Results of a Beamtest with irradiated Magnetic Czochralski Sensors

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Intention of the Beamtest

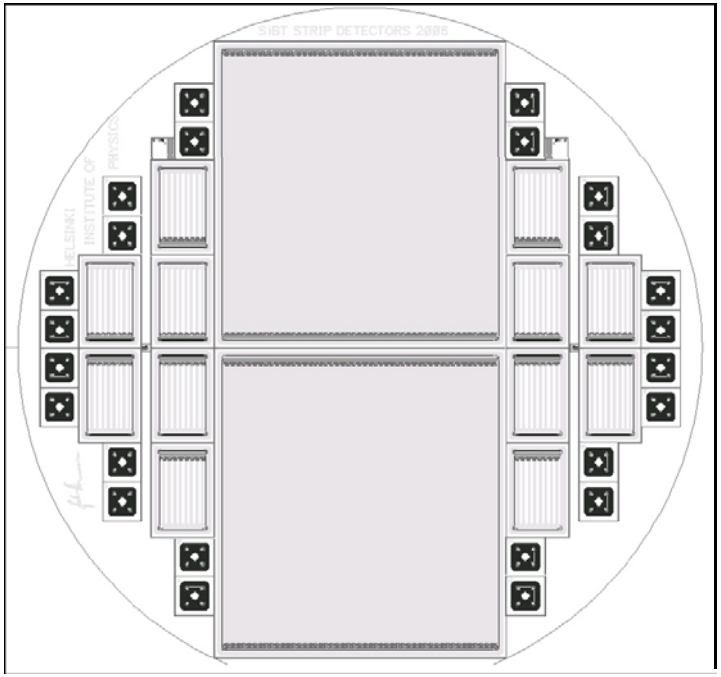
Open questions concerning the properties of irradiated Magnetic Czochralski sensors:

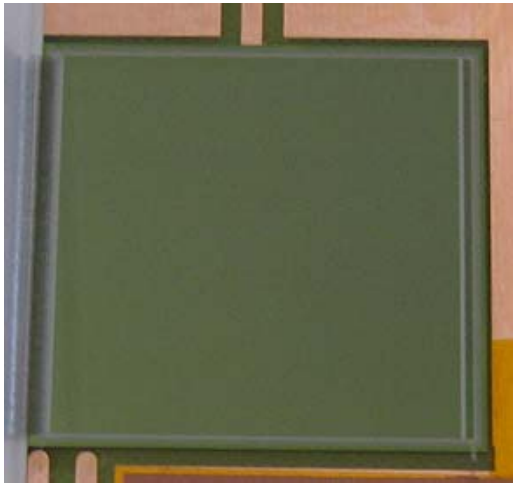
- Signal / Noise
- Efficiency
- Resolution
- Type-Inversion

Production of sensors → qualification of sensors → irradiation → testing of sensors → production of modules → testing → beamtest with a beam-telescope

Sensors

- Produced at the Helsinki Institute of Physics
- M-Cz bulk material
- 300µm thickness
- 768 channels, 50µm pitch
- size 4.3 x 4.1 cm^2
- ~350V full depletion voltage

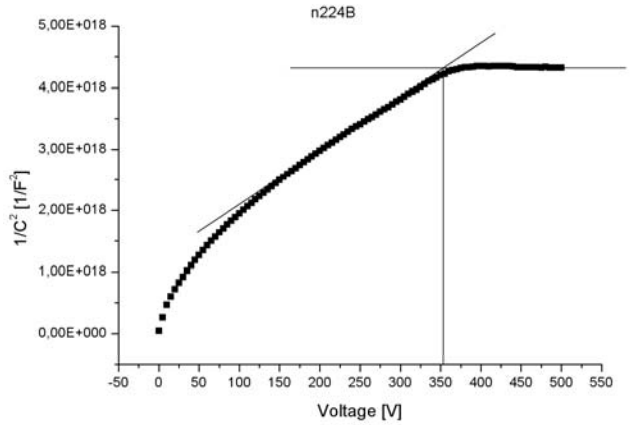




On one wafer:

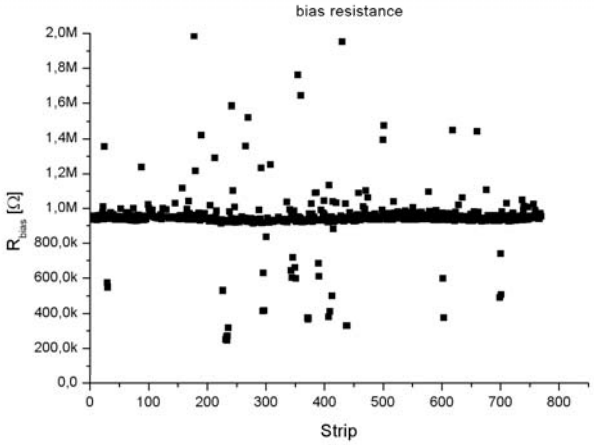
- 2 sensors
- 12 mini strip sensors 0.9×1.2 cm^2
  with 128 channels
- 24 diodes 0.25 ×0.25 cm^2

Sensor Testing Results

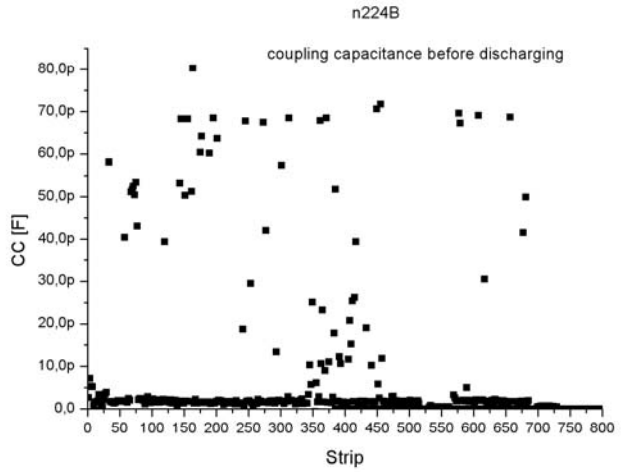


Full depletion voltages at ~350V. In very good agreement with the specifications.

