WG1: Precise determinations of V_{ud} and V_{us}, semileptonic/leptonic D decays and determinations of V_{cs} and V_{cd}.

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \cdot \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Conveners:
Anze Zupanc (Jozef Stefan Institute Ljubljana),
Elvira Gamiz (Univ. of Granada),
Stefan Baeßler

University of Virginia

Oak Ridge National Laboratory

Summary, part I: The determination of V_{ud}

Primary Motivation:

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

Is it?

(That is: Is "new physics" affecting the determination of the different elements of the CKM matrix?)

Superallowed beta decay: The idea

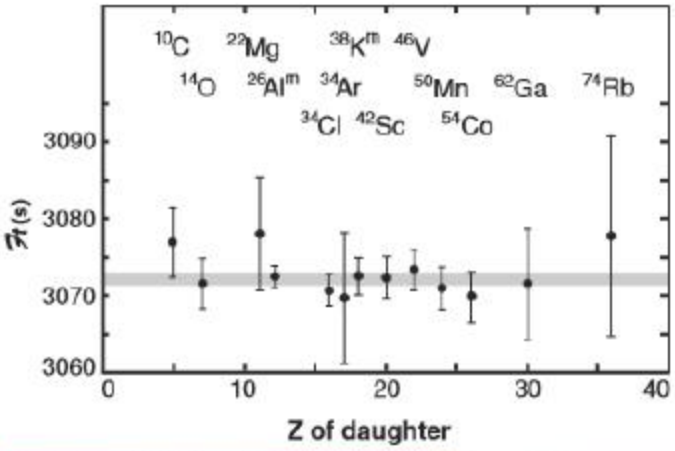
Slide from A. Garcia, CKM2014; Graph from Hardy / Towner, PRC 79, 055502 (2009).

Determine V_{ud} ; Fermi's golden rule:

$$\frac{1}{f(E)t} = \frac{2\pi}{\hbar}\left|\left\langle f\, e\nu\left|\hat{H}\right|i\right\rangle\right|^2 = \frac{(G_F V_{ud})^2}{K}\left|\left\langle f\left|\hat{O}\right|i\right\rangle\right|^2$$

Naïve appoach: *Measure $t_{1/2}$; approximate* $\left|\left\langle f\left|\hat{O}\right|i\right\rangle\right|^2 = I(I+1) - Iz(Iz-1)$

→ *extract G_F V_{ud}*



Works to few %.

Problem, for more precision:

the *ft*-value depends on Z.

Solution: isospin-breaking and radiative corrections:

$$Ft = ft\left(1+\delta_R'\right)\left(1+\delta_{NS}-\delta_C\right)$$

$$\frac{1}{Ft} = \frac{(G_F V_{ud})^2}{K}\left(1+\Delta_R^V\right)$$

If there is an issue, it is believed to be the isospin-breaking correction that is nuclear structure dependent.

News since CKM 2012: Update of survey

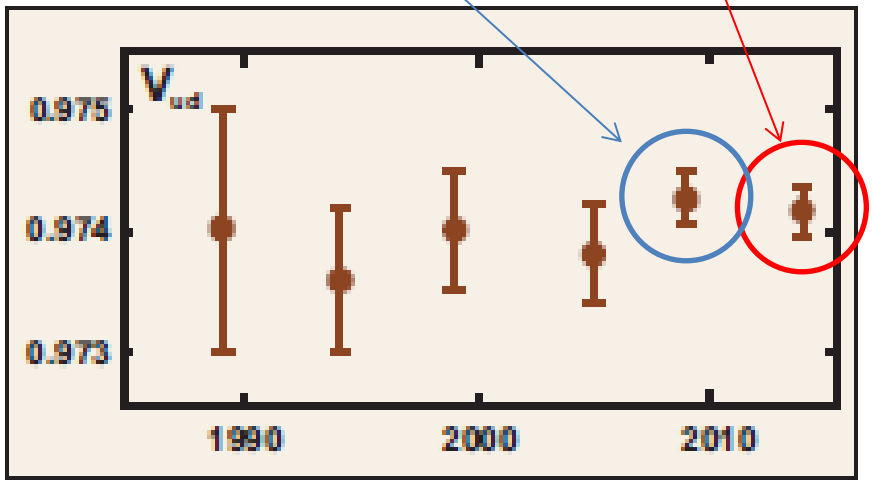
Basis of PDG 2014:

$V_{ud} = 0.97425(22)$

Recent announcement of an update:

$V_{ud} = 0.97417(21)$ (prelim.)

