Mass Producing Positrons Using Ultaintense Lasers and their Applications

Gerald D'Arco
Columbia University

Outline

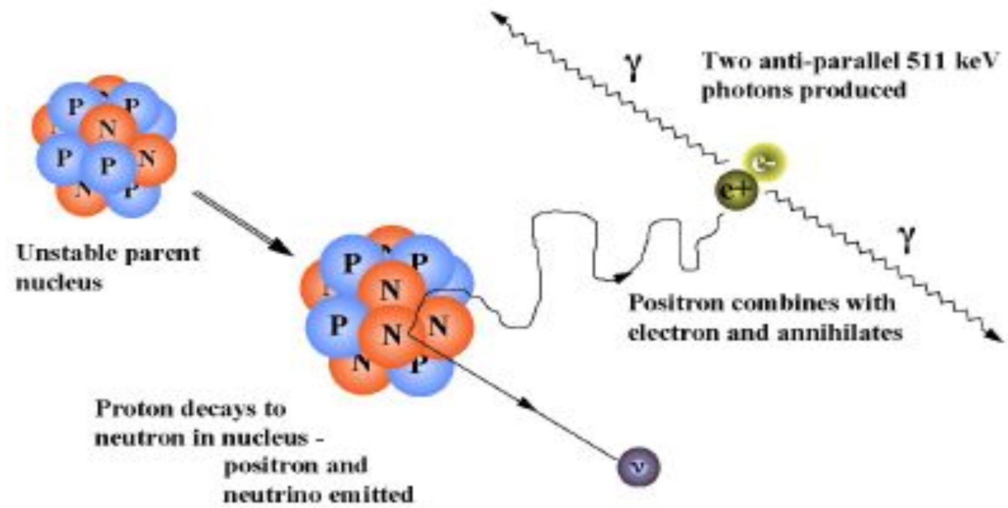
- What are positrons?
- How are they formed?
- Mass production of positrons (LLNL experiment)
- Various applications

What are Positrons?

- Antimatter partner of the electron
- $m_p = m_e$, $S_p = S_e = 1/2$, $Q = +e$
- First Theorized by Paul Dirac in 1928
- Discovered by Carl D. Anderson in 1932 who won the Nobel prize in 1936

How Positrons Are Created

- Radioactive β^+ Decay – "positron emission"
- Created by radioactive sources
- Low E ~ some thousand eV
- Used in medical imaging (PET)



How Positrons Are Created

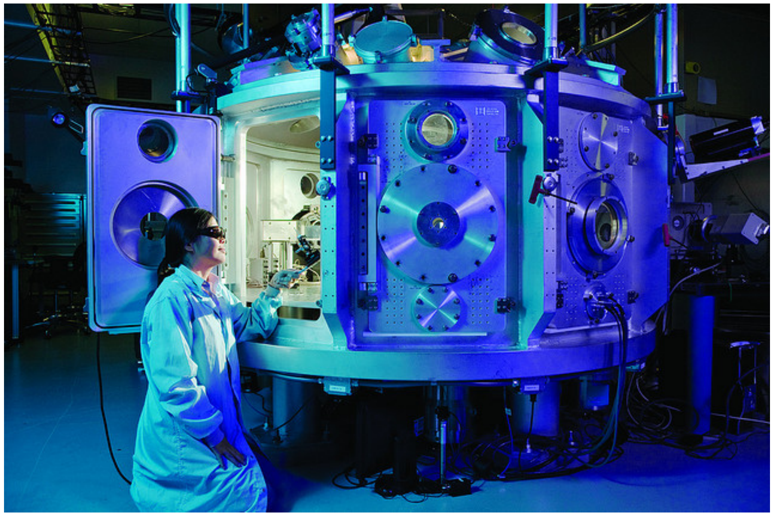
- Hot Electrons via two processes:
  - Trident Process
    - $e + A \rightarrow e' + A' + e^-e^+$
  - Bethe-Heitler Process
    - $e + A_1 \rightarrow e' + A_1' + \Upsilon$ followed by $\Upsilon + A_2 \rightarrow A_2' + e^-e^+$
- Hot electrons are typically produced by particle accelerators (Very High E ~ billions of eVs).
- More recently being produced by lasers.

