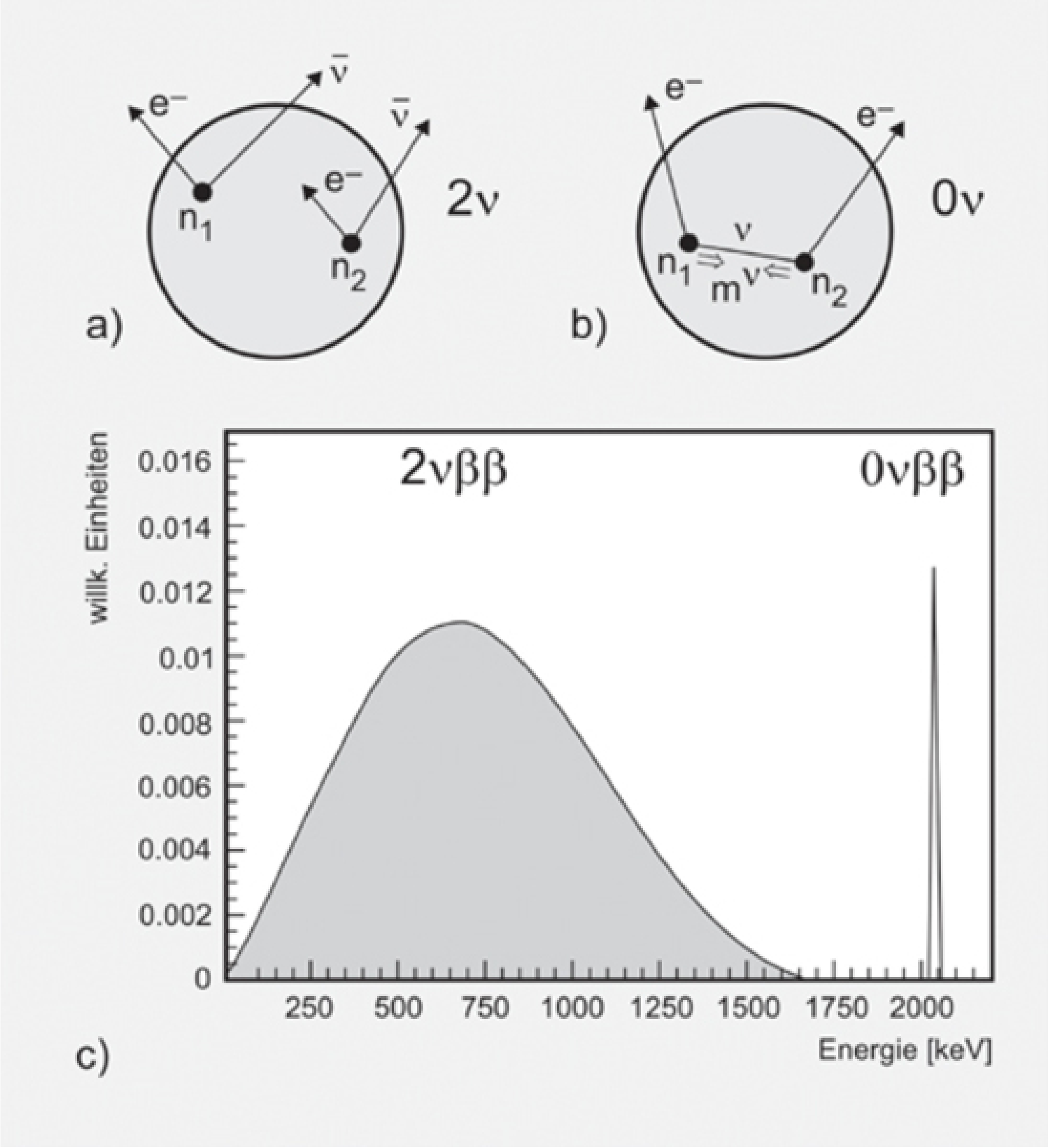
Double Beta Decay



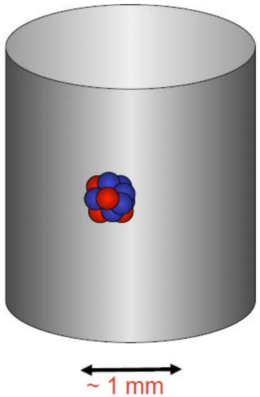
rate of 0νββ — phase space — nuclear matrix elements — effective Majorana neutrino mass

