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Harnessing Grid Resources with Ganga and Dirac

Durham Seminar, 15th October, 2014

Mark Slater, Birmingham University

An Introduction to the Grid

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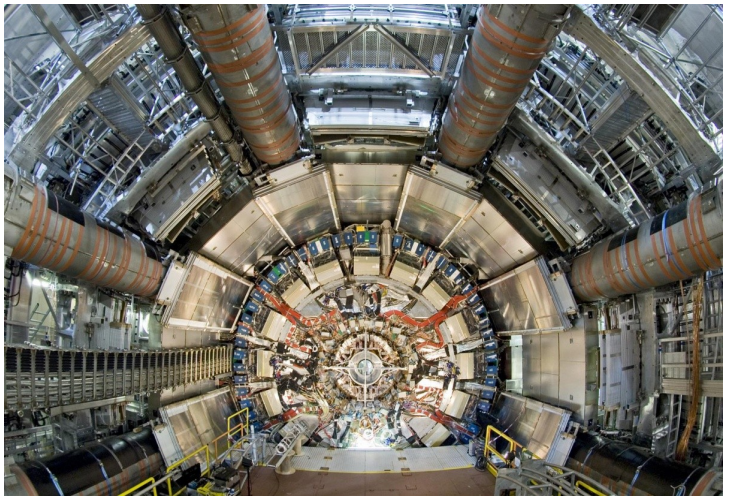
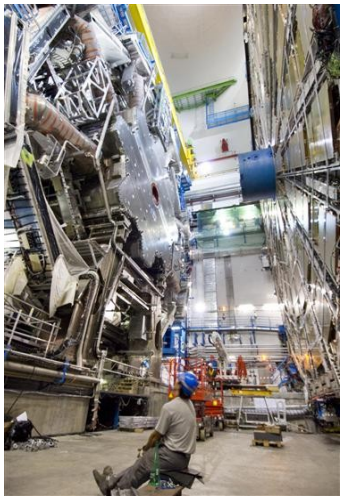
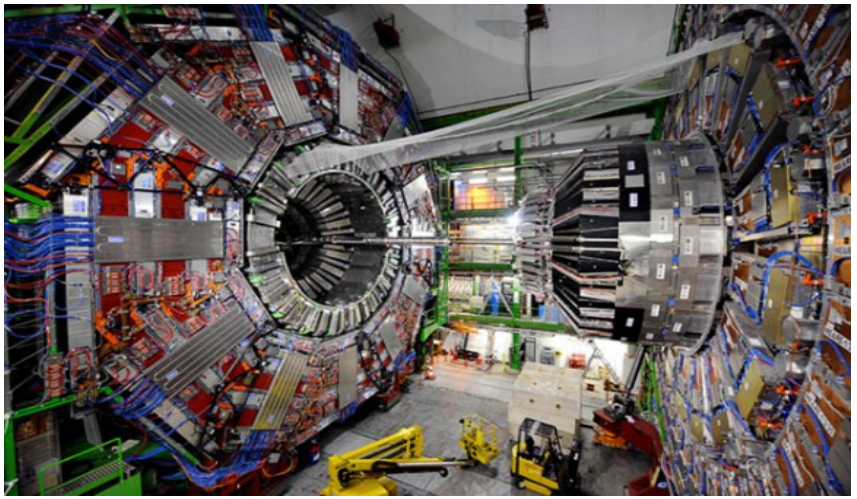
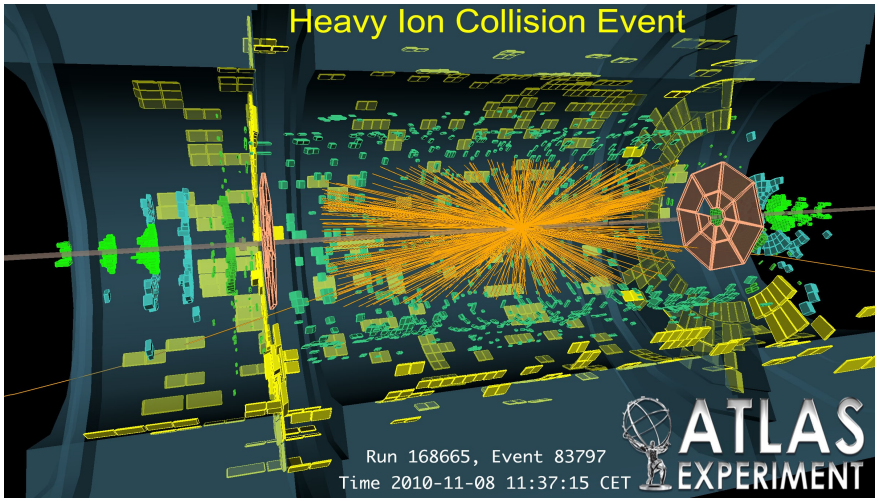
Why we need the Grid

As you all probably know, the LHC detectors are very large and complex:







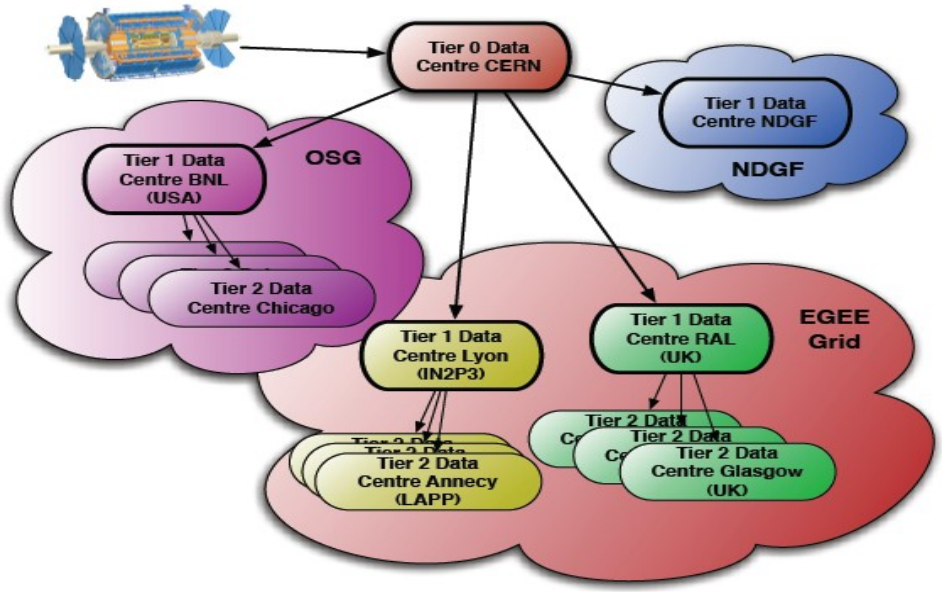


The many sub-detectors and systems not only produce vast amounts of data ***(30 Petabytes annually!)*** but also require a lot of computational analysis to measure the small signals we're looking for

Grid Overview

To store, process and provide access to this amount of data was not practical (or desirable) from one location, so the Worldwide LCG Computing Grid was developed consisting of ~170 computing centres around the world

- ~250000 CPU cores are available
- ~350PB of disk storage
- ~130PB of Tape storage



