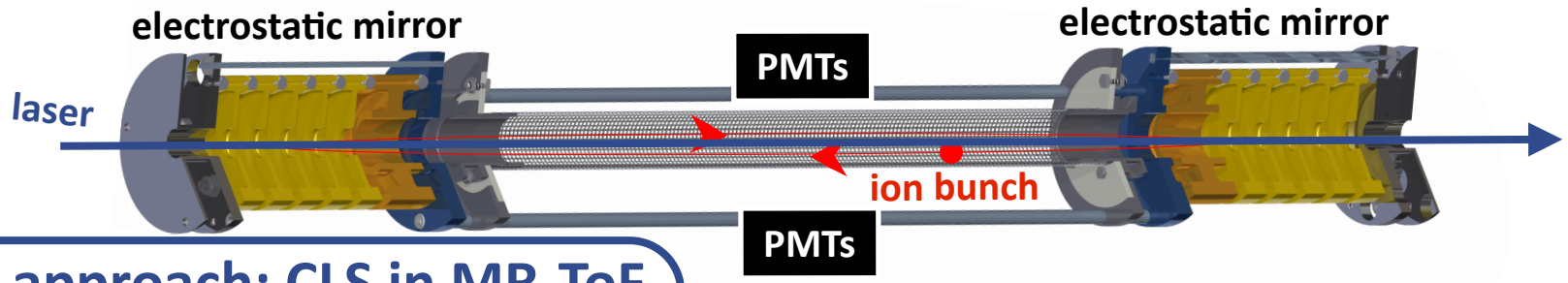
2 GeV proton driver: from Laser Spectroscopy to Fundamental Symmetries

Stephan Malbrunot-Ettenauer

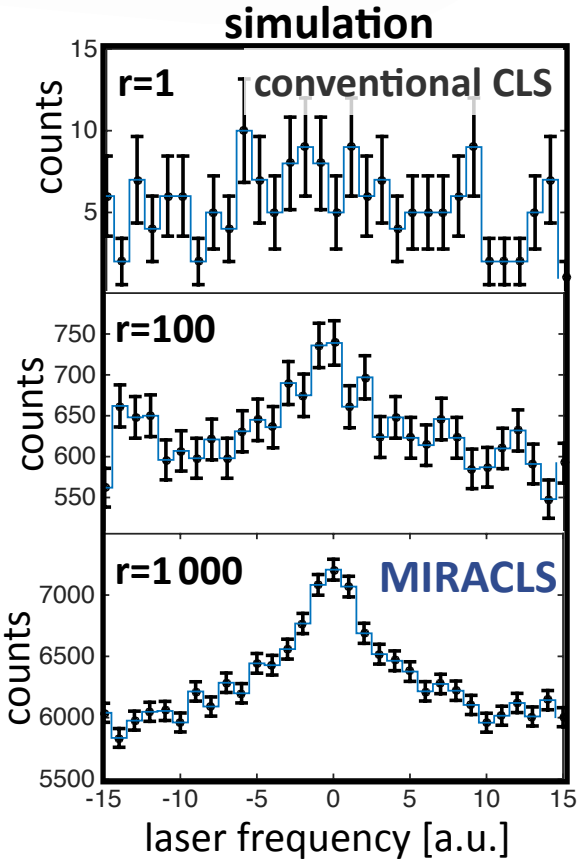
CERN Research Physicist

the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

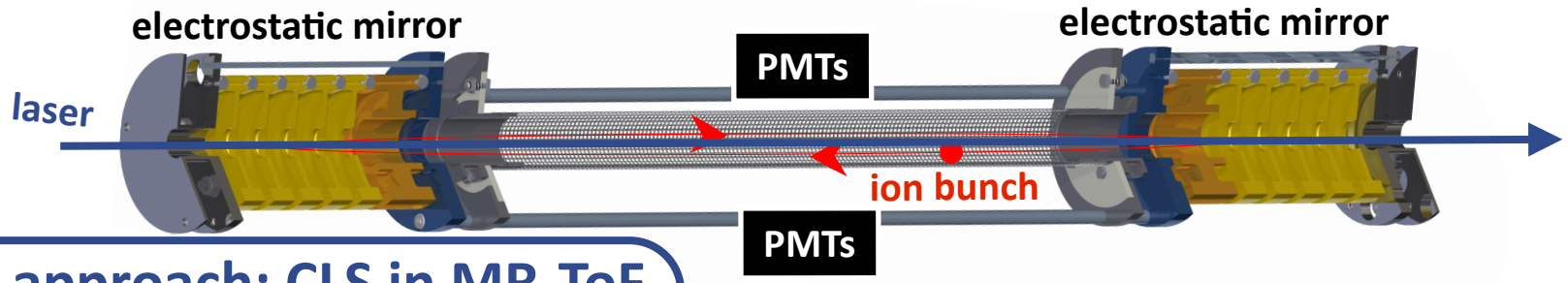


novel approach: CLS in MR-ToF

- ion trap ⇒ long observation time
- 30 keV beam ⇒ high resolution



the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy



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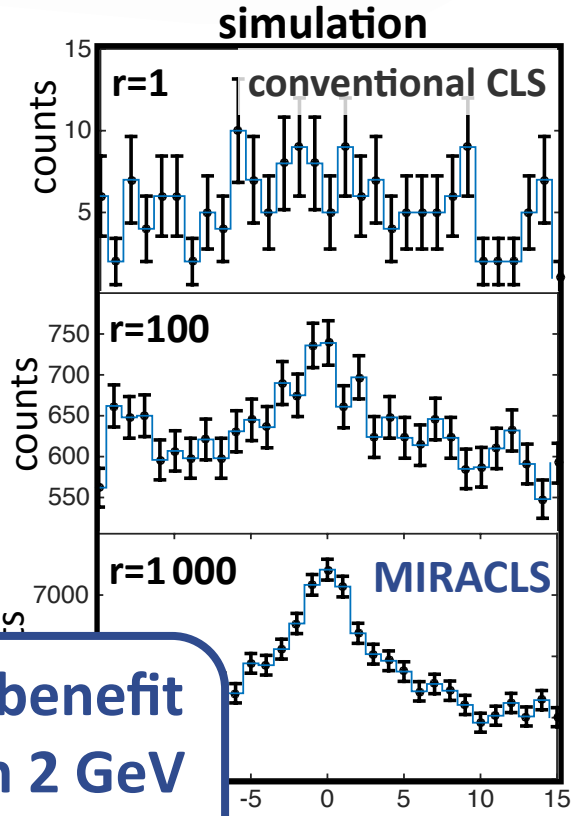
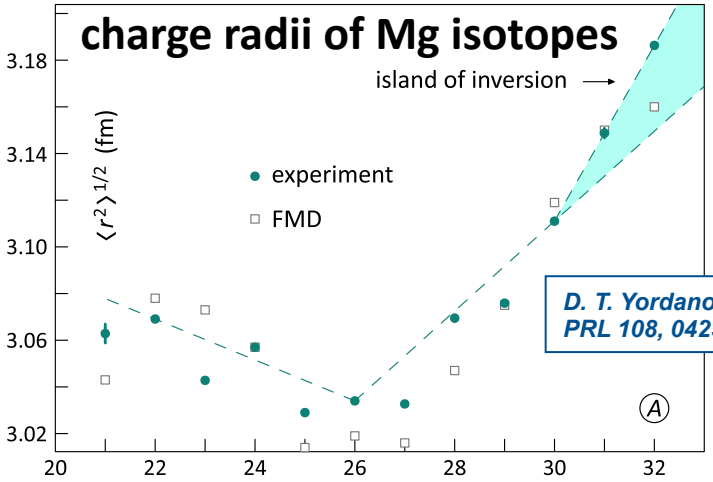


