Low – Noise Preamplifier for SC diamond detectors

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Summary

- SC diamond as radiation detector
- Front–end electronics
- Experimental data
- Conclusions

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SC Diamond as radiation detector

Promising features:

- High radiation resistance
- Fast response time
- High band–gap (5.45 eV)

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Very low leakage current

Low noise, even at high-temperature operation

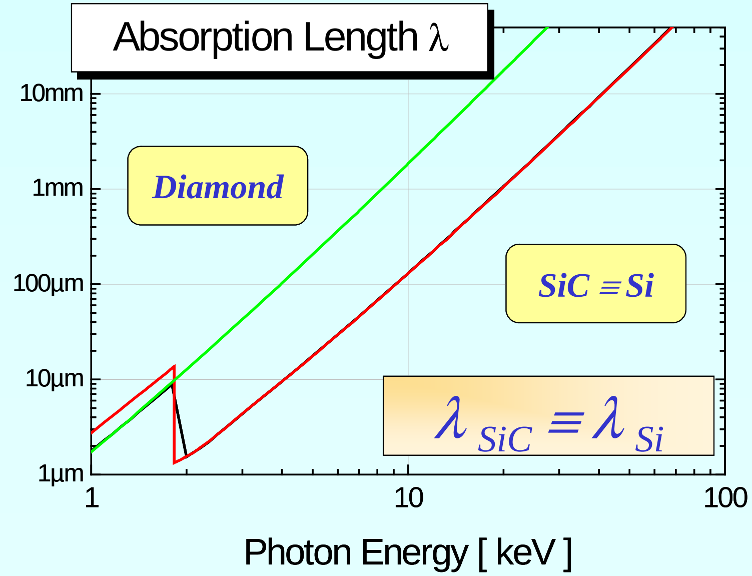
SC Diamond as radiation detector

Spectroscopy with α particle

Study for possible spectroscopy with X–rays

SC diamond could work at high temperature and in hostile environments with high resolution.

Absorption length short enough for photons < 8 keV



SC Diamond as radiation detector

Energy resolution depends mainly on:

FANO: intrinsic line broadening

Charge Collection Efficiency

ELECTRONIC NOISE:

Optimization of front–end electronics is necessary

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Front–end electronics

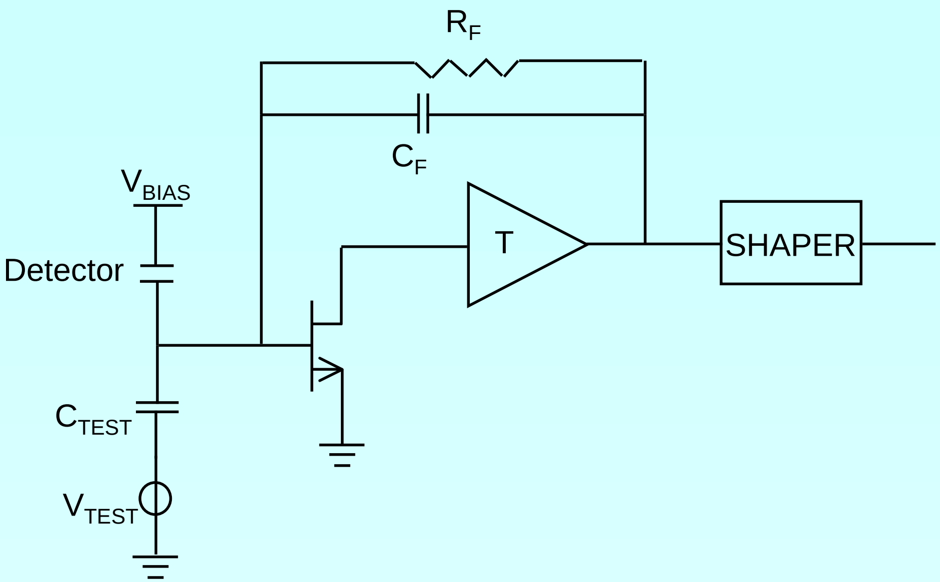
In well-designed systems the noise arises practically from the detector and the front-end electronics sources (input FET, feedback resistor and polarization detector resistor, feedback and test capacitance dielectrics).

