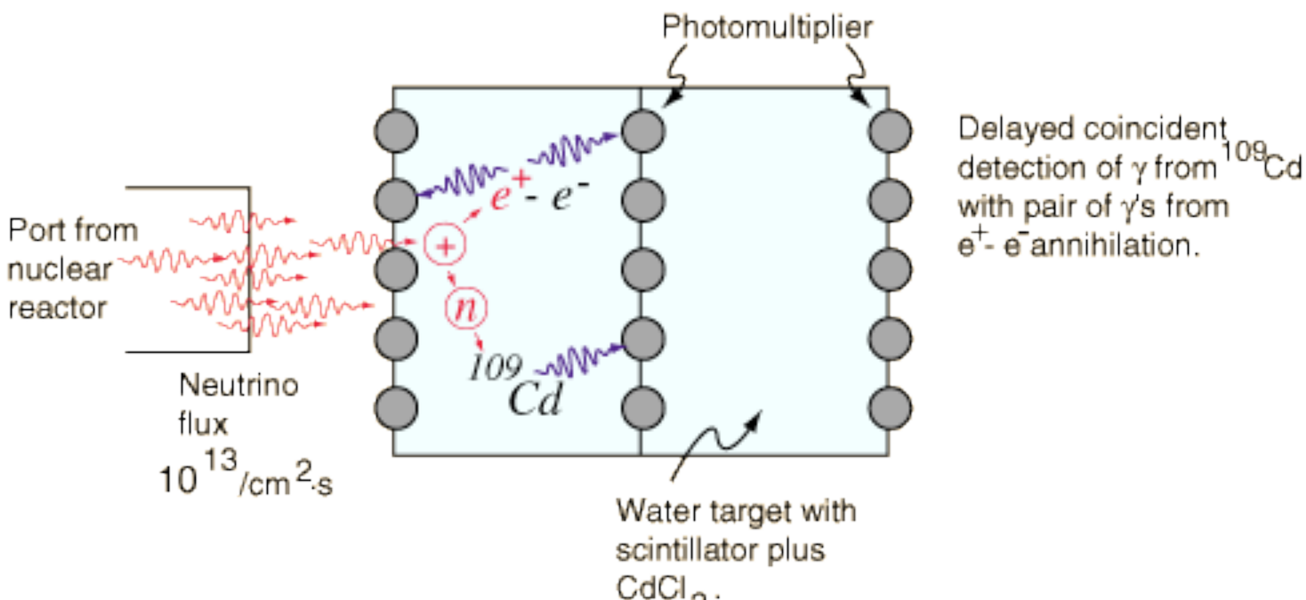
Reines and Cowan Experiement

Reines and Cowan experiment

$$\bar{\nu}_e + p \rightarrow n + e^+ \qquad n + {}^{108}Cd \rightarrow {}^{109}Cd^* \rightarrow {}^{109}Cd + \gamma$$



Distinctive signature for the neutrino reaction - the gamma pair in coincidence plus another gamma within 5 μs.

"Detection of the Free Neutrino: A Confirmation", C. L. Cowan, Jr., F. Reines, F. B. Harrison, H. W. Kruse and A. D. McGuire, Science 124, 103 (1956)

Recent m_ν constraints and Tritium Experiments

From F.Gatti and Philipp Chung-On Ranitzsch talks at Nu Telescope 2015

Introduction

- Since the the flavour oscillations paradigm has been fully a remarkable increase of interest has in investigating directly the absolute mass scale
- The absolute mass scale of neutrinos remains today an open question subject to experimental investigation from both particle physics and cosmology.
- Over the next decade, a number of proposal/projects from both disciplines will aim to test the mass scale further to the very limits of the predictions from oscillation results → sub eV sensitivity.
- After the discovery of a finite neutrino mass Presently the main common issue is: "We need to imagine a PRECISION EXPERIMENT"

Kinematical methods

- β decay: $m_j \neq 0$ affect β−spectrum endpoint. Sensitive to the "effective electron neutrino mass":

  $\mathbf{m}_\beta = \{ \Sigma_j m_j^2 \, |U_{ej}|^2 \}^{1/2}$

  Flavor-Mass Mixing Parameter

- 0ν2β decay: can occur if $m_j \neq 0$. Sensitive to the "effective Majorana mass":

