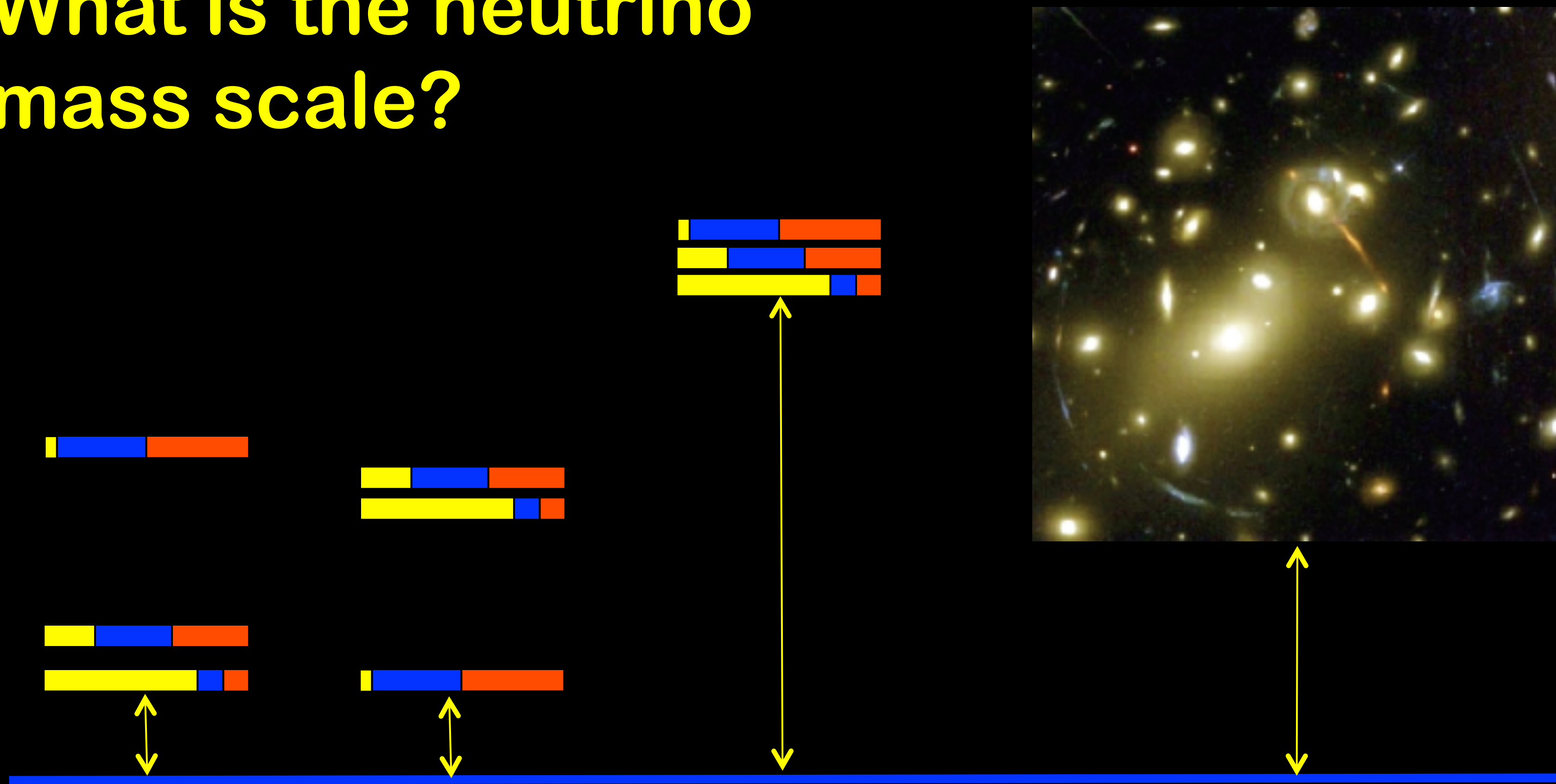
SUMMARY – SESSION NU-3
ABSOLUTE NEUTRINO MASS

SNOWMASS 2013,

MINNEAPOLIS AUG 2, 2013

Hamish Robertson, University of Washington

What is the neutrino mass scale?



Particle Physics

Cosmology

INPUTS

1. Present laboratory limit 1.8 eV (90% CL) from Mainz and Troitsk experiments on tritium
2. KATRIN experiment under construction.
3. Project 8 in proof-of-concept phase.
4. MARE Re-187 not being pursued at present.
5. ECHo Ho-163 in proof-of-concept phase.
6. PTOLEMY in proof-of-concept phase.
7. Cosmological inputs driven by Planck, SPT, ACT, …

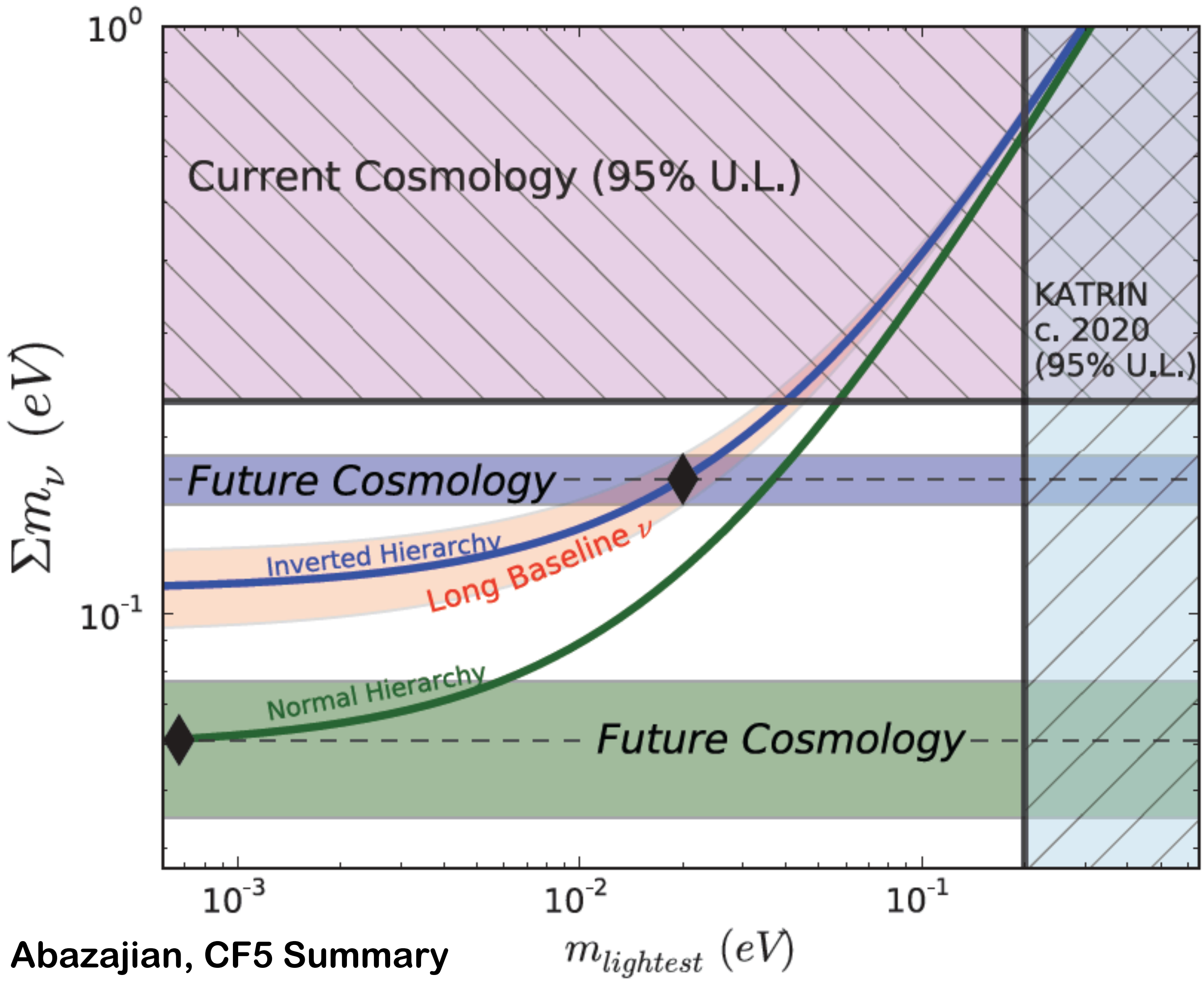
WHITE PAPERS

PTOLEMY: **Development of a relic neutrino detection experiment… 1307.4738**

KATRIN: **Neutrino mass from the beta decay of tritium. 1307.5486**

PROJECT 8: **coming soon…**

Cosmological & Laboratory Complementarity



K. Abazajian, CF5 Summary

FIRST PLANCK ANALYSIS (MARCH 2013)