The classical solution is:

Charge Sensitive Amplifier (CSP)

DC coupled to detector

Front–end electronics



Electronic Noise [coulomb rms]:

$$ENC^2 = \left(\alpha \frac{2kT}{g_m} C_{tot}^2 A_1\right)\frac{1}{\tau_{sh}} + \left(2\pi a_f C_{tot}^2 + \frac{b_f}{2\pi}\right) A_2 + \left(qI_L + \frac{2kT}{R_F}\right) A_3 \tau_{sh}$$

C_{tot} sum of capacitances at preamp input; A_1, A_2 and A_3 shaping constants; g_m transconductance of JFET; α coeff. of channel thermal noise JFET; a_f coeff. of JFET 1/f series noise; b_f coeff. of dielectric parallel noise; I_L leakage current; R_F feedback resistance; τ_{sh} shaping time

Front–end electronics

Good diamond detectors have $I_L < 1$ pA @ 300 K

For the best resolution, noise of R_F must be negligible as compared to shot noise of I_L. So……

$R_F > 52$ GΩ

Solution Proposed:

FBFA

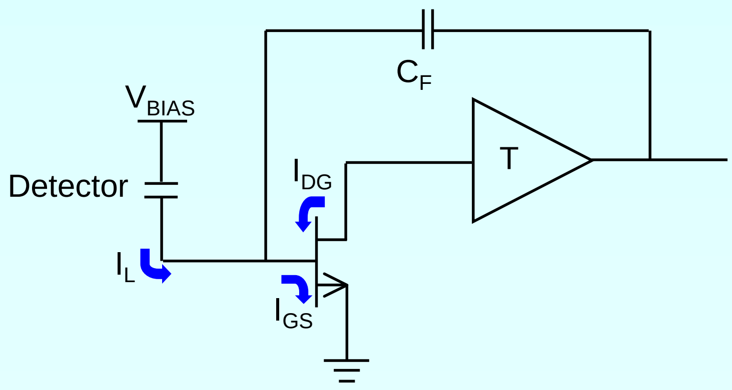
(Forward Bias FET charge Amplifier)*

*G. Bertuccio, P. Rehak and D. Xi, Nucl. Intrum. Methods, vol. A326, pp. 71-76, 1993

