Status of Cold Neutron Research Facility Installation In HANARO

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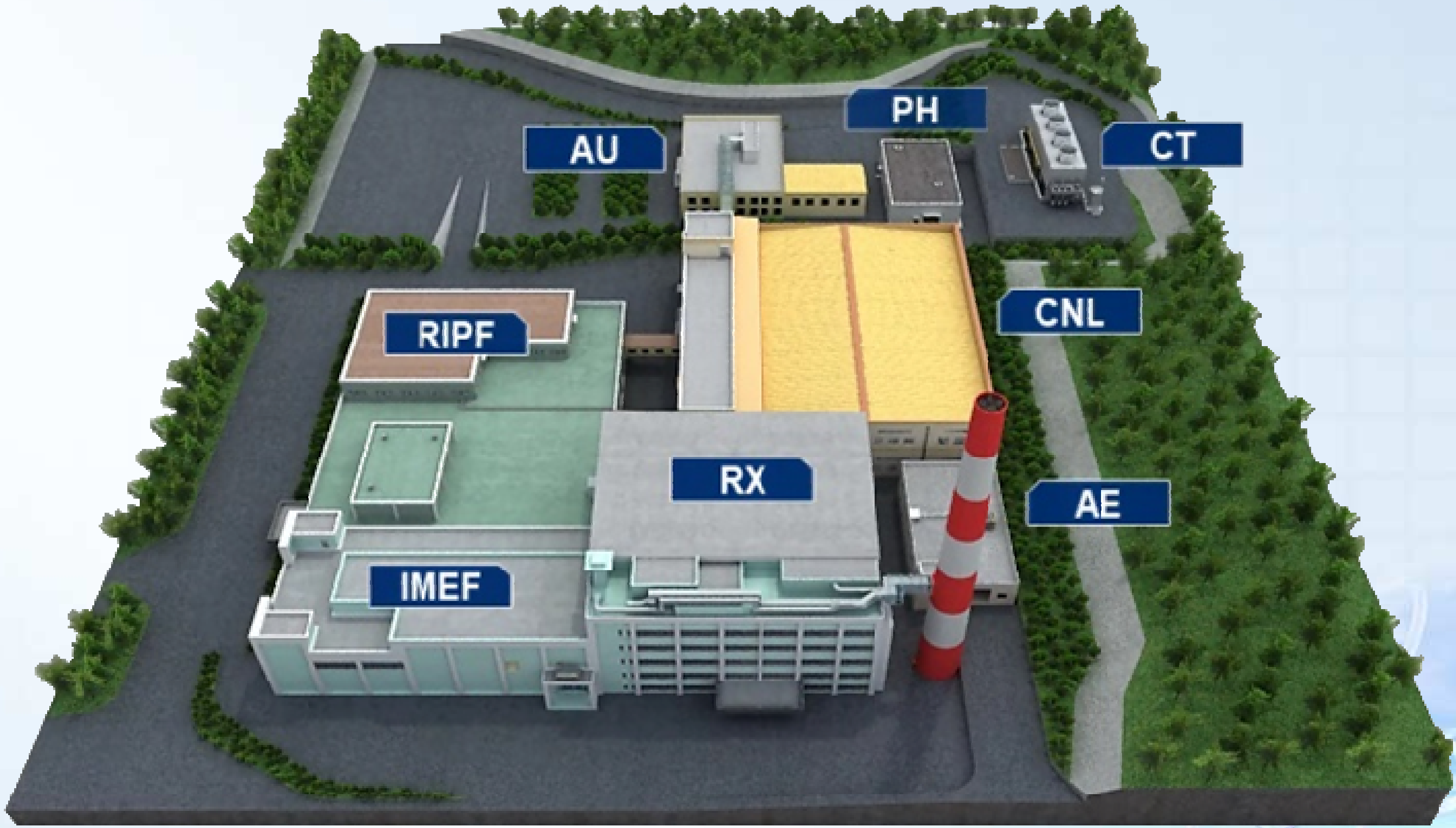
Introduction to HANARO

Korea Atomic Energy Research Institute

Korea Atomic Energy Research Institute

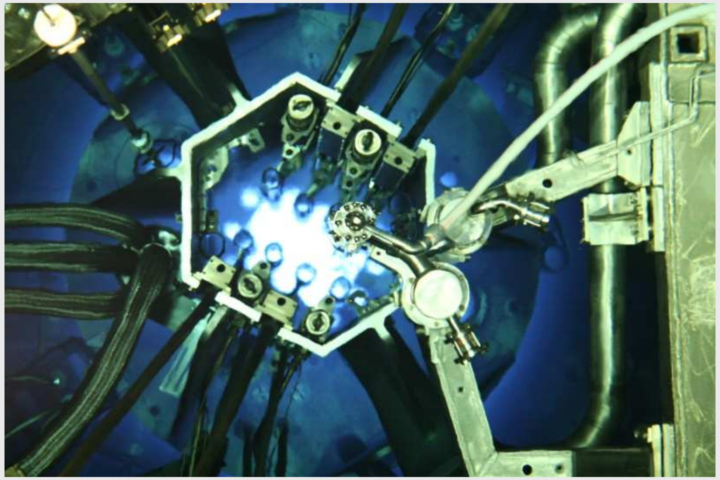
HANARO Complex in KAERI



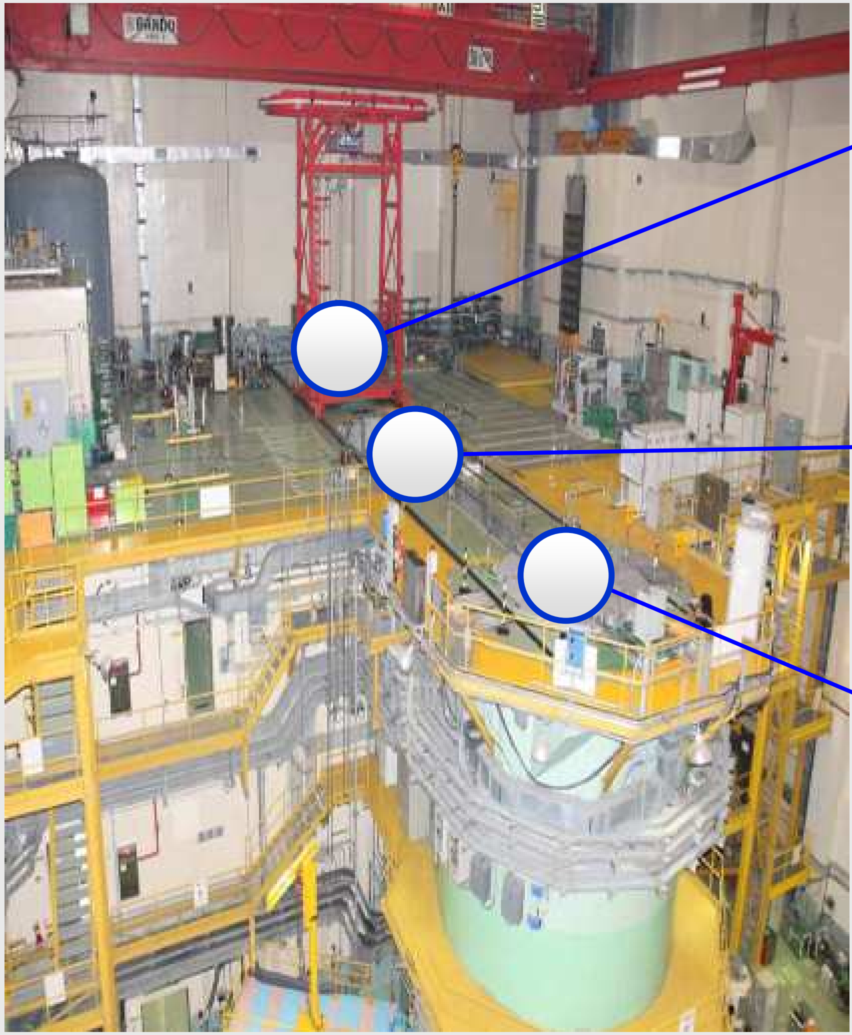
HANARO Reactor

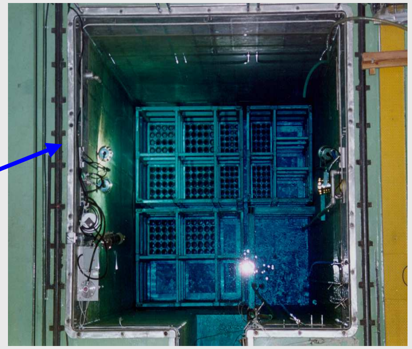
High-flux
Advanced
Neutron
Application
React**O**r

