High precision half-life measurement of ^{29}P

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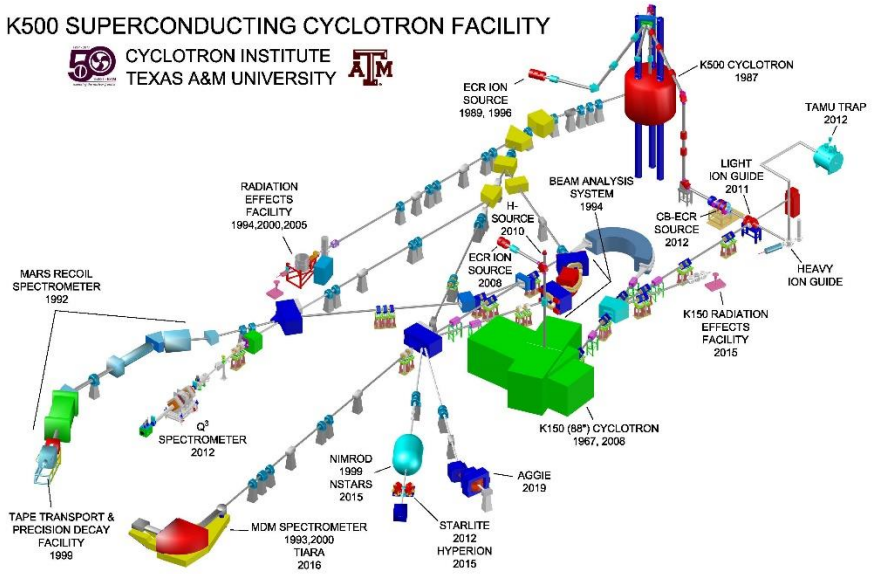
Outline

- Motivation
- Experimental setup
- Results
- Conclusion



Motivation

- Test of Conservation of Vector Current(CVC)
- Test of unitarity of CKM Matrix:

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 \stackrel{?}{=} 1$$

- Correlation experiments: $a_{\beta\nu}^{SM} \stackrel{?}{=} a_{\beta\nu}^{expt}$

Need to measure ft values

- Superallowed Transitions
- Nuclear Mirror Transitions

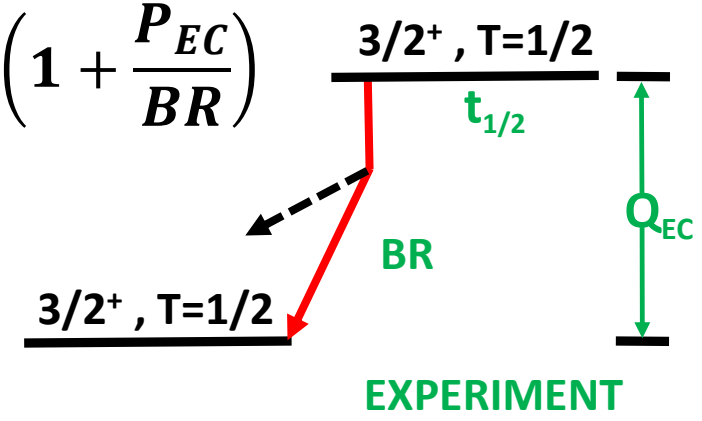
Sources in nuclear β decay

Mirror Transitions

$$\mathcal{F}t = f_V t(1+\delta'_R)\left(1+\delta^V_{NS}-\delta^V_C\right);\ t = ln2\tau\left(1+\frac{P_{EC}}{BR}\right)$$

$$\mathcal{F}t_0 = \mathcal{F}tC_V^2\left|M_F^0\right|^2\left[1+\left(\frac{f_A}{f_V}\right)\rho^2\right]$$

$$V_{ud}^2 = \frac{K}{\overline{\mathcal{F}t_0}G_F^2(1+\Delta_R^V)}$$



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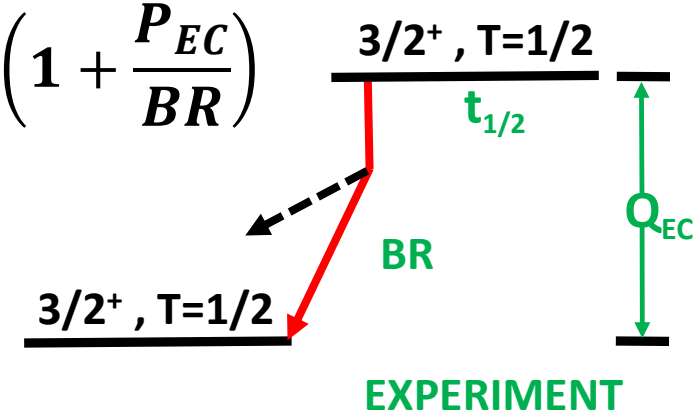

ρ and $ft(\tau, BR, Q_{EC})$ value are observables to test the unitarity of CKM matrix.

