Stitched Passive CMOS Strip Sensors

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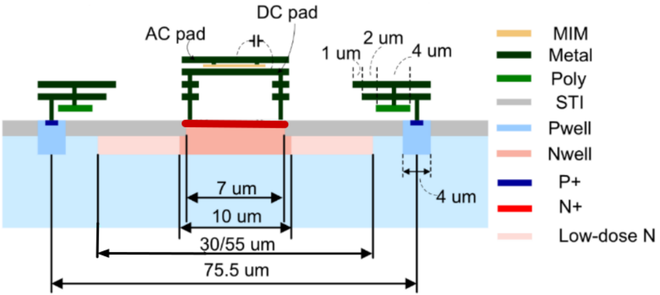
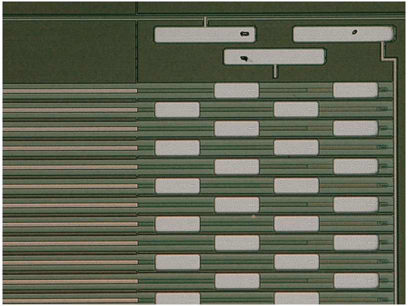
Stitched Passive CMOS Strip Sensors

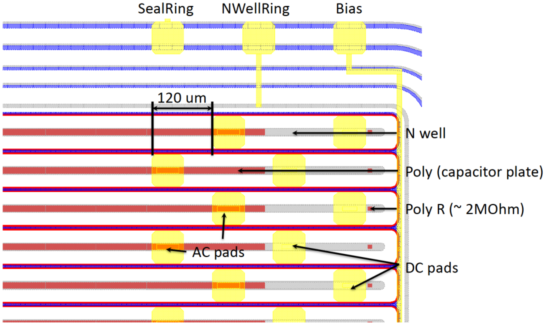
- L-Foundry 150 nm process
- float-zone silicon, 3-5 $\mathrm{k\Omega\,cm}$ resistivity
- $(150 \pm 10)\,\mathrm{\mu m}$ thickness
- 40 strips with $75.5\,\mathrm{\mu m}$ pitch
- $4.1 \times 1\,\mathrm{cm}^2$ or $2.1 \times 1\,\mathrm{cm}^2$
- 3 designs in one unit: *Regular & Low Dose 30/55*

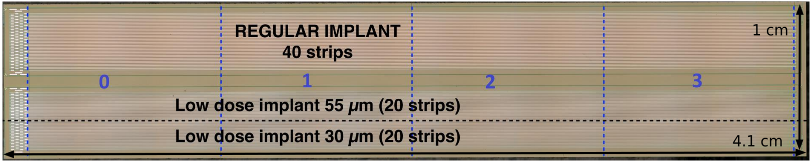


- frontside processing: reticle stitching with $1\,\mathrm{cm}^2$ masks for larger areas
- backside processing: laser annealing, highly doped p^+ layer and add. metallization

