# The READEX Project for Dynamic Energy Efficiency Tuning

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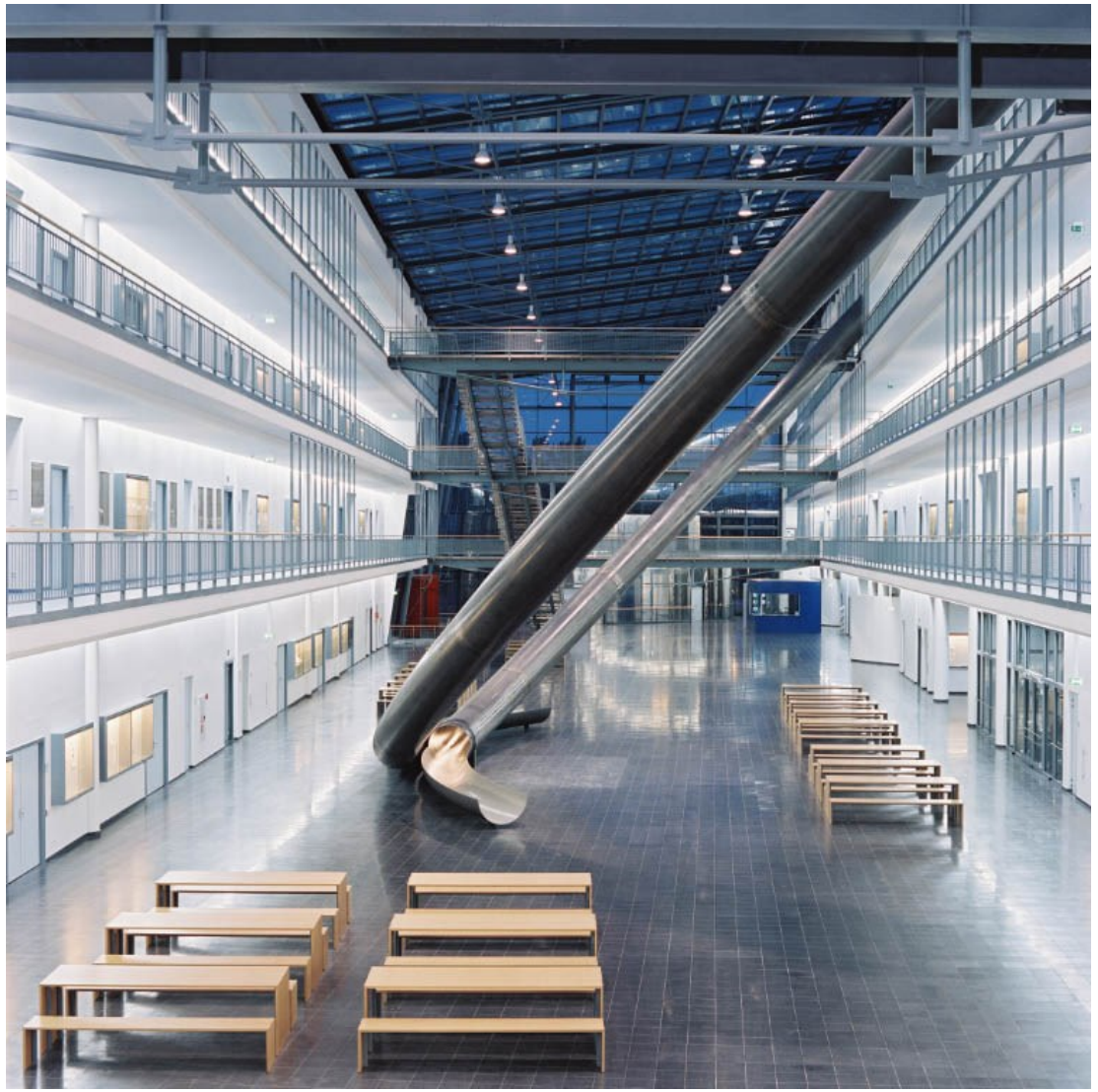
READEX
Runtime Exploitation of Application Dynamism for Energy-efficient eXascale computing

European Commission
Horizon 2020
European Union funding for Research & Innovation

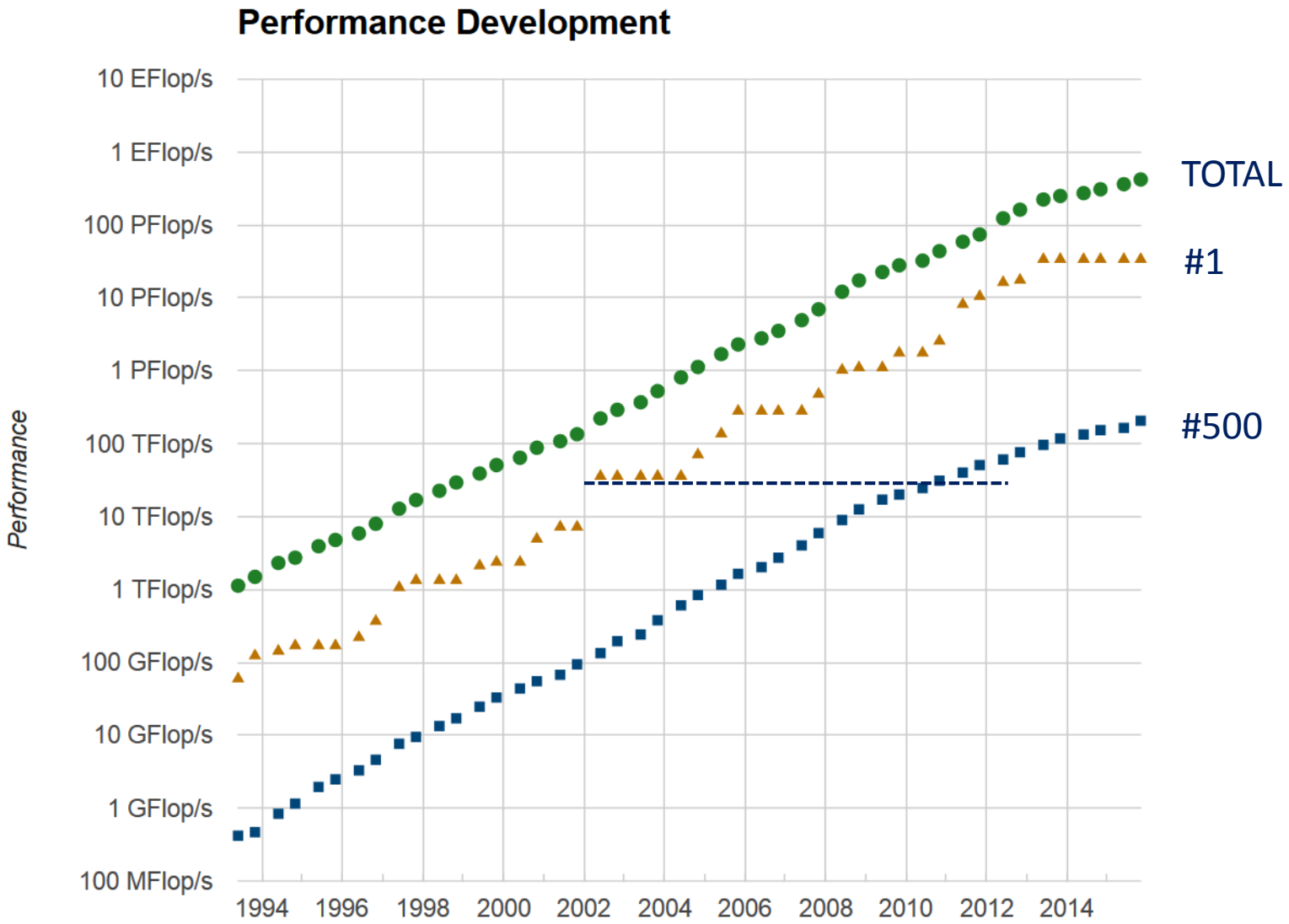
# Technical University of Munich, Campus Garching

