HIGH-PRECISION HALF-LIFE MEASUREMENTS FOR THE SUPERALLOWED BETA EMITTER ^{10}C

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WHY SUPERALLOWED FERMI BETA DECAY?

Can test fundamental properties of the electroweak interaction:

- **Use Ft measurements ($T_{1/2}$, Q-value, BR) to test CVC hypothesis**
- **Test CKM unitarity by constraining V_{ud}**
- **Test for possible extensions to the electroweak theory**

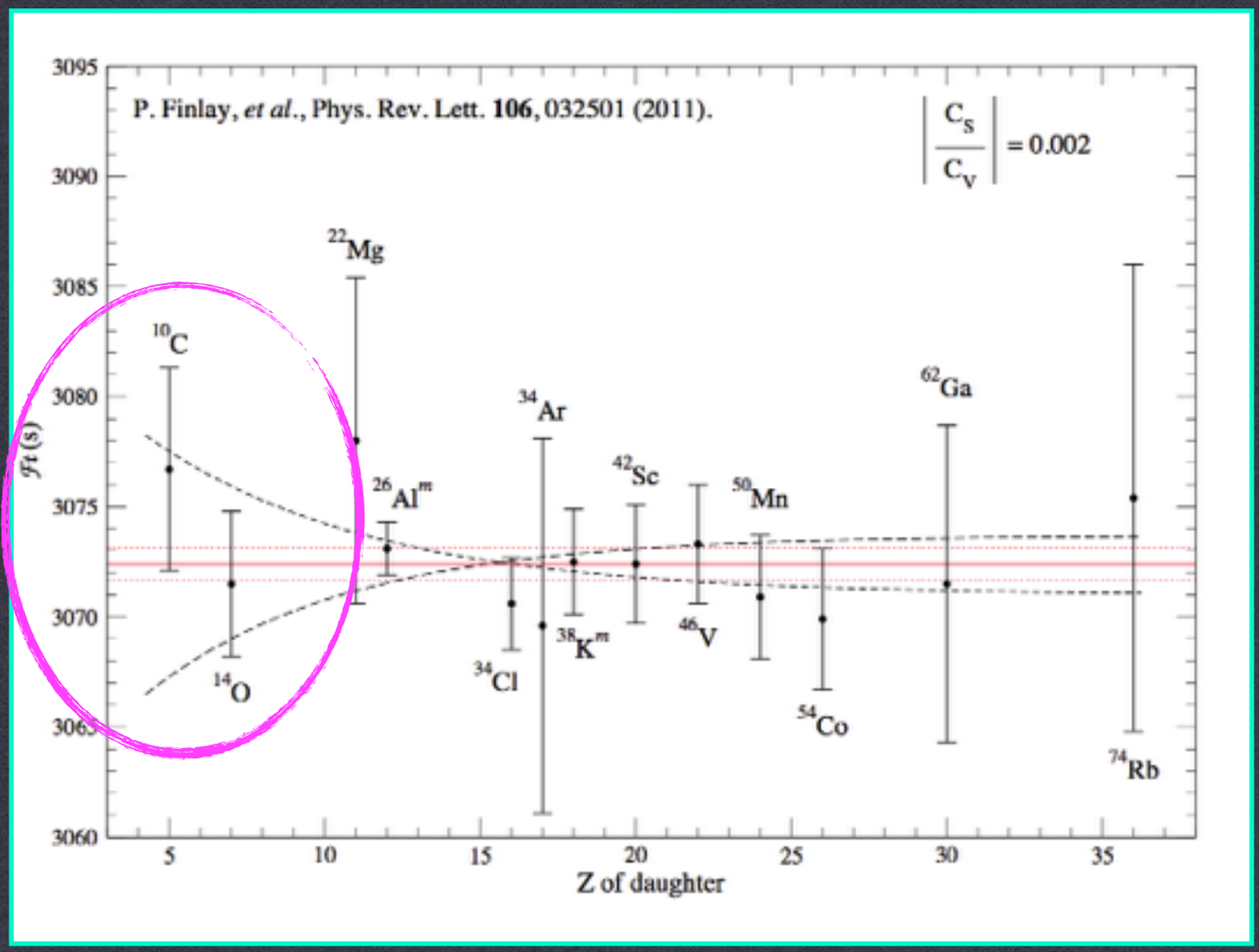
WHY ^{10}C?

One of the 10 high-precision T=1 superallowed emitters

- Lightest of them all

Low-Z superallowed emitters most sensitive to the presence of fundamental weak scalar currents

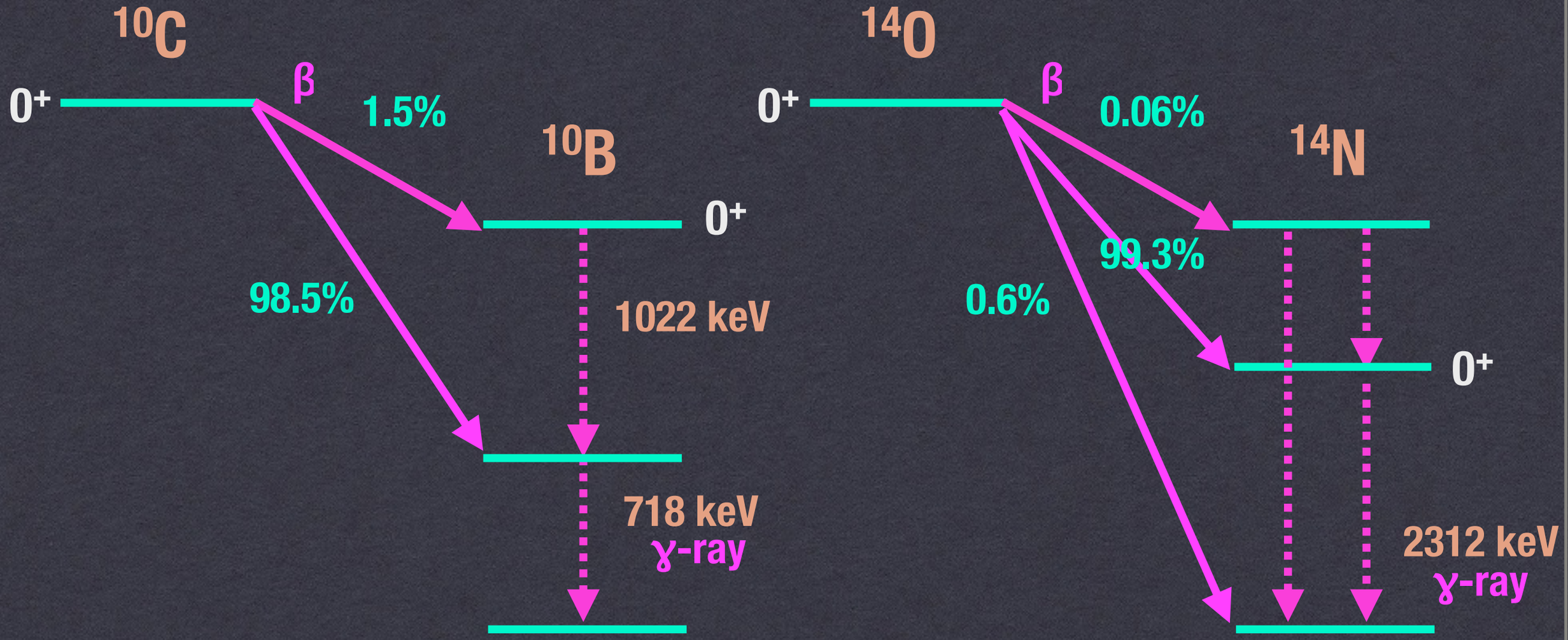
Ft ∝ 1/Q



^{10}C AND ^{14}O DECAY SCHEMES

$T_{1/2}$ = 19.3 seconds

$T_{1/2}$ = 70.6 seconds



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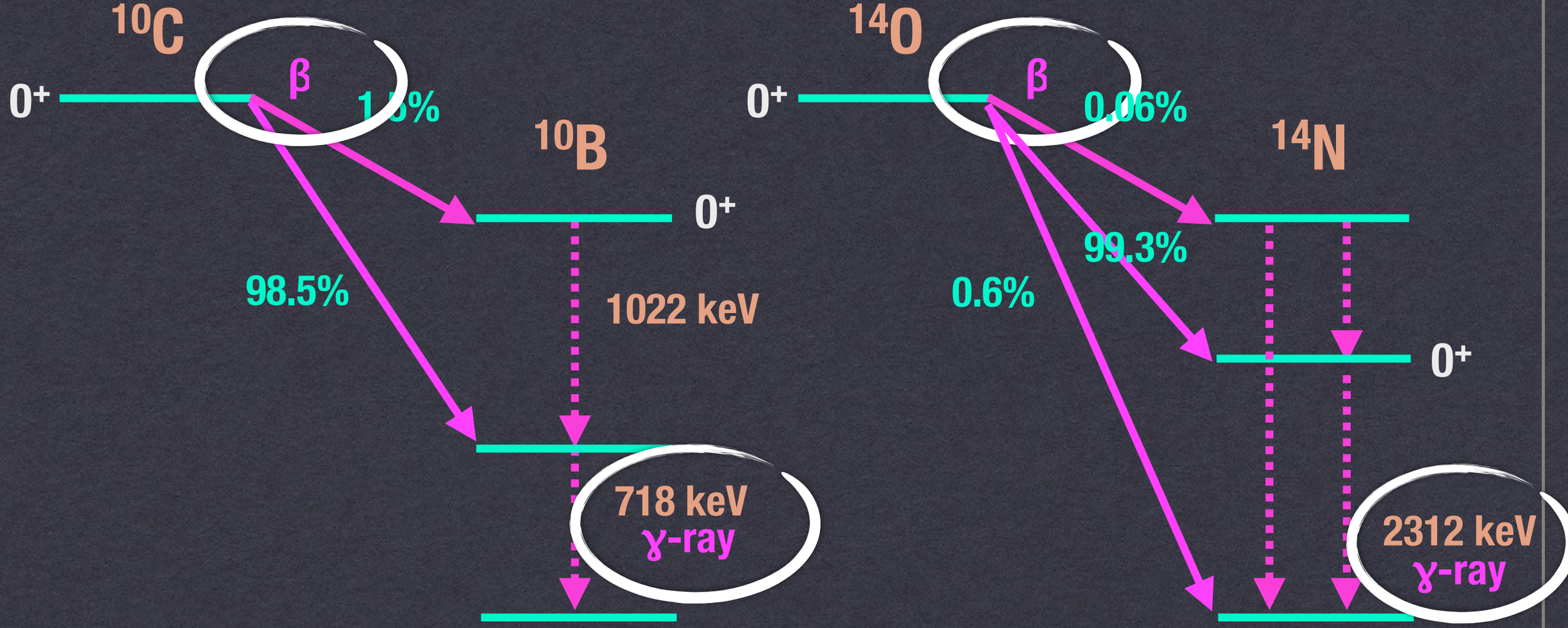


