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1.1 Software basics

- Modular software (Base, Dlts, Hall program modules)
- Software for Windows 9X, NT, 2000, XP, Vista, 7
- Entire hardware is software controlled
- High flexibility and easy use
- Routine and enhanced software
- Input/function restriction by selection of a user class
- Init files, different configurations, hot start
- Update from PhysTech homepage
- Demo programs at PhysTech homepage
- User interfaces by ASCII files or DLL (Dynamic link library)

1.2 Software examples

- Input of sample ID and contact number for database and automatic file names
- Saving of all measure data in binary or ASCII files
- Print out of relevant plots and results on one paper sheet
- Input of material parameters, definition of new materials
- Automatic and manual measurements
- Monitoring of commands and report files for diagnose
- Simulation of measurements available (training, demo)
- Personal style of software available (size, buttons, font ...)
- WebView for watching measurement via internet/intranet

1.3 Database

- Database files:
  - File database as a report of measured files
  - Evaluation database for results, saving by user
    - Standard DBase IV
    - User database, format select by user
    - DLL interface for saving in a customer database
  - Library (only Dlts)
- Export of DBase IV databases to ASCII, HTML, Paradox, Access, Excel, SQL-Server and user defined by ADO
- Program module for view, search and sort
- SQL commands available

1.4 Plot programs

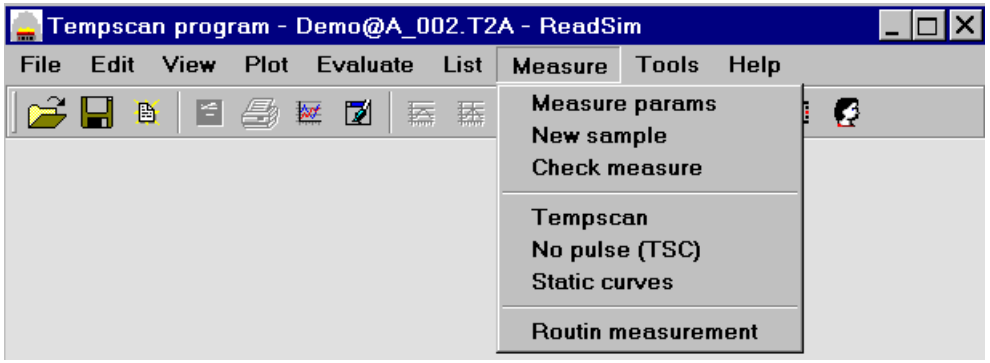
- Standard plot program: size, symbols, colors, axis, zoom ...
- Application plot program: combined plots, many curves/layers
- Edit plot program: edit data
- Presentation plot program: manual many curves/layers, text, ...
- Export to BMP, PCX, GIF, JPEG, WMF, EMF, HPGL, PLT, EPS, DXF, CSV, ASCII, XLS
- Evaluation (if available) by manual or auto linear regression
- Interpolation and smoothing by Splines, Gauss, polynom ...
- List of data in a data sheet
- Print out on half (top/bottom), one or more paper sheets

1.5 Cryo system

- Support of many cryo systems resp. temperature controllers
- All cryo system parameters in special ASCII init file
- Simple makro language for adaptation of controller commands
- User defined DLL possible
- Ramp modes:
  - Boxcar ramp, computer controlled
  - Linear ramp, computer controlled
  - Linear ramp by temperature controller, if available
- All ramp params (waiting time, delta T...) user defined
- Temperature depending PID params, if PID available
- Functions for adaptation and check

2.1.1 Dlts software structure

- Main modules (similiar structure):
  - Static measurements
  - Transient
  - Isothermal
  - Tempscan
  - Base tools (calibration)



- Check measure (preparations)
- Plot, Database, Library, ...

2.1.2 Preparation measurements

- Input of sample params (material, type, area, ID ...)
- Search of the polarity
- Check of contact
- Searching of minimum ranges
- Capacitance compensation
- Reverse I/V curve for check of leaking current
- C/V curve and calculation of shallow concentration Ns
- Preparation measurements from all program modules

2.1.3 Static measurements

- Measurement of C/V HF- and pulse-curves --> Ns
- Measurement of I/V curves --> n-factor of diode
- Measurement of FET UDS (drain source voltage), UGS (gate source voltage) and param curves
- Calculation of depth profile Ns(x)
- All measurements as function of temperature possible, for example Ns(T)
- Richardson plot for calculation of barrier height
- TSC and TSCAP (measurement without pulse versus temp)
- MIS evaluations

2.1.4 Transient measurements

- Measurement up to 4096 transient points by ADC
- Fourier transform of transient --> Fourier coefficients bn (sin) and an (cos)
- Using coefficients of low order (digital filter) --> good SNR
- Good SNR by variable anti-aliasing filter and averaging
- Automatic C/I-range, amplification and C-compensation
- Measurement of C (capacitance), V (voltage, CC-Dlts), I (current), Q (charge)
- Pulse modes: electrical, double, fast pulse, optical, combination optical/electrical
- Measurement during and after pulse possible
- Fix/variable period width, linear/logarithmic/quasilog time axis