Stitched Passive CMOS Strip Sensors

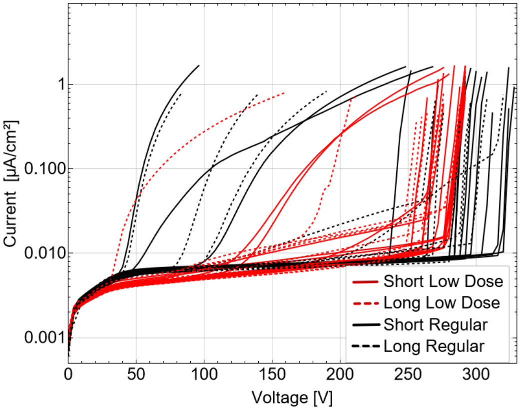




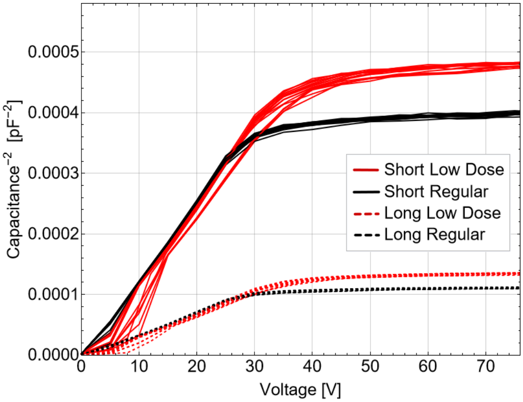


IV & CV Measurements

IV

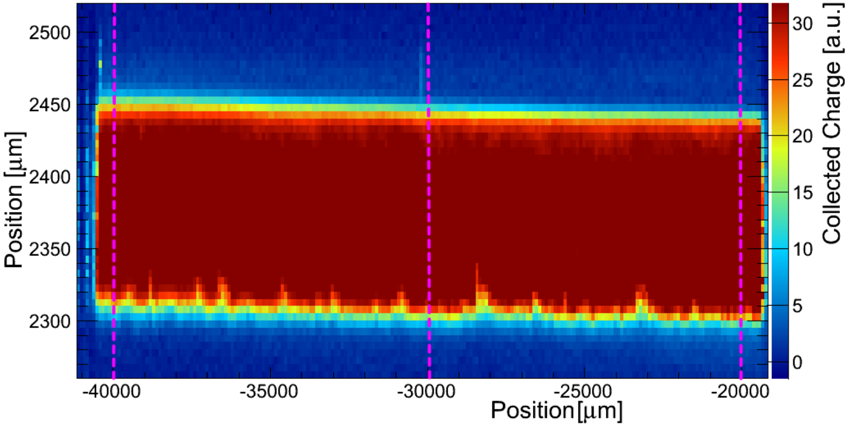


CV



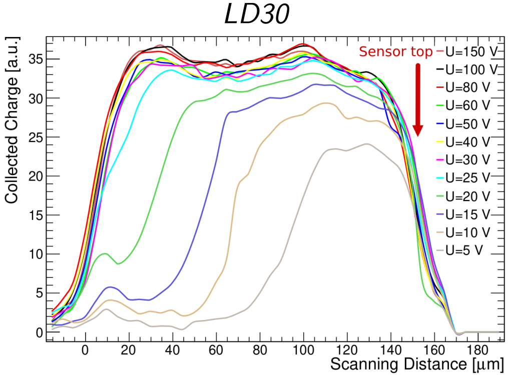
- unirradiated sensors
- breakdown at $\sim 250\,\mathrm{V}$, full depletion at $\sim 30\,\mathrm{V}$
- second batch improved over first batch

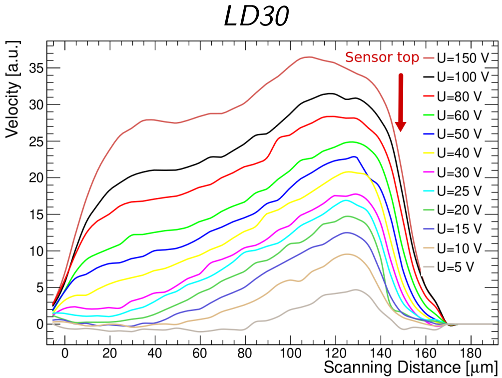
Edge-TCT: 2D Scan



- unirradiated, short *LD30* sensor at 100 V (fully depleted)
- homogeneous charge collection (apart from scratches on edge of sensor)
- stitches not visible

Edge-TCT: Charge Collection & Electron Velocity



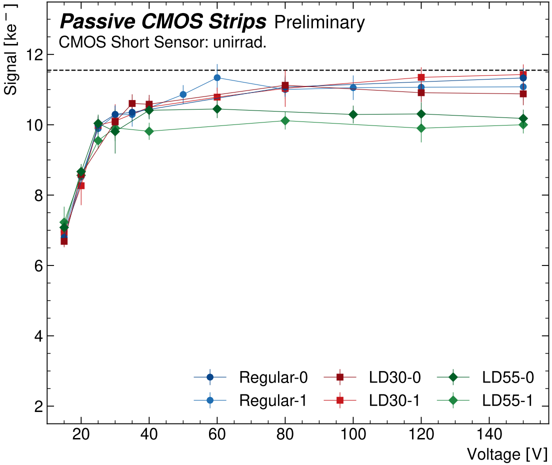


- sensors deplete top to back
- full depletion at 30-40 V
- complete sensor volume sensitive to charge
- collected charge remains constant after full depletion