DISCREPANCIES BETWEEN HALF-LIFE MEASUREMENTS

^{10}C measurements

β: $T_{1/2}$ = 19.307(4) s

γ: $T_{1/2}$ = 19.290(12) s

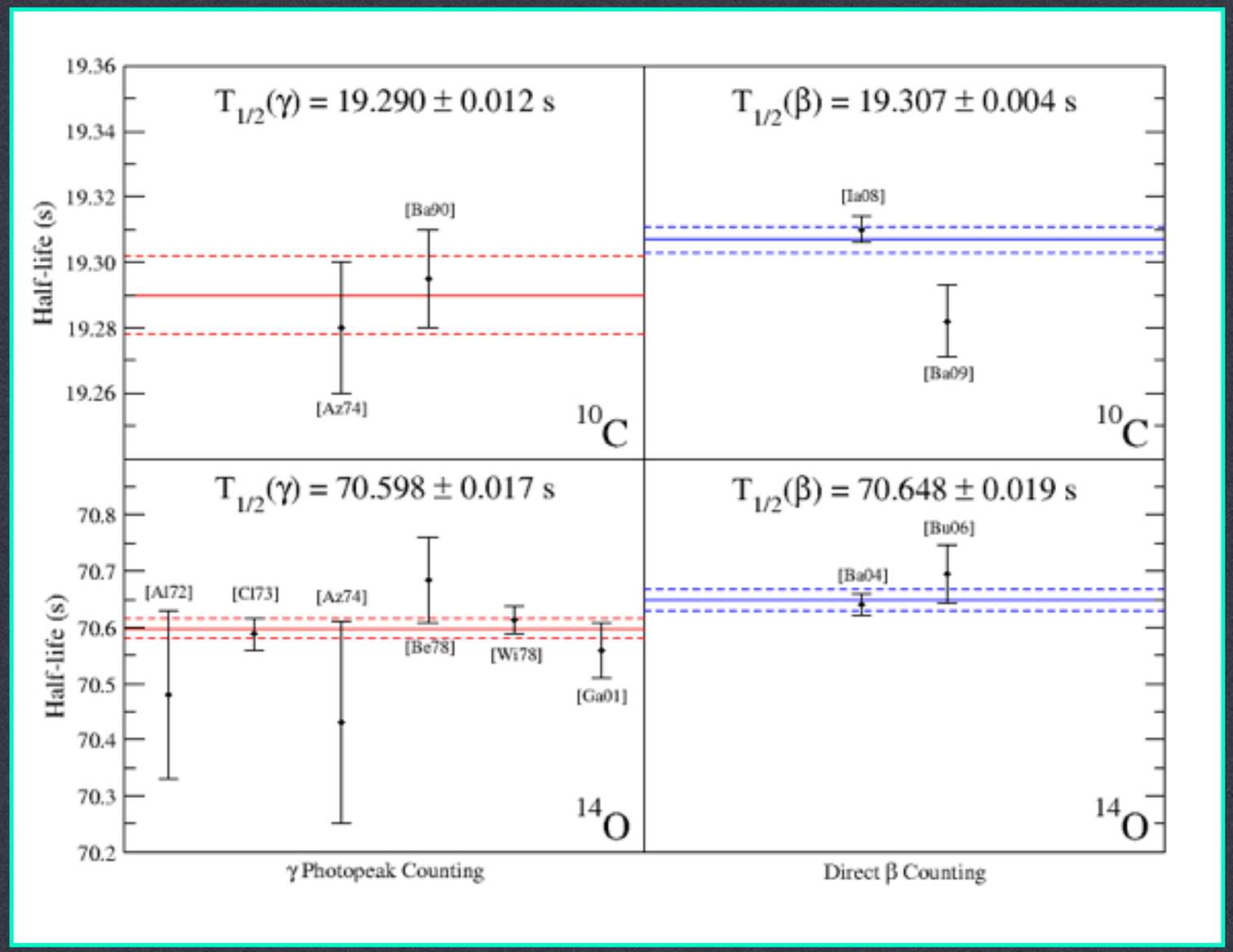
Differ by ~1.4σ

Effect also seen in ^{14}O measurements

β: $T_{1/2}$ = 70.648(19) s

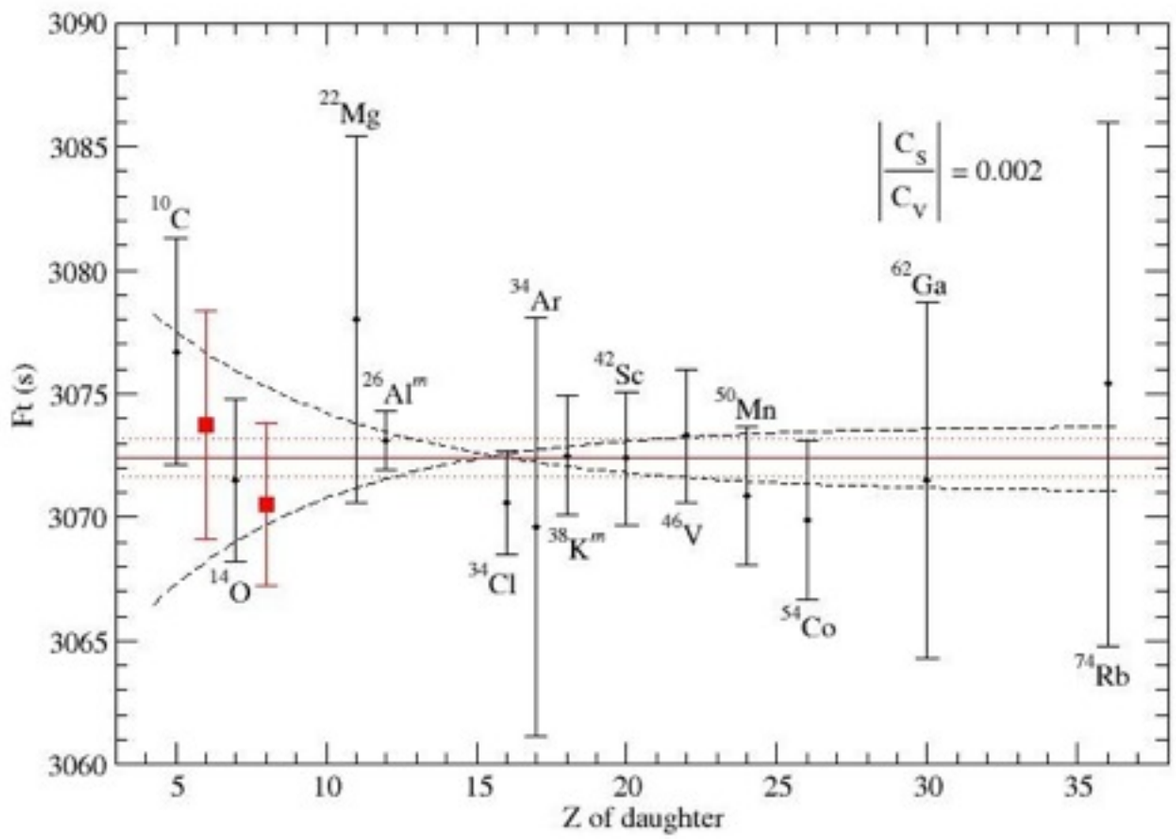
γ: $T_{1/2}$ = 70.598(17) s

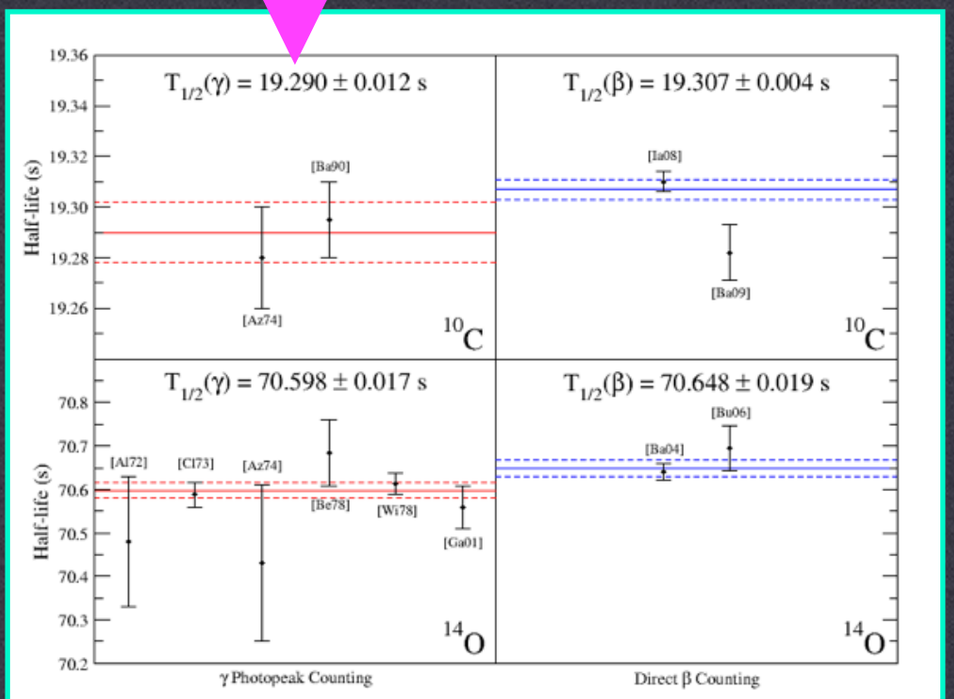
Differ by ~2.6σ



FT VALUES

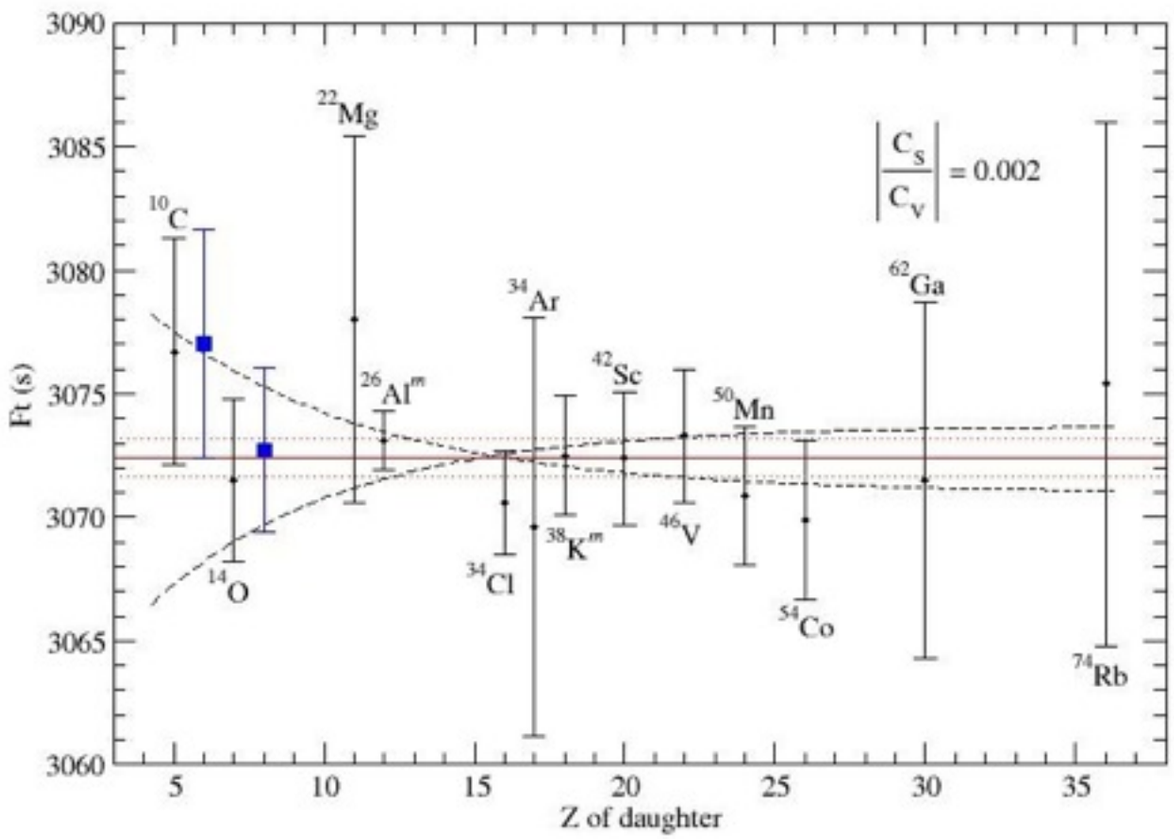
Ft value using half-life obtained via ɣ measurements

