A Long Term Study of Charge Multiplication

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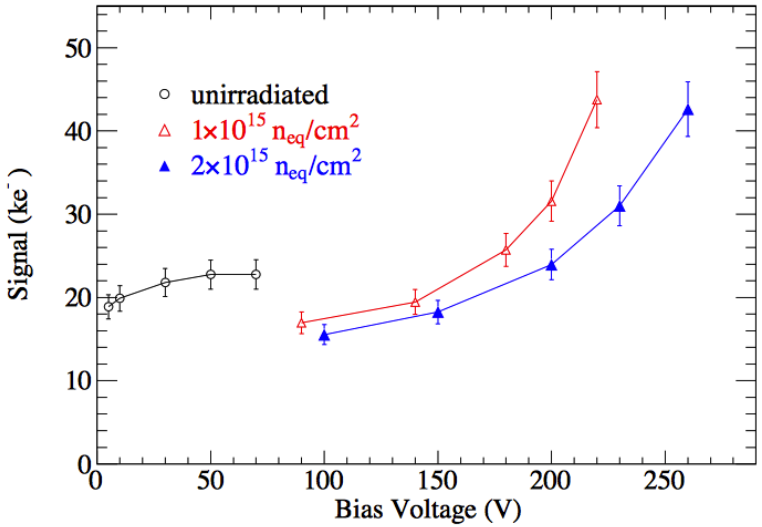
Introduction

- Charge Multiplication (CM) observed on variety of sensors: signal larger than expected from conventional Silicon detector wisdom
- Typical conditions:
  - very high bias voltages (high field)
  - heavily irradiated
  - run at -20° C or lower
  - tests done in short bursts
- CM could give extra signal after years of HL-LHC, increase S/N ratio

Signal in 3D ministrip sensors with CM,
M. Köhler et al, NIM A659 (2011) 272-281



- HL-LHC conditions would mean long fills with HV and cooling turned on
- Want to test if CM is long term stable effect
- Initial results (S. Wonsak et all) indicate potential signal drop with time

Test Equipment

- Sensors: Dedicated RD50 Micron production of p-type mini sensors, various parameters to enhance CM
  - different width/pitch ratios and implantation energies
  - “different thickness” turned out a false promise
  - Results of these sensors presented by several groups, also Chris Betancourt at 23rd RD50 Meeting
- LGAD sensors (discussed in this session)
- Charge collection measurements done with ALIBAVA system and Sr90-source
  - Liquid N_2 cooling system to reach -50° C or below if needed

