# S1188 Spin-polarized $^{37}$K $\beta^+$ decay with TRINAT

- **Status:**

**$^{37}$K $A_\beta$ = -0.5706± 0.0018**

**S.M. $A_\beta$=-0.5715±0.0007**

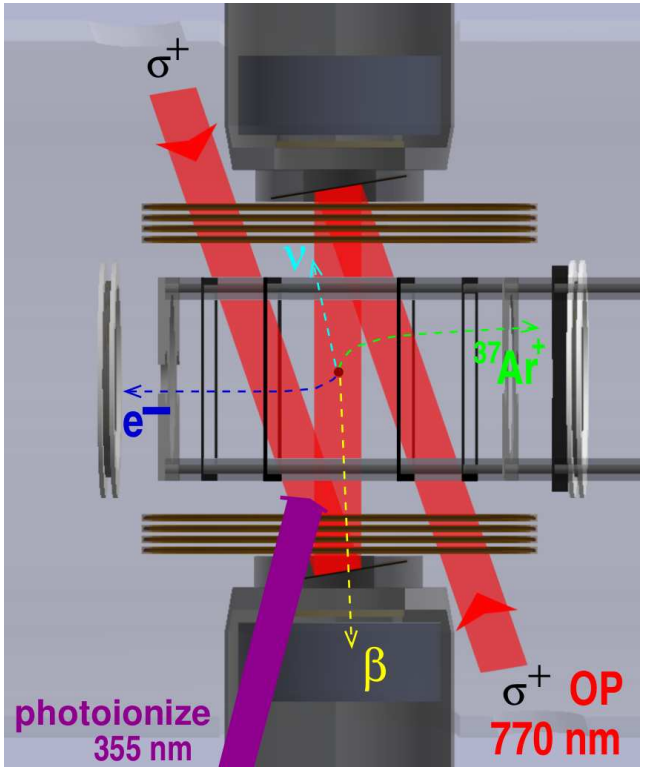
**The most accurate $A_\beta$ measurement**

**High-accuracy polarization measurement, continuous in situ probe**

- **Improvements to $A_\beta$**

**Phenomenology implications**

- **New observable $A_{recoil}$ in same geometry**
- **Shift request**




TRIUMF

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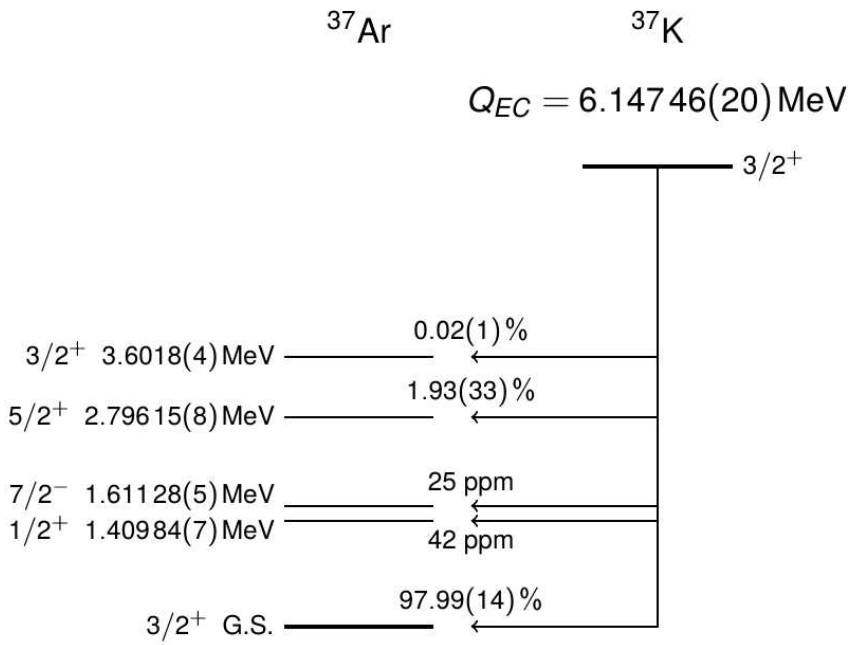
# $^{37}$K isobaric analog decay




**DFT for isospin mixing has improved its functional in this region**

**Recoil-order corrections from electromagnetic moments by CVC (One 2nd-order effect in axial current depends on nuclear structure and is small)**

