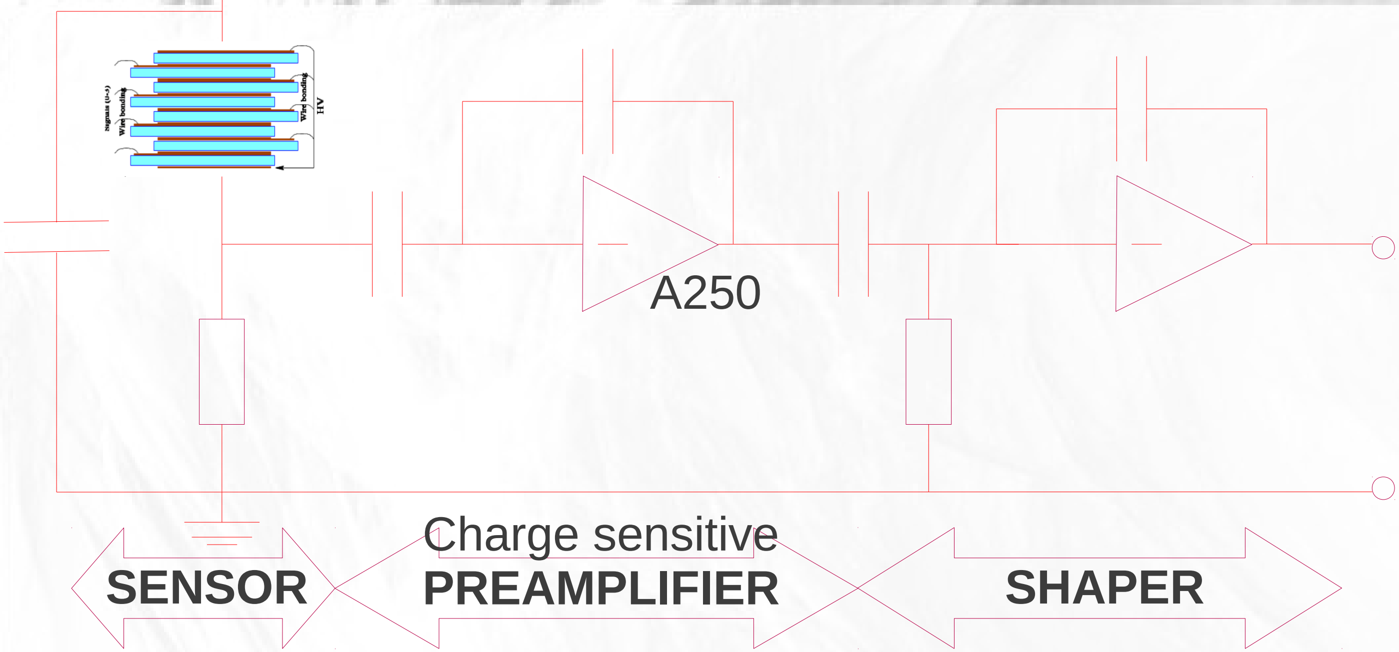
Holds 1000V with current in pA range!



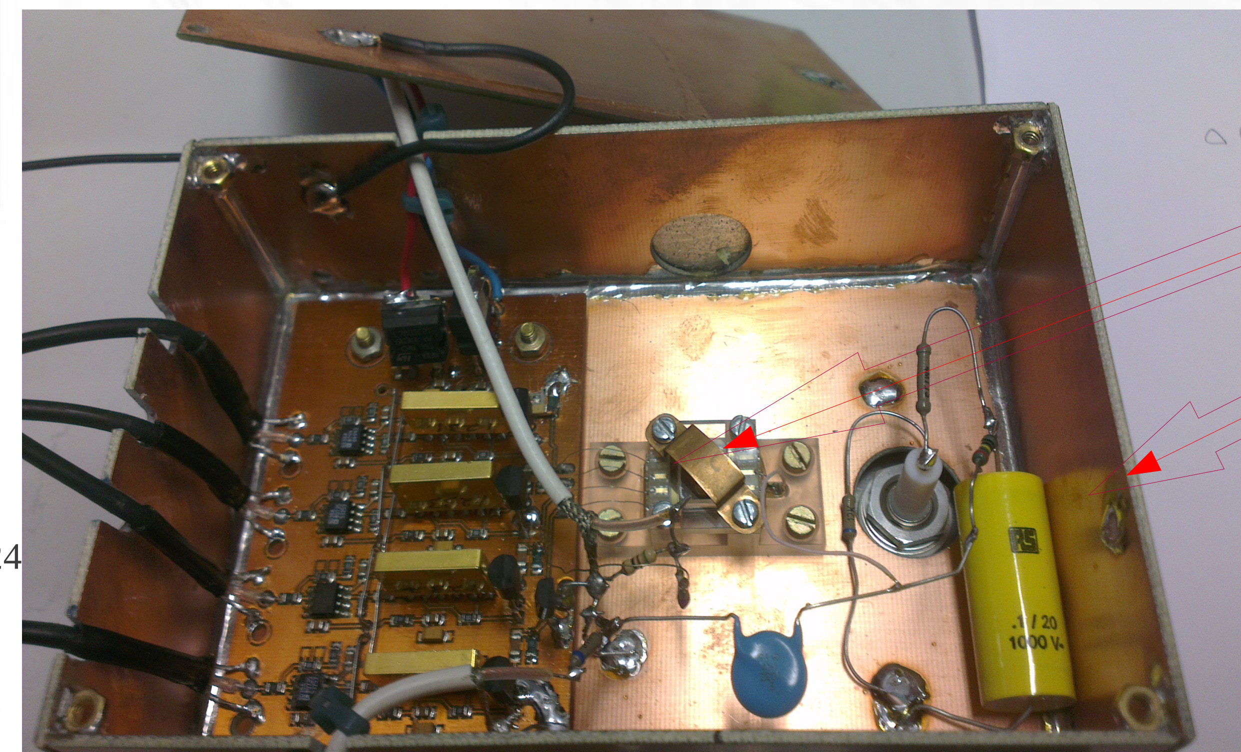
- 8 individual sapphire plates.

