SUPERVISOR: Professor Jukka K. Nurminen
ADVISOR: Zhonghong Ou (POST-DOC.)

Gonçalo Pestana

Energy Efficiency in High Throughput Computing

Tools, techniques and experiments

ENERGY EFFICIENCY IN HIGH THROUGHPUT COMPUTING (HTC)

MOTIVATION: HTC, CERN & energy consumption: Higgs boson and the future

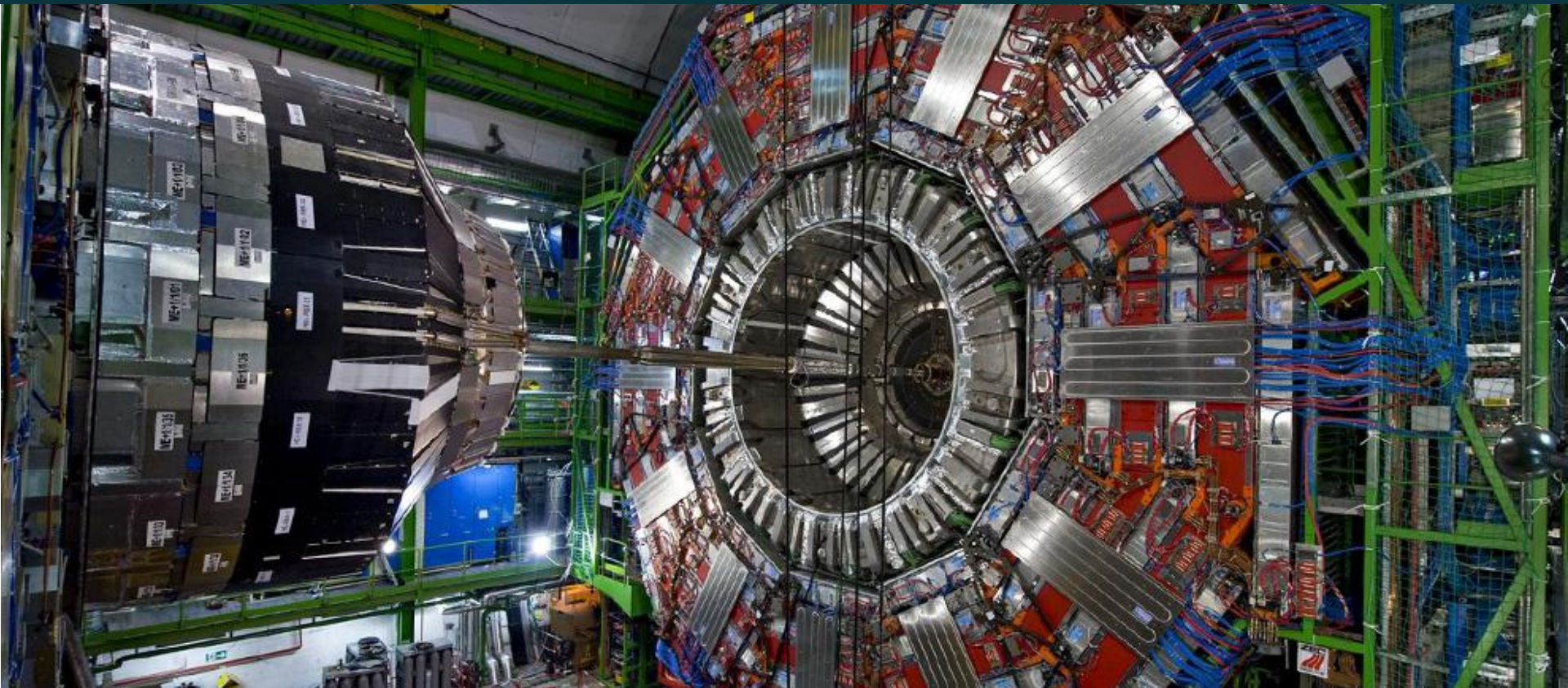
TOOLS: Measuring energy consumption

SOLUTION 1: ARM in HTC

SOLUTION 2: Dynamic pricing and task scheduling

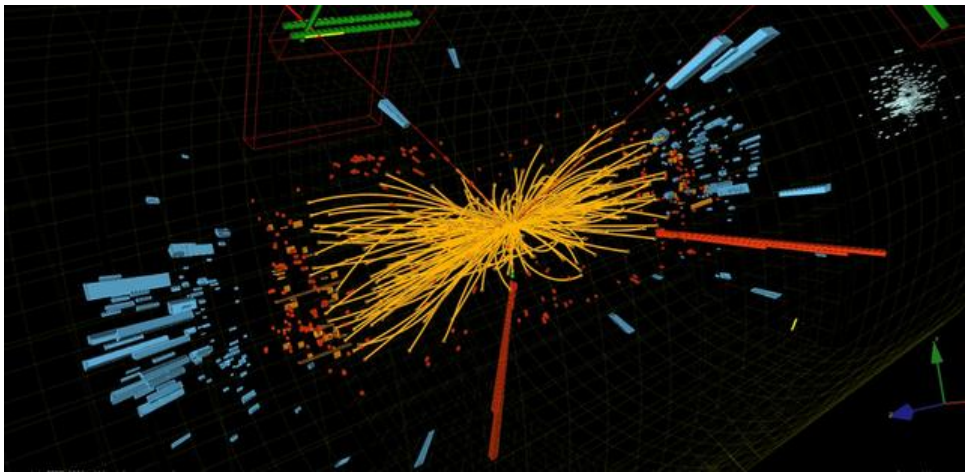
ENERGY EFFICIENCY IN HIGH THROUGHPUT COMPUTING (HTC)

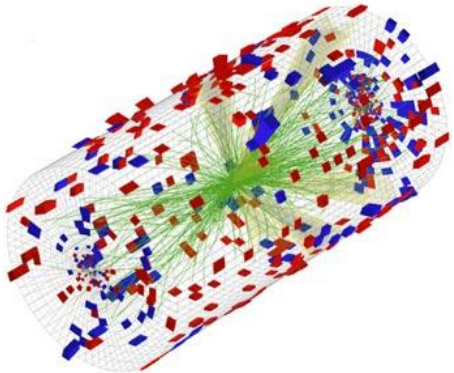
MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

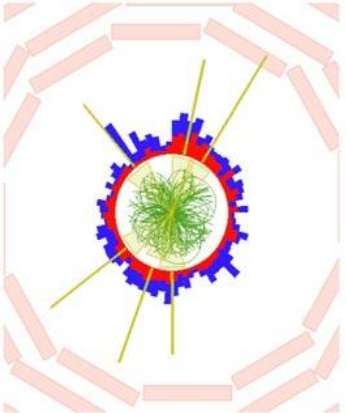


MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

Lots of **data** (1 Petabyte/s → 200 MB/s)







data in 2012

MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

In 2012, the Worldwide LHC computing grid *equivalent capacity* of

80,000 to **100,000** x86-64 cores

result: Higgs Boson tracked down

MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

Future

data will increase **2** - **3** orders of magnitude

processing power in proportion

Expectable to happen throughout all HTC industry

electricity bil question

MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

How to decrease electricity bill ?