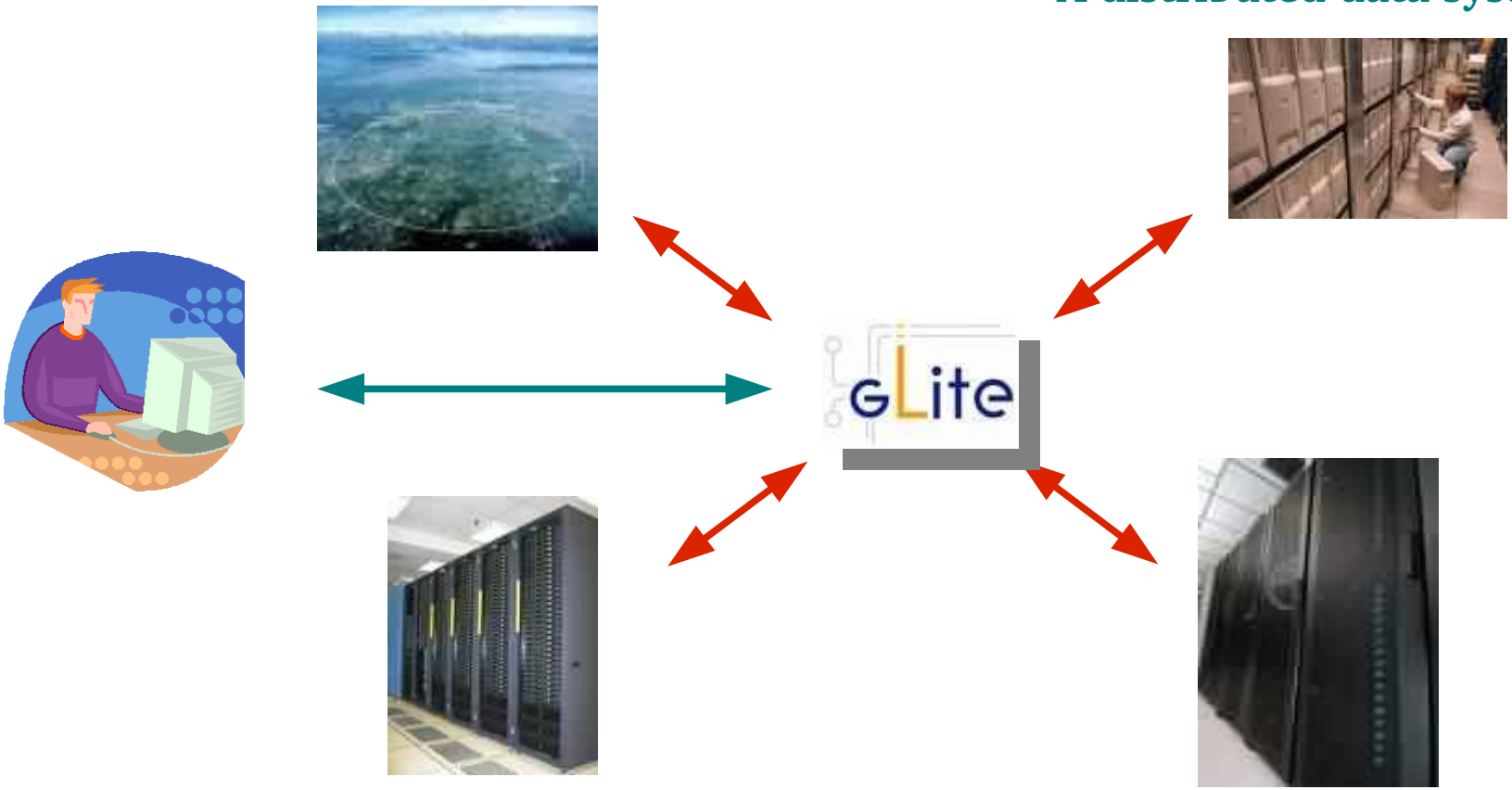
All this is arranged in a 'Tier' system so the data flows from the detectors at CERN, through 'countrywide' Tier 1's and finally out to smaller Tier 2's

Here is a 'live' snapshot from a few weeks ago of grid activity. In a 10min window, there were ~200000 running jobs and a transfer rate of 7 GiB/s. In 24 hours, there are ~1 million jobs run.

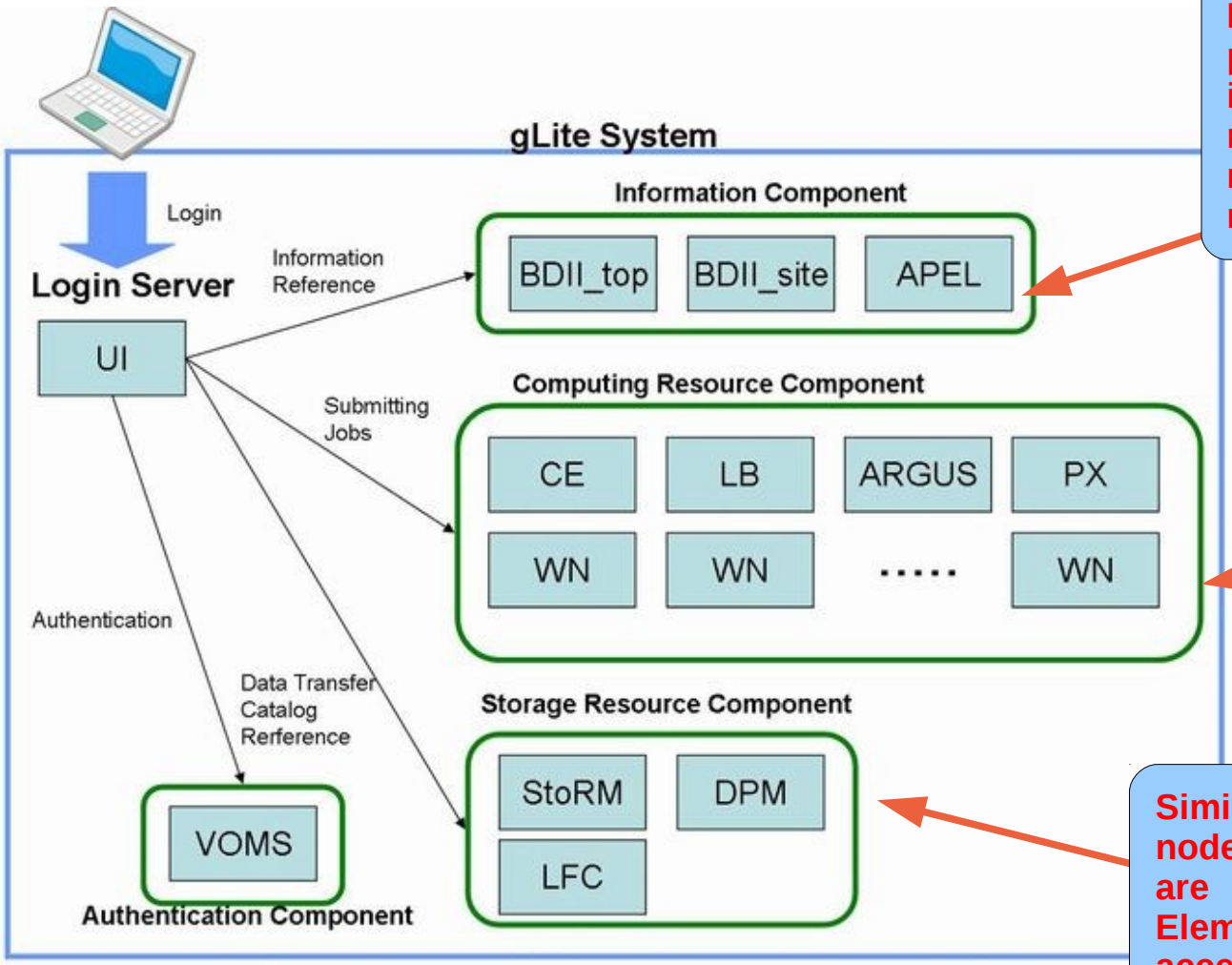
Grid Middleware

The 'glue' that sticks all of these disparate computing clusters and resources together is the Grid Middleware. This allows:

- Jobs to be submitted from anywhere
- An up-to-date reflection of a site's status
- A Workload Management system to ease job submission
- A distributed data system/catalog



GLite Middleware



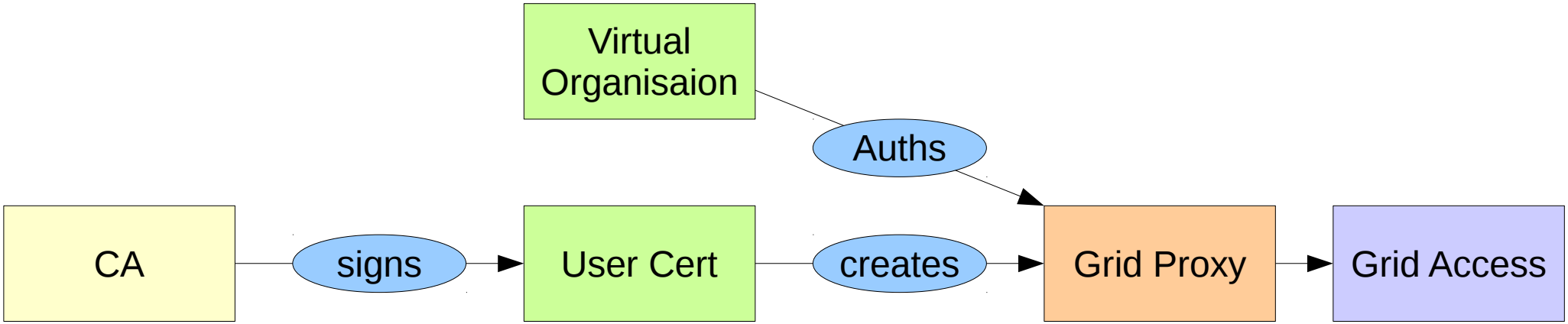
Information Systems provide up to date info on the available resources and how much work those resources are doing

Each cluster is fronted by a Computing Element system that accepts jobs from the Workload Management System

Similarly to the compute nodes, the storage systems are fronted by a 'Storage Element' system to allow access. There is also a central File Catalog (LFC) that stores the replica info

Security and Organisation

The security of the grid was a top priority. We could not let just anyone have access to such a massive resource, not only because of the chances of interfering with other peoples work but also due to intentionally (or not!) causing DDOS attacks or other problems



The security chain starts with a user requesting a Grid Certificate from a Certifying Authority. They then have to request membership of at least one 'Virtual Organisation' that will be somewhat 'responsible' for their actions on the grid

The user is then able to create a Grid Proxy file (which will have a limited lifetime) that is actually used to access resources

If any problems are found with a particular user, their proxy and certificate can be blocked within a few hours

Experimental Improvements

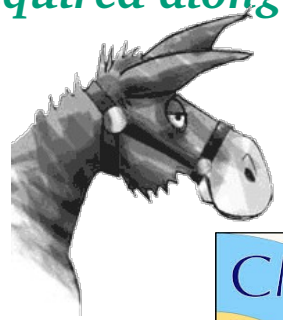
As time went on, the LHC experiments developed their own solutions to go 'on top' of the existing inferstructure to improve efficiency. In particular, Atlas and LHCb developed the following:

Pilot Systems

To avoid the high failure rate of jobs, small 'Pilot' jobs were sent instead that would request work from a central queue only after they were established on a machine.

