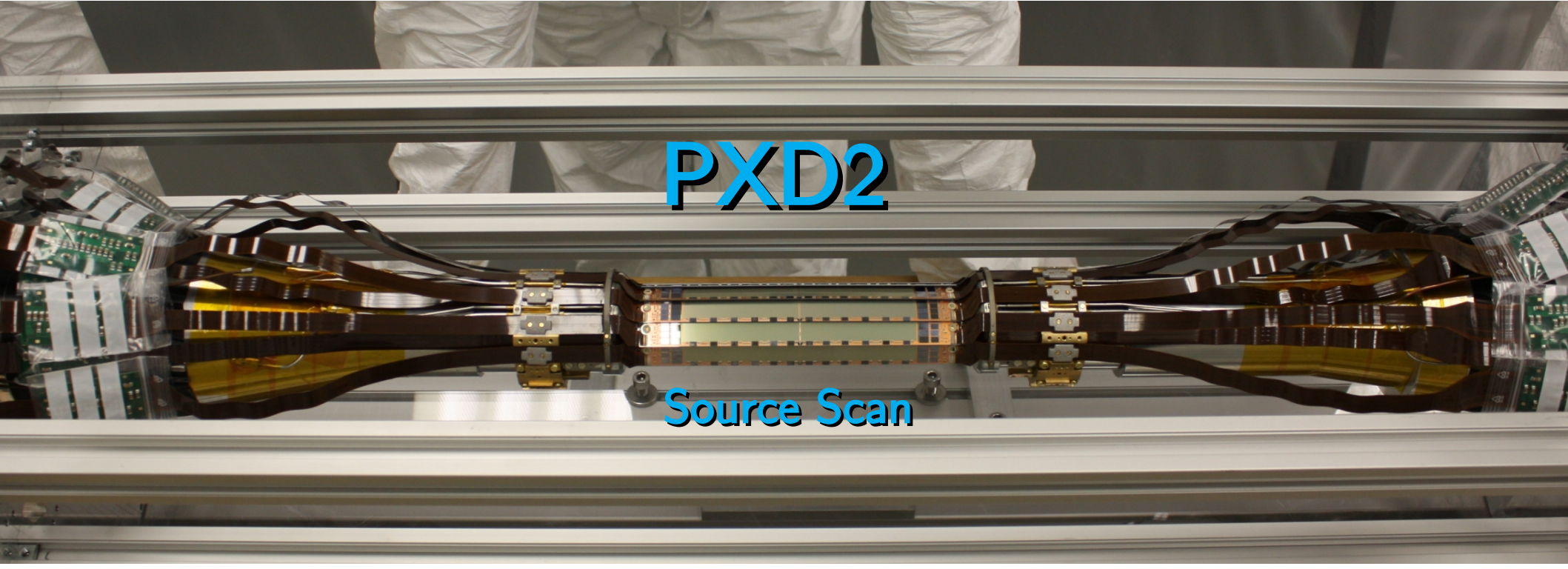


PXD2

Source Scan

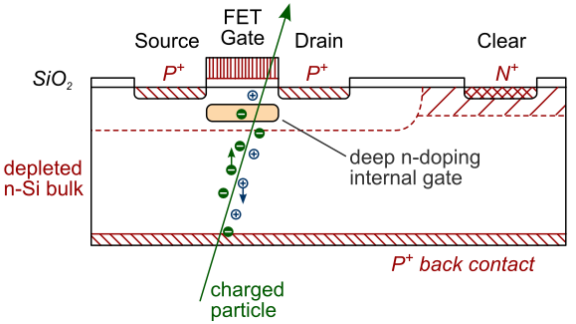
Anselm Baur (DESY)

Tutzing Castle, May 22, 2023

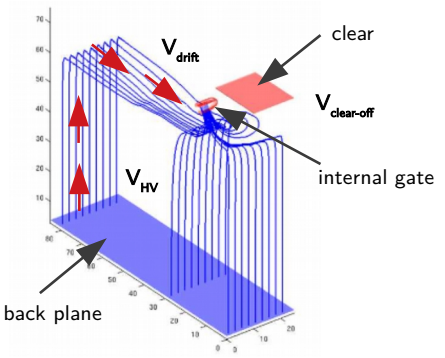
DEPFET Charge Collection Related Voltages

DEPFET Working Principle

- p-channel MOSFET on top of a fully depleted Si bulk
- Internal gate below FET gate
- Free electrons drift to internal gate
- Internal gate charge amplifies source-drain current
- Clear mechanism to empty internal gate



Source: https://doi.org/10.1016/S0168-9002(03)01802-3



Operating DEPFET

- DEPFET sensor biasing: 11 voltages with complex cross-dependencies
- Voltages dominant impact on charge collection:
  V_{HV}, V_{drift}, and $V_{clear-off}$

From Drain Current to Cluster Charge

- Drain current prop. to collected charge
- Digitize drain currents of pixel cells
- Cluster pixel hits: cluster charge prop. to dE/dx

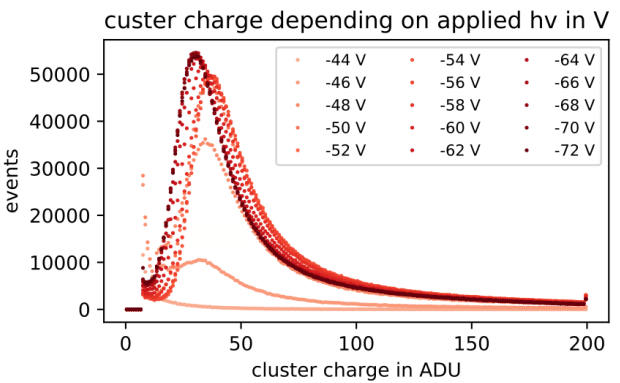
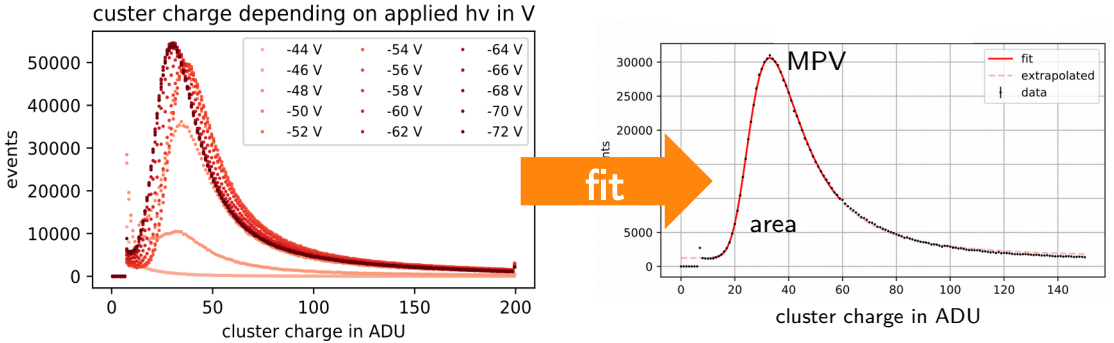


Figure of Merit

Fitting Cluster Charge Distribution:

- **LanGau (+ const. Backgr.) Fit**
  (LanGau: Landau convoluted with Gaussian read-out noise)
- Defining **Figure of Merit**:

$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \frac{\text{area}}{1000}$$

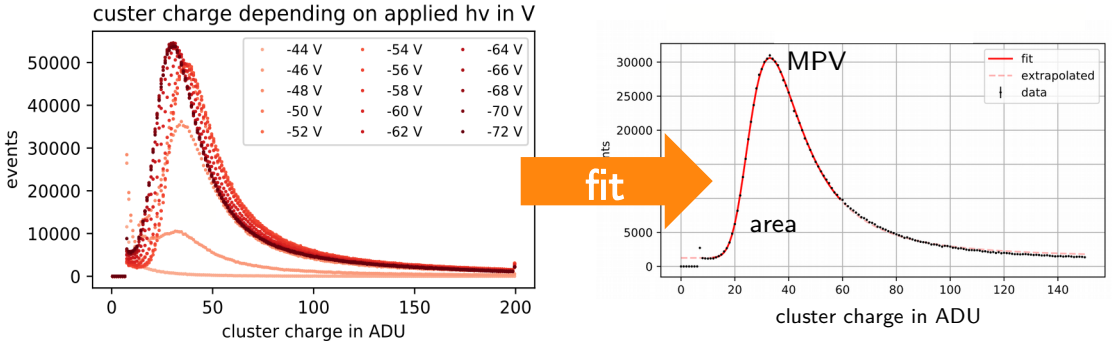


Optimal Parameter Settings

Fitting Cluster Charge Distribution:

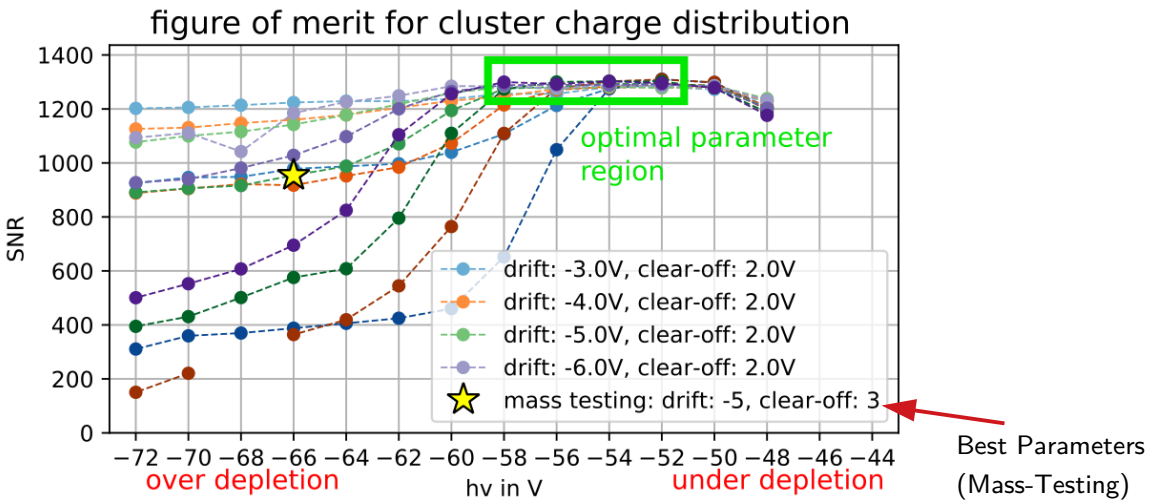
- **LanGau (+ const. Backgr.) Fit**
  (LanGau: Landau convoluted with Gaussian read-out noise)
- Defining **Figure of Merit**:

$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \frac{\text{area}}{1000}$$



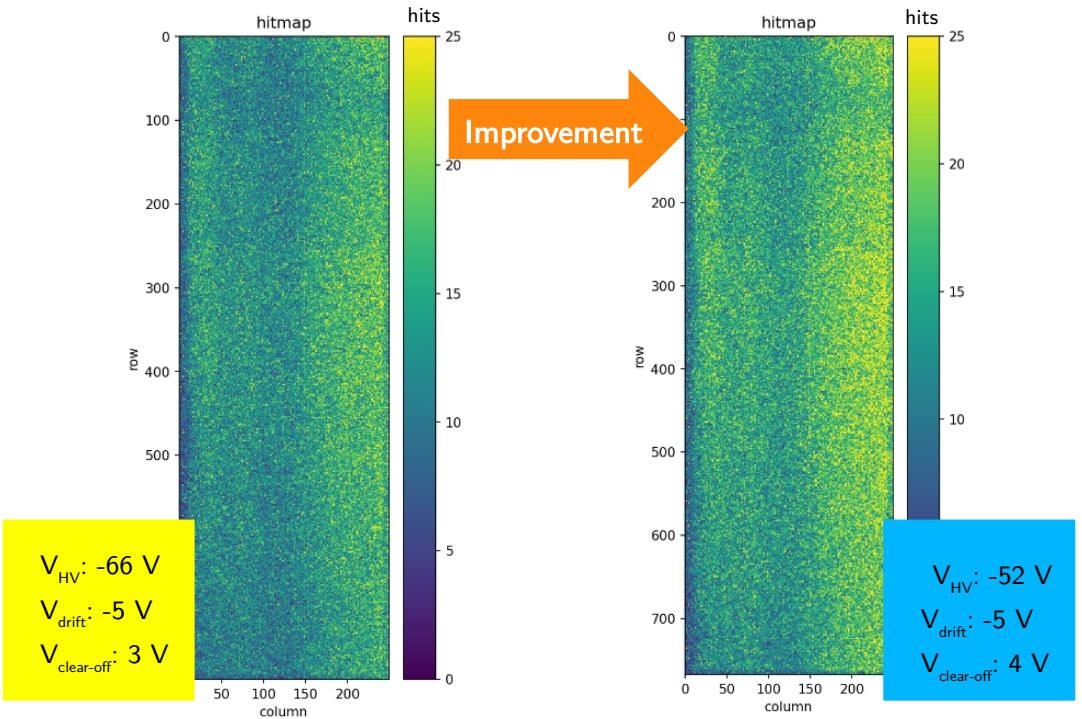
1st HS Source Scan

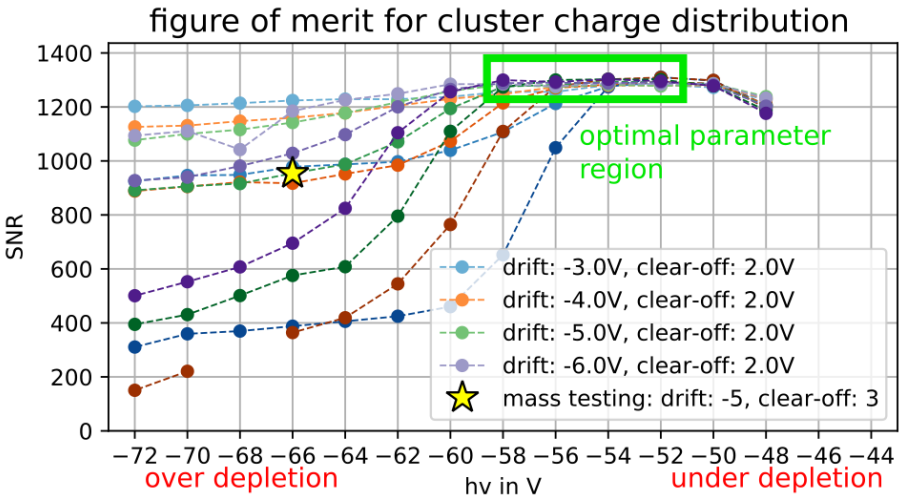
Measurement
- **HV**: -48V → -72V
- **Drift**: -3V → -6V
- **Clear-off**: 2V → 4V
- 15 min measurements



