$sum((X - UV^T)^2)$

- No sparsity exploitation
- $\approx$ **0.5 T ops** to compute UV^T

Construct RA plan

Distribute * into Σ; Combine *

Split CSE; Distribute * into +

Combine +; Factor Σ into +

Split CSE

Distribute * into Σ; Combine *; Constant fold -1 * -1

Factor Σ into *
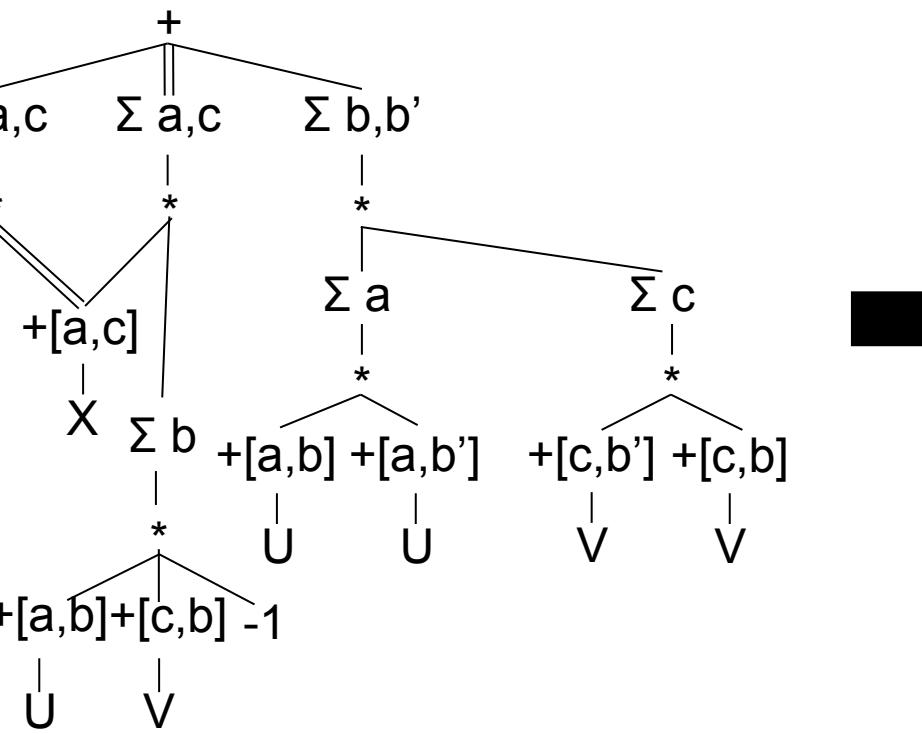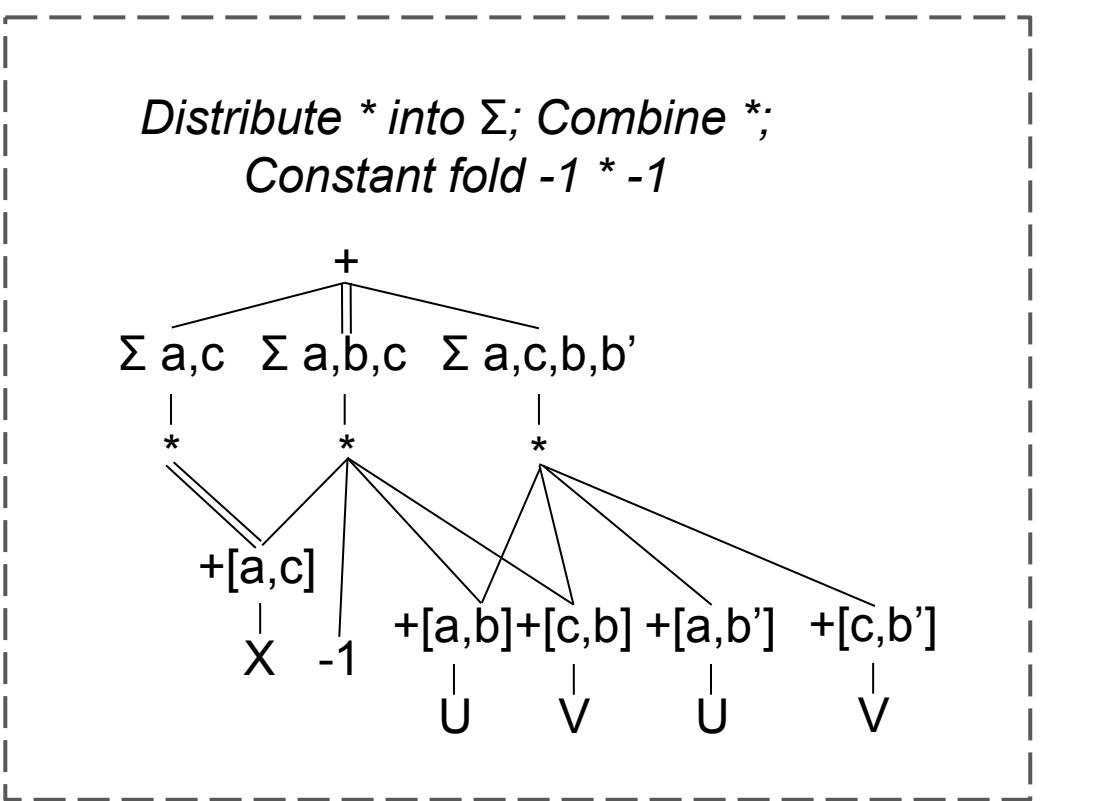