Super-NEMO
Proposal for a Design Study

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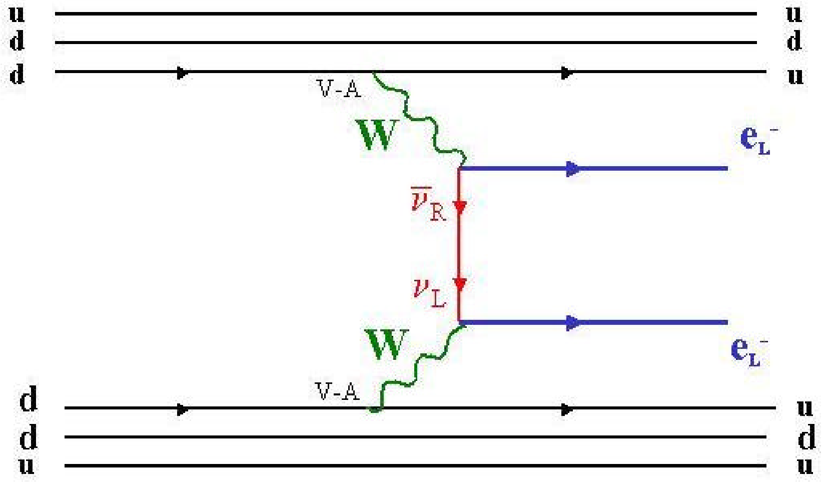
Preview

- Why search for $0\nu\beta\beta$ decay?
- Why Super-NEMO?
- What are the experimental issues?
  - Calorimeter : Ruben Saakyan
  - Tracker : Stefan Soldner-Rembold
- The request
  - Manpower, money
  - Will try to address referees questions throughout

Why search for 0nbb decay?

- If this c ajorana type (ν
- This is es
- All othe rac type (particl
- If the p lute mass s)



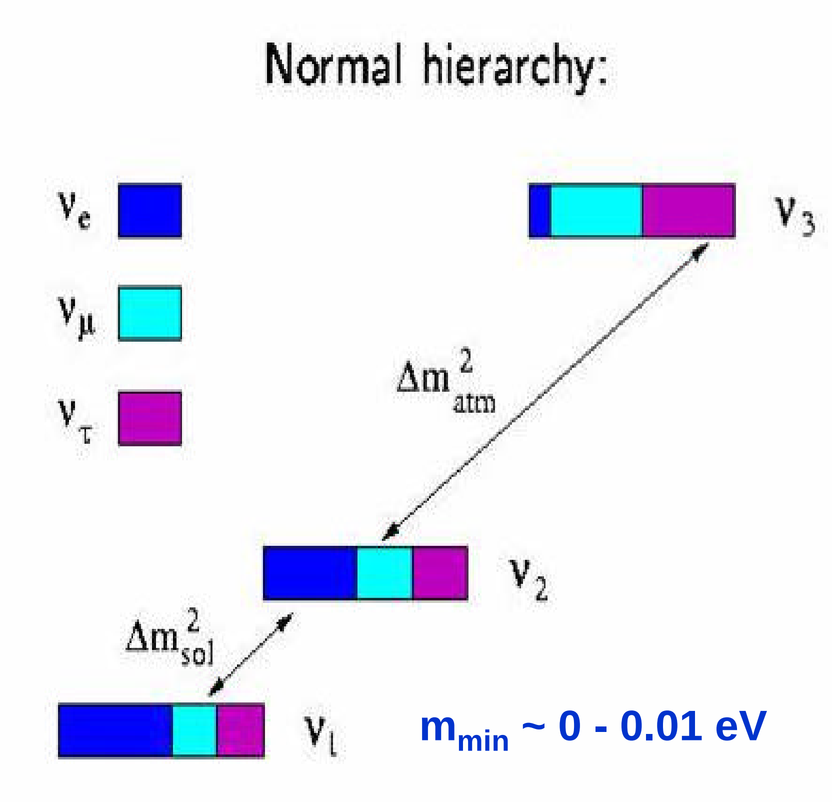
Why search for 0nbb decay?

- Oscillation experiments tell us that
  - $P(\nu_\mu \text{->} \nu_\tau)=\sin^2 2\theta \sin^2(1.27\Delta m^2 L/E)$
- From Super-K, $\Delta m^2_{atm} \sim 2.5 \times 10^{-3}$ eV^2
- Assume one mass is vanishing: $m_\nu \sim 0.05$ eV
- First time a clear goal is available for DBD experiments

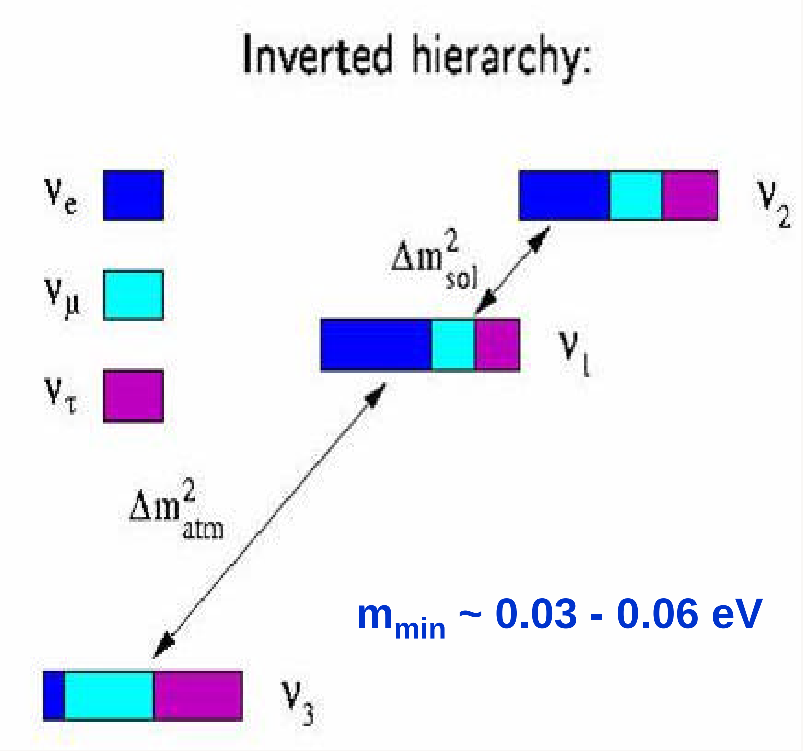
$$< m_n >^2 = \left| \sum_i^N U_{ei}^2 m_i \right|^2 = \left| \sum_i^N \left| U_{ei} \right|^2 e^{a_i} m_i \right|^2$$

- ***The aim for Super-NEMO is to achieve a reach in mn of 0.04 eV***
- ***It is not clear that Super-NEMO cannot be expanded further: modular approach just needs space!***

Why search for 0nbb decay?

