

# Synthesis-Free, Flexible and Fast Hardware Library for Biophysically Plausible Neurosimulations

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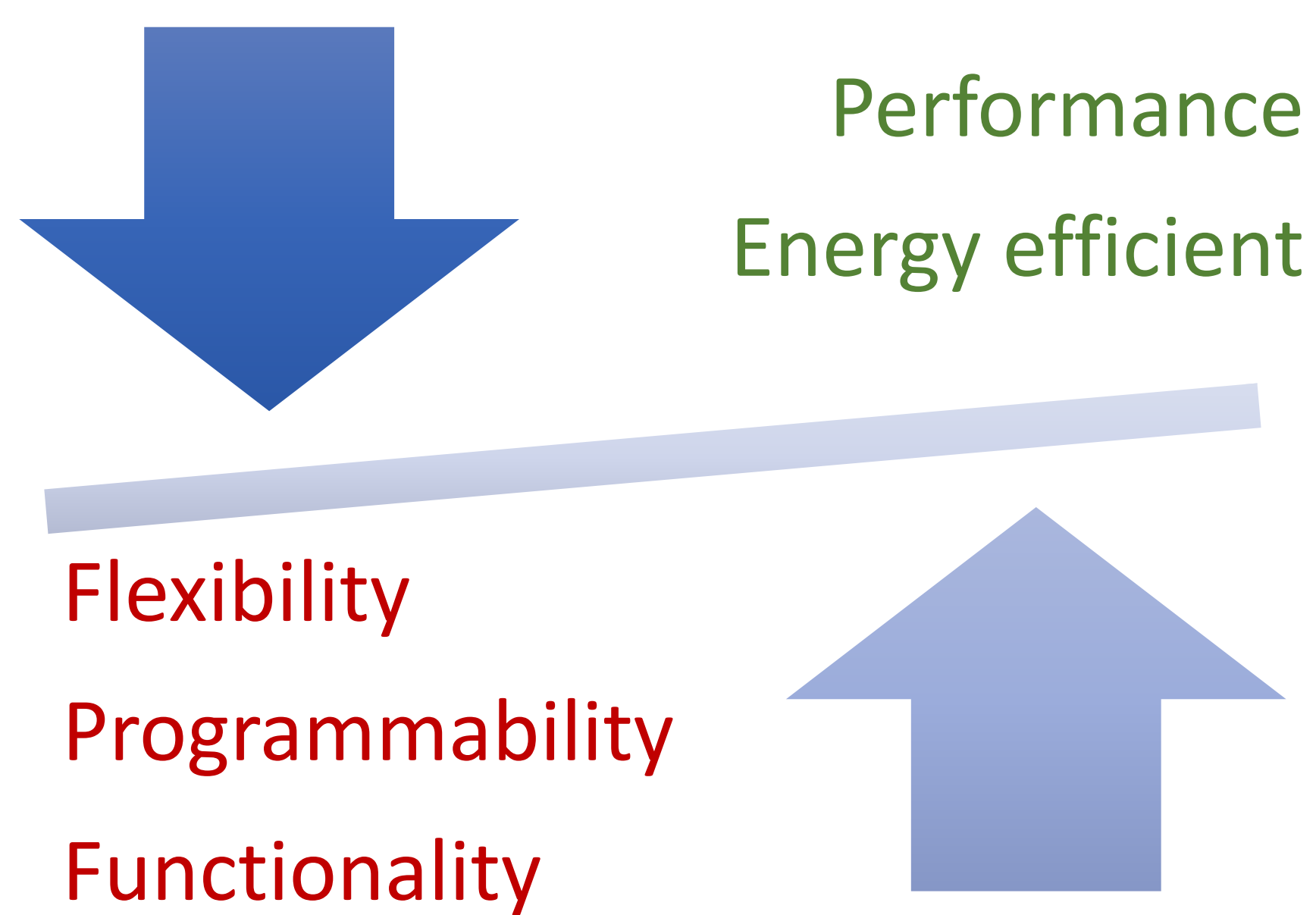
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## Introduction

### Goal

Flexible and fast simulations of computationally intensive and biophysically plausible models, Hodgkin-Huxley (HH) models

