Commissioning HV-MAPS with an HDR Amplifier

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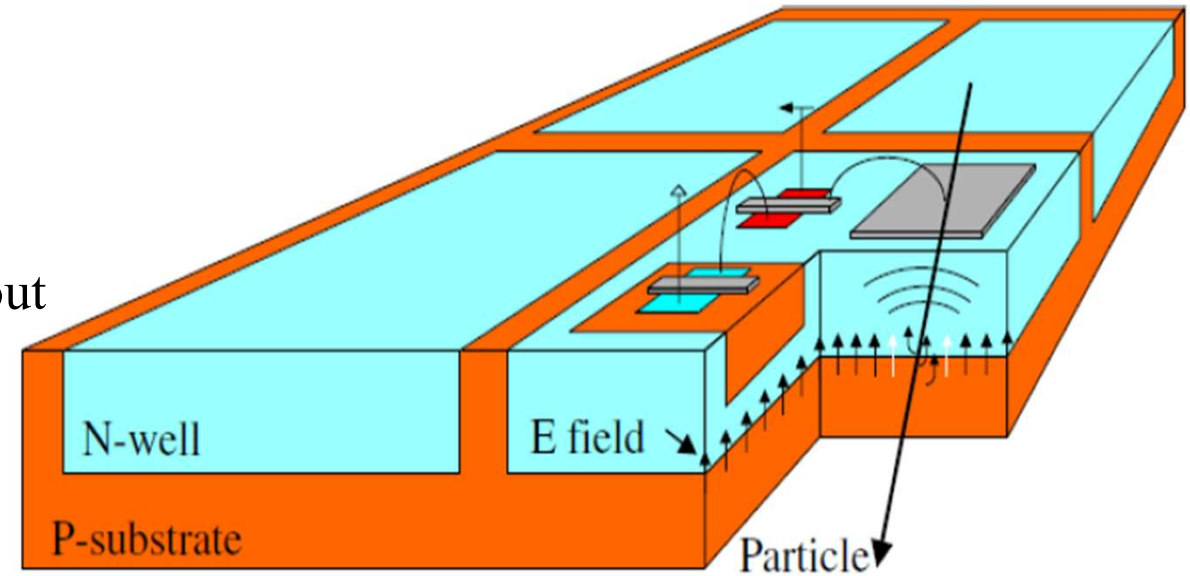
Bundesministerium
für Bildung
und Forschung

HV-MAPS

High **V**oltage – **M**onolithic **A**ctive **P**ixel **S**ensor

- 180nm HV-CMOS process by TSI
- Low-cost commercial production
- Integrated active pixel matrix & readout



(I. Peric, P. Fischer et al., NIM A 582 (2007) 876)

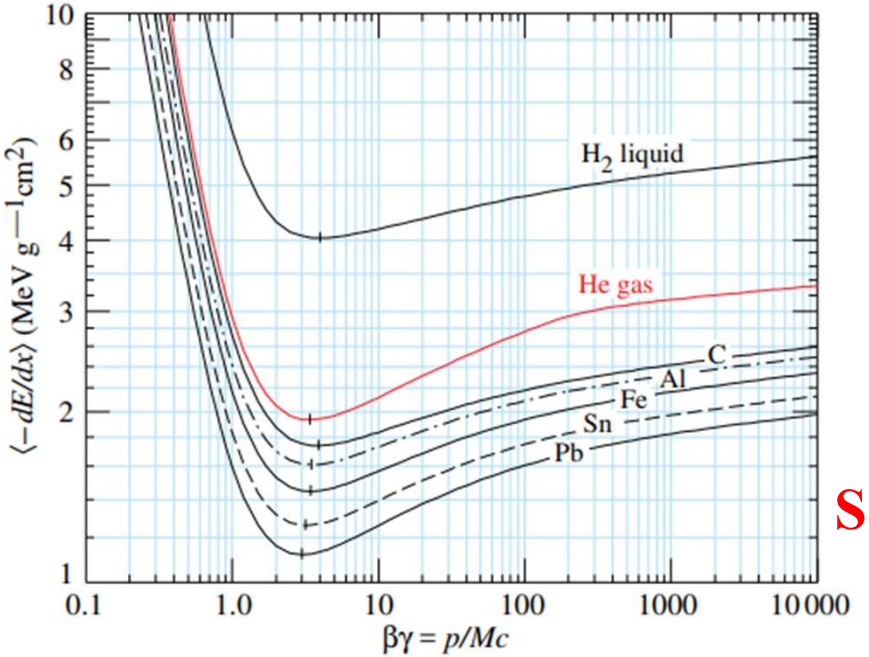
- P-doped substrate with embedded n-wells
- High voltage extends the depletion zone ➡ $depletion \propto \sqrt{\rho U}$
- A particle ionizes the depletion zone ➡ generated charge collected by electrodes via drift

Energy Deposition HV-MAPS

- Thin Sensors (e.g., MuPix)

  ⟶ Small signals
- Thick Sensors

  ⟶ Large signals ⟶ PID



R.L. Workman et al. (PDG), Prog. Theor. Exp. Phys. 2022, 083C01 (2022)

- Mean ionization energy $I_0 = 3.62eV$
- Mean energy loss per flight path of a MIP

  $dE/dx \approx 3.7MeV/cm \approx 0.37\ keV/\mu m$
- Total deposited energy:

$$E \approx dE/dx \cdot w$$

Saturation!