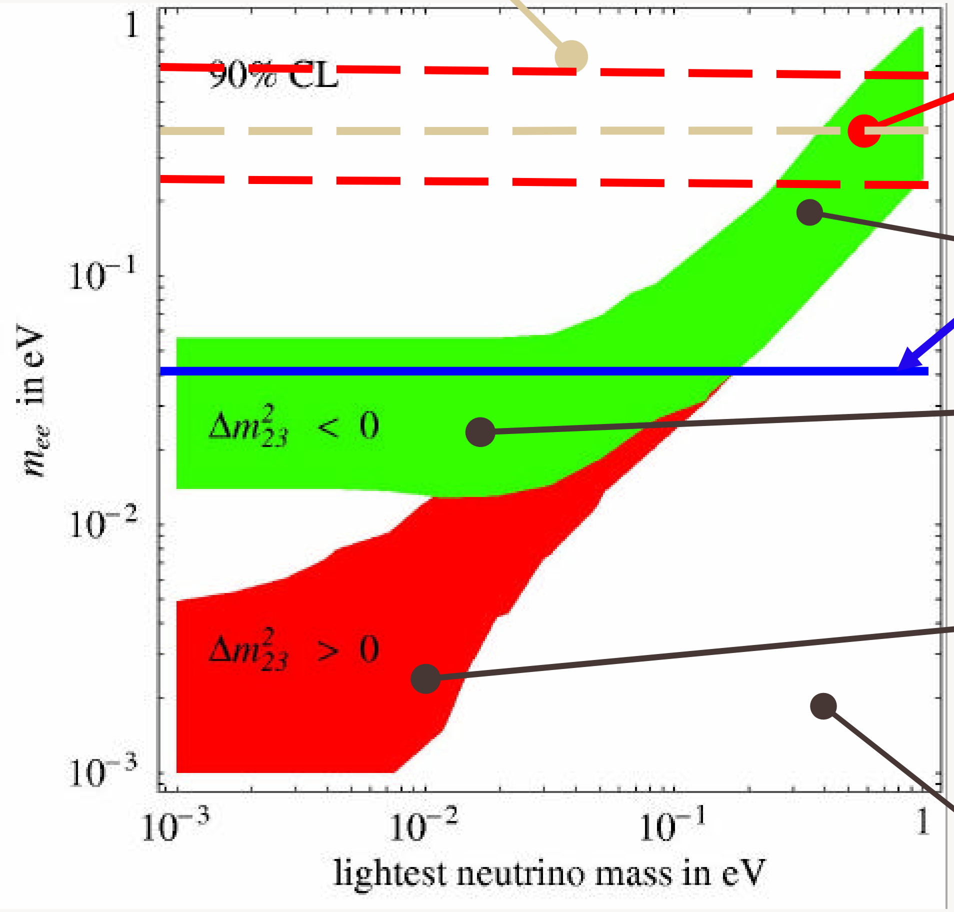


m_{min} ~ 0 - 0.01 eV



m_{min} ~ 0.03 - 0.06 eV

Present Cuoricino/NEMO-III region



Feruglio F. , Strumia A. , Vissani F. hep-ph/0201291

Possible evidence (best value 0.39 eV)

Super-NEMO reach

“quasi” degeneracy

$m_1 » m_2 » m_3$

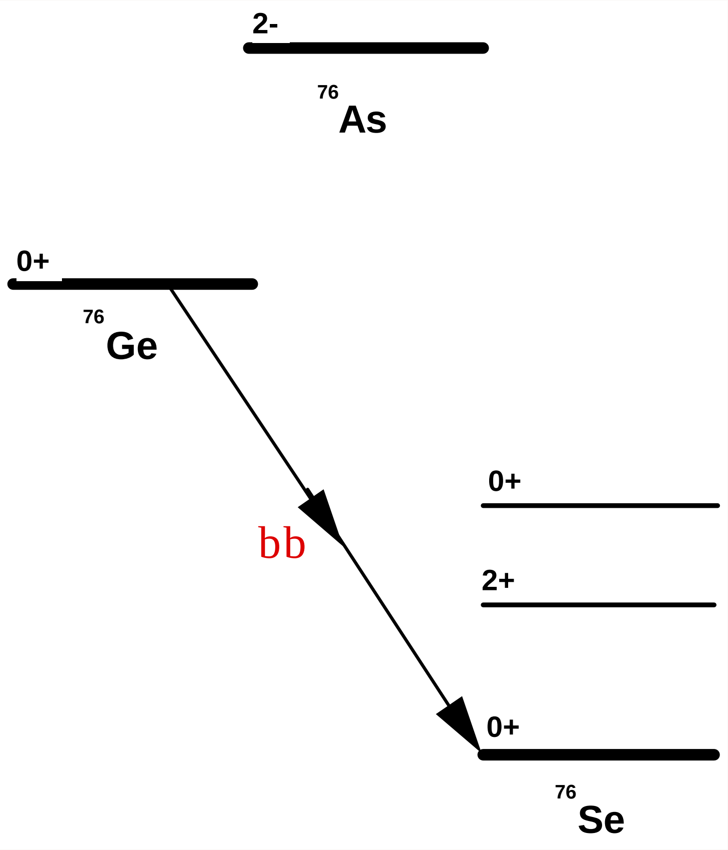
Inverse hierarchy

Normal hierarchy

Cosmological disfavoured Region (WMAP)

