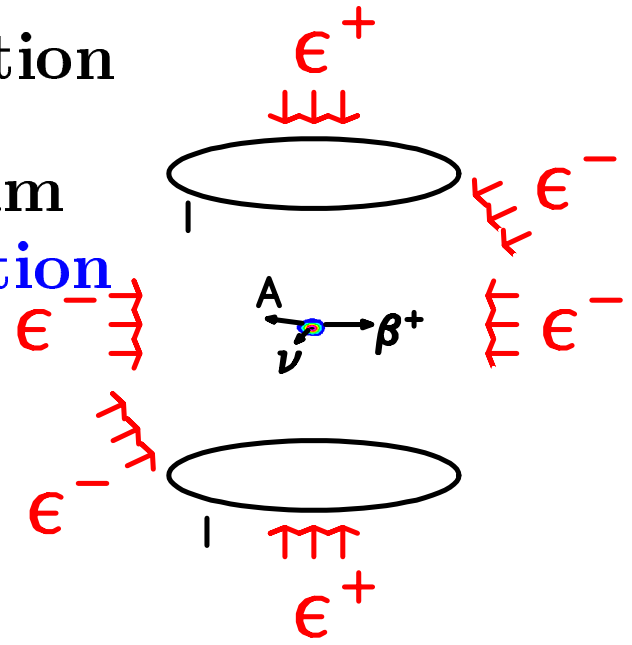
E1070
Upgrade of ^{38m}K β-ν correlation



Trap→ β^+–recoil coincidence ⇒ν momentum

Best general scalar Limits from β-ν correlation
Gorelov et al. PRL April 2005

The theory interpretation is clean,
so we should do it better

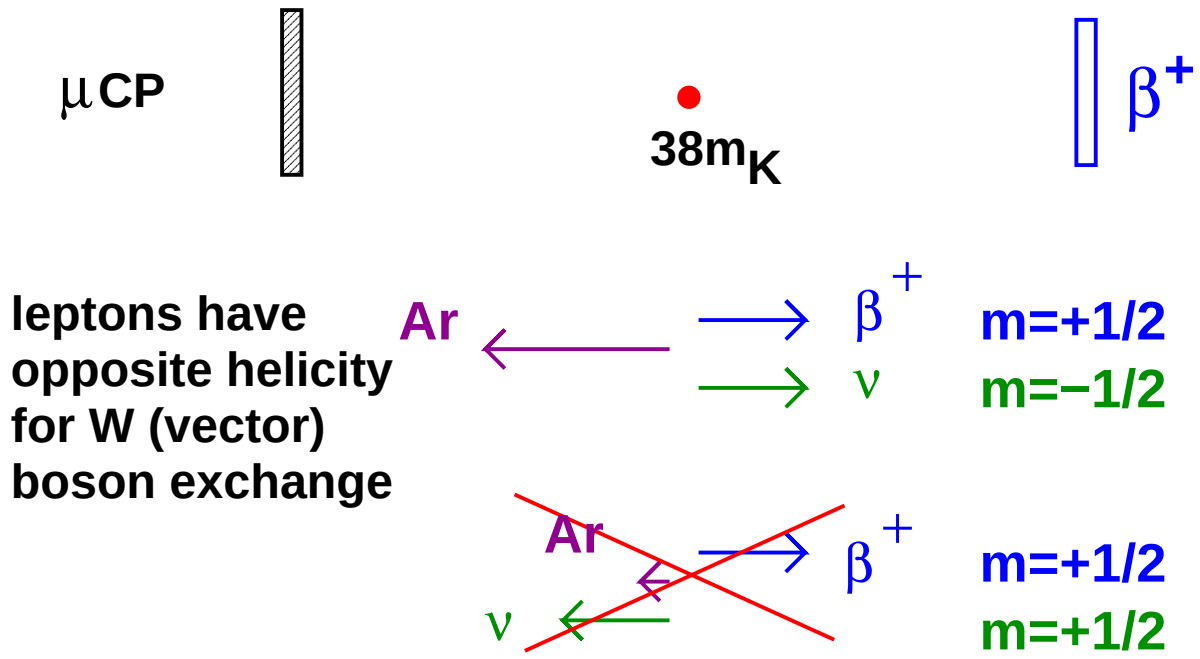
We propose a 3x better measurement of $\tilde{a}=a/(1+bm/E)$
and independent determination of a and b

Method I, II: Upgrade of present method with higher yields,
trapping efficiencies, and detection efficiencies

Method III:
New Tool: recoil- atomic e^- coincidence
10-50× statistics, different systematics, simpler analysis

Vector and Scalar bosons and the β-ν angular distribution

For ^{38m}K, $0^+ \rightarrow 0^+$ decay: (Just like $\pi \rightarrow e\nu$)



$$W[\theta_{\beta\nu}] = 1 + b\frac{m}{E} + a\frac{v_\beta}{c}\cos\theta_{\beta\nu} \quad \Rightarrow \text{a= +1}$$

Corrections independent of nuclear structure to <0.0002:
bremsstrahlung ≈ 0.002 (in M.C., F. Glück),
recoil order ≈ 0.0003

For scalar exchange, lepton helicities are same: a= -1

Deviation ⇒ non-standard model scalar interaction

Scalar Hamiltonian in 'modern' chirality notation

$$H_S = [(C_S + C'_S)\bar{e}(1-\gamma_5)\nu_e^{(L)} + (C_S - C'_S)\bar{e}(1+\gamma_5)\nu_e^{(R)}]\bar{u}d$$

$$W[\theta_{\beta\nu}] = 1 + b m_\beta / \langle E_\beta \rangle + \; a \; v/c \cos[\theta_{\beta\nu}]$$

$$a = \frac{|C_V|^2 + |C'_V|^2 - |C_S|^2 - |C'_S|^2 + (\frac{\alpha Z m}{p}) 2 Im(C_S C_V^* + C'_S C'_V *}{|C_V|^2 + |C'_V|^2 + |C_S|^2 + |C'_S|^2}$$

Note the sensitivity to $Im(C_S + C'_S)$

$$b = \frac{-2\sqrt{1-\alpha^2 Z^2}\; Re(C_S C_V^* + C'_S C'_V *)}{|C_V|^2 + |C'_V|^2 + |C_S|^2 + |C'_S|^2}$$

$$a \approx 1 - (|C_S|^2 + |C'_S|^2)$$

$$b \approx -Re(C_S + C'_S)$$

Sources of Scalars: Are there any?

