

# Measurement of Positronium Hyperfine Splitting with Quantum Oscillation

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## Introduction

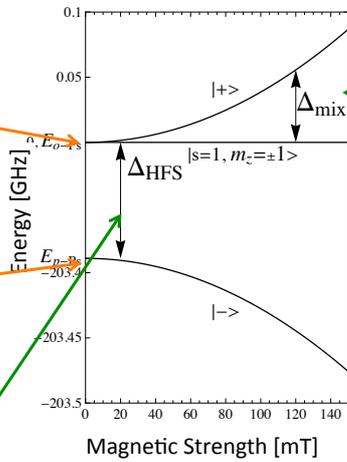
### Positronium

#### Ortho-Positronium (o-Ps)

- Spin 1 (triplet).
- Lifetime = 142ns.
- Mainly decays into three gamma rays.

#### Para-Positronium (p-Ps)

- Spin 0 (singlet).
- Lifetime = 125ps.
- Mainly decays into two 511keV gamma rays.



### Ps Hyperfine Splitting

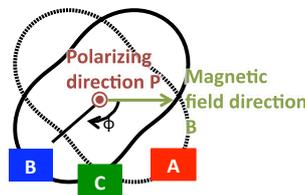
- Hyperfine Splitting (HFS) is the energy difference between o-Ps and p-Ps.
- We measure Ps Hyperfine splitting with "quantum oscillation".

### Quantum Oscillation

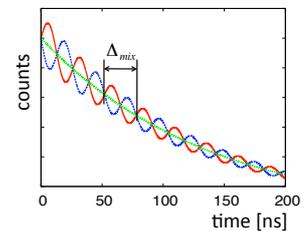
The superposition of  $|+\rangle$  and  $|s=1, m_z = \pm 1\rangle$  oscillates with the frequency  $\Delta_{mix} = \frac{\Delta_{HFS}}{2} (\sqrt{1 + \chi^2} - 1)$  ( $\chi(B, \Delta_{HFS}) \ll 1$ )

### How to detect the oscillation?

- A radioactive beta source emits polarized positrons. → Polarized Ps forms.
- In this system, the quantum oscillation becomes an observable quantity.
- The oscillation amplitude is maximized when the polarized direction is set perpendicularly to the magnetic field.
- The oscillation modulates the angular distribution of the gammas emitted from o-Ps decay. → The decay counts also oscillates.



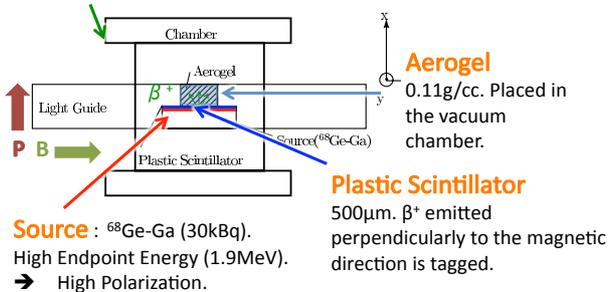
Angular distribution of the gamma rays (The radius shows the amplitude of emission.)



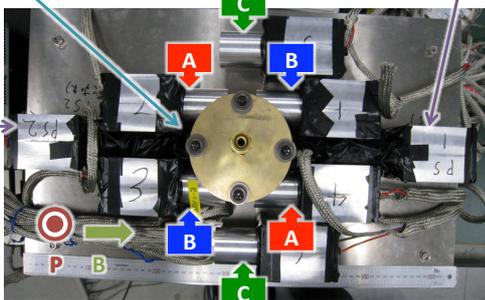
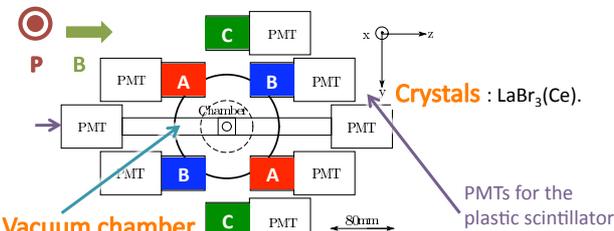
Expected decay curves

## Experimental Setup

### Vacuum Chamber

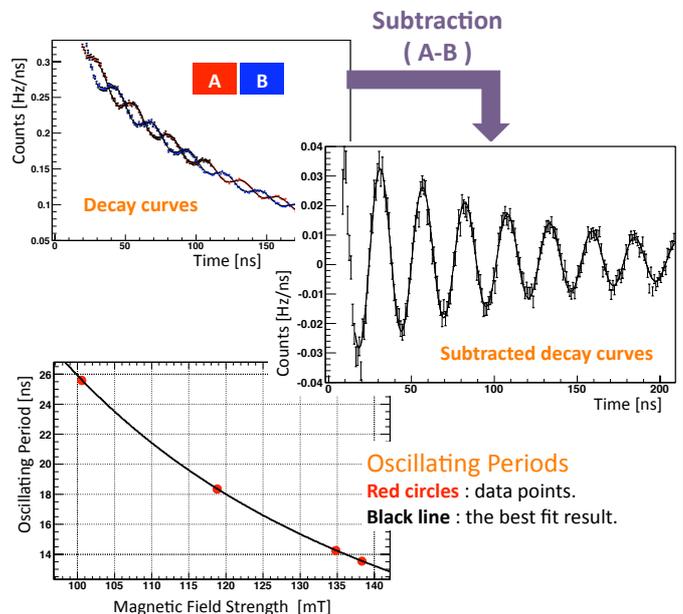


### Gamma Detectors



## Analysis and Conclusion

### Timing Histograms @ 100mT



### HFS value

- The combined result is  
 $HFS = 203.328 \pm 0.044(\text{stat.}) (215\text{ppm}) \pm 0.028(\text{sys.}) (140\text{ppm}) \text{ GHz}$   
cf. 202.5±3.5GHz (S. Fan et al., 1996)
- The systematic error mainly comes from the uncertainty in the calibration of the magnetometer.
- This result is consistent with the theoretical calculation and the previous experimental results.