Front–end electronics

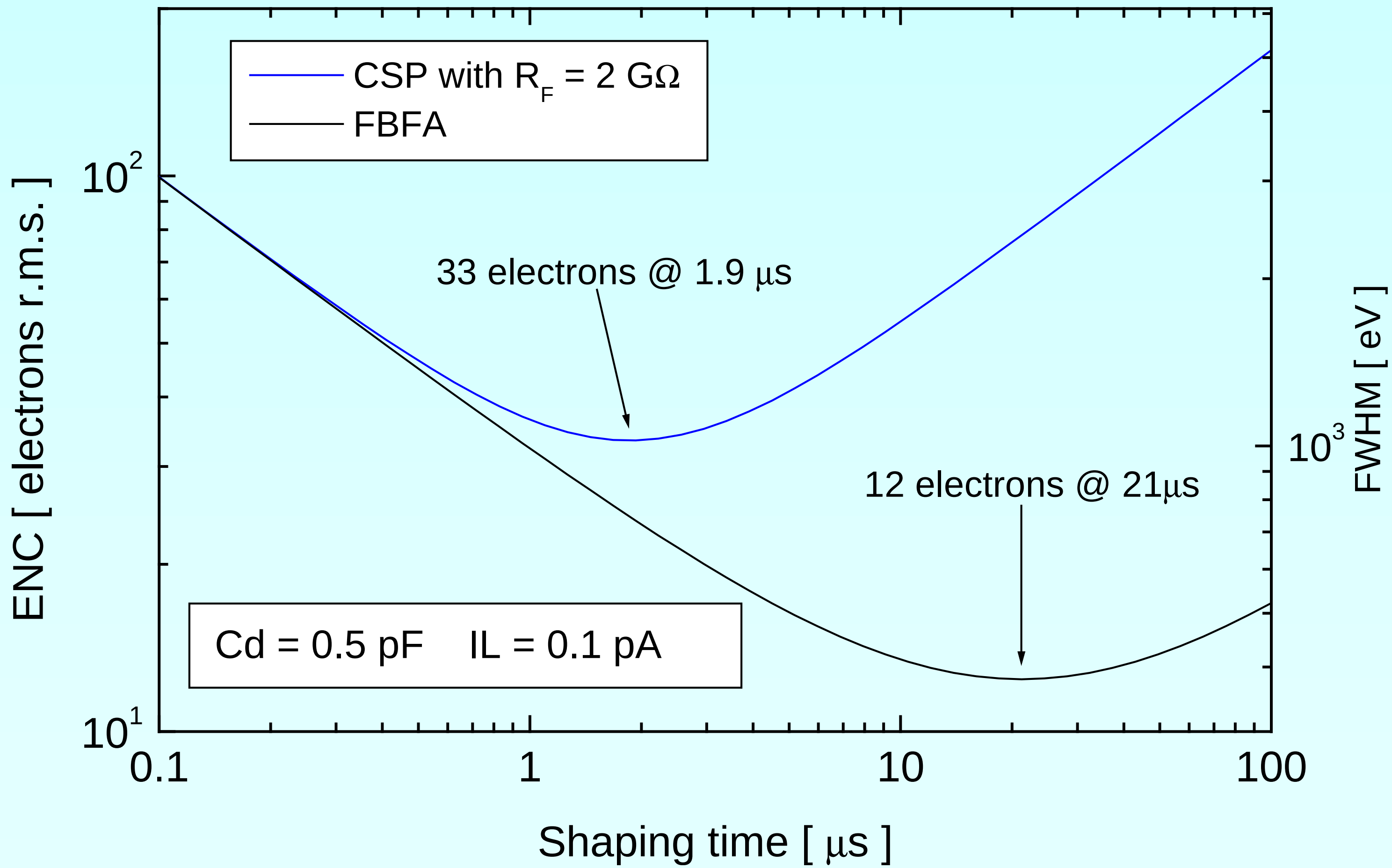
FBFA: basic idea

Use the gate-to-channel junction of the input JFET as a path for the detector leakage current and for the