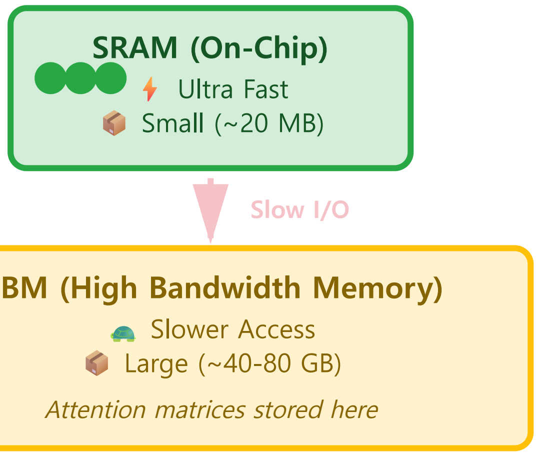
Flash Attention: IO-Aware Optimization

GPU Memory Hierarchy



SRAM (On-Chip)

●●● ⚡ Ultra Fast

📦 Small (~20 MB)

Slow I/O

HBM (High Bandwidth Memory)

🐢 Slower Access

📦 Large (~40-80 GB)

Attention matrices stored here

Standard Attention:

- ❌ Load full attention matrix
- ❌ Multiple HBM reads/writes
- ❌ $O(n^2)$ memory bottleneck

Flash Attention:

- ✓ Block-wise computation
- ✓ Minimize HBM access
- ✓ $O(n)$ memory usage

Flash Attention v1

- Tiling and recomputation
- Block-wise attention
- 2-4x speedup

Flash Attention v2

- Better parallelization
- Improved work partitioning
- 5-9x faster than standard

Medical Impact

- Real-time patient analysis
- Affordable long-context
- Clinical deployment ready

Key Innovation

- Fuse operations in SRAM
- Avoid materialization
- 3-10x less HBM access

🚀 Revolutionary Efficiency

Flash Attention achieves exact attention with O(n) memory and 3-10x speedup by optimizing GPU memory access patterns, making long-context medical AI practical. **The bottleneck is I/O, not computation!**