Development of Radiation tolerant Silicon microstrip sensors of n- and p-single-sided readout on n-bulk Silicon waters

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n-strip readout single-sided sensor

- **N-side microdischarge breakdown**

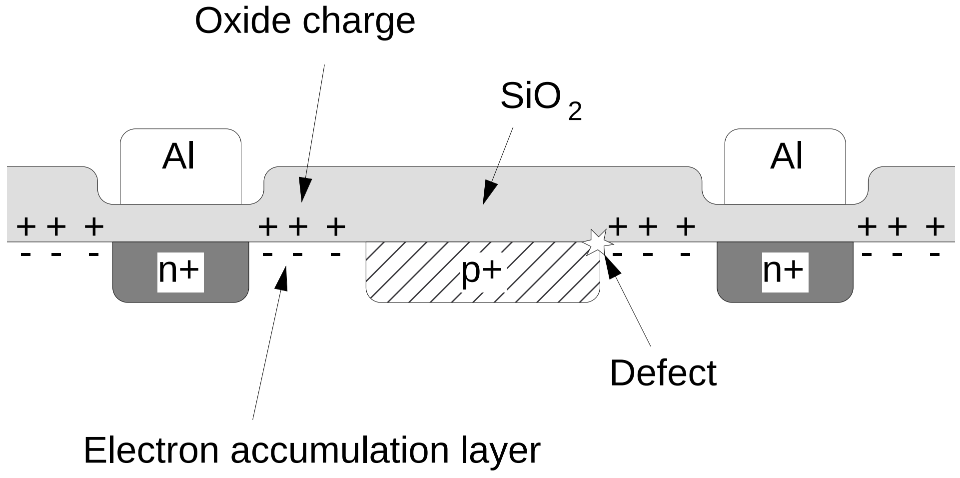
  n-side requires an isolation structure between n^+ readout strips: p-stop structure

  Bulk is p-type, after heavy irradiation

  Main p-n junction in the n^+ strips

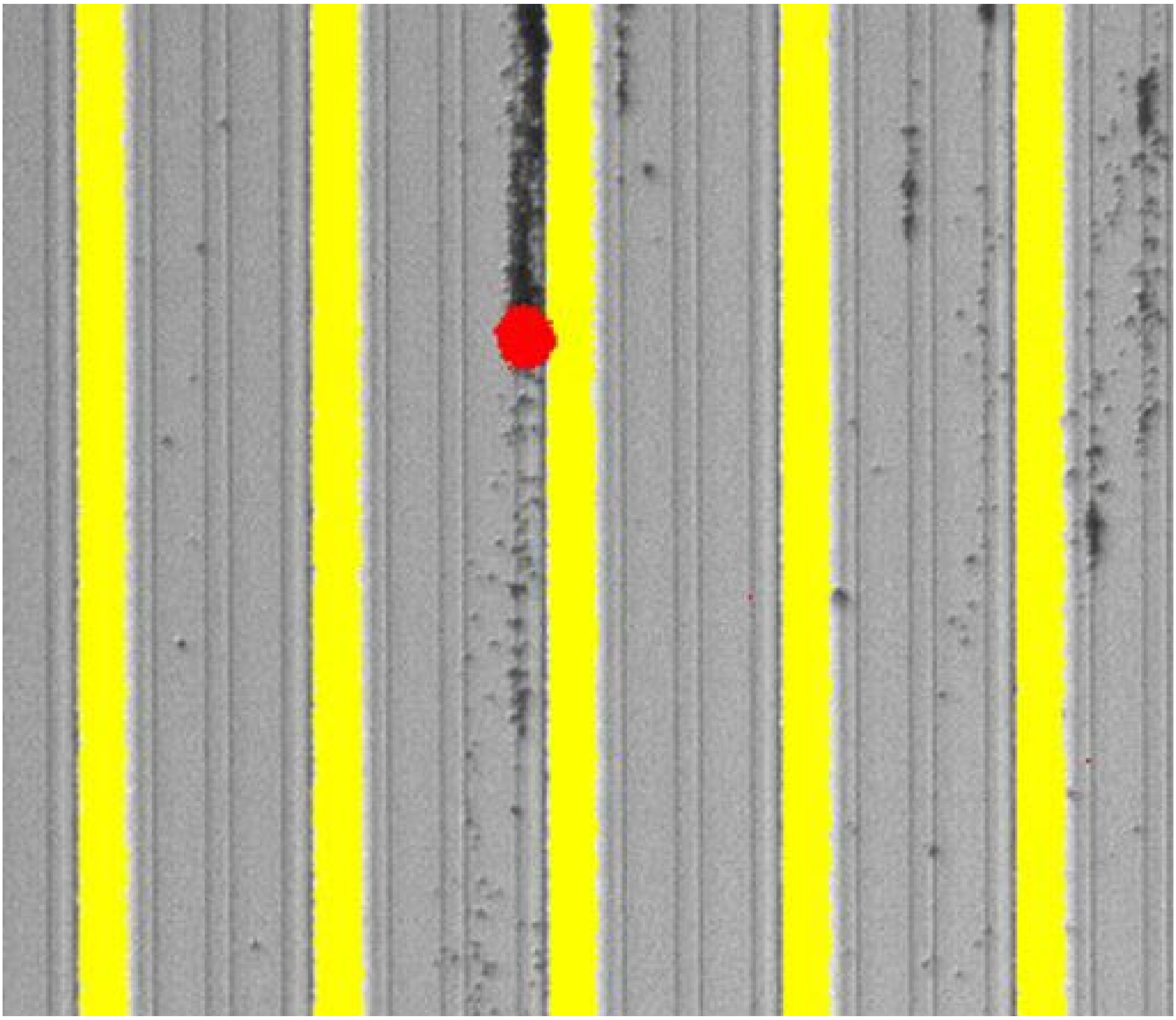
  After irradiation, accumulation of positive oxide charge creates conductive accumulation layer in Silicon