# High Performance @ TUM



# SuperMUC: 3 Petaflops ($3*10^{15}$=quadrillion), 3 MW

# TOP 500 List


Performance Development
Performance
10 EFlop/s
1 EFlop/s
100 PFlop/s
10 PFlop/s
1 PFlop/s
100 TFlop/s
10 TFlop/s
1 TFlop/s
100 GFlop/s
10 GFlop/s
1 GFlop/s
100 MFlop/s
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
TOTAL
#1
#500

# TOP 5 Systems: Linear Extens for Exascale

| RANK | SITE | SYSTEM | CORES | RMAX (TFLOP/S) | RPEAK (TFLOP/S) | POWER (KW) | |
|---|---|---|---|---|---|---|---|
| 1 | National Super Computer Center in Guangzhou<br>China | **Tianhe-2 (MilkyWay-2)** - TH-IVB-FEP Cluster, Intel Xeon E5-2692 12C 2.200GHz, TH Express-2, Intel Xeon Phi 31S1P<br>NUDT | 3,120,000 | 33,862.7 | 54,902.4 | 17,808 | *19 = 340 MW |
| 2 | DOE/SC/Oak Ridge National Laboratory<br>United States | **Titan** - Cray XK7 , Opteron 6274 16C 2.200GHz, Cray Gemini interconnect, NVIDIA K20x<br>Cray Inc. | 560,640 | 17,590.0 | 27,112.5 | 8,209 | *36 = 302 MW |
| 3 | DOE/NNSA/LLNL<br>United States | **Sequoia** - BlueGene/Q, Power BQC 16C 1.60 GHz, Custom<br>IBM | 1,572,864 | 17,173.2 | 20,132.7 | 7,890 | *50 = 390 MW |
| 4 | RIKEN Advanced Institute for Computational Science (AICS)<br>Japan | K computer, SPARC64 VIIIfx 2.0GHz, Tofu interconnect<br>Fujitsu | 705,024 | 10,510.0 | 11,280.4 | 12,660 | *89 = 1115 MW |
| 5 | DOE/SC/Argonne National Laboratory<br>United States | **Mira** - BlueGene/Q, Power BQC 16C 1.60GHz, Custom<br>IBM | 786,432 | 8,586.6 | 10,066.3 | 3,945 | *100 = 394 MW |

# Project overview

- READEX

  **R**untime **E**xploitation of **A**pplication **D**ynamism for **E**nergy-efficient e**X**ascale Computing

- Starting date:

  1. September 2015

- Duration:

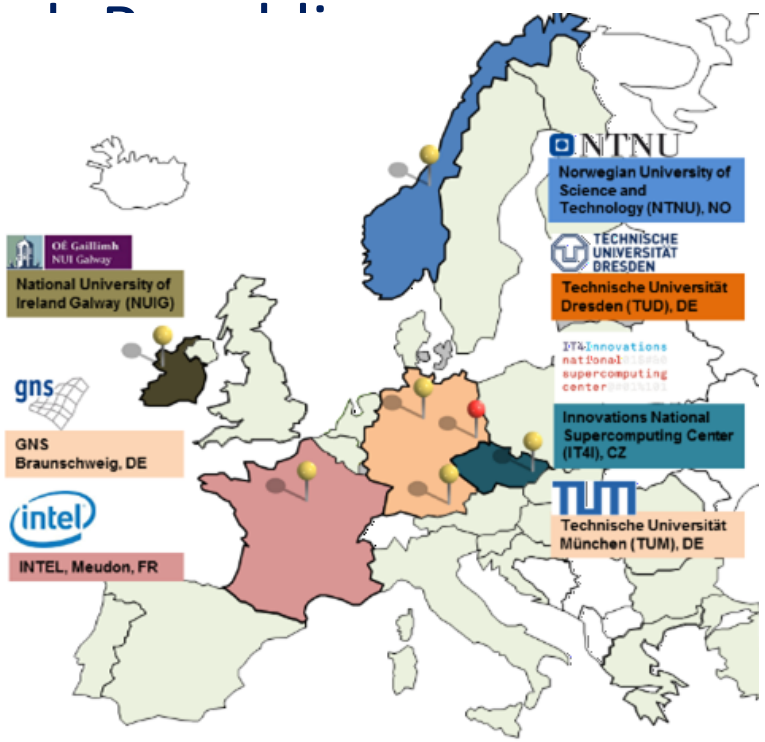
  3 years

- Funding:

  European Commission Horizon 2020 grant agreement 671657

# Project partners

- Technische Universität Dresden (Coordinator), Germany
- Norwegian University of Science and Technology, Norway
- Innovations National Supercomputing Center, Cz
- Technische Universität München, Germany
- Intel Exascale Centre, France
- GNS Braunschweig, Germany
- National University of Ireland Galway, Ireland