**Measured *Ft* value → $C_A M_{GT} / C_V M_F = \rho$ =0.5768±0.0021**

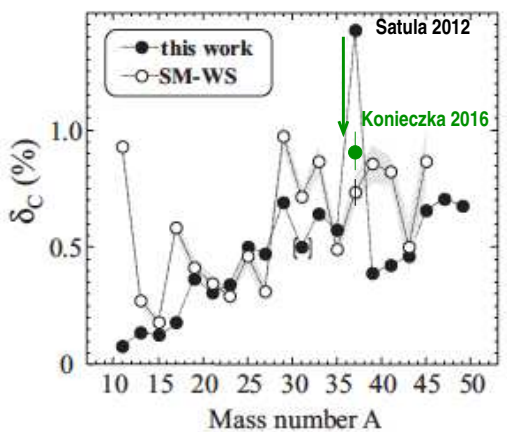
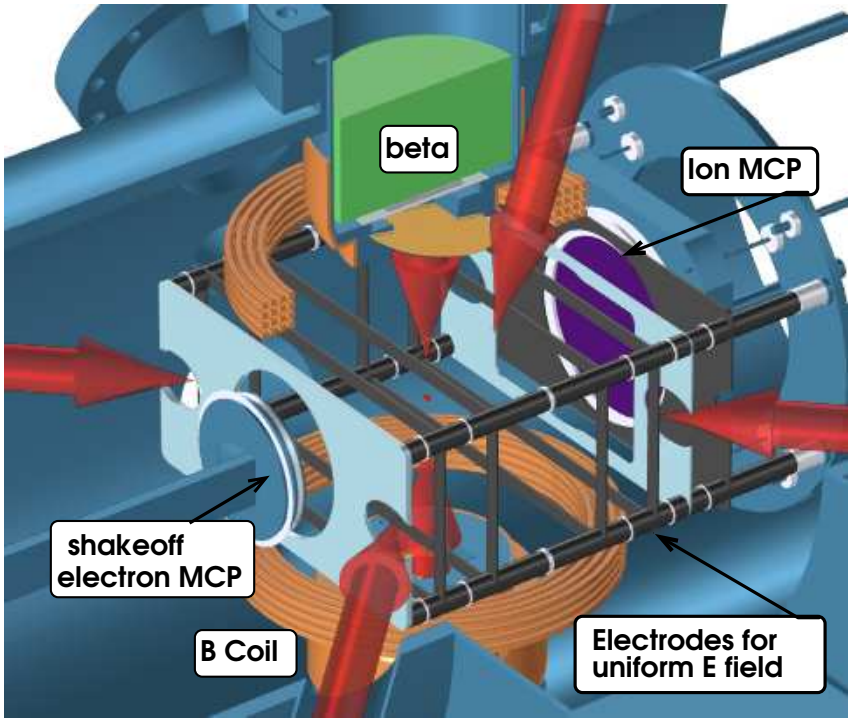
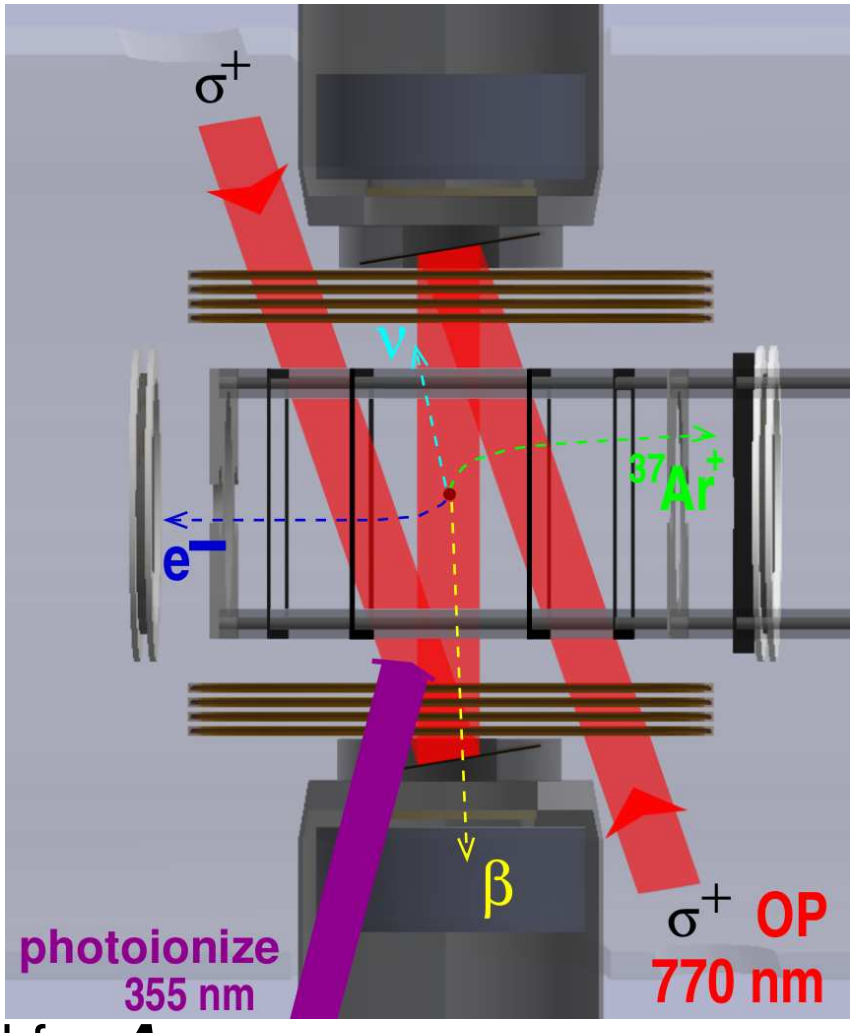



FIG. 13. Filled circles: Calculated values of ISB corrections to

# $^{37}$K decay geometry




- $\beta$, recoil nucleus
- shakeoff $e^-$ for TOF trigger

June 2014 data at reduced $E$ field for $A_\beta$
The decay pattern shown on the right is helicity-forbidden if the $\nu$ goes straight up, independent of Gamow-Teller/Fermi ratio.