Charged Higgs: Required in SUSY

•1st generation couplings unknown

⇒ most general limits on 1st generation couplings are from nuclear β decay

• Couplings in simplest MSSM:

like S.M. Higgs, couplings ∝ masses: (Not so in less simple Higgs models (Langacker hep-ph/0503068))

(Herczeg, Prog. Part. Nucl. Phys. 46/2 413 (2001), Haber et al. Nucl.Phys.B 161 493 (1979))

$$C_S + C'_S \approx 2g_s \frac{m_e m_d}{m_H^2} \tan^2\beta \leq 5\text{x}10^{-6}$$

for tanβ ≤65 and $m_H \geq$ 69 GeV neglects squark family mixing

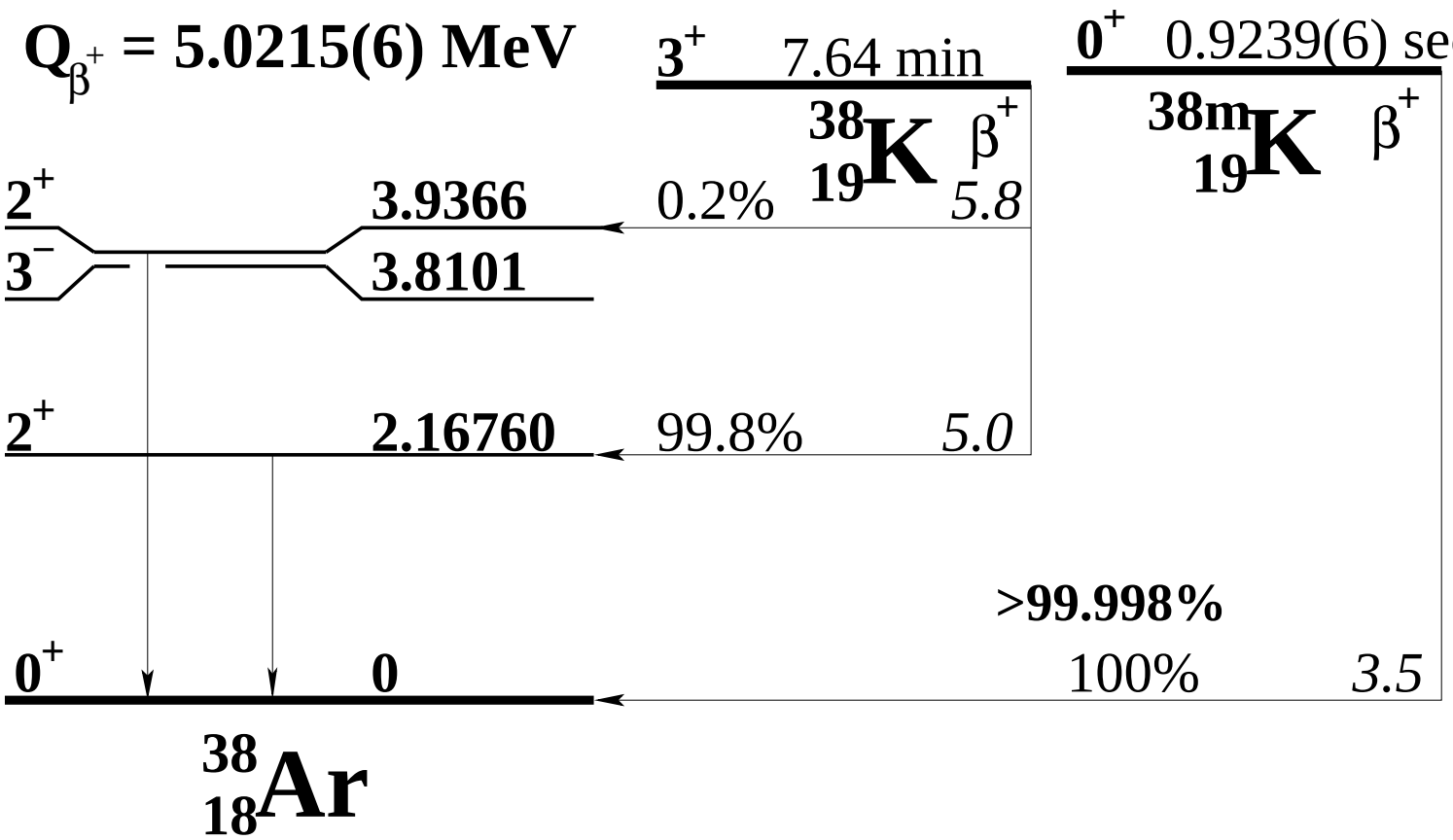
• R-parity violating sleptons

constrained by $\pi \to e\nu$, $C_S + C'_S$ can be $\sim -2\text{x}10^{-3}$

• B. Campbell et al. NPB 709 419 (2005) limits from $\pi \to e\nu$

Other searches:

^{32}Ar Garcia/Adelberger; WITCH $^{35}Ar^+$ Leuven/ISOLDE; $^{14}O^+$ ANL; superallowed ft Q-value dependence

