WP3.1: Bestrahlungen und Charakterisierung von Auslesekomponenten und Detektorelementen

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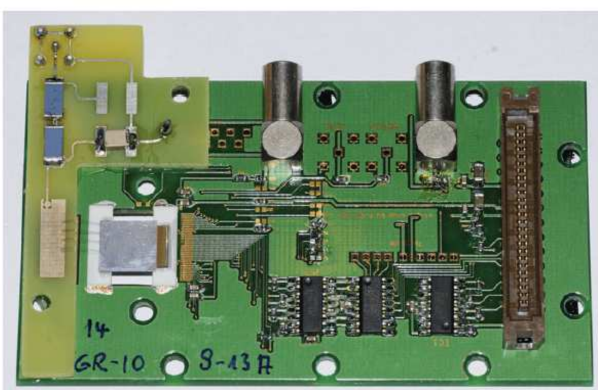
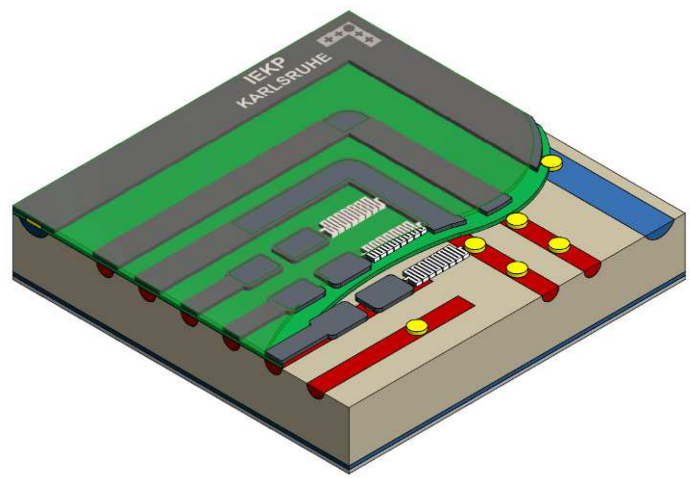
INSTITUT FÜR EXPERIMENTELLE KERNPHYSIK



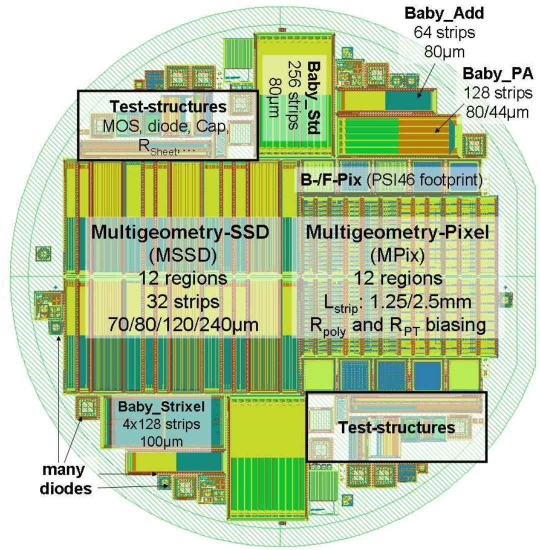


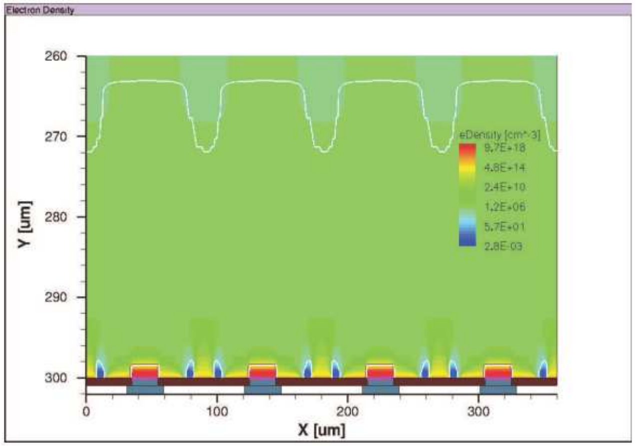
Workpackage 3.1

- Title: **Bestrahlungen und Charakterisierung von Auslesekomponenten und Detektorelementen**
- Participating institute and group leader: Karlsruhe (Th. Müller)
- In this working package we continue the research on radiation hard detector elements. The funding allows us to employ a technician who performs the irradiations and to cover irradiation costs for institutes within the HHA.
- Main interest is the radiation hardness of silicon sensors, but also other components like optical fibers to measure environmental parameters or ASICs have been investigated.

2010

- A total of 4.5h irradiation time
  - Preparation of a large irradiation campaign within CMS. Irradiation of samples for cross-calibration of the participating institutes.
  - Investigation of energy loss and increase in radiation damage in several layers of silicon. Three layers of 300µm thick silicon are possible within an increase in damage of 15%.
- The understanding of the measurements of irradiated structures is assisted by **device simulations**. With the funding of this WP we were able to acquire a good simulation server with large memory and several cores.





2011

- Total of 120h X-ray irradiations for HLL Munich
- Total of 15h proton irradiations for several groups
- Papers resulting from irradiations within this WP:
  - M. Köhler, R. Bates, G.-F. Dalla Betta, C. Fleta, J. Härkönen, K. Jakobs, M. Lozano, et al.
    „Measurements with Irradiated 3D Silicon Strip Detectors"
    Nuclear Physics B - Proceedings Supplements 215, Nr. 1 (June 2011): 247–249
  - A. Macchiolo, L. Andricek, M. Beimforde, H.-G. Moser, R. Nisius, R.H. Richter, und P. Weigell
    „Performance of thin pixel sensors irradiated up to a fluence of and development of a new interconnection technology for the upgrade of the ATLAS pixel system"
    NIM A 650, Nr. 1 (Sep 2011): 145–149
  - U. Parzefall, et al.
    „Silicon detectors for the sLHC"
    NIM A 658, Nr. 1 (Dec 2011): 11–16
  - M. Köhler, R. Bates, C. Fleta, K. Jakobs, M. Lozano, Ch. Parkes, U. Parzefall, G. Pellegrini, and J. Preiss
    „Comparative measurements of highly irradiated n-in-p and p-in-n 3D silicon strip detectors"
    NIM A 659, Nr. 1 (Dec 11, 2011): 272–281
  - P. Weigell, M. Beimforde, Ch. Gallrapp, A. La Rosa, A. Macchiolo, R. Nisius, H. Pernegger, and R.H. Richter
    „Characterization and performance of silicon n-in-p pixel detectors for the ATLAS upgrades"
    NIM A 658, Nr. 1 (Dec 2011): 36–40
  - C. Gallrapp, A. La Rosa, A. Macchiolo, R. Nisius, H. Pernegger, R.H. Richter, and P. Weigell
    „Performance of novel silicon n-in-p planar pixel sensors"
    NIM A 679, Nr. 0 (July 2012): 29–35
  - J.-W- Tsung, M. Havranek, F. Hügging, H. Kagan, H. Krüger, and N. Wermes
    „Signal and noise of diamond pixel detectors at high radiation fluences"
    Journal of Instrumentation 7, Nr. 09 (Sep 2012): P09009–P09009