Source Scan Results

$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \frac{\text{area}}{1000}$$





Conclusion:

- Partially not optimal parameters found during mass-testing for several modules

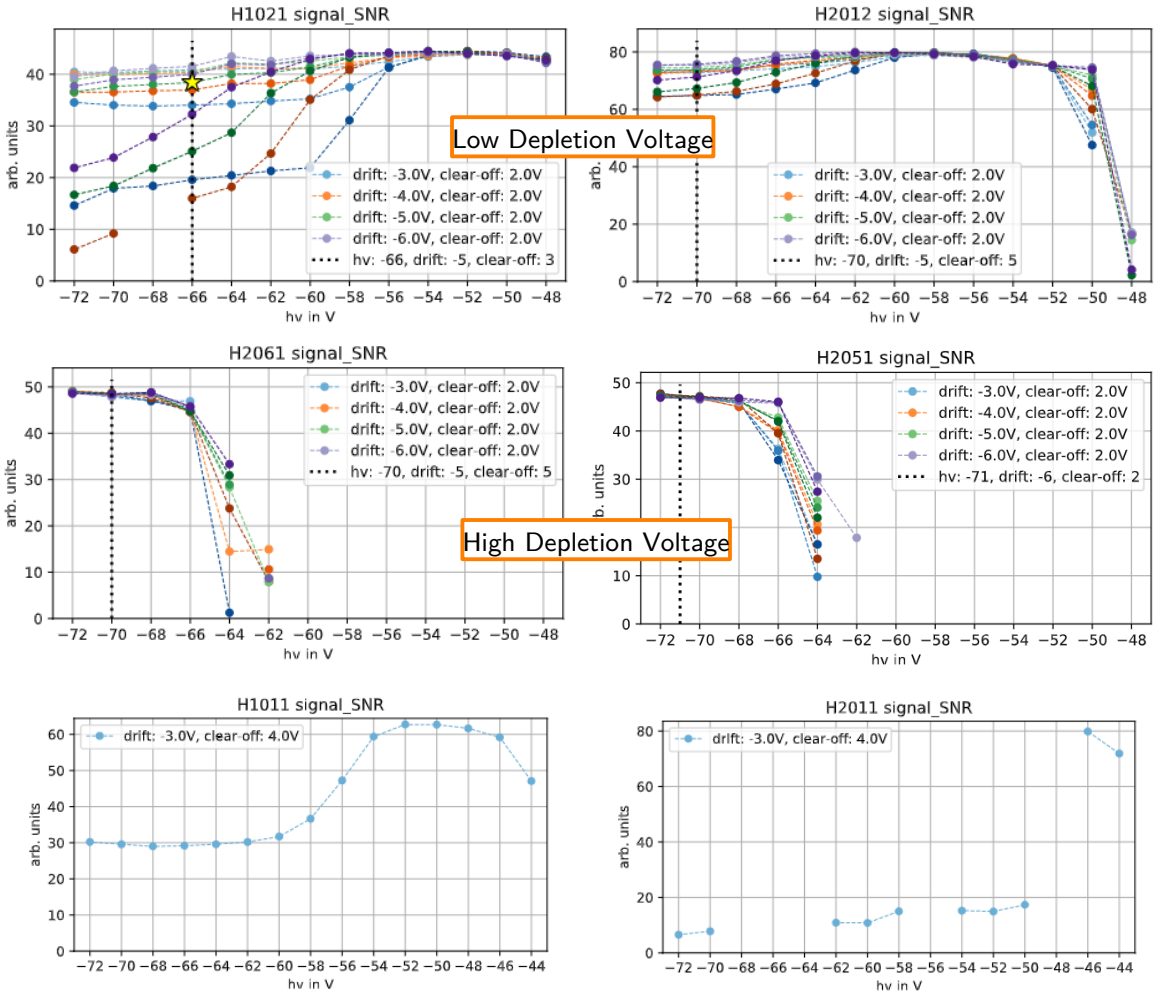
Characteristics of the SNR Curves

The Overall Picture 1st HS

- Plateau region
- Decrease of SNR for bad settings towards more negative HV
- Two module types regarding depletion voltage (HV)

Fast Coarse Scan 2nd HS and 1st HS v2

- Find the basic module characteristic
  → Scan HV using a bad setting
  - Clear-Off: 4 V
  - Drift: -3 V
- Only 15 measurement points (instead of 180)
- Start parameter for more granular scan
- Optimize cluster charge fit



