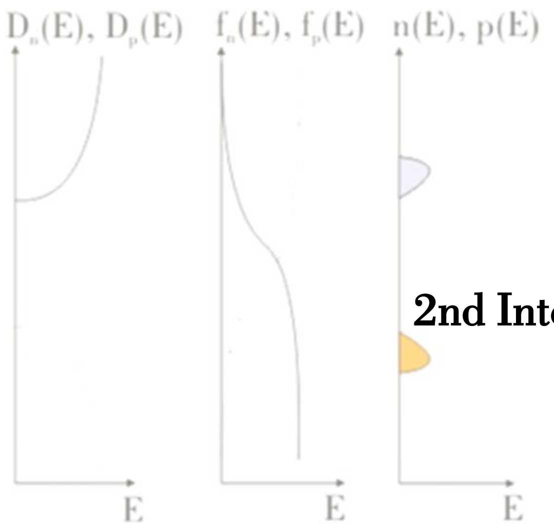
Minimatrix X-ray irradiations
and
new dosimetry at the x-ray facility



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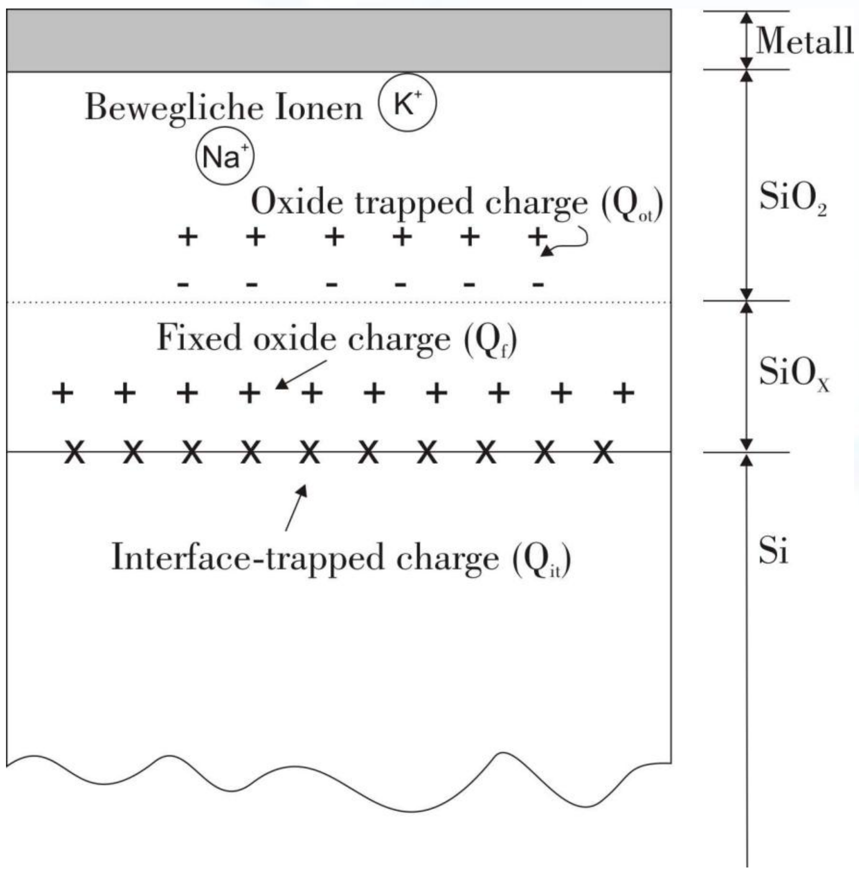
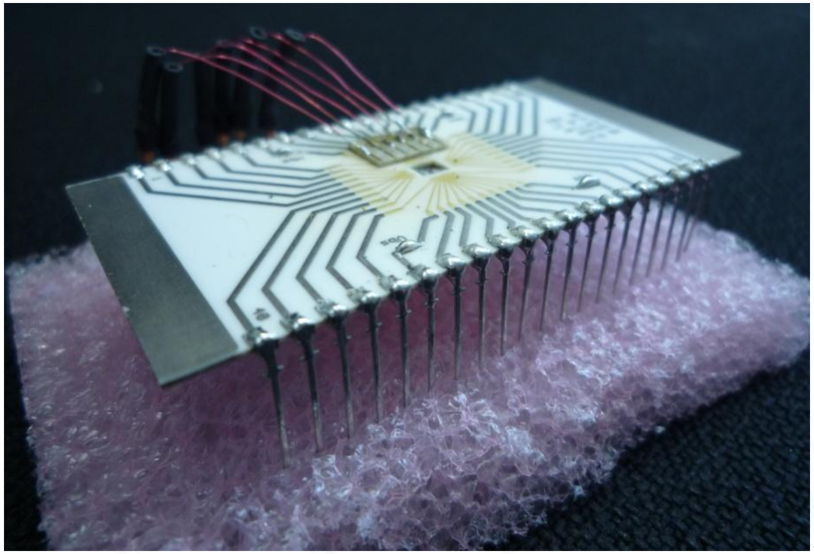
2nd International Workshop on DEPFET Detectors and Application
Ringberg Castle
Monday, 4. May 2009

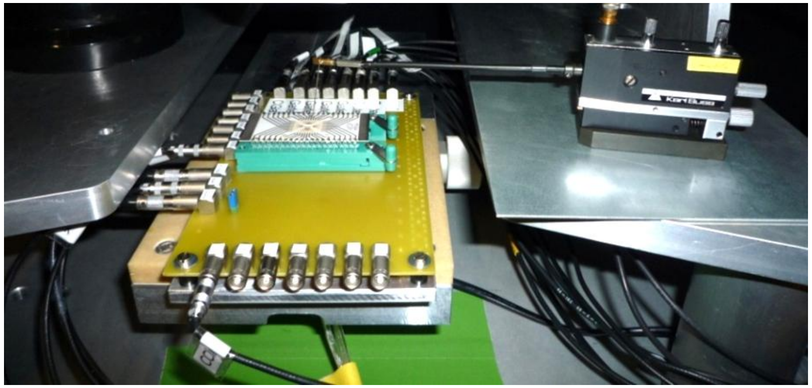
Why x-ray irradiations?



