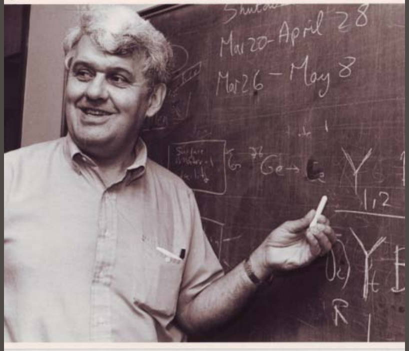
TRIUMF

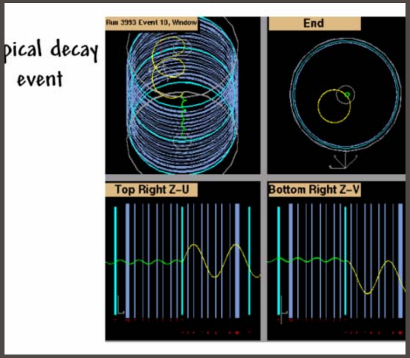
Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire
et en physique des particules



E.Vogt and Particle physics

Past ,present and future Searches for Physics Beyond the Standard Model at TRIUMF

Jean-Michel POUTISSOU, Research Scientist Emeritus



Accelerating Science for Canada
Un accélérateur de la démarche scientifique canadienne

Owned and operated as a joint venture by a consortium of Canadian universities via a contribution through the National Research Council Canada
Propriété d'un consortium d'universités canadiennes, géré en co-entreprise à partir d'une contribution administrée par le Conseil national de recherches Canada

Leadership

- **Leadership is not about driving the train but about laying down the tracks**
- Examples:
  - TRIUMF initial funding and organization
  - TRIUMF as an international laboratory
  - KAON

  - TRIUMF as a multidisciplinary laboratory
  - TRIUMF and Technology transfer office
  - TRIUMF and Universities: expanding the consortium
  - Community reach :
    - Science world
    - BC science council
    - Vancouver institute

Leadership is not about driving the train but about laying down the tracks

Particle physics at TRIUMF

- The early years
- The KAON years
- The Higgs years
- The BSM years

The early years (1975-85)

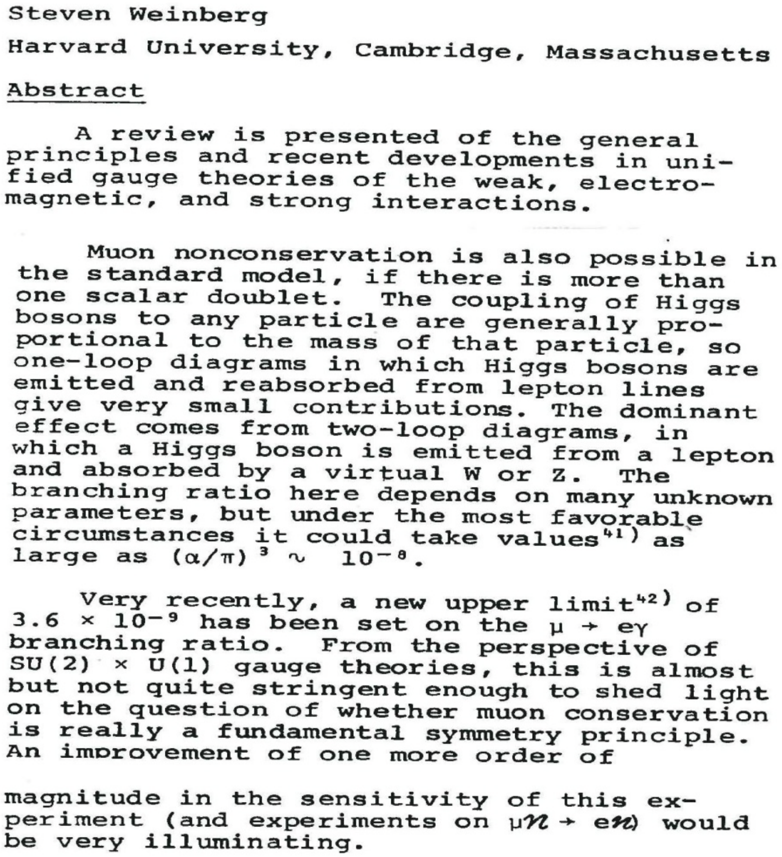
- **Meson factory years**

- From the beginning, weak interaction studies were part of the TRIUMF research program.
- U.Vic pienu branching ratio and rare Mu to E conversion
- U de Montreal rare pion/muon decays
- Berkeley muon decay precision measurements

Meson Factories

- LAMPF
  - MEGA (μ-> eγ)
- SIN/PSI
  - μ-> eγ, μ-> e+e+e-, SINDRUM
  - -MEG
- TRIUMF
  - μ->e$\gamma\gamma$, π–>eν, μN–>eN
- KEK/PS
- INR(Troisk)

The Zurich meeting (1977)



Steven Weinberg

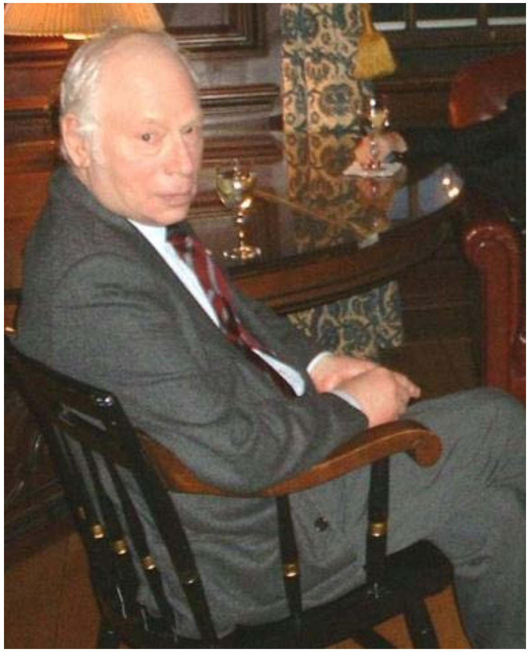
Harvard University, Cambridge, Massachusetts

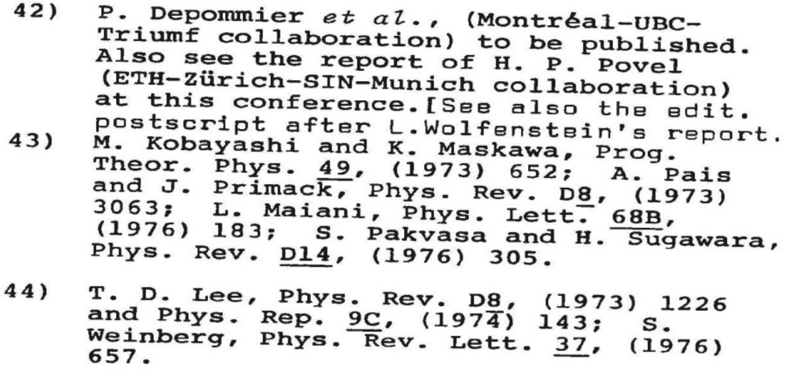
Abstract

A review is presented of the general principles and recent developments in unified gauge theories of the weak, electromagnetic, and strong interactions.

Muon nonconservation is also possible in the standard model, if there is more than one scalar doublet. The coupling of Higgs bosons to any particle are generally proportional to the mass of that particle, so one-loop diagrams in which Higgs bosons are emitted and reabsorbed from lepton lines give very small contributions. The dominant effect comes from two-loop diagrams, in which a Higgs boson is emitted from a lepton and absorbed by a virtual W or Z. The branching ratio here depends on many unknown parameters, but under the most favorable circumstances it could take values[41] as large as $(\alpha/\pi)^3 \sim 10^{-8}$.

Very recently, a new upper limit[42] of 3.6×10^{-9} has been set on the $\mu \to e\gamma$ branching ratio. From the perspective of SU(2) × U(1) gauge theories, this is almost but not quite stringent enough to shed light on the question of whether muon conservation is really a fundamental symmetry principle. An improvement of one more order of magnitude in the sensitivity of this experiment (and experiments on $\mu\mathcal{N} \to e\mathcal{N}$) would be very illuminating.



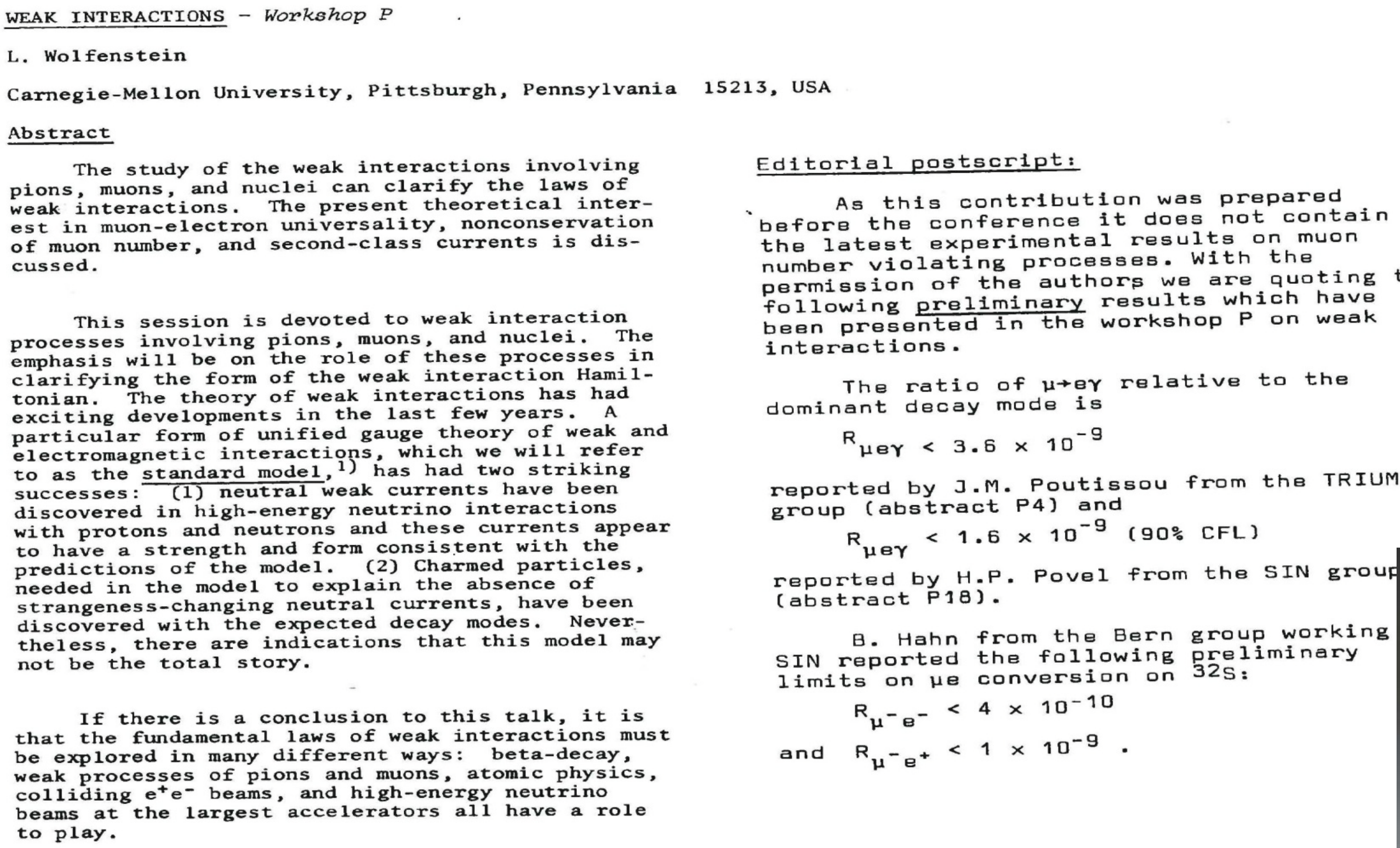


42) P. Depommier *et al.*, (Montréal-UBC-Triumf collaboration) to be published. Also see the report of H. P. Povel (ETH-Zürich-SIN-Munich collaboration) at this conference. [See also the edit. postscript after L. Wolfenstein's report.

43) M. Kobayashi and K. Maskawa, Prog. Theor. Phys. 49, (1973) 652; A. Pais and J. Primack, Phys. Rev. D8, (1973) 3063; L. Maiani, Phys. Lett. 68B, (1976) 183; S. Pakvasa and H. Sugawara, Phys. Rev. D14, (1976) 305.

44) T. D. Lee, Phys. Rev. D8, (1973) 1226 and Phys. Rep. 9C, (1974) 143; S. Weinberg, Phys. Rev. Lett. 37, (1976) 657.

The Zurich meeting



WEAK INTERACTIONS – *Workshop P*

L. Wolfenstein

Carnegie-Mellon University, Pittsburgh, Pennsylvania 15213, USA

Abstract

The study of the weak interactions involving pions, muons, and nuclei can clarify the laws of weak interactions. The present theoretical interest in muon-electron universality, nonconservation of muon number, and second-class currents is discussed.

This session is devoted to weak interaction processes involving pions, muons, and nuclei. The emphasis will be on the role of these processes in clarifying the form of the weak interaction Hamiltonian. The theory of weak interactions has had exciting developments in the last few years. A particular form of unified gauge theory of weak and electromagnetic interactions, which we will refer to as the standard model,1) has had two striking successes: (1) neutral weak currents have been discovered in high-energy neutrino interactions with protons and neutrons and these currents appear to have a strength and form consistent with the predictions of the model. (2) Charmed particles, needed in the model to explain the absence of strangeness-changing neutral currents, have been discovered with the expected decay modes. Nevertheless, there are indications that this model may not be the total story.

If there is a conclusion to this talk, it is that the fundamental laws of weak interactions must be explored in many different ways: beta-decay, weak processes of pions and muons, atomic physics, colliding e^+e^- beams, and high-energy neutrino beams at the largest accelerators all have a role to play.

Editorial postscript:

As this contribution was prepared before the conference it does not contain the latest experimental results on muon number violating processes. With the permission of the authors we are quoting the following preliminary results which have been presented in the workshop P on weak interactions.

