Germanium detectors and low temperatures

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Outline

- Motivation: $0\nu\beta\beta$
- Germanium detectors
  - Operation conditions
  - Test stands
- Electronics and data collection
  - Special kapton cable
  - Data acquisition system (DAQ)
  - Way from photons to spectrum
- Electronic pulses
  - Pulse properties: rise time, amplitude
  - Influense of temperature difference on pulses: results
- Additional features
- Summary

Motivation (again)

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- Higher Q-value is better
- Germanium is a good candidate for $0\nu\beta\beta$ experiments:
    - $Q_{\beta\beta} = 2039$ keV for ^{76}Ge
    - Germanium detectors are very sensitive to radiation

Germanium detectors

Germanium dioxide

Germanium detectors

Germanium dioxide

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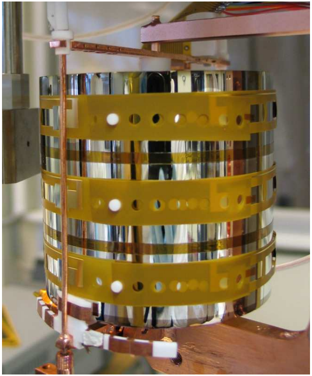
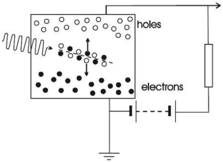


High-purity Very-expensive Gently-operated 18-fold-segmented Germanium detector

Why should germanium detectors feel cold and be at high voltage?



- They are semiconductors, cooling down reduces thermal movement of electrons and the band gap. Temperature: 70-100K
- Electrical field reduces number of electrons in conduction band: depletion. Voltage applied: 2-3kV
- When a particle hits the detector the clear signal can be collected by high electrical field as no other charge carriers present.

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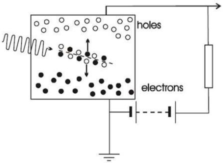

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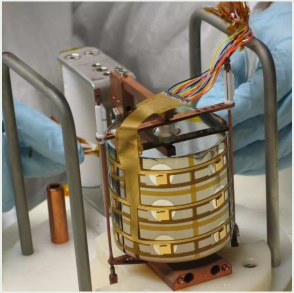
Detectors @ MPI Munich



- High-purity detector (electrically active impurities concentration $\sim 10^{10-11}\text{cm}^{-3}$)
- Segmented 18-fold ($3z \times 6\phi$)
- Operation voltage 2000 V

Things we do @ MPI Munich

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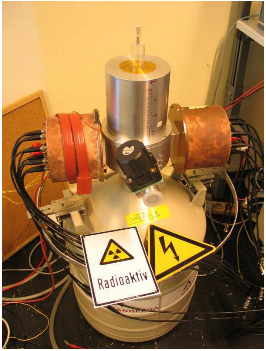
Germanium detectors
Electronics
Electronic pulses
Additional feature
Conclusions

GerdalinchenII

Liquid nitrogen (77.4 K)
Liquid argon (87.3 K)



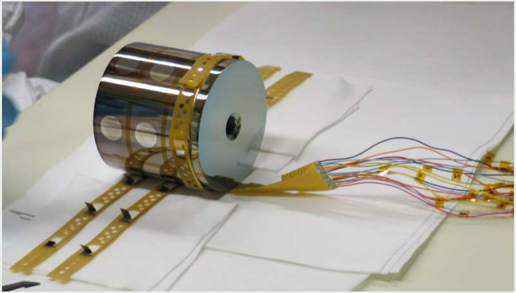
K1

A bit warmer: cooling finger submerged to liquid nitrogen or argon (80-100K)

