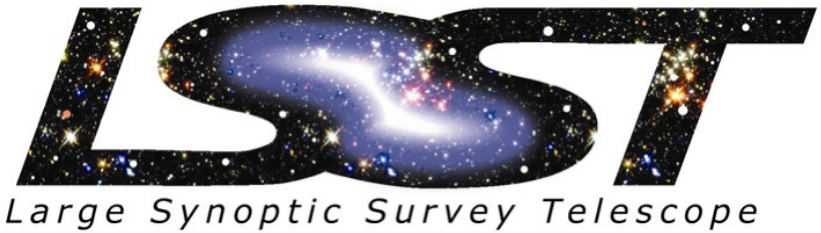
R&D LSST

rapport P2I

8 juin 2011



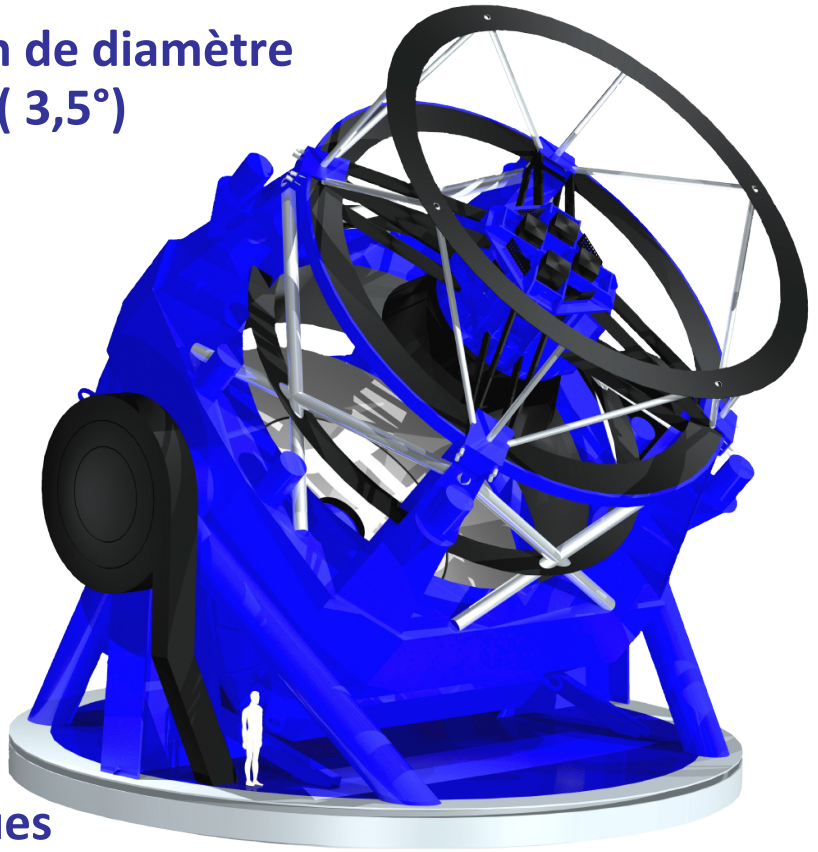
Marc Moniez

Outline

- Introduction: description et objectifs scientifiques de LSST
- Contributions de R&D à l'IN2P3
  - Mécanique (carousel)
  - Filtres
  - Capteurs CCD
  - Electronique: ASPIC (Front End ASIC for CCD readout)
  - Contrôle-commande (CCS)
  - Calibration
    - Modèle d'atmosphère
    - Simulation des opérations du télescope auxilliaire
    - CCOB (LSST Camera Calibration Optical Bench)
- Rapport qualité/prix. Perspectives

LSST : Large Synoptic Survey Telescope

- Télescope optique de 8,4 m de diamètre avec caméra grand champ (3,5°)
- Au Chili (Cerro Pachon)
- imaginé fin des années ‘90
- Caméra de 3.2 Gpixels
- Lecture 2s
- 6 filtres ugrizy
- WL jusqu’à z ~ 3
- SNIa jusqu’à z ~ 1
- BAO: oscillations acoustiques
- Galaxies et amas de galaxies
- Phénomènes transitoires