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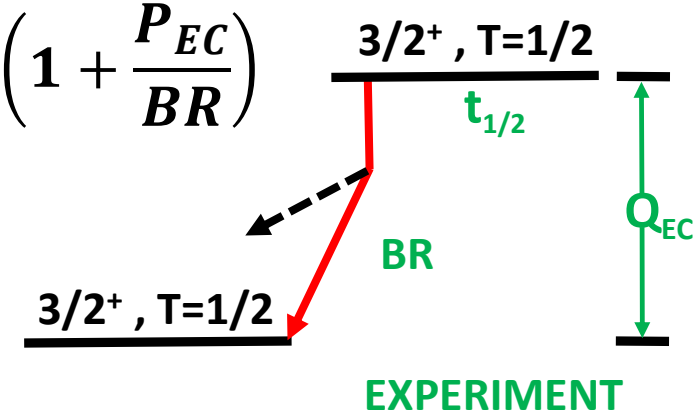

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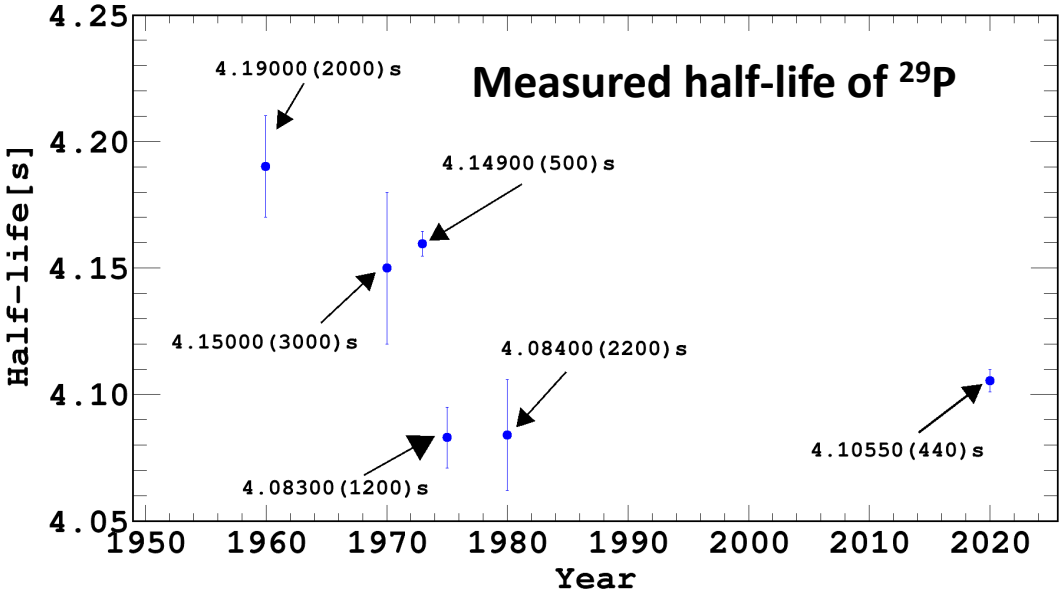
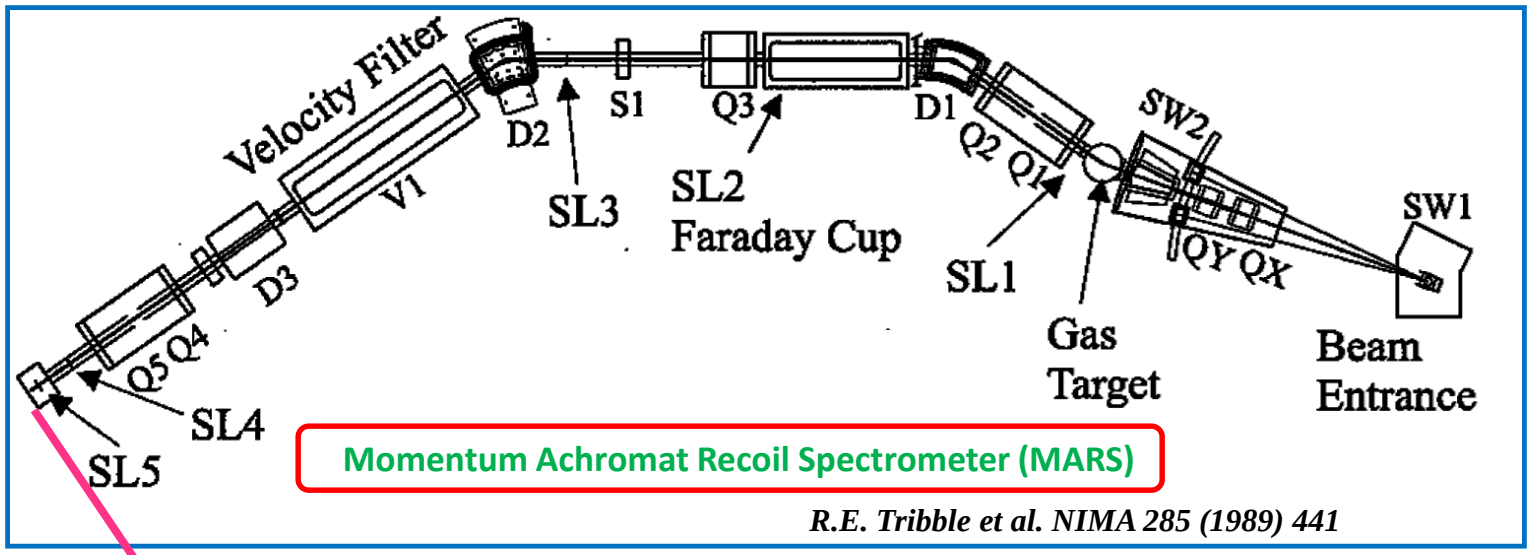
- **^{29}P is one out of five case used to determine V_{ud} and test the unitarity of CKM matrix in mirror transitions.**