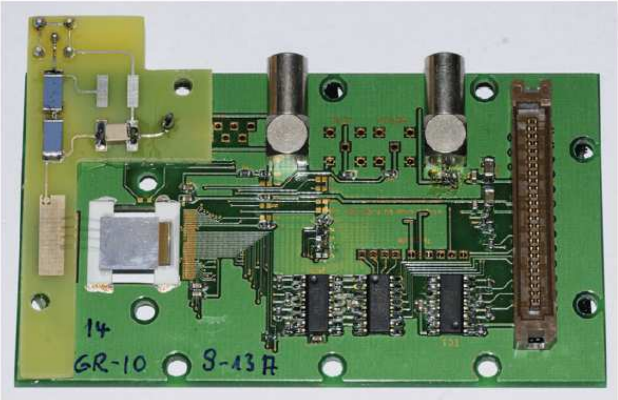
Characterization and performance of silicon n-in-p pixel detectors for the ATLAS upgrades

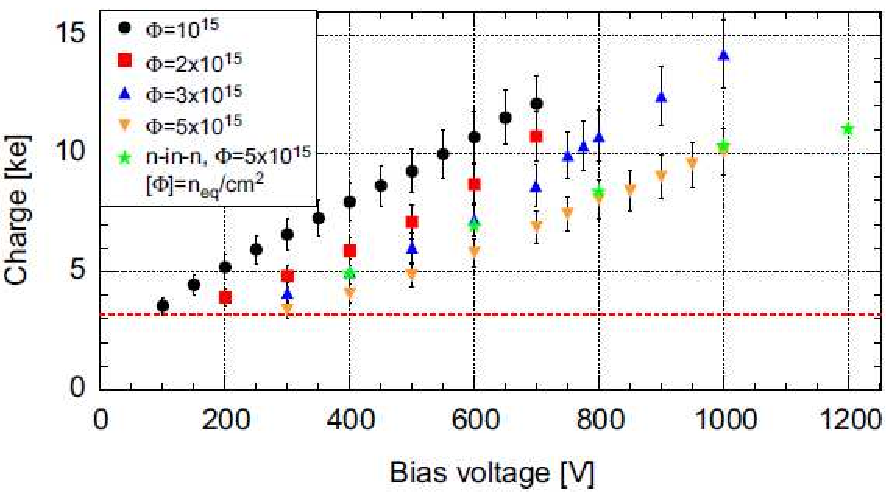
and

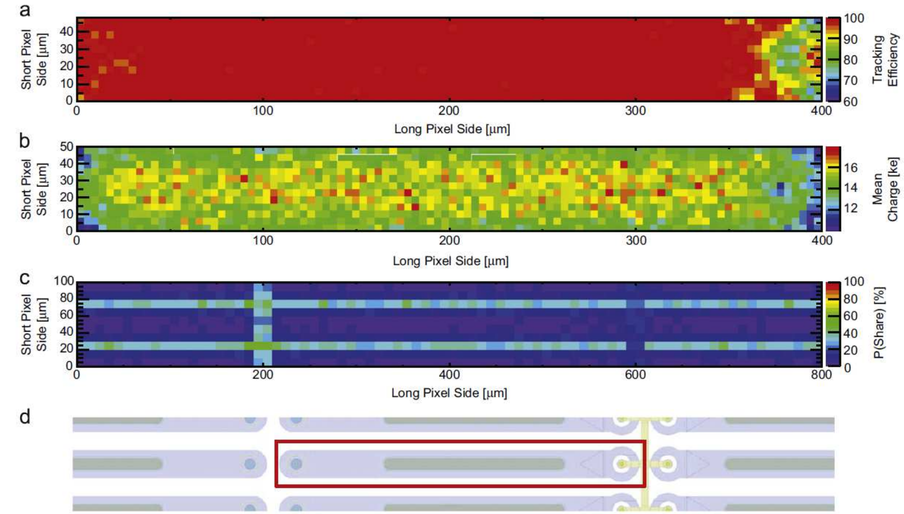
Performance of novel silicon n-in-p planar pixel sensors

NIM A 658 (2011): 36–40
NIM A 679 (2012): 29–35

- P. Weigell, A. Macchiolo (Munich)
- From conclusions:
  - The stable operation at 700V for several days indicates that the risk of sparks is low if Benzo-Cyclo-Butene is applied.
  - At $5 \cdot 10^{15} n_{eq} cm^{-2}$:
    - Signal over threshold of more than three, together with low noise, has been obtained
    - The tracking efficiency is (98.6±0.3)% with threshold of 3200 e, and biasing at 600 V.







Performance of thin pixel sensors irradiated up to a fluence of $10^{16} n_{eq}/cm^2$ and development of a new interconnection technology for the upgrade of the ATLAS pixel system

- A. Macchiolo, P. Weigell (Munich)
- From conclusions:
  - A first production of n-in-p pixel sensors with an active thickness of 75 and 150 µm has been completed in view of the ATLAS pixel detector upgrades.
  - CCE measurements performed after irradiation show that it is possible to recover 100% of the charge obtained before irradiation in the 75 mm thick sensors at a fluence of $10^{16} n_{eq}/cm^2$

