SESANS in Delft: dedicated, solid, flexible

Contents of this lecture

- **Components and setup Delft SESANS**
- Some extreme measurements
- SEMSANS
- Dissemination of SESANS technique

History Delft SESANS

1995 Theo Rekveldt concept to build on depolarimeter

1999 Funding to build dedicated instrument
Promised spin-echo length 1 μm
Tests $\pi/2$ and π foil flippers

2002 Present dedicated instrument ready
Spin-echo length 20 μm

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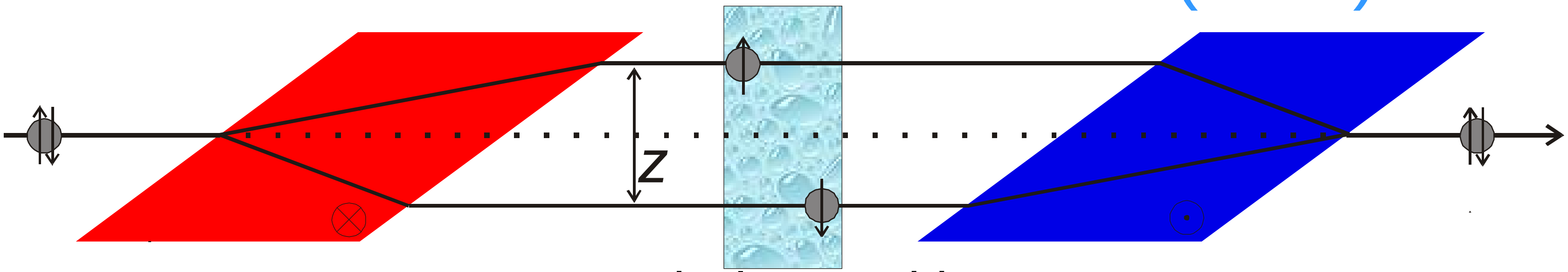
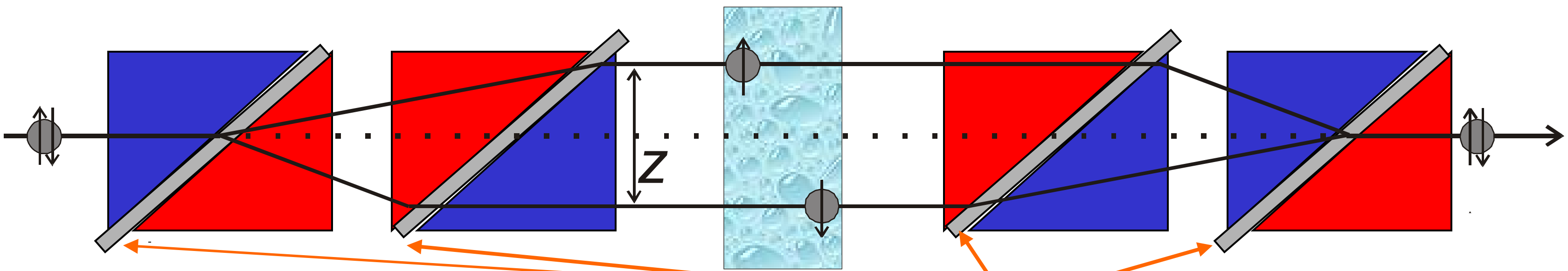
Practical realisation of SESANS (2002)



equivalent to this:



Use rectangular magnetic fields with magnetised foil
as spin flipper to “reverse” the precession field

Rekveldt et al. (2005)
Rev. Sci. Inst. **76**

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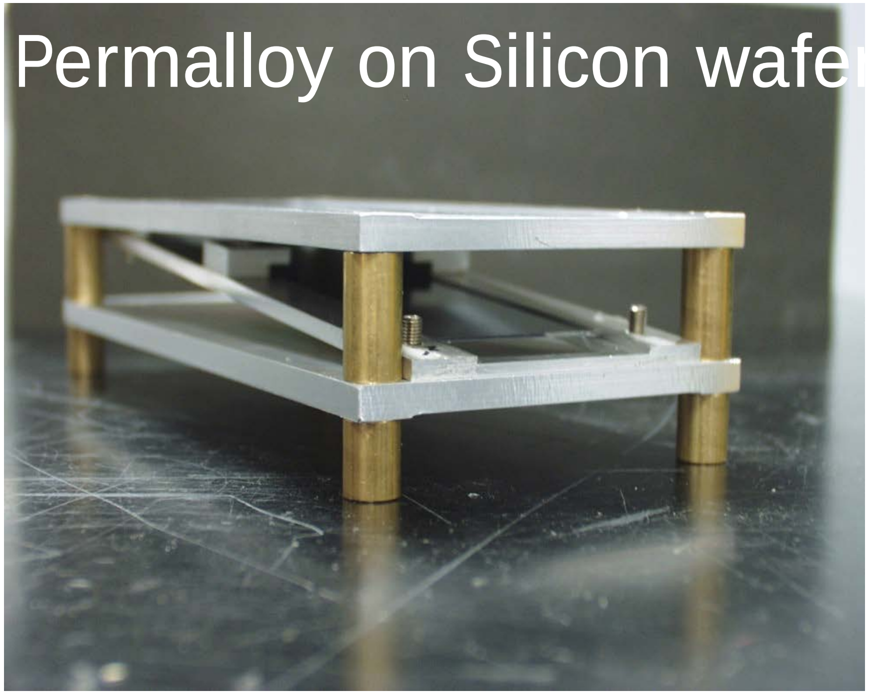
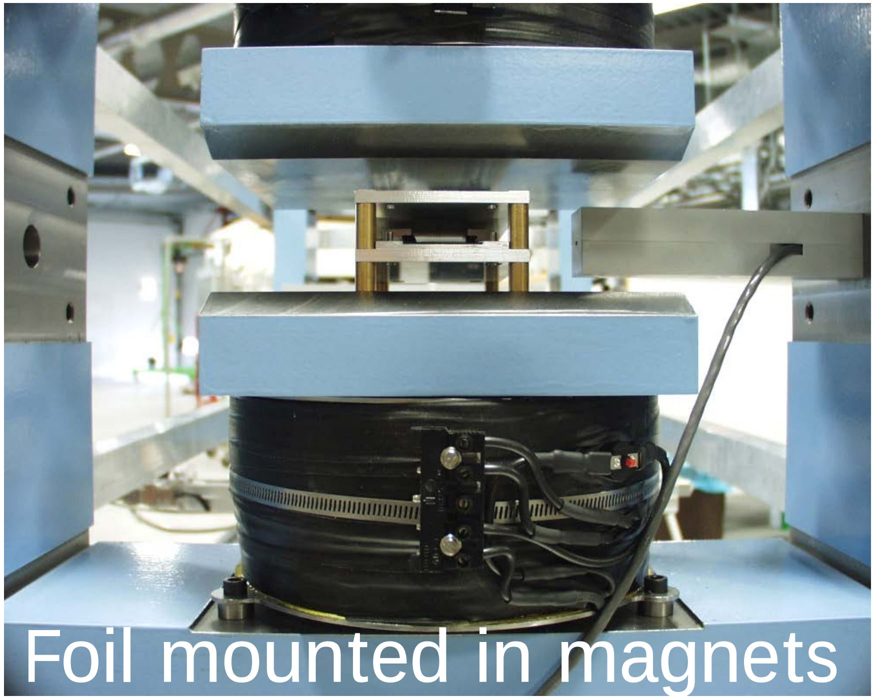
Magnetised foils
strong labelling effect and well defined interface

3 μm permalloy film





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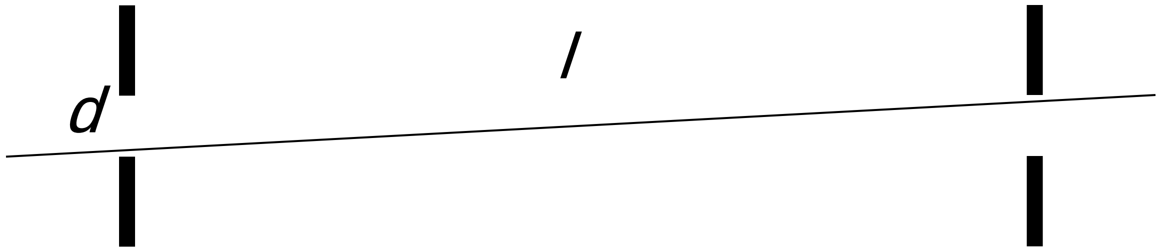
Why is Delft SESANS resolution higher than SANS?

SANS

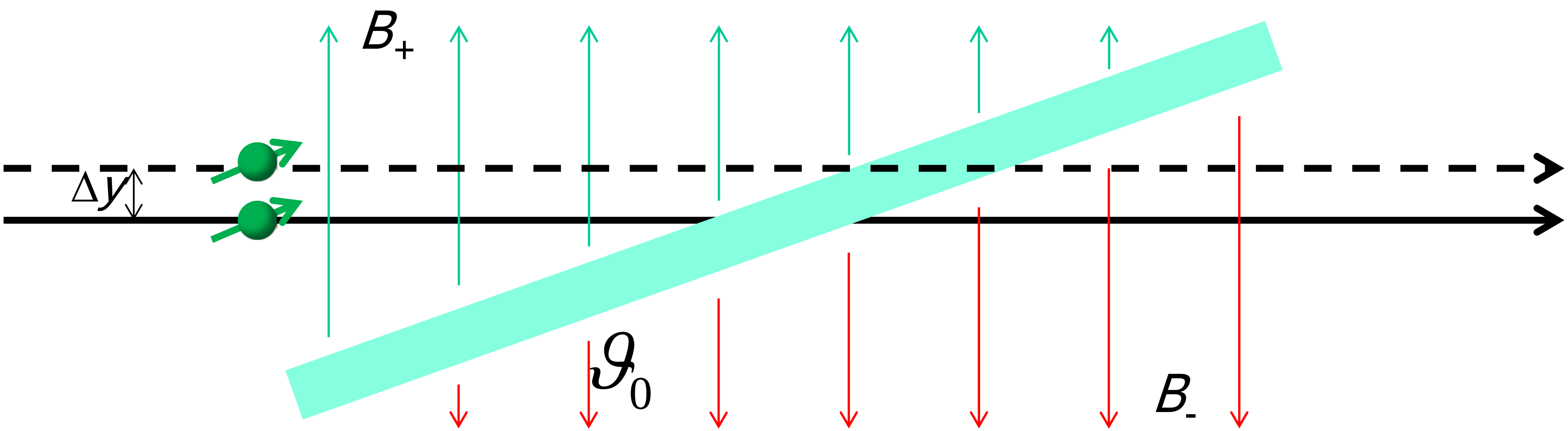


$$\delta\theta = d / l \quad = 10\text{mm}/10\text{m} = 1\text{mrad}$$

$$\varphi = cL\lambda B \qquad c = \frac{\gamma m}{h} \qquad \Delta\varphi = c\Delta y\cot(\vartheta_0)\lambda\Delta B$$

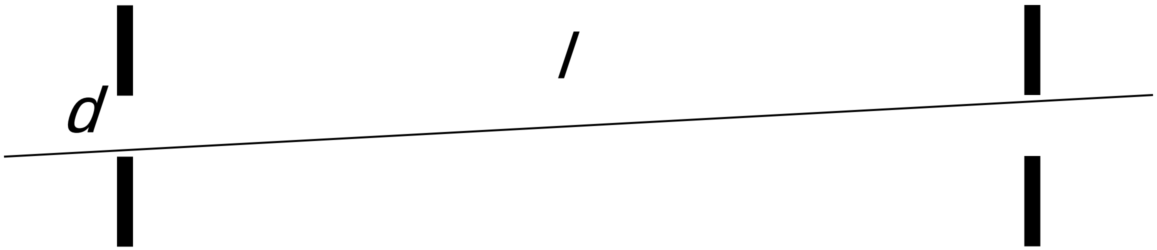
$$\Delta y = \frac{\Delta\varphi}{c\cot(\vartheta_0)\lambda 2B} = \frac{1}{(5\times10^{14}\,\mathrm{T}^{-1}\mathrm{m}^{-2})(10)(2\times10^{-10}\,\mathrm{m})(2\times0.2\,\mathrm{T})} \approx 3\mu\mathrm{m}$$

Effective slit width of foil flipper?