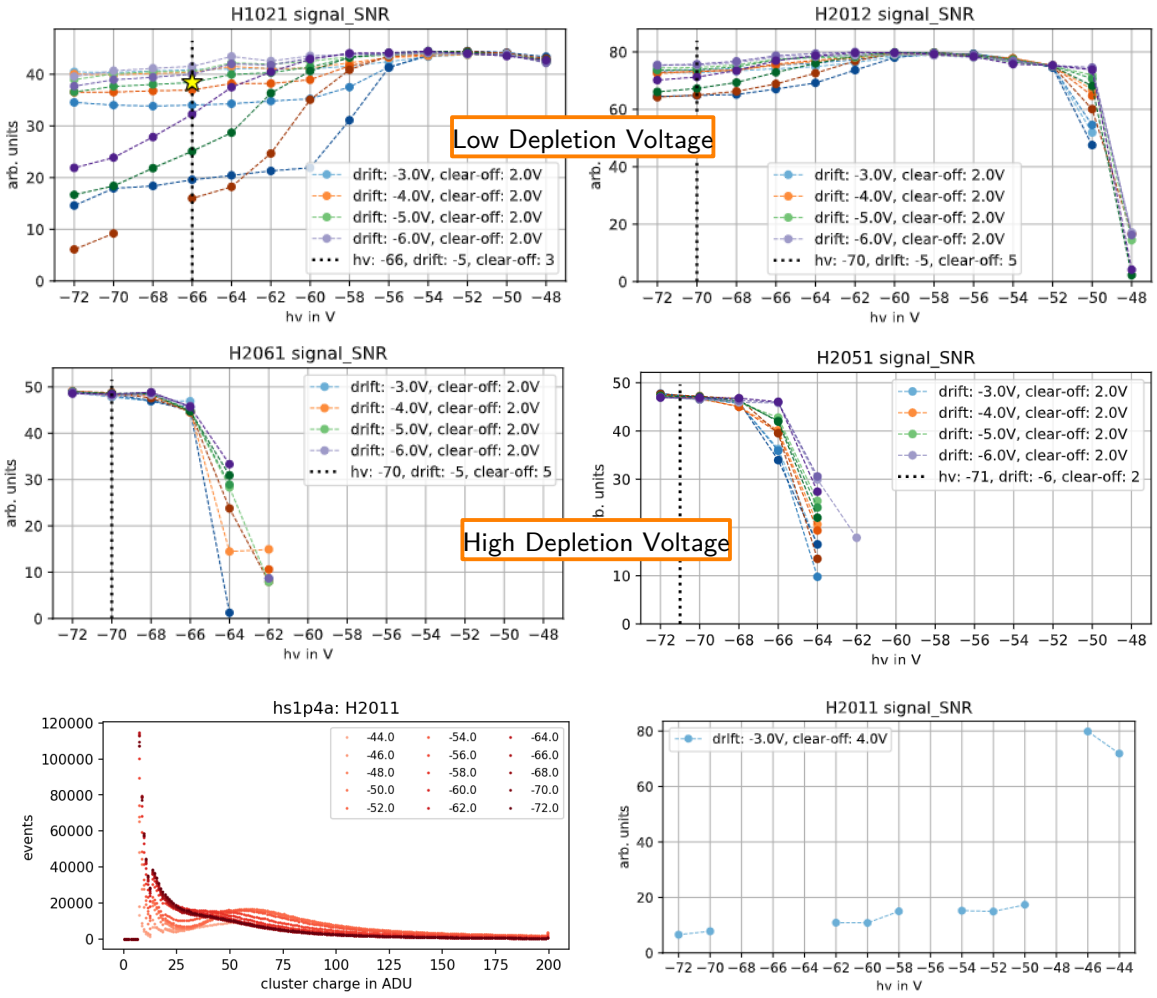
Characteristics of the SNR Curves

The Overall Picture 1st HS

- Two module types regarding depletion voltage (HV)
- Plateau region
- Decrease of SNR for bad settings towards more negative HV

Fast Coarse Scan 2nd HS and 1st HS v2

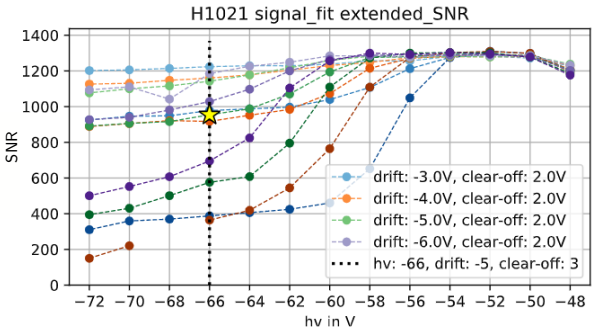
- Find the basic module characteristic
  → Scan HV using a bad setting
  - Clear-Off: 4 V
  - Drift: -3 V
- Only 15 measurement points (instead of 180)
- Start parameter for more granular scan
- Optimize cluster charge fit

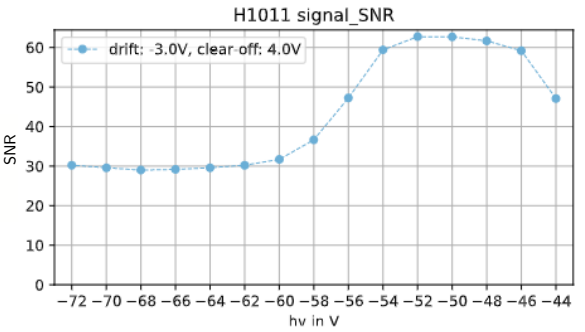


Summary and Outlook Source Scan

Large Parameter Space Scan

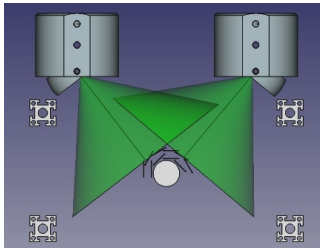
- Only with original 1st HS (before incident)
- Voltage settings
  - HV: -48 → -72
  - Drift: -3V → -6V
  - Clear-off: 2V → 4V

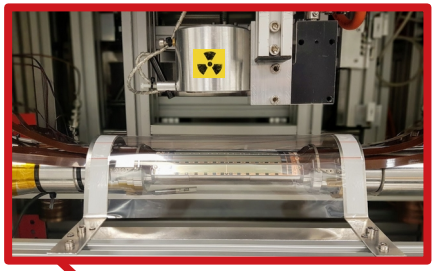


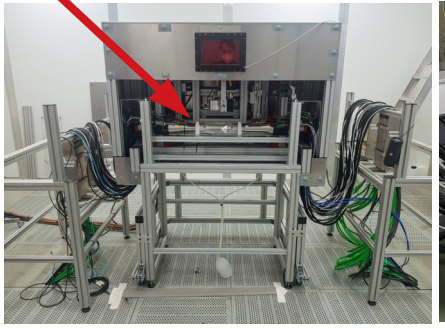


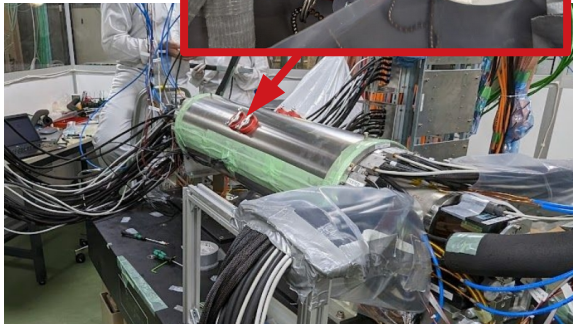
Coarse Scan

- With all modules of PXD2
  - 2nd HS DESY
  - 1st HS v2 KEK
- Voltage settings
  - HV: -48 → -72
  - Drift: -3V
  - Clear-off: 4V









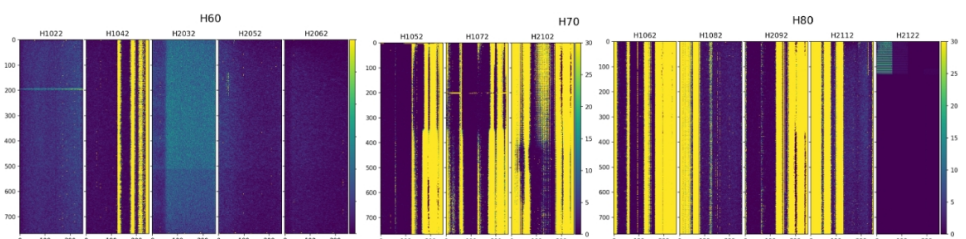
Detailed Scan With All Modules (for My Successor)

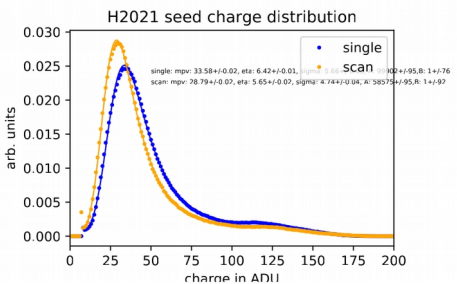
- Minimized beam time necessary for final scan
- Use optimal HV plateau from course scan as start parameter
  - HV: start → start – 4V
- Scan script needs to be adjusted