- SuperBelle: There will be high synchrotron radiation at the interaction point (~1 Mrad/a = 10 kGy/a)
- Simulate this ionizing radiation with x-rays
- DEPFET: Electron/Hole-pairs are generated in the oxide
- Trapped holes remain there for a long time
  - ➔ Change of electrical characteristics

Setup and DAQ



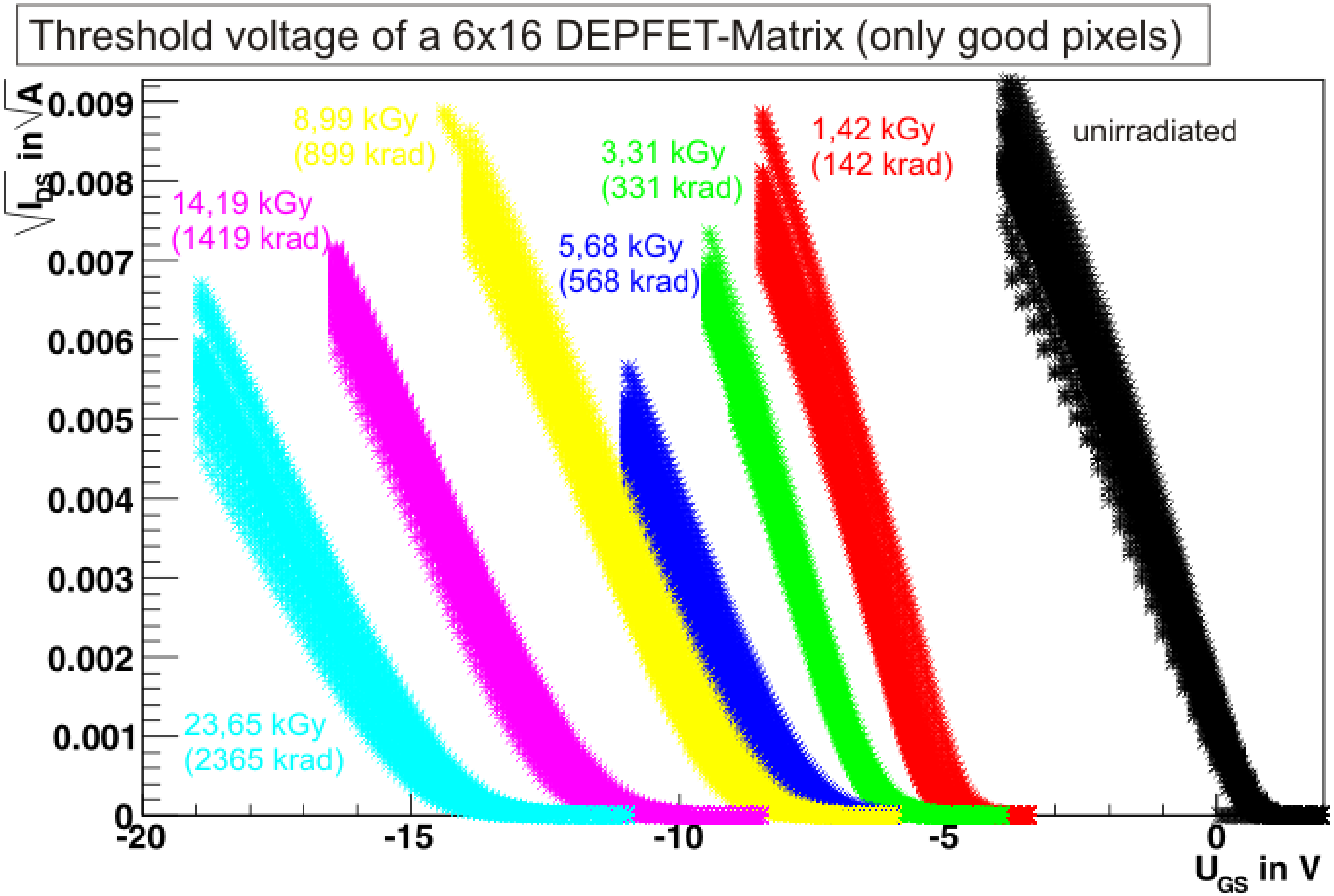


- Study with a 6x16 Minimatrix
- Important contacts on PCB → easy accessibility
- Drain contact needed probe needle
- Several irradiation and measurement steps
- Readout duration of input characteristic of all 96 pixels