J. Hardy, I. Towner



From J. Hardy @ Solvay conference, Sep 2014

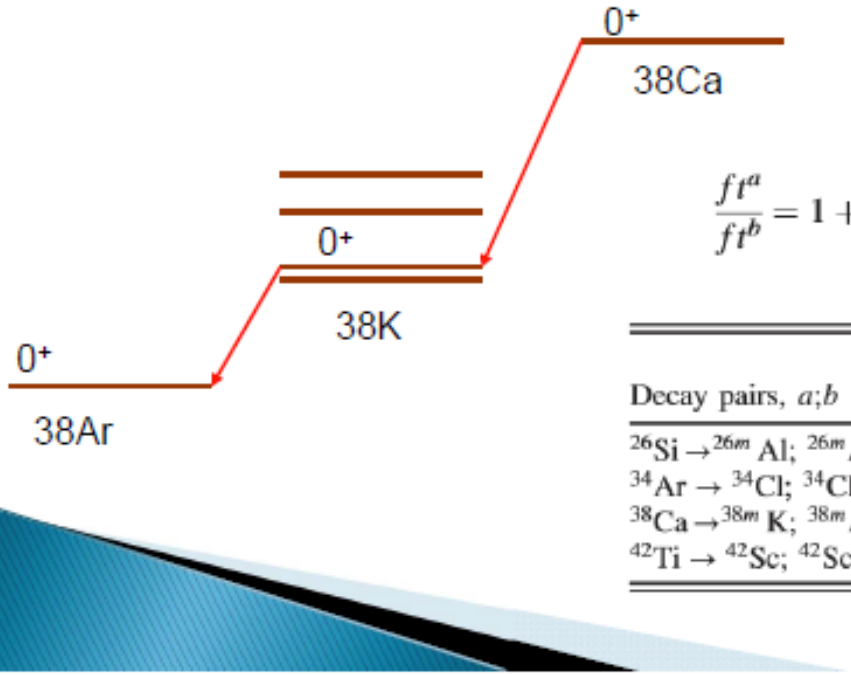
Experimental test of isospin-breaking corrections

Slide from A. Garcia, CKM2014.

PRL 112, 102502 (2014) PHYSICAL REVIEW LETTERS

β Decay of ^{38}Ca: Sensitive test of Isospin Symmetry-Breaking Corrections from Mirror Superallowed $0^+ \rightarrow 0^+$ Transitions

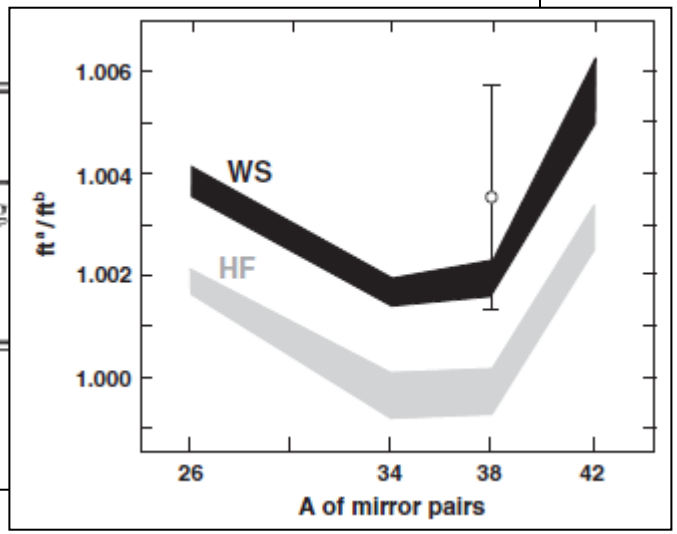
H. I. Park,* J. C. Hardy,† V. E. Iacob, M. Bencomo, L. Chen, V Horvat, N. Nica, B. T. Roeder, E. Simmons, R. E. Tribble, and I. S. Towner
Cyclotron Institute, Texas A&M University, College Station, Texas 77843-3366, USA
(Received 8 January 2014; published 12 March 2014)



$$\frac{ft^a}{ft^b} = 1 + (\delta_R'^b - \delta_R'^a) + (\delta_{NS}^b - \delta_{NS}^a) - (\delta_C^b - \delta_C^a),$$

Decay pairs, $a;b$

$^{26}\text{Si} \rightarrow {}^{26m}\text{Al}$; $^{26m}\text{Al} \rightarrow {}^{26}\text{Mg}$
$^{34}\text{Ar} \rightarrow {}^{34}\text{Cl}$; $^{34}\text{Cl} \rightarrow {}^{34}\text{S}$
$^{38}\text{Ca} \rightarrow {}^{38m}\text{K}$; $^{38m}K \rightarrow {}^{38}\text{Ar}$
$^{42}\text{Ti} \rightarrow {}^{42}\text{Sc}$; $^{42}\text{Sc} \rightarrow {}^{42}\text{Ca}$