Experimentally specific File Catalogs and Bookeeping

Organising data is very specific to an experiments need and so different implementations of a File Catalog are required along with particular ways of accessing the information

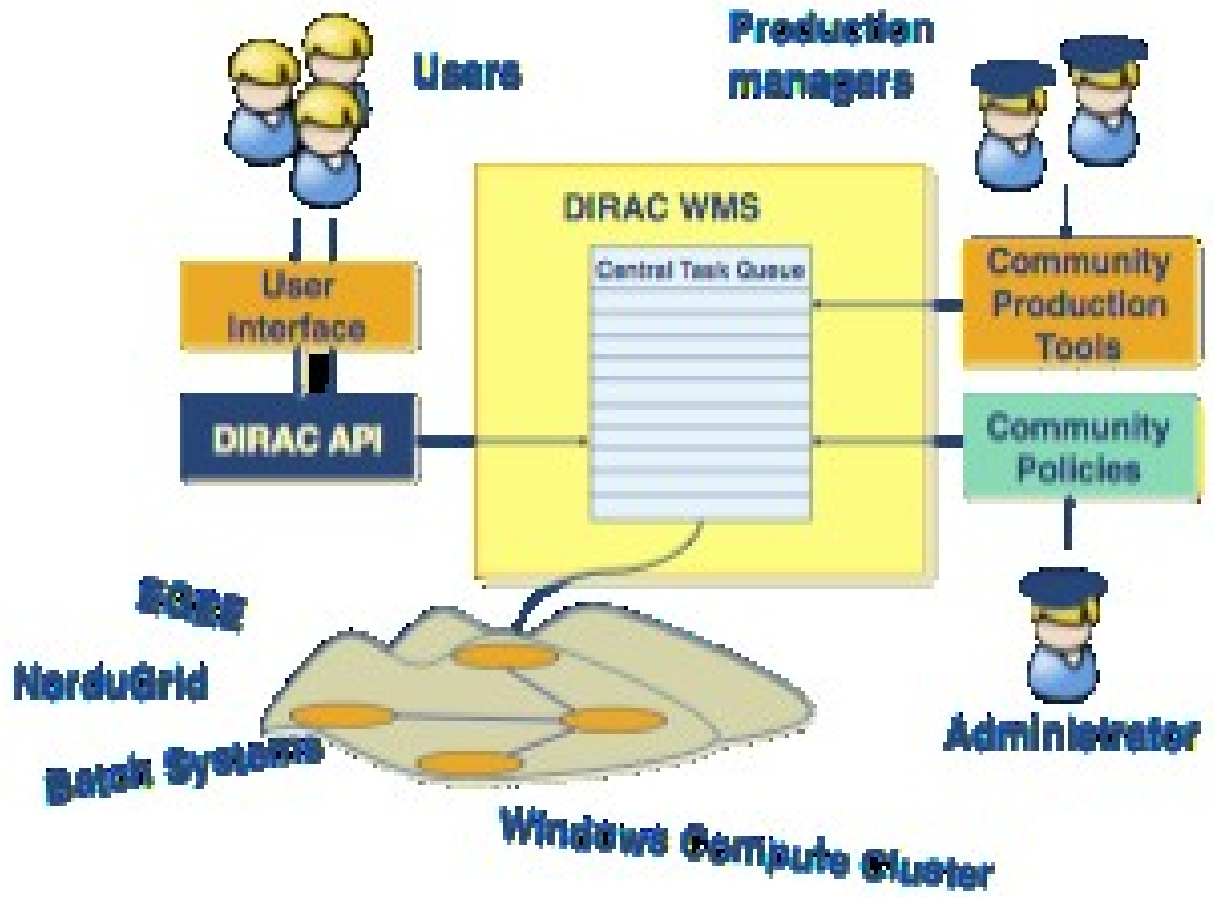


*The difficulty was making these improvements available to the wider community of grid users – **GridPP are now able to offer a DIRAC service with support through Ganga***

An Introduction to DIRAC

DIRAC Overview

DIRAC is Pilot based production management system that is designed to abstract the user from the various implementations of different sets of computing resources and other non-homogenous parts of the Grid



DIRAC Overview

The DIRAC (Distributed Infrastructure with Remote Agent Control) system is build on the idea of interconnecting:

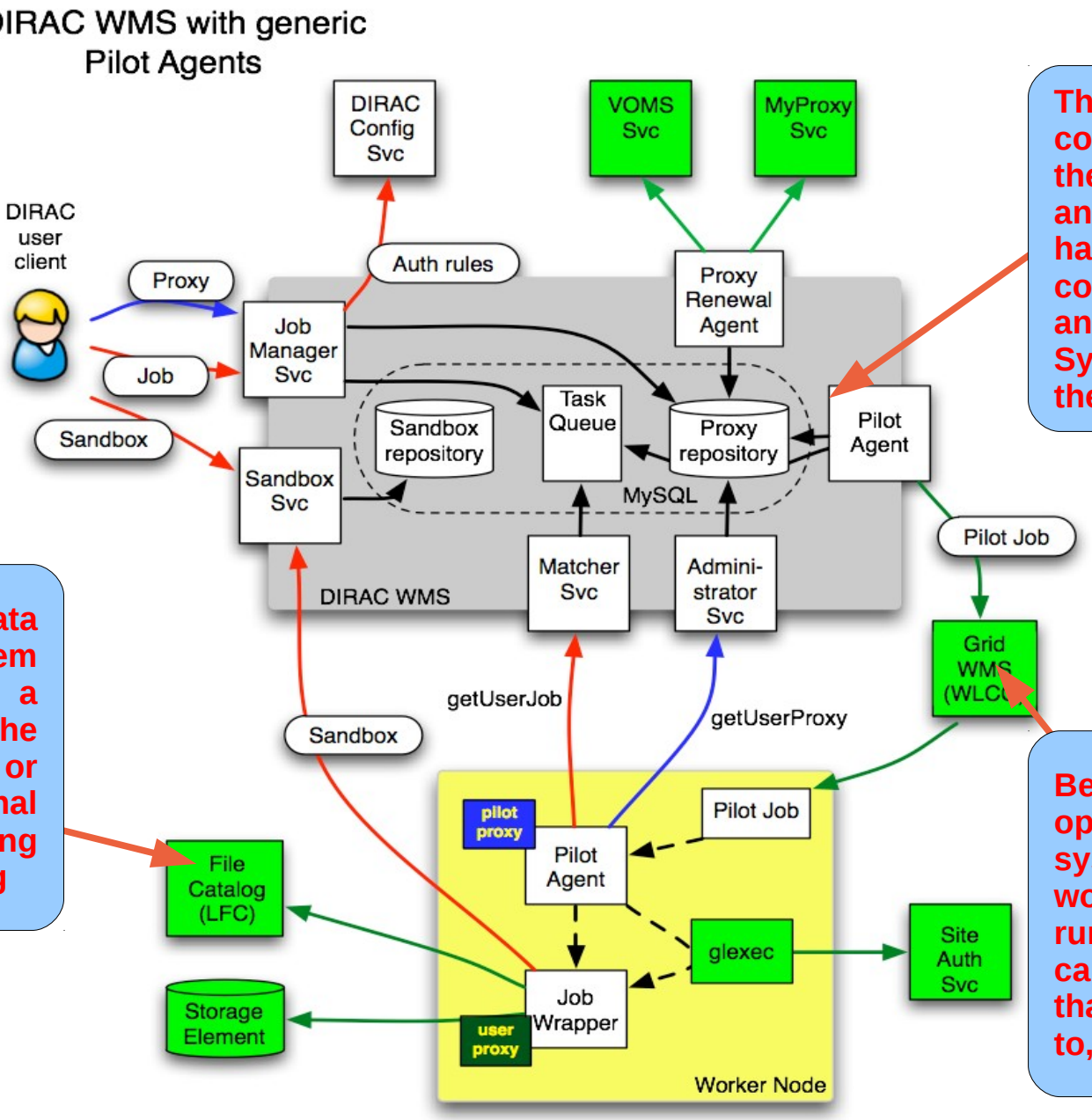
- ***Databases:*** Used to persist the state of a system
- ***Services:*** Passive, listen for reqs and serve/update the database
- ***Agents:*** Active, Periodically performing tasks on the databases

These then combine to form *Systems*.