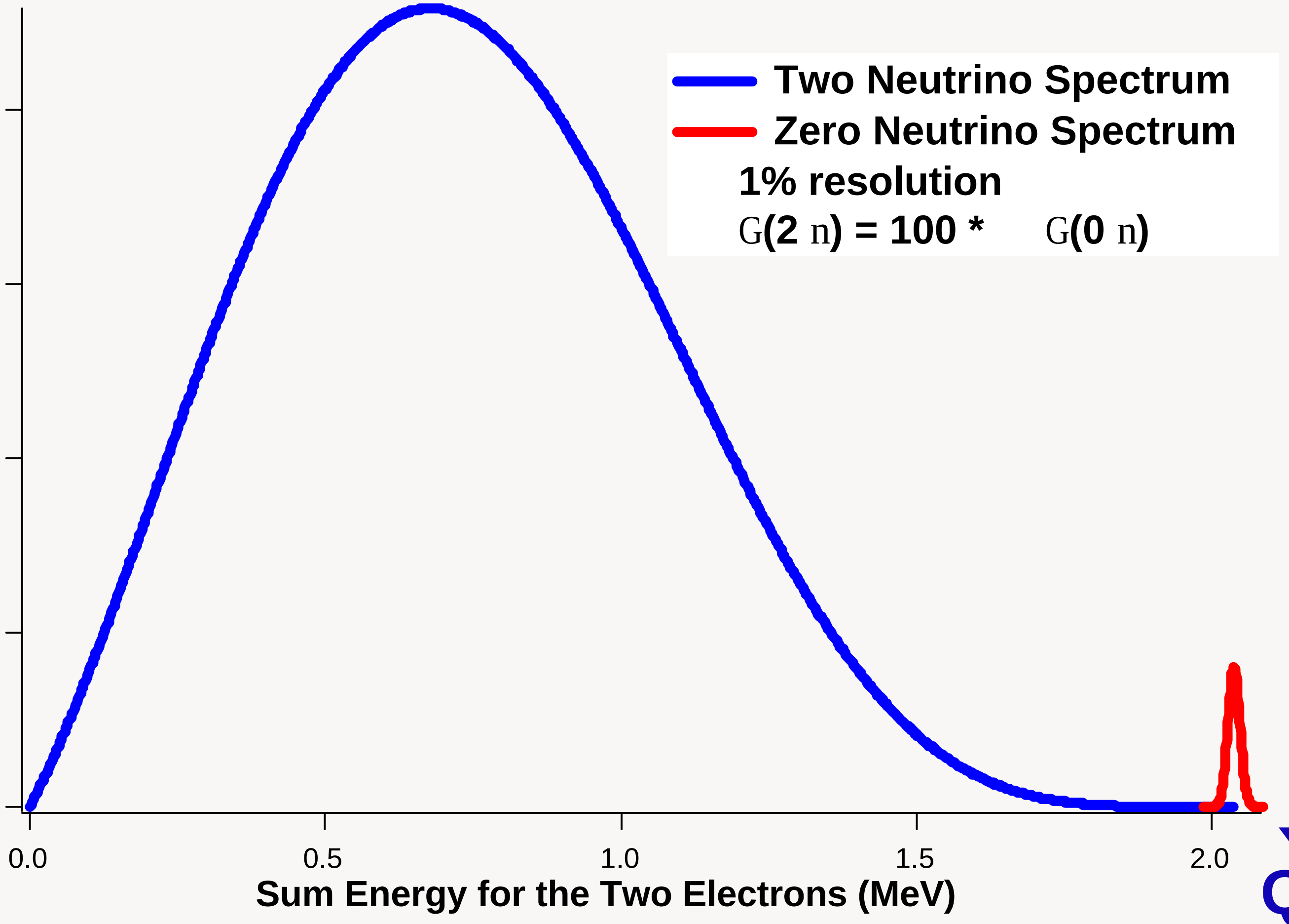
Double beta decay

- Large number of even-even nuclei undergo double-beta decay, but not single-beta decay
- This is a Standard Model process of 2νββ
- Enrichment procedure in place for about 10 isotopes
- 0νββ can therefore also occur
- Q value of this decay is well known (difference in energy between two isotopes)



double beta decay

^{76}Ge example



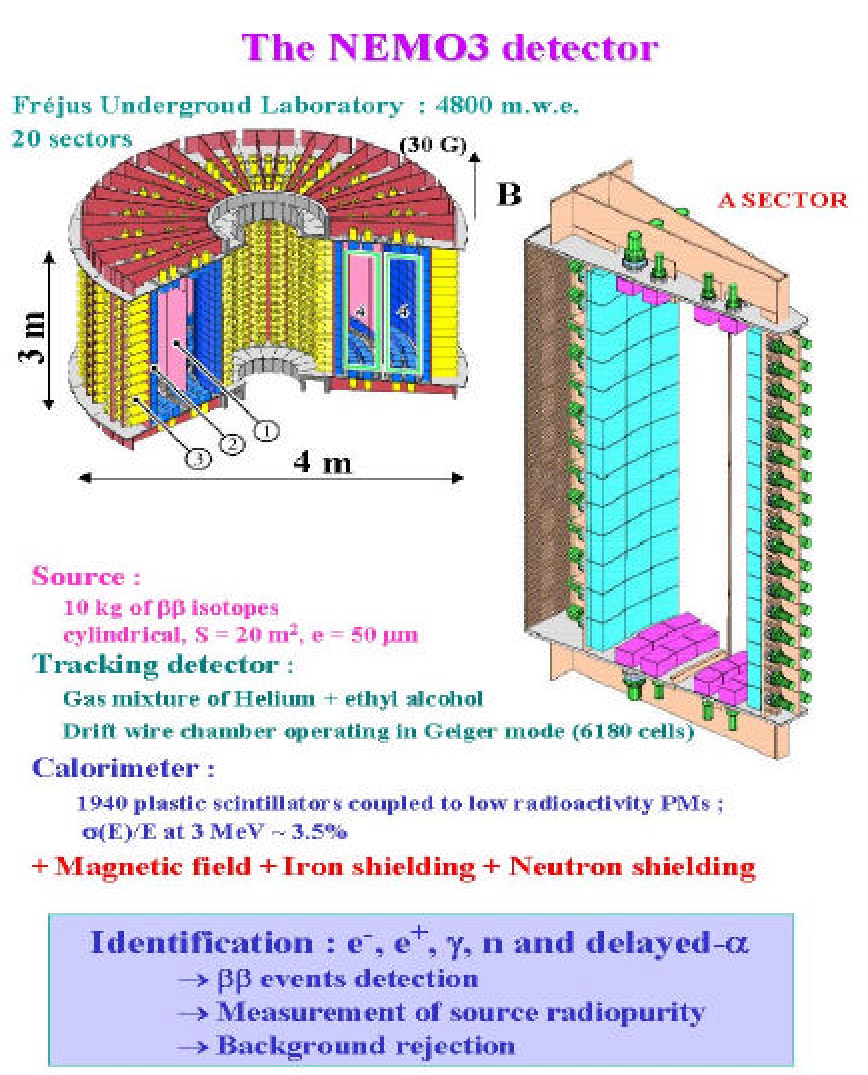
Q_{bb}

Endpoint Energy

Super NEMO

- Two classes of approach to the experiment:
  - Detector IS the isotope
  - Detector contains the isotope(s)
- Measure half-life, infer m_ν $\left[T^{0\nu}_{1/2}\right]^{-1} = G^{0\nu}\,|M^{0\nu}|^2 \langle m_\nu \rangle^2$
- Half life sensitivity given by experimental details
- G-phase space, exactly calculable: $G^{0\nu} \sim Q_{\beta\beta}{}^5$
- $M^{0\nu}$-Nuclear Matrix Element, hard to calculate
  - Uncertain to factor ~2-3 for interesting isotopes
  - Motivation to measure several isotopes

Super-NEMO: the idea



The NEMO3 detector

Fréjus Undergroud Laboratory : 4800 m.w.e.