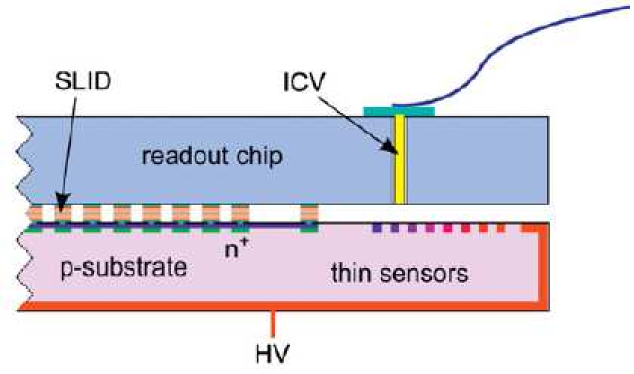
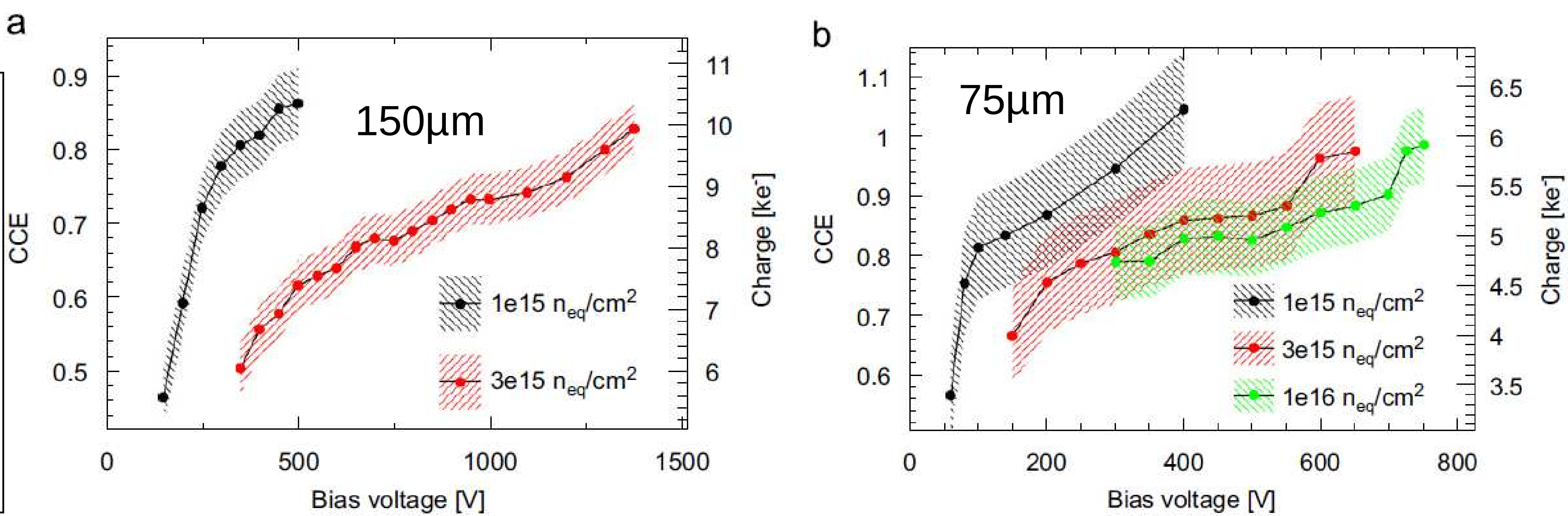


Illustration of the module concept, with the Solid Liquid Interdiffusion (SLID) as an alternative to the bump-bonding interconnection

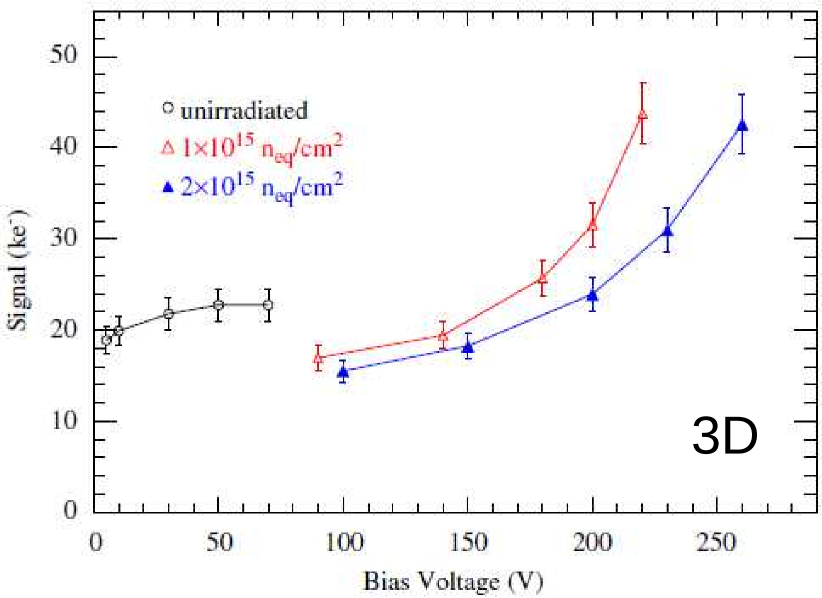
NIM A 650 (2011): 145–149

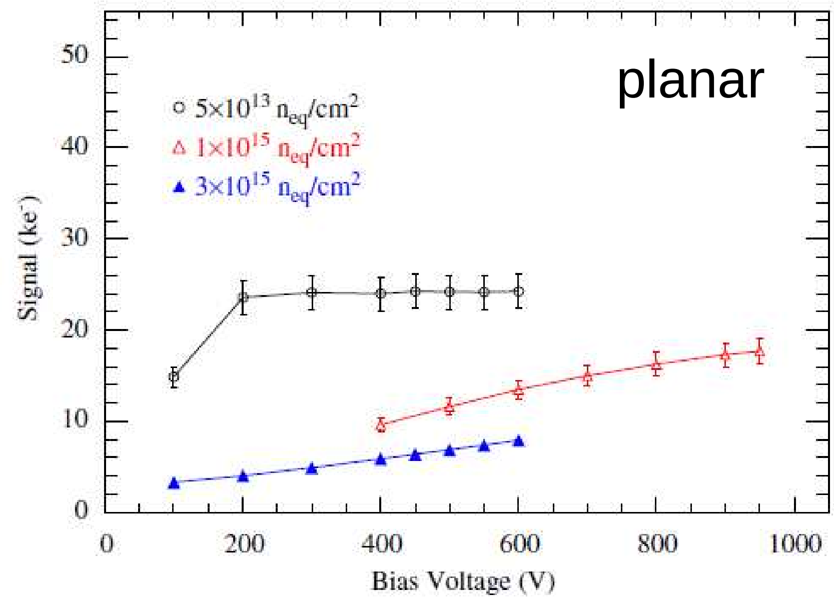


Silicon detectors for the sLHC

- U. Parzefall (Freiburg) for RD50
- From conclusions:
  - Several studies show that p-type planar silicon detectors have sufficient radiation hardness to be operated up to fluences in the order of a few 10^{15} $n_{eq}cm^{-2}$, provided that a sufficiently high bias voltage can be supplied.
  - 3D detectors would be able to offer a comparable radiation hardness at significantly lower bias voltages.

NIM A 658 (2011): 11-16

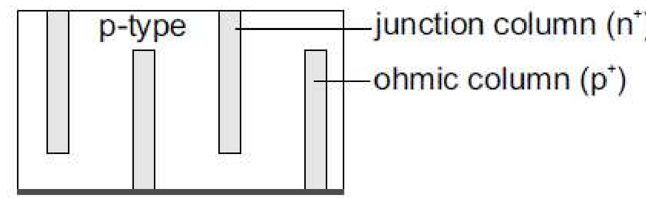




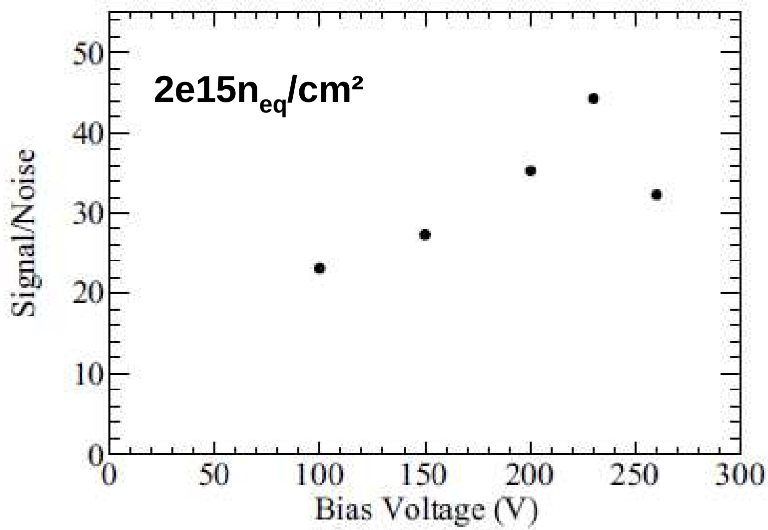
Measurements with Irradiated 3D Silicon Strip Detectors