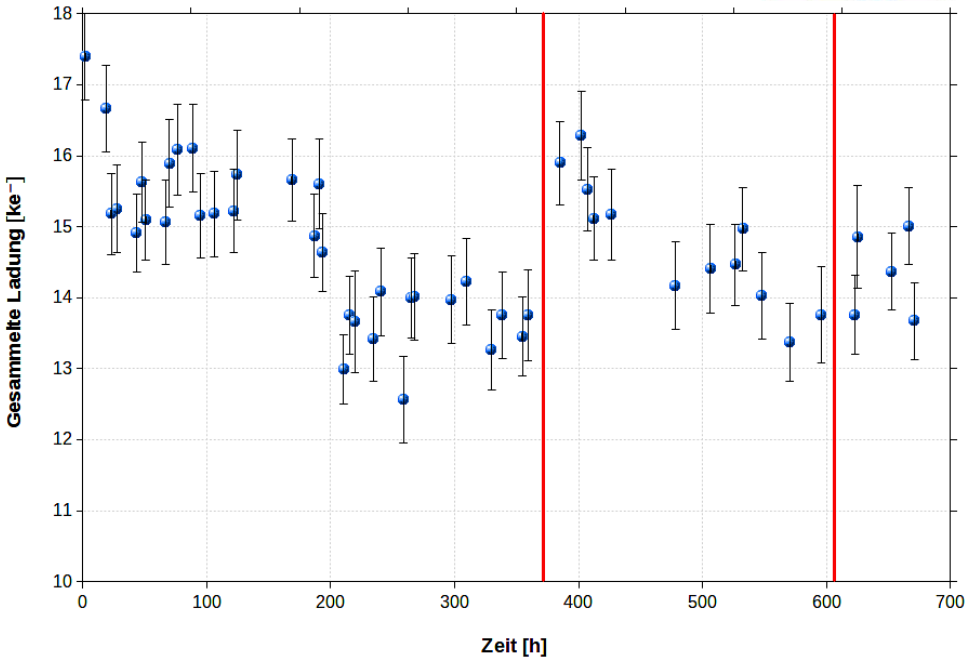
Test Setup & Strategy

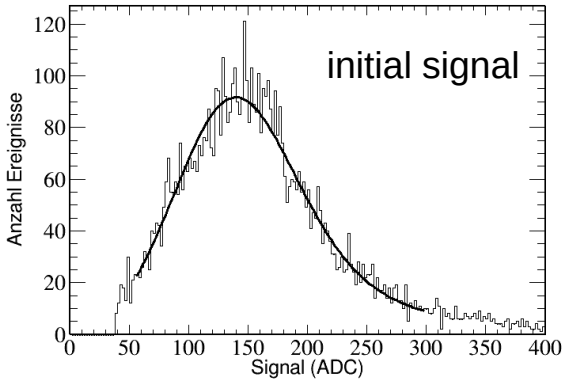
- Concentrate on sensors that (might) show CM
  - High signal after heavy irradiation
- Install in Alibava, keep bias and cooling on for days or weeks
  - Measure signal in regular intervals

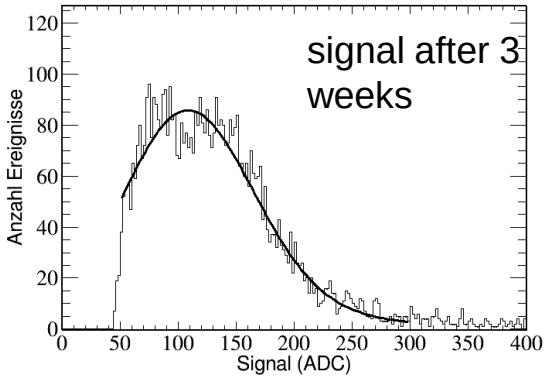
- Tests block crucial set-up for months
- Potential risks in extreme HV and long term operation
- Four detectors destroyed in such tests before 1st long term test ran successfully
  - during ramp-up: low HV wire bonds causing spark(1), spark with unclear cause (1)
  - breakdown after few days of normal operation (2)

Results on CM Sensor

- Detector 2488-7-1-18H
  - CM visible
  - low W/P ratio (10µm/100µm),
  - $5x10^{15}$Neq
- Tested for ≈4 weeks
- Bias 1300V, -40° C
- Signal initial high signal decreases with time
- Lines indicate 24h breaks where no bias was applied
- Initial HV pause restored some of the signal, but only temporarily
- 2nd HV pause did have no visible effect