# Motivation

## Challenges

- Energy consumption
- Extreme scale
- Dynamism

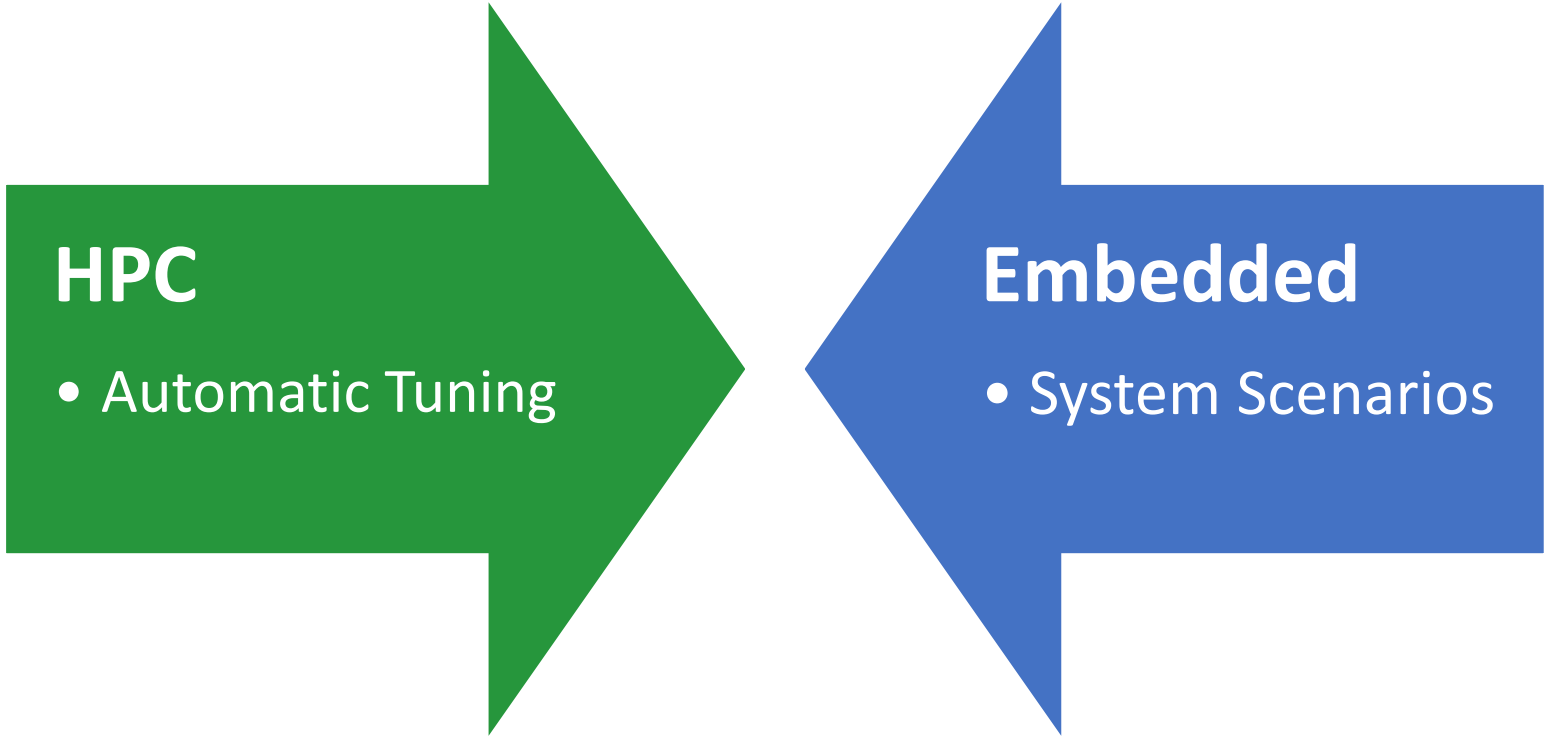
## Problems

- Awareness
- Ability
- Effort

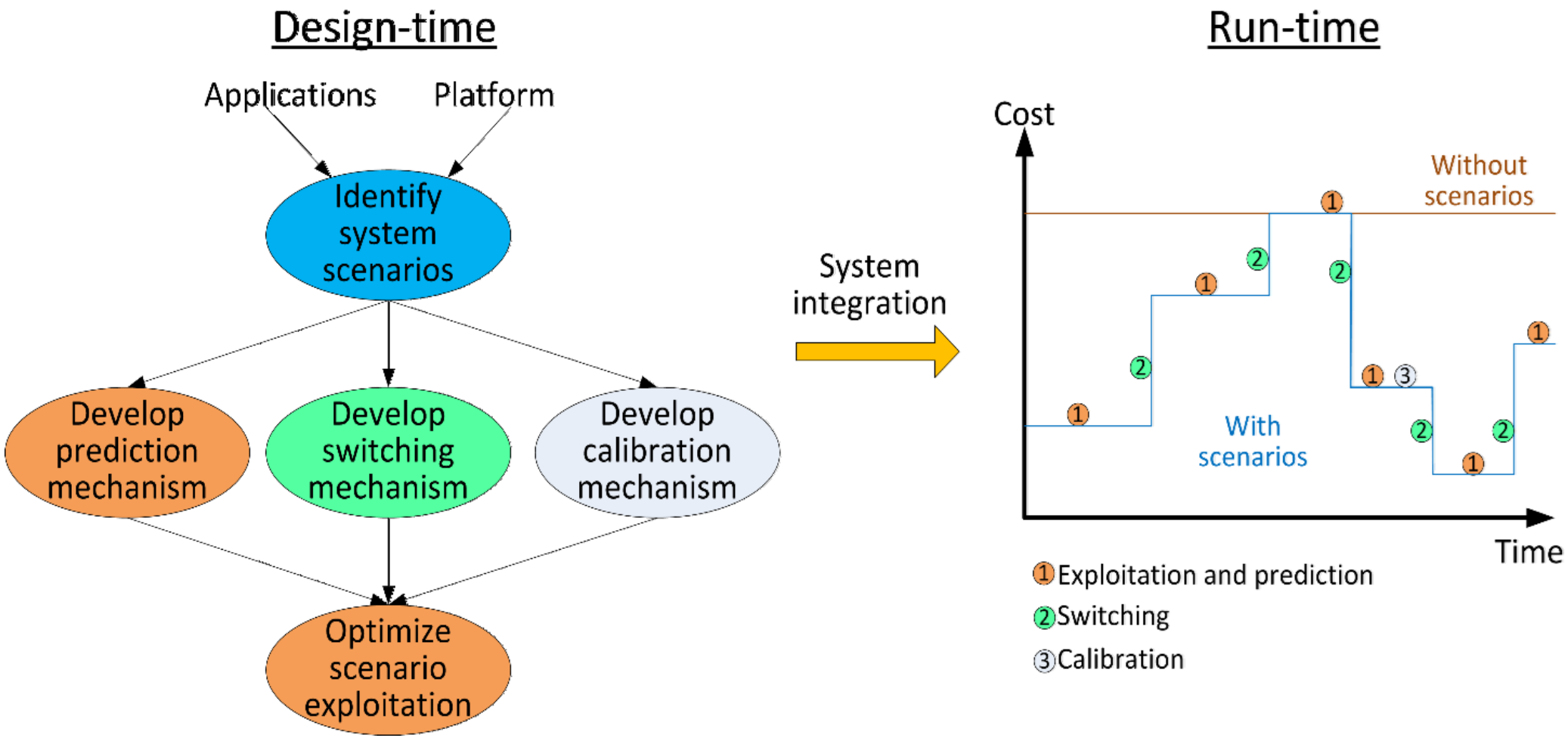
## Solution

- Dynamism
- Automatic tuning
- Design-/Run-time

# General idea



# Systems Scenario based Methodology

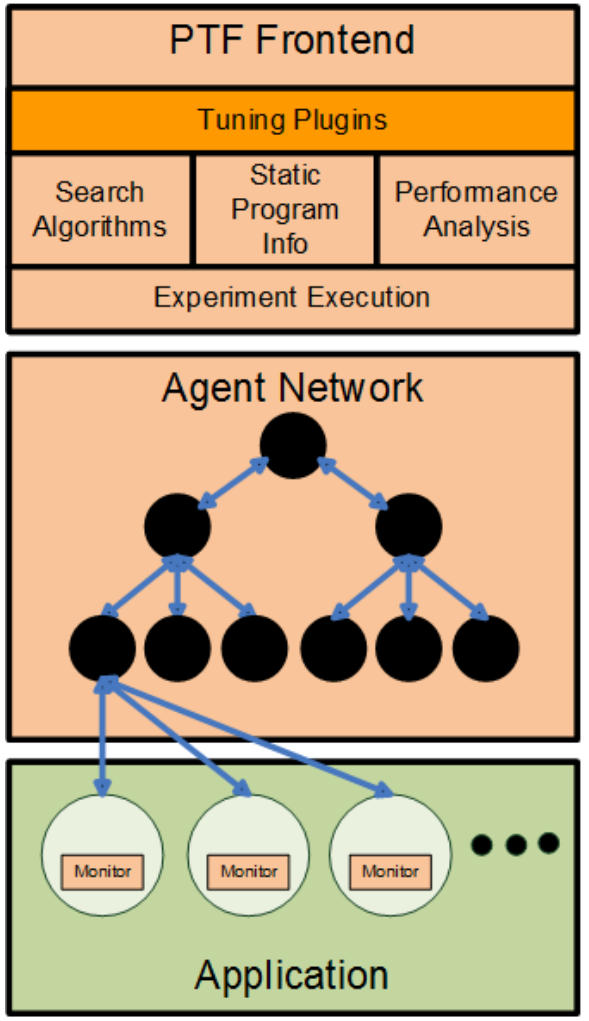


**Static Tuning** with the
Periscope Tuning Framework

**Dynamic Tuning** with the
READEX Tool Suite and Methodology

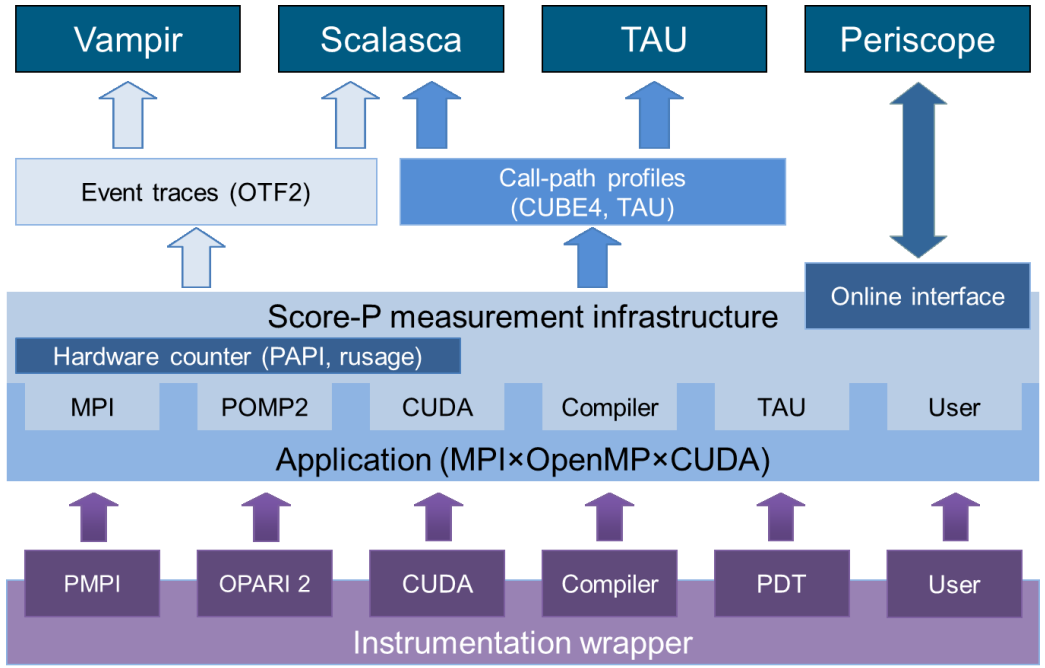
# Periscope Tuning Framework

- Automatic application analysis & tuning
  - Tune performance and energy (statically)
  - Plug-in-based architecture
  - Evaluate alternatives online
  - Scalable and distributed framework
