



Polarized Target R&D II

For the polarized Drell-Yan experiment
(, and the material science at J-PARC)

Contents

- Polarized Target R&D at Japan
- PPT system @ KEK
- Target material R&D
- Summary

@ Japan

Yoshiyuki Miyachi

(Yamagata University)

on behalf of Japanese PTT group



Polarized Target R&D at Japan

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- Motivation
 - Polarized proton induced Drell-Yan experiment
 - Spin structure of the proton
 - Orbital motion of parton inside the proton
 - TMD (e.g., Sivers for the sea quark)
 - PPT applications
 - Spin filter for the neutron beam at J-PARC, material science
- “Reuse” of Michigan PPT system @ KEK
- Target material R&D
 - $^3\text{He} + ^4\text{He}$ dilution cryo., and 2.5 T DNP & NMR system @ Yamagata University
 - Replacement of NH_3 and LiH

1 K ^4He Cryo
5 T DNP&NMR



Polarized target R&D at Japan

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RIKEN

Y. Goto, I. Nakagawa



Tokyo Tech

T.-A. Shibata, K. Nakano



KEK

S. Ishimoto, S. Sawada, S. Suzuki, K. Taketani, Y. Fukao



Yamagata University

T. Iwata, K. Kobayashi, N. Doshita, Y. Tochigi, H. Matsuda,
Y. Miyachi, G. Nukazuka, S. Asaki, R. Hashimoto



JSPS support

(Y. Goto, 22340070, 2010.4 – 2013.3)



FNAL-SeaQuest

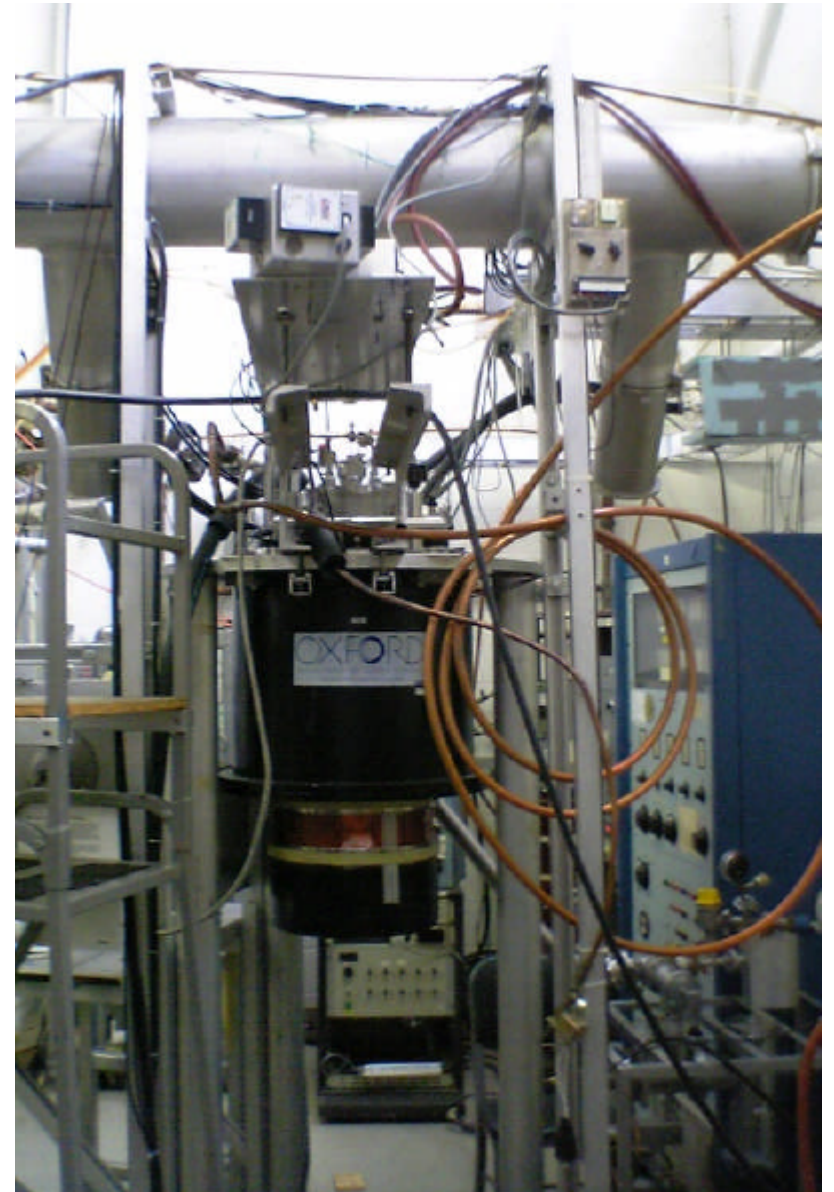
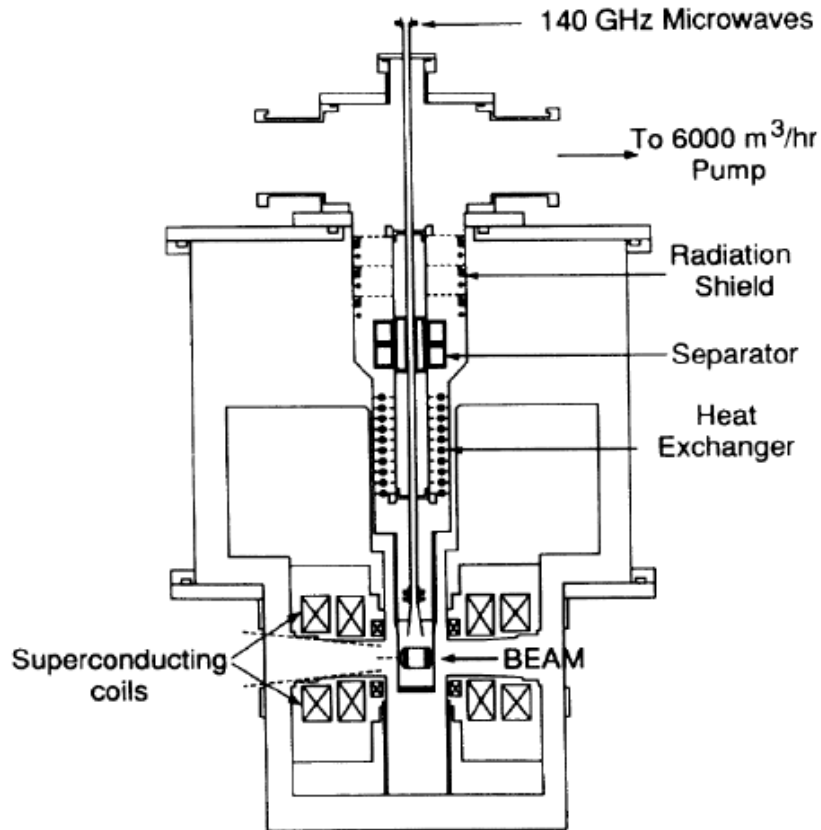
+

CERN-COMPASS (PT)



PPT System @ KEK

2013.01 @ KEK





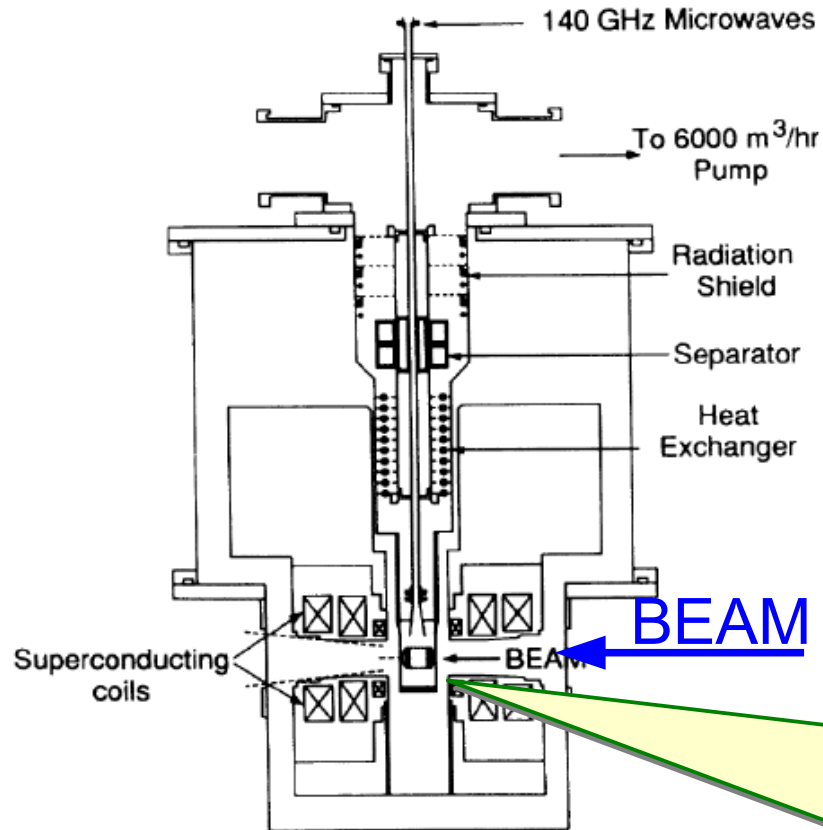
Michigan PPT System

D.G. Crabb et al., PRL64, 2627 (1990)

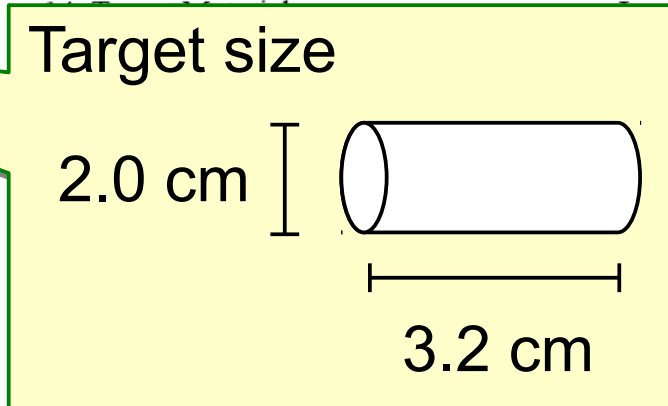
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5 T NMR system
 Larmor Freq. 213 MHz (proton)
 Microwave Freq. ~140 GHz

