J-PARC中性子小中角散乱装置"大観"(TAIKAN)の建設と性能

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中性子バイオ・ソフトマターサイエンス ワークショップ, Jul. 7, 2009, 東京

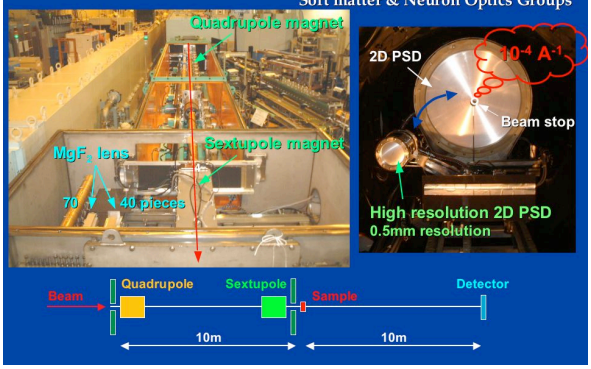
Outline

1. SANS-J-II (JRR-3)のUpgrade, 技術と経験の蓄積
2. SANS装置(J-PARC)に求められる性能
3. TAIKAN (J-PARC)の開発と性能
4. まとめ

J-PARC Japan Proton Accelerator Research Complex

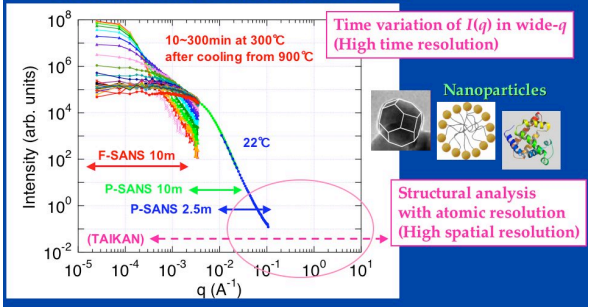
Upgrade of SANS-J-II (JRR-3), 2004~2007

Soft matter & Neuron Optics Groups



Success of upgrade, …… and requirements

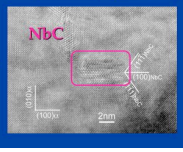
ex. Phase transformation of bainite steel



TAIKAN - Requirements for performance -

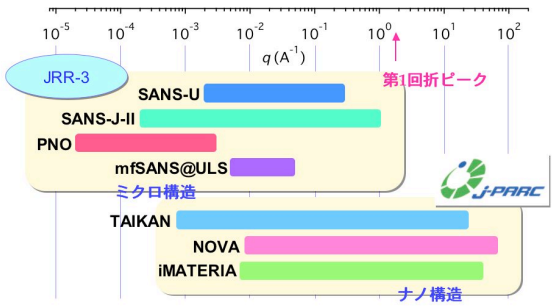
- Recent progress in nano science (nano structure and electronic state) and research of multi-phase, multi-component system and nonequilibrium system
- Efficient measurement with higher spatial resolution and higher time resolution

ex1. Pd 
polyhedron ≠ sphere
ferromagnetism on surface
quantum size effect, surface effect
Properties of nanoparticle

ex2. 

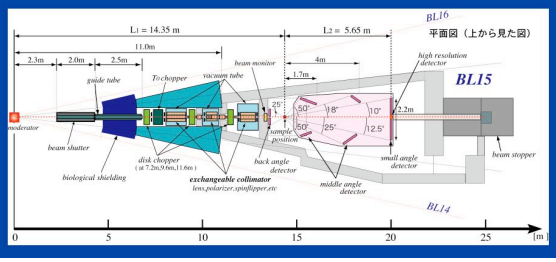
Mechanism of hydrogen inducing brittlement in high-strength steels which posing engineering problem in the context of a hydrogen economy

中性子小角散乱(が測れる)装置群 - 7台の装置 -



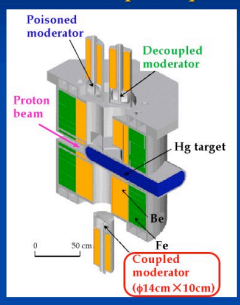
TAIKAN - Total system -

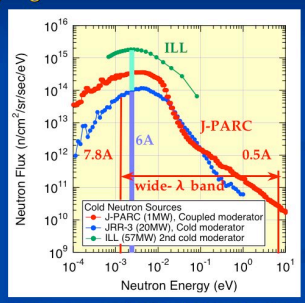
波長帯域： λ =0.5～8A
飛行距離： L_{total}=20m (L_1=14.35m, max{L_2}=5.65m)
散乱角： 2θ =0.2～50° (小中角バンク), 150～175° (高角バンク)
q領域： q=5×10^{-4}～6.6A^{-1} (小中角バンク), 1.5～15A^{-1} (高角バンク)



