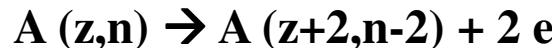
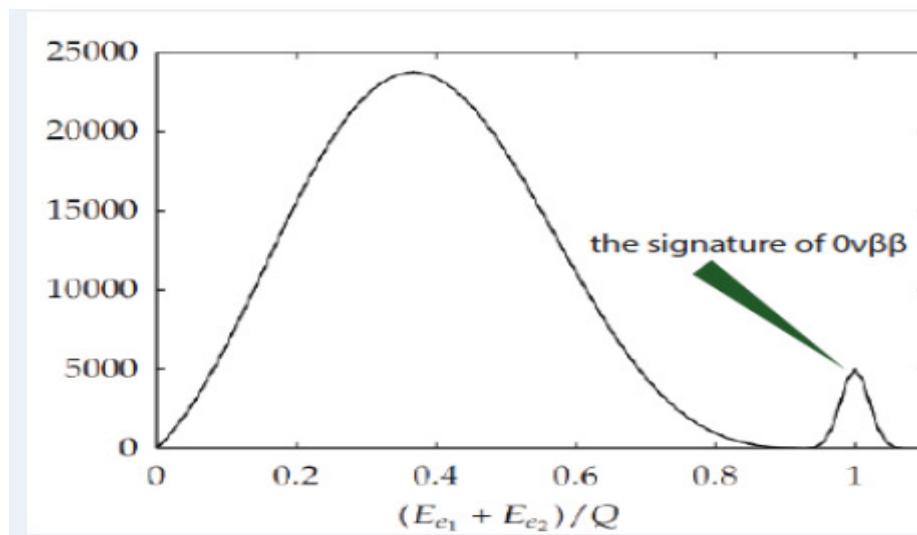


Коррекция модели безнейтринного двойного бета-распада.
Результаты коллаборации Н-М для 76-Ge и повторный анализ данных
эксперимента Cuoricino для 130-Te.



Современные модели $2\beta 0\nu$ -распада постулируют, что сигнал распада должен иметь энергию , равную величине $Q_{\beta\beta}$ (энергия $2\beta 0\nu$ -распада, определяемая как разность масс начального и конечного атомов).

Предложена коррекция модели безнейтринного двойного бета-распада, предсказывающая сдвиг сигнала $2\beta 0\nu$ -распада относительно значения $Q_{\beta\beta}$. Результаты анализа данных коллабораций Н-М и Cuoricino подтверждают коррекцию и указывают на то, что $2\beta 0\nu$ -распад 76-Ge и 130-Te наблюдался десять лет тому назад в двух экспериментах



Заявление о наблюдении $2\beta 0\nu$ -распада ^{76}Ge было сделано 10 лет назад группой участников коллаборации Heidelberg-Москва [1]. Однако результат коллаборации GERDA [2] не подтвердил этого заявления. В 2006 году Клапдор и Кривошеина представили результаты повторной обработки данных [3]. Значение $T_{1/2}$ возросло почти в два раза и составило $2.2 \cdot 10^{25}$ лет (что не противоречило выводам [2])

Попытка разобраться в возникшей ситуации привела к заключению о возможности и необходимости пересмотра существующей модели $2\beta 0\nu$ -распада, уточнения результатов коллаборации Heidelberg-Москва и повторного анализа экспериментальных данных коллаборации Cuoricino .

Предложена коррекция модели безнейтринного двойного бета-распада, предсказывающая сдвиг сигнала $2\beta 0\nu$ -распада относительно значения $Q_{\beta\beta}$ (энергии $2\beta 0\nu$ -распада). Возникновение сдвига объясняется возбуждением электронных оболочек атома-продукта, с де-возбуждением путём испускания рентгеновских гамма-квантов.

Возбуждение происходит при обмене импульсами отдачи непосредственно между «новорожденными» электронами и протонами. Вычислены сдвиги сигналов $2\beta 0\nu$ -распада относительно значений $Q_{\beta\beta}$ для $^{76}\text{-Ge}$ ($\Delta E = -2.6 \text{ keV}$) , $^{100}\text{-Mo}$ ($\Delta E = -4.7 \text{ keV}$) , $^{130}\text{-Te}$ ($\Delta E = -3.7 \text{ keV}$) .

$$\Delta E = [(p_1)^{**2} + (p_2)^{**2}] / 2m(p)$$

- still, community does not fully accept the result, because:
 - ▶ signal is indeed too faint (4σ) to be *blindly* accepted: people still find some weak points in the published analysis
 - ▶ presence of **not understood peaks** around the signal and with *similar* significance
 - ▶ impossibility to check an **energy window larger than the published one**
- nevertheless any future $\beta\beta$ - 0ν experiment will have to cope with this result

A Recent Claim

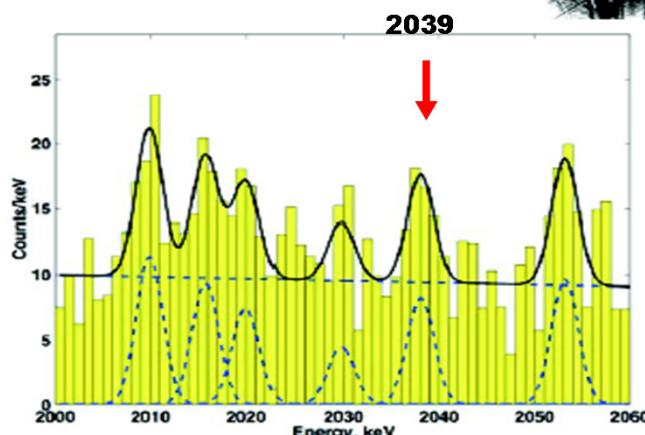


Klapdor-Kleingrothaus H V, Krivosheina I V, Dietz A and Chkvorets O, *Phys. Lett. B* **586** 198 (2004).

Used five ^{76}Ge crystals, with a total of 10.96 kg of mass, and 71 kg-years of data.

$$\tau_{1/2} = 1.2 \times 10^{25} \text{ y}$$
$$0.24 < m_\nu < 0.58 \text{ eV} \text{ (3 sigma)}$$

Background level depends on intensity fit to other peaks.

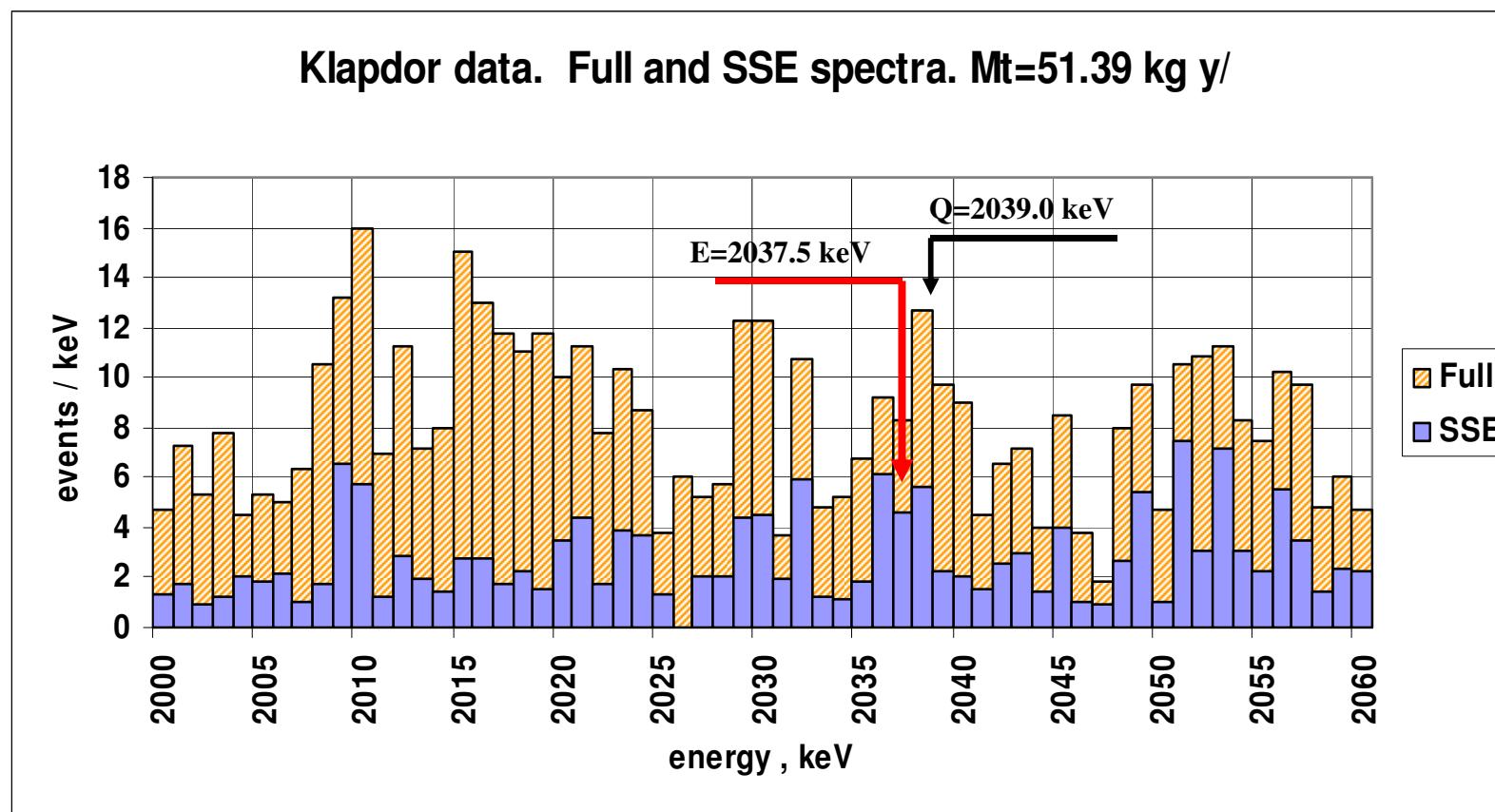


Заявление о наблюдении $2\beta 0\nu$ -распада ^{76}Ge было сделано 10 лет назад группой участников коллаборации Heidelberg-Москва [1]. Однако результат коллаборации GERDA [2] не подтвердил этого заявления.

Klapdor results 2004 [1]. Mt=51.39 kg y. Full and SSE spectra.

SSE spectrum = results of shape analysis. **SSE/Full=0.34**

A further analysis of Klapdor results indicated that the 2038 kev line had a complex origin [5].

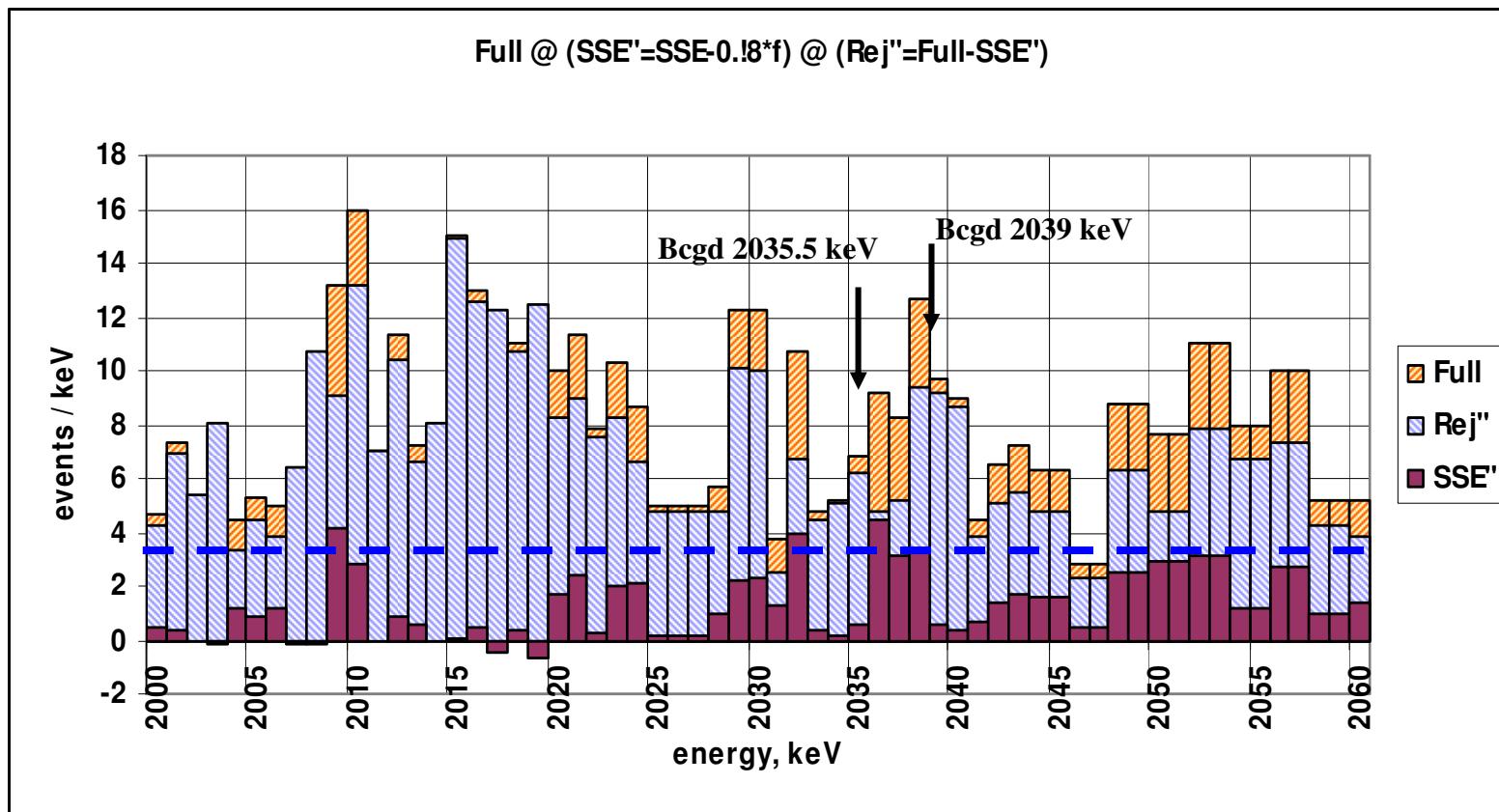


A correction of Klapdor results :

$$1. \text{ SSE}'' = \text{SSE} - 0.18 * \text{Full} \quad 2. \text{ Rej}'' = \text{Full} - \text{SSE}''$$

$$\text{SSE}''/\text{Full} = 0.157$$

It was indicated that the 2038 kev line had a complex origin [5]. It was produced by an overlapping of three unresolved peaks: ~2035.5 kev, ~2037.5 kev and ~2039.1 kev .