$$1/\tau = G(Q,Z)\ |M_{nucl}|^2 \ \langle m_{ee} \rangle^2$$

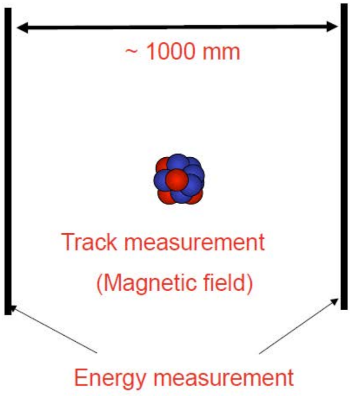
Expected half-lives $O(10^{25} \ldots 10^{26})$ yr for $\langle m_{ee} \rangle \approx 50$ meV

Measurement principle:

Source = Detector



Source ≠ Detector



Heidelberg-Moscow Experiment @ LNGS

Technical parameters of the five enriched ^{76}Ge detectors

Detector number	Total mass (kg)	Active mass (kg)	Enrichment in ^{76}Ge(%)	PSA
No. 1	0.980	0.920	85.9 ± 1.3	No
No. 2	2.906	2.758	86.6 ± 2.5	Yes
No. 3	2.446	2.324	88.3 ± 2.6	Yes
No. 4	2.400	2.295	86.3 ± 1.3	Yes
No. 5	2.781	2.666	85.6 ± 1.3	Yes

Germanium Detectors

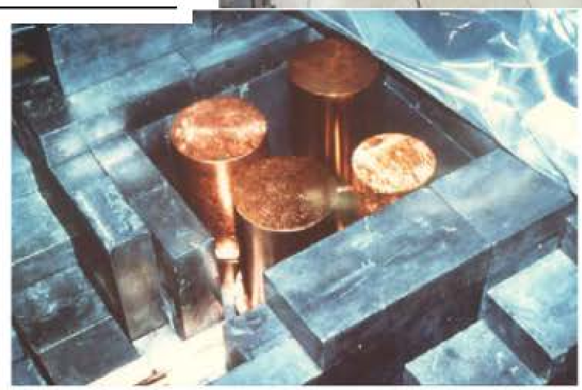


Fig. 1. The HEIDELBERG–MOSCOW ββ-experiment in the Gran Sasso (top), and four of the enriched detectors during installation (bottom left). The fifth detector was installed in an extra shielding using electrolytic copper as inner shield (bottom right).

Data acquisition and analysis of the ^{76}Ge double beta experiment in Gran Sasso 1990–2003

H.V. Klapdor-Kleingrothaus*[,1], A. Dietz, I.V. Krivosheina[2], O. Chkvorets

NIM A 522 (2004)

