



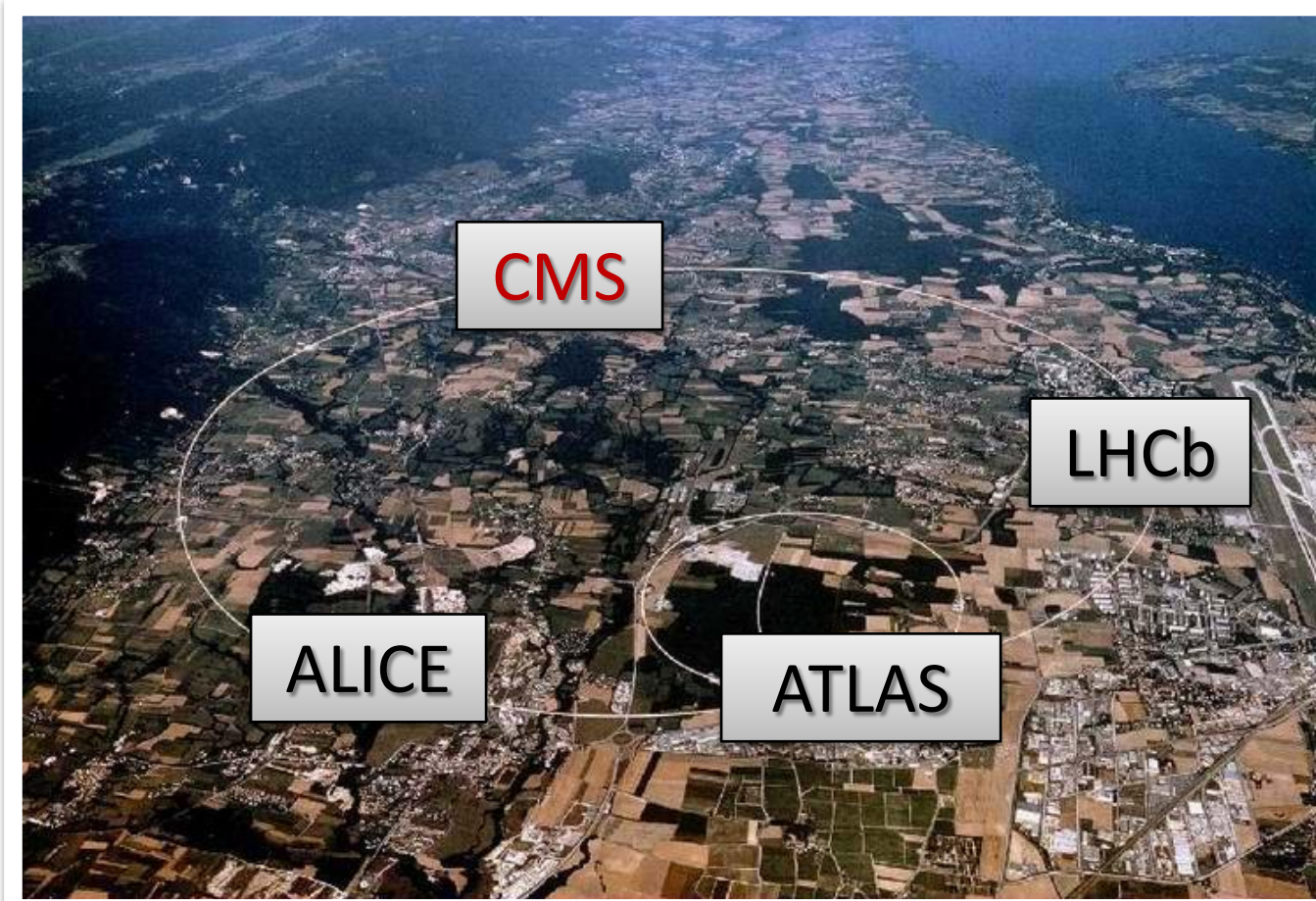
# German Contributions to the CMS Computing Infrastructure

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on behalf of the German CMS community