A further analysis of Klapdor results indicated that the 2038 kev line had a complex origin [5]. It was produced by an overlapping of three unresolved peaks: ~2035.5 kev, ~2037.5 kev and ~2039.1 kev . **So the above claim [1] and $T_{1/2}$ value were erroneous.**

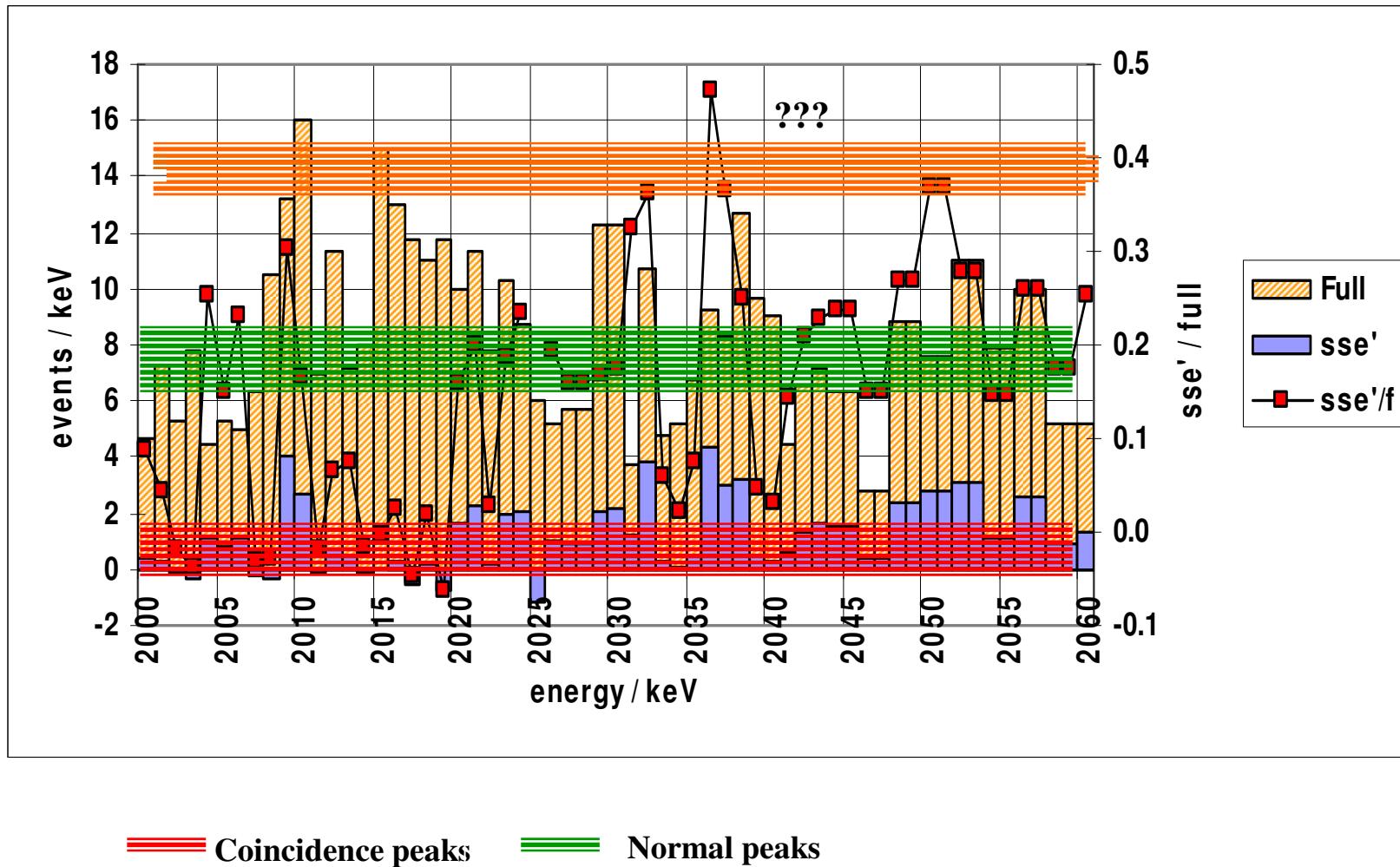
It was demonstrated that the 2038 keV line was a result of a superposition of three peaks : 2035.5, 2037.5 and 2039.1 keV. The 2035.5 kev and 2039.1 kev peaks were due to double-coincidences of gamma-quanta in the detectors. Only the 2037.5 kev line could be an expected signal of a $2\beta 0\nu$ -decay of 76-Ge .

The pulse-shape analysis of the data provided possibility to pick-out the 2037.5 keV line in the so called SSE spectrum. A number of events in the line decreased two times. and the new life-time was $T_{1/2}=1.98\times 10^{25}$ y .

This result was confirmed later (2006 y) by an improved pulse-shape analysis with the final life-time $T_{1/2}=(2.23+0.44-0.31)\times 10^{25}$ y.

Still an observed ≈ -1.5 keV shift of the peak position relative to the Q-value was a serious argument against the claim. The Q-value of the $2\beta 0\nu$ -decay of 76-Ge was known with a very high accuracy as $E=2039.0\pm 0.007$ keV . Attempts to explain the shift through law statistics or calibration uncertainties failed. It was necessary to understand a nature of this shift.

Отношения чисел событий в спектрах SSE'' / Full
SSE''= SSE – 0.18*Full



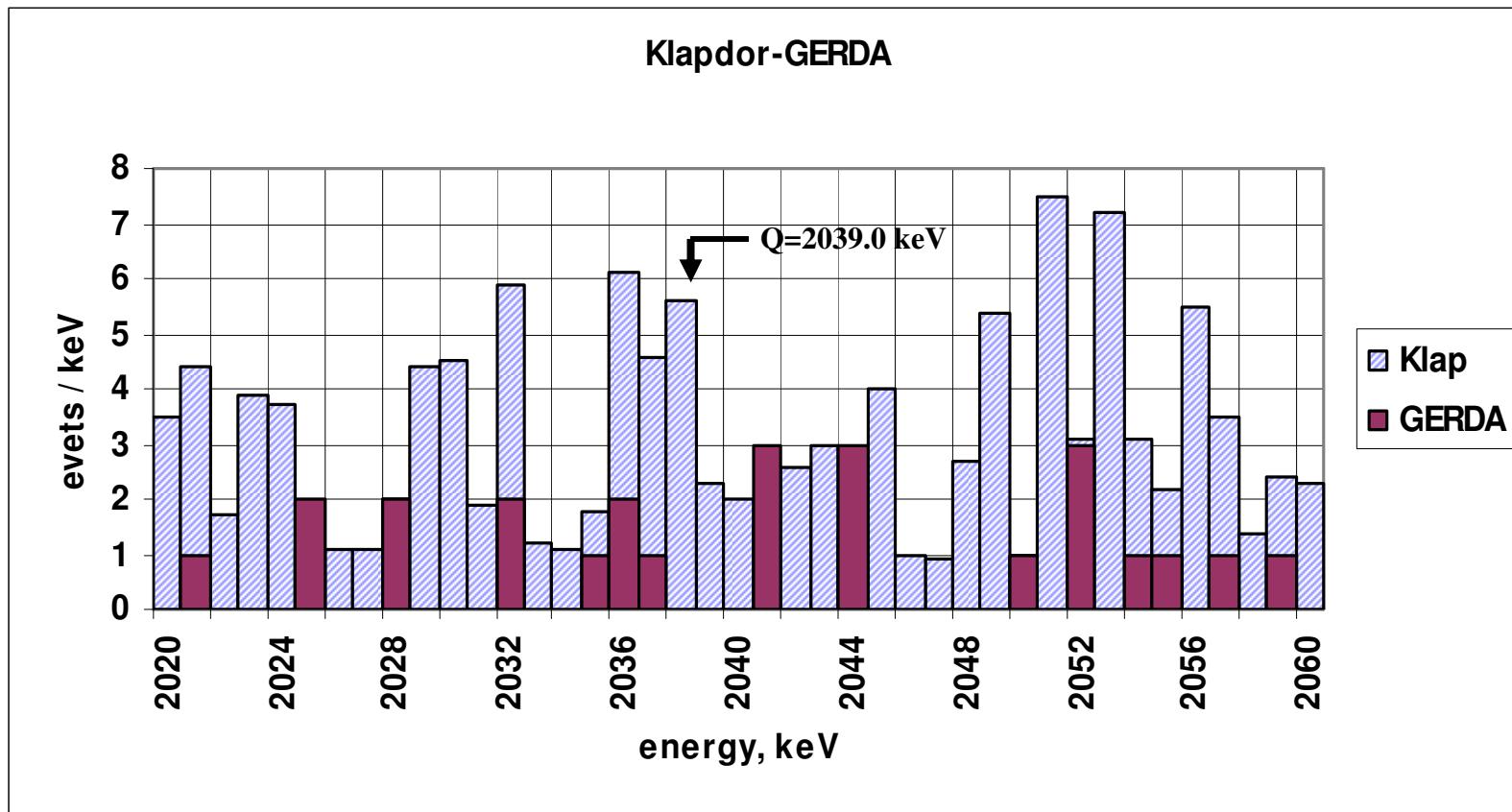
A comparison of Klapdor-HM (2004) and GERDA results. $Q=2039.07$ keV

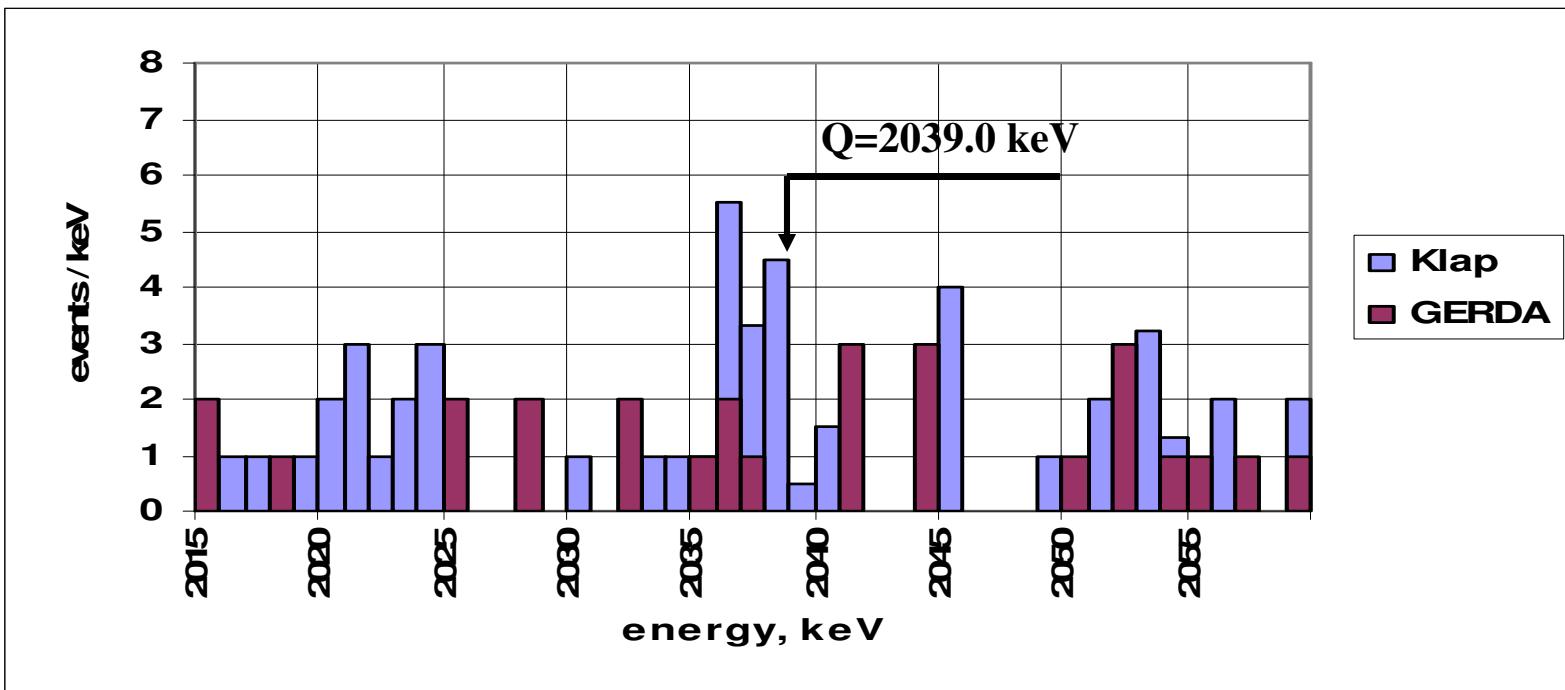
Klapdor-HM (SSE data). $M_t=51.39$ kg y). $T_{1/2}=2.0 \times 10^{25}$ y.

A position of the peak was $E = [2037.5 \pm 0.5(\text{stat}) \pm 1.2(\text{syst})]$ keV .

GERDA : full data ($M_t=21.6$ kg y).

Four events at the energy $E=2036.5$ keV were attributed to a background.





A comparison of Klapdor-HM (2006) and GERDA results.