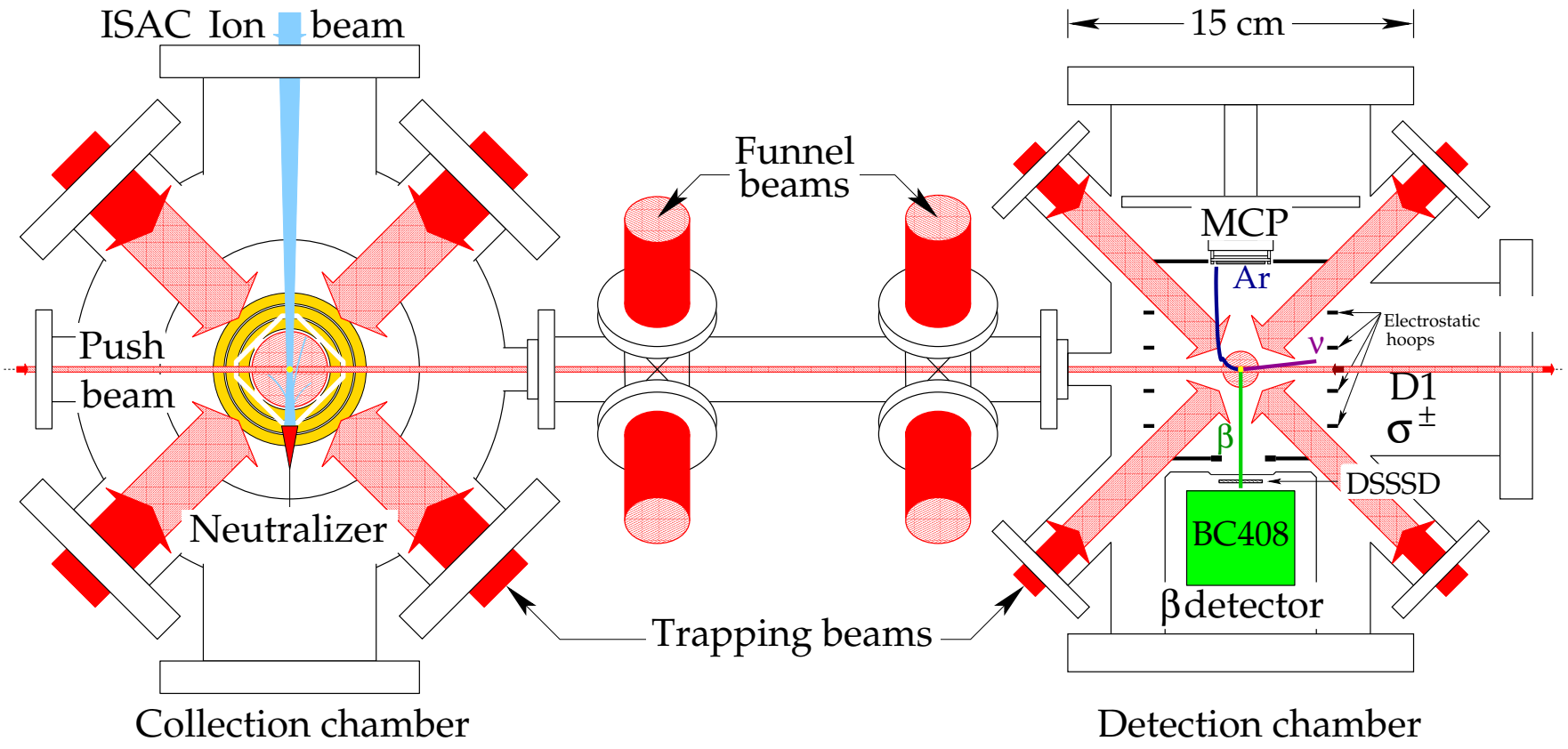


Excited-state branch known to be negligible

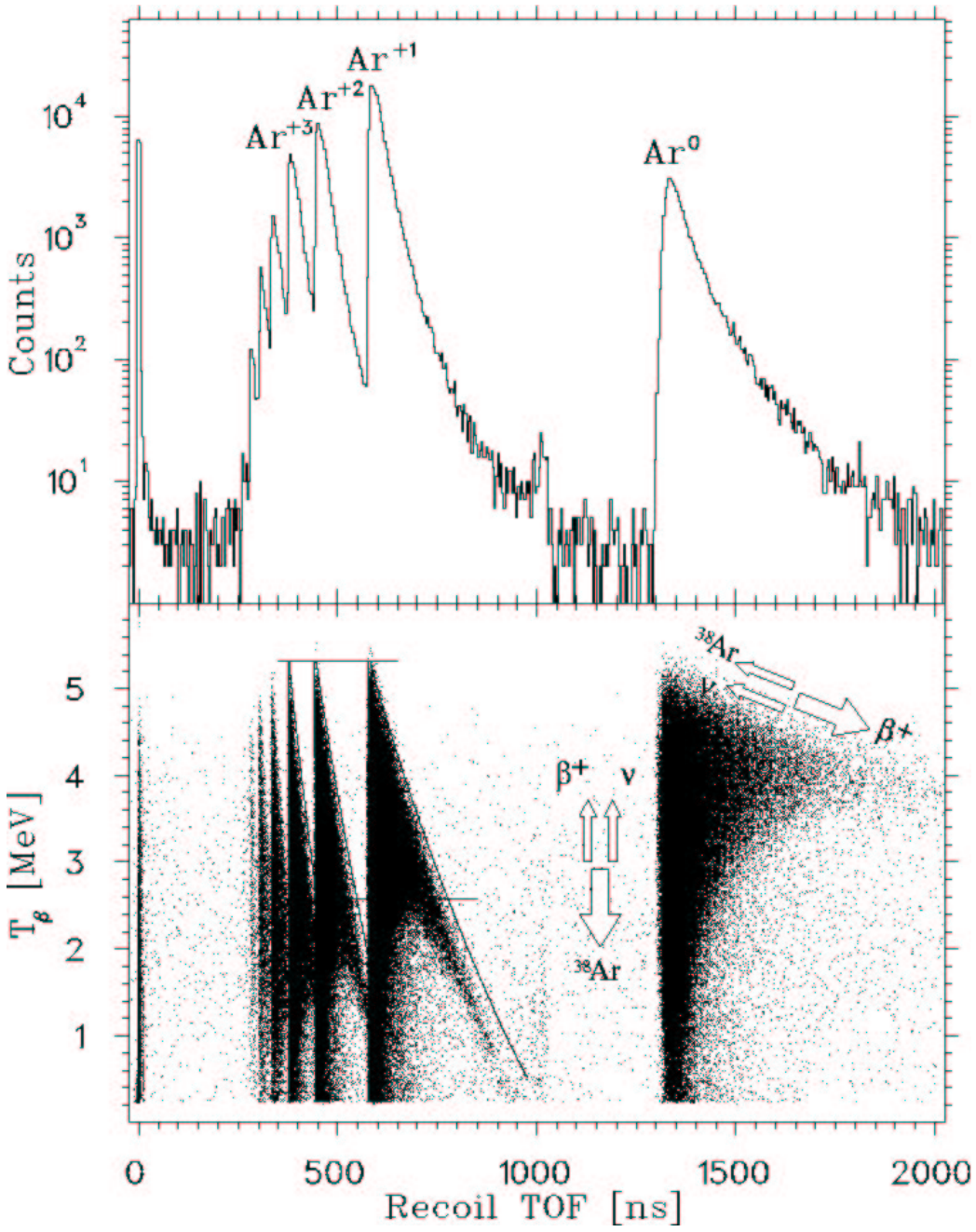
(Ground state makes a background in β singles: we can deal with this better)

TRIUMF's Neutral Atom Trap

- **Isotope/Isomer selective**
- **Evade 1000x untrapped atom background by → 2nd MOT**
- **75% transfer (must avoid backgrounds!); 10^{-3} capture**
- **0.7 mm cloud for β-Ar^{+} → ν momentum → β-ν correlation**

