Performance Evaluation of HPK Pad type and Segmented LGAD sensors

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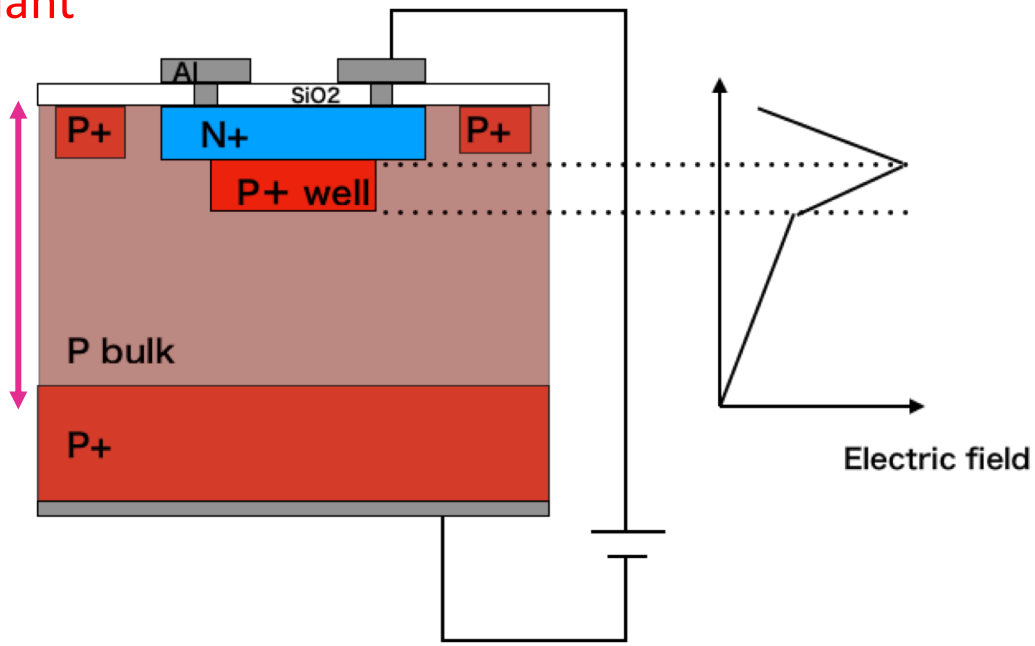
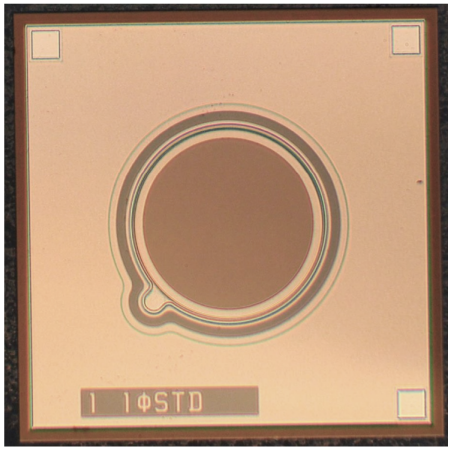
HPK LGAD

- N+ in P type silicon detector
- P+ layer under N+ readout implant
  ->high electric field
- Avalanche
  - High S/N ratio @gain~10
  - Thinner detector
- Time resolution ~30ps

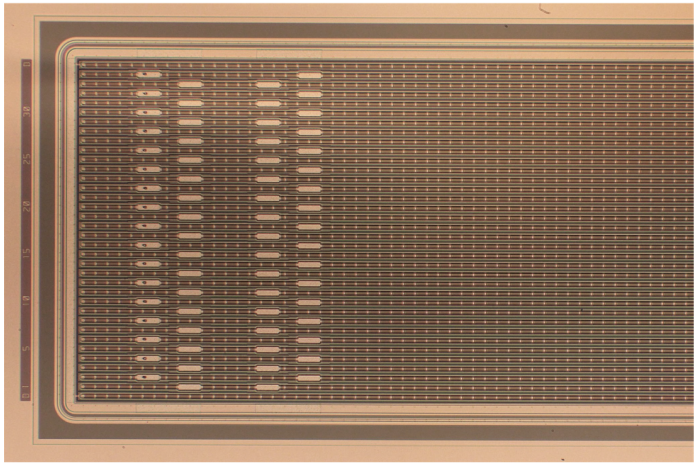


LGAD structure

Samples



Pad detector



Strip detector

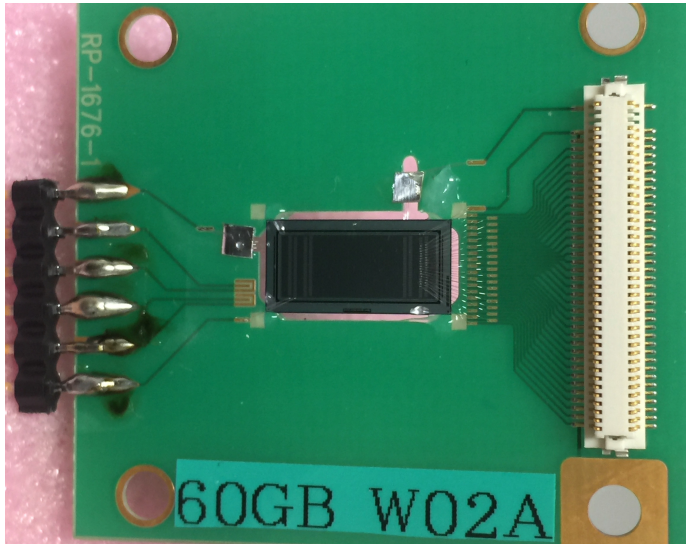
- Pad
  - Size: 2.5mm × 2.5mm
  - Oping window: 1mmϕ
- Strip
  - Size: 6mm × 12mm
  - Strip pitch 80μm
- Irradiation
  - γ irrad 0.1, 1.0, 2.5 MGy
  - n irrad 0.3, 1.0, 3.0 $\times 10^{15}$ $1MeVn_{eq}/cm^2$

