PM01

Road to the neutron polarization experiment with spallation neutron source

T. Yokoo[A),B),C)]

[A)]High Energy Accelerator Research Organization (KEK), Ibaraki, Japan
[B)]J-PARC Center
[C)]The Graduate University for Advanced Studies

Abstract

POLANO is a new concept neutron spectrometer with polarization capability for inelastic scattering experiments. The POLANO designed as middle energy and spatial resolution for the realization of material science. For the purpose of high-efficient polarization experiments in inelastic scattering technique, the POLANO was optimized for high transfer energy (HTE) polarization analysis. In order to realize the HTE polarization, we have made much efforts for developing new devices with new ideas and concepts. The HTE polarization can be realized by combining with SEOP ^{3}He gas spin filter and 5.5 Qc bending mirror analyzer, which is the most promising technique and highest Qc at the time. However, even with this technique the utilized neutron energy is restricted up to around Ef = 45 meV for out-going analyzed neutron energy (final neutron energy) by the reflecting capability of mirrors. But our final goal for HTE is 100 meV beyond the reactor-based neutron polarization energy. This range of energy experiment can be realized with ^{3}He spin filter analyzer covering very wide scattering angle.

e-mail: tetsuya.yokoo@kek.jp

Dawn of the Polarized Neutron Technique

Application to material science in 1950s

Nathans and Paoletti

MAGNETIC FORM FACTOR OF COBALT*

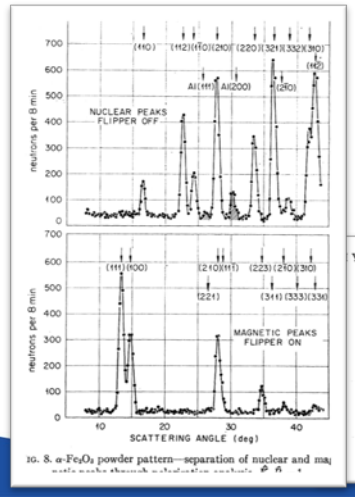
R. Nathans
The Pennsylvania State University,
University Park, Pennsylvania, and
Brookhaven National Laboratory,
Upton, New York
and
A. Paoletti
Comitato Nazionale Ricerche Nucleari,
Rome, Italy, and
Brookhaven National Laboratory,
Upton, New York
(Received February 26, 1959)

We wish to report preliminary results on the magnetic form factor of the face-centered cubic phase of metallic cobalt, which indicate a deviation from spherical symmetry for its 3*d* electrons. These measurements represent a continuation of studies on the angular dependence of the magnetic scattering in the transition elements using a polarized neutron beam spectrometer[1]; the results on iron and nickel have been already reported in reference 1. These studies were undertaken because of the current interest in the 3*d* electron configurations in the transition elements and the pertinence of magnetic form fac-

First polarized beam : measurements (of magnetic form factors of Ni, Fe and Co)

Advanced application to material science in 1960-70s

Moon and Blume



IG. 8. α-Fe_2O_3 powder pattern—separation of nuclear and mag

YSICAL REVIEW VOLUME 181, NUMBER 2 10 MAY 1965

Polarization Analysis of Thermal-Neutron Scattering*

R. M. Moon, T. Riste,† and W. C. Koehler
Solid State Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830
(Received 30 December 1968)

A triple-axis neutron spectrometer with polarization-sensitive crystals on both the first and third axes is described. The calculation of polarized-neutron scattering cross sections is presented in a form particularly suited to apply to this instrument. Experimental results on nuclear incoherent scattering, paramagnetic scattering, Bragg scattering, and spin-wave scattering are presented to illustrate the possible applications of neutron-polarization analysis.

