Running the CMS data analysis on the Grid

The workflow and the experience

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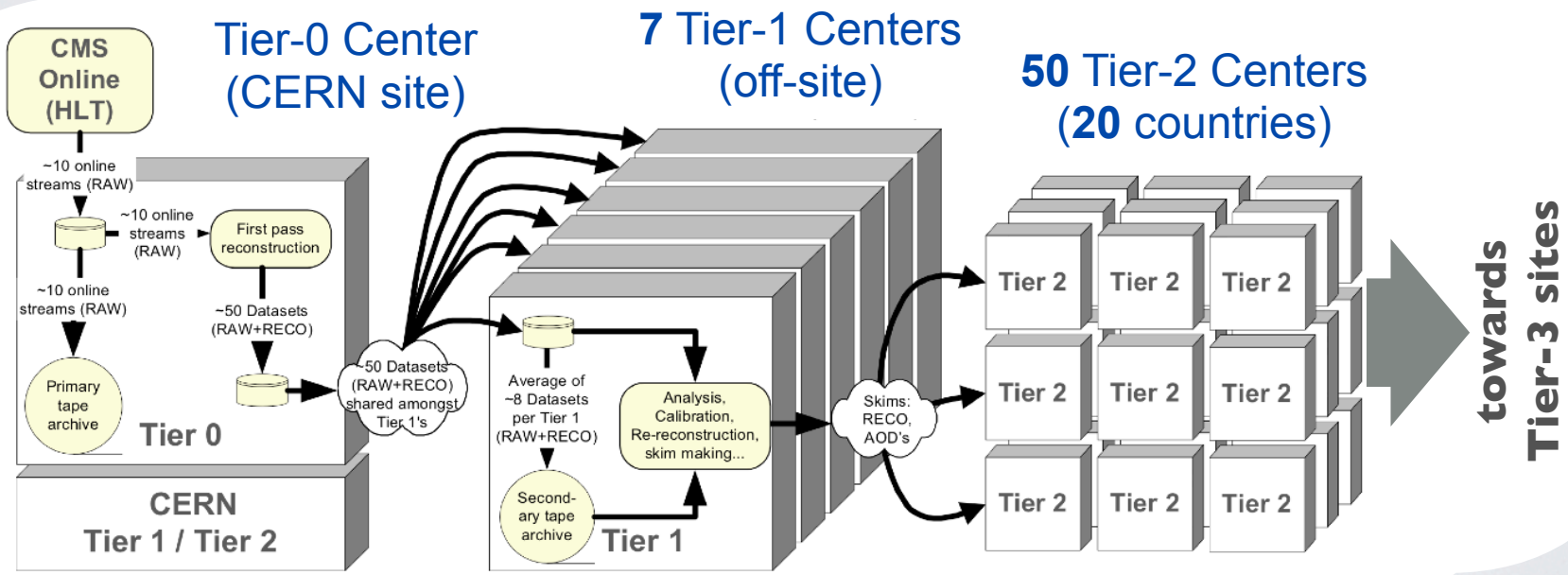
The LHC Grid and the CMS computing model

- The LHC experiments will produce approximately 15 PB of data each year (physicists around the world want to access and analyze this data)
- Computing and storage resources for the LHC Grid are distributed at 11 Tier-1 sites, ~160 Tier-2 sites (32 countries)

