Title: Oscillation/Rare Decay Experiments 2

Date: Jul 18, 2018 02:30 PM

URL: http://pirsa.org/18070027

Abstract:

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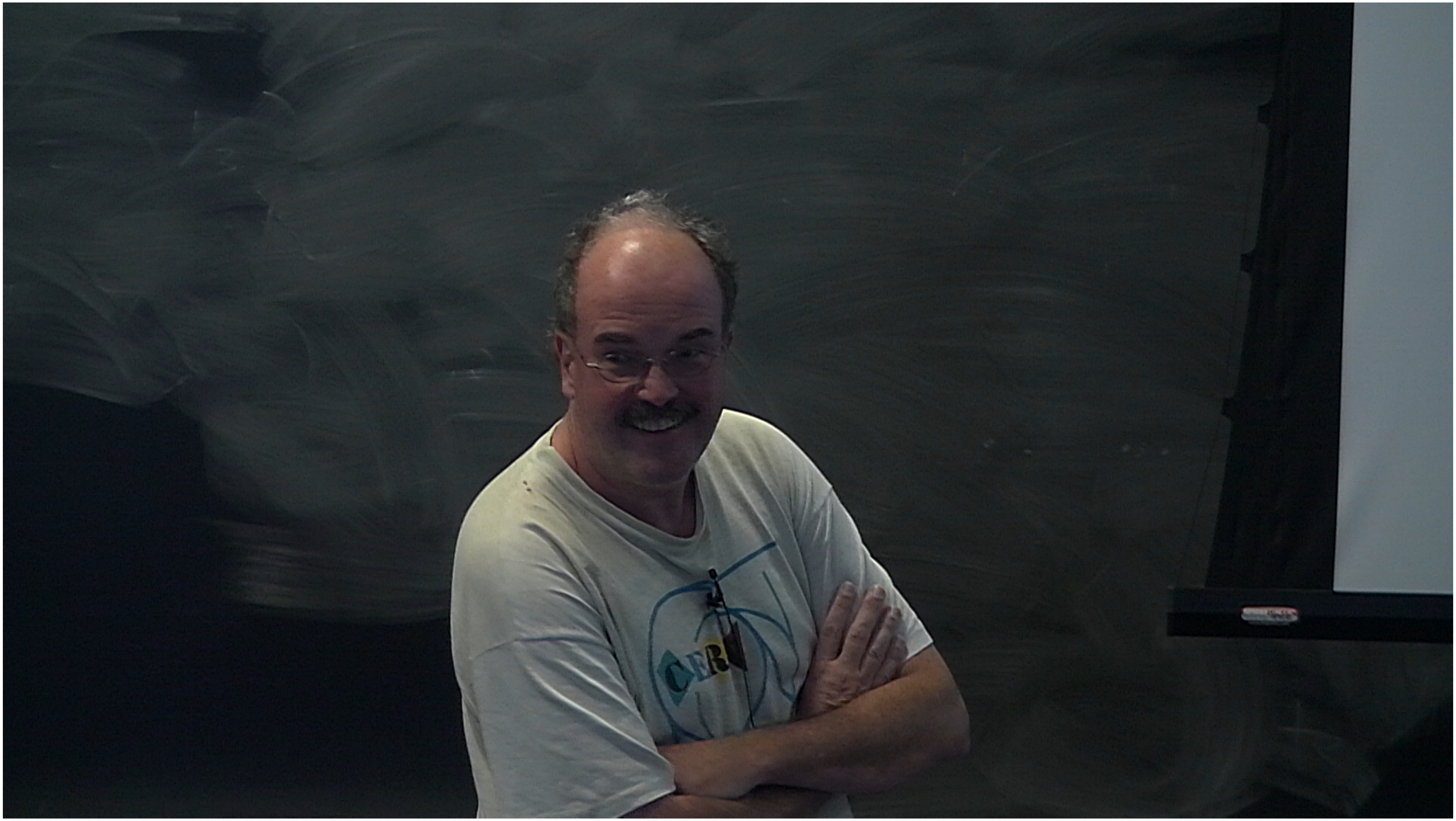
The next step

18.07.2018 Kai Zuber

DRESDEN concept Exzellenz aus Wissenschaft und Kultur



$$\text{"}m_{\nu_e}\text{"} = \sum |U_{ei}|^2 m_i^2 \lesssim 2{,}3\,\text{eV}$$

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KATRIN from inside

DRESDEN concept

Questions from last lecture-1 Neutrino masses in the SM

Easiest way: Include right-handed neutrino singlets in SM

$$\mathcal{L}_{\text{Yuk}} = -c_\nu \bar{\nu}_R \phi^\dagger \begin{pmatrix} \nu_{e_L} \\ e_L \end{pmatrix} + h.c.$$

$$= c_\nu \frac{v}{\sqrt{2}} \bar{\nu} \nu$$

Why is neutrino so much lighter?

$$\begin{pmatrix} u \\ d' \end{pmatrix}_L \quad \begin{pmatrix} c \\ s' \end{pmatrix}_L \quad \begin{pmatrix} t \\ b' \end{pmatrix}_L \quad \begin{pmatrix} e \\ \nu_e \end{pmatrix}_L \quad \begin{pmatrix} \mu \\ \nu_\mu \end{pmatrix}_L \quad \begin{pmatrix} \tau \\ \nu_\tau \end{pmatrix}_L$$

$$u_R \quad d_R \quad s_R \quad c_R \quad b_R \quad t_R \quad e_R \quad \mu_R \quad \tau_R.$$

$$\nu_{eR}; \nu_{\mu R}; \nu_{\tau R}$$

More symmetric solution

You have to explain why c_ν is so much smaller than the other couplings

Neutrinos would be Dirac particles (4-state objects like the other fermions)

Questions from last lecture-2

E. Fermi (1934)

Versuch einer Theorie der β-Strahlen. I[1]).

Von **E. Fermi** in Rom.

Mit 3 Abbildungen. (Eingegangen am 16. Januar 1934.)

Eine quantitative Theorie des β-Zerfalls wird vorgeschlagen, in welcher man die Existenz des Neutrinos annimmt, und die Emission der Elektronen und Neutrinos aus einem Kern beim β-Zerfall mit einer ähnlichen Methode behandelt, wie die Emission eines Lichtquants aus einem angeregten Atom in der Strahlungstheorie. Formeln für die Lebensdauer und für die Form des emittierten kontinuierlichen β-Strahlenspektrums werden abgeleitet und mit der Erfahrung verglichen.

7. Die Masse des Neutrinos.

Durch die Übergangswahrscheinlichkeit (32) ist die Form des kontinuierlichen β-Spektrums bestimmt. Wir wollen zuerst diskutieren, wie diese Form von der Ruhemasse μ des Neutrinos abhängt, um von einem Vergleich mit den empirischen Kurven diese Konstante zu bestimmen. Die Masse μ ist in dem Faktor p_σ^2/v_σ enthalten. Die Abhängigkeit der Form der Energieverteilungskurve von μ ist am meisten ausgeprägt in der Nähe des Endpunktes der Verteilungskurve. Ist E_0 die Grenzenergie der β-Strahlen, so sieht man ohne Schwierigkeit, daß die Verteilungskurve für Energien E in der Nähe von E_0 bis auf einen von E unabhängigen Faktor sich wie

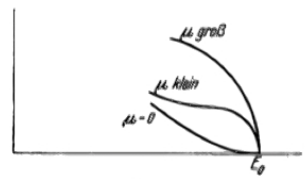

Fig. 1.

$$\frac{p_\sigma^2}{v_\sigma} = \frac{1}{c^3}(\mu c^2 + E_0 - E)\sqrt{(E_0 - E)^2 + 2\mu c^2 (E_0 - E)} \qquad (36)$$

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Questions from last lecture -3 Fermi theory of weak interaction

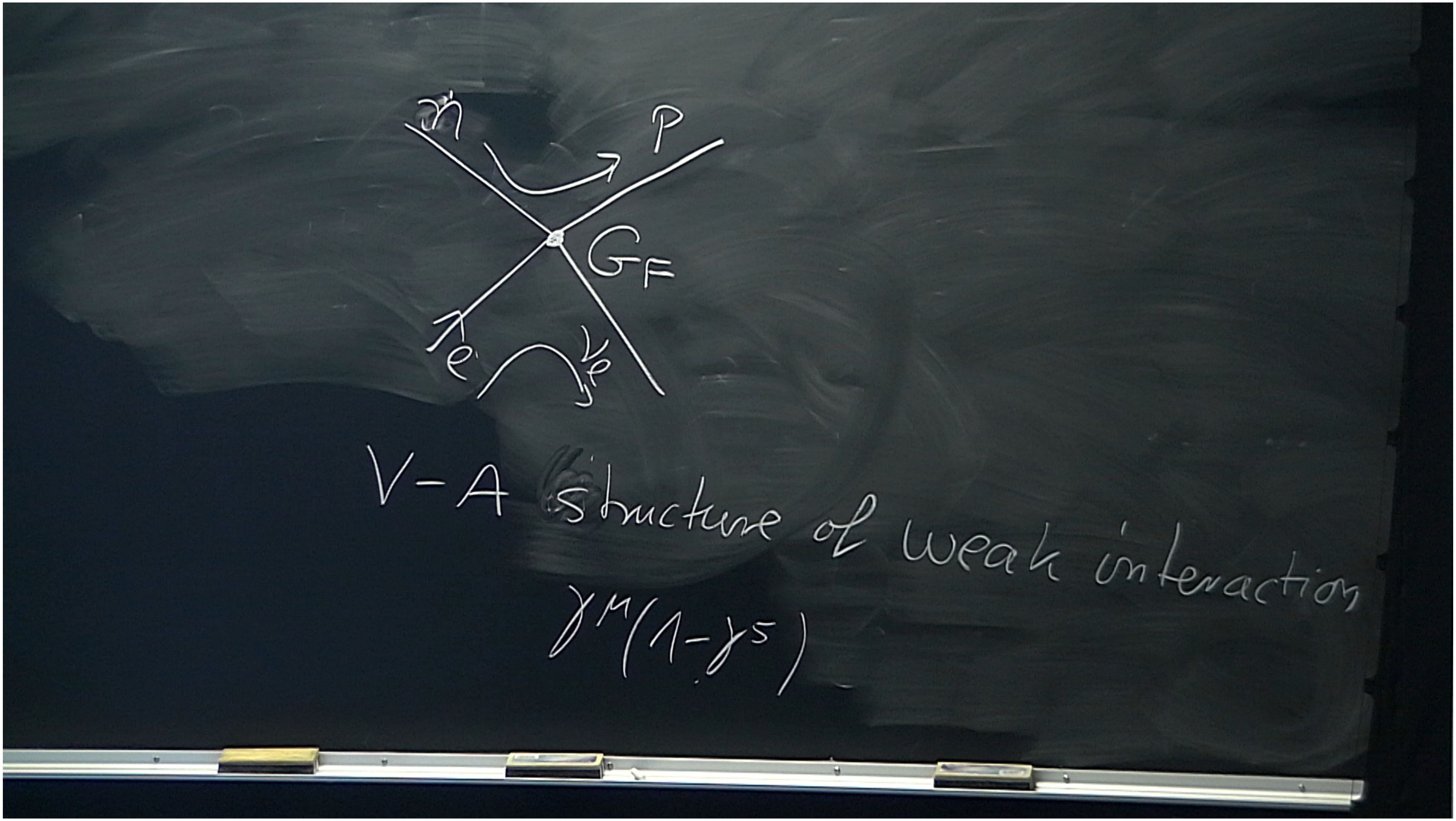
Neutron was discoverd 1932 by Chadwick

$$\mathcal{L}(x) = \frac{G_F}{\sqrt{2}} J_L \cdot J_H$$

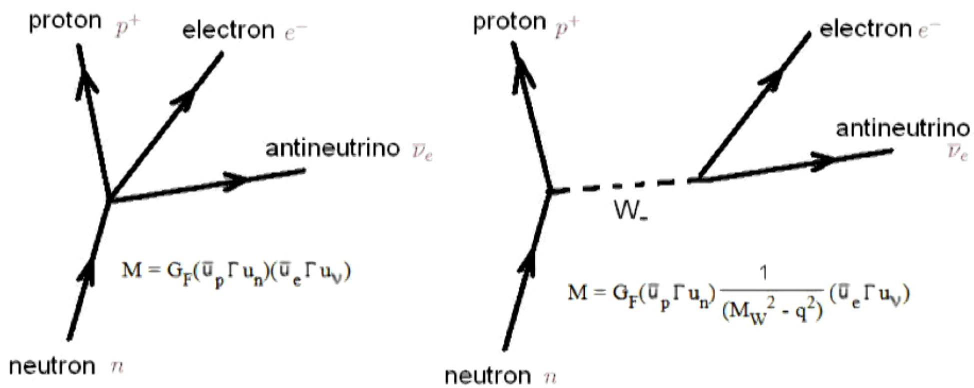
The most general Lagrangian for β-decay, which transforms as a scalar under a Lorentz transformation, is given by

$$\mathcal{L}(x) = \sum_{j=1}^{5} [C_j \bar{p}(x) O_j n(x) \bar{e}(x) O'_j \nu(x) + C'_j \bar{p}(x) O_j n(x) \bar{e}(x) O'_j \gamma_5 \nu(x)] + h.c.$$

Operator	Transformation properties ($\Psi_f O \Psi_i$)	Representation with γ matrices
O_S (S)	scalar	$\mathbb{1}$
O_V (V)	vector	γ_μ
O_T (T)	tensor	$\frac{i}{2}(\gamma_\mu \gamma_\nu + \gamma_\nu \gamma_\mu)$
O_A (A)	axial vector	$\gamma_\mu \gamma_5$
O_P (P)	pseudo-scalar	γ_5


n
p
G_F
e
ν̄_e
V-A structure of weak interaction
γ^μ(1-γ^5)

