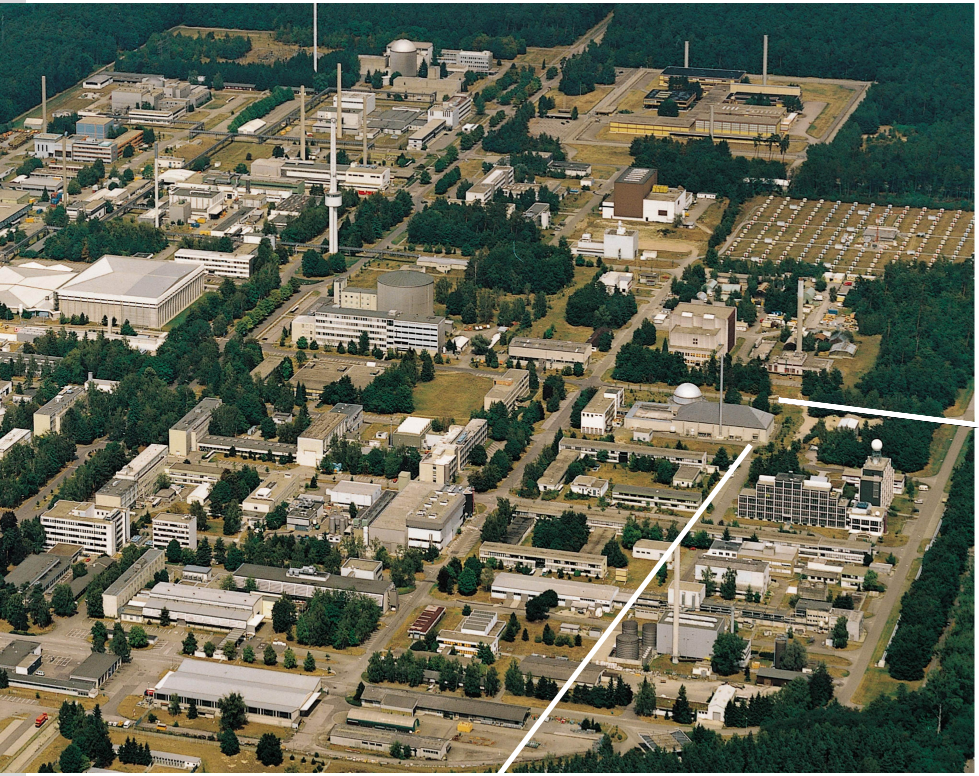
KATRIN Experiment 2009
– Systematic improvement.

N.A. Titov (for KATRIN collaboration),
INR RAS and IK FZ Karlsruhe
XIV Lomonosov Conference
Moscow, 19 – 25 August, 2009

KATRIN –

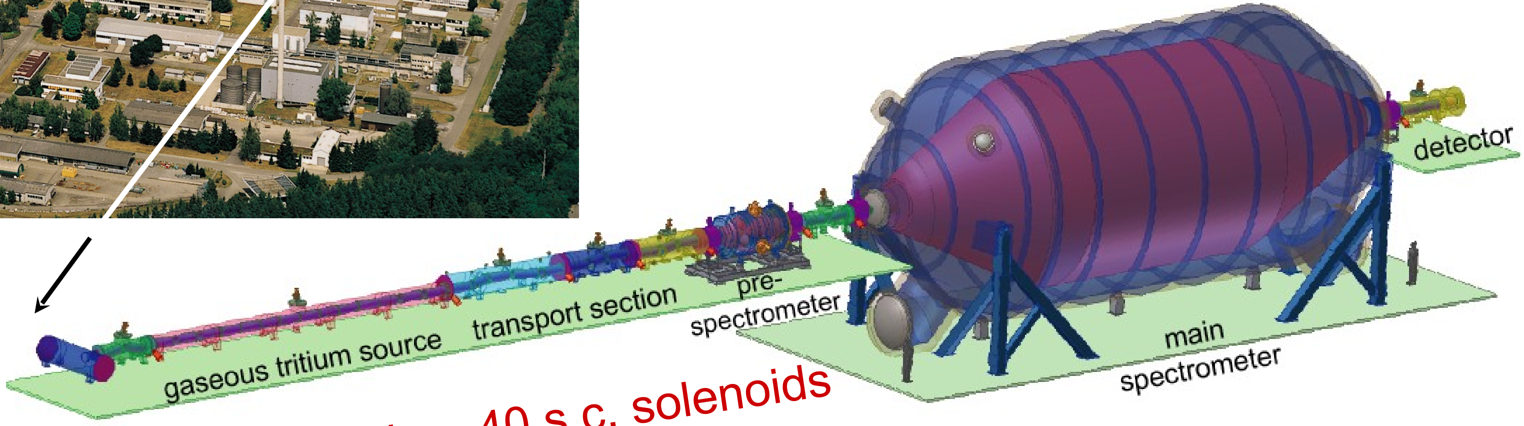
KArlsruhe TRItium Neutrino mass experiment



Located at Tritium Laboratory Karlsruhe (TLK)

~140 Collaboration members (12 institutions from Germany, USA,GB, CZ, Russia)

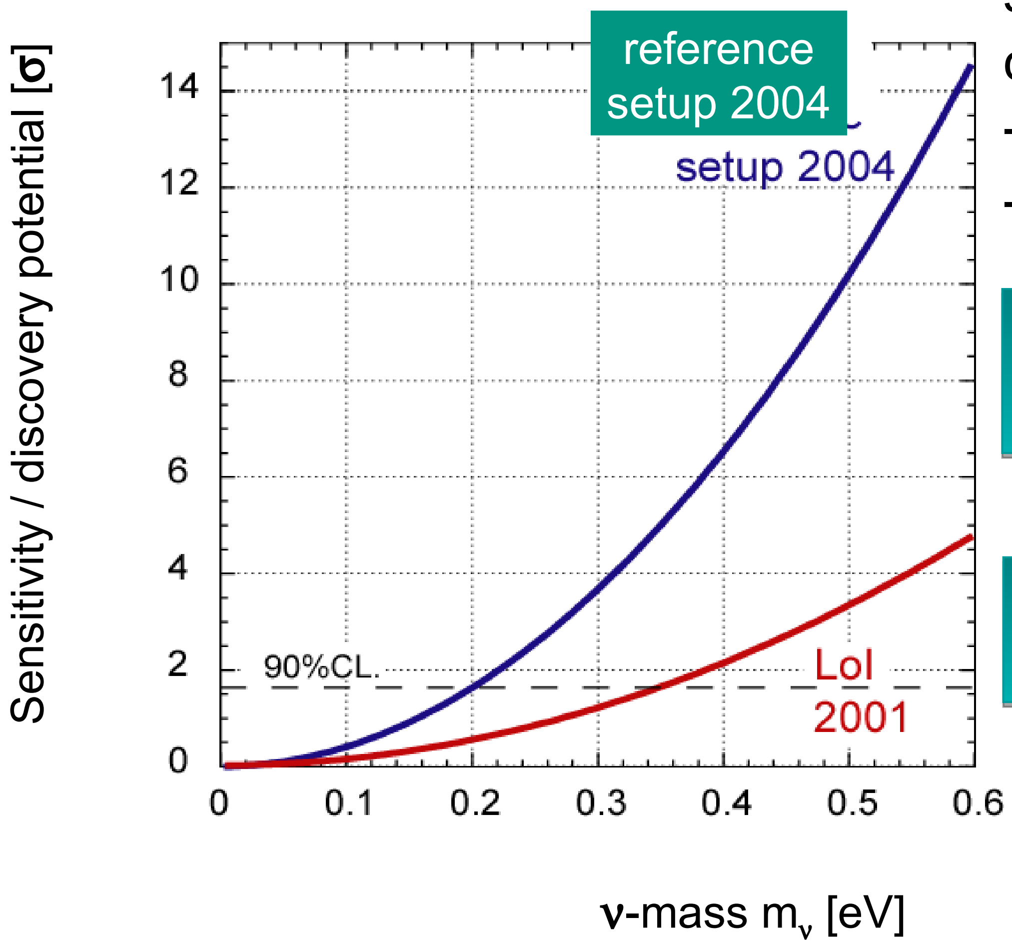
2012: beginning of T_2 measurements



~70 m beamline, 40 s.c. solenoids

KATRIN sensitivity

- ν-mass sensitivity for 3 ´full beam´ measuring years



statistical & systematic errors contribute equally:

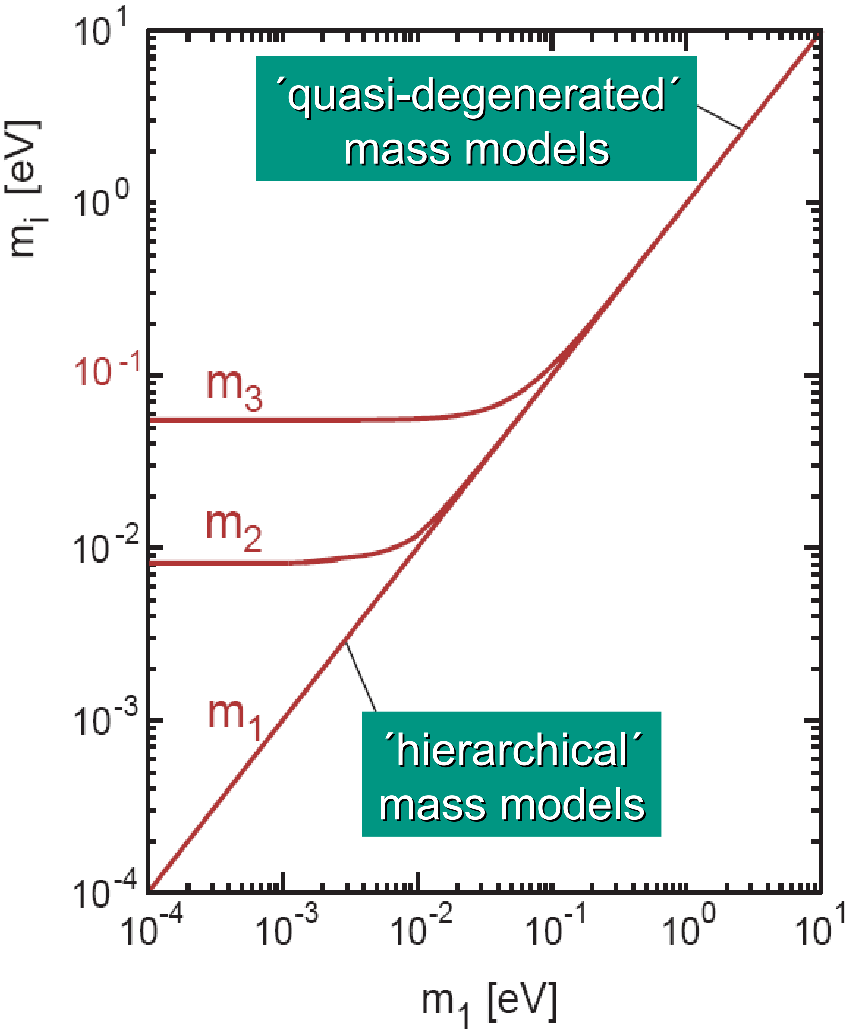
- statistical error σ_{stat} = 0.018 eV²
- systematic error σ_{syst} < 0.017 eV²

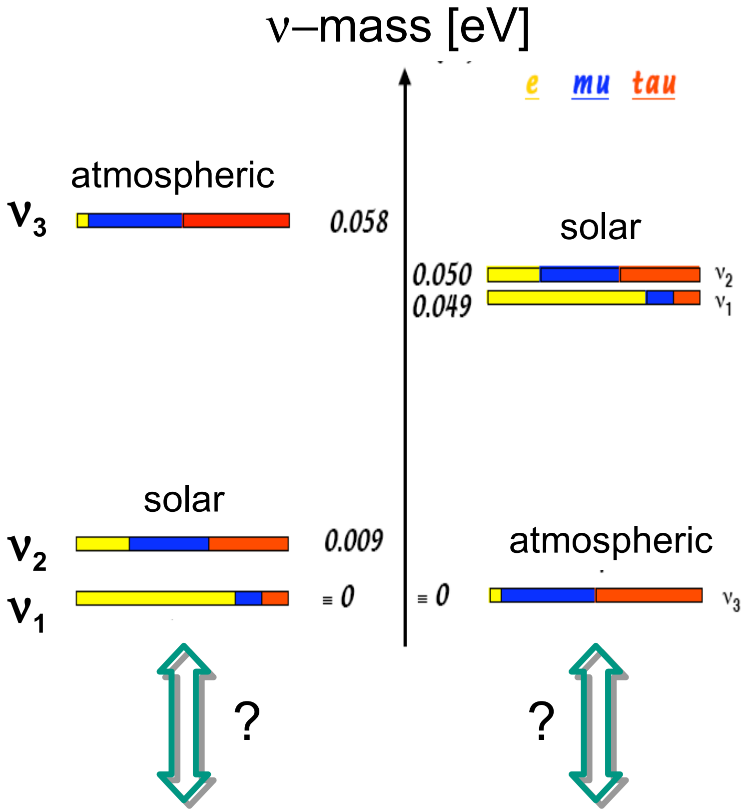
sensitivity (90% CL)
m(ν) < 200 meV

discovery potential
m(ν) = 350 meV (5σ)

neutrino masses in particle physics

normal hierarchy with $m_1 < m_2 < m_3$

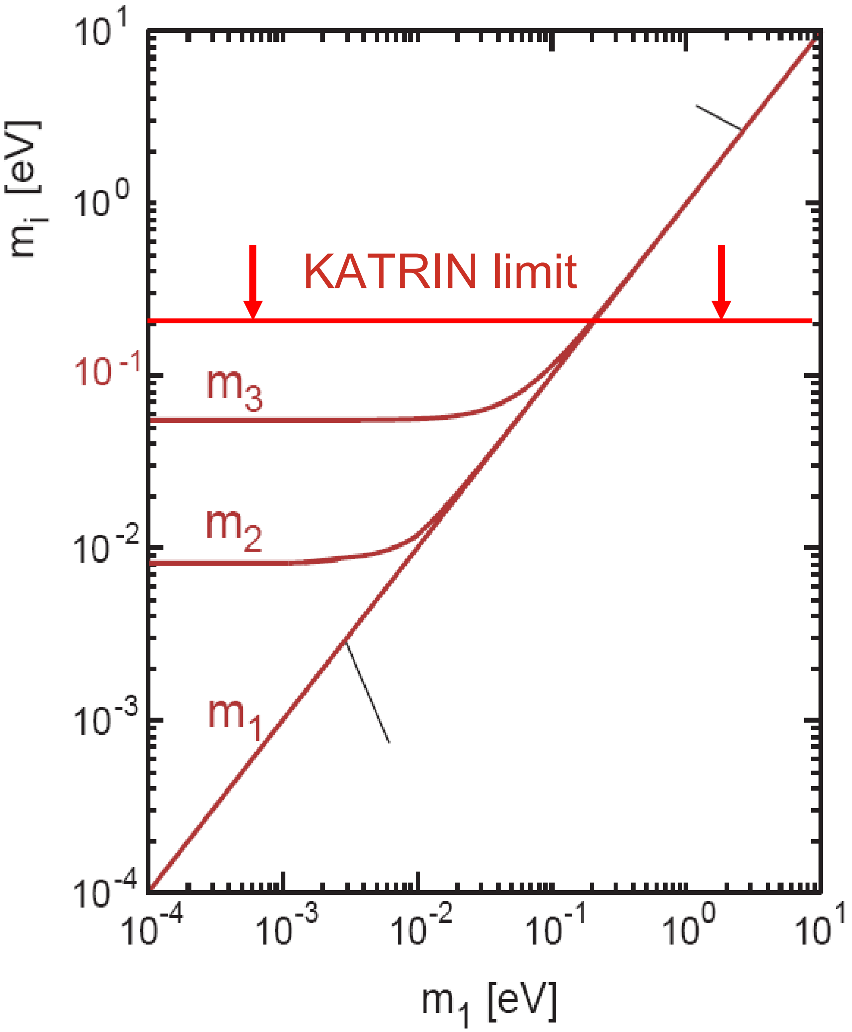


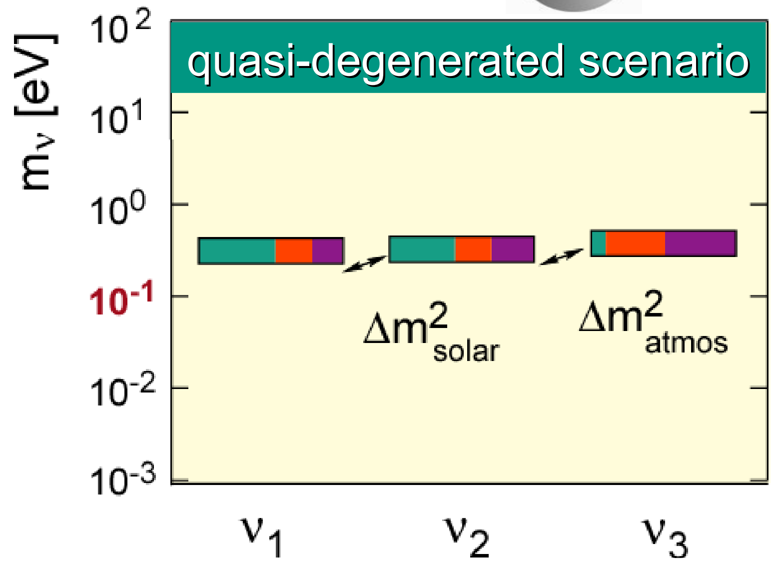


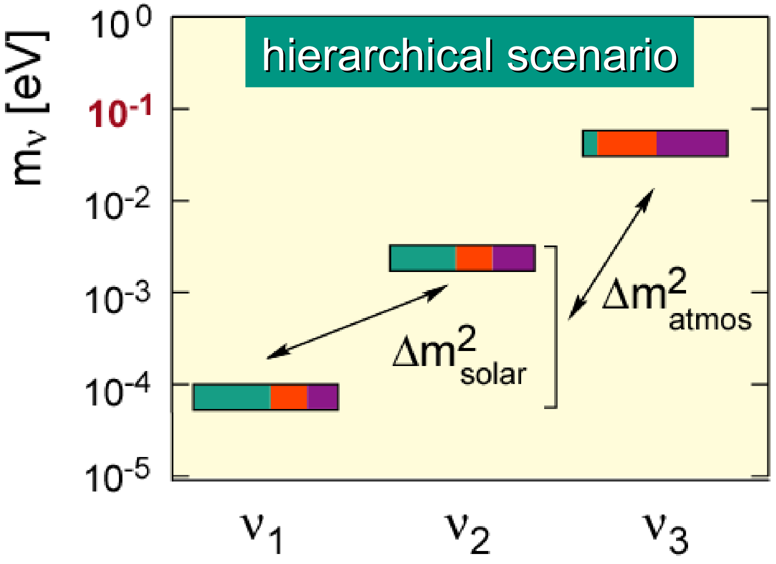
ν–mass offset?
absolute scale m_1?

neutrino masses in particle physics

normal hierarchy with $m_1 < m_2 < m_3$





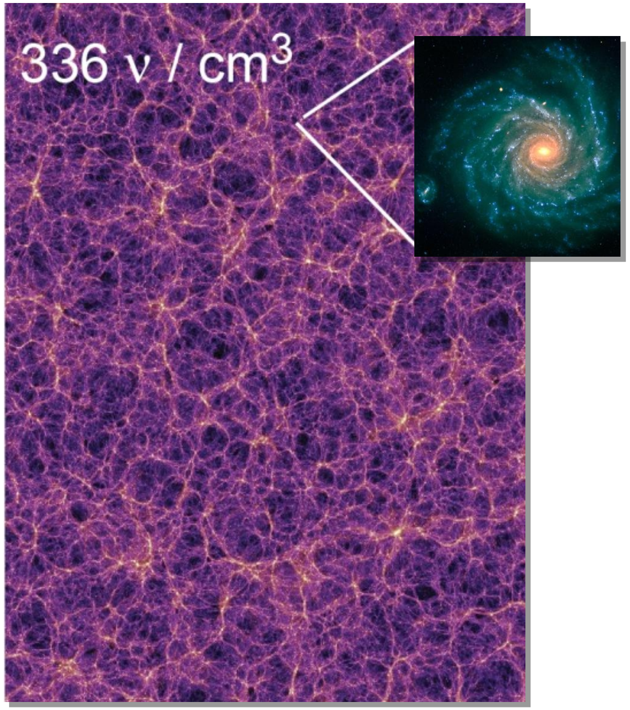


neutrinos in in cosmology

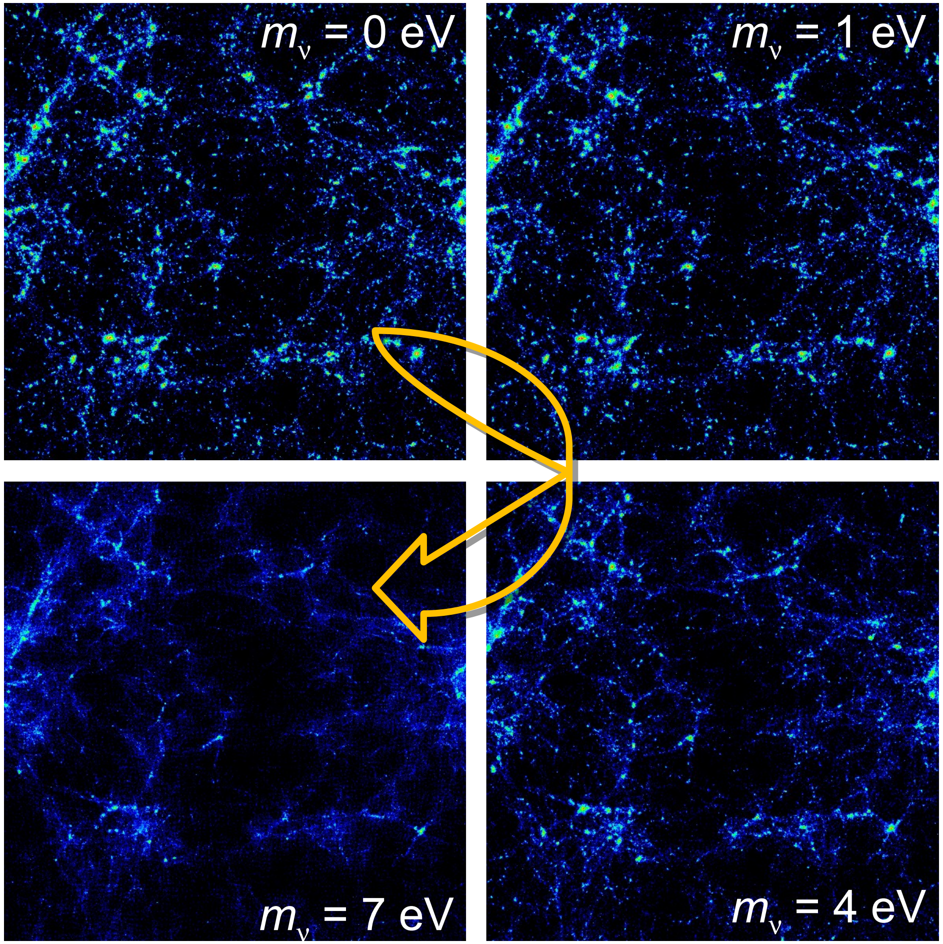
cosmic architects: what is the role of relic ν´s as **hot dark matter**?

large scale structures: free streaming of ν´s on Gpc scales (less small clusters)

cosmology



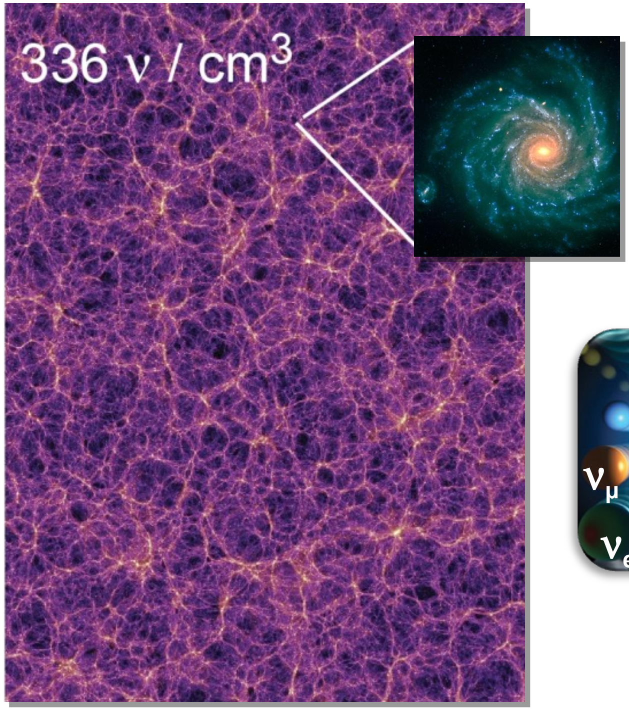
structure of the Universe
(Millenium Simulation)