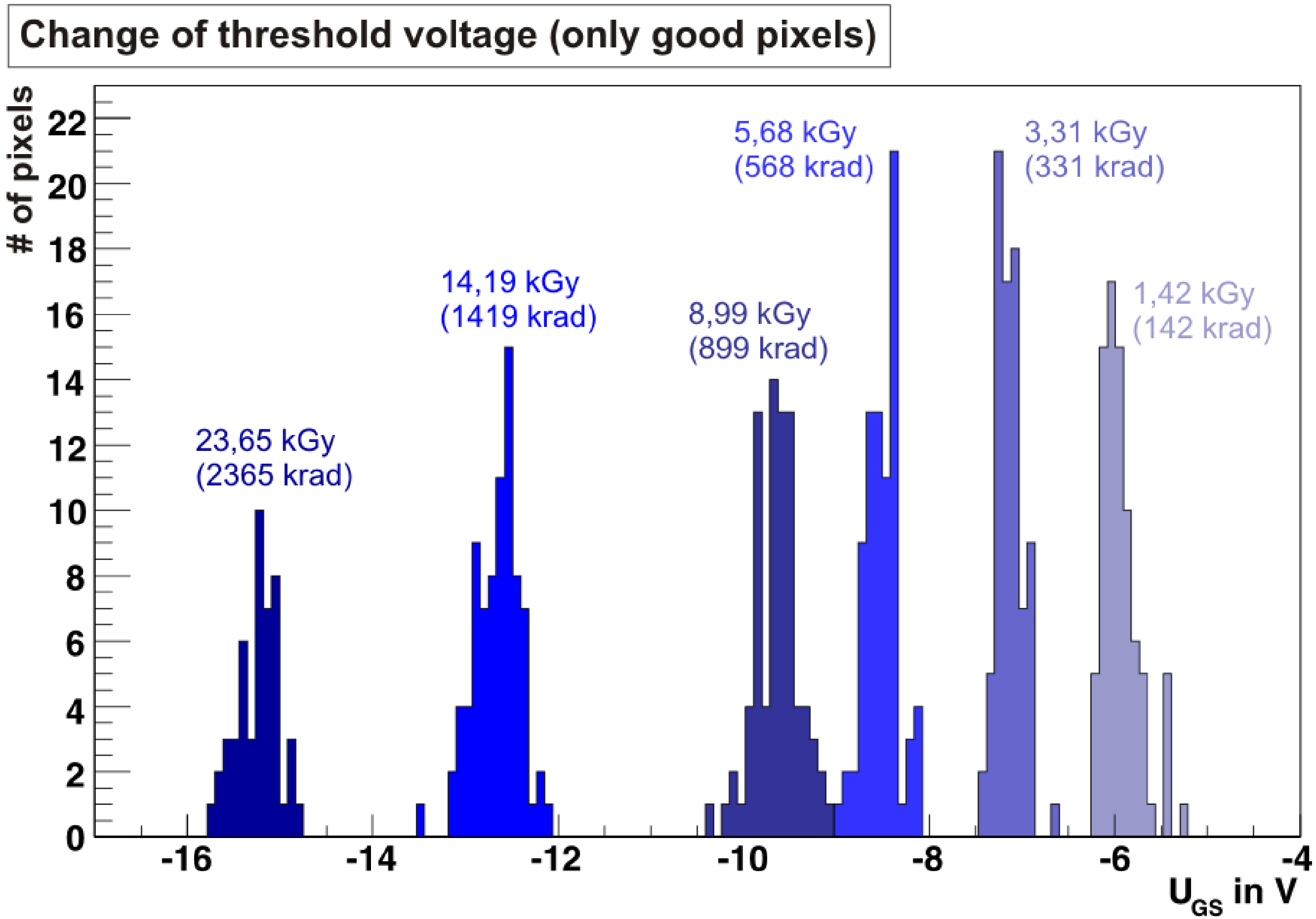
  ~ 6…7h

  → min. 4 days of room temperature annealing
- DAQ via LabVIEW: Sweep of Gate voltage, Drain current is measured

Results of input characteristics

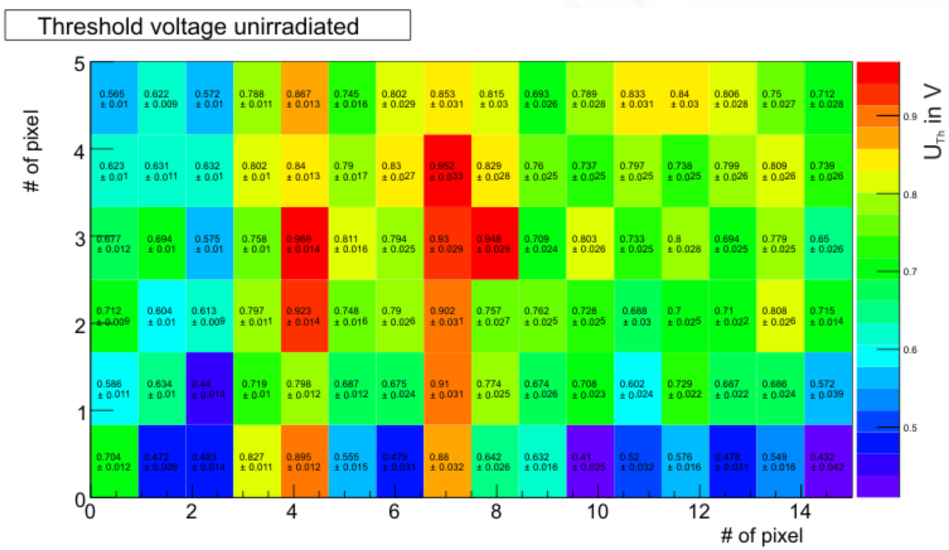


Change of threshold voltage

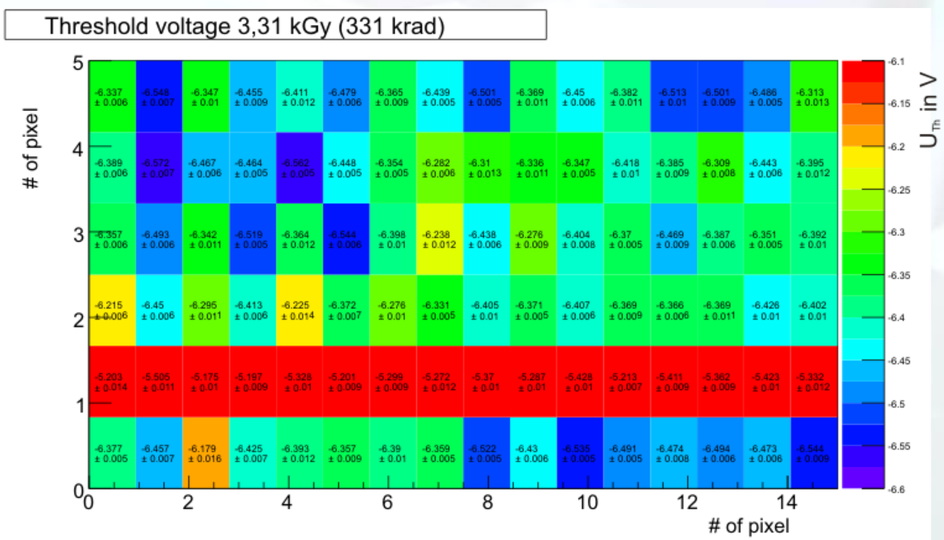


Homogeneity of the Minimatrix

Threshold voltage – Unirradiated
(scale: 0.4V…1.0V)