The CMS computing model

Worldwide LHC Computing Grid Infrastructure



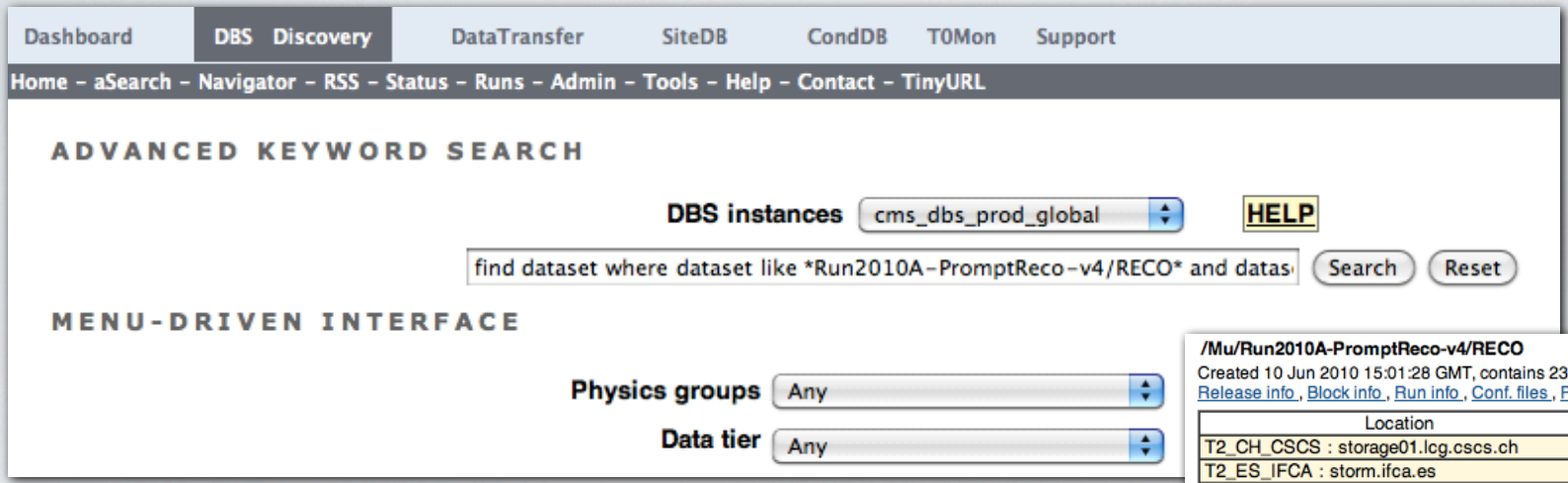
The analysis workflow

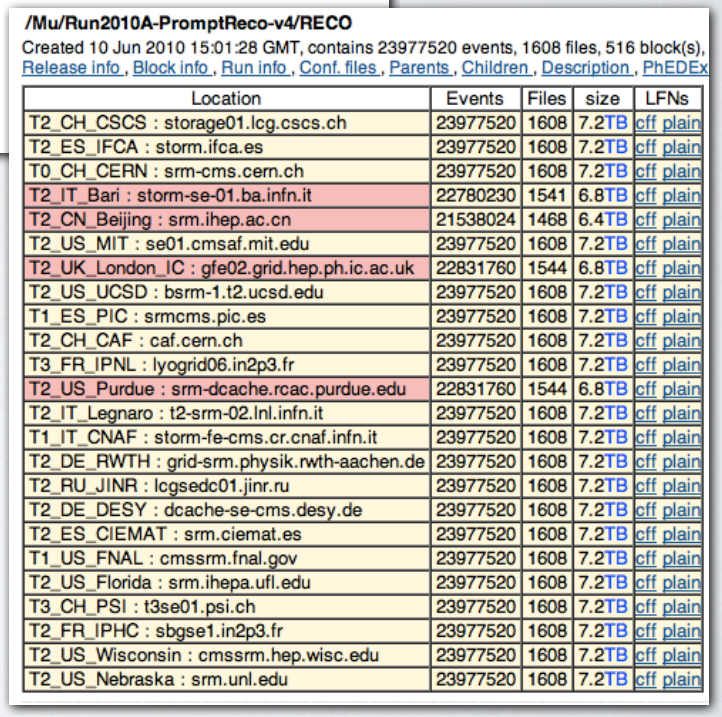
- A typical analysis workflow

- Several questions and tools to answer them:
  - Where is my data located? Where can I run my jobs? → DBS
  - How do I transfer data to where I want to run? → PHEDEX
  - Is the right software available at that site? → CRAB
  - How time consuming is my job?
  - Are my jobs running? Monitoring? → Dashboard

