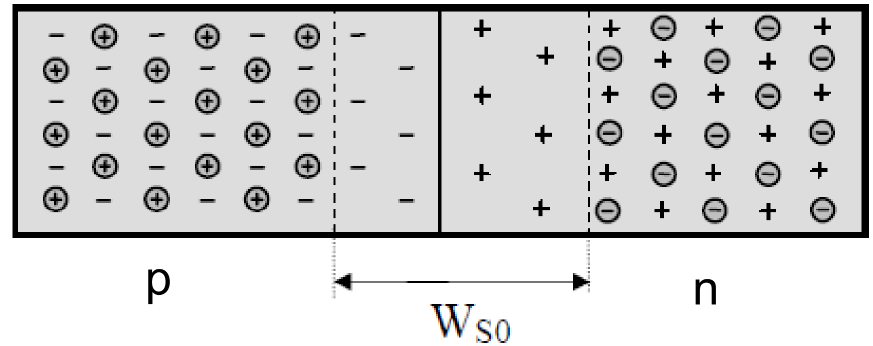
# Tool

For calculate the Depletion Voltage

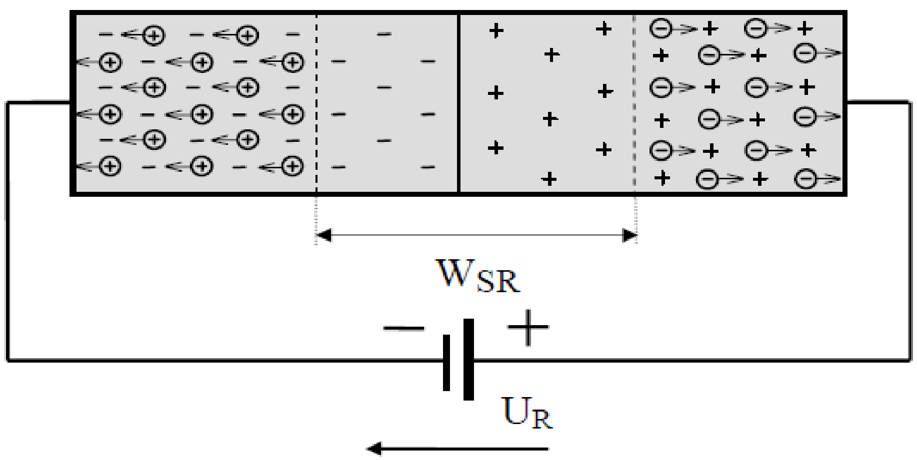
# What we do:

ohne äußere Spannung




$$W_{S0} = \sqrt{\frac{2\varepsilon}{e} \cdot \left(\frac{1}{N_A} + \frac{1}{N_D}\right) \cdot U_D}$$