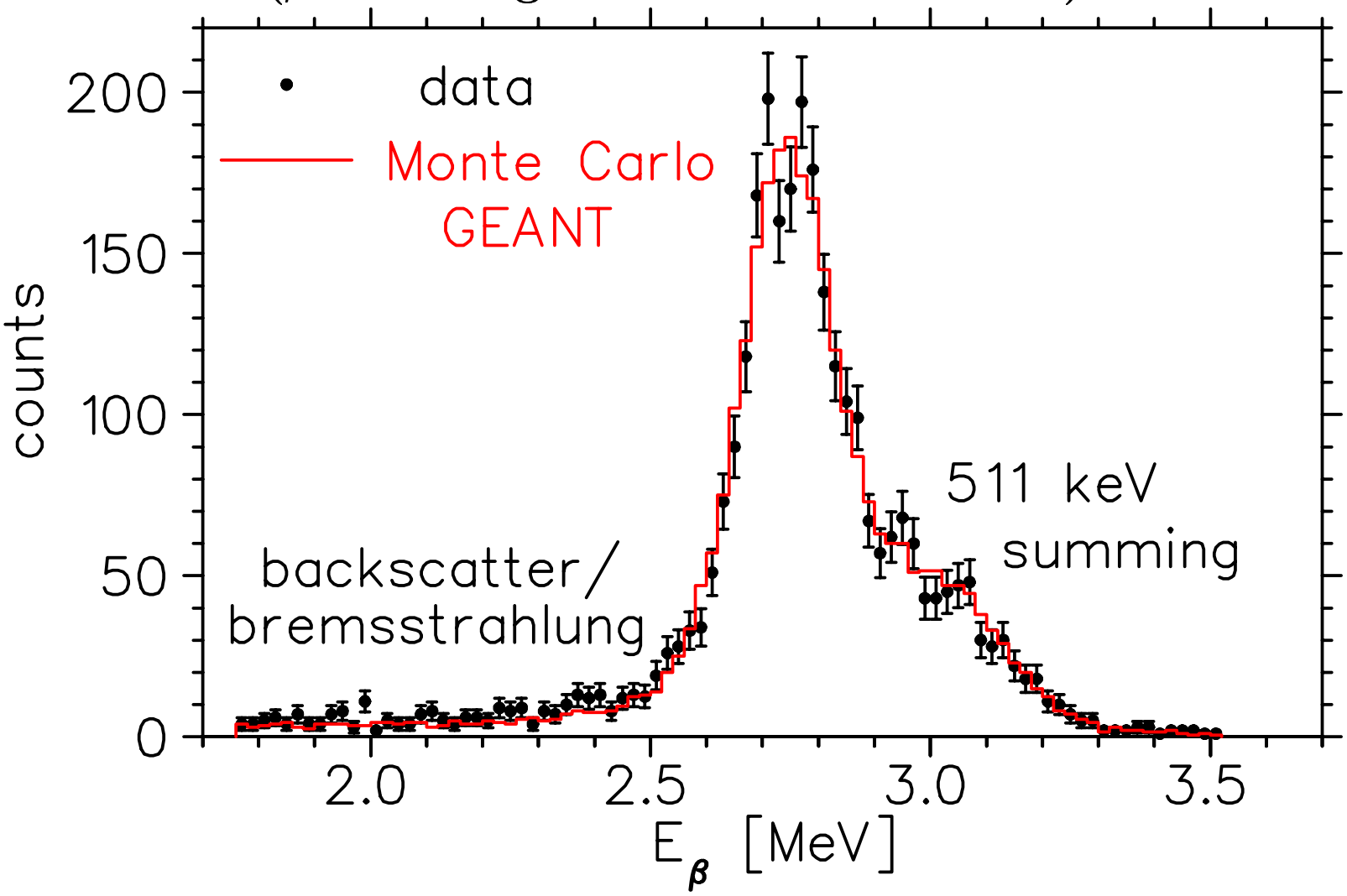


Method I,II: β-recoil coincidences Raw data



In-situ calibrations

E_β detector response for "monoenergetic" β's from kinematics of other observables (β-recoil angle and recoil momentum)

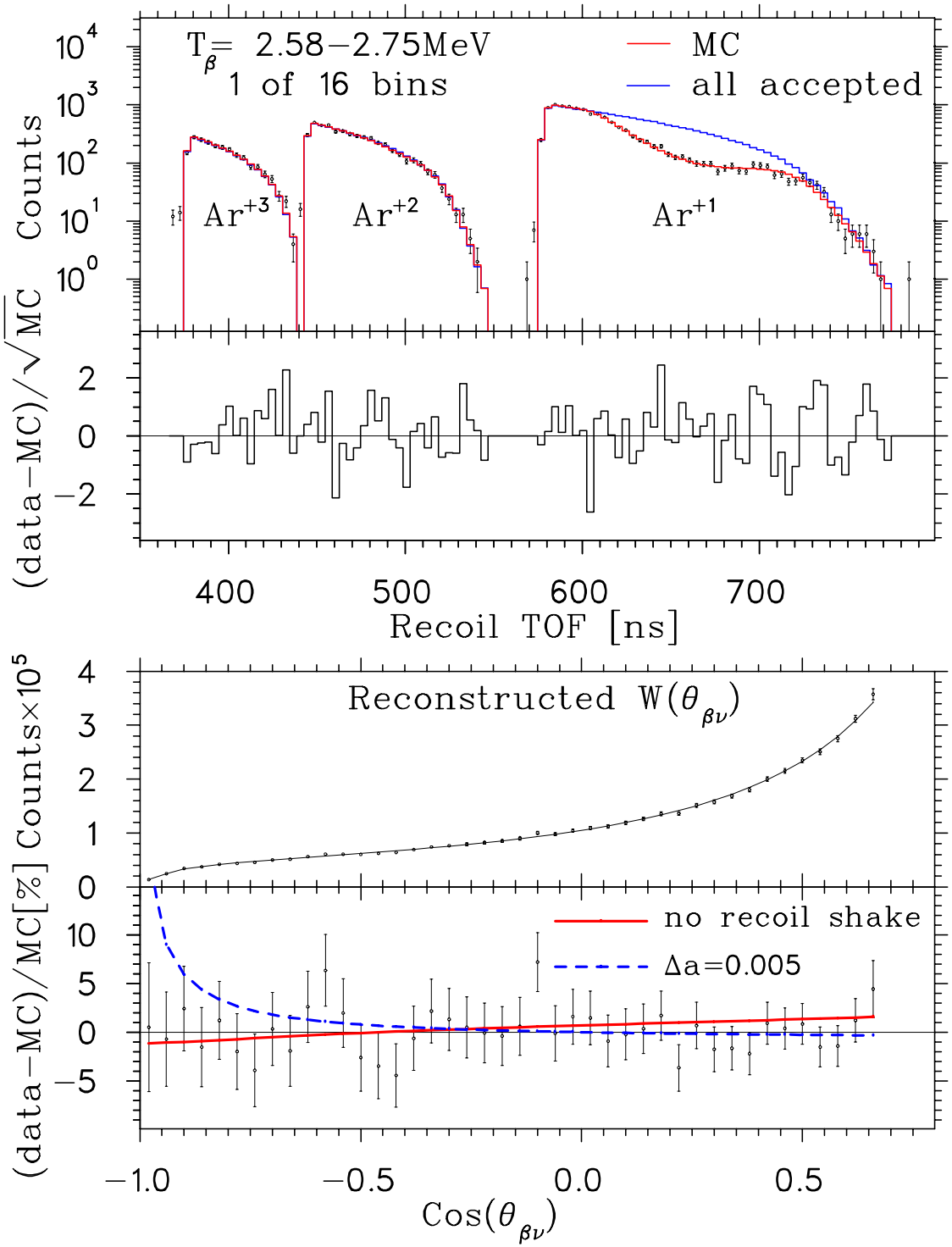


Methods I and II agree:
I: recoil TOF[T_β],
T_β>2.6 MeV
C.L. of total fit is 52%

II: Angular distribution determined from other observables (except E_β).
Can simultaneously fit E_{recoil}-dependent shakeoff

