Max-Planck-Institut für Plasmaphysik, EURATOM Association

Depth distribution of deuterium implanted into beryllium

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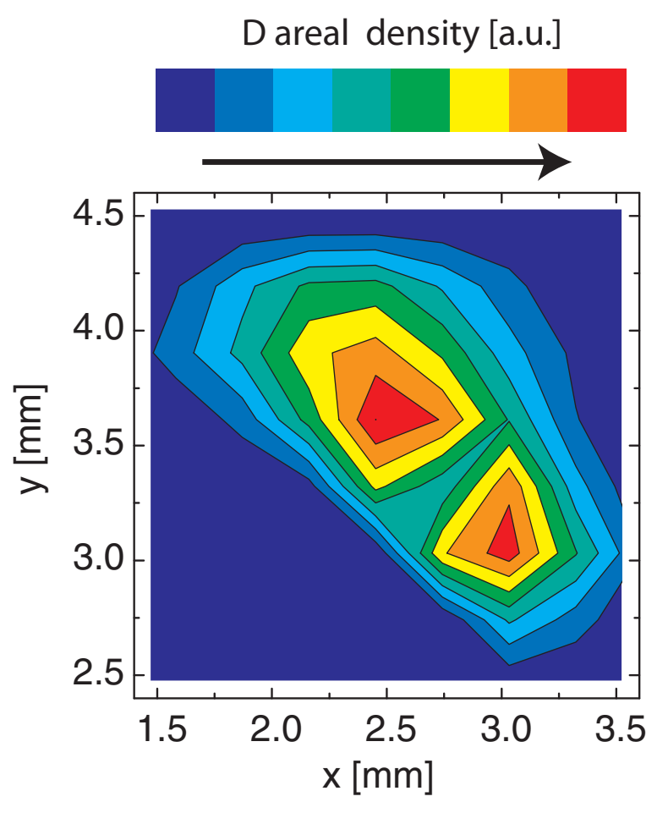
Motivation: Indications for trapping of implanted D within the ion range

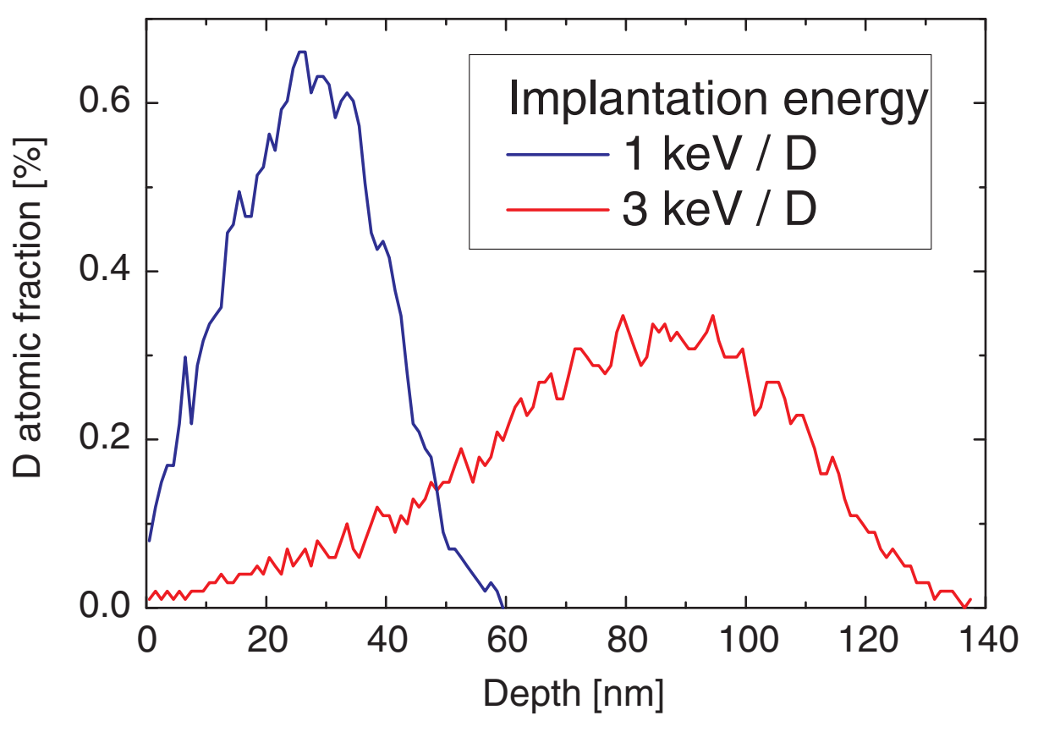
No lateral diffusion observed after implantation