The ratio of $\mu \to e\gamma$ relative to the dominant decay mode is

$$R_{\mu e\gamma} < 3.6 \times 10^{-9}$$

reported by J.M. Poutissou from the TRIUMF group (abstract P4) and

$$R_{\mu e\gamma} < 1.6 \times 10^{-9} \quad (90\% \text{ CFL})$$

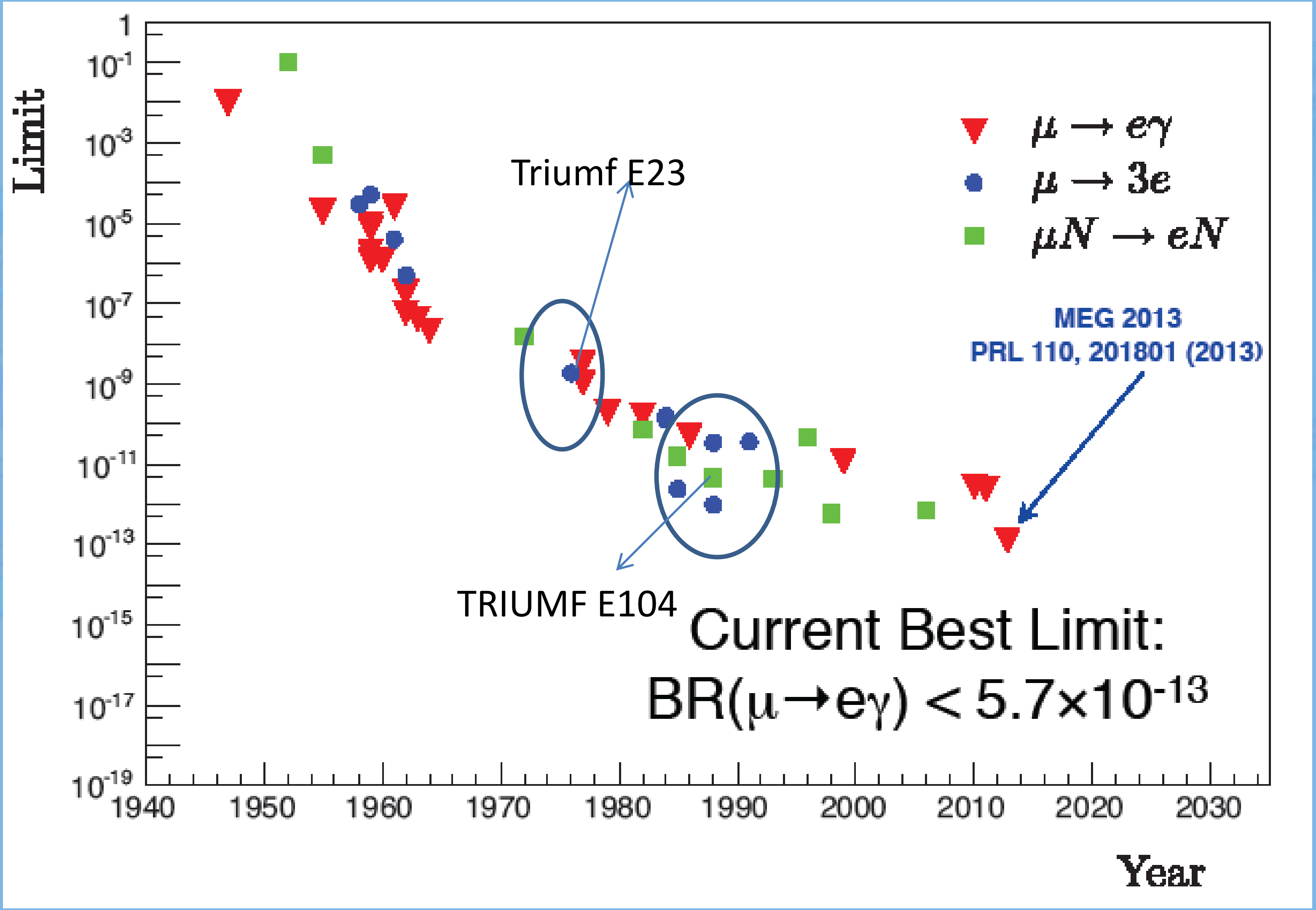
reported by H.P. Povel from the SIN group (abstract P18).

B. Hahn from the Bern group working SIN reported the following preliminary limits on μe conversion on ^{32}S:

$$R_{\mu^- e^-} < 4 \times 10^{-10}$$

and $R_{\mu^- e^+} < 1 \times 10^{-9}$.

Muon CLFV Searches



Triumf E23

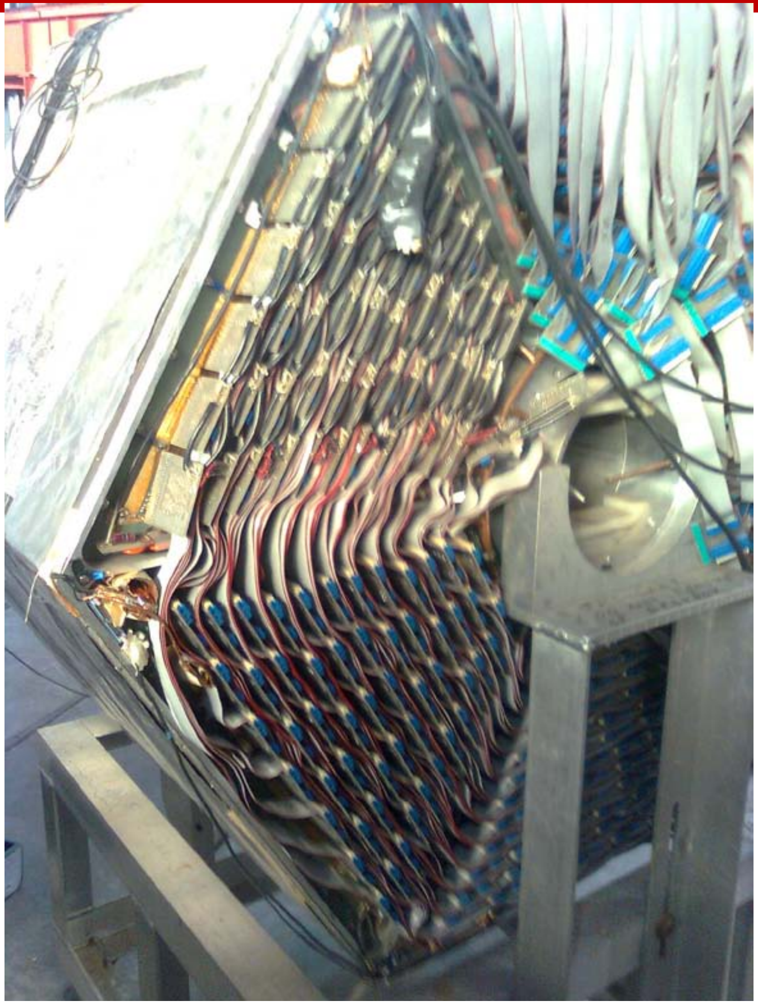
TRIUMF E104

MEG 2013
PRL 110, 201801 (2013)

Current Best Limit:

$BR(\mu \to e\gamma) < 5.7\times10^{-13}$

E104: $\mu N \to eN$ conversion (1978-1984) at TRIUMF



Many new technologies

- First TPC use in an experiment.
- RF separator
- High density read out
- Data acquisition
- VOGT counter

Led to:

- Hermes TRD’s chambers
- RMC drift chamber
- E787 drift chamber
- Babar drift chamber
- T2K TPC’s

Pion and Muon decay experiments

pienu (1), pienu(2), pienugamma, K.Crowe, M.Strovink, Twist, Pienu (3)

Partnership with US groups

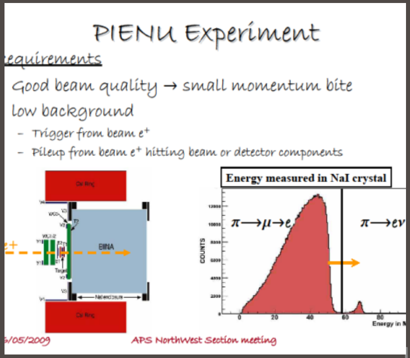

VOLUME 34, NUMBER 7

arch for right-handed currents in muon dec

,* B. Balke, J. Carr,† G. Gidal, K. A. Shinsky,‡ H. M
D. P. Stoker,§ M. Strovink, and R. D. Tripp
atory and Department of Physics, University of California, B

B. Gobbi
ment of Physics, Northwestern University, Evanston, Illinois

C. J. Oram
TRIUMF, Vancouver, British Columbia V6T 2A3, Canada
(Received 27 May 1986)


PIENU Experiment

equirements

Good beam quality → small momentum bite

low background

- Trigger from beam e^+
- Pileup from beam e^+ hitting beam or detector components

/05/2009 APS NorthWest Section meeting

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BSM search / Universality test

$$\Gamma_{\pi\to l+\nu_l} = G^2\frac{m_{\pi^+} f_{\pi^+}^2 m_l^2}{8\pi}(1-\frac{m_l^2}{m_{\pi^+}^2})^2[1+RC] \quad ; \quad \frac{G}{\sqrt{2}} = \frac{g_l^2}{8M_{W^+}}$$

$$\boxed{1-\frac{R^{New}_{e/\mu}}{R^{SM}_{e/\mu}} \sim \mp\frac{\sqrt{2}\pi}{G_\mu}\frac{1}{\Lambda^2_{eP}}\frac{m_\pi^2}{m_e(m_d+m_u)}}$$

$$\boxed{\sim (\frac{1TeV}{\Lambda_{eP}})^2 \times 10^3}$$

0.1% measurement → Λ_{eP}~ 1000 TeV

Massive ν's

R.E Schrock Phys.Rev.D 24, 5 (1981)

Scalar coupling

B.A. Campbell & David W. Maybury Nucl. Phys. B, 709 419-439 (2005)

R-Parity violation SUSY

M. J. Ramsey-Musolf, S. Su & S.Tulin, Phys. Rev. D 76, 095017 (2007)

...

Decay mode	$(g_\mu/g_e)^2$
$\tau\to\mu/\tau\to e$ *	1.0018 ± 0.0014
$\pi\to\mu/\pi\to e$ *	1.0021 ± 0.0016
$K\to\mu/K\to e$	0.9960 ± 0.005
$K\to\pi\mu/K\to\pi e$	1.002 ± 0.002
$W\to\mu/W\to e$	0.997 ± 0.010

* τ and π are complementary

Pion branching ratio is **one of the most precise** test of CC lepton universality

0.1% measurement in the BR → 0.05% in g_e/g_μ

- Real deviation from the SM → new physics observation
- Agreement with SM → constraints

Internationalization of the TRIUMF program

- To secure international contributions to KAON, Erich pushed for expanding the TRIUMF program beyond that on the cyclotron and supported an active external program:
  - Rare decays at TRIUMF moved to BNL (ex 787/949)
  - Parity Violation in p-p moved to Q-weak at TJNAF
  - Pol 3He program led to Hermes at HERA
- Physics studies during KAON led to
  - Neutrino BNL proposal(failed to be funded) and T2K
  - Kaon resonances studies at BNL and KEK
  - Antiproton studies at KAON led to ALPHA
  - Rare decays at BNL, KEK, J-PARC?

HERA model

- Erich introduces the so called “HERA Model” which was used to bring Canada into Hera and to support the Canadian participation in ZEUS and HERMES experiments in the early 80’s.
- It calls for contributions to both the accelerator and the detector/data analysis systems.
- This was the model Erich wanted for KAON.
- This model is the basis for the Canadian Participation in ATLAS/LHC, T2K/J-PARC.
- To some degree, It is the basis of the FAIR business model.

Connecting with world's physics drivers

1988 Kaon symposium: Erich shares a log with V.Soergel,(DESY), L. Maiani(Cern) and boat captain in Centre Bay on Gambier island.

Towards the HIGGS years

- TRIUMF-LHC contribution:
  - Cern-TRIUMF collaboration during KAON PDS led to TRIUMF-CERN contribution to the LHC
- ATLAS-CANADA
  - End Cap calorimeter
- TRIUMF Tier-1 computing centre

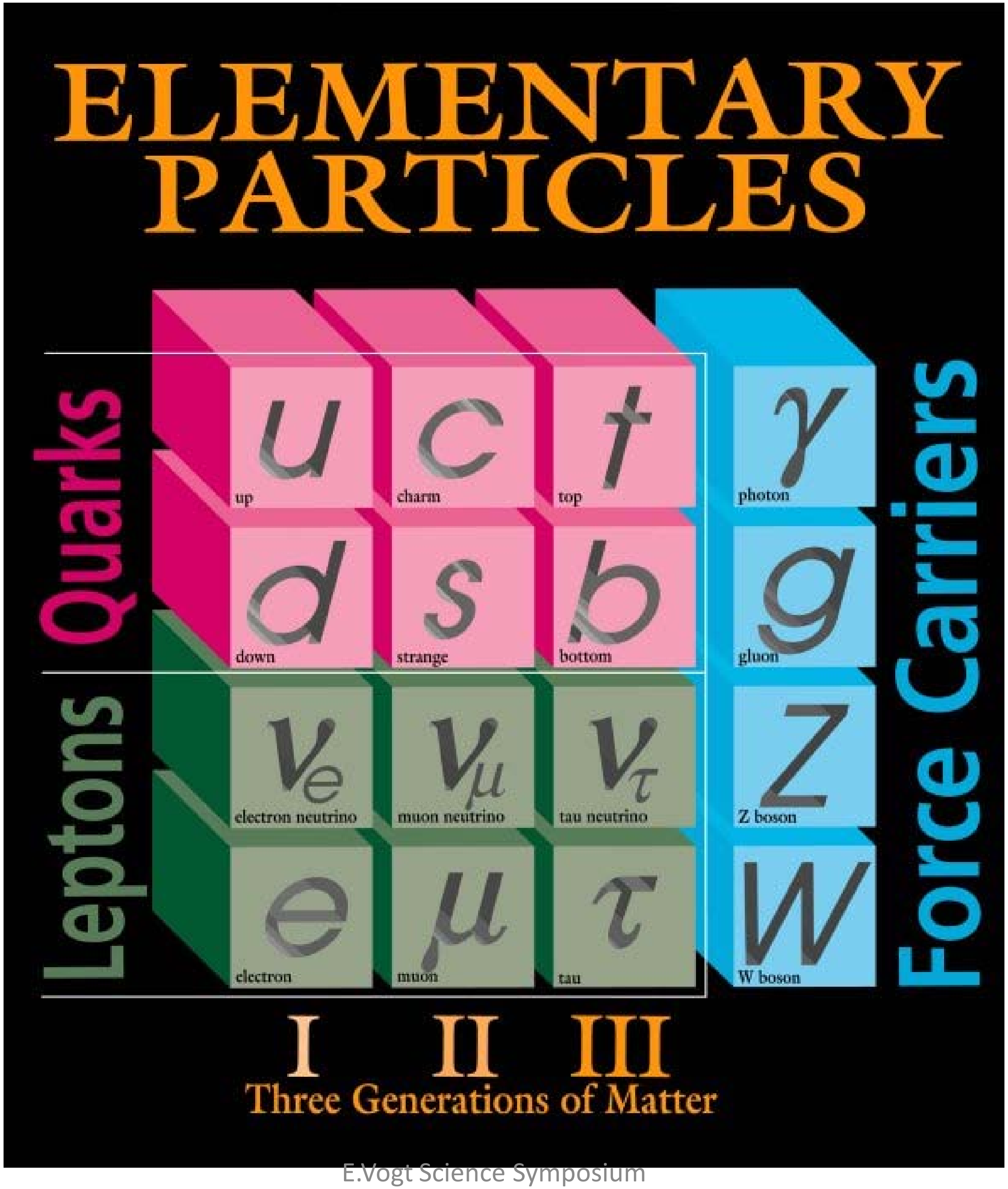
- The key decision that led to this was the creation of the Pearce chair at U-VIC and the hiring of A.Astbury.

