Characterization and Testbeam Analysis of irradiated Silicon n-in-p Pixel Detectors for the ATLAS Upgrade

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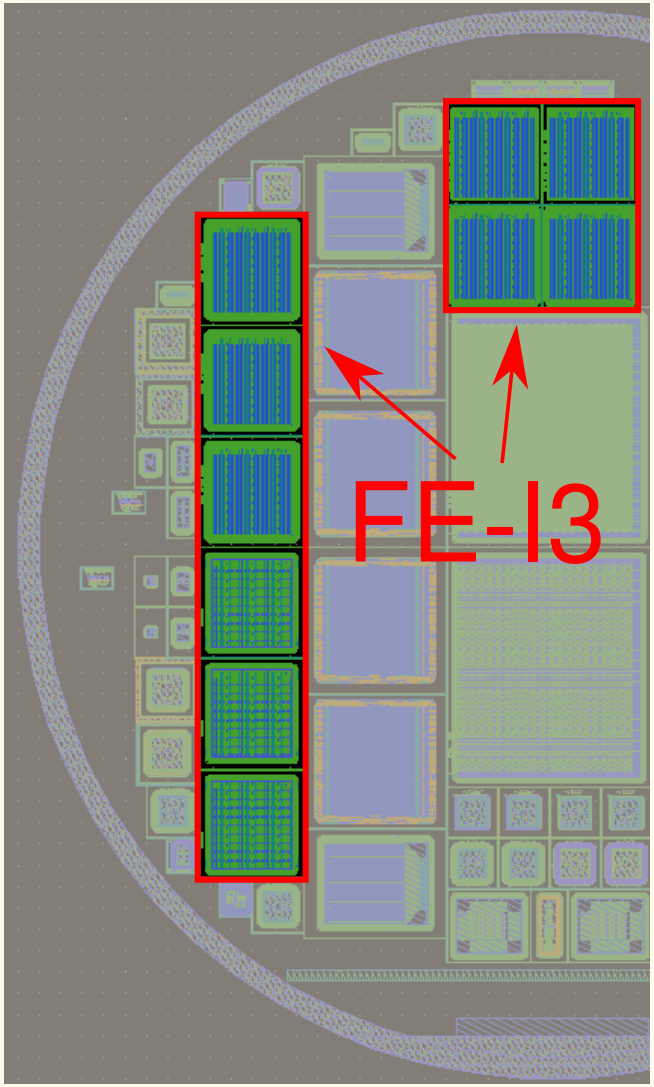
17th RD50 Workshop
CERN - November 2010

Contents

CiS-Production (n-in-p Batch)



Production within RD50 Collaboration &
ATLAS Planar Pixel Sensor Group

Technology

18 Fz n-in-p wafers, 300 µm thick delivered by CiS.

Advantages

Single-sided process ⇒ Simpler and less expensive

Structures

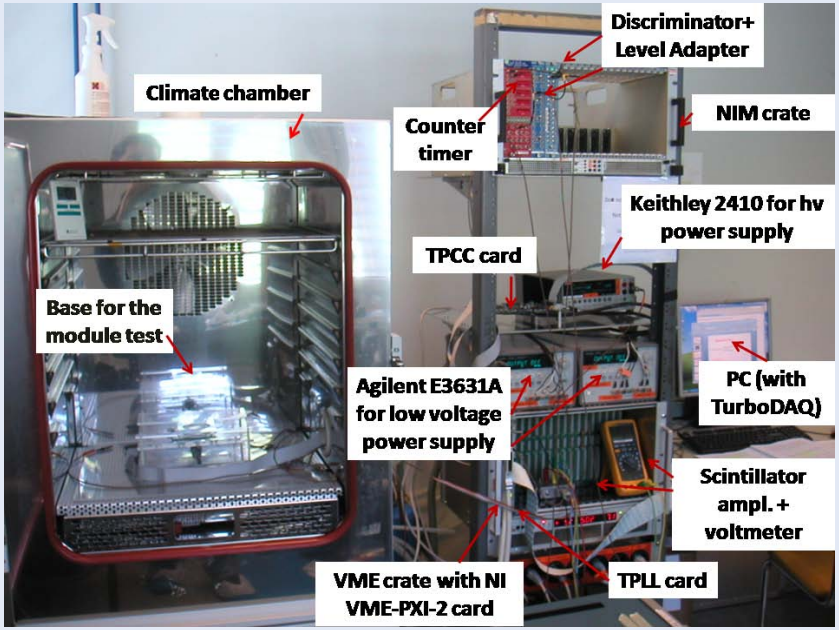
10 FE-I3: Single Chip Assembly (SCA) with different guard-ring (GR) and isolation schemes