discharge of the feedback capacitor



Front–end electronics

Simulations



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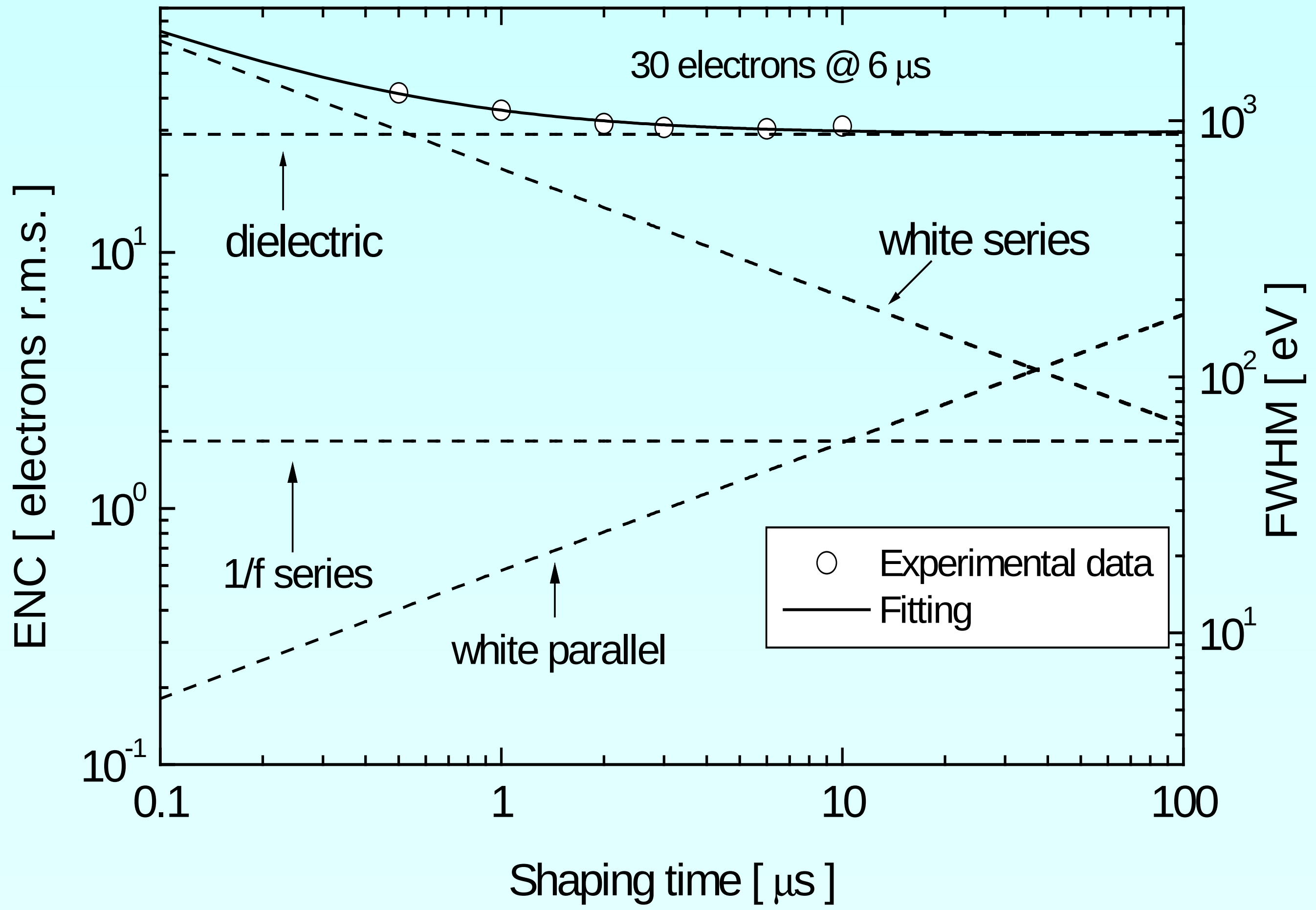
Electronic Noise