first physics cases:

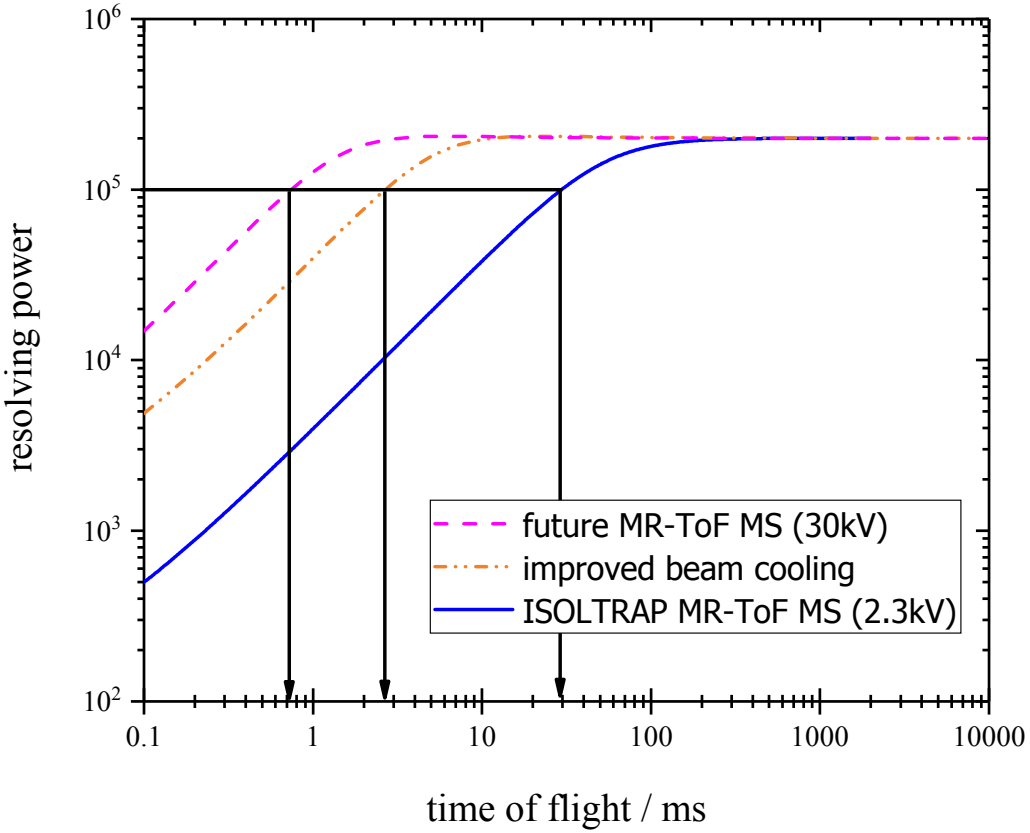
- $^{34-?}$Mg: Island of Inversion



- ^{96,98}Cd: N=50 shell closure in vicinity of ^{100}Sn

will benefit from 2 GeV p driver

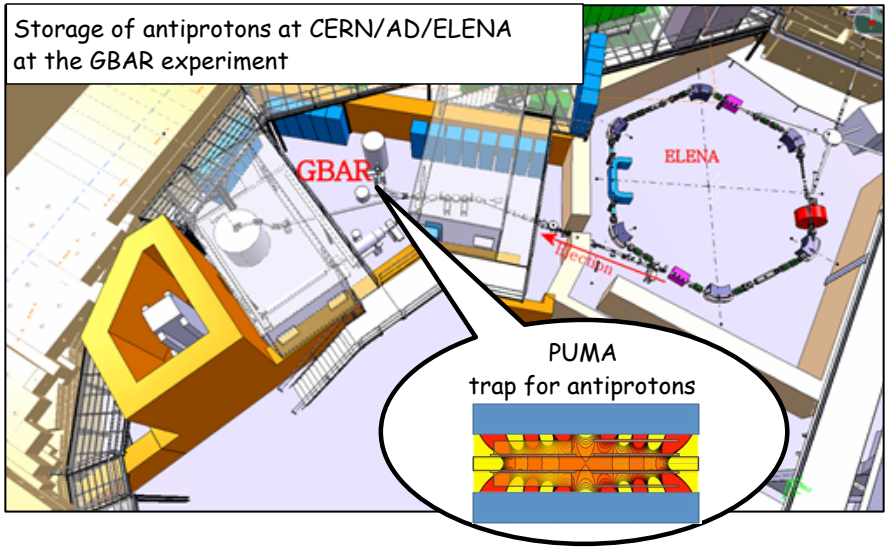
30 keV MR-ToF: new opportunities for purified beams



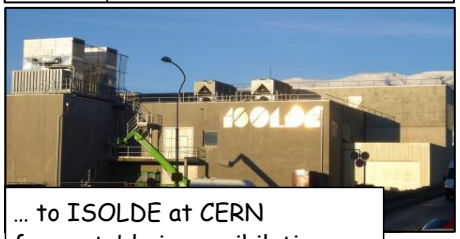
faster isobaric separation in MR-ToF while keeping high mass resolving power

- ➡ higher ion flux through MR-ToF
- ➡ crucial for applications in medical isotope production, SSP, **PUMA, or fundamental symmetries**

