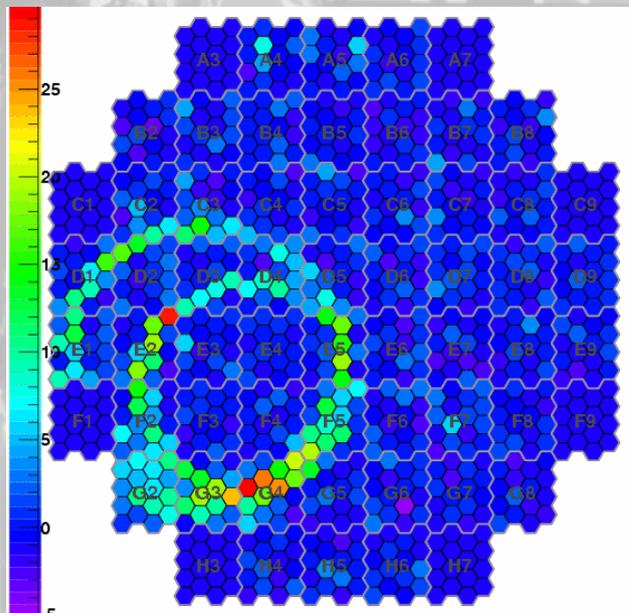


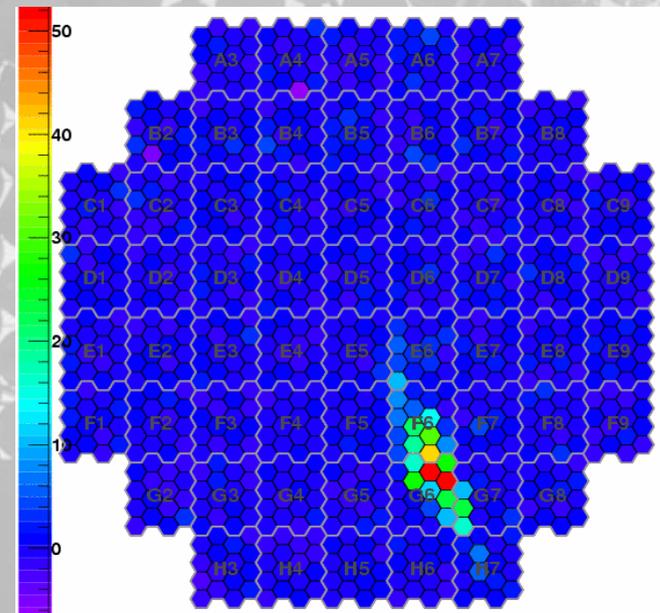
# Paris Calibration Procedures

Mathieu de Naurois, LPNHE Paris VI/VII

[denauroi@in2p3.fr](mailto:denauroi@in2p3.fr)