$\boldsymbol{\rho = 370\ \Omega cm}$

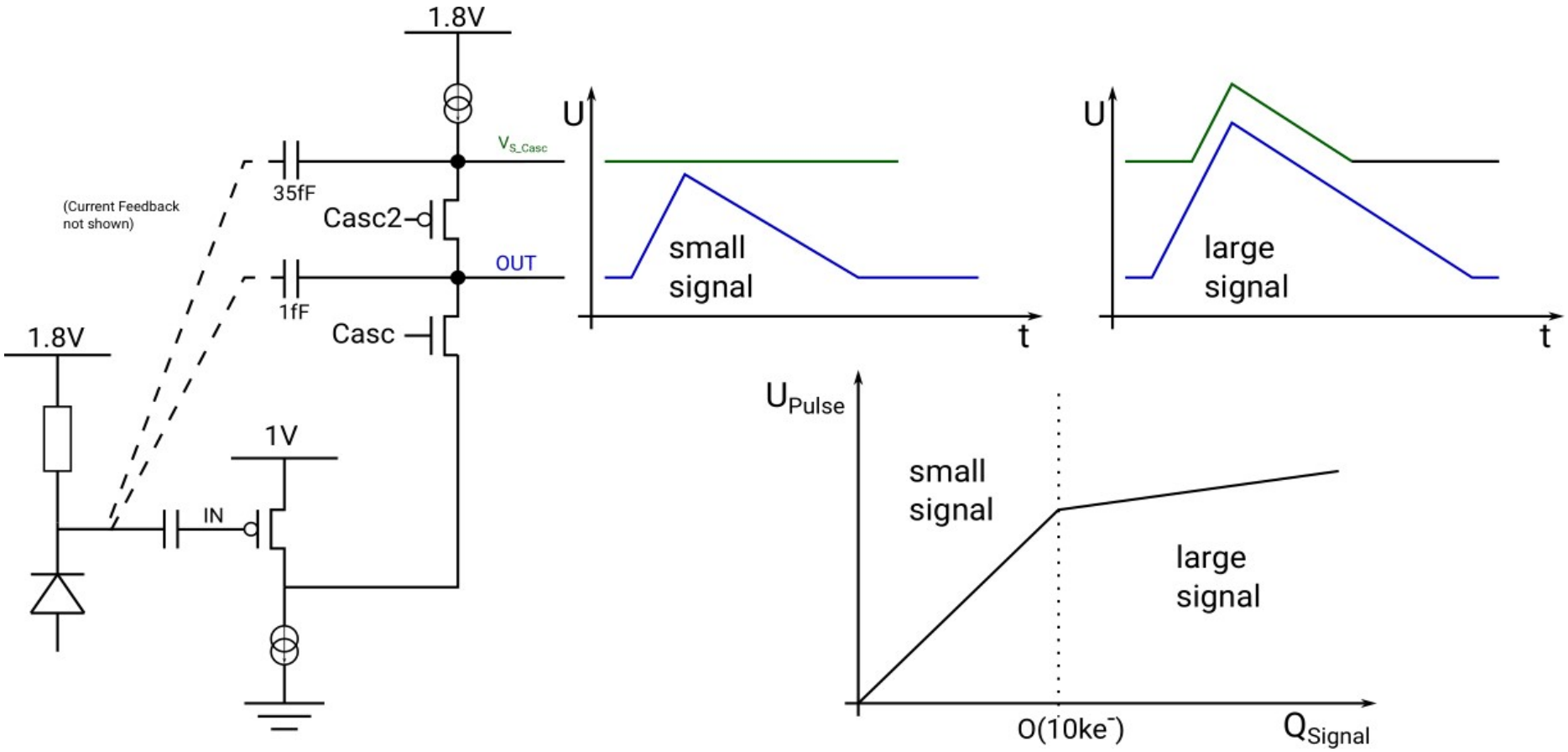
HV(-V)	$W(\mu m) \propto \sqrt{\rho V}$	E(keV)	$e^- h^+$ pairs
20	30	11.1	$3 \cdot 10^3$
80	60	22.2	$6.1 \cdot 10^3$
130	75	27.7	$7.7 \cdot 10^3$

$\boldsymbol{\rho = 10k\Omega cm}$

80	300	110	$30 \cdot 10^3$

How? Charge Sensitive Amplifier with High Dynamic Range

In-Pixel Amplifier



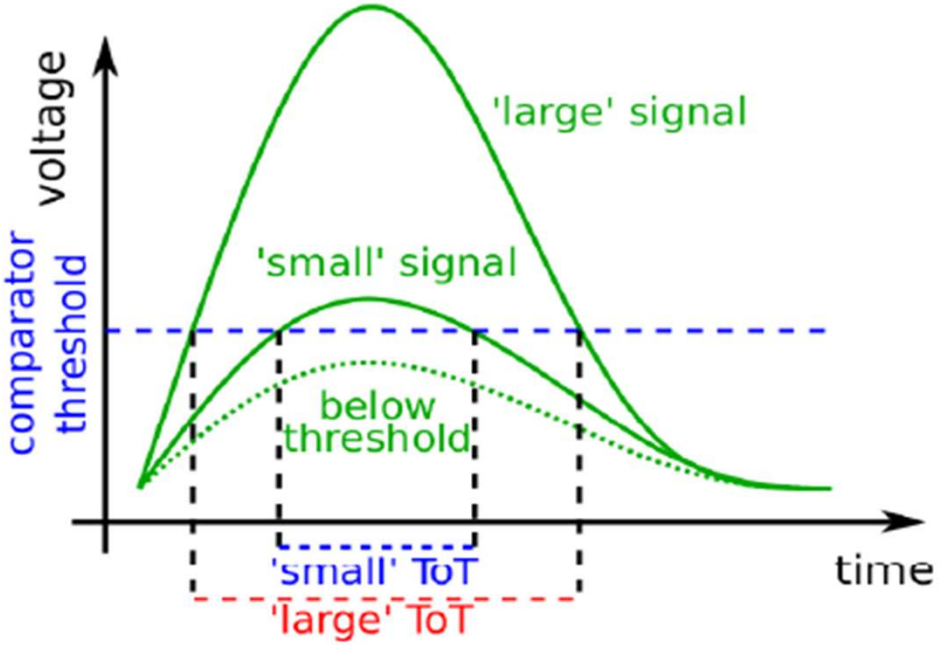
- Small signal → Casc Node
- Large signal → Casc2 Node

Source: Heiko Augustin, Heidelberg University

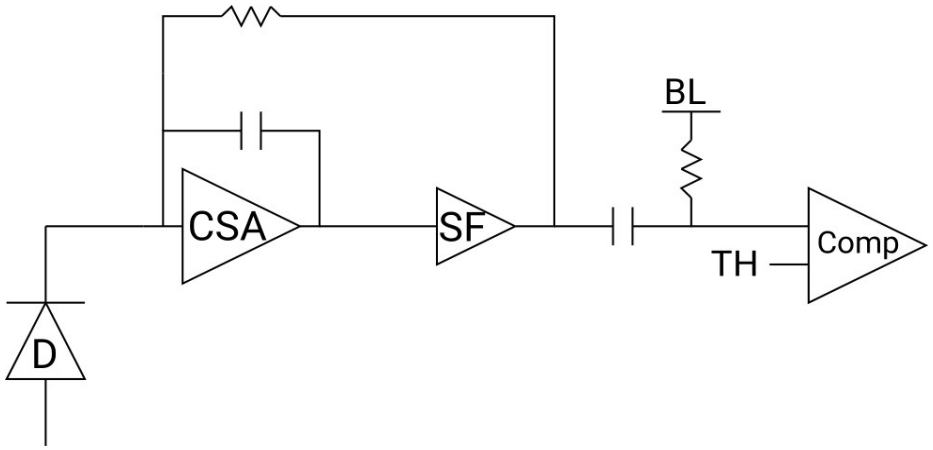
ToT & Charge Deposition

- TS1(ToA): time when rising edge of signal crosses threshold
- TS2(ToE): time when falling edge falls below threshold
- Time-over-Threshold (ToT) = TS2 – TS1
- ToT ➡ Energy dependent
- Saved data: ToA, ToE, Pixel address

