mfSANSの夜明け

ー小型集束型中性子小角散乱装置ー

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- 東大院工：高橋浩之、藤原健
- 日本原子力研究開発機構：遠藤仁
-

Long time project

圧倒的に多くの人に

中性子を

ただ幾つかの装置を開発しているのではありません。

X-ray SAS instrument

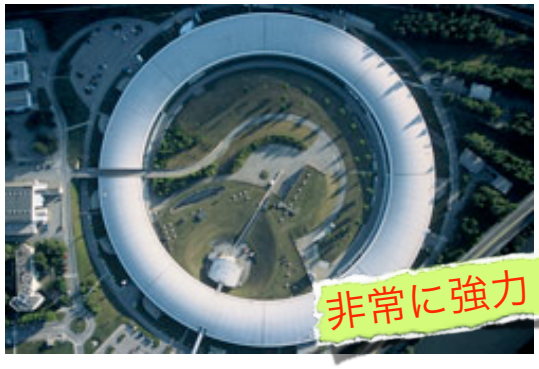
実験室 X線装置
（小角散乱装置）

何時でも出来る
どこにでも有る

例えばSAXS

http://matrix-dev.ansto.gov.au/research/bragg_institute/facilities/instruments/saxs/mimi_saxs

放射光施設
ヨーロッパ共同



非常に強力

例えばESRF、SPRING-8, PF

http://www.lightsources.org/cms/?pid=1000103

Neutron SAS instrument

実験室 中性子装置
（小角散乱装置）

?

何時でも使える。
どこにでも有る

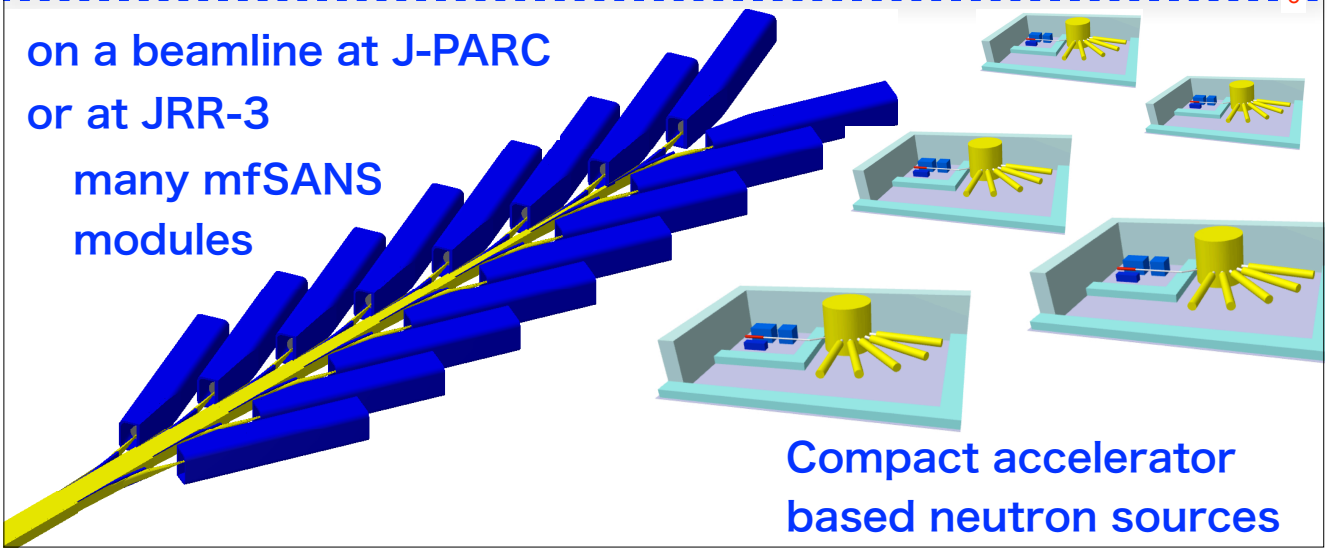
巨大中性子施設

例えばJ-PARC, JRR-3, ILL,
SNS, etc.

非常に強力

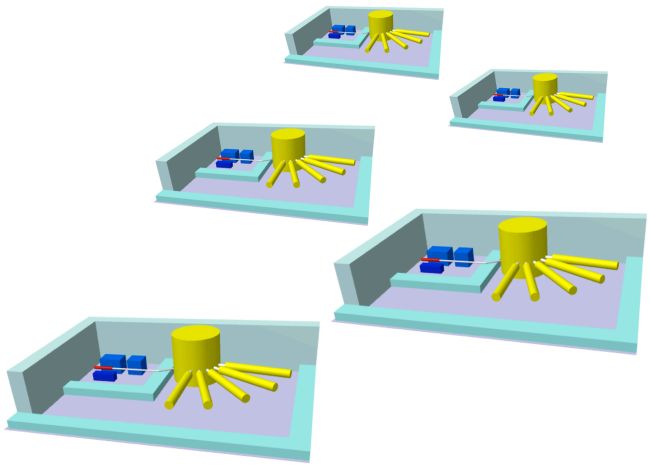
沢山の
小型集束型小角散乱装置を

on a beamline at J-PARC
or at JRR-3
many mfSANS
modules



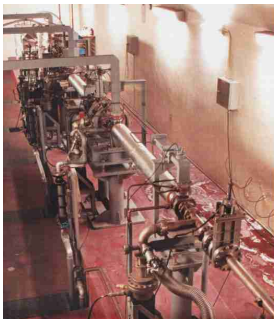
Compact accelerator
based neutron sources

Compact accelerator based pulsed cold neutron source



Accelerator-driven laboratory-size neutron-source

- RFQ accelerator + DTL ≈3-11MeV
  - Li or Be target
- Combined with:
  - many mfSANS modules,
  - mini-reflectometers,
  - mini-powder machines??



Hokkaido Univ.
Electron linac + mfSANS

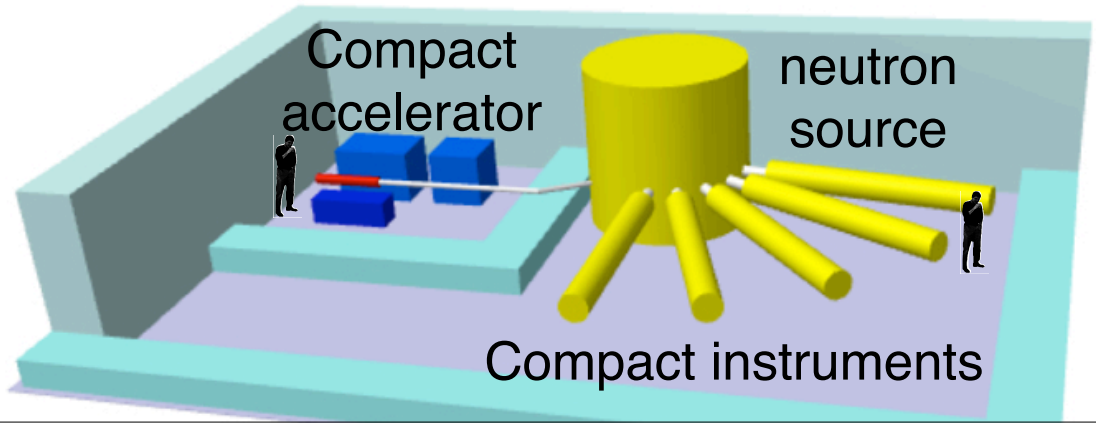
LENS @ Indiana Univ.
http://www.iucf.indiana.edu/lens/

- CPHS@Tsinghua Univ. China
  - under construction
- proton linac@Kyoto Univ.
  - under construction

Conceptual design of a compact accelerator

- Compact accelerator/
  - pulsed cold neutron source
  - instruments
- Electron accelerator of ~40-60 MeV, 3-10 kW
  - Cf. HU Linac: 35 MeV, 1 kW