TRIUMF-CERN

ATLAS-Canada project (C.Oram)

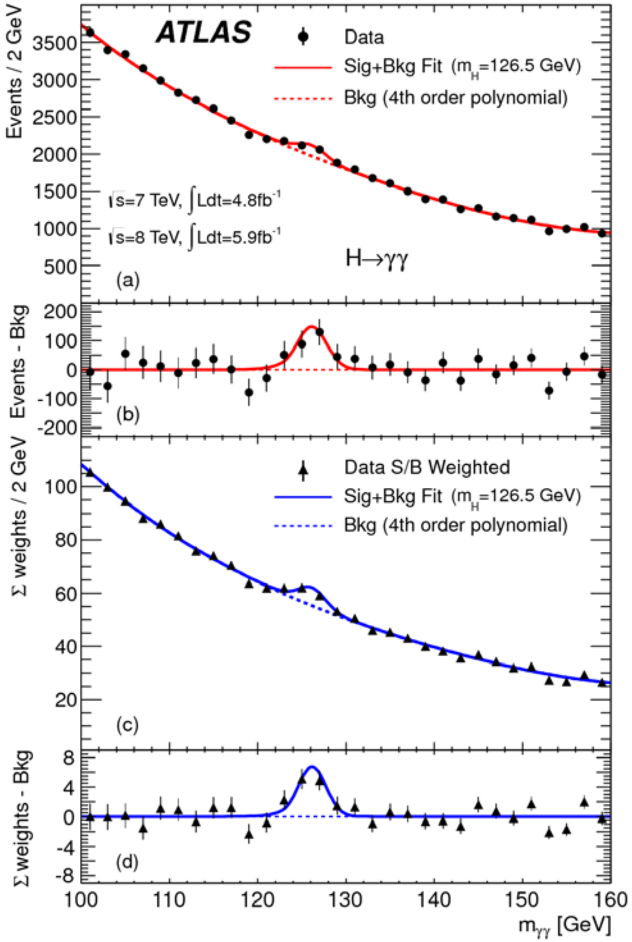
TRIUMF-LHC contributions (E. Blackmore)

Members of the ALSTOM Canada assembly team beside the last series magnet prior to shipping.



	I	II	III	Force Carriers
Quarks	u up	c charm	t top	γ photon
	d down	s strange	b bottom	g gluon
Leptons	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	Z Z boson
	e electron	μ muon	τ tau	W W boson

ATLAS discovery of HIGGS boson



Timeline for a Nobel prize in PP

- 1964 Theory of Higgs boson
- 1984 Higgs search Experiment design started
- 1984 LHC conceptual design
- 1993 SSC cancelled
- 1994 Atlas detector technical proposal
- 1998- 2008 LHC –ATLAS construction
- 1996 TRIUMF asked to build Parts for LHC
- 1998 ATLAS Canada funded
- 2008 LHC first beam
- 2012 Higgs found
- 2014 Nobel prize awarded

SNO

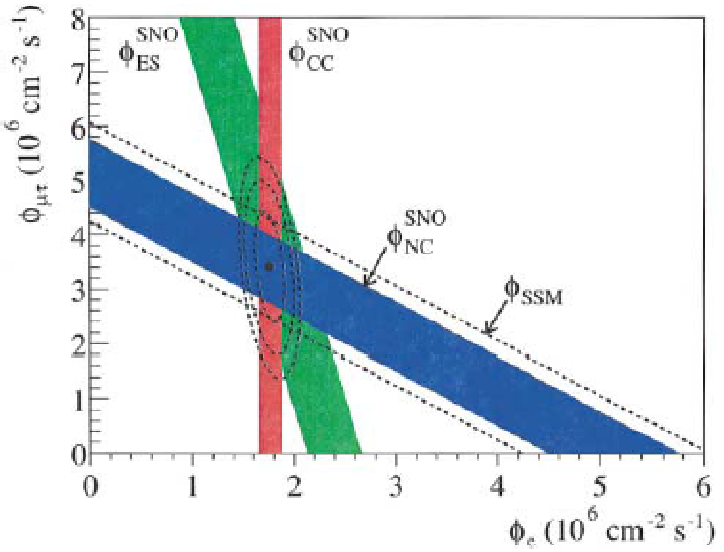


FIG. 3 (color). Flux of ^{8}B solar neutrinos which are μ or τ flavor vs flux of electron neutrinos deduced from the three neutrino reactions in SNO. The diagonal bands show the total ^{8}B flux as predicted by the SSM [13] (dashed lines) and that measured with the NC reaction in SNO (solid band). The intercepts of these bands with the axes represent the $\pm 1\sigma$ errors. The bands intersect at the fit values for ϕ_e and $\phi_{\mu\tau}$, indicating that the combined flux results are consistent with neutrino flavor transformation assuming no distortion in the ^{8}B neutrino energy spectrum.

Neutrino Oscillations

- Neutrino oscillation predicted by B. Pontecorvo 1957 if neutrino have a finite mass: This was bold prediction at the time

- Neutrino oscillation confirmed 1998 in SuperKamiokande Japan.
  - (M.Koshiba/R.Davis) Nobel prize 2002.
- Solar neutrino oscillation confirmed by the SNO experiment in Canada (2002) A.McDonald(Queen's) Pontecorvo prize awarded to the team.

- Neutrino oscillation confirmed for accelerator made neutrino and for reactor made antineutrino.(K2K and KAMLAND experiments in Japan 2004)

.

- First detection of neutrinos from the earth (Kamland, Japan 2005)

- First evidence for Theta13 from T2K (June 2011)

Now to the Future

- Study the scalar sector of the SM at the LHC
- Search for physics beyond the Standard Model
  - Direct search for new particles
    - LHC program
    - Dark matter search
  - Indirect search for deviation from SM
    - CP violation/ CPT tests/ gravity checks
    - Majorana or Dirac Neutrino
    - Charged Lepton Flavor violation (CLFV processes)
    - Neutrino mass scale

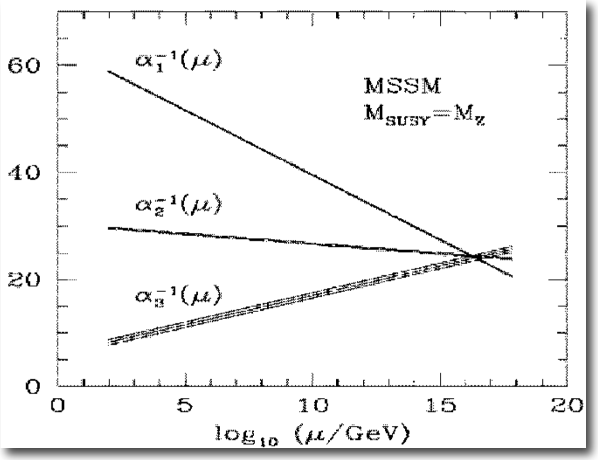
Physics beyond SM (Theory)

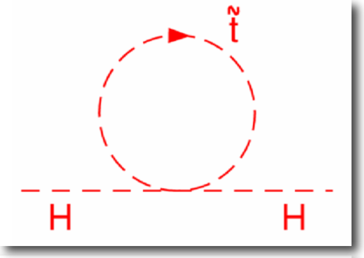
- Theory motivated reasons for it:
  - Flavor problem:
    - Masses and Mixing are arbitrary parameters
    - Number of independent families (3?)
    - Lepton coupling universality
    - Masses of fermions much spread out
  - Unification of strong interactions
    - Running of 3 coupling constants
  - Gauge Hierarchy problem

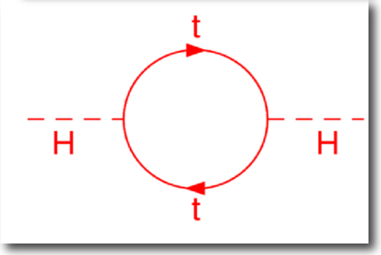
Beyond Standard Model experimental evidences

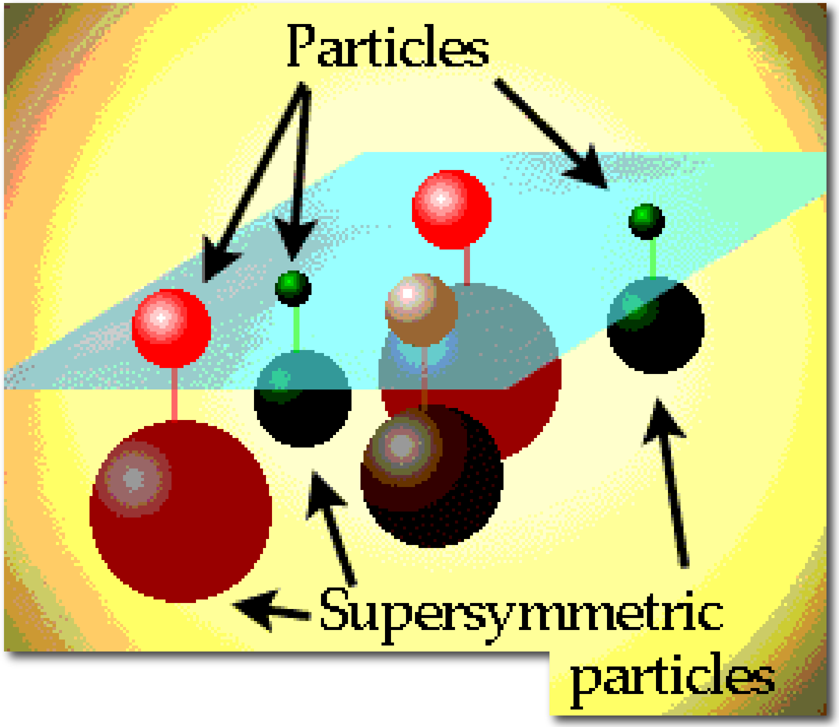
- Dark non-baryonic matter (neutrino cannot be it)
- Neutrino have mass (SNO-SK 2001)
- Universe is matter dominated (CP violation)
- Dark energy

Supersymmetry, SUSY









Unification of the Coupling Constants in the SM and the minimal MSSM

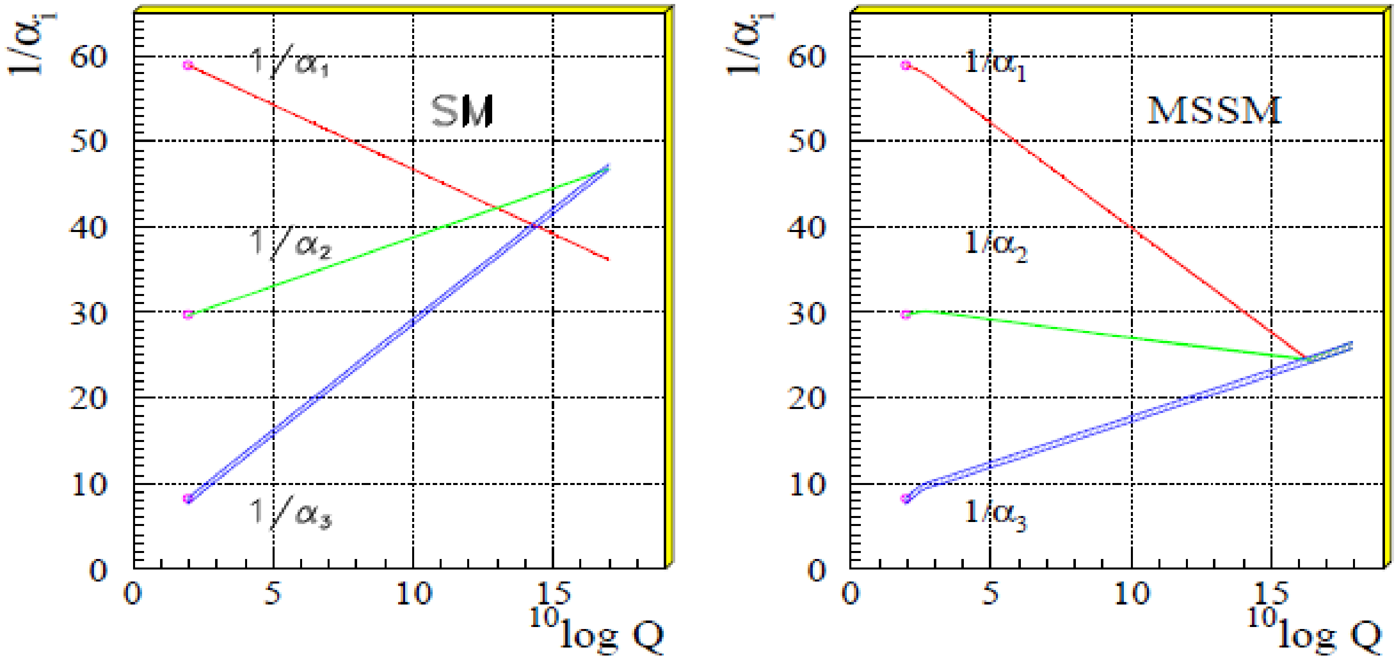
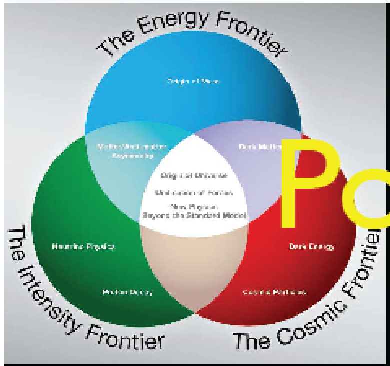
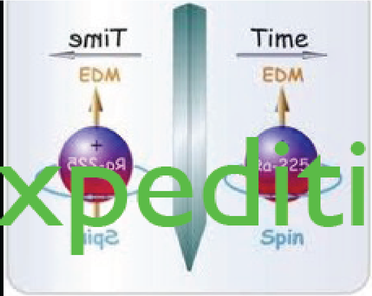
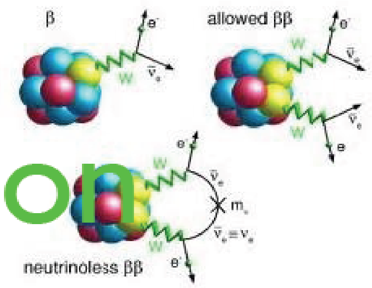


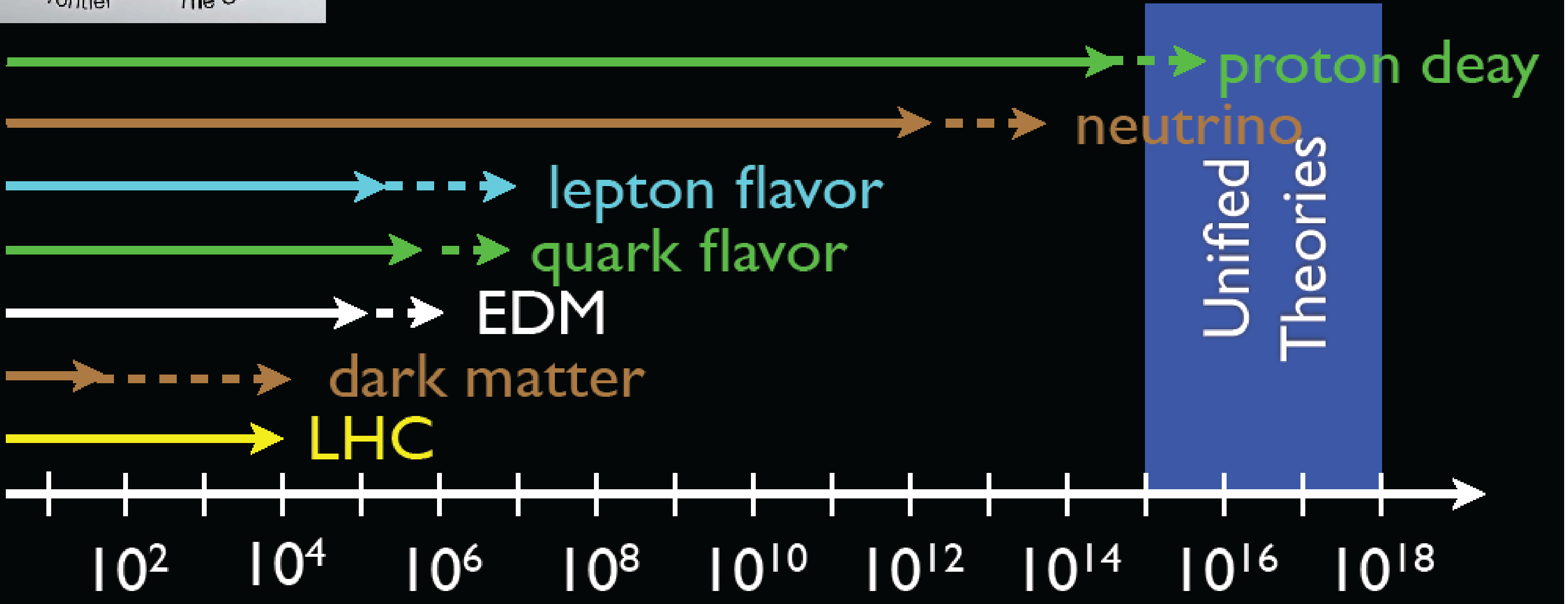
Figure 5: Evolution of the inverse of the three coupling constants in the Standard Model (left) and in the supersymmetric extension of the SM (MSSM) (right). Only in the latter case unification is obtained. The SUSY particles are assumed to contribute only above the effective SUSY scale M_{SUSY} of about 1 TeV, which causes a change in the slope in the evolution of couplings. The thickness of the lines represents the error in the coupling constants [15].

