GRAMPS Beyond Rendering

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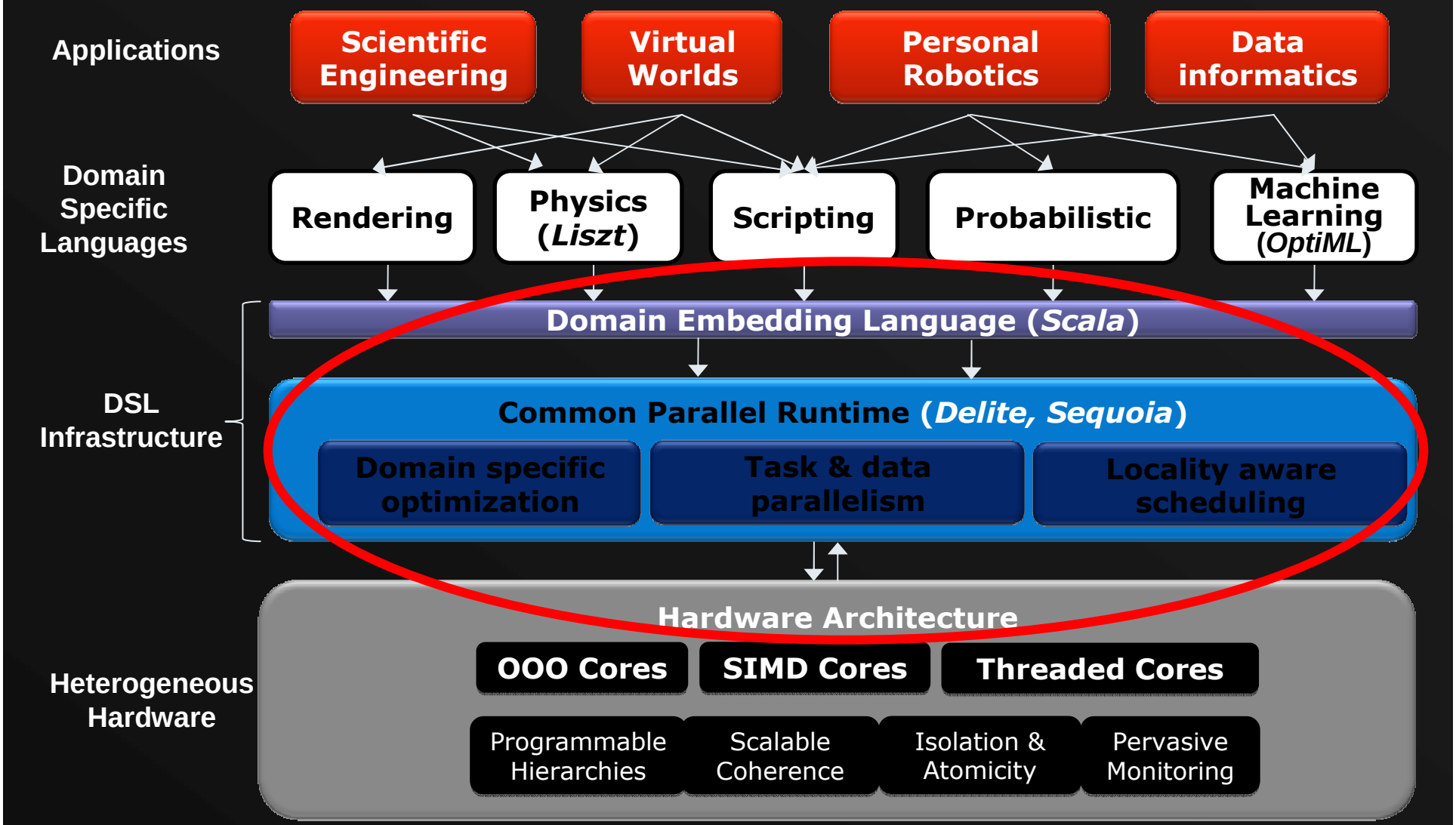
PPL Retreat

The PPL Vision: GRAMPS



Introduction

- Past: GRAMPS for building renderers
- This Talk: GRAMPS in two new domains: map-reduce and rigid body physics
- Brief mention of other GRAMPS projects

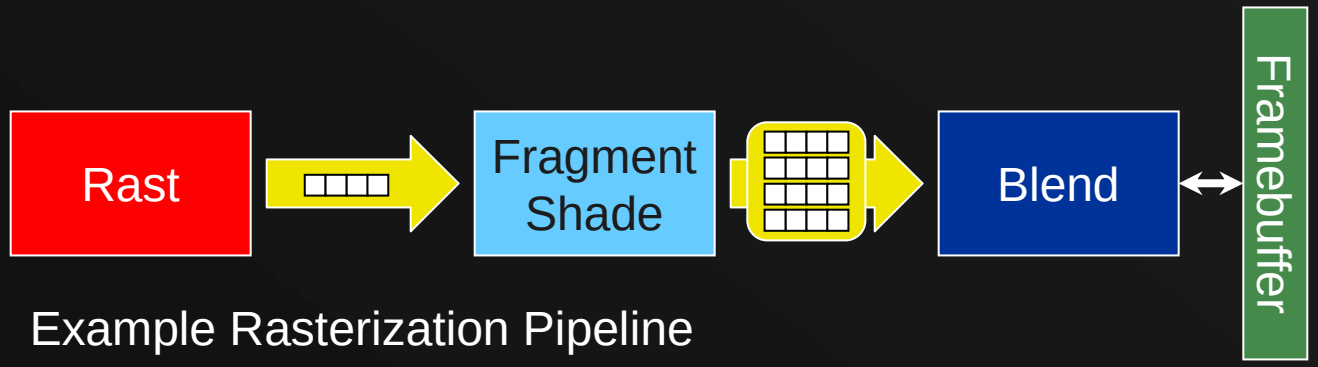
GRAMPS Review (1)

- Programming model / API / run-time for heterogeneous many-core machines

- Applications are:
  - Graphs of multiple stages (cycles allowed)
  - Connected via queues
- Interesting workloads are irregular

