

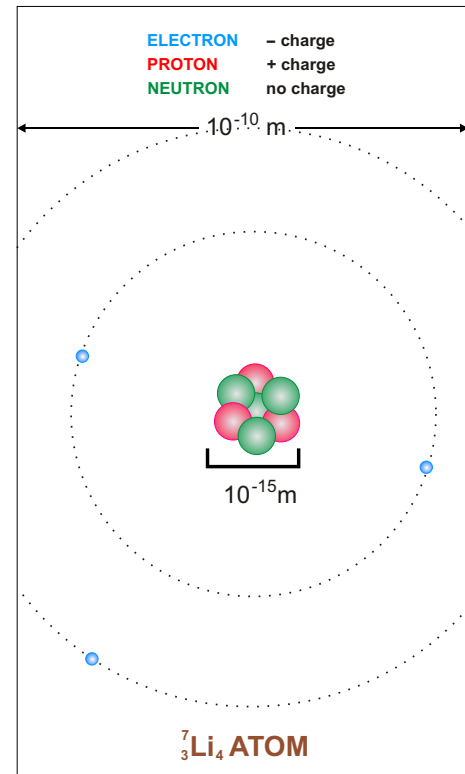
# THE WEAK FORCE: DANCING TO ITS OWN TUNE

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1. What is the weak force?
2. Is it universal?
3. The nucleus as laboratory
4. Current status of data
5. Measurements in progress
6. Summary and outlook

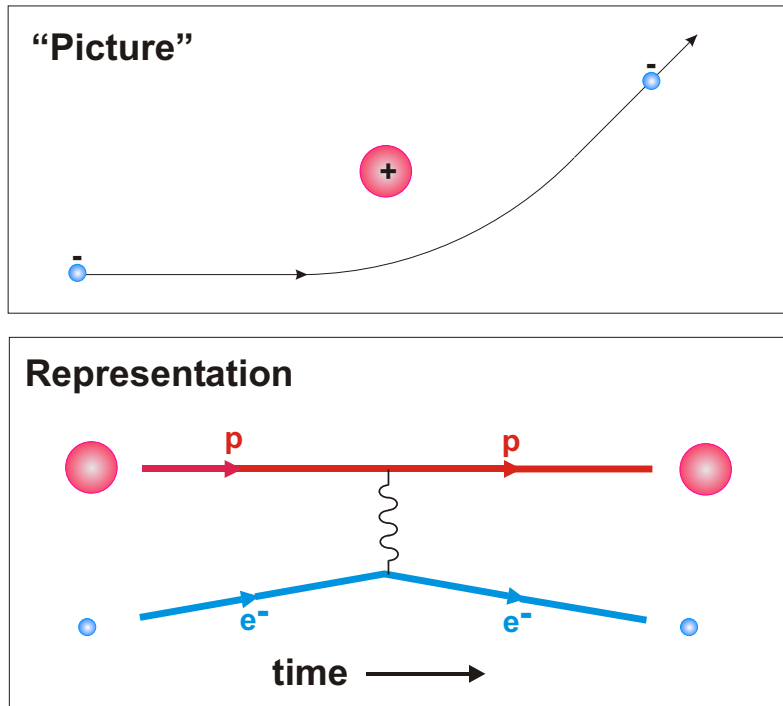
## THE FORCES IN NATURE

Name	Relative Strength	Range	Acts on
Strong	1	$10^{-15}\text{m}$	neutrons protons ...
Electromagnetic	$10^{-2}$	long ( $1/r^2$ )	charged particles
Weak	$10^{-5}$	$10^{-18}\text{m}$	all
Gravity	$10^{-41}$	long ( $1/r^2$ )	masses



