

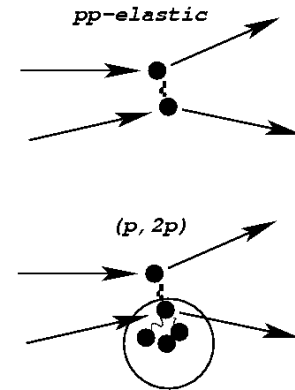
Study of hadron properties modification in
nuclear matter in (p,2p) reaction at PNPI

A.Kisselev

Workshop on QFS with Radioactive Ion beams
Trento, 11.04.2008

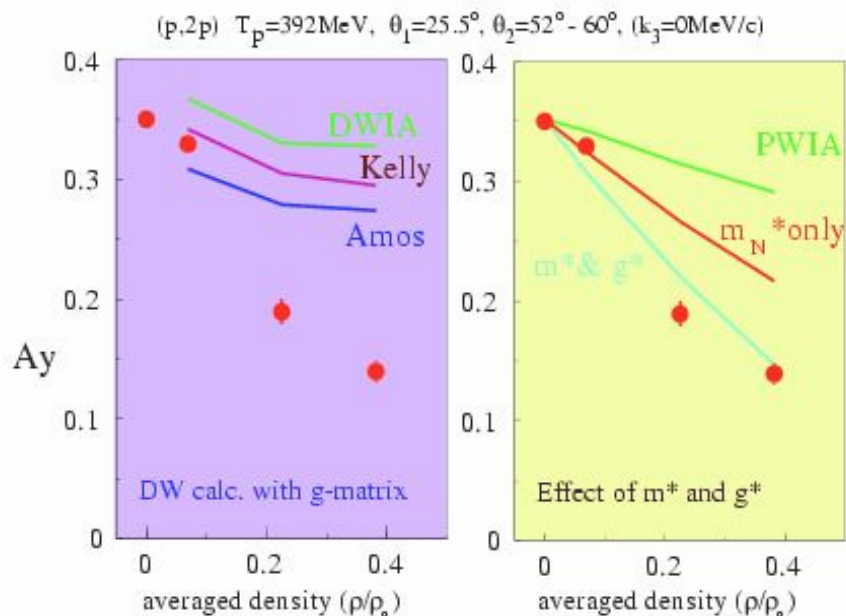
Layout of the talk

- (A short) introduction
- Experimental setup at PNPI
- Results
- Discussion and future plans



RCNP (p,2p) measurement at 392MeV

Medium Effect on A_y



- Clear reduction of asymmetry with density
- Can not be reproduced in non-relativistic framework
- Relativistic models do better
- A cross-check at higher beam energy needed

K.Hatanaka et al, PRL vol.78, no.6 (1997) 1014.

C.A.Miller et al, PRC vol.57, no.4 (1998) 1756.