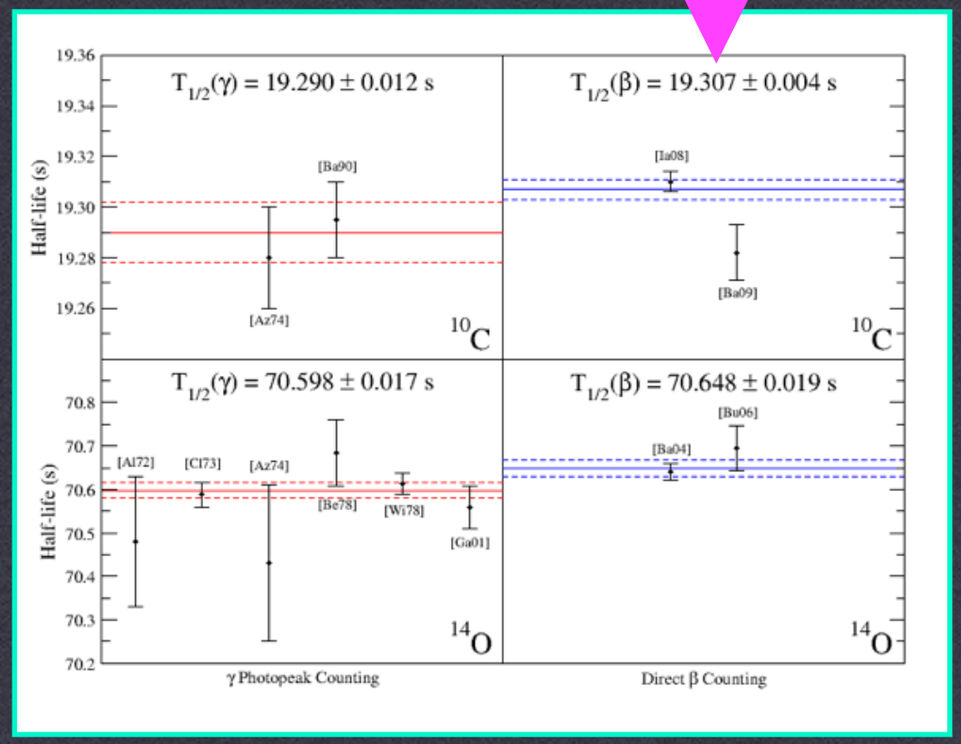




FT VALUES

Ft value using half-life obtained via β measurements





EXPERIMENTAL OVERVIEW

Performed in the ISAC hall at TRIUMF

NiO target used to obtain CO+ ions

Beams of $^{10}C^{16}O$ delivered to the 8π and GPS detectors

- Beam rates of ~1.75×10^5 ions/s achieved

Beams of ^{10}C delivered to the GPS detector

- Beam rates of ~1.0×10^4 atoms/s achieved

γ DETECTOR

THE 8π SPECTROMETER

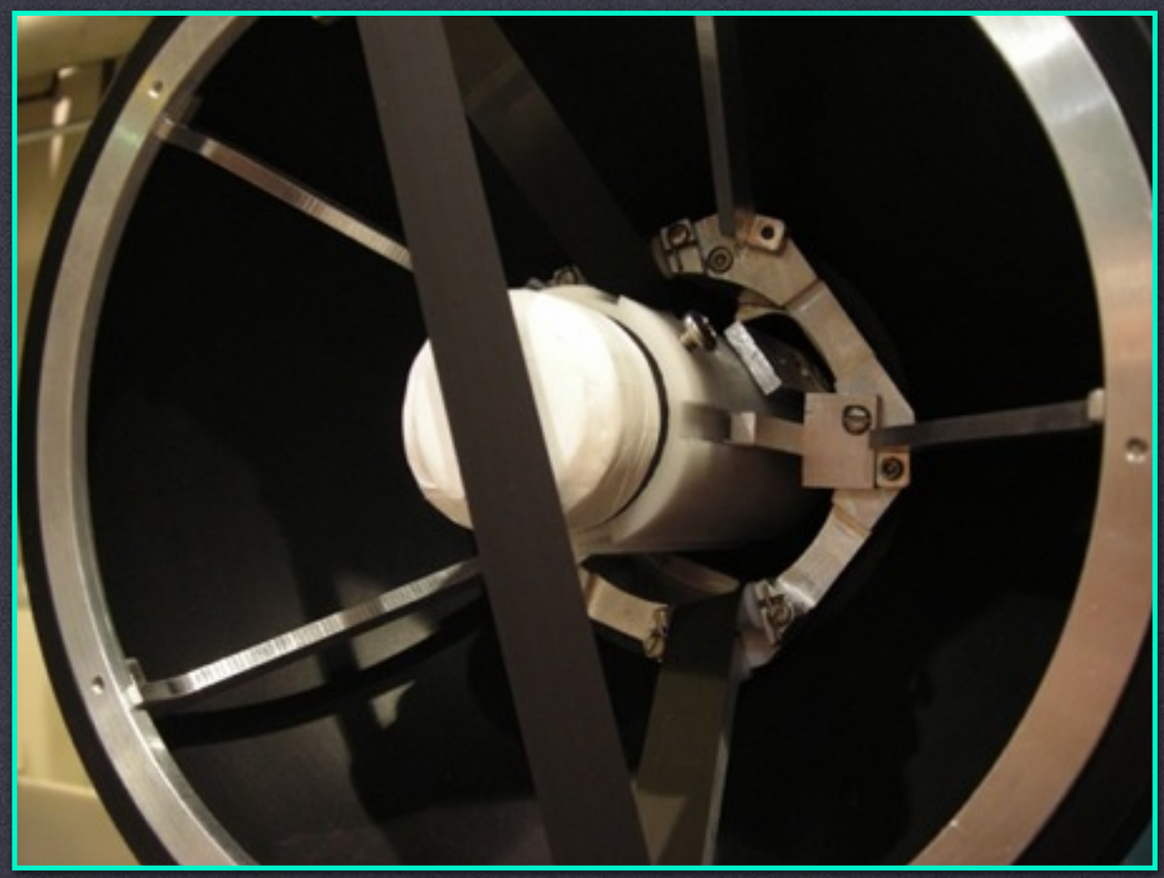
Spherical array of 20 Compton-suppressed HPGe detectors

Detects emitted gamma-ray from the excited daughter states

β DETECTORS

THE ZERO-DEGREE SCINTILLATOR

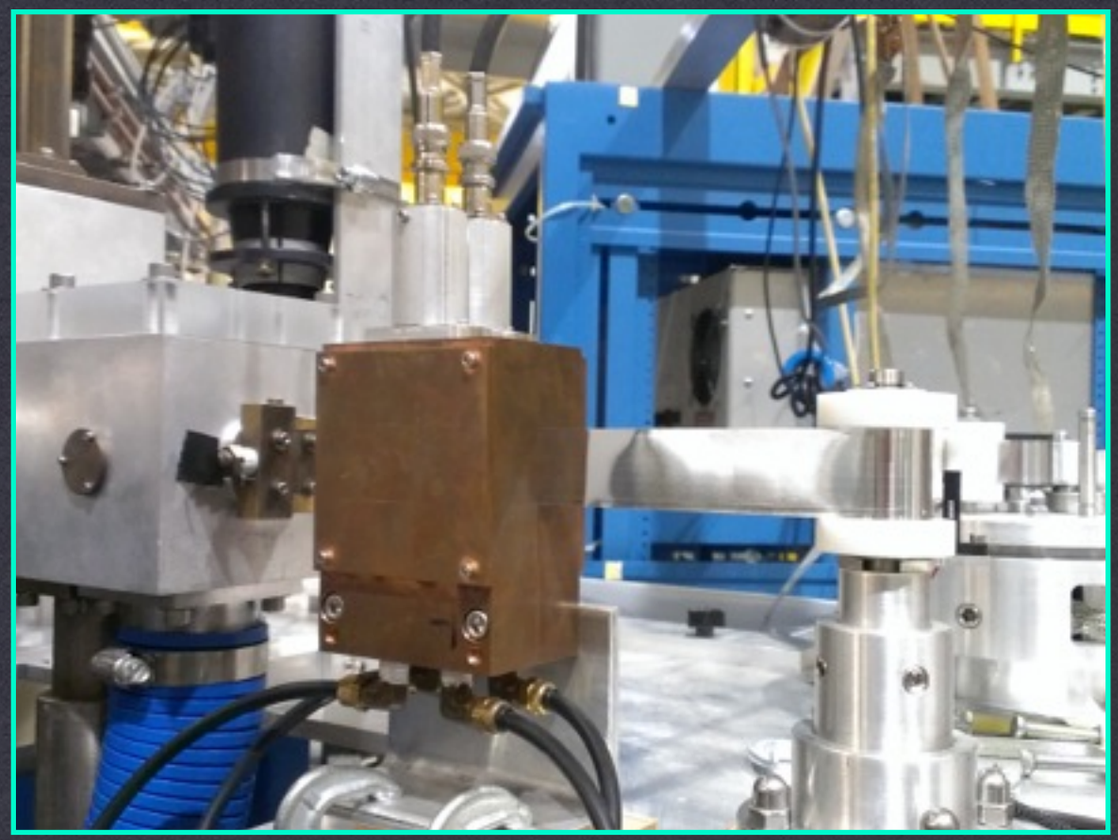
Fast plastic scintillator located directly behind the implantation site of the 8π spectrometer

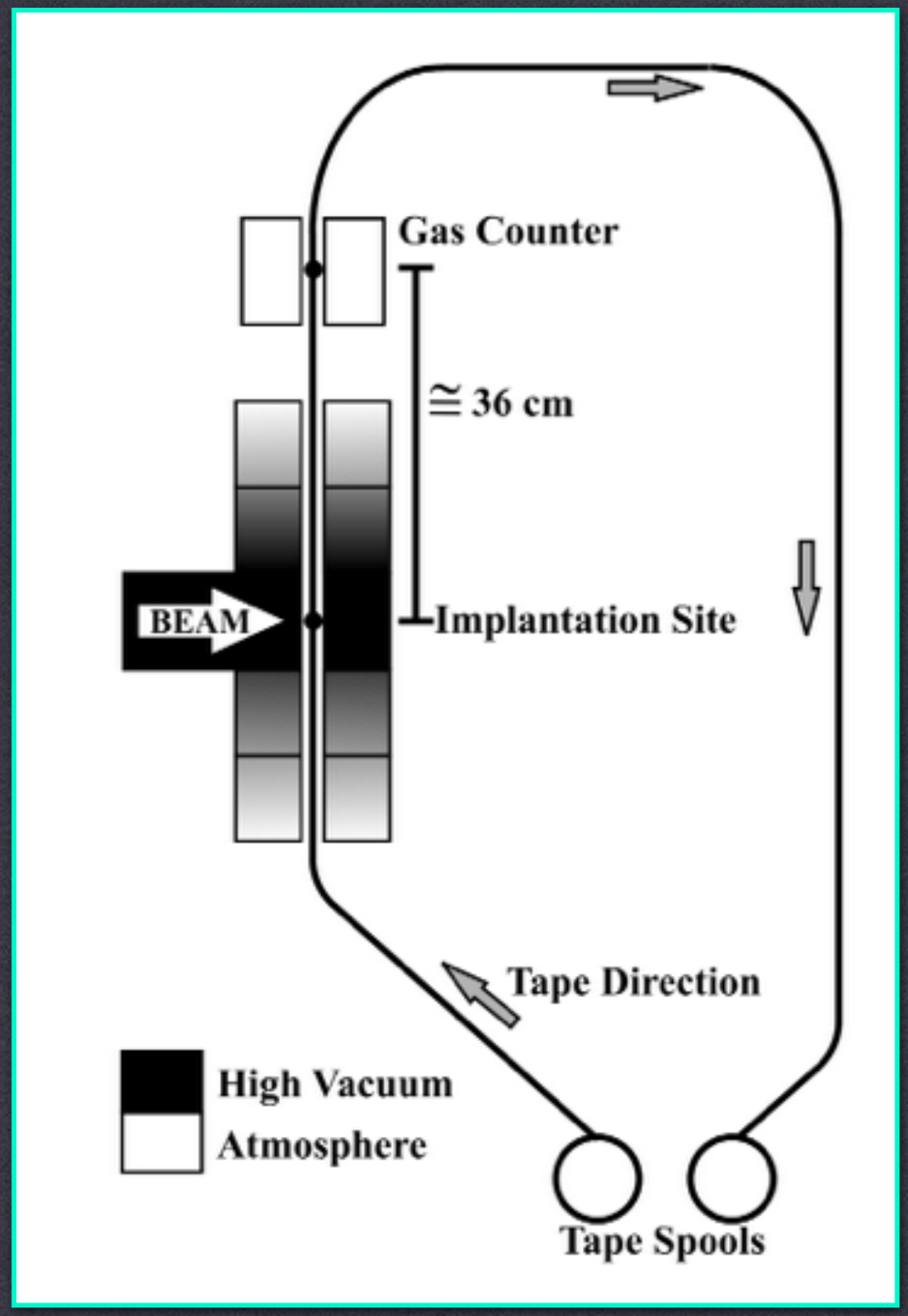


Directly detects β particles

β DETECTORS
THE GPS DETECTOR

4π proportional gas counter



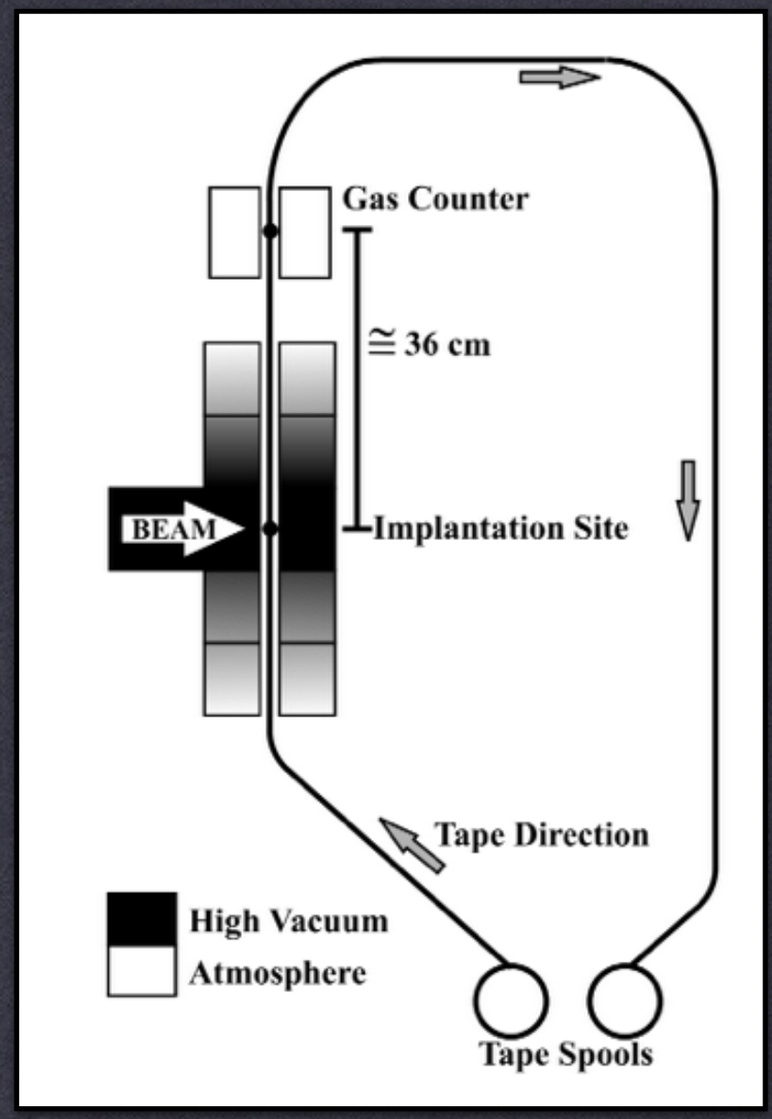


Directly detects β particles

GPS DATA COLLECTION

Data collected with 2 independent multichannel scalers (MCS)

- Fixed dead-times applied to each MCS



Data was collected in cycles mode:

- Beam implanted on the tape
- Tape moved into the gas counter
- Measure the decay for ~ 9 minutes
  - ie. ~30 half-lives ($T_{1/2}$ = 19.3 s)