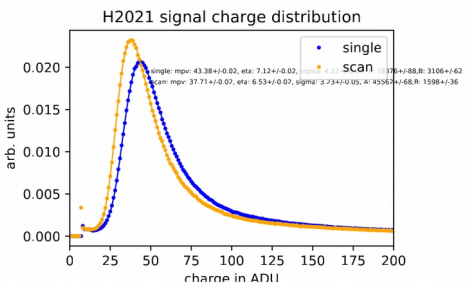
Cross Talk Measurements

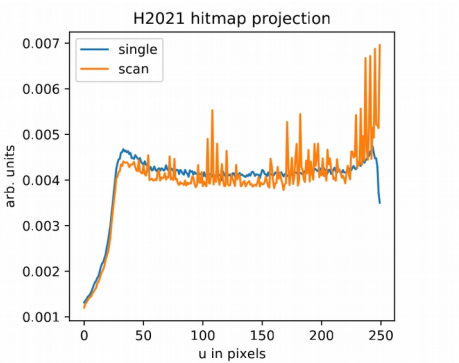
Measurement at 1st HS Only (Before Incident):

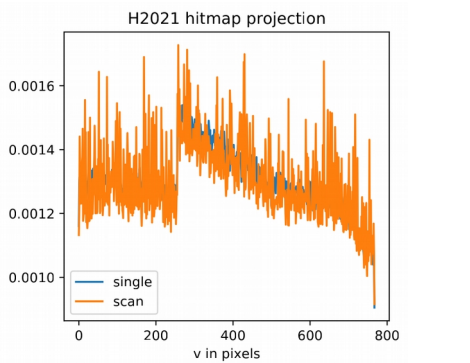
- Only 1 module ON → single
- All modules on ½ HS ON → scan
- Compare charge distributions and hit maps (projections)
  - Charge distributions shifted
  - Noise increased
  - Pedestals shifted (temperature?)
- This behavior showing many modules on 1st HS
  - Geometrical dependency?
- Noise introduced by neighboring switchers?
  - Observed large noise influence due to switchers of connected to DHCs which were out of sync

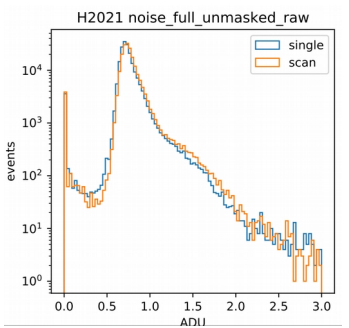


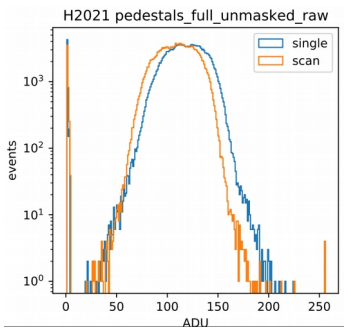








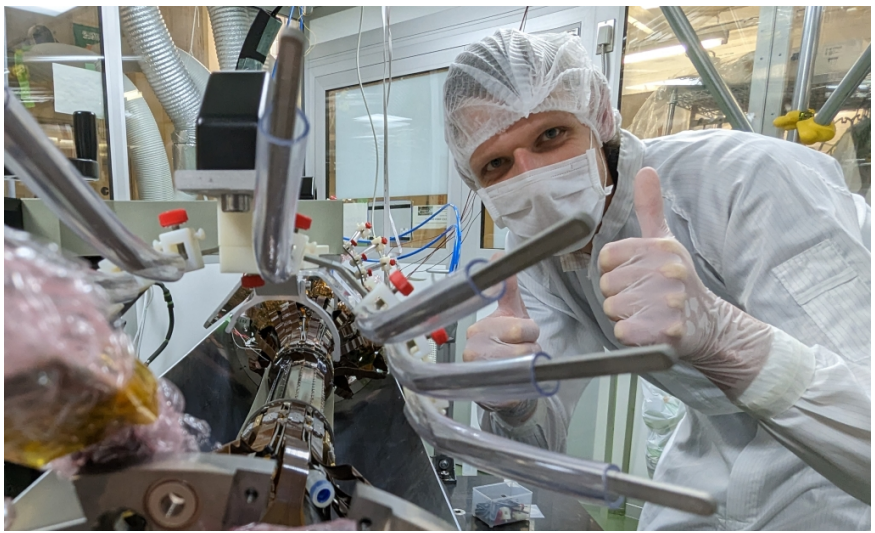




Summary

PXD2

- PXD2 commissioning at DESY and KEK finished
- Granular source scan data for 1st v1 HS of PXD2
- Course set of Source scan data taken for all PXD2 modules
- More precise source scan data analysis work in progress
- Cross Talk measurements shows interesting charge shift



Backup

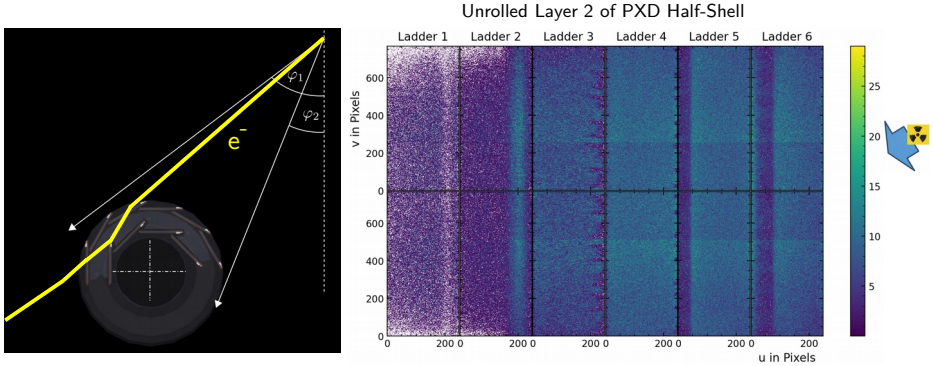
Simulation and Verification

Simulation

- Basf2: 2 layer PXD HS mounted on solid Al beam pipe
- Implemented two Sr90 source positions
  - Illumination of HS from both sides
- Estimate source position in source setup
  - Sufficient Statistic over all modules

Verification

- Dummy HS with one functional module
- Recorded data with source and compared with simulation
  - Transform simulation hit rate to measured hit rate
  - $$t_{\mathrm{sim}} = \frac{n}{f_{\mathrm{trig}} \cdot n_{\mathrm{readout}}^2}$$
  $$n_{\mathrm{readout}} = t_{\mathrm{readout}} \cdot a \cdot f_{\mathrm{Aw}}$$
  $$f_{\mathrm{Aw}} = \frac{A_{4\pi}}{A}$$
  $f_{\mathrm{trig}} = 5000$ Hz
  $t_{\mathrm{measure}} = 900$ s
  $t_{\mathrm{readout}} = 20$ us
  $a = 3.2\ 106\ \mathrm{s}^{-1}$
- Good agreement



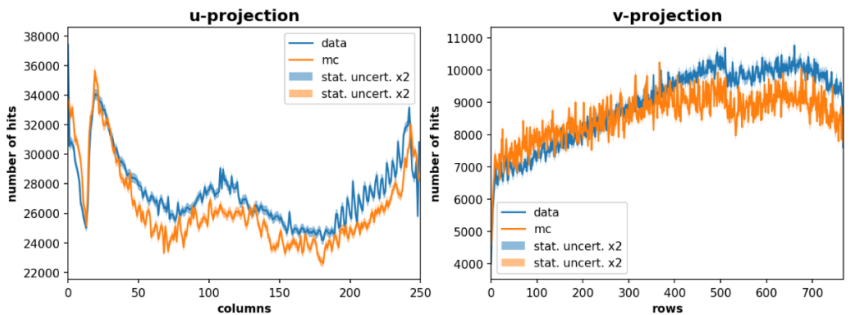


Figure 2: Comparison of measurement and simulation for the half-shell test stand. The measurement data was collected with the working module in the dummy half-shell. Simulation follows the data in shape and number of hits.