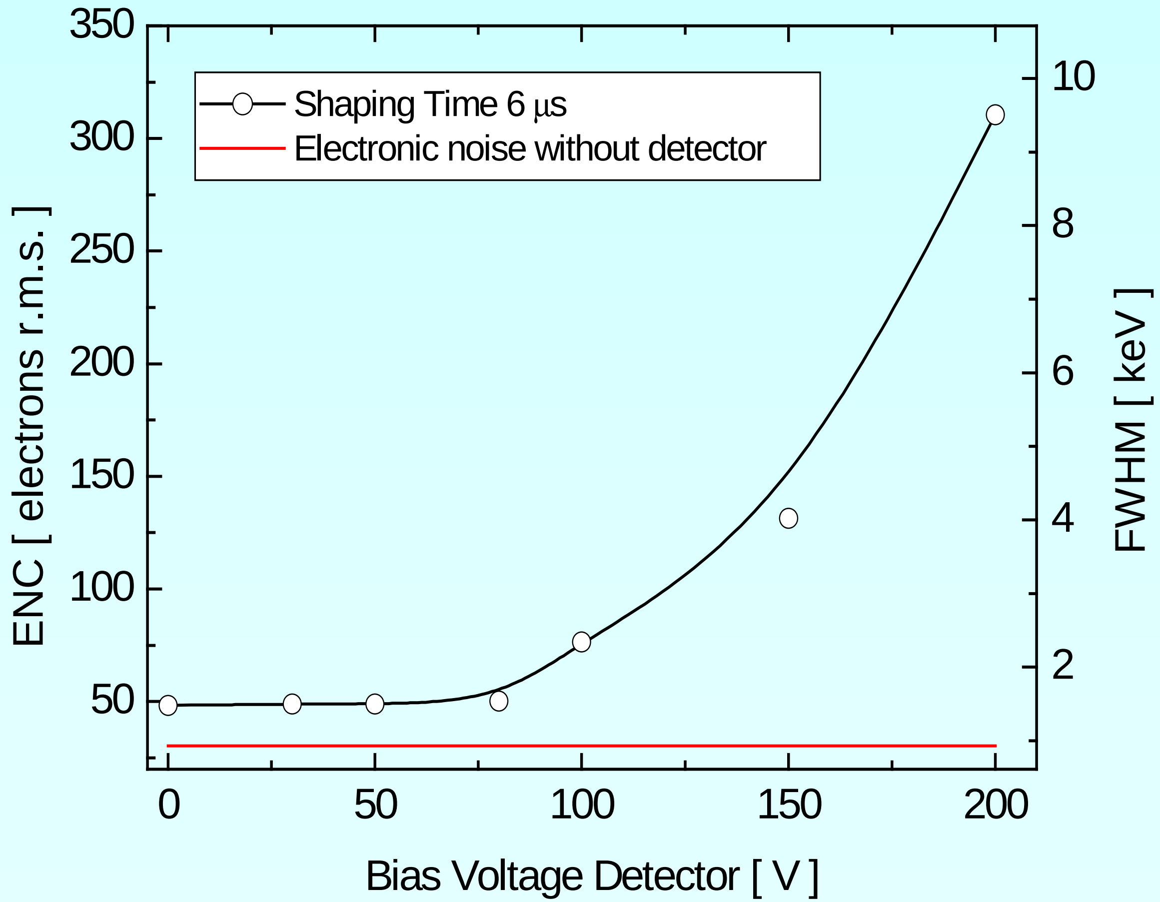
Diamond detector not connected



Electronic Noise

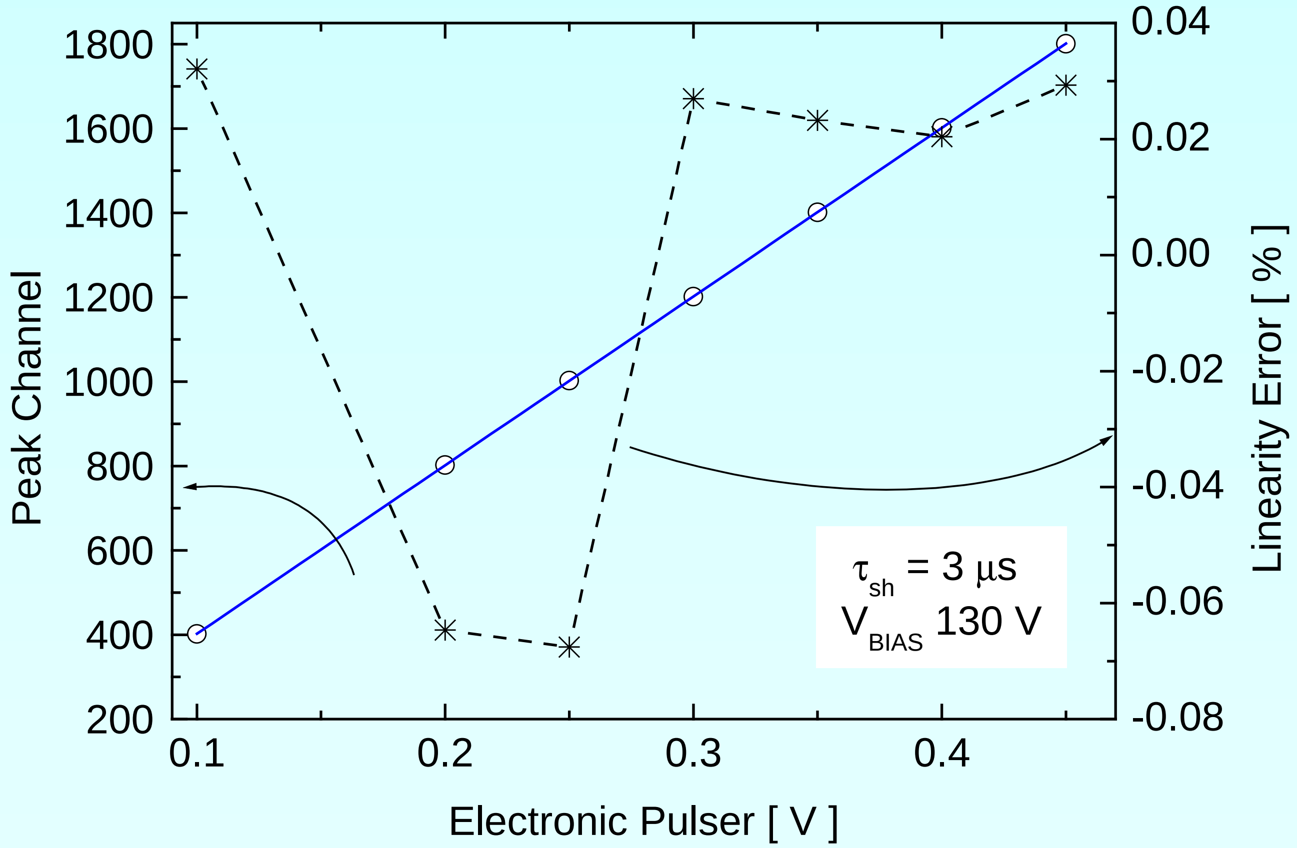
Diamond detector connected: #SC-E6-1

(thickness 440 μm, high leakage current: 100 pA @ 100 V)