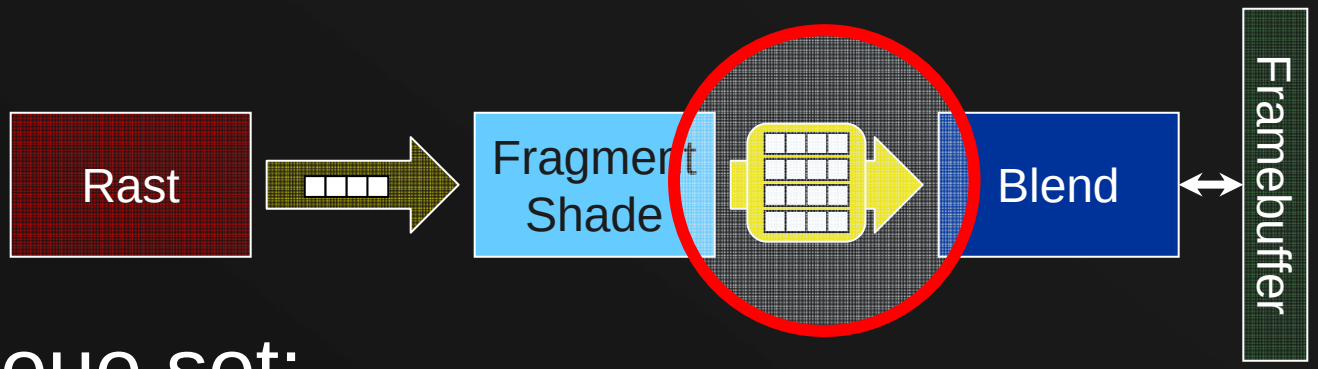
GRAMPS Review (2)

- Shaders: data-parallel, plus push
- Threads/Fixed-function: stateful / tasks



Example Rasterization Pipeline

GRAMPS Review (3)



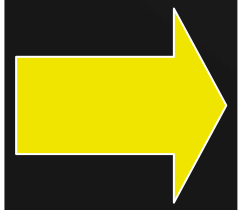
- Queue set:
  - single logical queue, independent subqueues
- Synchronization **and** parallel consumption
- Binning, screen-space subdivision, etc.

Map-Reduce

- Popular parallel idiom:

Map:

```
Foreach(input) {
    Do something
    Emit(key, &val)
}
```



Reduce:

```
Foreach(key) {
    Process values
    EmitFinalResult()
}
```

- Used at both cluster and multi-core scale
- Analytics, indexing, machine learning, …

Map-Reduce: Combine

- Reduce often has high overhead:
  - Buffering of intermediate pairs (storage, stall)
  - Load imbalance across keys
  - Serialization within a key
- In practice, Reduce is often associative and commutative (and simple).
- **Combine** phase enables *incremental*, *parallel* reduction

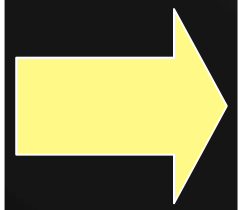
Preparing GRAMPS for Map-Reduce

Queue Sets, Instanced Threads

- Make queue sets more dynamic
  - Create subqueues on demand
  - Sparsely indexed ‘keyed’ subqueues
  - ANY_SUBQUEUE flag for Reserve

Make-Grid(obj):

```
For (cells in o.bbox) {
  key = linearize(cell)
  PushKey(out, key, &o)
}
```



Collide(subqueue):

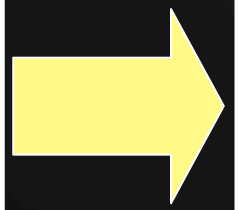
```
For (each o1, o2 pair)
  if (o1 overlaps o2)
    ...
```

Fan-in Shaders

- Use shaders for parallel partial reductions
  - Input: One packet, Output: One element
  - Can operate in-place or as a filter
  - Run-time coalesces mostly empty packets

Histogram(pixels):

```
For (i < pixels.numEl){
  c = .3r + .6g + .1b
  PushKey(out,c/256,1)
}
```



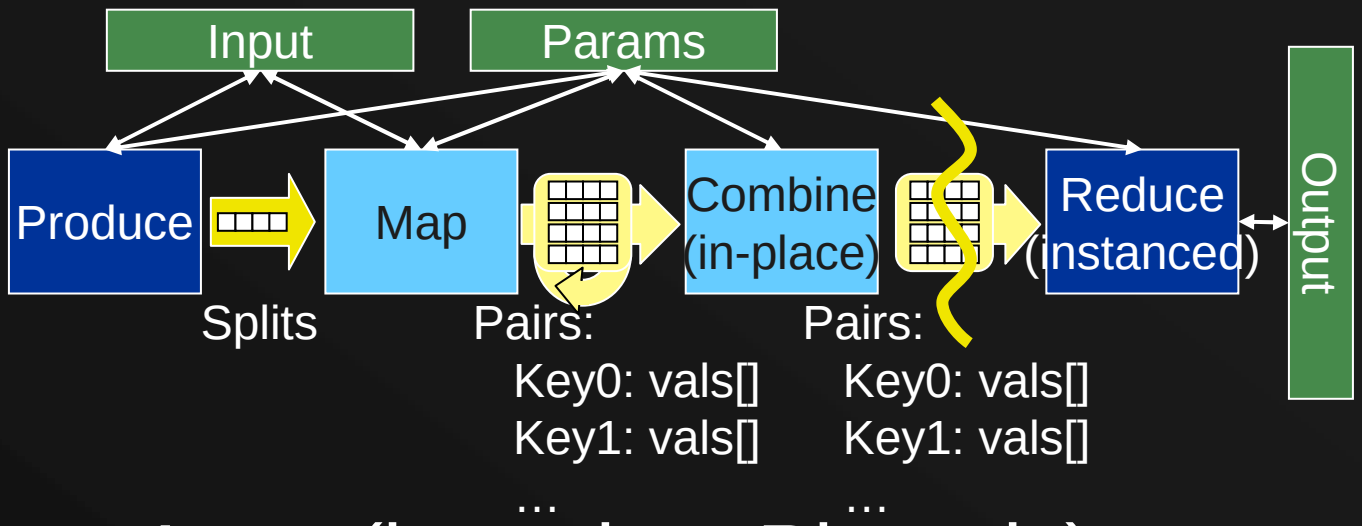
Sum(packet):

```
For (i < packet.numEl)
  sum += packet.v[i]
packet.v[0] = sum
packet.numEl = 1
```

Fan-in + In-place is a **builtin**

- Alternatives:
  - Regular shader accumulating with atomics
  - GPGPU multi-pass shader reduction
  - Manually replicated thread stages
  - Fan-in with same queue as input and output
- Reality: Messy, micro-managed, slow
  - Run-time should *hide* complexity, not export it