  Edge of p-stop is where the electric field concentrate and defect initiates microdischarge



  Passivation with Oxide over the surface is not drawn in the figures

Microdischarge at the p-stop edge

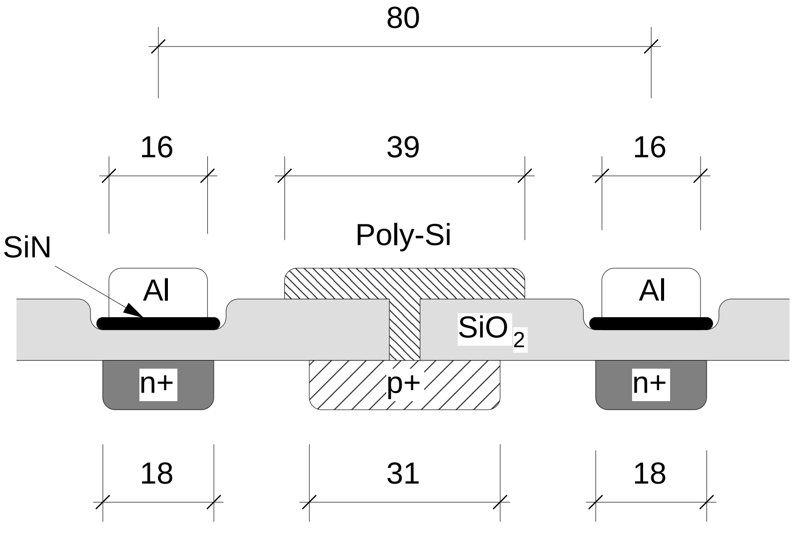


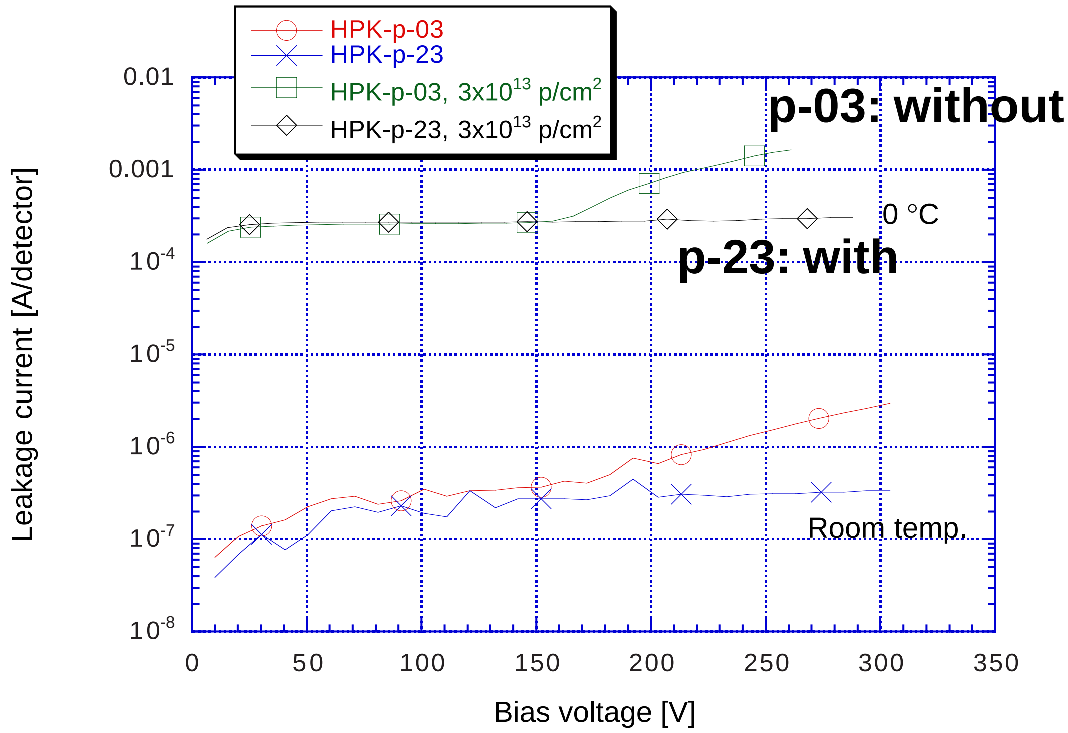
Individual (atoll) p-stop

Red: Hot spot viewed with a highly sensitive IR camera