Linearity

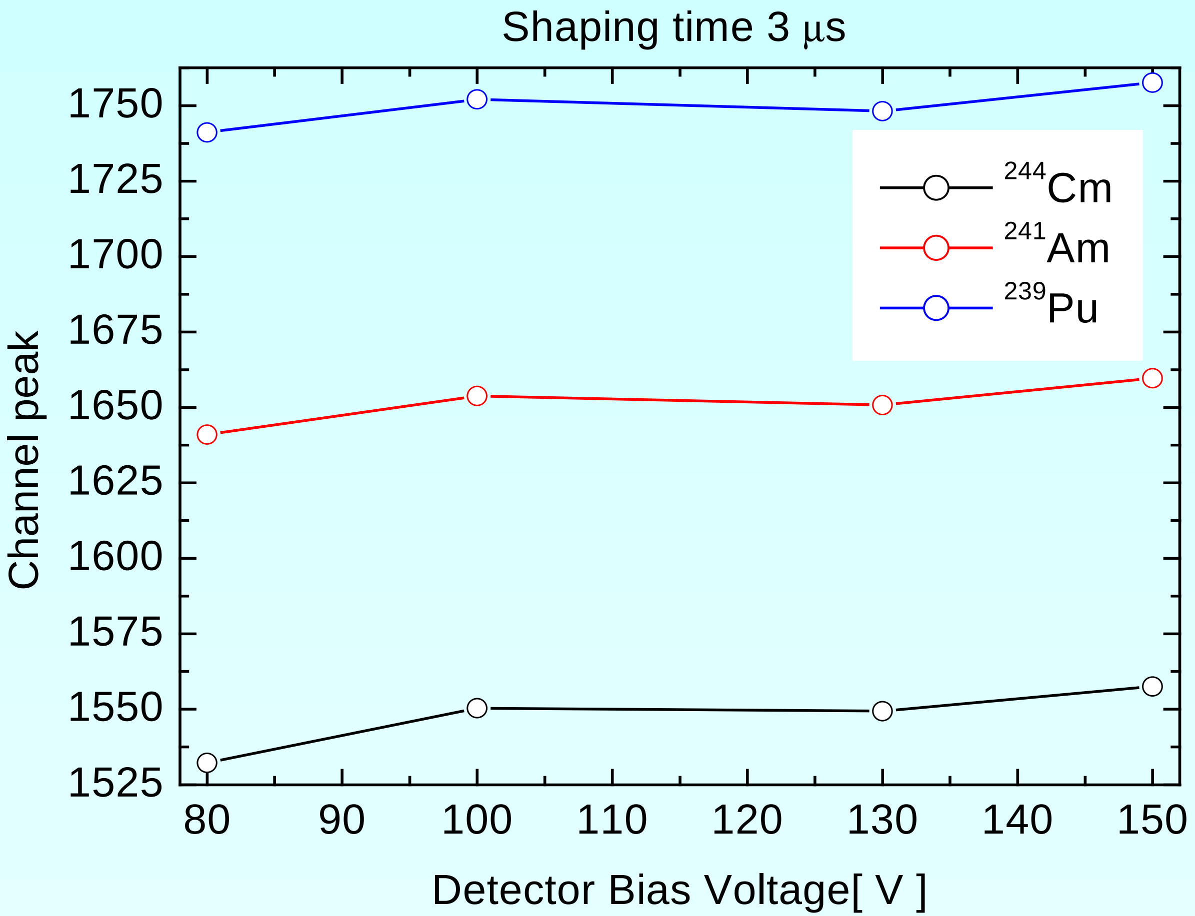
Electronic Chain for measurement: FBFA, Spectroscopy amplifier ORTEC 572, ADC ORTEC 919, Pulser Agilent 33220A



