The neutrons diffraction in the KBr single crystal.

Investigation of the neutrons diffraction on the single crystal KBr.

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What is interesting single crystals of KBr?

- **Half of the nuclei bromine are ^{81}Br in single crystal KBr.**
- **Nucleus of bromine-81 have a neutron p -wave resonance at 0.88 eV of energy in which there was a large P-odd asymmetry in the effect of the transmission (**2% from nuclear asymmetry [1]**).**

As was shown in [2,3] the coherent P-odd amplitude has the greater value in the vicinity p-resonance La (0.734 eV) when the measurements the spin rotation transversely polarized neutrons were performed on lanthanum sample.

Moreover in [4-7] it was shown that in the diffraction of neutrons it can be expected of the amplification P -odd effects as well in [8,9] pointed to the possibility of changing the parameters of the lower -lying nuclear parameters of neutron scattering on a regular structure

- 1. VP Alfimenkov. UFN, v.144, N.3, p.361, 1984
- 2. A.P.Serebrov et al., JETP Letters, v.62, p.529, 1995
- 3.W. Heil et all, Physica B 267-268, p.289, 1999

- **We can to discover unusual events in the neutron diffraction on the single crystal KBr because it occurs in medium having neutron - optical activity and near the p-wave resonance ^{81}Br.**

Installation

- **The experiments was carried out on pulsed neutron sources "RADEX" INR** (Proton pulse frequency of **50 Hz** , pulse current of protons **4÷6 mA**, proton pulse duration **90 μsec**, the width of a neutron flash $\mathbf{t_0}$**= 60 μs,** TOF base – **L= 50 m.**)
- **and the IBR-2m** (the width of a neutron flash $\mathbf{t_0}$**= 210 μs,** TOF base – **L= 28,3 m.**),
- **The data acquisition system was developed in the LNP JINR.**
- *V.N. Shvetsov, S.V.Alpatov, N.V. Astakhova et al. Instruments and Experimenttal Techniques, V.55, N 5, pp.561-568, 2012.*
- **As the neutron detectors used SNM-18 counters.** *Three crystals of potassium bromide. Their dimensions was : 9×45×90 mm^3; 9×90×90 mm^3 ; 14×60×60 mm^3.*

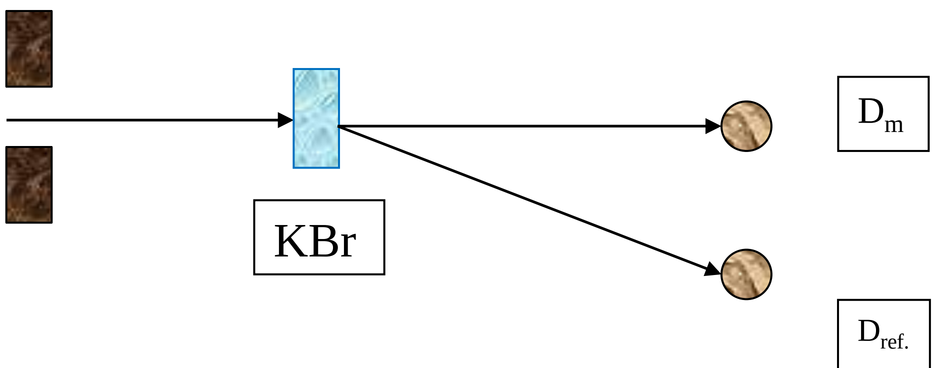


Figure 1.

TOF spectrum of neutron diffracted on the polycrystalline of an iron.

- In order to determine the delay time **t_0** neutron flash relative to the pulse start time and TOF base **L**, we measured the neutron diffraction from polycrystalline iron at the Bragg angle **$\pi / 4$**, shown in Figure 2. Measurement time was **70 minutes**. We defined **$t_0 = 3242\ \mu s$** and **$L = 28{,}31 \pm 0{,}03$ m** from the known iron reflections [11,29].The results are in good agreement with the results of [12, 20].

11. O.P.Sushkov, V.V.Flambaum, UFN, v.136, p.3 - 24 ,1982.
12. V.E.Bunakov, V.P.Gudkov Zs. Phys., Bd. 303, S. 285, (1981).
20. Yu.A. Alexandrov all. Physica ,B 151, p.108-112, 1988.
29. VL Kuznetsov et al. "First" neutron diffraction in INR. RSNE -2007, p.607, M,2007.