Power of Expedition









proton deay

neutrino

lepton flavor

quark flavor

EDM

dark matter

LHC

Unified Theories

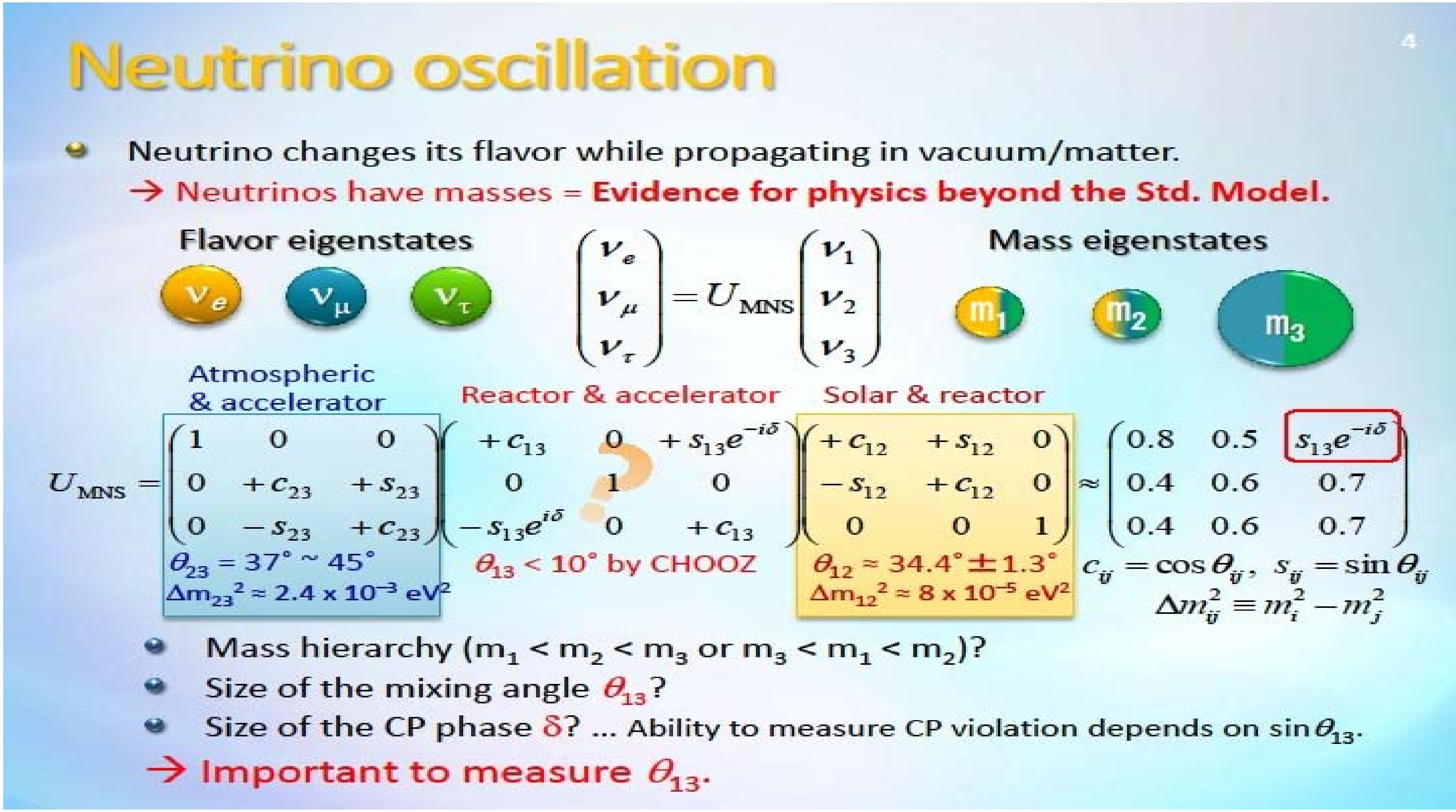
10^2 10^4 10^6 10^8 10^{10} 10^{12} 10^{14} 10^{16} 10^{18}

experimental reach [GeV]

(with significant simplifying assumptions)

baryon asymmetry

Ref: Murayama's talk ICFA
ν panel Nov 2013



Neutrino oscillation

- Neutrino changes its flavor while propagating in vacuum/matter.
  → Neutrinos have masses = **Evidence for physics beyond the Std. Model.**

Flavor eigenstates

$$\begin{pmatrix}\nu_e\\ \nu_\mu\\ \nu_\tau\end{pmatrix} = U_{MNS}\begin{pmatrix}\nu_1\\ \nu_2\\ \nu_3\end{pmatrix}$$

Mass eigenstates

Atmospheric & accelerator

Reactor & accelerator

Solar & reactor

$$U_{MNS} = \begin{pmatrix}1 & 0 & 0\\ 0 & +c_{23} & +s_{23}\\ 0 & -s_{23} & +c_{23}\end{pmatrix}\begin{pmatrix}+c_{13} & 0 & +s_{13}e^{-i\delta}\\ 0 & 1 & 0\\ -s_{13}e^{i\delta} & 0 & +c_{13}\end{pmatrix}\begin{pmatrix}+c_{12} & +s_{12} & 0\\ -s_{12} & +c_{12} & 0\\ 0 & 0 & 1\end{pmatrix} \approx \begin{pmatrix}0.8 & 0.5 & \boxed{s_{13}e^{-i\delta}}\\ 0.4 & 0.6 & 0.7\\ 0.4 & 0.6 & 0.7\end{pmatrix}$$

$\theta_{23} = 37^\circ \sim 45^\circ$
$\Delta m_{23}^2 \approx 2.4 \times 10^{-3}\ \mathrm{eV}^2$

$\theta_{13} < 10^\circ$ by CHOOZ

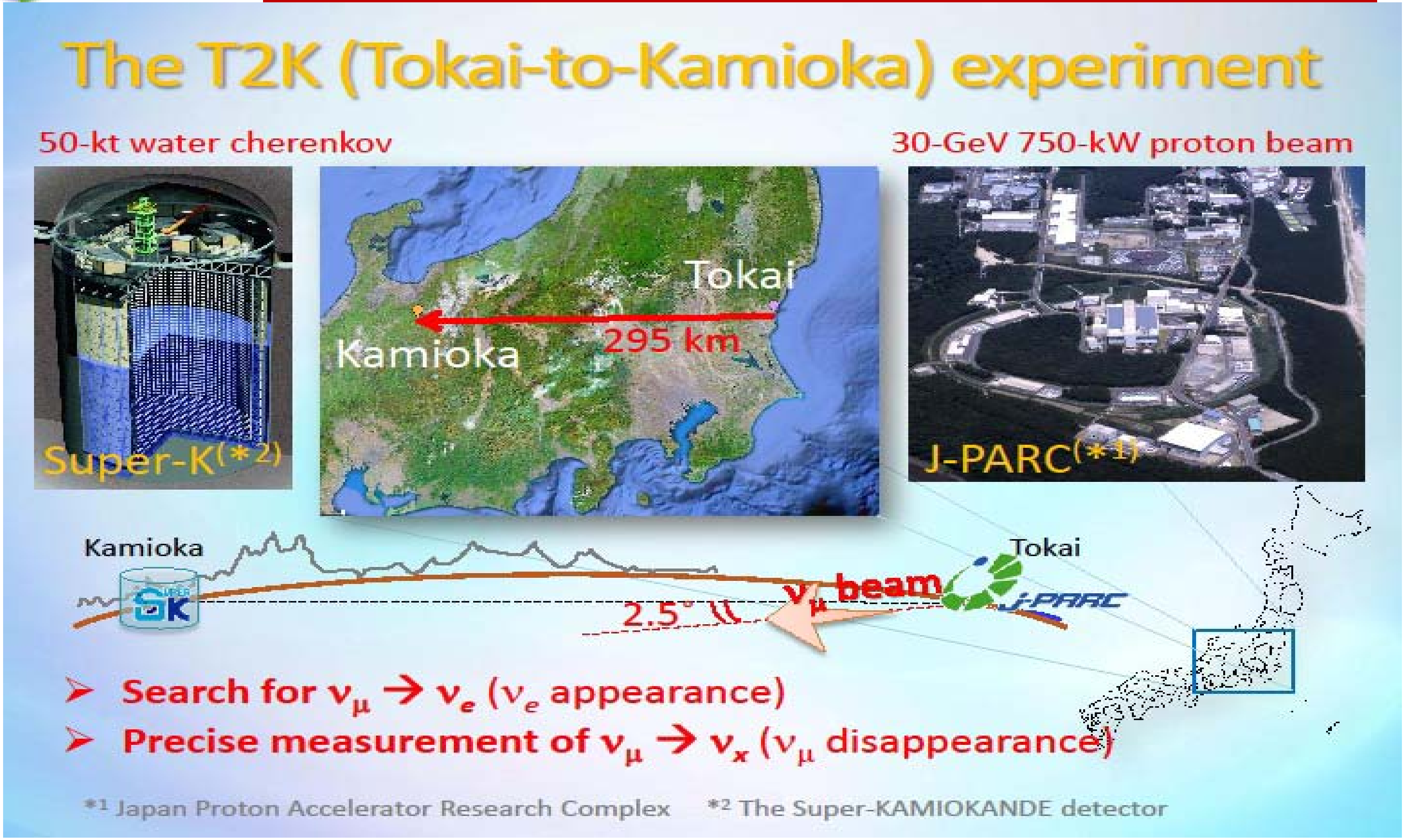
$\theta_{12} \approx 34.4^\circ \pm 1.3^\circ$
$\Delta m_{12}^2 \approx 8 \times 10^{-5}\ \mathrm{eV}^2$

$c_{ij} = \cos\theta_{ij},\ s_{ij} = \sin\theta_{ij}$
$\Delta m_{ij}^2 \equiv m_i^2 - m_j^2$

- Mass hierarchy ($m_1 < m_2 < m_3$ or $m_3 < m_1 < m_2$)?
- Size of the mixing angle θ_{13}?
- Size of the CP phase δ? ... Ability to measure CP violation depends on $\sin\theta_{13}$.

→ Important to measure θ_{13}.

New CP violation?