mit Sperrspannung

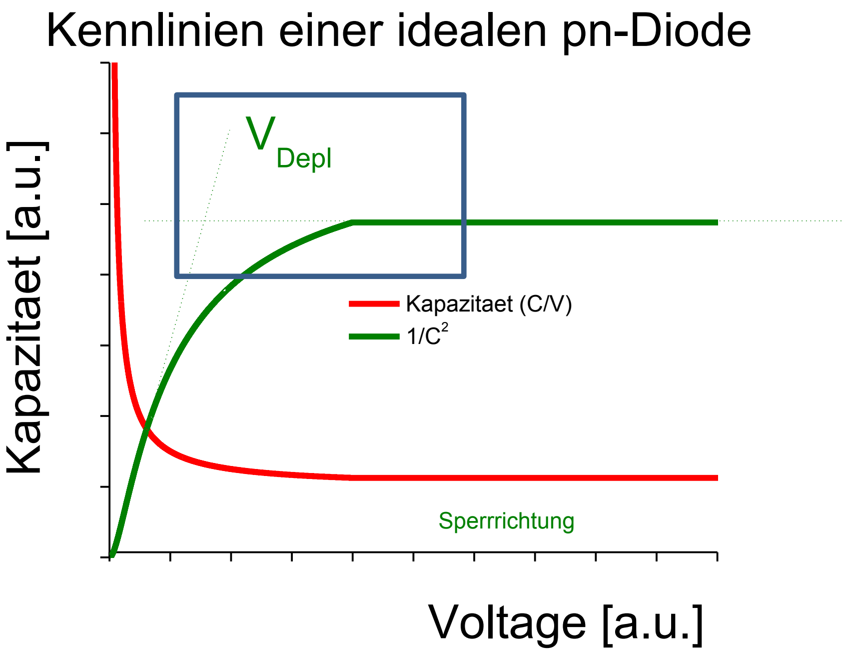


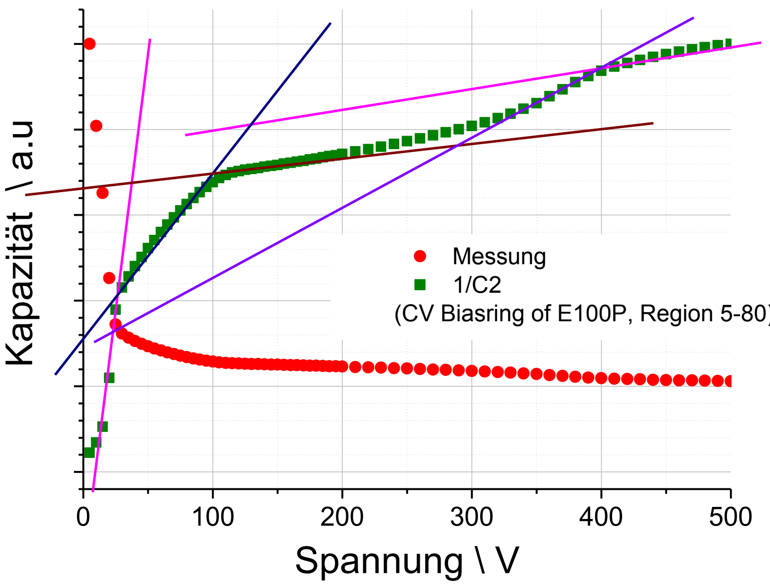

$$W_{S_R} = \sqrt{\frac{2\varepsilon}{e} \cdot \left(\frac{1}{N_A} + \frac{1}{N_D}\right) \cdot (U_D + U_R)} = W_{S0} \cdot \sqrt{\frac{U_D + U_R}{U_D}}$$

$$c_S = \frac{C_S}{A} = \frac{\varepsilon}{W_{S_R}} = c_{S0} \cdot \sqrt{\frac{U_D}{U_D + U_R}}$$

# Principle is known …

# … but real world is complicated




**Help me:** How should I fit???

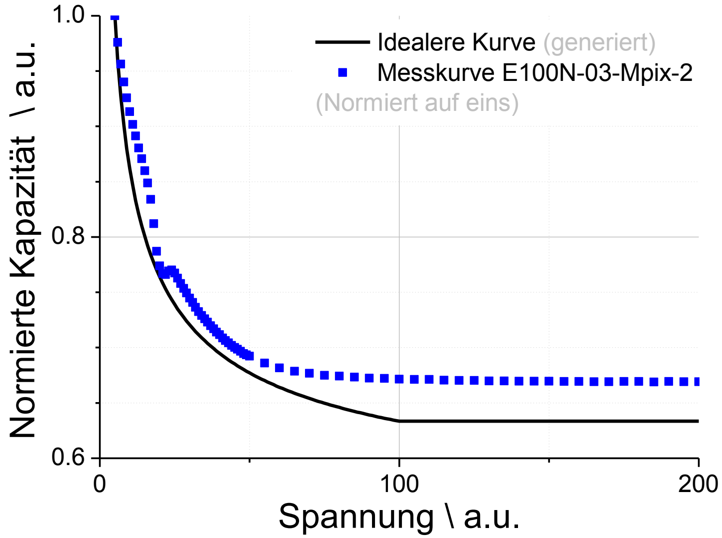
*Is there a way to do it automatically and independent from "see it"?*