The PNPI accelerator

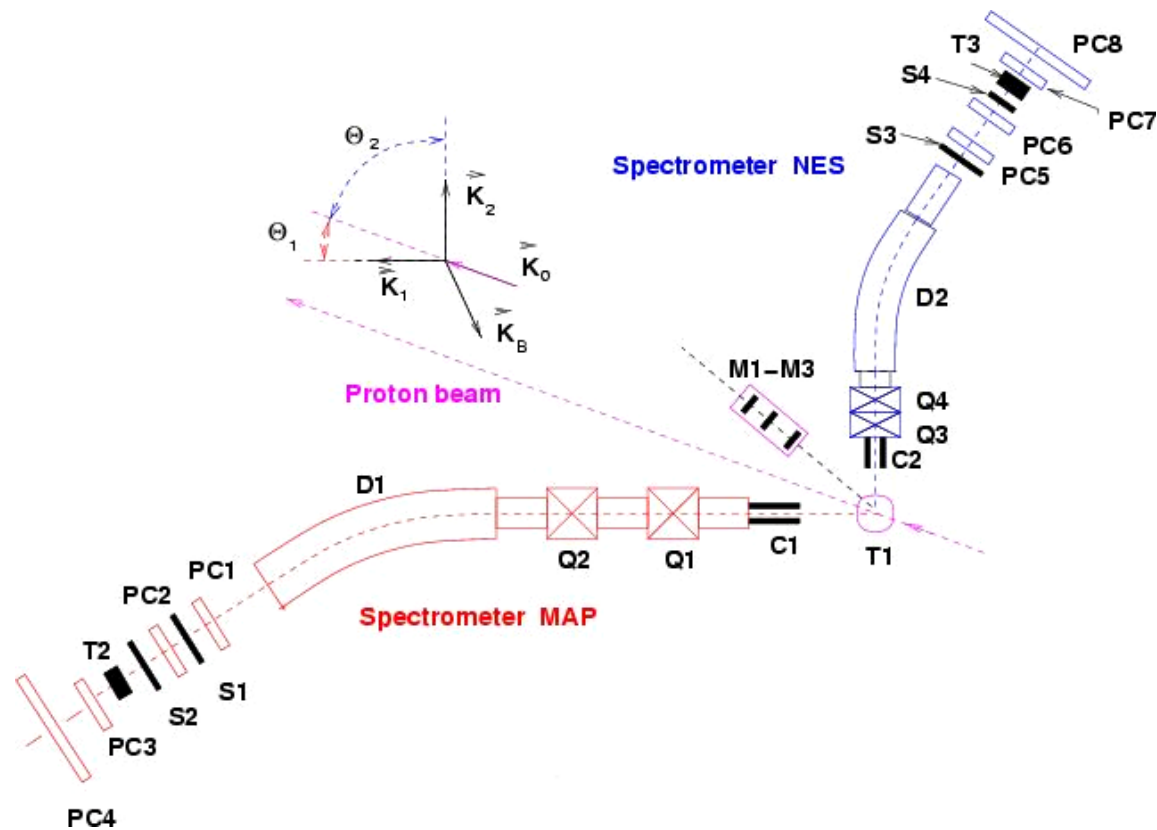
Proton energy	1.00 GeV
Current	$\sim 1\mu\text{A}$
Immediate energy spread	$\sim 300\text{KeV}$
Energy variation	$\sim 10\text{MeV}$
Spatial emittance	few mm
Angular emittance	< 0.15 degrees
Age	40 years
Polarization	0%

Requirements to the detector system

- (p,2p): spectrometer with 2 arms needed
- Few MeV overall separation energy resolution
- Non-vanishing acceptance
- Polarization measurement for emitted proton(s)