Questions from last lecture-4 Fermi theory of weak interaction



a. Fermi's 4-point Interaction, 1934   b. Weak Interaction mediated by boson,

V-A structure of weak interactions

$$J_L = \bar{e}(x)\gamma_\mu(1-\gamma_5)\nu(x)$$

$$J_H = \bar{u}(x)\gamma^\mu(1-\gamma_5)d(x)$$

$$J_H = \bar{p}(x)\gamma^\mu(g_V - g_A\gamma_5)n(x)$$

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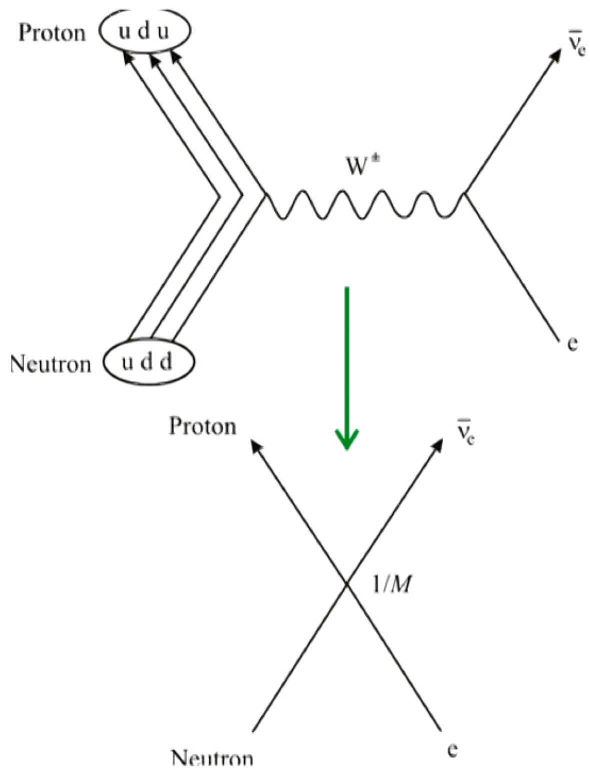
Questions from last lecture –5



$$\mathcal{L}(x) = \frac{G_F}{\sqrt{2}} J_L \cdot J_H$$

Operator	Transformation properties ($\Psi_f O_j \Psi_i$)	Representation with γ matrices
O_S (S)	scalar	$\mathbb{1}$
O_V (V)	vector	γ_μ
O_T (T)	tensor	$\frac{i}{2}(\gamma_\mu\gamma_\nu + \gamma_\nu\gamma_\mu)$
O_A (A)	axial vector	$\gamma_\mu\gamma_5$
O_P (P)	pseudo-scalar	γ_5

$$\frac{G_F}{\sqrt{2}} = \frac{g^2}{8m_W^2}$$

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Questions from last lecture –6

Helicity and nuclear β decay correlations

Ran Hong,[a] Matthew G. Sternberg, and Alejandro Garcia
Department of Physics and CENPA, University of Washington, Seattle, Washington 98195

(Received 13 May 2013; accepted 13 October 2016)

We present simple derivations of nuclear β-decay correlations with an emphasis on the special role of helicity. This topic provides a good opportunity to teach students about helicity and chirality in particle physics with exercises that use simple aspects of quantum mechanics. In addition, this paper serves as an introduction to nuclear β-decay correlations from both a theoretical and experimental perspective. This article can be used to introduce students to ongoing experiments searching for hints of new physics in the low-energy precision frontier.
[http://dx.doi.org/10.1119/1.4966197]

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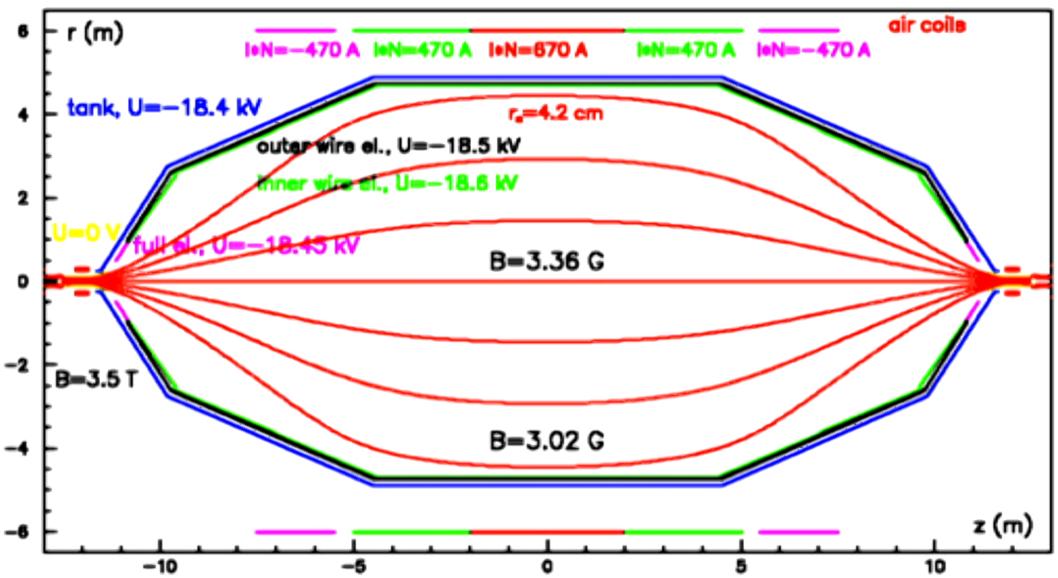
Questions from last lecture – 7a



Electron detector

Detector inside or outside?

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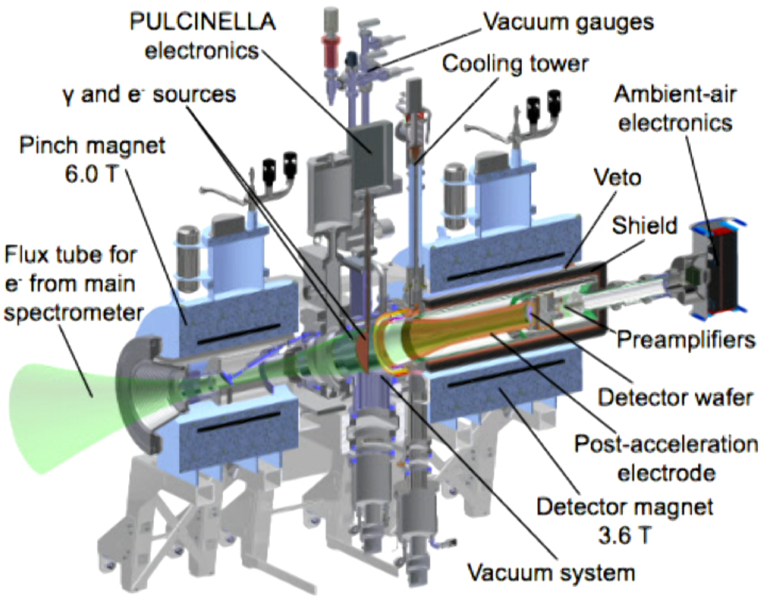
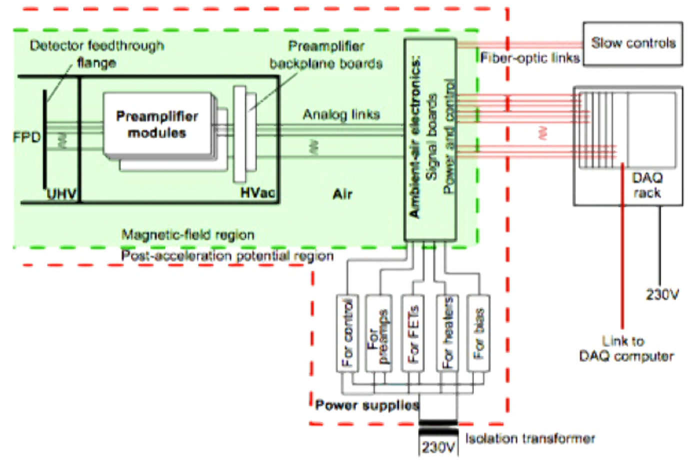
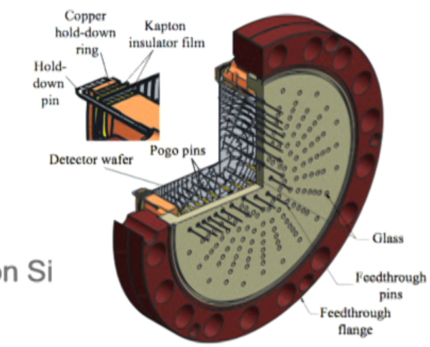
Questions from last lecture – 7b





148 Pixel p-i-n diode aarray on Si



J. Amsbaugh et al., Nucl. Inst. Meth. A 778, 40 (2015)

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From last lecture-8 Birthday party (4.12.1930)

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B. Monreal, J. Formaggio, PRD 80 (2009)

Project 8

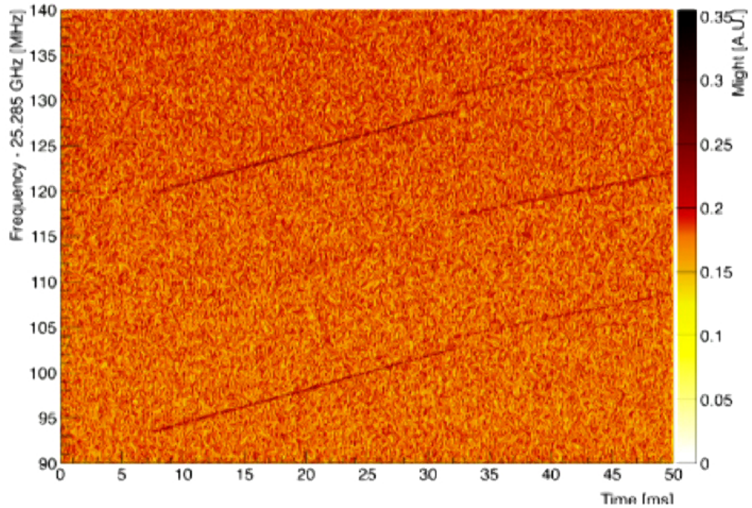
Idea: Use frequencies (and later T atoms)

Cyclotron radiation emission spectroscopy (CRES)

$$f_c = \frac{1}{2\pi} \frac{eB}{m_e + E_{kin}/c^2}$$

Energy emission of microwaves to be detected by antenna array

$$P(\beta,\theta) = \frac{1}{4\pi\epsilon_0} \frac{2q^2\omega_0^2}{3c} \frac{\beta^2 \sin^2(\theta)}{1-\beta^2}$$



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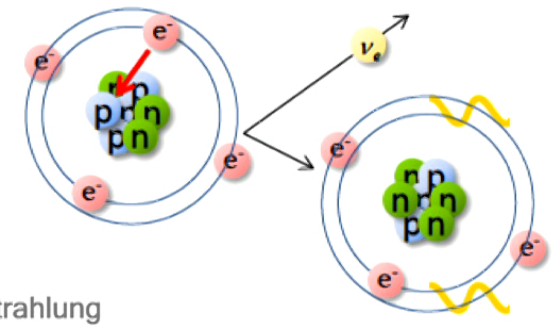
Alternative: Electron capture (EC) and neutrino mass

Measures the neutrino mass (not anti-neutrino mass like in beta decay -> CPT test)



Radiative EC, internal bremsstrahlung

$$\frac{dW}{dE_C} = A(Q_{EC} - E_C)^2 \sqrt{1 - \frac{m_\nu^2}{(Q_{EC} - E_C)^2}} \sum_H B_H \varphi_H^2(0) \frac{\frac{\Gamma_H}{2\pi}}{(E_C - E_H)^2 + \frac{\Gamma_H^2}{4}}$$

- De-excitation spectrum depends on neutrino mass
- Calorimetric measurement

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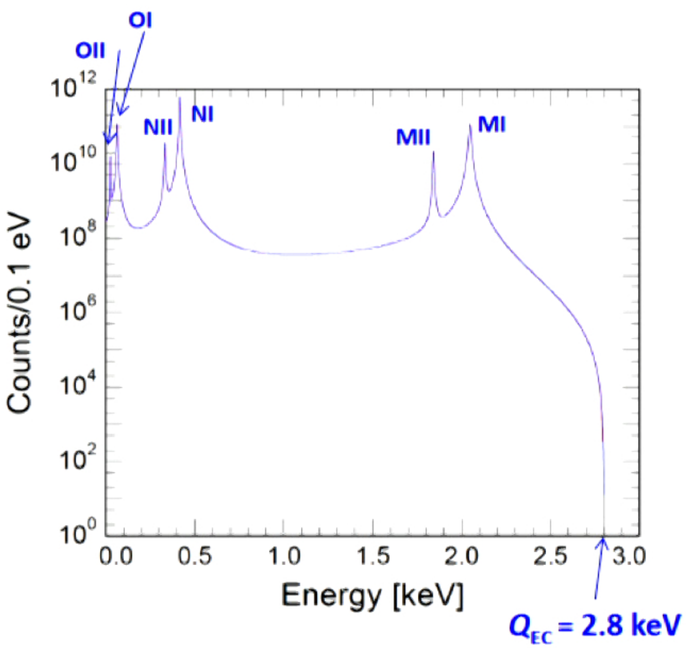
The case of Ho-163

$$e^- + {}^{163}_{67}\mathrm{Ho} \rightarrow {}^{163}_{66}\mathrm{Dy}^* + \nu_e$$



$$ {}^{163}_{66}\mathrm{Dy}^* \rightarrow {}^{163}_{66}\mathrm{Dy} + E_C $$

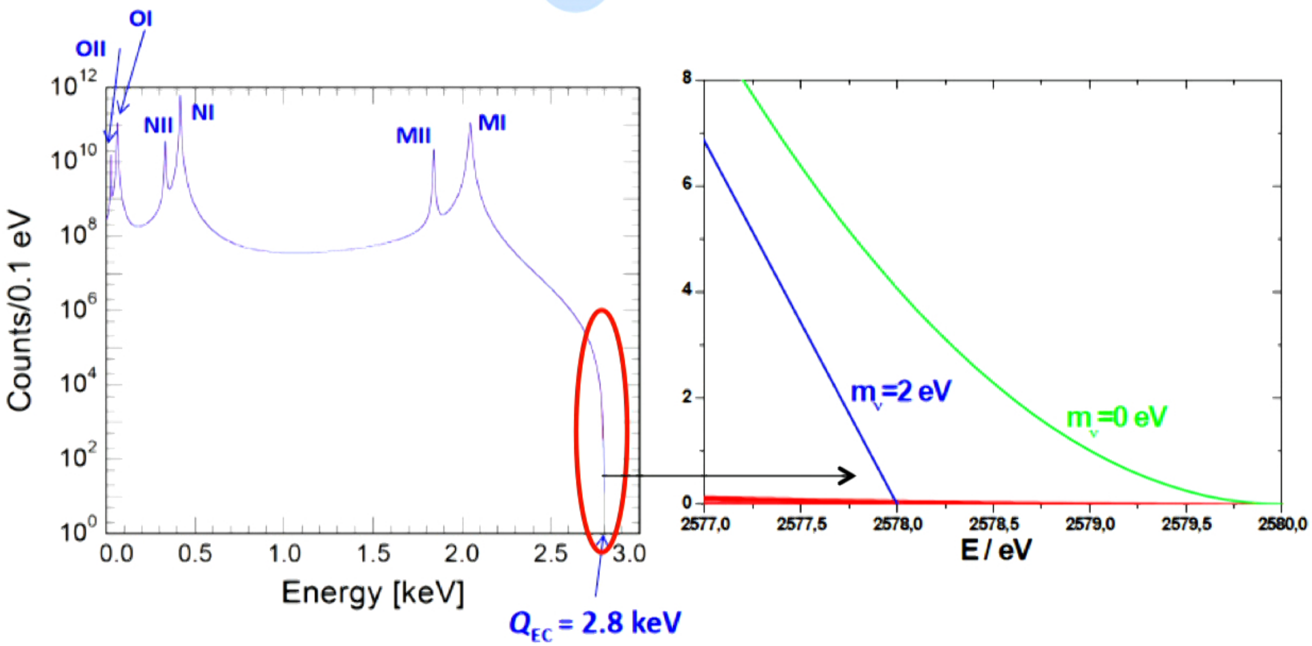
Endpoint of internal bremsstrahlung spectrum