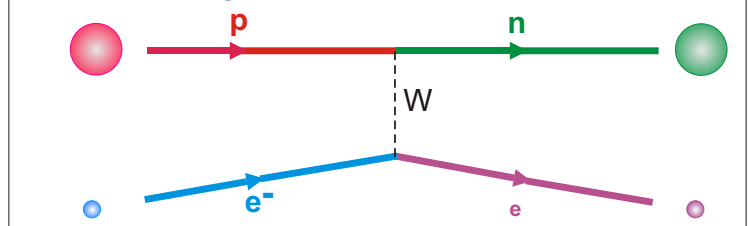
# ELECTROMAGNET FORCE

## Electron scattering:

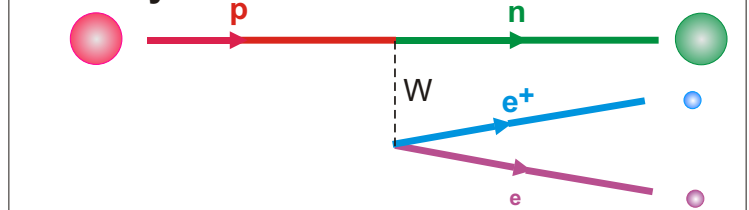


## WEAK FORCE

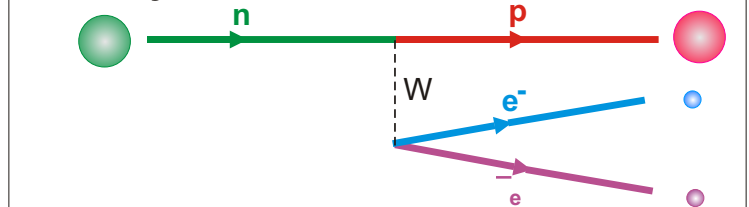
### Electron capture



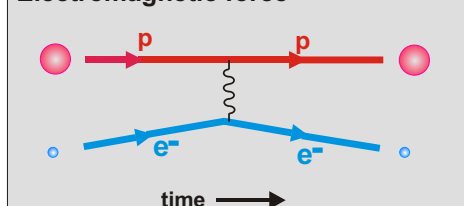
### $^+$ decay



### $^-$ decay



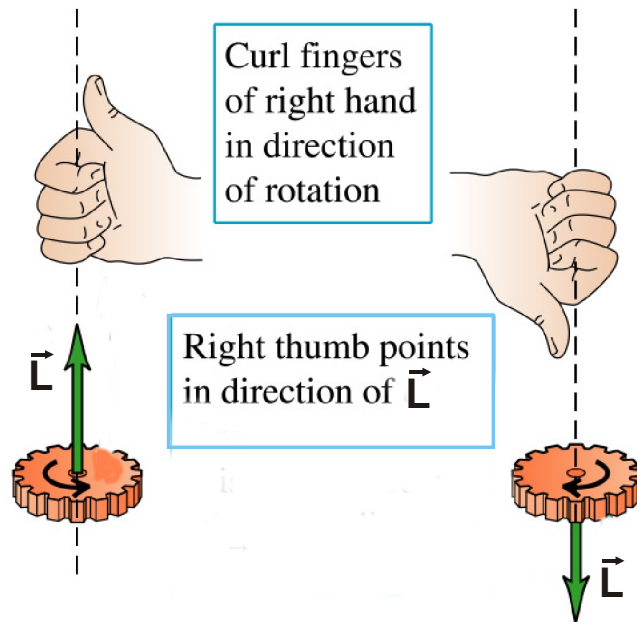
### Electromagnetic force



# ANGULAR MOMENTUM

All sub-atomic particles (including nuclei) have intrinsic angular momentum (or spin).

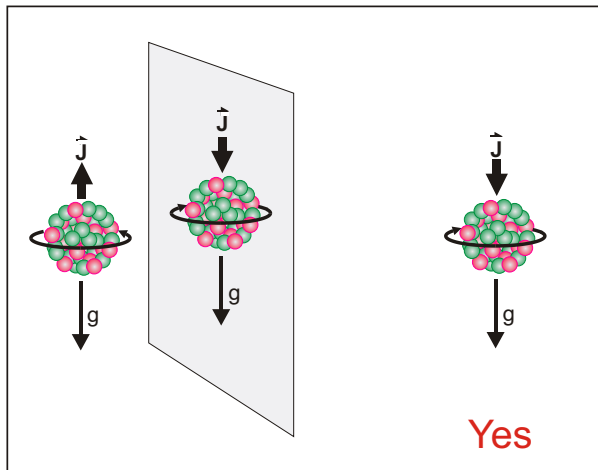
We represent spin as a vector according to a “right-hand rule”



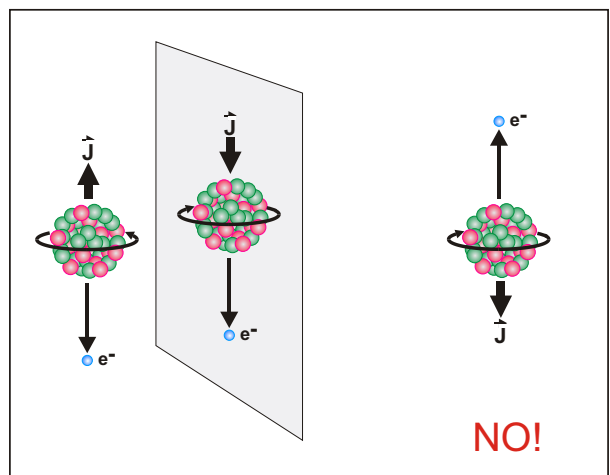
ANGULAR MOMENTUM IS CONSERVED

## IS PARITY CONSERVED?

Gravity



Weak interaction

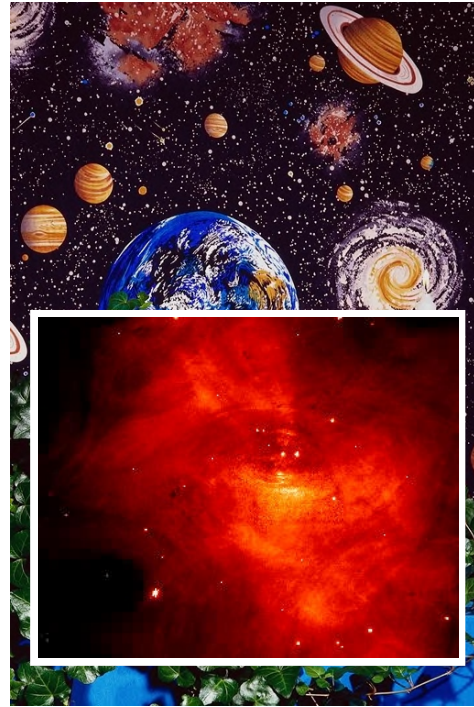


# WHAT ABOUT UNIVERSALITY?



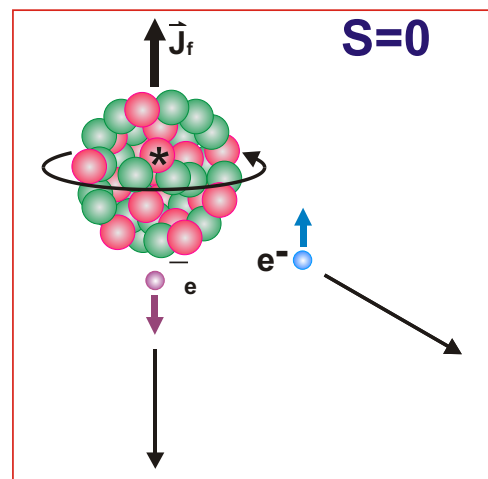
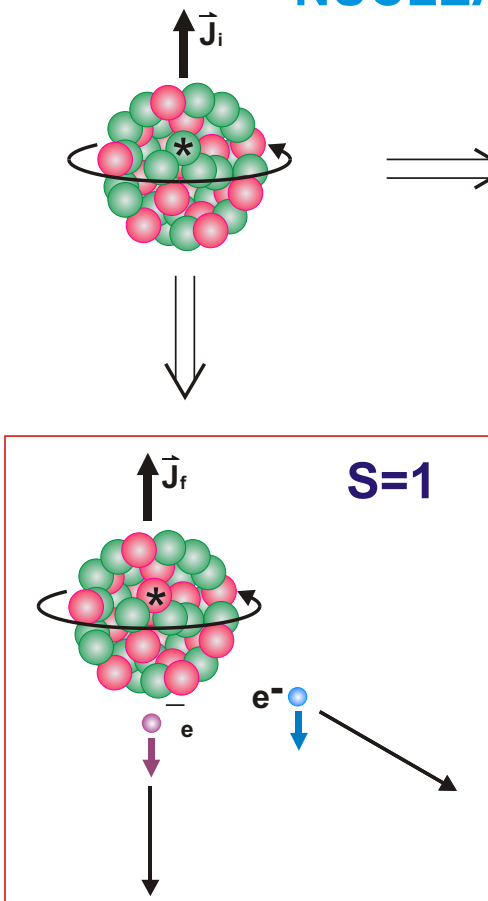
Newton's Insight  
~1700

