Prospects for Lepton Number Violation with SuperNEMO and future $0\nu\beta\beta$ experiments

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Outline

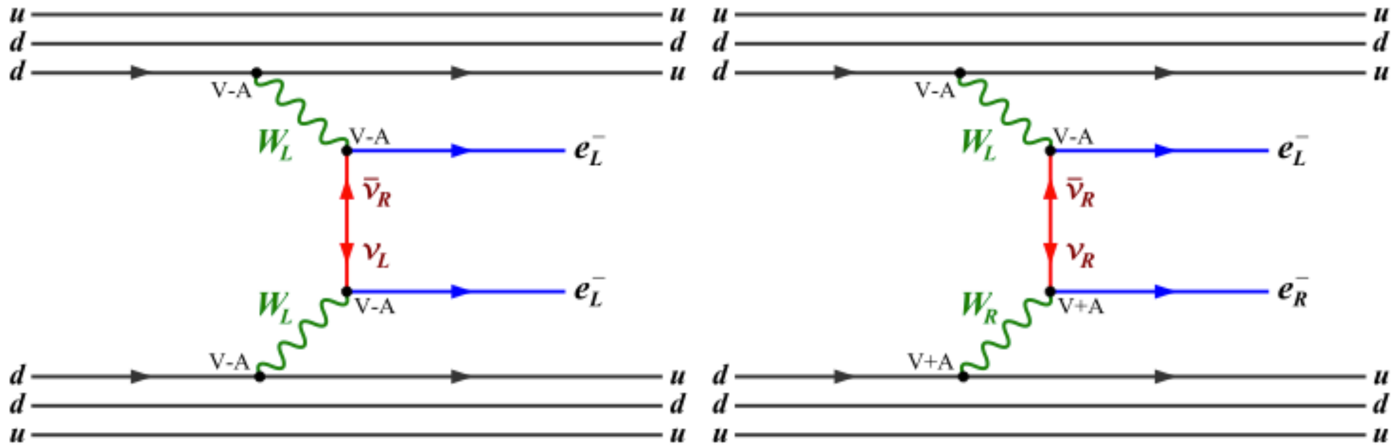
- Lepton number violating (LNV) mechanisms for $0\nu\beta\beta$
- Techniques for experimental determination of mechanisms
- Current and future experiments with potential mechanism sensitivity
  - SuperNEMO, DCBA, (n)EXO, NEXT, KamLAND-Zen
  - See Carla Macolino's talk for other experiments

LNV MECHANISMS

Right handed weak currents

- λ mode: W_R coupling to heavy ν_R state
  - $\lambda = (M_L/M_R)^2 \Sigma U_{ei} U'_{ei}$
- η mode: as λ but with W_L-W_R mixing (angle ξ)
  - $\eta = \tan\xi \, \Sigma U_{ei} U'_{ei}$

U – PMNS matrix
U’ – mixing ν_α-N_i



‘Standard’ mass mechanism (MM)

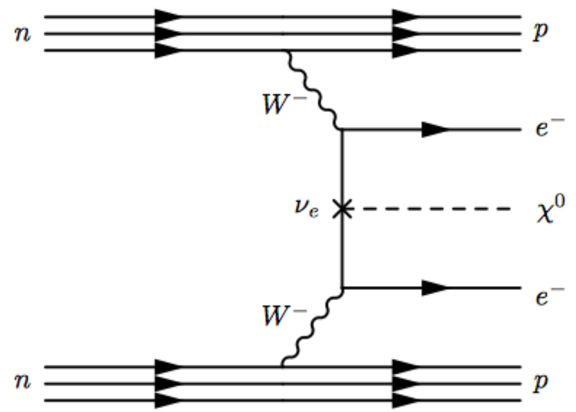
RHC (λ)

Eur.Phys.J.C70:927,2010

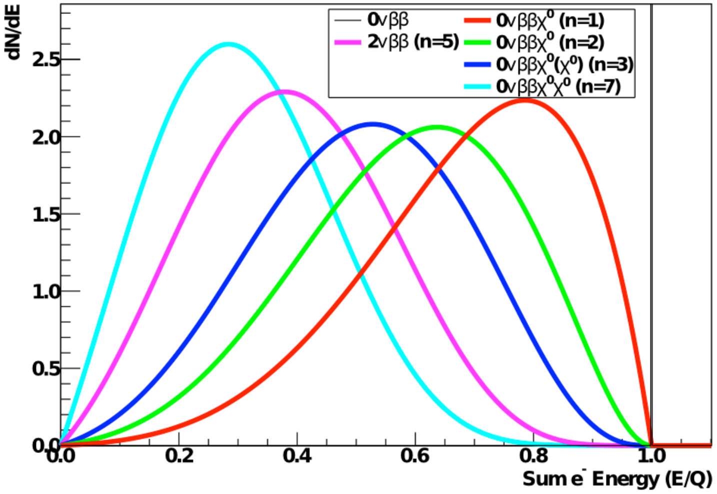
Majoron emission

- Emission of 1 or 2 neutral scalar bosons
  - e.g. Goldstone boson of new Higgs-like field giving neutrinos mass
- Characterised by spectral index n
- Distortion on top of 2νββ spectrum (n=5)

PRL B 99:411 (1981); NPB 193:297 (1981); PLB 98:265 (1981); PLB 291:99 (1992); NPB 449:25 (1995)



