WG3: report part 1

Contents

1 Status

topics

topic	convener	progress
- LFV theory	Raidal	some progress
- LFV experiment	van der Schaaf	not known
- EDMs & g-2	Semertzidis	plan for next meeting
- CP(T) tests	Bigi	plan
- lepton universality	van der Schaaf	started this meeting

- Two-hour discussions on Monday and Wednesday morning.
- Should continue by e-mail since only small fraction of participants present.
- Working plans in progress. Authors will be asked to produce outlines.

2 LFV experiment

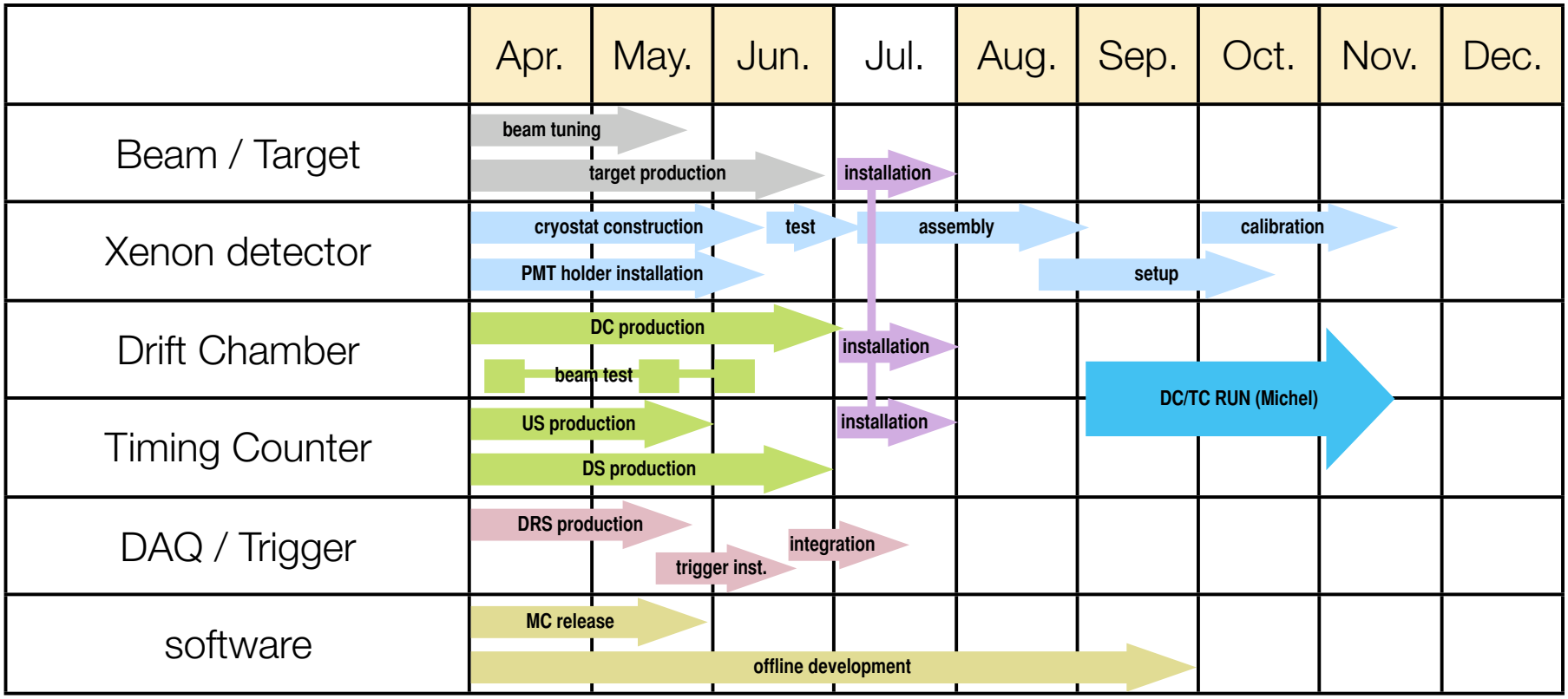
talks so far:

- **Alessandro Baldini** — **Improving the $\mu \to e\gamma$ sensitivity, MEG and beyond**
- **Swagato Banerjee** — **Lepton Flavour Violation in τ decays: Status and perspectives**
- **Wilhelm Bertl** — **Final result of the SINDRUM II search for $\mu - e$ Conversion**
- **Manuel Giffels** — **Status and plans of $\tau \to 3\mu$ at CMS**
- **Yoshi Kuno** — **A high-intensity high-luminosity muon source PRISM and a sorce for muon-electron conversion**
- **Yoshi Kuno** — **A study on muon (electron) to tau conversion in deep inelastic scattering**
- **Alberto Lusiani** — **Feasibility study for a fixed target $\mu \to \tau$ conversion experiment**
- **Giovanni Marchiori** — **Study of $\mu \to \tau$ conversion with high-intensity muon beams**
- **Toshi Mori** — **LFV, status and prospects**
- **Hajime Nishiguchi** — **Update on the status of MEG**

Final SINDRUM II result: $B^{\mathrm{Au}}_{\mu-e} < 7 \times 10^{-13}$ 90% C.L.