Finding the dataset

- The tool named Dataset Bookkeeping Service (DBS) provides means to describe, discover and use the CMS event data





/Mu/Run2010A-PromptReco-v4/RECO

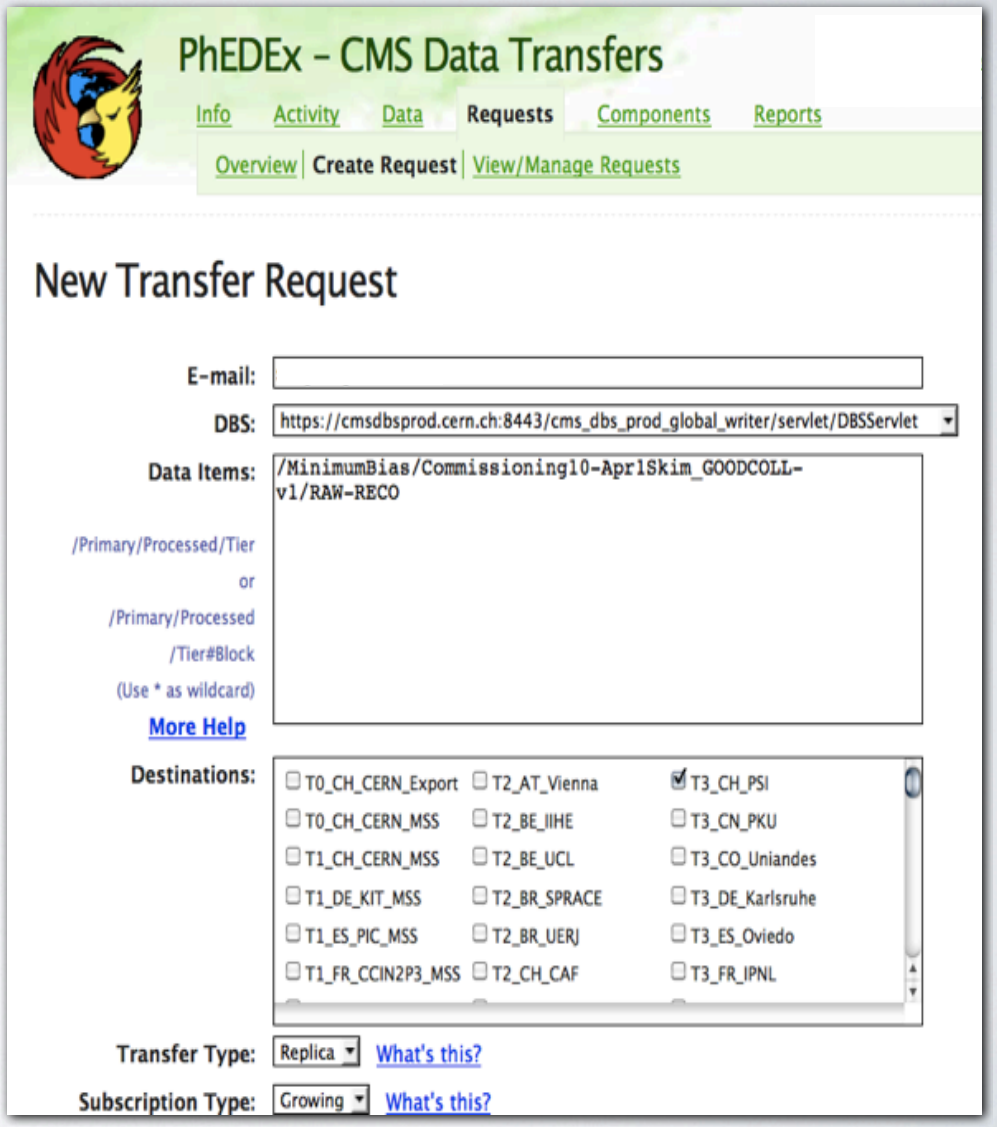
Created 10 Jun 2010 15:01:28 GMT, contains 23977520 events, 1608 files, 516 block(s),
Release info , Block info , Run info , Conf. files , Parents , Children , Description , PhEDEx