Evidence by Part of HM

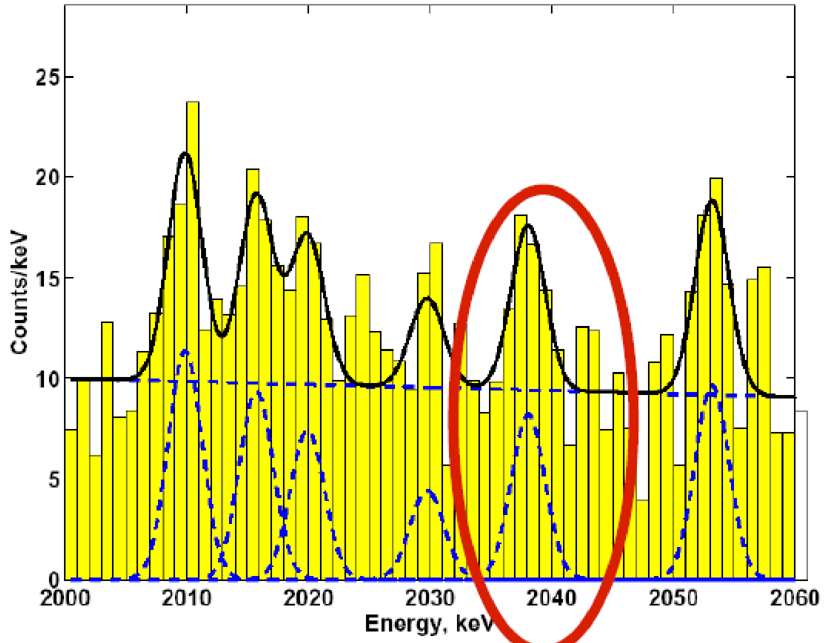


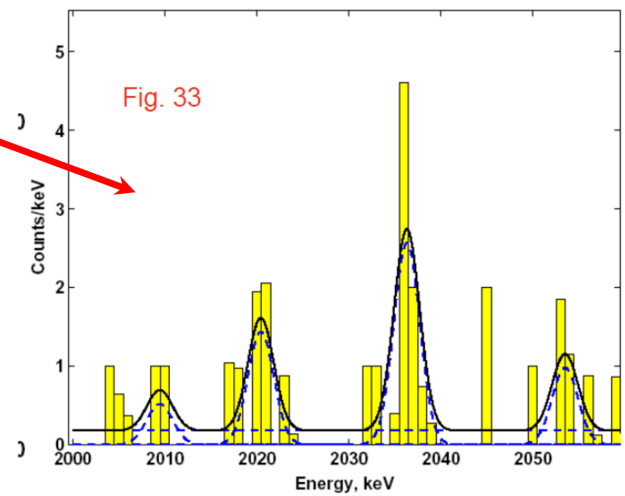
Fig. 17. The total sum spectrum of all five detectors (in total 10.96 kg enriched in ^{76}Ge), for the period November 1990–May 2003 (71.7 kg year) in the range 2000–2060 keV and its fit (see Section 3.2).

- Nov 1990- May 2003
- 71.7 kg year
- Bgd 0.11 / kg y keV
- 28.75 ± 6.87 events (bgd:~60)
- 4.2 sigma evidence for $0\nu\beta\beta$

