Measurement of Spin-Polarized Observables in the β^+ decay of ^{37}K

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Outline

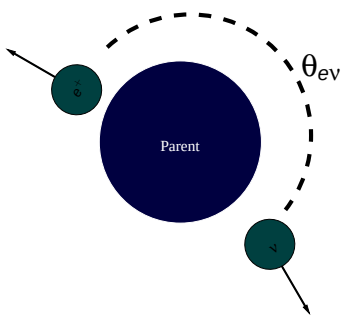
- *Brief* physics goals
- Outline of TRINAT's double-MOT system
- Overview of recent run

Motivation: Fundamental Symmetries

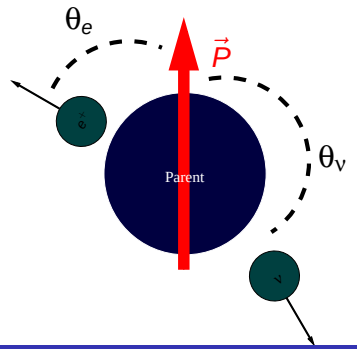
- Standard model weak interaction is strictly Vector $-$ Axial-Vector $(V-A)$
  - Parity is conserved in strong and EM interactions but violated in weak ones?
  - $SU(2)_L \otimes U(1)_Y \xrightarrow{?} SU(2)_R \otimes SU(2)_L \otimes U(1)_Y$
- Angular correlations in β-decay are sensitive to new physics

$$\frac{d^5W}{dEd\Omega_e d\Omega_\nu} \sim 1 + a_{\beta\nu}\frac{p_e p_\nu \cos(\theta_{e\nu})}{E_e E_\nu} + b\frac{m_e}{E_e} + P\left(A_\beta \frac{p_e}{E_e}\cos(\theta_e) + B_\nu \frac{p_\nu}{E_\nu}\cos(\theta_\nu)\right)$$

Unpolarized



Polarized

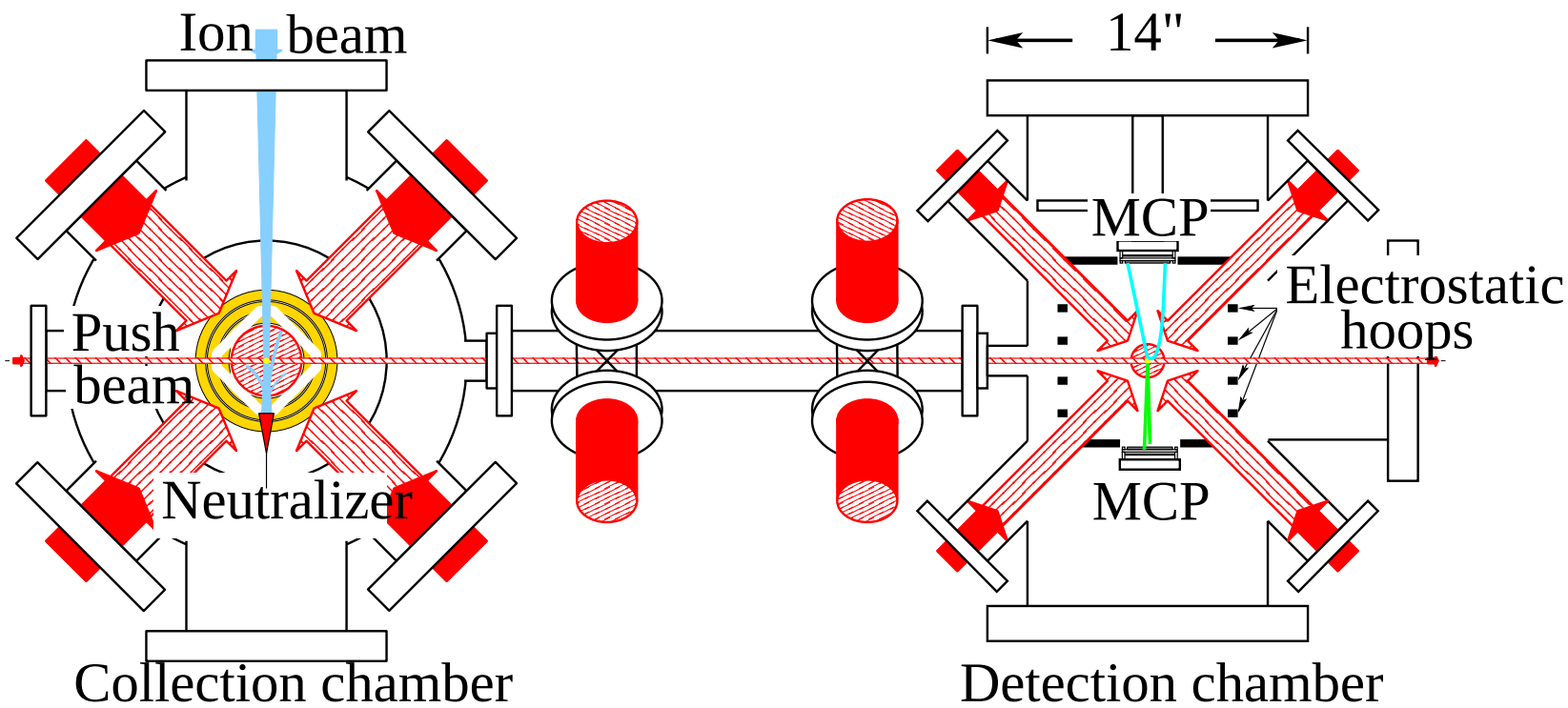


$$A_\beta \overset{SM}{=} -0.5702(6)$$
$$B_\nu \overset{SM}{=} -0.7692(15)$$

TRINAT's x2-MOT system

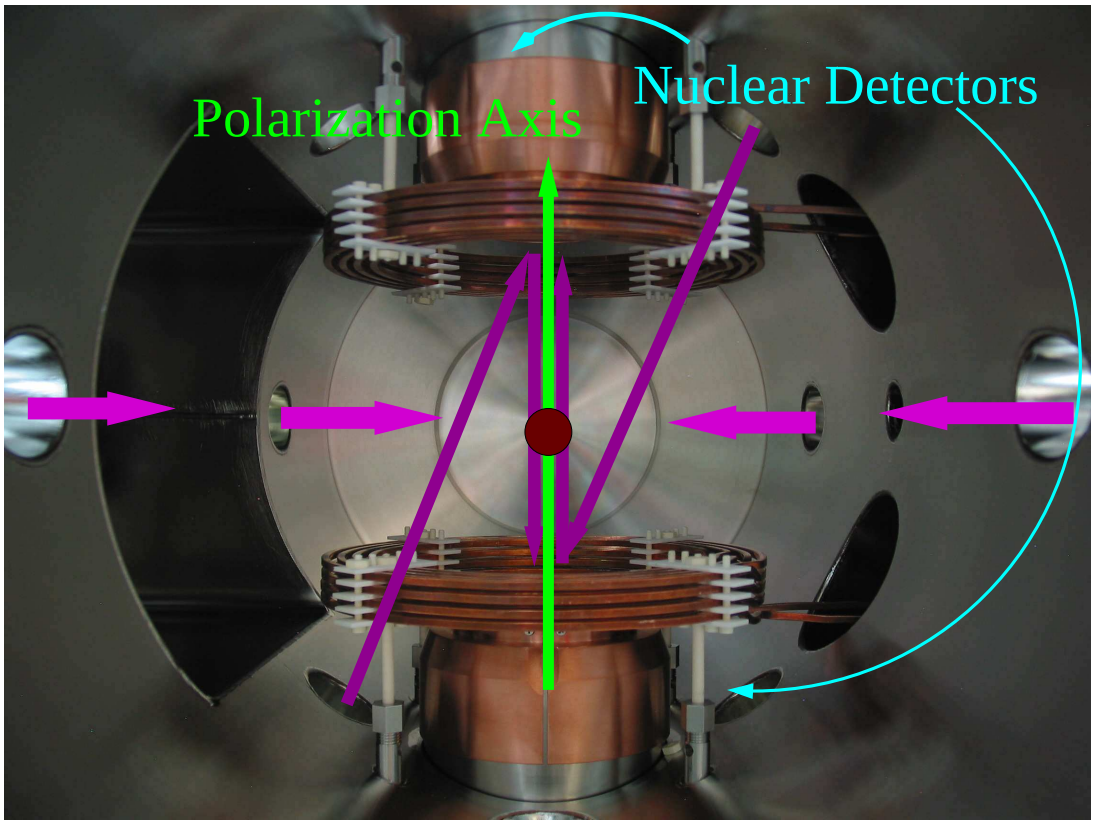
Collection trap is coupled to ISAC beamline