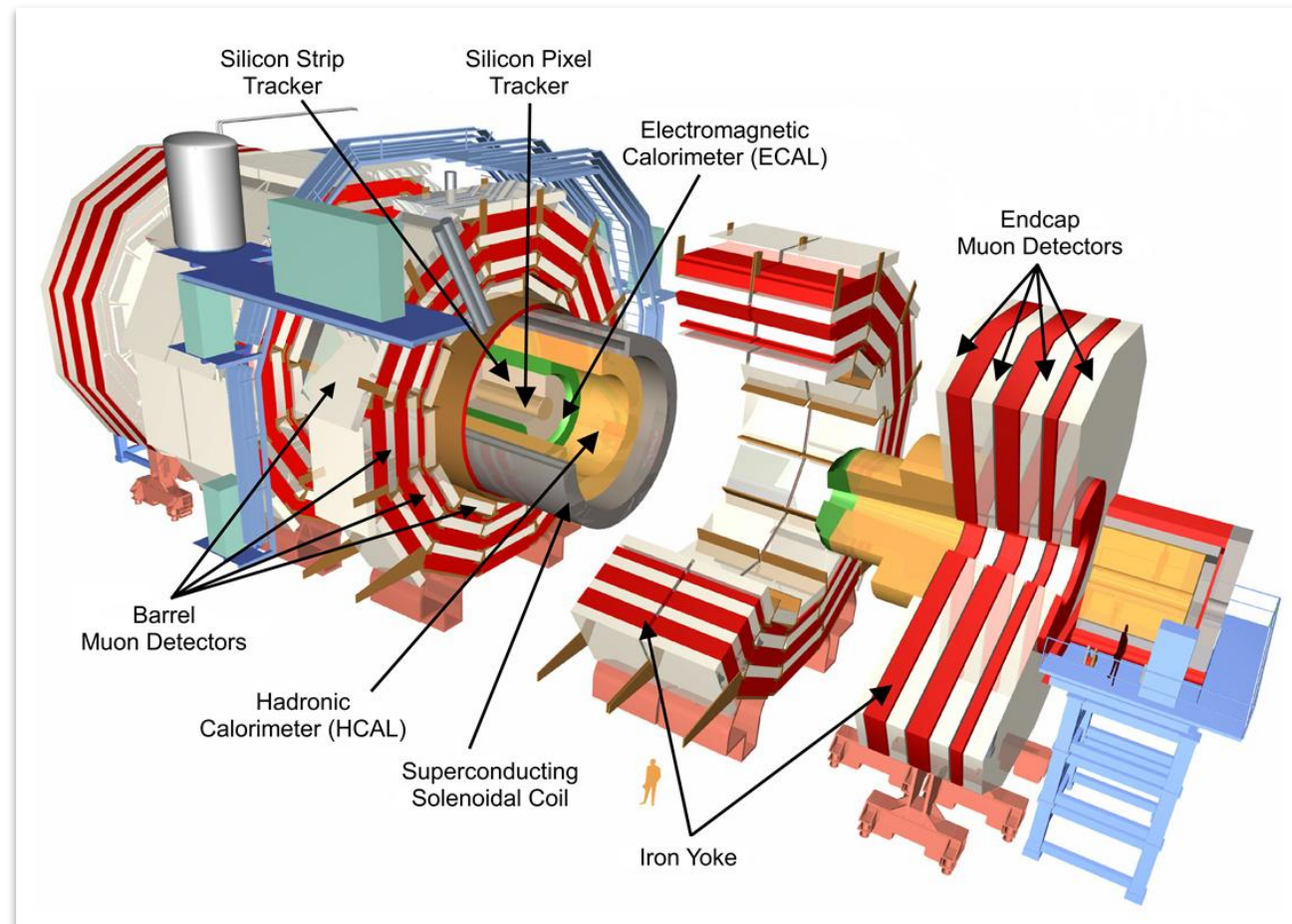
Bundesministerium  
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## The Large Hadron Collider & the CMS Experiment