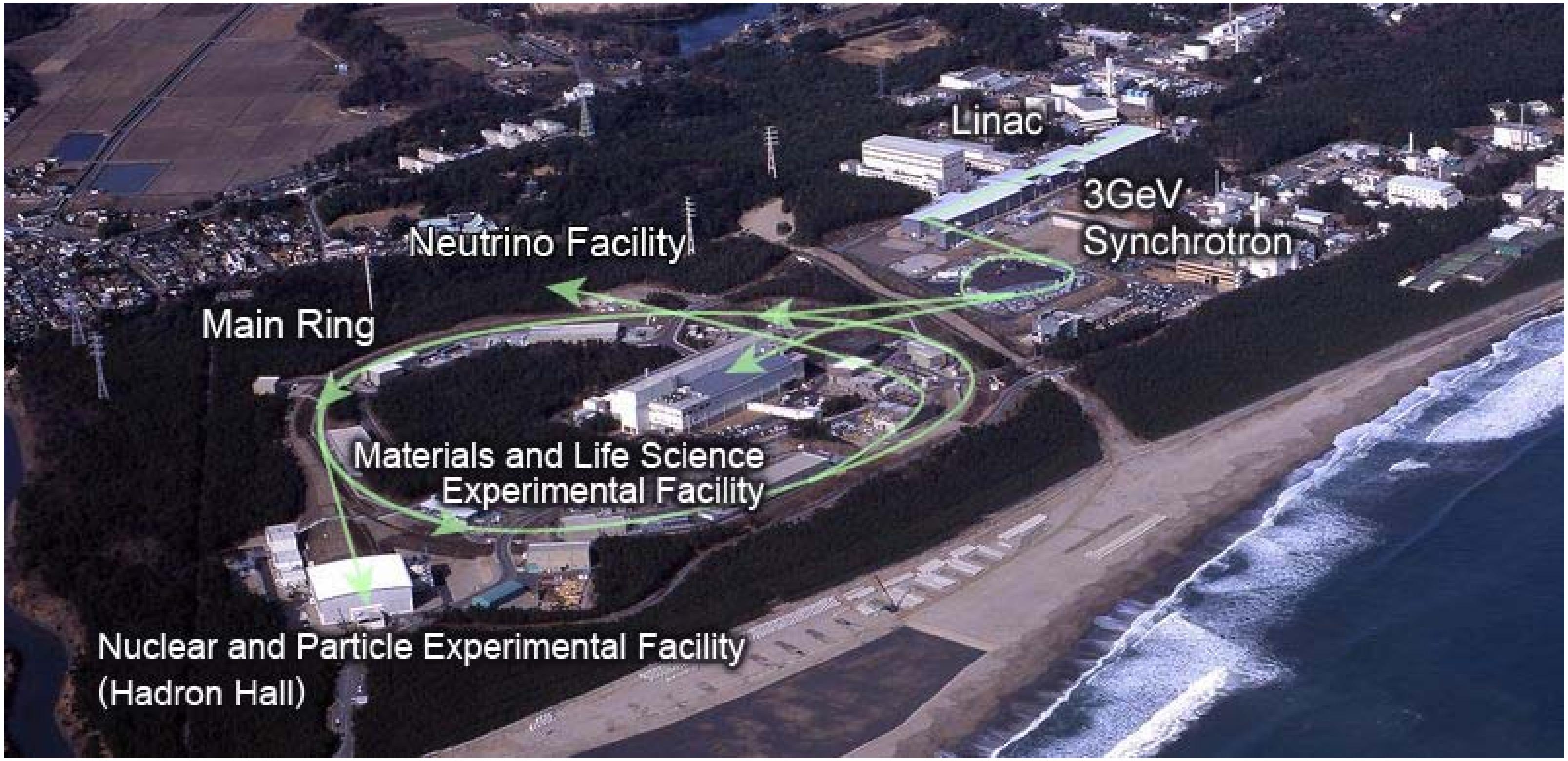


The T2K (Tokai-to-Kamioka) experiment

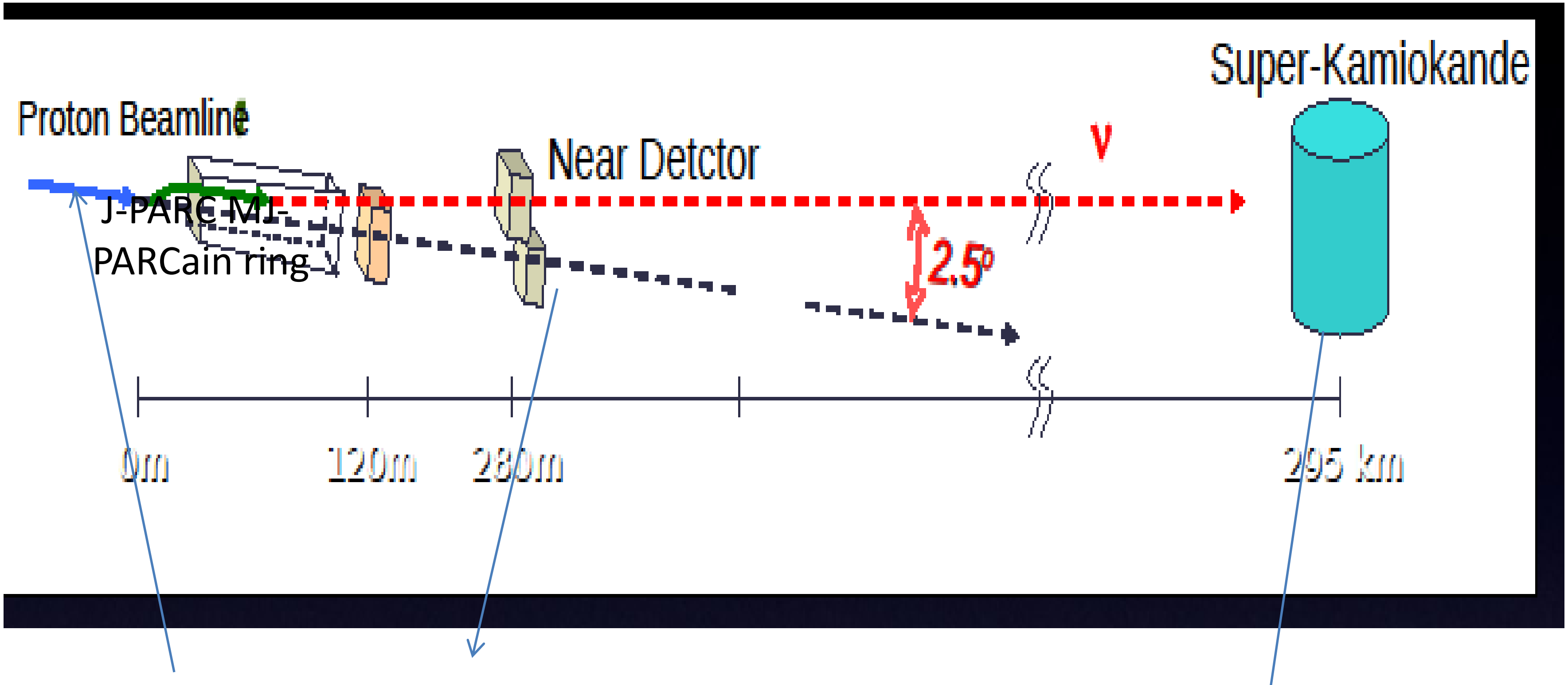
- Search for $\nu_\mu \rightarrow \nu_e$ (ν_e appearance)
- Precise measurement of $\nu_\mu \rightarrow \nu_x$ (ν_μ disappearance)

*1 Japan Proton Accelerator Research Complex *2 The Super-KAMIOKANDE detector

J-PARC complex



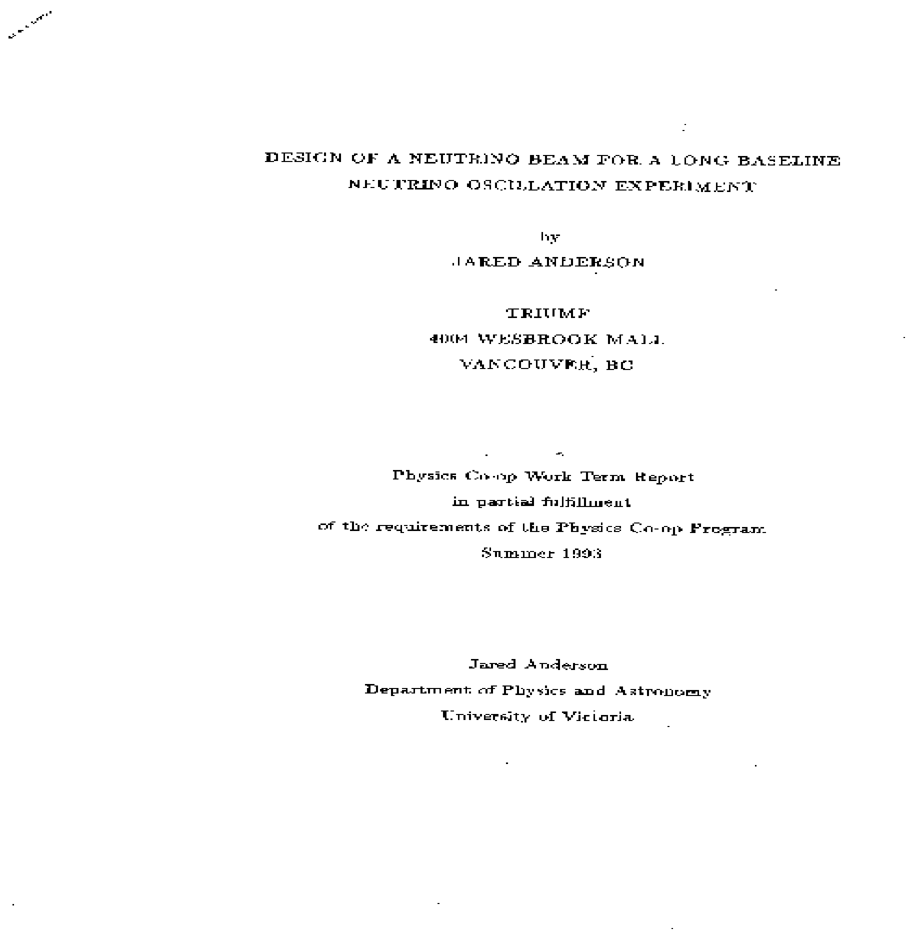
T2K experiment



J-PARC complex at Tokai

Kamioka mine(W-Japan)

Summer/Coop students at TRIUMF (Erich’s favorite program)



DESIGN OF A NEUTRINO BEAM FOR A LONG BASELINE
NEUTRINO OSCILLATION EXPERIMENT

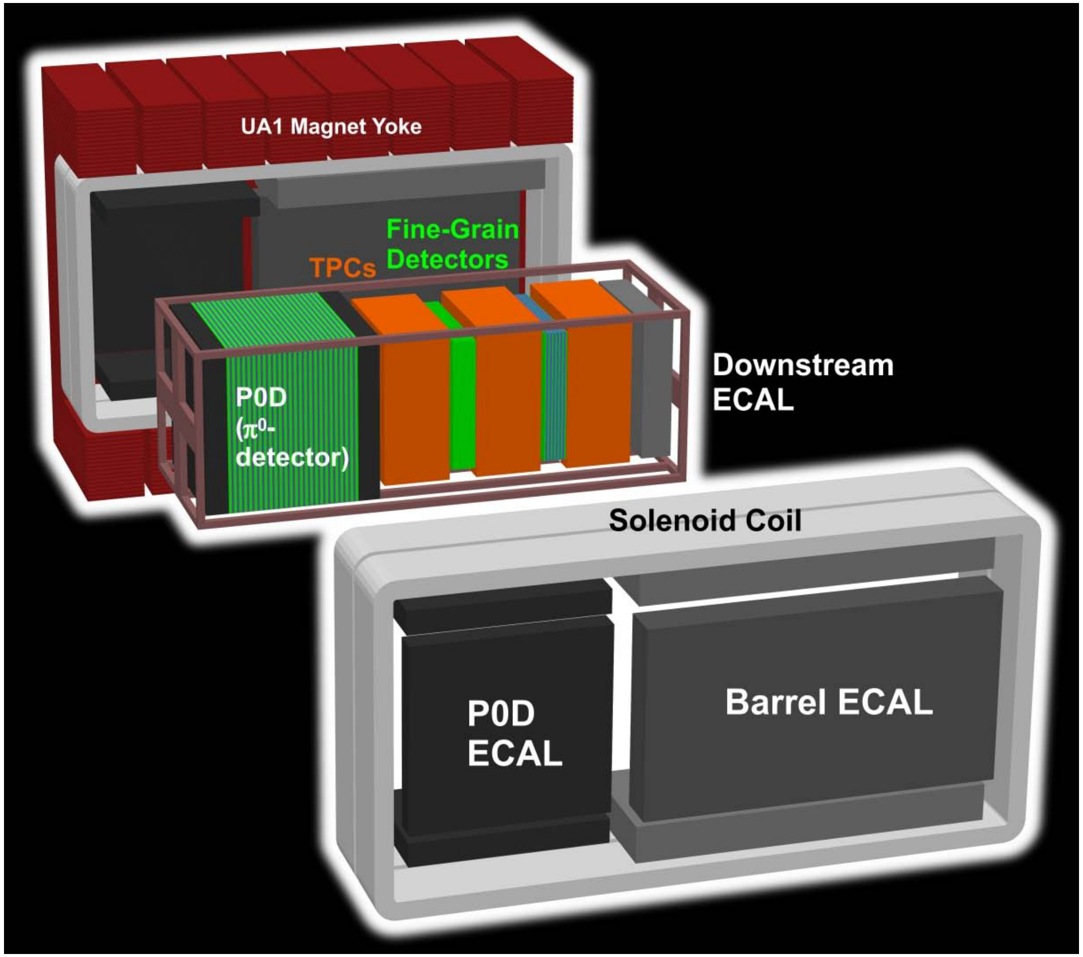
by
JARED ANDERSON

TRIUMF
4004 WESBROOK MALL
VANCOUVER, BC

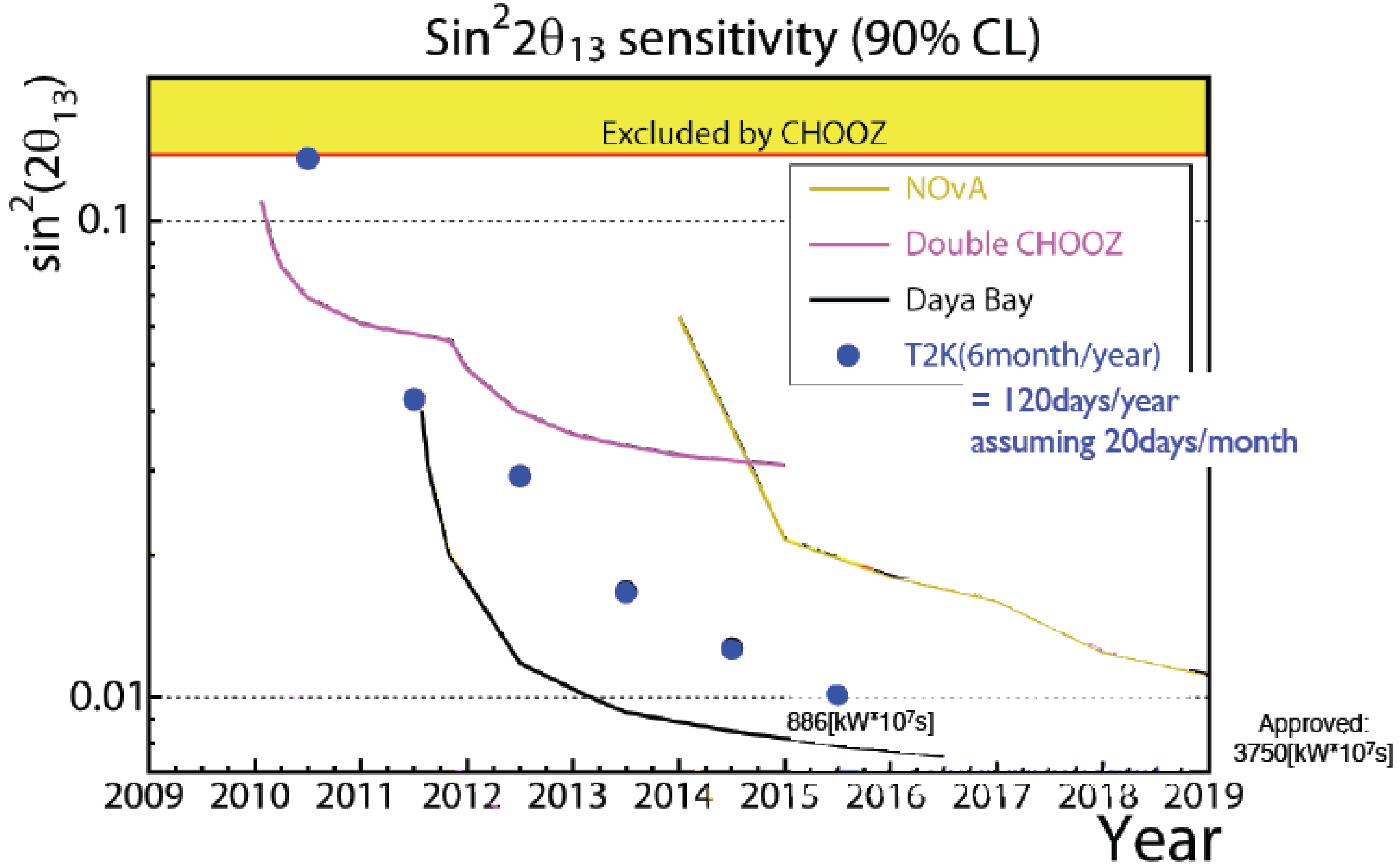
Physics Co-op Work Term Report
in partial fulfillment
of the requirements of the Physics Co-op Program
Summer 1993

Jared Anderson
Department of Physics and Astronomy
University of Victoria

ND280 Off Axis detectors



International competition



= 120days/year
assuming 20days/month

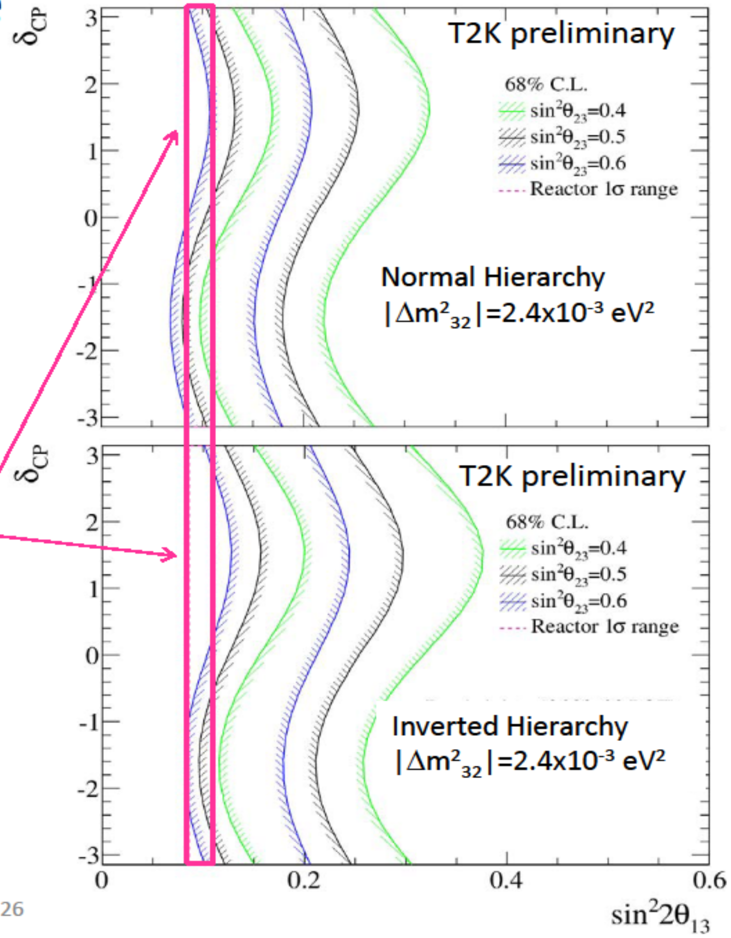
Request beam time of more than 10^7 sec(=~120days) per year in order to keep leading international competition