### Problem



### Solution

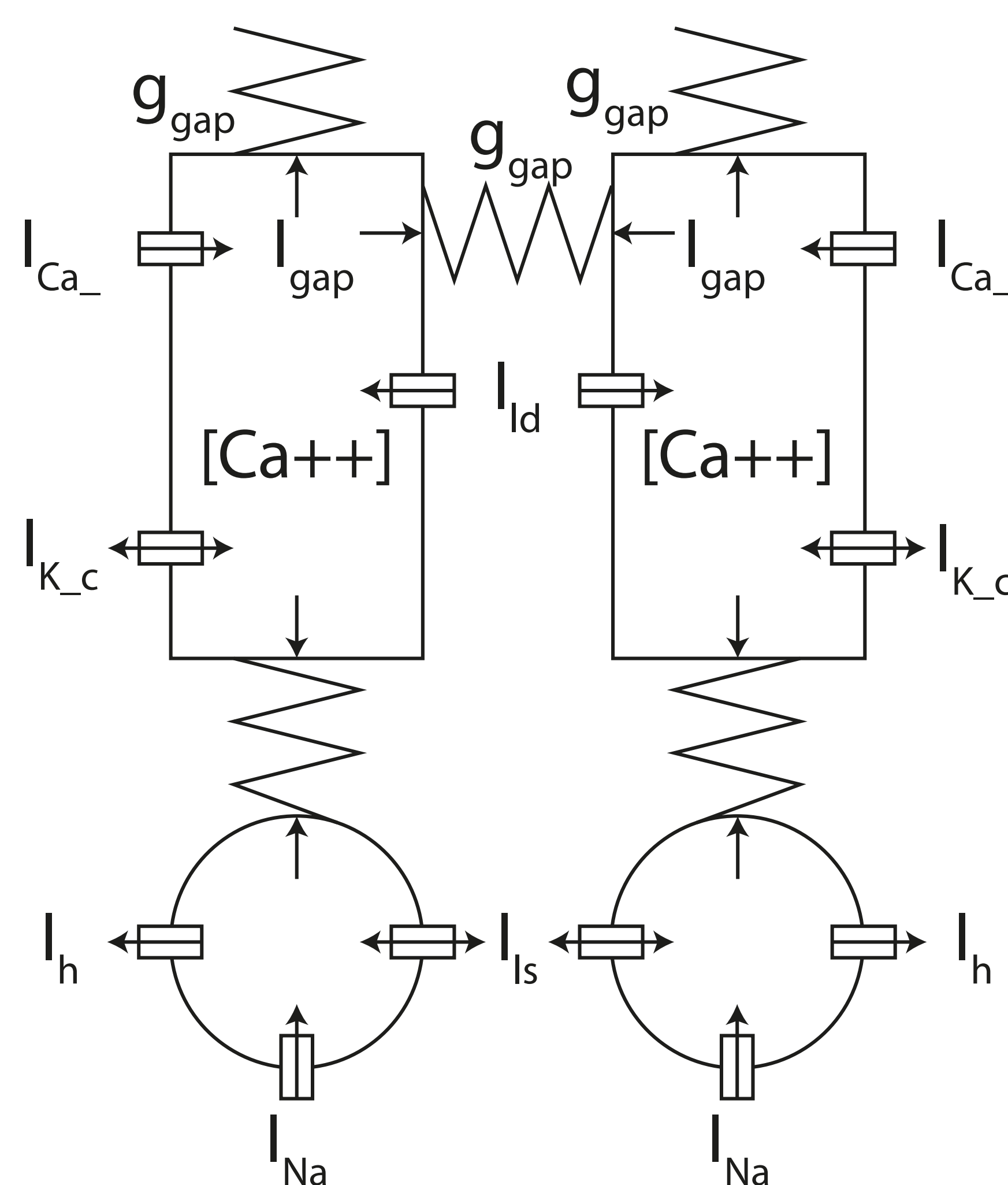
Provide *efficient* hardware library with *precompiled* kernels

