# Silicon Detectors for High Luminosity Colliders

## RD50 Status Report

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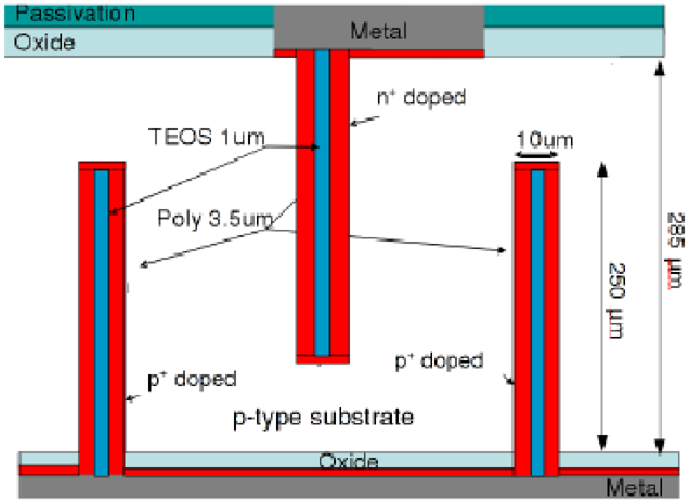
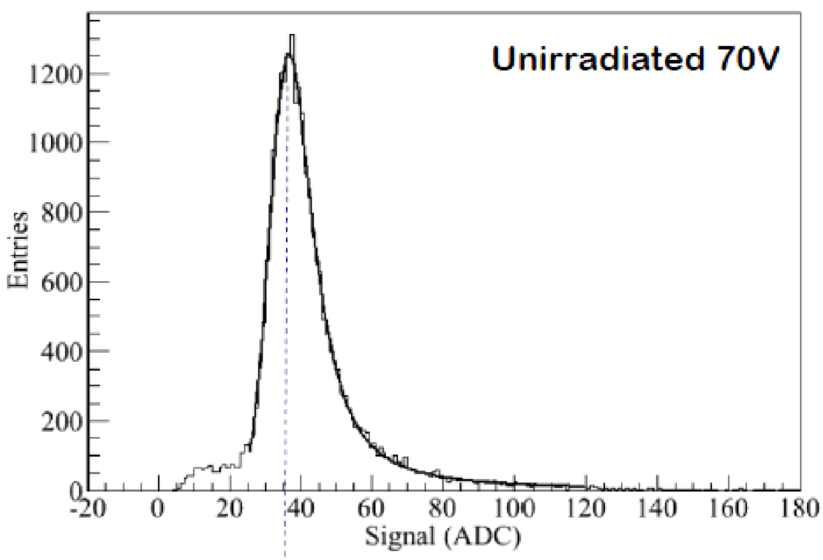
- On Behalf of the RD50 Collaboration -

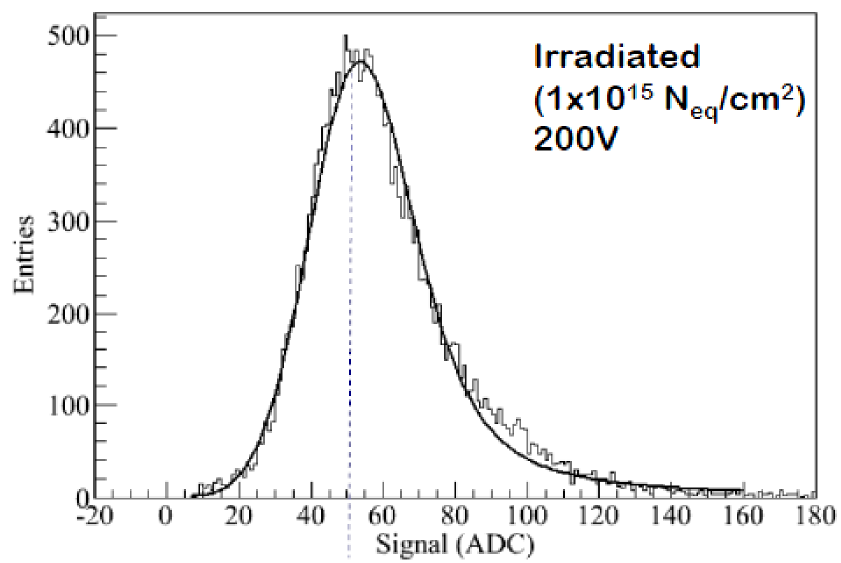
# Charge Collection – 3d Detectors




- Double Sided 3d p-type sensors (made by CNM) in SPS testbeam
- Irradiation at Karlsruhe KIT cyclotron with 26MeV protons
- Higher signal after irradiation than before
  - <u>Charge multiplication</u>