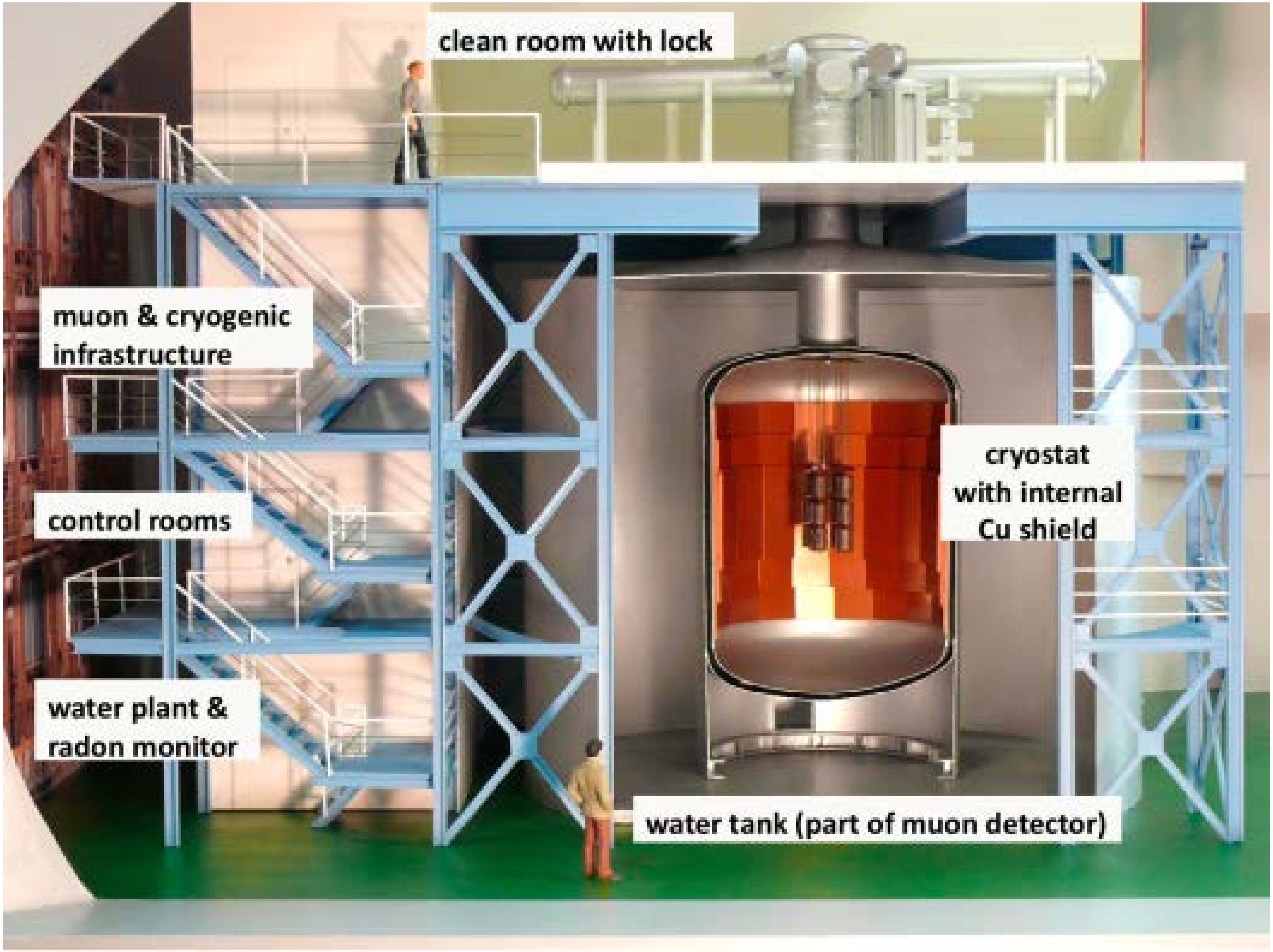
- 0.34-2.03 x10^{25} y (3 sigma)
- Best fit 1.19 x10^{25} y

- m_{ee} = 0.1-0.9 eV
- best fit 0.44 eV

?



Gerda


clean room with lock
muon & cryogenic infrastructure
control rooms
water plant & radon monitor
cryostat with internal Cu shield
water tank (part of muon detector)

Gerda Results

PRL **111**, 122503 (2013)