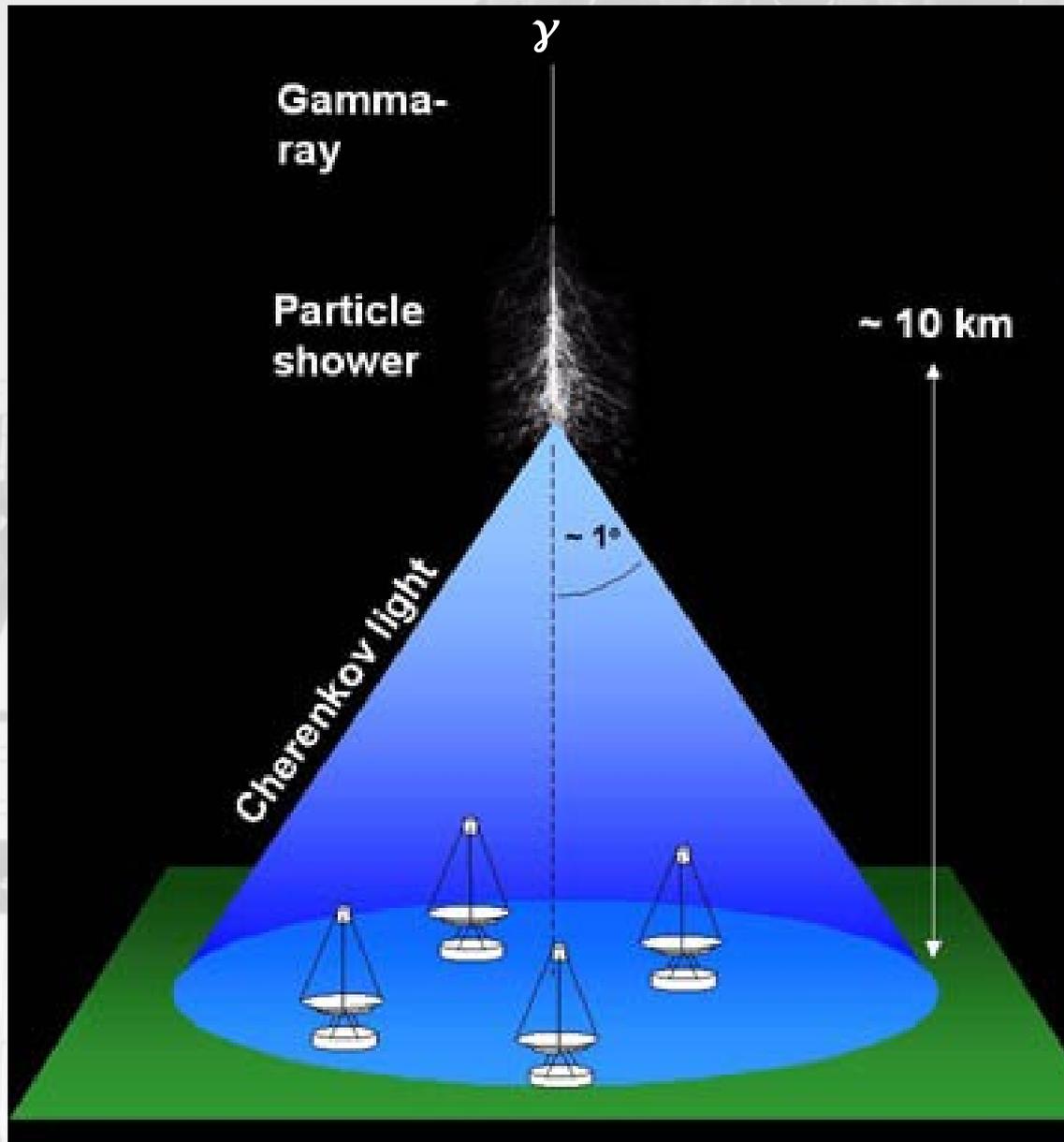


Muons



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

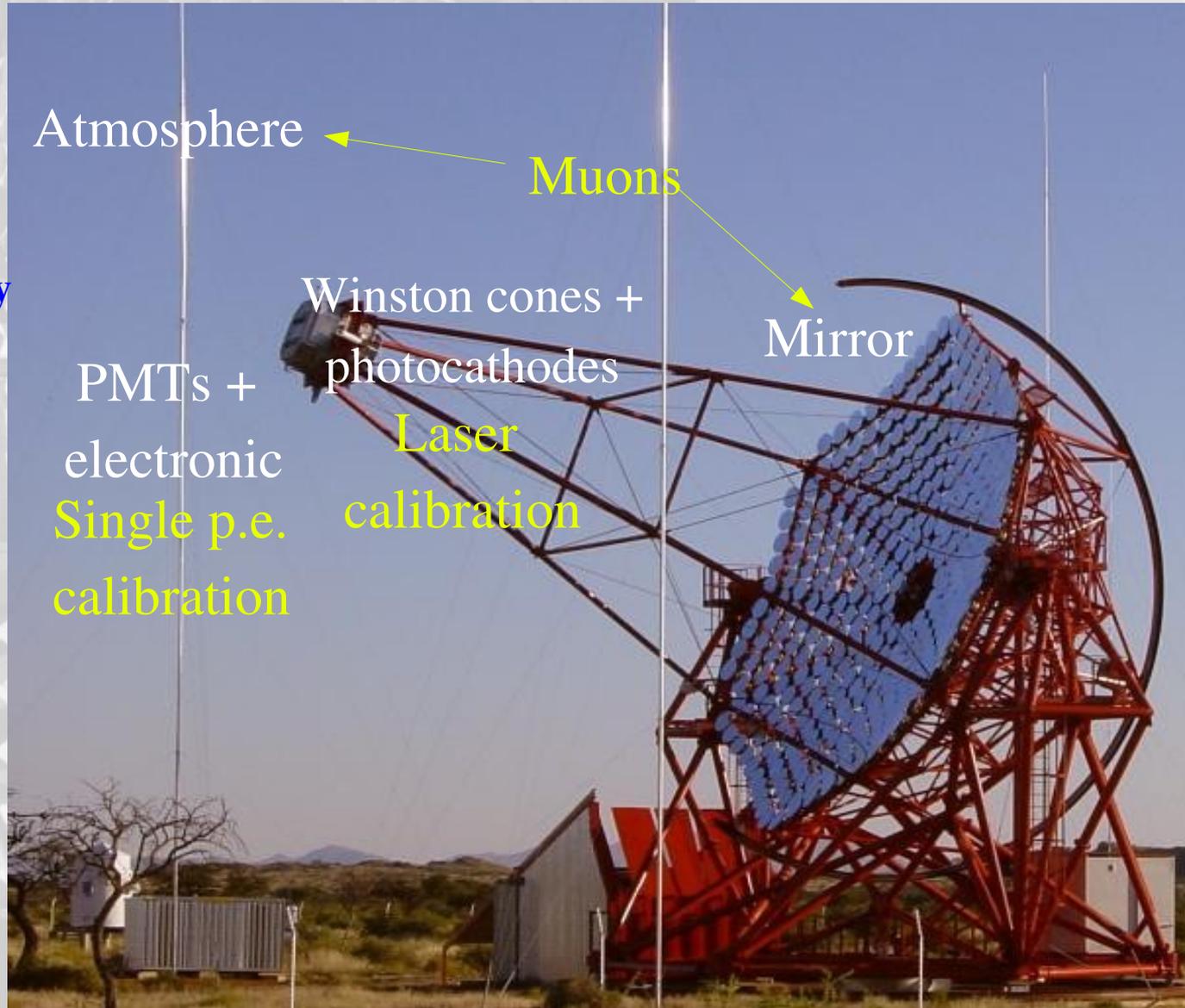
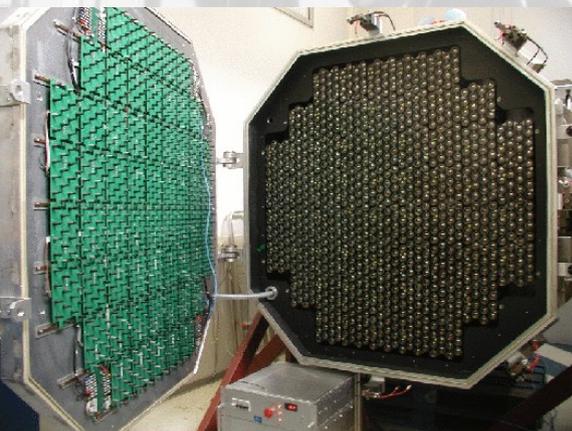


Pedestals

Gains

High/Low ratio

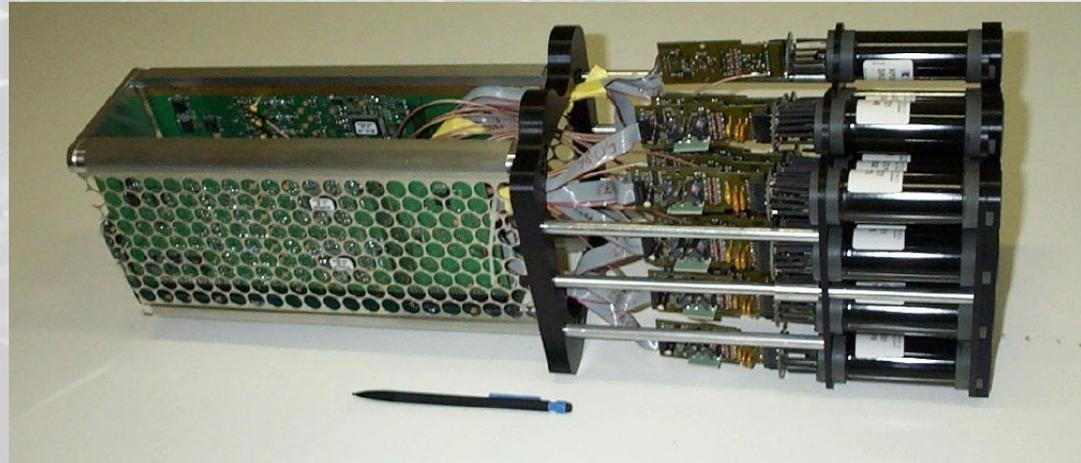
Collected charge



# H.E.S.S. drawer electronics

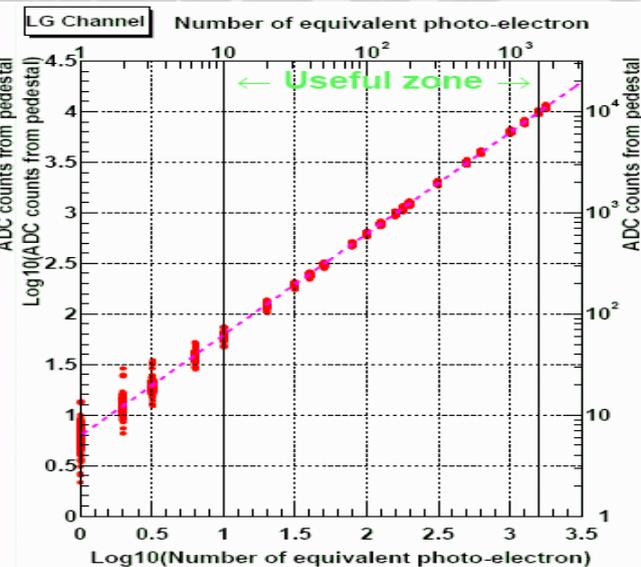
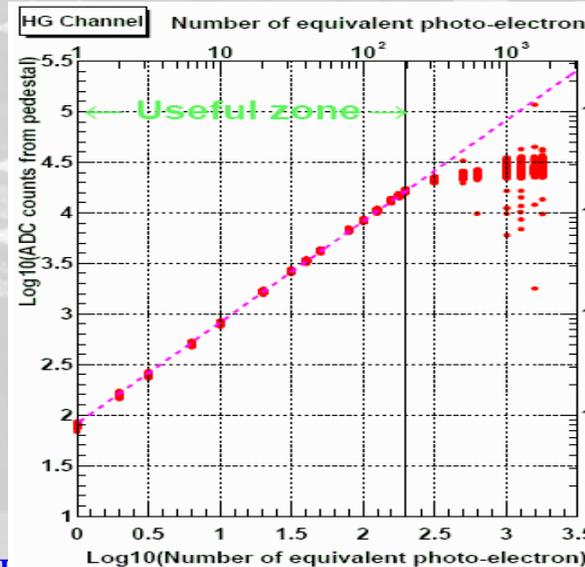
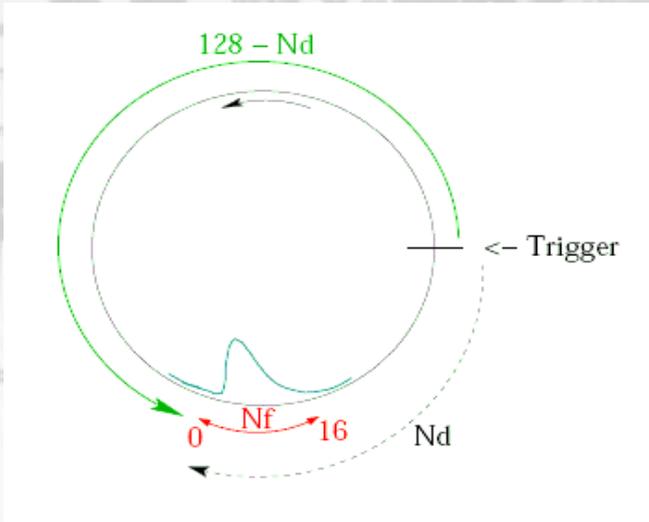
- *H.E.S.S. drawer electronics comprises*