Schedule in 2006

MEG beam time ; April-June, August-December

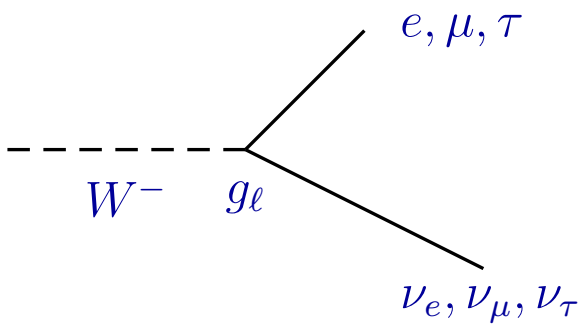


Ready to start MEG commissioning RUN in November

3 Lepton universality

Talks this week:

- **Paride Paradisi** — **Probing new Physics through Lepton Universality**
- **Miguel-Angel Sanchis-Lozano** — **Test of lepton universality in Upsilon decays: searching for a light Higgs boson**
- **Luca Fiorini** — **Testing LFV measuring $K \to e\nu / K \to \mu\nu$ in NA48: status and perspectives**
- **Olga Igonkina** — **Test of lepton universality in tau decay**
- **Andries van der Schaaf** — **Two new $\pi \to e\nu$ experiments**



Where to look for New Physics?

- **Processes forbidden or much suppressed in the SM**
  - FCNC processes ($\mu \to e\gamma$, $\tau \to \mu\gamma$....) or
  - CPV effects (electron edm, d_e....)
- **Processes predicted with high precision in the SM**
  - EWPO as $\Delta\rho, (g-2)_\mu$.....
  - LU in $R_M^{e/\mu} = \Gamma(M \to e\nu)/\Gamma(M \to \mu\nu)$ $(M = \pi, K)$

Marriage of LFV and LU in $R_M^{e/\mu}$

- $\mu - e$ universality in $R_K = \Gamma(K \to e\nu_e)/\Gamma(K \to \mu\nu_\mu)$

$$R_K^{exp.} = (2.416 \pm 0.043_{stat.} \pm 0.024_{syst.}) \cdot 10^{-5} \quad \text{NA48/2}$$

$$R_K^{exp.} = (2.44 \pm 0.11) \cdot 10^{-5} \quad \textit{PDG}$$

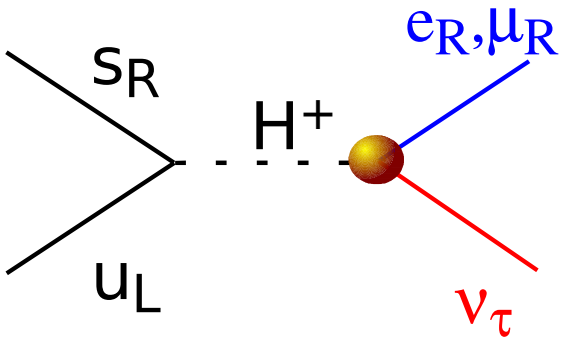
$$R_K^{SM} = (2.472 \pm 0.001) \cdot 10^{-5} \quad \textit{SM}$$

- $\mu - e$ universality in $R_\pi = \Gamma(\pi \to e\nu_e)/\Gamma(\pi \to \mu\nu_\mu)$

$$R_\pi^{exp.} = (1.230 \pm 0.004) \cdot 10^{-4} \quad \text{PDG}$$

$$R_\pi^{SM} = (1.2354 \pm 0.0002) \cdot 10^{-4} \quad \text{SM}$$

$$R_K^{LFV} = \frac{\sum_i K \to e\nu_i}{\sum_i K \to \mu\nu_i} \simeq \frac{\Gamma_{SM}(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma_{SM}(K \to \mu\nu_\mu)} \quad , \quad i = e, \mu, \tau$$



$$eH^\pm\nu_\tau \to \frac{g_2}{\sqrt{2}} \frac{m_\tau}{M_W} \Delta_R^{31} \tan^2\beta$$

$$\Delta_R^{31} \sim \frac{\alpha_2}{4\pi} \delta_{RR}^{31}$$

$$\Delta_R^{31} \sim 5 \cdot 10^{-4} \quad t_\beta = 40 \quad M_{H^\pm} = 500 \text{GeV}$$

