Polarized Neutron Production and Measurements of $\Delta\sigma_L$ for $E_n = 11$-35 MeV

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Outline

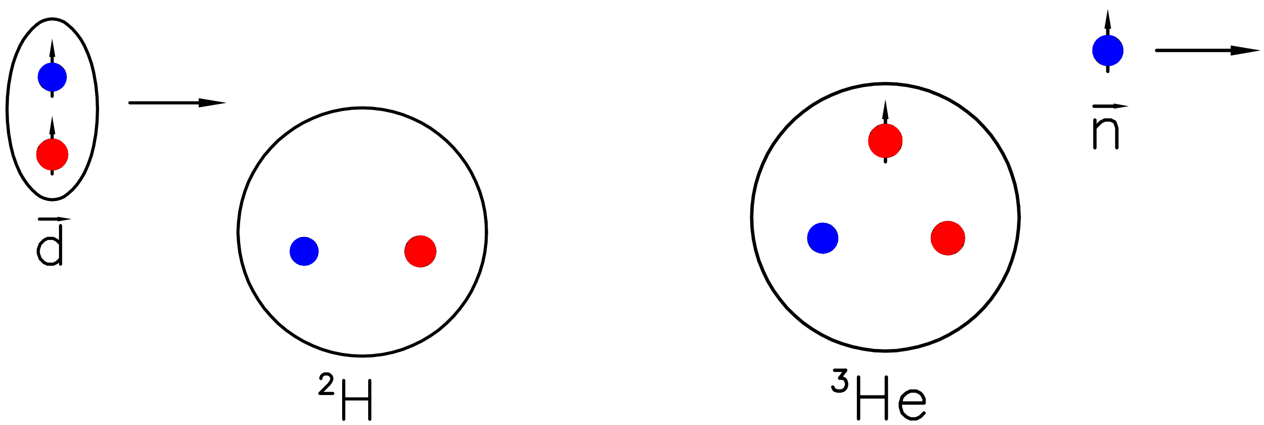
- Polarized neutron production
- Measurement of polarization transfer
- ϵ_1 and $\Delta\sigma_L$
- Polarized proton target
- Summary

Polarized Neutron Production

Beams of polarized monoenergetic neutrons

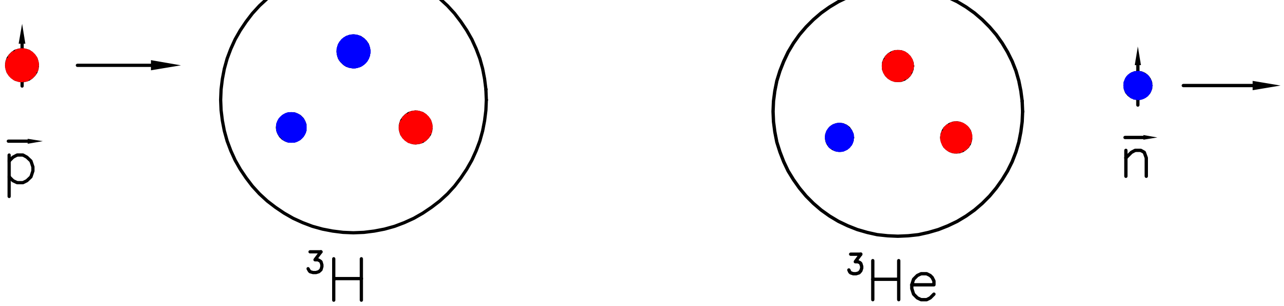
Common Reactions:

$$^2H(\vec{d},\vec{n})^3He$$



Incoming Outgoing

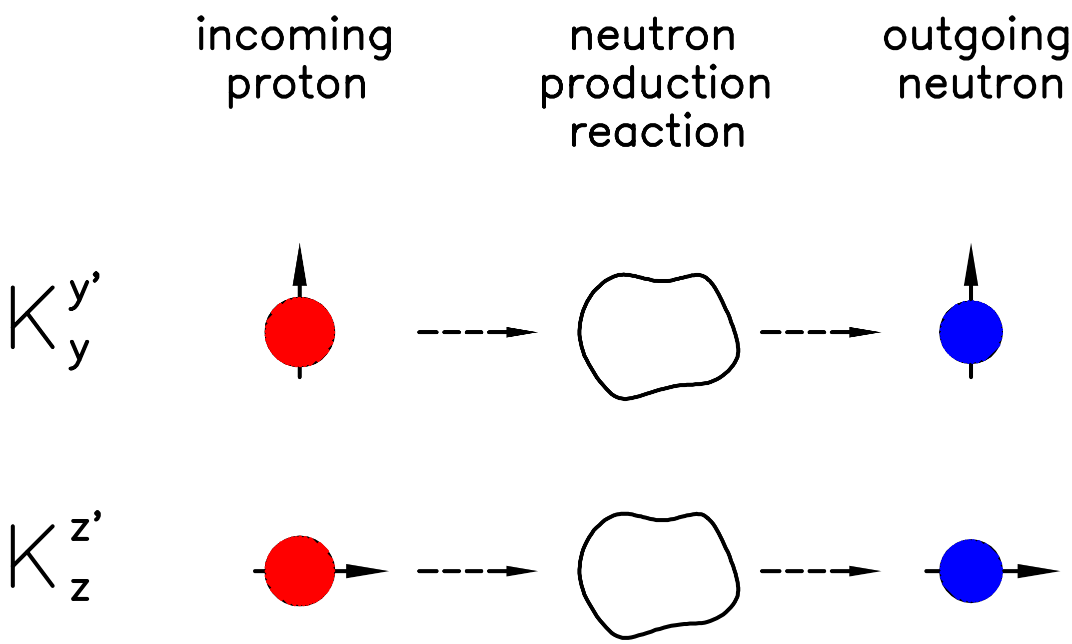
$$^3H(\vec{p},\vec{n})^3He$$



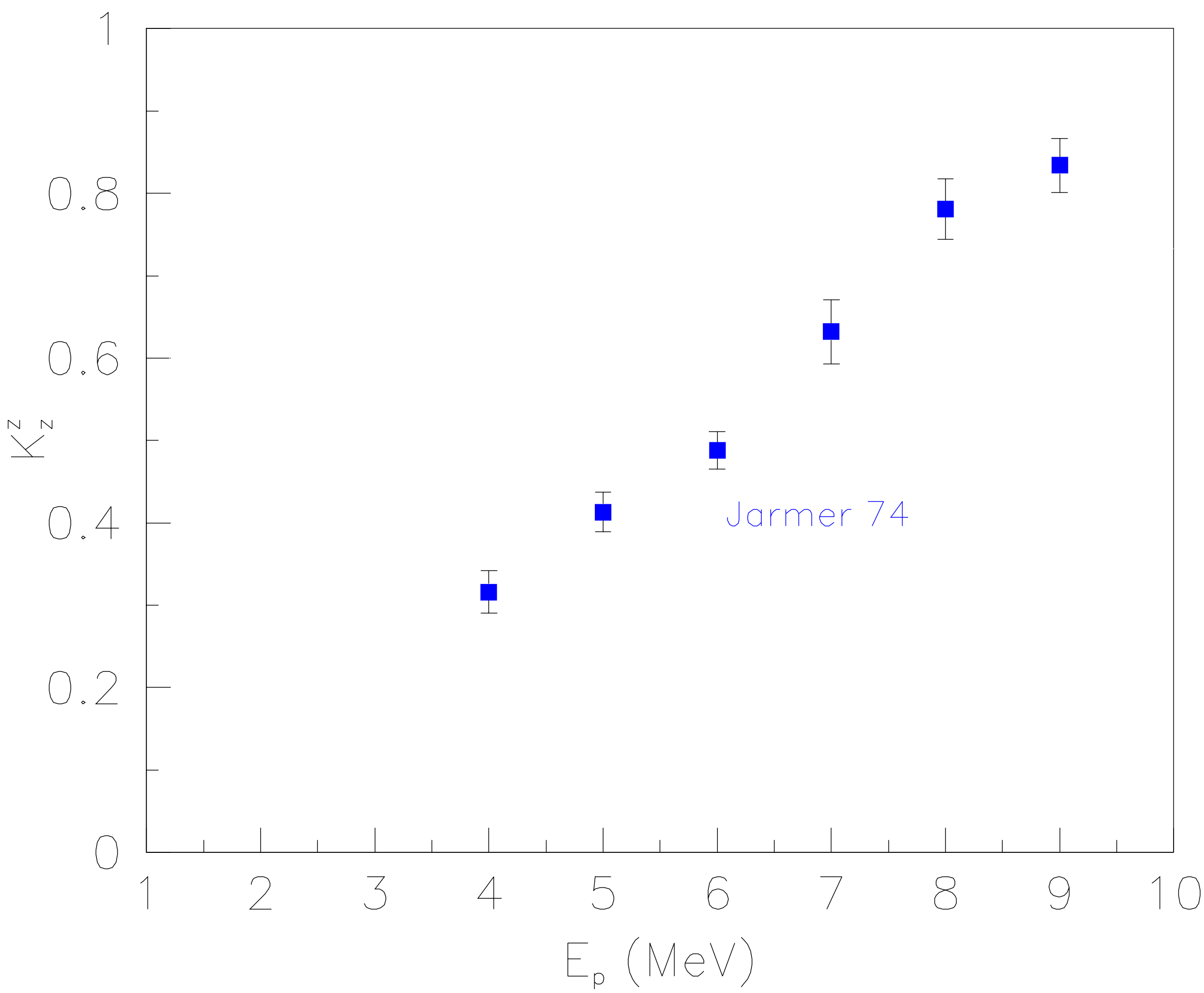
How much of the polarization is transferred from charged particles to neutrons?

