Beta decay of ^{32}Ar for fundamental tests

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Argonne-ATLAS user meeting
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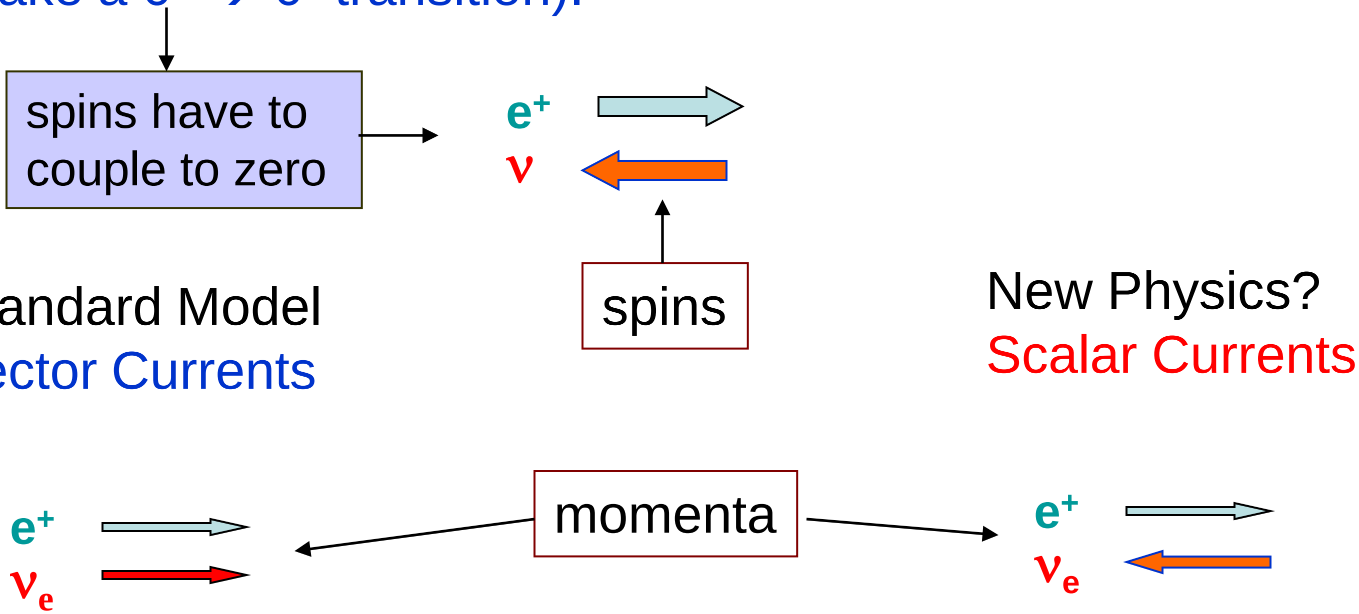
Outline

- 1999 measurement of positron-neutrino correlation in ^{32}Ar(e^+ nu_e): ISOL facility (CERN-ISOLDE)
- 2008 measurement the *ft* value for superallowed ^{32}Ar(e^+ nu_e) decay to test isospin symmetry breaking corrections: fragmentation facility (MSU-NSCL)
- Where does ATLAS fit in to this? A bridge from stability to ^{32}Ar!

Detecting scalar currents in weak decays

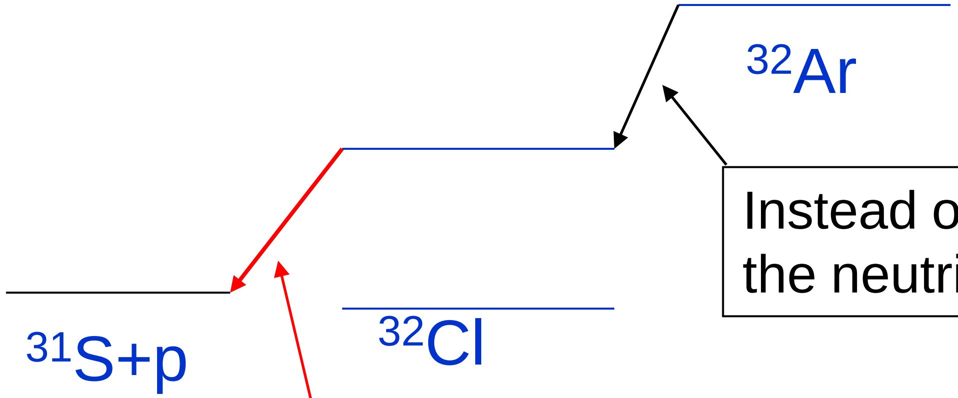
The e-ν correlation depends strongly on the nature of the carrier (we take a $0^+ \rightarrow 0^+$ transition).



