Optimizing Temporal Decoupling using Event Relevance

Lukas Jünger[1], Carmine Bianco[2], Kristof Niederholtmeyer[2], Dietmar Petras[2], Rainer Leupers[1]

[1]: Institute for Communication Technologies and Embedded Systems, RWTH Aachen University
[2]: Synopsys GmbH, Aachen

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Motivation

- HW/SW Systems become ever more complex
- Today millions of lines of code
  - Many bugs
  - High complexity
- Fast and precise Virtual Platforms (VPs) needed for software verification

Space Shuttle: ~400.000 LOC

Summary

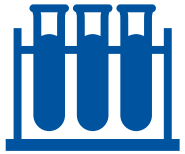
- Thoroughly analyzed two prevalent SystemC TLM2.0 temporal decoupling schemes
- Novel performance optimization (+14,32%) in temporally decoupled VPs with near perfect accuracy
- Representative case study with industrial state-of-the-art VP

Agenda

Temporal Decoupling In SystemC

Related Work

Event Relevance Optimization



Case Study

Conclusion & Future Work

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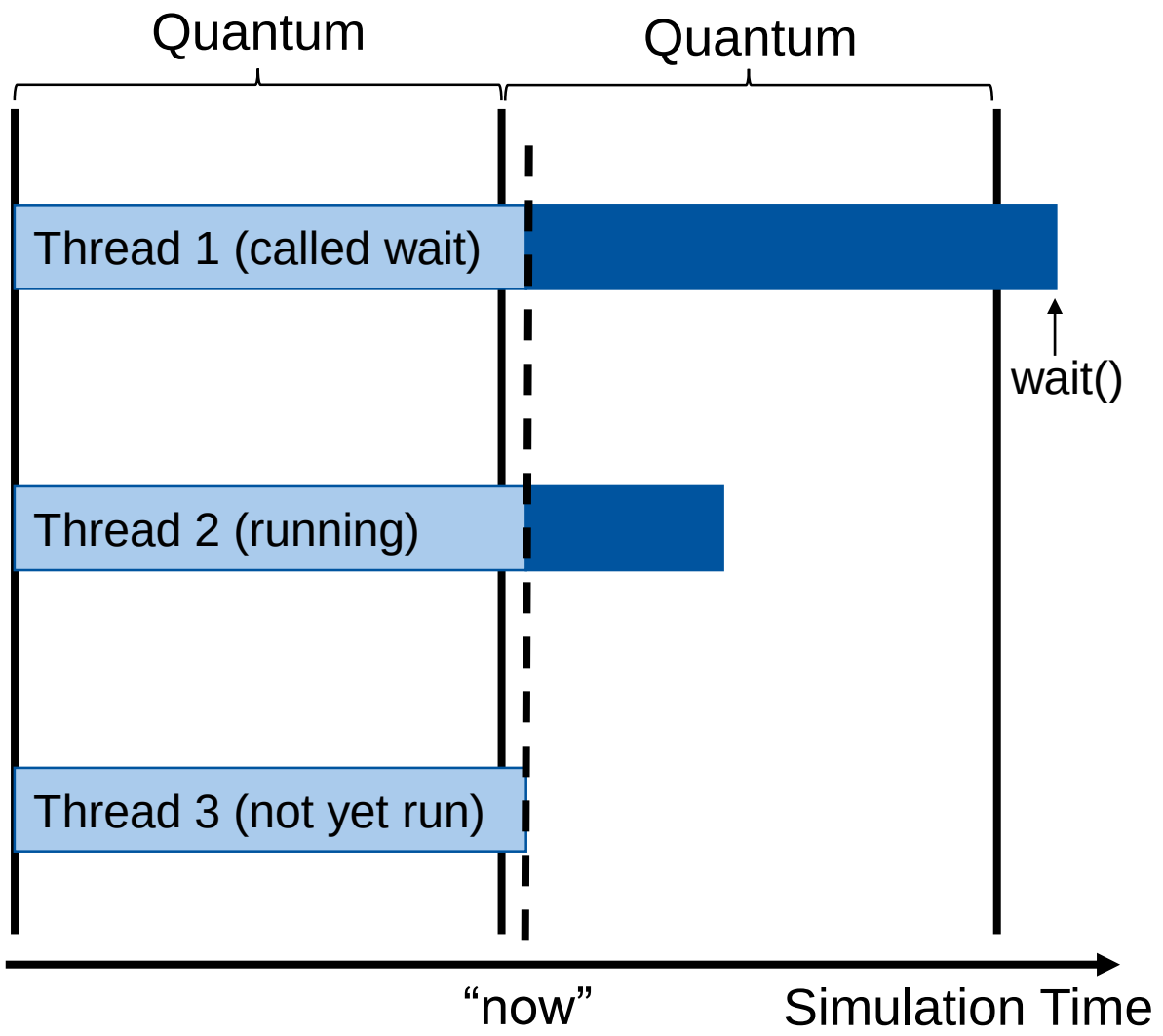
Temporal Decoupling in SystemC