Test of CP violation

T2K ν_e appearance
δ_{CP} vs. $\sin^2 2\theta_{13}$
for different θ_{23}

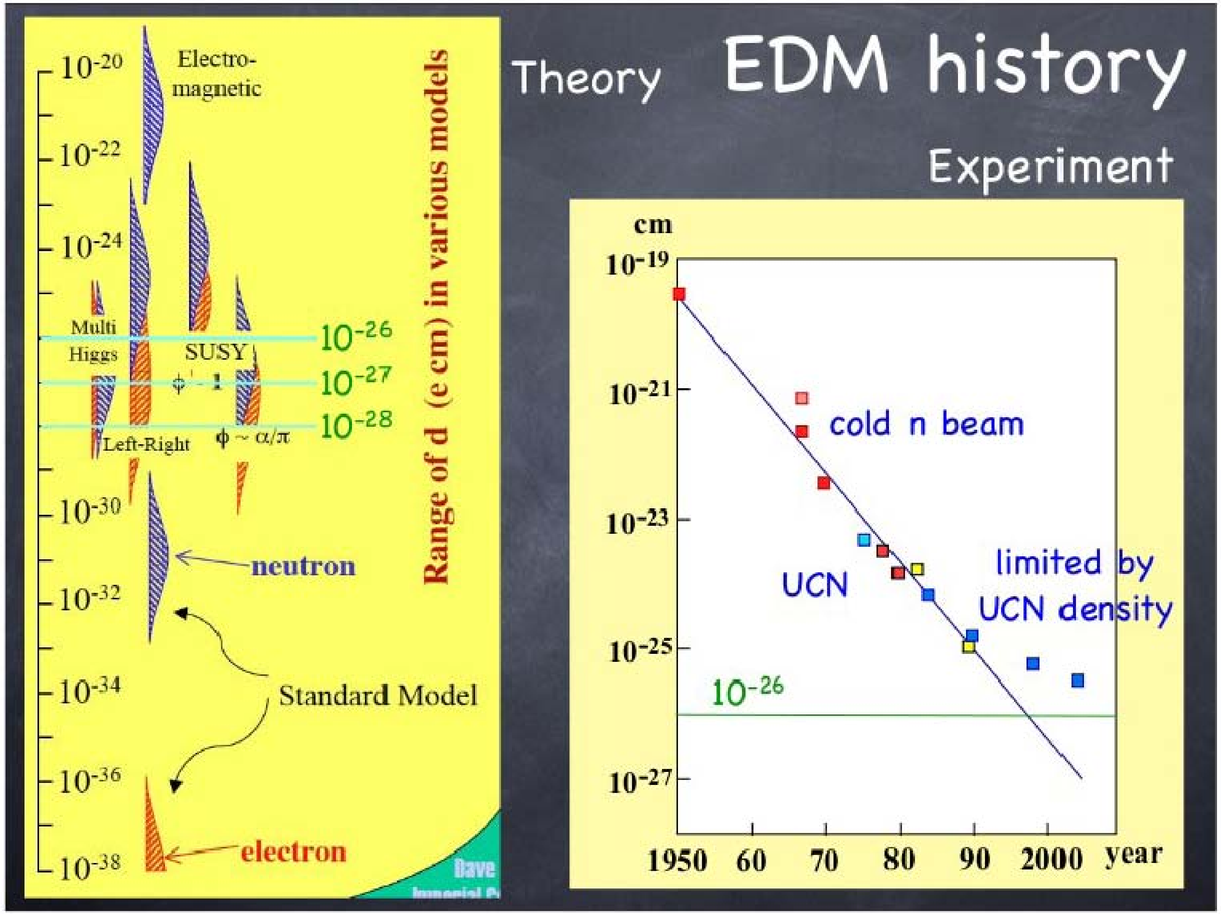
NOTE: PDG'12 3σ region for $\sin^2\theta_{23}$:0.34-0.64

reactor 1σ region (PDG '12)
$\sin^2 2\theta_{13} = 0.098 \pm 0.013$



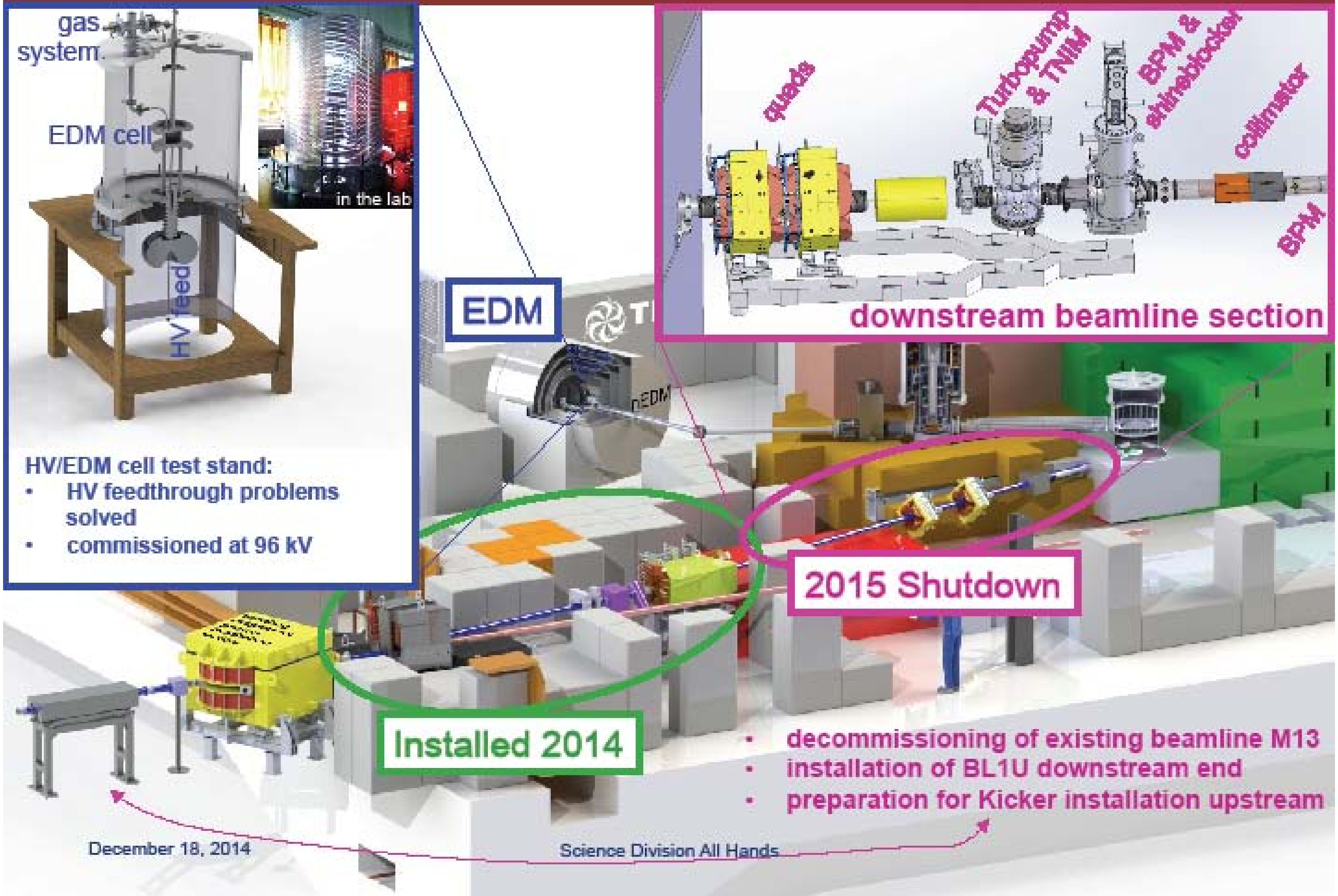
Ichikawa@EPS2013

n/Rn EDM at TRIUMF



TRIUMF

UCN/EDM update



HV/EDM cell test stand:

- HV feedthrough problems solved
- commissioned at 96 kV

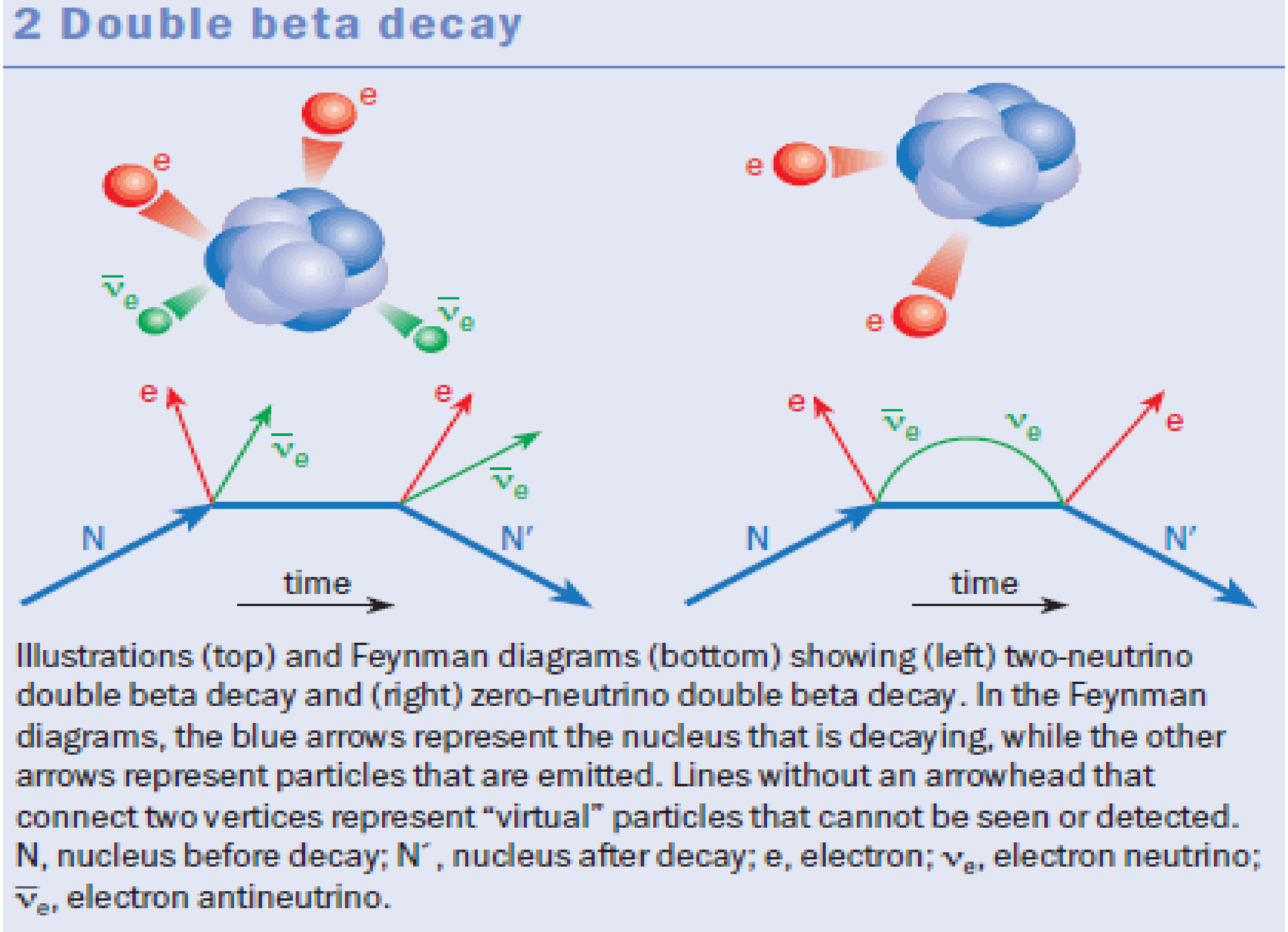
EDM

downstream beamline section

2015 Shutdown

Installed 2014

- decommissioning of existing beamline M13
- installation of BL1U downstream end
- preparation for Kicker installation upstream



2 Double beta decay

Illustrations (top) and Feynman diagrams (bottom) showing (left) two-neutrino double beta decay and (right) zero-neutrino double beta decay. In the Feynman diagrams, the blue arrows represent the nucleus that is decaying, while the other arrows represent particles that are emitted. Lines without an arrowhead that connect two vertices represent "virtual" particles that cannot be seen or detected. N, nucleus before decay; N´, nucleus after decay; e, electron; ν_e, electron neutrino; $\bar{\nu}_e$, electron antineutrino.

2βdecay

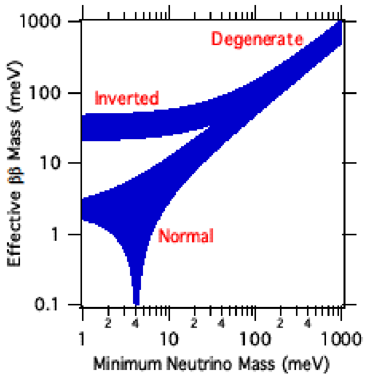


FIG. 4 The effective Majorana mass $\langle m_{\beta\beta}\rangle$ as a function of the mass of the lightest neutrino, $m_{lightest}$. In making the plot, we have used the best fit values for the parameters in Table I. The filled areas represent the range possible because of the Majorana phases and are irreducible. If one incorporates the uncertainties in the mixing parameters, the regions widen. See Bilenky *et al.* (2004) for an example of how the mixing parameter uncertainty affects the regions.

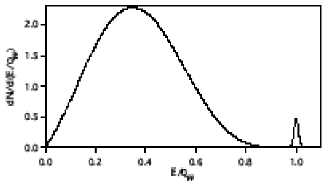


FIG. 5 The distribution of the sum of electron energies for $\beta\beta(2\nu)$ (dotted curve) and $\beta\beta(0\nu)$ (solid curve). The curves were drawn assuming that $\Gamma_{0\nu}$ is 1% of $\Gamma_{2\nu}$ and for a 1-σ energy resolution of 2%.