2.1.5 Tempscan program module

- Up to 20 files during 1 tempscan possible
- All files in 1 temperature cycle or in different cycles
- Variation of: Tw (period width = measure time per transient), UR (reverse bias), UP (pulse voltage), tp (pulse width), pulse modes, DS/Aux voltage, 2. pulse, wave length
- Automatic variation of period width possible
- Automatic/manual variation/search of temperature steps or predefined temps possible
- Manual input of params or by predefined init files for easier use
- Saving of some or all transient points
- Measurement of C/V, I/V, TSC/TSCAP curves available
- Option multi sample interface

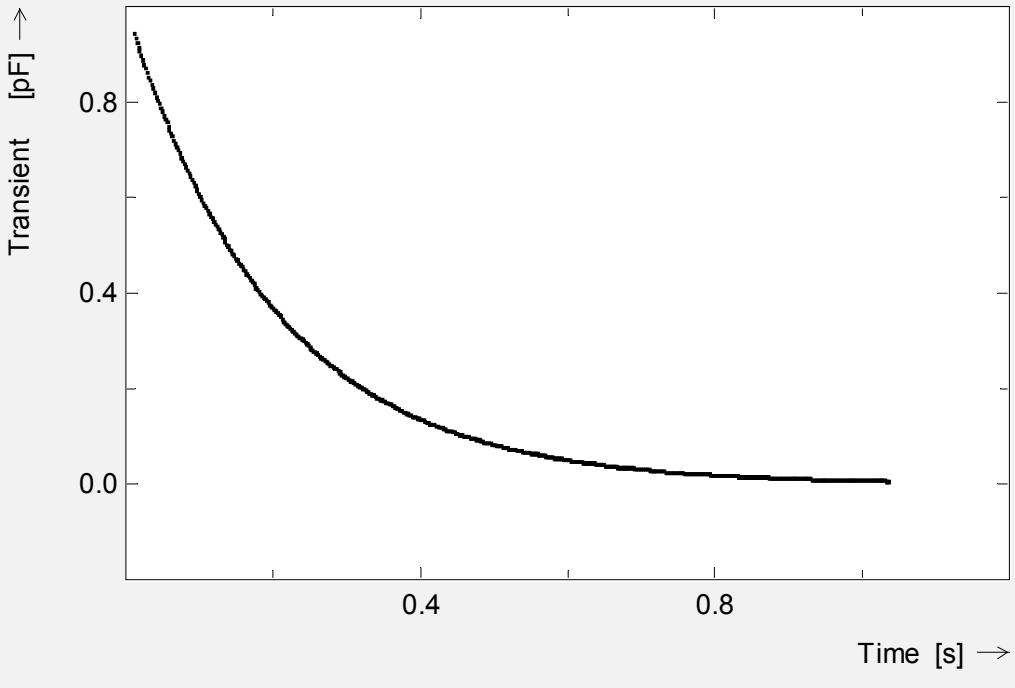
2.1.6 Isothermal program module

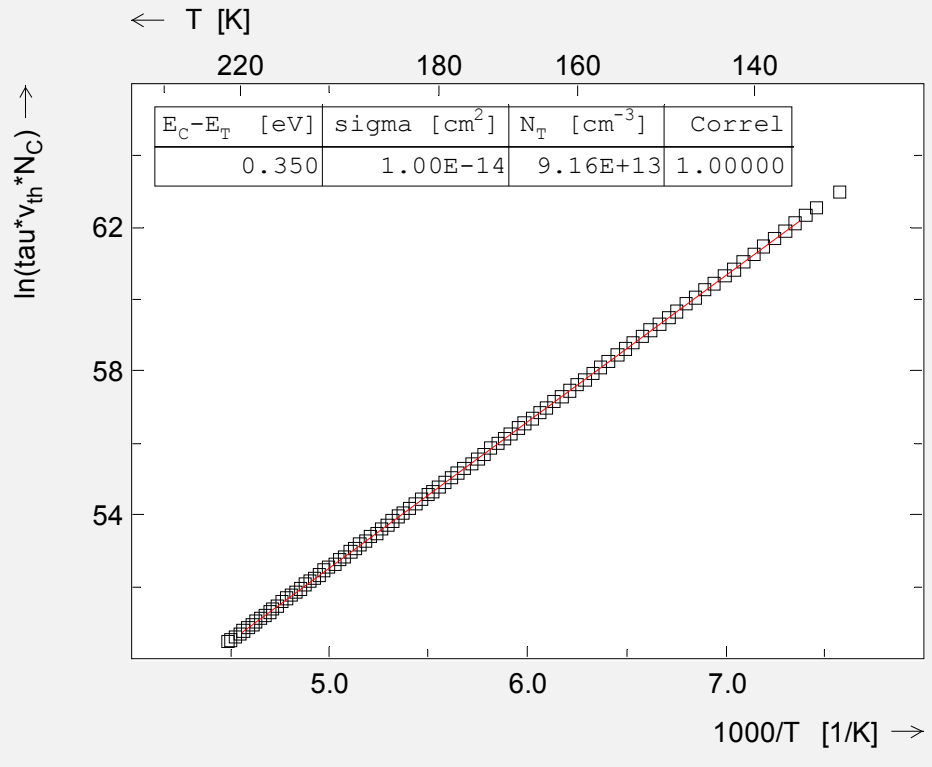
- Measurement at fix temperature and variation of one parameter: Tw, UR, UP, UR/UP, tp (lin and log), UAux, UDS, wave length, UserX
- Plot coefficient versus this parameter
- Measurement of period width (frequency) scan
- ITS parameter variation: period width scan files with variation of T (temperature), UR, UP, tp, ...
- Arrhenius plot of period width scans
- Application measurements for easier use of inputs
- Calculation of depth profiles and field-dependence of tau
- Indirect capture evaluation by tp-variation (b1 % tp) for determination of capture cross section