PUMA: Pbar Unstable Matter




Transport the antiprotons…

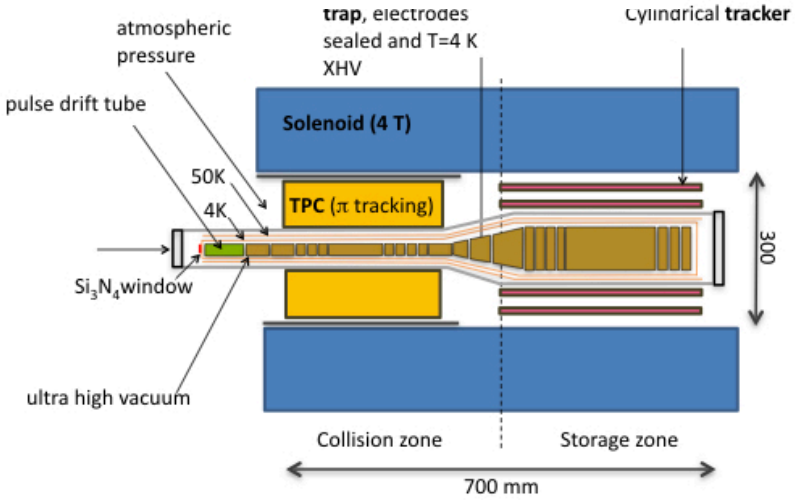

… to ISOLDE at CERN
for unstable ion annihilation.

Antiproton annihilation: a probe for the nuclear density tail

European Research Council

Alexandre Obertelli
TU Darmstadt

PUMA trap



ISOLDE GUI, May 2018, S. Malbrunot-Ettenauer

"Day one" physics cases

Nucleus	Expected ρ_n/ρ_p
^{6}He	Neutron halo > 100
^{8}He	Thick skin 70(10)
^{11}Li	Neutron halo > 100
^{17}Ne	Proton halo < 0.010
^{31}Ne	Neutron halo > 100
$^{104\text{-}138}$Sn	Progression of skin: From 1.0(2) to 4.0(6)

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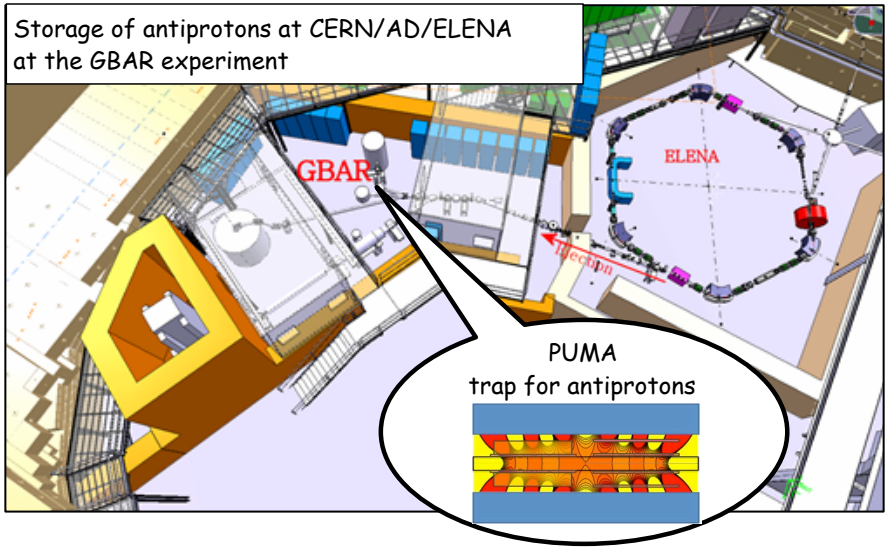


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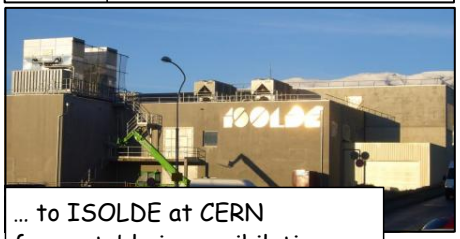
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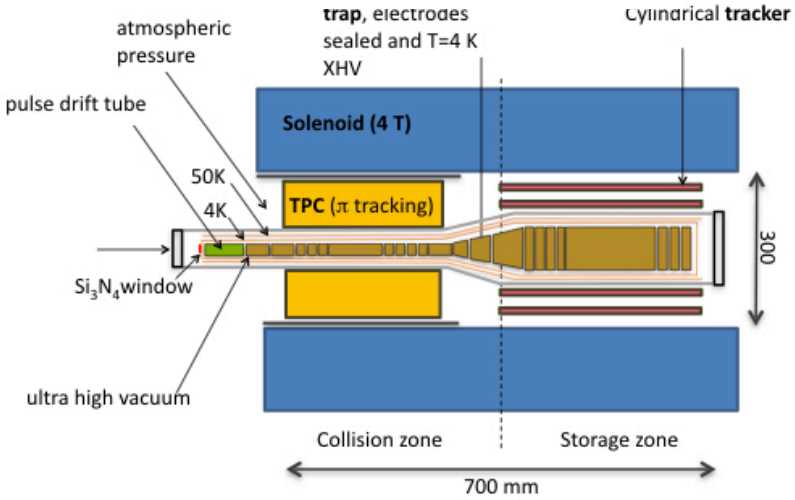

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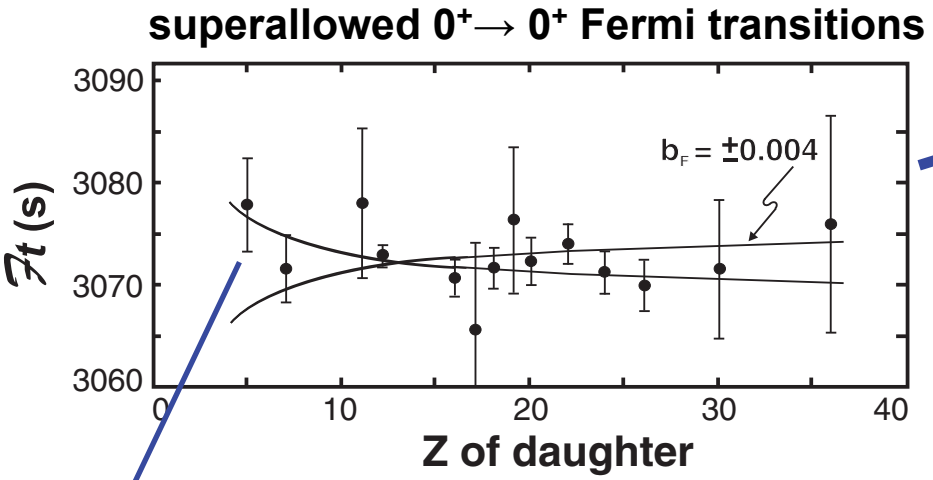
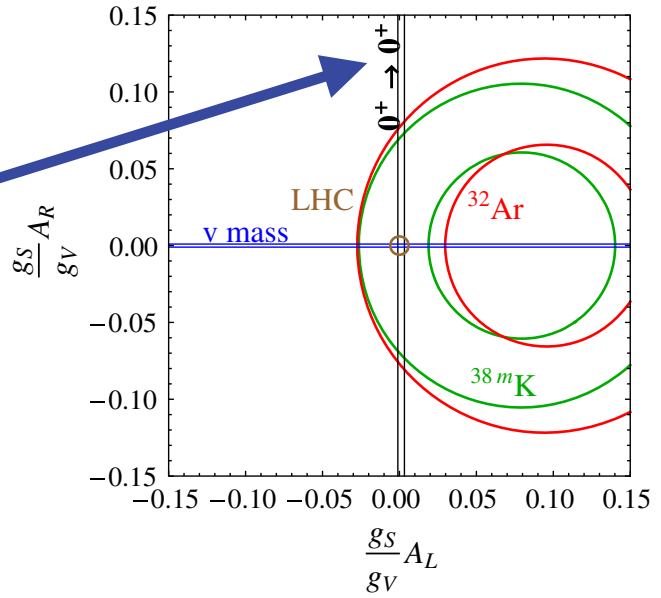
will benefit from 2 GeV p driver