- Acceleration technique in SystemC TLM2.0 LT coding style
- Threads run ahead of simulation time
  - Reduces context switching overhead
- Threads yield execution with wait()
- Reduced accuracy, because events can be missed
- **Quantum size defines tradeoff between accuracy and performance**



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Related Work

- Gläser et al. [5] (2016): Predicting quantum size to optimize accuracy by switching to cycle accurate simulation before event is triggered
- Jung et al. [7] (2019): Avoid correctness issue using a rollback mechanism for each quantum
- Schumacher et al. [9] (2010): Accelerate simulation by executing events in parallel without temporal decoupling

Publication	Accuracy	Performance	Applicability
Gläser et al.	+	-	~
Jung et al.	+++	--	-
Schuhmacher et al.	++	+	+
This work	++	++	++

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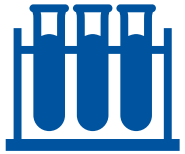

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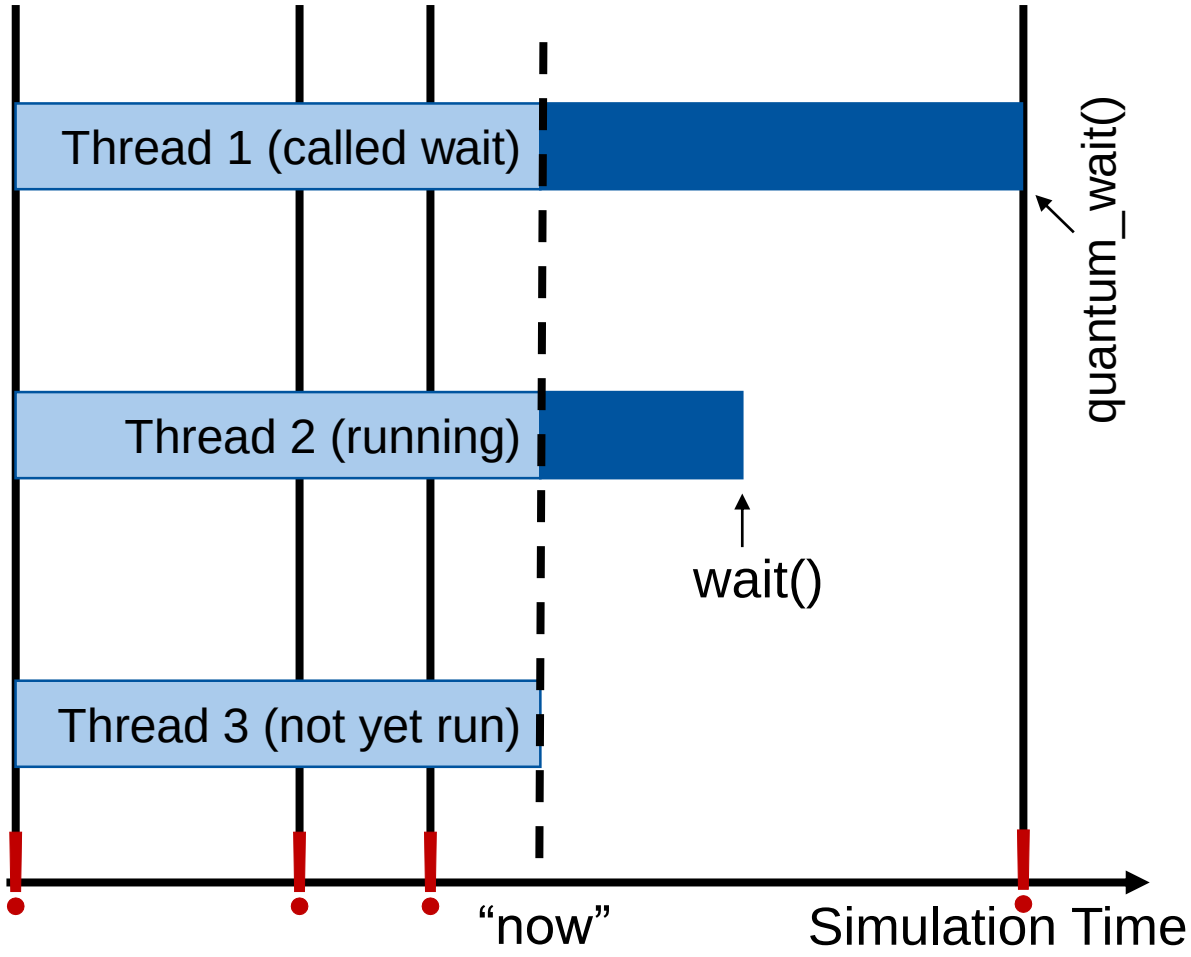
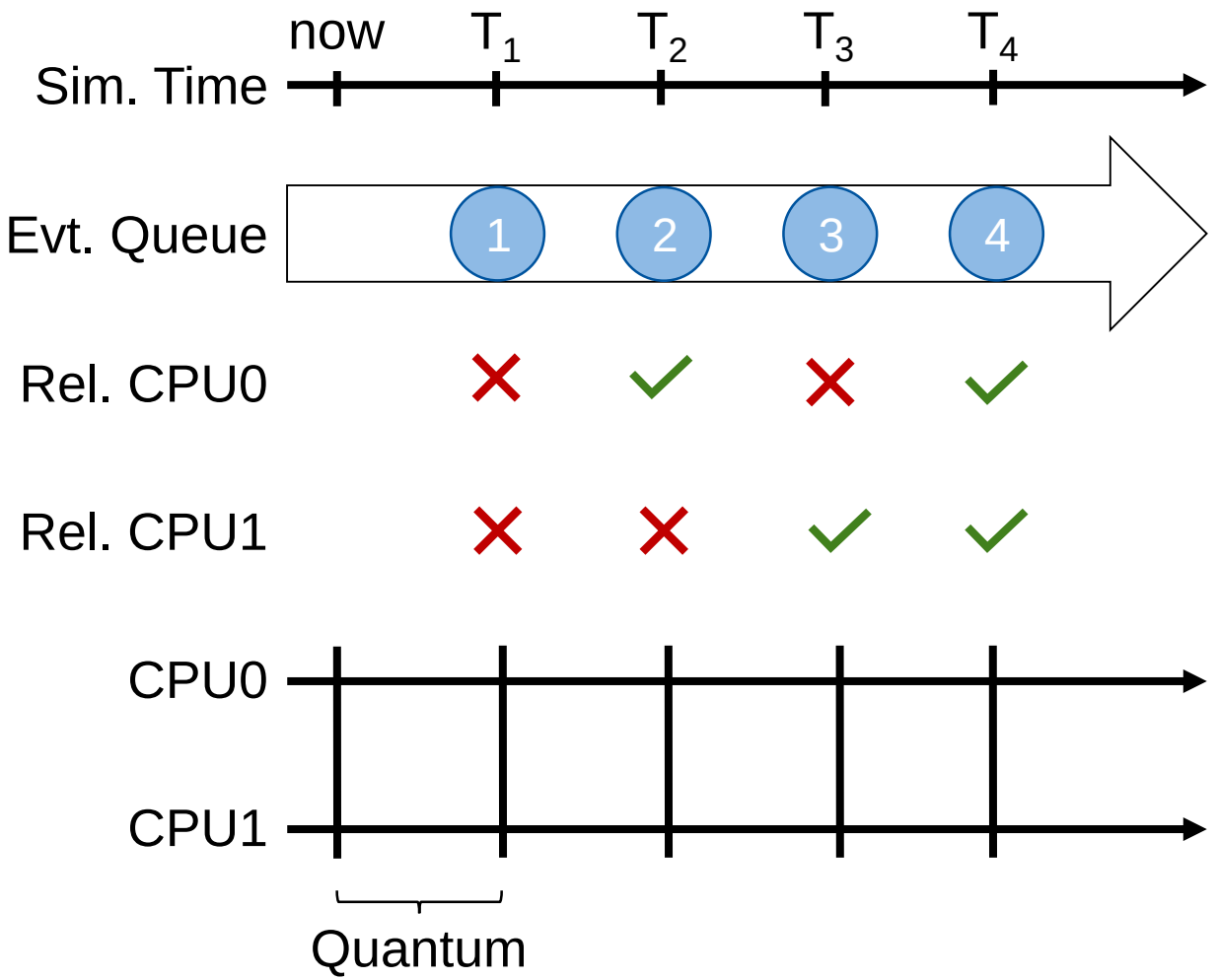
The Dynamic Quantum

- Temporal Decoupling strategy to improve accuracy
- Set Quantum boundary at next timed event notification (!)
  - No event can be missed
- Global Quantum is only an upper limit



Event Relevance Optimization

- Not all events are equally relevant
  - E.g. events internal to a module
- Global timed event queue in SystemC
- Quantum of thread can be limited even by irrelevant events
  - Leads to reduced performance



