Australian Government

ansto

Nuclear-based science benefiting all Australians

Reactor-based time-of-flight SANS instrument BILBY: accumulated experience in collecting scattering from samples of various nature, dealing with incoherent backgrounds and complex transmissions along with solving issues in non-trivial data reduction

Anna Sokolova

Andrew E. Whitten and Liliana de Campo

Australian Centre for Nuclear Scattering

Australian Nuclear Science and Technology Organisation

Project history

October 2009	General design concept
December 2013	Commissioning licence granted by ARPANSA
1 March 2014	Neutrons on detectors are recorded, hot commissioning started
January 2016	In operation fourth cycle in operation (from July, 2017)

Nuclear-based science benefiting all Australians

Brief project history

BILBY: **started October, 2009**
A$11M, 5 years
design, procurement, installation, commissioning

- Design – Jason Christoforidis
- Engineering – Andrew Eltobaji
- Mechanical – John Barnes and mechanical team
- Electrical – Frank Darmann and EE team
- DAE – Andrew Berry and DAE team
- Data reduction and collection software – Nick Hauser group
- Procurement – Craig Ross

Instrument scientists (started mid 2014):

Dr Andrew Whitten, Dr Liliana de Campo

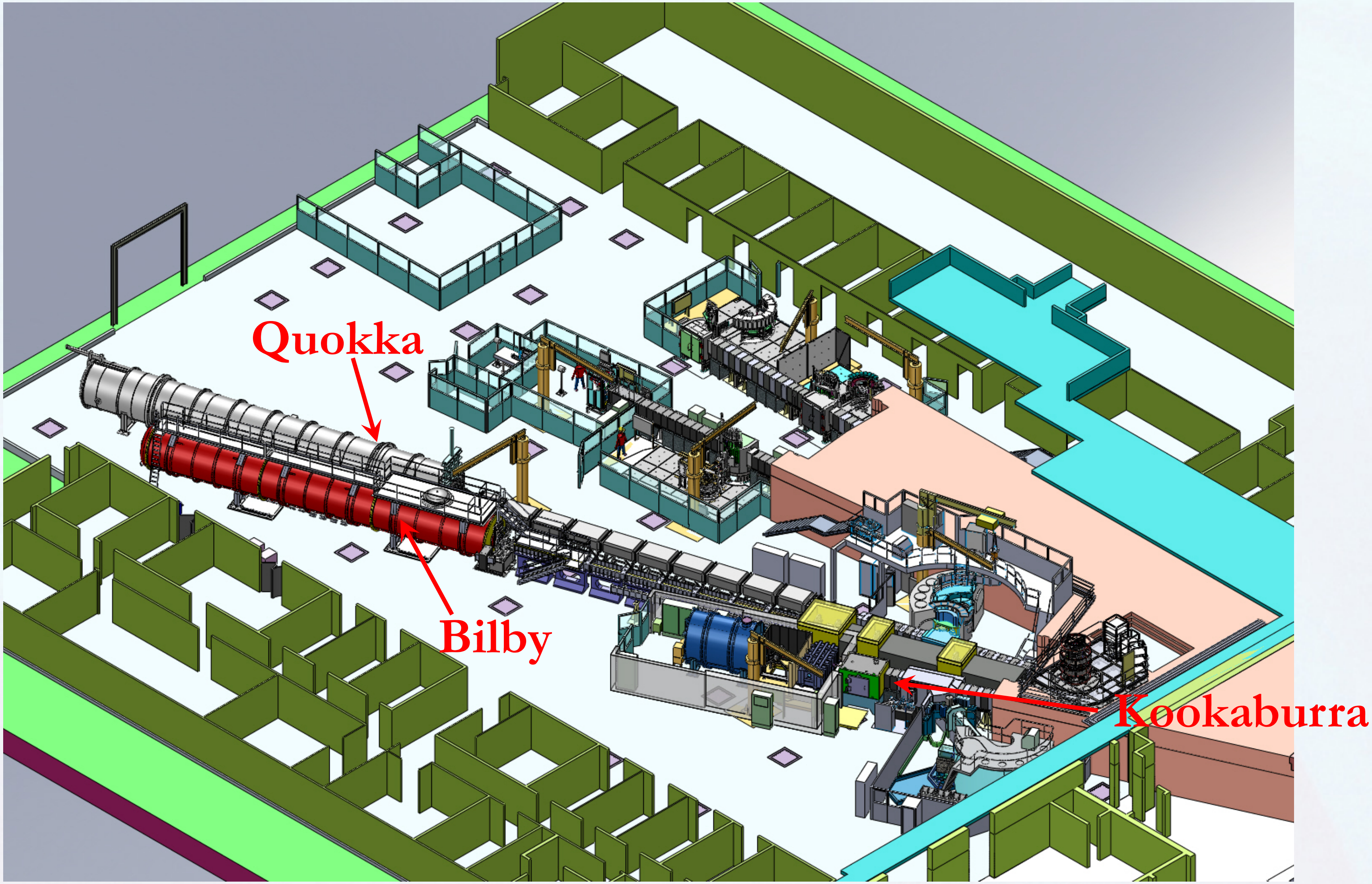
Hot commissioning: End 2015

Robert Knott
Elliot Gilbert
Katy Wood
Bill Hamilton
Glenn Ford
David Howes
Phil Bentley

HMI
ILL
Saclay
NIST
SNS
ISIS

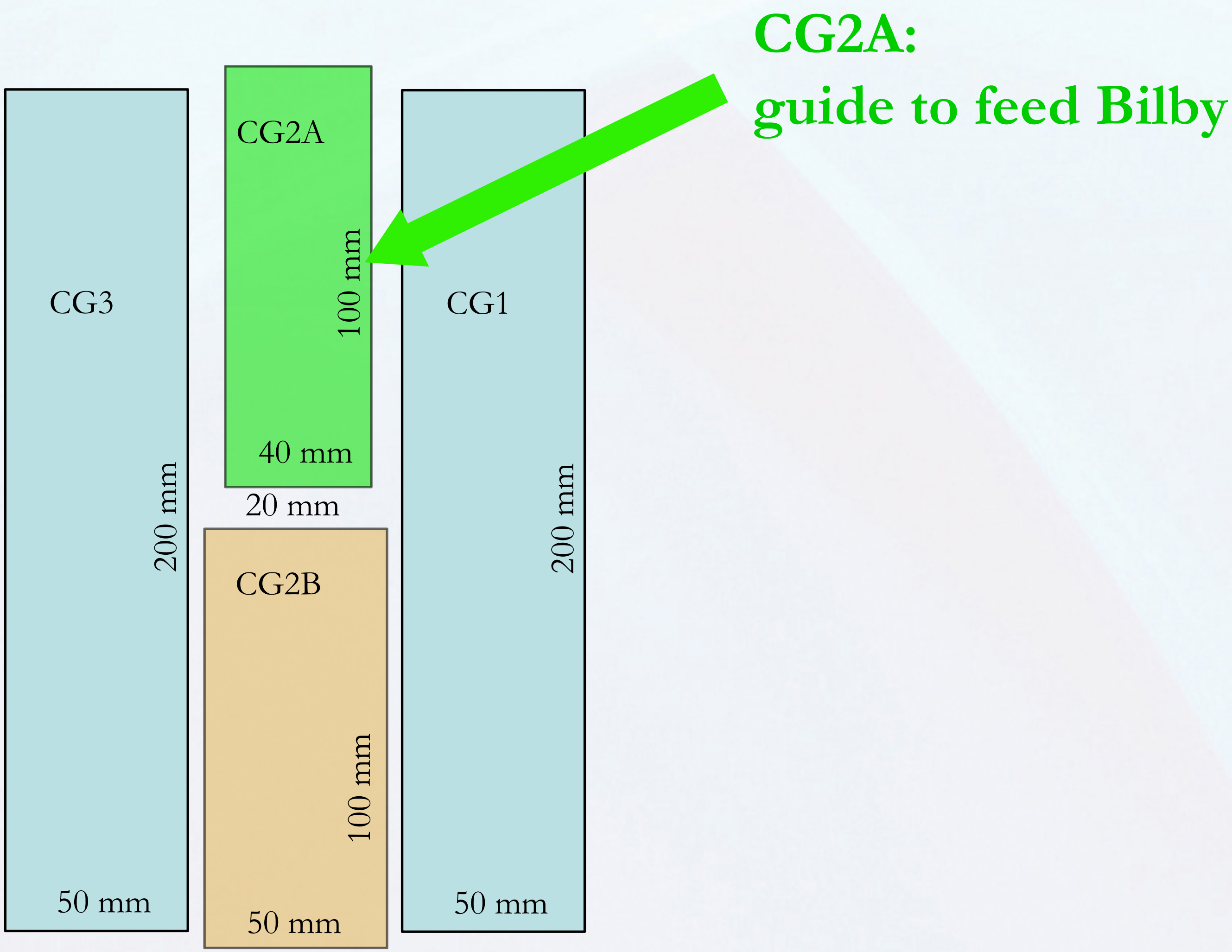
ansto
Nuclear-based science benefiting all Australians

ACNS: Neutron Small Angle Scattering

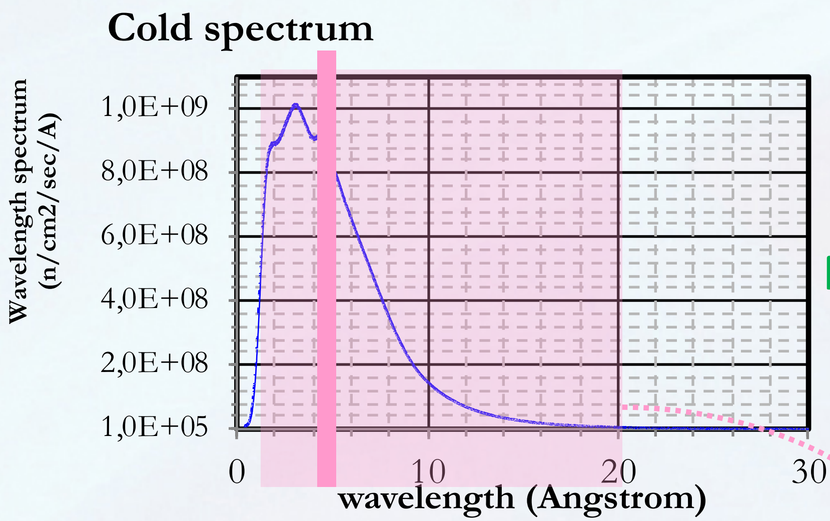


http://www.ansto.gov.au/ResearchHub/OurInfrastructure/ACNS/

ANSTO: Guides looking at the cold source

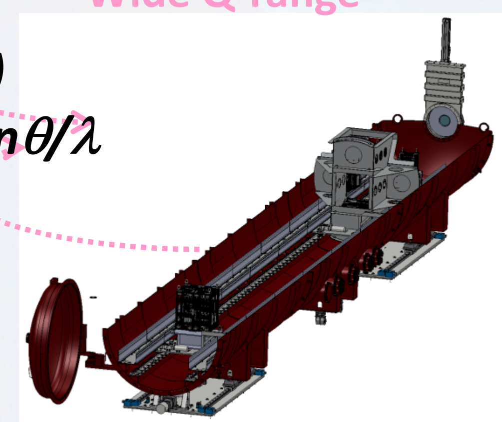


Monochromatic vs polychromatic SANS



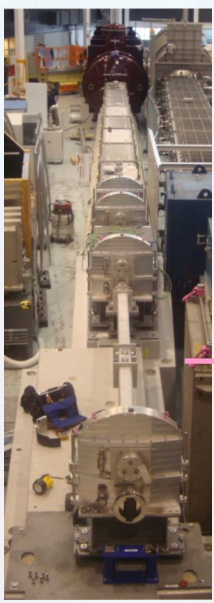
NO time structure in neutron flow

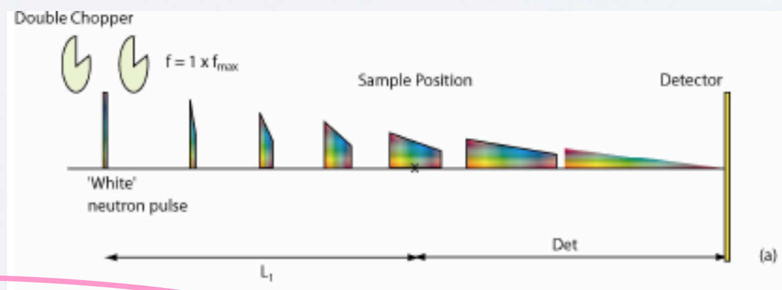
Wide Q-range



I(Q)