TAIKAN - Neutron source -

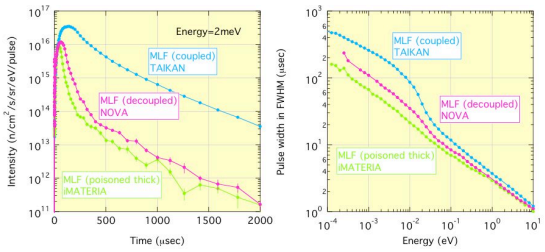
BL15 (Coupled liquid hydogen moderator)





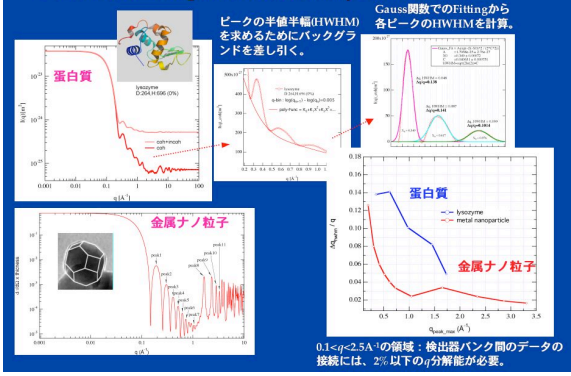
Time-averaged intensity@moderator

Pulse structures - Coupled, Decoupled, Poisoned -



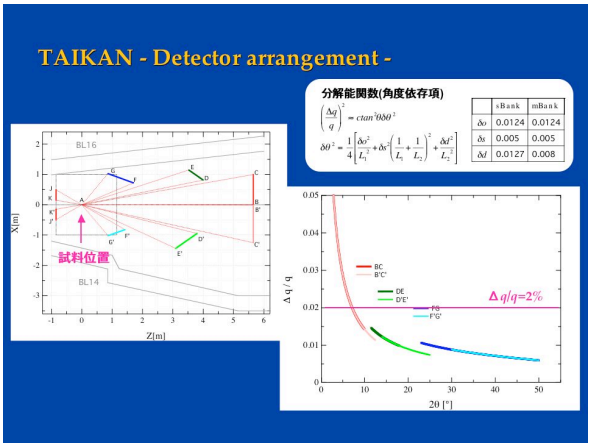
TAIKAN - Requirements for q-resolution -

Takata, et al.

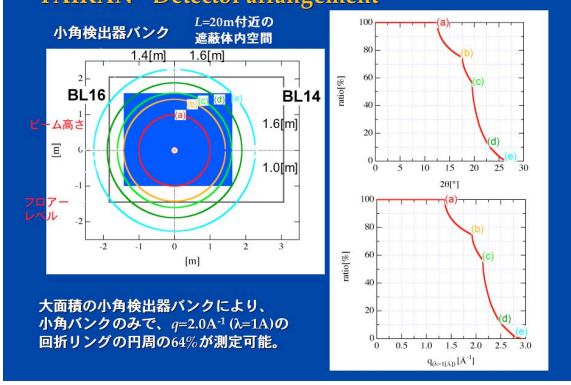


0.1<q<2.5A^{-1}の領域：検出器バンク間のデータの接続には、2%以下のq分解能が必要。

TAIKAN - Detector arrangement -



TAIKAN - Detector arrangement -

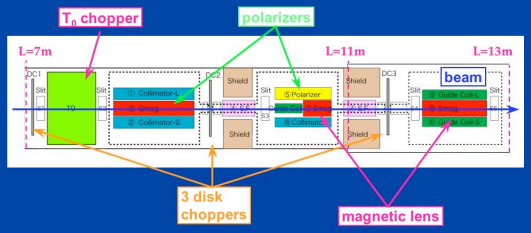


大面積の小角検出器バンクにより、小角バンクのみで、q=2.0A^{-1} (λ=1A)の回折リングの円周の64%が測定可能。

TAIKAN - Advanced neutron optics -

Shinohara, et al.

Efficient usage of intense beam

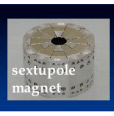


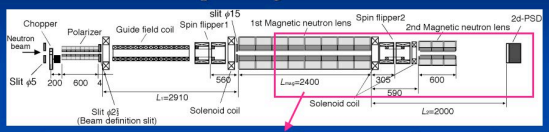
Recovery of decline in q resolution caused by limited path length

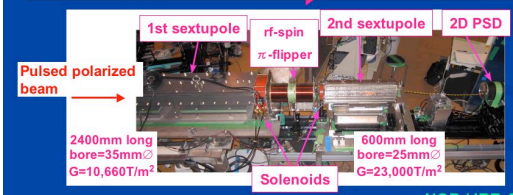
- Magnetic lens -

Oku, et al.