- velocity still increases after full depletion
- expected approx. triangular shape visible
- similar results for *Regular* design

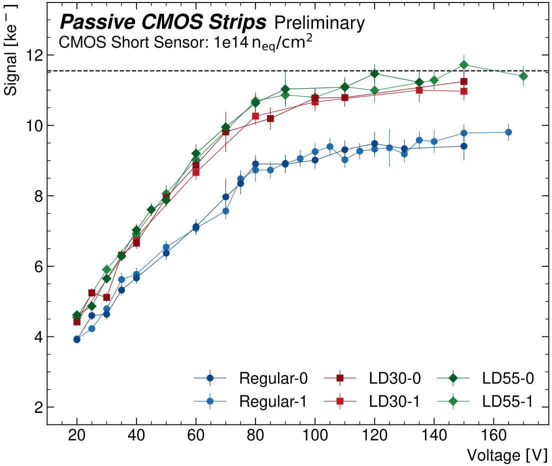
Charge Collection: Short Sensor

- ^{90}Sr β-decay source gives MIP-like e^- for charge creation in sensors
- unirradiated
- full depletion at $\sim 40\,\mathrm{V}$
- constant signal after full depletion
- *Regular* and *LD30* reach expected charge of $\sim 11.5\,\mathrm{ke}^-$
- *LD55* systematically low charge $\rightarrow$ *highest capacitance, maybe read-out electronics unable to handle it*
- no effect of stitching visible



Charge Collection: Short Sensor

- irradiated up to $1 \cdot 10^{14}\,\mathrm{n_{eq}/cm^2}$
- full depletion at $\sim 80\,\mathrm{V}$
- *LD30/55* have suspiciously high charge
  → *sensor specific measurement error?*
- *Regular* significantly less charge after irradiation
- small increase of signal after full depletion:
  higher bias voltage ⇒ *stronger E-field*
  ⇒ *lower trapping probability*
- no effect of stitching visible

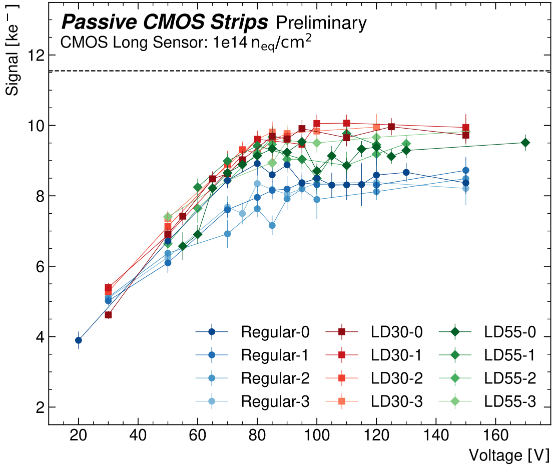


Charge Collection: Long Sensor

- irradiated up to $1 \cdot 10^{14}\ \mathrm{n_{eq}/cm^2}$

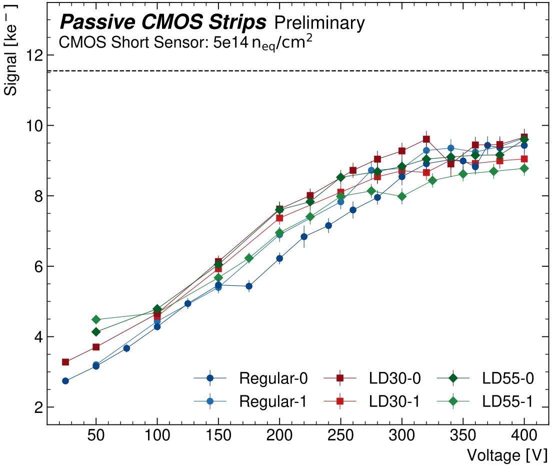
- full depletion at $\sim 90\,\mathrm{V}$
- behaves more expectedly than short sensor
- *LD30/55* show higher signal than *Regular*
- slight signal increase after full depletion

