COMPASS polarization data
2002 - 2004 quality check

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Project Proposal:

The NA58 COMPASS target uses ^{6}LiD material with high amount of polarizable nuclei. Presently continuous wave nuclear magnetic resonance technique is used to determine the target polarization. In the project the possibilities of pulsed nuclear magnetic resonance for polarized material are studied. This includes electromagnetic modeling of the detection circuit and numerical simulations on the spin density matrix of the polarized target. Practical experimental work on the detection system may also be included.

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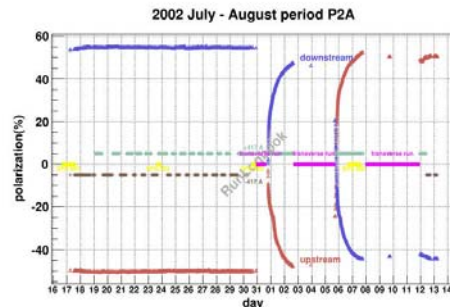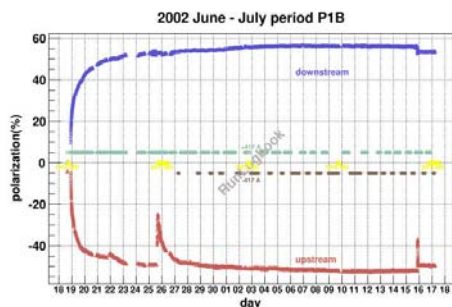## 1. Introduction and general remarks

My Summer Work Project was concentrated on different checks of deuteron, ^{6}Li, ^{7}Li and proton polarization data. These nuclei fill the COMPASS polarized target. The original project proposal was modified because the polarization data is used in the physics analysis and thus verifying its quality has high priority for the collaboration.
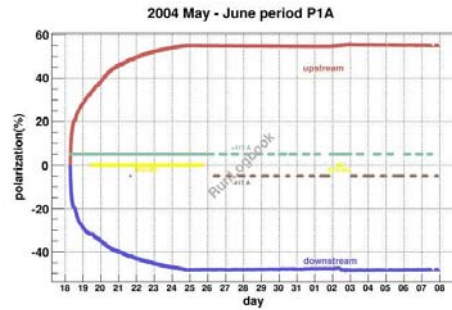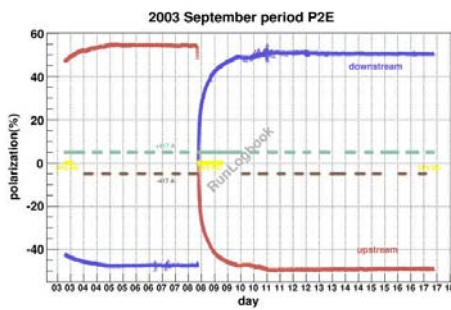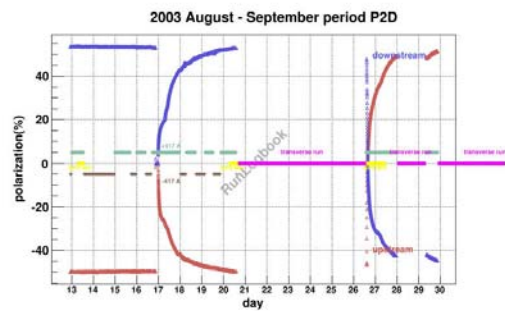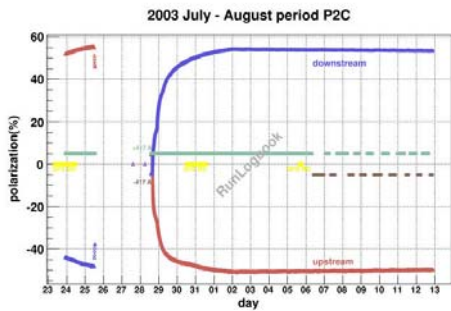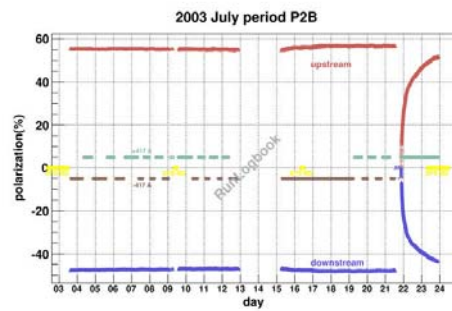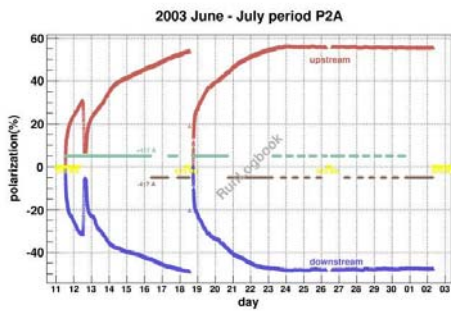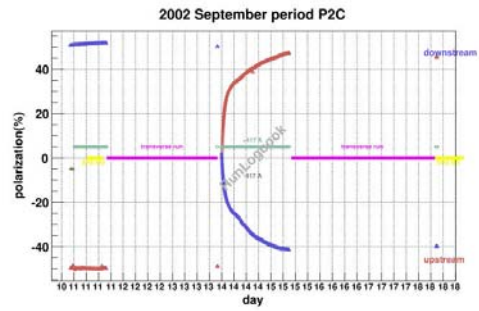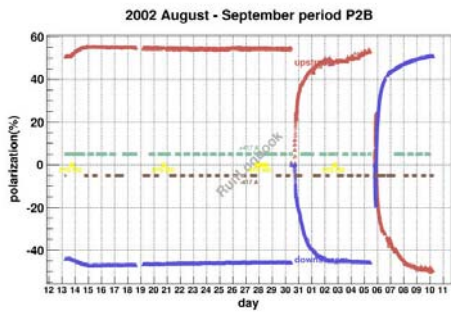
I was looking for mistakes and missing data in the COMPASS MySQL RunLogbook database. This data was plotted in graphs with CERN Root Object-Oriented Data Analysis Framework. The graphs can be checked by the experimental group working on the polarized target. I checked the target solenoid currents in the database too. They were compared with the run physics+, physics- and field rotation flags for any kind of errors.
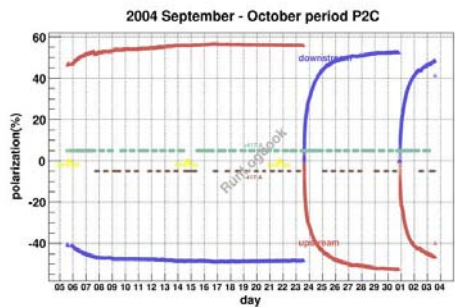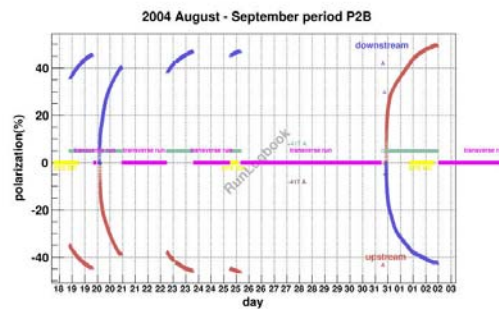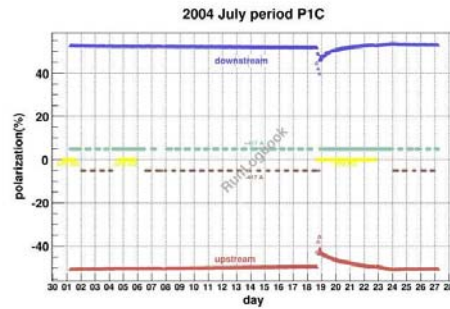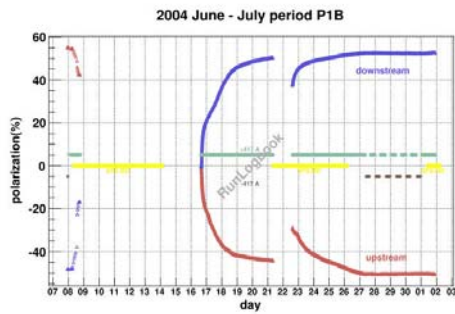
All the data for analysis was read from COMPASS MySQL RunLogbook database with a Root script. The time stamps in the polarization data were in format yyyy-mm-dd hh:mm:ss, where yyyy is the year, mm the month, dd the day, hh the hour, mm minutes and ss seconds. This stamp was converted into Unix seconds using script tounixtime.C. The file was slightly modified depending on data used. The program uses 'aname' variable for the name of input file and 'oname' for the name of output file. One problem occurred when we were plotting the data with ROOT. To receive correct dates and times the file that contains data must be sorted according to Unix time. The files were simply sorted with 'sort' command and the suffix 's' was added to the end of the file's name.