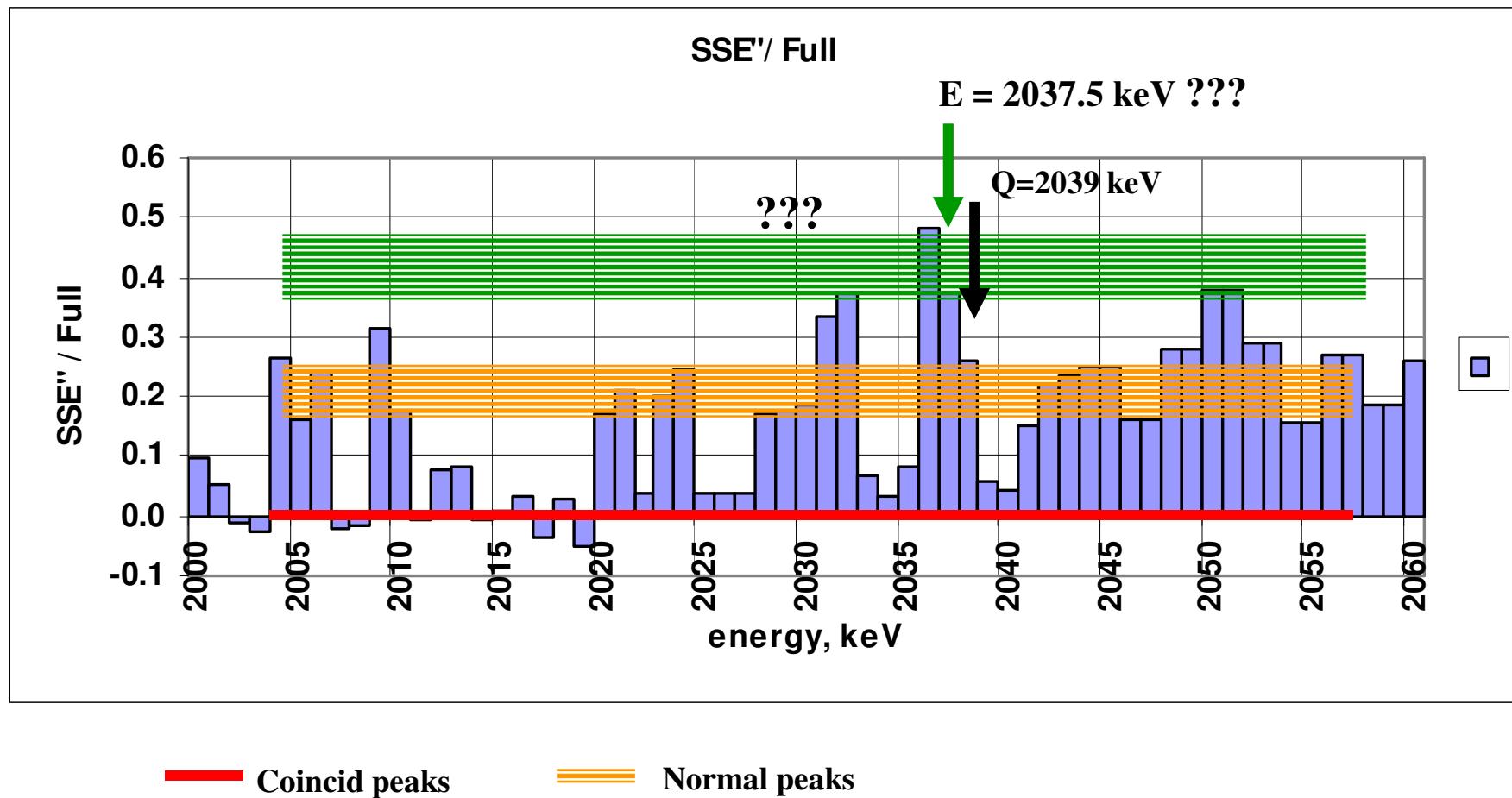
K-HM results : the “NN+low cut” spectrum [3]. A shift of the peak relative to the Q-value was $\Delta E = -1.5 \text{ keV}$. $T_{1/2} = 2.2 \times 10^{25} \text{ y}$.

GERDA : full data ($M_t = 21.6 \text{ kg y}$). Four events just at the predicted energy were attributed to a background [3].

The shift of the peak was a serious argument against the Klapdor claim for an observation of the $2\beta 0\nu$ -decay of ^{76}Ge

Отношения чисел событий в спектрах SSE'' / Full

$SSE'' = SSE - 0.18 * Full$



Calculations for Ge

Let us consider the most probable variant of the $2\beta 0\nu$ -decay of 76-Ge. Two electrons had equal energies $t=2039 \text{ keV}/2 = 1.0195 \text{ Mev}$. Their momentums were $p(e)2=t^2+2\cdot m(e)\cdot t = 2.081 \text{ MeV}^{**2}/c^{**2}$. Sum loss of energies of the two electrons was $\Delta E=2\cdot p(e)2/2\cdot m(p) = 2.081/938=2.22 \text{ кэв}$.

This value had to be corrected due to a distribution of single electron energies in the $2\beta 0\nu$ -decay process. The correction was rather small (~18 %) and the final shift of the signal was $\Delta E=-2.6 \text{ keV}$.

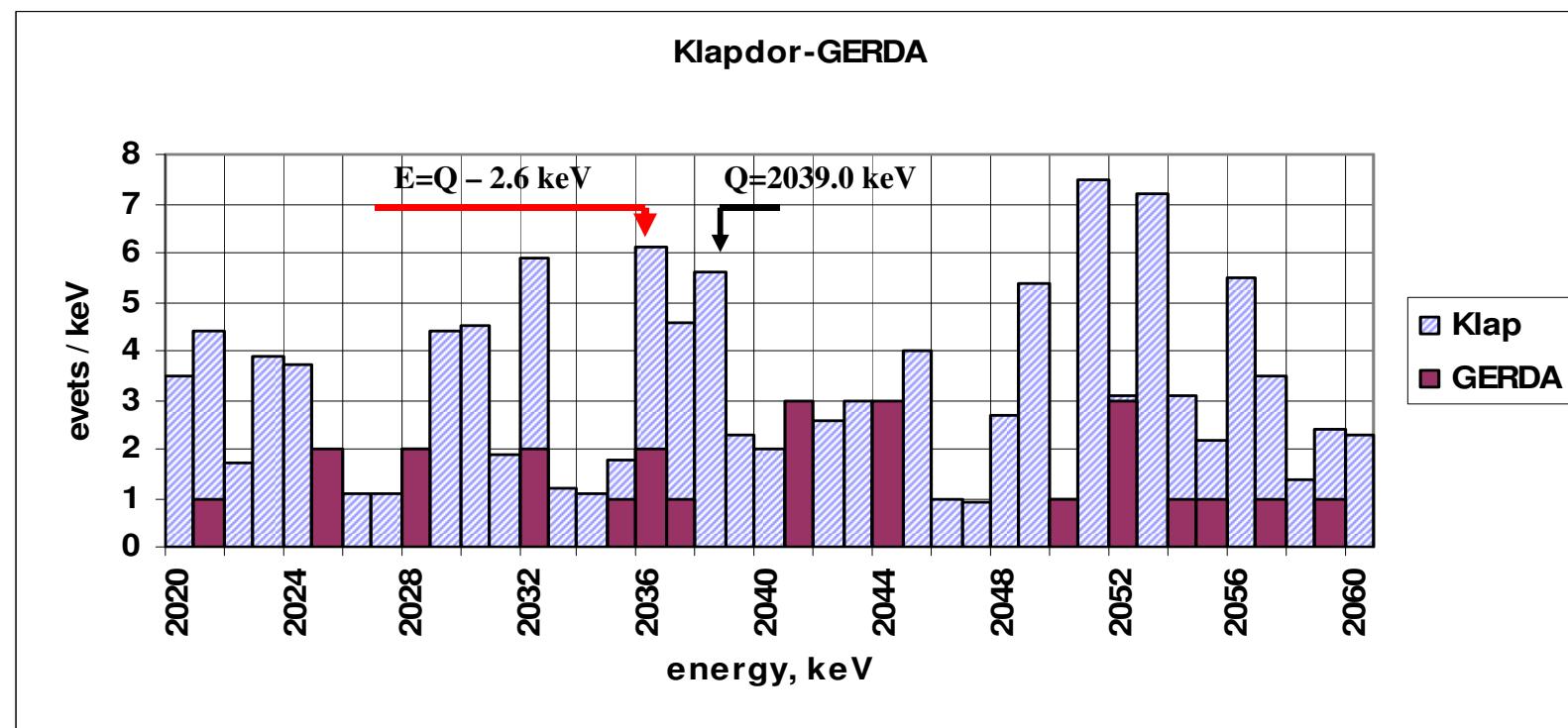
The value of shift could be calculated with a rather high accuracy as it was calculated directly and not as a difference of big numbers.

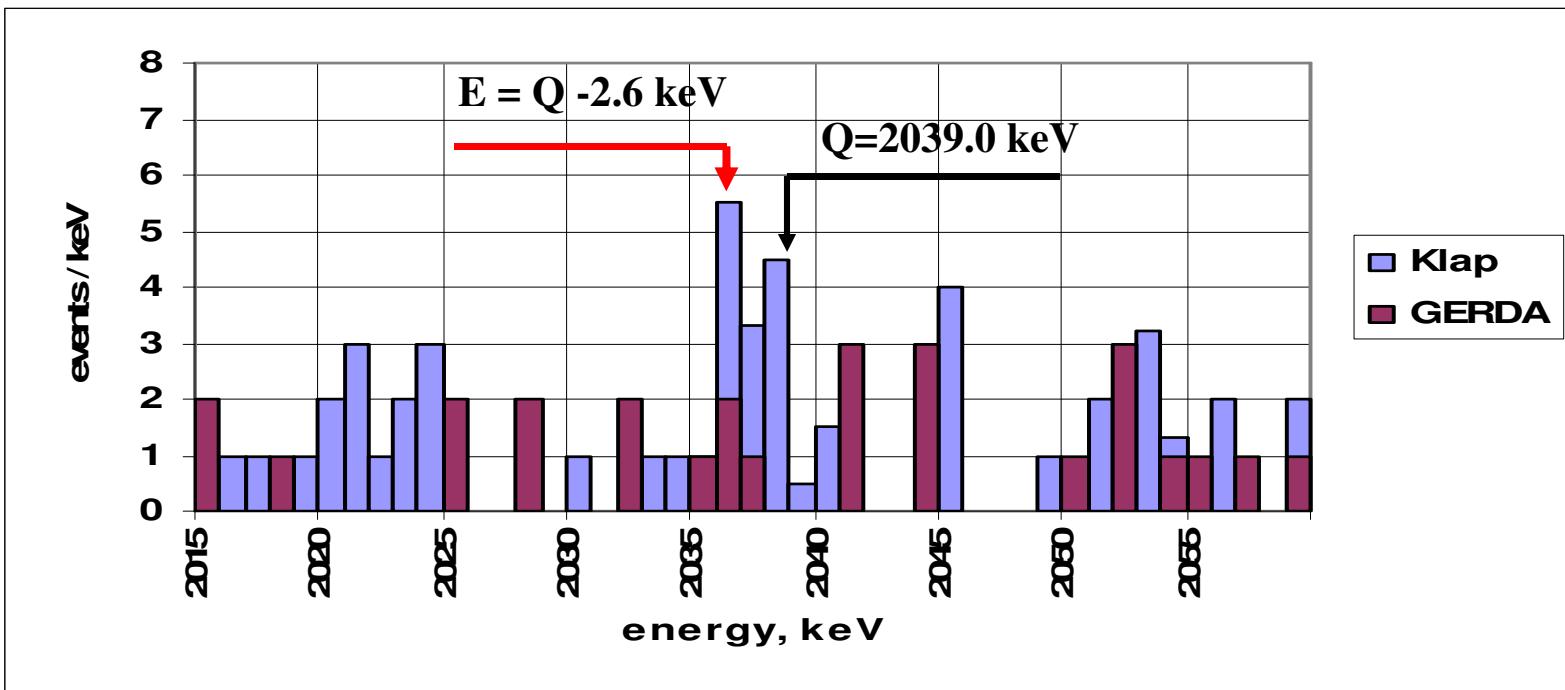
The calculated shift was $\Delta E = -2.6$ keV according to the new model . It was within an uncertainty of a calibration of K-M results (the SSE spectrum, $Mt=51.39$ kg y).

A shift of the peak relative to the Q-value was $\Delta E = -1.5$ keV . A position of the peak was $E = [2037.5 \pm 0.5(\text{stat}) \pm 1.2(\text{syst})]$ keV .

GERDA : full data ($Mt=21.6$ kg y). Four events just at the predicted energy were attributed to a background.

The model removed a very serious argument against the Klapdor's claim for an observation of a $2\beta 0\nu$ -decay of ^{76}Ge . An independent support of the hypothesis was given by an analysis of the published Cuoricino data [4,5]





Klapdor-HM (51.39 kg y, 2006 y) and GERDA (21.6 kg y, 2013 y) results.

$T_{1/2}=2.2 \times 10^{25}$ y (Klapdor).

GERDA : Four events just at the predicted energy were attributed to a background.