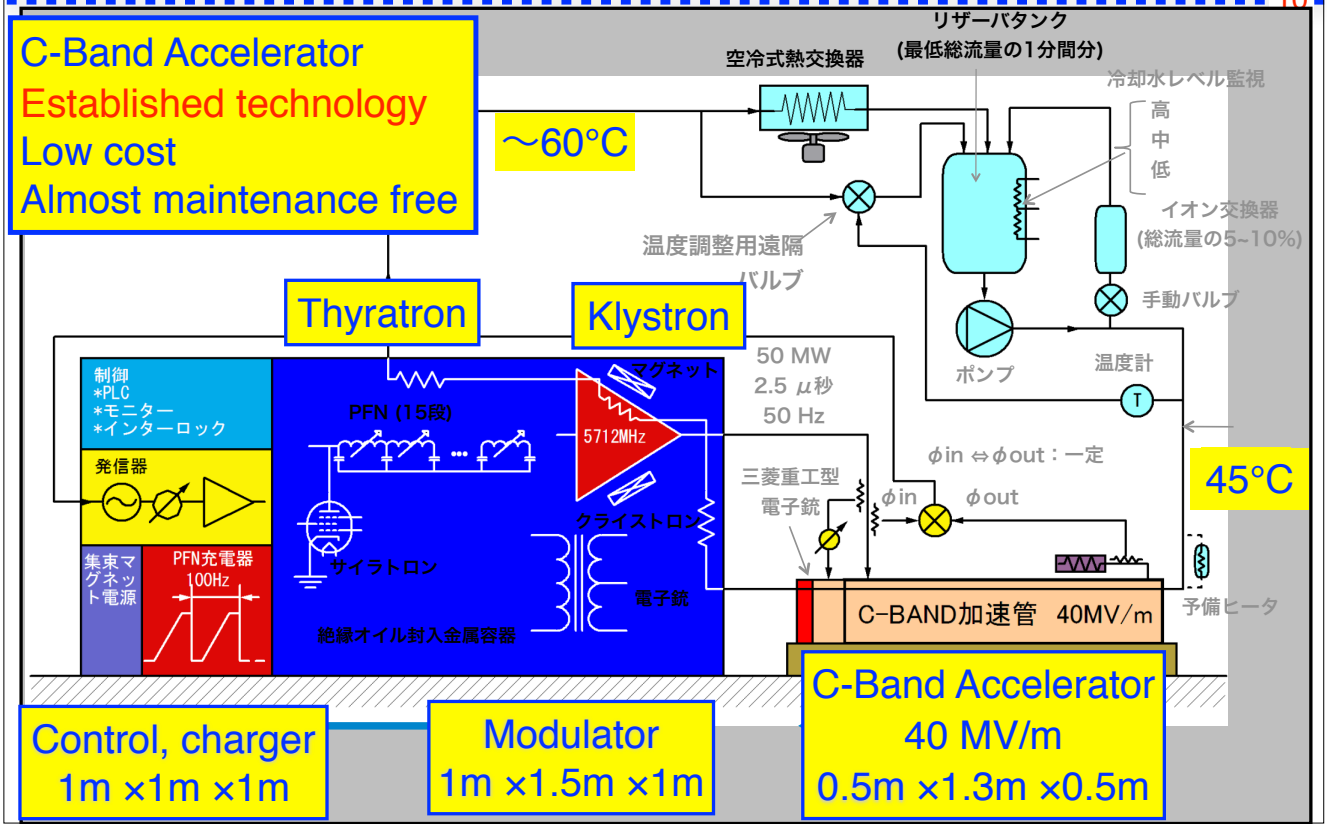
Collaboration with KEK accelerator people



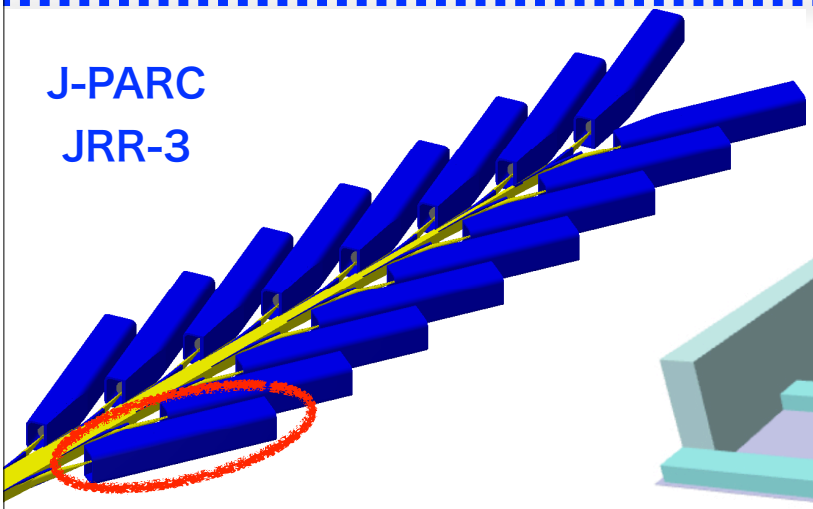
Accelerator conceptual design

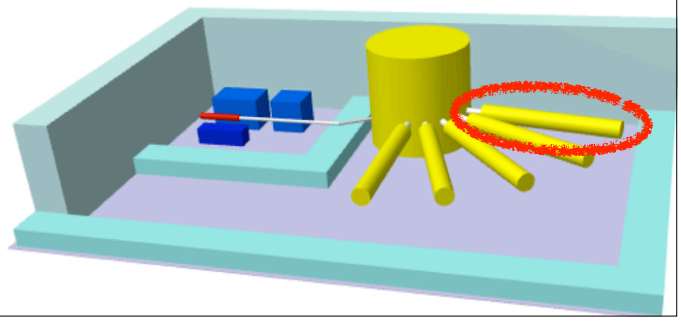
Kobayashi, Yoshioka, Matsumoto@kek

C-Band Accelerator
Established technology
Low cost
Almost maintenance free



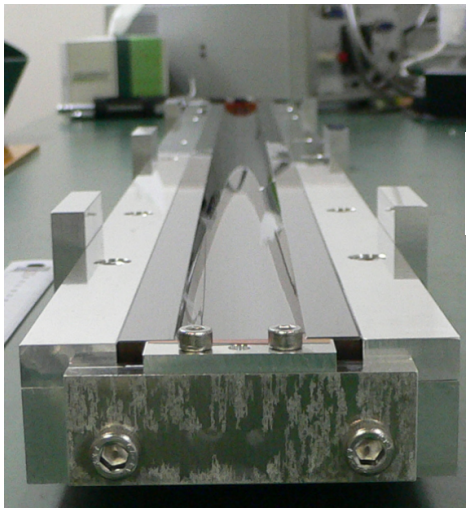
モジュールとしての
小型集束型中性子小角散乱装置
mfSANSの開発



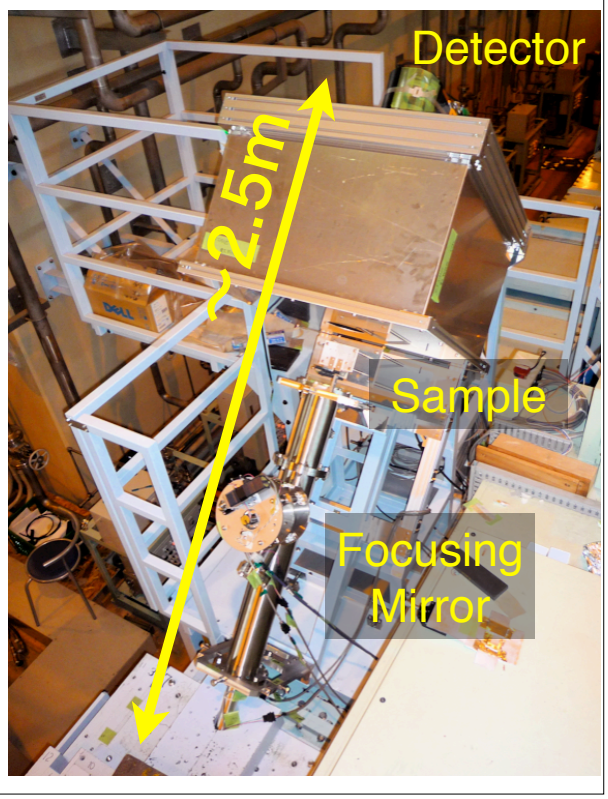


Mini-focusing SANS @ JRR-3
using a focusing mirror

- Ellipsoidal mirror
  - 2.5 Q_c supermirror
  - 2.5 m between focal points
  - short radius 20 mm



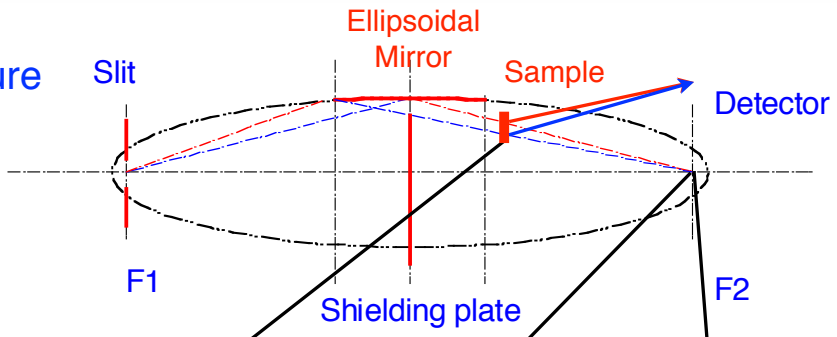
L: 900mm
W: 20mm

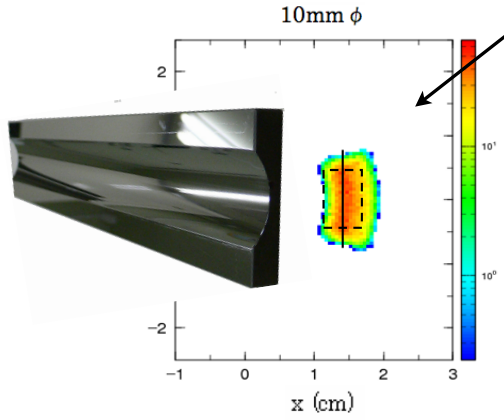


Ellipsoidal mirror focusing SANS

Kamada et al. (Hokkaido Univ.)