- no effect of stitching visible



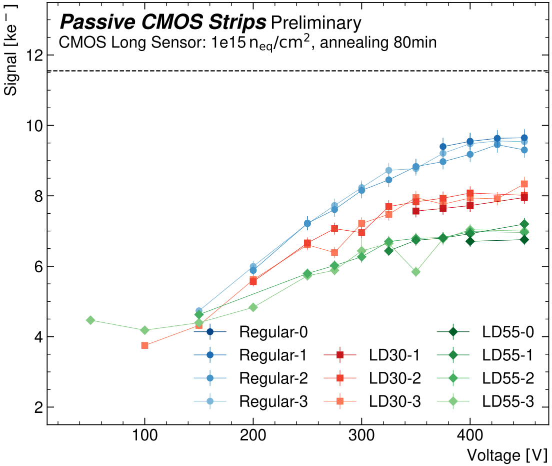
Charge Collection: Short Sensor

- irradiated up to $5 \cdot 10^{14}\,\mathrm{n_{eq}/cm^2}$
- full depletion at $\sim 300\,\mathrm{V}$
- increase of signal after full depletion
- *Regular* collects more charge again:
  this already happens at $3 \cdot 10^{14}\,\mathrm{n_{eq}/cm^2}$
- *LD30/55* collect more charge than *Regular* at low voltages:
  simulations show lower E-field at sensor top and stronger field in bulk
  $\Rightarrow$ *lower trapping probability*
- no effect of stitching visible



Charge Collection: Long Sensor

- irradiated up to $1 \cdot 10^{15}\,\mathrm{n_{eq}/cm^2}$
- after beneficial annealing of $80\,\mathrm{min}$ at $60\,^{\circ}\mathrm{C}$
- *Regular* still reaches $\sim 10\,\mathrm{ke^-}$
- *LD30/55* significantly lower signal
- no effect of stitching visible



Conclusion

several unirrad. and irrad. stitched strip sensors have been investigated:

- no effects of stitching observed
- promising radiation hardness

BUT still ongoing investigation:

- unclear systematic errors
  - low charge in unirrad. *LD55* short sensor
  - high charge in irrad. *LD30/55* short sensor
- more sensors need to be measured

outlook:

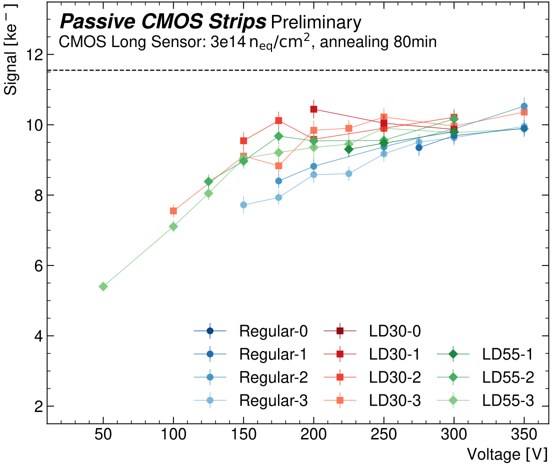
- even higher fluences ($\mathcal{O}\left(10^{17}\right) \mathrm{n_{eq}/cm^2}$ for FFC)
- 3$^{\text{rd}}$ batch: separate *LD30* and *55* sensors
- larger areas (more stitches), more strips
- fully utilise CMOS process and include electronics on substrate

Thank you for your attention!