HV stability

No sparks up to 700 V due to BCB (Benzo Cyclo Butene) passivation

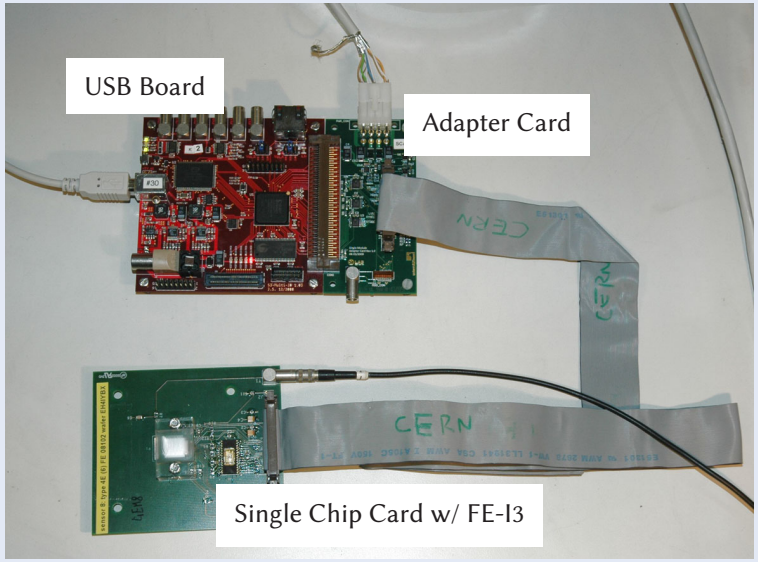
DAQ-Systems

TurboDAQ setup



- TPLL and TPCC, VME based
- ATLAS FE-I3

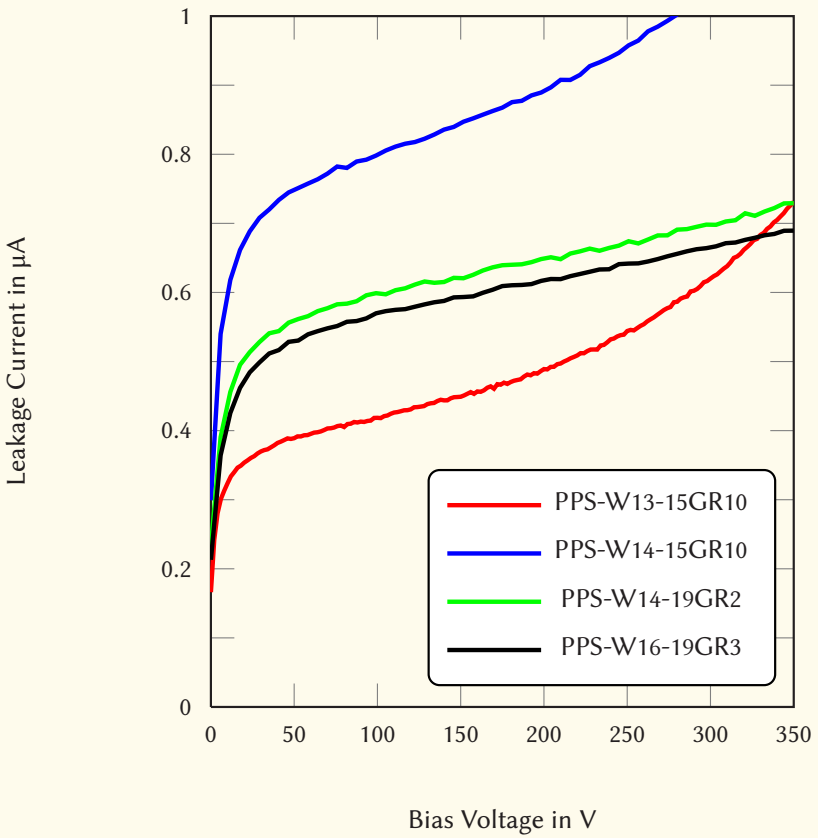
USBPix setup



- USB based
- ATLAS FE-I3 and FE-I4

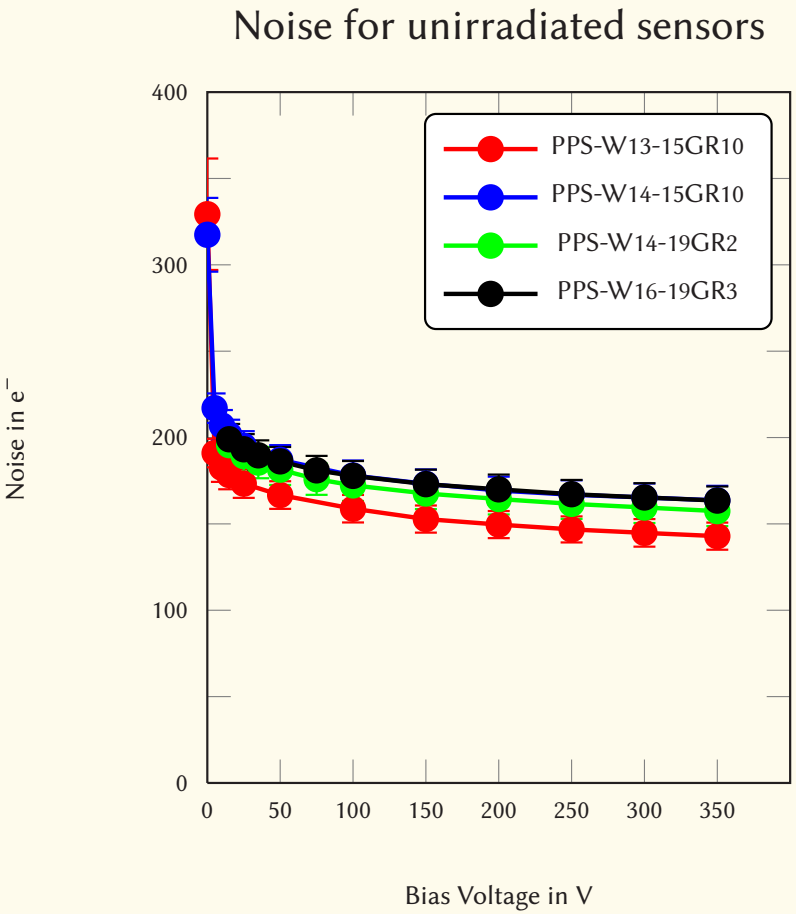