Location	Events	Files	size	LFNs
T2_CH_CSCS : storage01.lcg.cscs.ch	23977520	1608	7.2TB	cff plain
T2_ES_IFCA : storm.ifca.es	23977520	1608	7.2TB	cff plain
T0_CH_CERN : srm-cms.cern.ch	23977520	1608	7.2TB	cff plain
T2_IT_Bari : storm-se-01.ba.infn.it	22780230	1541	6.8TB	cff plain
T2_CN_Beijing : srm.ihep.ac.cn	21538024	1468	6.4TB	cff plain
T2_US_MIT : se01.cmsaf.mit.edu	23977520	1608	7.2TB	cff plain
T2_UK_London_IC : gfe02.grid.hep.ph.ic.ac.uk	22831760	1544	6.8TB	cff plain
T2_US_UCSD : bsrm-1.t2.ucsd.edu	23977520	1608	7.2TB	cff plain
T1_ES_PIC : srmcms.pic.es	23977520	1608	7.2TB	cff plain
T2_CH_CAF : caf.cern.ch	23977520	1608	7.2TB	cff plain
T3_FR_IPNL : lyogrid06.in2p3.fr	23977520	1608	7.2TB	cff plain
T2_US_Purdue : srm-dcache.rcac.purdue.edu	22831760	1544	6.8TB	cff plain
T2_IT_Legnaro : t2-srm-02.lnl.infn.it	23977520	1608	7.2TB	cff plain
T1_IT_CNAF : storm-fe-cms.cr.cnaf.infn.it	23977520	1608	7.2TB	cff plain
T2_DE_RWTH : grid-srm.physik.rwth-aachen.de	23977520	1608	7.2TB	cff plain
T2_RU_JINR : lcgsedc01.jinr.ru	23977520	1608	7.2TB	cff plain
T2_DE_DESY : dcache-se-cms.desy.de	23977520	1608	7.2TB	cff plain
T2_ES_CIEMAT : srm.ciemat.es	23977520	1608	7.2TB	cff plain
T1_US_FNAL : cmssrm.fnal.gov	23977520	1608	7.2TB	cff plain
T2_US_Florida : srm.ihepa.ufl.edu	23977520	1608	7.2TB	cff plain
T3_CH_PSI : t3se01.psi.ch	23977520	1608	7.2TB	cff plain
T2_FR_IPHC : sbgse1.in2p3.fr	23977520	1608	7.2TB	cff plain
T2_US_Wisconsin : cmssrm.hep.wisc.edu	23977520	1608	7.2TB	cff plain
T2_US_Nebraska : srm.unl.edu	23977520	1608	7.2TB	cff plain

- Contains all the necessary information on:
  - locations
  - num. of events / num. of files / size
  - date of production
  - configuration used for production of dataset
  - software versions...
- Accessible via web-interface & command line

Data transfer

- The tool for data transfer is called PhEDEx (Physics Experiment Data Export)
- Create subscription requests on the web interface. Choose:
  - dataset, destination
  - transfer and subscription type...
- Request handled by site data managers (storage quotas)
- If approved - transfer starts (handled by the PhEDEx system)
- User can monitor the transfer performance using web interface



CRAB jobs

- CMS uses a python front-end tool called the CMS Remote Analysis Builder (CRAB) for job creation and submission in a user-friendly way:

- User only needs to specify some minimal information:
  - configuration of the analysis
  - dataset name
  - number of events/jobs
  - output handling

- The rest is handled by CRAB
  - splitting of jobs
  - finding appropriate sites
  - submission
  - basic monitoring
  - output retrieval