## eHH modeling

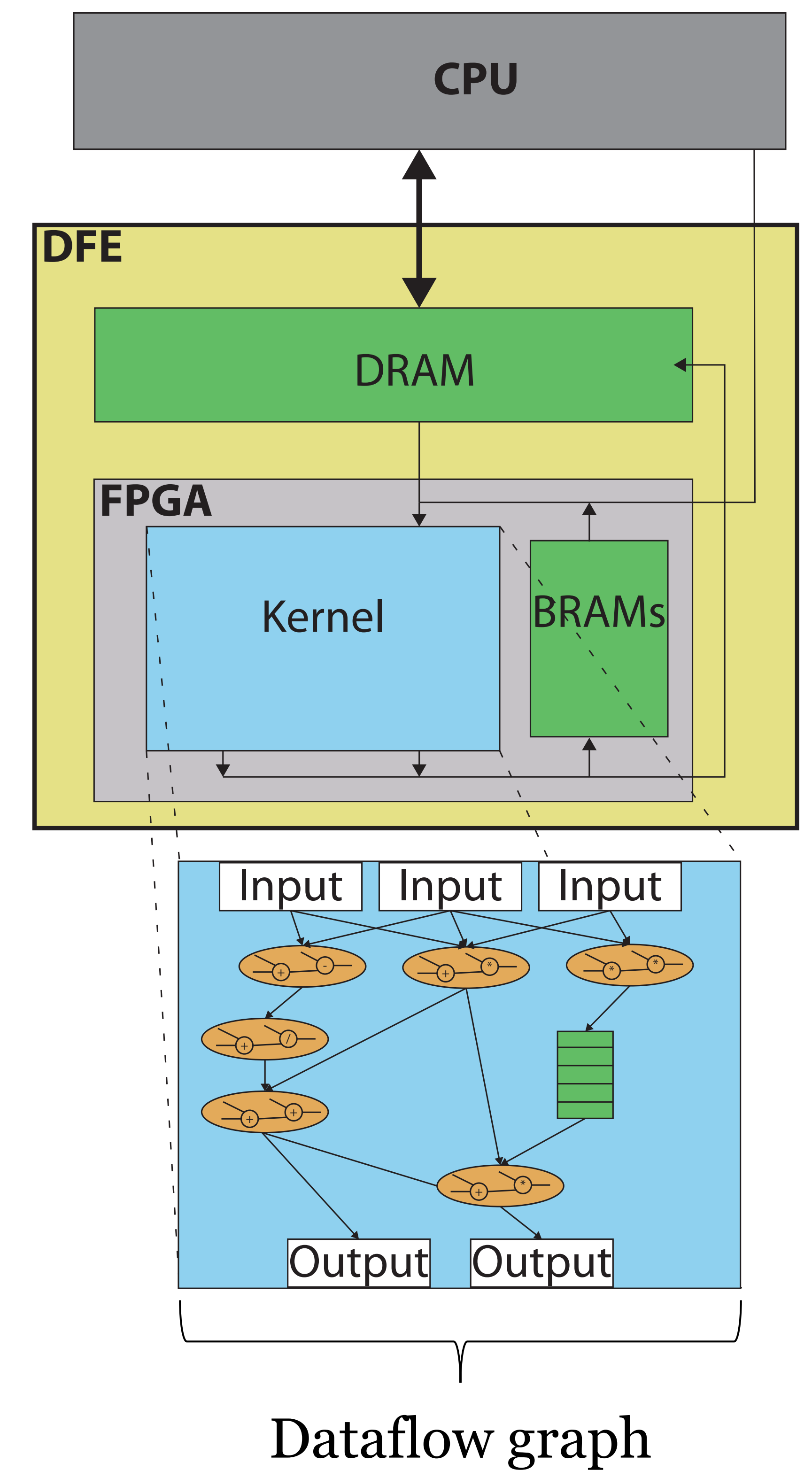
HH models comprise ODE systems, typically solved via Fwd-Euler

Three crucial features added, extending the original HH model:

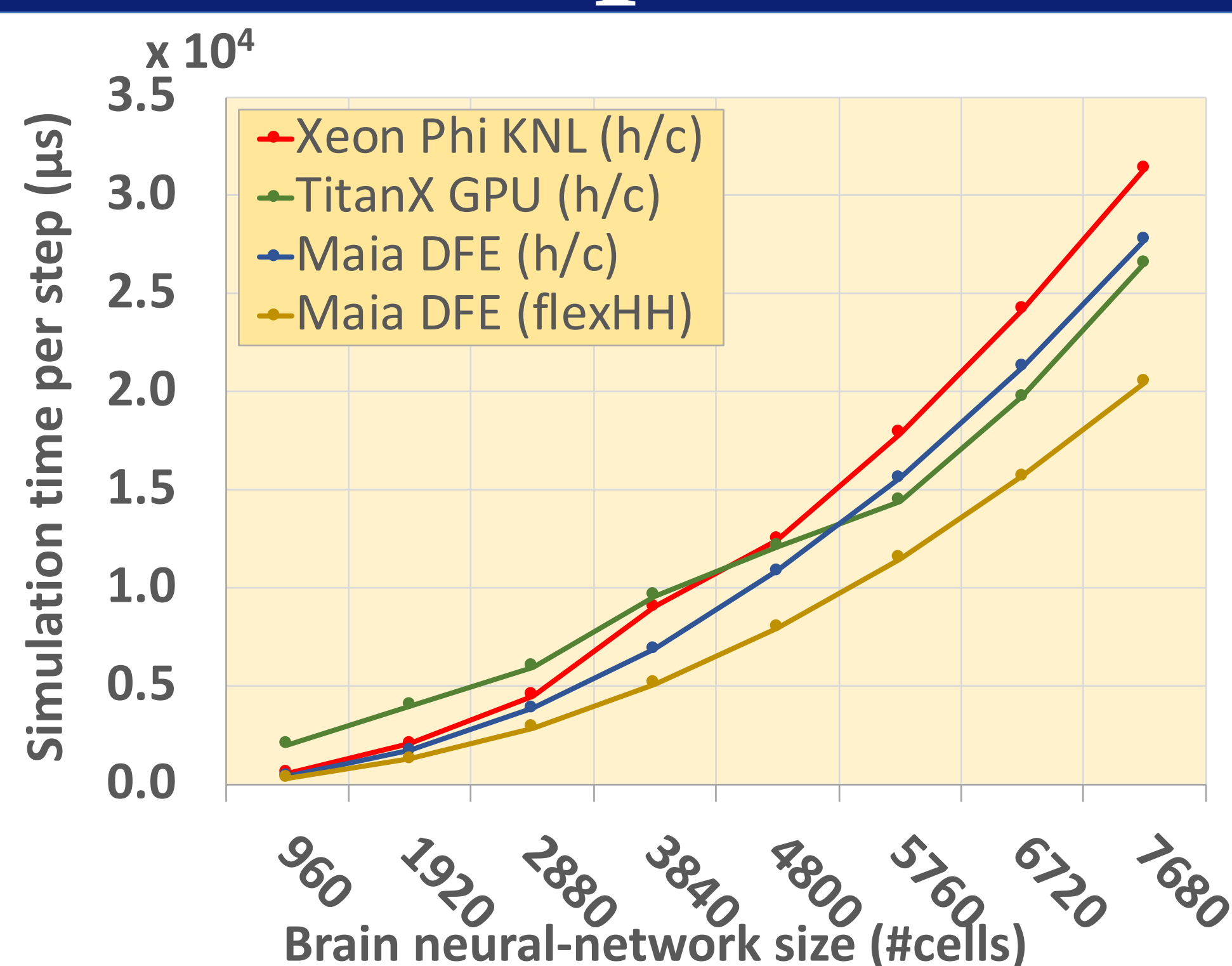
- Custom ion gates
- Gap junctions
- Multi-compartmental neurons



## Hardware architecture



## Results: Performance vs HPC platform



## Precompiled kernels

Kernel	Custom ion gates	Gap junctions	Multiple cell compartments	uf	$N_{comps,max}$	Speedup
HH	×	×	×	4	53,248	20.05x
HH+gap	×	✓	×	24	24,576	17.82x
HH+custom	✓	×	×	3	52,248	11.18x
HH+custom+multi	✓	×	✓	4	28,672	8.63x
HH fully featured	✓	✓	✓	16	24,676	14.11x

## Results: Performance vs. FPGAs

Kernel	flexHH HH	flexHH fully featured	BrainFram DFE (h/c)	Beuler et al. (h/c)	Zjajo et al. (h/c)
Model	HH	IO (eHH)	IO (eHH)	simplified HH	IO (eHH)
Time-step size (ms)	0.06	0.01	0.05	0.10	0.05
RT performance (GFLOPS)	11.22	44.07	28.38	1.60	14.33
Speedup	20.05x (C)	14.11x (C)	17.69x (C)	2.49x (C++)	>3,500x (SystemC)
RT Perform. Density (FLOPS/LUT)	21,395	91,180	54,096	10,721	16,931

## Conclusions

- + Flexible, scalable & high-performing eHH-model library
- + Meaningful H/W library for neuroscientists
- + High efficiency in resource usage
- + Predictable power and performance results
- Potentially higher compute requirements

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