GRAMPS Map-Reduce



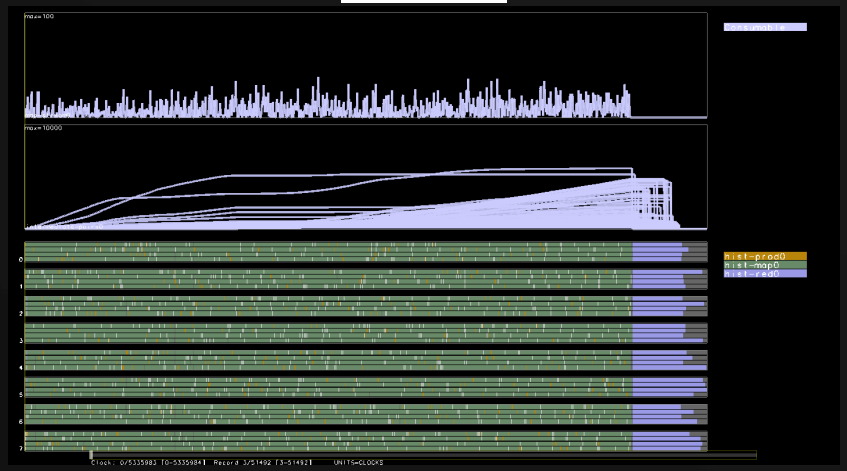
- Three Apps (based on Phoenix):
  - Histogram, Linear Regression, PCA
- Run-time Provides:
  - API, GRAMPS bindings, elems per packet

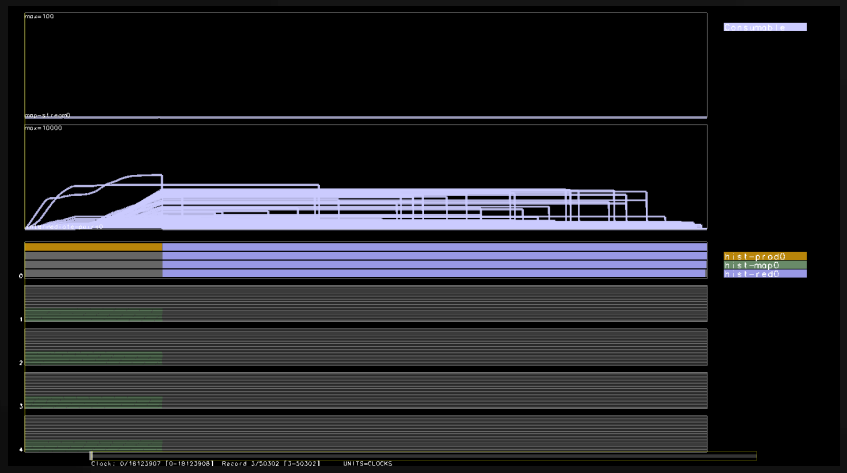
Map-Reduce App Results

	Occupancy (CPU-Like)	Footprint (Avg.)	Footprint (Peak)
Histogram-512	97.2%	2300 KB	4700 KB
(combine)	96.2%	10 KB	20 KB
LR-32768	65.5%	100 KB	205 KB
(combine)	97.0%	1 KB	1.5 KB
PCA-128	99.2%	.5 KB	1 KB