http://www.lsst.org/

Caractéristiques générales

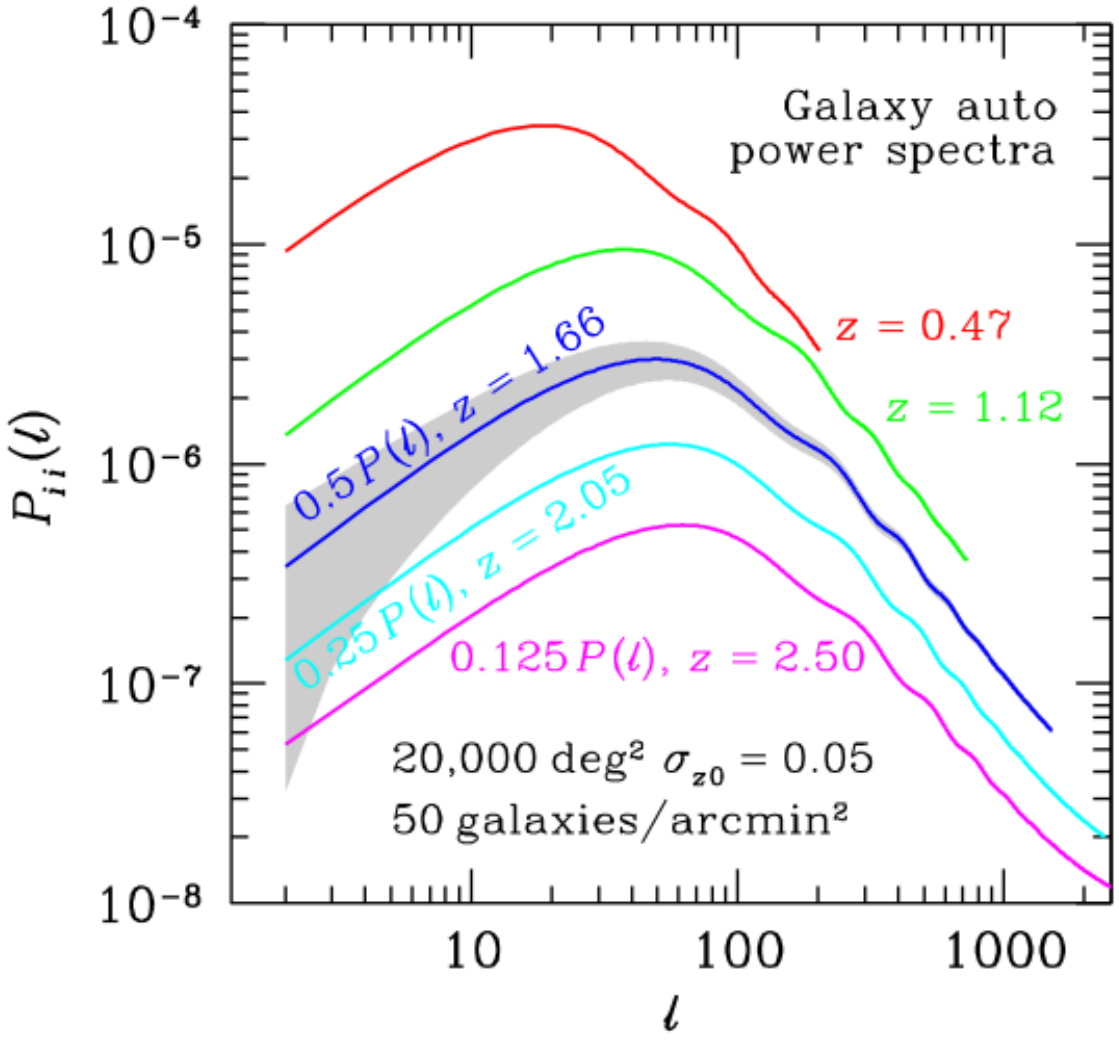
- Champ total : 20 000 deg.^{2}
- Poses courtes (2x15s) petit temps mort (2x2s)
  - ✓ Système d'alerte rapide (60s) pour phénomènes violents
- Retour sur chaque région du ciel toutes les 4 nuits durant 10 ans.
- Environ 10^{10} étoiles: r_{lim}=27.8 après addition des ~1000 images
- Environ 10^{10} galaxies: r_{lim}=27
  - ✓ Redshifts photométriques pour 0<z<4
  - ✓ Transmission atmosphérique en temps-réel pour prise de vues par « tous temps »

The Science Opportunities are Summarized in the LSST Science Book

- **Contents:**
  - Introduction
  - LSST System Design
  - System Performance
  - Education and Public Outreach
  - The Solar System
  - Stellar Populations
  - Milky Way and Local Volume Structure
  - The Transient and Variable Universe
  - Galaxies
  - Active Galactic Nuclei
  - Supernovae
  - Strong Lenses
  - Large-Scale Structure
  - Weak Lensing
  - Cosmological Physics