Lateral implantation profile measured with NRA

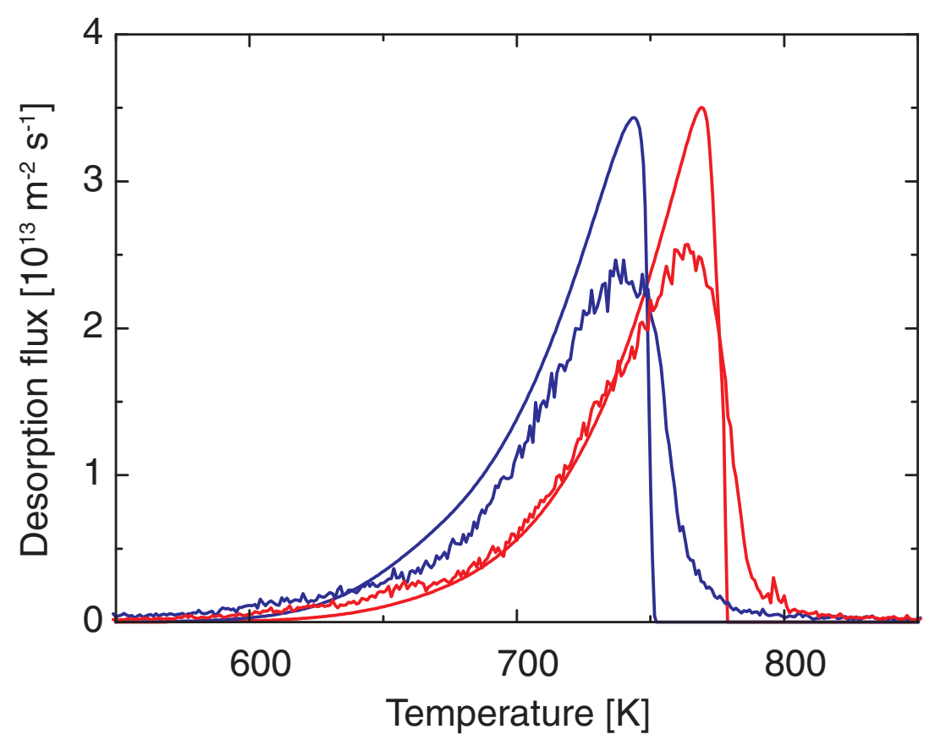


Variation of implantation energy leads to shift in desorption temperatures

Depth profiles at a fluence of 10^{15} cm^{-2} calculated with SDTrim.SP

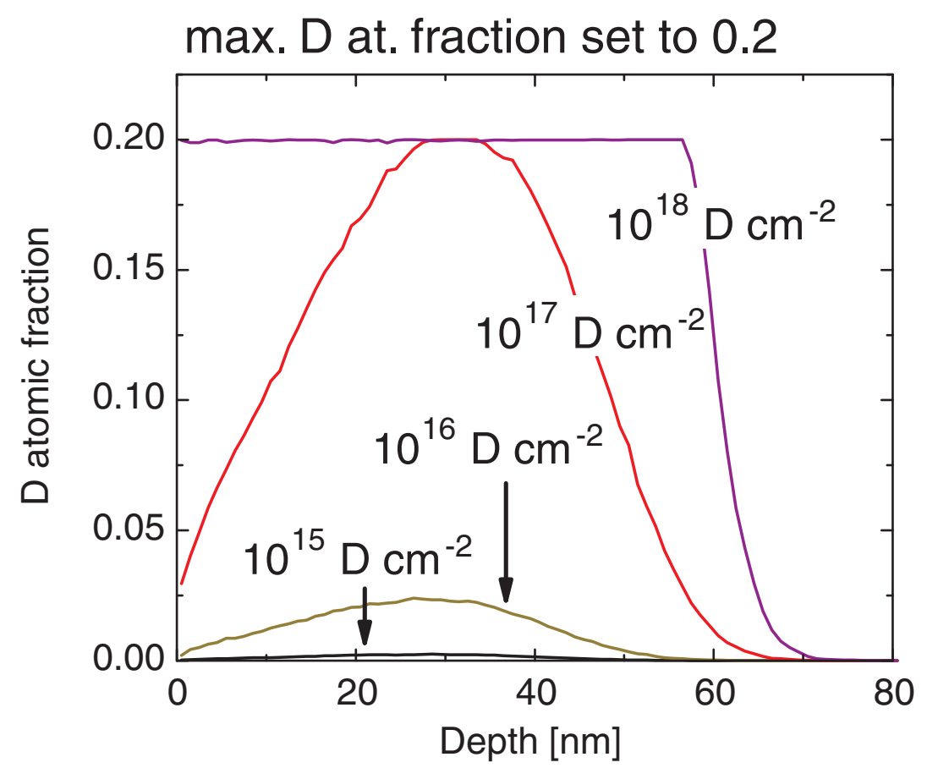


Experimental desorption behaviour reproduced in simulations with CRDS [1]

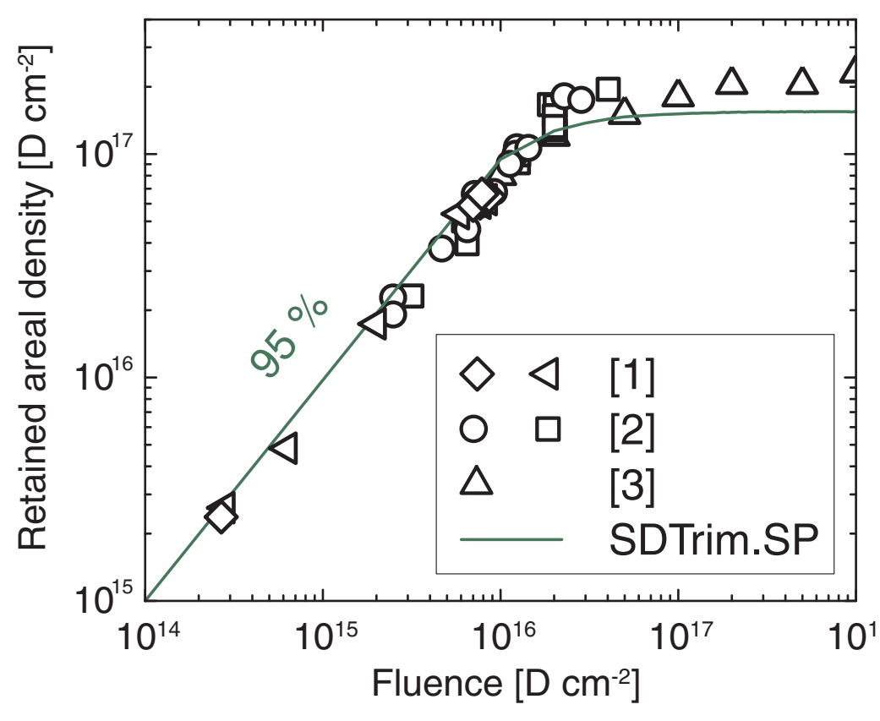


Implantation at high fluences leads to saturation of the retained amount

Depth profiles at 1 keV / D calculated with SDTrim.SP

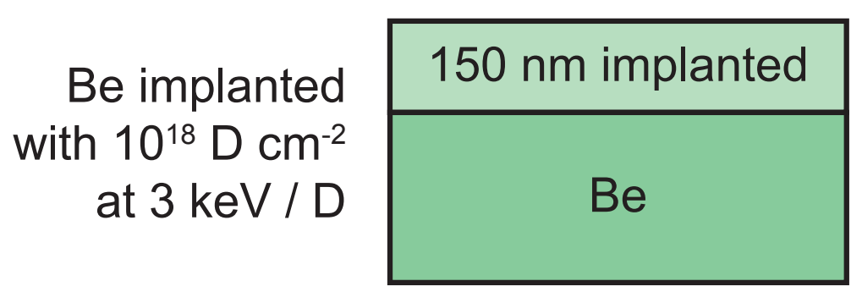


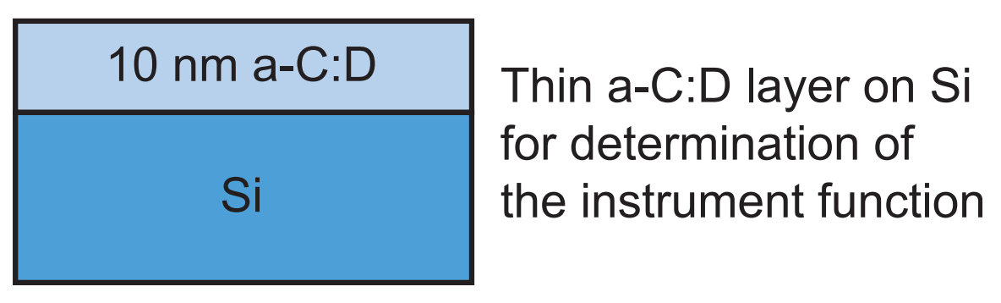
Experimental saturation behaviour reproduced in simulations with SDTrim.SP