Multi-purpose Research Reactor



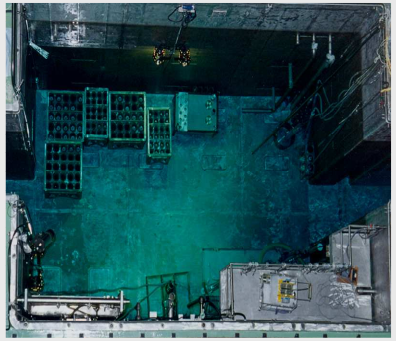
Reactor Pools

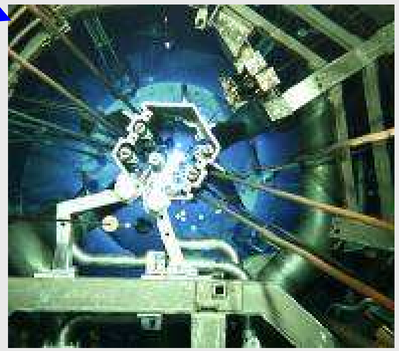




Spent Fuel Storage Pool

Service Pool





Reactor Pool

Mission of HANARO

User Community

- Industry
- University
- Institute
- International Cooperation

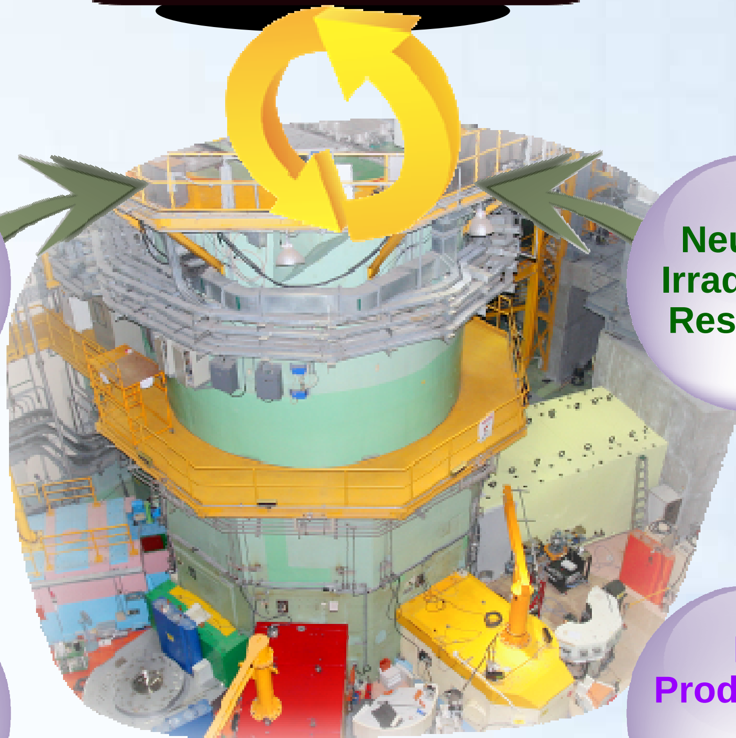
Platform for Nuclear Basic Research

National Demand

- Basic R&D
- Competitiveness in Technology

- Cold Neutron Bea
- Radiography

Neutron Beam Research



Neutron Irradiation Research

- Fuel Test Loop
- Material Irradiation
- Neutron Activation Analysis
- NTD

- Reactor Operation
- Experimental Facility Operation

Operation & Development

SAFETY

RI Production & Utilization

- Public Welfare
- Industrial Application

Chronology

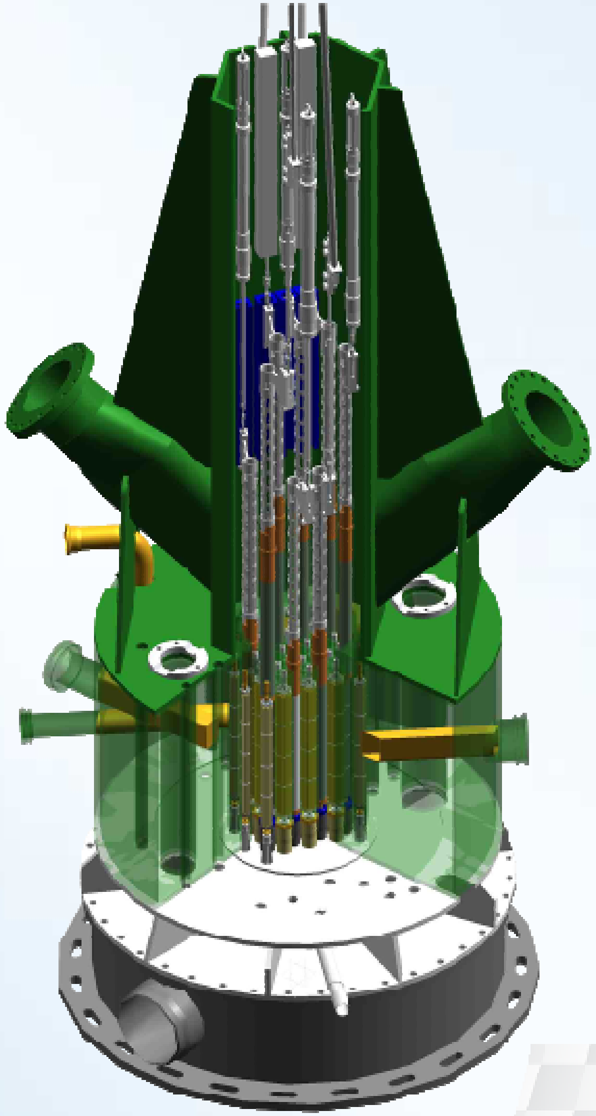
- 1985 JAN Start of HANARO Project
- 1989 JAN Start of HANARO Construction
- 1993 AUG Installation of HANARO Reactor Structure
- 1995 FEB Fuel Loading and Achievement of Initial Criticality
- 1996 JAN 15MW Power Operation
- 1999 DEC 22MW Power Operation
- 2004 NOV 30MW (Design Power) Power Operation started
- 2005 MAR First Loading of HANARO Fuel Made by KAERI
- 2006 APR Start of Cold Neutron Laboratory Construction (Completed in May 2008)
- 2006 JUL Start of Fuel Test Loop Installation (Completed in Feb. 2008)
- 2008 MAY Start of Cold Neutron Source System Installation
- 2009 SEP 3 First Generation of Cold Neutron

HANARO, Past and Present

Feb., 1995

Oct., 2009

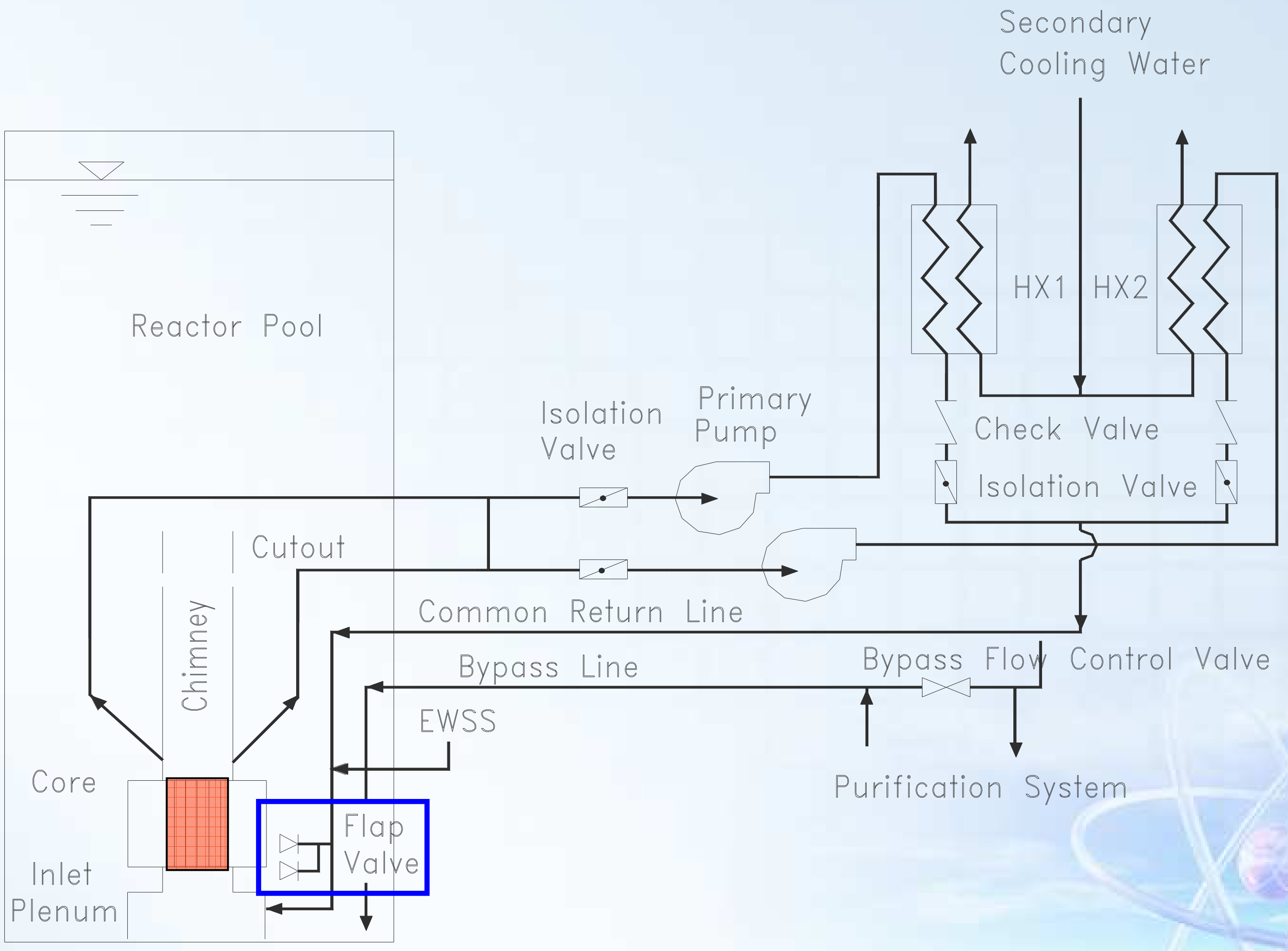
Reactor Structure and Characteristics



Features

- Type — Open-tank-in-pool
- Power — 30 MW_{th}
- Coolant — Light Water
- Reflector — Heavy water
- Fuel Materials enriched — U_3Si, 19.75%
- Absorber — Hafnium
- Reactor Building — Confinement
- Max Thermal Flux — $5x10^{14}$ n/cm^2s
- Typical flux at port nose — $2x10^{14}$ n/cm^2s
- 7 horizontal ports & 36 vertical holes
- Vertical hole for cold neutron source
- Operation Cycle — 28 days@38 days

Primary Cooling System



Reactor Hall, 2010

In-service
Under way

IR Port
Ex-Core Neutron Irradiation Facility (ENF), 2005

ST1 Port
Prompt Gamma Neutron Activation Analysis(PGAA), 2003

Residual Stress Instrument(RSI), 2003

NR Port
Neutron Radiography Facility (NRF),1997 Upgrade

ST4 Port
Triple Axis Spectrometer (TAS), 2010

Neutron Reflectometer (REF-V), 2006
Moved to CNL in 2010

CN Port
Small Angle Neutron Scattering (SANS),2001
Moved to CNL, 2010

Cold Neutron Guide, 2009

Bio-Diffractometer (Bio-D), 2010

Neutron Reflectometer, (REF-H), 2008
Moved to CNL, 2010

ST3 Port
High Intensity Powder Diff. (HIPD), 2008

ST2 Port
High Resolution Powder Diff. (HRPD),1998

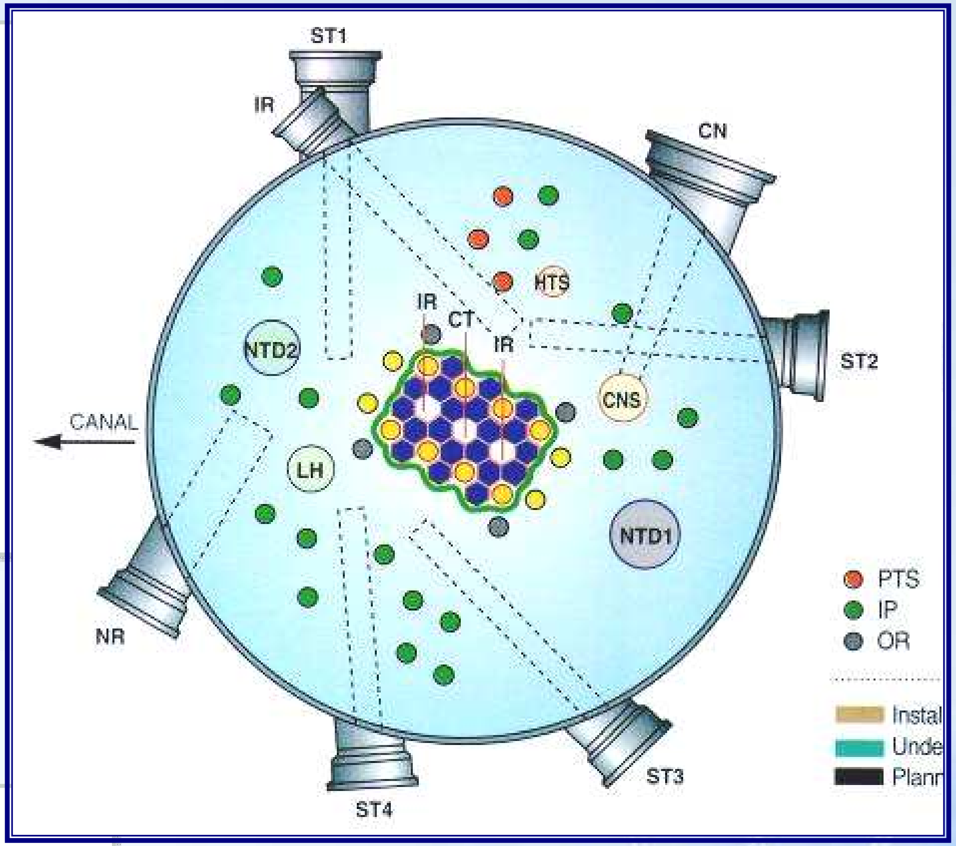
Four Circle Diffractometer (FCD),1999 Upgrade ’05-’06

