# Microwave spectroscopy of the n=2 positronium fine structure



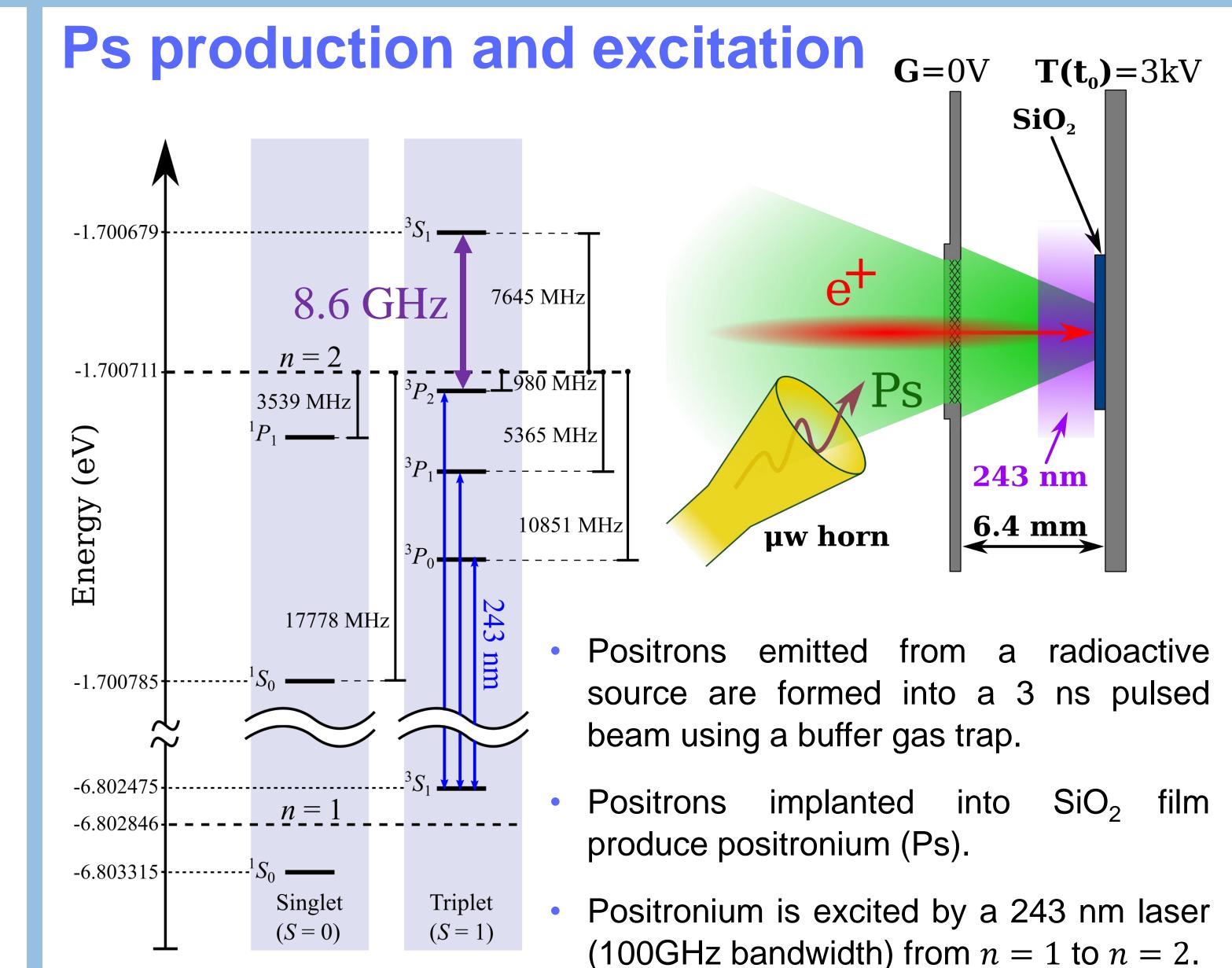
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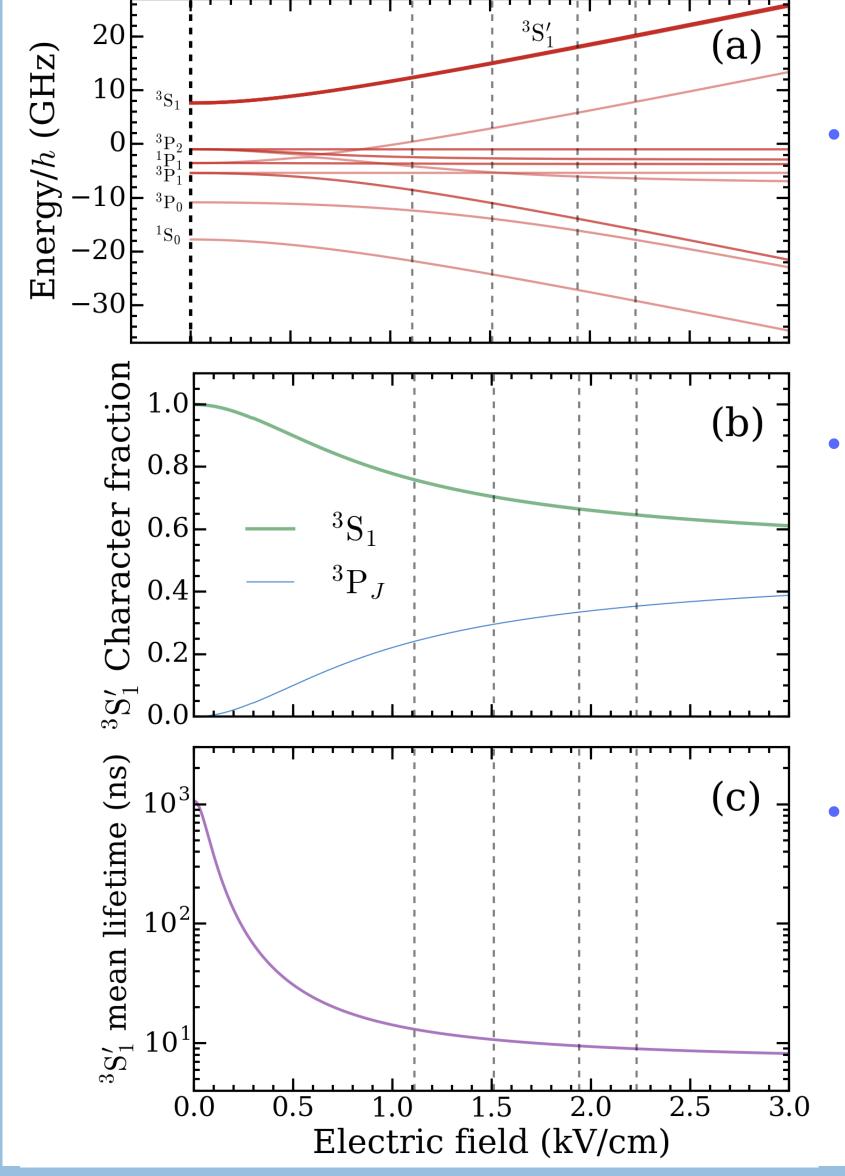
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## Introduction