- **Novel p-stop structure**

Extended Polysilicon dc-coupled plate over the p-stop structure





Polysilicon - high resistivity not to deteriorate the interstrip capacitance

p-strip readout single-sided sensors

- **p-in-n sensors after irradiation**

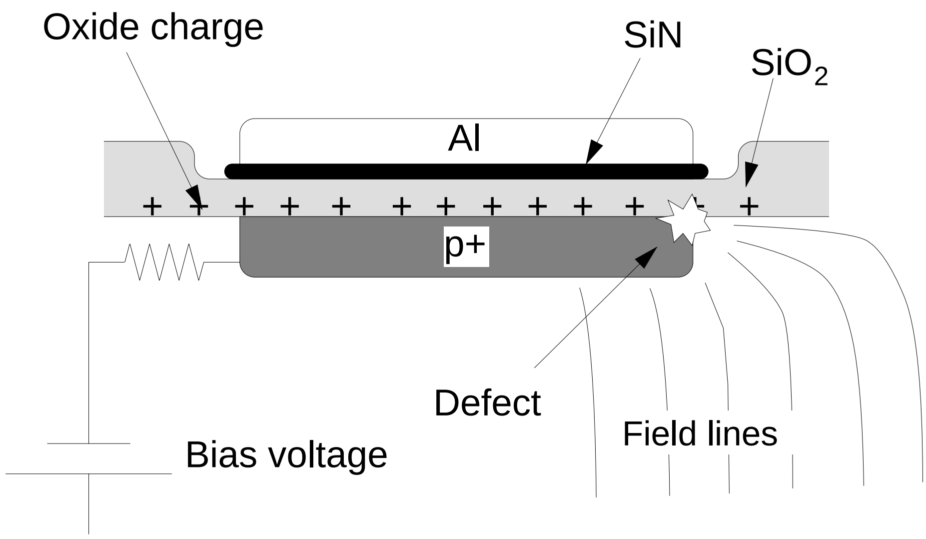
  Main p-n junction moved to the backside -- still work

