Mass Producing Positrons Using Ultaintense Lasers and their Applications

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Outline

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

- Antimatter partner of the electron

- \( m_p = m_e, \; S_p = S_e = \frac{1}{2}, \; Q = +e \)

- 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 $\beta^+$ Decay – “positron emission”
- Created by radioactive sources
- Low $E \sim$ 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
    \[ e + A_1 \rightarrow e' + A_1' + \gamma \text{ followed by } \gamma + A_2 \rightarrow A_2' + e^-e^+ \]

- 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 \( \sim 1 \times 10^{20} \) 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 \(10^{19} \text{ W/cm}^2\) 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 > 250 microns

- $1.6 \times 10^{10}$ positrons/sr measured from the rear spectrometer

- $2 \times 10^9$ positrons/sr measured from the front spectrometer

- Angular distribution is anisotropic
Experimental Results

- $10^{16}$ positrons/cm$^2$ inside the target

- Rate of positron production was $\sim 2 \times 10^{22}$ positrons/s/sr

- Because the number 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


Questions?