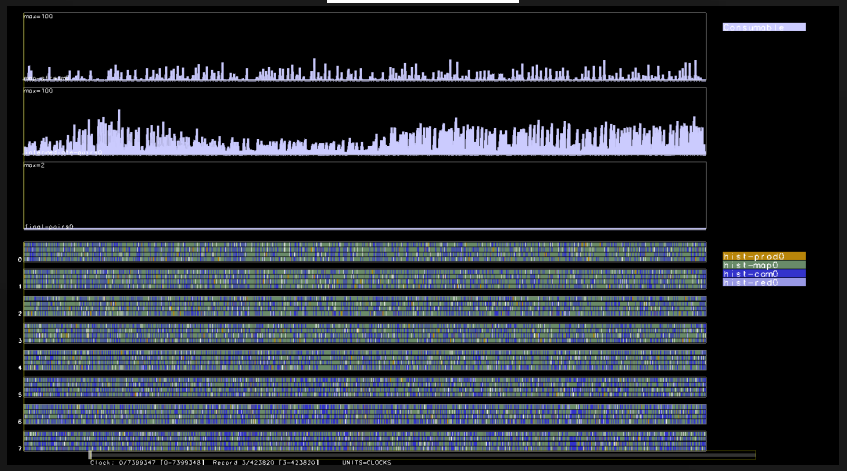
Reduce vs Combine: Histogram

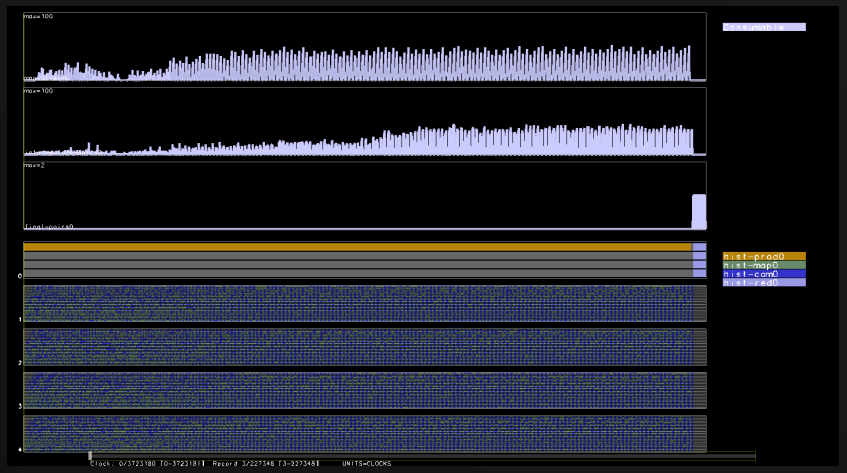
Reduce



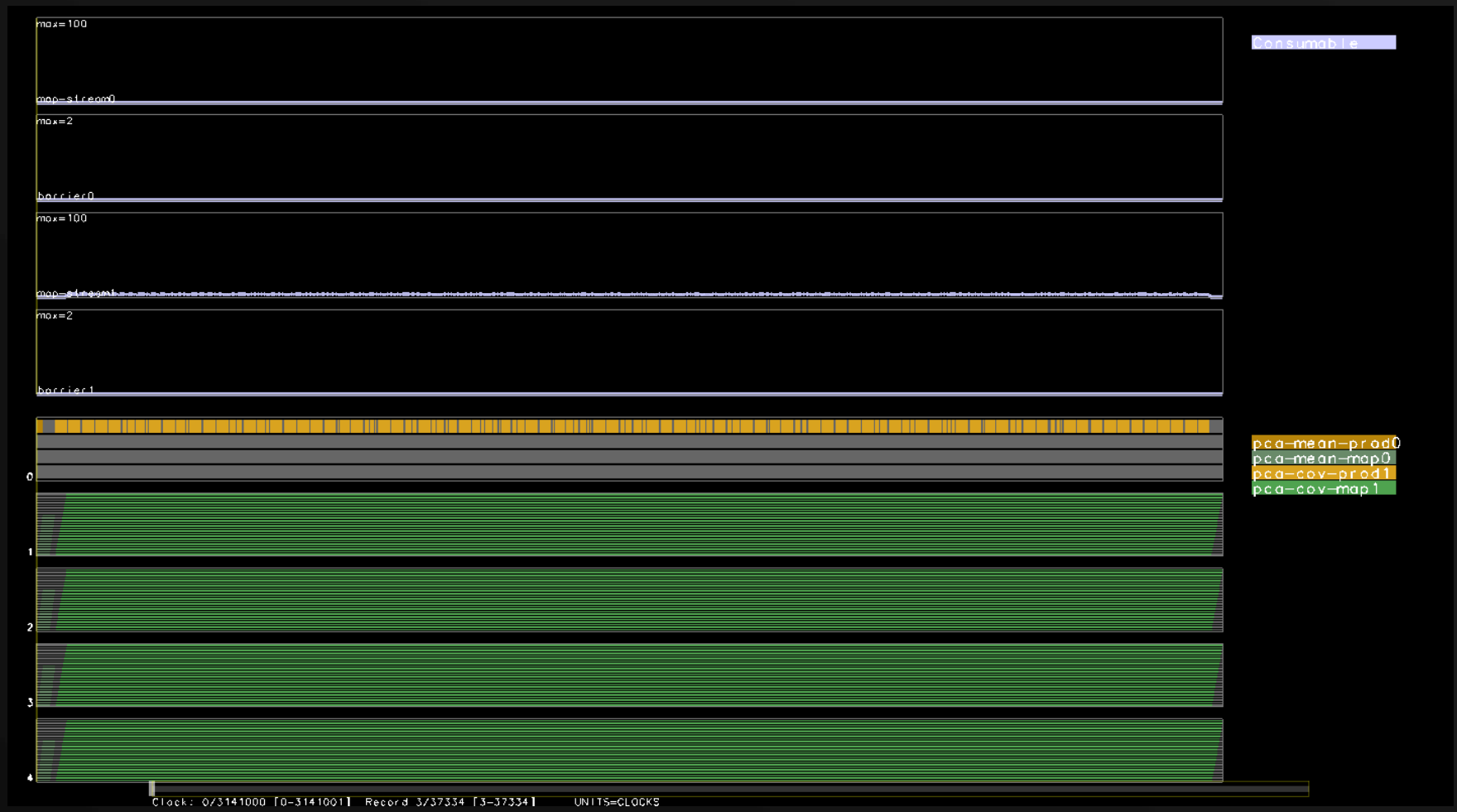