Aerial view of the LHC and its 4 main experiments

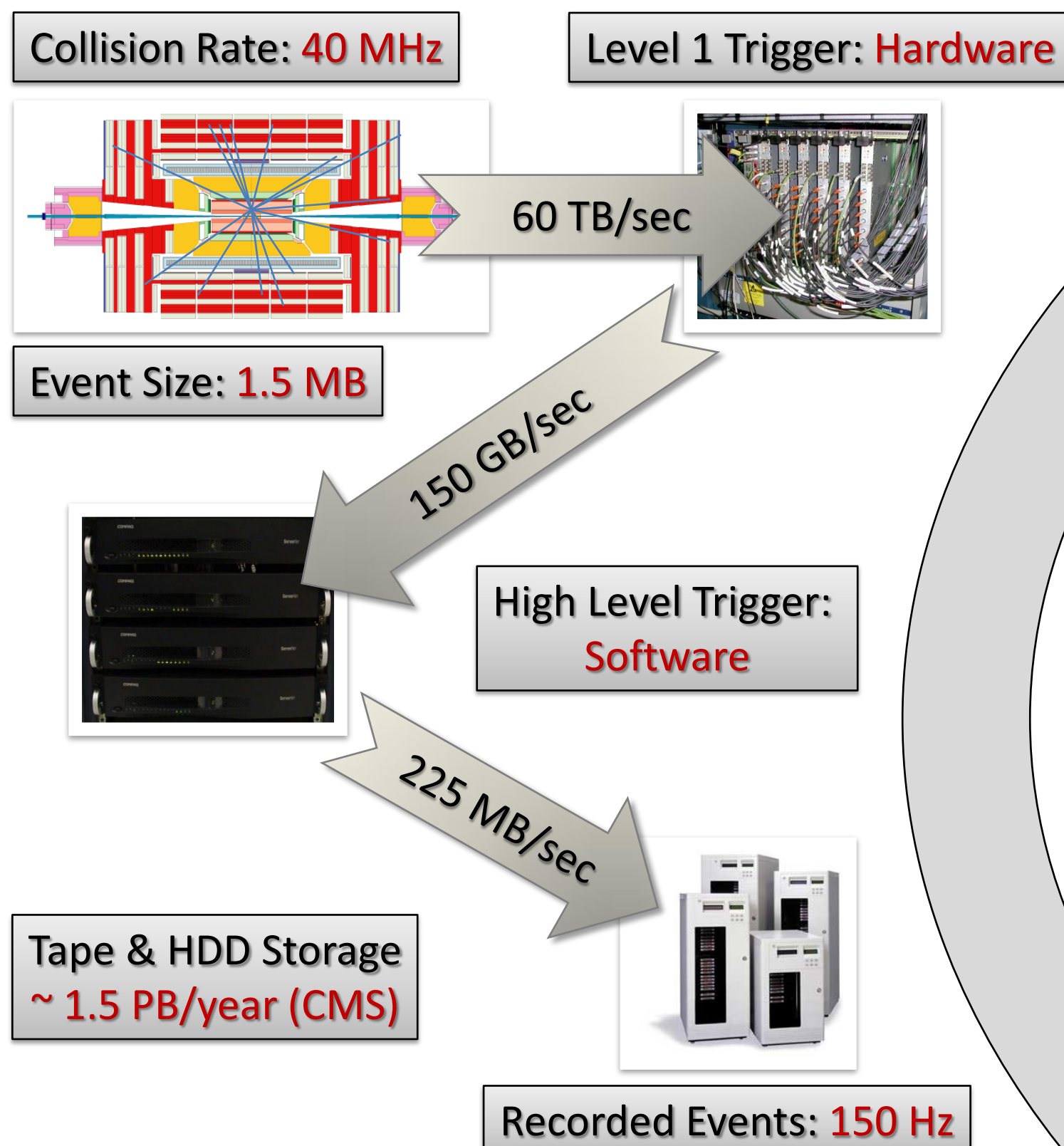
- Proton – Proton Collider:
- Circumference: 27 km
- Beam Energy: 7 TeV
- Below Surface: 100 m
- Temperature: -271 °C
- Energy Use: 1 TWh/a
- 2 General Purpose Experiments: CMS & ATLAS
- 4 Dedicated Experiments: ALICE, LHCb, LHCf, Totem



The Compact Muon Solenoid experiment

- Total Weight: 12 500 t
- Overall Diameter: 15 m
- Overall Length: 21.5 m
- Readout Channels: > 100 Mio.
- Magnetic Field: Solenoid: ~ 4 Tesla, Yoke: ~ 2 Tesla
- Nations: 38
- Institutions: 182
- Scientists & Engineers: > 2000

### CMS Trigger and Event Rate:



## German Tier Sites & Resources

### Tier 1:

The German Tier 1 Centre GridKa is located at Forschungszentrum Karlsruhe (KIT, Campus Nord) and operated by the Steinbuch Centre for Computing (SCC). GridKa is a multi-VO Tier 1 which supports in total 8 large HEP (and to a lesser extent Astroparticle) experiments):