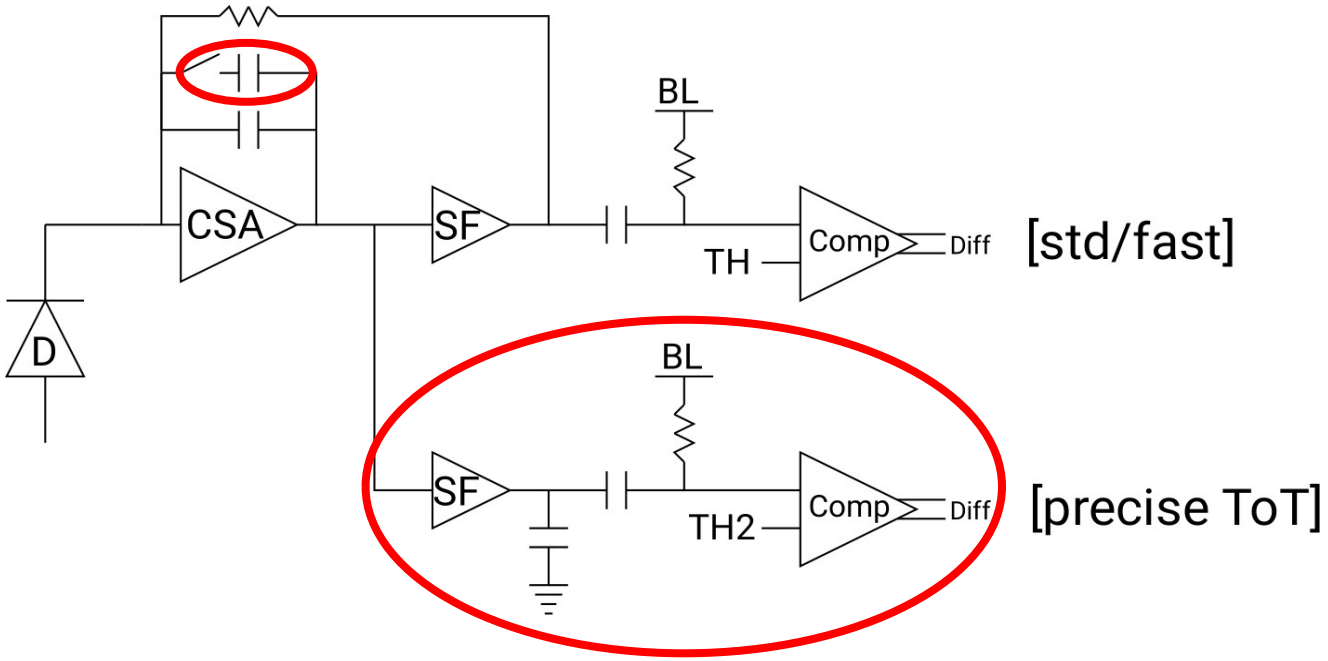
ToT ∝ Pulse Height ∝ Q_{signal}



Run2021v3 Pixel Architecture

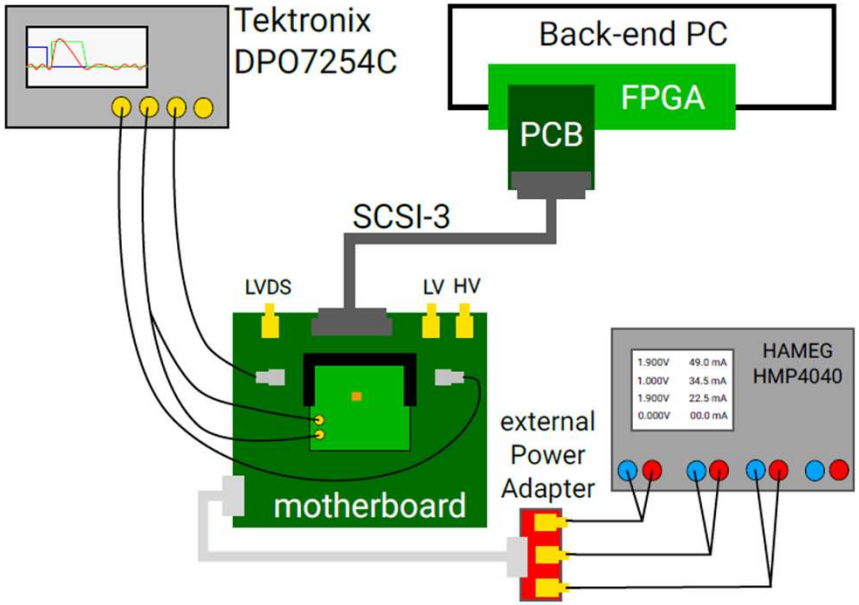


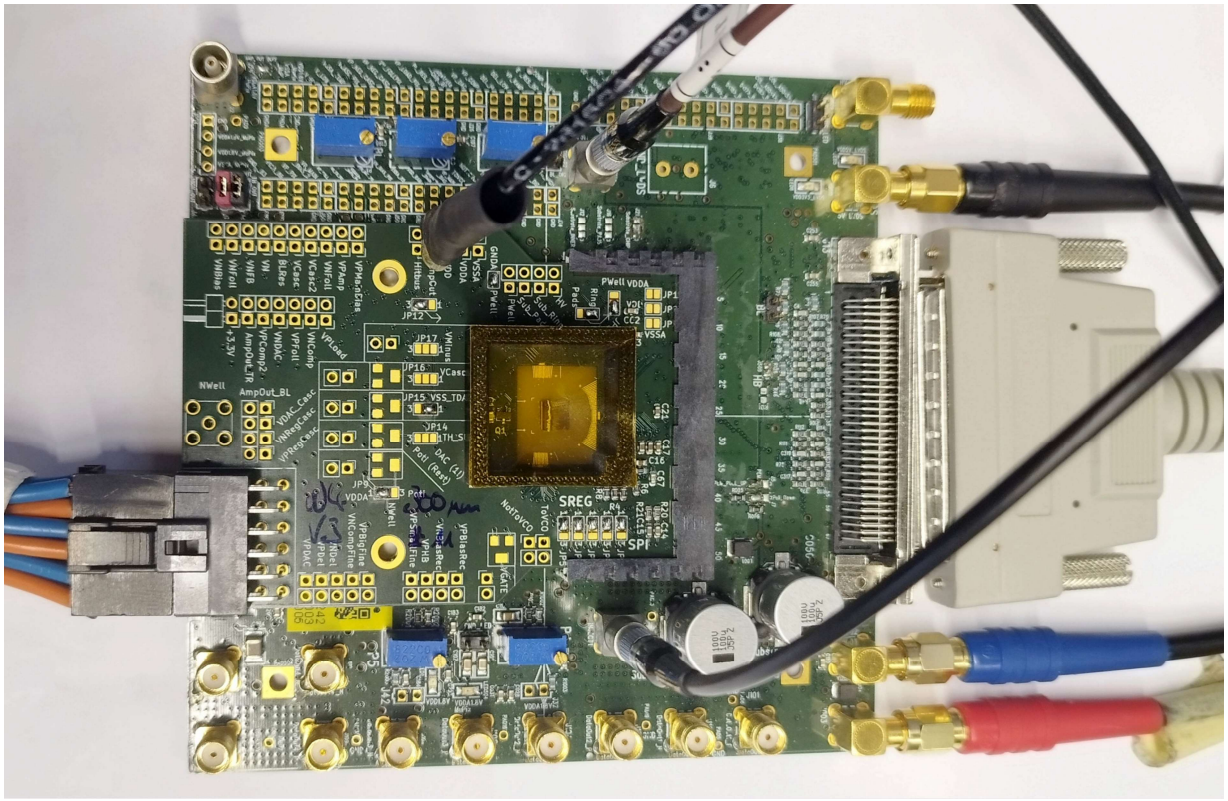
Run2021v3 Pixel Architecture



- HDR: Providing the possibility to increase Feedback capacity
- Two (distributed) CMOS comparators per pixel with differential signal transmission to two periphery cells