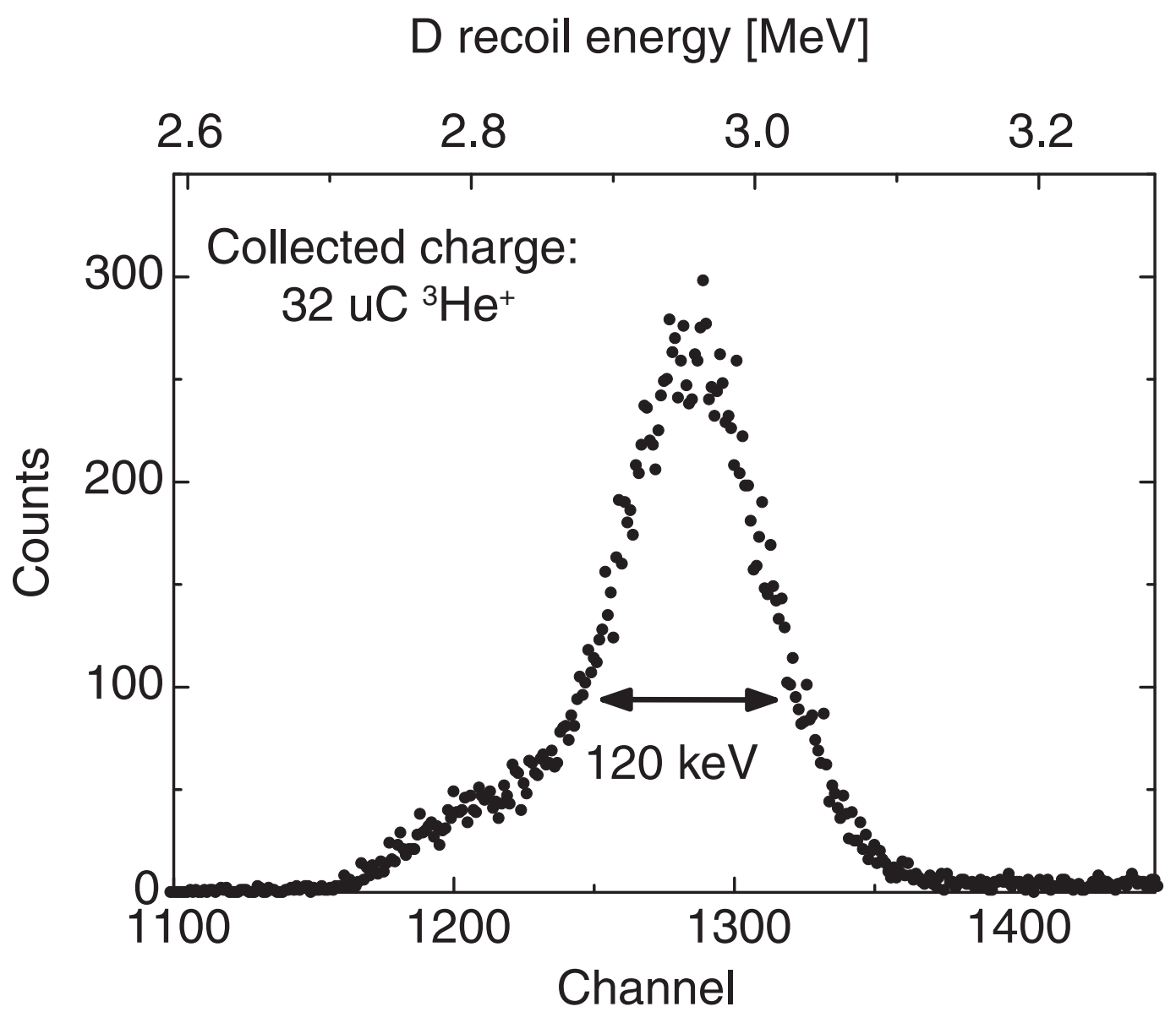


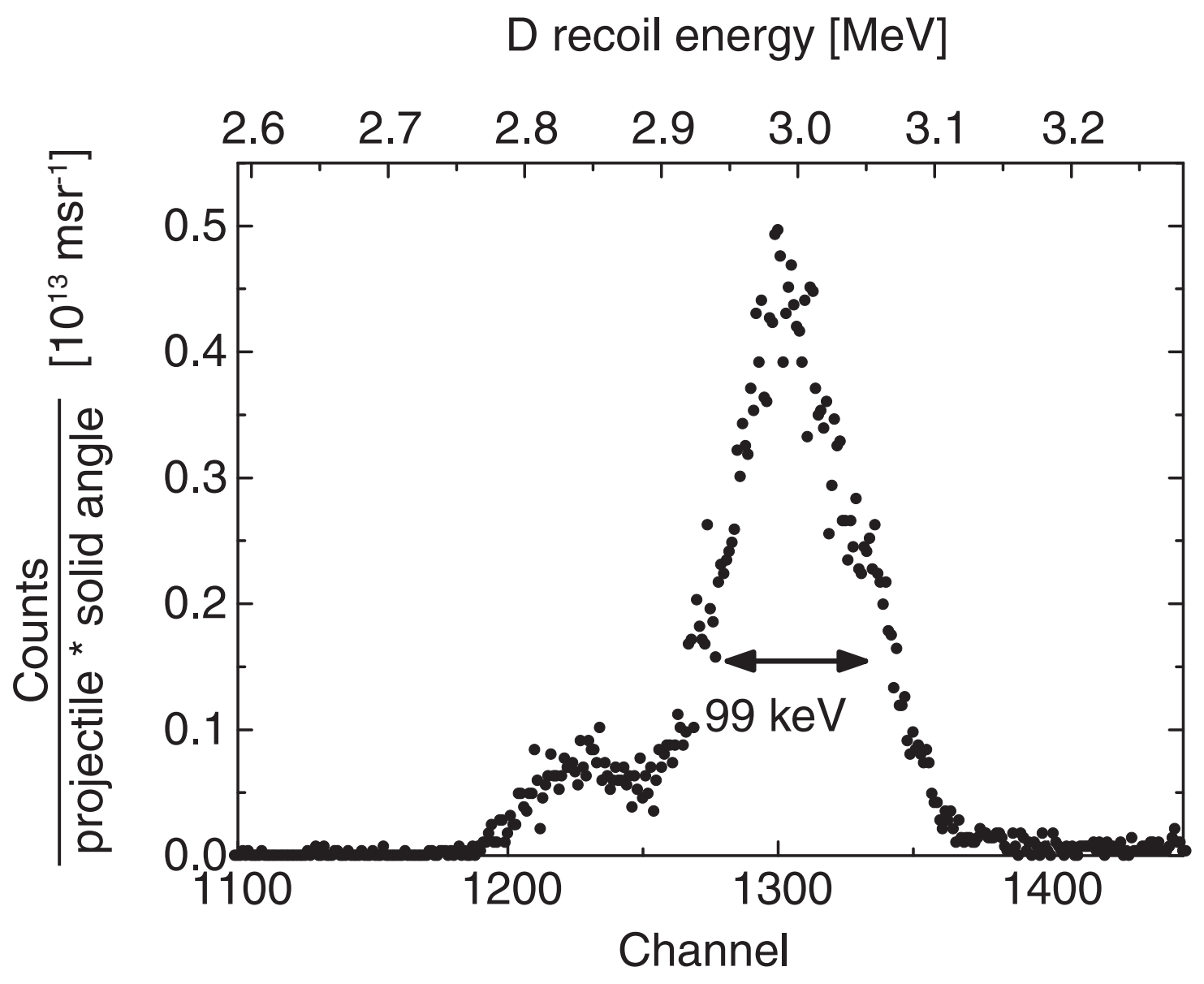
Direct assessment of D depth profiles by means of ion beam analysis

