How The Atomic Bombs Were Made ?

A deep dive into the physics behind disaster of atomic bombs

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Introduction

- In 1942, before the Manhattan Project, Robert Oppenheimer held conferences where physicists discussed nuclear bomb design issues.
- A gun-type design was initially chosen, where two sub-critical masses of plutonium would be brought together by firing a "bullet" into a "target".
- The alternative implosion-type design, suggested by Richard Tolman, was considered far more complex and received scant consideration.

Thin Man

- In early 1943, Oppenheimer prioritized the gun-type weapon but created the E-5 Group at Los Alamos to investigate implosion as a hedge against predetonation.
- Implosion-type bombs were determined to be more efficient in terms of explosive yield per unit mass of fissile material due to compressed fissile materials reacting more rapidly and completely.
- However, the plutonium gun-type bomb received the bulk of the research effort due to less uncertainty involved, with the assumption that the uranium gun-type bomb could be easily adapted from it.

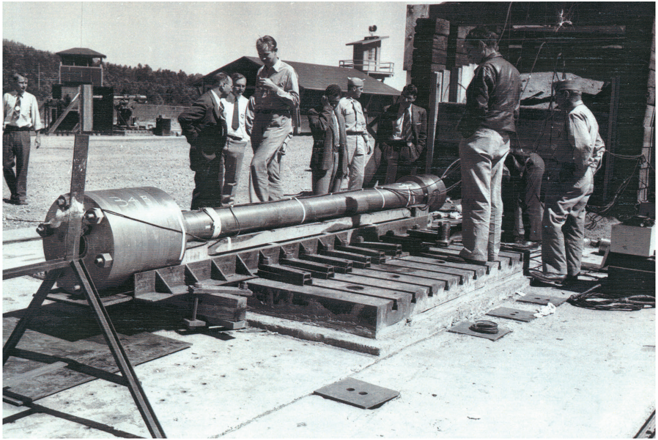

Figure 1: A prototype of the "Thin Man" gun being tested at Anchor Ranch, at Los Alamos.

- "Thin Man" was an early nuclear weapon design proposed before plutonium breeding.
- It assumed plutonium could be assembled by a gun-type method, requiring a "bullet" speed of at least 910 m/s.
- Dimensions: 5.2 m long, 0.97 m wide tail and nose, 0.58 m midsection.
- Weight: approximately 3,600 kg.
- No USAAF aircraft could carry it without modifications.
- Avro Lancaster (10 m bomb bay) or modified Boeing B-29 Superfortress were suggested.
- B-29 modification involved removing part of the bulkhead and oxygen tanks (Serial No. 42-6259).

Figure 2: A USAAF B-29 Superfortress. B-29s dropped the atomic bombs on Hiroshima and Nagasaki, the only aircraft ever to drop nuclear weapons in combat.

Predetonation

- Experiments in April 1944 by Emilio G. Segrè's group at Los Alamos showed reactor-produced plutonium contained the isotope plutonium-240.
- Plutonium-240 has a high spontaneous fission rate, increasing the risk of predetonation.
- This meant the plutonium would likely predetonate and blow itself apart during critical mass formation.
- The distance required to avoid predetonation would need an impractically long gun barrel for any bomber.

- The only viable option was the more difficult implosion method.[2]
- At a meeting on July 17, 1944, it was agreed that gun-type work would focus on the `Little Boy` uranium design.
- Almost all Los Alamos research was re-oriented toward solving the implosion problems for the `Fat Man` plutonium bomb.

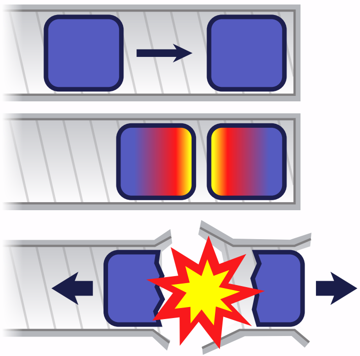

Figure 3: If two pieces of subcritical material are not brought together fast enough, nuclear predetonation can occur, whereby a smaller explosion than expected will blow the bulk of the material apart.

$$ {}^{238}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \longrightarrow {}^{239}_{92}\mathrm{U} \xrightarrow[23.5\ \mathrm{min}]{\beta^-} {}^{239}_{93}\ \mathrm{Np} \xrightarrow[2.3565\ \mathrm{d}]{\beta^-} {}^{239}_{94}\mathrm{Pu} $$

Neutrons from the fission of uranium-235 are captured by uranium-238 nuclei to form uranium-239; a beta decay converts a neutron into a proton to form neptunium-239 (half-life 2.36 days) and another beta decay forms plutonium-239.[1]

Isotope	Decay mode	Half-life (years)	Spontaneous fission n (1/(gůs))
^{238}Pu	alpha to ^{234}U	87.74	2600
^{239}Pu	alpha to ^{235}U	24100	0.022
^{240}Pu	alpha to ^{236}U	6560	910

References & Conclusion

Conclusion

- Majorana fermion braiding explored through a series of measurements.
- Ancilla Majorana fermions contribute to robustness.
- Error assessment provides insights into the fidelity of braiding.

References

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Thank you for listening.