- Support variety of parallel paradigms
  - MPI, OpenMP, OpenCL, Parallel pattern
- Developed in the AutoTune EU-FP7 project

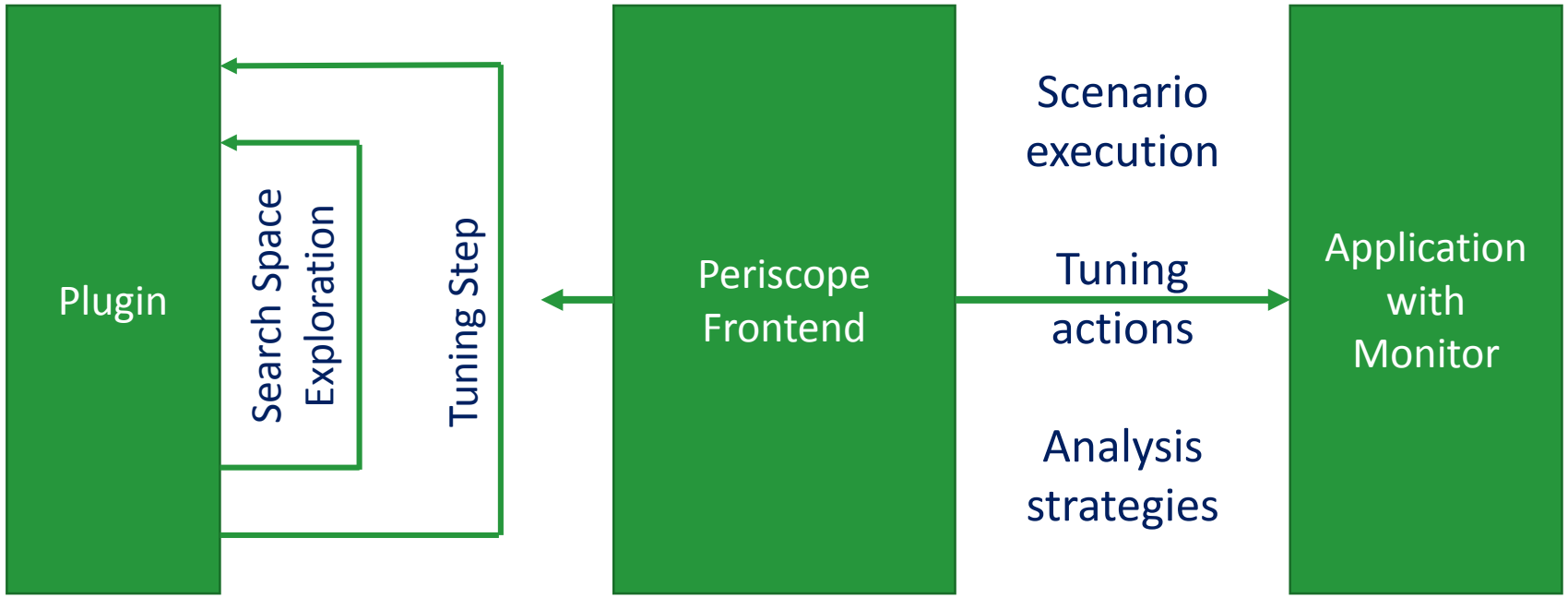


# Scalable Performance Measurement Infrastructure for Parallel Codes

## Common instrumentation and measurement infrastructure



# Tuning Plugin Interface



# Tuning Plugins

- MPI parameters
  - Eager Limit, Buffer space, collective algorithms
  - Application restart or MPIT Tools Interface
- **DVFS**
  - **Frequency tuning for energy delay product**
  - **Model-based prediction of frequency**
  - **Region level tuning**
- Parallelism capping
  - Thread number tuning for energy delay product
  - Exhaustive and curve fitting based prediction