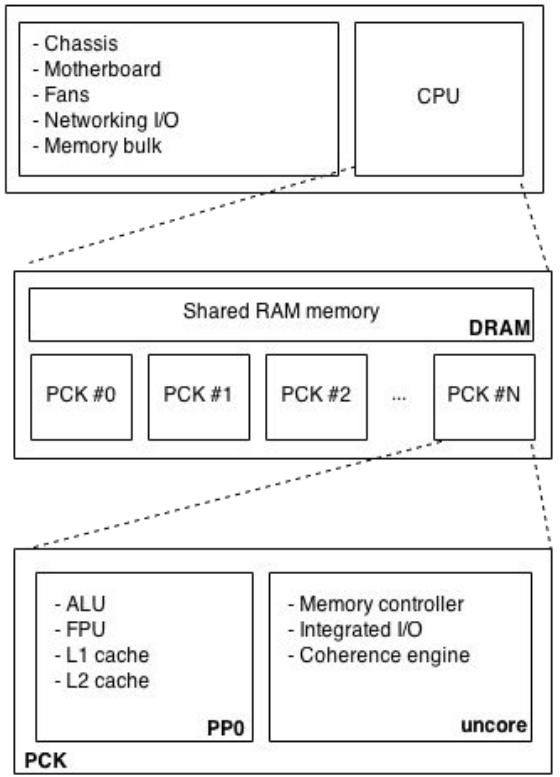
first: measure

TOOLS: MEASURING ENERGY EFFICIENCY

Techniques and **tools** for measuring energy consumption are important …

TOOLS: MEASURING ENERGY EFFICIENCY

… and systems are **complex**



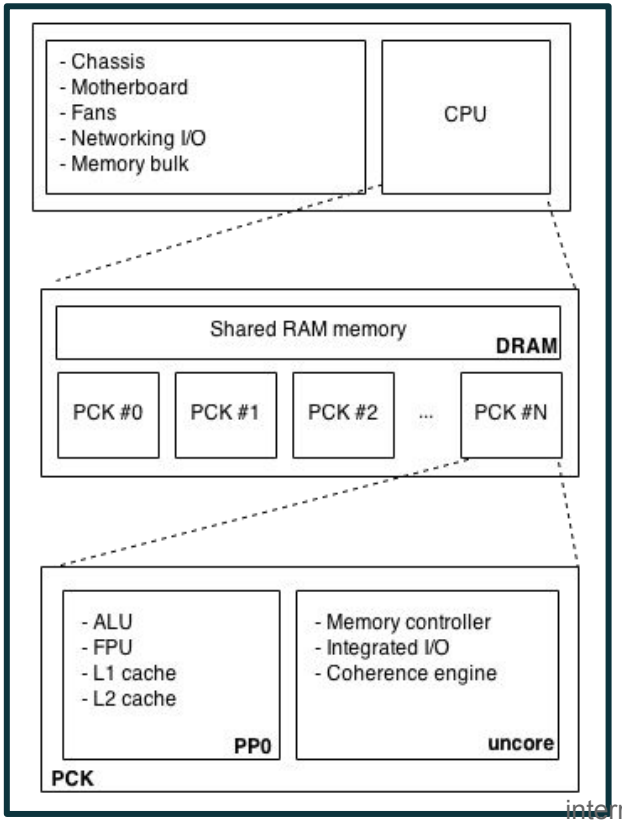
several layers and granularities

external

TOOLS: MEASURING ENERGY EFFICIENCY

External measurements

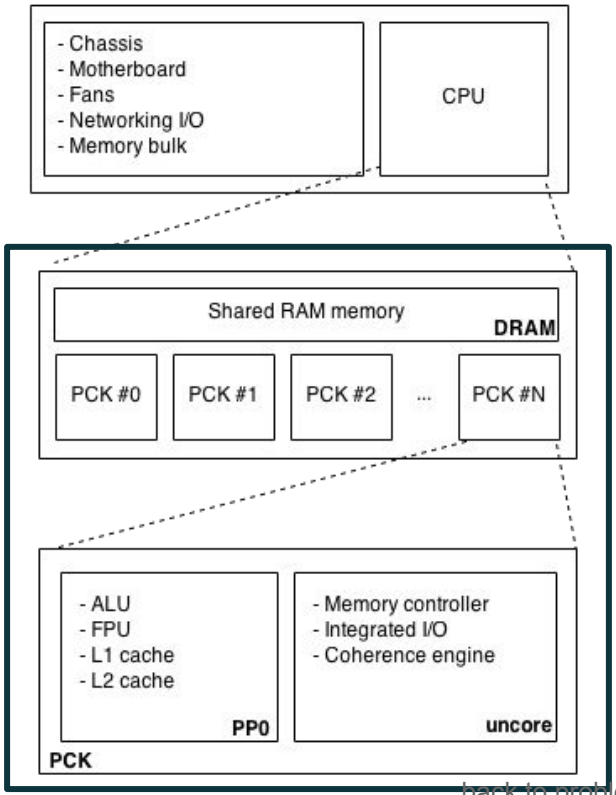
Power consumed without breaking down the system into components



TOOLS: MEASURING ENERGY EFFICIENCY

On-chip measurements

Power consumed by different components of the CPU



back to problem

MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

back to our main problem:

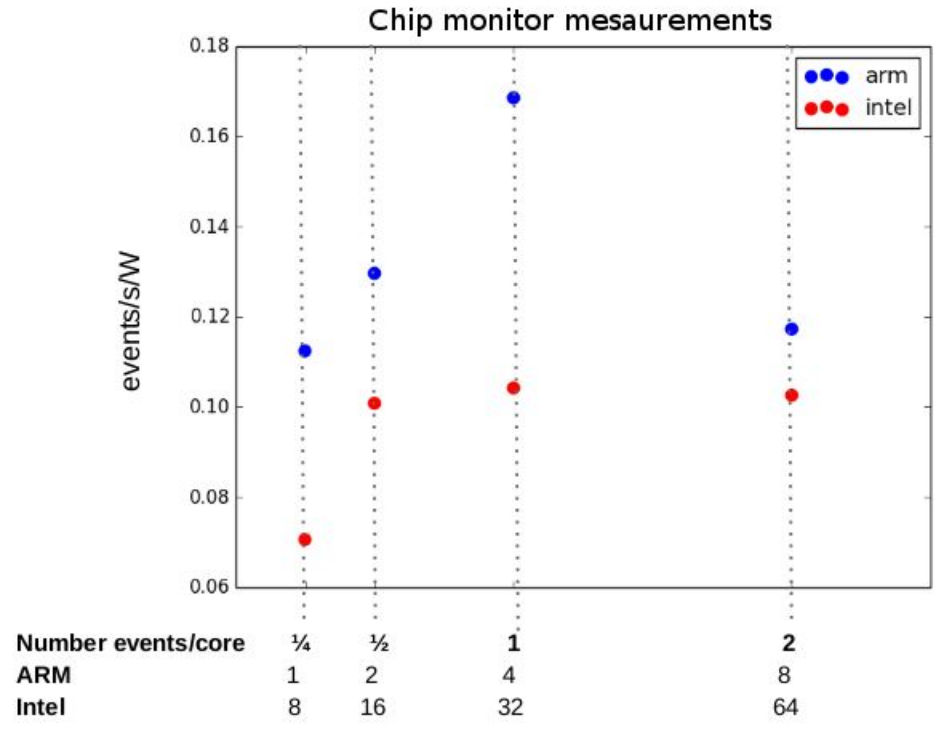
How to decrease electricity bill ?

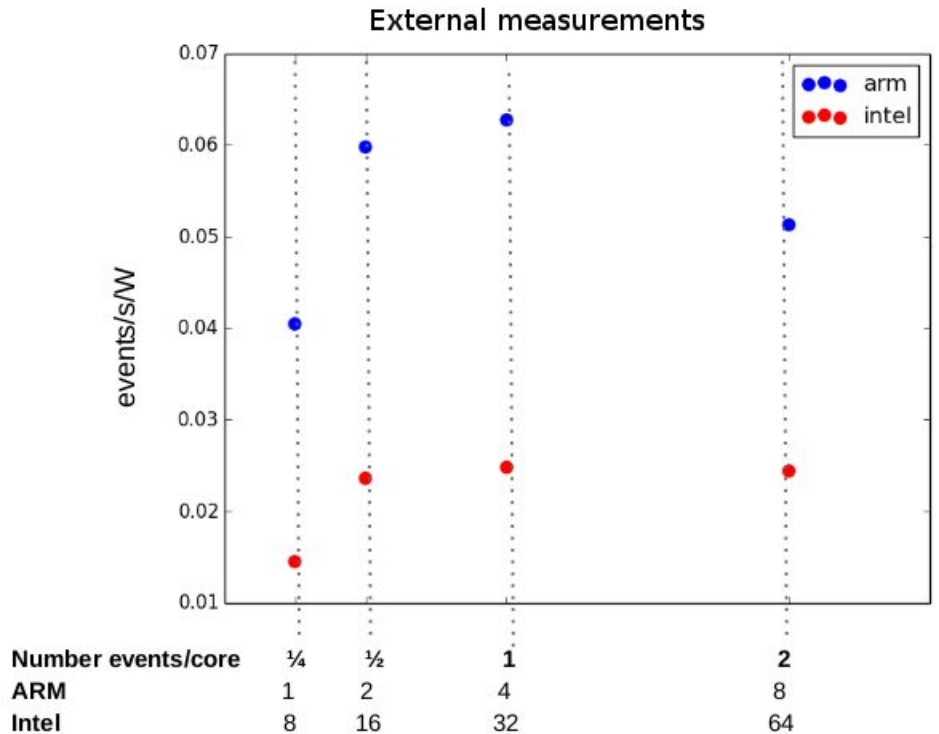
SOLUTION 1: ARM IN HTC?