ISOLDE

Fierz term, scalar currents, and the case of ^{10}C



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

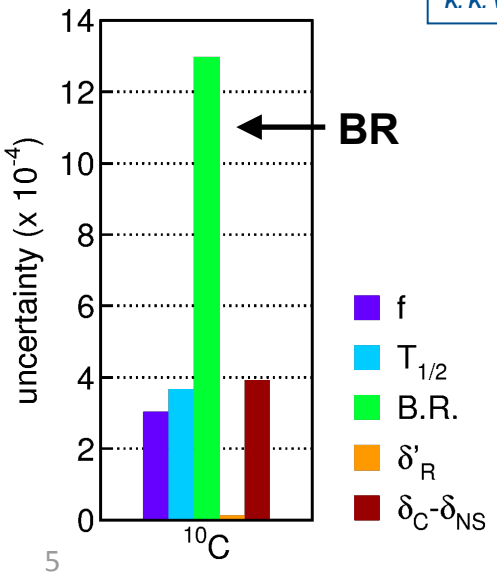


K. K. Vos et al., Rev. Mod. Phys. 87, 1483 (2015)

^{10}C

- high sensitivity to scalar currents
- limited by **BR**

G. Savard et al, PRL 74, 1521 (1995)
B.K. Fujikawa et al., PLB 449, 6(1999)



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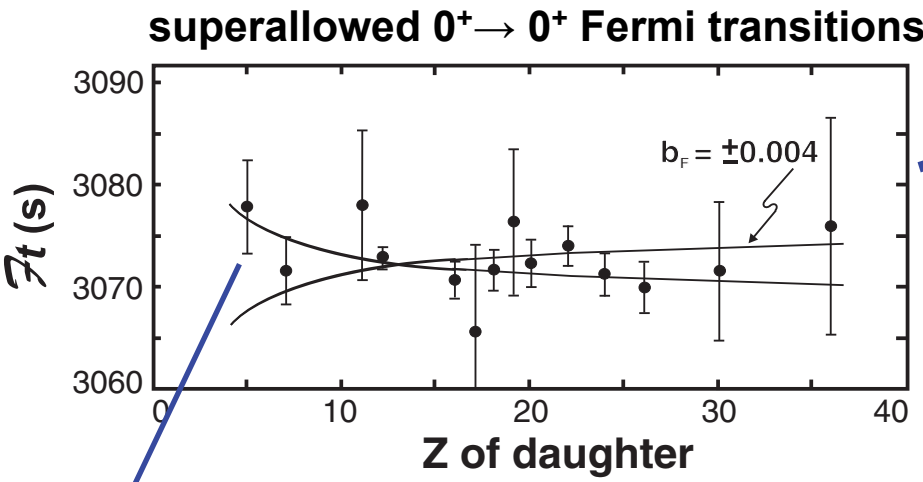

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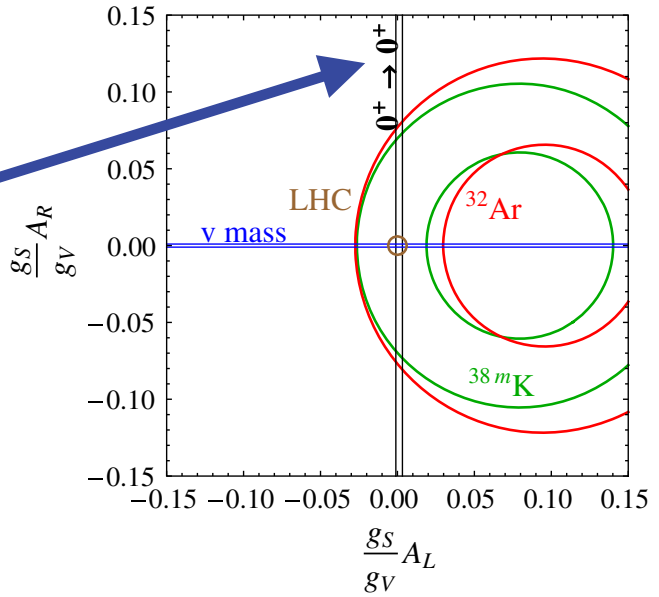

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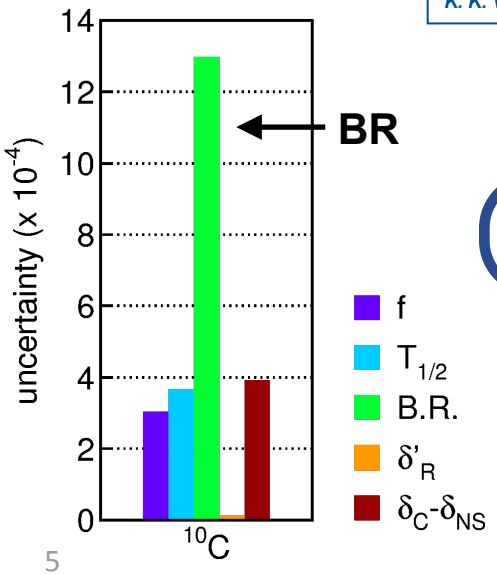