- 16 photomultipliers
- Active 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 ( $\Rightarrow$  2000 pe)



# Calibration Coefficients

## Signal Amplitude:

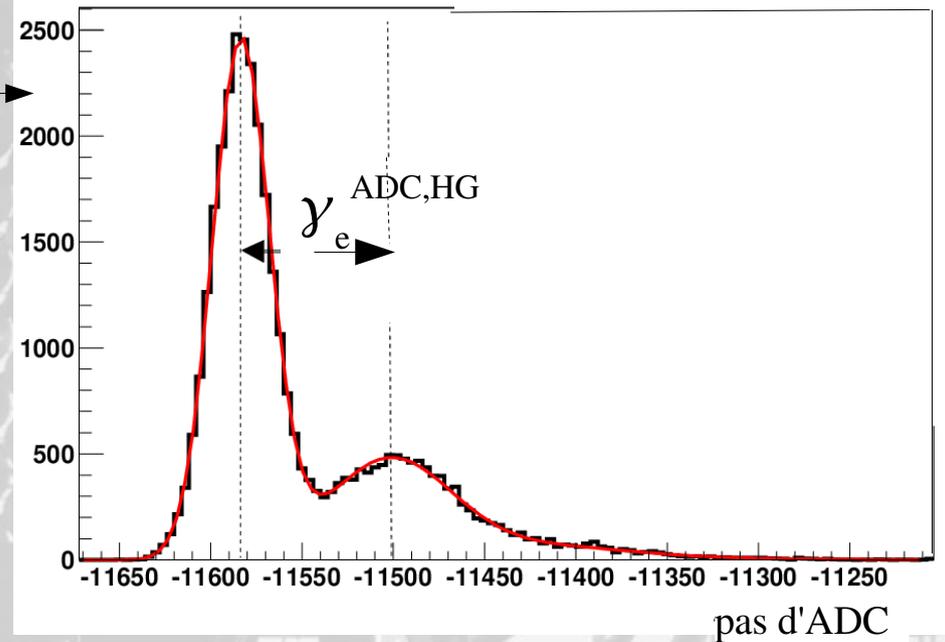
High Gain channel

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

Low Gain channel

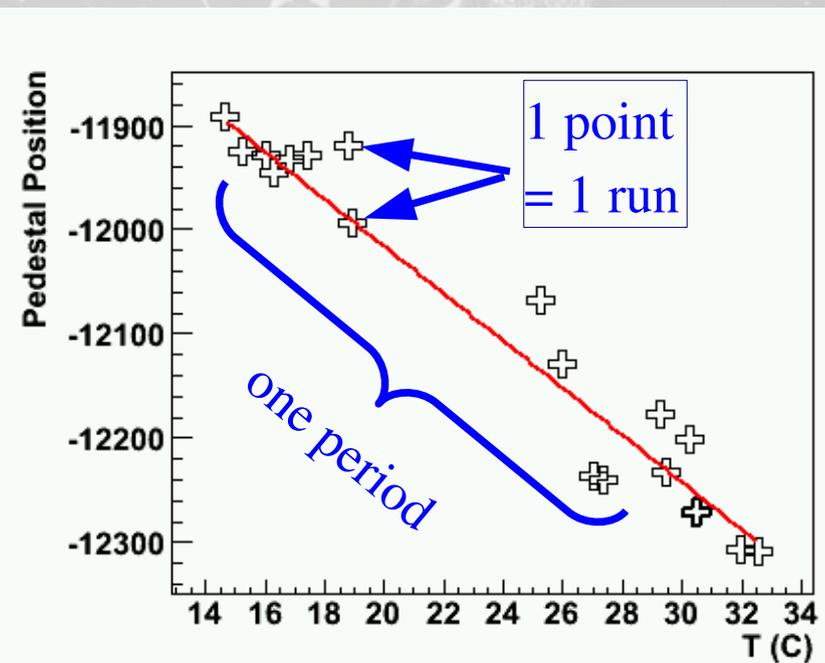
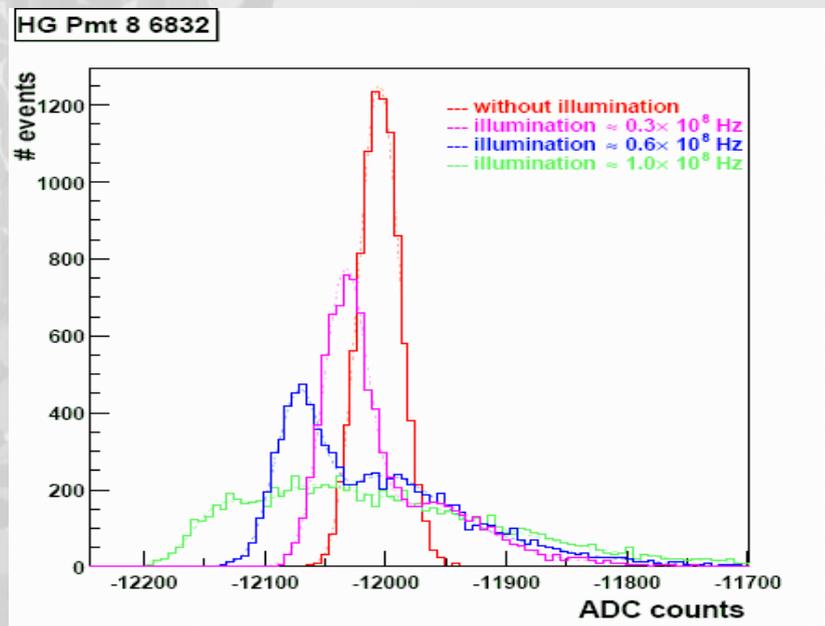
$$A^{BG} = \frac{ADC^{BG} - P^{BG}}{\gamma_e^{ADC,HG}} \times (HG/BG) \times FF$$

