Paris Calibration Procedures

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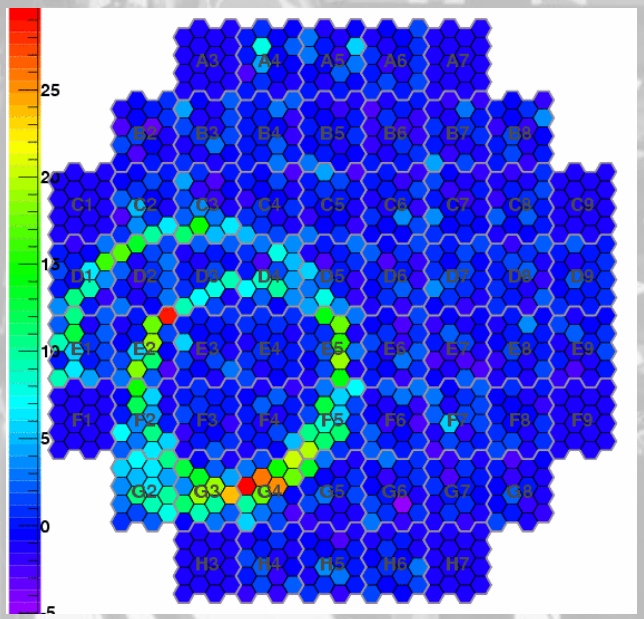
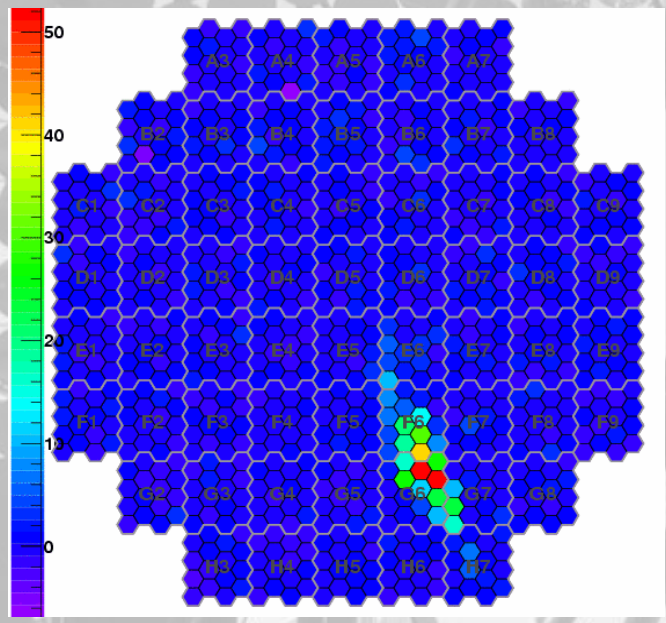
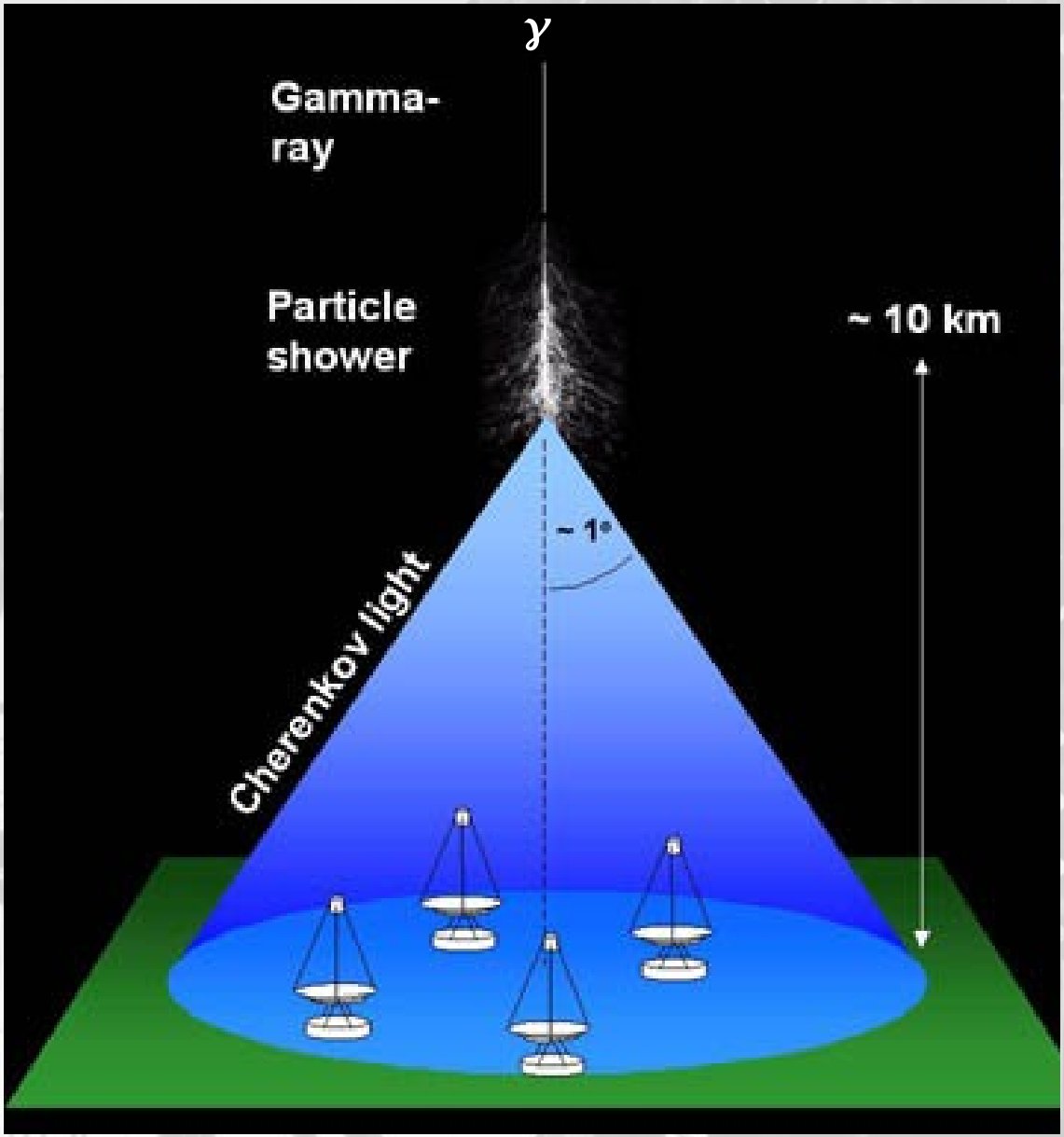


