

CORRELATION BETWEEN LEAKAGE CURRENT AND NOISE

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INTRODUCTION

For detectors measuring absorbed energies it is useful to quantify the noise in terms of

Equivalent Noise Charge (ENC)

This ENC corresponds to the amount of charge that would have to traverse the detector to yield a signal as big as the actual noise:

$$\text{noise} = \varepsilon \cdot \text{ENC}$$

ε ... calibration constant

AMPLIFIER NOISE

- main noise source: input transistor at the amplifier
- contributions of further stages usually neglected
- load capacitance plays an important role due to the integrating nature

In a simple approach, the amplifier noise can be described by the sum of:

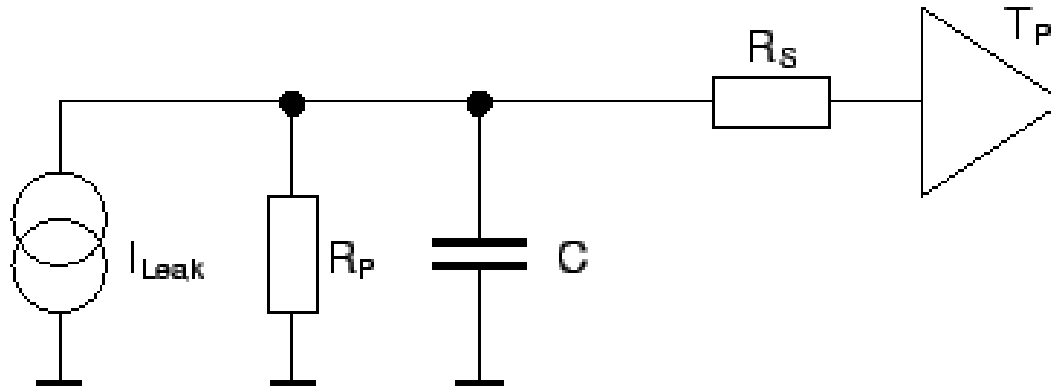
- a constant value (parallel noise) and
- a part which scales with the load capacitance C (series noise)

$$ENC_{APV} = ENC_{APV, parallel} + C \cdot ENC_{APV, series}$$

$$ENC_{APV} [e] = \begin{cases} 250 + 36 \text{ pF}^{-1} & \text{(peak)} \\ 400 + 60 \text{ pF}^{-1} & \text{(deconvolution)} \end{cases}$$

ADDITIONAL NOISE SOURCES

equivalent network for a single strip & readout:



- I_{leak} ... fraction of the detector leakage current seen by one strip
- R_{poly} ... polysilicon resistor
- C ... strip capacitance
- R_{strip} ... line resistance of one strip
- T_p ... peaking time

numerical noise equations:

$$\text{ENC}_{\text{leak}} [\text{e}] = 106 \cdot \sqrt{I_{\text{leak}} [\text{nA}] \cdot T_{\text{P}} [\mu\text{s}]}$$

$$\text{ENC}_{\text{poly}} [\text{e}] = 758 \cdot \sqrt{\frac{T_{\text{P}} [\mu\text{s}]}{R_{\text{poly}} [\text{M}\Omega]}}$$

$$\text{ENC}_{\text{RS}} [\text{e}] = 0.395 \cdot C \cdot \sqrt{\frac{R_{\text{strip}} [\Omega]}{T_{\text{P}} [\mu\text{s}]}}$$

The total noise figure is the square sum of the individual contributions, since the individual sources are uncorrelated:

$$\text{ENC}^2 = \sum \text{ENC}_i^2$$

CORRELATION FOR OB2-MODULES

OB2-sensors:

- $R_{\text{poly}} = 1.5 \text{ M}\Omega$

- $C = C_{\text{int}} + C_{\text{back}} = 0.8 + 1.6 \frac{W_{\text{strip}}}{\rho_{\text{strip}}} \text{ pF cm}^{-1}$

$$\Rightarrow C = 11.5 \text{ pF}$$

- R_{strip} :

$$W_{\text{strip}} = 1.15 \cdot w_{\text{implant}} = 52.6 \text{ }\mu\text{m}$$

$$d_{\text{strip}} \approx 1.5 \text{ }\mu\text{m}$$

$$L_{\text{strip}} = 9.44 \text{ cm} \Rightarrow R_{\text{strip}} = \rho_{\text{Al}} \frac{L_{\text{strip}}}{W_{\text{strip}} \cdot d_{\text{strip}}} = 31.7 \text{ }\Omega$$

