Modeling a Lithium Vapor Box Divertor and Resulting Ion Flows on NSTX-U using SOLPS

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Introduction: Divertor Detachment Can Be Problematic

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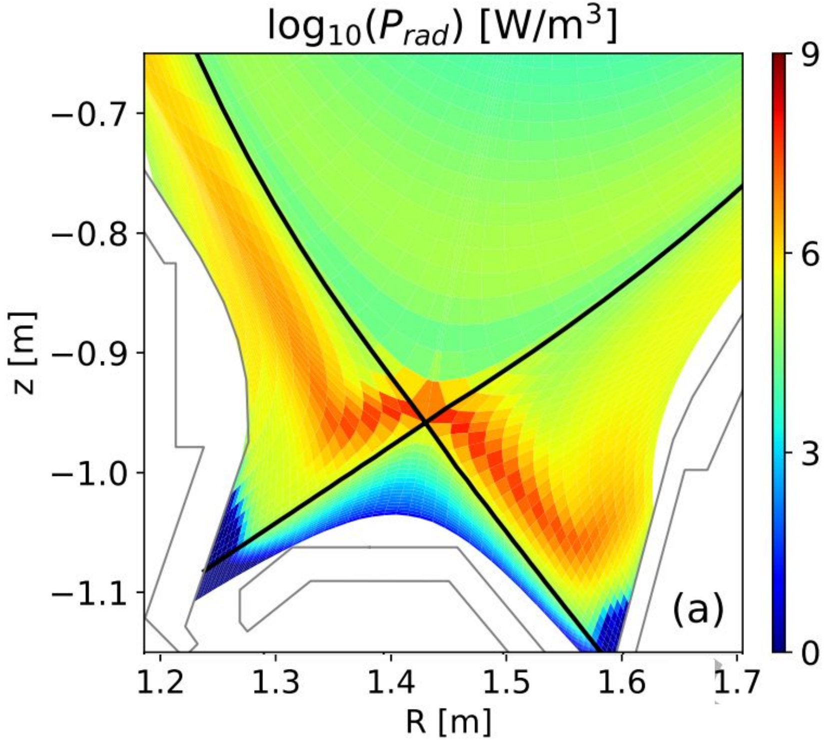
- Divertor detachment is necessary for future fusion devices to ensure PFC lifetime
- Divertor detachment with medium-Z impurities has the tendency to create a highly radiating region at the X-point
  - Can reduce core & pedestal performance
  - Heat flux reduction can be maintained at the cost of high Z_{eff}
- Goal: create a detached divertor that confines radiation and impurities close to the target



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Introduction: The Lithium Vapor Box

- The lithium vapor box seeks to detach via lithium vapor evaporation near the target, and condensation further upstream

- Original vapor box design imagines different chambers for condensation and evaporation

- A large focus of this work is determining the importance of the specific geometry to:
  - Keep radiation below X-pt
  - Keep impurities in box