- 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*



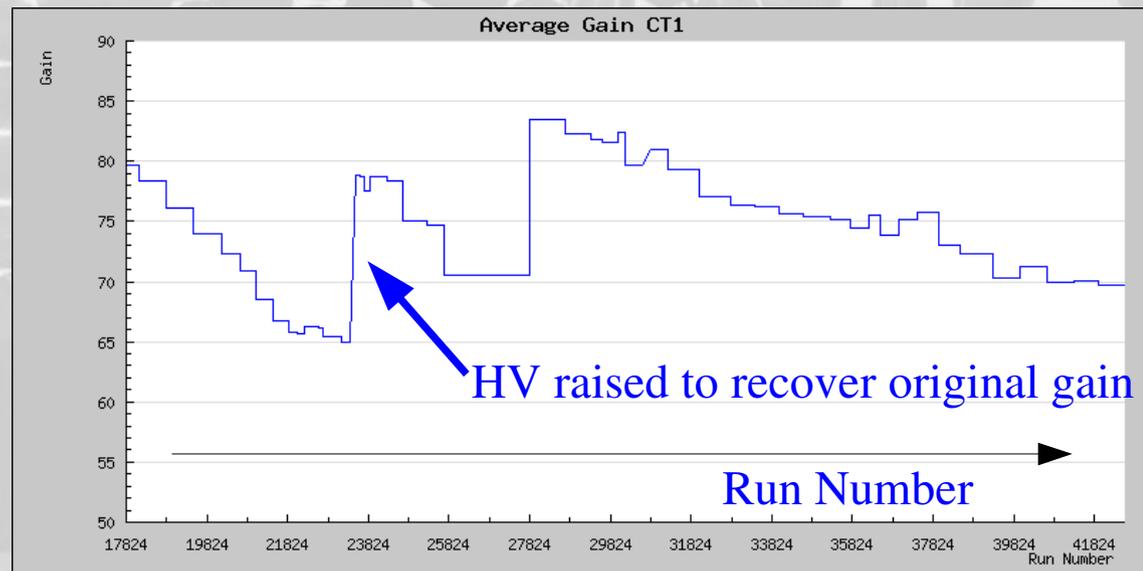
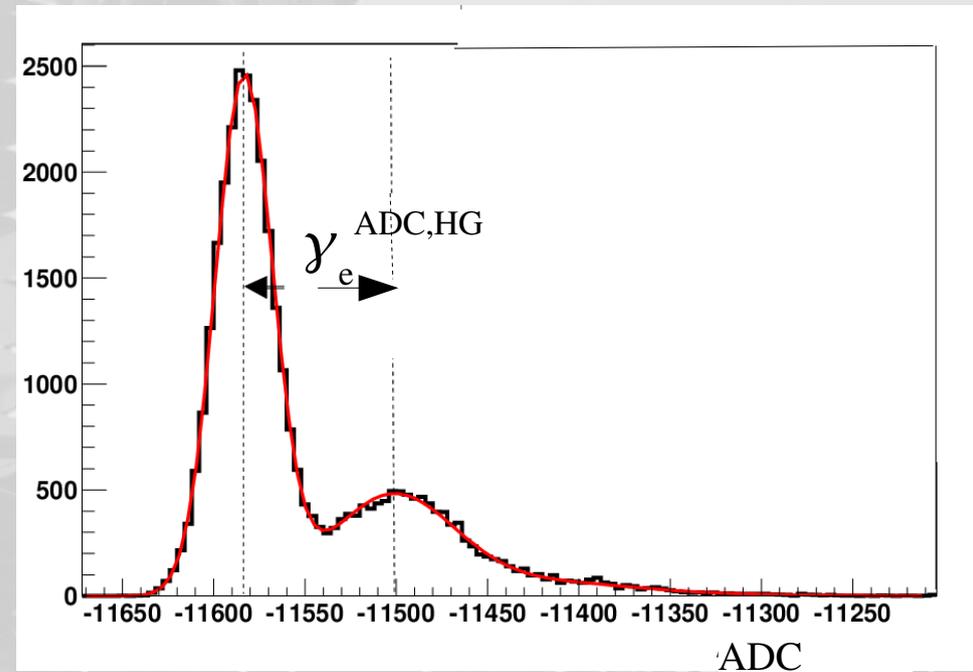
# Photomultiplier Gains

- *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*

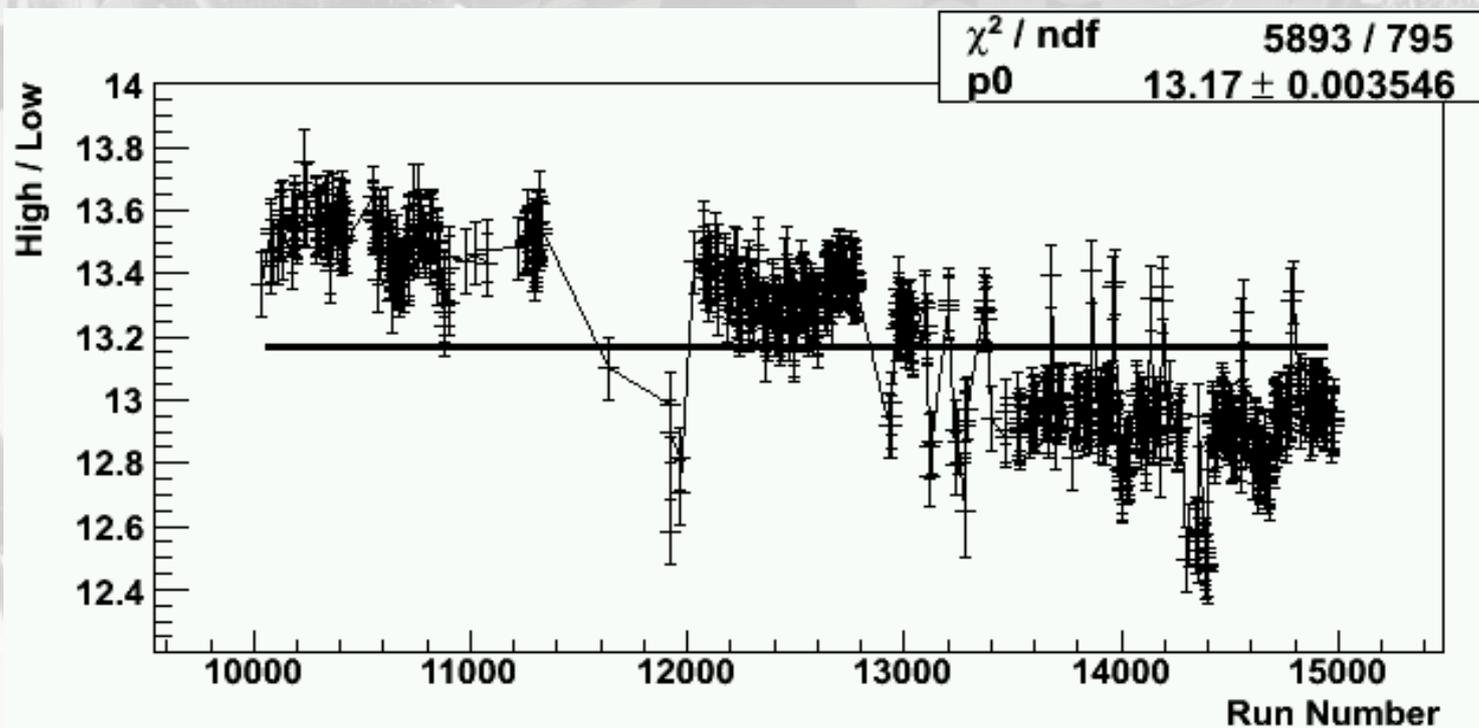
- *Gain evolution*

- *Gain decrease with PMT aging*
- *HV periodically raised to recover original gain (80 ADC / pe)*



# High/Low ratio

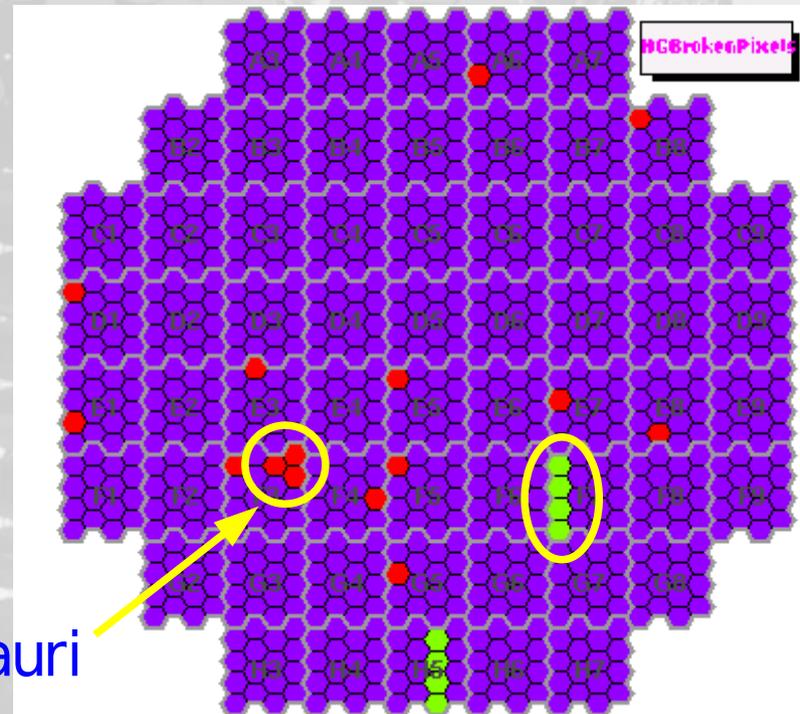
- *Calibrate the relative electronic gains of High versus Low gain channels*
- *Done offline (in Lyon)*
  - *Using real data (pixels with signal in the transition region  $\sim 20 \Rightarrow 200$  pe)*
  - *After pedestal estimation*



