Virtualizing a Batch Queuing System at a University Grid Center

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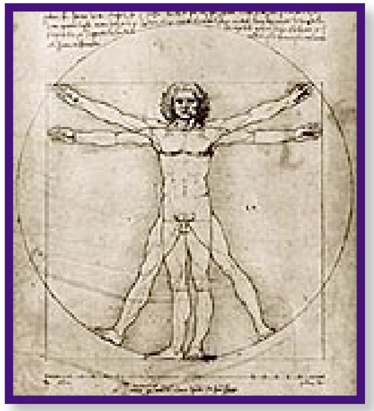
Outline:

- Particle Physics & Computing in Particle Physics
  - The Grid and the LHC Tier-Architecture
- OS problems encountered at Karlsruhe Tier 3
- Possible solutions:
  - Partitioning of clusters
  - Using XEN virtualization technique
  - Integration into Batch Queueing system
- Experience from running a prototype

Physics: Scales

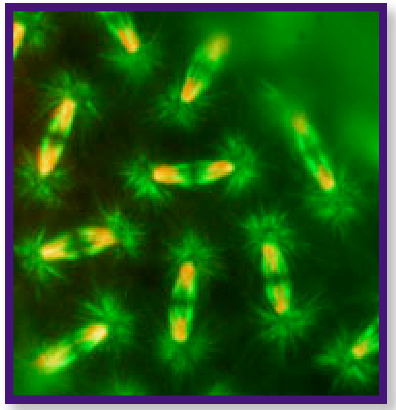
Galaxy: 10^{26}m