Muons



Gamma-like

Calibration principles



Atmosphere:
- Shower development
- Cherenkov light yield
- Absorption

Instrument:
- Photon detection efficiency
- Charge conversion

Calibration coefficients

Cerenkov light

↑ **FlatField**

↑ **Optical Efficiency**

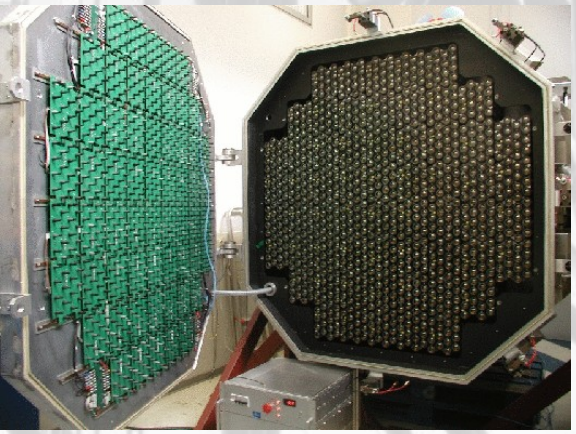
Collected photoelectrons

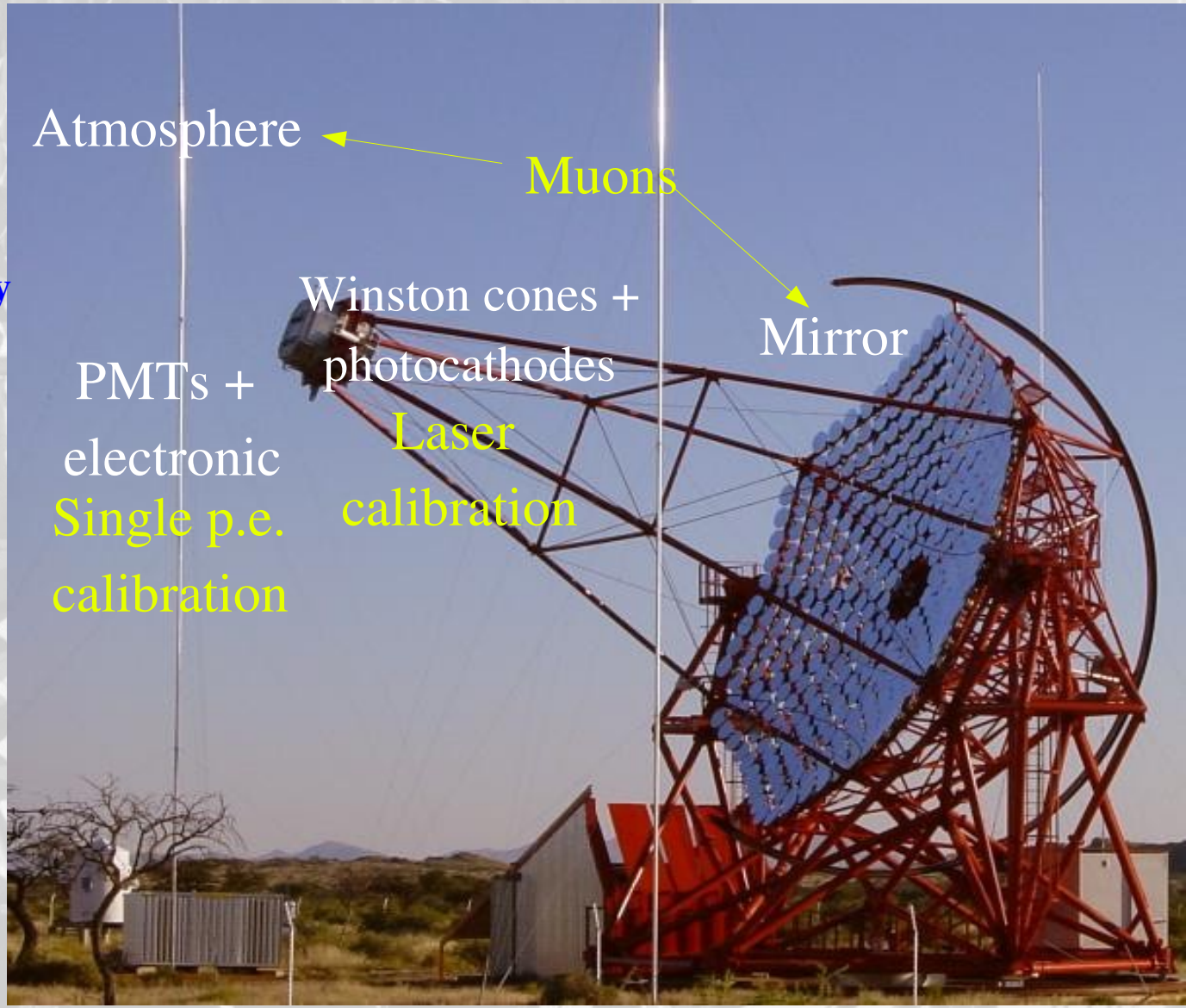
↑ **Pedestals**

↑ **Gains**

↑ **High/Low ratio**

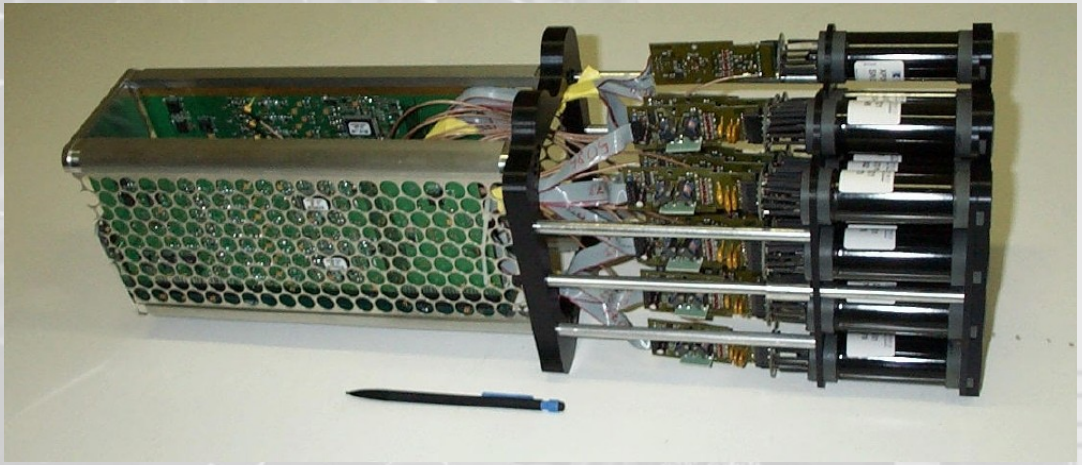
Collected charge



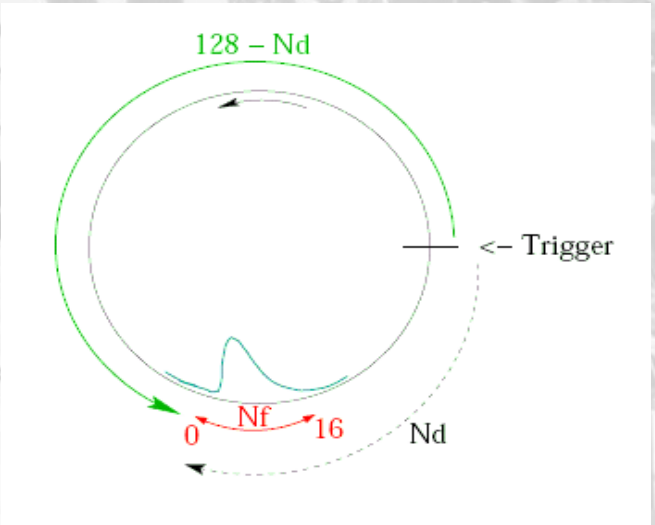


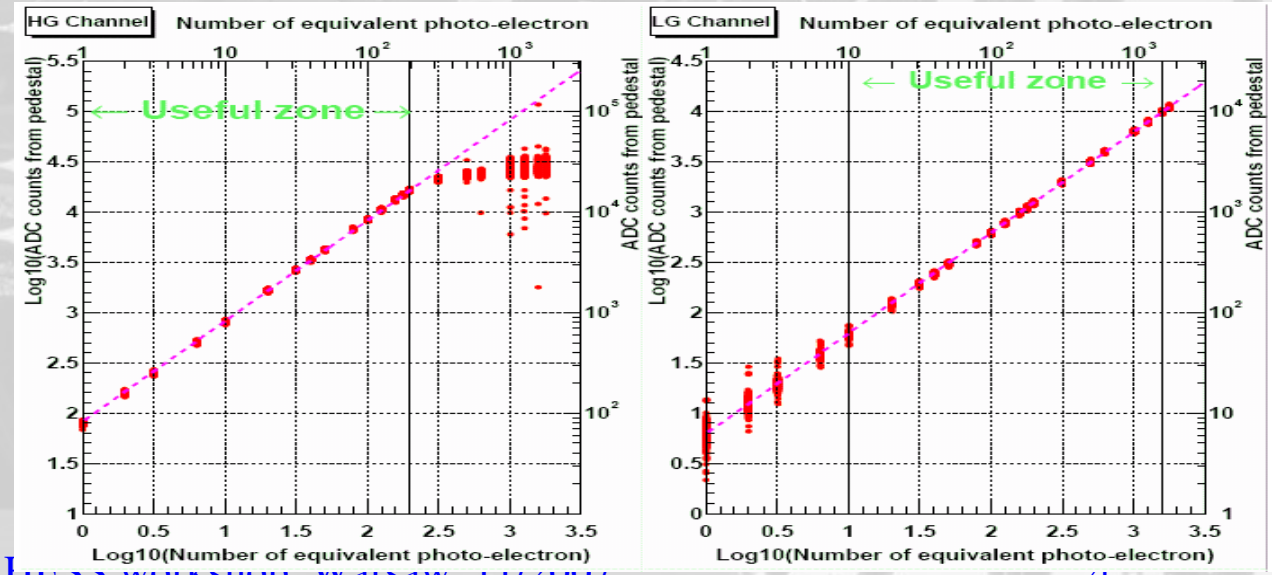
H.E.S.S. drawer electronics

- *H.E.S.S. drawer electronics comprises*
  - *16 photomultipliers*
  - *Actives bases (HV control and readout)*
  - *Control, trigger and readout electronics*



- *Readout electronics*
  - *Based on "Ring Analog Memories" (ARS)*
  - *Two gains: High gain (0 – 200 pe) and low gain (=> 2000 pe)*





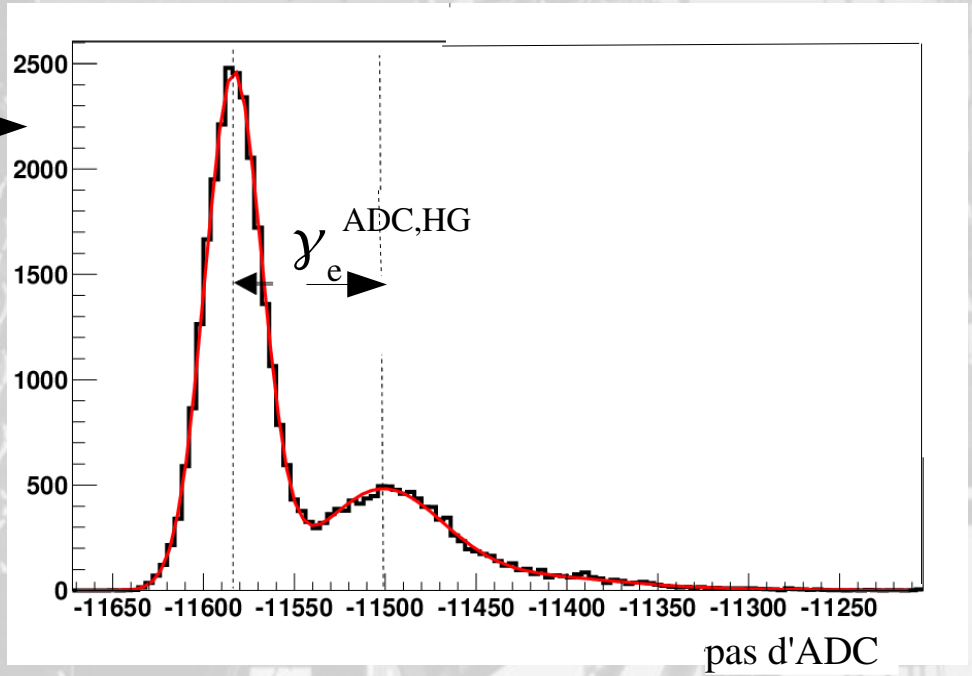
Calibration Coefficients

Signal Amplitude:

High Gain channel $A^{HG} = \frac{ADC^{HG} - P^{HG}}{\gamma_e^{ADC,HG}} \times FF$