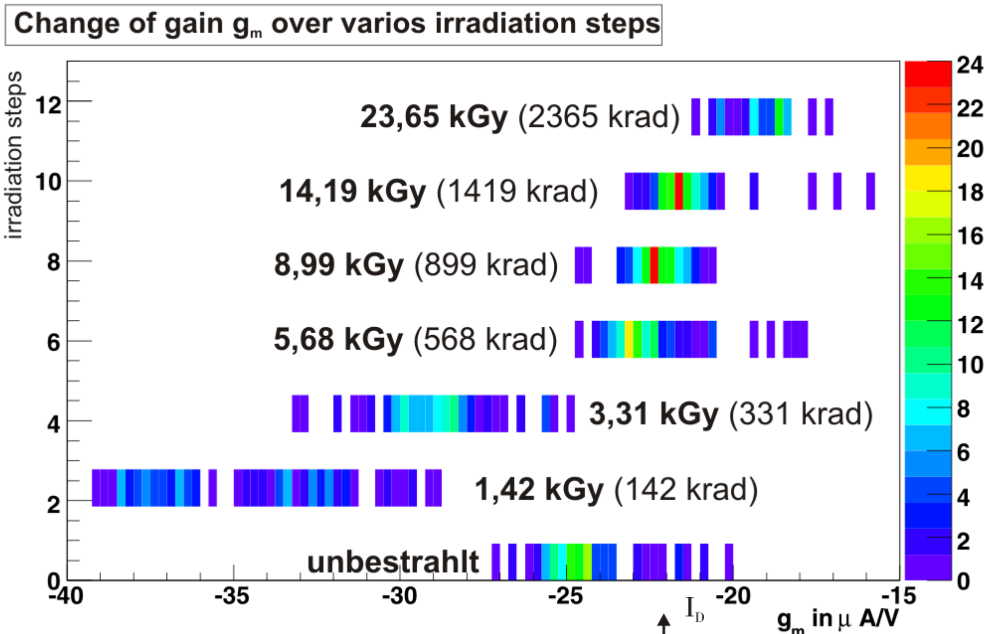


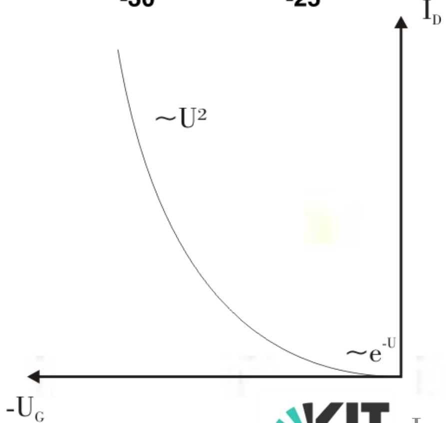
Threshold voltage at 3.31 kGy
(scale: -6.6V…-6.1V)



→Fluctuations are not severe

Change of gain g_m





- Input characteristic curve fitted with
  - $I=aU^2+bU+c$
  - Gain $g_m=mU+b$ via dI/dU → $m=2a$

    → no numeric deviation
  - Gain evaluated at Drain current = 50 μA
- Maybe effect is part of setup and readout process → needs to be rechecked to find out if effect still occurs

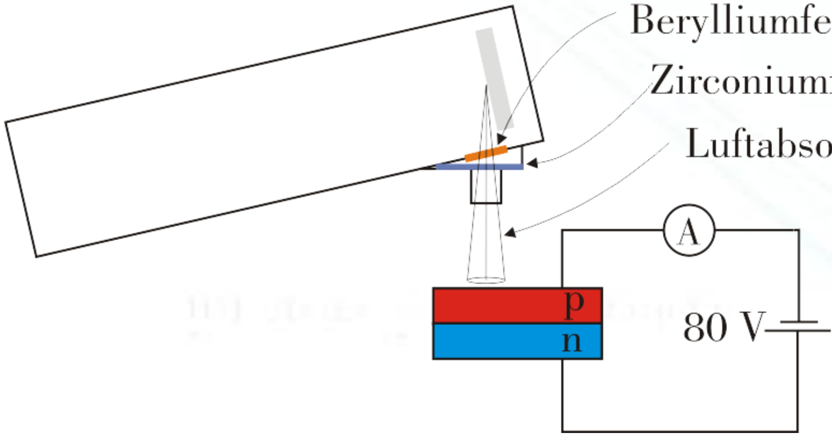
Conclusions

- Threshold shift is high (~15 V at 23 kGy), but Switcher 4 should handle it
- Tests on thinner oxides (Minimatrix 180 nm) show much smaller shift, maybe Switcher 3 can do the job
- Homogeneity of threshold voltage shouldn't be a problem, though inhomogeneous irradiation at SuperBelle may prove difficult
- Change of gain may be a problem for clusterfinding (difference about 20 %) at 1.4 kGy. Should be rechecked

New dosimetry at the x-ray facility Karlsruhe

Using a GEANT4 simulated energy spectrum of a tungsten anode by Oksana Brovchenko