For example: DIRAC's central Task/Job Queue is the Database, a service shows the status of the task queue and updates it when requested and the Pilot agent queries what tasks are required and sends pilots to perform them at sites

It was designed to replace and improve on the Glite WMS and LFC Data Management systems and offers many advantages to both

DIRAC Overview



The DIRAC WMS contains the 'meat' of the job management and production handling and comprises Request and Transform Systems as well as the main Task Queue

The DIRAC Data Management system can be used as a frontend for the existing LFC or provide additional functionality using it's own File Catalog

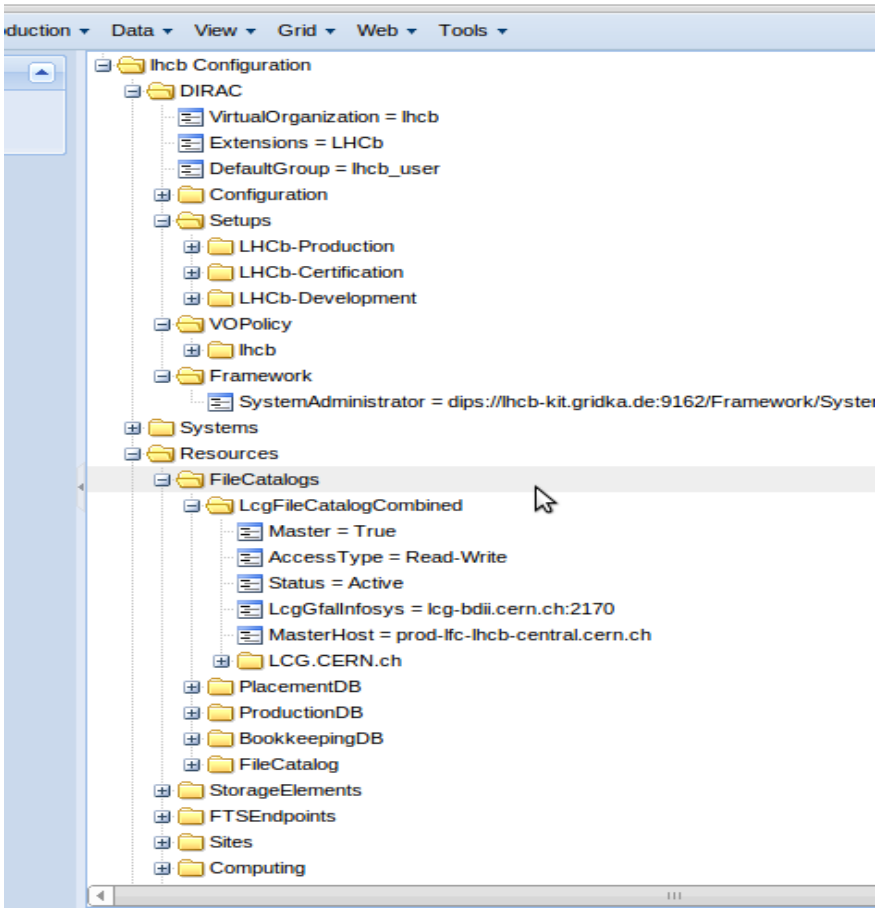
Because DIRAC pilots operate as a 'pull' system – asking for work when they start running – DIRAC jobs can run on anything that the pilots can get to, e.g. Clouds

Configuration System

The configuration system is a (nominally!) static description of resources, variables, etc. that is used by other systems

It is used as a global 'configuration file' with a service controlling the access to the data

```
/Resources/Sites
                /CERN.ch
                ...
                /IN2P3.fr
                        /Domains = EGI, LCG
                        /ContactEmail =
someone@somewhere
                        /MoreDetails =
blah, blah, blah
                        /Computing
                                /...
                        /Storage
                                /...
                /PIC.es
                ...
```



Resource Status System

The Resource Status System (RSS) is the way DIRAC keeps track of the status of sites, storage elements, Catalogs, etc. by working in conjunction with the Configuration Service that holds the definitions of the 'Grid Elements').

In order to have a more fine grained status than ON/OFF, 4 major statuses are possible for each Grid Element: Active, Degraded, Probing, Banned and even have multiple statuses

Monitoring Agents perform regular checks on each type of Grid Element and makes changes to the RSS in response to the policy settings stored in the CS

This allows a VO to set the policy on what constitutes a 'working site/service' (based on some standard tests) and tailor the job and data submissions appropriately

Data Management System

The Data Management System (DMS) together with the Storage Management System (SMS) provides the following:

Upload and manage files on Storage Elements

DIRAC provides an abstraction of the normal SE interfaces to provide access through a single interface, the configuration of each is handled by the Configuration Service

Manage FTS requests

The DMS agents interface with the FTS servers assigned to your VO to manage any FTS requests. After setting the channels up in the CS, retrievals, transfers and removals can all be added to the Task Queue and thus automating the bulk transfer of data

Interface to the LFC

DIRAC can provide it's own File Catalog but it also has an interface to the current LFC (or other FC as required). Through this both users and agents have access to Registrations, replica management, etc.

Cmd Line and Python Interfaces

If you want to interact with DIRAC directly, there are two ways – Command line or Python interface

```
> dirac-wms-job-submit job.jdl
JobID = 11758

> dirac-wms-job-status 11758
JobID=11758 Status=Waiting; MinorStatus=Pilot
Agent Submission; Site=CREAM.CNAF.it;

>  dirac-wms-job-get-output 11702
Job output sandbox retrieved in 11702/
```

The command line tools allow you to submit, (using a JDL config file), get the status and retrieve the output of jobs

There is also a number of useful commands to interact with the Data Management Service

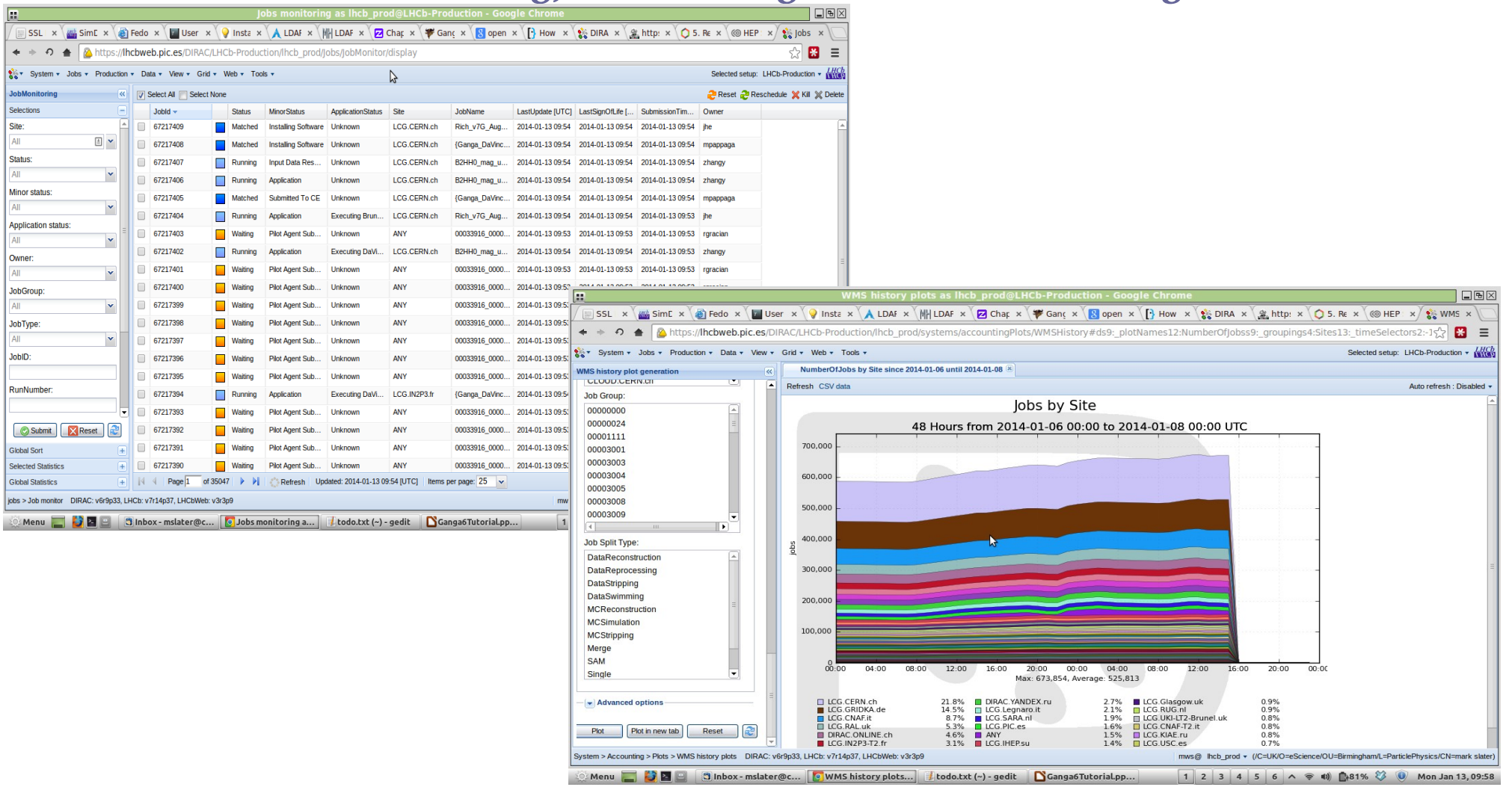
Similar results can be acheived using the DIRAC Python interface