  10 x 10 x 0.5 mm each.
- Al-Pt-Au metallization on both sides.
- 4 readout channels.

Front-End for DESY II TB



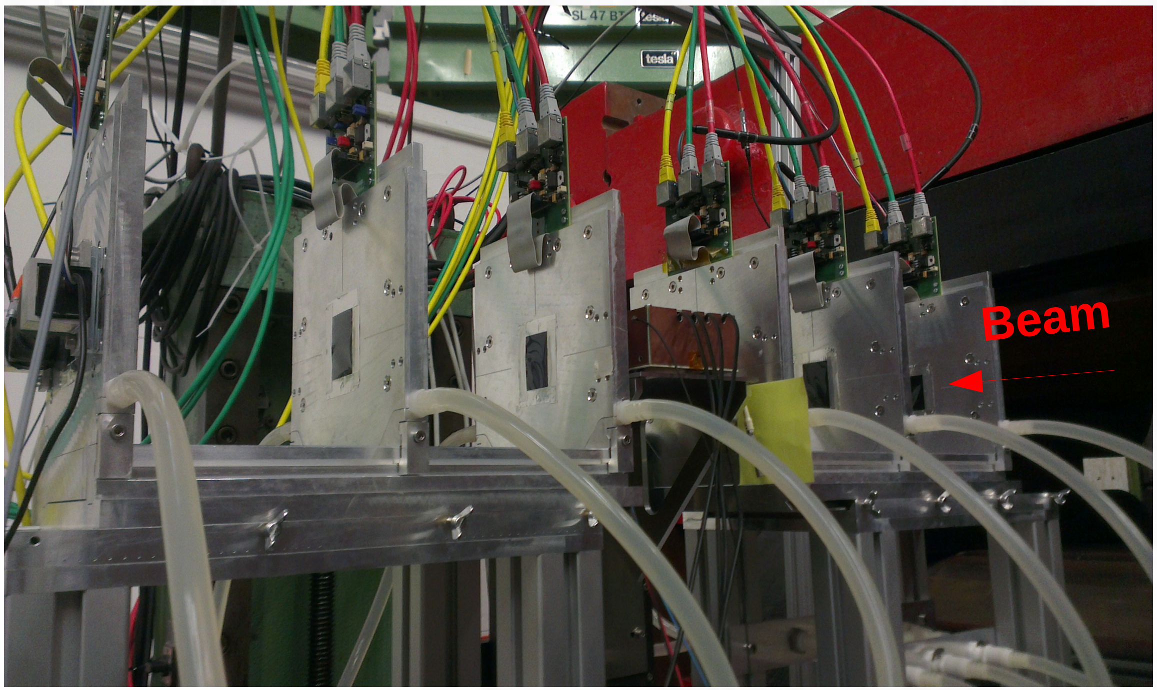
After shaper signal length is 350-400 ns.

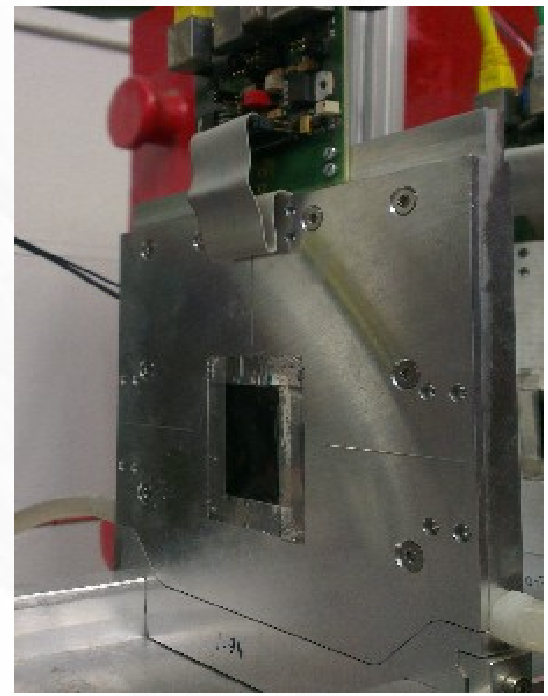


EUDET Telescope -

tracking device designed for detector prototype characterisation at the test beam.