The detector system scheme



Advantages

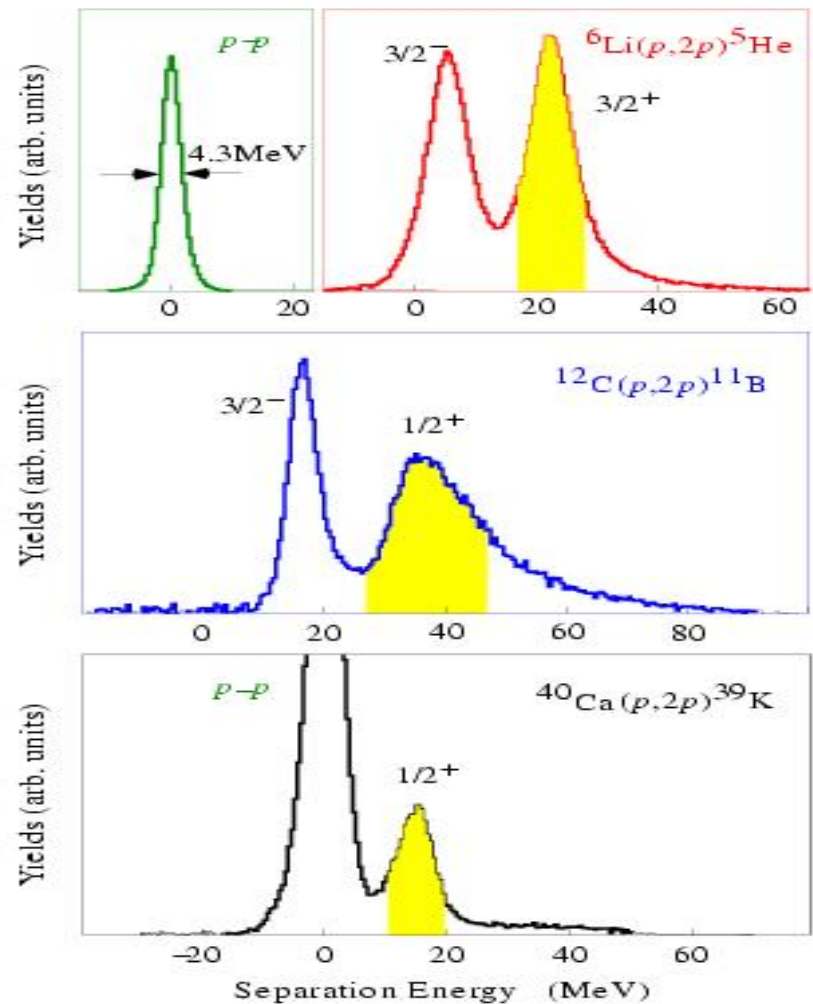
- All the ones given by (p,2p) reaction
- All the ones given by knock-out of S-shell protons at zero recoil momentum condition
- Exchange term in NN amplitudes suppressed
- Larger momentum transfer range available
- Polarization measurement for both outgoing protons

Spectrometers and polarimeters

	MAP	NES
Max momentum	1.7GeV/c	1.0GeV/c
Solid angle	4.0E-4 sr	3.0E-3 sr
Momentum acceptance	~8%	~8%
Angular range, degrees	13 ... 40	53 ... 64
Energy resolution (FWHM)	~1.5MeV	~2.0MeV
Polarimeter acceptance	3-18 degrees	5-16 degrees
Carbon analyzer thickness	155mm	70mm

Energy separation spectra

- Few MeV overall resolution
- Just sufficient to distinguish nuclear shells



Polarization measurement

- Secondary scattering on a carbon analyzer:

$$d\sigma(\vartheta, \varphi) = \sigma_0(\vartheta) \times (1 + P \cdot A(\vartheta) \cdot \cos(\varphi - \varphi^0)) \cdot d\Omega$$

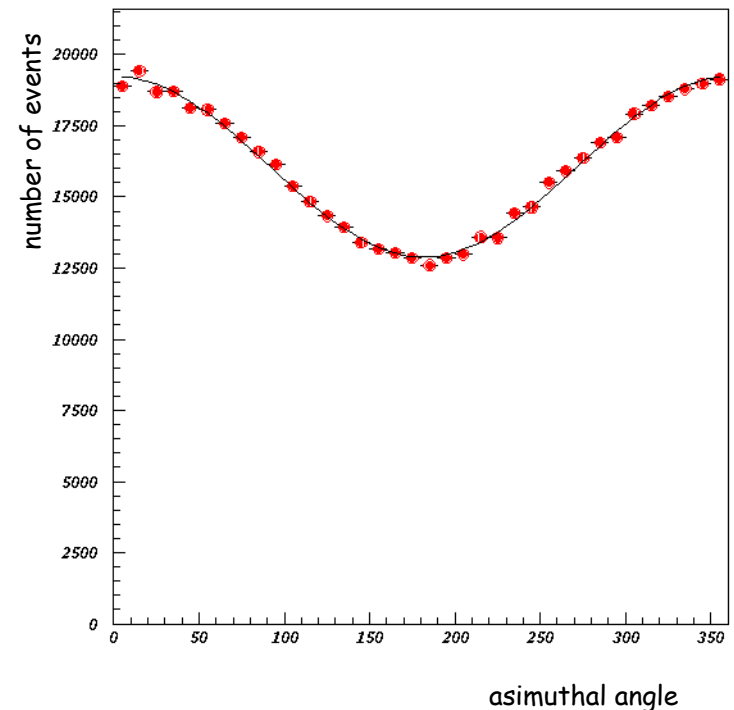
- Measurement "complexity" is $\sim \langle d\sigma_0(\vartheta)/d\vartheta \rangle / \langle A(\vartheta) \rangle$
- Polarimeter efficiency issues
- *pC*-scattering analyzing power