Linearity Error < 0.1%

α–spectroscopy

Charge Collection Efficiency of used sample < 100 %



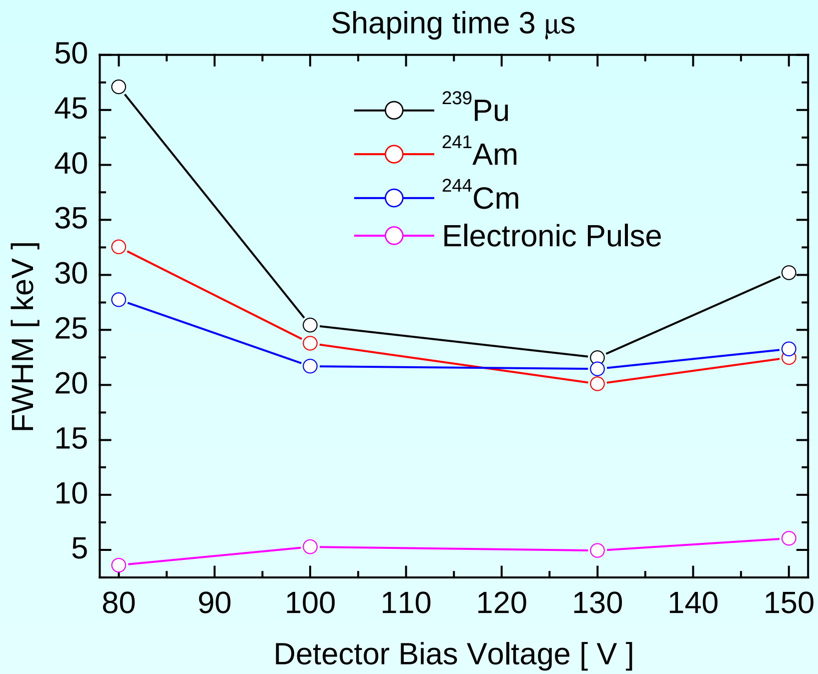
α-spectroscopy

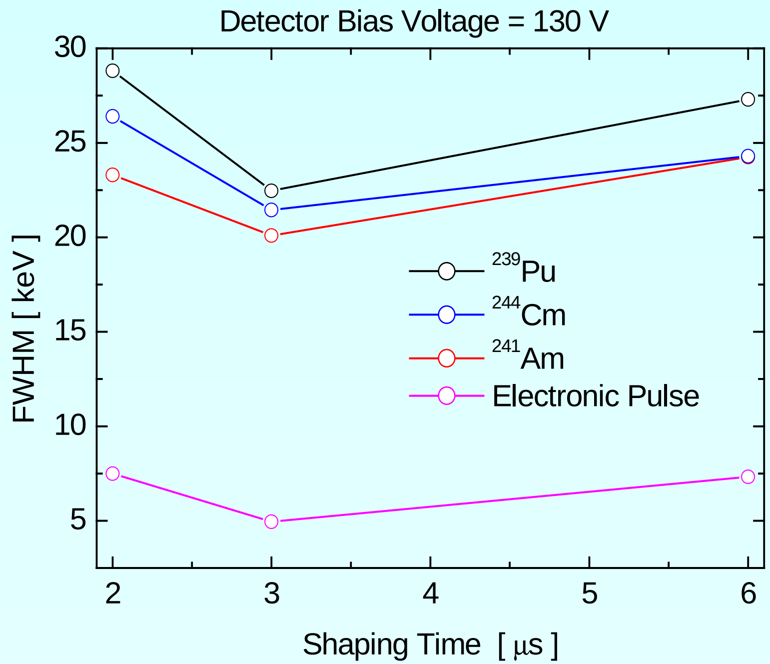
- for low electronic noise: low detector bias voltage
- for high CCE: high detector bias voltage