$dW/d\Omega = 1 + \mathbf{p}_e \mathbf{p}_\nu / E_e E_\nu$

$dW/d\Omega = 1 - \mathbf{p}_e \mathbf{p}_\nu / E_e E_\nu$

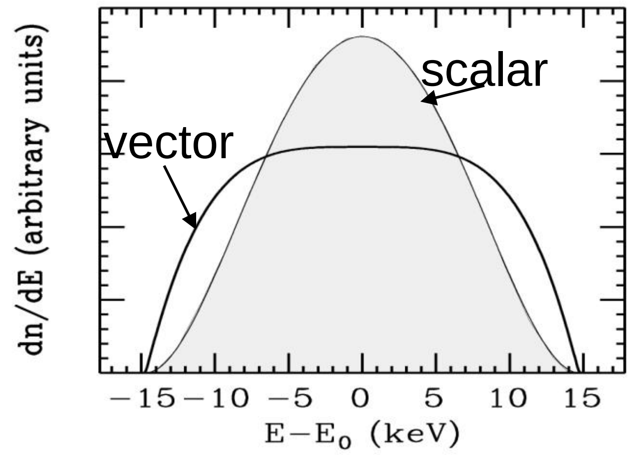
A trick to avoid detecting the neutrino



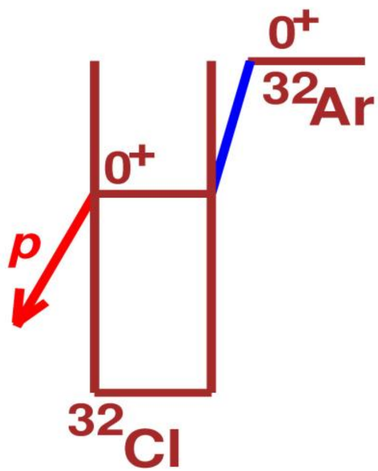
Instead of detecting the neutrino

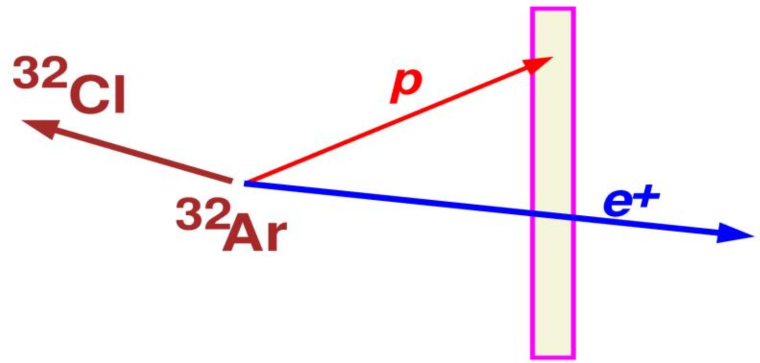
We detect the proton that contains the info about the ^{32}Cl recoil (Doppler)

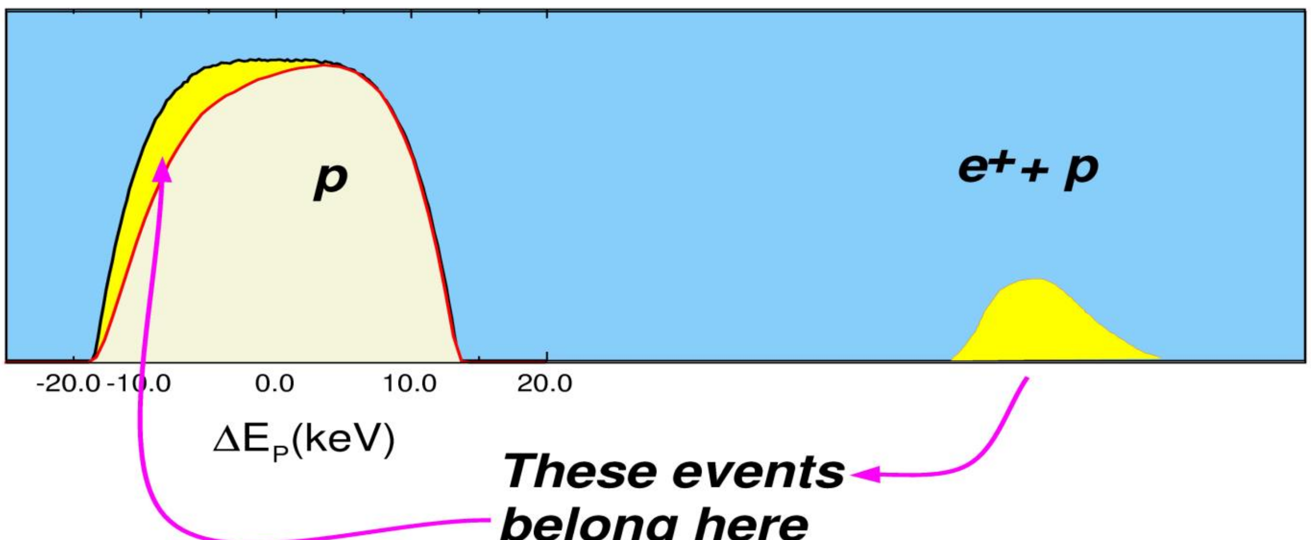
Monte-Carlo calculation of proton energy