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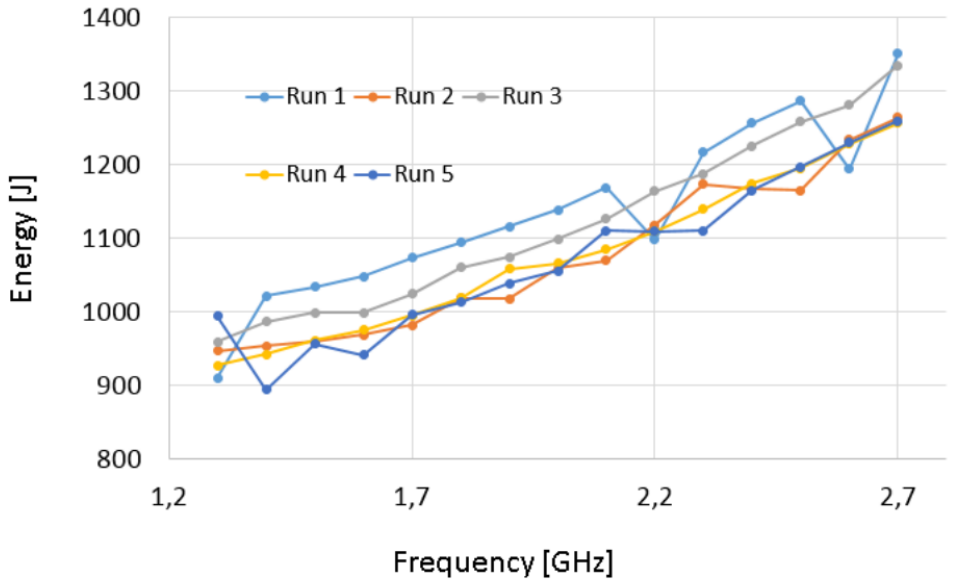
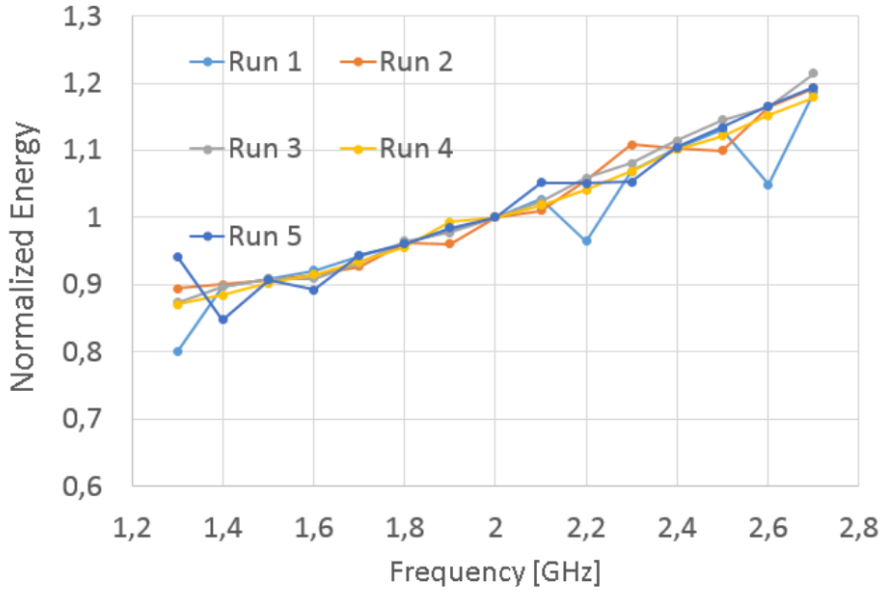
# Variation of Energy Measurements

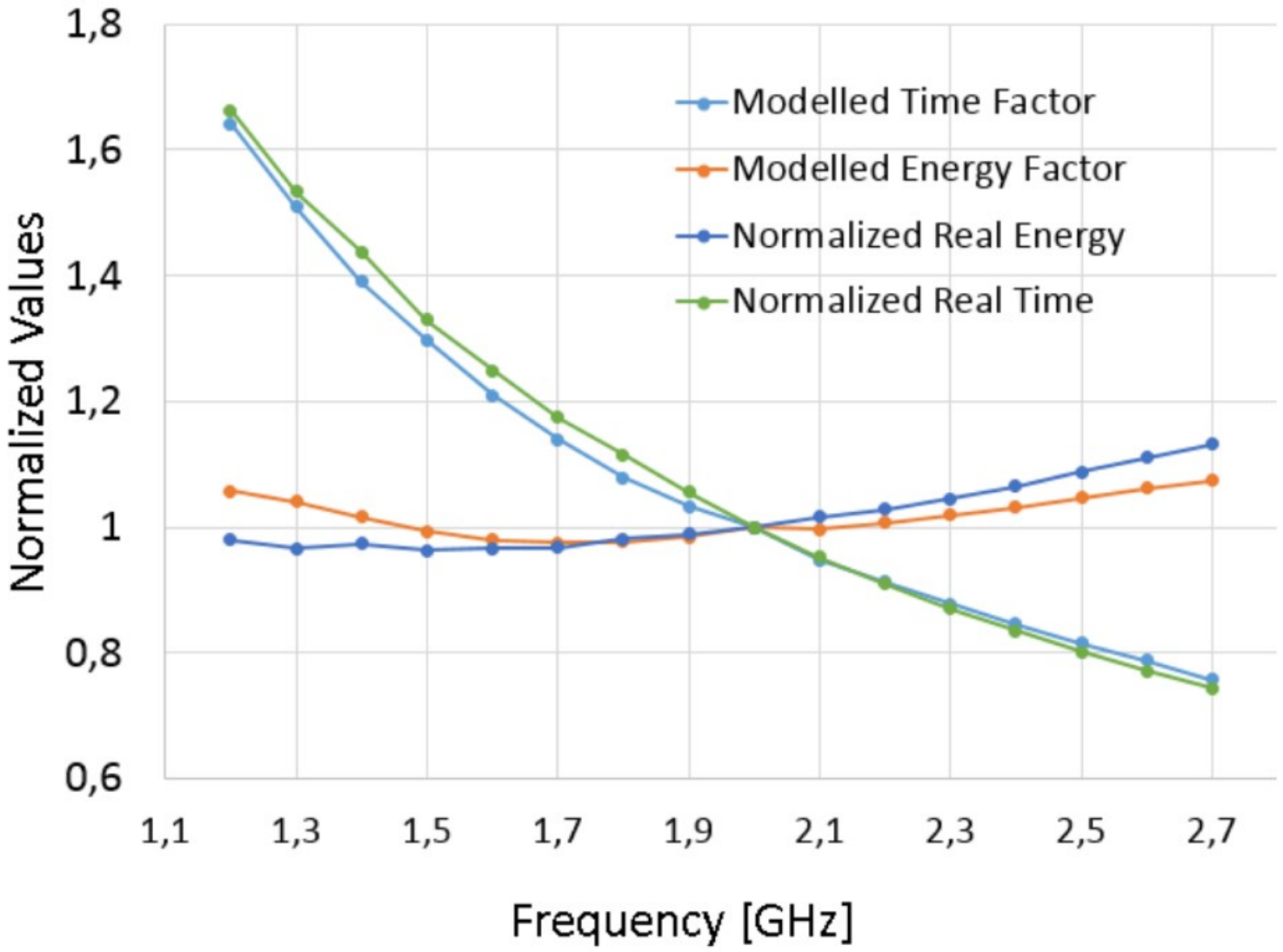



Energy consumption of the SeisSol application at different compute nodes.

