INJECTOR FOR POLARIZED ELECTRONS AT THE S-DALINAC

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Outline

- Introduction of the S-DALINAC
- Need for Polarized Electrons: Polarized Experiments
- Characteristics of the polarized electron source
- Implementation at the S-DALINAC
S-DALINAC

Experiment sites:

1. Injector: Photon scattering
2. NEPTUN: Tagged Photon scattering
3. QClam spectrometer
4. High-resolution spectrometer

1. Thermionic Gun: 250 keV
2. Injector Linac: 10 MeV
3. Main Linac: 130 MeV (after 3 passes)
Design values:

- Max. energy: 85 MeV
- Energy spread: $\pm 10^{-4}$
- Max. beam current: 60 $\mu$A
- Duty cycle: 3 GHz cw
Planned Experiments

• Low-q (< 1 fm⁻¹) experiments with polarized beams
  → Completely unexplored field

Polarized electron and photon scattering

• Parity-violation effects
  → Polarized bremsstrahlung

• Measurement of additional structure functions
  → Polarized electron scattering
Polarized Source: Requirements

- Polarization: \( \approx 80\% \)
- Average current: \( > 60 \mu A \)
- Repetition frequency: \( 3 \text{ GHz } \text{cw} \)
- Long lifetime
- Good availability, robustness of operation
- Compact form: 
  \( \rightarrow \) max. height including safety distance 2.3 m

\( \rightarrow \) Polarized source with GaAs cathode
Test Stand

Mai 2007 – Februar 2010 in operation:

- Bulk und Strained/Superlattice-GaAs-Photocathods
- 830 und 780 nm Diode laser
- Vacuum: ≤ 10^{-11} mbar
- Kathode lifetime: 430 h
- 50 μA beam current
- Time structure: 3 GHz
Polarimetry

100 keV Mott Polarimeter:

- \( P_{\perp} = \frac{A}{S(\theta)} \)

- Elimination of the instrumental asymmetry by helicity switching

- Foil thickness extrapolation – self supported gold foils 40 - 500 nm
Spin dynamics

Angle between spin and electron momentum

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<th>Experimentierplatz</th>
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Spin manipulation

Wien filter:

- Spin manipulation for Mott Polarimetry and future experiments
- Crossed electric and magnetic fields
- Spin rotation without beam deflection
Test Stand: Summary

Experiments at test stand:

December 2008 and August/Oktobe 2009:
measurement of bremsstrahlung polarization correlations

Polarized Injector at S-DALINAC

Experimental Area

10 MeV Injector

40 MeV Linac

1st Recirculation

2nd Recirculation

100 keV Polarized Electron Gun

250 keV Thermionic Electron Gun

To Experimental Hall

Optical Transfer From Laser Lab
Polarized Injector at S-DALINAC

Same transport for 100 keV polarized and 250 keV unpolarized beams

2 options: Pulsed laser beam from Ti:Sa laser system
Cw laser beam from diode laser system
Laser Beam Transfer Line

Distance between polarized source and laser lab ca. 40 m
Diode laser → Fiber optic cable
TiSa → Transfer system in vacuum (10 mirrors)
Talk M. Wagner
Polarized electron source

- Bulk- and Superlattice-GaAs-Photocathoden
- Titan Sapphire Laser with 380 fs Pulses and 75 MHz Repetition rate and Diode laser
- Load-Lock system for quick cathode exchange
- Total Height 1.8 m
- NEG-coating of beamline
- Additional NEG-Pump in cathode chamber
- Vacuum lifetime: ca. 1000 h
First Performance

- 5 ps electron pulse for acceleration at S-DALINAC necessary
  
  Limited cathode lifetime: < 5 ps direct from photo cathode
  → pulsed laser beam: 400 fs laser pulse ~ 4 ps electron pulse