Current bound : m < 225 eV

P.F. Springer et al., Phys. Rev. A 35 (1987)

EC signal

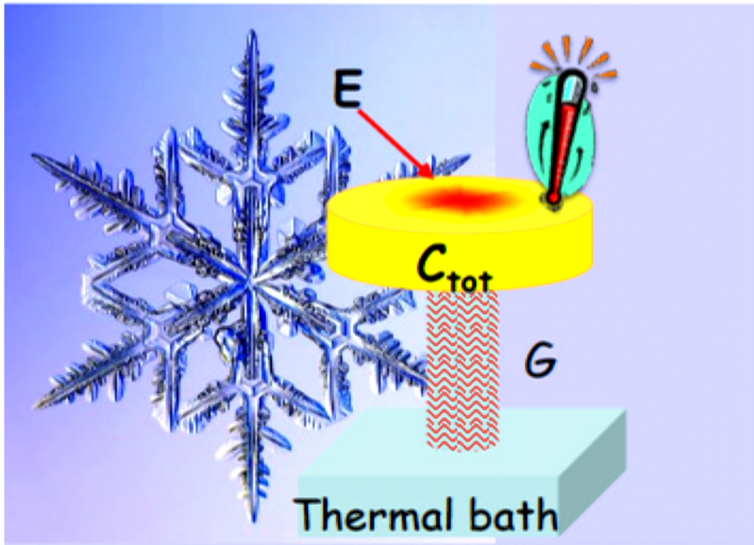
Very low Q-value, allows only M-capture and higher shells



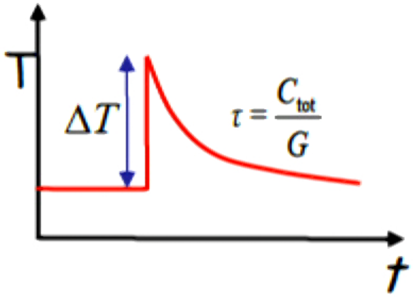
Again, precision mass measurement is neccesssary

Ho-163 measurement

Use cryo-detectors (same technology used in most dark matter experiments)



$$\Delta T \cong \frac{E}{C_{tot}}$$



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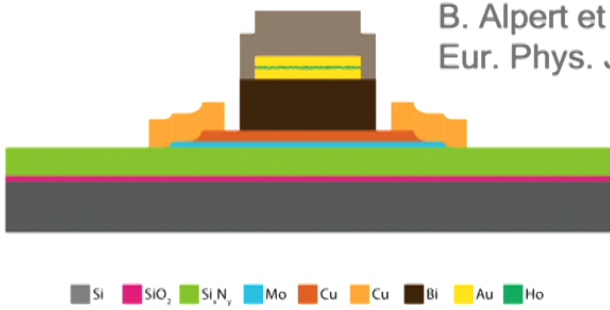
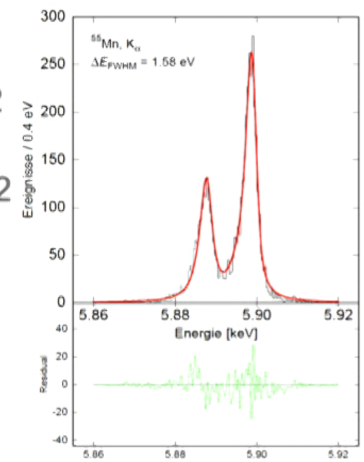
Holmes and ECHO

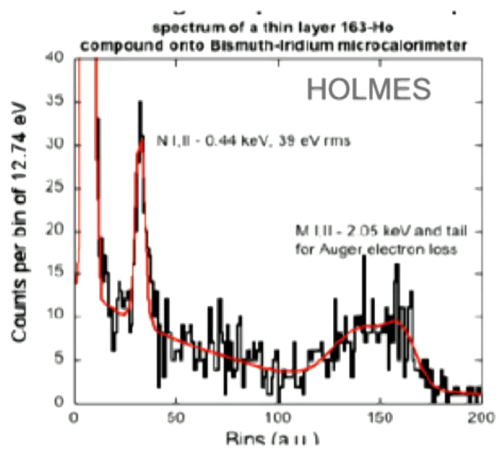
The ECHo Collaboration
EPJ-ST 226 8 (2017) 162

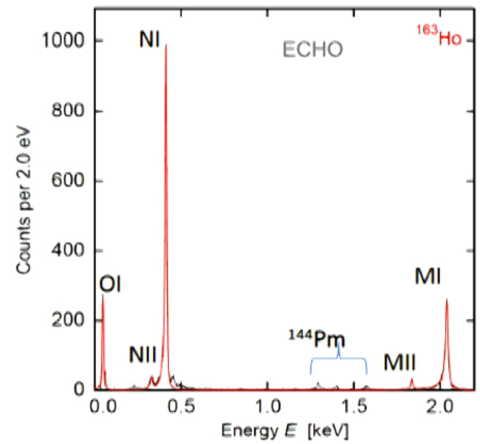
B. Alpert et al,
Eur. Phys. J.C 75 (2015)112





ECHO





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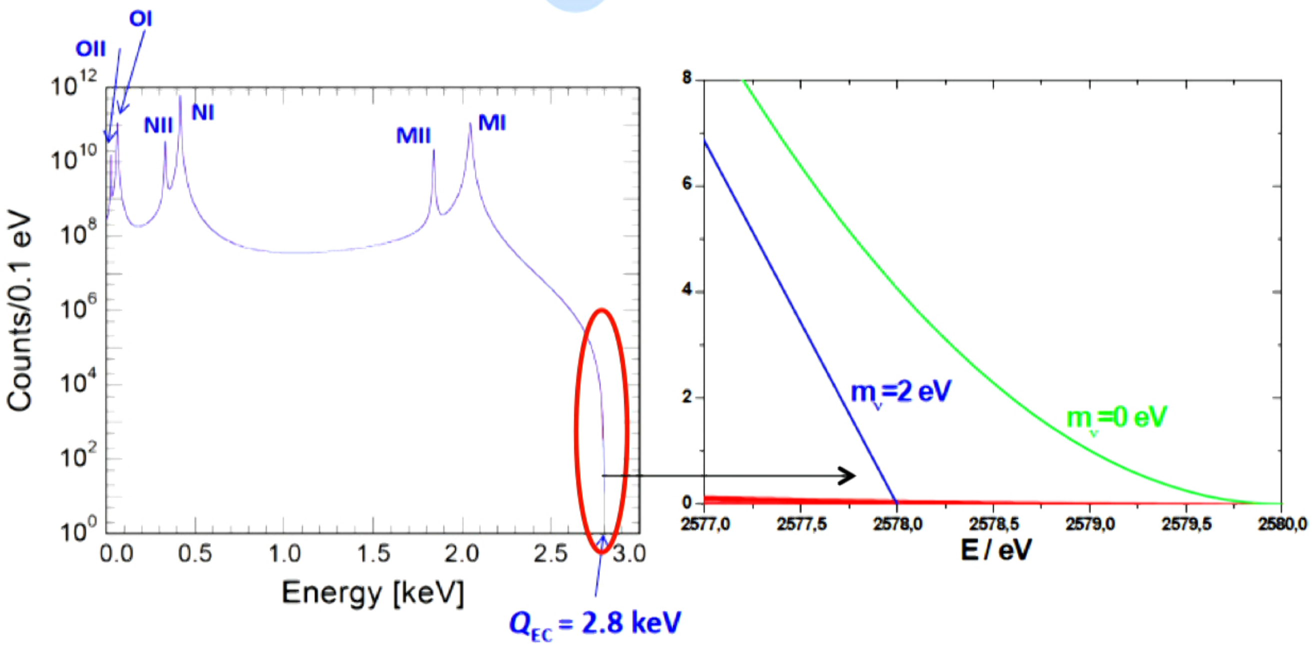
EC signal

Very low Q-value, allows only M-capture and higher shells



Again, precision mass measurement is neccesssary

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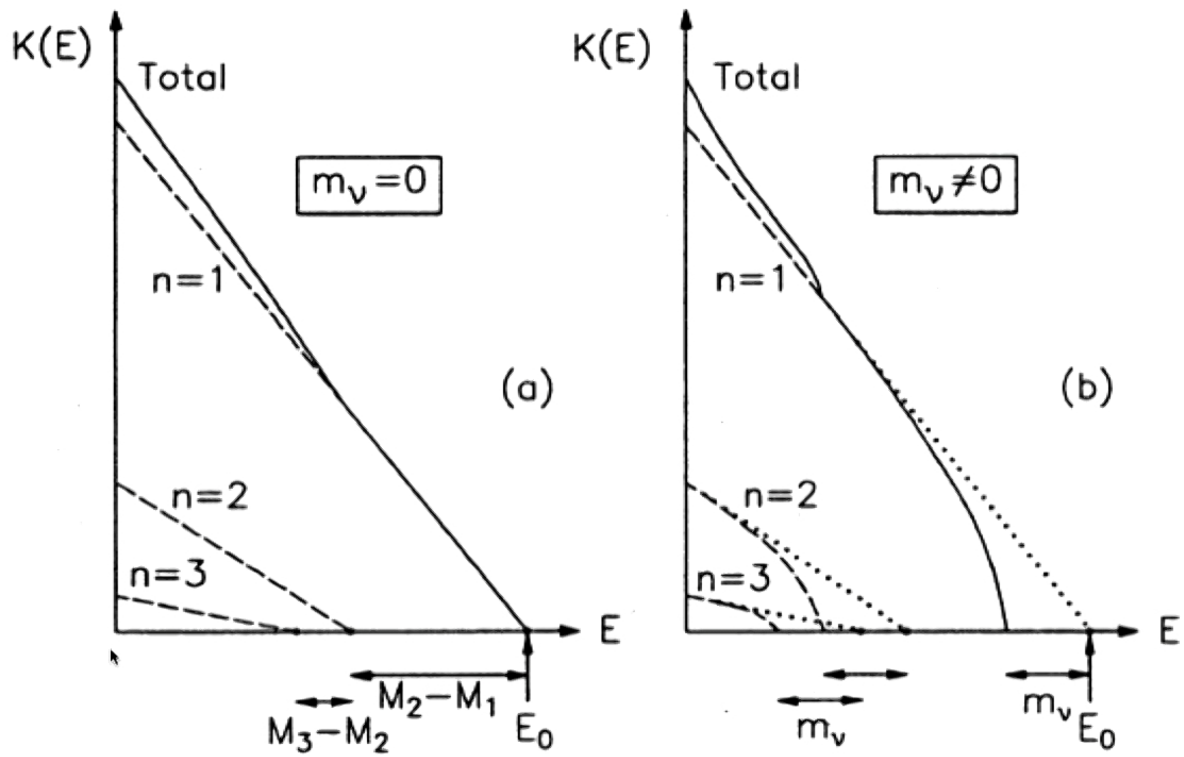
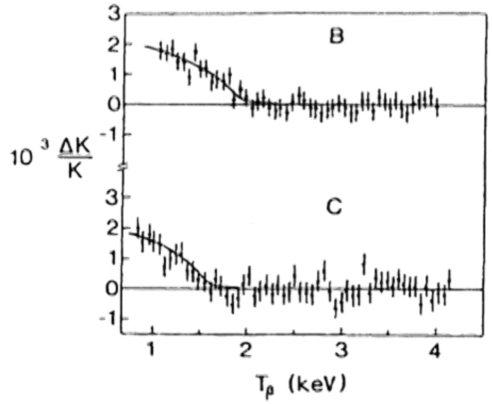
Kinks in beta decay - Mixing and sterile neutrinos

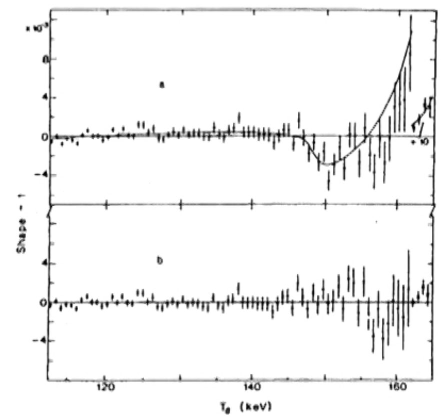


The „famous" 17 keV neutrino (around 1990)

Tritium



Sulphur-35

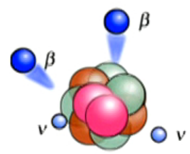


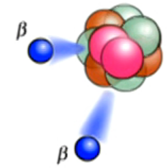
Finally ruled out (almost as many positive than negative observations)

2. **Observational evidences for the existence of 17.4 keV decaying degenerate sterile neutrinos near the Galactic Center**
Man Ho Chan, Ming-Chung Chu. Sep 2010. 6 pp.
Published in **Astrophys.J. 727 (2011) L47**
DOI: 10.1088/2041-8205/727/2/L47
e-Print: **arXiv:1009.5872 [astro-ph.HE]** | PDF

Double beta decay

- $(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$ $2\nu\beta\beta$
- $(A,Z) \rightarrow (A,Z+2) + 2e^-$ $0\nu\beta\beta$





Unique process to measure character of neutrino

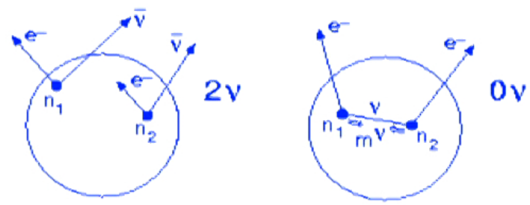
The smaller the neutrino mass the longer the half-life

Neutrino mass measurement via half-life measurement

Requires half-life measurements well beyond 10^{20} yrs!!!