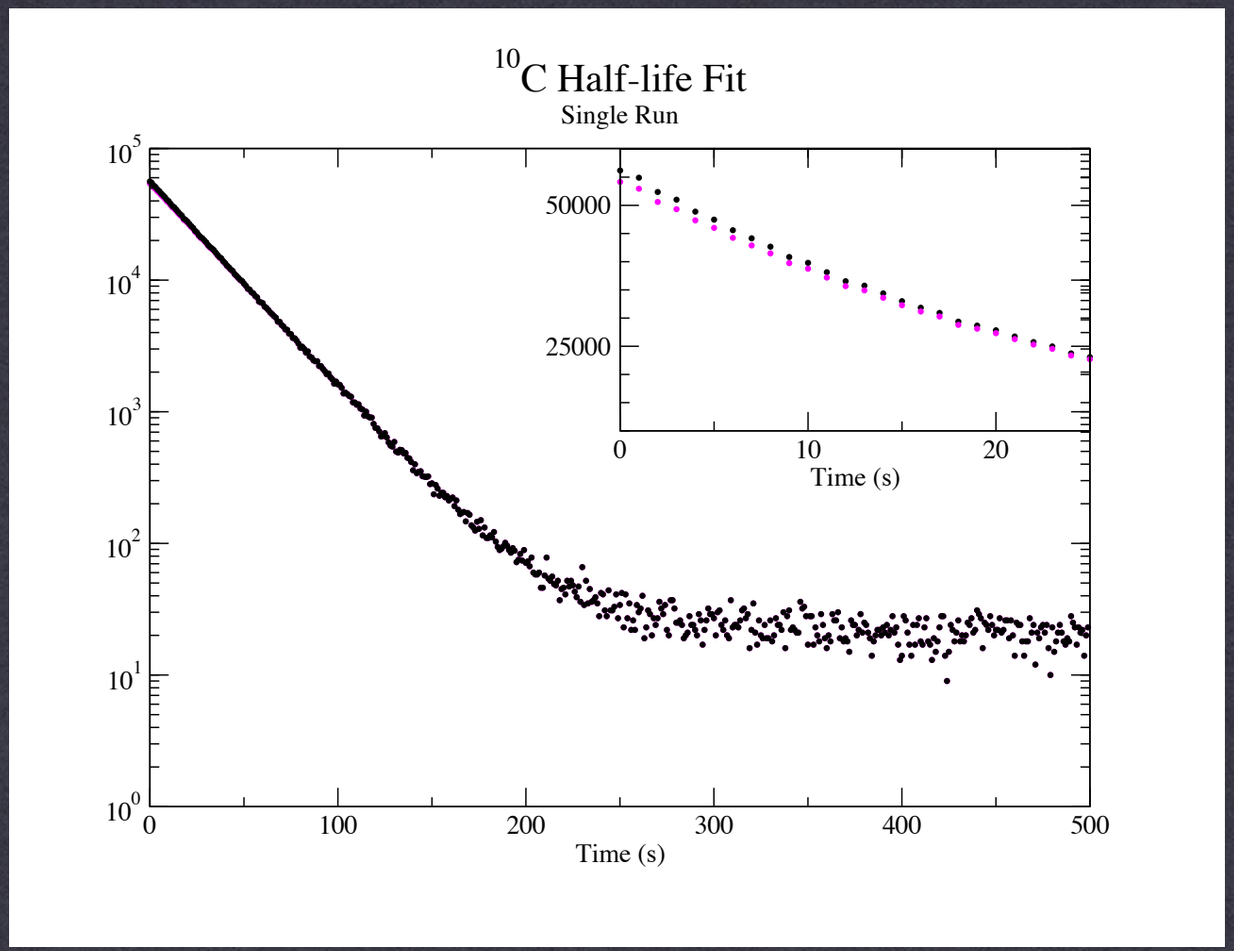
GPS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied

$$N = \frac{N'}{1 - N' \cdot \frac{\tau}{\Delta t}}$$

$\tau = 4\ \mu s$

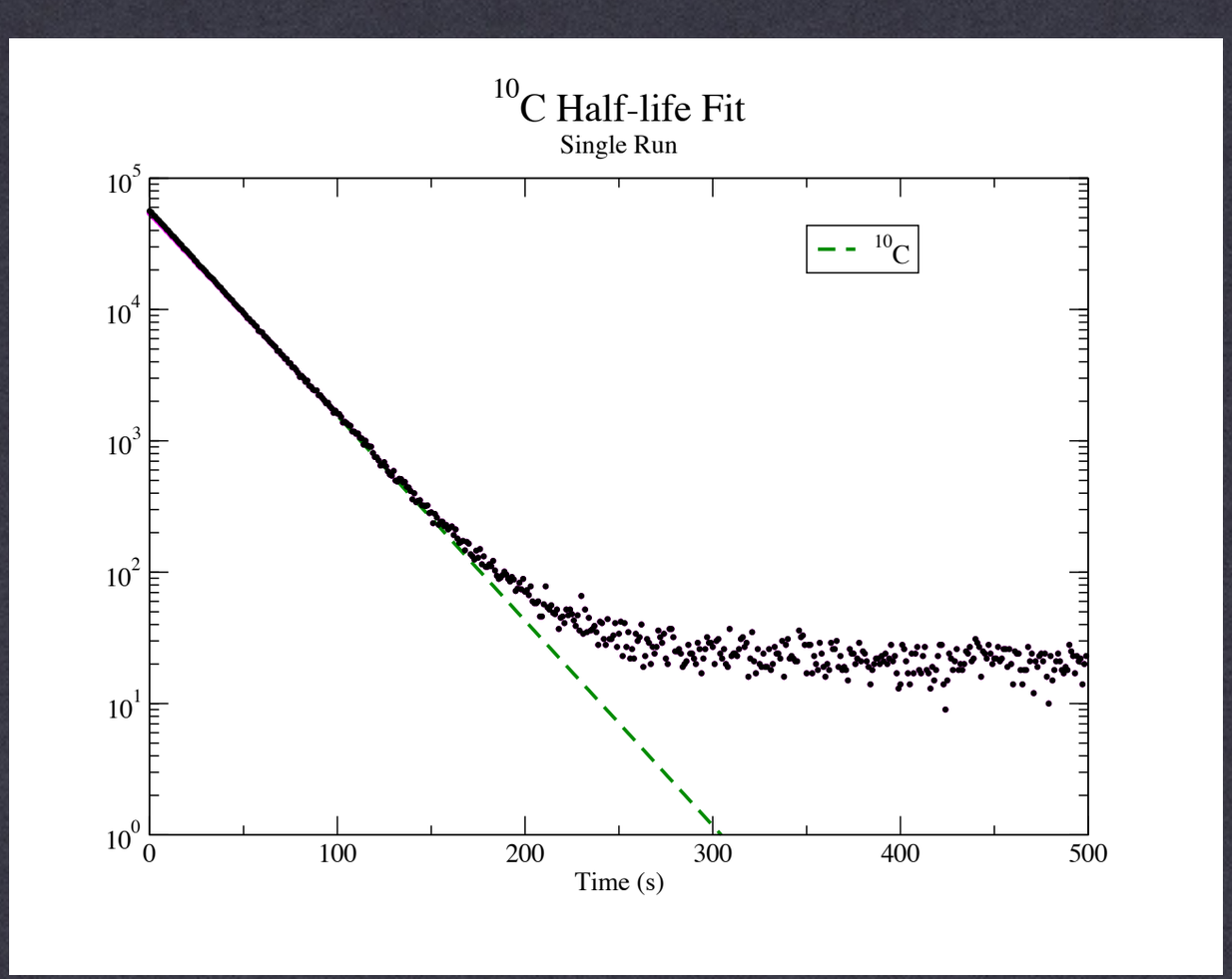
$\Delta t = 1\ s$



GPS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied
Fit the data with:

- **Exponential decay of the primary nucleus (^{10}C)**



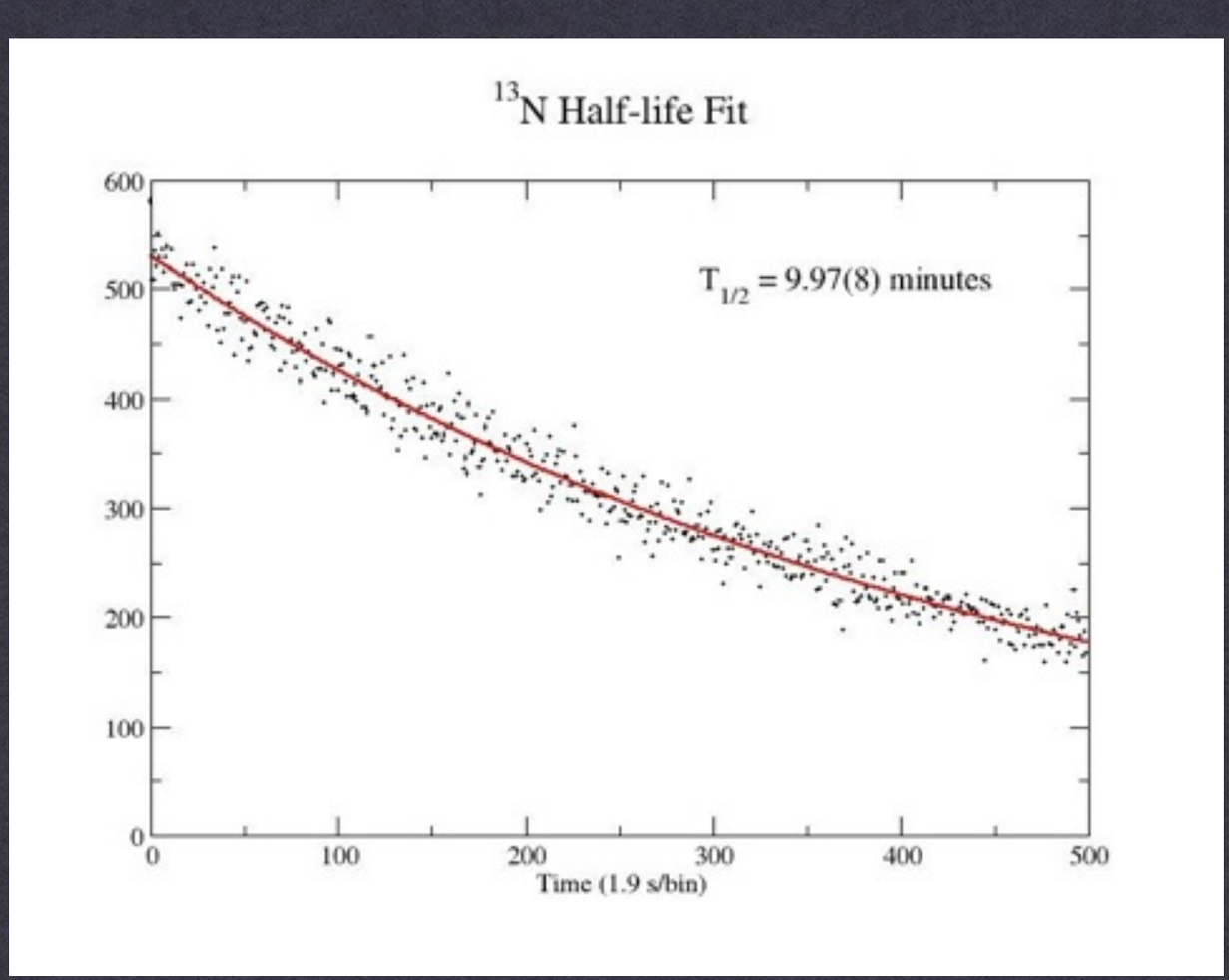
GPS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied

Fit the data with:

- **Exponential decay of the primary nucleus (^{10}C)**
- **Exponential decay of a contaminant (^{13}N)**

mass difference between $^{10}C^{16}O$ and $^{13}N_2$ ~5 ppm



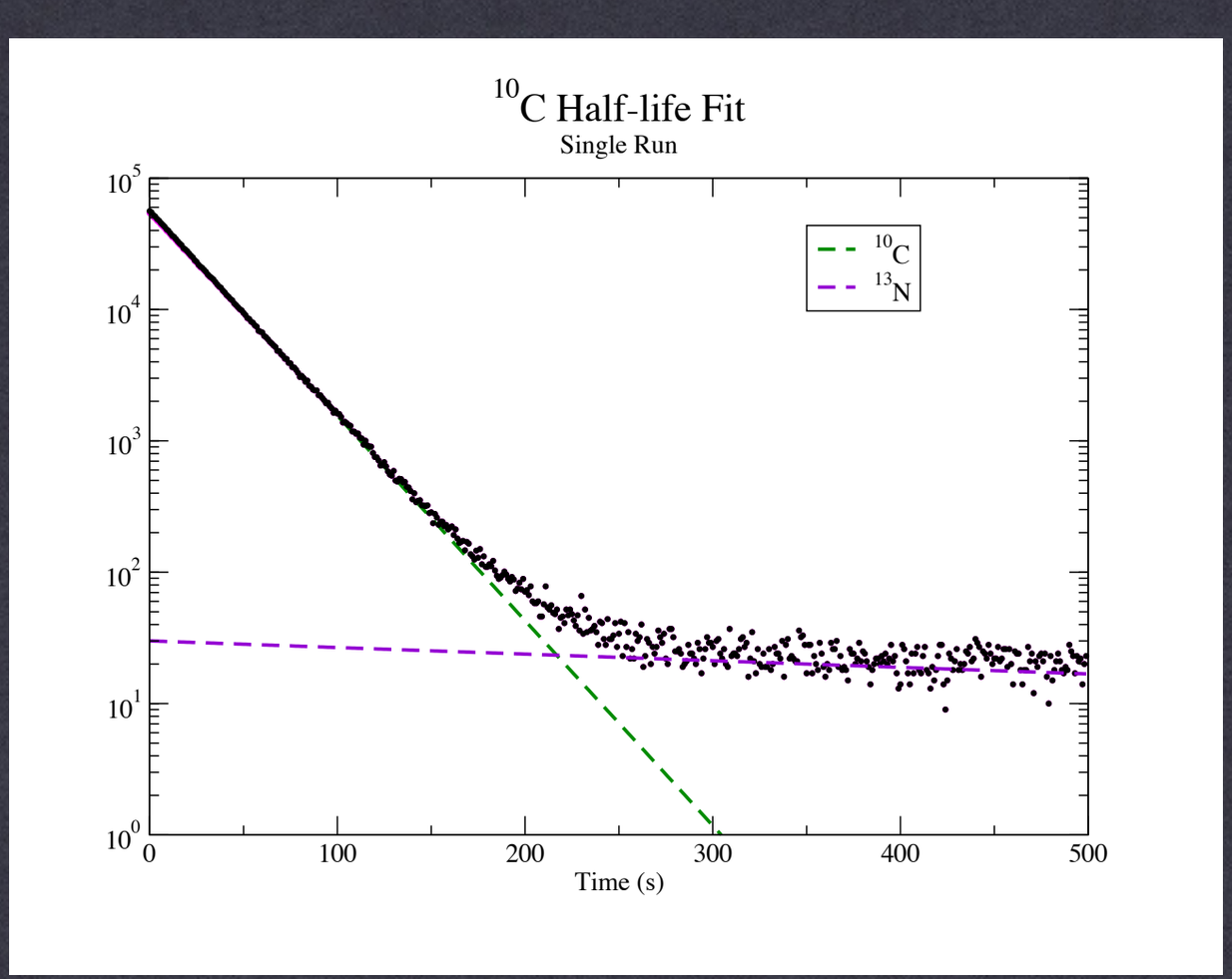
Intensity of ~200-250 molecules/s

GPS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied

Fit the data with:

- Exponential decay of the primary nucleus (^{10}C)
- Exponential decay of a contaminant (^{13}N)

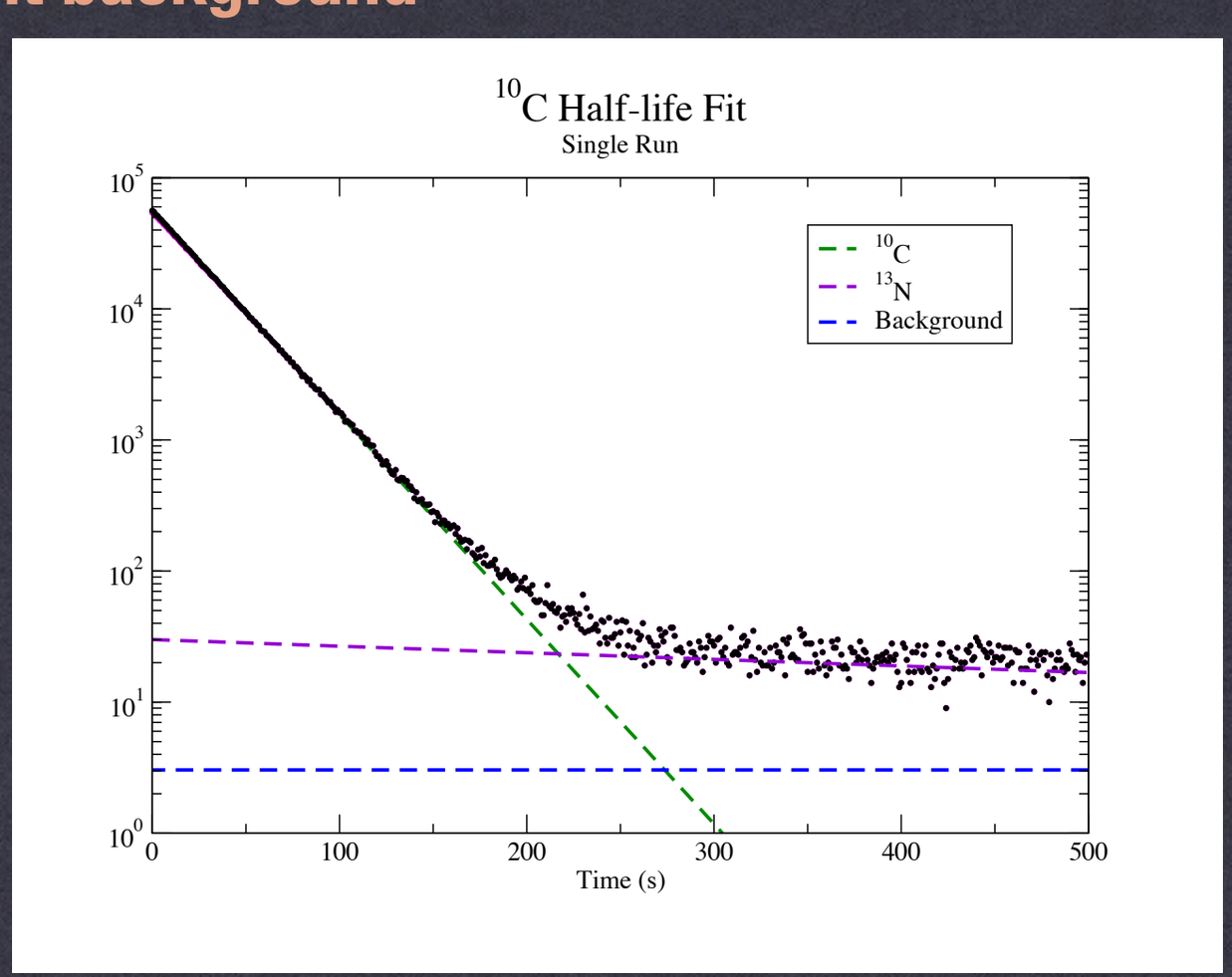


GPS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied

Fit the data with:

- Exponential decay of the primary nucleus (^{10}C)
- Exponential decay of a contaminant (^{13}N)
- A constant background



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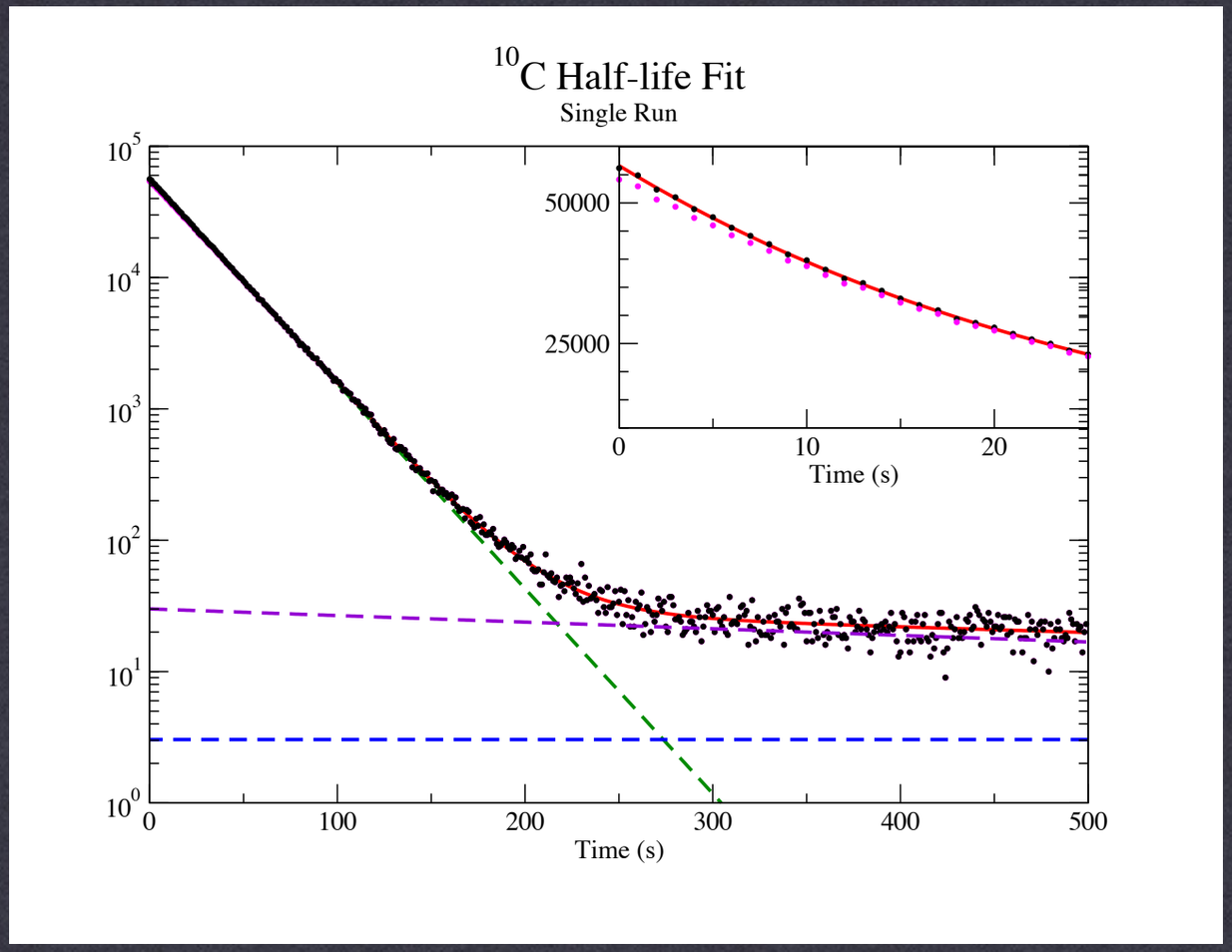
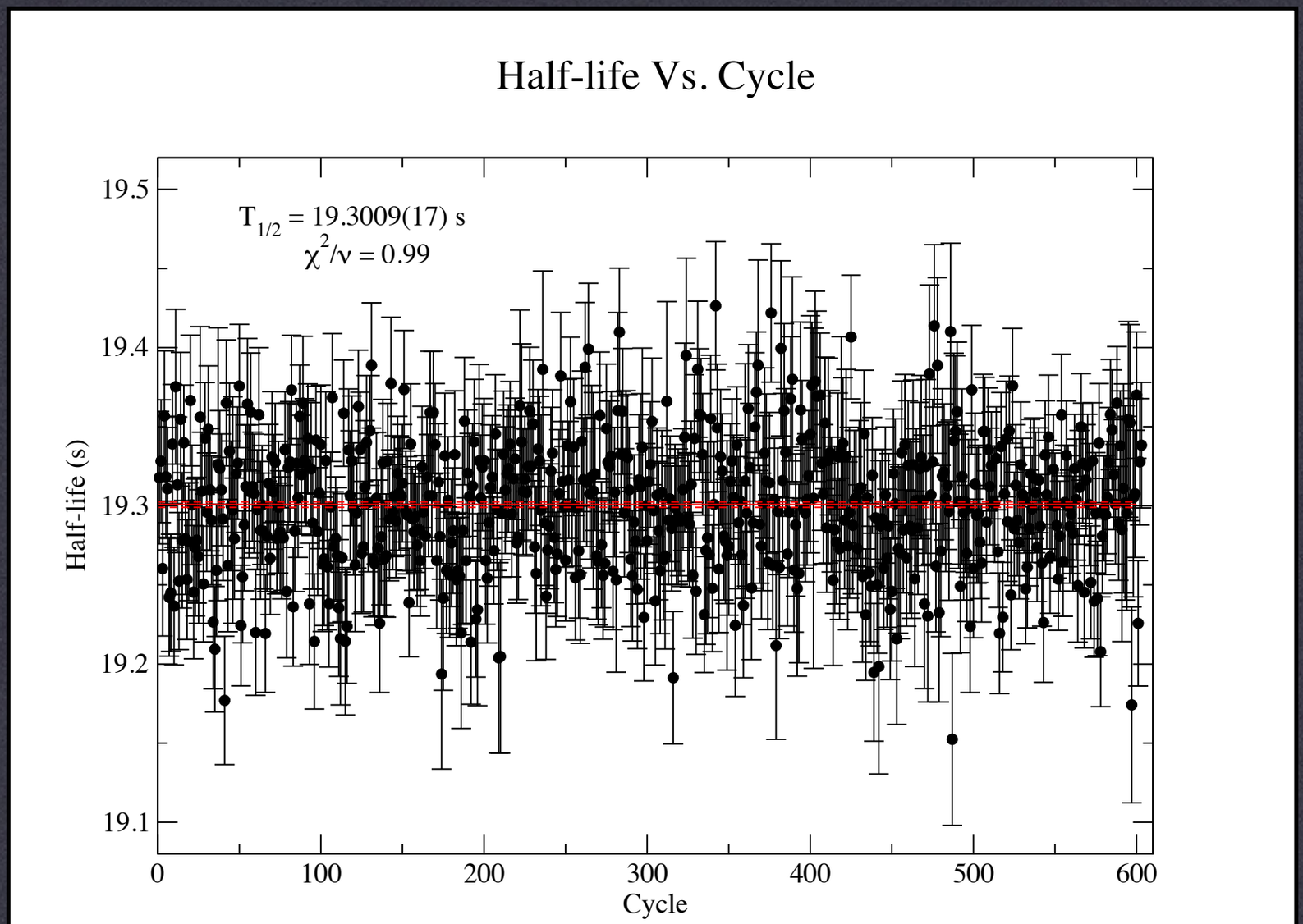