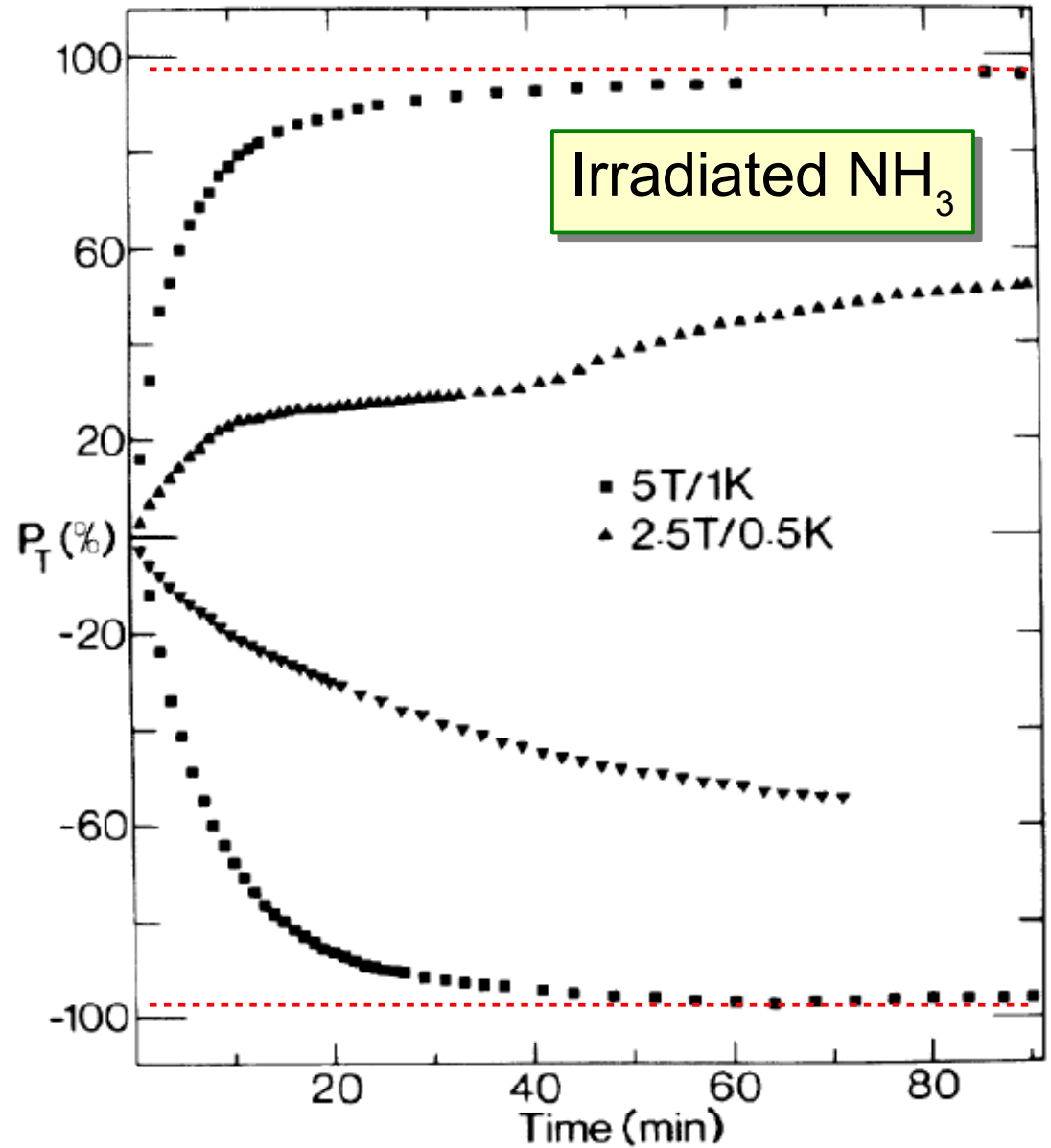
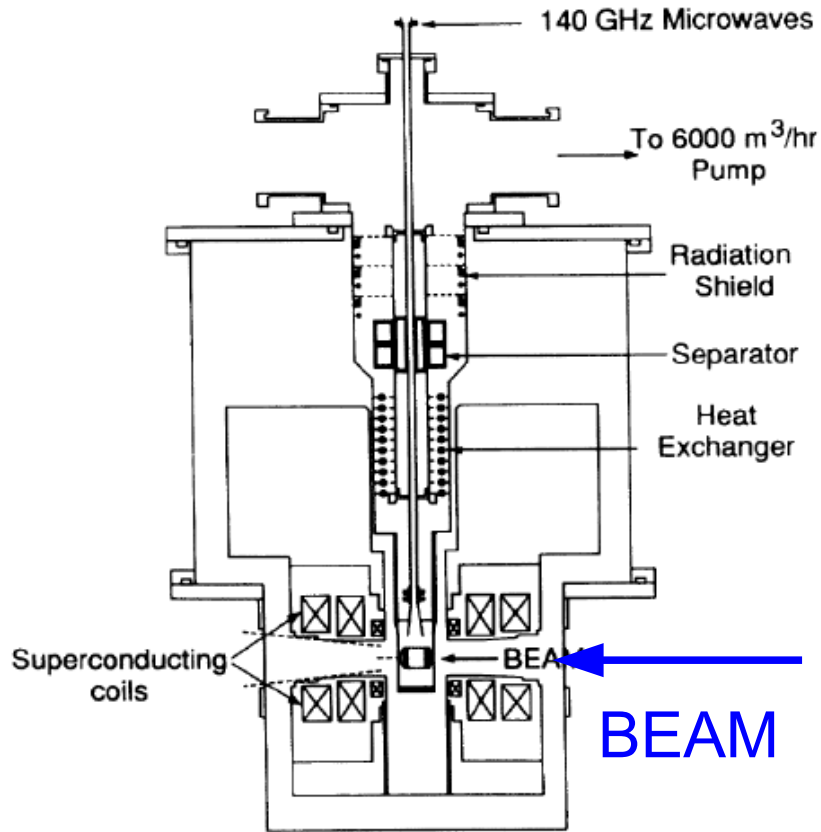
1 K ⁴He cryo.



- | | |
|-----------------------------------|---|
| 1. Cryostat Temperature | 1 K |
| 2. Cooling Fluid | He ⁴ |
| 3. Cooling Power | 0.927 w |
| 4. Operating Magnetic Field | 5.0 T |
| 5. Field Uniformity Region | 10 ⁻⁴ in 4 diam. by 3 cm high cylinder |
| 6. ∫B·dl | 0.885 T |
| 7. Power Supply Voltage | 3 V |
| 8. Superconducting Coil Current | 66 A |
| 9. Microwave Frequency | ~140 GHz |
| 10. NMR Frequency | 213.0 ± 0.3 MHz |
| 11. Vertical Angular Acceptance | ± 6 |
| 12. Horizontal Angular Acceptance | ± 34 |
| 13. Target Size | 3.2 cm long by 2.0 cm diam. cylinder |