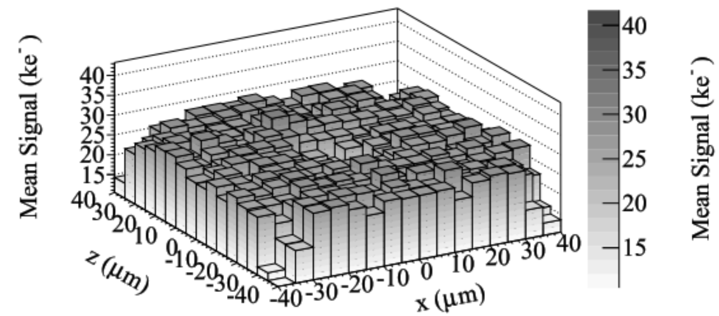
- M. Köhler, U. Parzefall (Freiburg)
- From text:
  - The MPV measured at 230 V (after $2e15n_{eq}/cm^2$) is 31000e-. This observation indicates that the electric field, increased by radiation induced defects, is sufficiently high to cause charge multiplication due to impact ionisation.
  - The signal measured with the irradiated detector is less uniform, larger signals are measured for tracks impinging close to the junction column.

Nucl. Phys. B – Proc. Suppl. 215, (2011): 247–249

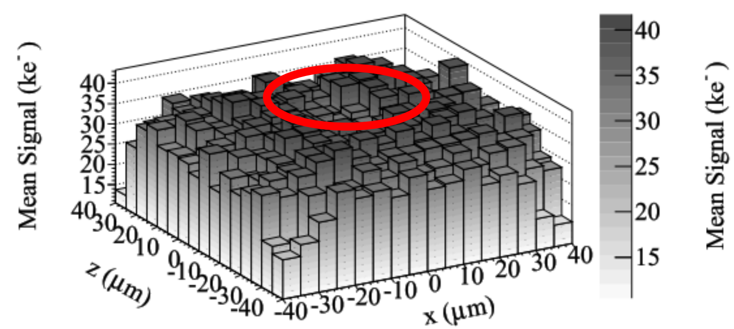


Cross-section of double-sided 3D p-type detector





(a) Unirradiated detector, 70 V.

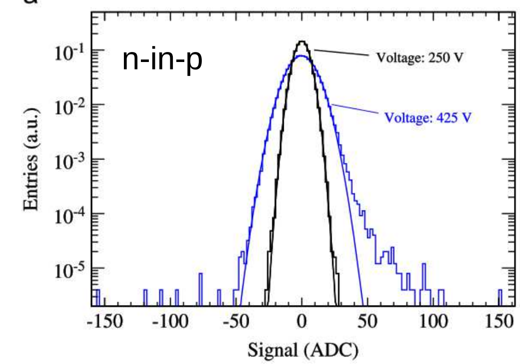


(b) Irradiated to $2 \times 10^{15}\ n_{eq}/cm^2$, 230 V.

Comparative measurements of highly irradiated n-in-p and p-in-n 3D silicon strip detectors

- M. Köhler, U. Parzefall (Freiburg)
- From conclusions:
  - It could be shown that both designs yield the same signal after the highest irradiation fluence of 2e16n_{eq}/cm²:
    15ke- at ~400 V (CCE~70%).
  - The noise distribution of the highly irradiated detectors deviates from a Gaussian, when high bias voltages are applied. This effect is possibly caused by micro-discharges.

a



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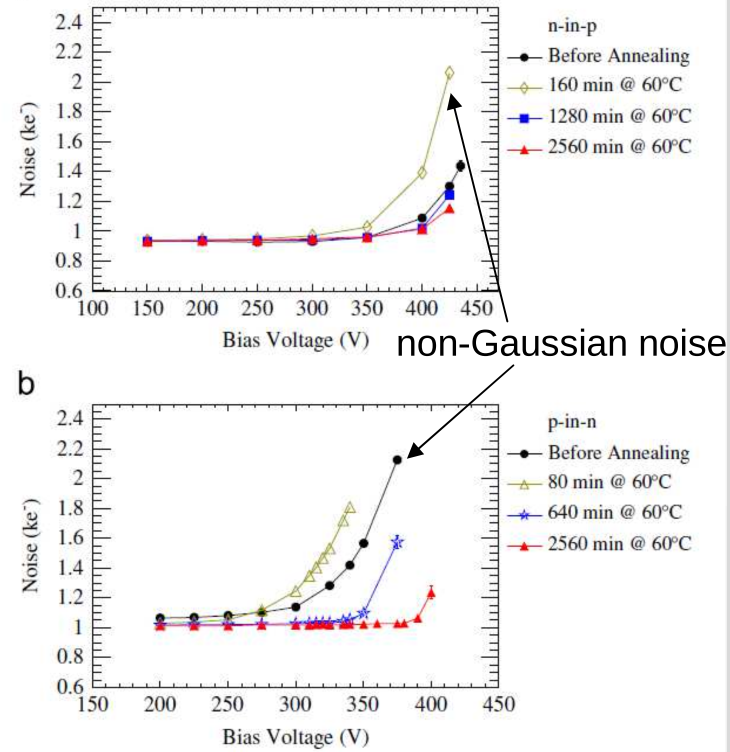
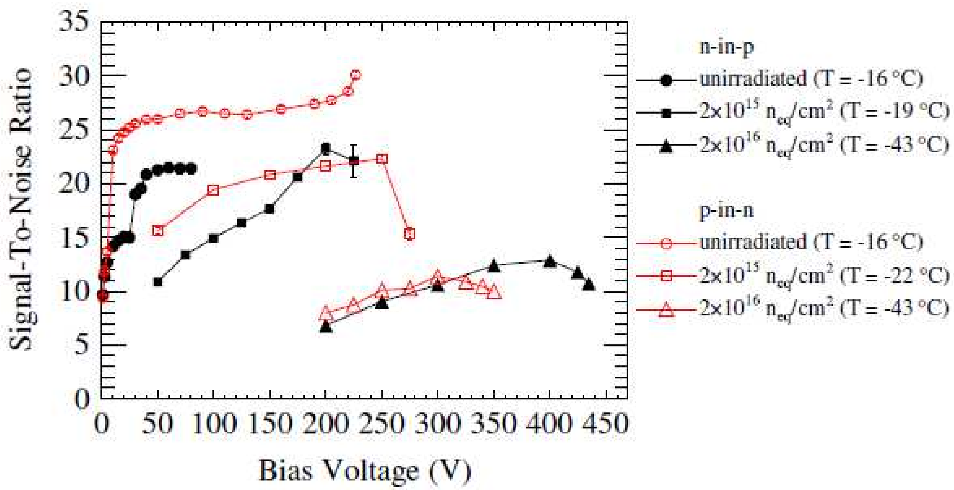