# 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*

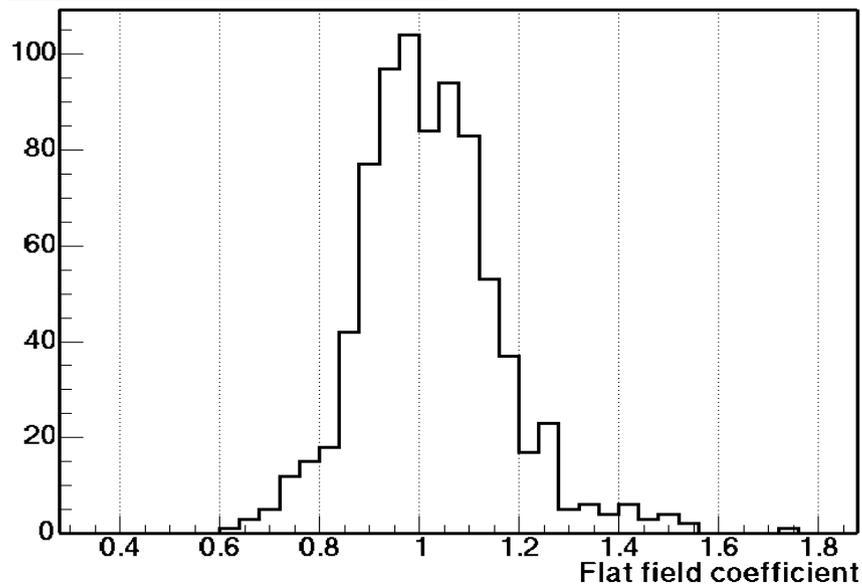


Analogue Ring Sampling  
chip not synchronised

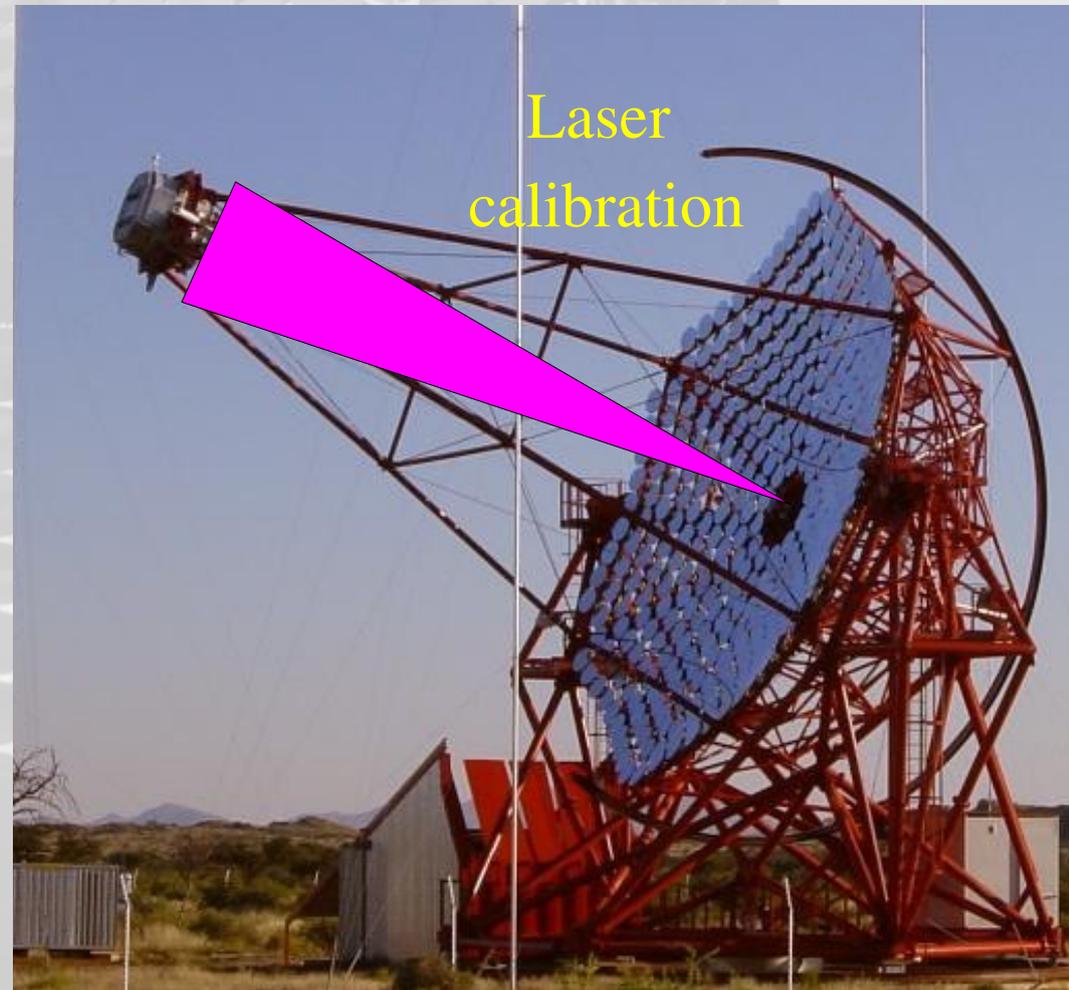
# FlatFielding

- *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 Distribution

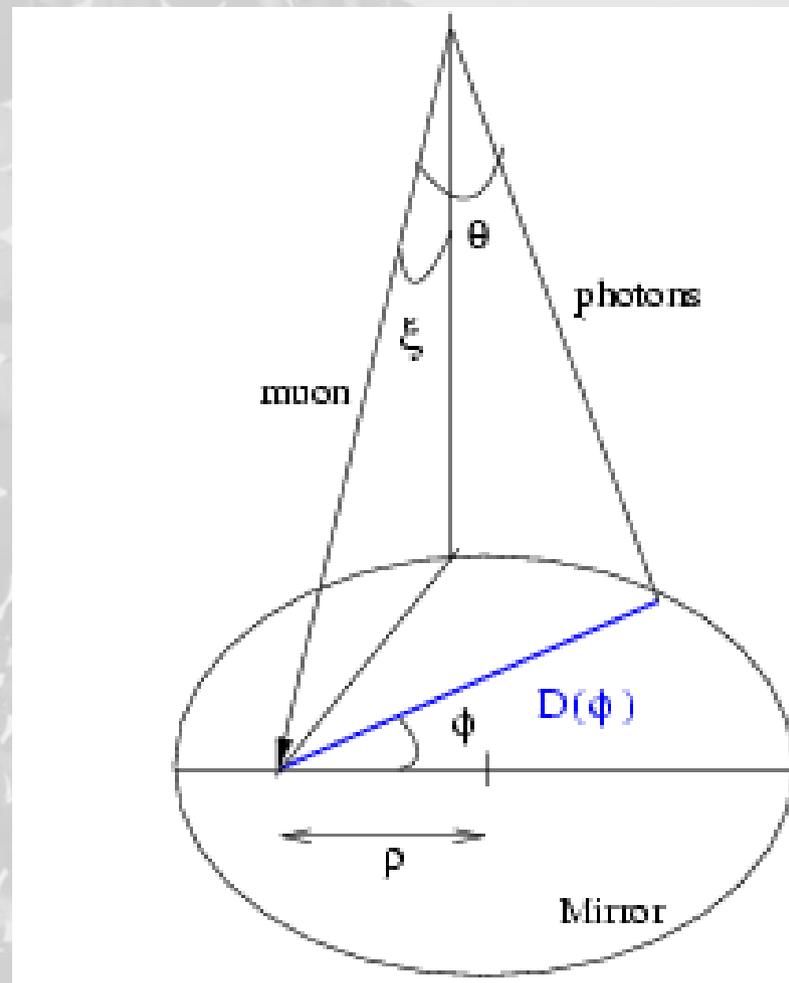
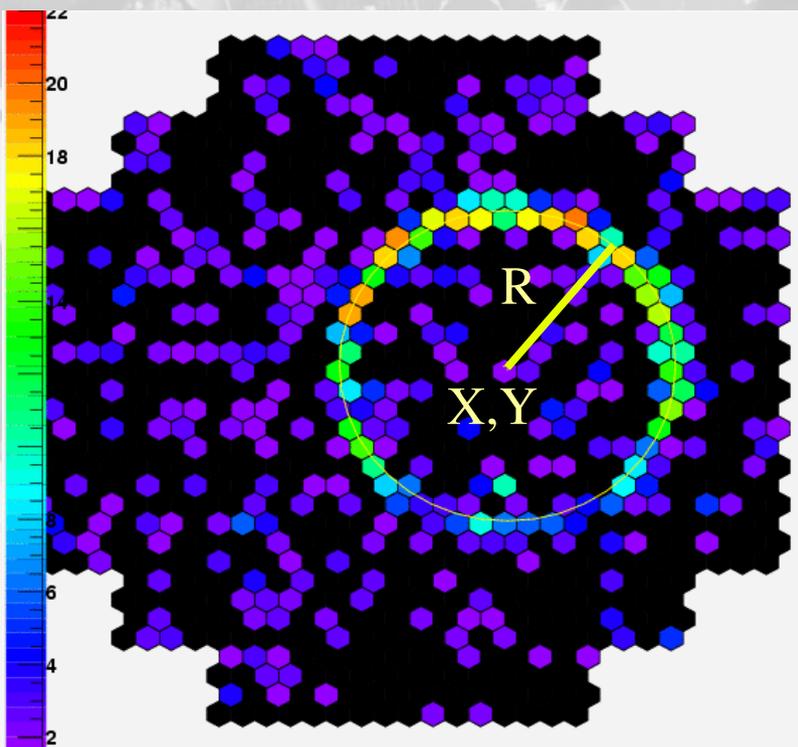


Flat-Field coefficients



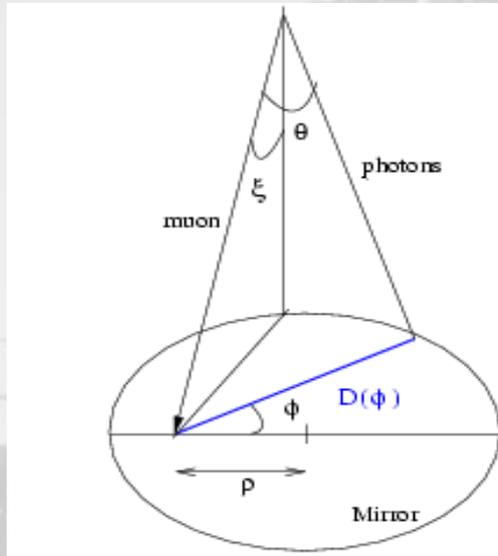
# Optical Efficiency calibration using Muons from hadronic showers

- *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  $\times$  optical efficiency,*
  - *Provide validation of detector simulation*