Exposure: 21.6 kg yr

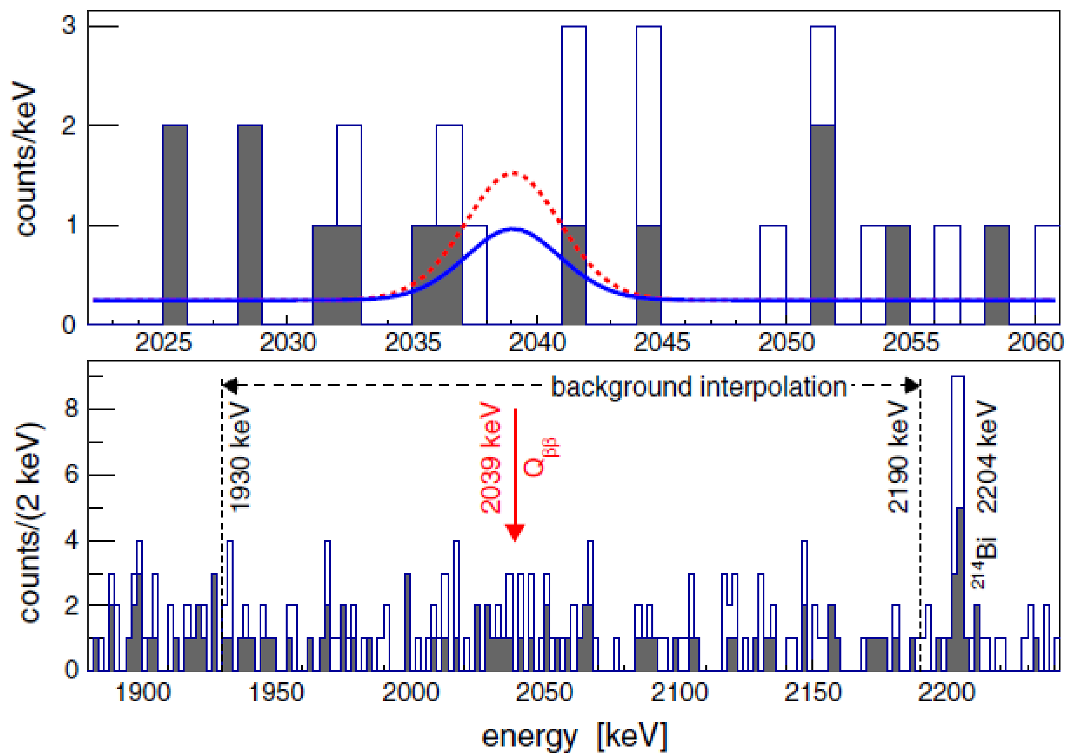


FIG. 1 (color online). The combined energy spectrum from all ^{enr}Ge detectors without (with) PSD is shown by the open (filled) histogram. The lower panel shows the region used for the background interpolation. In the upper panel, the spectrum zoomed to $Q_{\beta\beta}$ is superimposed with the expectations (with PSD selection) based on the central value of Ref. [11] $T^{0\nu}_{1/2} = 1.19 \times 10^{25}$ yr (red dashed) and with the 90% upper limit derived in this work, corresponding to $T^{0\nu}_{1/2} = 2.1 \times 10^{25}$ yr (blue solid).

Gerda Results

PRL **111**, 122503 (2013)