Earth: 10^{7}m

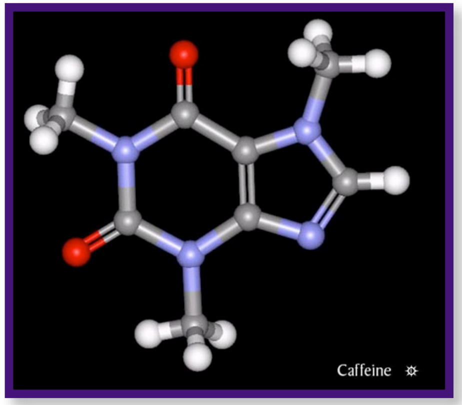


Man: 10^{1}m

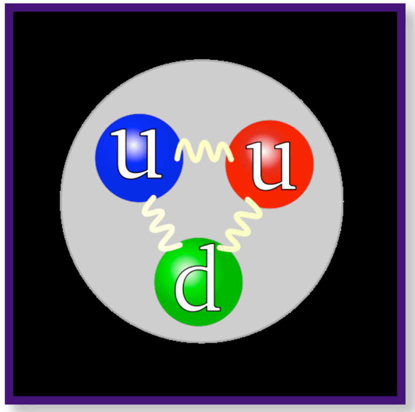
Cells: 10^{-4}m



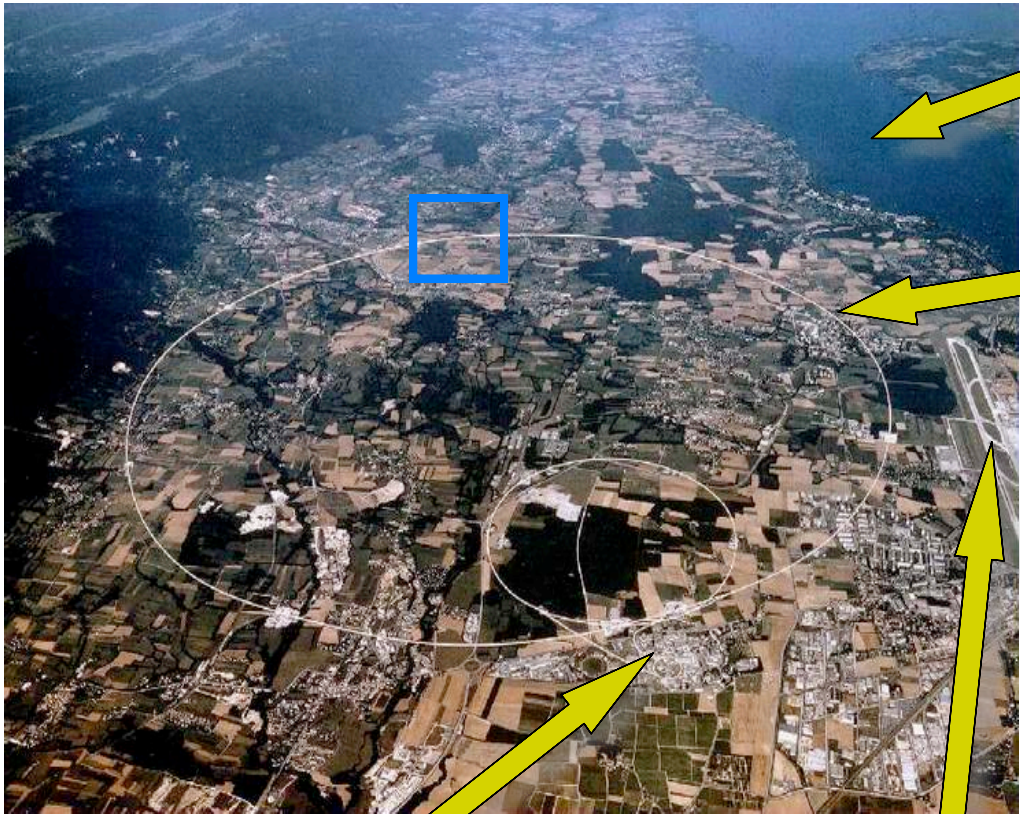
Molecules: 10^{-8}m



Elementary particles: 10^{-15}m



Particle Physics: Accelerator:



Lake Geneva

CERN

Airport

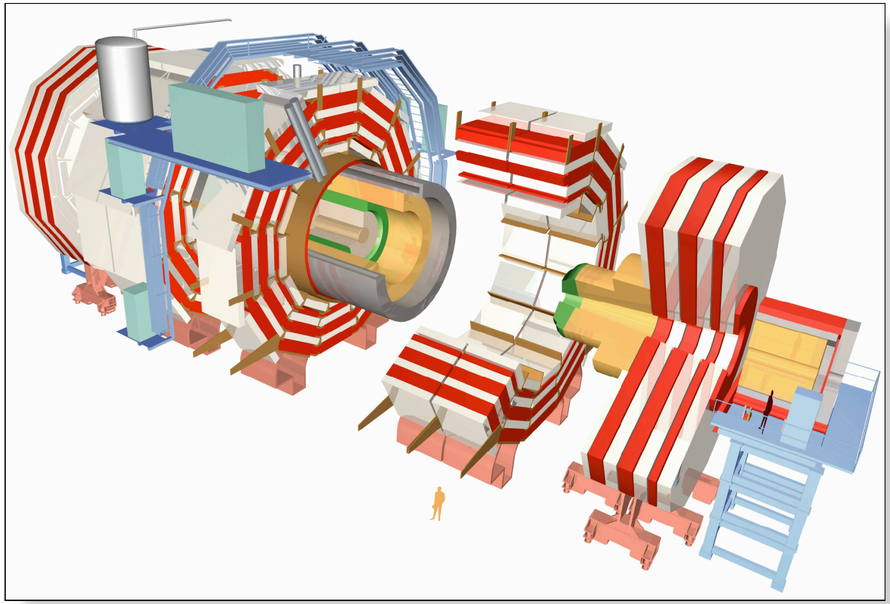
Large **H**adron **C**ollider

Circumference:	27 km
Beam energy:	7 TeV
(Proton →← Proton)	
Below surface:	100 m
Temperature:	-271 °C
Energy use:	1 TWh/a

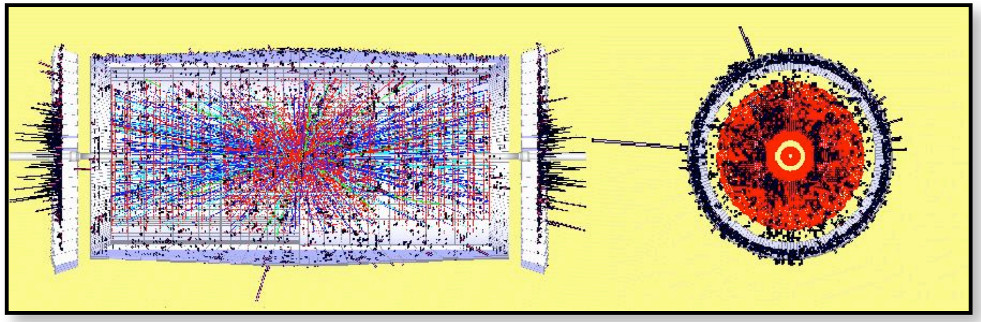
4 large experiments:

CMS	ATLAS
LHCb	ALICE

Particle Physics: Detectors:



Example of a collision:



Compact Muon Solenoid:

total weight: **12 500 T**
overall diameter: **15 m**
overall length: **21,5 m**
magnetic field: **4 Tesla**

Data rates:

Event size: 1.5 MB
Collision rate: 40 MHz
→60 TByte/s raw data
First reduction: 150 Gbyte/s
Second reduction: 225 Mbyte/s
→storage for subsequent analysis

Access to data in the LHC era

Constraints and Approaches:

- HEP experiments very expensive!
  - → redundant storage of 1.5 PetaByte per year only for CMS!
- not wise at one single computing centre
  - → distribution of data to participating computing centres all over the world
- huge datasets (~TeraByte) cannot be transferred to each user
  - → the analysis job goes "where the data set is"
- ensure access to these data for more then 2000 physicists from 182 institutes in 38 countries (in CMS)
  - → access to data and computing resources without local login for the user

The LHC experiments cope with these challenges using grid technologies – The Worldwide LHC Computing Grid

The Worldwide LHC Computing Grid (WLCG)

The WLCG Computing Model:

- computing centres are organised in a hierarchical structure
- different policies concerning computing power and data storage

The tiered architecture:

1 Tier0 (at CERN):

- *accepts raw data from detectors*
- *data transfer to Tier1 centres*

8 Tier 1 centres:

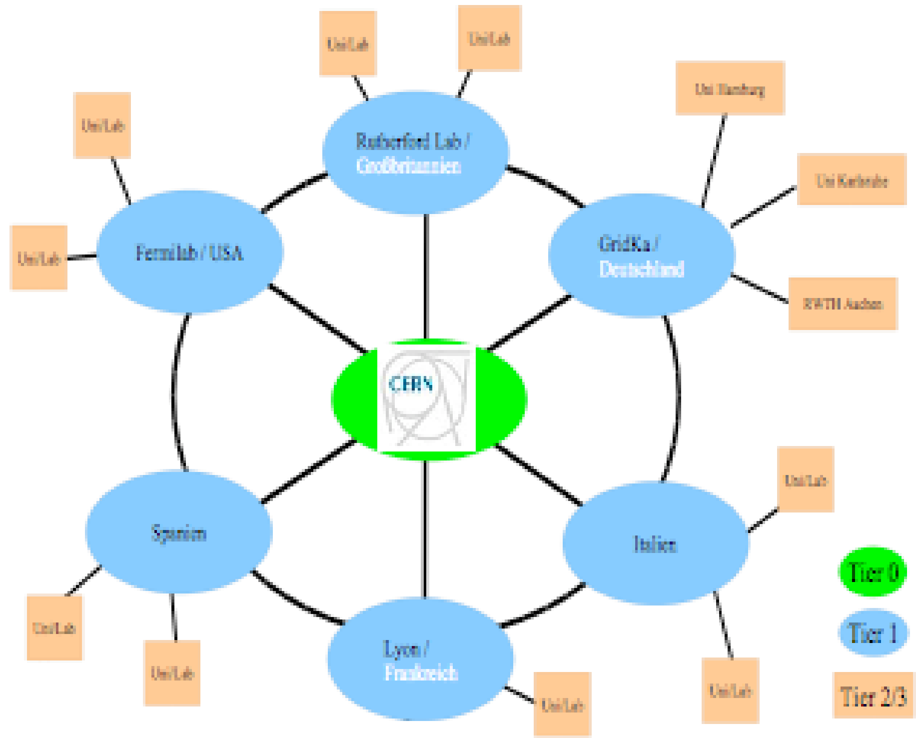
- *secure data archiving*
- *reconstruction & reprocessing*
- *coordination of associated Tier2s*