Additional equipment

Special cable: kapton cable

Kapton cable: elastic and thin

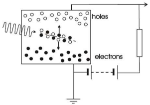


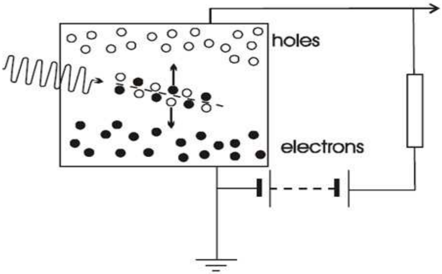
Additional equipment

Data acquisition system and read out cables

Signalway to data

Detection

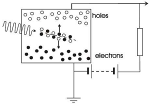




Detecting particle

Signalway to data

Detection



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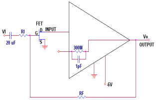
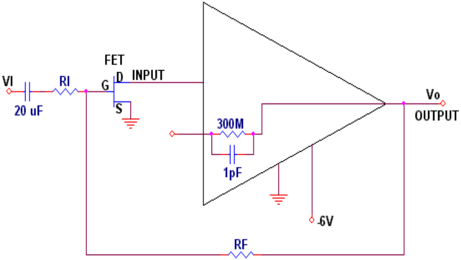
Amplification

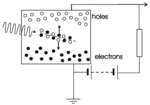




Amplifying signal

Signalway to data

Detection



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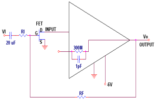

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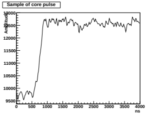
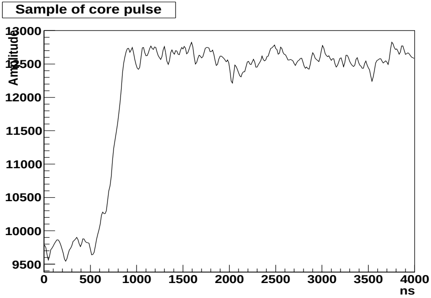
Recording

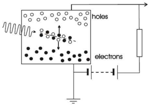




Pulse recording

Signalway to data

Detection



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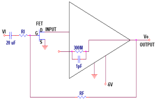

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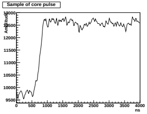
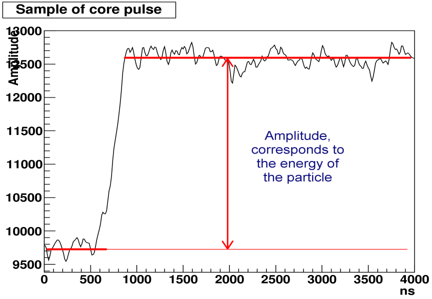
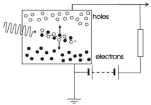




Estimating energy

Signalway to data

Detection



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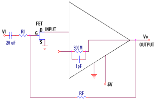

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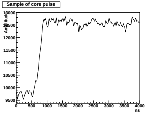

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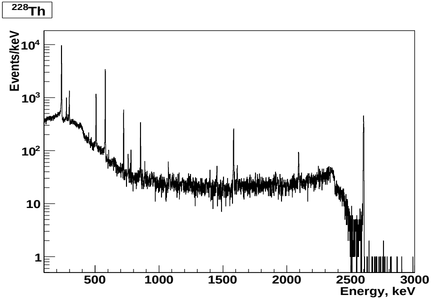
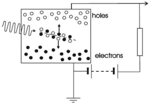


Obtaining spectrum

Signalway to data

Detection



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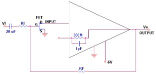
Amplification



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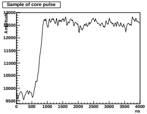