$$\Downarrow$$

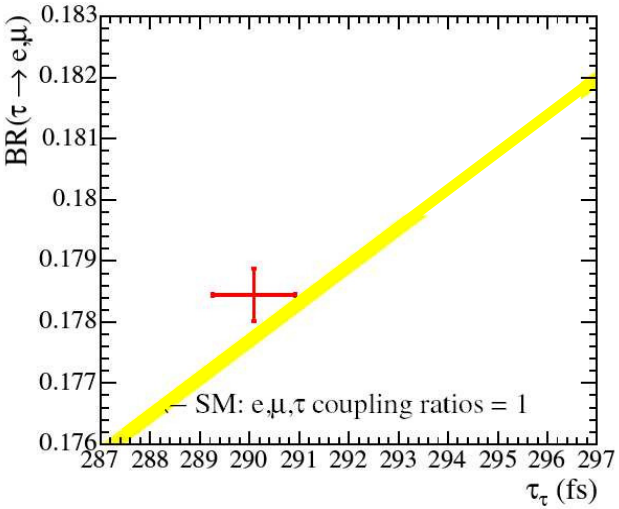
$$\Delta r_{K\,SUSY}^{e-\mu} \simeq \left(\frac{m_K^4}{M_{H^\pm}^4}\right)\left(\frac{m_\tau^2}{m_e^2}\right) |\Delta_R^{31}|^2 \tan^6\beta \approx 10^{-2}$$

$$\Delta r_{\pi\,SUSY}^{e-\mu} \simeq \left(\frac{m_d}{m_u + m_d}\right)^2 \left(\frac{m_\pi^4}{m_k^4}\right) \Delta r_{K\,SUSY}^{e-\mu} \leq 10^{-4}$$

Results from leptonic τ decays

Extract lepton charged current coupling constants from τ leptonic decays.

Combing old τ leptonic decays and new τ_τ, m_τ averaged with PDG04:



courtesy of A.Lusiani

$$\frac{g_e}{g_\mu} = 0.9997 \pm 0.0024 \qquad \frac{g_\mu}{g_\tau} = 0.9981 \pm 0.0022$$

Perfect agreement with SM

Main systematics for g_e/g_μ is $\delta\mathcal{B}(\tau \to \ell\nu\nu)$.
For g_μ/g_τ the main uncertainties are :
$Br(\tau \to e\nu\nu)$ $(1.7 \cdot 10^{-3})$, τ_τ $(1.4 \cdot 10^{-3})$

4 Comparing the two experiments

Main parameters

	PSI	TRIUMF
beam momentum (MeV/c)	70 - 75	70 - 75
resolution	0.5%	1%
π rate	$\approx$3000	$\mathbf{5-10\times10^4}$
$\pi/\mu/e$	1:1:1	100:10:1
Ω	3π	π
$\Delta E_e/E_e$	13%	5%
tail fraction	0.8%	1.4%
final error	<0.05%	0.1%

Time table

preliminary data	2006	2006
engineering run	2006	2007
production run	2007/8	2008

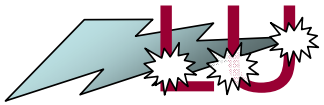
Luca Fiorini: *Testing LFV measuring $K \to e\nu / K \to \mu\nu$ in NA48: status and perspectives*