similar situation in ^{14}O

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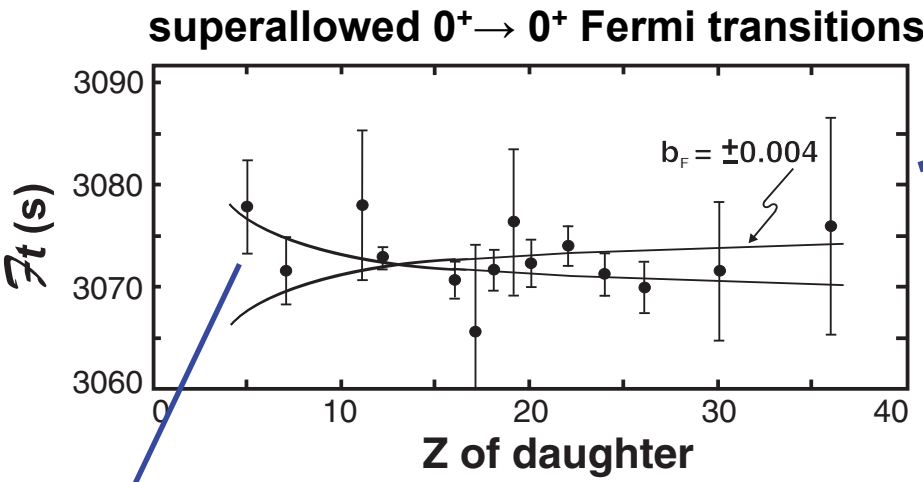

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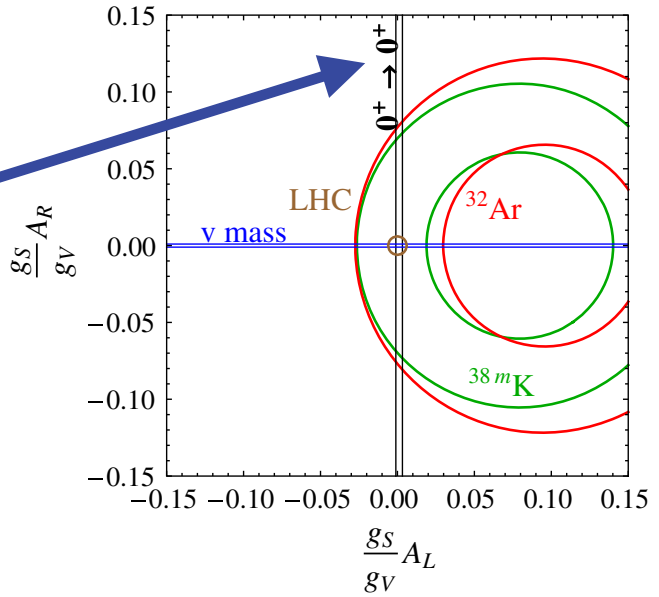

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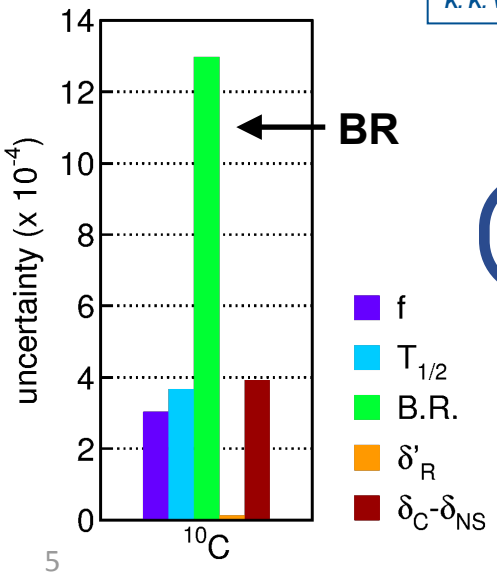
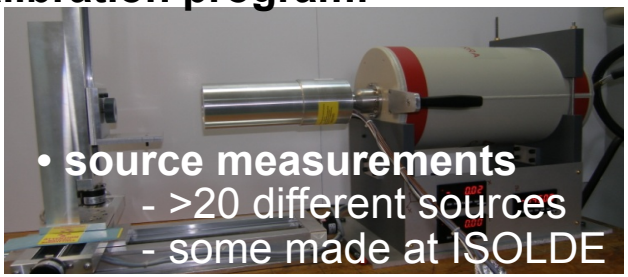
motivates new measurements with state-of-the-art detectors

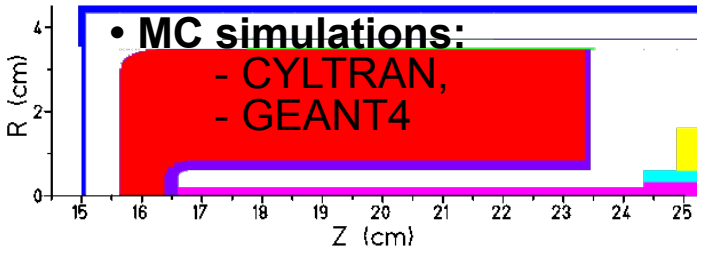


similar situation in ^{14}O

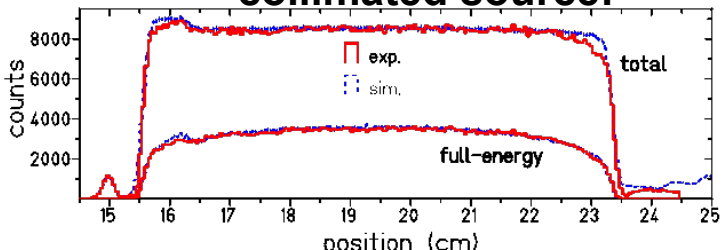
HPGe detector with high precision efficiency

calibration program:

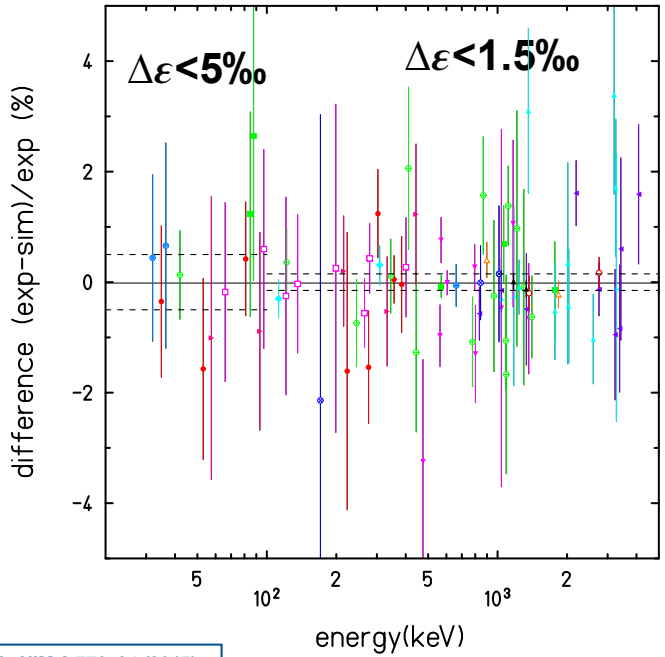




• **scan of the crystal with collimated source:**



Results for remaining uncertainty in efficiency

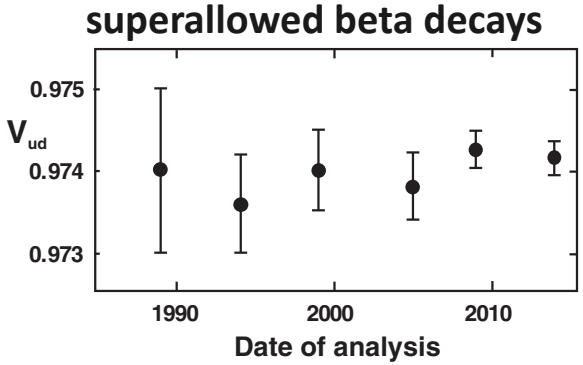


B. Blank et al., NIM A 776, 34 (2015)

status BR of ^{10}C

- goal: <0.15% in BR
- focus on systematics
- 1st data taking completed at ISOLDE
- will benefit of future beam purification capabilities
- **<u>will benefit from intensity gain</u>**

V_{ud}, CKM unitarity, and ISB corrections δ_c



$$Ft = ft(1+\delta_R)(1+\delta_{NS}-\delta_C) = \frac{K}{2G_V^2(1+\Delta_R^V)} = \text{const}$$

$$|V_{ud}| = \frac{G_V}{G_F}$$

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.999\,78 \pm 0.000\,55$$

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

… provides **unique bounds on vertex corrections (V_{ff})** (LHC not sensitive)

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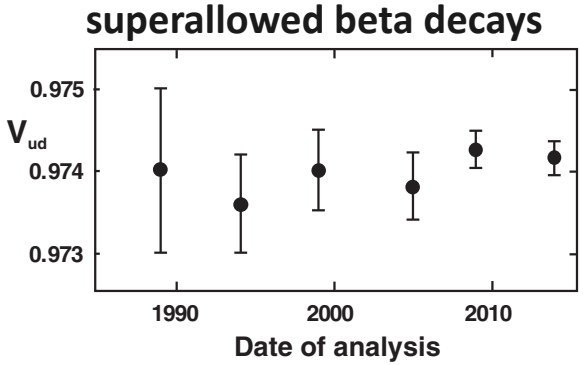

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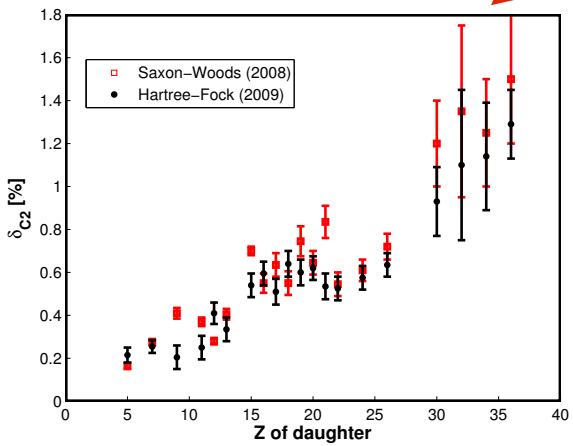
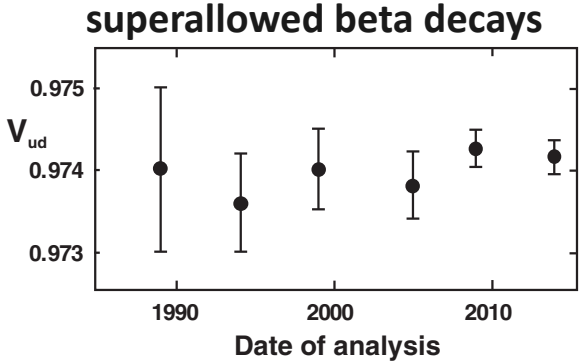


- intensively studied in experiment&theory
- scale approx. $\propto Z^2$
- heavier cases: probe different δ_c models

V_{ud}, CKM unitarity, and ISB corrections δ_c



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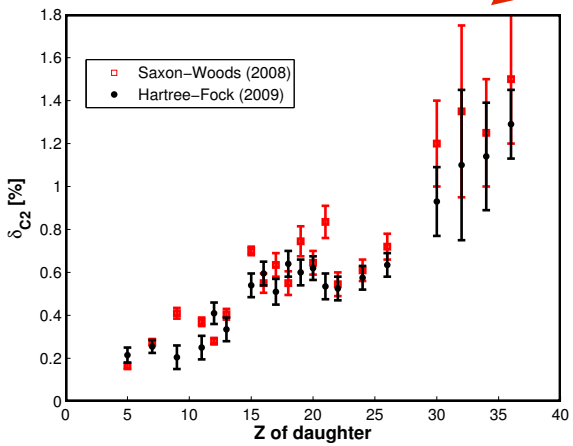