O.Fedorov, LNPI preprint #484 (1979).

M.McNaughton et al, NIM A241 (1985) 435.

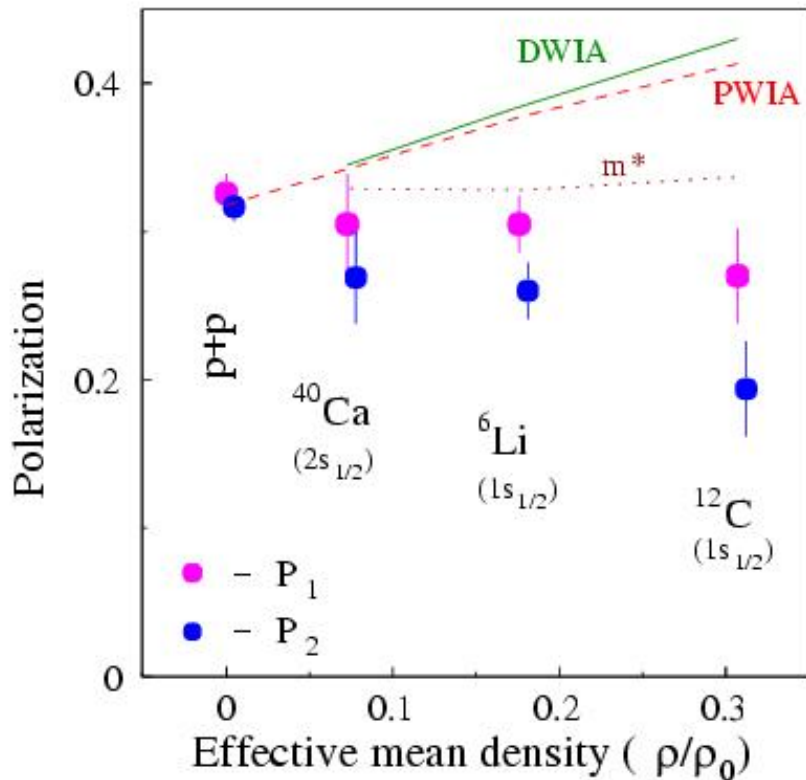
G.Waters et al, NIM 153 (1978) 401.

Recoil proton case



First series of measurements: results

recoil proton at ~ 53.2 degrees lab. system



$$\rho_0 = 0.16 \text{ fm}^{-3}$$

$$\bar{\rho} = \frac{\int_0^{\infty} \rho(r) D(r) dr}{\int_0^{\infty} D(r) dr},$$