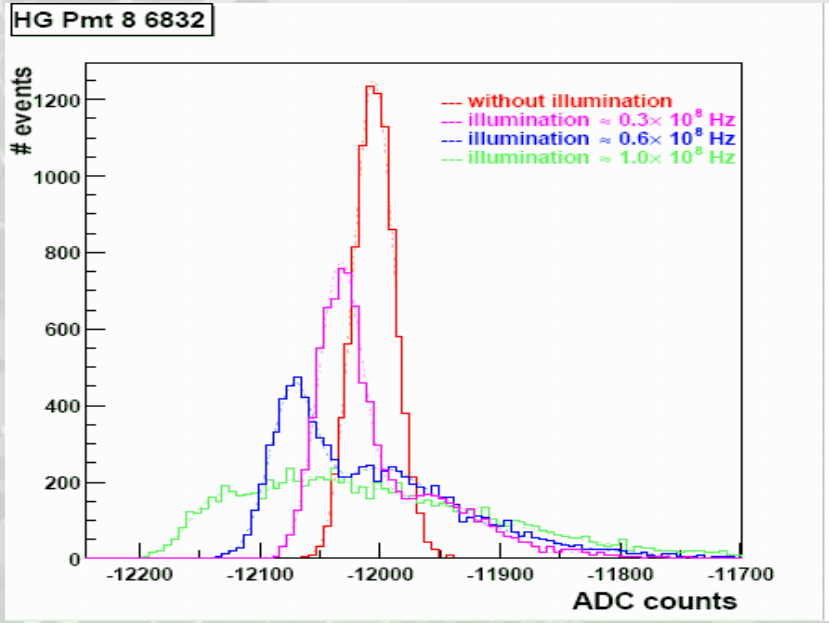
Low Gain channel $A^{BG} = \frac{ADC^{BG} - P^{BG}}{\gamma_e^{ADC,HG}} \times (HG/BG) \times FF$

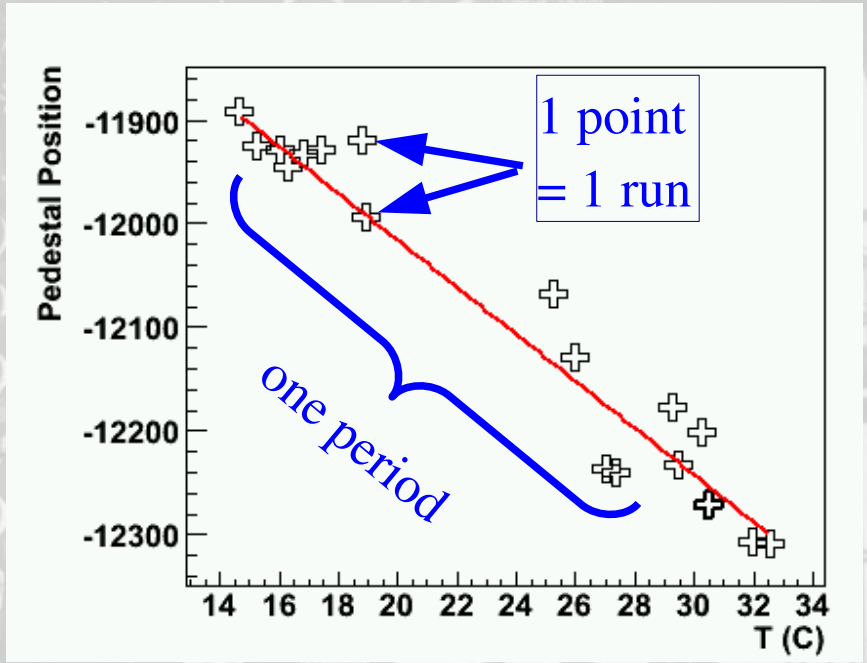
- *Pedestals* P^{HG} *et* P^{LG}
- *Photomultiplier + Electronic Gain* $\gamma_e^{ADC,HG}$
- *Ratio High/Low gain*
- *Floatfielding corrections FF*
- *"Broken" pixels (<5%)*



Pedestals

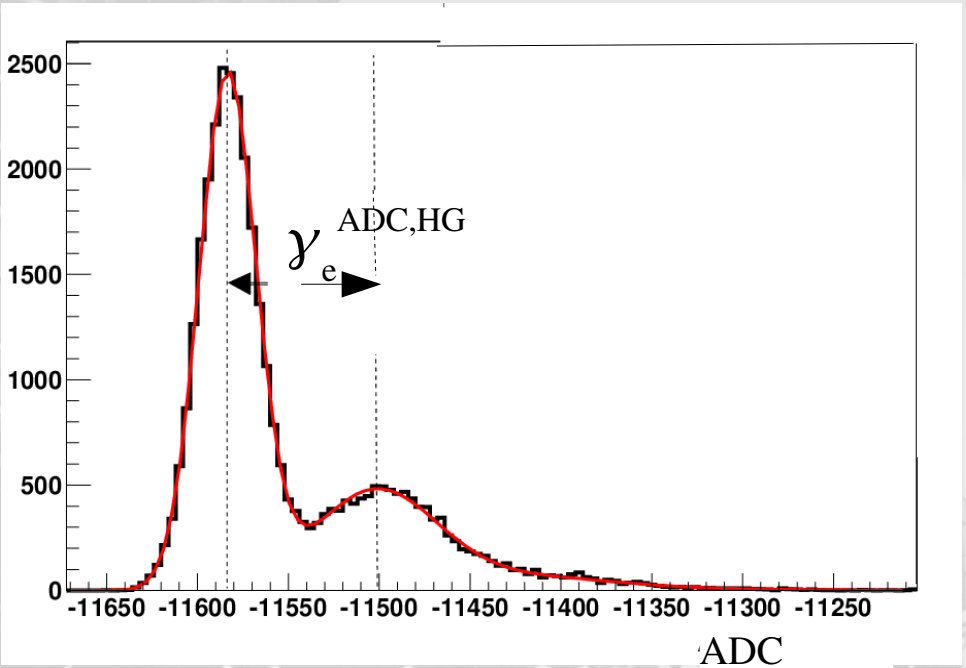
- *Shape of pedestal (charge distribution in absence of signal) depends on:*
  - *Level of night sky background*
  - *Temperature*
- *Relation between pedestal position and temperature calibrated using dedicated runs (dark pedestals, lid closed)*
  - *Runs of ~ 2mn done every 2-3 nights in Namibia*
  - *Analysis done on site, results written to database in Paris*
  - *Merging (for getting the slope) done offline in Paris*
- *Pedestal in real data estimated every 2mn (stored in ROOT files)*
  - *Done offline, in Lyon*