  $\mathbf{m}_{\beta\beta} = \{ \Sigma_j m_j \, |U_{ej}|^2 e^{i\varphi_j} \}$

  Flavor-Mass Mixing parameter + imaginary phase

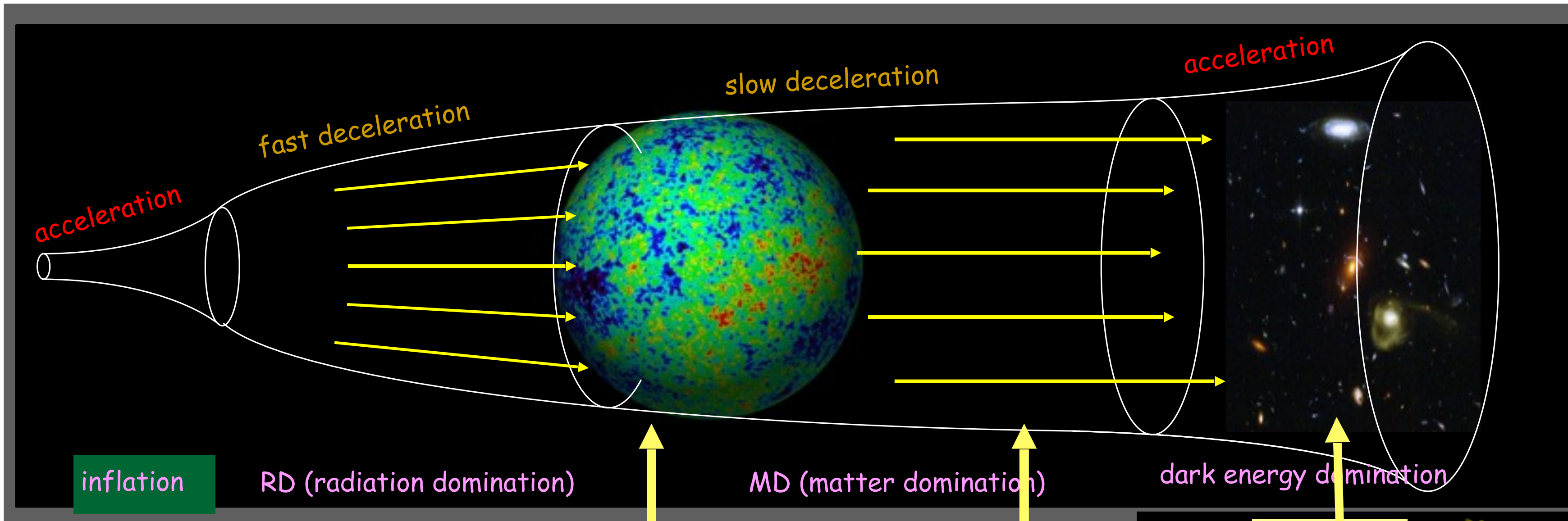
- Cosmology: $m_j \neq 0$ can affect large scale structures in (standard) cosmology constrained by CMB and not CMB (LSS,Lyα) data. Sensitive to:

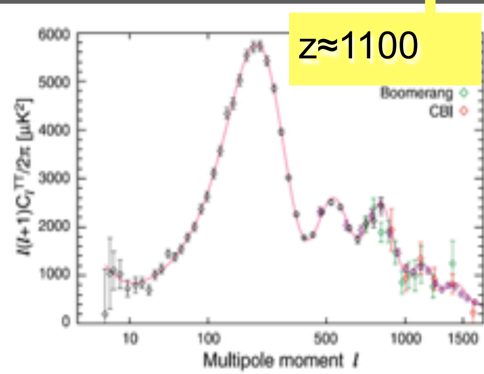
  $\mathbf{m} = \Sigma_j m_j$

  Flavor-Mass Mixing independent

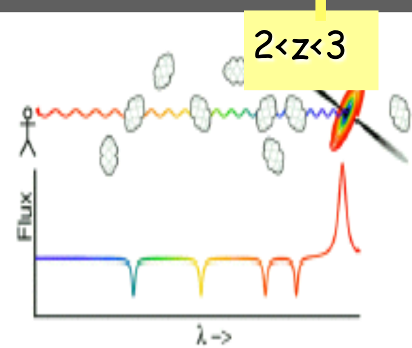
Cosmological constraints (overview)