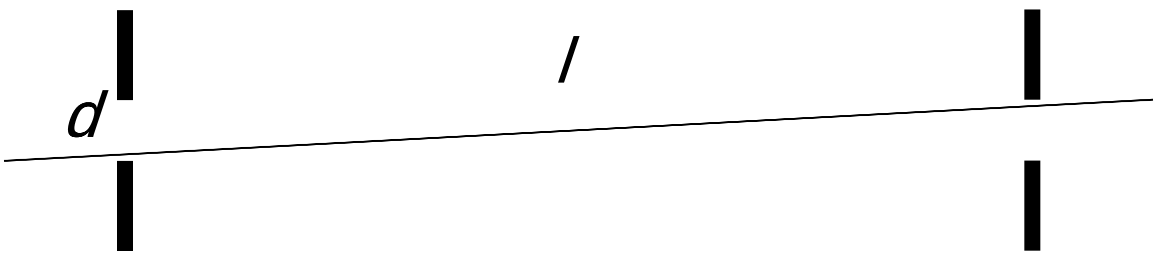
Why is Delft SESANS resolution higher than SANS?

SANS



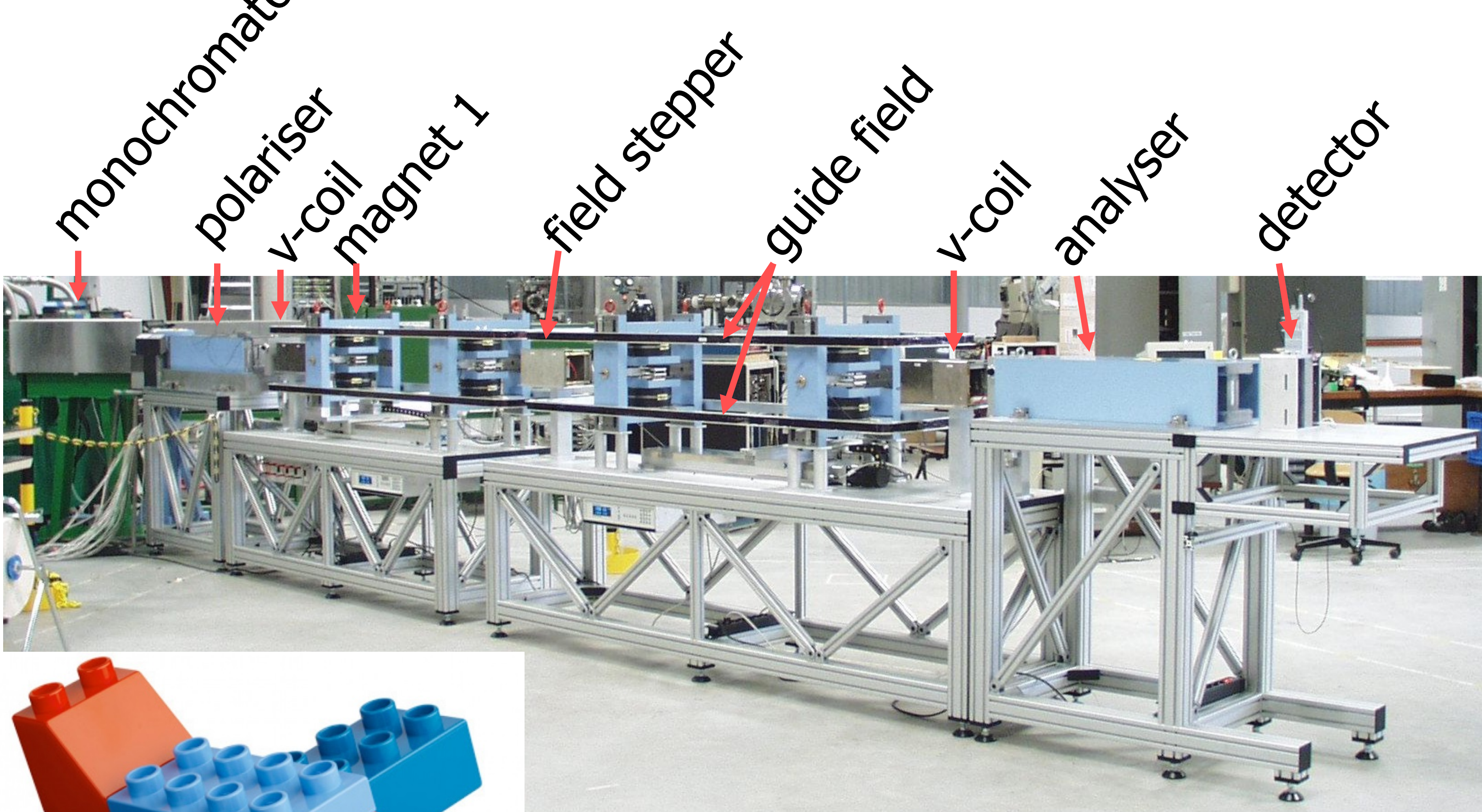
$$\delta\theta = d / l \quad = 10\mathrm{mm}/10\mathrm{m} = 1\mathrm{mrad}$$

SESANS



$$\delta\theta = d / l \quad = 3\mu\mathrm{m}/1\mathrm{m} = 3\mu\mathrm{rad}$$

Realisation SESANS



Technical details

- Graphite monochromator λ=0.21 nm, $\Delta\lambda/\lambda$=0.01 or 0.05
- Stacked bent supermirrors
- Controlled electromagnets 0.3 mT-0.18 T
- Beam cross section 18 mm x 8 mm
- 1000 or 5000 neutrons/s
- Spin-echo length 30 nm – 20 μm

Rekveldt et al. Rev. sci. Inst. **76** 033901 (2005)

