Status of the Mainz Frozen Spin Target

3rd Meeting 'Polarized Nucleon Targets for Europe' in the 6th European Framework Program

Mauricio Martínez Fabregate Rech, February 3rd 2006

- Polarization of a nucleon
- The Frozen Spin Target
- Microwave System
- Magnet
- N.M.R.
- Cryostat
  - Separator-Evaporator
  - Temperature measurement
  - Needle valve
  - Control System
- Conclusions and Outlook
Polarization of nucleon

- Particles with \( S=1/2 \) in an external magnetic field, follow Boltzmann law in thermal equilibrium:

\[
P = \frac{N_+ - N_-}{N_+ + N_-} = \tanh\left(\frac{\mu B}{kT}\right)
\]

- Magnetic moment \( \mu_v = 660\mu_p \)

- \( T=1K, \ B=2.5T \quad P_e=92\%, \ P_p=0.25\% \)
- \( T=0.02K, \ B=10T \quad P_e=100\%, \ P_p=40\% \)

- **Dynamical Nuclear Polarization**: Microwave are applied to induce a simultaneous spin flip, and transfer polarization from electron to nucleon.

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The Frozen Spin Target

- **Microwave System**
- **Cryostat**
- **Target**
  - BUTANOL
  - \( C_4H_{10} \)
  - \( 80\% \)
  - \( 20\% \)
- **Control System**
- **Pumping System**
- **Magnet**
- **NMR**

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Microwave system

- Varactor tuning
- IMPATT diode
- Tunable frequency
  70GHz ± 200MHz
- Used in the GDH Sum Rule experiment 2003
- LabView control panel

Magnet

- Maximum field: 5 Tesla
- High Uniformity:
  \[
  \frac{\Delta B}{B} < 10^{-4}
  \]
- Liquid He bath at 4 K
- Radiation shield cooled by nitrogen
- Refilling time:
  - 12 days He
  - 5 days N
- LabView program
Magnet, uniformity test
(Heiko Rochholz Diplomarbeit in XI group)

NMR System

- Serial resonance circuit LC with a coil around the target material
- Change in polarization induce change in susceptibility of the coil
- Signal obtained by frequency scan over the resonance Larmor frequency
- Andrea Knezevic and Milorad Korolija from Ruddjer Boscovic Institut Zagreb and important collaboration from Bochum University.
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February 3rd 2006

Cryostat

- Temperatures of 50 mK. He3-He4 mixture. He3 line
- Cooling power of 100 mW
- Superconducting holding coil integrated
- Separator and Evaporator precooling stages. He4 line
- Target insert along the beam axis
- Fits in the geometry of the Crystal Ball detector

Separator T=3K
Evaporator T=1.8K
He3-He4 mixture T=50mK
Needle valves
Mixing chamber

Separator and Evaporator precooling stages. He4 line
He4 line
(Mohamed Mouahid Diplomarbeit)

Separator
• 2 Rotary pumps
• 18 Electro pneumatic valves
• 6 pressure sensors
• 2 Flow meters
• Temp = 3 K

Evaporator
• 1 Rotary pumps
• 9 Electro pneumatic valves
• 3 pressure sensors
• 1 Flow meters
• Temp 1.8 K

Separator and Evaporator
He3 line

- 39 Valves
- 1 Flow meter
- 4 Pressure sensors
- 4 Rotary Pumps
- 2 Cooling Traps
- 5 Roots Pumps
Cooling trap

- Series of 5 Roots pumps: 4000 m³/h, 2000 m³/h, 1000 m³/h, 500 m³/h and 250 m³/h
- Very low leak rate
- Pressure and temperature sensors
- Simatic program to control it
Temperature measurements

Type of sensors:
PT100, Allen Bradley, Speer and TVO (4 and 2 poles measurement)

Number of Sensors:
- Insert: 8 sensors, 1AVS
- Shields: 8 sensors, 1AVS
- Precooling: 8+20 sensors, 1AVS + 1Keithley Digital Voltmeter

**AVS Resistor Bridge**
- 8 Channels
- GPIB connection to PC
- Optical coupling
- Read/Write parameters with LabView

Heaters: Indium sealing, Mixer, Separator, Evaporator, Still

Motor for needle valves

- 6 Step motors
- Guide system
- Technosoft software
- LabView connection (Joachim Scholz)
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**Hardware Control System**

- **Coil**
- **Freq. generator**
- **Freq. scan**
- **Amplifier circuit**

**N.M.R.**

- **GPIB**
- **RS232**

**CPU master**
- **He3 line**
- **M.W.**

- **Source**
- **Power meter**
- **Freq. sensor**
- **Motor attenuator**

**Magnet**

- **Thermo sensors**
- **AVS**

**Needle valves**

**Motor**

**Valves, Pumps**
- **D/I/O**
- **A/I/O**

**Sensors**

**Balance**

**R**

**S**

**2**

**3**

**2**

**Hardware Control System Status**

- **Coil**
- **Freq. generator**
- **Freq. scan**
- **Amplifier circuit**

**N.M.R.**

- **GPIB**
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**CPU master**
- **He3 line**
- **M.W.**

- **Source**
- **Power meter**
- **Freq. sensor**
- **Motor attenuator**

**Magnet**

- **Termosensors**
- **AVS**

**Needle valves**

**Motor**

**Valves, Pumps**
- **D/I/O**
- **A/I/O**

**Sensors**

**Balance**

**R**

**S**

**2**

**3**

**2**
Software Control System

LabView

Technosoft Motor

AGLink

Simatic Step7

N.M.R.

AVS

Main Program

M.W.

Magnet

He4

He3

Roots

CPU Master

Profibus

CPU Slave

LabView Main program
Summary & Outlook

Microwave system used in 2003.
Magnet working and tested by X1 group.
NMR under construction.
Roots Pumps working and tested.
He³ and He⁴ line (66 valves, 7 pumps, 13 pressure sensors, 4 flow meters) working, leak test missing.
AVS Thermo sensors software system done.
Cooling trap refilling system working, trap is being produced in Dubna.
Motor-needle valve connection missing, software done.
LabView-Simatic control system done, but more parts have to be implemented.
Cryostat will be mounted and tested in May-June.

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GRACIAS!

+ Bonn + Bochum + COMPASS
Magnet

- Liquid He bath at 4 K
- Radiation shield cooled by nitrogen
- Maximum field: 5 Tesla
- High Uniformity: $\frac{\Delta B}{B} < 10^{-4}$
Summary & Outlook

- Microwave working and tested since 2003
- Magnet
- AVS
- LabView-Simatic control System
- Needle valve motor
  - N.M.R.

Roots Pumps
- 66 valves, 7 pumps,
- 13 pressure sensors,
- 4 flowmeters

Cooling trap

Leak test
- Mount and test Cryostat

N.M.R.

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He3 line

- 1 tank of $^3$He gas
- 1 tank of $^4$He gas
- 39 Valves
- 1 Flow meter
- 4 Pressure sensors
- 4 Rotary Pumps
- 2 Cooling Traps
- 5 Roots Pumps

Summary & Outlook

- Microwave
- Magnet
- AVS
- LabView-Simatic control System
- Needle valve motor
- N.M.R.

- Roots Pumps
- 66 valves, 7 pumps,
- 13 pressure sensors,
- 4 flowmeters

- Cooling trap
- Leak test
- Mount and test Cryostat