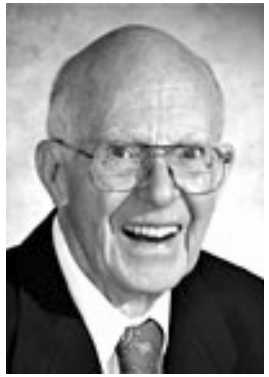
Nuclear Science & the New Standard Model:

Neutrinos & Fundamental Symmetries in the Next Decade

Fifty years of PV in nuclear physics

The next decade presents NP with a historic opportunity to build on this legacy in developing the "new Standard Model"

The value of our contribution will be broadly recognized outside the field



Solar νs & the neutrino revolution

Michael Ramsey-Musolf, NSAC March, 2007

Community Input

- *Pre-Town Meetings:*
  - *Santa Fe Nov 2006*
  - *Caltech Dec 2006*
- *DNP Town Meeting*
  - *Chicago Jan 2007*
- *White paper (merging two)*

Substantial work by the organizing committee

Scientific Questions, Achievements & Challenges

Primary Scientific Questions

- *What are the masses of neutrinos and how have they shaped the evolution of the universe?* $0\nu\beta\beta$ *decay,* θ_{13}, β *decay,…*
- *Why is there more matter than antimatter in the present universe? EDM, DM, LFV,* $0\nu\beta\beta$, θ_{13} *…*
- *What are the unseen forces that disappeared from view as the universe cooled? Weak decays, PVES,* g_μ*-2,…*

Tribble report

Related Scientific Questions

- *What is the internal landscape of the proton? PVES, hadronic PV, ν scattering,…*
- *What causes stars to explode? Large scale supernova simulations, ν flavor transformation…*
- *What is the origin of the heavy elements from iron to uranium? Weak interactions and ν interactions in heavy nuclei,…*

Tribble report

Scientific Achievements

- *Discovery of flavor oscillations in solar neutrinos; Solution of the solar neutrino problem; 1300+ citations*
- *Discovery of flavor oscillations in reactor neutrinos; Identification of LMA solution; over 1000 citations*
- *World's most precise measurement of (g_μ-2) Possible first indications of supersymmetry; over 1000 citations*
- *Most precise measurement of $\sin^2\theta_W$ off the Z^0 resonance using PV Moller scattering; constrains new physics at the TeV scale (Z', RPV SUSY…)*

Scientific Achievements

- *Definitive determinations of strange quark contributions to nucleon EM form factors using PV electron-proton & electron-nucleus scattering; confirmed theoretical estimates of hadronic effects in electroweak radiative corrections*
- *Quark-lepton universality tested to 0.05% using superallowed nuclear β-decay, yielding most precise value of any CKM matrix element (V_{ud})*
  2006 Bonner Prize in Nuclear Physics recognizing work of Towner & Hardy

Scientific Achievements

- *Completion of a comprehensive set of computations of supersymmetric effects in low-energy electroweak observables; 2005 Dissertation Award in Nuclear Physics to A. Kurylov*
- *Reduction in the theoretical hadronic uncertainty in extraction of V_{ud} from neutron and nuclear β-decay*
- *New theoretical breakthroughs in simulating neutrino flavor transformation in supernovae; modeling ν flavor transformation effects nucleosynthesis with SN's; understanding weak interaction effects in SN shock dynamics*

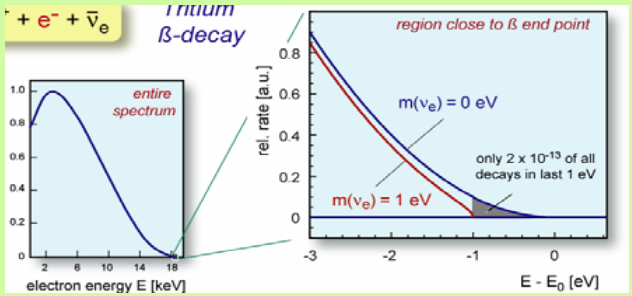
Scientific Achievements

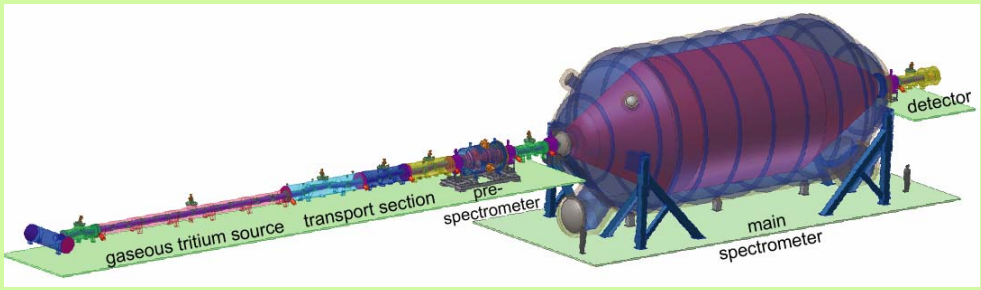
- *Development of a EFT treatments of parity violation in the nucleon-nucleon interaction that will guide the future experimental program at the SNS and NIST*
- *Reduction in theoretical uncertainty in QRPA computations of $0\nu\beta\beta$ decay matrix elements*
- *Substantial technical developments opening the way for searches for the permanent EDMs of the neutron, neutral atoms, deuteron and electron with 2-4 orders of magnitude greater sensitivity*