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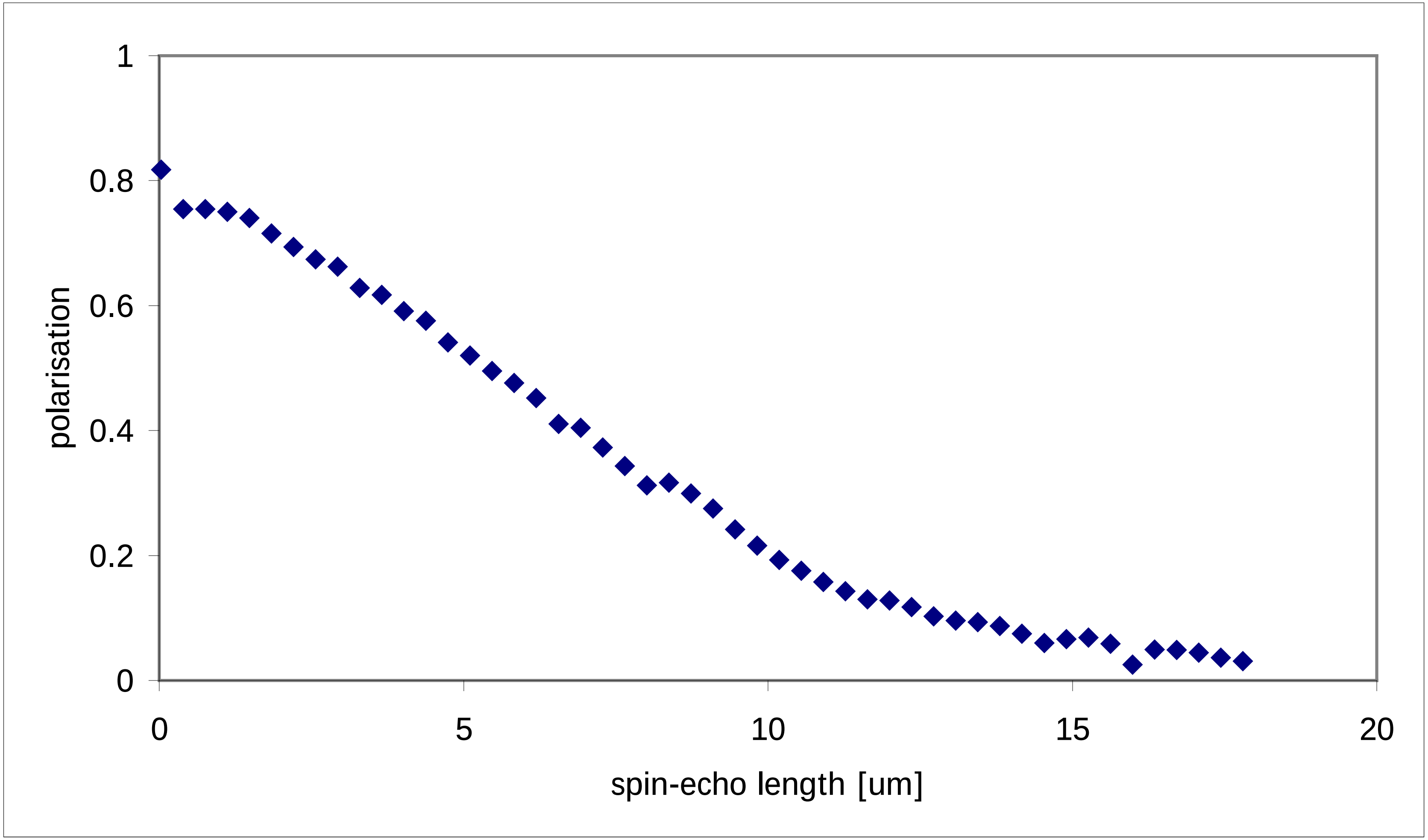
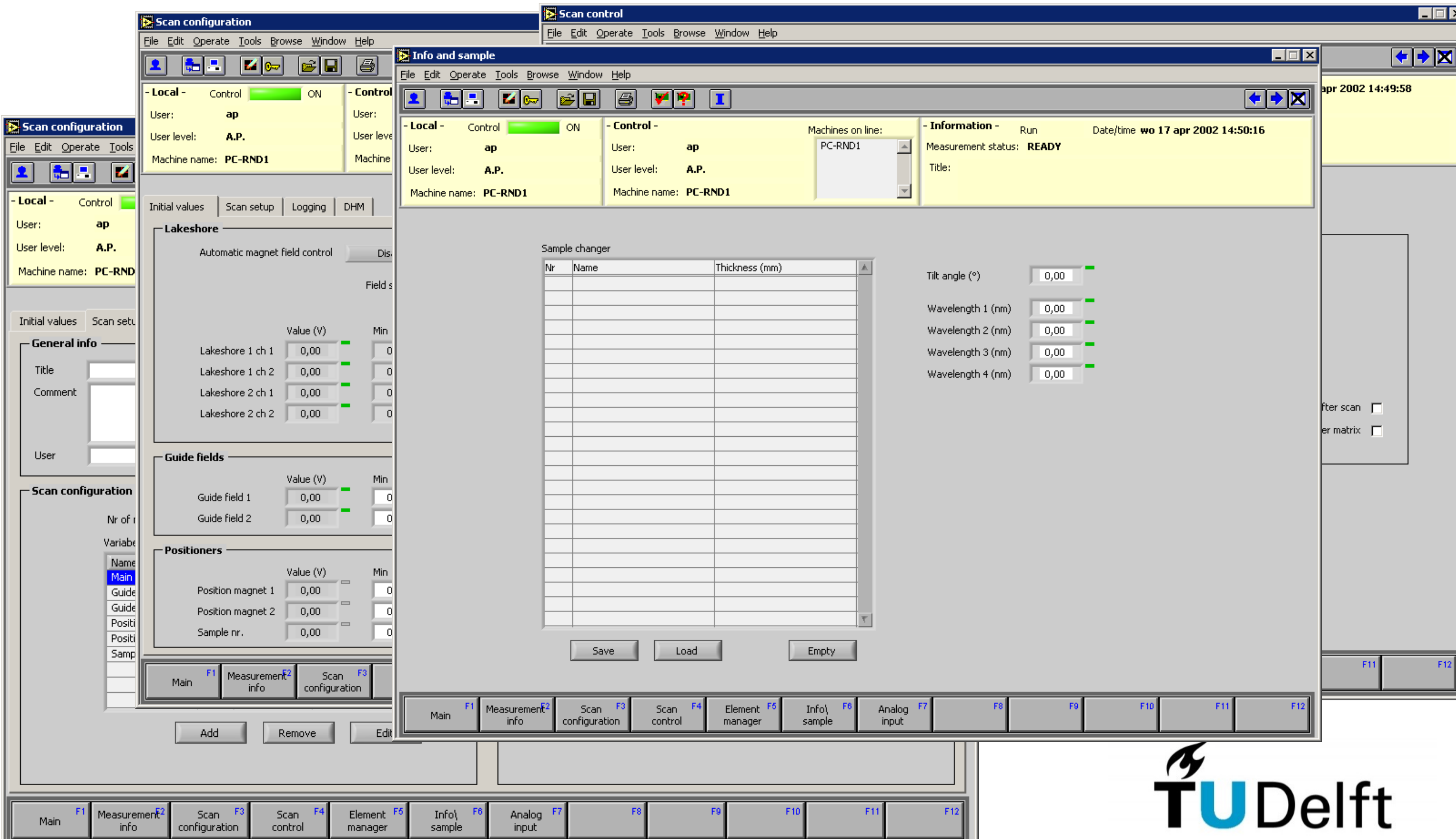
Length range



User hostile software
Cumbersome standard measurements
Extreme flexibility



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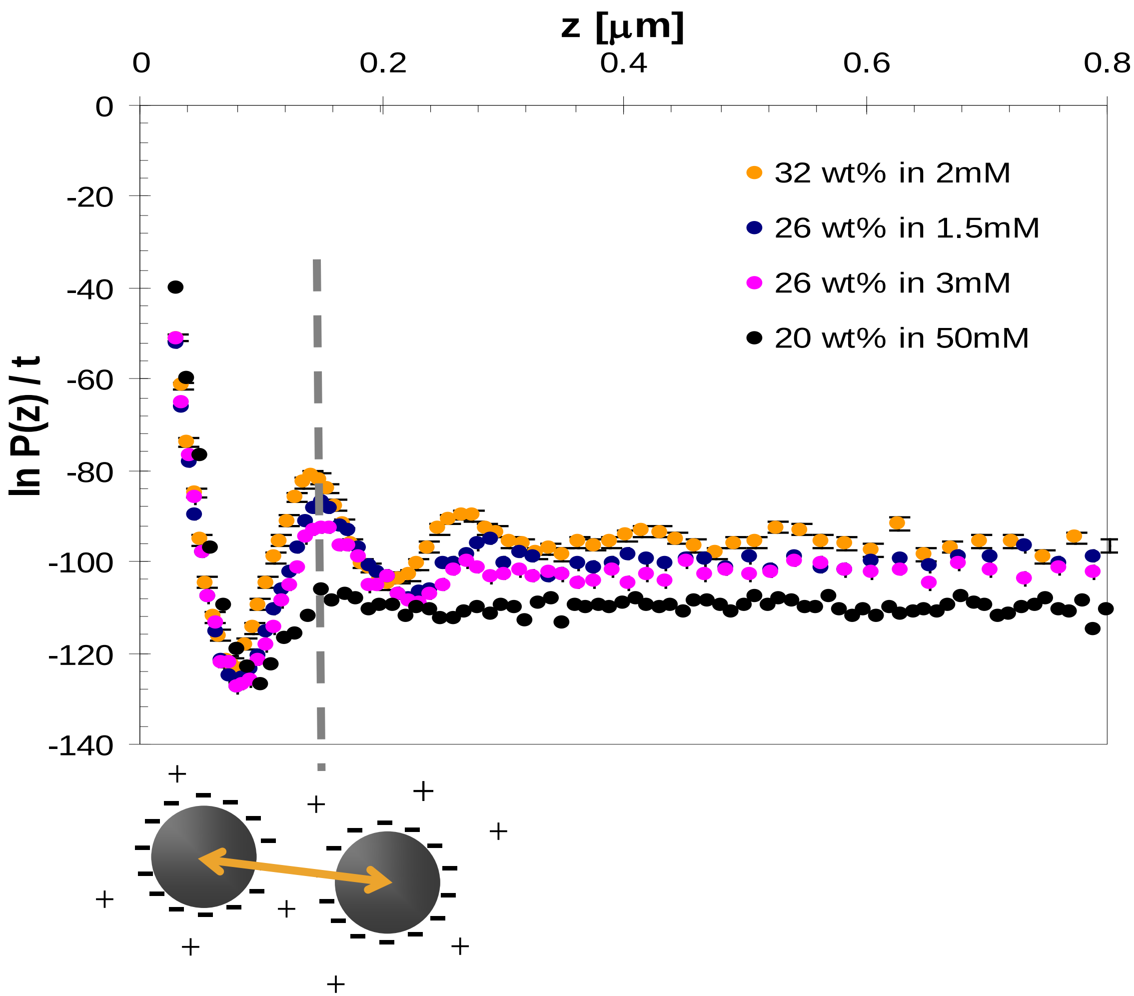
Colloids 70 nm, tunable interactions



Gruijthuijzen et al. EPL **106** 28002 (2014)

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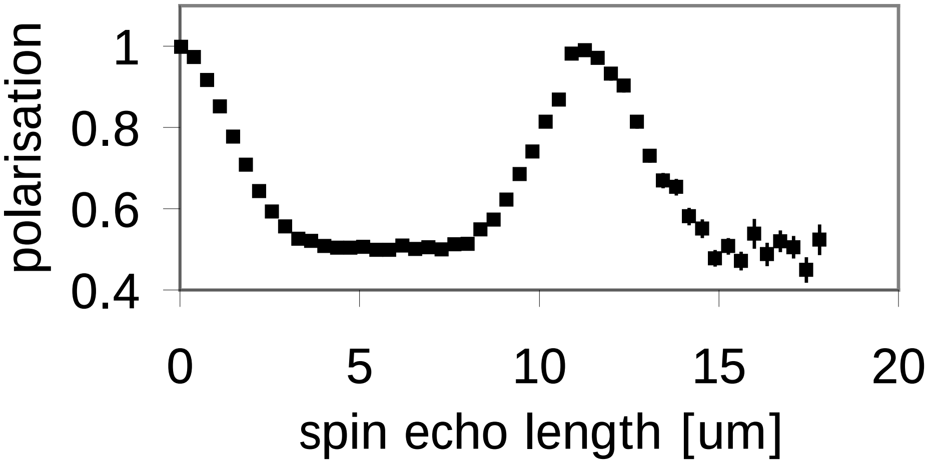
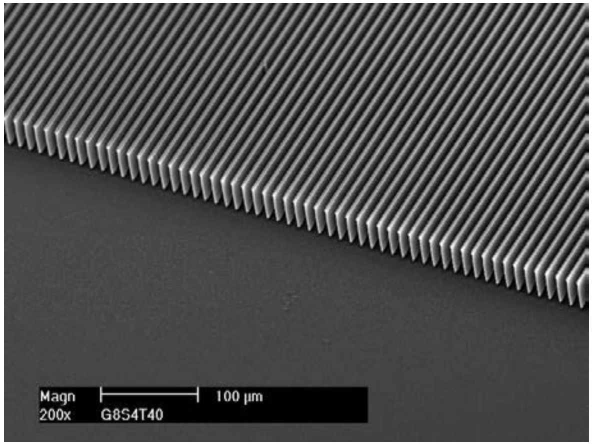
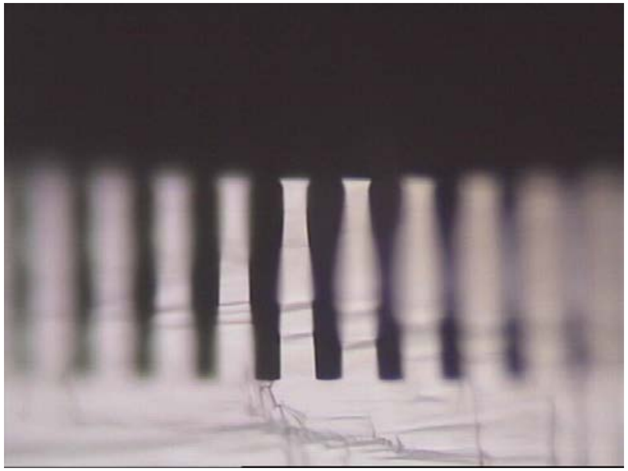
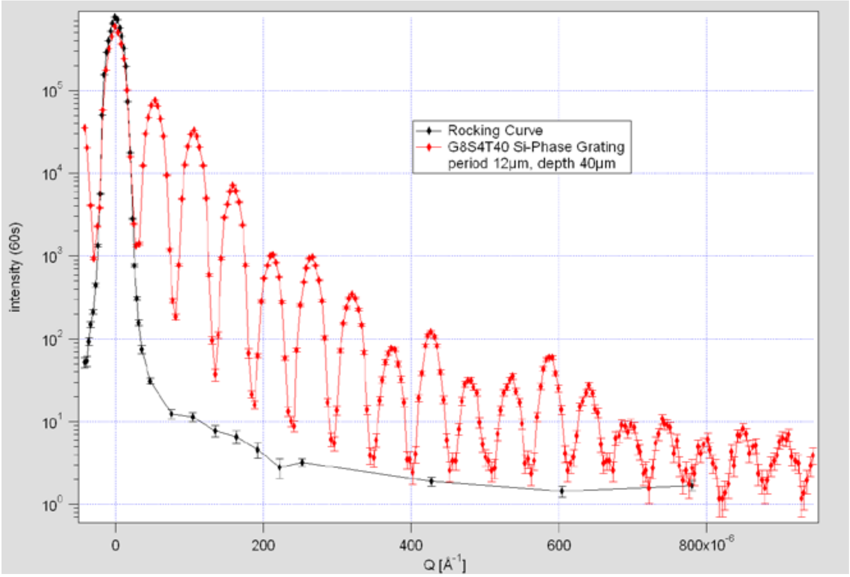
SESANS on grating: Direct visual data analysis
Spacing, ridge width, height