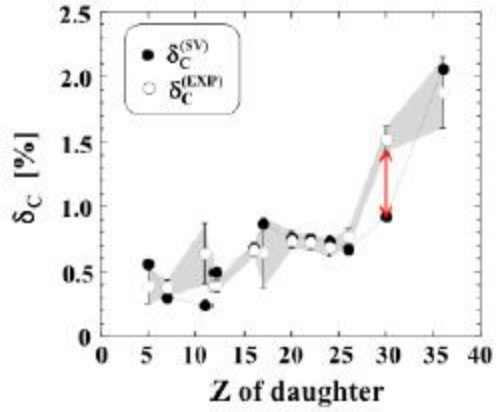


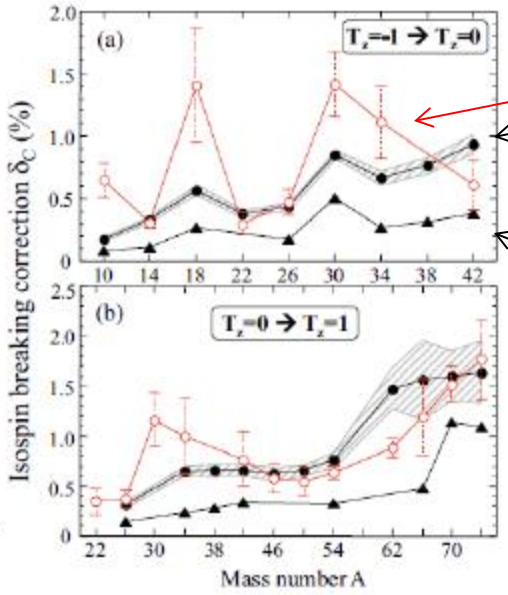
This is one of several confirmations of isospin-breaking corrections discussed in A. Garcia's talk.

Independent calculation of Isospin-Breaking corrections

Slide from A. Garcia, CKM2014.

Density-functional theory calculations:
Satuła, Dobaczewski, Nazarewicz, Rafalski,
PRL **106**, 132502 (2011)





Red: Satula et al.
Upper black circles:
Towner, Hardy, 2008
Lower black triangles:
Liang et al., 2009

A variation on the potential:
Satuła, Dobaczewski, Nazarewicz, Werner,
PRC **86**, 054316 (2012)

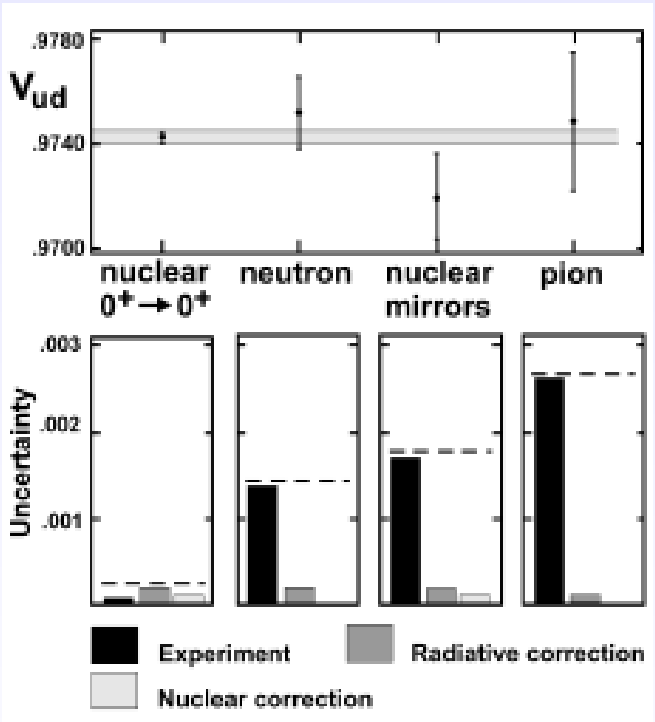
FIG. 6. (Color online) ISB corrections to superallowed $0^+ \rightarrow 0^+ \beta$ decays calculated for (a) $T_z = -1 \rightarrow T_z = 0$ and (b) $T_z = 0 \rightarrow T_z = 1$ transitions. Our adopted values from Table II (open circles with error bars) are compared with ISB corrections from Refs. [2] (filled circles; shaded band marks errors) and [12] (filled triangles).

17

- Satula et al. agrees within error with Towner / Hardy; Liang et al. does not
- V_{ud}(Satula et al. alone) is lower by 1.0σ, with similar uncertainty.
- Hardy / Towner criticize Satula et al., and Liang et al., for not obeying CVC

Alternatives: The value of V_{ud}

Slide from M. Pitschmann, CKM2014 .
Graph from Hardy / Towner, Ann Phys. 525, 443 (2013).