- 4 LHC experiments: ALICE, ATLAS, CMS & LHCb

- 4 non-LHC experiments: BaBar, CDF, Compass & D0

- Network: 10 Gbit: GridKa – CERN, 3 x 10 Gbit: GridKa – T1, 10 Gbit: GridKa – T2
- Storage: Based on dCache (developed at DESY and FNAL), CMS Disk: ~ 650 TB, CMS Tape: ~ 900 TB
- CPU: CMS Resources: ~ 800 cores, ~ 2 GB RAM per core

	2010	2011	2012
CPU [MS12k]	8.5	4.3	5.1
Disk [PB]	1.6	2.0	2.4
Tape [PB]	2.8	3.7	4.6

CMS GridKa resource pledges for the next three years. In addition, the German D-Grid initiative provides resources for e.g. the German HEP community.

### Tier 2:

The Tier 2 centre in Germany is a federation of installations at the University of Aachen and the research centre DESY in Hamburg. The Tier 2 part at DESY is especially built to provide the infrastructure for storage-intensive user analyses, whereas the Aachen part is meant mainly for e.g. Monte Carlo production or detector calibration tasks which rely on a fast and potent computing infrastructure.

- Resources of e.g. the Aachen part: Based on dCache, about 100 TB disk space, ~ 360 cores (+ substantial T3 resources integrated coherently)

- Share of the Cluster Hardware 2008/2009: 90% CMS, 5% Auger, 5% IceCube

### Tier 3s & National Analysis Facility:

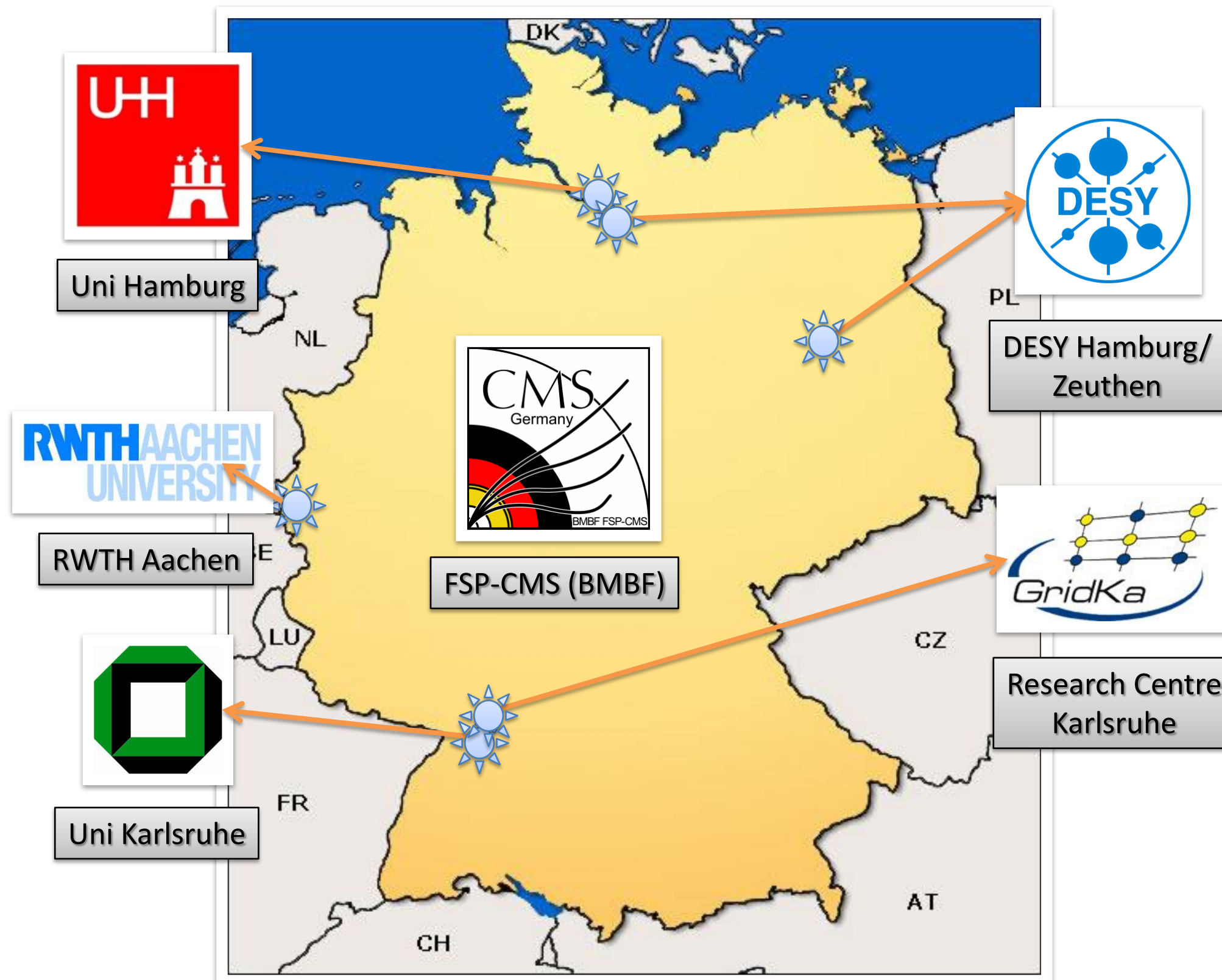
At all CMS member sites in Germany, varying amounts of computing and storage resources are grouped together to form several Tier 3 centres. They offer some of their resources to the whole CMS community, but are especially built to provide reliable and fast access to the huge amount of CMS data for local users and German CMS members. In addition, a so-called National Analysis Facility (NAF) was set-up at the research centre DESY.