$\tilde{a}$=0.9981 ± 0.0030(stat) ± 0.0037(syst)

(Adelberger ^{32}Ar PRL 1999
$\tilde{a}$=0.9989 ± 0.0052(stat) ± 0.0039(syst)
still being re-evaluated)



^{38m}K β^+-ν Error Budget a=0.9981±0.0030(stat)

Error	PRL	Future
$\vec{E}$ field/trap width :	0.17%	0.04%
E field nonuniformity	0.14%	0.03%
β^+ backscattering bkgd	None	None
$E_{\beta+}$ Detector Response:		
Lineshape tail/total	0.06%	0.03%
511 keV Compton sum	0.09%	0.04%
Calibration, nonlinearity	0.17%	0.08%
MCP Eff[E_{Ar+}]	0.07%	0.03%
MCP Eff[θ]/XY position	0.08%	0.04%
e^- shakeoff [E_{recoil}]	0.18%	0.08%
Sum systematics	0.37%	0.14%
Total error	0.48%	0.19%

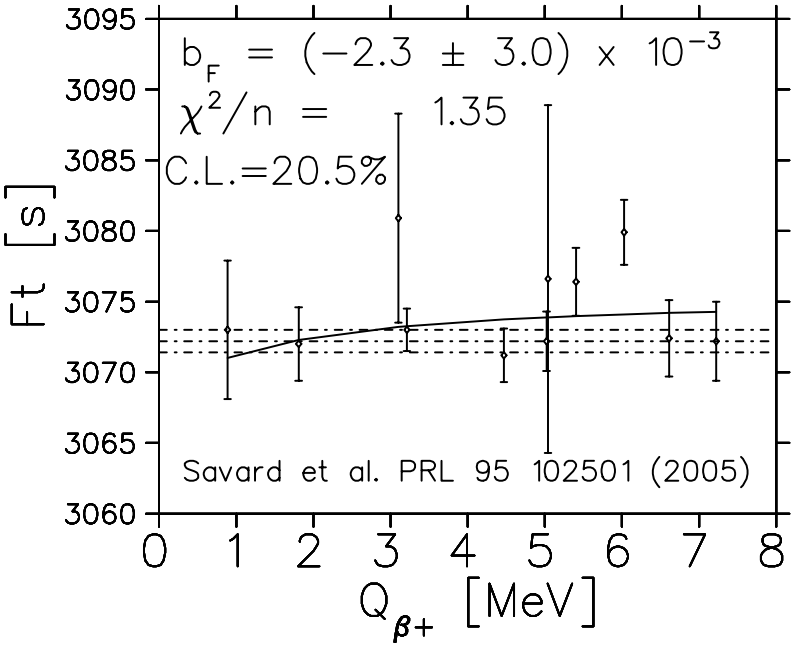
Method I

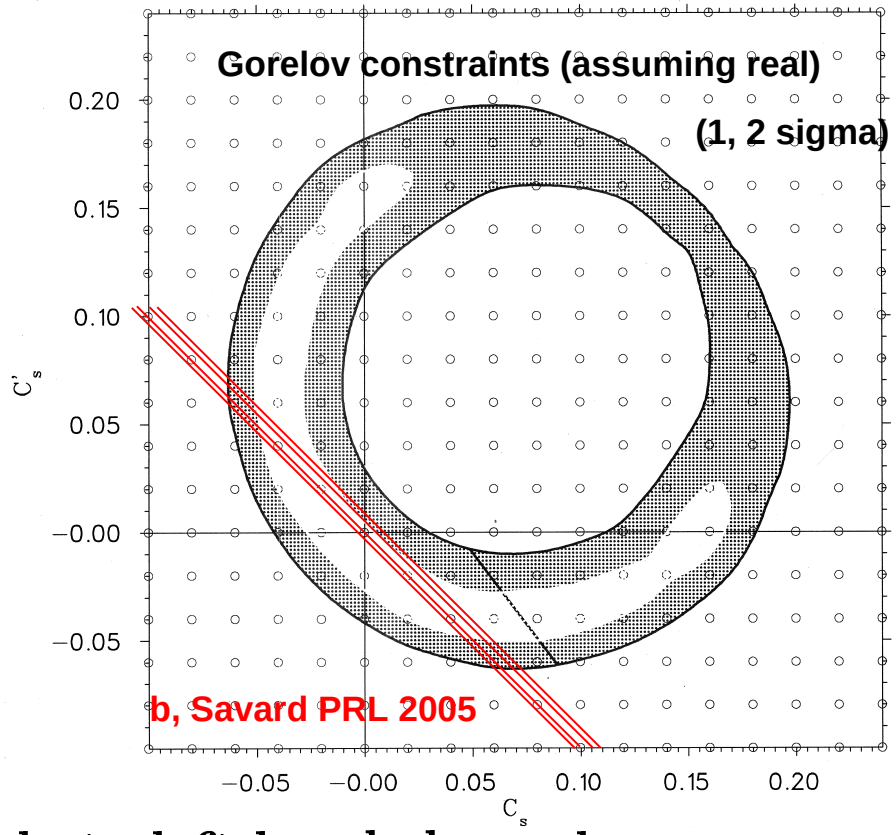
Planned Improvements:

- Larger MCP
- E_β calibration from interwoven background-free ^{37}K
- $1/\sqrt{5}$ statistical error (conservative)
  larger ISAC yields
  more laser power
- Permanent mask on MCP for position info test

- Most systematic errors determined by statistics-limited data evaluation.
- Further improvements possible: use all kinematic information.

