Accelerator Laboratory
Advanced Research Center for Beam Science
Institute for Chemical Research
Kyoto University

Kyoto Area Neutron Source Activity

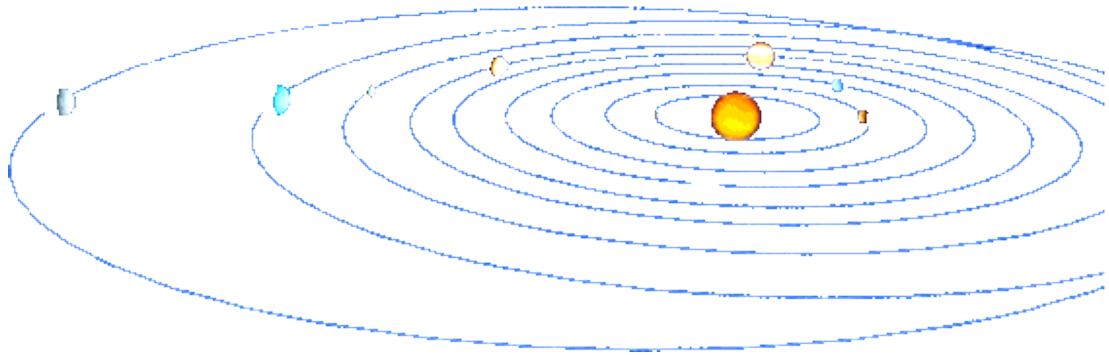
– Satellite Pulsed Tiny Neutron Source –

Y.Iwashita, M.Ichikawa, M.Yamada, H.Tongu,
T.Nagae, T.Tanimori, H.Fujioka, K.Imai
- *Kyoto University*

H.M.Shimizu - *KEK*

Background (skipped)

- Why Satellite?



- Big Facility Irony
- Flexibility, Usability, Availability, Freedom, etc.
- Education, Incubation of Ideas
- Excavation of needs, potential users
- .....

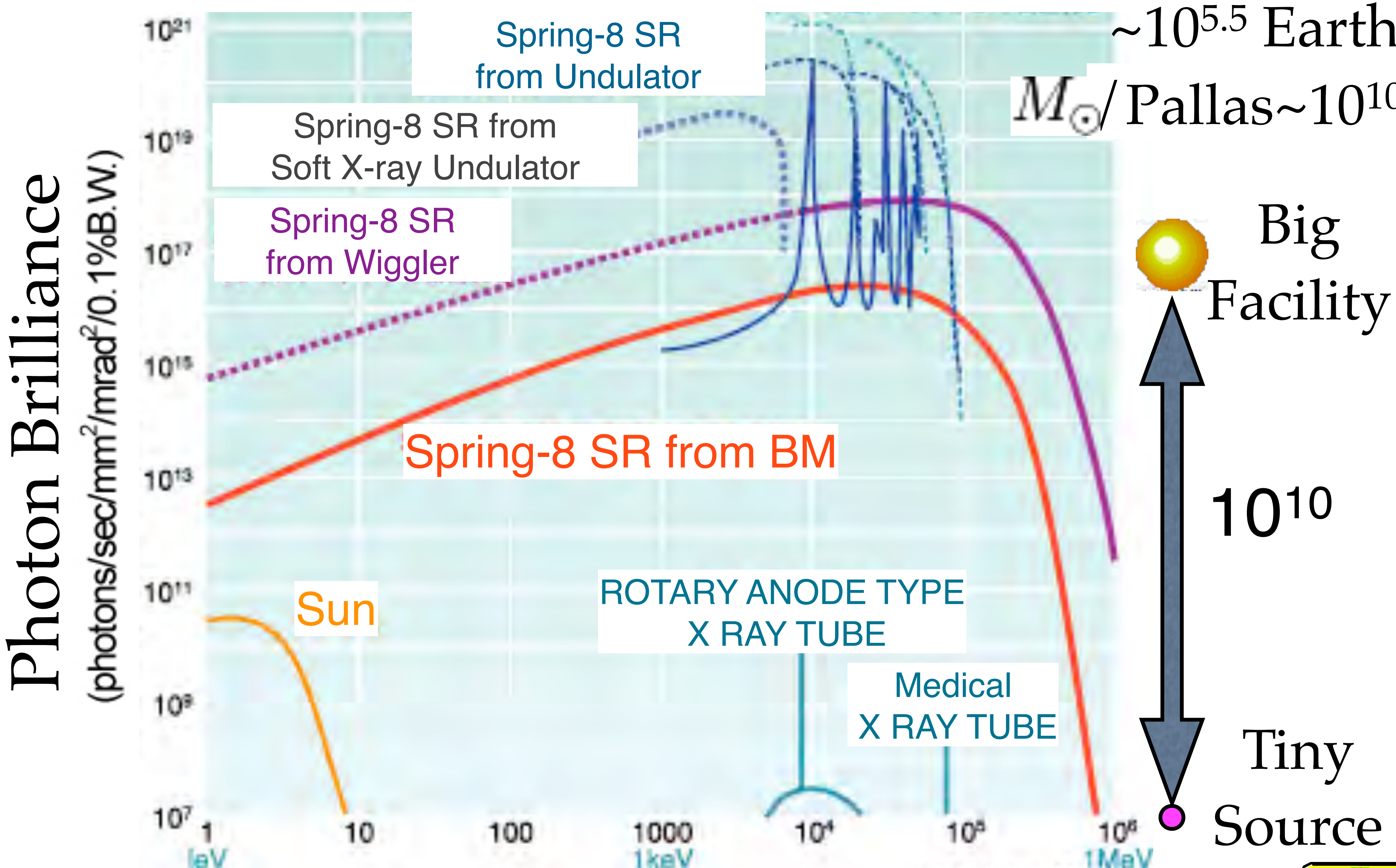
SPULTNS

Satellite **Pul**sed **T**iny **N**eutron **S**ource

Photon Case

$M_\odot$:Solar Mass ~$10^{5.5}$ Earth

$M_\odot$/ Pallas~10^{10}

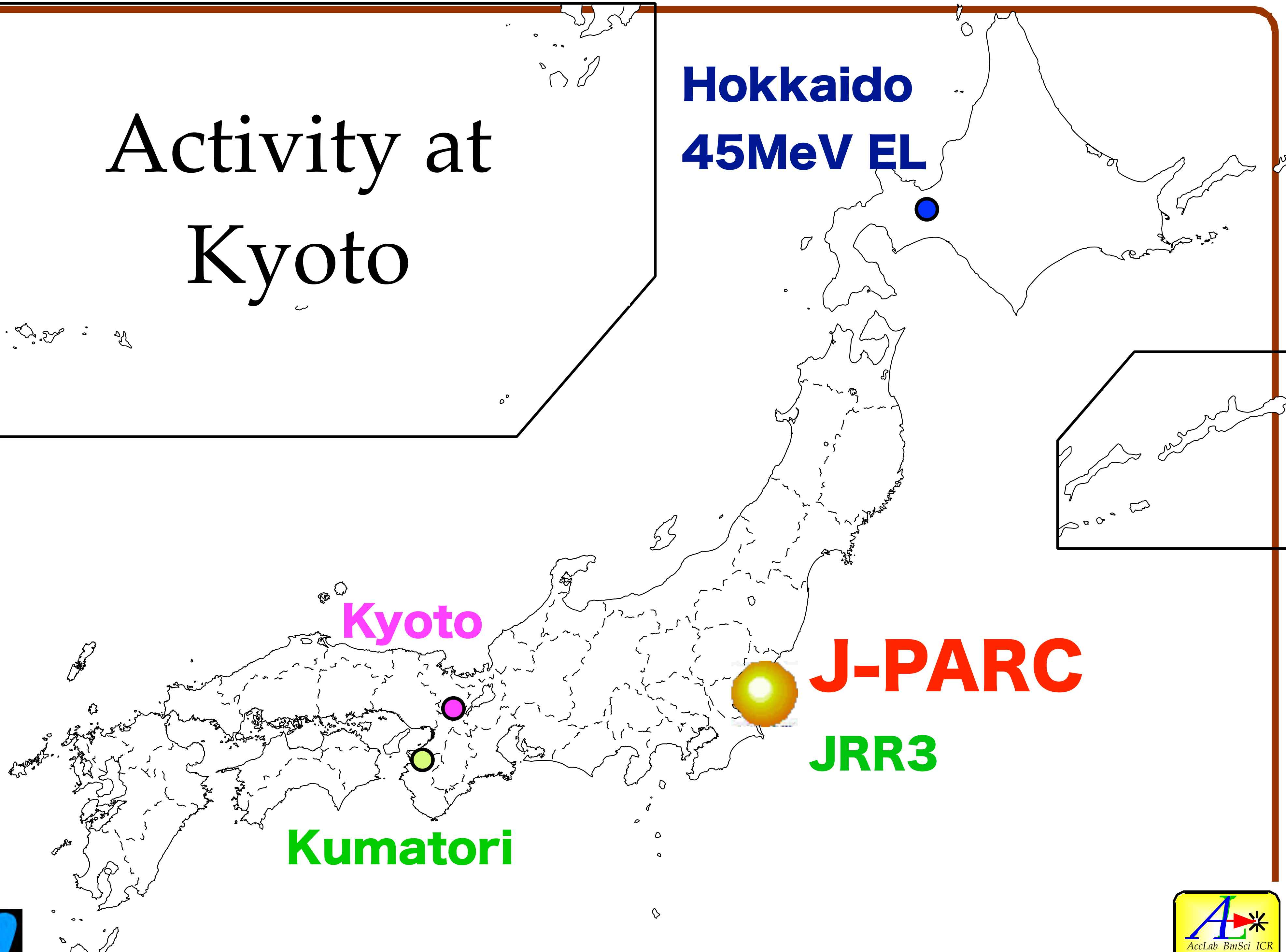


http://www.atomin.go.jp/atomin/high_sch/reference/radiation/radiation_light/index_05.html

Network beyond Satellite?

Makes all neutronians happy!