- Ellipsoidal mirror
- 1~10 mmø aperture





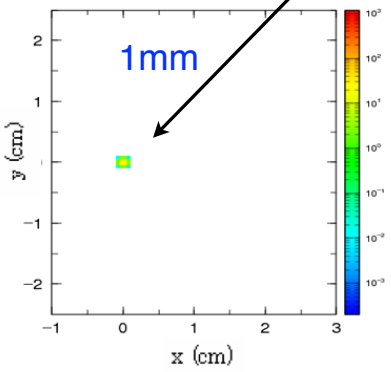


図 4.12 Aperture：1mm ϕ

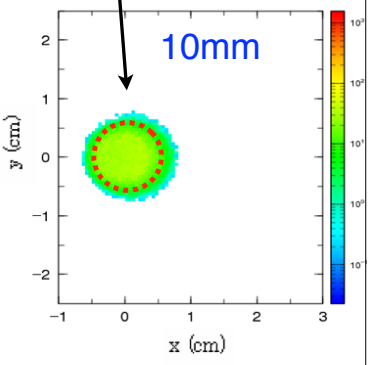
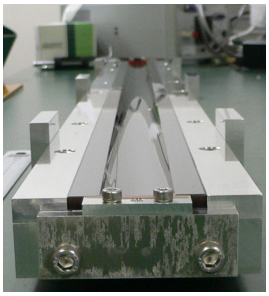


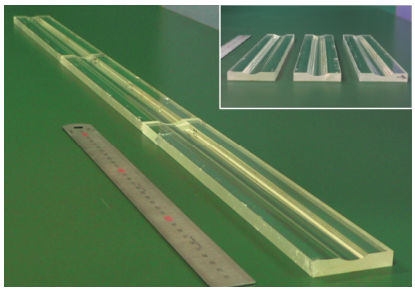
図 4.17 Aperture：10mm ϕ

苦労してます-1

Adjusting mirror-misalignment

- The mirror is made of 3 pieces

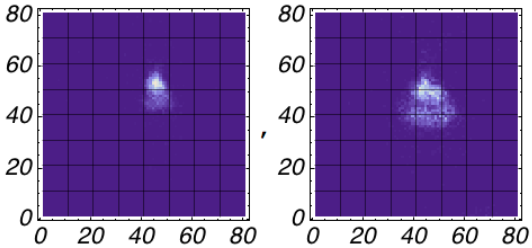




Alignment:

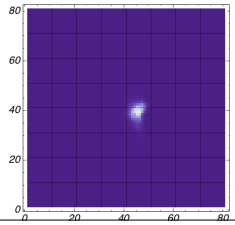
- Alignment in a few 10s of μm
- Dusts really affect
- Very fine mechanical

Aperture alignment matters.



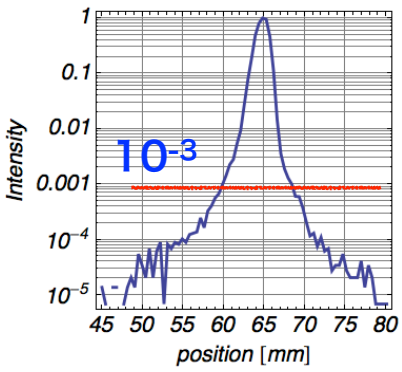
Three spots

Eventually



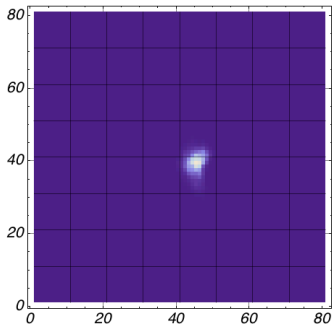
The mirror is not perfect, but OK.

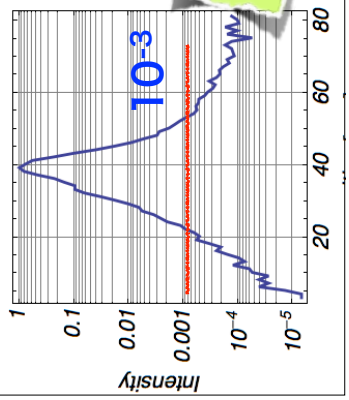
- Beam broadening starts at around 1/1000 of the peak.
- Grinder mesh was #1200 where #8000 was required.
- New mirror has already been made, but...
  - #8000 finished
  - not coated yet



FWHM≈2.5mm with 2mm aperture

Surface roughness



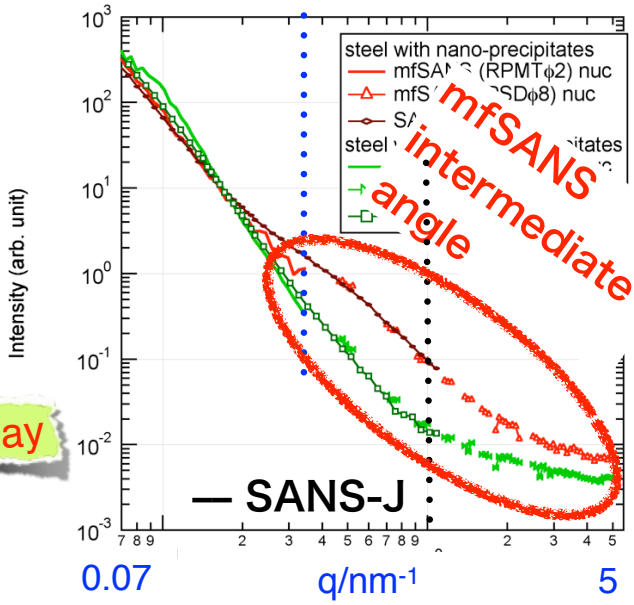


Nano-precipitates in Steel

- Nano-size inhomogeneities

— mfSANS

— Low Angle bank



mfSANS intermediate angle

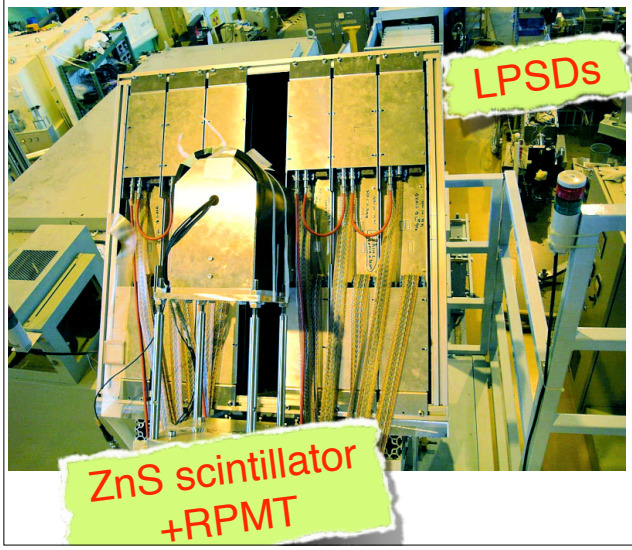
Nearly 1 day

— SANS-J

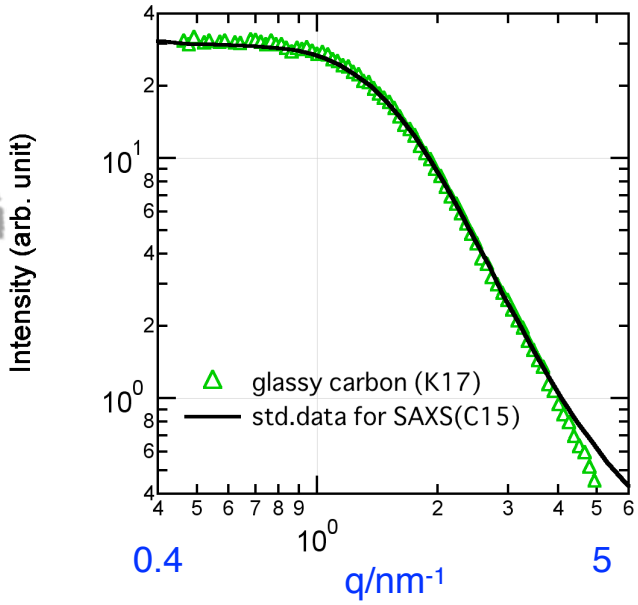
Y. Oba, M. Ohnuma@NIMS

wider-angle scattering

- 48 Linear position sensitive detectors at higher angle pos.
  - 1/2 inch dia, 600 mm in length
  - GE made