2. Cell average deuteron polarization

The upstream and downstream deuteron polarizations averaged for the four upstream and downstream NMR-coils in the RunLogbook were plotted. Programs plotper02.C, plotper03.C and plotper04.C generate the plots of every period that was saved as a postscript document. Its name contains the year when polarization was measured and the period's name.
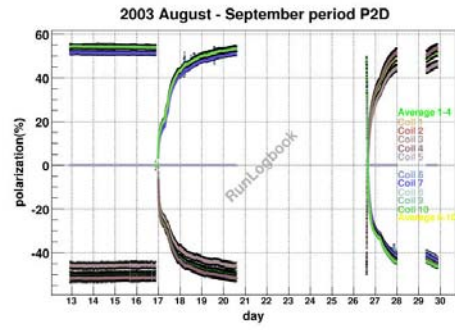
2002 August - September period P2B
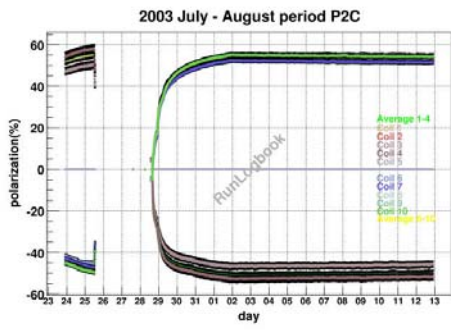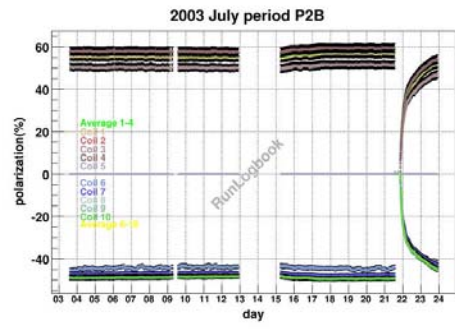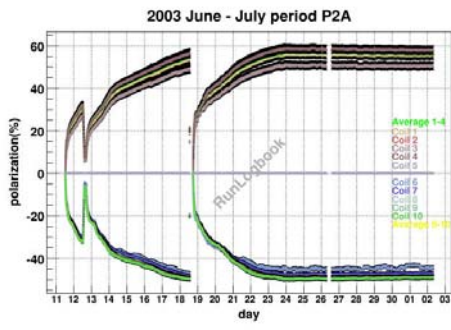