Many experiments

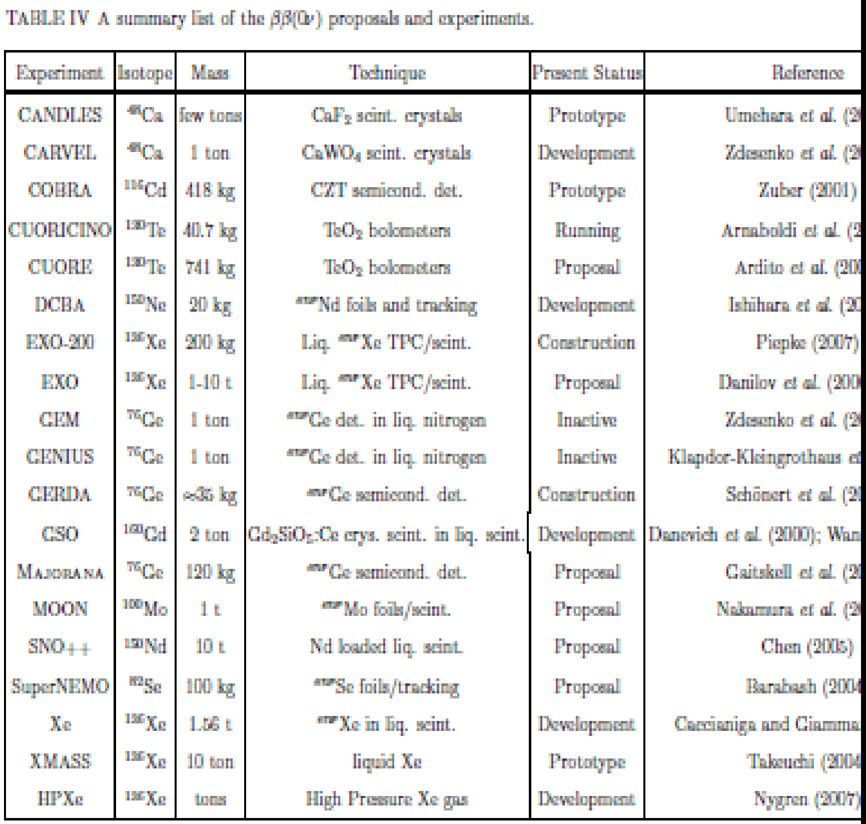


TABLE IV A summary list of the $\beta\beta(0\nu)$ proposals and experiments.

Experiment	Isotope	Mass	Technique	Present Status	Reference
CANDLES	^{48}Ca	few tons	CaF$_2$ scint. crystals	Prototype	Umehara et al. (2
CARVEL	^{48}Ca	1 ton	CaWO$_4$ scint. crystals	Development	Zdesenko et al. (2
COBRA	^{116}Cd	418 kg	CZT semicond. det.	Prototype	Zuber (2001)
CUORICINO	^{130}Te	40.7 kg	TeO$_2$ bolometers	Running	Arnaboldi et al. (2
CUORE	^{130}Te	741 kg	TeO$_2$ bolometers	Proposal	Ardito et al. (20
DCBA	^{150}Ne	20 kg	^{enr}Nd foils and tracking	Development	Ishihara et al. (2
EXO-200	^{136}Xe	200 kg	Liq. ^{enr}Xe TPC/scint.	Construction	Piepke (2007)
EXO	^{136}Xe	1-10 t	Liq. ^{enr}Xe TPC/scint.	Proposal	Danilov et al. (200
GEM	^{76}Ge	1 ton	^{enr}Ge det. in liq. nitrogen	Inactive	Zdesenko et al. (2
GENIUS	^{76}Ge	1 ton	^{enr}Ge det. in liq. nitrogen	Inactive	Klapdor-Kleingrothaus et
GERDA	^{76}Ge	≈35 kg	^{enr}Ge semicond. det.	Construction	Schönert et al. (2
CSO	^{160}Gd	2 ton	Gd$_2$SiO$_5$:Ce crys. scint. in liq. scint.	Development	Danevich et al. (2000); Wan
MAJORANA	^{76}Ge	120 kg	^{enr}Ge semicond. det.	Proposal	Gaitskell et al. (2
MOON	^{100}Mo	1 t	^{enr}Mo foils/scint.	Proposal	Nakamura et al. (2
SNO++	^{150}Nd	10 t	Nd loaded liq. scint.	Proposal	Chen (2005)
SuperNEMO	^{82}Se	100 kg	^{enr}Se foils/tracking	Proposal	Barabash (2004
Xe	^{136}Xe	1.56 t	^{enr}Xe in liq. scint.	Development	Caccianiga and Giamma
XMASS	^{136}Xe	10 ton	liquid Xe	Prototype	Takeuchi (2004
HPXe	^{136}Xe	tons	High Pressure Xe gas	Development	Nygren (2007)

Double Beta decay

- Nuclear structure (Theory and experiments)
- EXO
- SNO+

Charge Lepton Flavor Violation

- Rare muon decays
  - PSI
  - FERMILAB
  - J-PARC

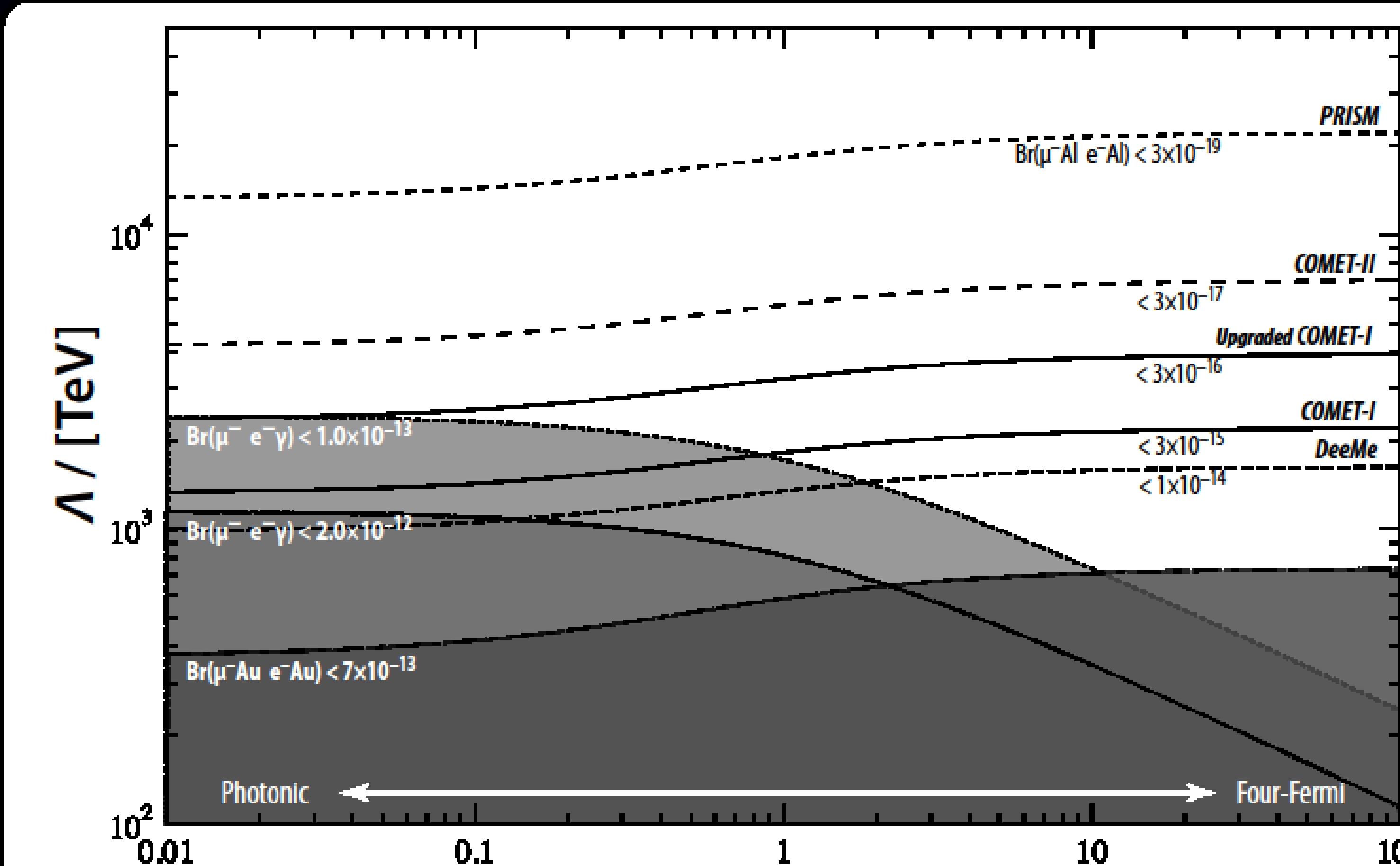
- Rare tau decays
  - Super B

Sensitivity to High Energy Scale Physics
Exercise (1) : Tree Level

A. de Gouvea's effective interact

$$L_{\rm CLFV} = \frac{1}{1+\kappa}\frac{m_\mu}{\Lambda^2}\bar{\mu}_{\rm R}\sigma^{\mu\nu}e_{\rm L}F_{\mu\nu} + \frac{\kappa}{1+\kappa}\frac{1}{\Lambda^2}(\bar{\mu}_{\rm L}\gamma^\mu e_{\rm L})(\bar{q}_{\rm L}\gamma_\mu$$

Λ: energy scale of new physics



What is needed

- Huge flux of μ-: 10^{11}/sec
  - This is 10^3 times what a 2MW proton beam can produce in the best conventional muon channel at PSI.
- Pulse beam to avoid prompt background
- Improve spectrometer energy resolution
- Improve muon momentum selection

R.M.Dzhilkibaev, V.M.Lobashev
INR 1989 proposal

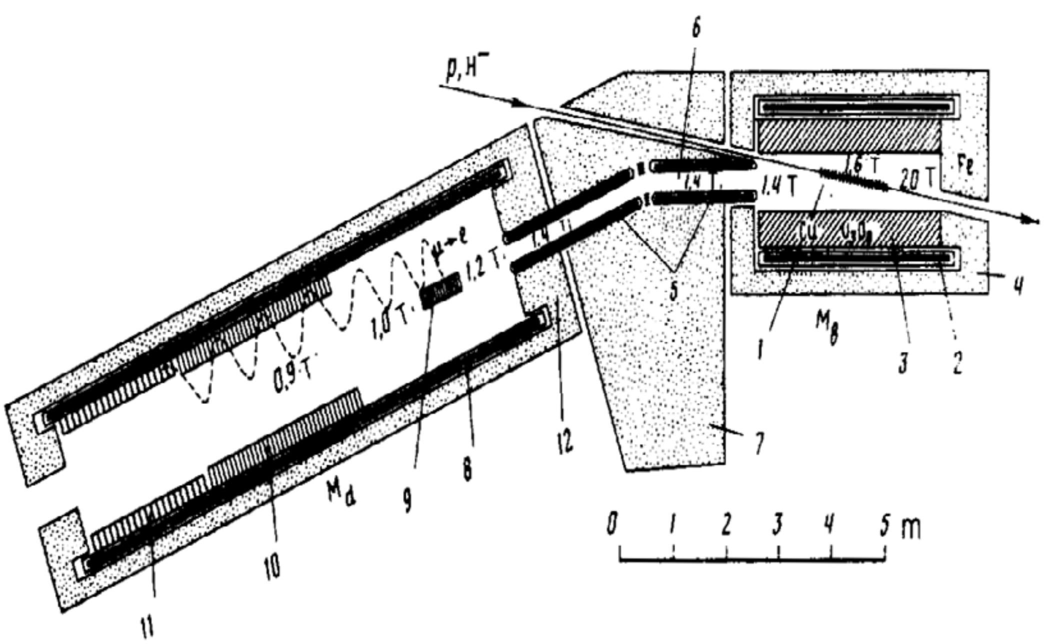
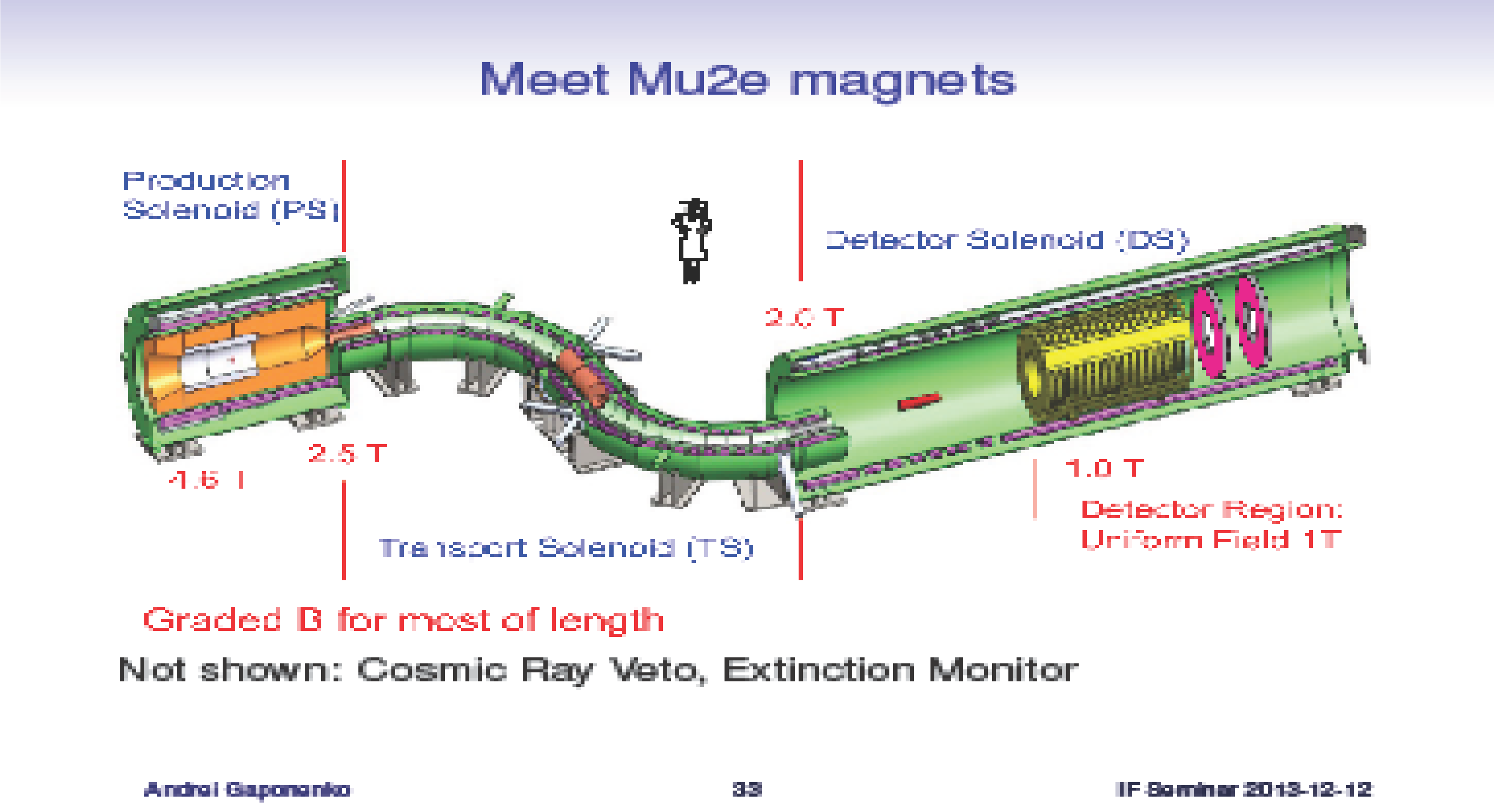


FIG. 1. Diagram of the apparatus: 1—meson-producing target (tungsten); 2—superconducting solenoid; 3—solenoid shield; 4—steel magnet yoke; 5—collimator solenoids; 6—collimator; 7—shielding (heavy iron); 8—detecting-system solenoid; 9—targets for stopping of muons; 10—detector (proportional chambers); 11—total-absorption scintillation spectrometer; 12—magnet yoke.