$Q=4\pi \sin\theta/\lambda$





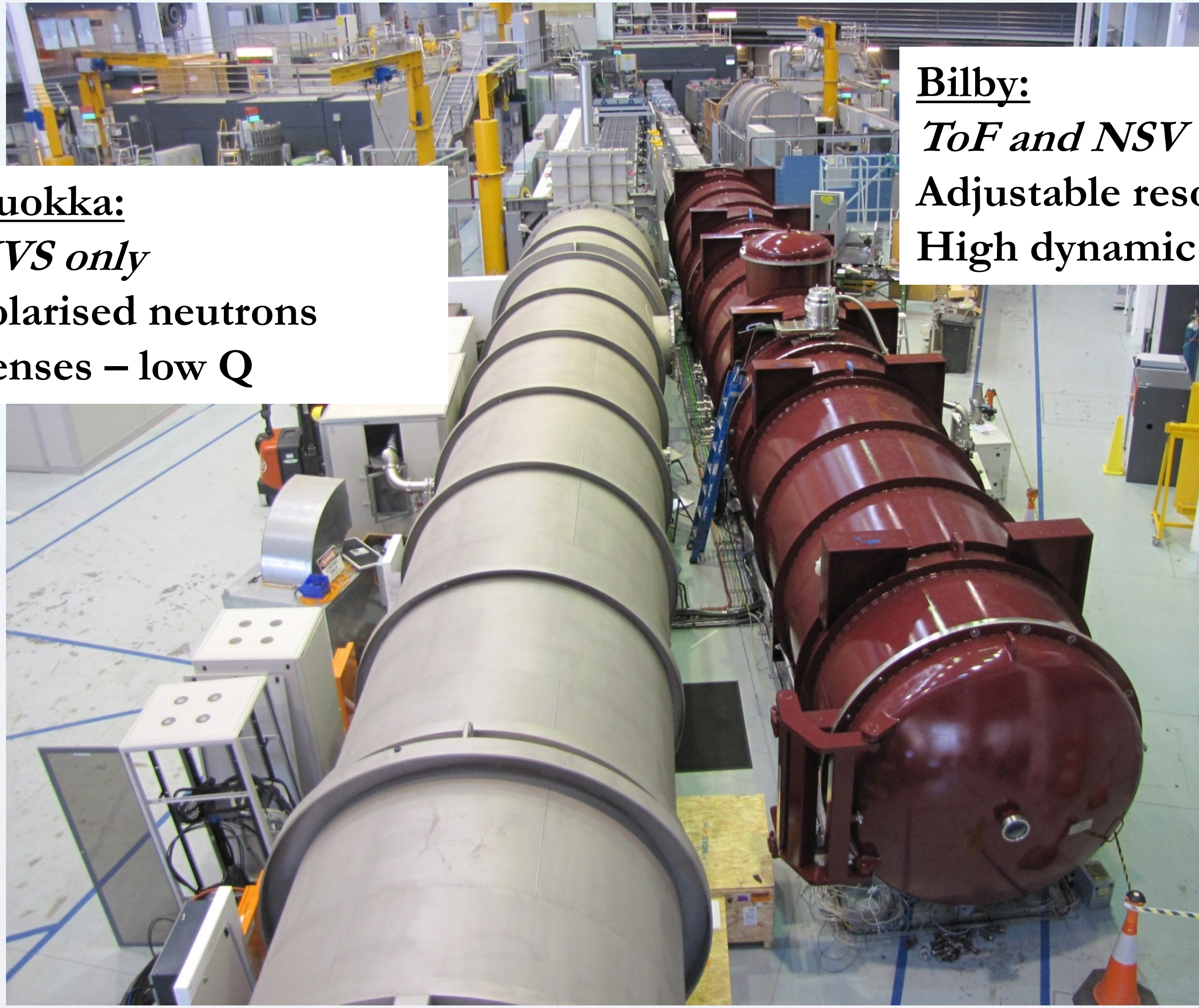
TIME structure in neutron flow

$\Delta\lambda/\lambda = \Delta D/D$

ansto
Nuclear-based science benefiting all Australians

Flexible resolution: 10% of mono → 3-30% on poly

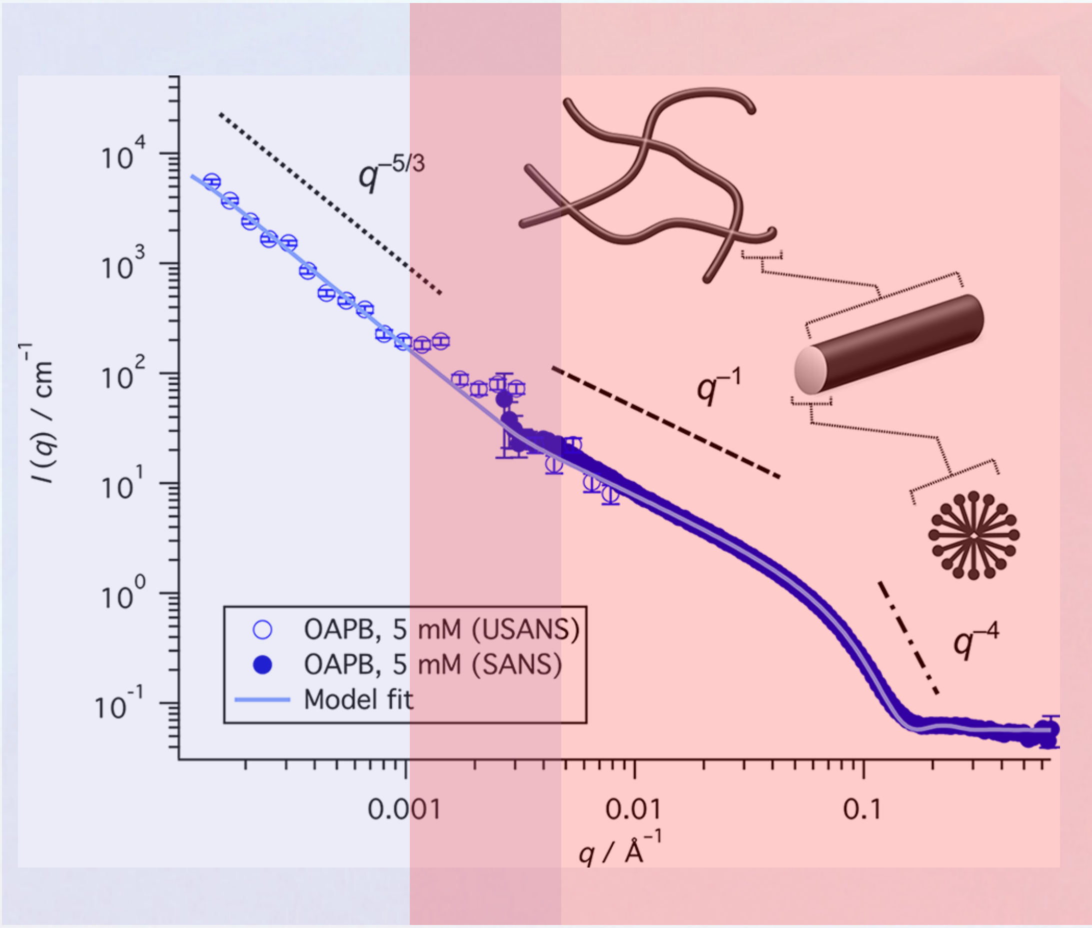
Australian Centre for Neutron Scattering: two SANS machines



Quokka:
NVS only
Polarised neutrons
Lenses – low Q

Bilby:
ToF and NSV
Adjustable resolution
High dynamic Q range

Bilby + Kookaburra



SANS data over four decades
in Q (KOOKABURRA & BILBY)

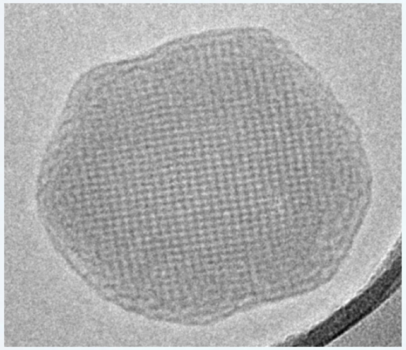
Kelleppan et al, Langmuir 2018

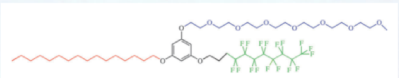
1×10⁻³ Å⁻¹ **Bilby** *1.8 Å⁻¹*

Q (Å^{-1})

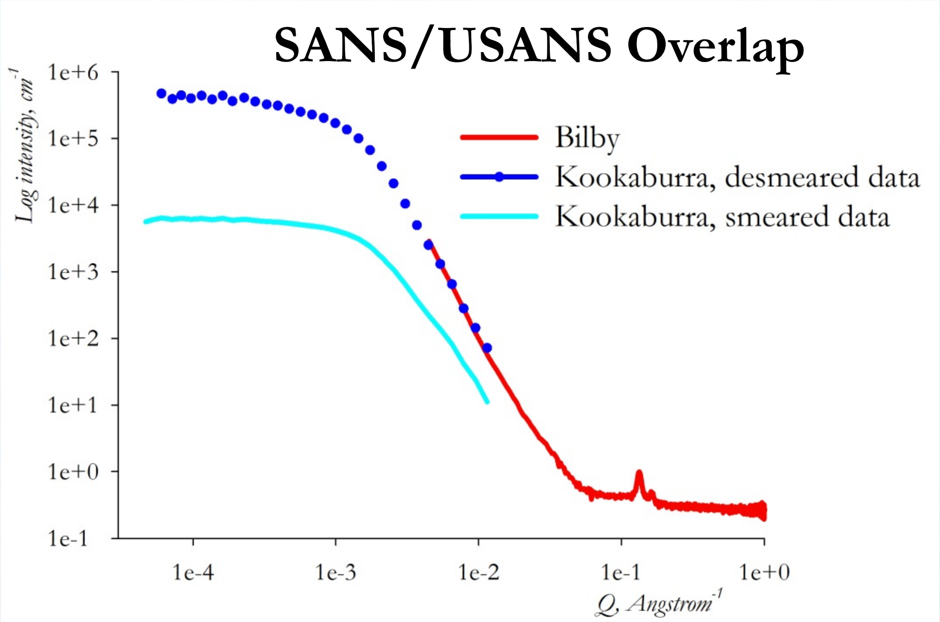
Bilby - large dynamic Q-range in ToF mode

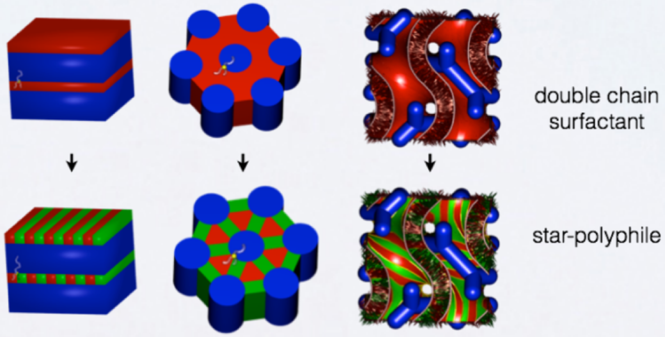
Liquid Crystals based on Star-Polyphiles





Reduction of selected wavelengths (3Å-10Å)



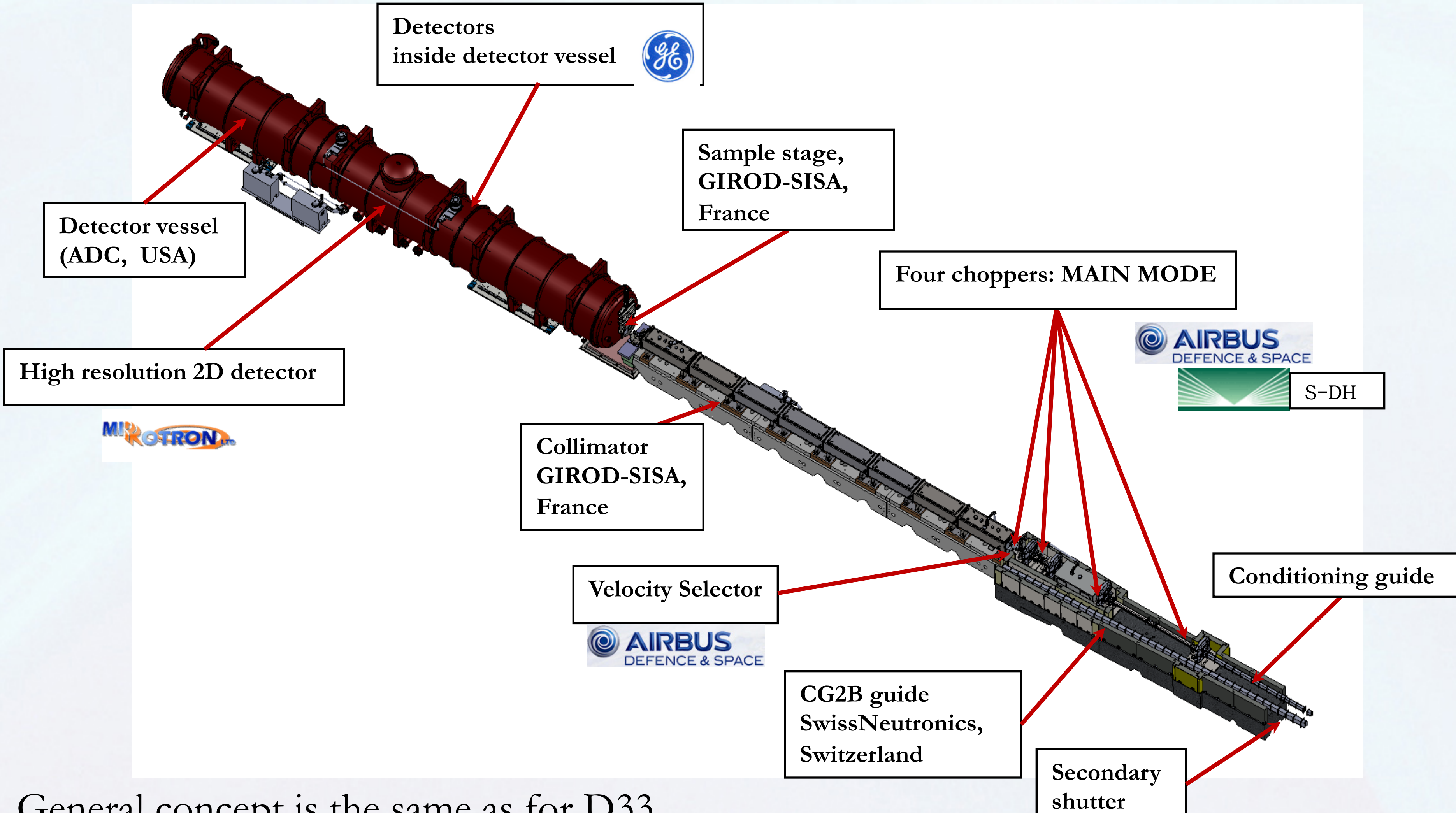


A novel lyotropic liquid crystal formed by triphilic star-polyphiles: hydrophilic/oleophilic/fluorophilic rods arranged in a 12.6.4. tiling
Liliana de Campo et al
Phys. Chem. Chem. Phys., 2011,**13**, 3139-3152

Nuclear-based science benefiting all Australians

Representative CryoTEM image taken by L.Waddington (CSIRO), figure courtesy of S.Hyde (ANU) and M. Moghaddam (CSIRO).