$$\frac{d\Gamma}{dE_1 dE_2} \sim (Q - E_1 - E_2)^n p_1 p_2 E_1 E_2$$

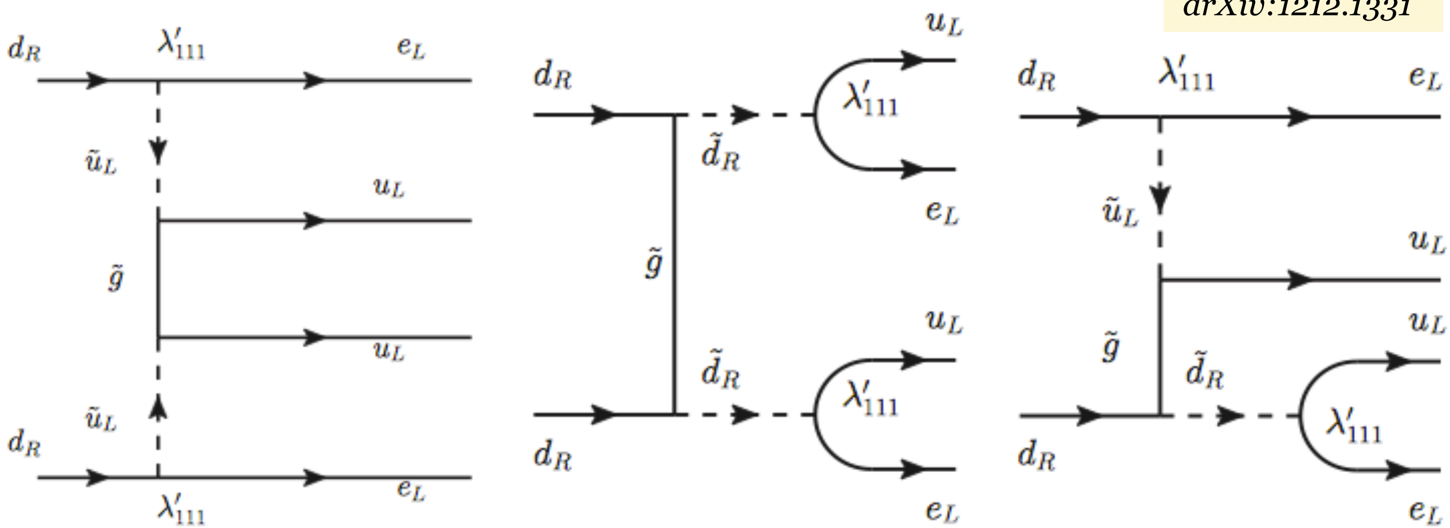


S Herrin

SUSY, H⁻⁻

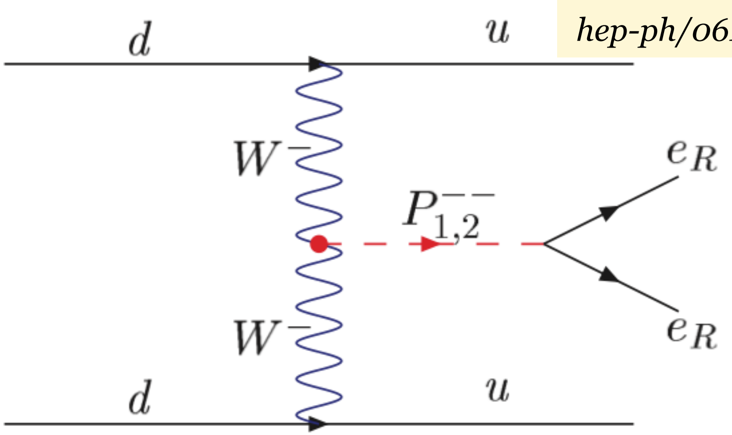
- Squark – gluino coupling

arXiv:1212.1331



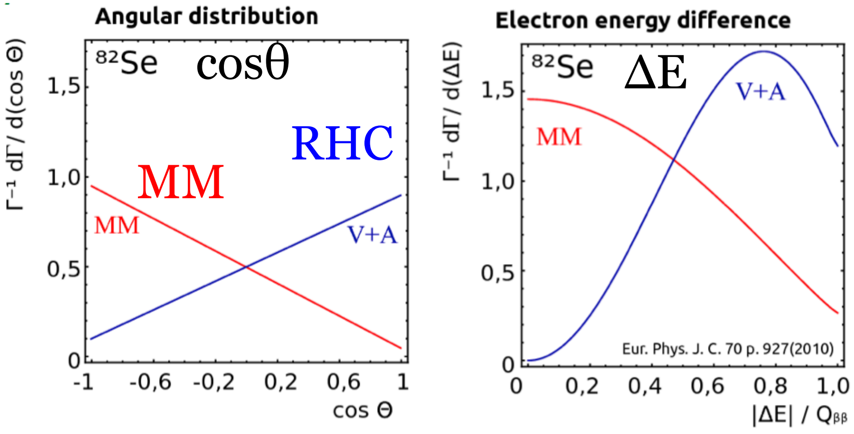
- Doubly-charged Higgs

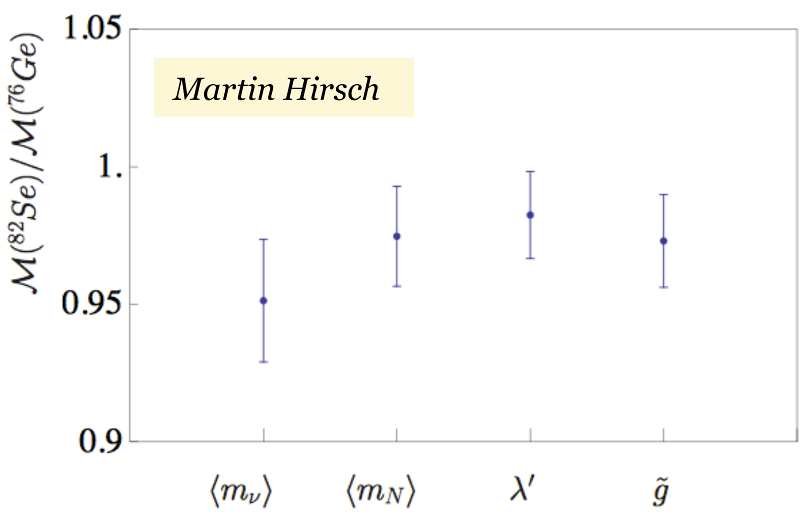
hep-ph/0610118



Decoupling the mechanisms

- Two-electron angular correlations and energy differences are model dependent
- Comparing isotopes also allows some decoupling
  - Will require much more precise NME calculations than currently available
- 0νββ experiments with kinematic information are vital!