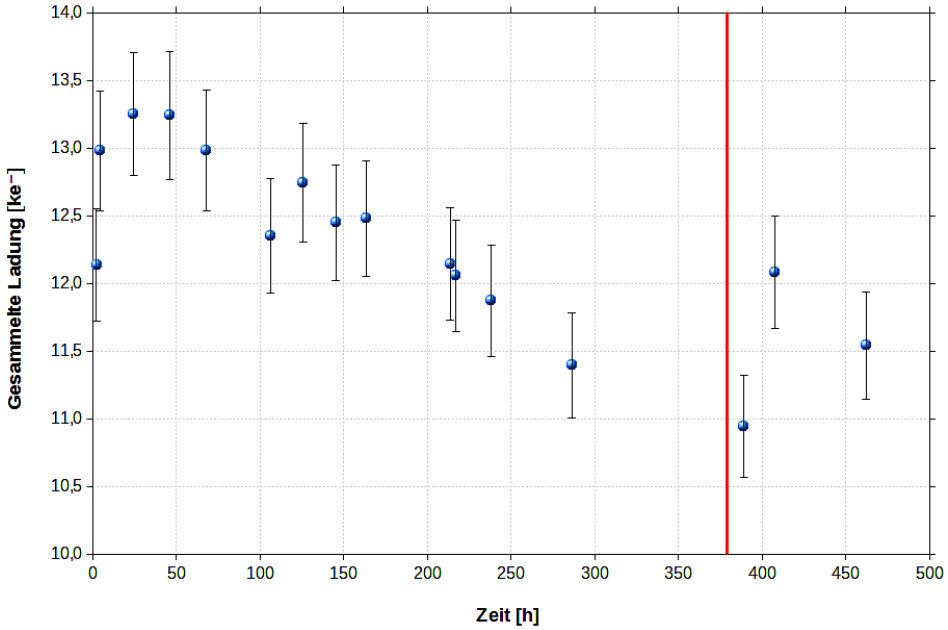






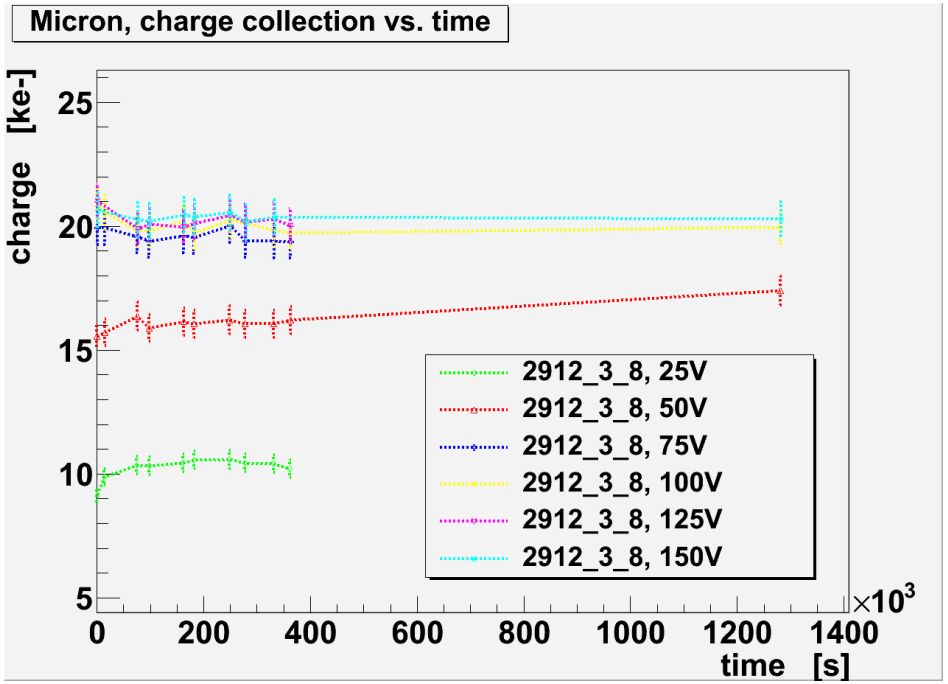
Results for non-CM Sensor

- Detector 2912-3-1-14H
  - no CM visible
  - normal W/P ratio ratio (25µm/80µm), ,
  - $5x10^{15}$Neq
- Tested for ≈3 weeks
- Bias 1300V, -40° C
- Initial 2 measurements during ramp-up included (800V, 1000V)
- Initial signal decreases with time, even for sensor without apparent CM
  - Line indicates 24h break
- Does the ongoing HV “stress” the sensor?
- Does the presence of a 37MBq ^{90}Sr source change the field via surface charges (CMS suggestion)?