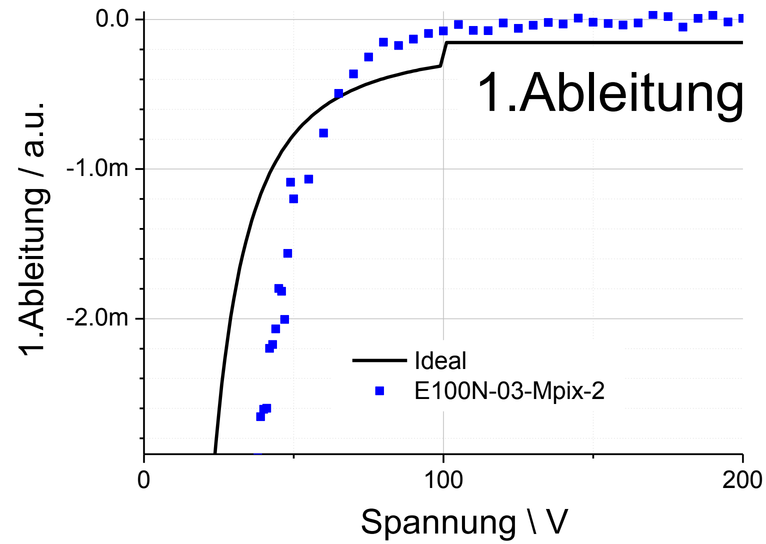
# My approach

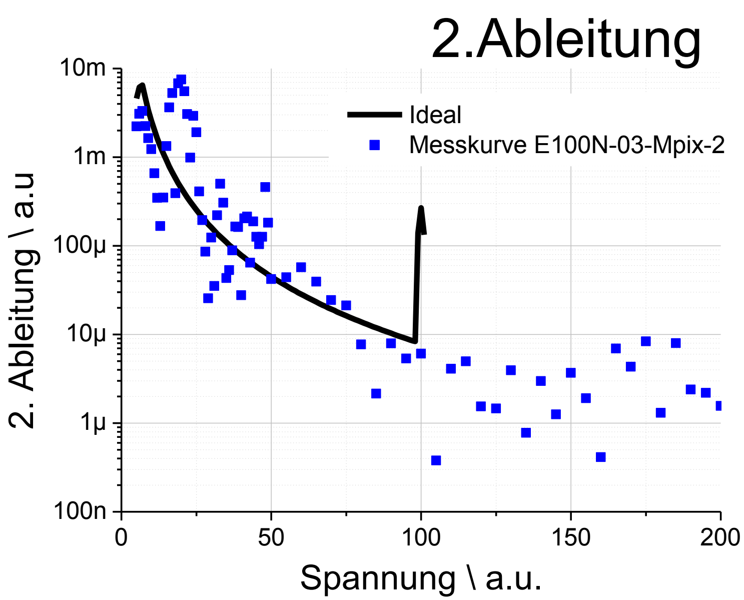
- Analyze curve shape and find properties that help to make a raw estimation of VDepl
  - **First Way**: What text book says: Derivation!
  - **Second Way:** Maybe curve can be fitted?