Universality  
of  
Gravitational force



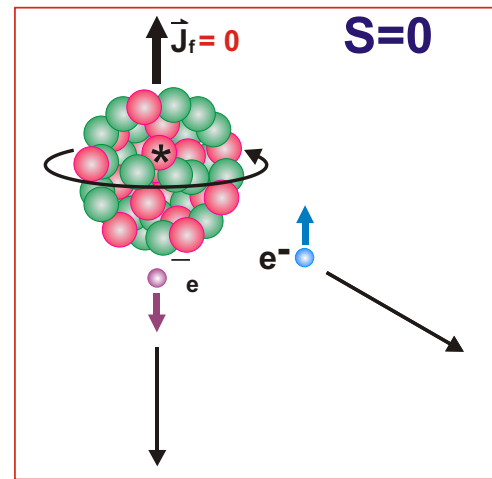
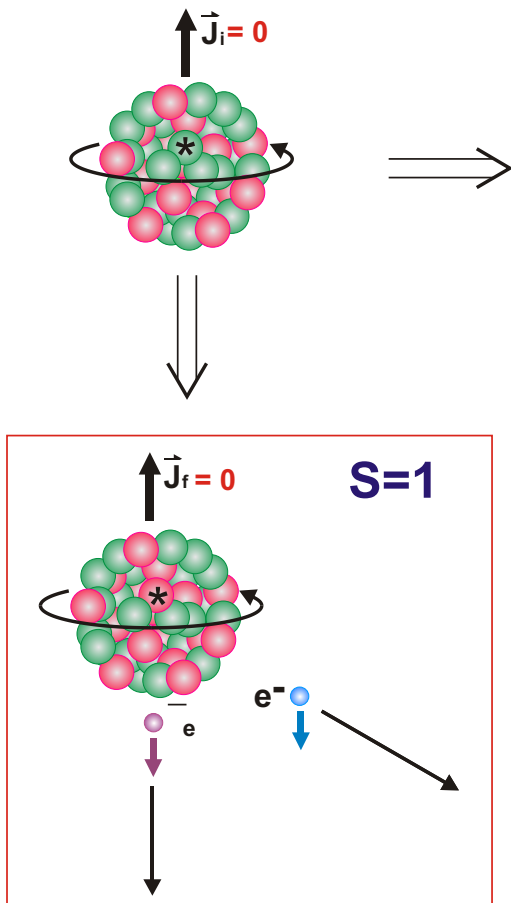
Now in 2006 .... Is  
this idiosyncratic  
weak force  
universal too?

## NUCLEAR BETA DECAY



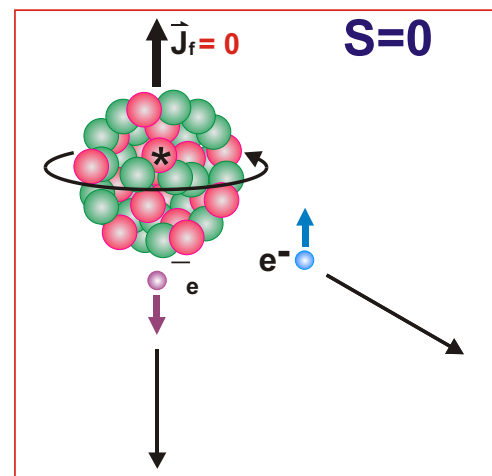
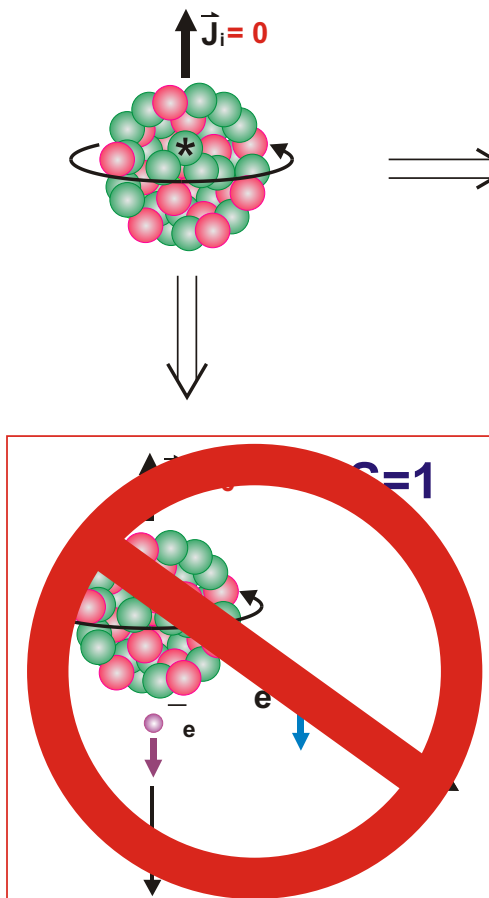
Both  $S=0$  and  
 $S=1$  transfers  
are allowed in  
general.