Double beta decay

- $(A,Z) \rightarrow (A,Z+2) + 2\,e^{-} + 2\bar{\nu}_e$ 2νββ
- $(A,Z) \rightarrow (A,Z+2) + 2\,e^{-}$ 0νββ



Unique process to measure character of neutrino

The smaller the neutrino mass the longer the half-life

Neutrino mass measurement via half-life measurement

Requires half-life measurements well beyond 10^{20} yrs!!!

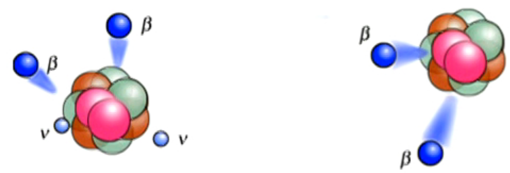
Within a few years...

PHYSICAL REVIEW

Double Beta-Disintegration

M. Goeppert-Mayer, *The Johns Hopkins University*

(Received May 20, 1935)



DECEMBER 15, 1939 PHYSICAL REVIEW

On Transition Probabilities in Double Beta-Disintegration

W. H. Furry
Physics Research Laboratory, Harvard University, Cambridge, Massachusetts

(Received October 16, 1939)

+ Racah (1936) and Majorana (1937)

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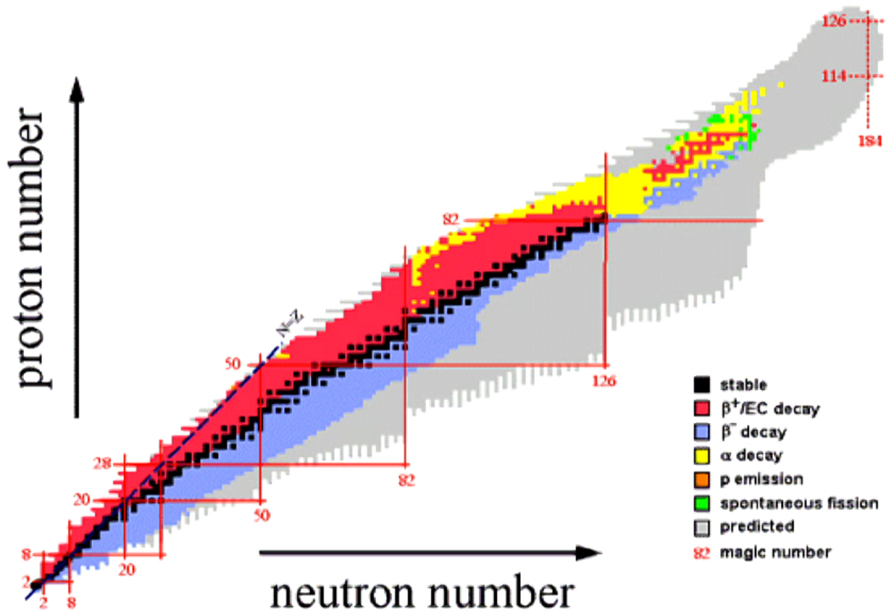
Requirements - I



1.) m(A,Z) > m(A,Z+2)

2.) Single beta decay must be forbidden (m (A,Z) < m (A,Z+1)) or at least strongly suppressed (large change in angular momentum)

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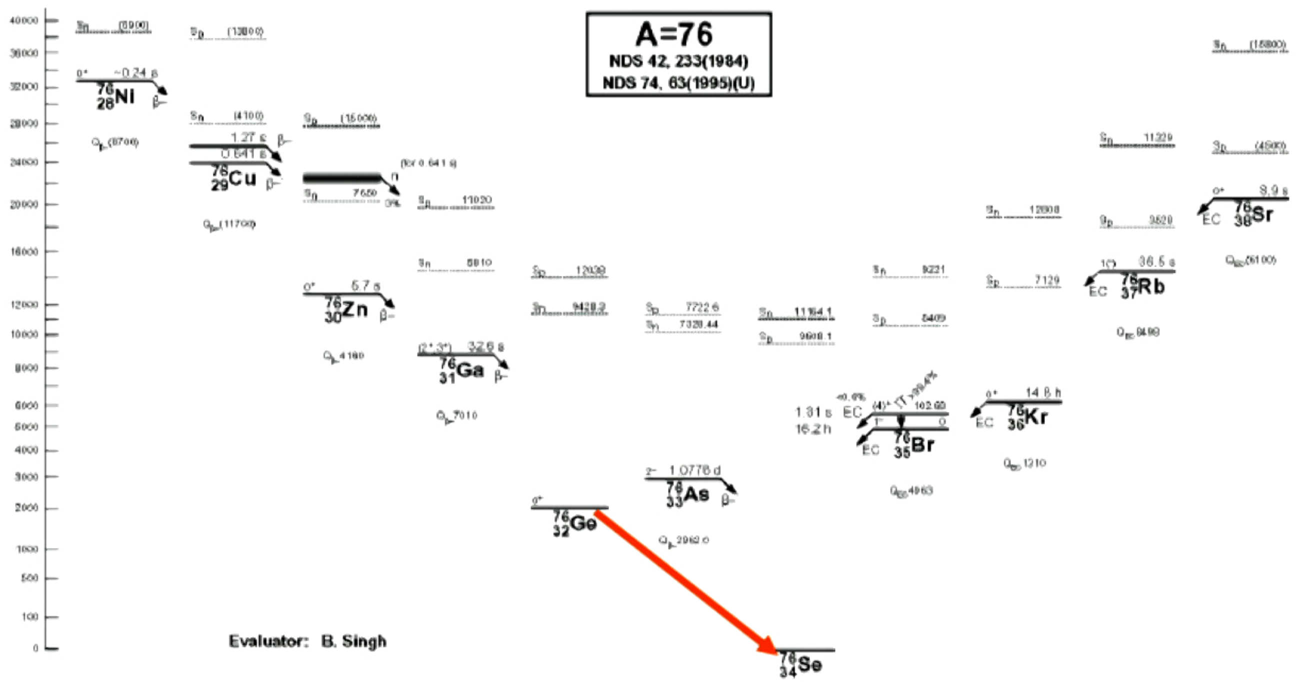
Example: Ge-76



There are only 35 isotopes in nature for double electron emission

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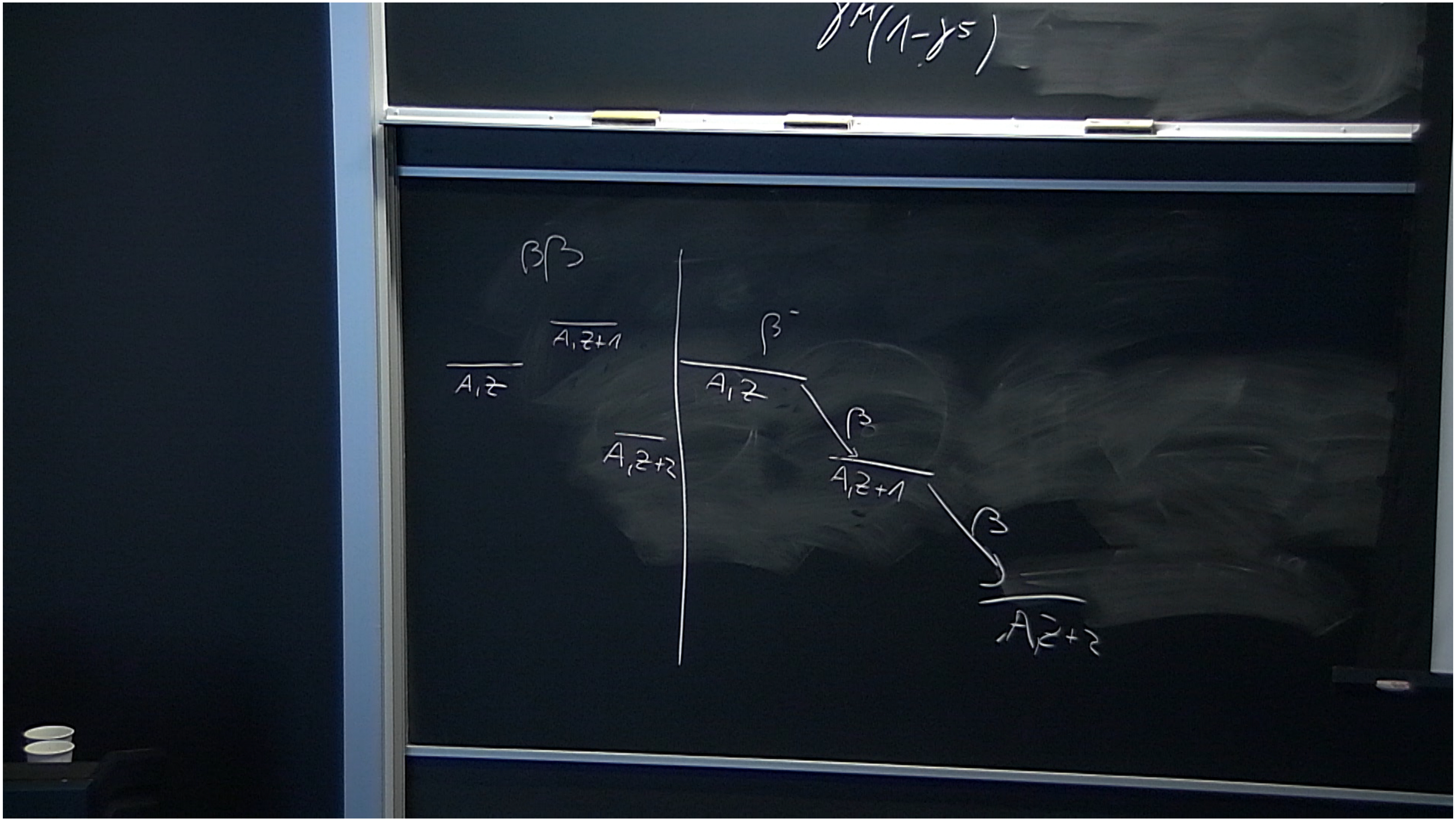
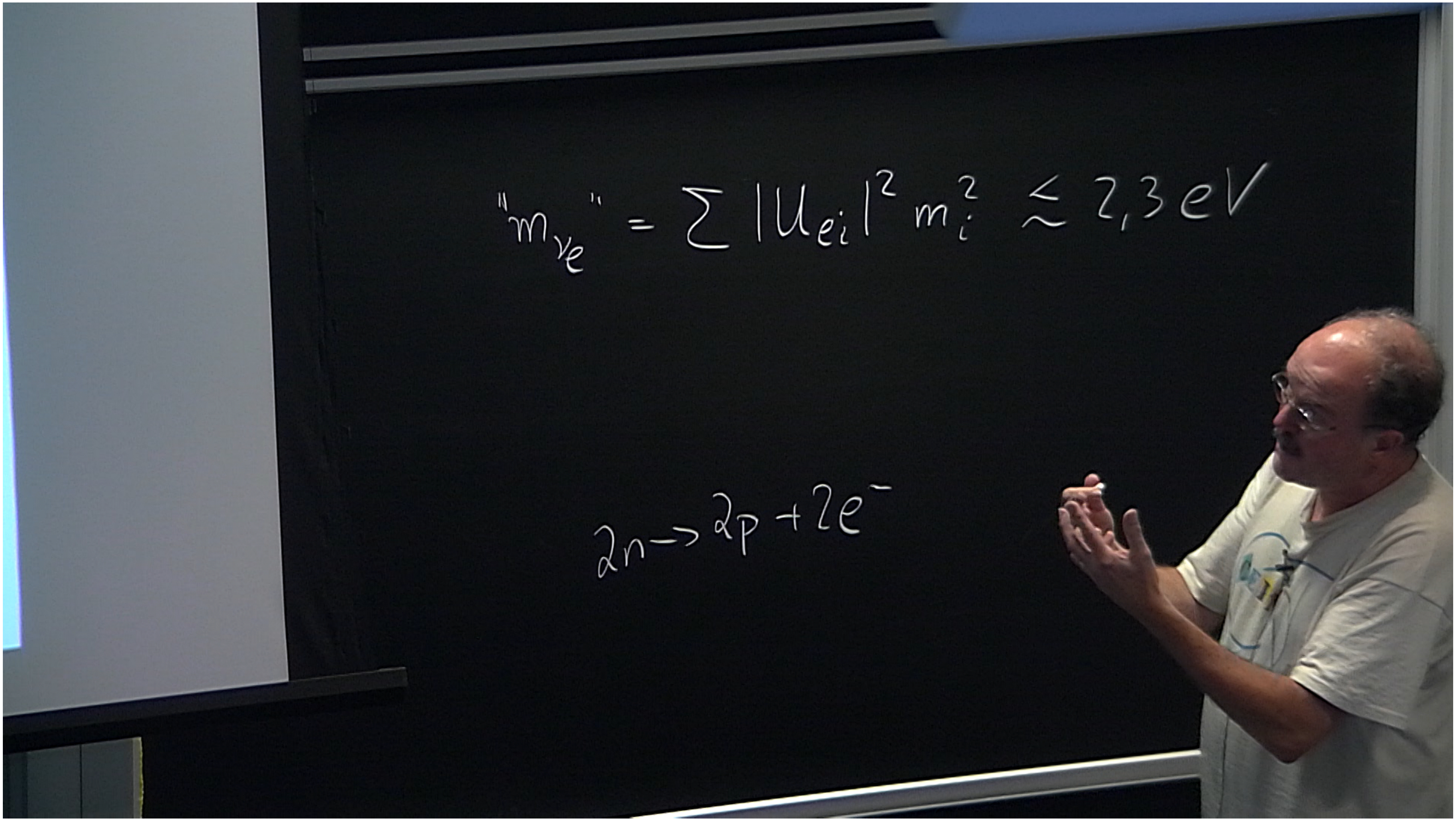
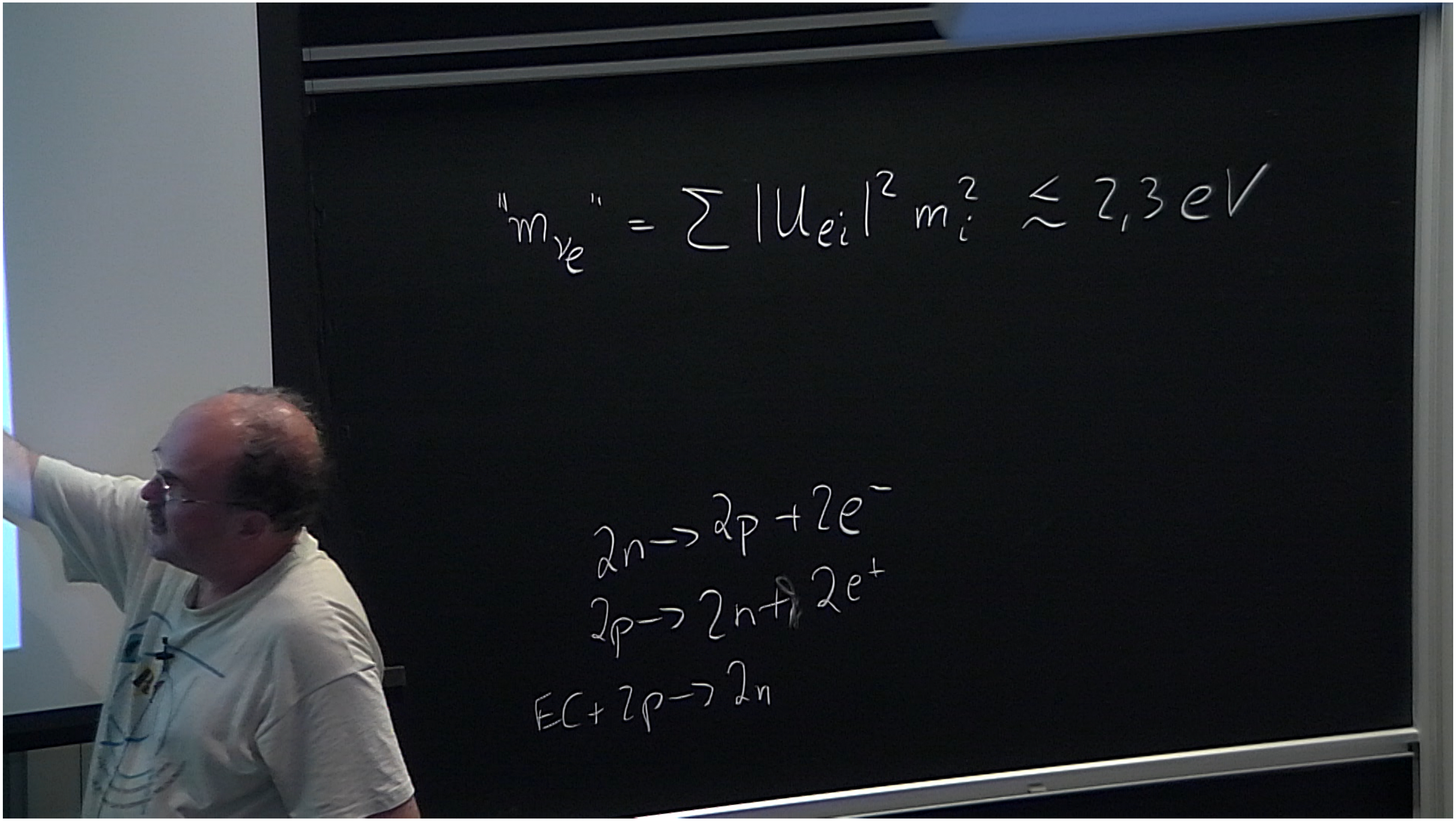