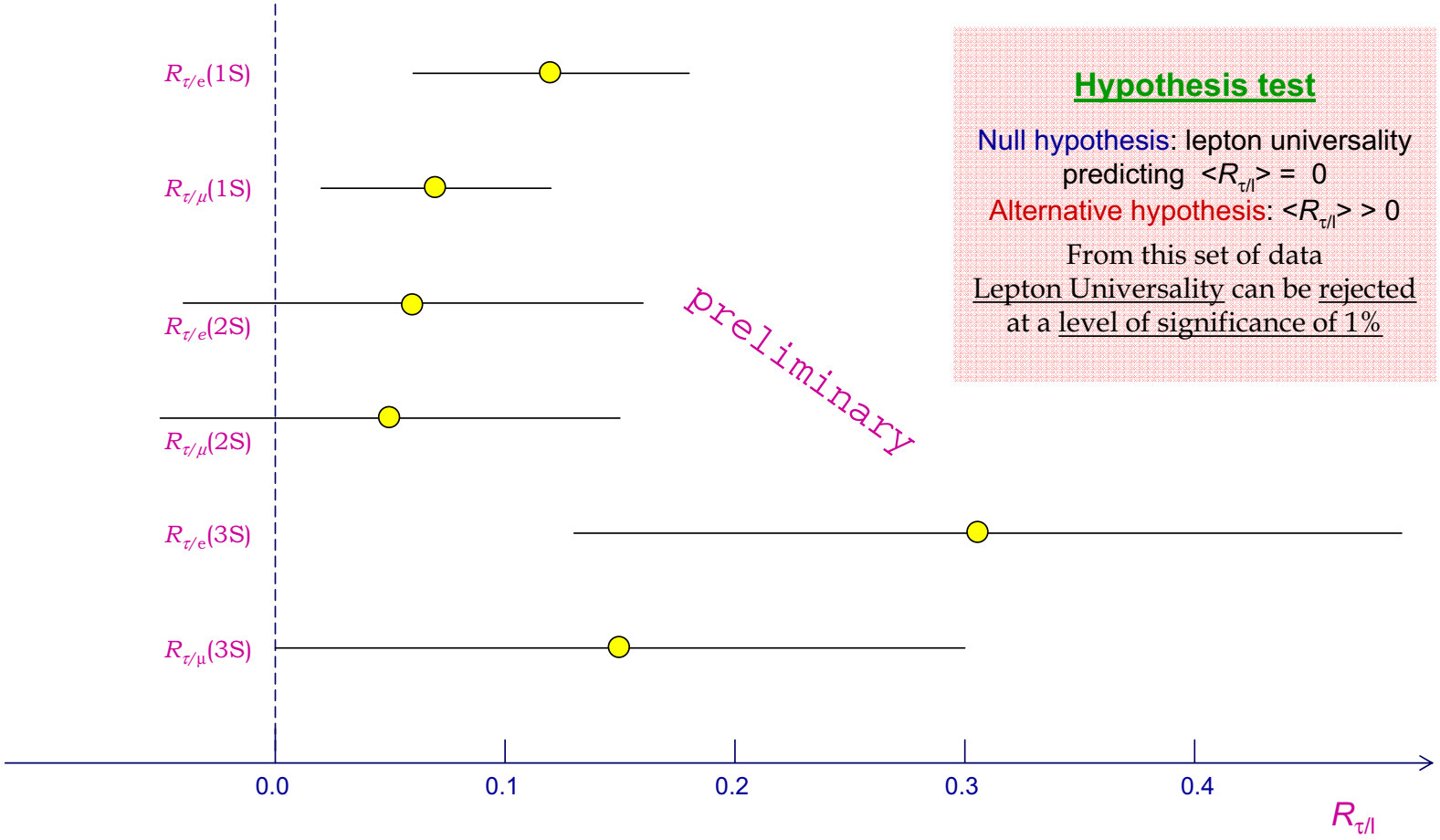
	$\frac{\Gamma(K \to e\nu(\gamma))}{\Gamma(K \to \mu\nu(\gamma))} \cdot 10^5$
SM prediction	**2.472 ± 0.001**
PDG value	**2.45 ± 0.11**
NA48/2 (2003)	**$2.416 \pm 0.043_{(stat)} \pm 0.024_{(syst)}$**
NA48/2 (2004)	*Analysis in progress*

- R_K measurement with 2003 statistics is already 2 times more precise than PDG world average. MB2004 Statistics is similar in size, with a better systematic error.
- 2003 + 2004 yield is NOT sufficient to measure accurately a possible $\Delta R_K(LFV) \sim$ 2-3%

Miguel-Angel Sanchis-Lozano: *Test of lepton universality in Upsilon decays: searching for a light Higgs boson*

Lepton Universality Breaking?





Hypothesis test

Null hypothesis: lepton universality predicting $\langle R_{\tau/l} \rangle = 0$

Alternative hypothesis: $\langle R_{\tau/l} \rangle > 0$

From this set of data Lepton Universality can be rejected at a level of significance of 1%

4 EDMs & g-2

WG3 October meeting will focus on g-2 &EDM

participants so far

Bill Marciano	**g-2**	**theory**
Lee Roberts	**g-2**	**experiment**
Junji Hisano	**Hadronic EDMs**	**theory**
Rob Timmermans	**hadronic EDMs**	**theory**
Klaus Jungmann	**Ra, Rn,...**	**experiment**
Yuri Orlov, YkS	**deuteron, muon**	**experiment**
Philip Harris	**neutron**	**experiment**
Klaus Kirch	**neutron,**	**experiment**
Isabella Masina	**leptonic EDMs**	**theory**
Ed Hinds	**electron**	**experiment**
Dennis DeMille	**electron**	**experiment**

More will be invited.