For the best resolution

$V_{BIAS} = 130V$

Optimum Shaping Time = 3 μs

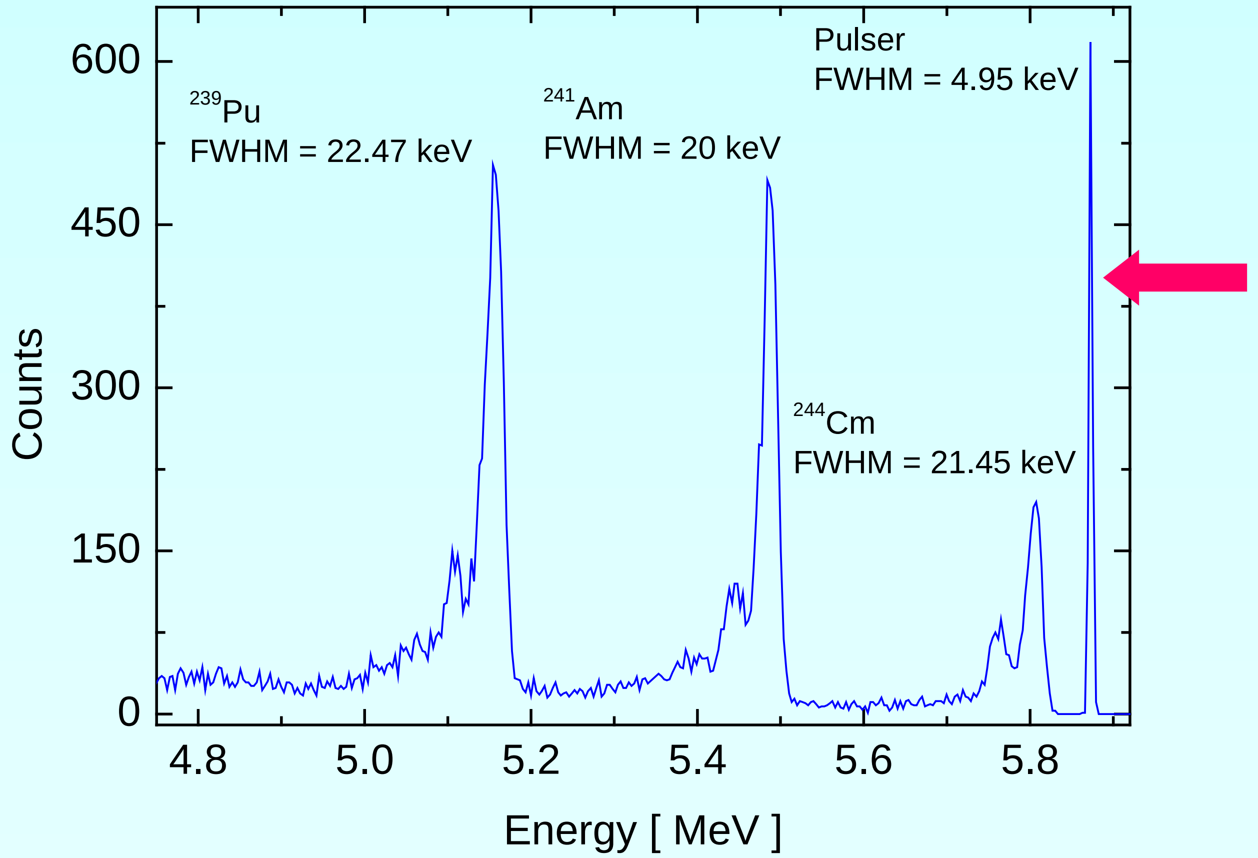




α–spectroscopy

Best spectroscopy resolution: 0.36 % @ 5.5 MeV

Bias Detector: 130 V - Shaping Time: 3 μs

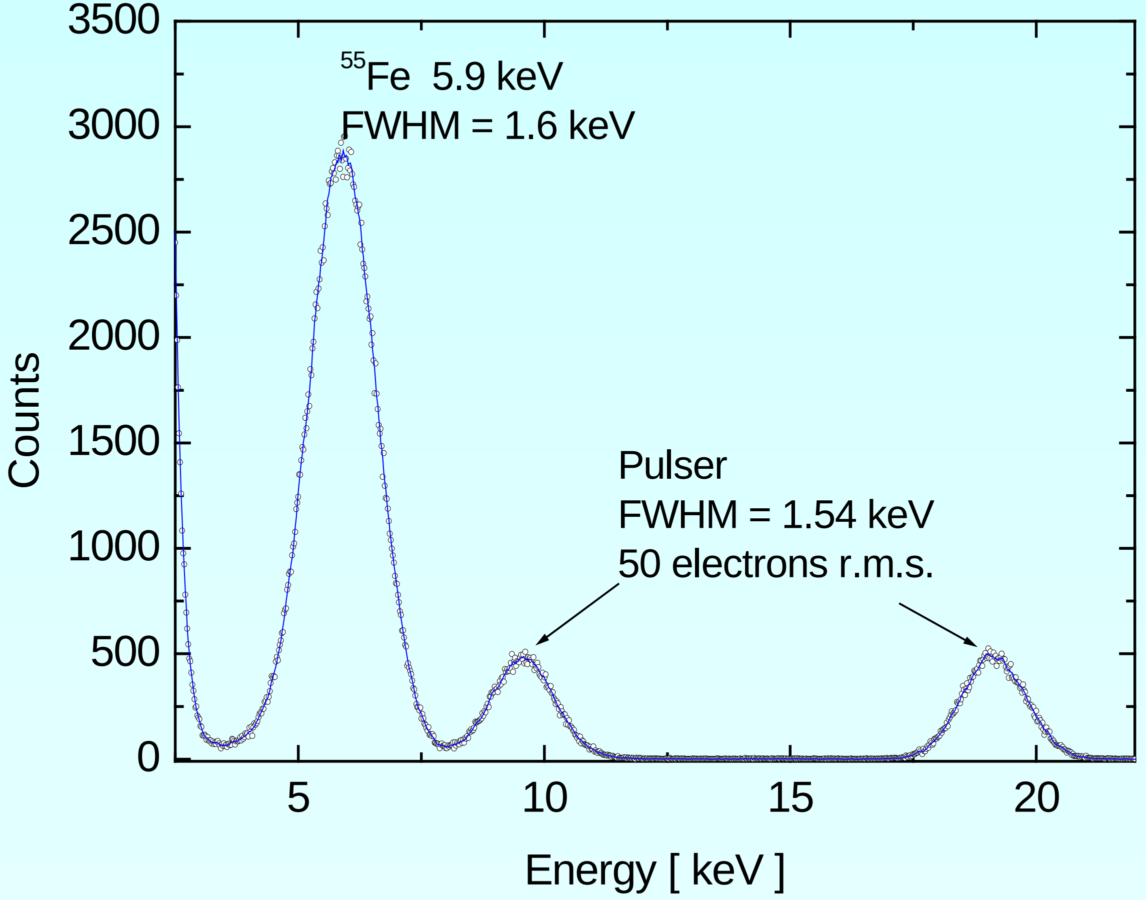


Pulser Line resolution 0.08% !

X–ray spectroscopy

Best resolution

Bias Detector: 50 V - Shaping Time: 4 μs



Conclusions

- The FBFA has an intrinsic resolution of 920 eV with SCD detectors.
- The high leakage current of the tested sample makes the electronic noise higher in our experimental measurements.
- For α spectroscopy with our sample the resolution is limited above all by the Fano and the incomplete charge collection efficiency.
- Low energy X–ray spectroscopy is possible with very low leakage current.

Future goals

- FBFA with an electronic noise < 20 e (612 eV).
- With a very-low leakage current (<1pA) detector an improved resolution for α and (above all) X–ray spectroscopy is possible.