GPS EXPERIMENTAL RESULTS

Preliminary



GPS EXPERIMENTAL RESULTS

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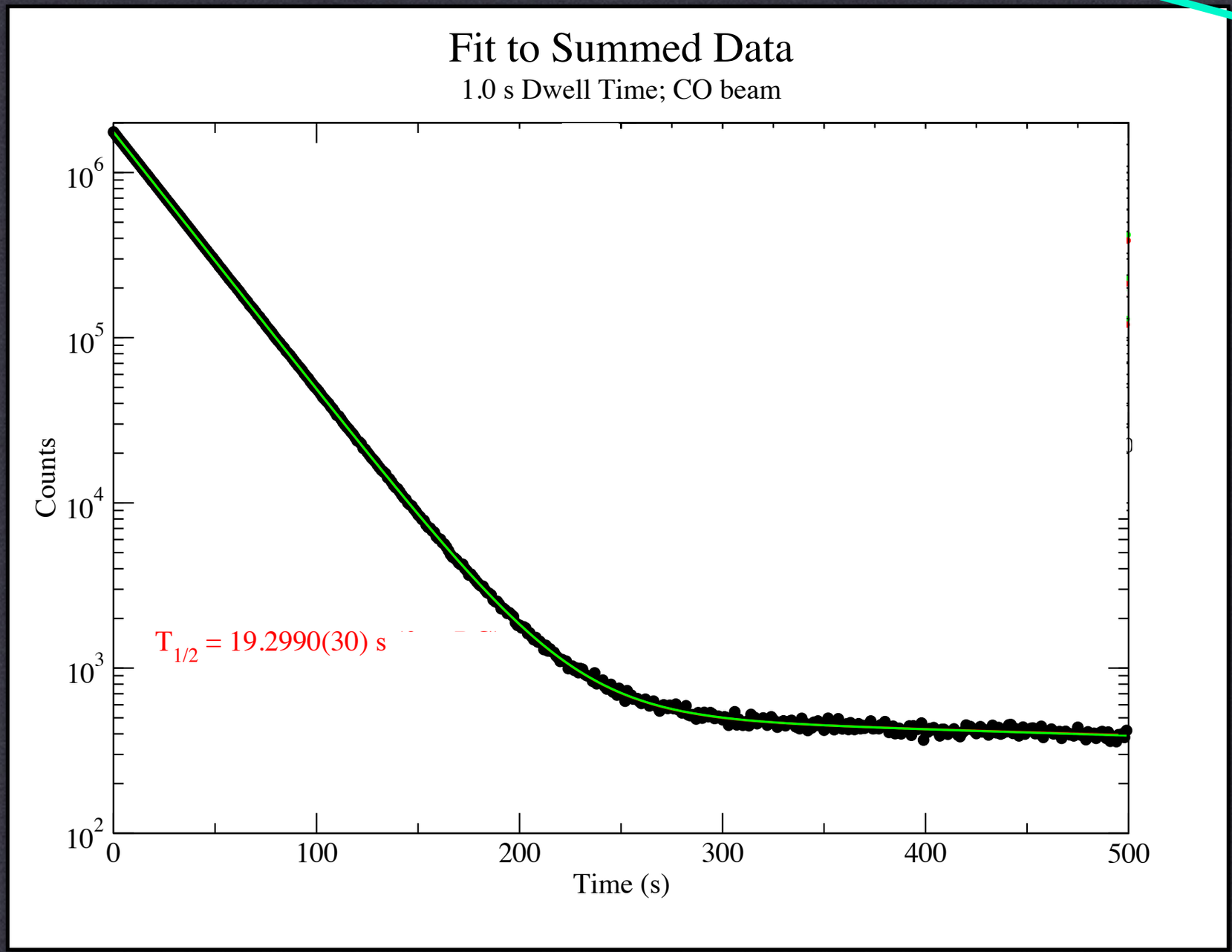
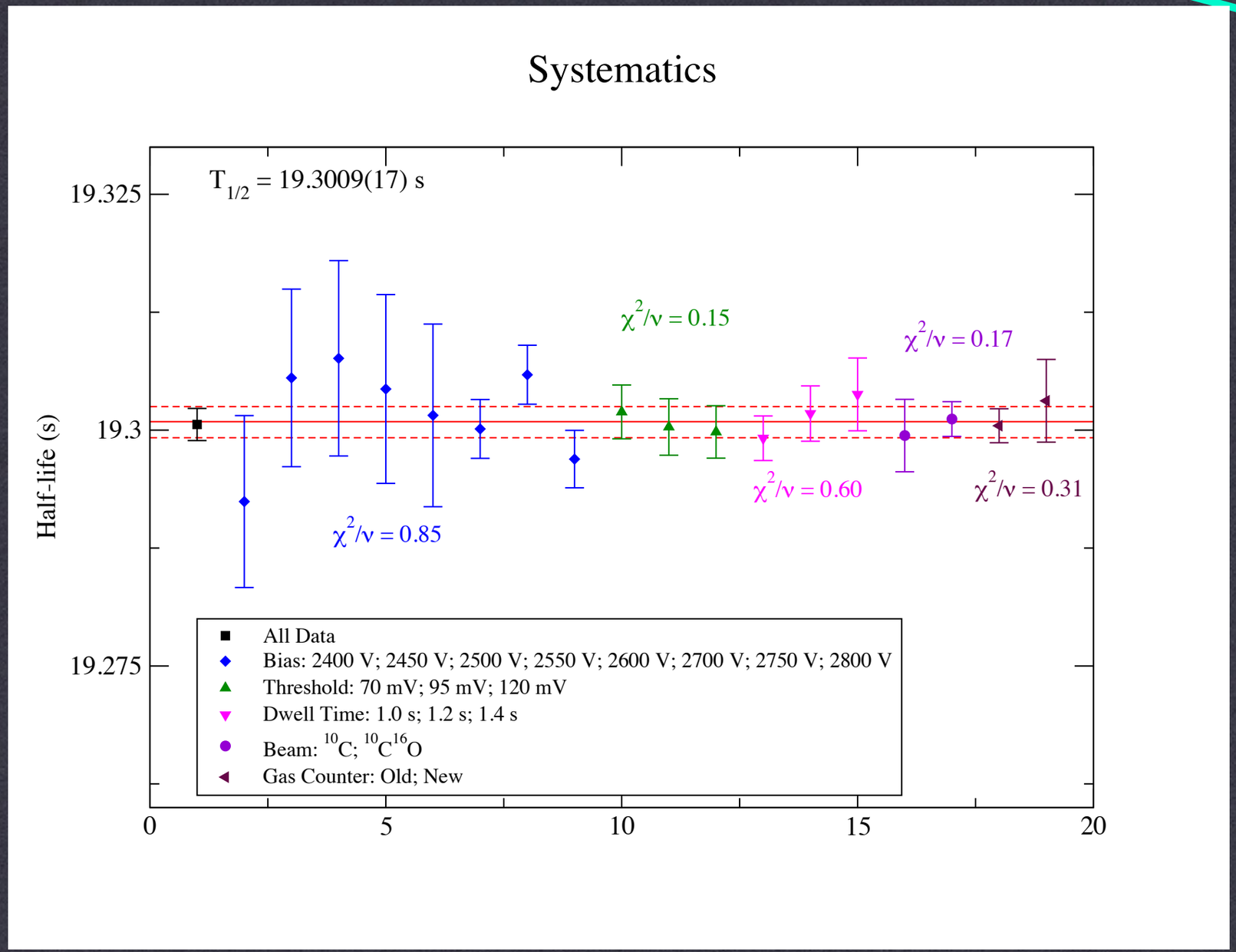


GPS EXPERIMENTAL RESULTS

Preliminary



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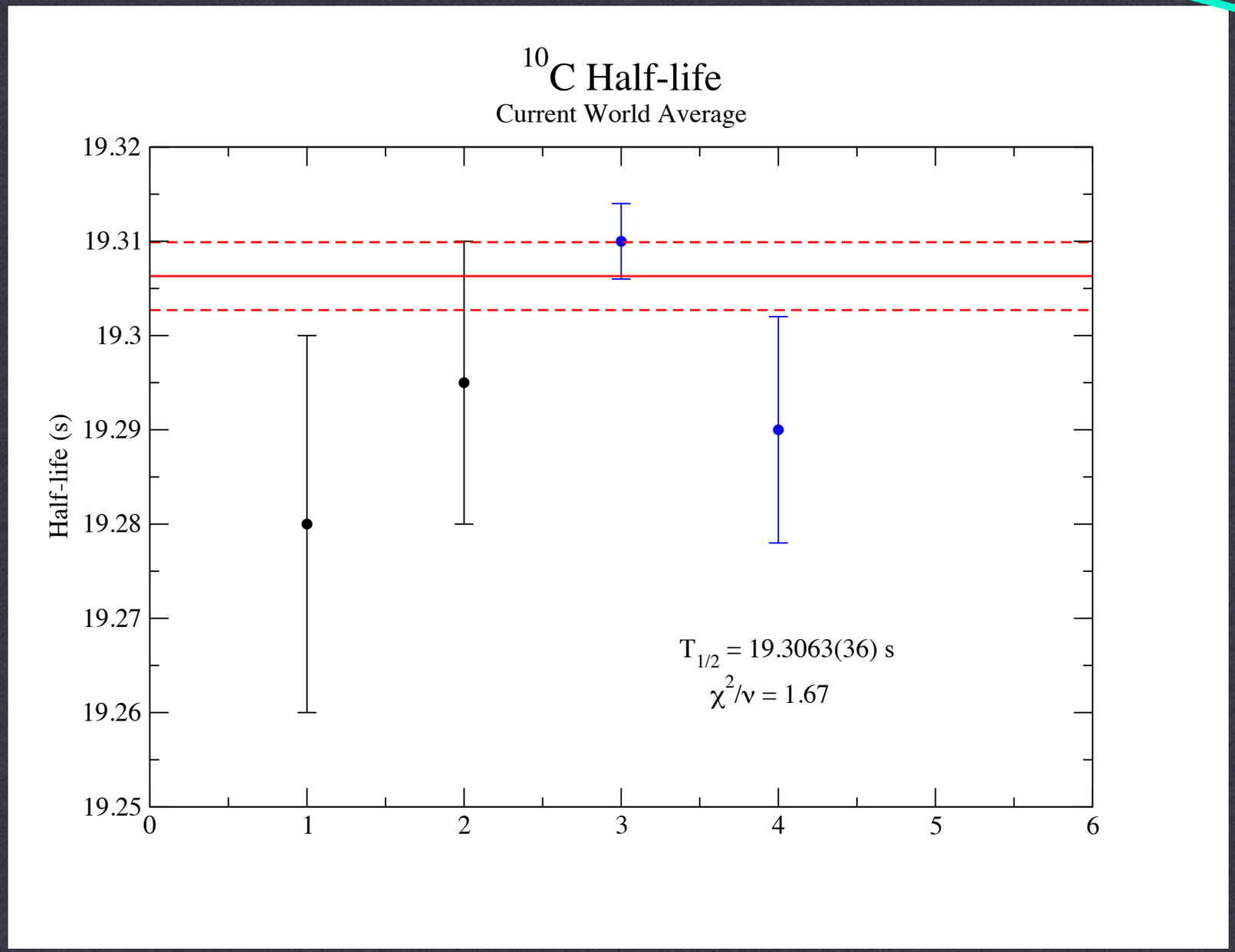
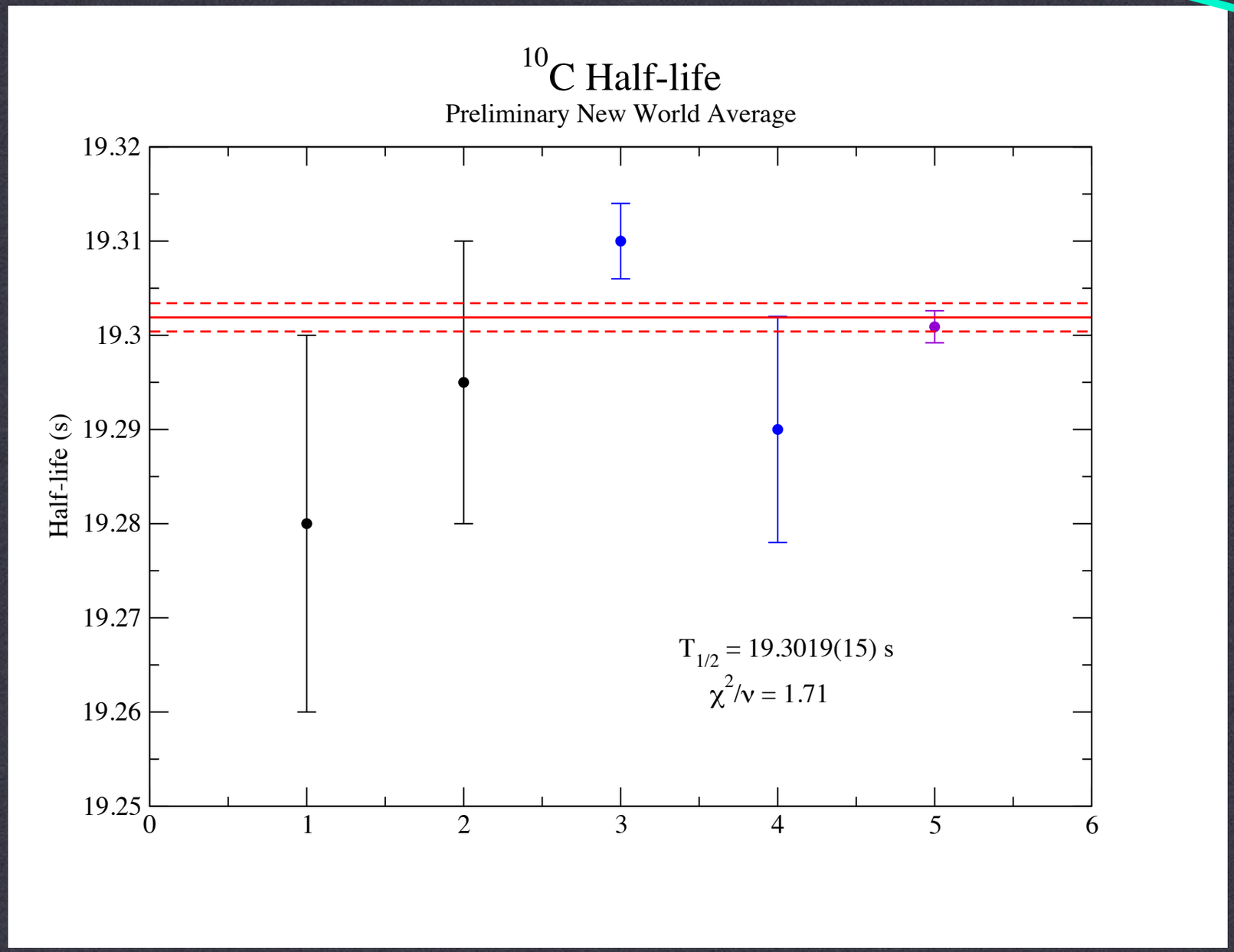
Preliminary