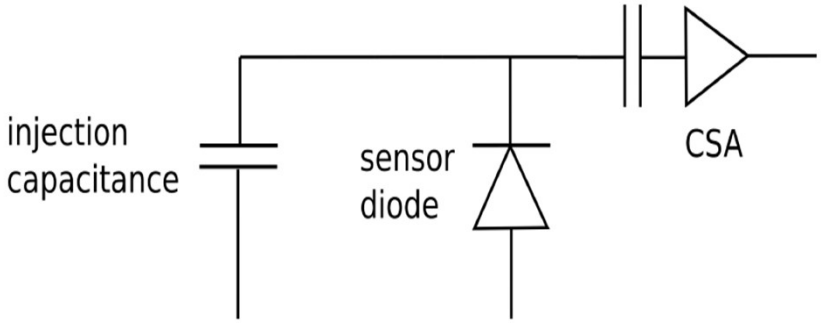
Experimental Setup





Sources of charge signals:

- Injection
  - Reliable artificial signal.
  - Discharge of capacitor imitates charge pulse of real particle
- ^{55}Fe - 5.9keV Monochromatic source
- ^{90}Sr - 2.3MeV continuous e^- source
- ^{241}Am - 5.486 MeV discrete α source



Optimization : Motivation & Approach

- Measurement of Large charge deposition
- Optimize the amplifier and comparator
- Pulse height and Energy resolution need to be improved
- Best use of available ToT range
- Considering the noise-free stability of the sensor

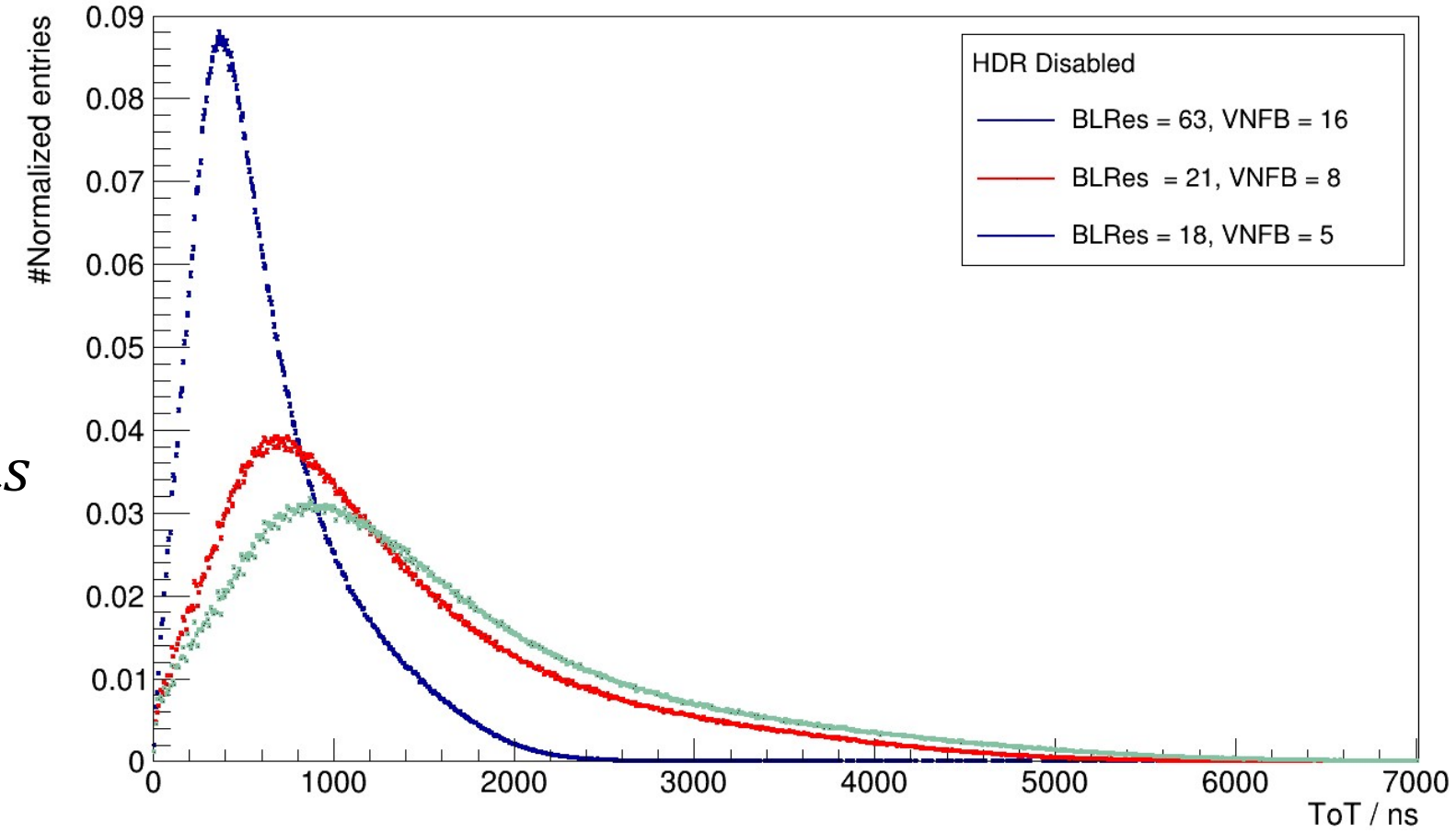
Main optimization parameters:

VNFB: Resistive feedback for the CSA → the pulse width control

BLRes: Baseline restoration → Noise control

Example: Sr90 Spectra

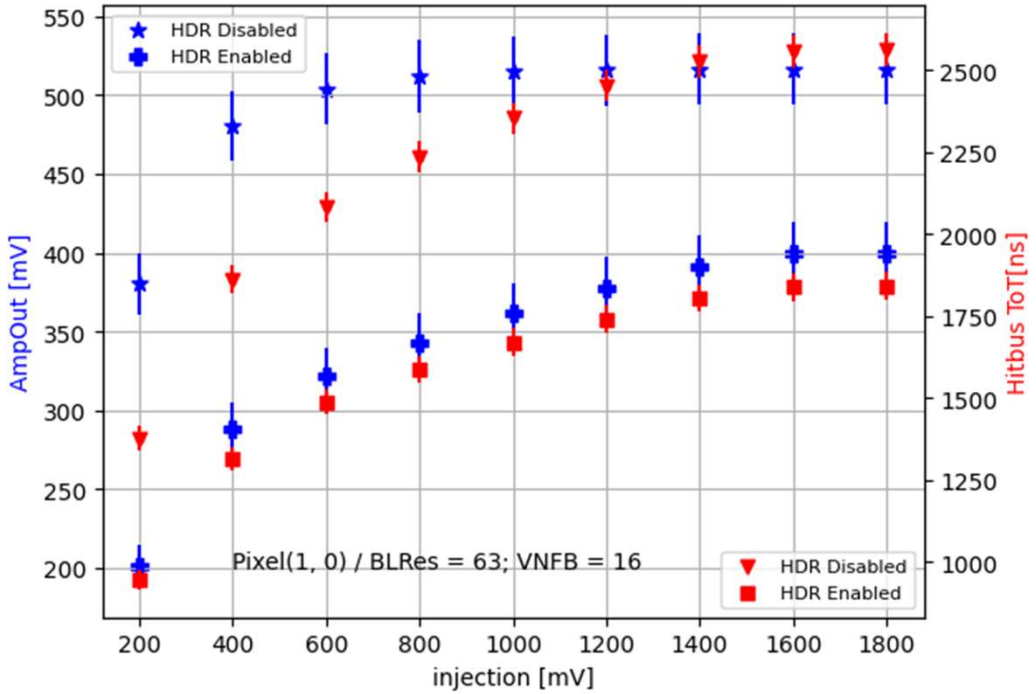
$ToT \sim 10bits$
$\rightarrow 1024\ bins\ @\ 8ns$
$\rightarrow\ \sim 8\ \mu s$

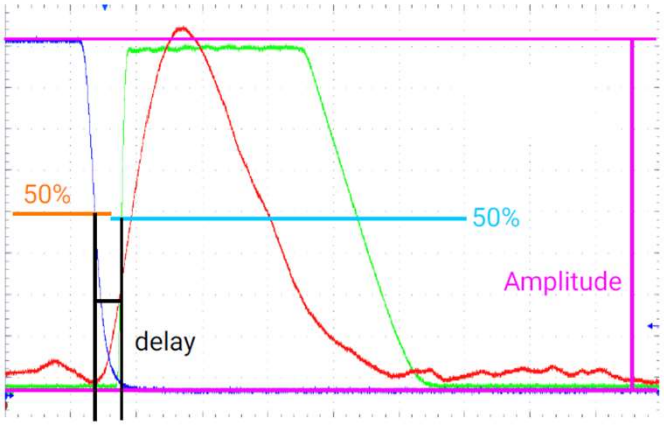


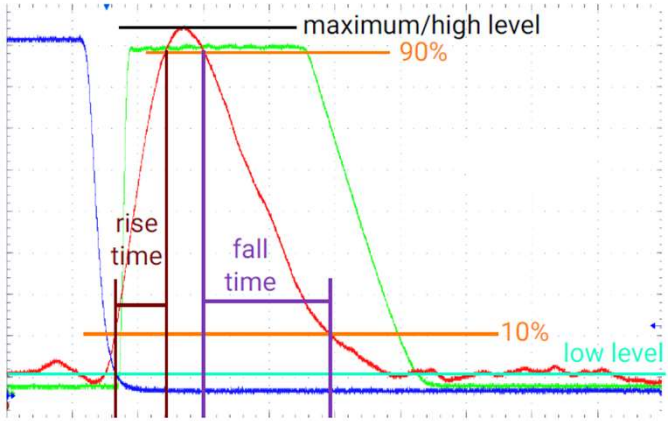
ToT range increased!

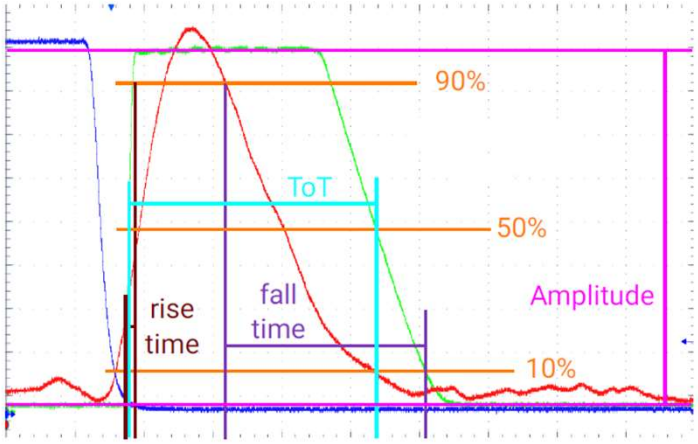
Measurement with Injection - Oscilloscope