Neutron polarization at TOF method in 21st century

Stewart and others

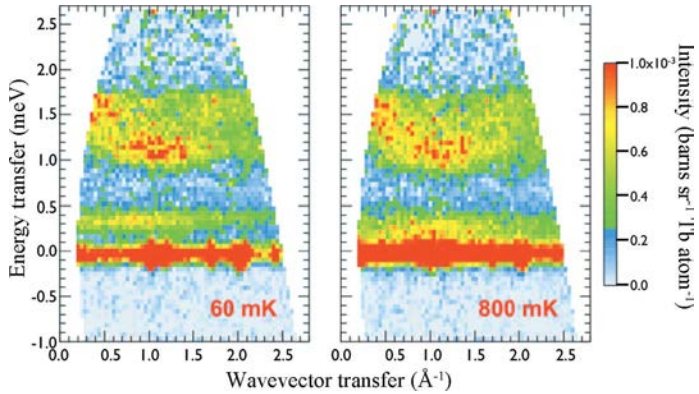


Figure 16
Polarized neutron scattering (spin-flip channel only) of $Tb_2Sn_2O_7$. Left panel: 60 mK spectrum revealing a low-lying excitation at 0.35 meV. Right panel: 800 mK, just below the transition, with broad quasi-elastic scattering. At both temperatures, a soft 1.2 meV mode can be seen at the first antiferromagnetic correlation wavevector.

Requirements (problems) for TOF Polarization Experiment

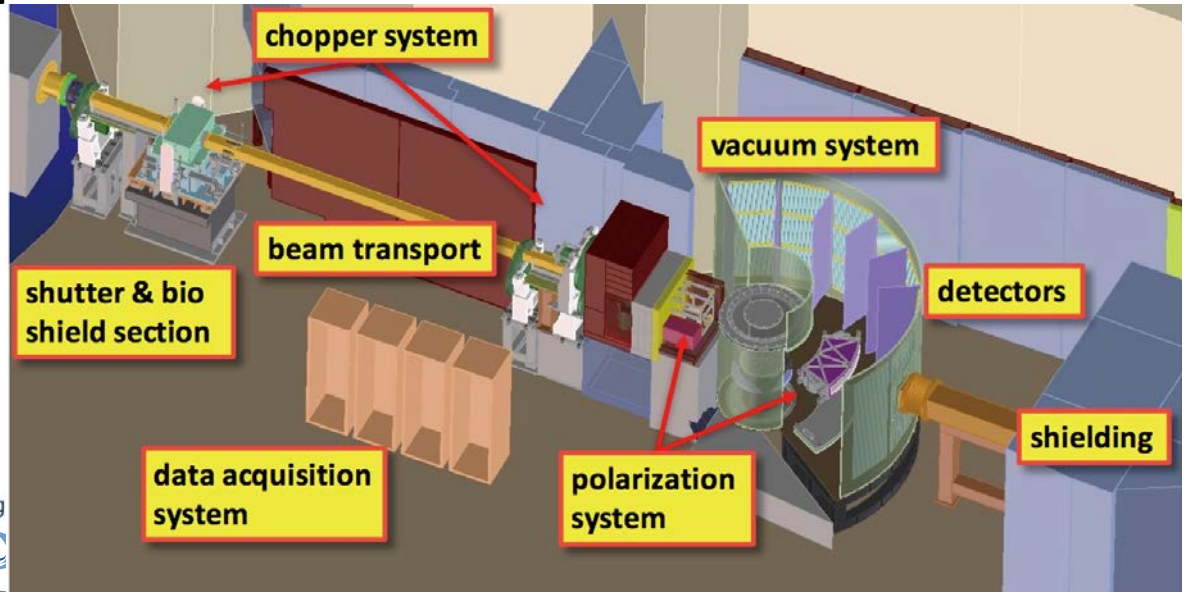
easy middle hard very tough enigma

1) restricted space
2) in vacuum
3) wide scattering angle almost 150˚
4) non-magnetic design

POLANO

For effective use of higher energy neutron

5) high-energy neutron polarization



Neutron Inelastic Instruments Suite at MLF

Direct geometry

BL01 : 4SEASONS (JAEA-CROSS)
High-flux・Middle-energy band・Middle-energy resolution