IV-Analysis

IV-Measurements for unirradiated sensors



- Suggested working point for unirradiated sensors:
  - Bias voltage 150 V

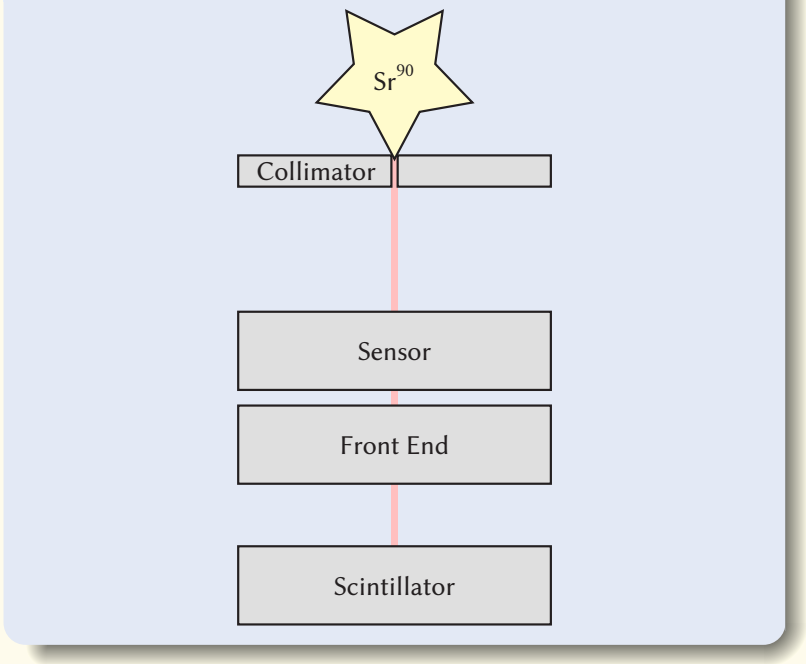
Threshold-Tuning



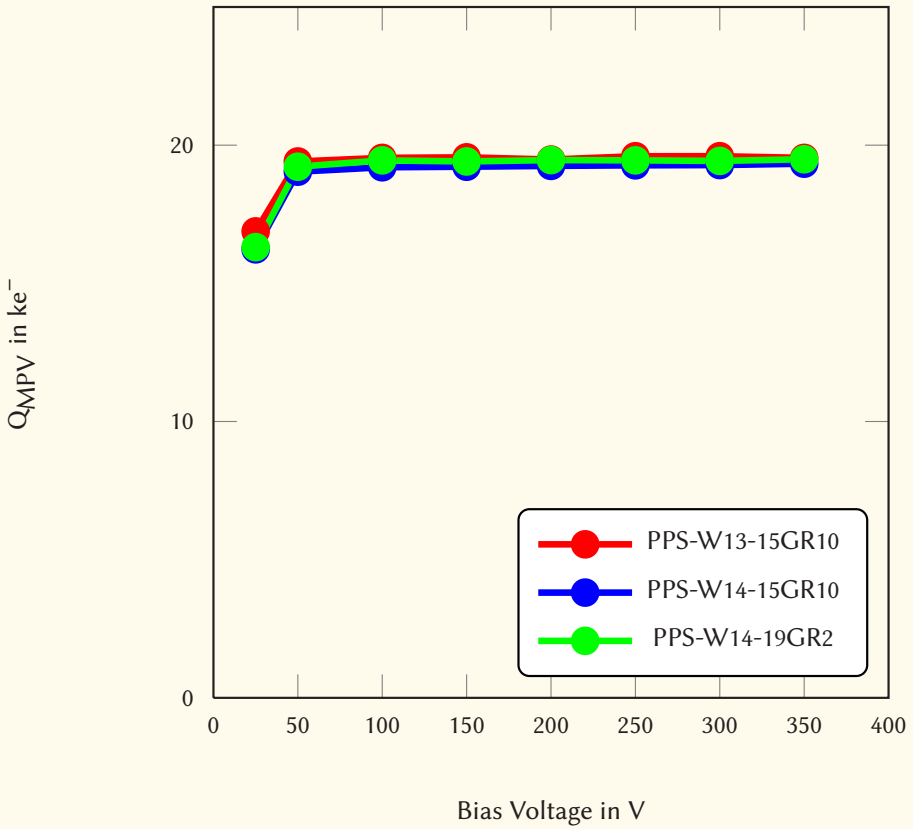
- Noise behavior is consistent with theory
- FE-noise is ~130 e^-
  - Sensor noise @ 150 V = ~40 e^-