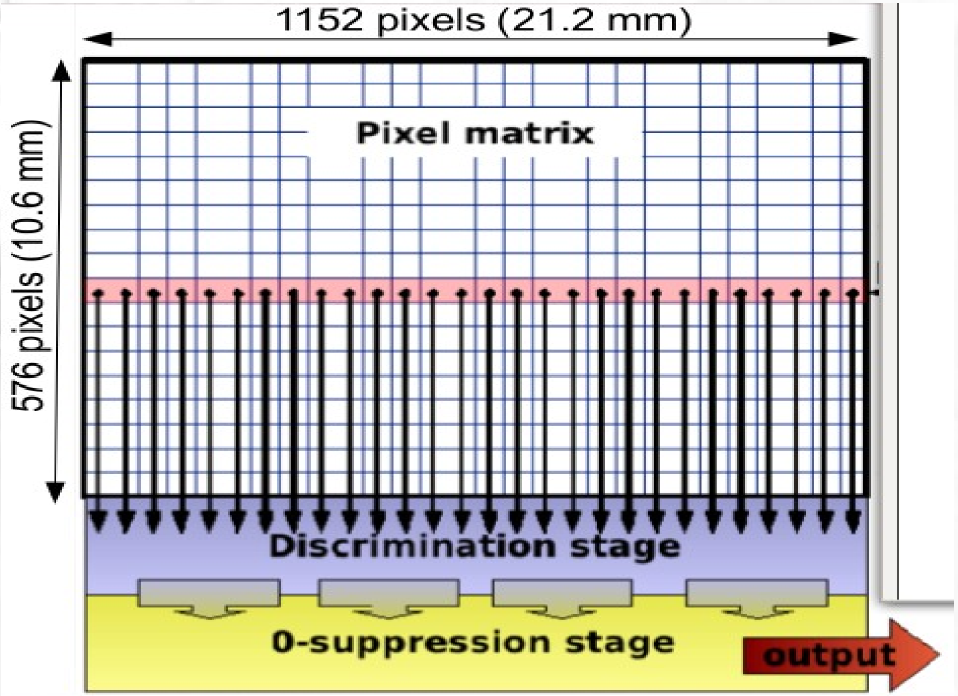
- Active area of the telescope - six Mimosa26 pixel sensors.
- Six space points per track.





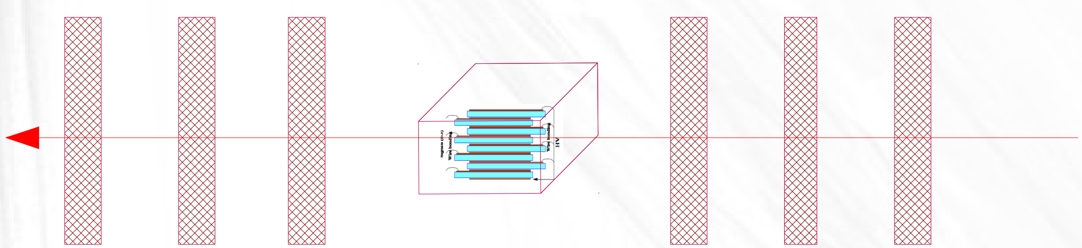
DESY II, TB area 22, 5 GeV electrons, 100 Hz rate.