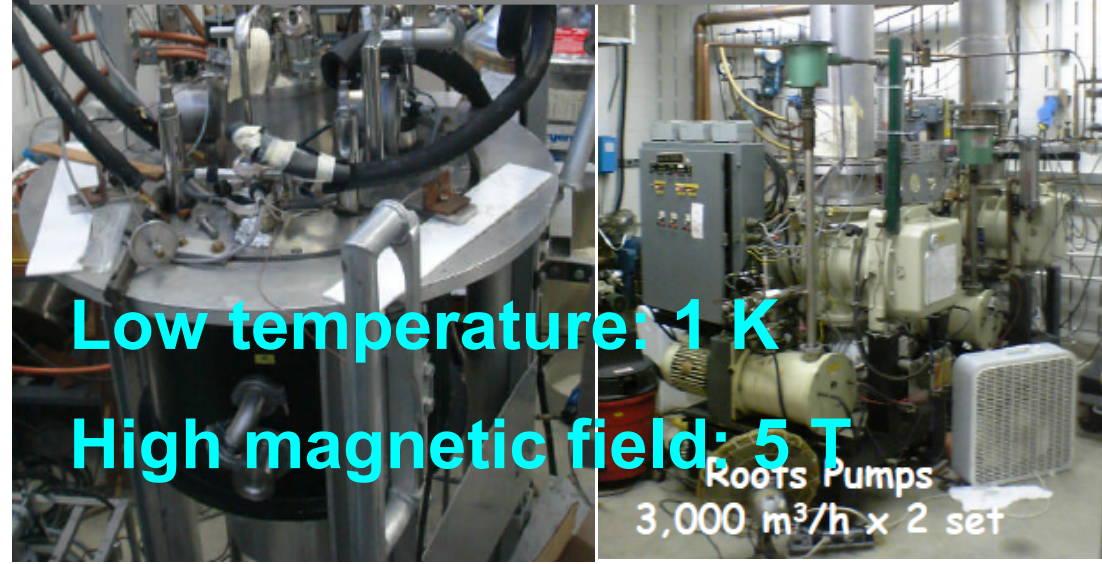


irradiated NH₃ beads
 10¹¹ p per 1 s pulse per 2.4 s cycle

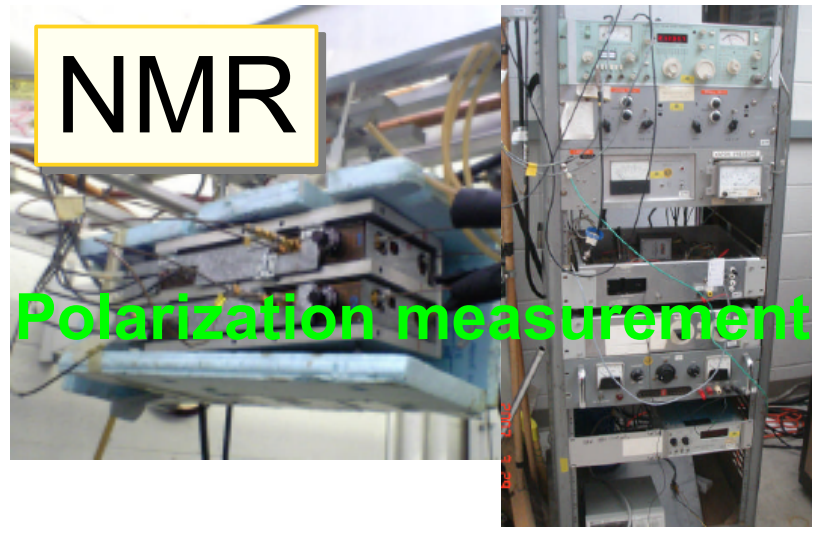




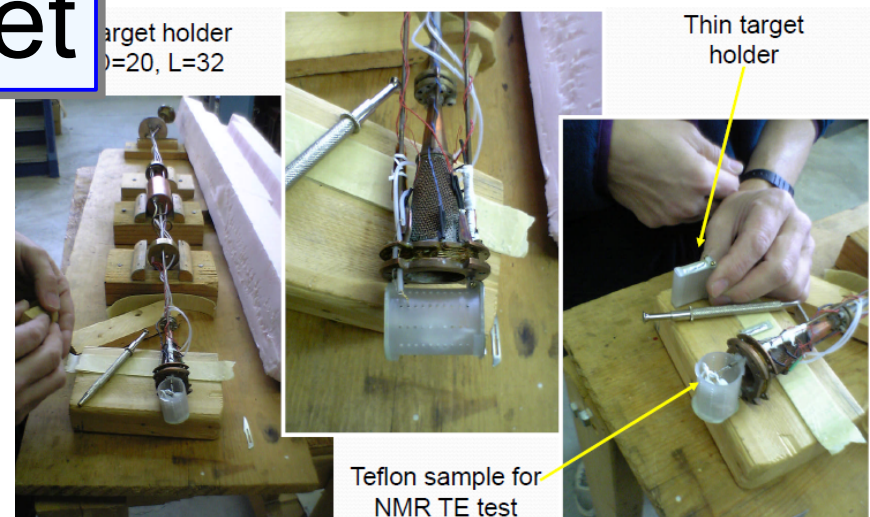
Cryostat & Magnet



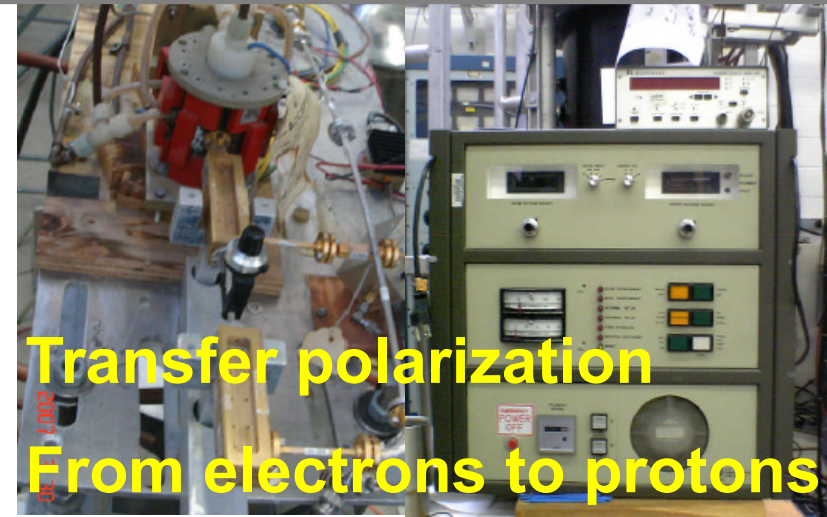
NMR



Target



Microwave (DNP)

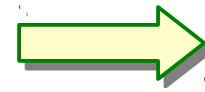




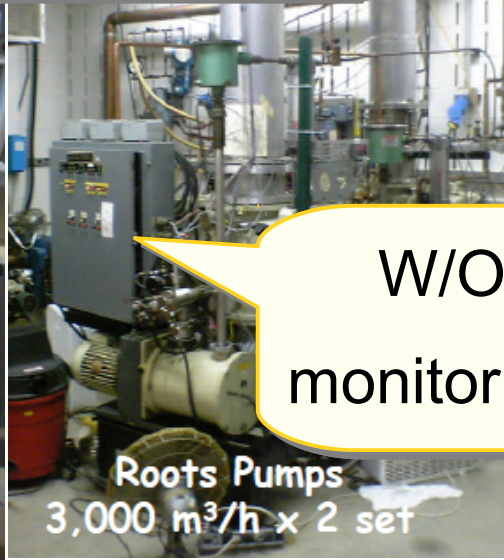
PPT system development at KEK, Japan

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- 2007 Michigan PPT system shipped to KEK
PPT system setup started
- 2010 April
- 2011 March Earthquake
- 2012 1K ^4He and 5 T Magnet system test re-started
- 2013 Feb. Magnet (5T) test
- 2013 March TE signal (F and H) measurement
- ??? DNP test

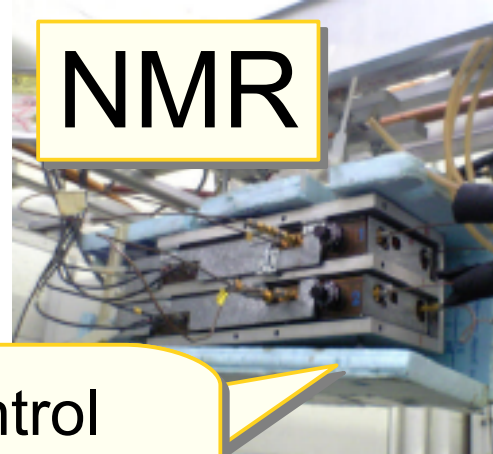


Cryostat & Magnet



W/O control monitoring system

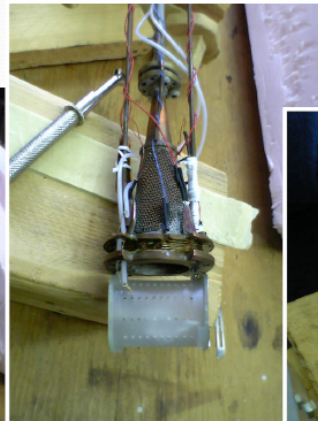
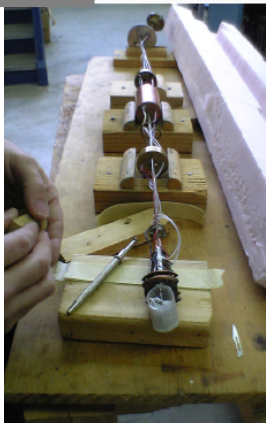
NMR



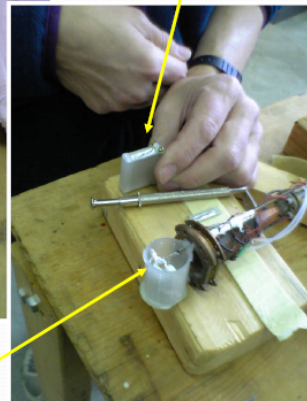
Microwave (DNP)

Target

target holder
D=20, L=32



Thin target holder



Teflon sample for
NMR TE test





PPT system development at KEK, Japan

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2010 April



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2013 Feb. Magnet (5T) test

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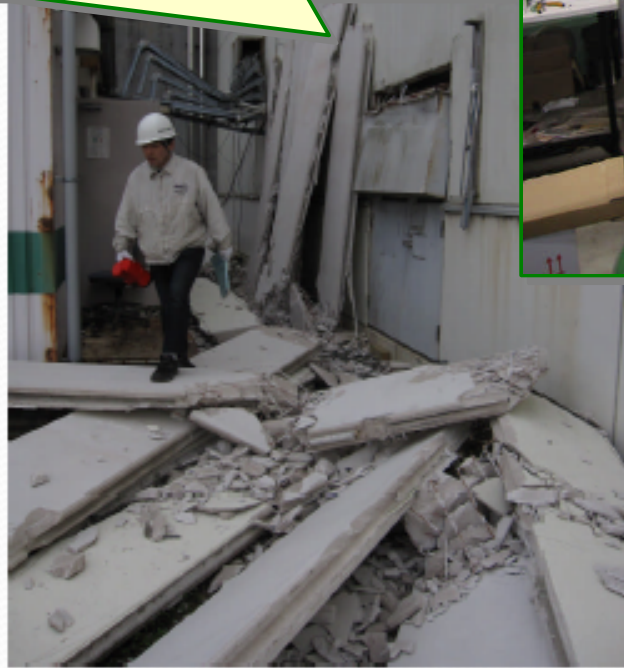
PPT system development at KEK, Japan

- 2007 Michigan PPT system shipped to KEK
PPT system setup started
- 2010 April  科研費
KAKENHI
- 2011 March Earthquake 
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KEK North Counter Hall

March 24-25, 2011


PPT system was fine,
but the counter hall had some damaged.





PPT system development at KEK, Japan

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1 K ^4He Cryostat and 5 T Magnet

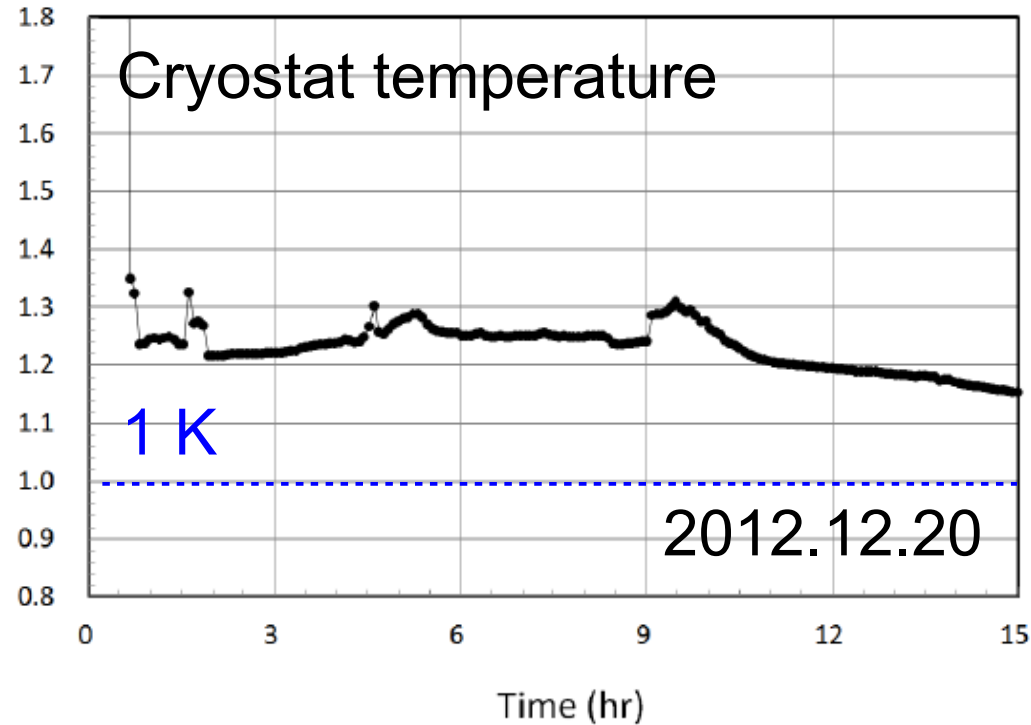
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2012.10 Pre-cooling with Liq. N

2012.11 Cooling with Liq. ^4He
(Reached to ~ 1.5 K)

Magnet test (10 A)

2012.12 Stable operation ~ 1 K



2013.2 Magnet test

Quench at 16 A, 63 A

2013.3 Reached to 5 T

($I = 65.965$ A)