Are smartphones' CPUs

the future of High Throughput Processing ?

SOLUTION 1: ARM IN HTC?





SOLUTION 1: ARM IN HTC?

energy efficiency

vs

speed

back to problem

MOTIVATION: HTC, CERN & ENERGY CONSUMPTION

back to our main problem:

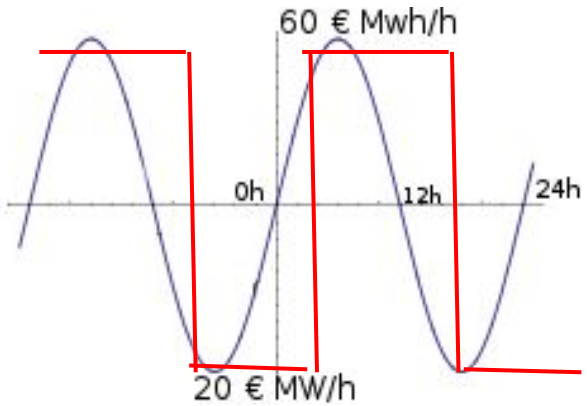
How to decrease electricity bill ?

SOLUTION 2: DYNAMIC PRICING AND TASK SCHEDULING

Task scheduling across different computing architectures in a dynamic pricing energy market

SOLUTION 2: DYNAMIC PRICING AND TASK SCHEDULING

Dynamic electricity price



Machines with different energy profiles

ARM more energy efficient, slower

INTEL less energy efficient, faster

SOLUTION 2: DYNAMIC PRICING AND TASK SCHEDULING

Idea

Schedule tasks to **INTEL** when electricity is cheaper

Schedule tasks to **ARM** when electricity is more expensive

how

SOLUTION 2: DYNAMIC PRICING AND TASK SCHEDULING

How

Algorithm that computes which machines should compute data based on:

- **deadline** (how many tasks in how much time)
- **energy pricing dynamics**
- **energy profiling of the machines**

CONCLUSIONS

PROBLEM: Energy consumption is bottleneck in HPC

SOLUTION 1: ARM shows potential for HPC (but tradeoffs)

SOLUTION 2: Scheduling tasks based on energy pricing

How to measure energy consumption in complex systems ?

vague but exciting

Vague but exciting ...

CERN DD/OC

Tim Berners-Lee, CERN/DD

Information Management: A Proposal

March 1989

Information Management: A Proposal

Abstract

This proposal concerns the management of general information about accelerators and experiments at CERN. It discusses the problems of loss of information about complex evolving systems and derives a solution based on a distributed hypertext sytstem.

Keywords: Hypertext, Computer conferencing, Document retrieval, Information management, Project control

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Q & A

backup

IgProf

IgProf

application profiler developed at CERN by the CMS software team

general purpose. open source. not experiment specific
measures performance (time spent in functions) and memory usage at *runtime*

allows developer to understand:
- bottlenecks
- where code needs to be optimised

cross platform: recently ported to 64-bit ARM, also supports 32-bit ARM, Intel x86 and x86-64

IgProf & energy profiling

Uses RAPL and PAPI to measure energy consumed.

Map functions and low level operations with **energy consumption**

more info (strategies, results, examples)
paper** and **http://igprof.org/

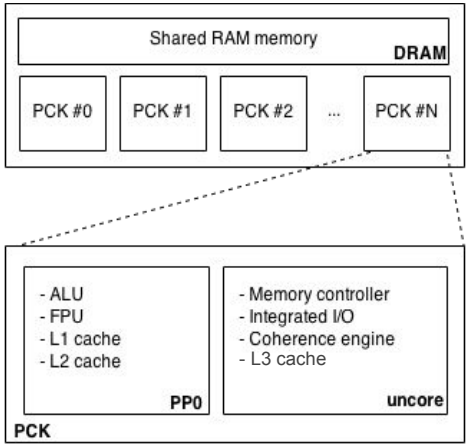
RAPL

Running Average Power Limiting *(RAPL) by Intel*

Provides a platform for power monitoring and power limiting of SoC.