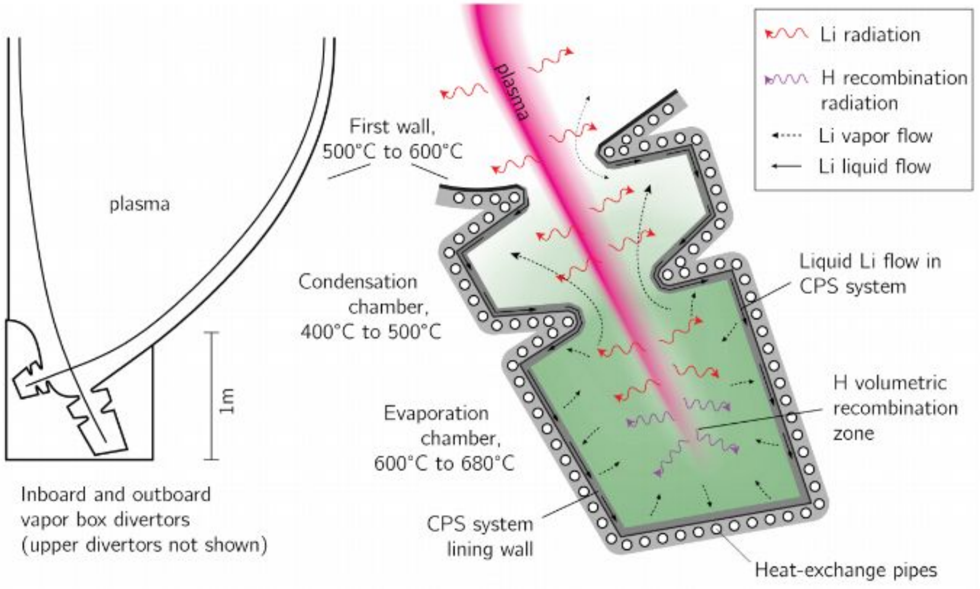
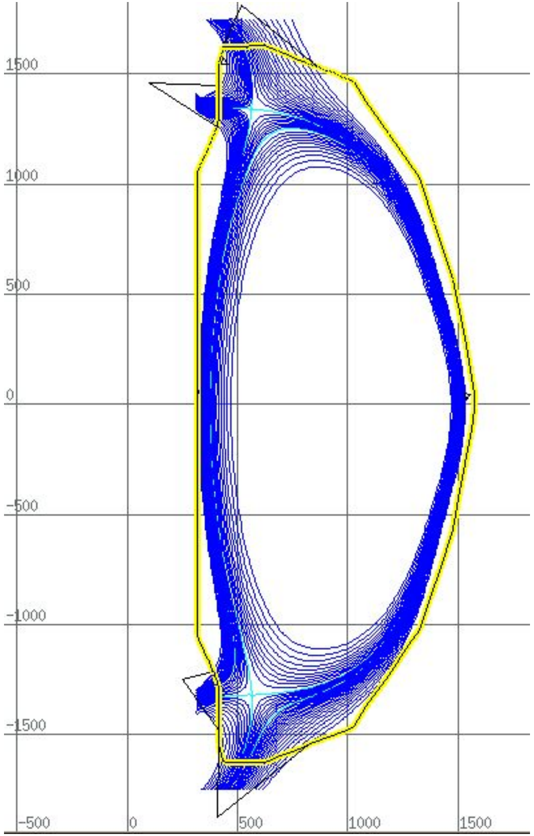


Diagram Credit: Jacob Schwartz

Modelling High Power Conditions

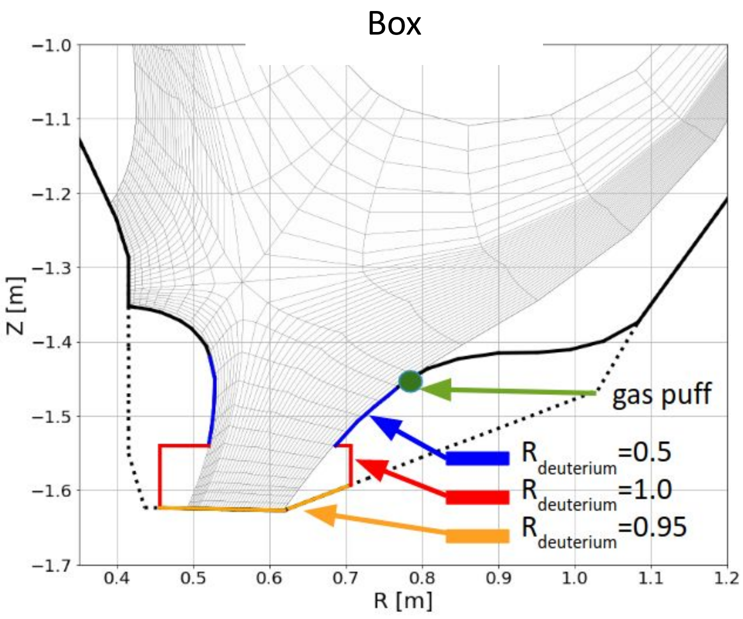
- Low power lithium vapor box can have nearly non-existent upstream lithium fraction (Emdee et al. 2021)