PPT system development at KEK, Japan

2007 Michigan PPT system shipped to KEK

PPT system setup started

2010 April



2011 March Earthquake

2012 1K ⁴He and 5 T Magnet system test re-started

200 MHz NMR @ Yamagata

2013 Feb. Magnet (5T) test

2013 March TE signal (F and H) measurement

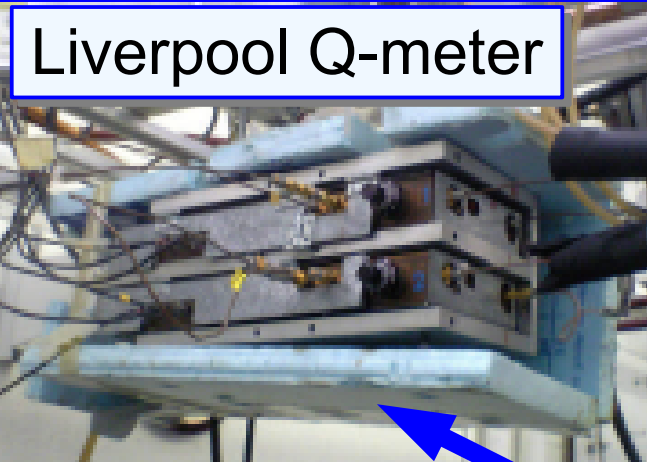
??? DNP test



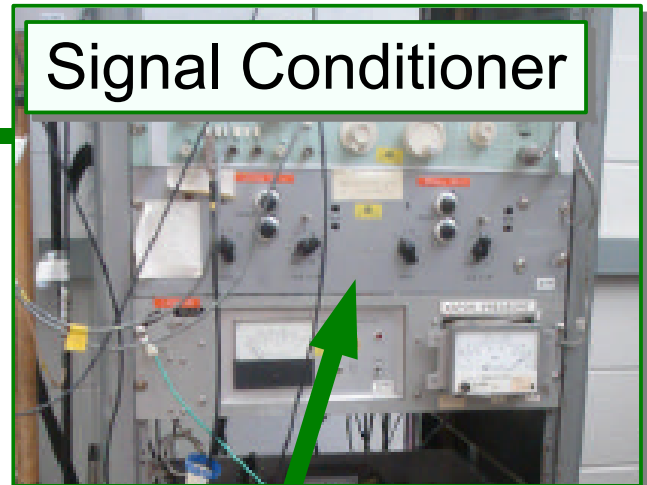


200 MHz NMR system

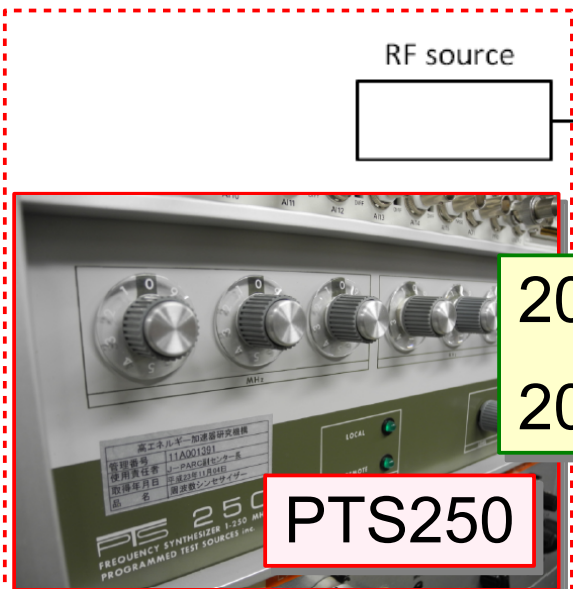
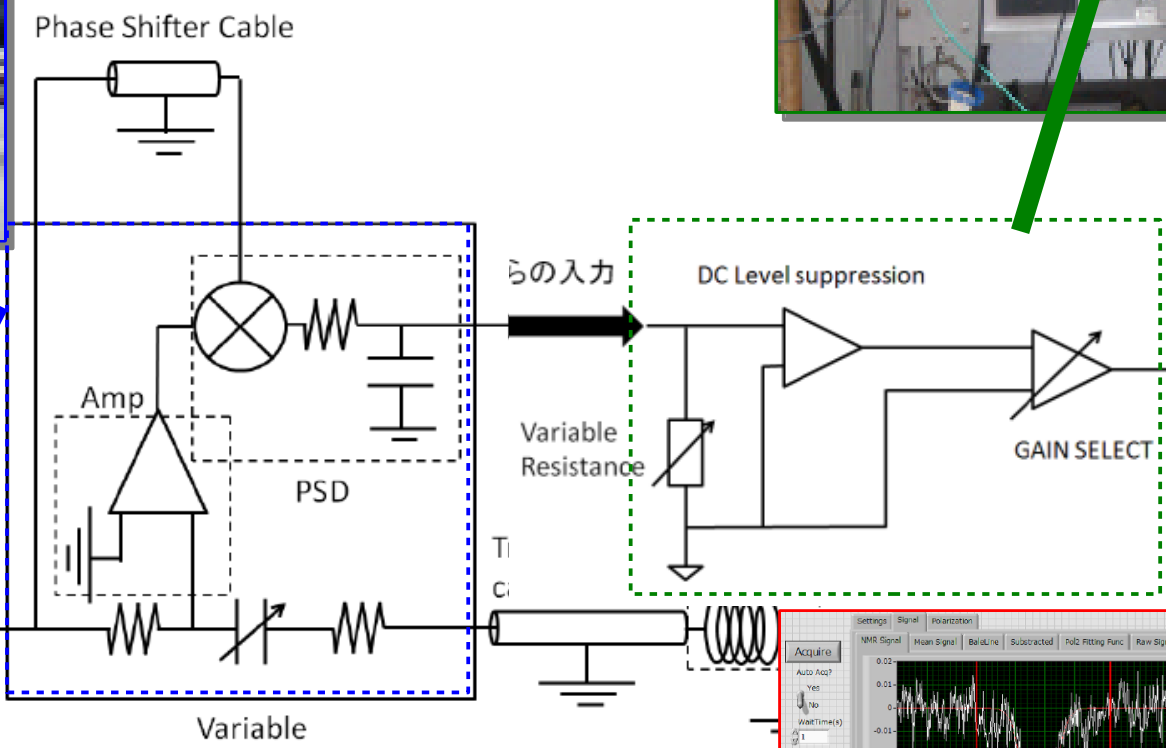
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Liverpool Q-meter

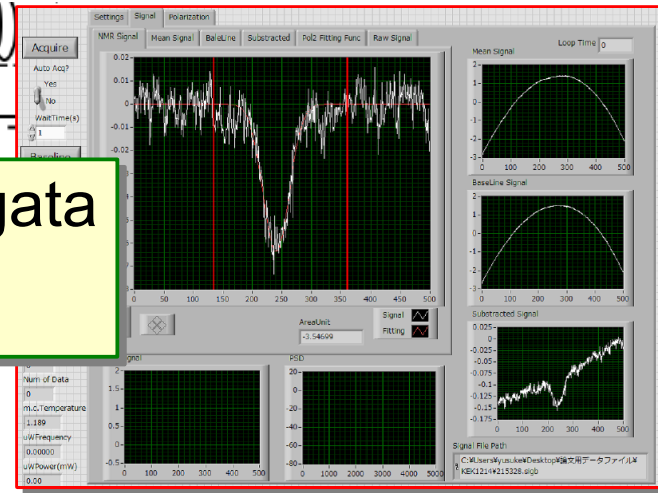


Signal Conditioner



PTS250

2012.10 Setup+Test@Yamagata
 2013.1 Setup+Test@KEK





PPT system @ KEK, **NOW!!**

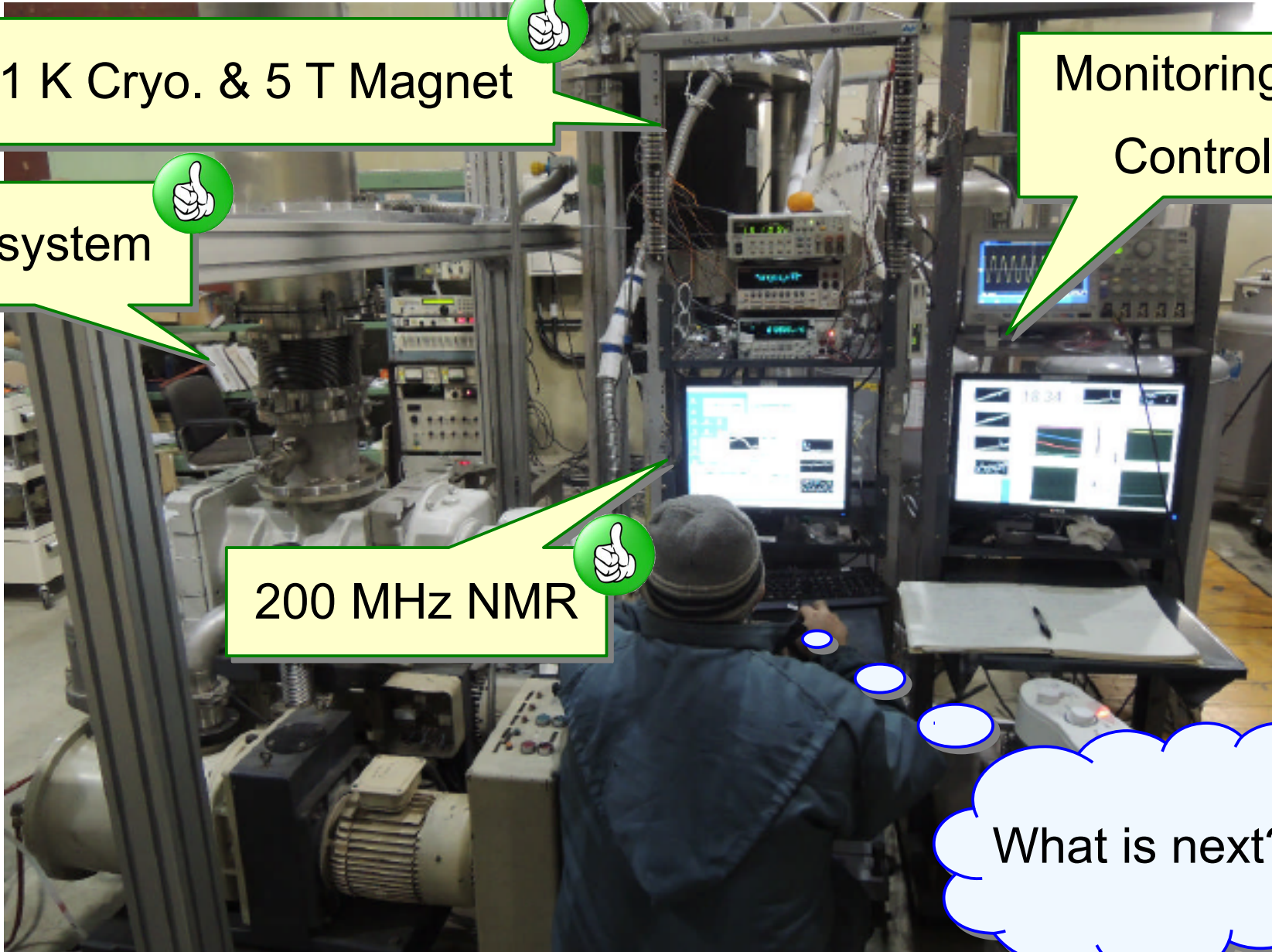
1 K Cryo. & 5 T Magnet

Pump system

200 MHz NMR

Monitoring & Control

What is next?