  p-side, after heavy irradiation, is the ohmic contact

  Positive oxide charge keeps the Silicon in n-type

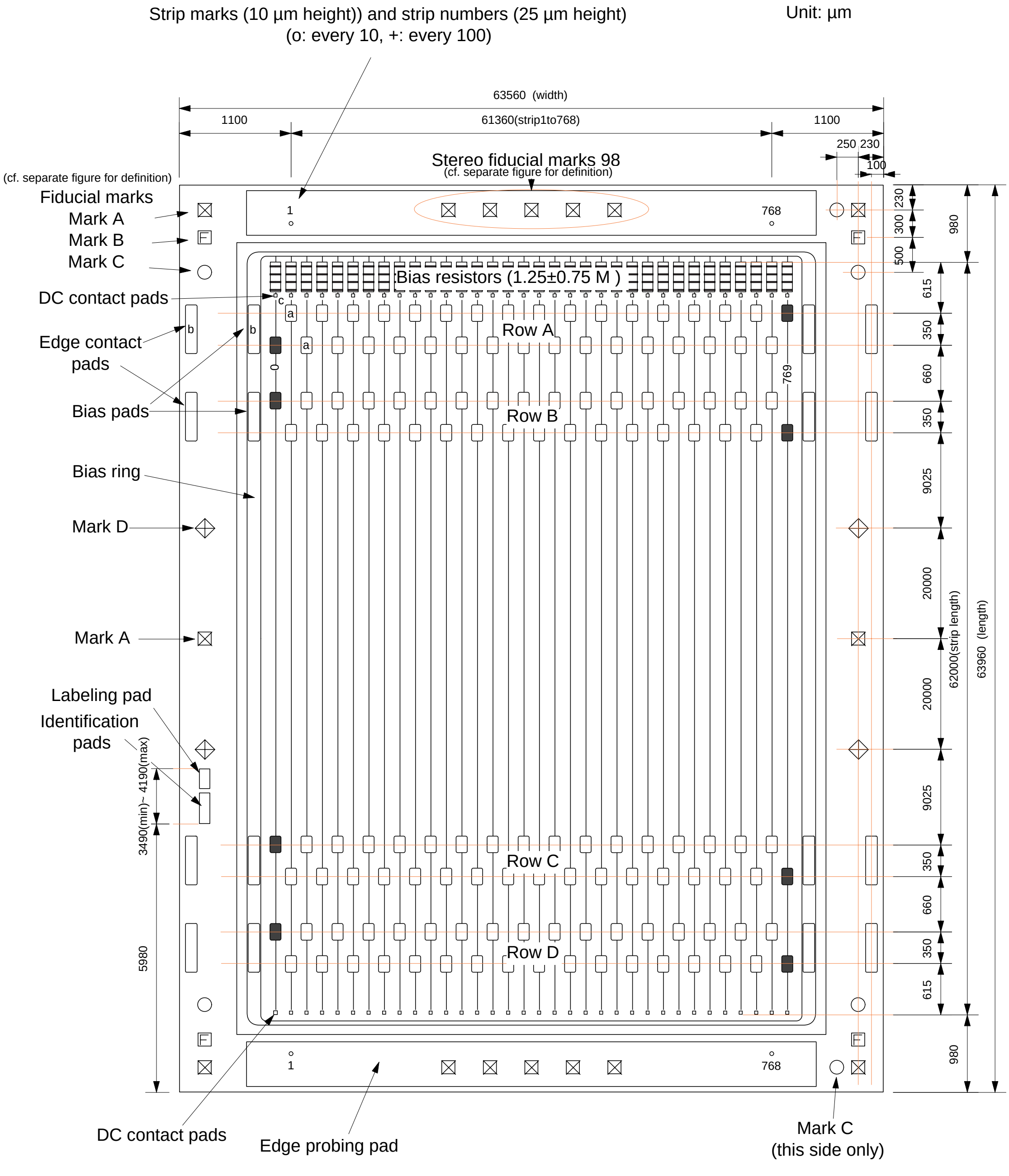
  No need of an isolation structure between p^+ strips