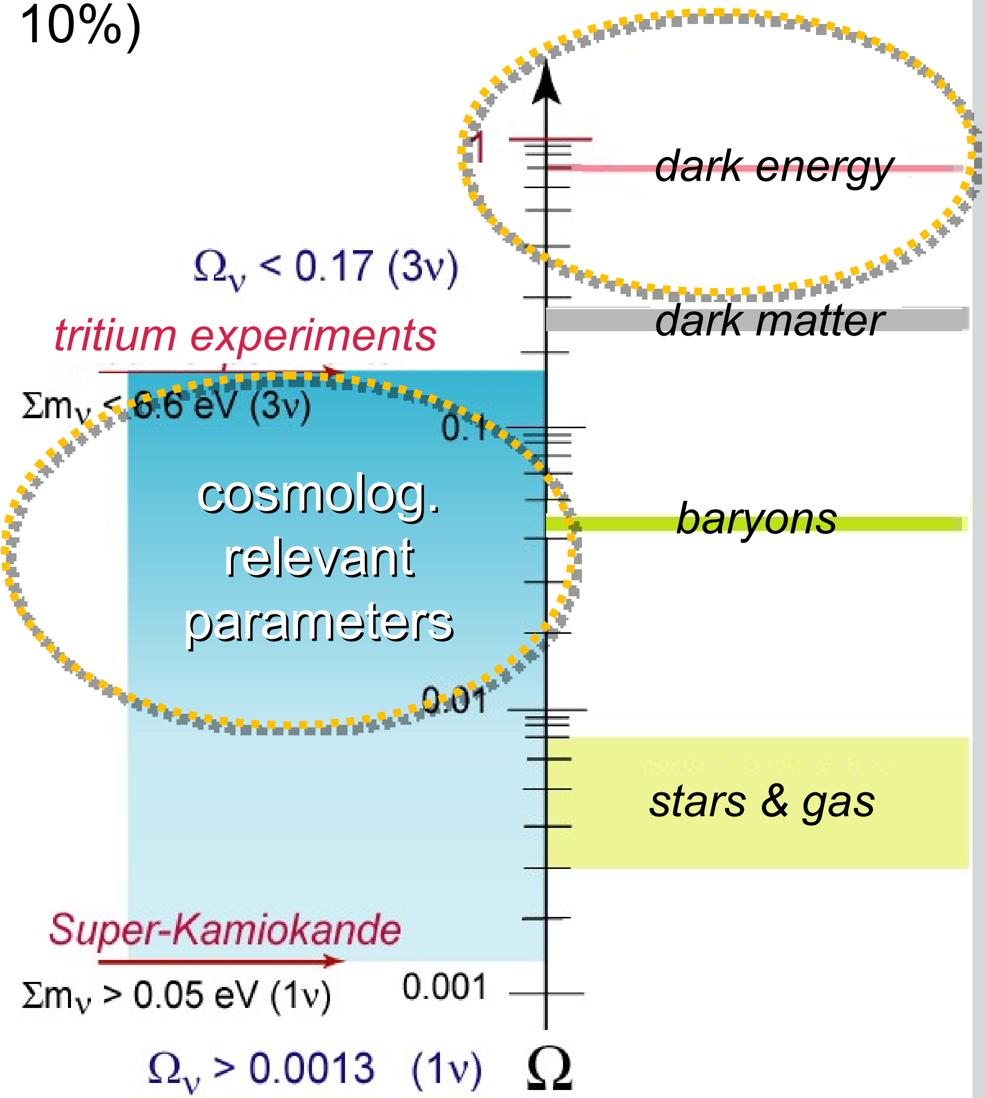
motivation: ν´s in astroparticle physics

HDM contribution: 2 orders (0.1% → 10%)
lower limit: **ν**-oscillations
upper limit: tritium ß-decay

$\Omega_\nu h^2 = \Sigma m_\nu / 92$ eV

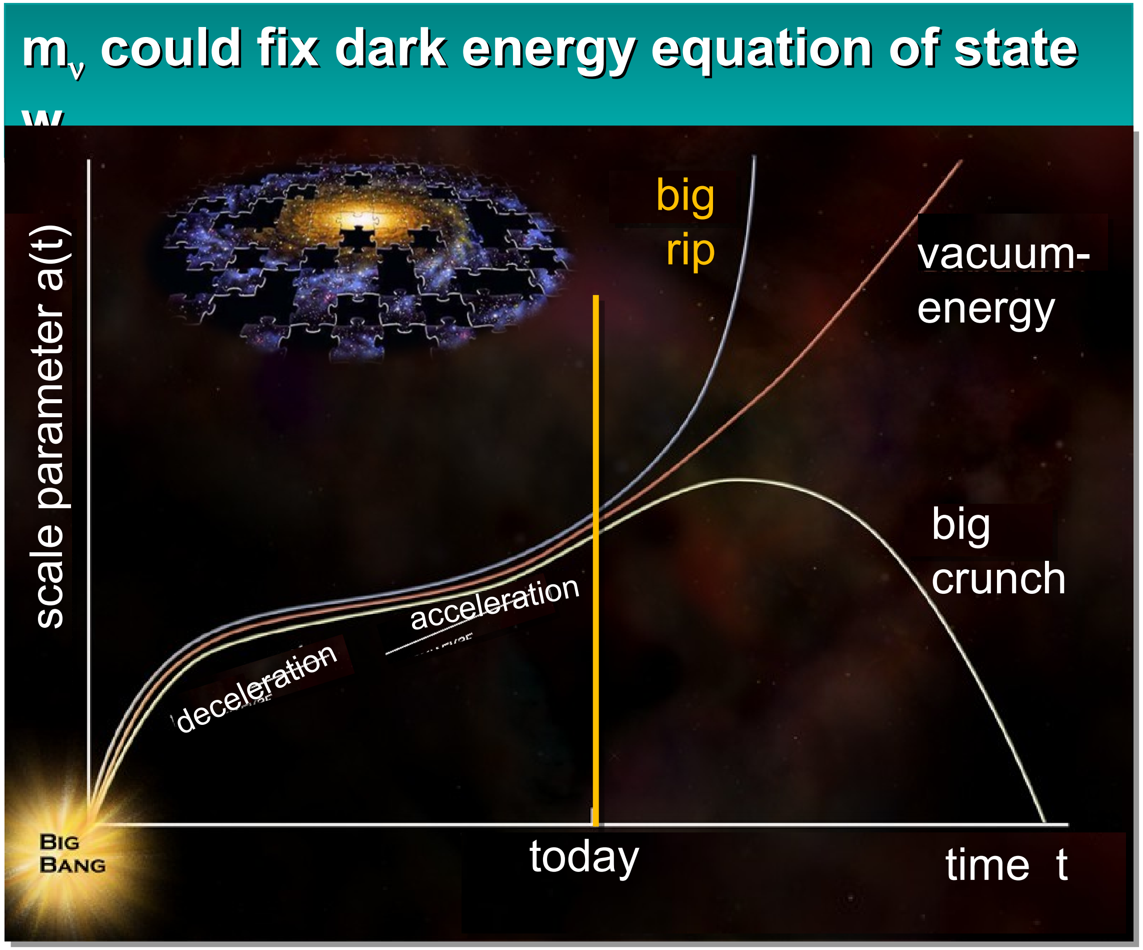


structure of the Universe
(Millenium Simulation)

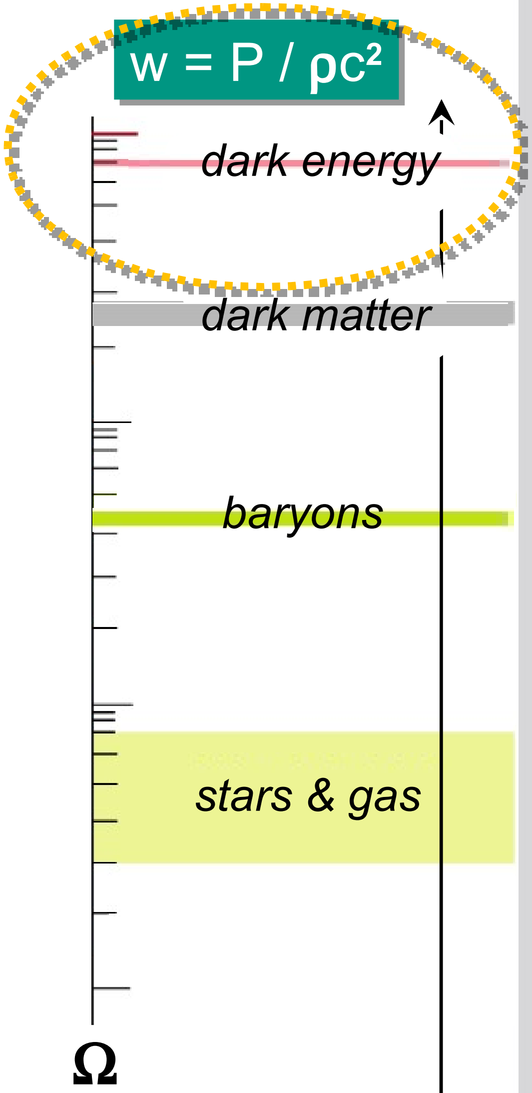


motivation: ν´s in astroparticle physics

global analysis of cosmological data (CMBR & LSS):
correlation of ν–mass m(ν) & DE equation of state *w*



m_ν could fix dark energy equation of state w



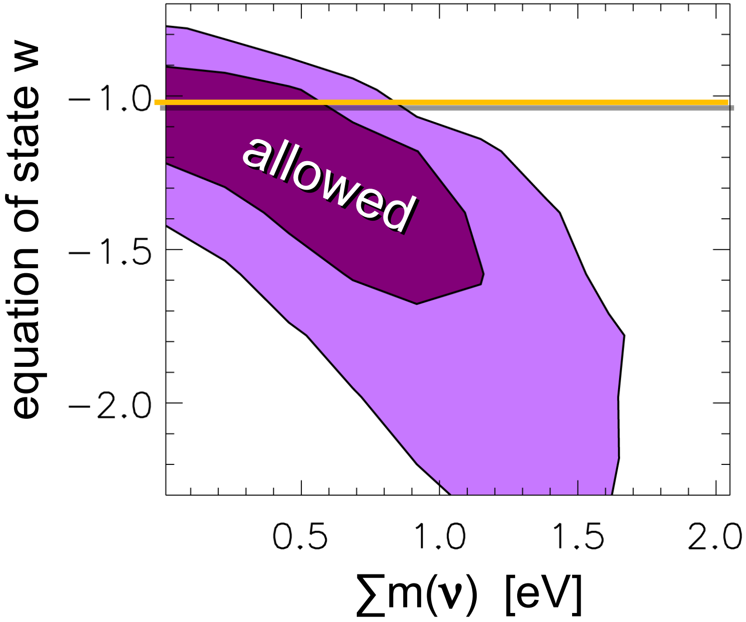
neutrino mass & dark energy

global analysis of cosmological data (CMBR & LSS):
correlation of ν–mass m(ν) & DE equation of state *w*

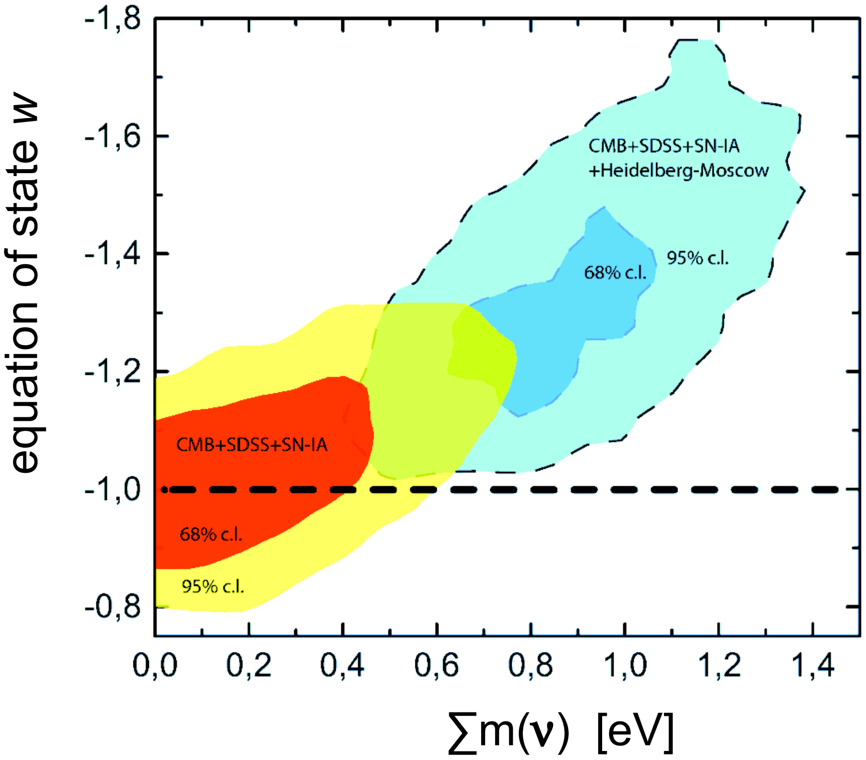
$w = P / \rho c^2$

laboratory measurement of m(ν) > 0.2 eV
could imply *w* < - 1 (quintessence)

G. La Vacca, J.R. Kristiansen, L.P.L. Colombo,
R. Mainini, S.A. Bonometto
arXiv:0906.3369v1 [astro-ph.CO]



S. Hannestad, arXiv: 0710.1952v1 [hep-ph]



Experiment is based on the kinematics of ß-decay -absolute ν_e -mass: m_ν

$$N(E) = \text{const} * |M|^2 F(Z,E)\, p(E + m_e c^2) \underbrace{(E_0 - E)}_{E_\nu} \underbrace{\sqrt{(E_0 - E)^2 - m_\nu^2 c^4}}_{P_\nu}$$

Nuclear matrix element

Fermi function

Tritium: E_0 = 18.6 keV, $T_{½}$ = 12.3 a

- **Superallowed transition:** ➔ **matrix element M is not energy dependent**
- **Low endpoint energy:** ➔ **relative decay fraction at the endpoint is comparatively high**
- **Short half life:** ➔ **specific activity is high**
  - ➔ **low amount of source material**
  - ➔ **low fraction of inelastic scattered electrons**
- **Hydrogen isotope:** ➔ **simple atomic shell**
  - ➔ **final states precisely calculable**

The same arguments: 6 decades before (short history)

Curran, S. C.; Angus, J.; Cockcroft, A. L.

Nature (London, United Kingdom) (1948), 162, 302

The β- spectrum of tritium is of particular interest because (1) the relatively simple structure of the $_1H^3$ nucleus makes it well suited to a test of the Fermi theory of β -decay, (2) the unusually low energy of the β -particles means that the shape of the spectrum near the upper limit is an extremely sensitive function of the rest mass of the neutrino if the Fermi theory is confirmed, (3) a discrepancy exists between the half-life and the upper energy limit, (4) the mass difference $_1H^3$ - $_2He^3$ can be accurately determined. A new technique was developed for rapid and accurate detection and energy measurement of β -rays, conversion electrons, grays, and x-rays from weak sources. The method, applicable to radiations of energy from 0.5 to 150 e.kv., uses a proportional counter containing an A-CH_4 mixture at a pressure of one atmospheric or more, connected to a linear amplifier of high gain. The counter contained sufficient tritium gas to give about 5000 counts per minute and the b-spectrum is shown for the range 1-18 e.kv. with an upper limit at 16.9 ± 0.3 e.kv. and maximum near 2.5 e.kv. definitely wider than the maximum of the theoretical curve. This experiment seems to indicate that the mass of the neutrino is less than m/300. Since there is no evidence of g-radiation following the β emission the mass equation is written $_1H^3$ - $_2He^3$ = 0.000018.

1948: First measurements of the shape of tritium beta spectrum – basic problems

S. C. Curran, J. Angus and A. L. Cockroft Phys. Rev. 76, 853 - 854 (1949)

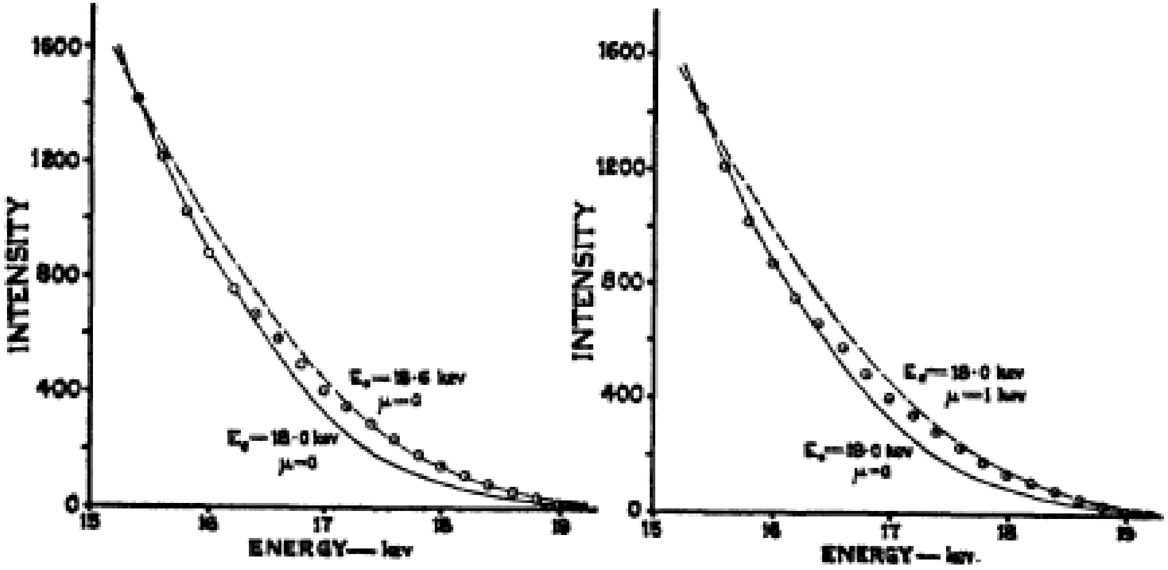


FIG. 1. Comparison of experimental and theoretical Fermi curves for tritium near the end point.

Experiment:

- proportional counter
- tritium mixed with counting gas
- measurement of pulse height distribution

Resolution underestimation leads to the excess of counts near the endpoint.
Endpoint shifted:
17.9 ± 0.3 keV

1949: First measurements of the shape of tritium beta spectrum

Measurements by Hanna and Pontecorvo Phys. Rev. 75 (1949) 983

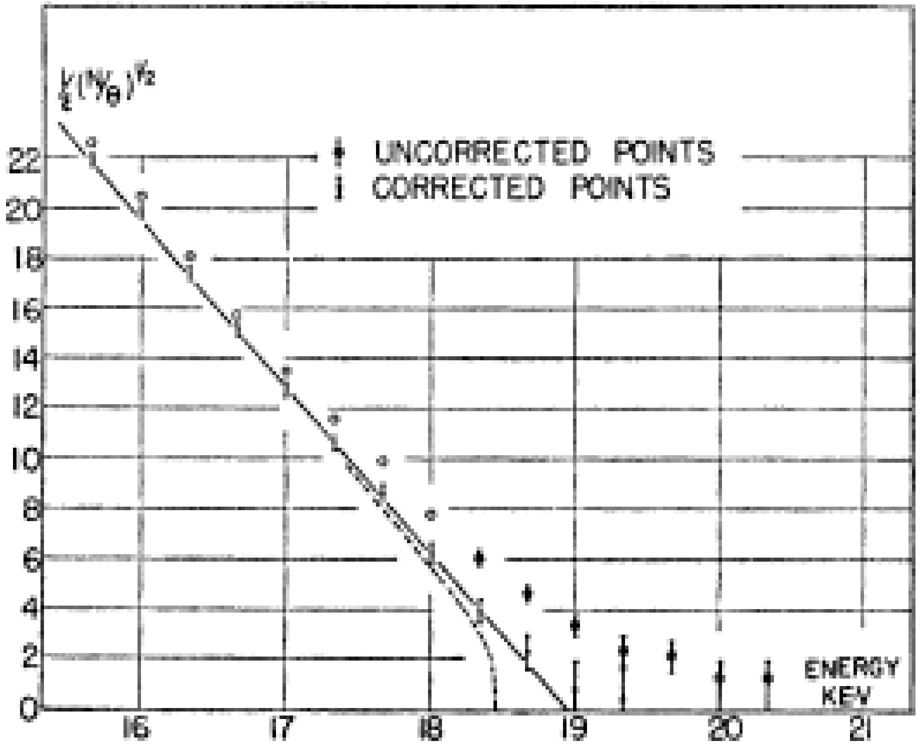


FIG. 2. "Kurie" plot of the end of the H^3 spectrum. The theoretical curve (shown dotted) corresponding to a finite neutrino mass of 500 ev (or 1 kev —see text) has been included for comparison.