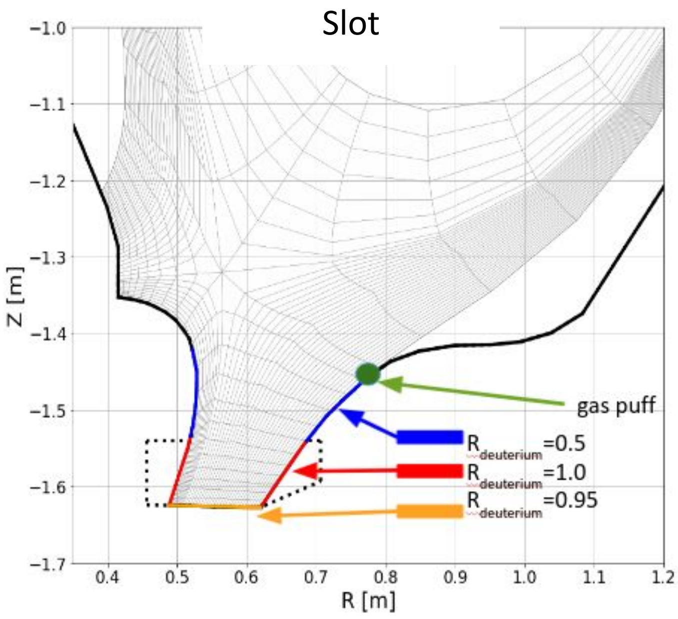
- Moved to predictive modeling of high power NSTX-U H-mode shots using SOLPS
  - P_{in} = 10 MW
  - q_{target}^{max} ~ 65 MW/m^2
  - λ_q ~ 3 mm



Set Up: Box to Slot Comparison

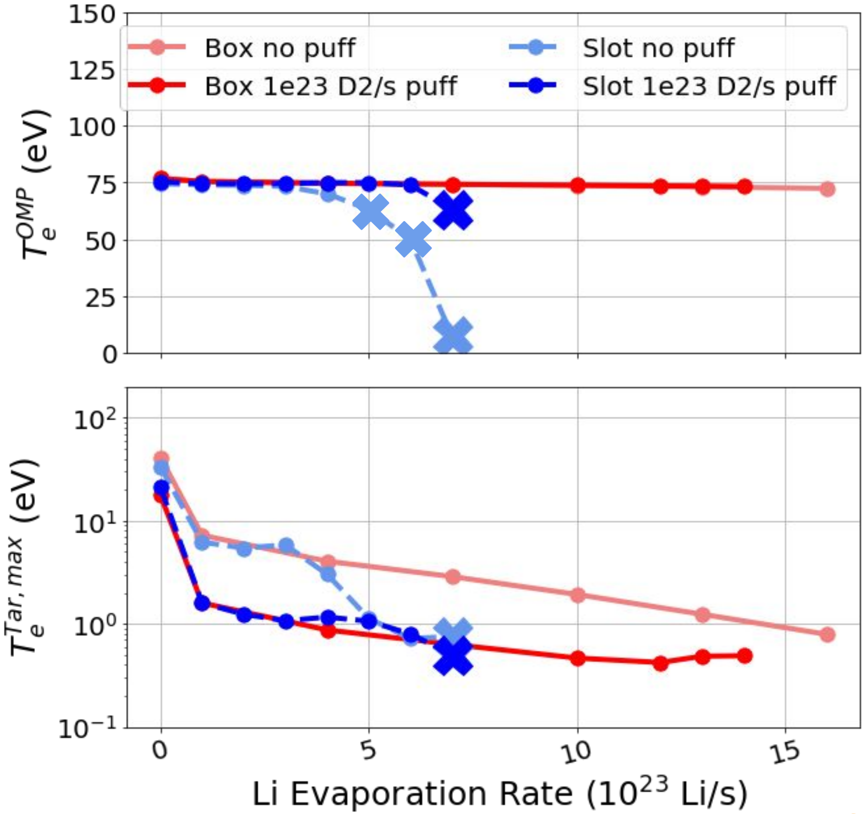
- Set up two divertor designs, one closer to the original vapor box design with a box and one a slot divertor geometry