Nuclear reaction analysis: D(^{3}He,α)p





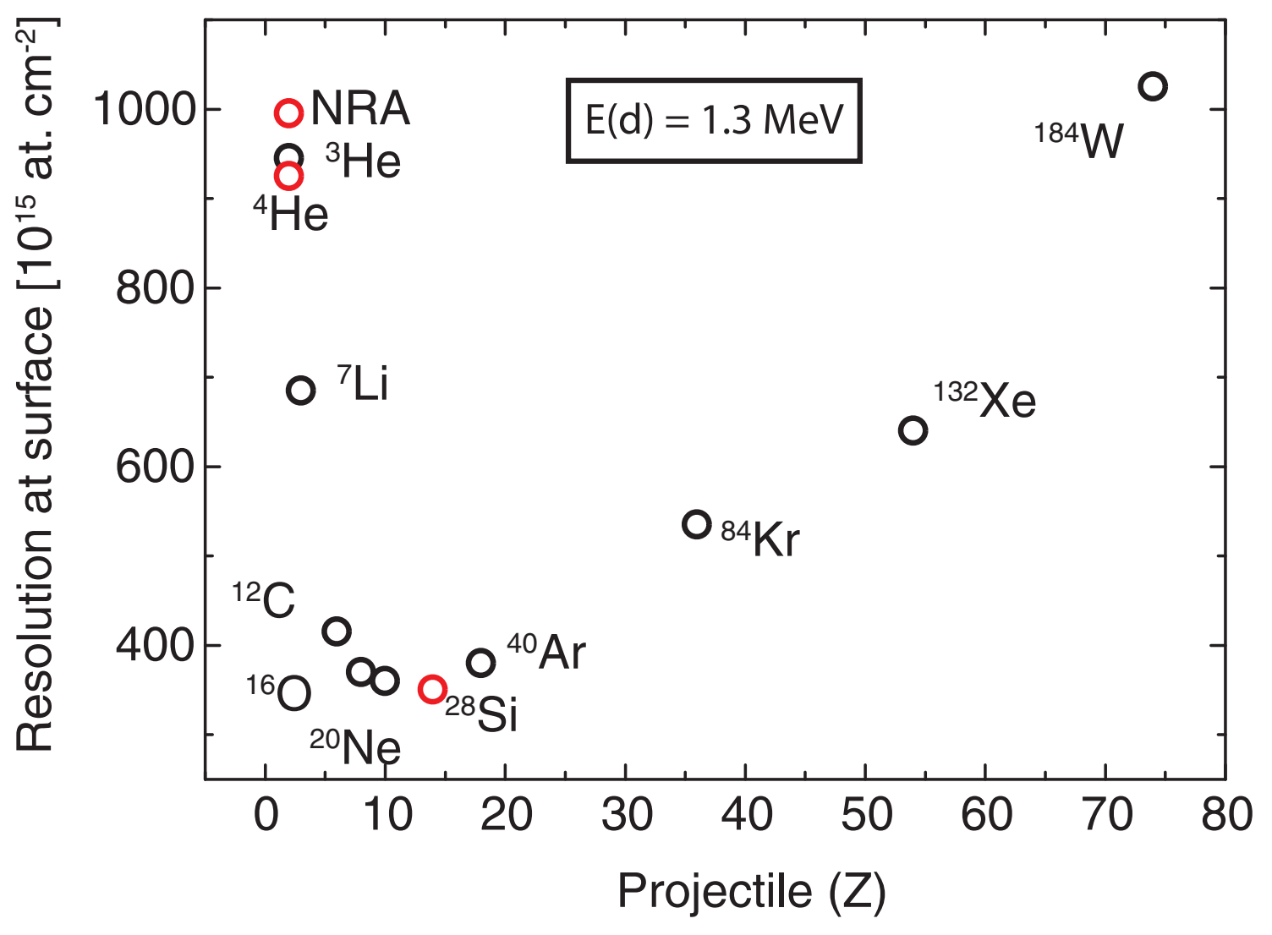




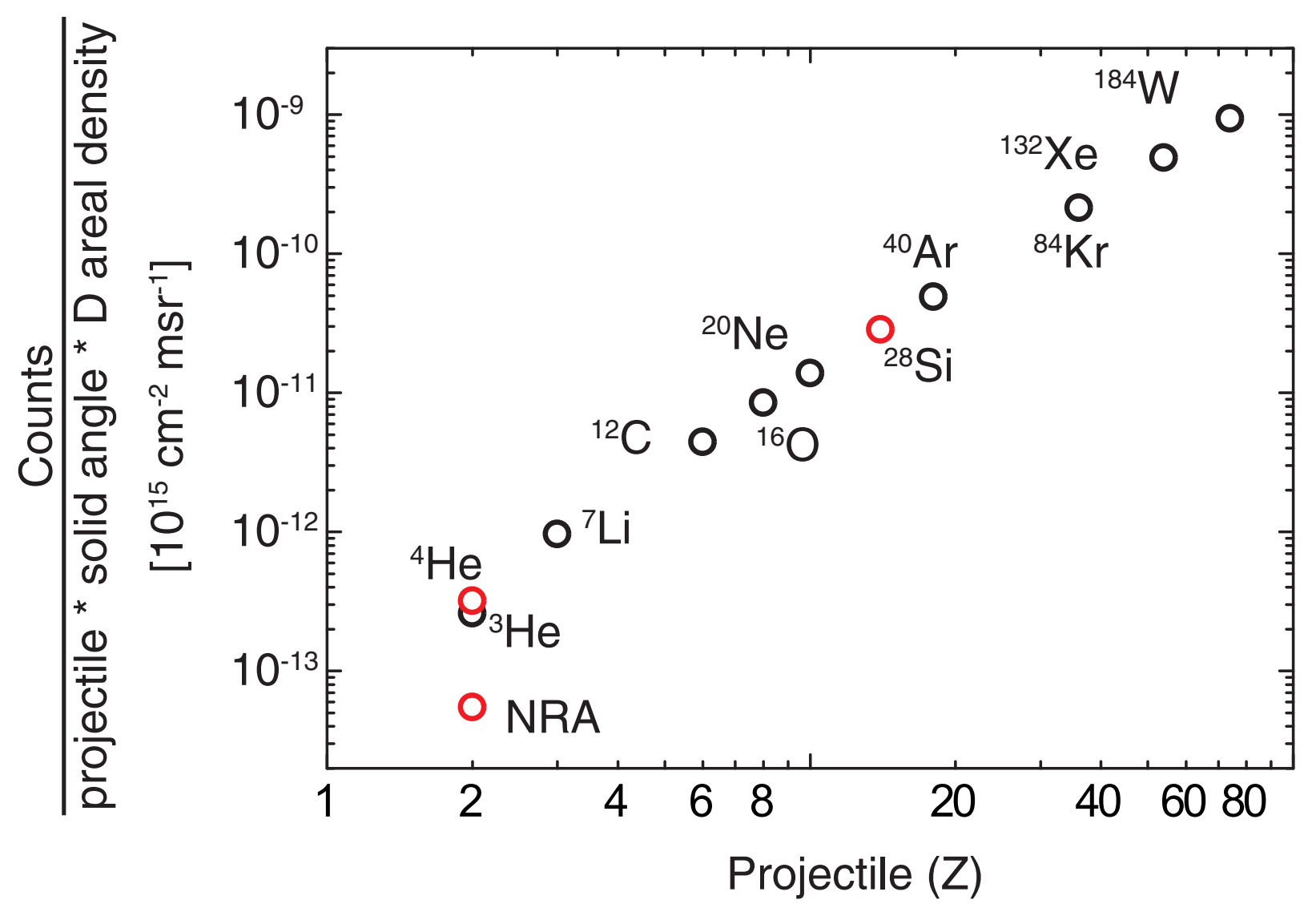
- The narrow energy distribution of the detected α particles indicates that D resides in a shallow surface layer
- The signal from a thin a-C:D layer represents the apparatus function for the measurement
- The width of the spectrum from D-implanted Be is dominated by the apparatus function
- The D depth distribution cannot be resolved with NRA