Activity at Kyoto

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Shingu
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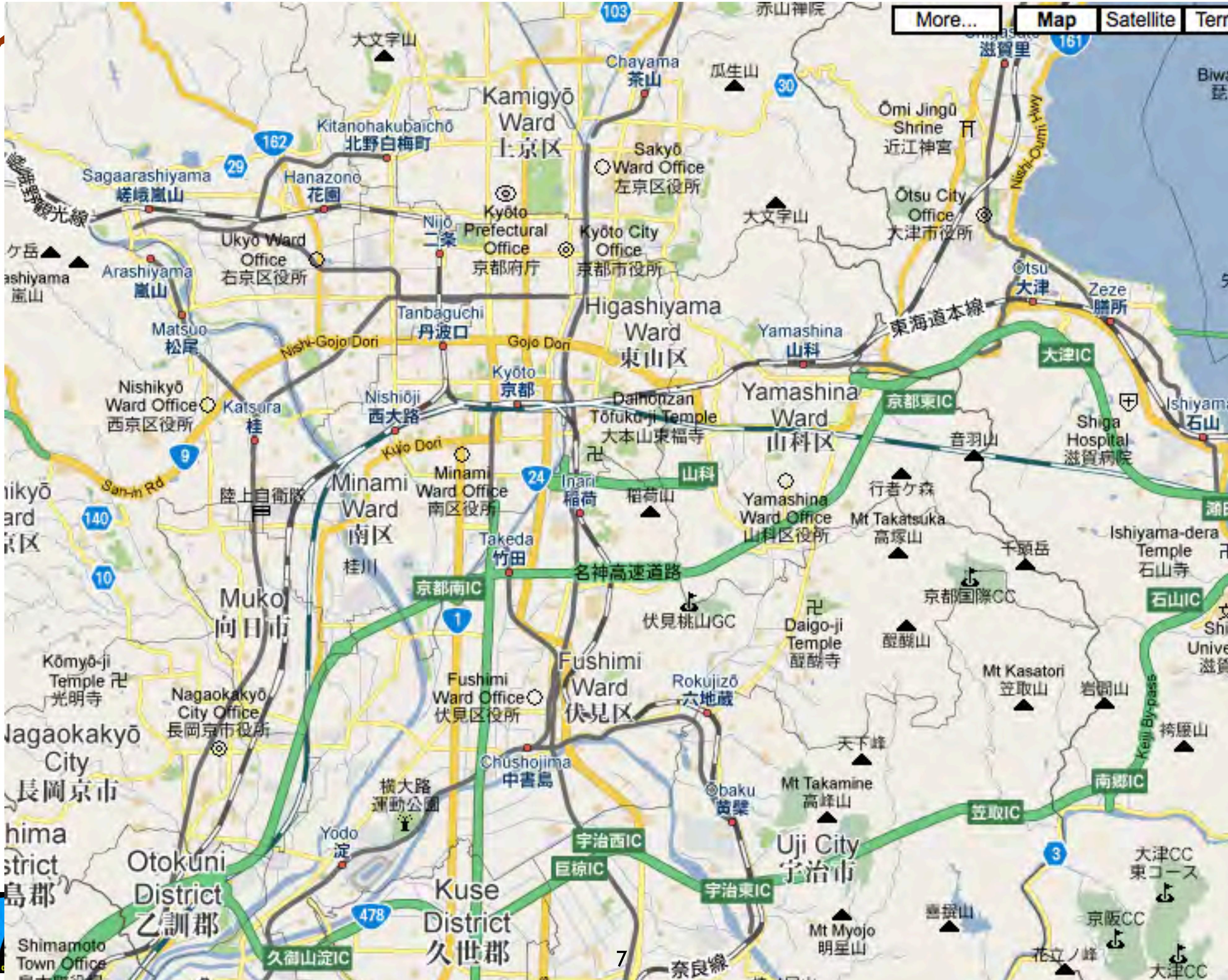
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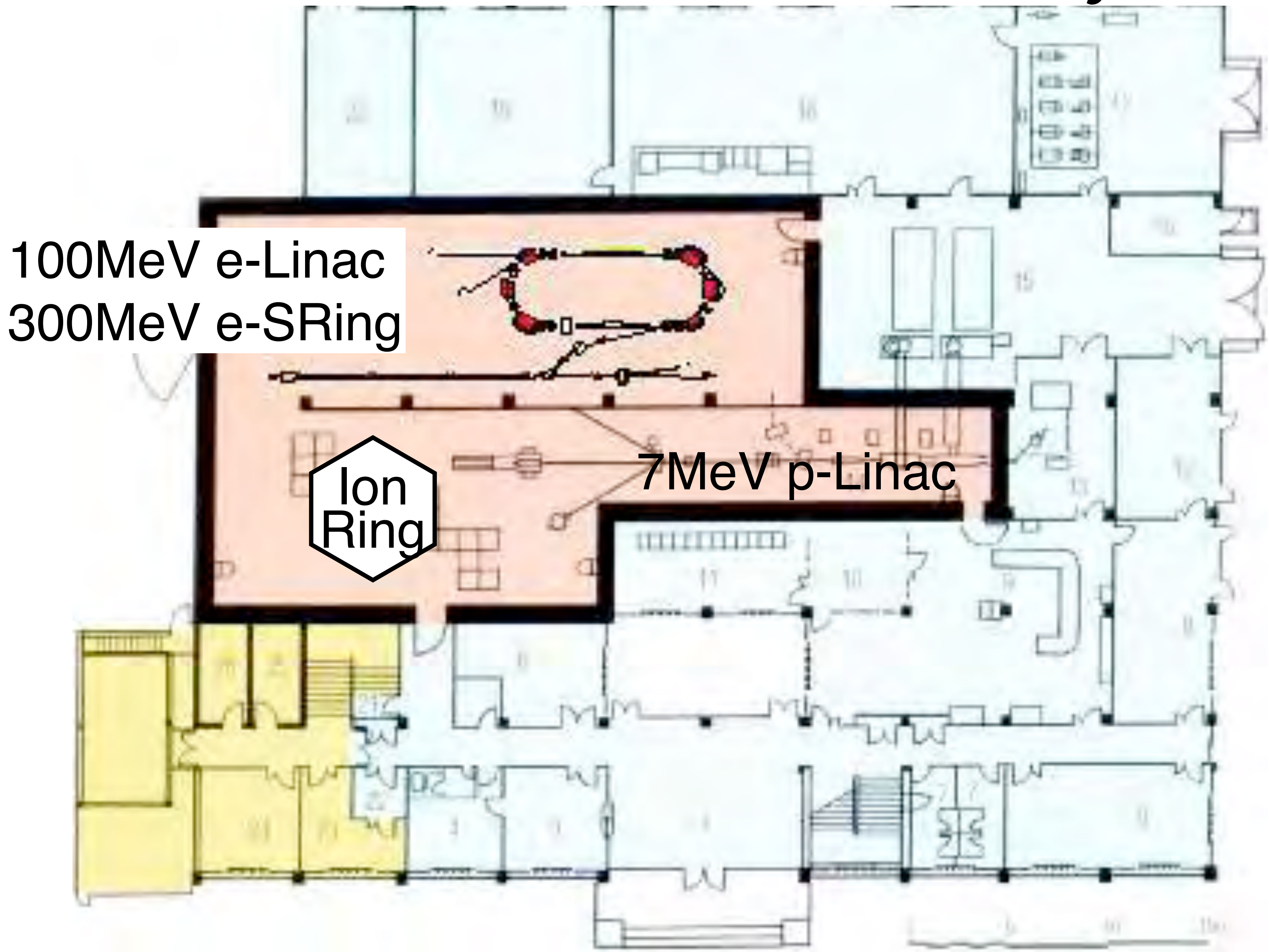
Uji Campus

Neutron Optics and Physics

AccLab BmSci ICR
KyotoUniversity

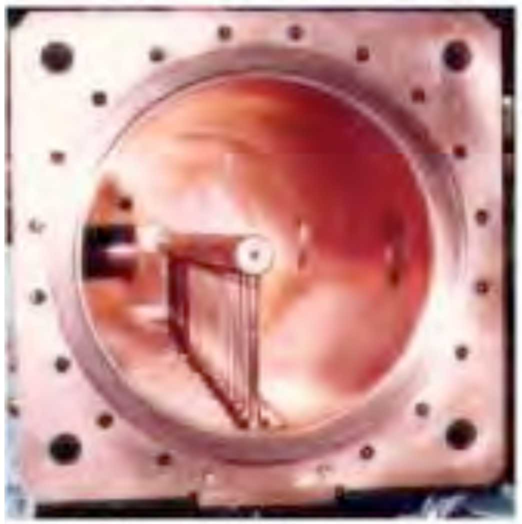
Institute for Chemical Research Accelerator Laboratory