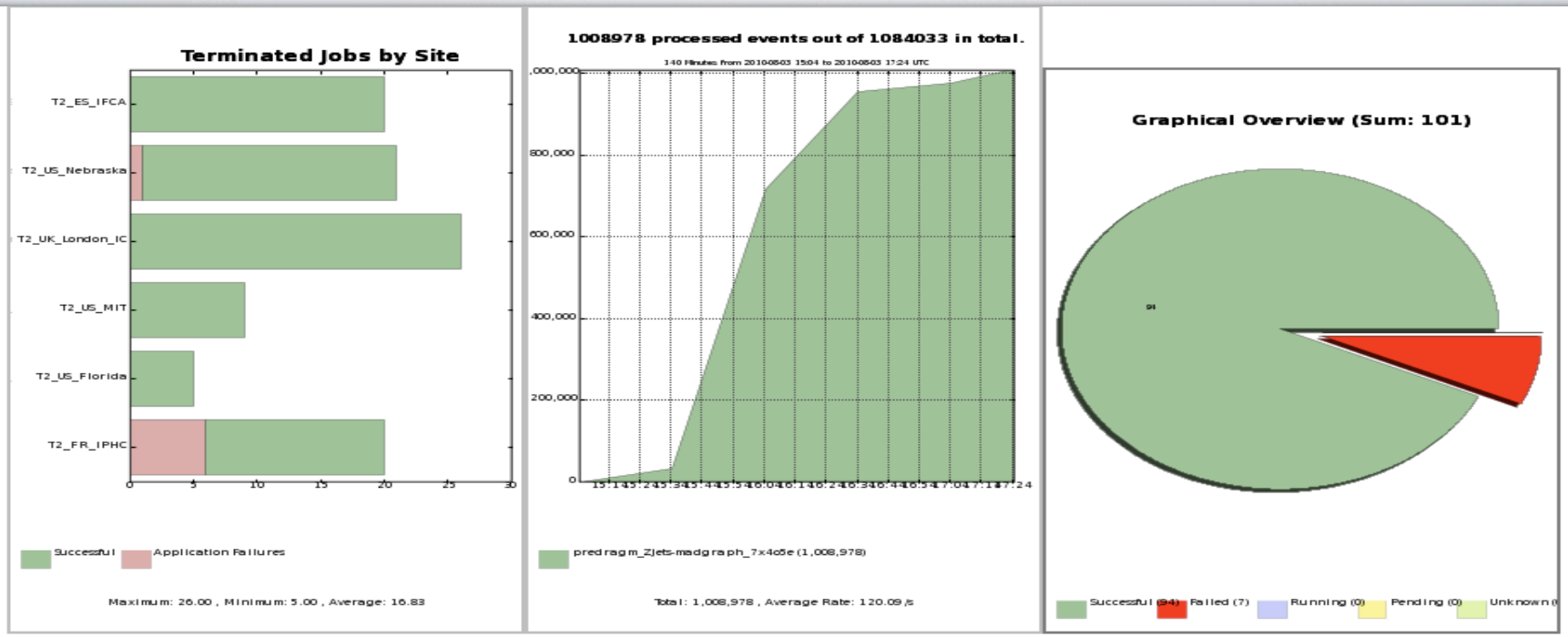
CRAB configuration file

```
[CMSSW]
### The data to access (defined in multicrab cfg)
#datasetpath=

### The parameter set to use and additional options
pset                    = ../../ntupleproducer_cfg.py
pycfg_params            = runon=data recoType=RECO

### Splitting parameters (defined in multicrab cfg)
total_number_of_events  =-1
events_per_job          = 20000
number_of_jobs          = 300
total_number_of_lumis   =-1
lumis_per_job           = 30
split_by_run            = 1

### run number restrictions (defined in multicrab cfg)
runselection=132440-135735
lumi_mask=Cert_132440-135735_7TeV_StreamExpress_Collisions10_JSON.txt

### The output files (defined in ntupleproducer_cfg)
#output_file =


[USER]
### output back into UI
return_data             = 0
#ui_working_dir         = data

### output files into a SE
copy_data               = 1
storage_element         = t3se01.psi.ch
storage_path            = /srm/managerv2?SFN=/pnfs/psi.ch/cms/trivcat/
user_remote_dir         = ntuples/data/
```