Standard sample
Glassy carbon



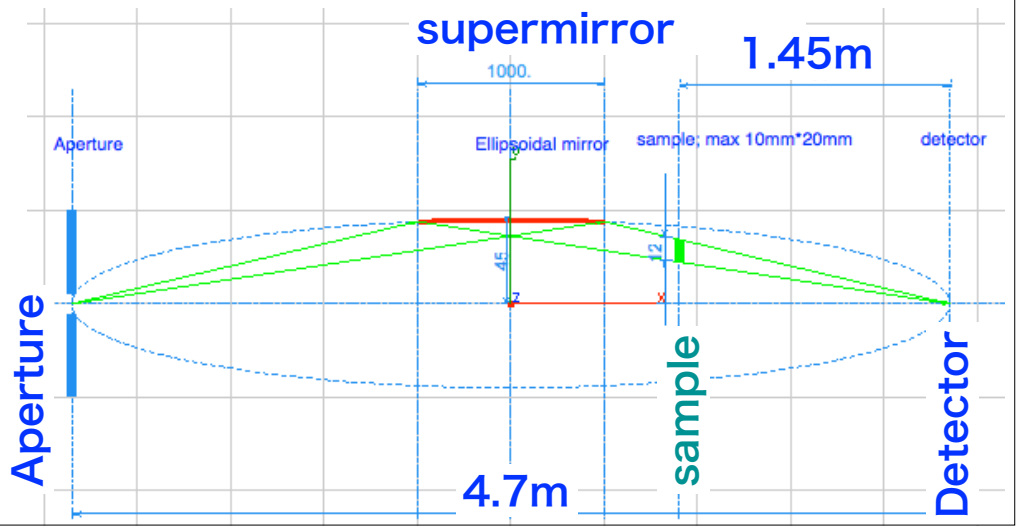
focusing SANS for low power reactors

KUR version of focusing SANS

First Draft design

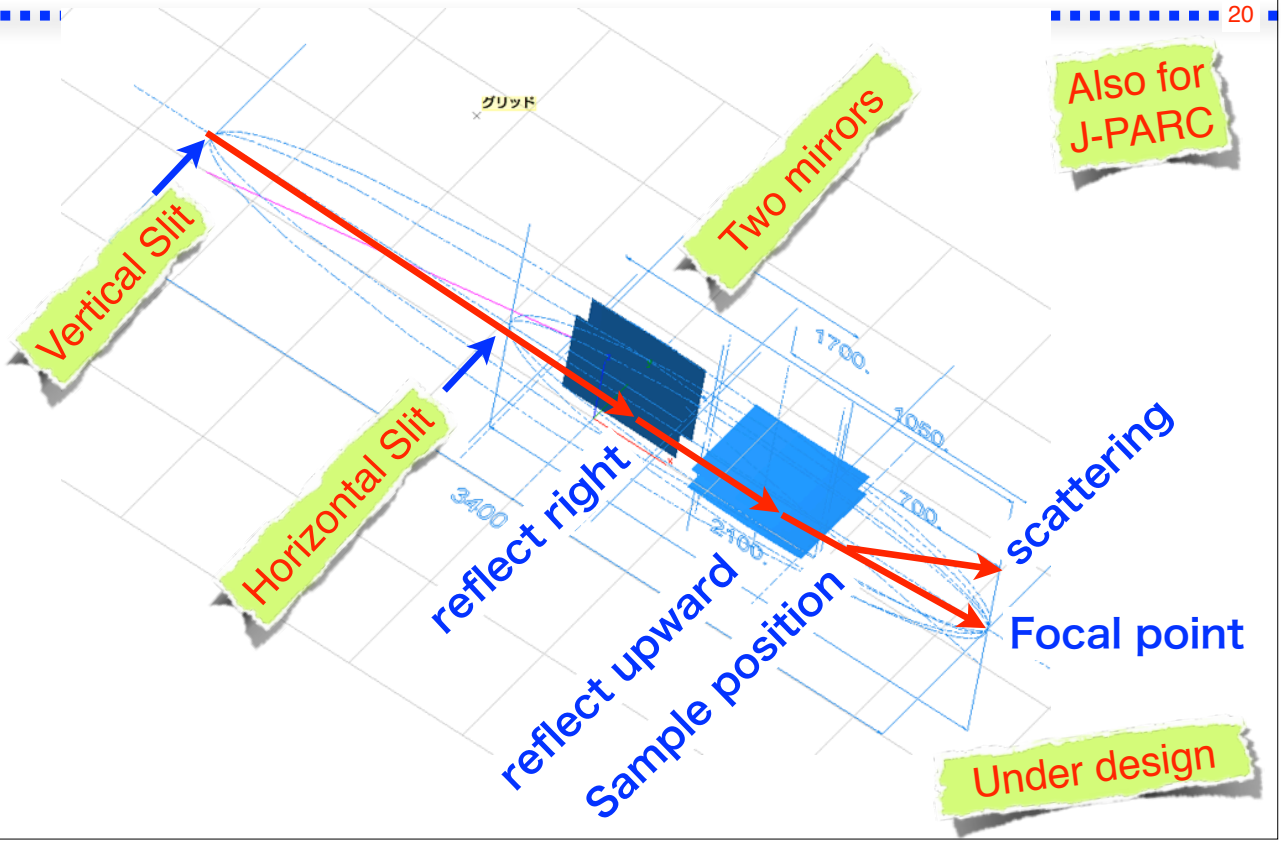
- boundary conditions:
  - 1MW thermal, use 2.7 A
    - Ni guide exit
  - Aim at $Q_{min} \leq 0.01$ A^{-1}
  - Use 5 mm resolution detector
  - 4.7m limit

Ellipsoidal mirror
4Qc; 1m
Monochromating supermirror



Kircpatric-Baez mirror focusing SANS

Also for J-PARC



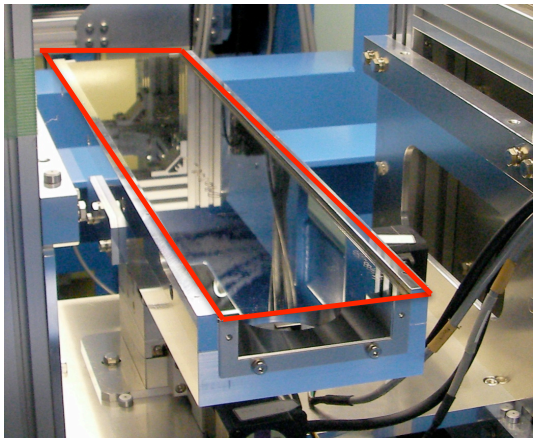
Under design

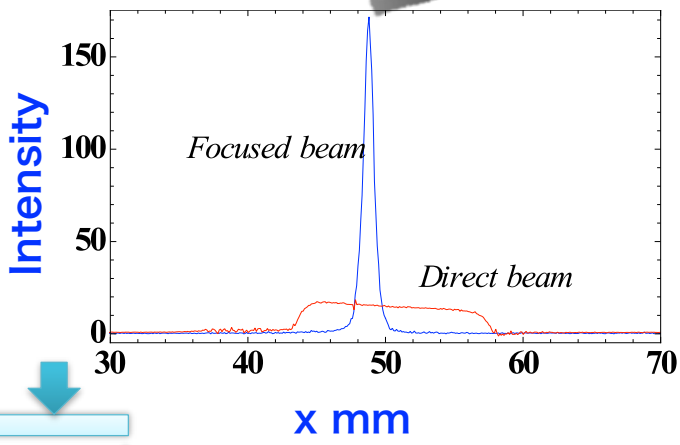
Focusing by a bent supermirror

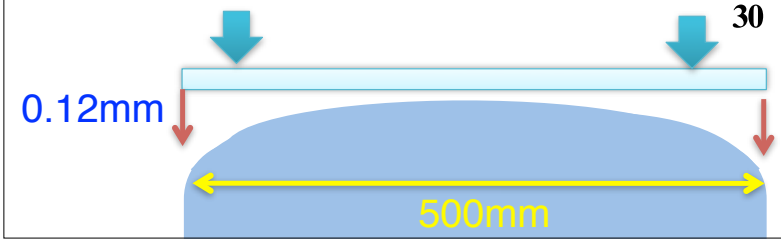
- Bent gently
  - Only a slight bending≈120μm

For reflectometer
& K-B mirror type SANS

1 mm focusing



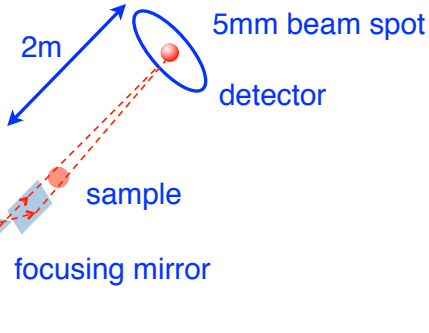


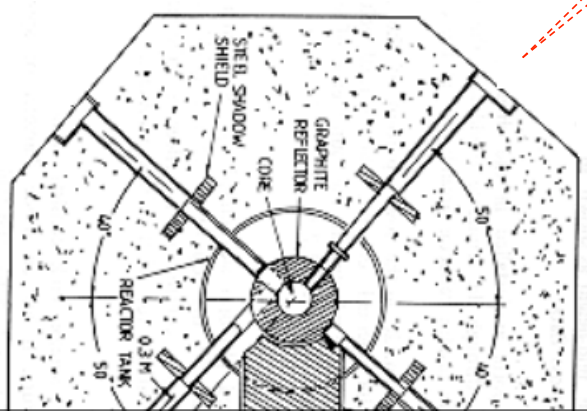


N. Yamada@kek, N.Torikai@Mie Univ.
T. Sugita@Hokkaido Univ.

Reaktor TRIGA PUSPATI (RTP), Malaysia

- 1 MW TRIGA reactor
  - No cold source
  - Radial beam port
- Focusing SANS instrument under design:
  - ≈10^4 n/s @ 4.5 A estimated
  - Reasonable Q-range
    with 5mm beam spot