Resources of e.g. Tier 3 Karlsruhe

- Storage: 750 GB HDD space per node, 370 TB Lustre space (accessible via Infiniband)

- CPU: 200 worker nodes (1600 cores), 2 GB RAM per core

## German CMS Members



German CMS Member Institutions:

- I. Physikalisches Institut B, RWTH Aachen
- III. Physikalisches Institut A, RWTH Aachen
- III. Physikalisches Institut B, RWTH Aachen
- Deutsches Elektronen-Synchrotron DESY, Hamburg und Zeuthen
- Institut für Experimentalphysik, Universität Hamburg
- Institut für Experimentelle Kernphysik, Universität Karlsruhe

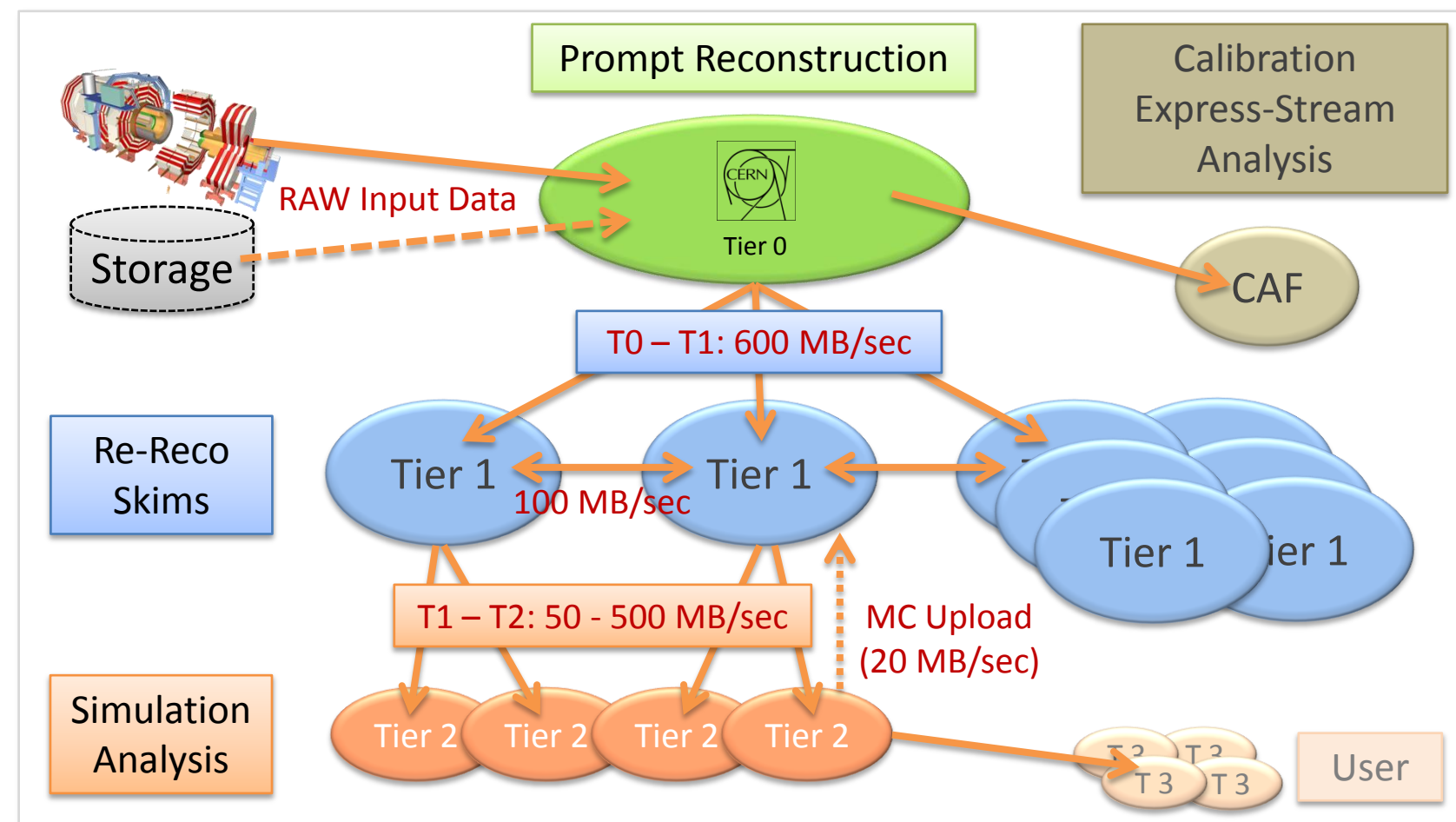
## CMS Computing, Service and Analysis Challenges