# “SUPERALLOWED” $0^+ \rightarrow 0^+$ BETA DECAY



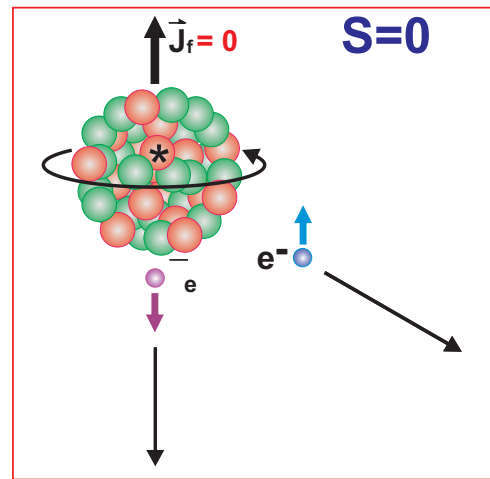
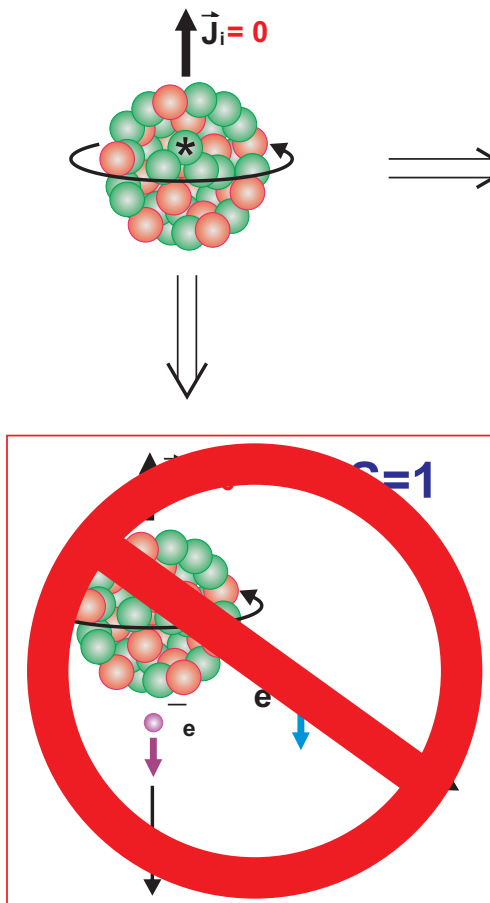
Both  $S=0$  and  $S=1$  transfers are allowed in general.

# “SUPERALLOWED” $0^+ \rightarrow 0^+$ BETA DECAY



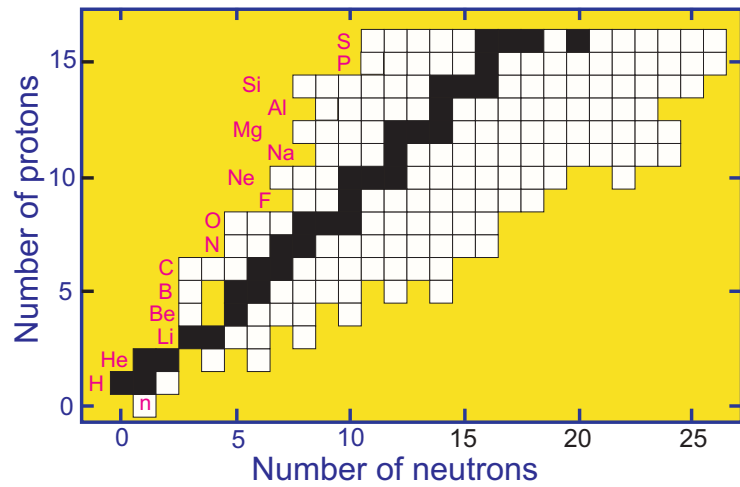
Only  $S=0$  transfer allowed between  $J=0$  states.

# "SUPERALLOWED" $0^+ \rightarrow 0^+$ BETA DECAY



Test universality  
by measuring this  
decay in a wide  
variety of nuclei.