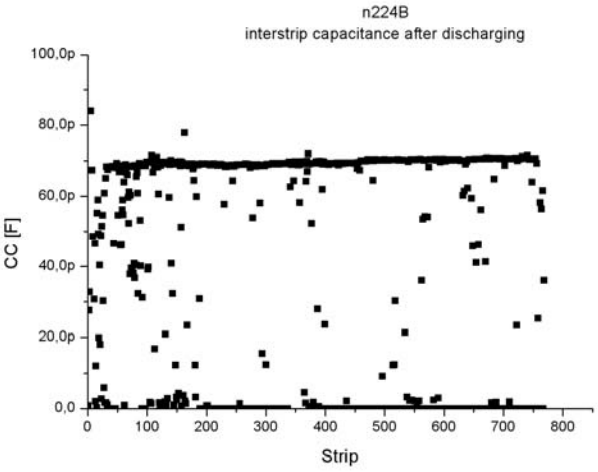
Some sensors showed quite high currents which were nearly independent of temperature so that they were most probably surface currents. After the irradiation the currents were lower.



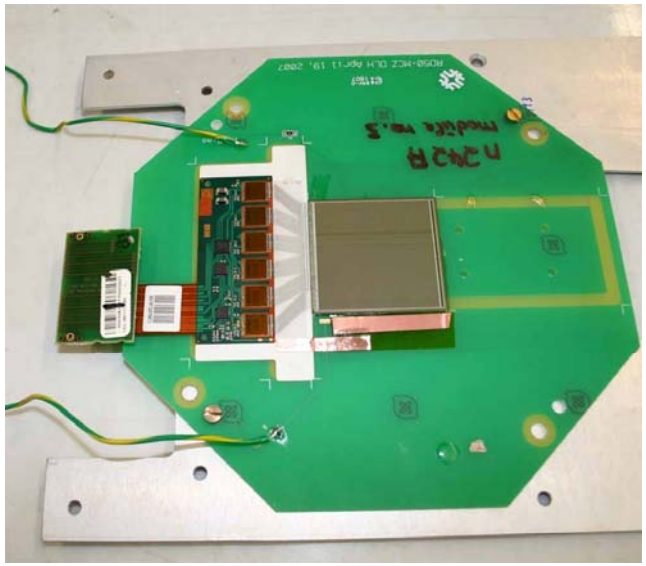
Bias resistances ~1MΩ. In very good agreement with the specifications.

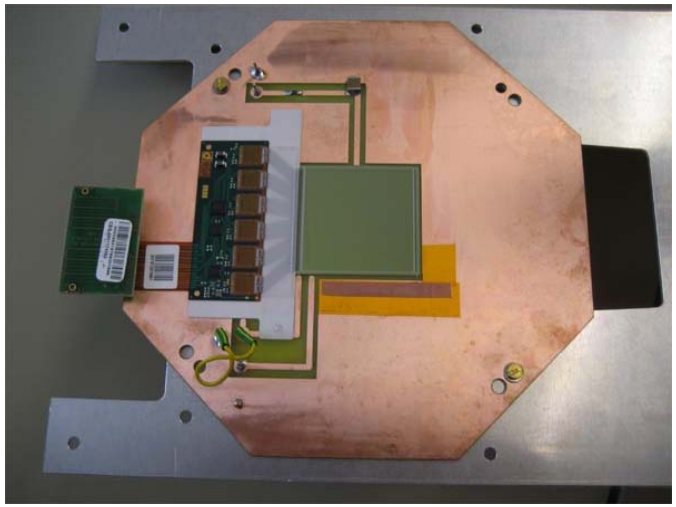


Coupling capacitances with too low values at the beginning. After a „discharging“ over the dielectric the values are in good agreement with the specifications.



Modules and Irradiation





Prototype and reference module

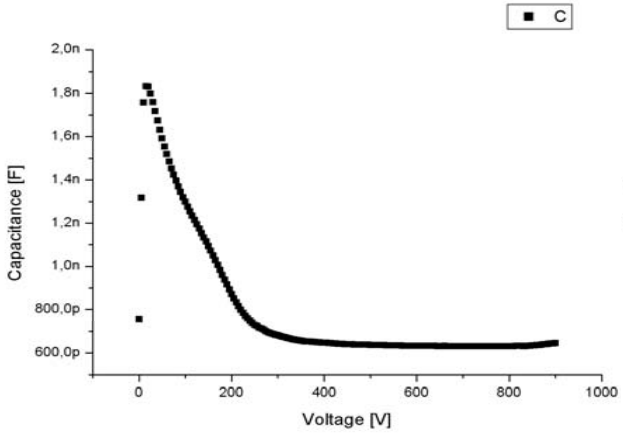
- Hexagonal support structures to fix sensors in +45° and -45° positions to the telescope and to cope best with geometrical conditions of the telescope.
- One sensor
- Pitchadaptor
- Hybrid with 6 APV
- Mounted on a „Vienna-Box plate“

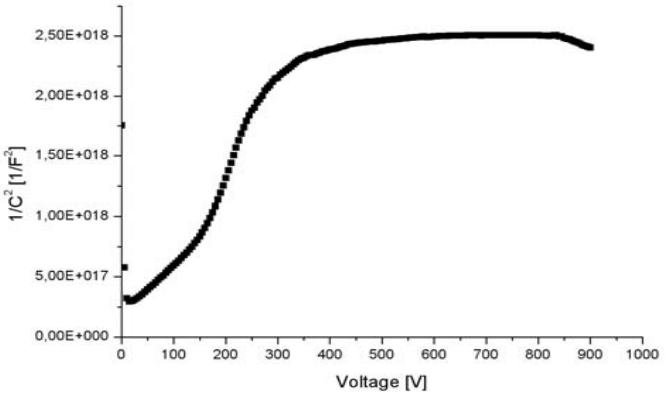
Modules were built with proton irradiated sensors. Irradiation at the proton cyclotron in Karlsruhe

Fluences:

- **$1*10^{14}$ neq. cm^{-2}**
- **$5*10^{14}$ neq. cm^{-2}**

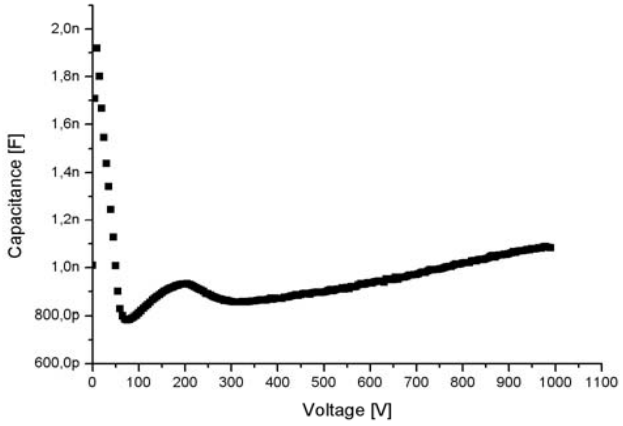
CV, Vdep after irradiation

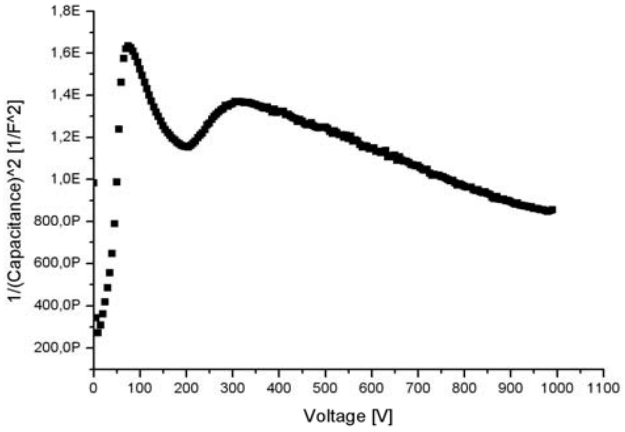




n224A: protons $5*10^{14}$ cm^{-2}

Data indicate a full depletion voltage of 350V – 400V.





n017A: protons $1*10^{14}$ cm^{-2}

Full depletion Voltage of ~200V?

Beamtests

1st beamtest:

Test of the beam telescope (SiBT, see Panja-Riina Luukka's talk). Test of the unirradiated module (reference).

2nd beamtest:

Test of modules with sensors irradiated with $1*10^{14}$ neq. cm^{-2} and $5*10^{14}$ neq. cm^{-2} proton fluences.

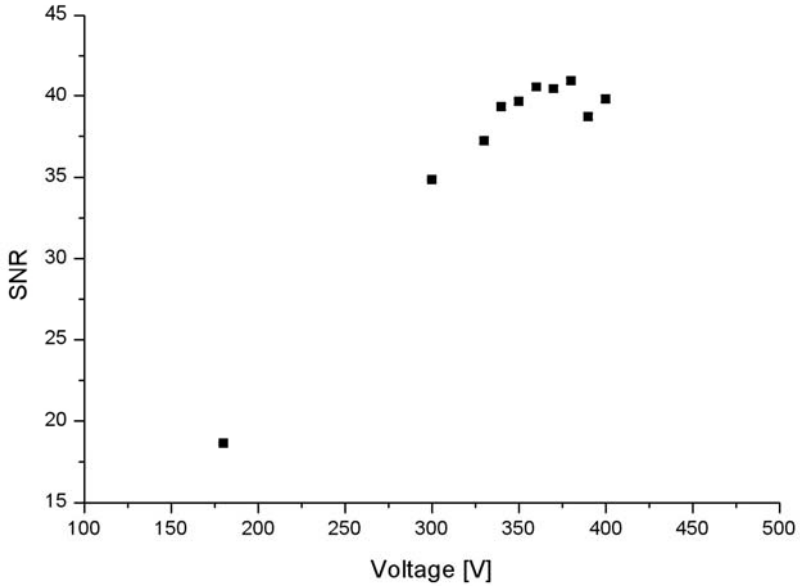
Test in parasitic mode → only muons.

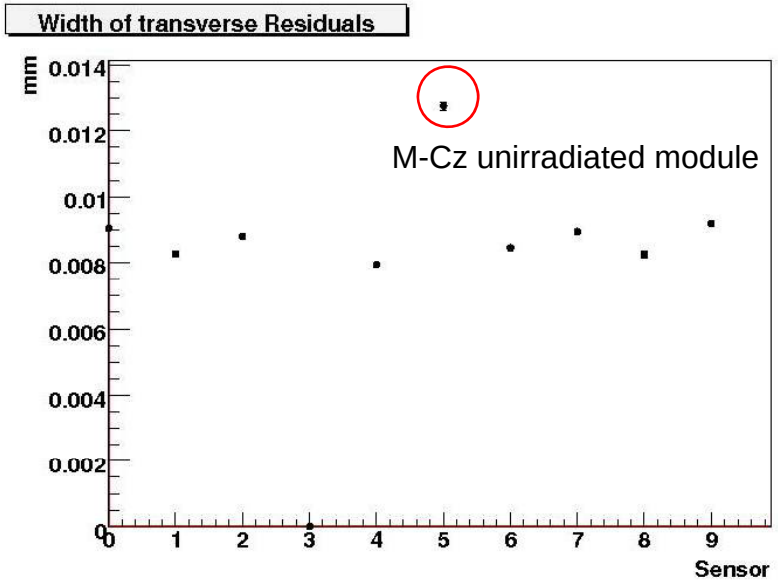
One peltier-element broke during the test → less cooling power → higher temperature → higher currents, higher voltages not always possible

Higher noise on the modules (reason?)