Dark Energy

Galaxy Angular Auto Power Spectra with Baryon Acoustic Oscillations



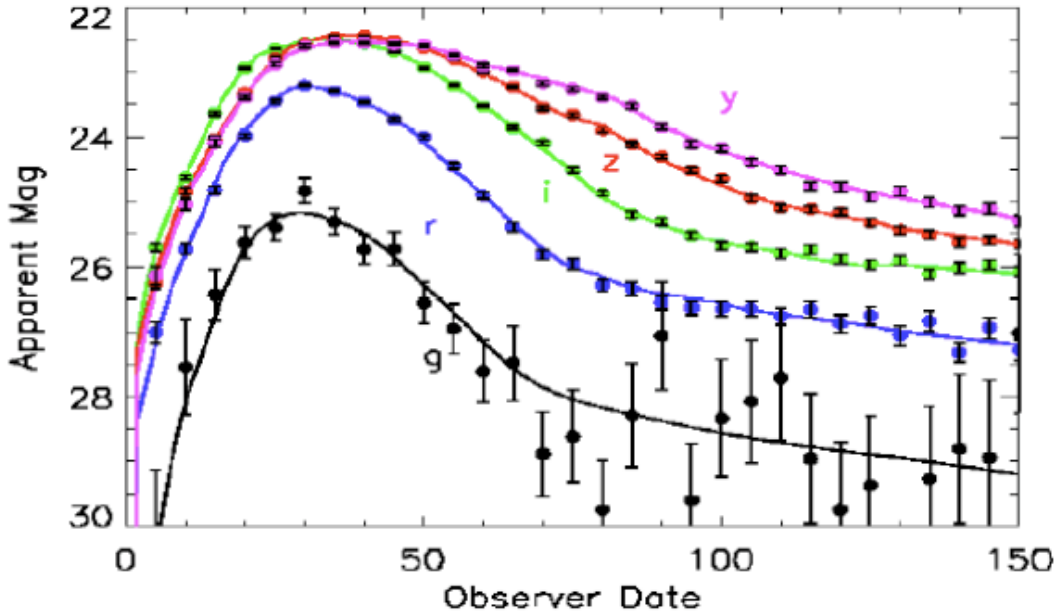
Assumed photometric redshift errors: **$\sigma_z = 0.05(1 + z)$**.

BAO features are prominent at multipole ℓ of several 100's.

Gray area indicates the statistical error (cosmic variance and shot noise) per multipole for z = 1.66.

SN: Projection LSST

250 000 SNIa @ z<1 par an



Courbes de lumière simulées d'une SN1a @ z=0.832

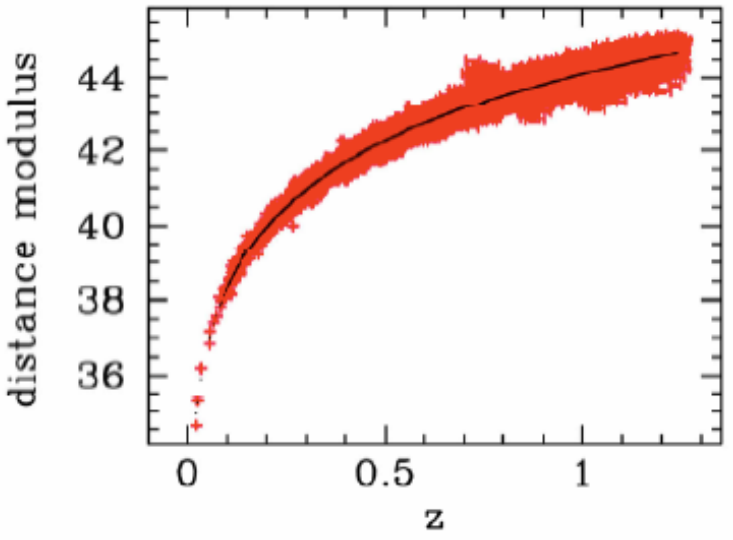


Diagramme de Hubble attendu pour 30 000 SN1a avec z par photométrie + fit de courbe de lumière

Combinaison de contraintes

Mesure de paramètres de l'équation d'état de l'énergie noire:
$p/\rho = w_0 + w_a(a(z)-1)$