BL12 : HRC（KEK-Tokyo Univ.）
Middle・Wide・High

BL14 : AMATERAS（JAEA）
High・Narrow・High

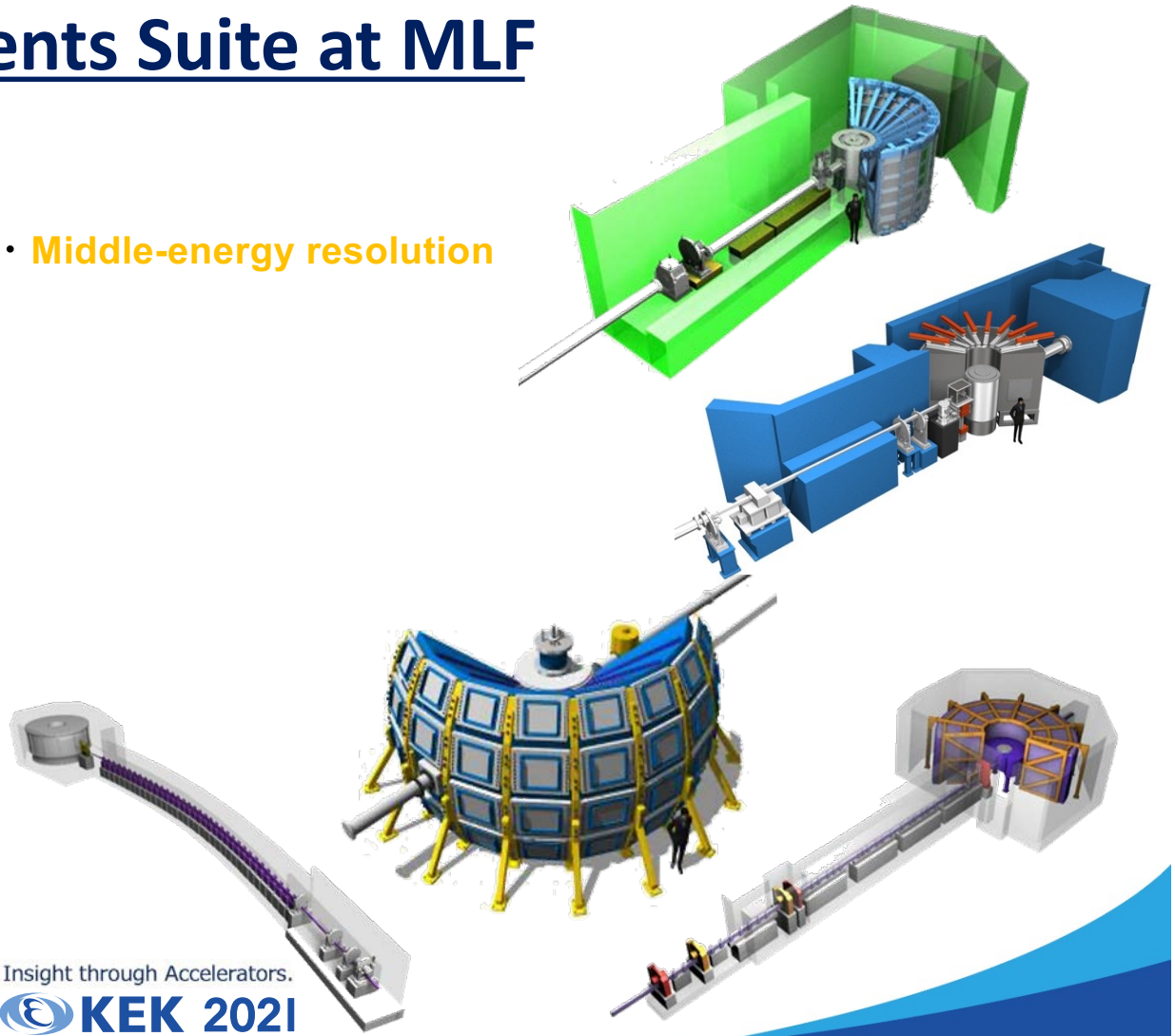
BL23 : POLANO (KEK-Tohoku Univ.)
Middle・Middle・Middle
→polarized neutron dedicated