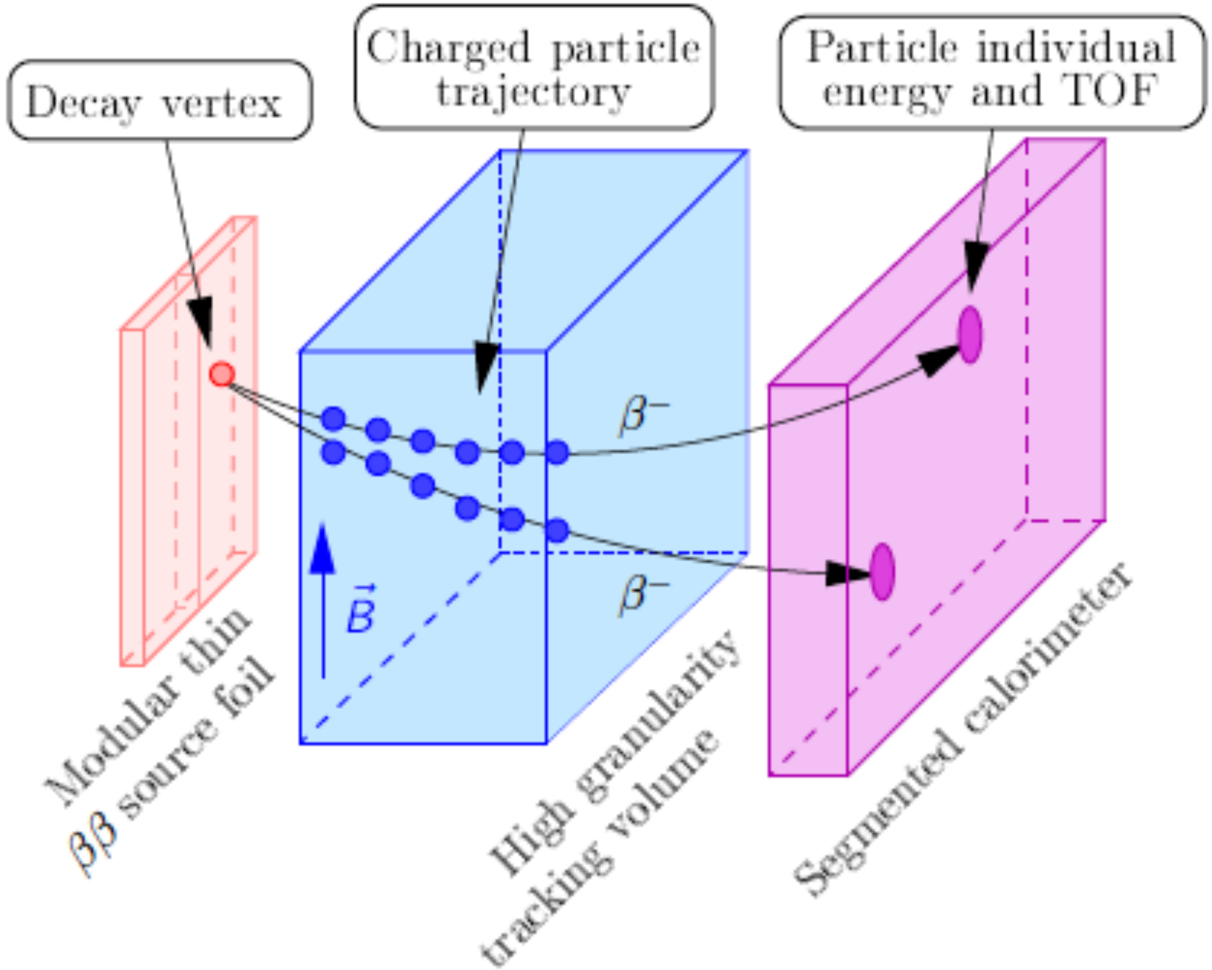




SUPERNEMO

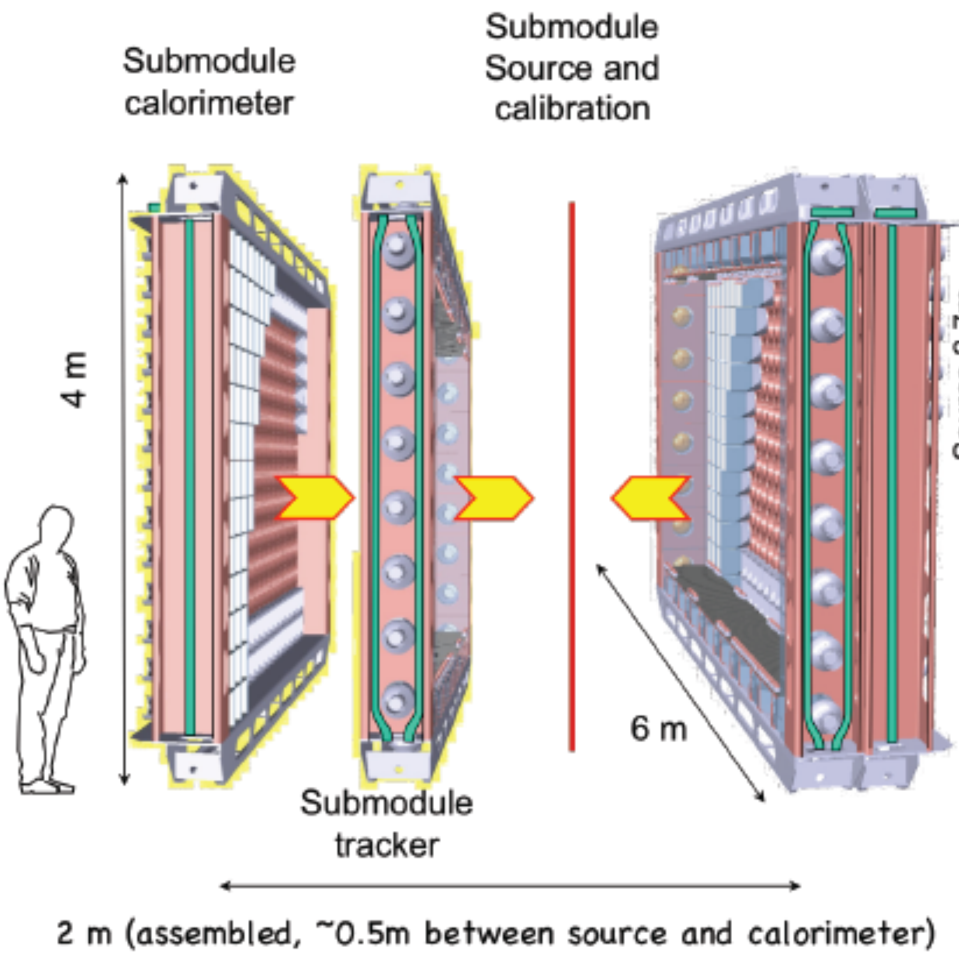
SuperNEMO

- Source independent from detector
  - Choice of isotopes
- Tracking + calorimeter
- Full event kinematics & particle PID
  - Background reduction