γ^μ(1-γ^5)
ββ
A,Z+1
A,Z
A,Z+2
β⁻
A,Z
β
A,Z+1
β
A,Z+2


"m_{ν_e}" = $\sum |U_{ei}|^2 m_i^2 \lesssim 2{,}3$ eV
$2n \to 2p + 2e^-$


"m_{ν_e}" = $\sum |U_{ei}|^2 m_i^2 \lesssim 2{,}3\,eV$
$2n \to 2p + 2e^-$
$2p \to 2n + 2e^+$
$EC + 2p \to 2n$

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Signal information

Signal: One new isotope (ionised), two electrons (fixed total energy)

- Single electron energies
- Angle between electrons
- Sum energy of both electrons
- Daughter ion (A,Z+2)
- Gamma rays (eg. four 511 keV photons in $\beta^+\beta^+$ or excited state transitions)

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2νββ

All even-even ground state transitions are $0^+ \rightarrow 0^+$

$(A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$

Fermi's Golden rule: $$d\lambda = 2\pi\delta(E_0 - \sum_f E_f)\left|\sum_{m,\beta} \frac{< f|H_\beta|m >< m|H^\beta|i >}{E_i - E_m - p_\nu - E_e}\right|^2$$

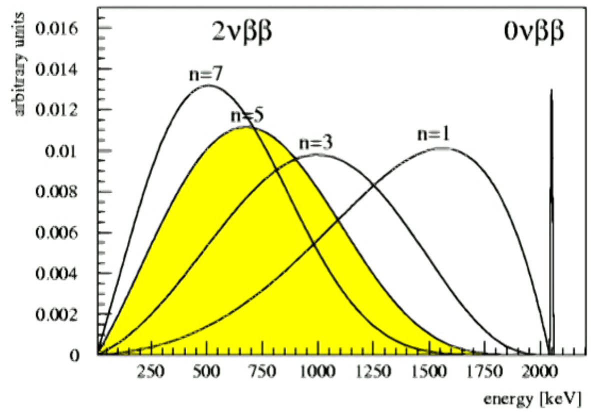
Single electron spectrum

$$\frac{dN}{dT_e} \approx (T_e+1)^2(Q-T_e)^6[(Q-T_e)^2+8(Q-T_e)+28]$$

Angular distribution

$$P(\theta_{12}) \propto 1 - \beta_1\beta_2\cos\theta_{12} \qquad (0^+ \rightarrow 0^+)$$

with β = p/E



Sum energy spectrum: $$\frac{dN}{dE} \approx E(Q-E)^5(1+2E+\frac{4E^2}{3}+\frac{E^3}{3}+\frac{E^4}{30})$$

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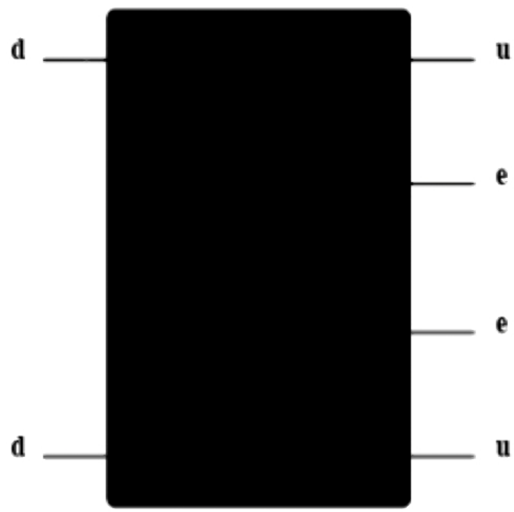
0νββ -Total lepton number violation

Any ΔL=2 process can contribute to 0νββ



- R_p violating SUSY
- V+A interactions
- Extra dimensions (KK- states)
- Leptoquarks
- Double charged Higgs bosons
- Compositeness
- Heavy Majorana neutrino exchange
- Light Majorana neutrino exchange
- ...

Nice interplay with LHC

$$1 / T_{1/2} = PS * NME^2 * \varepsilon^2$$

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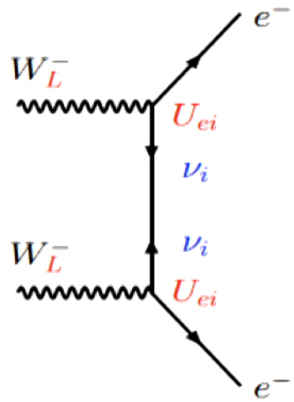
18.07.2018 Kai Zuber

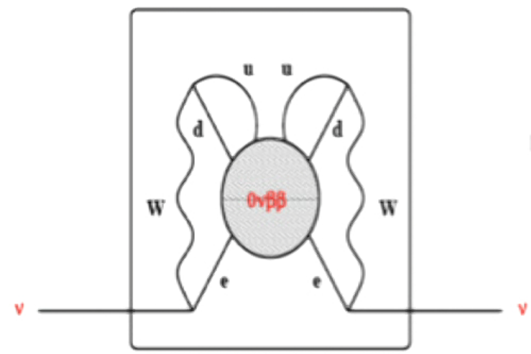
Light Majorana neutrinos



$$\varepsilon \equiv \langle m_\nu \rangle = \left| \sum_i U_{ei}^2 m_{\nu_i} \right|$$

$$\langle m_\nu \rangle = \left| \sum_i U_{ei}^2 m_{\nu_i} \right| = \left| c_{12}^2 c_{13}^2 m_1 + s_{12}^2 c_{13}^2 e^{i\alpha_1} m_2 + s_{13}^2 e^{i\alpha_2} m_3 \right|$$

$$1 / T_{1/2} = PS * NME^2 * (<m_\nu> / m_e)^2$$



Schechter and Valle 1982:

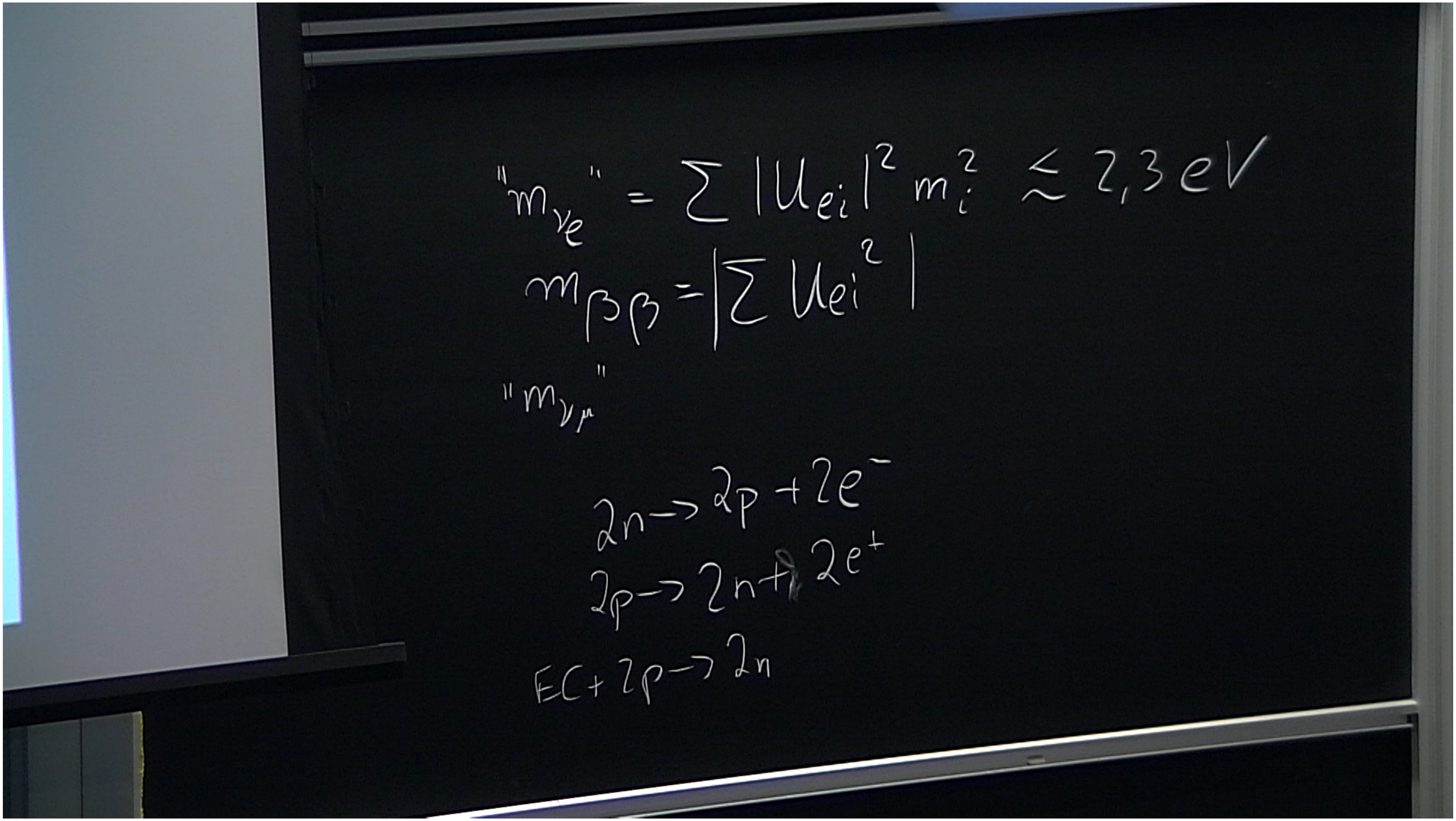
Independent of mechanism for neutrinoless DBD
Majorana neutrino mass will appear in higher order!