Trinker et al. NIMA **579** 1081 (2007)

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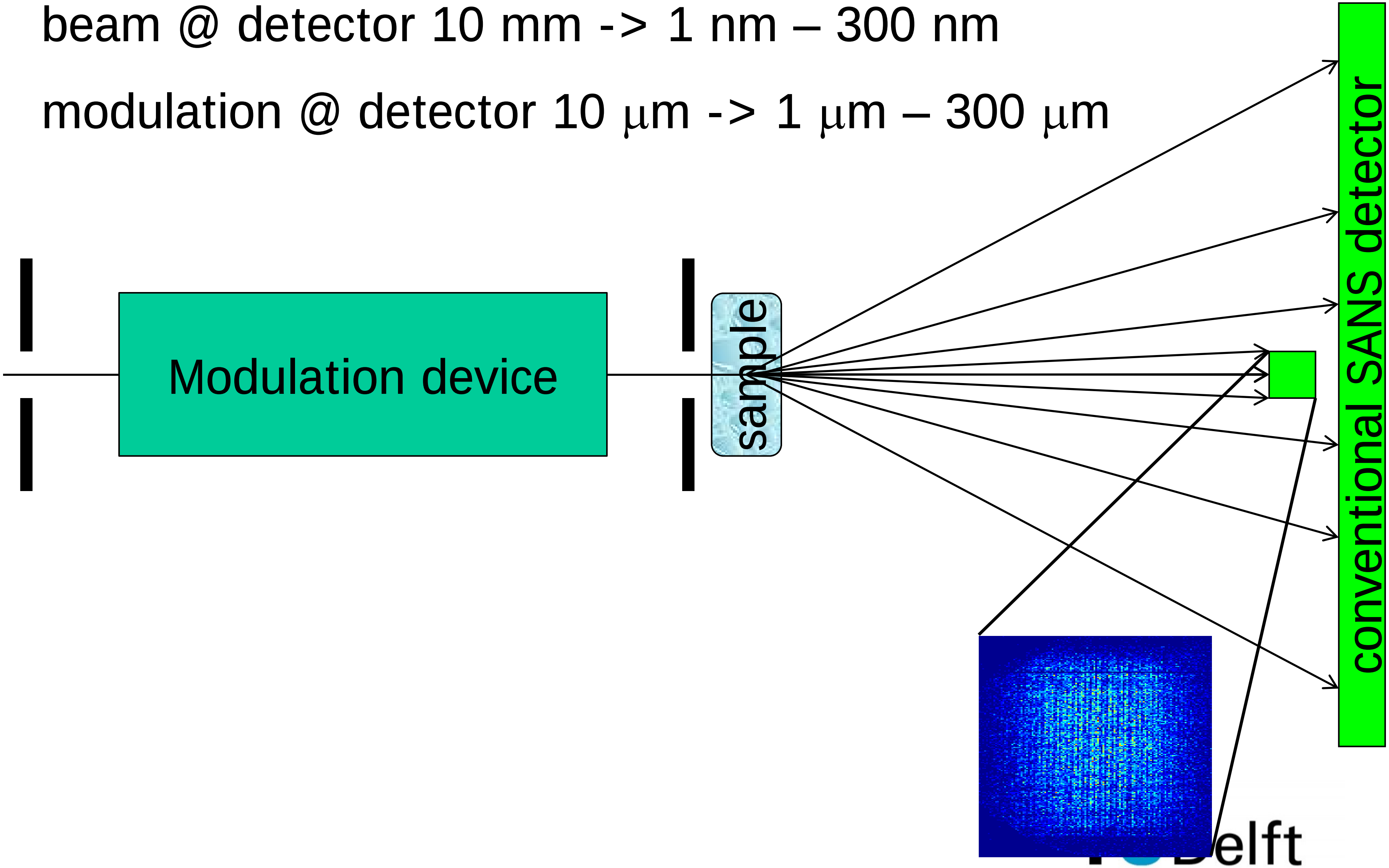
SANS + SESANS with "green box"
Roland Gahler (2006)

beam @ detector 10 mm -> 1 nm – 300 nm

modulation @ detector 10 μm -> 1 μm – 300 μm



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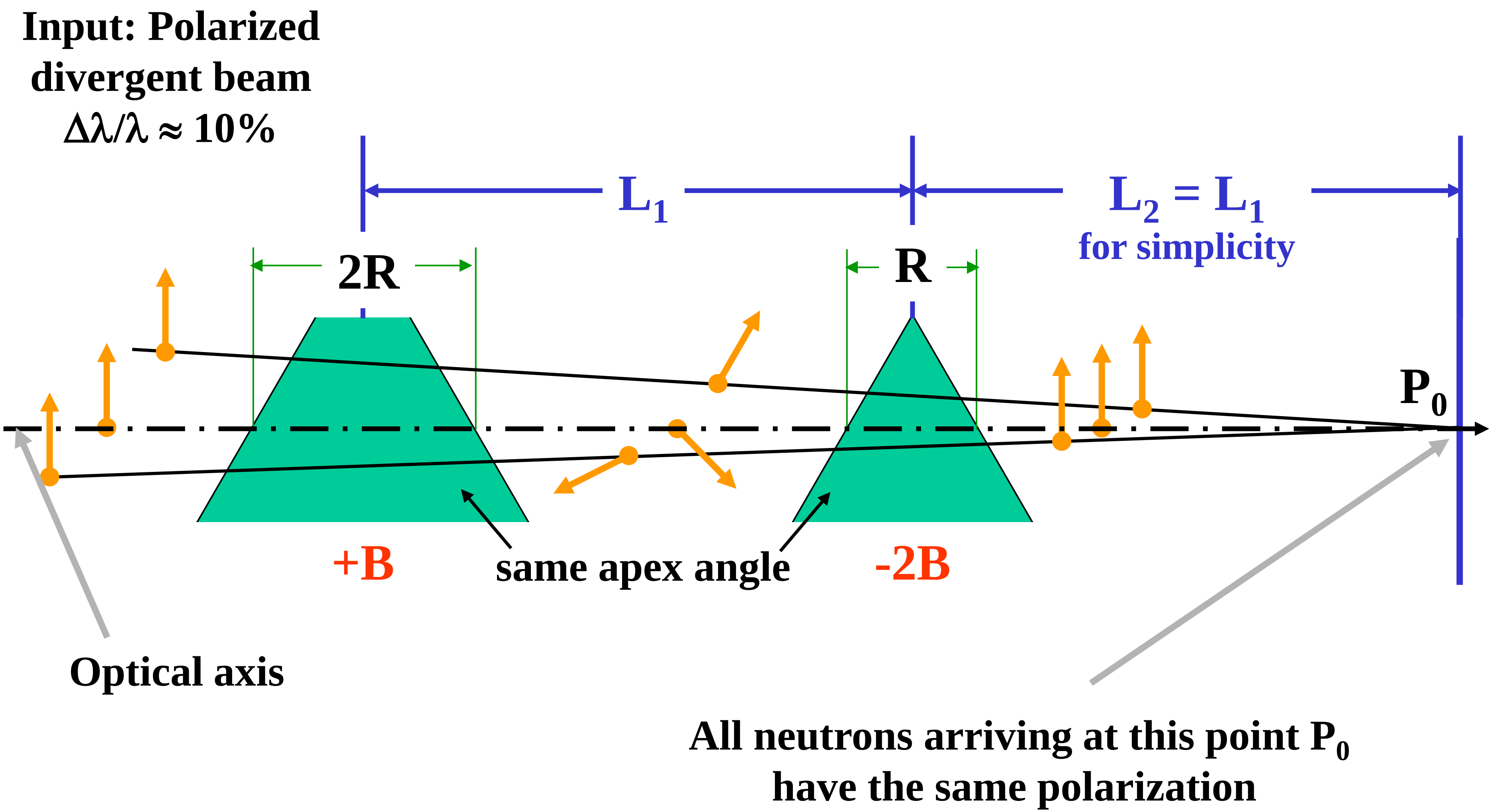
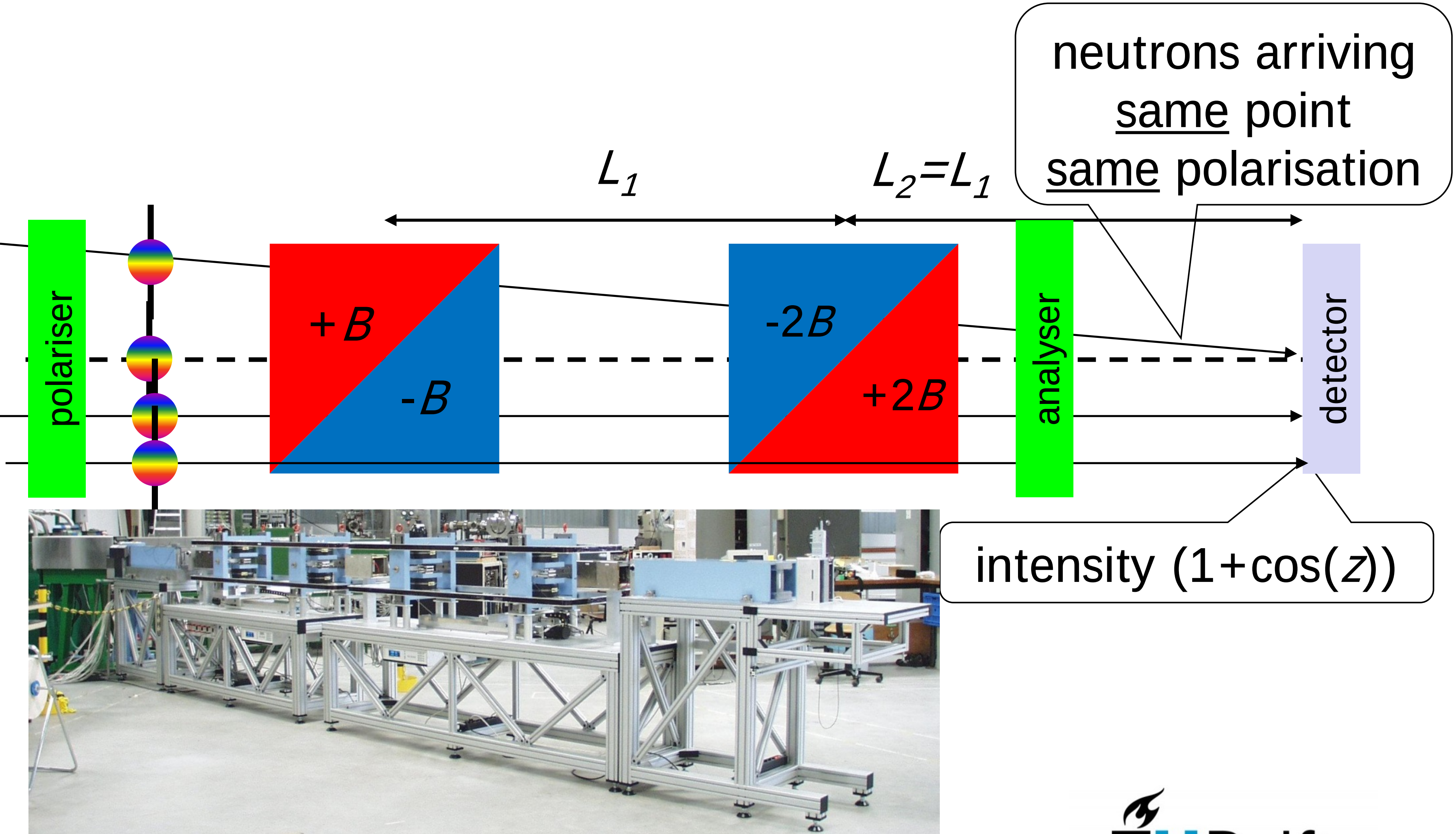
IX The ‘green box’ for beam modulation in space:



Roland Gähler PNCMI 2006

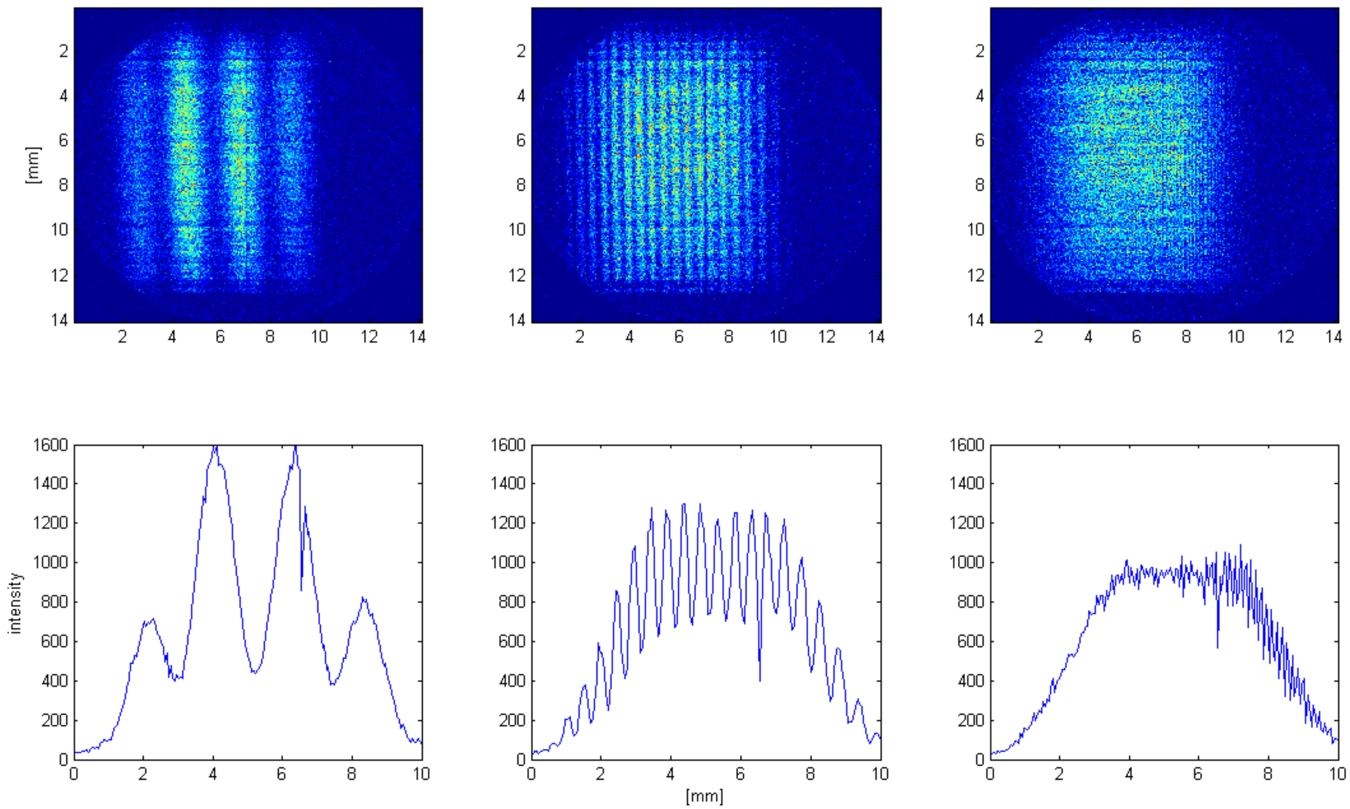
Beam modulation by Larmor precession
Even for large divergent beam



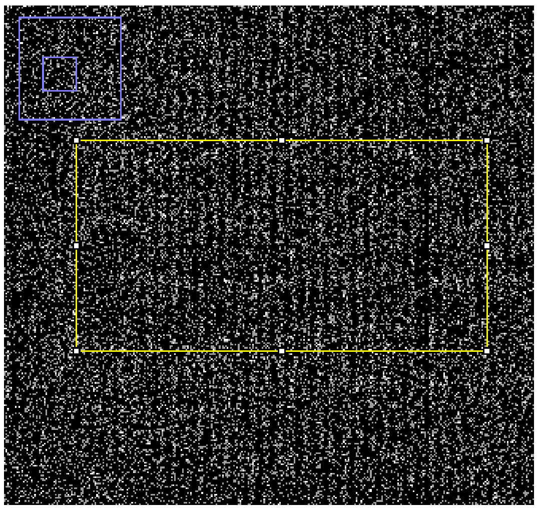
W.G. Bouwman, C.P. Duif, R. Gähler, Physica B **404** 2585-2589 (2009)

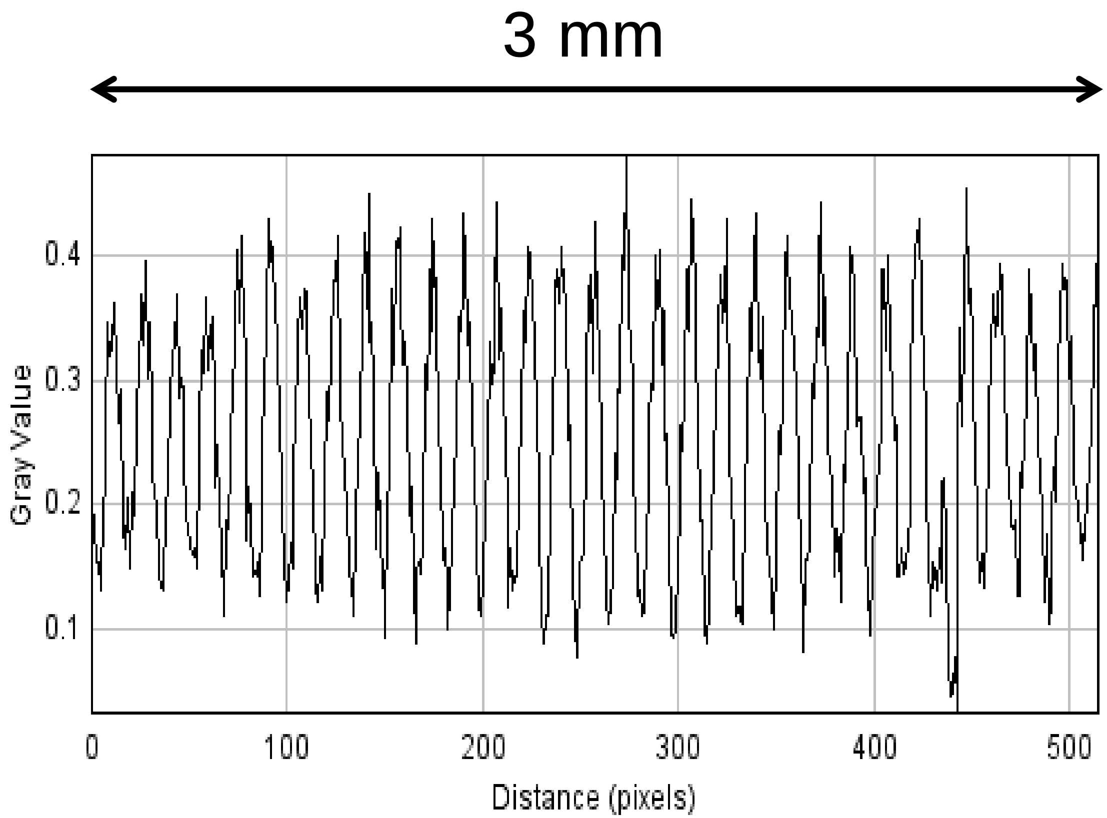
Monochromatic modulation with increasing fields

1-1.7 mT	4.4-7.9 mT	16-26 mT
2 mm	0.5 mm	0.13 mm



~100 μm modulation period (20-34 mT)