# Geometry of Cherenkov emission from a muon

- Use only complete ring in the camera ( $\sim 1\text{Hz}$ ) falling in the mirror



$x, y$  : ring centre in the camera

$R$  : ring radius

$\epsilon$  : total collection efficiency

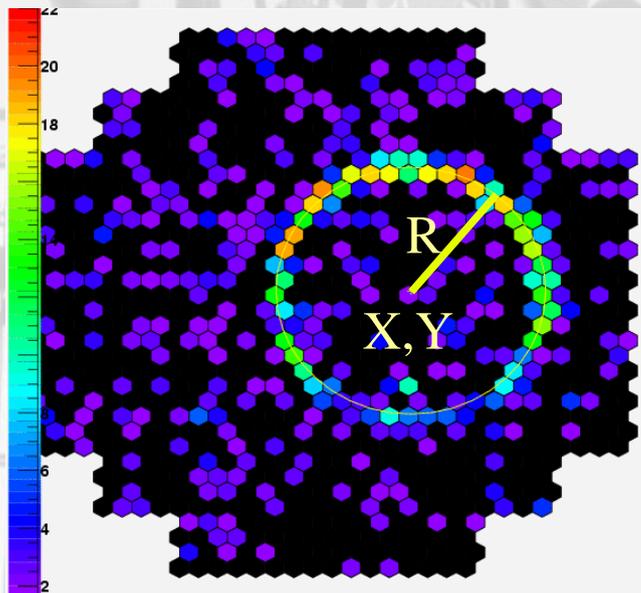
$\rho$  : impact parameter

$\sigma$  : ring width

$\phi_{\max}$  : azimuth of the maximum in intensity

Simple geometrical fit

Cherenkov emission



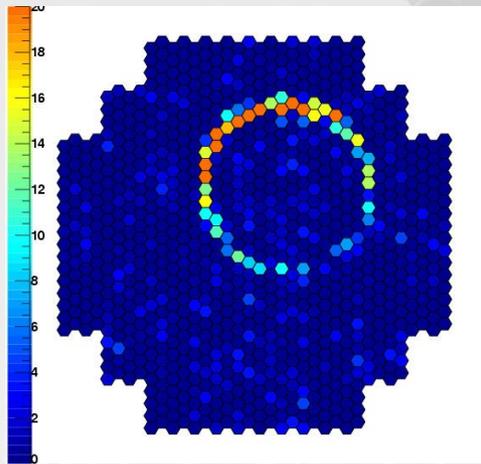
$\theta_c$  is the Cherenkov angle,  
i.e., the ring radius in the camera

$\epsilon$  is the conversion factor  
between p.e. and photons

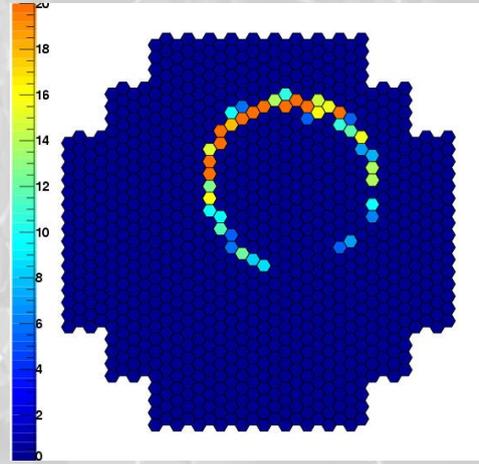
For each pixel, we determine  $\epsilon$  from