Neutron β–Decay

pro: no *isospin-symmetry breaking* & nuclear structure

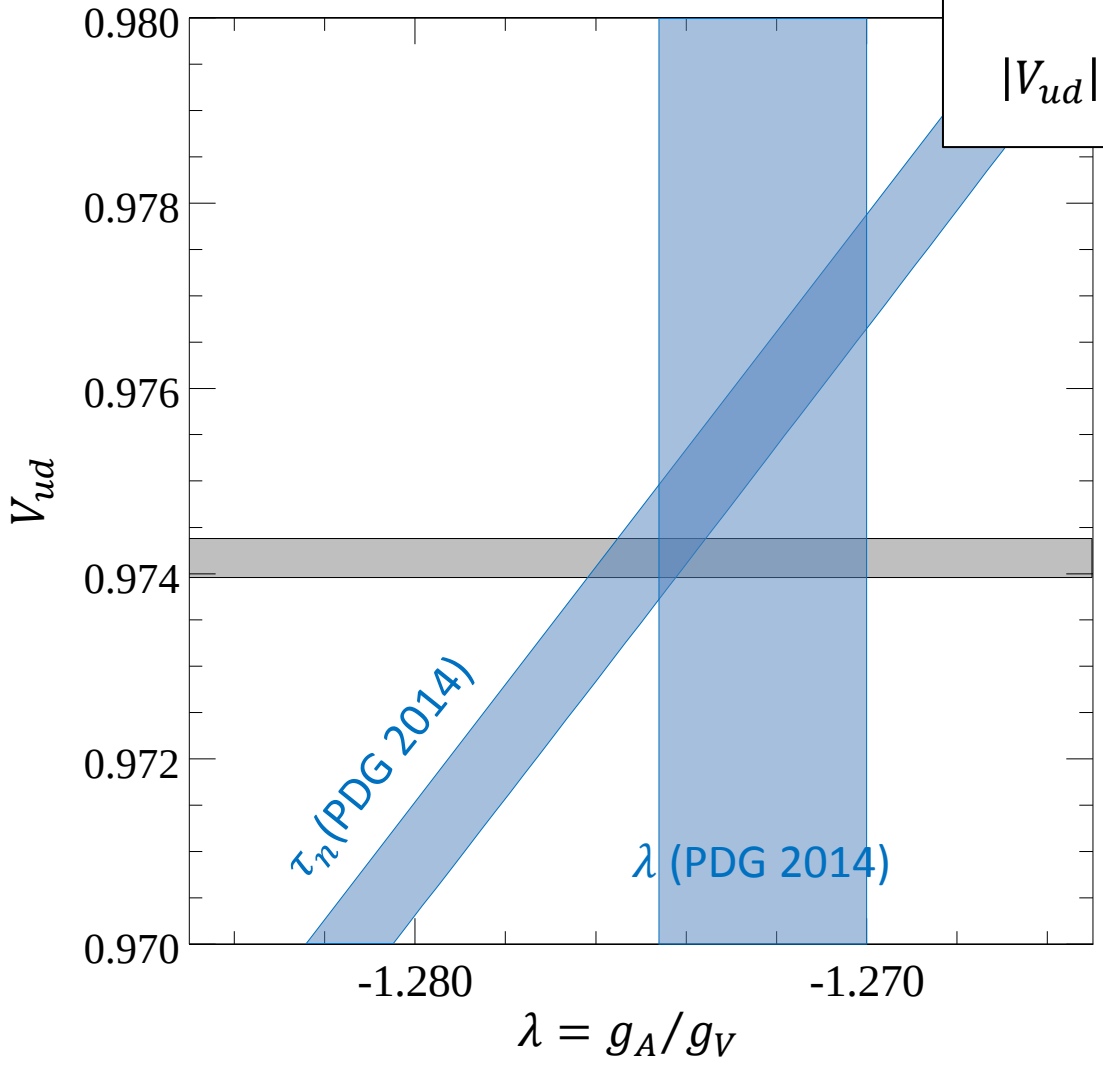
con: difficult to confine, also *axial-vector current* involved ⇒ need λ which introduces big *exp. uncertainties*

⇒ *uncertainty* still more than six times **nuclear** $0^+ \to 0^+$, intrinsically *small corrections* → promising future

The value of V_{ud} from neutron beta decay

Marciano, Sirlin:

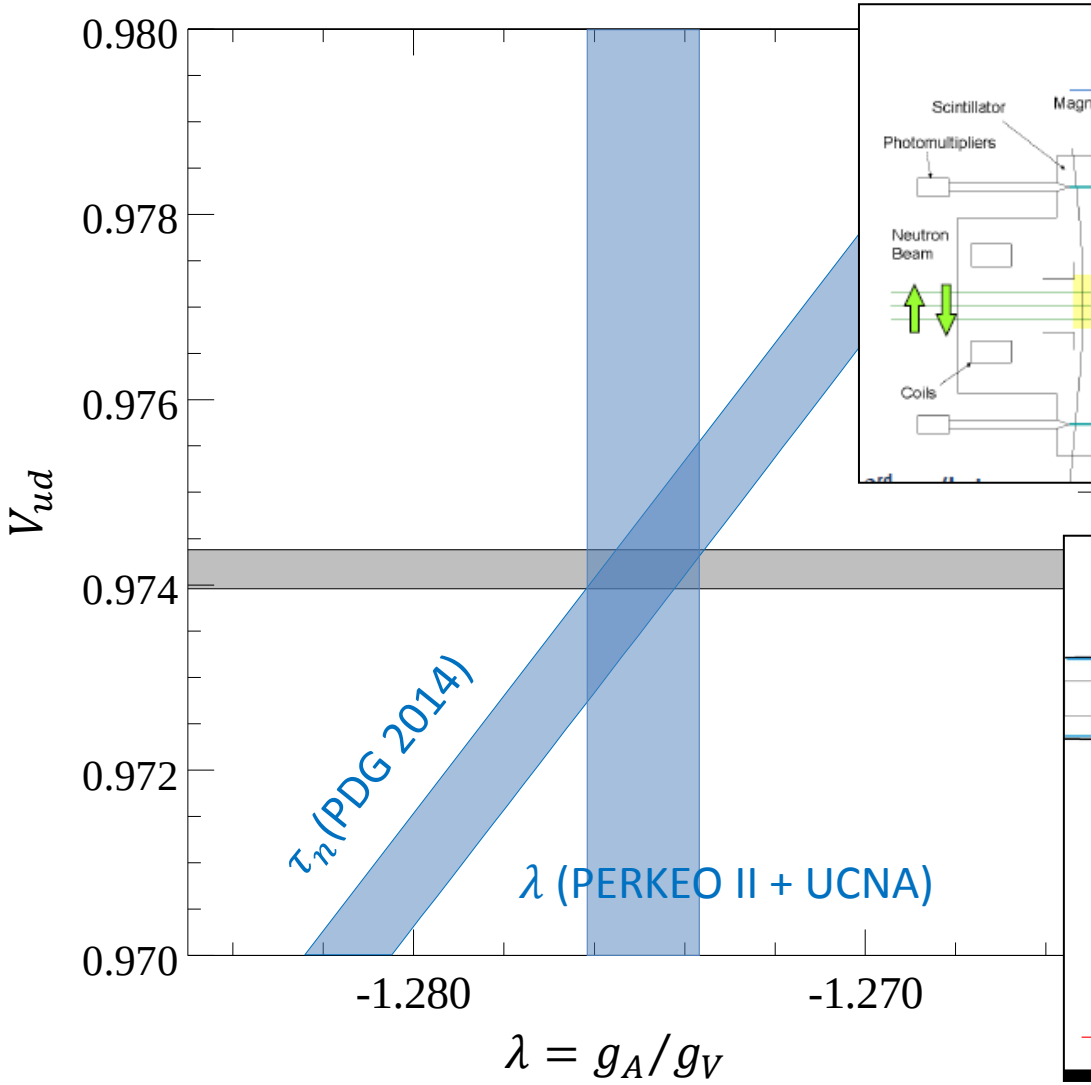
$$|V_{ud}|^2 = \frac{4908.7(19)s}{\tau_n(1+3\lambda^2)}$$