Several Tier 2 centres:

- *capacity for data-intensive analysis*
- *calibration & Monte Carlo simulation*

Multitude of Tier 3 centres at institutes:

- Offer ressources on *“best-effort” basis*



Tier 3 site at the University of Karlsruhe

- 30 Computing nodes
- 20 TB on file servers
- 100 Mbit/Gbit network

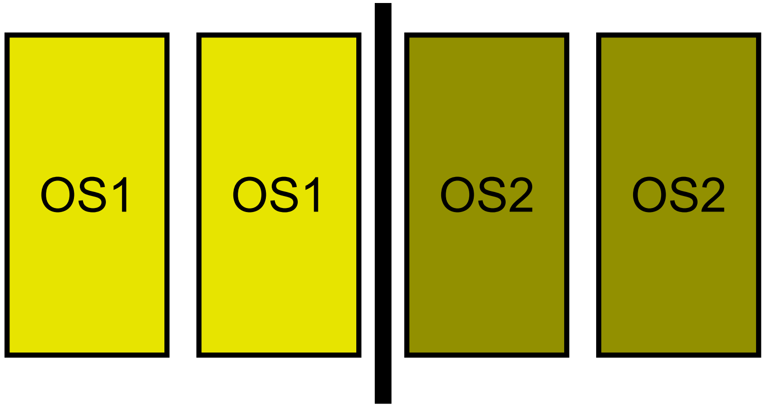
- 3 local user groups (working on different large-scale experiments)
  - CDF (20 users)
  - CMS (16 users)
  - AMS (6 users)
- Grid users through middleware:
  - Mainly CMS
  - Some CDF users (GlideCAF)

Problem: Different user groups

- CMS: Software requires SLC 3.0.X
- CDF: SL Fermi 3.0.X recommended
- AMS: Can easily recompile their software on different platforms
- gLite middleware: SLC 3.0.X recommended
- Now: Compromise possible: SLC 3.0.6 32bit
  - AMS could benefit from 64bit
- Future: Diverging needs:
  - e.g.: CMS SLC4, CDF SLC3
  - e.g.: CMS needs both SLC3 and SLC4
  - e.g.: Some need 32bit, other 64bit.
  - Sharing with other groups using modern distributions
- Additionally: Security issues:
  - Different user groups, same cluster

→ Partition your cluster! But how?

Static (vertical) partitioning



Example:

- 4 nodes, 2 groups
  - 2 nodes with OS1
  - 2 nodes with OS2
- Sharing common storage, network and control infrastructure

- Changes in the resource allocation difficult
- Old OS on new hardware problem persists
- No real resource sharing possible

Dynamic (horizontal) partitioning

- All nodes have two OS running all the time
- The OS needed gets all CPU and RAM resources
- Sharing all resources