Leptonic EDM vs LFV processes

MEG experiment will start soon and cover $Br(\mu \to e\gamma) \approx 10^{-(13-14)}$, and improvement of $10^{(2-3)}$ may be achieved.

$$Br(\mu \to e\gamma) \propto \left(\left| \delta^{LL}_{\mu e} + 1.8 \delta^{RR}_{\mu\tau} \delta^{LL}_{\tau e} \right|^2 + \left| 0.05 \delta^{RR}_{\mu e} + 1.8 \delta^{LL}_{\mu\tau} \delta^{RR}_{\tau e} \right|^2 \right)$$

Seesaw GUT w.ν_R SU(5) GUT GUT w.ν_R

Current bound implies that for $\tan\beta = 10$ and $m_{SUSY} = 200\mathrm{GeV}$.

$$|\delta^{LL}_{e\mu}| < 2\times10^{-4}, \quad |\delta^{RR}_{e\mu}| < 3\times10^{-3}, \quad |\delta^{LL}_{e\tau}\delta^{RR}_{\tau\mu}|, |\delta^{RR}_{e\tau}\delta^{LL}_{\tau\mu}| < 1\times10^{-4}$$

Electron EDM bound is competitive to it:

$$\mathrm{Im}[\delta^{LL}_{e\tau}\delta^{RR}_{\tau e}] < 2\times10^{-5}.$$

The future EDM measurement is useful to discriminate models even when $\mu \to e\gamma$ is discovered. When left- and right-handed sleptons have mixing and they dominate in the process,

$$d_e \approx 2.5\times10^{-26}\, e\,cm \times \left(\left| \delta^{LL}_{\mu\tau} / \delta^{LL}_{e\tau} \right|^2 + \left| \delta^{RR}_{\mu\tau} / \delta^{RR}_{e\tau} \right|^2 \right)^{-1/2} \sqrt{\frac{Br(\mu \to e\gamma)}{1.2\times10^{-11}}}$$

Search for $\tau \to \mu\gamma$ improve bounds on $\delta^{LL}_{\mu\tau}\delta^{RR}_{\tau\mu}$. It implies $d_\mu <\sim 10^{-24}\, e\,cm$.

Philip Harris: *The Neutron EDM Experiment: Progress, plans, systematics*

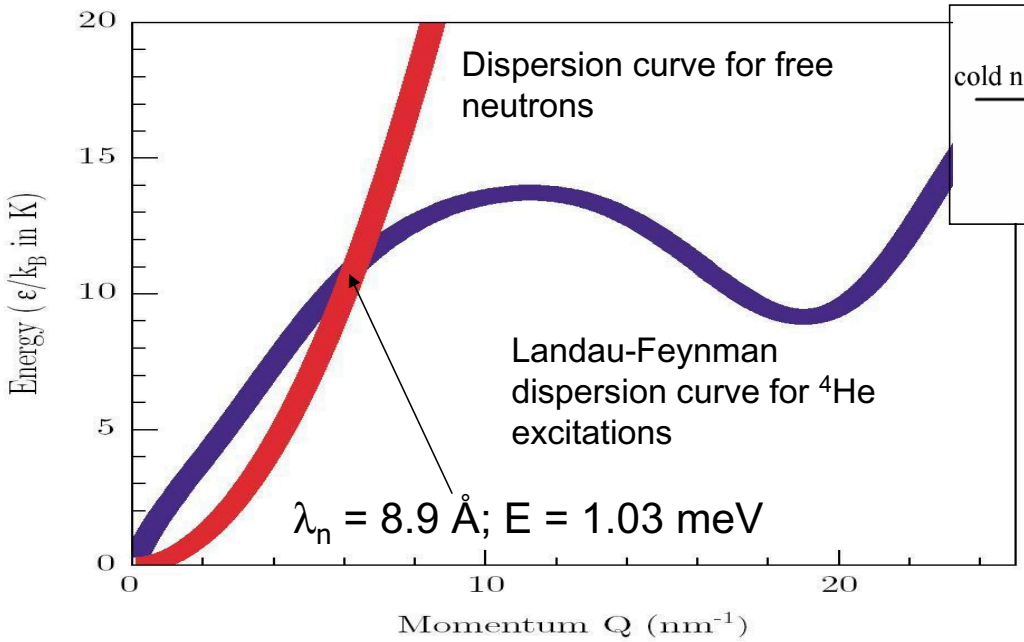
New limit:
$|d_n| < 3.0 \times 10^{-26}$ e.cm (90% CL)

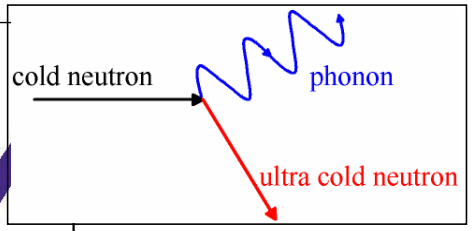
Preprint hep-ex/0602020
("probable acceptance" from PRL)