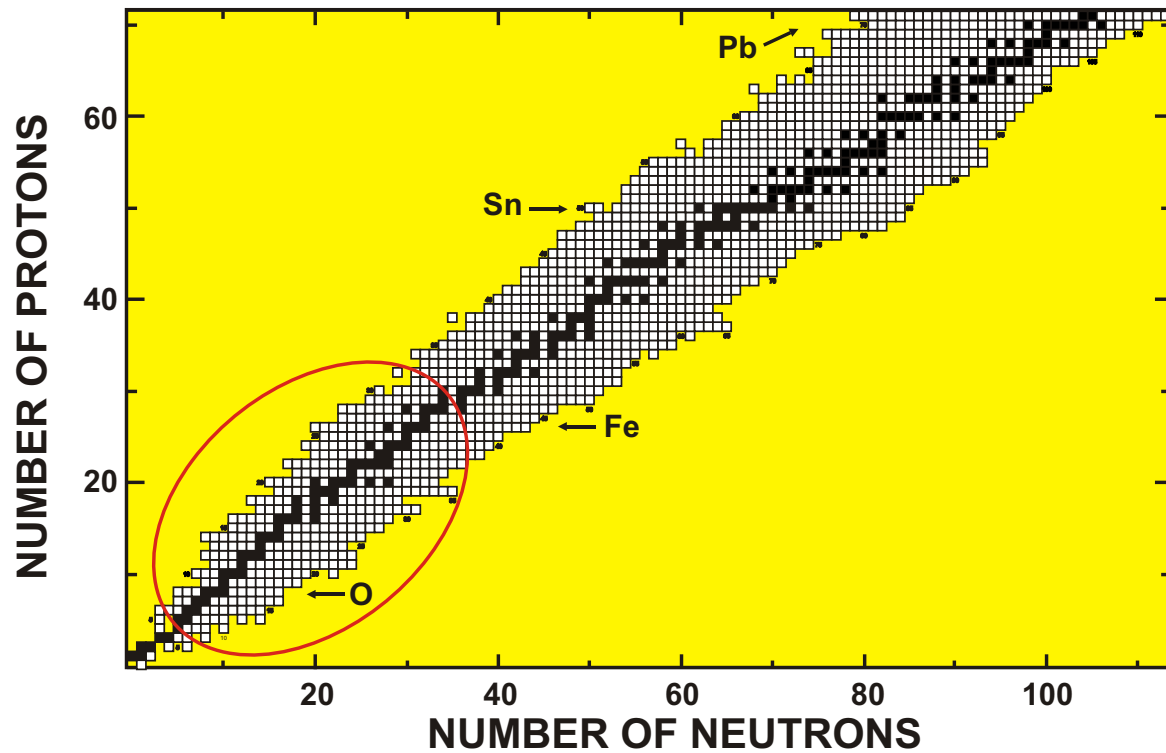
Chart of Nuclides



Periodic Table

IA																0										
1	H																He									
2	Li Be																Ne									
3	Na Mg																Ar									
4	K Ca Sc Ti V Cr Mn Fe Co Ni Cu Zn																Kr									
5	Rb Sr Y Zr Nb Mo Tc Ru Rh Pd Ag Cd																Xe									
6	Cs Ba *La Hf Ta W Re Os Ir Pt Au Hg																Rn									
7	Fr Ra +Ac Rf Ha 106 107 108 109 110																									

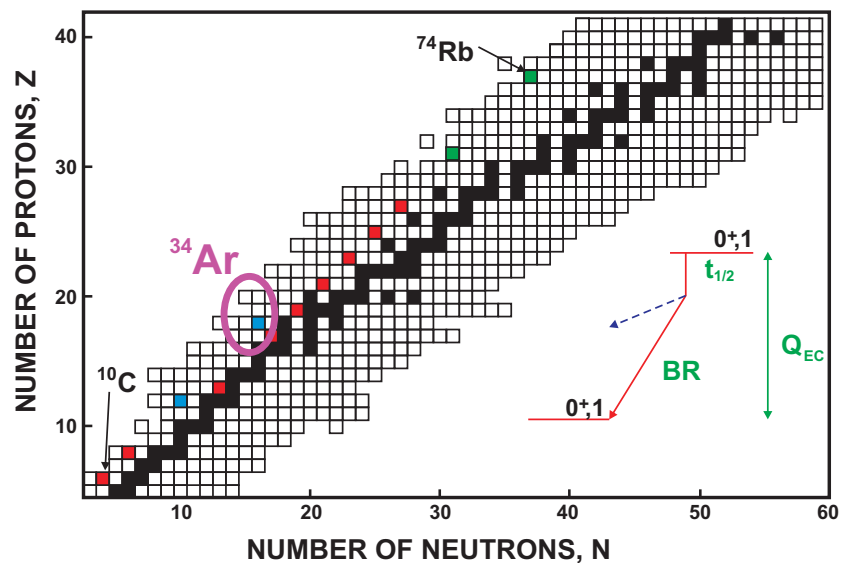
# NUCLEAR CHART



## WHAT WE MEASURE

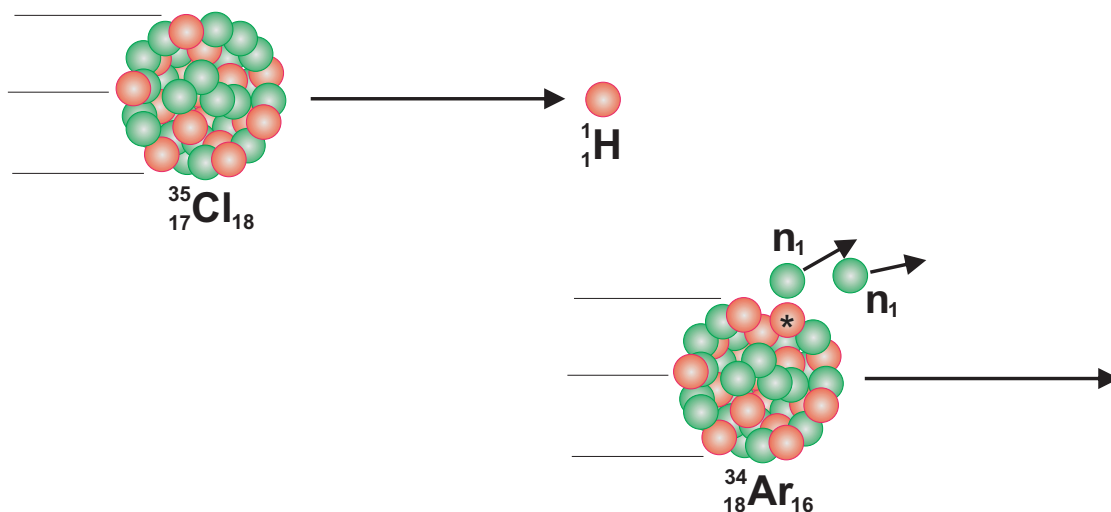
We must measure three quantities (all to a precision of  $\pm 0.1\%$  or better):

- Energy released in the decay,  $Q_{EC}$
- Half-life,  $t_{1/2}$
- Fraction of decays in path of interest, BR