Mimosa26 Sensors

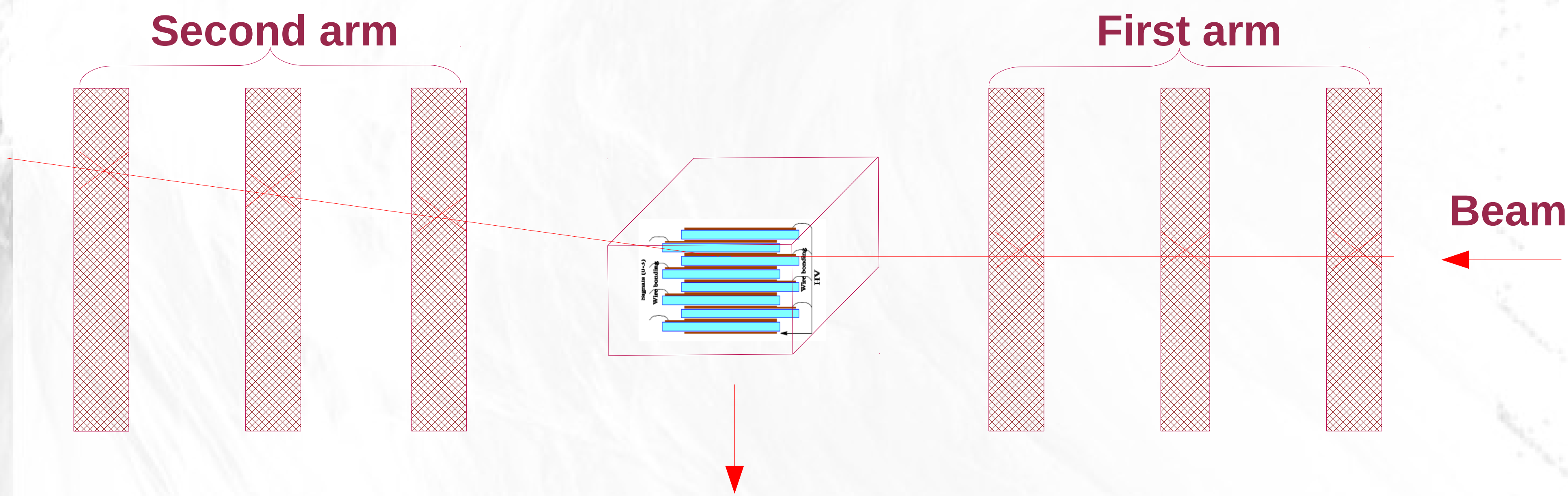


- Pixel size 18.4 um
- MAX Track pointing resolution ~2 µm.
- EUTelescope includes software for offline analysis.
  - Converter →
  - Clustering →
  - Filter →
  - Hitmaker →
  - Alignment →
  - Fitter →
  - DUT analysis.

Using hits from 6 planes of Telescope, tracks are precisely reconstructed!