Constraints on scalars from 'Fierz interference term'



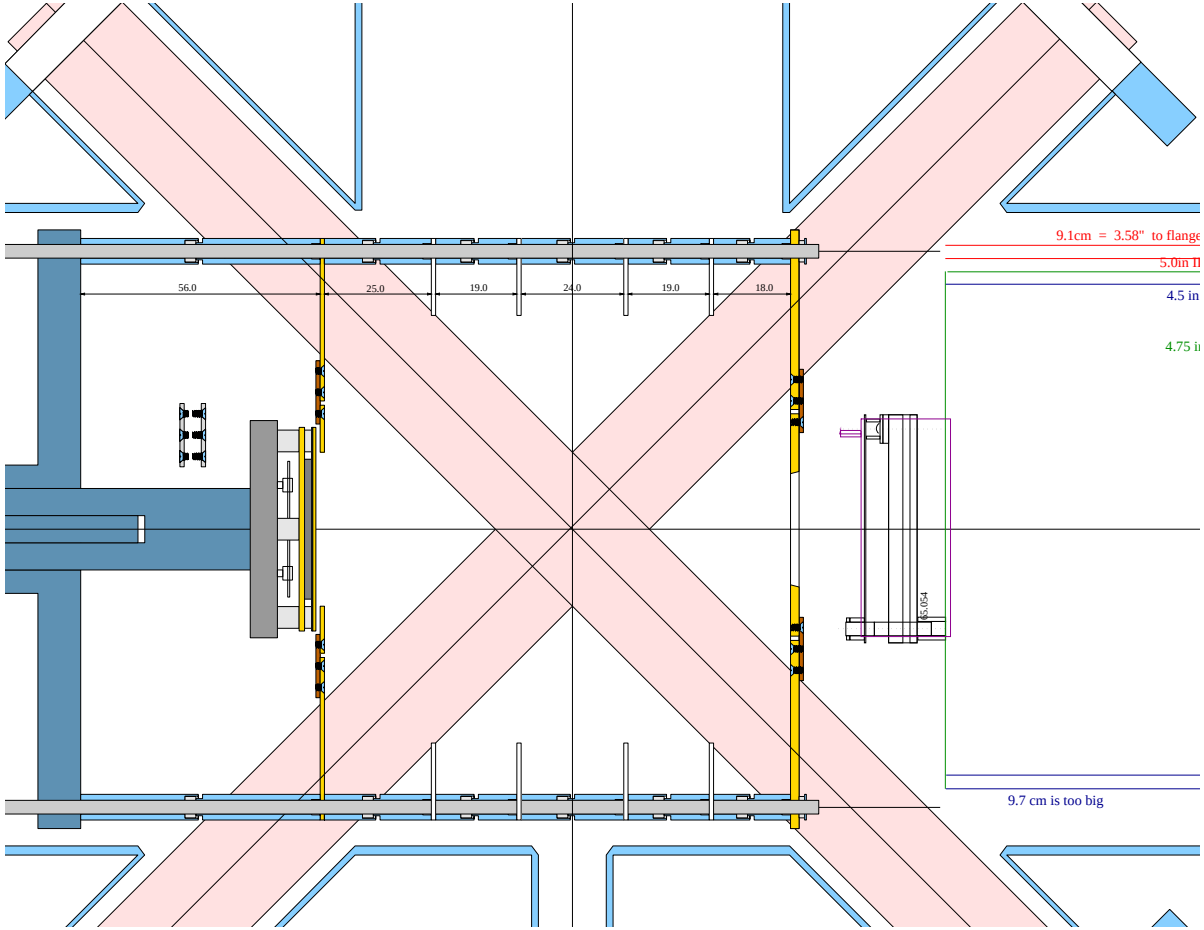


$b_f = -Re(C_S + C'_S)$, scalars that couple to left-handed ν only

$W[\theta_{\beta\nu}] = 1 + b_F m_\beta / \langle E_\beta \rangle + a\ v/c\ \cos[\theta_{\beta\nu}]$ $\quad a \approx 1 - |C_S|^2 + |C'_S|^2$

- TRINAT present statistical error is 4x bigger
- Would improve systematics by using kinematic info for E_β at $E_\beta < Q/2$
- Would achieve similar accuracy within one β-ν experiment
- Goal: a window left open by $\pi \rightarrow e\nu$ for sleptons at 2×10^{-3}
  [Herczeg Prog. Part. Nucl. Phys. 46/2 413 (2001)]

Method III: New: Geometry with e^- detector



For E1070:

- **High-statistics**
- **free of β bias**
- **expect collection for all e−'s < 100 eV**

Also with higher statistics:

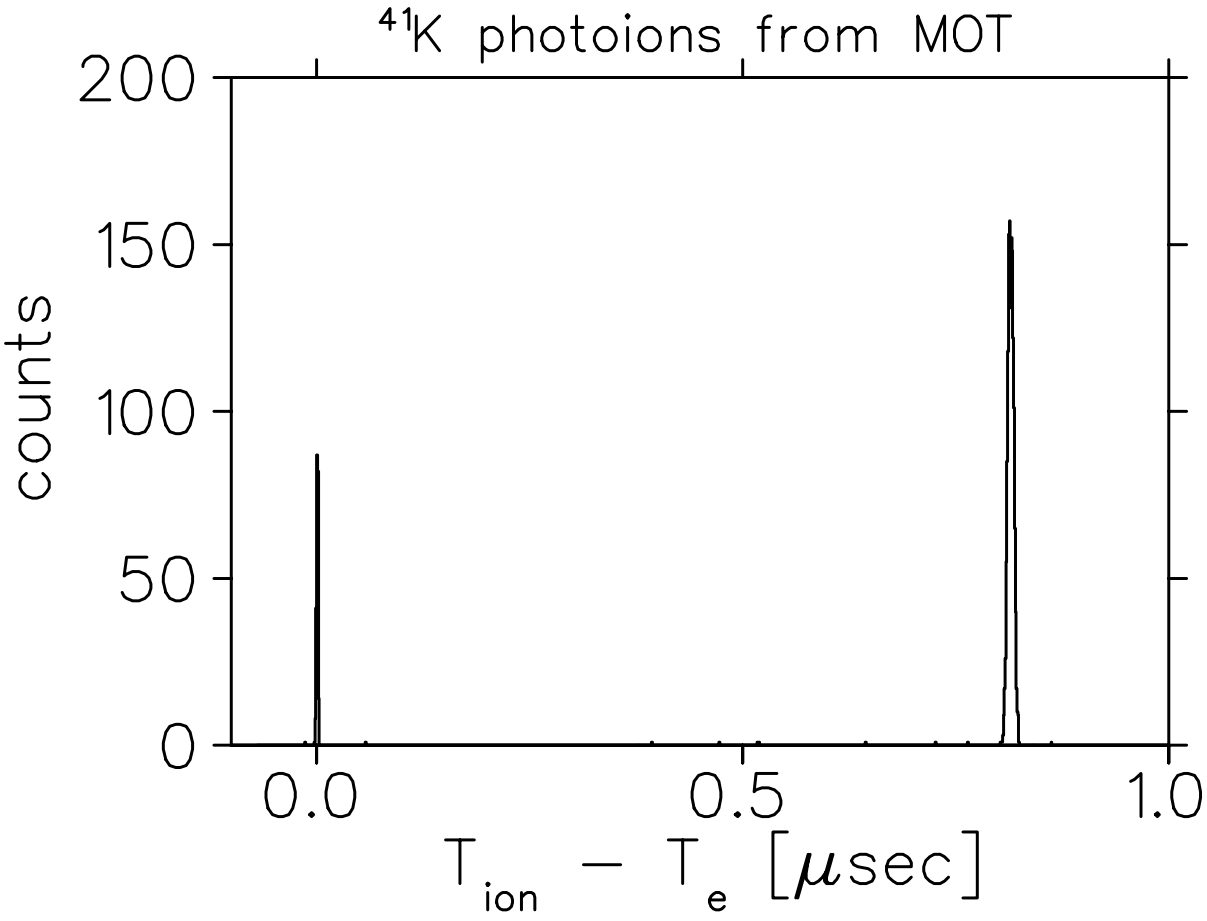
^{80}Rb tensor search by recoil singles: starts 16:00 today