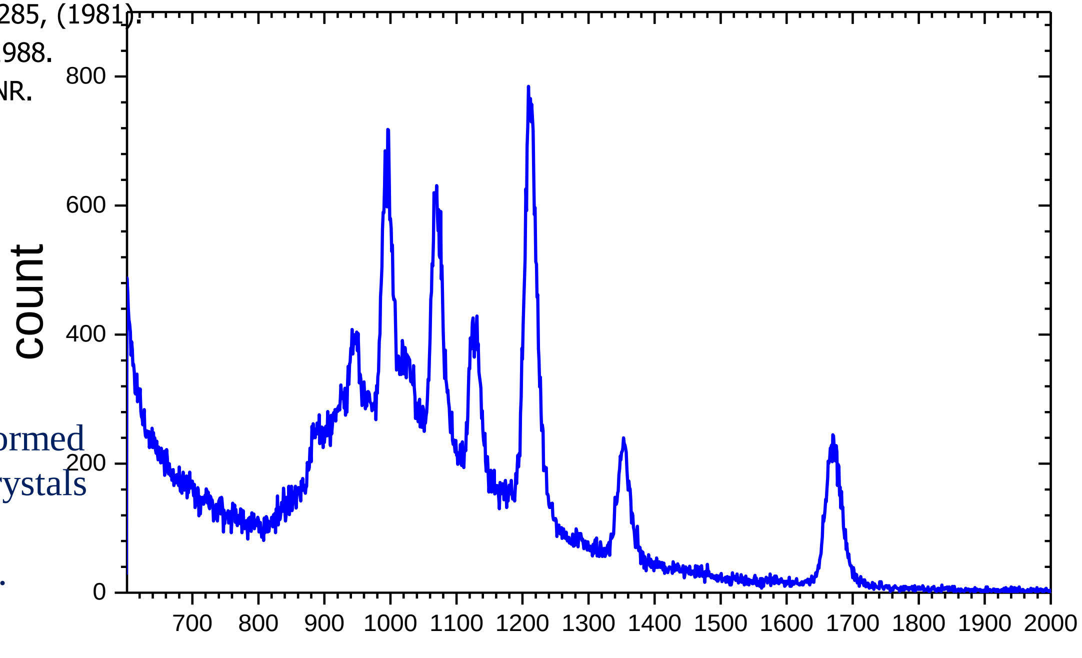


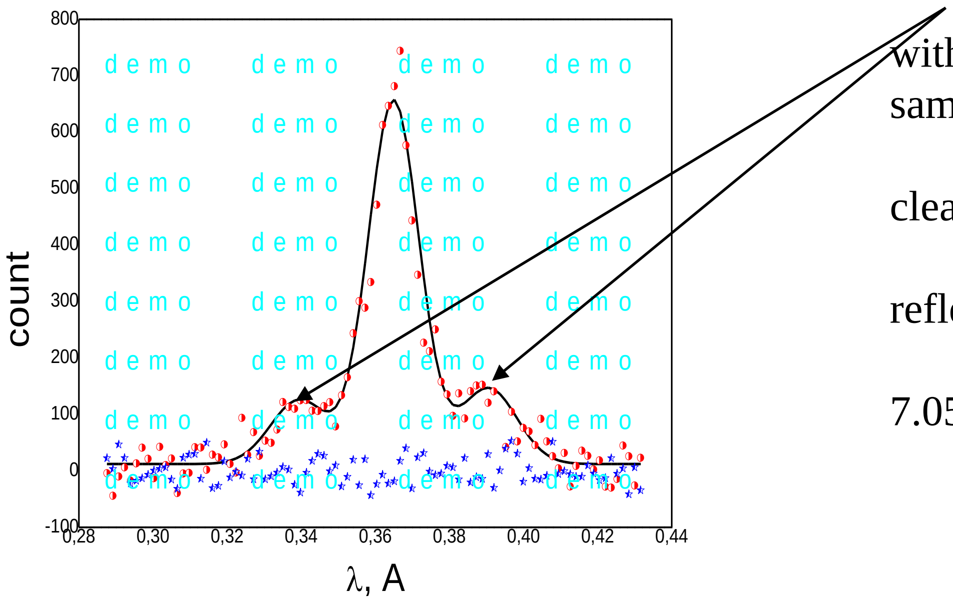
Figure 2.

Many diffraction measurements were performed for different conditions and for different single crystals of potassium bromide.

More interesting results are presented here.

The experiment."RADEX" INR RAS.

- The neutron spectrum of diffraction from KBr crystal near the p-resonance ^{81}Br.



Satellite peaks are disposed symmetrically with respect reflex and have approximately the same intensity.

This picture can hardly be explained by cleavage of the crystal lattice (mosaic).

It is interesting that half-width of all three reflexes are the same within error.

The ratio of the areas under reflexes is: 1.39; 7.05; 1.64.

Figure 3. The results of measurements of the neutron spectrum diffraction are red circles. Background spectrum – blue stars. Solid line - approximation of the neutron spectrum diffraction by means of three Gaussians. Background spectrum was approximated by a smooth curve and then subtracted from the spectrum of the neutron diffraction and background spectrum

The experiments. IBR-2m.

Conclusion: at small changing the angle the splitting was strongly increase. This happened in the first reflex, and the second reflex.

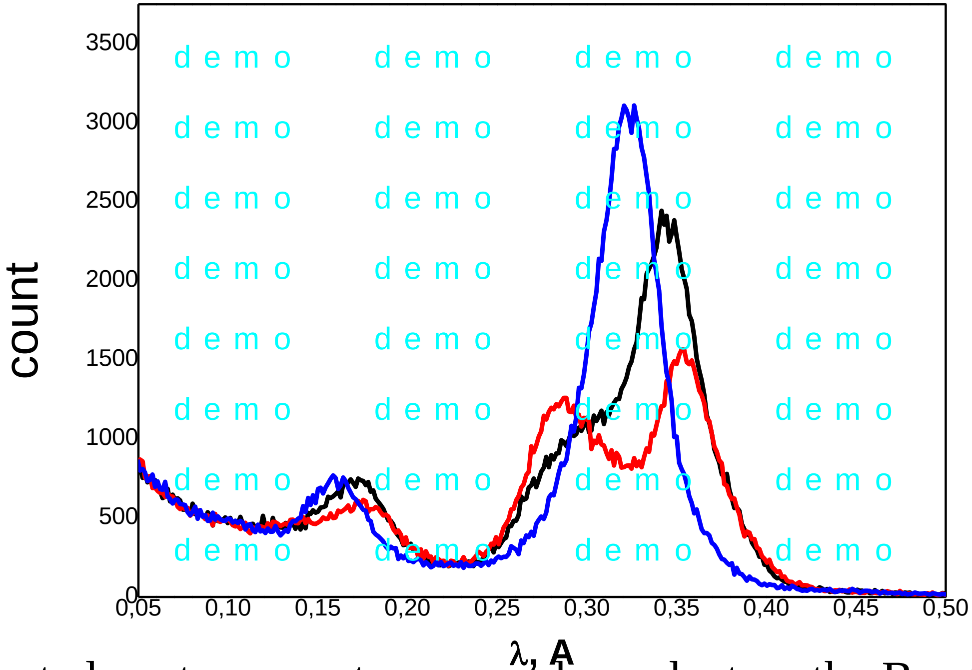


Figure 4. TOF diffracted neutron spectrum was dependent on the Bragg angle. The Bragg angle is Blue line $\theta_B = 0^0$; black - θ_B = 100”; red line - θ_B = 140”.

TOF diffracted neutron spectrum at Bragg angle - $\theta_B = 140''$ (arcseconds).

Conclusion: at small changing the angle the splitting was strongly increase. This happened in the first reflex, and the second reflex.

- The first order of reflection
- The second order of reflection

Fig. a.