# TRIUMF Optical pumping and probing $^{37}$K

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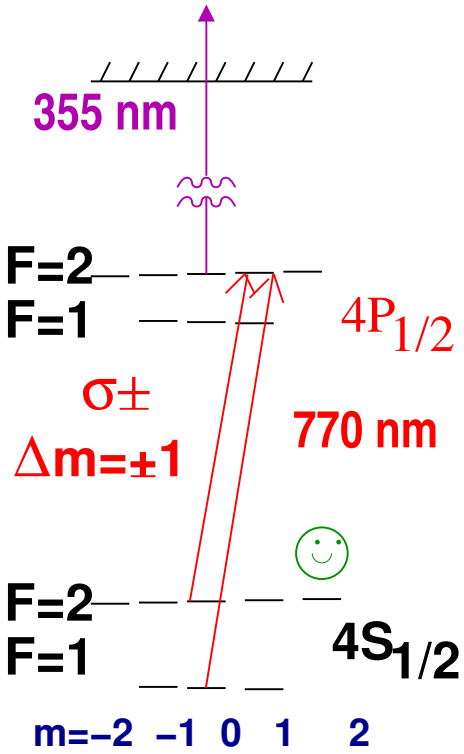
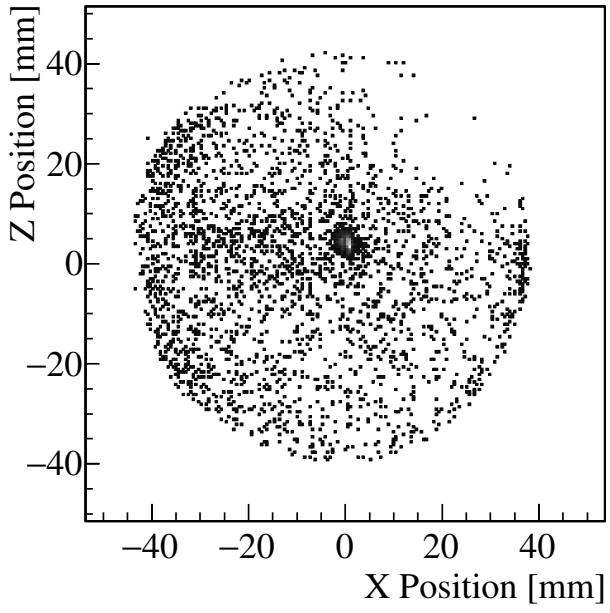
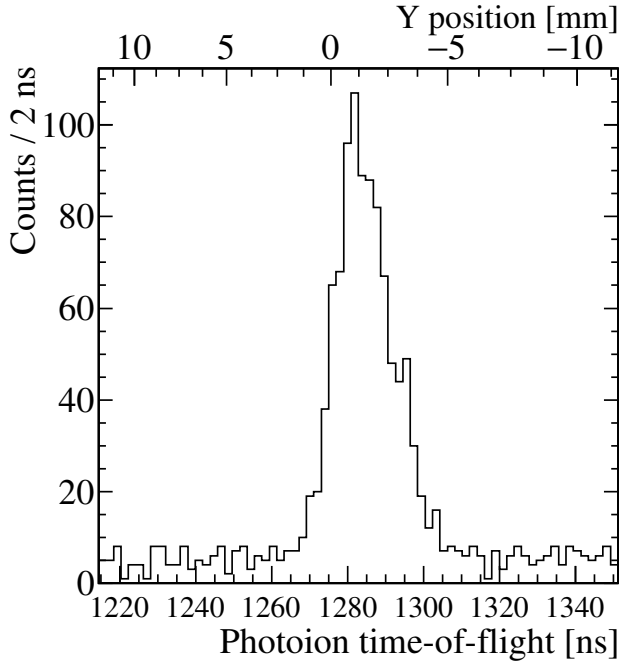
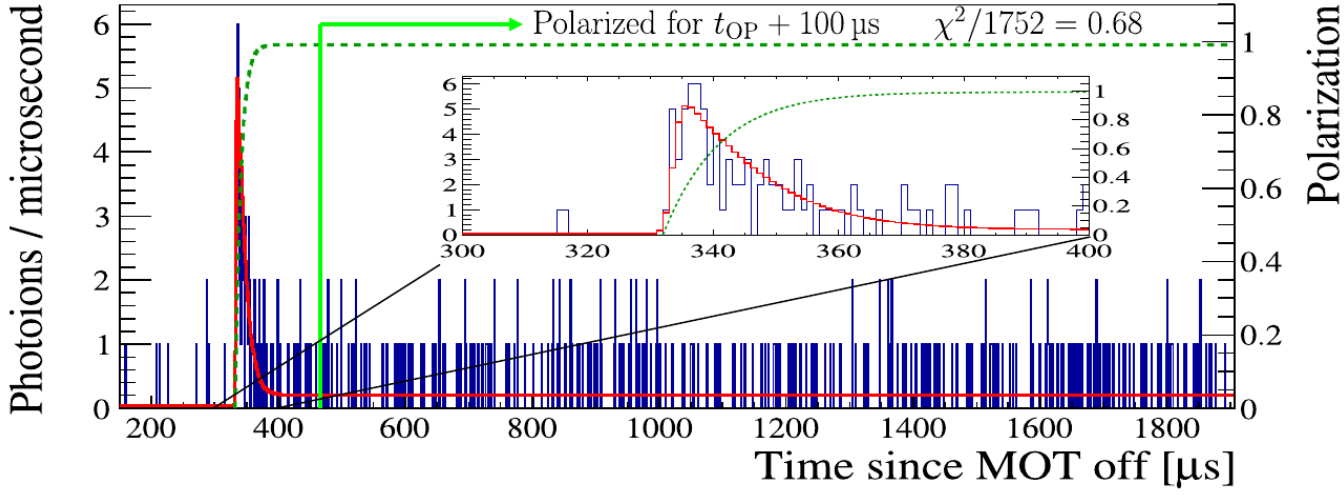



- **Photoionize ~ 1%**
- **continuous *in situ* probe**



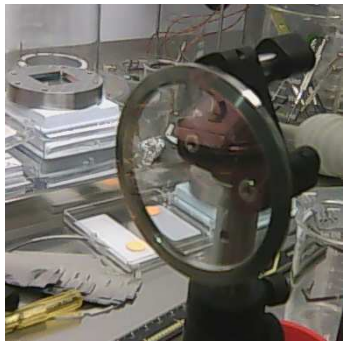



# Polarization Improvements

| SYST $\times 10^{-4}$ | $\Delta P$ | | $\Delta T$ | |
|---|---|---|---|---|
| | $\sigma^-$ | $\sigma^+$ | $\sigma^-$ | $\sigma^+$ |
| Initial $T$ | 3 | 3 | 10 | 8 |
| Global fit v. ave | 2 | 2 | 7 | 6 |
| $S_3^{out}$ Uncertainty | 1 | 2 | 11 | 5 |
| Cloud temp | 2 | 0.5 | 3 | 2 |
| Binning | 1 | 1 | 4 | 3 |
| $B_z$ Uncertainty | 0.5 | 3 | 2 | 7 |
| Initial $P$ | 0.1 | 0.1 | 0.4 | 0.4 |
| Require $\mathcal{I}_+ = \mathcal{I}_-$ | 0.1 | 0.1 | 0.1 | 0.2 |
| Total SYSTEMATIc | 5 | 5 | 17 | 14 |
| STATISTICS | 7 | 6 | 21 | 17 |

B. Fenker New J. Phys **18** 073028 2016



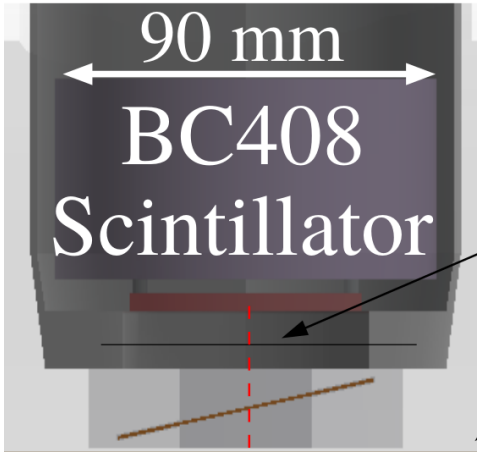
- pellicle mirrors: less $\beta$ scattering
- trim B gradients
- improve $S_3$ flipping and gradients
- add flipping of $B_z$
- higher-power photoionizing laser
- gentler RAC-MOT