Experiment:

- proportional counter
- tritium mixed with counting gas
- measurement of pulse height distribution

Results:

E_0 = 18.9 ± 0.5 keV

Neutrino mass < 1000 eV/c^2

Hanna G.C. and Pontecorvo B., Phys. Rev. 75 (1949) 983

MAC-E filter – principle

MAC – Magnetic Adiabatic Guiding

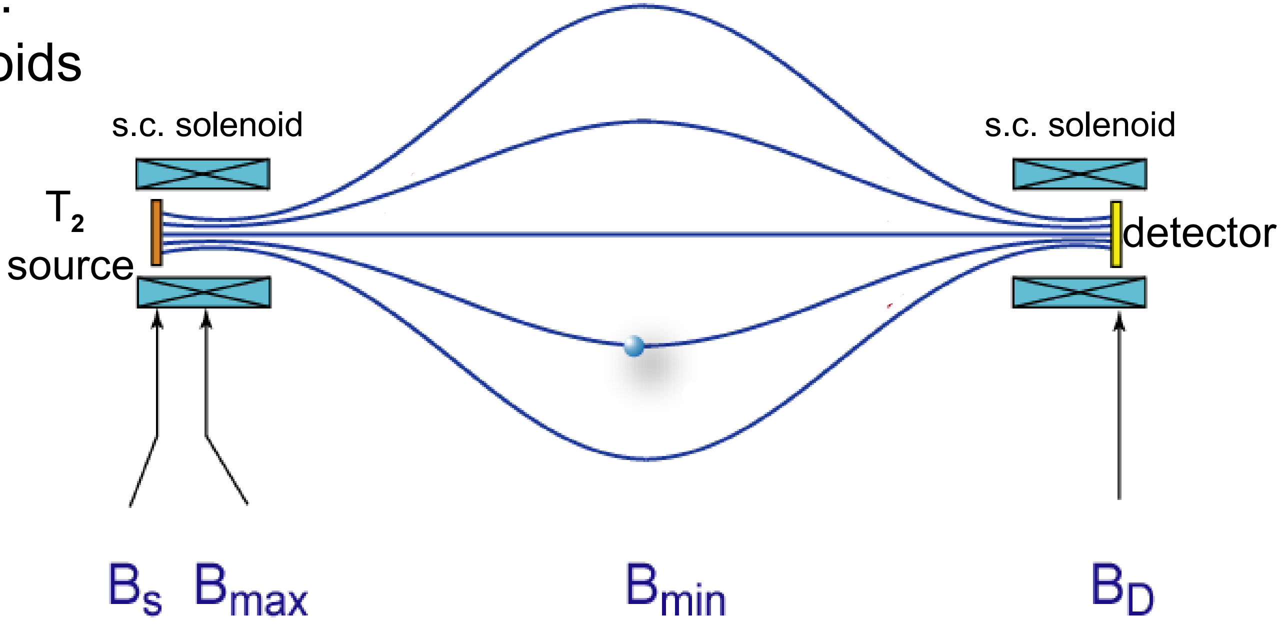
Inhomogeneous B-field:
superconducting solenoids
$B_{max} \sim 6$ T
$B_{min} \sim 3$ mT

solid angle $d\Omega \sim 2\pi$

Adiabatic guiding of electrons along magnetic field lines

$$\varepsilon = \omega_B / \omega_C << 1$$

$$\mu = \frac{E_\perp}{B} = const.$$



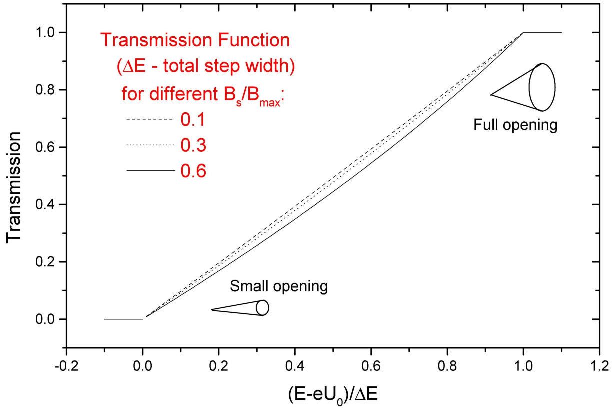
Momentum alignment due to conservation of **adiabatic invariant** μ. Adiabatic transformation $E_\perp \rightarrow E_{||}$

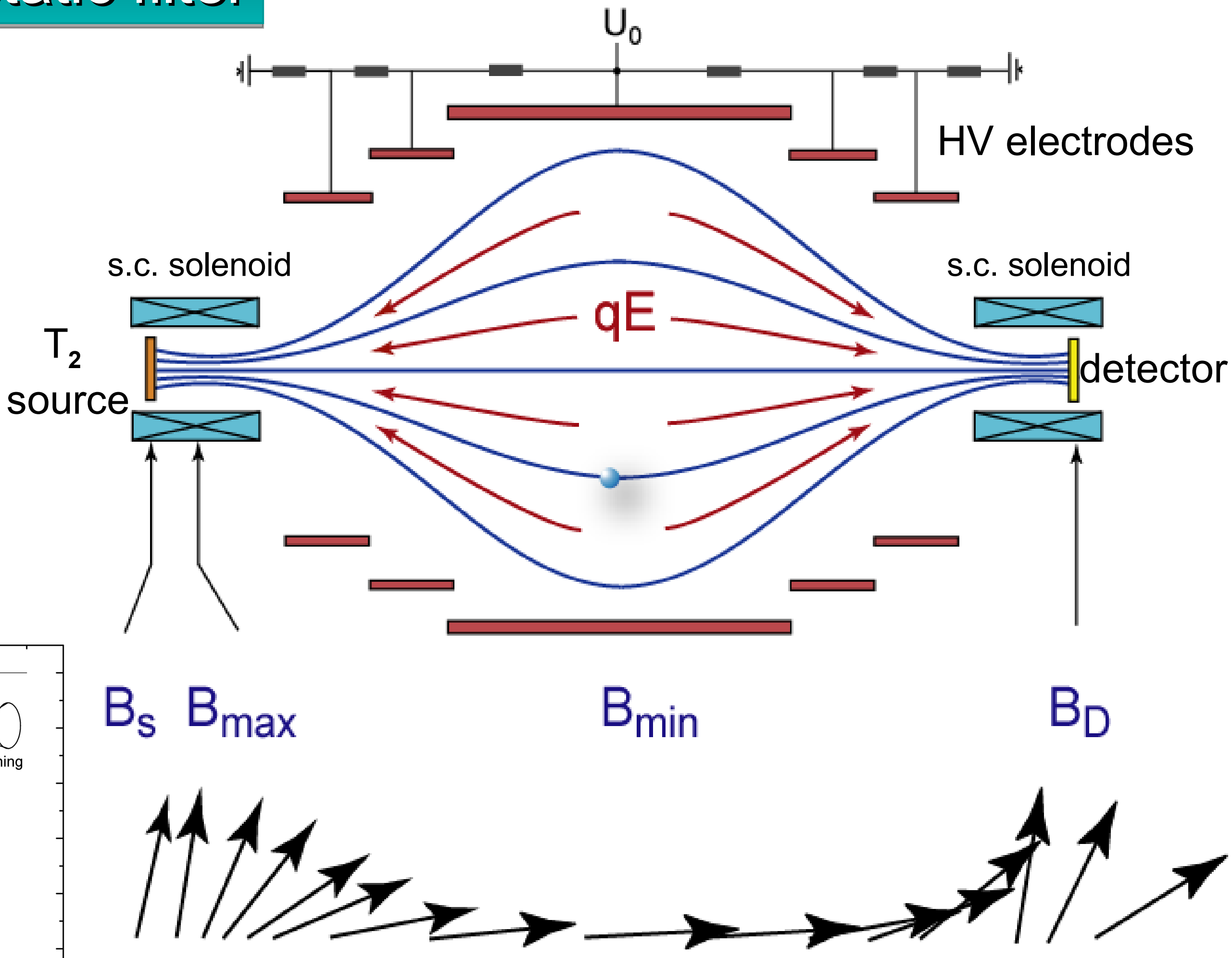
MAC-E filter – principle

E Filter – Electrostatic filter

Energy analysis by an electrostatic retarding potential: integral transmission for E > eU_0
„high pass filter“

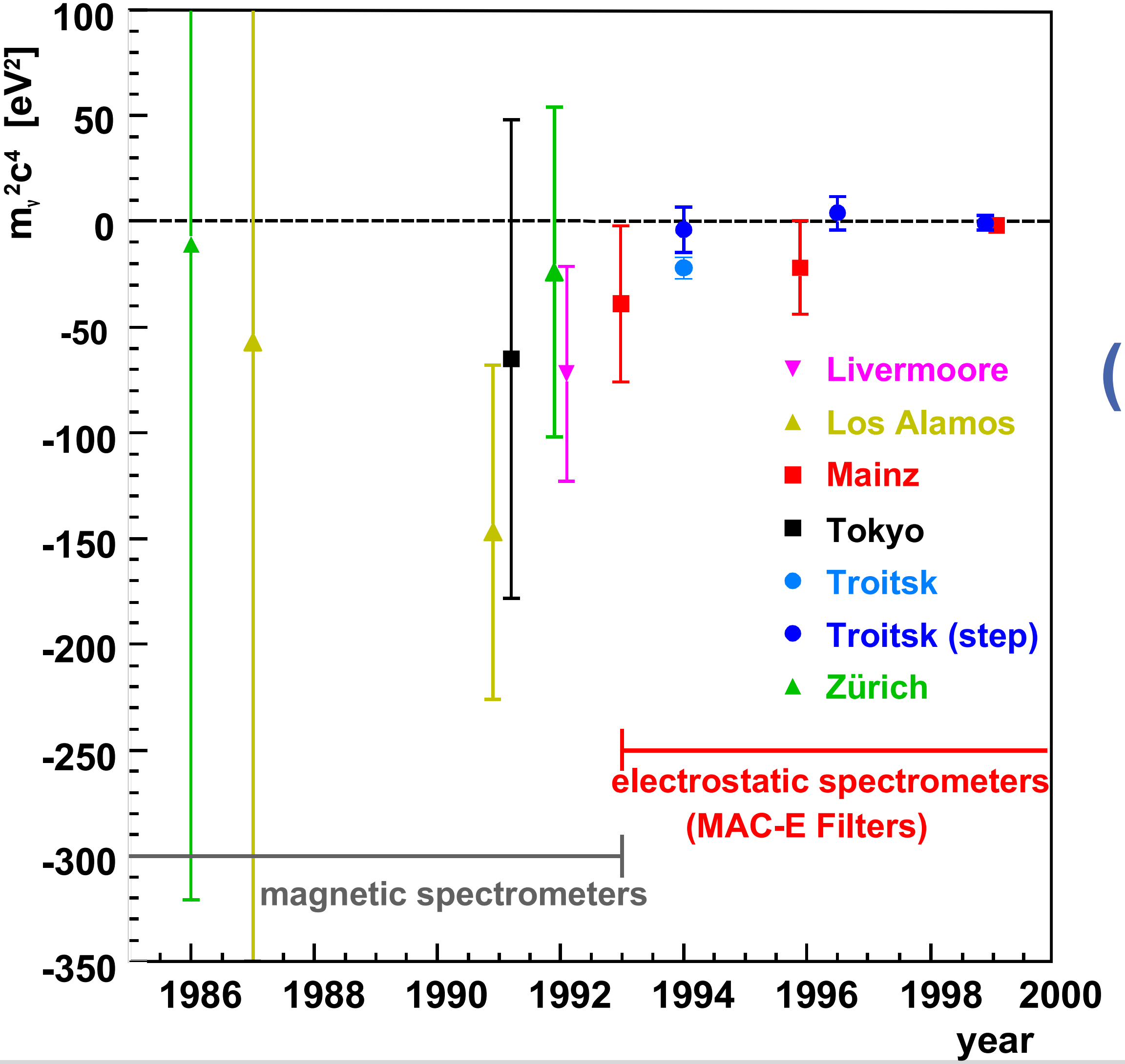
$$\Delta E = |eU_0| \frac{B_{Analys}}{B_{Max}}$$





adiabatic transformation $E_\perp \rightarrow E_{||} \rightarrow$ retarding

MAC-E filter –
decoupled resolution and luminosity



KATRIN

(proposed 2001)

- another factor

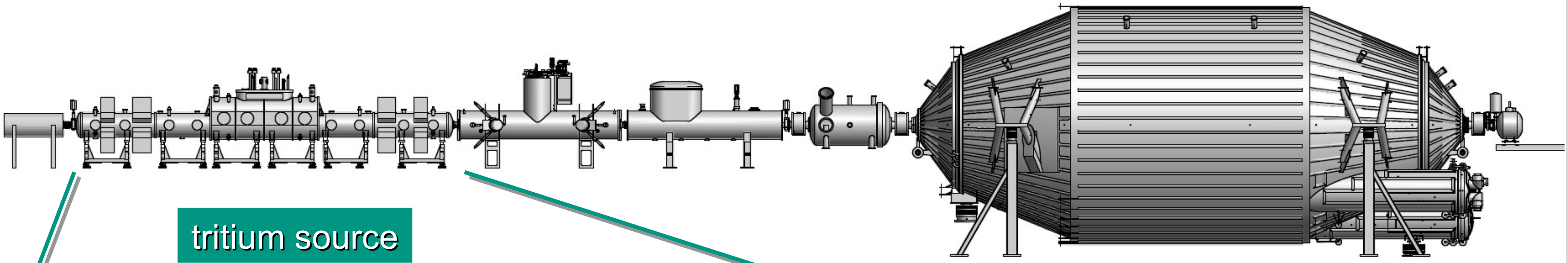
1/100 in m_ν^2

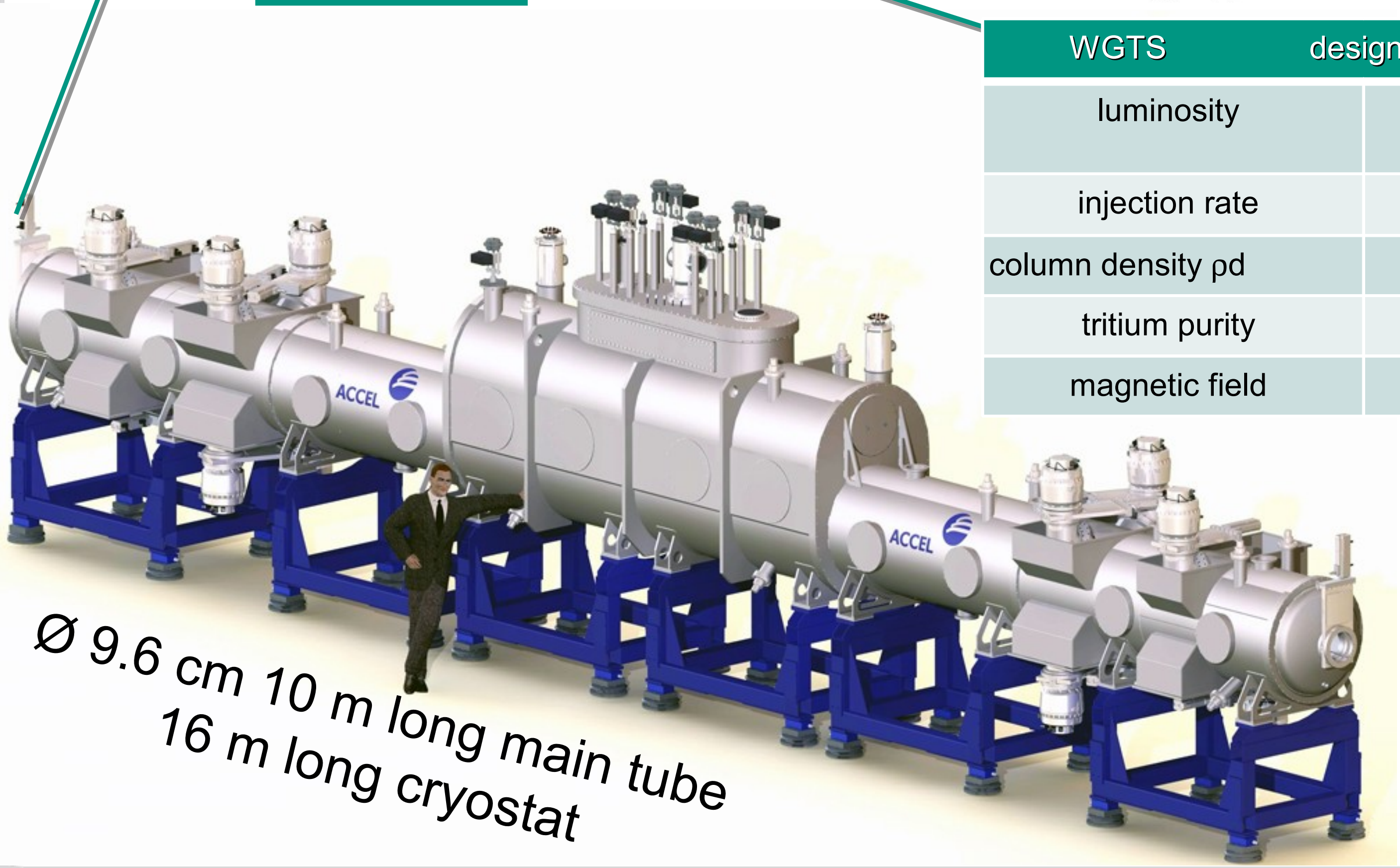
statistical and

<u>systematic</u>

error bar

WGTS – windowless gaseous source





Ø 9.6 cm 10 m long main tube
16 m long cryostat

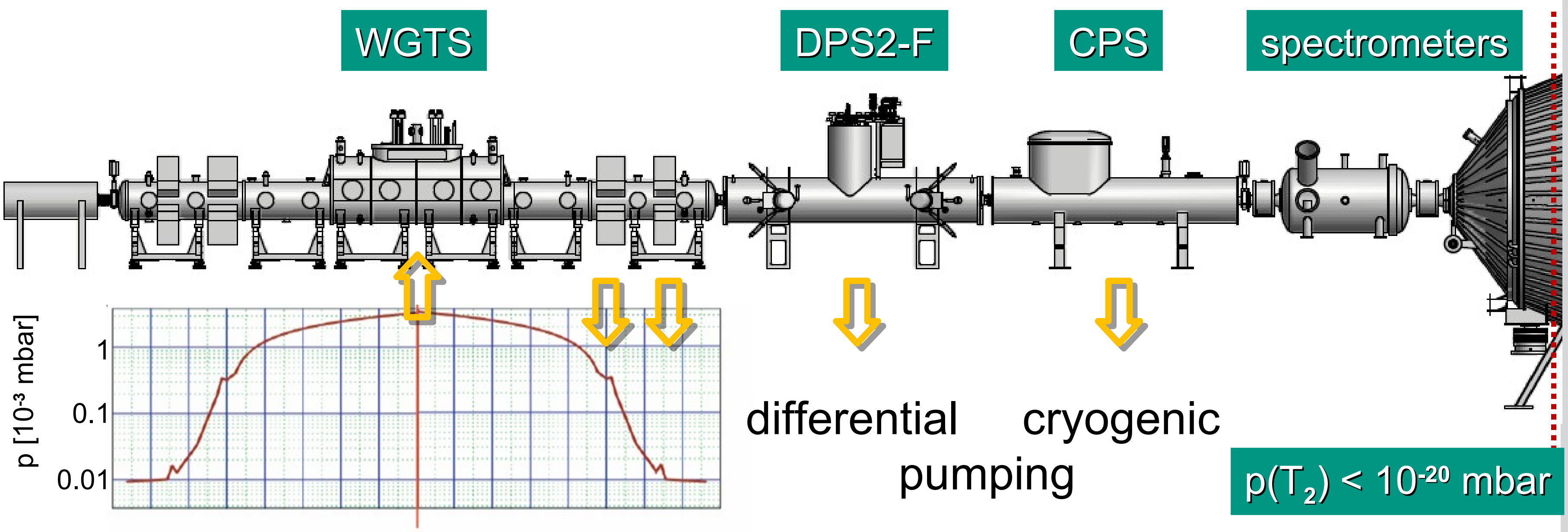
WGTS	design value	precision
luminosity	1.7×10^{11} Bq	
injection rate	5×10^{19} mol/s	±0.1 %
column density ρd	5×10^{17} mol/cm^2	±0.1 %
tritium purity	> 95%	±0.1 %
magnetic field	3.6 T	± 2%

KATRIN – tritium retention

the tritium flow out of the WGTS has to be reduced by **factor ~10^{14}**

tritium bearing components

tritium free



WGTS

DPS2-F

CPS

spectrometers

differential

cryogenic

pumping

$p(T_2) < 10^{-20}$ mbar

injection rate = 1.8 mbar ℓ / s

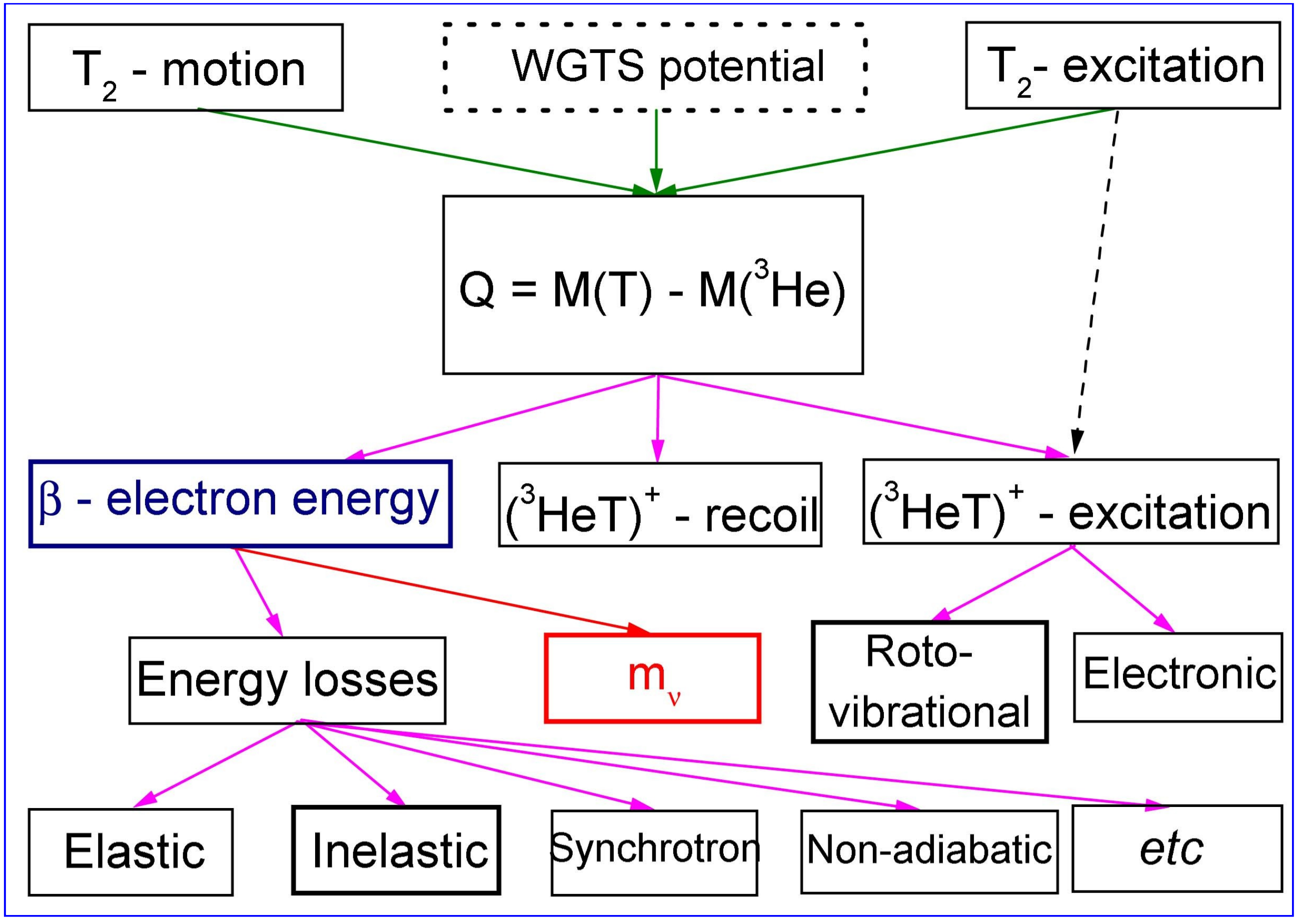
R>10^7

10^{-7} mbar ℓ/s

R>10^7

10^{-14} mbar ℓ/s

“Kinematics method” – scrupulous bookkeeping of electron energy budget



T_2 - motion

WGTS potential

T_2- excitation

$Q = M(T) - M(^3He)$

β - electron energy

$(^3HeT)^+$ - recoil

$(^3HeT)^+$ - excitation

Energy losses

m_ν

Roto-vibrational

Electronic

Elastic

Inelastic

Synchrotron

Non-adiabatic

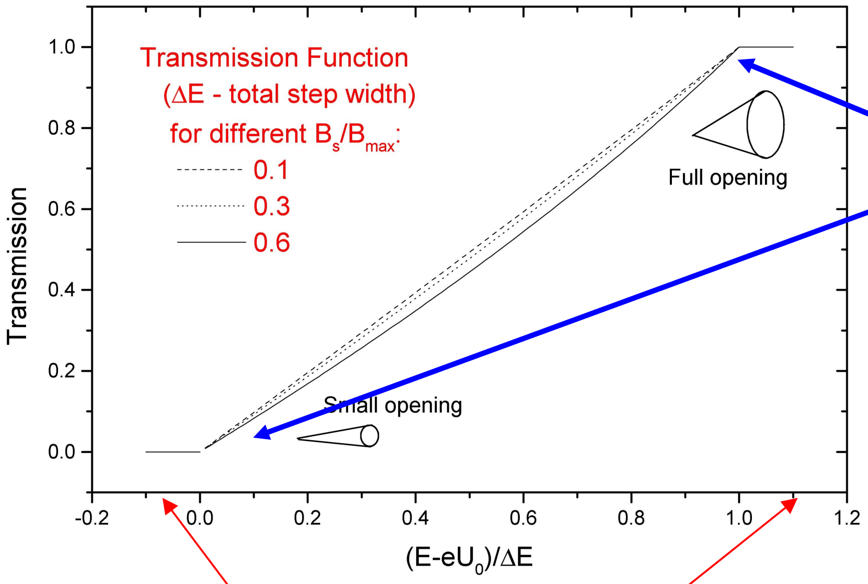
etc

$$\delta m_\nu^2 = -2\sigma_{E_0}^2$$

Endpoint broadening dispersion (no effect from the total shift)

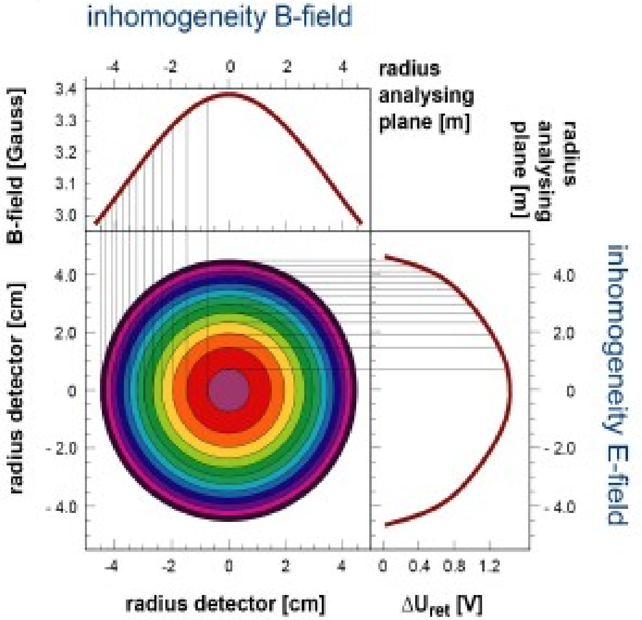
Plus:
Non-flatness of background
Backscattering from and decay on rear wall
Electron trapping
T-ions and atomic T
Etc ……