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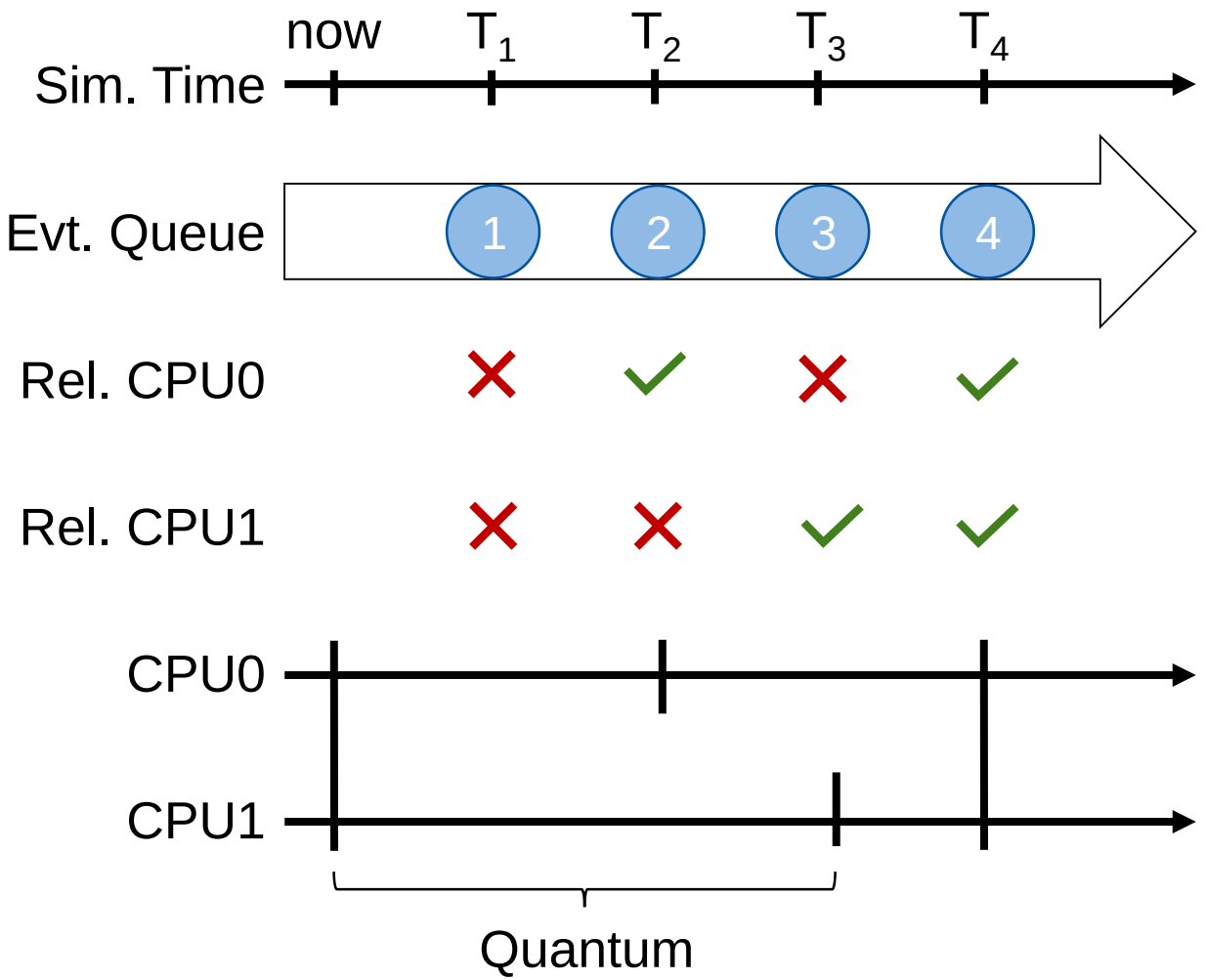
- **Idea: Only take relevant events into account for Quantum computation**



Determining Event Relevance

- Annotation not always possible, e.g. models form third parties

- Lightweight SystemC profiler to generate Event Dependency Graph
  - Data collection during profiling run
  - Separate data analysis step