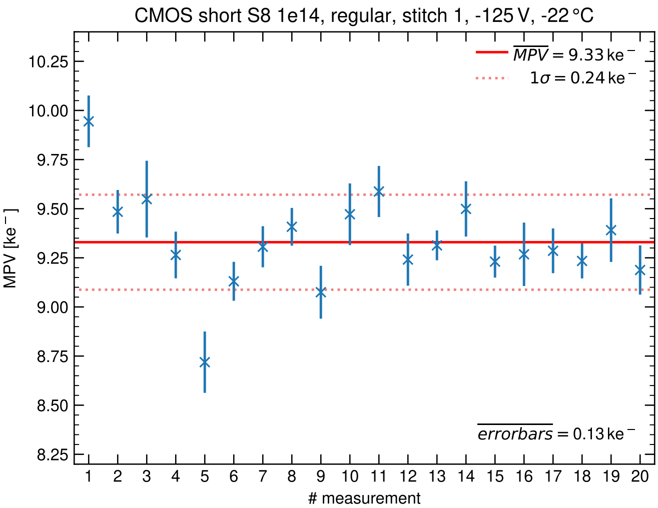
Back-up

Charge Collection: Long Sensor

- irradiated up to $3 \cdot 10^{14}\,\mathrm{n_{eq}/cm^2}$
- full depletion at $\sim 160\,\mathrm{V}$
- after beneficial annealing of $80\,\mathrm{min}$ at $60\,^\circ\mathrm{C}$
- *Regular* collects more charge than lower fluence
- so far promising radiation hardness

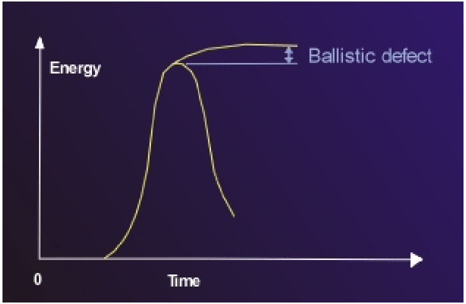


Statistical Fluctuations



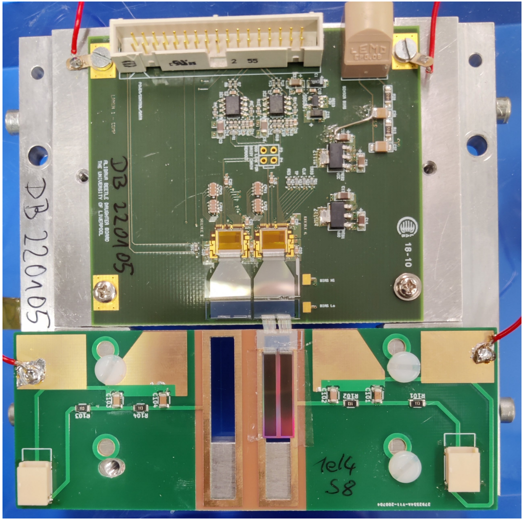
Ballistic Deficit

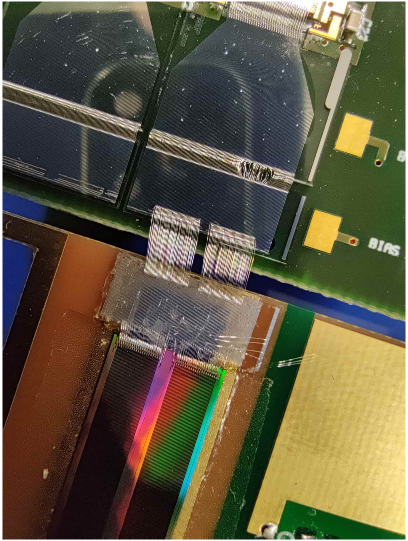
- bottom curve shows pulse shape with practical shaping time constant
- upper shows pulse shape with very large shaping time constant
  $\rightarrow$ allows full charge collection
- difference in pulse height is called ballistic deficit