Spectrometer resolution and inelastic scattering probability

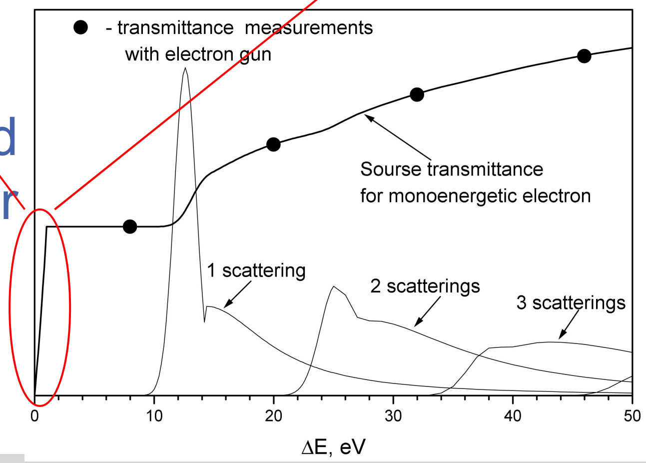


ΔE should be known better than $3\cdot10^{-2}$

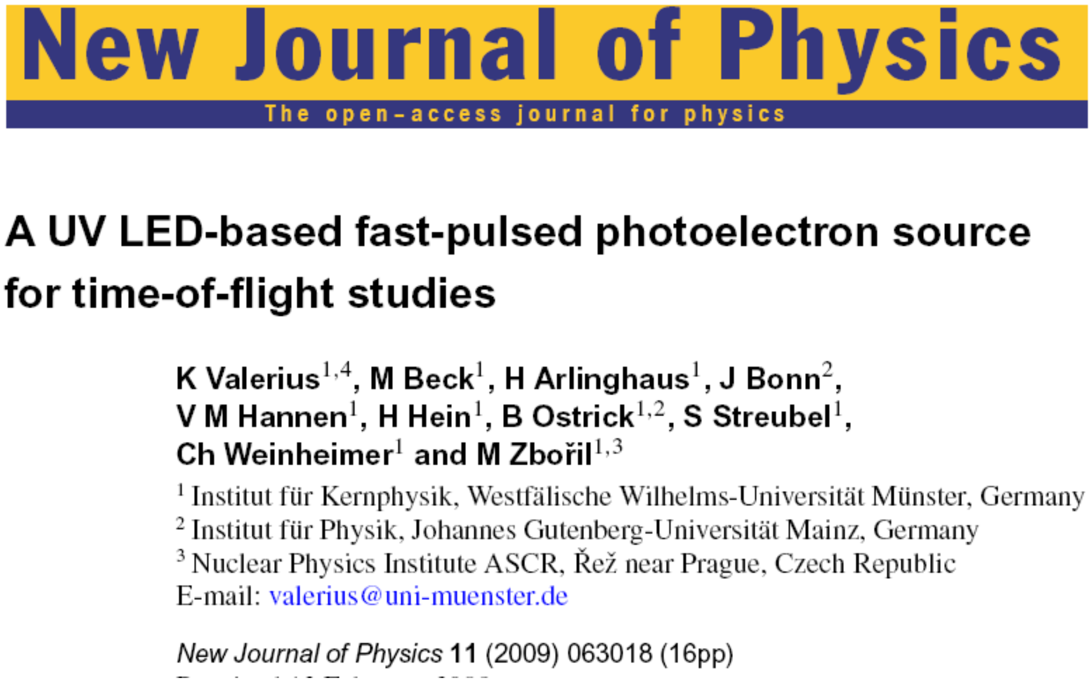
Different “spirality” correction determined by ratio B_{source} to $B_{analysis}$ should be known better than $4\cdot10^{-3}$



Total source thickness should be known better than $1\cdot10^{-3}$



Spectrometer resolution and inelastic scattering probability measurement by the use of Electron gun



New Journal of Physics

The open-access journal for physics

A UV LED-based fast-pulsed photoelectron source for time-of-flight studies

K Valerius[1,4], M Beck[1], H Arlinghaus[1], J Bonn[2], V M Hannen[1], H Hein[1], B Ostrick[1,2], S Streubel[1], Ch Weinheimer[1] and M Zbořil[1,3]

[1] Institut für Kernphysik, Westfälische Wilhelms-Universität Münster, Germany
[2] Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany
[3] Nuclear Physics Institute ASCR, Řež near Prague, Czech Republic
E-mail: valerius@uni-muenster.de

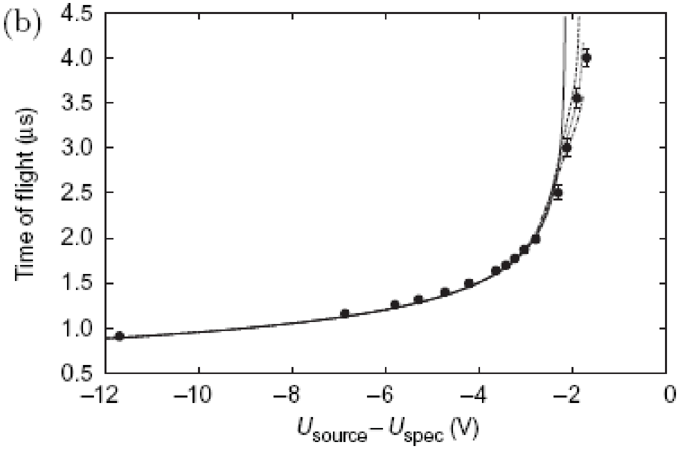
New Journal of Physics **11** (2009) 063018 (16pp)

UV-LED

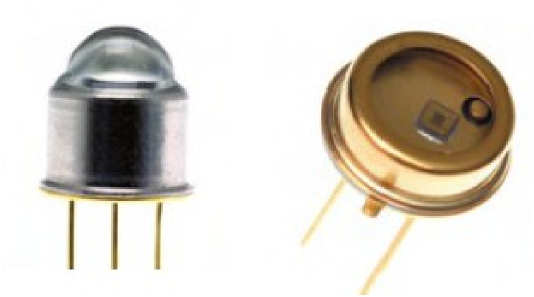
$\Delta t \geq 40$ ns

$\sigma_E \approx 0.2$ eV

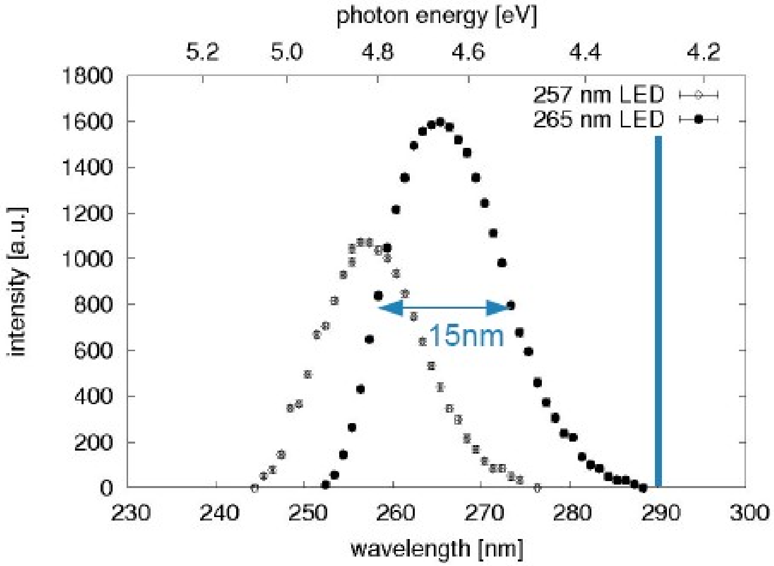
frequency – few kHz



Ultraviolet -LED

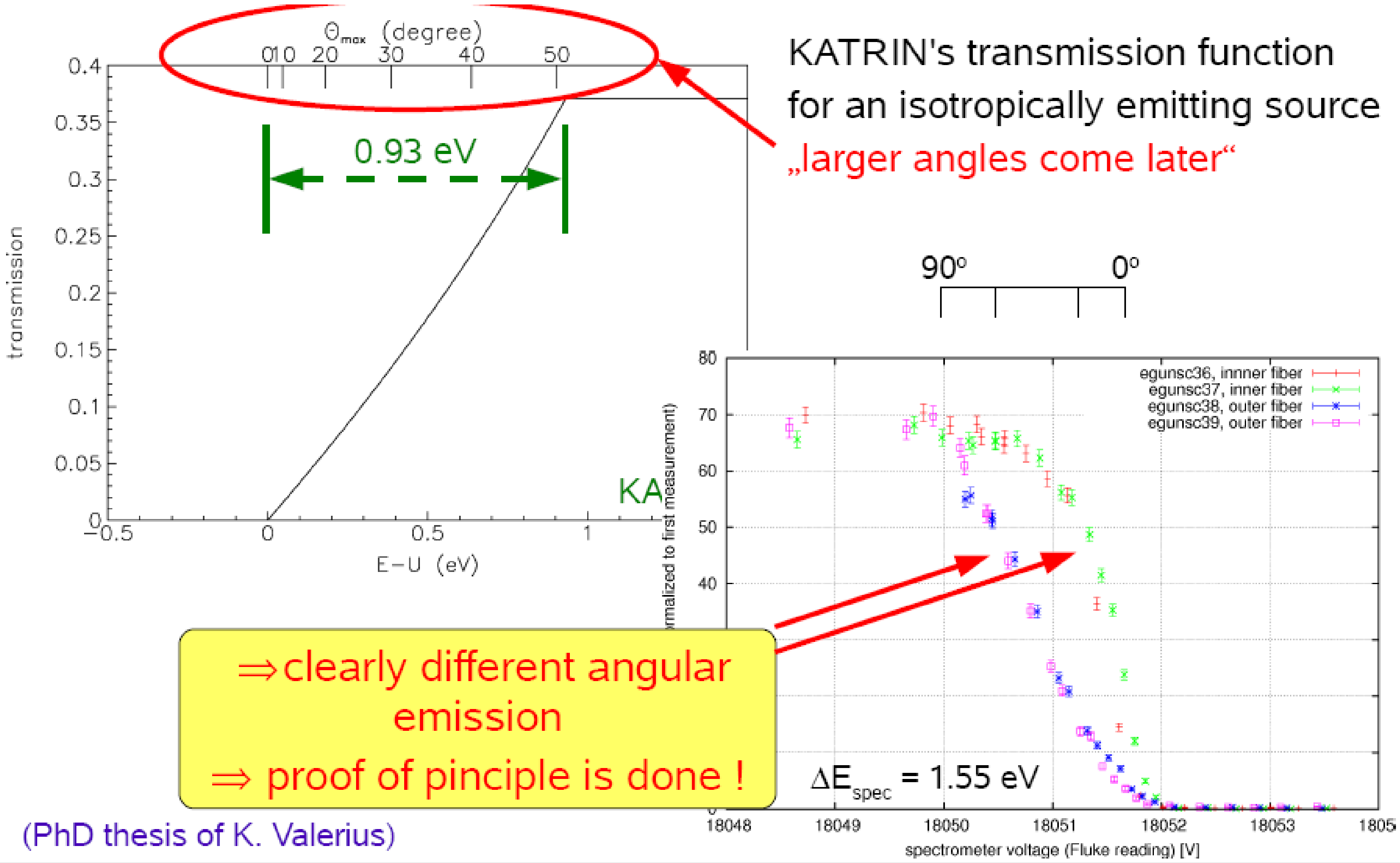


manufacturer:	Seoul Optodevice Co., Ltd
type:	T9B26C with **ball lens**
emitted wavelength:	$\lambda_{central}$ = 265 nm, FWHM = 15 nm (from manufacturer's data sheet)
optical power output:	$P_{opt} \leq 400\ \mu W$



- photon energy:
  E (λ = 265 nm) = 4.67 eV
  $>$
  W_{silver} $\geq$ 4.26 eV
- small energy spread expected from wavelength characteristics only

Fibre UV-photoelectron gun with angle selective emission (Uni Muenster)



KATRIN's transmission function for an isotropically emitting source

„larger angles come later“

⇒clearly different angular emission

⇒ proof of pinciple is done !

ΔE_{spec} = 1.55 eV

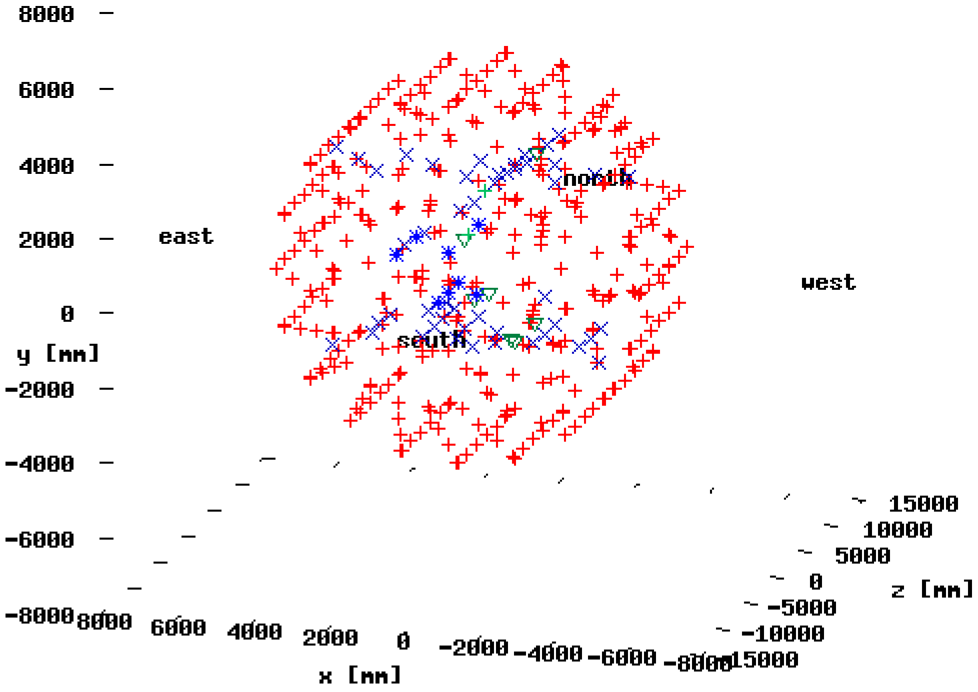
(PhD thesis of K. Valerius)

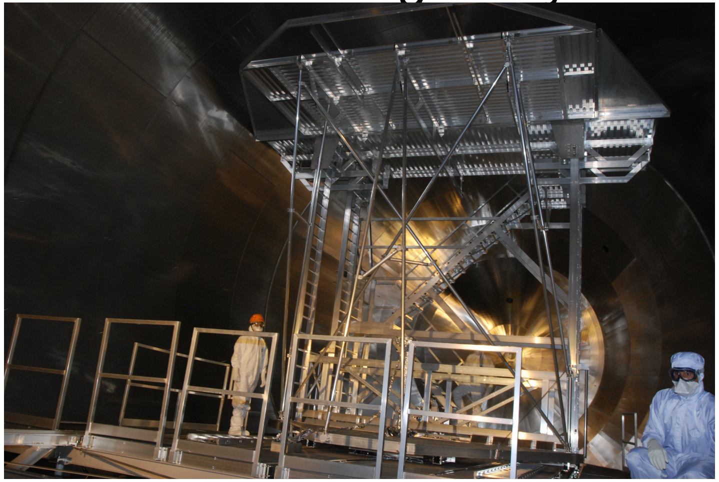
Magnetic Field Inside the Spectrometer:

(Jan Reich, U of Karlsruhe, Diploma Thesis, 2009)

- The largest magnetic field difference in the central plane:

  1.7 μT
- For the absolute field in final setup: 0.3 mT it is ≈ 0.6 % inhomogeneity





Precision HV–dividers

KATRIN specification: σ(U) < 0.06 V (3.3 ppm)

Precision high voltage divider for the KATRIN experiment

(Accepted for publication by IOP New Journal of Physics)

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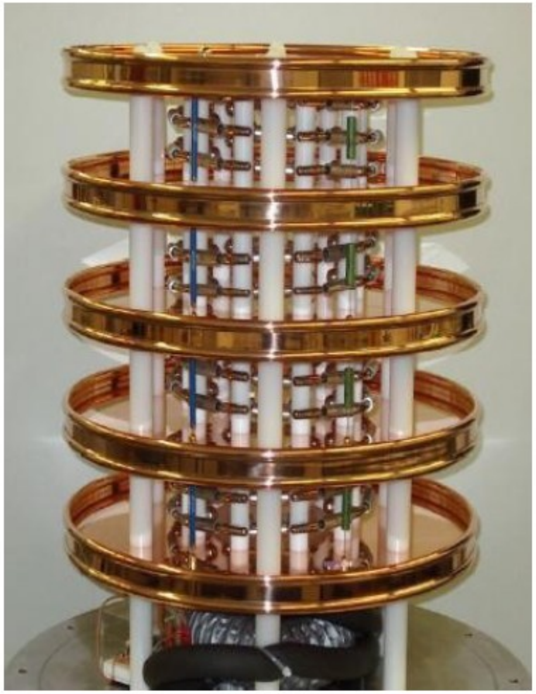
[2] Physikalisch–Technische Bundesanstalt (PTB) Braunschweig, Bundesallee 100,
38116 Braunschweig, Germany

- 100 selected 1.84MΩ resistors (VISHAY) in four planes
- Stored in a steel cylinder in dry nitrogen gas
- Temperature stabilised ΔT<0.1K
- Maximum voltage 35kV
- Scalefactors 1972:1 and 3944:1
- **Long term stability 0.6ppm/month** (between last calibrations at PTB in 2005 and 2006 and cross-checked with ^{83m}Kr conversion electrons measured in 2006 and 2007)



HV-divider: absolute accuracy

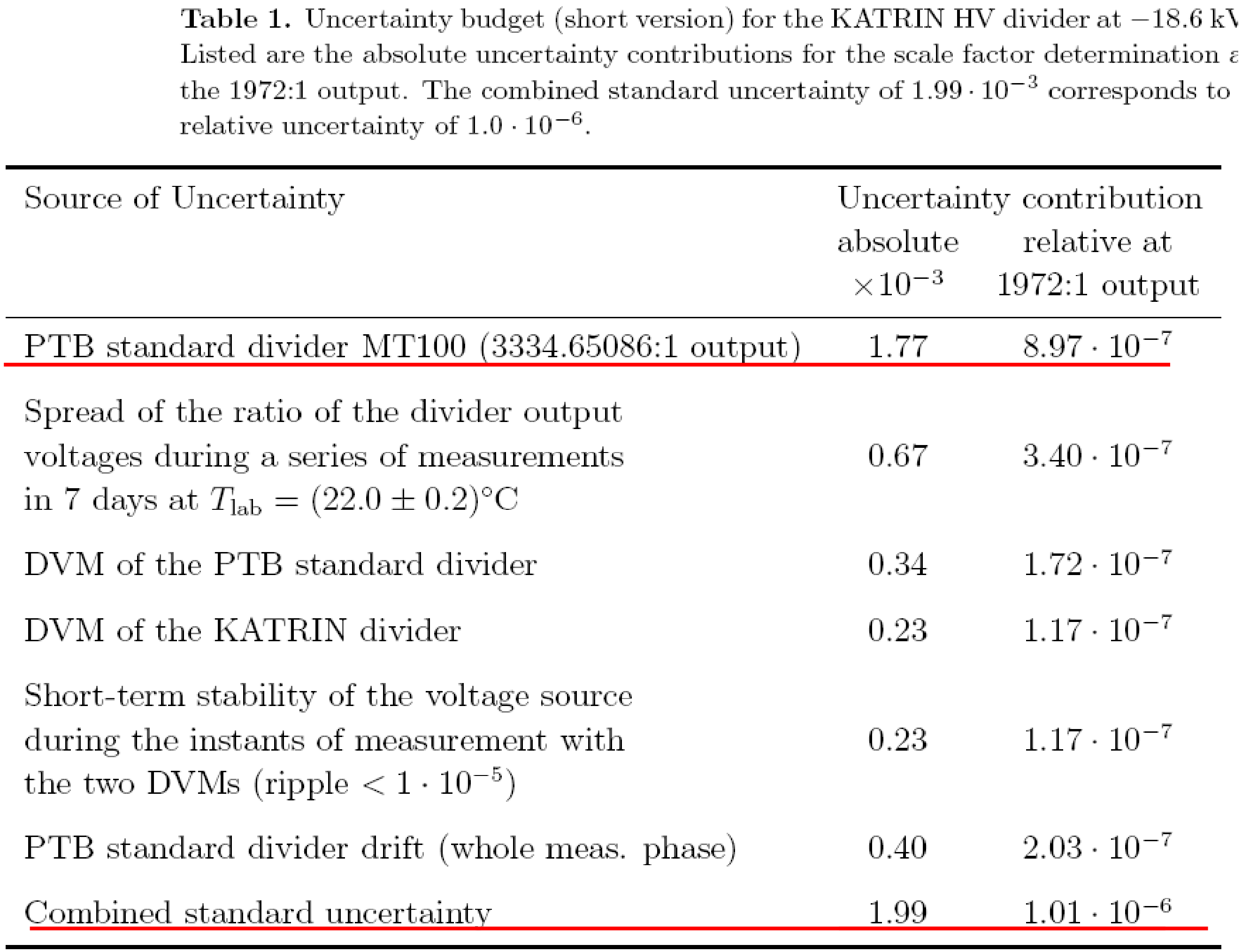


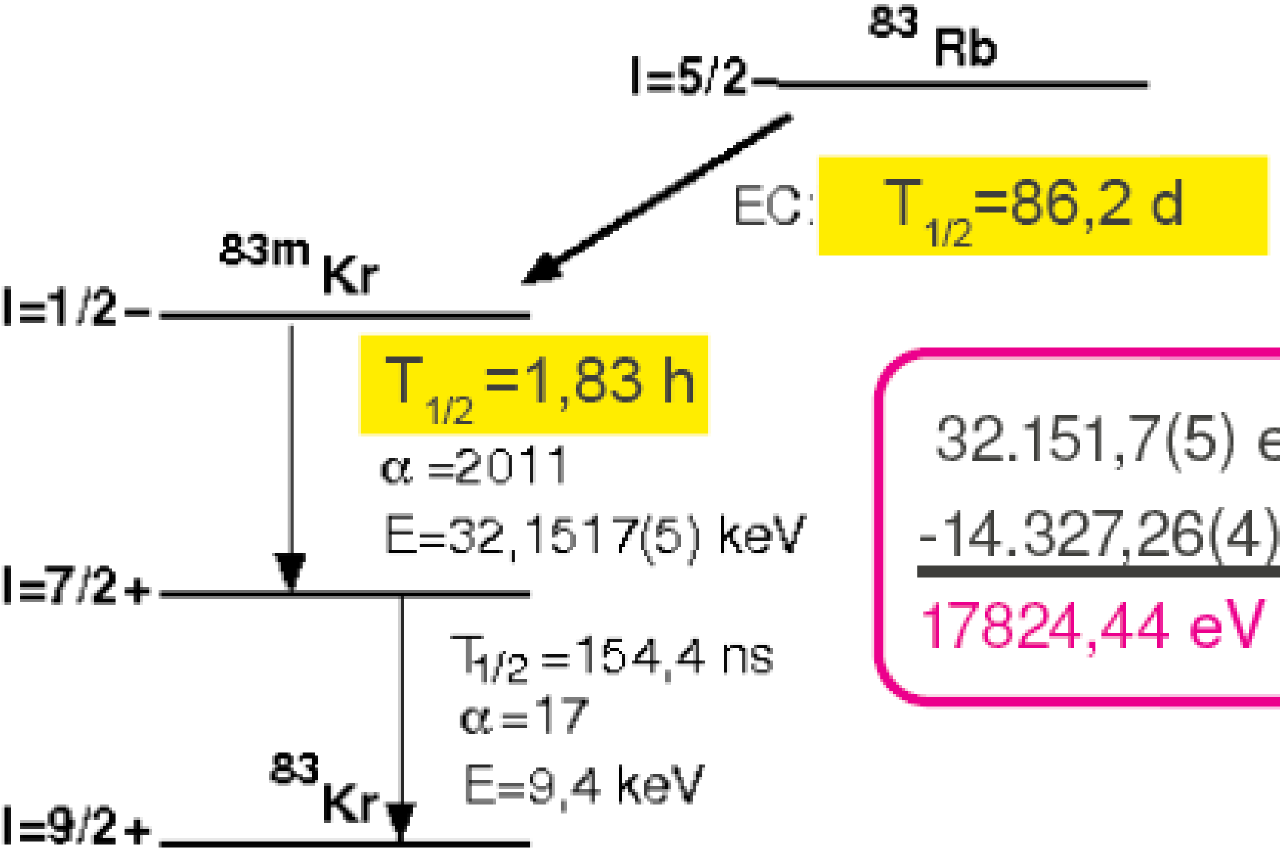
Table 1. Uncertainty budget (short version) for the KATRIN HV divider at −18.6 k
Listed are the absolute uncertainty contributions for the scale factor determination
the 1972:1 output. The combined standard uncertainty of $1.99 \cdot 10^{-3}$ corresponds to
relative uncertainty of $1.0 \cdot 10^{-6}$.