Status of Experimental Facilities

Vertical Holes

Installed

IR1: Fuel Test Loop
CT, IR2: Capsule Irradiation& RI Production
OR : Capsule Irradiation & RI Production
IP : RI Production
HTS : Hydraulic Transfer System for RI Production
PTS : Pneumatic Transfer System for Neutron activation Analysis
NTD : Neutron Transmutation Doping of Silicon
CNS : Cold Source Installation



Horizontal Tubes

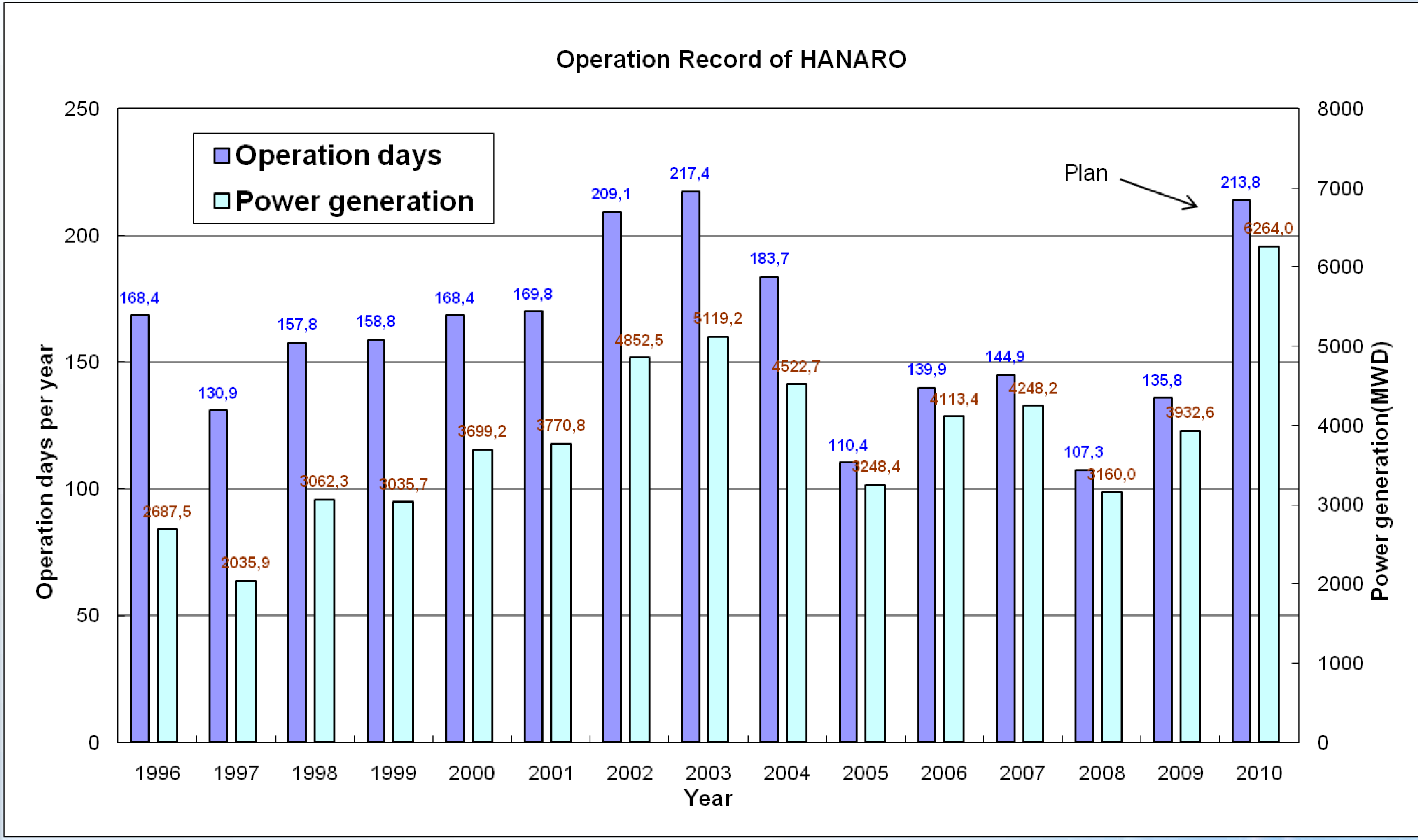
Installed

ST2 : High Resolution Powder Diffractometer, Four Circle Diffractometer
NR : Neutron Radiography Facility
CN : Cold Neutron Guide
IR : Ex-core Neutron-irradiation Facility for BNCT & DNR
ST1 : PGAA and RSI
ST3 : High Intensity Powder Diffractometer

Under-development

ST3 : Bio-diffractometer
ST4 : Triple Axis Spectrometer

Reactor Operation Record



Regional Cooperation for Neutron Science

The Asia-Oceania Neutron Scattering Association was officially formed on August 28th, 2008

Members

- Korean Neutron Beam Users Association
- Japanese Society of Neutron Science
- Australian Neutron Beam Users Group
- Indian Neutron Scattering Society
- Taiwan Neutron Science Society

Observers

- China
- India
- Indonesia
- Malaysia
- Singapore

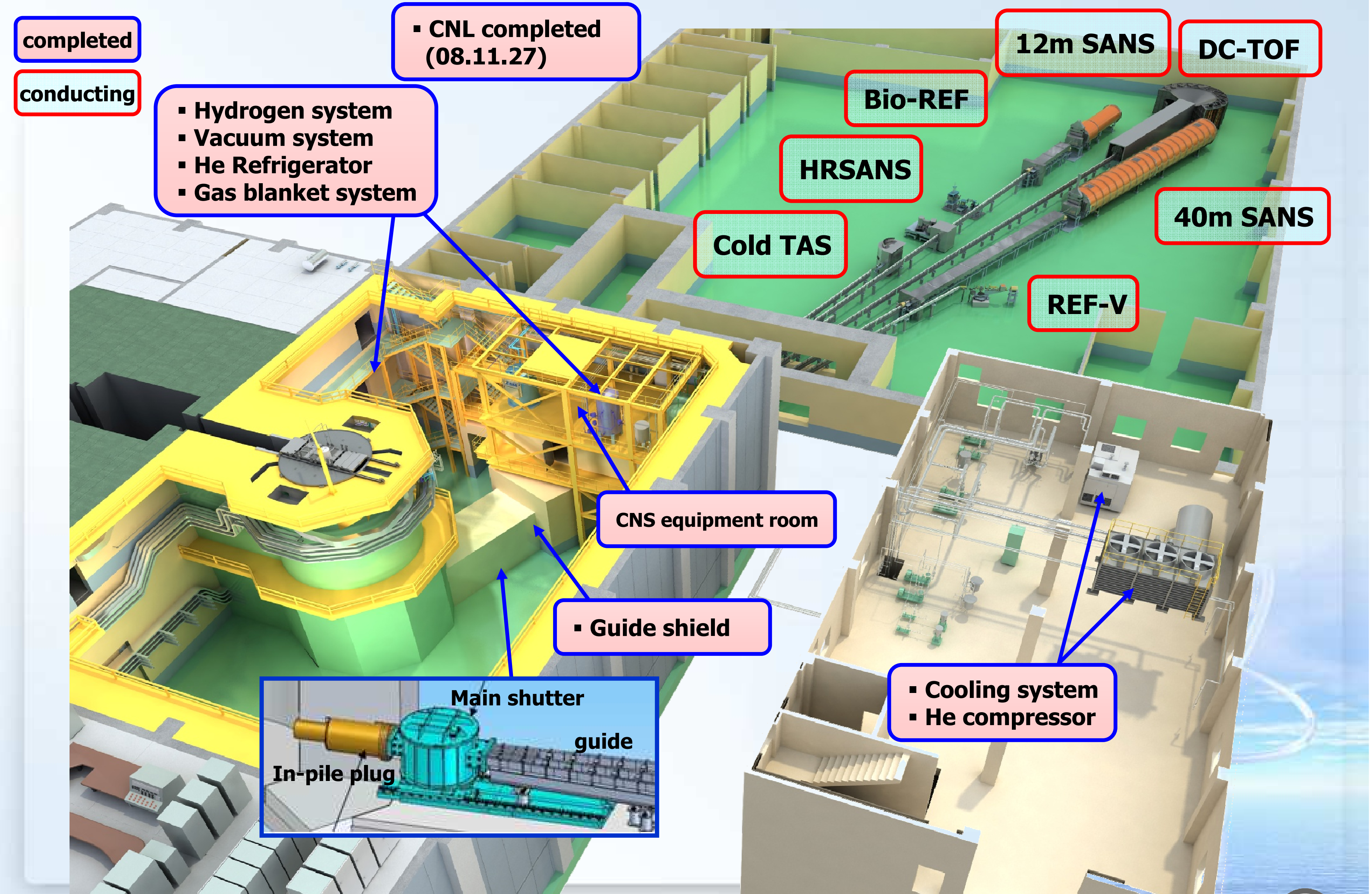
Cold Neutron Research Facility Installation Project

Korea Atomic Energy Research Institute

Cold Neutron Research Facility

Project	Development of the Cold Neutron Research Facility and Utilization Technology
Project Period	2003. 7 – 2010. 4
Major Parts	Cold Neutron Source and System Utilities (CNS) Neutron Guides (NG) Neutron Spectrometers (NS) Users program and international collaboration Cold Neutron Laboratory (CNL)

View of Cold Neutron Research Facility



Construction of Cold Neutron Laboratory(04.1-08.11)