Imprint of cosmological neutrinos upon the structure evolution of the universe is testable by cosmology observation

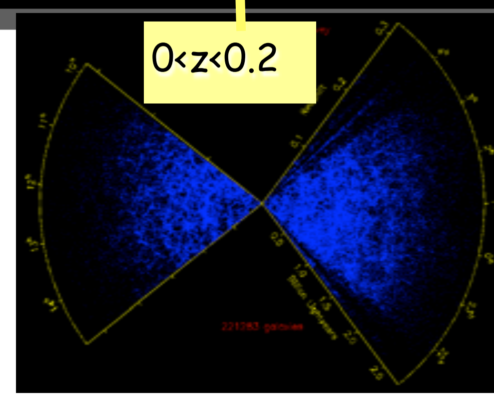




CMB temperature/polarization anisotropies

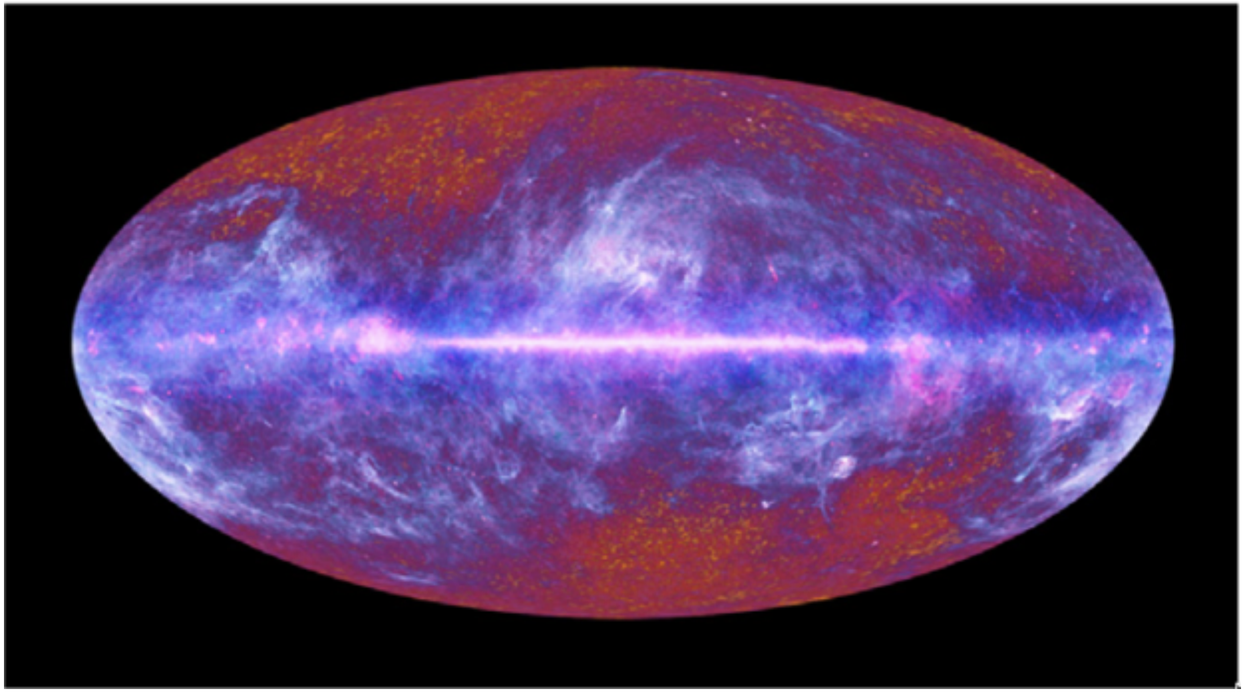


Lyman-α forests in quasar spectra



galaxy redshift surveys

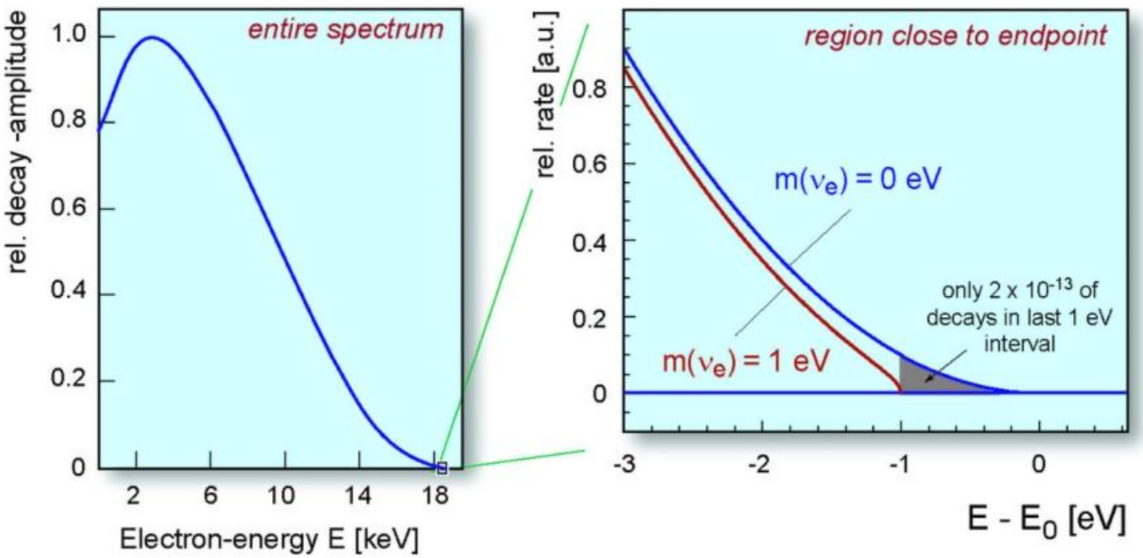
Cosmological Constraints (Planck)

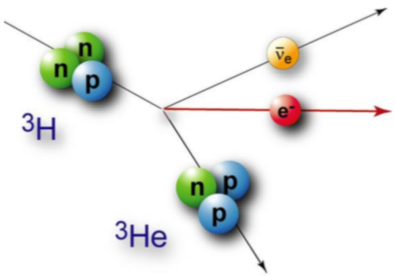


Parameter	TT	TT+lensing	TT+lensing+ext	TT, TE, EE	TT, TE, EE+lensing	TT, TE, EE+lensing+ext
Ω_K	$-0.052^{+0.049}_{-0.055}$	$-0.005^{+0.016}_{-0.017}$	$-0.0001^{+0.0054}_{-0.0052}$	$-0.040^{+0.038}_{-0.041}$	$-0.004^{+0.015}_{-0.015}$	$0.0008^{+0.0040}_{-0.0039}$
Σm_ν [eV]	< 0.715	< 0.675	< 0.234	< 0.492	< 0.589	< 0.194