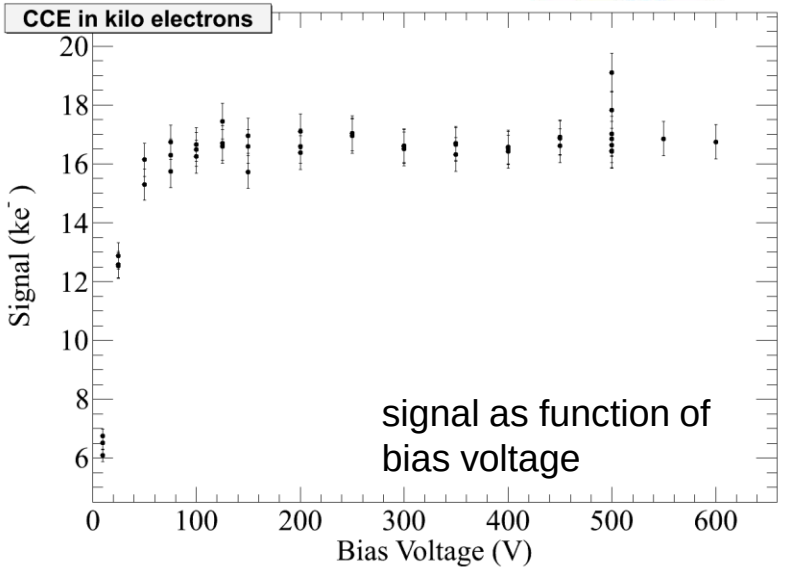
Results of Unirradiated Sensor

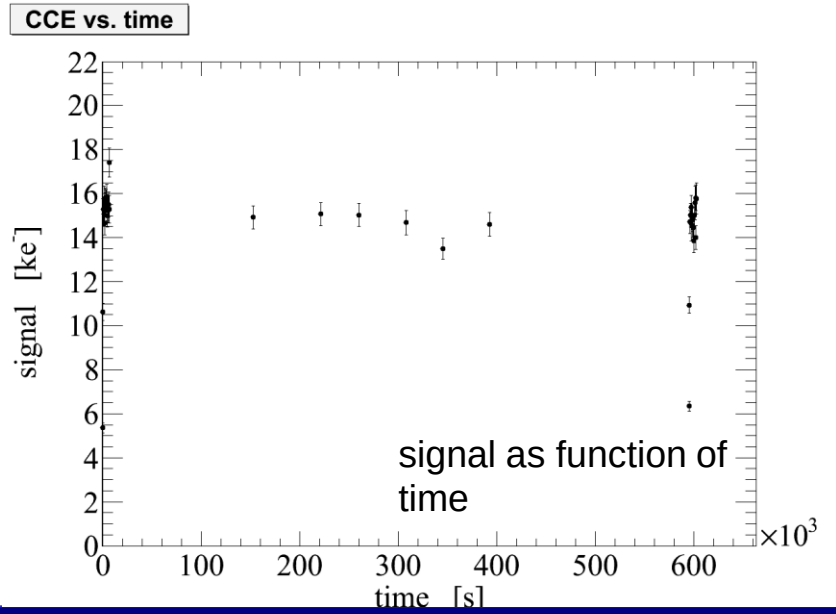
- Look for surface effects
- Detector 2912-3-8-LT
  - Unirradiated
  - Test at 21° C
  - Source always present
- Test ≈2 weeks but with bias off in between signal measurements
- Scan HV bias in signal measurement
- Signal unchanged



LGAD Results

- Similar long term test on un-irradiated LGAD
  - courtesy of CNM, V. Grecco, G. Pellegrini et al
  - place LGAD in front of source
- Measure signal for increasing bias
- No sign of charge multiplication
- Test ≈1 week with bias on
  - run at 300V and -17° C
- Bias ramp-up and down shown also in signal measurement
- Signal unchanged





Discussion

- Long term operation at HL-LHC conditions (HV, cold, dry) reduces charge seen in irradiated sensors
- Effect exists for sensors with and without charge multiplication
- LT operation of unirradiated sensor at low bias stable

- Possible causes
  - CM could simply be an instable effect
  - HV stress (*Potential Induced Damage* PID known from solar cells), this should be reversible damage
  - CMS sees similar effect but mostly for unirradiated sensors. Presence of source could generate oxide charges (see Robert Klanner's presentation at TIPP last week, also shown yesterday by Thomas Poehlsen)