I test methods on real measurement data and two different generated curves. I show in the talk one of them and call it "ideal" text book curve. (Later more on that)

# First Way: Derivation

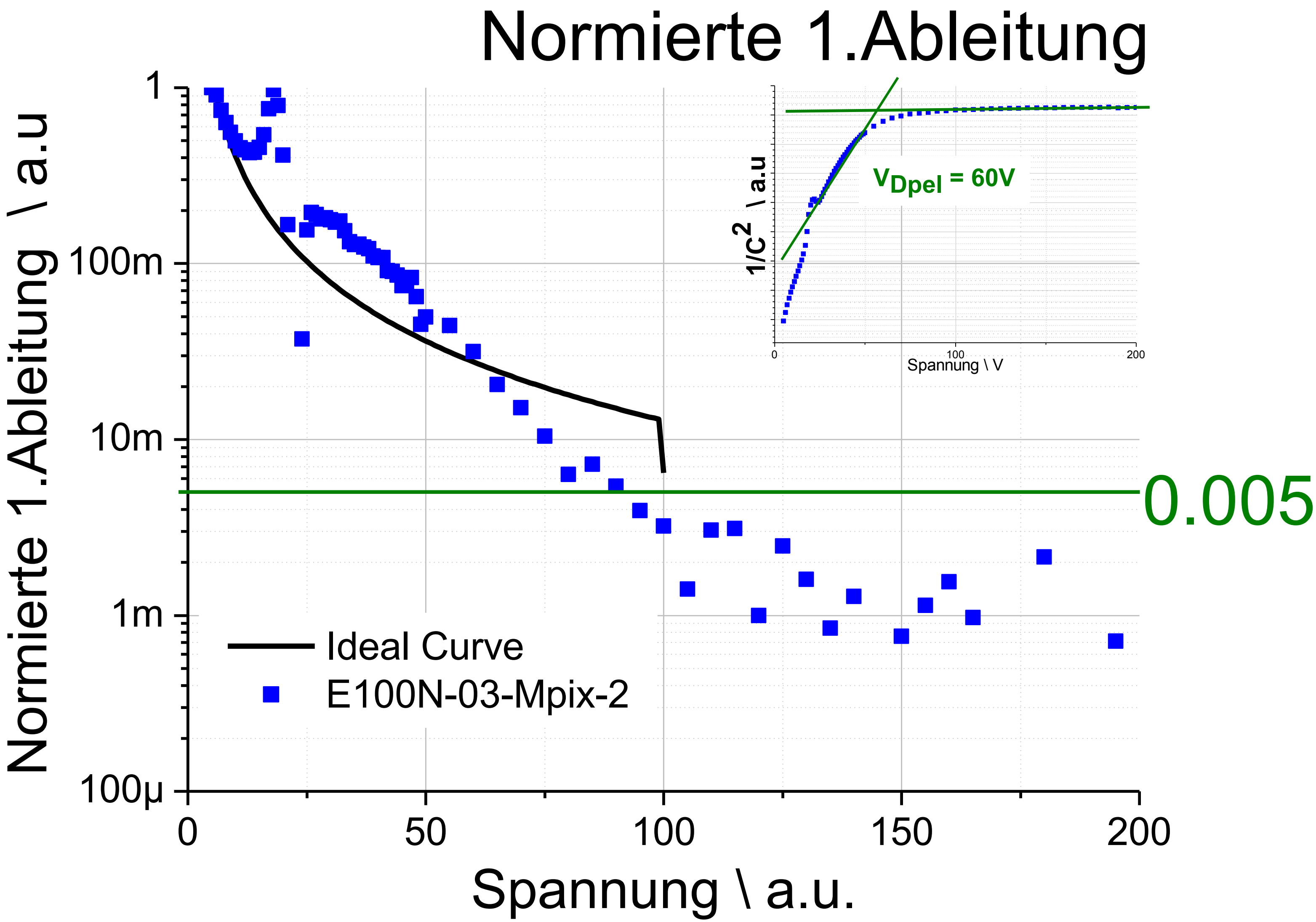



**Work in Theory….**

Can I just use the first derivation?