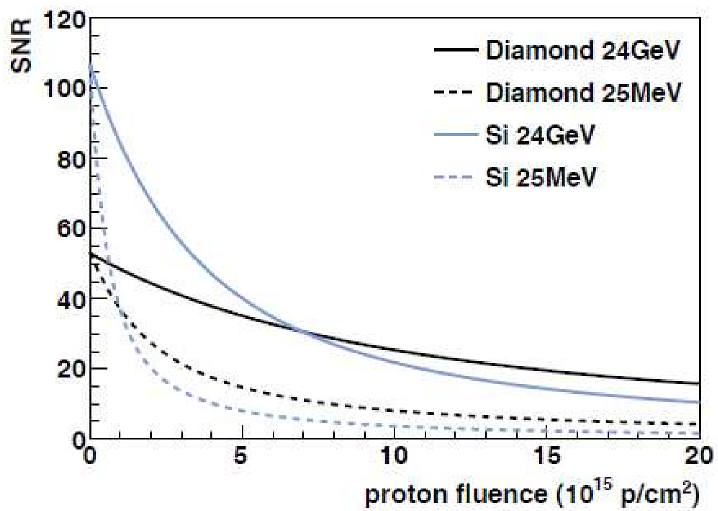


NIM A 659 (2011): 272–281

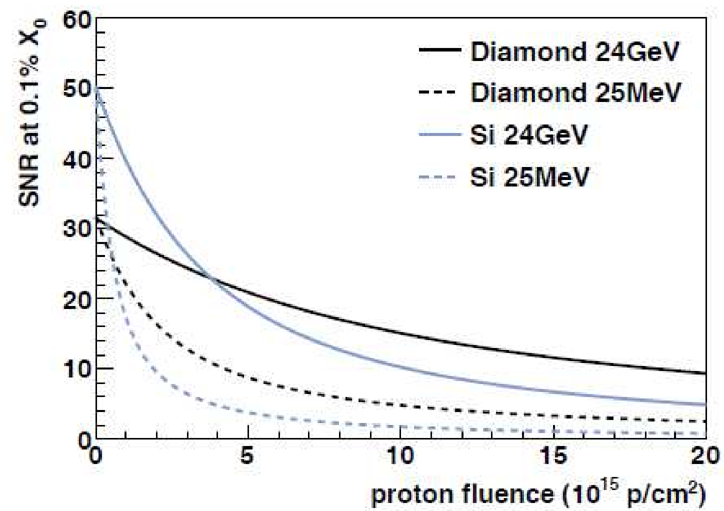
Signal and noise of diamond pixel detectors at high radiation fluences

- J.-W. Tsung, N. Wermes (Bonn)
- From conclusions:
  - The signal development with fluence is extracted from dedicated irradiation campaigns up to fluences of 10^{16} p/cm^2 at two different energies, 25MeV and 24GeV protons, as well as from published data on silicon.
  - The resulting SNR leads to the conclusion that the SNR of diamond pixel sensors exceeds that of planar Si at fluences above several 10^{15} p/cm^2 .

JINST 7, Nr. 09 (2012): P09009



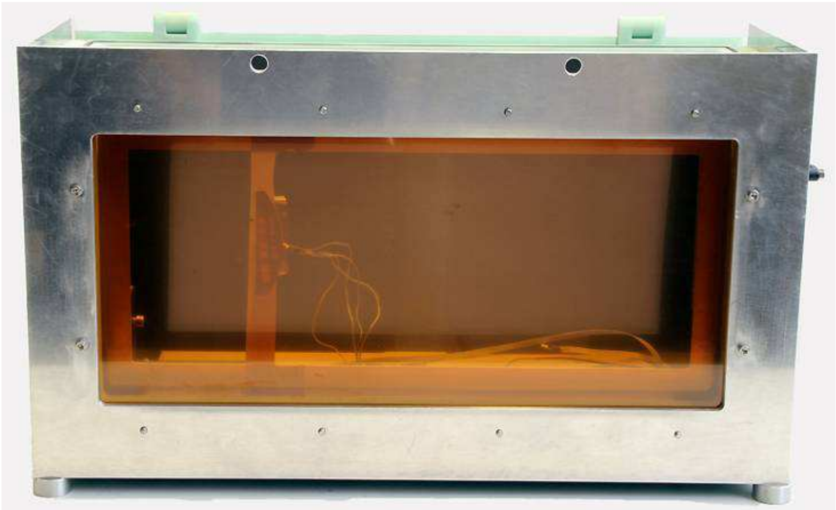
(a) SNR for 200 μm sensor thickness

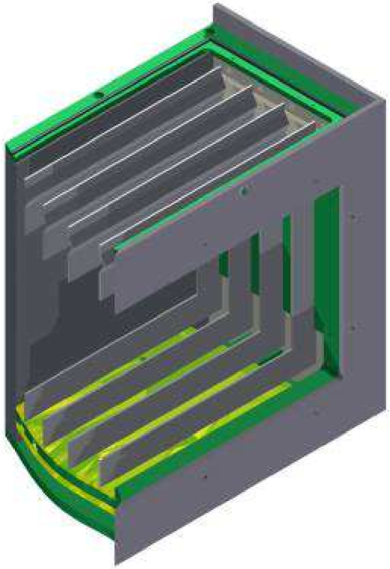


(b) SNR for sensors with 0.1% x/X_0

2012

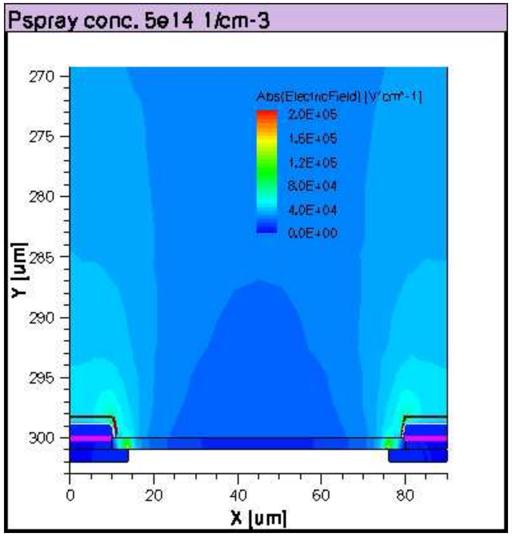
- Total of 1h proton irradiation for HLL Munich
  - Test of SOI n-in-p sensors on FE-I4 and Parylene coating
- Construction of a new irradiation box allowing up to 4 layers and N_2 flushing to all layers (currently 2 nozzles blowing on target)
- 2 diploma theses profiting from HHA support:
  - S. Frech, *Quantifizierung der Strahlenhärte von Siliziumstreifensensoren aus unterschiedlichen Grundmaterialien*, KIT, 2012, IEKP-KA/2012-021
  - M. Strelzyk, *Design studies of n-in-p silicon strip sensors for the CMS Tracker*, KIT, 2012, IEKP-KA/2012-022