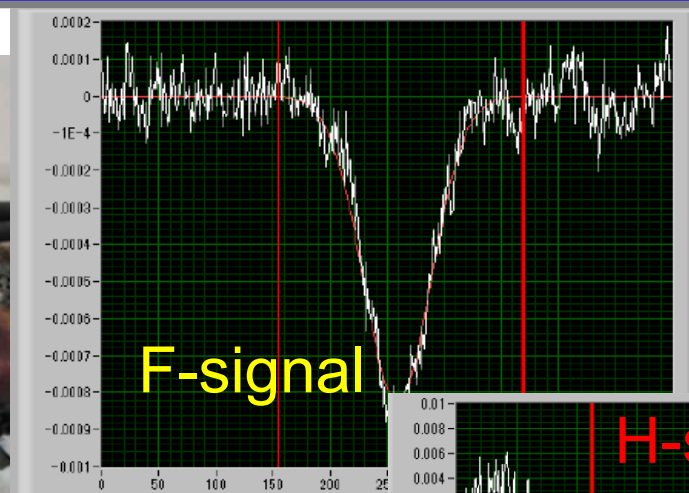
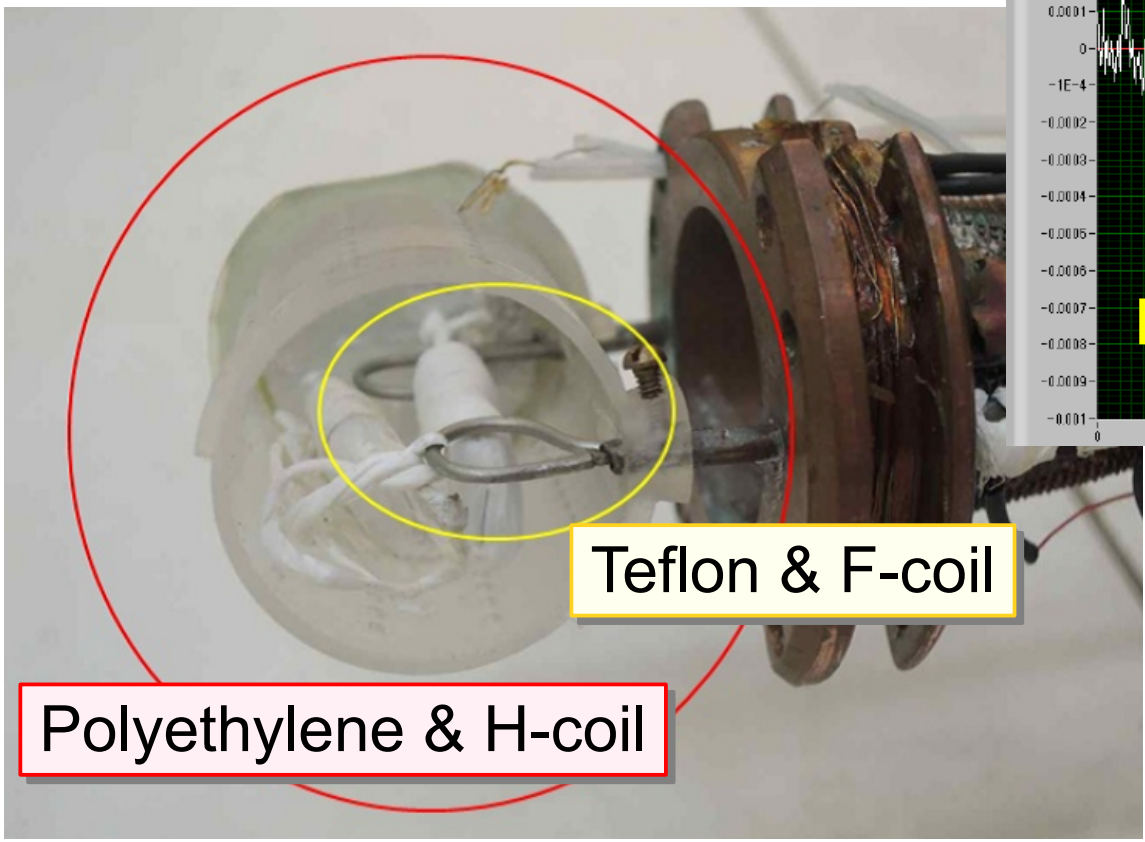


TE signal test

Thermal Equivalent Signal
Natural spin polarization with Zeeman splitting

2013.3
TE test (1 K, 5 T)

“TE signal” is reference of polarization measurement (i.e., **calibration**)





5T DNP system: 140 GHz Microwave

in preparation



2012年3月納品済

HIGH POWER MMW OSCILLATOR WITH MANUAL TUNING, 120 - 140 GHz MODEL SERIES VKT 2438L

DESCRIPTION
 The VKT 2438L series of manually tuned CW Extended Interaction Oscillators (EIOs) are targeted for F-Band radar and scientific instrumentation applications. This EIO delivers output power in excess of 10W over a 3 GHz tuning range and has a typical electronic tuning range of 200 MHz. The VKT 2438L series of EIOs can be integrated with the VPW2827 series of power supply to provide a highly stable and low noise source.



TYPICAL ELECTRICAL PERFORMANCE

EIO: delivered 2012.3



PS for EIO: delivered 2013.5



Microwave system design started.



2013年3月納品予定

Electronic Power Conditioner for CW Millimeter Wave EIKs

EPC Model VPW2827

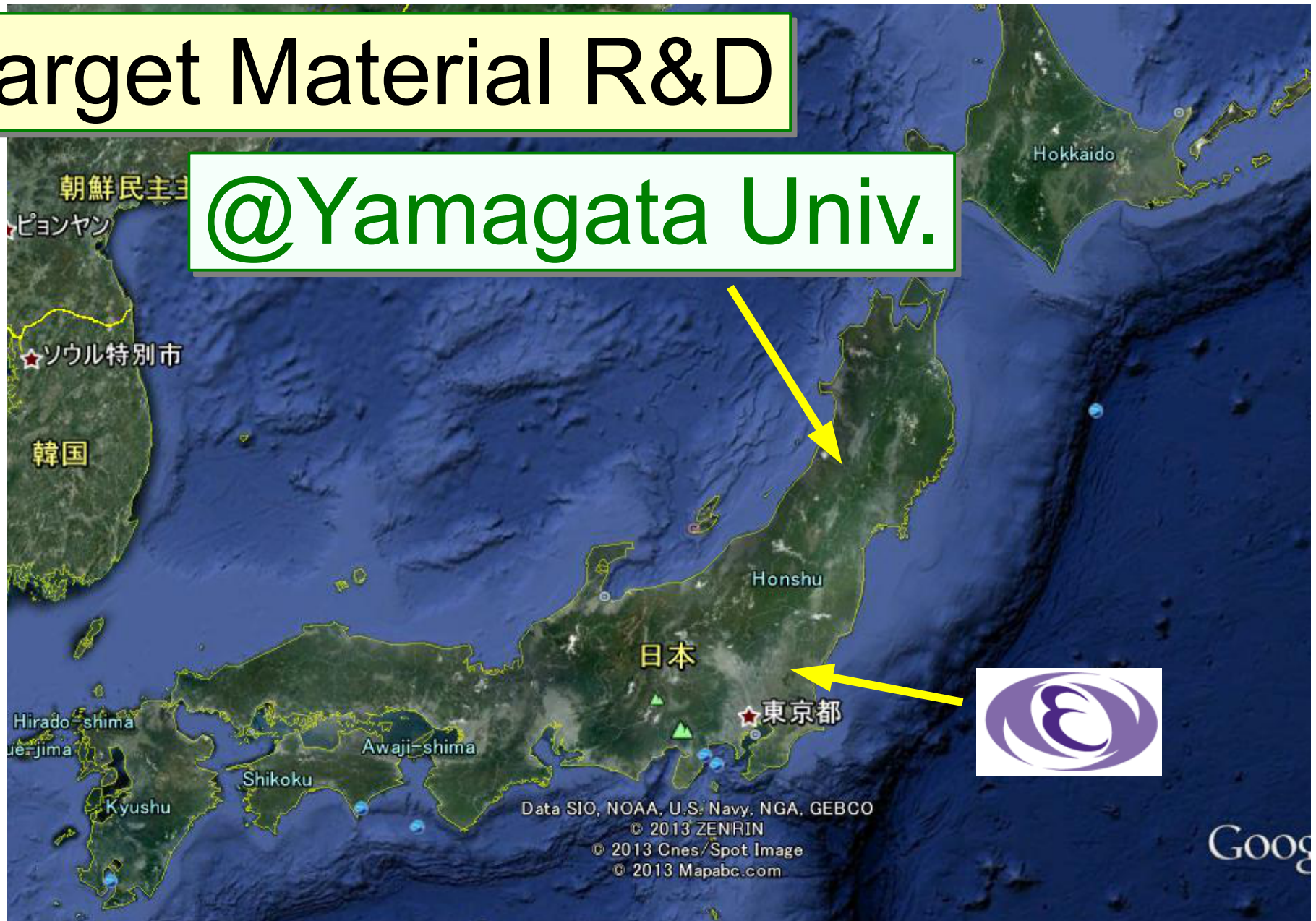


DNP test in this FY



Target Material R&D

@Yamagata Univ.





Target material R&D: history

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PT-Material History

Crystal (LMN)

↓

Chemical Reaction (Cr^{V+})

↓

Stable Radical (EHBA, TEMPO)

↓

Radiation Damage (NH_3 , LiH)

↓

Radiation Damage for Organic Material, Water ... ?

Target materials

Present candidate for pol. DY experiment (e.g., COMPASS II DY)

Polymer: better cooling (foil/powder)?