Mass-Producing Positrons with Lasers

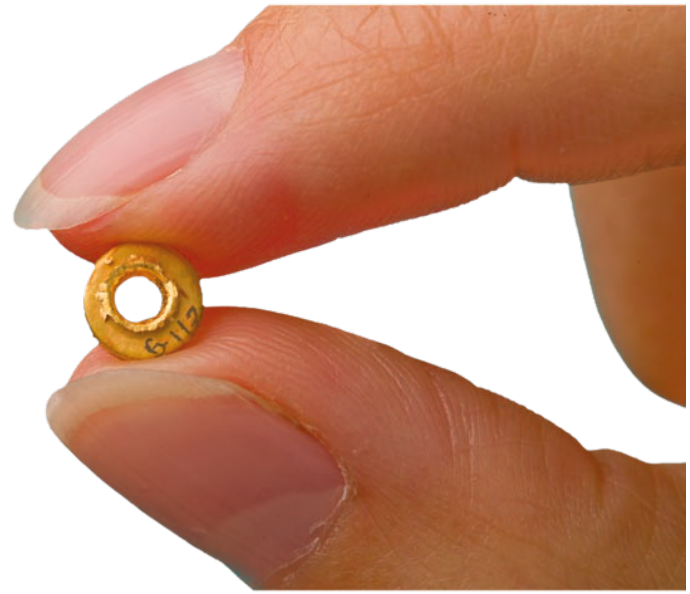
- Lawrence Livermore National Lab (headed by Chen and Wilks) started research in 2003 (published results in 2009)

- Experiment carried out with Titan Laser

  - Laser energy 120-250 J
  - Ultraintense ~ 1 x 10^{20} W/cm^2
  - Ability to couple short and long pulse



Mass-Producing Positrons with Lasers

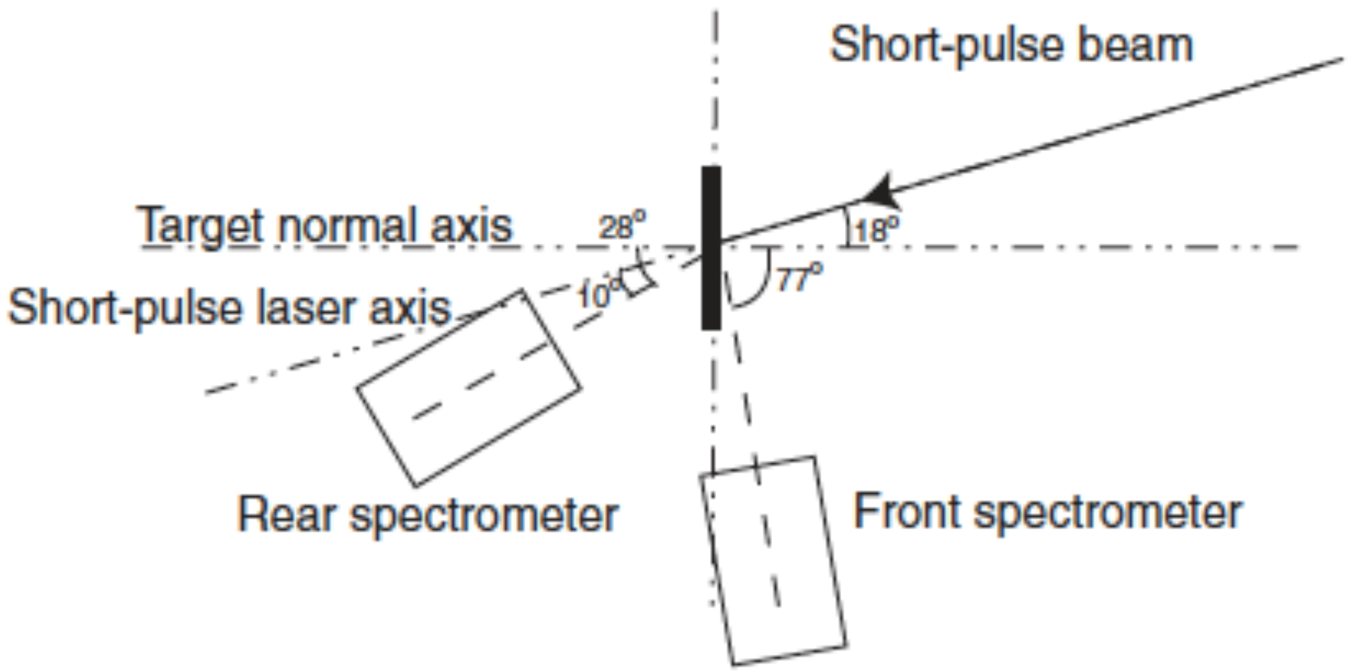


- Fired two laser pulses at high-Z targets

- A) 100J for 1 nanosecond
  - Creates plasma on surface of target

- B) Ultraintense 10^{19} W/cm^2 for a few
- picoseconds
  - Accelerates hot electrons into target
  - Electrons interact with Au nucleus and undergo pair-production via B-H process