Inverted geometry

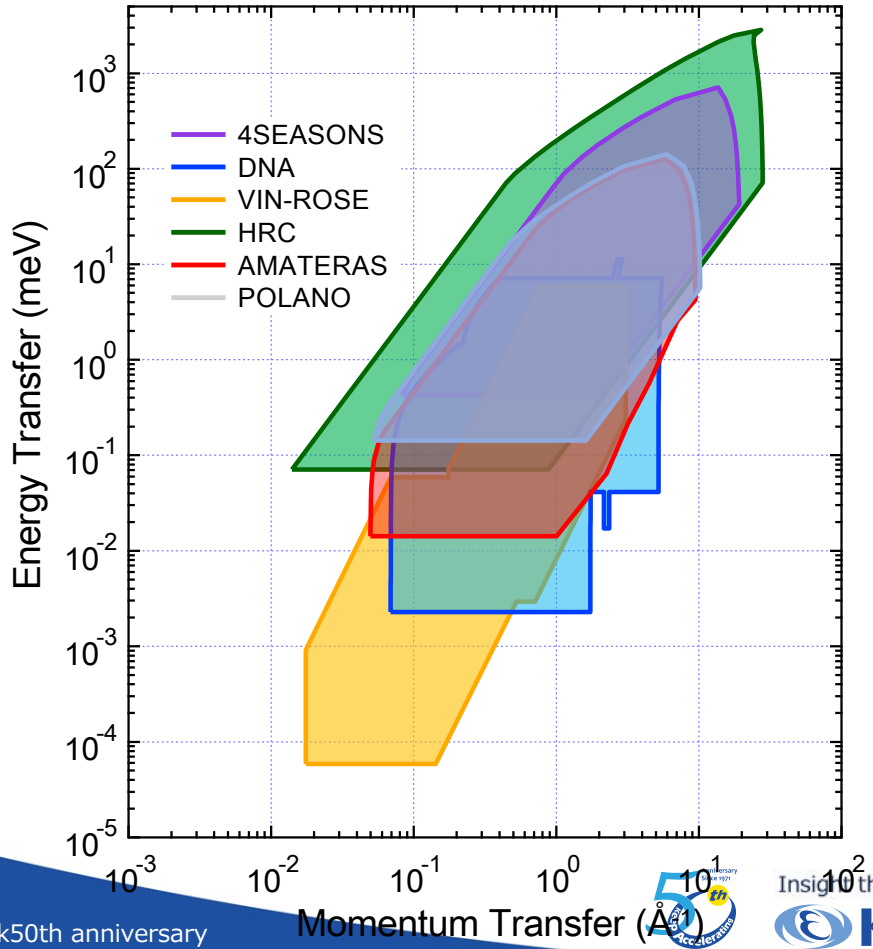
BL02 : DNA（JAEA）

Spin echo

BL06 : VIN ROSE（KEK-Kyoto Univ.）



A New Spectrometer in MLF, POLANO



Polarization Neutron Spectrometer POLANO

1) Chopper-type spectrometer with
higher flux and middle resolution
➔cross correlation method

2) Dedicated spectrometer for
polarization analysis
➔several spectrometers for unpolarized experiments

3) Aiming at wide Q-w range
Ei = 100 meV, Q_{max} = 12 $Å^{-1}$
➔observation of multi-pole excitations

4) Compact design
➔easy to access to sample space

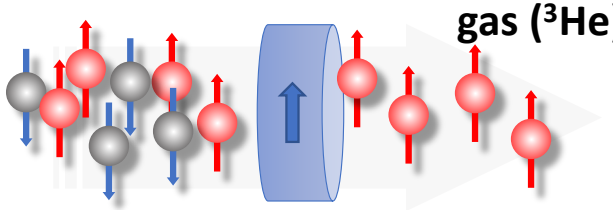
Polarization Strategy for sub-eV Polarimetry

Our goal…
1) 100 meV energy polarization experiment with wide momentum coverage
2) spherical polarimetry with large solid angle
=> wide band and wide angle

Stage	Polarizer & Analyzer	Target E-range
1st Phase 2020 ~	SEOP polarizer Fan-shape supermirror analyzer	Ef<30 meV (42 meV)
2nd Phase 2024-20??	SEOP polarizer Large solid angle SEOP/MEOP	Ei, Ef~100meV
3rd Phase 20??-	DNP High P_n SEOP/MEOP Analyzer	E>100meV: P_n~95%