2.2.1 Direct analysis by DLTFS

- Tau calculated directly from the transient by Fourier transform
- Examination of results by calculation of several ways
- Constant and computer controlled variable period width
- Many Arrhenius points, large range

```
tau(a1,b1) = 199.987 ms    Amplitude =    1.000 pF
tau(a2,b2) = 199.979 ms    NT        = 9.09E+13 cm-3
tau(b1,b2) = 200.004 ms    NTs       = 1.72E+14 cm-3
tau(a1,a2) = 200.019 ms    Energy    =    0.627 eV
tau(Tw/4)  = 199.743 ms    tau,ts/Tw = 0.20,1.53
tau(Tw'/2) = 199.999 ms    ExpClass  = 1.00
tau(a0,b1) = 199.685 ms    TauClass  =   75
```

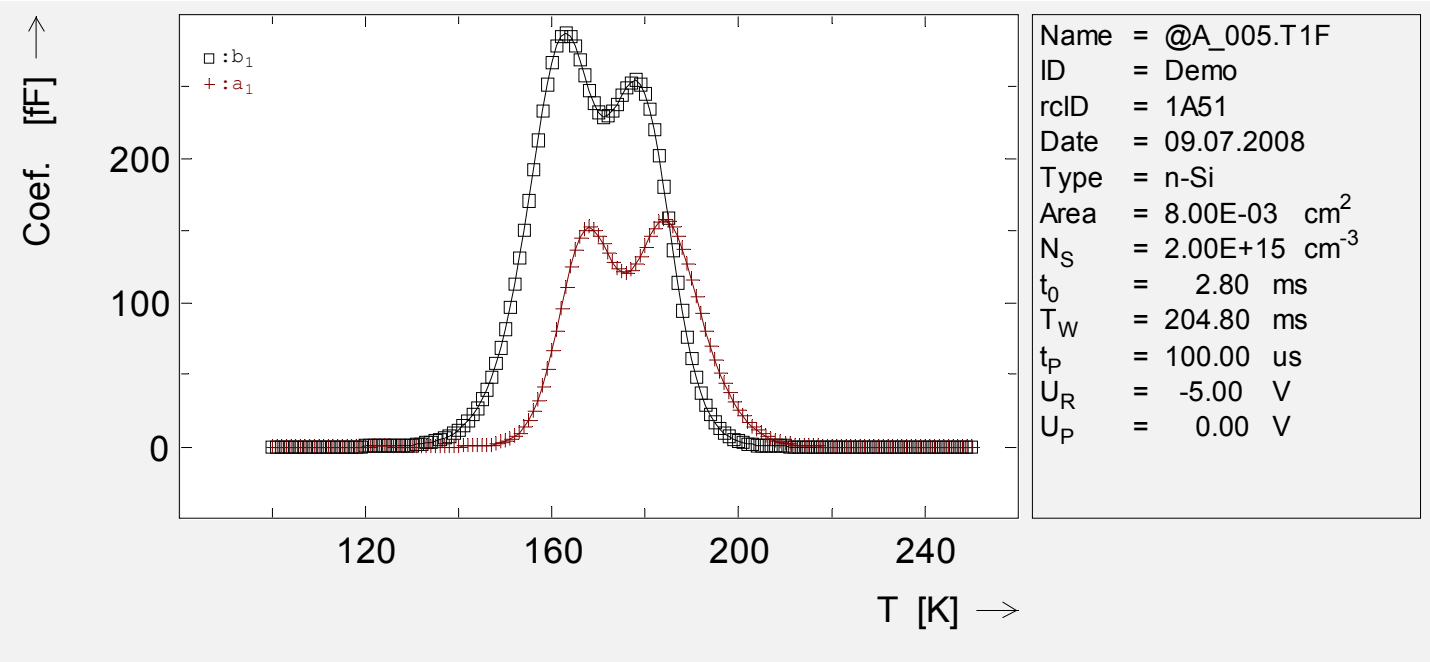




E_C-E_T [eV]	sigma [cm^2]	N_T [cm^{-3}]	Correl
0.350	1.00E-14	9.16E+13	1.00000

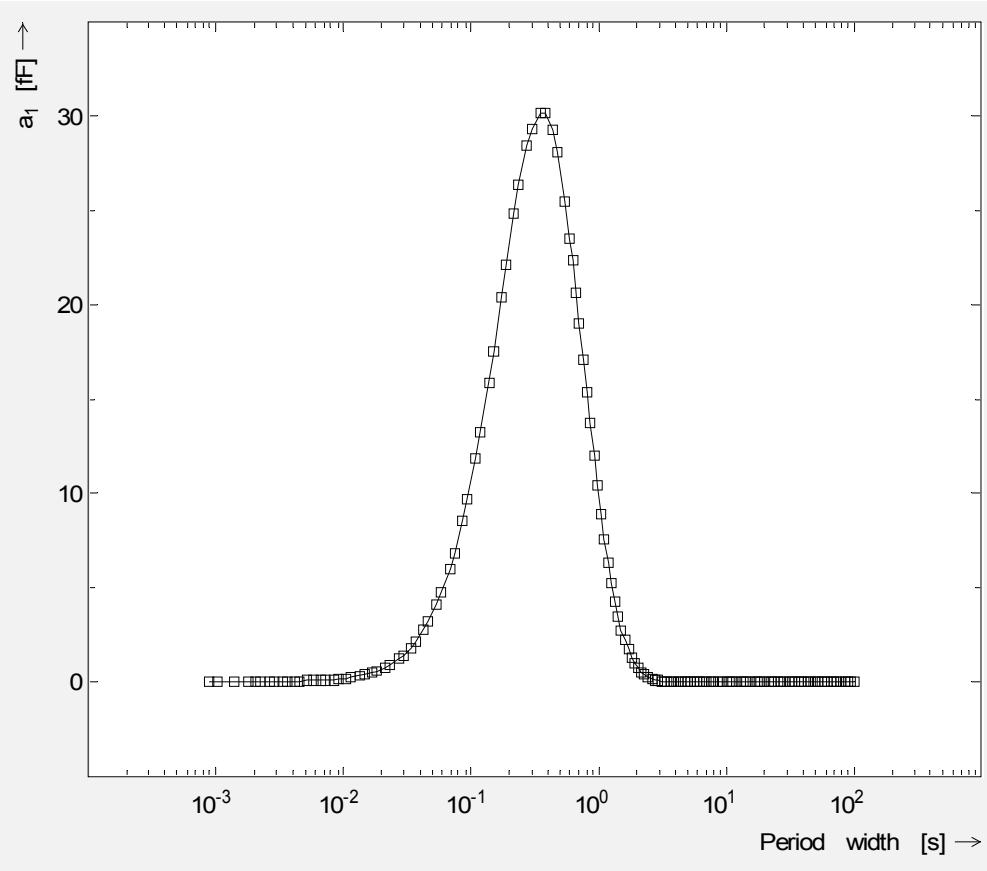
2.2.2 Tempscan maximum evaluation

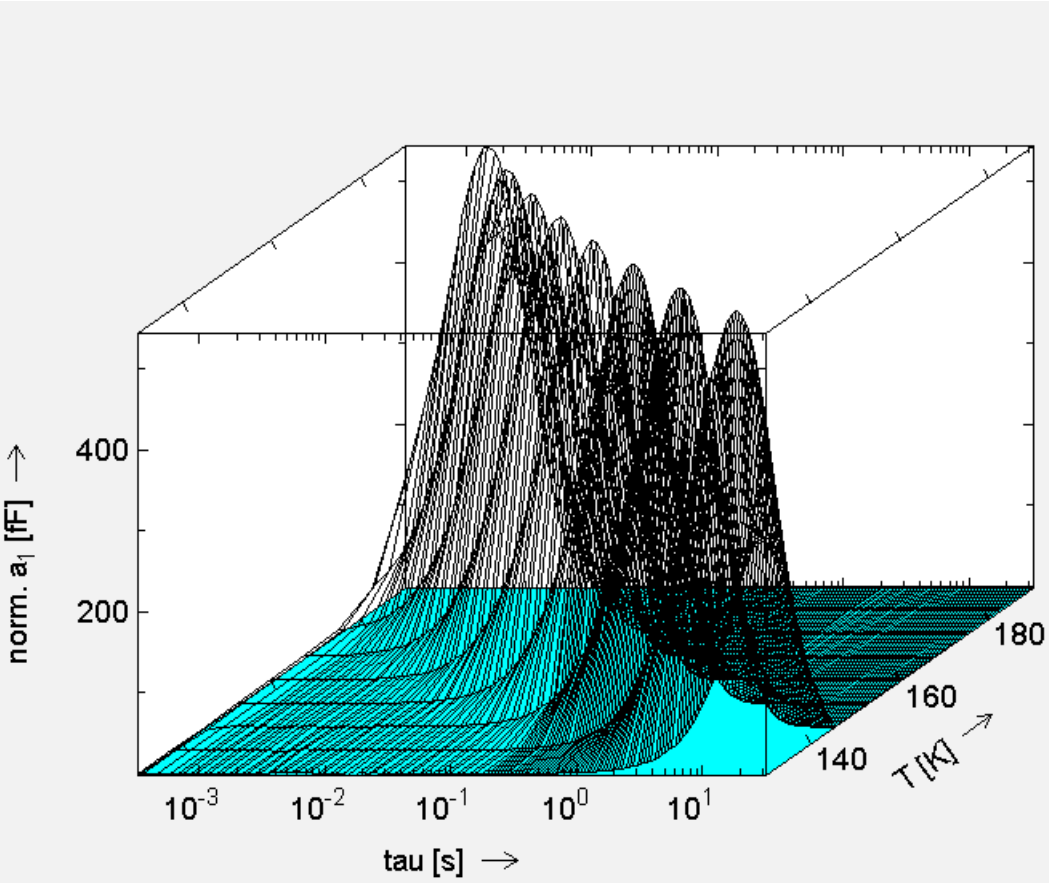
- 28 Fourier coefficients resp. correlation functions per period width (file): sin, cos, boxcar, double-rectangular, Dlts ...