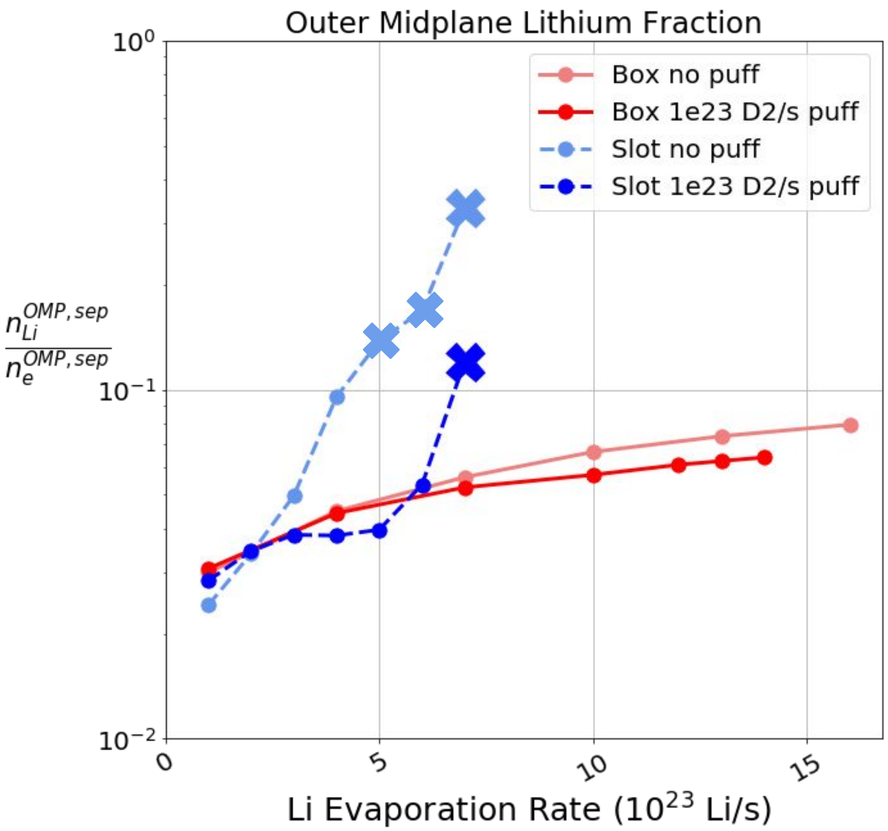
Upstream Temperature Can Be Sustained With a Box Geometry

- The upstream temperature is unaffected by lithium evaporation if the divertor has a box geometry
- Slot sees upstream temperature degradation as lithium evaporation is increased
  - Corresponds to $n_{Li}/n_e > 0.1$ upstream



Lithium Fraction Controlled Better in Box

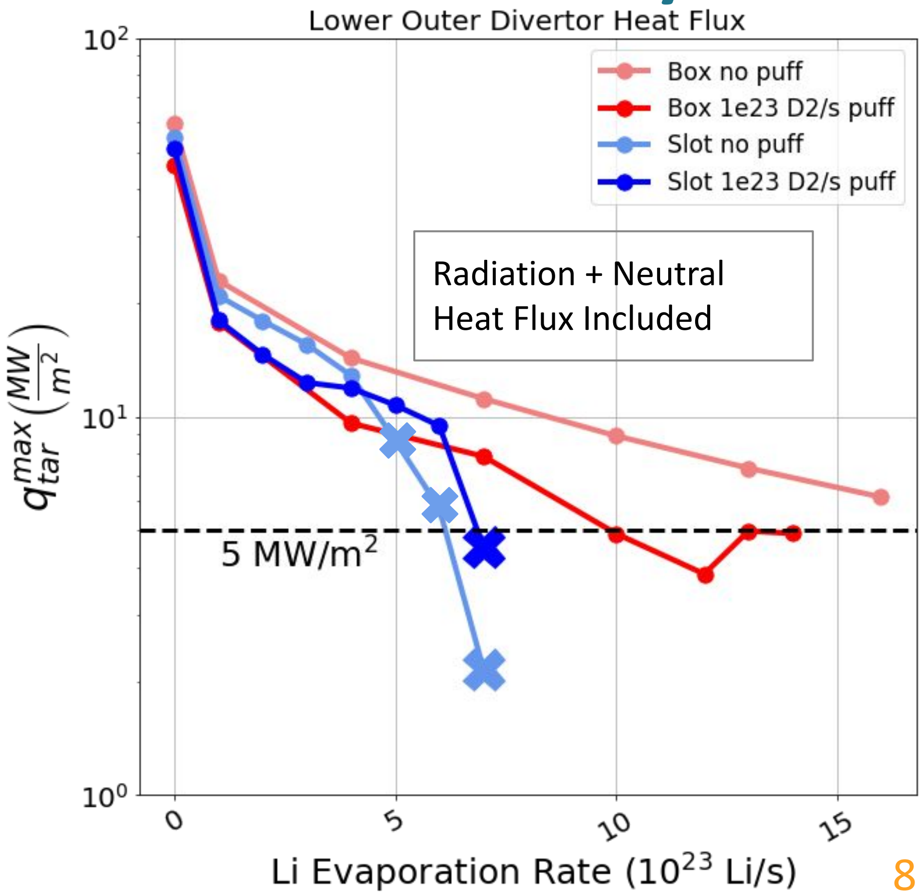
- Upstream lithium content in the slot geometry is less controlled
- The baffles are important for lithium containment