ICR 7MeV Proton Linac

RFQ-2MeV
DTL-7MeV
<180pps, 50μs
duty <~1%

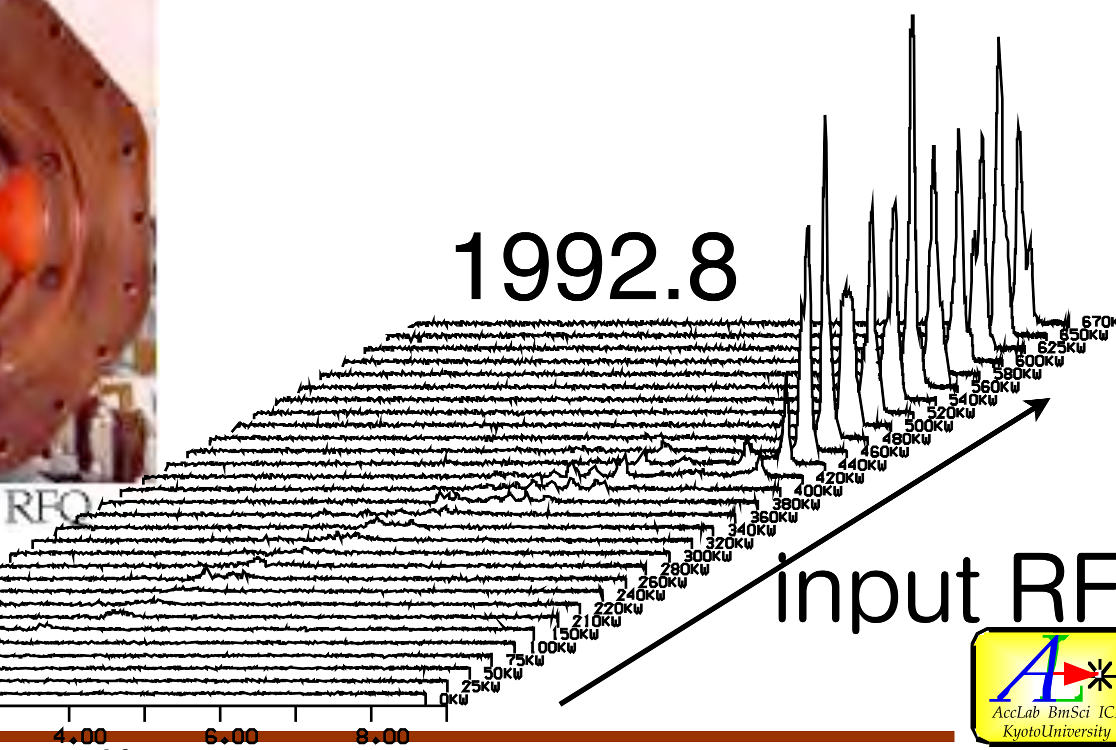
2MeV±1%



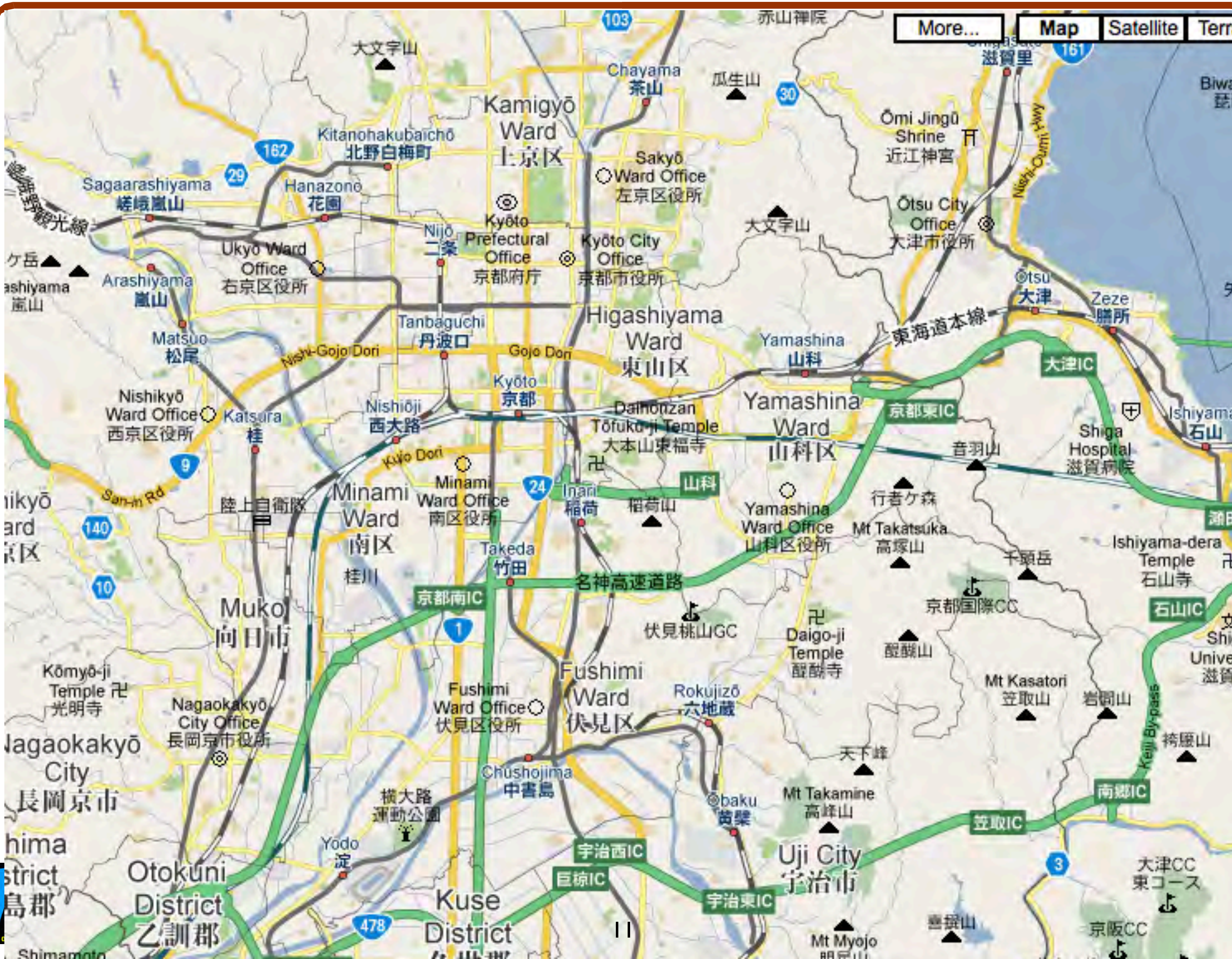
433MHz 7MeV DTL

433MHz 2MeV RFQ

1992.8



L5773 x 2
(L3403)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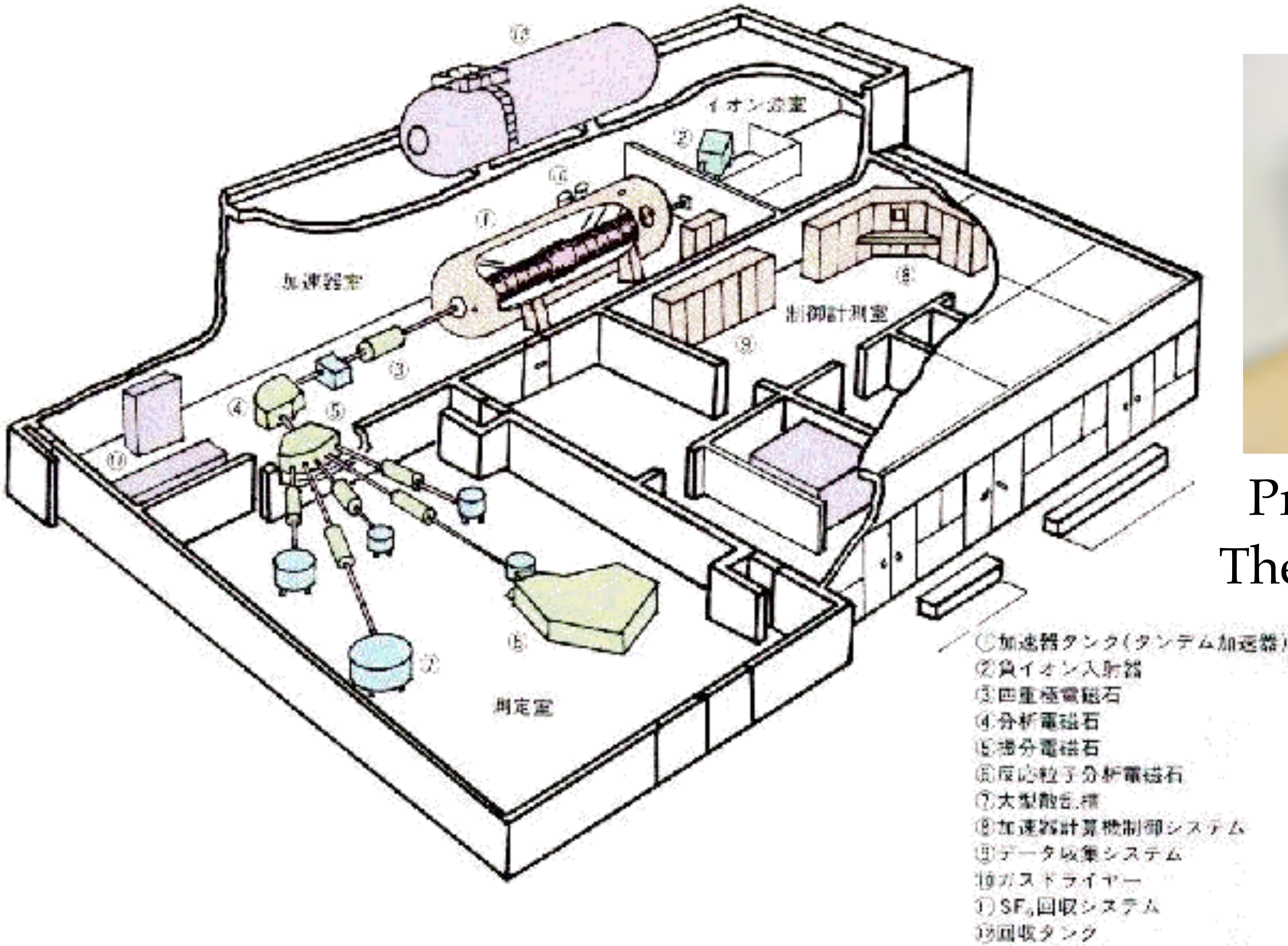
Main Campus at Sakyo

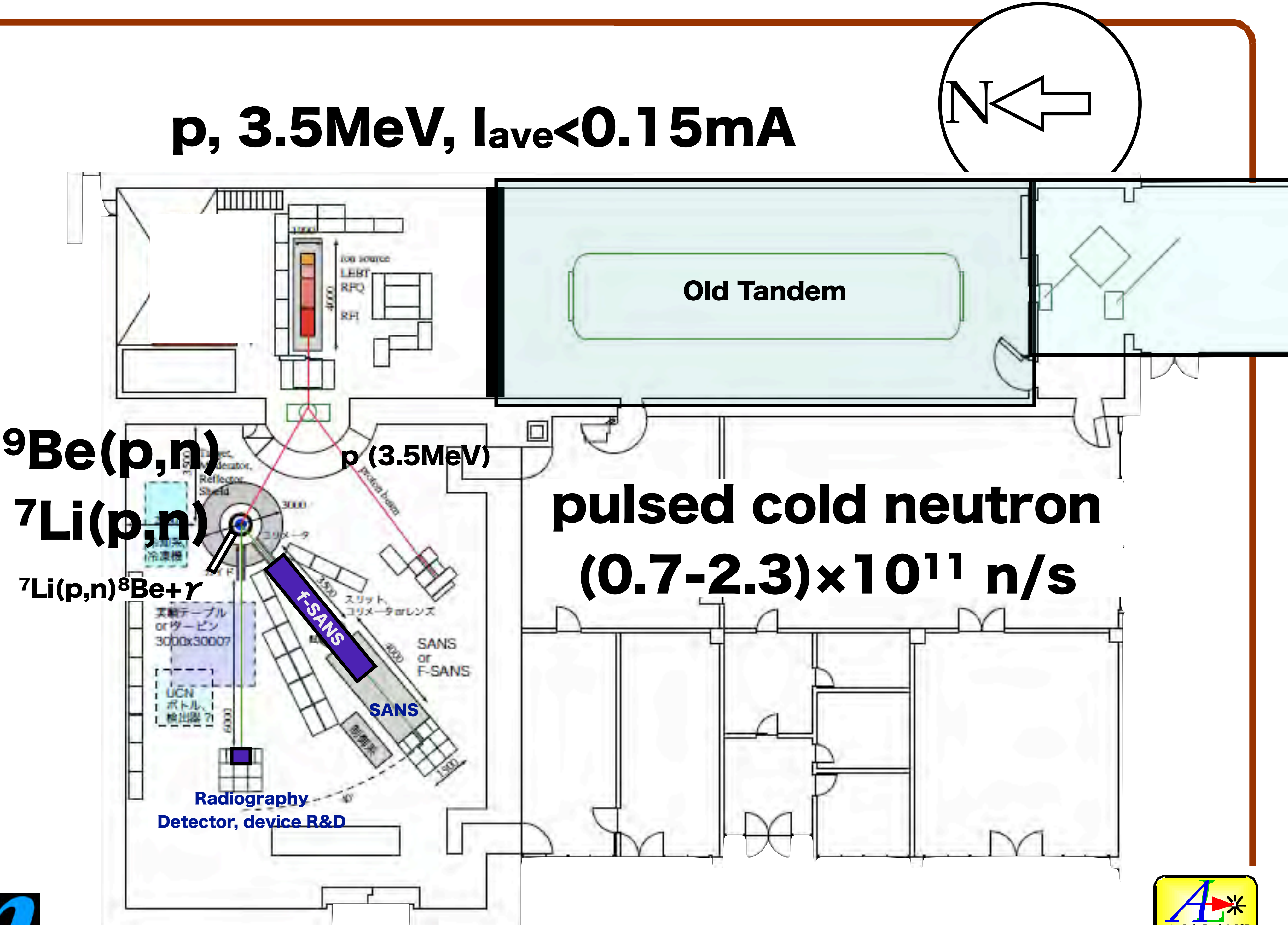
8MV Tandem van de Graaff at Faculty of Science



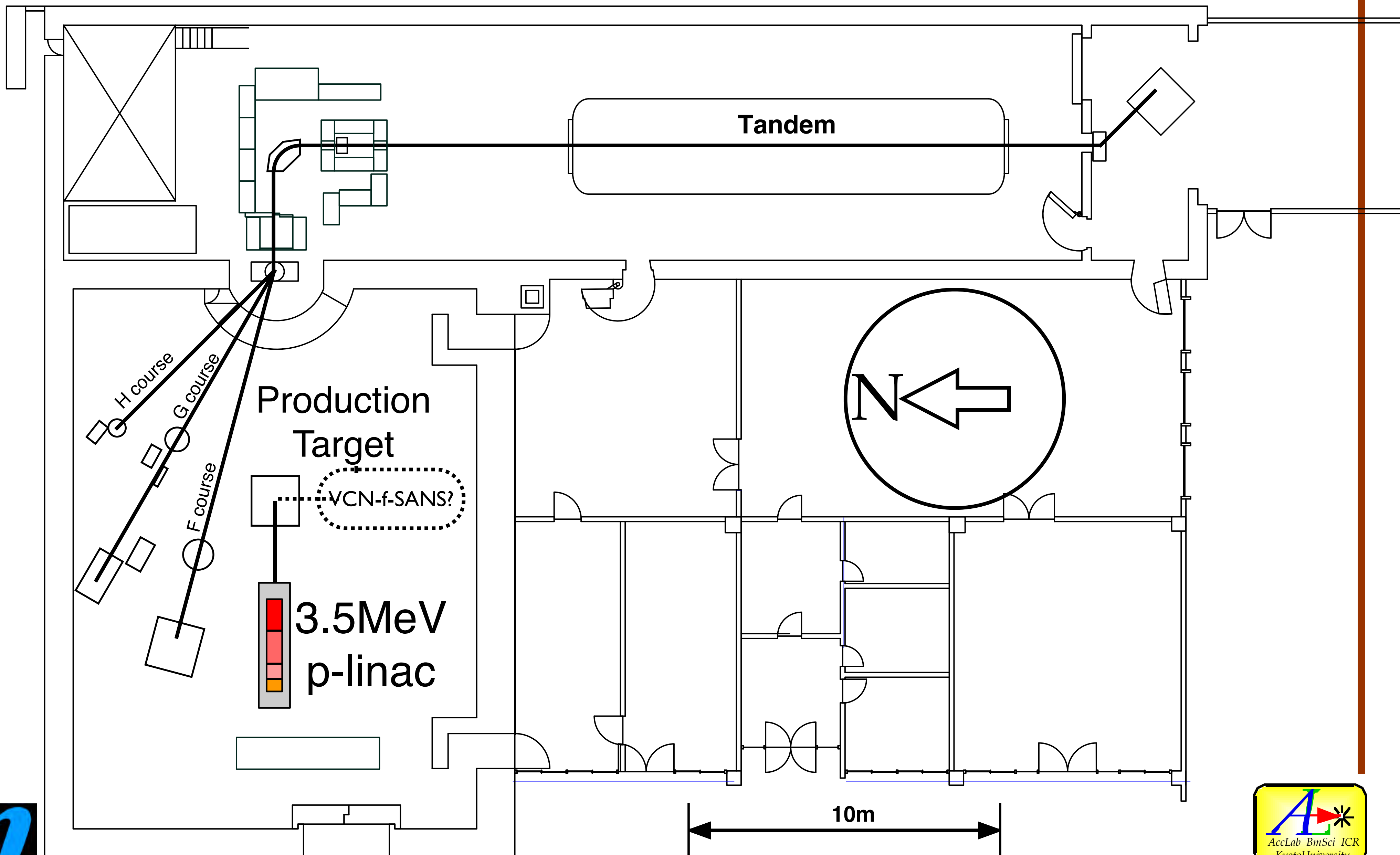
Prof. T.Nagae
The spokesman.

Prof. K.Imai
has retired
this March.

p, 3.5MeV, I_{ave}<0.15mA



Layout as of 2010.8.13



Specifications

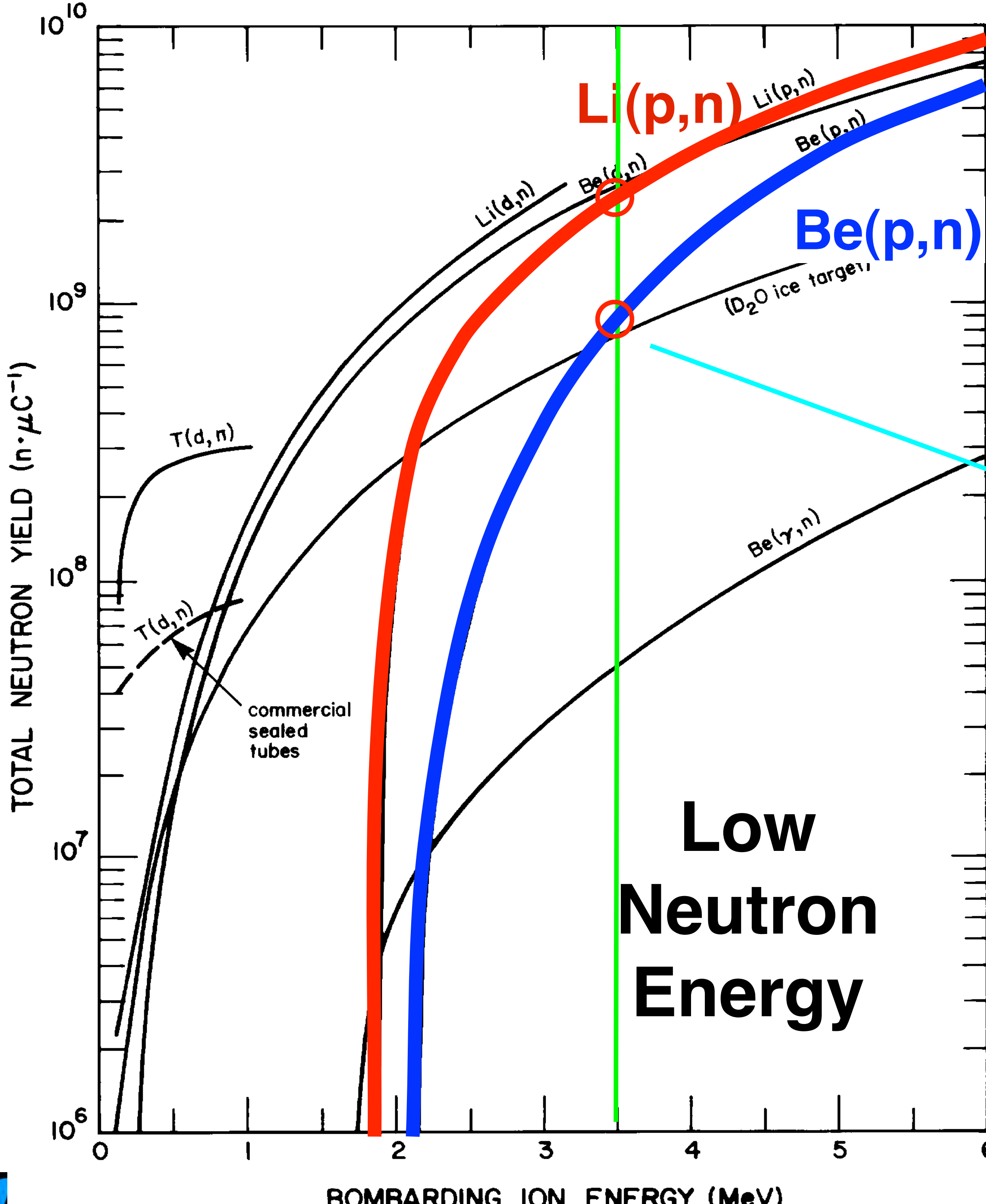
- 3.5MeV, <15mApk, <100μAave.
  <100Hz, <0.1ms, duty <1%,
  Beam Power < 0.35kW
- Compact （< 4m)
  ✓ low energy
  ✓ less shield and moderator
  ➡ gain neutron flux

pLinac will be installed this year.