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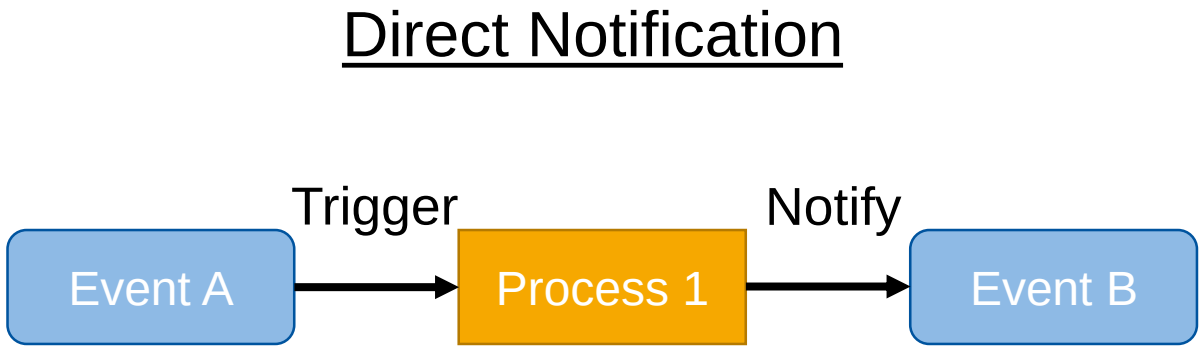
- Different event notification patterns



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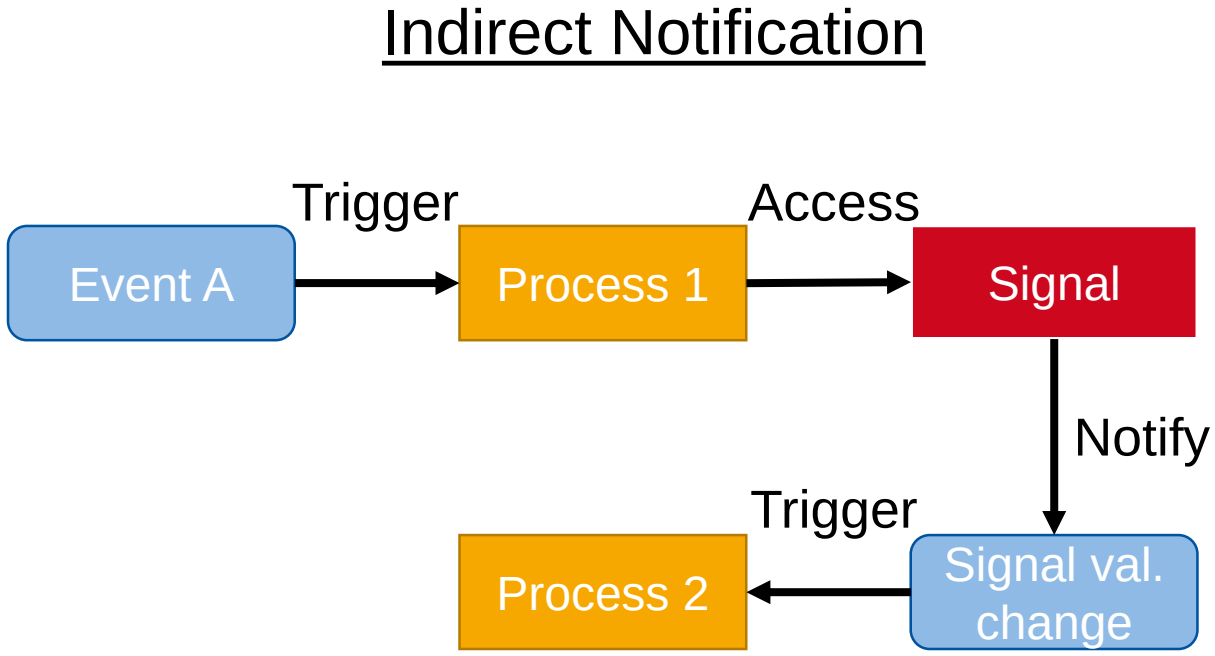

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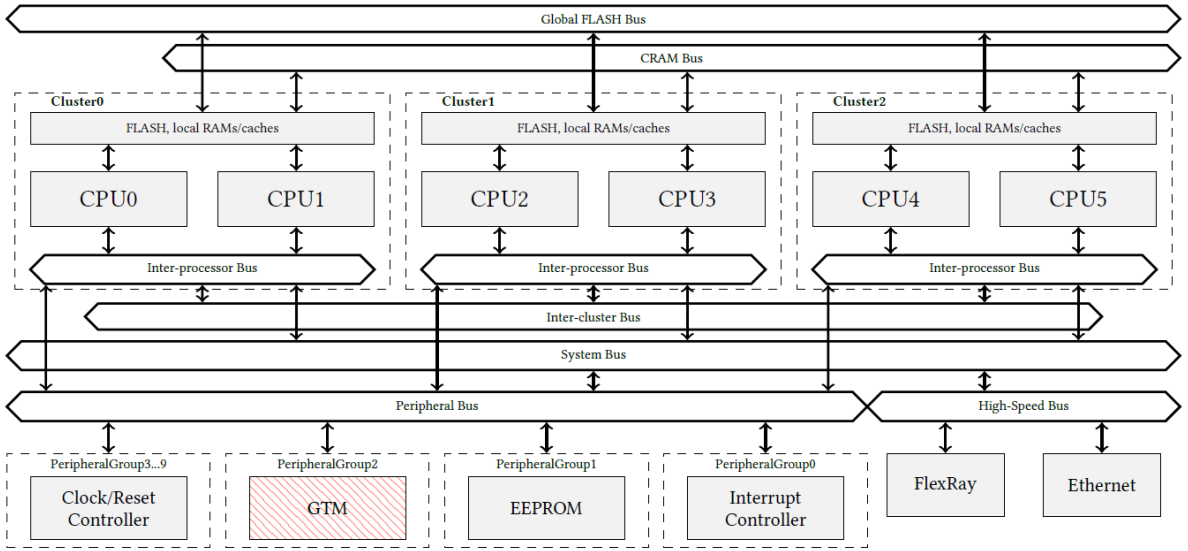
Industrial VP Case Study