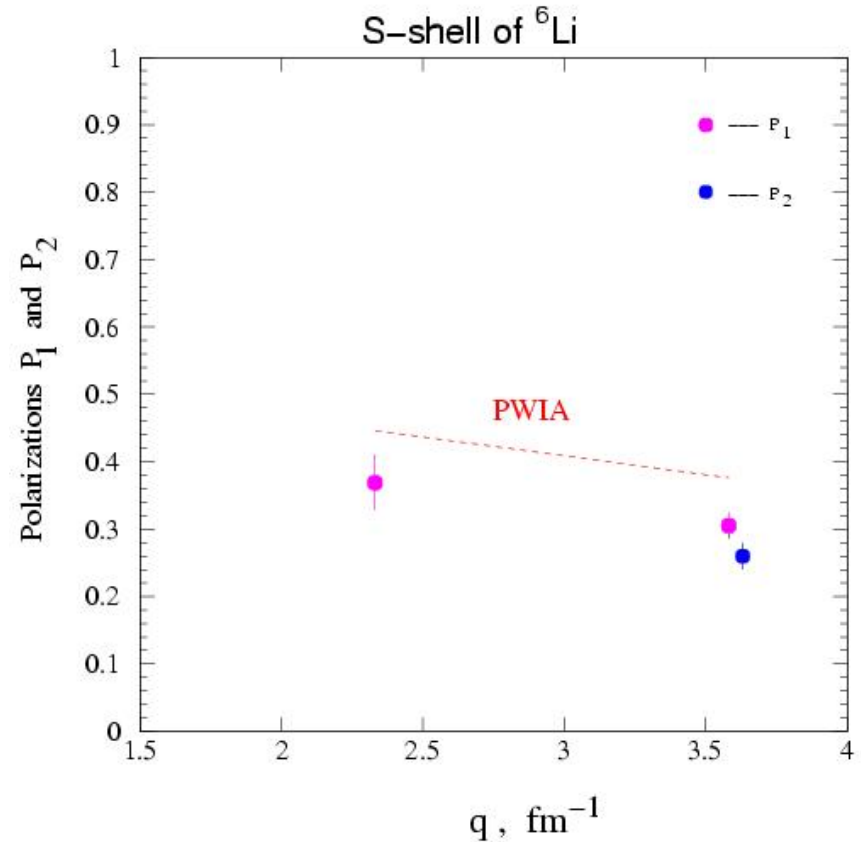
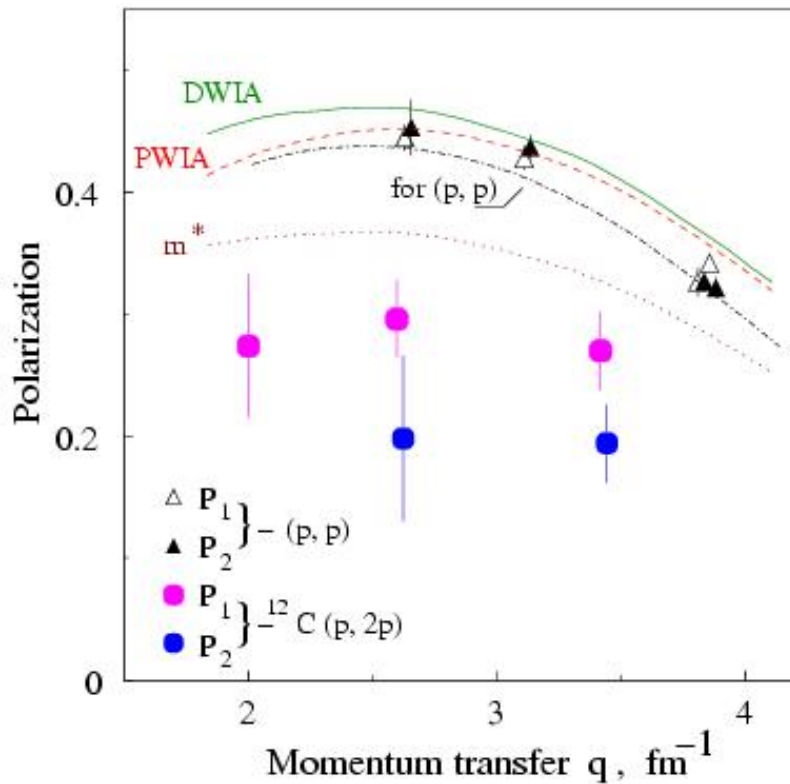
$$D(r) = \int \chi_1^*(\vec{r}) \chi_2^*(\vec{r}) \chi_0(\vec{r}) \phi(\vec{r}) r^2 d\Omega$$

K.Hatanaka et al, PRL 78 (1997) 1014.

V.A.Andreev et al, PRC 69 (2004) 024604.