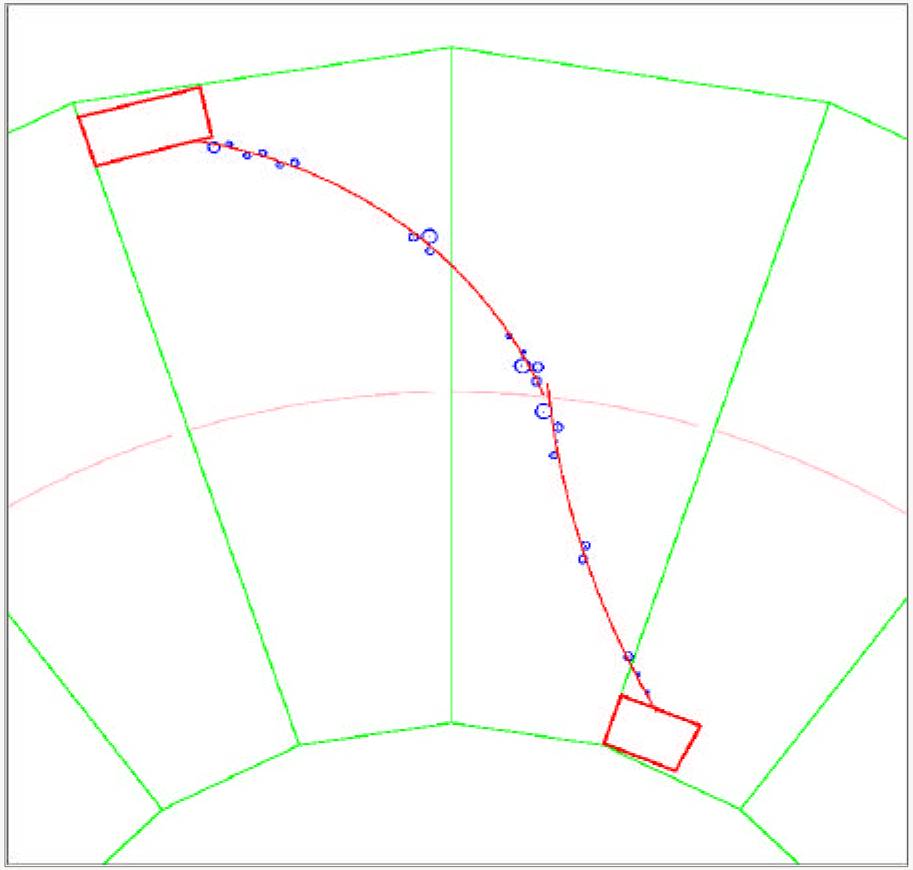
Source :
10 kg of ββ isotopes
cylindrical, S = 20 m², e = 50 μm

Tracking detector :
Gas mixture of Helium + ethyl alcohol
Drift wire chamber operating in Geiger mode (6180 cells)

Calorimeter :
1940 plastic scintillators coupled to low radioactivity PMs ;
σ(E)/E at 3 MeV ~ 3.5%

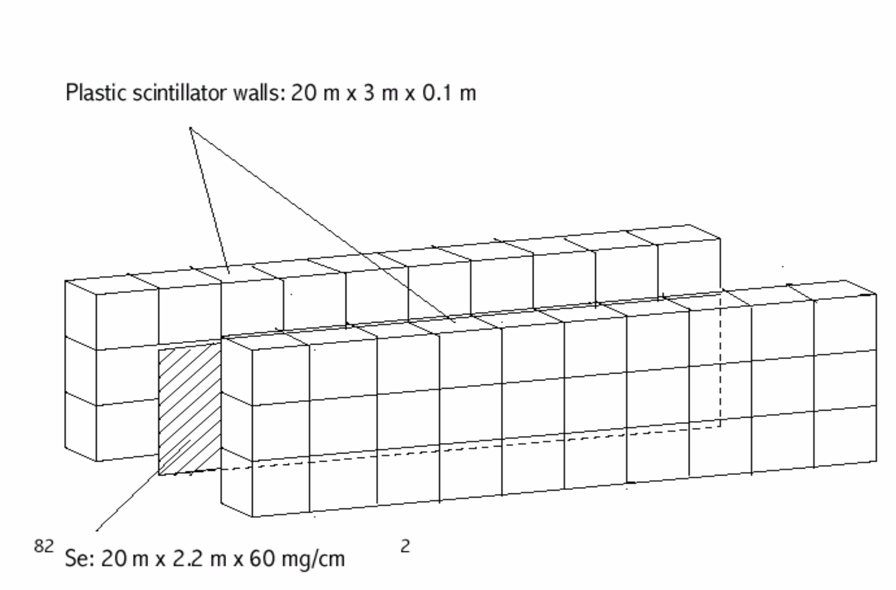
+ Magnetic field + Iron shielding + Neutron shielding

Identification : e⁻, e⁺, γ, n and delayed-α
→ ββ events detection
→ Measurement of source radiopurity
→ Background rejection