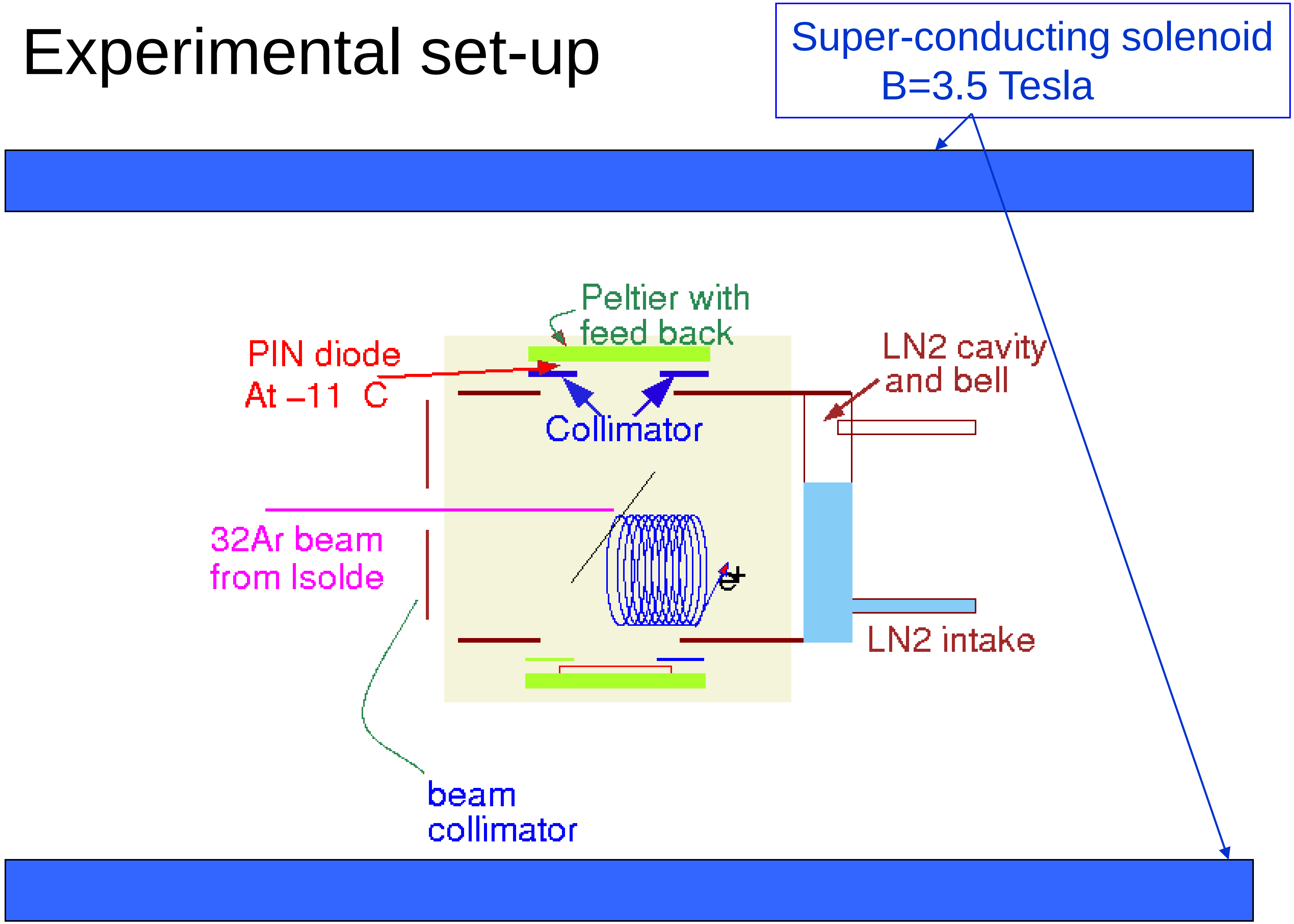
Problem: Summing with positrons distorts the shape of the proton peak