2002 September period P2C

2003 June - July period P2A

2003 July period P2B

2003 July - August period P2C

2003 August - September period P2D

2003 September period P2E

2004 May - June period P1A

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2004 June - July period P1B

2004 July period P1C

2004 July - August period P2A

2004 August - September period P2B

2004 September - October period P2C

In the plots besides the average deuteron polarization the solenoid current, SPS machine development times and transverse runs were marked.

3. Coil-by-coil deuteron polarization

The more deep examination of deuteron polarization correctness was made as well. The polarization value measured with all the coils with corresponding error for each period was plotted. The average polarization was calculated and added to the graph. The programs that plot these data for different periods are plotdeut02.C, plotdeut03.C and plotdeut04.C.

2002 June - July period P1B

2002 July - August period P2A

2002 August - September period P2B

2002 September period P2C

2003 June - July period P2A

2003 July period P2B

2003 July - August period P2C

2003 August - September period P2D

2003 September period P2E

2004 May - June period P1A

2004 June - July period P1B

2004 July period P1C

2004 July - August period P2A

2004 August - September period P2B

2004 September - October period P2C

It can be easily seen that there are some time intervals, when polarization values are unknown. It is also worth to mention that for 2004 error bars are pretty small, because much better calibration of the setup.

4. ^{6}Li, ^{7}Li and protons polarization

The RunLogbook has also polarization values for ^{6}Li, ^{7}Li and proton. These values have been obtained from the measured deuteron polarization assuming equal spin temperature between the nuclei. The polarization values of ^{6}Li, ^{7}Li and proton were plotted as function of deuteron polarization for upstream and downstream cells for each year.
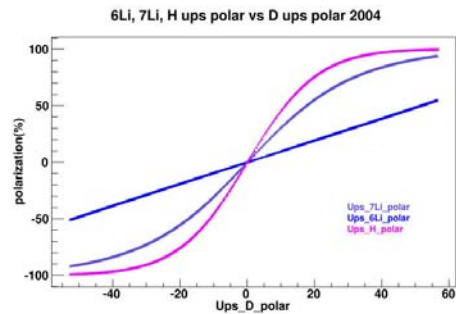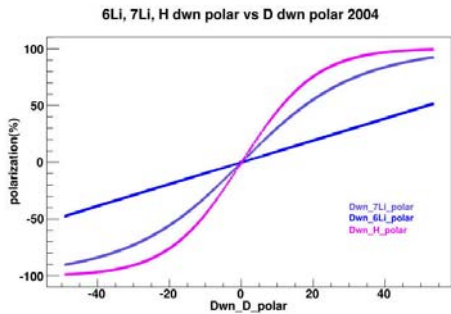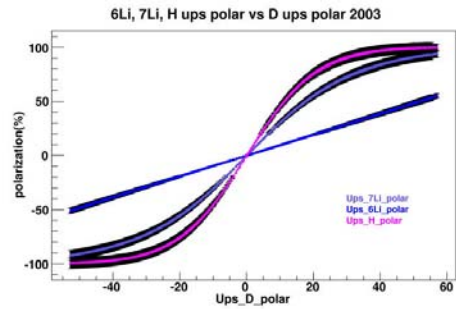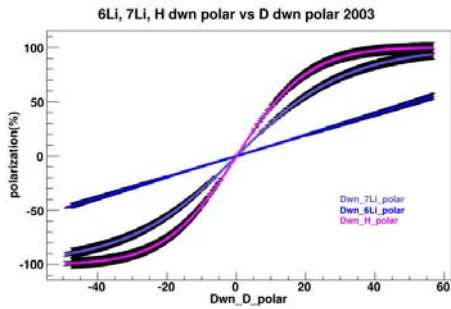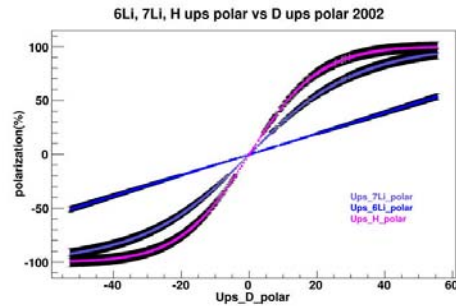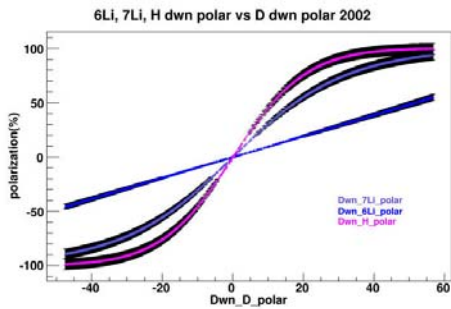
Each nucleus was also plotted independently and the Equal Spin Temperature (EST) function was fitted to ROOT function:

$$\frac{2z+1}{2z\tanh\left(\frac{2z+1}{2zx}\right)} - \frac{1}{2z\tanh\left(\frac{x}{2z}\right)},$$

where z is free parameter and $x = \dfrac{hf_0J_0}{k_BT}$, where h - Planck constant, f_0 - nuclear resonance frequency for respective nucleus, J_0 - its spin, k_B - Boltzmann constant and T - spin temperature of the system. We used deuteron polarization values to estimate polarization of other nuclei. The deuteron spin number is 1 and frequency for nuclear resonance is at 16.3791 MHz in 2.506 T magnetic field. For ^{6}Li the spin number is 1 and the nuclear resonance frequency is 15.702 MHz. ^{7}Li nuclei have spin 3/2 and frequency for nuclear resonance is 41.465 MHz in 2.506 T magnetic field. Proton has spin equal to 1/2 and the nuclear resonance frequency 106.5 MHz. All the values of the nuclear resonance frequency are given for 2.5 K. We used this function to iterate spin temperature for deuteron. When we know it, we can assume that every nucleus has the same spin temperature and using this value we are able to calculate the polarization of the other nuclei. The programs used for fit are:

|		
Hdwn2002_prog.C,	Li6dwn2002_prog.C,	Li7dwn2002_prog.C,
Hdwn2003_prog.C,	Li6dwn2003_prog.C,	Li7dwn2003_prog.C,
Hdwn2004_prog.C,	Li6dwn2004_prog.C,	Li7dwn2004_prog.C,
Hups2002_prog.C,	Li6ups2002_prog.C,	Li7ups2002_prog.C,
Hups2003_prog.C,	Li6ups2003_prog.C,	Li7ups2003_prog.C,
Hups2004_prog.C,	Li6ups2004_prog.C,	Li7ups2004_prog.C.

Each program generates not only the graph with fitted function, but also the histograms for fit quality check:
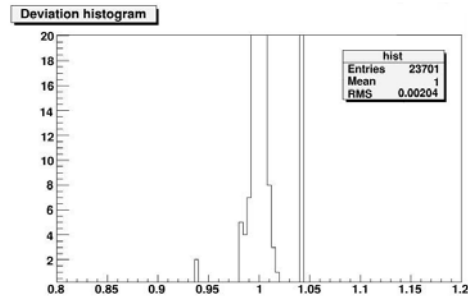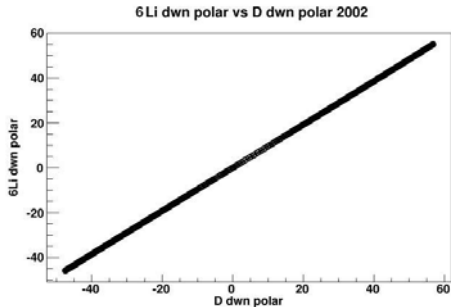
Fit parameter: 1.00010±0.00014; Quantiles: 0.1%: 0.992735, 99.9%: 1.04129
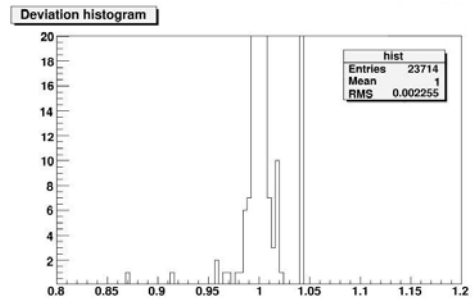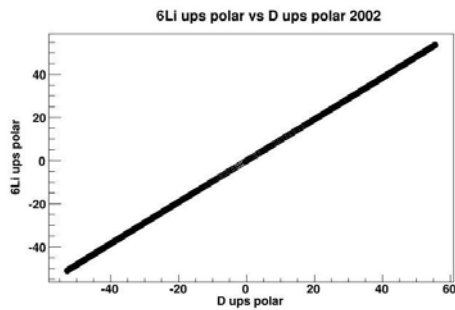
Fit parameter: 1.00007±0.00014; Quantiles: 0.1%: 0.992517, 99.9%: 1.04113
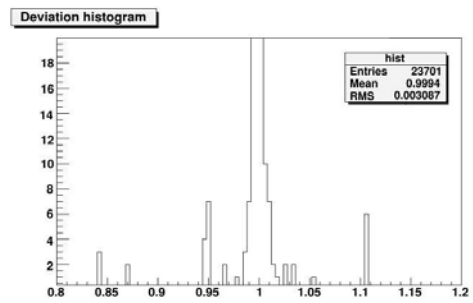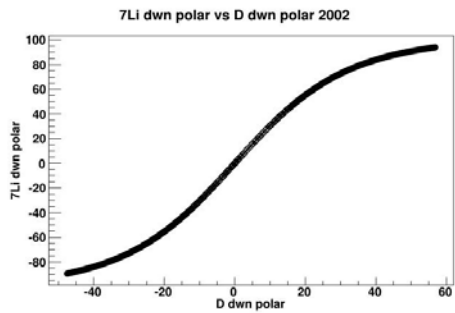
Fit parameter: 0.99945±0.00007; Quantiles: 0.1%: 0.988967, 99.9%: 1.00692