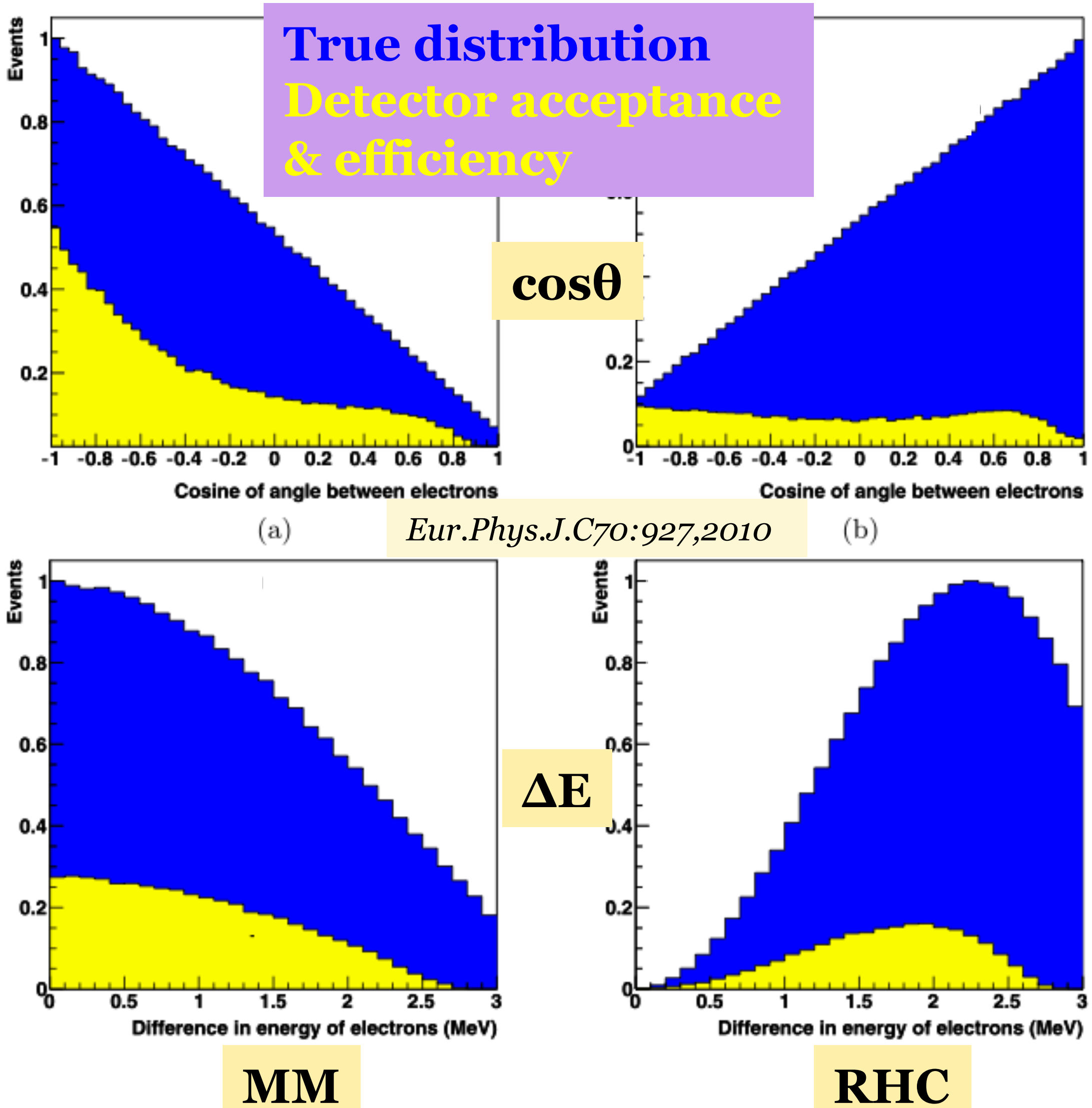
SuperNEMO status

- Demonstrator module currently being constructed
  - Run from late 2015
  - 7kg ^{82}Se
  - 6.6×10^{24} y $T_{1/2}$ sensitivity
- 20 modules in all for full experiment
  - ~100kg of isotope
  - ~10^{26} y $T_{1/2}$ sensitivity



Reconstruction

- Detector acceptance
  - collinear tracks unresolved as two separate tracks
  - low energy β do not reach calorimeter
- Asymmetry
  - $(N_+ - N_-)/(N_+ + N_-)$
  - splitting at
    - $\cos\theta = 0$
    - $\Delta E = Q/2$



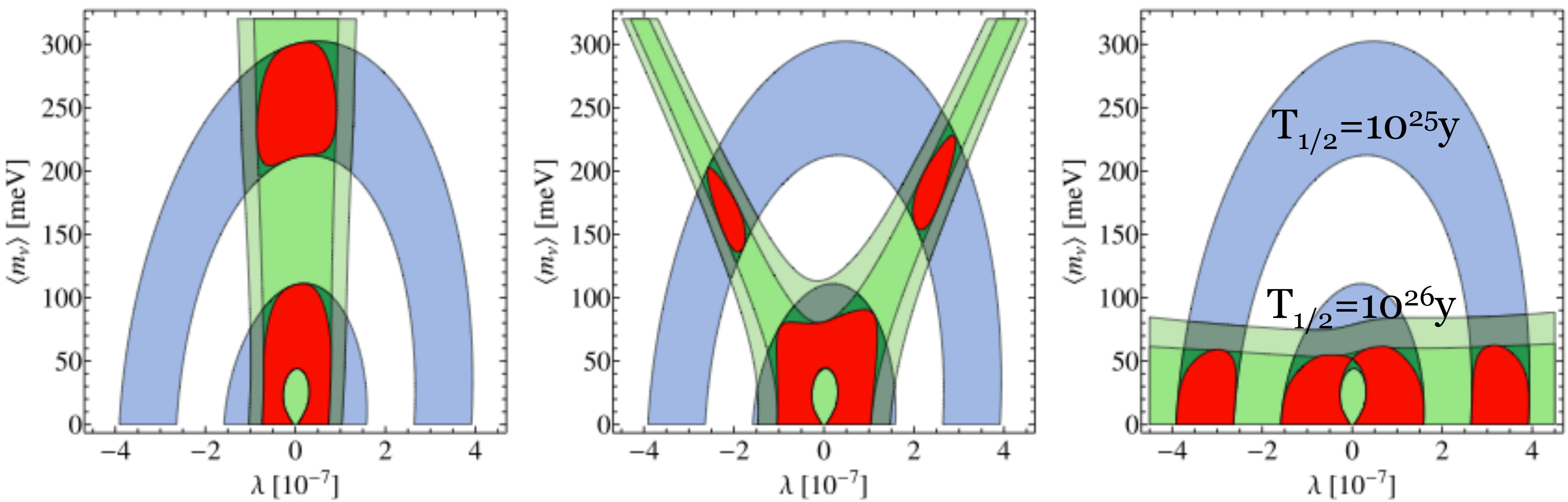
Mechanism sensitivity

- $\Gamma = a\langle m_\nu\rangle^2 + b\lambda^2 + \ldots$
  - Only a hypersphere in parameter space can be resolved traditionally
  - Use kinematics to tighten constraints