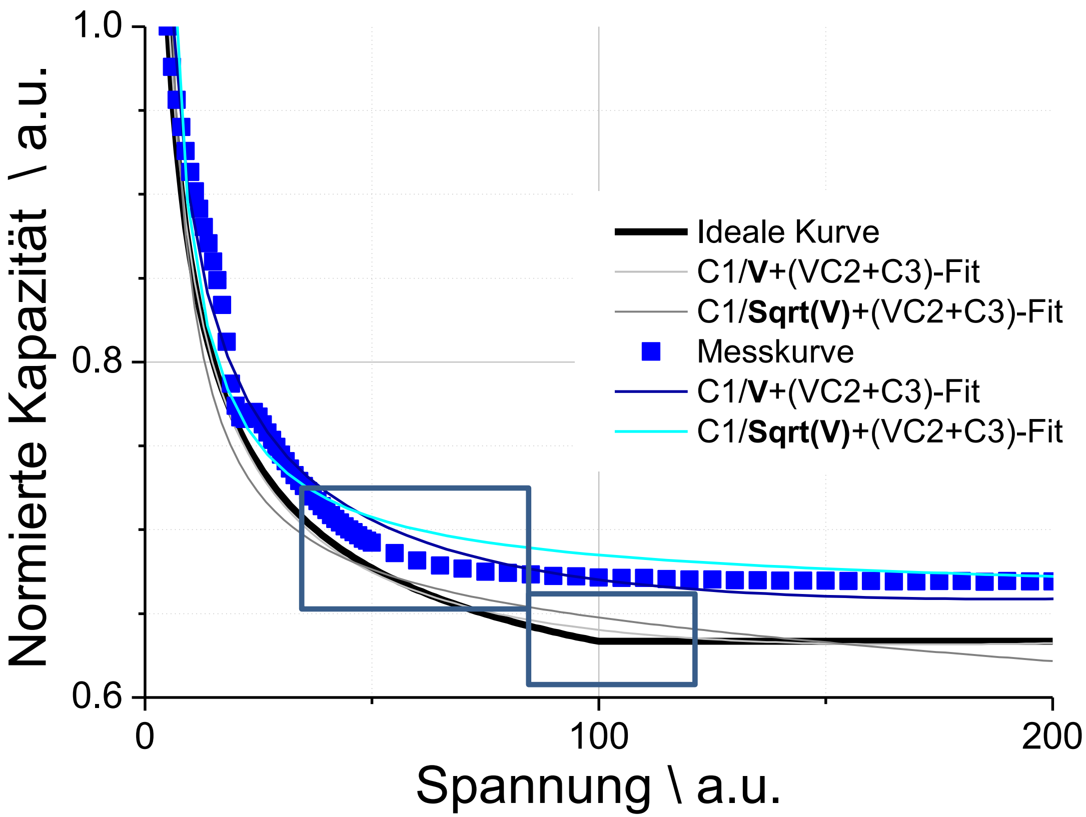



**Value of 0.005 is good to estimate, but not in any case…** (0.01…0.002 to have same result than hand fits)

**Second way to cross check?**

# Methode 2: Fitting

- Curve should be ~1/sqrt (V) for lower voltages than VDpel and const [slight linear] after