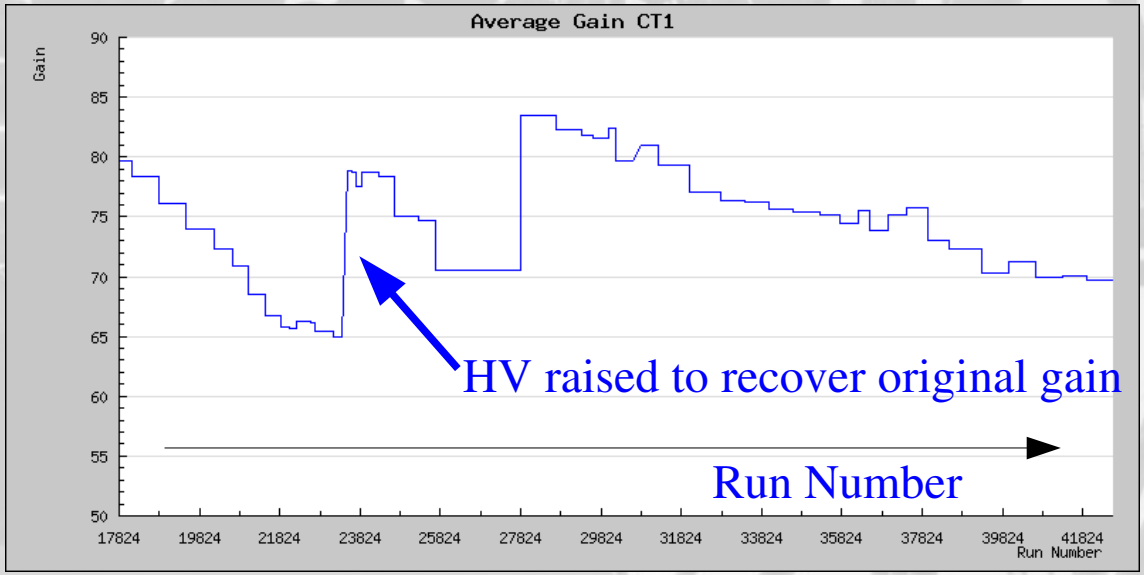




Photomultiplier Gains

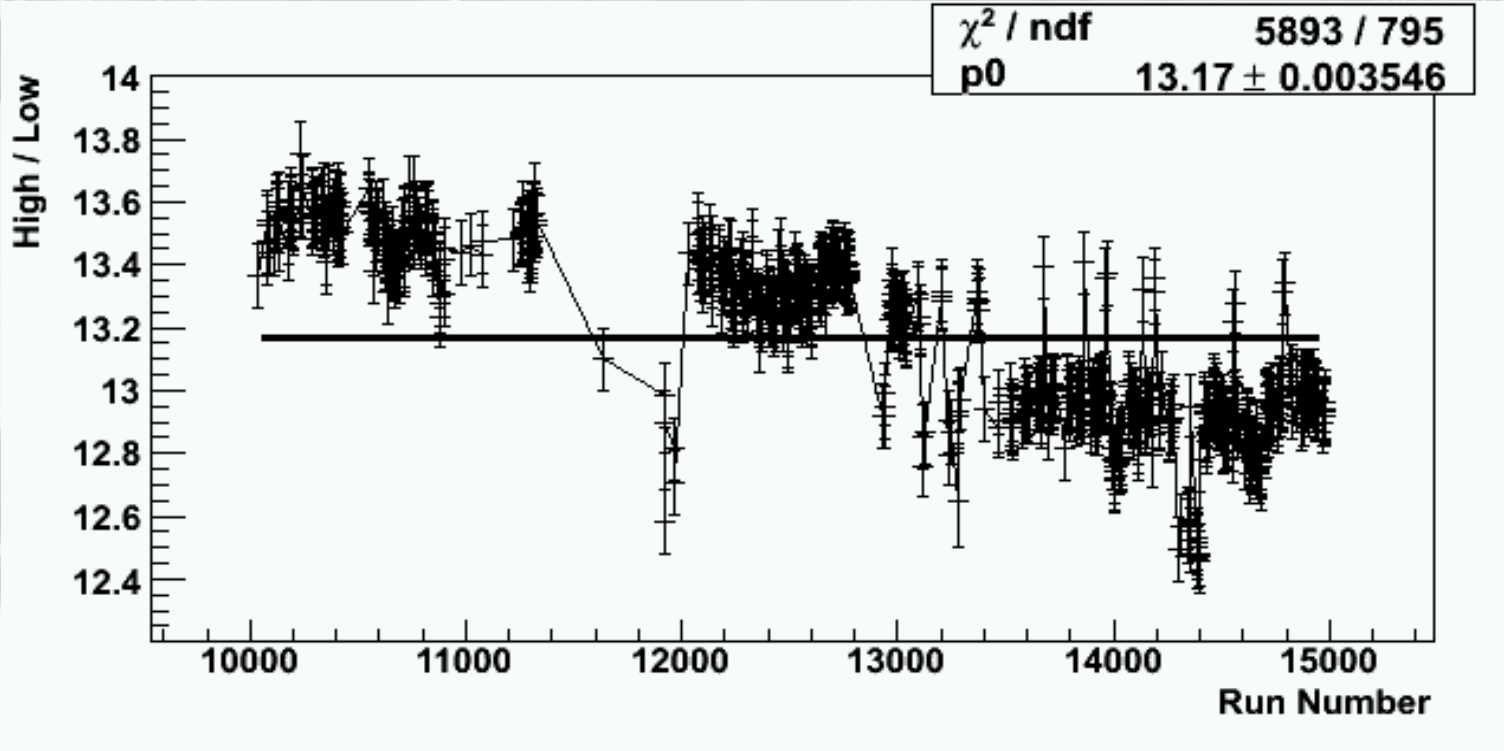
- *Dedicated runs in Namibia*
  - *Low illumination LED flashing in front of camera and triggering the camera*
  - *LID opened*
  - *Shelter closed, no moon (dark)*
  - *Analysis done on site, coefficients written to database in Paris*
  - *Merging per period done offline in Paris*
- *Gain evolution*
  - *Gain decrease with PMT aging*
  - *HV periodically raised to recover original gain (80 ADC / pe)*





High/Low ratio

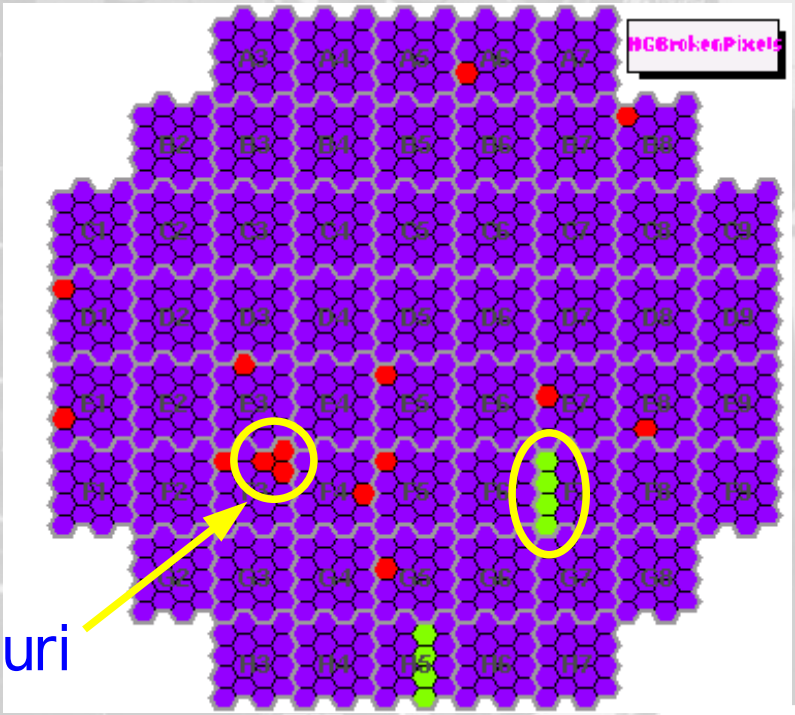
- *Calibrate the relative electronic gains of High versus Low gain channels*
- *Done offline (in Lyon)*
  - *Using real data (pixels with signal in the transition region ~ 20 => 200 pe)*
  - *After pedestal estimation*



Broken Pixels

- *Some pixels need to be excluded*
  - *HV Off (switched off in advance to avoid damage by stars,...),*
  - *PMTs without signal*
  - *HV Unstable (supply problem)*
  - *Stars, highly illuminated pixels*
  - *Analogue Ring Sampler chip not synchronised,*
  - *...*

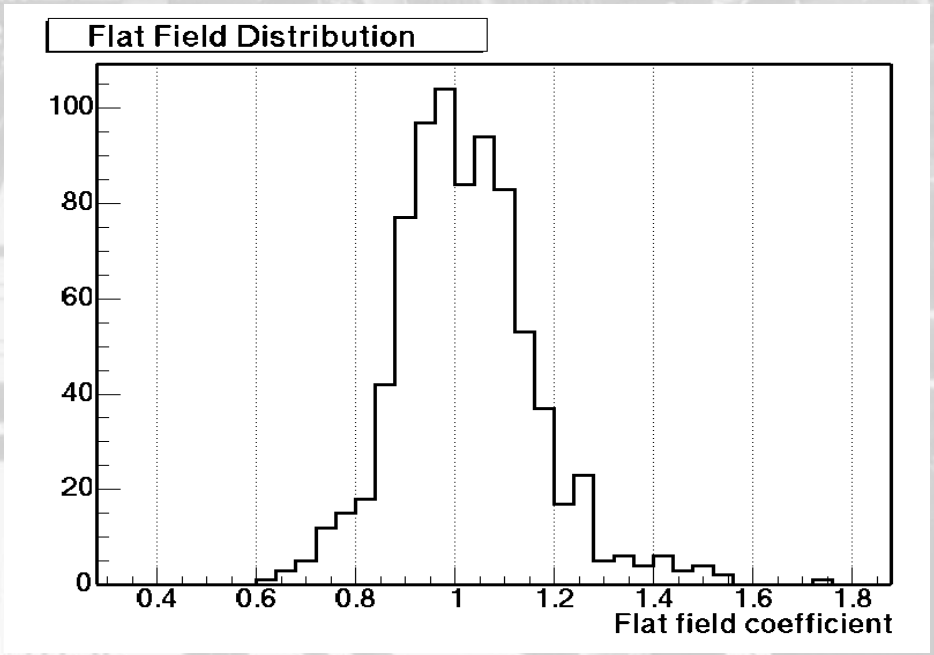
- *~ 4% of the pixels per run are excluded*
- *Done offline, in Lyon*
- *Broken pixels stored in ROOT files (one per run),*
- *List of broken pixel changing during the run*



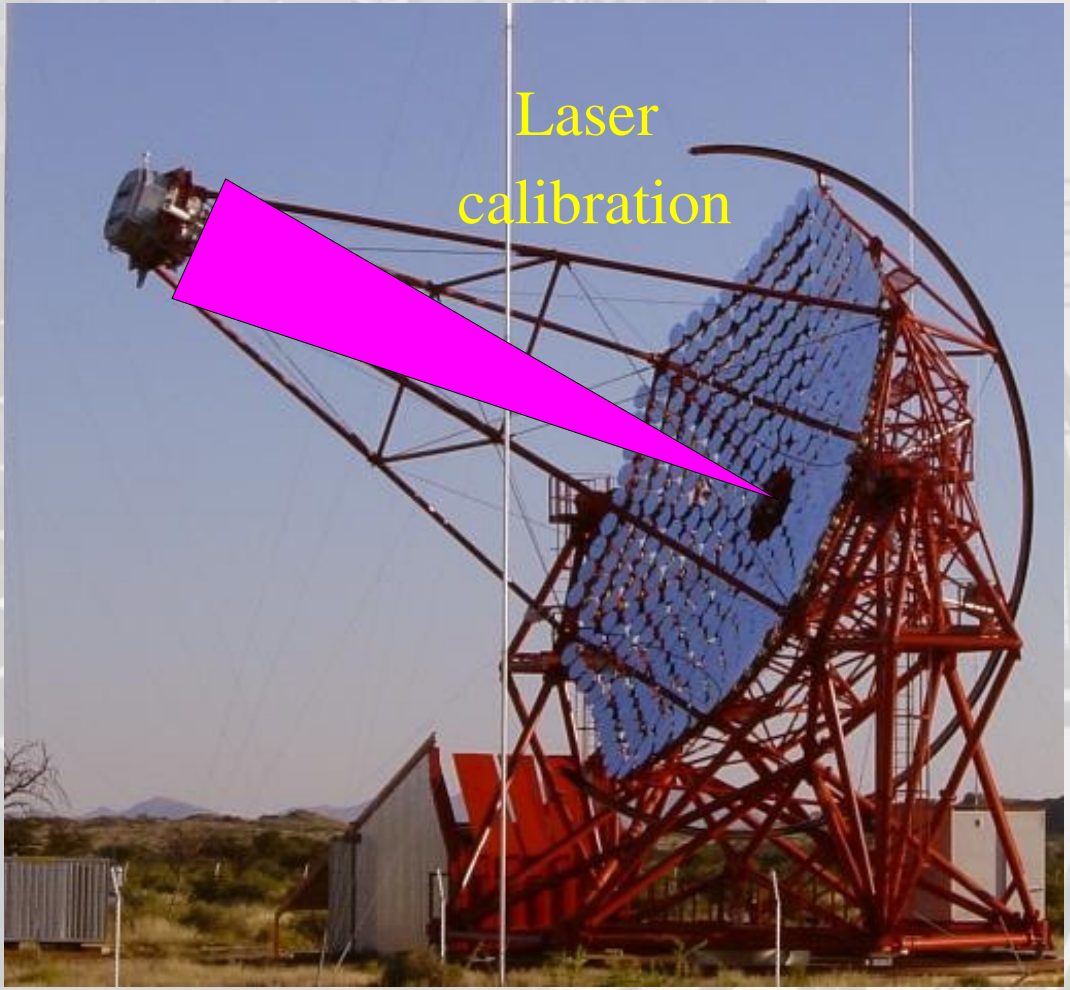
Analogue Ring Sampling chip not synchronised