Using half-life alone

Using angular / energy asymmetry

Eur.Phys.J.C70:927,2010

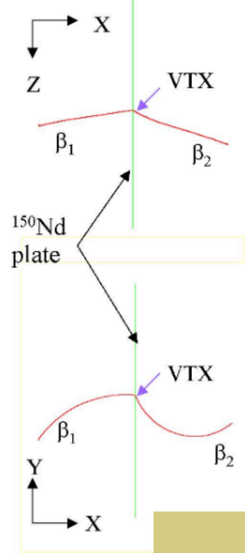


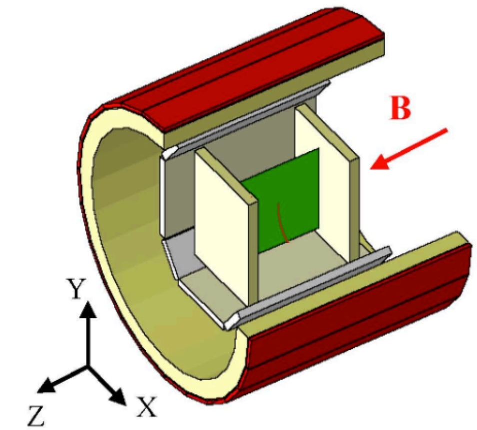
MM 2:1 **MM/RHC** **RHC**

OTHER EXPERIMENTS

DCBA

- Similar to SuperNEMO, without calorimetry



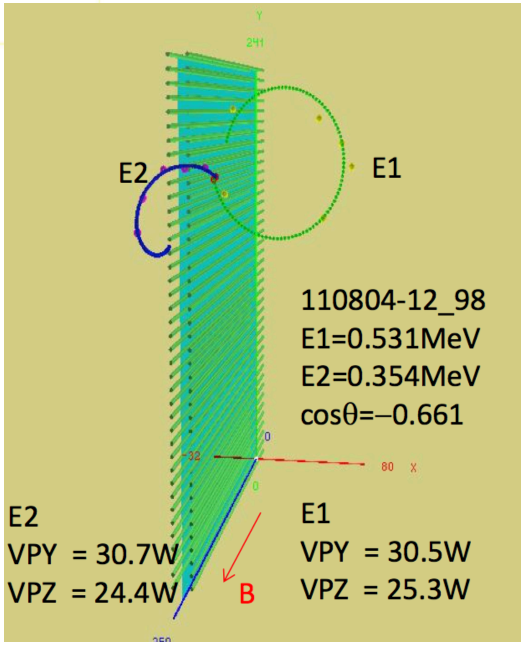


2011 DCBA-T2.5
- 6 mm pitch wires (xy + xz)
- ^{100}Mo source (natural Mo 30g)
- 0.8 kG magnetic field
- super-conducting magnet: 24h nonstop operation

now

2014 DCTA-T3
- 3 mm pitch wires (xy + xz)*8
- ^{150}Nd (5.6% in natural Nd_2O_3)
- B=3 kG at the maximum

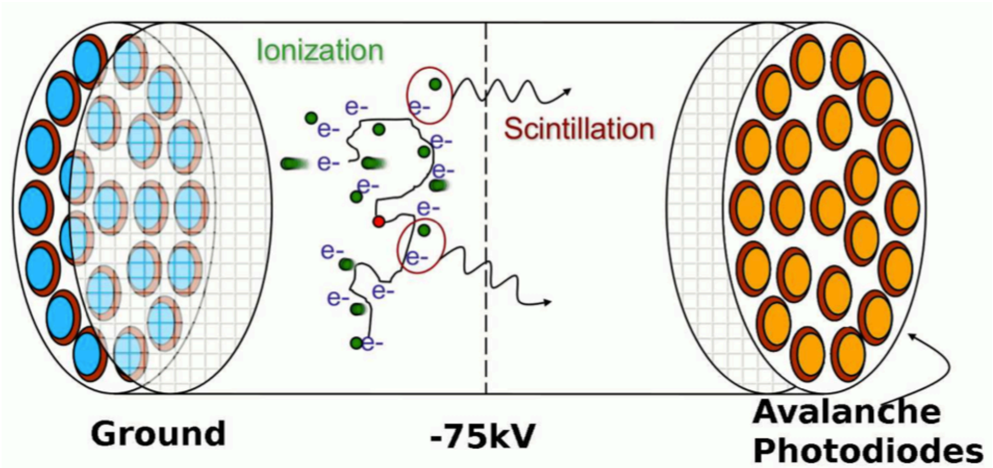
2017 MTD (tentative name)
- ^{82}Se ^{150}Nd(enriched) several 10 kg



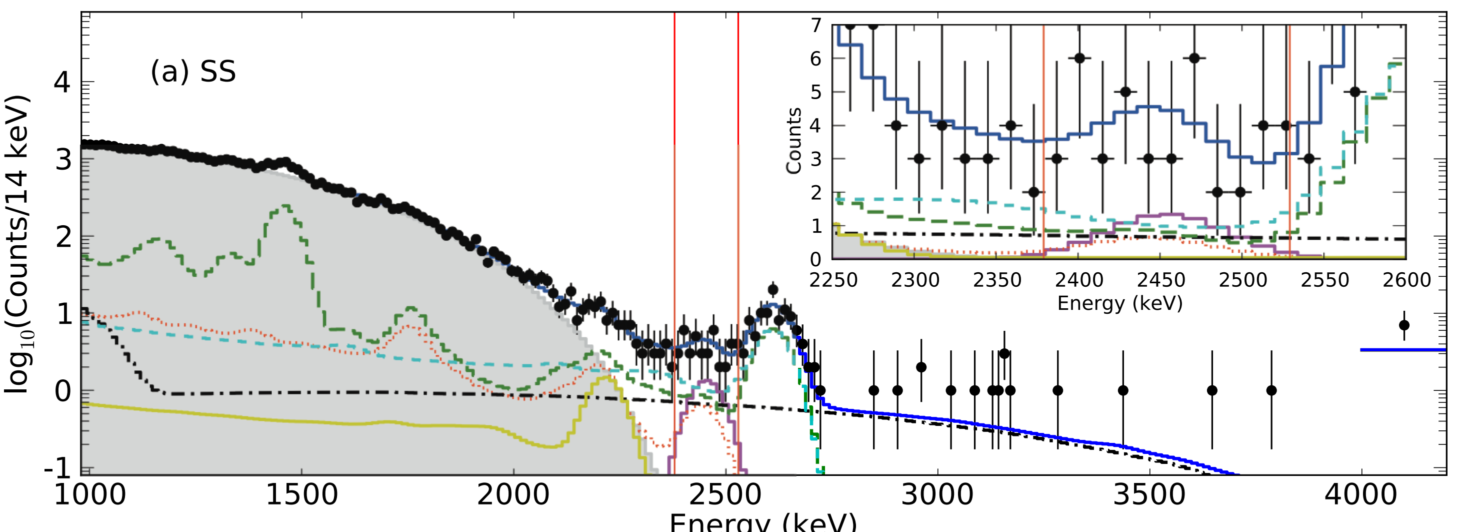
Hidekazu Kakuno

EXO

- 200kg liquid xenon TPC
- 80% ^{136}Xe enriched
- Measures ionisation and scintillation