https://ns.ph.liv.ac.uk/~ajb/radiometrics/glossary/ballistic_deficit.html

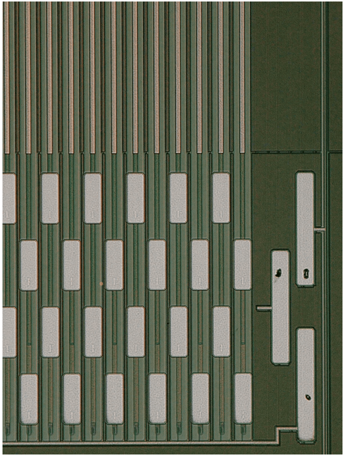
DB & Bonds



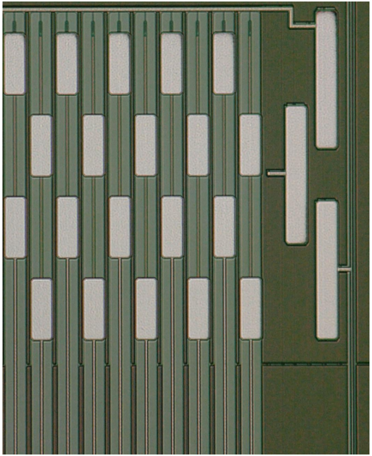


Sensor Design

regular



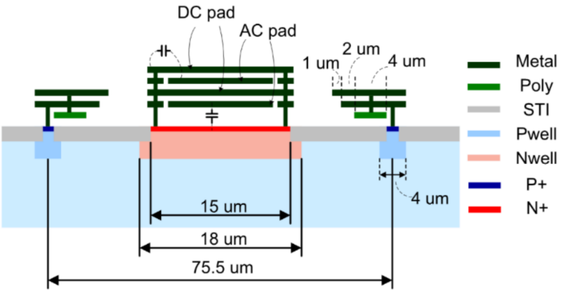
low dose 30/55

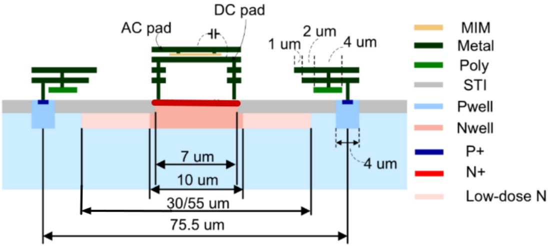


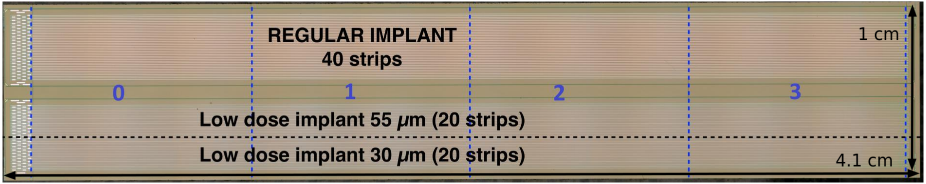
Sensor Design

regular design

low dose 30/55 design

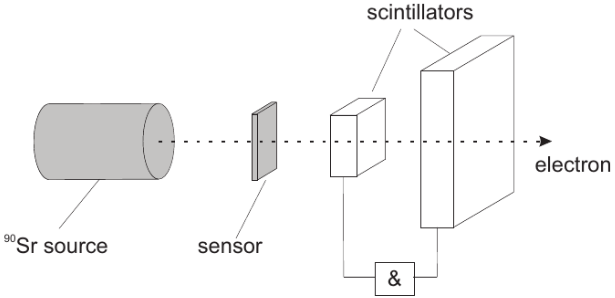






ALIBAVA Setup

- ^{90}Sr β-decay source
  - gives MIP-like e^-
  - collimated
  - placed in front of different design and stitch regions
- two scintillators
  - trigger in coincidence
  - low energy cut
- sensor on daughterboard with beetle electronics