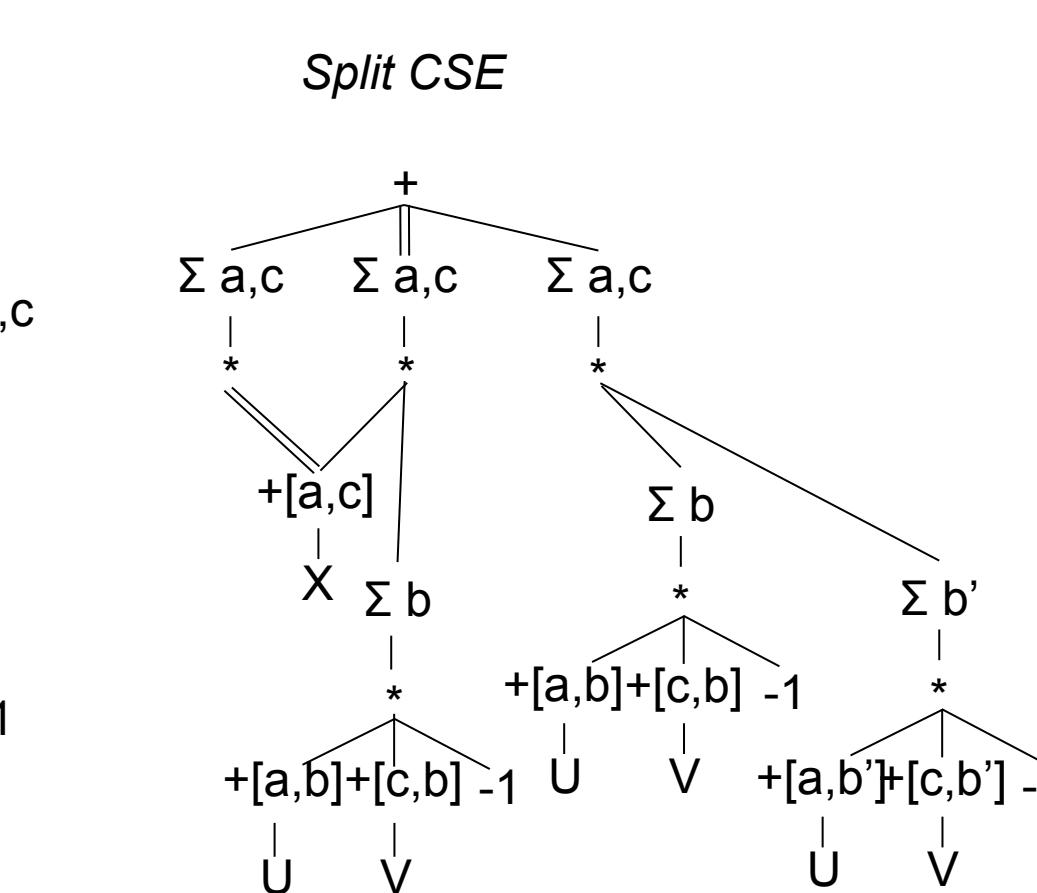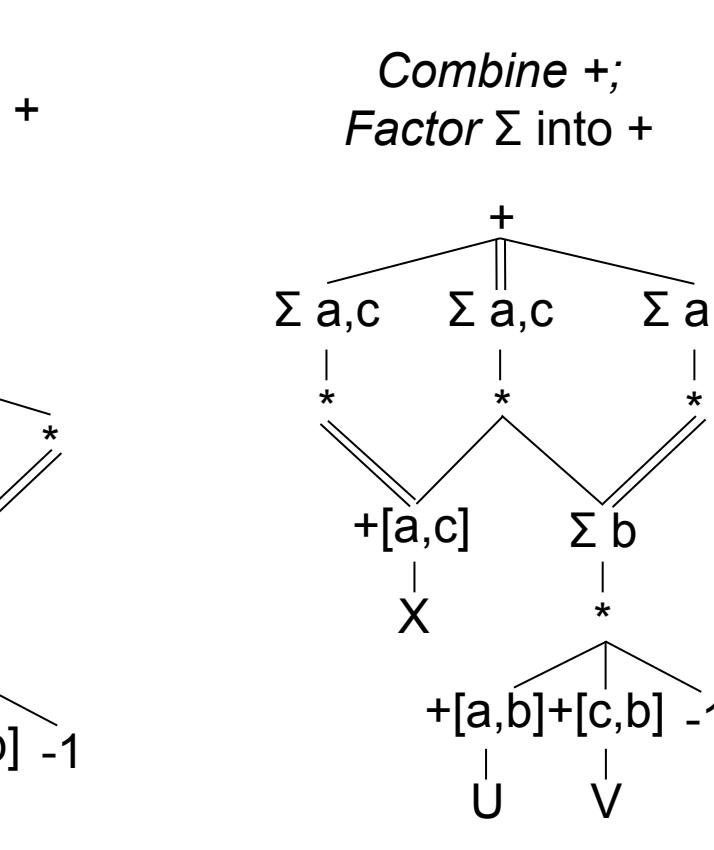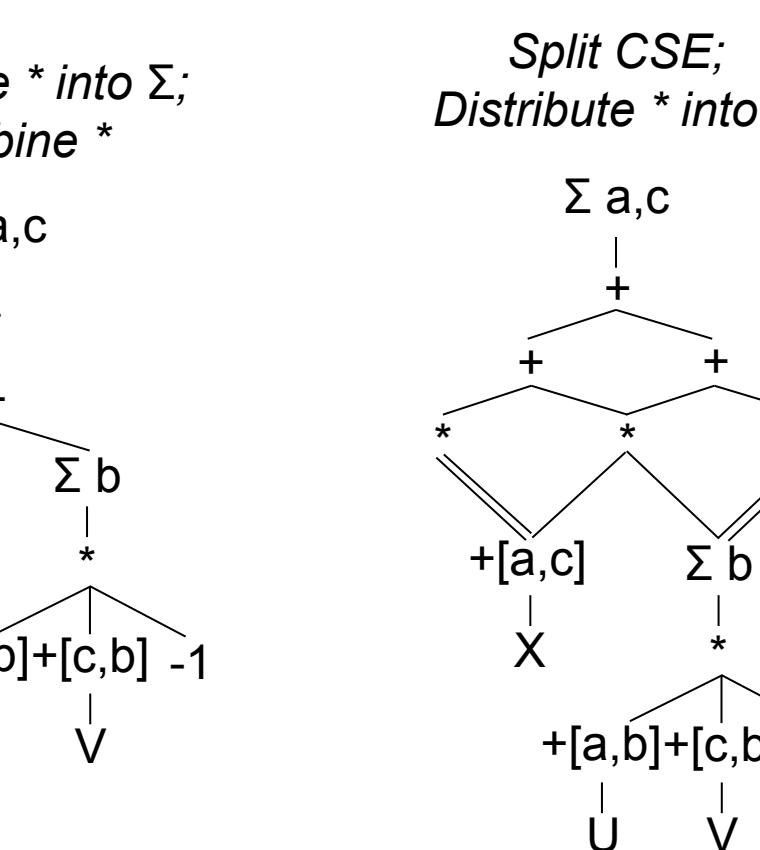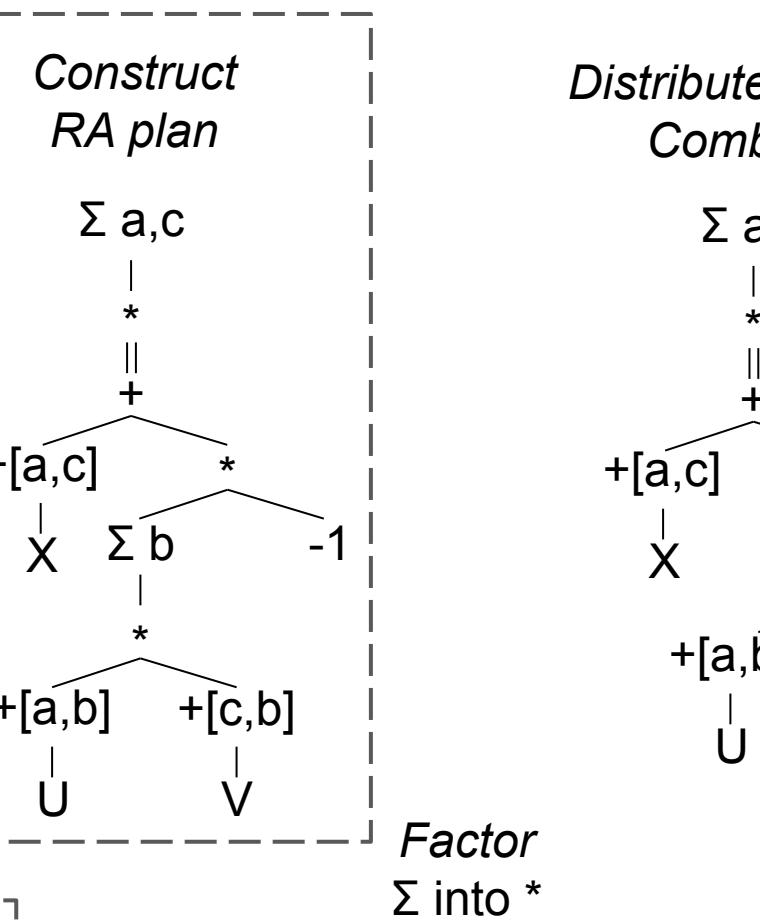
$sum(X^2) - 2sum(X*UV^T) + sum(U^TU * V^TV)$