OB2-modules:

- 2 electrically daisy-chained sensors
- R_{poly} of each sensor in series
- C of each sensor parallel
- APV: $T_P = 0.05 \mu\text{s}$

This yields:

$$\text{ENC}_{\text{APV}}[\text{e}] = \begin{cases} 1066 & (\text{peak}) \\ 1759 & (\text{deconv.}) \end{cases}$$

$$\text{ENC}_{\text{poly}}[\text{e}] = 138$$

$$\text{ENC}_{\text{RS}}[\text{e}] = 319$$

$$\Rightarrow \text{ENC}(I_{\text{leak}})[\text{e}] = \begin{cases} (561.8 \cdot I_{\text{leak}}[\text{nA}] + 1\,254\,949)^{1/2} & (\text{peak}) \\ (561.8 \cdot I_{\text{leak}}[\text{nA}] + 3\,214\,805)^{1/2} & (\text{deconv.}) \end{cases}$$

RESULTS

In order to correlate the noise from different sensors the *relative noise* of each sensor is used:

$$\frac{\text{noise}(I_{\text{leak}})}{\text{noise}(I_{\text{leak}}=0)} = \frac{\text{ENC}(I_{\text{leak}})}{\text{ENC}(I_{\text{leak}}=0)}$$

left side of the equation: data from 57 OB2 modules

- I_{leak} for each strip from the tracker database
- $\text{noise}(I_{\text{leak}}=0)$ is taken as the noise from daisy-chained strips where the sum of I_{leak} is less than 2 nA (minimal error – less than 0.5‰)

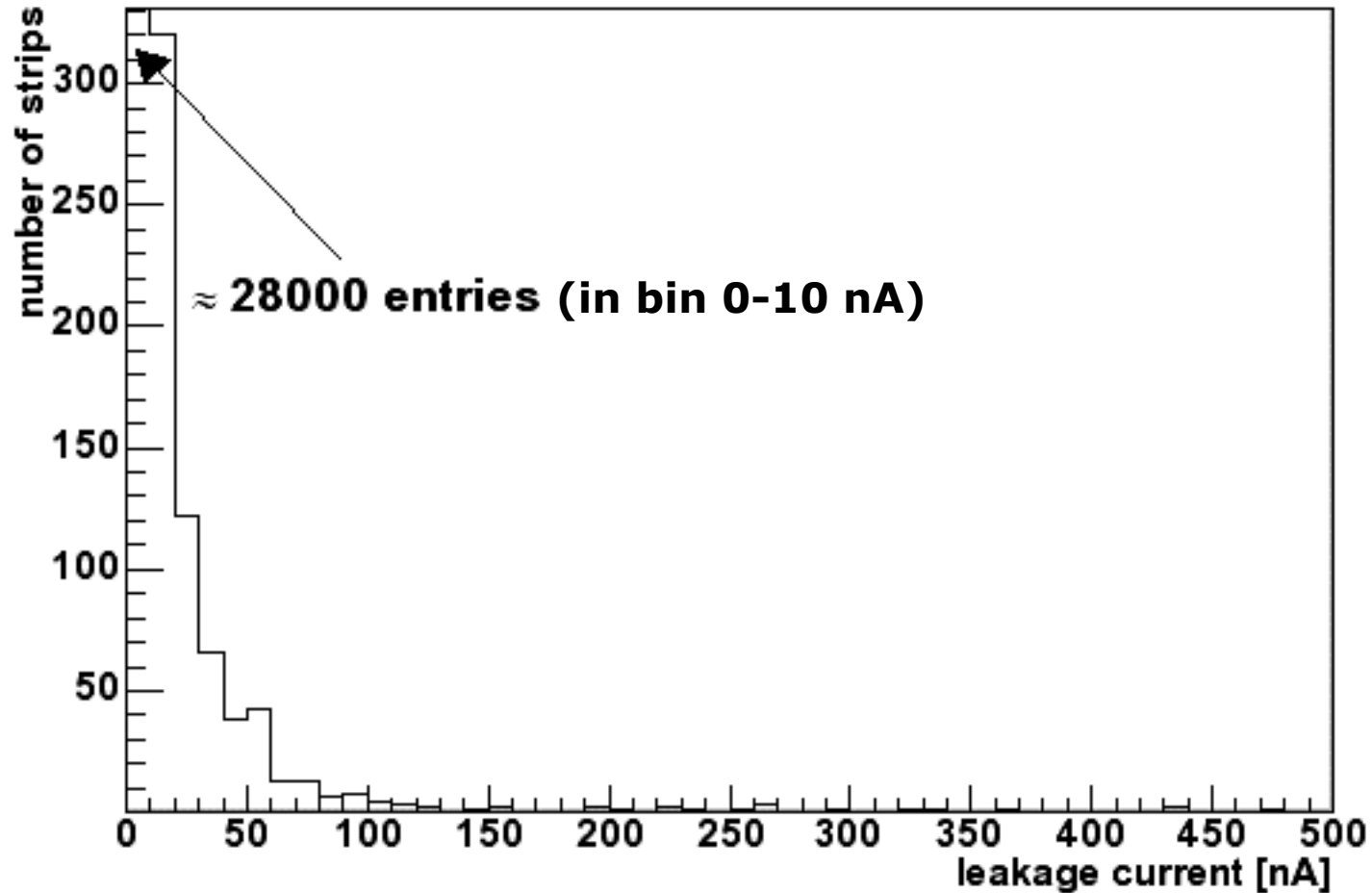
right side of the equation: theoretical relative noise