- Industrial automotive VP
- Many components
  - Cores, peripherals busses
- Executing engine management task
- Calculation done on GTM coprocessor
  - Interrupts to main CPU
- Small quantum in GTM (10 cycles)



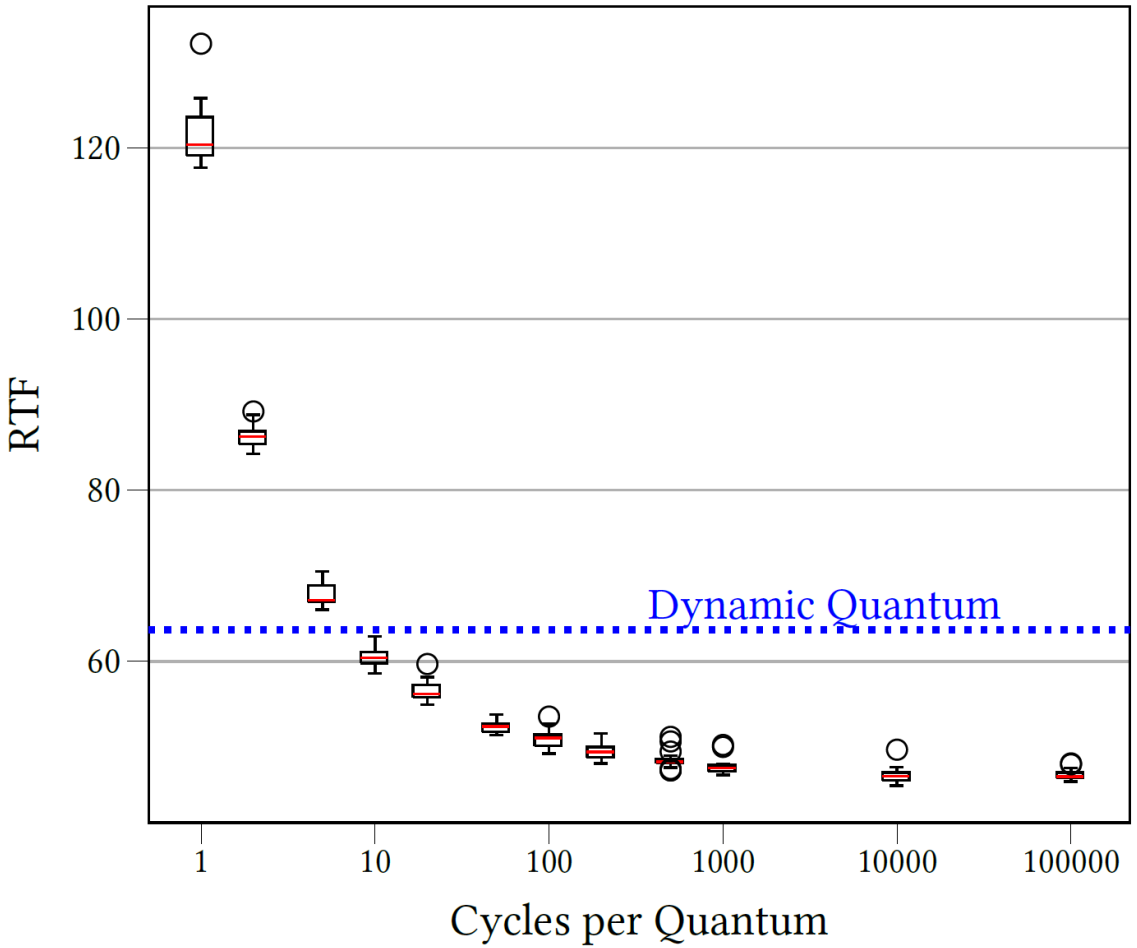
Evaluation Metrics

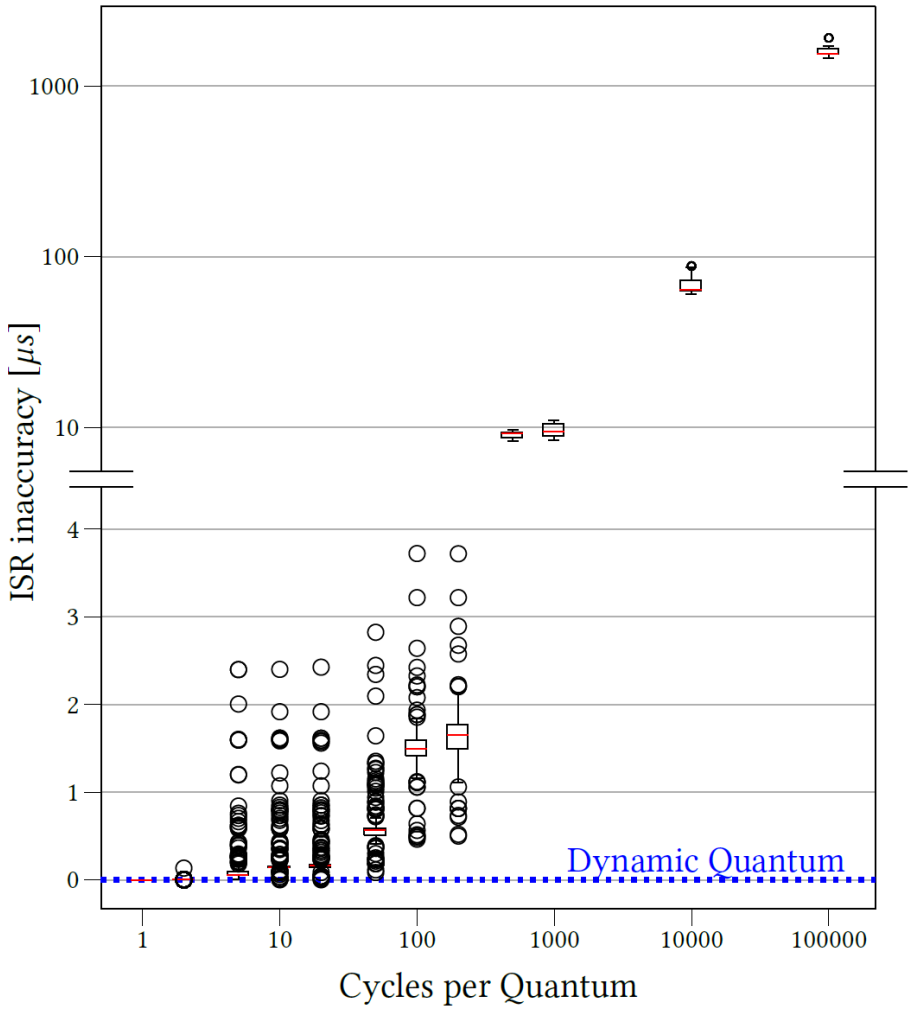
- Evaluation of performance and accuracy
- Performance metric: **Real-Time Factor (RTF)**

$$RTF[t_{sim}] = \frac{Wall-clock\ time}{Simulation\ time} = \frac{T_{WC}[0; t_{sim}]}{t_{sim}}$$

- Accuracy metric: **Delay in Interrupt Service Routine (ISR)** execution
  - Interrupt propagation delayed by temporal decoupling