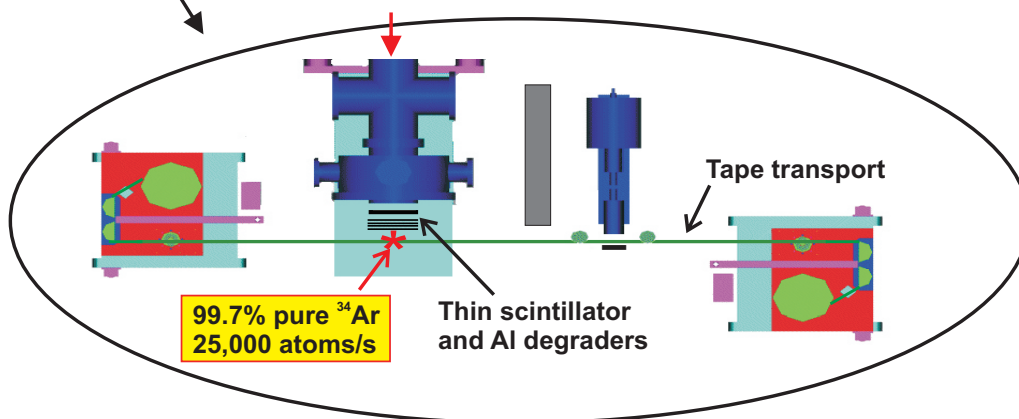
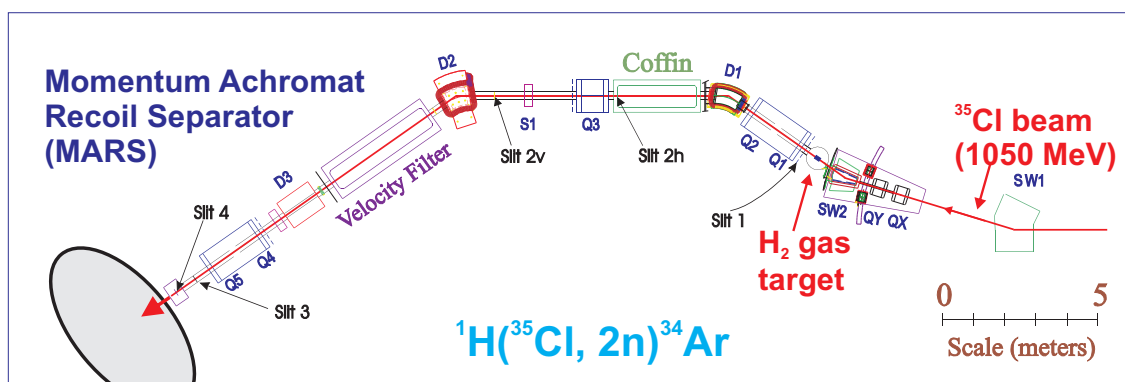
An example of one experiment done here:  $^{34}\text{Ar}$  decay

## HOW WE PRODUCE $^{34}\text{Ar}$



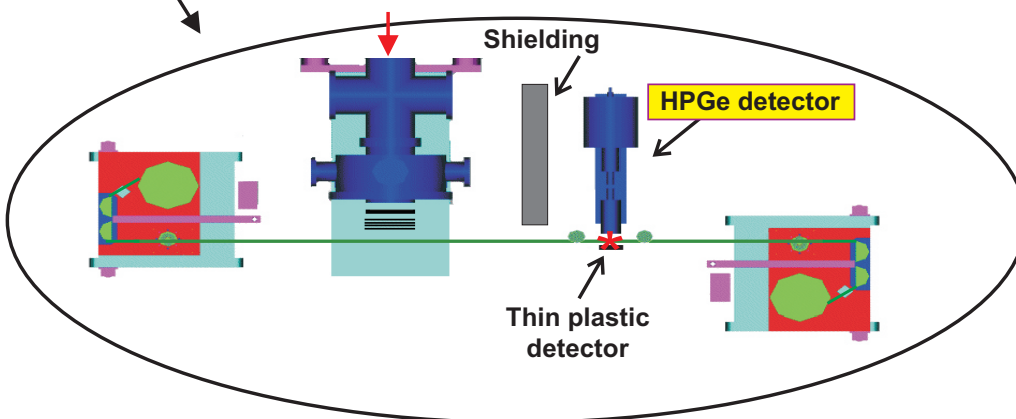
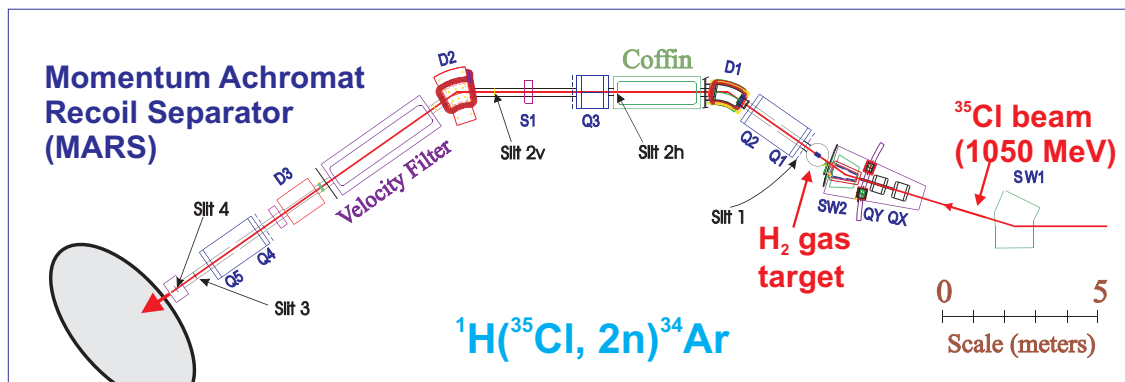
But other nuclei can be produced too, so we need to apply a “filter” that lets  $^{34}\text{Ar}$  through but nothing else.