Experiment design with RESOLNRA [4]: elastic recoil detection analysis with various projectiles

Resolution



Sensitivity

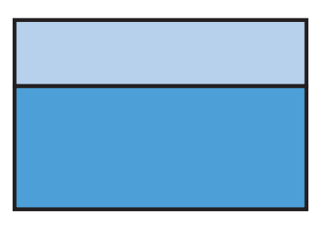


- Better depth resolution can be obtained with ERDA compared to NRA
- The resolution goes through a minimum as a function of atomic number of the projectile
- Drawback: Heavier projectiles induce more damage in the analyzed sample
- But: The sensitivity is higher than for NRA and increases with atomic number of the projectile

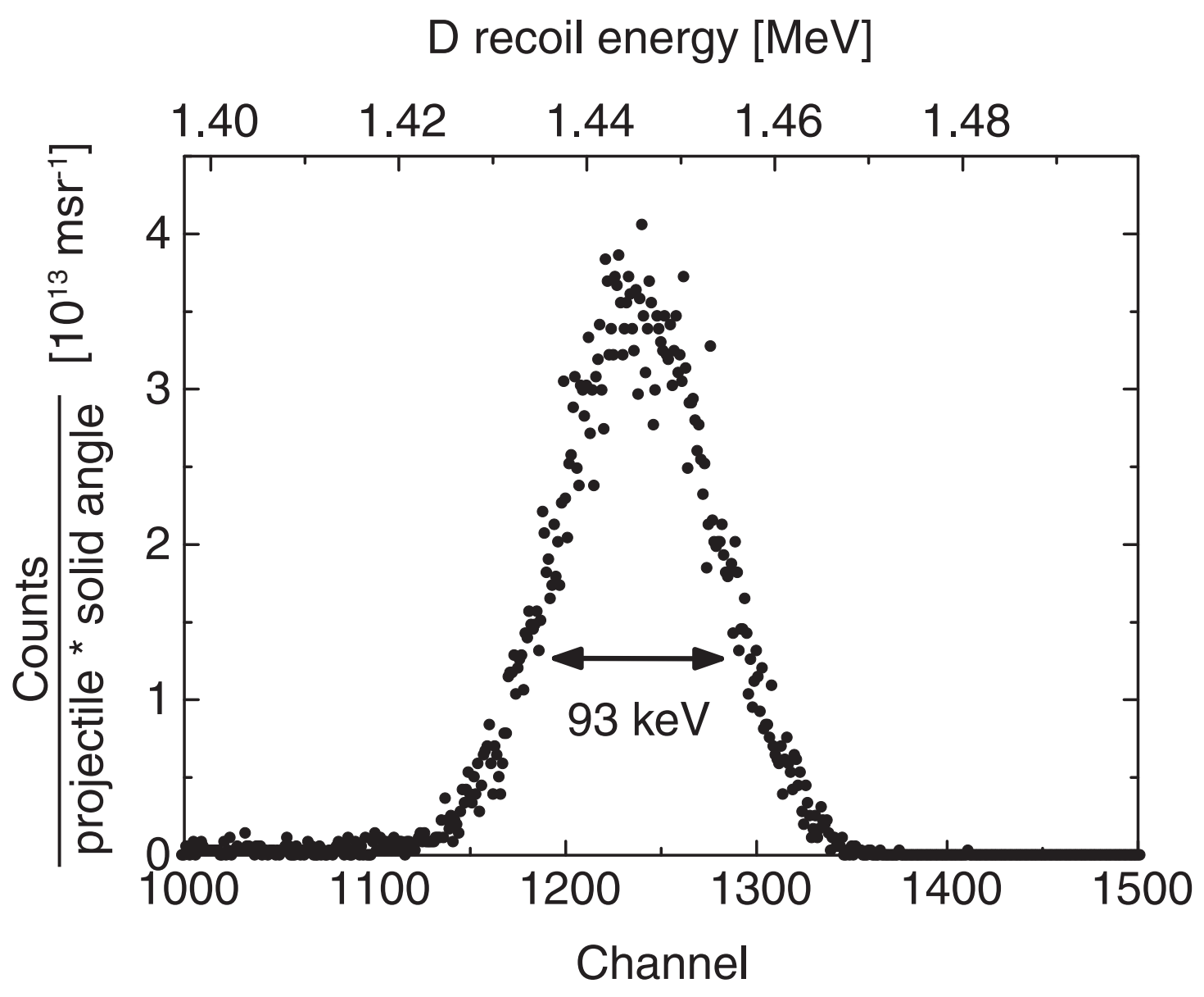
ERDA with ^{4}He and ^{28}Si

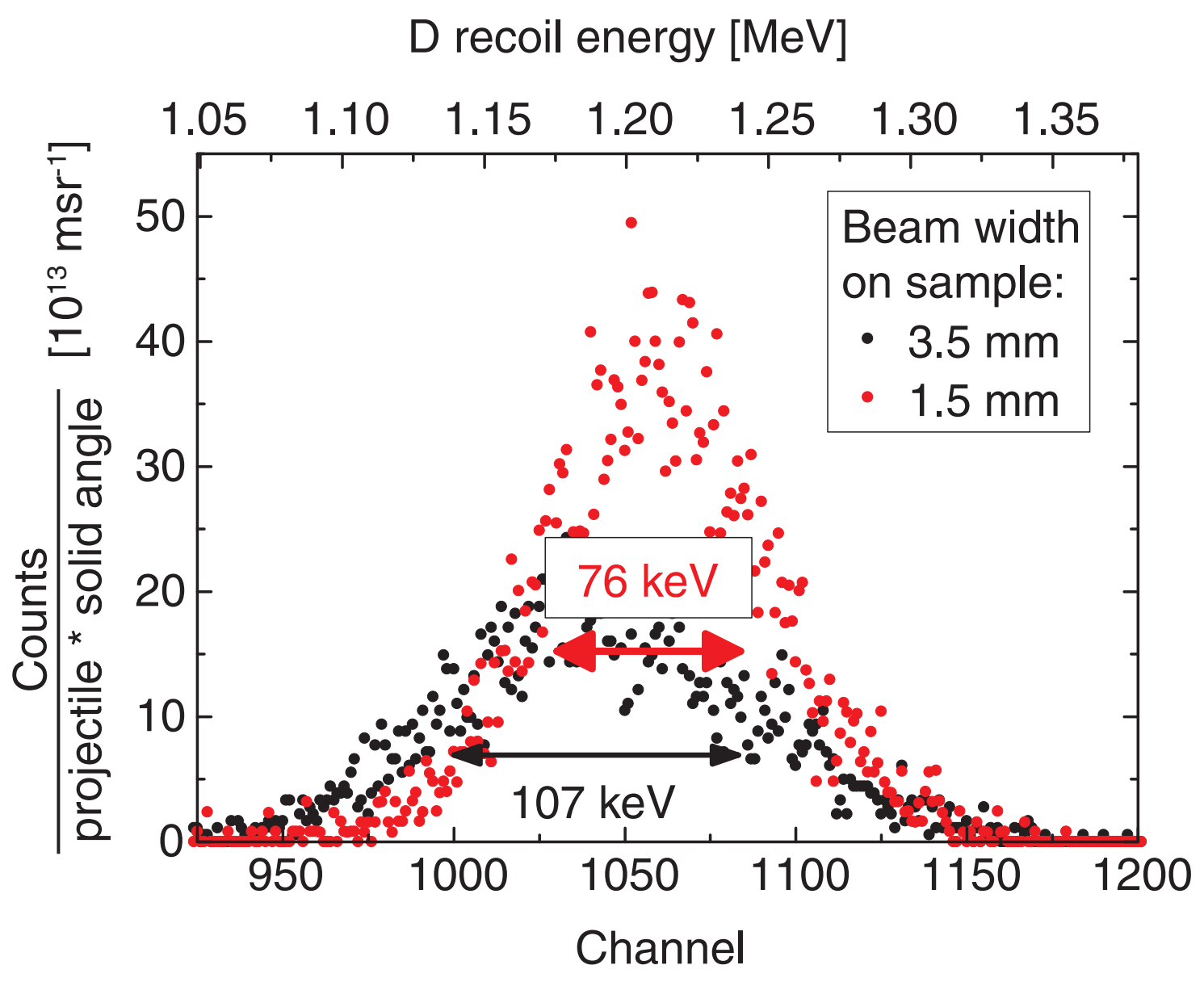
Experimental energy resolution and sensitivity