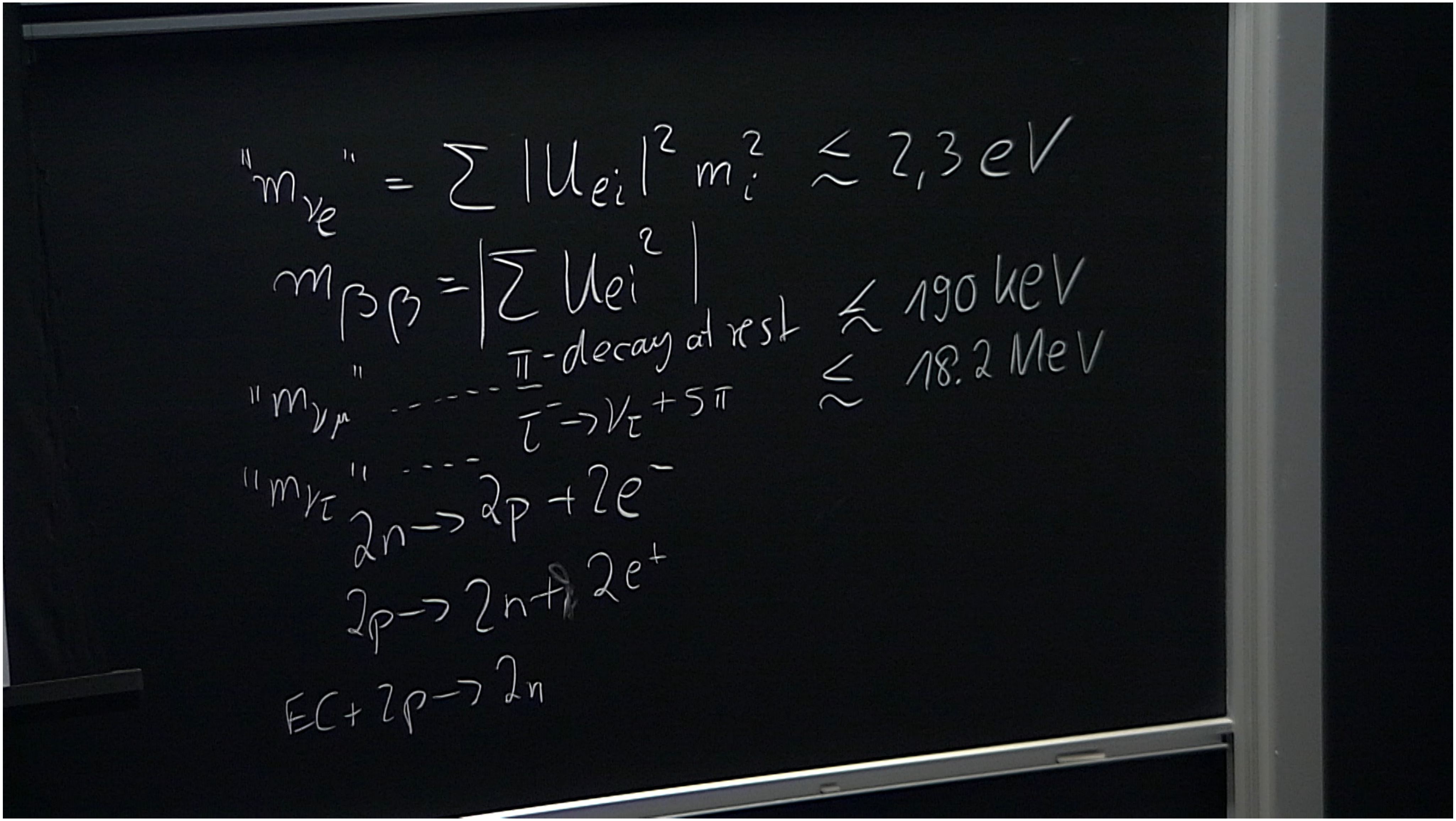
Observe $0\nu\beta\beta$ decay

≡

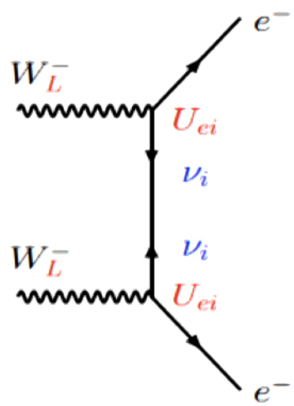
Neutrinos are Majorana particles

Actual calculation: M. Duerr, M. Lindner, A. Merle, JHEP 1106,091 (2011) -> very small


"m_{ν_e}" = $\sum |U_{ei}|^2 m_i^2 \lesssim 2,3$ eV
$m_{\beta\beta} = |\sum U_{ei}^2|$
"m_{ν_μ}"
$2n \to 2p + 2e^-$
$2p \to 2n + 2e^+$
$EC + 2p \to 2n$


"m_νe" = Σ |U_ei|² m_i² ≲ 2,3 eV
m_ββ = |Σ U_ei²|
"m_νμ" ...... π-decay at rest ≲ 190 keV
"m_ντ" .... τ⁻ → ν_τ + 5π ≲ 18.2 MeV
2n → 2p + 2e⁻
2p → 2n + 2e⁺
EC + 2p → 2n

Light Majorana neutrinos



$$\varepsilon \equiv \langle m_\nu \rangle = \left| \sum_i U_{ei}^2 m_{\nu_i} \right|$$

$$\langle m_\nu \rangle = \left| \sum_i U_{ei}^2 m_{\nu_i} \right| = \left| c_{12}^2 c_{13}^2 m_1 + s_{12}^2 c_{13}^2 e^{i\alpha_1} m_2 + s_{13}^2 e^{i\alpha_2} m_3 \right|$$

$$1 / T_{1/2} = PS * NME^2 * (\langle m_\nu \rangle / m_e)^2$$

Schechter and Valle 1982:

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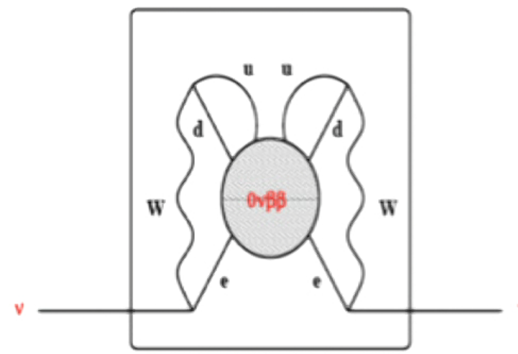

Observe $0\nu\beta\beta$ decay

$\equiv$

Neutrinos are Majorana particles

Actual calculation: M. Duerr, M. Lindner, A. Merle, JHEP 1106,091 (2011) -> very small

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0νββ -Total lepton number violation

Two more phases (Majorana phases) only appear in double beta decay

$$U = \begin{pmatrix} \cos\theta_{12} & \sin\theta_{12} & 0 \\ -\sin\theta_{12} & \cos\theta_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \cos\theta_{13} & 0 & \sin\theta_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -\sin\theta_{13}e^{i\delta} & 0 & \cos\theta_{13} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_{23} & \sin\theta_{23} \\ 0 & -\sin\theta_{23} & \cos\theta_{23} \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & e^{i\alpha_1} & 0 \\ 0 & 0 & e^{i\alpha_2} \end{pmatrix}$$

$$\langle m_\nu \rangle = \left| \sum_i U_{ei}^2 m_{\nu_i} \right| = \left| c_{12}^2 c_{13}^2 m_1 + s_{12}^2 c_{13}^2 e^{i2\alpha_1} m_2 + s_{13}^2 e^{i2(\alpha_2 - \delta)} m_3 \right|$$

Compare to beta decay

$$m^2(\nu_e) = \sum_i |U_{ei}|^2 m^2(\nu_i)$$

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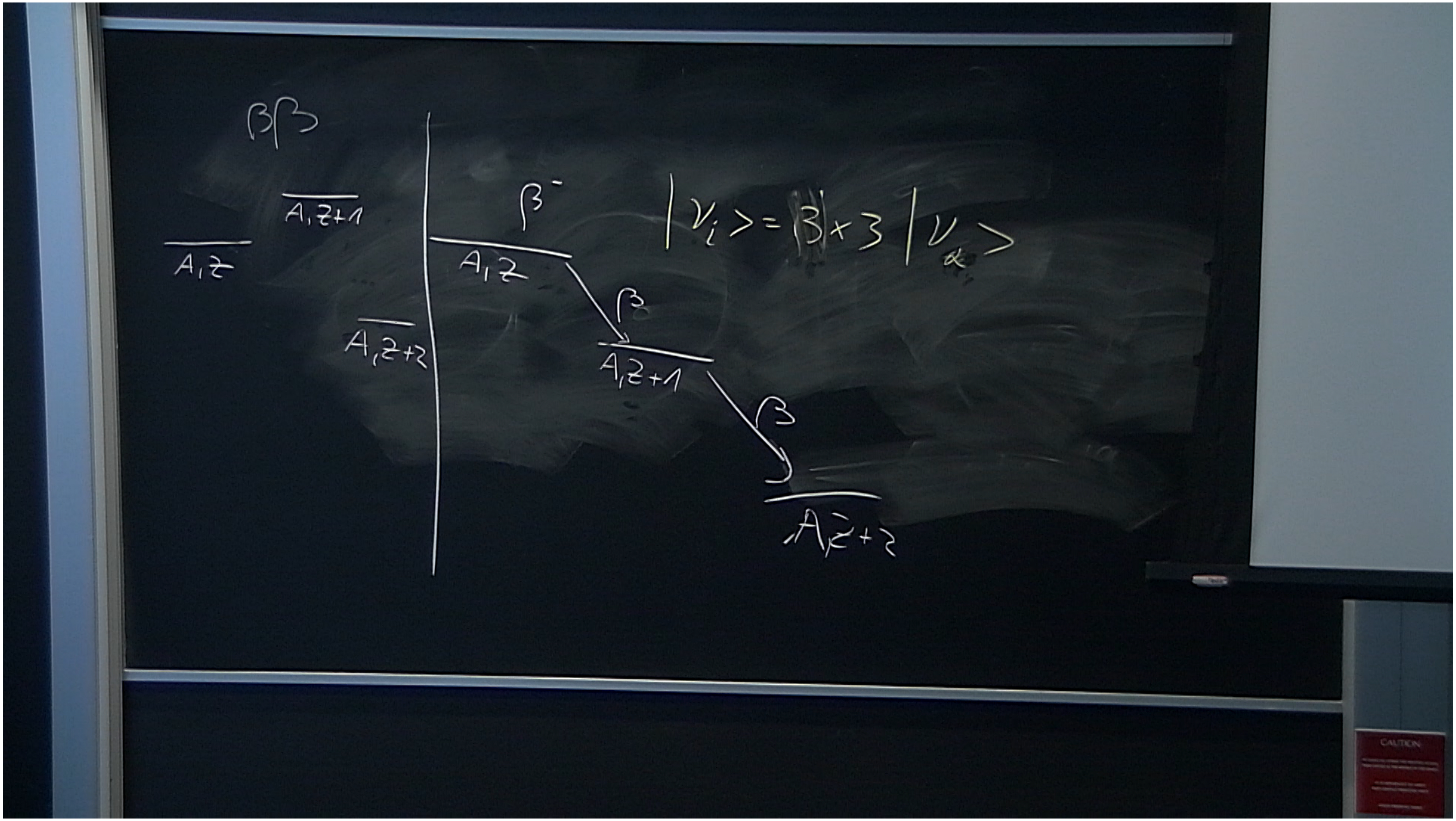
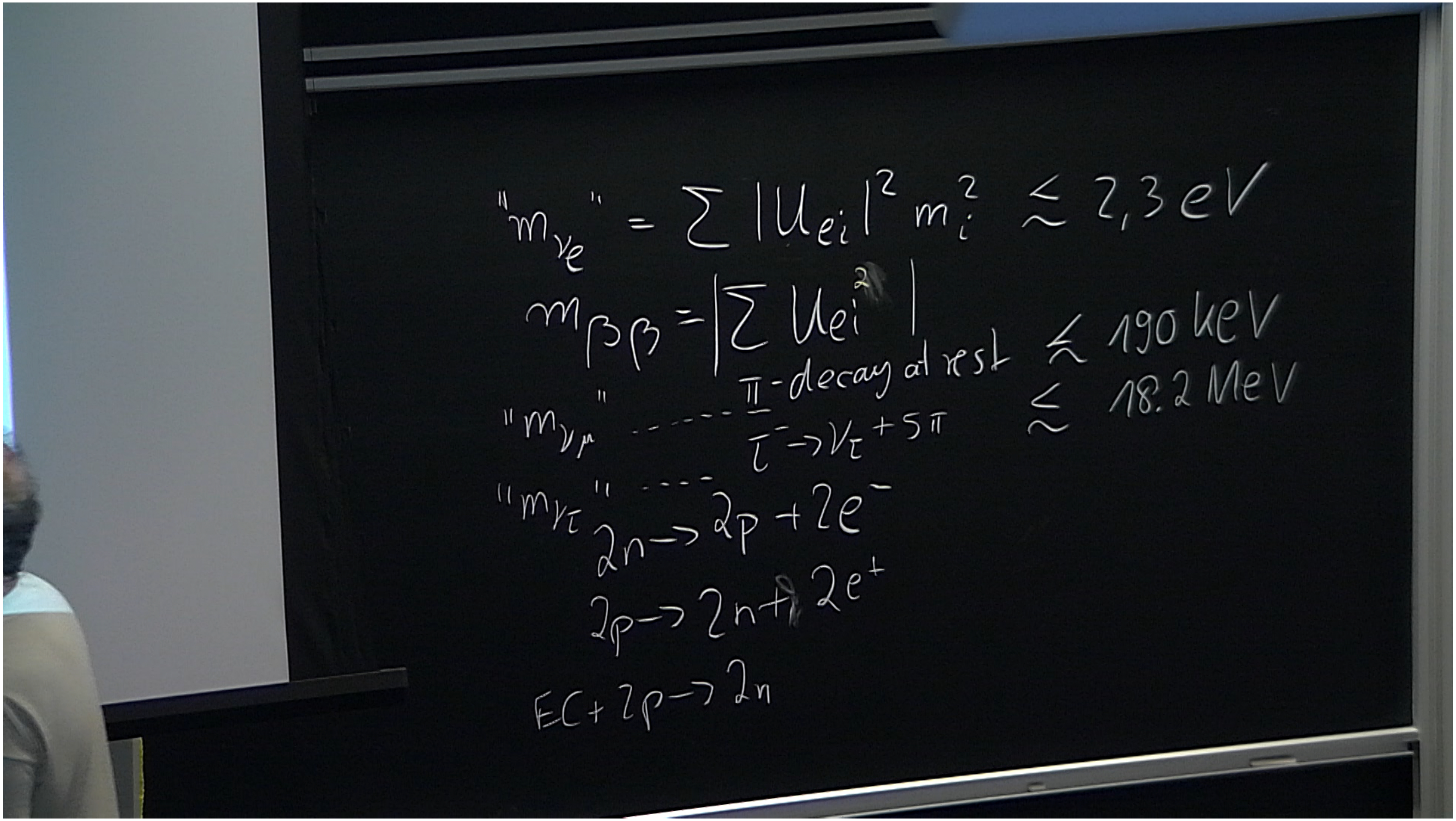
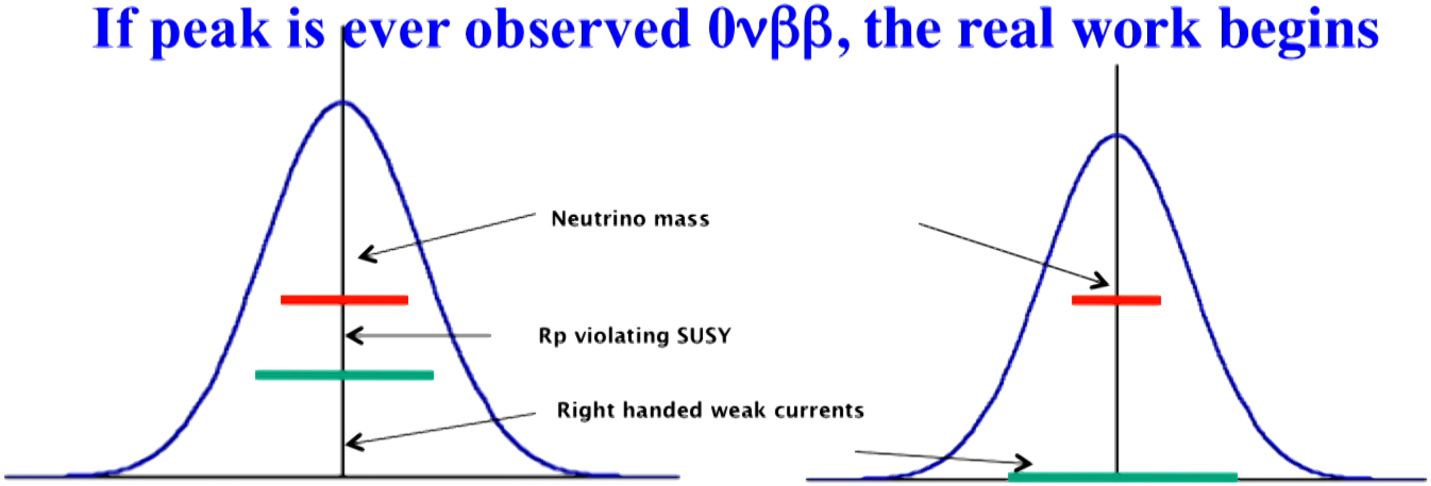