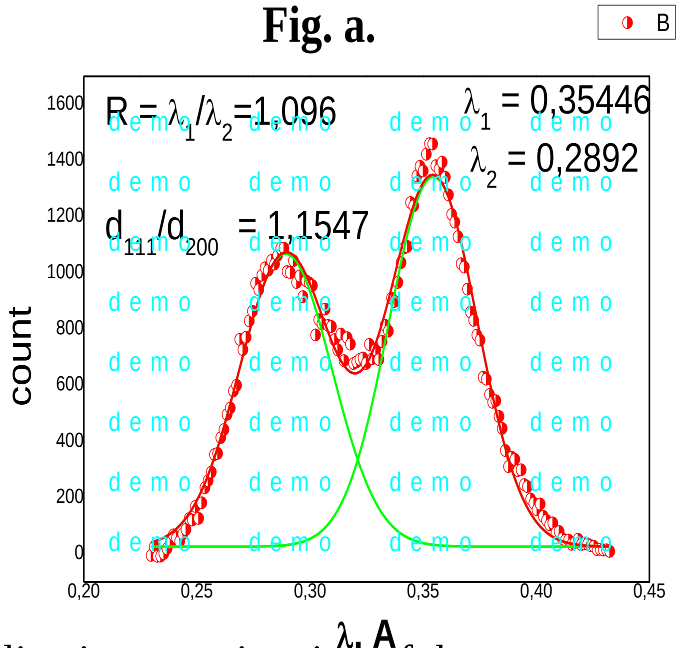


Fig. b.

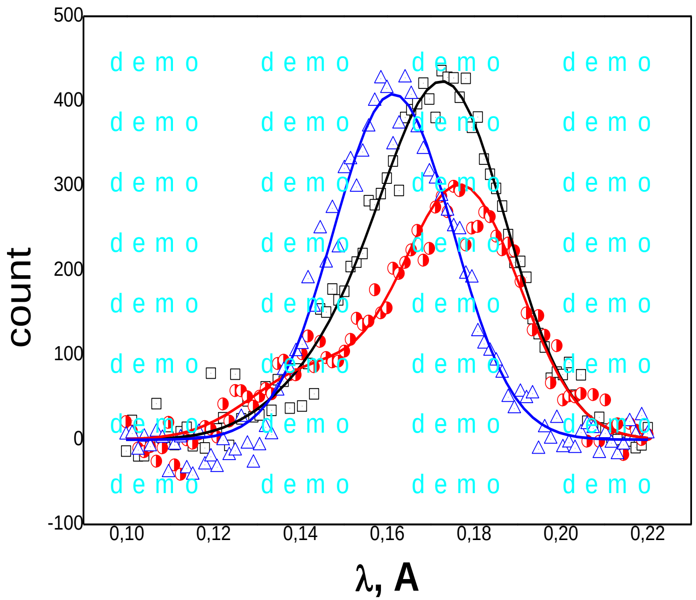


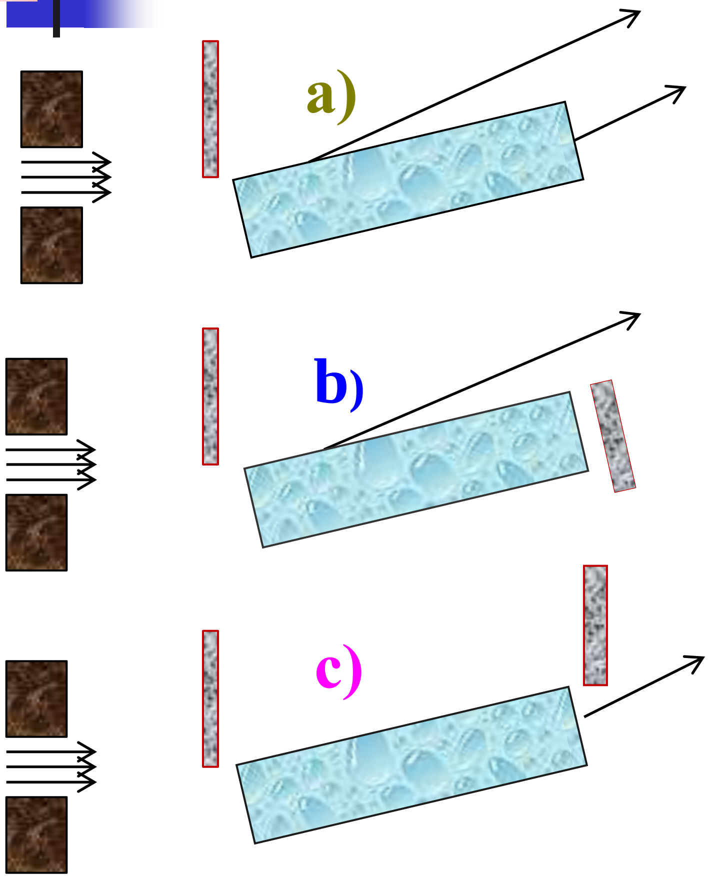
Figure 4.

Green line is approximation of the neutron spectrum diffraction by means of two Gaussians.

divided into

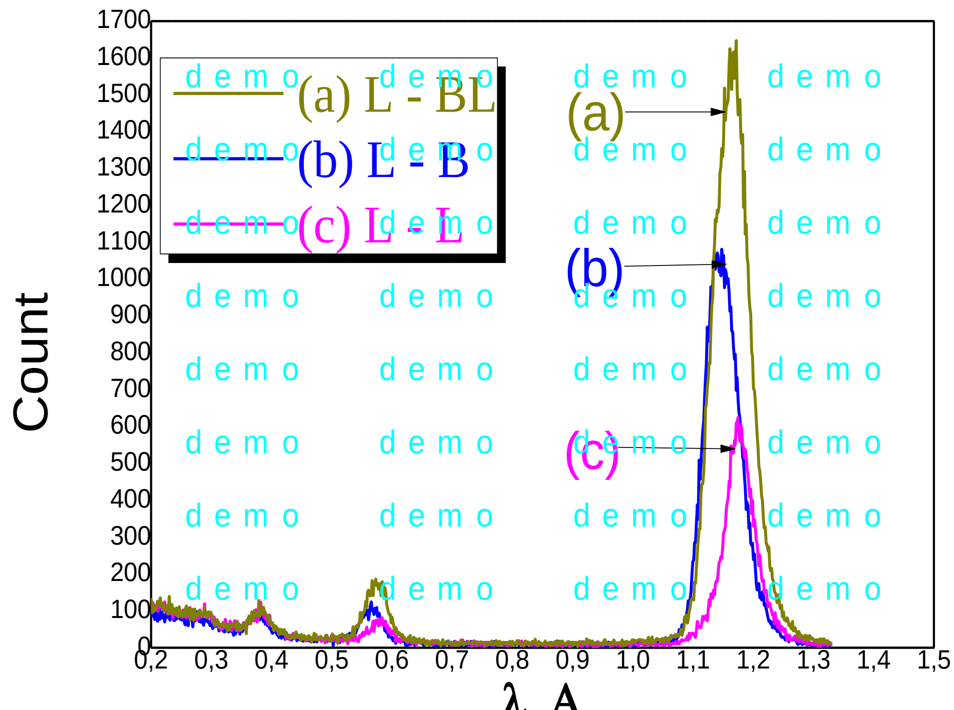
The neutron beam is incident on the front face of the crystal (in the Laue position).