Combine

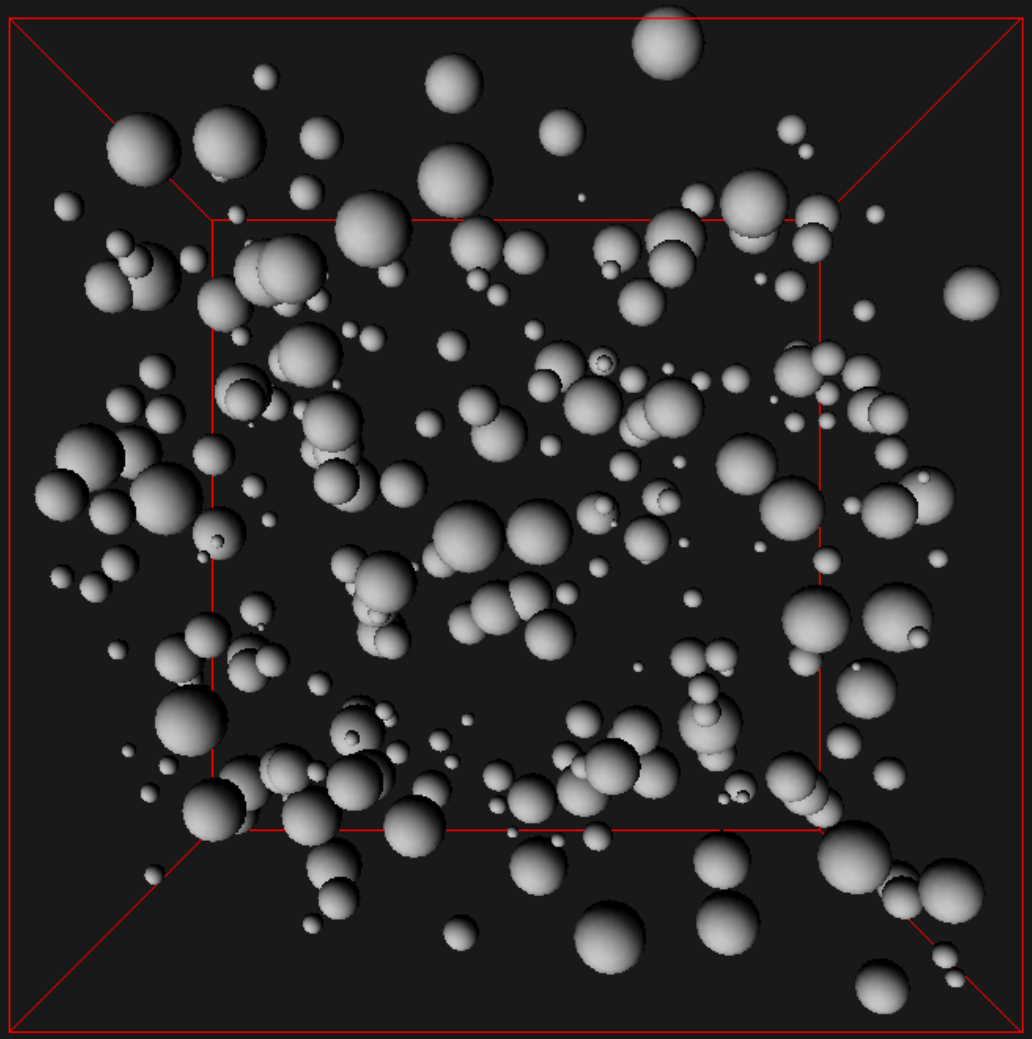




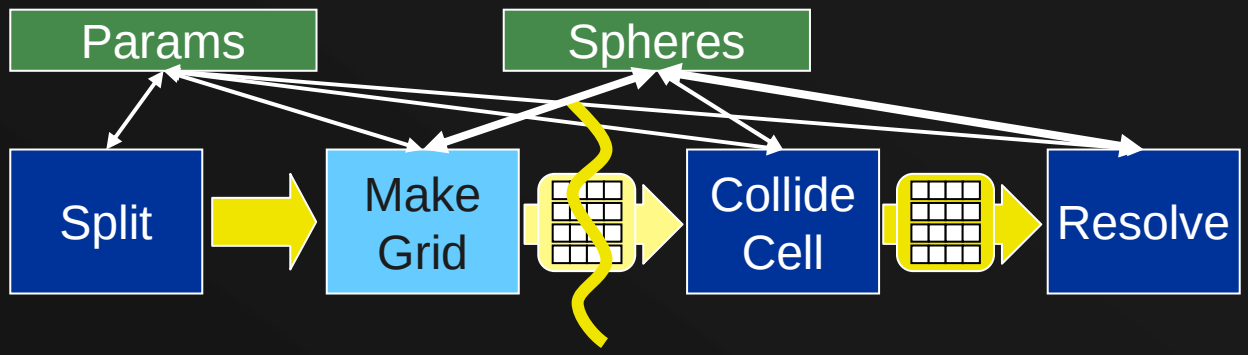
Two Pass: PCA (GPU-Like)