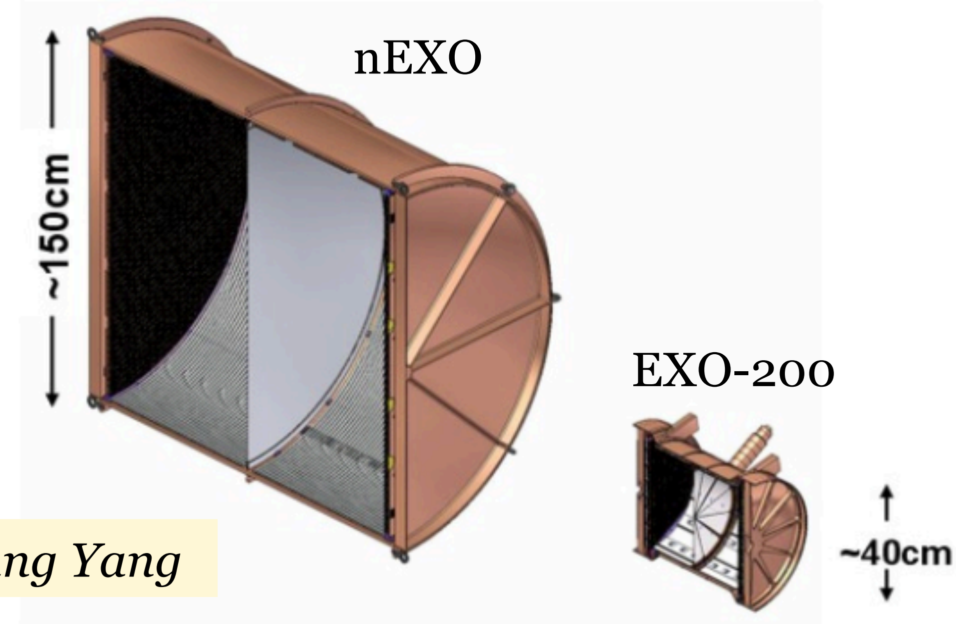


Nature 510, 229 (2014)

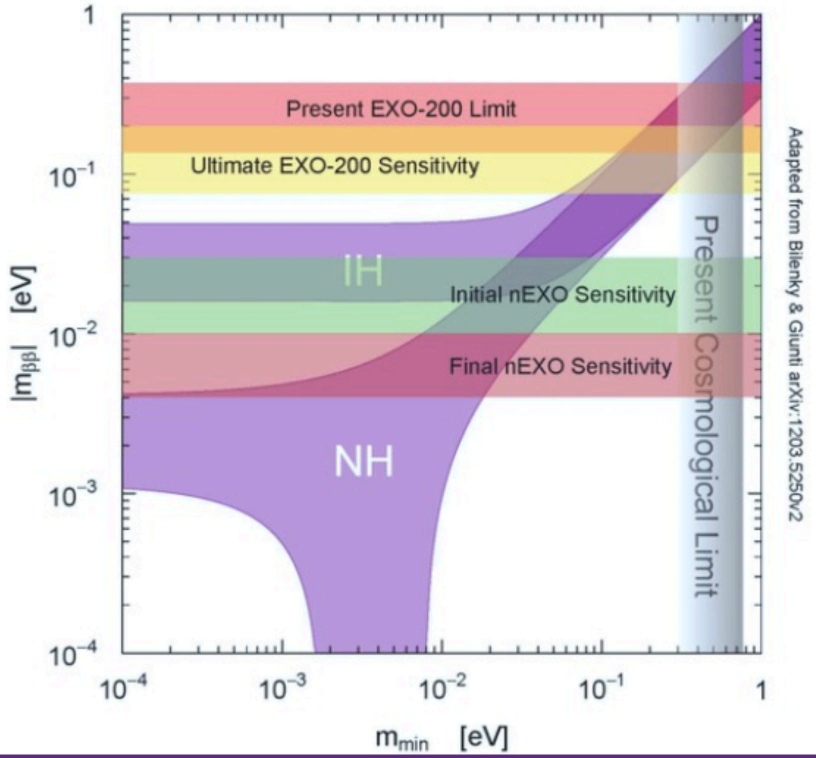


nEXO

- 5 tonne Liquid Xenon TPC
- ‘as similar to EXO-200 as possible’
- 4 tonnes ^{136}Xe (80% enrichment)
- 1.4% energy resolution