Source of Uncertainty	Uncertainty contribution absolute $\times 10^{-3}$	relative at 1972:1 output
PTB standard divider MT100 (3334.65086:1 output)	1.77	$8.97 \cdot 10^{-7}$
Spread of the ratio of the divider output voltages during a series of measurements in 7 days at $T_{\text{lab}} = (22.0 \pm 0.2)$°C	0.67	$3.40 \cdot 10^{-7}$
DVM of the PTB standard divider	0.34	$1.72 \cdot 10^{-7}$
DVM of the KATRIN divider	0.23	$1.17 \cdot 10^{-7}$
Short-term stability of the voltage source during the instants of measurement with the two DVMs (ripple $< 1 \cdot 10^{-5}$)	0.23	$1.17 \cdot 10^{-7}$
PTB standard divider drift (whole meas. phase)	0.40	$2.03 \cdot 10^{-7}$
Combined standard uncertainty	1.99	$1.01 \cdot 10^{-6}$

Second HV-divider

- **Maximum voltage up to 65kV**
- **Improvement of the low voltage area** (higher thermal stability)
- Four scale factors instead of two (self-calibration)
- 170x 880kΩ instead of 100x 1.84MΩ VISHAY resistors (reduction of thermal load per resistor)
- **pre-aged resistors** (long term stability)
- **Implementation of a built in ripple probe** (to check HF and 50Hz noise)
- New sealed fan
- Humidity sensor
- Advanced temperature regulation (simulation and tests)

Absolute HV-monitoring: ^{83m}Kr K-line



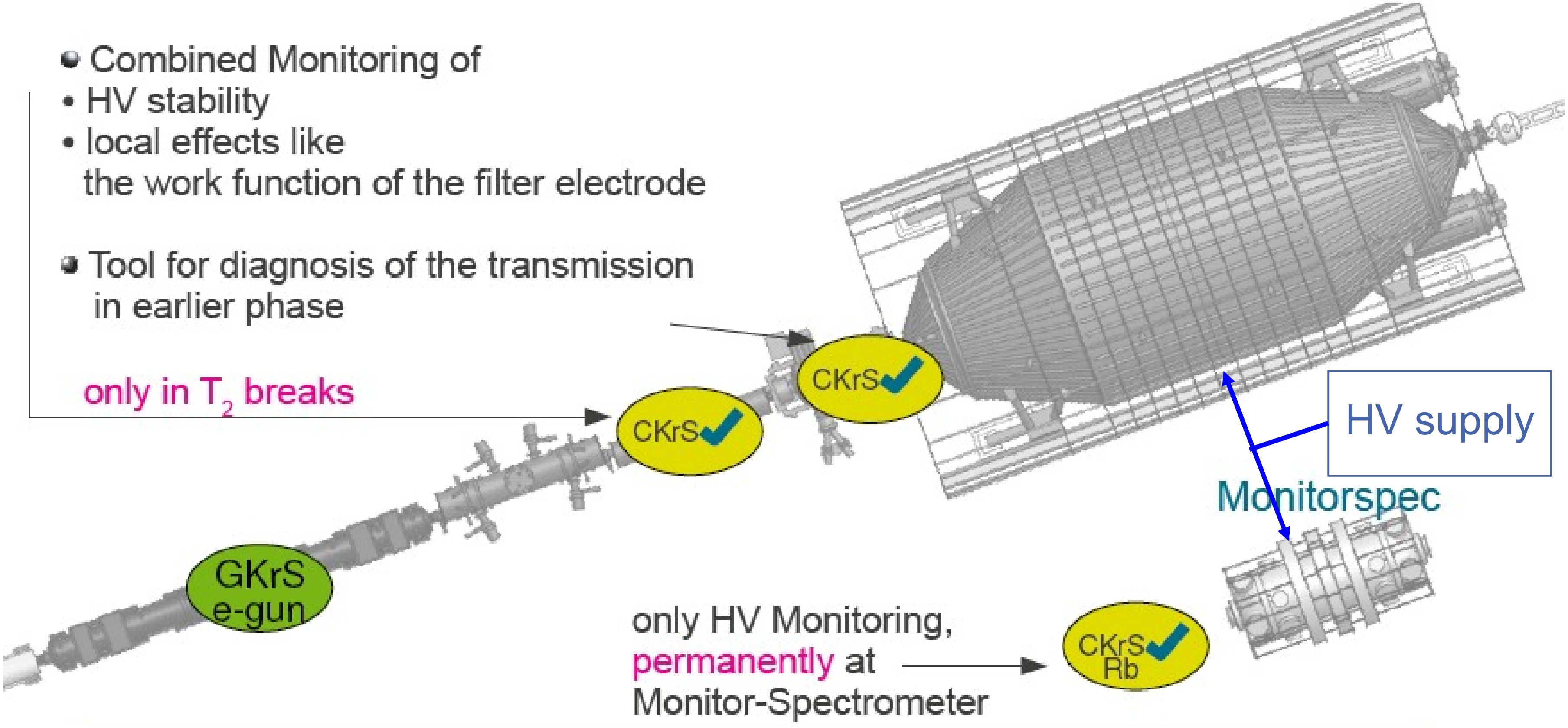
32.151,7(5) eV*(Γ)
-14.327,26(4) eV** (K)
17824,44 eV + corr.

* Venos et al, Nucl Instr. Meth. A560 (2006) 352-359,

** Dragoun et al., Czech. J. Phys. 54 (2004) 833-839

Absolute HV-monitoring: ^{83m}Kr K-line

- Combined Monitoring of
  - HV stability
  - local effects like the work function of the filter electrode
- Tool for diagnosis of the transmission in earlier phase



only in T_2 breaks

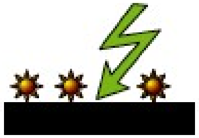
only HV Monitoring, permanently at Monitor-Spectrometer

Monitoring of HV ≠ Monitoring the retardating potential
⇒ Measurements inside the main beam line necessairy and (only) possible with CKrS (no danger of contamination with $T_{1/2}$= 1,83 h)

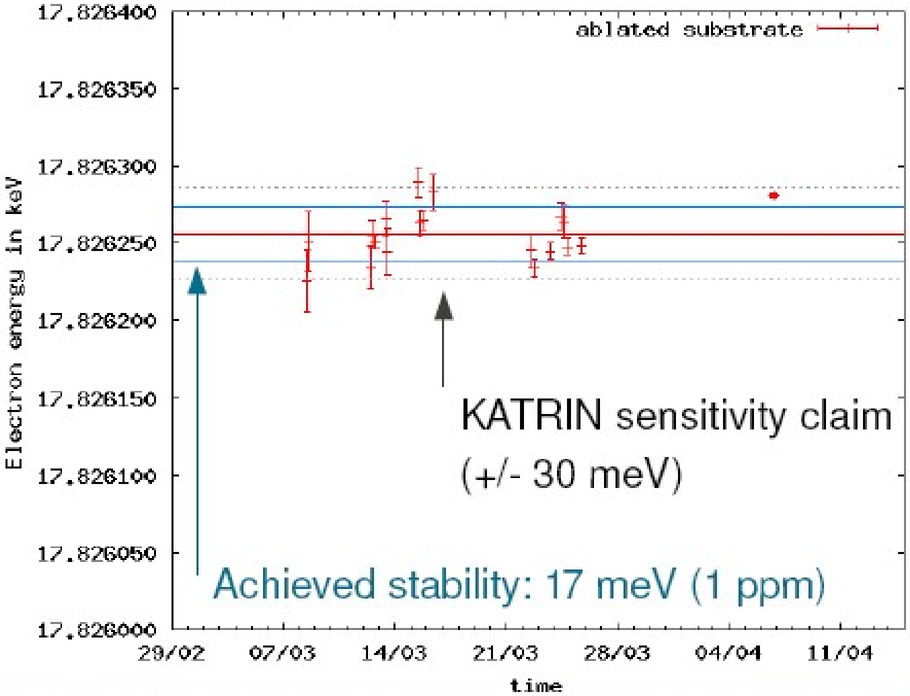
Condensed ^{83m}Kr source: K-line position stability 1 ppm achieved during 1 month

(PhD thesis B. Ostrick, WWU Muenster, 2008)

^{83m}Kr on
bare HOPG, Ablation

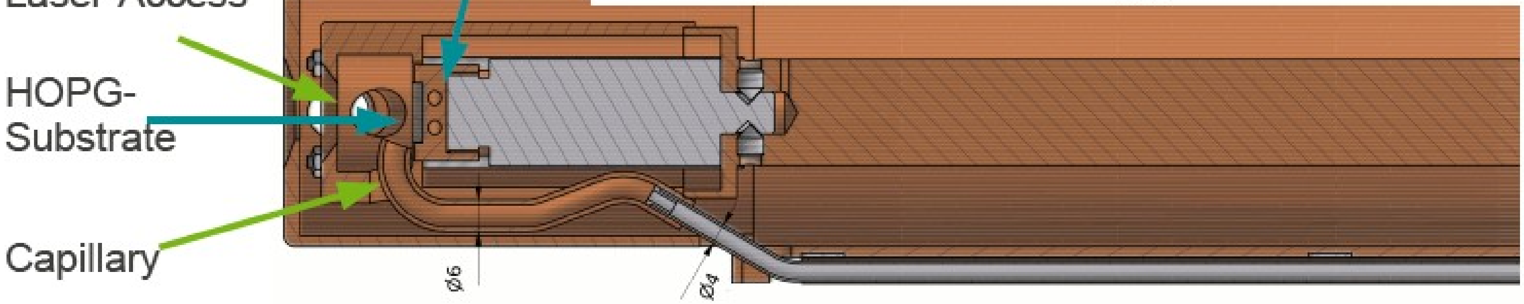


Ablation:
thin hot surface



KATRIN sensitivity claim
(+/- 30 meV)

Achieved stability: 17 meV (1 ppm)



On-line tritium purity control

(Should be known better than 0.1%)

Why Laser Raman Spectroscopy (LARA) ?

Non-contact laser-spectroscopic techniques:

Absorption spectroscopy (AS):
requires different far-IR wavelengths for each species

Laser-induced fluorescence spectroscopy (LIFS):
requires different deep-UV wavelengths for each species

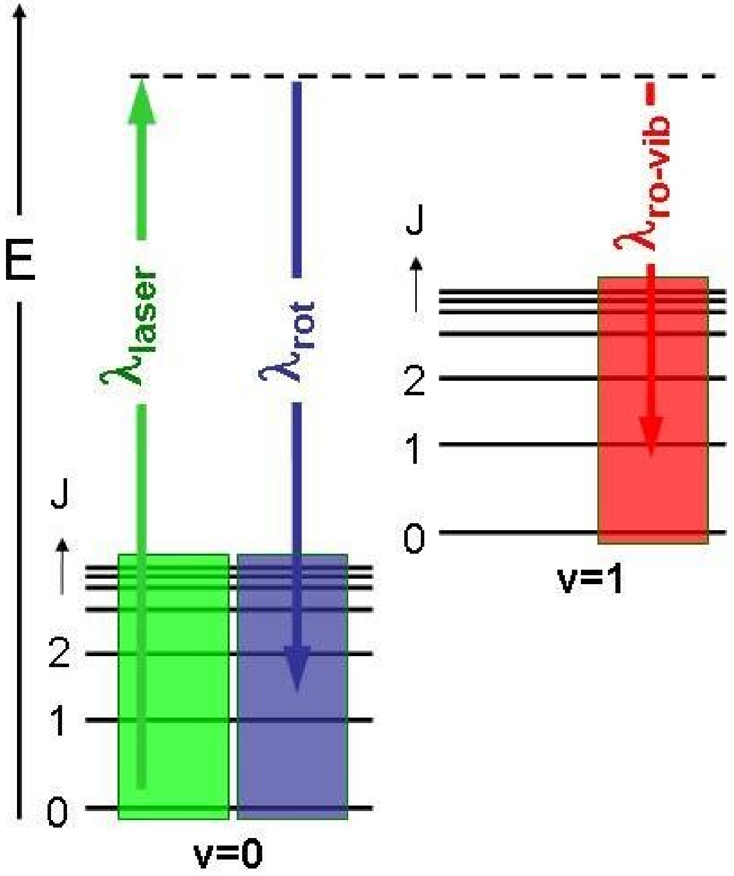
Raman spectroscopy:
requires only single wavelength for all species

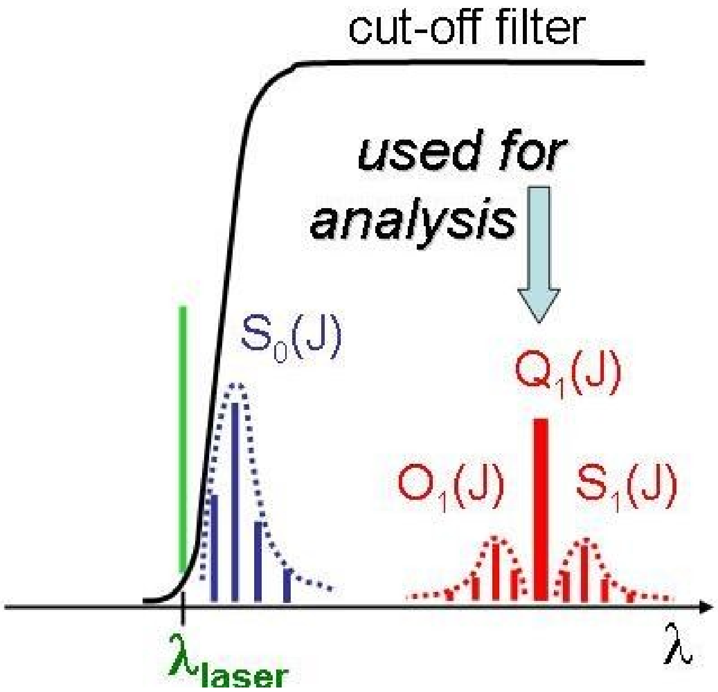
The only viable multi-species method is (laser) Raman spectroscopy for **in-line, near real-time monitoring**

Concepts of Raman spectroscopy

The probability for a Raman transition is orders of magnitudes smaller than that for AS and LIFS

→ large particle densities or/and high laser powers required





On-line tritium purity control

Dynamic Raman spectroscopy of hydrogen isotopomer mixtures in-line at TILO

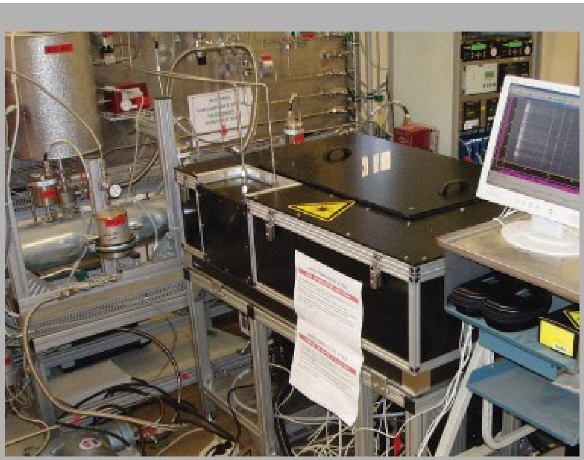
R.J. Lewis, [1,*] *H.H. Telle,* [1] *B. Bornschein,* [2] *O. Kazachenko,* [2] *N. Kernert,* [3] *and M. Sturm* [4]

[1] Department of Physics, Swansea University, Singleton Park, Swansea, SA2 8PP, United Kingdom
[2] Tritium Labor Kalrsruhe (TLK), Forschungszentrum Karlsruhe, Postfach 3640, 76021 Karlsruhe, Germany
[3] Institut für Kernphysik (IK), Forschungszentrum Karlsruhe, Postfach 3640, 76021 Karlsruhe, Germany
[4] Institut für Experimentelle Kernphysik (IEKP), Universität Karlsruhe, Postfach 6980, 76128 Karlsruhe, Germany

Laser Physics Letter 5, 522-531 (2008)

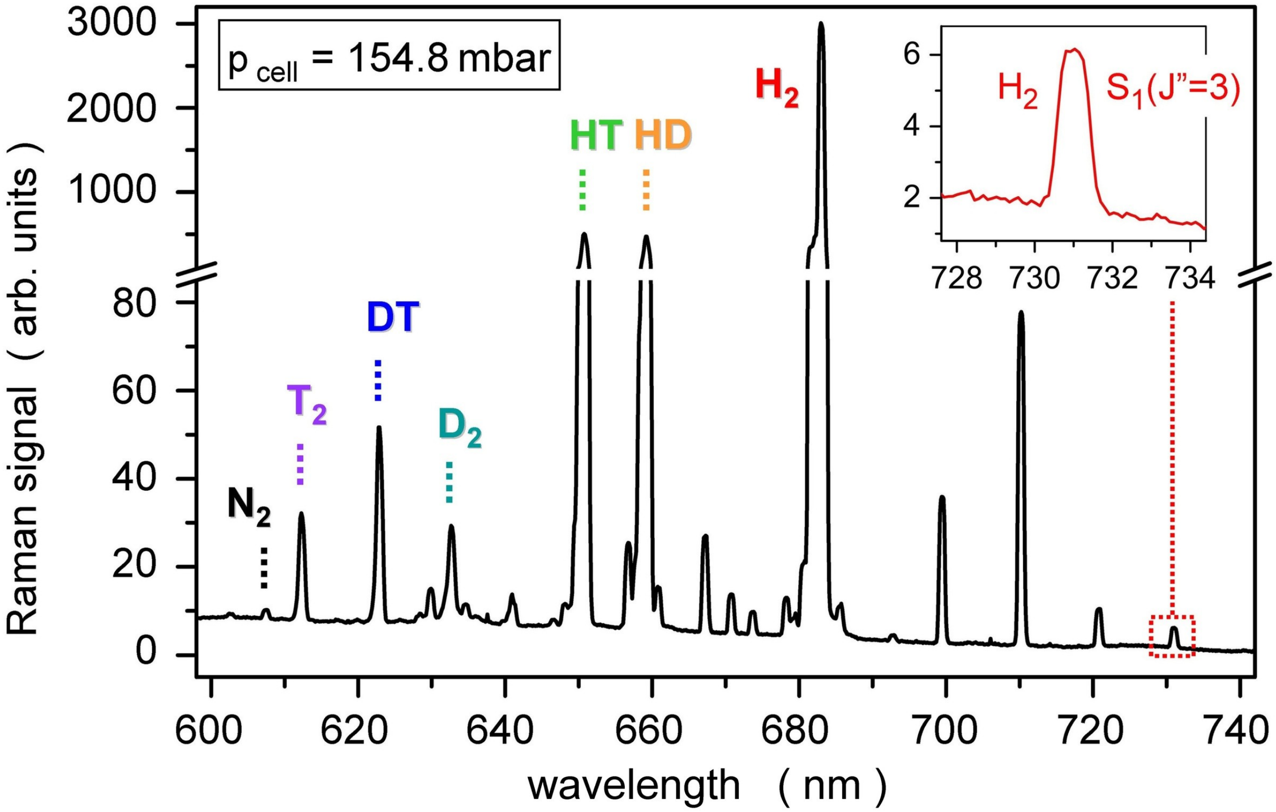
Laser Physics Letters 1

Abstract: The pure rotational and vibration-rotational Stokes Raman spectra of flowing gaseous mixtures of the hydrogen isotopomers H_2, HD, and D_2 were measured in order to test the performance of the proposed tritium purity monitoring system designed for the Karlsruhe Tritium Neutrino (KATRIN) mass experiment, which utilises 532 nm CW laser excitation and fibre-coupled scattered light collection, exploiting 90° excitation observation geometry. Short (100–300 s) exposure times were used to simulate the real-time in-line measurement of hydrogen isotopomer composition at the low ($\sim$ 100–150 mbar) pressure required for KATRIN. At 100 s exposure time, an in-line sensitivity of better than 1% was achieved for dynamic changes in the sample gas composition.