The geometry of the experiment was made of cadmium plates.



Cadmium plates installed here and there

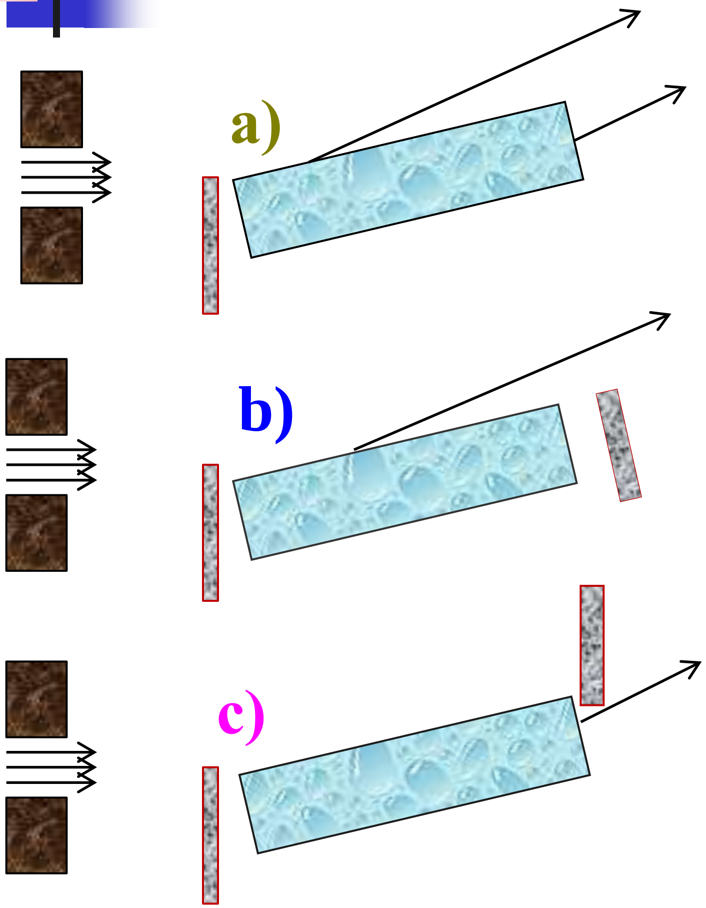
- As a result of experiments, it was found that the neutron beam entered in Laue geometry of neutron diffraction, and came out of the side surface of the crystal as in the Bragg geometry.



In **Figure 5** shows a typical measurement result TOF spectra of neutron diffraction when the neutron beam enters the crystal in the Laue geometry

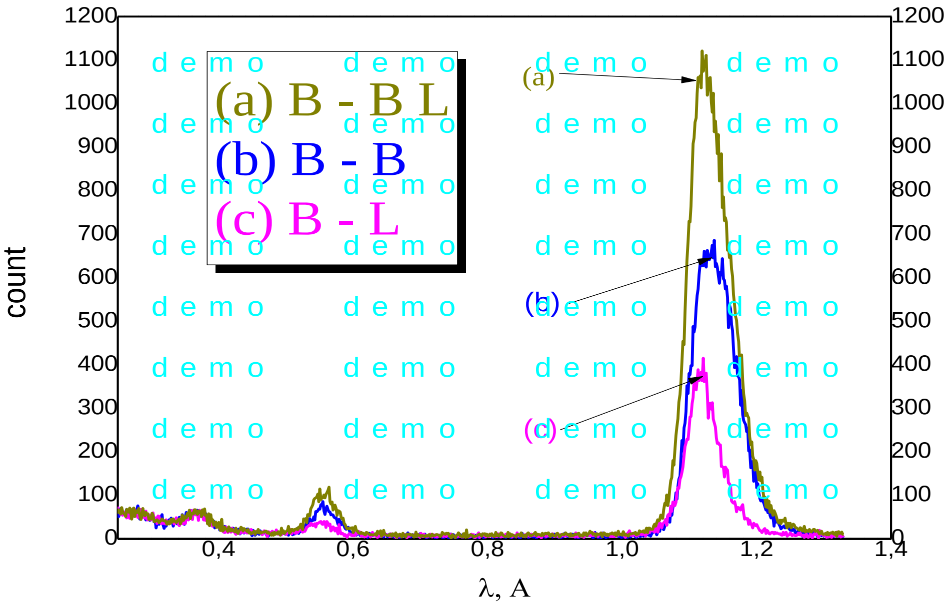
The neutron beam is incident on the lateral surface of the crystal (in the Bragg position).

The geometry of the experiment was made of cadmium plates.



Cadmium plate was placed in front of the plane.

- As a result of experiments, it was found that the incident the neutron beam in Bragg diffraction geometry, the neutrons came out from the back surface of the crystal in Laue geometry.



In **Figure 6** shows a typical measurement result TOF spectra of neutron diffraction when the neutron beam enters the crystal in the Bragg geometry.