Hope further progress (in budget?).

Neutron yield

M.R. Hawkesworth,
Neutron Radiography: Equipment and Methods,
Atomic Energy Review **15**, No. 2, 169-220, 1977.
R.W.Hamm, Proc. SPIE 4142 (2000) 39-47



$n \cdot \mu C^{-1} = n / (\mu A \cdot s)$

→

~10^{11} n/s @ $0.1mA_{ave}$

3.5MeV x 0.1mA=350W

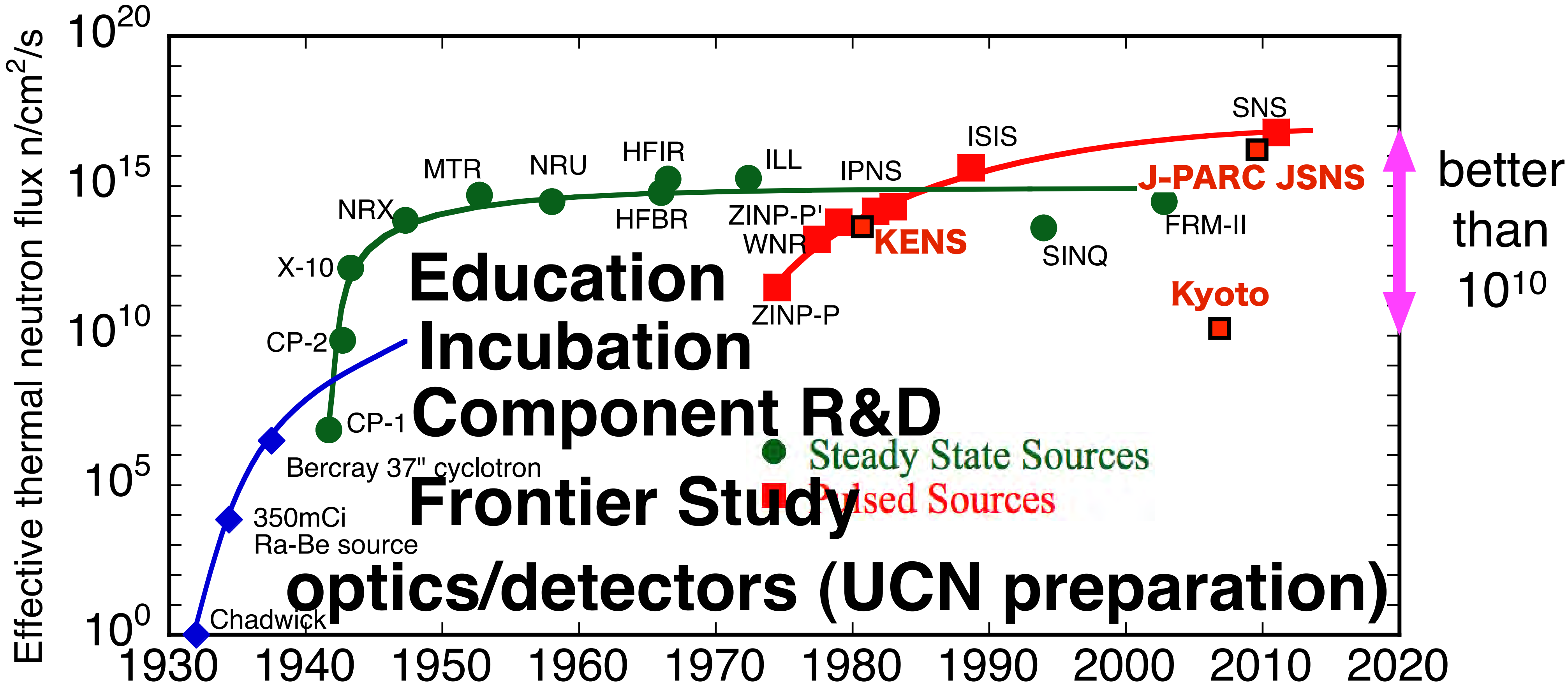
$1\mu C = 6x10^{12}$ p

$2x10^9$ n/μC^{-1}

→

one n / 3000 p

How weak?



History of neutron sources. Updated from Ref. [4].

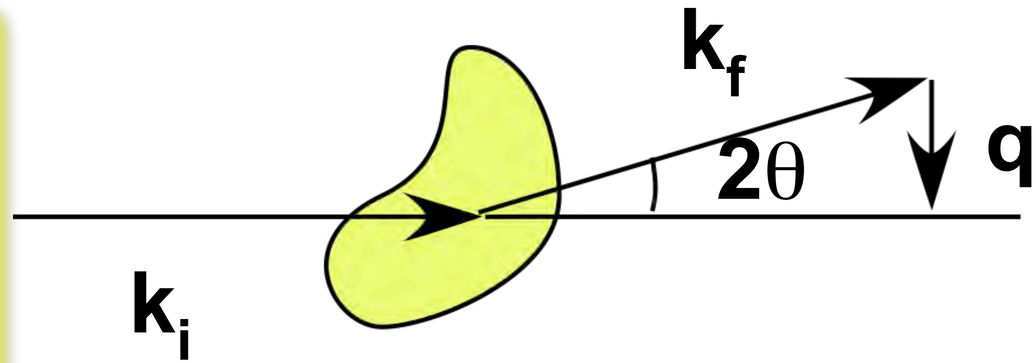
VCN
-focusing-
SANS

using modulating PMSx lens

Small Angle Neutron Scattering

$$q = \frac{4\pi \sin\theta}{\lambda},$$

$$d = \frac{2\pi}{q}, 2\theta \approx \frac{\lambda}{d}$$



⇒Particles

1. Size(rotating radius)
2. Form (sphere/clinder/…)
3. Surface structure

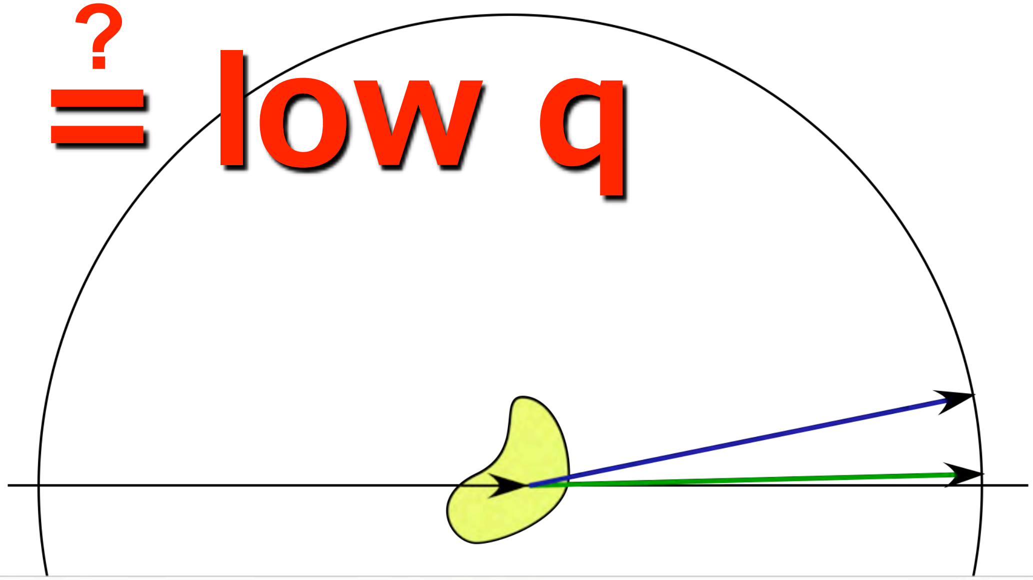
Neutron's features …

- sensitivity **to light elements**
  - e.g. H, Li, C, N, O,… ⇔ **SAXS**
- **magnetism**
  - ferro-, antiferro-, spin glass…
- **excitations**
  - e.g. atomic motion (vibration, libration, diffusion,…)

VCN-f-SANS

SANS $\overset{?}{=}$ low q

$$q = \frac{4\pi \sin\theta}{\lambda}$$



	2θ[º]	v[m/s]	E[meV]
Cold Neutron 5Å	1.41	800	3.3
Very Cold Neutron 40Å	11.3	100	0.05

ex. q=0.031Å^{-1}
(micell of Pluronic)