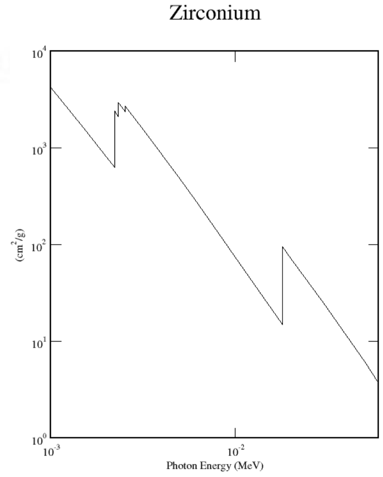
Determining dose rate in Silicon

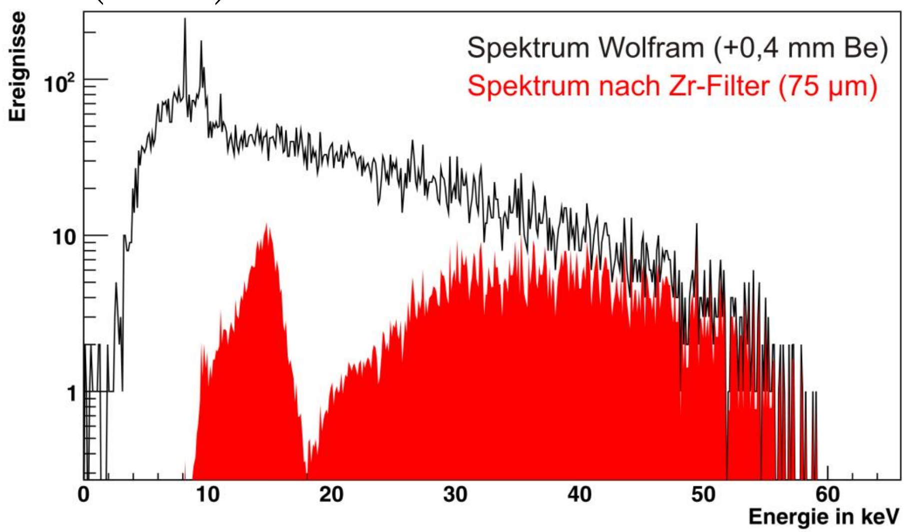


- Dose rate measurement via depleted diode
- Measuring of reverse-current
- X-ray photons generate electron/hole-pairs in Si-Bulk
  - Every charge carrier pair represents an energy of 3.6 eV
  - With the x-ray generated current one gets the deposited power, with the mass of the diode → dose rate in Si

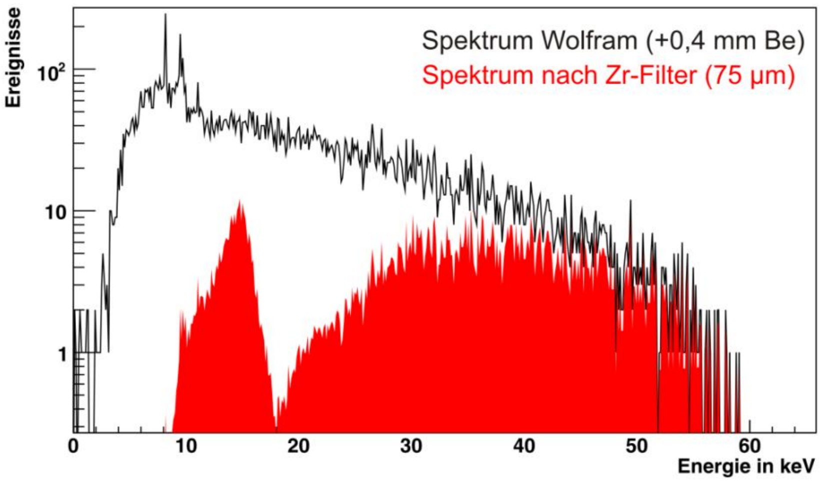
Making use of the spectrum

- Spectrum of tungsten anode (including a 0.4 mm Be filtering, black)
- Generate via absorption function of Zr a new transmitted spectrum (red)





Calibrate silicon spectrum with power measurement in diode



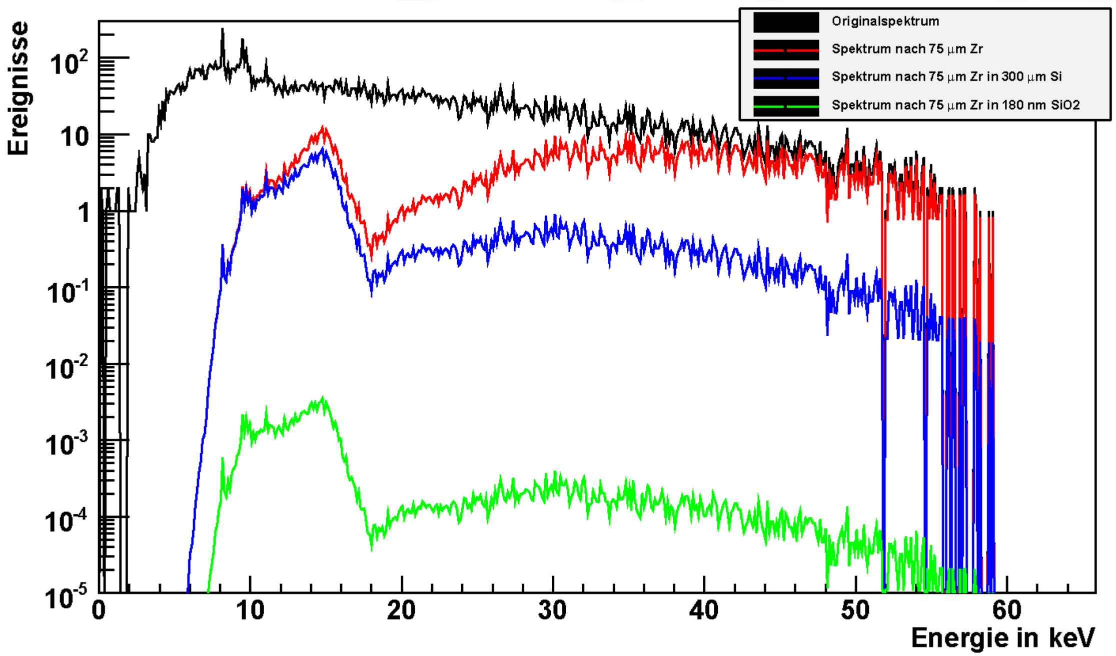
- Simulated Spectrum (red) hits simulated silicon of 300 μm thickness (thickness of diode)
- Calculate arbitrary power