Bilby: general layout



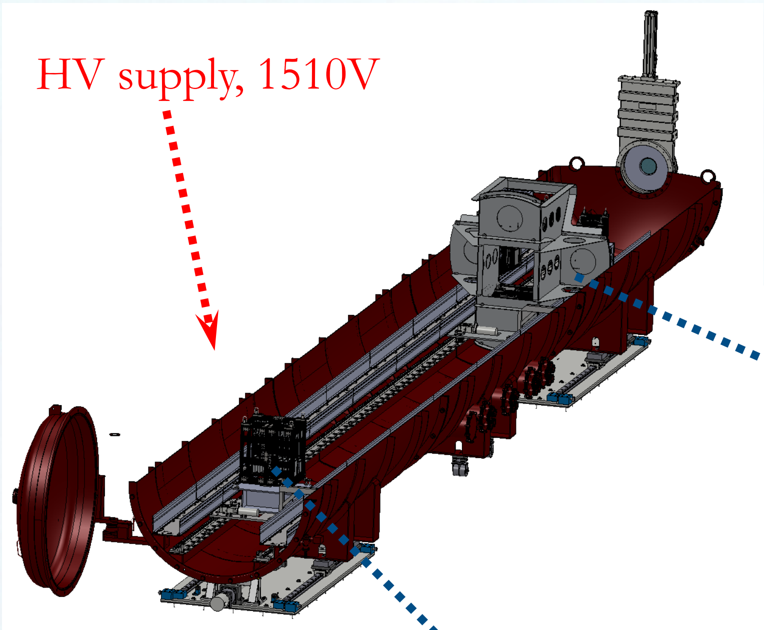
General concept is the same as for D33 machine at ILL

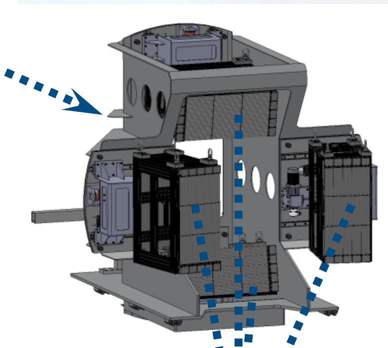
C. D. Dewhurst et al

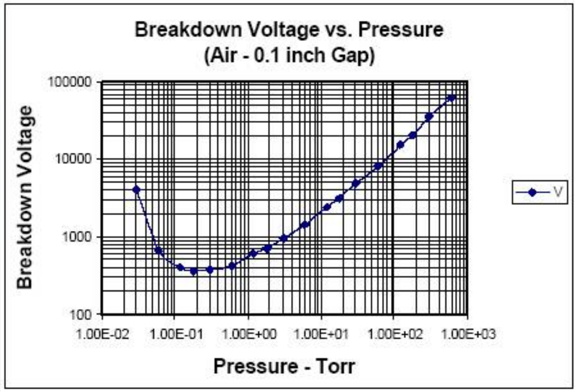
" The small-angle neutron scattering instrument D33 at the Institut Laue–Langevin", J Appl Cryst 2016 ***49*** *p.1-14*

Nuclear-based science benefiting all Australians

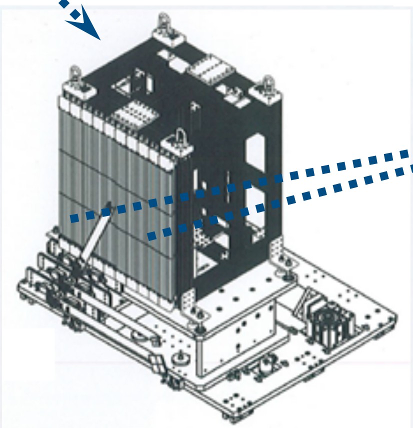
Detectors

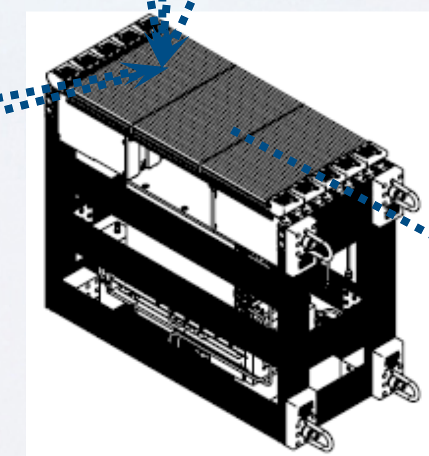


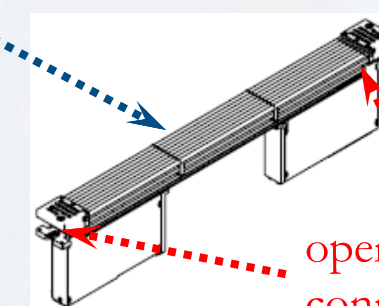




Forbidden region:
600 mbar ÷ $1 \cdot 10^{-3}$mbar



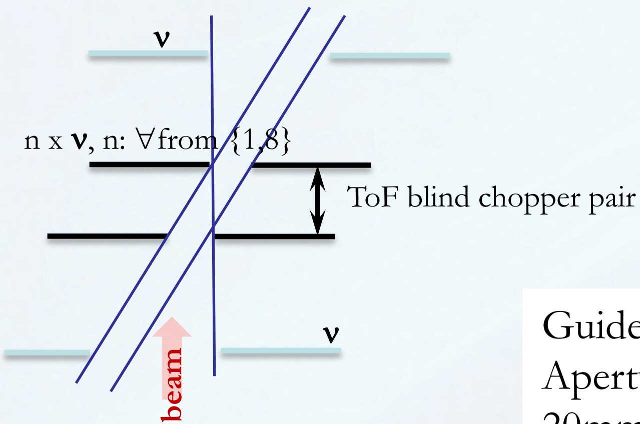


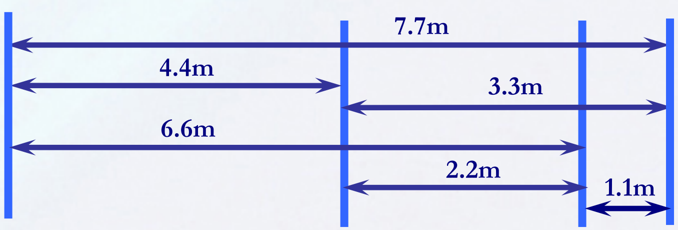


- Entire vessel sits on rails
- Vacuum: $1 \cdot 10^{-4}$mbar (with confidence, ~30hours)
  - Possibility to open beam at ~700mbar

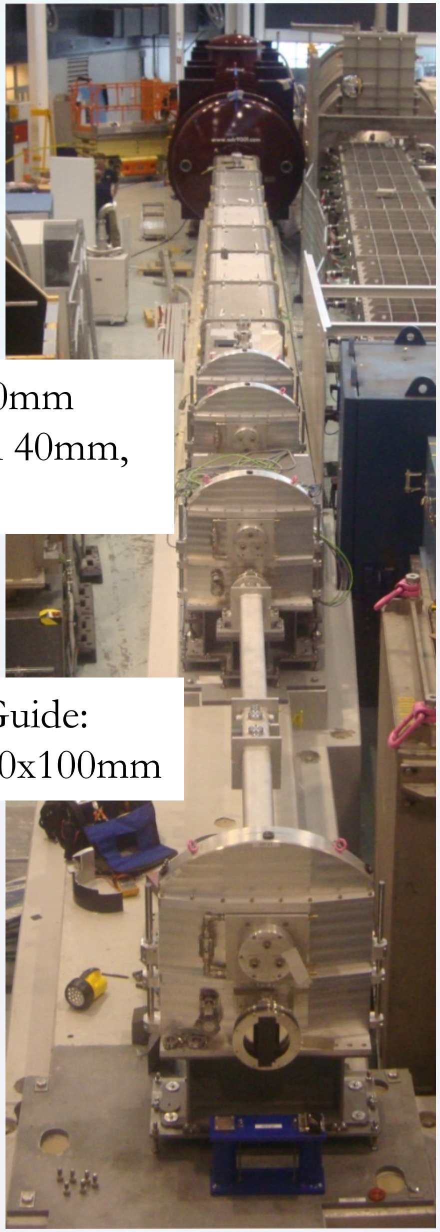
ansto
Nuclear-based science benefiting all Australians

Choppers & Collimator





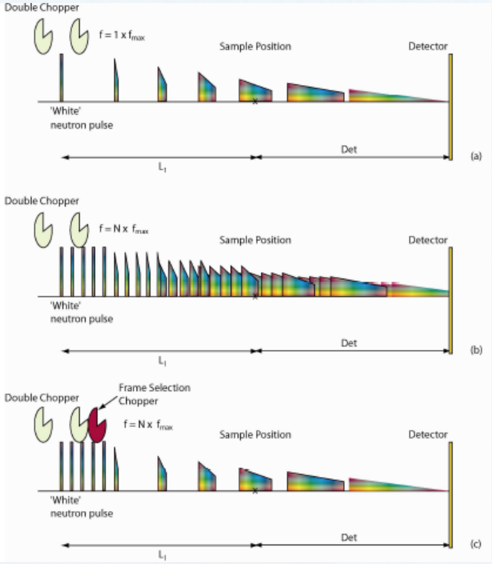
- **Low resolution:**
  - porosity, large biomacromolecules etc
- **High resolution:**
  - liquid crystals, polymers etc



Guides: 40x40mm
Apertures: incl 40mm, 20mm, 10mm

Guide:
40x100mm

$$\frac{\Delta\lambda}{\lambda} = \frac{\Delta t}{t} = \frac{\Delta D}{D}$$



λ: 2Å÷20Å

$\Delta\lambda/\lambda$: 4%÷30%

Nuclear-based science benefiting all Australians

Data reduction

Main equation:

$$I(Q)=\frac{1}{d_{sam}}\cdot\frac{\Sigma_{R,\lambda\subset Q}C_{sam,corr}(R,\lambda)}{M\cdot\Sigma_{R,\lambda\subset Q}T_{corr}(\lambda,R)\cdot\left[I_{empty\ \ beam}(\lambda)\Big/\left(M_{empty\_beam}\cdot att_{empty\_beam}\right)\right]\cdot\Omega(R)\cdot Det_{flood}(R)}$$

Important: to reduce data on different wavelength ranges

Pixel size: 8mm x 2.7mm

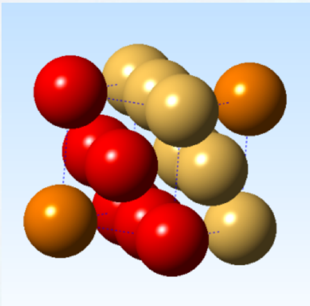
Deadtime, beam monitor, detector efficiency: no correction

Software: **www.mantidproject.org**

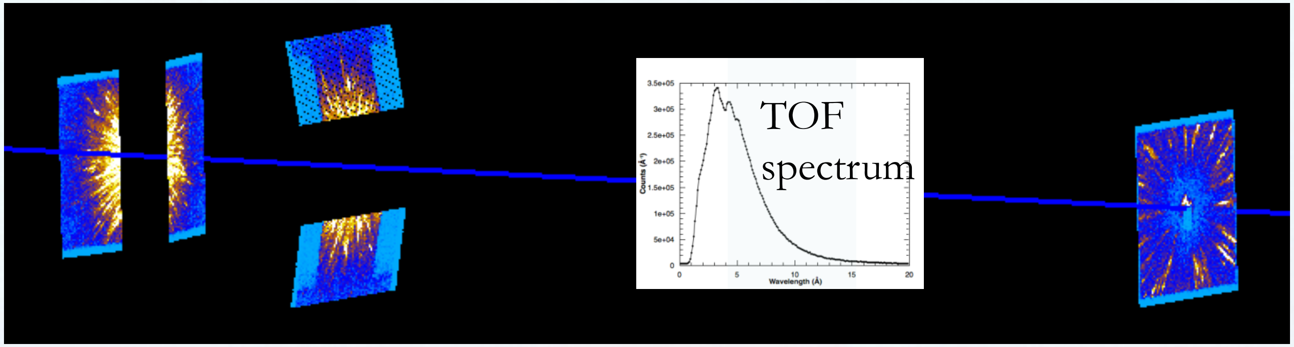
O. Arnold, et al., Mantid—Data analysis and visualization package for neutron scattering and μSR experiments, Nuclear Instruments and Methods in Physics Research Section A, ***764****, 2014, p.156-166*

Bilby - in ToF mode at high resolution (~4.5%Δλ/λ)

Sample



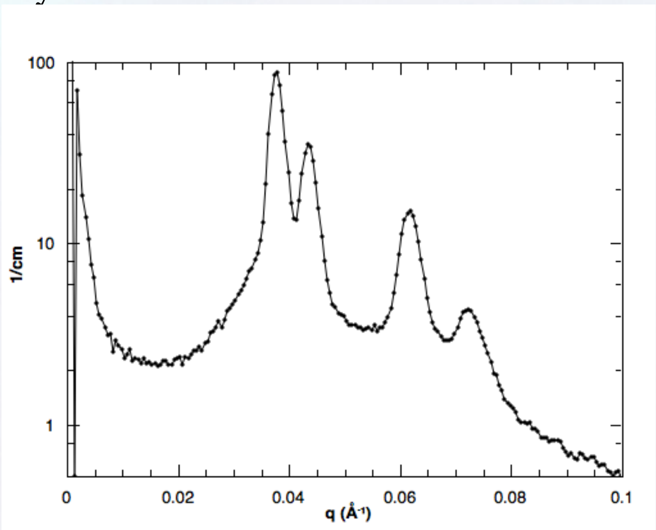
Raw data: (5m SDD to closest curtains, 10m SDD for rear detector)