Cold Neutron (CN) + small θ → **Very CN** + large θ

on-sample focusing is applicable

small size sample

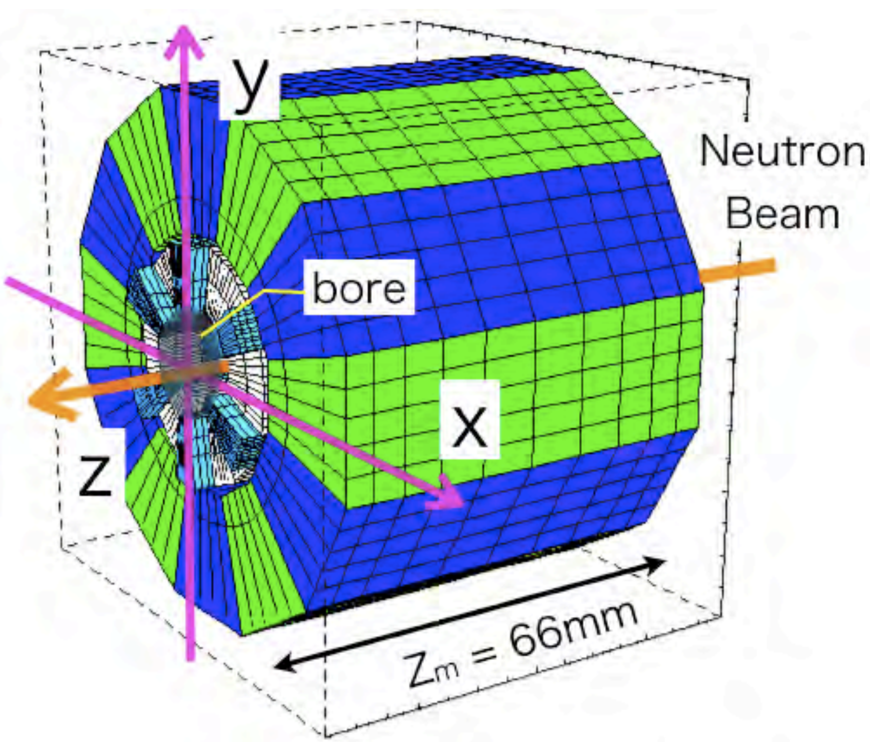
VCN-f-SANS

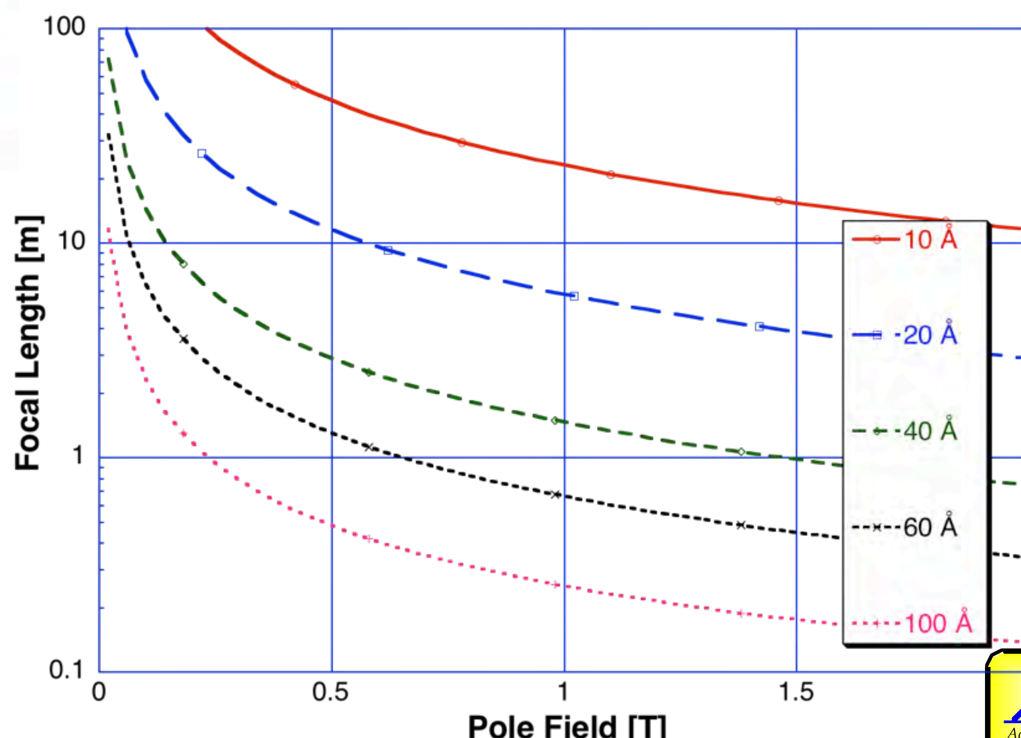
rot-PMSx

rotating – Permanent Magnet Sextupole

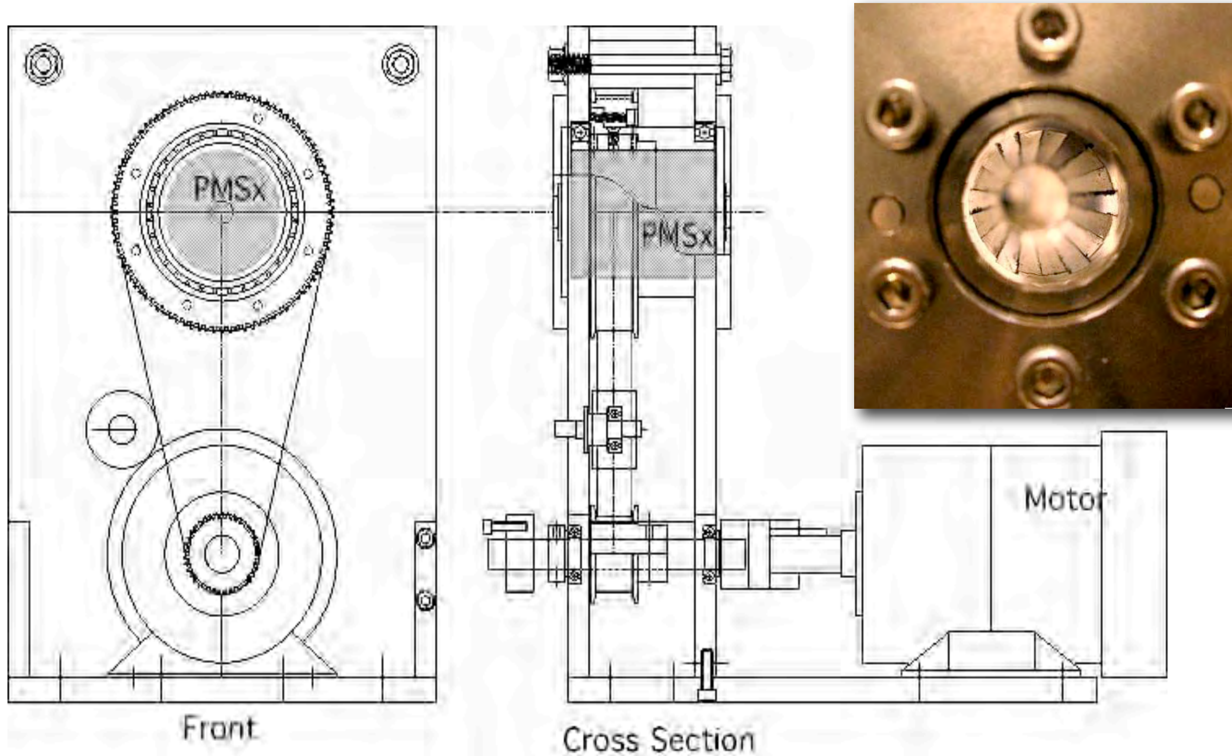
$$|B| = \frac{1}{2} g' r^2,$$

g'; *sextupole field gradient*



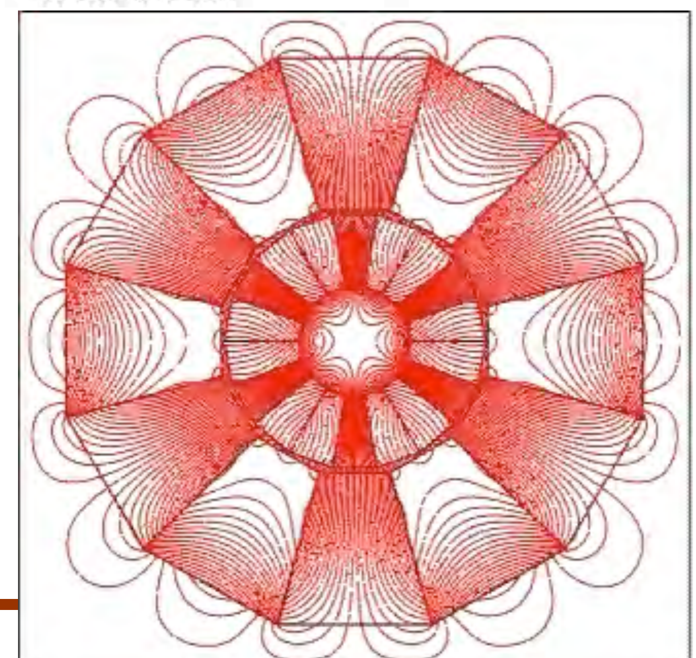


VCN-f-SANS rotating – Permanent Magnet Sextupole



Permanent Magnet size
ID=15mm
OD=80mm

Inner: 18 sections
Outer: 12 sections



Neutron Optics and Physics

AccLab BmSci ICR KyotoUniversity

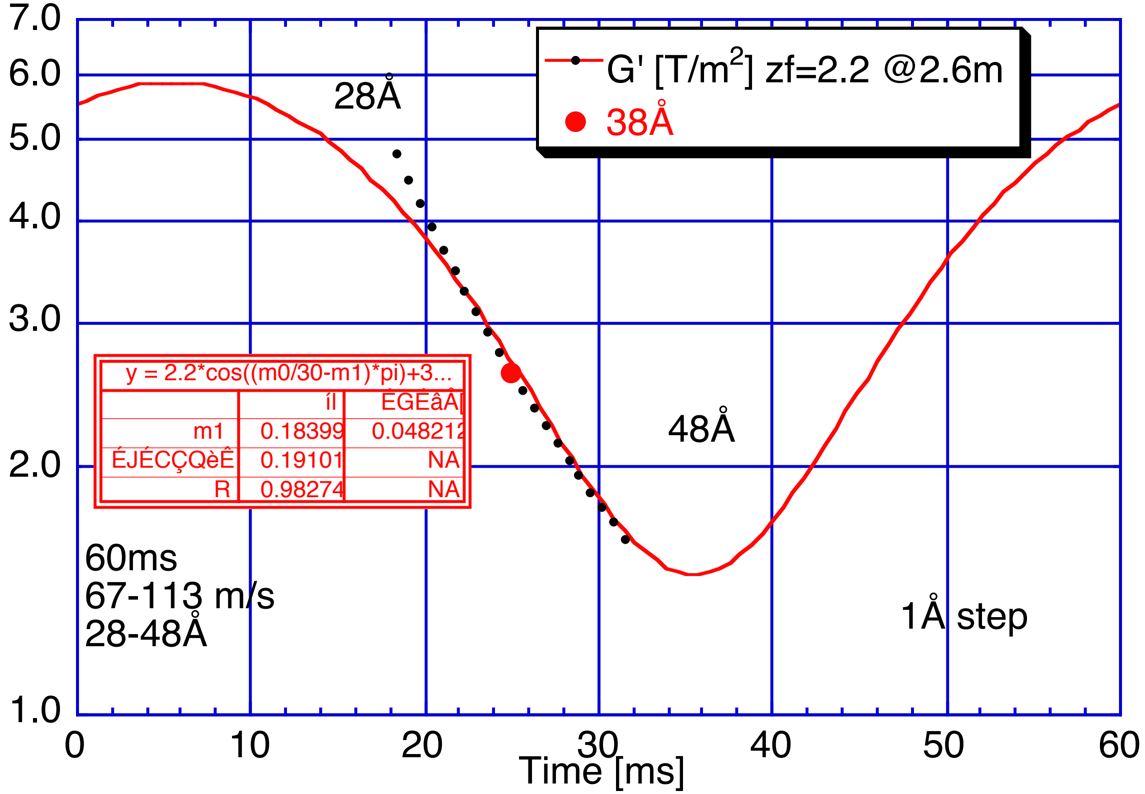
VCN-f-SANS

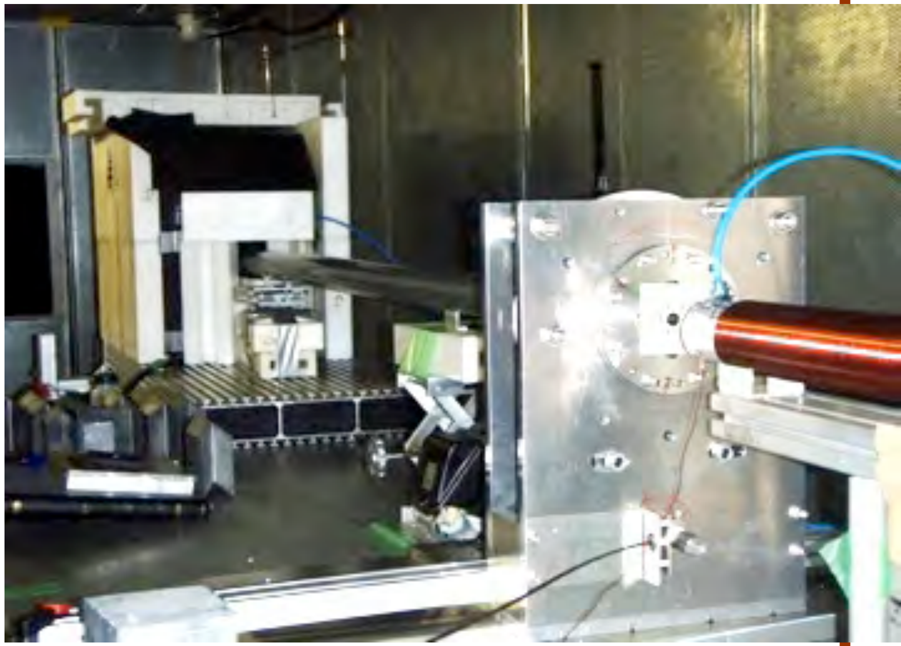
Synchronization between rot-PMSx and pulsed VCN

ToF method

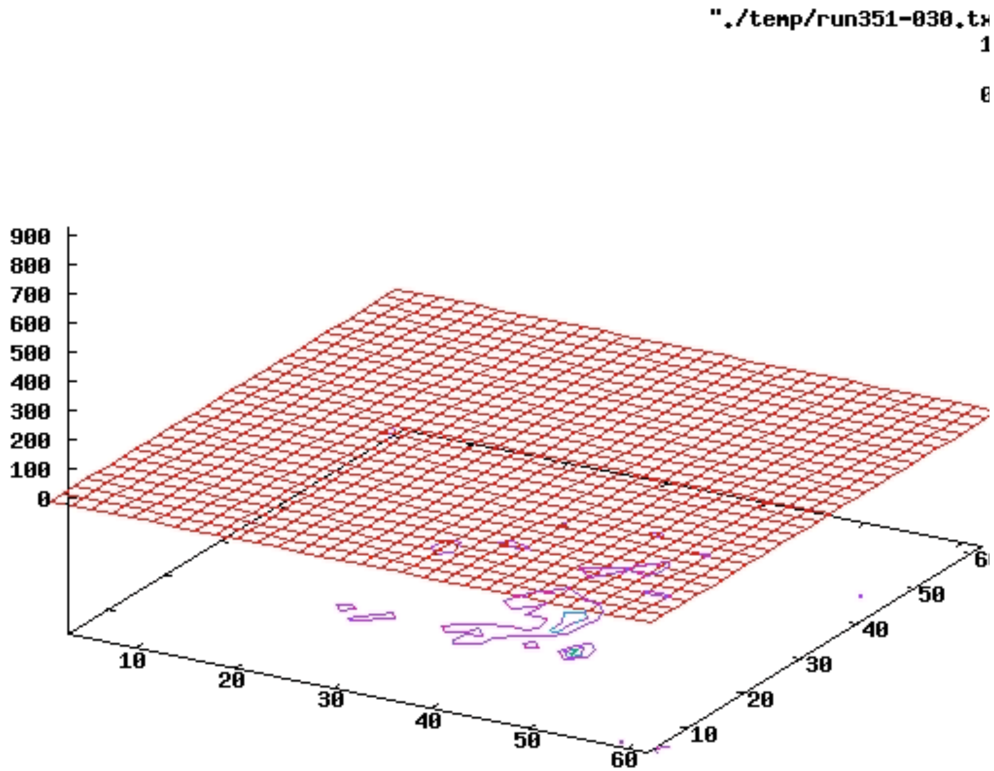
$$\lambda = \frac{h}{mv} \propto t^{-1}$$

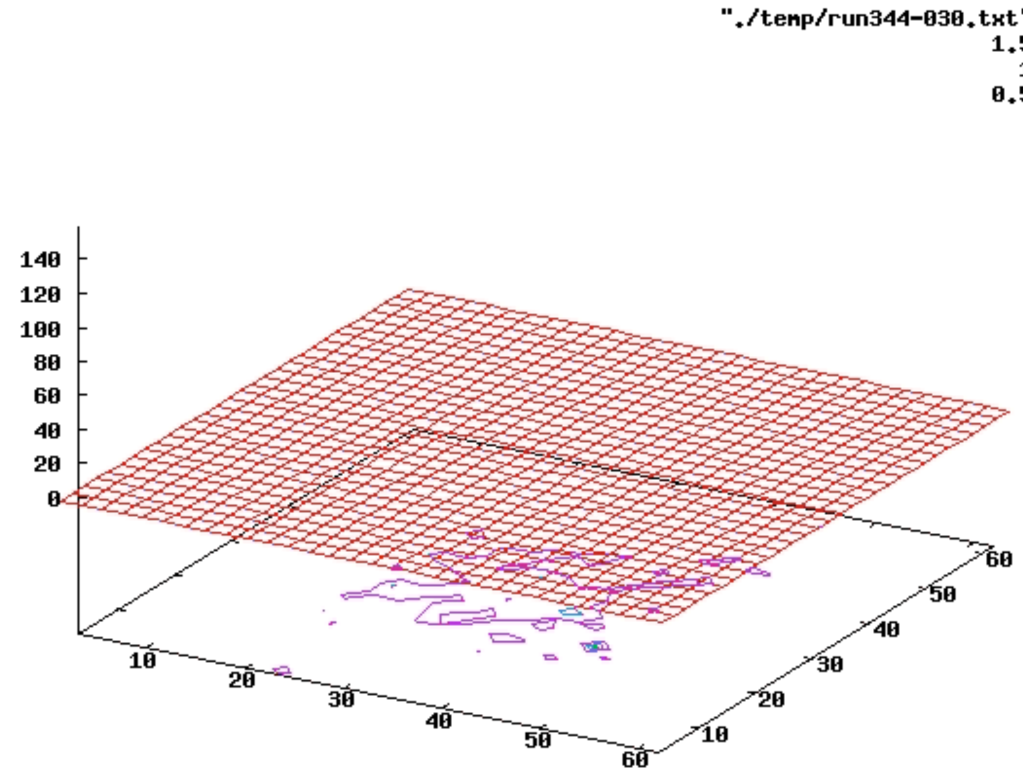
$$Z_f = const \Rightarrow g' \propto \lambda^{-2} \propto t^{-2}$$