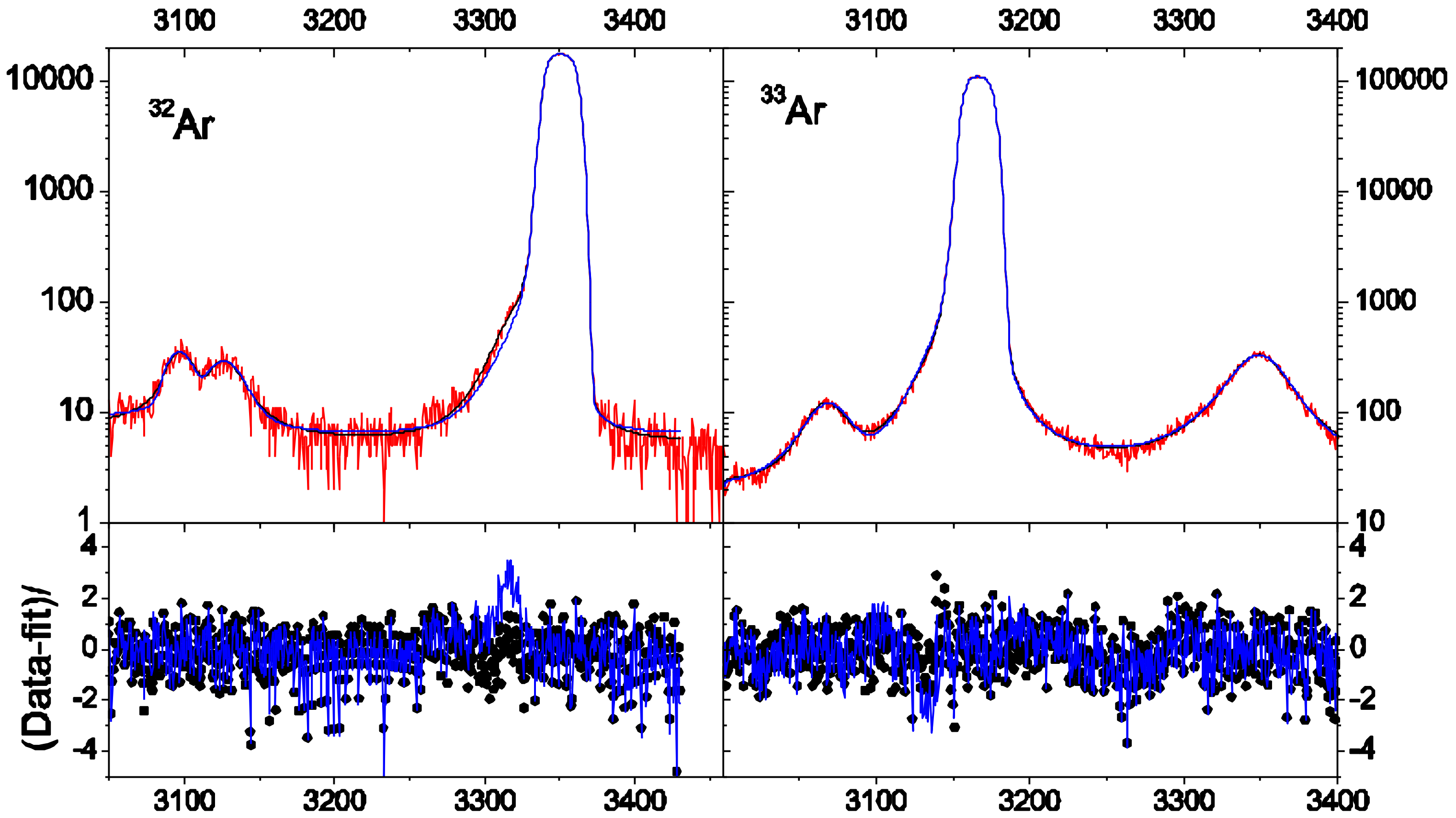




Experimental set-up



Simultaneous fit of ^{32}Ar and ^{33}Ar data



1999 result: ã=0.9980(52)$_{stat}$(39)$_{syst}$

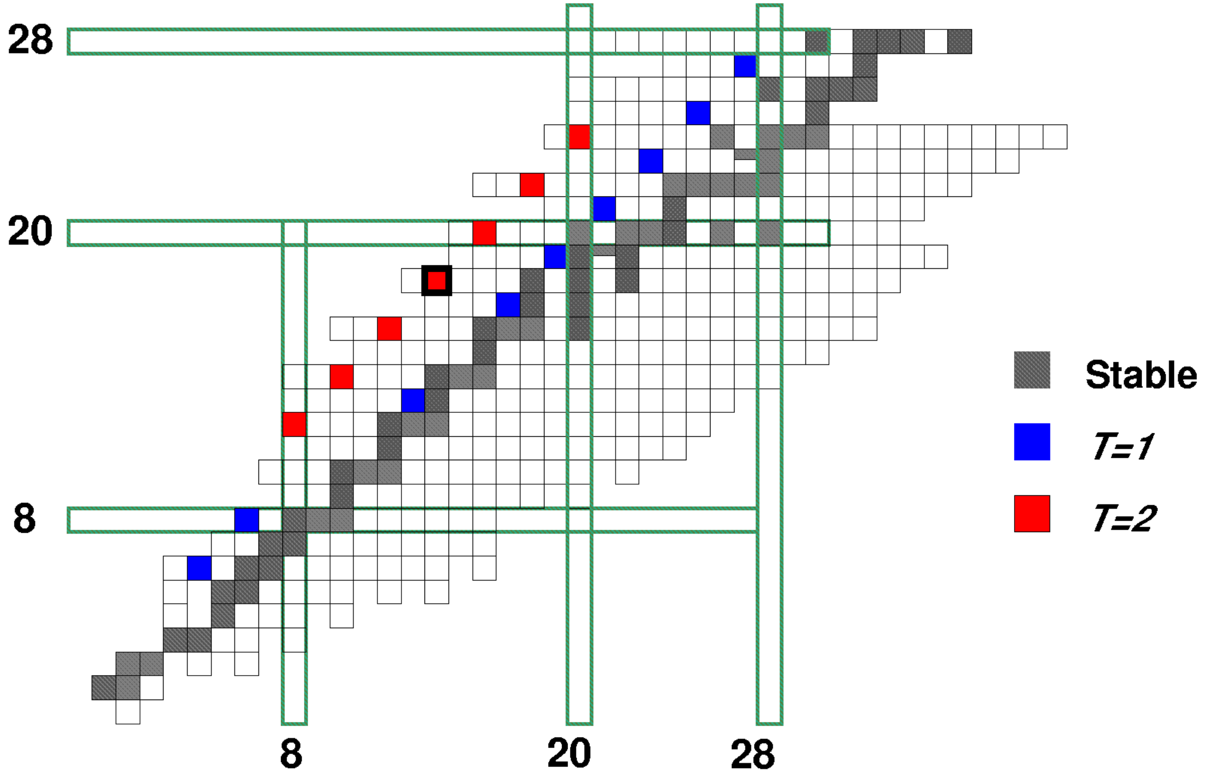
[Adelberger *et al*., PRL 83 (1999) 1299]