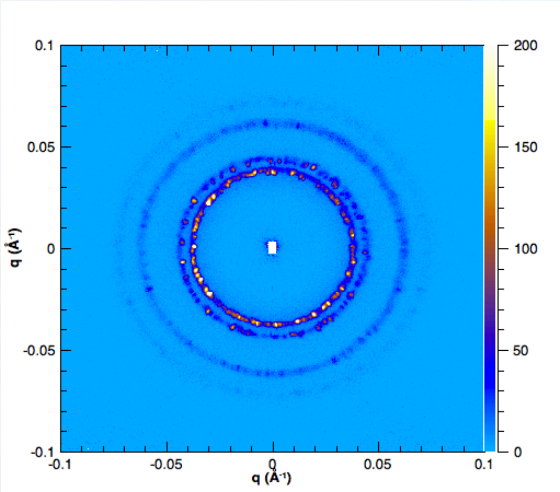
Reduction of selected wavelengths (4Å-15Å)

close packed micelles
block co-polymer F127 + 80% D2O

1D data



2D data



Resolution

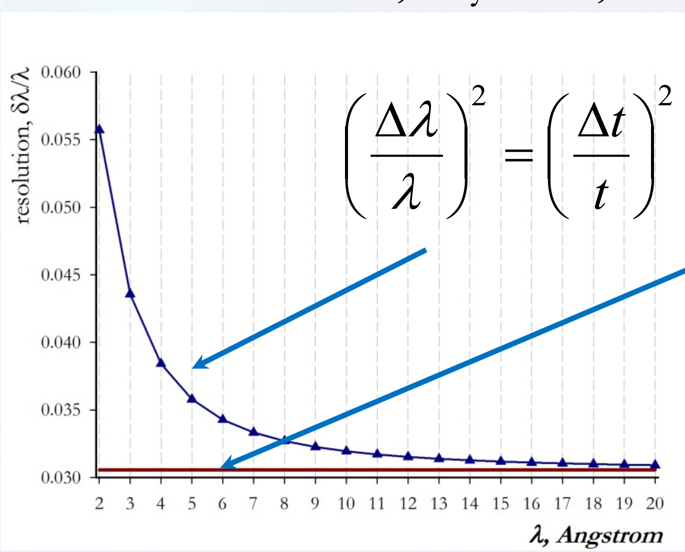
D.F.R. Mildner & J.M. Carpenter, J. Appl. Cryst. 17(1984)249-256

$$(\sigma_Q)^2 = \frac{1}{12}\left(\frac{2\pi}{\lambda}\right)^2\left[3\frac{R_1^2}{L_1^2} + 3\frac{R_2^2}{L'^2} + \frac{(\Delta R)^2}{L_2^2} + \frac{R^2}{L_2^2}\left(\frac{\Delta\lambda}{\lambda}\right)^2\right] \qquad \frac{1}{L'} = \frac{1}{L_1} + \frac{1}{L_2}$$

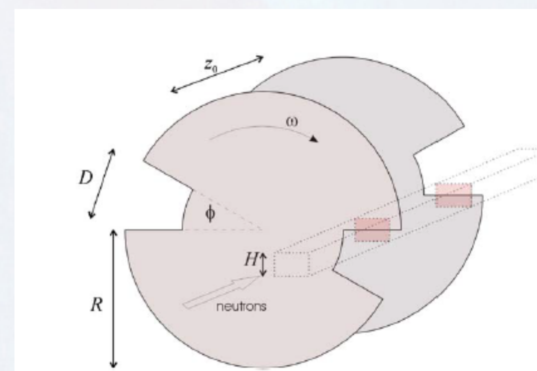
$$\left(\frac{\sigma_Q}{Q}\right)^2 = \frac{4\pi^2}{\lambda^2 Q^2}\left[\left(\frac{R_1}{2L_1}\right)^2 + \left(\frac{R_2(L_1+L_2)}{2L_1L_2}\right)^2 + \frac{1}{12}\left(\frac{\Delta R}{L_2}\right)^2\right] + \frac{1}{12}\left(\frac{\Delta\lambda}{\lambda}\right)^2 \qquad Q \approx \frac{2\pi\theta}{\lambda} \approx 2\pi\frac{R}{\lambda L_2}$$

R. Heenan. ISIS

Based on A.A. van Well, H Fredzikze "On the resolution and intensity of a time-of-flight neutron reflectometer", Physica B, 2005



$$\left(\frac{\Delta\lambda}{\lambda}\right)^2 = \left(\frac{\Delta t}{t}\right)^2 \cong \left\{\left(\frac{\tau_c}{t}\right)^2 + \left(\frac{\tau_h}{t}\right)^2\right\}$$



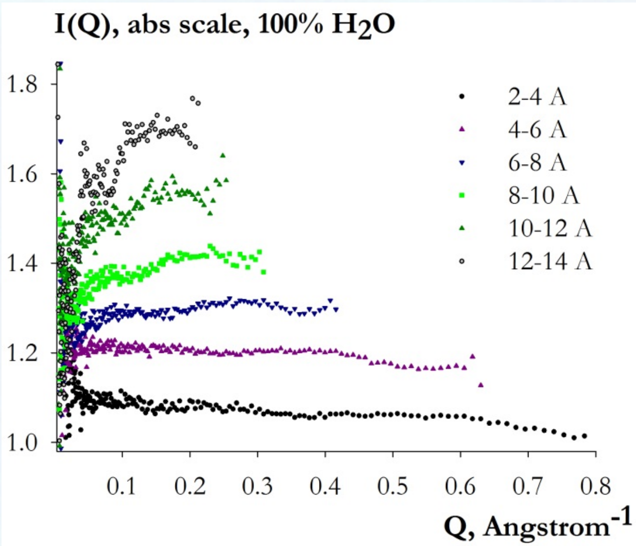
$$\tau_h = D/\omega R \qquad \tau_c/t = z_0/L$$

not considering electronics response time and detector' depth

A. Nelson and C. Dewhurst "Towards a details resolution smearing kernel for time-of-flight neutron reflectometers.", J Appl Cryst 2015

ansto — Nuclear-based science benefiting all Australians

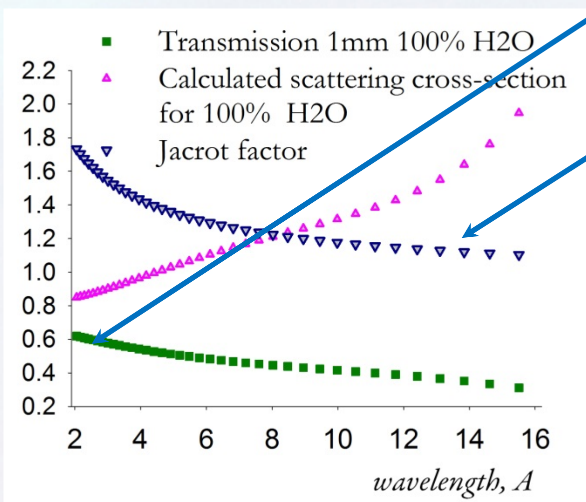
Background: elastic incoherent

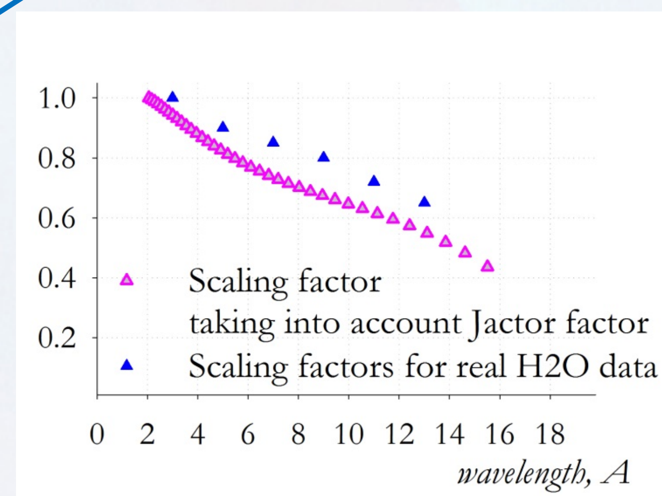


$$\frac{d\Sigma}{d\Omega}_{inc} = \frac{g_\lambda}{4\pi}\left[\varphi_H \frac{d\Sigma}{d\Omega}_{inc,H_2O} + (1-\varphi_H)\frac{d\Sigma}{d\Omega}_{inc,D_2O}\right]$$

$$\left(\frac{d\Sigma}{d\Omega}\right)_{inc} = \frac{1}{4\pi}\frac{1-T}{tT}$$

$$g_\lambda \cong 1 \Big/ \left[1-\exp\left(-0.6\lambda^{1/2}\right)\right]$$





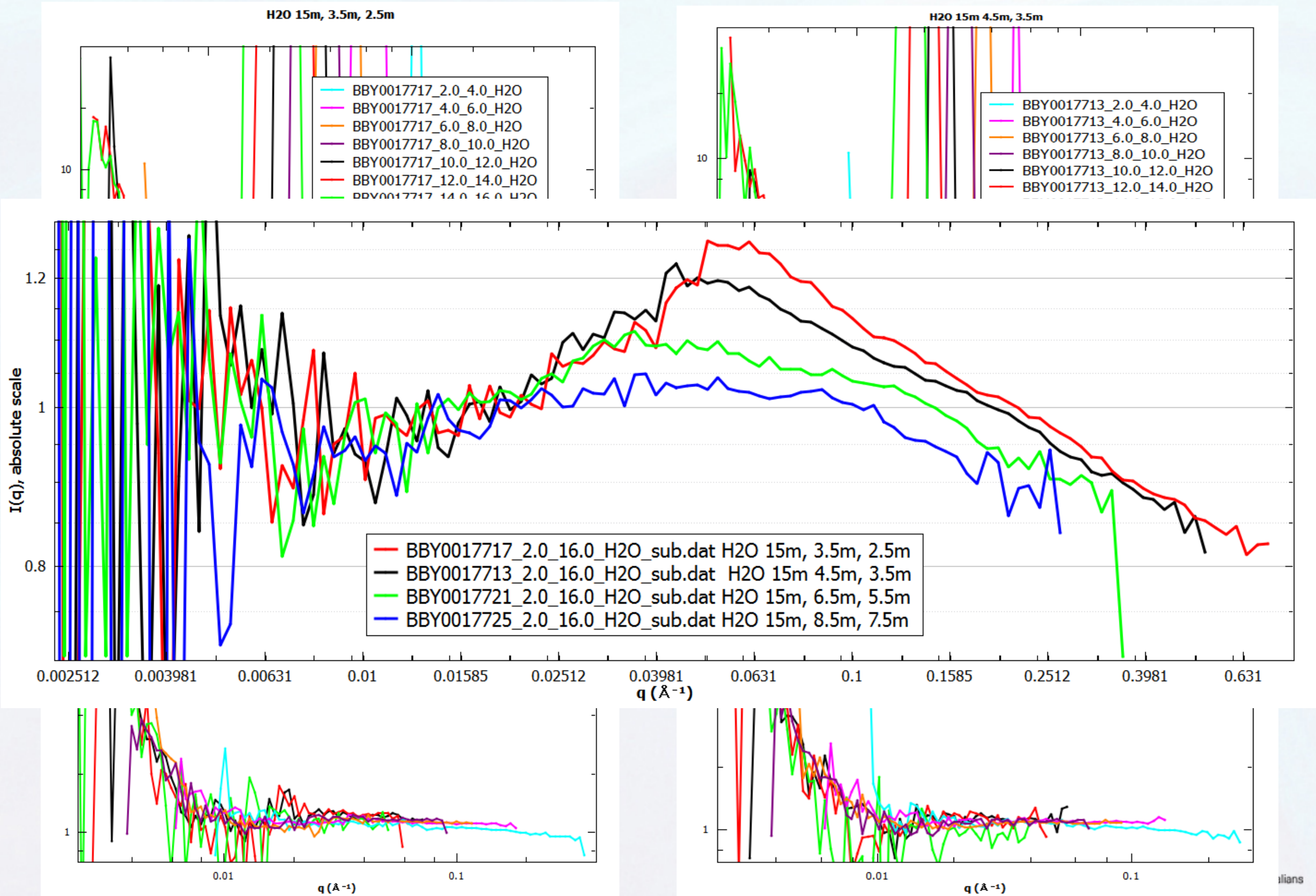
"Evaluation of incoherent scattering intensity by transmission and sample thickness", M. Shibayama et al, J Appl Cryst, 2009

Still a question: to check how seriously we see _inelastic_ component.