1st Half-Shell

Status:

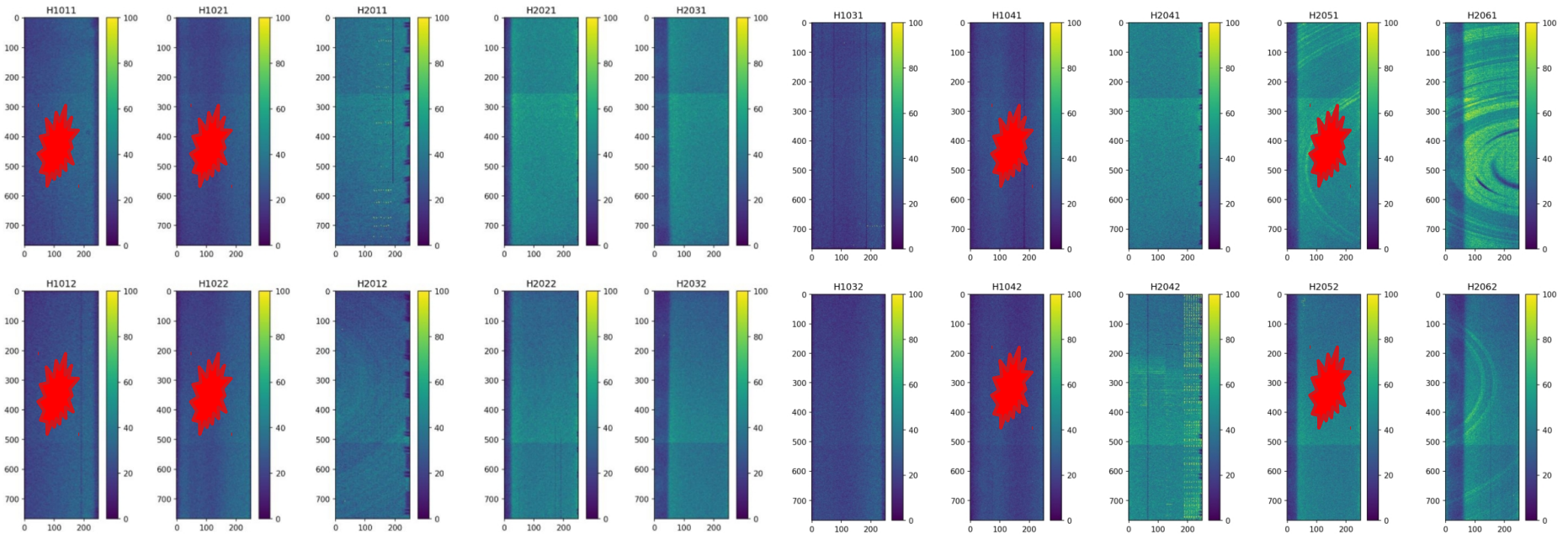
- All 20 modules **fully functional**
- **Basic-calibrations** and **source scan** finished
- 4 ladders replaced

Source Scan:

- **Optimize** DEPFET **biasing voltages** for maximal charge collection
- Scan 144 voltage settings

Measurement
- **HV**: -48V → -72V
- **Drift**: -3V → -6V
- **Clear-off**: 2V → 4V
- 15 min measurements

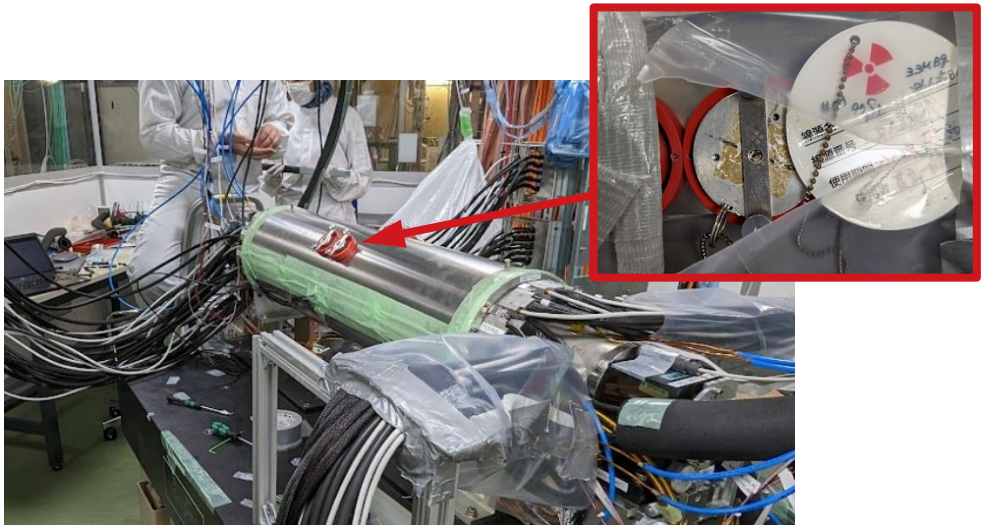
Sr90 hitmaps (re-measure hit efficiencies, tune working point)

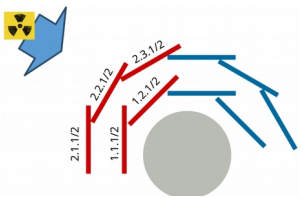


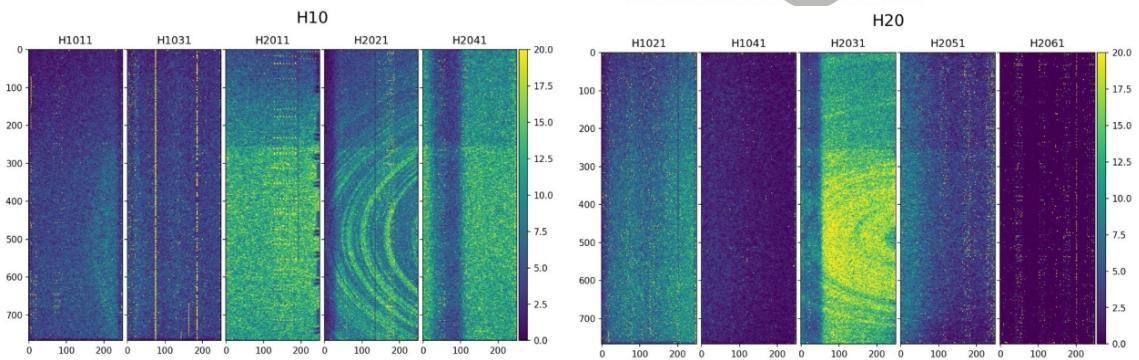
1st HS v2 Source Scan at KEK

Course Scan of Depletion Voltage (HV)