## SOURCE PURIFICATION

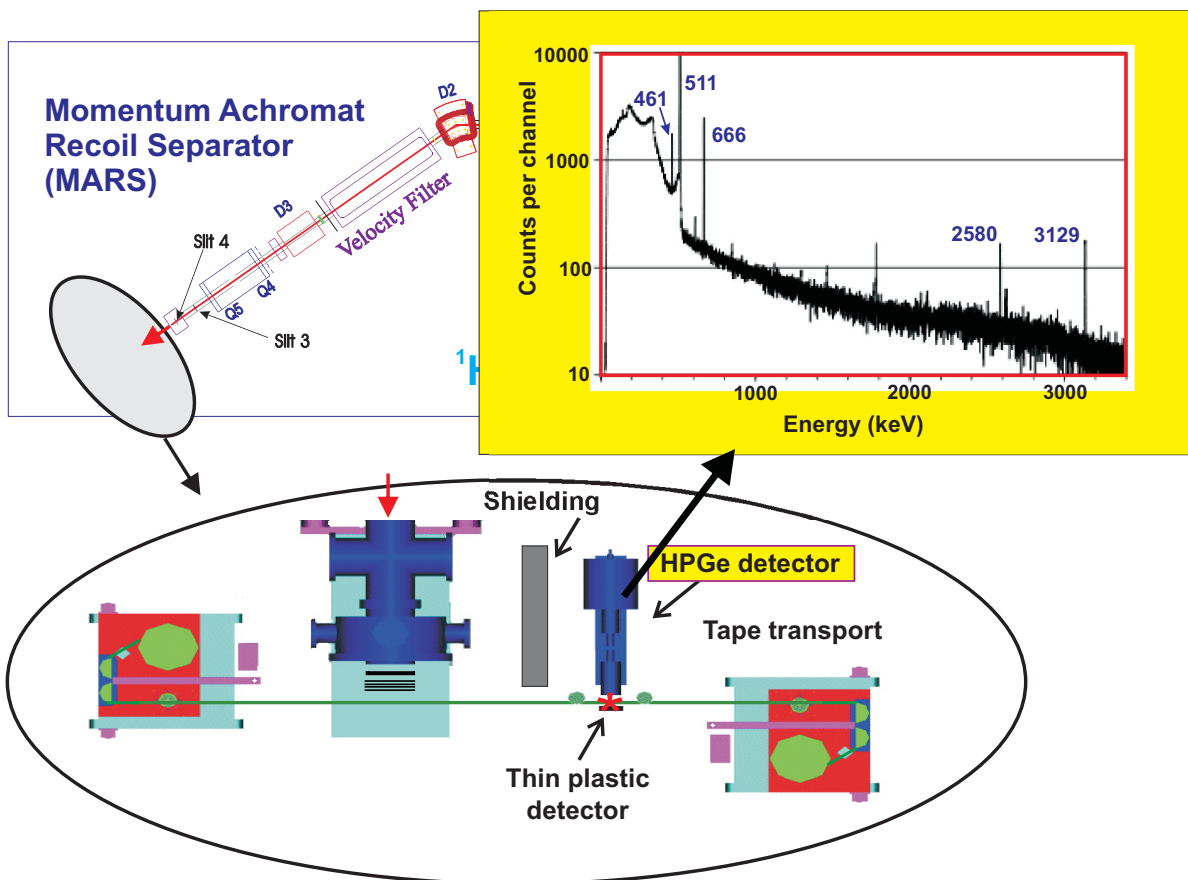




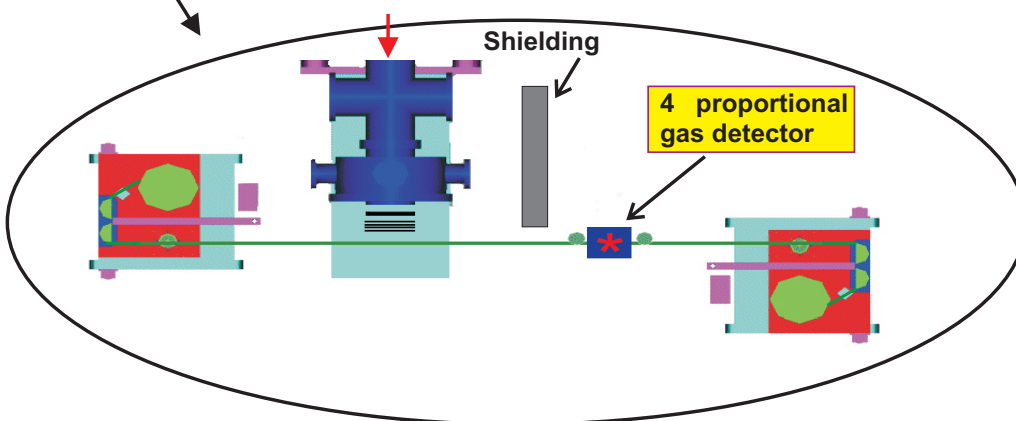
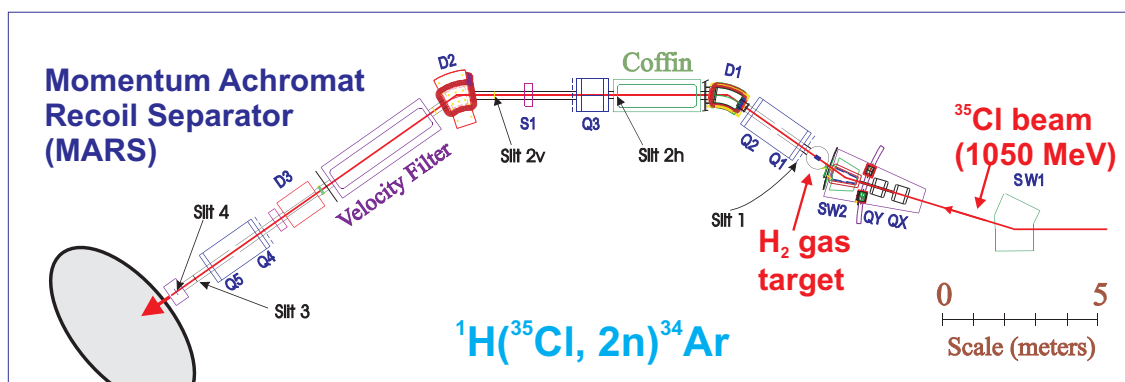
# SOURCE PURIFICATION