Momentum transfer (in)dependence

recoil proton: [53.2 .. 63.9] degrees lab.system



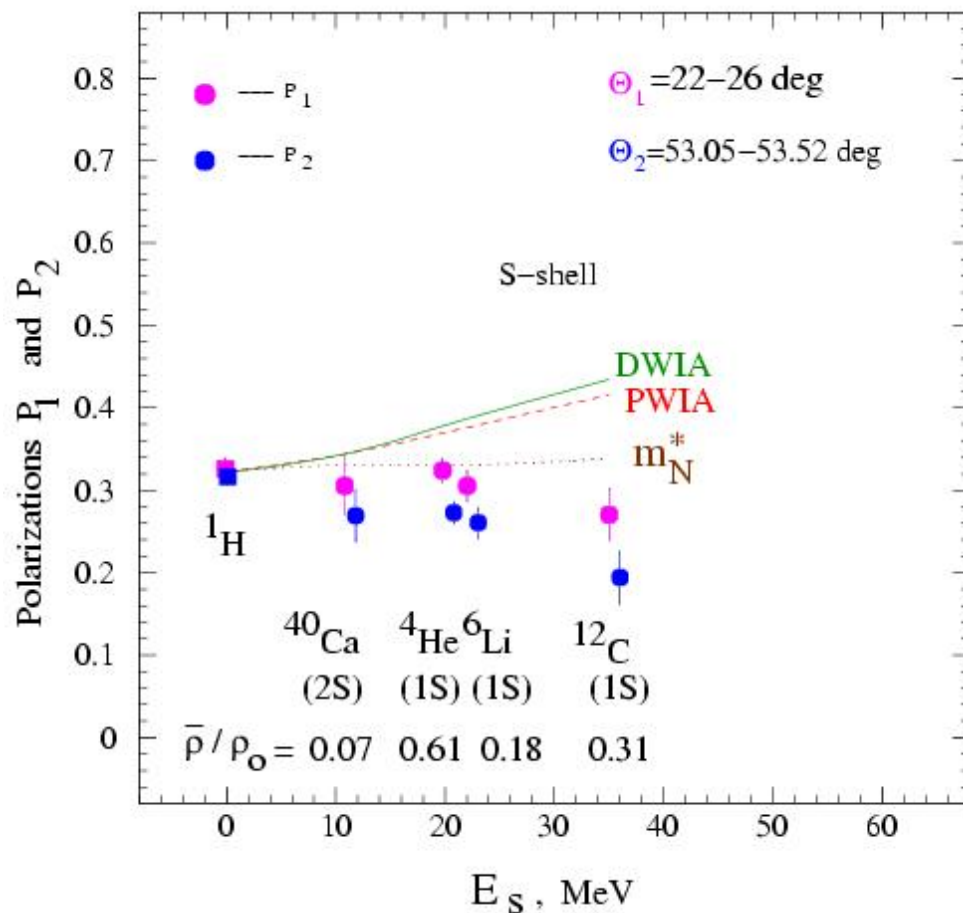
→ what could we do next?