- Luckily we could run IBBelle 1 week with a leaking pump
- Scanned the same parameter range as for 2nd HS
  - HV: -72 V → -44 V
  - Drift: -3 V, Clear-off: 4 V
- 4 Source positions (camera ring)
- Source activity ½ of DESY source (~1.5 Mbq)
- No time for any debugging
- Analysis ongoing



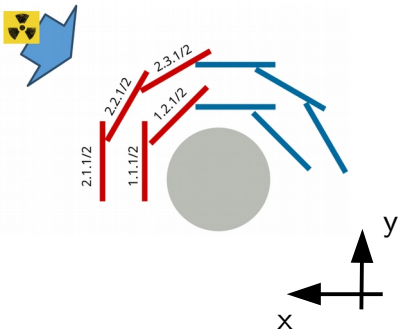


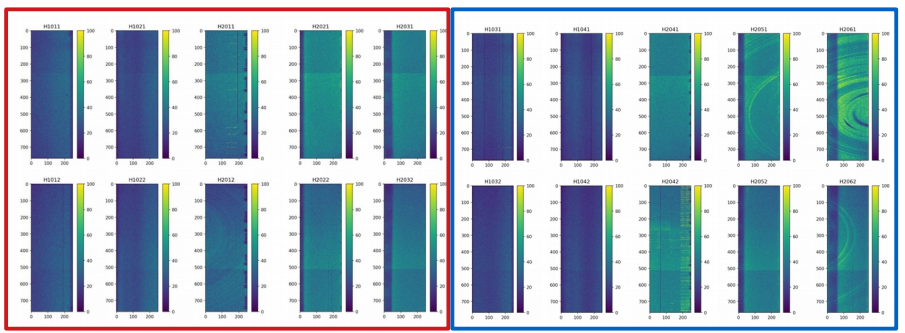


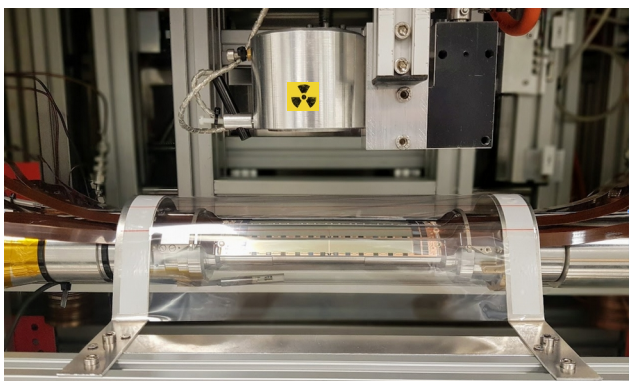
DESY Source Setup

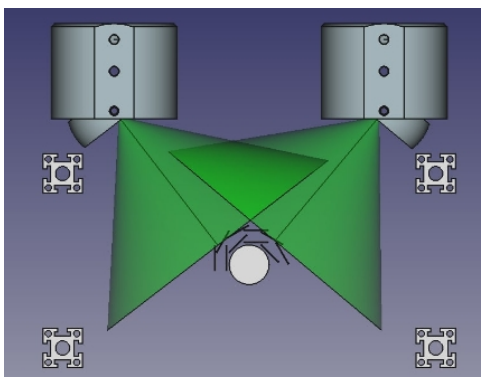
Source Positions

- Optimal illumination within the given geometrical boundaries
- Source movable along 4 axes
- 1 Source: 1st HS powered and measured asymmetrically (left/right)
- 2 Sources: 2nd HS powered symmetrically (fwd/bwd)







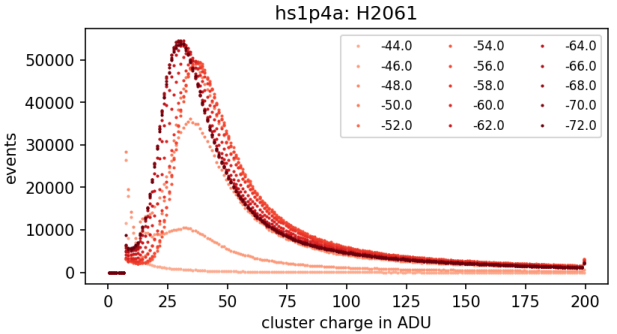


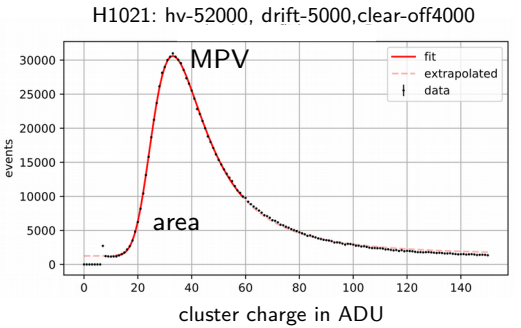
Source Scan Analysis

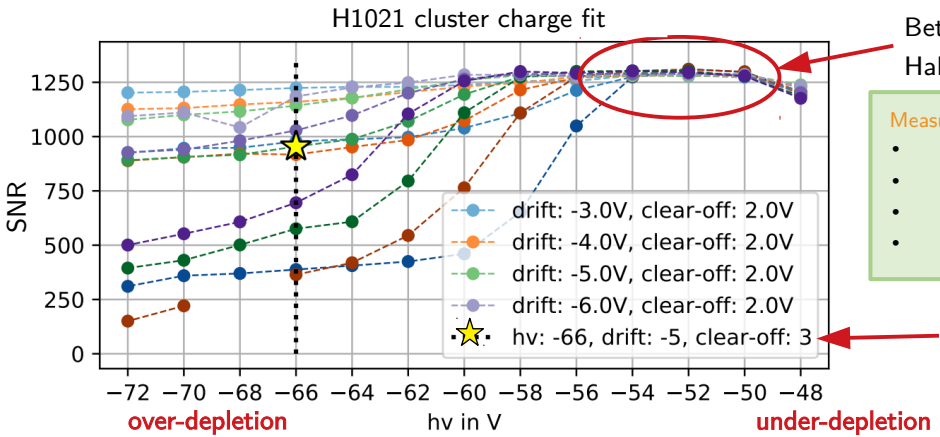
Fitting Cluster Charge Distribution:

- **LanGau (+ const. Backgr.) Fit**
  (LanGau: Landau convoluted with Gaussian read-out noise)
- Defining **Figure of Merit**:

$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \frac{\text{area}}{1000}$$



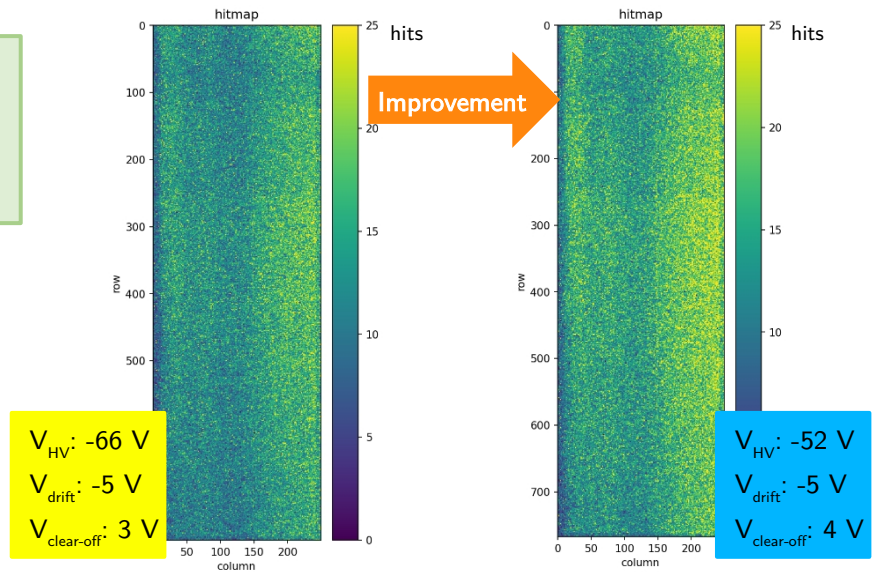




Better Parameters
Half-Shell Scan

Measurement
- **HV**: -48V → -72V
- **Drift**: -3V → -6V
- **Clear-off**: 2V → 4V
- 15 min measurements

Best Parameters
Mass-Testing



Conclusion:

- Optimal **parameters** determined during **mass-testing** **partially not optimal** for several modules

Source Scan Measurements Scenarios

- Measure at (per ½ HS)
  - HV -58V - -62V (3 points),
    drift -3V - -6V (4 points),
    clear-off 2V – 4V (3 points)

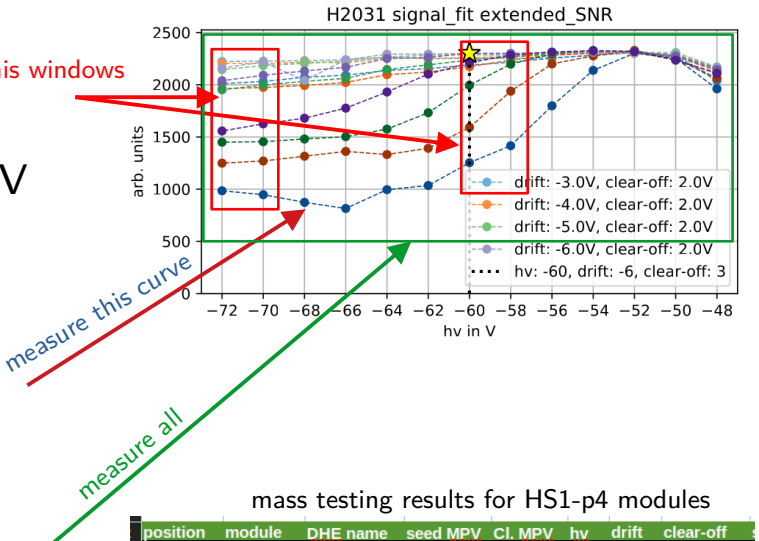
→ total 36 points a 20 min
→ 12 h (for HV -70V - -72V as well)

  - HV -48V – 72V (13 points)
    drift -3V (1 point)
    clear-off 4V (1 point)

→ total 13 points a 20 min
→ 4:20 h

  - HV -48V – 72V (13 points)
    drift -3V - -6V (4 points),
    clear-off 2V - 4V (3 point)

→ total 156 points a 20 min
→ 52 h



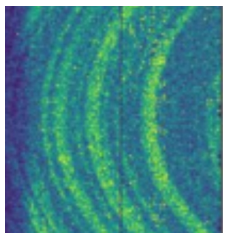
mass testing results for HS1-p4 modules

position	module	DHE name	seed MPV	Cl. MPV	hv	drift	clear-off
L1-a	W67_IB	1012	29	32	-54	-6	2
L1-a	W67_IF	1011	30	33	-56	-6	2
L1-b	W58_IB	1022	32	37	-58	-4	2
L1-b	W66_IF	1021	32	35	-54	-6	2
L1-c	W59_IB	1032			-64	-4	3
L1-c	W69_IF	1031			-56	-6	2
L1-d	W53_IB	1042			-68	-5	3
L1-d	W53_IF	1041			-66	-4	2
L2-a	W59_OB2	2012			-52	-6	2
L2-a	W57_OF2	2011			-50	-6	2
L2-b	W54_OB1	2022			-52	-5	2
L2-b	W56_OF2	2021			-54	-5	2
L2-c	W56_OB1	2032			-56	-5	2
L2-c	W60_OF1	2031			-51	-6	2
L2-d	W10_OB1	2042			-60	-5	3
L2-d	W45_OF2	2041			-66	-3	3
L2-e	W04_OB1	2052			-68	-5	4
L2-e	W05_OF1	2051			-60	-5	2
L2-f	W33_OB1	2062			-67	-6	2
L2-f	W43_OF1	2061			-60	-5	2

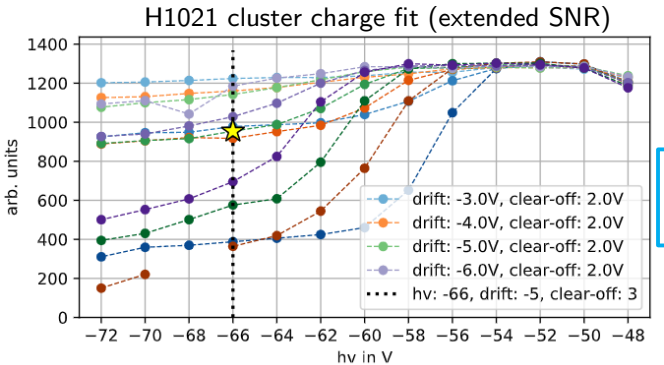
SNR w/o Number of Hits

Event loss during data taking 1st HS v2 at KEK

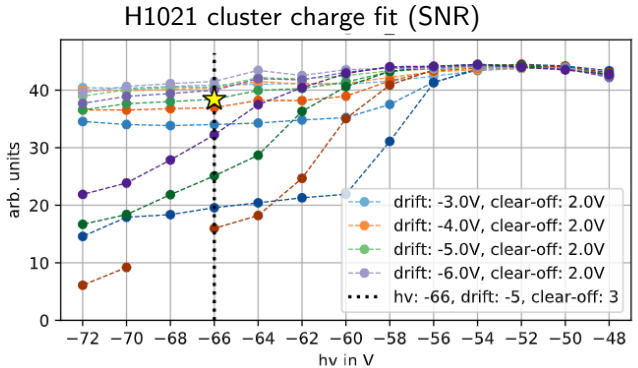
- Number of hits is sensitive to data loss
  - e.g. full buffers in DAQ chain
- Might be recovered by nr. hits per data frame
  - Needs high intensity
    → needs further investigation
- Number of hits is correlated with high MPV
  - Exception: rings



- SNR w/o nr. of hits is for now the better Figure of Merit



$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \frac{\text{area}}{1000}$$



$$SNR = \frac{\text{MPV}}{\text{noise}_{\text{pedestal}}} \cdot \cancel{\frac{\text{area}}{1000}}$$