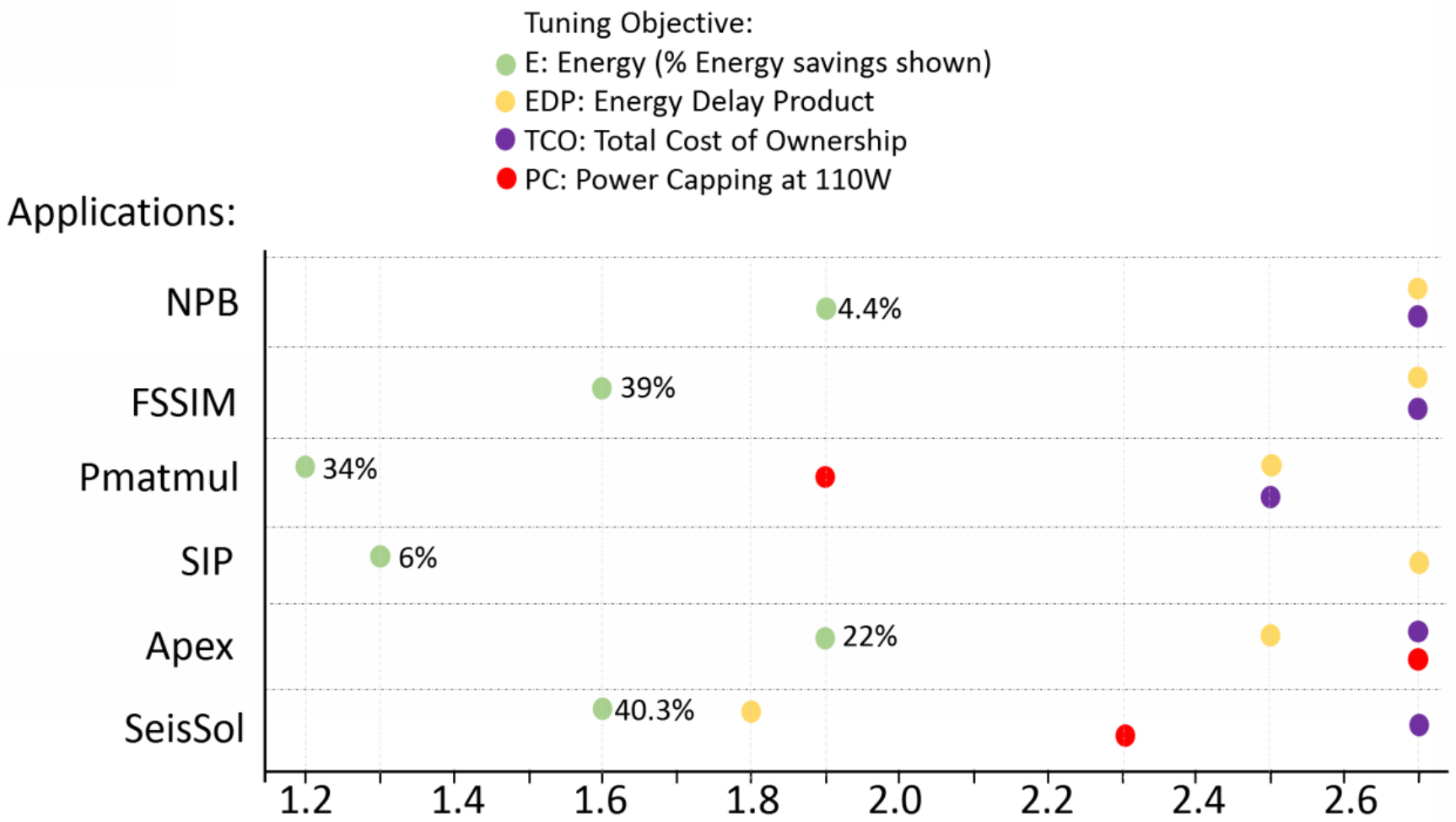



Normalized energy consumption of the SeisSol application at different compute

# Predicted vs Measured Time for Seissol



# Tuning with the Persicope Tuning Framework



# Application Dynamism: Beyond Static Tuning

```
int main(void) {

  // Initialize application
  // Initialize experiment variables

  int num_iterations = 2;

  for (int iter = 1; iter <= num_iterations; iter++) {
    // Start phase region
    // Read PhaseCharct
    laplace3D(); // significant region
    residue = reduction(); // insignificant region
    fftw_execute(); // significant region
    // End phase region
  }

  // Post-processing:
  // Write noise matrices to disk for visualization
  // Terminate application

  MPI_Finalize();
  return 0;
}
```