Error budget (10^{-26} *e*.cm)

Effect	Shift	Uncertainty
Statistical	0	1.51
Door cavity dipole; quadrupole fields	-1.10	0.45
Other GP dipole shifts	0	0.60
(**E** x **v**)/c^2 from translation	0	0.05
(**E** x **v**)/c^2 from rotation	0	0.10
Light shift: direct & GP	0.35	0.08
B fluctuations	0	0.24
E forces – distortion of bottle	0	0.04
Tangential leakage currents	0	0.01
AC B fields from HV ripple	0	0.001
Hg atom EDM	0	0.05
2nd order **E**x**v**	0	0.002
Total	–0.75	1.51 stat, 0.80 sys

UCN production in liquid helium





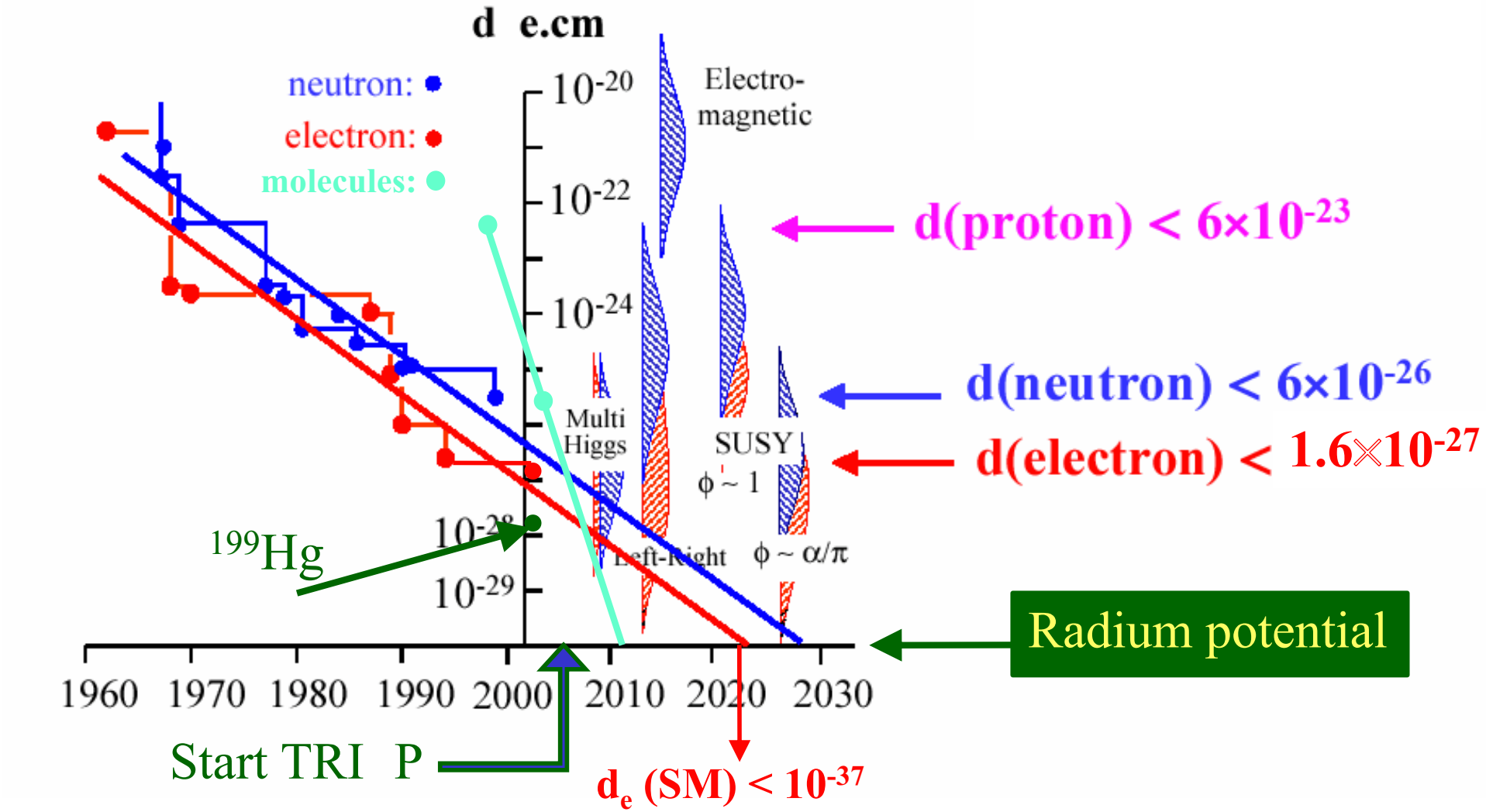
R. Golub and J.M. Pendlebury
Phys. Lett. **53A** (1975),
Phys. Lett. **62A** (1977)