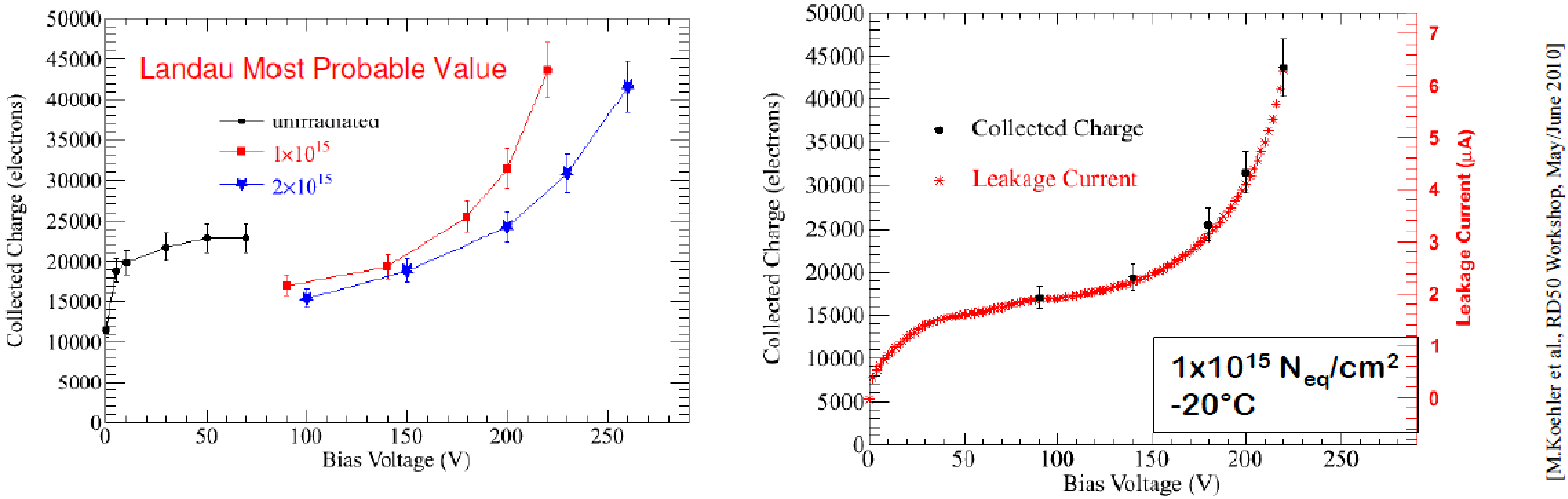

Landau MPV: 35 ADC




Landau MPV: 49 ADC

[M.Koehler et al., RD50 Workshop, May/June 2010]