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

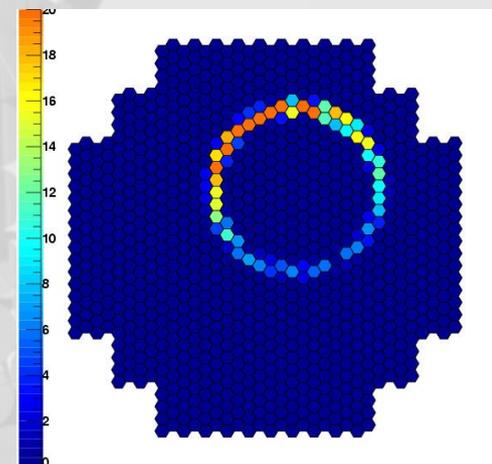
# Reconstruction performances



raw data

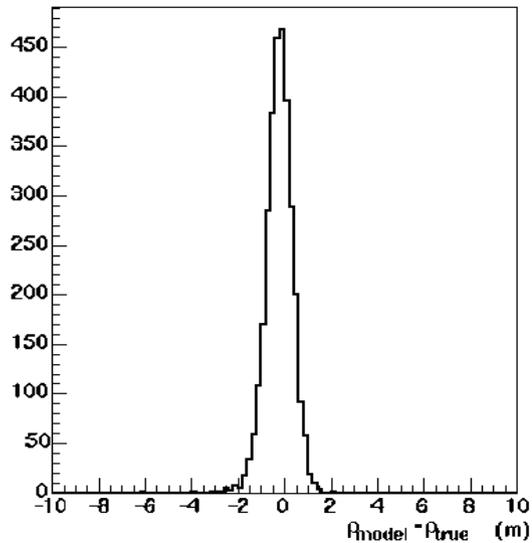


cleaned data

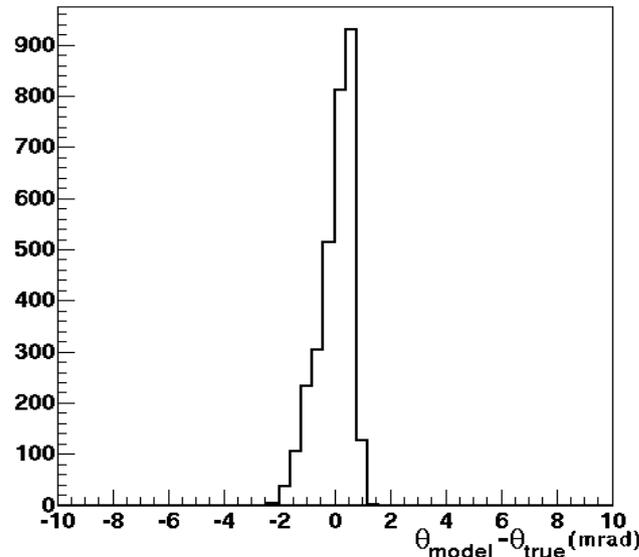


model

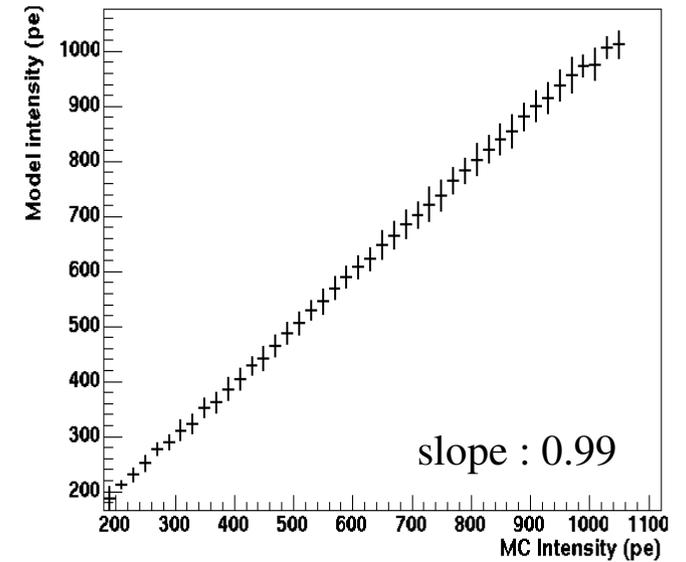
Obtained resolutions:



impact parameter

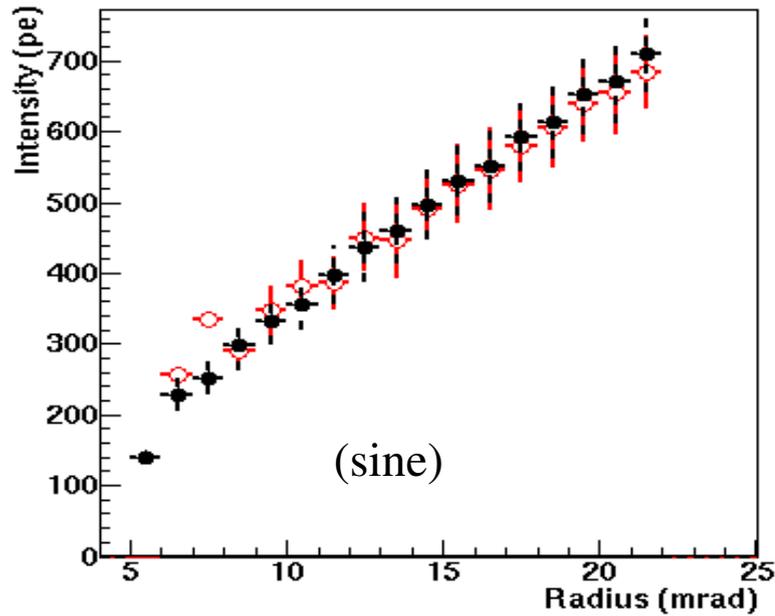


Cherenkov angle

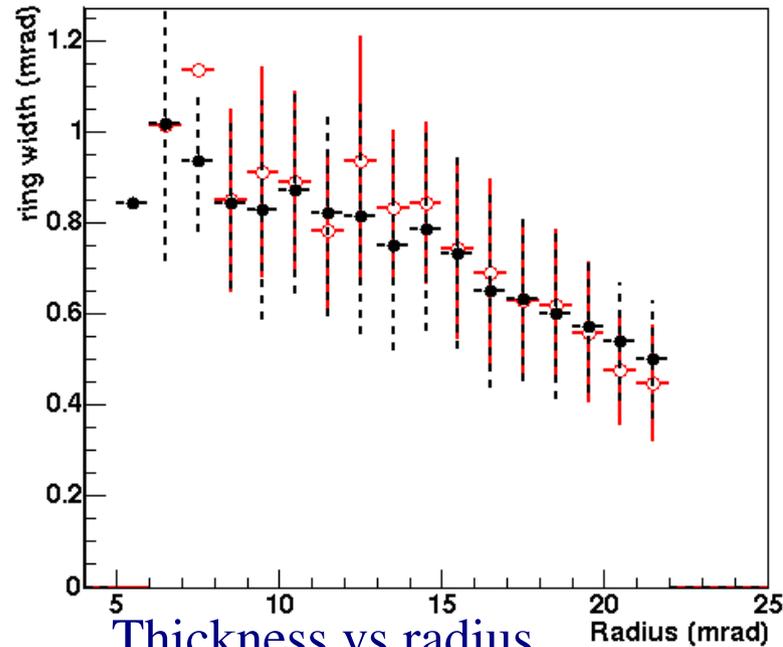


Charge (MC vs model)