Sphere Physics

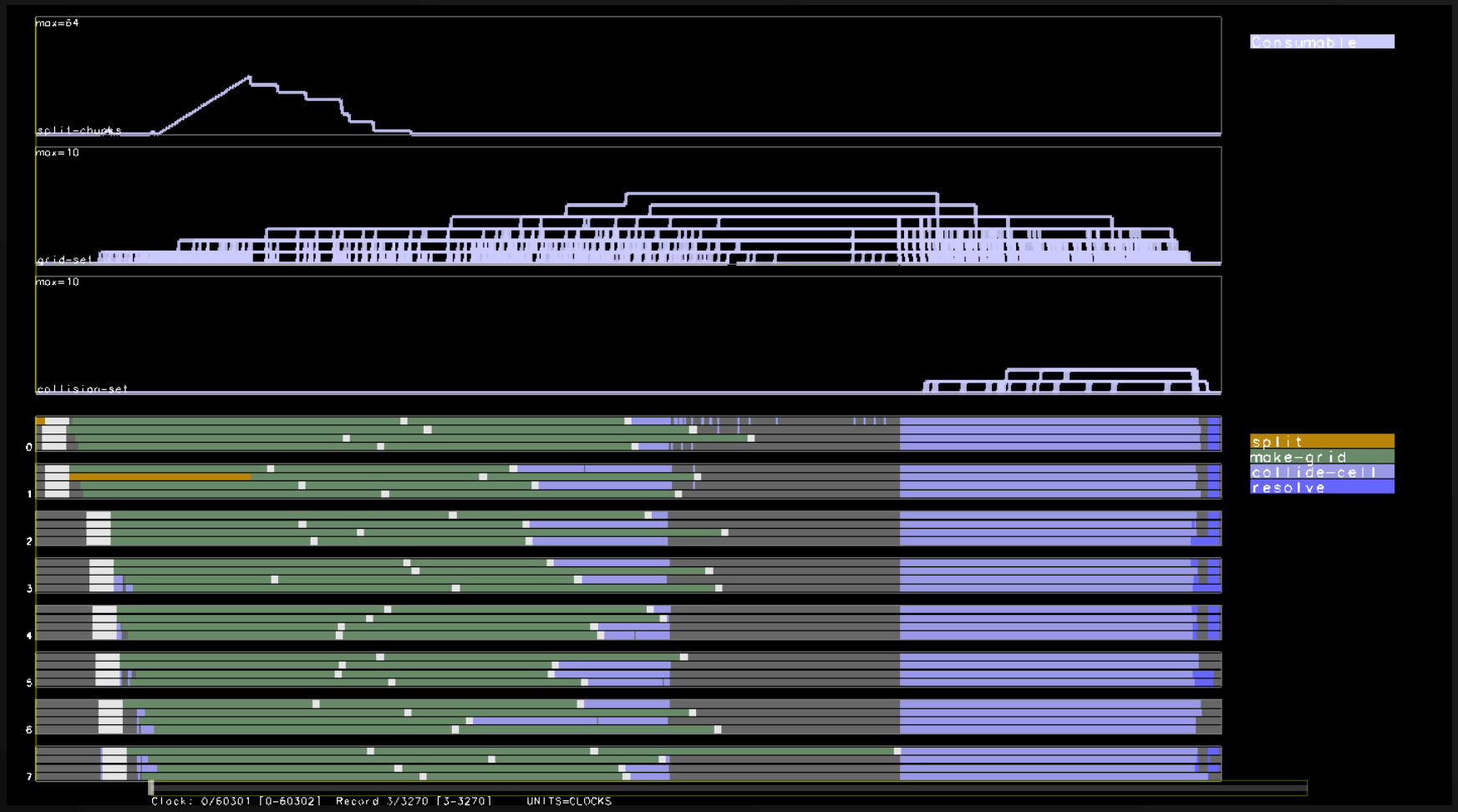


GRAMPS: Sphere Physics



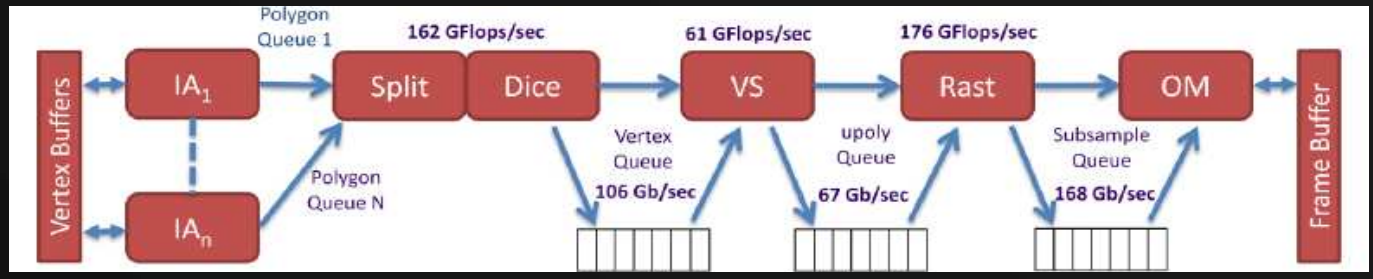
1. Split Spheres into chunks of N
2. Emit(cell, sphereNum) for each sphere
3. Emit(s1, s2) for each intersection in cell
4. For each sphere, resolve and update

256 Spheres (CPU-Like)

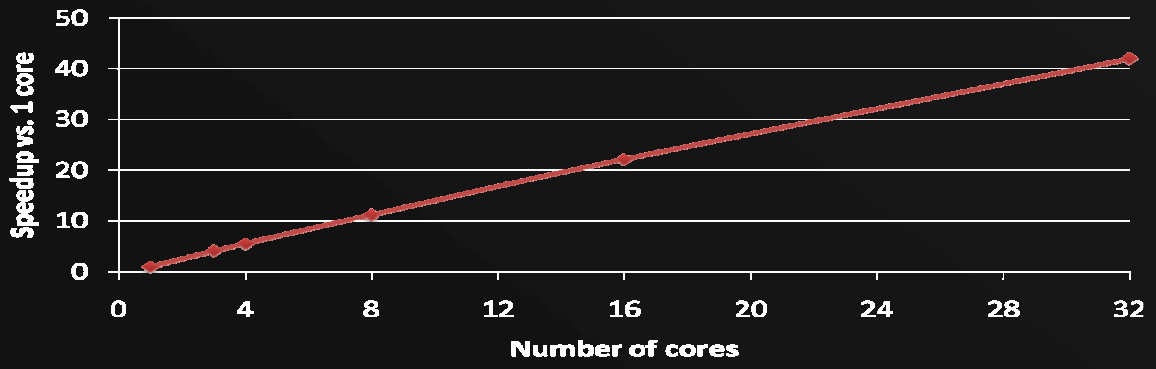


Other People's Work

- Improved sim: model ILP and caches
- Micropolygon rasterization, fixed functions



- x86 many-core:



Thank You

- Questions?

Backup Slides

Optimizations for Map-Reduce

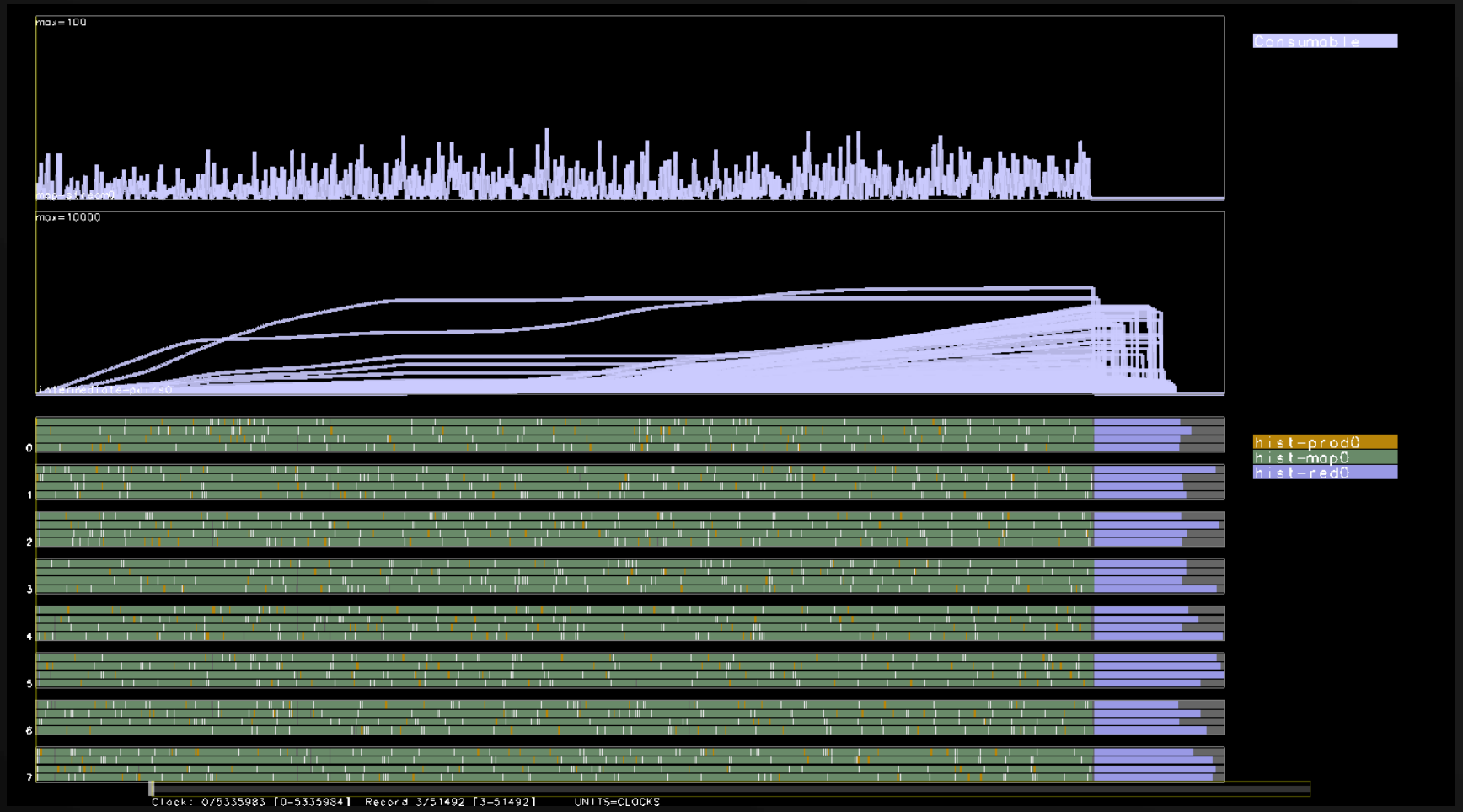
- Aggressive shader instancing
- Per-subqueue push coalescing
- Per-core scoreboard