Results for Static and Dynamic Quantum





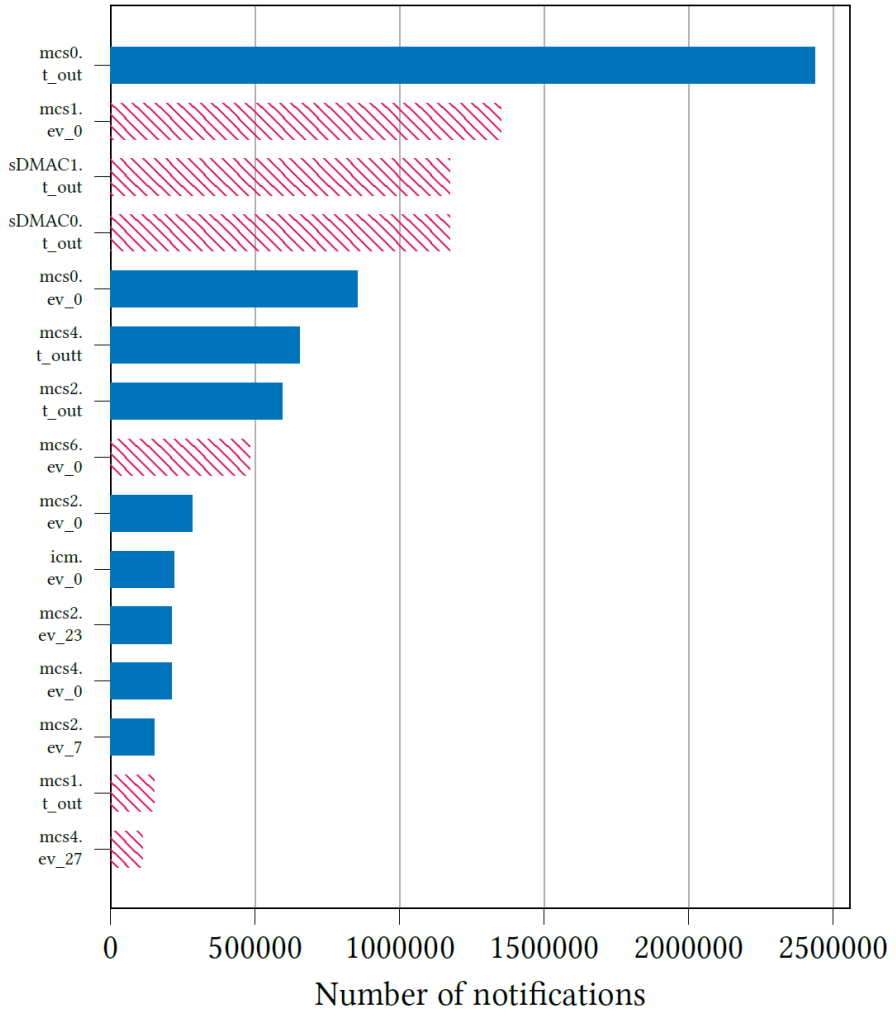
VP Event Notification Analysis

- SystemC profiler to generate Event Dependency Graph

- ~10.000.000 Quanta per simulation run
- ~11.000.000 Quantum limiting event notifications
- 3860 events

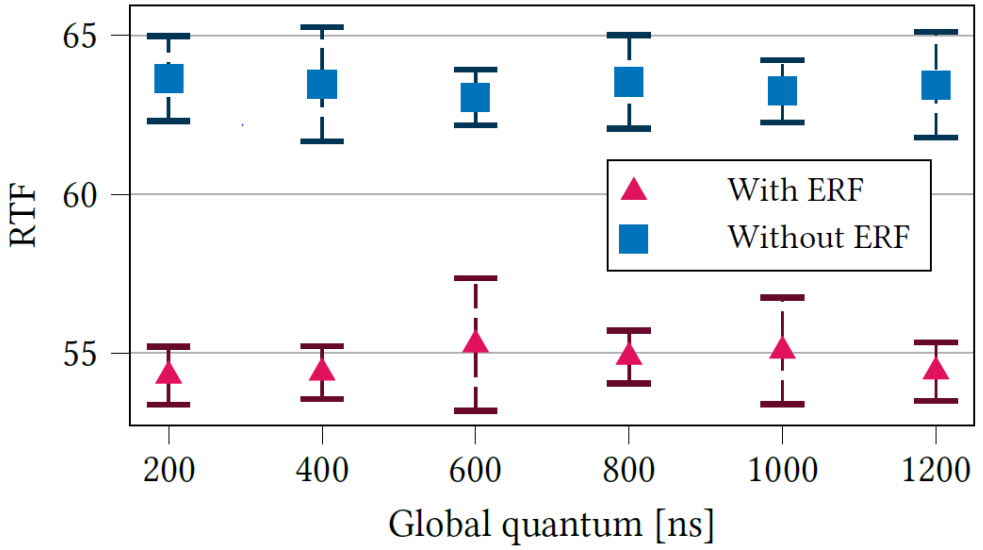
- Analyze Quantum limiting event notifications
- 10 most frequent events 81,61% of total

- Classify most frequent events using the graph
  - Red irrelevant, Blue relevant



Results with Event Relevance Optimization (ERO)

- Deploy Event Relevance Optimization
- Performance improvement 14,32%
- Reduction in context switches nearly 29%
- Reduction quantum limiting events 35,58%
- Keeping near-perfect accuracy



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Conclusion and Future Work

- ERO offers performance improvement keeping near-perfect accuracy
- Proven value in extensive case study
- Future work: Automatic method for determining event relevance
  - Brute-force profiling
  - Heuristic
  - Machine Learning

Thank you!