Technological Achievements & Investments

β-decay: Neutrino Mass

KATRIN, NexTex, MARE…





Total Lepton Number & Neutrino Mass Term

0νββ-decay

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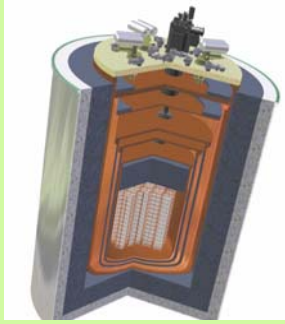

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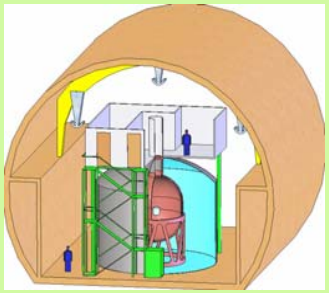
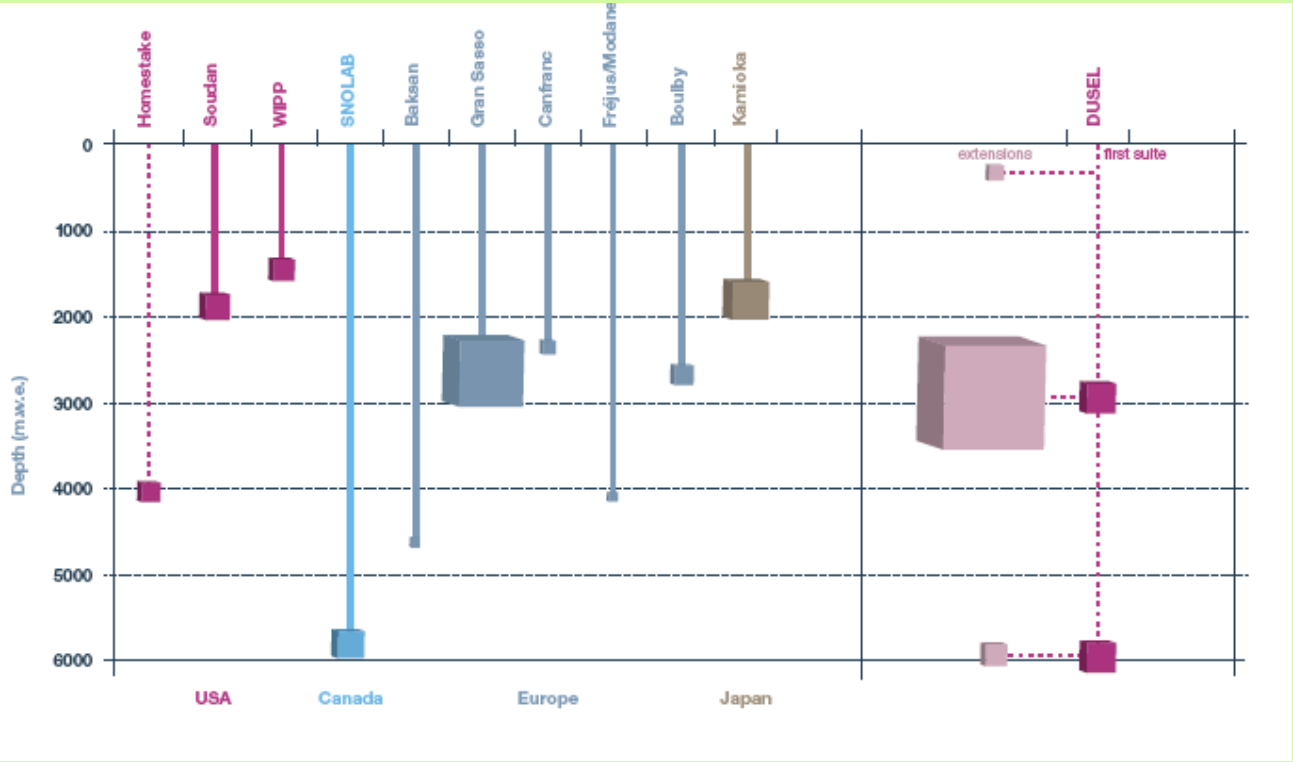