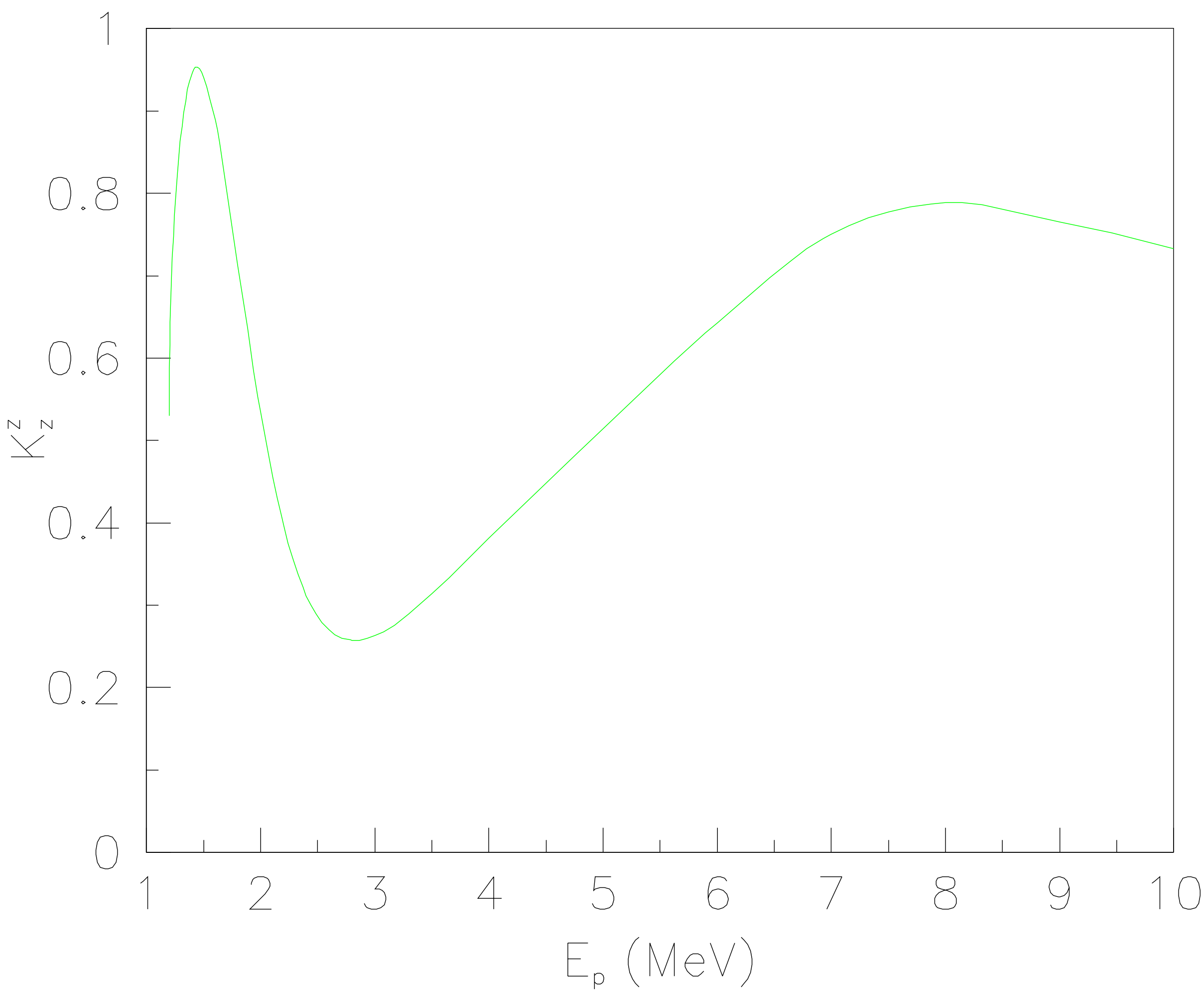
For T($\vec{p}, \vec{n}$): (Q-value of -0.764 MeV)