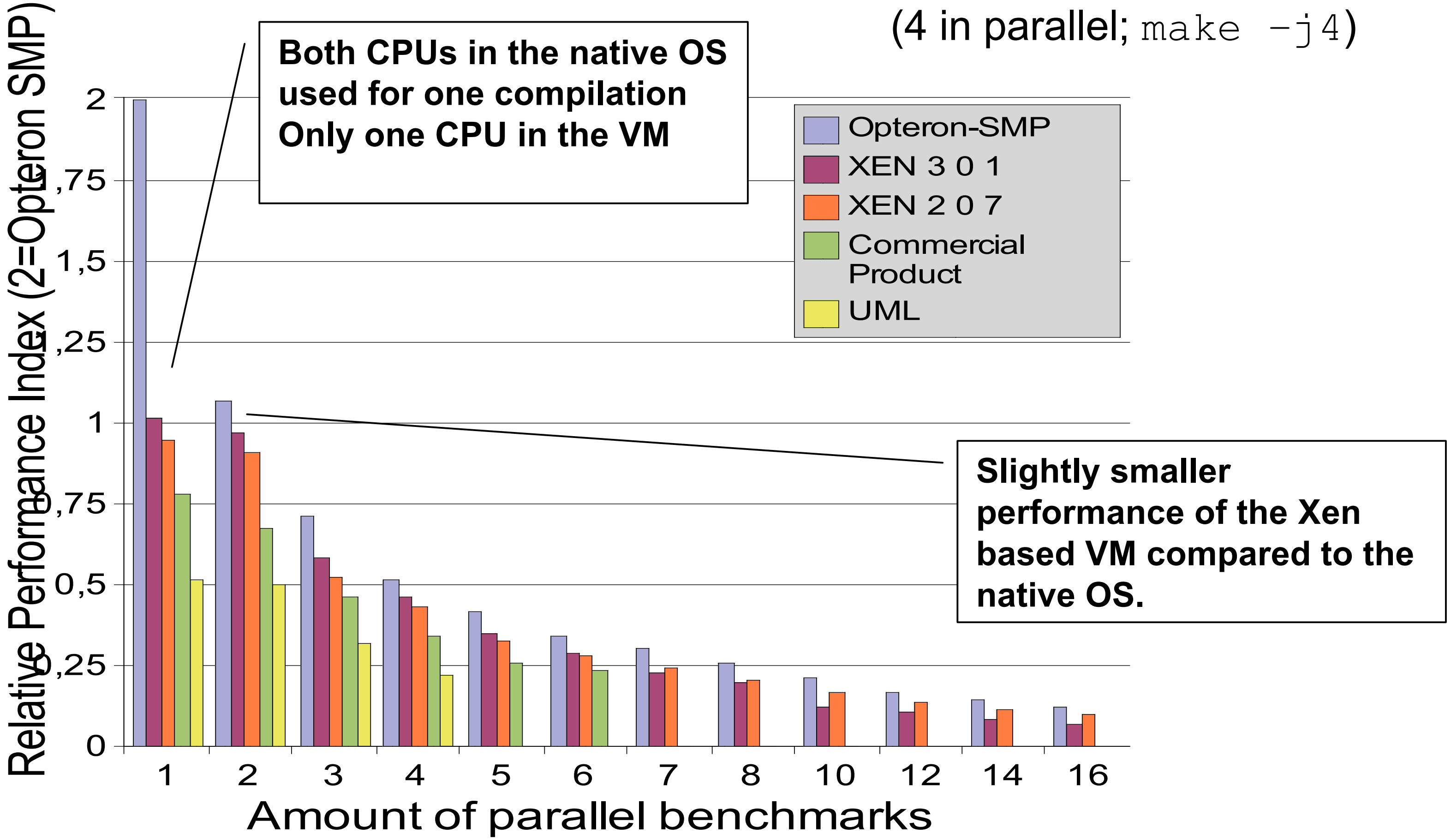
Using Virtualization

- Dynamic and fast changes in resource allocation
- Only host OS must fit the hardware
- Security and privacy through encapsulation

Virtualization Techniques: Performance comparison

Standard application benchmark: Linux kernel compilation

(4 in parallel; `make -j4`)



Performance considerations

- No noticeable performance loss due to virtualization:
  - Around 3-4% loss for CMS software (32 bit)

- Even performance gain is possible:
  - AMS group could benefit from 64 bit, but 32 bit common agreement
  - Galprop (AMS main application) runs 22% faster in a virtual 64-bit machine than on 32-bit native system! (Same Opteron hardware)

→ A overall performance gain can be possible

(at least no drastic performance losses)

Benefits:

- Optimal OS for each user group
- Security and privacy through encapsulation
- Enables possibiliy of desktop harvesting:
  - Desktop OS must support virtualization
- Easy deployment of OS
  - VM can be managed centrally
  - small adaptions at local site
  - local site admin only in charge of Dom0

Connection to the Batch Queue

Users do not login to the nodes: Using Batch Queuing Server!

Users are not to control the resources: Batch Queuing Server?