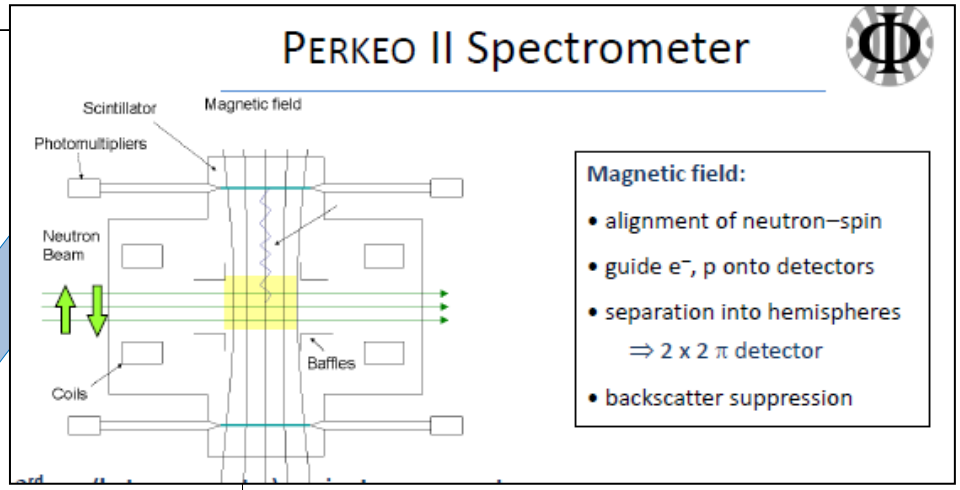


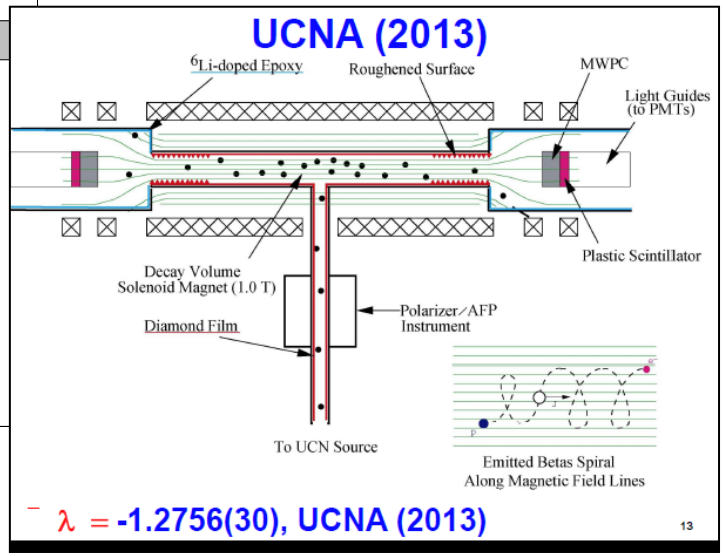
The value of V_{ud} from neutron beta decay

Pictures on right from H. Abele, CKM2014

News since CKM 2012:

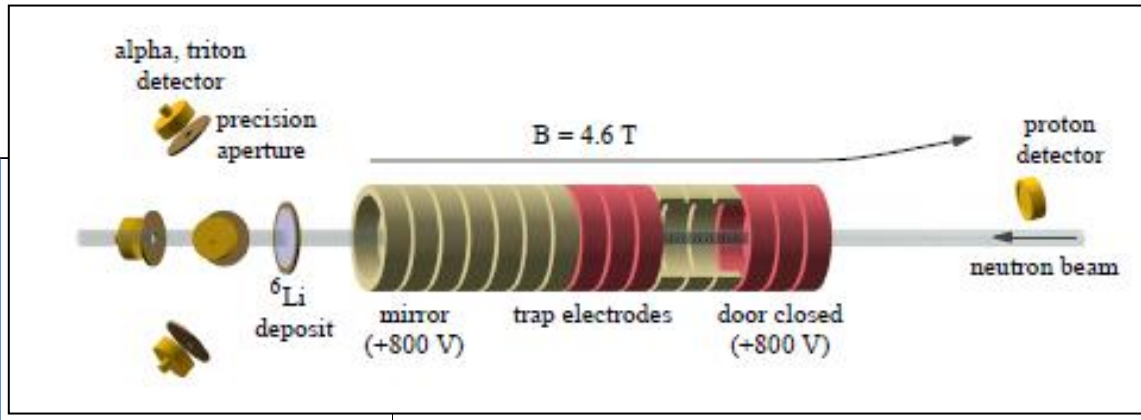




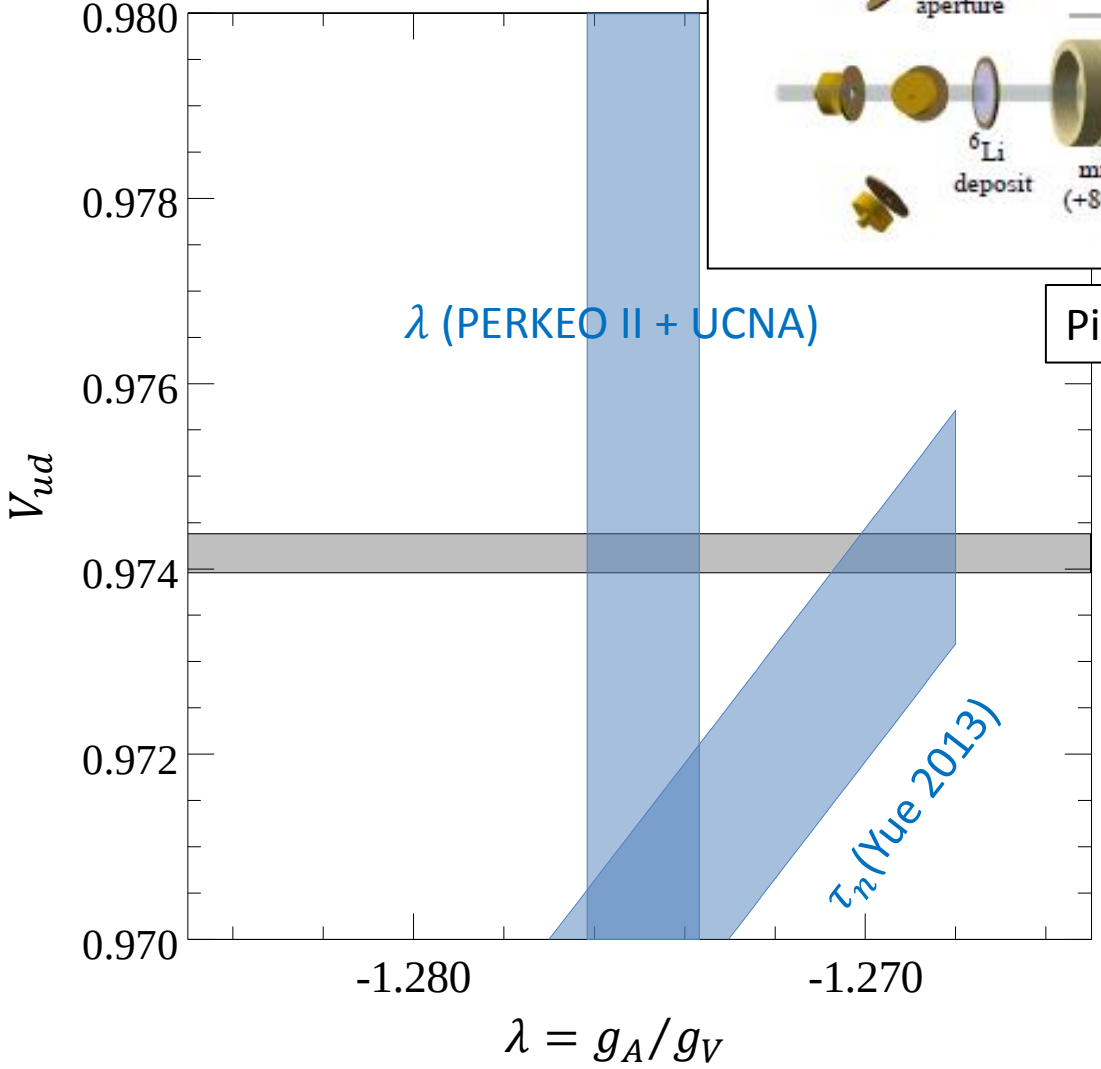


The value of V_{ud} : Summary

News since CKM 2012:
Confirmation and improvement of neutron beam lifetime



Picture from F. Wietfeldt, CKM2014.



Takeaway: At present, V_{ud} from neutron beta decay is all over the place.

Consistency and experimental precision in neutron beta decay needs to be improved:

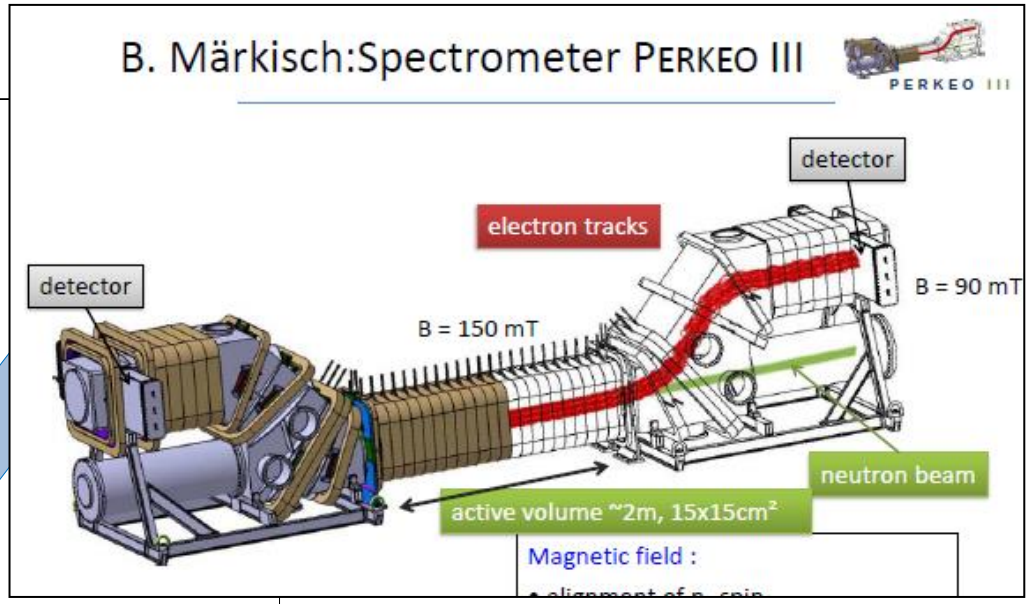
$$\Delta\tau_n = 1.1s \rightarrow 0.35s$$