Compartmentalised Raman measurement system – in the centre – for the monitoring of flowing hydrogen isotopomer mixtures, attached to the testing inner-loop (TILO) gas flow system – in the background

On-line tritium purity control –latest results



Filling:

(CAPER GC analysis) :

H_2 - 82.5% (7.2)

HD - 8.33% (0.66)

HT - 8.51% (0.13)

DT - 0.48% (0.02)

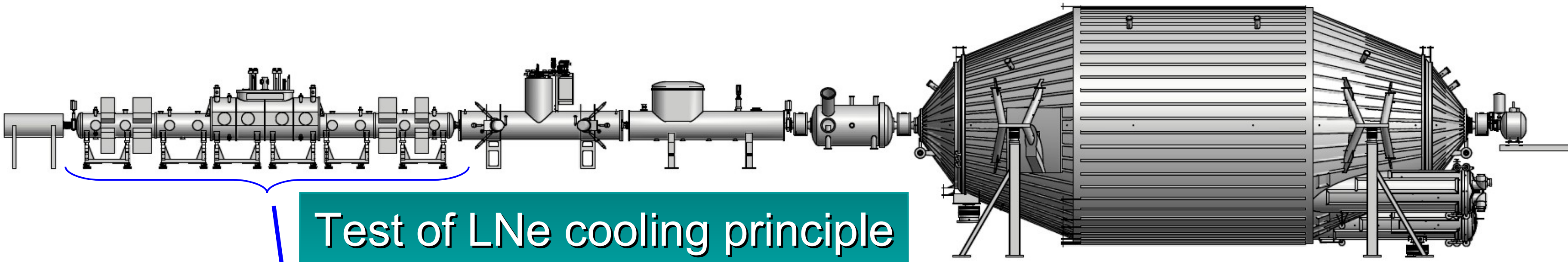
T_2 - 0.27% (0.02)

Laser power :

5W @ 532nm

Data acquisition time : 1000s

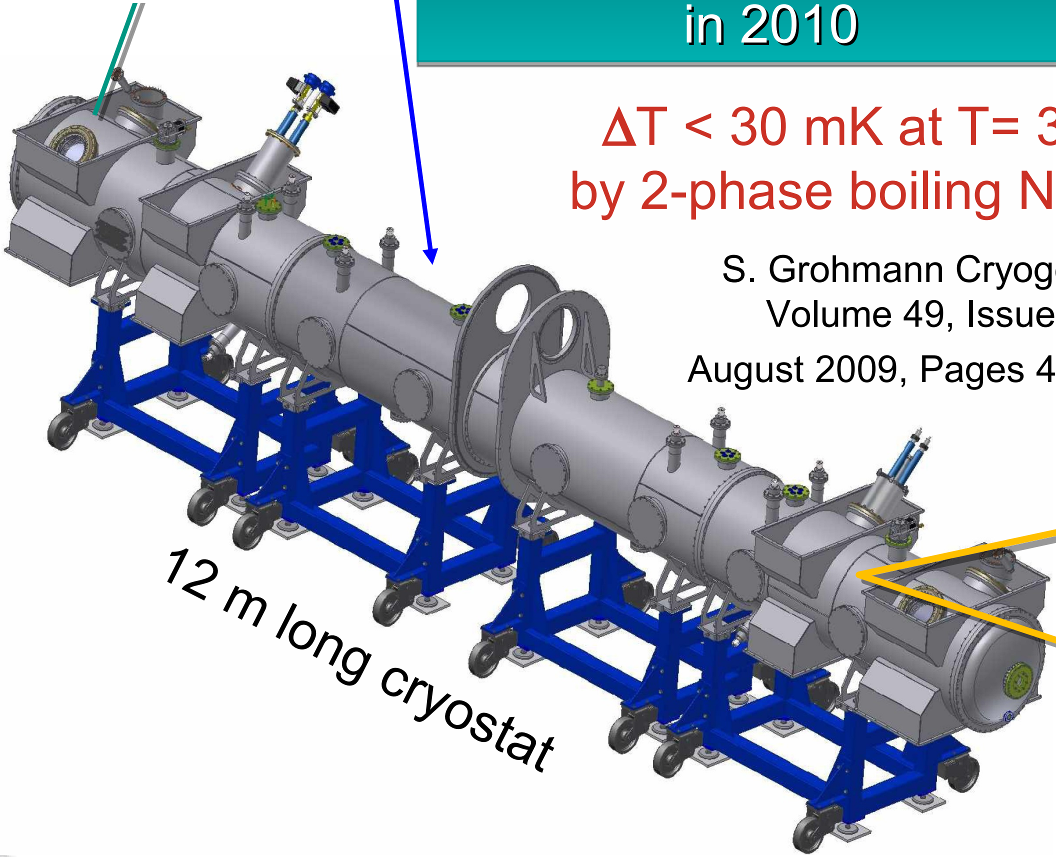
WGTS – demonstrator



Test of LNe cooling principle in 2010

ΔT < 30 mK at T= 30 K
by 2-phase boiling Neon

S. Grohmann Cryogenics
Volume 49, Issue 8,
August 2009, Pages 413-420



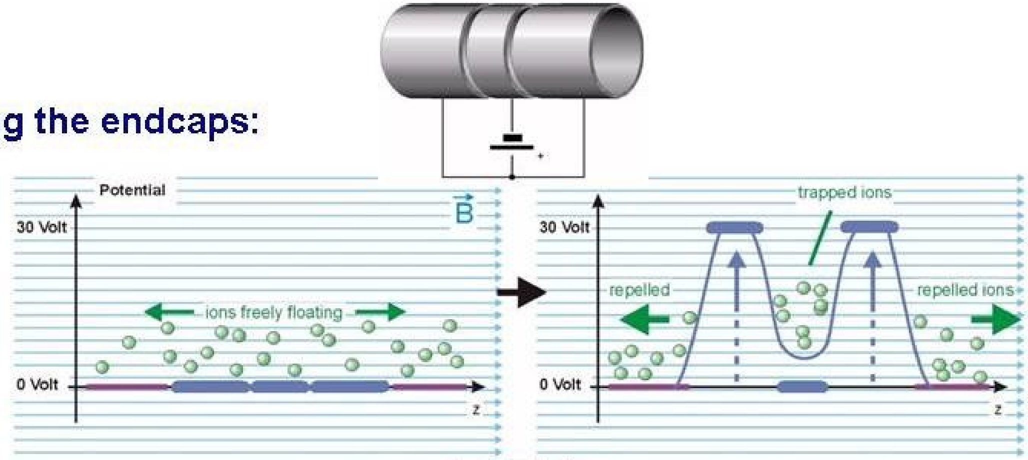
Tritium ions in the WGTS - FT-ICR analysis

3pole-Brown-Gabrielse-type trap

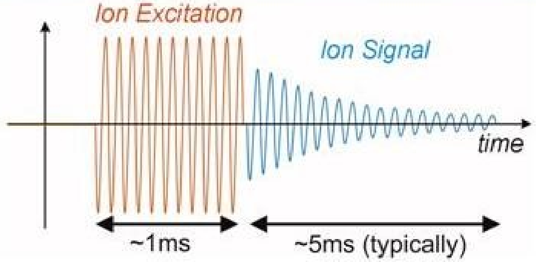
L.S. Brown, G. Gabrielse,Rev. Mod. Phys. 58, 233 (1986).

Measurement Cycles

Pulsing the endcaps:

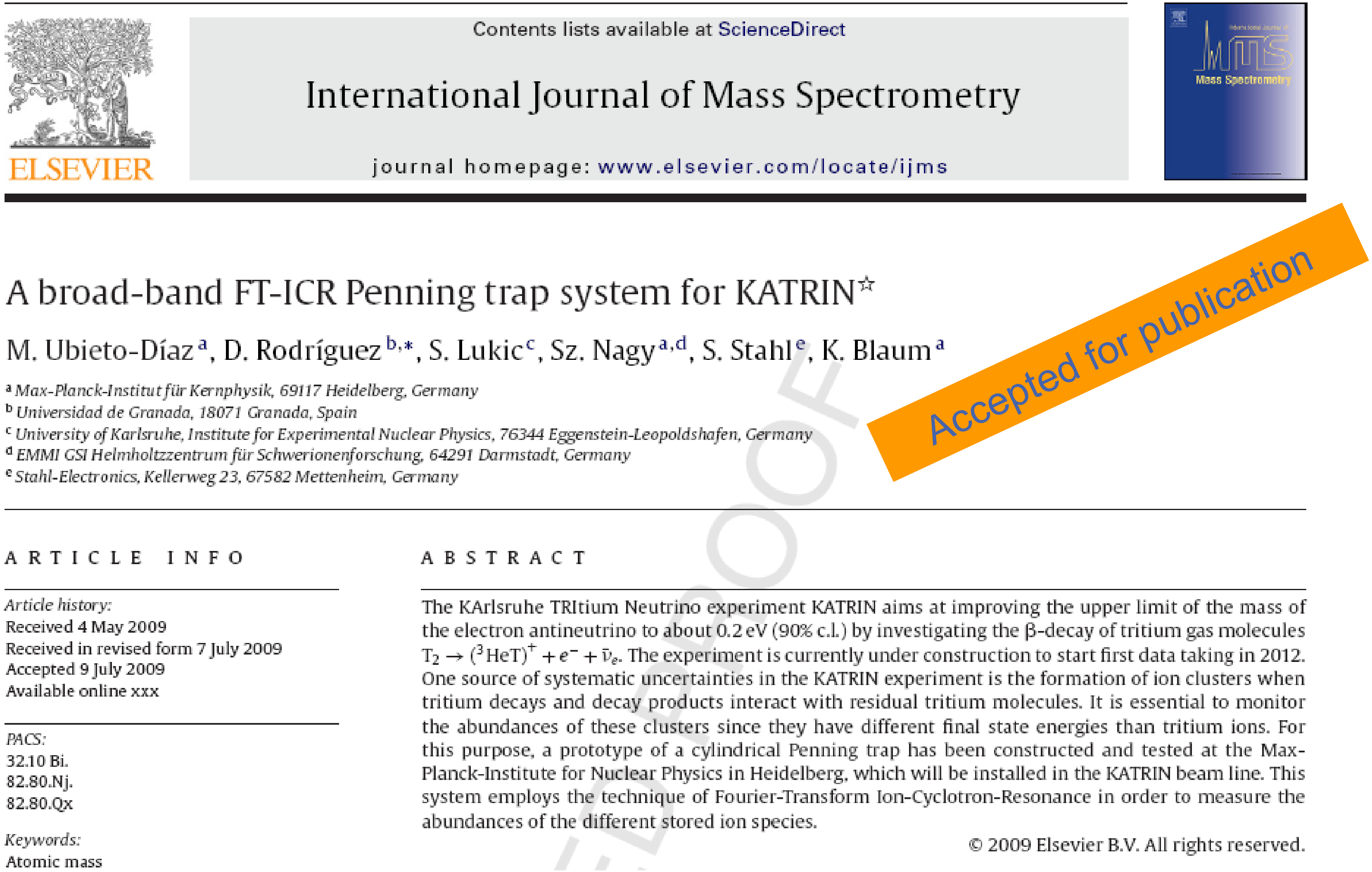


Excitation and detection:



Whole cycle can be run ~ 20x per second

Tritium ions in the WGTS
- FT-ICR analysis



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Accepted for publication

A broad-band FT-ICR Penning trap system for KATRIN☆

M. Ubieto-Díaz[a], D. Rodríguez[b,*], S. Lukic[c], Sz. Nagy[a,d], S. Stahl[e], K. Blaum[a]

[a] Max-Planck-Institut für Kernphysik, 69117 Heidelberg, Germany
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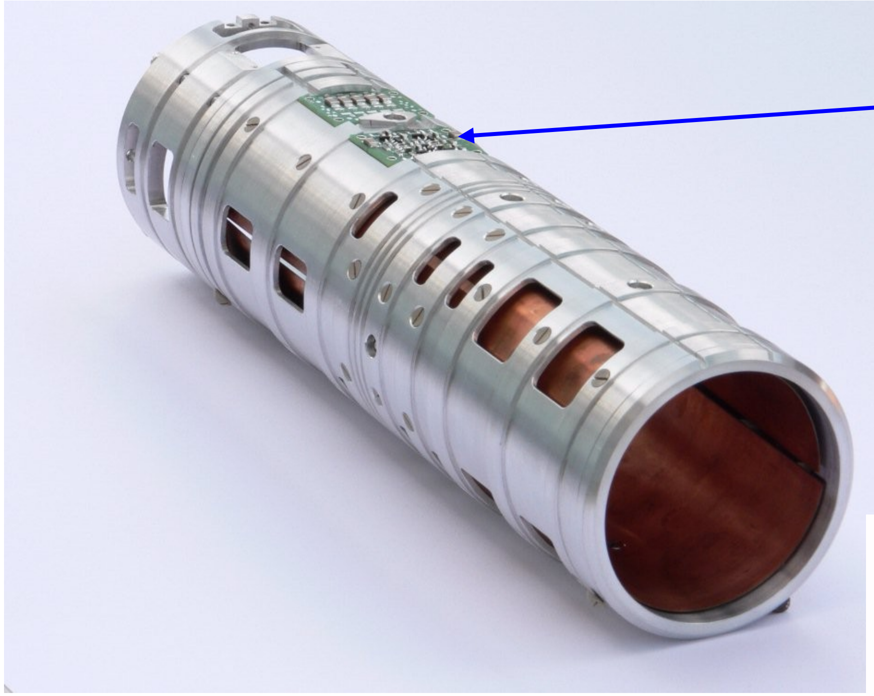
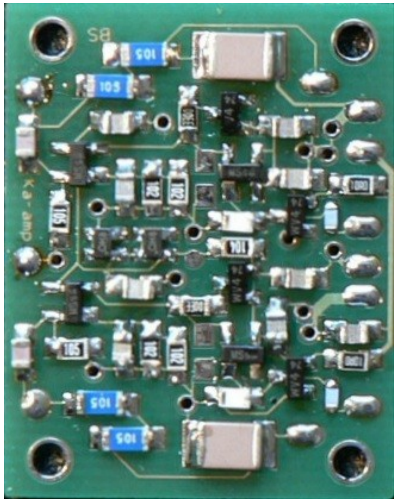
ABSTRACT

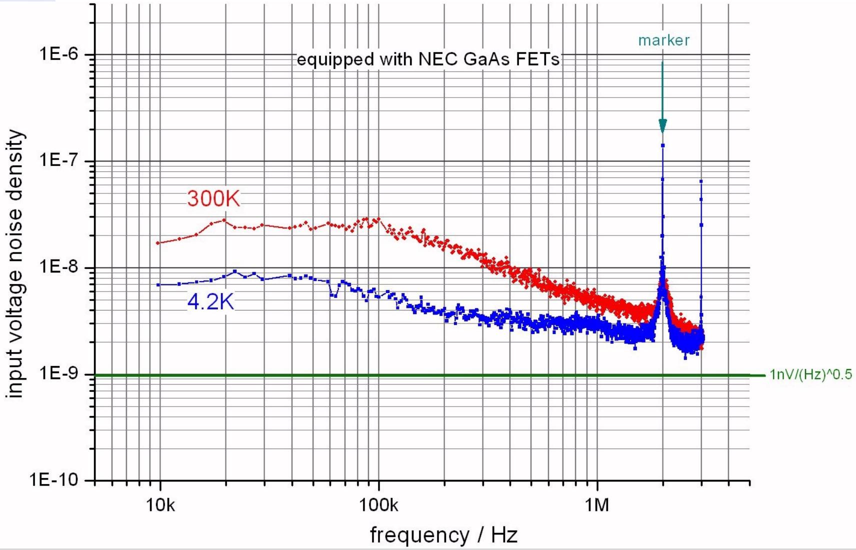
The KArlsruhe TRItium Neutrino experiment KATRIN aims at improving the upper limit of the mass of the electron antineutrino to about 0.2 eV (90% c.l.) by investigating the β-decay of tritium gas molecules $T_2 \rightarrow (^3\mathrm{HeT})^+ + e^- + \bar{\nu}_e$. The experiment is currently under construction to start first data taking in 2012. One source of systematic uncertainties in the KATRIN experiment is the formation of ion clusters when tritium decays and decay products interact with residual tritium molecules. It is essential to monitor the abundances of these clusters since they have different final state energies than tritium ions. For this purpose, a prototype of a cylindrical Penning trap has been constructed and tested at the Max-Planck-Institute for Nuclear Physics in Heidelberg, which will be installed in the KATRIN beam line. This system employs the technique of Fourier-Transform Ion-Cyclotron-Resonance in order to measure the abundances of the different stored ion species.

Tritium ions in the WGTS
- FT-ICR analysis

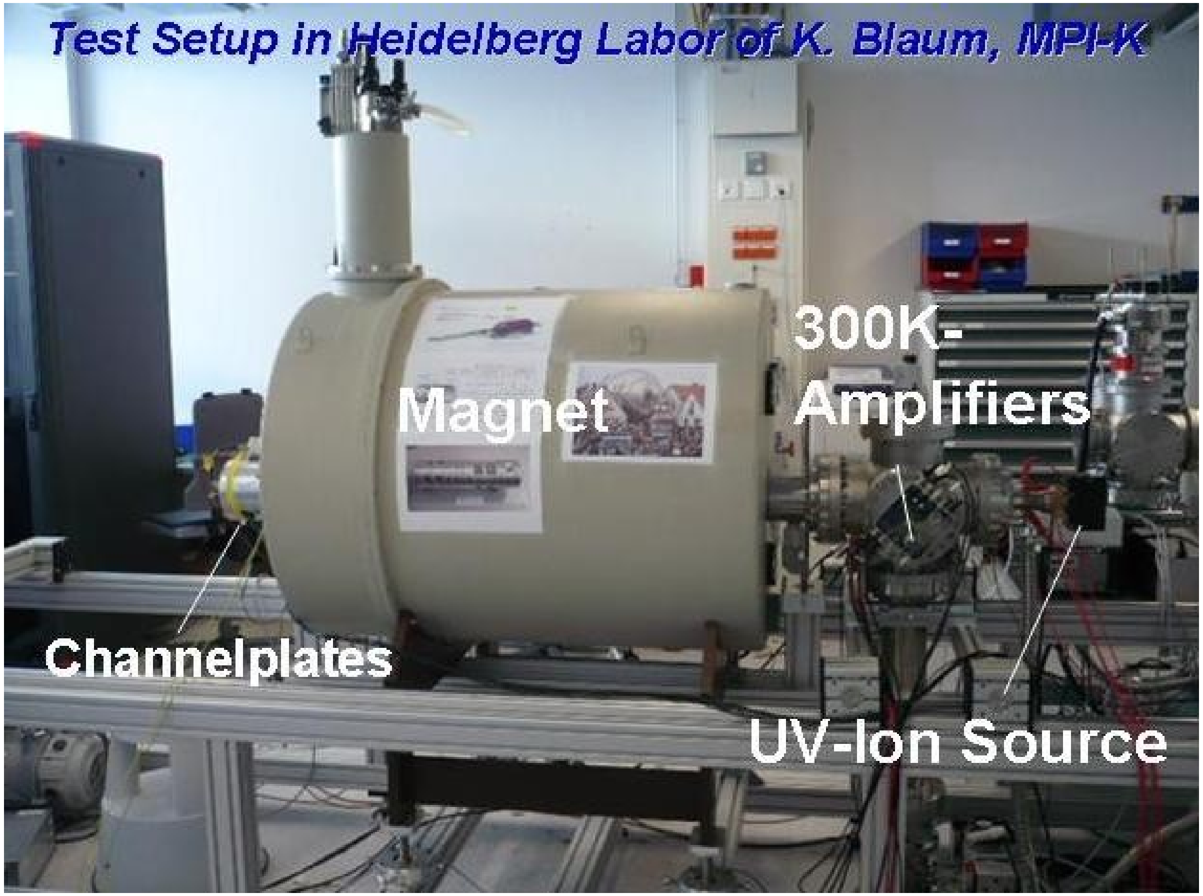




stahl-electronics.com



Tritium ions in the WGTS - FT-ICR analysis



Expected Sensitivity

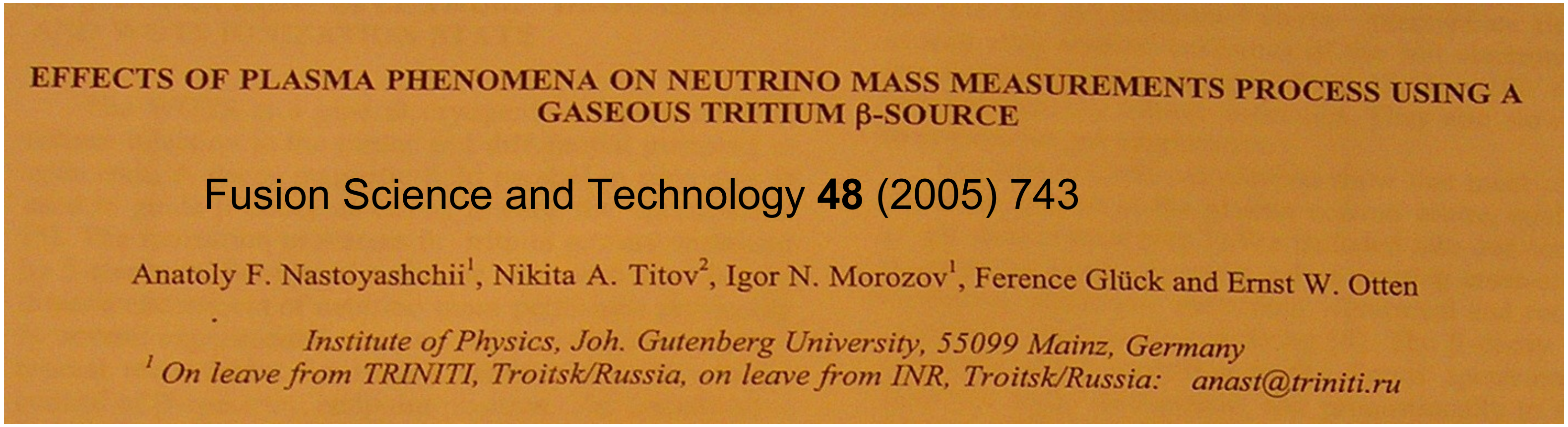
(depending on rest gas pressure, B-inhomogeneity)

Ion Species	Minimum Detectable Ion Number
D^+, H_2^+	6000
$^3He^+, T^+$	4000
DT_2^+	1500
T_3^+	1300
T_5^+	800

maximum charge in trap: ~ 10^8 e

⇒Measurements (up to now) show nice agreement compared to predictions

Tritium ions in the WGTS
- plasma effects



EFFECTS OF PLASMA PHENOMENA ON NEUTRINO MASS MEASUREMENTS PROCESS USING A GASEOUS TRITIUM β-SOURCE

Fusion Science and Technology **48** (2005) 743

Anatoly F. Nastoyashchii[1], Nikita A. Titov[2], Igor N. Morozov[1], Ference Glück and Ernst W. Otten

Institute of Physics, Joh. Gutenberg University, 55099 Mainz, Germany
[1] On leave from TRINITI, Troitsk/Russia, on leave from INR, Troitsk/Russia: anast@triniti.ru

Observations:

- Ion / electron density is about $(10^7 \div 10^8)/\mathrm{cm}^{-3}$ in the center of WGTS
- Ions and electrons are thermal with gas temperature 27K

Consequences:

- electrical “quasyneutrality”
  - electric potential variation of the order of few $kT \approx 10$ *meV*
  - ambipolar diffusion took place
- high conductivity along magnetic field lines
  - electric potential could be determined by “rear wall

Surface potential of WGTS

Gas adsorption is changing surface potential (pure iron data):

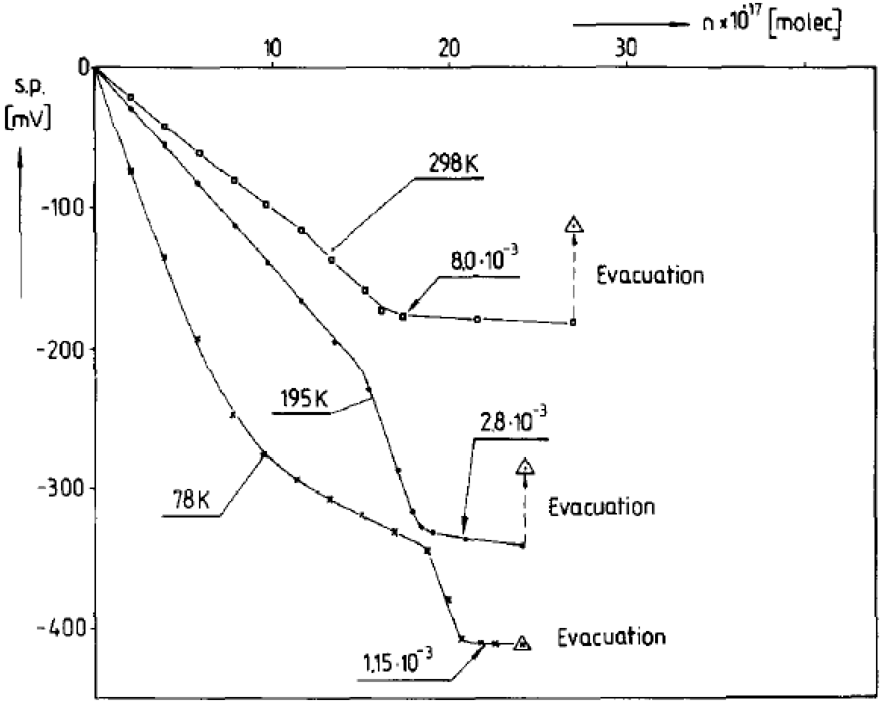
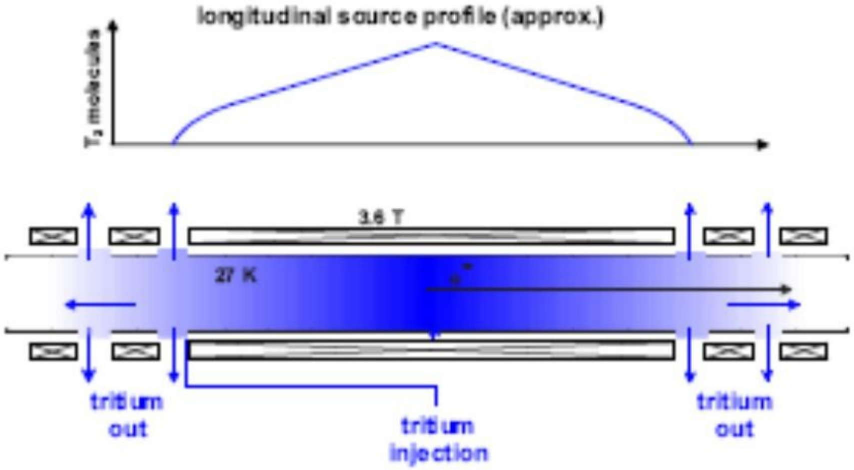


Fig. 1. Surface potential isotherms showing the dependence of the surface potential of thin iron film on the amount of hydrogen adsorbed at 78, 195 and 298 K. The equilibrium pressure at some population of the adsorbate is shown (in Torr).

E. NOWICKA *, W. LISOWSKI and R. DUŚ

Surface Science 137 (1984) L85–L91

Maximal surface potential change up to 400 meV !