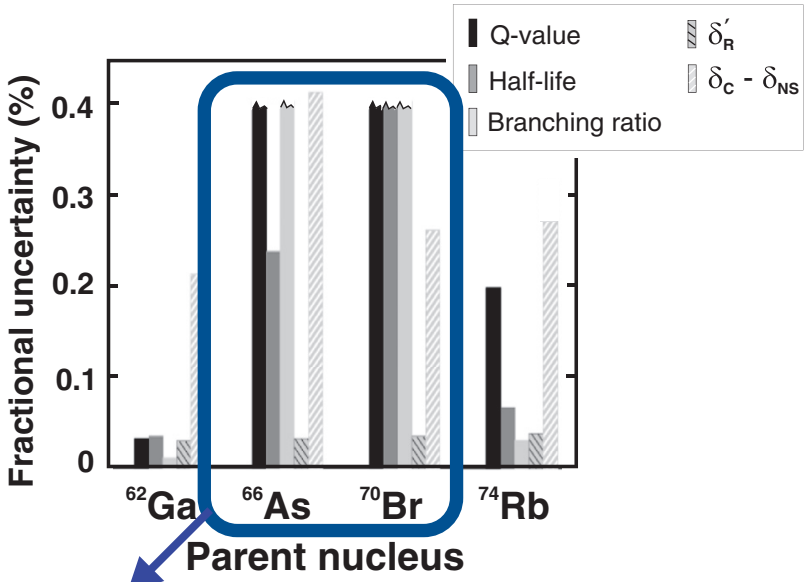

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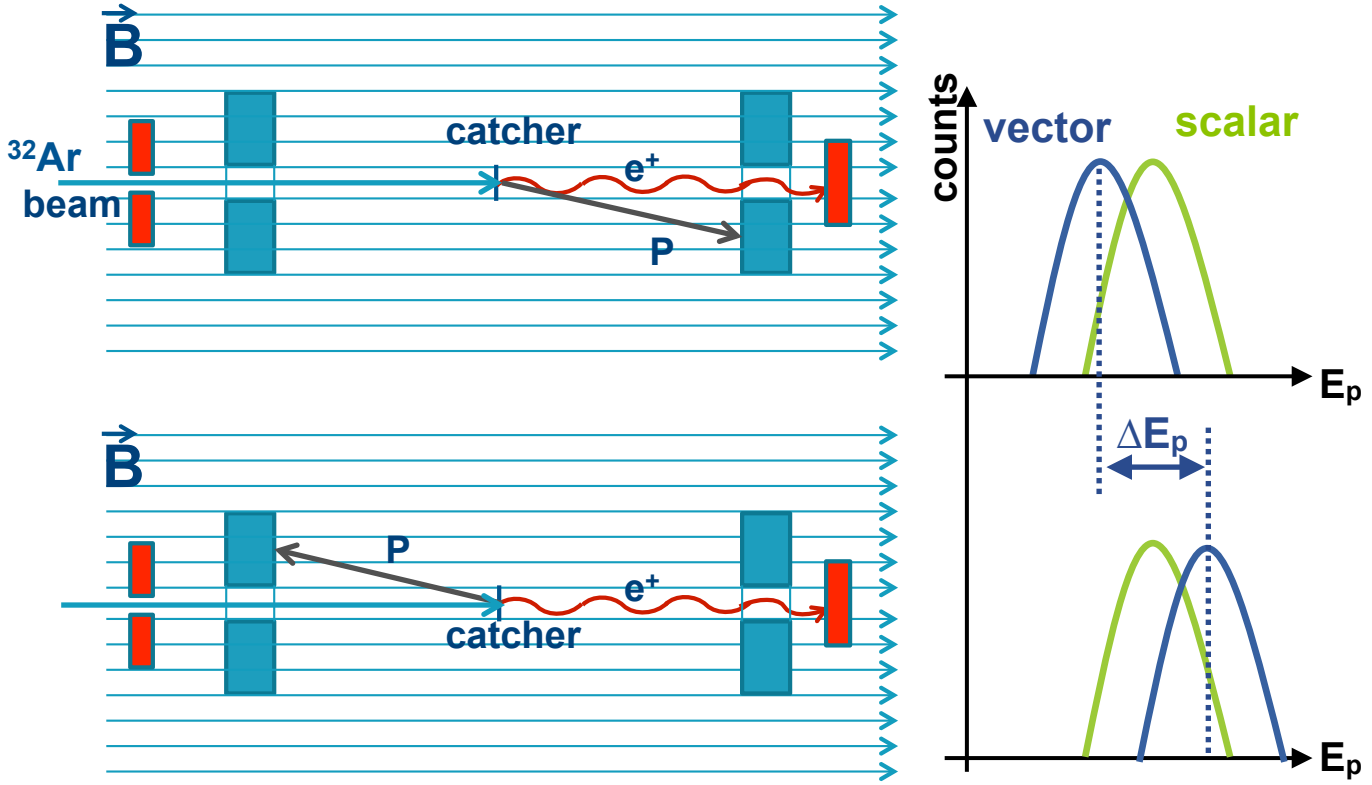
new opportunities
(accessible with higher yields)

WISArD: Weak-interaction studies with ^{32}Ar decay



- goal: limit on $a_{\beta\nu}$ of the order of 0.1% (factor ~6 improvement)
- future case: ^{20}Mg
- **intensity gain in ^{32}Ar and ^{20}Mg highly desirable**

collaboration. Bordeaux, Leuven, LPC Caen, NPI-Prague

N. Severijns and B. Blank, CERN-INTC-2016-050 / INTC-I-172 (2016)

Summary

will benefit from…

- **MIRACLS:** >^{33}Mg, ^{96,98}Cd
- **PUMA:** **^{31}Ne, neutron-deficient Sn isotopes**

} **2 GeV p driver & 6 µA**

- **Fundamental Symmetry Studies**
  - ➡ scalar currents in light superallowed T=1 β decays: ^{10}C, ^{14}O
  - ➡ scalar currents@WISArD : ^{20}Mg, ^{32}Ar
  - ➡ heavier superallowed T=1 β decays & ISB corrections: ^{66}As, ^{70}Br
  - ➡ atomic parity violation with Ra ions (KVI) ?

} **6 µA**

backup

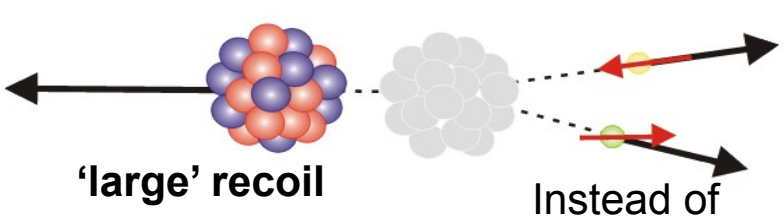
WISArD: Weak-interaction studies with ^{32}Ar decay

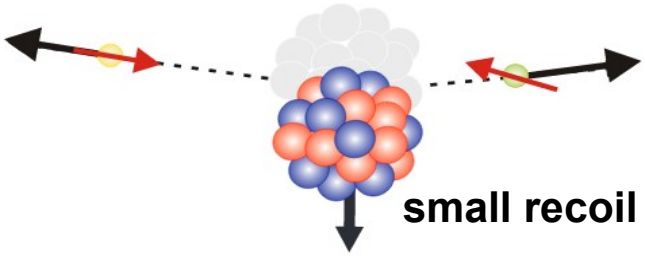
Standard Model
Vector currents

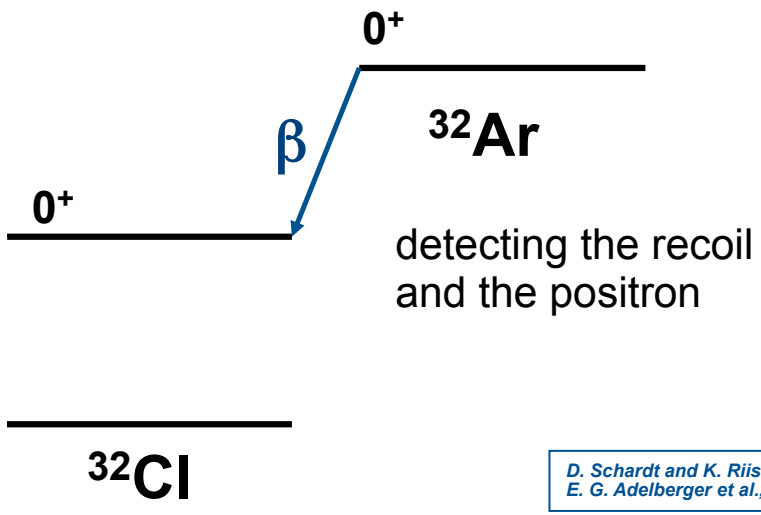
$$\frac{dW}{d\Omega} = 1 + \frac{p_e \cdot p_\nu}{E_e E_\nu}$$