Divertor Heat Flux Dramatically Reduced

- Slot has difficulty getting below 5 MW/m^2 without reductions in upstream temperature

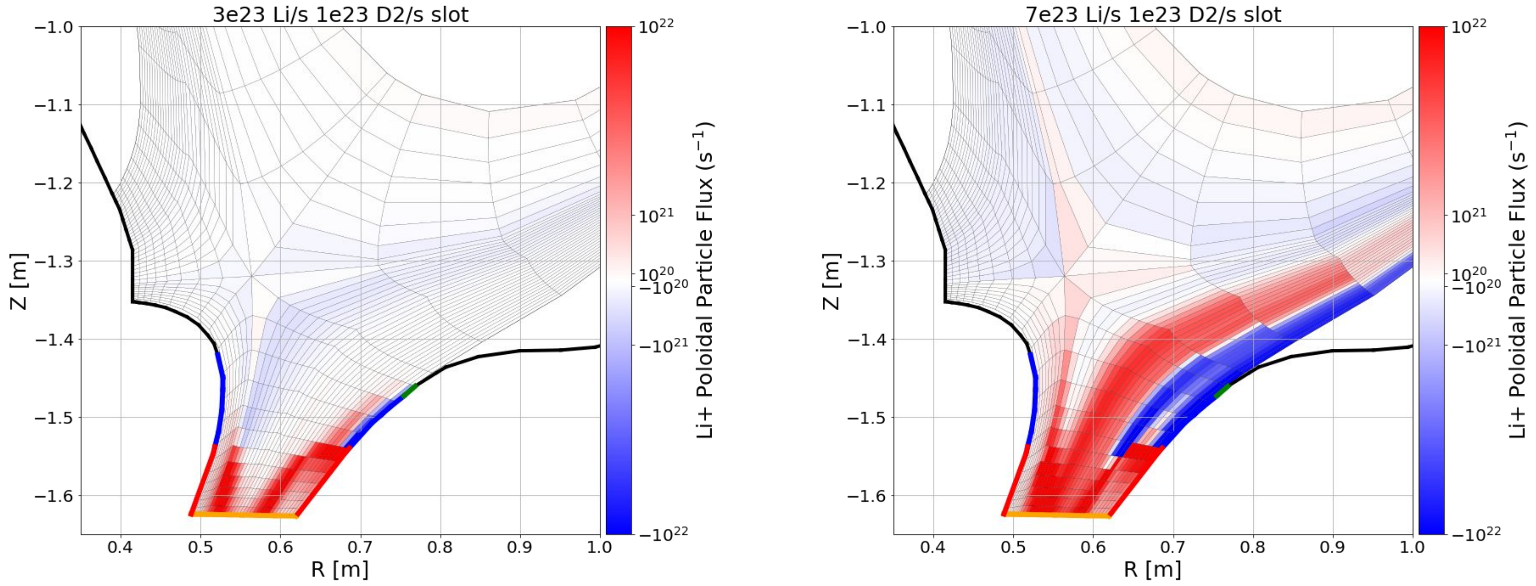
- Box can contain the lithium and reduce heat to the target further



Flow Reversal in Far SOL in Slot Geo.

