First experiments with the polarized internal gas target at ANKE/COSY

September 9, 2009 | Maxim Mikirtychyants for the ANKE collaboration
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Outline

- Introduction
- Setup overview
- Target commissioning
- Summary & Outlook
**Introduction**

**COoler SYnchrotron (COSY) @ FZ Jülich**

**Key features:**
- protons and deuterons
- high-intensity
- unpolarized and polarized

$p$ & $d$ beams with momenta up to 3.7 GeV/c available for:
- internal experiments (circulating beam) ⇒ ANKE, WASA etc
- external experiments (extracted beam) ⇒ TOF, BIG KARL
Apparatus for Studies of Nucleon and Kaon Ejectiles (ANKE)

Spectrometer Magnets
- D2 - analyzing dipole
- D1, D3 - beam bending dipoles

Detector systems
- Positive & Negative
- Forward & Backward
- Silicon Tracking Telescope

Targets
- Solid state (CH$_2$, C, Cu, Au etc)
- Cluster jet (H$_2$, D$_2$)
- **PIT** - Polarized Internal gas Target (H, D)
  - vector & tensor polarization
  - storage cell
  - gas jet
Introduction

PIT structure

- **Atomic Beam Source (ABS)**
  - high intensity atomic jet
  - high nuclear polarization of the jet
  - appropriate jet dimensions at the interaction point or at the storage cell entrance

- **Storage cell**
  - thin walls to allow registration of low-energy projectiles
  - PTFE coating to suppress depolarization
  - movable support to allow fast extraction from the beam

- **Lambshift Polarimeter (LSP)**
  - online jet polarimetry
  - high sensitivity
  - short measuring time
Setup overview

Design constraints due to specific conditions at ANKE

- Target chamber suitable for all targets (solid, cluster, PIT) used at ANKE
- Target support compatible with D2 movement
- Compact and mobile design allowing target exchange within a maintenance week
- Reliable operation in strong magnetic stray field of D2 (up to 1.6T)
Atomic Beam Source

- target gas ⇒ hydrogen or deuterium
- beam intensity ⇒ $7.6 \times 10^{16}$ atoms/s (H-beam in 2 hyperfine states)
- beam dimensions at the interaction point ⇒ $\sigma = 2.85 \pm 0.42$ mm
- beam polarization ⇒ hydrogen/deuterium (preliminary)
  - $P_z = +0.89 \pm 0.01$
  - $P_z = -0.96 \pm 0.01$
  - $P_{zz} = +0.77 \pm 0.06$
  - $P_{zz} = -1.17 \pm 0.08$

Lambshift Polarimeter

- target gas ⇒ hydrogen or deuterium
- sensitivity ⇒ $\sim 10^{15}$ atoms/s
- measuring time ⇒ $t \leq 1$ min

Target chamber

- Solid state (CH$_2$, C, Cu, Au etc)
- Cluster jet (H$_2$, D$_2$)
- PIT (H, D) ⇒ storage cell
  - gas jet
Storage cell & support

- dimensions 15×20 mm², length 390 mm
  ⇒ adopted to beam size at flattop;
  losses at injection are compensated by stacking
  and electron cooling!

- thin walls (25 μm Al foil)
  ⇒ registration of low-energy projectiles

- PTFE coating (5 μm)
  ⇒ low depolarization

- movable support
  ⇒ online ABS jet polarimetry with LSP

- unpolarized gas supply system (UGSS)
  ⇒ background measurements

Silicon Tracking Telescope (STT)

- detection of spectator protons nearby the storage cell center
**Gas jet target**

- point-like polarized target
  - low background
  - ~100× lower density compared to storage cell
- cryogenic beam catcher
  - coldhead driven (no LHe)
  - short cooling-down time
  - easy maintenance

![Pressure in the target chamber (mbar)]

<table>
<thead>
<tr>
<th></th>
<th>ABS jet OFF</th>
<th>ABS jet ON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without catcher</td>
<td>4.0×10⁻⁹</td>
<td>3.0×10⁻⁷</td>
</tr>
<tr>
<td>With catcher</td>
<td>4.0×10⁻⁹</td>
<td>3.7×10⁻⁸</td>
</tr>
</tbody>
</table>
First commissioning run ($dp$) - Jan/Feb 2007

- Approbation of the COSY beam injection procedure with storage cell
  - Cooling and stacking at injection
  - Stochastic cooling on the flattop

- Verification of the designed parameters of the target
  - Influence of the D2 stray field on the ABS intensity and polarization
  - Online jet polarization measurements with LSP

- Development of the reaction identification procedure
  - Background determination
  - Target polarization measurements using quasi-free $np \rightarrow d\pi^0$
COSY beam injection procedure (cooler stacking)

28 stacks followed by
- 2s electron cooling
- after 58s acceleration to $T_p = 600$ MeV

Cooler Stacking provides significantly higher polarized beam intensities with cell.