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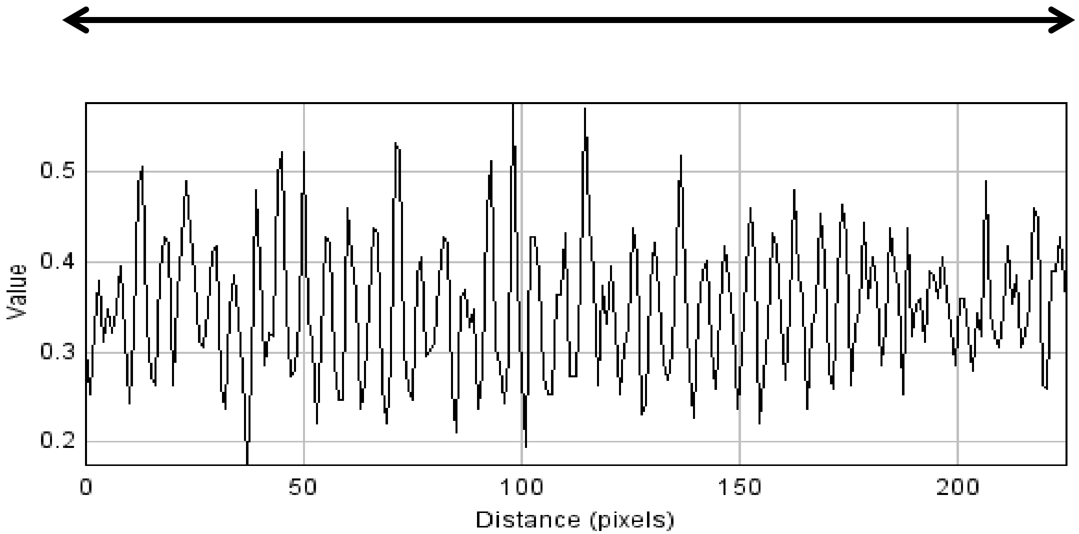
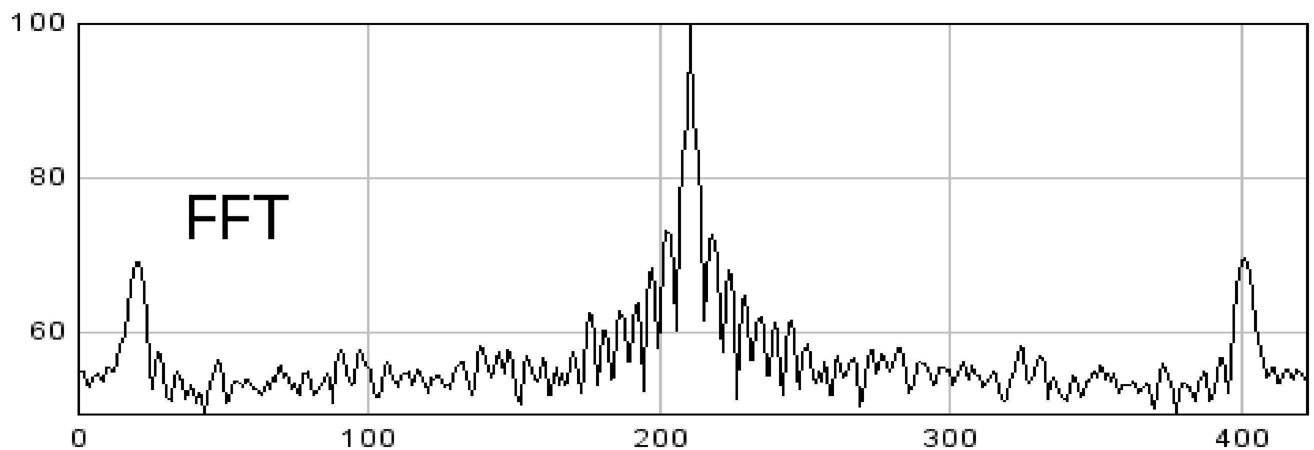
~35 μm modulation period (60-103 mT)

1.4 mm





1/pixels

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- **Dissemination of SESANS technique**

Peter Falus: Dissemination SESANS?

- SESANS comparable USANS (~ 10 times more efficient in counts)*
- Microscopy, SAXS with focussing lenses same length scales
- Data-analysis methods
  - Use of SANS software
  - Combining other length scales

*Rehm et al. J. Appl. Cryst. **64** 354 (2013)

Science case Delft

- Colloids 50 nm – 2 μm
- Fine powders 50 nm - 10 μm
- Protein gels 50 – 2 μm
- Fat emulsions 0.3 – 15 μm
- Cellulose dispersions 30 nm - 10 μm
- Liposomes 50 nm - 3 μm
- Oil water emulsions 30 – 500 nm
- Porous materials 30 nm - 20 μm

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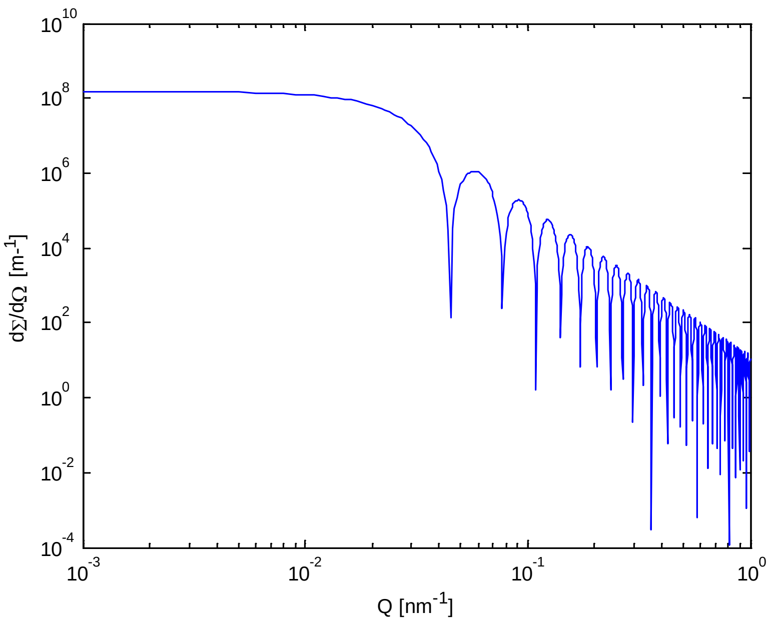
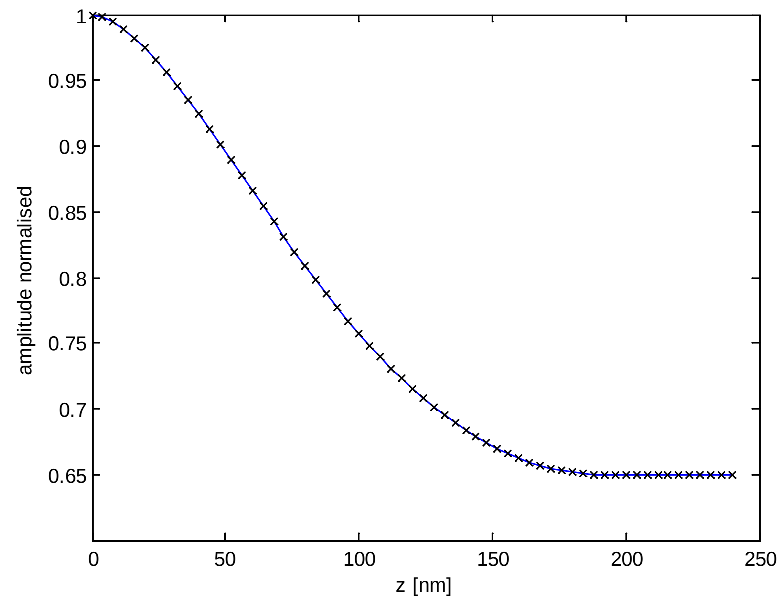
User-friendly software for dissemination
Data-analysis: SANS into SESANS conversion





$$\tilde{G}(z) = \int_0^\infty J_0(Qz) \frac{d\Sigma}{d\Omega}(Q) Q dQ \qquad P(z) = e^{\frac{t\lambda^2}{2\pi}\left(\tilde{G}(z)-\tilde{G}(0)\right)}$$

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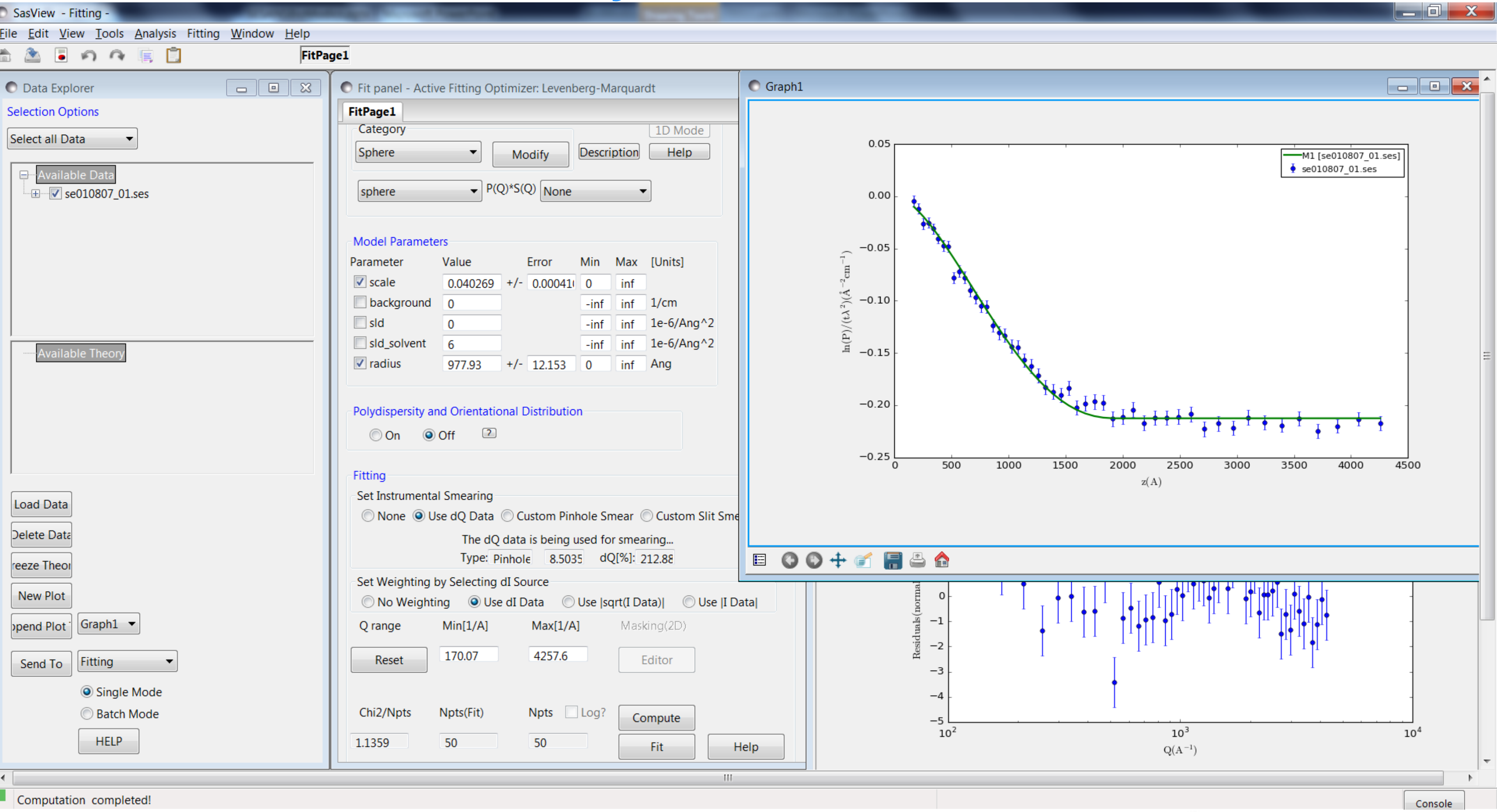
Data analysis with SasView 4.1
and Sasfit by Joachim Kohlbrecher