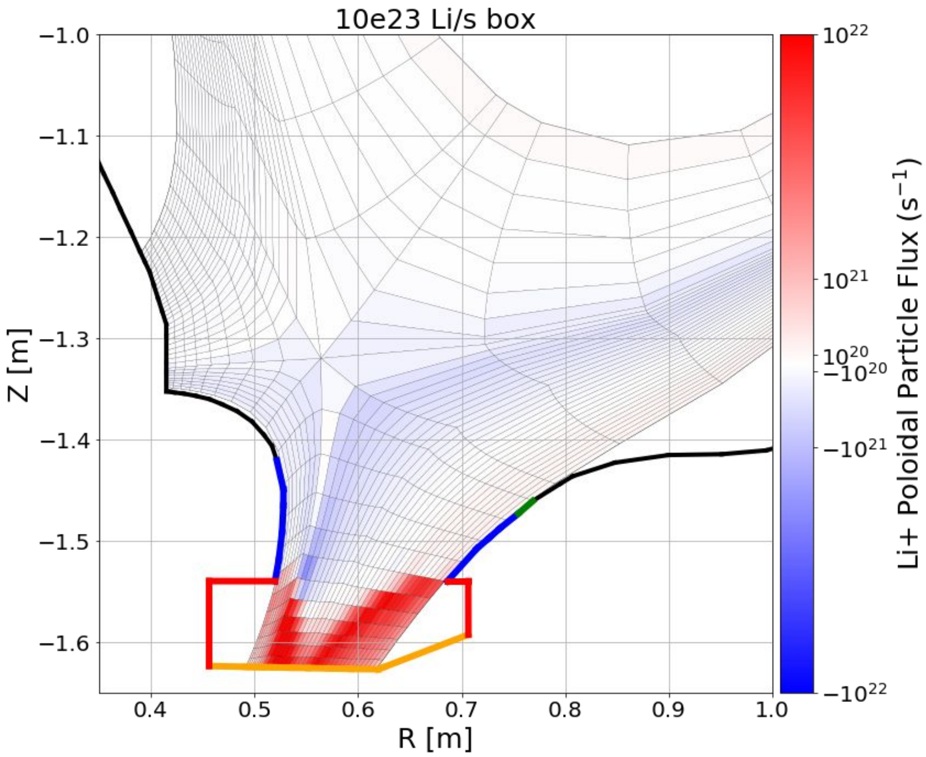
- The far SOL lithium flow eventually becomes upstream-directed with enough lithium evaporation in the slot

Downstream-directed Li Flow
Upstream-directed Li Flow



Flow Never Reverses in Box Geo.

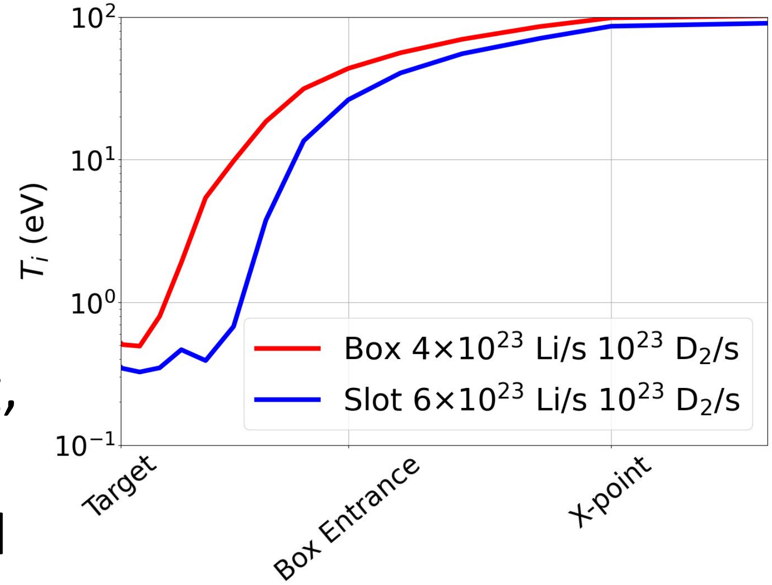
- In the box geometry the far SOL lithium flow is never reversed for any of the cases tested



Thermal Gradient Location Leads to Important Differences

- Higher temperature within box leads to more radiation from the lithium due to higher ϵ_{cool}

- Box has more efficient lithium cooling, thus requiring a lower source so cooling requirements can be achieved without reversing flow in far SOL



Line Radiation Peaks Below X-Point

- Line radiation peaks at box entrance, succeeding in keeping radiation below X-point

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C_N~3-4%

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