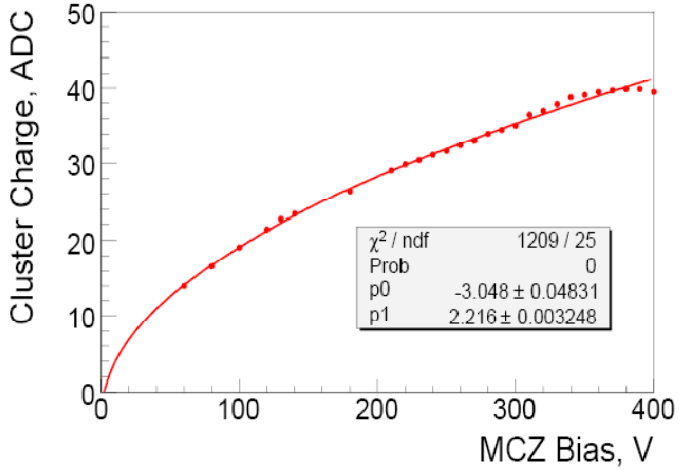
→ No optimal conditions

Results Unirradiated Module





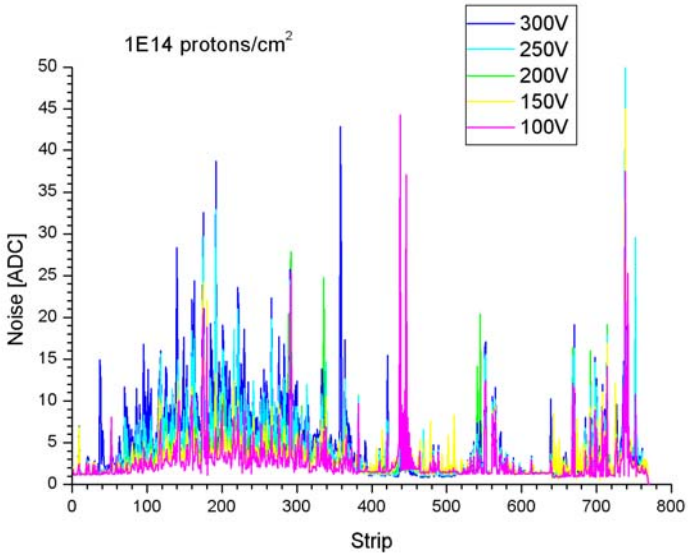
- 350V full depletion voltage
- SNR ~40



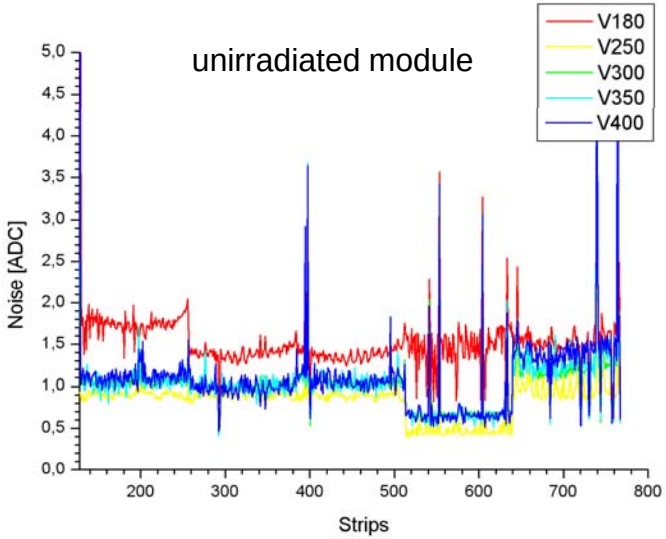
- Theory: pitch/sqrt(12) → ~14.4µm
- Resolution ~13µm
- Efficiency: 98.5 % +- 0.3%

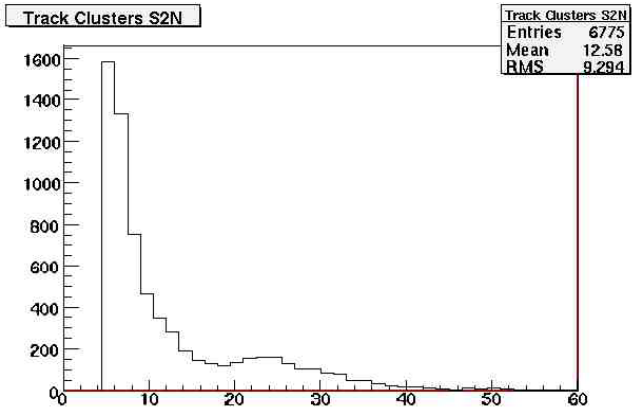
Results module n017A

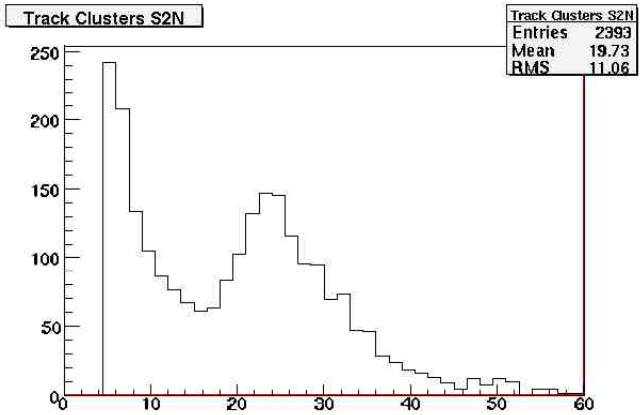
Fluence: protons 1*10^{14} neq. cm^{-2}

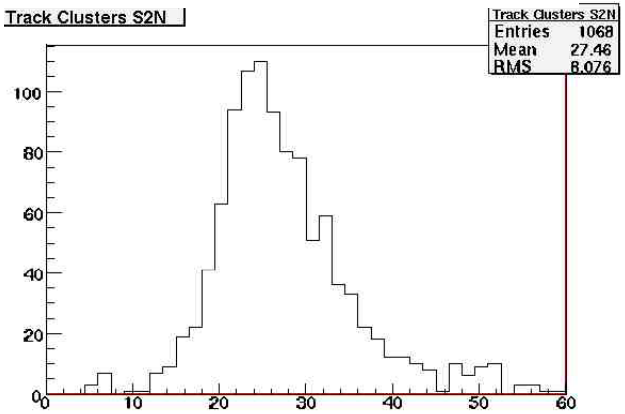


Higher noise in comparison to the reference module!