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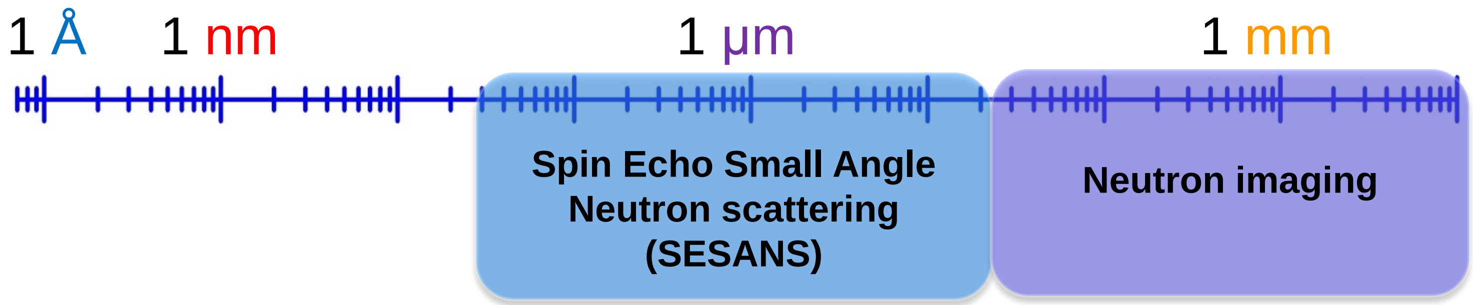
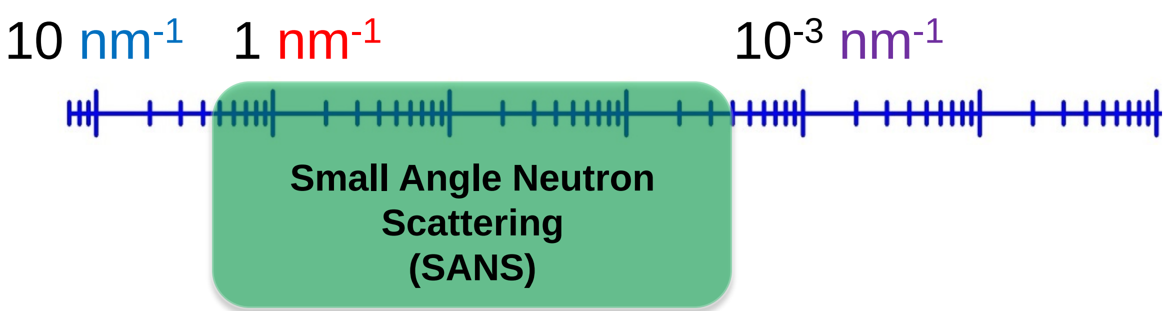
Combined analysis

- Size range (real space)



- Q range (reciprocal space)

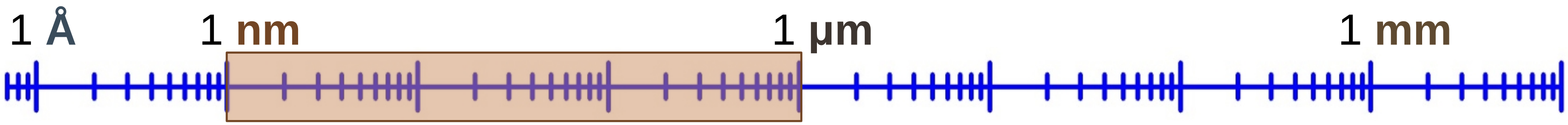


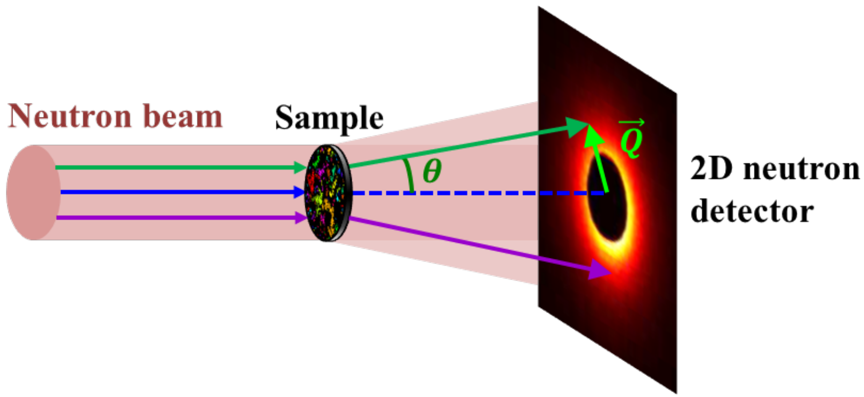
$$Q = \frac{2\pi}{l}$$

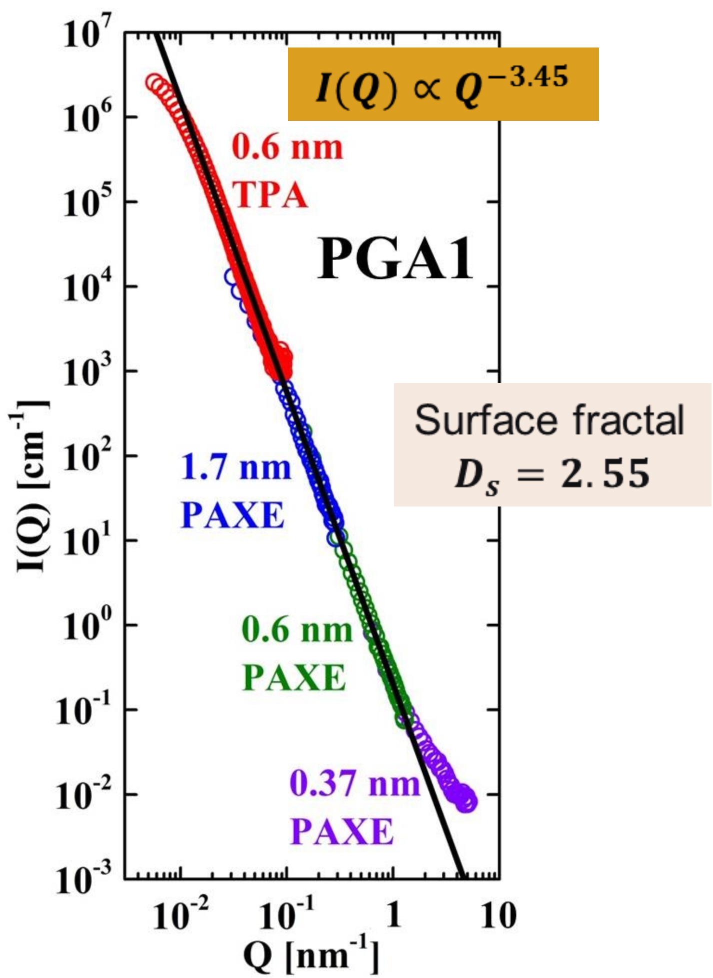
PGA graphite sample

Zhou et al. Carbon **96** 541 (2016)

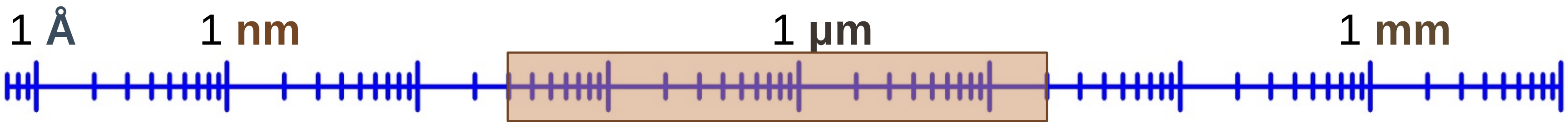
Mesoscopic scale - SANS

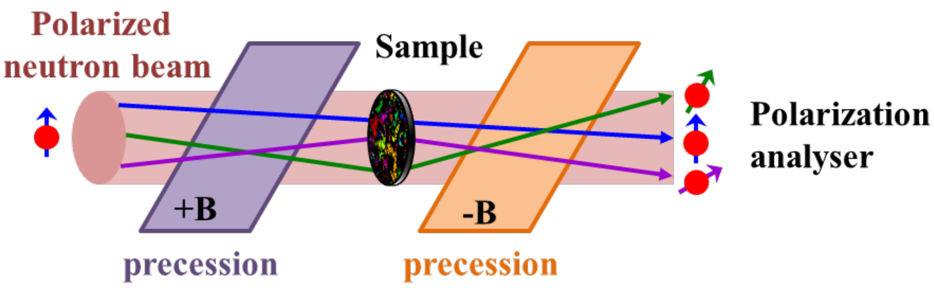


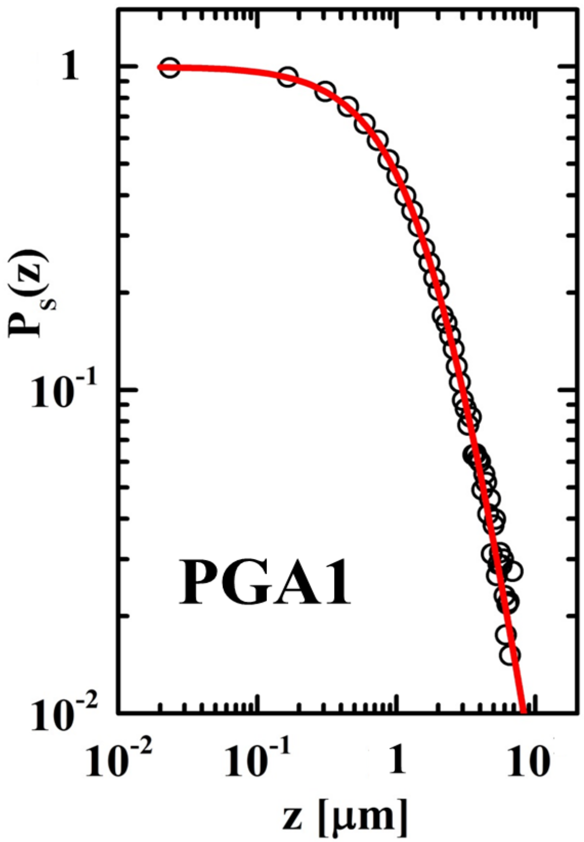




Mesoscopic scale - SESANS







✓ Structural in-homogeneities extend beyond 10 µm.