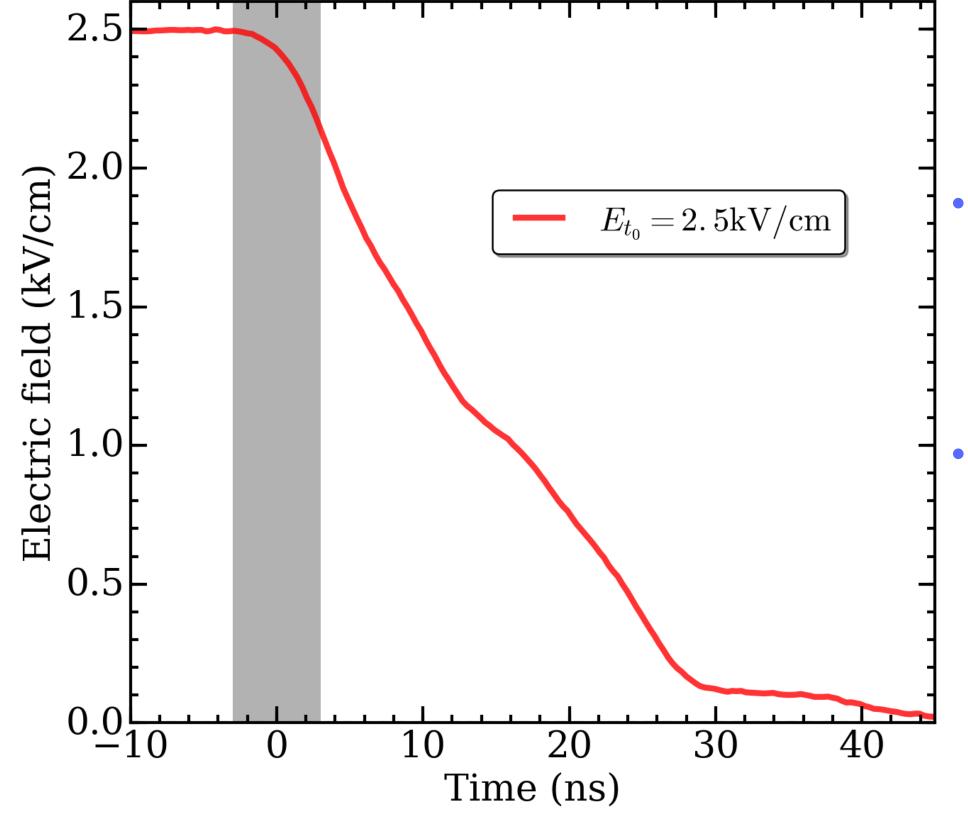
- Positronium (Ps) is the bound state of an electron and a positron.
- Ps can be used to test QED [1] since it is purely leptonic.
- Previous studies [2] have performed n=2 microwave spectroscopy of Ps with ~200 ppm uncertainty.
- Previous microwave studies of n=2 used a small fraction of  $2^3S_1$  atoms (~0.01%) that were produced by colliding positron ( $e^+$ ) pulses into metal surfaces [3].
- Atoms produced this way [2] had large kinetic energies, interaction times of ~20 ns during which microwave transitions had to be driven, large amounts of microwave power was needed to achieve the required Rabi frequencies.
- We have developed a new method of 2<sup>3</sup>S<sub>1</sub> production using single-photon laser excitation into stark mixed states [4] which efficiently produces slower Ps atoms with interaction times of ~500 ns (until collision with vacuum chamber), thus requiring lower Rabi frequencies and less microwave power.