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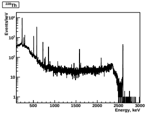
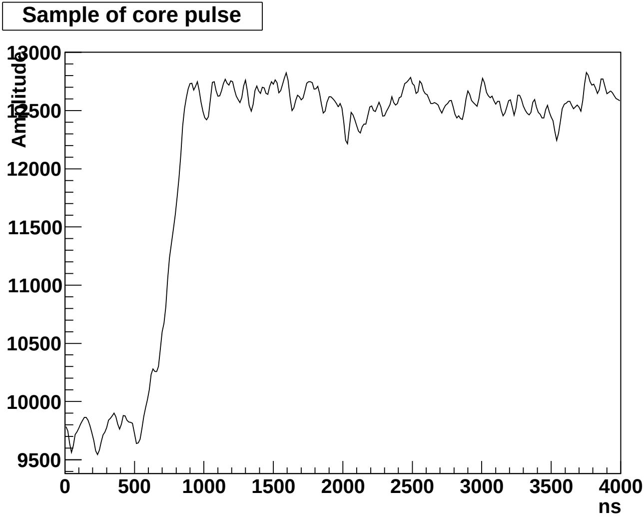
Spectrum

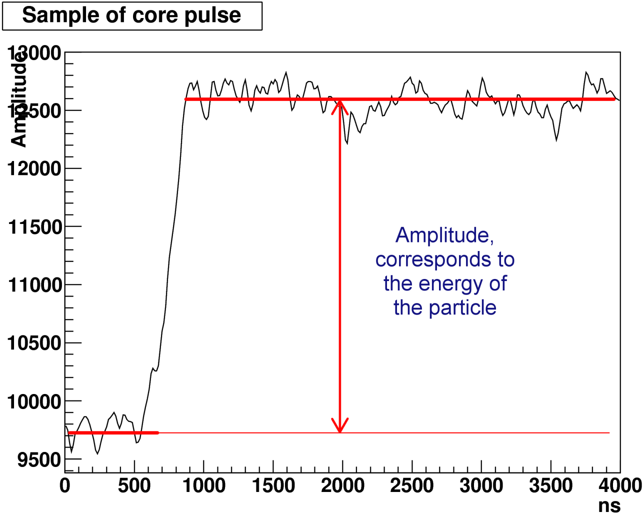


Electronic pulses

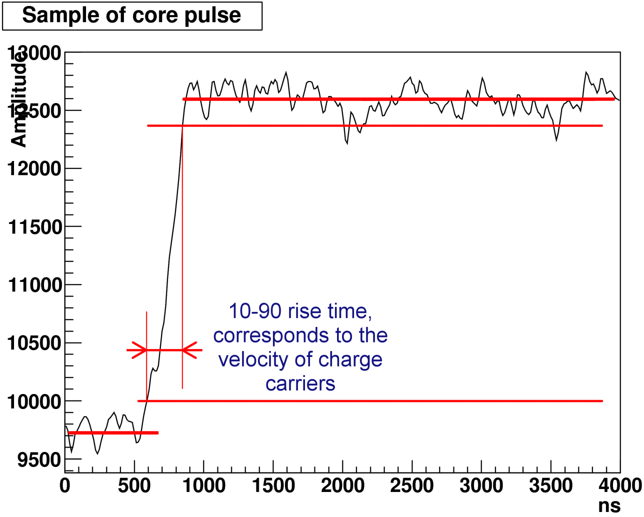
Pulse


Sample of core pulse
Amplitude
13000
12500
12000
11500
11000
10500
10000
9500
0
500
1000
1500
2000
2500
3000
3500
4000
ns

Pulse properties: amplitude



Pulse properties: rise time



A bit of theory

Rise time

Rise time $\sim \mathbf{v}^{-1}$

- $\mathbf{v}$ - Velocity of charge carriers (electrons, holes)

A bit of theory

Rise time

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Velocity of charge carriers

$\mathbf{v} = \mu \cdot \mathcal{E}$

- $\mathbf{v}$ - Velocity of charge carriers (electrons, holes)
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- $\mathcal{E}$ - electrical field;