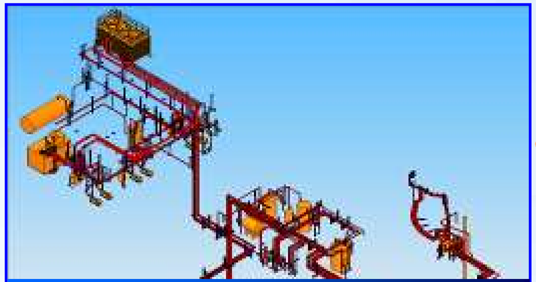
Installation of CNS for the Operating HANARO

Basic Design

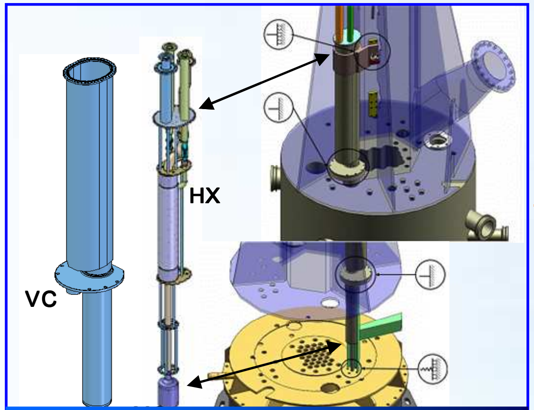
Full Scale Thermo-siphon Mock-up Test Using H_2

Localization of Al moderator cell

Detail Design



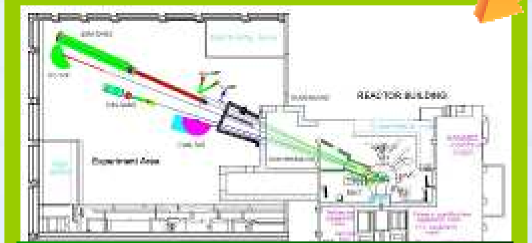
Safe & Reliable Process System Design



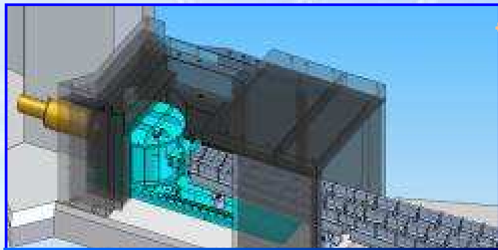
Optimum Source Design at existing Reactor Structure

Construction & Commissioning

System Commissioning on Schedule & the 1st Cold Neutron in Sep. 2009

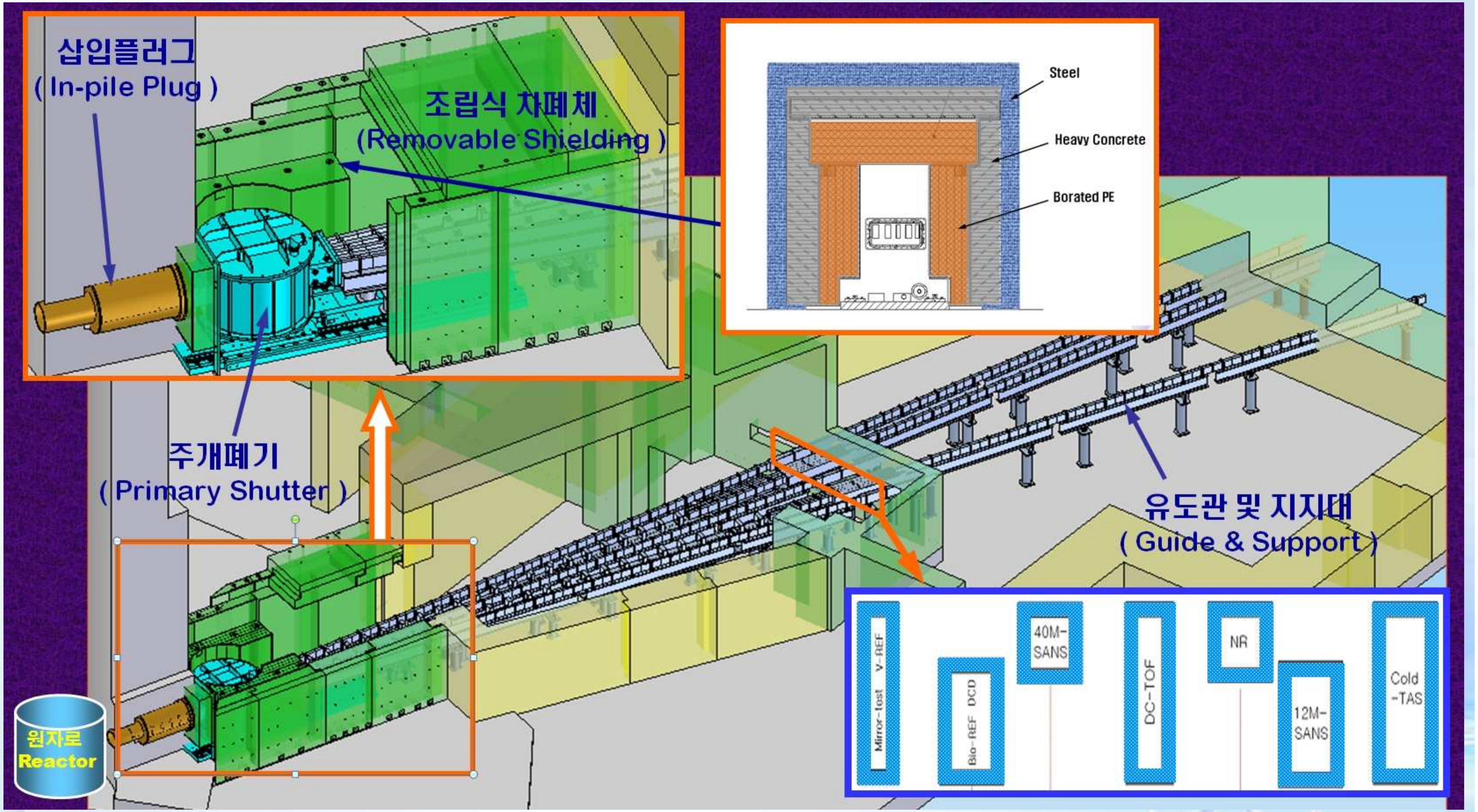


Beam Instrument Layout



Successful Installation of Neutron Guide System at High Radiation Environment

Neutron Guide Installation



Neutron Guide Installation(2)

Strategy

- Combination of imported parts and local fabrication

Local Fabrication

- Fabrication : Super-mirror guides(M=2, >150 m) with different shape
  30m Ni guide for two SANS as collimator
  10m super-mirror guide as beam flight path for Hr-SANS, Bio-REF
- Coating : A sputtering machine was developed.
  super-miror(M=2) has minimum reflectivity of 88 percent.

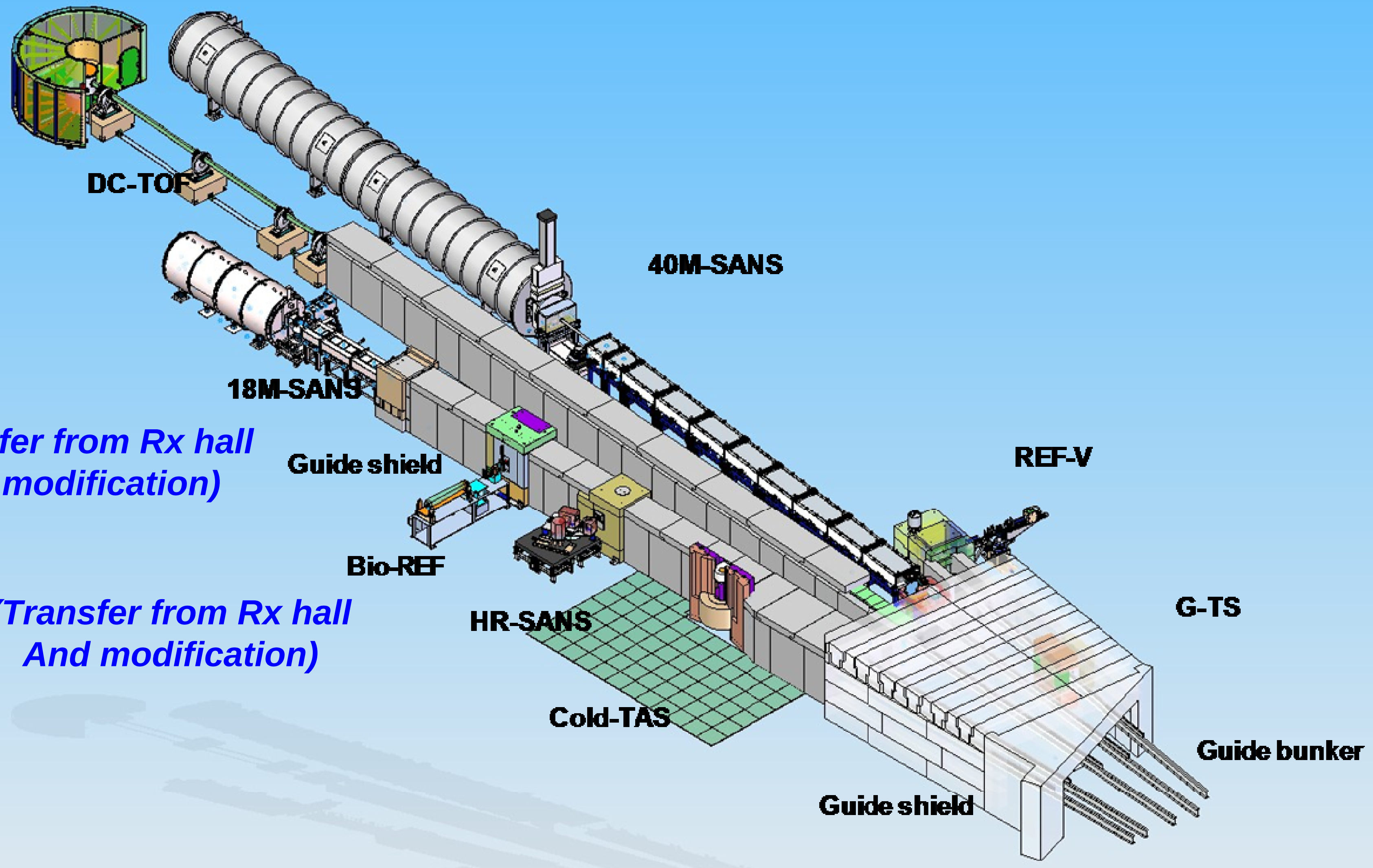
Cooperation

- MTF(consultation) & SwissNeutronics(Supply of front guides)
- Foreign experience (ILL, HMI, PSI)

Neutron Guide Installation(3)

