Experiment for the First Direct Measurement of the Hyperfine Splitting of Positronium

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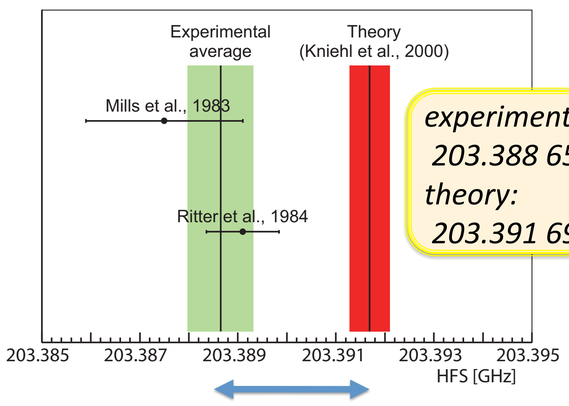
HFS problem in Positronium & Direct measurement

HFS problem

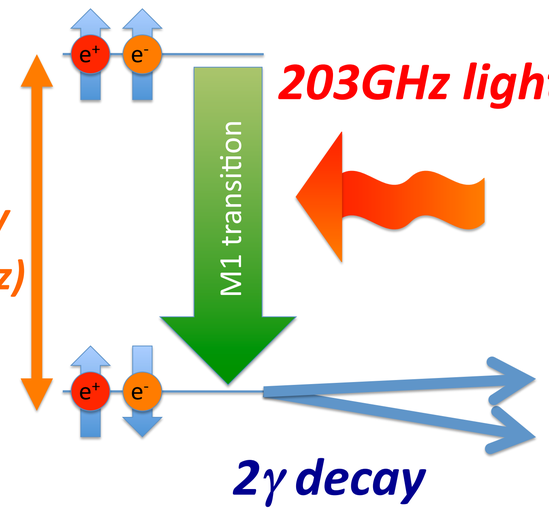


experiment:
203.388 65(67) GHz 3.3ppm
theory:
203.391 69(41) GHz 2.0ppm

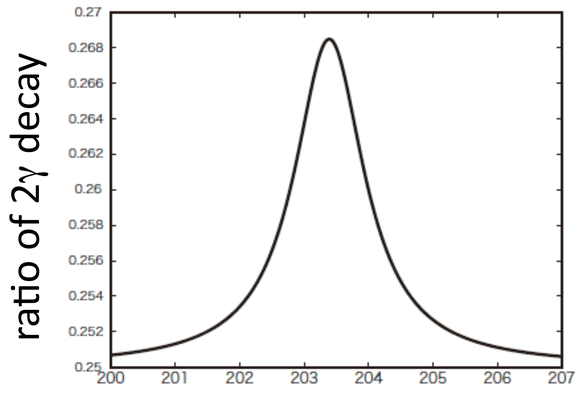
15ppm (3.9σ)

o-Ps
lifetime: 142nsec
3γ Decay

p-Ps
lifetime: 125psec
2γ Decay



2γ-decay Resonance at HFS=203GHz

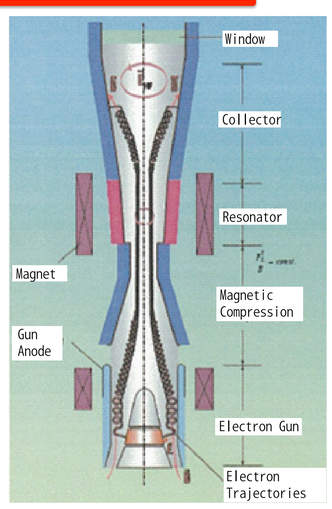


- We suspect overlooked systematic errors in former experiments, and plan to measure HFS directly with M1 transition.
- No direct measurements have been performed ever.
- Since transition rate is 0.3×10^{-8} sec^{-1}, we need high power sub THz light → Gyrotron & Fabry-Pérot cavity.

High power sub THz light source: Gyrotron

The principle of Gyrotron

- electron-gun
- electrons rotate under strong magnetic field
- cavity in Gyrotron tuned in resonant frequency of cyclotron motion of electrons
- radiation from this cavity is picked out from upper side of Gyrotron



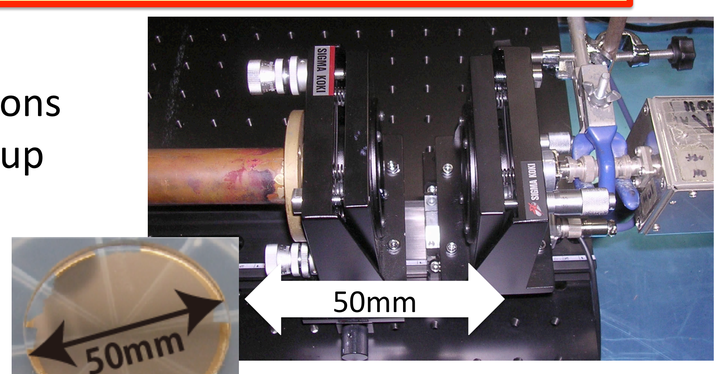
Gyrotron FU CW V

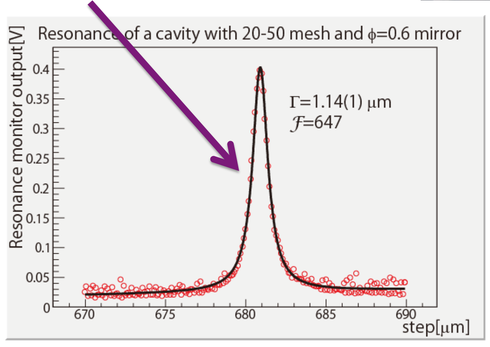
- 203GHz (1.4mm) light source
- High power (600W)
- Monochromatic
- Stable
- Dedicated for our HFS study