- The CRAB is operated as a command line tool

Job monitoring - Dashboard

- General overview of all running tasks and a detailed overview of jobs provided also via the CMS Dashboard

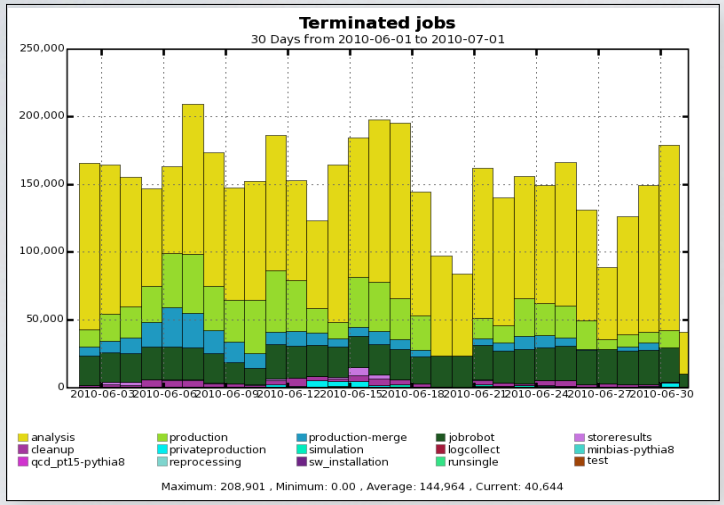


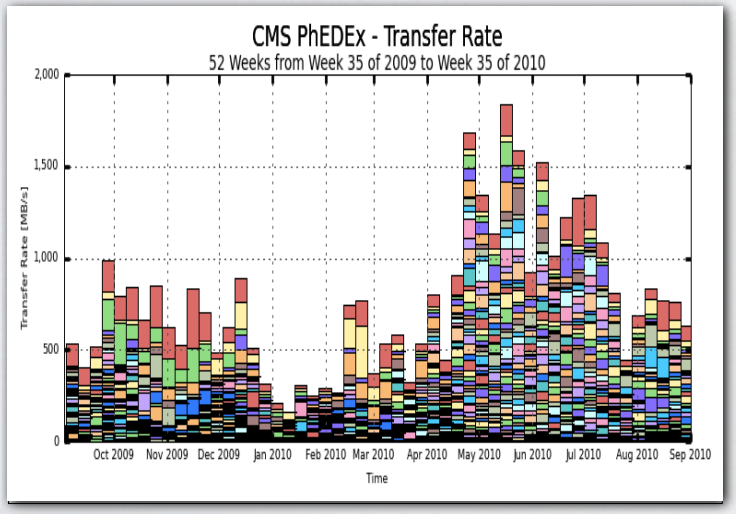
Click on a plot to increase its size.

SchedulerJobId	Id in Task	Appl Status	Appl Exit Code	Grid End Status	Retries	Site	Submitted	Started	Finished
https://prod-lb-01.ct.infn.it:9000/ckr7LPZ7Me1TjTxNrGa5Eg	1	Appl Succeeded	0	Unknown	1	T2_US_Nebraska	2010-08-03 16:20:47	2010-08-03 16:20:47	2010-08-03 16:53:59
https://prod-lb-01.ct.infn.it:9000/ad5pAJStBe5FvEi5VKWsKg	2	Appl Succeeded	0	Unknown	1	T2_US_MIT	2010-08-03 16:20:21	2010-08-03 16:20:21	2010-08-03 16:41:07
https://prod-lb-01.ct.infn.it:9000/HULJiswijgBijhjUl-lbaw	3	Appl Succeeded	0	Unknown	1	T2_UK_London_IC	2010-08-03 16:58:46	2010-08-03 16:58:46	2010-08-03 17:18:42
https://prod-lb-01.ct.infn.it:9000/_V1Z_P60aEC8wVIxgx7V_g	4	Appl Succeeded	0	Unknown	1	T2_ES_IFCA	2010-08-03 16:18:24	2010-08-03 16:18:24	2010-08-03 16:46:48

