Precise measurements of half-lives and branching ratios for two mirror β decays involving ^{23}Mg and ^{27}Si

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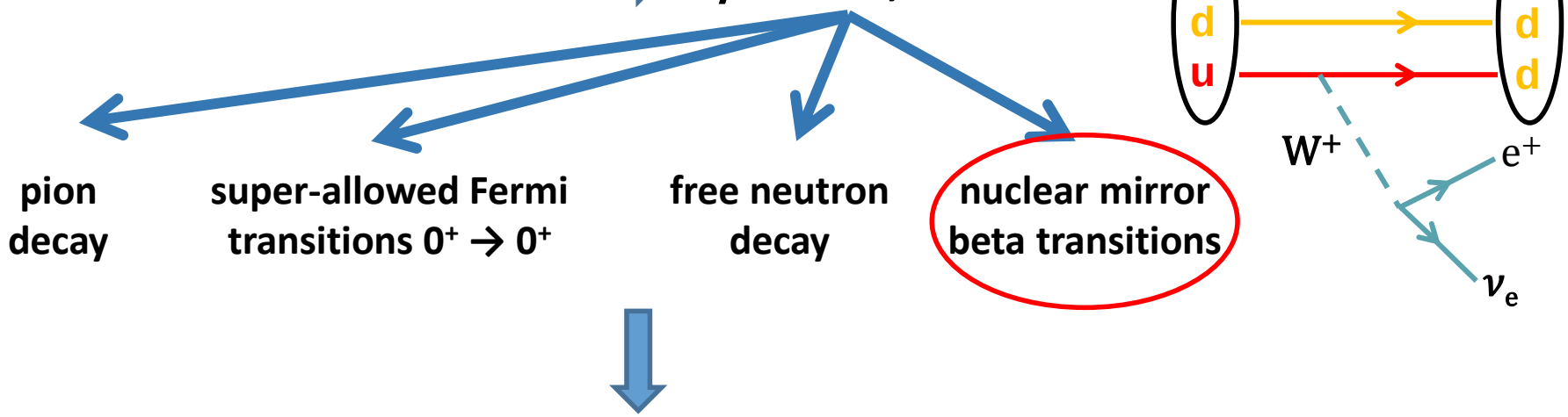
OUTLINE OF THE TALK

- Purpose of this work
- JYFL13 experiment
- Analysis and results

PURPOSE OF THIS WORK

- Standard Model describes 3 of the 4 fundamental interactions:
  - Strong interaction
  - Electromagnetic interaction
  - Weak interaction ⇒ β decays



- Two hypotheses of the SM can be tested:
  - Conserved Vector Current (*CVC*)
  - Unitarity of the Cabibbo-Kobayashi-Maskawa (*CKM*) matrix

J. C. Hardy and I. S. Towner, Phys. Rev. C**91**, 025501 (2015).

PURPOSE OF THIS WORK

- *CVC* hypothesis: G_v unique for all beta transitions

experimental parameters

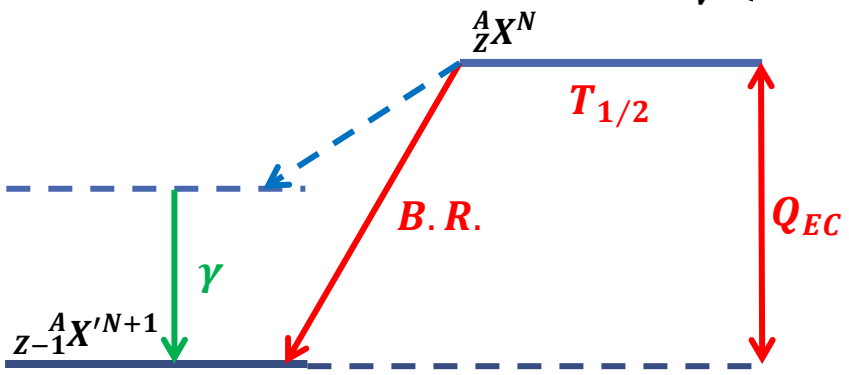
$$ft = \frac{f(\boldsymbol{Q_{EC}})\,(1+P_{EC})\;\boldsymbol{T_{1/2}}}{\boldsymbol{B.R.}}$$

theoretical corrections

$$\mathcal{F}t = ft(1+\delta_R')\left(1+\delta_{NS}^V-\delta_C^V\right)$$

constant for mirror transitions

$$\mathcal{F}t_0 = \mathcal{F}tG_V^2|M_F^0|^2[1+(f_A/f_V)\boldsymbol{\rho}^2] = \frac{cst}{G_V^2(1+\Delta_R^V)}$$



PURPOSE OF THIS WORK

- Unitarity of the CKM matrix
  - First raw: $V_{ud}{}^2 + V_{us}{}^2 + V_{ub}{}^2 = 1$

$$V_{ud}{}^2 = \left(\frac{G_V}{G_\mu}\right)^2 : \text{main term}$$

Quark mixing matrix:

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

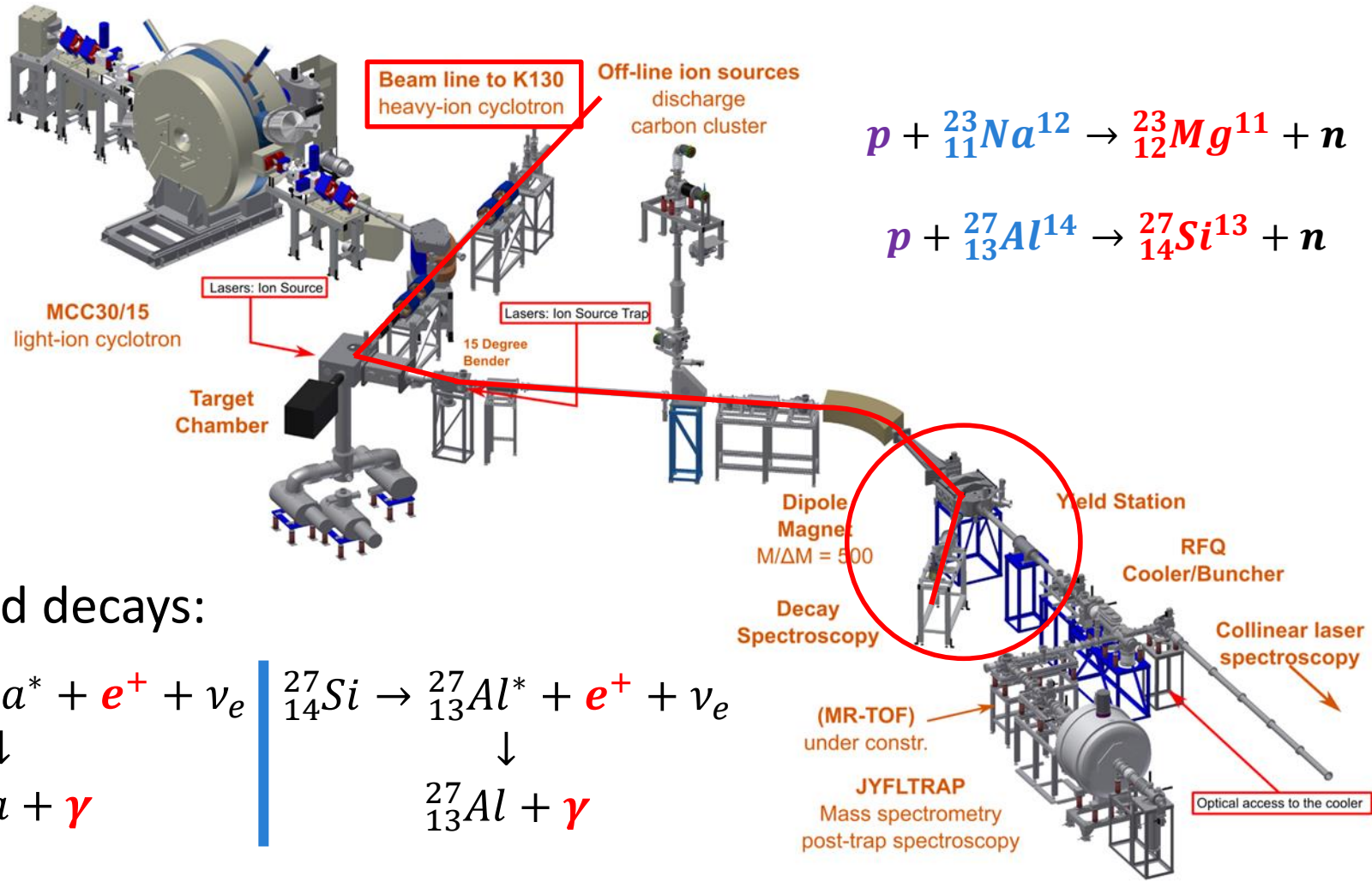
- Current values for 5 mirror transitions:
  - $\mathcal{F}t_0 = 6173(22)$ s (0.4% precision)
  - $V_{ud} = 0.9719(17)$ (0.2% precision)

Need for better precision to compete with super-allowed transitions

N. Severijns *et al.*, Phys. Rev. C**78**, 055501 (2008).

JYFL13 EXPERIMENT (^{23}Mg, ^{27}Si)

- Performed at Jyväskylä University (Finland) with IGISOL



$$p + {}^{23}_{11}Na^{12} \rightarrow {}^{23}_{12}Mg^{11} + n$$

$$p + {}^{27}_{13}Al^{14} \rightarrow {}^{27}_{14}Si^{13} + n$$

- Observed decays:

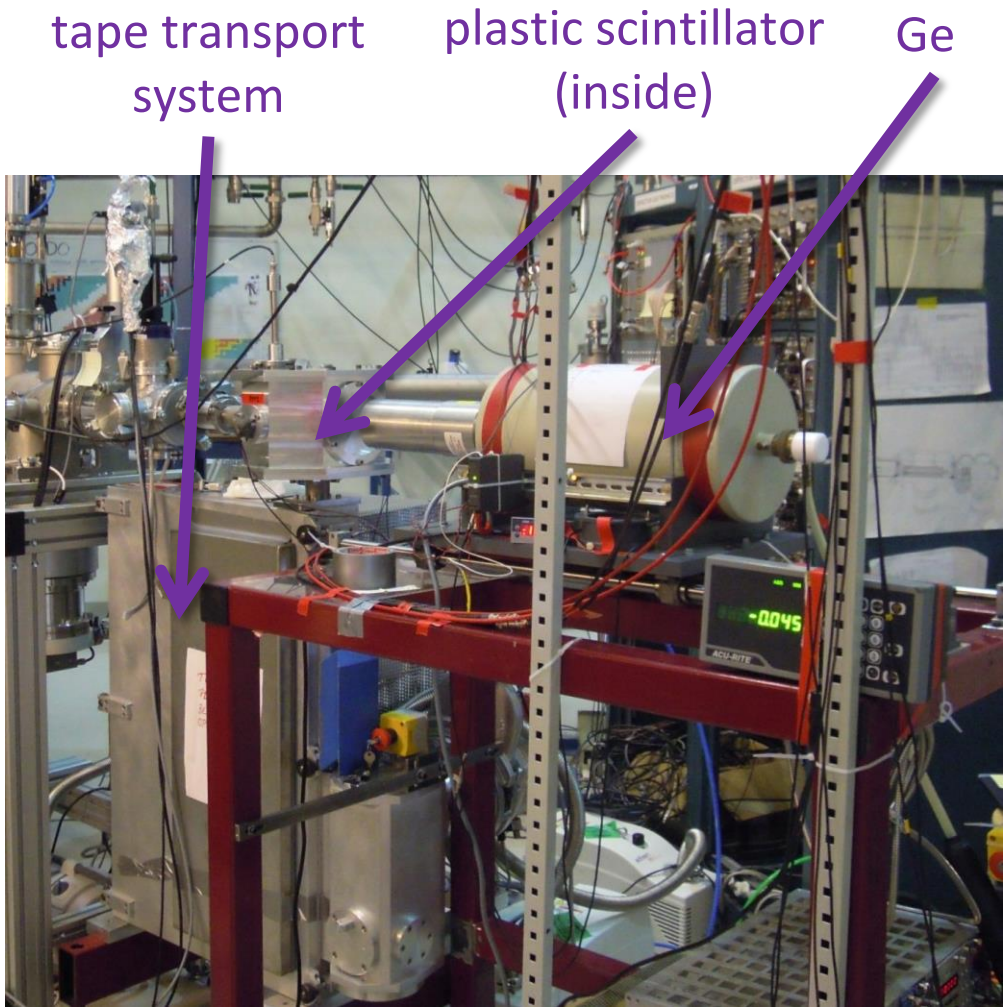
$$^{23}_{12}Mg \rightarrow {}^{23}_{11}Na^{*} + e^{+} + \nu_e$$
$$\downarrow$$
$$^{23}_{11}Na + \gamma$$

$$^{27}_{14}Si \rightarrow {}^{27}_{13}Al^{*} + e^{+} + \nu_e$$
$$\downarrow$$
$$^{27}_{13}Al + \gamma$$

JYFL13 EXPERIMENT (^{23}Mg, ^{27}Si)

- Half-lives:
  - β^+ particles detected with plastic scintillator
- Branching ratios:
  - γ rays recorded with germanium detector (Ge) precisely calibrated in efficiency (10^{-3})

  B. Blank *et al.*, NIM A 776 (2015).
- Two data acquisitions:
  - a scaler for half-lives (fast)
  - a list mode for branching ratios (slow)



ANALYSIS AND RESULTS

Focus on ^{23}Mg analysis

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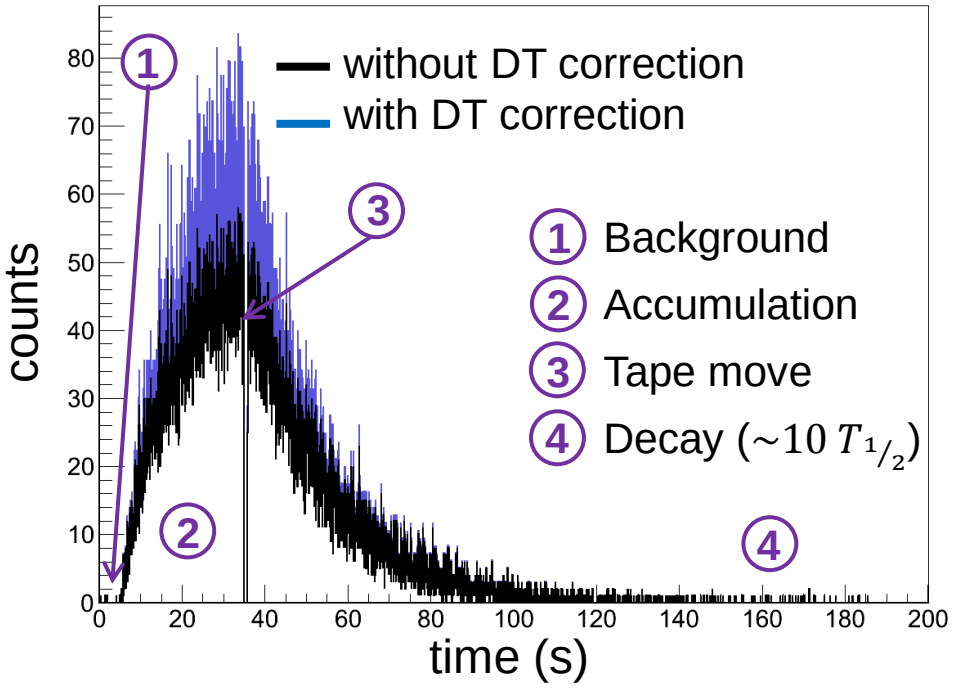
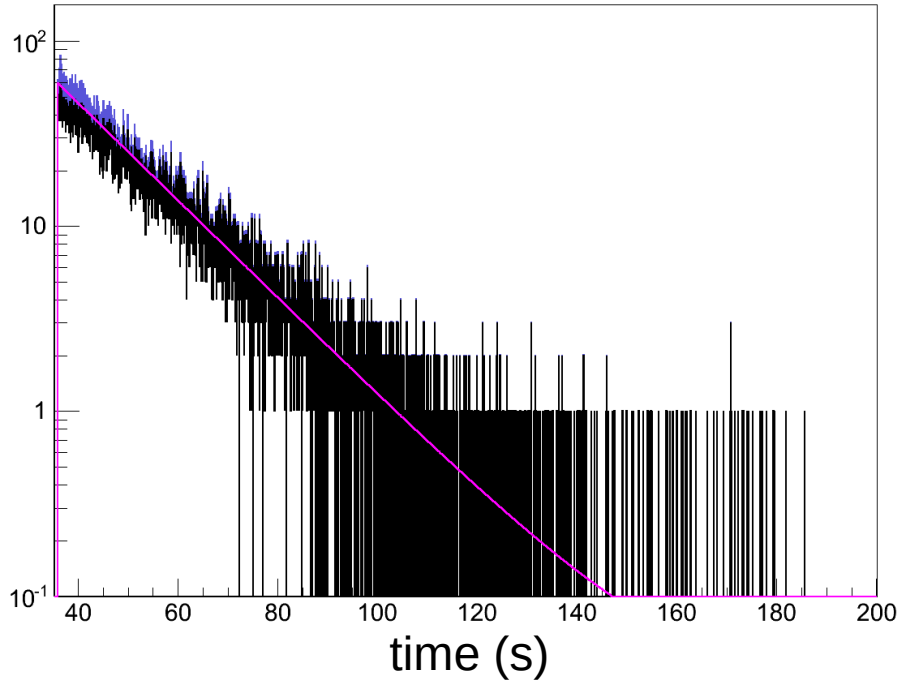
- Half-life:





fit of the decay part

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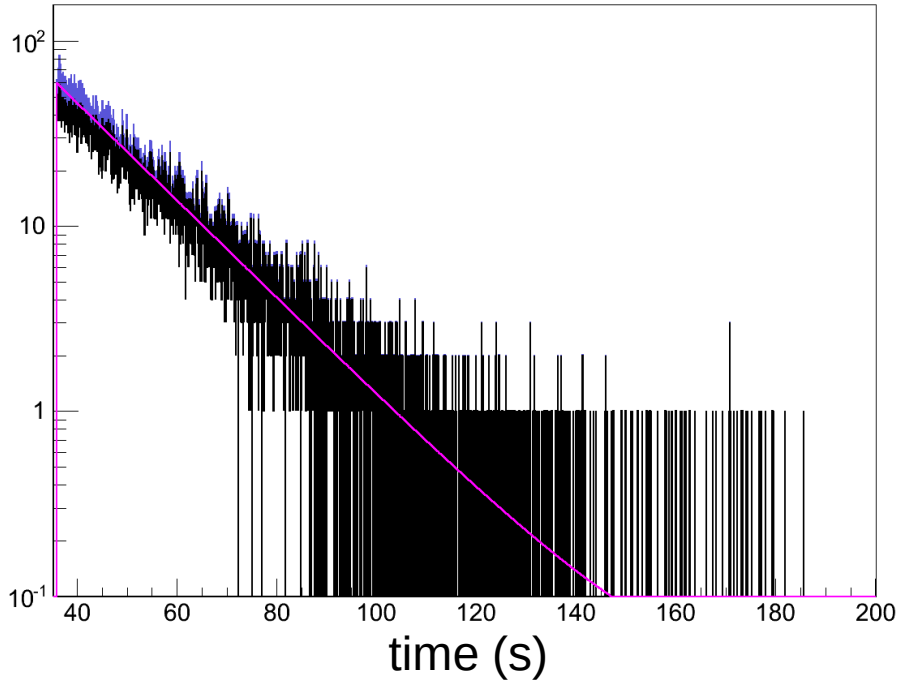

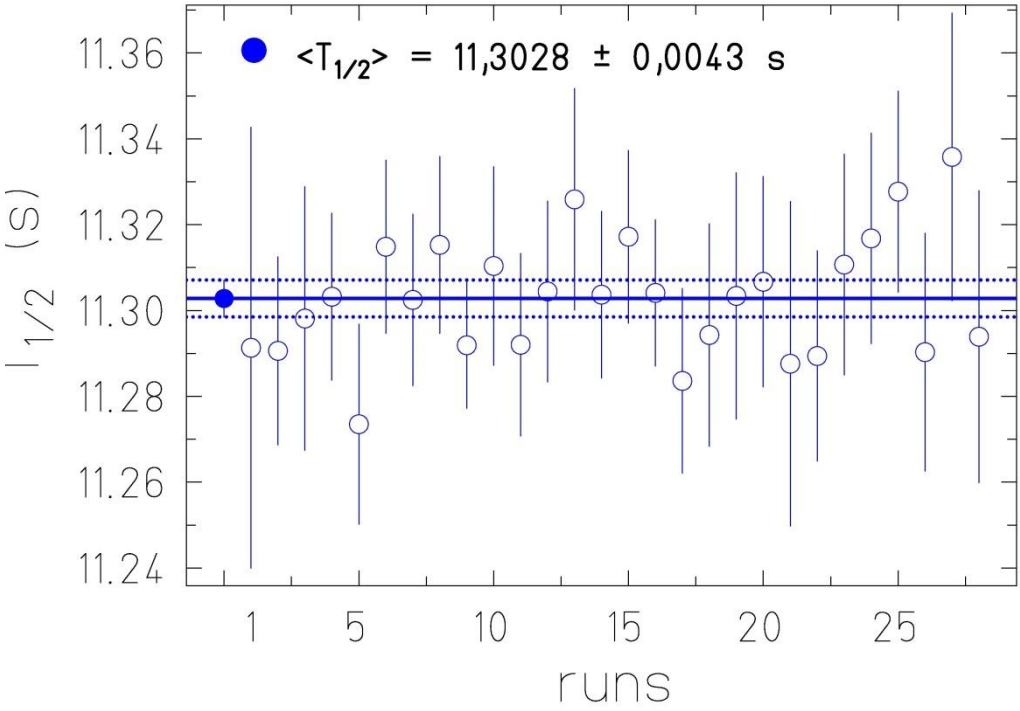

same analysis for all runs

ANALYSIS AND RESULTS

Focus on ^{23}Mg analysis

- Half-life:
  - No systematic dependence on analysis and experiment parameters:
    - beginning and end of the fit,
    - number of nuclei in the decay phase,
    - background,
    - high voltage.