From this, you can setup and submit jobs, manage data, etc. just like the cmd line

```
from DIRAC.Interfaces.API.Job import Job
from DIRAC.Interfaces.API.Dirac import Dirac

dirac = Dirac()
j = Job()

j.setCPUTime(500)
j.setExecutable('/bin/echo hello')
j.setExecutable('/bin/hostname')
j.setExecutable('/bin/echo hello again')
j.setName('API')

jobID = dirac.submit(j)
print 'Submission Result: ',jobID
```

Web Portal

DIRAC provides a fully-featured web portal to handle all aspects of the DIRAC instance from Job Monitoring, Data Management to Accounting



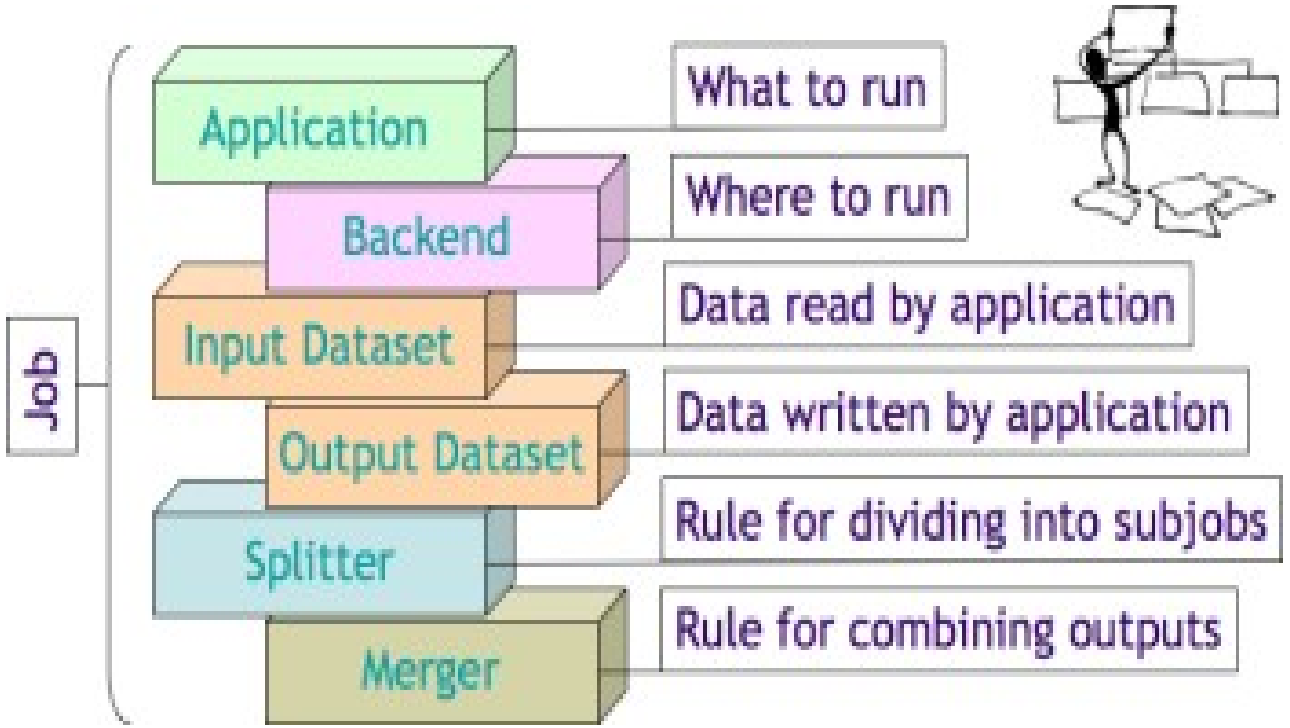
DIRAC Demo

An Introduction to Ganga

Ganga Overview

Ganga is a general job management tool used by many HEP experiments (and beyond) to simplify the submission and monitoring of both local and grid based tasks

It is built on the idea of *independent modules* that perform the various functions required by a typical job



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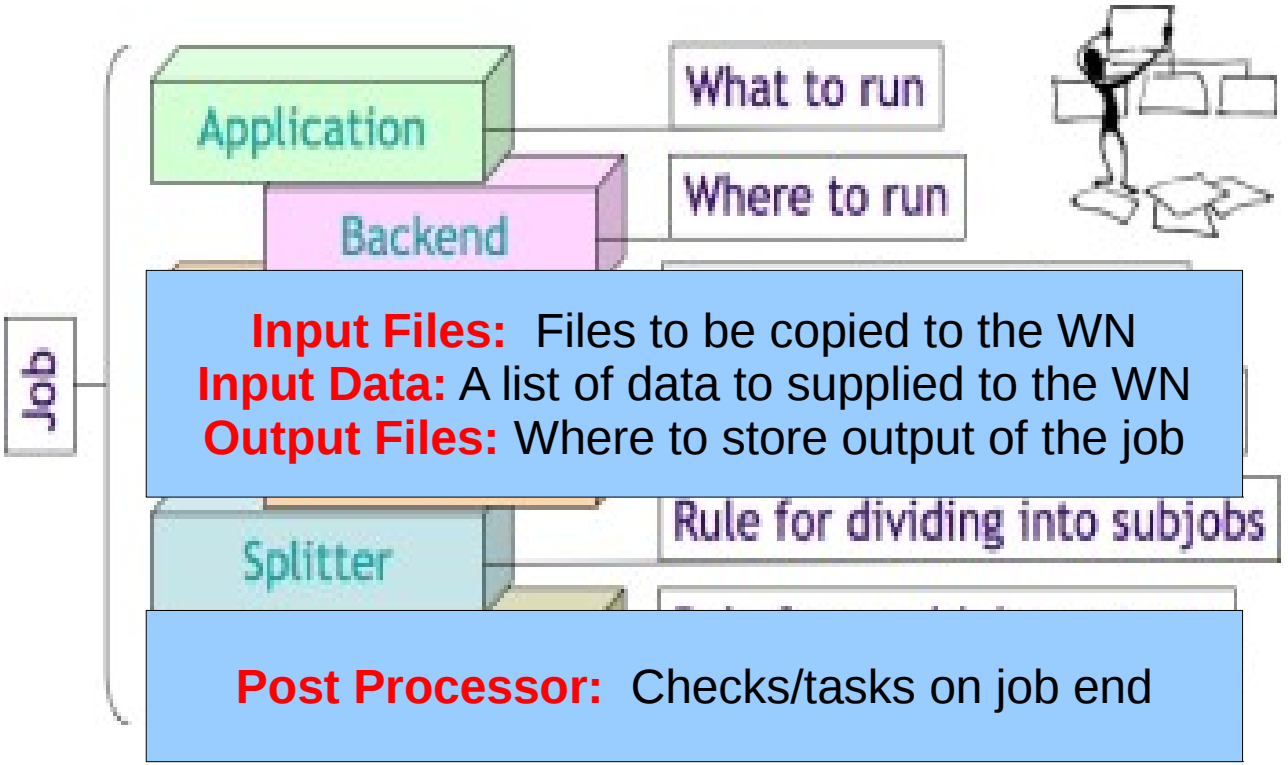


Most users deal with mulitple computing backends – one of the principles of Ganga is to simplify changing from e.g. LSF → Dirac

Benefits of Ganga

There are several reasons why Ganga can help with job submission and management:

- It provides a common 'API' for many different backends
- Multiple ways of submission (command line, IPython, Service, etc)
- Hides much of the complexity for monitoring, etc.
- Easily customisable/expandable to suit the need and situation
- Written in plain python so will work with almost everything
- Active developers on hand to help
- Significantly lowers the barrier to entry for the grid
- Has many advanced features for performing complex tasks

Typical Job Submission

Ganga provides you with interfaces to the application your running (if available) and the backend you're running on. This allow you to completely configure the job and how it's run

```
In [2]:j = Job()

In [3]:j.application = Executable()

In [4]:j.application.exe = File("test.sh")

In [5]:j.outputfiles = LocalFile("out.txt")

In [6]:j.backend = LCG()

In [7]:j.backend.requirements.cputime = 3600

In [8]:j.submit()
```

Start by creating a basic Job object

Set what you want the job to do (run the test.sh script)

What output is this script going to poduce?