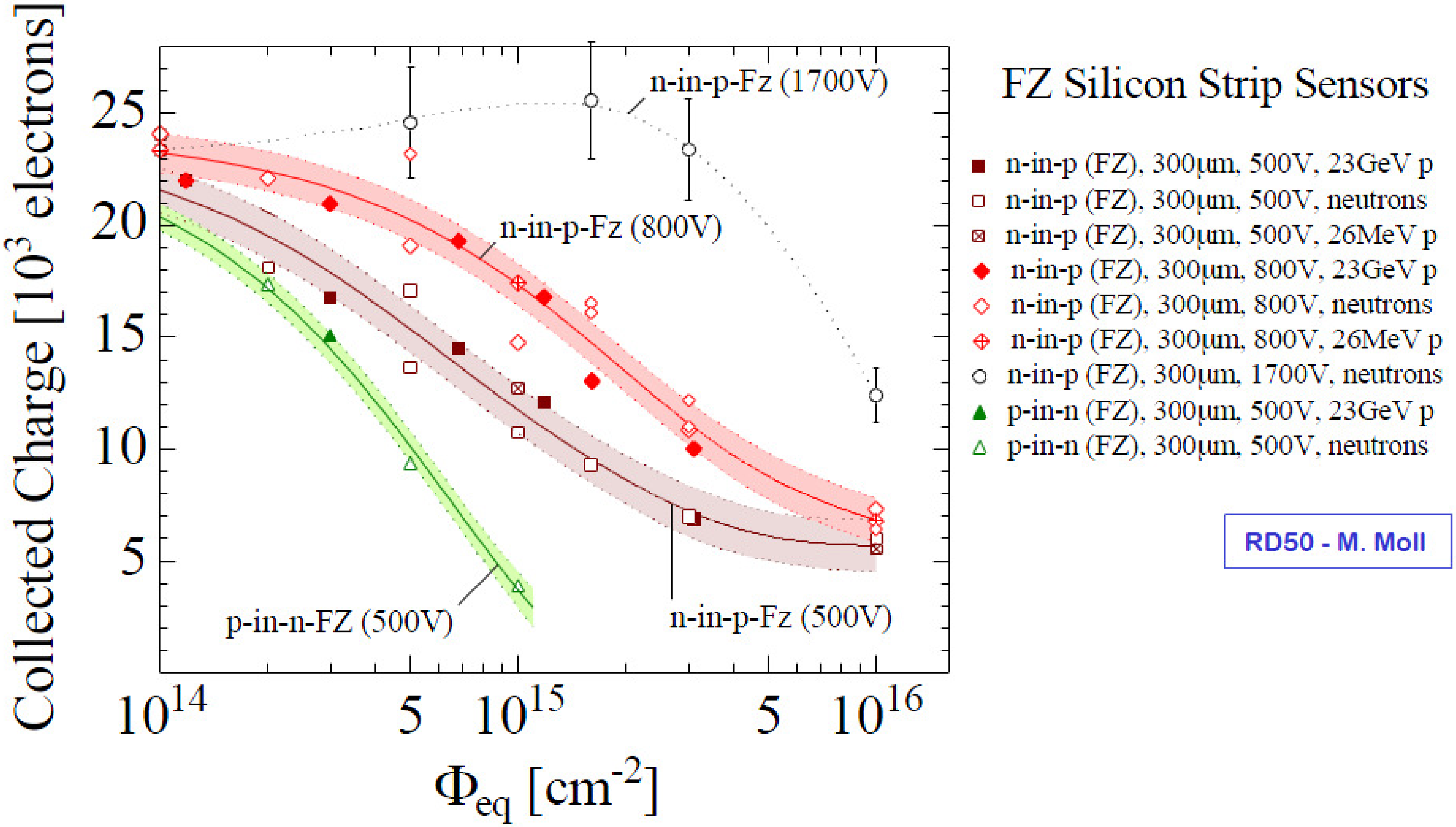
# Charge Collection – 3d Detectors




- All charge is multiplied (also thermally generated charge)
- Origin: avalanche multiplication in high-field region close to junction columns
- P-type detector: $e^-$ drifting near columns get multiplied
  - Effect has also been observed on similar n-type 3D DDTC, but to lesser extent
  - Holes seem to not multiply so easily (due to 3x lower mobility ?)
- Charge multiplication also in irradiated planar p-type detectors, but for higher $V_{bias}$
- High field in 3D detectors facilitates charged multiplication compared to planar designs

# Planar Detector Compilation






RD50 - M. Moll

- p-in-n fades away well before $10^{15} N_{eq}/cm^2$
- n-in-p still gets 50% charge at $10^{16} N_{eq}/cm^2$ at high bias voltages
- n-in-p benefits from charge multiplication (at high bias voltages)
- n-in-p (n-in-n) superior material for high radiation environments

# Conclusions

- RD50 working across experiment boundaries on developing radiation-hard silicon detectors for e.g. the HL-LHC
- Large progress in understanding the effective doping concentration
- For high fluences, significant electric field exists even in undepleted region, resulting in higher signals
- Charge amplification observed on many sensors. CCE benefits from it, but open questions remain
  - The S/N ratio benefits too (mostly), but this may be an issue of the way we derive the noise
  - Can the extra signal be exploited to increase the radiation hardness ?
  - Need to study long-term stability

# Recommendations

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- Disclaimer: some views may be biased
- Planar detectors do better than expected
  - P-type detectors reduce trapping effects and can operate partially depleted
  - Significant electric field exists in undepleted region
  - Charge multiplication gives extra signal
- HL-LHC Si detector recommendations:
- N-in-p (n-in-n) planar detectors
  - good enough for most regions, well understood, expect this to be the default material at HL-LHC
- 3D detectors
  - could add extra radiation hardness and facilitate operation at lower voltage if required for innermost HL-LHC tracking layer(s)
  - watch out for extra costs and risks
- Credits: Tony Affolder, Gianluigi Casse, Paula Collins, Doris Eckstein, Alexandra Junkes, Michael Köhler, Gregor Kramberger, Igor Mandic, Michael Moll, Ioana Pintilie