$$P_{rel_{Si}} = \int N_{abs_{Si}} \cdot E \cdot dE$$

- Simulated power is linked to the measured power via

$$P_{Si} = \alpha \cdot P_{rel_{Si}}$$

Calibrate SiO_2 spectrum



- Same calculation for SiO_2 spectrum (green) as for Si (blue)

$$P_{rel_{SiO_2}} = \int N_{abs_{SiO_2}} \cdot E \cdot dE$$

- Dose rate of Si spectrum is known, so the SiO_2 spectrum can be calibrated

New dose rates

- Every dose rate matches to a specific set of parameters, we assume
  - U=60 kV (max. tube voltage)
  - I=33 mA (max. tube current)
  - Distance is 155 mm ($\dot{D} \propto \frac{1}{r^2}$)

    [total distance to electron spot on anode is 155mm+25mm = 180 mm, but distance (155mm) can easily be measured in lead container]
- Dose rate in silicon (300 μm)

  $$\dot{D}_{Si}\big|_{60kv,33mA,155mm,300\mu m} = 0{,}305\frac{Gy}{s}$$
- Dose rate in silicon dioxide (180 nm)

  $$\dot{D}_{SiO_2}\big|_{60kV,33mA,155mm,180nm} = 0{,}239\frac{Gy}{s}$$

Correct old dose rates by factor 0.47

Uncertainty on dose rates

- To check it, we need to measure the spectrum…
  (Equipment should come any time now…)
- Until then: Use other filters
  1. X-ray facility has 6 kinds of filters (Zr, Fe, Mn, …), which are easy to install
  2. Check power by all filters with diode
  3. Simulate power by all filters
  4. Compare measured results, like Zr/Fe
  5. Compare simulated results, e. g. Zr/Fe

Q: Did the relations in step 4 and 5 match?