Where do you want it to run (the LCG grid in this case) and configure this as you want

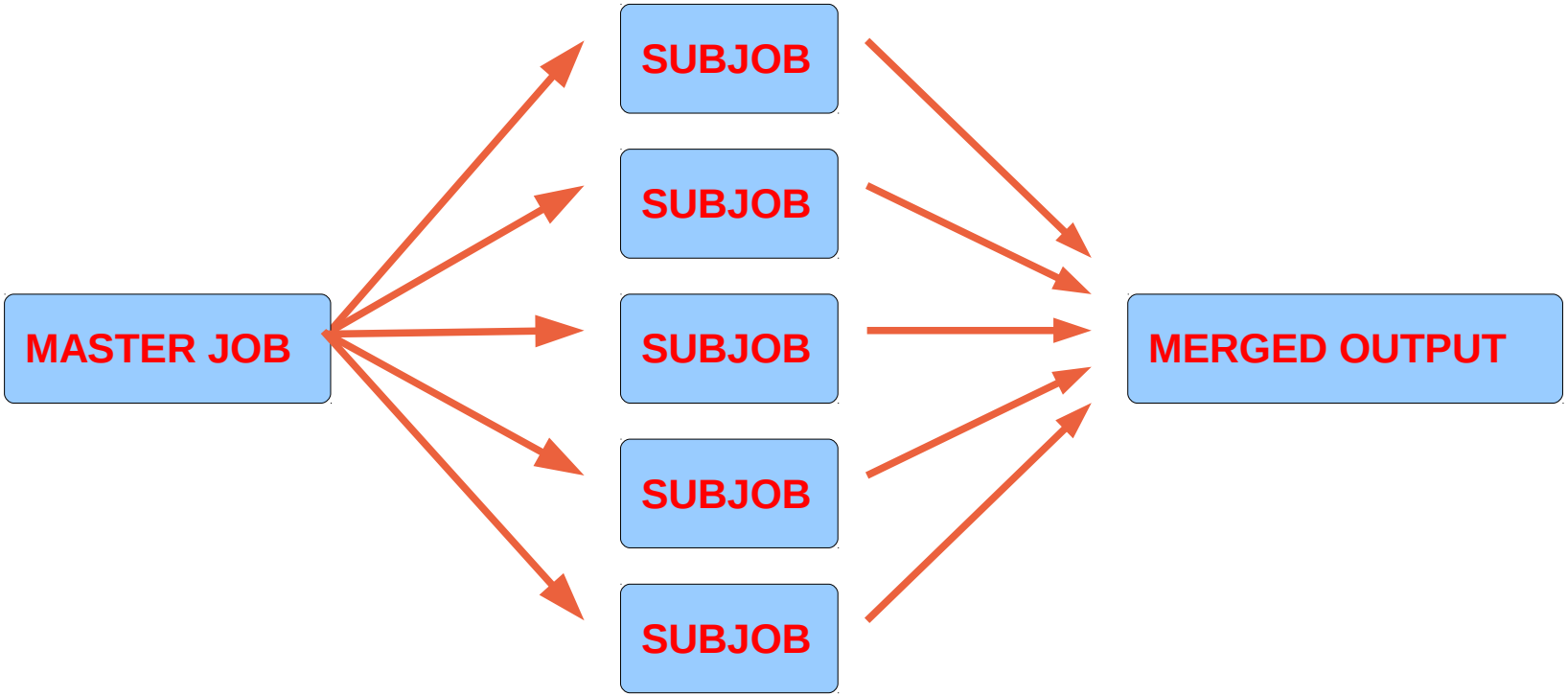
And finally, submit the job!

Splitting and Merging

Where Ganga starts to show some of it's power is through the splitting of jobs – i.e. taking a single job definition and creating a number of subjobs from this 'master' job config

For example, running the same program over a number of input files or running many MC generation jobs with different initial states

In addition to the splitting, Ganga can also merge the output using the 'PostProcessors' field



Supported Plugins

There are a number plugins supplied with Ganga Core outside of the experimentally specific ones for e.g. LHCb and Atlas:

Backends

Local – The computer you're on
PBS – Torque/Slurm style batch system
SGE – Sun Grid Engine
Condor
LCG – Glite WMS Grid
CREAM – Direct CREAM CE
Dirac – The Dirac WMS
ARC – Diract ARC CE

Input/OutputFiles

LocalFile – A Local (direct access) File
DiracFile – File handled by DIRAC DMS
MassStorageFile – e.g. CASTOR
LCGSEFile – Glite/LFC Storage
GoogleFile – Google Drive
CERN Box File – The new Cloud serice

Applications and Splitters

As each individual/VOs needs are going to be very dependent on the software they use and how it can be split, there are only a few generic ones available to run Executable or Root jobs and split any particular parameter of the application

Configuring Ganga

Ganga is incredibly configurable – the behaviour of all Ganga objects, including default values, can be set in three places:

- .gangarc file which lists all avaiable variables and their description
- From the command line by specifying the options when running Ganga
- At runtime with Ganga using the 'config' dictionary style variable

In addition to this, you can also get help on all the Ganga Objects using the help system and (type 'help(<object>)')

A typical IPython tab-complete service is also available for specifying arguments as well as viewing methods/variables of a class

Scripting in Ganga

As Ganga is written in Python and runs through the IPython interface, you have complete flexibility about how you submit and manipulate your jobs

```
# only tar up once – use this for all jobs
a = Athena()
a.prepare()

for dsln in open("ds_input.txt").readlines():

     # assume you have <dsname>  <jobname>
     toks = dsln.strip().split()

     # submit the job over this dataset
     j = Job()
     j.name = toks[1]
     j.application = a
     j.inputdata = DQ2Dataset()
     j.inputdata.dataset = toks[0]
     j.splitter = DQ2JobSplitter()
     j.splitter.numsubjobs = 20
     j.backend = Jedi()
     j.submit()
```

The script to the left loops over an input file containing a dataset names and job names and submits a job for each. Note that the preparation of the Athena area only happens once!

Also, note that Ganga can store 'job templates' as well so reducing the code to 2-3 lines!

The script to the right loops over any completed jobs and retrieves the datasets produced by each

```
# loop over the set of completed jobs and
# grab the datasets
# (could also use jobs.select(status='completed'))

for j in jobs:

     if j.status == 'completed':
          for sj in j.subjobs():
               sj.outputdata.retrieve()

          # could also do:
          # os.system('dq2-get %s' % \
               j.outputdata.datasetname)
```