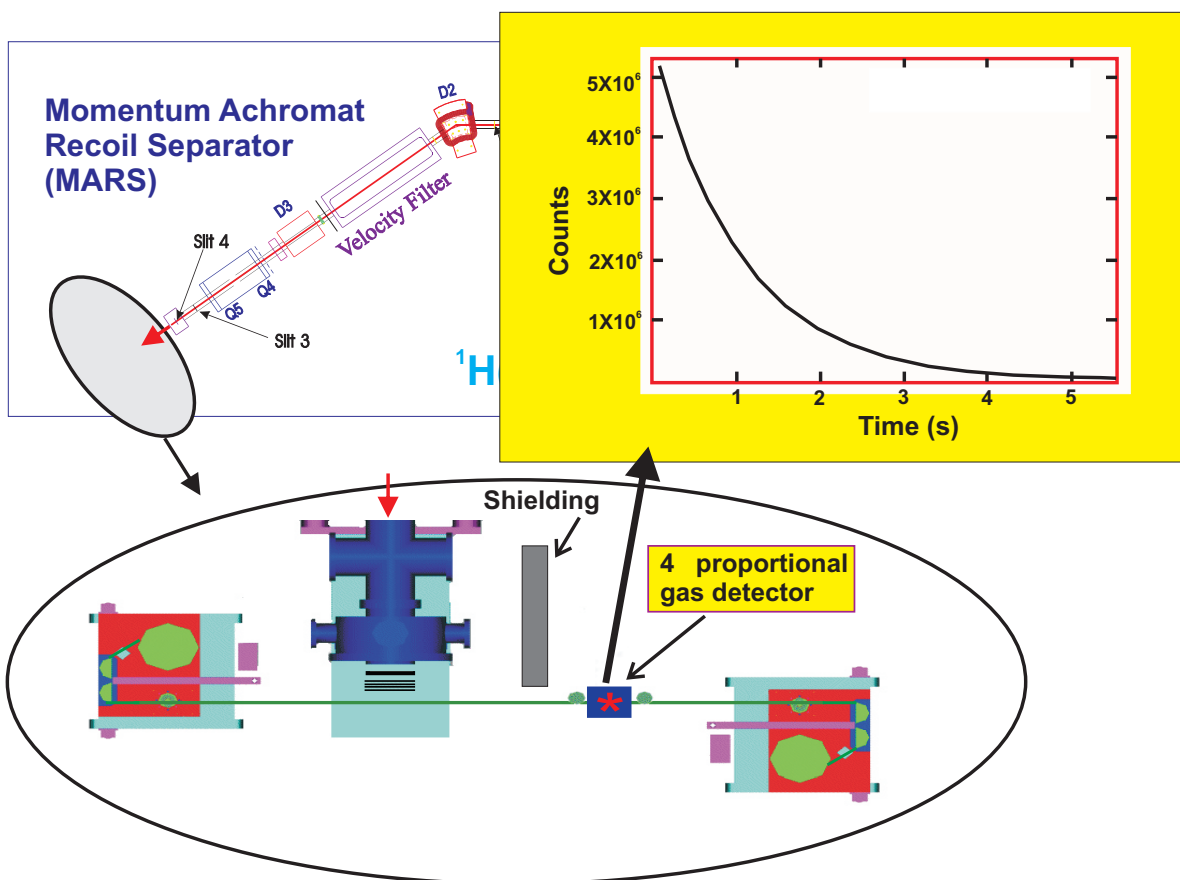
# SOURCE PURIFICATION



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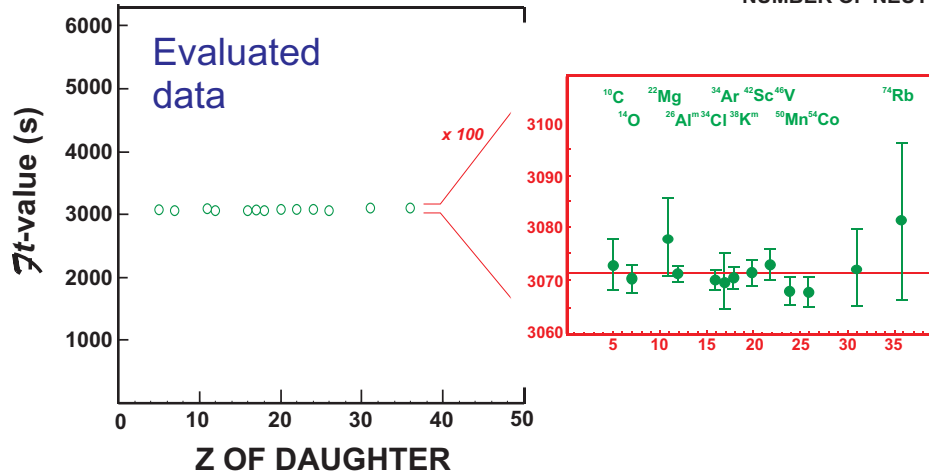
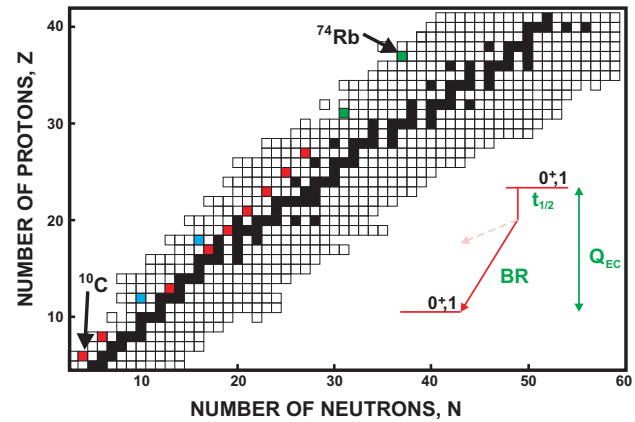


# SOURCE PURIFICATION



# WORLD DATA FOR $0^+ \rightarrow 0^+$ DECAY, 2008

- 10 cases with  $ft$ -values measured to  $\sim 0.1\%$  precision; 3 more cases with  $< 0.4\%$  precision.
- $\sim 125$  individual measurements with compatible precision



## SUMMARY AND OUTLOOK

### We know now that ...

1. The weak force (vector component) is constant in nuclei to 0.026%.
2. We can also test full universality of the weak force -- including the decay of other particles like the kaon -- and this also agrees within 0.1%!
3. Nuclear physics is the source of key data for these tests, the most precise ones available.

### Within 5 years, expect ...

1. Nuclear measurements will reduce uncertainty still further.
2. Full universality of the weak force will be tested to a precision of  $\leq 0.1\%$ .