Majorana *CUORE* *EXO* *GERDA*

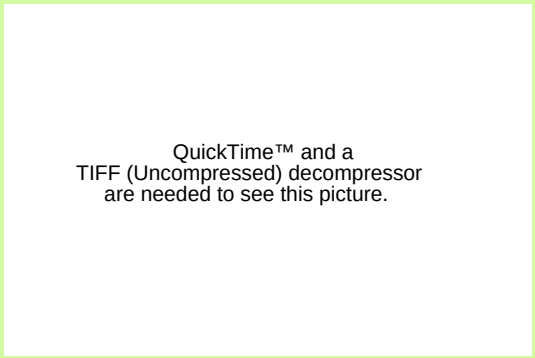
Technological Achievements & Investments

Multi-purpose Facility

DUSEL



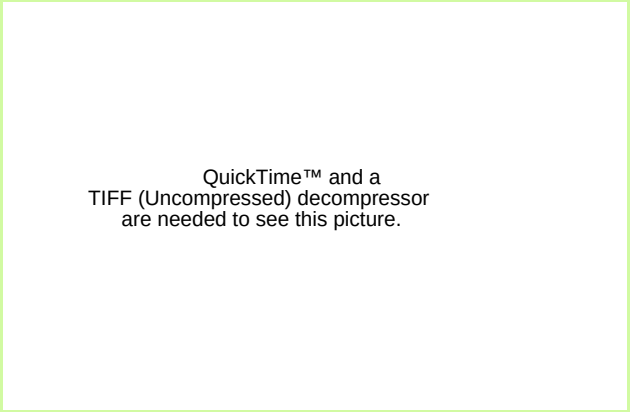
Technological Achievements & Investments

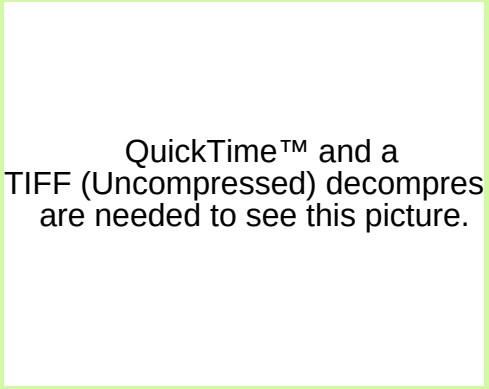


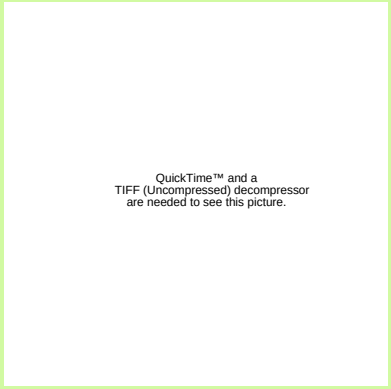
Fundamental Neutron Physics Beamline at SNS

1.4 MW , 1 GeV H^- beam on L Hg

Also new capabilities at LANSCE, NIST…







CEBAF 12 GeV Up-grade

Muon storage ring at BNL

ISAAC, RIAcino….

Challenges: *What role can low energy studies play in the LHC era ? (and beyond!)*

Two frontiers in the search for new physics

Collider experiments (pp, e^+e^-, etc) at higher energies ($E >> M_Z$)

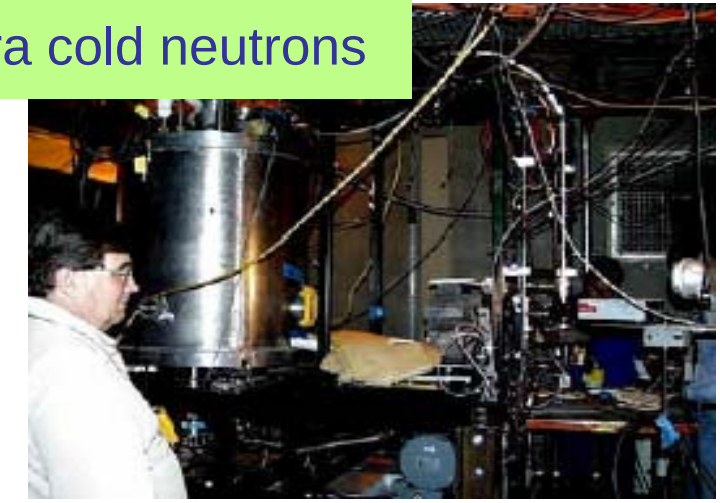
Large Hadron Collider

CERN

High energy physics

Indirect searches at lower energies ($E < M_Z$) but high precision

Ultra cold neutrons



Particle, nuclear & atomic physics