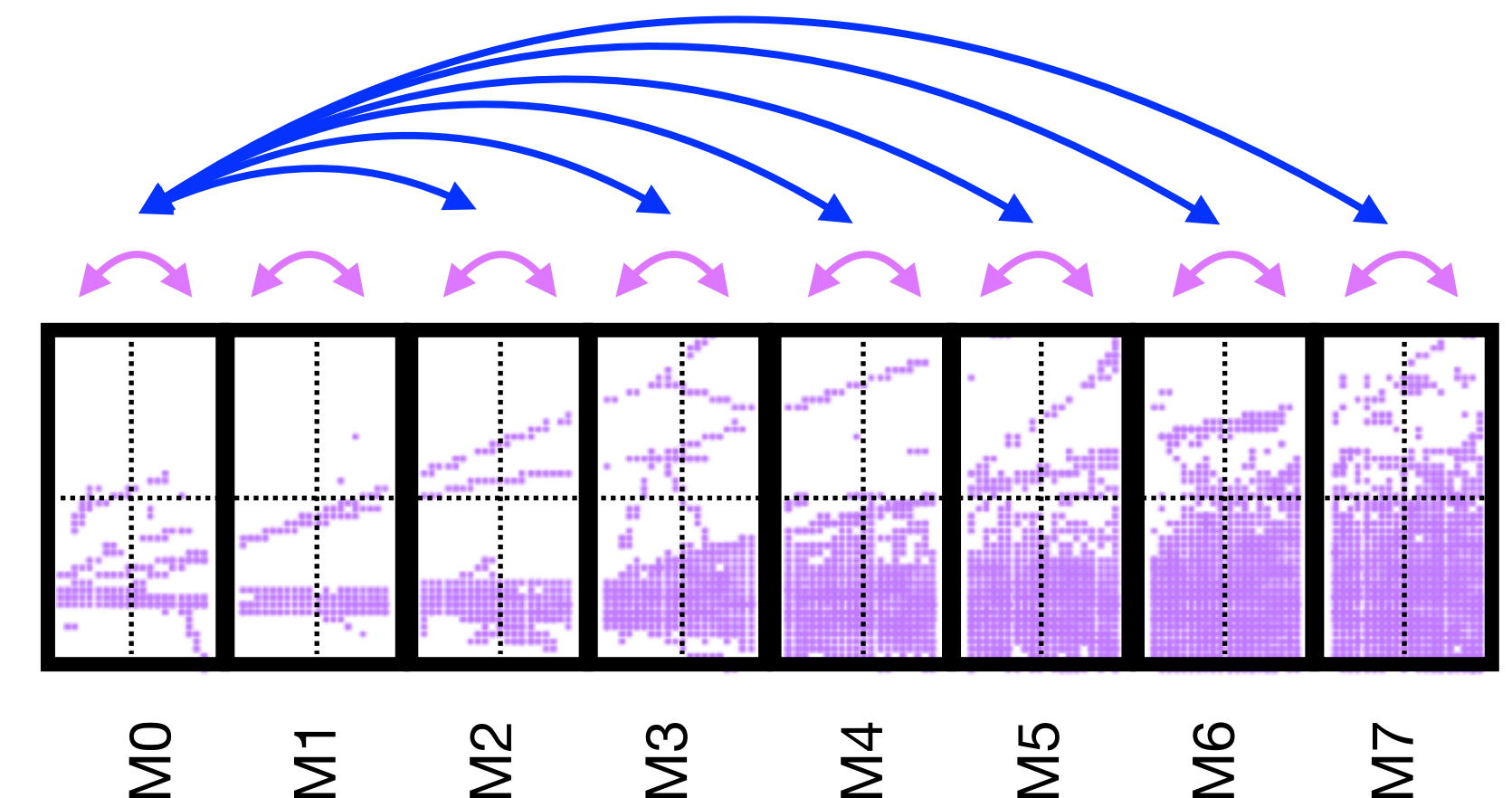
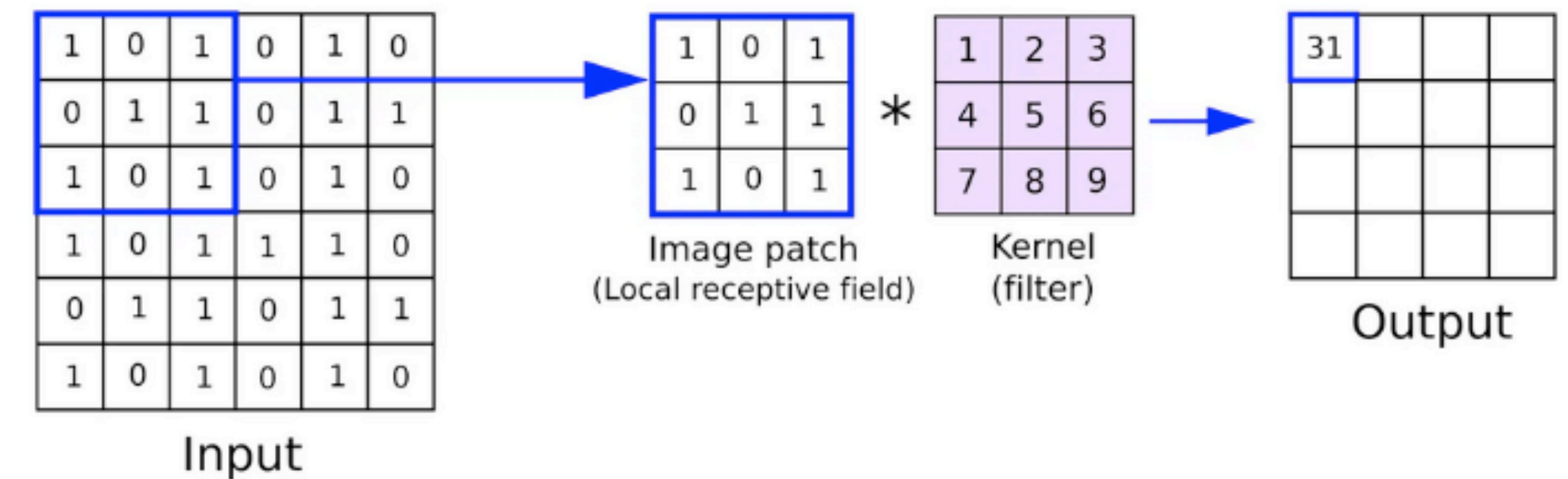