$$\mathbf{T_{1/2} = 11.3028 \pm 0.0043\ s}$$ (0.04% precision)

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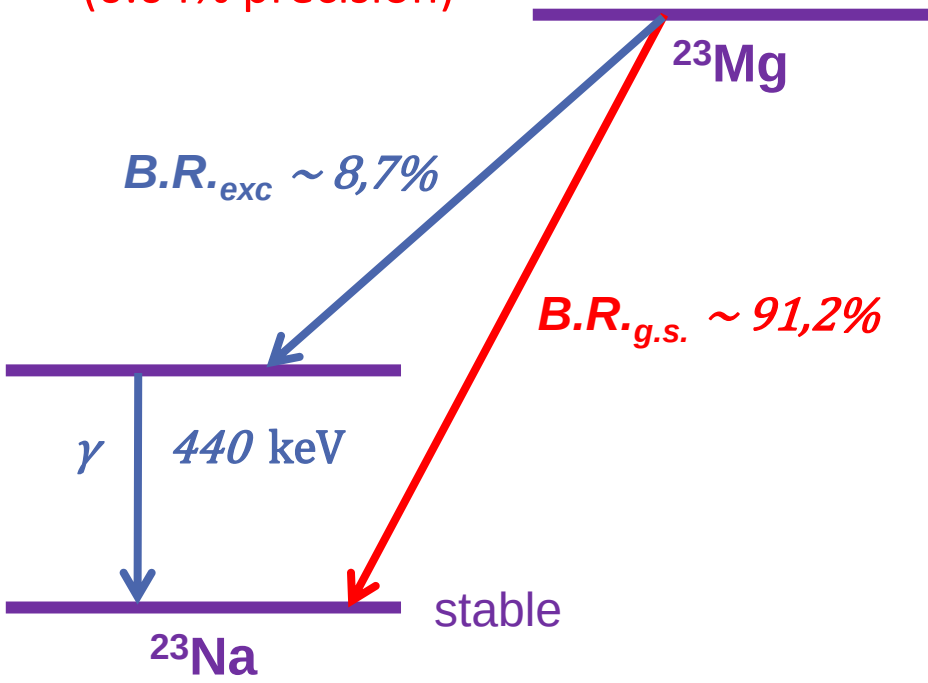
- Branching ratio:

$$B.R._{g.s.} = 1 - \left(\frac{N_{\gamma,detected}}{\varepsilon_{\gamma}} \frac{1}{N_{\beta,detected}} \right)$$