To avoid backgrounds from untrapped atoms, transfer to second trap for precision measurement



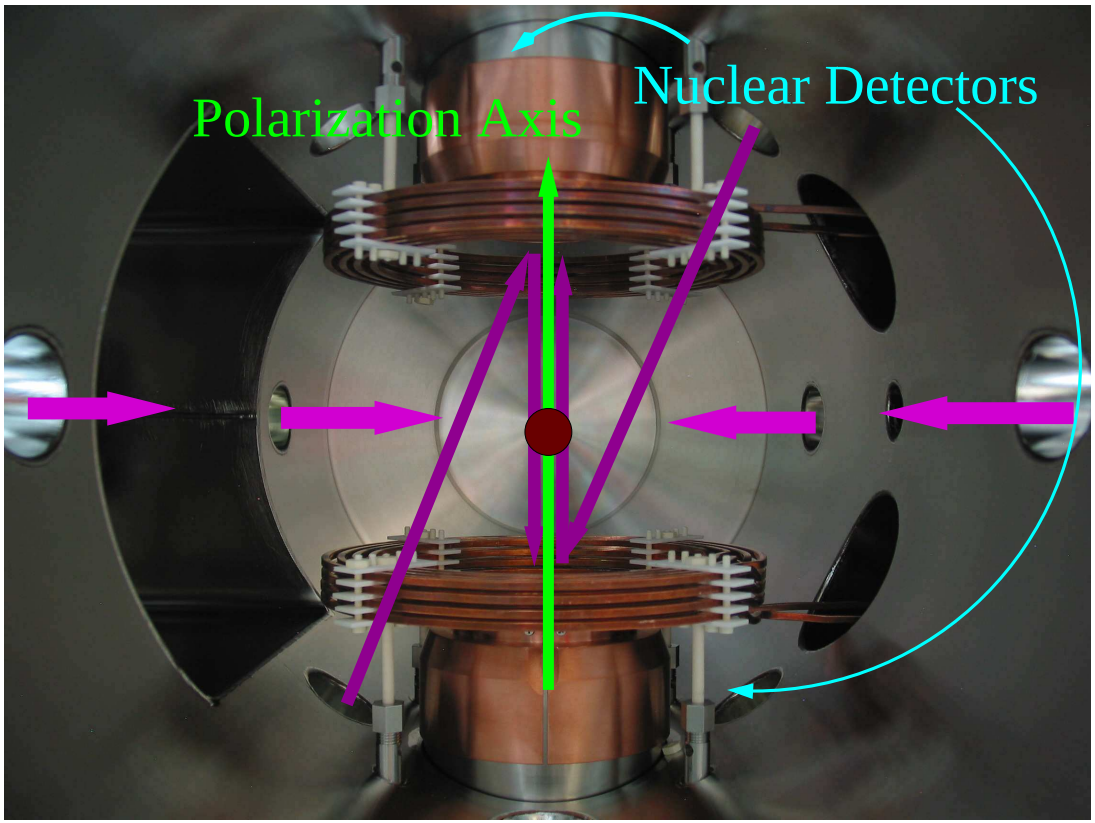
Overview

- Magneto-Optical Trap (MOT)
  - Provides a cold ($\sim 1\,\mathrm{mK}$), localized ($\sim \varnothing 1\,\mathrm{mm}$) source of atoms
  - Shallow trap so products emerge unperturbed



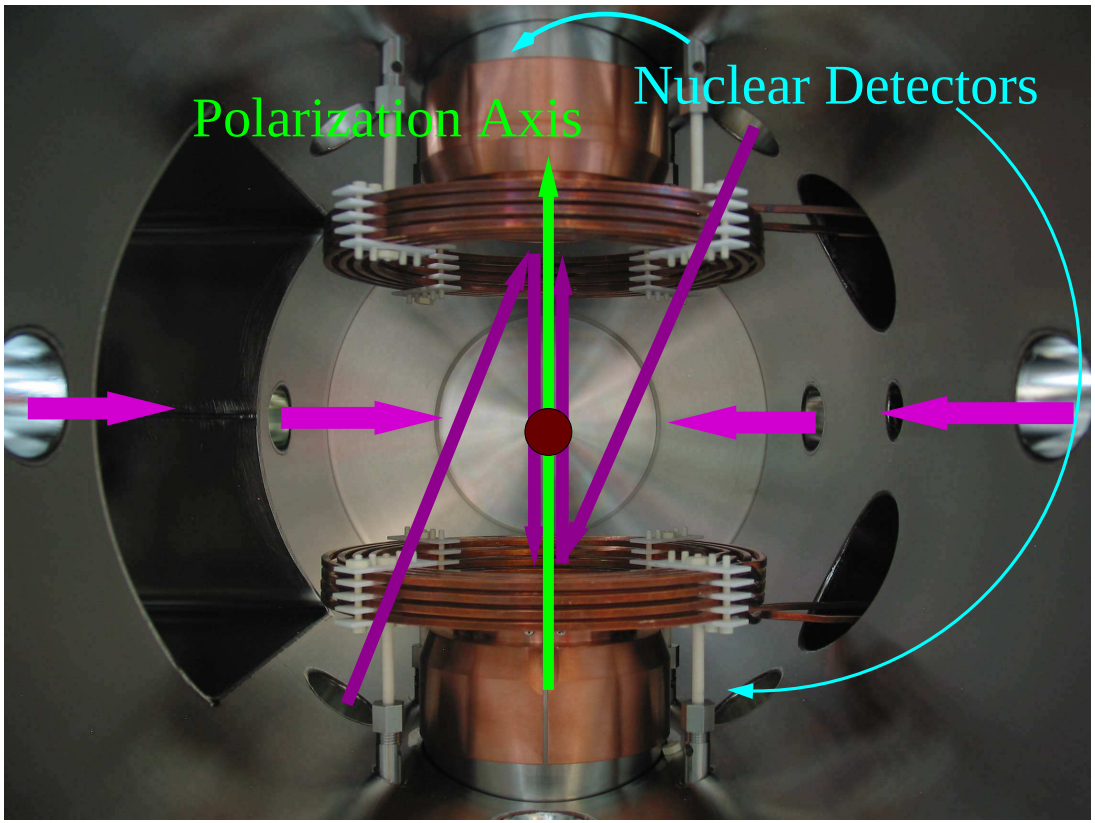
Overview

- Magneto-Optical Trap (MOT)
- Optical Pumping Polarizes the Atoms
  - $\sigma^{\pm}$ lasers drive biased random walk towards $P_{\mathrm{nucl}} = \pm 1$