One iteration of the progress loop



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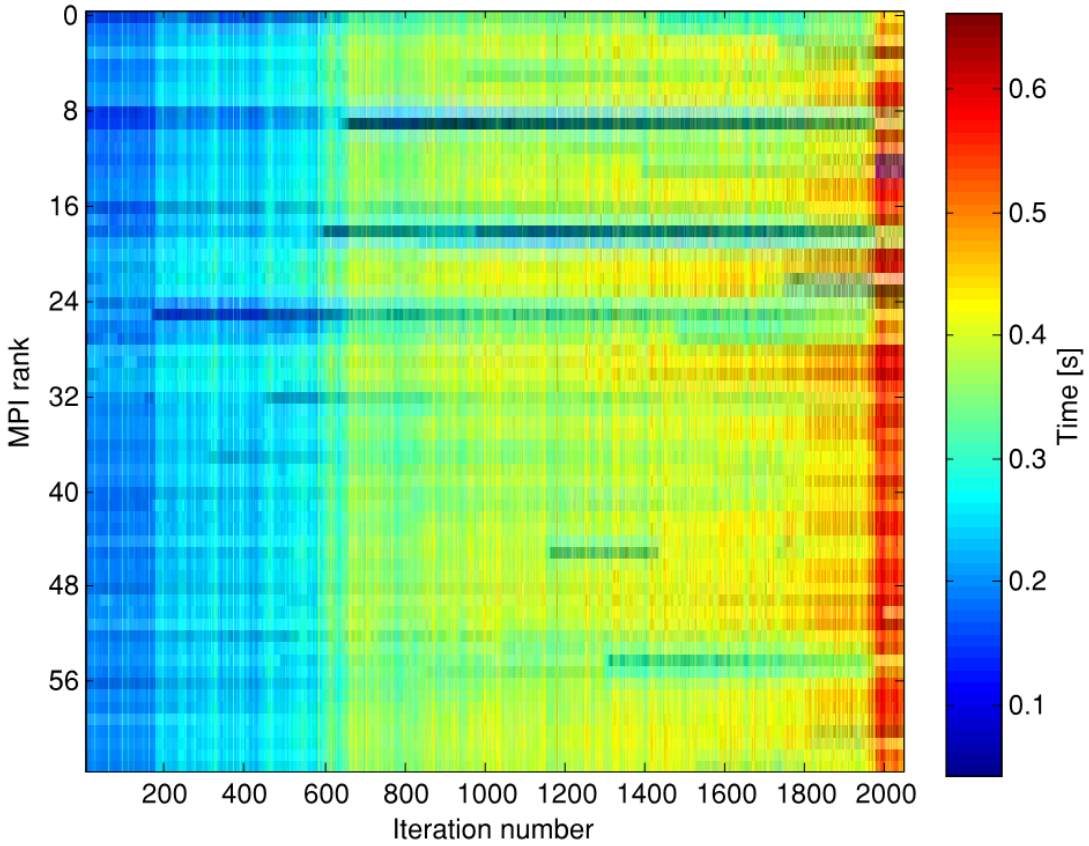
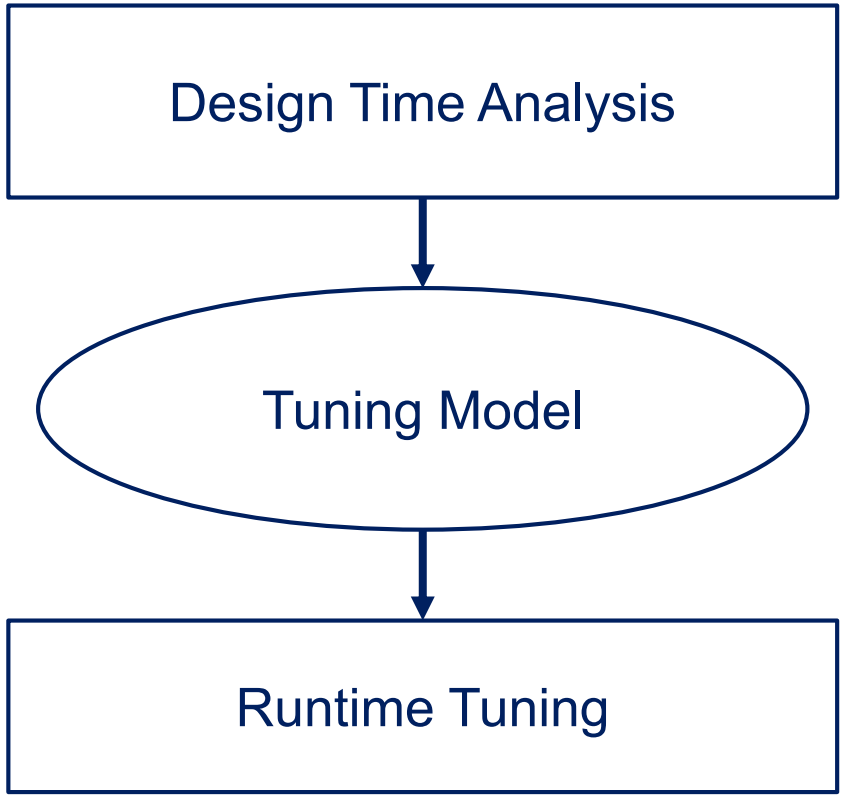
# Inter-phase Dynamism

All-to-all Performance
2048 phases




PEPC Benchmark of the DEISA Benchmark Suite

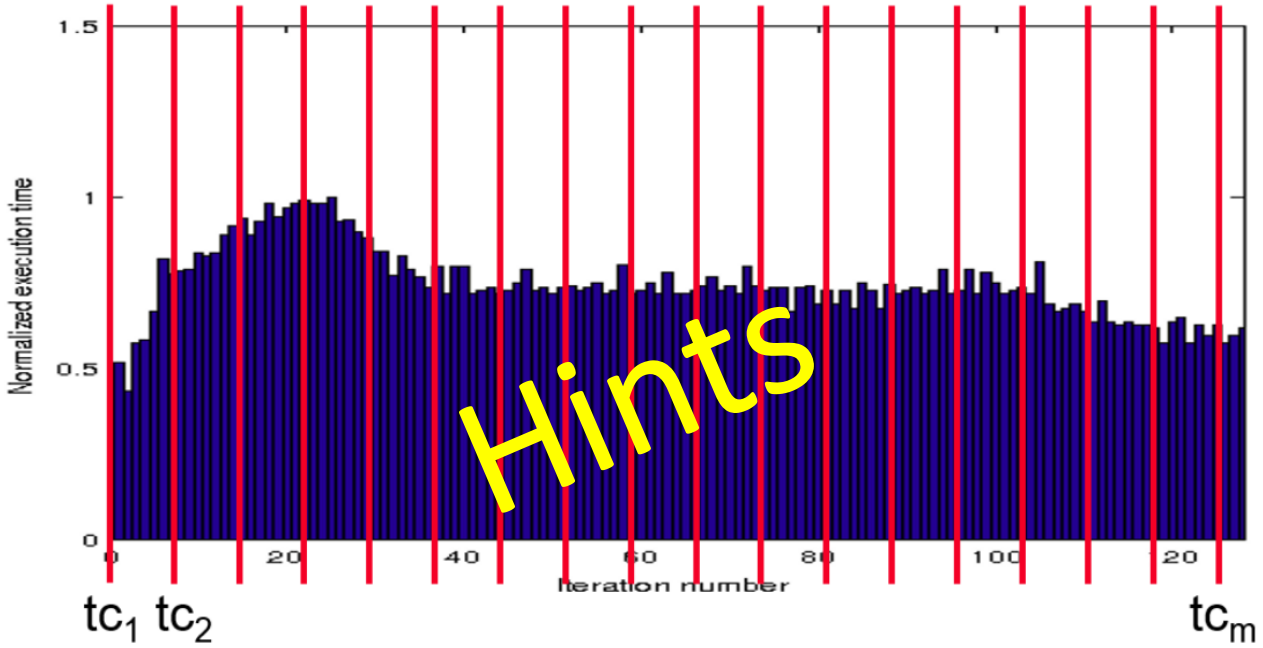
# Scenario-Based Tuning




Periscope Tuning Framework (PTF)

READEX Runtime Library (RRL)

# Design Time Analysis

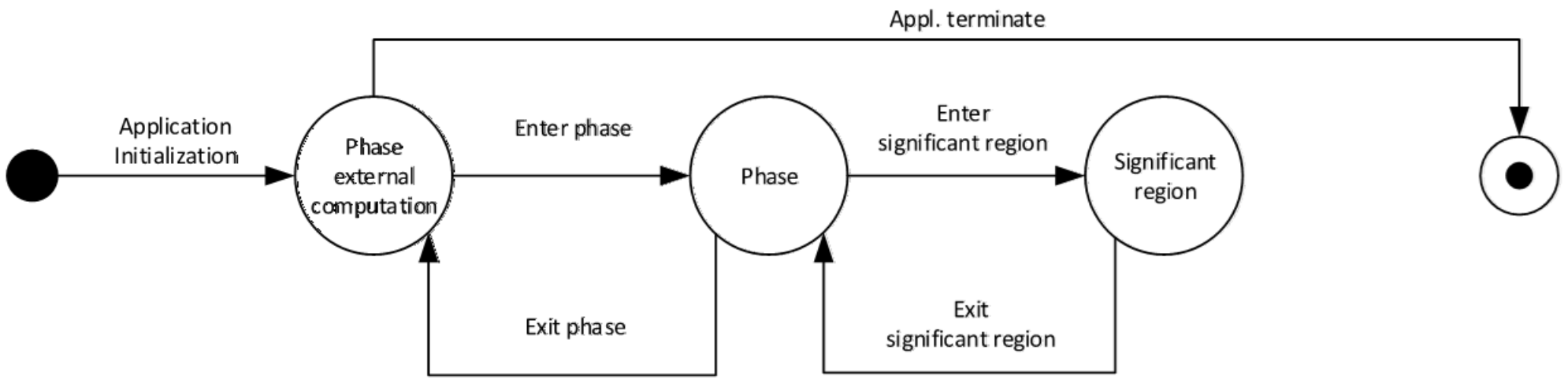



**Tuning Model**

- Scenarios: set of runtime situations (rts)
- Classifiers: RTS → S
- Selector: Context → CFG