sparsity exploitation
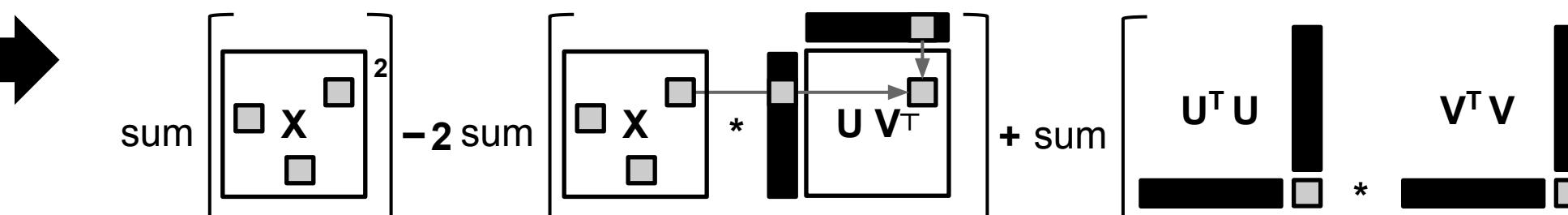
- Left term exploits sparsity and is **O(nnz(X)) ops**
- Right term cost is $\approx$ **3 M ops** (100,000x reduction)