The CMS computing model anticipates various hierarchically linked Tier centres to counter the challenges provided by the enormous amounts of data which will be collected by the CMS detector at the Large Hadron Collider, LHC, at CERN. During the past years, various computing exercises were performed to test the readiness of the computing infrastructure, the Grid middleware and the experiments' software for the startup of the LHC which took place in September 2008.

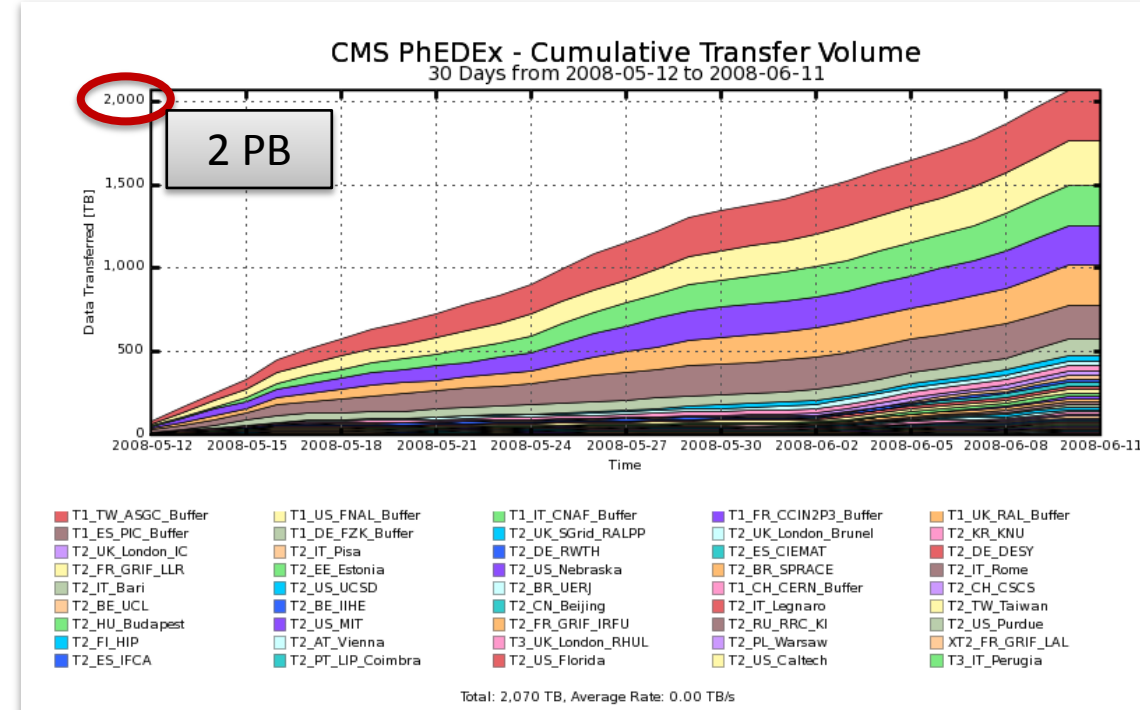
In 2006, 2007 and 2008, three of those Computing, Software and Analysis (CSA) Challenges have been performed. The latter one, CSA 2008, was operated at a level of 100% of the computing and network resources which are required for the startup of the LHC and the CMS experiment.