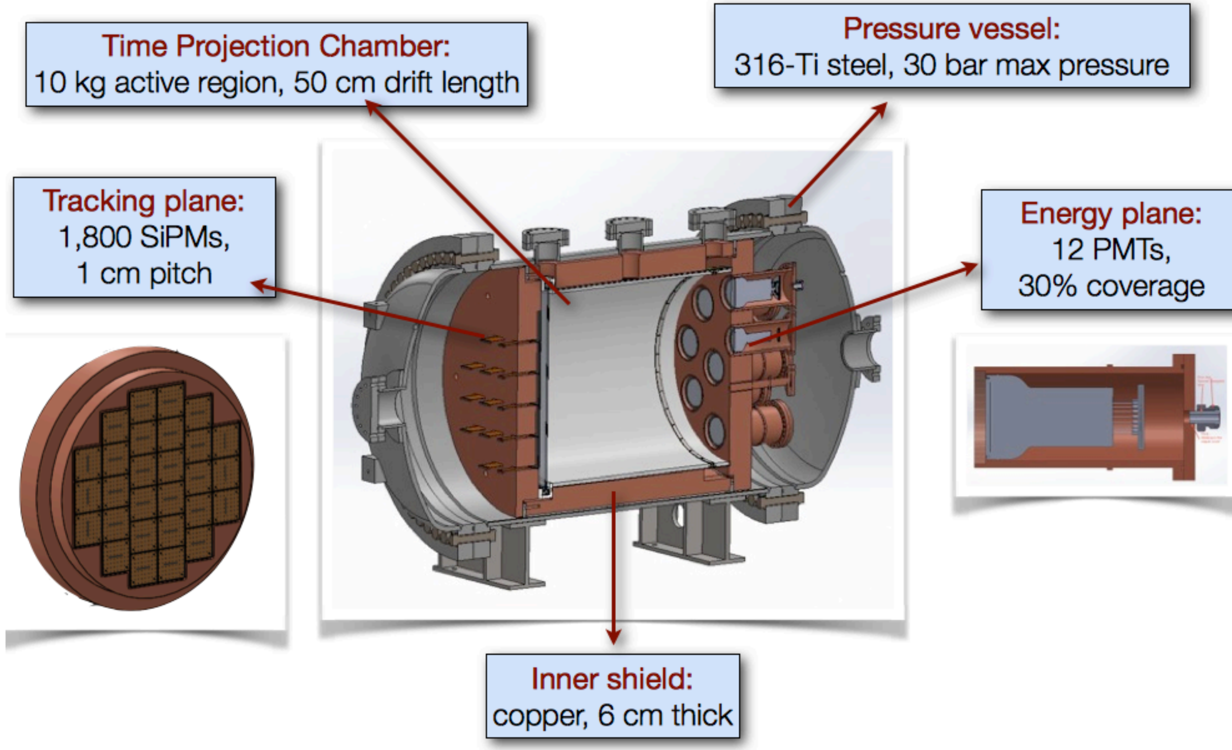


Liang Yang



NEXT

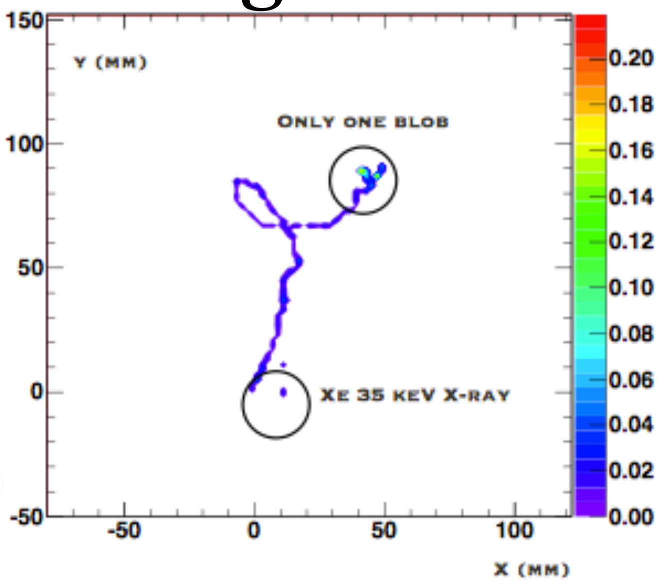
- High pressure gaseous argon TPC
- Currently 10kg
- 100 kg (2016-2020)
- 1t (2020-?)
  - 20 meV sensitivity

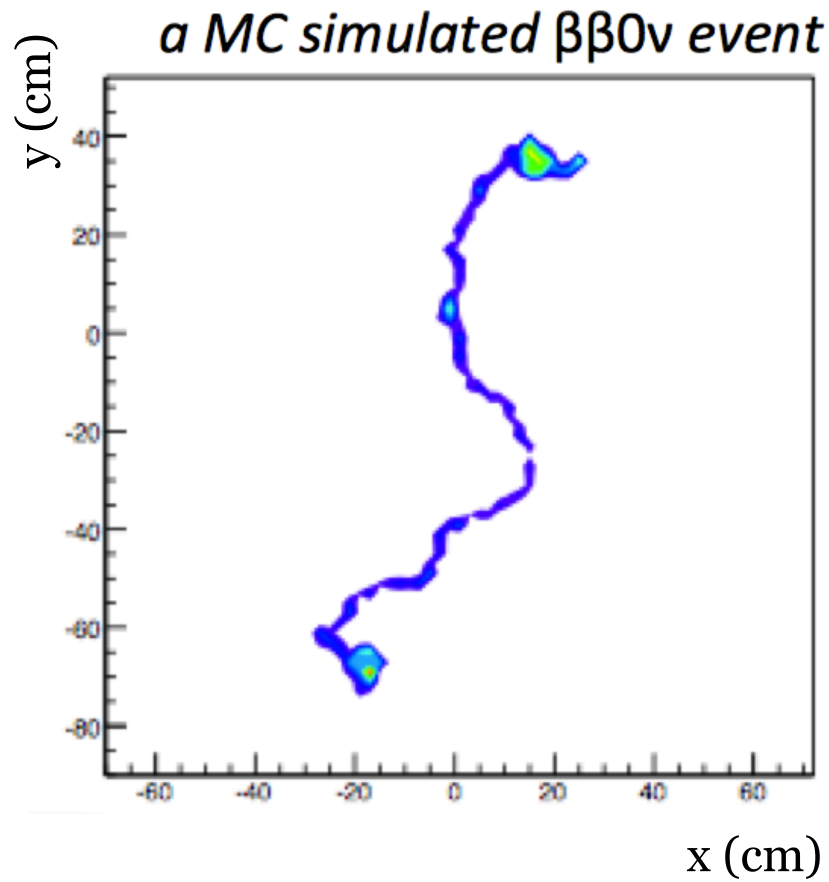


J.J. Gómez Cadenas

NEXT

- ββ event with tens of cm length, energy 'blobs' at each end
- Easily distinguishable from background