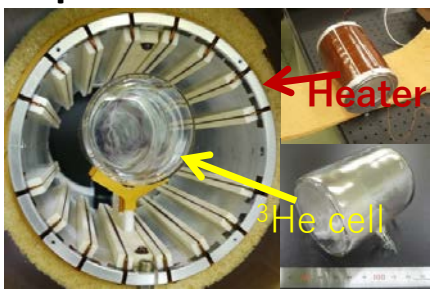
Polarization Experiment with TOF Method

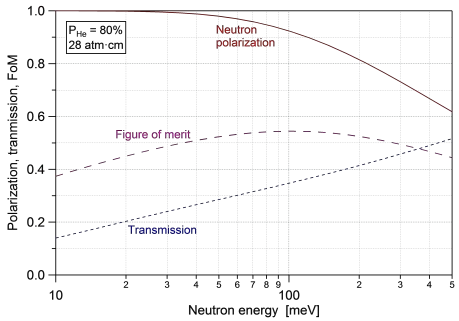
gas (^{3}He) spin filter



spin polarization = 0.5

SEOP polarizer

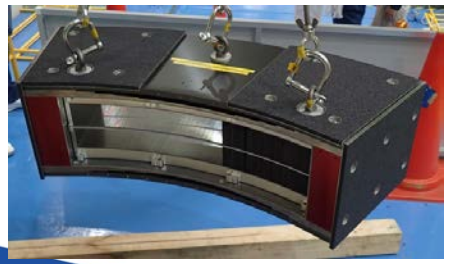


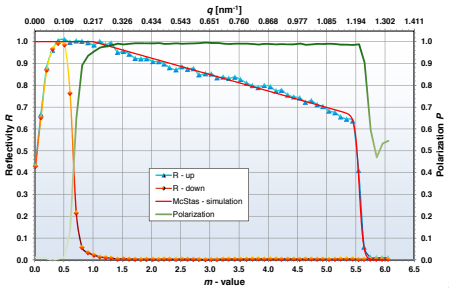


SEOP spin polarizer = 0.3

optimized for 100meV neutron energy

bending analyzer mirror





analyzer mirror = 0.6

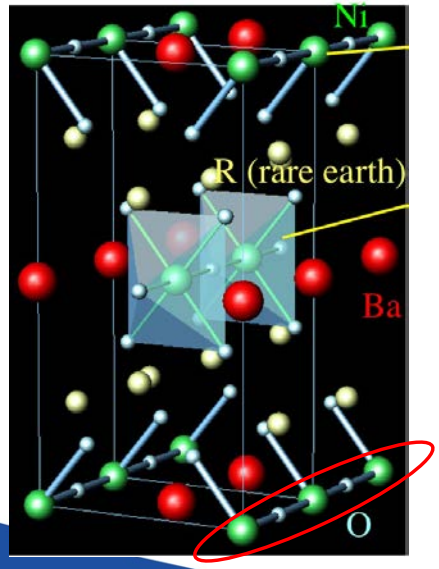
5.5Qc mirror for high-energy spin polarization

transmission =
0.5 x 0.3 x 0.6 = 0.09

Spin & Lattice Dynamics Measured at POLANO (Unpolarized)