Analysis activities

Routinely delivering 100k jobs per day





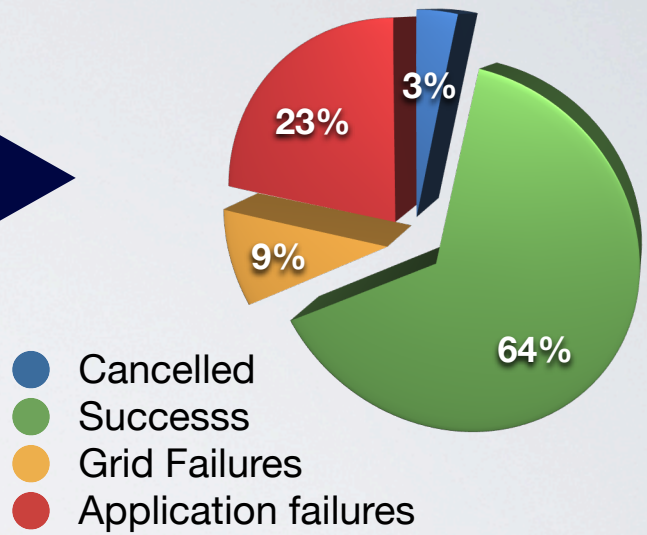
Hundreds of active users running analysis

General user experience

- The sources of analysis failures:
  - Grid-related problems
    (not easy to control or have influence on)
  - CMS user-related errors and problems:
    - in configuration files
    - in analysis code
    - issues with stage-out of job outputs

    (good support from the CRAB team)

Analysis Jobs (2008-2009)

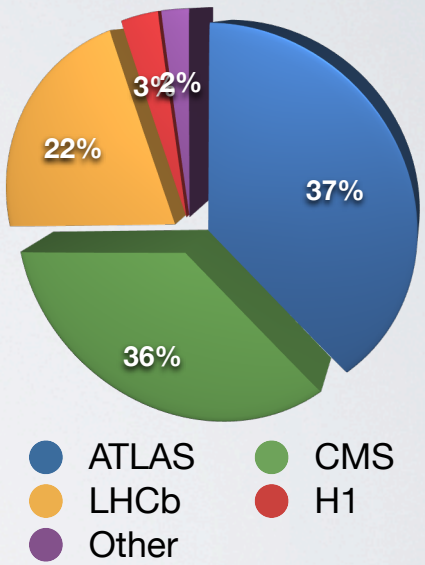


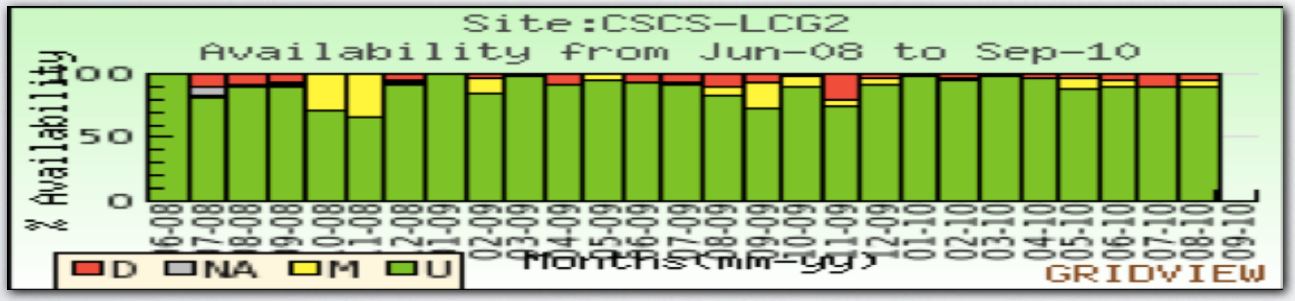
- Users would like to have improved:
  - the total time needed for 100% of jobs to be completed
    ➡ e.g. we can have 90% of jobs finished within ~2-3 hours
    and the other 10% of jobs could be on the Grid for up to 20-30 hours!
    (various reasons could lead to this issue - not easy to tackle this problem)
  - better synchronization of the monitoring information provided by our two tools: the CRAB and the Dashboard