Planck XVI

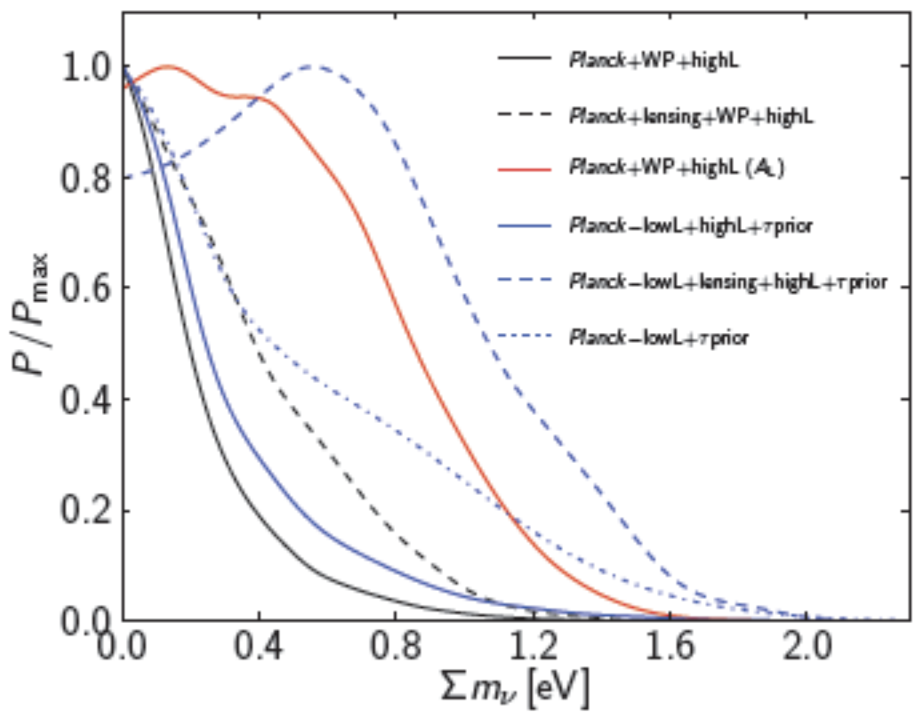


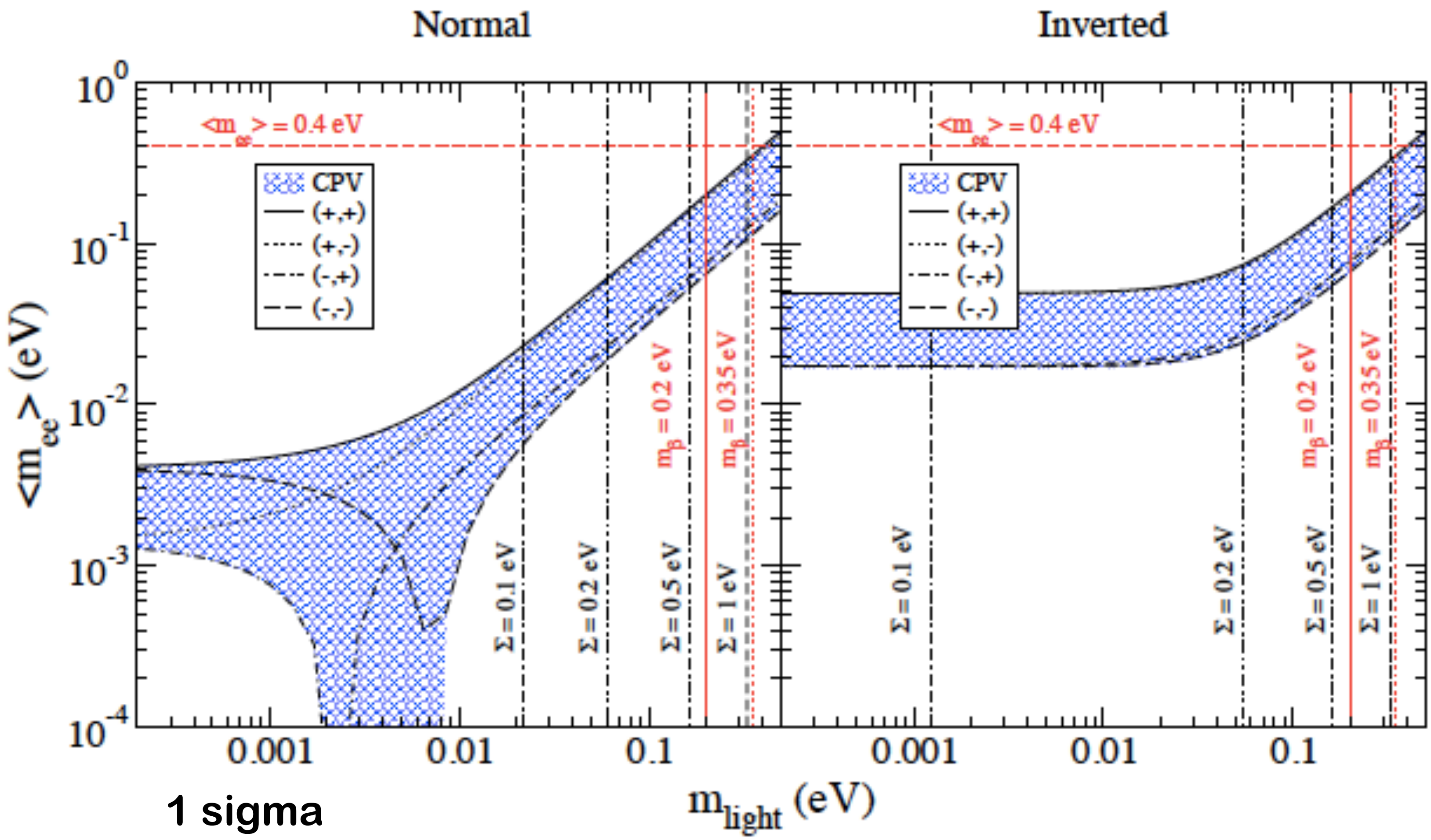
Fig. 26. Marginalized posterior distributions for $\sum m_\nu$ in flat models from CMB data. We show results for *Planck*+WP+highL without (solid black) and with (red) marginalization over A_L, showing how the posterior is significantly broadened by removing the lensing information from the temperature anisotropy power spectrum. The effect of replacing the low-ℓ temperature and (*WMAP*) polarization data with a τ prior is shown in solid blue (*Planck*−lowL+highL+τprior) and of further removing the high-ℓ data in dot-dashed blue (*Planck*−lowL+τprior). We also show the result of including the lensing likelihood with *Planck*+WP+highL (dashed black) and *Planck*−lowL+highL+τprior (dashed blue).

WP = WMAP Polarization data
A_L = weak lensing parameter
τ = optical depth at recombination

"…Planck lensing likelihood favours larger Σ m than the temperature power spectrum."

NEUTRINOLESS DOUBLE BETA DECAY

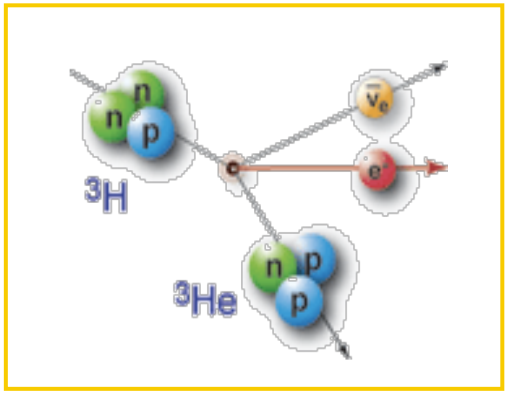
Depends on m_ν but not a `direct' measurement