TB geometry

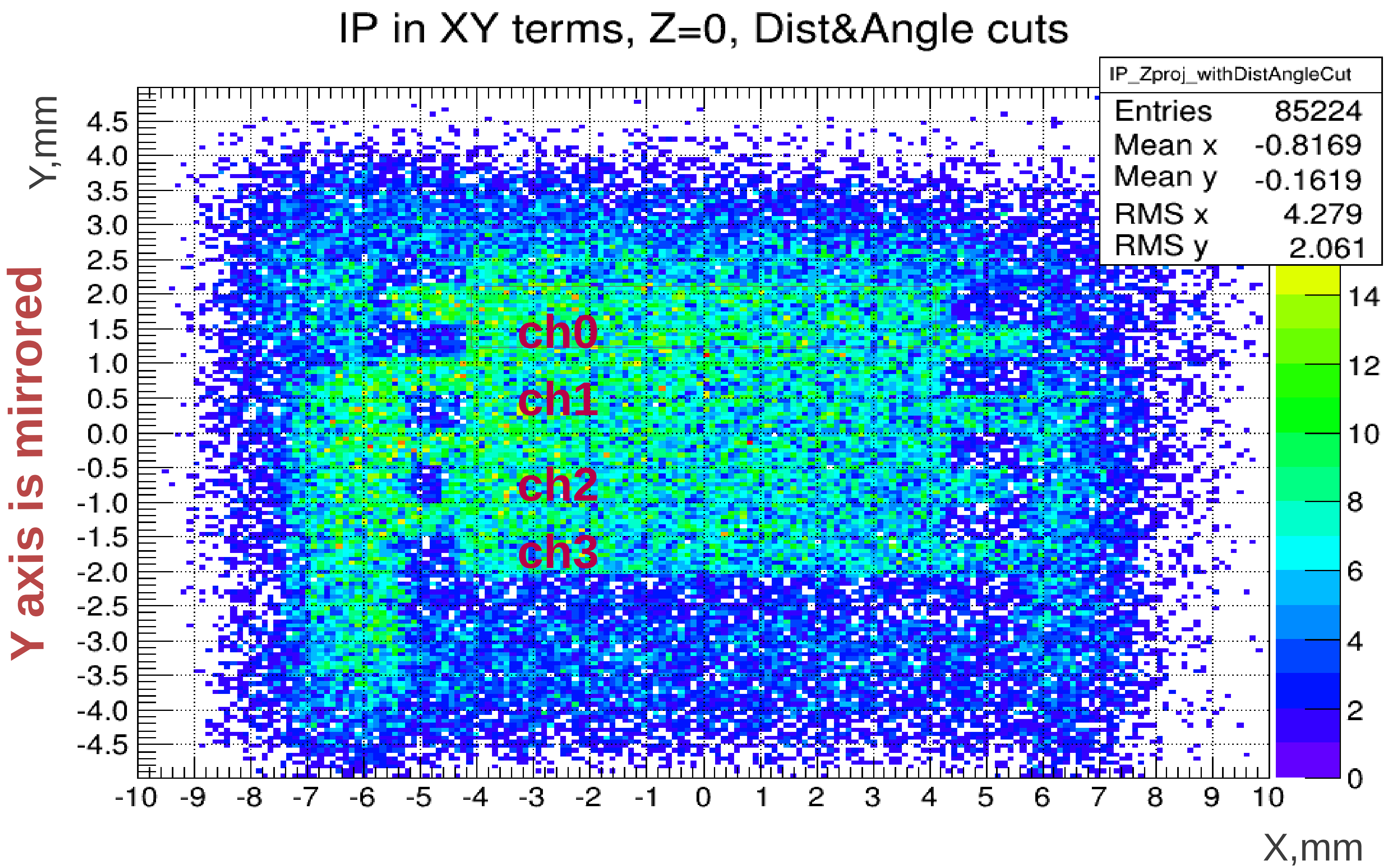


ADC output
in .root format

Telescope output in
.raw format

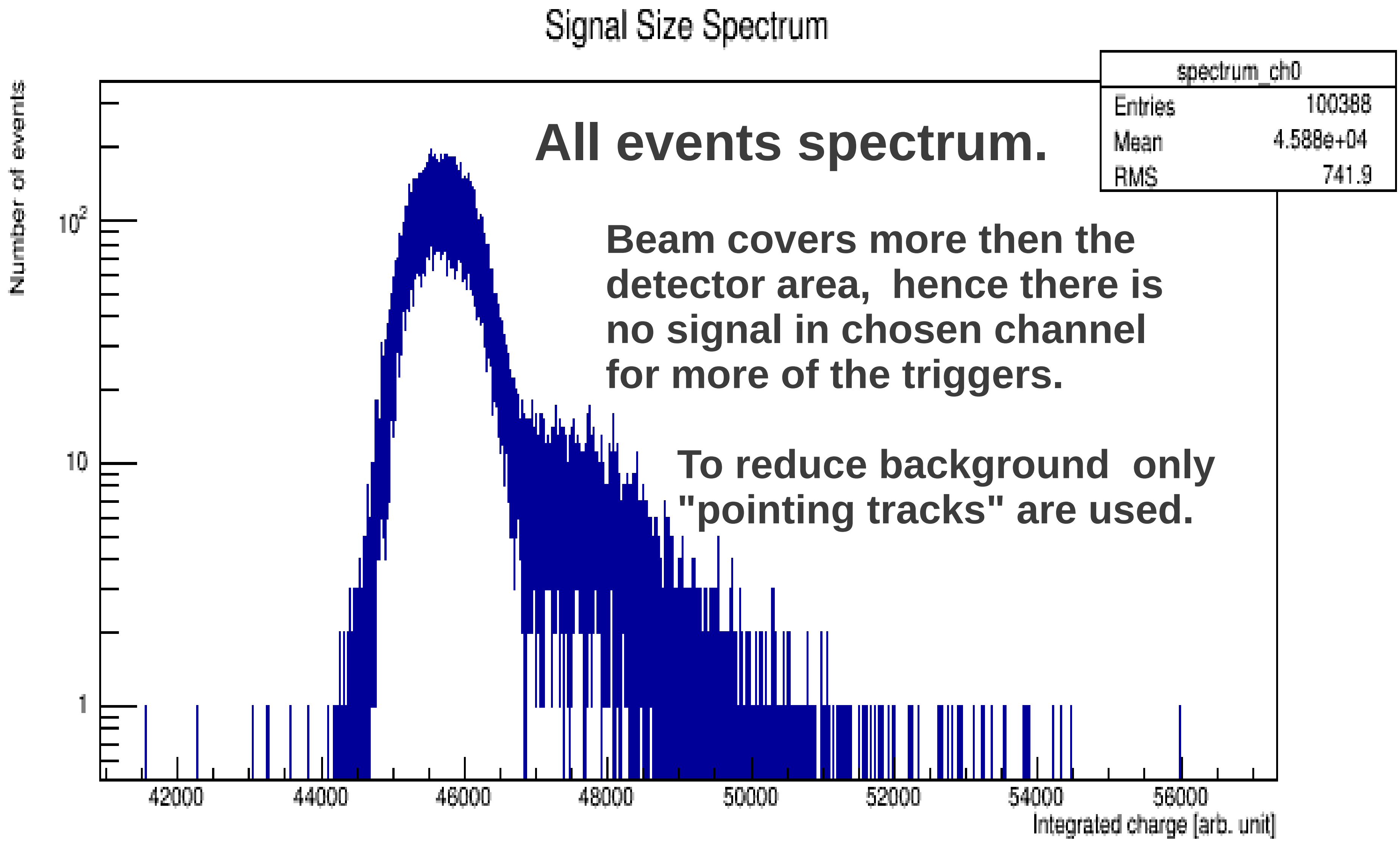
Tracks in .root file after EUTelescope
analysis chain

Detector view, reconstructed from tracks scattered in sapphire material



Synchronization of Telescope and ADC is done using TLU numbers.

Why do we need track reconstruction?



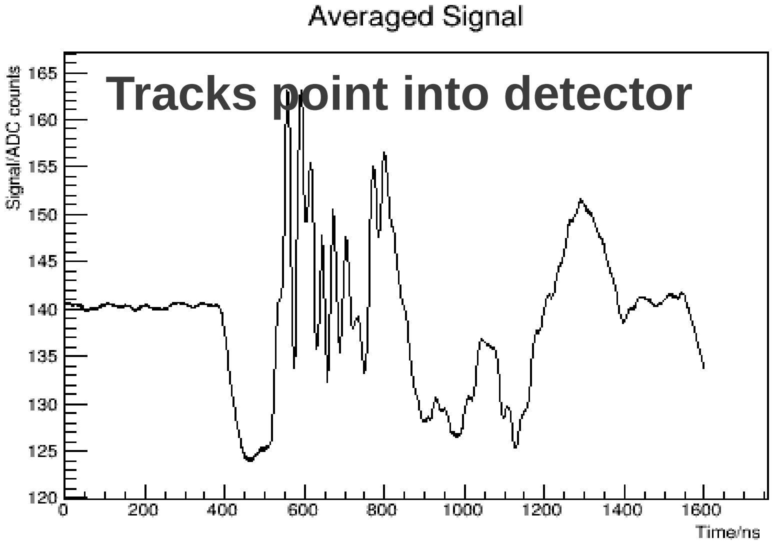
All events spectrum.