following strips were **not** included:

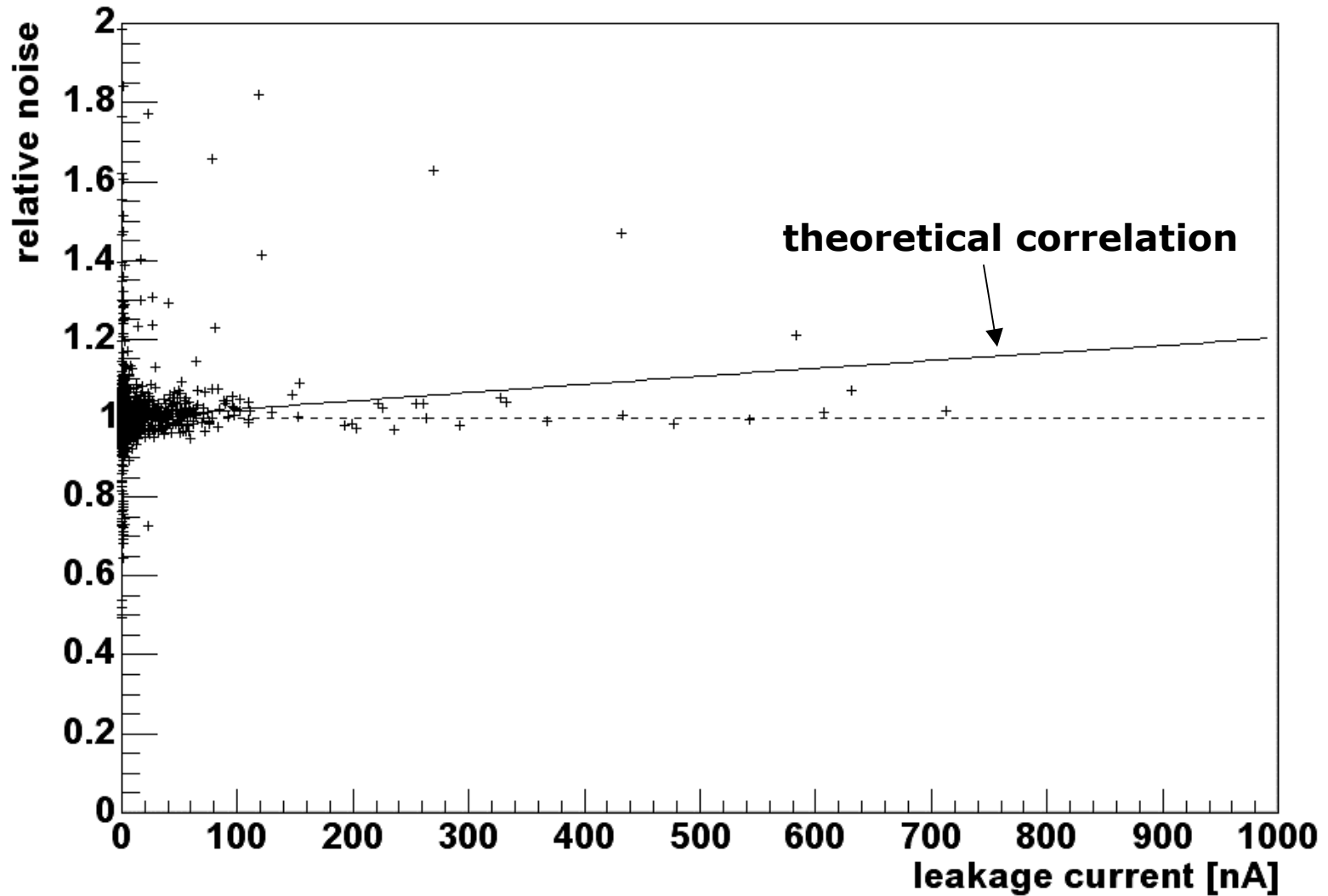
- strips #1 & #128 of each APV (are known to have higher noise)
- strips with an I_{leak} -entry in the database higher than the total detector current at 400V
- unbonded strips