Sr90 Mesurements

external trigger setup



Charge distribution for CS2



- Theoretical values for 285 µm Silicon:
  - Q_{mean} ~30.7 ke^-
  - Q_{MPV} ~21.9 ke^-

Irradiation

Finished irradiation:

- **CERN** protons at 24 GeV
  1 sensor at $\sim 6.2 \times 10^{14}\ n_{eq}/cm^2$
  1 SCA at $\sim 2 \times 10^{15}\ n_{eq}/cm^2$
  1 sensor at $\sim 2.5 \times 10^{15}\ n_{eq}/cm^2$
  1 SCA at $\sim 2.5 \times 10^{15}\ n_{eq}/cm^2$
  1 SCA at $\sim 3 \times 10^{15}\ n_{eq}/cm^2$
  1 sensor at $\sim 4.4 \times 10^{15}\ n_{eq}/cm^2$
  SCA cooling down
- **Karlsruhe** protons at 25 MeV
  1 SCA at $1 \times 10^{15}\ n_{eq}/cm^2$
- **Ljubljana** neutrons
  1 SCA at $1 \times 10^{15}\ n/cm^2$

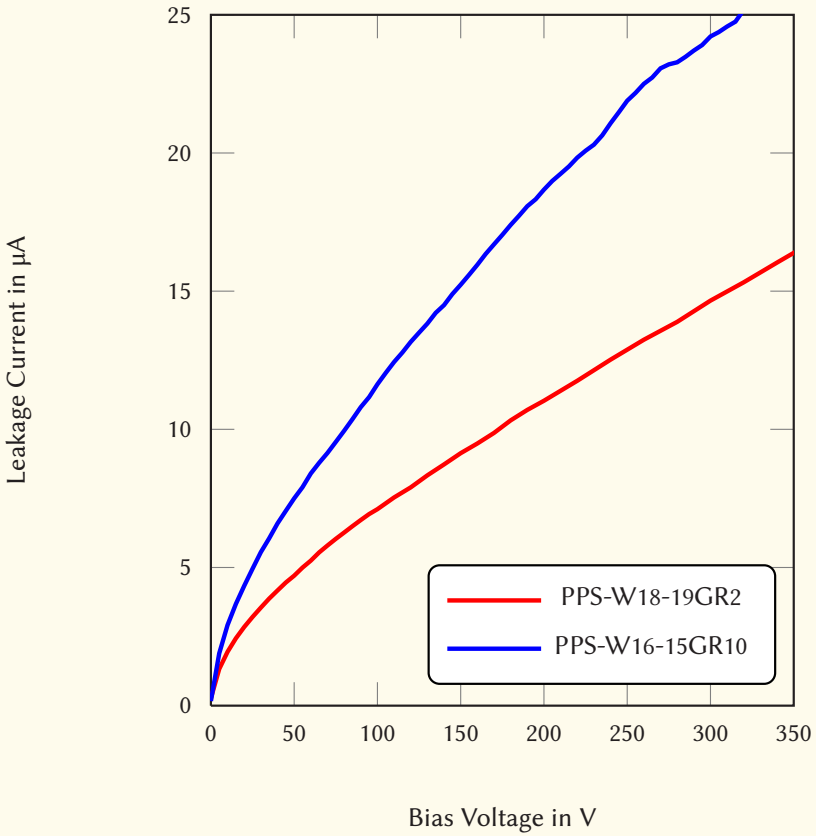
Upcoming irradiation:

- **Karlsruhe** protons at 25 MeV
  1 SCA at $3 \times 10^{15}\ n_{eq}/cm^2$
  1 SCA at $5 \times 10^{15}\ n_{eq}/cm^2$
- **Ljubljana** neutrons
  1 SCA at $3 \times 10^{15}\ n/cm^2$
  1 SCA at $5 \times 10^{15}\ n/cm^2$