Exotic quantum excitation in 1D spin chains Nd2BaNiO5

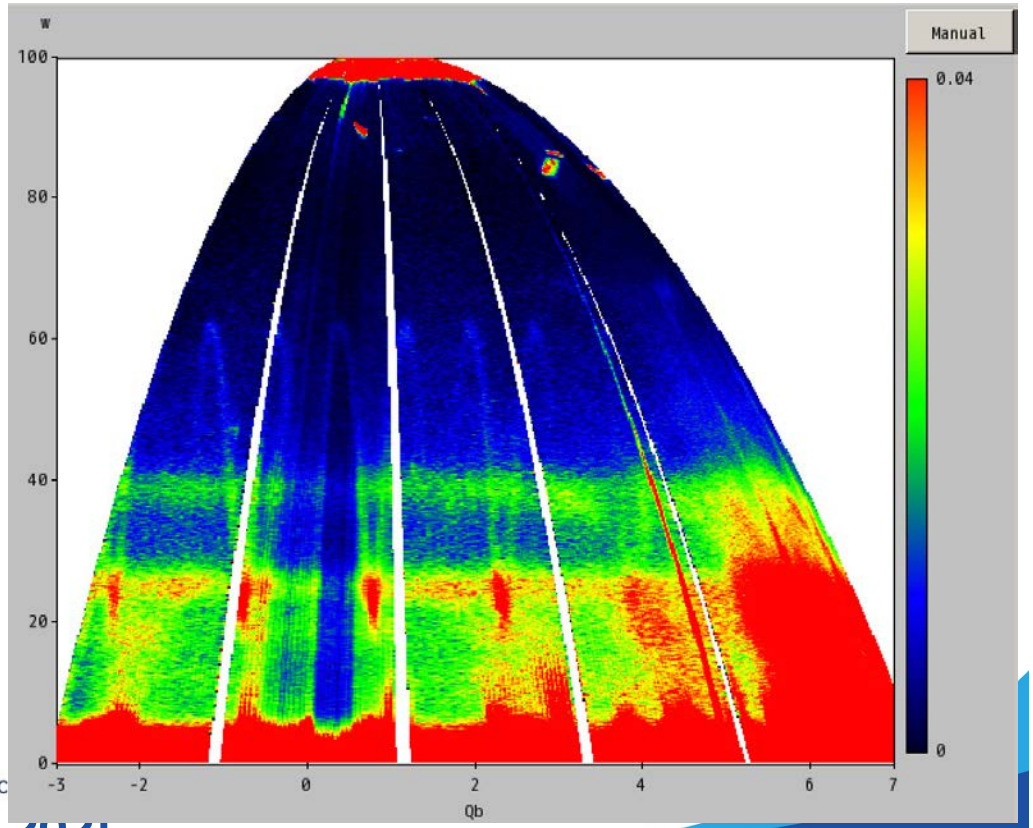
Reference material in POLANO, Nd_2BaNiO_5 known as quantum spin chain system, that shows many exotic (unknown and complicated) spin dynamics due to quantum spin fluctuations in Haldane chains.



Quantum Spin Chain

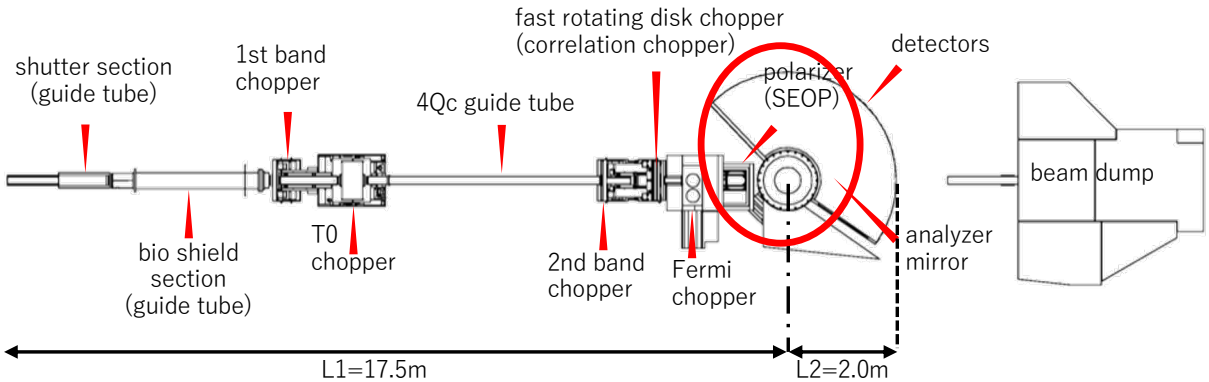
Haldane gap? -> triplet-mode

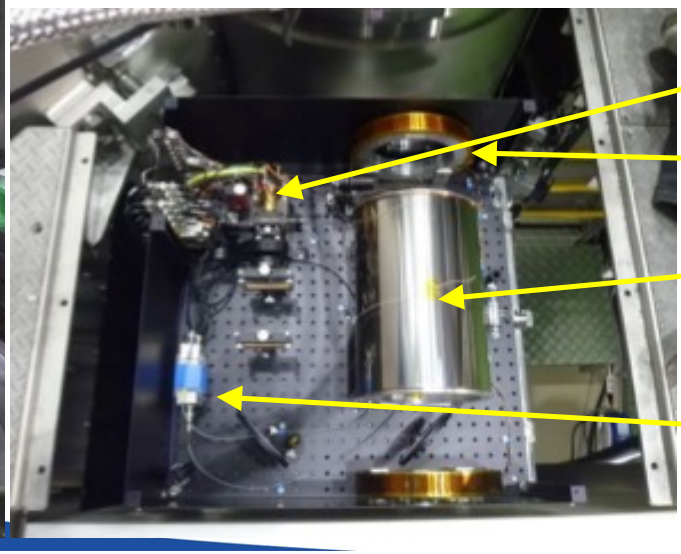
Also, interested in hole-doped 1D chain system.
1D hole <-> 2D hole in the analogy with high-Tc superconductivity