3 MeV ^{4}He



10 MeV ^{28}Si



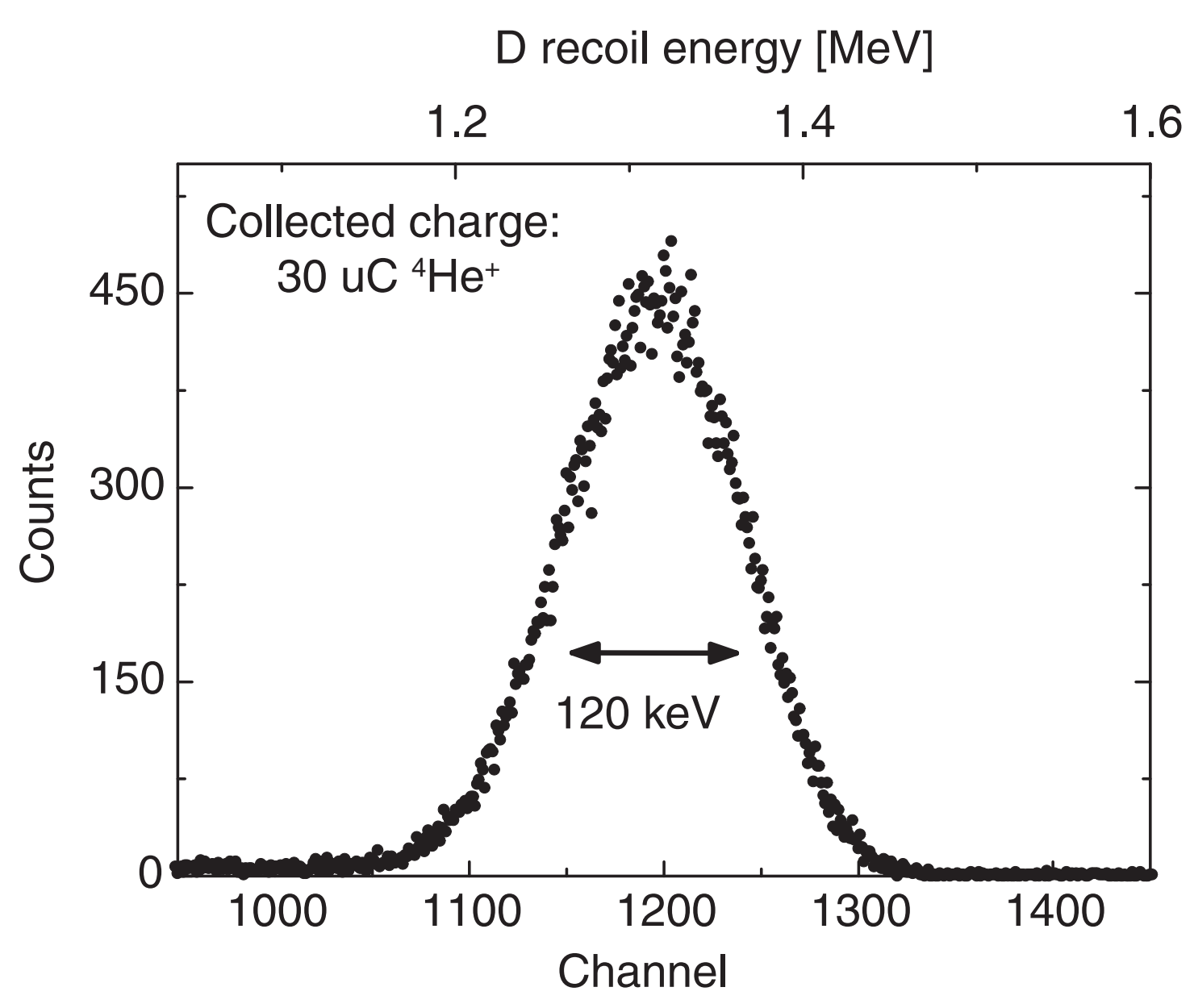


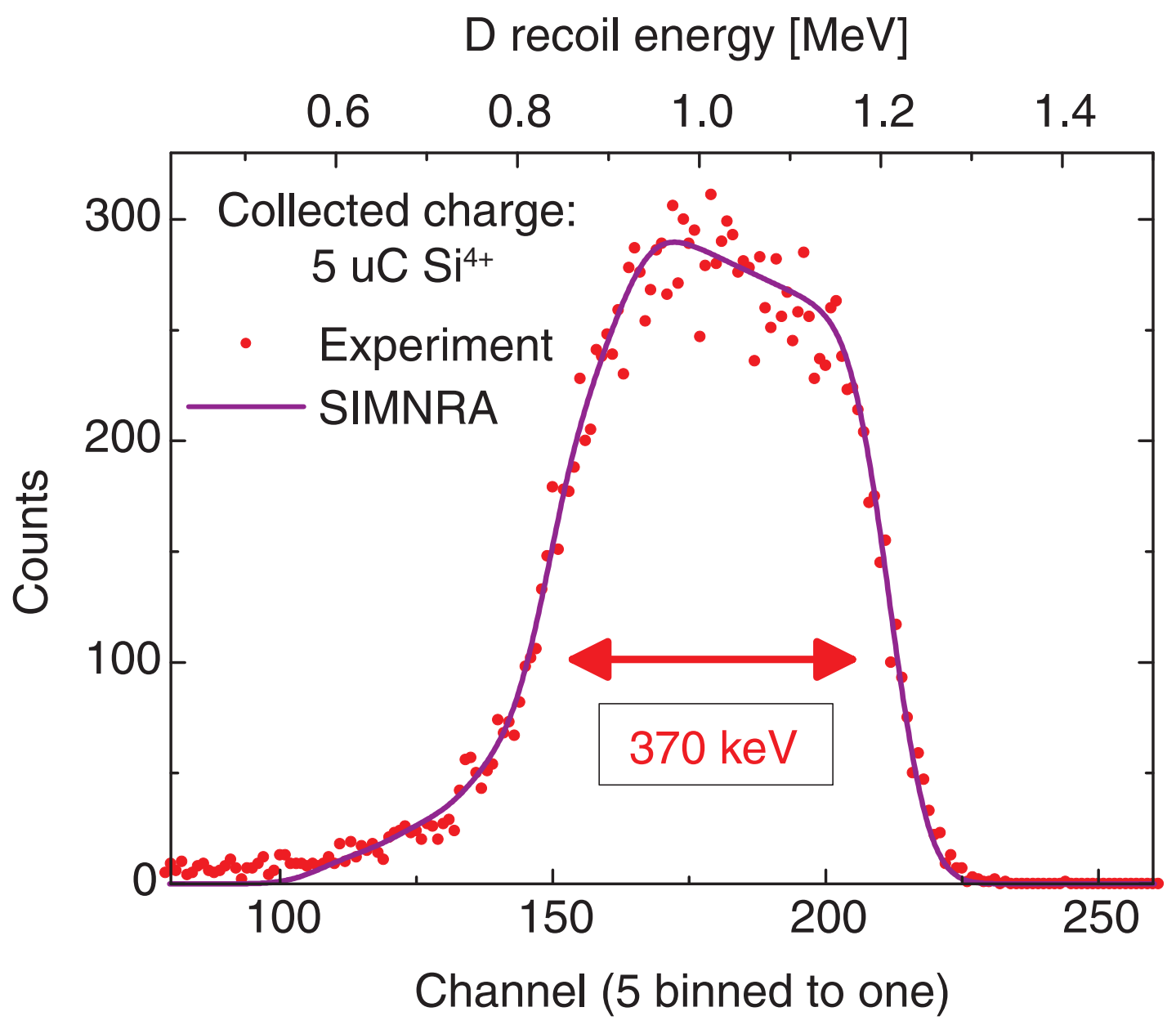
- ERDA with ^{4}He provides comparable energy resolution and greater sensitivity compared to NRA
- ERDA with ^{28}Si provides considerable improvements in energy resolution and sensitivity
- The energy resolution in ERDA is strongly affected by geometrical straggling
- A narrow analyzing spot is therefore crucial for good depth resolution

Depth profile assessment in D-implanted Be