1 sigma

W. Rodejohann, 1206.2560

NEUTRINO MASS FROM BETA SPECTRA



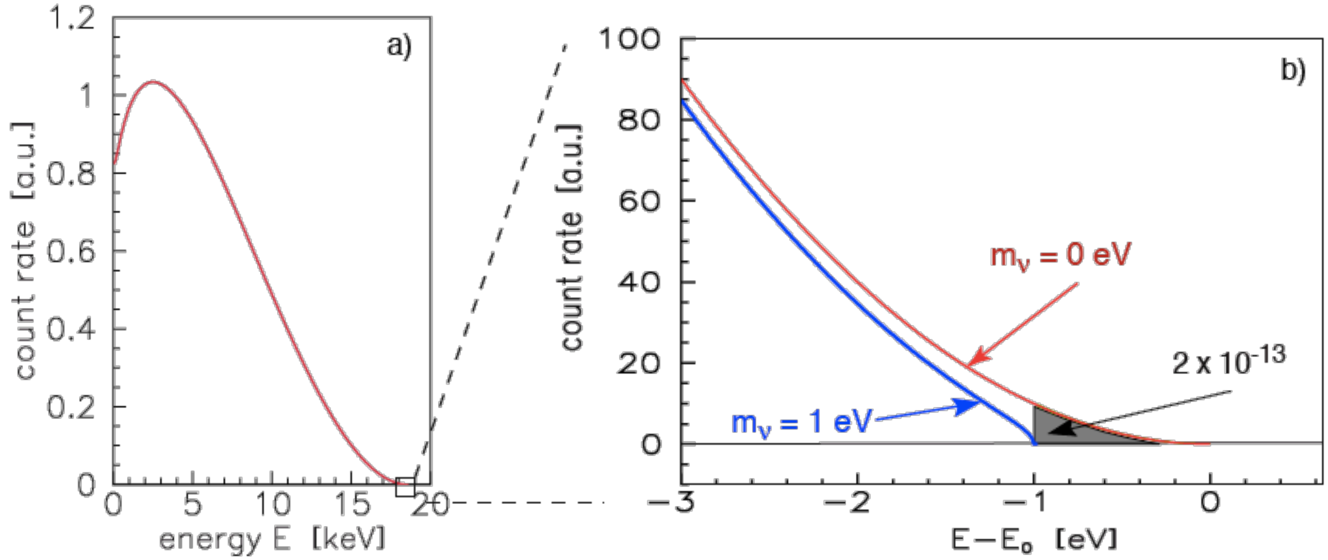
With flavor mixing:

$$\frac{dN}{dT} = \frac{G_F \cos\theta_C}{2\pi^3} |M_{\rm nuc}|^2 F(Z,T)(T+m)(T^2+2mT)^{1/2}(T_0-T)\sum_i |U_{ei}|^2 \left[(T_0-T)^2 - m_i^2\right]^{1/2}$$

$$m_i^2 = \Delta m_{i0}^2 + m_0^2$$

mixing — neutrino masses

from oscillations — mass scale



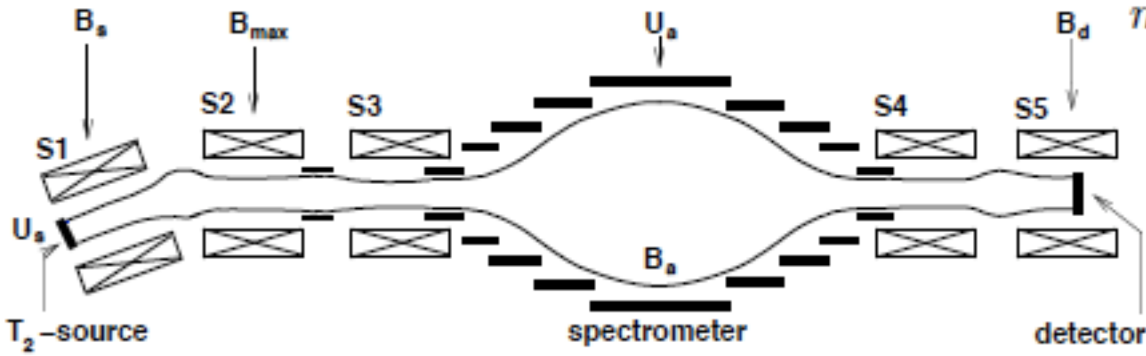
CURRENT STATUS OF DIRECT MASS MEASUREMENT

Mainz: solid T_2, MAC-E filter

C. Kraus et al., Eur. Phys. J. C40, 447 (2005)

$$m^2(\nu_e) = (-0.6 \pm 2.2_{\text{stat}} \pm 2.1_{\text{syst}})$$

$$m(\nu_e) < 2.3\ \text{eV}/\text{c}^2 \quad (95\%\ \text{C.L.})$$

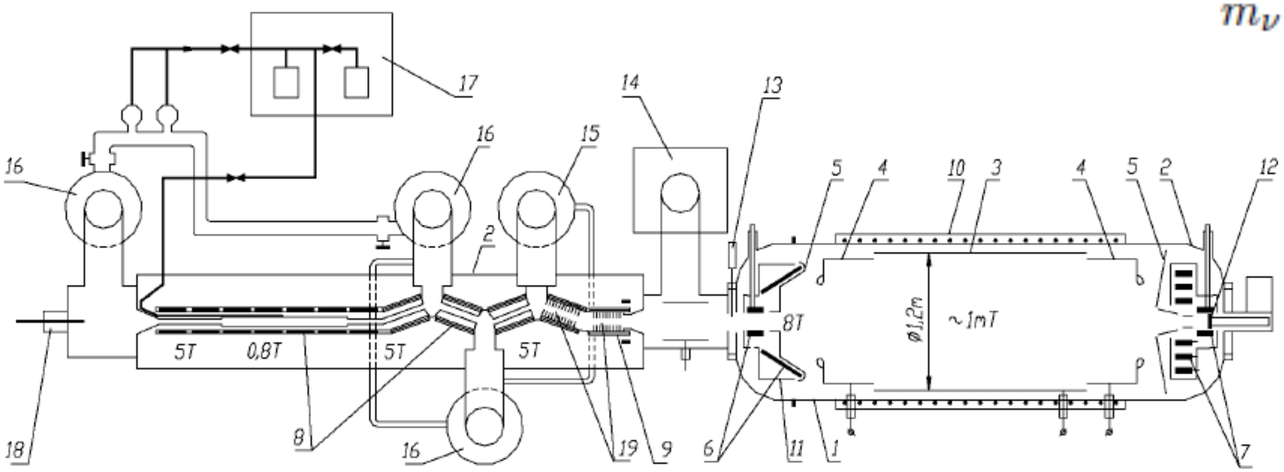


Troitsk: gaseousT_2, MAC-E filter

V. Aseev et al., PRD in press (2011)

$$m_\nu^2 = -0.67 \pm 1.89_{stat} \pm 1.68_{syst}$$

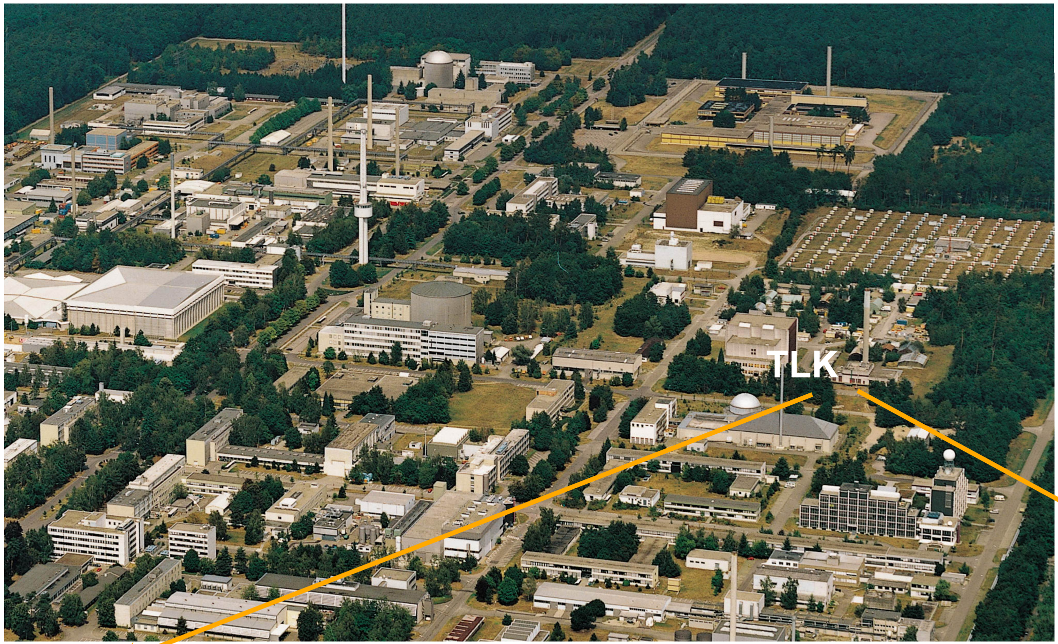
$$m_\nu < 2.05\ eV,\ 95\%\ C.L.$$



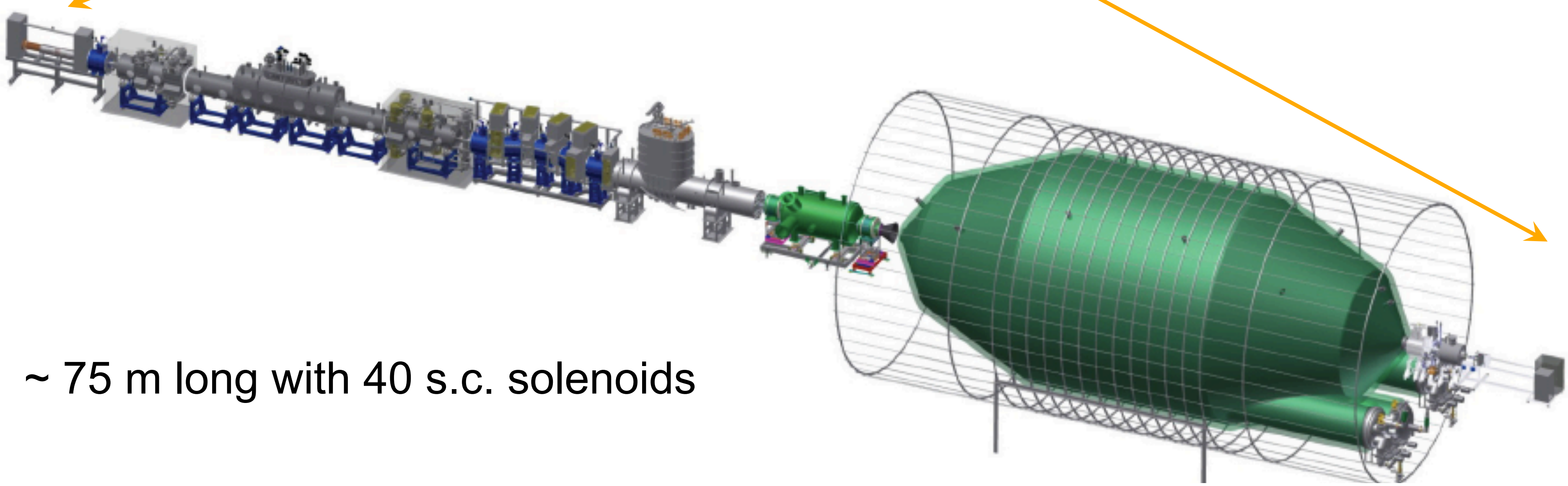
Together:…
$m_\nu < 1.8$ eV
(95% CL)

KATRIN

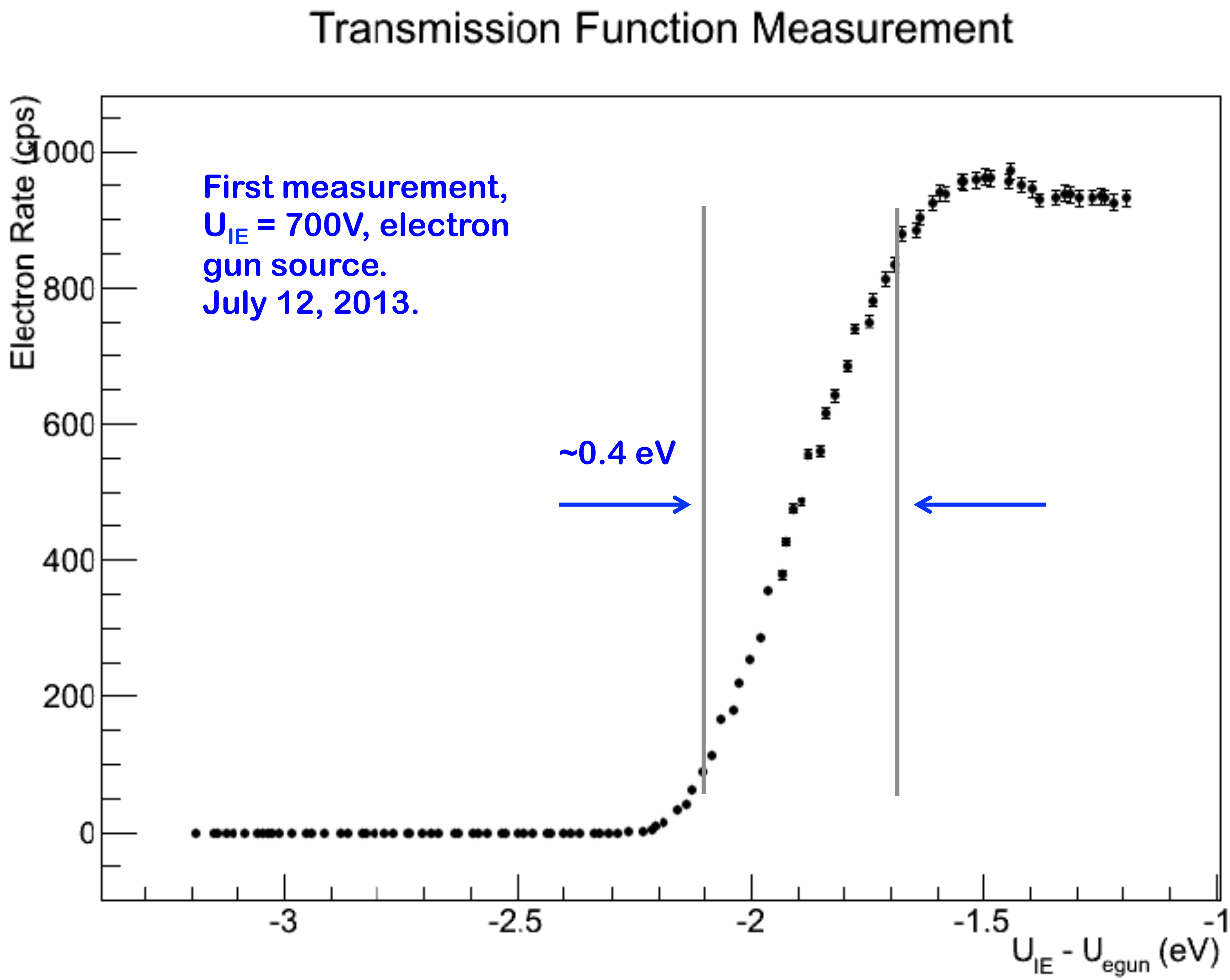
At Karlsruhe Institute of Technology unique facility for closed T_2 cycle: Tritium Laboratory Karlsruhe



A direct, model-independent, kinematic method, based on β decay of tritium.

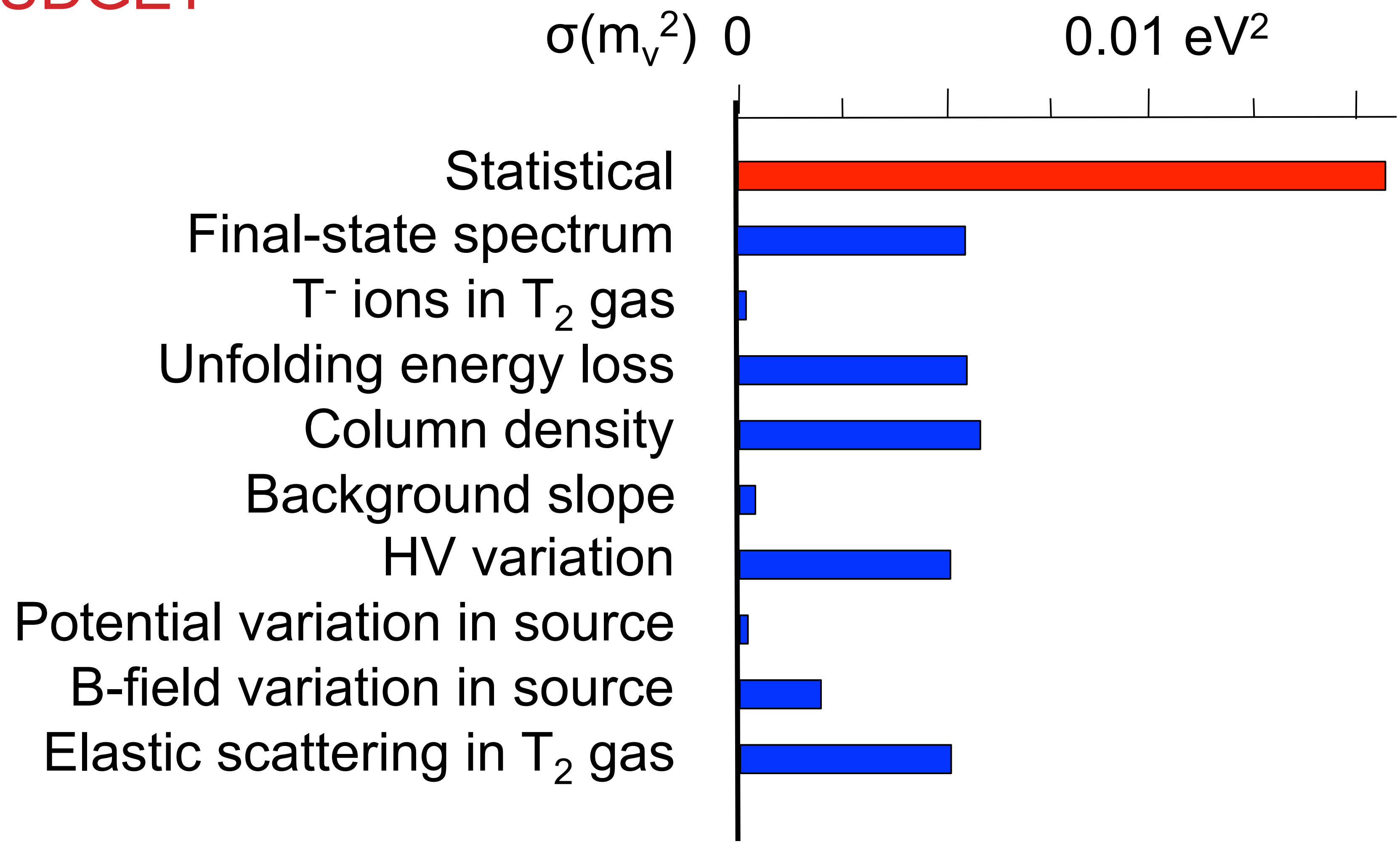


~ 75 m long with 40 s.c. solenoids



Transmission Function Measurement
Electron Rate (cps)
1000
800
600
400
200
0
-3
-2.5
-2
-1.5
-1
U_{IE} - U_{egun} (eV)
First measurement,
U_{IE} = 700V, electron
gun source.
July 12, 2013.
~0.4 eV

KATRIN' S UNCERTAINTY BUDGET

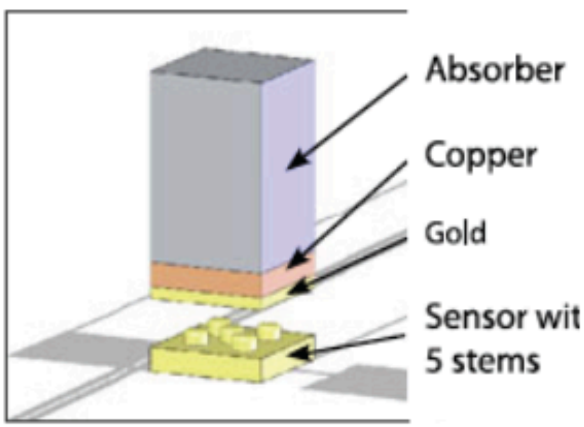


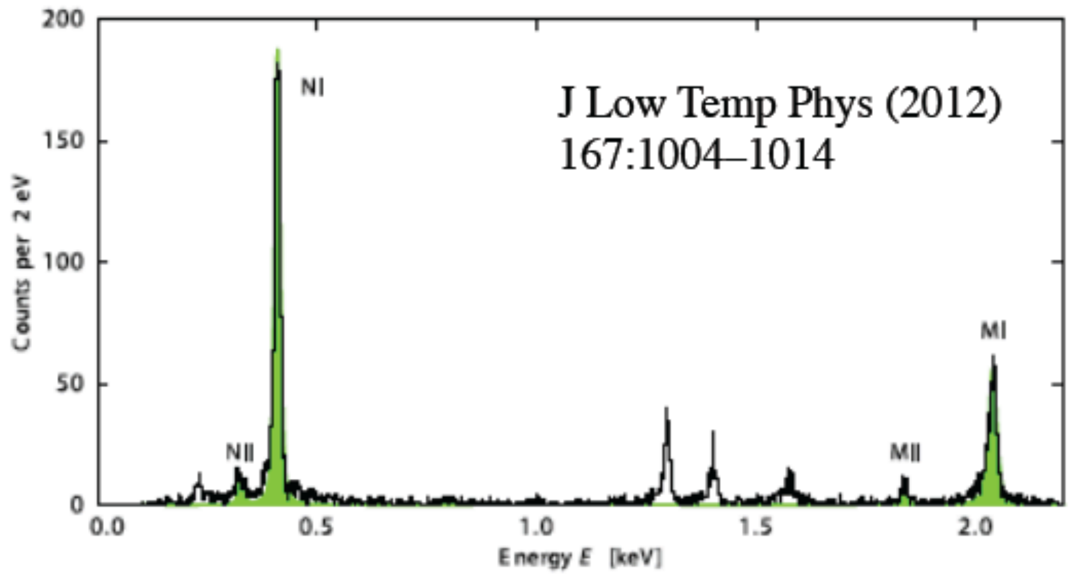
$\sigma(m_\nu^2)_{total} = 0.025$ eV^2

$m_\nu < 0.2$ eV (90 % CL)

ELECTRON CAPTURE HOLMIUM EXPT (ECHO)

- Using low-temperature Metallic Magnetic Calorimeters to study both ^{187}Re and ^{163}Ho.
  - should be able to achieve ultimate resolution ~ 2 eV and rise-times of 90 ns





  - report Q_{EC} = 2.80 ± 0.16 keV
  - shapes of N and M lines not entirely understood

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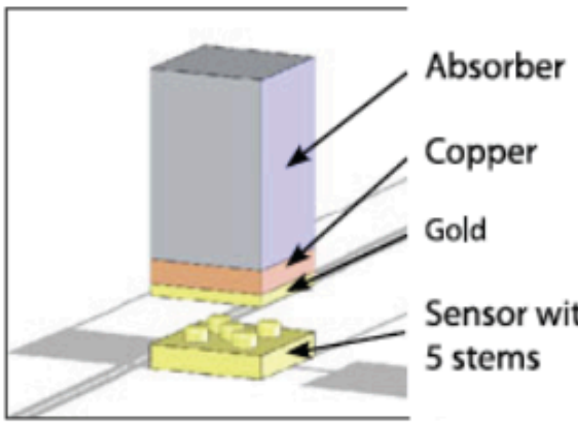

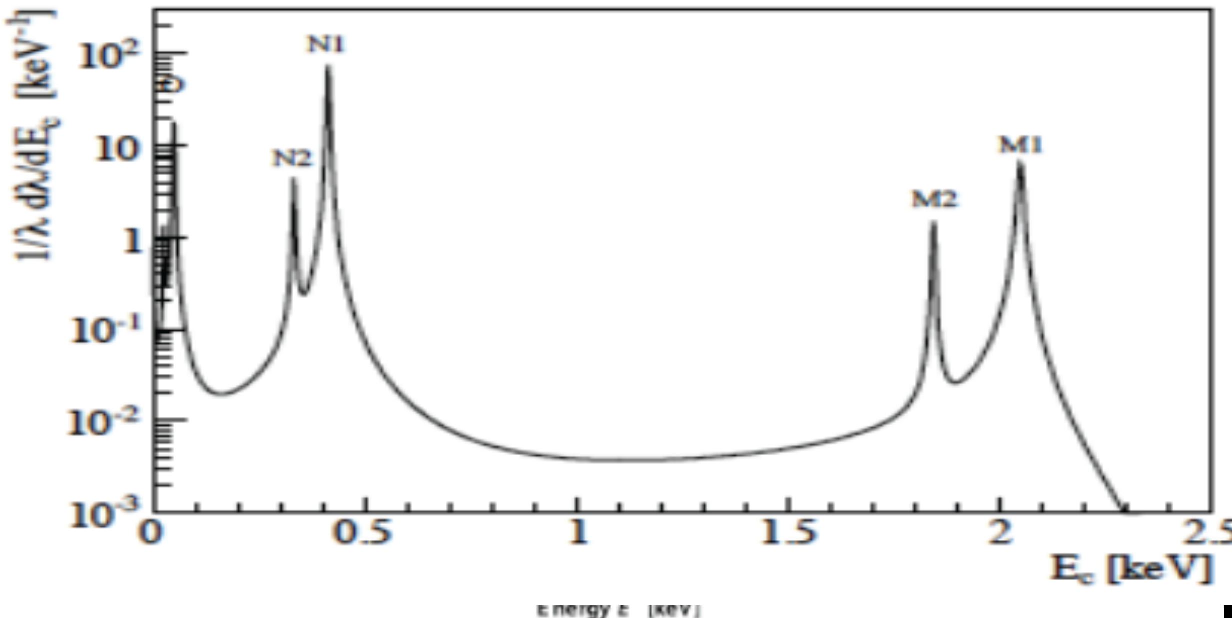

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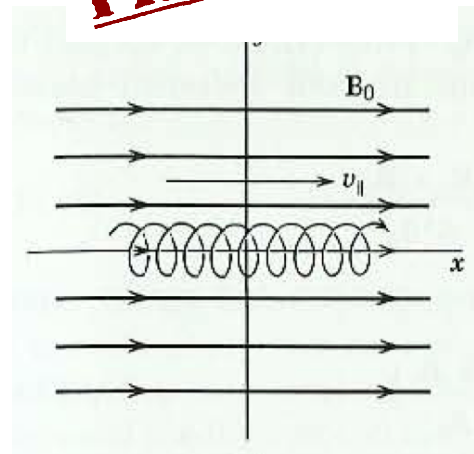
CYCLOTRON RADIATION FROM TRITIUM BETA DECAY

(B. Monreal and J. Formaggio, PRD 80:051301, 2009)

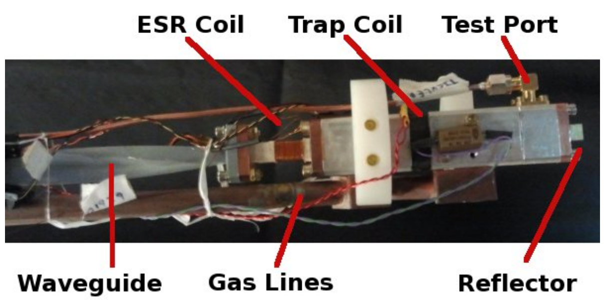
PROJECT 8



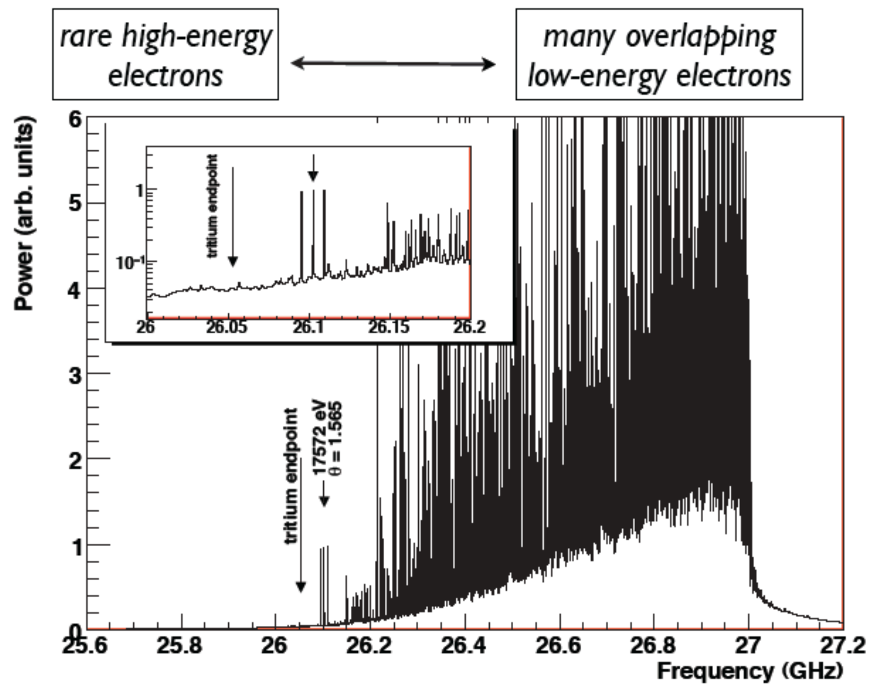
$$\omega = \frac{qB}{\gamma m} \equiv \frac{\omega_c}{\gamma}$$

$$\omega_c = 1.758820150(44) \times 10^{11} \text{ rad/s/T}$$

Parameter	Value	Unit
Electron energy	18.6	keV
β	0.2627	
γ	1.0364	
Field	1	T
ω_c	27.009	GHz

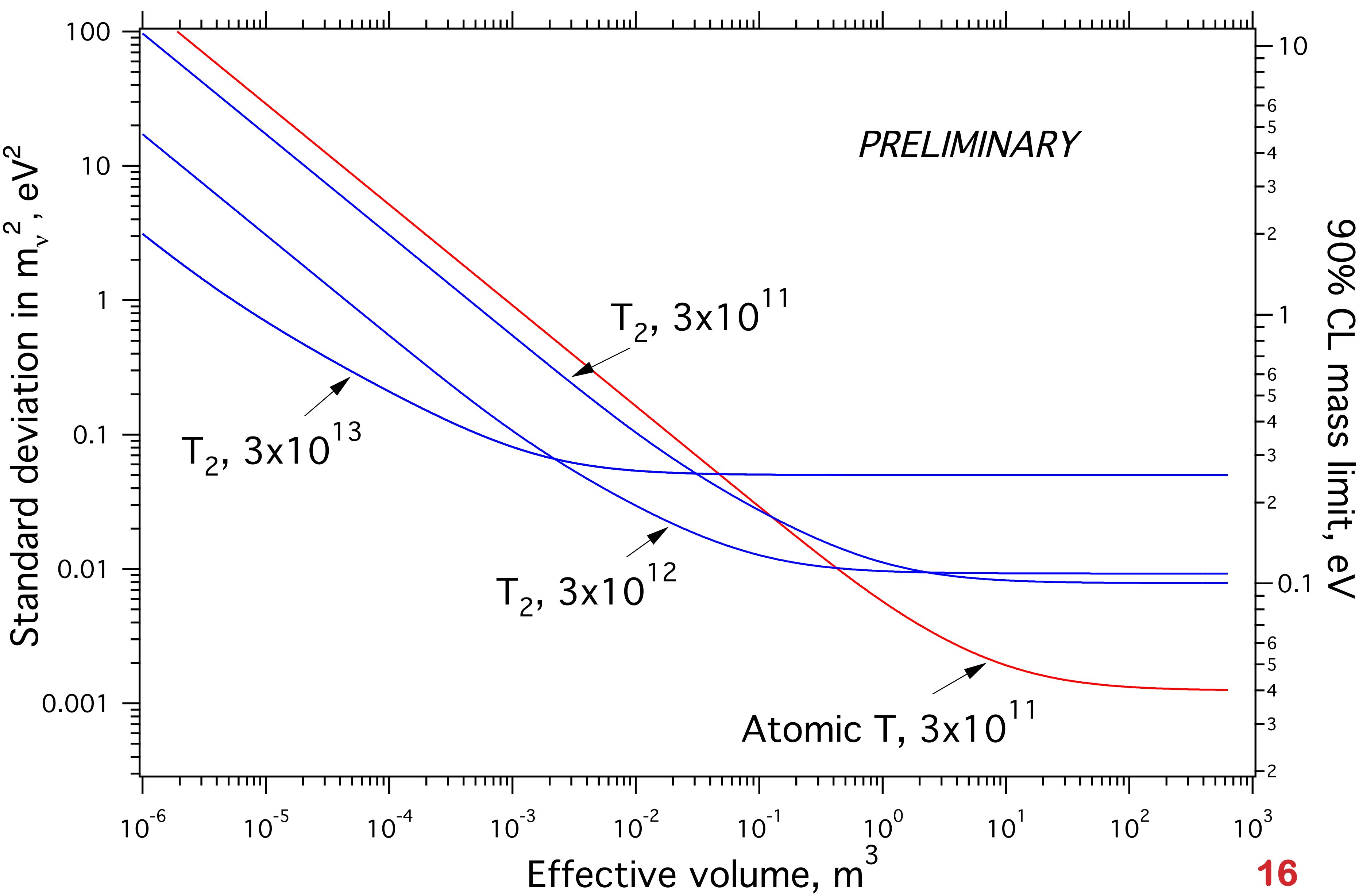


25.5-GHz waveguide cell



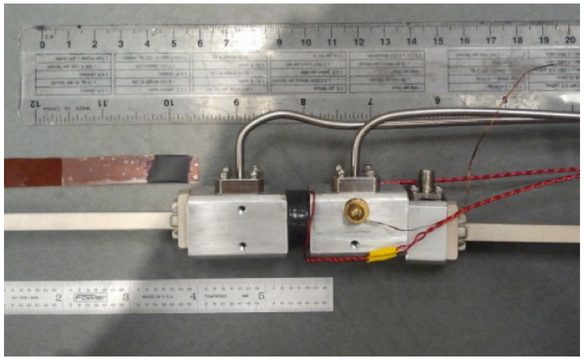
100,000 tritium decays in 30μs

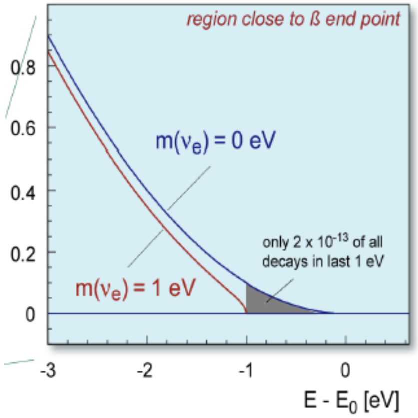
PROJECT 8 SENSITIVITY

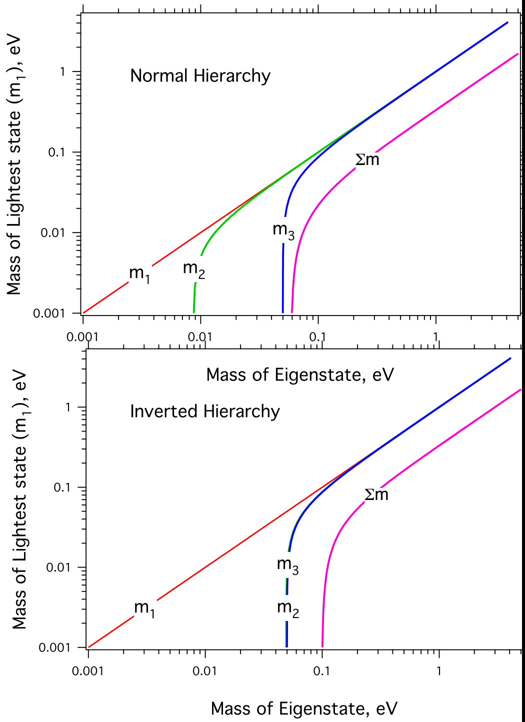


PROJECT 8: A PHASED APPROACH

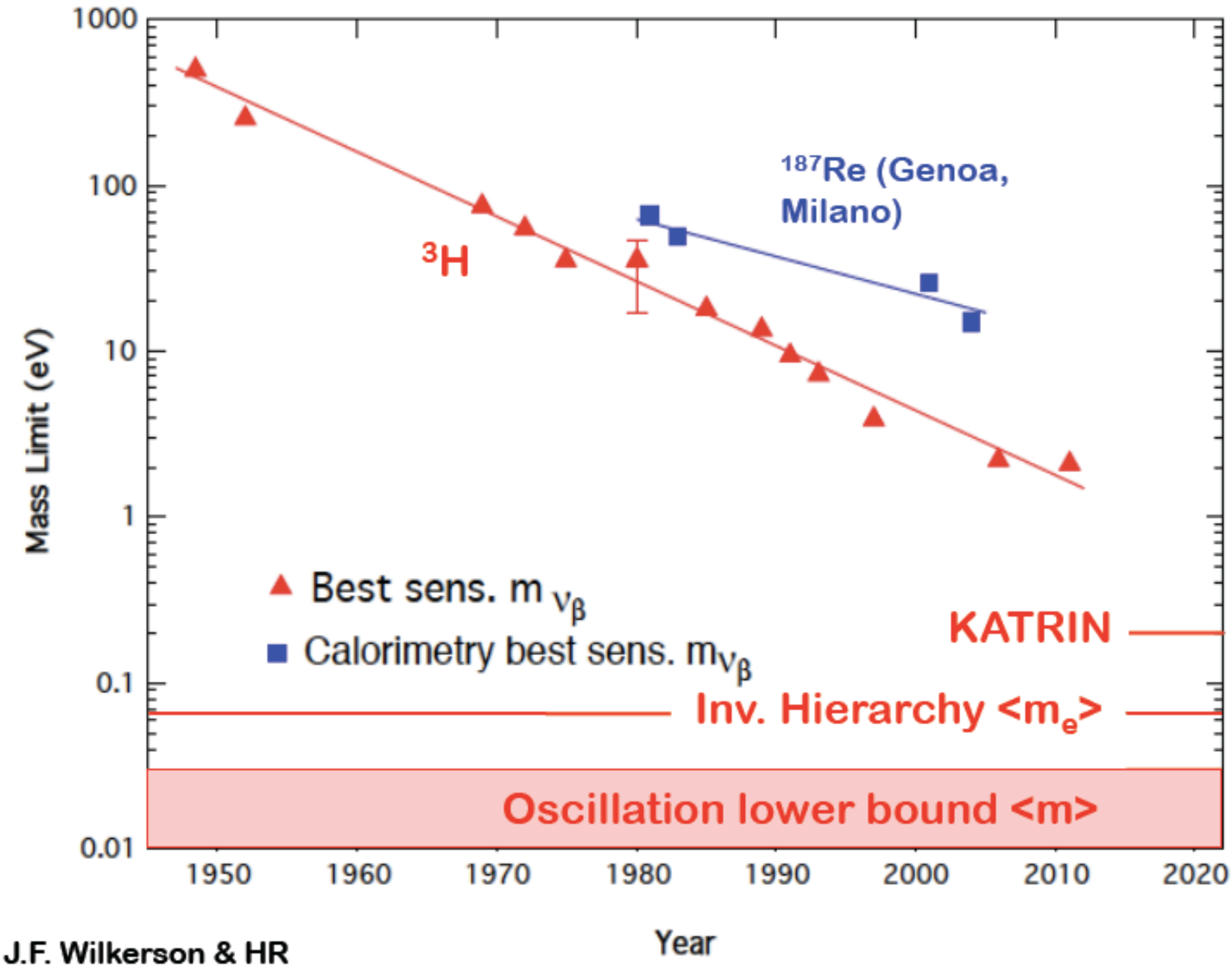
Phase: Timeline	I 2010-2014	II 2014-2016	III 2016-2017	IV 2018+
Science Goals	Proof of Principle; Kr Spectrum	T-He Mass Difference	$m_\nu < 2$ eV	$m_\nu < 0.2$ eV
Source	^{83m}Kr	Molecular ^{3}H	Molecular ^{3}H	Atomic ^{3}H
R & D Milestones	Single electron detection	Tritium spectrum; calibration and systematic error studies	High rate sensitivity	







NEUTRINO MASS LIMITS FROM BETA DECAY

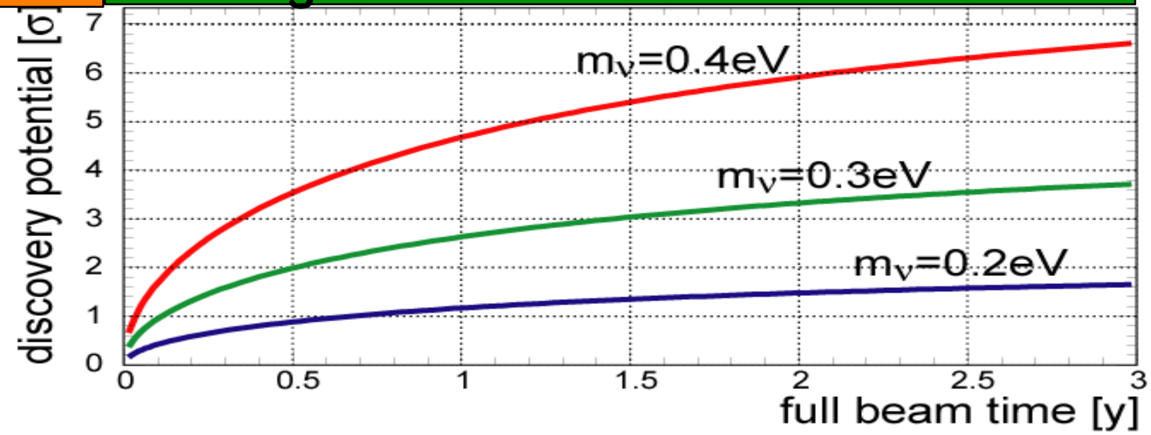


J.F. Wilkerson & HR

NEUTRINO MASS: SOME MILESTONES

KATRIN:

Construction | Running



Project 8:

Proof concept | Prototype | Phase I

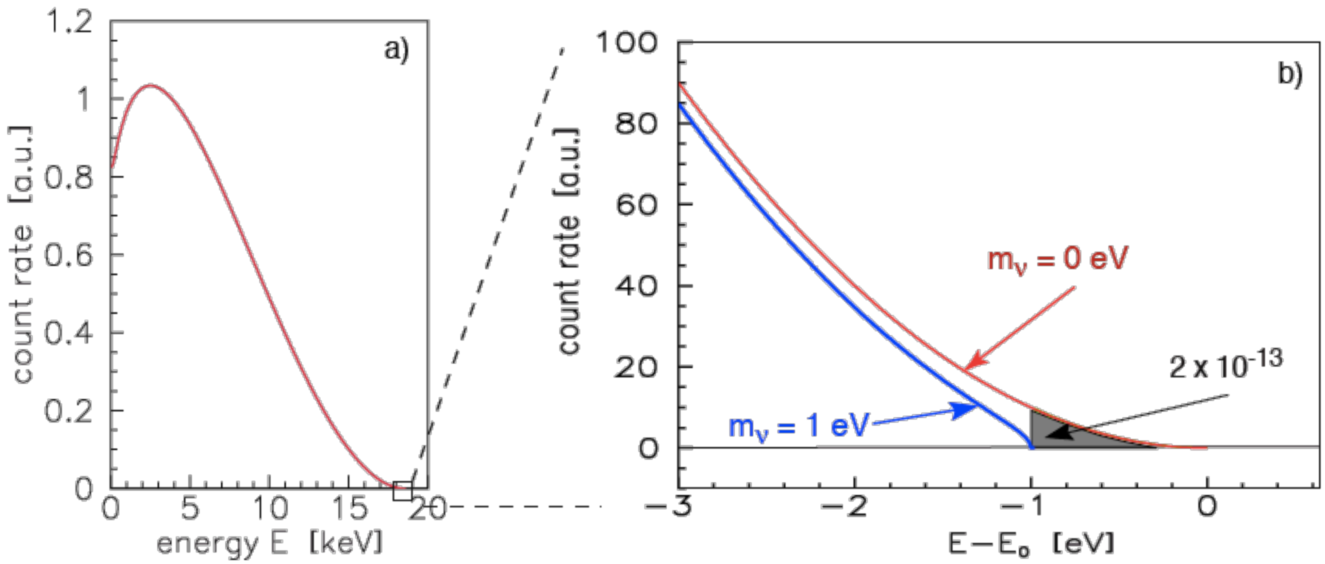
Planck:

Analysis 1 | Analysis 2

2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018

CAPTURE OF RELIC NEUTRINOS

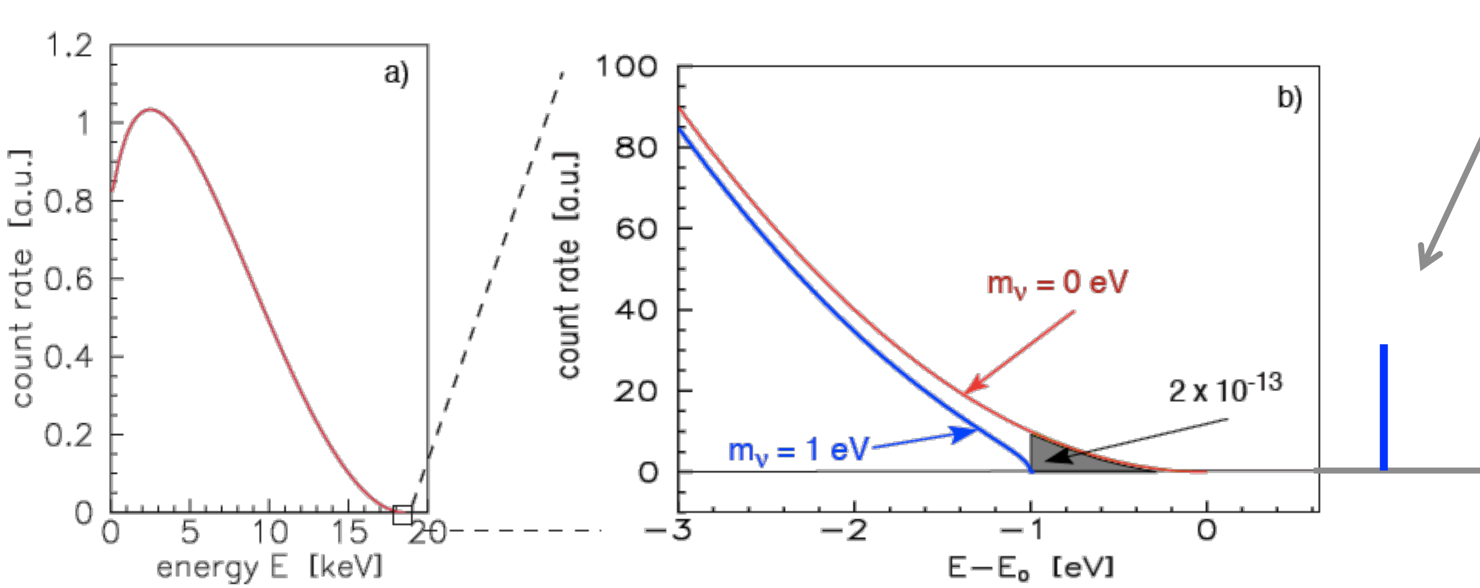
PTOLEMY project



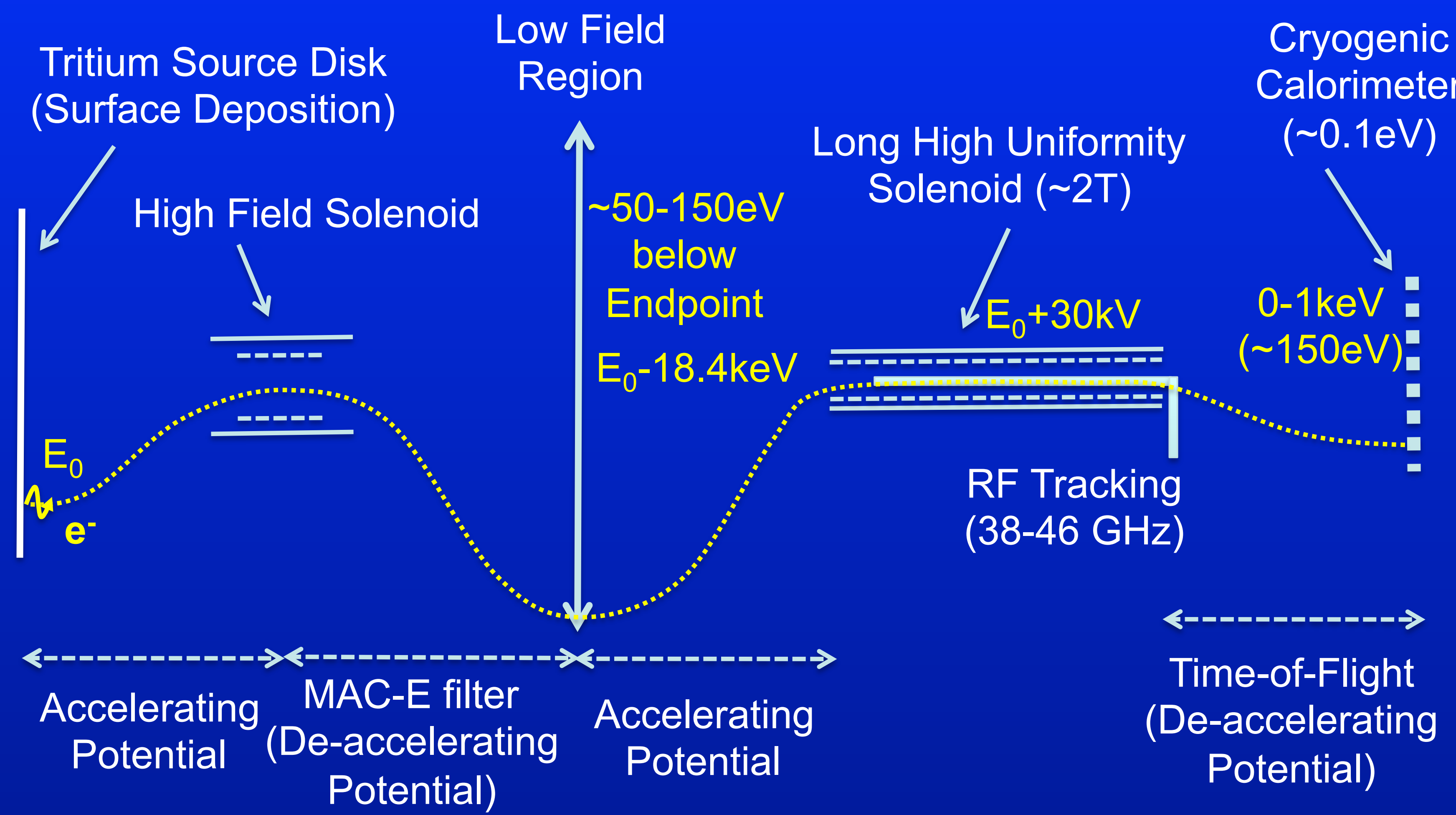
CAPTURE OF RELIC NEUTRINOS

PTOLEMY project

$$\nu_e + {}^3H \rightarrow {}^3He + e$$



PTOLEMY Experimental Layout



PTOLEMY SUMMARY

100 g of tritium (1 MCi) on 12-m diameter disk.

Relic capture rate ~ 10/year without local clustering.

Also presumably able to measure mass, active and sterile.

Transition-edge sensor array to provide basic 0.1-eV resolution.

Tagging with RF cyclotron radiation a la Project 8.

Necessary to understand quantum effects of binding of T_2 on surface.

NEUTRINO MASS PHYSICS IMPACT

Neutrino Mass Sensitivity	Scale	Possible Experiments	Impact
$m_\nu < 2$ eV (current sensitivity)	eV	Mainz, Troitsk, Project 8 (Phase II)	Neutrinos ruled out as primary dark matter
$m_\nu > 0.2$ eV	Degeneracy	KATRIN Project 8 (Phase III)	Cosmology, $0\nu\beta\beta$ reach
$m_\nu > 0.05$ eV	Inverted Hierarchy	Project 8 (Phase IV)	Resolve hierarchy if null result, Cosmology, $0\nu\beta\beta$ reach
$m_\nu > 0.01$ eV	Normal Hierarchy	Unknown	Oscillation limit, possible relic neutrino sensitivity

SUMMARY

Direct mass measurements are largely model independent:

- Majorana or Dirac
- No nuclear matrix elements
- No complex phases
- No cosmological degrees of freedom

One experiment in construction (KATRIN); 2015 start.

Three experiments in R&D (Project 8, ECHo, PTOLEMY)