TOF diffracted neutron spectrum

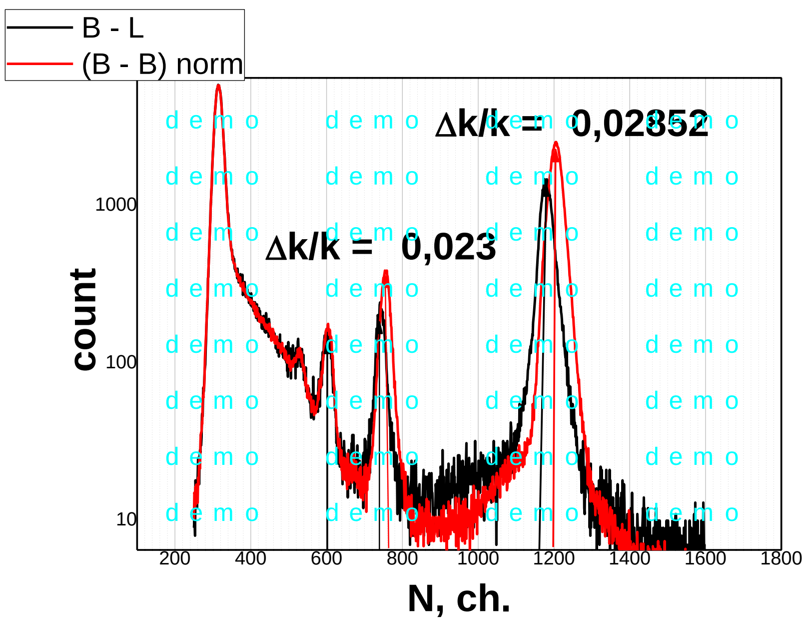


Figure 8

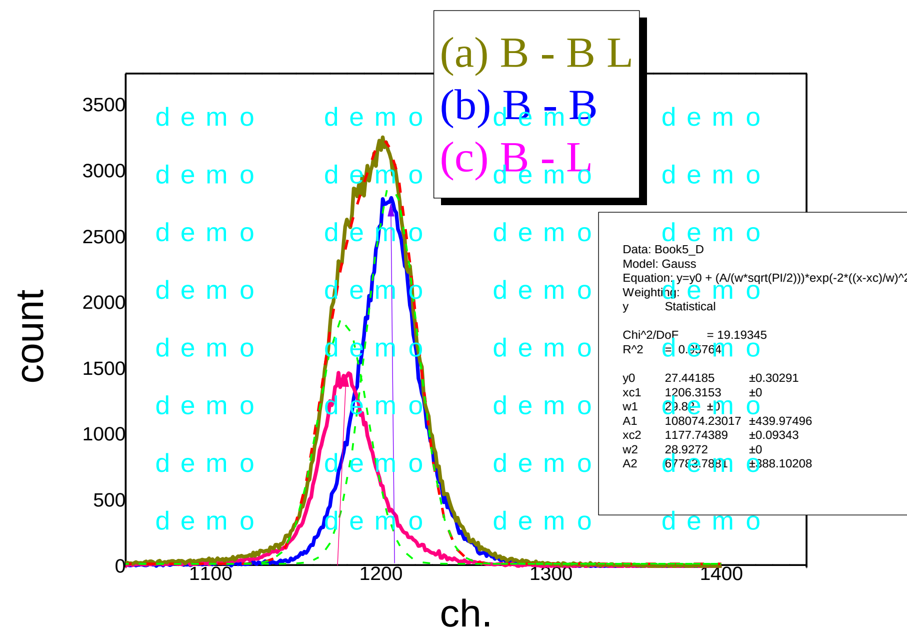
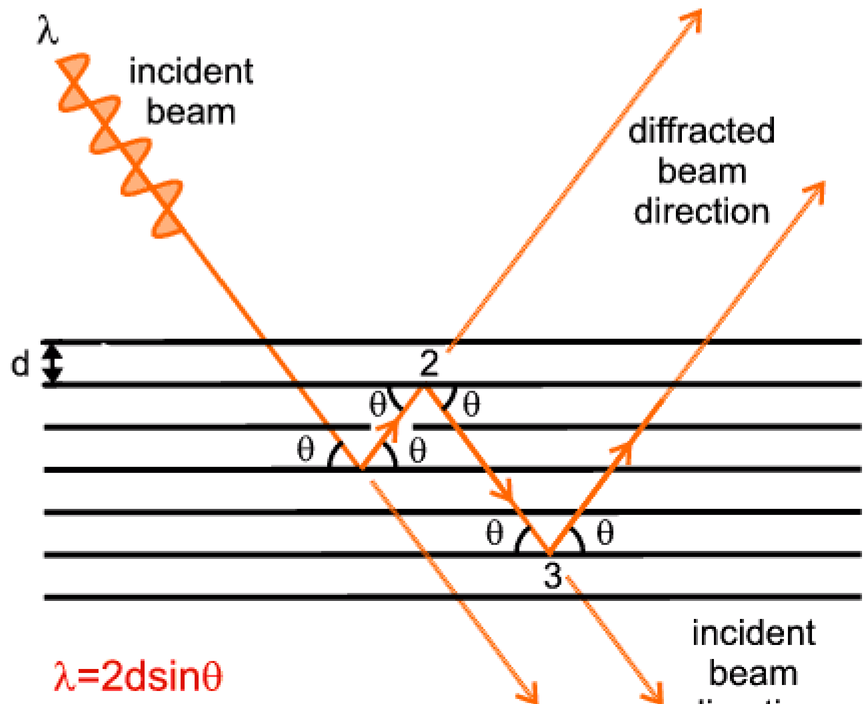


Figure 9

Conclusions.