FlatFielding

- *Make the response of the camera uniform*
  - *Dedicated runs in Namibia*
  - *Using a UV laser or a pulsed LED at the centre of the mirror (~15% relative variations)*
  - *Analysis done offline (needs other calibration coefficients)*
  - *Merged by period*

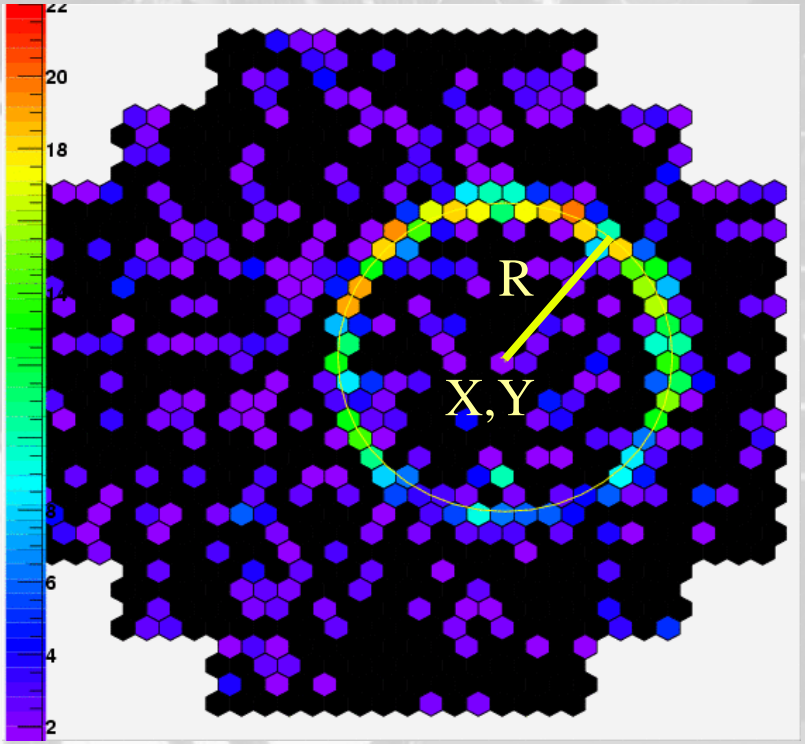


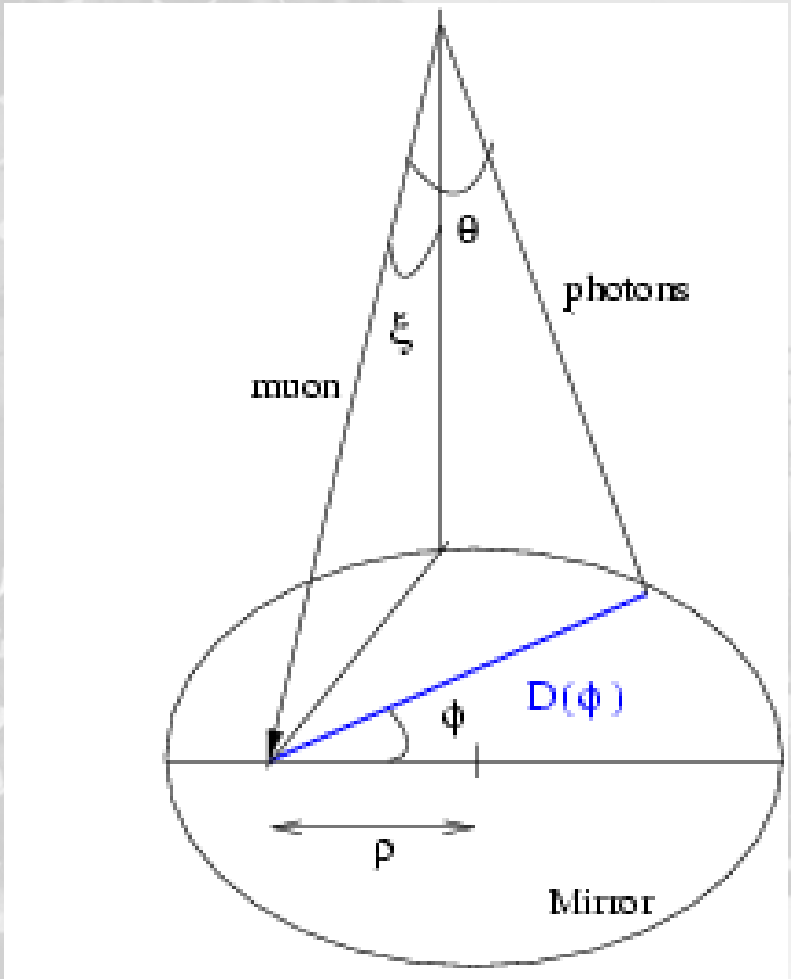
Flat-Field coefficients



Optical Efficiency calibration using Muons from hadronic showers

- *Cherenkov emission of a single particle, going through the whole detector*
  - *Easily calculable*
  - *Amount of light depends on atmosphere refractive index and detector optical efficiency*
  - *Provide a direct way of measuring light yield × optical efficiency,*
  - *Provide validation of detector simulation*

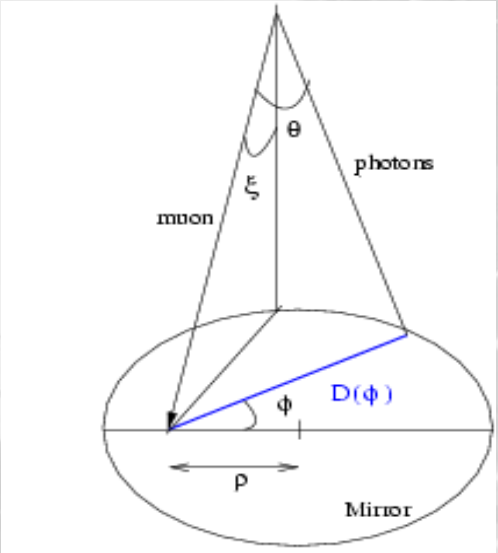


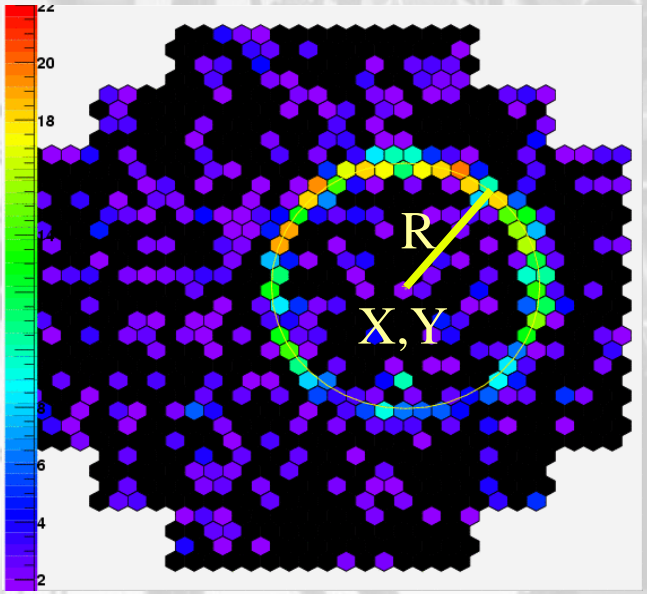


Geometry of Cherenkov emission from a muon

- Use only complete ring in the camera (~1Hz)

falling in the mirror





x,y : ring centre in the camera

R : ring radius

Simple geometrical fit

ε : total collection efficiency

ρ : impact parameter

σ : ring width

φ_{max} : azimuth of the maximum in intensity

Cherenkov emission

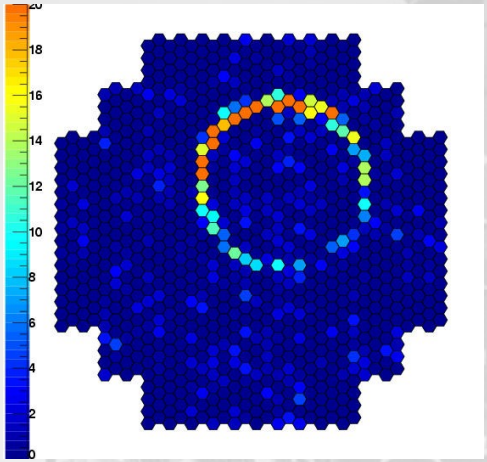
θ_c is the Cherenkov angle,
i.e., the ring radius in the camera