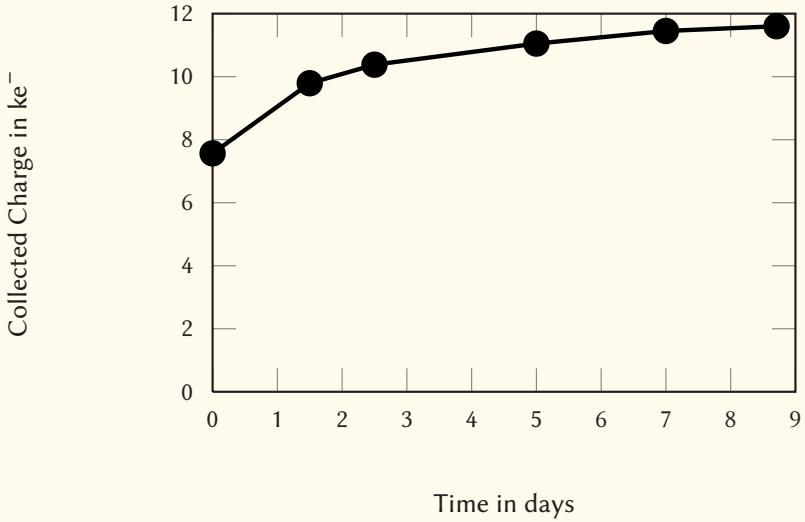
thanks to M. Glaser for the irradiation at CERN
thanks to A. Dierlam and the Helmholtz Alliance for the irradiation in Karlsruhe
thanks to V. Cindro for the irradiation in Ljubljana

IV-Analysis

Irradiated sensors at $-20\,℃$; fluence $\sim 1 \times 10^{15}\ n_{eq}/cm^2$



Annealing of W16-15GR10

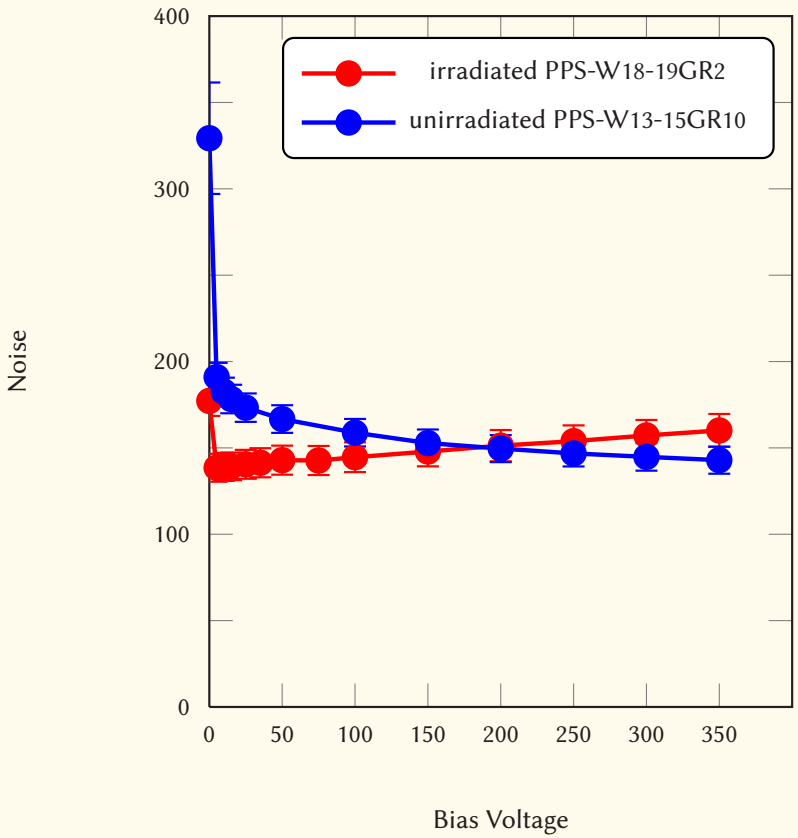


P. Weigell et al. / 8th International Conference on Radiation Effects on Semiconductor Materials Detectors and Devices, Florence October 2010