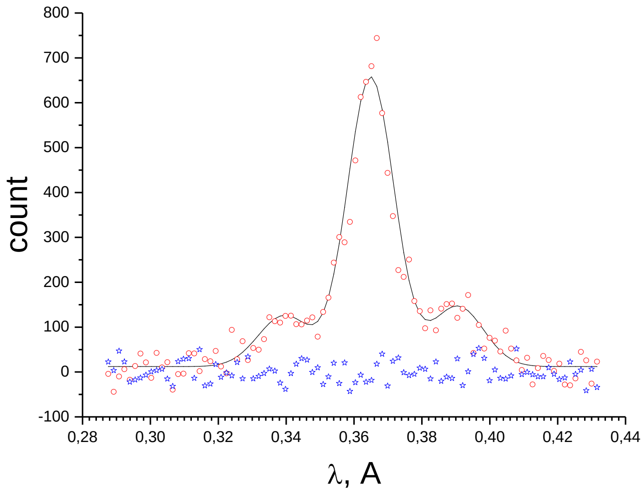
- **The neutron detection efficiency and angular divergence of the neutron beam falling on the crystal were taken into account.**
- **In experiments on RADEX INR in the time-of-flight spectra were detected the satellite peaks. Satellite peaks are disposed symmetrically with respect reflex and have approximately the same intensity.**
- **As a result of experiments on IBR-2M, it was found that there was a rather large splitting of the reflex. Moreover, at small changing the angle the splitting was strongly increase.**
- **As a result of experiments on IBR-2M, it was found that the neutron beam entered in Laue geometry of neutron diffraction, and came out of the side surface of the crystal as in the Bragg geometry.**
- **As a result of experiments on IBR-2M, it was found that the incident the neutron beam in Bragg diffraction geometry neutrons came out from the back surface of the crystal in Laue geometry.**

Thank you for attention!



$\lambda = 2d\sin\theta$

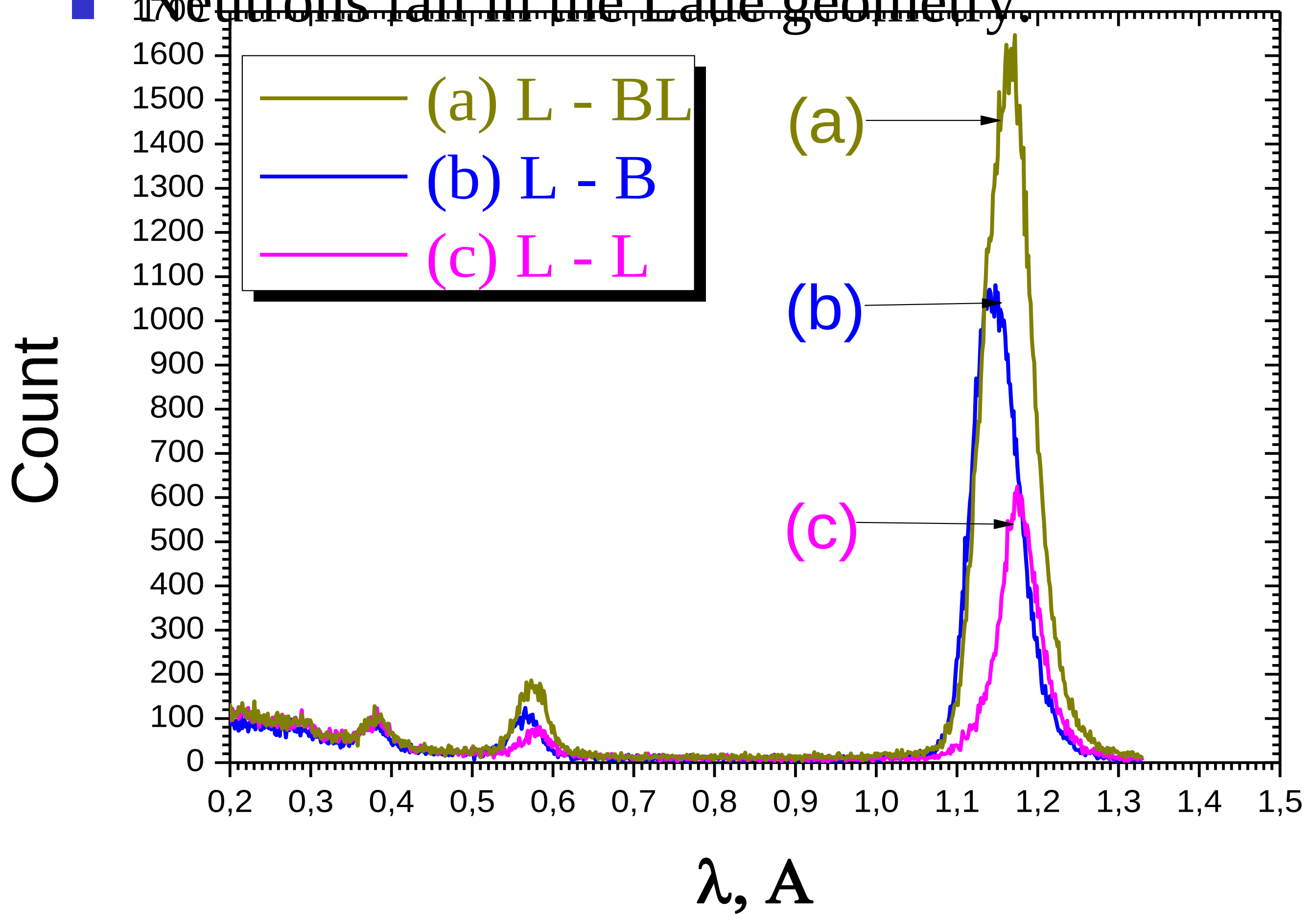
RADEX experiment. The neutron diffraction KBr sample in a neighborhood of p-resonance ^{81}Br.



- Пики сателлитов расположены симметрично относительно рефлекса и имеют, примерно, одинаковую интенсивность. Такую картину вряд ли можно объяснить расщеплением решетки кристалла (мозаичностью).
- Интересно, что полуширины всех трех рефлексов одинаковы в пределах погрешности. Соотношение площадей под рефлексами таково: 1,39; 7,05; 1,64.