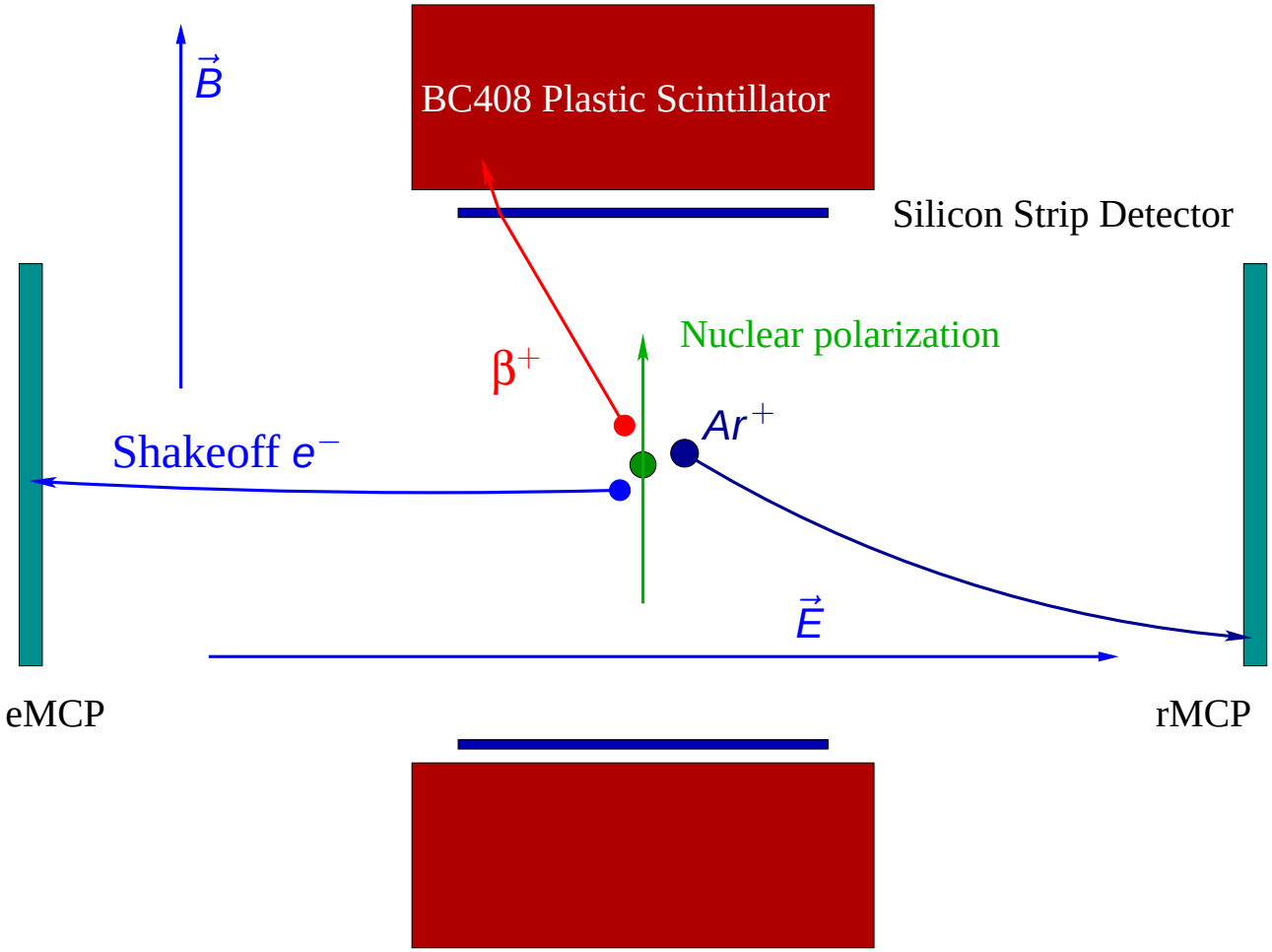


Overview

- Magneto-Optical Trap (MOT)
- Optical Pumping Polarizes the Atoms
- Nuclear Detectors
  - β-telescopes measure position, energy along polarization axis



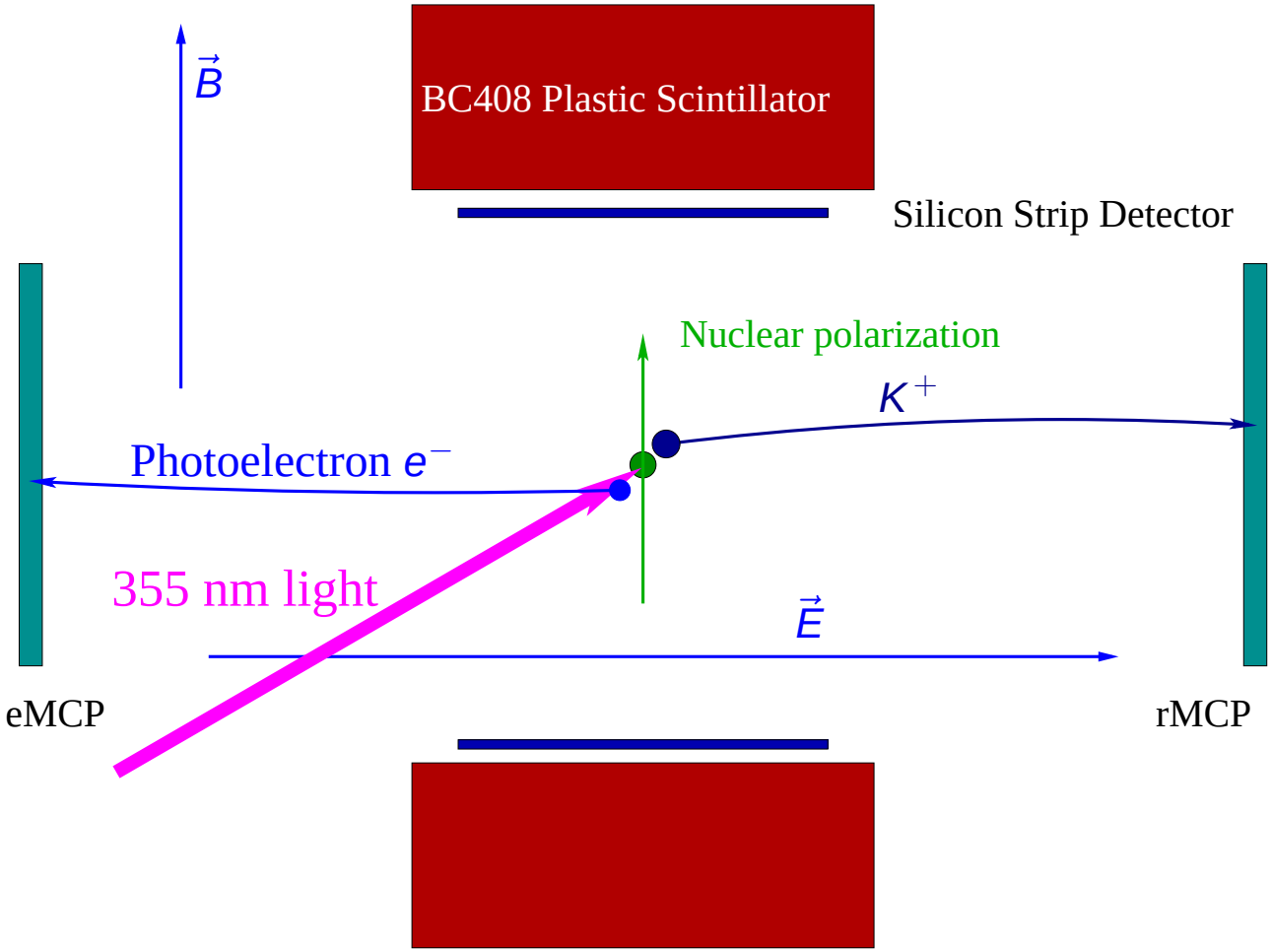
Types of events



- β^+ in coincidence with either MCP
- ν is unobserved

- Only able to bias one MCP at a time
- Development to bias both will reduce background *and* systematics