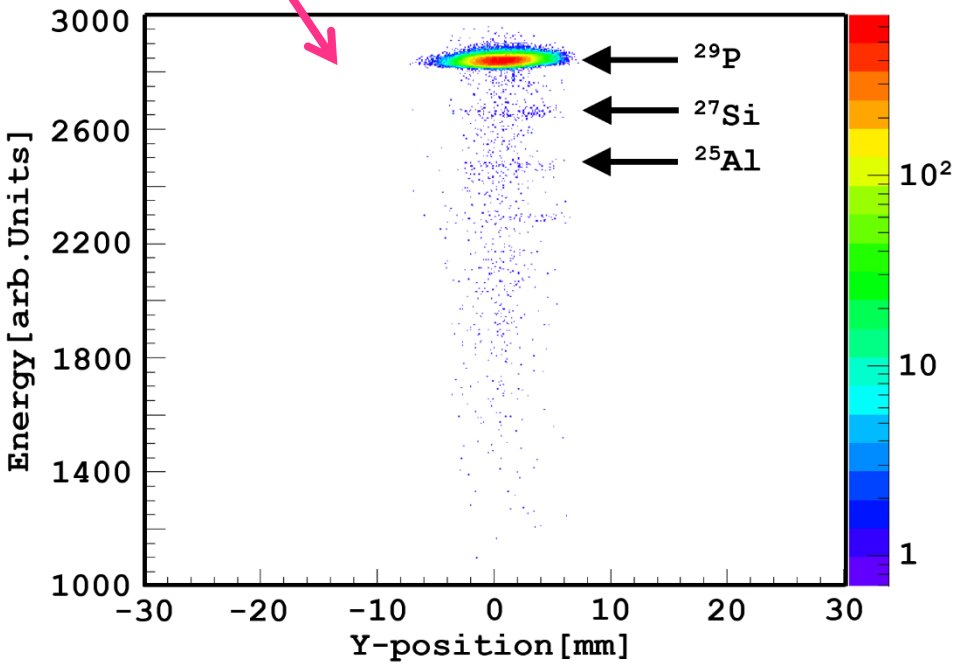
$t_{1/2}$= 4.1031(40) (0.1%)
(weighted average)
= 4.1055(44) (0.11%)
(most precise)
BR = 98.29(3) (0.03%)
(average value)
= 98.29(3) (0.03%)
(most precise)
Q_{EC} = 4942.18(37) 0.008%