Mass-Producing Positrons with Lasers



Experimental Results

- High number of positrons were observed in Au and Ta targets > 250microns
- 1.6×10^{10} positrons/sr measured from the rear spectrometer
- 2×10^{9} positrons/sr measured from the front spectrometer
- Angular distribution is anisotropic

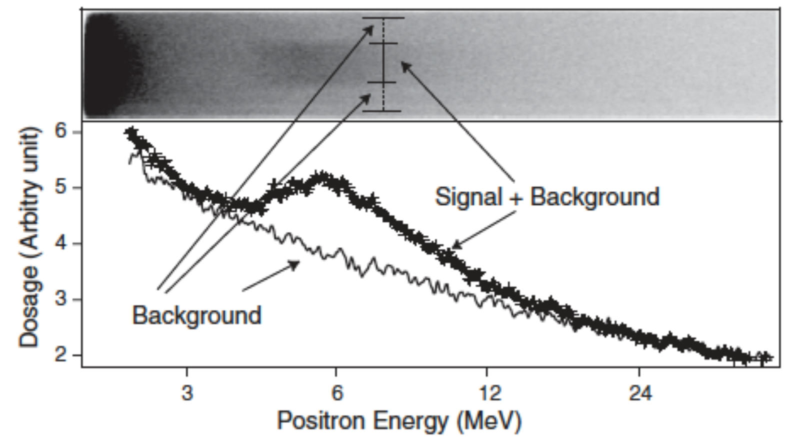
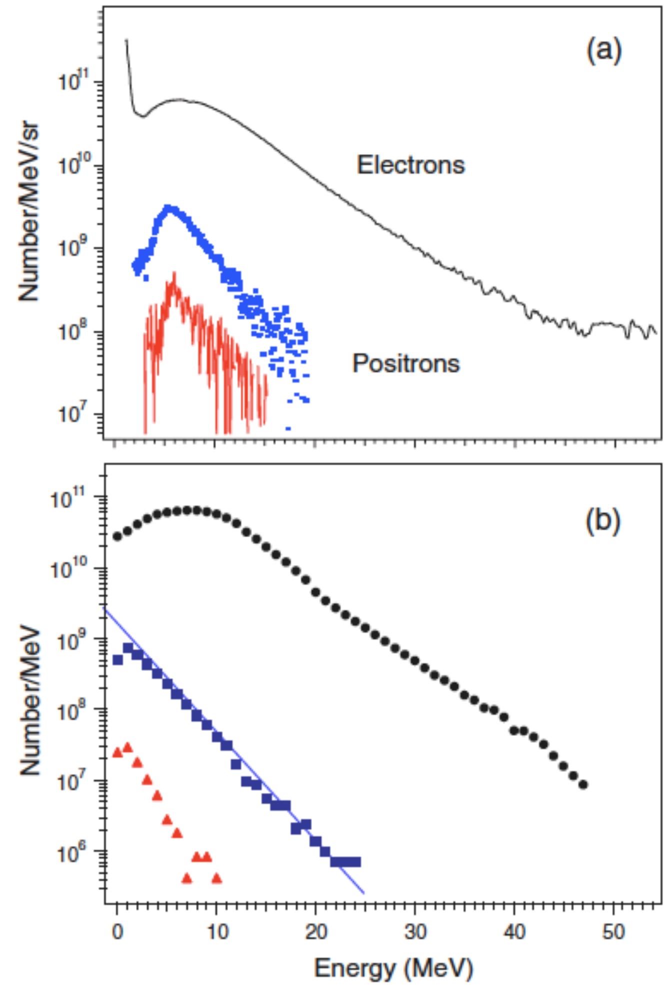


FIG. 2. Raw positron data image and line outs. This shot had 2 ps and 126 J. The laser intensity was about 6×10^{19} W/cm^2. The target thickness was 1 mm.