ε is the conversion factor
between p.e. and photons

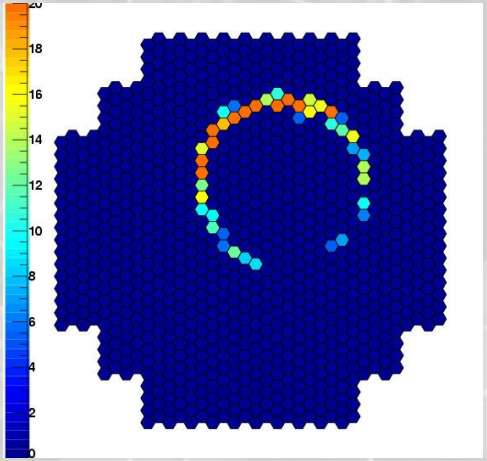
For each pixel, we determine ε from

$$I(\phi) \propto \sin(2\theta_c) D(\phi) \epsilon$$

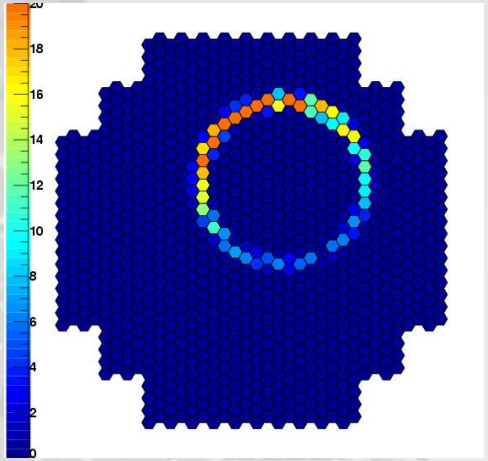
Reconstruction performances



raw data

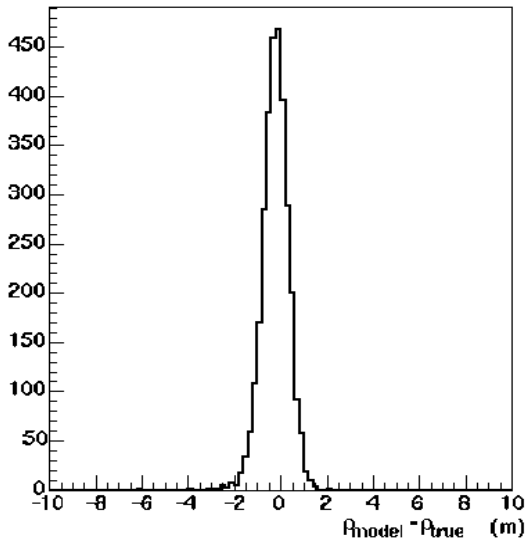


cleaned data

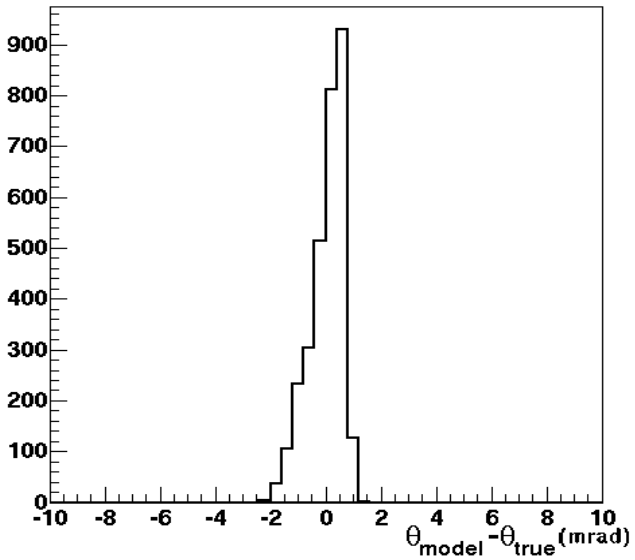


model

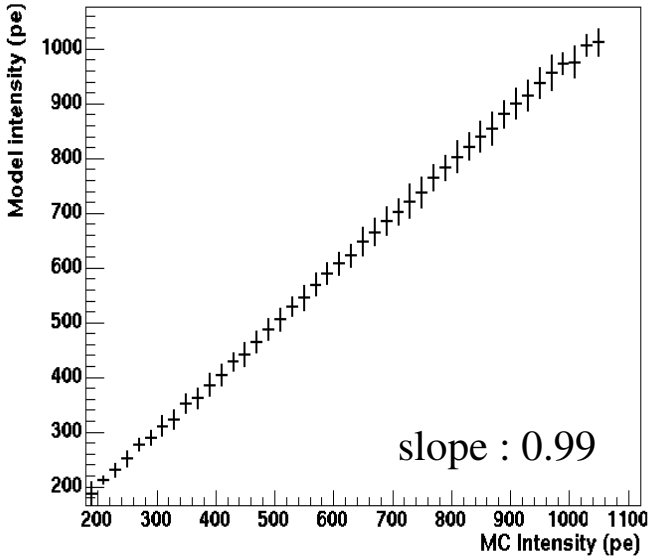
Obtained resolutions:



impact parameter

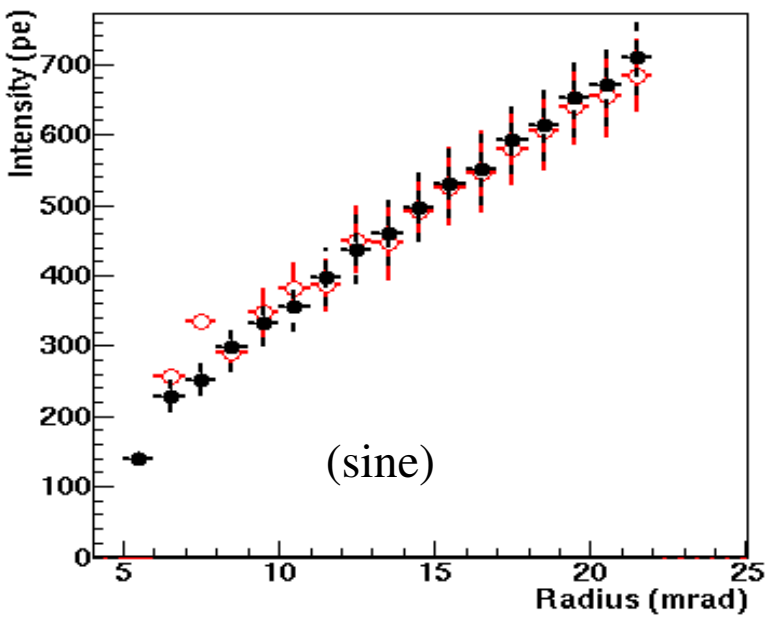


Cherenkov angle

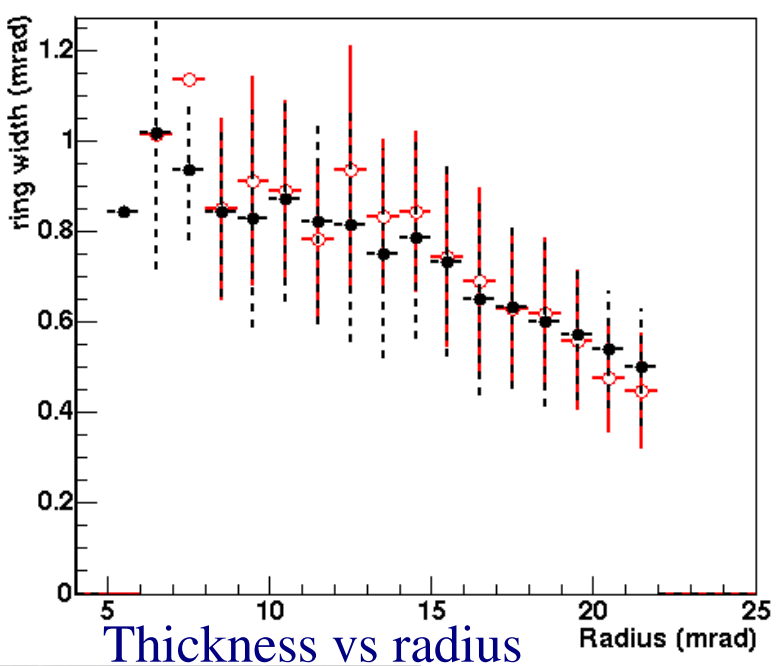


Charge (MC vs model)