Production of ^{29}P



R.E. Tribble et al. NIMA 285 (1989) 441

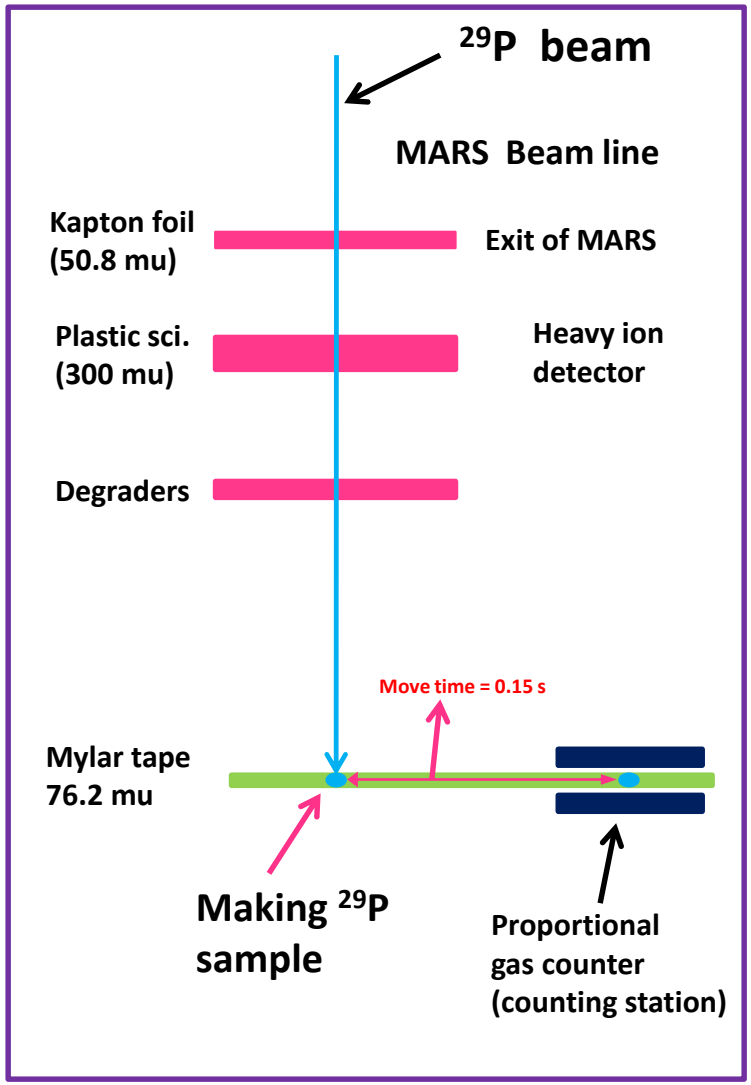


Reaction: ^{30}Si (p,2n)^{29}P @ 25 MeV/u

Produced: ^{29}P @ 23 MeV/u

Contaminant	Impurity Level at the exit of MARS	Half-life (sec)
^{27}Si	0.1%	4.15 ± 0.04
^{25}Al	0.1%	7.183 ± 0.012

Transport & detection



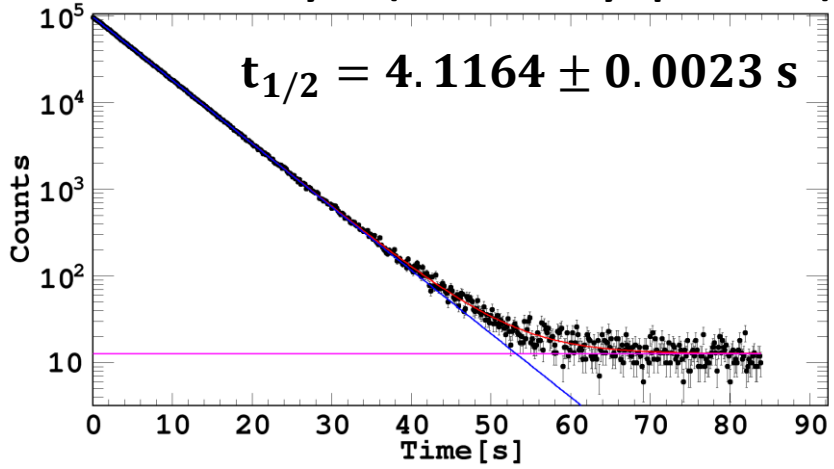
Systematic studies

- Plastic scintillator: To detect heavy ions and used to monitor the ratio between betas and heavy ions.
- Gas counter: To detect the beta particles from the decay of ^{29}P.
- The Al degrader along with the plastic scintillator further purify the beam ^{29}P beam to > 99.9%.

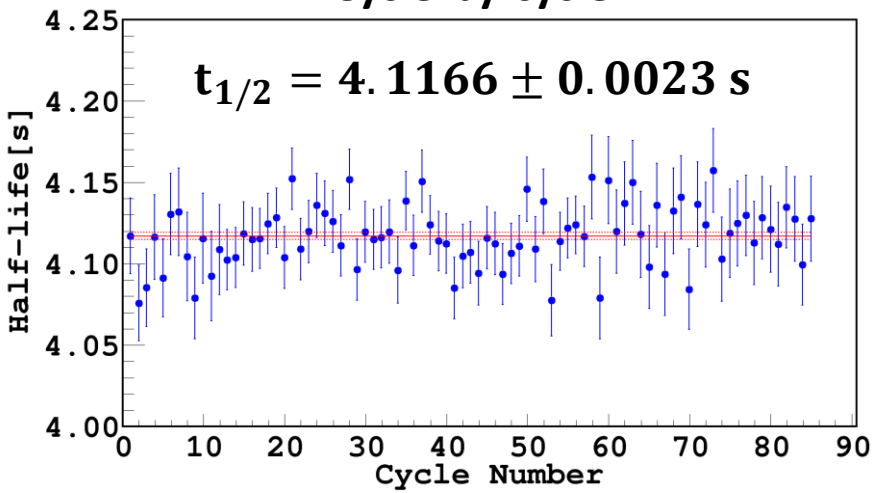
- Bias voltages:
  2600V, 2650V, 2700V, 2750V.
- Discriminator threshold :
  150 mV, 200 mV, 250 mV.
- Dead time:
  4 & 8 μs , 6 & 10 μs.