Without storage cell $2.5 \cdot 10^{10}$ ions were reached. (With cell: $6 \cdot 10^9$ ions)

Further improvement of the beam quality

⇒ Stochastic cooling at $T_p \geq 831$ MeV

Details in NIM A 599, Issue 2-3, pp. 130-139
Target commissioning

**Commissioning run**

- **Stacking injection**: 120 injections with 10 s e-cooling
- **Flat top**: 30 min, to have about 2/3 duty time

- **Acceleration without gas in the storage cell**
- **Switching on the gas to feed the storage cell**

~$7 \cdot 10^9$ polarized deuterons!!!
**ABS performance**

😊 jet intensity and MFT efficiency are independent of D2 field
😊 jet intensity is stable over the run
😊 4 weeks of running OK!
😊 regeneration of the target every 3-4 days

**Polarimetry**

😊 online tuning of WFT at the ANKE TP with D2 being switched on
😊 measured asymmetry is stable over the run
😊 the magnetic stray field of the D2 magnet deflected the produced H\(^+\) ions!
😊 D2 stray field rotates the quantization axis! ⇒ LSP measures only the projection!
Target commissioning

Background determination

Target: N2 (from UGSS)

Target density $d_N = \frac{Z_H^2}{Z_N^2} d_H \approx \frac{1}{50} d_H \Rightarrow$ same beam “heating”

$dp \rightarrow dp \quad @ \quad T_d = 1.2 \text{ GeV}$
Target polarization in $dp \rightarrow (dp_{sp})\pi^0 \quad @ \quad T_d = 1.2 \text{ GeV}$

Target commissioning

$\theta_d = 5^0 - 15^0$

$\theta_d = 15^0 - 22^0$

$\theta_d = 22^0 - 28^0$

$\theta_d = 28^0 - 40^0$

$\theta_d = 155^0 - 165^0$

$\theta_d = 165^0 - 170^0$

$\theta_d = 170^0 - 177^0$

quasi-free

$np \rightarrow d\pi^0$

$\langle Q_y \rangle = 0.75 \pm 0.06$
Summary

First $dp$ experiment @ ANKE - Jan/Feb 2007

**Target performance**

- Cell-target thickness $\Rightarrow \sim 2 \times 10^{13} \text{ cm}^{-2}$
- Jet-target thickness $\Rightarrow \sim 1.5 \times 10^{11} \text{ cm}^{-2}$
- Average luminosity $\Rightarrow L \geq 10^{29} \text{ cm}^{-2}\text{s}^{-1}$
- Cell-target polarization $\Rightarrow |Q_y| = 0.75 \pm 0.06$

(determined by nuclear reaction $np \rightarrow d\pi^0$)

- It's certainly a success!...
- ... but
- A lot of work ahead!

![Graph showing the distribution of events with spin up and spin down with a peak at $M^{2}_{\pi^0} = (28^\circ - 40^\circ)$ and the reaction $np \rightarrow d\pi^0$.](image)
To do list

ABS

- Improvement of the oxygen feeding system to extend running time up to 7-8 days without regeneration
- Upgrade of the pumping system by exchange of recently used cryopumps with TP to reduce maintenance costs (?)
- Optimization for deuterium (*in progress...*)

LSP

- Rotatable Wien filter to compensate for the misalignment of the polarization axis
- Installation of improved magnetic shielding at LSP
Outlook

- Precision Spectroscopy of Hydrogen with ABS and Lamb-Shift Polarimeter
  - Measurements of the complete Breit-Rabi diagrams for $n=2$
    - Hyperfine splitting
    - Access to g-factors
    - Classical Lamb-shift
  - Measurements of the remaining polarization in molecules (*)
    - Studies of depolarization of atoms on Au-coated cell under various conditions (T, Bz, atomic beam intensity, HFS etc.)
    - Polarization measurement of molecular beam under various conditions (T, Bz, atomic beam intensity, HFS, cell coating material etc.)

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more details in talk by R. Engels (Wed., Sept. 9, 2009)