Beam covers more then the detector area, hence there is no signal in chosen channel for more of the triggers.

To reduce background only "pointing tracks" are used.

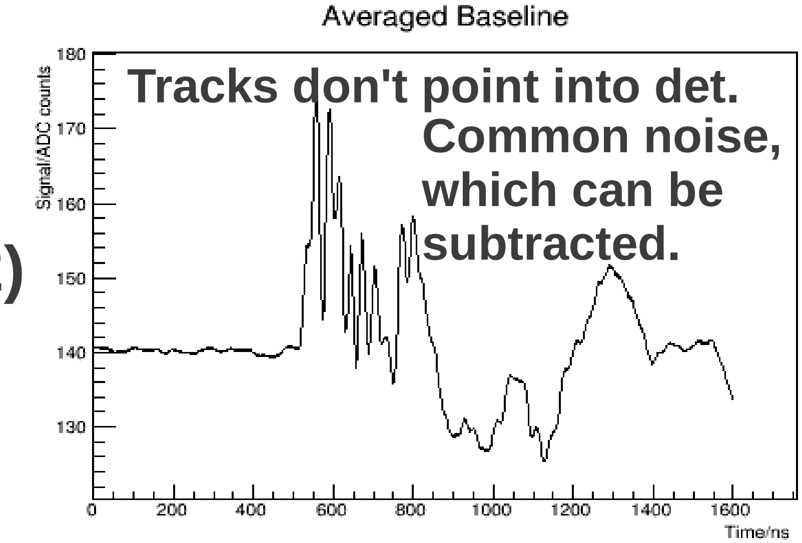
Synchronisation is done using TLU number.

1)



Tracks point into detector

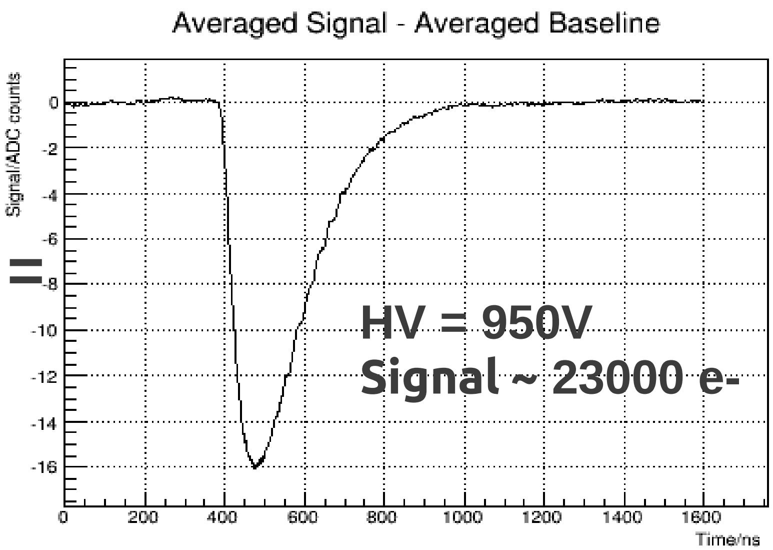
2)



Tracks don't point into det.

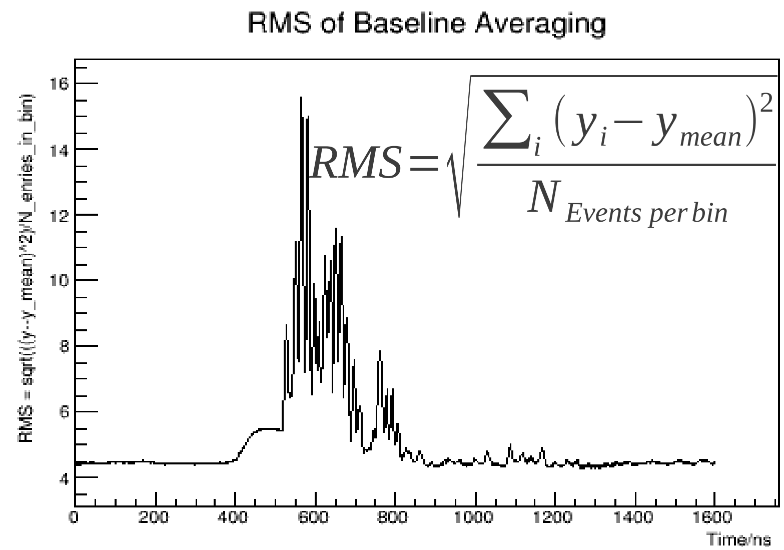
Common noise, which can be subtracted.