- 1.03 meV (11 K) neutrons downscatter by emission of phonon in liquid helium at 0.5 K
- Upscattering suppressed: Boltzmann factor $e^{-E/kT}$ means not many 11 K phonons present
- **Observed:** C.A.Baker *et al.*, Phys.Lett. **A308** 67-74 (2002)

Systematics: Summary

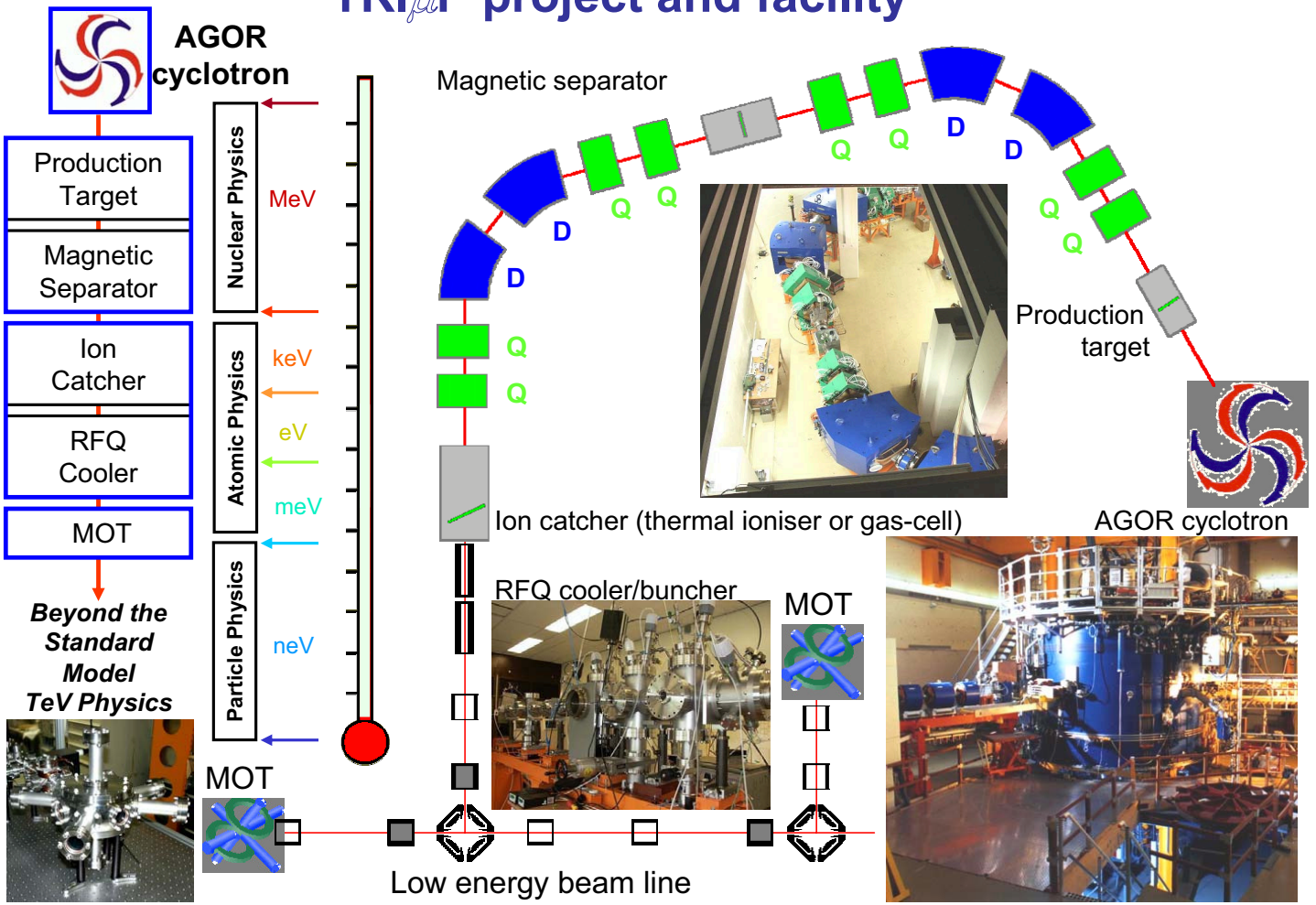
Effect	Size (e.cm)
B fluctuations	1×10^{-30}
Geometric phase	3×10^{-29}
Ex**v** translational	2×10^{-29}
Ex**v** rotational	1×10^{-29}
Ex**v** 2nd order	3×10^{-29}
metal hysterisis	1×10^{-30}
E-induced cell movement	1×10^{-28}
Leakage currents	5×10^{-29}
HV line contamination	1×10^{-29}

