Status of the Polarized Ion Source at the Cooler Synchrotron COSY/Jülich

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Outline

• Introduction
• Status, performance and some details
  – Cesium ionizer and neutralizer
  – Extraction
  – Pulsed atomic beam source
  – RF transition units
• Polarimeter status
• Conclusion / Outlook - HGF ARD program
Introduction: COSY

Cooler and storage ring for (polarized) protons and deuterons

\[ p = 0.3 \text{ – } 3.7 \text{ GeV/c} \]

Phase space cooled internal & extracted beams

(*) The 2 MeV e-cooler will be installed in 2013
... and superconducting snake: 1m, 5 T, full ramp in 30 s
Introduction: COSY’s Injector

AEG design
Request for quote: 1961
First internal beam: 1968
Upgrade for COSY: 1990
Pole diameter 3.3 m / 700 t iron
$<B>_{\text{max}} = 1.35 \text{ T}$ $B_{\text{hill}} = 1.97 \text{ T}$
20 – 30 MHz ($h=3$)
22.5-45 MeV/A
2-4.5 keV/A injection
3 ion sources (2 multicusp + pol. CBS)

For COSY: routinely 45 MeV H\textsuperscript{-} and 75 MeV D\textsuperscript{-}

AEG cyclotron
Status: COSY and Cyclotron Operation

Availability (Up time) of the injector cyclotron
Delivered beam species
Ion Sources at the Injector Cyclotron

- Injection energy: 4.5 +/- 0.02 keV/u
- Acceptance: 150 µm rad
- Transmission: <0.1

Diagram showing the layout of the ion sources and the injector cyclotron, including:
- Wien filter
- Lamb shift polarimeter
- AEA Source
- IBA Source
- QBL
- Pulsed chopper
- Bunchers
- Cyclotron JULIC
- RF
- North DEE

Scale: 5 m
COSY’s Polarized Ion Source

Charge exchange reaction

\[ \overline{H}^0(\overline{D}^0) + Cs^0 \rightarrow \overline{H}^-(\overline{D}^-) + Cs^+ \]

Ref.: Haeberli, NIM 62 (1968)
Ion Source Performance

- With 6 pmA Cs @ 50 kV
- Gradient voltage -> energy spread

- High polarization is preferred
- Magnetic field -> emittance growth
Performance (Reference values)

Beam current at the source exit*  
*compare to routine COSY fill of a few $10^{10}$ protons or deuterons  
(space charge limit of about $10^{11}$)

Polarization inside COSY

$P_{\text{avg}} = (91.4 \pm 2.2)\%$
Keeping Performance

- Identify and replace weak components
- Get spares (build or inherit (EDDA ABT))
  - Dissociators (> 4 + prototypes)
  - Transition units (9 + spare cavities)
  - Cs ionizers(3 + 6 ovens + N W-ionizer)
  - Neutralizers (3 cells, > 6 flapper units, ...)
  - ...
- Improve diagnostics (Polarimeter,...)
- Provide test facilities
Cs Ionizer development

DC version (x2) with
- Reservoir under vacuum
- Short transfer line
- Improved positioning
- FZJ made tungsten ionizer
- Electron beam heating

Pulsed mode (x3) with separation of heater and reservoir

1 of 3 Cs ionizers, and within the external test facility
Examples for Cs\(^+\) pulses
FZJ made Tungsten Ionizer

Similar to dispenser cathode for electron guns, but with:
• Electron beam welded permeable tungsten molybdenum (TZM) connection
• Capability to withstand heating to over 1100°C (e.g. for conditioning)
• Optional special shaping of the emitter surface by spark erosion
• Quality control and assurance of all production steps

Experienced Issues, with consequences for reproducibility and performance:
Porosity variation, contamination, surface quality, cracks, welding quality....

• > 100 samples tested
• Potential to improve
Successful Cleaning with IR Laser

Application samples:
Tungsten, Mo, Ti, Steel ...
Speed: up to several cm²/s
Neutralizer

- Improved geometry
- Modular design with exchangeable flapper unit
- Cs reservoir: 45 - 60 g
- Exchange interval: > 2 years (> 5000 hours beam)
- Neutralization > 90%

Vapor cell (32° C) (water, double wall)
Magnetic flapper valve
Shielded Cs oven (278° C)
Replacement of Deflectors

- New chamber with
  - E-deflector for Cs⁺
  - Water cooled EM-PM-Hybrid for H⁻/D⁻
- Improved cooling (to trap Cs)
Pulsed ABS development

- New design for pulsed operation
- Improved performance:
  - doubles density for free atomic beam
  - better beam cooling
  - higher gas flux
  - up to 3 kW RF power

Next: New fast inline injection valves (CNG, 0.# ms)
RF Transitions

For Protons:
\( \lambda/2 \approx 1.43 \) GHz
Q: 800 - 1200

For Deuterons:
tuneable!
\( \lambda/4 \approx 0.3 \) – 0.45 GHz
Q: 800 - 1100
Testbench for Atomic beams

Used for offline tests of transition units

Equipment for neutral beams:

- Quadrupole mass spectrometer,
- TOF spectrometer,
- Compression tubes,
- Diaphragms, Chopper, Scanner etc.

For:

- Intensity
- Density, profiles
- Velocity distribution

cw operation: $4 \times 10^{16}$ (initial CBS)
Pulsed: $7.5 \times 10^{16}$ (COSY operation)
Improved: $11 \times 10^{16}$ with spare PM hexapoles (EDDA)
Breit Rabi-Polarimeter

- RFT 3 @ 5.65 MHz (D)
- RFT 2 @ 328 MHz (D)

Cesium Ionizer
Quad. Triplet with Steerer
Scanner
Neutralizer
El. Lens
Steerer

Deflection Chamber
Charge Exchange
Extraction Elements
Transition Units
Dissociator

Polarized Atomic Beam Source

PM Hexapole

Wienfilter
Cup/Viewer

RFT 3 @ 5.65 MHz (H)

RFT 3 @ 5.65 MHz (D)

RFT 2 @ 328 MHz (D)

Magnetic field

Intensity

0.01xG
Lambdshift-Polarimeter

Possible polarization losses

- Alignment
- Double stripping of H⁻/D⁻
- Neutralization of p/d
- Spin filter
Lambshift-Polarimeter

Operational, but deviations from the 45 MeV polarimeter results.
45 MeV Polarimeters
45 MeV Polarimeter

- pC elastic
- NaI scintillator @ 52.5° (Lab)
- Amplifier & TSCA for MHz Counter
- Pulse height analysis

Several Carbon targets (C, CH₂)

Chromox viewer
Monitoring Beam Asymmetries

11 days of deuteron beam

Solenoid reversal
Transition unit retuned
45 MeV-Polarimeter (New)

- 12 Plastic scintillators (NE110)
  - More statistics
  - Similar resolution
  - Now C and CH2 targets
  - With CH2 kinematic dp coincidences
  - allow fast electronics / 100 MHz
  - Cross calibration with NaI and C Target

Pol. H⁻ on C target

Pol. D⁻ on CH₂ target
Outlook

R&D for Hadron Storage Rings

Topics (with FZJ as leading lab)

• (polarized) Ion sources for hadron storage rings
  • Assure high intensity beams for COSY
  • Enable experiments at FAIR with polarized beams
• Combined electrostatic and magnetic deflectors
  • Search for an electric dipole moment in p, d and He3
• High energy beam cooling and broad band stochastic cooling
  • Electron cooling up to COSY’s maximum momentum
  • Electron cooling for HESR
  • Fast stochastic cooling at different energies
Thank you for your attention