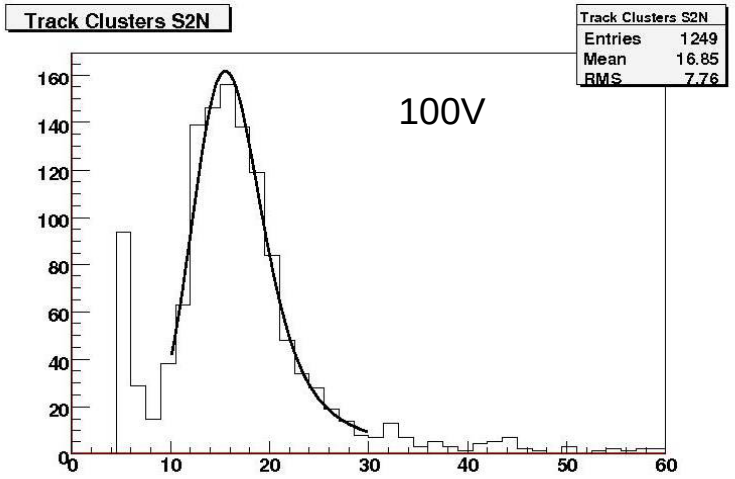


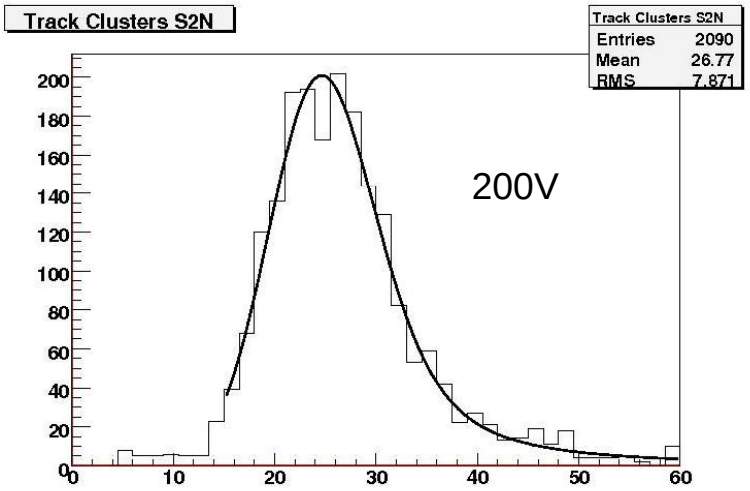


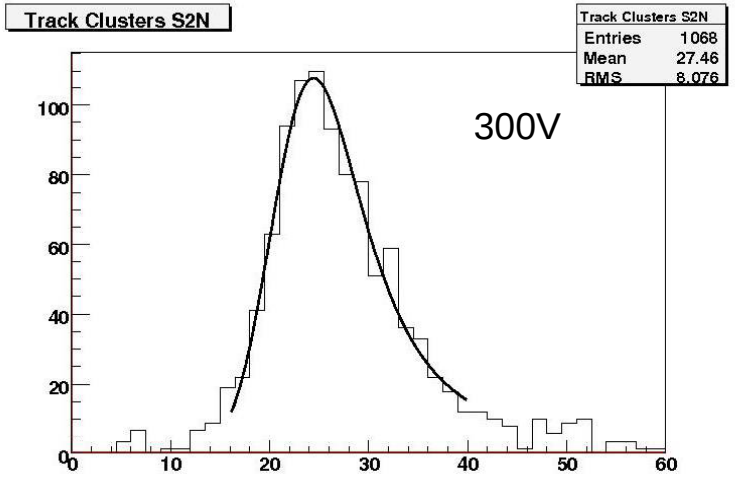
300V, no noisecut, all APV only good APV → 300V, no noisecut, best APV noise cut (>2ADC) → 300V, noisecut, best APV