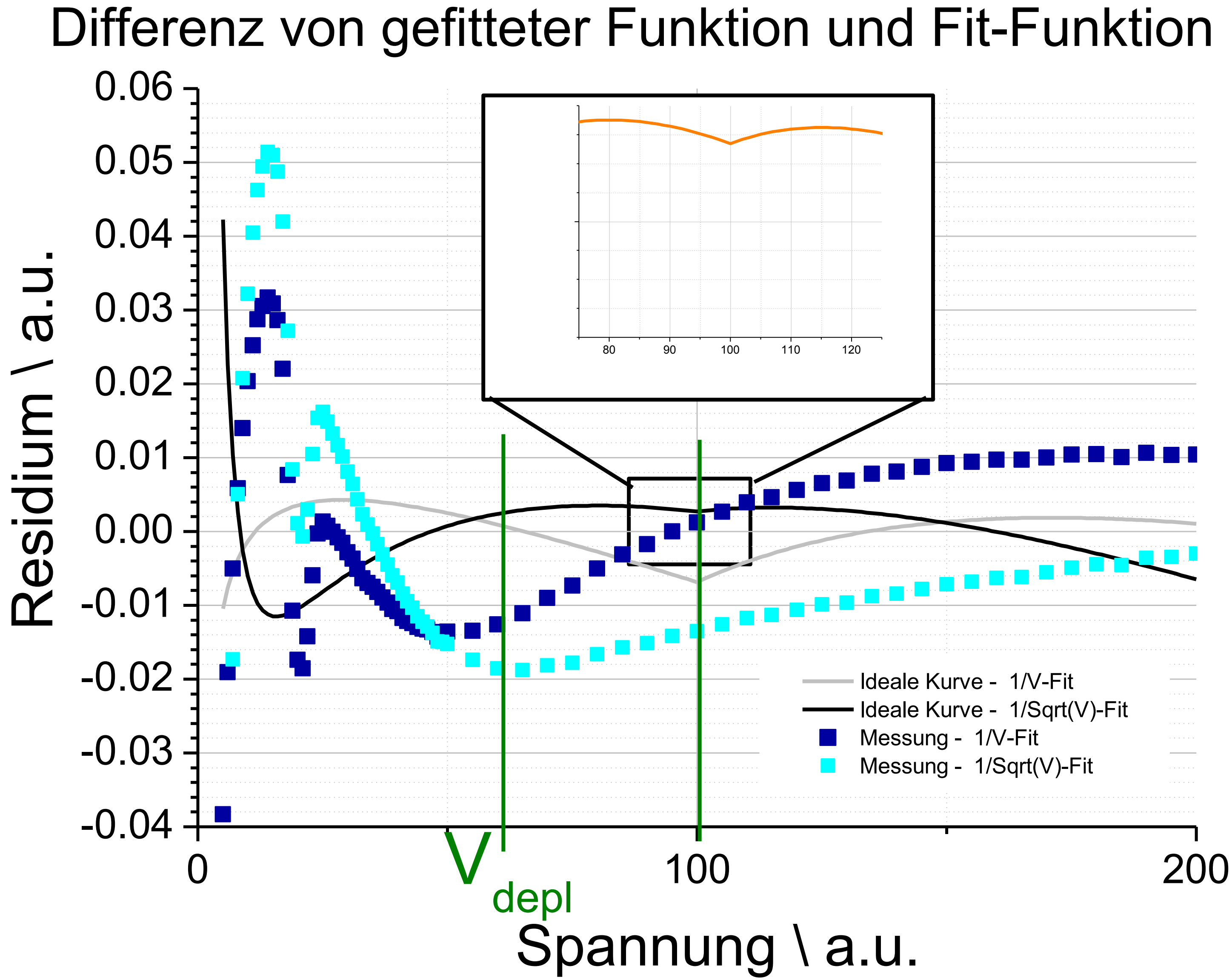



Fit fail to reproduce measurement and sample curves very well…

But is it a bad news?

Levenberg-Marquardt algorithm:

Linearization of original function and minimize the least square. Standard library in Labview, Origin, Root, …