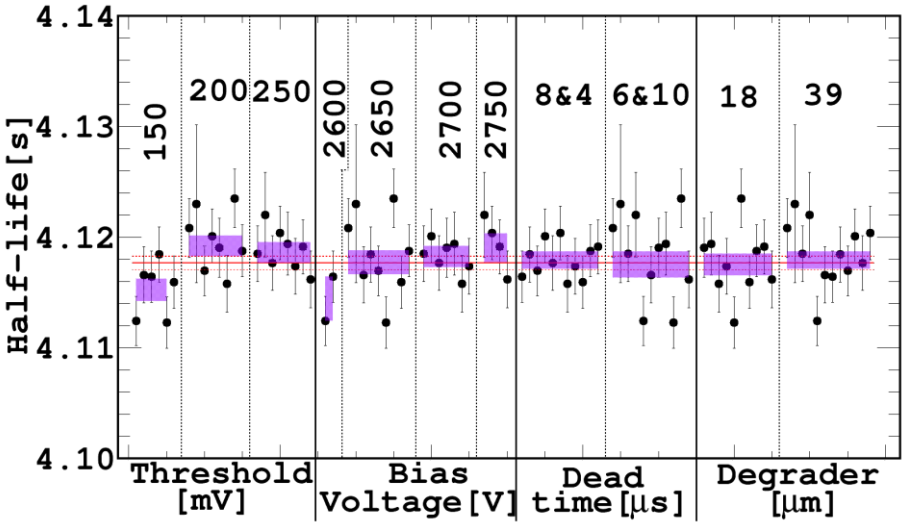
Results

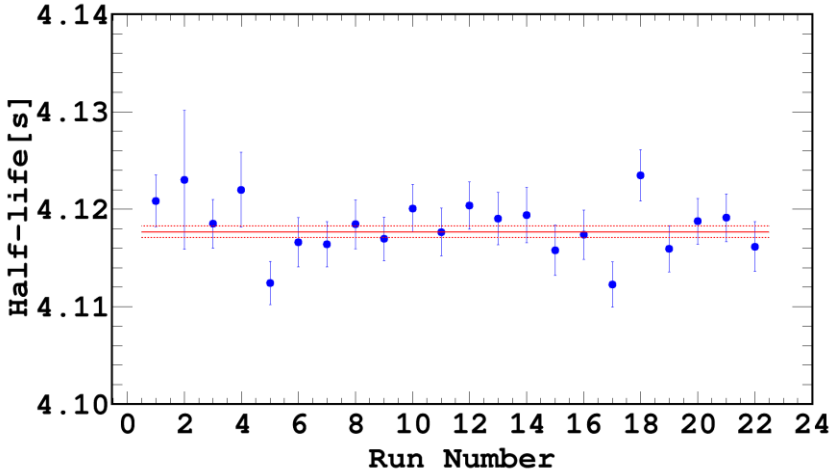
Summed Analysis (Total decay spectrum)