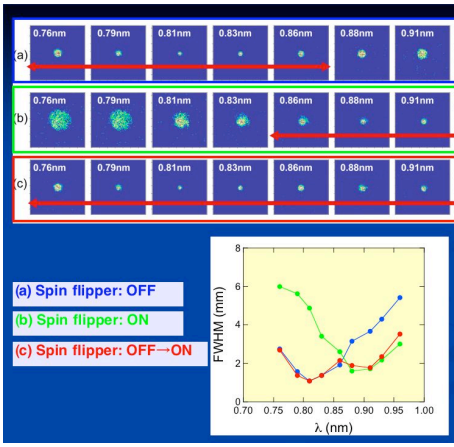
Demonstration of focusing pulsed neutrons with a double sextupole magnet





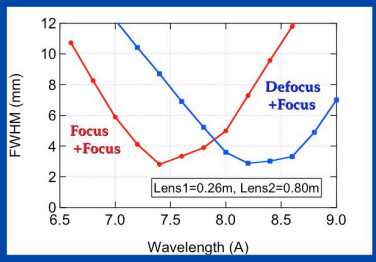


NOP (JRR-3) port



TAIKAN - Beam focusing by magnetic lens-

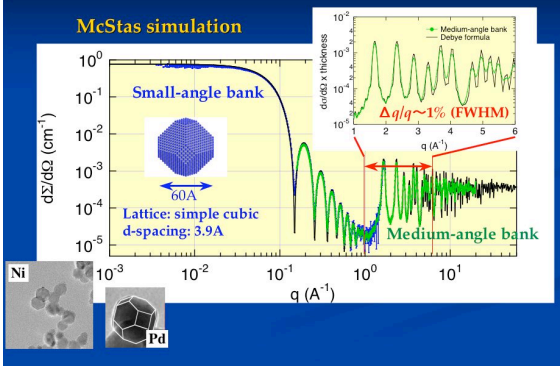
Shinohara, et al.



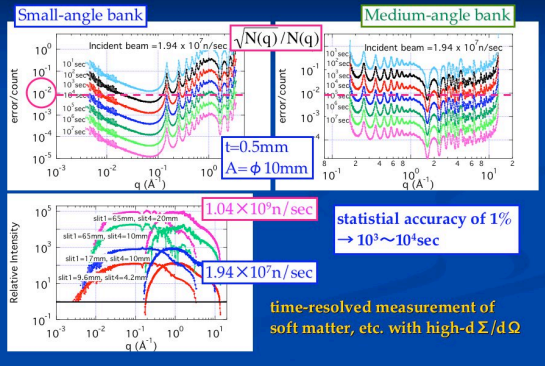
TAIKAN - q range, q resolution -

Shinohara, et al.