Papers on similar issue

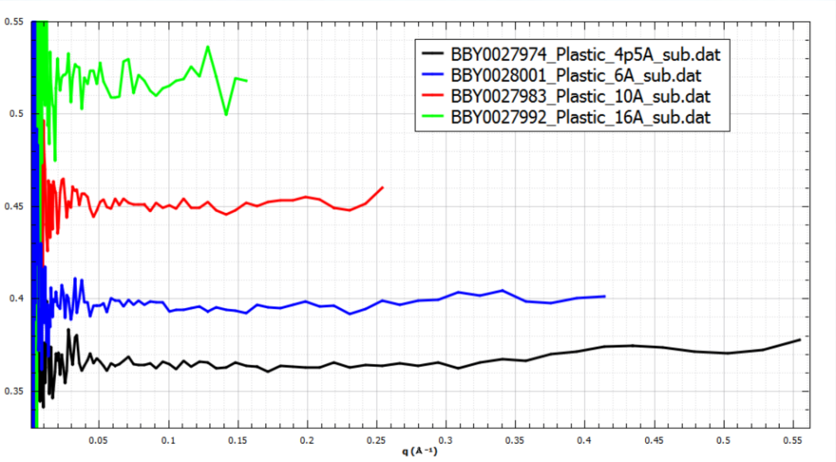
- B Jacrot, G. Zaccai, Biopolymers (1981) 20, 2413-2426
- P. Lindner J Appl Cryst (2000) 33, 807-811
- B. Jacrot 1976
- May, Ibel, Haas 1982 (1-T) correction for H/D mixture
- M. Shibayama 2005; 2009
- J. Barker
- J. Copley 1988
- R.E. Ghosh, A. Rennie, 1990
- A.R. Rennie, R.K. Heenan 1992
- W.S. Dubner, J.M. Schultz 1990
- C. Do, 2014

H2O ToF @ambient

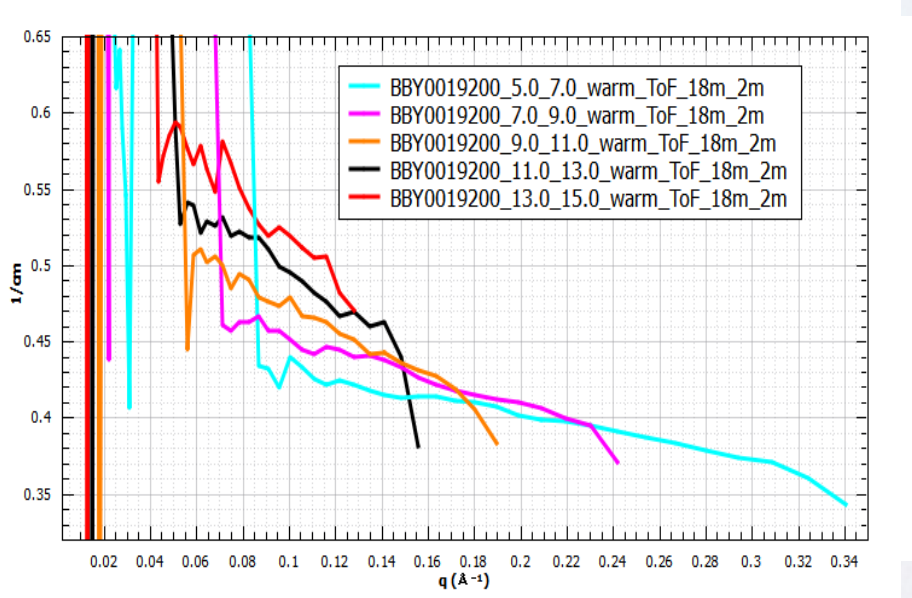


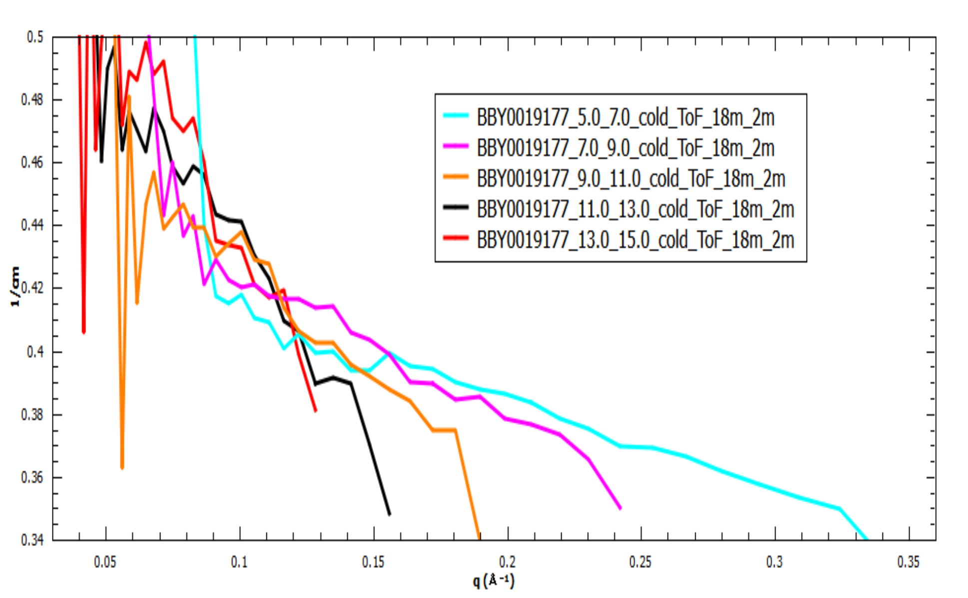
Polycarbonate

NSV Ambient



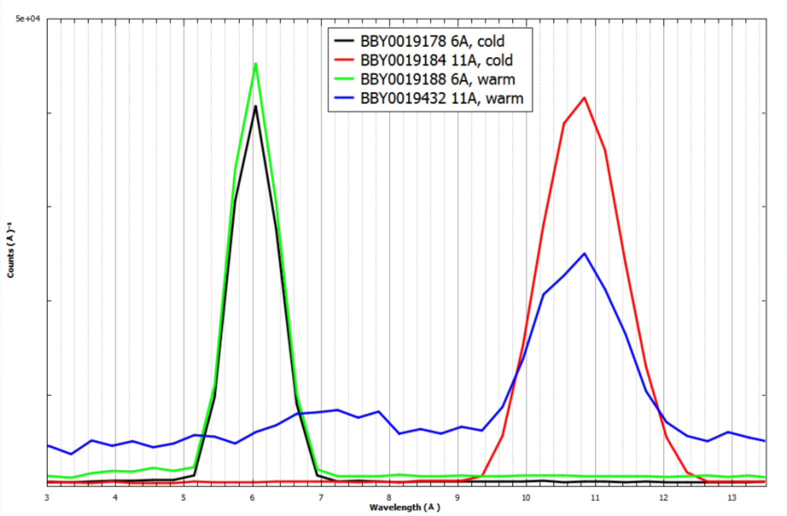
ToF Cold & ambient: cannot see much difference



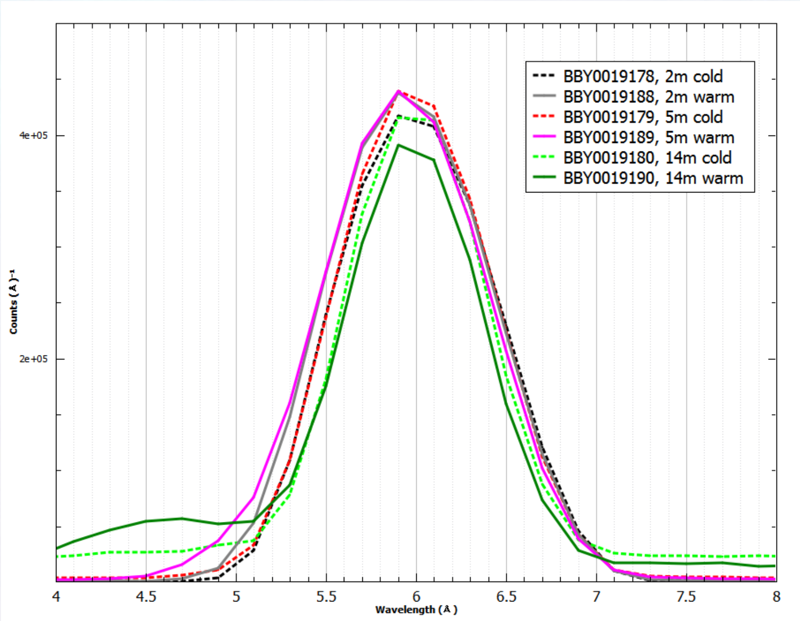


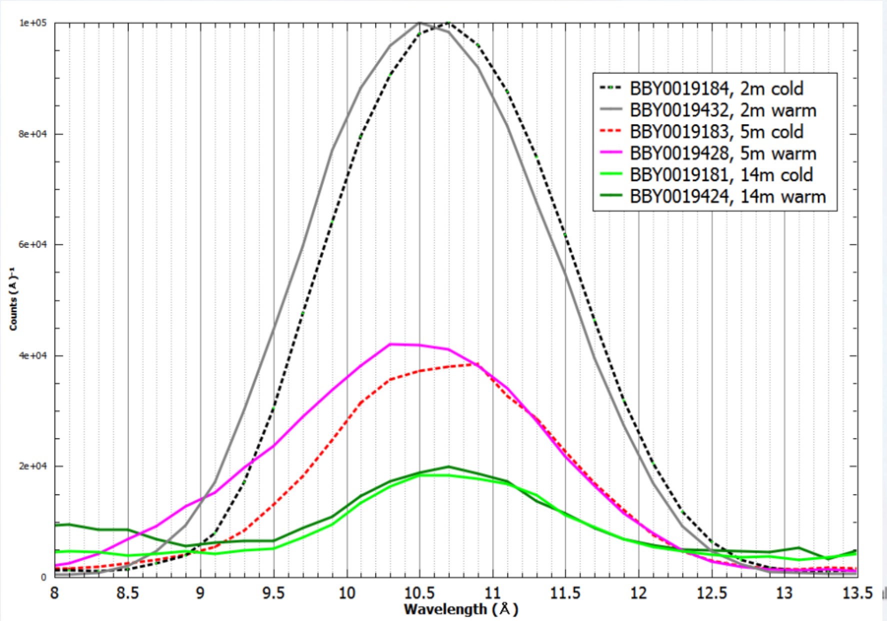
Polycarbonate

ToF wavelength spectrum, rear detector only



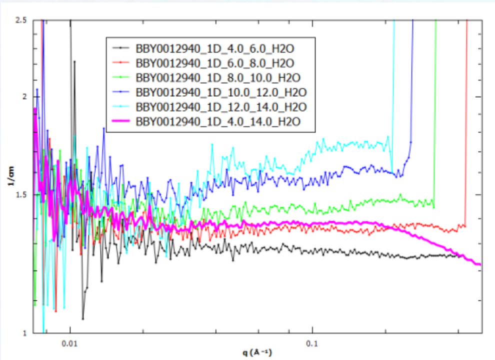
ToF wavelength spectrum, curtains only

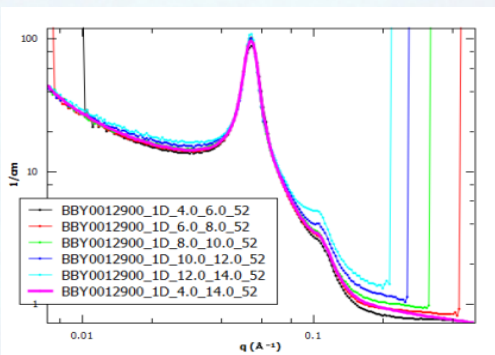


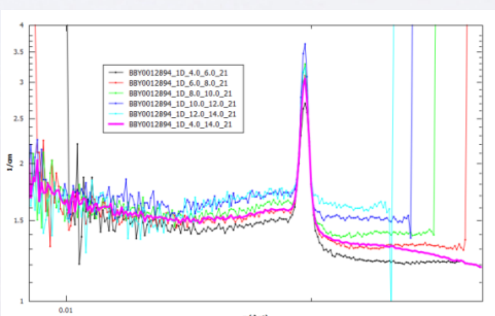


Background: selected wavelengths – in advance

Dr Rico Tabor, Monash University, Melbourne, Australia







Hydrogen from the sample:

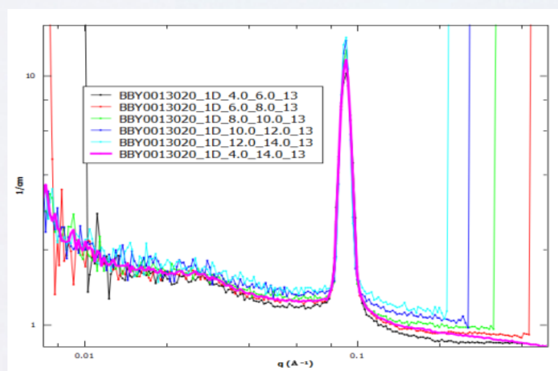
how serious the influence is?

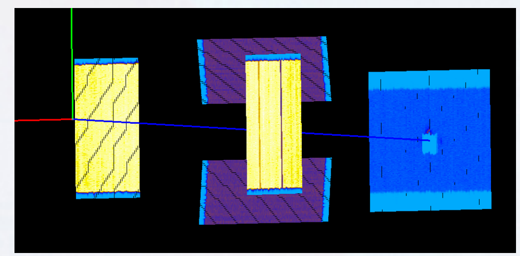
How to subtract ?