- Coefficients with better energy resolution or SNR
- Until 3 user defined correlation functions by ASCII file or DLL
- Recalculation (tempfit) and smoothing of coefficients possible



2.2.3 Period width scan resp. frequency scan

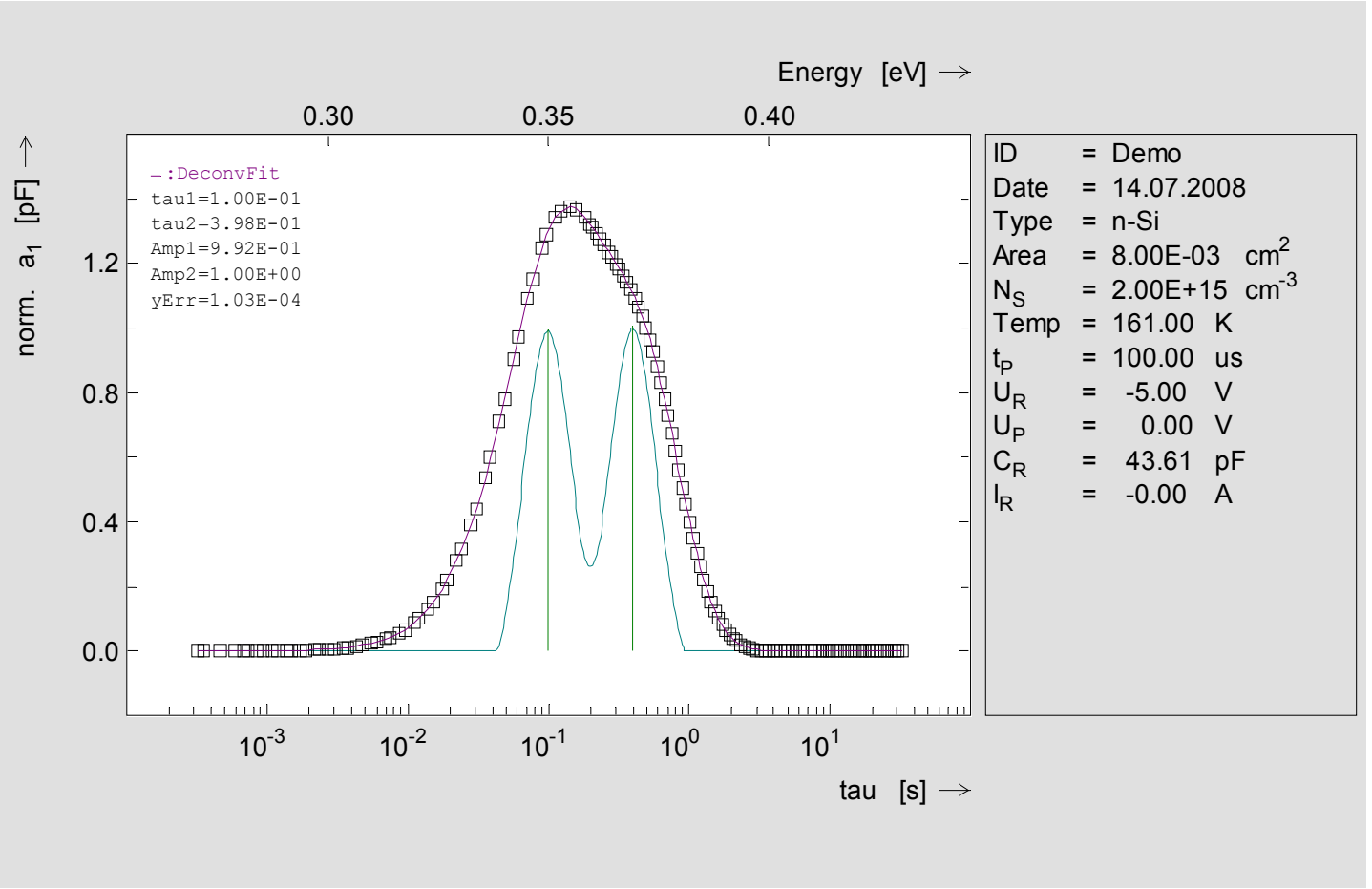
- Period with scan --> (numerical) normalized tau scan
- Tau calculated from the maximum position
- All coefficients as in tempscan and ICTS signal available
- Automatic variation of temperature available --> Arrhenius