Sample name	P+ dose A<B<C<D	Physical thickness	Active thickness
50A	A	150	50
50B	B		
50C	C		
50D	D		
80A	A		80
80B	B		
80C	C		
80D	D		

Measurement

- Samples wire bonded on print circuit board
- measured at 20℃(nonirrad), -20℃(irrad)
  - IV
  - Bulk capacitance
  - Charge collection

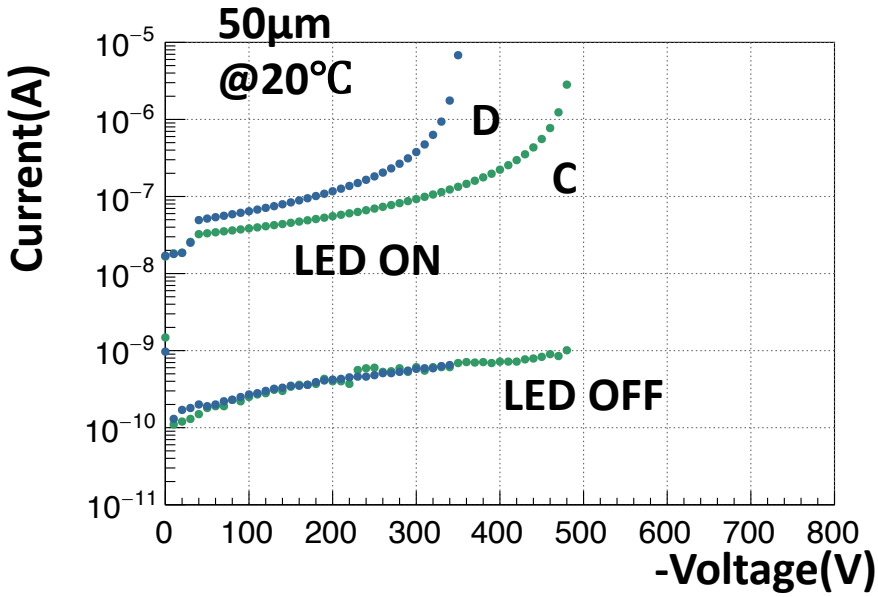
thermostat

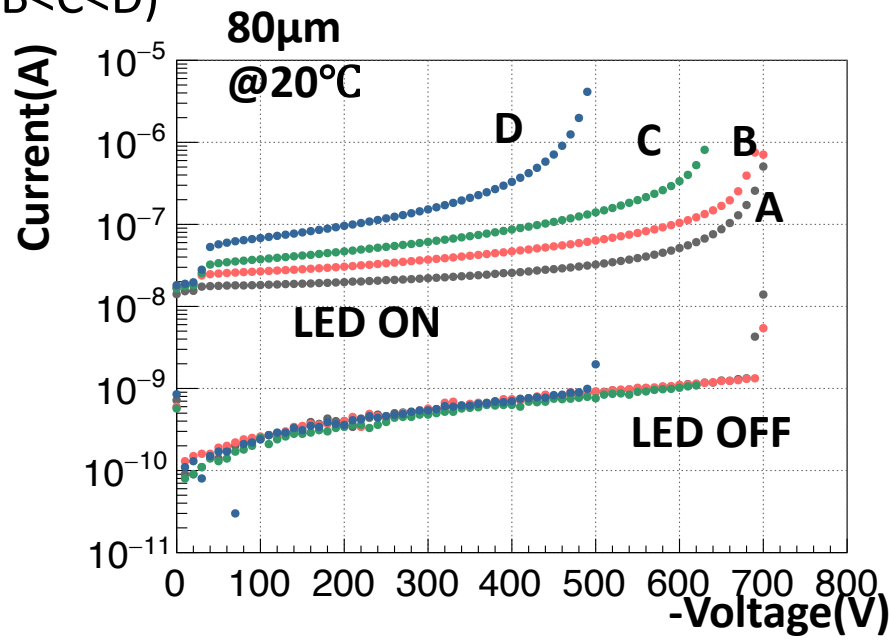


Sample on PCB

Pad Sensor IV

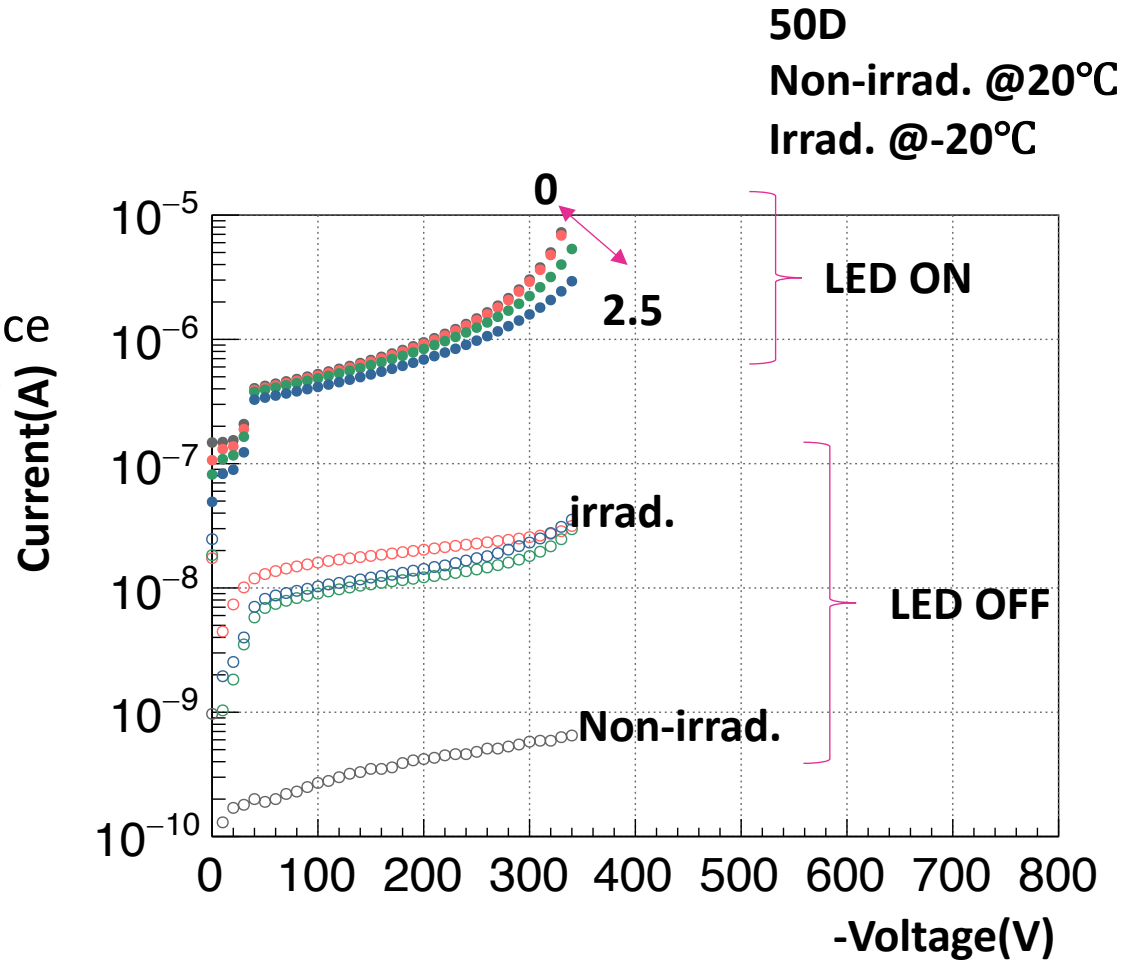
- Leakage (LED OFF)
  - Independ of P+ concentration
  - All samples ~nA
- IR LED response (LED ON)
  - P+ concentration dependence (A<B<C<D)
    - Higher(D)
      ->lager gain @lower voltage
      ->breakdown @lower voltage
  - Active thickness dependence
    - 50µm
      ->breakdown, gain
      @lower voltage