Guide (dimension)		incline angle	Curvature	Length of curved part	Line of sight	Instrument
CG1 (20x150mm)		+3.04	400m	26m	8m	(Mirror-Test) (V-REF)
CG2 (50x150mm)	CG2A (50 x 50mm)	+2.03	800m	24m	17.9m	(40M-SANS)
	CG2B (50 x 95mm)		350m	26.3m	11.8m	***
CG3 (30x150mm)		+0.54	2500m	25.6m	24.5m	(DC-TOF)
CG4 (50x150mm)	CG4A (50x50mm)	-0.93	2500m	32m	31.6m	***
	CG4B (50x95mm)		600m	16m	15.5m	(Hr-SANS) (Bio-REF) (18M-SANS)
CG5 (50x150mm)	CG5A (50x150mm)	-2.50	1500m	26m	24.5m	(Cold-TAS)

Cold Neutron Instrument Arrangement



(Transfer from Rx hall And modification)

(Transfer from Rx hall And modification)

Cold Neutron Instrument Availability

To be available from Nov. 2010

- 40m-SANS, 18m-SANS

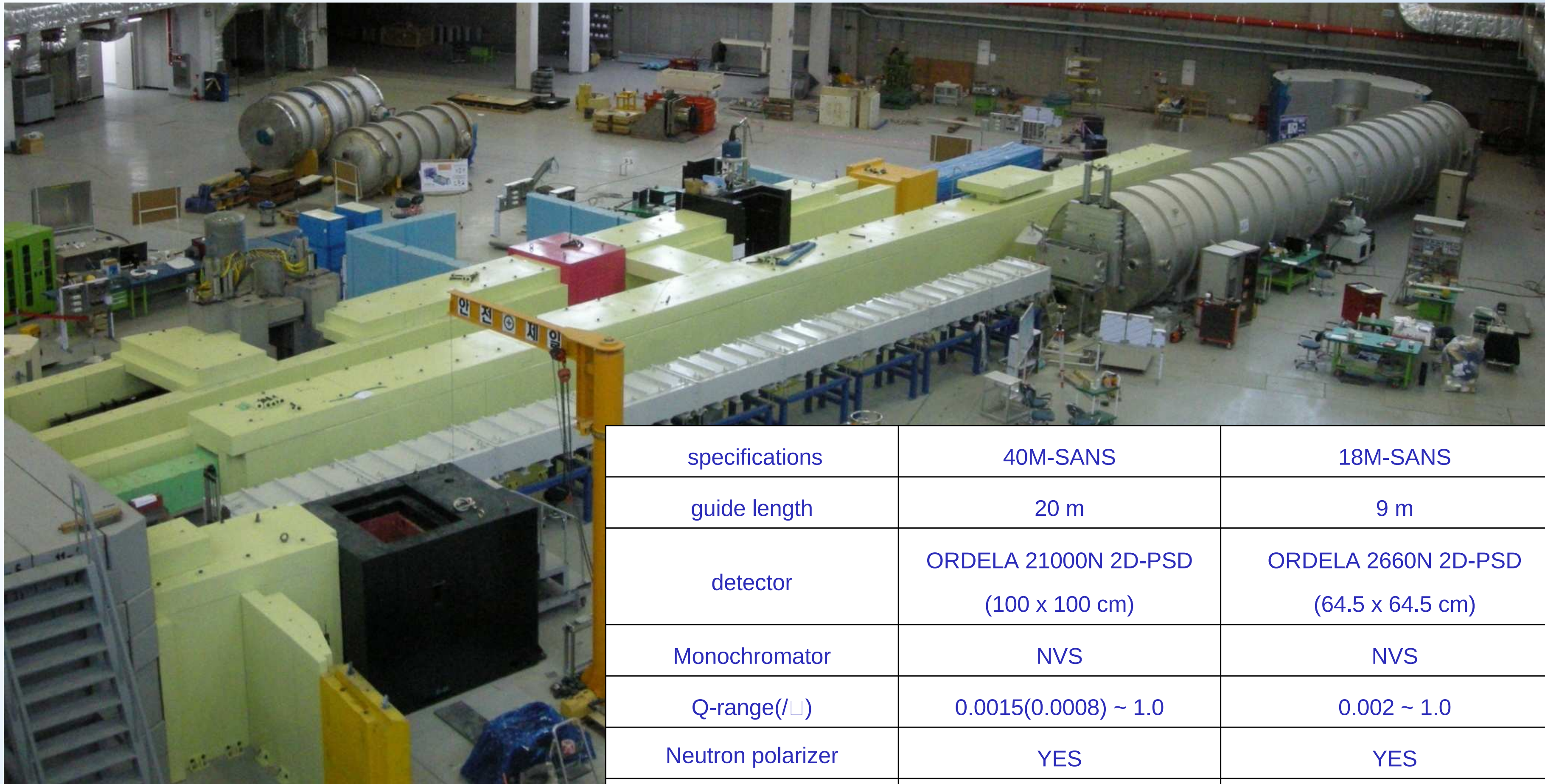
To be available from 2nd half of 2011

- REF-V, Bio-REF, HR-SANS

Others from CNRF Projects

- Cold TAS : First half of 2012
- DC-TOF : Depending on the availability of He-3

SANS



specifications	40M-SANS	18M-SANS
guide length	20 m	9 m
detector	ORDELA 21000N 2D-PSD (100 x 100 cm)	ORDELA 2660N 2D-PSD (64.5 x 64.5 cm)
Monochromator	NVS	NVS
Q-range(/□)	0.0015(0.0008) ~ 1.0	0.002 ~ 1.0
Neutron polarizer	YES	YES
scale	1 ~ 400 nm	1 ~ 150 nm

Sample Environments Available in Nov. 2010

- **Automatic Sample Exchanger in Room Temperature**
- **Circulation Bath (Temperature Control -25°C/90°C)**

REF-V

Rx REF REF-V (2006/6 User Open)

CN REF-V (2010/4 relocation)

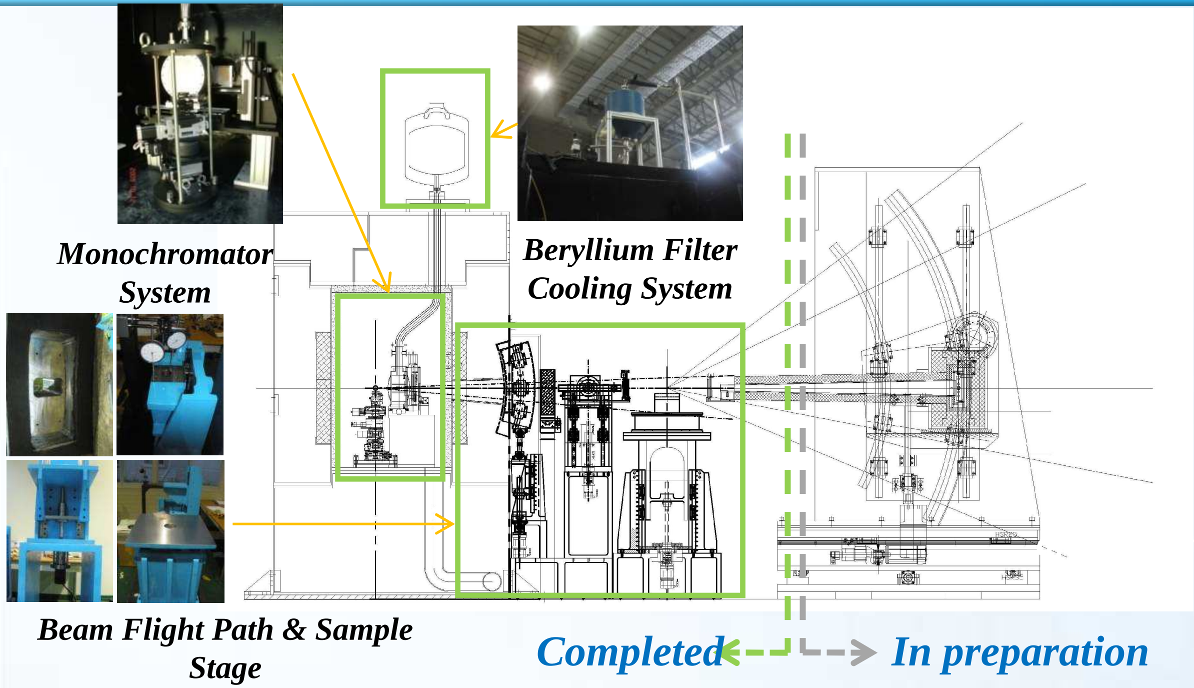
Instrument Characteristics

Part	Characteristic
Monochromator Wavelength Wavelength Resolution Filter system Neutron Flux at	Vertical focusing PG(002) 4.75 □, $2\theta_M$ =90° $\Delta\lambda/\lambda$ < 1.0% LN_2, Cooled Be ~ 3.5 x 10^6 n/cm^2/sec
Single detector 1-D PSD (plan)	He^3 6 atm. 8 x 12 cm, efficiency 90% at 4□
Polarizer, Analyzer Spin flipper Polarization Efficiency	Fe/Si super mirror(m=3) Mezei type, FR=>0.98 P =>0.9
Q region Min. reflectivity	0.003 ~ 0.4 $□^{-1}$ 10^{-8}

Sample Environment Facility

High Temp. Vacuum Chamber : ~650 K
Low Temp. CCR : 10 K <
Magnetic Field : Max. 0.8 T, Electromagnet
Max. 500G, Helmhlotz Coil
Cryo-Furnace : Plan

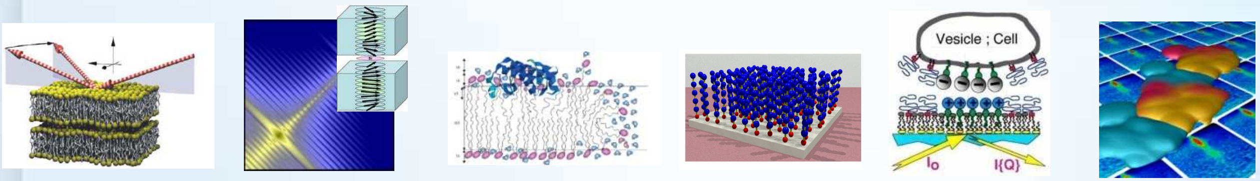
Bio-REF



SPECIFICATIONS	
Monochromator-to-sample distance	2 m
Sample-to-detector distance	2 m
Sample Area	500 mm^2
# of monochromators	1 Set (4 ea)
Filter	Beryllium(Cooled)
Q_z range (Liquid) (Solid)	0.002 - 0.6 Å^{-1} 0.002 - 0.25 Å^{-1}
Wavelength	4.75 Å
Measurements	Solid/Liquid Air/Liquid Air/Solid
Minimum reflectivity	1 X 10^{-8}
Flux	8.0 X 10^{6}n/cm^2/sec
Detector (Liquid) (Solid)	2D PSD Point type
Sample environments	Temp, Press Cell Liquid Cell, LB
Strategies	Under construction