A bit of theory

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Velocity of charge carriers

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Mobility

$\mu \sim T^{-3/2}$

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A bit of theory

Rise time

Rise time $\sim \mathbf{v}^{-1}$

Velocity of charge carriers

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Mobility

$\mu \sim T^{-3/2} \Rightarrow$
Rise time $\sim T^{3/2}$

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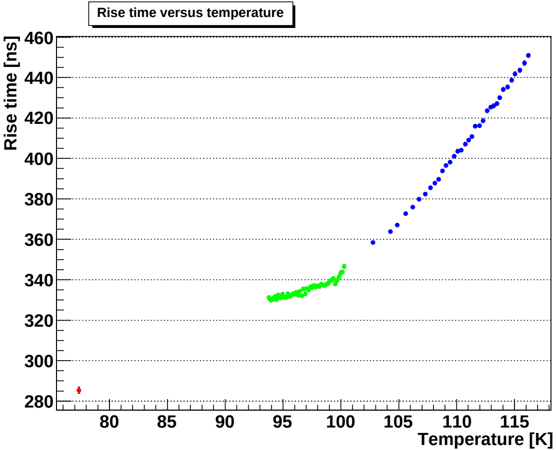
Rise time



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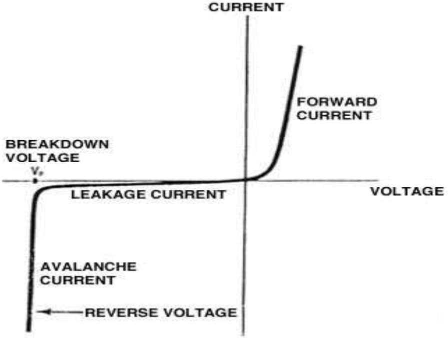
Additional feature

Reminder: diode properties

- Germanium is a semiconductor material
- Germanium detector acts as a diode in reversed mode:



Leakage current

- Leakage current is expected to be $\sim 100\text{pA}$ for wide temperature range $(50 - 200\,\text{K})$

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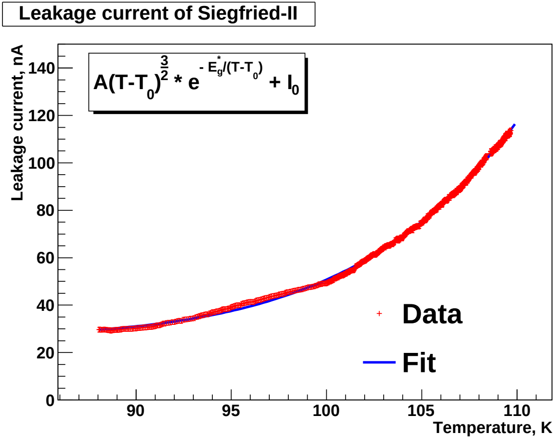
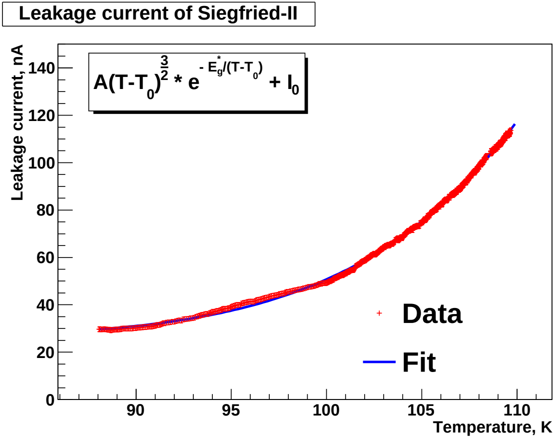
- One of our detectors is damaged and it has $10 - 100\,\text{nA}$ of LC and which is temperature dependent

Leakage current



Leakage current



New temperature monitoring method revealed!

Summary

- Germanium detectors are a perfect tool for $0\nu\beta\beta$: detector and source
- Detector manufacture and operation are complicated procedures
- Stability of operation is important, all deviations have to be understood

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- It is crucial for analysis on pulse shapes!
- There is an additional temperature monitoring method

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- Detector manufacture and operation are complicated procedures
- Stability of operation is important, all deviations have to be understood
- There is a strong temperature dependence of pulse parameters
- It is crucial for analysis on pulse shapes!
- There is an additional temperature monitoring method for partially broken detectors

Thank you for yor attention!

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