^{37}K A_{recoil} gives Fermi/GT interference, right-handed currents; A_β

^{36}K isospin mixing becomes practical: A_{recoil}, A_β

^{74}Rb Q-value

e^- detector is working

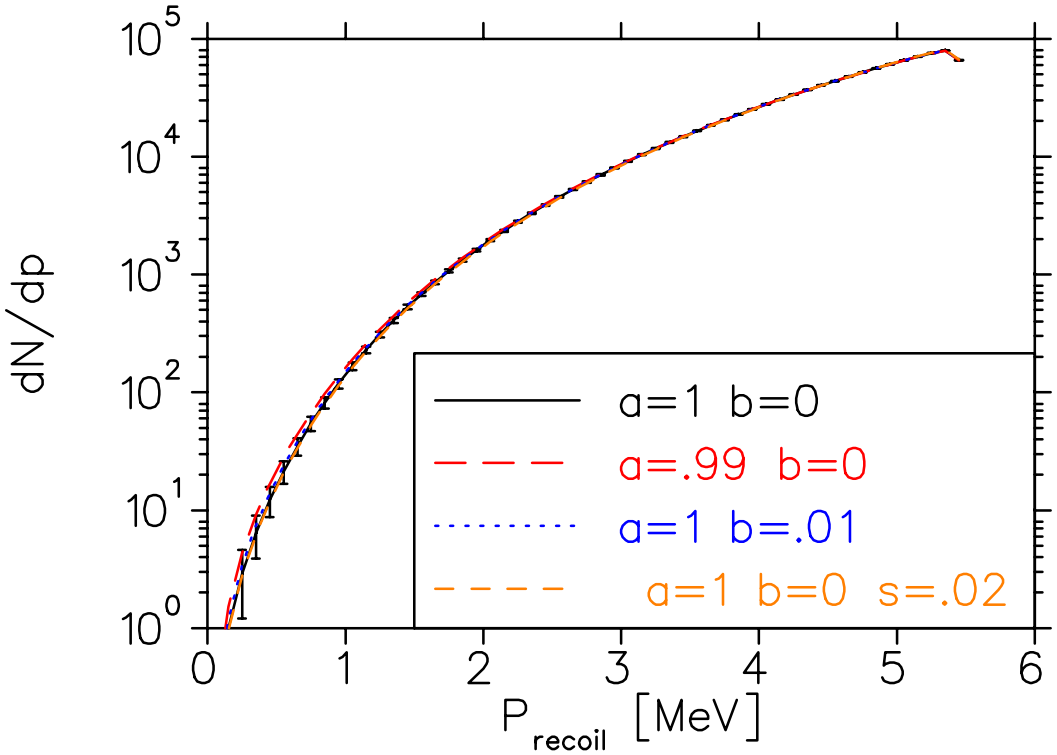


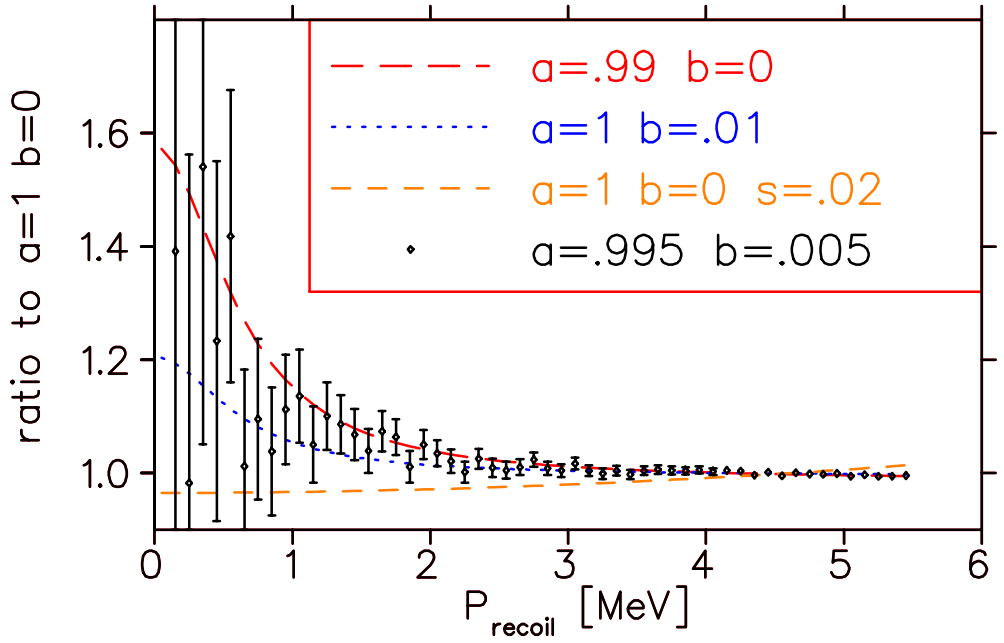
- **Efficiency $\approx$ 47% for 1 eV photo-electrons**
- **Background $\sim$ 10-20 Hz. (Expected 100 KHz.)**

Other practical uses:

Energy spectrum of atomic e^-'s (do they perturb recoils?)