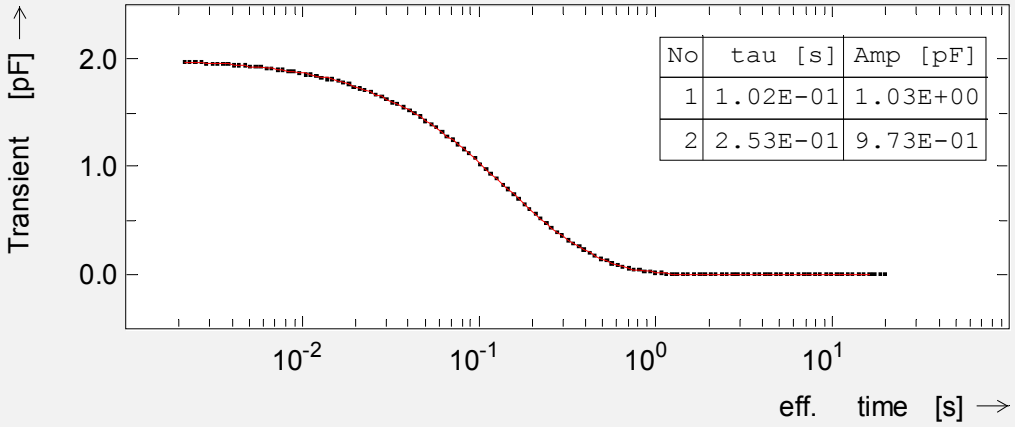
2.2.4 HERA (High Energy Resolution Analysis) of coefficients by deconvolution

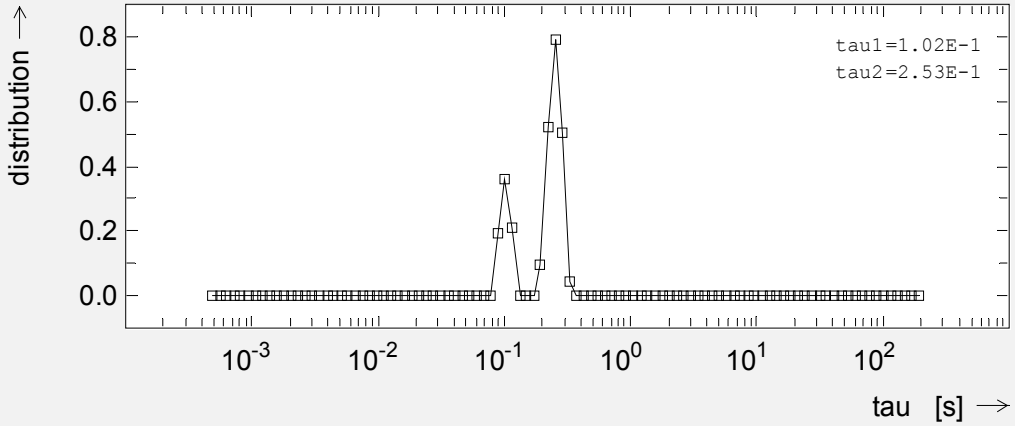
- Deconvolution of coefficient at period width scan
- Deconvolution of tempscan