$P(\sigma^+) = +0.9913(8)$ $T(\sigma^+) = -0.9770(22)$

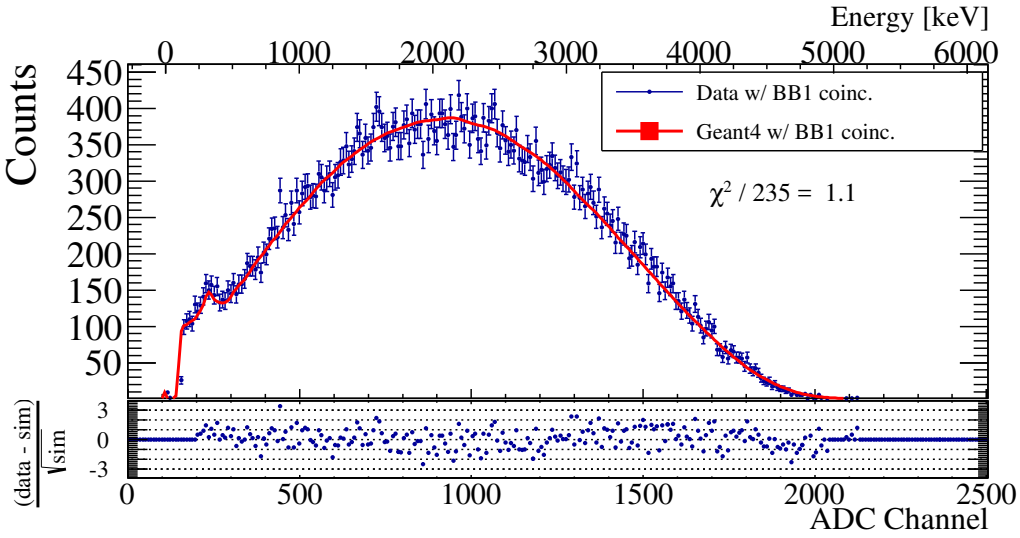
$P(\sigma^-) = -0.9912(9)$ $T(\sigma^-) = -0.9761(27)$

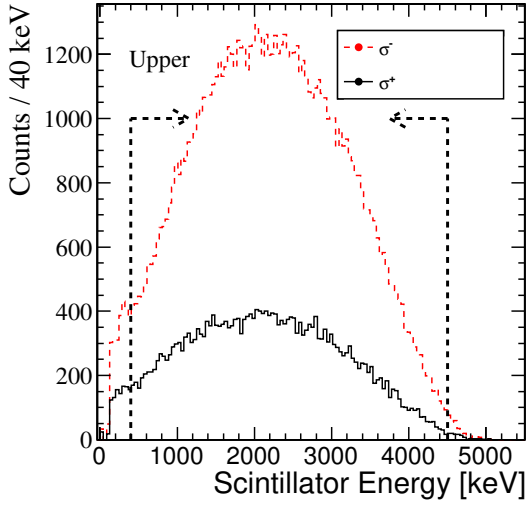
- Uncertainty $\propto$ (1-P)

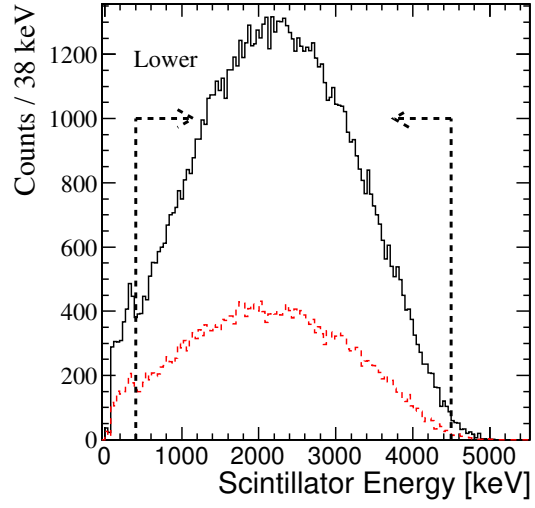
# $\beta^+$ Spectra




- 300 $\mu$m DSSSD + plastic scintillator
- Backscatter understood in GEANT4 when $>$ 1 pixel fires
- linear calibration to 511 keV Compton edge and $E_\beta$ endpoint



# $A_{\beta+}$ Uncertainties

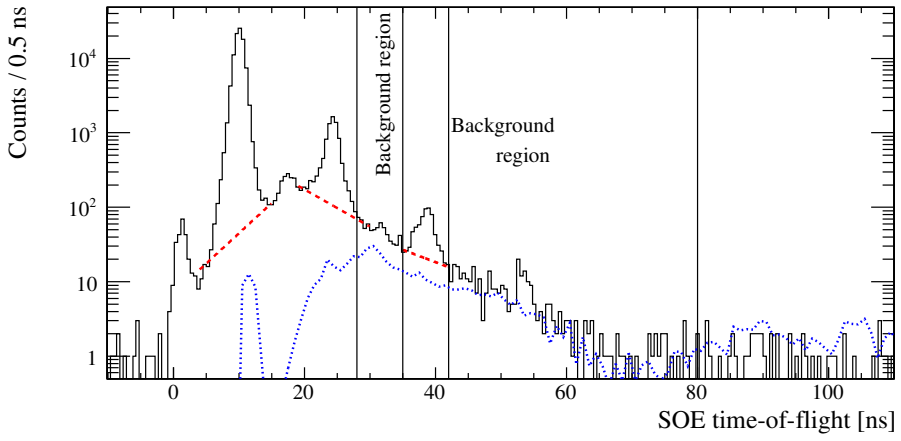
| Source $\times 10^{-4}$ | $\Delta A_\beta$ |
|---|---|
| Background (Correction 1.0013) | 7 |
| Trap Position | 4 |
| Trap Sail velocity | 5 |
| Trap Temperature & width | 1 |
| BB1 Radius† | 4 |
| BB1 Energy agreement | 2 |
| BB1 threshold | 1 |
| Scintillator threshold | 0.3 |
| GEANT4 physics list† | 4 |
| Shakeoff electon t.o.f. region | 3 |
| SiC mirror thickness† | 1 |
| Be window thickness† | 0.9 |
| Scintillator or summed† | 1 |
| Scintillator calibration | 0.1 |
| Total systematics | 12 |
| Statistics | 13 |
| Polarization | 5 |
| Total uncertainty | 18 |