Photoionization makes an e^- tag to measure ion MCP efficiency as a function of impact energy





SIMULATION

Recoil momentum spectrum

Sensitive to a (a, b highly correlated)

Can extract momentum dependence of shakeoff separately

From 10^6 events $\sigma_a = 0.001$ (3 hours)

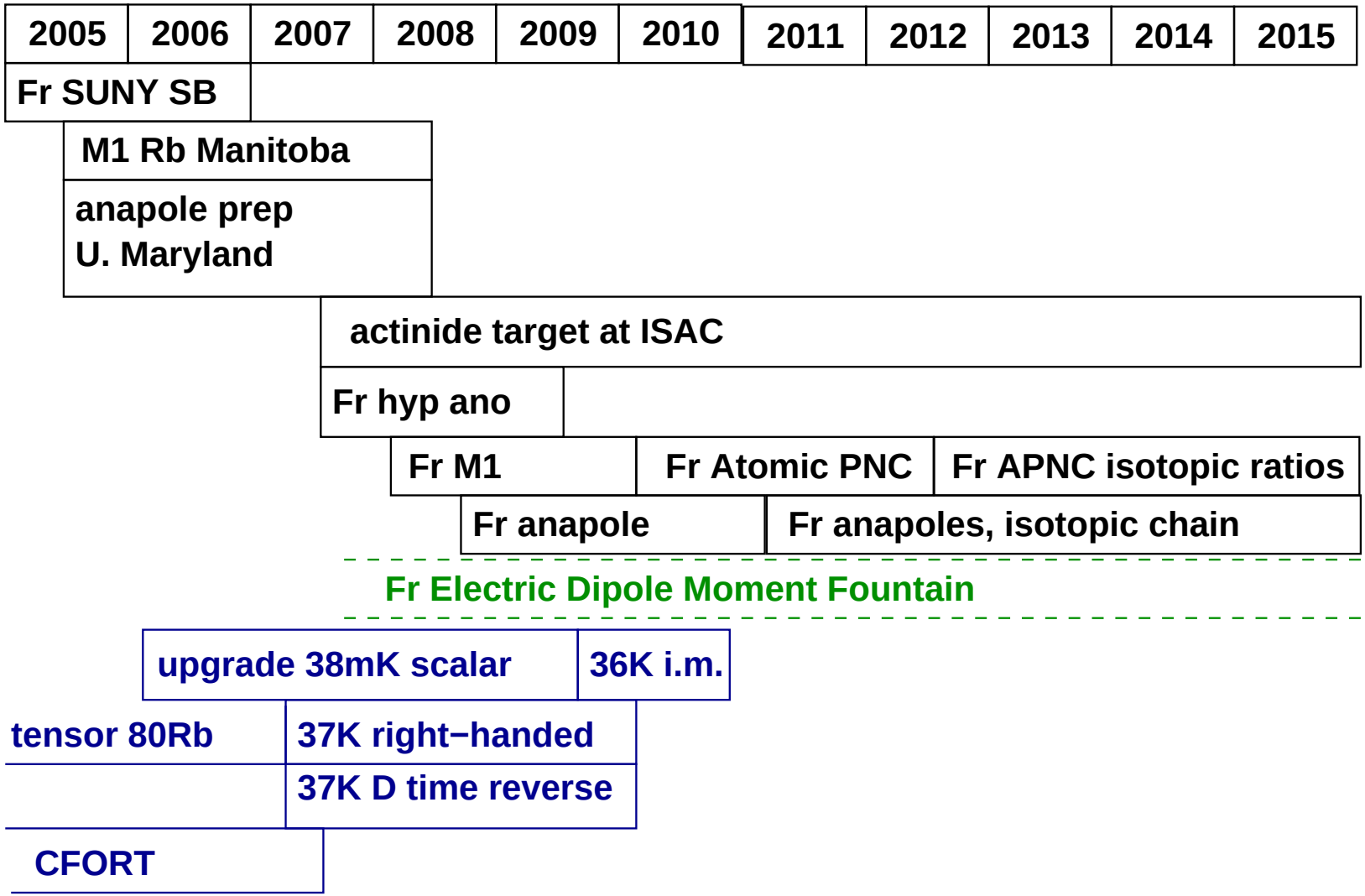
Superallowed Q-dependence of b error 0.003: 1 shift

0.001 (sleptons) in 10 shifts

- **In reality will run under many conditions like other precision experiments**

Upgrade of ^{38m}K β-ν correlation

Name	Institution	Status	Time
C. Höhr	TRIUMF	Postdoc Research Associate	100%
New. Student	UBC	Student	100%
or R. Pitcairn	UBC	M.Sc. Student–>Ph.D.	or 100%
or D. Roberge	UBC	M.Sc. Student–>Ph.D.	or 100%
J. Behr	TRIUMF	Research Scientist	100%
M. Pearson	TRIUMF	Research Scientist	40%
K.P. Jackson	TRIUMF	Emeritus Research Scientist	30%
D. Ashery	Tel Aviv Univ.	Professor	20%
A. Gorelov	S.F.U.	Ph.D. Student until Mar06	E715
P. Bricault	TRIUMF	Research Scientist	5%
M. Dombsky	TRIUMF	Research Scientist	5%
F. Glück	Budapest	Theorist	theory
D. Melconian	U. Washington	postdoc	5%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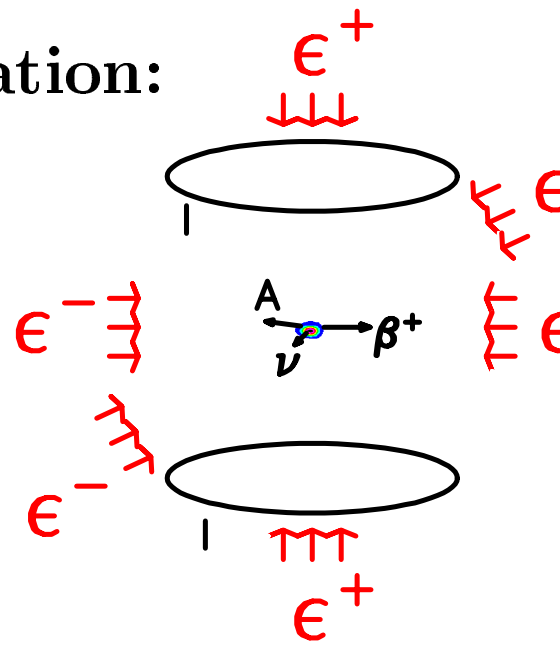
Fr SUNY SB
M1 Rb Manitoba
anapole prep
U. Maryland
actinide target at ISAC
Fr hyp ano
Fr M1
Fr Atomic PNC
Fr APNC isotopic ratios
Fr anapole
Fr anapoles, isotopic chain
Fr Electric Dipole Moment Fountain
upgrade 38mK scalar
36K i.m.
tensor 80Rb
37K right−handed
37K D time reverse
CFORT

Summary: E1070 Upgrade ^{38m}K β-ν correlation:
Pioneered Capabilities:
β^+–recoil coincidence $\Rightarrow\nu$ momentum
We have the best general scalar limits
from β-ν correlation in ^{38m}K
$\tilde{a}$=0.9981±0.0030±0.0037



The limits on scalar interactions are model-independent
(TRV, chirality) and
free of nuclear structure-dependent corrections to ≈0.0002

- **Proposed: Improve accuracy by factor of 3**
  Separate a,b
  Compete with $0^+\rightarrow0^+$ on Fierz term
- **Shift request:**
  Method I, II: improvements of present β-recoil coincidence method: 30 shifts

Method III: atomic e^--recoil TOF method: 20 shifts