3 MeV ^{4}He

10 MeV ^{28}Si





- The width of the ^{4}He-ERDA spectrum is dominated by the apparatus function (as for NRA)
- In the ^{28}Si-ERDA spectrum a plateau becomes apparent indicating a constant D concentration
- With Si the energy range of the detected D atoms is several times the width of the apparatus function
- With Si the depth distribution can be resolved and fitted with SIMNRA

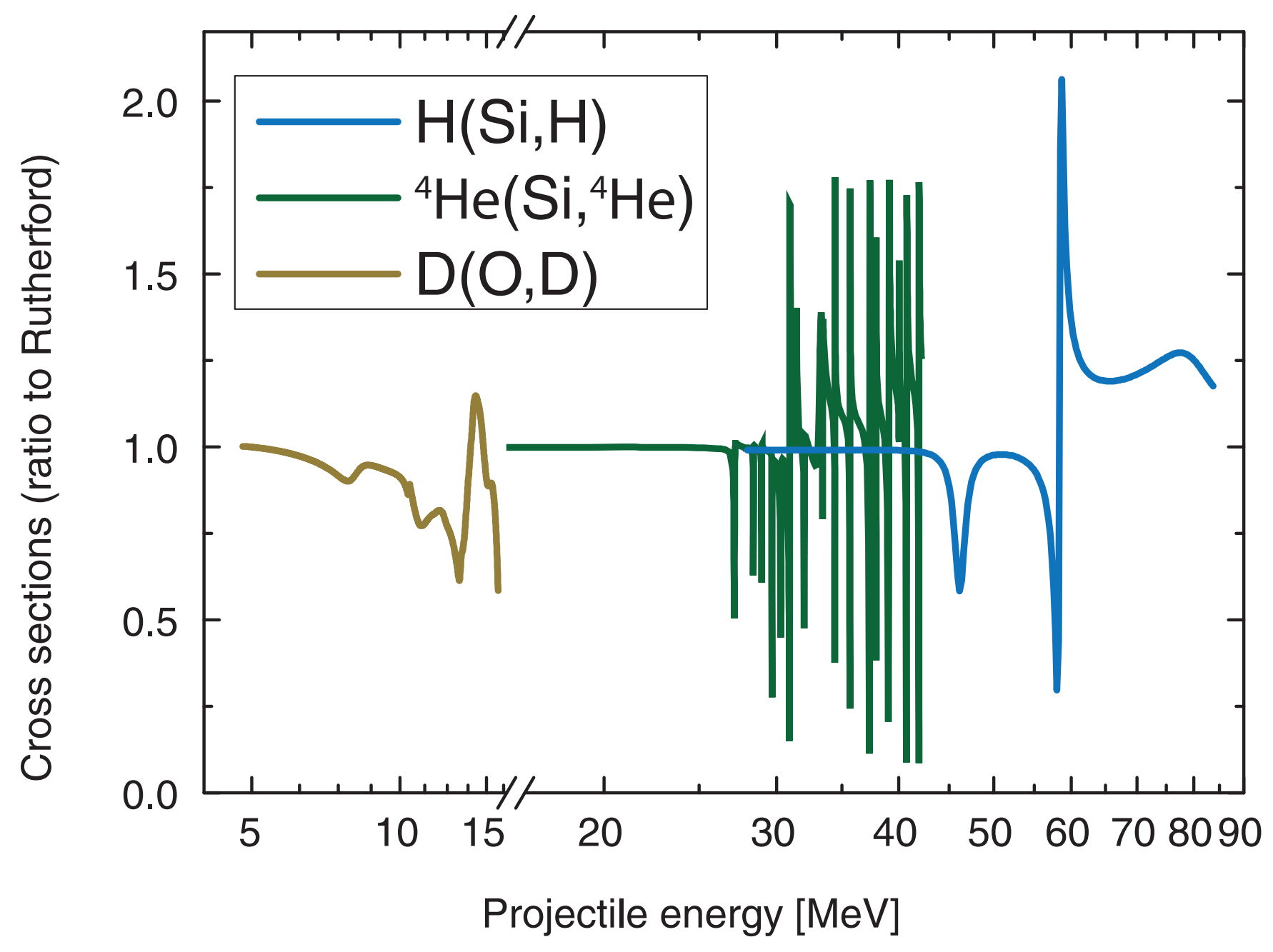
Deviation of ERDA cross sections from the Rutherford values