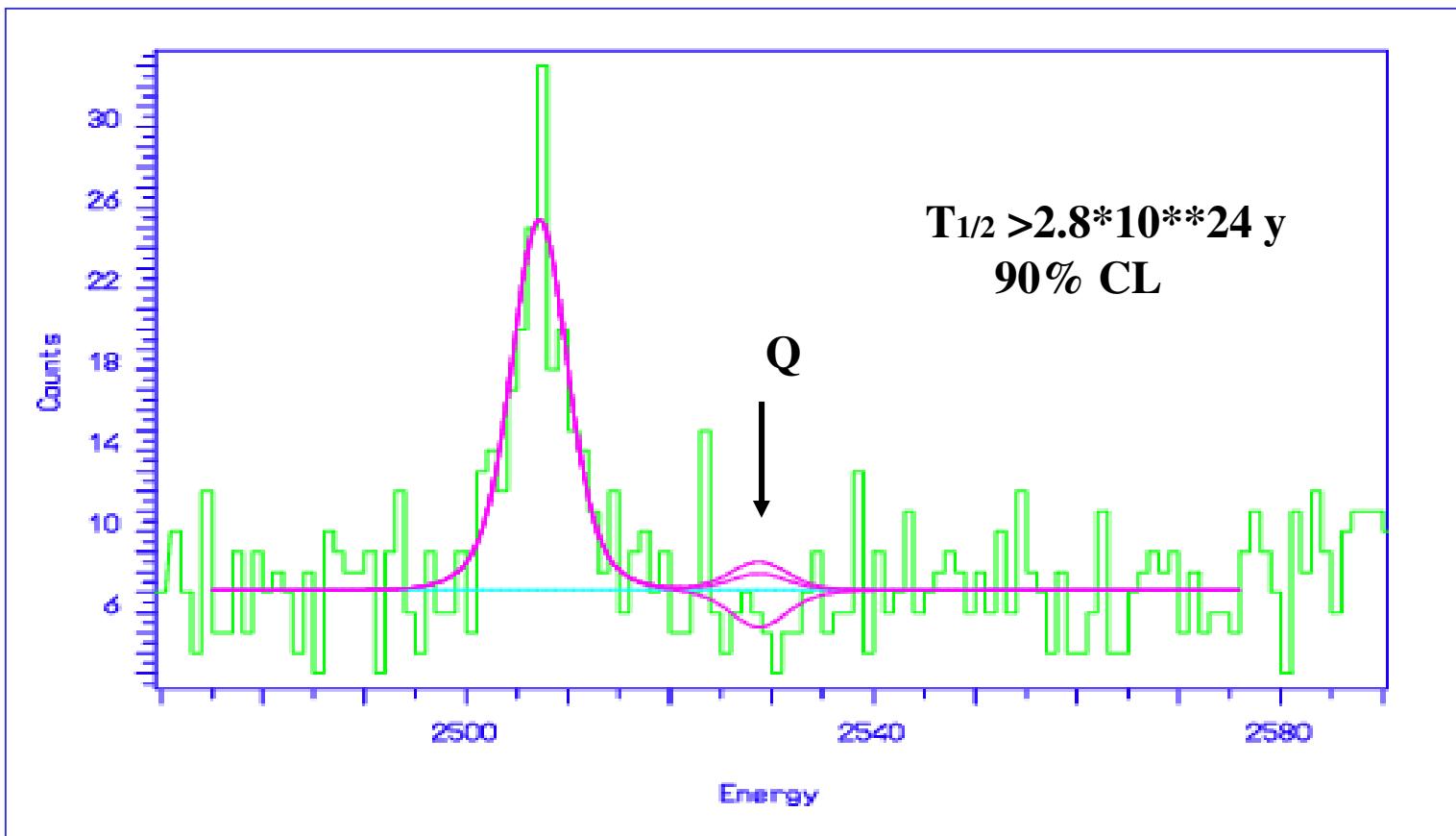
It was expected 3-4 events according Klapdor data.

CUORICINO

The project “Cuoricino” was devoted to a search for the $2\beta 0\nu$ -decay of ^{130}Te and was also, as the HM experiment, performed in LNGS, Italy. The first results were presented at the Neutrino-2004, Paris, by E.Fiorini . The final publication was in 2011 year. The bolometric detectors of TeO_2 (source = detector) were used with parameters close to those of the Heidelberg-Moscow device. The total mass of 62 detectors was 44.7 kg, which contained 34% of an active ^{130}Te isotope (active mass ~11 kg, to be compared with 10 kg in the case of HM). The energy resolution of the device was 7.2 keV FWHM at 2.6 MeV (3.4 keV FWHM at 2 MeV for HM). The last publication presented the total collected statistics 19.75 kg y. A signal of the $2\beta 0\nu$ -decay was searched at energies close to the Q value ($Q=2527$ keV).

No trace of the signal was found and only a limit for the process

$T_{1/2} > 2.8 \cdot 10^{24}$ y was claimed (90% CL).



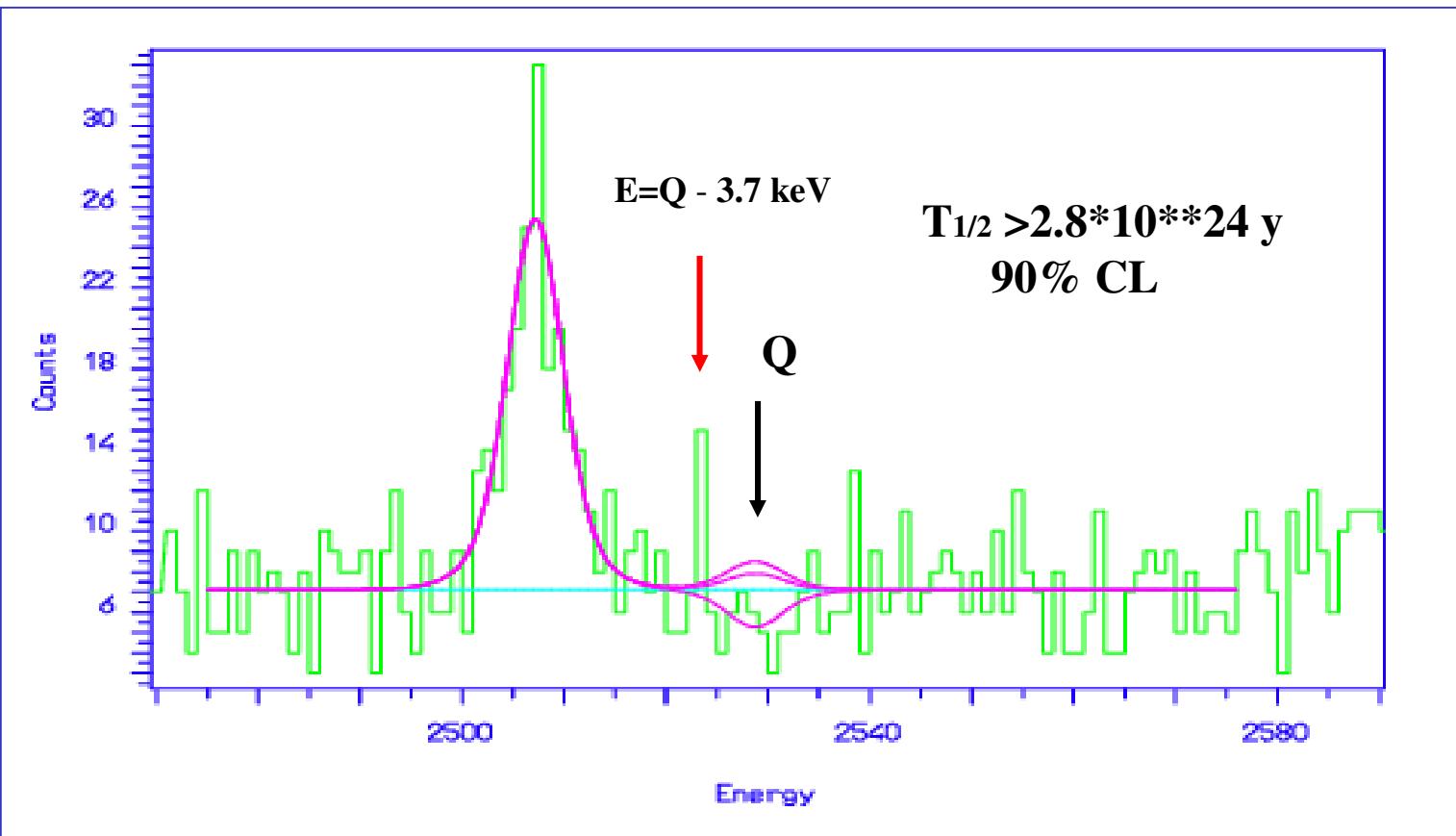
TAUP-07

Mt=11.83 kg y (Te-130). FWHM: 7 keV

Только 40% фона объяснялись вкладом комптона от пика 2614 кэв.

Остальное приписывалось неизвестным гамма-источникам.

C. Arnaboldi *et al.*, Physical Review C 78, 035502 (2008)



TAUP-07

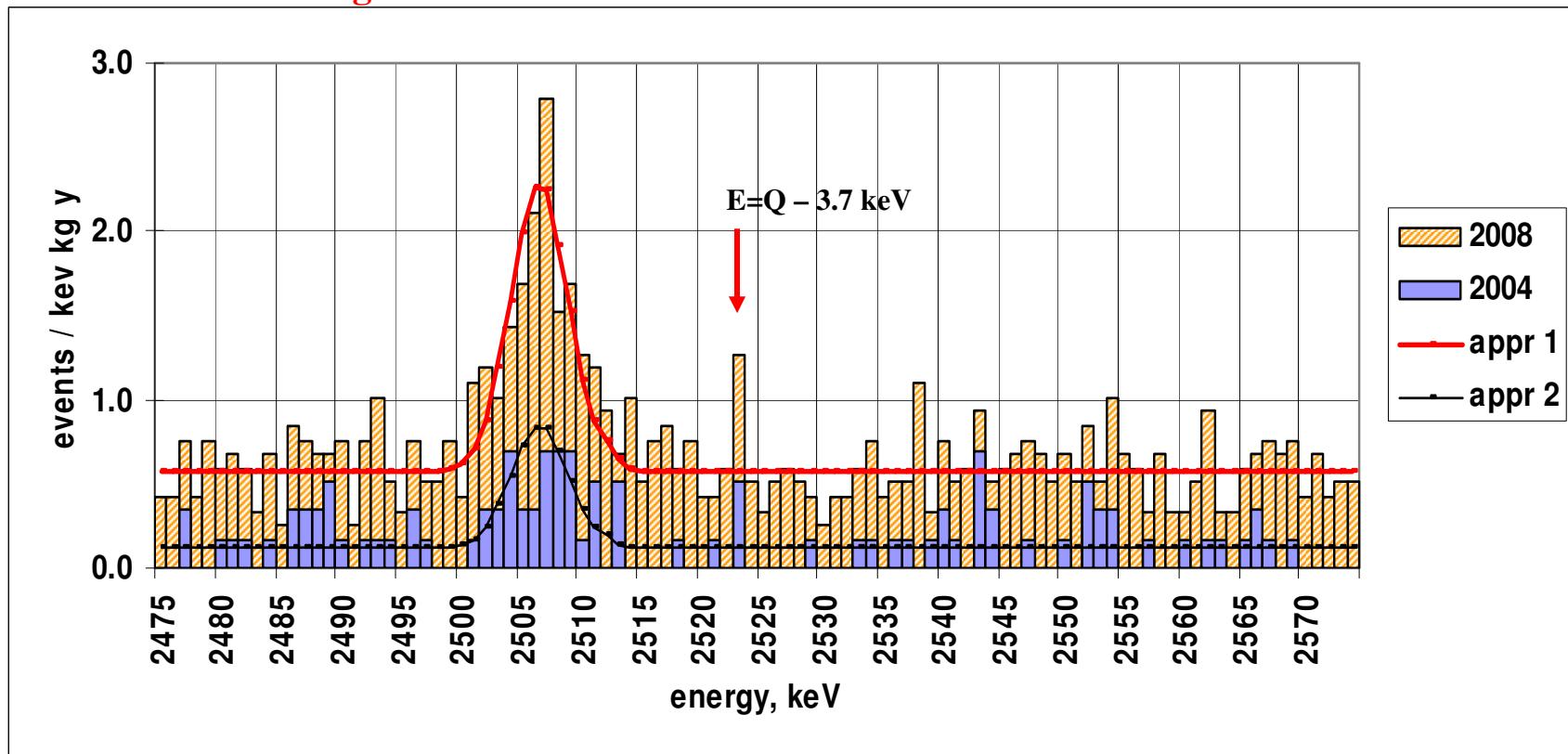
Mt=11.83 kg y (Te-130). Расчётный сдвиг $\Delta E = -3.7$ кэв. Интенсивность сдвинутого пика над фоном 8 событий. Это более чем в три раза превышает ошибку фона. На то, что это не случайный выброс, указывают результаты первого представления на Neutrino-2004

A comparison of the 2004 year and 2008 year Cuoricino data.

The data were normalized through Mt values (5.8 kg y and Mt=11.83 kg y).

A significant change of the background was indicated. An intensity of the both components in the 2004 y data was ~3.5 times less then in all further exposures. Flat components were calculated as a mean background (peak at E=2506 keV was excluded). The approximation 2 was given by E.Fiorini.

The shifted peaks have the same normalized intensities in both the spectra in spite of quite different levels of backgrounds.