Swiss CMS Tier-2

- CSCS at Manno hosts a CMS Tier-2 which offers a total of 768 cores and about 800 TB of storage space (reached this upgrade phase in Q1/2010)
- Network traffic via two redundant lines of 10Gbps (to CERN and Europe)
- Tier-2 is up & has been in stable operation for years!
- Shares of resources per VO are pretty well balanced. (spare cycles given to other VOs: H1, theory...)
- Typical reliability and availablity in last two years are higher than 95%!

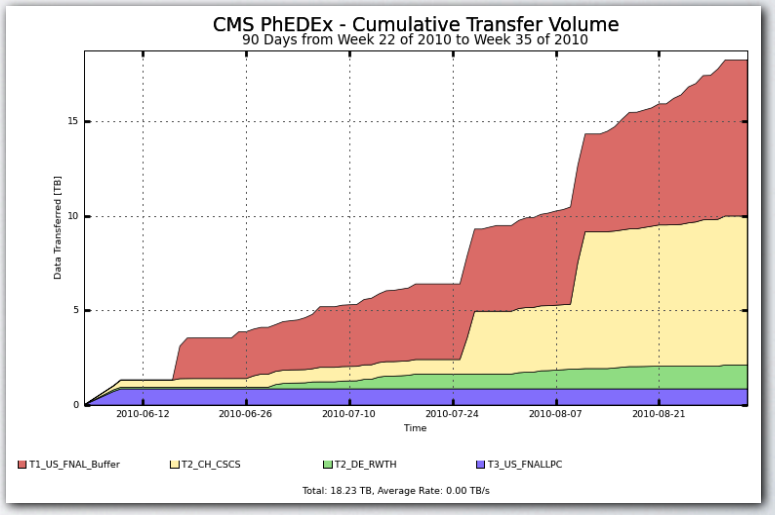
CPU share per VO (2007-2010)





Swiss CMS Tier-3

- The PSI hosts a CMS Tier-3 which offers ~250 TB of storage space and 28 nodes with 224 cores. It is available to all CMS users from Swiss institutes (ETH Zurich, University of Zurich and PSI)
- Datasets can be transferred via PhEDEx from some Tier centers directly to the storage element (SE) and from the others via the Swiss Tier-2.
- Analysis jobs are typically submitted and run as CRAB jobs.
  - if the output is small, it is retrieved directly on the PSI SE (or at the UI)
  - otherwise, it is preferred to use CSCS SE for stage-out (and transfer data to PSI SE with tools provided by our T3 team)
- The analysis/simulation jobs can be submitted directly to the local batch farm on worker nodes of the PSI Tier-3
- It has become The Tool for members of swiss institutes (CMS)



Conclusions

- The CMS has entered the data analysis era in a full swing!
- All the challenges we had in CMS in recent years have led to many improvements and resulted in a reliable system for analysis
  - exercised in many computing aspects...
    (DC04, CS06, CSA07, CSA08, STEP09, OctoberExercise ...)
  - ...and in most of the analysis aspects (dataset skimming, analysis at T2s etc.)
- The complete infrastructure has sustained an enormous load and successfully supported the analysis "marathon" prior to the ICHEP 2010
- The Swiss Tier-2 and Tier-3 centers are extensively used and play an essential role in our everyday-analysis life
- The main building blocks for data analysis are fully in place and working in a production environment (and being debugged and regularly updated to improve the user experience)