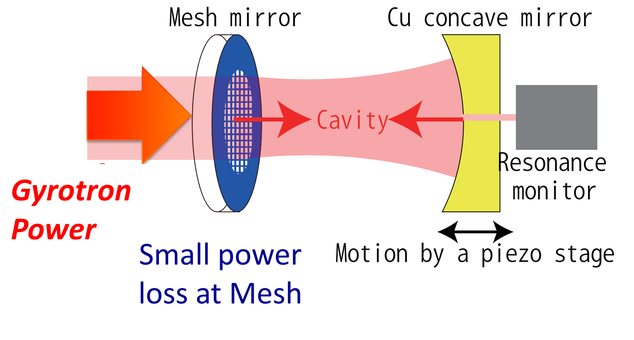
Resonator for sub THz light: Fabry-Pérot cavity

Fabry-Pérot cavity

- It can accumulate photons to increase their density up to 100 times
- Fine mesh mirror (99% reflection)
- Good Coupling
- Finesse > 630 obtained

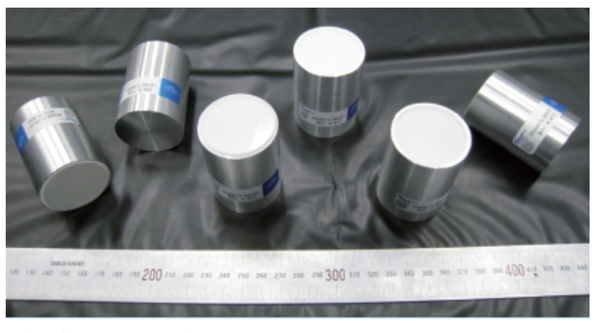






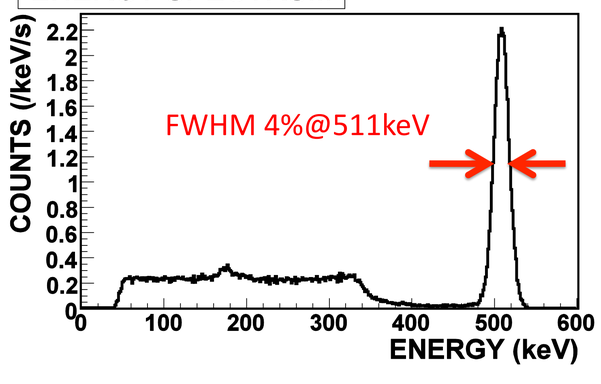
γ detectors & β^+ detectors

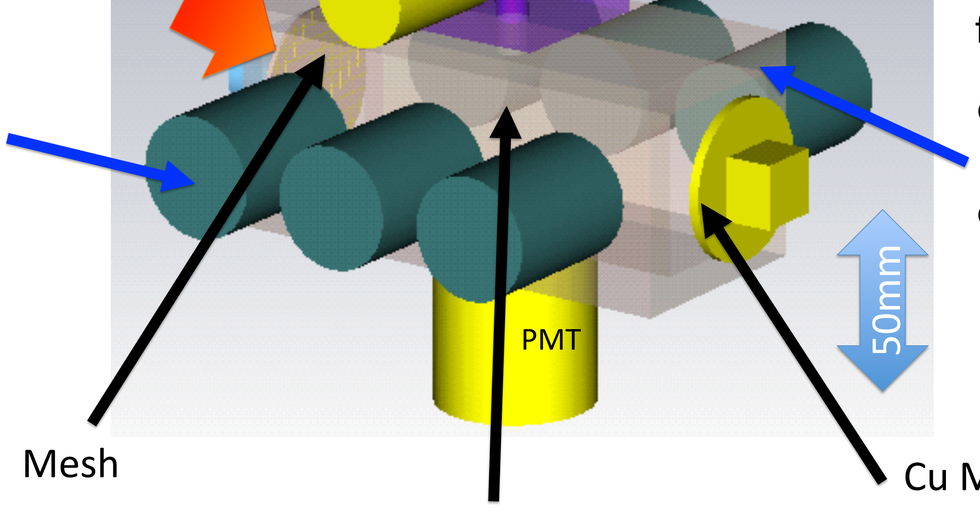
- $LaBr_3$(Ce) γ-detector: detects decayed γ with high energy resolution (FWHM 4%@511keV)
- High energy resolution is important to eliminate 3γ contamination



$LaBr_3$ crystals
(2.0 inches long, 1.5 inches in diameter)

ENERGY SPECTRUM





- ^{22}Na β^+ source (700kBq)
- Plastic scintillator: detects the timing of β^+ emission
- Timing information is used to eliminate γ from positron annihilation → enhance S/N
- Veto scintillator: discards events if β^+ doesn't stop in Cavity
- It eliminates Accidental backgrounds

- Positronium is formed in Fabry-Pérot Cavity
- Fabry-Pérot Cavity is filled with N_2+ isobutane 1.0atm
- N_2: e^- source
- Isobutane: quencher

Current status & Future plan

- Now optimizing some parameters of resonator and detection system
- First measurement of transition is planned in about a year