ToF – only middle wavelengths

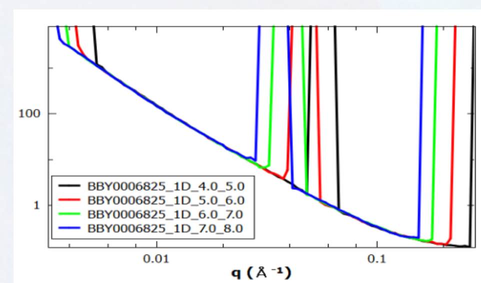
to cover desirable Q

Careful: wavelengths stitching in the background



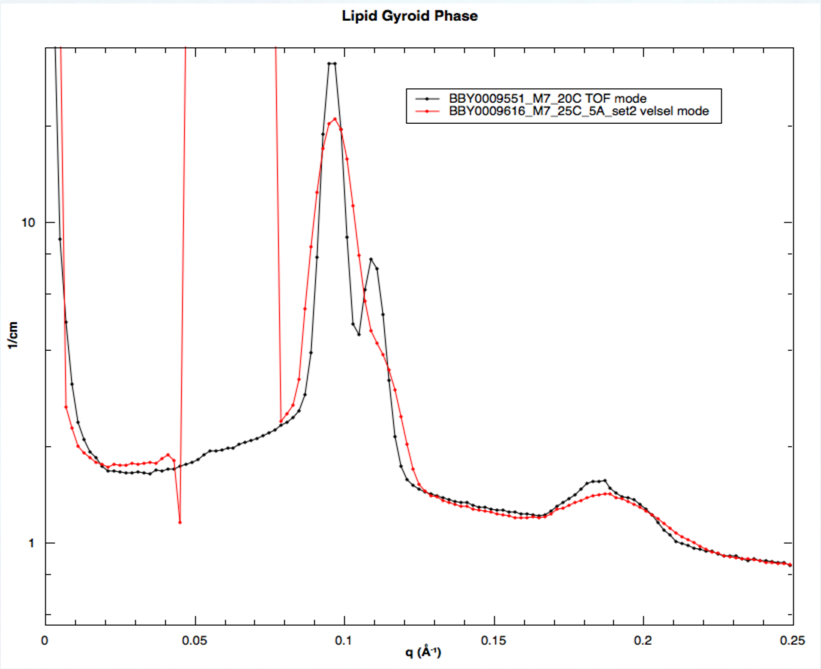


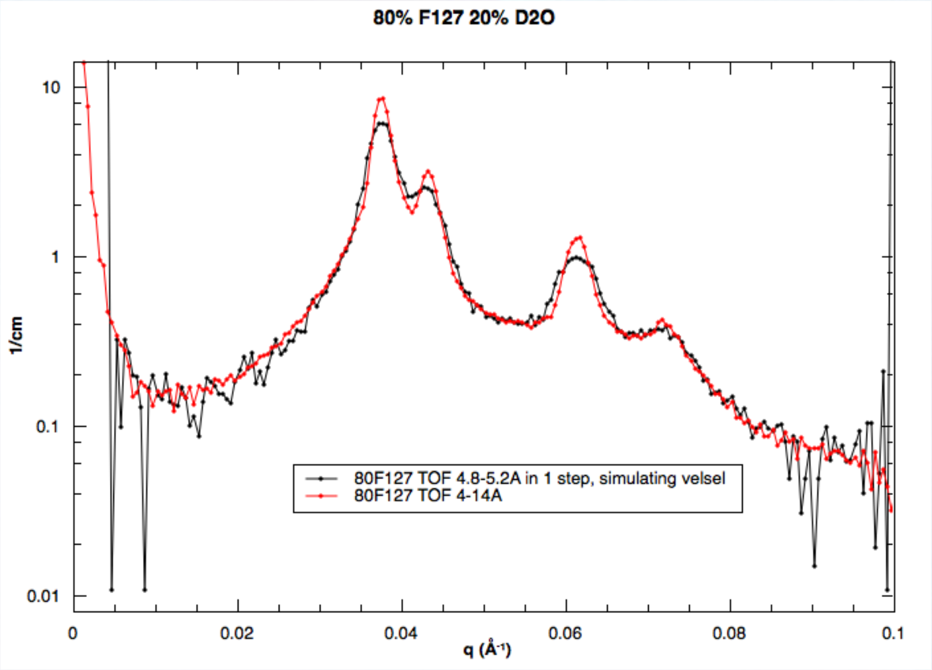
$q = 4\pi \sin\theta / \lambda$



Non-conventional set-up: NVS + ToF simultaneously

Making peaks bright and sharp
eliminating background issue, sacrificing flux

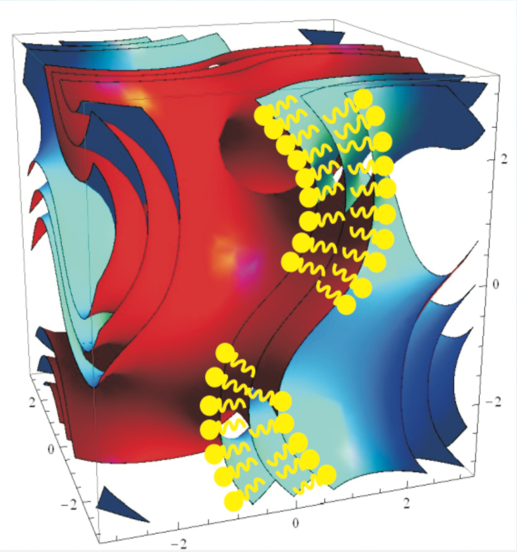




ansto
Nuclear-based science benefiting all Australians

Single transmembrane peptides during in meso crystallization

Charlotte Conn, Leonie van't Hag, Liliana de Campo, Raffaele Mezzenga



- Viscoelastic properties similar to biological membranes
- Flexible structure can partially adapt to accommodate the protein
- Able to incorporate high protein loading
- Protein can diffuse across the plane of the bilayer

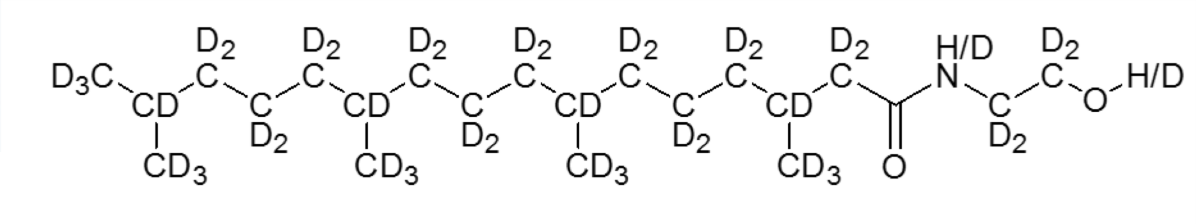
Conn, C. E.; Drummond, C. J. *Soft Matter* **2013,** 9 (13) 3449-3464
Conn, C.E. et al. *Soft Matter* **2010,** 6, (19), 4838-4846
Conn, C.E. et al. *Soft Matter* **2010,** 6, (19), 4828-4837

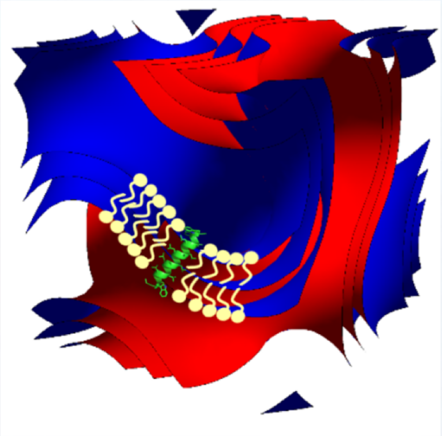
What is the mechanism of crystal growth?

How is this impacted by the nanostructure of the cubic phase?

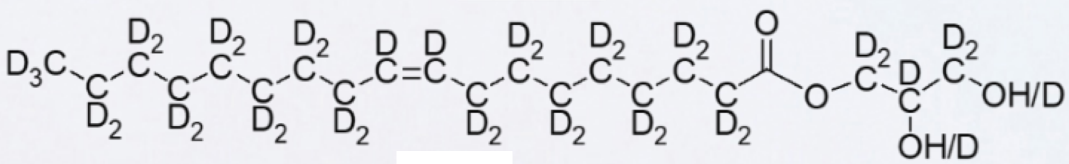
Single transmembrane peptides during in meso crystallization

Matrix: D-PE (phytanoyl monoethanolamide)





Matrix: D-MO (monoolein)



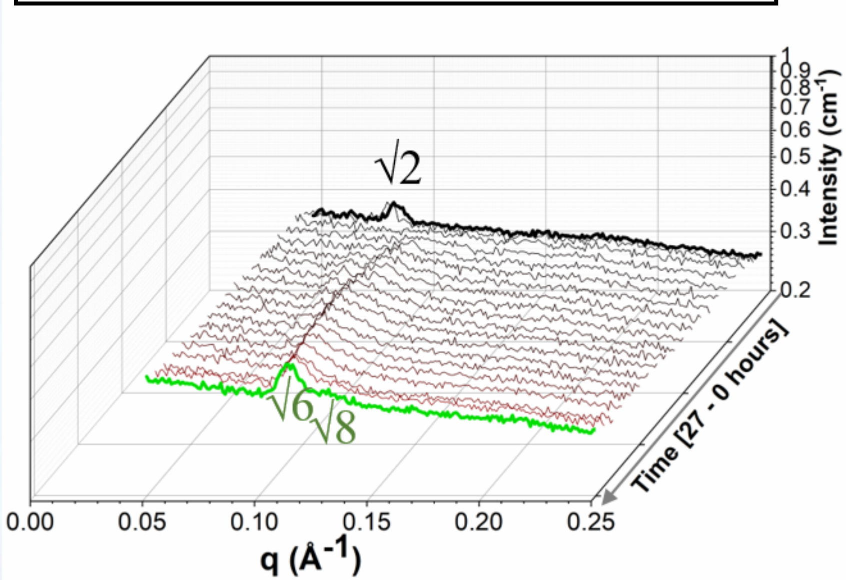
van 't Hag et al. *J. Phys. Chem. Lett.* 2016 7 (14) 2862-2866

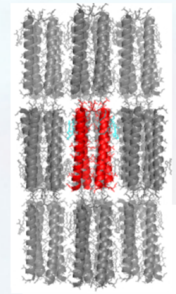
van 't Hag et al., Langmuir, 2019

Nuclear-based science benefiting all Australians

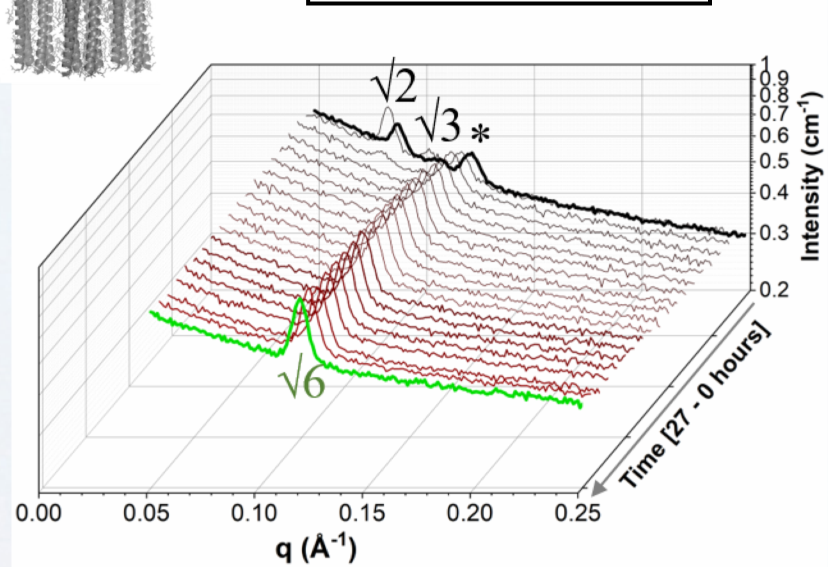
Single transmembrane peptides during in meso crystallization

No peptide, MO9 cubic matrix





DAP12, peptide



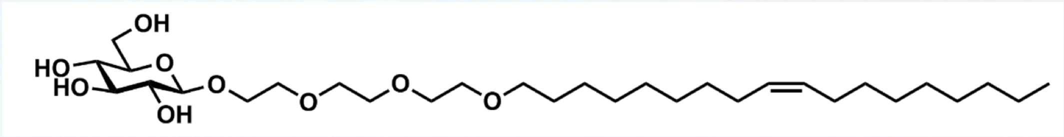
- Transition from diamond cubic phase to gyroid cubic phase (effect of screen)
- More contrast so higher peak intensity. Scattering is mainly from the peptide.
- Variations in peak intensity reflect peptide behaviour.

van 't Hag et al., Langmuir, 2019

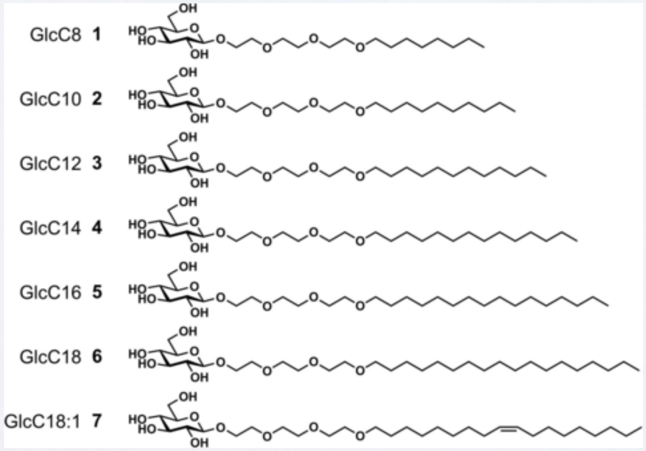
ansto
Nuclear-based science benefiting all Australians

Wormlike micelle formation of novel alkyl-tri (ethylene glycol)-glucoside carbohydrate surfactants: structure–function relationships and rheology

Aim: To synthesise and characterise new carbohydrate-based surfactants with a focus on potential applications.