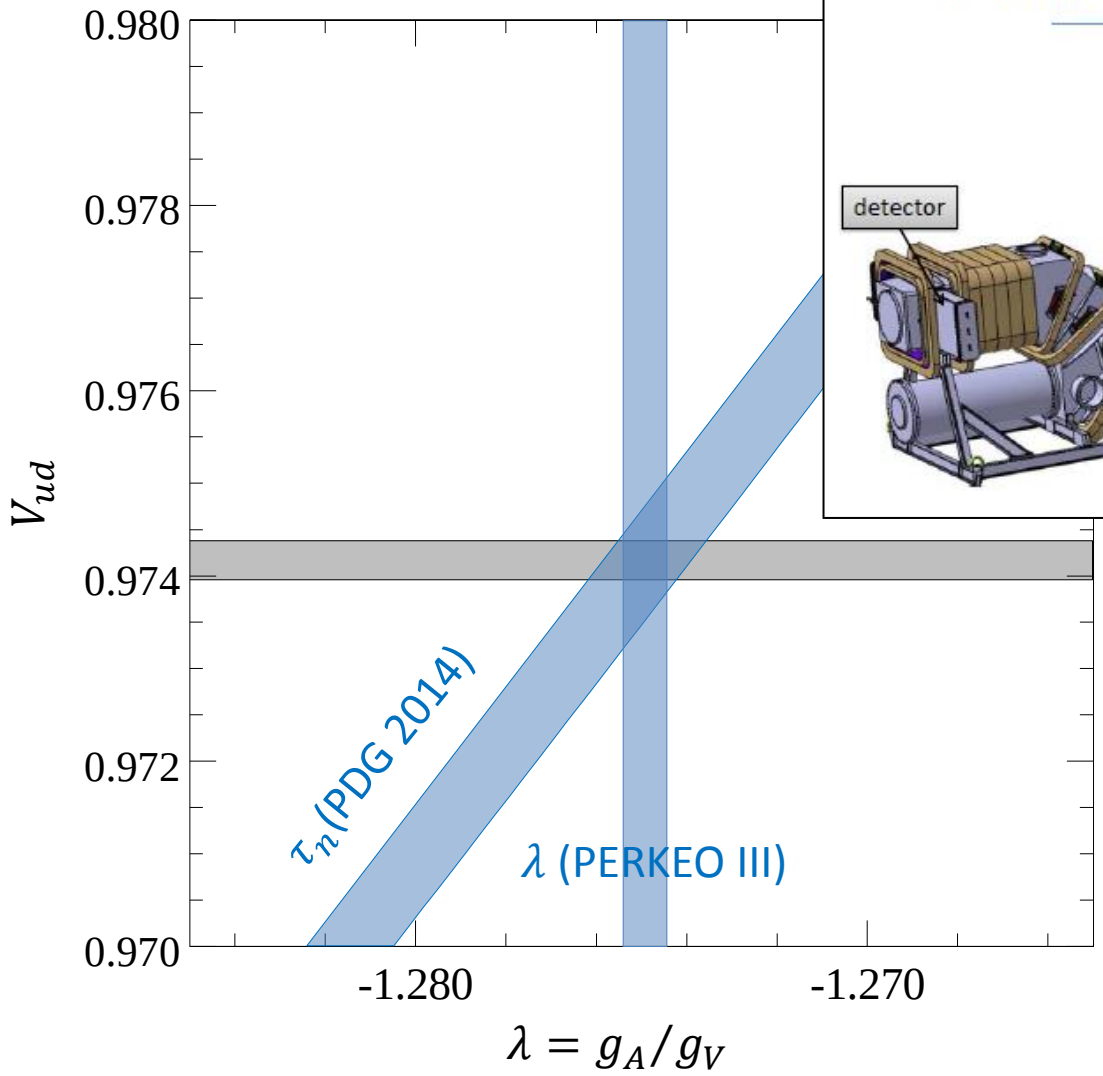
$$\Delta\lambda/\lambda = 0.18\% \rightarrow 0.03\%$$

The value of V_{ud} from neutron beta decay

PERKEO III has announced uncertainty for new λ measurement; unblinding is imminent.

Picture on right from H. Abele, CKM2014.





The value of V_{ud} : Summary

- The most precise value for V_{ud} is extracted from superallowed beta decays. The limitation is in the knowledge of the theoretical corrections. Isospin-breaking (nuclear structure-dependent) corrections are being scrutinized, and survive tests.
- More stringent tests are underway.

- Neutron beta decay could provide a value with at least equal precision, and free from isospin-breaking corrections. However, their precision needs to be increased, and the neutron lifetime puzzle resolved. Experiments that aim to do so are underway (beam lifetime @ NIST, UCNτ @ LANL, HOPE @ ILL, PERC @ Vienna / FRM2, Nab @ ORNL, …) .