** Applications in Nanotechnology & Biotechnology*

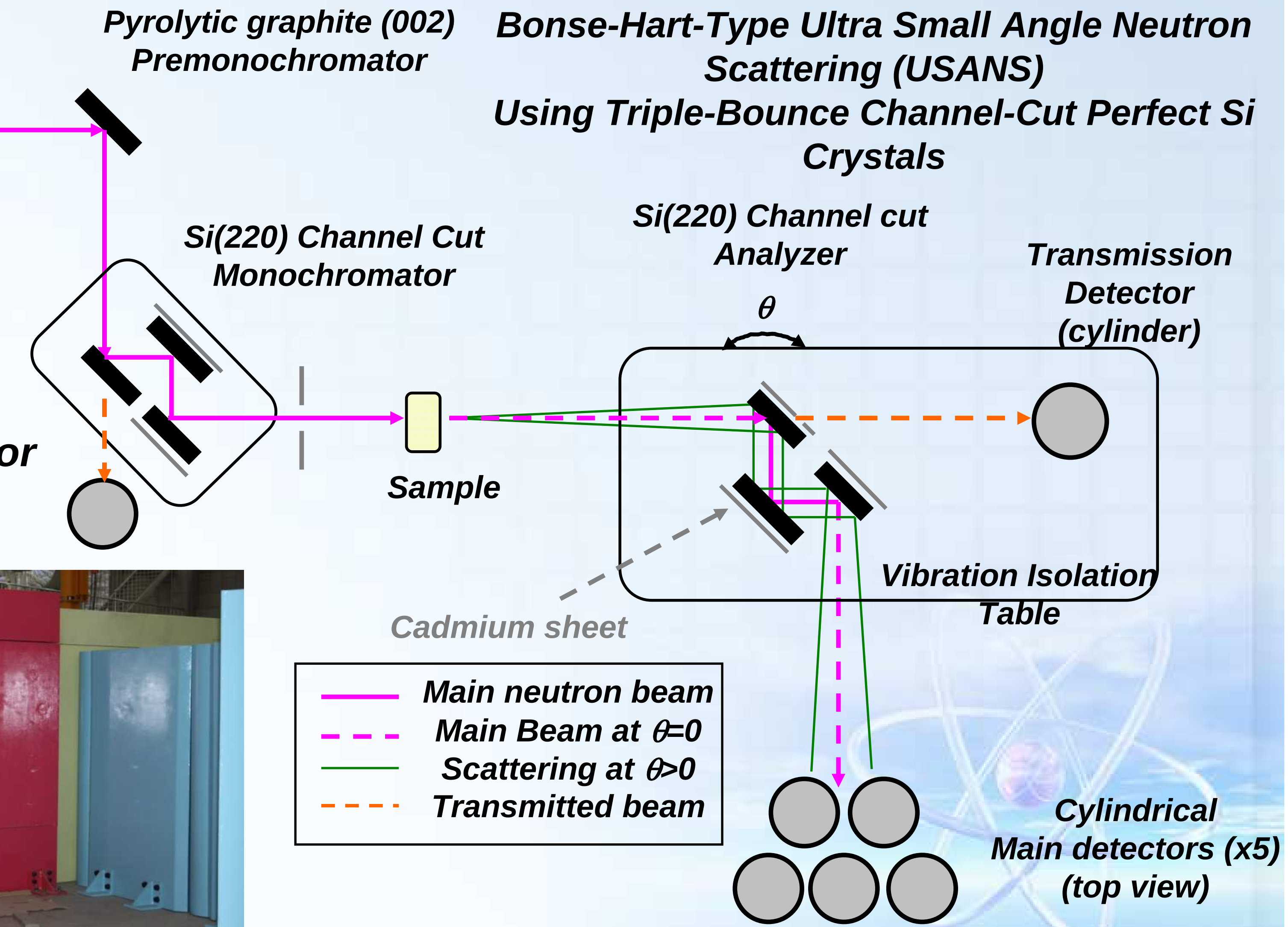
- *Nano-structured polymer thin films*
- *Polymer/metal nanostructures*
- *Nano-porous materials characterization*
- *Thin Films at high pressure*
- *Bio mimetic materials*
- *Bio mimetic materials*
- *Langmuir monolayer characterization.*
- *Poly-electrolytes at the air/water interface*
- *Wetting transition on water surface*
- *Protein (DNA) adsorption in solution.*



Bio-membranes *Magnetic multilayer* *Enzyme, proteins* *Polymer Brush* *Adhesion* *Wetting/de-wetting*

HR-SANS (KIST)

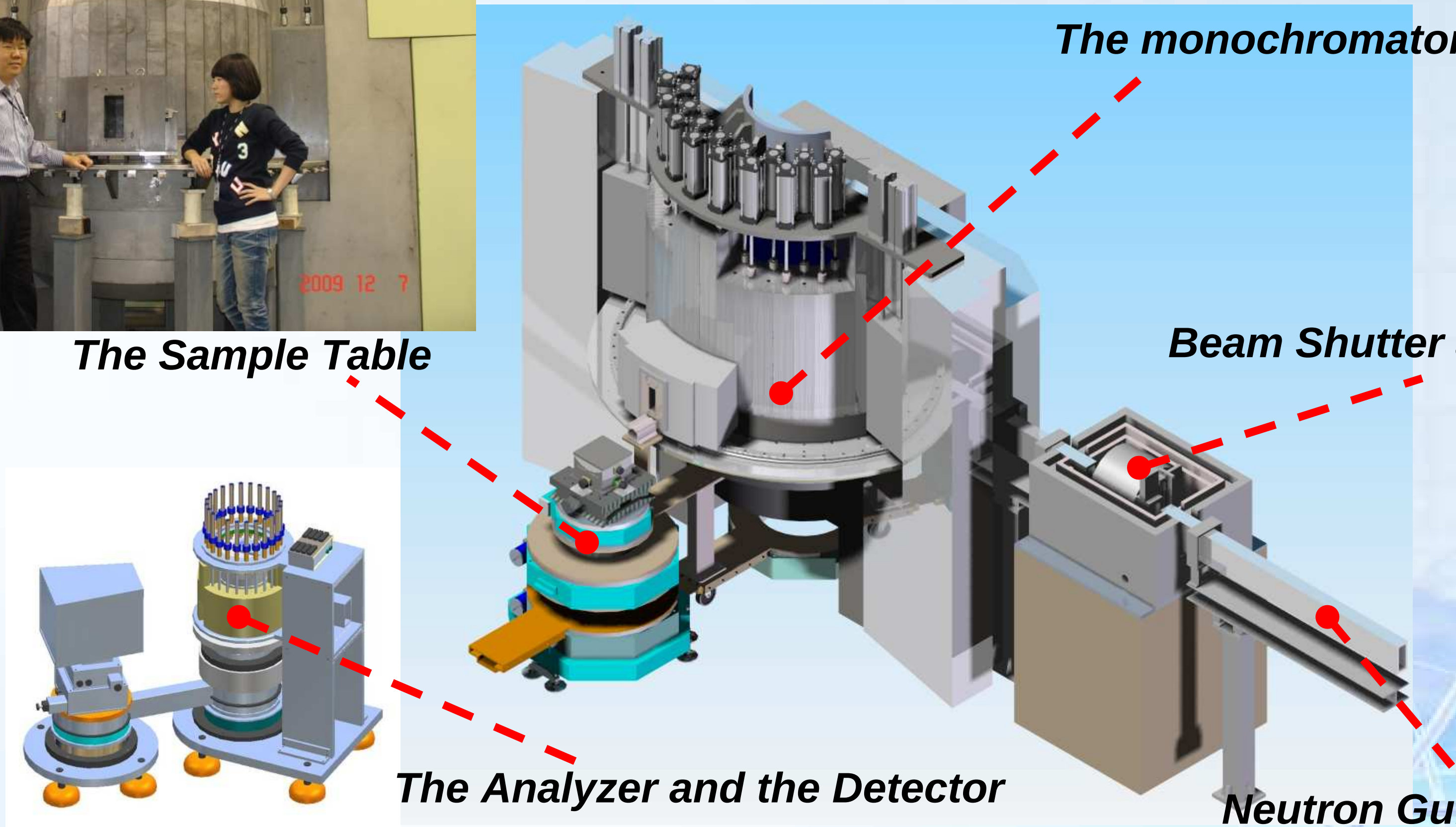
Bonse-Hart-Type Ultra Small Angle Neutron Scattering (USANS) Using Triple-Bounce Channel-Cut Perfect Si Crystals



J.G. Barker et. al. J. Appl. Cryst.38 (2005) 1004

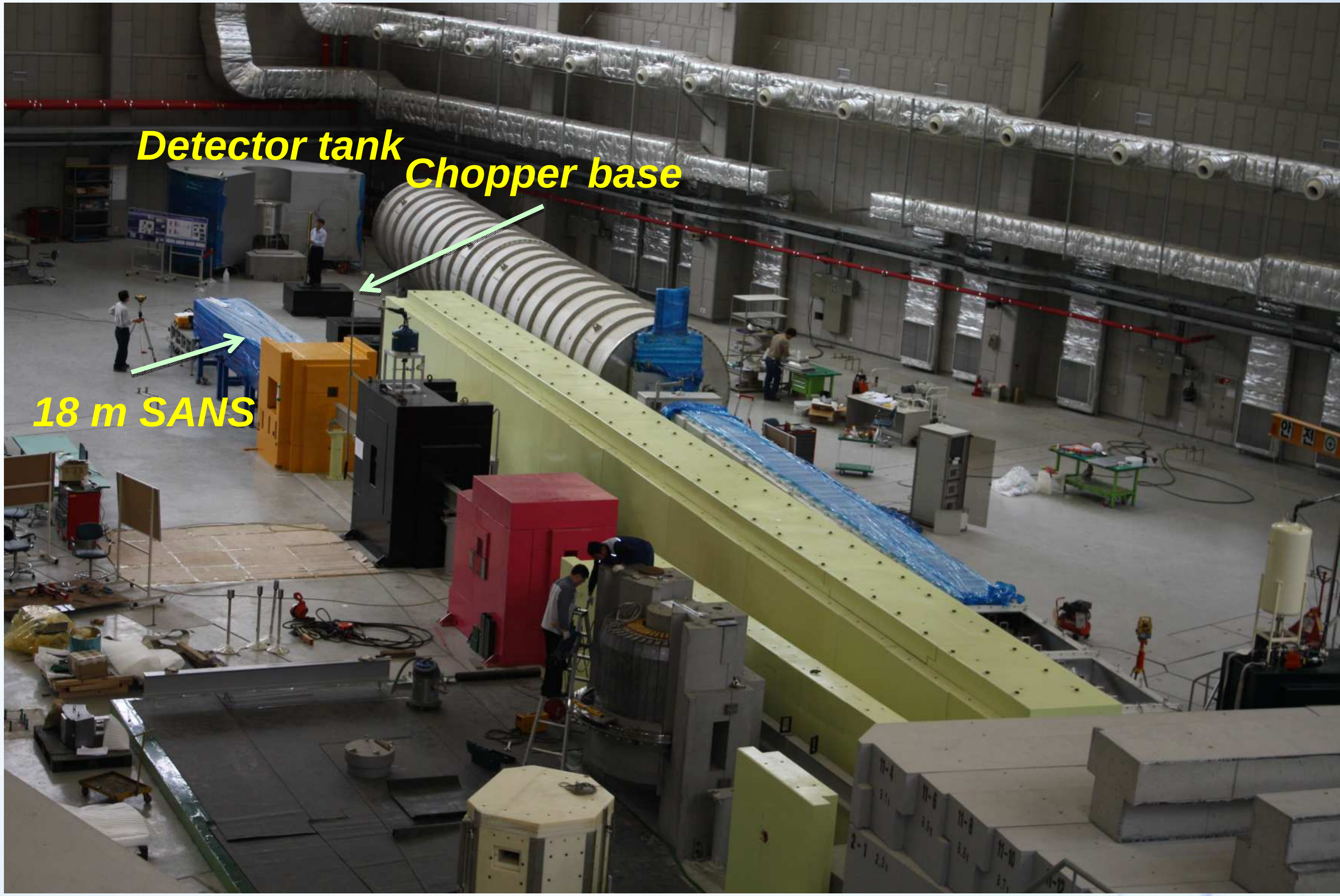
M.-H. Kim & C. J. Glinka Micropor. Mesopor. Mater. 91 (2006) 305