Cycle-by-cycle

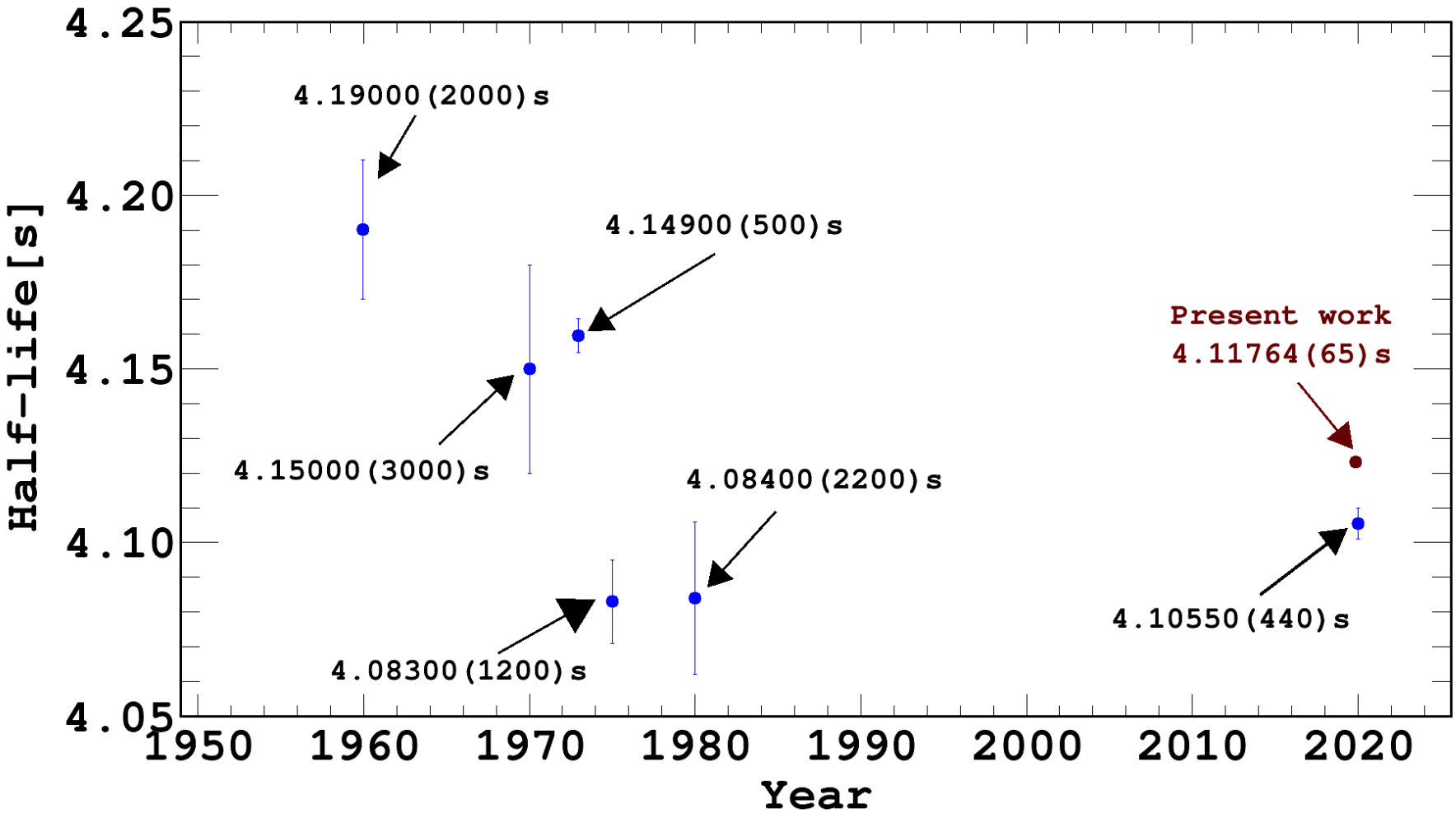




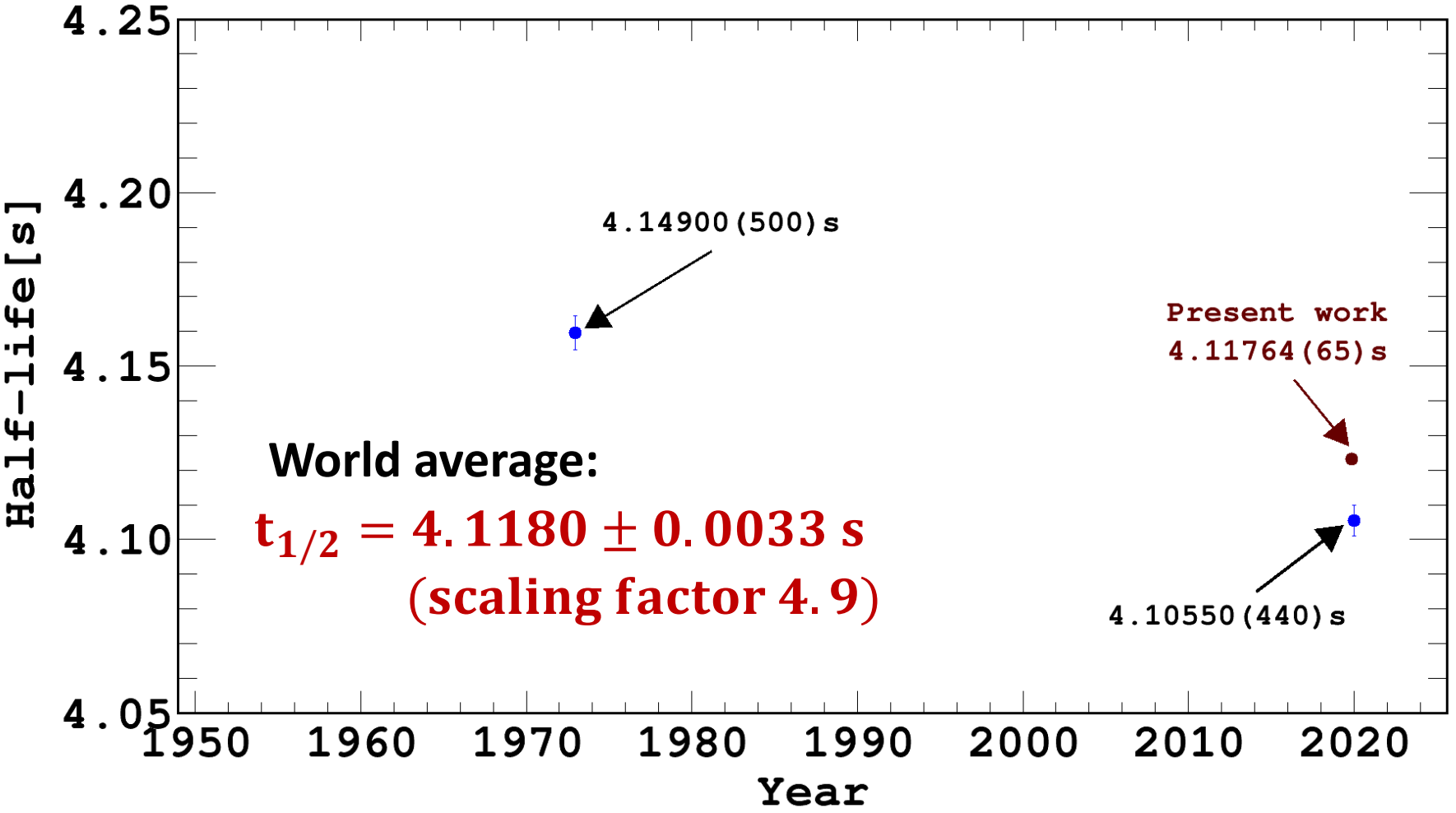


$t_{1/2} = 4.11764 \pm 0.00065$ s ; (preliminary)

Results


4.25
4.20
4.15
4.10
4.05
Half-life[s]
1950
1960
1970
1980
1990
2000
2010
2020
Year
4.19000(2000)s
4.14900(500)s
4.15000(3000)s
4.08400(2200)s
4.08300(1200)s
Present work
4.11764(65)s
4.10550(440)s