Focusing Test: Beam size



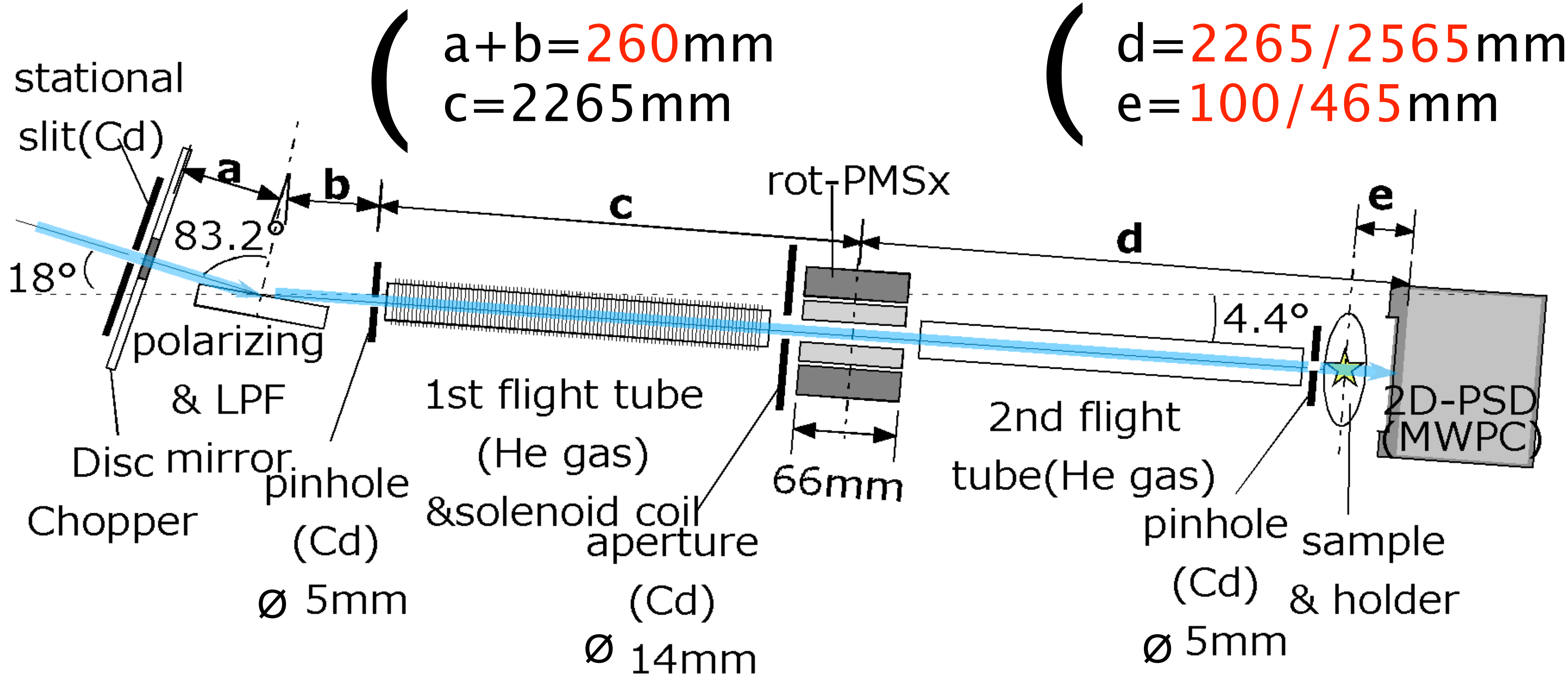


Well Synchronized

Off Synchronization

Caution: different scales!

VCN-f-SANS setup overview sample focus



- **tof length : 4790/5090mm**
- **optics : ø5mm - ø14mm**
- **frequency : 16.7Hz(60ms)**
- **opening angle : 3ms**
- **polarized by magnetic super mirror (by K. Andersen)**
- **spin transport field : > 50Gauss**
- **band width : 30 ≤λ≤ 48Å**

$\Delta\lambda/\lambda = 6.8 \pm 1.5\%$

Sample: Pluronic F127 in D_2O 15wt%

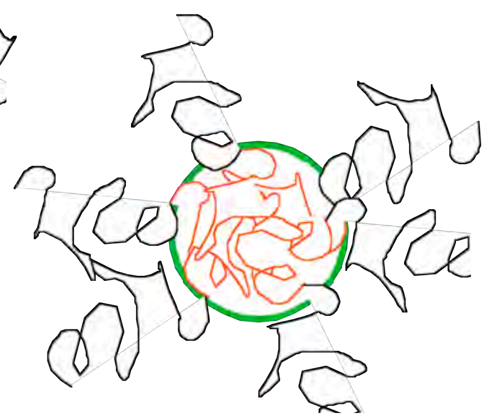
non-ionic polymeric surfactants

PEO_{100}-PPO_{65}-PEO_{100} ; the water soluble triblock copolymer

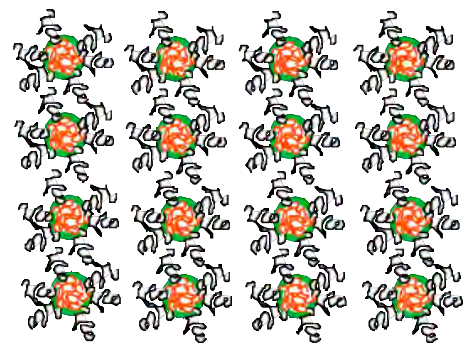
4±2 | 28±2 | 51±2 | 70±2

0 | 15 | 30 | temperature [C°]

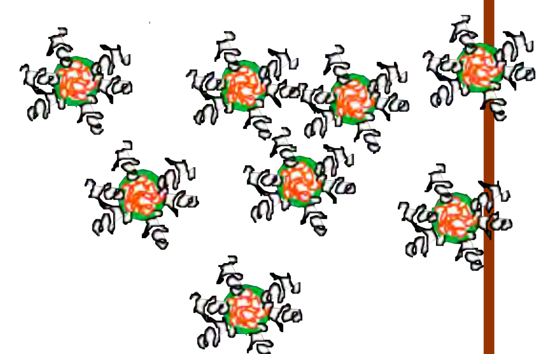
unimer



formation of spherical micelle



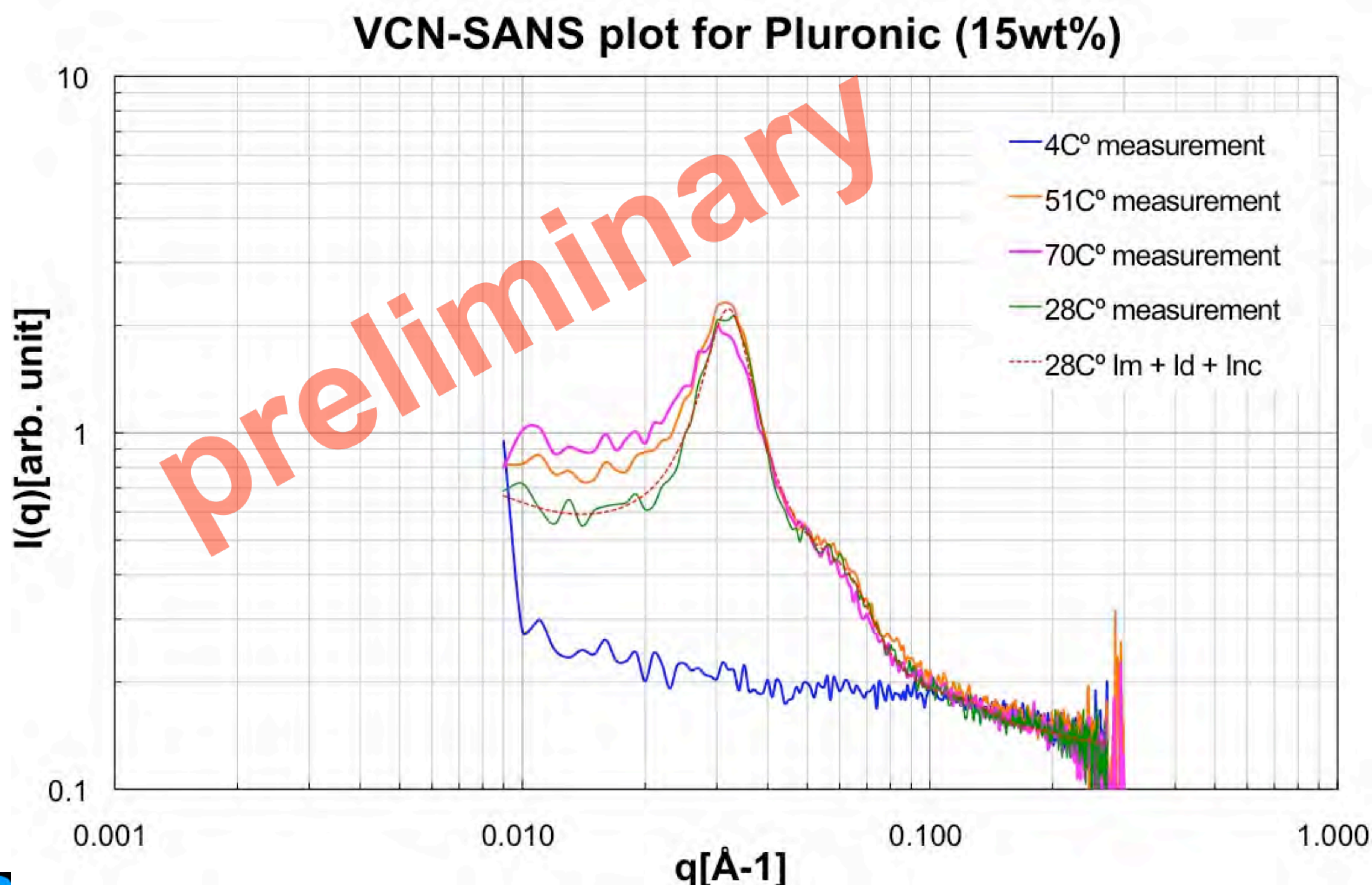
formation of gel (long range order)



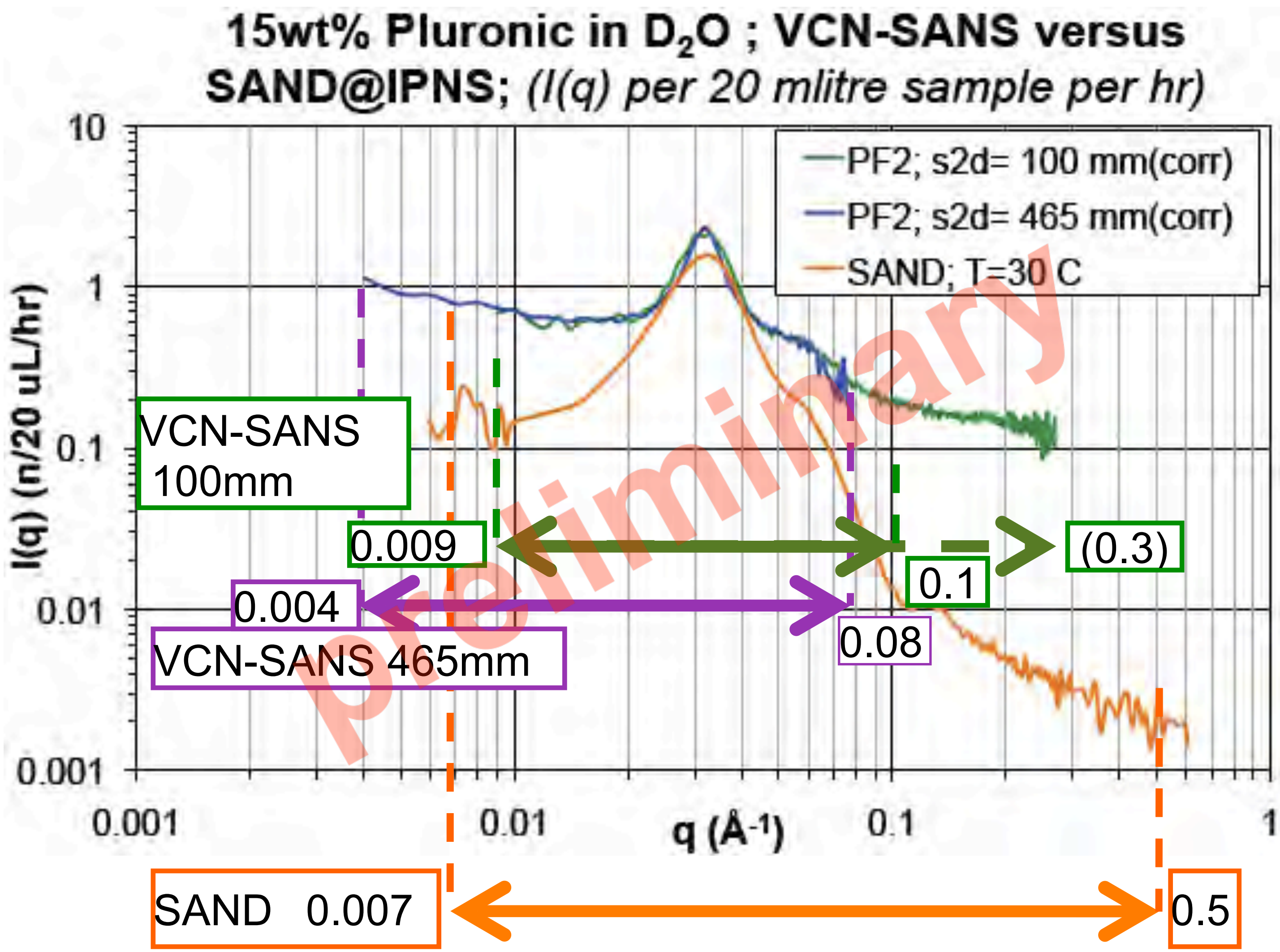
loss of long range order (disordered)