ββ
A,Z+1
A,Z
A,Z+2
β⁻
A,Z
β
A,Z+1
β
A,Z+2
|ν_i> = U|ν_α>



"m_{ν_e}" $= \sum |U_{ei}|^2 m_i^2 \lesssim 2{,}3\,eV$
$m_{\beta\beta} = |\sum U_{ei}^2 |$ $\lesssim 190\,keV$
"m_{ν_μ}" ...... π-decay at rest $\lesssim 18.2\,MeV$
$\tau^- \to \nu_\tau + 5\pi$
"m_{ν_τ}" ....
$2n \to 2p + 2e^-$
$2p \to 2n + 2e^+$
$EC + 2p \to 2n$

0νββ

If peak is ever observed 0νββ, the real work begins



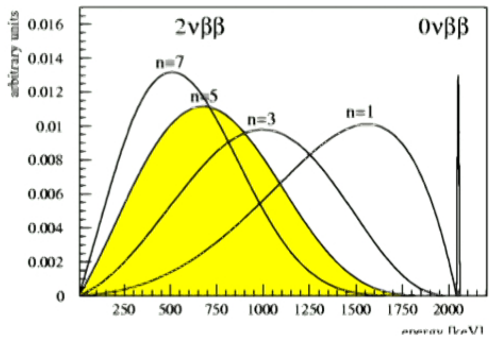
There could be more contributions....

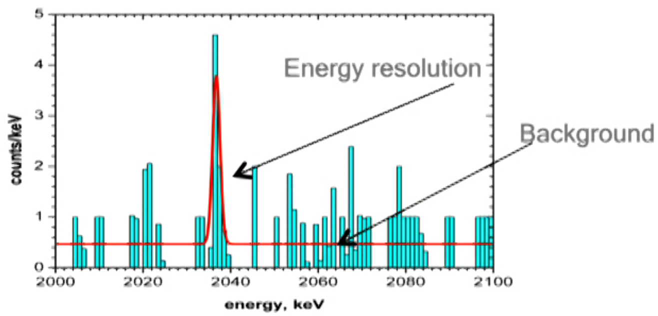
However, constraints from LHC

Spectral shapes

0νββ: Peak at Q-value of nuclear transition

Sum energy spectrum of both electrons





Measured quantity: Half-life

$$1 / T_{1/2} = PS * NME^2 * (<m_\nu> / m_e)^2$$

Experimental sensitivity depends on

$$T_{1/2}^{-1} \propto a\varepsilon\sqrt{\frac{Mt}{\Delta EB}}$$ (BG limited)

$$T_{1/2}^{-1} \propto a\varepsilon Mt$$ (BG free)

If background limited $$m_\nu \propto \sqrt[4]{\frac{\Delta EB}{Mt}}$$

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Double beta decay – a rare event search

or

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18.07.2018 Kai Zuber

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or

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Perfect world experiment

- No background
- δ function as peak
- 100 % abundance
- 100% detection efficiency
- Infinite measuring time
- Infinite mass

$$T_{1/2}^{-1} \propto a\varepsilon\sqrt{\frac{Mt}{\Delta E B}}$$

In perfect case half-life goes linear with measurement time

Life is easy, the rest is just details

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Back of an envelope

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This is the 50 meV option, just add 0's to moles and kgs if you want smaller neutrino masses

$$T_{1/2} = \ln 2 \cdot a \cdot N_A \cdot M \cdot t \,/\, N_{\beta\beta} \;\; (\tau \gg T) \quad \text{(Background free)}$$

For half-life measurements of 10^{26-27} yrs

1 event/yr you need 10^{26-27} source atoms

This is about 1000 moles of isotope, implying about 100 kg

Now you only can loose: nat. abundance, efficiency, background, ...

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Experimental approaches

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$0\nu\beta\beta$ decay rate scales with $Q^5 \rightarrow$ only those with Q>2000 keV

11 isotopes of interest

Isotope	Nat. abund. (%)	Q-values 2016
Ca-48	0.187	4262.96 ± 0.84
Ge-76	7.44	2039.006 ± 0.050
Se-82	8.73	2997.9 ± 0.3
Zr-96	2.80	3356.097 ± 0.086
Mo-100	9.63	3034.40 ± 0.17
Pd-110	11.72	2017.85 ± 0.64
Cd-116	7.49	2813.50 ± 0.13
Sn-124	5.79	2292.64 ± 0.39
Te-130	33.80	2527.518 ± 0.013
Xe-136	8.9	2457.83 ± 0.37
Nd-150	5.64	3371.38 ± 0.20

Candles

GERDA, Majorana

SuperNEMO, LUCIFER

MOON, AMore

COBRA

Tin.Tin

CUORE, SNO+

EXO, KamLAND-Zen, NEXT, XMASS

MCT

There is no super-isotope!

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Going underground

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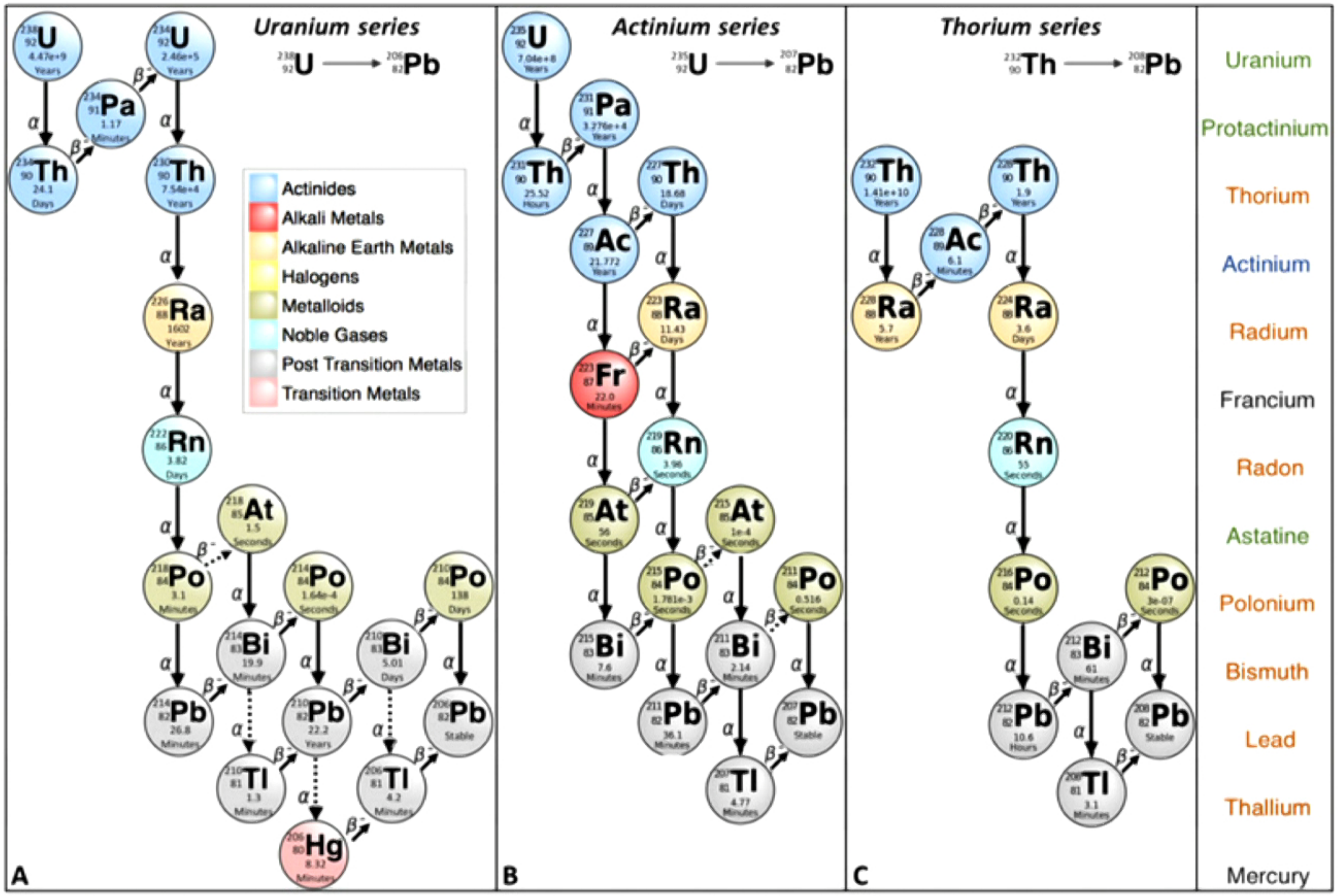
Next enemy – primordial decay chains of U,Th



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Experiment around 1995

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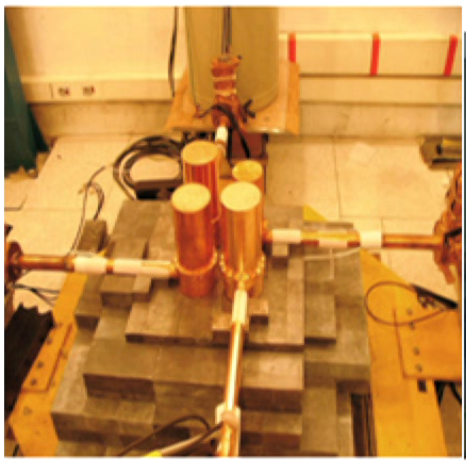
Example: Isotope of interest: 76Ge

- **The detectors are decaying!!**
- **5 isotopical enriched Ge-detectors**
- **Sum energy -> Peak at 2039 keV**

Early stage: Still only 1 decay per year per 10 kg Ge

Background obtained 0.1 count/keV/kg/yr



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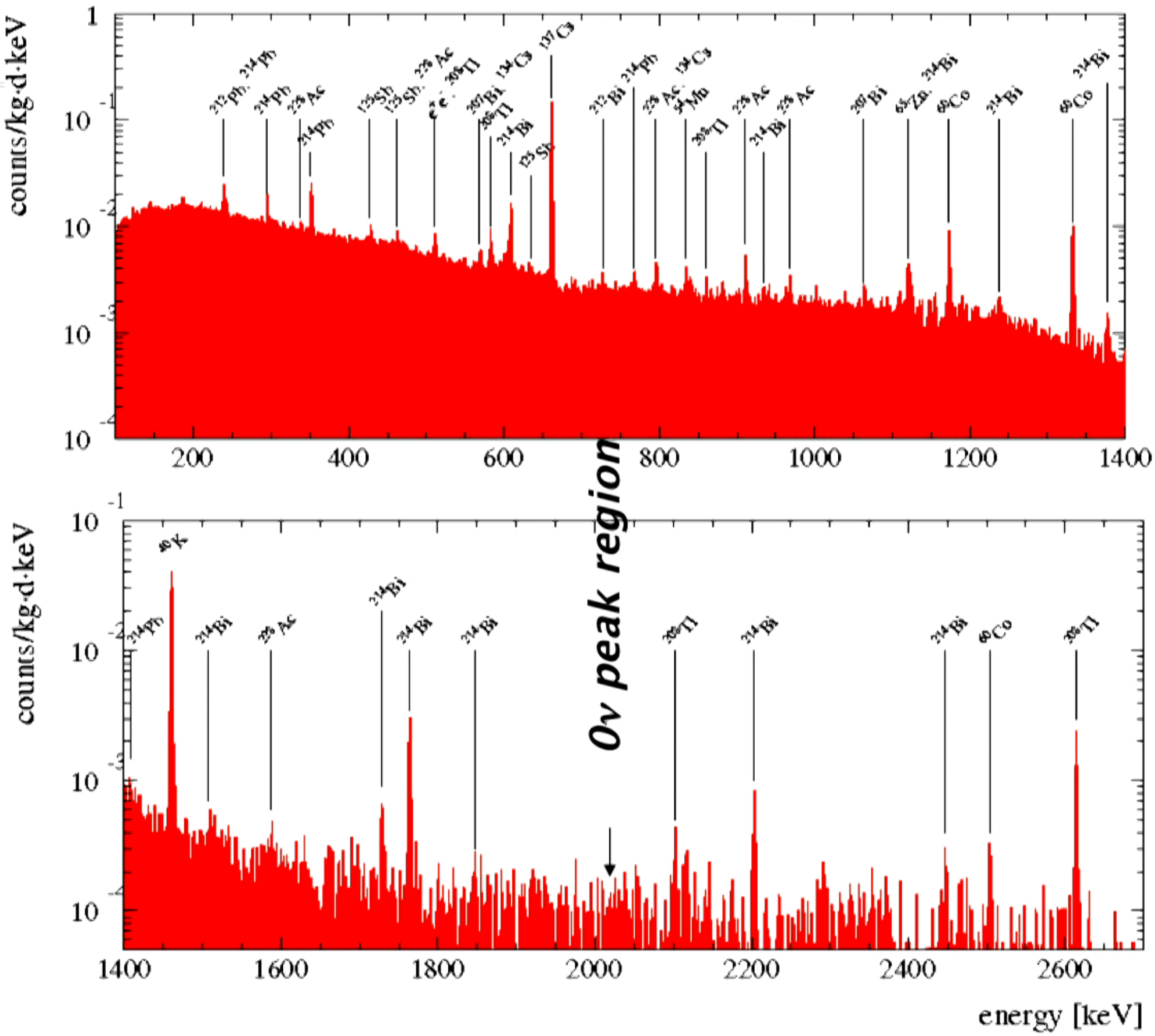
Ge-spectrum