- The pulse height saturates early
- Maximum ToT difference is ≈ 800 ns





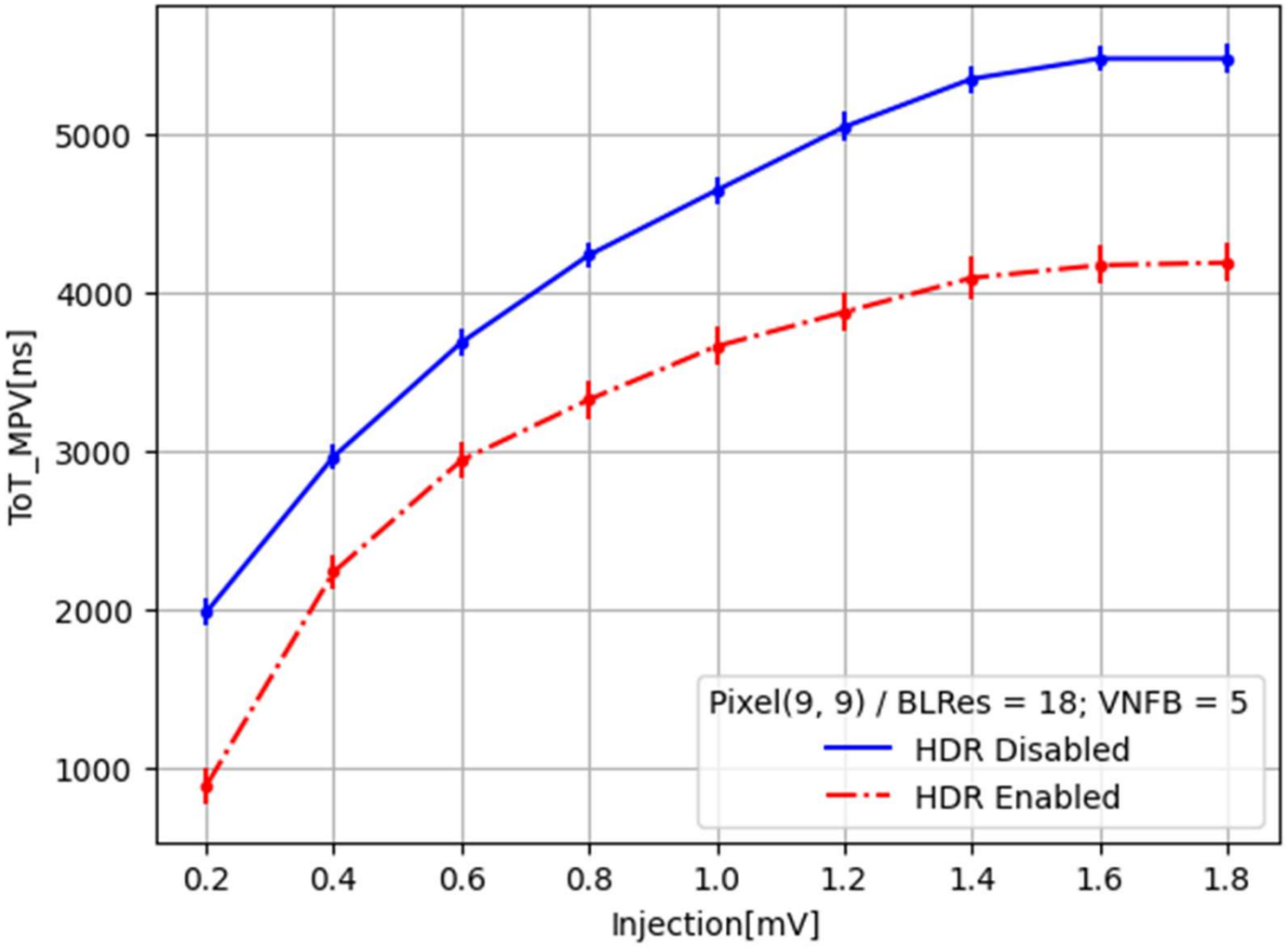




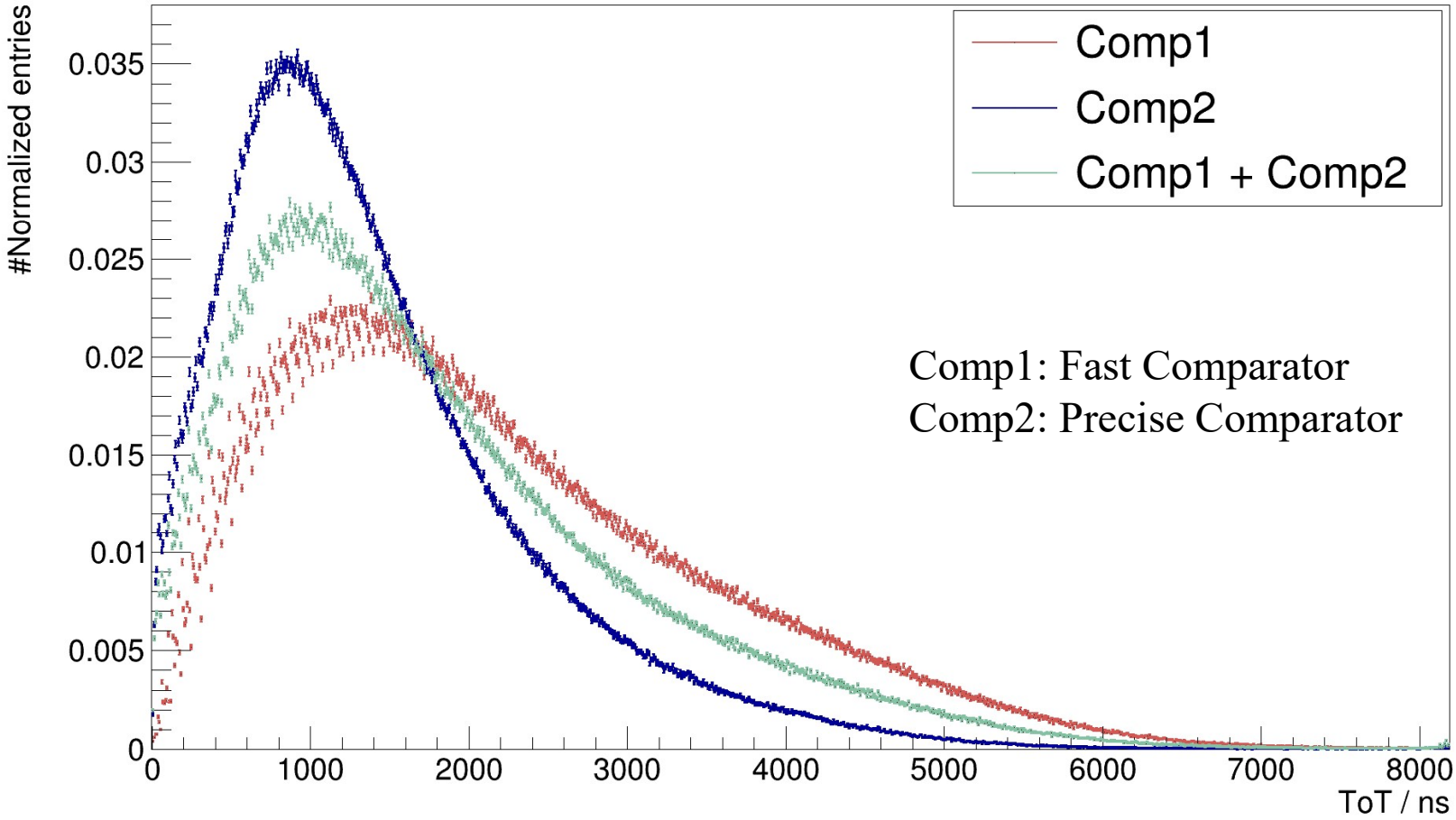
$$Amp[mV] = maximum - low\ level \qquad ToT[ns] = fall_{50\%} - rise_{50\%}$$

Measurement with Injection - Data

- Data collected using injection for a single pixel
- ToT range has significantly improved
- Pixel to pixel variation has been observed