WGTS potential definition

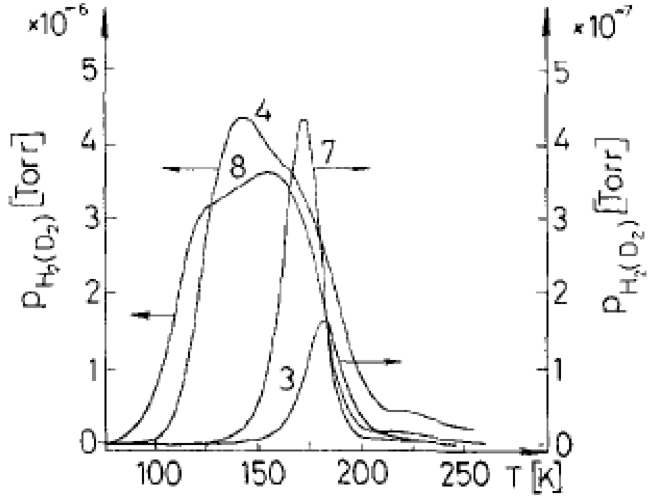
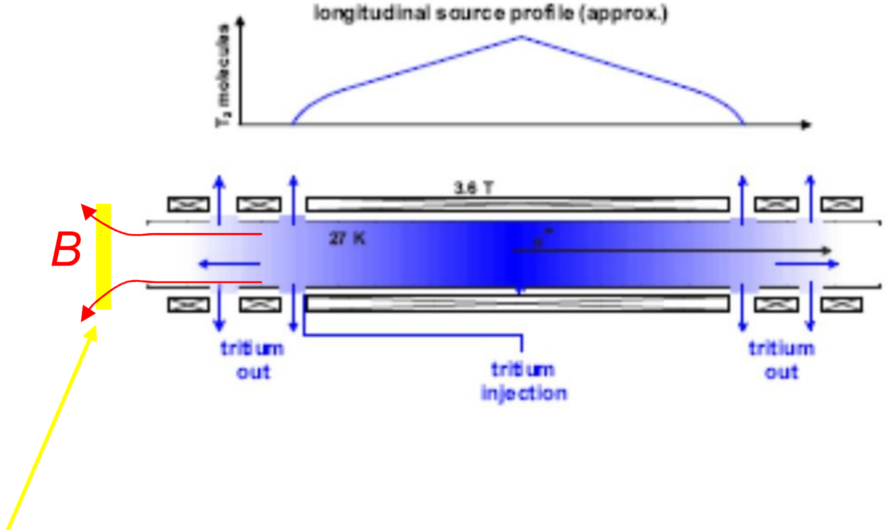


Fig. 3. The symmetrical TD spectra 3 and 7 ($\theta \leq 0.01$) indicate an associative desorption of strongly adsorbed deuterium and hydrogen species on thin, sintered gold films at 78 K plotted against a background of the TD spectra 4 and 8 with high coverages $\theta \cong 0.4$.

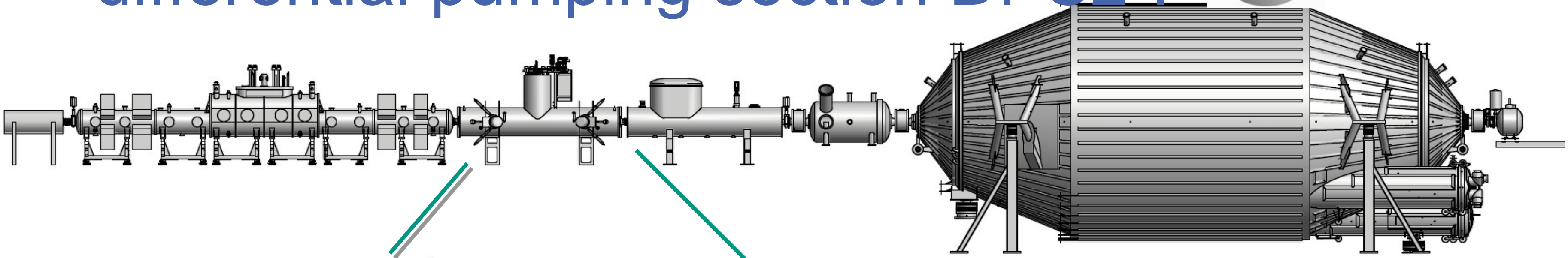
L. Stobiński / Applied Surface Science 103 (1996) 503–508

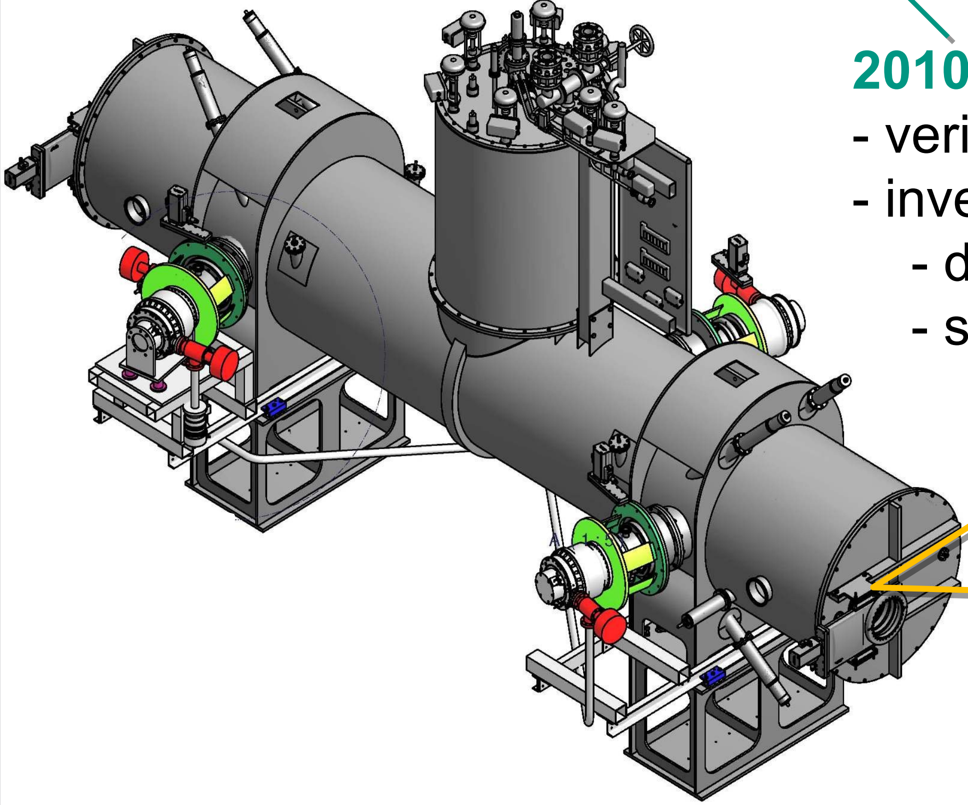
There are no *molecular* hydrogen adsorption on Au [111] surface above 30K, *atomic* hydrogen is desorbed above 200K.



Rear wall from Au[111] covers magnetic flux and is placed at low tritium density and has temperature above 200K

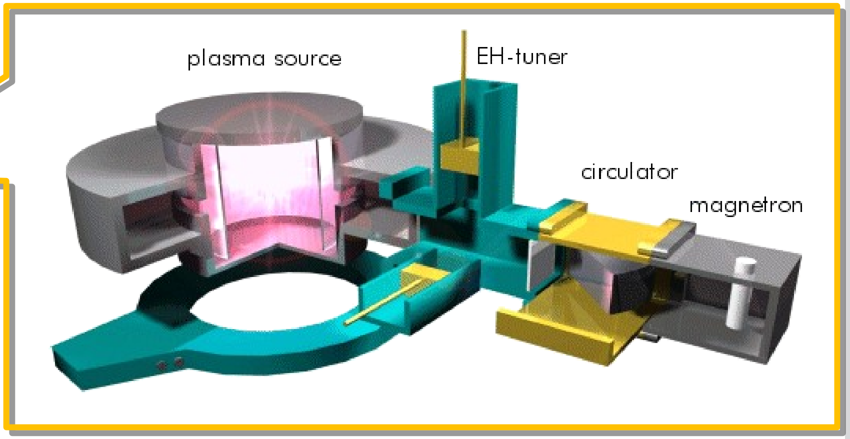
Plasma effects study at differential pumping section DPS2-F





2010 DPS2-F experimental programme

- verify H-isotopologue retention $R = 10^5$
- investigations of ion properties:
  - diagnostics with FT-ICR measurements
  - suppression with dipoles



KATRIN beginning of T_2 measurements is scheduled at 2012

Thank you for your attention on behalf of the KATRIN collaboration

Karlsruhe Institute of Technology

The KATRIN Experiment

KATRIN Karlsruhe Tritium Neutrino Experiment

PRIFYSGOL CYMRU ABERTAWE
UNIVERSITY OF WALES SWANSEA

Academy of Sciences
of the Czech Republic

Westfälische
Wilhelms-Universität
Münster

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

University of Washington

universität mainz

UNIVERSITÄT
KARLSRUHE (TH)

Fachhochschule Fulda
University of Applied Sciences

Massachusetts
Institute of
Technology

Uni Bonn
Rheinische Friedrich-Wilhelms-Universität

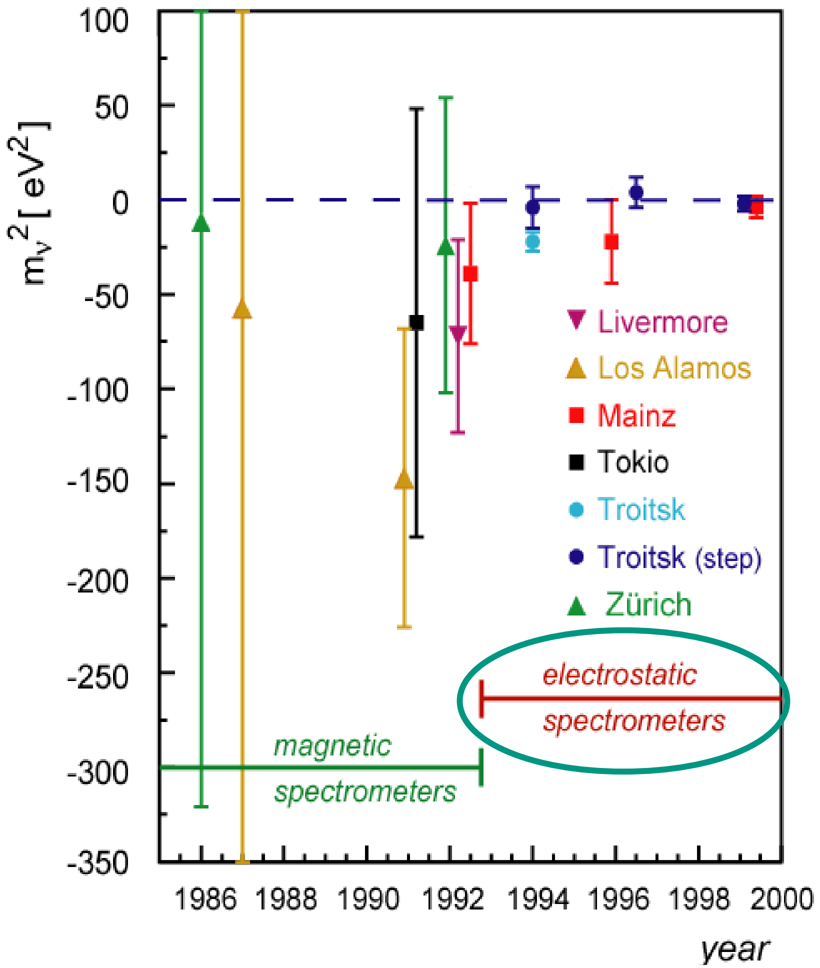
ASTeC

Joint Institute for Nuclear Research

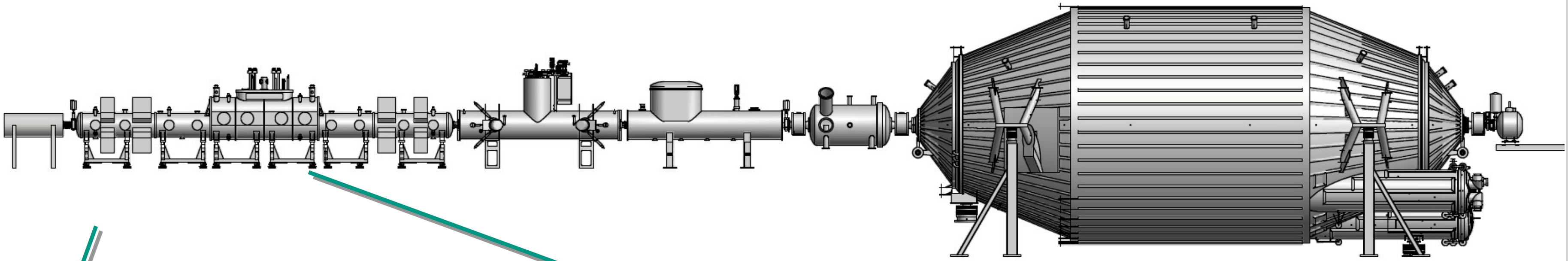
history of tritium ß-decay experiments

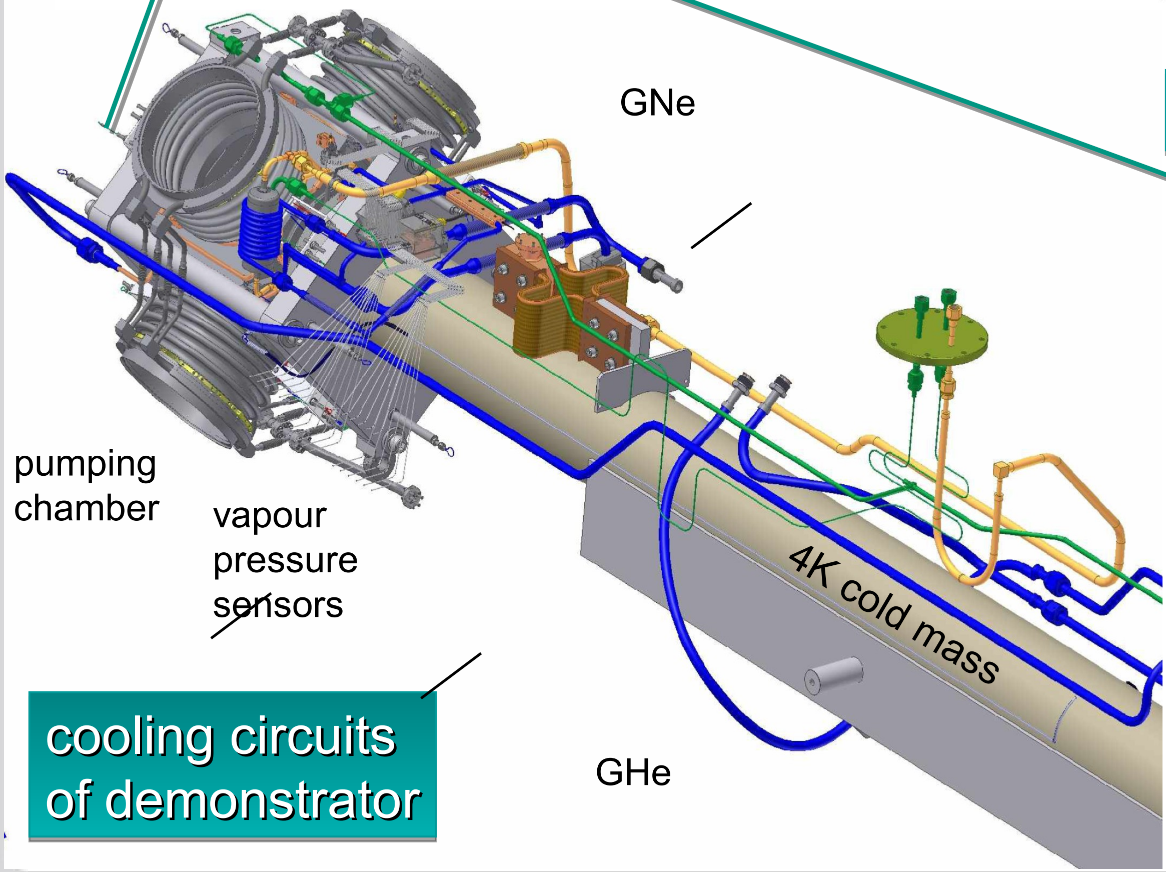
	m_ν
ITEP *T_2 in complex molecule* *magn. spectrometer (Tret'yakov)*	17-40 eV
Los Alamos *gaseous T_2 - source* *magn. spectrometer (Tret'yakov)*	< 9.3 eV
Tokio *T - source* *magn. spectrometer (Tret'yakov)*	< 13.1 eV
Livermore *gaseous T_2 - source* *magn. spectrometer (Tret'yakov)*	< 7.0 eV
Zürich *T_2 - source impl. on carrier* *magn. spectrometer (Tret'yakov)*	< 11.7 eV
Troitsk (1994-today) *gaseous T_2 - source* *electrostat. spectrometer*	< 2.3 eV
Mainz (1994-today) *frozen T_2 - source* *electrostat. spectrometer*	< 2.3 eV

experimental results for m_ν^2



WGTS – demonstrator





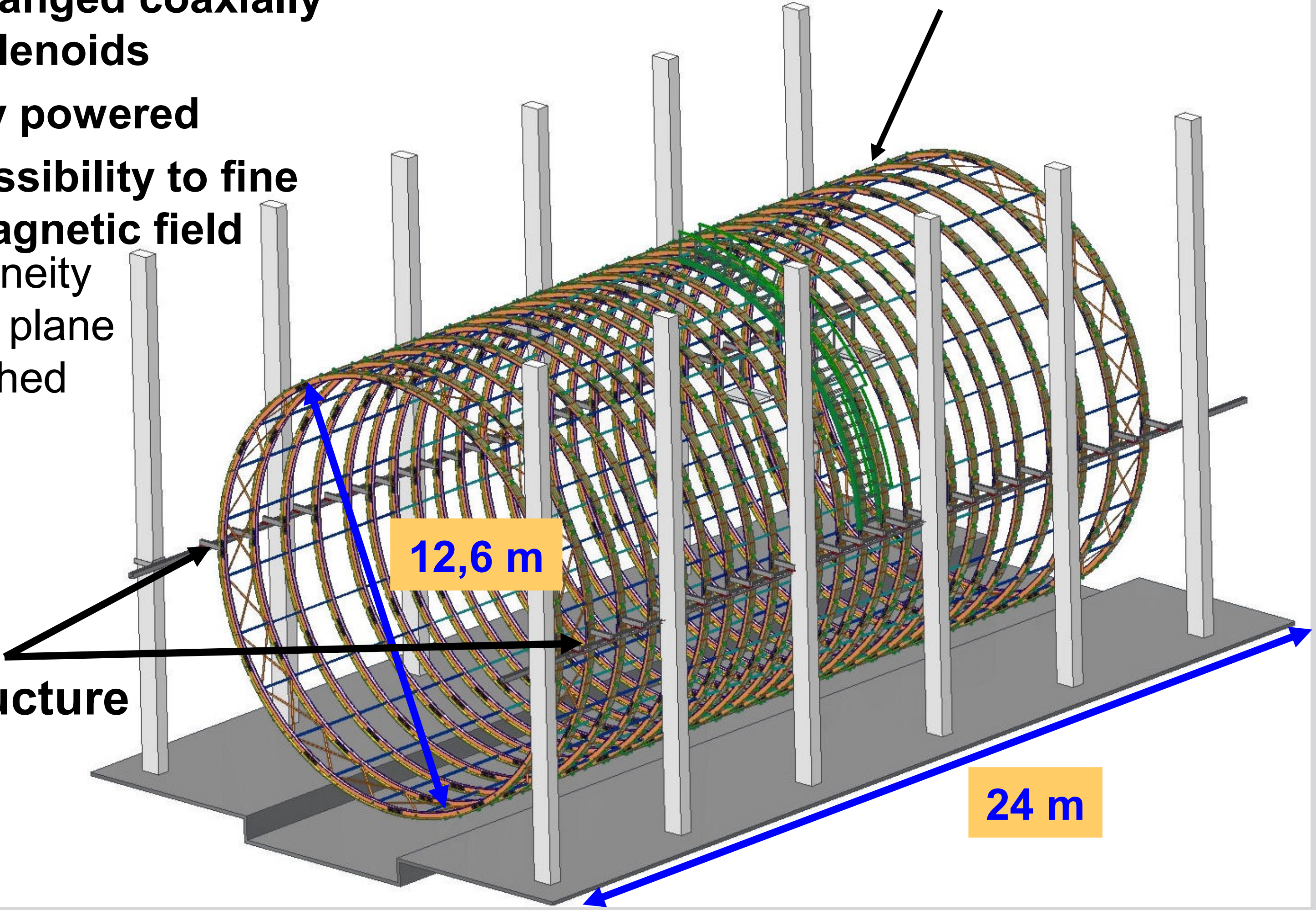
cooling circuits of demonstrator

demonstrator/WGTS status

- beam tube and pumping chambers leak tested
- demonstrator assembly finished in 10/2009
- 3 months test of LNe circuit & ΔT profiles
- reassembly to WGTS until mid-2011
- WGTS operational by end 2011, then system integration

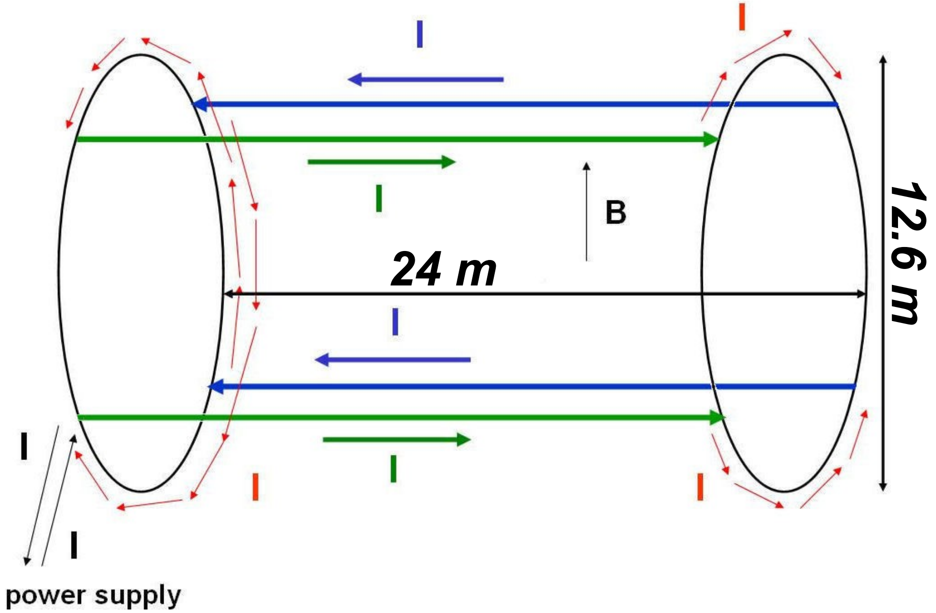
Low Field Coil System (LFCS)

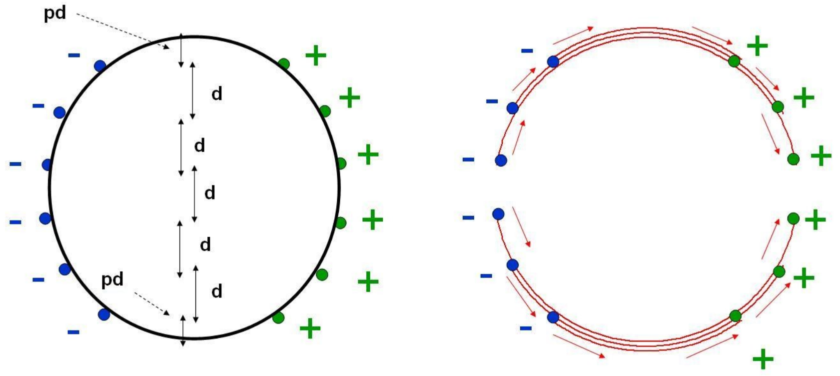
- **15 coils arranged coaxially with the solenoids**
- **Individually powered**
- **Provide possibility to fine tune the magnetic field**
- 1% homogeneity in analysing plane can be reached



Earth Magnetic Field Compensation System (EMCS)