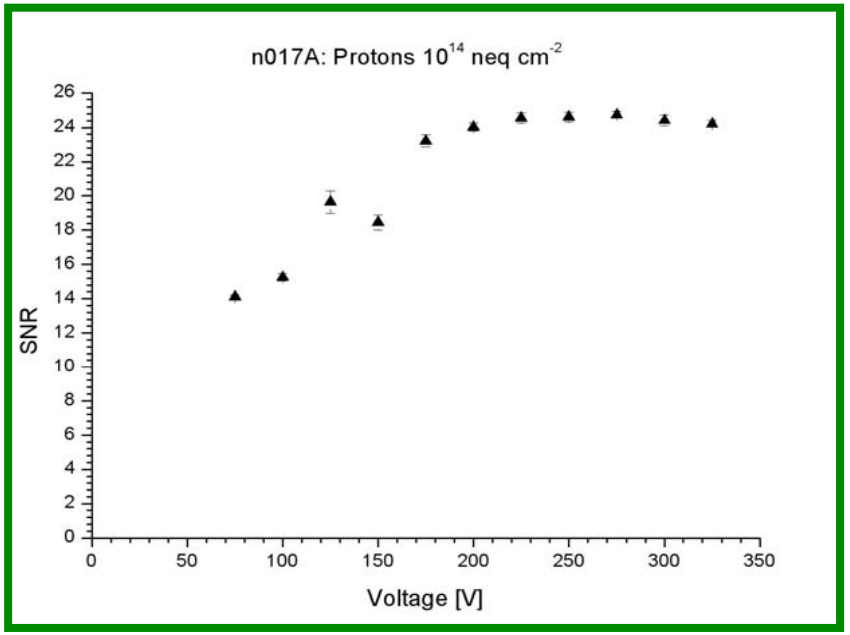
Results module n017A

Fluence: protons 1*10^{14} neq. cm^{-2}



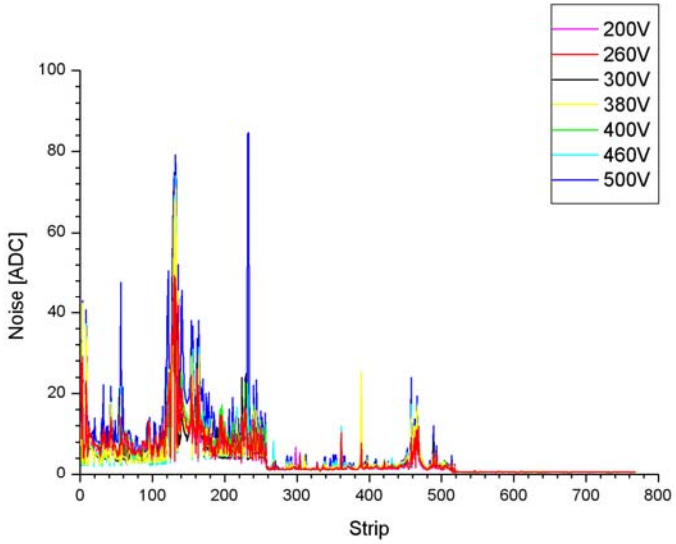






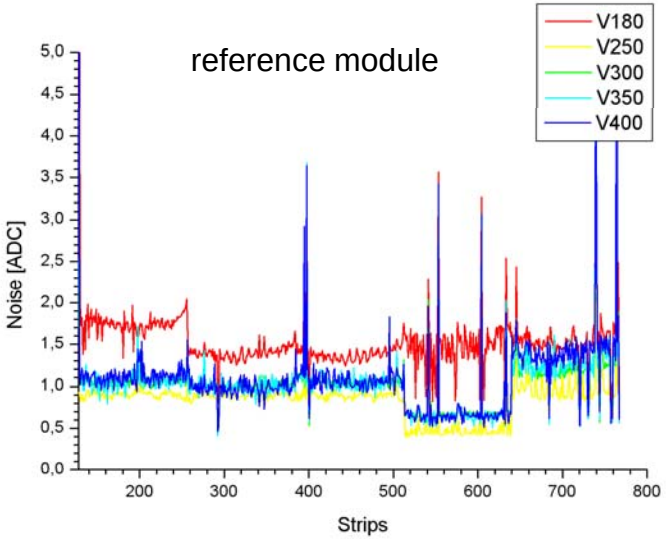
Results module n224A

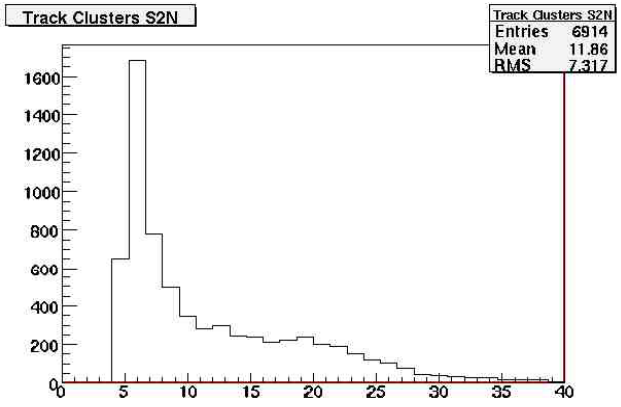
Fluence: protons 5*10^{14} neq. cm^{-2}

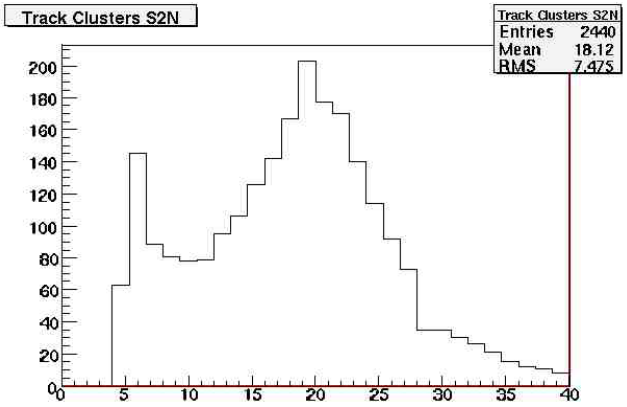


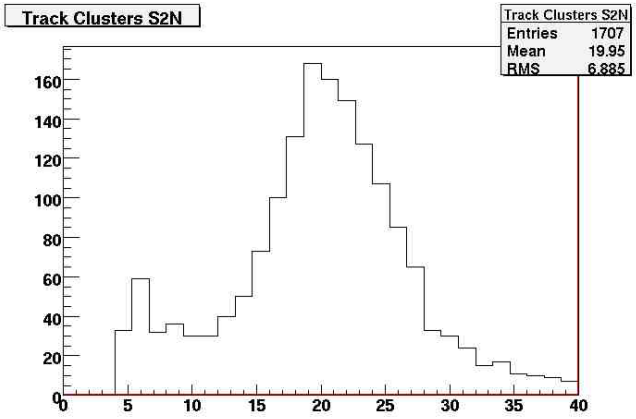
Higher noise in comparison to the reference module!

reference module





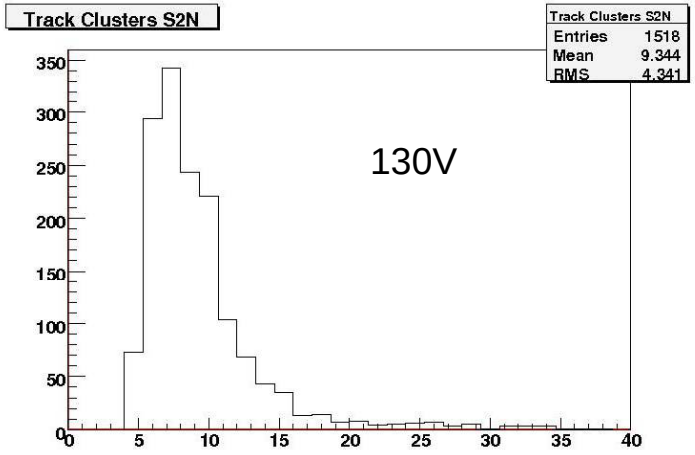


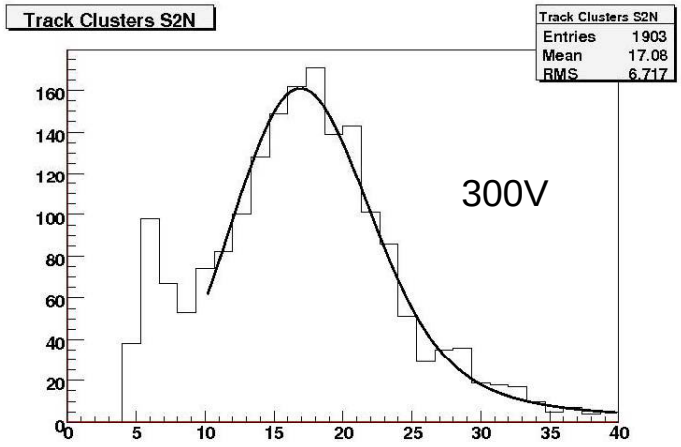


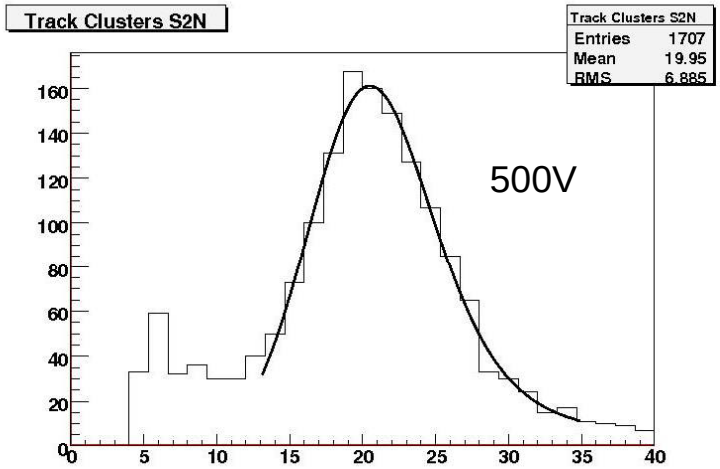
500V, no noisecut, all APV noise cut (>2ADC) → 500V, noisecut, all APV only good APV → 500V, noisecut, best APV