KRAEMER@UXNHD.CERN.CH

13-JUL-95



Irradiation with 2 MeV electrons

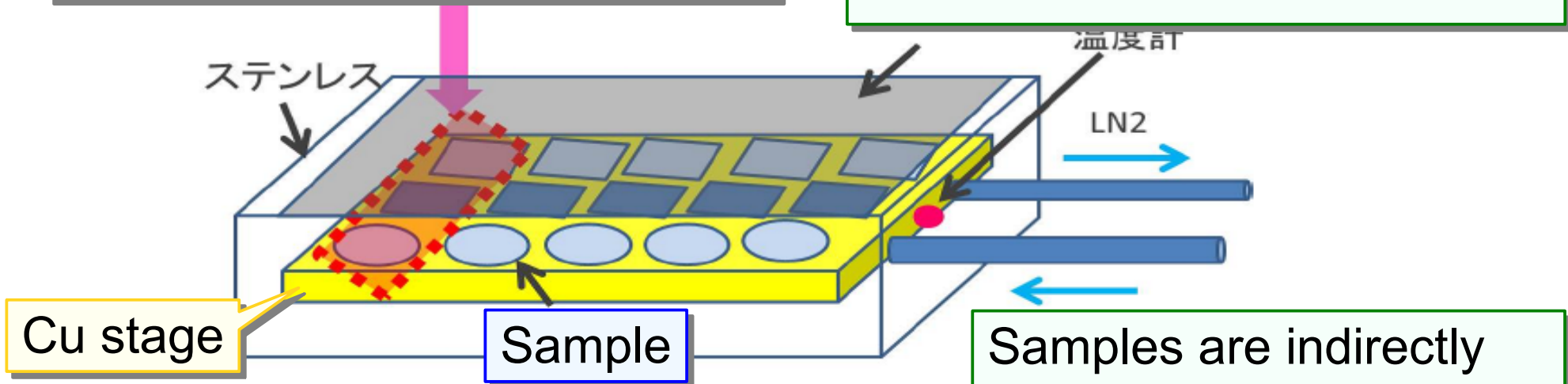
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Irradiation setup

2 MeV electrons

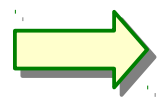
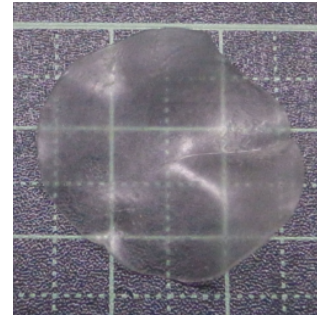
Dose: $10^{14} \sim 10^{16}$ electrons/cm²

@ the electron acceleration facility in Takasaki Advanced Radiation Research Institute, Japan Atomic Energy Agency



Samples are indirectly cooled down with Liq. N2

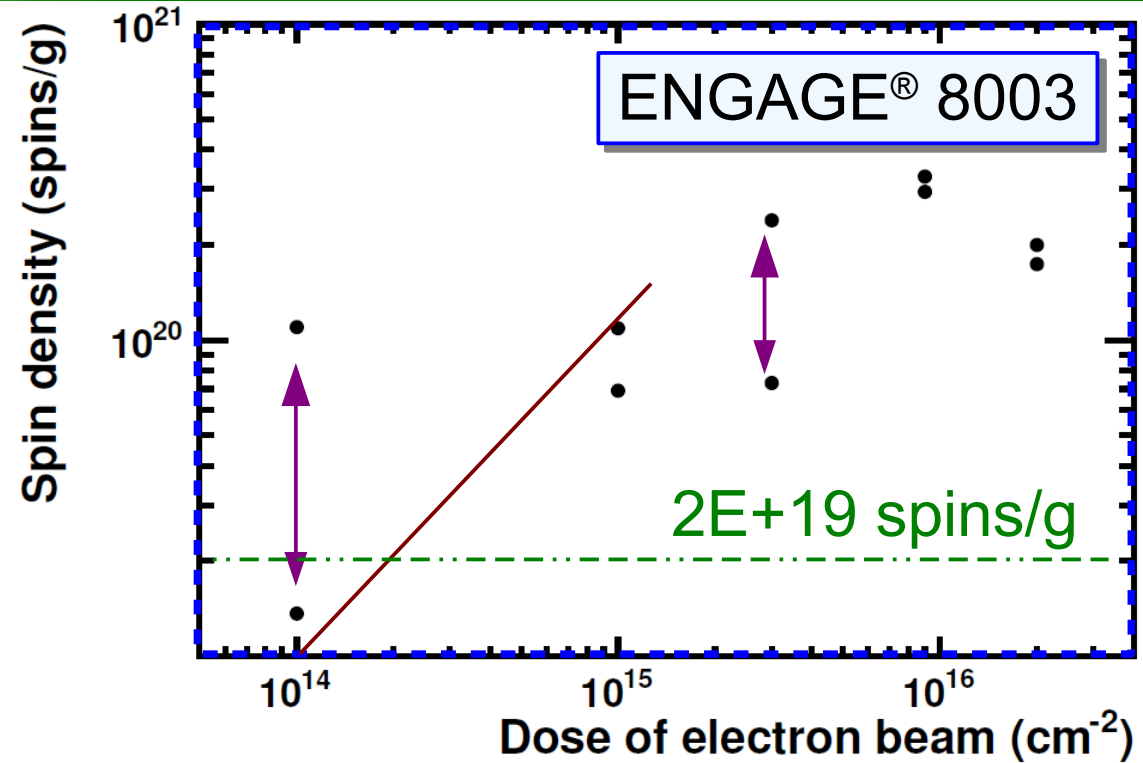
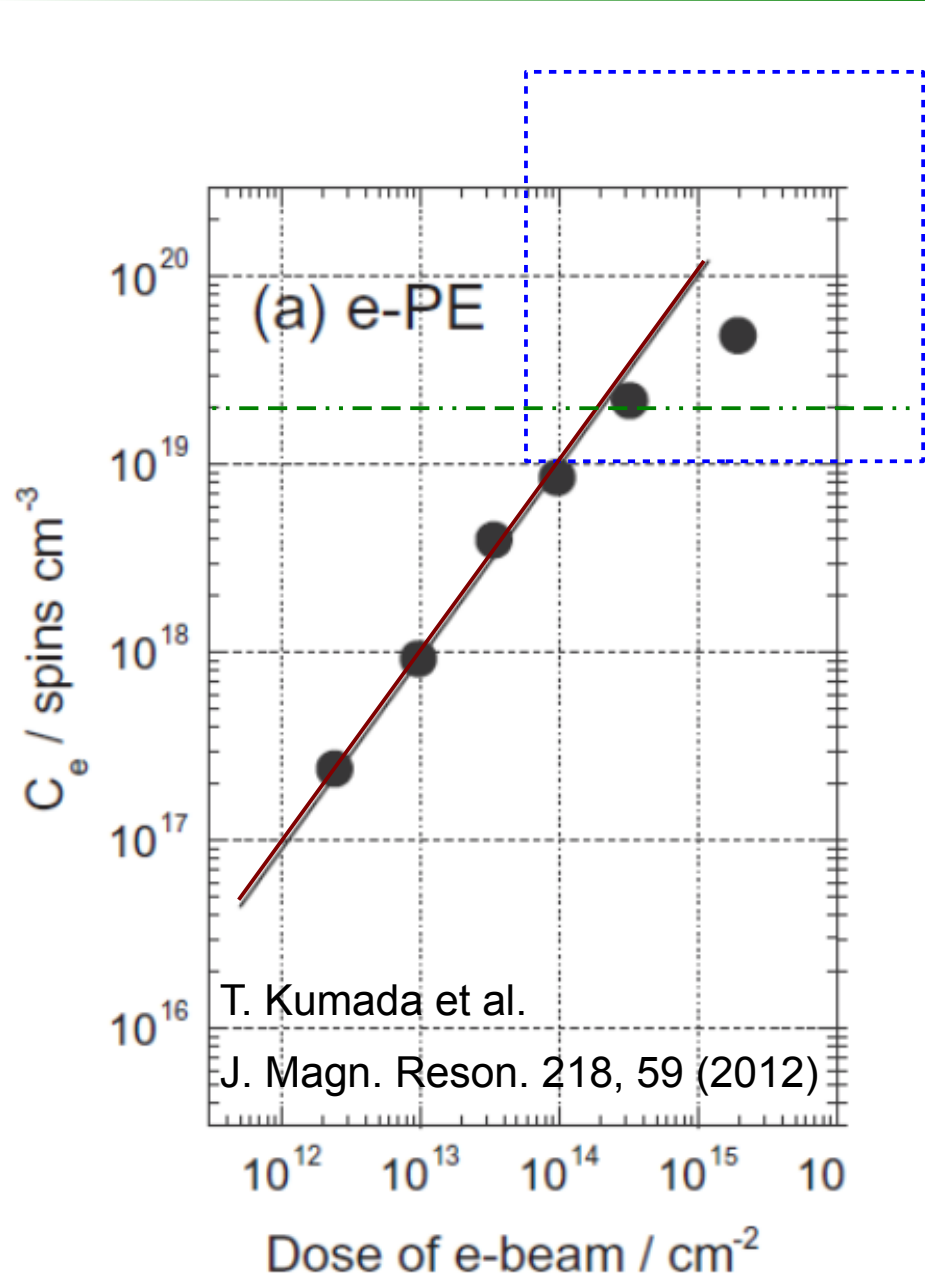
Several types of polyethylene Foil (**ENGAGE® 8003**), String, texture,





Spin density of the irradiated sample

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Re-produce **general tendency**