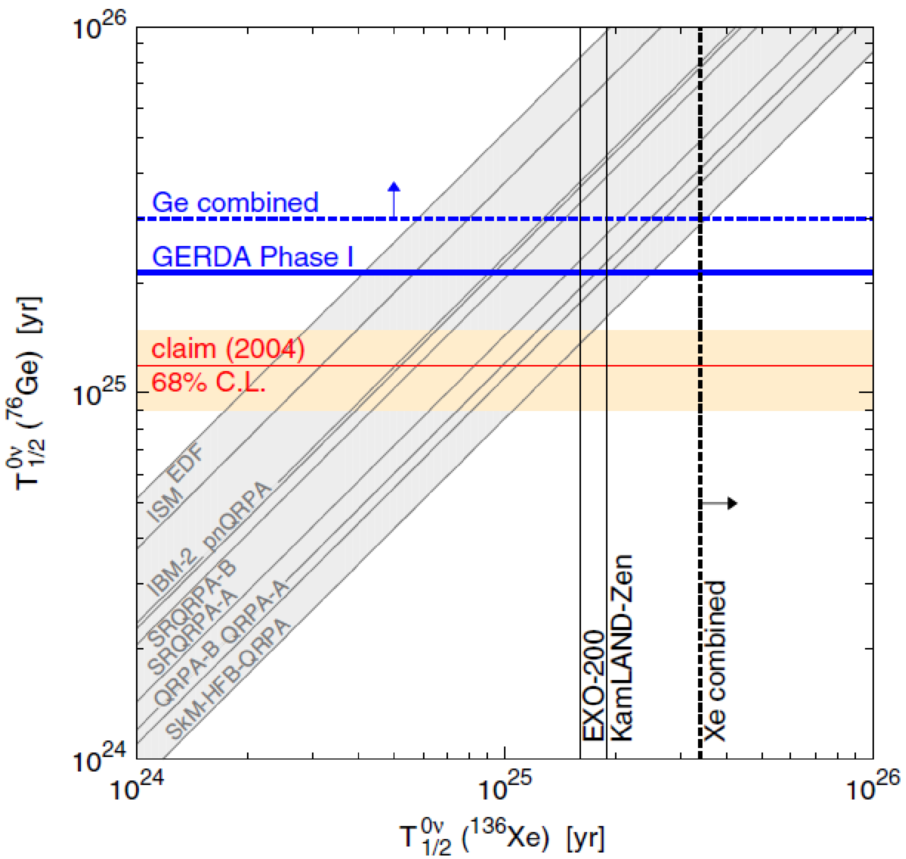


FIG. 2 (color online). Limits (90% C.L.) on $T^{0\nu}_{1/2}$ of ^{76}Ge (this work) and ^{136}Xe [14,15] compared with the signal claim for ^{76}Ge of Ref. [11] (68% C.L. band). The lines in the shaded gray band are the predictions for the correlation of the half-lives in ^{136}Xe and in ^{76}Ge according to different NME calculations [27,28,33–37]. The selection of calculations and the labels are taken from Ref. [29].

$$T^{0\nu}_{1/2} > 3.0 \times 10^{25} \text{ yr}$$

$$T^{0\nu}_{1/2} > 2.1 \times 10^{25} \text{ yr (90\% C.L.)}$$

Neutrino Masses

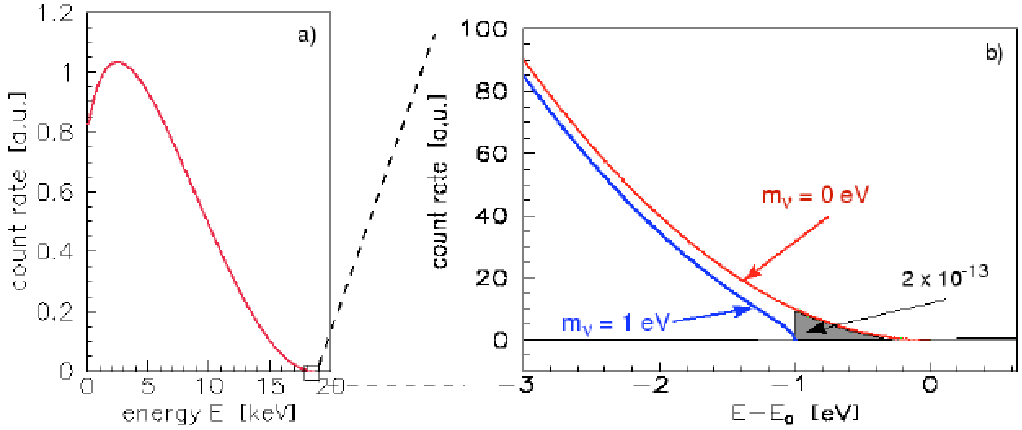
Kinematical Determination from Beta-Decay:

Relativistic kinematics:

$$E^2 = p^2 + m^2; \;\; \sum p_i^\mu = \sum p_f^\mu$$

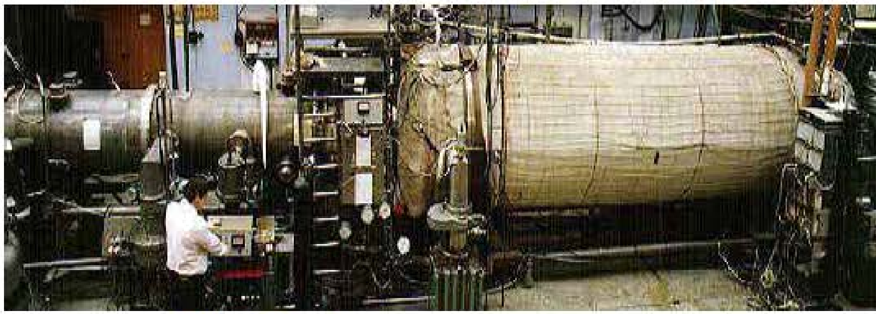
Endpoint of decays:

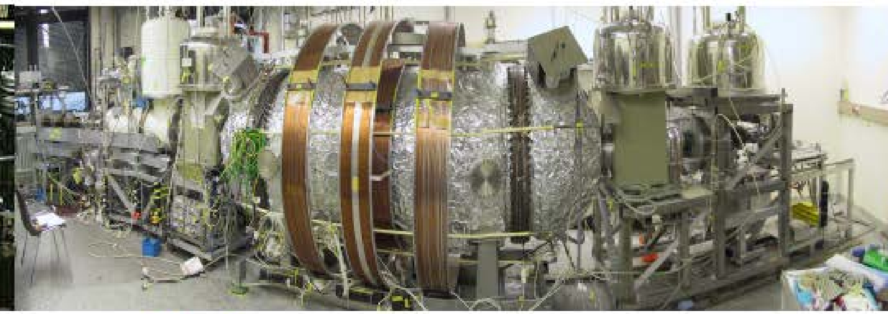
Tritium $\rightarrow He^3 + e^- + \overline{\nu}_e$



Bounds:	"Elektron-Neutrino":	$m < 2.2$ eV	(Mainz, Troitsk)
	"Muon-Neutrino":	$m < 170$ keV	
	"Tau-Neutrino":	$m < 15.5$ MeV	

Tritium-Experiments





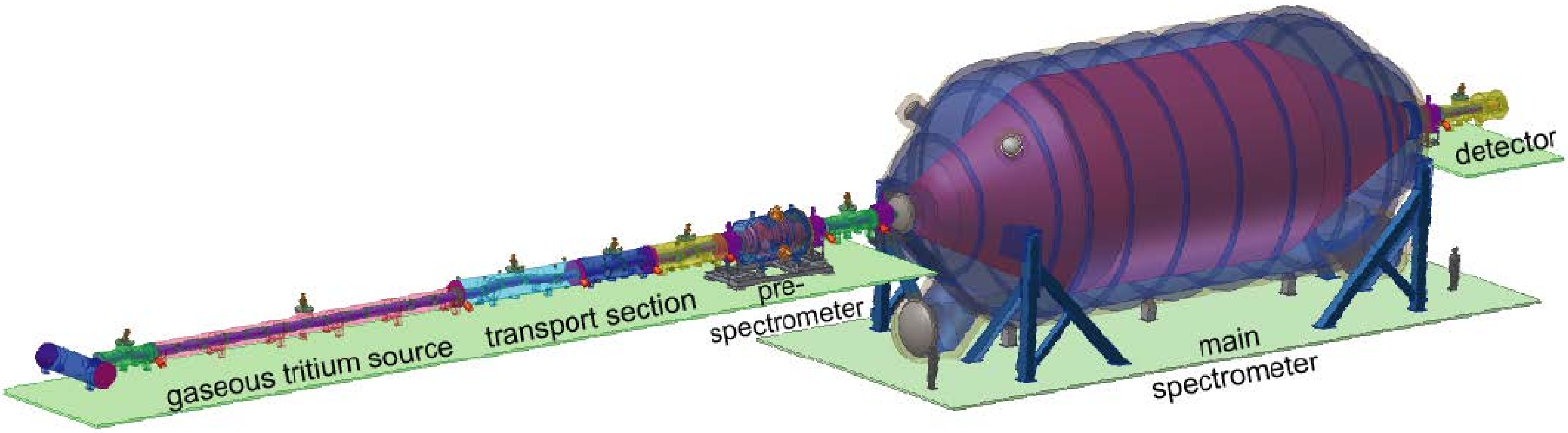
Troitsk	Mainz
windowless gaseous T_2 source	quench condensed solid T_2 source
analysis 1994 to 1999, 2001	**analysis 1998/99, 2001/02**
$m_\nu^2 = -2.3 \pm 2.5 \pm 2.0\ eV^2$	$m_\nu^2 = -1.2 \pm 2.2 \pm 2.1\ eV^2$
$m_\nu \leq\ 2.2\ eV$ (95% CL.)	$m_\nu \leq\ 2.2\ eV$ (95% CL.)

both experiments have reached their intrinsic sensitivity limit

KATRIN

KATRIN - Karlsruhe Tritium Neutrino Experiment

direct n-mass measurement with sub-eV sensitivity



Sensitivity: 0.2 eV

KATRIN