Hans Wilschut: *Tests of Time Reversal Violation in atomic and nuclear physics - The TRImP facility nearing its completion*



Hans Wilschut: *Tests of Time Reversal Violation in atomic and nuclear physics - The TRImP facility nearing its completion*

TRIμP project and facility



KVI Trapped Radioactive Isotopes: μicro-laboratories for Fundamental Physics

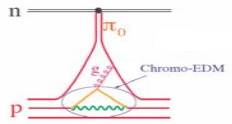
Yannis Semertzidis: *The deuteron EDM*

Deuteron Statistical Error:

$$\sigma_d \approx \frac{16\hbar}{\delta\beta_0 c \langle B \rangle A P \sqrt{N_c f \tau_p T_{Tot}}}$$

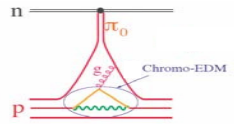
τ_p : 1000s **Polarization Lifetime (Coherence Time)**
A : 0.4 **The left/right asymmetry observed by the polarimeter**
P : 0.95 **The beam polarization**
N_c :10^{12}d/cycle **The total number of stored particles per cycle**
T_{Tot}: 5000h/yr. **Total running time per year**
f : 0.016 **Useful event rate fraction**
$\delta\beta_0$: 0.01-0.03 **Velocity modulation amplitude**
$\langle B \rangle$: 1.2 T **The average magnetic field around the ring**

$$\sigma_d \approx 1-3\times10^{-29}\ \mathrm{e\cdot cm\ /\ year}$$



Possible labs for 0.7-2GeV/c EDM Exps

Lab	D, P, ^{3}He (Polarized)	Equipment needed	Comment
BNL	Y, Y, Y	OK!	EBIS
CERN	N, N, N	Polarized Source, Spin manipulating devices	LHC +
COSY	Y, Y, N	Spin manipulating devices	Intensity, commitment to GSI, Funding
Frascati	N, N, N	IUCF's front end, Spin manipulating devices	New direction, Intensity
KVI	Y, Y, ?	Accumulator, Spin manipulating Dev.	Funding?



Yannis Semertzidis: *The deuteron EDM*

Deuteron EDM Timeline

- June 2006 Letter of Intent
- We need to develop the final ring lattice and tolerances on parameters
- Goal for a proposal within a year from June 2006

Neutron/deuteron EDM Timeline

	Exp begin data taking	Exp goal
2006		
2007		
2008	UCN-PSI	10^{-27}e·cm
2009	UCN-ILL	2×10^{-28}e·cm/yr
2010		
2011	UCN-LANL/SNS	10^{-28}e·cm
2012	Deuteron in Storage Ring	10^{-29}e·cm

5 CP(T) tests

Charge for the *Charged* Lepton CP/T Subgroup

Ikaros Bigi
Notre Dame du Lac

- CP/T in ν oscillations
- atomic EDM's etc.

} *other* subgroups

- CP/T with *charged* leptons
  - μ decays — new ideas?
  - positronium decays — '*clarify*' phenomenology & NP
  - K Æ $\mu^+\nu\pi$ — '*clarify*' NP
  - τ decays — '*clarify*' phenomenology & NP
  - τ prod. in e^+e^- Æ $\tau^+\tau^-$ — search for τ EDM

`clarify' --

- phenom.:

  optimal observables, experim. sensitivities & tools

- New Physics:
  - sensitivity of observables to NP features
  - complementary or competitive to LFV, EDM's?
  - interprete findings at LHC -- including `no-shows'

Question

Adopt benchmark models of NP
-- like Snowmass Variants of SUSY --

or more generic approach with effective Lagrangians?

Memento:

Searches for CP in τ & μ & e interactions

hypothesis generating
-- i.e. probing for a new paradigm --

rather than

hypothesis driven
-- i.e. testing an existing paradigm --

research!

Procedure

- summarize experimental status
- critical review of theoretical literature
- list scheduled/approved experiments
- evaluate new initiatives

Practical issues

- Who is volunteering to spend some time on which topic?
- How to stay in touch -- create electronic forum?
- How to involve people that cannot attend meetings in person?

6 Guidelines for writing the report (thanks to Yannis)

Physics motivation:

- **Energy scale reach**
- **Establish the sensitivity to various physics parameters for each major experiment**
- **Create a TABLE with sensitivity reach for each system**

Experimental efforts:

- **Description of the method**
- **Sensitivity goal**
- **Status**
- **R&D needed, timeline of expected progress**
- **Critical items**
- **Timeline of the experimental effort**
- **Create a TABLE with goals and expected results**

7 Overall working plan and discussion of LFV theory

presented by Martti Raidal