- inside freezer, additional liquid nitrogen cooling possible
- external motherboard for further signal processing and communication with software
- signal distribution: Landau-Gauss fit to determine MPV

ALIBAVA measurement & analysis

- position source for different sensor design & stitch regions
- pedestal and source run
- motherboard 40 MHz signal sampling (LHC timing, 25 ns)
- TDC compares signal sample and trigger times
  $\rightarrow$ sort *snapshots* of signals acc. to time
- time cut: bias to smaller charge collected if too long
- seed & neighbour cut $\rightarrow$ cluster algorithm
- get collected charge from Landau-Gauss signal-fits

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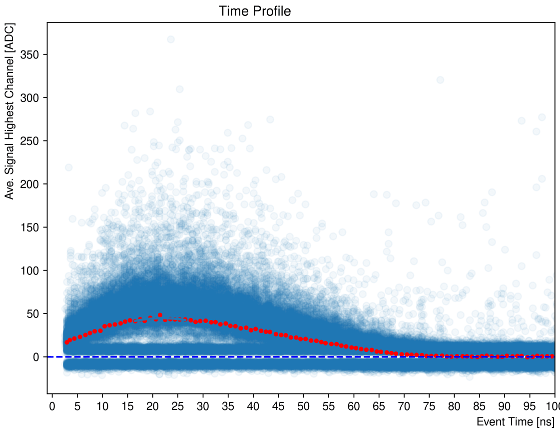

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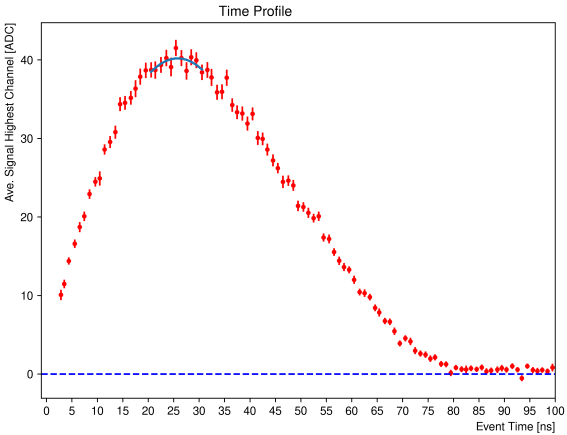

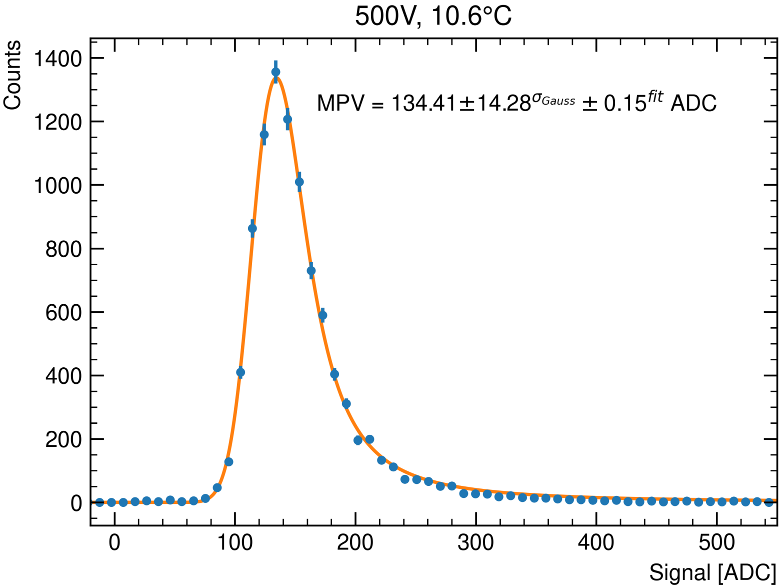
500V, 10.6°C
MPV = 134.41±14.28^σGauss ± 0.15^fit ADC
Counts
1400
1200
1000
800
600
400
200
0
100
200
300
400
500
Signal [ADC]