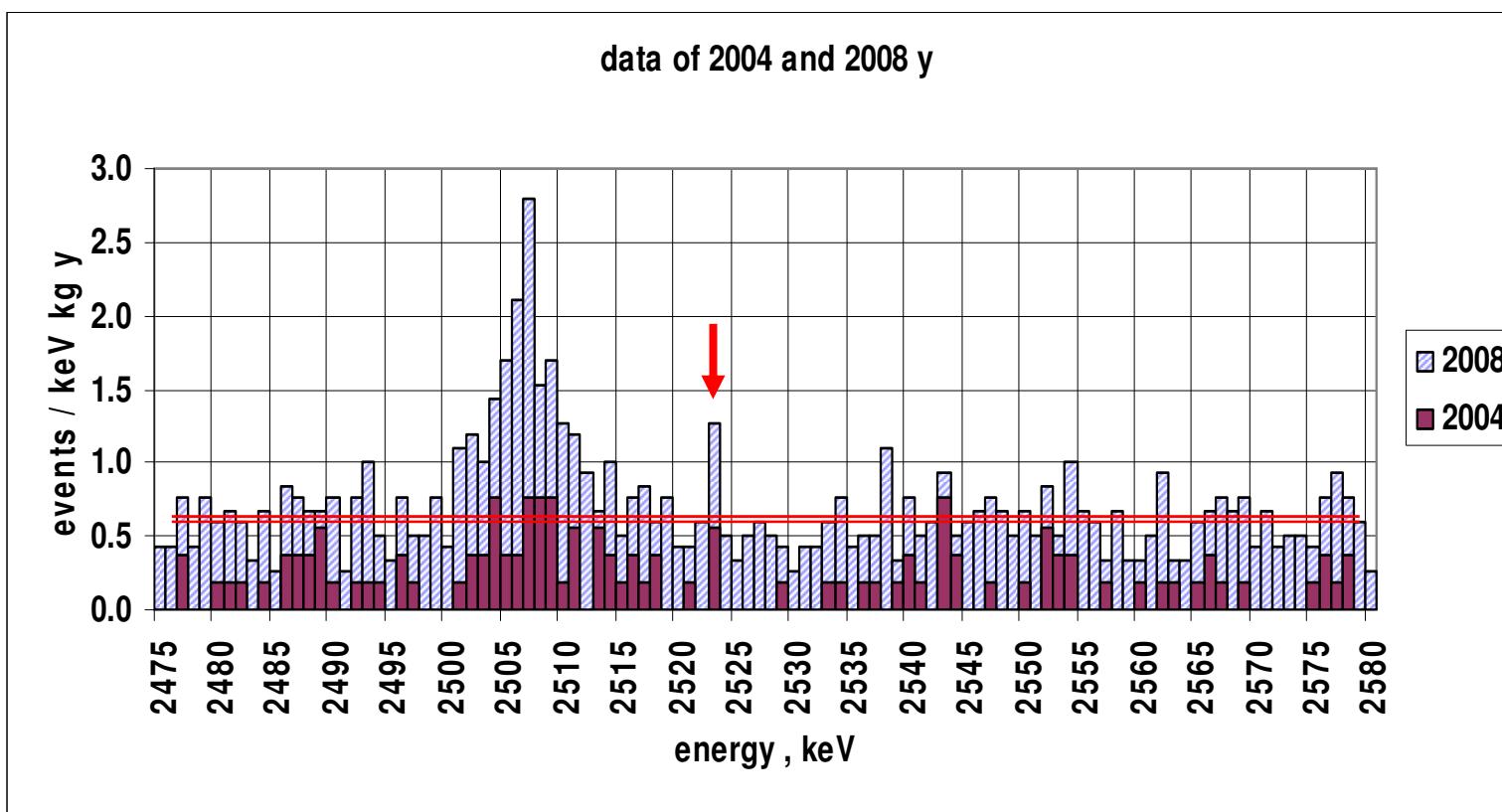


A comparison of the 2004 year and 2008 year Cuoricino data.

The data were normalized through Mt values (5.29 kg y and Mt=11.83 kg y).

A significant change of the background was indicated. An intensity of the both components in the 2004 y data was ~3.5 times less than in all further exposures. Flat components were calculated as a mean background (peak at E=2506 keV was excluded).

The shifted peaks have the same normalized intensities in both the spectra in spite of quite different levels of backgrounds.



An attempt to get a shape of the single 2023.5 keV line [8].

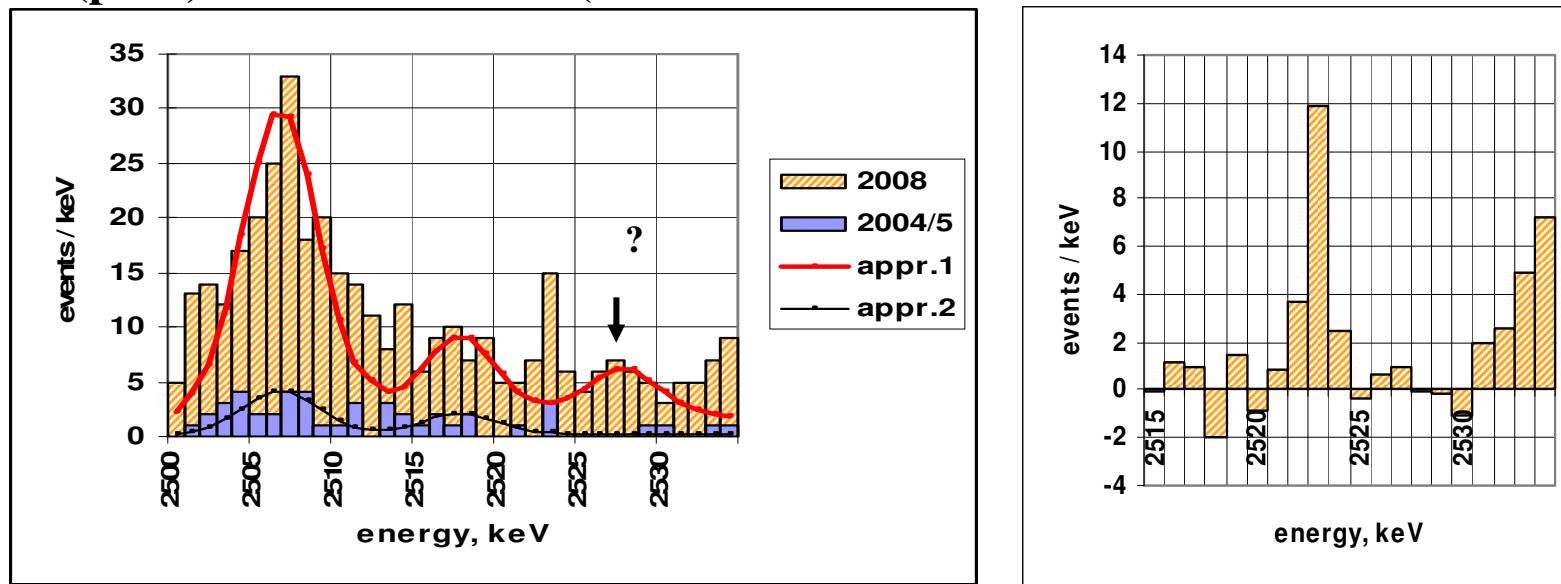
5a. A lower part : the data 2004/5 [5b] were used instead of [5a]. It included some other choice of exposures. The main difference was an existence of a bunch of events (11 counts) at 2017 keV - an extra gamma line ? A presence of this gamma-line was indicated also in the 2008 y data.

The approximations 1 took into account possible levels at 2017.5 and 2027 keV . Parameters of the peaks were chosen rather arbitrary (except for widths w=7.2 keV) to reproduce the experimental piece of the spectrum .

Flat components were calculated according [8] as belonging to the 2.6 MeV peak.

5b. The difference “data 2008 minus approximation 1”

$$S(\text{peak}) = 18.5 \text{ events/5 ch}(\#2521-2525)$$

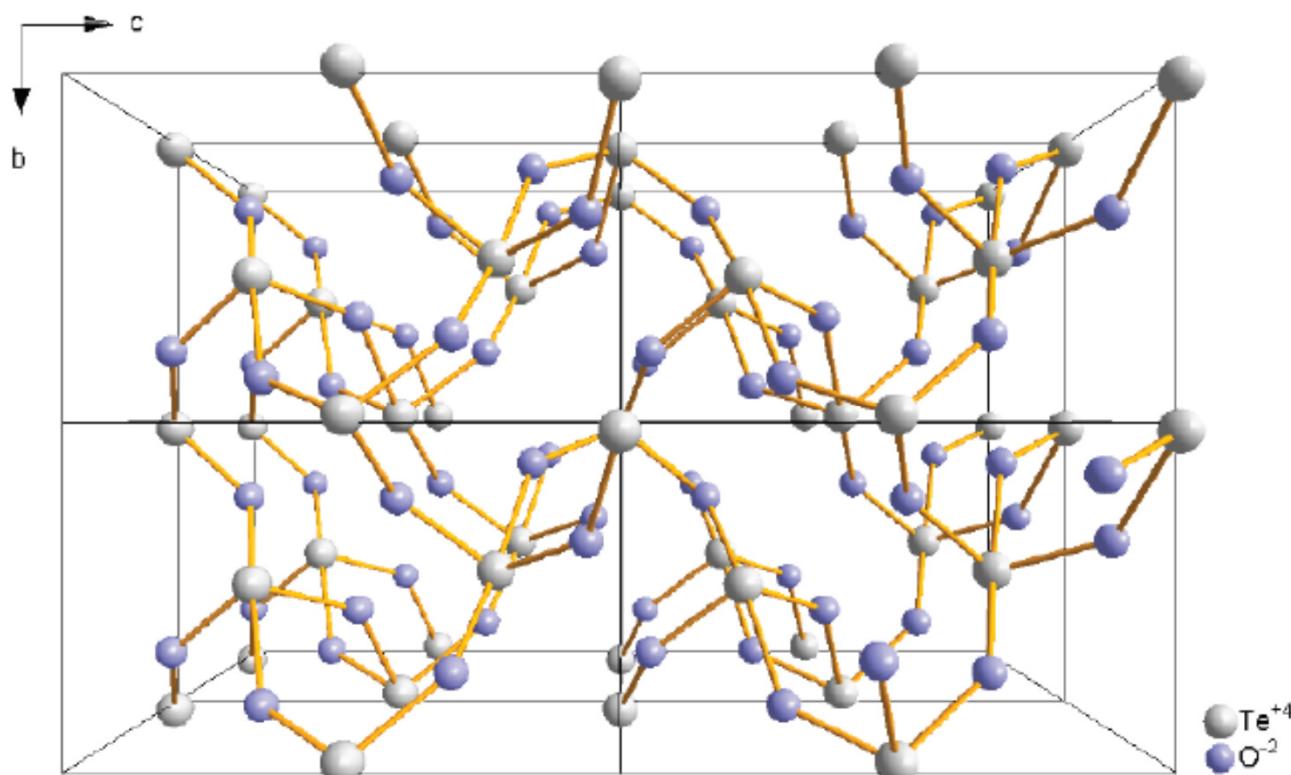


The shifted signal in a bolometric detector could be seen only if a part of active agents left the detector. And it was possible due to a TeO₂ crystal structure, which provided a possibility for a canalization of low -energy gamma-rays (X-rays).

TeO₂ crystal viewed along a-axis:

a=0.550 nm, b=1.175 nm, c=0.559 nm. 8 units in the cell

$\lambda/2\pi = 5.33 \times 10^{-9}$ cm (e=3.7 keV)



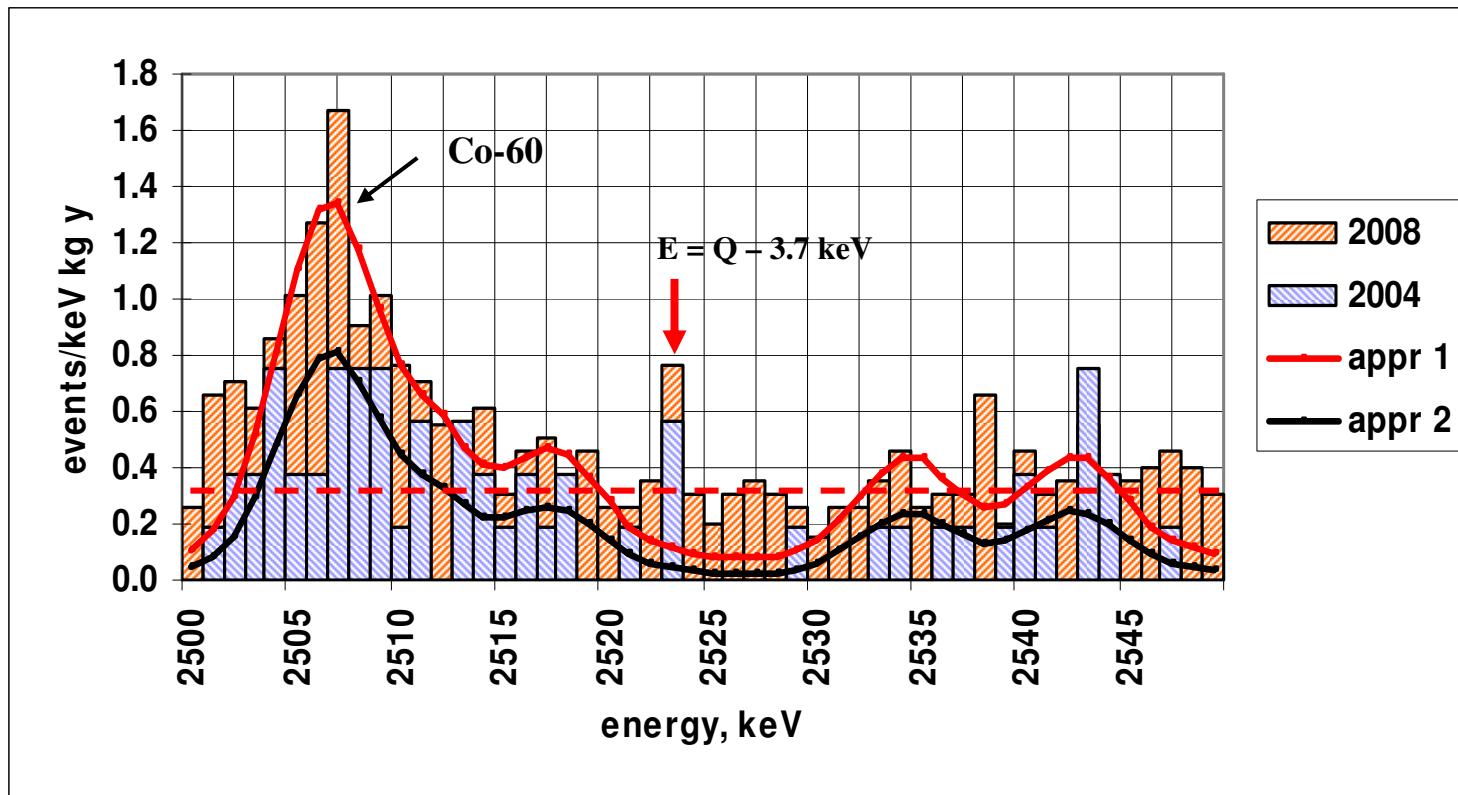
The total signal of a detector should include both the components, the shifted and non-shifted ones. An attempt was made to get a more realistic shape of the line. Results of the attempt were presented at the figures. A presence of the two peaks were clearly indicated (the existence of the non-shifted peak at 2527 keV was found earlier but was attributed to a background). The width of the 2527 keV line seemed noticeably less (≈ 4 keV) than the widths of the normal gamma-peaks (7.2 keV).