Located in Frejus Underground Lab

SuperNEMO Baseline Scenario



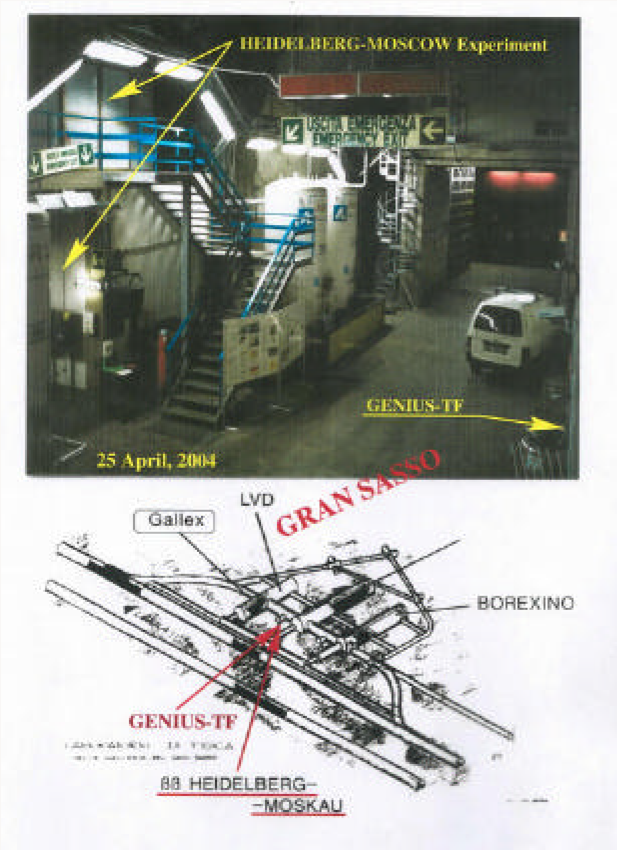
- 100 kg of ^{82}Se
- 5yr of data taking
- Background from 2ν tail only
- Sensitivity to $\langle m_\nu \rangle \sim 0.04 - 0.1$ eV depending on NME

Super-NEMO: the idea

- The plan is NOT to promote a completely new design:
  - ***Low energy electrons means keeping energy losses at a minimum: Helium+Geiger wires are the best solution***
  - ***Low background plastic scintillator production expertise exists with collaborators in Russia: irrespective of material***

Heidelberg-Moscow experiment

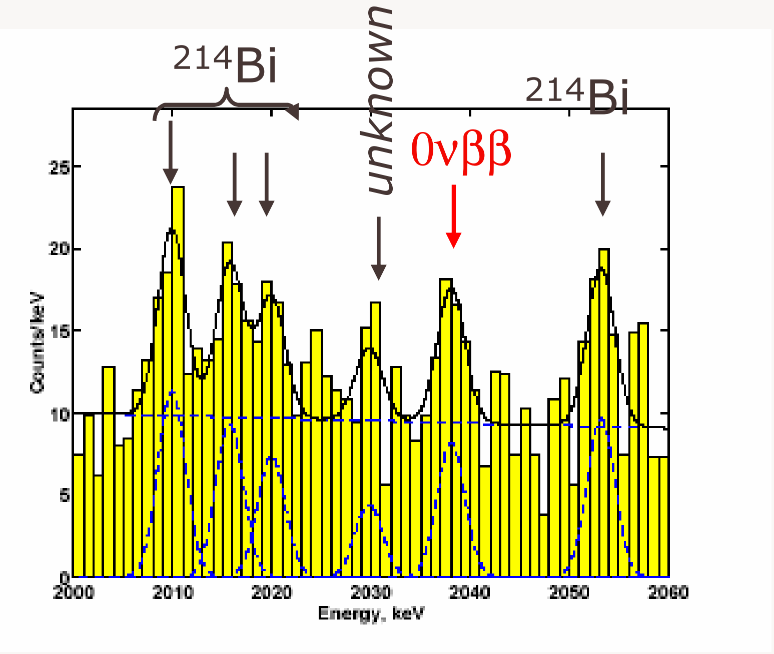
- Enriched Germanium ionisation detector




History of HEIDELBERG-MOSCOW

Heidelberg claim

hep-ph/0403018.



71.7 kg·yr

- New analysis provides evidence of a peak at the expected value
- Total 71.7kgy of data
- Significance is claimed to be 4.2 σ
- $m_\nu = 0.24$-0.58eV
- Corresponds to quasi-degenerate neutrino masses

Future Plans

- There are presently 15+ projects in various stages of R&D/planning/approval in Italy, Japan, US, France and perhaps other places, target ~0.05eV in mass
- The final mass sensitivity depends on the NME chosen

Tracking, TPC, Drift

- **DCBA Nd**
- **MOON Mo**
- **Super-NEMO Mo,Se,Nd**
- **EXO Xe**

Ionisation/Bolometer

- **Cobra, CdTe**
- **GEM**
- **GERDA**
- **CUORE**
- **Majorana**

Scintillator

- **CAMEO Cd**
- **GANDLES Ca**
- **CARVEL Cd**
- **GSO Gd**
- **Xe Xe…….**

CUORE is the only funded project (~80%)

Future Plans

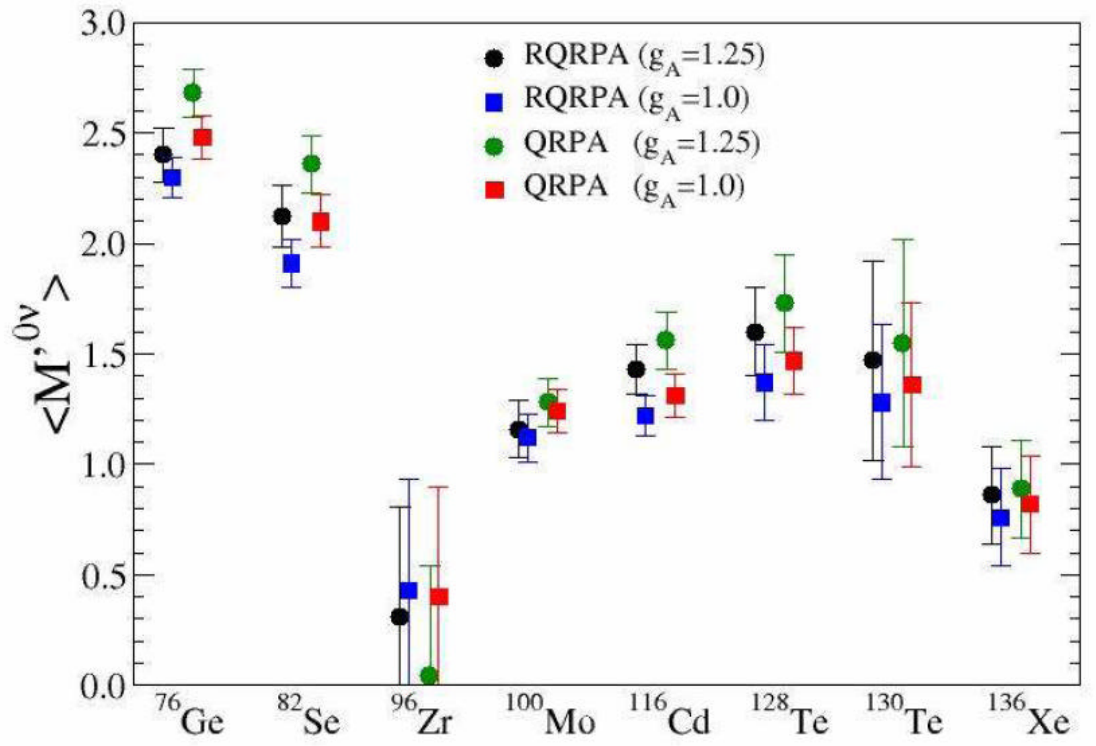
- Certain factors dominate reach
  - Some factors are intrinsic to a particular isotope (NME), others to the experimental approach

$$\left[T^{0\nu}_{1/2}\right]^{-1} = G^{0\nu} \left| M^{0\nu} \right|^2 \langle m_\nu \rangle^2$$