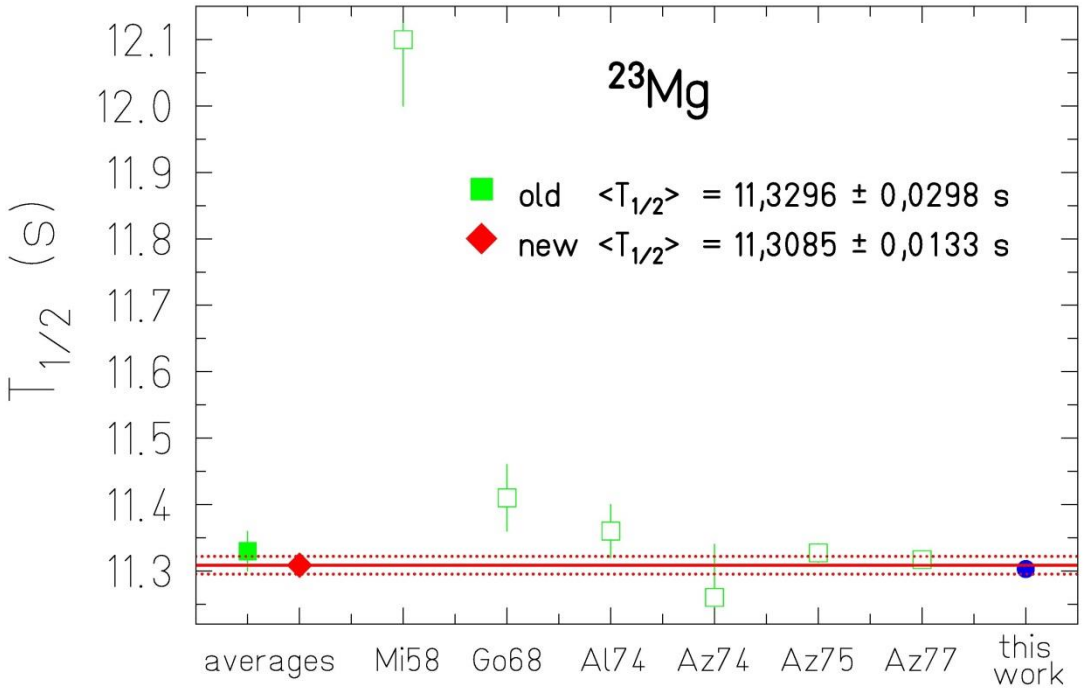
$B.R._{exc}$



CONCLUSIONS

- New $T_{1/2}$ averages:
  - ^{23}Mg: 3 times more precise

    $T_{1/2}$ = 11.3085(133) s



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  - ^{27}Si: twice more precise
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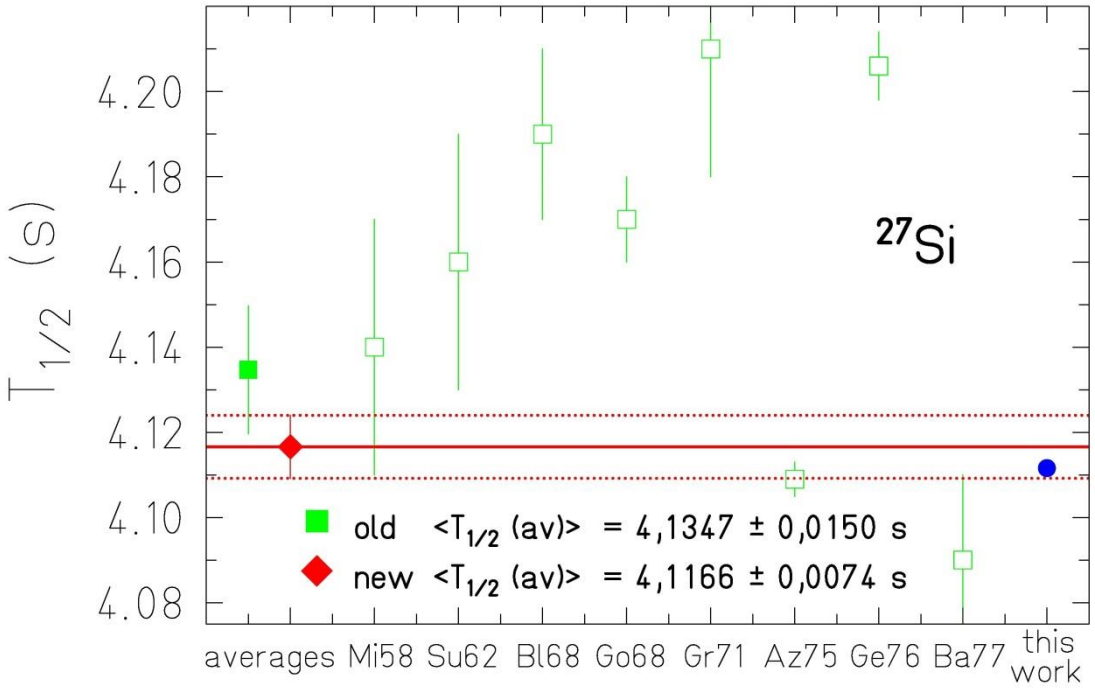

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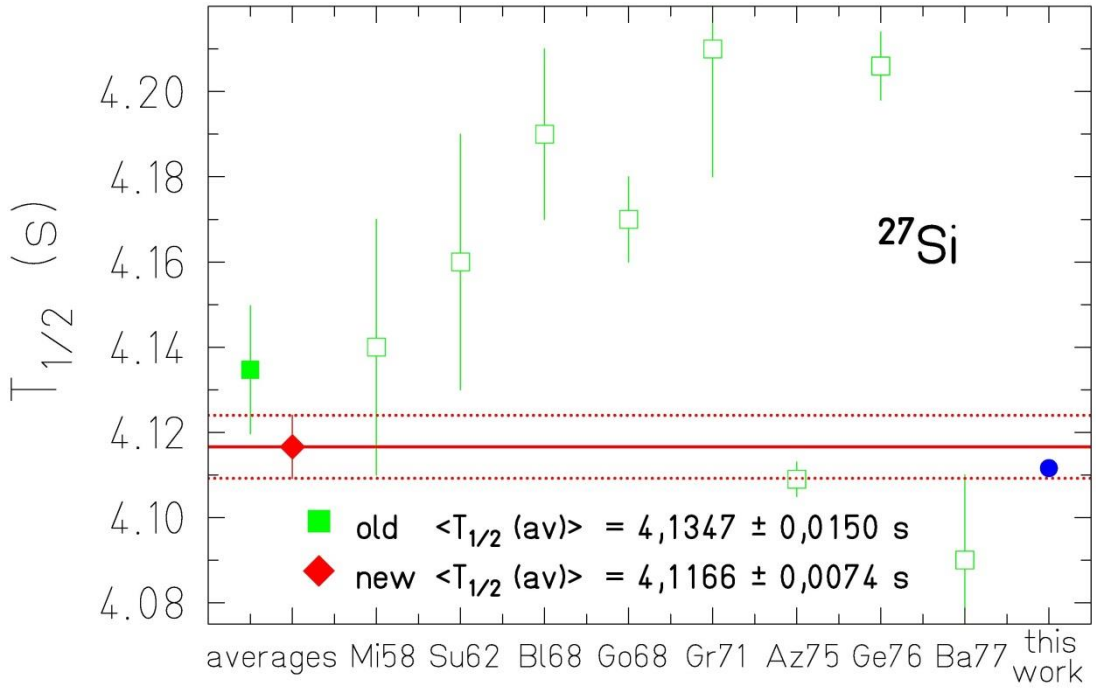

