Interleaving high-Z plates with scintillator or silicon pads for charge producing device from gamma rays from

If an atom "accepts" a positron but not an electron, the distinctive energy it releases is annihilation radiation: typically two back-to-back gamma rays at 511 keV each from electron–positron annihilation, or a 3-gamma decay if positronium forms in the triplet state.

An electron linac sends ~5–100 MeV electrons into a tungsten converter; bremsstrahlung photons inside the target convert to e+e− pairs, and a dipole magnet separates and transports the positron beam for moderation and use.

make a paper

Interleaving high-Z plates with scintillator or silicon pads yields an efficient, charge-producing detector for gamma rays across 511 keV to multi-GeV: the high-Z absorber converts photons via Compton/pair production, and the active layers collect charge or light from the ensuing electromagnetic shower for precise timing, imaging, and energy measurement. [1] [2]

Abstract

- Objective: Design a modular converter–sampler that detects both 511 keV annihilation photons from e+e− interactions and GeV-scale gammas from linac-bremsstrahlung, providing >50% conversion in a compact form and scalable readout for spectroscopy and imaging. [3] [4]
- Approach: Alternate tungsten plates of order 1 radiation length X0 with silicon pad planes or scintillator tiles; at 511 keV the device functions as a high-efficiency coincidence spectrometer, while at GeV energies it acts as a compact electromagnetic calorimeter for shower capture. [2] [5]

Physics basis

- Conversion: At ≥100 MeV, pair production dominates; a stack of 6–8 X0 achieves >50% interaction probability, while 20–30 X0 contains most of the shower for accurate energy sums; tungsten's X0≈3.5 mm enables compact layers. [6] [2]
- 511 keV regime: Detection relies on photoelectric/Compton interactions in dense scintillators or converters with high solid angle and fast coincidence timing to tag back-to-back annihilation photons, as in PET-style systems. [7] [3]

Detector architecture

- Absorber: Tungsten plates, 3.5 mm each (≈1 X0), purity ≥99.9%, stacked for total depth 18–24 X0 depending on target energy; small Molière radius (~9 mm) improves shower compactness and two-photon separation.[8] [2]
- Active layers:
  - Silicon pads: 300 µm n-type FZ wafers diced into 1×1 cm pads on each plane; reverse-biased to collect e–h pairs from shower secondaries with pad-level imaging and summing for energy.[9] [1]
  - Scintillator tiles: Alternatively, plastic or crystal tiles (e.g., LYSO, PbWO4) coupled to SiPM arrays for higher light yield and fast timing; LYSO improves 511 keV efficiency and spatial resolution relative to NaI(Tl) modules.[10] [7]

Readout and electronics

- Front-end: Low-noise charge-sensitive preamplifiers on silicon pads or SiPM transimpedance stages on scintillators; per-layer digitizers sample amplitude and time for clustering and longitudinal shower profiling.[1] [2]
- Trigger: Two-level logic—coincidence timing windows of a few ns for 511 keV pairs; energy-sum and topological triggers for GeV showers, with optional preshower pixel layers near shower maximum to resolve close photon pairs.[9] [3]

Performance targets

- 511 keV: Coincidence detection with high efficiency and improved angular resolution using small-pitch LYSO or finely segmented silicon planes; true/scatter/random classification follows PET practice with tight timing windows.[3] [7]
- GeV gammas: Sampling resolution scales roughly as $a/\sqrt{E} \oplus b$; silicon–tungsten prototypes with 18–20 X0 and cm-scale pads demonstrate accurate shower centroids and energy sums suitable for π0/η photon reconstruction and compact calorimetry.[5] [1]

Applications

- Positron annihilation studies: Line-of-response imaging and lifetime/ACAR-style coincidence leveraging 511 keV back-to-back gammas; high-granularity readout supports materials and detector R&D.[7] [3]
- Linac and bremsstrahlung beams: Diagnostic calorimetry for 5–100 MeV electron linacs with tungsten converters; monitor spectra, dose, and alignment while supporting positron-source development downstream of the converter.[4] [11]

>50% conversion and containment

- Front converter: A 6–8 X0 tungsten front-end layer in front of silicon tracking planes ensures >50% conversion to e+e− at GeV energies, enabling direction reconstruction before the main calorimeter. [2] [5]
- Full stack: A 20–30 X0 silicon–tungsten sampling calorimeter achieves high detection efficiency and energy containment for compact GeV detection; layer counts and pad sizes are tuned to Molière radius and readout cost. [12] [2]

Integration with positron sources

- An electron linac impinging on a tungsten target produces bremsstrahlung; those photons create e+e− pairs within the converter; dipole optics separate positrons for moderation/trapping, while a downstream calorimeter stack characterizes the photon field and shower properties. [13] [11]
- Energy-recovery linac concepts spatially separate the bremsstrahlung radiator from isotope/positron targets, improving photon yield and efficiency—compatible with using the calorimeter as an inline diagnostic. [14] [11]

Example prototypes and references

- Silicon–tungsten calorimeters with 19–30 alternating layers have been built and beam-tested, using 3.5 mm W plates and 300 µm silicon pads, demonstrating granular shower imaging and robust energy measurement in compact geometries. [1] [2]
- FoCal-E and similar pad/pixel silicon–tungsten designs document absorber thickness, pad sizes, and readout schemes, providing templates for modular buildouts and preshower integration. [12] [9]

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