Data-MC comparison



Intensity vs radius

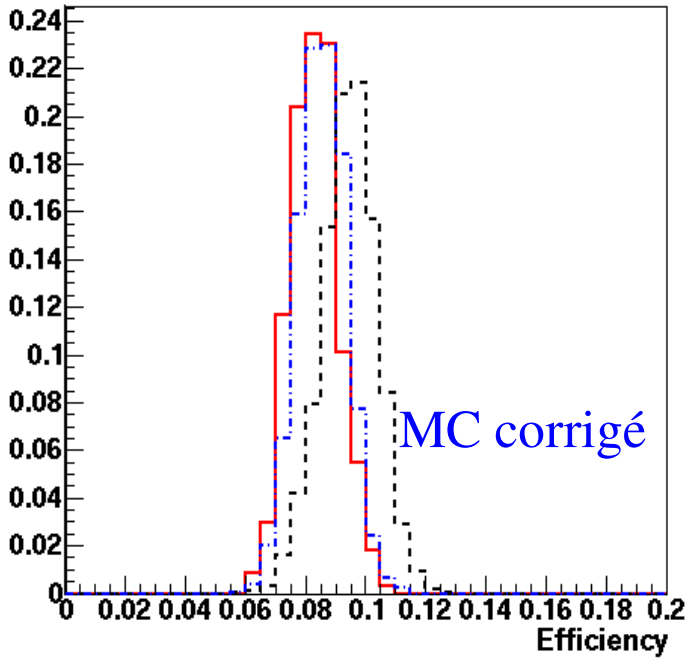


Thickness vs radius

MC

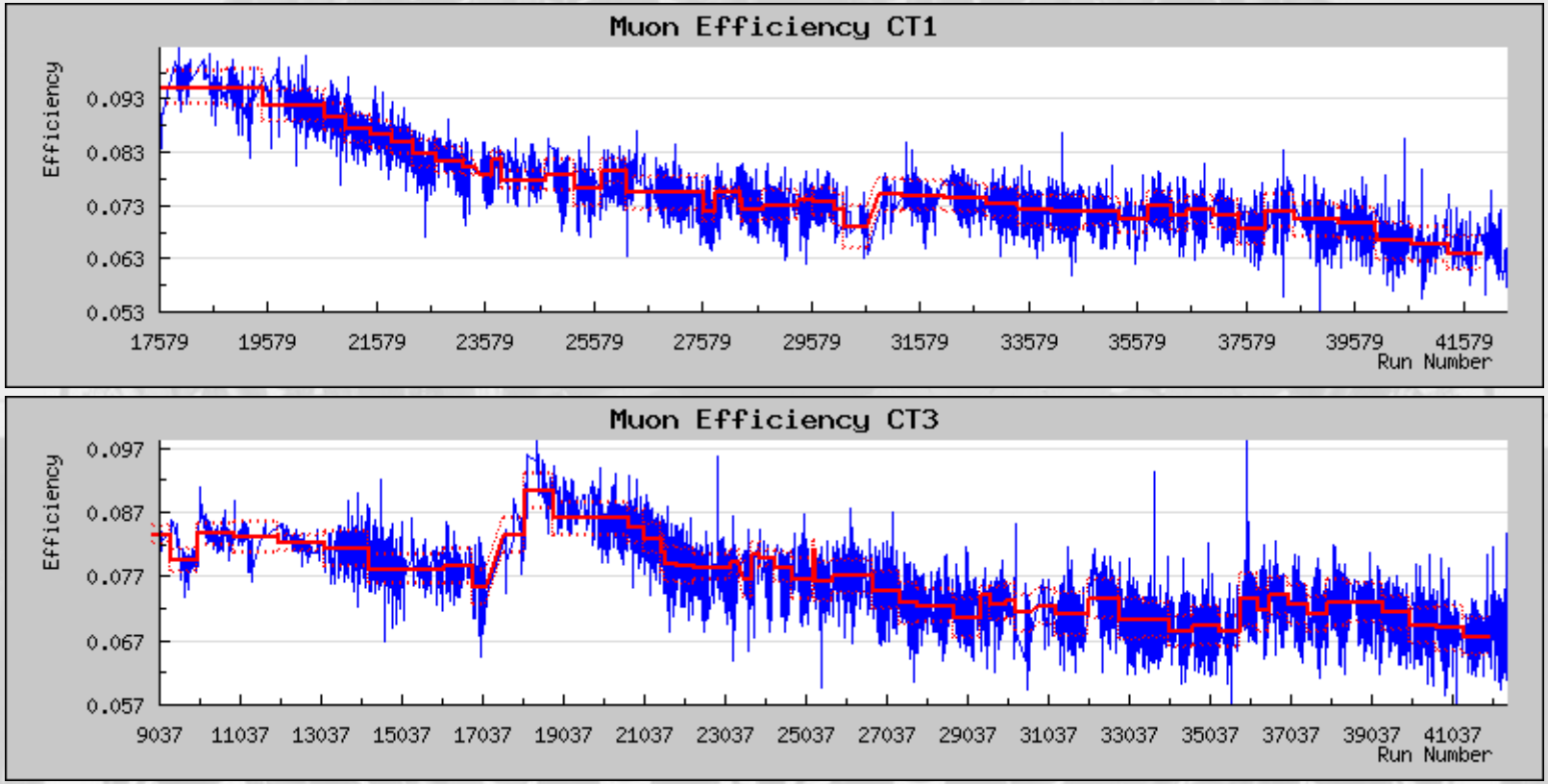
Data

- *Can be used to crosscheck the simulation (by simulating muons and comparing the optical efficiencies)*
- *Can provide alternate flatfielding (contribution of each pixel)*



Evolution of optical efficiency

- *Obvious degradation with time*



- *Not caused by the PMT ageing*
- *Most probably due to mirror degradation (need recoating)*

Calibration Procedure (I)

- *1 – Pedestal and gains*
  - *Dark Pedestal*
  - *Single Photoelectrons*

  } *Dedicated runs, analysed on-site, results in Paris's DB*

  Merged offline by periods

- *2 – Calibration of real data runs*
  - *Pedestal*
  - *Broken pixels*
  - *High/Low ratio*

  } *Offline analysis in Lyon*

  For each individual run, ROOT files,

  → *DB, Merged by periods*

- *3 – Flatfielding calibration*
  - *Dedicated runs in Namibia* → *Offline analysis in Lyon, merged by periods*

- *4 – Optical efficiency*
  - *Second pass on real data runs (in lyon)* → *Offline analysis in Lyon, merged by periods*

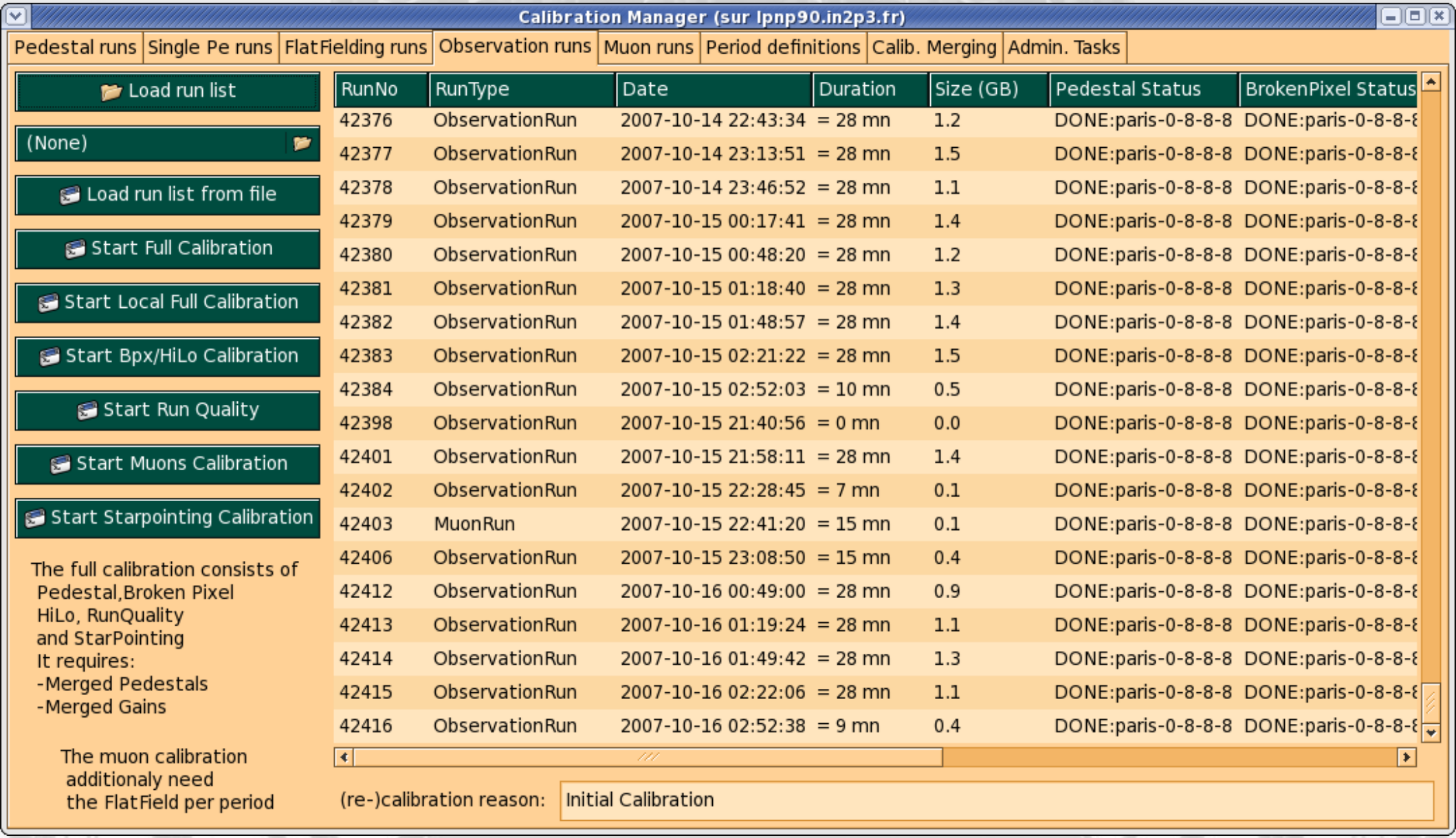
Calibration Procedure (II)
Involved software

- *Software available in HESS Berlin's CVS:*
  - *cvs -d :pserver:hess@hess01.physik.hu-berlin.de:/cvs co ....*

- *"calibration" module:*
  - *Storage classes for calibration coefficients*
  - *Common to french and german software*
- *"pariscalibrationmakers" module:*
  - *Determination of calibration coefficients, using french algorithms ("calibrationmakers" german equivalent)*
- *"pariscalibrationmergers" module:*
  - *Merging of calibration coefficients by period*
- *"pariscalibration" module*
  - *Access to french calibration coefficients (from DB or files)*
  - *Fills the "calibration" module classes*

Involved software

- *Graphical User Interface used throughout calibration procedure*
- *One period calibration usually within a few days*