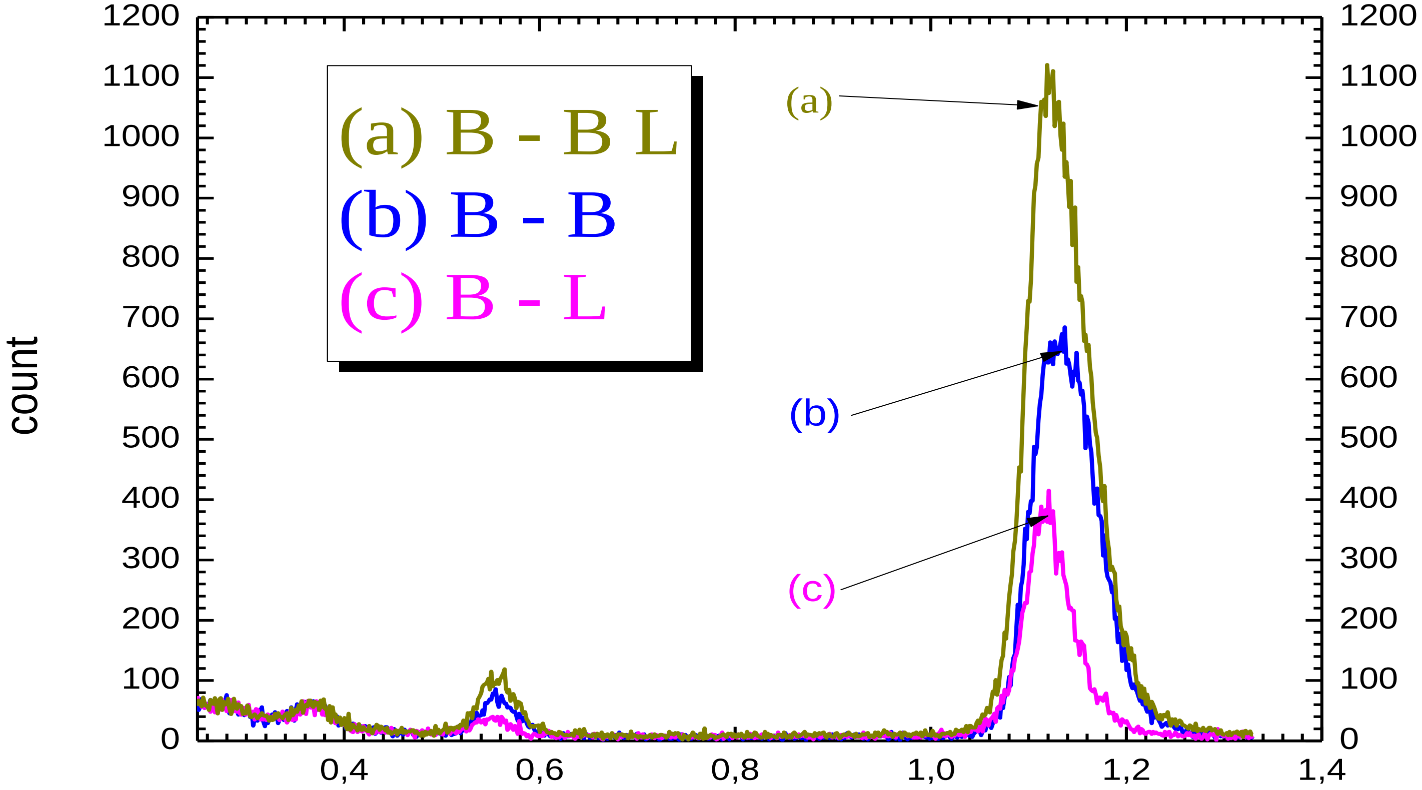
The experiment. IBR-2m. 2013-2014 гг.

- Neutrons fall in the Laue geometry.



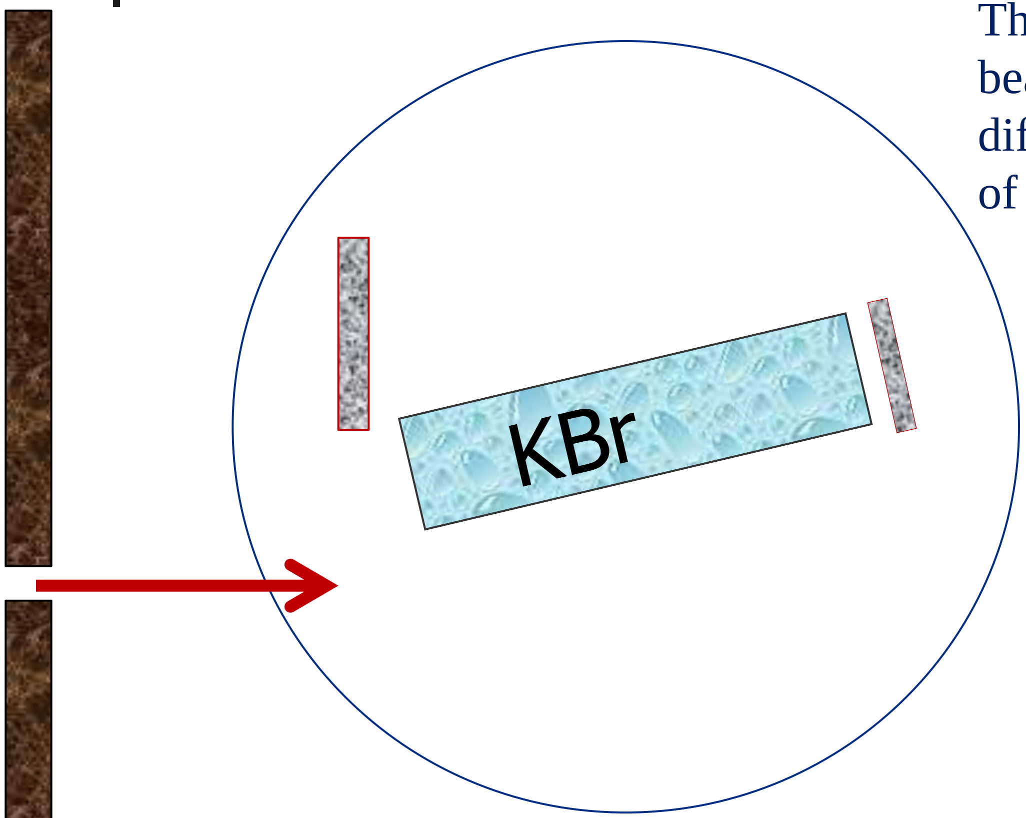
The experiment. IBR-2m. 2013-2014 гг.

- Neutron diffraction (neutrons fall in the Bragg geometry).



The intensity of the diffracted beam of neutrons according to the place of incidence on the surface of the crystal

This is **case (b) in Figure 5**. The neutron beam entered in Laue geometry of neutron diffraction, and came out of the side surface of the crystal as in the Bragg geometry.