  Large bias voltage creates high electric field at the edge of p^+ strips, and hence, microdischarge



ATLAS98 p-in-n Silicon microstrip sensor

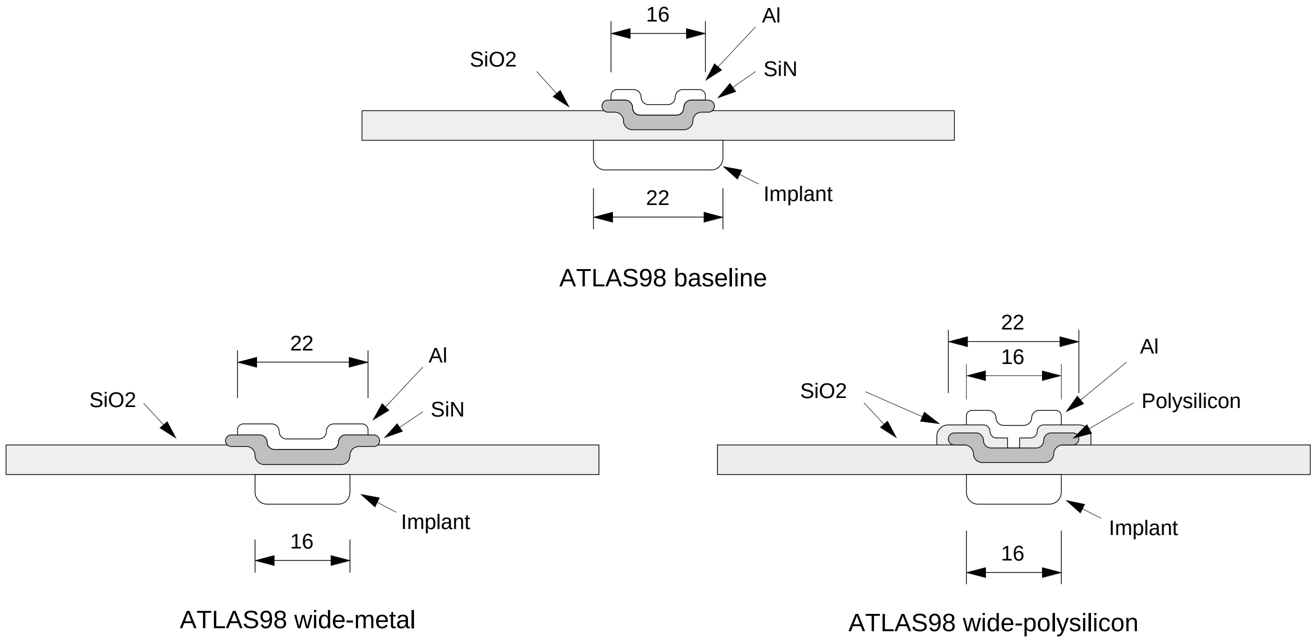
- **6.36 x 6.40 mm2, 80 μm pitch, AC-coupled**



Notes:
(1) Pad sizes: a = 56 µm x 200 µm, b = 80 µm x 550 µm, c = 50 µm x 60 µm
(2) Fiducial marks A & B are "metal-in-opening"
(3) Fiducial marks C & D are either "hole-in-metal" or "metal-in-opening"
(4) Bonding pads of strip 0 and 769 are required if the metal is not connected
to the bias ring permanently
(5) Use "Row C" pads for probing
(6) Dicing tolerance: ±25 µm to fiducial marks and ±25 µm overall