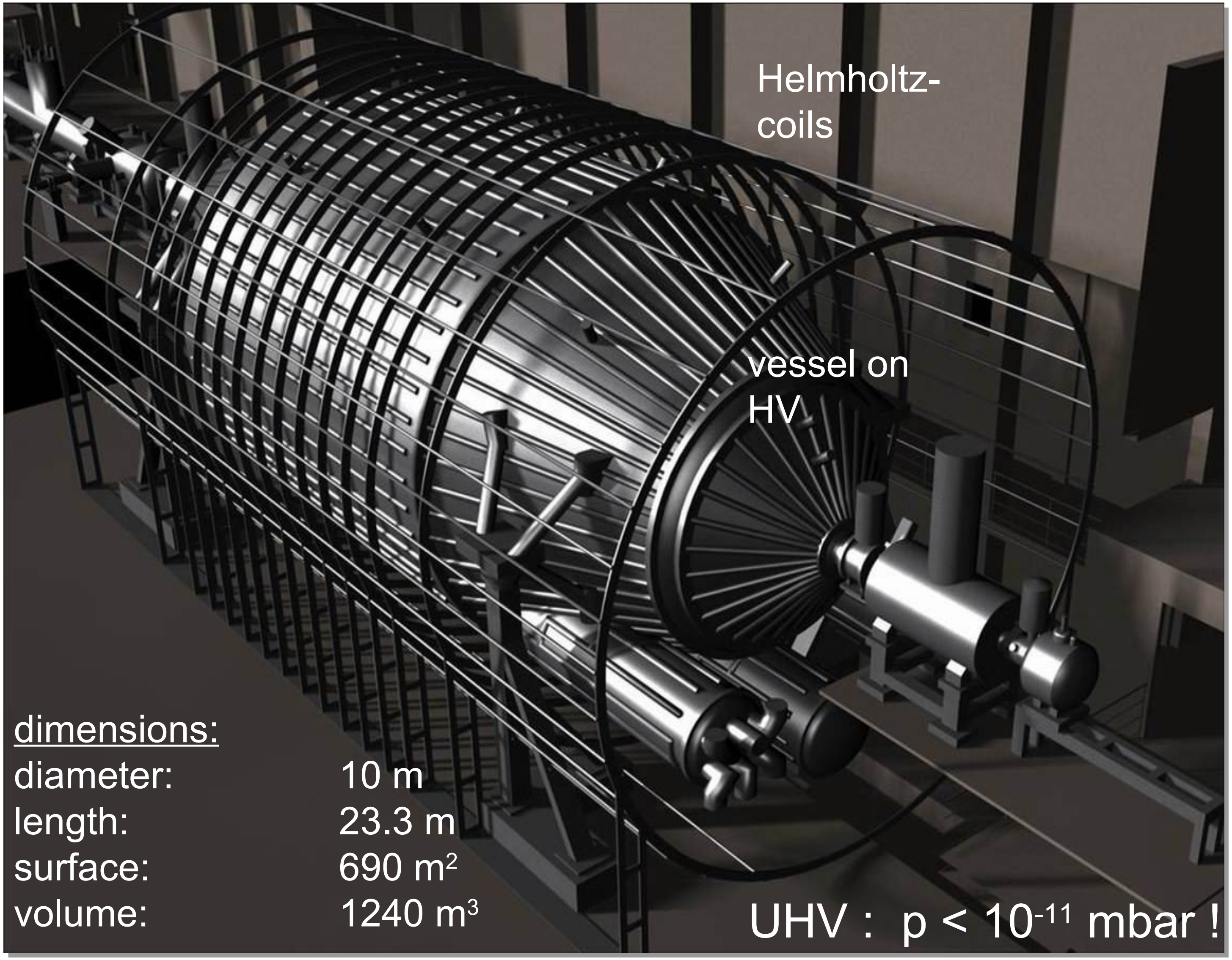
- Two perpendicular cosine coils
- Only non-axial components need to be compensated
- Vertical compensation:
  16 current loops at ca. 50 A
- Horizontal compensation:
  10 current loops at ca. 15 A
- Cylindrical geometry:
  inhomogeneity < 2% in analysing plane (0.5 µT at 0.41 mT)





main spectrometer: world´s largest UHV recipient

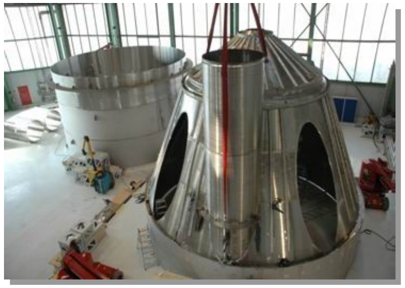
MAN DWE GmbH



<u>dimensions:</u>

diameter:	10 m
length:	23.3 m
surface:	690 m^2
volume:	1240 m^3

UHV : $p < 10^{-11}$ mbar !



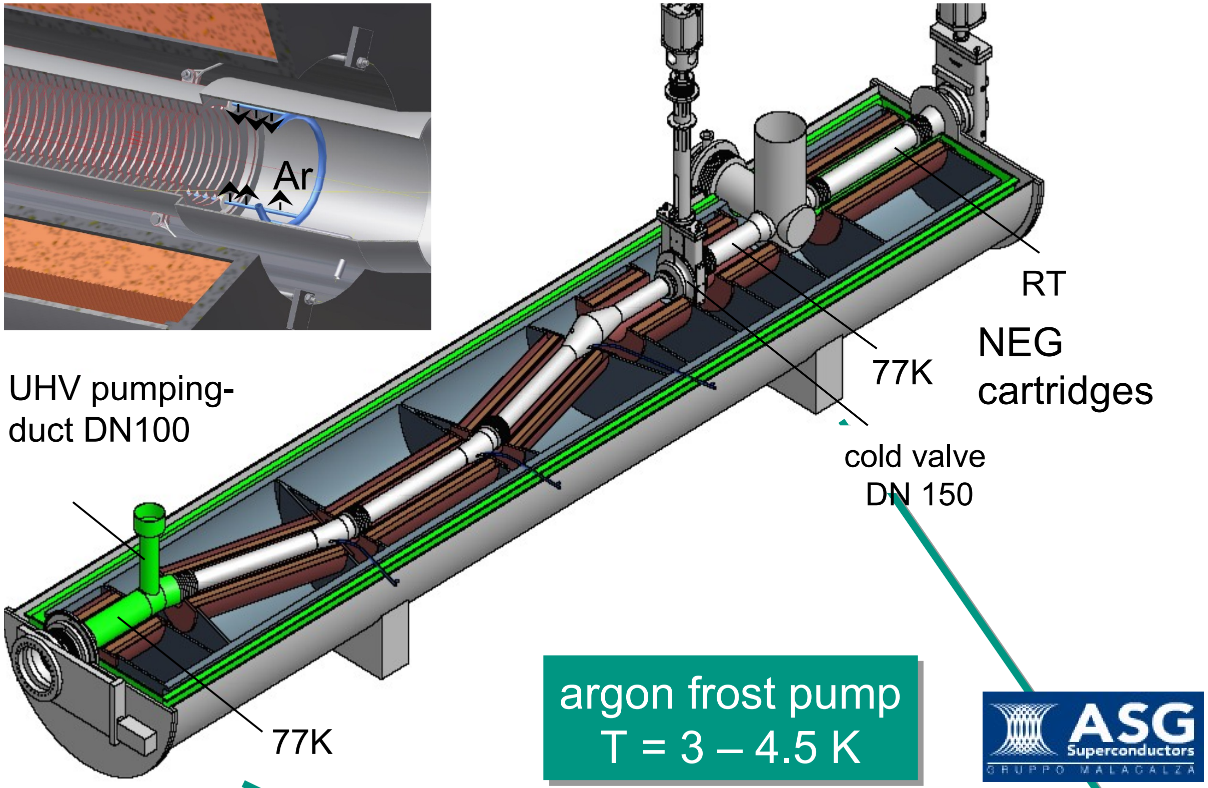
cryogenic pumping section CPS

objective: reduction of T_2-flux by factor 10^7 : 10^{-7} mbar ℓ/s → 10^{-14} mbar ℓ/s

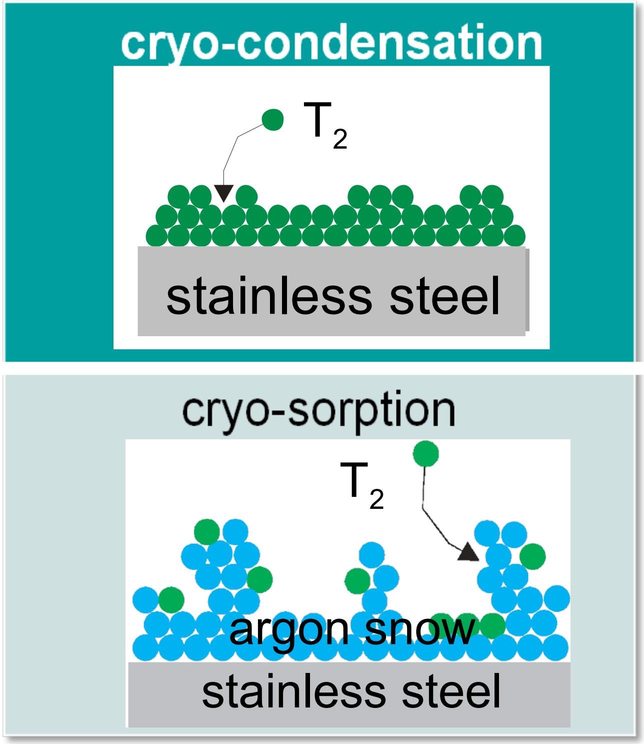
↳ T_2-partial pressure in spectrometer: $p < 10^{-20}$ mbar

method: cryo-sorption on condensing Ar-frost

T_2-rate: <1 Ci T_2 in 60 days = 1 run (regeneration with warm He-gas)



argon frost pump
T = 3 – 4.5 K



WGTS: sensitivity & source parameters

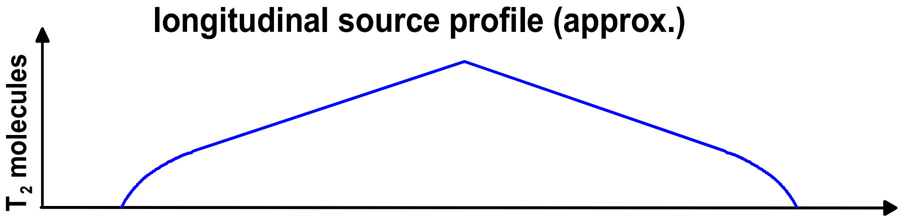
Source strength $N(T_2) = A_S * \rho d * \varepsilon_T$

A_S = source area
ρd = column density
ε_T = tritium purity

Optimized source design parameter:

- $\rho d = 5*10^{17}$ cm^{-2} (= 86% of maximum count rate of non-scattered electrons)
- A_S = 53 cm^2, B = 3.6 T
- ε_T = 95%

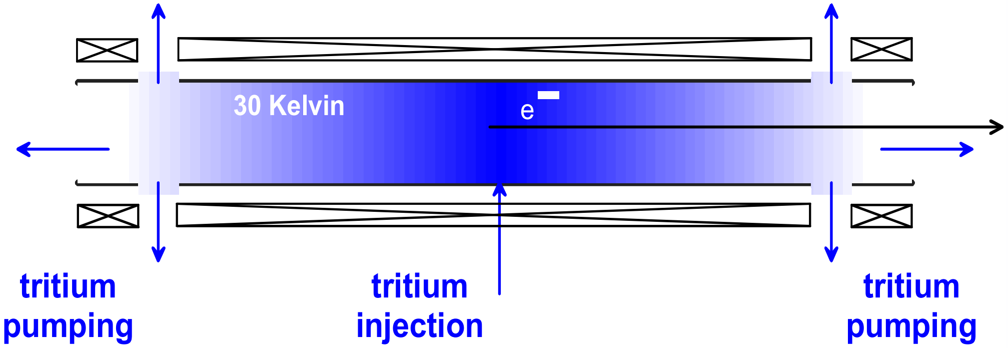
➔ required tritium gas injection:
1.8 mbar l/s = 160 l/day


longitudinal source profile (approx.)

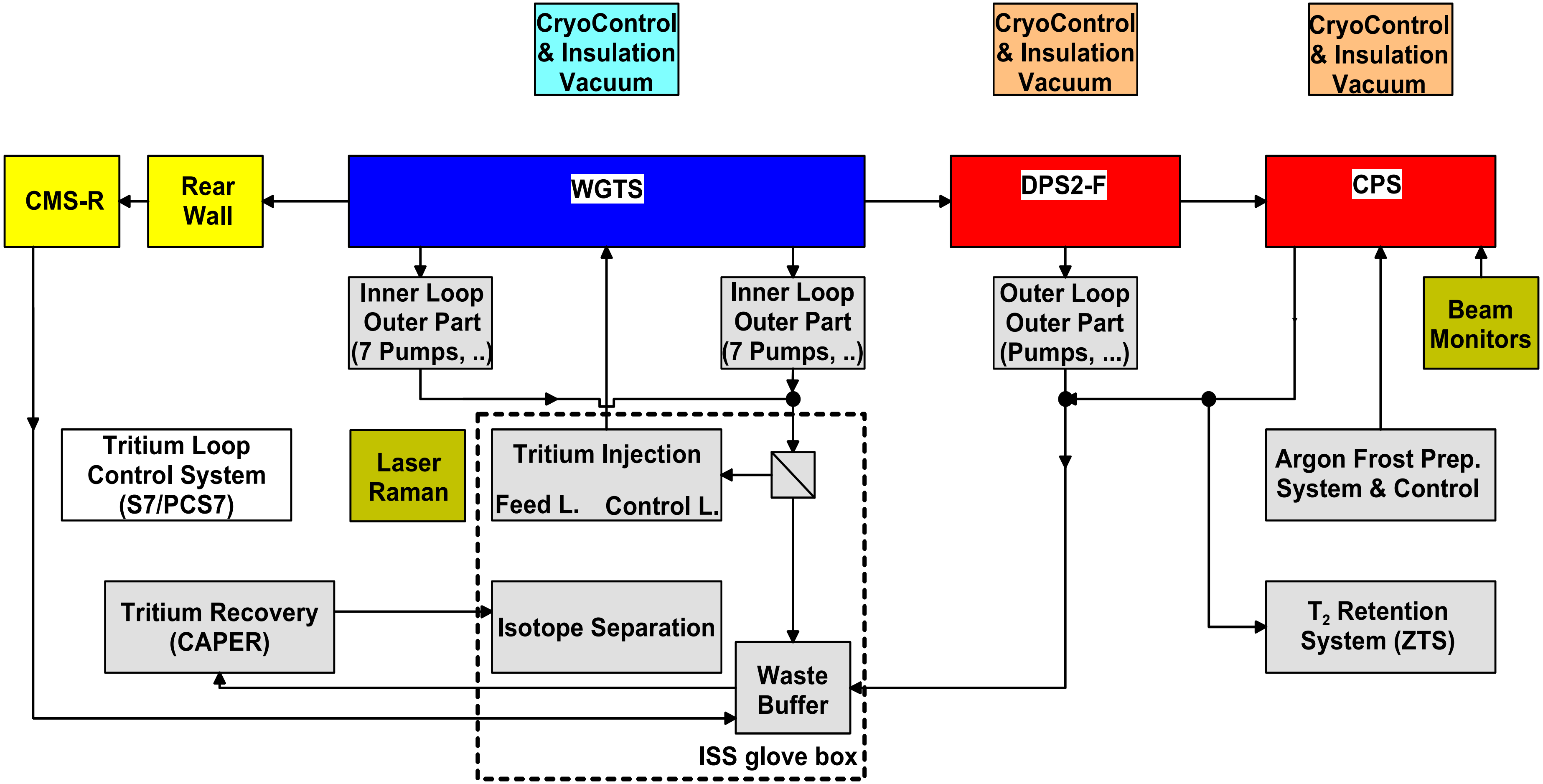
Source stability requirements:

ρd needs to be stable ➔

- $\Delta\varepsilon_T/\varepsilon_T < 0.002$
- $\Delta T/T < 0.002$
- $\Delta p_{inj}/p_{inj}$, $\Delta p_{ex}/p_{ex} < 0.002$



The most complex tritium source ever planned



CryoControl & Insulation Vacuum

CryoControl & Insulation Vacuum

CryoControl & Insulation Vacuum

CMS-R

Rear Wall

WGTS

DPS2-F

CPS

Inner Loop Outer Part (7 Pumps, ..)

Inner Loop Outer Part (7 Pumps, ..)

Outer Loop Outer Part (Pumps, ...)

Beam Monitors

Tritium Loop Control System (S7/PCS7)

Laser Raman

Tritium Injection

Feed L. Control L.

Argon Frost Prep. System & Control

Tritium Recovery (CAPER)

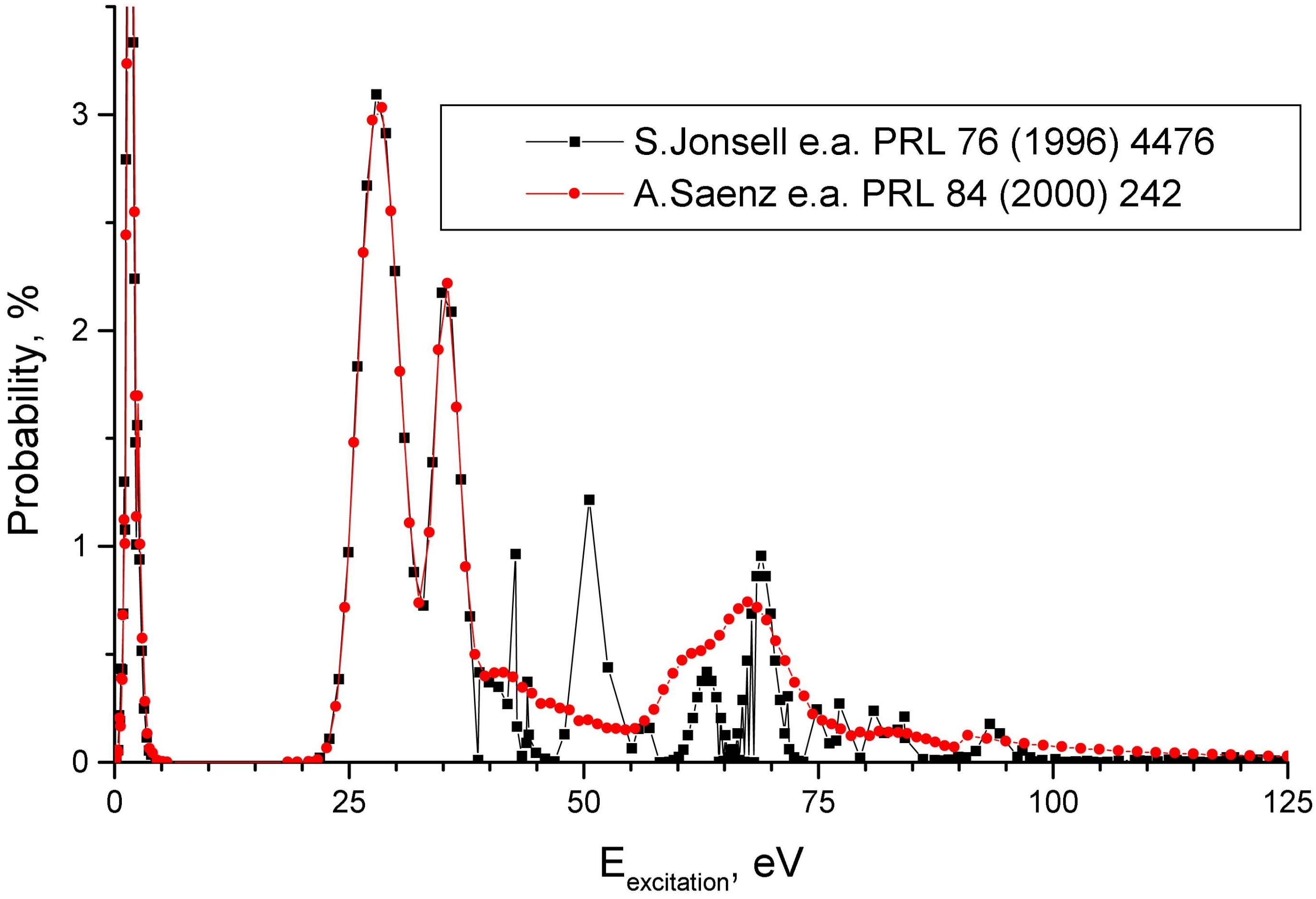
Isotope Separation

Waste Buffer

T_2 Retention System (ZTS)

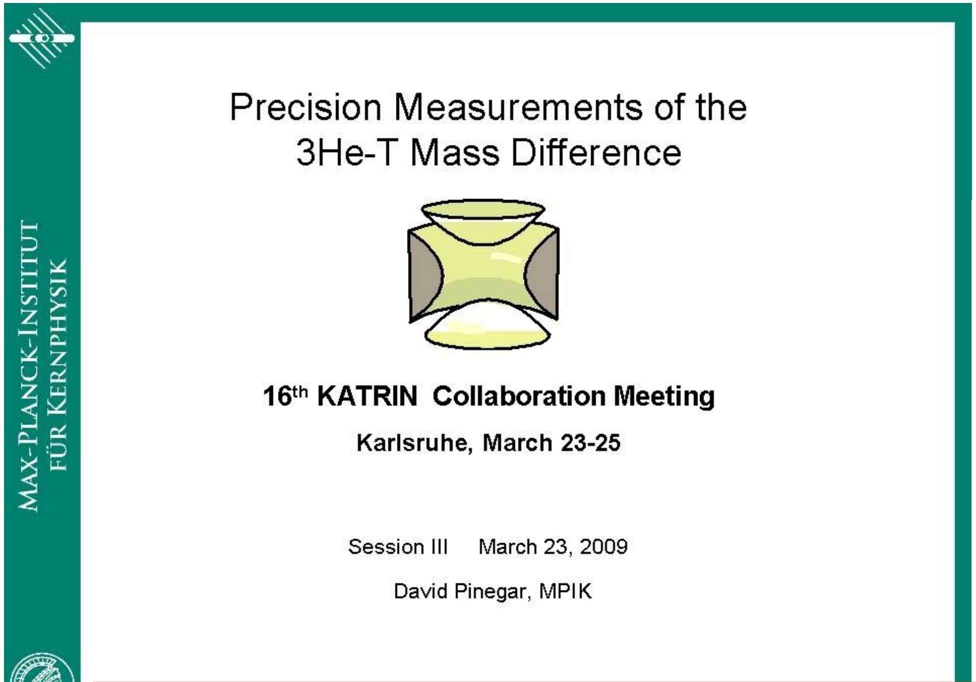
ISS glove box

Molecular tritium excitation spectrum



Absolute endpoint value

MPI-K / UW He-T Mass Collaboration



Precision Measurements of the
3He-T Mass Difference

16th KATRIN Collaboration Meeting

Karlsruhe, March 23-25

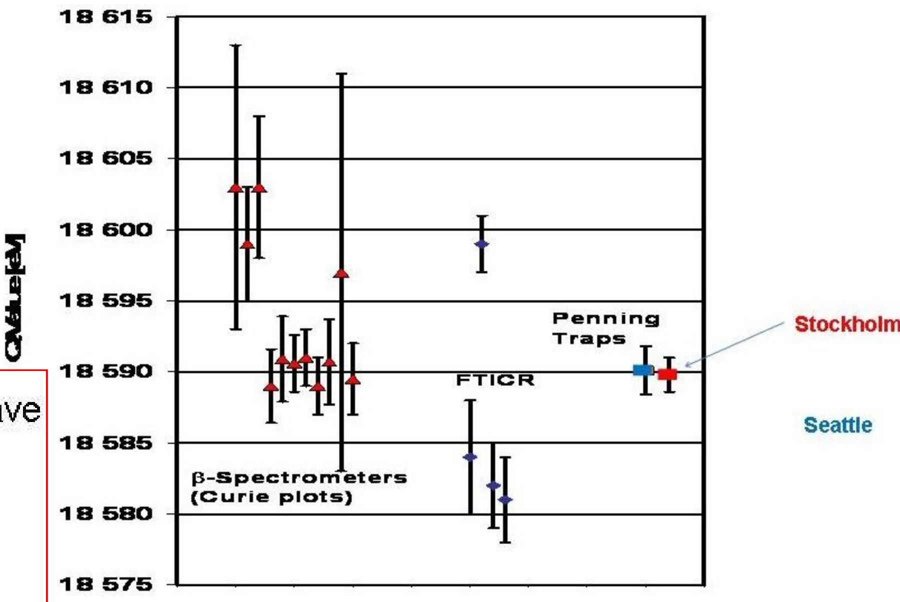
Session III March 23, 2009

David Pinegar, MPIK

Several completed measurements of these species have
~300 ppt uncertainties (3×10^{-10}),
but higher precision is within reach.

Our goal is a new measurement of uncertainty
(3 GeV)(10 ppt) = 30 meV

UW-PTMS and SMILETRAP
$M(^3H)$ and $M(^3He)$ Measurements



Sz. Nagy et al. Europhys. Lett., 74, 404 (2006)

Thank you for your attention on behalf of the KATRIN collaboration