Drawings : Jyotsana Lal (ANL) private communications

VCN-SANS results for Pluronic F127(15wt%)



VCN-SANS vs. SAND@IPNS



$\Delta q = 0.001 Å^{-1}$

	q_{min} $Å^{-1}$	q_{max} $Å^{-1}$
VCN-SANS 100mm	0.009	0.1 (0.3)
VCN-SANS 465mm	0.004	0.08
SAND (IPNS)	0.007	0.5

VCN-f-SANS

Future Plan

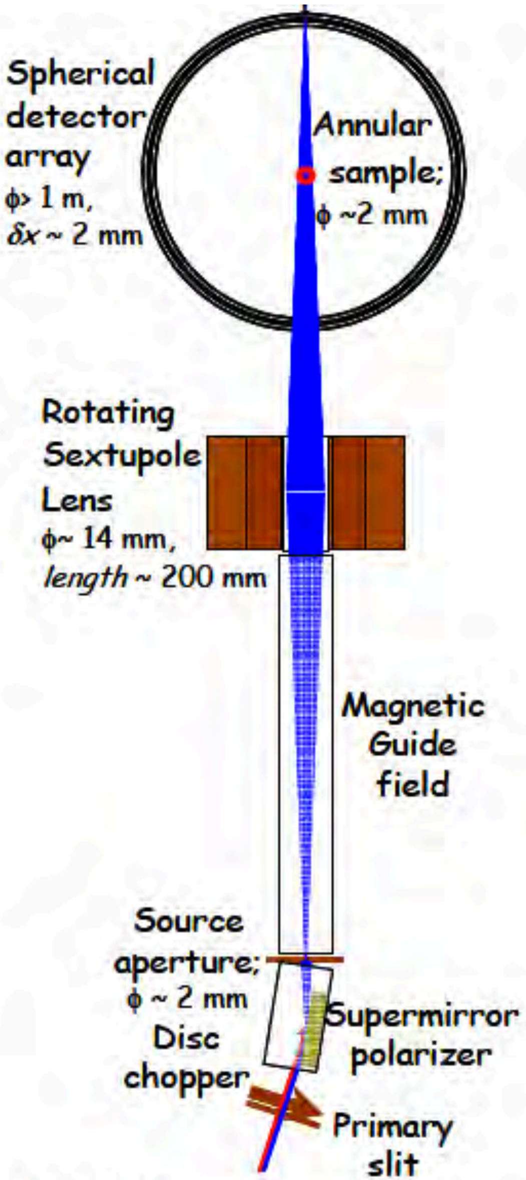


Fig. 1. VCN-SANS configuration

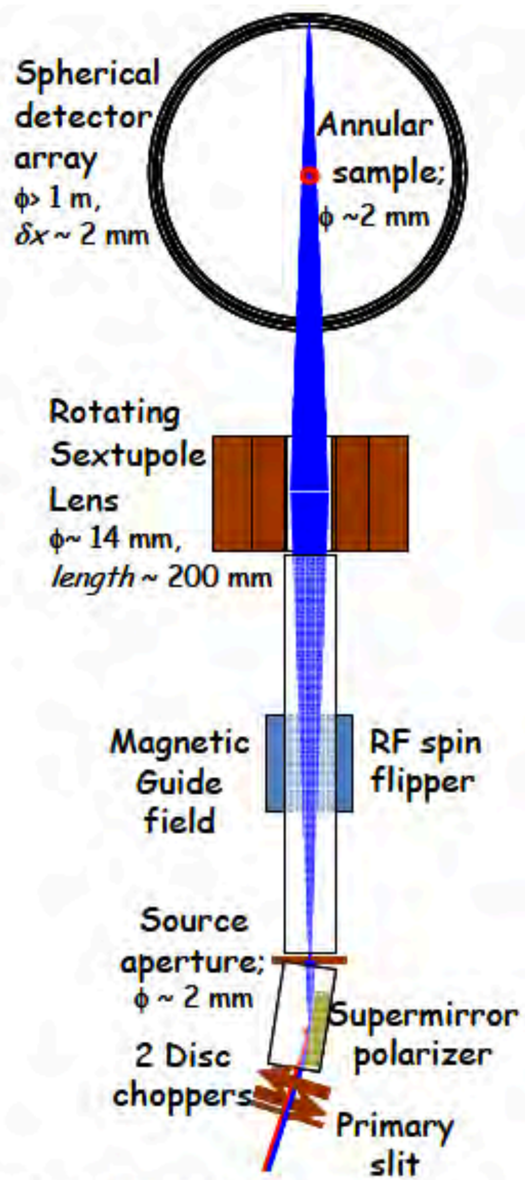


Fig. 2 VCN-MIEZE SANS configuration

VCN-f-SANS

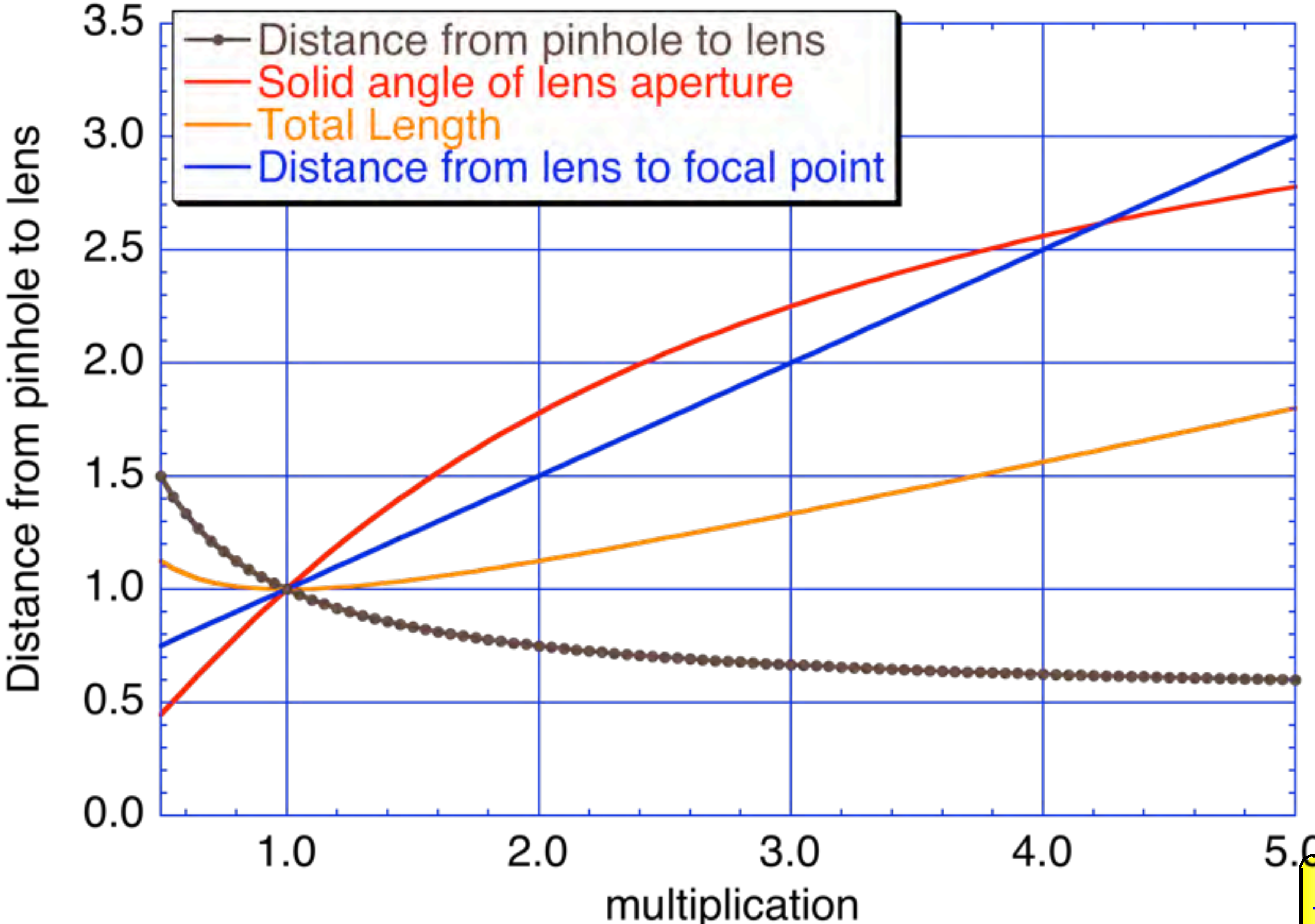
Scaling Laws

1) Lens focal strength is proportional to (lens aperture)$^{-2}$ x (lens length)
2) Solid angle of the lens aperture is proportional to (focal strength)$^{-2}$
3) The total distance is scaled as (focal strength)$^{-1}$
4) The focal length is proportional to (wavelength)$^{-2}$
5) Rep. rate of the chopper can increase for the shorter total length .

When we use three set of the same PMSx, the total length would be 5/3m, which is less than 2m (not 5m).

VCN-f-SANS

Figure of Merit



Concluding Remarks

- PL will be delivered by the end of Dec. 2010. –
- Will help to enhance the neutronian's activities: Education, Incubating new ideas, etc.
- PECRIS R&D is on going.
(Far upstream)
- f-SANS with VCN can be very short and handy.
- rot-PMSx version is under investigation.

just a poor playing words:

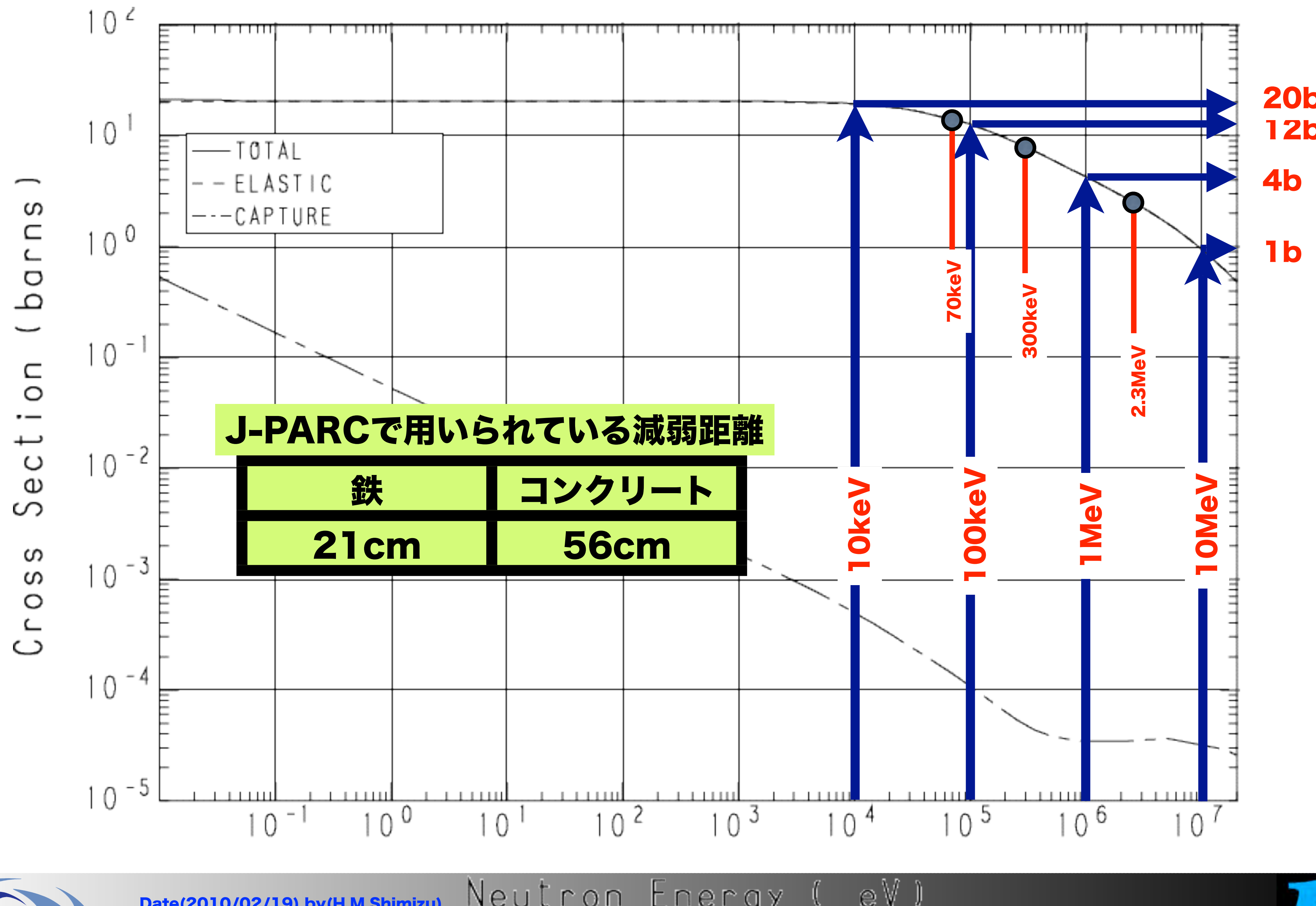
Ultra Cold Accelerator based Natural Science

Thank you!