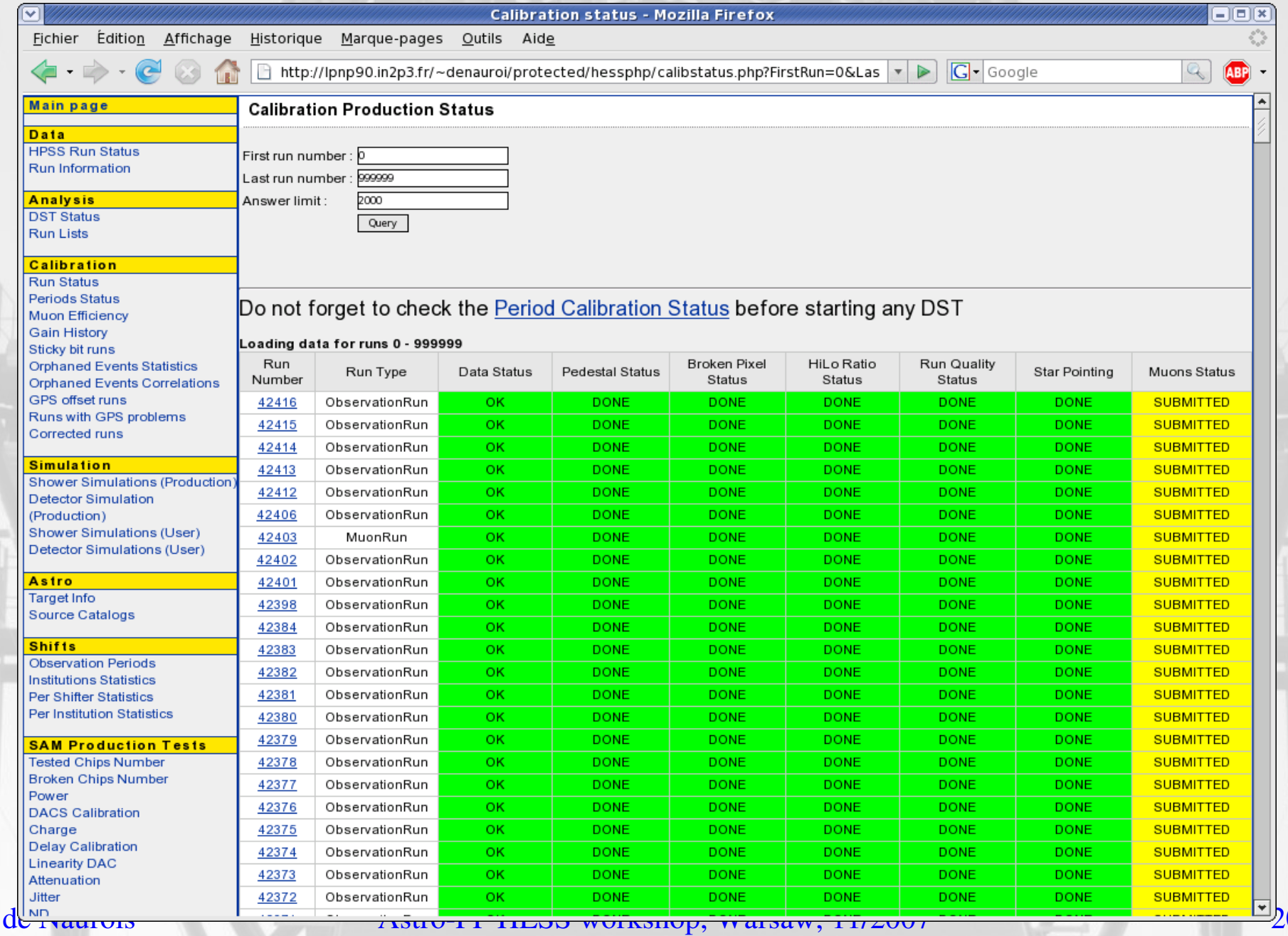
Web-access to calibration status

http://lpnp90.in2p3.fr/~denauroi/protected/hessphp

- *PHP based interface to calibration (and other databases)*
  - *Status of run calibration*
  - *Status of period merging*
  - *Evolution of calibration coefficients (gain, optical efficiency) with time*
  - *Detailed informations about every run*
    - Run Quality information
    - Calibration history (with date, version and reason of each recalibration)
  - *Access privileged by password + IP address filtering*

Web-access to calibration status

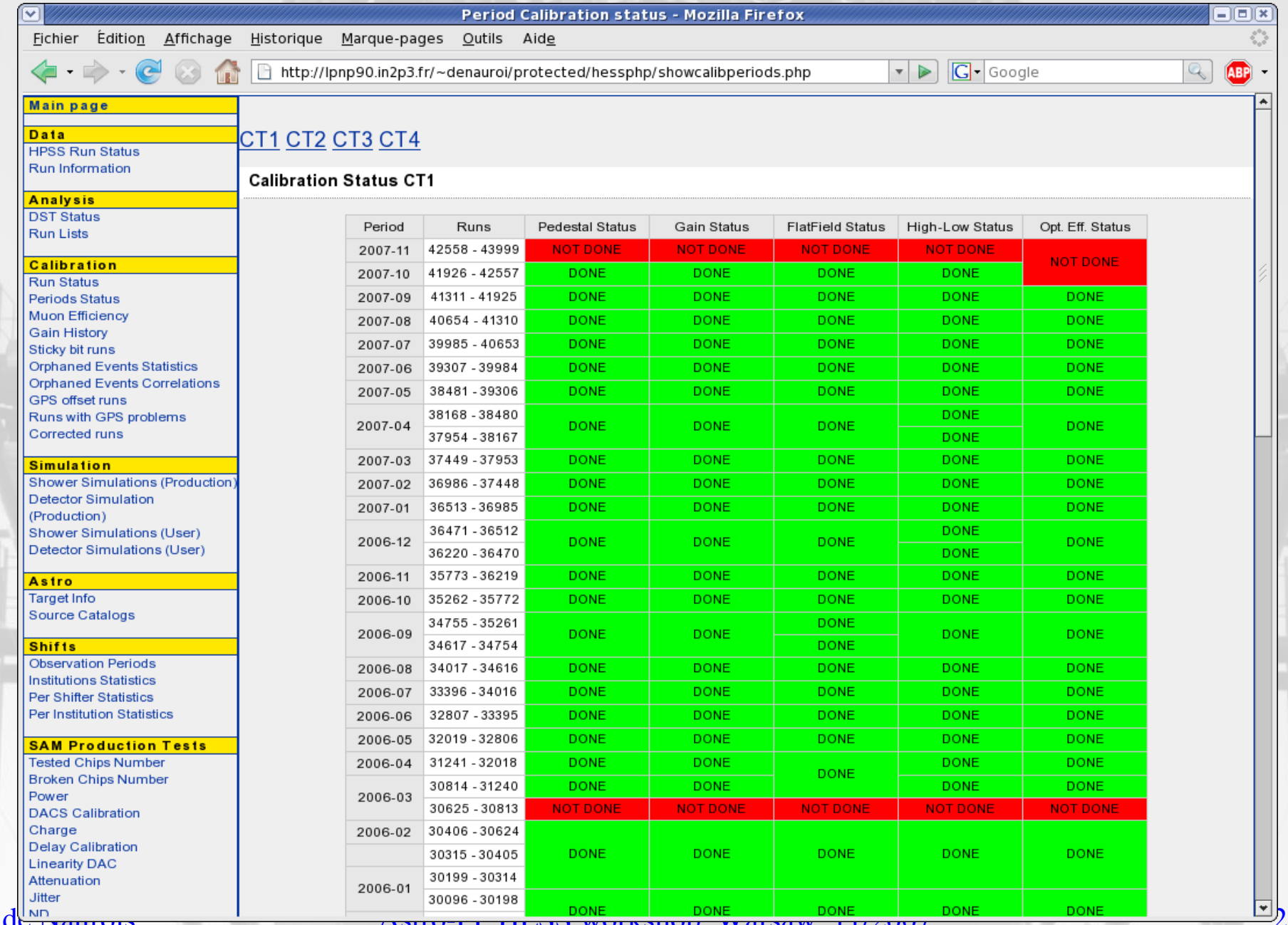
http://lpnp90.in2p3.fr/~denauroi/protected/hessphp/calibstatus.php



Run Number	Run Type	Data Status	Pedestal Status	Broken Pixel Status	HiLo Ratio Status	Run Quality Status	Star Pointing	Muons Status
42416	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42415	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42414	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42413	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42412	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42406	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42403	MuonRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42402	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42401	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42398	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42384	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42383	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42382	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42381	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42380	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42379	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42378	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42377	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42376	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42375	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42374	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42373	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED
42372	ObservationRun	OK	DONE	DONE	DONE	DONE	DONE	SUBMITTED

Web-access to calibration status

http://lpnp90.in2p3.fr/~denauroi/protected/hessphp/showcalibperiods.php



Period	Runs	Pedestal Status	Gain Status	FlatField Status	High-Low Status	Opt. Eff. Status
2007-11	42558 - 43999	NOT DONE	NOT DONE	NOT DONE	NOT DONE	NOT DONE
2007-10	41926 - 42557	DONE	DONE	DONE	DONE	
2007-09	41311 - 41925	DONE	DONE	DONE	DONE	DONE
2007-08	40654 - 41310	DONE	DONE	DONE	DONE	DONE
2007-07	39985 - 40653	DONE	DONE	DONE	DONE	DONE
2007-06	39307 - 39984	DONE	DONE	DONE	DONE	DONE
2007-05	38481 - 39306	DONE	DONE	DONE	DONE	DONE
2007-04	38168 - 38480	DONE	DONE	DONE	DONE	DONE
	37954 - 38167				DONE	
2007-03	37449 - 37953	DONE	DONE	DONE	DONE	DONE
2007-02	36986 - 37448	DONE	DONE	DONE	DONE	DONE
2007-01	36513 - 36985	DONE	DONE	DONE	DONE	DONE
2006-12	36471 - 36512	DONE	DONE	DONE	DONE	DONE
	36220 - 36470				DONE	
2006-11	35773 - 36219	DONE	DONE	DONE	DONE	DONE
2006-10	35262 - 35772	DONE	DONE	DONE	DONE	DONE
2006-09	34755 - 35261	DONE	DONE	DONE	DONE	DONE
	34617 - 34754			DONE		
2006-08	34017 - 34616	DONE	DONE	DONE	DONE	DONE
2006-07	33396 - 34016	DONE	DONE	DONE	DONE	DONE
2006-06	32807 - 33395	DONE	DONE	DONE	DONE	DONE
2006-05	32019 - 32806	DONE	DONE	DONE	DONE	DONE
2006-04	31241 - 32018	DONE	DONE	DONE	DONE	DONE
2006-03	30814 - 31240	DONE	DONE		DONE	DONE
	30625 - 30813	NOT DONE	NOT DONE	NOT DONE	NOT DONE	NOT DONE
2006-02	30406 - 30624	DONE	DONE	DONE	DONE	DONE
	30315 - 30405					
2006-01	30199 - 30314					
	30096 - 30198	DONE	DONE	DONE	DONE	DONE

Access to calibration

- *Calibration coefficients needed at several stages:*
  - *At DST production (conversion from charge to intensity)*
  - *At analysis stage (at least for optical efficiency)*

- *Acces to calibration coefficients provided by the "pariscalibration" module*
  - *Reads gains, flatfield, optical efficiency from the database*
    - Accessible from everywhere
  - *Reads pedestals, broken pixels from ROOT files*
    - located in Lyon, downloadable if needed
  - *Fills the calibration module classes*
    - Compatible with any analysis chain

Conclusion

- *Careful calibration is an essential part of IACT business*
- *French collaboration has design a robust and easy to use calibration scheme (Maintained by the LPNHE group)*
- *Efficient calibration procedure (~ 2-3 days for one period when everything fine in Lyon*
- *Good book-keeping using databases*
- *The French groups are the only one keeping untouched original data (thus allowing recalibration if needed)*
- *Calibration procedure still evolving*
  - *Sometimes new hardware problems are found...*