A: Yes, to 2.3 % ± 12.6 %. So roughly 15 % uncertainty

Acknoledgements

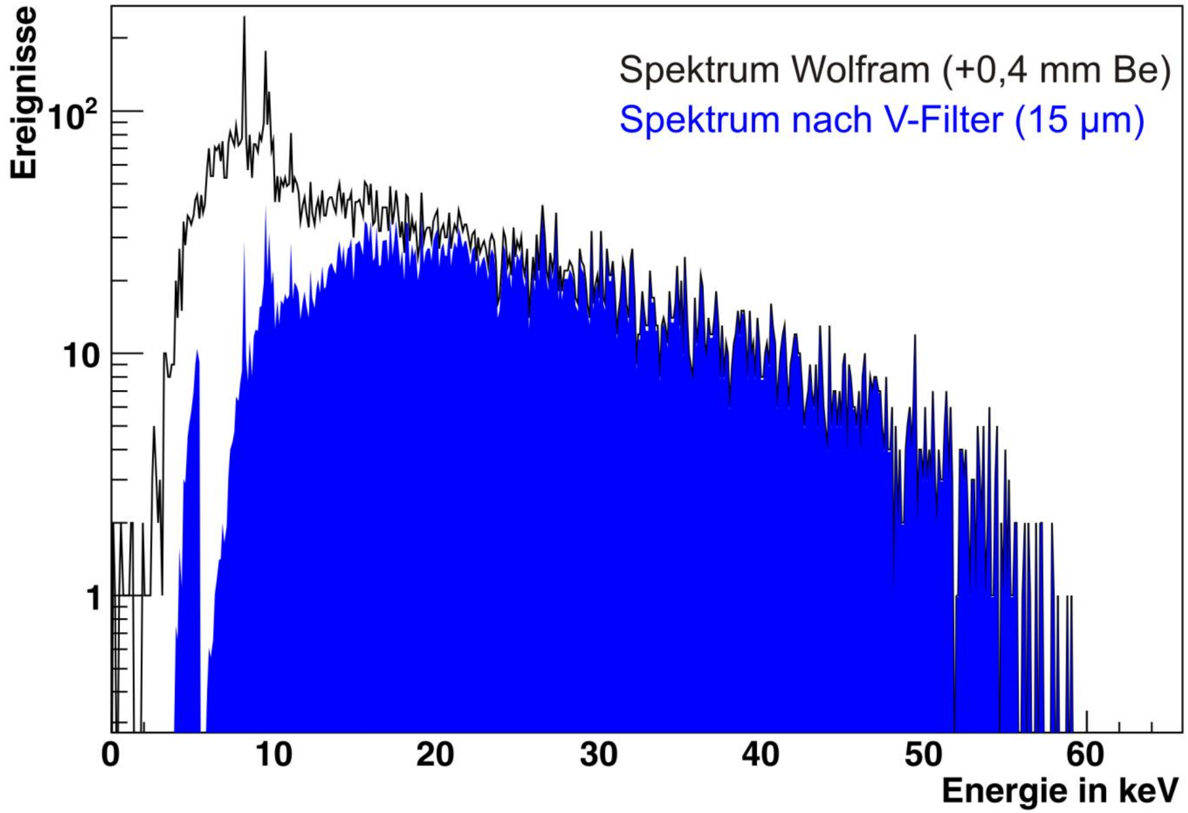
Thank you for listening

Thanks to the MPI HLL in Munich for the matrices and richfull discussions

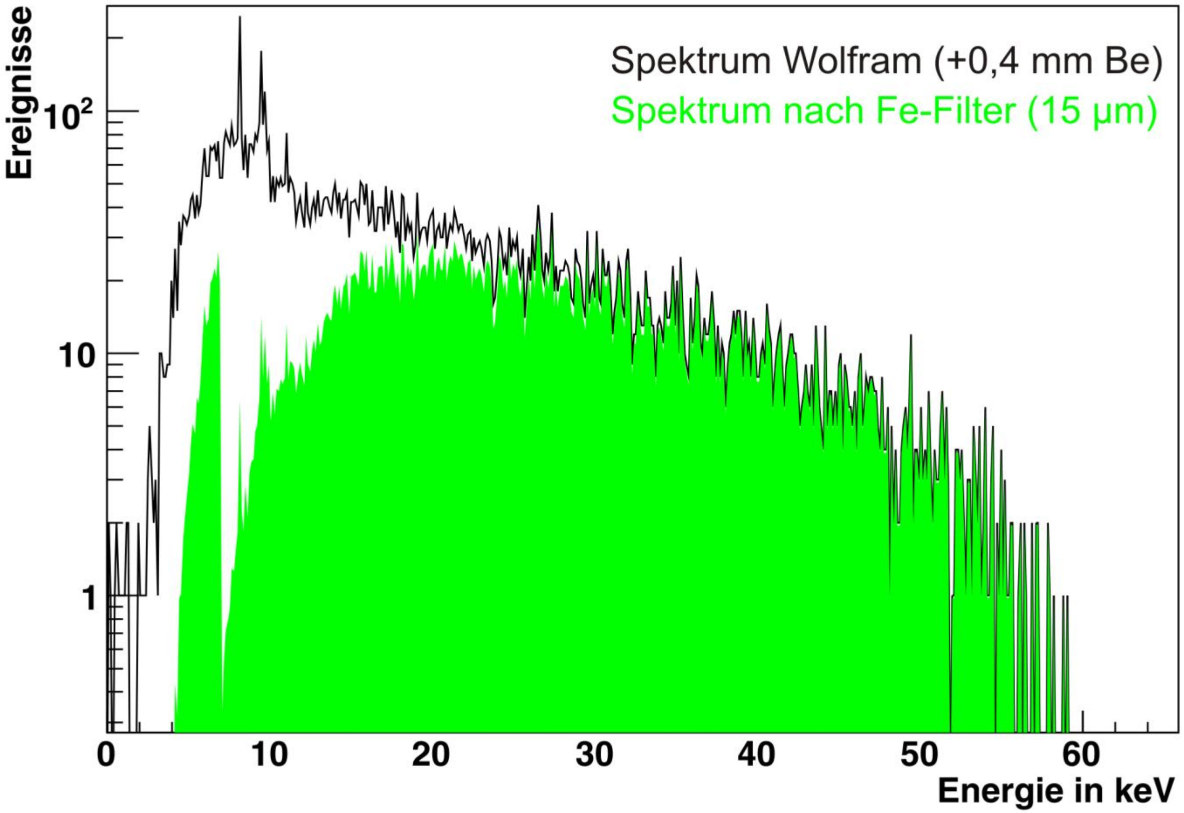
Thanks also to Oksana Brovchenko for her simulated spectrum