It confirmed a particular nature of the line and could be connected with its origin as the $2\beta 0\nu$ -signal.

An attempt to get the full signal. The data and approximations.

An existence of a background levels at 2012 , 2015, 2035 and 2043 keV was supposed. A presence of these levels was indicated in both the spectra . Energies of the levels and intensities were chosen arbitrary ones to reproduce the experimental data.

The slow varying components were postulated as belonging to 2615 keV levels
(0.136 events/keV kg y and 0.026 events/keV kg y)



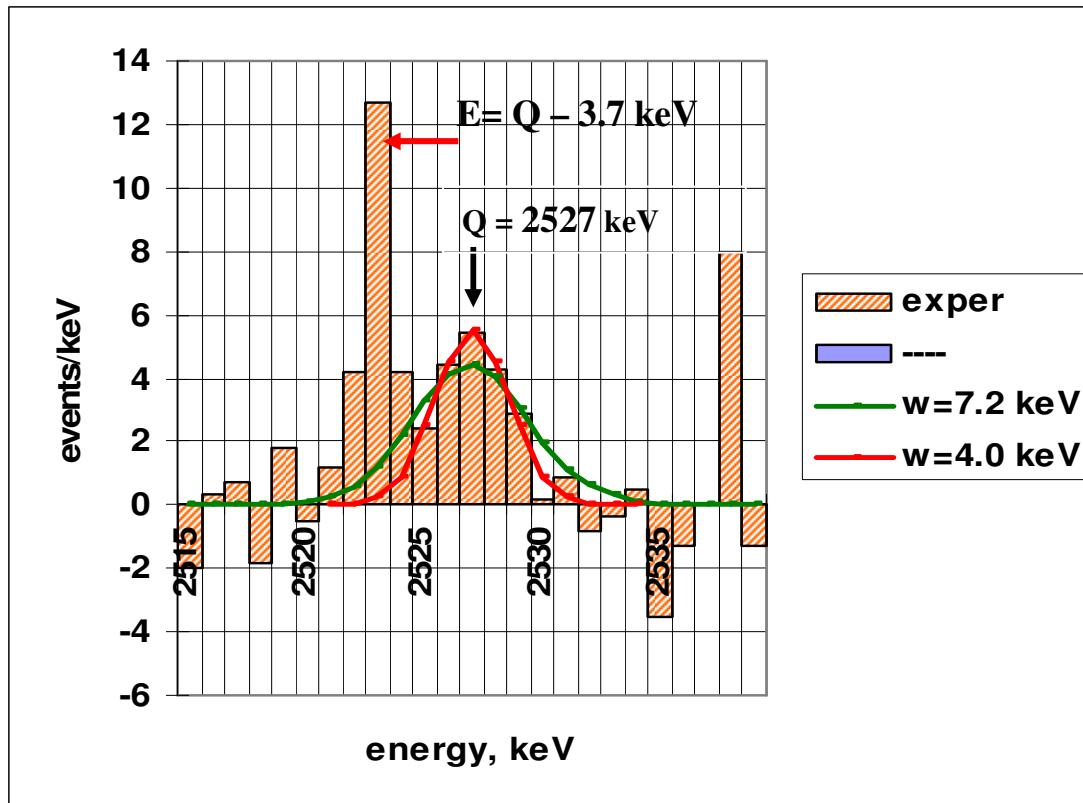
The full shape of the signal.

A difference between the data 2008 and the approximation
(5 levels+1.6 events/keV).

A width of 2527 keV line was about 4 keV (7.2 keV for the normal gamma-lines).

The total intensity of the line was $N(\text{sign}) = 44.6 \pm 8.1(\text{stat}) \pm 4.6(\text{syst})$ events

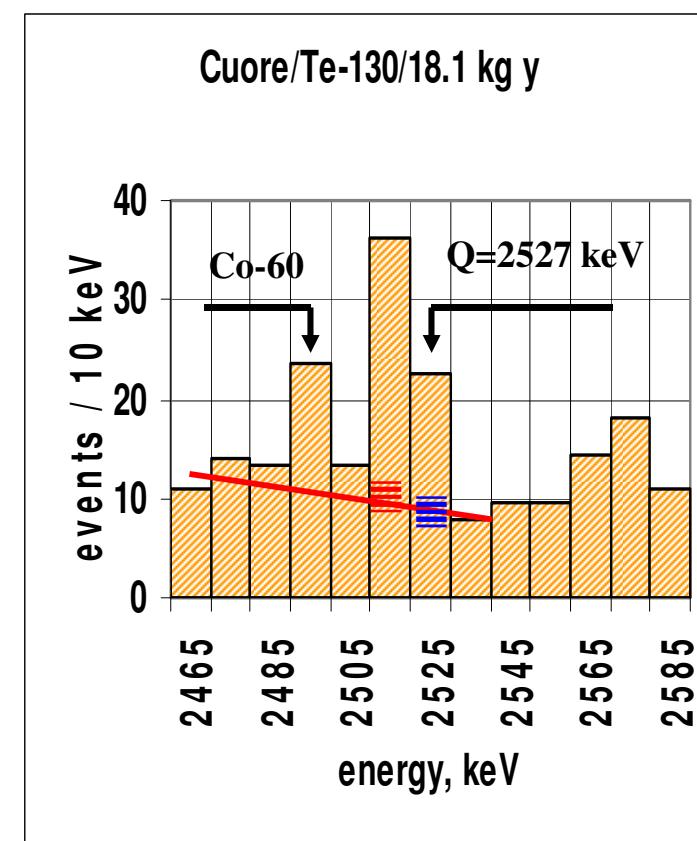
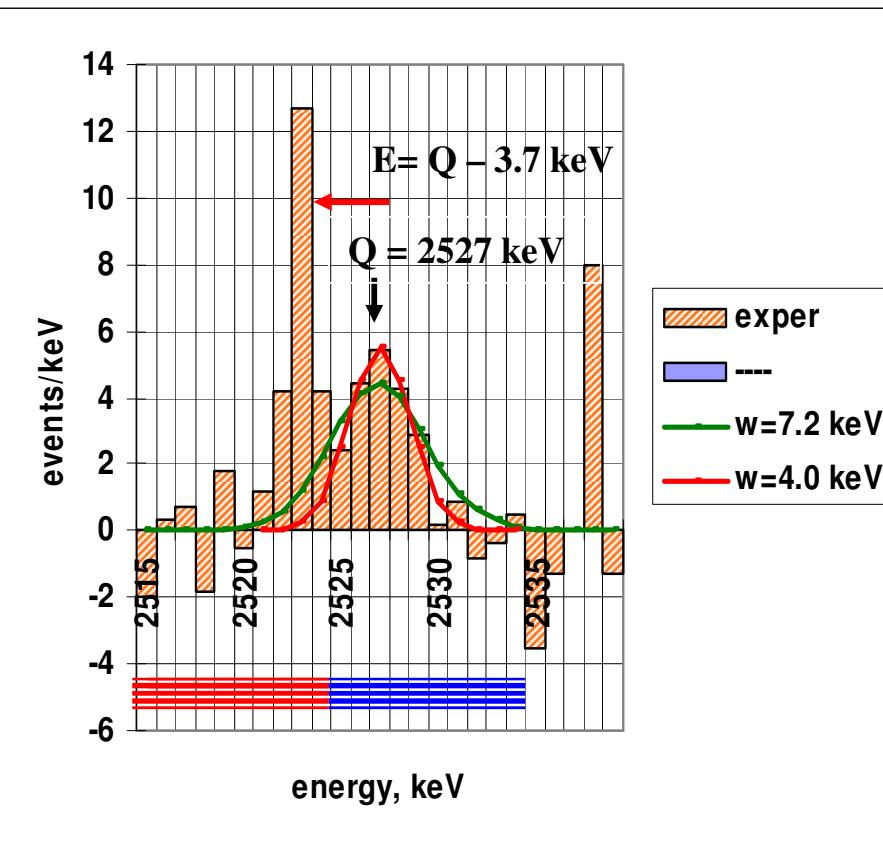
It corresponded $T_{1/2} = 1.0 \times 10^{24}$ y (data of 2004+2008 , $M_t = 17.04$ kg y).



Cuoricino (2008 y) and Cuore (summer 2014 y) results

$N = (44.6 \pm 8.1 \pm 4.6)$ соб / 17.04 kg y = (2.6 ± 0.7) соб кг год [T_{1/2}=1.0*10**24 лет]

$N = (43 \pm 7.5)$ соб / 18.1 kg y = (2.4 ± 0.4) соб кг год [T_{1/2}=1.1*10**24 лет]



All results of the investigation are summarized in the table I. The table contains the calculated shifts ΔE and the results of the proper experiments ΔE_{exper} . It includes also the expected result of a project AMoRe [8]. Still one should remember that the intensity of the shifted gamma-line and the possibility to observe it depends on the type (structure) of the crystal which was used in the experiment.

Table I. All numbers in [keV]

decay	$Q_{\beta\beta}$	$E_{\beta\beta}$	ΔE_{calc}	ΔE_{exp}	$T_{1/2}$, years
76-Ge \rightarrow 76-Se enriched Ge	2039.0 ± 0.005	$2037.5 \pm 0.5(\text{stat}) \pm 1.2(\text{syst})$ [Klap] ≈ 2036.5 [gerda]	-2.6	-1.5 -2.5	$2.2 \cdot 10^{25}$
130-Te \rightarrow 130-Xe bolometric detector	≈ 2527	≈ 2023.5 [2004+2005]	-3.7	≈ -3.5	$1.0 \cdot 10^{24}$
100-Mo \rightarrow 100-Ru bolometric detector	≈ 3531	a project	-4.7	???	???

*) ΔE_{calc} – calculated with $[(p_1)^2 + (p_2)^2] / 2 \cdot m(p)$ **) ΔE_{exp} – experiment

Coincidences of the predicted shifts with the results of analysis of the experimental data for ^{76}Ge and ^{130}Te strongly support the hypothesis under discussion.

C o n c l u s i o n

The investigation pointed out definitely that the $2\beta 0\nu$ -decay does exist and has been experimentally observed ten years ago in the two experiments.

The life-time for $2\beta 0\nu$ -decay of $^{130}\text{-Te}$ was $T_{1/2}=1.0 \cdot 10^{24}$ years.

The life-time for $2\beta 0\nu$ -decay of $^{76}\text{-Ge}$ was $T_{1/2}=2.2 \cdot 10^{25}$ years.

Коррекция модели $2\beta 0\nu$ -распада

Для начала отметим, что сигнал $2\beta 0\nu$ -распада смещён относительно значения $Q\beta\beta$ в любом случае. Распадаются два нейтрона, связанных обменом виртуальным нейтрино. Электроны уносят импульсы , p_1 and p_2 , несколько МэВ/с каждый. Импульсы отдачи рождённых электронов передаются ядру-продукту. В случае, *если ядро воспринимает их как целое*, потеряянная электронами энергия $\epsilon \approx [(p_1)^{**2} + (p_2)^{**2}] / 2 \cdot M(Z)$, где $M(Z)$ есть масса ядра-продукта. Эта величина составляет несколько сотых долей кэВ и не может быть обнаружена экспериментально (преобразуется в кинетическую энергию ядра)

Так было бы, если бы импульсы электронов передавались ядру-продукту как целому. Но так ли это ? Распадаются два нейтрона и одновременно рождаются две пары (протон + электрон). Логично предположить, что «новорожденные» электроны делят свои импульсы с соответствующими «новорожденными» протонами. Суммарная потеря энергии электронами этом случае :

$$\Delta E = M(Z) \cdot \epsilon = [(p_1)^{**2} + (p_2)^{**2}] / 2 \cdot m(p) ,$$

где $m(p)$ есть теперь масса протона . Это на два порядка больше чем в первом варианте, и величина ΔE составляет теперь несколько кэВ.

Обмен запрещён законом сохранения энергии/импульса. Обсуждаемая модель предполагает , что два «новорожденных» протона в процессе преобразования ядра $Z(z,n) \rightarrow Z(z+2,n-2)$ образуют виртуально возбуждённое ядро, с энергией возбуждения, достаточной для того, чтобы не только преодолеть потенциальный барьер на пути $2\beta 0\nu$ -распада, но и сделать возможным обмен импульсами между электронами и протонами. Ядро передаёт энергию возбуждения оболочкам атома-продукта, решая таким образом проблему отсутствия возбуждённых состояний ядра-продукта. При этом электронные оболочки атома-продукта возбуждаются . Возникшее в результате $2\beta 0\nu$ -распада ядро образуется в основном состоянии, однако *новый атом образоваться в стабильном состоянии не может.*

Энергия возбуждения может быть оценена как разность суммарных энергий электронов на оболочках начального и конечного атомов, то есть ΔE составляет несколько кэв.

Отношение $\Delta E/Q_{\beta\beta} \approx 10^{**-3}$, но источник этой энергии должен существовать. И таким «источником», видимо, и является обмен импульсами между «новорожденными» электронами и соответствующими «новорожденными» протонами.