Deviation > 4% [5]:

$$E_{proj} > \frac{m_{proj}+m_{tar}}{m_{tar}} \frac{Z_{proj} Z_{tar}}{8}$$

Scattering process	E_{dev} [MeV]
D(O,D)	9.00
^{4}He(Si,^{4}He)	28.00
H(Si,H)	50.75
D(^{4}He,D)	0.75
D(Si,D)	26.25

ERDA cross sections from inversion of RBS cross sections calculated with SigmaCalc [6] in the inverse geometry



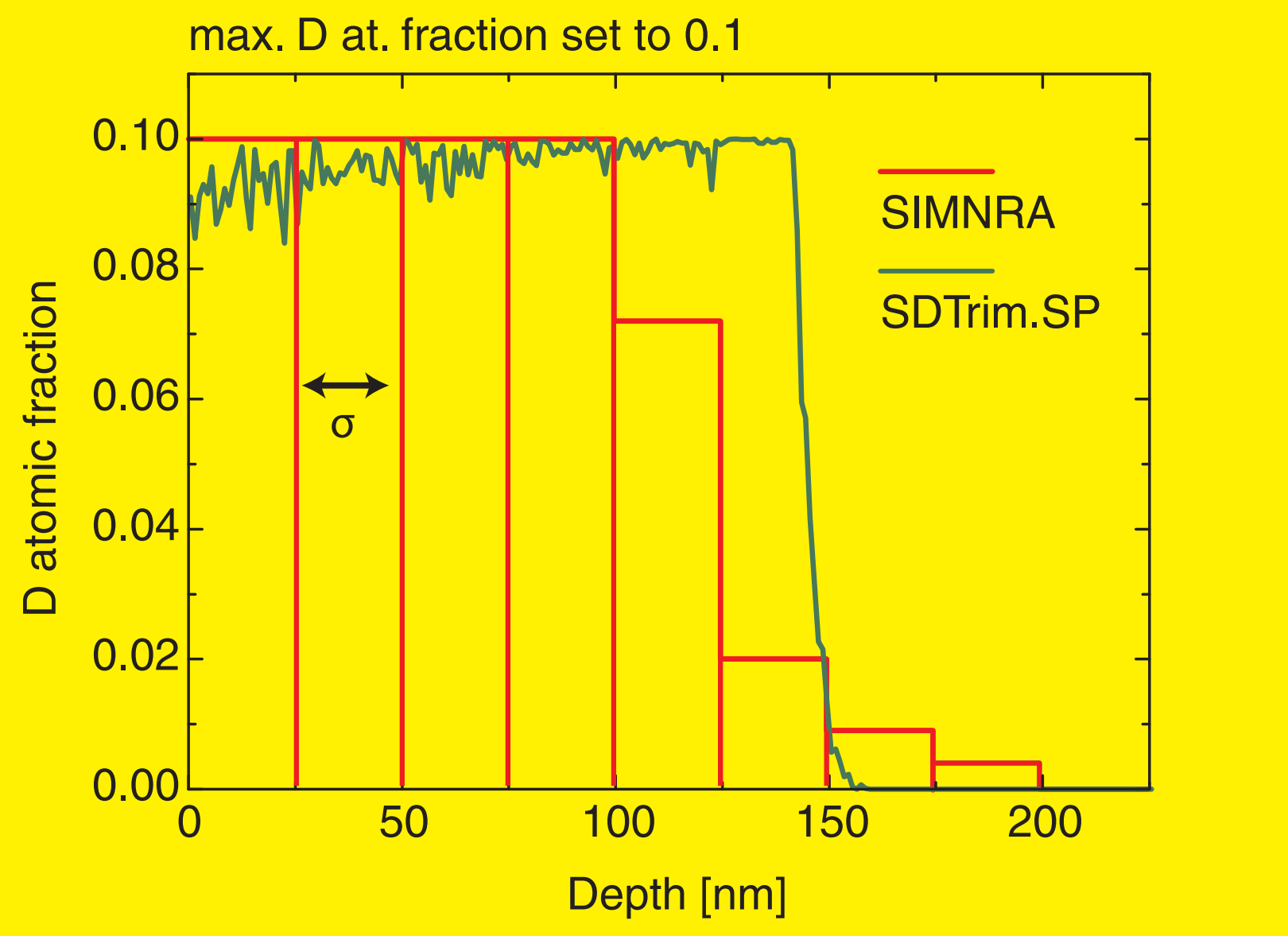
- The energy limits according to [4] are in reasonable agreement with experiments
- The Rutherford cross section can be used for D(Si,D)-ERDA with 10 MeV Si ions

Resolution for D in Be (close to the surface) achieved with various IBA methods

Analysis method	Energy resolution (2 σ)	Depth resolution (2 σ)
NRA	99 keV	140 nm
4He-ERDA	93 keV	116 nm
Si-ERDA	76 keV	47 nm

- Considerable enhancement of depht resolution (and sensitivity) is achieved with Si-ERDA

D depth profile from the SIMNRA-fit to the Si-ERDA spectrum and corresponding calculation with SDTrim.SP



- The D atomic fraction saturates within the ion range
- The maximum D atomic fraction built up by implantation is 0.1

[1] M. Oberkofler et al., Nucl. Instrum. Meth. B (2011) doi: 10.1016/j.nimb.2010.11.058
[2] M. Reinelt et al., New J. Phys. 11(4) (2009) 043023
[3] A.A. Haasz et al., J. Nucl. Mater. 241-243 (1997) 1076
[4] M. Mayer, Nucl. Instrum. Meth. B 266(8) (2008) 1852
[5] M. Bozoian, Nucl. Instr. Meth. B 82 (1993) 602
[6] http://www-nds.iaea.org/sigmacalc/