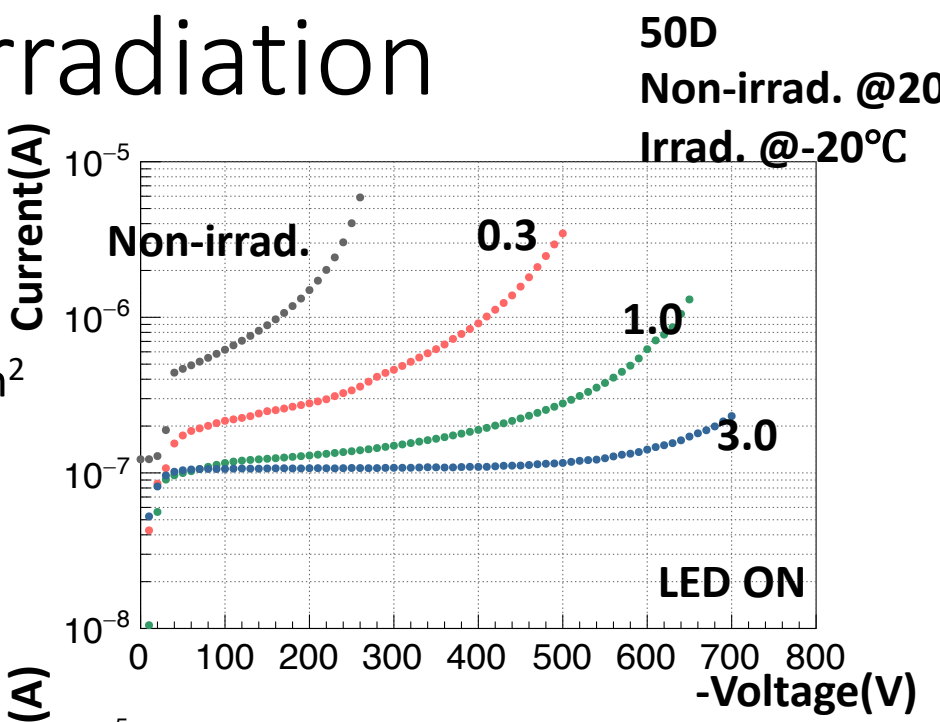
IV after γ-ray irradiation

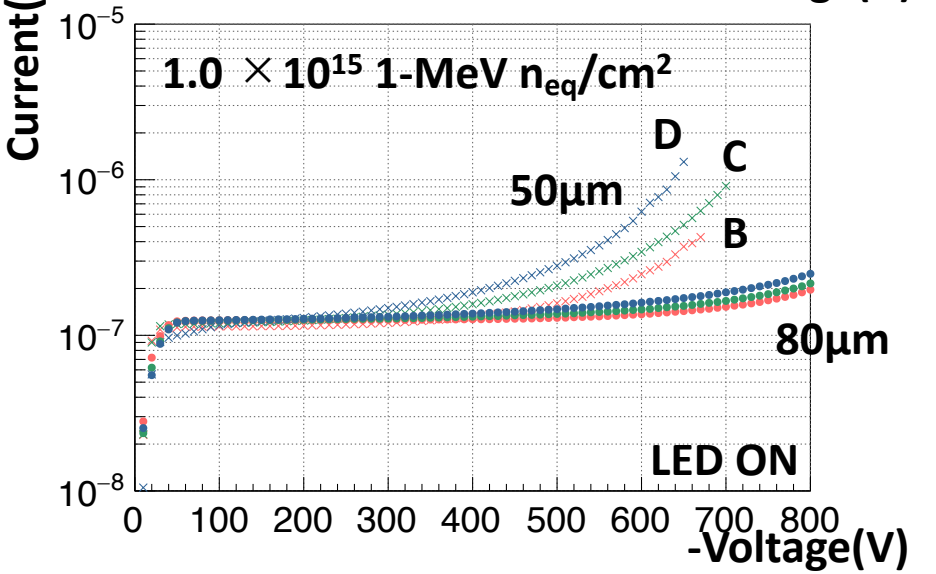
- 24 Nov.- 20 Dec. 2016 @ QST, Takasaki, Japan
  - 0.1/ 1.0/ 2.5 MGy
- Leakage(LED OFF)
  - Increases
    but no dose dependence
    ->only surface damage
- Gain
  - Not degraded
    significantly



IV after neutron irradiation

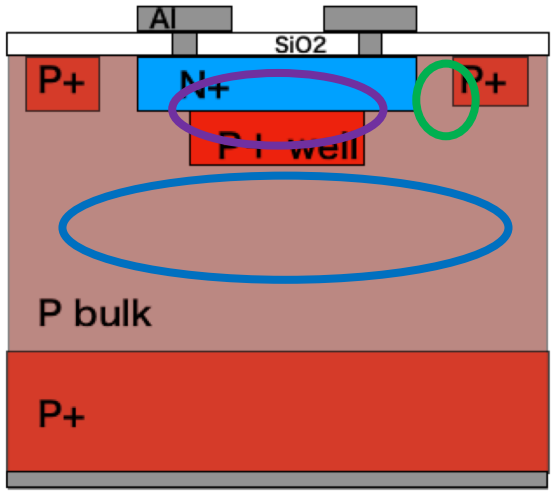
- 15 Dec. 2016 @Ljubljana, Slovenia
  - 0.3/ 1.0/ 3.0 × 10^{15} 1-MeV n_{eq}/cm^2
  - After 60℃, 80min. Annealing
- Gain
  - Degraded
    depend on fluence
    -> requires higher voltage
    to retain same gain
- P+ concentration and active thickness
  - More gain for
    - Higher concentration
    - thinner