Fit parameter: 0.99969±0.00007; Quantiles: 0.1%: 0.985851, 99.9%: 1.00413

Fit parameter: 1.01199±0.00007; Quantiles: 0.1%: 1.00401, 99.9%: 1.15816

H ups polar vs D ups polar 2004

Deviation histogram

hist
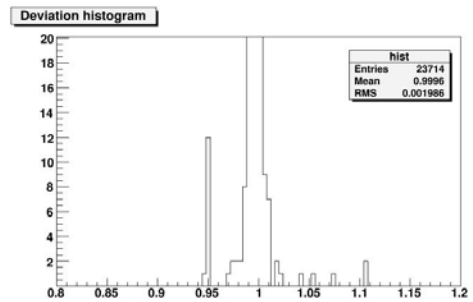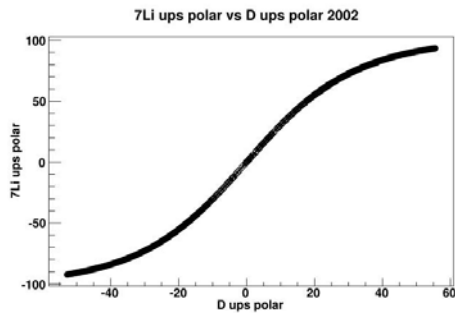|	
Entries	23714
Mean	1.014
RMS	0.01658

Fit parameter: 1.01178±0.00007; Quantiles: 0.1%: 1.00401, 99.9%: 1.15816

6Li dwn polar vs D dwn polar 2003

Deviation histogram

hist
Entries	50152
Mean	1
RMS	0.001808

Fit parameter: 1.00010±0.00010; Quantiles: 0.1%: 0.993204, 99.9%: 1.01013

6Li ups polar vs D ups polar 2003

Deviation histogram

hist
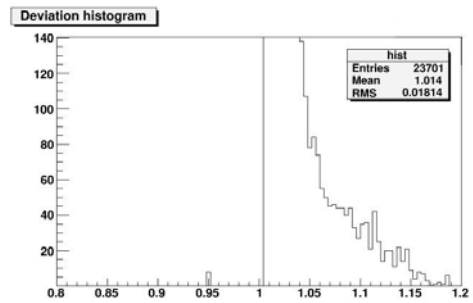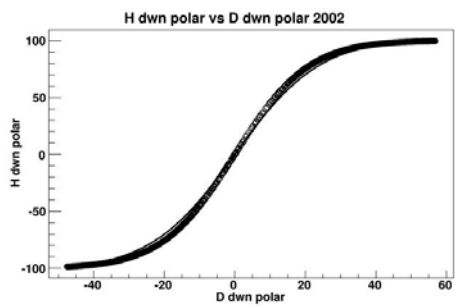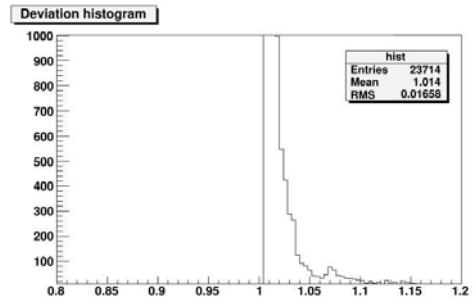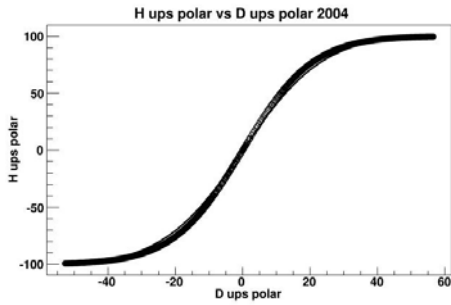|	
Entries	40058
Mean	1
RMS	0.00173

Fit parameter: 1.00007±0.00014; Quantiles: 0.1%: 0.992517, 99.9%: 1.04113

7Li dwn polar vs D dwn polar 2003

Deviation histogram

hist
Entries	50152
Mean	0.9998
RMS	0.002189

Fit parameter: 0.99976±0.00005; Quantiles: 0.1%: 0.992927, 99.9%: 1.004

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Fit parameter: 0.99976±0.00005; Quantiles: 0.1%: 0.992927, 99.9%: 1.004