Cold Neutron Triple-Axis Spectrometer



Cold Neutron Triple-Axis Spectrometers measure Spin dynamics, Lattice dynamics, Structural and Magnetic Phase transitions of any different magnetic materials including High T_C Superconductors and Multiferroics

DC-TOF



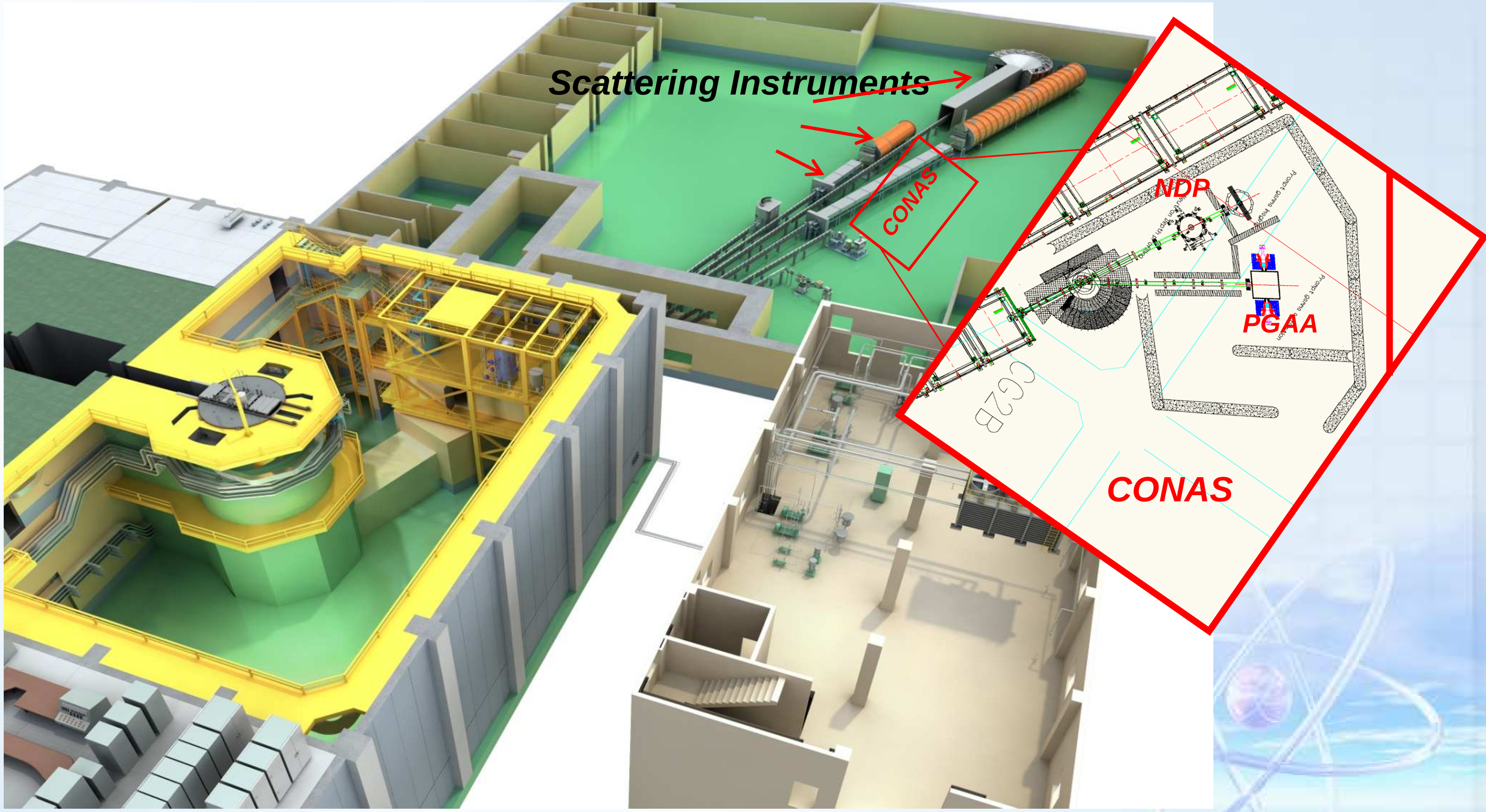
Guide shield and monochromator installed in Aug. 2009

Shield performance test in Dec. 2009

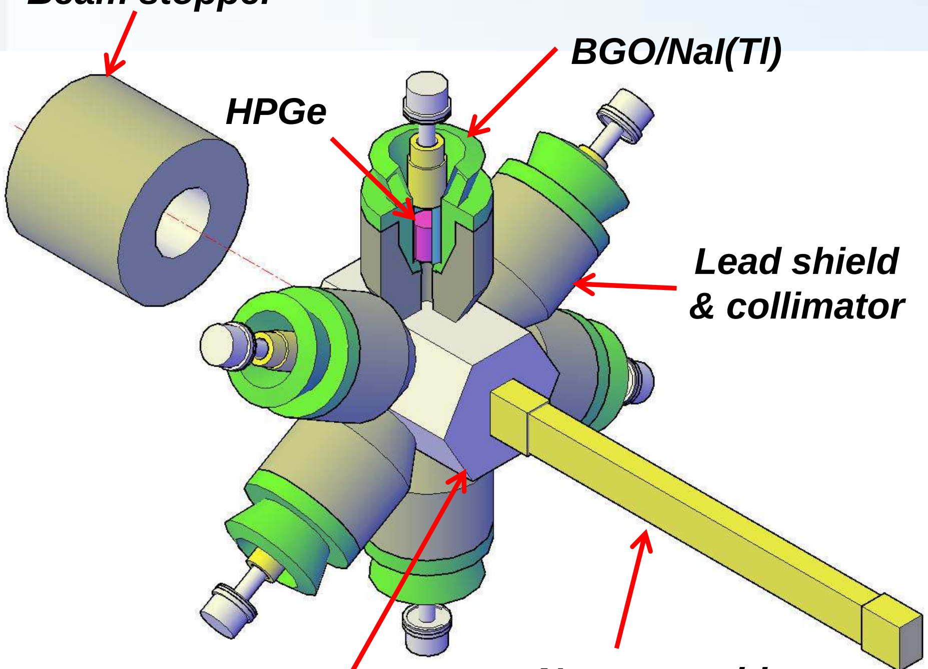
Guide Hall as of Sept. 15, 2010

New Project for Cold Neutron Activation Station(CONAS)

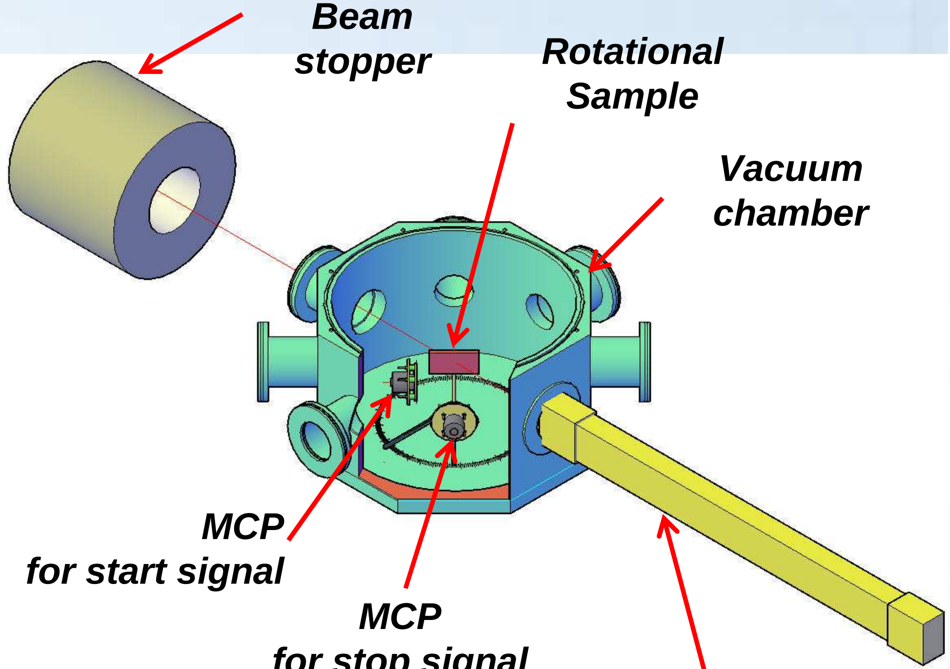
(April 2010~April 2012)



CN-PGAA (CN-Prompt Gamma Activation Analysis) and CN-NDP (Neutron-induced charged particle Depth Profiling)



Schematic diagram of a CN-PGAA instrument configuration at a cold neutron beam guide



Schematic diagram of a CN-NDP instrument configuration at a cold neutron beam guide