But, since then…

- Precision measurement of ^{32}S(p,p)^{32}S 3374.7-keV resonance energy [Pyle *et al*. PRL 88, 122501 (2002)]
- Precision measurement of ^{32}Ar mass [Blaum *et al*., PRL 91, 260801 (2003)]
- Precision determination of the mass of the lowest T=2 level in ^{32}Cl via precision measurement of ^{31}S mass [CPT collaboration, to be submitted]
- All of these change ã substantially!

T=2 nuclei present an alternative way to check

Isospin breaking corrections

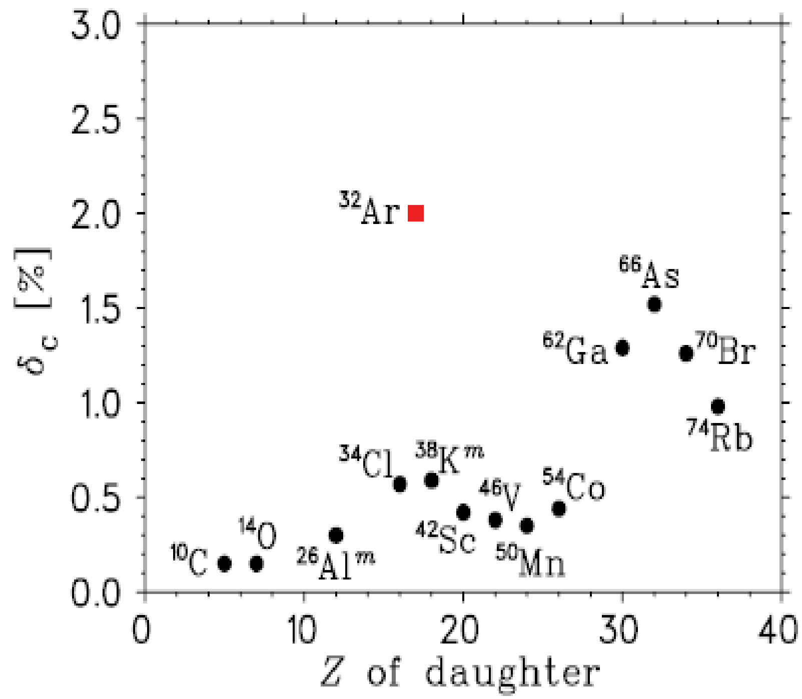


Bhattacharya *et al*., PRC 77, 065503 (2008)