Types of events

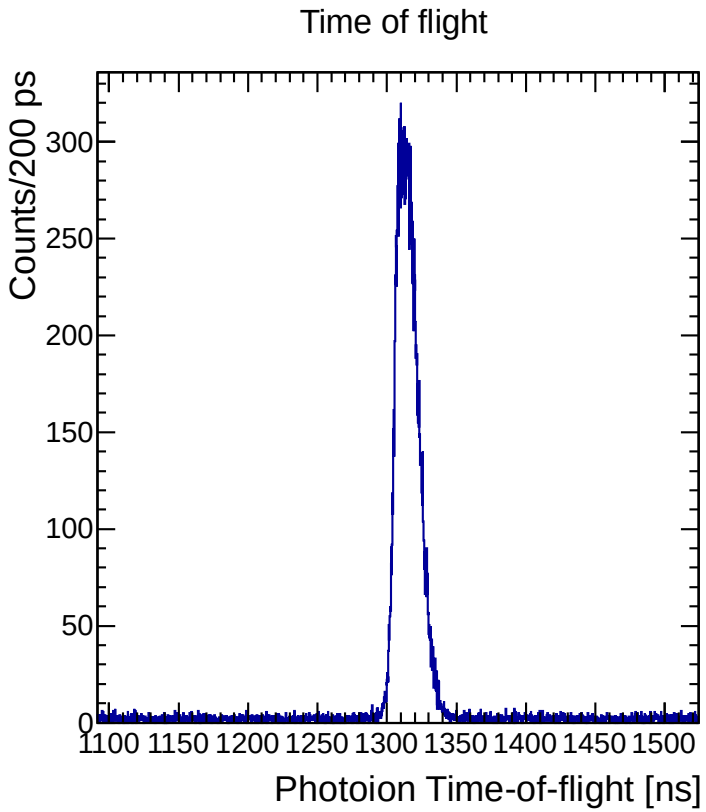


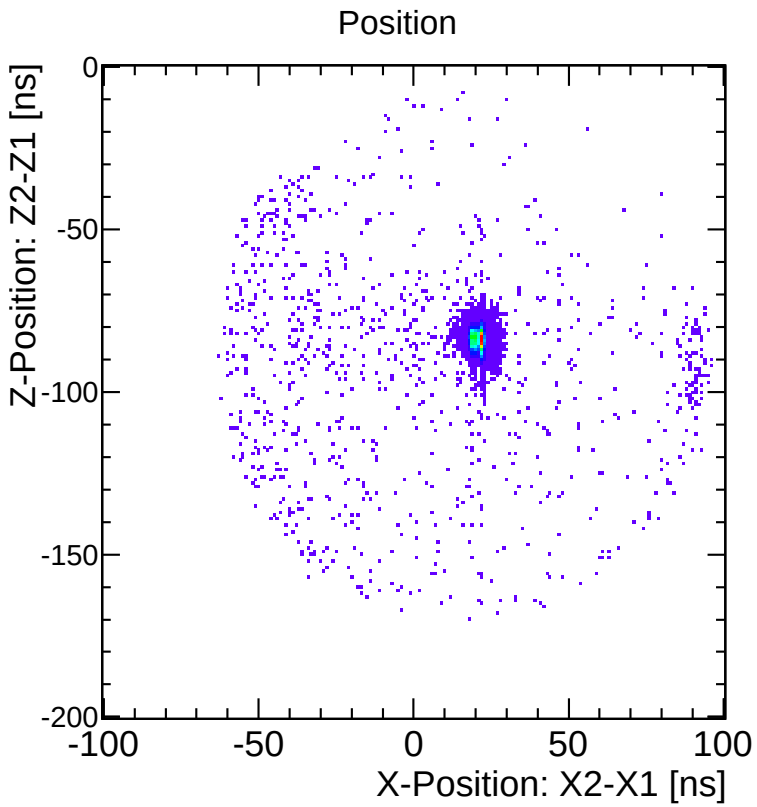
- Monitor of trap position, size, temperature
- Ultra-clean measure of nuclear polarization

- Only able to bias one MCP at a time
- Development to bias both will reduce background *and* systematics

Photoionization signal

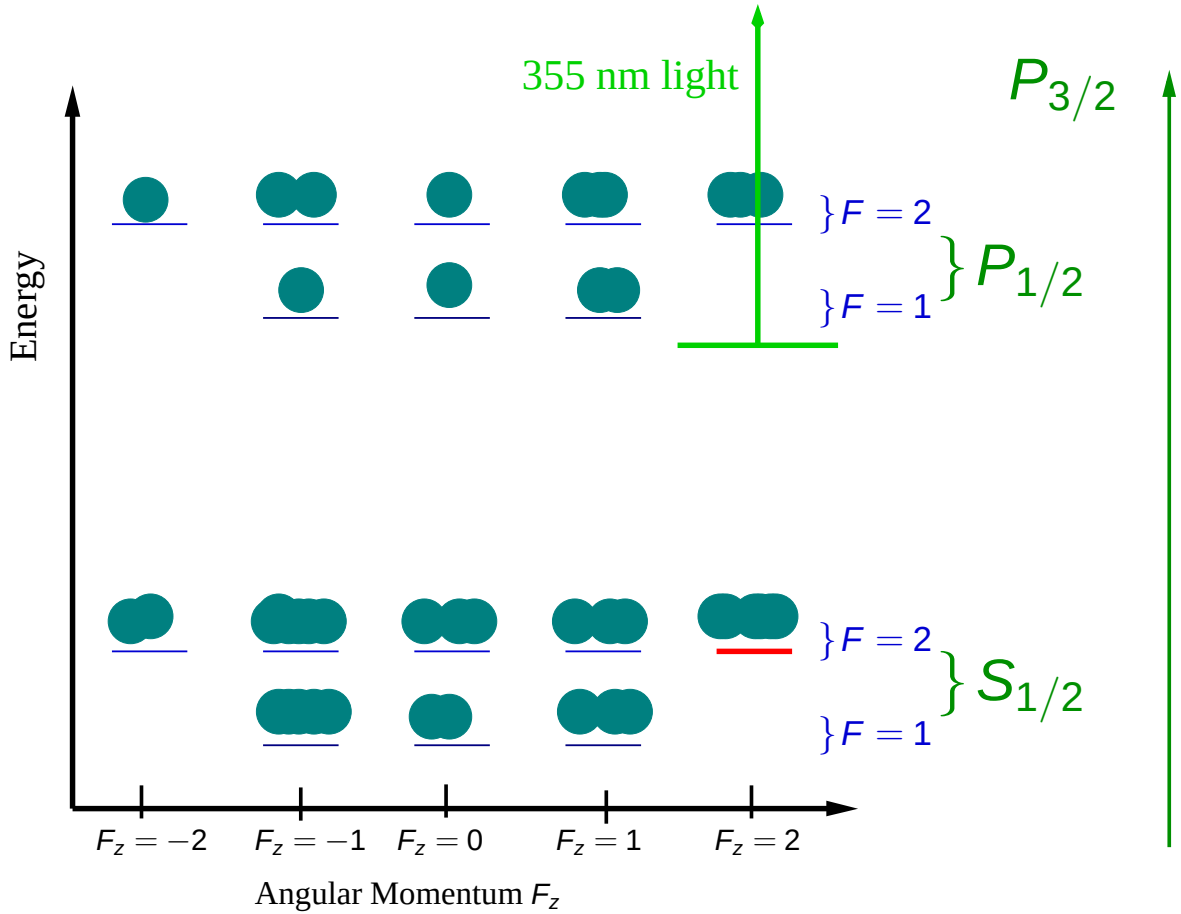
With time-of-flight *and* position cuts, this signal is very clean





Optical Pumping

- Stretched state has $F = 2$, $M_F = 2$ or equivalently $I_z = \frac{3}{2}$, $J_z = \frac{1}{2}$
- An atom in this state is dark to the laser light and is trapped
- This state corresponds to total atomic and nuclear polarization