  - $T^{0\nu}_{1/2}$ given by experimental parameters: background, resolution, efficiency
  - The larger M, the lower the reach in m_ν

Recent developments in NME calculations are encouraging

Rodin, Faessler, Simcovic, Vogel, PRC 68 (2003) 044303
nucl-th/0503063.



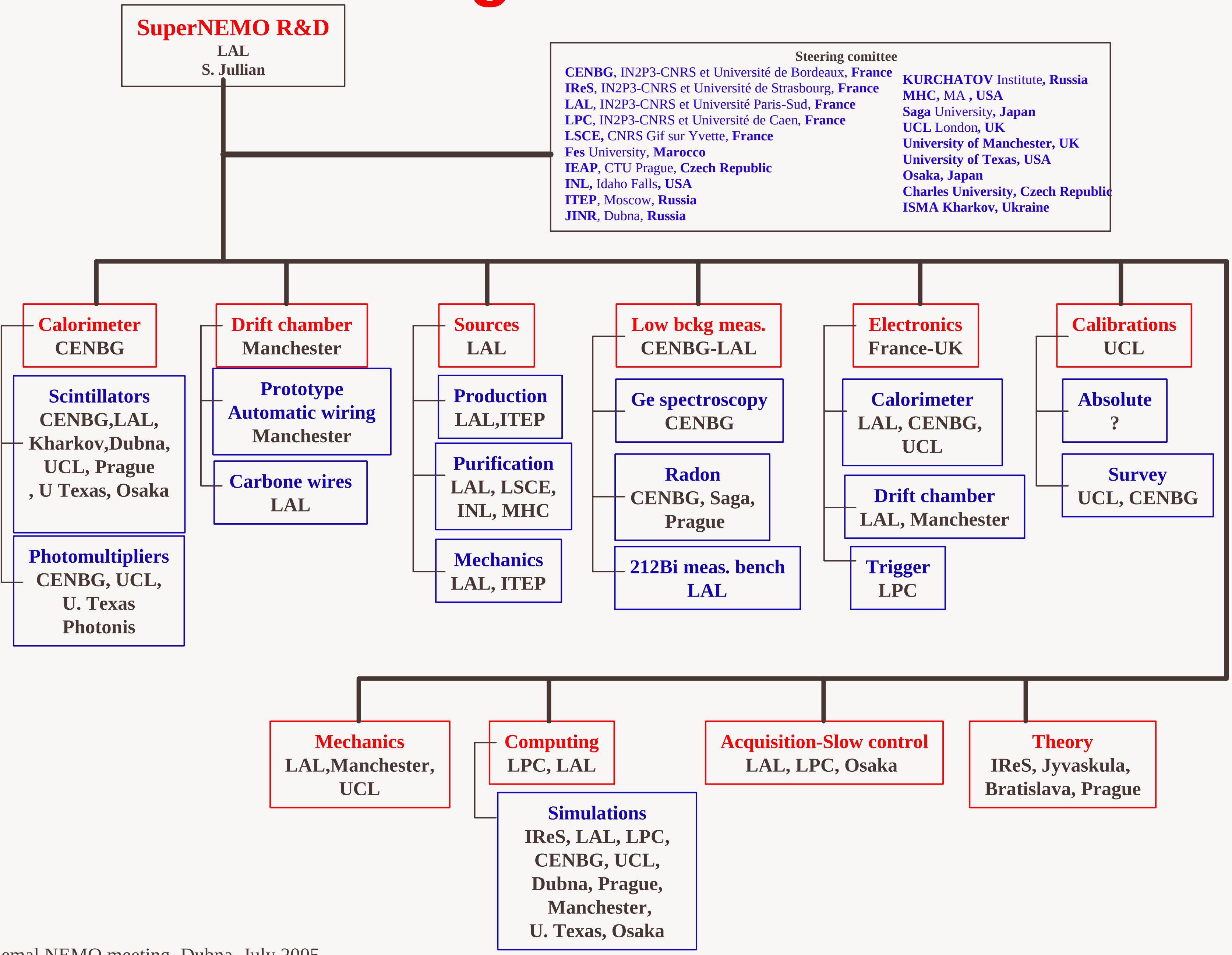
Error bars are from
experimental errors on $T_{1/2}^{2n}$

✓ g_{pp} fixed from *experimentally* measured $M^{2\nu}$
✓ Different calculations converge
✓ Underlines the importance of $2\nu\beta\beta$ *precise* measurements

Experiment	Source and Mass	Sensitivity to $T_{1/2}$ (y)	Sensitivity to $\langle m_\nu \rangle$(eV)*
Majorana $50M-100M	^{76}Ge, 500kg	3×10^{27}	0.03 – 0.07
CUORE $30M	^{130}Te, 750kg(nat)	2×10^{26}	0.04 – 0.17
EXO $50M-100M	^{136}Xe 1 ton	8×10^{26}	0.05 – 0.12
SuperNEMO **$40M**	**^{82}Se(or other)** **100 kg**	**2×10^{26}**	**0.04 – 0.08**

* 5 different *latest* NME calculations

Organisation



SuperNEMO R&D
LAL
S. Jullian

Steering comittee

CENBG, IN2P3-CNRS et Université de Bordeaux, **France**
IReS, IN2P3-CNRS et Université de Strasbourg, **France**
LAL, IN2P3-CNRS et Université Paris-Sud, **France**
LPC, IN2P3-CNRS et Université de Caen, **France**
LSCE, CNRS Gif sur Yvette, **France**
Fes University, **Marocco**
IEAP, CTU Prague, **Czech Republic**
INL, Idaho Falls**, USA**
ITEP, Moscow, **Russia**
JINR, Dubna, **Russia**
KURCHATOV Institute**, Russia**
MHC, MA **, USA**
Saga University**, Japan**
UCL London**, UK**
University of Manchester, UK
University of Texas, USA
Osaka, Japan
Charles University, Czech Republic
ISMA Kharkov, Ukraine