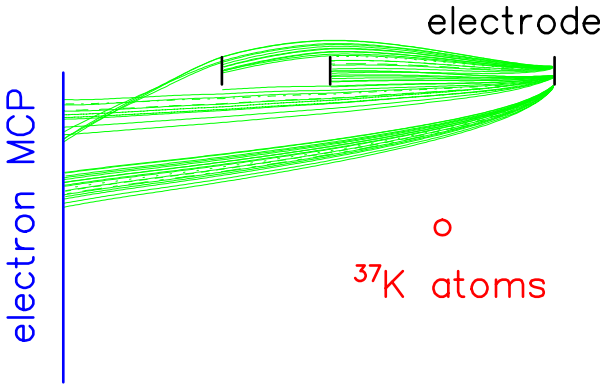
Background see next slide

Trap parameters: new trap control system, faster CMOS camera have let us make modest gains in temperature and cloud size

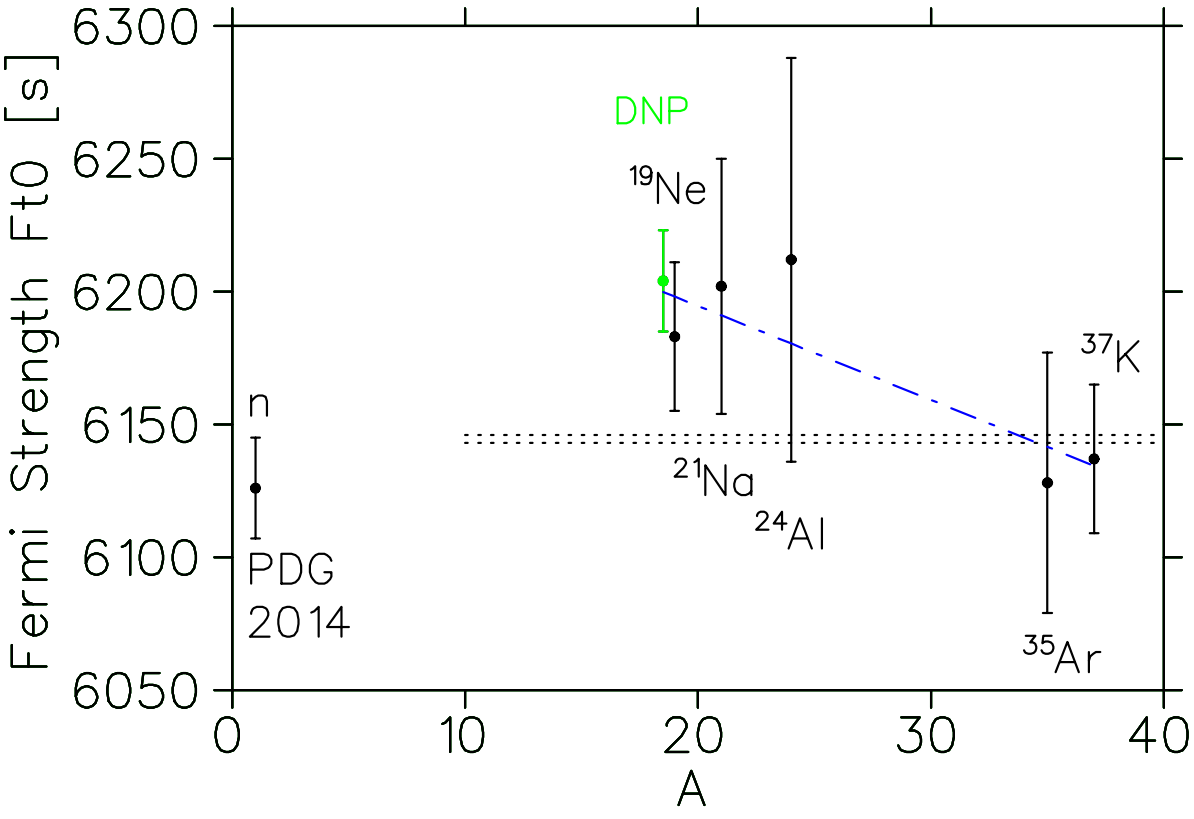
$A_\beta[E_\beta]$: gain calibration of upper vs. lower detector produces a small uncertainty

# Background




- $\beta$ telescope and shakeoff $e^-$ coincidence remove most decays not from the trap cloud
- Conservatively assume polarized between 0 and 100%.
- Calculated trajectories suggest these will miss plate when we increase to design field