Liquid helium target

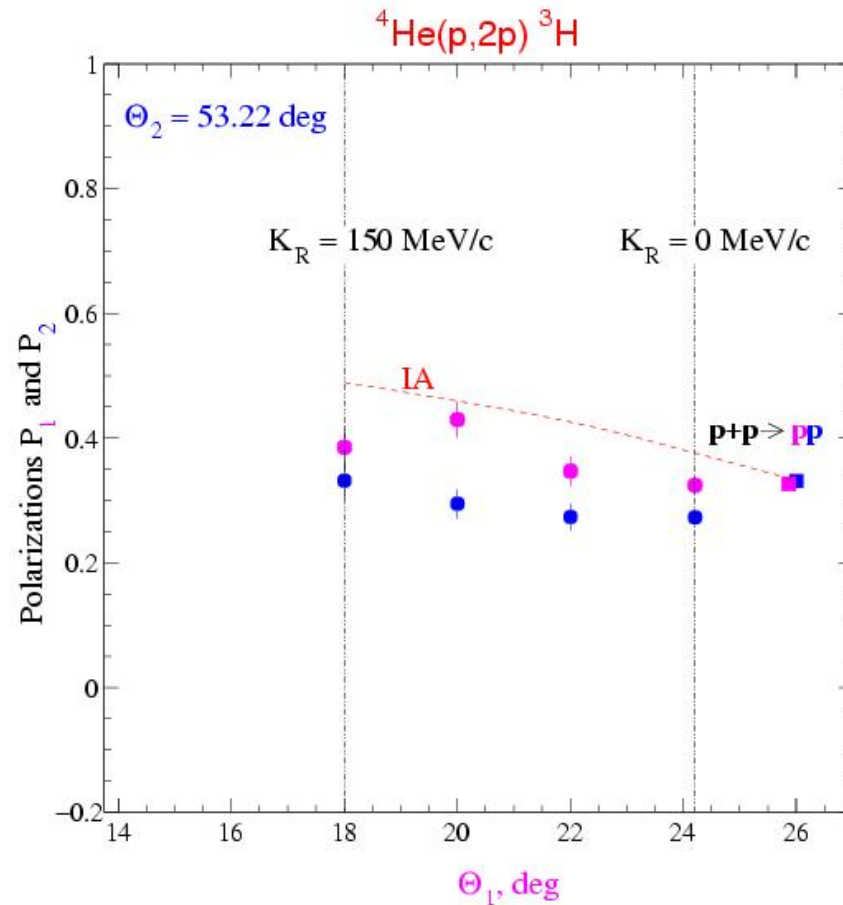


- Put into operation in 2004
- Modified to be used with liquid hydrogen in 2007

Combined result for all targets



Recoil momentum dependence



→ what could we do next?

Future plans

- Measure S-shells on other nuclei?
- Consider to use P-shells?
- Extend kinematical range?
- Measure different polarization observables?

Polarization correlation coefficient

- Secondary scattering of outgoing protons in coincidence

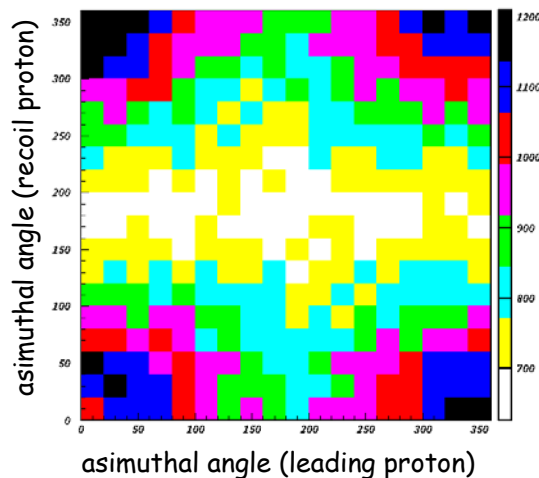
$d\sigma(\Omega_1, \Omega_2) = \sigma_0(\mathcal{G}_1, \mathcal{G}_2) \times (1 + \Pi_1 + \Pi_2 + \Sigma_{12}) d\Omega_1 d\Omega_2$, where

$$\Pi_1 = P_1 \cdot A(\mathcal{G}_1) \cdot \text{Cos}(\varphi_1 - \varphi_1^0),$$