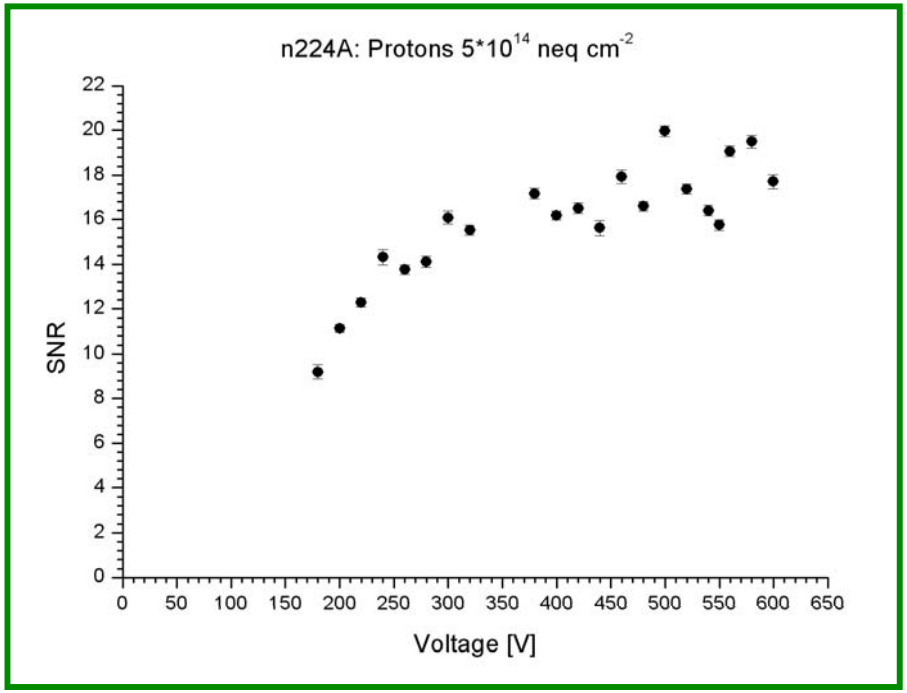
Results module n224A

Fluence: protons 5*10^{14} neq. cm^{-2}

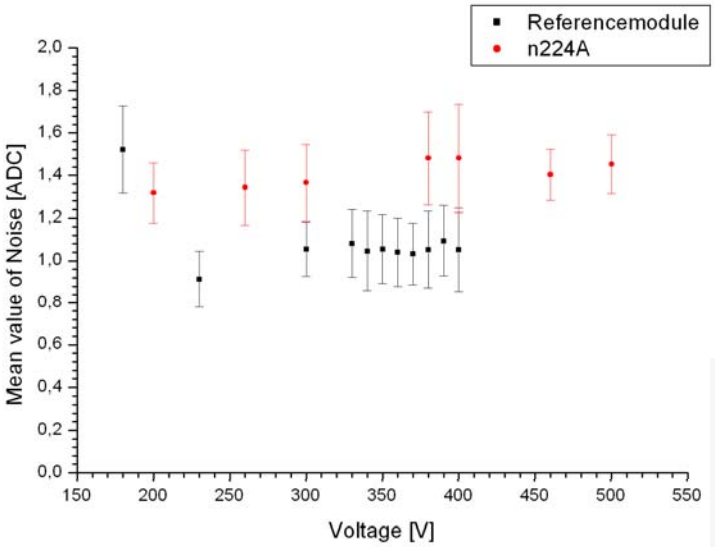


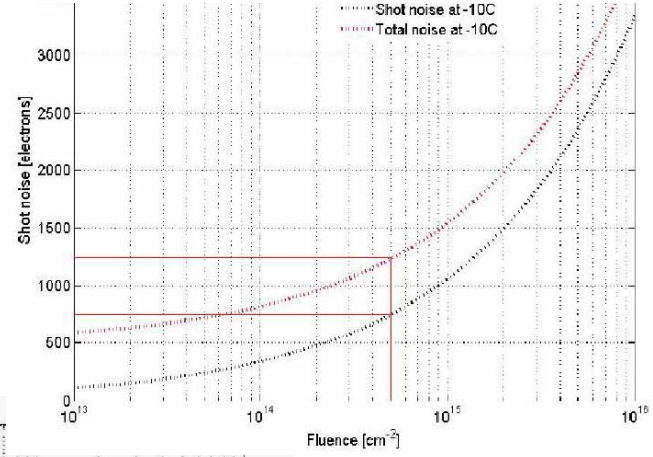


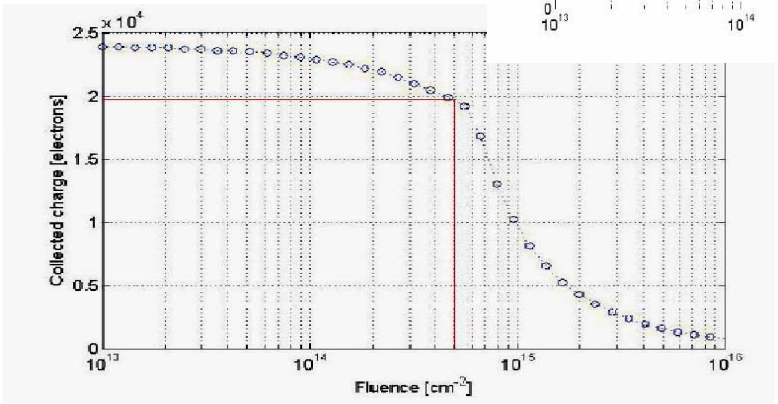




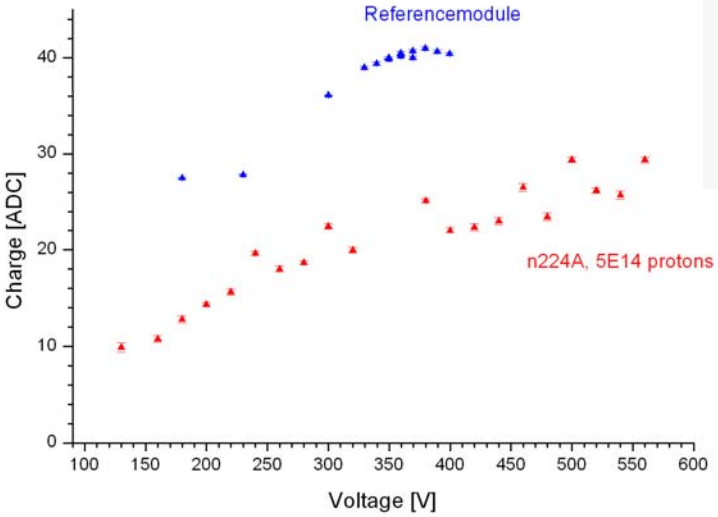
Noise-Voltage, Charge-Voltage







Simulations
(by Jaakko Härkönen)



Noise(5E14) = 1.38*Noise(Ref.)