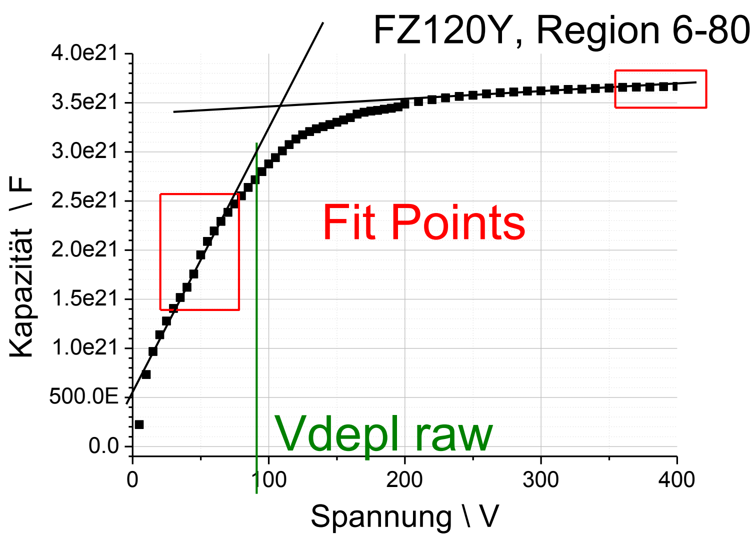



(Curve-Fit): For sample curve and measurements at ~Vdepl is a clear minimum ☺ Sometime it is good to be not to perfect?

***On sample curve it is more pronounced for 1/V-Fit on real curves with 1/sqrt-Fit.***

# Now I have something to work with

- Estimated with both methods VDpel
- Look if both results are into 33% bounds
  - If they are:
    - Calculate average
    - Calculate 1/C2 from measurement data
    - Take the last 5 points and 50 to 75% points before the raw depletion voltage for linear fit of both regions and calculate the crossing point



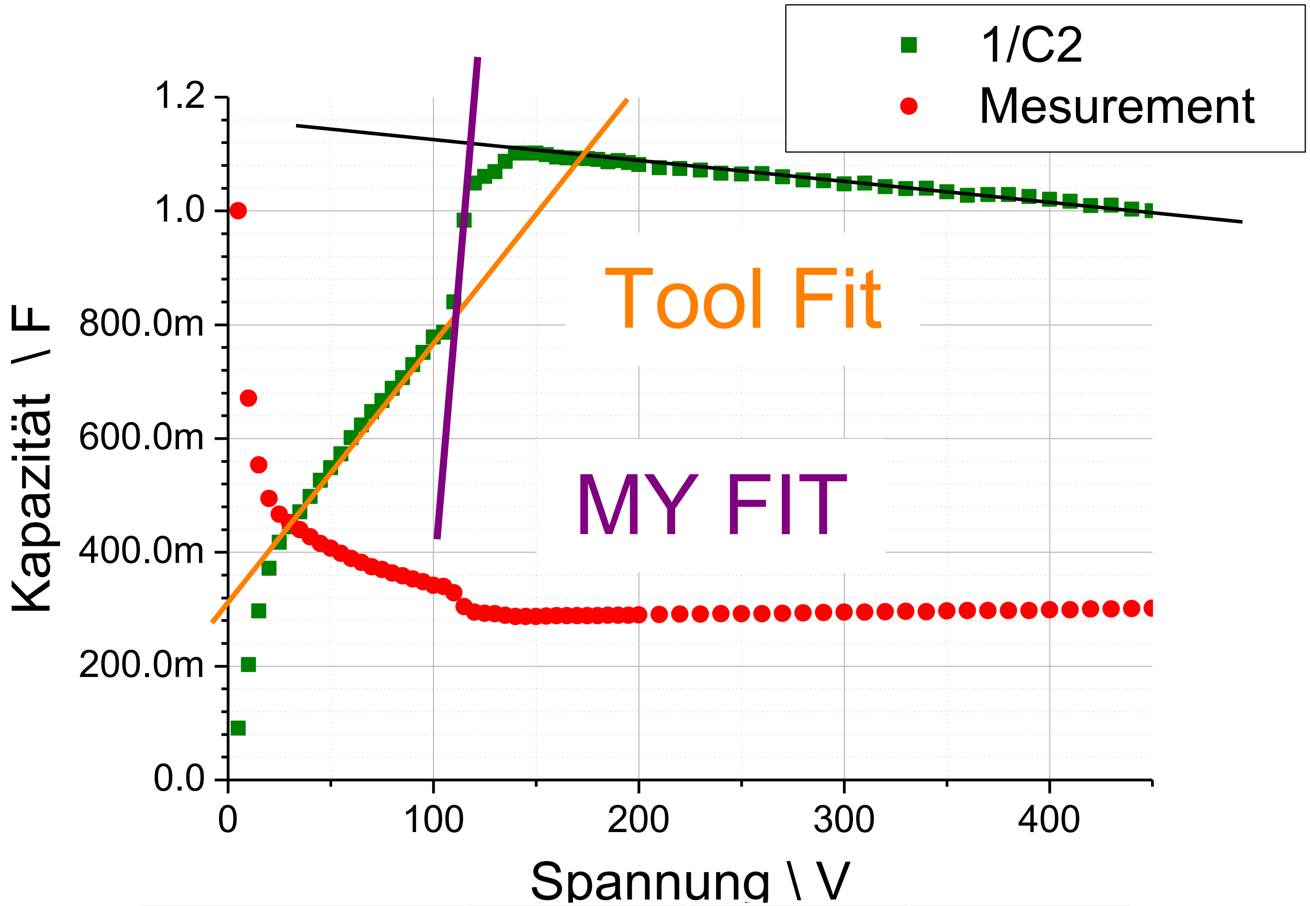
# So how good it work?