Calorimeter
CENBG

- **Scintillators**
  CENBG,LAL, Kharkov,Dubna, UCL, Prague , U Texas, Osaka
- **Photomultipliers**
  CENBG, UCL, U. Texas Photonis

Drift chamber
Manchester

- **Prototype Automatic wiring**
  Manchester
- **Carbone wires**
  LAL

Sources
LAL

- **Production**
  LAL,ITEP
- **Purification**
  LAL, LSCE, INL, MHC
- **Mechanics**
  LAL, ITEP

Low bckg meas.
CENBG-LAL

- **Ge spectroscopy**
  CENBG
- **Radon**
  CENBG, Saga, Prague
- **212Bi meas. bench**
  LAL

Electronics
France-UK

- **Calorimeter**
  LAL, CENBG, UCL
- **Drift chamber**
  LAL, Manchester
- **Trigger**
  LPC

Calibrations
UCL

- **Absolute**
  ?
- **Survey**
  UCL, CENBG

Mechanics
LAL,Manchester, UCL

Computing
LPC, LAL

- **Simulations**
  IReS, LAL, LPC, CENBG, UCL, Dubna, Prague, Manchester, U. Texas, Osaka

Acquisition-Slow control
LAL, LPC, Osaka

Theory
IReS, Jyvaskula, Bratislava, Prague

F. Piquemal NEMO meeting, Dubna, July 2005

UK involvement

- The UK group is a significant part of the international Super-NEMO collaboration
  - Only 2-3 countries will make major financial contributions
- ***This proposal is part of a coordinated approach with the French to start Super-NEMO***
- UK/French groups agreed (meeting in Manchester Jan-2005) on the sharing of the main work

Why Super-NEMO now?

- There are other experiments starting up now:
  - US has identified this field as a priority
  - So far only CUORE has been approved by Italy
- Using tried and tested technology Super-NEMO can start fast
  - Design study driven by physics
  - Being first to measure several isotopes would be a major coup
- If any signal seen in any isotope, it will HAVE to be observed by this type of experiment to be sure it is $0\nu\beta\beta$

Academic effort

- Present
  - Ruben Saakyan – 80%
  - Jenny Thomas – 40%
  - Stefan Soldner-Rembold – 25%
  - Apostolos Pilaftsis – 10%
- Increase in near future
  - Julia Sedgbeer (IC) – simulation and reconstruction software
    - 80% starting in 2006 Academic year
    - contingent on the subsequent bid to PPRP
  - Effort in UCL to be increased
  - Possible additional academic effort from Manchester

Conclusions

- Very exciting time for neutrino physics in general and $0\nu\beta\beta$ in particular
- A positive signal is now a serious possibility in light of oscillation results
- Costs of experiments all in the £25M range: this is small potatoes for the potential scientific gain

The Request

- UK: Tracker Construction, Scintillator R&D
    - Wire stringing robot : key to the manpower problem of ~60000 anode wires + cathodes
    - Wire thickness/length R&D, wire electronics
    - Mechanical design of tracker frame
    - Continuation of R&D/PMT development
    - Calibration (light injection survey and absolute calibration)

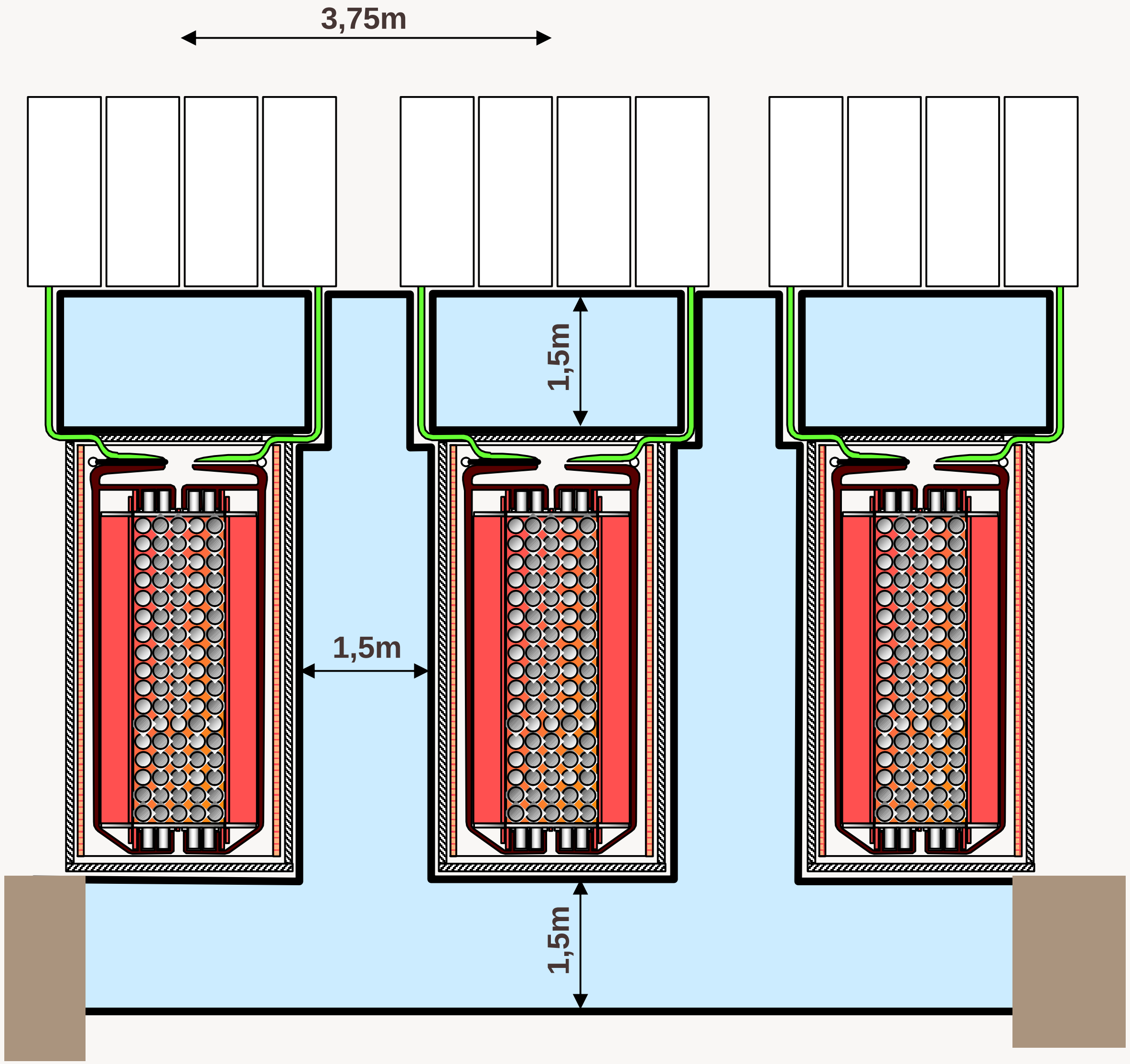
- France : Calorimeter construction, some tracker R&D, ββ sources, low background measurements
- ALL : Conceptual design studies, impact on site decision