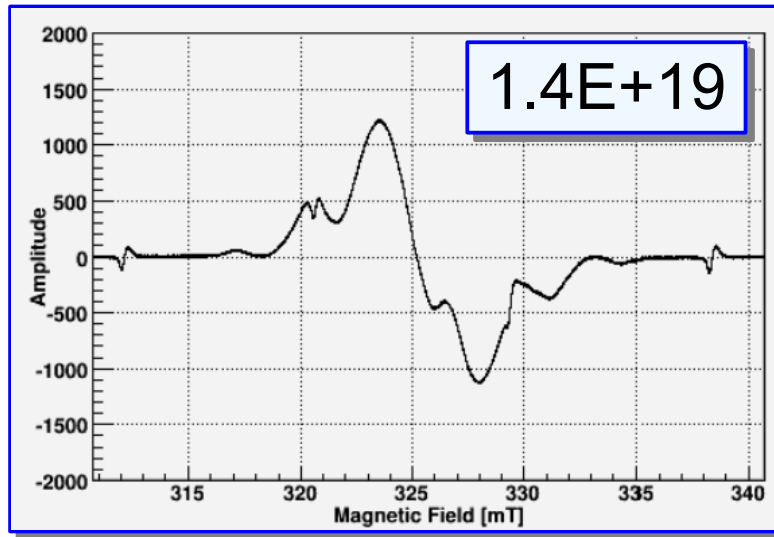
Variation due to re-combination

during the irradiation

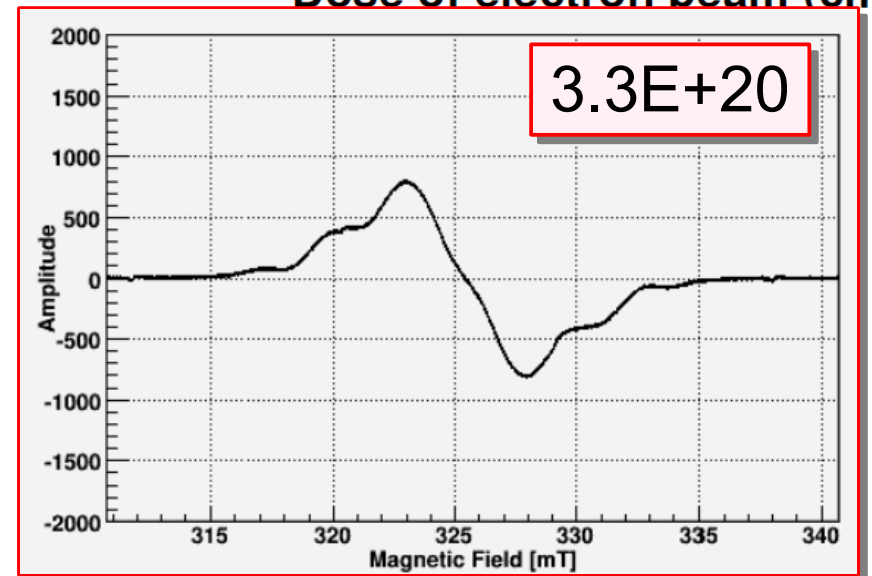
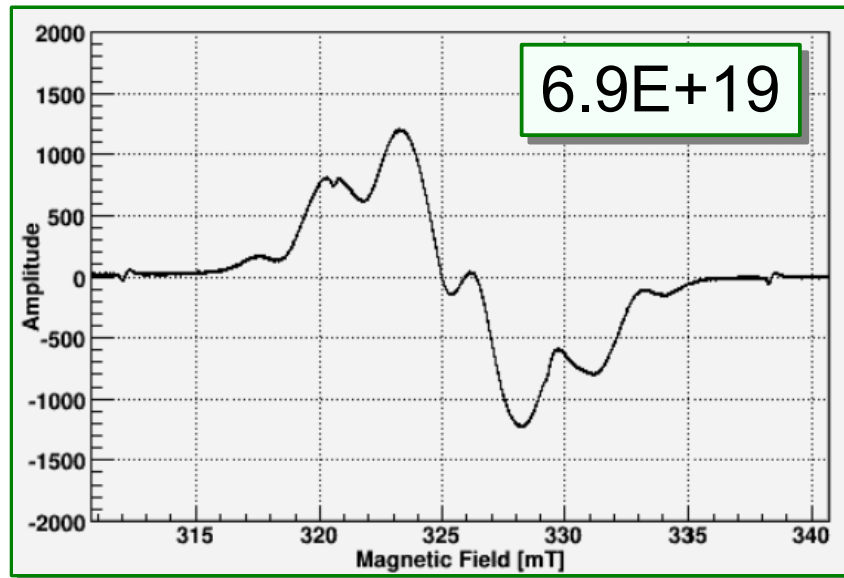
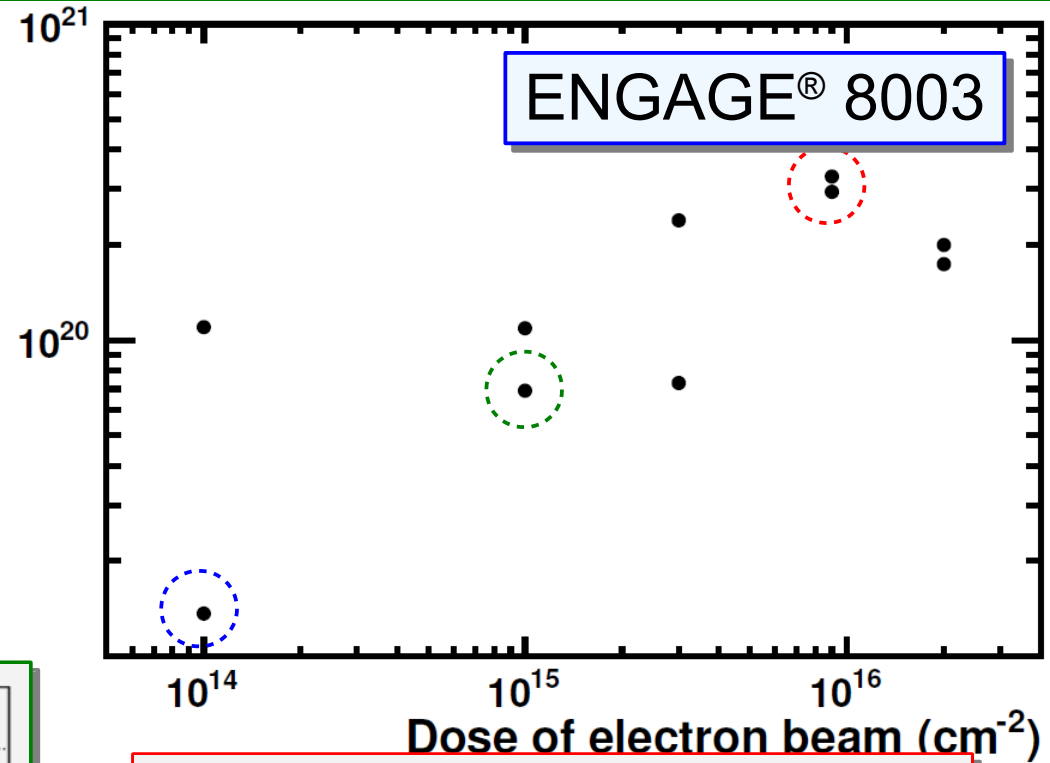


ESR signals at 77 K

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Spin density (spins/g)