SNR(5E14)=0.45*SNR(Ref.)

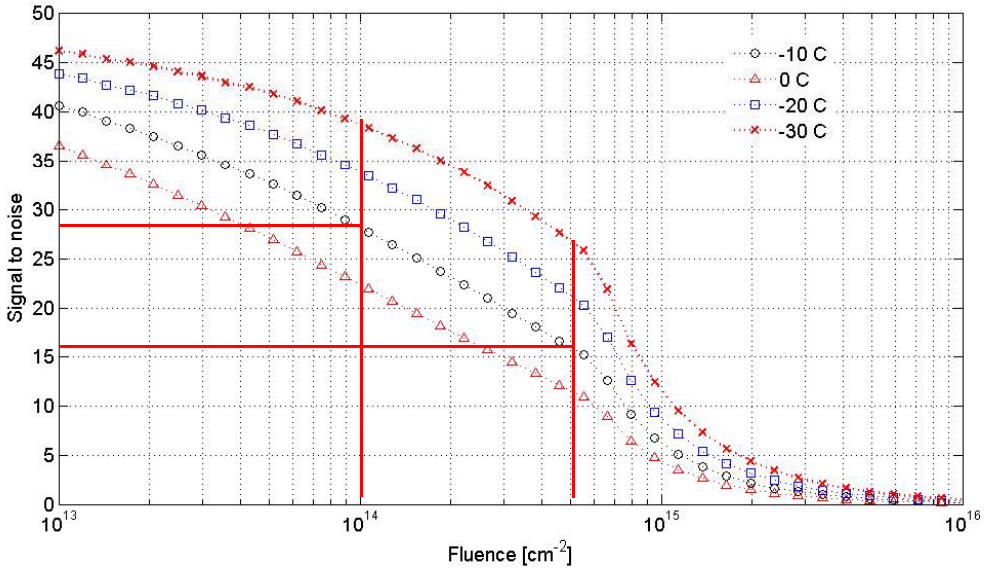
→Charge(5E14)=0.62*Charge(Ref.)

Theory: Charge(5E14)=0.7*Charge(Ref.)

The results fit well in the expected range.

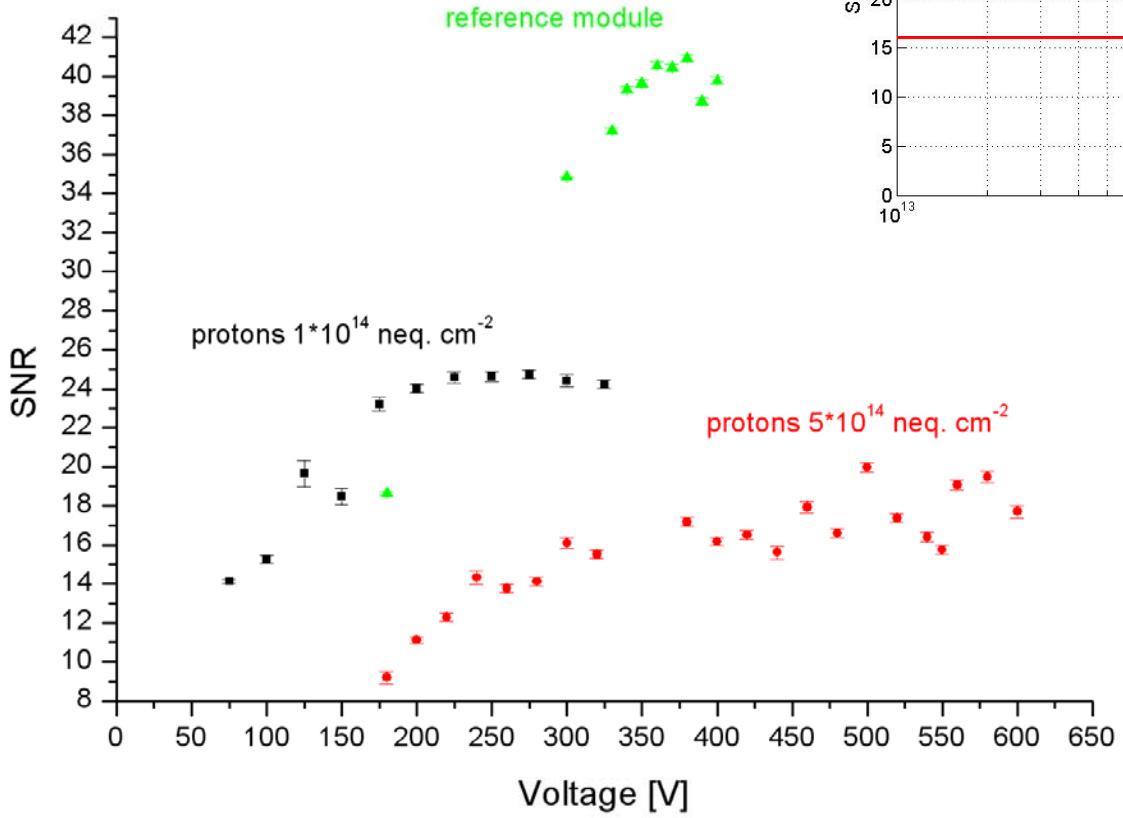
Summary of SNR results

The results are very well conform with the prediction!



simulation (Jaakko Härkönen)

test results



Module:	SNR:
Reference	~40
1E14p	~24
5E14p	~18

Conclusion

- Test of proton irradiated M-Cz sensors
- Successful use of the Silicon Beam Telescope SiBT
- Some noise problems with the tested modules, reason still to be found out
- Resolution and efficiency difficult to determine because of noise
- Broken cooling → higher leakage currents
- Despite the problems, the results are very promising
- SNR values are in the expected ranges with tendency to be even higher
- SNR(unirradiated)=40; SNR(1E14)=24; SNR(5E14)=18
- Test with new sensors irradiated with different and higher fluences (neutrons and protons) planned