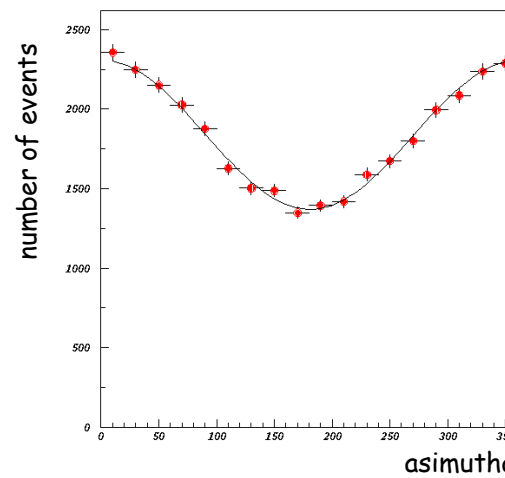
$$\Pi_2 = P_2 \cdot A(\mathcal{G}_2) \cdot \text{Cos}(\varphi_2 - \varphi_2^0),$$

$$\Sigma_{12} = A(\mathcal{G}_1) \cdot A(\mathcal{G}_2) \cdot \left[C_{mn} \cdot \text{Cos}(\varphi_1 - \varphi_1^0) \cdot \text{Cos}(\varphi_2 - \varphi_2^0) + C_{ss}' \cdot \text{Sin}(\varphi_1 - \varphi_1^0) \cdot \text{Sin}(\varphi_2 - \varphi_2^0) \right]$$

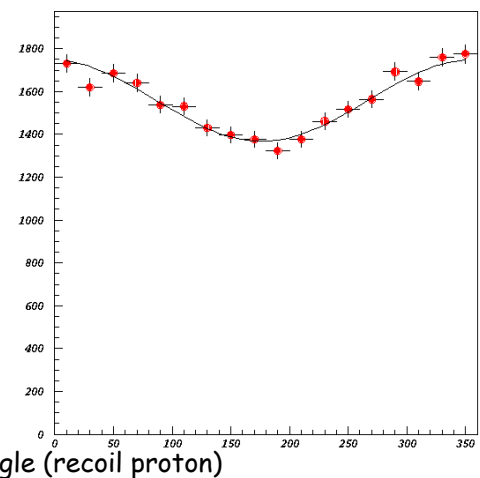
O.Fedorov, PNPI preprint #2432 (2001).



leading proton at 0 degrees



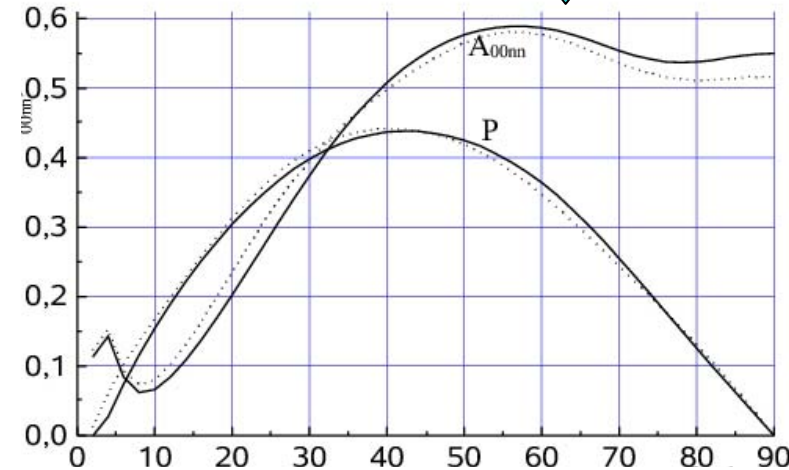
leading proton at 180 degrees



Results of Dec'2007 run for pp-elastic



	Data	PSA Arndt
P (leading proton)	34.40(0.20)%	~33%
P (recoil proton)	34.95(0.16)%	-"-
Cnn	65.5(2.8)%	~57%



O.Fedorov, to be published.

- Final error on Cnn in pp-elastic will be ~2%
- Will measure He in Dec'2008 with ~3% stat.error
- Need to increase detector efficiency!

Detector "efficiency" upgrade

- Improve multi-hit event selection
- Upgrade time-of-flight system
- Improve separation energy resolution
- New fast electronics was tested during the last run
- Liquid He target modification (hydrogen usage) in progress
- DAQ upgrade for higher counting rates in progress
- In general: prepare to work with higher intensity and thick targets

How will it look by the next run