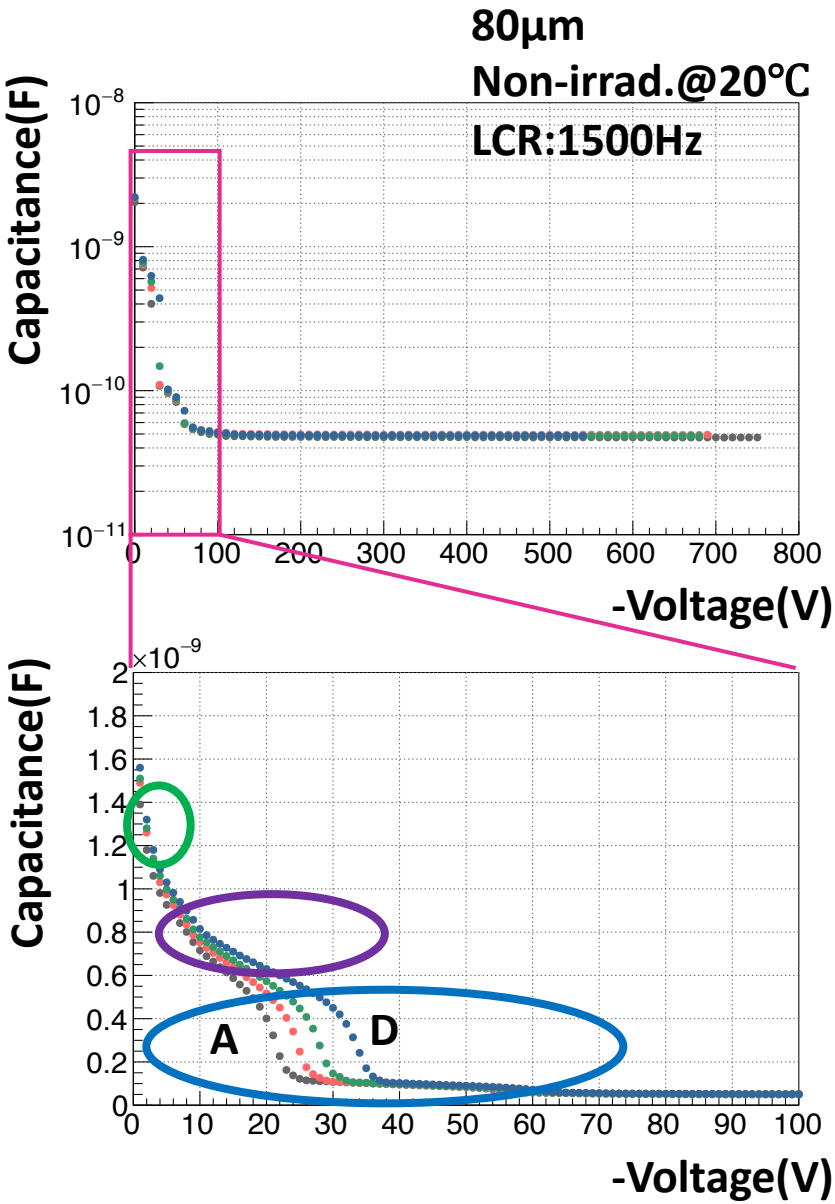




Bulk capacitance

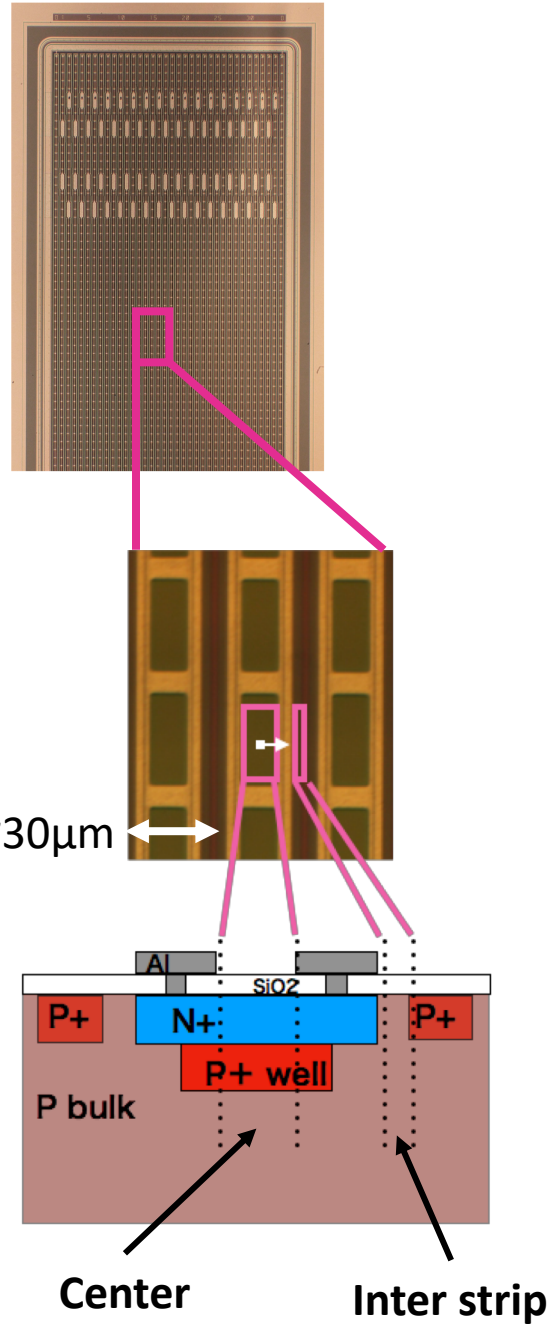
- Full depletion Voltage
  - 25(80A) -35V(80D)
- Depletion steps
  1. Side regions
  2. Multiplication region
     ->more p+ concentration,
     higher depletion voltage
  3. bulk

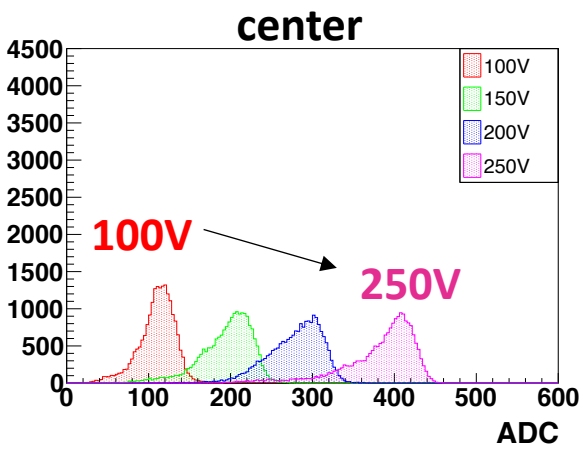


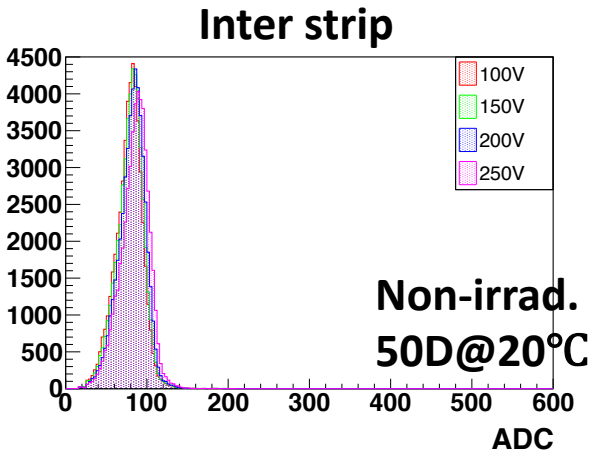


Charge collection

- Gain evaluation by charge collection
  - Measured using Alibava system
  - incident IR-Laser(spot size 2μm × 2μm)
    -> uniformly generate h-e pairs
  - Center region
    - Charge collection increase with bias
  - Inter strip region
    - Charge collection stays constant





