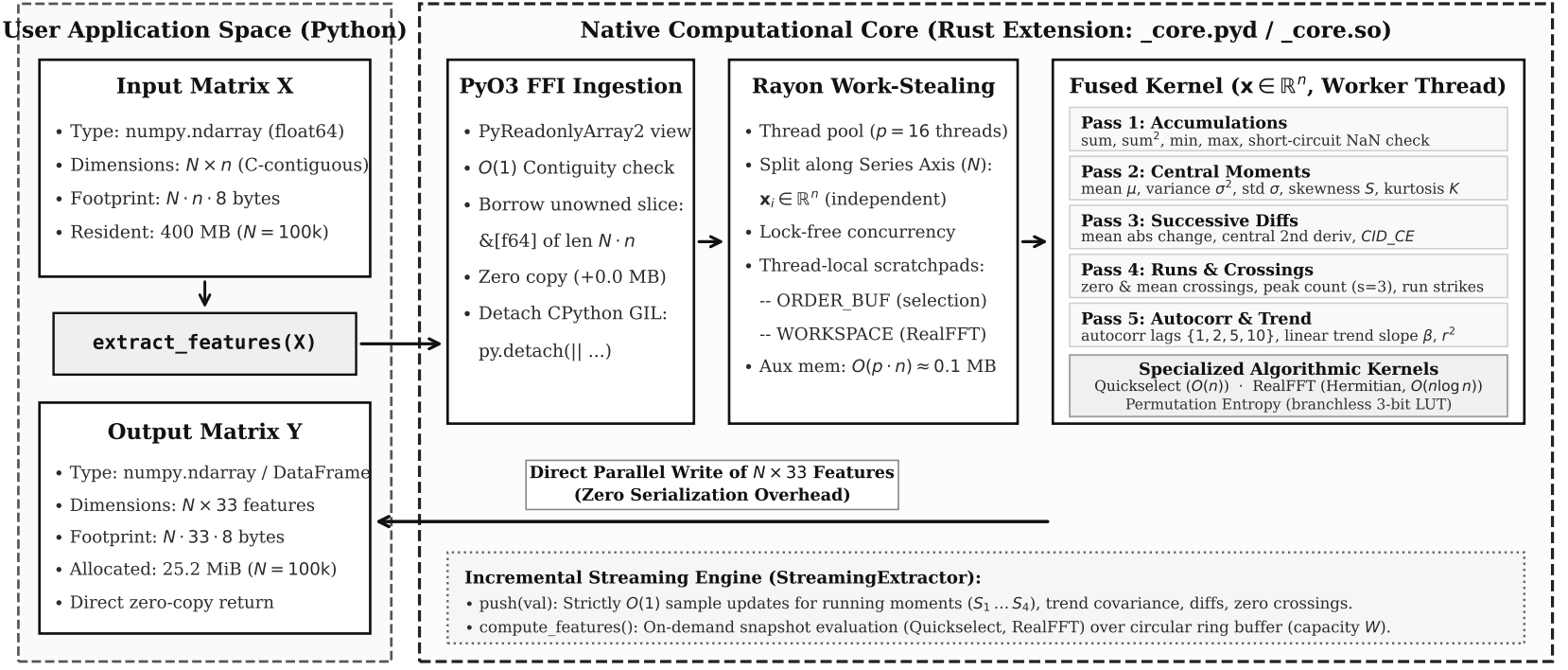

User Application Space (Python)
Input Matrix X
• Type: numpy.ndarray (float64)
• Dimensions: $N \times n$ (C-contiguous)
• Footprint: $N \cdot n \cdot 8$ bytes
• Resident: 400 MB ($N = 100$k)
extract_features(X)
Output Matrix Y
• Type: numpy.ndarray / DataFrame
• Dimensions: $N \times 33$ features
• Footprint: $N \cdot 33 \cdot 8$ bytes
• Allocated: 25.2 MiB ($N = 100$k)
• Direct zero-copy return
Native Computational Core (Rust Extension: _core.pyd / _core.so)
PyO3 FFI Ingestion
• PyReadonlyArray2 view
• $O(1)$ Contiguity check
• Borrow unowned slice:
&[f64] of len $N \cdot n$
• Zero copy (+0.0 MB)
• Detach CPython GIL:
py.detach(|| ...)
Rayon Work-Stealing
• Thread pool ($p = 16$ threads)
• Split along Series Axis (N):
$\mathbf{x}_i \in \mathbb{R}^n$ (independent)
• Lock-free concurrency
• Thread-local scratchpads:
-- ORDER_BUF (selection)
-- WORKSPACE (RealFFT)
• Aux mem: $O(p \cdot n) \approx 0.1$ MB
Fused Kernel ($\mathbf{x} \in \mathbb{R}^n$, Worker Thread)
Pass 1: Accumulations
sum, sum^2, min, max, short-circuit NaN check
Pass 2: Central Moments
mean μ, variance σ^2, std σ, skewness S, kurtosis K
Pass 3: Successive Diffs
mean abs change, central 2nd deriv, CID_CE
Pass 4: Runs & Crossings
zero & mean crossings, peak count (s=3), run strikes
Pass 5: Autocorr & Trend
autocorr lags $\{1, 2, 5, 10\}$, linear trend slope β, r^2
Specialized Algorithmic Kernels
Quickselect ($O(n)$) · RealFFT (Hermitian, $O(n \log n)$)
Permutation Entropy (branchless 3-bit LUT)
Direct Parallel Write of $N \times 33$ Features
(Zero Serialization Overhead)
Incremental Streaming Engine (StreamingExtractor):
• push(val): Strictly $O(1)$ sample updates for running moments ($S_1 \dots S_4$), trend covariance, diffs, zero crossings.
• compute_features(): On-demand snapshot evaluation (Quickselect, RealFFT) over circular ring buffer (capacity W).