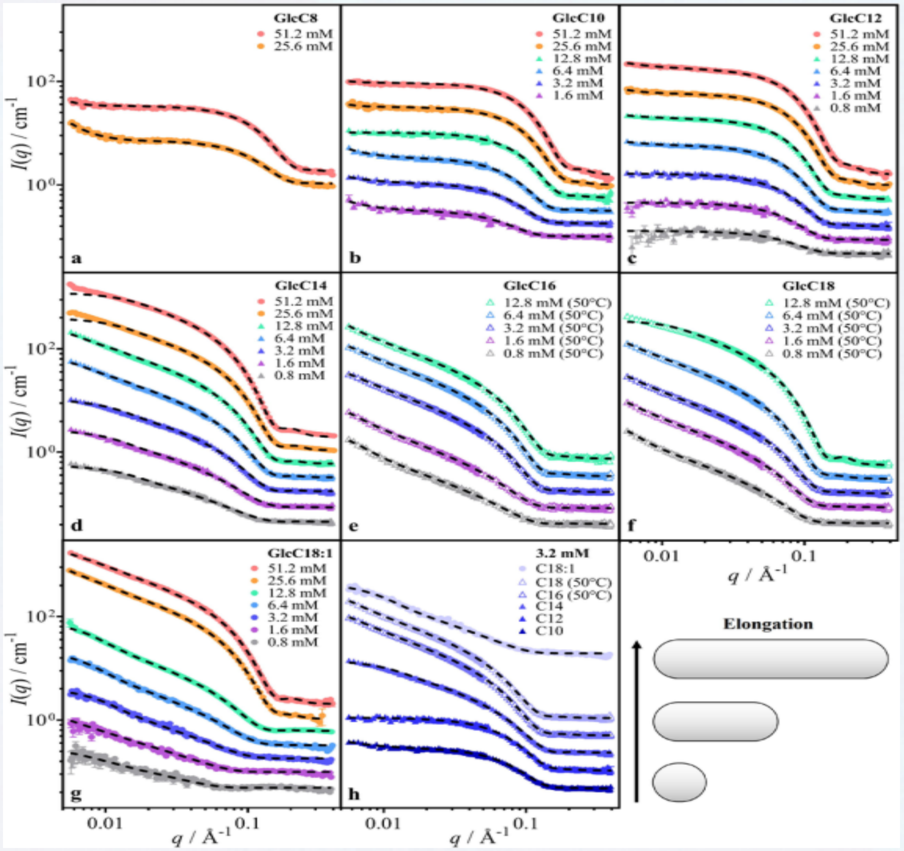
Sugar ———— tri(ethylene glycol) ———— alkyl



Jackson E. Moore, Thomas M. McCoy, Liliana de Campo, Anna V. Sokolova, Christopher J. Garvey, Graeme Pearson, Brendan L. Wilkinson, Rico F. Tabor
Journal of Colloid and Interface Science 529 (2018) 464–475

Wormlike micelle formation of novel alkyl-tri (ethylene glycol)-glucoside carbohydrate surfactants: structure–function relationships and rheology

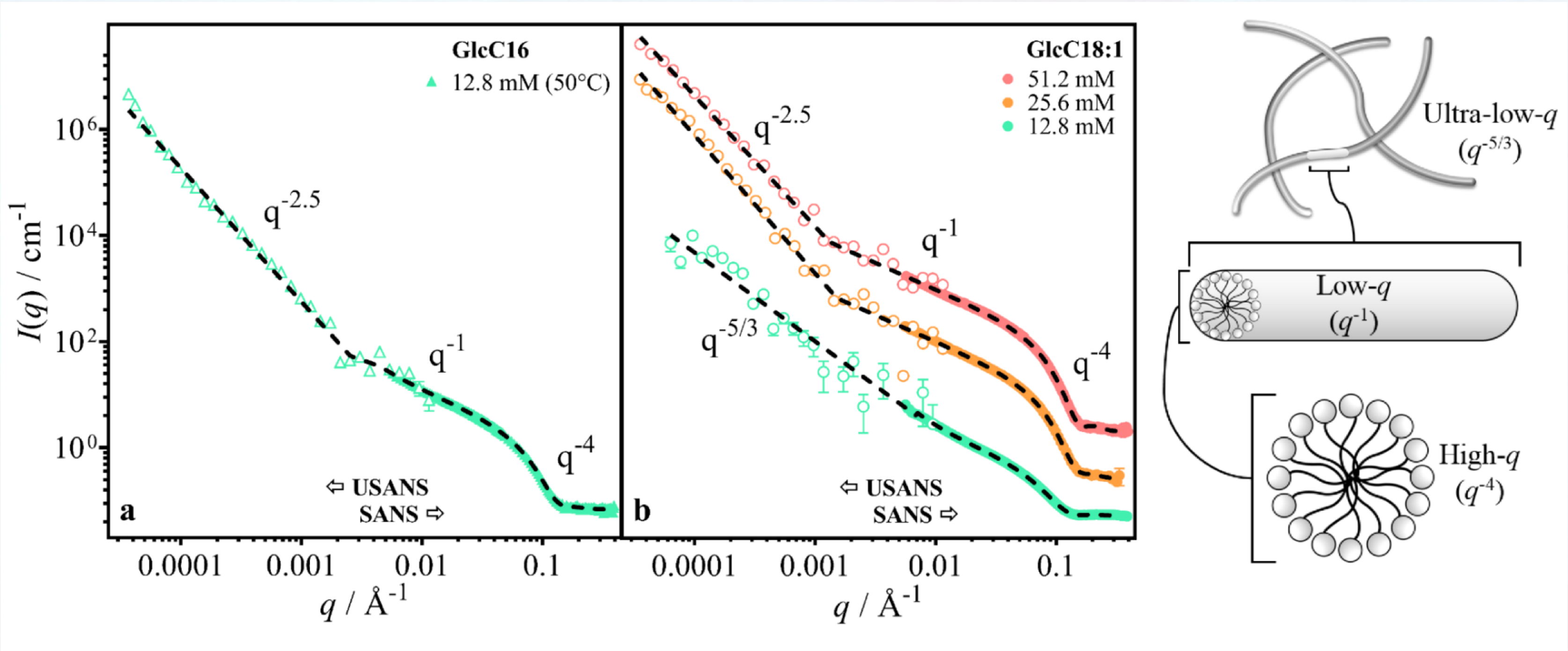
- Short chain (C8, C10) form spherical micelles
- C12 starts to elongate
- C14 pronounced rods
- C16/C18 Krafft point ~45°C; insoluble at 25°C, long cylinders/worms @ 50°C
- C18:1 worms @ 25°C!
  In summary: increasing tail length increases effective packing parameter = spheres → rods → worms
- *cis* unsaturation decreases crystallinity



J.E. Moore et al Journal of Colloid and Interface Science 2018 529, 464–475

Wormlike micelle formation of novel alkyl-tri (ethylene glycol)-glucoside carbohydrate surfactants: structure–function relationships and rheology

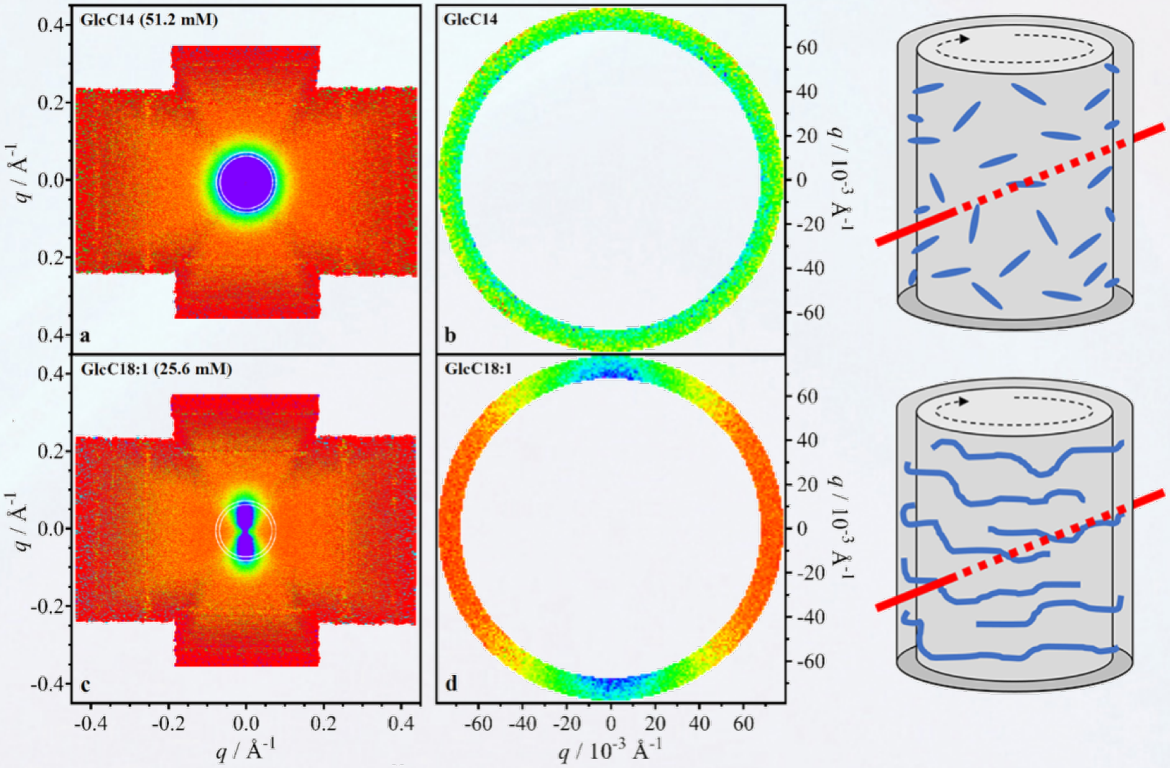
- **USANS allows exploration of wormlike micelles at longer length-scales**



Nuclear-based science benefiting all Australians

J.E. Moore et al Journal of Colloid and Interface Science 2018 529, 464–475

Wormlike micelle formation of novel alkyl-tri (ethylene glycol)-glucoside carbohydrate surfactants: structure–function relationships and rheology



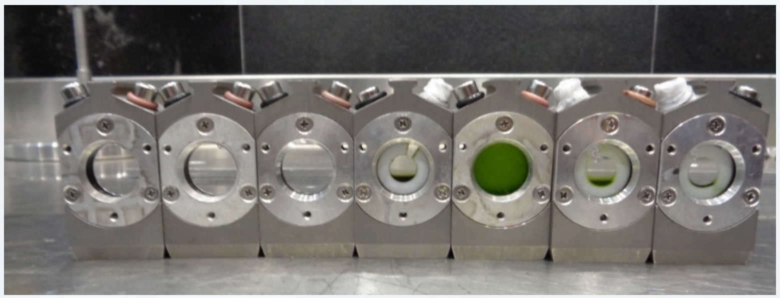
C14 tail = rods
No alignment
under shear

C18:1 tail = worms
Strong alignment under
shear

J.E. Moore et al Journal of Colloid and Interface Science 2018 529, 464–475

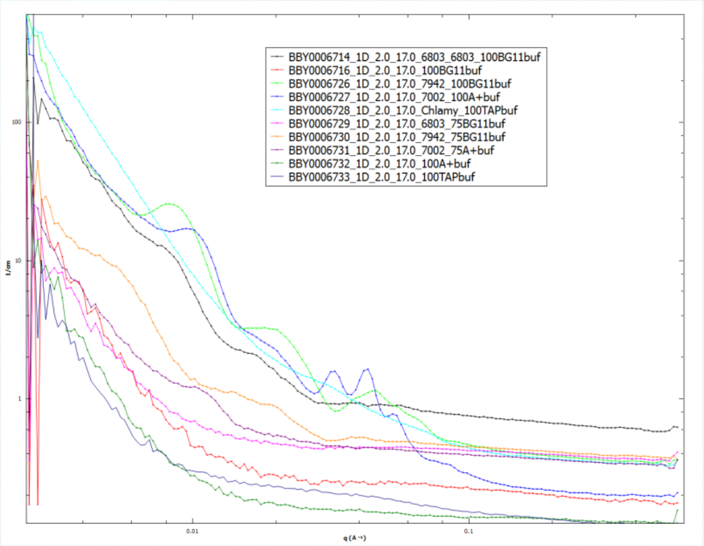
Photosynthetic systems in cyanobacteria & leaves

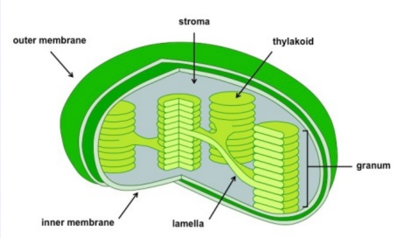
Jacob J K Kirkensgaard **(**University of Copenhagen, Denmark**)**
Kell Mortensen **(**University of Copenhagen, Denmark**)**
Dainius Jakubauskas **(**University of Copenhagen, Denmark**)**
Chris Garvey (ANSTO, Quokka instrument)



Preliminary work:
Optical microscopy

SANS: characteristic distances inside thylakoids

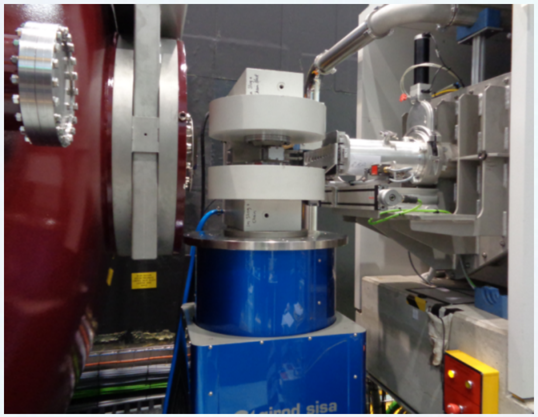




Nuclear-based science benefiting all Australians

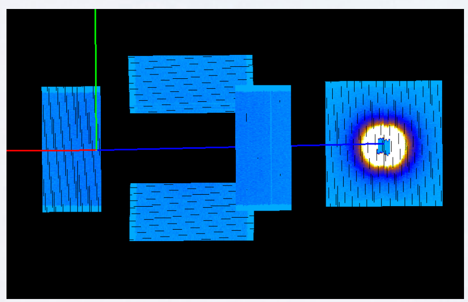
Carbide precipitation kinetics in cryogenically treated tool steels

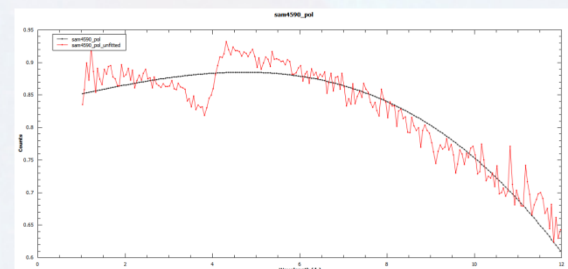
Nicole Stanford (Monash Uni) & Kathleen Wood (ANSTO)
Ajesh Antony (Deakin Uni) & Thomas Dorin (Deakin Uni)

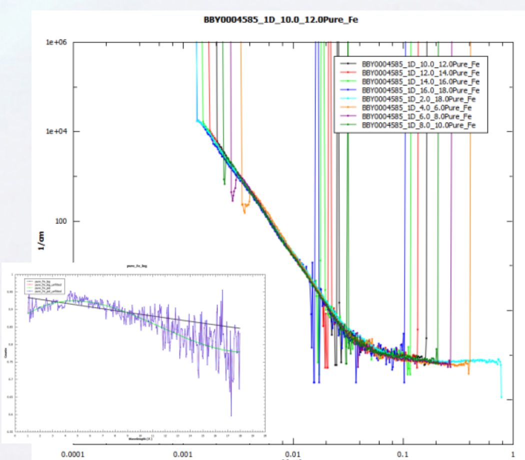


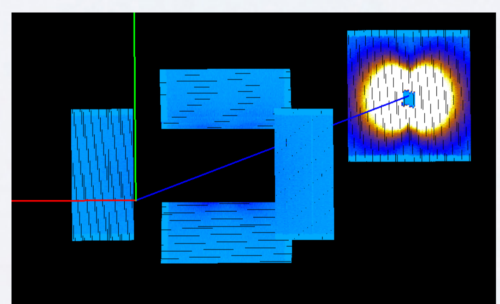
Preliminary work:
Optical microscopy; Lab-scale x-ray diffraction
Transmission electron microscopy;
Atom probe tomography