Polarization Devices Installation

SEOP polarizer system





laser and optics

guide coil

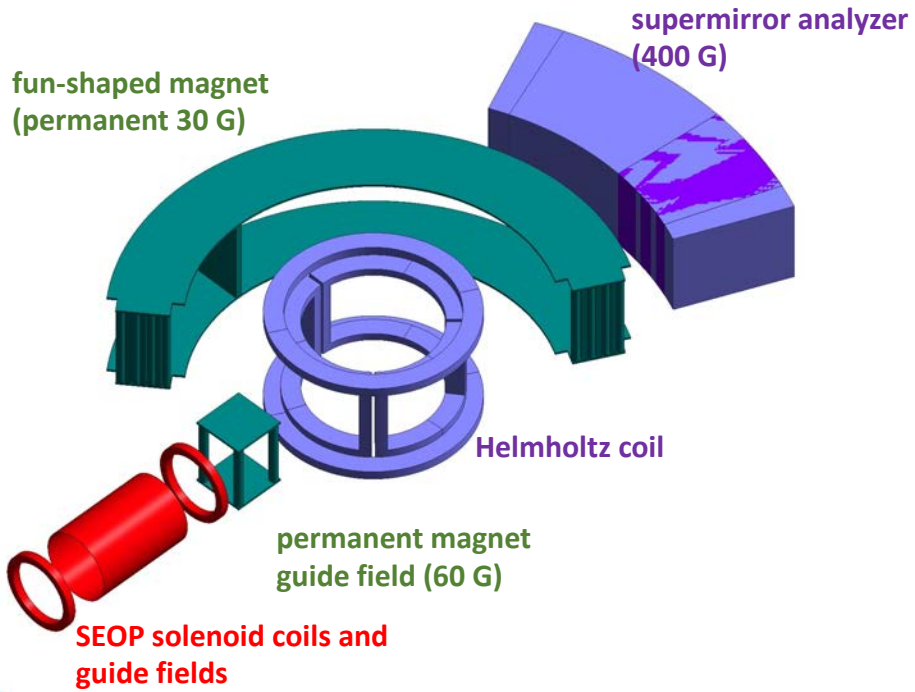
magnetically-shielded solenoid coils

low-noise amplifier for NMR

Polarization Devices Installation

Magnet system & Helmholtz coils

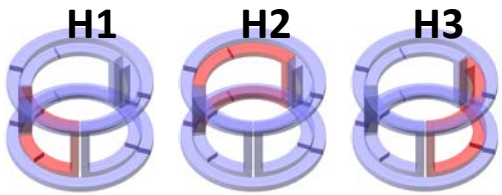
1) total magnetic guide fields system



2) Helmholtz coil at sample position

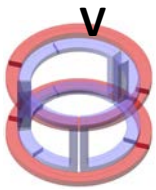
horizontal field

10 amps x 3 coils
(magnetic field control
and reducing dark angle)

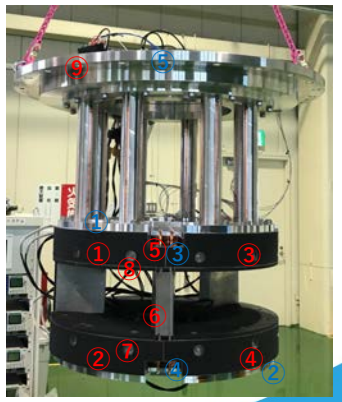


vertical field

a pair of coil (8 amps)



cooling system



Road to the Polarization Experiment at MLF

POLANO Scheme