The Request

- Calorimeter hardware £47k
- Tracker hardware £163k
- Light Injection system £10k
- 2 New posts £174k
- MSSL technical and engineering staff £210k
- Travel £80k
- Total £684k

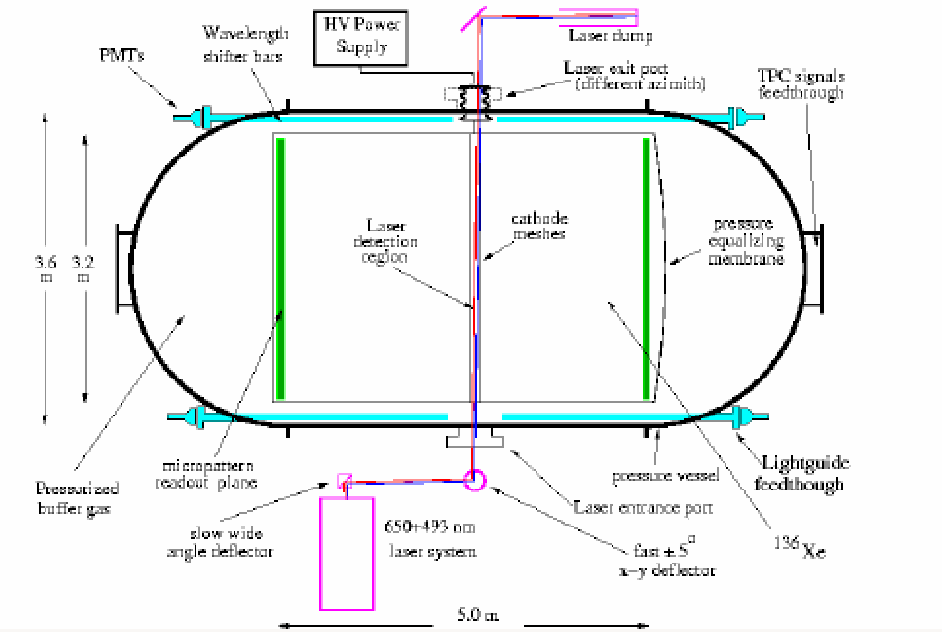
Summary

- The manpower estimate has been from bottom-up and from top-down : confident that manpower request is warranted (see new table)
- Expertise in tracking at Manchester/UCL, Scintillator at UCL
- ***Technical expertise in low background issues is something which will be acquired at UCL-MSSL/Manchester in collaboration with French experts: not as stringent as for source=detector approach.***
- Important new field and UK must get this technical expertise


3,75m
1,5m
1,5m
1,5m

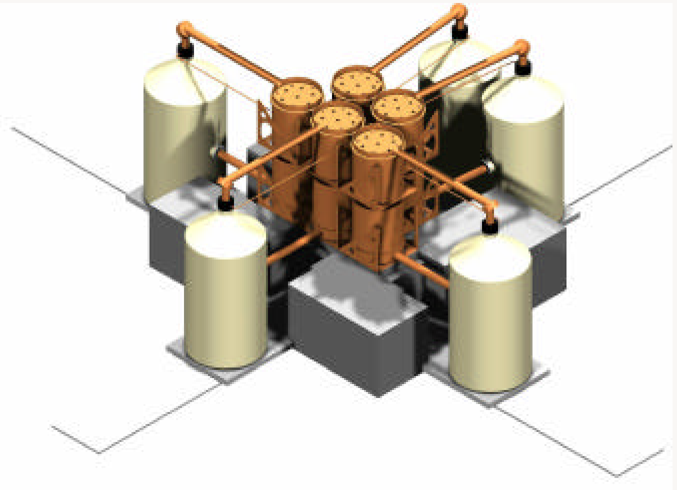
Future Plans : EXO

- High Pressure Xe TPC with laser tagging of +Ba daughter for background-free measurement
- 2 Tonne of ^{136}Xe at 10Atm or Liq Xe with cold-finger tagging
- Energy resolution 2% at 2.5MeV
- 200kg prototype of Liq Xe funded by DoE (no tagging) will be built at WIPP, New Mexico.
- 200kg isotope already in hand



Future Plans : Majorana/MPI

- 500kg enriched segmented conventional Ge detector
- Feasability has been demonstrated, waiting fo approval
- Will use pulse-shape information to reduce background
- Based on theory that dominant background is ^{68}Ge from cosmogenics



- MPI-Ge experiment also proposed
- Uses Ge mono-crystal in Liquid N or Ar for passive/active shielding
- Based on theory that dominant background is from Cu etc external to

Introduction:the isotopes

- What are the usable bb decay isotopes?
  - ^{76}Ge, Q=2.038MeV : MG = $7.3^{+0.6}_{-0.6} \times 10^{-14}$
  - ^{48}Ca,Q = 4.272MeV :MG = $5.4^{+3.0}_{-1.4} \times 10^{-14}$
  - ^{82}Se, Q = 2.995MeV : MG = $1.7^{+0.4}_{-0.3} \times 10^{-13}$
  - ^{100}Mo, Q = 3.034MeV :MG = $1.0^{+0.3}_{-0.3} \times 10^{-12}$
  - ^{116}Cd,Q = 2.804MeV :MG = $1.3^{+0.7}_{-0.3} \times 10^{-13}$
  - ^{130}Te,Q = 2.528MeV :MG = $4.2^{+0.5}_{-0.5} \times 10^{-13}$
  - ^{136}Xe,Q = 2.481MeV :MG = $2.8^{+0.4}_{-0.4} \times 10^{-14}$
  - ^{150}Nd,Q = 3.368MeV: MG = $5.7^{+1.0}_{-0.7} \times 10^{-12}$
- These can all be enriched by standard processes