Fit parameter: 1.01604±0.00005; Quantiles: 0.1%: 1.00401, 99.9%: 1.15993

Fit parameter: 1.01414±0.00005; Quantiles: 0.1%: 1.00401, 99.9%: 1.1615

Fit parameter: 1.00009±0.00011; Quantiles: 0.1%: 0.996002, 99.9%: 1.00537
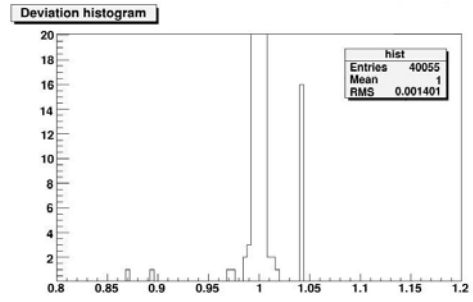
Fit parameter: 0.99956±0.00006; Quantiles: 0.1%: 0.996001, 99.9%: 1.00398
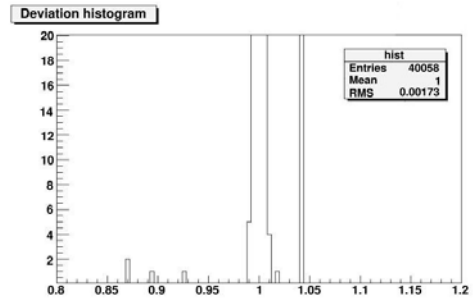
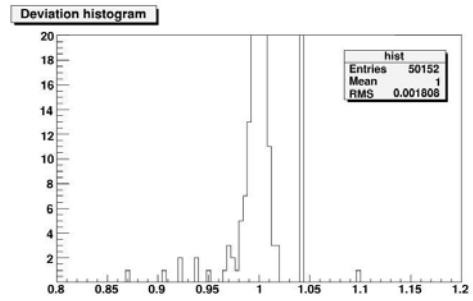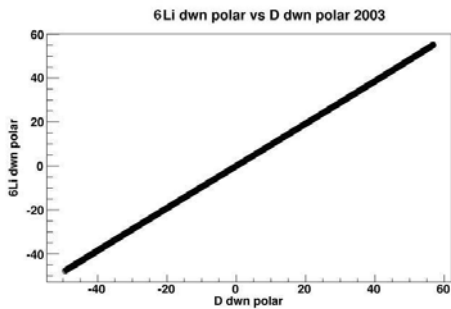Fit parameter: 0.99939±0.00006; Quantiles: 0.1%: 0.995688, 99.9%: 1.00398
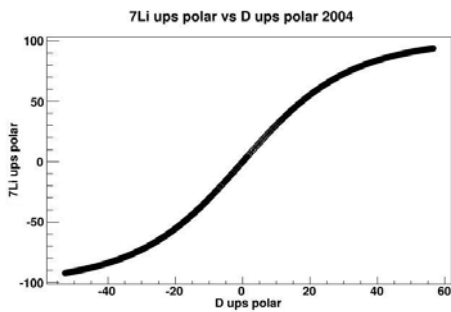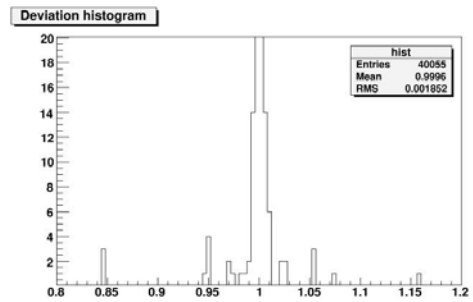
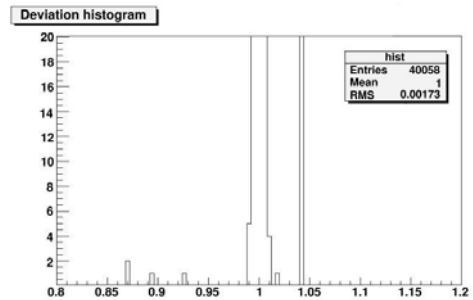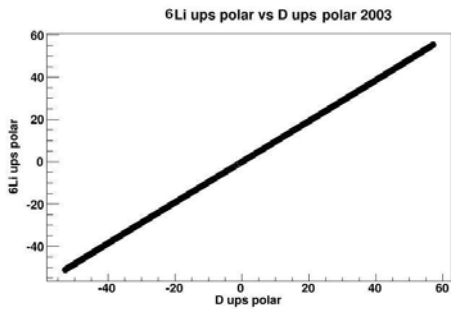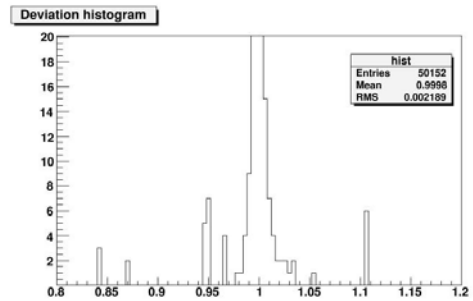Fit parameter: 1.01199±0.00007; Quantiles: 0.1%: 1.00401, 99.9%: 1.15816
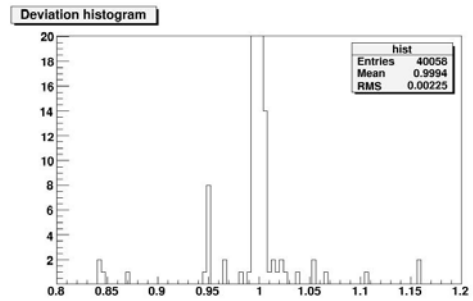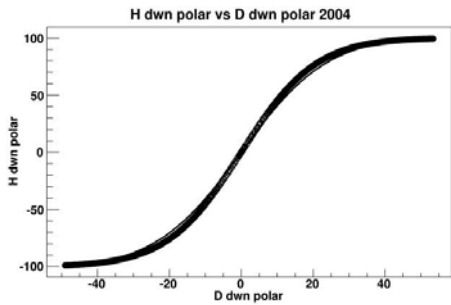
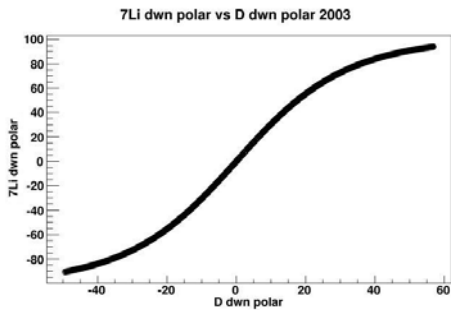Fit parameter: 1.01647±0.00005; Quantiles: 0.1%: 1.00402, 99.9%: 1.15704