Different sampling **domains**

package *(PKG),* DRAM, core



Low level measurements	package, cores, dram
Resolution	according to Intel, sampling frequency up to ~1 kHz
Power capping	is also supported by RAPL
Accuracy	high (according to *Intel*)

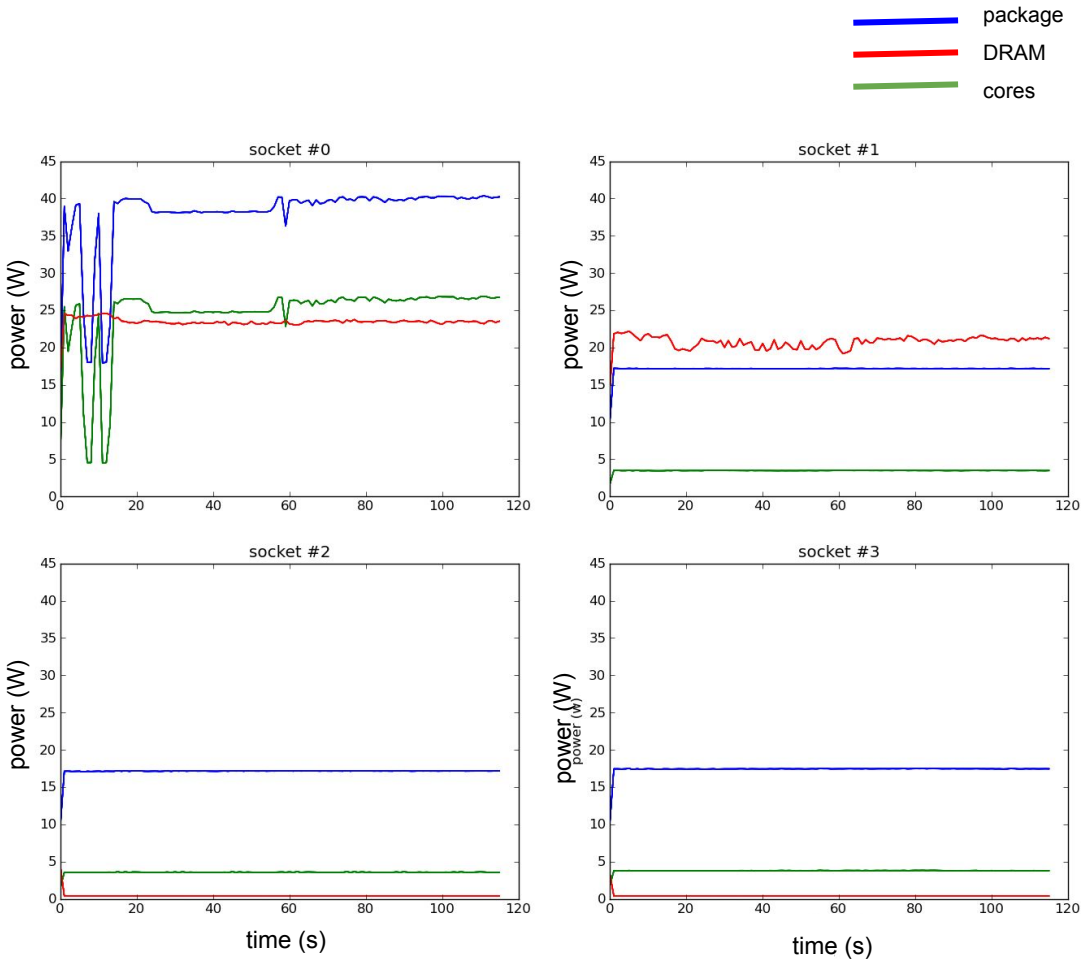
Example of RAPL

System with 4 sockets

Sockets #0 and #1 working

Sockets #2 and #3 idle

Possible to understand how **packages**, **cores** & **dram** consume energy



Comparison ARM vs Intel

Comparison ARMv7 vs Intel XEON

32bit ARMv7 is used on smartphones. comparison with Intel XEON

measurements

Internal

RAPL for *Intel*

cross platform *chip monitor* integrated (TI INA 231) for ARMv7

External

workload

ParFullCMS

Multithreaded

Geant4 benchmark application

Uses the CMS geometry

ARMv7 Exynos5 Octa Cortex™
4x A15 @ 1.6Ghz and/or A7 cores (big.LITTLE technology)
2 GB RAM
ARMv7/32bit
development board

Intel **32x** Intel™ Xeon™ CPU E5-2650 @ 2.00GHz
252 GB RAM
system on a rack