Experimental Results

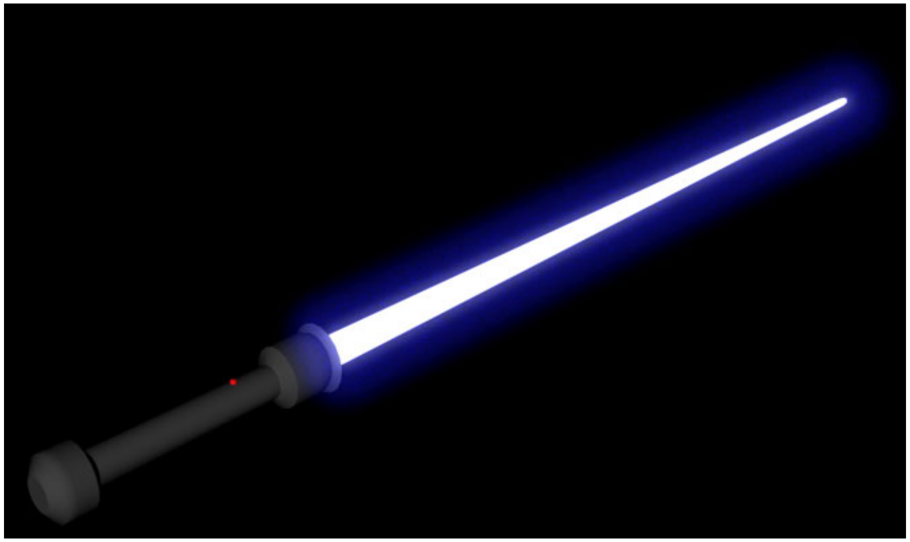
- 10^{16} positrons/cm^2 inside the target
- Rate of positron production was ~$2x10^{22}$ positrons/s/sr
- Because the # of positron $\propto$ E there can be 10 times these rates for kJ
  - OMEGA EP laser, NIF-ARC laser



High Yield Positron Applications

- Can help us understand more astrophysical anomalies such as deep space gamma-ray bursts

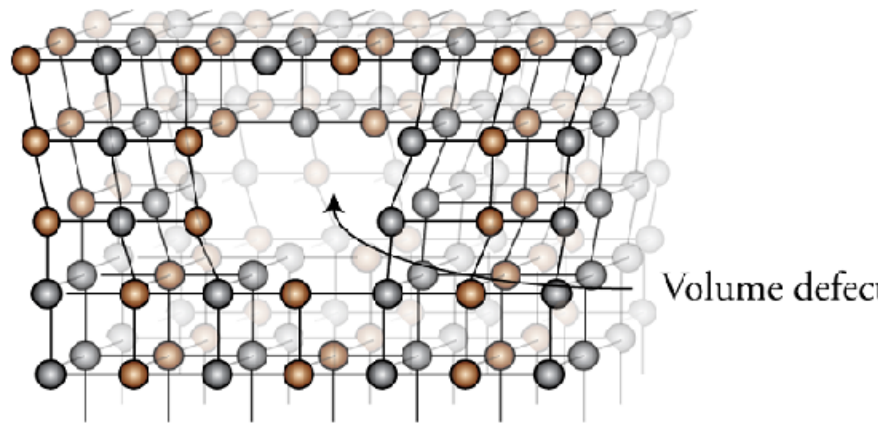
- Will provide a much more efficient way of creating positronium gas
  - Gamma Lasers
  - Light sabers
  - Antimatter rocket fuel



High Yield Positron Applications

- Non-destructive testing (NDT)
  for aeronautical and defense weapons

  - Based on the lifetime of positrons in a defect, we can deduce what and where it is



Sources

- Chen, Hui and Wilks, Scott C. and Bonlie, James D. and Liang, Edison P. and Myatt, Jason and Price, Dwight F. and Meyerhofer, David D. and Beiersd. "Relativistic Positron Creation Using Ultraintense Short Pulse Lasers." *Phys. Rev. Lett.* 102.10 (2009): 105001-05005. American Physical Society. Web. http://link.aps.org/doi/10.1103/PhysRevLett.102.105001

- Positron Dynamics. http://www.positrondynamics.com/materialscience.html

- Titan Laser Facility. LLNL. https://jlf.llnl.gov/html/facilities/titan/titan.php

- "Focus: Lasers Provide Antimatter Bonanza." *Physics*. N.p., n.d. Web. 03 Dec. 2012. http://physics.aps.org/story/v23/st8.

- C.M. Surko and R.G. Greaves, Phys. Plasmas 11, 2333 (2004).

- Meissner, Caryn. "S&TR | July/August 2009: Mass-Producing Positrons." *S&TR | July/August 2009: Mass-Producing Positrons*. N.p., n.d. Web. 03 Dec. 2012. https://str.llnl.gov/JulAug09/chen.html

Questions?