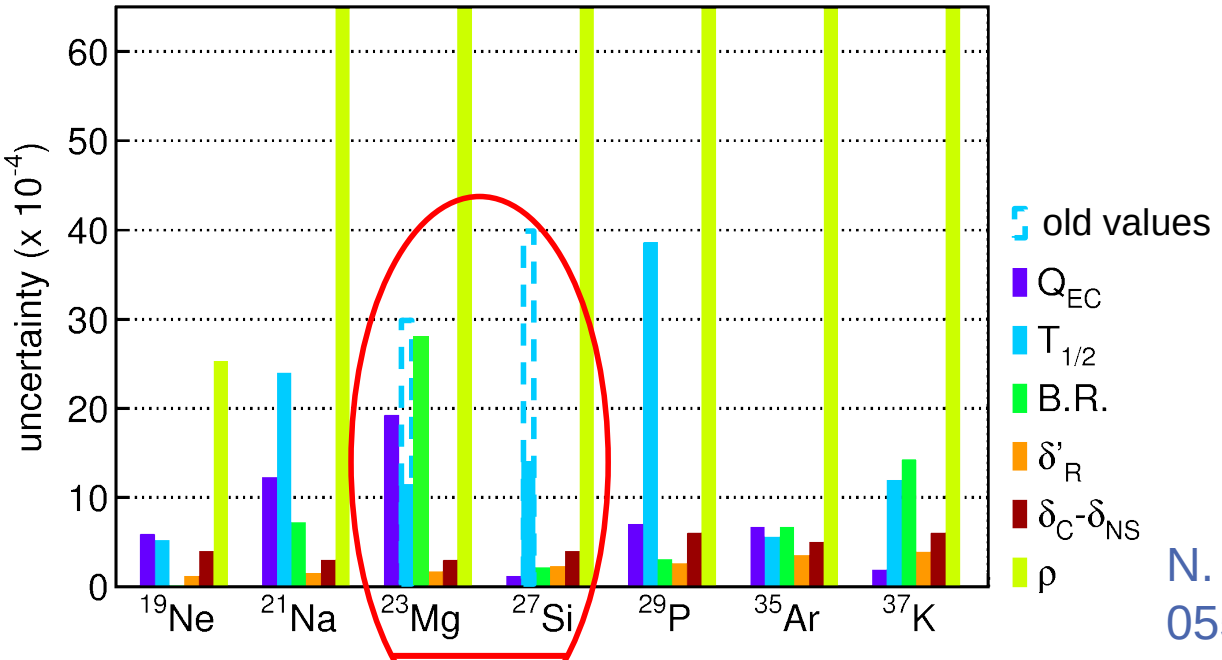

- To continue:
  - better precision for branching ratio of ^{23}Mg
  - measure ρ coefficients for these nuclei

N. Severijns *et al.*, Phys. Rev. C**78**, 055501 (2008).

Thank you for your attention

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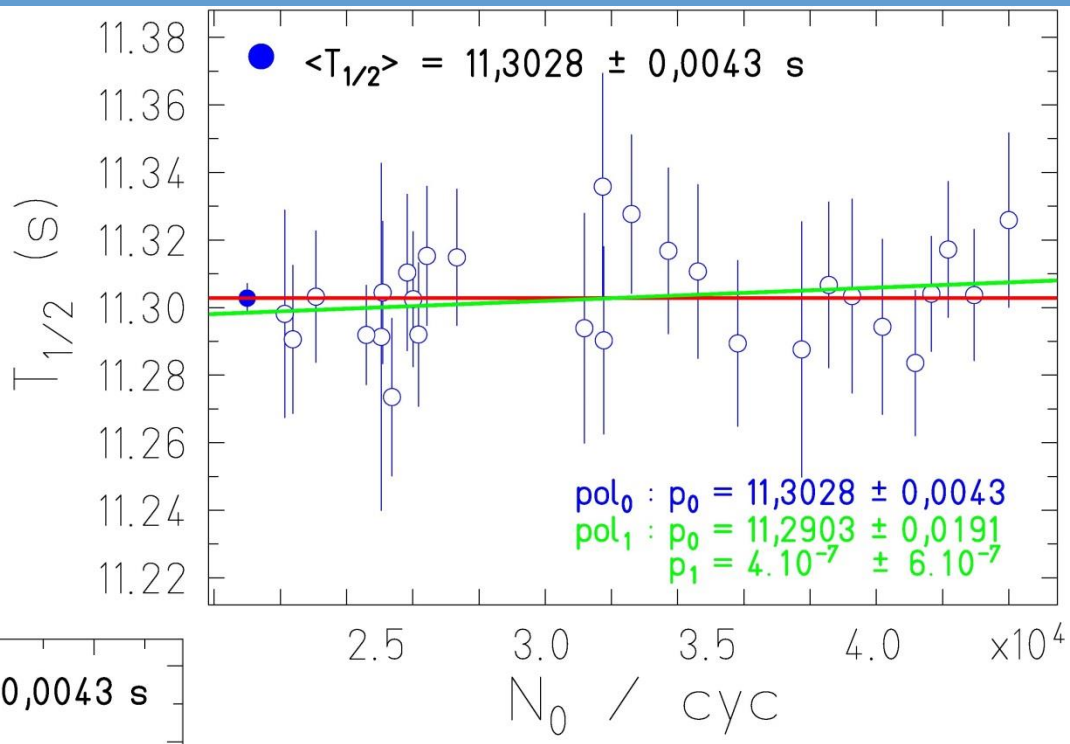
Backup