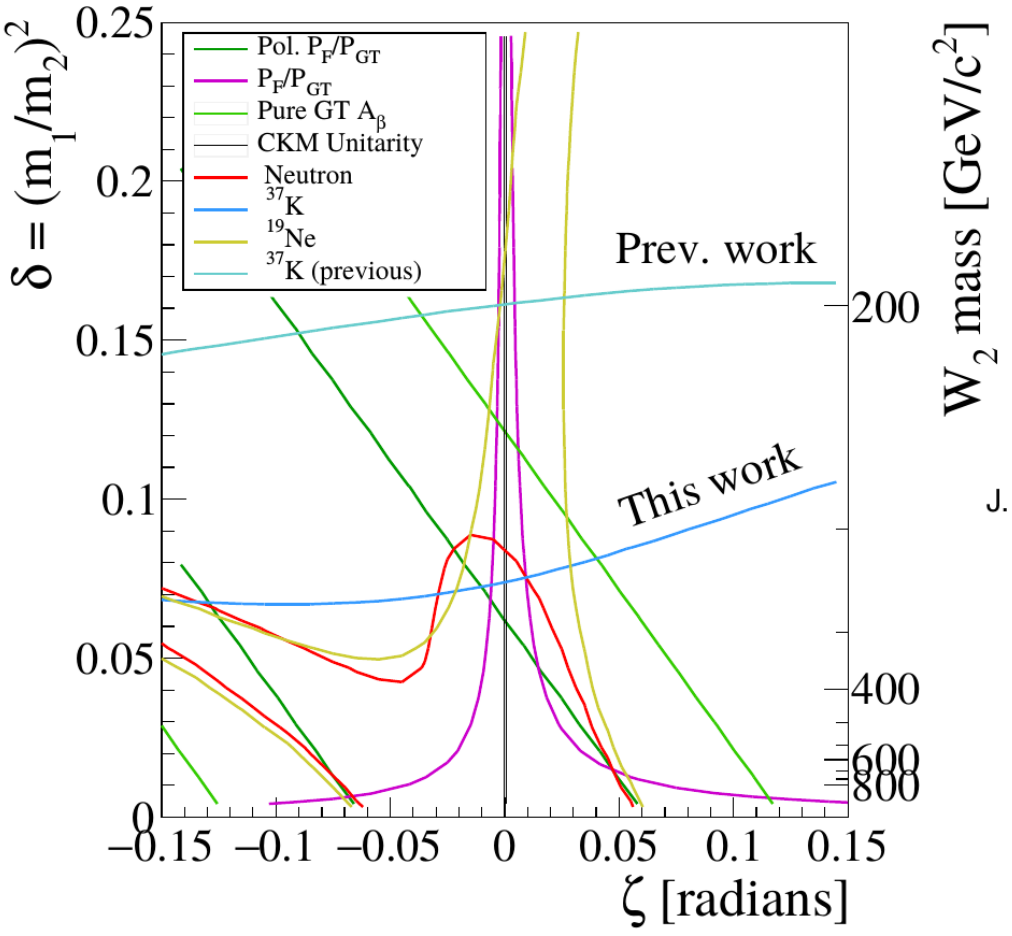



- **CVC hypothesis can be assumed only where we can test it**

**CVC tests constrain SM physics in addition to isospin mixing. E.g. Salam Nature 1974: phase transitions at very high B fields could drive $\theta_{\text{Cabibbo}} \rightarrow 0$ Hardy Towner PLB 1975 applied to the $^{35}$Ar $A_\beta$ controversy.**

# Right-handed vector currents

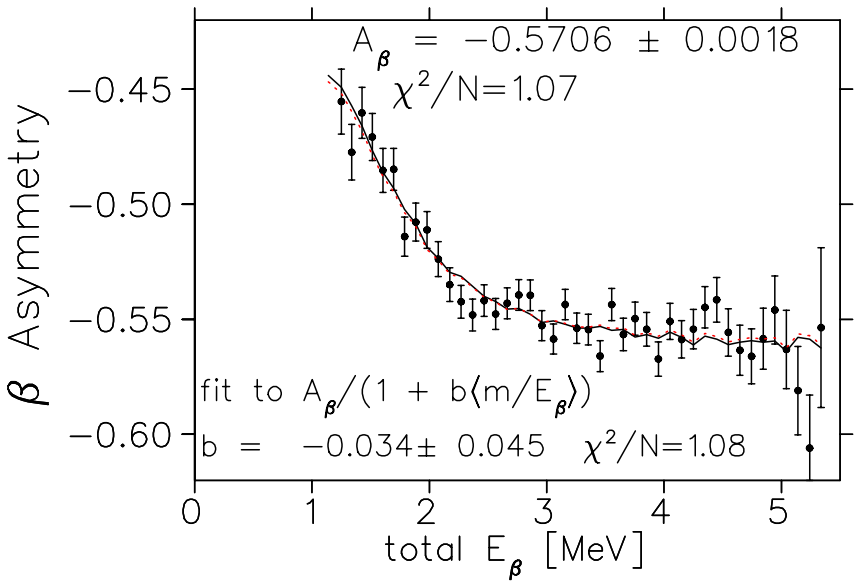
Standard model W exchange produces left-handed $\nu$ and right-handed $\beta^+$ ("V-A")

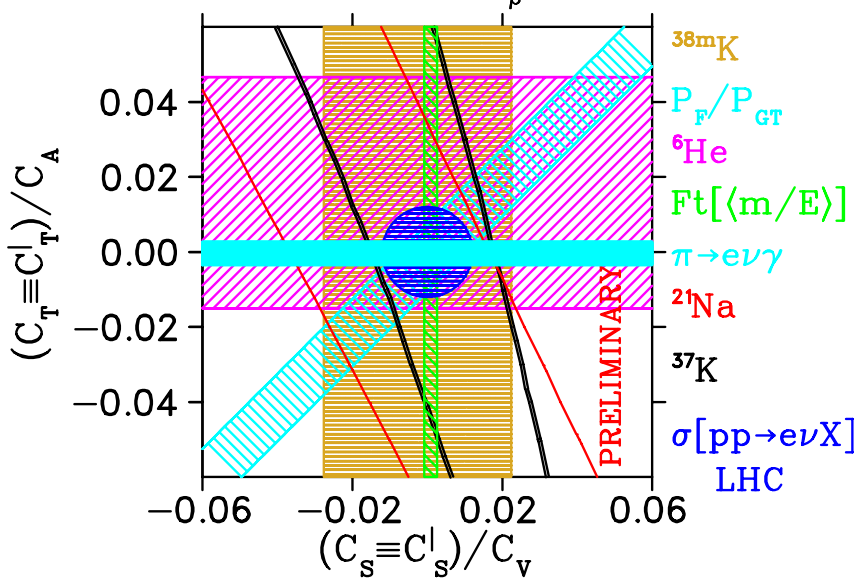



J.

**$^{37}$K complementary constraint to other nuclear $\beta$ decay.**
**$W_R$ $M > 310 GeV$ at 90% CL.**
**Nuclear $\beta$ decay average $g_R < 6.7$ at 4 TeV**
**For $M'_W < 70$ GeV, nuclear $\beta$ decay constrains $Vud_R$ (Severijns Naviliat-Cuncic ARNPS 2011)**

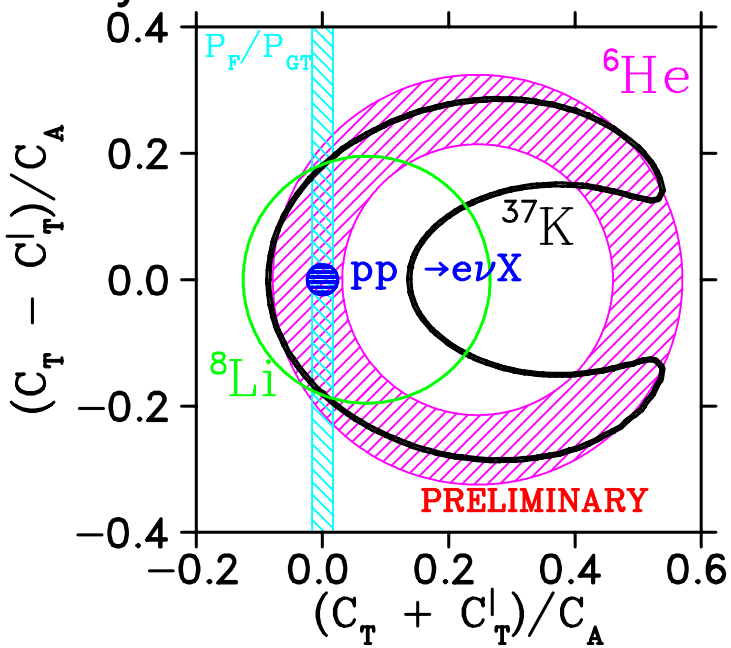
# $A_\beta$ [$E_\beta$] agrees with S.M.