Fermilab MU2E



Meet Mu2e magnets

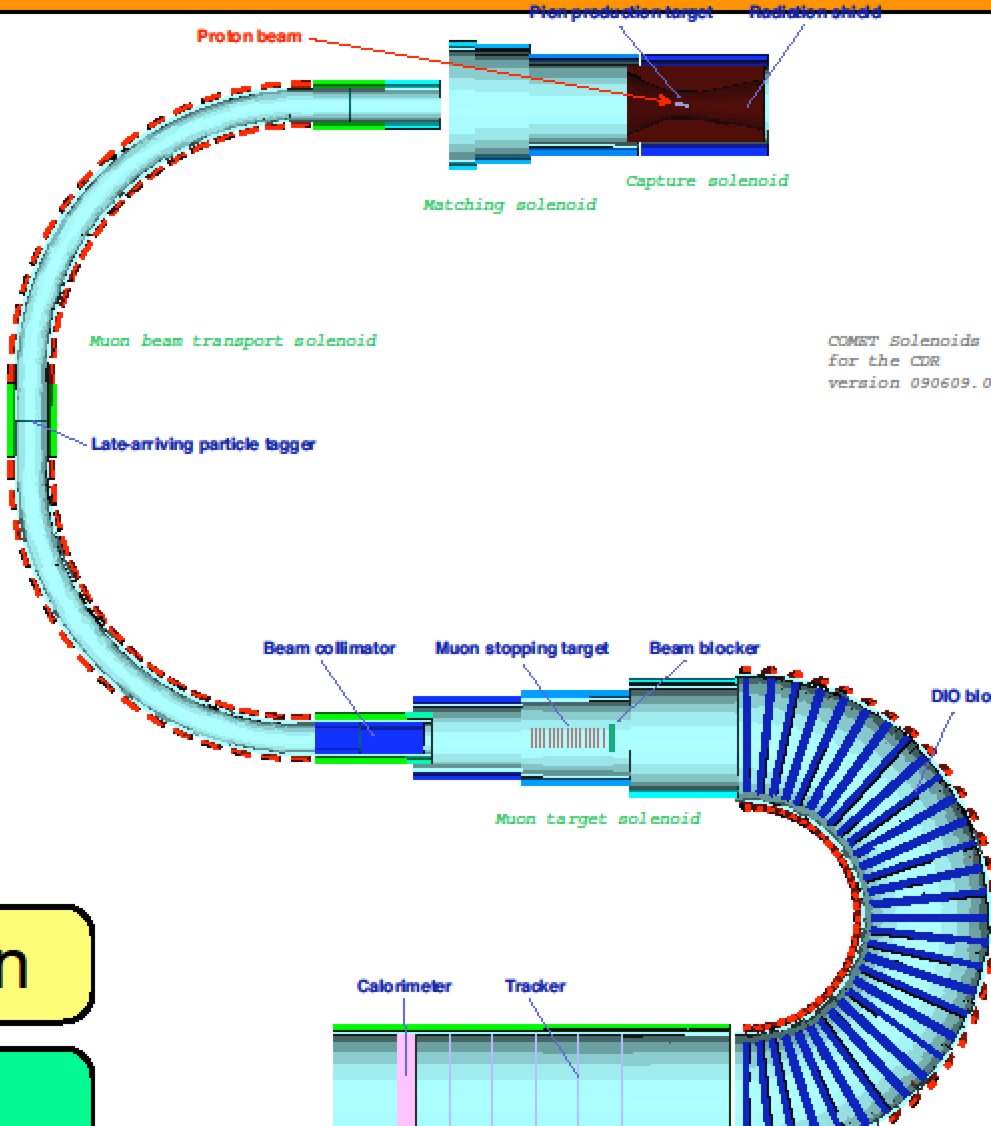
Graded B for most of length

Not shown: Cosmic Ray Veto, Extinction Monitor

Andrei Gaponenko 33 IF Seminar 2013-12-12

Muon Transport System for COMET

- The muon transport system consists of curved solenoids.
  - bore radius : 175 mm
  - magnetic field : 2 T
  - bending angle : 180 degrees
  - radius of curvature : 3 m
- Dispersion is proportional to a bending angle.
- muon collimator after 180 degree bending.
- Elimination of muon momentum > 70 MeV/c



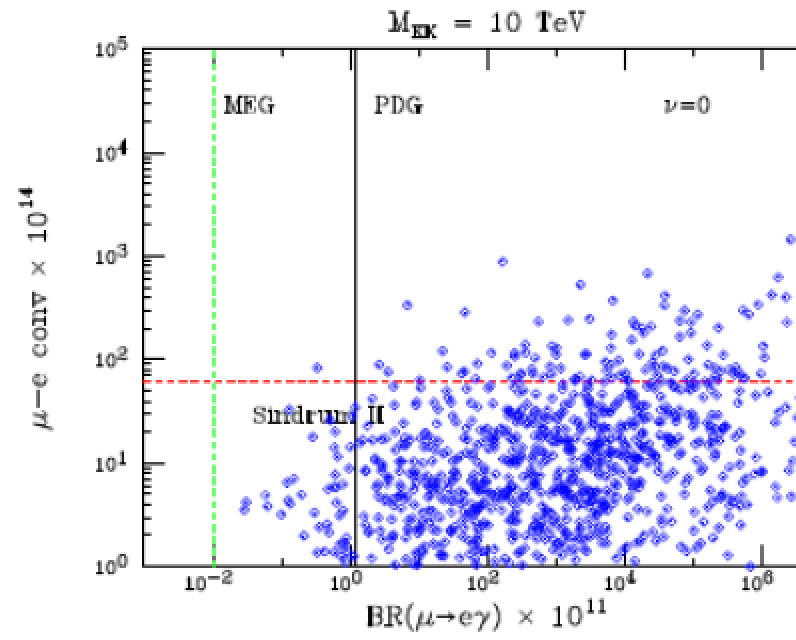
good momentum selection

no high-energy muons

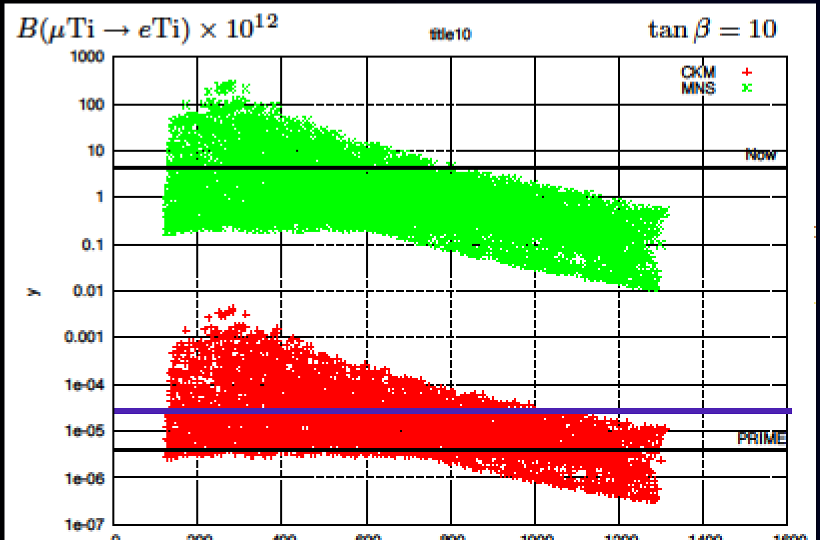
CLFV Predictions

Various BSM models predict sizable CLFV.

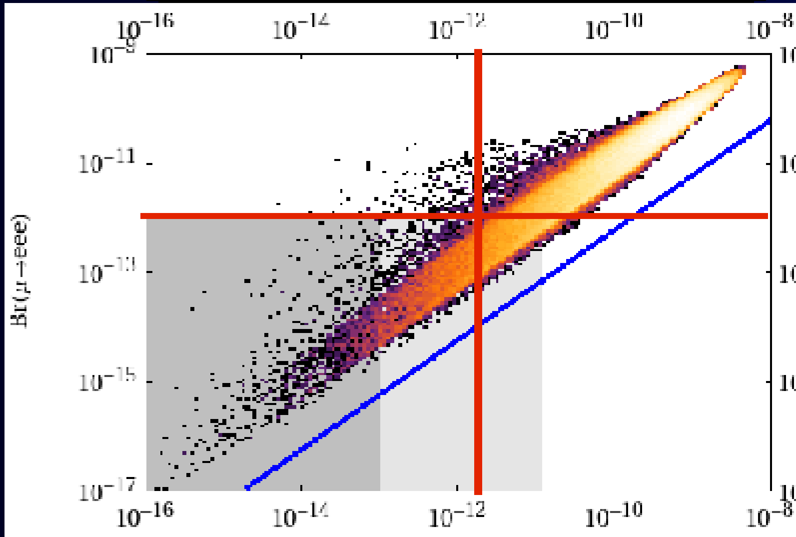
extra dimension model



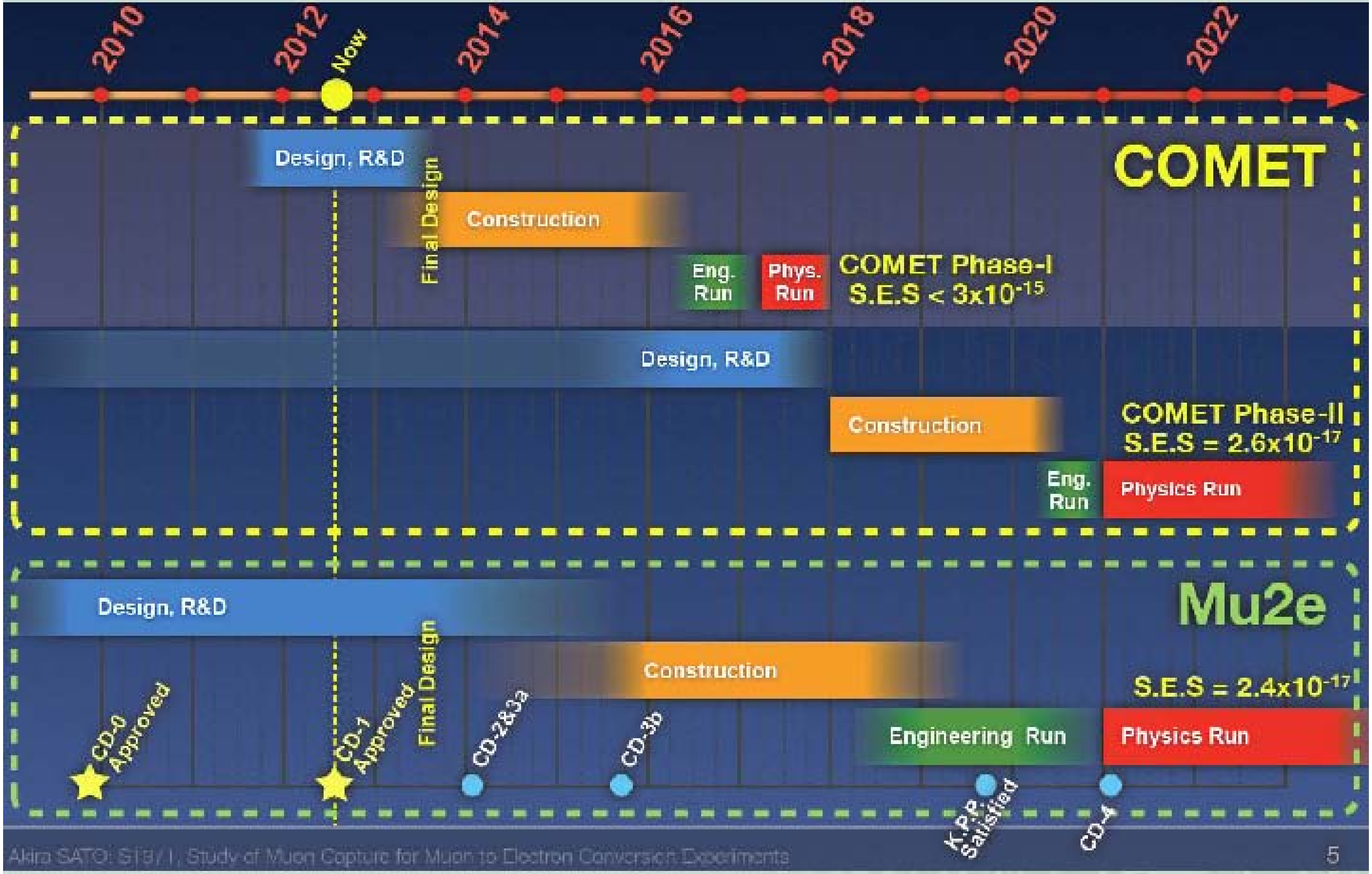
SUSY model



little Higgs model



Schedules for COMET and Mu2e



Akira SATO: S13/1, Study of Muon Capture for Muon to Electron Conversion Experiments

Conclusion

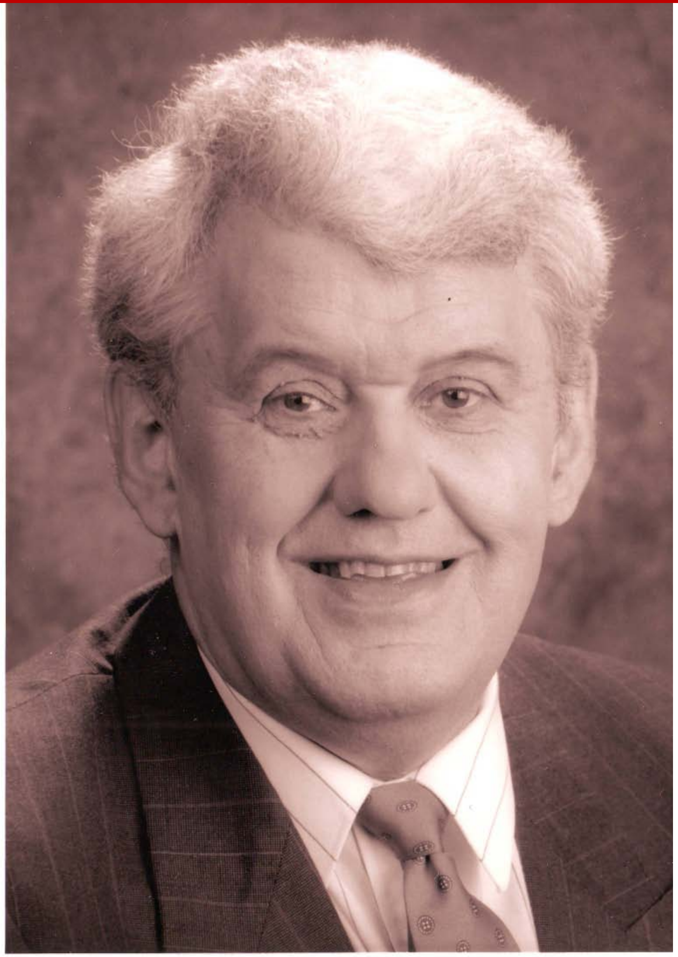
- LHC has given us the last missing piece of the Standard Model at the energy frontier, the Higgs boson.
- LHC has failed to reveal any anticipated new particle

  (for ex. SUSY)....so far.
- BSM physics can manifest itself in various observables to be studied at the intensity frontier.
- TRIUMF is well positioned to participate in these many quests for the new Holy Grail.

- For Canadian Particle Physics, Erich put us on the right tracks

Leadership is laying the tracks but many “drivers” are needed to go beyond the Standard Model

Merci, Erich



Thank you!
Merci

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D-Pace

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ICPN

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imagination at work
Canada

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Positron Emission Tomography Imaging
at
THE UNIVERSITY OF BRITISH COLUMBIA

Pacific Parkinson's Research Institute