SANS: the size and volume fraction of precipitates @ 1T



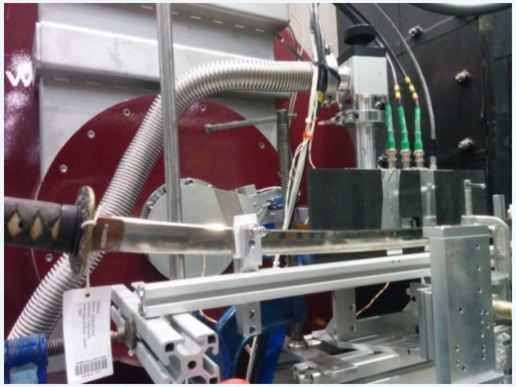






Nuclear-based science benefiting all Australians

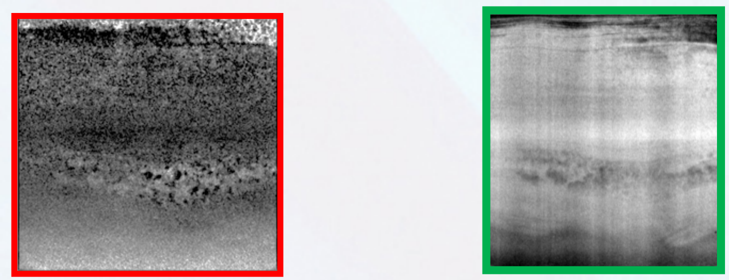
Non-standard set-up: imaging with cold neutrons
The Samurai Sword

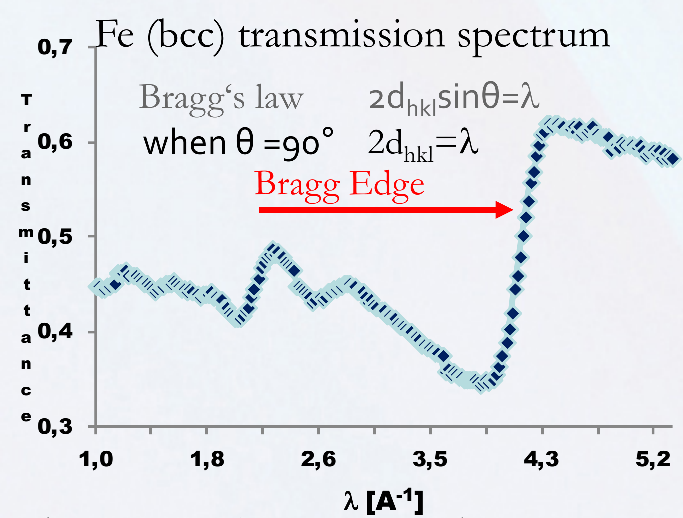


A. Tremsin et al "Energy-resolved neutron imaging options at a small angle neutron scattering instrument at the Australian Center for Neutron Scattering"

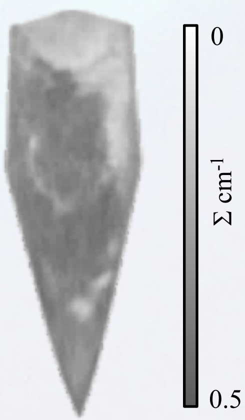
"Review of scientific instruments", 2019

ToF Bragg-edge transmission analysis

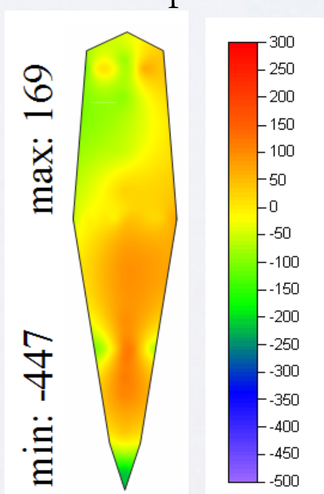




Dingo: Tomographic cross section



Kowari: Residual stress map



- Morphology
- Structure
- Porosities
- Defects

- Stress components
- d_0-value
- peak width

Shape, magnitude and location of the Bragg edges can be correlated to texture, crystalline phase, crystallite size, and lattice strain

ansto
Nuclear-based science benefiting all Australians

Bilby papers (those with pages)

1. Dorishetty, P; Balu, R; Sreekumar, A; De Campo, L; Mata, JP; Choudhury, NR and Dutta, NK, Robust and Tunable Hybrid Hydrogels from Photo-Cross-Linked Soy Protein Isolate and Regenerated Silk Fibroin, *ACS Sustainable Chemistry and Engineering* **7**(10), 9257-9271 (2019) (**from BILBY, KOOKABURRA, QUOKKA**) DOI
2. Kihara, S; van der Heijden, NJ; Seal, CK; Mata, J; Whitten, AE; Köper, I and McGillivray, DJ, Soft and hard interactions between polystyrene nanoplastics and human serum albumin protein corona, *Bioconjugate Chemistry* **30**(4), 1067-1076 (2019) (**from BILBY**) DOI
3. Loy, CW; Matori, KA; Zainuddin, N; Whitten, AE; de Campo, L; Nasir, NIM; Pallan, NFB; Zaid, MHM; Zarifah, NA and Schmid, S, Small Angle Neutron Scattering Study of a Gehlenite-Based Ceramic Fabricated from Industrial Waste, *Solid. State Phenom.* **290**, 22-28 (2019) (**from BILBY**) DOI
4. McCoy, TM; King, JP; Moore, JE; Kelleppan, VT; Sokolova, AV; de Campo, L; Manohar, M; Darwish, TA and Tabor, RF, The effects of small molecule organic additives on the self-assembly and rheology of betaine wormlike micellar fluids, *J. Colloid Interface Sci.* **534**, 518-532 (2019) (**from BILBY**) DOI
5. Moore, JE; McCoy, TM; Sokolova, AV; de Campo, L; Pearson, GR; Wilkinson, BL and Tabor, RF, Worm-like micelles and vesicles formed by alkyl-oligo(ethylene glycol)-glycoside carbohydrate surfactants: The effect of precisely tuned amphiphilicity on aggregate packing, *J. Colloid Interface Sci.* **547**, 275-290 (2019) (**from BILBY, KOOKABURRA**) DOI
6. Sokolova, A; Whitten, AE; de Campo, L; Christoforidis, J; Eltobaji, A; Barnes, J; Darmann, F and Berry, A, Performance and characteristics of the BILBY time-of-flight small-angle neutron scattering instrument, *J. Appl. Crystallogr.* **52**, 1-12 (2019) (**from BILBY**) DOI
7. Tremsin, AS; Sokolova, AV; Salvemini, F; Luzin, V; Paradowska, A; Muransky, O; Kirkwood, HJ; Abbey, B; Wensrich, CM and Kisi, EH, Energy-resolved neutron imaging options at a small angle neutron scattering instrument at the Australian Center for Neutron Scattering, *Rev. Sci. Instrum.* **90**(3), 035114 (2019) (**from BILBY**) DOI
8. Baek, P.; Mata, J. P.; Sokolova, A.; Nelson, A.; Aydemir, N.; Shahlori, R.; McGillivray, D. J.; Barker, D. & Travas-Sejdic, J., Chain Shape and Thin Film Behaviour of Poly(thiophene)-graft-poly(acrylate urethane), *Soft Matter* **14**, 6875-6882 (2018) (**from BILBY, PLATYPUS**) DOI
9. Brice, CA; Tayon, WA; Newman, JA; Kral, MV; Bishop, C and Sokolova, A, Effect of compositional changes on microstructure in additively manufactured aluminum alloy 2139, *Mater. Charact.* **143**, 50-58 (2018) (**from BILBY**) DOI
10. Jang, JD; Bang, J; Han, YS; Sokolova, A and Kim, TH, Phase behaviors of a mixture of two kinds of Pluronic triblock copolymers in aqueous solution, *Phys. B* **551**, 184-190 (2018) (**from BILBY**) DOI
11. Jiang, B; Guo, Y; Kim, J; Whitten, AE; Wood, K; Kani, K; Rowan, AE; Henzie, J and Yamauchi, Y, Mesoporous Metallic Iridium Nanosheets, *J. Am. Chem. Soc.* **140**(39), 12434-12441 (2018) (**from BILBY**) DOI
12. Kelleppan, VT; Moore, JE; McCoy, TM; Sokolova, AV; de Campo, L; Wilkinson, BL and Tabor, RF, Self-Assembly of Long-Chain Betaine Surfactants: Effect of Tailgroup Structure on Wormlike Micelle Formation, *Langmuir* **34**(3), 970-977 (2018) (**from BILBY**) DOI
13. Kiani, A; Sakurovs, R; Grigore, M and Sokolova, A, Gas sorption capacity, gas sorption rates and nanoporosity in coals, *International Journal of Coal Geology* **200**, 77-86 (2018) (**from BILBY**) DOI
14. Lee, KJ and Yun, SI, Nanocomposite hydrogels based on agarose and diphenylalanine, *Polymer* **139**, 86-97 (2018) (**from BILBY**) DOI
15. Loy, CW; Whitten, AE; de Campo, L; Appadoo, D; Zainuddin, N; Matori, KA; Rehm, C; Sokolova, A; Wang, C; Xia, Q; Whittle, TA; and Schmid, S., Investigation of the siliceous hydrogel phase formation in glass-ionomer cement paste , *Phys. B* **551**, 287-290 (2018) (**from BILBY**) DOI
16. Marlow, JB; Pottage, MJ; McCoy, TM; De Campo, L; Sokolova, A; Bell, TDM and Tabor, RF, Structural and rheological changes of lamellar liquid crystals as a result of compositional changes and added silica nanoparticles, *Phys. Chem. Chem. Phys.* **20**(24), 16592-16603 (2018) (**from BILBY**) DOI
17. McCoy, TM; De Campo, L; Sokolova, AV; Grillo, I; Izgorodina, EI and Tabor, RF, Bulk properties of aqueous graphene oxide and reduced graphene oxide with surfactants and polymers: Adsorption and stability, *Phys. Chem. Chem. Phys.* **20**(24), 16801-16816 (2018) (**from BILBY, KOOKABURRA**) DOI
18. Moore, JE; McCoy, TM; de Campo, L; Sokolova, AV; Garvey, CJ; Pearson, G; Wilkinson, BL and Tabor, RF, Wormlike micelle formation of novel alkyl-tri(ethylene glycol)-glucoside carbohydrate surfactants: Structure–function relationships and rheology, *J. Colloid Interface Sci.* **529**, 464-475 (2018) (**from BILBY, KOOKABURRA, QUOKKA**) DOI
19. Sakurovs, R; Koval, L; Grigore, M; Sokolova, A; Ruppert, LF and Melnichenko, YB, Nanometre-sized pores in coal: Variations between coal basins and coal origin, *International Journal of Coal Geology* **186**, 126-134 (2018) (**from BILBY**) DOI
20. Sakurovs, R; Koval, L; Grigore, M; Sokolova, A; de Campo, L and Rehm, C, Nanostructure of cokes, *International Journal of Coal Geology* **188**, 112-120 (2018) (**from BILBY, KOOKABURRA**) DOI
21. Subianto, S; Balu, R; De Campo, L; Sokolova, A; Dutta, NK and Choudhury, NR, Sulfonated Thiophene Derivative Stabilized Aqueous Poly(3-hexylthiophene):Phenyl-C61-butyric Acid Methyl Ester Nanoparticle Dispersion for Organic Solar Cell Applications, *ACS Appl. Mater. Interfaces* **10**(50), 44116-44125 (2018) (**from BILBY, KOOKABURRA**) DOI
22. Baek, P; Aydemir, N; An, Y; Chan, EWC; Sokolova, A; Nelson, A; Mata, JP; McGillivray, D; Barker, D and Travas-Sejdic, J, Molecularly Engineered Intrinsically Healable and Stretchable Conducting Polymers, *Chem. Mater.* **20**(29), 8850-8858 (2017) (**from BILBY**) DOI
23. Iqbal, M; Li, C; Wood, K; Jiang, B; Takei, T; Dag, Ö; Baba, D; Nugraha, AS; Asahi, T; Whitten, AE; Hossain, MSA; Malgras, V and Yamauchi, Y, Continuous Mesoporous Pd Films by Electrochemical Deposition in Nonionic Micellar Solution, *Chem. Mater.* **29**(15), 6405-6413 (2017) (**from BILBY**) DOI

ansto

Nuclear-based science benefiting all Australians

Bilby, Quokka, Kookaburra references

- "Performance and characteristics of the BILBY time-of-flight small-angle neutron scattering instrument"

Sokolova A. et al, J. Appl. Crystlography , 52, p.1-12 (2019)

- "QUOKKA, the pinhole small-angle neutron scattering instrument at the OPAL Research Reactor, Australia: design, performance, operation and scientific highlights "

Wood, K et al, J. Appl. Crystallography , 51(2), p.294-314 (2018)

- "Design and performance of the variable-wavelength Bonse–Hart ultra-small-angle neutron scattering diffractometer KOOKABURRA at ANSTO"

Rehm C. at al, J. Appl. Crystallography, 51(1), p.1-8 (2018)

User access

https://www.ansto.gov.au/research/facilities/australian-centre-for-neutron-scattering

Neutrons proposals call: twice a year, 15 March & 15 September

https://www.ansto.gov.au/research/facilities/national-deuteration-facility