V_{ud} from superallowed $0^+ \Rightarrow 0^+$ beta decay

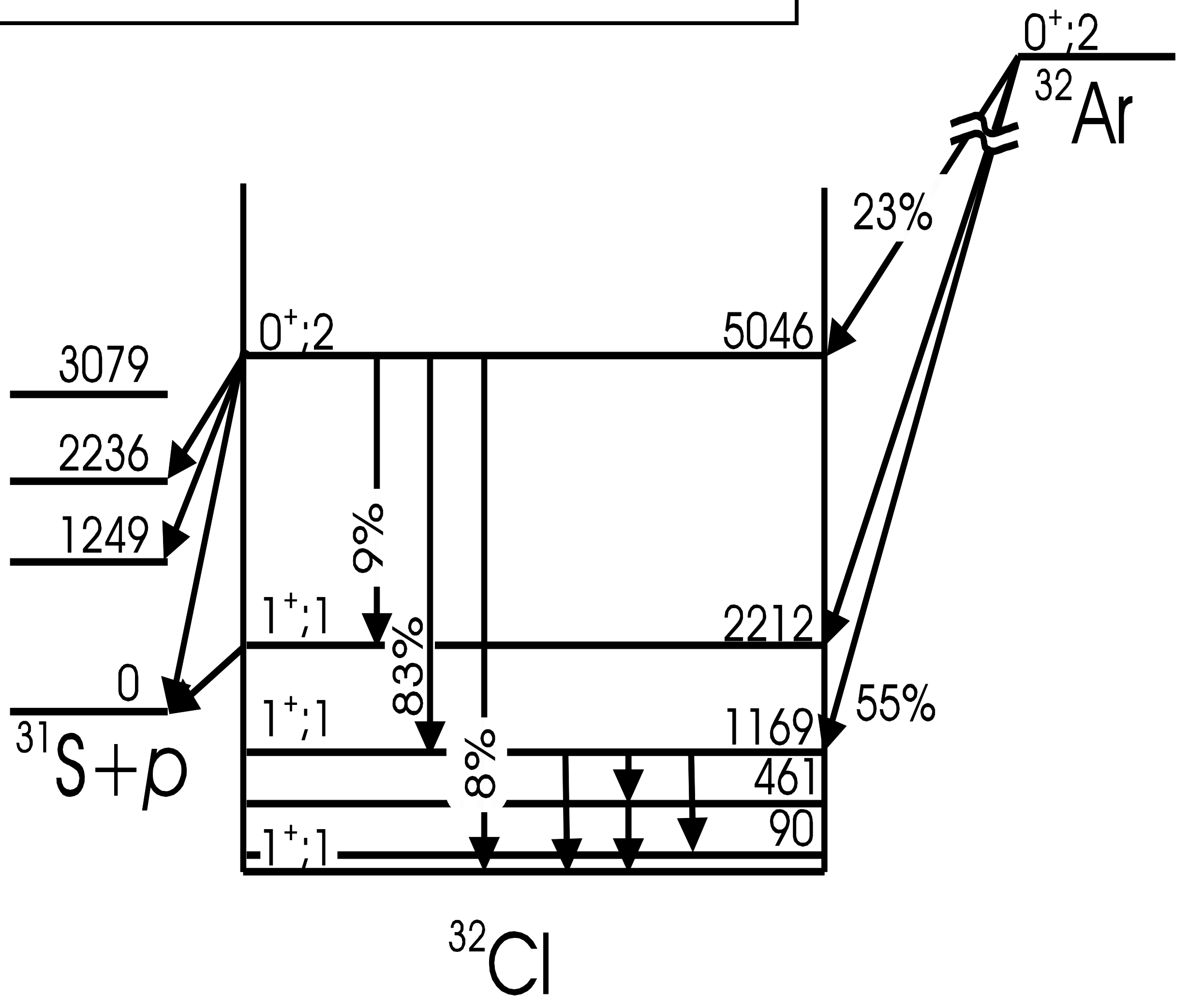
- Determining *ft* value requires precision measurements of Q value, $t_{1/2}$, and superallowed branching
- Extracting corrected *Ft* from *ft* requires radiative and isospin-symmetry-breaking corrections
- Measurements on T=1 decays are so precise that correction terms now dominate uncertainty in the average *Ft,* which determines V_{ud}
- Need to test theoretical corrections by experiment: eg. test delta$_C$ for T=2 ^{32}Ar

$$\mathcal{F}t \equiv ft(1-\delta_C)(1+\delta_R)$$

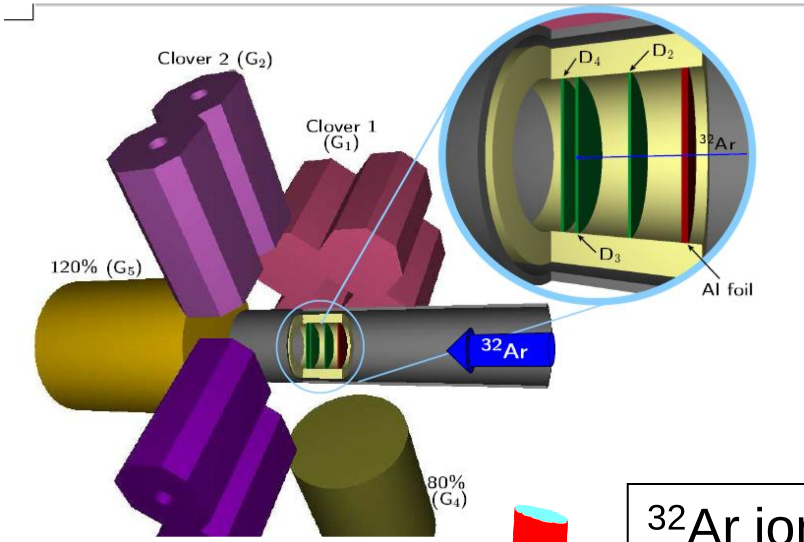


$$\delta_C^{\mathrm{exp}} = 1 - \frac{\overline{\mathcal{F}t}(T=1)}{2(1+\delta_R)\,ft(^{32}\mathrm{Ar})}$$