GPS EXPERIMENTAL RESULTS

Preliminary



8π/ZDS DATA COLLECTION

ZDS data collected with 6 independent multichannel scalers (MCS)

8π measures the energy of the γ-rays

Data was collected in cycles mode:

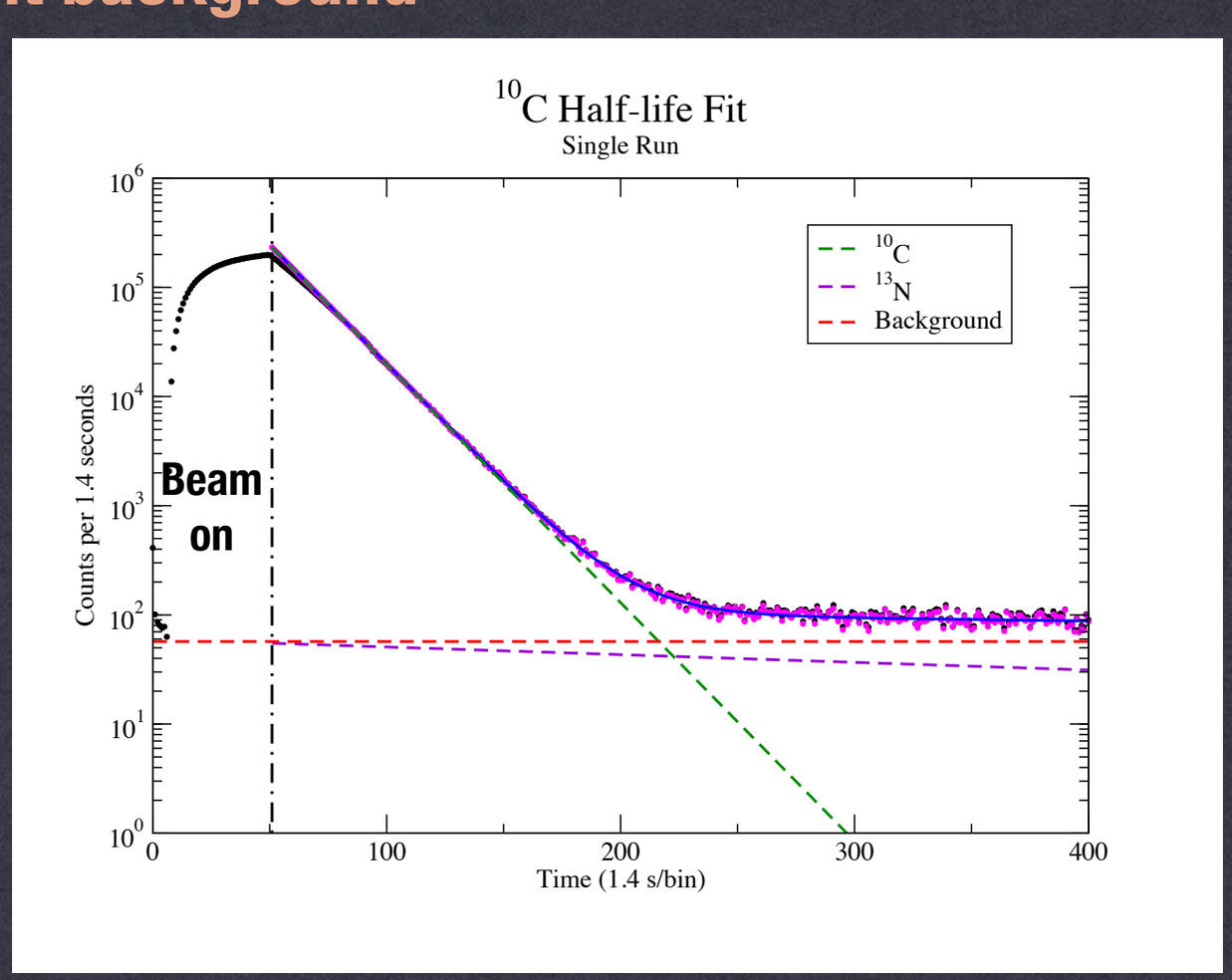
- Beam implanted on the tape already within the detector
- Measure the decay for ~ 9 minutes

ZDS EXPERIMENTAL RESULTS

Correct the raw data, accounting for dead-time applied

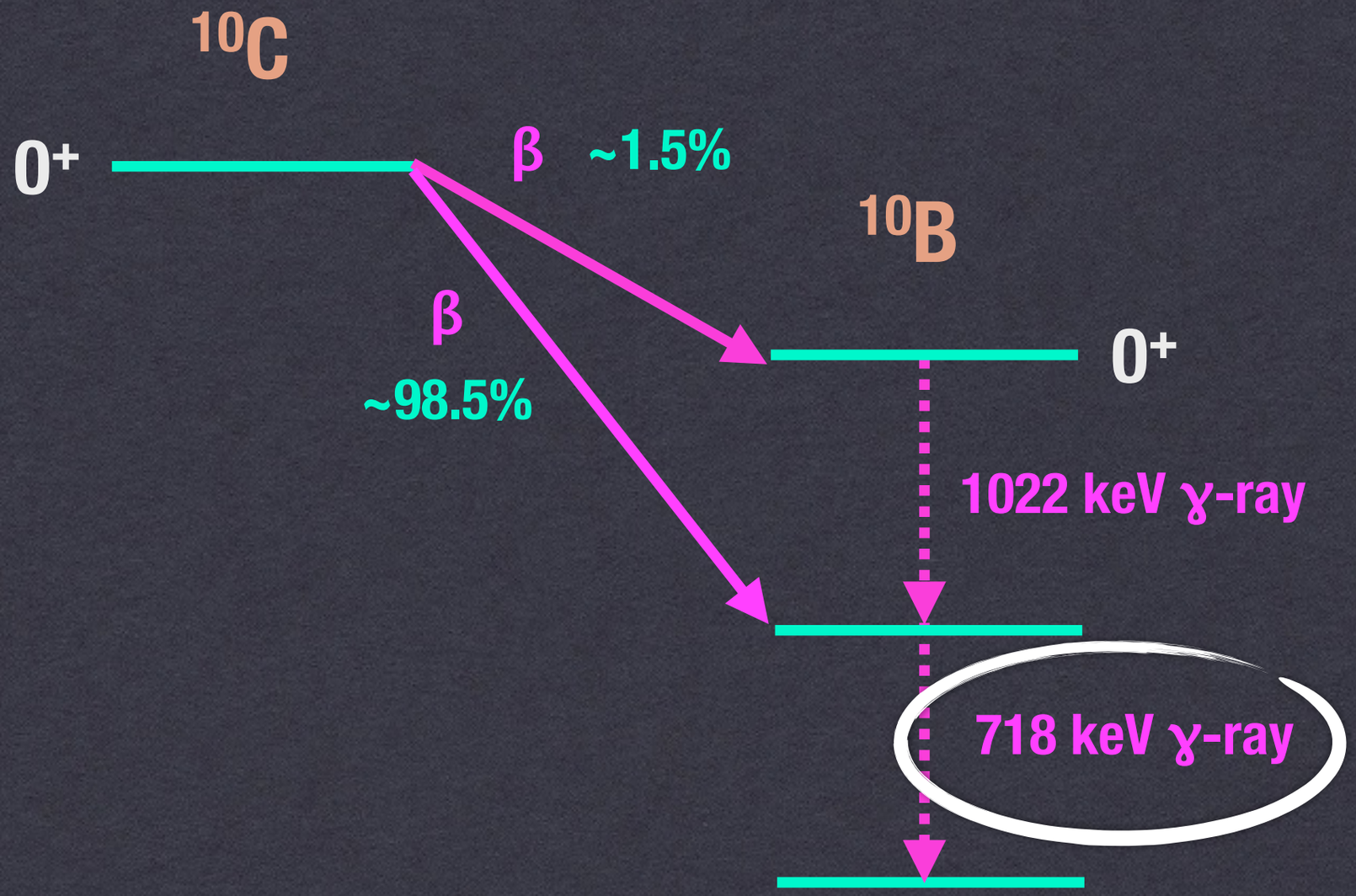
Fit the data with:

- Exponential decay of the primary nucleus (^{10}C)
- Exponential decay of a contaminant (^{13}N)
- A constant background