Neutron Flux Measurement

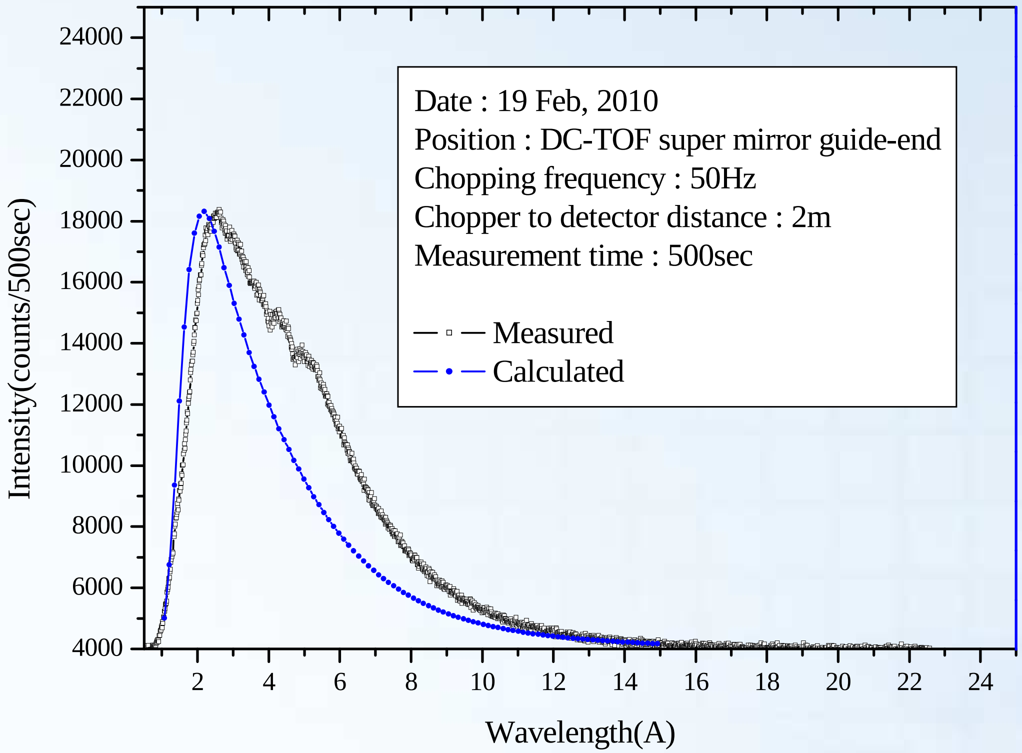
Korea Atomic Energy Research Institute

Neutron Flux Measurement Results (Interim Report)

Position	$\bar{\lambda}$ [Å]	Thermal flux	Real flux
CG1	**4.48***	**2.01E+09**	8.08E+08
CG2A	**4.54 ***	**5.82E+09**	2.31E+09
CG3	**3.87 ***	**6.74E+09**	3.14E+09
CG4B	**4.83 ***	**7.71E+09**	2.87E+09
CG5	**4.21 ***	**8.16E+09**	3.49E+09
BIO-REF	**4.90[1]**	**2.79E+09**	1.02E+09
DC-TOF	**4.16***	**2.58E+09**	1.12E+09
REF-V	**4.57***	**1.49E+09**	5.87E+08
HR-SANS	**4.90[1]**	**3.57E+09**	1.31E+09
Cold-TAS(#1)	**4.03+**	**5.37E+09**	2.40E+09
Cold-TAS(#2)	**4.03+**	**3.58E+09**	1.60E+09
18M-SANS	**4.90[1]**	**4.96E+08**	1.82E+08
40M-SANS	**4.97[2]**	**7.76E+07**	2.81E+07

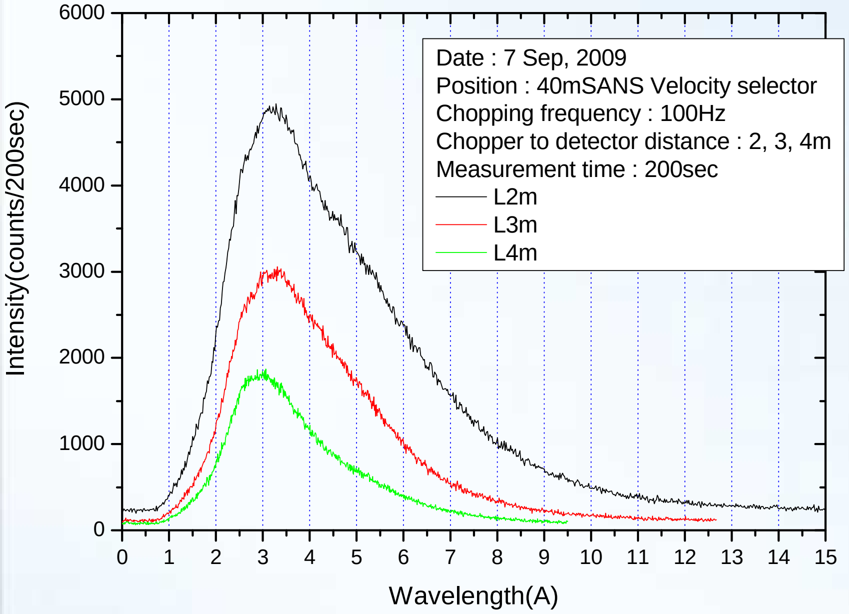
[1] Assumed value, [2] Iterated value using spectrum measurement
*** Calculation from McStas simulation + Calculation from VITESS simulation**

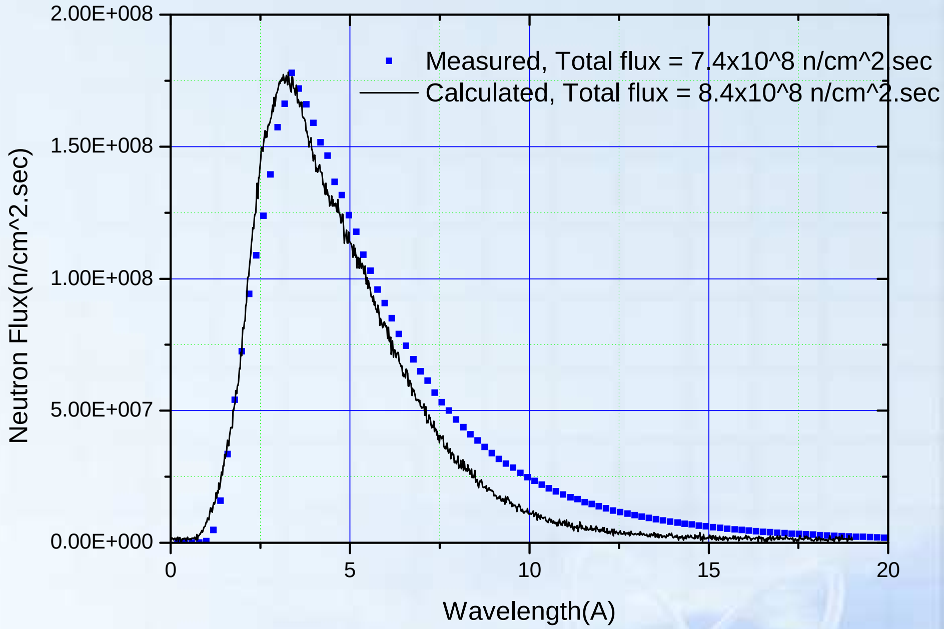
DC-TOF Neutron Spectrum



- **Measurement results showed more cold neutrons than the Monte-Carlo calculation.**
- **The measurement was made in vacuum condition.**

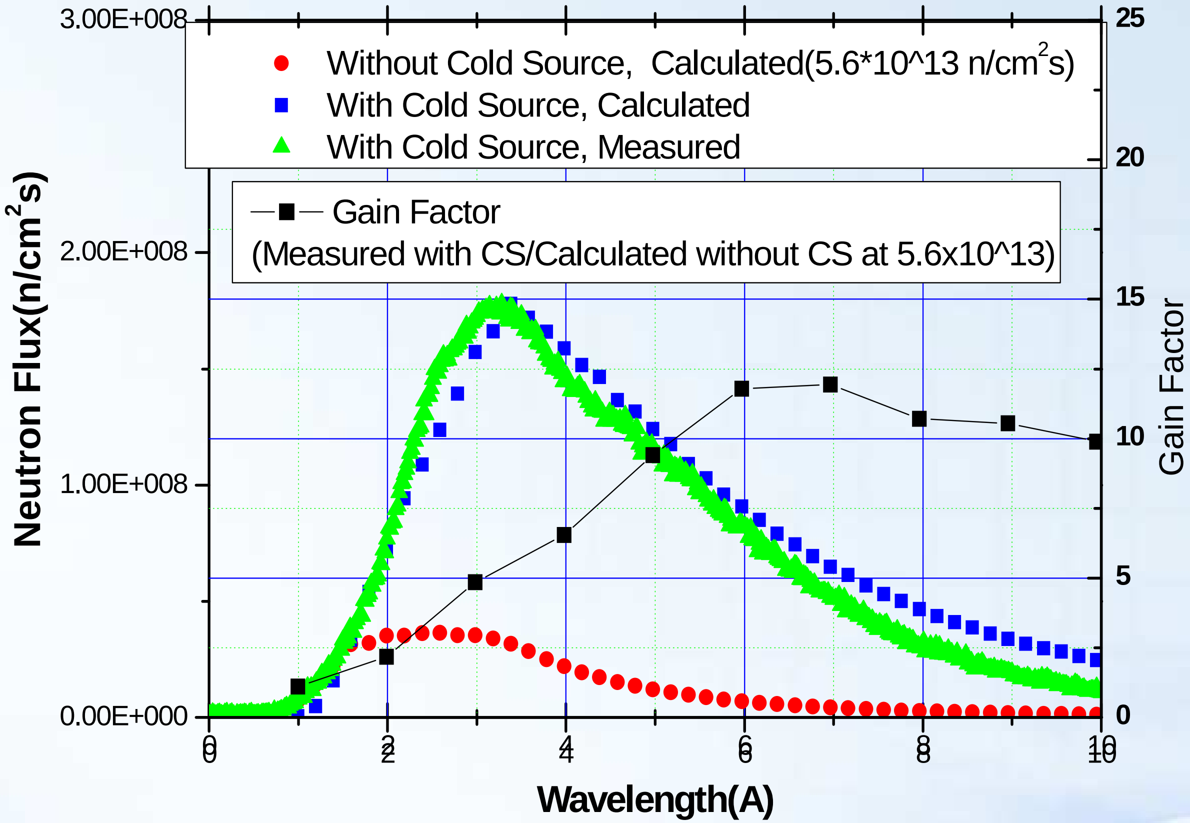
40M SANS Neutron Spectrum





Chopper distance and spectrums

Cold Neutron Gain @ CG2A Guide



- **Gain is larger than 10 for over-5Å neutrons. (Target :10-20)**
- **The gain will be greater that 15 if the measurement is made in vacuum.**

Remarks

KAERI Korea Atomic Energy Research Institute

- The flux measurement results show that the CN beam facilities in HANARO have the potential to become world class instruments.

- The SANSs will be available to the users from this Nov.

- The activities to complete the installation and commissioning of instruments will continue together with the installation of new cold neutron activation stations.

- The user programs will be expanded in cope with the progress in beam instruments.

HANARO Symposium 2010 to celebrate the inauguration of CNRF
Daejeon, Rep. of Korea
Nov. 1-2, 2010

2010 15th ANNIVERSARY HANARO

http://hanarosymposium.kaeri.re.kr

Embedded Meetings

- IAC(Int. Advisory Committee) meeting
- IAEA meeting on RR coalitions and user's network (NB in East Asia-pacific region)


Thank You!
KAERI
Korea Atomic Energy
Research Institute