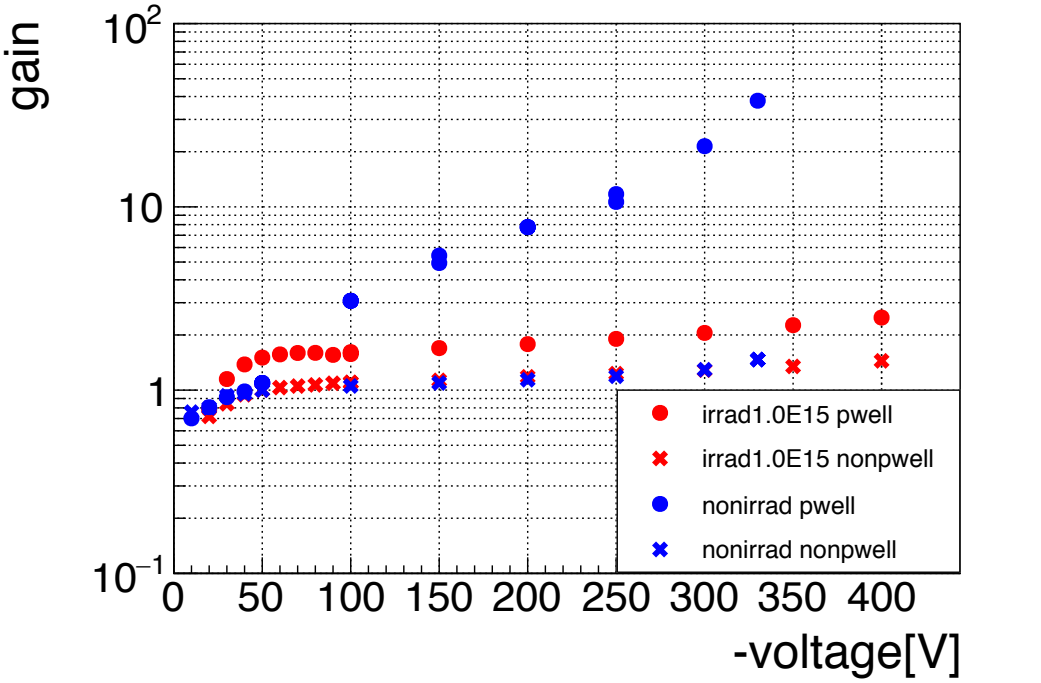


Gain

- Evaluation of gain

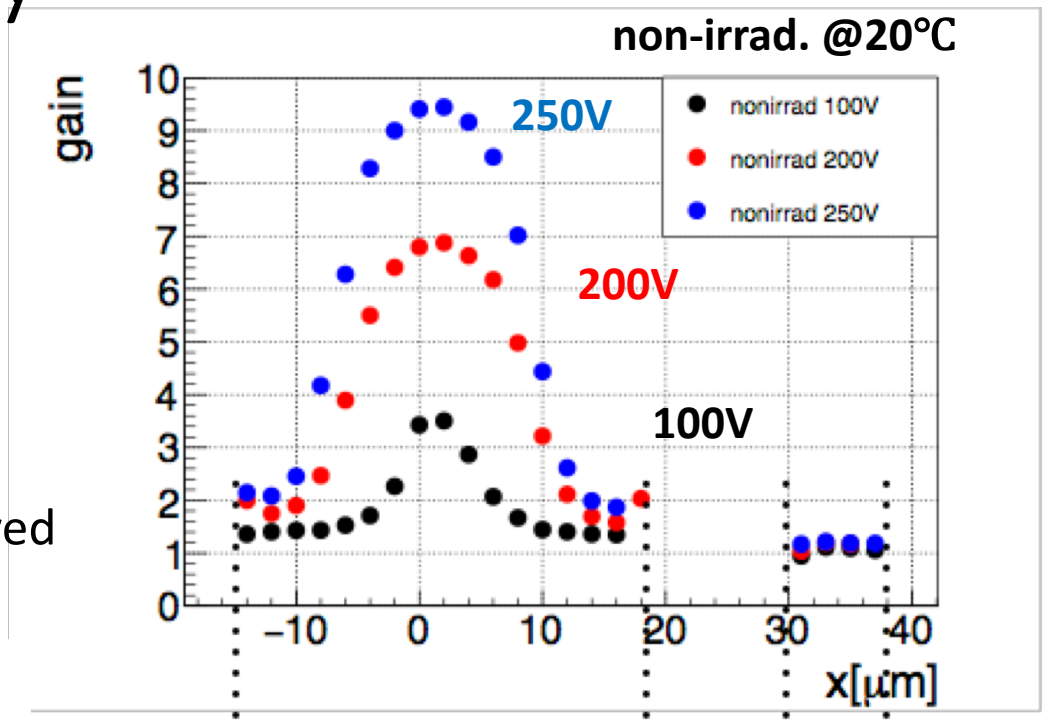
$$Gain(V) = \frac{ADC(V)}{ADC(50V@inter\ strip)}$$