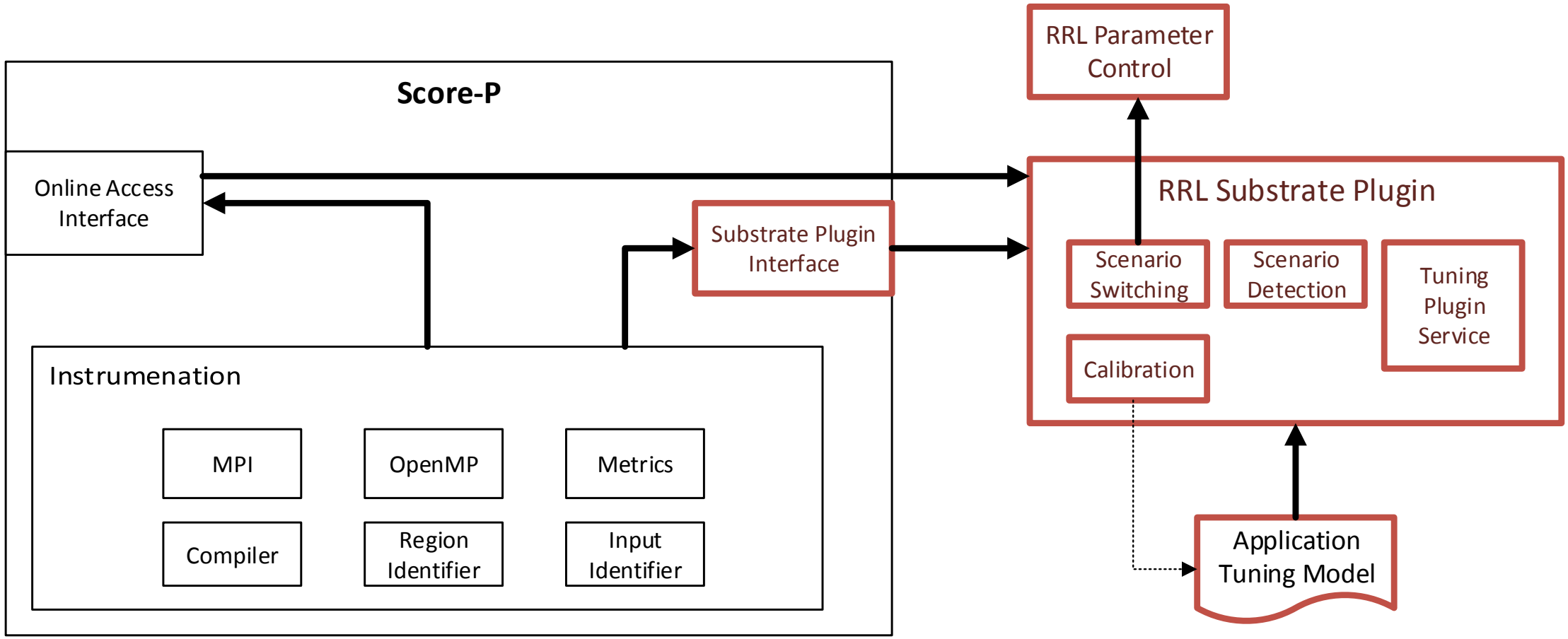
- Tuning cylces
  - Captures intra-phase dynamism
  - Creates phase TM
- Sequence of tuning cycles
  - Captures inter-phase dynamism
  - Creates inter-phase TM
- DTA for multiple inputs
  - Captures input dynamism
  - Creates application TM

# Runtime Tuning with the READEX Runtime Library



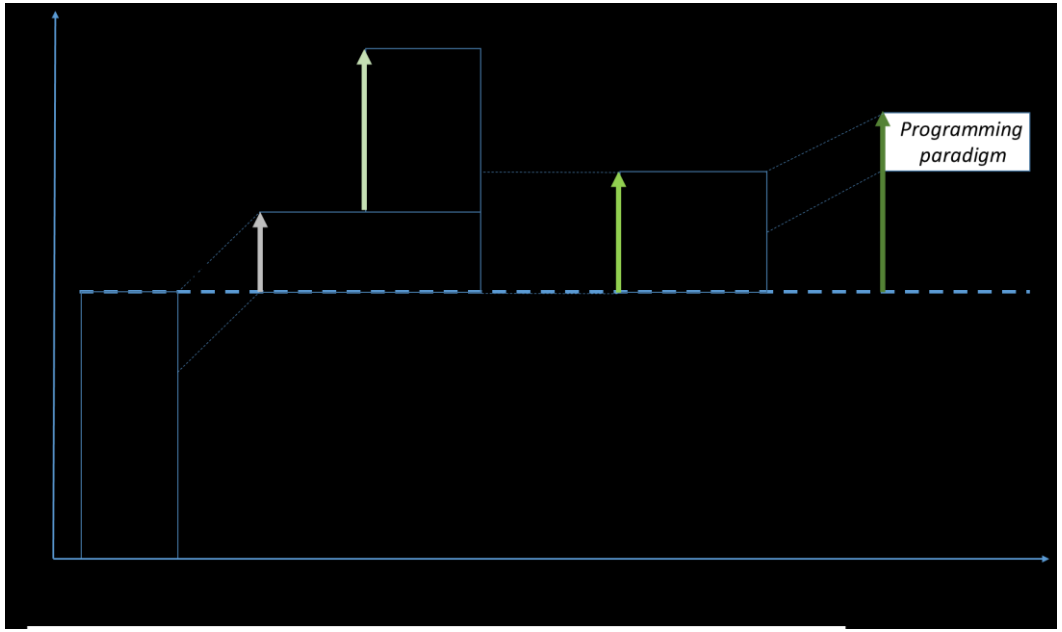

| | |
|---|---|
| Enter phase: | Capture phase identifiers |
| Enter significant region: | Classify rts; apply selector; perform switching |
| Exit significant region: | Save objective value |
| Exit phase: | Perform calibration |

# RRL Architecture



# Validation and project goals

- **Goal: Validate the effect of READEX using real-world applications**
  - Co-design process:
    - Hand-tune selected applications
    - Compare results with automatic static and dynamic tuning
  - Energy measurements using HDEEM infrastructure



# Conclusion

- Energy-efficiency at exascale
  - Application developers and users will have to care
- Lack of capabilities
  - Awareness
  - Expertise
  - Resources
- Proposed solution – READEX:
  - Exploit dynamism
  - Detect at design time, exploit at run-time
  - Tools-aided autotuning methodology

# Thank you! Questions?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