28623 strips remaining

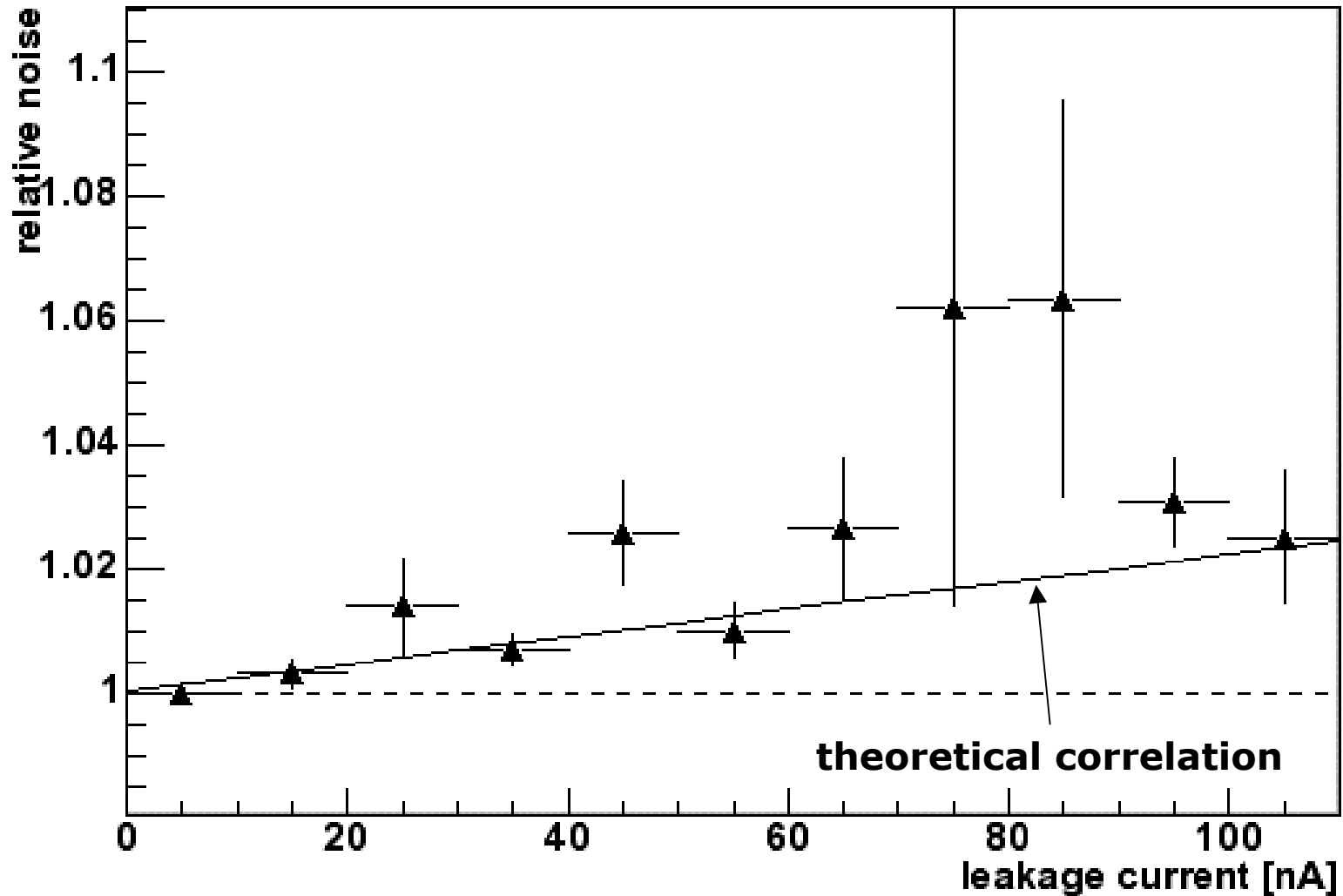
leakage current distribution:



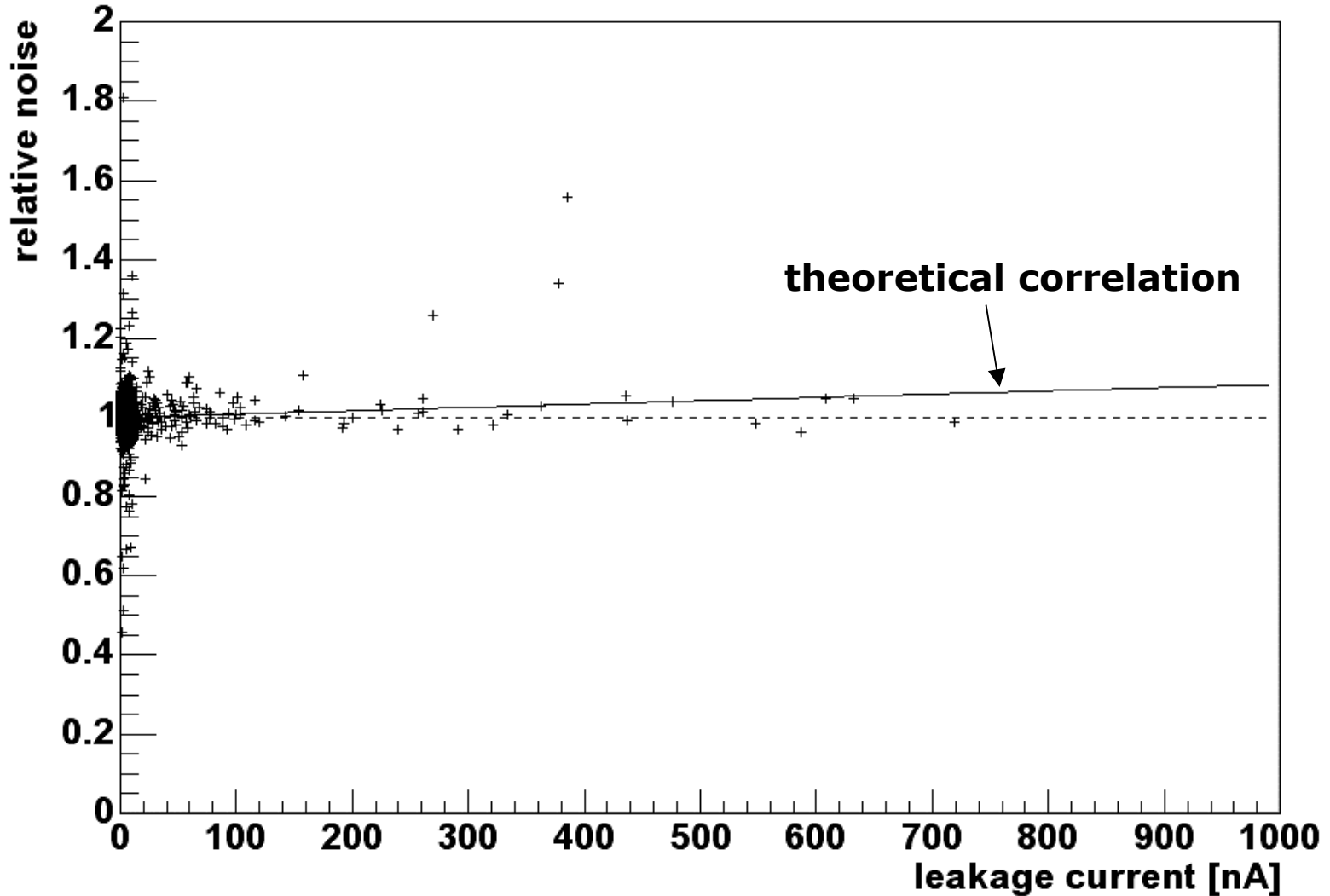
leakage current vs. strip noise (peak mode):