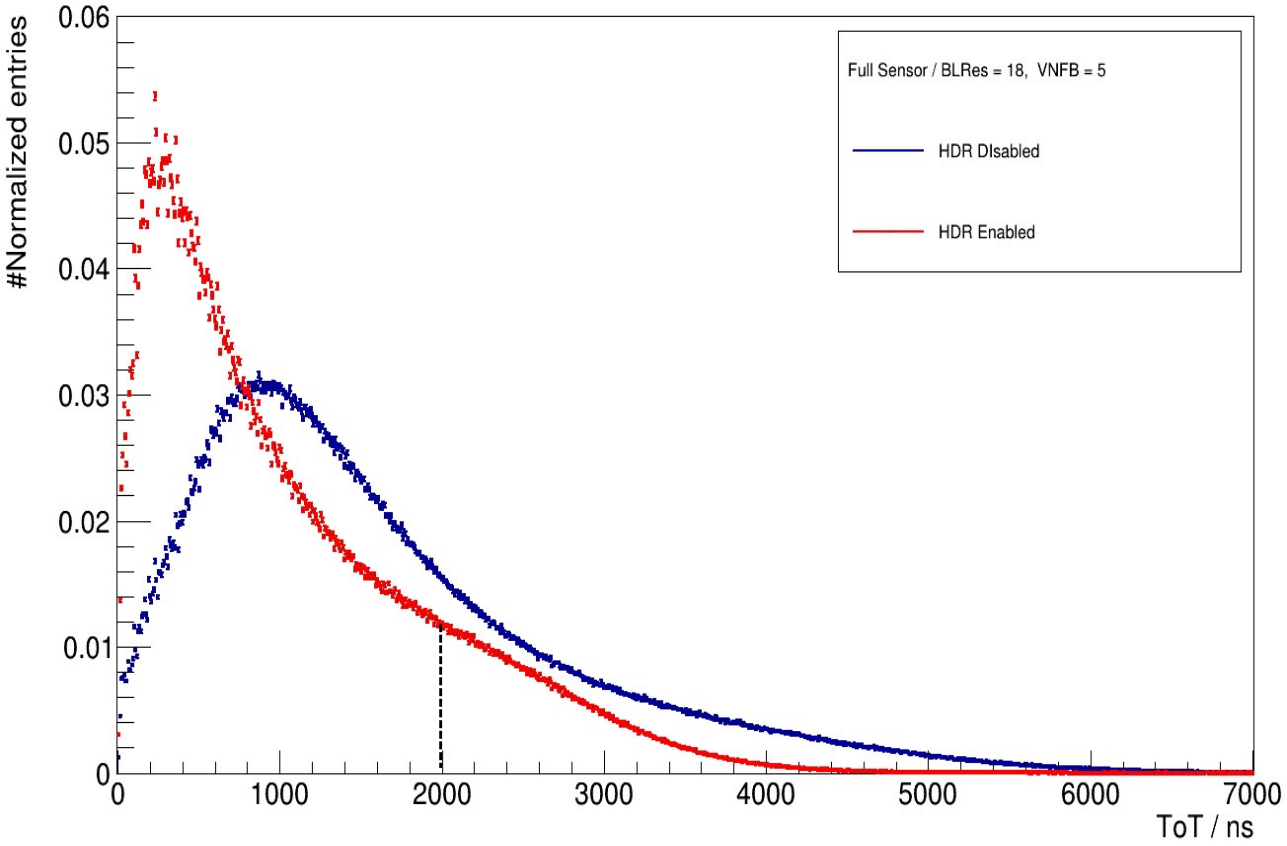


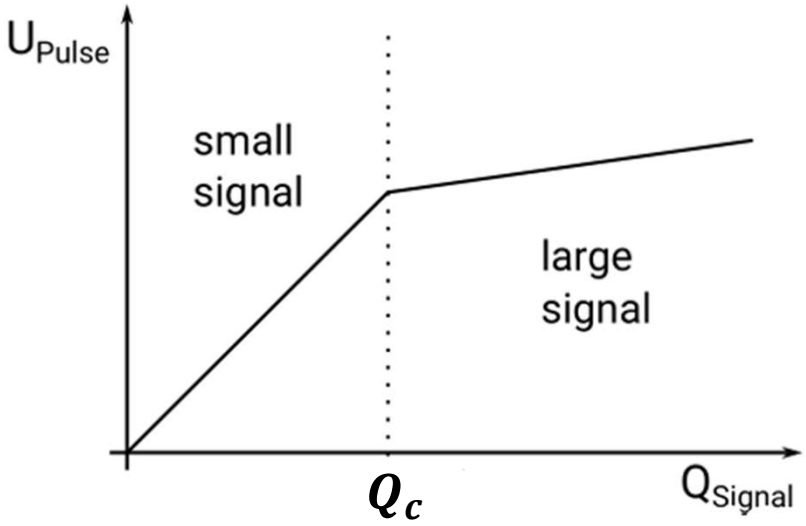
Sr90 Spectra - Comparators



- Precise Comparator → sharp ToT spectra

Sr90 Spectra - HDR



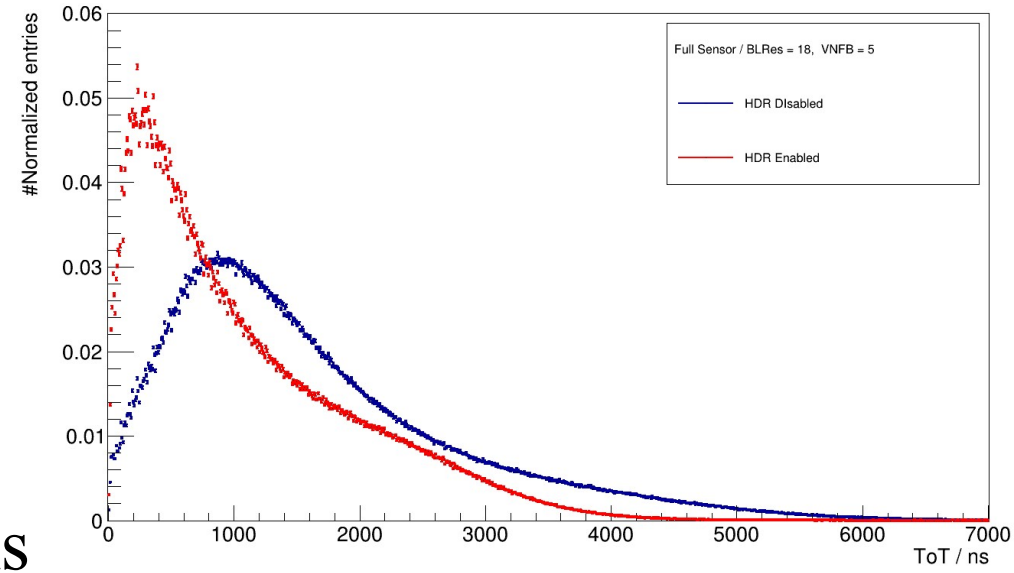


- HDR Enabled → Squeezes ToT spectra

Conclusions

- Optimisation on-going
- HDR implementation seems successful

  → Need more investigation