The whole CMS computing workflow was tested during CSA 2008 simultaneously. The following steps were performed:

- Production/Simulation at the Tier 2s as input for the Tier 0
- Prompt reconstruction at the Tier 0
- Re-reconstruction at the Tier 1s
- Data distribution to the Tier 1s and Tier 2s
- Data analyses at the Tier 2s



Schematic view of the CMS computing workflow. The numbers correspond to the metrics of CSA 2008.



Cumulative amount of data transferred during the 4 weeks of CSA 2008 operation

## CSA Achievements

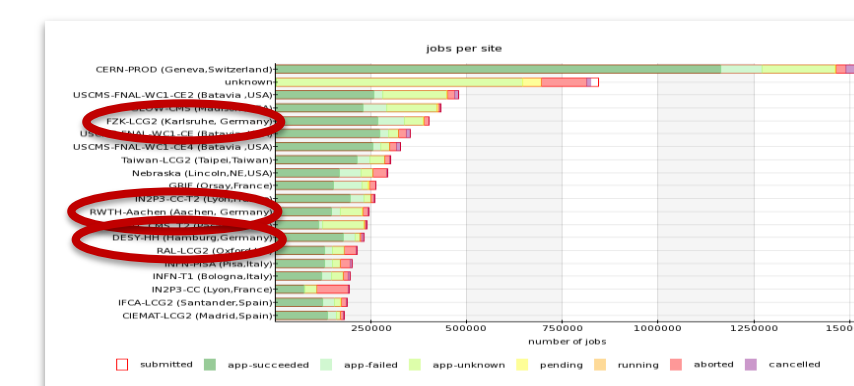
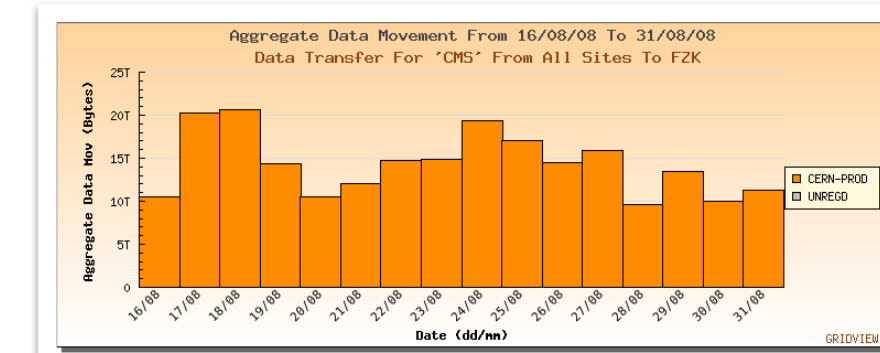
Service	Goal 2008	Status 2008	Goal 2007	Status 2007	Goal 2006	Status 2006
Tier 0 Reco Rate	150-300 Hz	Achieved	100 Hz	Only at bursts	50 Hz	Achieved
Tier 0 → Tier 1 Transfer Rate	600 MB/sec	Achieved partially	300 MB/sec	Only at bursts	150 MB/sec	Achieved
Tier 1 → Tier 2 Transfer Rate	50-500 MB/sec	Achieved	20-200 MB/sec	Achieved partially	10-100 MB/sec	Achieved
Tier 1 → Tier 1 Transfer Rate	100 MB/sec	Achieved	50 MB/sec	Achieved partially	N/A	-
Tier 1 Job Submission	50 000 jobs/day	Achieved	25 000 jobs/day	Achieved	12 000 jobs/day	3 000 jobs/day
Tier 2 Job Submission	150 000 jobs/day	Achieved	75 000 jobs/day	20 000 jobs/day	48 000 jobs/day	Achieved
Monte Carlo Simulation	1.5 x 10 <sup>6</sup> events/year	Achieved	50 x 10 <sup>6</sup> events/month	Achieved	N/A	-

Achievements of CMS Computing, Software and Analysis challenges performed in 2008, 2007 and 2006 at levels of 100%, 50% and 25% of the required resources for the LHC startup, respectively.