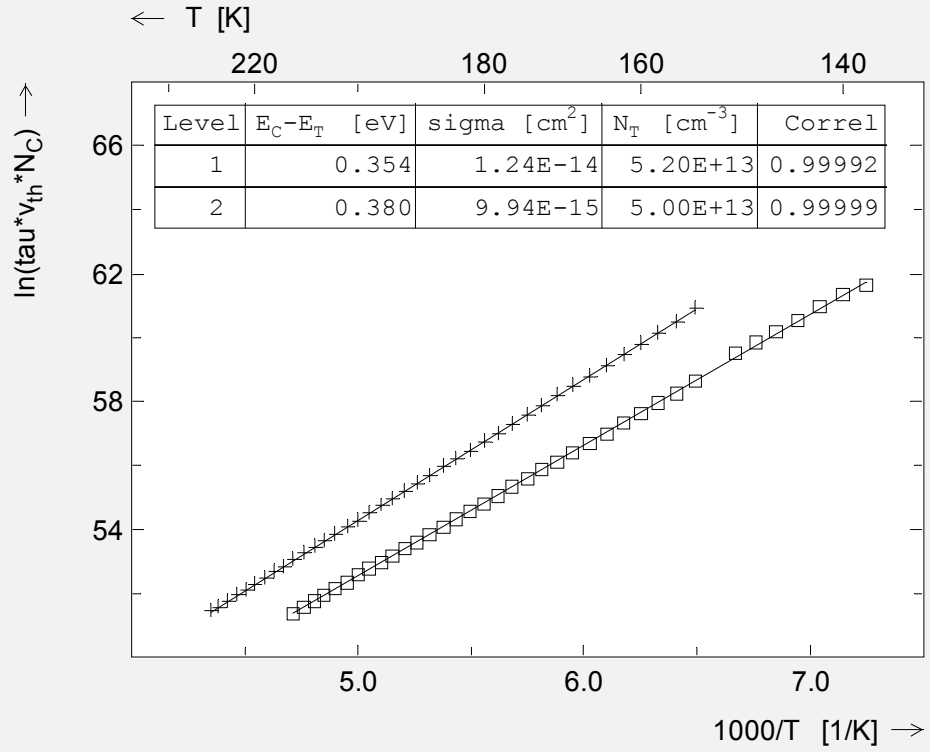


2.2.5 HERA transient evaluation

- Multi exponential fit: DISCRETE by Provencher
- Laplace transfrom: CONTIN, FTIKREG
- Combination with DLTFS for amplitude and NT