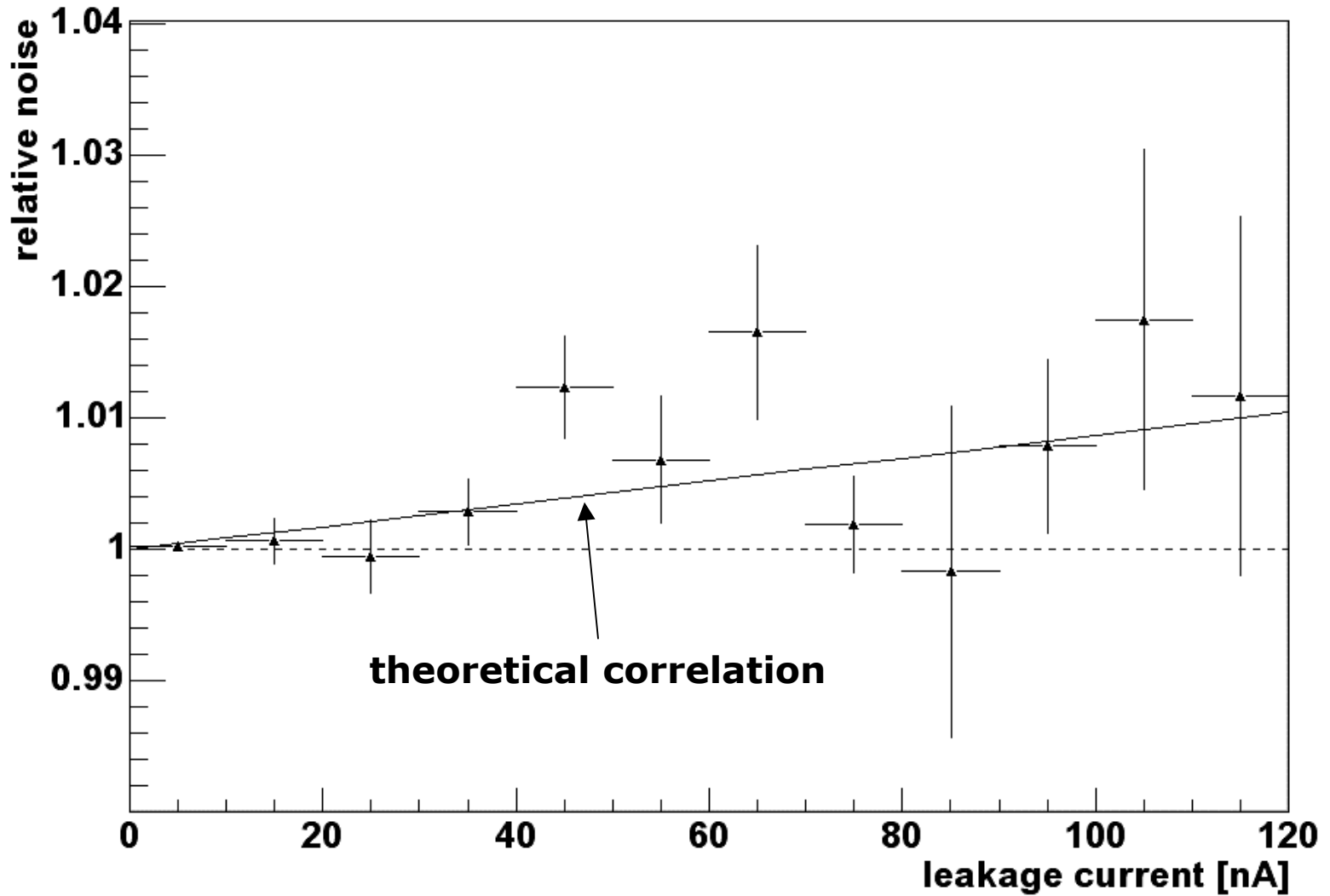
leakage current vs. strip noise (peak mode):