GRAMPS Map-Reduce Apps

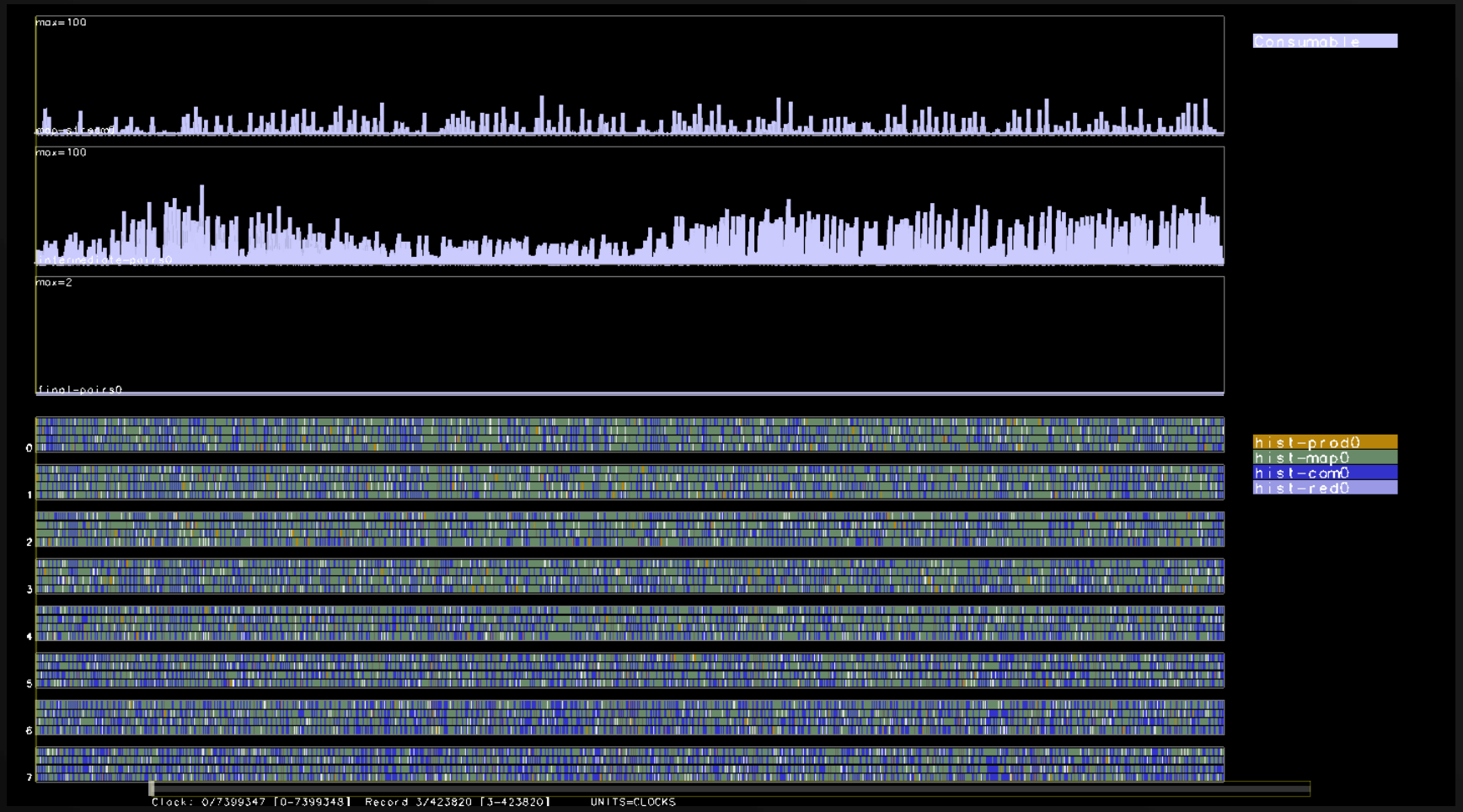
Based on Phoenix map-reduce apps:

- Histogram: Quantize input image into 256 buckets
- Linear Regression: For a set of (x,y) pairs, compute average x, x^2, y, y^2, and xy
- PCA: For a matrix M, compute the mean of each row and the covariance of all pairs of rows