Nucleon, Lepton Currents making up Lagrangian (a scalar) can separately transform like scalars or tensors as vector and axial vector.

Early version of EFT.

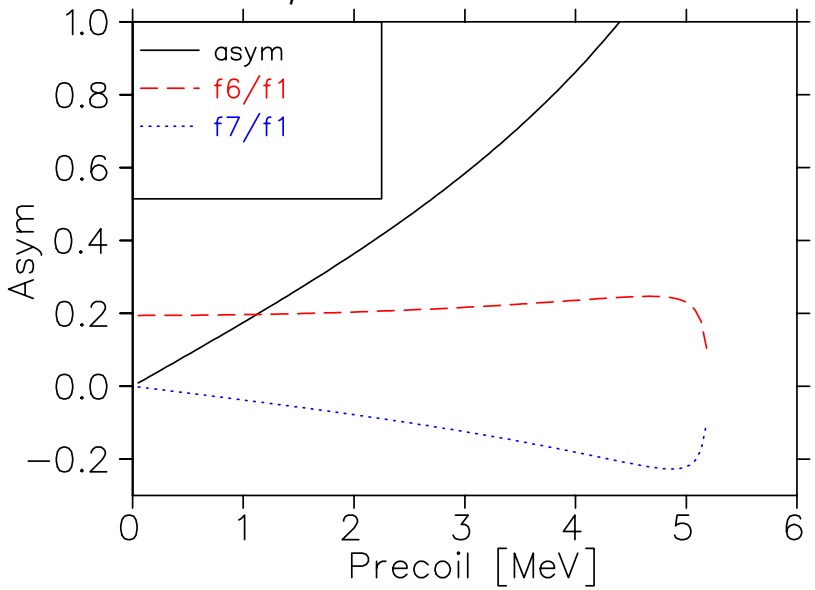


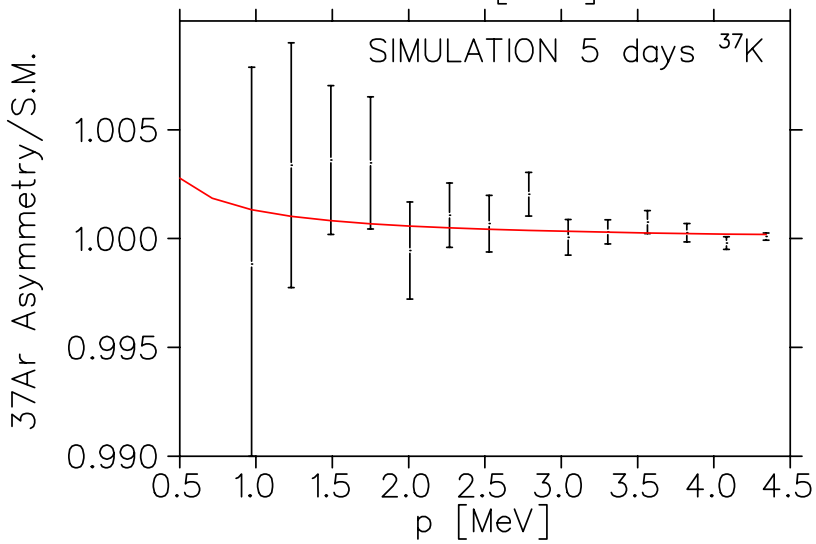

Specific models: spin-1 leptoquarks make S and T; MSUSY makes combinations of S,T