ATLAS98 variants

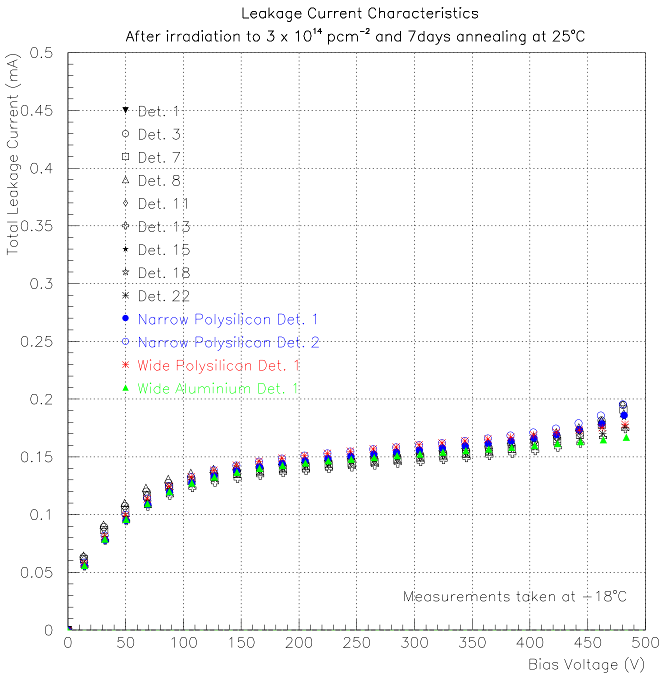
- **ATLAS SCT uses the AC-coupled p-in-n sensors in the configuration that the p-implant and the readout metal are in the same potential, namely ground**
  - **This allows to use the readout metal to move the electric field concentration from the edge of the implant to the edge of the metal in the oxide**
  - **4variants: narrow metal, narrow Polysilicon, wide metal, wide polysilicon**



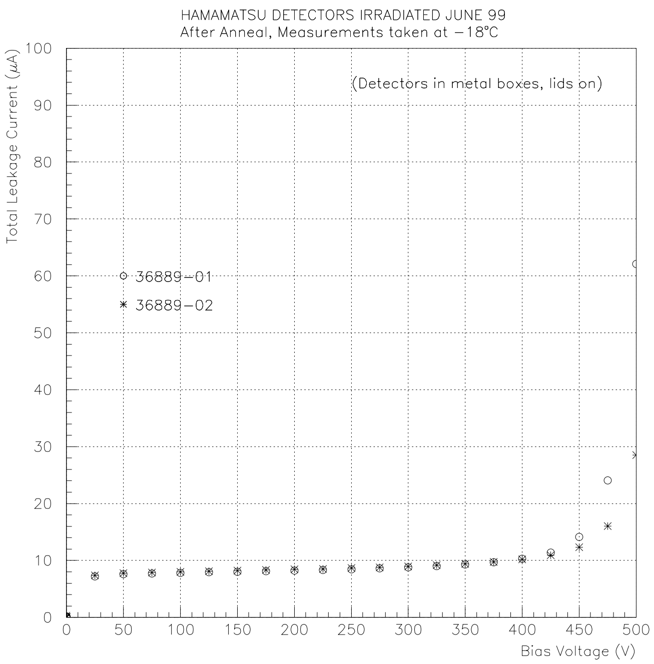
Note: All dimensions are of finish
Passivation layer is excluded