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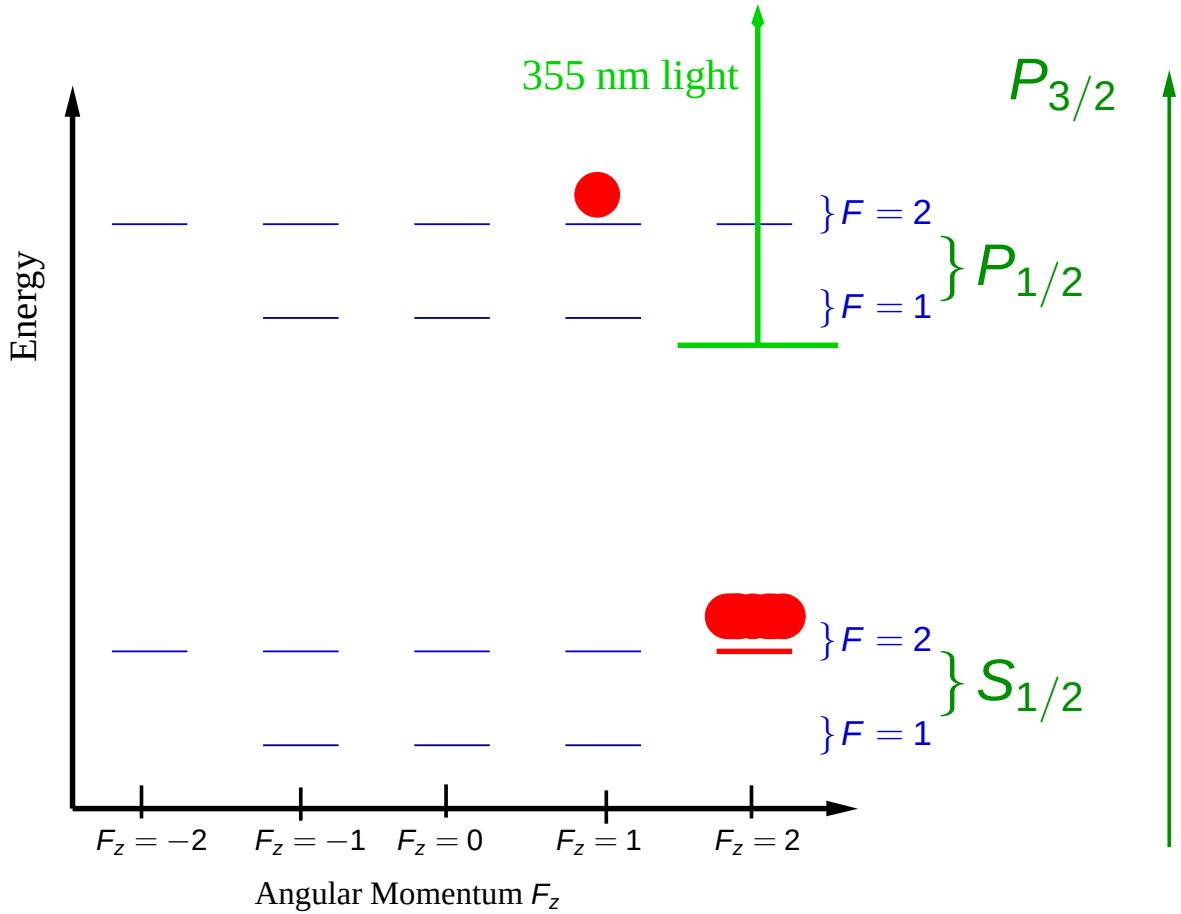
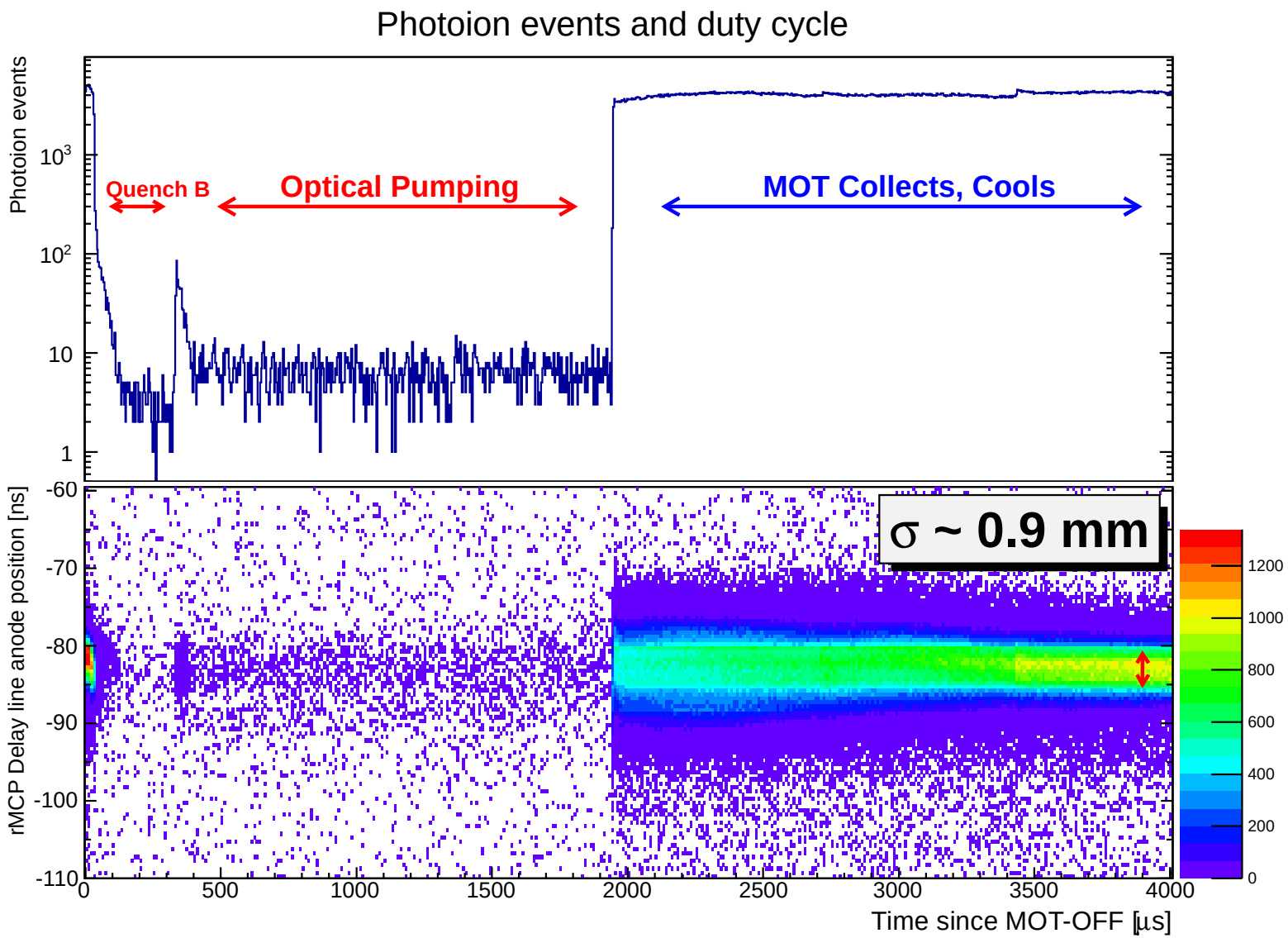