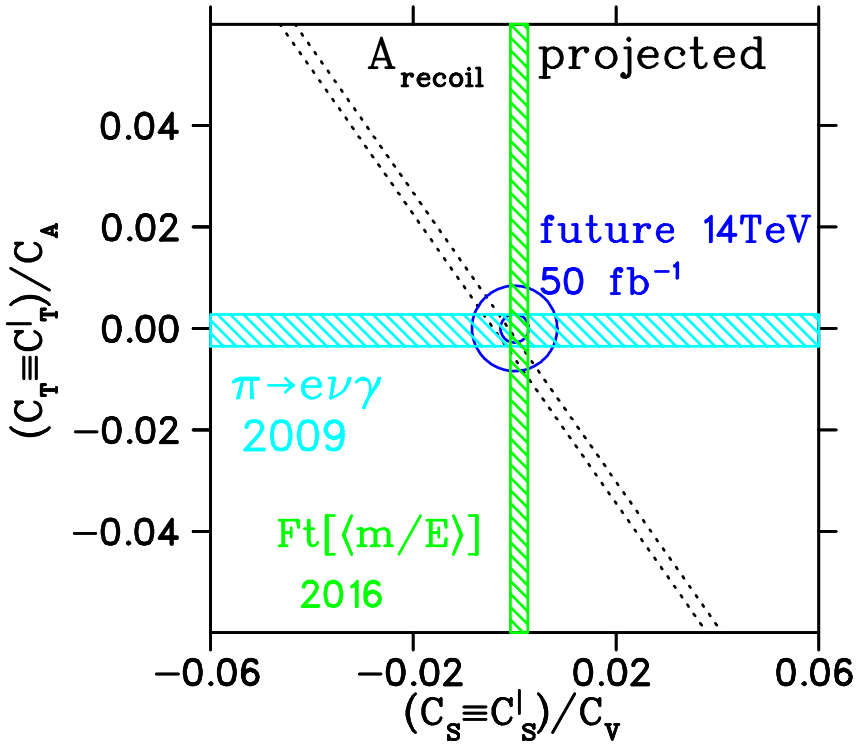
# Recoil singles asymmetry

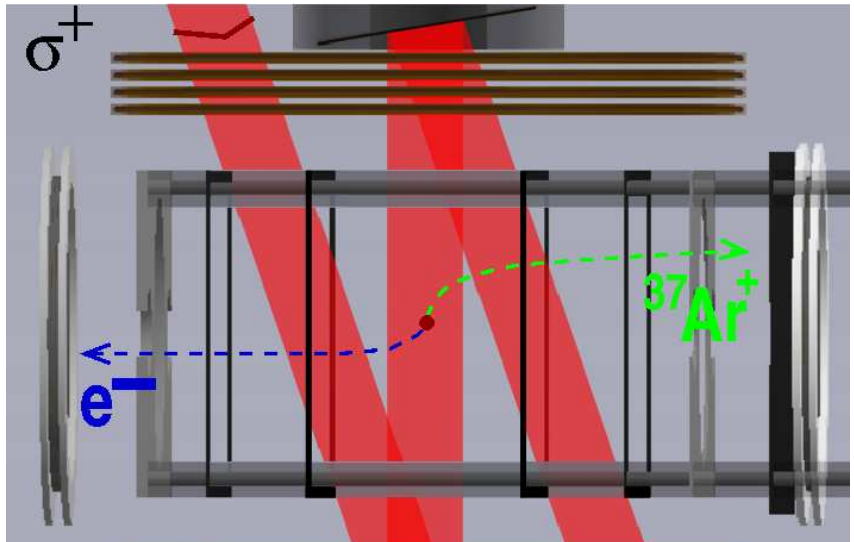
Pitcairn PRC 2009 $^{80}$Rb

$A_{recoil} \propto A_\beta + B_\nu$



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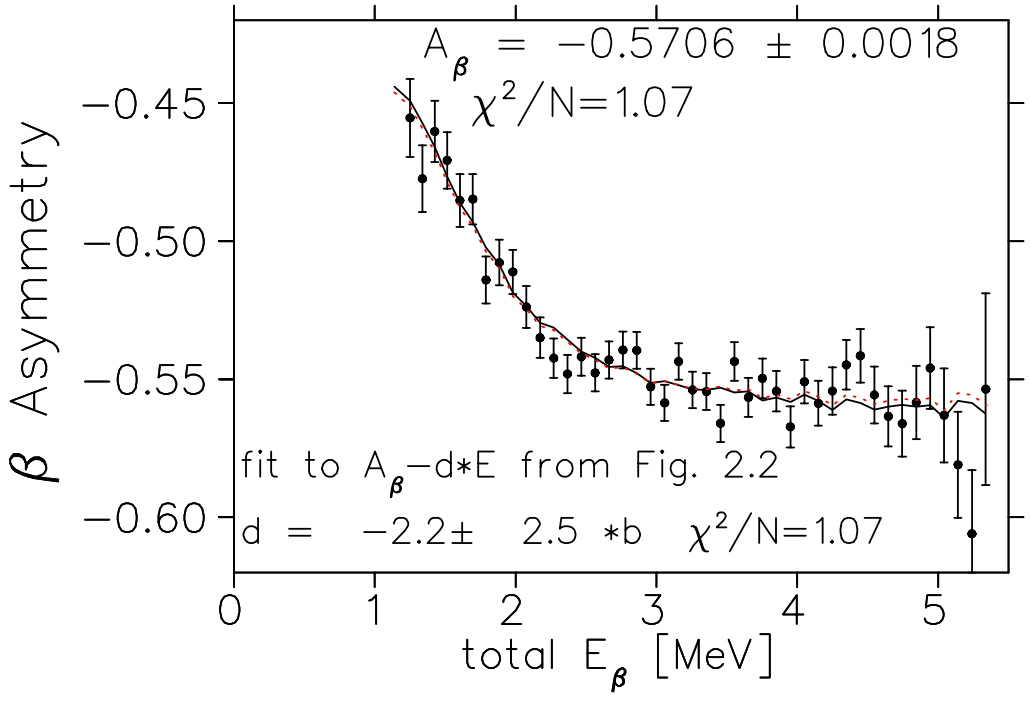
# E field status

nested insulators: E no longer falls across dielectric surfaces
1.2 kV/cm reached
improved ion MCP mount (as in Hong et al. NIM Seattle-Argonne) in progress
more compact shakeoff $e^-$ MCP to allow simulataneous ion and $e^-$ detection.

# Summary and request S1188

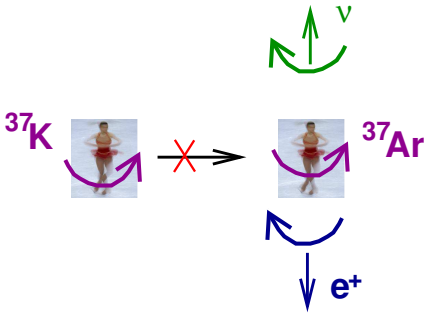
High polarization accuracy 99.13±0.09% → program of polarized correlations.
Plan: finish upgrades of present geometry, beamtime measuring $\boldsymbol{A_\beta}$, $\boldsymbol{A_{\mathrm{recoil}}}$, and the $\rho$-insensitive $\beta$-recoil coincidence.
Future possibilities: replacing the $\boldsymbol{e^-}$ MCP by a $\beta$ detector, optimized geometry for $\boldsymbol{B_\nu}$. This geometry may be compatible with S1077 $^{38m}$K $\beta$-$\nu$ correlation.
**Shift Request:** We have 6 shifts now for S1188. We would use these for development.
**We request an additional 20 shifts for $\boldsymbol{A_\beta}$ and $\boldsymbol{A_{\mathrm{recoil}}}$ geometry measurement.**
Our projected result would be a decrease in the uncertainty on $\boldsymbol{A_\beta}$ by a factor of 3, enabling better sensitivity than the existing LHC information to $\boldsymbol{S}$, $\boldsymbol{T}$.
The higher-statistics observable $\boldsymbol{A_{\mathrm{recoil}}}$ would be complementary to projected LHC 14 TeV sensitivity.

# 2nd-class currents




2nd-class currents violated isospin symmetry.
'induced tensor' ***d*** is predicted zero in isobaric mirror decay.
although the limit on ***d*** is not competitive yet, there are models where 2nd-class currents change with system where this result is complementary

# Helicity-driven null in mirror decay




$$W(\theta_{\beta\nu i}) \approx 1 + a_{\beta\nu i}\cos(\theta_{\beta\nu i})$$

$$a_{\beta\nu i} = \frac{a+PB-2cT/3}{1+PA}$$

**For P=-1, a=1, independent of $M_{GT}/M_F$**