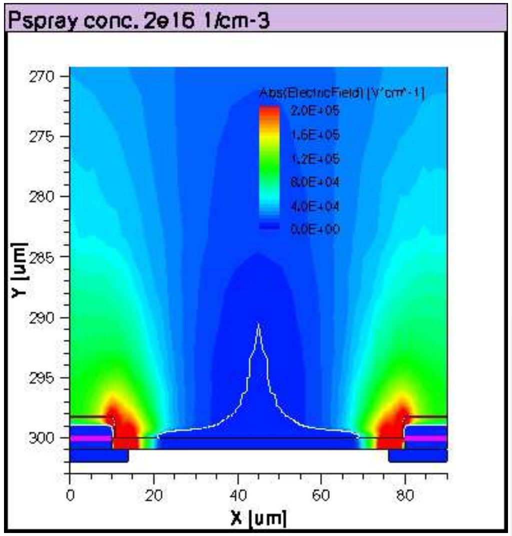




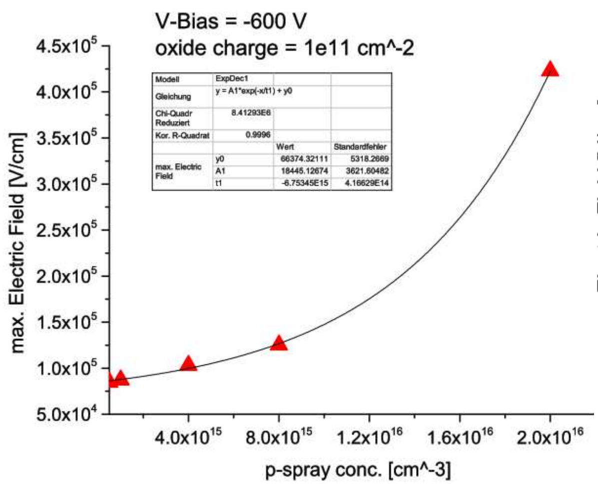
Design studies of n-in-p silicon strip sensors for the CMS Tracker

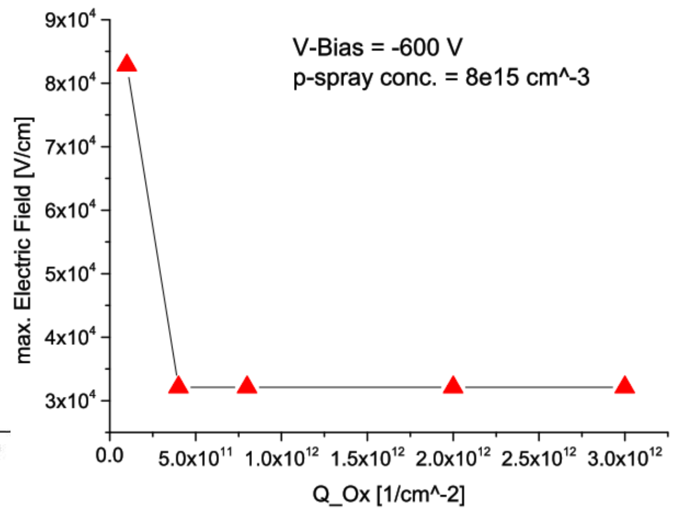
- M. Strelzyk (Karlsruhe)
- E.g.: Strip isolation T-CAD study
  - p-spray technique requires some care to avoid high field break-down before irradiation
  - p-stop works for a wider range of concentrations and should not be placed close to the strip implants





IEKP-KA/2012-022





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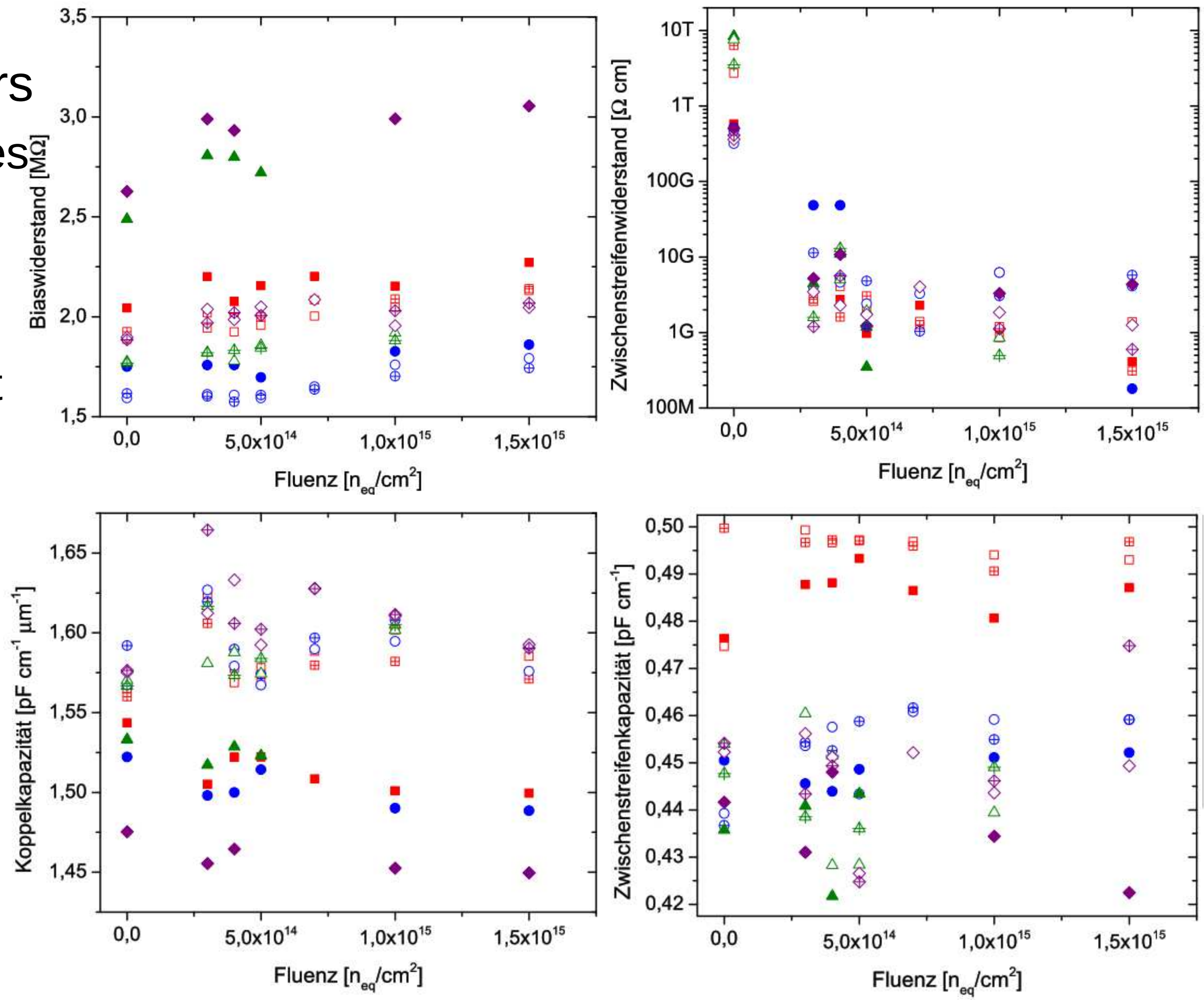
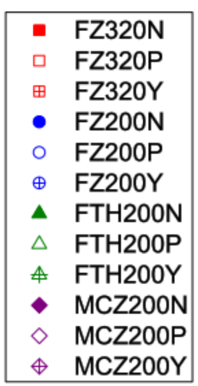
Quantifizierung der Strahlenhärte von Siliziumstreifensensoren aus unterschiedlichen Grundmaterialien