1) - 2) =



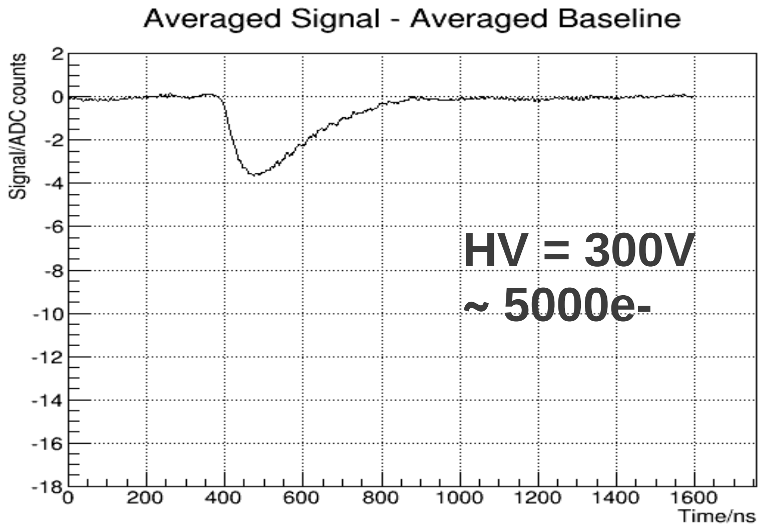
HV = 950V

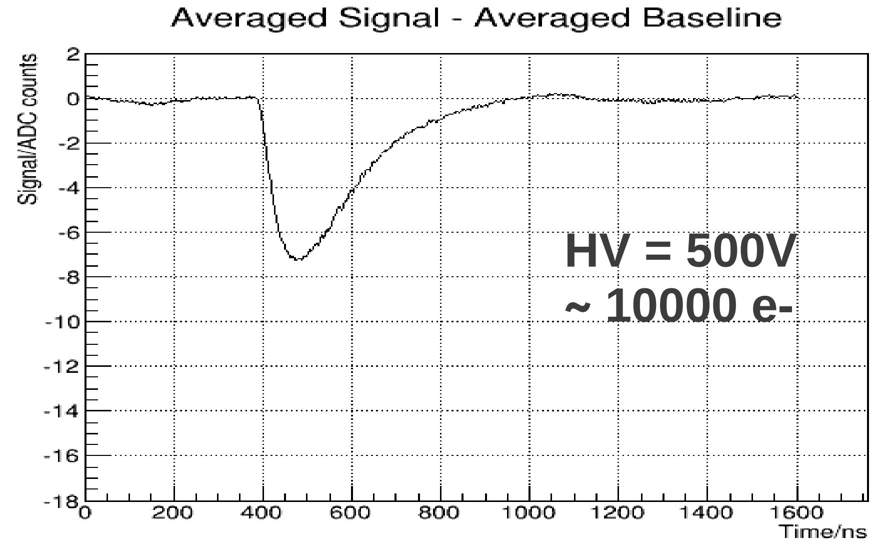
Signal ~ 23000 e-

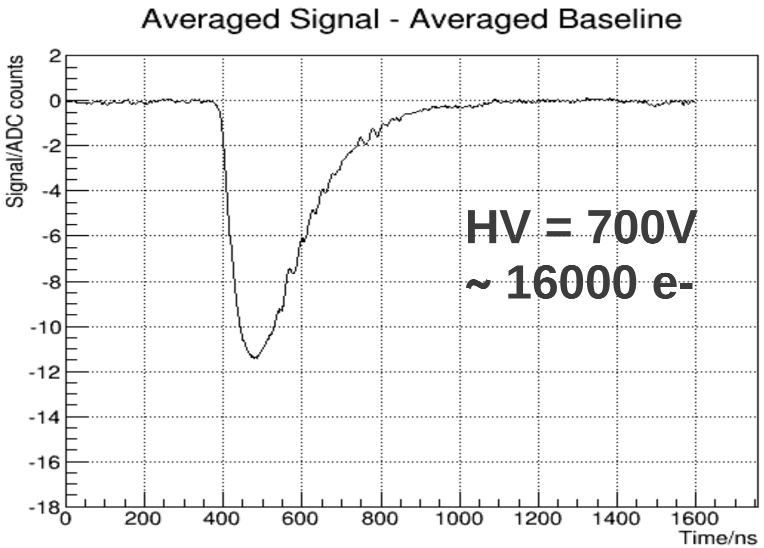


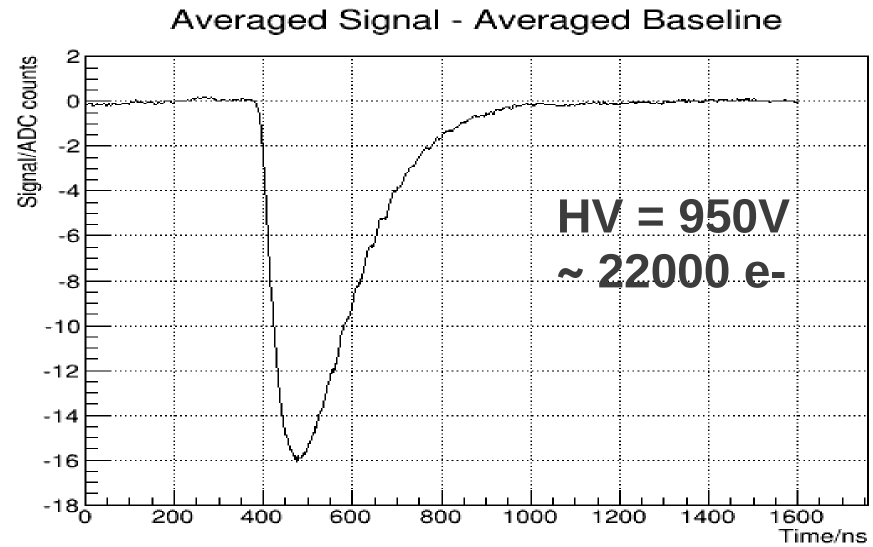
$$RMS=\sqrt{\frac{\sum_i (y_i - y_{mean})^2}{N_{Events\ per\ bin}}}$$