Backupslides

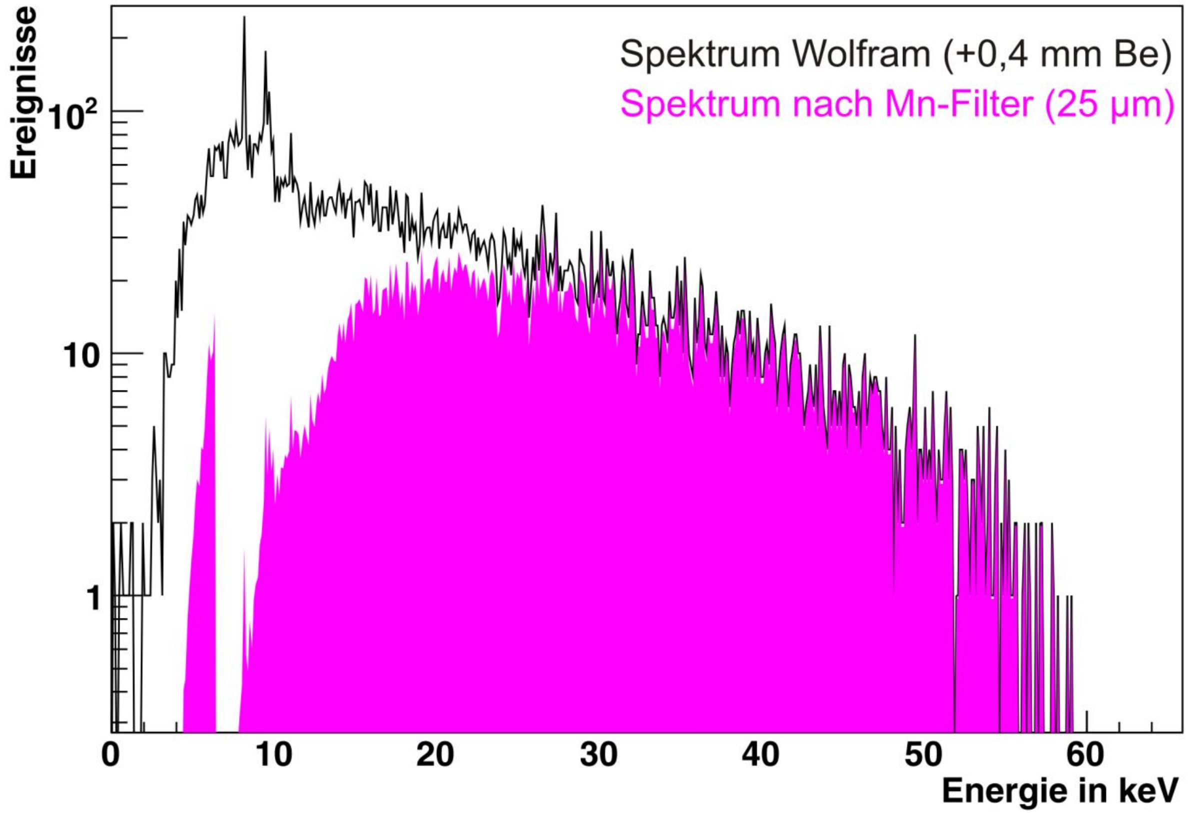
Different Filters - Vanadium



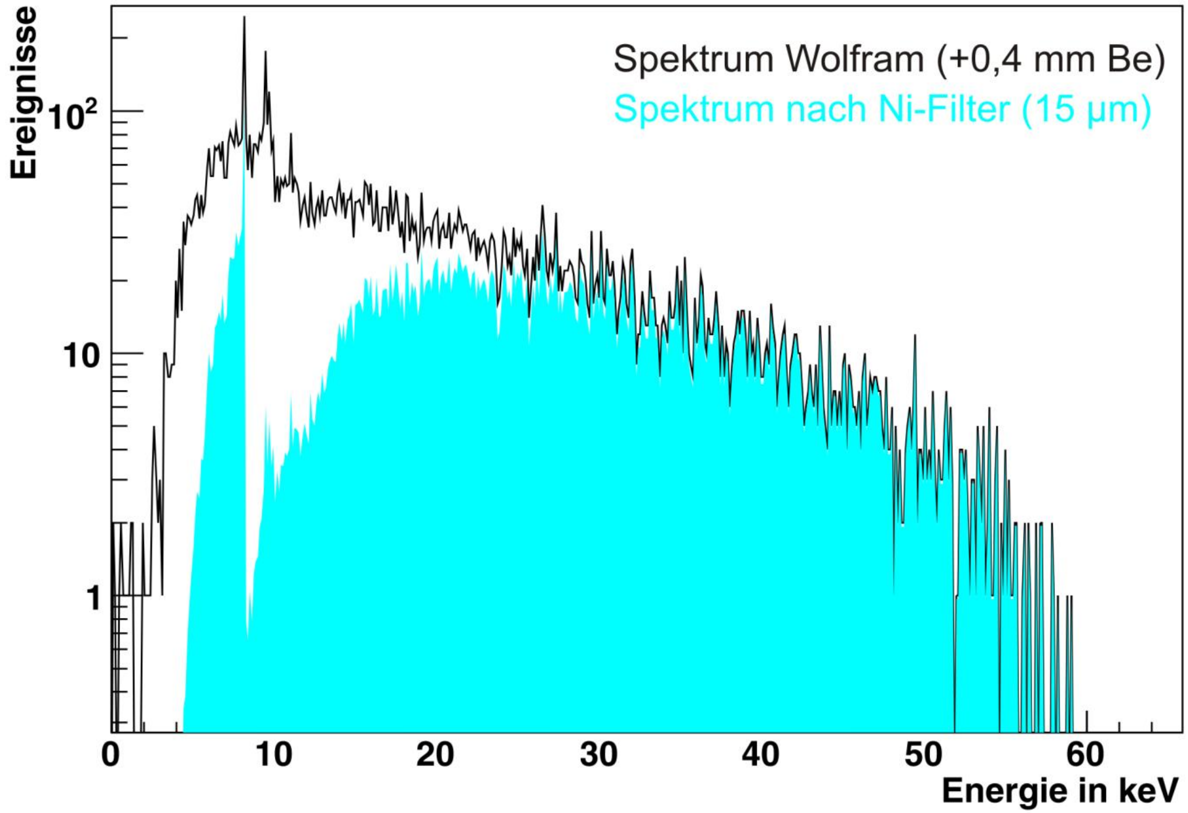
Different Filters - Iron



Different Filters - Mangan



Different Filters - Nickel



Measurement and Simulation (I)

Data Filtertyp	Signalstrom in nA	Simulation in a. u.
Zr	85,2	622,537
Ni	268,4	2579,98
Mn	242,7	2221
V	448,5	3560,17
Fe	309	2790,75

Measurement	Zr	Ni	Mn	V	Fe
Zr	100,00	315,02	284,86	526,41	362,68
Ni	31,74	100,00	90,42	167,10	115,13
Mn	35,11	110,59	100,00	184,80	127,32
V	19,00	59,84	54,11	100,00	68,90
Fe	27,57	86,86	78,54	145,15	100,00

Measurement and Simulation (II)

Simulation	Zr	Ni	Mn	V	Fe
Zr	100,00	414,43	356,77	571,88	448,29
Ni	24,13	100,00	86,09	137,99	108,17
Mn	28,03	116,16	100,00	160,30	125,65
V	17,49	72,47	62,38	100,00	78,39
Fe	22,31	92,45	79,58	127,57	100,00

Match	Zr	Ni	Mn	V	Fe
Zr	0,00	31,56	25,24	8,64	23,61
Ni	-23,99	0,00	-4,80	-17,42	-6,04
Mn	-20,16	5,04	0,00	-13,26	-1,31
V	-7,95	21,09	15,28	0,00	13,78
Fe	-19,10	6,43	1,32	-12,11	0,00