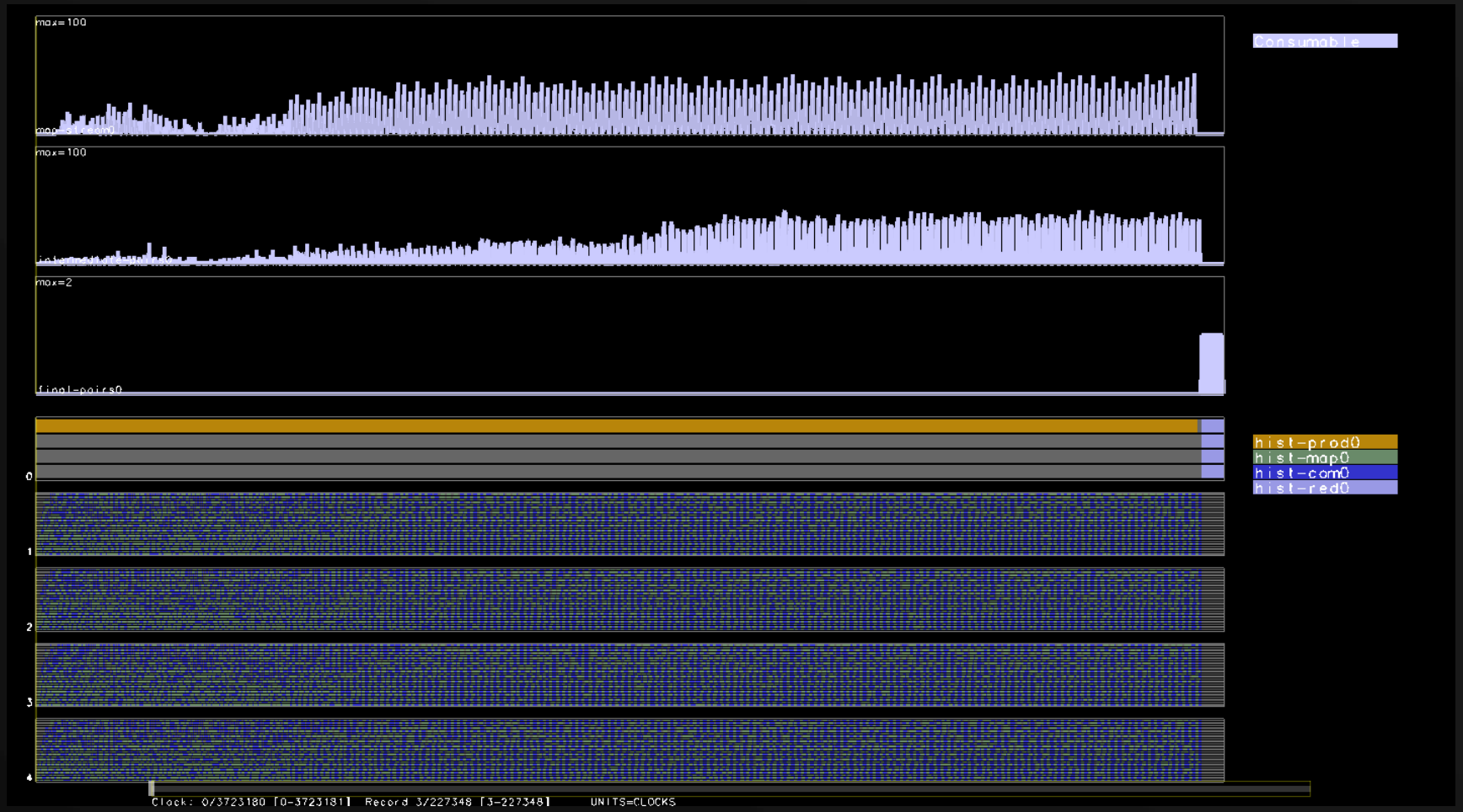
Histogram 512x512



Histogram 512x512 (Combine)

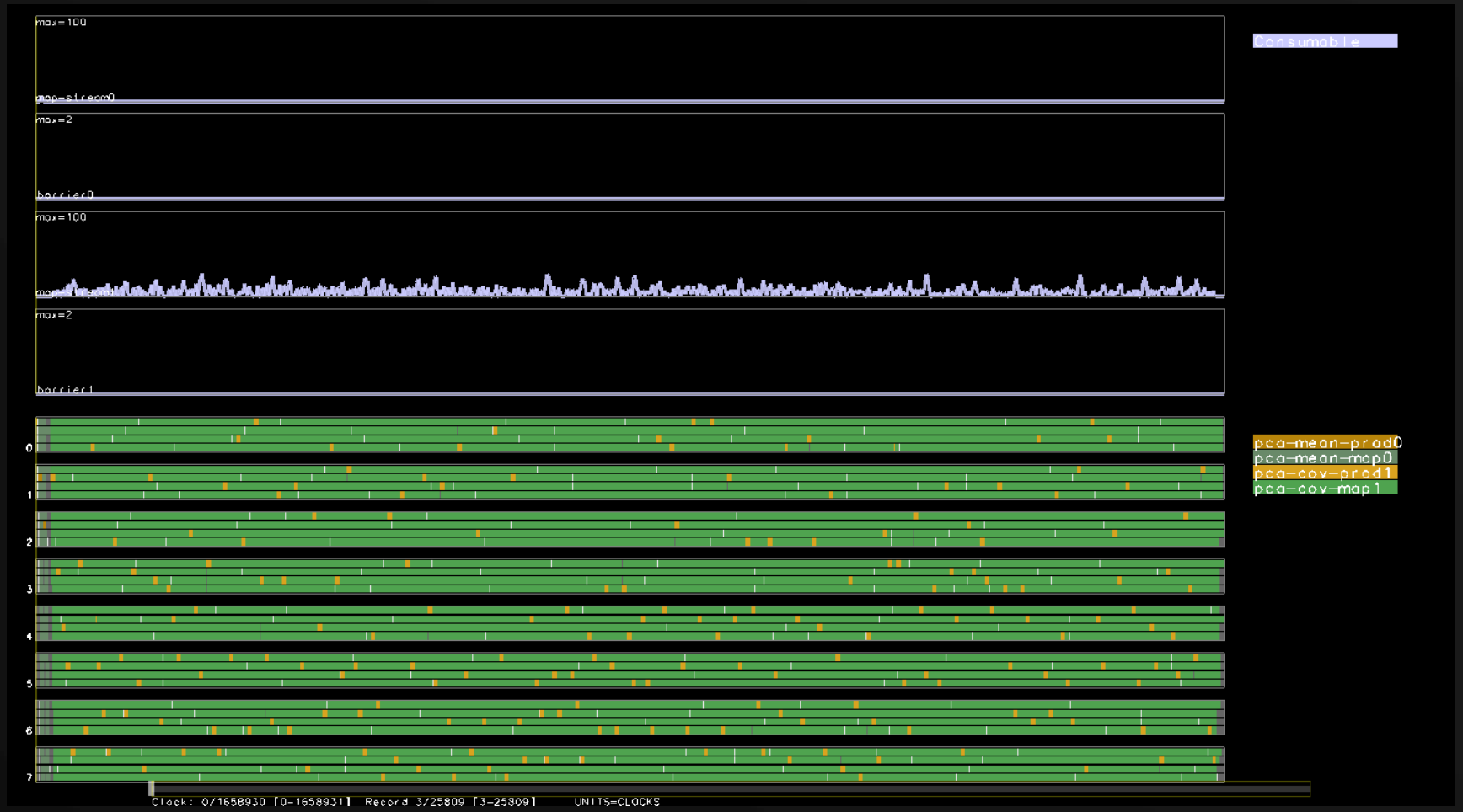


Histogram 512x512 (GPU)



Linear Regression 32768

PCA 128x128 (CPU)



Sphere Physics

A (simplified) proxy for rigid body physics:

```
Generate N spheres, initial velocity
while(true) {
```

- Find all pairs of intersecting spheres
- Compute Δv to resolve collision (conserve energy, momentum)
- Compute updated result velocity and position

```
}
```

Future Work

- Tuning:
  - Push, combine coalesce efficiency
  - Map-Reduce chunk sizes for split, reduce
- Extensions to enable more shader usage in Sphere Physics?
- Flesh out how/where to apply application enhancements, optimizations