- Charge lifetime (54 ± 2) C at 7 μA

- Stable operation with diode laser

- Intensity and position controlling of Ti-Sa laser system required

- Preacceleration of 100 keV beam for superconducting structures of S-DALINAC with 2-cell capture cavity: RF-power limit
Polarimeters

Source

i Source of Polarized Electrons

ii Laser Systems

Polarimeters

A 100 keV Mott Polarimeter

B 10 MeV Mott Polarimeter

C Möller Polarimeter

D Compton Transmission Polarimeter

E Experiments with polarized electrons/photons
Outlook

- Installation at S-DALINAC: January – September 2010
- Vacuum lifetime: 1000 h
- Charge lifetime: 54 C
- Installation & commissioning of polarimeters for experiments
  - 5-10 MeV Mott polarimeter: September 2011
- Test of 2-cell accelerating structure
Collaboration

Institut für Kernphysik, TU Darmstadt


Institut für Theorie Elektromagnetischer Felder, TU Darmstadt

W. Ackermann, W. F. O. Müller, T. Weiland

Institut für Kernphysik, Universität Mainz

K. Aulenbacher
Polarized Bremsstrahlung

Theory: H.K. Tseng and R.H. Pratt, Phys. Rev. 7 (1973) 1502
Exp.: No exp. results for long. pol. Electrons
Collaboration: KTH Stockholm, GSI, Universität Heidelberg

J.W. Motz and R.C. Placius, Nuovo Cimento 15 (1960) 571
Spin Manipulation and Polarimetry

- Electron gun
- Prebuncher
- Chopper
- Wien filter
- 100 keV Mott polarimeter
- Detector holder
- Target wheel
- Differential pumping stage
- Beam
- Laser system
- Magnet
- 1 m
Quantum Efficiency and Polarisation

![Graph showing quantum efficiency and polarisation versus wavelength (nm)]
Photofission Experiments

Role of weak interaction in nuclei

Bremstarget

$\overrightarrow{e}^{-}$

$\gamma$

$\theta$

$\gamma$

$\theta$

$\geq 75\%$

$^{238}\text{U Target}$

Bremsstrahlungspectrum

$P_{\gamma} \geq 75\%$

$N_{\gamma}$

$E_{\gamma}$

Unpolarized test experiment

Sensitivity $A \approx 10^{-3}$

Expected $A \approx 10^{-4}$

$\rightarrow$ Active Target
(e,e ′ x) Experiments

\[
\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega}\bigg|_{\text{Mott}} (v_L W_L + v_T W_T + v_{LT} W_{LT} + v_{TT} W_{TT} + v_{LT'} W_{LT'} + v_{T'} W_{T'})
\]

- **Inclusive electron scattering**
  - two structure functions: longitudinal/transversal

- **Exclusive electron scattering**
  - interference terms: L, T, LT, TT

- **Polarized electron scattering**
  - parity violation, final state interaction

- **Polarized electrons and polarized targets**
  - polarization transfer
"Fifth Structure Function"

- Only two data sets:
  \( D(e,e'p) \)
  \(^{12}\text{C}(e,e'p)\)
- S-DALINAC
  Low momentum transfer

\[ f_{pT}^L \quad (\text{fm}) \]

\[ \begin{align*}
\theta_{\text{lab}} \quad (\text{deg}) & \\
0 & 10 & 20 & 30 & 40 \\
-0.06 & -0.04 & -0.02 & 0.00 & \end{align*} \]

S. Dolfini et al., PRC 60 (1999) 064622
3He Break-Up Reaction

Three-Body-Force investigation

No data at low momentum transfer

Calculations by J. Golak, Crakow

Estimated statistical uncertainty after two weeks of beam time

\( \frac{d^3\sigma}{dE d\Omega_p d\Omega_e} \) [nb/(MeV sr^2)]

\( ^3\text{He}(e,e'p)d \)

\( E_e = 60 \text{ MeV} \)

\( E_x = 10 \text{ MeV} \)