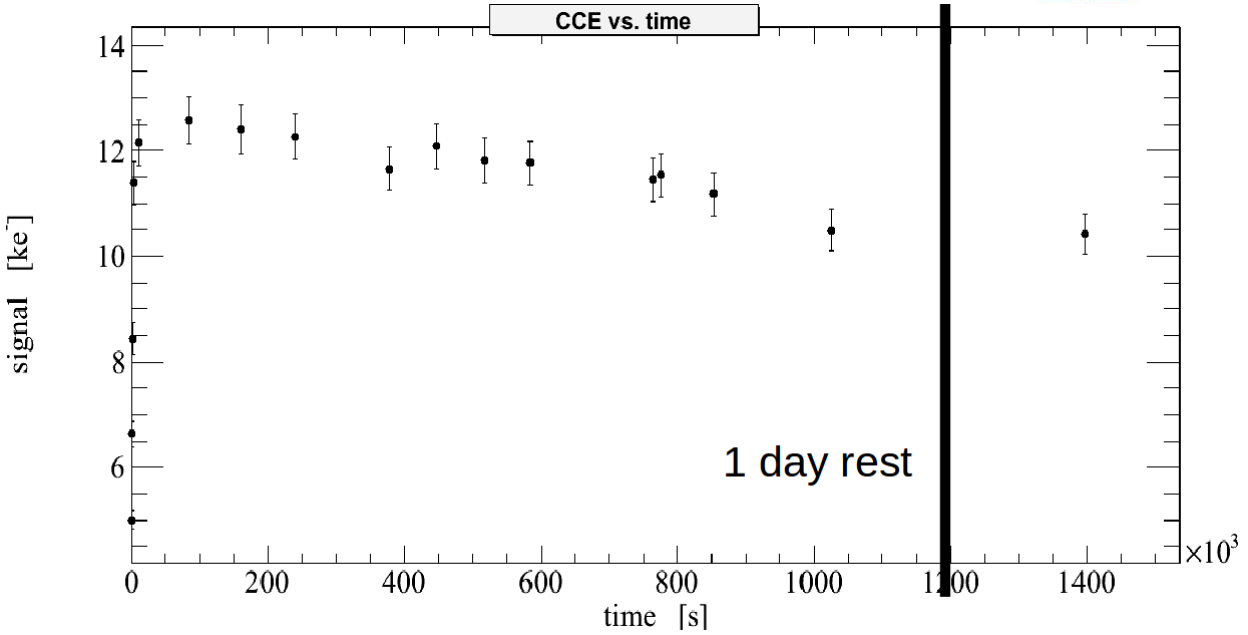
Conclusion

- Long term evolution of highly-irradiated charge multiplication sensors studied at high bias
- Tests are risky and time-consuming
- Signal degrades with time, even without CM
- Several explanations exist

- Next steps
  - Re-analyse to look for increased charge sharing (as seen by CMS)
  - More measurements on other sensors foreseen when cold ^{90}Sr set-up is free

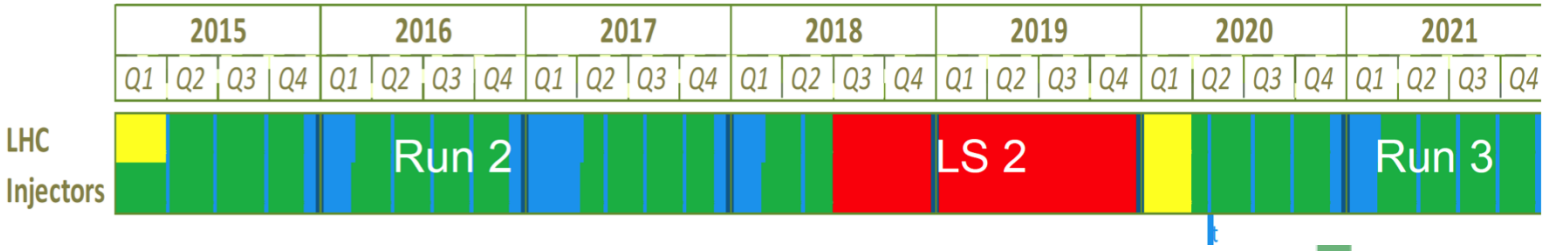
BACKUP ONLY

- Detector 2912-3-1-14H
- Excluding measurements at below -50C
- Gets rid of outliers



From LHC to High Luminosity-LHC

2014: LS 1: go to design energy, nominal luminosity



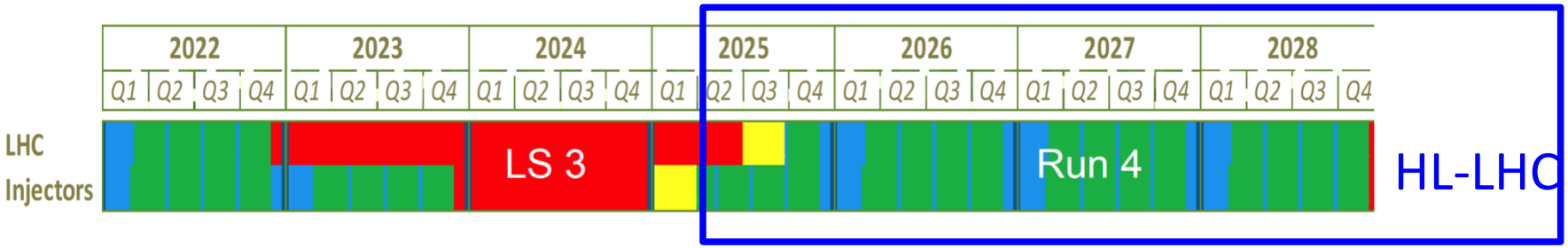
Run 2: $\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

~75-100 fb^{-1}

LS 2: Injector and LHC Phase-1 upgrade to ultimate design luminosity

Run 3: $\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

~350 fb^{-1}



LS 3: HL-LHC Phase-2 upgrade, IR, crab cavities?

Run 4: $\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling

~3000 fb^{-1}

LHC Schedule (CERN management, spokespersons and techn. Coord. Dec 2013)