$N_{\rm eff}$	$3.13^{+0.64}_{-0.63}$	$3.13^{+0.62}_{-0.61}$	$3.15^{+0.41}_{-0.40}$	$2.99^{+0.41}_{-0.39}$	$2.94^{+0.38}_{-0.38}$	$3.04^{+0.33}_{-0.33}$
$Y_{\rm P}$	$0.252^{+0.041}_{-0.042}$	$0.251^{+0.040}_{-0.039}$	$0.251^{+0.035}_{-0.036}$	$0.250^{+0.026}_{-0.027}$	$0.247^{+0.026}_{-0.027}$	$0.249^{+0.025}_{-0.026}$
$dn_s/d\ln k$	$-0.008^{+0.016}_{-0.016}$	$-0.003^{+0.015}_{-0.015}$	$-0.003^{+0.015}_{-0.014}$	$-0.006^{+0.014}_{-0.014}$	$-0.002^{+0.013}_{-0.013}$	$-0.002^{+0.013}_{-0.013}$
$r_{0.002}$	< 0.103	< 0.114	< 0.114	< 0.0987	< 0.112	< 0.113
w	$-1.54^{+0.62}_{-0.50}$	$-1.41^{+0.64}_{-0.56}$	$-1.006^{+0.085}_{-0.091}$	$-1.55^{+0.58}_{-0.48}$	$-1.42^{+0.62}_{-0.56}$	$-1.019^{+0.075}_{-0.080}$