The calculated damage rate α is within the expected range

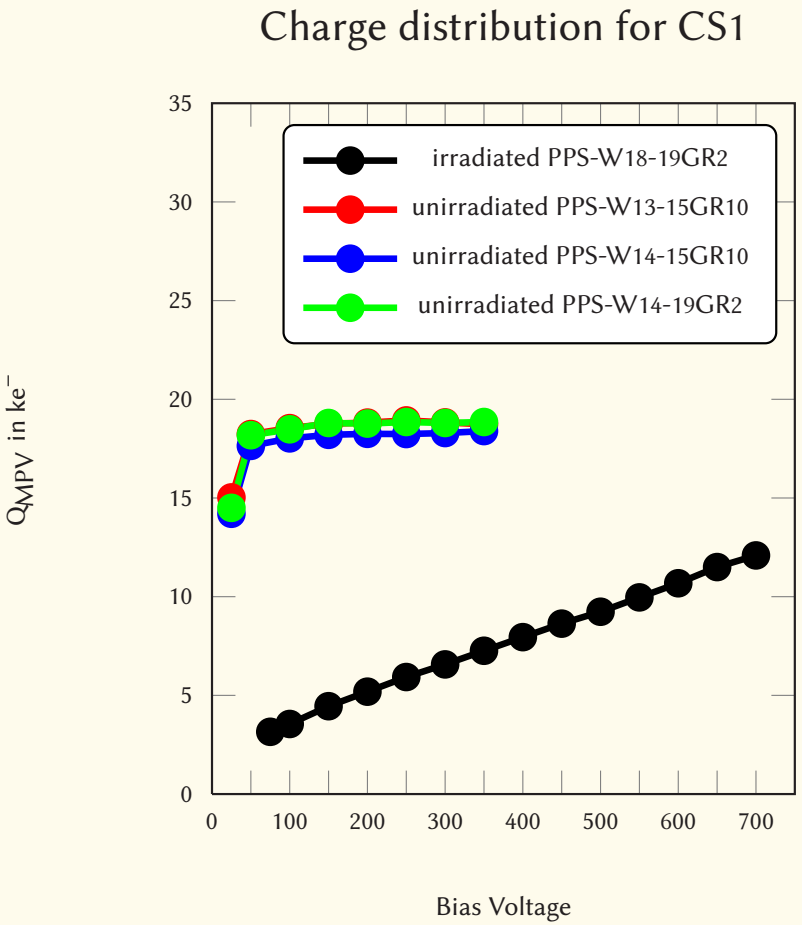
Noise-Analysis

Noise for irradiated and unirradiated sensors



- PPS-W18-19GR2 was neutron irradiated up to 1×10^{15} n/cm^2 in Ljubljana
- Noise for irradiated sensors is increasing with higher bias voltage

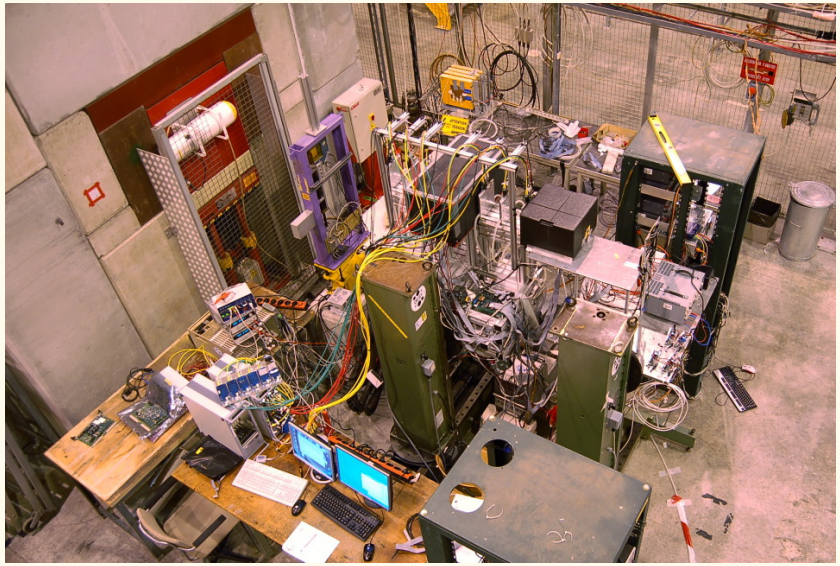
Sr90 Mesurements



- Sufficient charge collection after irradiation
- Increasing charge collection for higher bias voltages
- ~65% of charge collection at 700 V bias voltage compared to unirradiated sensors

Test-Beam Setup

- SPS beamline (H6) with 200 MeV pions
- 6 weeks of beam in 3 periodes
- several samples from different groups
- 6 samples from Munich

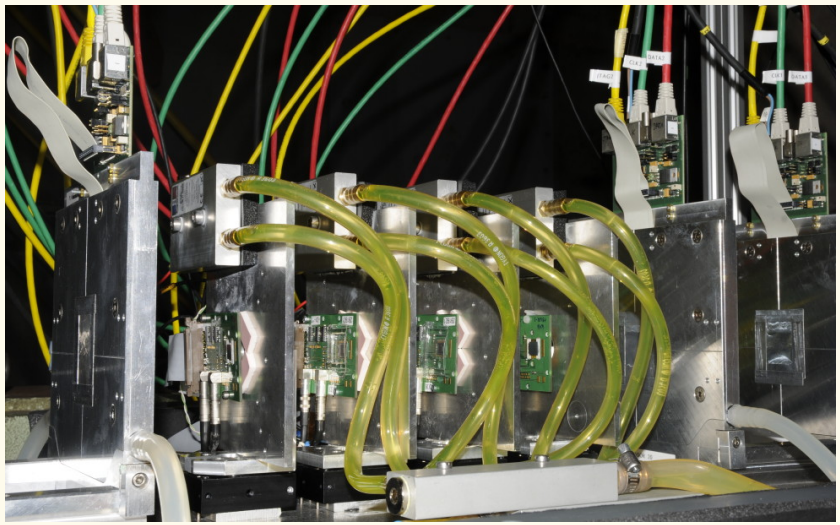


Testbeam-Group July 2010:

M. Benoit, Ch. Gallrapp, M. George, S. Grinstein, Z. Janoska, J. Jentsch, A. La Rosa, S. Libov, D. Muenstermann, G. Piacquadio, B. Ristic, I. Rubinsky, A. Rummler, D. Sutherland, G. Troska, S. Tsiskaridze, P. Weigell, J. Weingarten, T. Wittig

Test-Beam Setup

- EUDET-Telescope with ~4 µm resolution
- Test Beam Analysis
  - Matched clusters
  - All cluster sizes



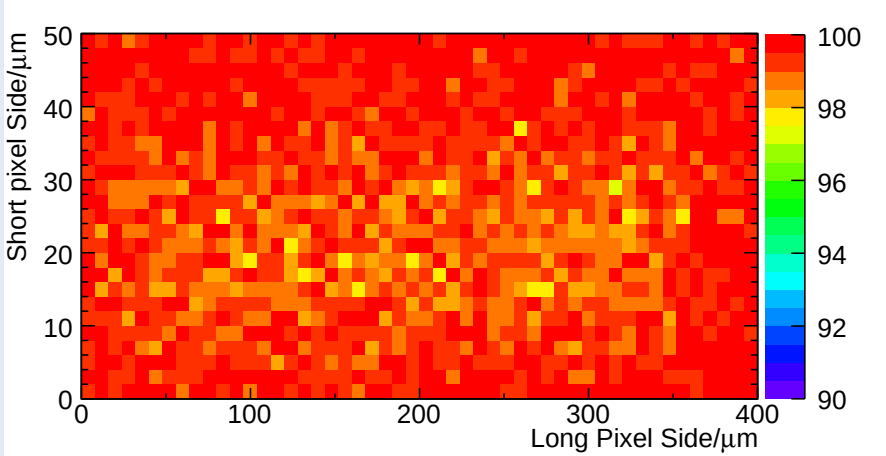
Testbeam-Group October 2010:

M. Beimforde, M. Benoit, M. Bomben, G. Calderini, Ch. Gallrapp, M. George, S. Gibson, S. Grinstein, Z. Janoska, J. Jentzsch, O. Jinnouchi, T. Kishida, A. La Rosa, V. Libov, A. Macchiolo, G. Marchiori, D. Muenstermann, R. Nagai, G. Piacquadio, B. Ristic, I. Rubinskiy, A. Rummler, Y. Takubo, G. Troska, S. Tsiskaridze, I. Tsurin, Y. Unno, P. Weigell, J. Weingarten, T. Wittig

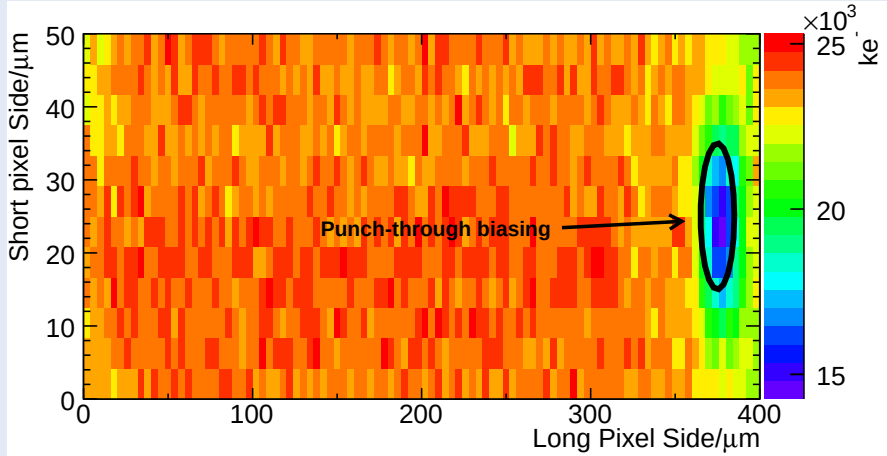
Test-Beam Results - Unirradiated Sensors

- High efficiency for unirradiated sensor: $\epsilon = 99.31\%$
- Good charge collection, also in the punch-through region well above threshold