- S. Frech (Karlsruhe)
- E.g.: Strip parameters
  - No severe changes of most strip parameters with irradiation
  - R_{int} drops fast, but settles at high enough values to guarantee strip isolation

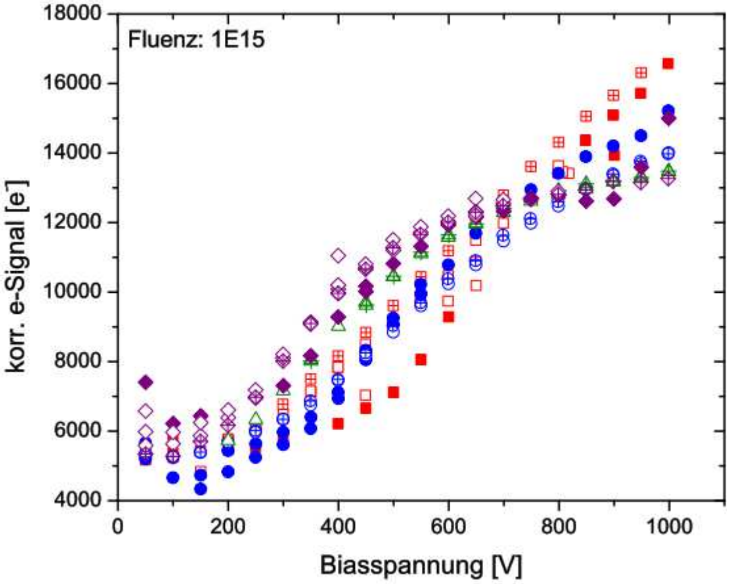


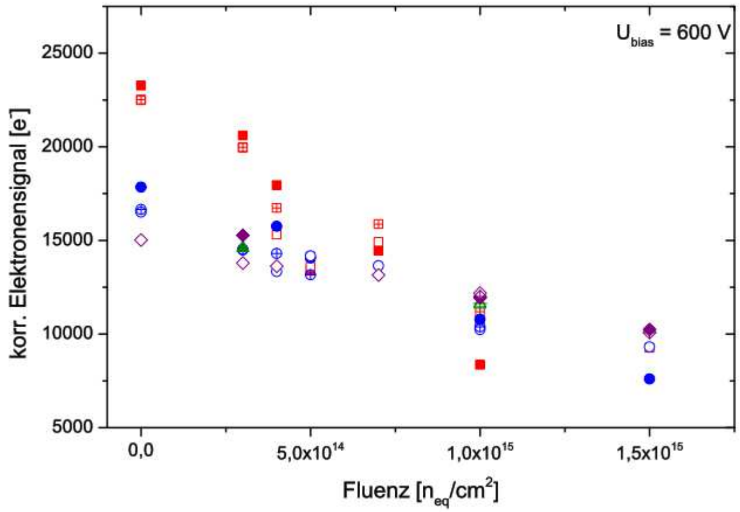


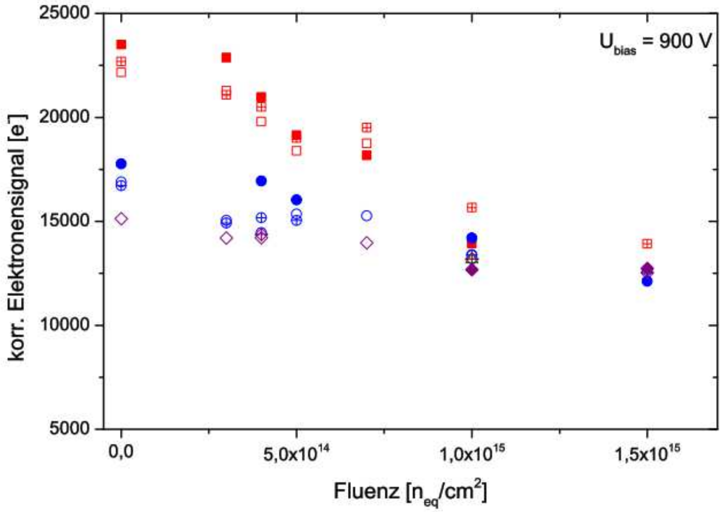
IEKP-KA/2012-021

Quantifizierung der Strahlenhärte von Siliziumstreifensensoren aus unterschiedlichen Grundmaterialien

- S. Frech (Karlsruhe)
- E.g.: Charge collection
  - Thin sensor materials become superior to standard 320µm sensor at around 1e15neq/cm² especially for low bias voltages
  - No reasonable signal seen on FZ320N at 1.5e15n_{eq}/cm² (max. expected fluence for CMS Strip Tracker)