McStas simulation



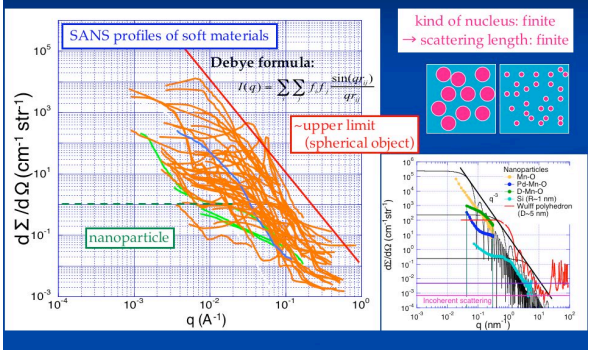
TAIKAN - Efficiency of measurements -



statistial accuracy of 1%
→ 10^3~10^4sec

time-resolved measurement of soft matter, etc. with high-d Σ/d Ω

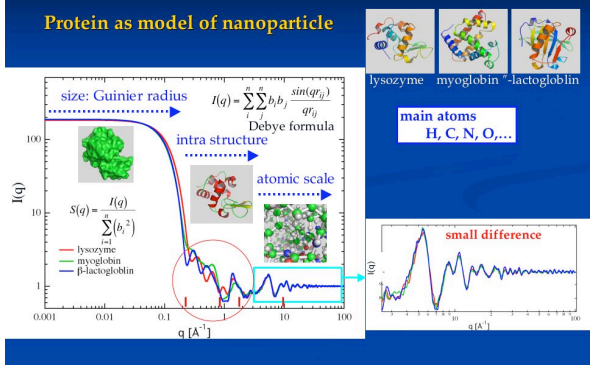
- dΣ/dΩ for various systems -



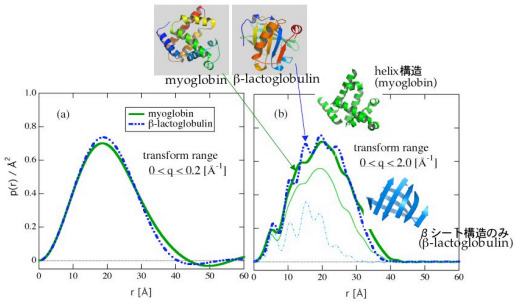
- Nanostructural analysis in wide-q -

Takata, et al.

Protein as model of nanoparticle



広域空間測定により得られる分布関数の変化



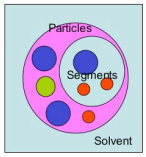
異なるq領域(a) $0<q<0.2A^{-1}$、(b) $0<q<2.0A^{-1}$において、散乱関数を逆フーリエ変換して計算した分布関数P(r)の変化

両蛋白質分子の大きさはほぼ等しく、(a)では大きな違いは見られない。

一方、高q領域のデータを使用した(b)では、分子内部の相関の寄与が分布関数に現れ、両蛋白質分子の分子内部の特徴が明瞭に観測される。

Scattering functions of Lysozyme

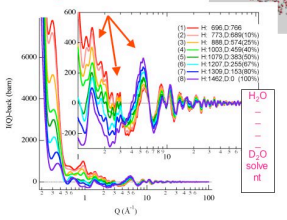
Contrast variation in wide q range
Contrast matching with various segments and particles
(100 contrasting measurements)



Lysozyme + hydration water

coherent scattering curve

large difference

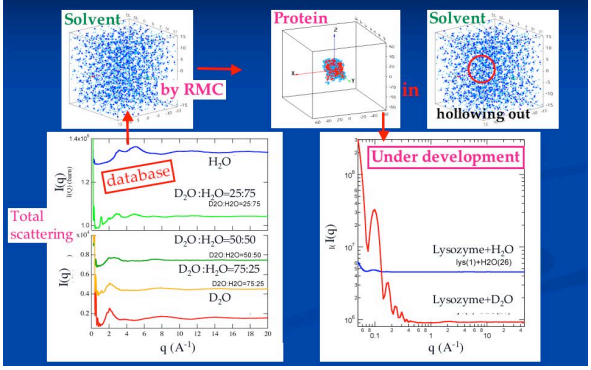


Hundreds of independent $I_i(Q)$s

$$I(Q)=\sum_i\sum_j b_i b_j \frac{\sin(qr_{ij})}{qr_{ij}}+\sum_i \frac{\sigma_{inc,i}}{4\pi}$$

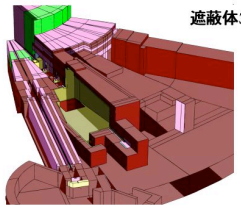
⇒ 3D atomic scale information could be obtainable.

- Effect of solvent, incoherent scattering -

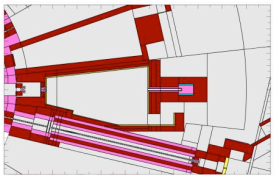


TAIKAN - Shield, background -

遮蔽体3D図

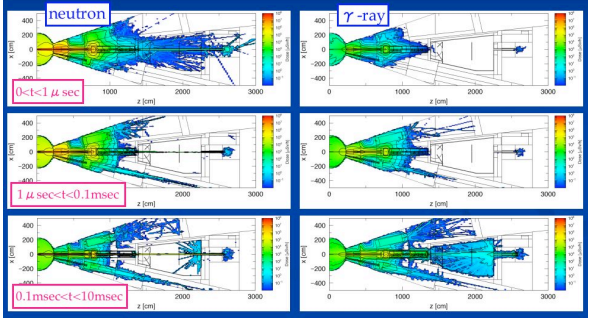


遮蔽体平面図



TAIKAN - Shield, background -

PHITS simulation (with T_0 chopper) → data analysis



Summary

1. The smaller-angle neutron scattering instrument TAIKAN of the J-PARC will give new opportunity for research of nano-materials and multi-phase, multi-component system and nonequilibrium system by simultaneous efficient and high precision measurement in wide-q range.

2. Start of construction of neutron guide tubes

3. Beam commission in JFY2011 is planned.