$$P_{n_{j'}} = K_i^{j'} P_{p_i} \qquad i, j = x, y, z$$

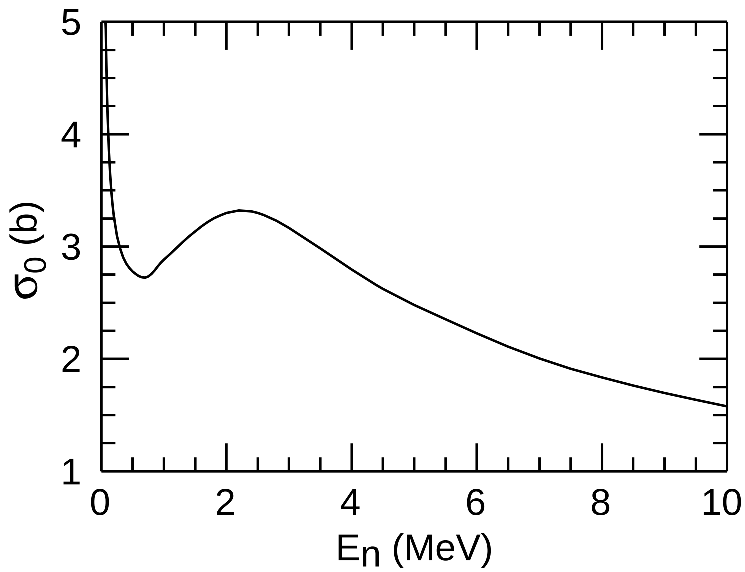


K_z^z for $T(\vec{p},\vec{n})$ reaction

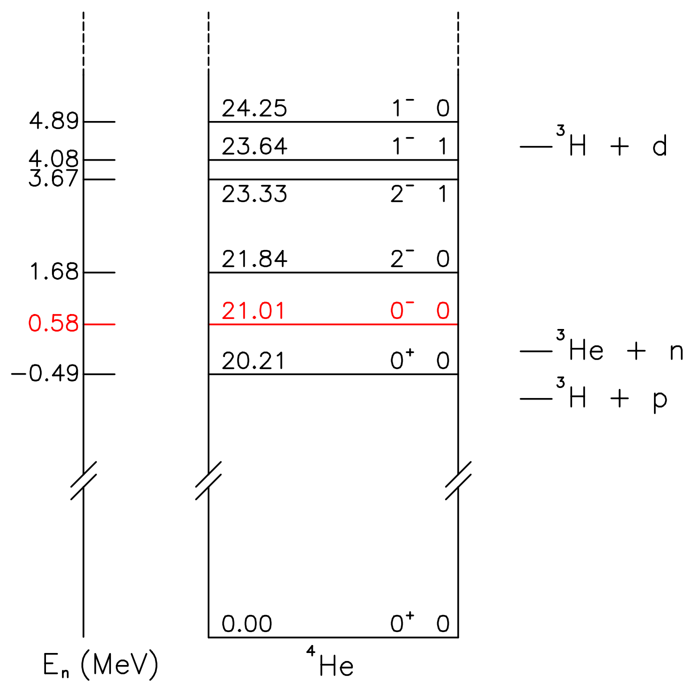




1
0.8
0.6
0.4
0.2
0
K_z^z
1
2
3
4
5
6
7
8
9
10
E_p (MeV)



n-^{3}He total cross section.

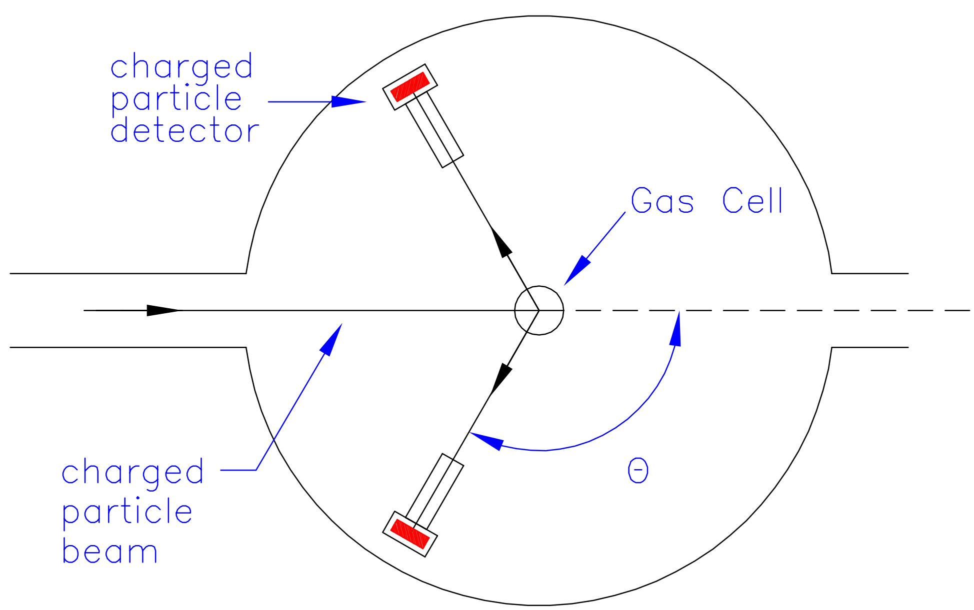


^{4}He level diagram.

Measurement of K_z^z

Proton Polarization Measurement:

- Lamb-shift spin filter polarimeter on source
- Proton elastic scattering polarimeter



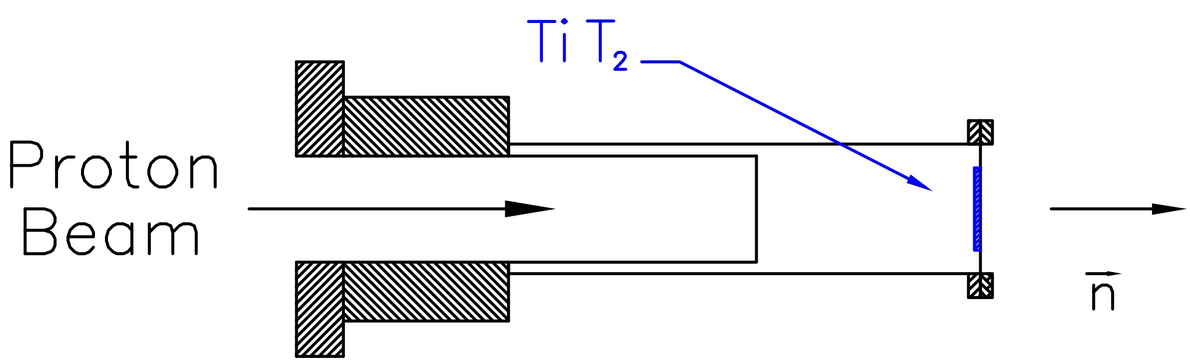
Gas cell filled with ^{4}He for $\vec{p}$'s and ^{3}He for $\vec{d}$'s.