leakage current vs. strip noise (deconv.):



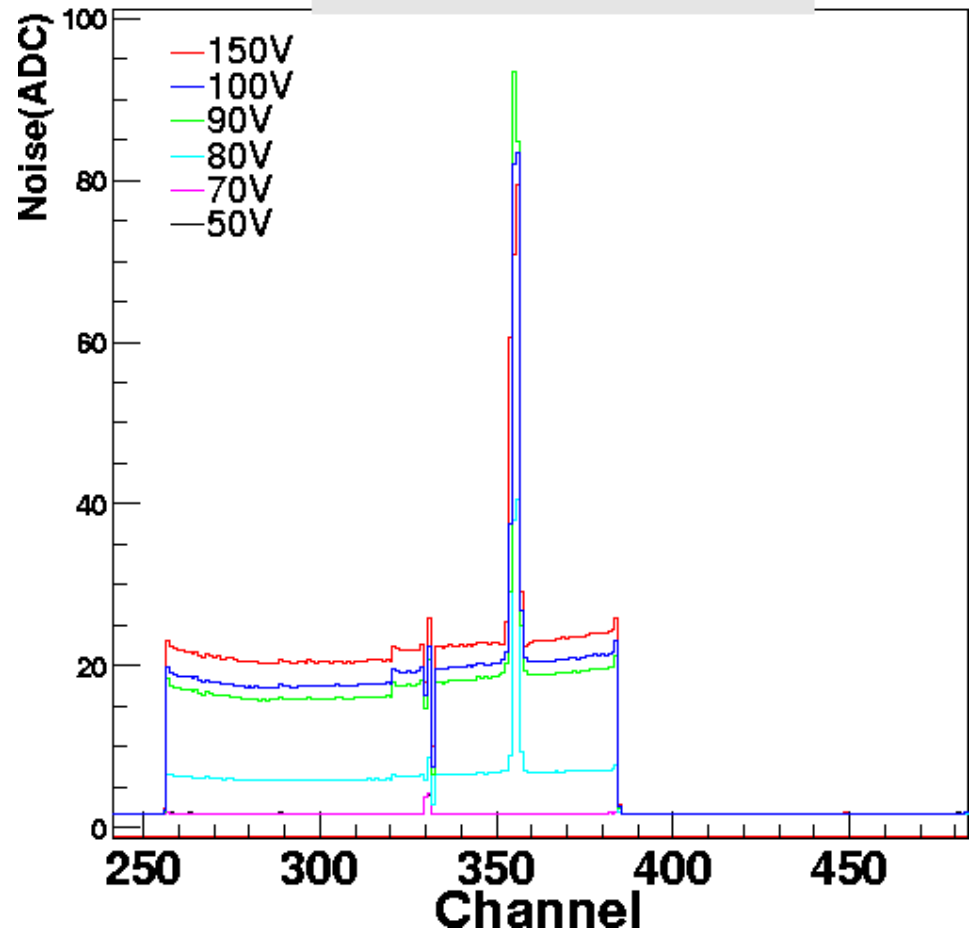
leakage current vs. strip noise (deconv.):



MODULES WITH CM-PROBLEMS

Several modules showed drastically increased noise on single APVs, obviously caused by single, extreme leaky strips.

Module 1015



None of these strips showed an *abnormal* behavior prior to assembly:

