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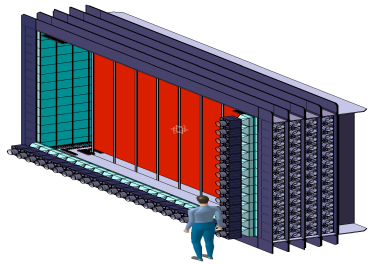


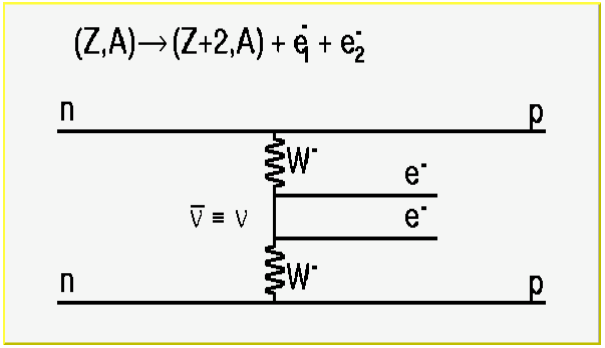
Understanding the mechanism of neutrinoless double beta decay at SuperNEMO

Chris Jackson
In collaboration with Frank Deppisch

NuFlavour Workshop

10/06/09

Neutrinoless Double Beta Decay



0νββ: BSM

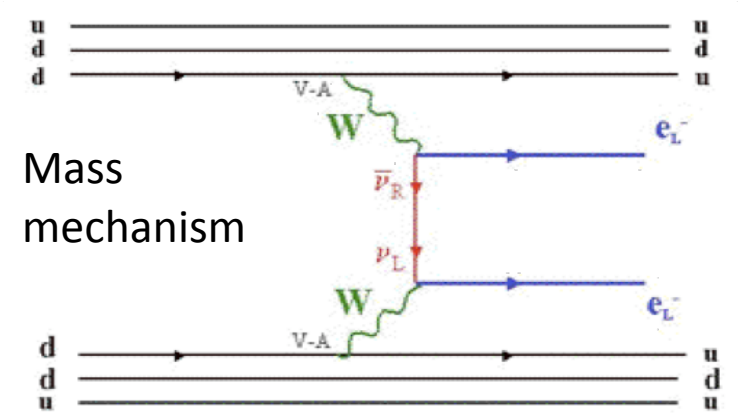
$T_{1/2} \geq 10^{25}$ yr

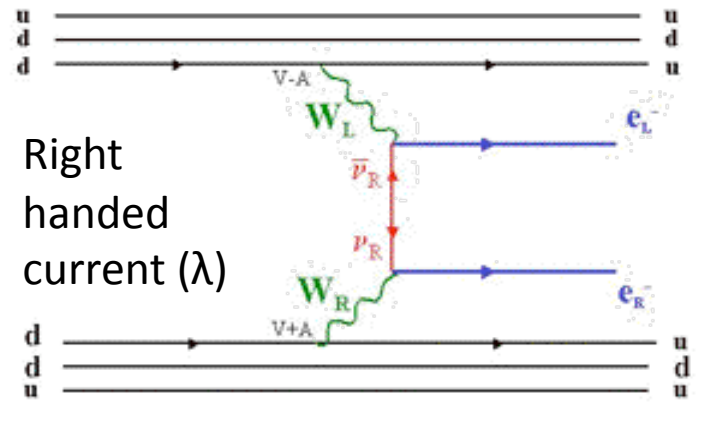
$$\left(T_{1/2}^{0\nu}\right)^{-1} = G^{0\nu}\left|M^{0\nu}\right|^2\left(\frac{\langle m_{\nu_e}\rangle}{m_e}\right)^2$$

- Mass mechanism need not be only or dominant contribution to decay rate.
- Other lepton number violating models include right handed currents, R-parity violating SUSY, extra dimensions…
- Need to identify mechanism:
  - Compare to electron capture rates (Hirsch, Muto, Oda, Klapdor-Kleingrothaus '94)
  - Compare to excited state decays (Faessler, Kaminski, Nowak, Raduta, Simkovic '94)
  - Compare half lives in different isotopes (Deppisch, Päs '06; Gehman, Elliot '07)
  - Use angular and energy distributions of electrons (Doi, Kotani, Nishiura, Takasugi '83; Ali, Borisov, Zhuridov '06)

Right Handed Current

- Arise in left-right symmetric models (e.g. SO(10)).

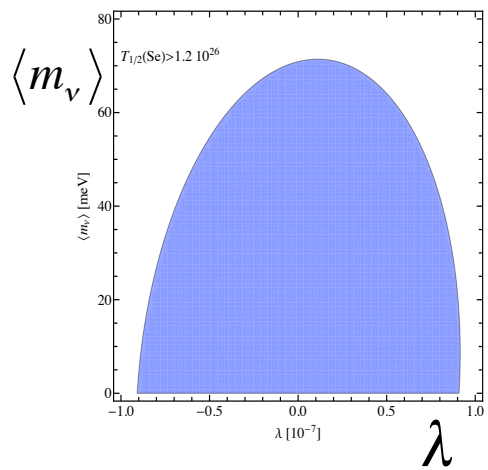




- General 0nbb decay rate:

$$\left(T_{1/2}^{0\nu}\right)^{-1} = C_{mm}\left(\frac{\langle m_{\nu_e}\rangle}{m_e}\right)^2 + C_{\lambda\lambda}\langle\lambda\rangle^2 + C_{m\lambda}\left(\frac{\langle m_{\nu_e}\rangle}{m_e}\right)\langle\lambda\rangle$$

Includes phase space factors and nuclear matrix elements



- λ coupling from V+A at hadronic and leptonic vertices.

SuperNEMO Design

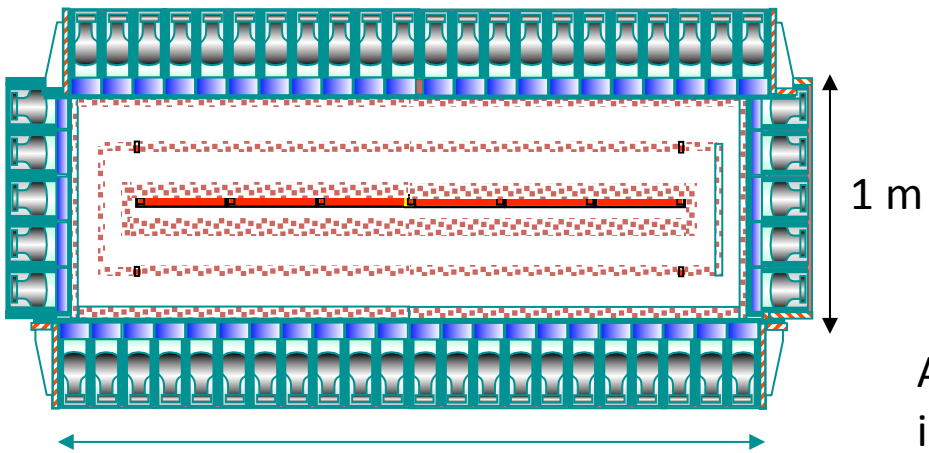
Planar and modular design: ~ 100 kg of enriched isotopes (20 modules × 5 kg)

1 module:

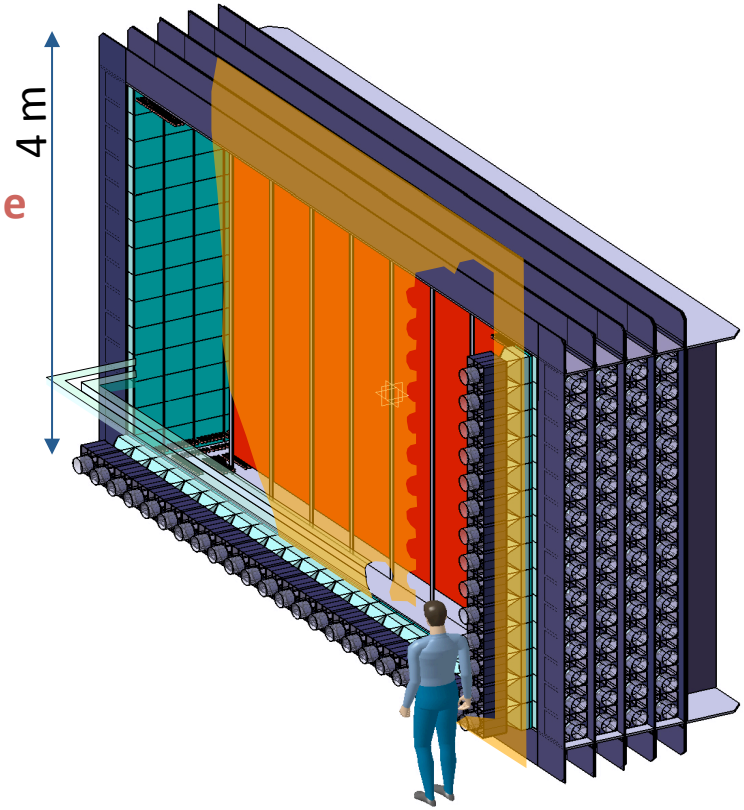
Source (40 mg/cm²) 4 x 3 m² ^{82}Se or ^{150}Nd

Tracking : drift chamber ~3000 cells in Geiger mode

Calorimeter: scintillators + PM
~1 000 PM if scint. blocs
~ 100 PM if scint. bars



Top view



A next generation experiment currently in R+D. First module construction to start 2010.

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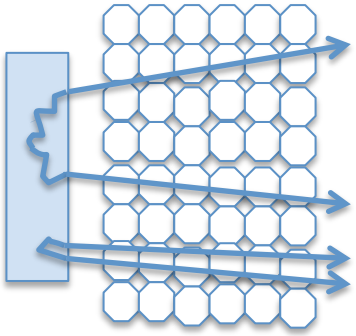
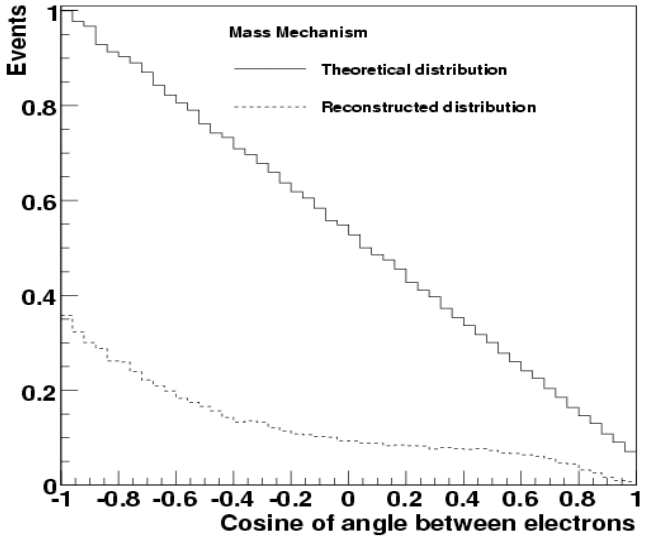
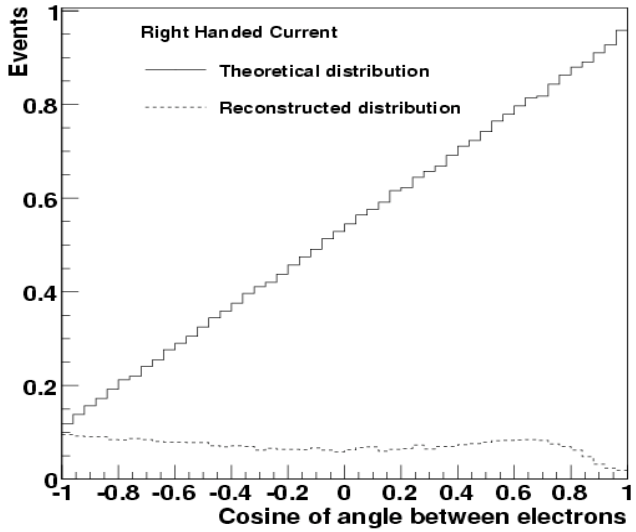
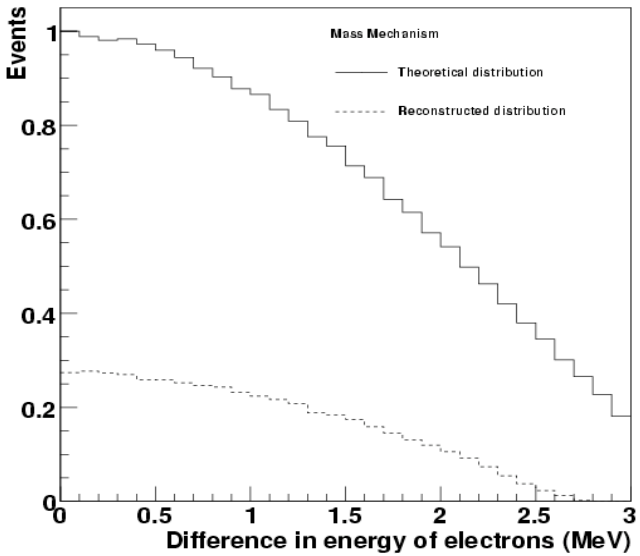
Reconstructed distributions

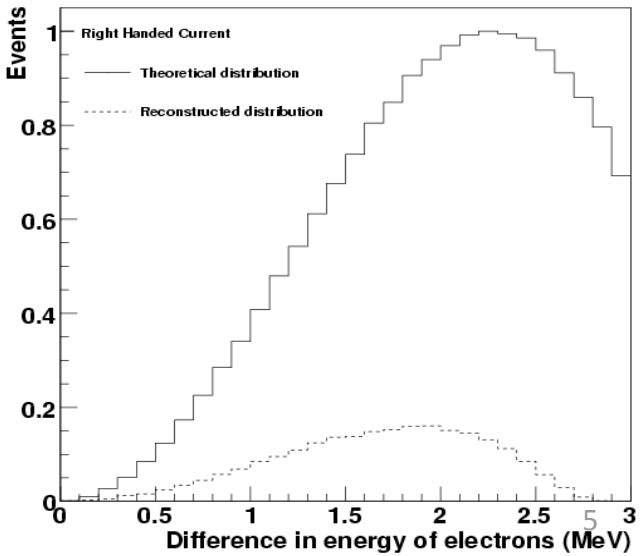






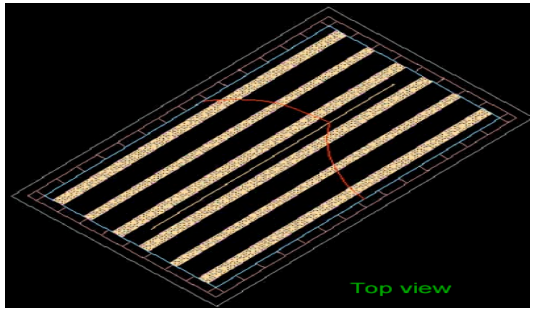
Acceptance effects due to scattering in foil and poor reconstruction of tracks of small opening angle

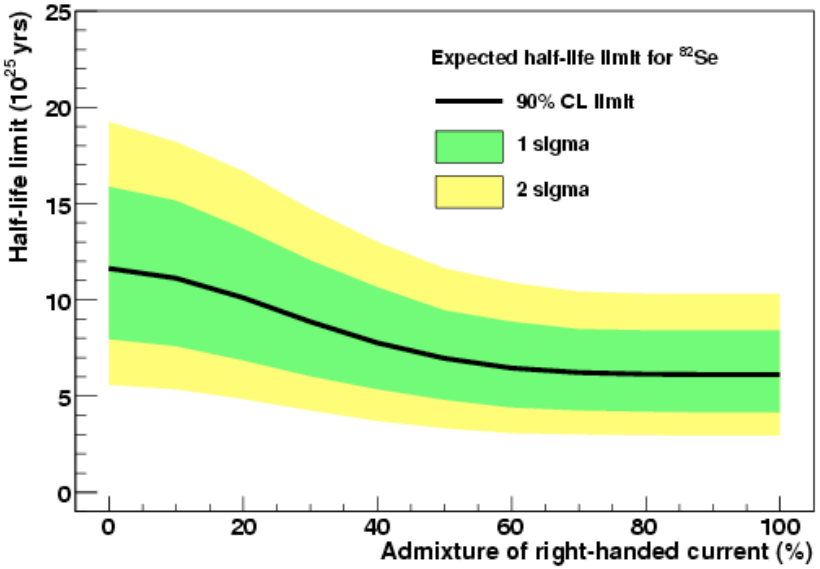


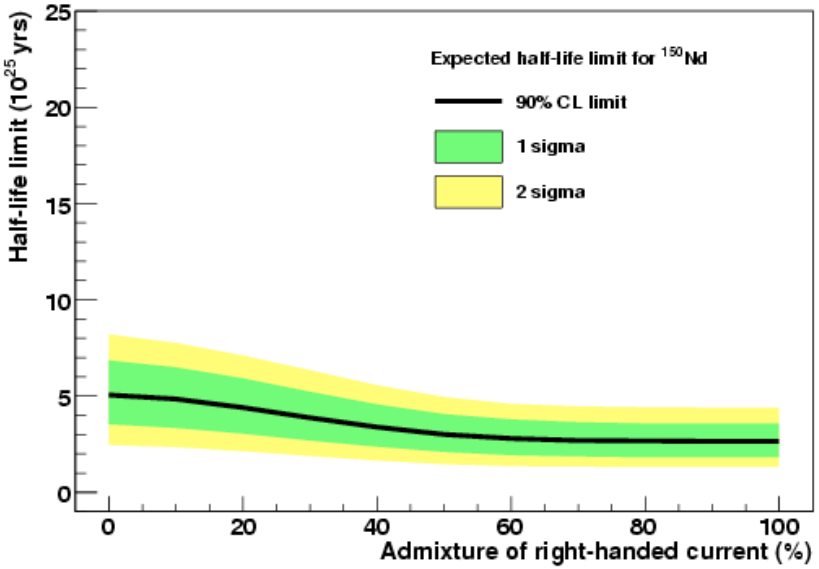


Expected Sensitivity

- Performed full Geant 4 Monte Carlo simulation of detector including digitisation, track reconstruction and realistic event selection.
- Simulated signal and internal backgrounds (2νββ, ^{214}Bi (< 10 μBqkg^{-1}), ^{208}Tl (< 2 μBqkg^{-1})).
- Calorimeter resolution (7% (FWHM) at 1 MeV). Foil thickness 40mg/cm^2. Exposure 500 kgyrs.
- Set expected limits at 90% CL using CL_S method.
- Following results are all preliminary.

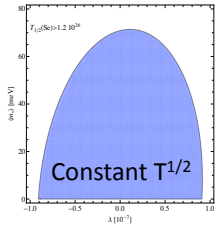


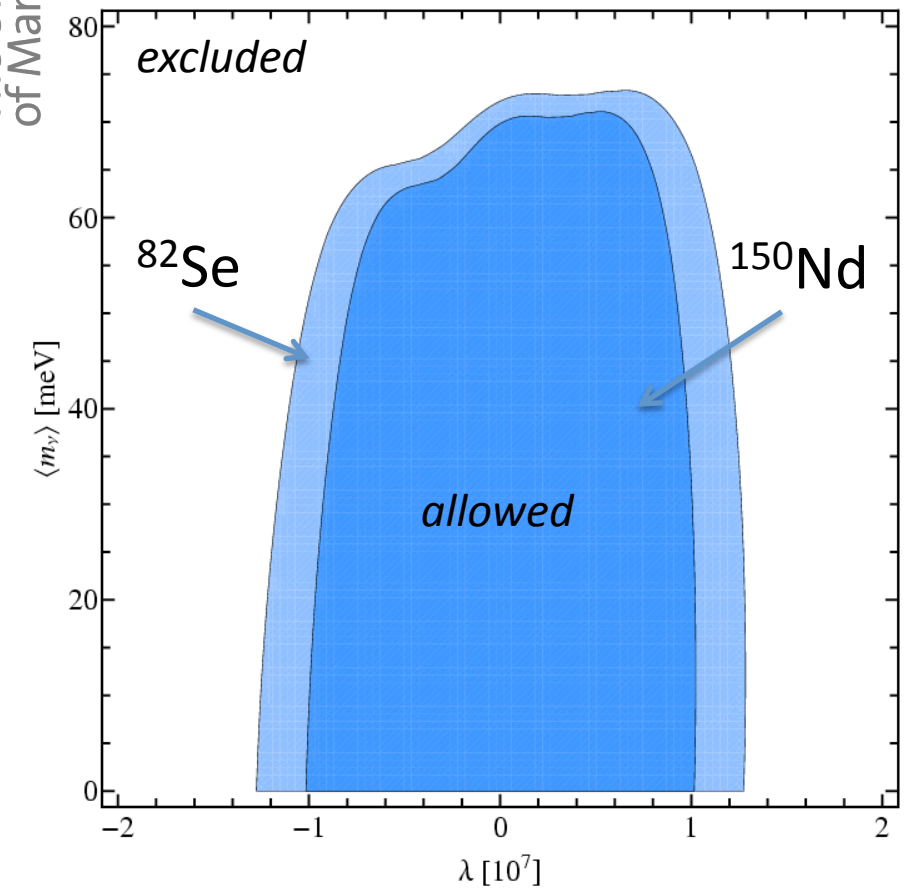


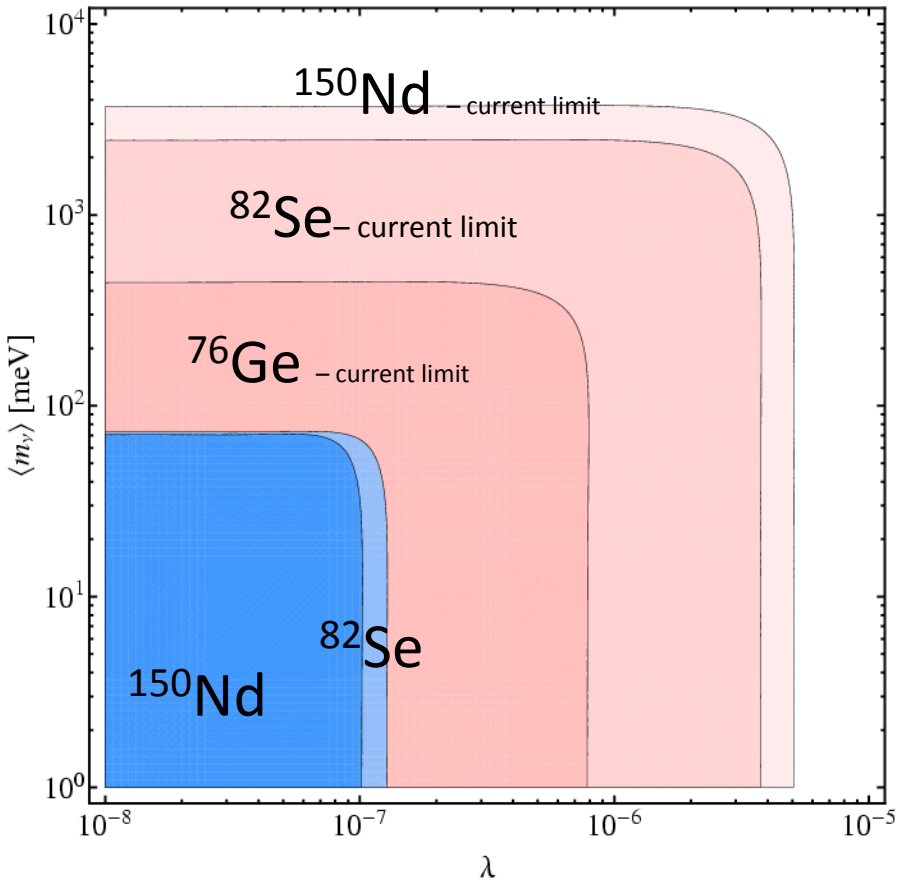


$T_{1/2}$ lower for right handed currents as efficiency is lower.

Parameter Exclusion







Nuclear matrix elements from Muto, Bender, Klapdor '89.
Correction of 2.7 to NME for deformed nucleus of ^{150}Nd (Simkovic '07).

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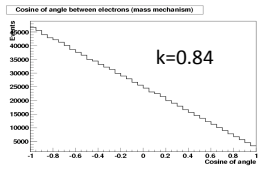
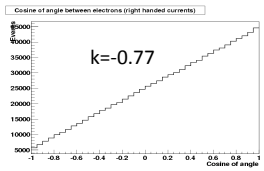
Discovery





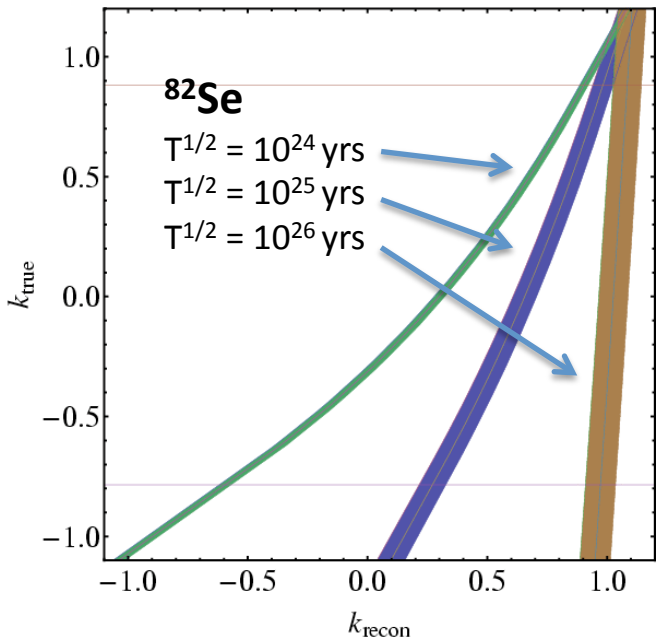
- In case of discovery can use energy and angular information to determine mechanism.
- Angular distribution of electrons given by:

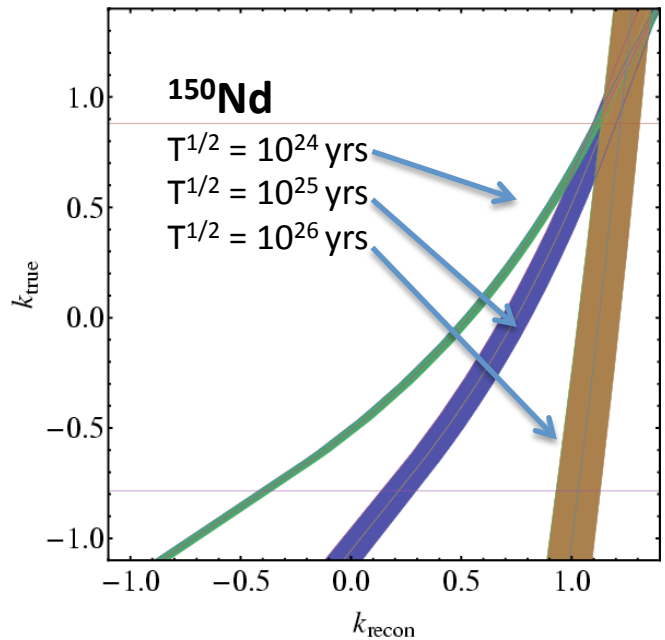
$$\frac{d\Gamma}{d\cos\theta} = \frac{\Gamma}{2}(1 - k\cos\theta)$$

(Ali, Borisov, Zhuridov 2007)

- Define angular asymmetry above and below cosθ=0.
- Analogously define energy asymmetry above and below $Q_{\beta\beta}/2$.

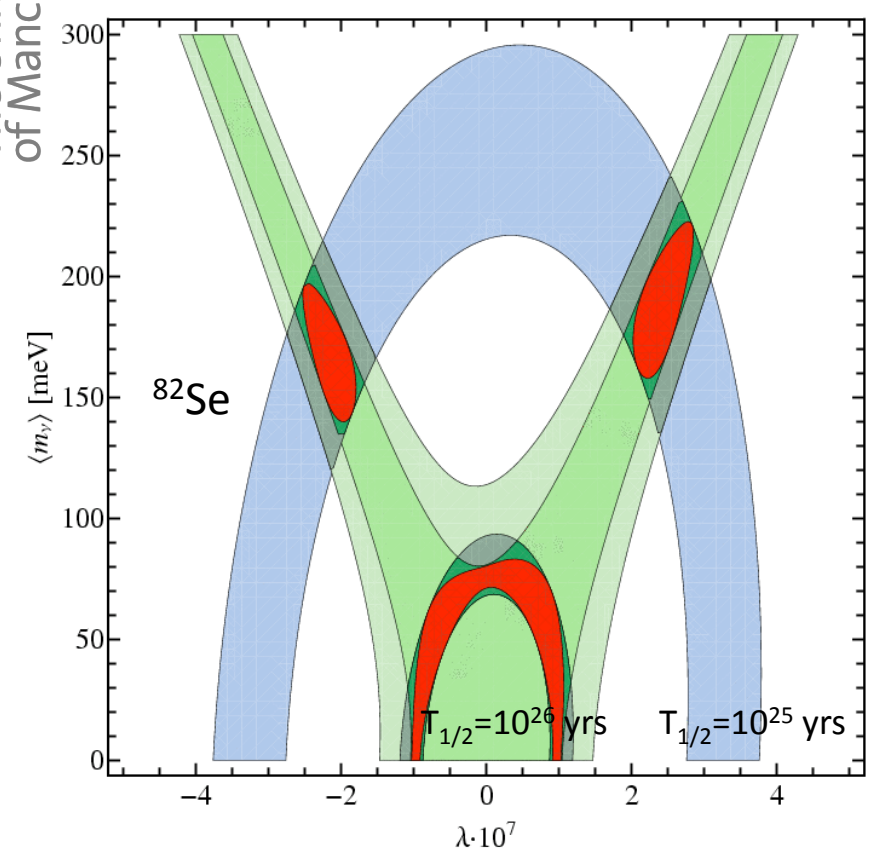
$$k = 2\left(\frac{N^{+} - N^{-}}{N^{total}}\right)$$

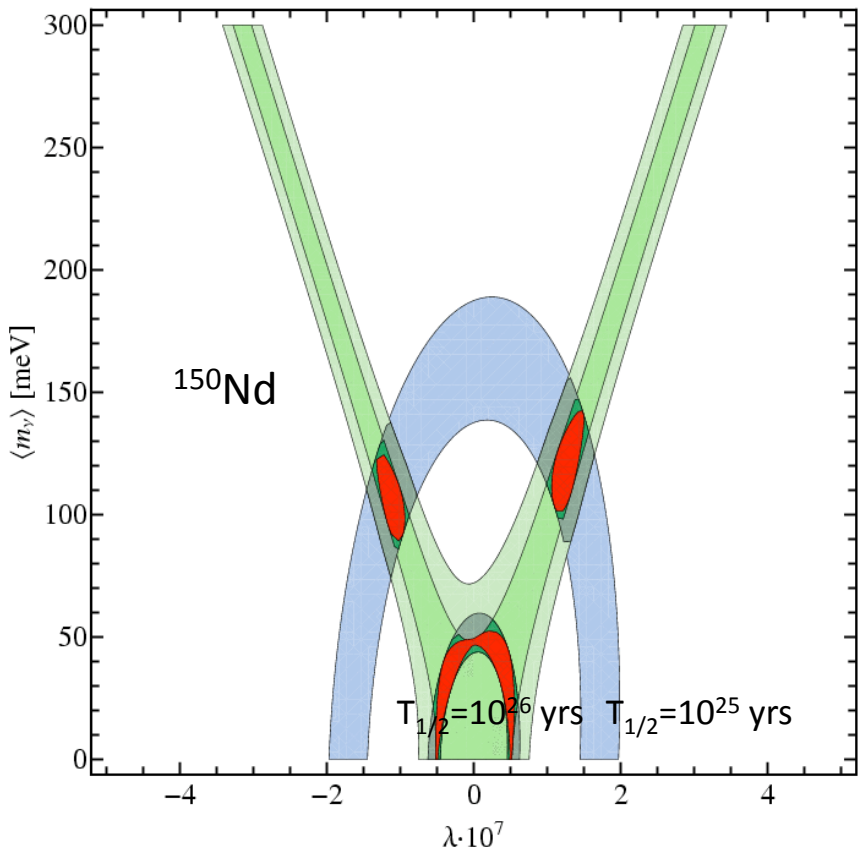




Plots relate measured k to theoretical k (for angular distribution).
At $T_{1/2}=10^{26}$ yr can distinguish pure mass mechanism and right handed current at ~2σ.
At $T_{1/2}=10^{25}$ yr can identify admixture to ~20%.

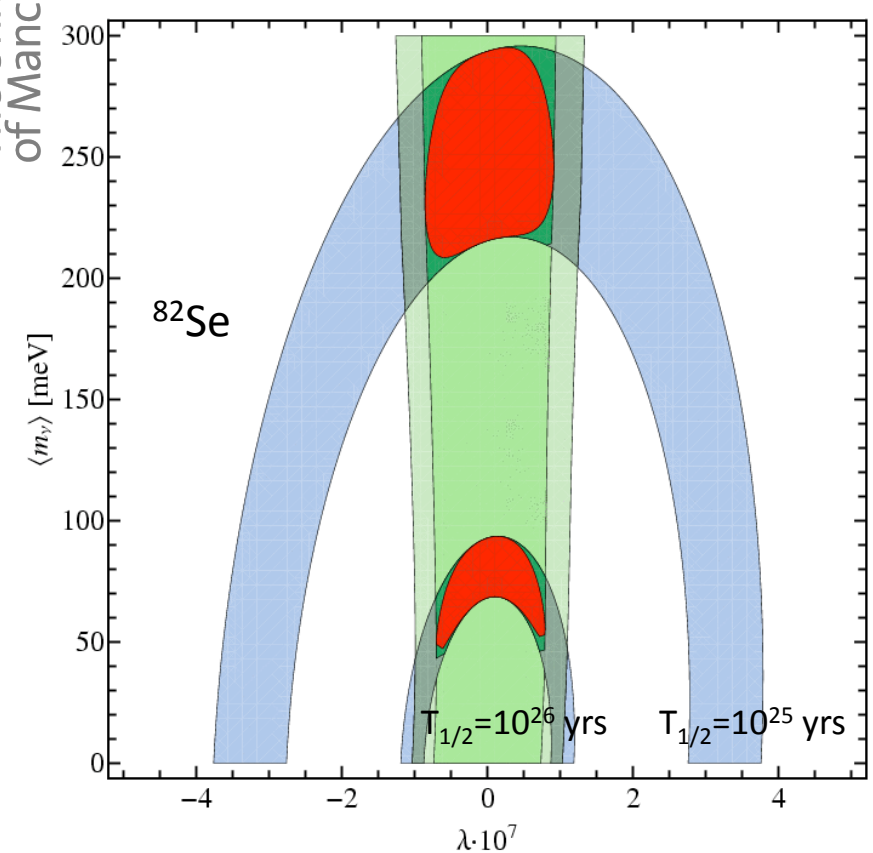
Discovery



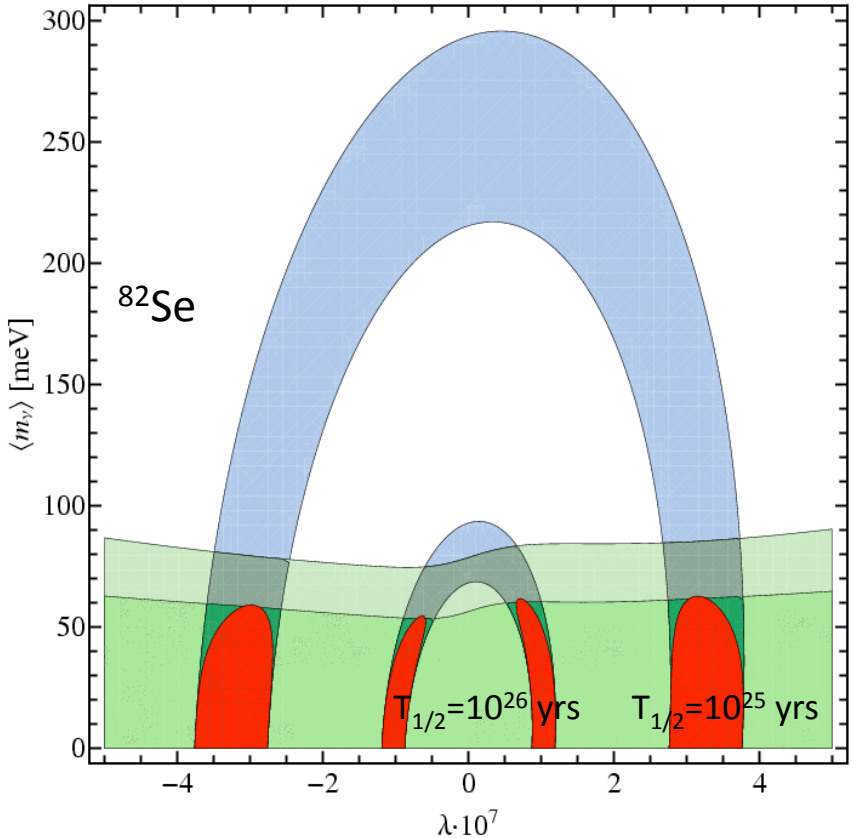


- Two measurements can define parameters:
  - Light blue ellipse from measured $T_{1/2}$ including theoretical NME errors of 30%. Shown at values of 10^{25} and 10^{26} yrs.
  - k parameter measurement defines band in parameter space (here k=0.3, 25% rhc admixture). Statistical errors included. Dark green from energy difference and light green from angle.
- Red region shows 1 σ statistical combination of measurements.

Discovery



Pure mass mechanism



Pure right handed current

Conclusions

- $0\nu\beta\beta$ can be caused by many new physics mechanisms. Experimental techniques to understand mechanism are important.
- Half life sensitivity to the mass mechanism will be:
  - $T_{1/2} > 1.15 \times 10^{26}$ yr for ^{82}Se
  - $T_{1/2} > 0.50 \times 10^{26}$ yr for ^{150}Nd
- Sensitivity to effective neutrino mass and right handed currents (λ) will be:
  - $m_\nu < \sim 70$ meV and $\lambda < \sim 1.2 \times 10^{-7}$
- In the case of discovery SuperNEMO can identify admixture of right handed current using the electron angular and energy distributions:
  - $\sim 2\sigma$ for pure right handed current at $T_{1/2} = 10^{26}$ yr
  - ~20% admixture for $T_{1/2} = 10^{25}$ yr