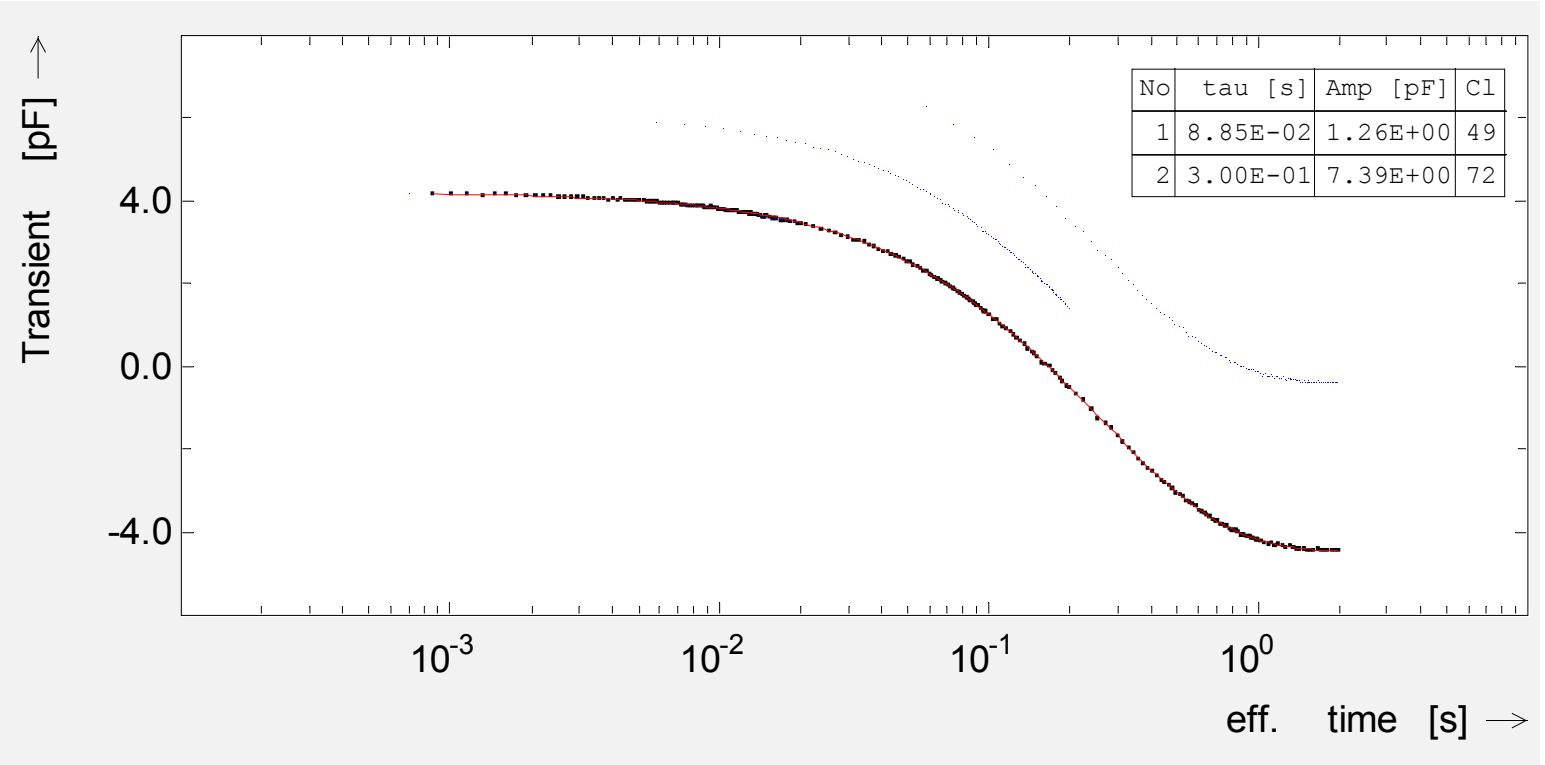






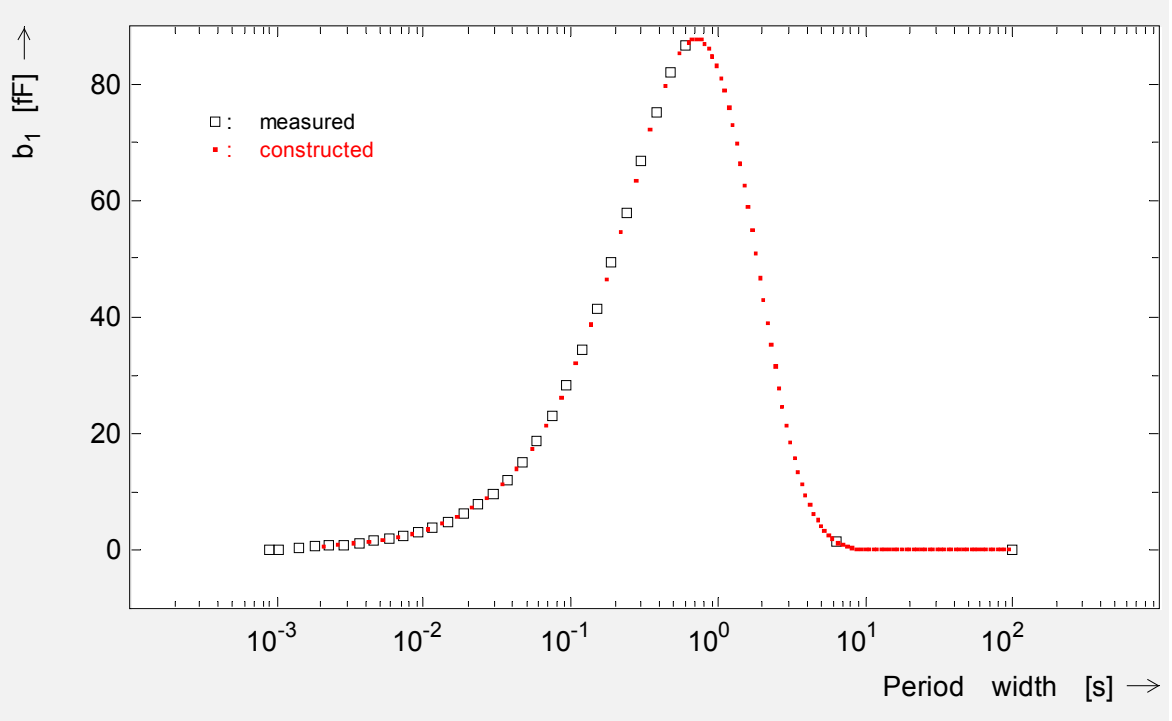
2.3.1 Quasi logarithmic time axis

- Log. time axis by meas. 65000 sample points and interpolation, bad SNR because high filter frequency and no averaging
- Quasi log. time axis by combination of 3 or many transients with different Tw (tempscan or isothermal program), for every transient optimal analog filter frequency and averaging



2.3.2 Oversampling at period width scan

- Transient oversampling measurements until 65000 points, building of transients from these points by digital filtering
- Many b1/Tw points by building many transients from 1 measure
- Good SNR because averaging at small period widths
- Reduction of ITS measurement time down to 10 %



2.3.3 Some specials

- Evaluations for exp., lin. and log. transient
- Three terminal FET current transient measurement
- Surface states Nss(E) calculation for MIS samples
- Zerbst plot at MIS for life time evaluation
- Temperature depepending Zerbst plots --> Arrhenius
- Measurements at 2 params (UR, UP, tP) and making difference, for example DDLTS
- Level seperation by measurements with 2 pulse widths (small and big capture cross section)
- Database library for discrete levels, predefined values by literature, expansible by user