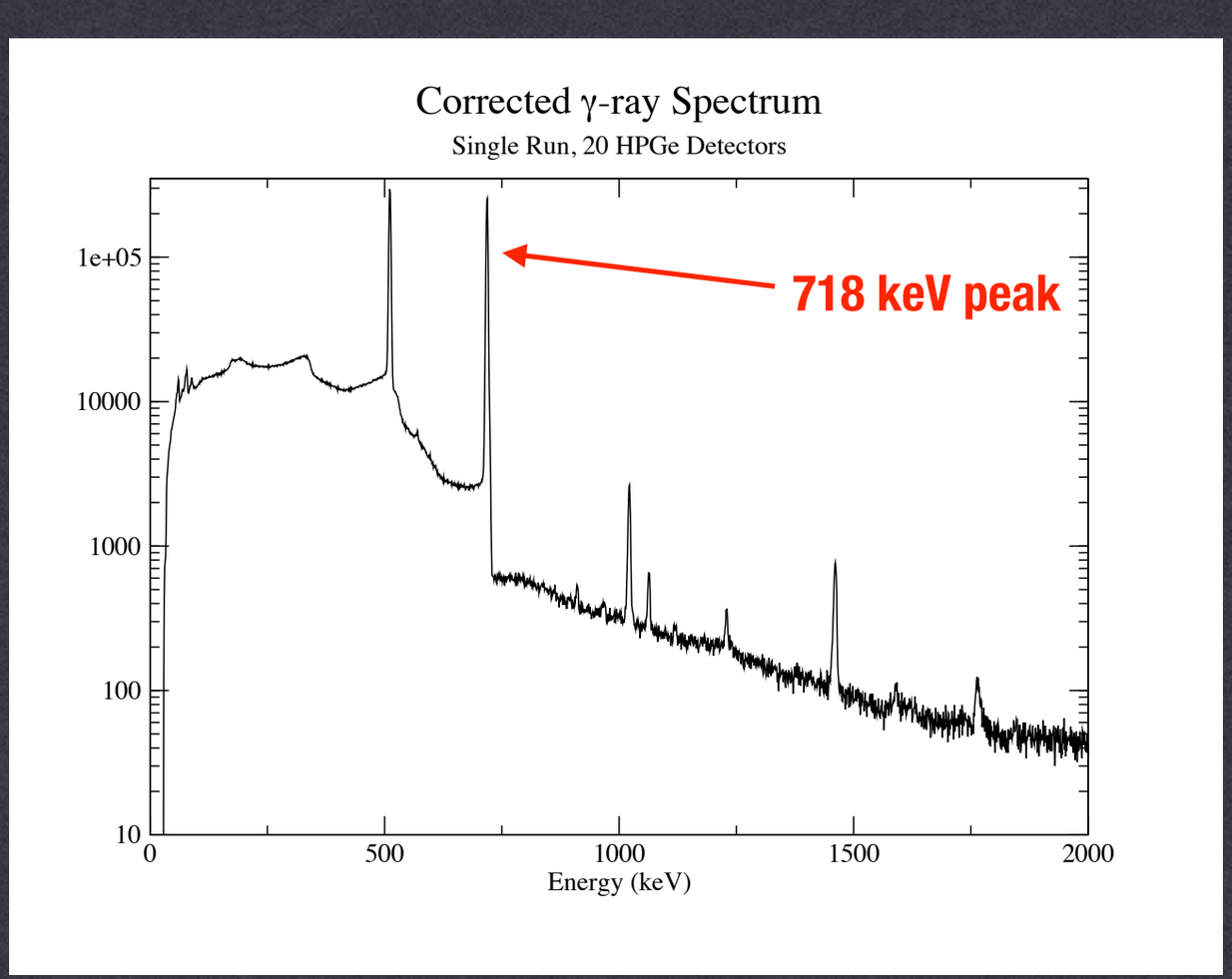
8π EXPERIMENTAL RESULTS

$T_{1/2}$ = 19.3 seconds



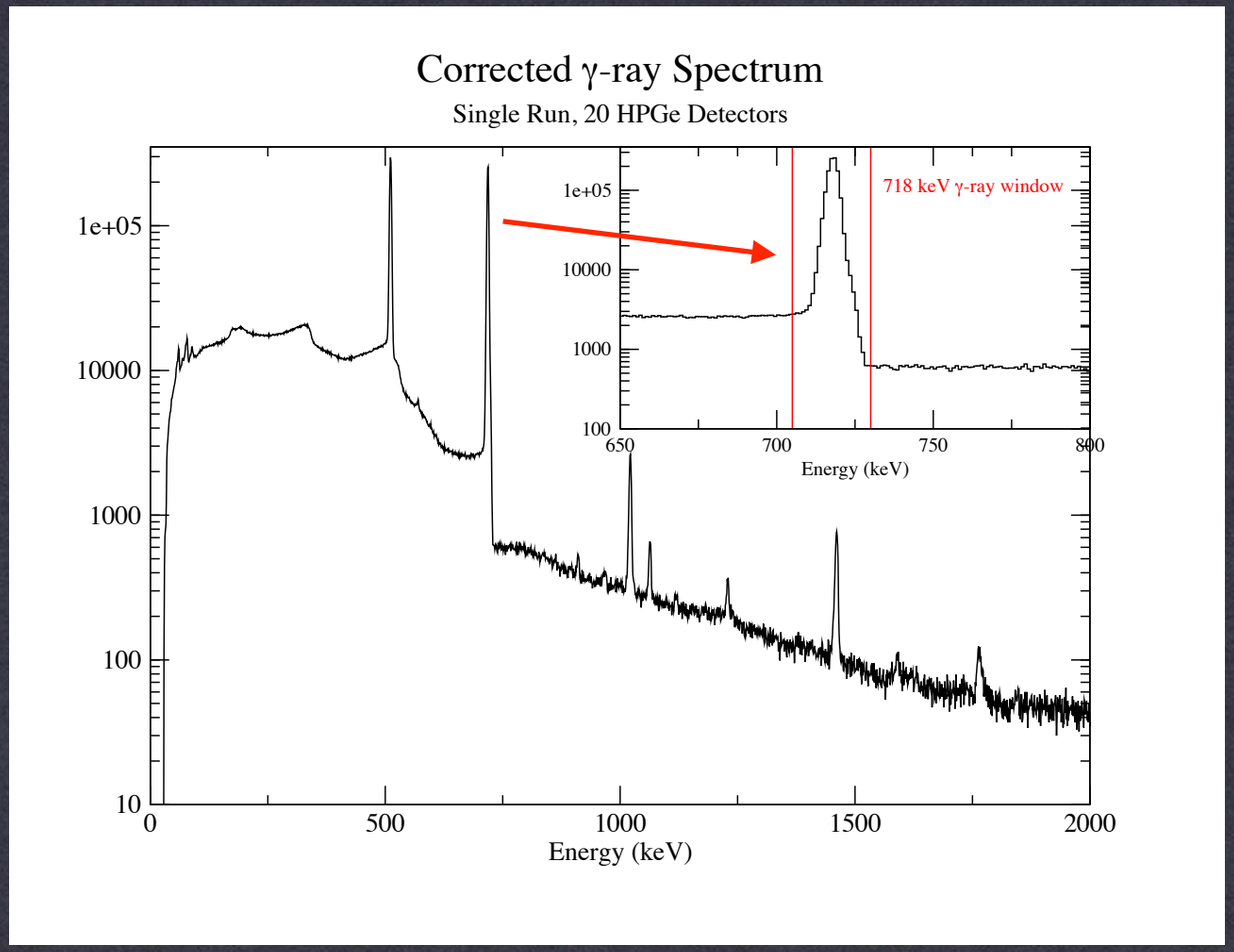
8π EXPERIMENTAL RESULTS

Correct the raw data and sum all 20 HPGe detectors



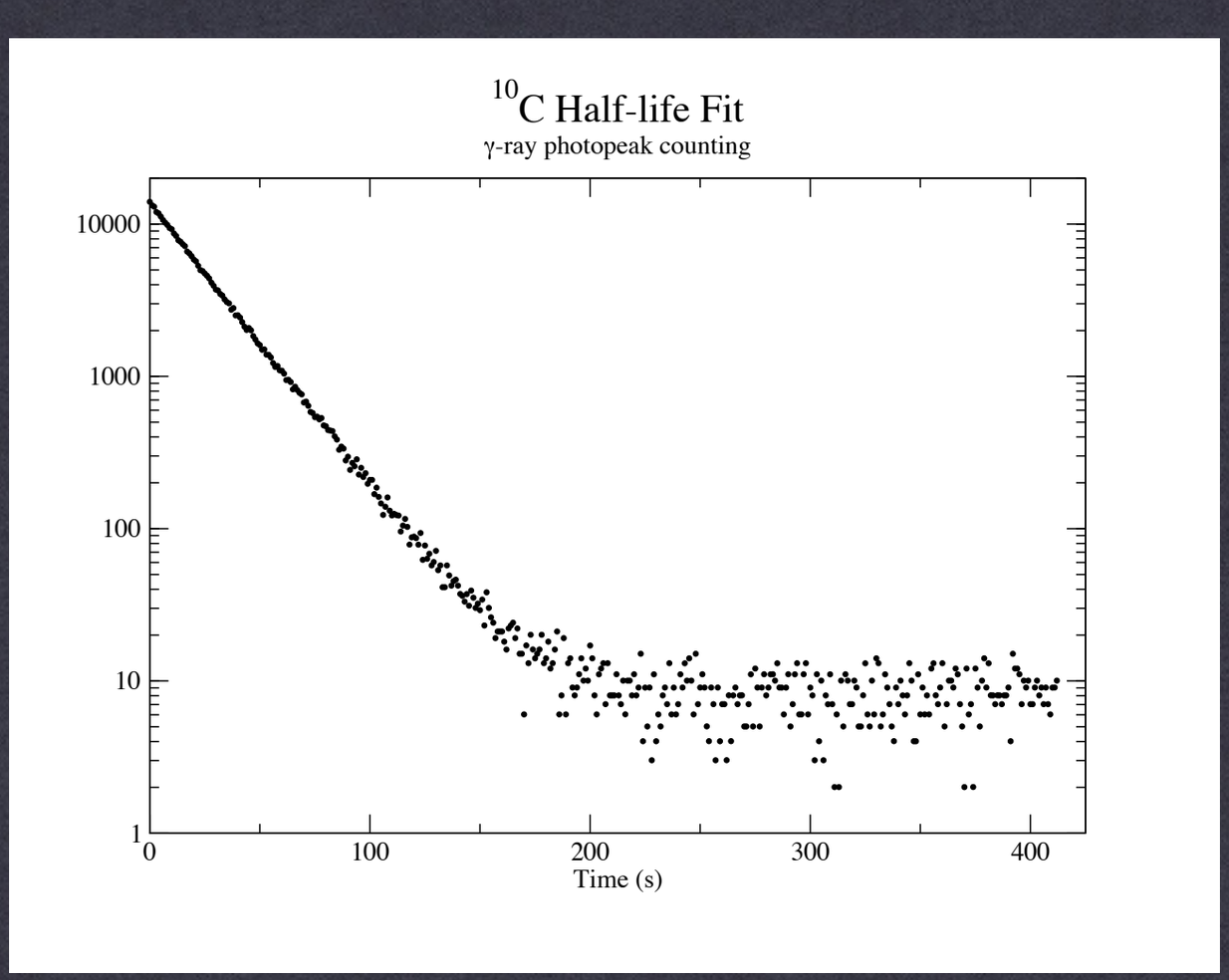
8π EXPERIMENTAL RESULTS

Correct the raw data and sum all 20 HPGe detectors
Gate on 718 keV photopeak



8π EXPERIMENTAL RESULTS

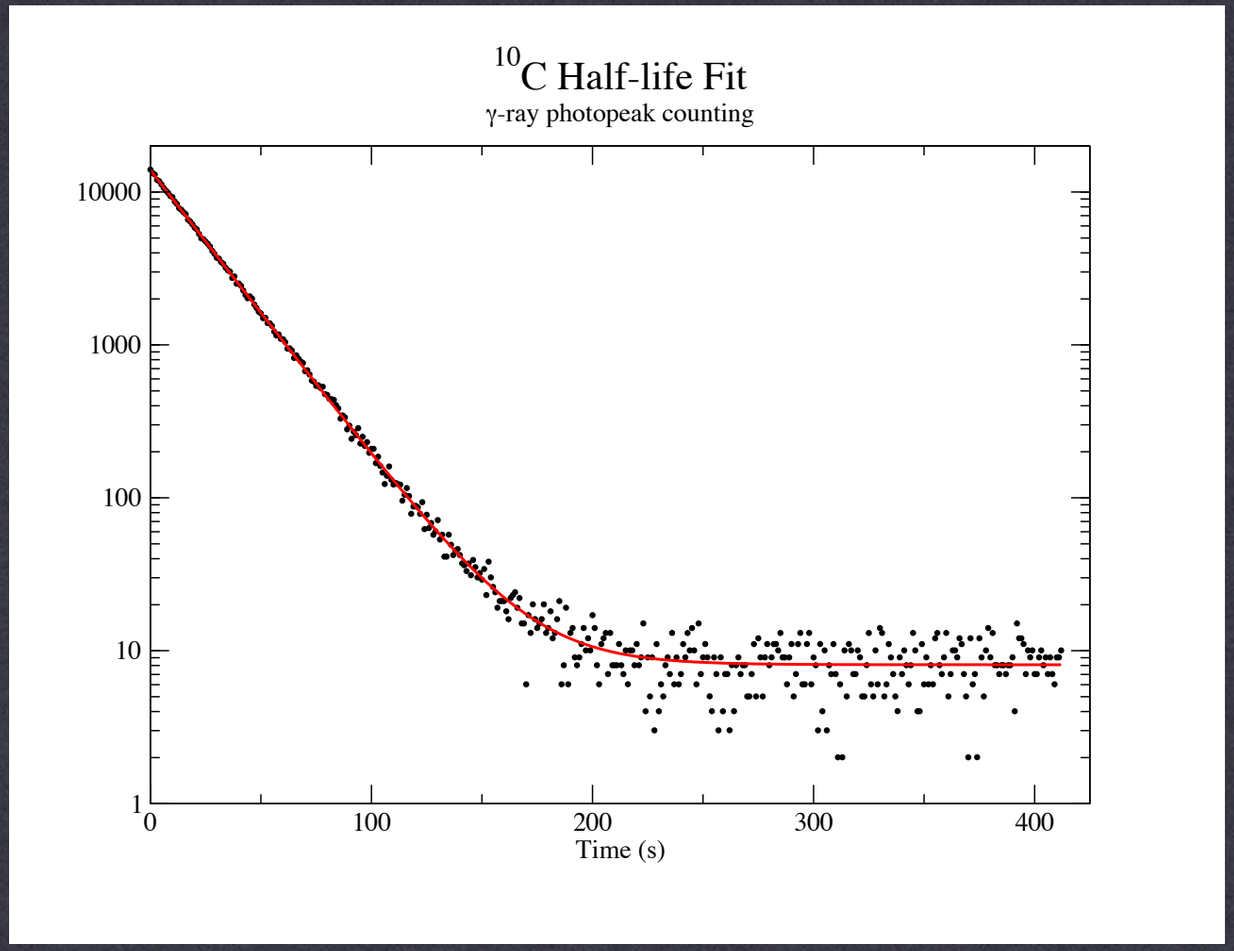
Correct the raw data and sum all 20 HPGe detectors
Gate on 718 keV photopeak and get the corresponding time projection



8π EXPERIMENTAL RESULTS

Correct the raw data and sum all 20 HPGe detectors
Gate on 718 keV photopeak and get the corresponding time projection
Dead-time and pile-up correct data
Fit the data with:

- Exponential decay of the primary nucleus (^{10}C) and a constant background



CONCLUSIONS

High-precision ^{10}C half-life measurement experiments were performed at TRIUMF's ISAC facility

- **Simultaneous β^+ and γ-ray measurements performed**

Statistical precision of 0.02% (γ) and 0.009% for each β^+ measurement was achieved

Full γ-ray and second β analysis to be completed

University of Guelph

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BACKUP SLIDES

FT VALUES

Ft value obtained using new (preliminary) $T_{1/2}$ value