## Performance

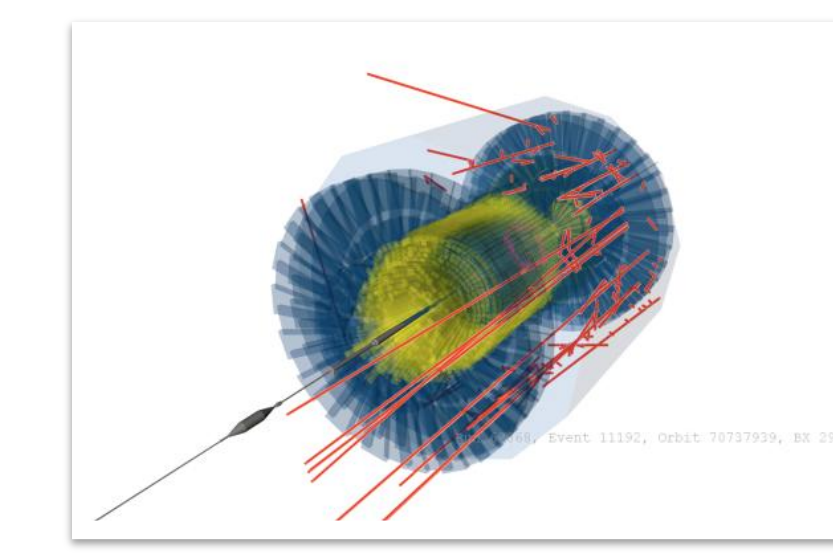
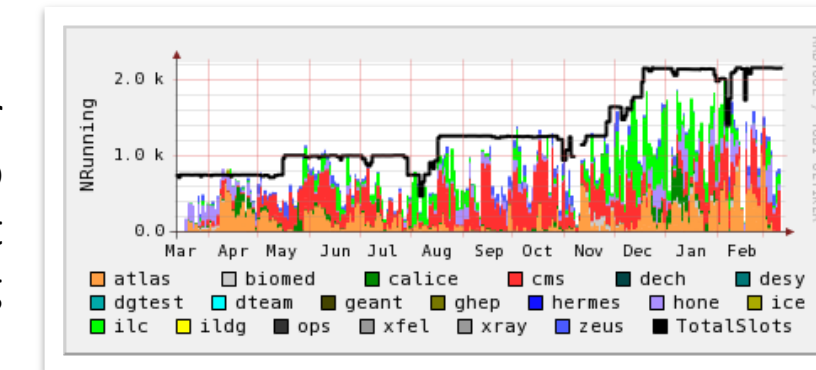
During the last years, CMS has tested intensively the computing and network infrastructure of the experiment in order to cope with the challenges provided by the LHC after its startup. It can be seen that all German Tier sites and especially the Tier 1 centre GridKa and the Tier 2 at DESY and Aachen performed very well during these tests. Additionally, the daily business of each tier site was covered excellently during a long and stable period of running in 2008 and 2009.

Data Distribution: Transfer of cosmic muon datasets from the Tier 0 at CERN to GridKa over 2 weeks of stable operation at rates of 10 to 20 TB/day.



Grid-Job Performance: Cropped ranking-list of the CMS Grid-job performance from May to August 2008. The German Tier 1 and Tier 2 centres are performing well and are ready for incoming collision data at the end of 2009.

Monte Carlo & User Analyses: Number of running jobs at the German Tier 2 during the last year (March 2008 to February 2009). The plot illustrates different stages of extension of the computing infrastructure during the last year.



First Real Data: The first real beam event which was recorded by CMS in September 2008. During the 10 days of LHC operation and CMS data taking, a lot of data was recorded and distributed among the different tier sites. GridKa was the first centre outside CERN which obtained first beam data.

## Selected Publications

- Experience Building and Operating the CMS Tier-1 Computing Centers C. Grandi et al., 2009, CHEP 09
- Algorithms for the Identification of b-Quark Jets with First Data at CMS A. Scheurer, 2008, IEKP-KA/2008-19
- Challenges of the LHC Computing Grid by the CMS experiment A. Scheurer, M. Ernst, A. Flossdorf, C. Hof, T. Kress, K. Rabbertz, G. Quast German e-Science, 2007, ID: 316623.0
- CMS Computing, Software and Analysis Challenge in 2006 (CSA06) Summary The CMS Collaboration, 2007, CERN/LHCC 2007-010