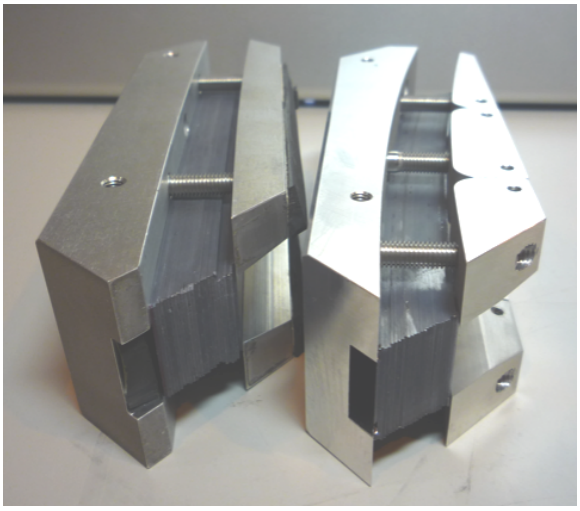
By Megat Harun modified by M.F.

ビーム分岐

苦労しています。

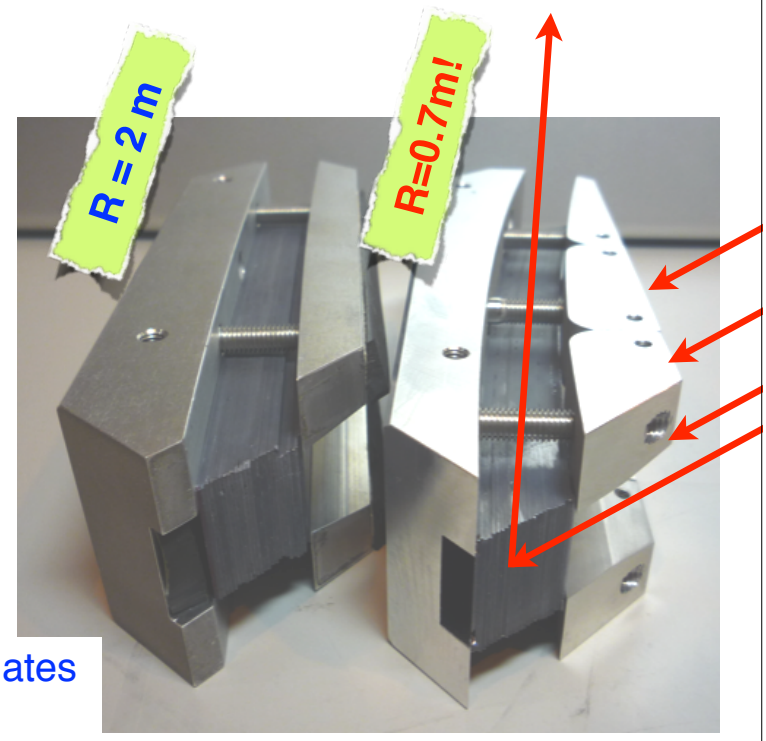
準モノクロメータ開発

- 原子炉で装置をたくさん並べる
- 分岐が必要



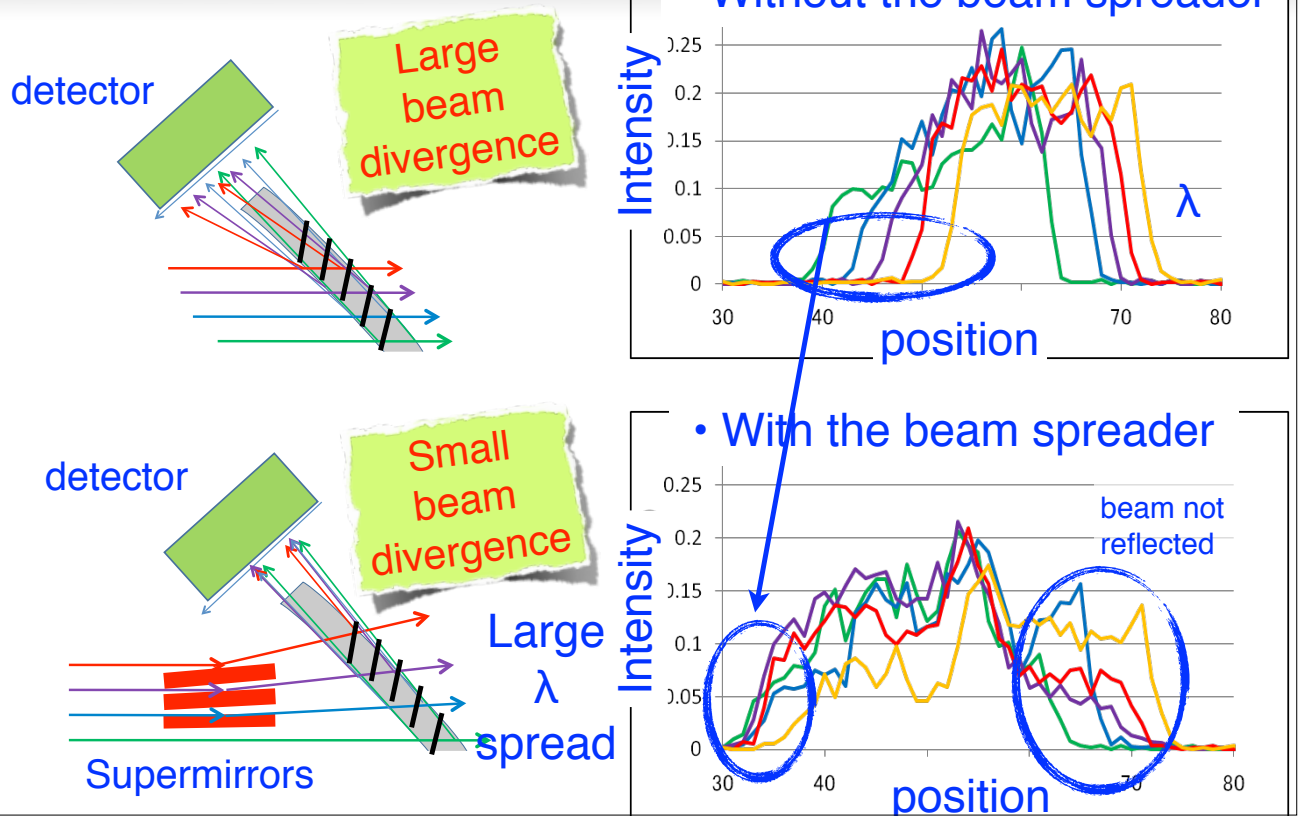
Strongly bent perfect Si crystal plates

- Fully asymmetric geometry
  - 5.8 A
  - 0.5 mm thick Si plates×30 plates
  - Brighter than a PG monochromator