Appendix

中性子遮蔽 (+中性子減速)

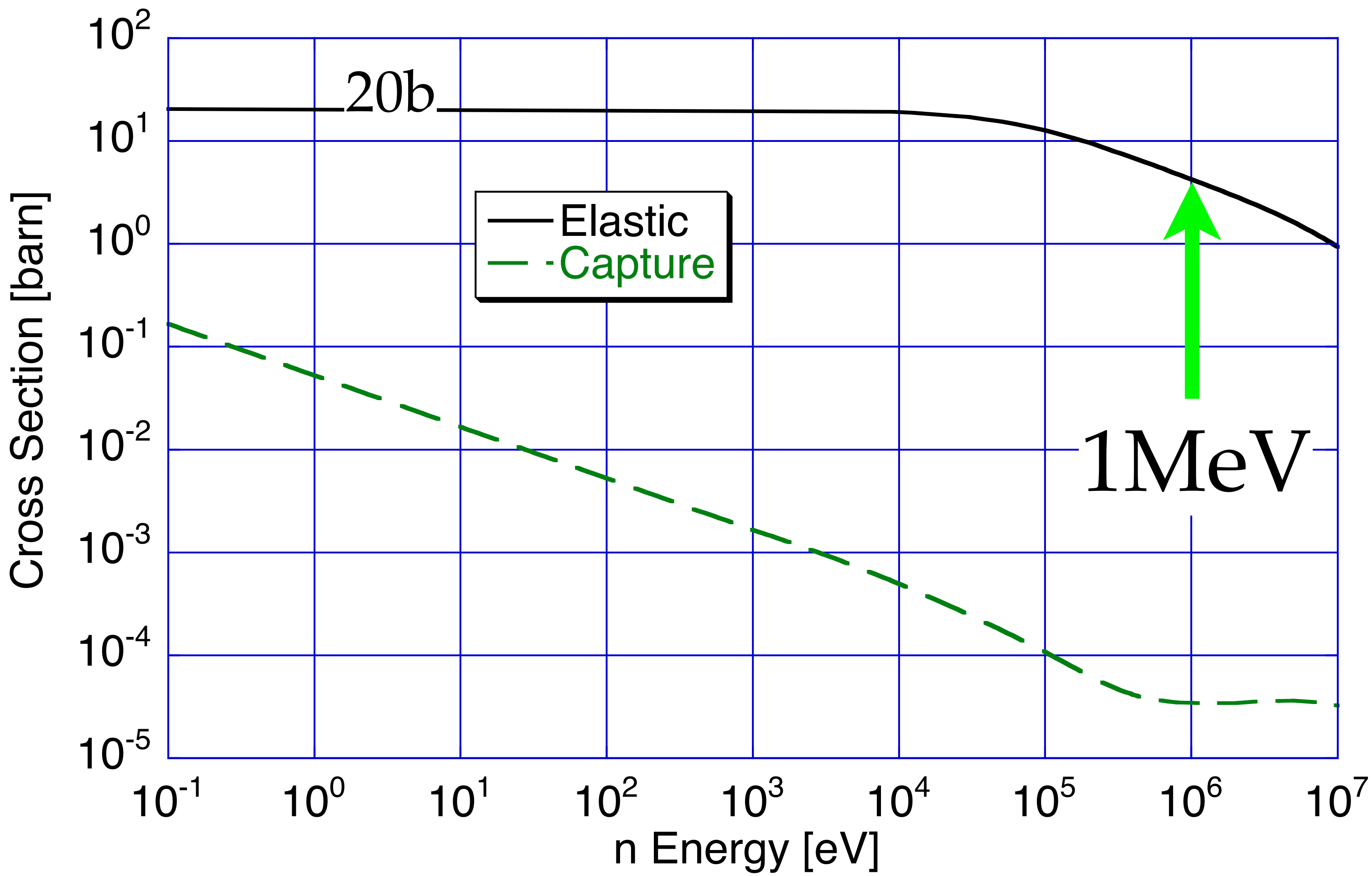
cross section of $^{1}H+n$



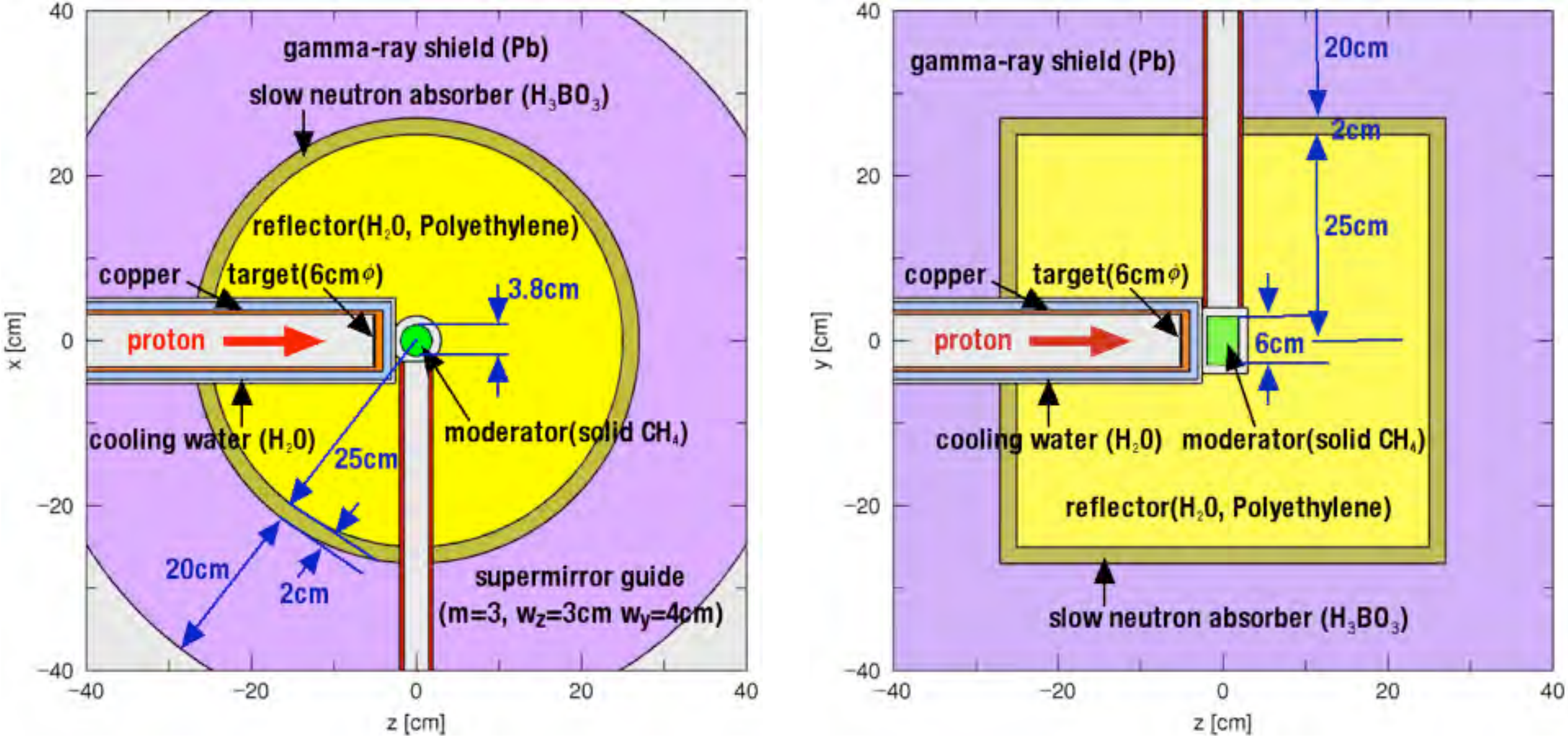
J-PARCで用いられている減弱距離

鉄	コンクリート
21cm	56cm

Cross-section of H + n (from JENDL-3.3 [2]).

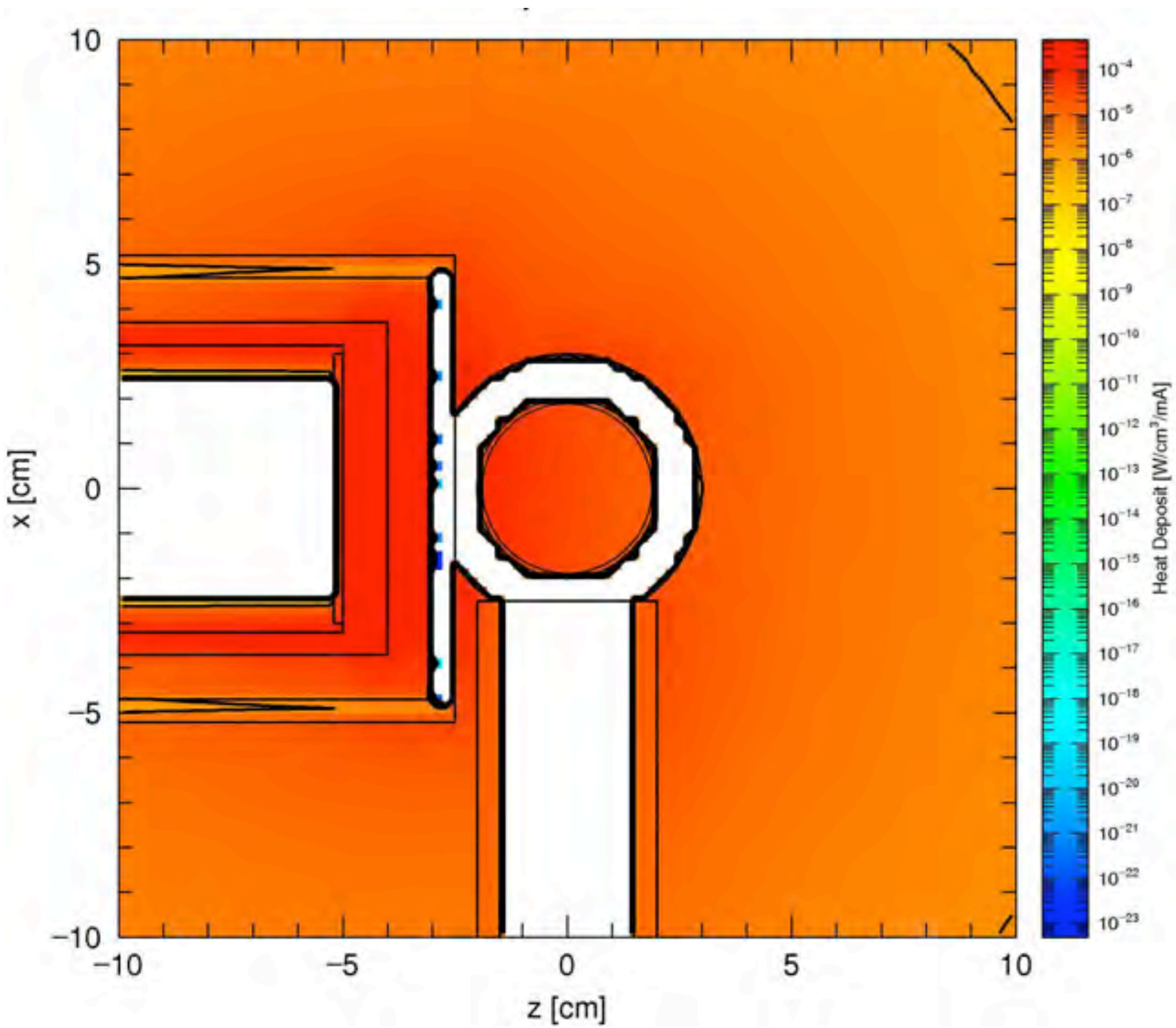


Moderator



gamma-ray shield (Pb)
slow neutron absorber (H_3BO_3)
reflector(H_2O, Polyethylene)
copper
target(6cmφ)
3.8cm
proton
cooling water (H_2O)
moderator(solid CH_4)
25cm
20cm
2cm
supermirror guide
(m=3, w_z=3cm w_y=4cm)
x [cm]
z [cm]
gamma-ray shield (Pb)
20cm
2cm
25cm
copper
target(6cmφ)
6cm
proton
cooling water (H_2O)
moderator(solid CH_4)
reflector(H_2O, Polyethylene)
slow neutron absorber (H_3BO_3)
y [cm]
z [cm]

Heat Load



Beam Intensity