| Struktur | Handfit | Ableitung | Fit | Finaler Fit | Differenz |
|---|---|---|---|---|---|
| E50N_12-80 | 35 | 45 | 20 | ---[1] | --- |
| E50P_9-100 | 30 | 55 | 30 | 35 | -5 |
| E50Y_1-120 | 120 | 110 | 105 | 125 | -5 |
| E100N_8-120 | 60 | 70 | 60 | 55 | 5 |
| E100P_7-120 | 90 | 100 | 35 | ---[2] | --- |
| E100Y_3-100 | 140 | 130 | 170 | 145 | -5 |
| FZ120N_4-100 | 115 | 115 | 120 | 115 | 0 |
| FZ120P_7-120 | 130 | 130 | 130 | 180 | -50 |
| FZ120Y_6-80 | 115 | 90 | 85 | 130 | -15 |
| FZ200N_9-100 | 185 | 180 | 210 | 190 | -5 |
| FZ200P_12-80 | 105 | 105 | 100 | 100 | 5 |
| FZ200Y_1-120 | 160 | 140 | 135 | 175 | -15 |
| FZ320N_2-120 | 230 | 220 | 220 | 220 | 10 |
| FZ320P_3-100 | 235 | 120 | 120 | 220 | 15 |
| FZ320Y_6-80 | 245 | 240 | 260 | 260 | -15 |
| M200N_10-100 | 170 | 175 | 180 | 180 | -10 |
| M200P_5-80 | 200 | 200 | 210 | 220 | -20 |
| M200Y_6-80 | 130 | 140 | 140 | 135 | -5 |
| **1/sqrt(V)** | **95** | **85** | **100** | **85** | **10** |

Take for the each of the 18 sensor types by chance one measurement and fit it by hand. AFTER that I use the tool and compare the results
**-> Real control sample, Not only good examples**

[1] Less than 3 Points for Fitting on low voltage side
[2] Differenz between both methode is to high!

- Tool reproduce my hand made results into 20V
- Internal cross checks work
- One result is out of range, lets see what happens here




| Struktur | Handfit | Ableitung | Fit |
|---|---|---|---|
| FZ120P_7-120 | 130 | 130 | 130 |

Good: Both methods have the right estimate of Vdpel!

Bad: Curve shape let final fit run into “wrong” Value

But: Why I believe my understanding of how to fit this nasty curve is right? (I just take 2 point). Was the measurement itself right??

I think this example is not showing that the method has general problems!

# Conclusion

- I develop a fit tool for the Depletion Voltage
  - Tool consists of two independent methods to find a raw estimate the depletion voltage
- The tool gives for 15 out of 18 test measurements a results that are into a 20V range to the hand fits
  - For 2 of the remaining results, the internal cross checks work
  - For the last measurement the curve shape is far away from ideal