# Data-MC comparison

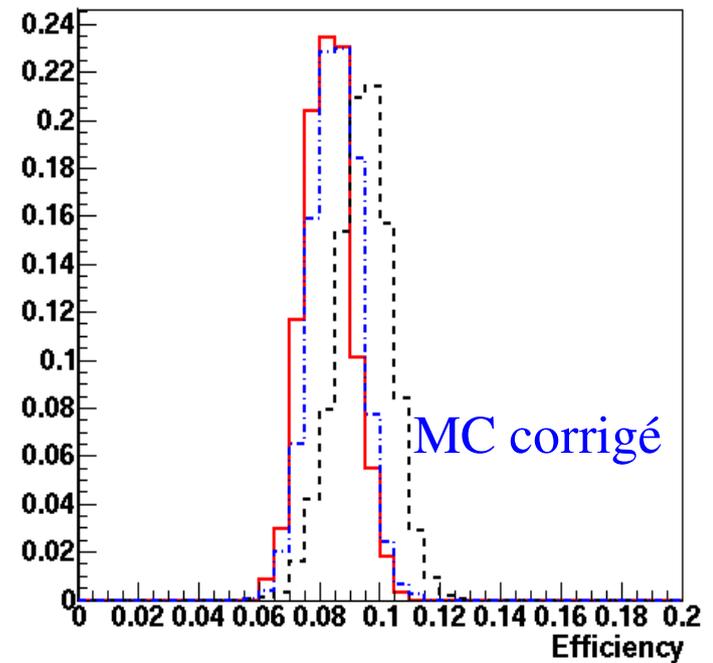


Intensity vs radius



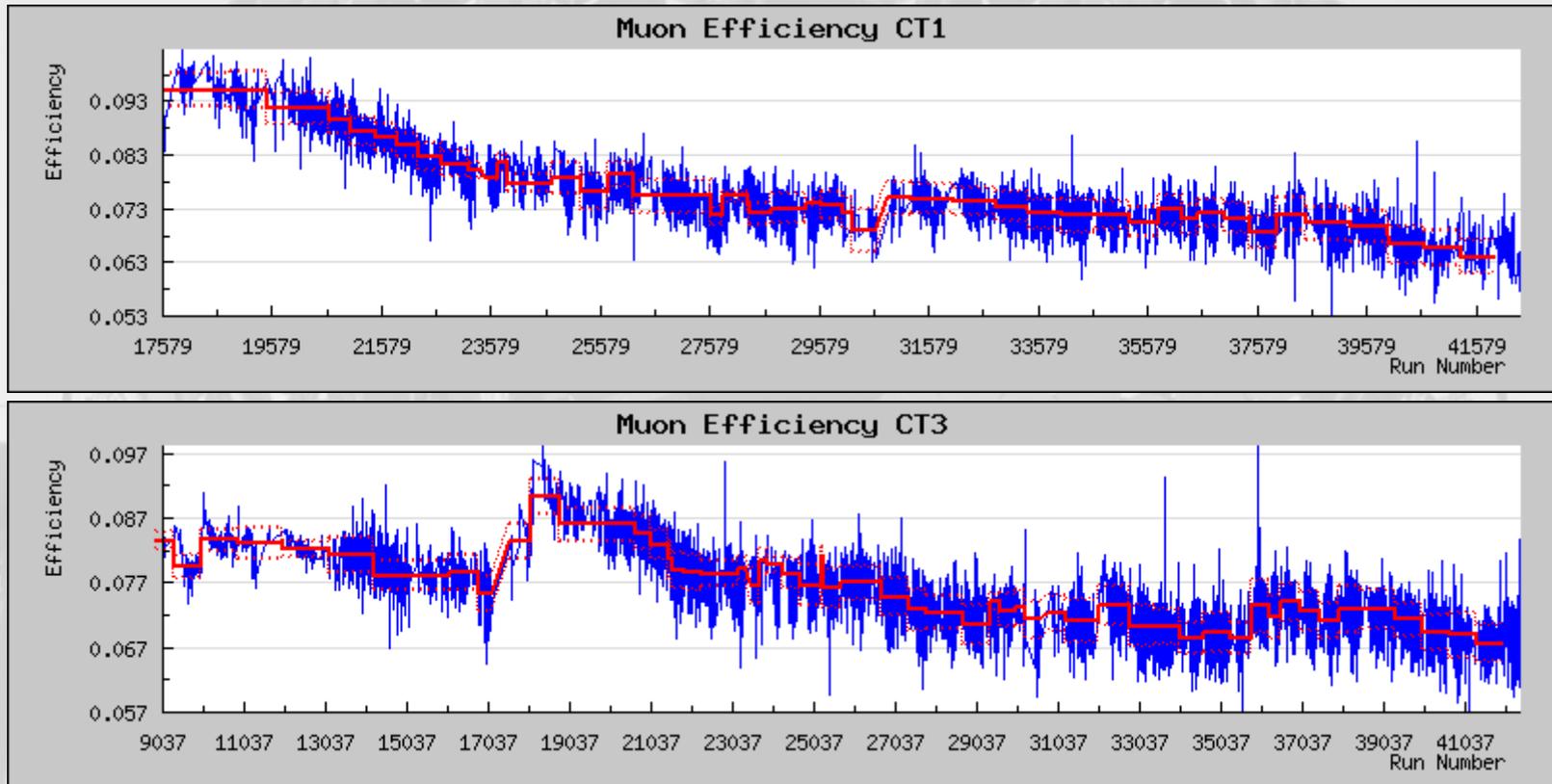
Thickness vs radius

- *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*

Calibration Manager (sur lppn90.in2p3.fr)

Pedestal runs | Single Pe runs | FlatFielding runs | Observation runs | Muon runs | Period definitions | Calib. Merging | Admin. Tasks

RunNo	RunType	Date	Duration	Size (GB)	Pedestal Status	BrokenPixel Status
42376	ObservationRun	2007-10-14 22:43:34	= 28 mn	1.2	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42377	ObservationRun	2007-10-14 23:13:51	= 28 mn	1.5	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42378	ObservationRun	2007-10-14 23:46:52	= 28 mn	1.1	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42379	ObservationRun	2007-10-15 00:17:41	= 28 mn	1.4	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42380	ObservationRun	2007-10-15 00:48:20	= 28 mn	1.2	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42381	ObservationRun	2007-10-15 01:18:40	= 28 mn	1.3	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42382	ObservationRun	2007-10-15 01:48:57	= 28 mn	1.4	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42383	ObservationRun	2007-10-15 02:21:22	= 28 mn	1.5	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42384	ObservationRun	2007-10-15 02:52:03	= 10 mn	0.5	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42398	ObservationRun	2007-10-15 21:40:56	= 0 mn	0.0	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42401	ObservationRun	2007-10-15 21:58:11	= 28 mn	1.4	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42402	ObservationRun	2007-10-15 22:28:45	= 7 mn	0.1	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42403	MuonRun	2007-10-15 22:41:20	= 15 mn	0.1	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42406	ObservationRun	2007-10-15 23:08:50	= 15 mn	0.4	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42412	ObservationRun	2007-10-16 00:49:00	= 28 mn	0.9	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42413	ObservationRun	2007-10-16 01:19:24	= 28 mn	1.1	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42414	ObservationRun	2007-10-16 01:49:42	= 28 mn	1.3	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42415	ObservationRun	2007-10-16 02:22:06	= 28 mn	1.1	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8
42416	ObservationRun	2007-10-16 02:52:38	= 9 mn	0.4	DONE:paris-0-8-8-8	DONE:paris-0-8-8-8

The full calibration consists of Pedestal, Broken Pixel HiLo, RunQuality and StarPointing  
It requires:  
- Merged Pedestals  
- Merged Gains

The muon calibration additionally need the FlatField per period

(re-)calibration reason:

# Web-access to calibration status

<http://lphp90.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://lphp90.in2p3.fr/~denauroi/protected/hessphp/calibstatus.php>

**Calibration Production Status**

First run number :   
Last run number :   
Answer limit :

Do not forget to check the [Period Calibration Status](#) before starting any DST

Loading data for runs 0 - 999999

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

# Web-access to calibration status

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

Period Calibration status - Mozilla Firefox

Fichier Édition Affichage Historique Marque-pages Outils Aide

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

Google

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[Run Information](#)

**Analysis**  
[DST Status](#)  
[Run Lists](#)

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[Detector Simulation \(Production\)](#)  
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[ND](#)

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**Calibration Status CT1**

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	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
	34755 - 35261				DONE	
2006-09	34617 - 34754	DONE	DONE	DONE	DONE	DONE
	34017 - 34616				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
	30814 - 31240				DONE	
2006-03	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	DONE	DONE	DONE	DONE	DONE
	30096 - 30198					

# 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)*
- *Access 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...*