Theme: Physics

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Abstract Title: A Method for Reducing Energy Layers in Pencil Beam Scanning Proton Therapy

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Background / Aims:

- IMPT with pencil beam scanning achieves superior dose conformity but requires numerous energy layers, significantly increasing beam delivery time.
- This prolonged delivery compromises treatment efficiency, exacerbates intrafraction motion effects, and reduces patient compliance.
- This study presents a novel algorithm that: (1) reduces energy layers by ~50% through systematic alternating layer removal, (2) minimizes total spot count by redistributing dose exclusively to existing spot positions, (3) preserves dosimetric quality equivalent to original plans.

Subjects and Methods:

- Layer Removal Strategy: For each spot in removed layer L: (1) Identify neighboring spots within 10mm radius in adjacent layers L±1. (2) Calculate distance-MU weighted allocation ratios: $F=\Sigma[w/(d+\varepsilon)]$. (3) Assign dose to nearest existing spot in each layer—no new spots created.
- This exploits overlapping Bragg peaks between adjacent layers .

Result:

- Plan Complexity Reduction:
  - Energy layers: 25±8 → 13±4 (48% reduction)
  - Total spots: 3641±342 → 1814±298 (50.2% reduction)
  - Estimated beam delivery time: 43.5 ±15.1s → 26.7±7.2 s (38.6% reduction)
- This energy layer reduction algorithm achieves ~50% reduction in energy layers and ~50% reduction in total spots while maintaining dosimetric equivalence to original IMPT plans. The method offers clinically significant improvements in treatment efficiency without quality compromise.