Neutron Production

Polarized proton beam from ion source

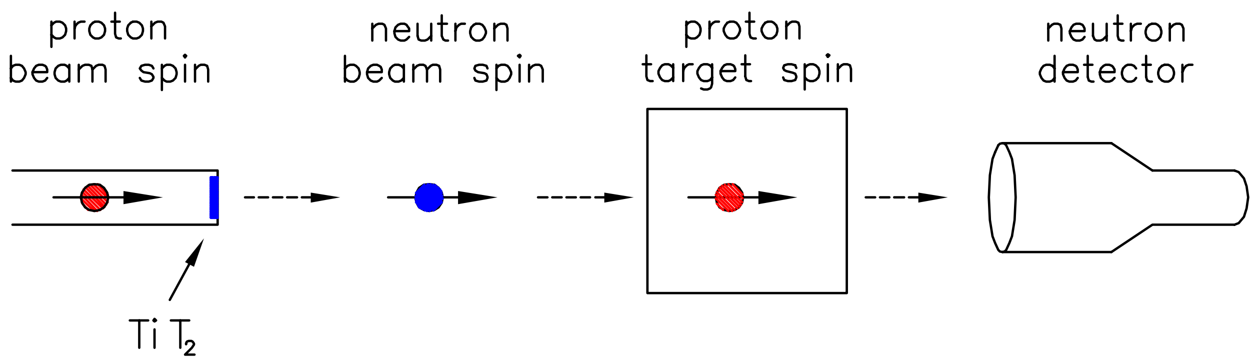
Beam accelerated in Van de Graff

Neutron production reaction with tritiated titanium located on beamstop



Neutron Polarimeter

Neutron polarimeter - Polarized proton target



$$P_n = \frac{2\epsilon}{P_t x \ \Delta\sigma_L}$$

$\Delta\sigma_L \rightarrow 2-5$ b where $\Delta\sigma_L = \sigma(\rightleftarrows) - \sigma(\leftleftarrows)$

$\epsilon \rightarrow$ measured neutron asymmetry

$P_t x$ = target polarization times thickness

Neutron Asymmetry Measurement

Neutron flux asymmetry $= \frac{N_{+} - N_{-}}{N_{+} + N_{-}}$

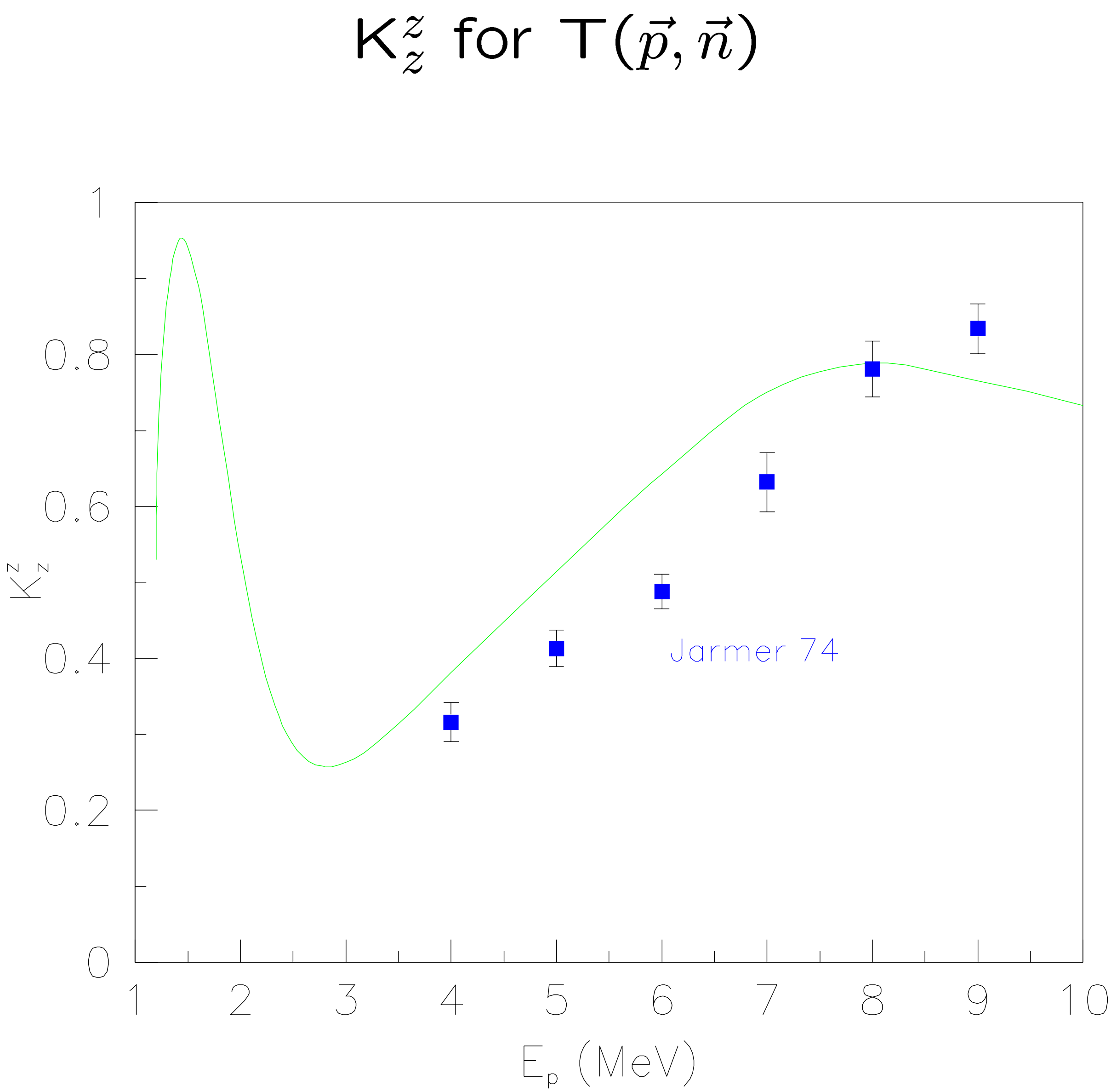
Nominal values at E_n = 500keV:

- $P_t x \approx 0.04$ b^{-1}
- $\Delta\sigma_L \approx 5$ b
- From K_z^z plot $P_n \approx 0.5$

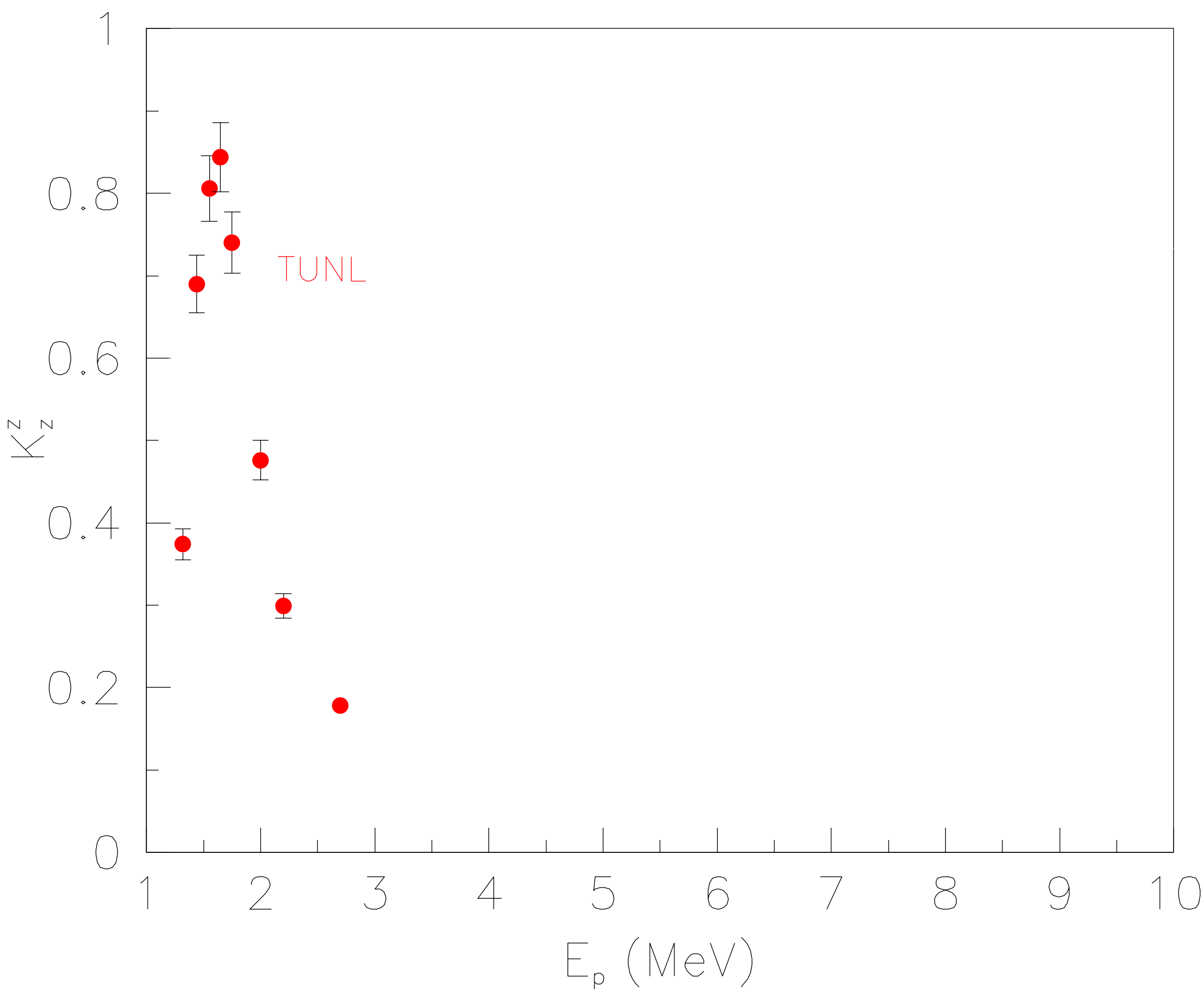
We expect a neutron asymmetry $\epsilon \approx 0.05$

With count rate of 1 kHz, each energy to 1% in $\approx$ 70 minutes.