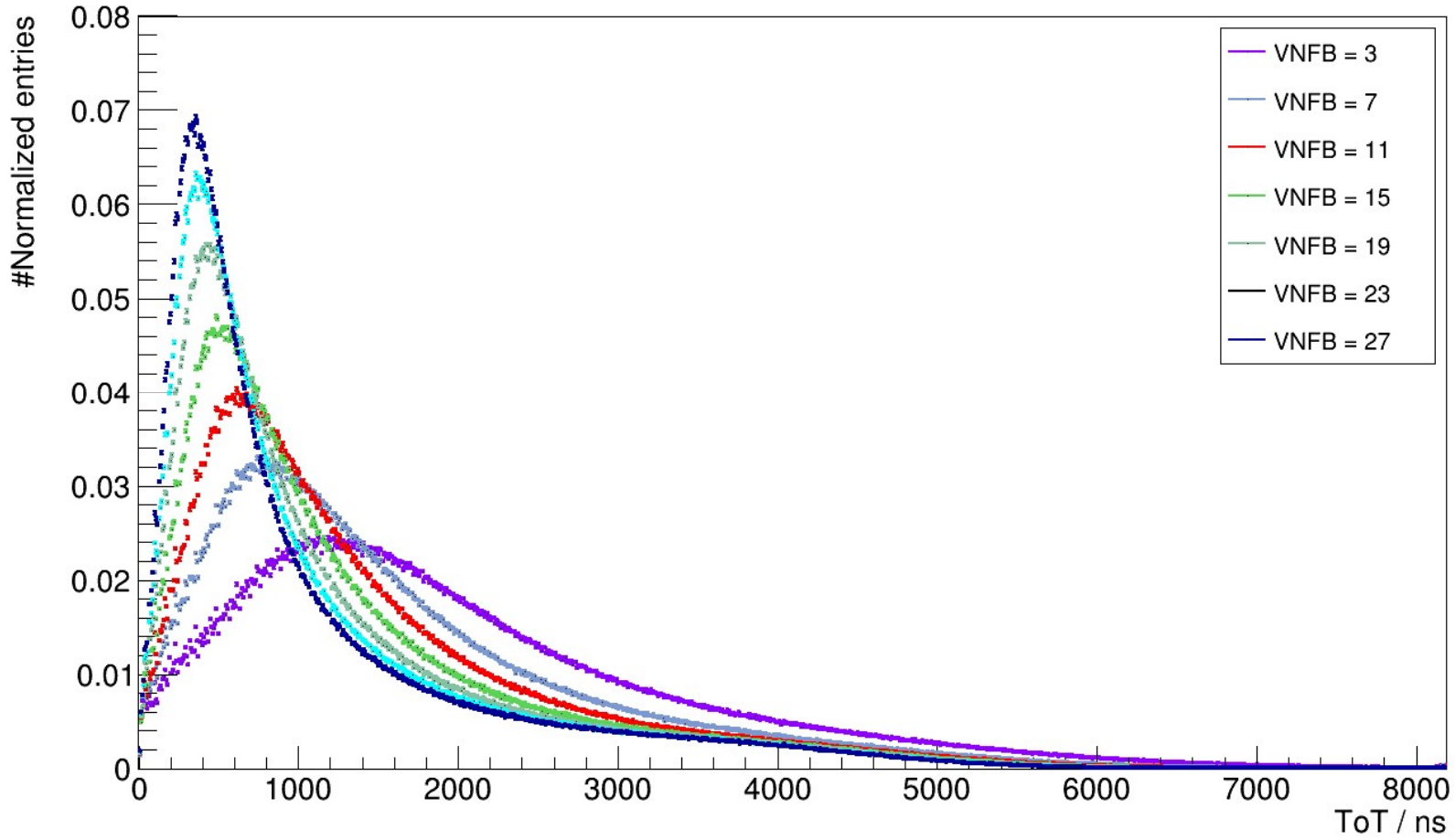
Next steps:

- Investigate large charge depositions
  - ^{241}Am, high ohmic Sensors
- Sensor calibration

Thank you for your attention

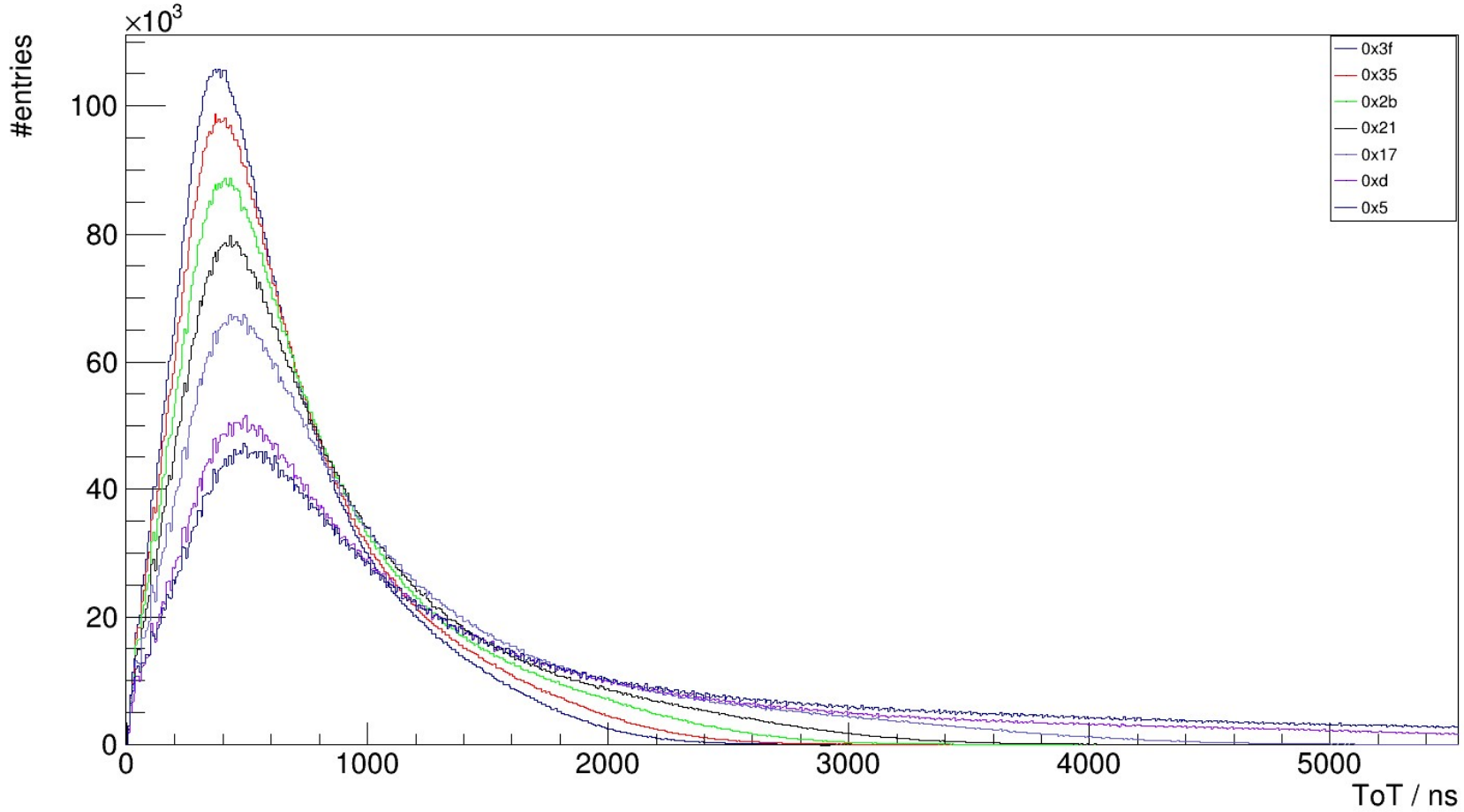
Backup Slides

Backup



- Lower feedback value → Higher the pulse height

Backup



- Lower BLRes value → better energy resolution