Энергия электронов оболочки зависит только от числа протонов в ядре. При $2\beta 0\nu$ -распаде ядро увеличивает заряд сразу на две единицы. Но атом сохраняет на оболочках прежнее число электронов, так как **два «новорожденных» электрона покидают ядро не встраиваясь в систему электронных оболочек атома-продукта.** В результате число электронов в атоме на две единицы меньше, чем должно быть в конечном нейтральном атоме $A(z+2,n-2)$. Но ядро+атом – квантовая система, и z -электронов приобретают энергию, достаточную для перехода в новое состояние ($z+2$) электронов. Несколько электронов переходят на более высокие оболочки, и атом $A(z+2,n-2)$ возбуждается. При этом энергия возбуждения ΔE может быть снята только в виде рентгеновского излучения. Испускание электрона энергетически невыгодно, поскольку при этом дефицит числа электронов возрастает.

Передача может быть эффективно осуществлена путём электромагнитного взаимодействия, так как электронные орбиты потенциально $2\beta 0\nu$ -активных атомов частично лежат внутри их ядер.

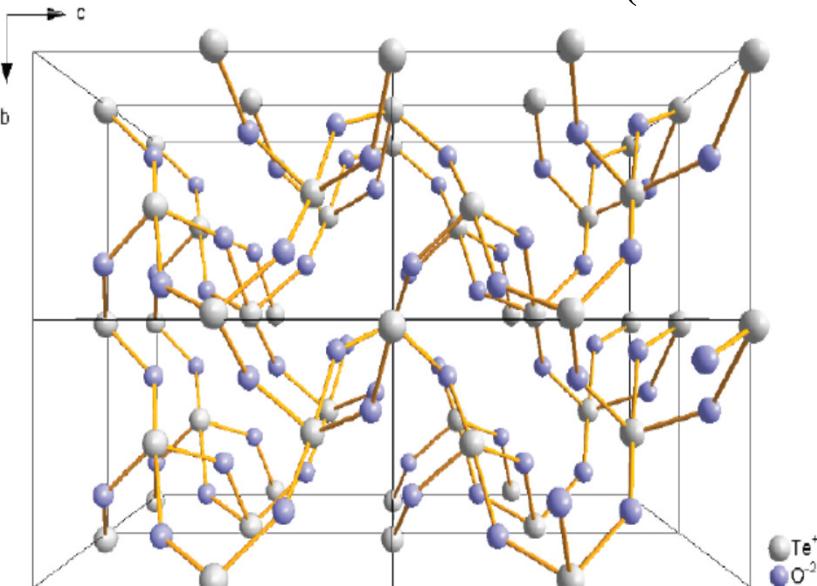
Испускание X-лучей приводит к частичному сдвигу сигнала $2\beta 0\nu$ -распада относительно $Q_{\beta\beta}$. При этом вид сигнала (его форма) зависит от используемого при измерениях детектора.

Сигнал , появляющийся в Ge детекторе при захвате гамма-кванта с энергией порядка кэв , видимо, намного меньше чем отклик на электрон с такой же энергией. Видимый суммарный сигнал детектора будет поэтому меньше суммарной энергии, выделенной в детекторе, практически на величину ΔE .

Болометрический детектор регистрирует изменение температуры кристалла, независимо от того, чем это изменение вызвано. Поэтому сдвиг сигнала говорит о том, что часть гамма-квантов вылетела из детектора. И эта возможность обеспечивается эффектом канализации гамма-квантов низких энергий в структурах кристалла TeO₂ [6]

Вид кристалла вдоль оси а: a=0.550 nm, b=1.175 nm, c=0.559 nm.

8 units in the cell $\lambda/2\pi = 5.33 \times 10^{-9}$ cm (e=3.7 keV)

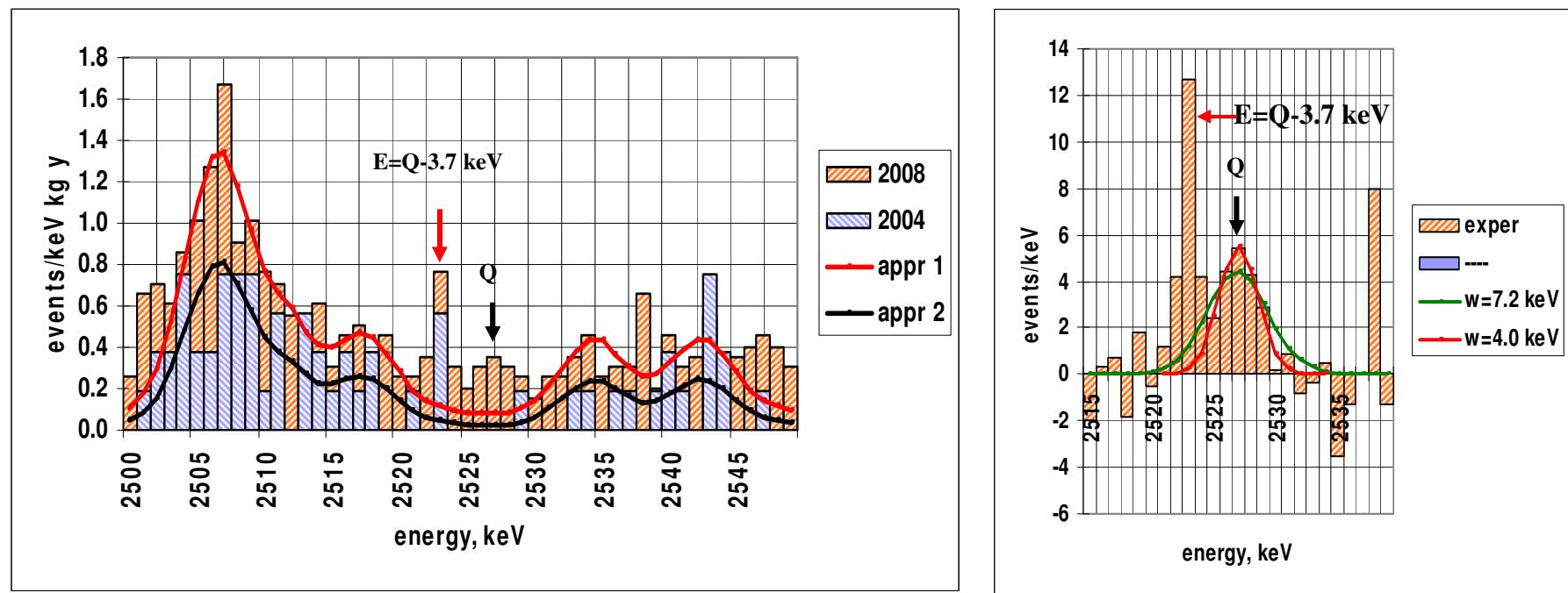


An attempt to get a full shape of the signal [9].

6a. The data [4,5b] and approximations. An existence of a background levels at 2012 , 2015, 2035 and 2043 keV was supposed. A presence of these levels was indicated in both the spectra . Energies of the levels and intensities were chosen arbitrary ones to reproduce the experimental data. The slow varying components were postulated as belonging to 2615 keV level.

6b. A difference between the data 2008 [4] and the approximation (4 levels+1.57 events/keV).

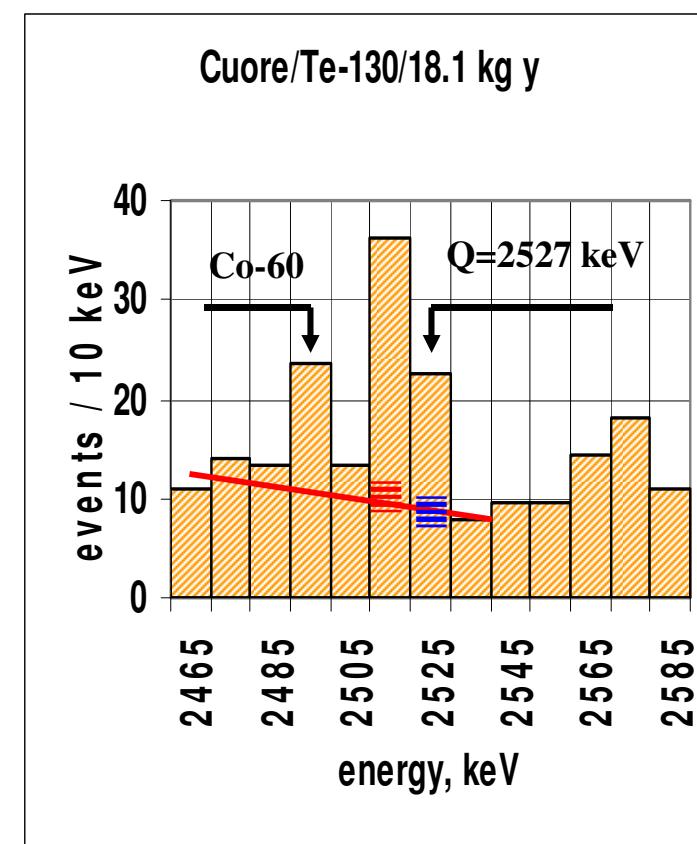
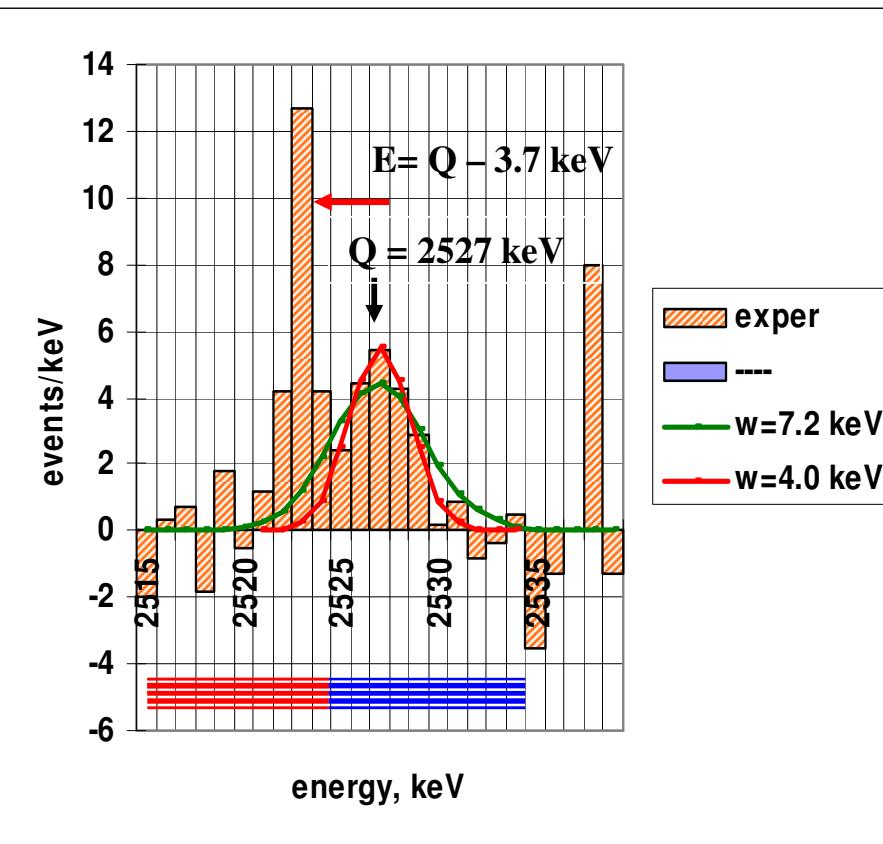
A width of 2527 keV line was about 4 keV (7.2 keV for the normal gamma-lines).



Cuoricino (2008 y) and Cuore (summer 2014 y) results

$N = (44.6 \pm 8.1 \pm 4.6)$ соб.кг год / 17.04 kg y = (2.6 ± 0.7) соб.кг год [T_{1/2}=1.0*10**24 лет]

$N = (43 \pm 7.5)$ соб.кг год / 18.1 kg y = (2.4 ± 0.4) соб.кг год [T_{1/2}=1.1*10**24 лет]



All results of the investigation are summarized in the table I. The table contains the calculated shifts ΔE and the results of the proper experiments ΔE_{exper} . It includes also the expected result of a project AMoRe [10]. Still one should remember that the intensity of the shifted gamma-line and the possibility to observe it depends on the type (structure) of the crystal which was used in the experiment.

Table I. All numbers in [keV]

decay	$Q_{\beta\beta}$	$E_{\beta\beta}$	ΔE_{calc}	ΔE_{exp}	$T_{1/2}$, years
76-Ge \rightarrow 76-Se enriched Ge	2039.0 ± 0.005	$2037.5 \pm 0.5(\text{stat}) \pm 1.2(\text{syst}) \text{ keV [KI]}$ $\approx 2036.5 \text{ [gerda]}$	-2.6	-1.5 -2.5	$2.2 \cdot 10^{25}$
130-Te \rightarrow 130-Xe bolometric detector	≈ 2527	$\approx 2023.5 \text{ [2004+2005]}$	-3.7	≈ -3.5	$1.0 \cdot 10^{24}$
100-Mo \rightarrow 100-Ru bolometric detector	≈ 3531	a project	-4.7	???	???

*) ΔE_{calc} – calculated with $[(p_1^2 + p_2^2) / 2 \cdot m(p)]$ **) ΔE_{exp} – experiment

Coincidences of the predicted shifts with the results of analysis of the experimental data for ^{76}Ge and ^{130}Te strongly support the hypothesis under discussion.