0.5 mm thick Si plates
×30 plates

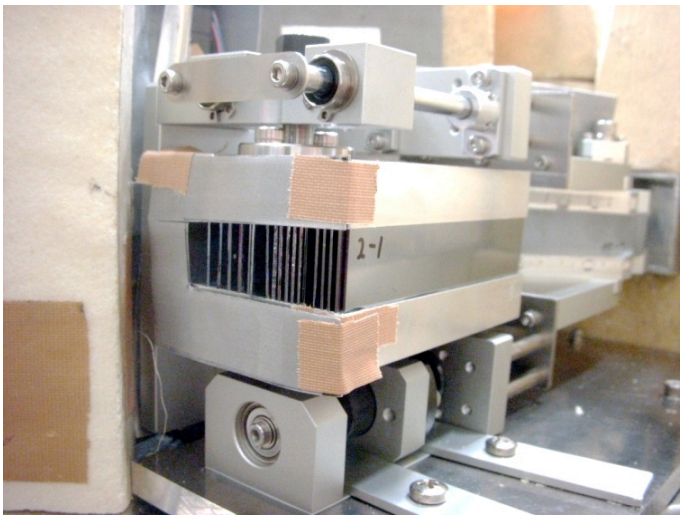
With and without the beam spreader



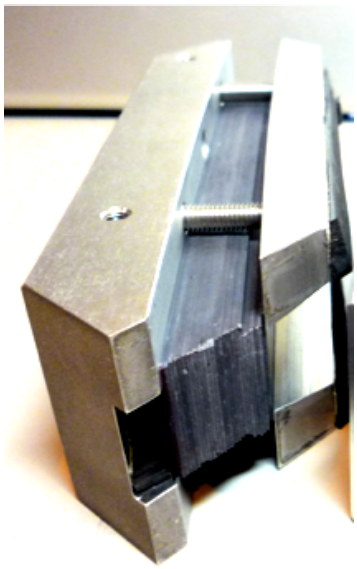
Monochromator with a beam spreader

Bent R=2m

Beam spreader
with 2.2 & 4.4Q_c supermirrors



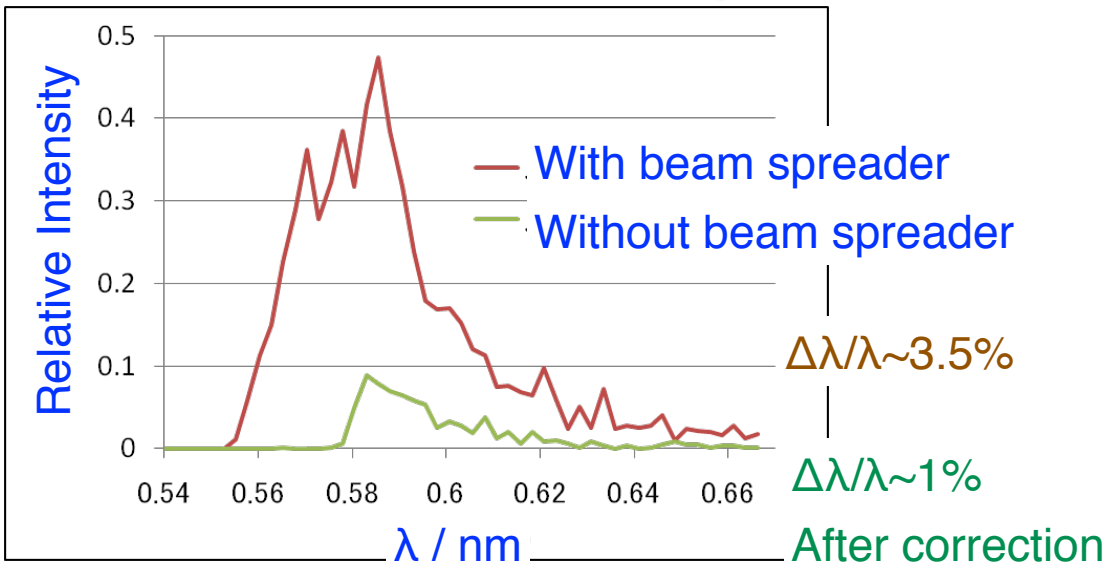
Strongly bent perfect Si
crystal plates, R=2m



バンド幅はOKしかし、R≈0.7mが必要

Bent R=2m

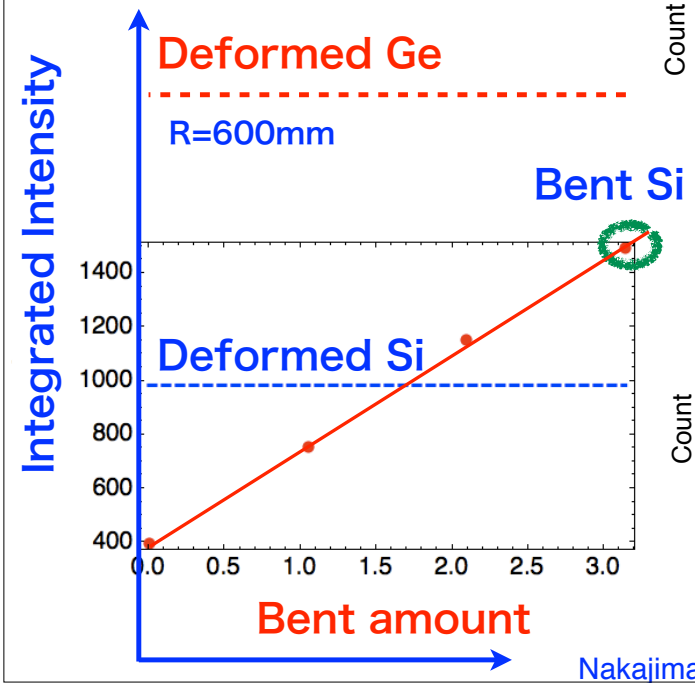
- Estimated beam intensity at the mirror

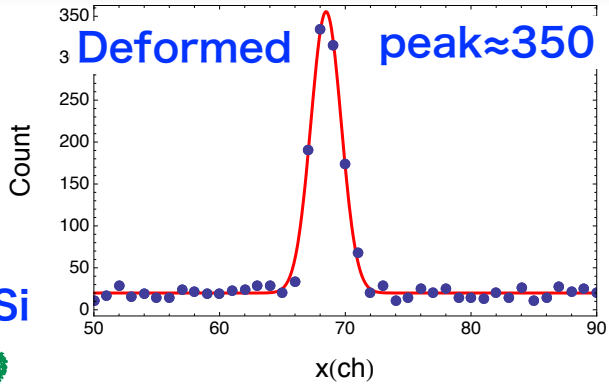


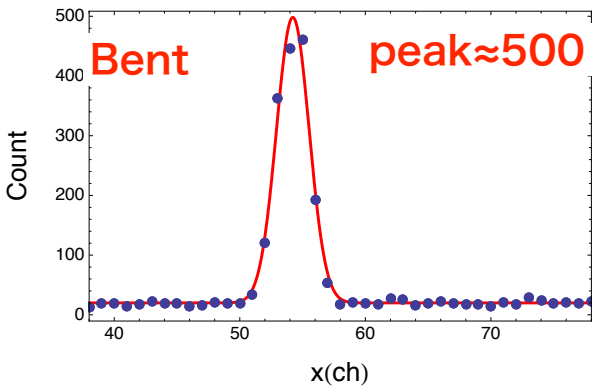
- ~ 8 times intense?

Deformed Si/Ge & Bent Si

- Si/Geを高温高圧で変形

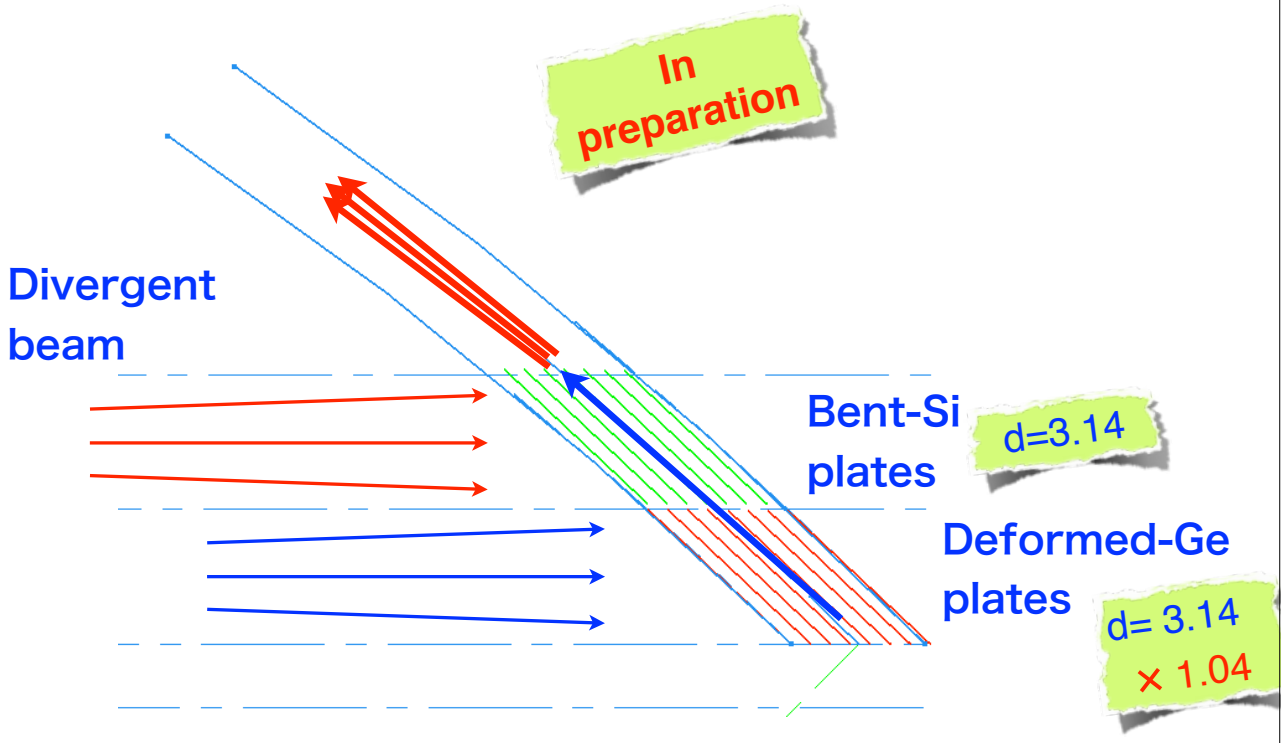






Nakajima&Hiraka@Kinken, K. Ohkubo@Hokkaido Univ.