(Tritium) β-decay and neutrino mass

β-decay: $${}^{A}_{Z}X_{N} \rightarrow {}^{A}_{Z+1}X_{N-1} + e^{-} + \bar{\nu}_{e}$$





Tritium ${}^{3}H$:

E_0 = 18.6 keV

$T_{1/2}$ = 12.3 y

Rhenium ${}^{187}Re$:

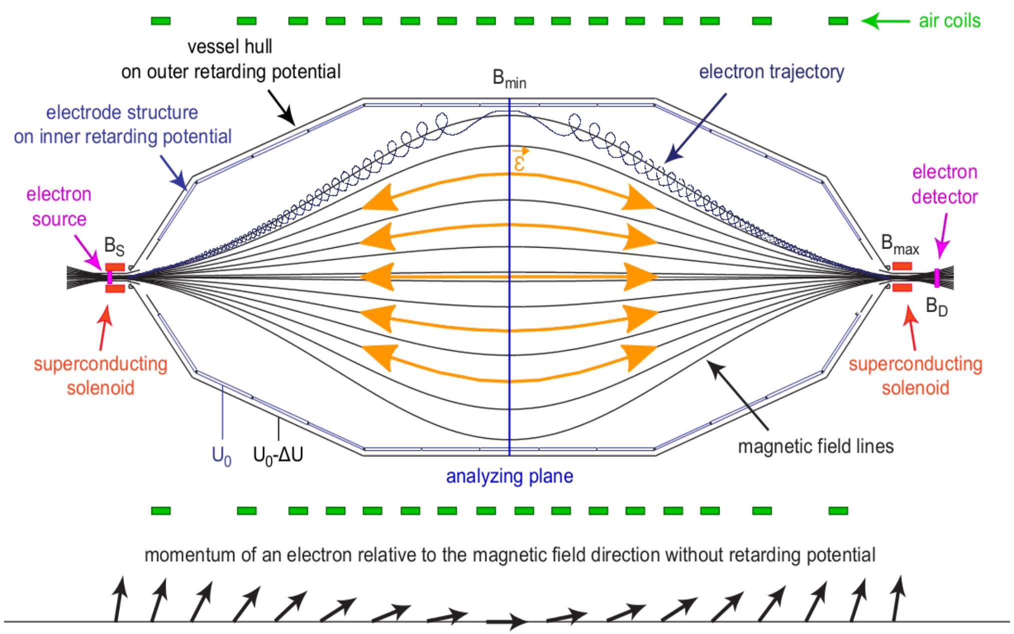
E_0 = 2.47 keV

$T_{1/2}$ = 4.3 10^{10} y

$$\frac{dN}{dE} = K\ F(E,Z)\ p\ (E_e + m_e)(E_0 - E_e)\sqrt{(E_0 - E_e)^2 - m(\bar{\nu}_e)^2}$$

MAC-E Filter

Magnetic **A**diabatic **C**ollimation and **E**lectrostatic Filter:



Magnetic guiding and collimation of e^-

- Transform $E_\perp$ to $E_{||}$

Electrostatic field for energy analysis

- Sharp transmission depending on:
  - Emission angle
  - Radius in at B_{min}

Integrated energy resolution:

$$\Delta E = E\ \frac{B_{min}}{B_{max}}$$

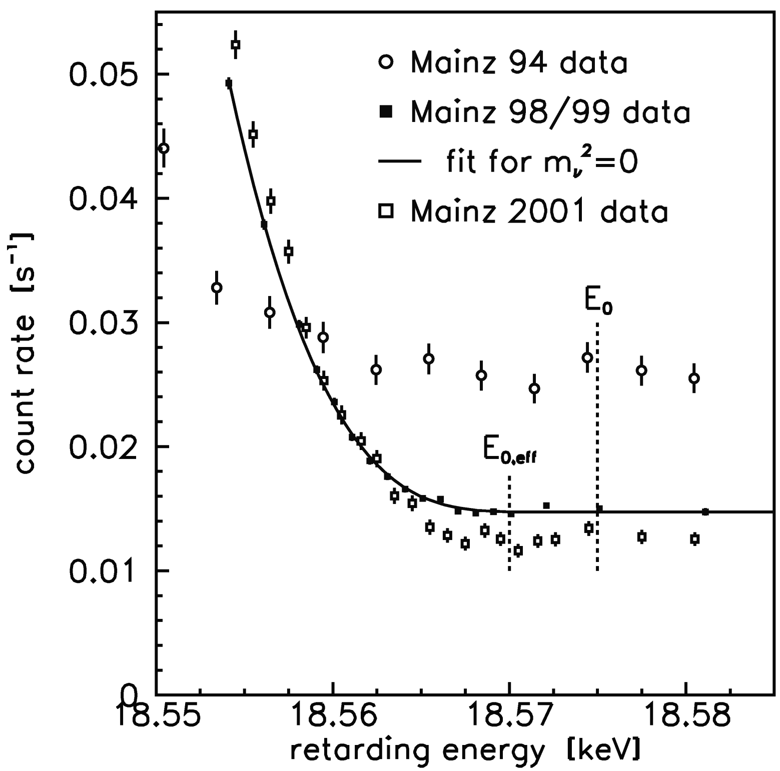
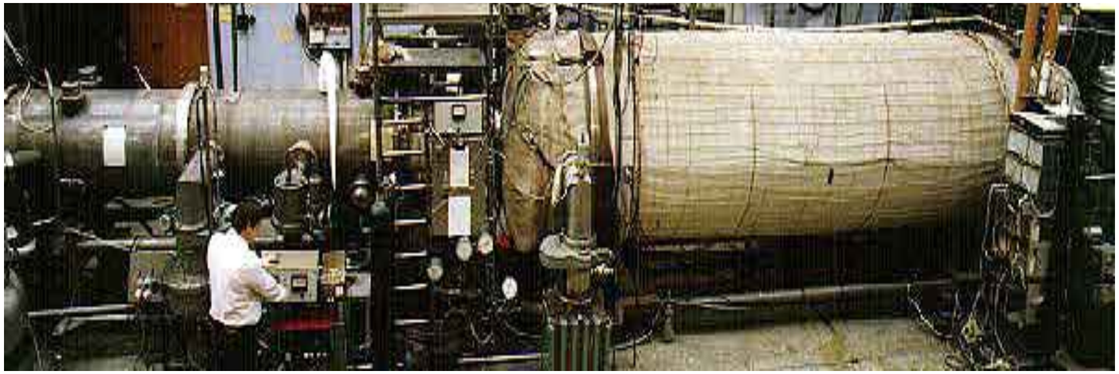


Fig. 20. Averaged count rate of the 98/99 data (filled squares) with fit for $m^2(\nu_e) = 0$ (line) and the 2001 data (open squares) in comparison with previous Mainz data from phase I (open circles) plotted as function of the retarding potential near the endpoint E_0.

Previous MAC-E filter experiments: Troisk & Mainz

Troisk experiment:



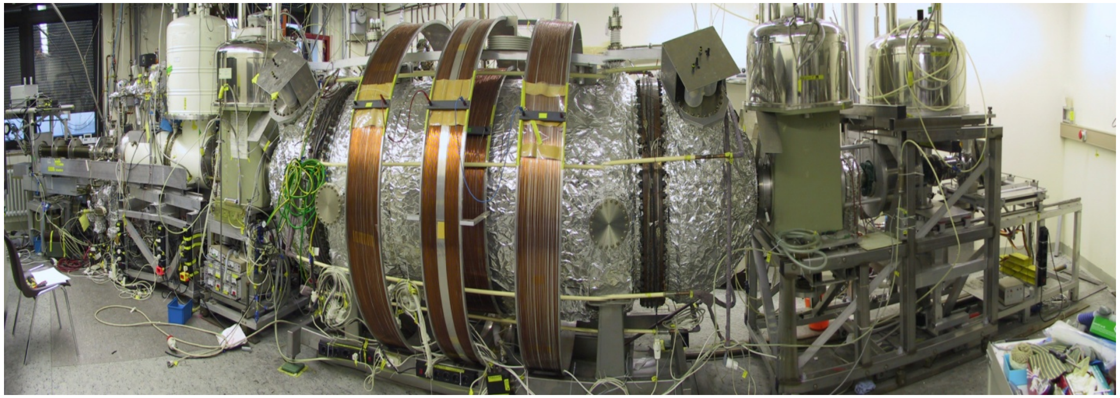
Re-analysis 2011:

$$m^2(\nu_e) = (-0.67 \pm 1.89 \pm 1.68)\ eV^2$$

$$m(\nu_e) < 2.05\ eV$$

V.N. Aseev et al., Phys. Rev. D 84 (2011) 112003

Mainz experiment:



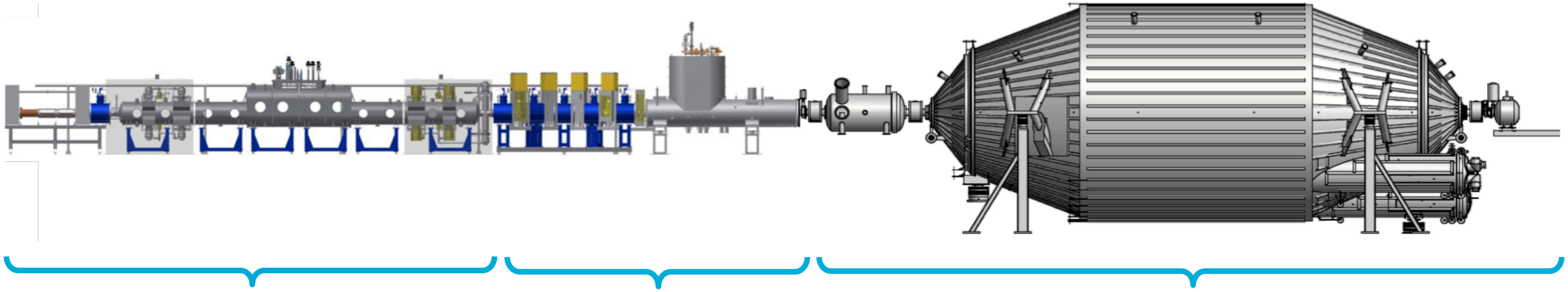
Final result 2004:

$$m^2(\nu_e) = (-0.6 \pm 2.2 \pm 2.1)\ eV^2$$

$$m(\nu_e) < 2.3\ eV$$

C. Kraus et al., Eur. Phys. J. C 40 (2005) 447

The KATRIN experiment



Source section:
High intensity, highly stable T_2 source

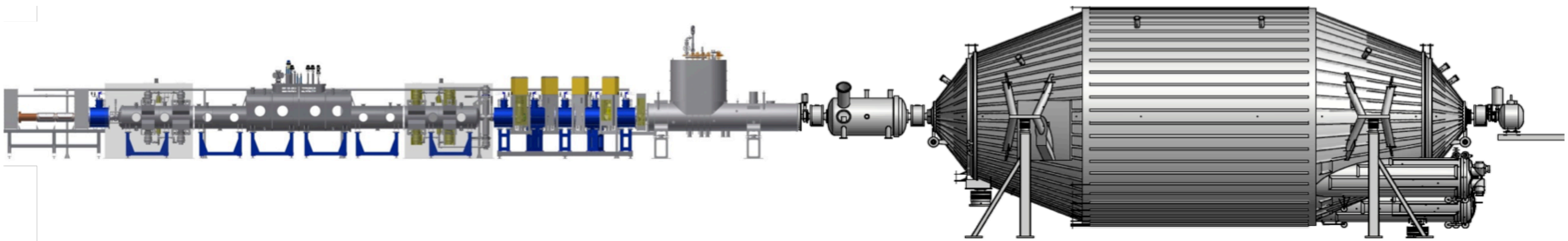
WGTS

Transport section:
Tritium retention by a factor 10^{14}

DPS, CPS

Spectrometer and detector section:
Electron analysis and detection

The KATRIN experiment



KATRIN sensitivity:

- 3 full years of beam time:
- systematic and statistical error about equal:
  - $\sigma_{stat} = 0.018\ eV^2$
  - $\sigma_{syst} < 0.017\ eV^2$
- Sensitivity:
  - $m(\nu)$ = 200 meV (90 % C.L.)
    = 350 meV (5 σ)

KATRIN beyond $m(\nu)$:

- sterile neutrinos:
  - light (eV-range)
    - ➢ reactor anomaly
  - heavy (keV-range)
    - ➢ warm dark matter
- Technological advances:
  - Vacuum technology
  - Field calculation & Particle tracking simulation
- etc.