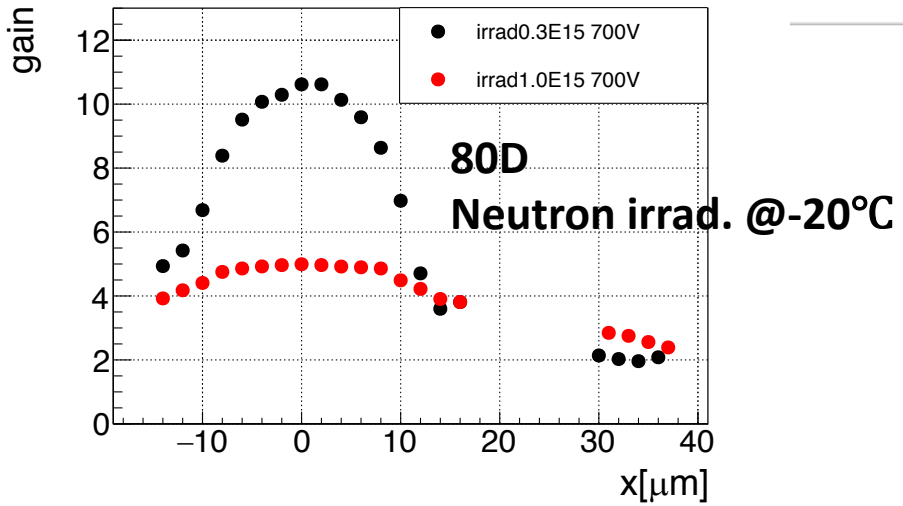
- Dependence on bias voltage
  - Gain increases with bias voltage
- Non-irrad.
  - Gain ~ 10@ 250V
- Neutron irrad.
  (1.0 × 10^{15}1-MeV n_{eq}/cm^2)
  - Gain ~ 2.5 @400V
    ->higher voltage required
    for gain~10

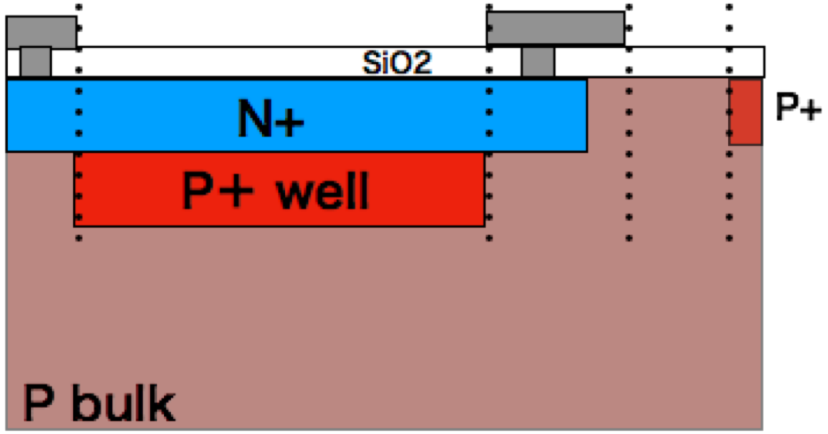


Gain uniformity

- Gain dependent on incident position of IR laser
- uniformity dependent on bias voltage
- After neutron irrad.
  - Uniformity seems improved (gain in inter strip region)