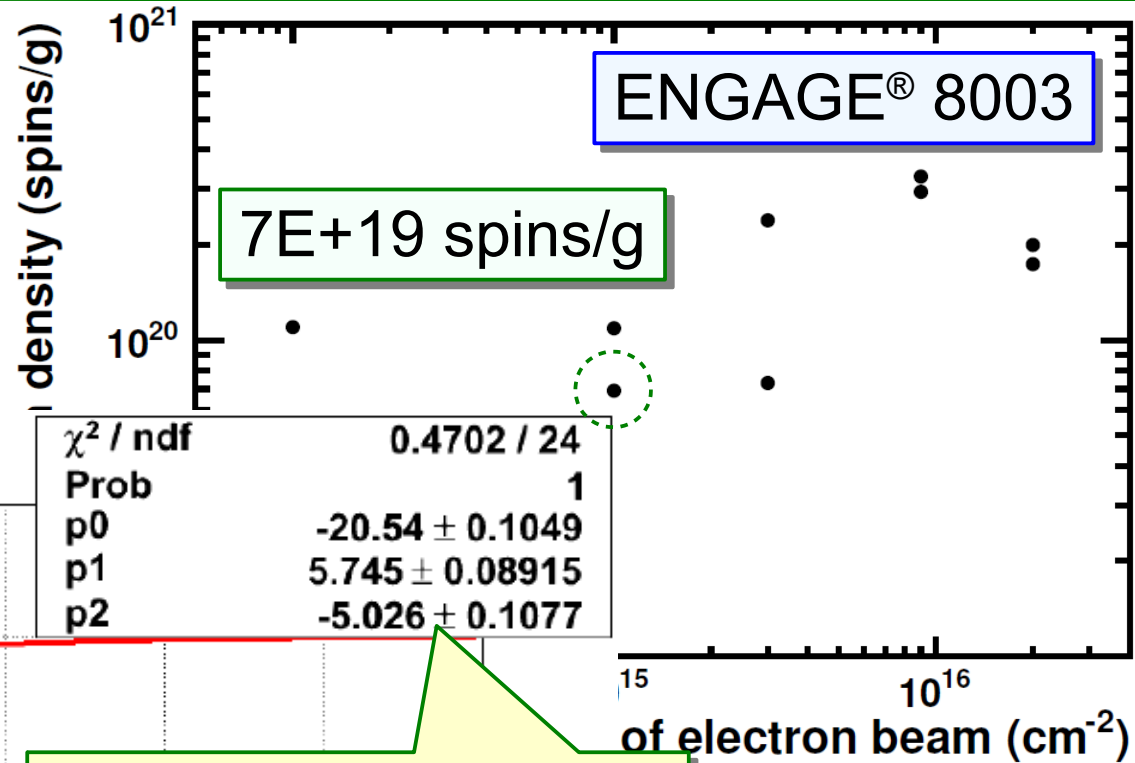




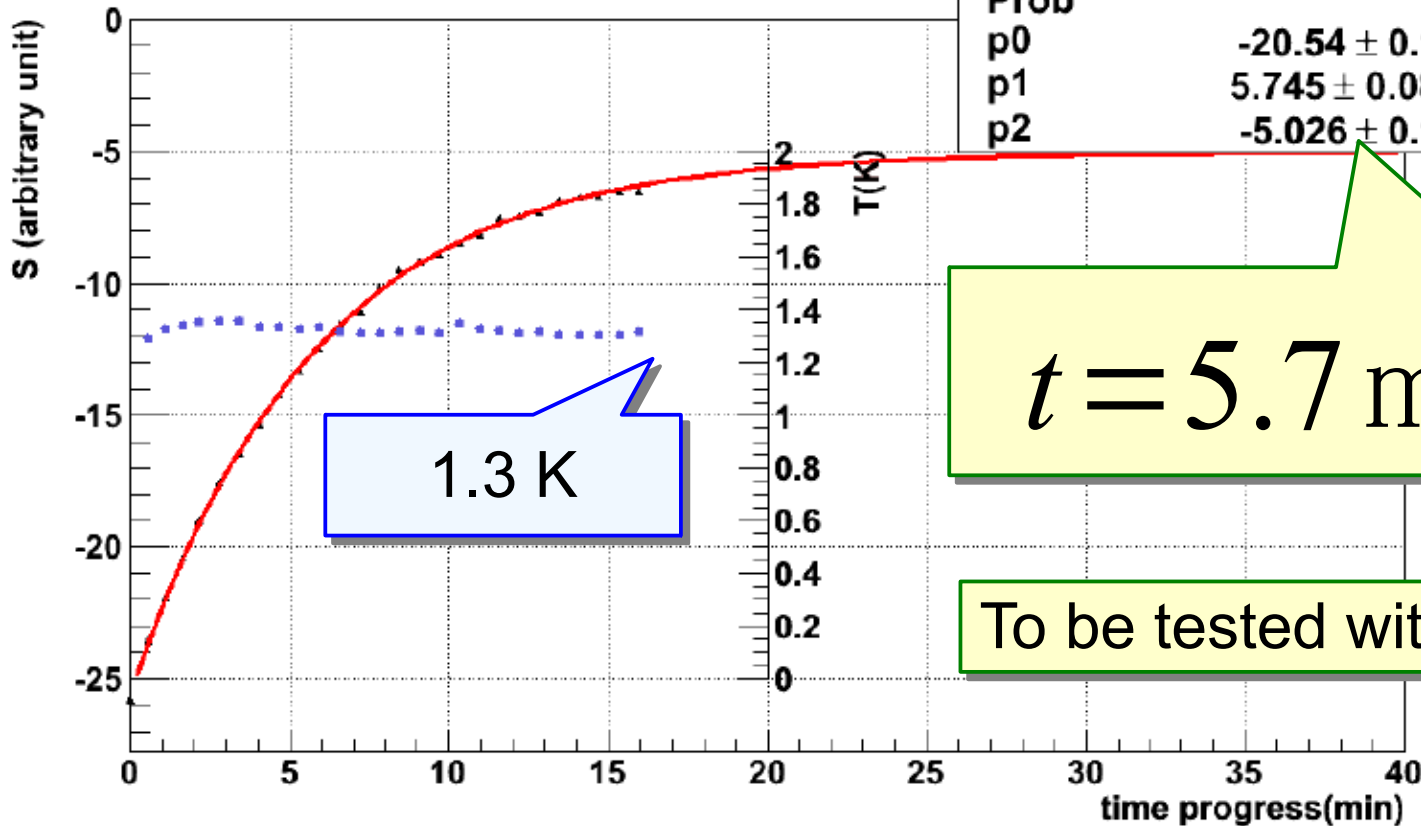
Relaxation time, @ 1.4 K & 2.5 T

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DNP with
2.5 T system @ Yamagata



relaxation time



$t = 5.7 \text{ min}$

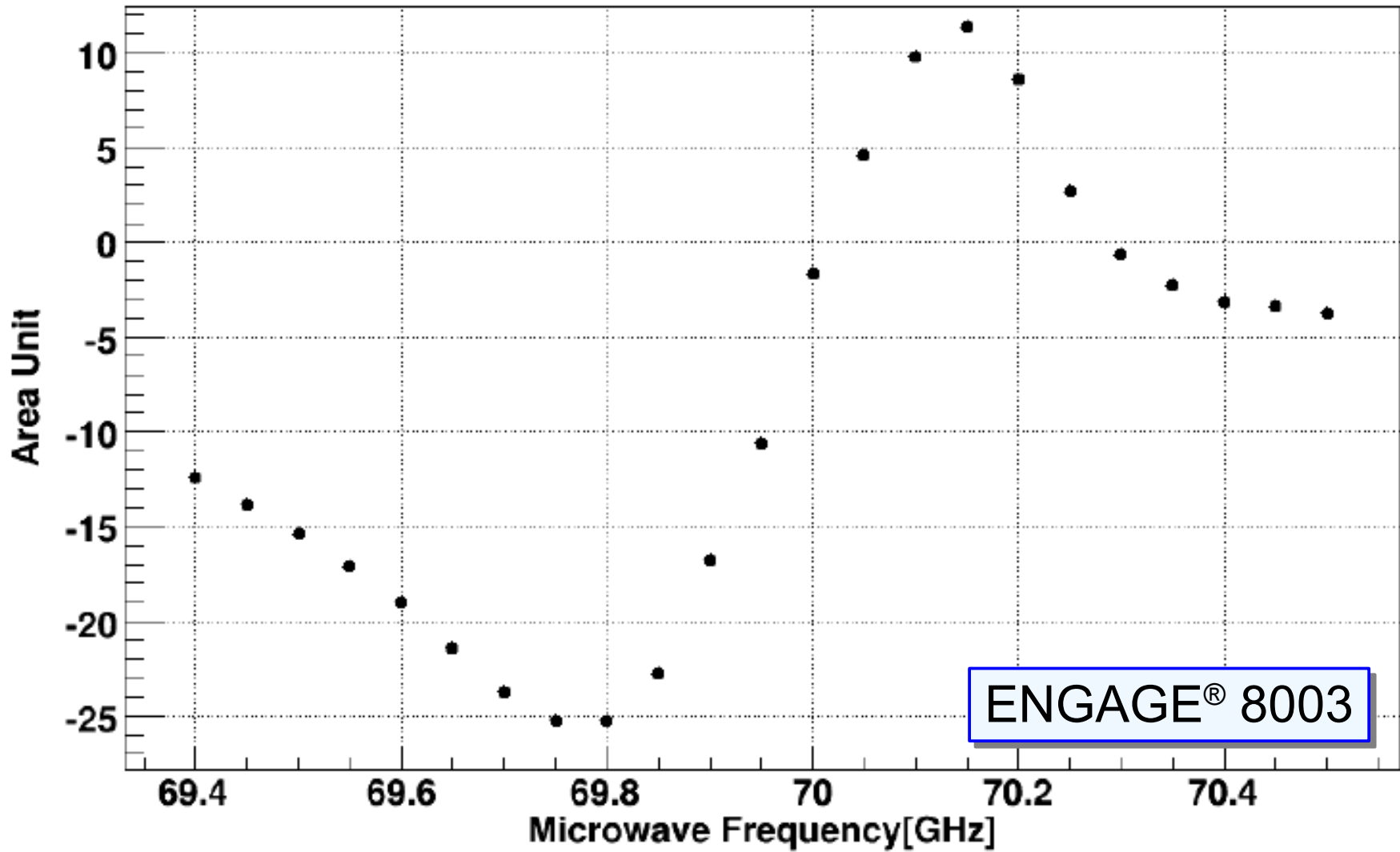
To be tested with 5 T system @ KEK

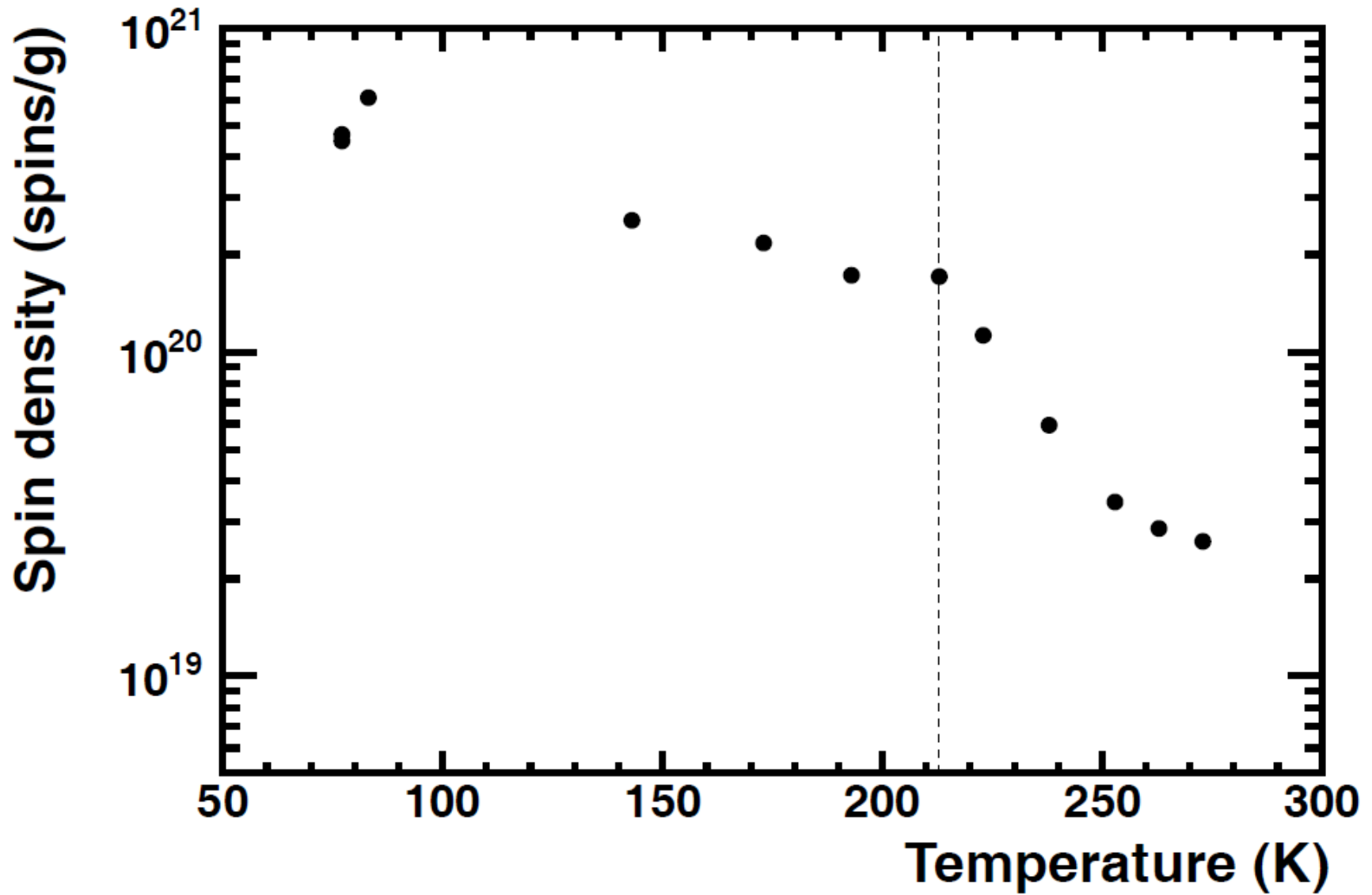
- PPT system @ KEK
 - Re-use of Michigan PPT system
 - Shipped to KEK on 2007
 - Cryo., Magnet, and NMR system ready
 - TE signal measurement at 5 T successfully done.
 - 140 GHz Microwave system in preparation for DNP
- Target material R&D @ Yamagata
 - Polyethylene samples were irradiated with 2 MeV electron
 - Spin density, ESR spectrum, Spin relaxation time were measured
 - DNP test with 5 T system @ KEK





Frequency scan test: 2.5 T, 1.3 K







Cu stage for the irradiation

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