To run these, do either:

ganga <scriptname> **OR** *execfile('<scriptname>') at the python prompt*

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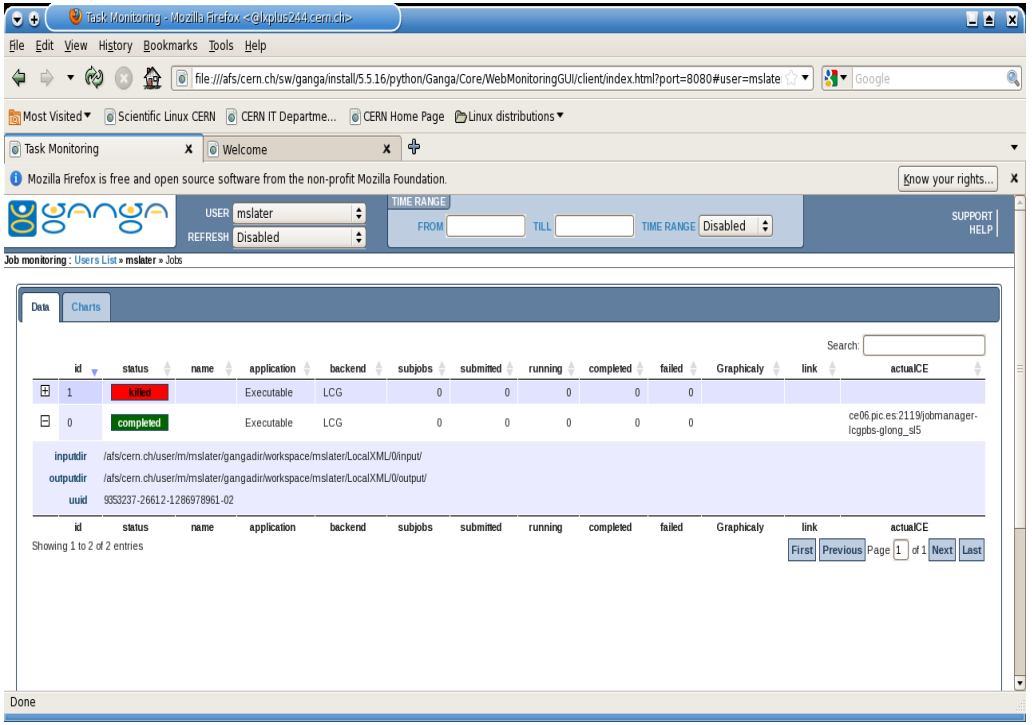
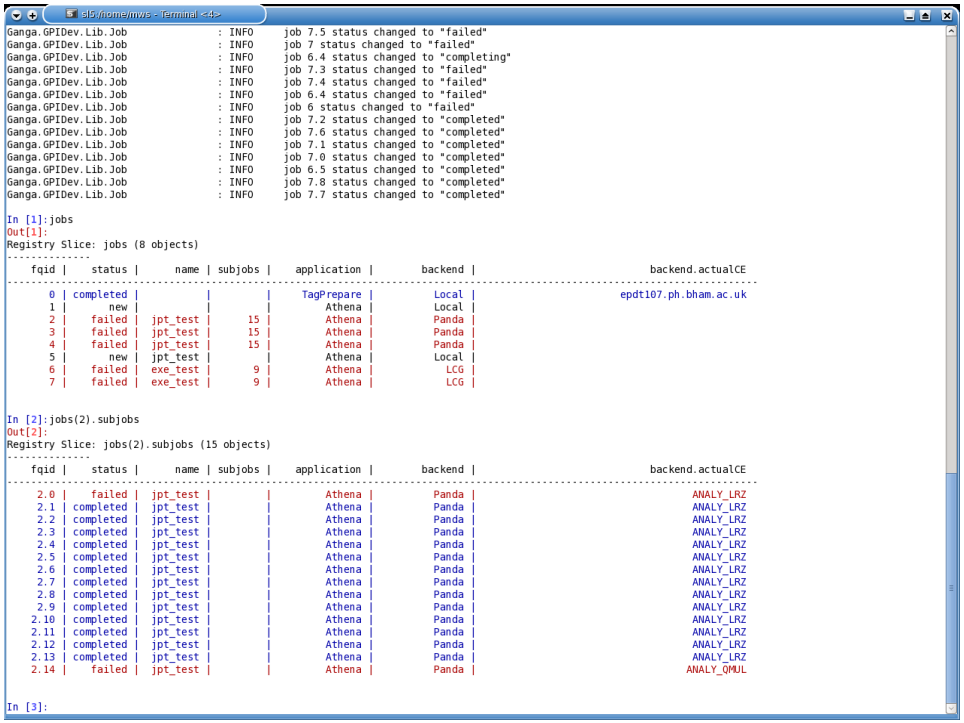
Monitoring Jobs

After submission, you can use Ganga to monitor and manage your jobs using Ganga's IPython interface by just typing 'ganga'

Ganga keeps track of all your jobs over all backends and gives you access to all the information using a local job repository

There is also a web gui available by starting Ganga with the –-webgui option





Ganga Demo

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Advanced Ganga Topics

Durham Seminar, 15th October, 2014

Mark Slater, Birmingham University

GangaTasks

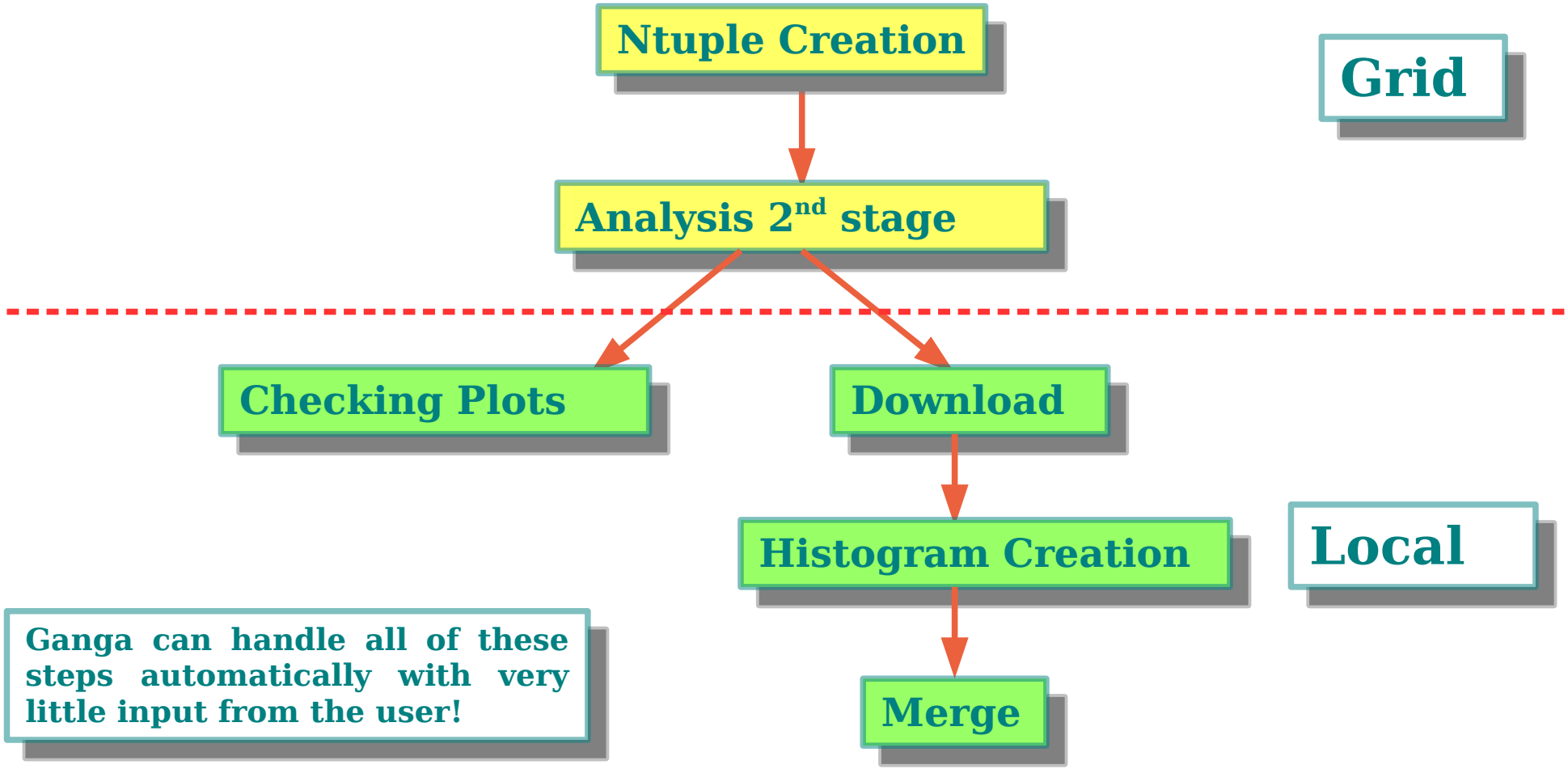
As analyses progress, you will probably encounter scaling problems:

- More failures on both grid and locally
- Keeping track of 100s-1000s of jobs both locally and on the grid
- Having multi-stage analyses across multiple systems

Originally developed for Atlas, Ganga provides a framework to help you handle these issues – Tasks – which will (while Ganga is running):

- Resubmit failed jobs if it seems sensible to do so
- Submit more jobs when others complete
- Monitor and track running jobs, storing output data in appropriate containers
- Automatically retrieve and merge data
- Chain types of jobs together across any backend

Typical Analysis Example



More info on this will soon be up on the Ganga and GridPP Twiki!

Queues/Thread Control

A number of jobs in Ganga can take some time, e.g. job submission, output download, etc. and quite often, these happen synchronously and hold up the user.