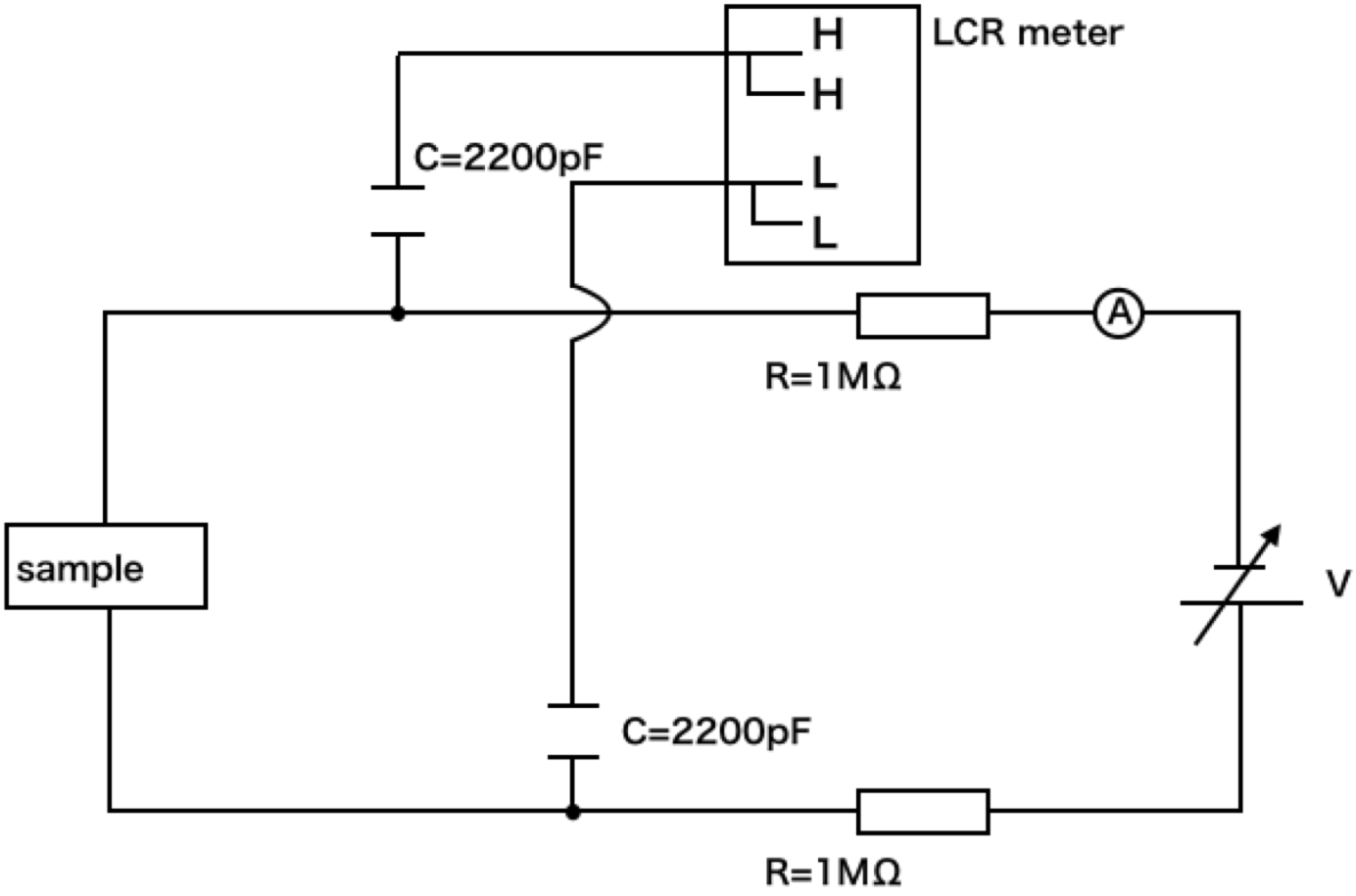


Summary

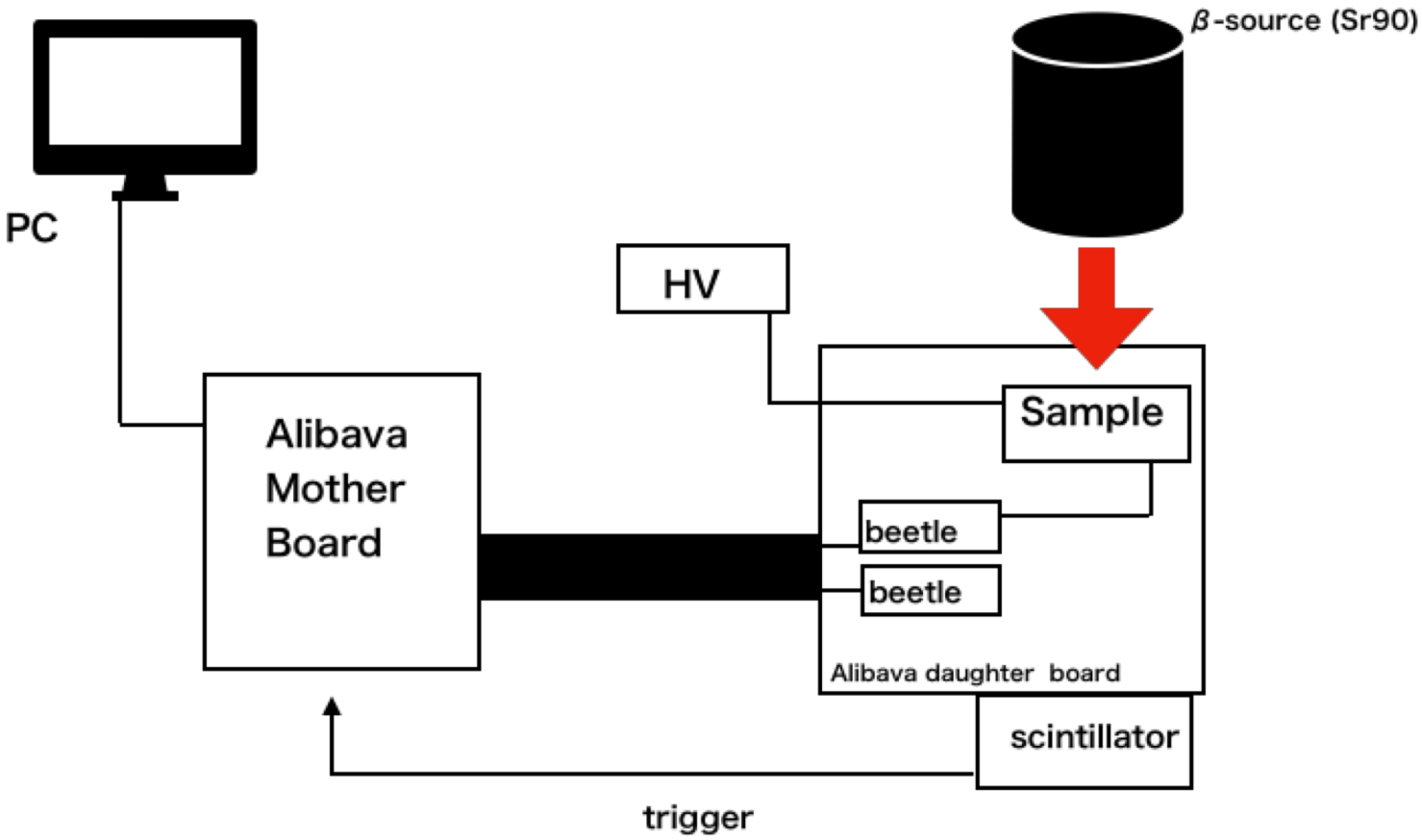
- We evaluated characteristics of HPK LGAD samples
  - IV
    - Thinner and high P+ dose -> gain @low voltage
    - Gain retains after γ-ray irradiation
    - After neutron irradiation, gain drops
  - Bulk Capacitance
    - Stepwise depletion progress is observed
  - Charge Collection
    - After neutron irradiation gain drops
      -> need high voltage
    - Gain uniformity measured for strip LGAD
    - Irradiation induces gain in inter strip region

back up

IV,CV Circuit



CC Circuit


β-source (Sr90)
PC
HV
Alibava
Mother
Board
Sample
beetle
beetle
Alibava daughter board
scintillator
trigger

γ- ray irrad. IV 80μm