New Physics
Scalar currents

$$\frac{dW}{d\Omega} = 1 - \frac{p_e \cdot p_\nu}{E_e E_\nu}$$







detecting the recoil
and the positron

D. Schardt and K. Riisager, ZPA 345, 265 (1993)
E. G. Adelberger et al., PRL 83 (1999) 1299

WISArD: Weak-interaction studies with ^{32}Ar decay

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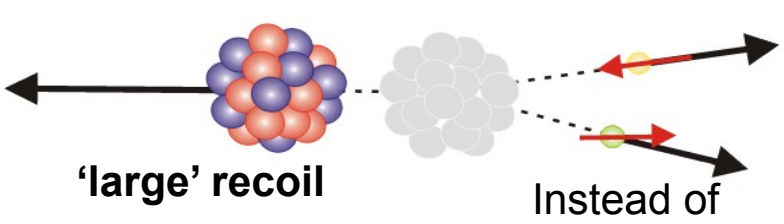
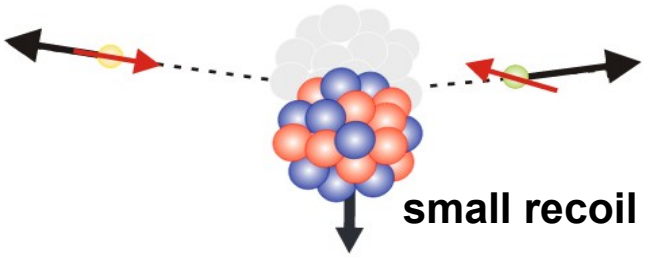
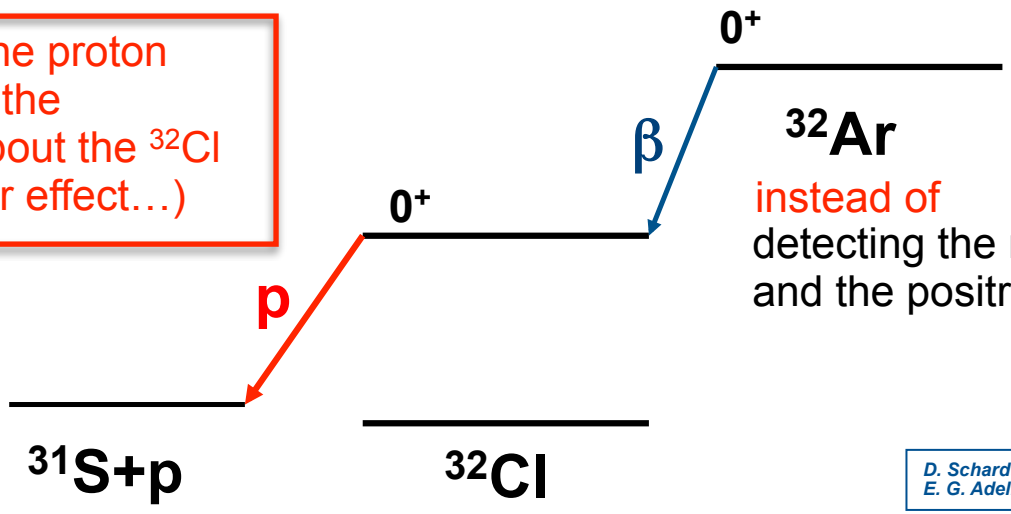




Detection of the proton that contains the information about the ^{32}Cl recoil (Doppler effect…)



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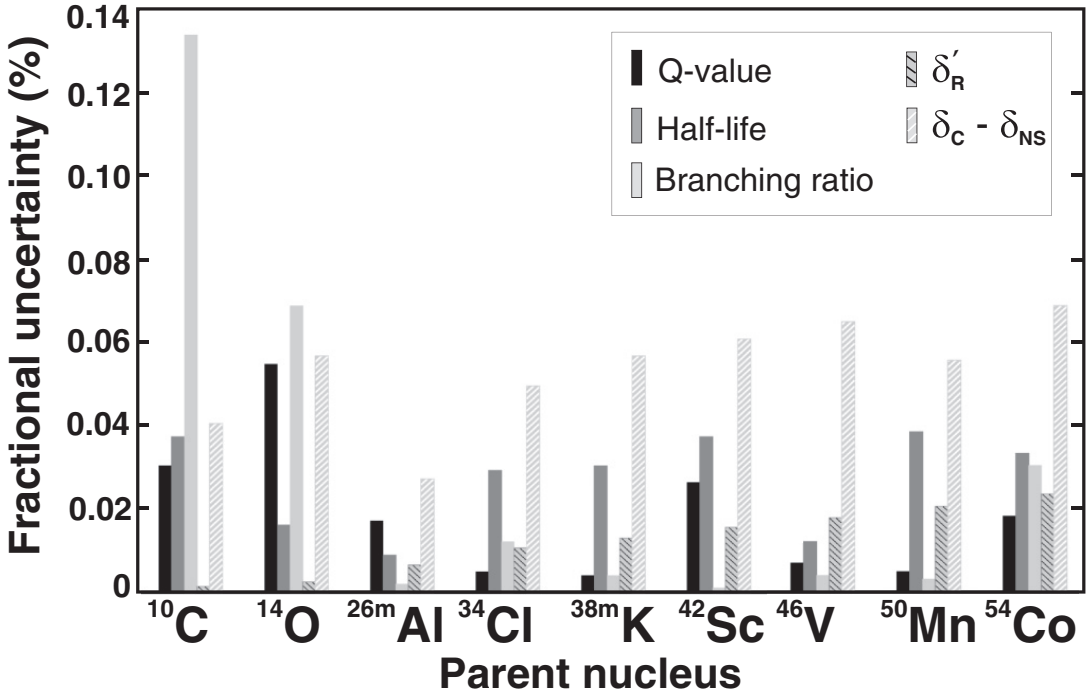

FIG. 3. Summary histogram of the fractional uncertainties attributable to each experimental and theoretical input factor that contributes to the final $\mathcal{F}t$ values for the "traditional nine" superallowed transitions. The bars for δ'_R are only a rough guide to the effect on each transition of this term's systematic uncertainty. See text.

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