Measurement is well within our means and quick enough for several energies.



K^z_z for $T(\vec{p},\vec{n})$
K^z_z
E_p (MeV)
Jarmer 74
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10



TUNL
K_z^z
E_p (MeV)
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10

Polarized Proton Target

- Propandiol doped with EHBA-CrIV
- ^{3}He evaporation refrigerator ($\sim$500 mK)
- 2.5 Tesla magnetic field
- Dynamic nuclear polarization with microwaves
- Continuously measure polarization with NMR

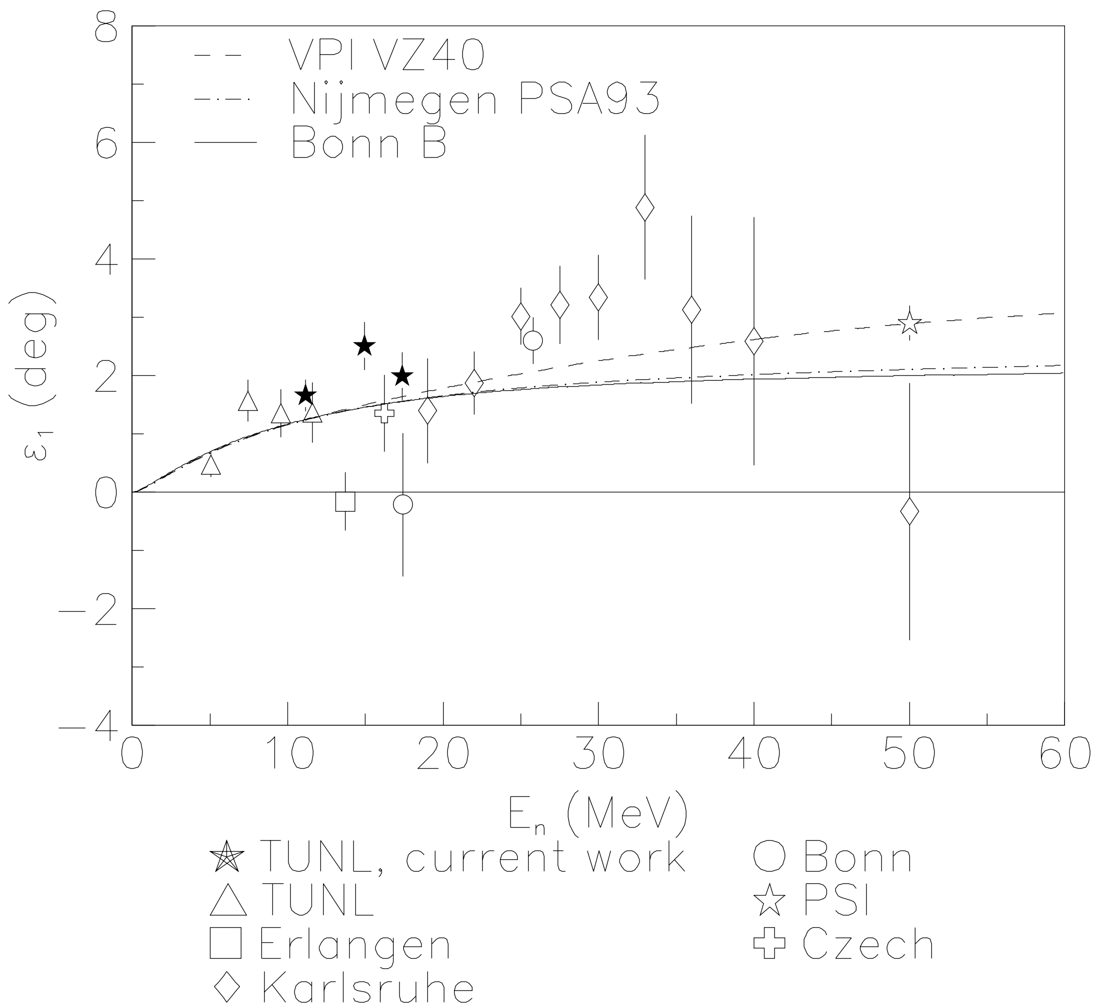
Polarization calibrated at thermal equilibrium

at 1 K TE polarization is 1/4%

at 1/2 K TE polarization is 1/2%

The phase shift parameter ϵ_1 characterizes the tensor force

The tensor force causes $^3S_1$ and $^3D_1$ mixing.



Low energy (1-20 MeV) $n-p$ scattering can be described by three phase shifts: $\delta(^1S_0)$, $\delta(^3S_1)$, and the mixing angle ϵ_1.