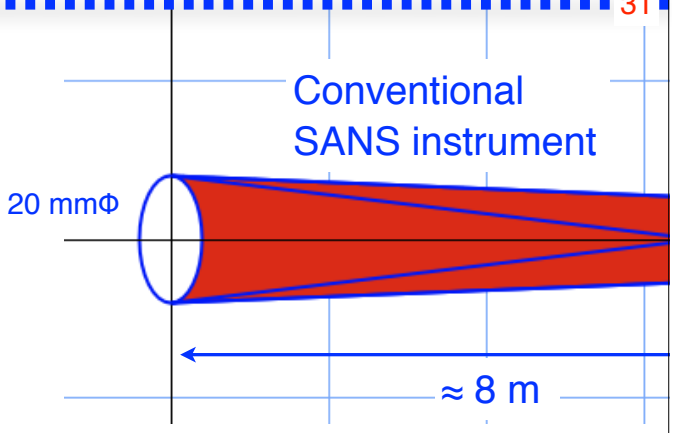
Bent-Si/Deformed-Ge monochromator



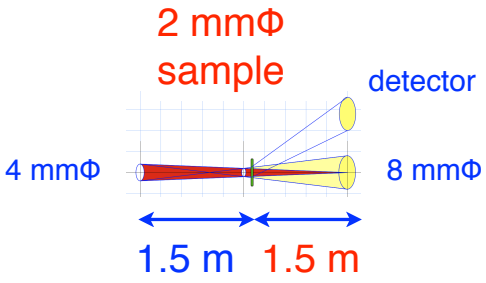
Multi-pinhole scanning SANS

小さなピンホールでの中性子小角散乱

- ピンホール ≈ 2 mm ø
  - 試料も2mmø
- 強度は落ちる
  - マルチピンホールで強度を稼ぐ



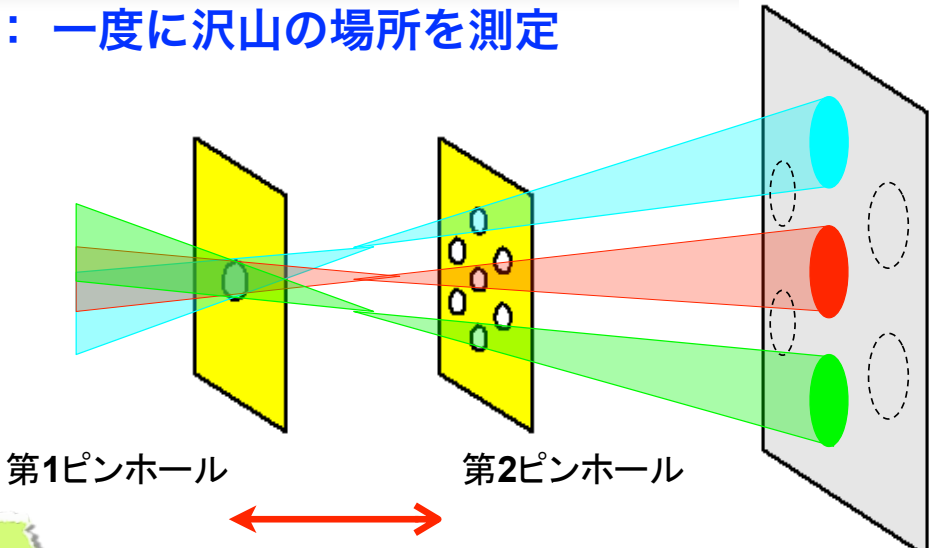
$$I(Q) \propto \phi \cdot d\Omega_i \cdot \frac{d\Sigma}{d\Omega} \cdot V_{\text{sample}} \cdot \eta \cdot d\Omega_f$$