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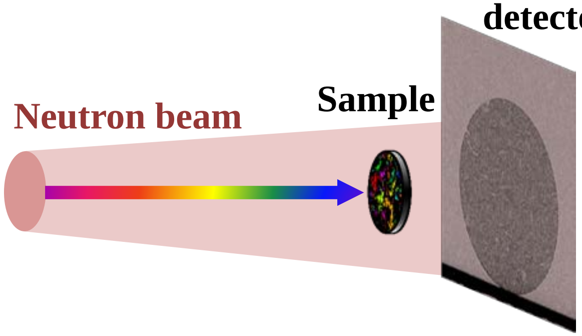
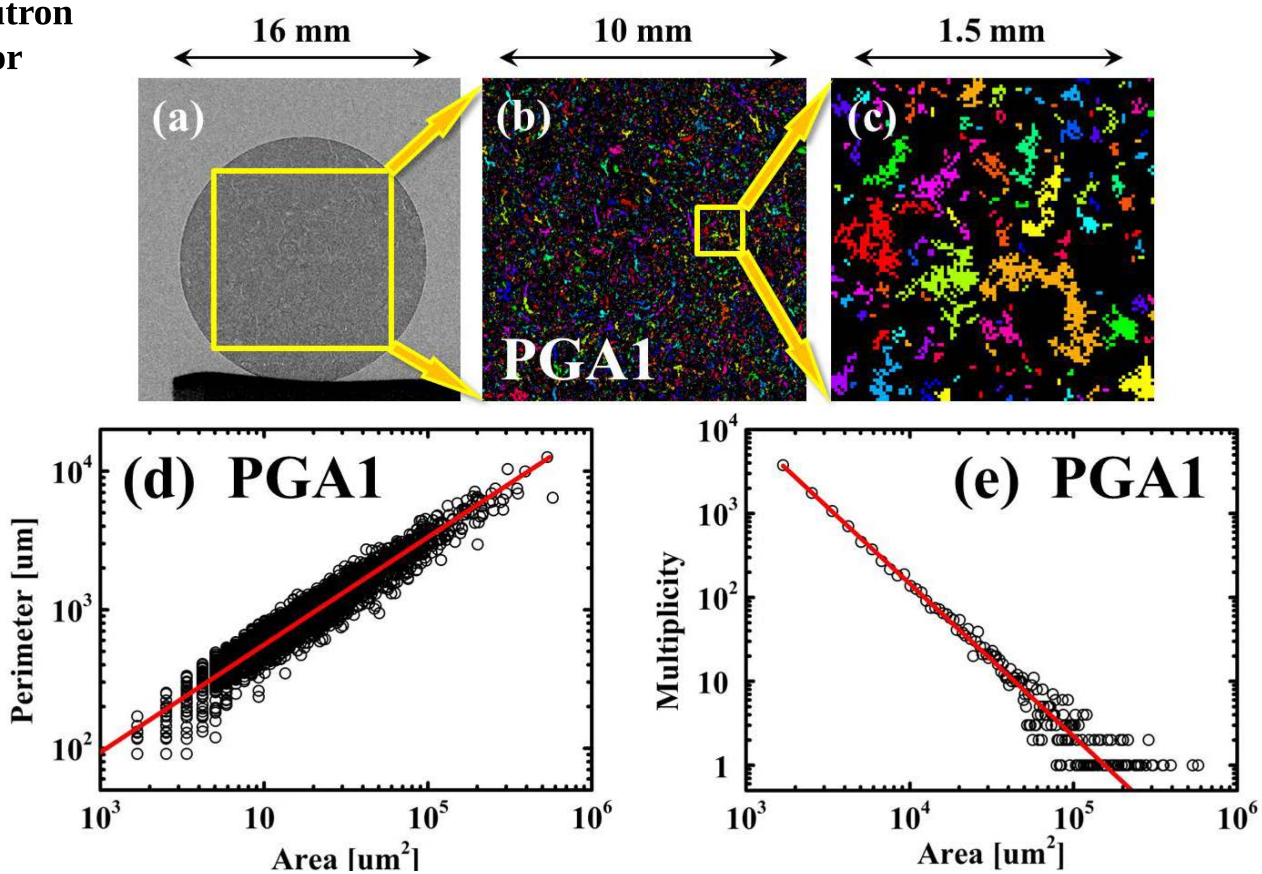
Neutron imaging





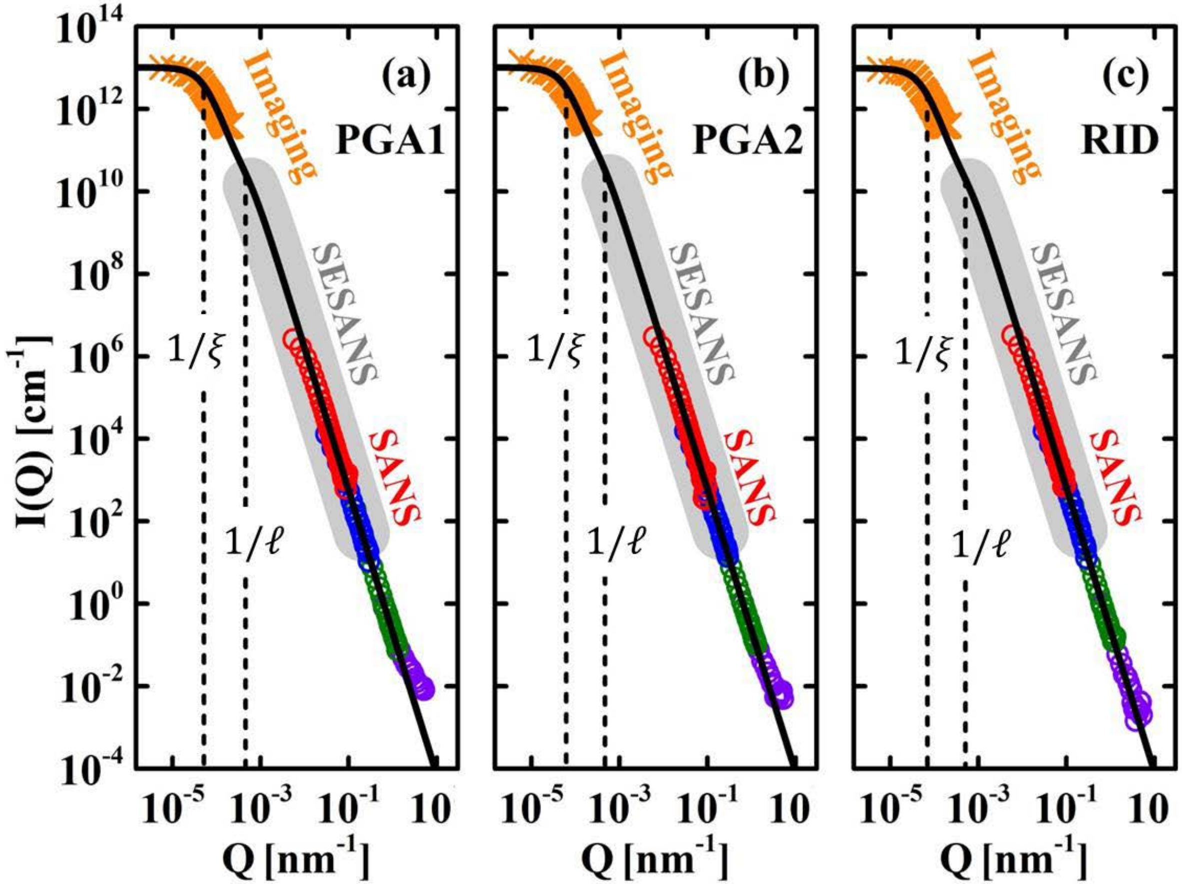
Perimeter-Area relationship
M. Beech, et al. 1991

$$P \propto A^{(D_s - 1)/2}$$

$$\Rightarrow D_s = 2.54$$

Data interpretation → Fractal model

$$I(Q) = \mathcal{B} \cdot P(Q, D_s, \ell) \cdot S(Q, D_m, \ell, \xi)$$



pre-factor $\mathcal{B}$ from SANS fit

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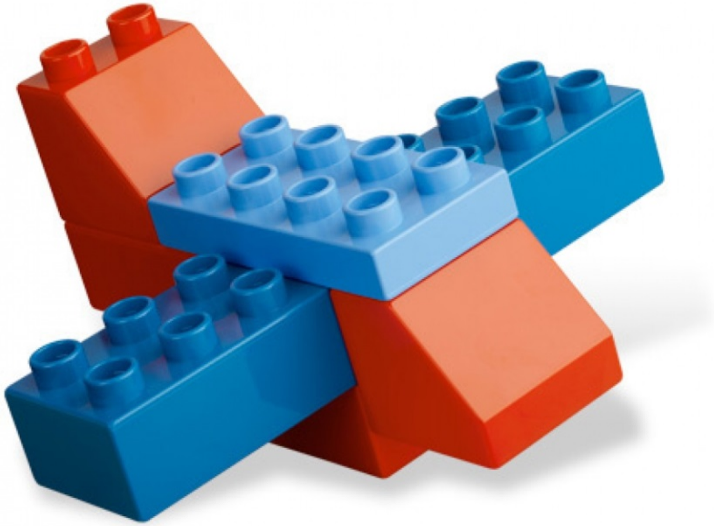
SESANS instruments, outdated list when I made it ;-(

place	name	method	mono/ TOF	dedi- cated	max δ [μm]
Berlin	FLEX	bootstrap	M	no	0.7
Delft	SESANS	π-flip foils	M	yes	20
~~Delft~~	~~WESP~~	~~RF-flippers~~	~~TOF~~	~~no~~	~~1~~
ILL	EVA	bootstrap	M	refl	
FRM II	MIRA	bootstrap	M	no	1
FRM II	N-REX$^+$	BS + Δ	M	refl	
LENS	SESANS	triangle		yes	1
SNS		triangle	TOF	refl	> 0.1
ISIS	OFFSPEC	RF-flippers	TOF	refl	15
PNPI	SESANS	RF-flippers	M	yes	
ISIS	LARMOR	RF-flippers	TOF	no	10-20

SESANS in Delft, dedicated, solid and flexible



Wim Bouwman
Theo Rekveldt
Jeroen Plomp
and many others

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