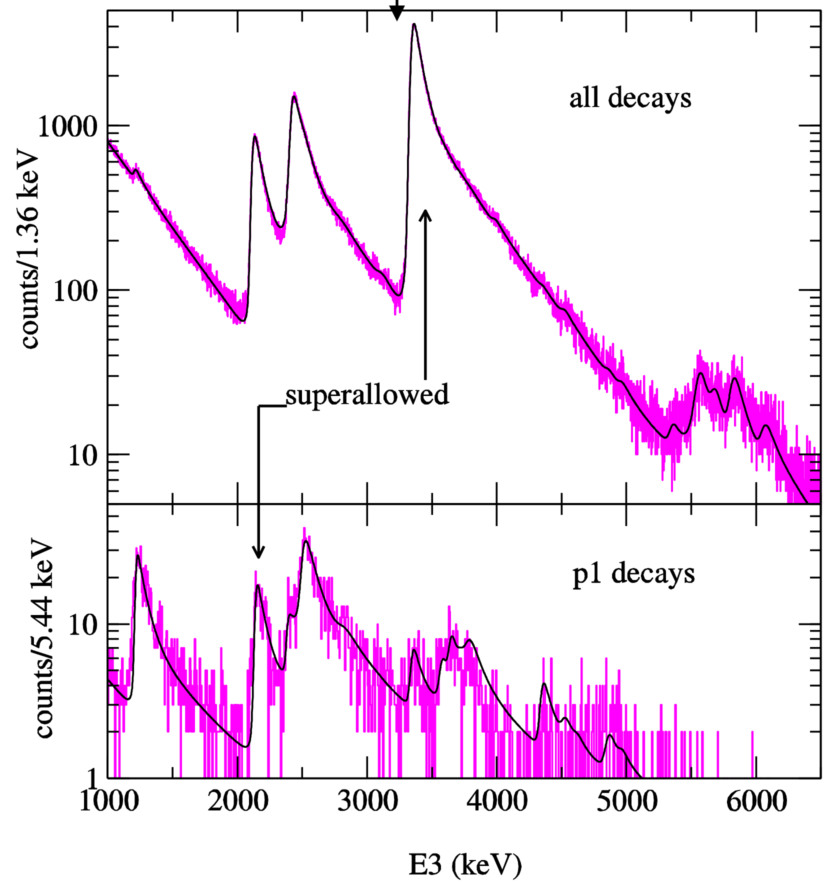
proton and gamma-ray emission from T=2 state



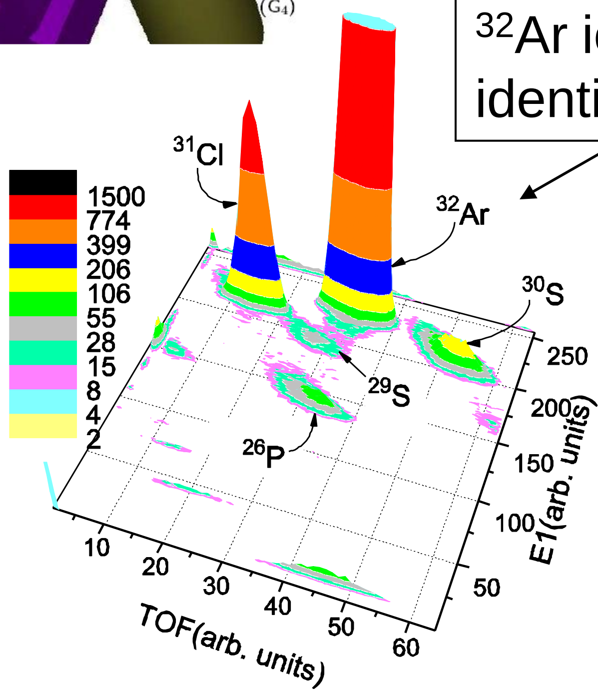
Experiment to determine branch of ^{32}Ar super-allowed transition (MSU)



Beta-delayed proton spectrum



^{32}Ar ion identification



Summary of super-allowed ^{32}Ar branches:

$$\frac{N_p}{N_{Ar}} = \underbrace{\frac{N_{p0}}{N_{Ar}}}_{\approx 20.4\%}\left(1+\frac{N_{p1}}{N_{p0}}+\frac{N_{p2}}{N_{p0}}\right) = 20.9(1)\%$$

$$\frac{N_\gamma}{N_{Ar}} = \frac{\overbrace{\sum_i N_\gamma(i)}^{from\ spectrum}}{\underbrace{N_{Ar}\sum_i \varepsilon_\gamma(i)\varepsilon_\beta}_{from\ ^{32}Cl}} = 2.03(10)\%$$

Systematic uncertainties

Component	*b*(%)
implt. ^{32}Ar's	0.2
p0 branch	0.5
p1 branch	0.04
p2 branch	0.04
p3 branch	0.07
gamma branch	0.4
other	0.01

Isospin-breaking correction:

Measurement: $\delta_c^{\exp} = 2.1(8)\%$

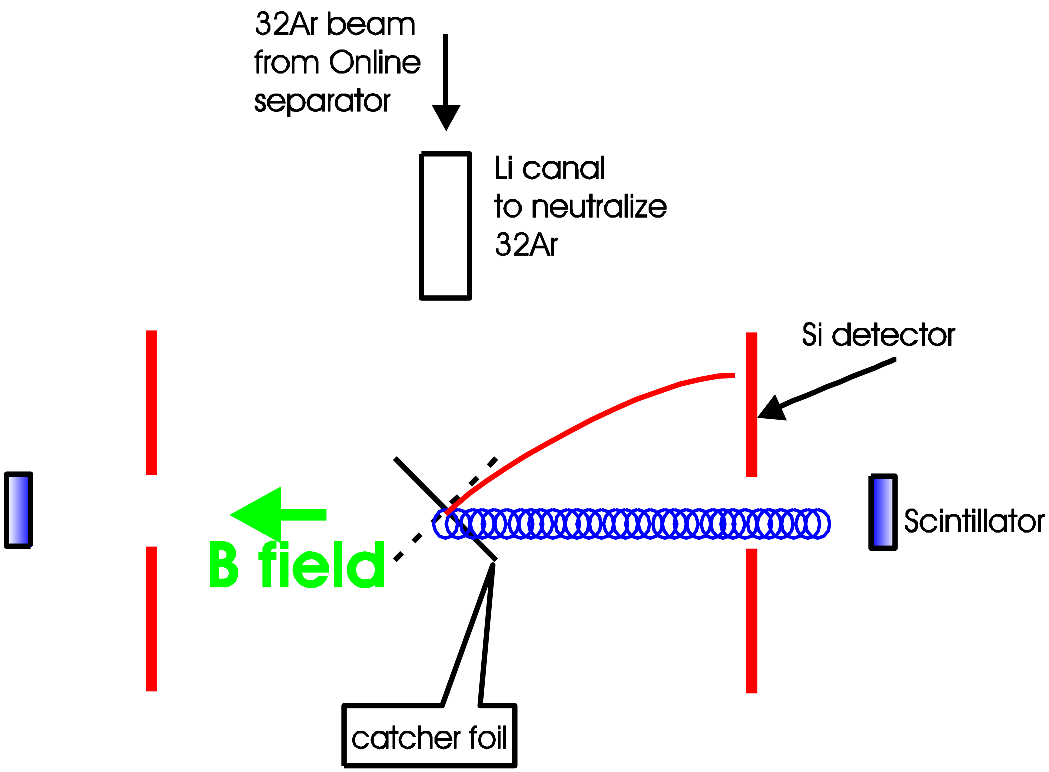
Theory: $\delta_c^{th} = 2.0(4)\%$

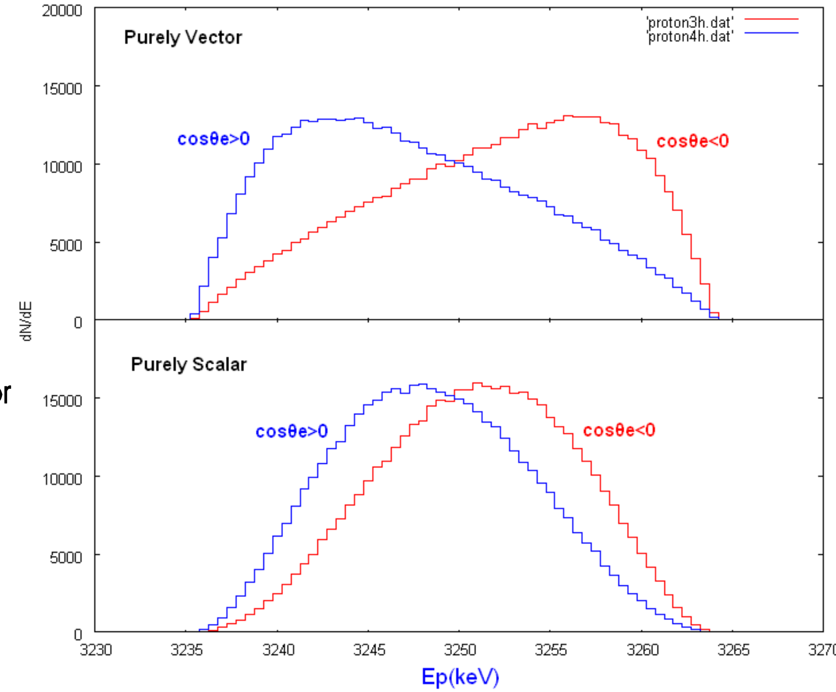
But, results are dependent on…

- Absolute gamma-ray branchings from ^{32}Cl(beta gamma)^{32}S: measured separately [Melconian *et al*., to be submitted]
- Results of the lepton-correlation experiment described previously [Adelberger *et al*. PRL 83 (1999) 1299], which are in turn strongly dependent on quantities that are still being measured!

An idea to determine lepton correlations and particle branches with high precision to be used with FRIB

In the short term we can improve determination of *a* in 32Ar by a factor of 5!





In the longer range this device can be used in FRIB to produce useful standards for calibration of particle branches and as a spectroscopic tool.

Where does ATLAS fit in to this?

- In this mass region and below ATLAS has unique capabilities (eg CPT & Gammasphere) to obtain precision data on nuclides 1 or 2 nucleons from stability on the proton-rich side
- Would be very useful if this information were more complete before other precision decay studies on *T*=2 nuclides commence
- Request that ATLAS PAC take into consideration proposed measurements of unstable nuclides near stability that utilize ATLAS’s unique capabilities simply to “fill in” detailed information about these nuclides and facilitate future precision experiments at FRIB

Thank you!