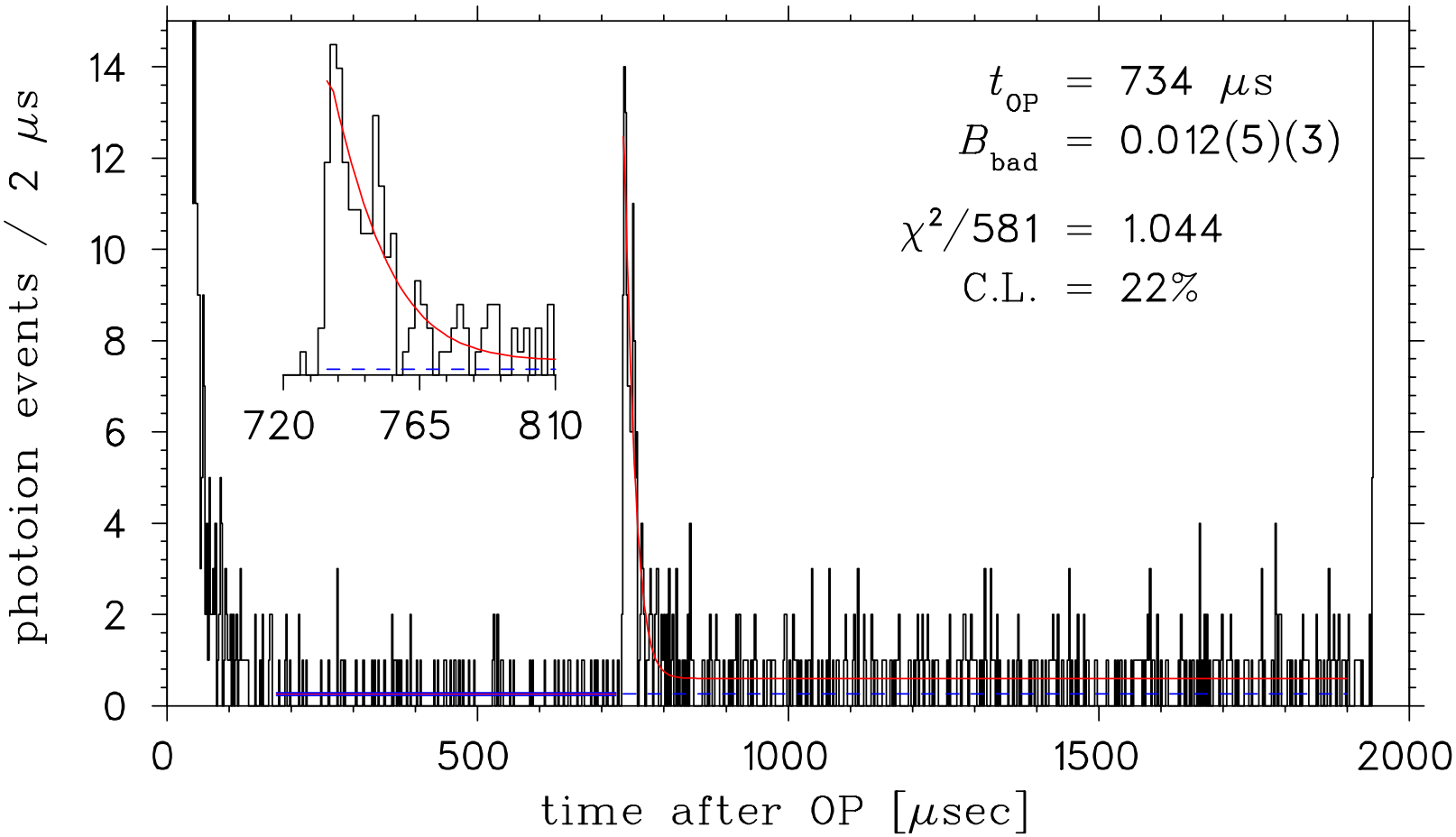
Polarized measurements must be done with MOT off

When MOT is off, cloud expands; therefore alternate counting/trapping



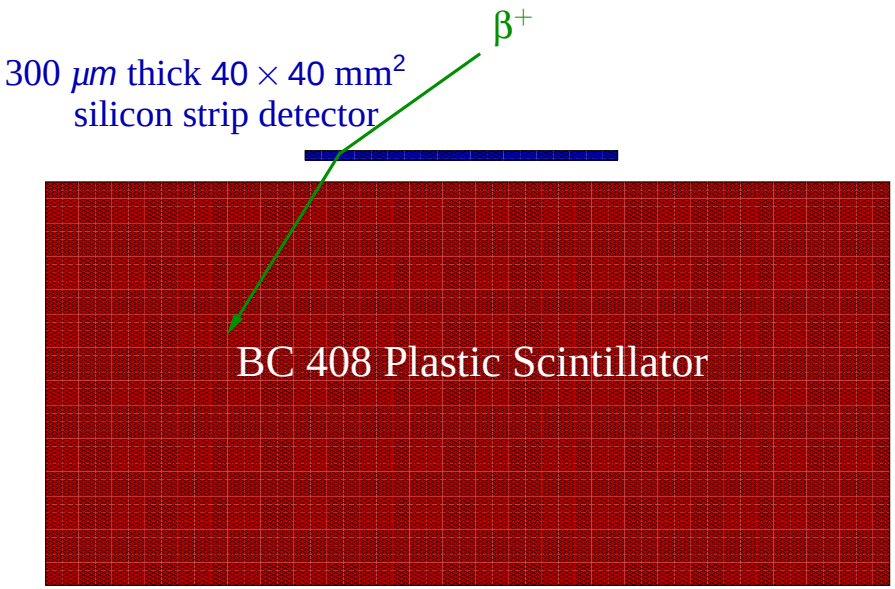
This great signal allows clean measurement of polarization

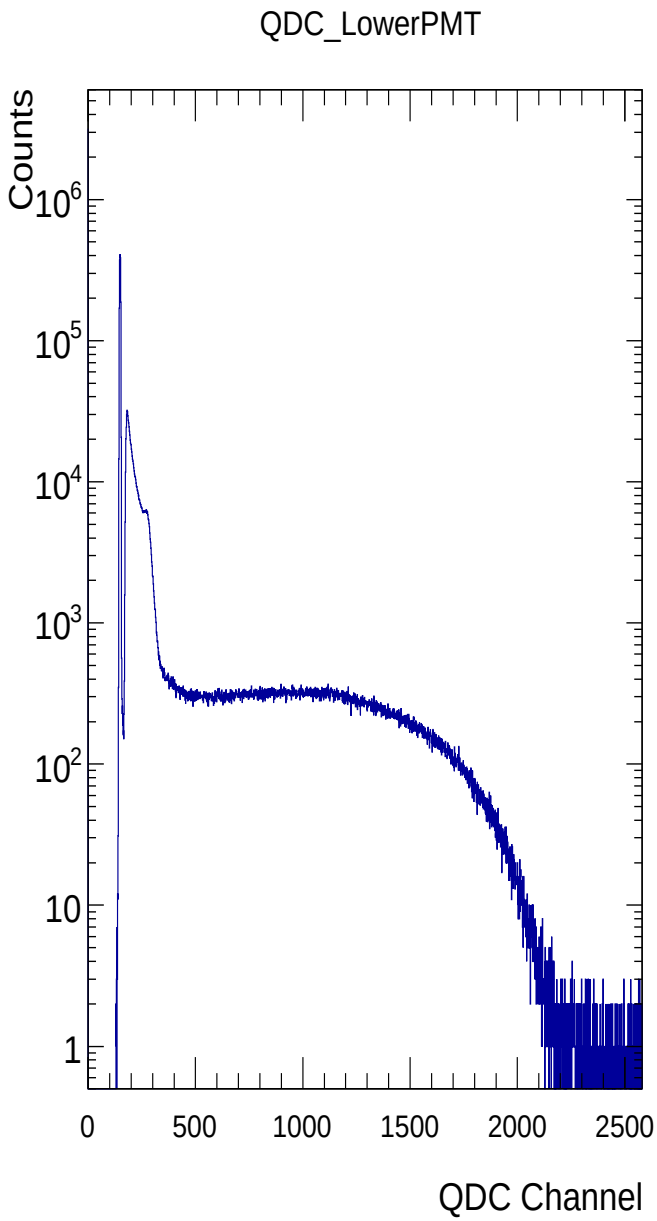
Online analysis gives $P \gtrsim 0.990$, but that is not even the full data set



β^+ energy spectrum

- Coincidence with silicon detector will reduce 511 background
- Have enough β-electron coincidences for $< 0.5\%$ measurement