Case (b)   (L - B)

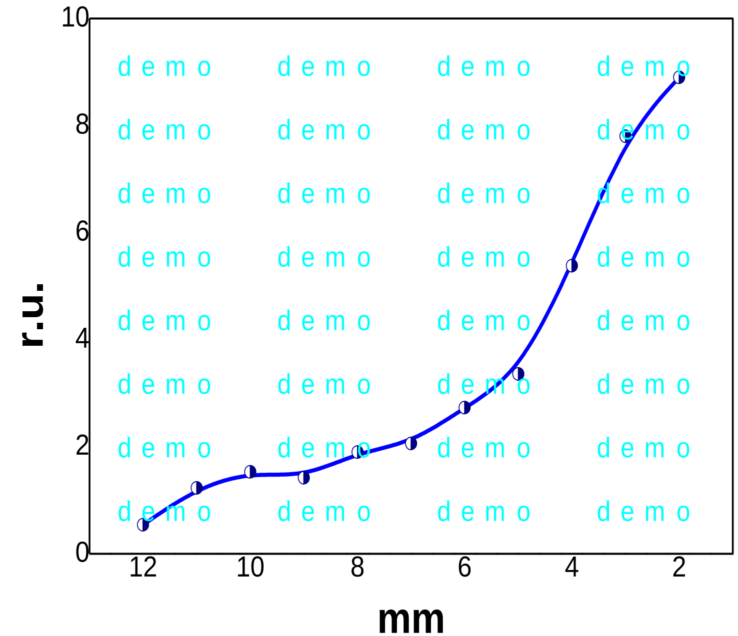


Figure 7

The amplitude of the coherent scattering .

$$f_{ch} = f_{ch0} + f_{ss} + f_{pp} + f_{sp}$$

The amplitude f_{sp} has form:

$$f_{sp} = f_{PV}\ \mathbf{s}\cdot(\mathbf{p} + \mathbf{p}') + f_{(PT)\,V}\ \mathbf{s}\cdot(\mathbf{p} - \mathbf{p}')$$

here f_{PV}, $f_{(PT)\,V}$ - amplitude of the weak neutron- nuclear interaction with the parity violation and with the parity and time reversal violation, respectively, **s** - spin of the neutron, **p** and **p'** - the unit vectors corresponding to the direction of the momentum of the incident and scattered neutrons.

The integral intensity of the reflected neutrons.

$$J_n = \int \sin^2[(\pi t/\Delta)(1+y^2)^{0,5}]/(1+y^2)dy$$

$y = 1$ is ~ 10^{-5} arc.

$$J_n = \pi/2\cdot(1+ (0,8\cdot\cos(T + \pi/4))/T^{0,5})$$

$$b = b_{ch0}\ (1\pm f_w);\ T = \pi t/\Delta = 2A\cdot b\cdot tg(\theta)$$

$$A = 2d_{hkl}N_cF_{hkl}\ ;$$

$$f_w \sim 2\ 10^{-4};\ \Delta = \pi\cdot v_c\cdot\cos(\theta)/(\lambda_n\cdot|f(k)|\cdot F_{200}\cdot e^{-2W})$$

Taking into account the angular divergence of the neutron beam

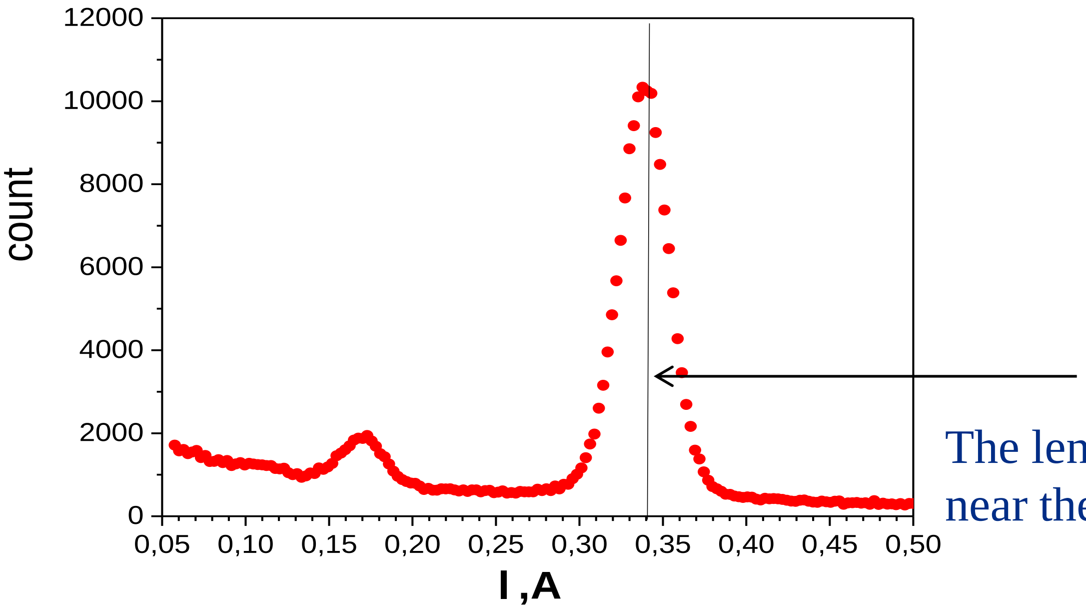
$$J(\theta_n) = J_0\cdot\exp(-((\theta_B - \theta_n)/\ \Delta\theta_n)^2)$$

.

$$P_{PVD} = \int(R^+\cdot J^+ - R^-\cdot J^-)d\theta\ /\ \int(R^+J^+ + R^-J^-)d\theta$$

The experiment.

Neutron spectrum from a single crystal diffraction experienced KBr.



l=0.34 Å

The length of wave of neutrons in the region near the p- resonance nuclei ^{81}Br.

The experiment. IBR-2m (1-th run)

TOF spectrum of neutron diffracted on the single crystal KBr- the red line, on polycrystalline of an iron – the black line. The time of a neutron flash ~ 211 μs, TOF base ~ 30 m, counting rate - 30 n/sec

The data acquisition system was developed in the LNP JINR.

V.N. Shvetsov, S.V.Alpatov, N.V. Astakhova et al. *Instruments and Experimenttal Techniques, V.55, N 5, pp.561-568, 2012.*