- The different VM running on one host are not independent:

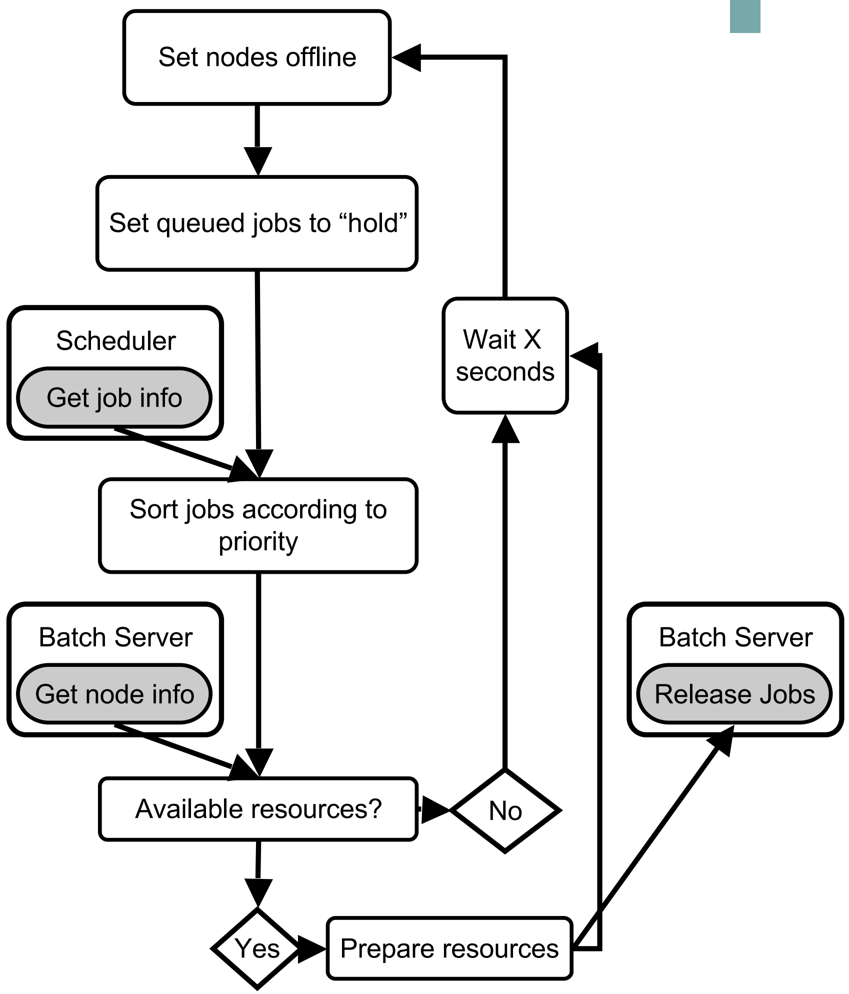
  They share the same resources
- The batch queue server must know about this sharing
  - Either natively
  - Or with the help of a separate process

Requirements of such a process:

- Independence of batch system server and scheduler:
  - No modifications
  - Flexibility
- Respect current policies:
  - Node occupancy
  - Prioritization

Implementation of process: Daemon

- Maui/Torque (used at EKP): Used to show working principle of daemon
- Daemon implemented in Perl language
  - First running on test system:
    - 2 Dual-Opteron simulating 19 nodes with 2 different OS
  - Now: Running on EKP production system with real users and real jobs
  - Working stable
- No changes to Maui/Torque necessary
- No change noticeable for users
- (Should be) easily adaptable for other products



Experiences at EKP

Setup

- 15 dual-core AMD64 boxes
  - 32bit ScientificLinux 3 VM
  - 64bit Debian VM
- 11 single-core 32bit boxes
  - 32bit ScientificLinux 3 VM
- 2 jobs per core
- Only one VM active (i.e. all memory and jobs)
- Host: Small debian 32/64bit with Xen 3.0.2 patched 2.6.16.27 kernel

Experiences during testing

- ~500 user jobs served
- Transparent to user
- No jobs lost or on wrong machine
- Lacks flexibility:
  - Advanced configuration in PBS only difficult to implement (max_jobs per user,…)
  - Reimplementation in daemon
- **Native integration in batch server preferable!!!**

Conclusions & Outlook

- Particle Physics heavy users of grid computing
- Grid computing profits from virtualization techniques
- XEN most utilized virtualization technique
  - Very good performance behavior
- Virtualization of the Computing Nodes necessary:
  - Different user groups: OS & security, desktop harvesting…
- Integration into existing Batch Queuing system possible:
  - Daemon working stable on EKP production system
  - **Native integration preferable**
    - Grouping of nodes to resources
    - “pbs_hardware_mom” (running on host, governing VMs and contacting PBS server)

Horizontally partitioned cluster demanded in Grid computing!

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