Sapphire detector signal vs. HV

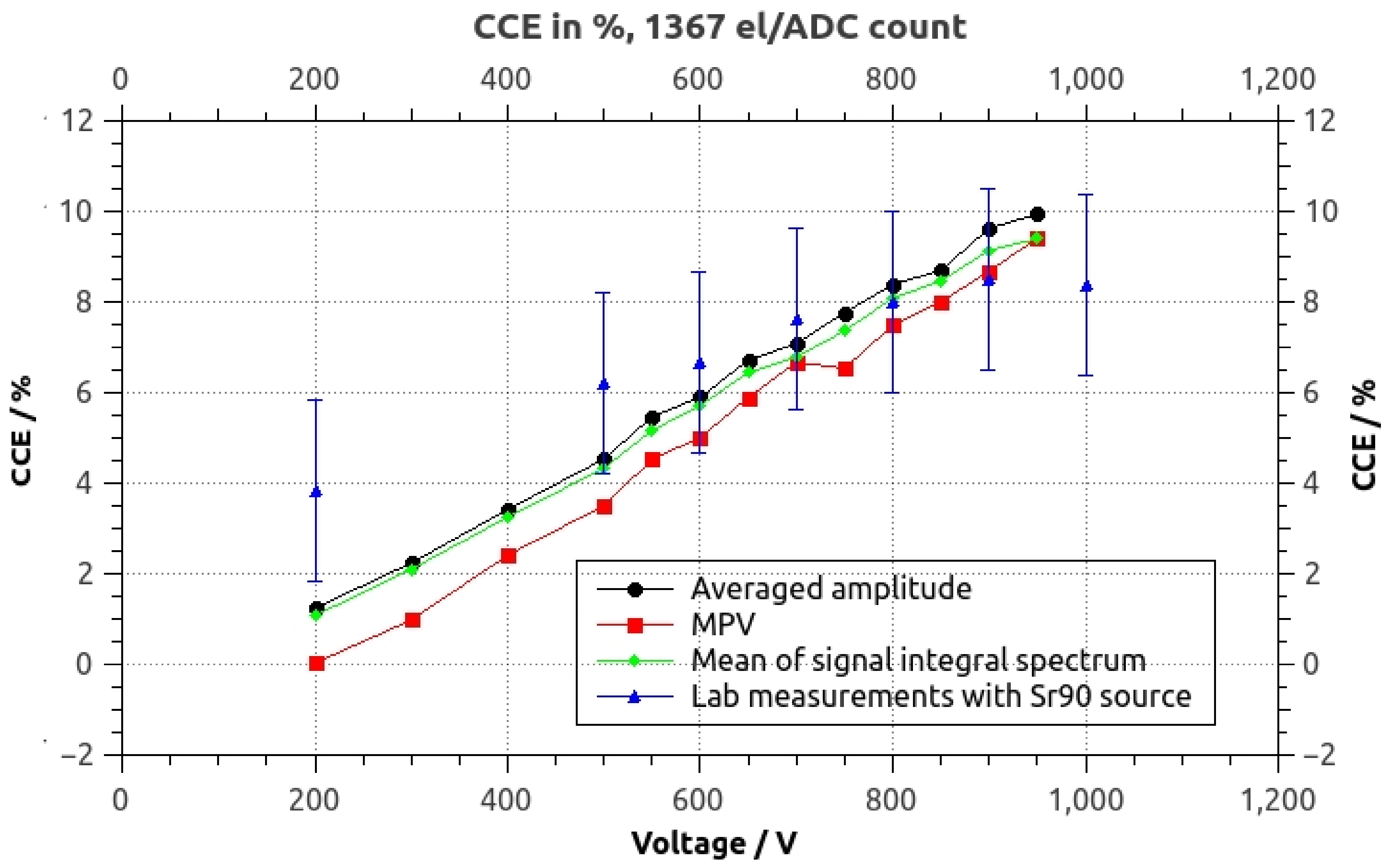








Charge collection efficiency



Conclusion

- Single crystal sapphire is a very promising radiation hard material for single particle detection.
- A sapphire detector designed for MIP detection was tested at the DESY II test beam. Signal size vs. HV shows expected behavior. @950V signal size reached ~22000 e-.
- Charge collection efficiency ~ 10% @950V.
- Further investigations of the direction sensitivity will follow.