# Ps 2<sup>3</sup>S<sub>1</sub> state production



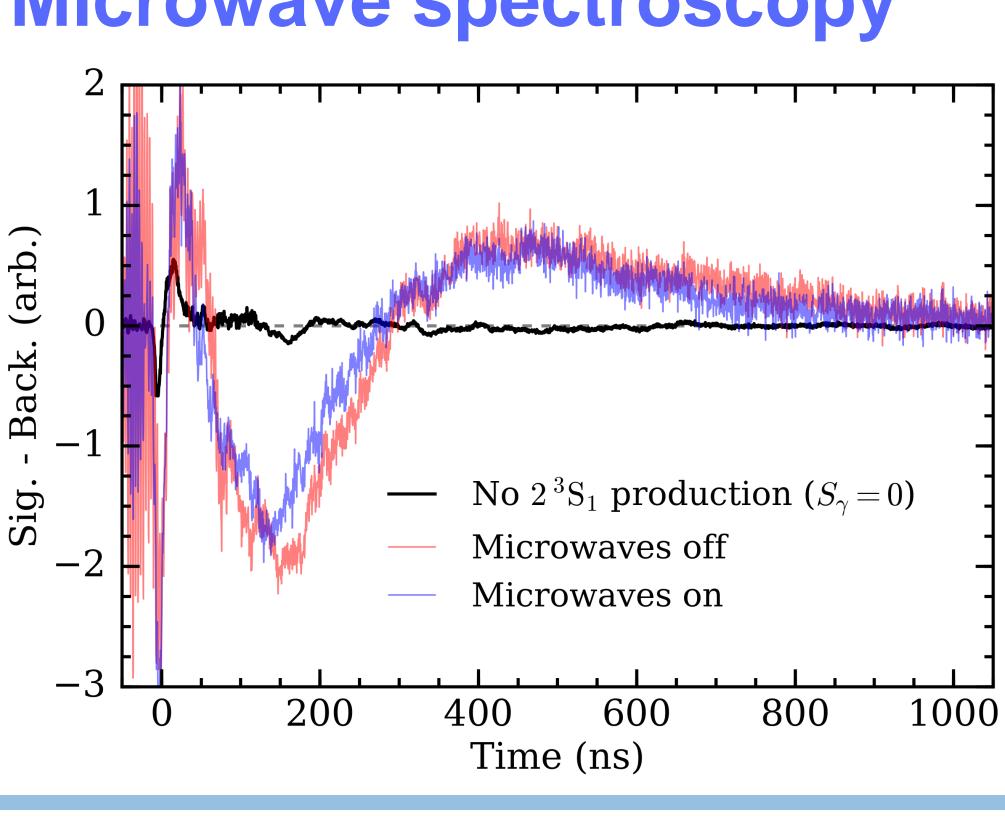
- the  $2^3S_1 \rightarrow 2^3P_2$ measure microwave transition, 2<sup>3</sup>S<sub>1</sub> states are created via a one-photon transition.
- n = 1 Ps atoms excited to Stark- 21.0mixed n=2 states (in a large  $\frac{1}{2}$ electric field) which are  $\sim 60\% \ 2^3 P_I \ \Box$ and  $\sim 40\% \ 2^3S_1$ . These states are labelled  $2^3S'_1$ .
- The  $2^3P_I$  character makes the dipole-allowed. transition Therefore it can be driven by a single laser.