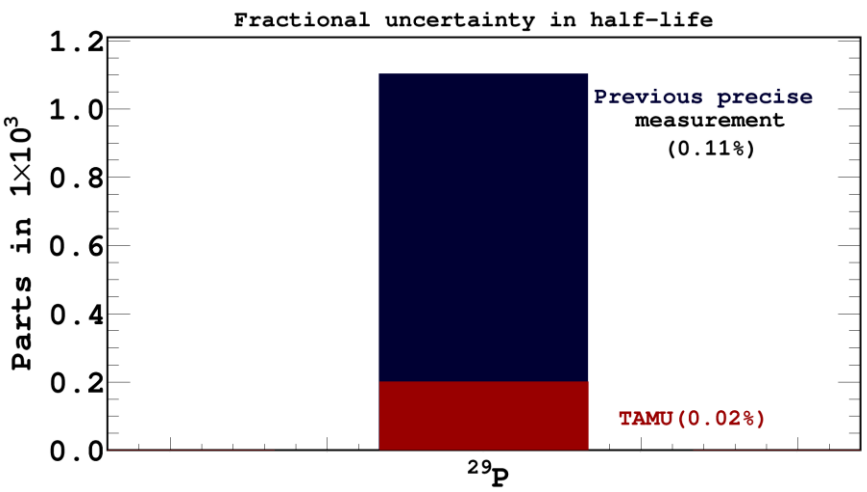
Results

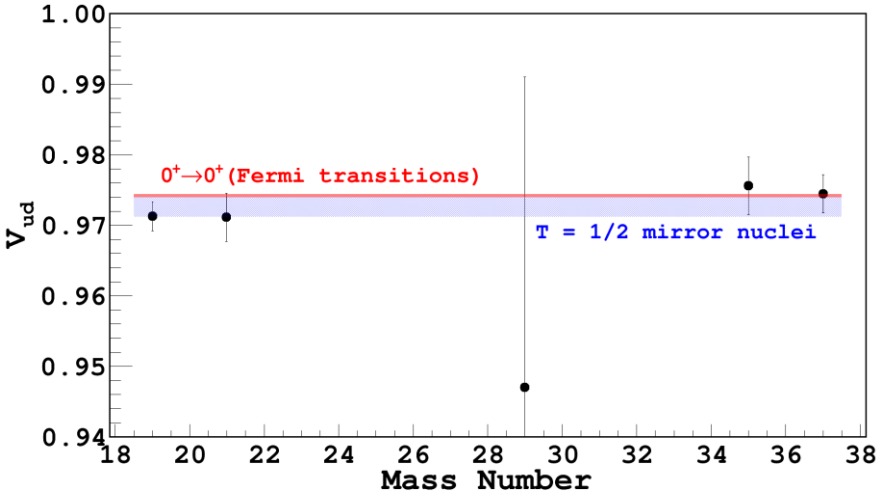


$$\mathcal{F}t = 4781.0 \pm 5.6 \text{ s}$$

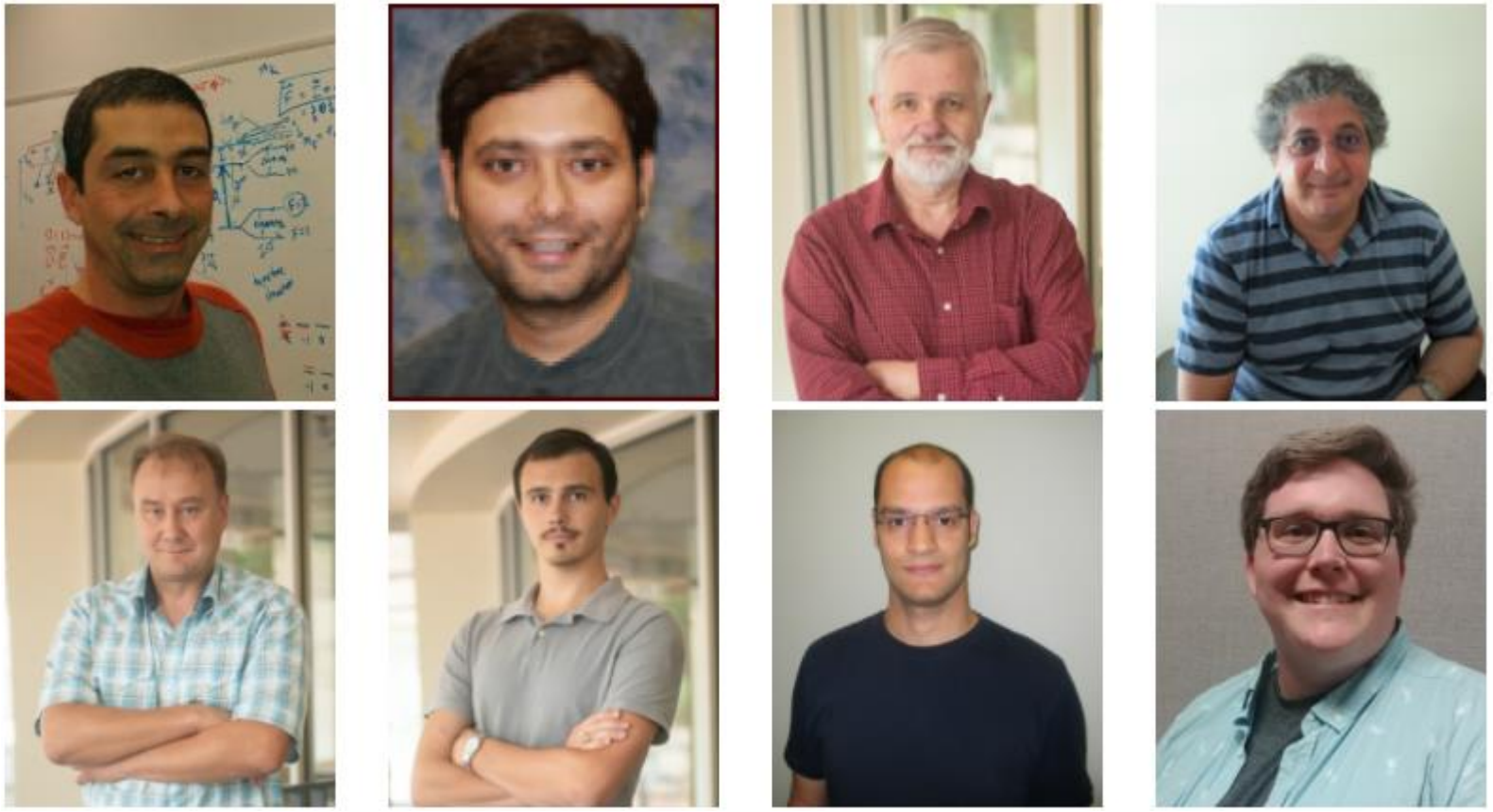
$$V_{ud} = 0.947 \pm 0.044$$

Conclusion





- Produced ^{29}P with > 99.9% purity.
- Order of magnitude improvement in the uncertainty of half-life.
- Large scaling factor in world average is still problematic.
- Need more measurements from other groups with > 99.9%.
- Uncertainty in V_{ud} value is still dominated by the uncertainty in ρ value.
- Group from University of Notre Dame (Prof. M. Brodeur) plan to measure $a_{\beta\nu}$, for ^{29}P.



Thank you