IEKP-KA/2012-021

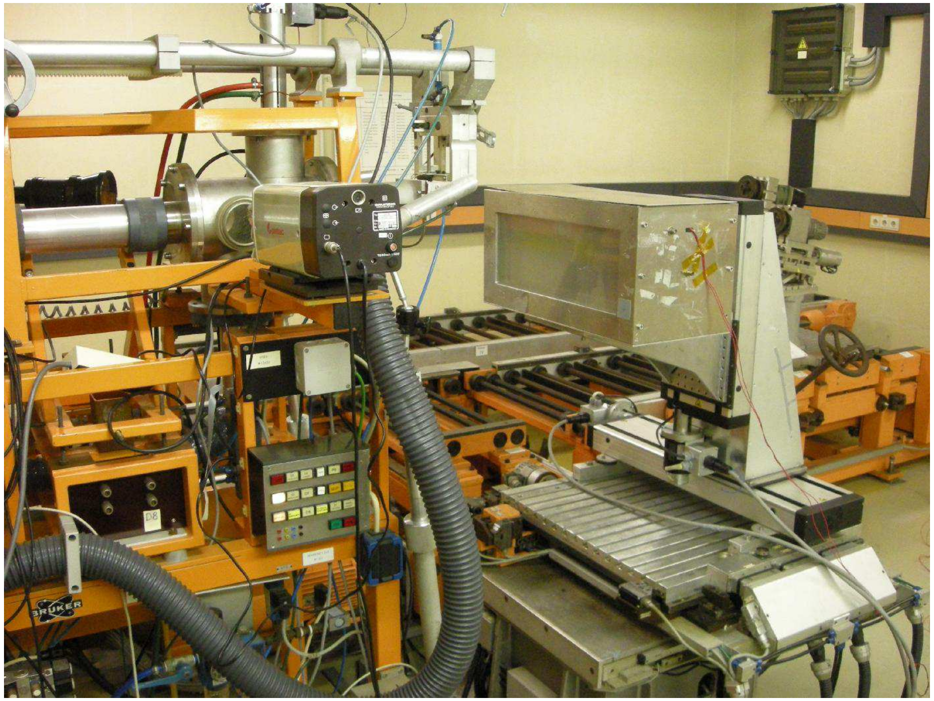
Conclusion

- Many irradiation studies have been performed with the help of the Alliance funding resulting in several publications (including acknowledgement of Alliance! ☺).
- Due to the participation of many Alliance members this workpackage was successfully run in the sense of the Alliance initiative.

Thank you!

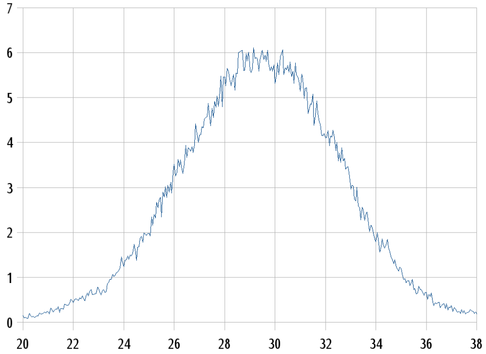
Backup

Proton Irradiation Facility

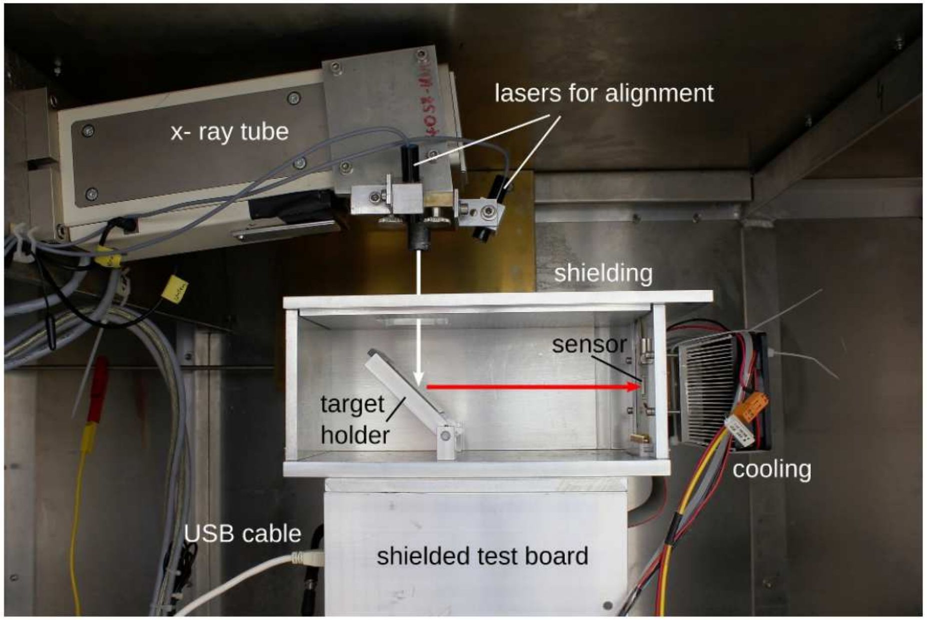


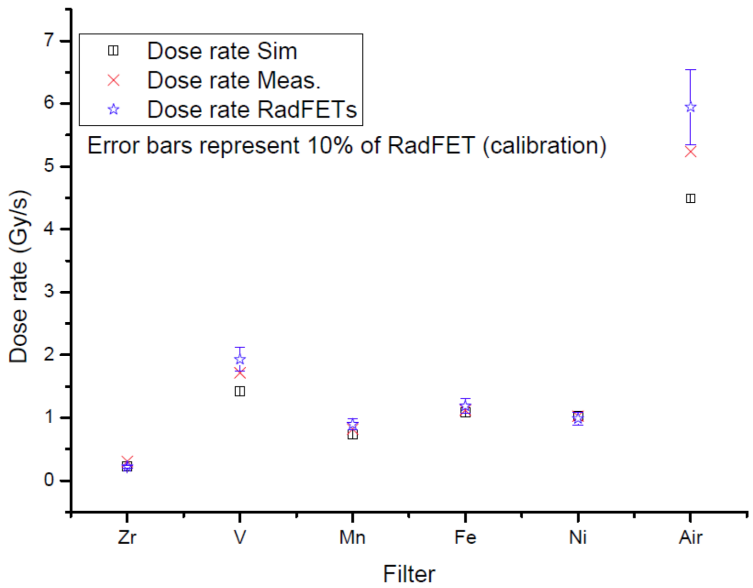
Irradiation box on XY-stage with beam line. Samples are fixed to Al-frames inside the box and scanned to reach uniform exposure.

Proton Energy	~23MeV (25.3MeV at extraction)
Proton Current	~1.5µA (100nA - 20µA)
Max. Object Width	44cm
Max. Object Height	17cm
N2-Cooling Temp.	≥-30°C
Beam Diameter	~5-10mm

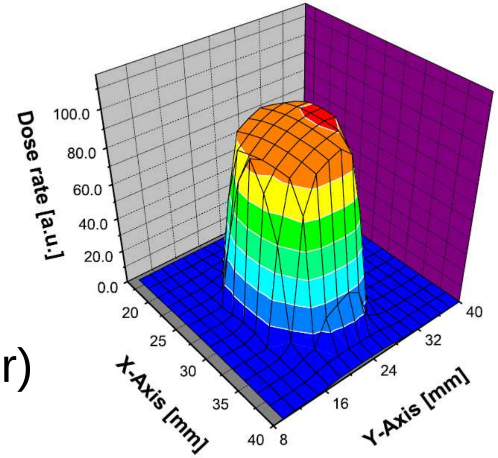


X-Ray Setup





Accelerating Voltage	20-60 kV
Electron Current	2mA - 33mA (Pmax=2kW)
Beam Spot Diameter	1-2cm
Dose Rate	< 18kGy/h
	(depends on distance and filter)



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