$\delta(^1S_0)$, $\delta(^3S_1)$, and ϵ_1 can be determined from the observables σ_{tot}, $\Delta\sigma_T$, and $\Delta\sigma_L$.

$$\Delta\sigma_T = \sigma(\uparrow\downarrow) - \sigma(\uparrow\uparrow)$$

$$\Delta\sigma_L = \sigma(\rightleftarrows) - \sigma(\leftleftarrows)$$

$$\sigma_{tot} \simeq \frac{\pi}{2k^2}\{\sin^2[\delta(^1S_0)] + 3\sin^2[\delta(^3S_1)]\}$$

$$\Delta\sigma_T \simeq \frac{2\pi}{k^2}\{\sin^2[\delta(^1S_0)] - \cos[2\epsilon_1]\sin^2[\delta(^3S_1)] - \sqrt{2}\sin[2\epsilon_1]\sin[\delta(^3S_1)]\}$$

$$\Delta\sigma_L \simeq \frac{2\pi}{k^2}\{\sin^2[\delta(^1S_0)] - \cos[2\epsilon_1]\sin^2[\delta(^3S_1)] + 2\sqrt{2}\sin[2\epsilon_1]\sin[\delta(^3S_1)]\}$$

Measuring $\Delta\sigma_{T,L}$ requires a polarized beam and polarized target.

$$\Delta\sigma_T = \frac{2\,\epsilon_T}{P_n P_t x} \qquad\qquad \Delta\sigma_L = \frac{2\,\epsilon_L}{P_n P_t x}$$

where

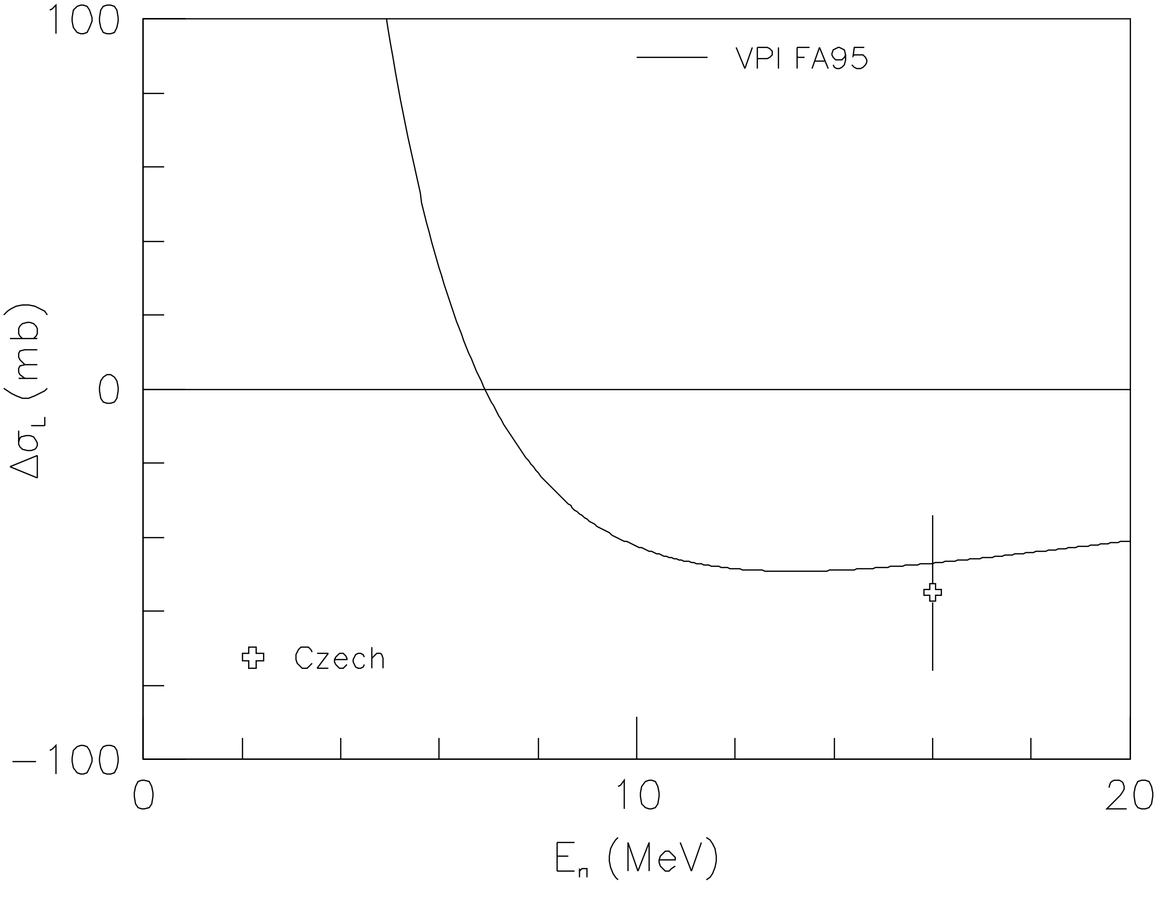
- P_n is the beam polarization.

- P_t is the target polarization.

- x is the target thickness.

- $\epsilon_{T,L}$ is the transmission asymmetry.

$$\epsilon = \frac{N_+ - N_-}{N_+ + N_-}$$



100
0
−100
0
10
20
$\Delta\sigma_L$ (mb)
E_n (MeV)
VPI FA95
Czech

Summary

- Measurement of K_z^z
- Description of ϵ_1 and $\Delta\sigma_L$
- Description of polarized proton target

Future Work

- $\Delta\sigma_L$ measurements E_n = 11-35 MeV
- Extract ϵ_1 from $\Delta\sigma_T$ and $\Delta\sigma_L$
- Investigate n-d interaction