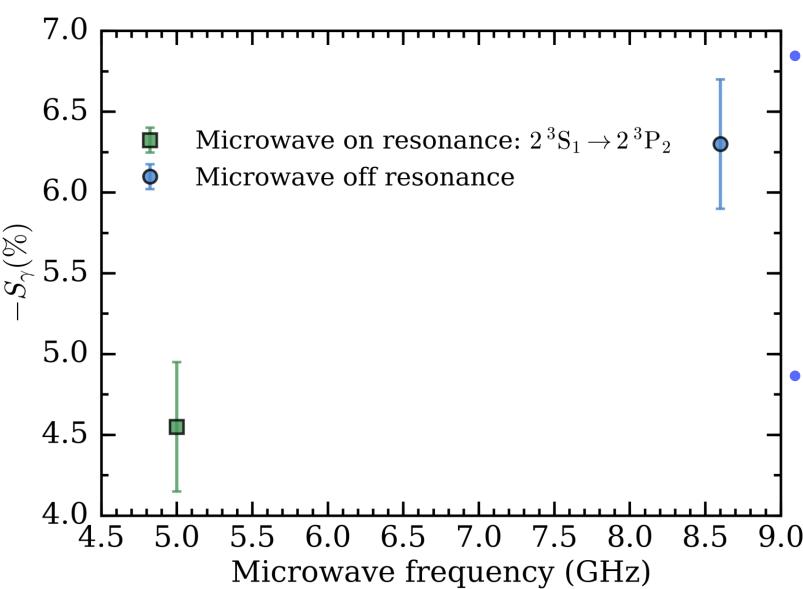
 After laser excitation (grey bar) the electric field is quickly reduced to ~0 V/cm by lowering the voltage applied to the target electrode.

- adiabatically states evolve to pure 23S1 states with ~13% efficiency.
- Ps atoms in pure 2<sup>3</sup>S<sub>1</sub> states have long lifetimes (~1.1µs) and flight times.
- interaction times Long (~500 ns before colliding with chamber walls) during which  $2^3S_1 \rightarrow 2^3P_2$  transition can be driven, but we don't currently use a waveguide, so power density is low.
- Power will be increased once a waveguide is used, flight time will still be a few hundred ns.

## Microwave spectroscopy



- Background-subtracted spectra data of Ps annihilation gammarays.
- **Black** spectrum: no 2<sup>3</sup>S<sub>1</sub> state creation (constant electric field).
- Red spectrum: Adiabatic extraction of 2<sup>3</sup>S<sub>1</sub> states signal.
- Blue spectrum: 2<sup>3</sup>S<sub>1</sub> states microwaves resonant with the  $2^3S_1 \rightarrow 2^3P_2$  transition.



Ps fractional change in signal microwave  $S_{\nu}(\%)$ shows a effect difference of resonance  $\sim 3.5\sigma$ .

Need more datapoints to make a measurement of the resonance lineshape width (expected ~50MHz).

Current microwave horn coupling scheme has strong power wavelength dependence.

waveguide Using a provide better power coupling to system.

#### Outlook

Data shows that we can drive this microwave transition. It will be necessary to increase microwave power to increase signal. New method uses a nearthermal source of slow Ps [5] and measurements are time-resolved so background from other decay channels is negligible. Measurements with ~100 kHz accuracy are possible thus improving previous measurements comparing QED and experiment [2] by an order of magnitude.

### References

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