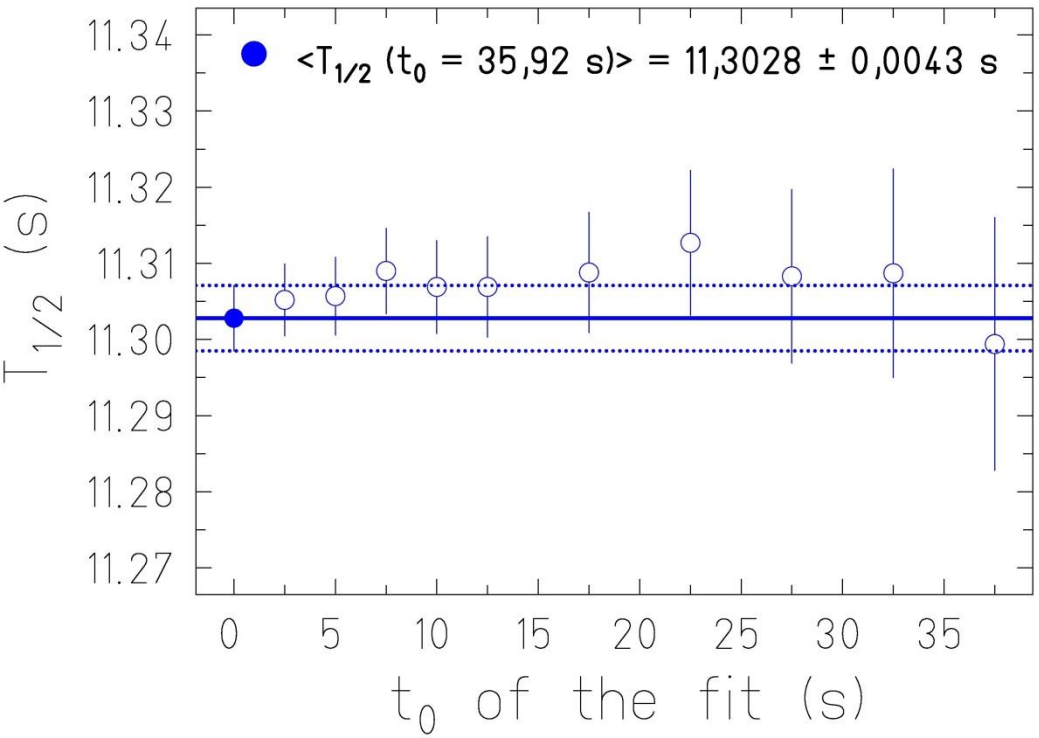
Dead time correction:

$$c = \frac{chv}{1 - \frac{chv * DT}{T_{bin}}}$$

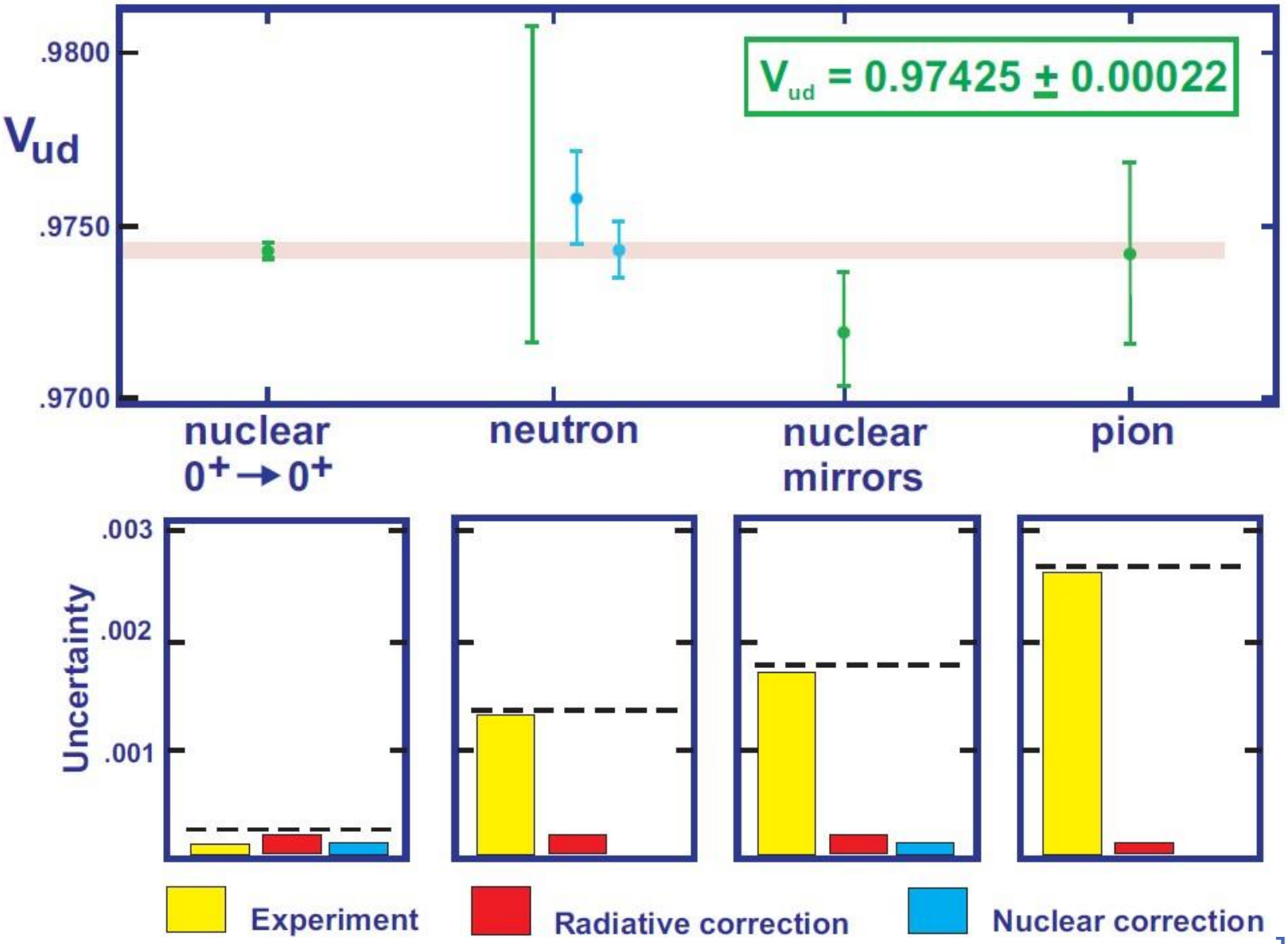
chv: channel value, number of counts before correction,
DT: dead time of the run,
T_{bin}: time per channel.

Systematic errors





Precision on Vud for the different decays



J. Hardy