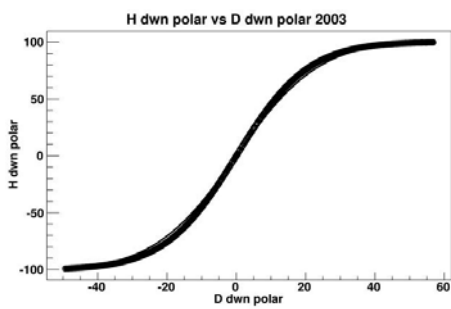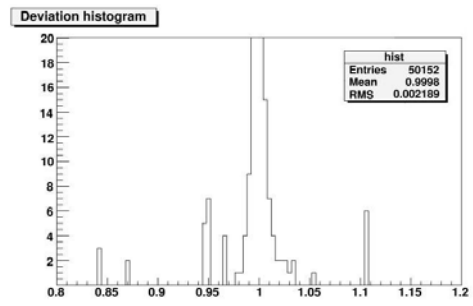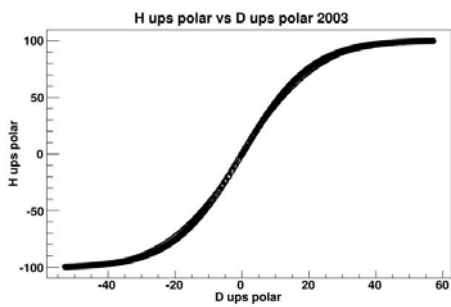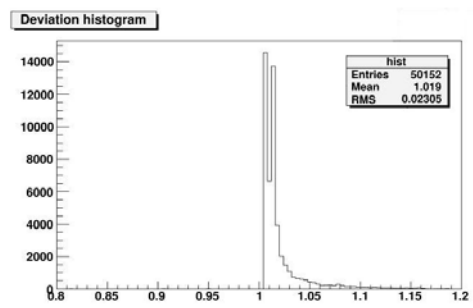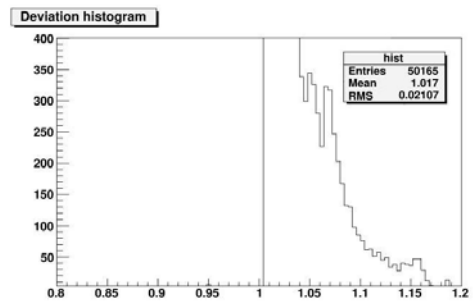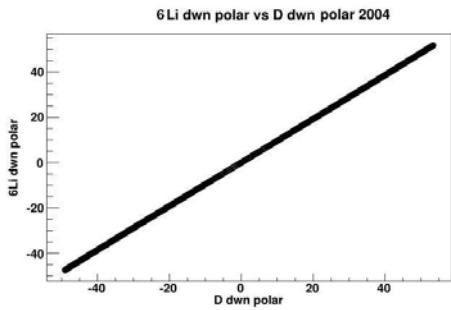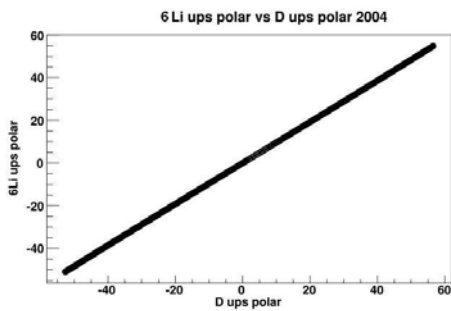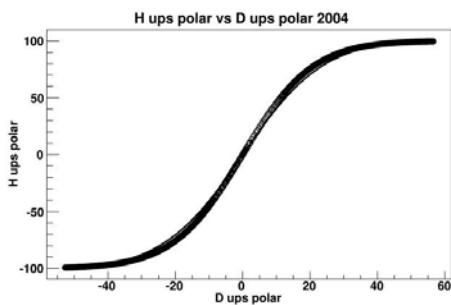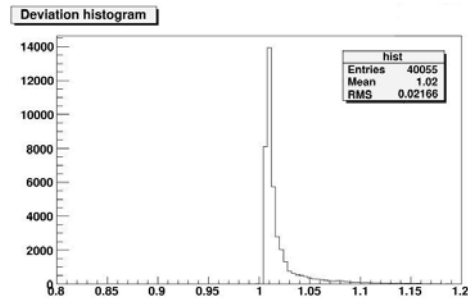Fit parameter: 1.01583±0.00005; Quantiles: 0.1%: 1.00401, 99.9%: 1.15559
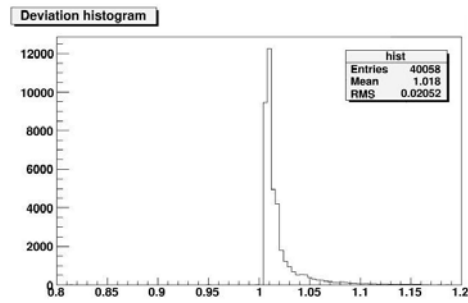
The parameter of the fit with the error and the ratio between the measured polarization and value estimated from the fit for every point is calculated and the quantiles are taken (0.1% and 99.9%). The results are shown in following files:

Hdwn2002_text,	Li6dwn2002_text,	Li7dwn2002_text,
Hdwn2003_text,	Li6dwn2003_text,	Li7dwn2003_text,
Hdwn2004_text,	Li6dwn2004_text,	Li7dwn2004_text,
Hups2002_text,	Li6ups2002_text,	Li7ups2002_text,
Hups2003_text,	Li6ups2003_text,	Li7ups2003_text,
Hups2004_text,	Li6ups2004_text,	Li7ups2004_text.

Finally, the points which mentioned above ratio are bigger than 0.999 or smaller than 0.001 are saved in separate files:

Hdwn2002_diff,	Li6dwn2002_diff,	Li7dwn2002_diff,
Hdwn2003_diff,	Li6dwn2003_diff,	Li7dwn2003_diff,
Hdwn2004_diff,	Li6dwn2004_diff,	Li7dwn2004_diff,
Hups2002_diff,	Li6ups2002_diff,	Li7ups2002_diff,
Hups2003_diff,	Li6ups2003_diff,	Li7ups2003_diff,
Hups2004_diff,	Li6ups2004_diff,	Li7ups2004_diff.

In these files there is time stamp, the nuclei polarization from the measurement and fit, the absolute difference between these two values and the error of the nuclei polarization obtained in the experiment. As an example a few beginning lines of Li6ups2004_diff file are shown:

time	Li6ups	fit	deviation	errLi6ups
1084863376	0.02	0.0251203	0.00512034	0
1084863504	-0.03	-0.0287612	0.00123884	0
1084863616	0.28	0.278002	0.00199841	0
1086719536	0.06	0.057519	0.00248097	0
1087400000	0.04	0.038343	0.00165698	0
1087400592	0.03	0.0287612	0.00123884	0
1087401200	0.02	0.0287612	0.00876116	0
1087401808	0.03	0.0287612	0.00123884	0
1087402128	-0.17	-0.16296	0.00704005	0
1087402368	-1.15	-1.14089	0.00911318	0.01
1087406992	-9.86	-9.7815	0.0784973	0.09
1087408448	-11.3	-11.2209	0.0790796	0.1
1087410272	-12.4	-12.4692	0.0692273	0.11
1087413808	-14.5	-14.5825	0.0825227	0.13
1087413936	-14.6	-14.6772	0.0772251	0.13
1087414176	-14.7	-14.7732	0.0731562	0.13

One can see why there are bins spread discretely in the histogram. It is because of rounding of polarization values from experiment. The calculated points have much more digits after the dot.

5. Solenoid current

The solenoid current check was done. The program for scaling the solenoid current values from polarsnx2a file is named cur_scal.C. It gives two files: cur_scal with scaled solenoid current and cur_err with points that differ from +417A or -417A of more than 40A. The solenoid current was scaled regarding to the formula:

I'[A] = (I[A] – 417A) * 100A + 20A

for positive solenoid current and

I'[A] = (I[A] + 417A) * 100A – 20A

for negative solenoid current, where I is the solenoid current value and I' is scaled solenoid current value. After scaling the file should be sorted. Resulting file cur_scals is used by plotcurscl.C to plot the scaled points.

6. Physics+/physics- and solenoid current correspondence check

The physics+ and physics- points should correspond to positive and negative solenoid current, respectively. The relevant check was done. The run types with proper starting and finishing time were downloaded from RunLogbook to polarsnx file. Because it sometimes happened that finishing time was missing, the new file polarsnx_imp was prepared. In this file all the "bad" points were excluded. The program runtype.C uses polarsnx_imp to calculate the middle time for each run type. The resulting file is called run type, too. Because the numbers corresponding to time are big and small problem occurred when adding them (it is because there where two integer values added that final number exceeded the size of integer variable). It is simply solved by decreasing every number by 100000000, then taking the average and increasing the result by the same number. To plot the physics+/physics- and the solenoid current in the same graph plotphys.C may be used. We compared the physics+/physics- with the solenoid current values and found following differences (the dates are given just approximately):
2 July - 4 July 2002: There is physics- marked for positive solenoid current and after field rotation physics+ for negative solenoid current,
31 August - 1 September 2002: No physics- marked although there was negative solenoid current,
18 August - 2 September 2004: No physics+ marked.
Some of points for field rotations are missing, but they could be easily obtained from the middle time between two opposite solenoid currents times before and after field rotation.

7. Summary

A lot of time consuming checks were made. All the plots were presented and discussed with the group I was assigned to on my last working day. Possibilities of further analysis were also mentioned.