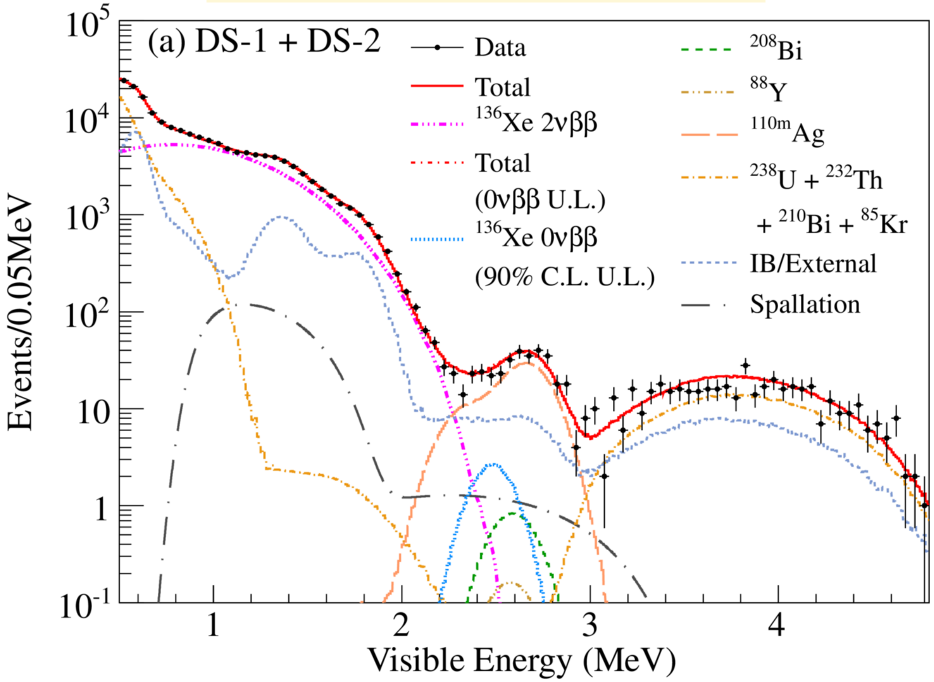


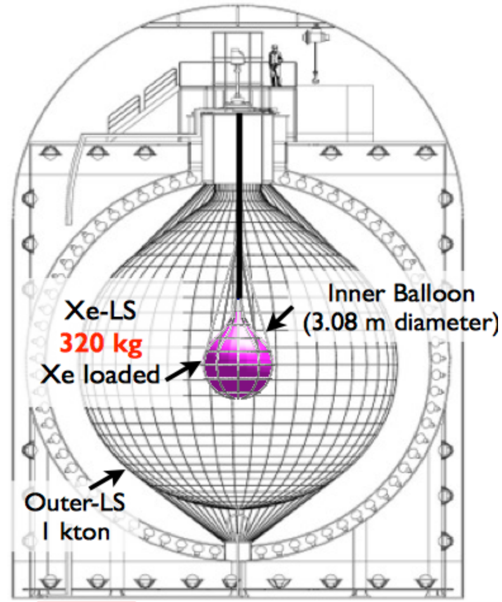
J.J. Gómez Cadenas

KamLAND-Zen

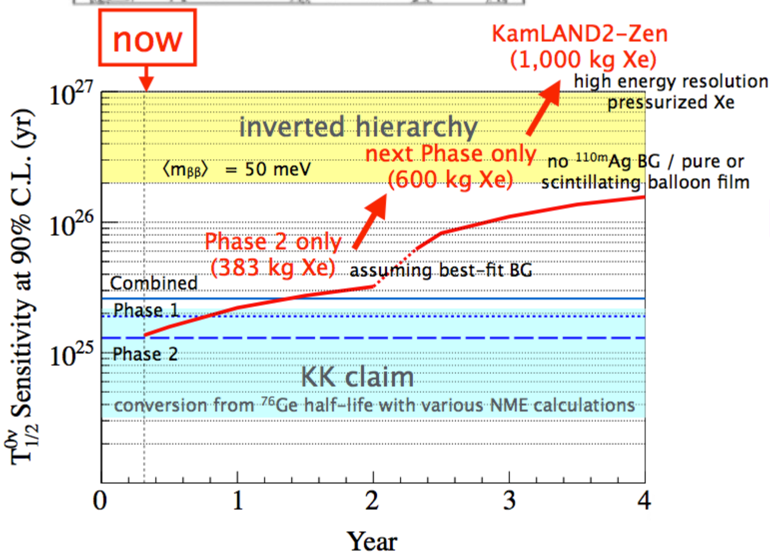
- Liquid scintillator doped with ^{136}Xe

PRL 110 062502 (2013)



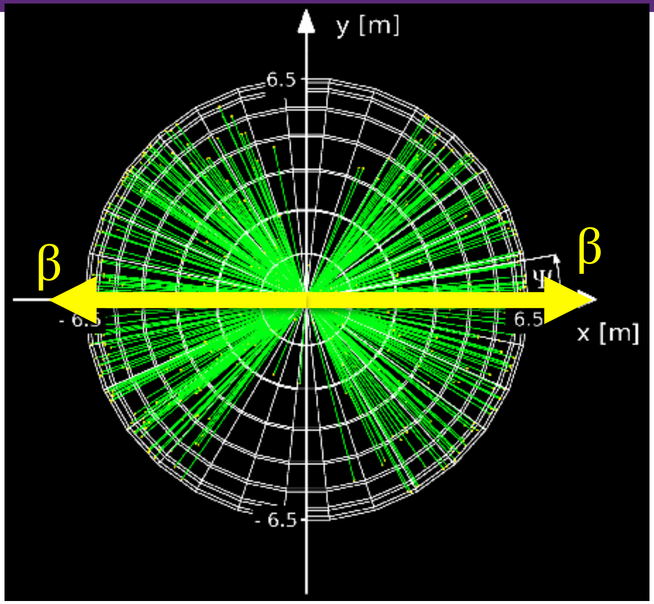


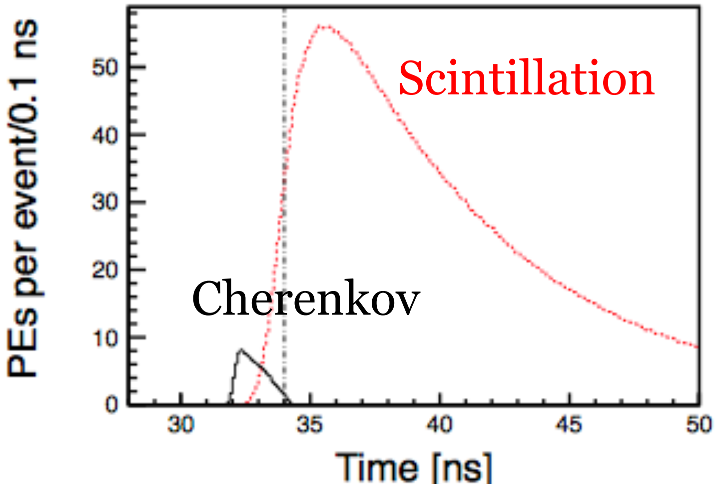
Itaru Shimizu



LS + Cherenkov

- Aberle *et al*
  - arXiv:1307.5813
- Use Cherenkov light to provide kinematic information
- Current problems
  - Low number of photons compared to scintillation
  - Absorption of short wavelengths by scintillator
  - Poor timing resolution





Simulation

Summary

- No 1 priority: discovery of $0\nu\beta\beta$
- Disentangle mechanisms:
  - Angular correlations
  - Energy differences
  - Comparing isotopes
- Not mutually exclusive goals – kinematics also excellent for background reduction