Efficiency map



Collected charge by track

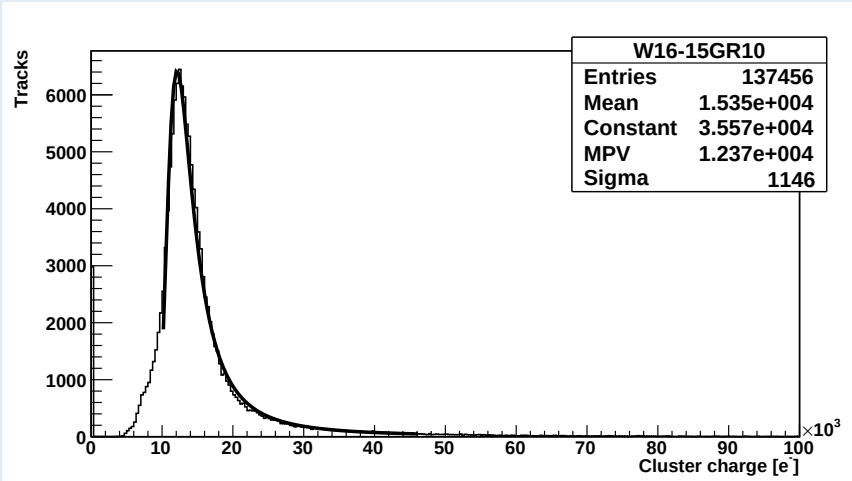


Preliminary TB results

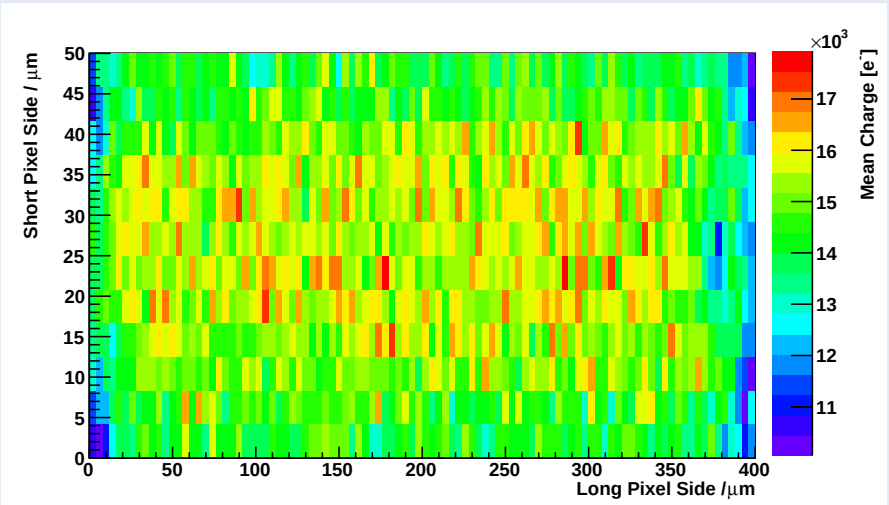
Test-Beam Results - Proton Irradiated Sensor $10^{15} n_{eq}/cm^2$

- Collected charge is in aggreement with lab-measurements
- Good charge collection in the whole sensor area

Collected charge at 500V



Collected charge by track at 500V

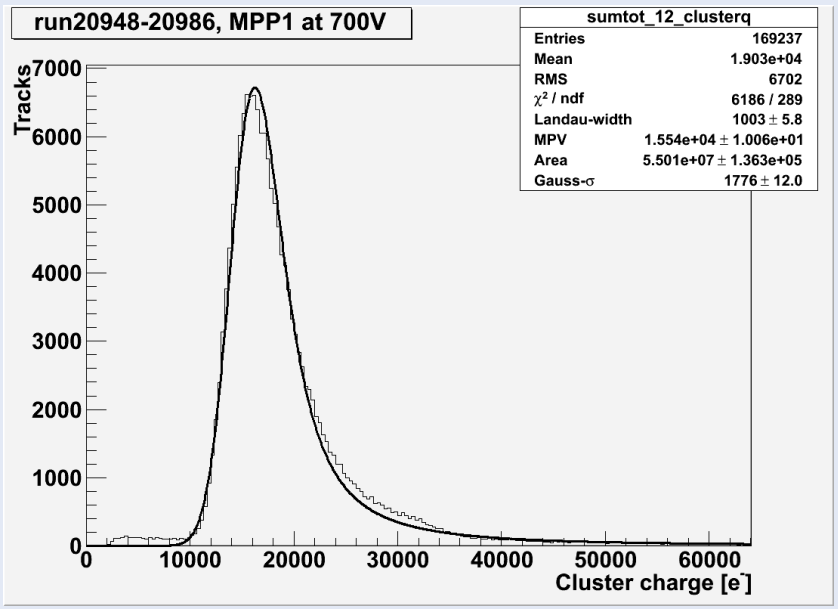


Preliminary TB results

Test-Beam Results - Neutron Irradiated Sensor $10^{15} n_{eq}/cm^2$

- stable performace for several days at 700 V
- Good charge collection well above threshold

Collected charge at 700V



Preliminary TB results

Summary

Results

- Good threshold to noise ratio
- Good performance for irradiated sensors with Sr^{90}
- First promissing test-beam results for irradiated sensors
- HV-Stability up to 700 V

Plans

- Show HV stability for higher voltages needed for IBL fluences
- Measurements on higher irradiated sensors

Thank you for the attention!
Questions?