Cool, but How?

Advance Deep Learning Approach

Hybrid Model to Capture Local & Global Information:

- **Sparse Submanifold Convolutional Network (Local Info):**
 - A convolution that operates only on active voxels.
 - Efficiently learns local 3D features (shower shapes, track segments).
 - Efficiency SCNN: (16 times faster than a CNN on a GPU) [[Link](#)]
- **Hierarchical Transformer (Global Info):**
 - **Intra-Module Attention:** Summarizes patterns *within* each detector module.
 - **Inter-Module Attention:** given the created module summaries, combines them to learn the *entire event topology*.



Our Training Strategy

A Two-Stage Approach

- **Stage 1: Pre-Training**

- **Goal:** Force the model to learn a rich, physical representation of events.
- **How:** A dual-objective Masked Autoencoder (MAE).
 - ▶ *Self-Supervised Reconstruction Task:* Reconstruct masked (hidden) parts of the event.
 - ▶ *Supervised Contrastive Task:* Machine learning framework for grouping hits that share the same voxel ID.

- **Stage 2: Supervised Fine-Tuning**

- *Goal:* Adapt the "smart" pre-trained encoder to specific physics tasks.
- *How:* Use the pre-trained weights as a starting point and fine-tune on the labeled dataset for classification and regression.
 - **Classification Task:**
 - *NuE CC, NuMu CC, NuTau CC, NC*
 - **Regression Task:**
 - *Vis Momentum (E_{vis} , Pt_{miss}), Jet Momentum, Lepton Momentum*