Q分解能は同じ、
強度は落ちる
→マルチピンホール

Multi-pinhole SANS

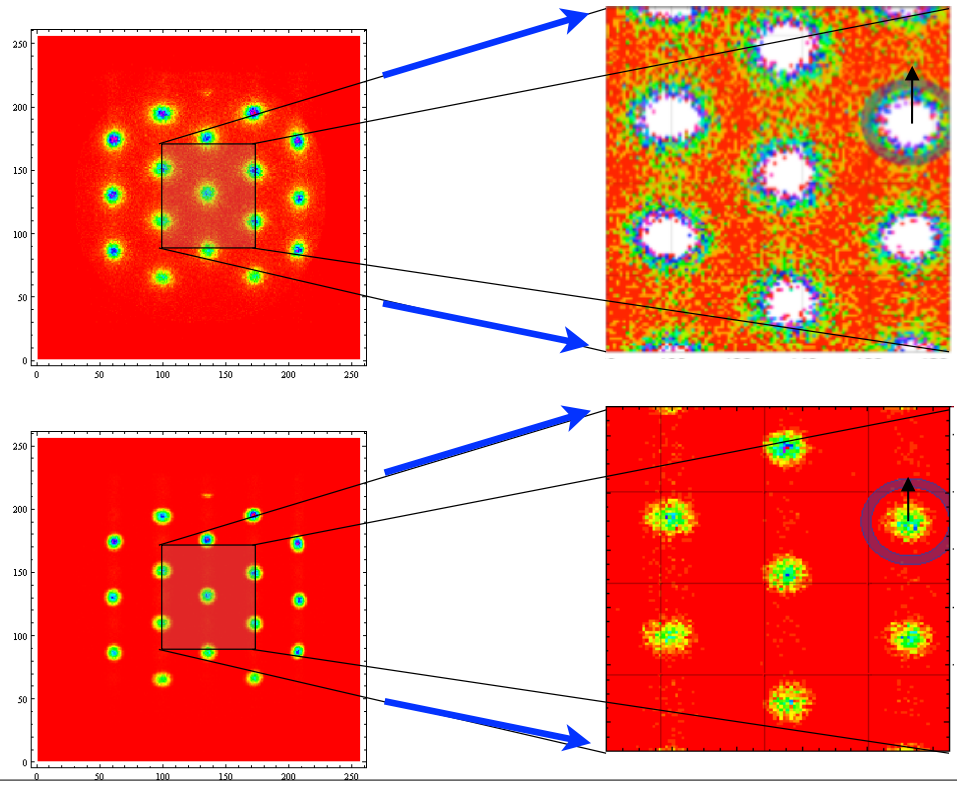
- Scanning： 一度に沢山の場所を測定



または逆転配置

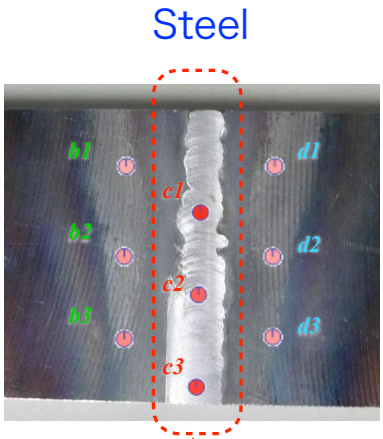
- 小さなスポットを大強度で測定

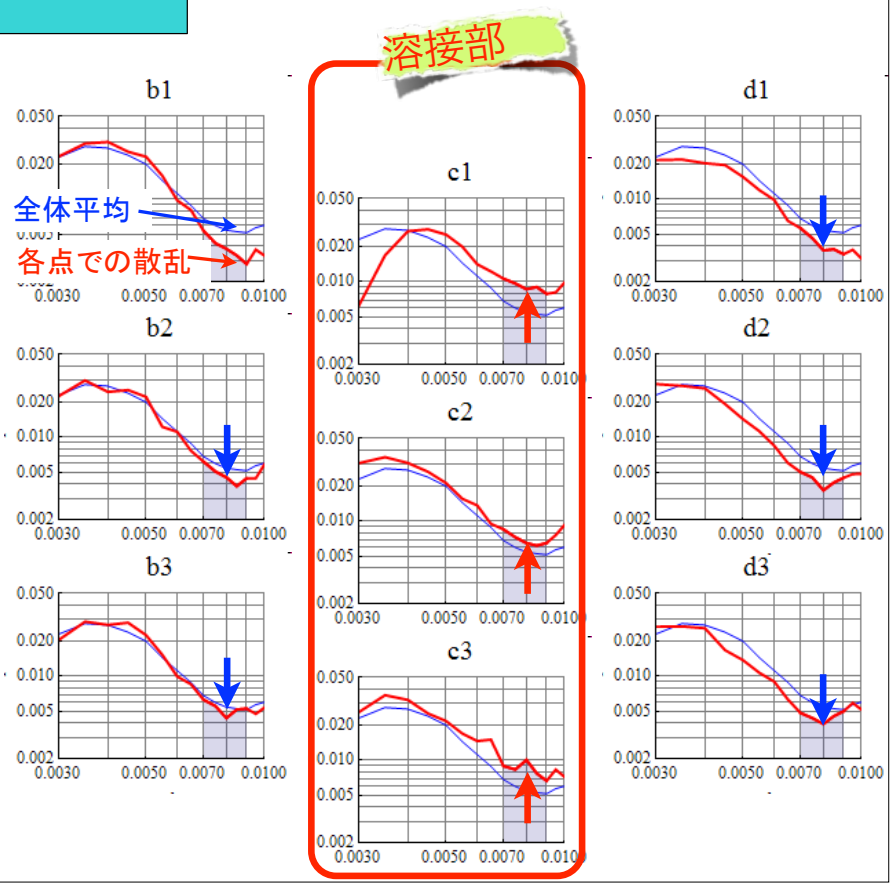
SANS patterns



溶接鉄の部位ごとの散乱強度の違い

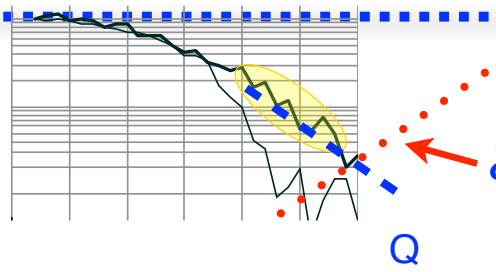
4.4～6.2Å





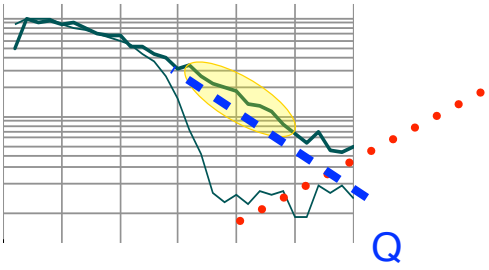
Resolving overlap, under development

3.76 ~
4.39 Å

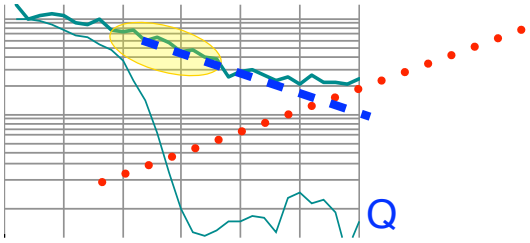


となりのピンホールからの影響は少ない

4.56 ~
5.28 Å



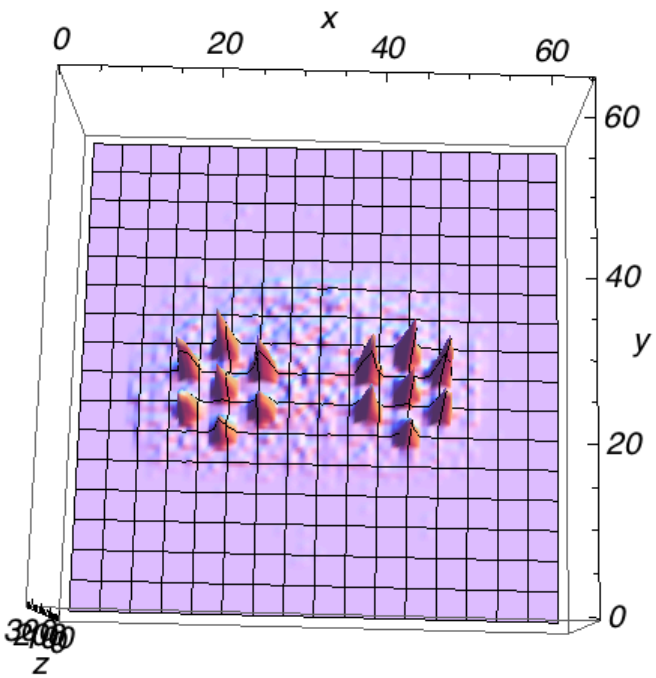
5.46 ~
6.18 Å



TOFだから出来る技

1mmΦ Pinhole@Hokkaido Univ.

Direct beam

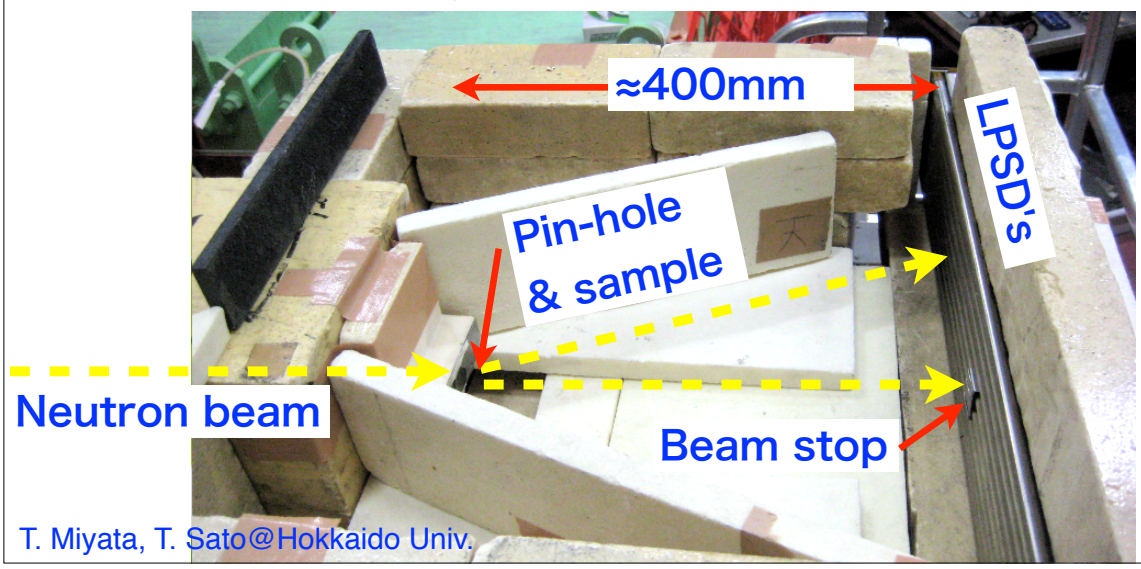


Techniques for compact neutron sources

Intermediate-angle scattering instrument @HU Linac

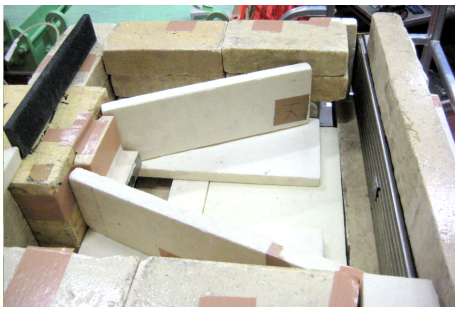
Intermediate angle scattering instrument HU linac

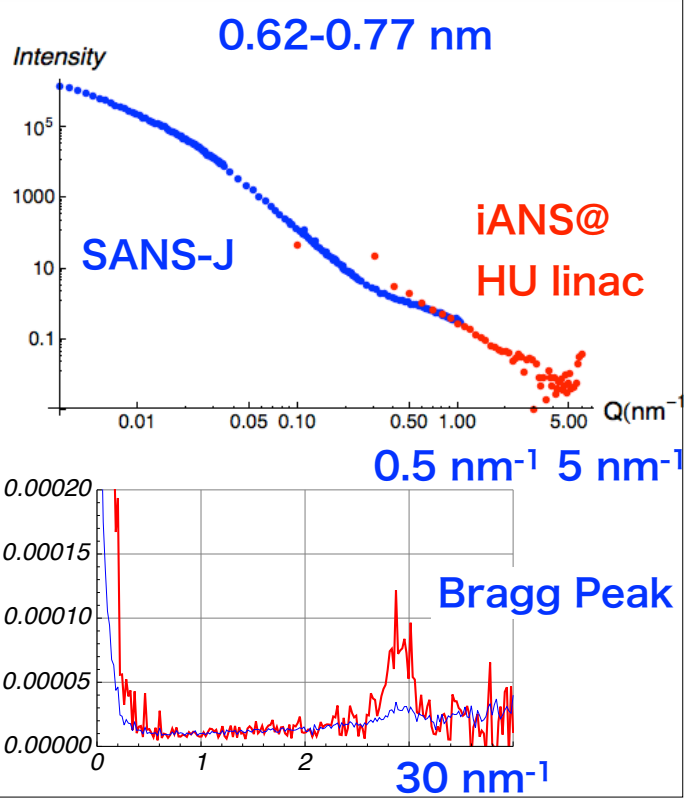
- Very low angular-resolution
  =highly efficient at an intermediate-q range
- Large sample size; up to 20 mm
- Reasonable Q-range; $0.05 \leq Q \leq 2\ A^{-1}$



Test experiment using iANS@HU Linac

- Steel sample "RSO414"
- Measuring time ≈ 1hr
- 1 kW beam power!
- Enough for nanoscopic structure study of alloy samples





まとめ

まとめ

- mfSANS@mfSANSのphase Iが完成した。
  - 高い散乱強度の試料なら測定可能
  - nmスケールの高いQ領域の測定に向いている。
- 今後の性能向上が必要
  - 新型モノクロメータの高性能化
  - 検出器の高性能化（MSGC）
  - 集束ミラーの改良が出来れば散乱強度が弱いものも
- mfSANS@J-PARCに向けて
  - 変形Kircpatric-Baez型を開発中
- 北大でも結構測定出来る
  - 1mm scanning SANSで測定、解析中
  - 0.02 A^{-1}-5 A^{-1} なら測定可能。