Irradiation

- **Narrow metal or narrow Polysilicon**



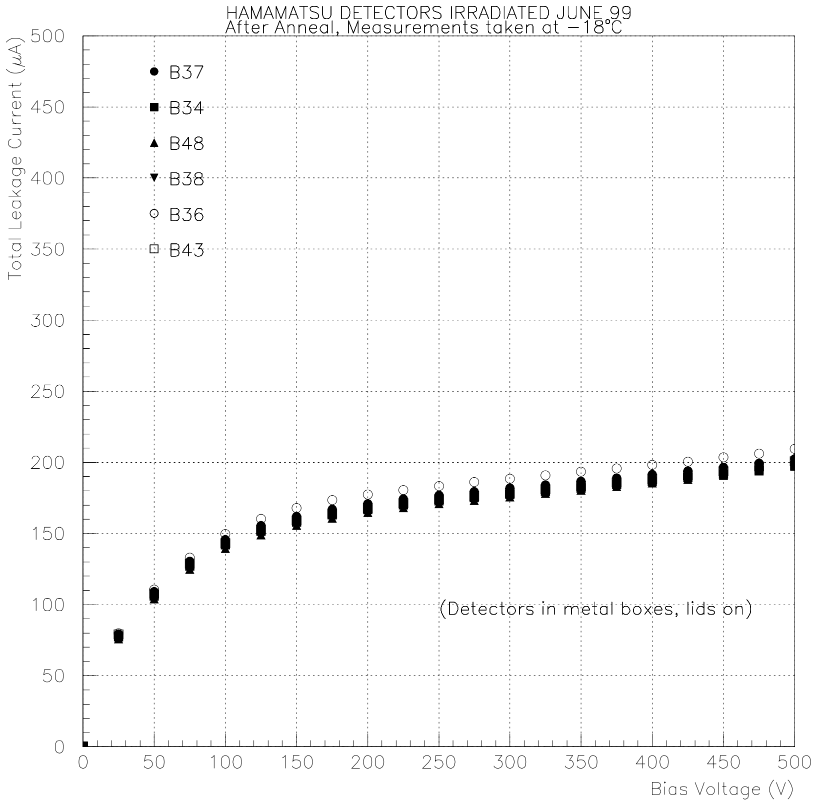
$3x10^{14}$ p/cm^2

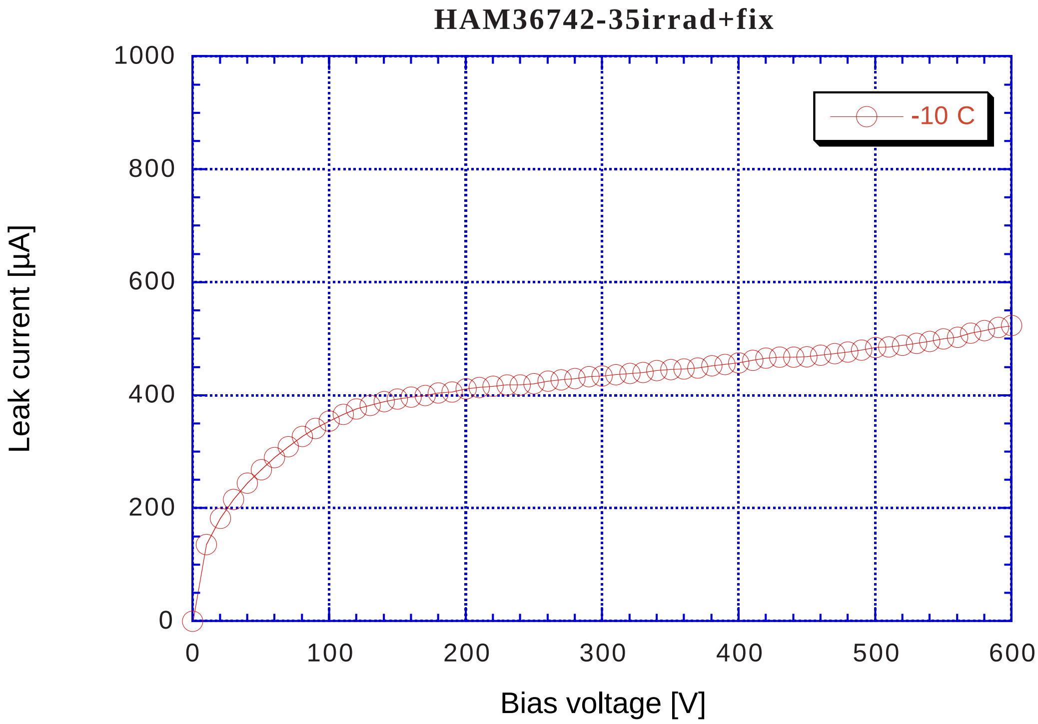


$1.5x10^{13}$ p/cm^2

Irradiation (cont'd)

- **Wide metal**





Summary

- **We have succeeded to suppress microdischarges in the n-in-n and p-in-n Silicon microstrip sensors, after the irradiation of 3×10^{14} protons/cm^2**

- **Our key concept is to have an extended electrode over the edge of the implant in the Silicon, where the electric field gets strong enough to generate the microdischarge, specially the early ones associated with defects, so that the strongest field is inside oxide**

- **In the n-in-n sensors, DC-coupled Polysilicon over the p-stop structure**

- **In the AC-coupled p-in-n sensors, when the potential of the implant and the metal is the same, wide AC metal over the p-implant strip**