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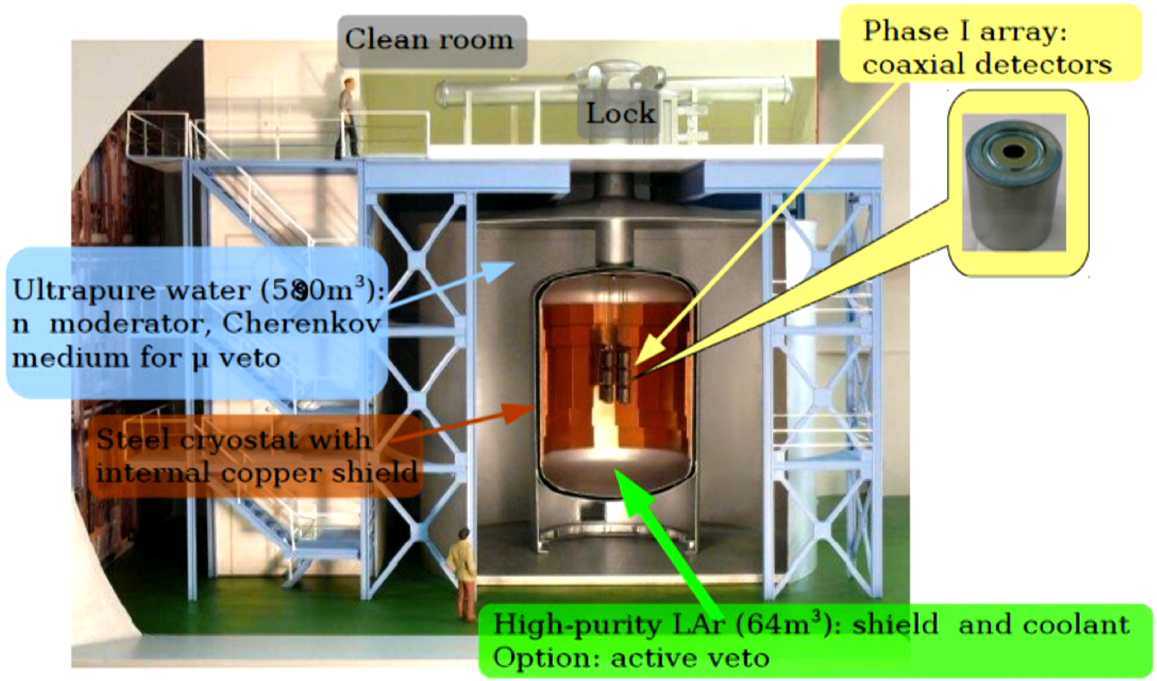
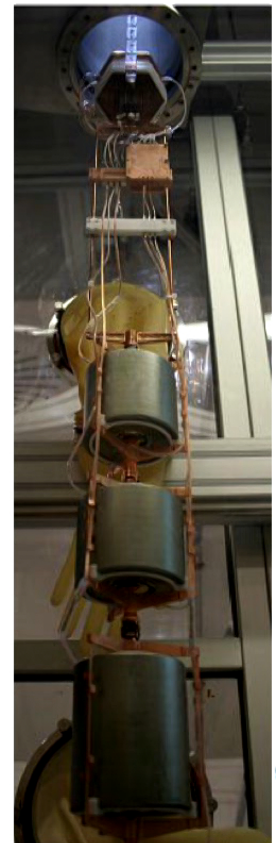
GERDA-Principal Setup

Idea : Running bare Ge crystals in LAr



The Gerda experiment for the search of $0\nu\beta\beta$ decay in ^{76}Ge

Eur. Phys. J. C (2013) 73:2330



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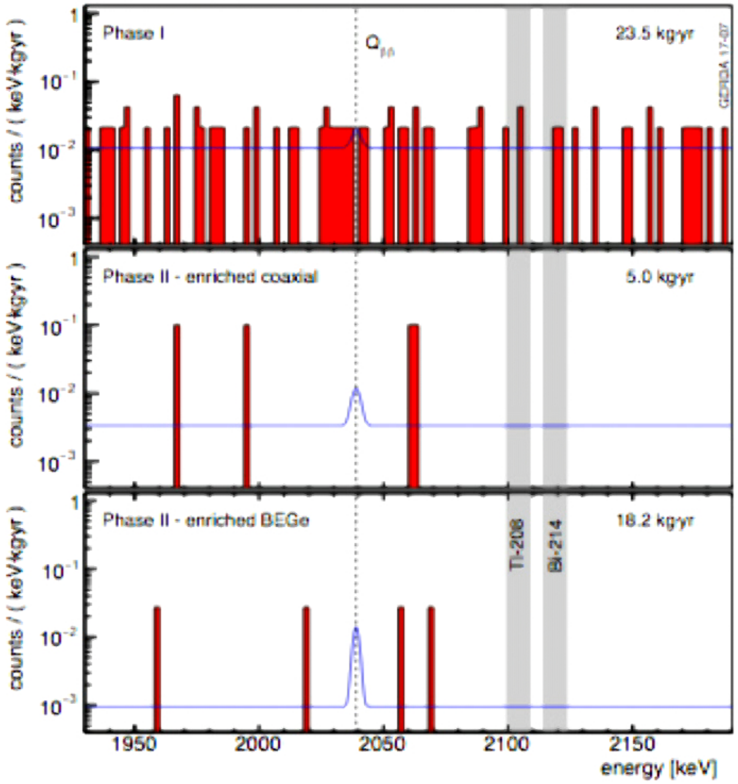
GERDA



Next step: LEGEND

$$T_{1/2} > 8 \times 10^{25} yrs$$

M. Agostini et al., PRL 120, 132503 (2018)

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What have low background experiments and a good bottle of vine in common?

K. Zuber, TU Dresden

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The „red wine“ files

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AFP

Sat May 31, 2008

A case of **6 magnums of Chateau Mouton Rothschild, vintage 1945**, is seen going under the hammer at a fine wine auction in a hotel in Hong Kong, on May 31, 2008. The auction has raised an Asian record of more than **eight million dollars**, organisers said, highlighting the region's growing passion for fine vintages. (AFP/Antony Dickson)

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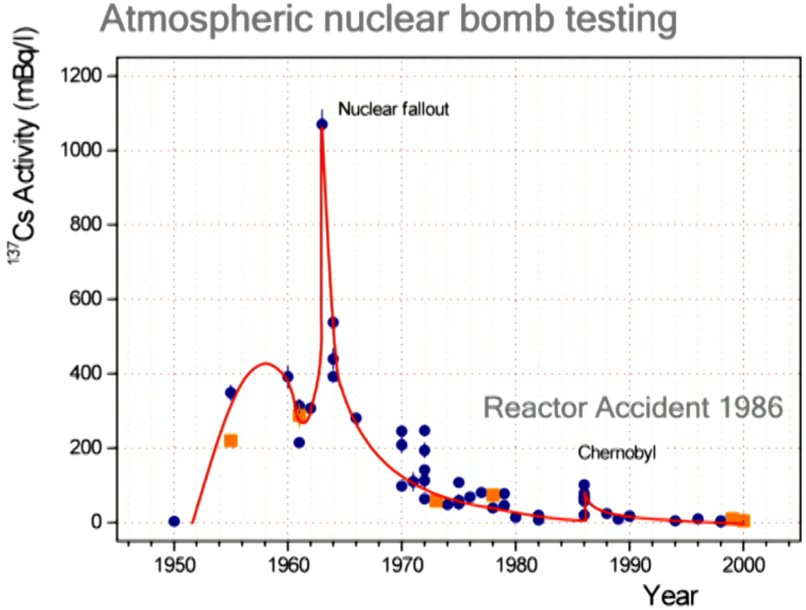
The evidence: Cs-137

❖The wine „remembers" the year of growth

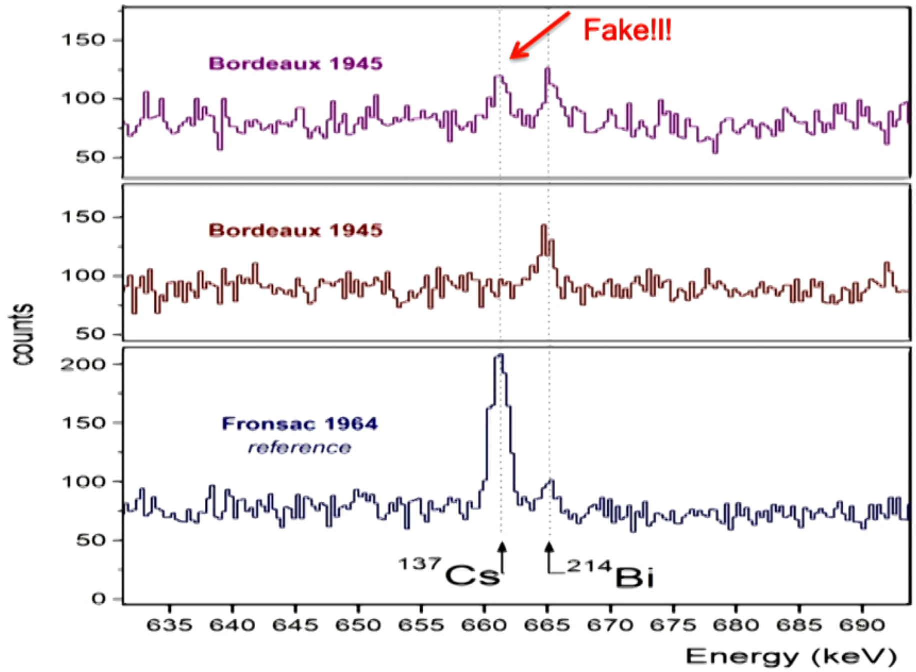


Calibration with red wine from Bordeaux-area

Determine Cs-137activity and you know the age!... Before 1952 no Cs-137

The next suspects

❖ Wine reference: Fronsac 1964, 2 Bordeaux 1945



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Mouton-Rothschild + Lafite 1900?

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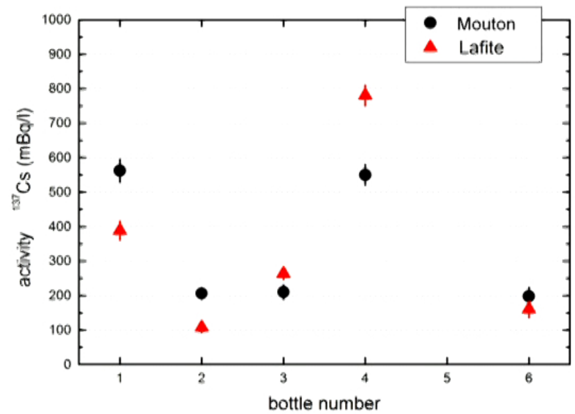
❖ 6 bottles provided by French government (franz. Justiz),

Einzelpreis 8000$



All bottles showCs-137, i.e. none is correct t!
Even worse, different values, some mixing was done!!

Bottle 5 was opened and date with radiocarbon method (C-14). Wine is from the sixties!

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The 100000$ bottles

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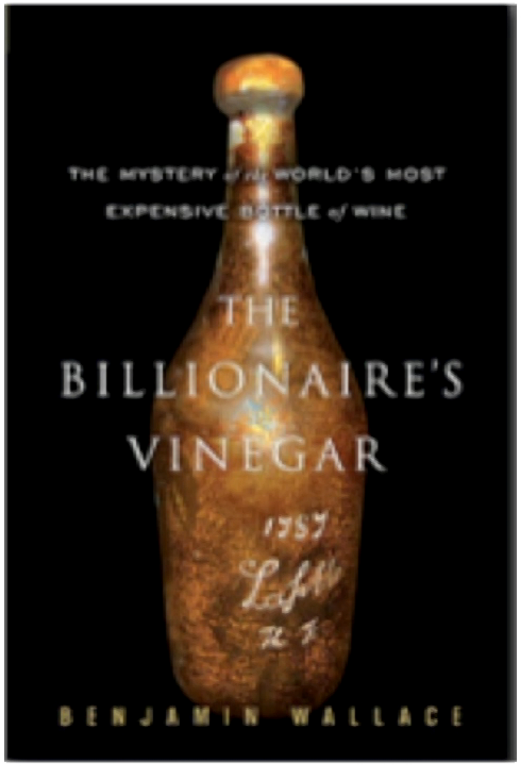

Photographie der Weinflaschen von Thomas Jefferson *höchstwahrscheinlich* aus den Jahren 1784 und 1787. Zwei Flaschen sind vom Chateau Lafite, zwei weitere von Branne Mouton, heute Mouton Rothschild genannt.

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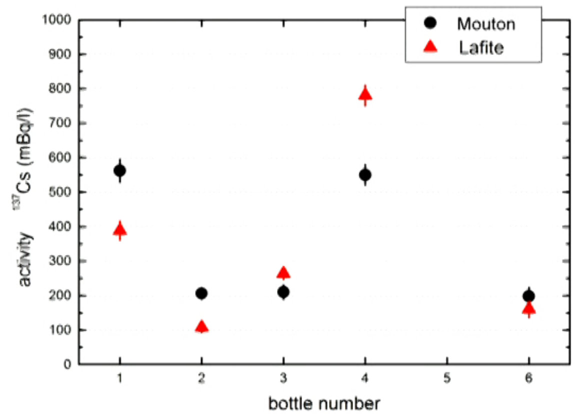

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