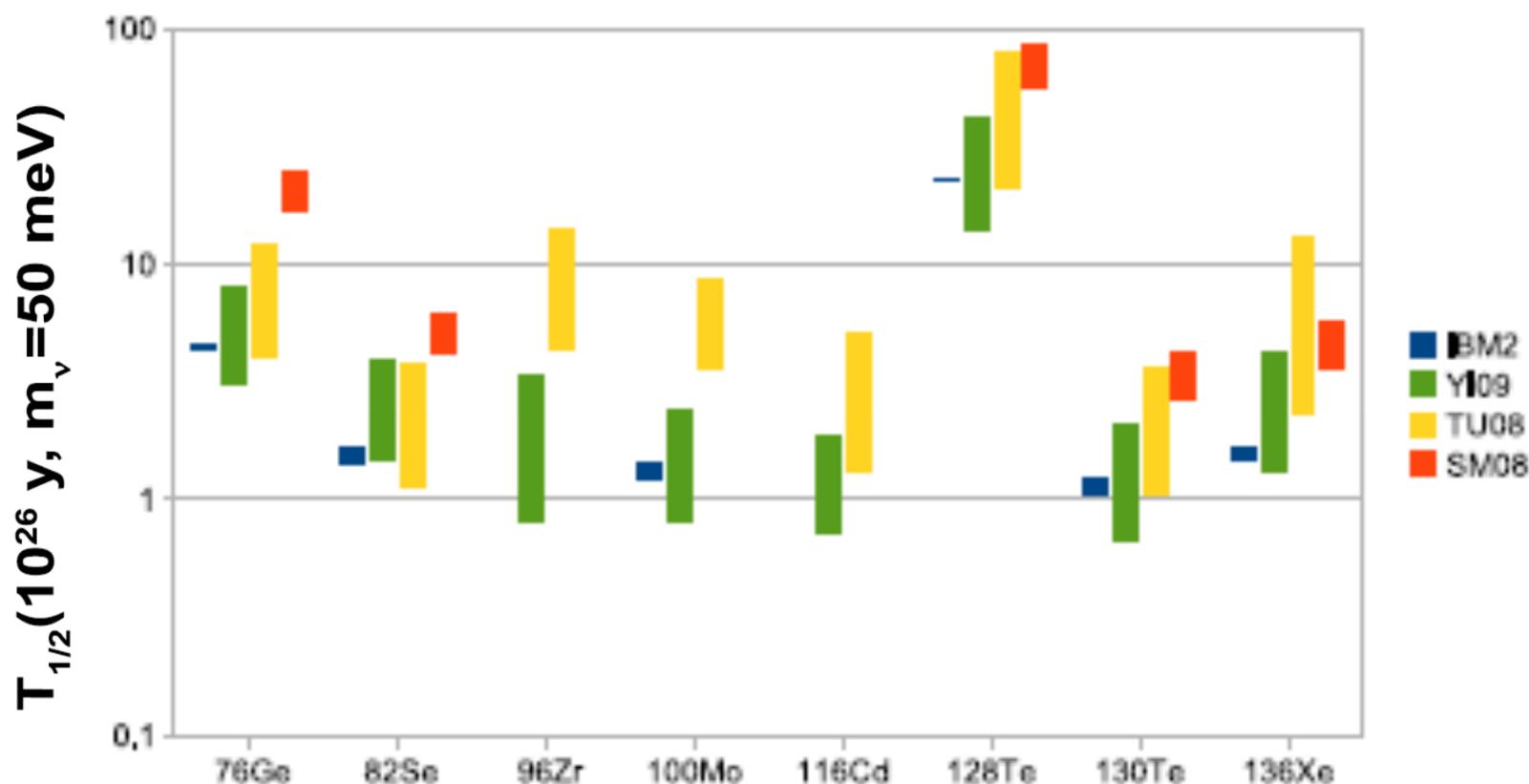
Заключение

Coincidences of the predicted shifts with the results of analysis of the experimental data for 76-Ge and 130-Te strongly supported the hypothesis under discussion.

The investigation pointed out definitely that the $2\beta 0\nu$ -decay does exist and has been experimentally observed ten years ago in the two experiments – 76-Ge and 130-Te.

Figure 1: Expected $\beta\beta(0\nu)$ half lives for 50 meV effective neutrino mass and different NME calculations: IBM2 [17], YI09 [18], TU08 [19] and SM08 [20].

The life-time for $2\beta0\nu$ -decay of 130-Te ($1.0 \cdot 10^{24}$ years) did not agree with the Klapdor results for 76-Ge ($2.2 \cdot 10^{25}$ years).



Литература.

1. Klap 2004 H. V. Klapdor-Kleingrothaus *et al.*, Nucl.Instrum.Methods A 522, 371 (2004).
H. V. Klapdor-Kleingrothaus *et al.*, Phys. Lett. B 586, 198 (2004).
2. M. Agostini *et al.*, Phys. Rev. Lett. 111 (2013) 122503.
3. H. V. Klapdor-Kleingrothaus and I.V.Krivosheina, Mod. Phys. Lett. A21 , 1547 (2006)
4. C. Arnaboldi *et al.*, Physical Review C 78, 035502 (2008)
5. E. Fiorini, Neutrino 2004 Paris , June 17, 2004.
 - a. Nuclear Physics B(Proc.Suppl.)143(2005)225-228.
 - b. R. Arditto *et al.*, arXiv:hep-ex/0501010
6. I.V.Kirpichnikov. arXiv:hep-ex/1006.2025 [hep-ph , hep-ex cross-list]
7. F.S.Djeparov. From http://en.wikipedia.org/wiki/file:cryst_struct_teo2.png
8. I.V.Kirpichnikov. arXiv:hep-ex/1405.4703
9. I.V.Kirpichnikov. arXiv:hep-ex/1409.7507v2
10. S.J. Lee *et al.*, Astroparticle Physics 34 (2011) 732–737

Neutrinoless double beta decay observed already ten years ago?

The observation of neutrinoless double beta decay by the HEIDELBERG-MOSCOW experiment has been defended again in CERN Courier (H.V. Klapdor-Kleingrothaus, November 2013). It is up to now the only claim for an observation of the $2\beta 0\nu$ -decay.

Another high-sensitivity experiment in Gran Sasso, CUORICINO, looking for $\beta\beta$ decay of ^{130}Te , at first glance seemed not to support this positive result . Also the recent GERDA experiment, again looking for $\beta\beta$ decay of ^{76}Ge in Gran Sasso, though up to now with smaller statistics, was claimed not to support these findings .

However, a recent reconsideration of the theoretical process of neutrinoless double beta decay changes this picture completely. It is found that the signal of the decay should be shifted by a few keV from the Q-value for $2\beta 0\nu$ -decay. The shift is predicted to be $\Delta E = -2.6 \text{ keV}$ for ^{76}Ge and -3.7 keV in the case of ^{130}Te .

This model prediction is consistent with the energy shift of the $2\beta 0\nu$ -decay signal in the Klapdor-experiment. Moreover, reanalysis of the ^{130}Te experiment yields now *observation* of $2\beta 0\nu$ -decay also of ^{130}Te . Even the GERDA experiment shows an indication of the weak intensity expected from the HEIDELBERG-MOSCOW result at the model-corrected energy.

Concluding, indeed neutrinoless double beta decay definitely does exist, and has been experimentally observed ten years ago in two experiments.. It is the rarest nuclear decay process ever registered in a laboratory.

Literature to the Letter-4

- [1] H.V. Klapdor-Kleingrothaus et al., Nucl. Instr. Meth. A522 (2004)371,
Phys. Lett. B586 (2004) 198, Mod. Phys. Lett. A 21(2006) 154
- [2] Klapdor-Kleingrothaus, CERN Courier, November 2013, p.42.
- [3] E. Fiorini, Nucl. Phys. B (Proc. Suppl.)143(2005)225-228, C. Arnaboldi et
al., Phys. Rev. C78 (2008)035502, and Astrop. Phys. 34(2011)822
- [4] Gerda coll., CERN-Courier.com/cws/article/cern/56229 (2014)
- [5] I.V. Kirpichnikov, arxiv:1405. 4703v2 (2014) , arxiv 1409.7507 (2014)

Neutrino masses and Neutrinoless Double Beta Decay: Status and expectations

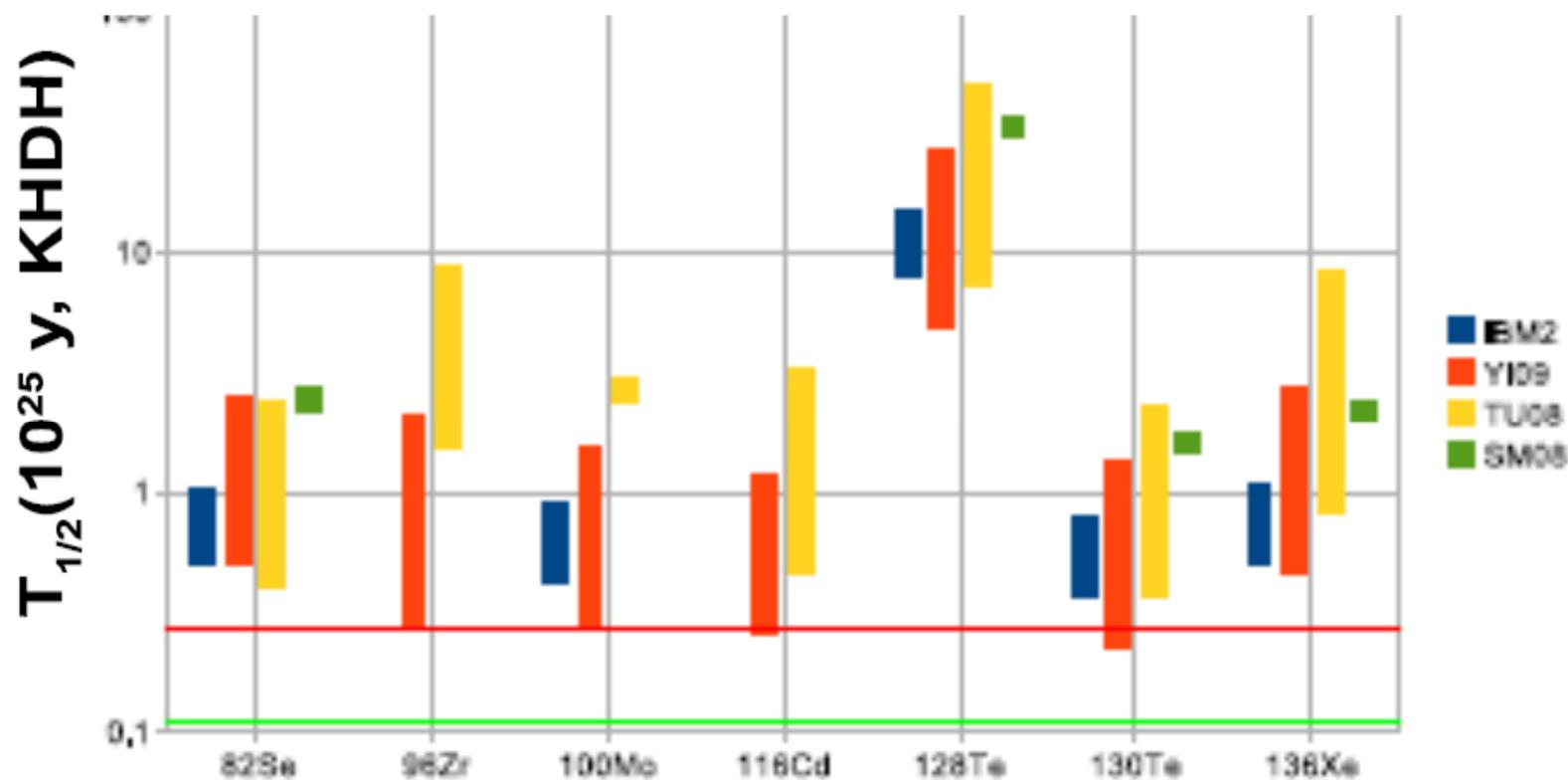
Oliviero Cremonesi*

INFN Sez. Milano Bicocca, Milano, Italy

August 12, 2011

arXiv:1002.1437v1 [hep-ex] 7 Feb 2010

Figure 2: $\beta\beta(0\nu)$ half life intervals corresponding to the 90% CL range of the KHDH claim, rescaled ($T_k = T_{Ge} G(Ge) M(Ge)^2 / G(k) M(k)^2$) according to different NME calculations: IBM2 [17], YI09 [18], TU08 [19] and SM08 [20]. Available lower limits for ^{130}Te (CUORI-CINO: red line) and ^{82}Se (NEMO3: green line) are also shown.



Harry Miley <harry.miley@pnl.gov>; Craig Aalseth <craig.aalseth@pnl.gov>;
Dale Anderson <dale.anderson@pnl.gov>; Theodore Bowyer <ted.bowyer@pnl.gov>;
Ronald Brodzinski <ron.brodzinski@pnl.gov>; David Jordan <david.jordan@pnl.gov>;
Richard Kouzes <richard.kouzes@pnl.gov>; William Pitts <karl.pitts@pnl.gov>;
Eric Smith <eric.smith@pnl.gov>; Bob Thompson <rc.thompson@pnl.gov>;
Ray Warner <ray.warner@pnl.gov>; Peter Doe <pdoe@u.washington.edu>;
kareem@u.washington.edu <kareem@u.washington.edu>;
Hamish Robertson <rghr@u.washington.edu>; John Wilkerson <jfw@u.washington.edu>;
Frank Avignone <waters@sc.edu>; F. T. Avignone <titus3@mac.com>;
Frank Avignone <avignone@scuch8.physics.sc.edu>; Werner Tornow
<tornow@tunl.duke.edu>;
Albert Young <aryoung@unity.ncsu.edu>; Albert Young <albert_young@ncsu.edu>;
Joel Webb <jwebb@cemrc.org>; Juan Collar <collar@uchicago.edu>;
Rick Gaitskell <Richard_Gaitskell@brown.edu>; A. Barabash
<Alexander.Barabash@itep.ru>;
A. Barabash <barabash@vitep5.itep.ru>; andreas@bama.ua.edu
<andreas@bama.ua.edu>; gratta@HEP.Stanford.EDU <gratta@HEP.Stanford.EDU>;
mkmoe@home.com <mkmoe@home.com>; ppxv@caltech.edu <ppxv@caltech.edu>;
vogel@citnp14.caltech.edu <vogel@citnp14.caltech.edu>; boehm@caltech.edu
<boehm@caltech.edu>; lbaudis@stanford.edu <lbaudis@stanford.edu>;
hazama@marie.npl.washington.edu <hazama@marie.npl.washington.edu>;
jmorales@posta.unizar.es <jmorales@posta.unizar.es>;
amorales@posta.unizar.es amorales@posta.unizar.es