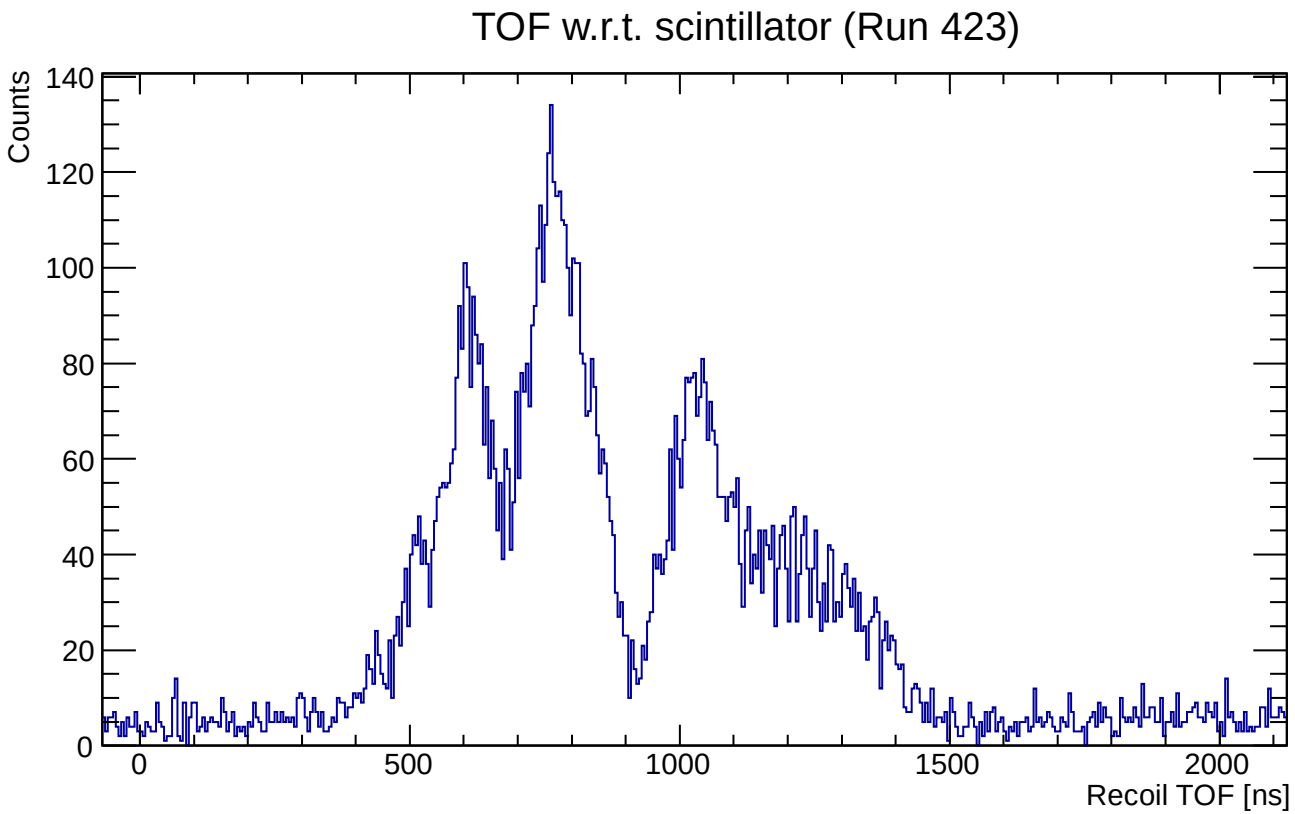


Recoil Ar^+ time-of-flight spectrum

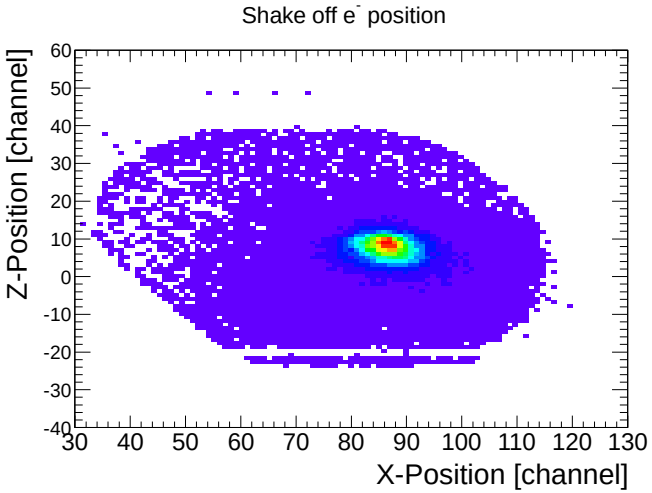
Recoiling Ar ion is swept to rMCP and detected in coincidence with β

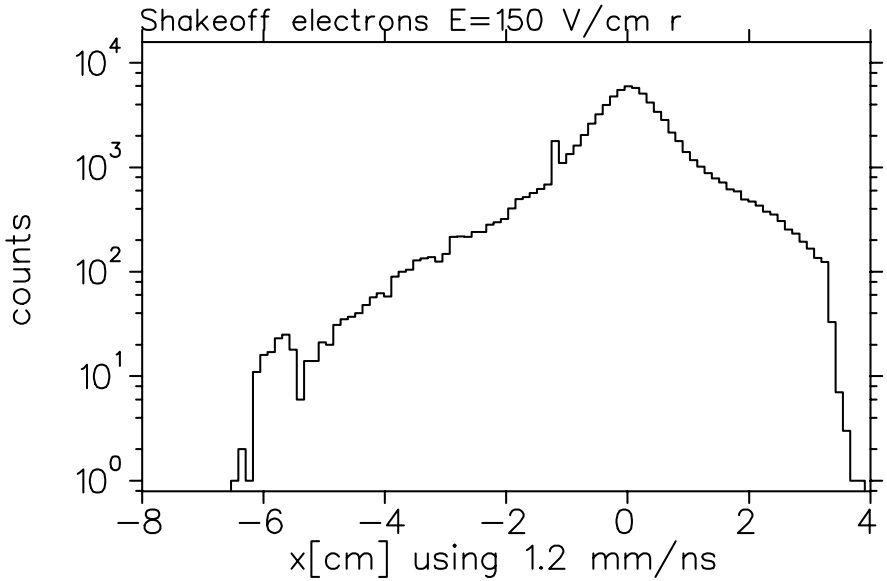
Time-of-flight spectrum can be used to measure

- Beta-neutrino correlation when ^{37}K is unpolarized
- R_{slow} when ^{37}K is polarized

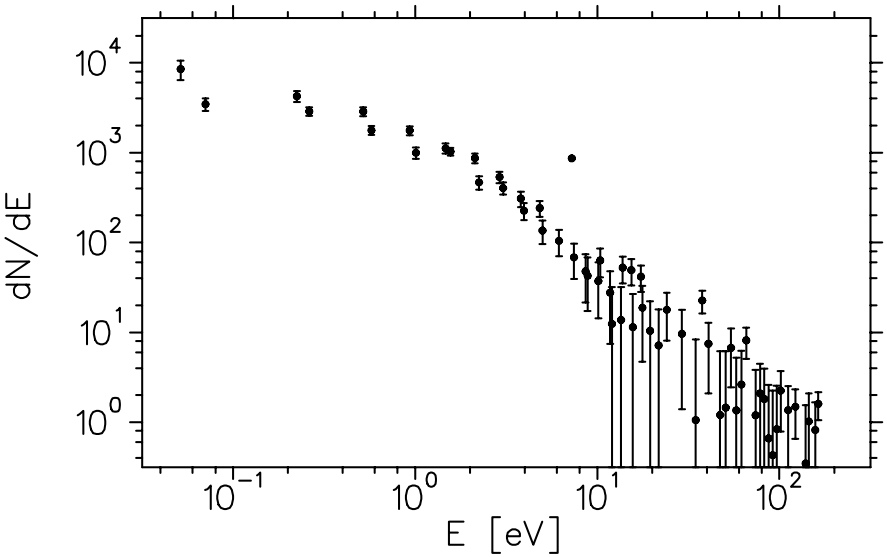


Shake-off electron spectroscopy (S1446)





- Electrons deflected $1\,\mathrm{cm}$ by field of $2\,\mathrm{G}$
- Position spectrum in perpendicular direction $\rightarrow$ energy spectrum