A similar problem existed in monitoring in that, even though jobs could in theory be monitored in parallel, this wasn't possible given the previous implementation

To get around this, a thread pool was created to handle system and user generated 'Ganga-aware' threads that:

- Execute commands asynchronously
- Allow tasks that can be carried out independently to be done so
- Balance performance issues by limiting the no. of concurrent threads

Queues/Thread Control

Viewing the status of the queues:

```
In [4]:queues
Out[4]:
                Ganga user threads:                  |            Ganga monitoring threads:
                -------------------                  |             ------------------------
Name       Command                        Timeout    | Name       Command                        Timeout
----       -------                        -------    | ----       -------                        -------
Worker_0   idle                           N/A        | Worker_0   idle                           N/A
Worker_1   idle                           N/A        | Worker_1   idle                           N/A
Worker_2   idle                           N/A        | Worker_2   idle                           N/A
Worker_3   idle                           N/A        | Worker_3   idle                           N/A
Worker_4   idle                           N/A        | Worker_4   idle                           N/A

Ganga user queue:
----------------
[]
Ganga monitoring queue:
----------------------
[]
```

Adding function calls to the queue:

```
In [3]:queues.add(j.remove)

In [4]:Ganga.GPIDev.Lib.Job                : INFO     removing job 8
```

```
In [5]:def f(x):
   ...:     print x
   ...:

In [6]:queues.add(f, args=(123,))

In [7]:123
```

Named Templates

Ganga already provides a Template system for storing often used job descriptions. As an aid to the user, we have extended this to allow these templates to be named and included in a Ganga release

This allows documentation to simply say: Use template 'Basic Analysis' and change X and Y values

This also now includes everything that can be put in the Ganga Box (the storage area for Ganga Objects), e.g. “Use Backend template 'LCG setup 1' and it should work.”

These will start to be included in GangaCore to go along with the GridPP User Guides

Input/Output Files

The Input/Output File system is very powerful and can be used to include and send files to and from all sorts of systems:

```
In [1]:j=Job()

In [2]:

In [2]:j.outputfiles = [ SandboxFile('BdKsMuMu.root'), DiracFile('Stripped.Dimuon.dst') ]

In [3]:j.outputfiles
Out[3]: [SandboxFile (
 namePattern = 'BdKsMuMu.root' ,
 compressed = False ,
 localDir = ''
 ), DiracFile (
 namePattern = 'Stripped.Dimuon.dst' ,
 guid = '' ,
 compressed = False ,
 localDir = None ,
 lfn = '' ,
 failureReason = '' ,
 locations = []
 )]

In [4]:j.submit()
```

A DiracFile will copy the output to to Dirac storage and can be downloaded using the 'get' method on job completion

A LocalFile (NOT SandboxFile!) has been declared that will be copied back to the local machine

Post-Processors

Previously, it was only possible for a user to specify the type of Merger they wanted to be performed on a job after completion

We have now extended this to include 3 types of post processor (but with the option to extend to arbitrary objects):

- Mergers
- Checkers
- Notifiers

Serveral types of these objects are already available, e.g. LHCbFileMerger, FileChecker, EmailNotifier

These are added to the new postprocessor job attribute that replaces the merger attribute. This is a list and so you can have as many as you want operate on one job

Post-Processors

A Custom Merger is also provided so you can execute any arbitrary code at job completion

Simply provide a python file with a check function that returns a bool:

```
import ROOT
import os

def check(job):
    outputfile = os.path.join( job.outputdir, 'BdKsMuMu.root' )
    if not os.path.exists( outputfile ): return False
    if os.path.getsize( outputfile ) <= 100: return False

    tfile = ROOT.TFile( outputfile )
    tree = tfile.Get( 'Jpsi_Tuple/DecayTree' )
    return tree.GetEntries() >= int( job.events['input'] )
```

```
In [5]:cc = CustomChecker()

In [6]:cc.module = './checker.py'

In [7]:cc.checkSubjobs = True

In [8]:j.postprocessors.append( cc )
```

It is also relatively simle to create your own from scratch!

Ganga Service

The GangaService was developed to fill more production roles with Ganga or when long term submissions, etc. need to be run

It behaves as you would expect a service to behave. It can:

- Run Ganga as a daemon
- Access a running Ganga instance using a simple API

A typical use of the GangaService is shown:

```
from GangaService.Lib.ServiceAPI.ServiceAPI import
GangaService

gs = GangaService()
gs.gangadir = "/home/mws/TaskTest/gangadir-server"
gs.prerun = "export GANGA_CONFIG_PATH='GangaAtlas/Atlas.ini'"
gs.gangacmd = "/home/mws/Ganga/install/6.0.21-
hotfix2/bin/ganga"

print gs.sendCmd("""
j = Job()
j.submit()
""")

gs.killServer()
```

Import the API

Setup how you want the Ganga service to run

Send the commands as if you were in IPython. The returned string is stoud/err

Future Credential System

The current credential system is having a compete overhaul in the near future to provide:

- Multiple local and backend credentials handled (not just grid and AFS)
- Easy runtime management of required credentials
- Credential dependent submission/monitoring

This is in beta and should be available by the end of the year

```
# examine startup creds
for c in CredentialStore.getCredentials():
     print c.identity()
     print c.timeleft()

# create a new credential
c = VomsProxy( role = “..”, proxy_path = “..” )
c.renew()


# submit job with a particular cred
j = Job()
j.credentials = [ AFSToken(), c ]
j.submit()


# Define default credentials in .gangarc:
DefaultCredentials = { {'AFSToken' : {'Backend':'LCG','Application':'Athena'},
 {'UID/Type' : {'Backend':'Westgrid', 'Application':'Athena'} }
```

Plugin Development

One of the main advantages with Ganga is that you can relatively easily develop plugins to handle the specifics of certain elements of your use case

Any plugin type can be added, however the most usual are:

Applications

These usually prvoide a set of parameters that map to the specific program to be run and perform some checks to make sure they are sensible

Splitters

These can be dependant on how you want to split up a master job into smaller subjobs, e.g. by input files or parameters and can therefore provide a simpler interface than the generic splitter provided

If these plugins are designed correctly, they will fit seamlessly into the Ganga framework and will be able to take advantage of all the other functionality

Note that though it is relatively easy to develop plugins for Ganga, it's recommended to get in touch with the developers to get some guidance!

'Quickstart' Guide

Getting on the Grid

To get going on the grid, you need a Grid Certifcate and be a member of a VO:

Getting a Grid Certificate:

http://ngs.ac.uk/ukca/certificates

Follow the link to 'Apply for a new certificate' and go through the instructions.

Becoming a member of a VO:

https://www.gridpp.ac.uk/wiki/GridPP_approved_VOs#Approved_EGI_VOs

http://www.phenogrid.dur.ac.uk/

This depends very much on the VO but for IPPP, the Pheno VO is what you want!

You should now have a valid grid certifcate in yuor browser that is ergistered with a VO!

First Steps with DIRAC

Now you'll want to try to submit jobs. It's recommended to move straight to DIRAC so please use these links to get you started

Sign up to the DIRAC instance by emailing and giving your VO:

janusz.martyniak<AT>imperial.ac.uk

Export your Cert to your login machine:

```
< Export your certificate from your browser as *.p12 >
> mkdir ~/.globus
> cd ~/.globus
> mv ~/grid.p12 .
> openssl pkcs12 -in grid.p12 -clcerts -nokeys -out usercert.pem
> openssl pkcs12 -in grid.p12 -nocerts -out userkey.pem
> chmod 400 userkey.pem
> chmod 600 usercert.pem
```

Install and test the DIRAC Client:

https://www.gridpp.ac.uk/wiki/Quick_Guide_to_Dirac

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First Steps with Ganga

Install Ganga using these instructions (if there is no 'global' version):

http://ganga.web.cern.ch/ganga/user/installation/other.php

When running for the first time:

Before running Ganga, setup DIRAC and run `'env > /my/dirac/envfile'`

Run ganga with the '-g' flag to create a .gangrc file

Edit this file and set `'[Configuration]RUNTIME_PATH=GangaDirac'`

```
'[Dirac]DiracEnvFile=/my/dirac/envfile'
'[defaults_GridCommand]info=dirac-proxy-info'
'[defaults_GridCommand]init = dirac-proxy-init -g gridpp_user'
```

When running Ganga after that, Always have the DIRAC environment setup!

There will be an in-depth Twiki appearing at:

https://www.gridpp.ac.uk/wiki/Guide_to_Ganga

You can always get help at:

project-ganga<AT>cern.ch OR project-ganga-developers<AT>cern.ch

Or emailing me: mws@hep.ph.bham.ac.uk