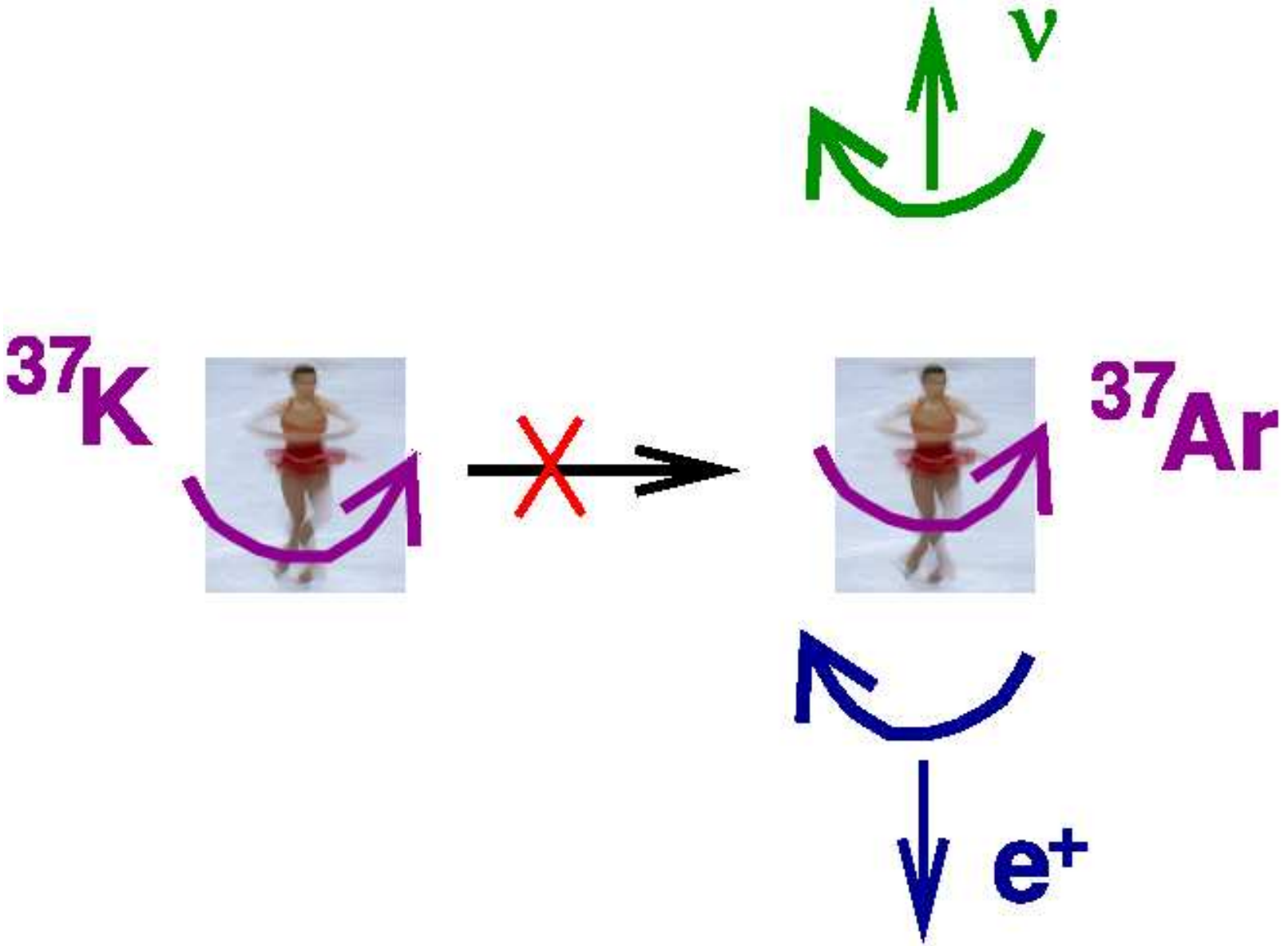


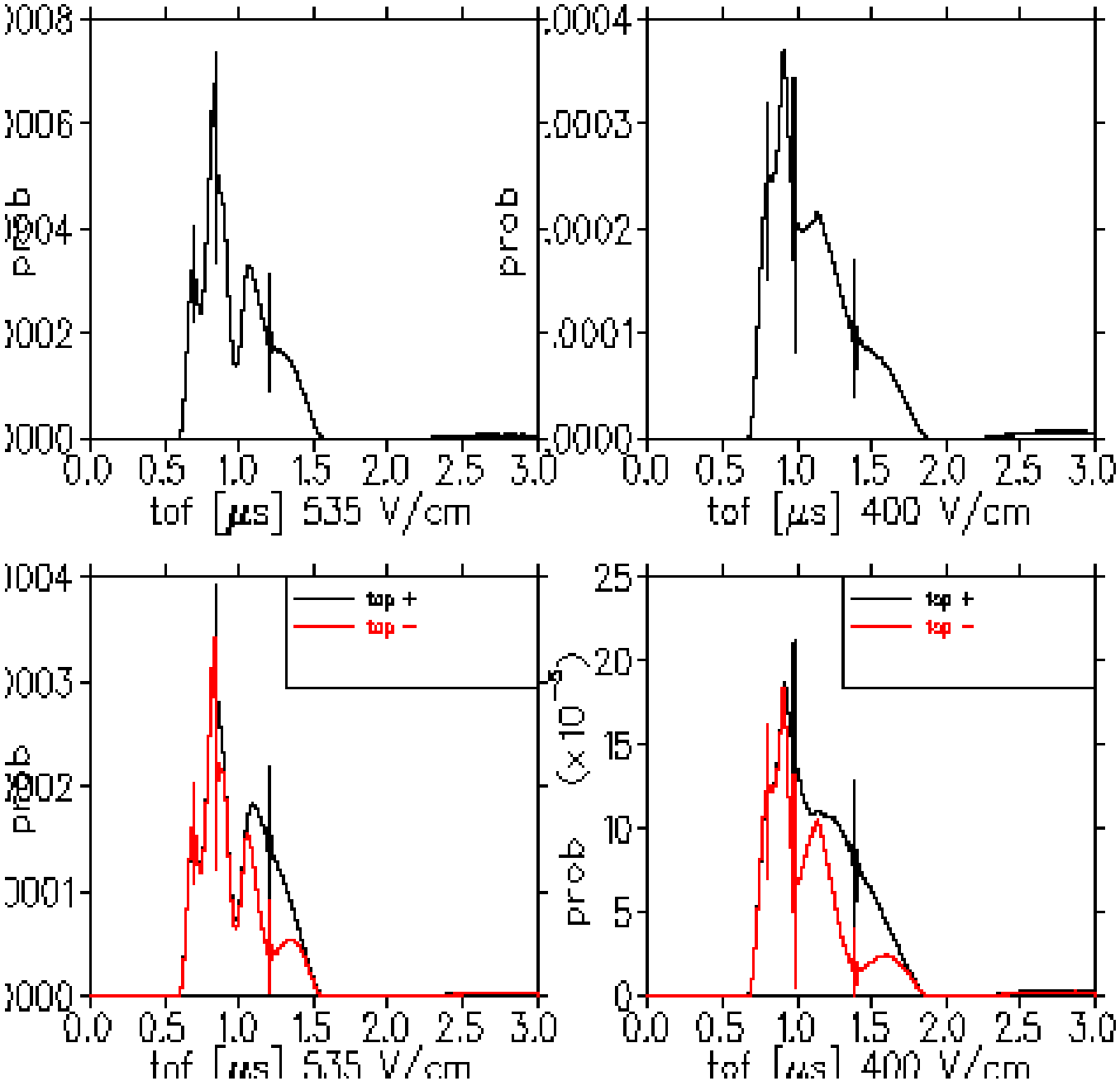
Conclusions

- TRINAT's x2 MOT system provides an ideal source of β-decaying atoms for studying fundamental symmetries of the weak interaction
- Highly spin-polarized with clean measurement of polarization
- Multiple physics observables all measured simultaneously
  - β-asymmetry with respect to polarization axis (A_β)
  - β-ν correlation ($a_{\beta\nu}$) with recoil time-of-flight spectrum
  - R_{slow} is a sensitive probe of right-handed currents
  - Shakeoff electron energy spectrum down to a few eV
- Stay tuned, lots of analyses under way!

Acknowledgments

- Collaboration members: Melissa Anholm (TRIUMF), Daniel Ashery (Tel Aviv), Spencer Behling (TAMU), John Behr (TRIUMF), Iuliana Cohen (Tel Aviv), Alexandre Gorelov (TRIUMF), Gerald Gwinner (U of Manitoba), Michael Mehlman (TAMU), Dan Melconian (TAMU), Praveen Shidling (TAMU)
- Thanks to the targets group for developing the HpTiC target
  - Consistently 2×10^8 $^{37}\mathrm{K}/\mathrm{s}$!
  - 5-10 thousand atoms in the trap
- Thanks to Konstantin Olchanski and the DAQ group


ν
37K
37Ar
e+


prob
tof [μs] 535 V/cm
tof [μs] 400 V/cm
top +
top −
(x 10⁻⁶)