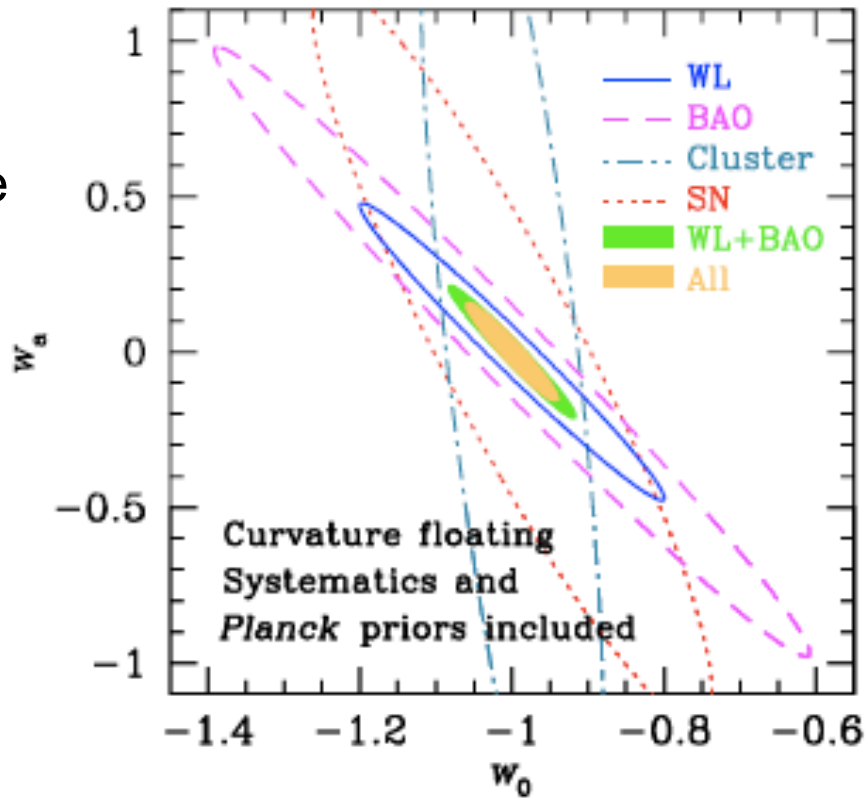


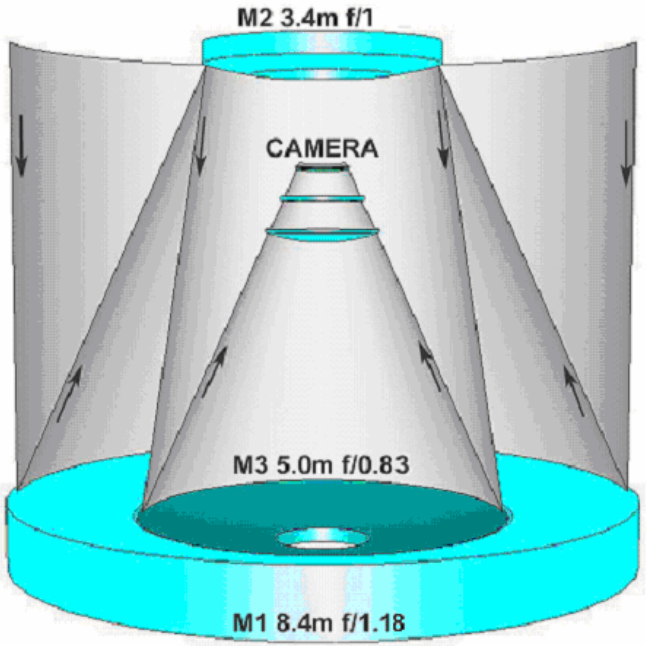
Figure 15.3: Joint w_0–w_a constraints from LSST BAO (dashed line), cluster counting (dash-dotted line), supernovae (dotted line), WL (solid line), joint BAO and WL (green shaded area), and all combined (yellow shaded area).

Summary of High Level Science Requirements

Large Synoptic Survey Telescope

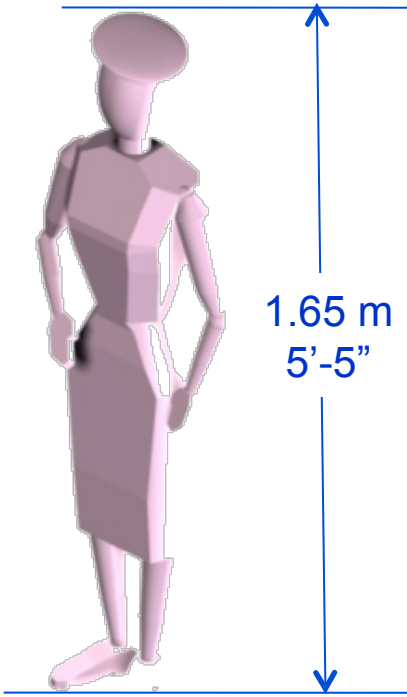
Survey Property	Performance
Main Survey Area	18000 sq. deg.
Total visits per sky patch	825
Filter set	6 filters (ugrizy) from 320-1050nm
Single visit	2 x 15 second exposures
Single Visit Limiting Magnitude	u = 23.9; g = 25.0; r = 24.7; I = 24.0; z = 23.3; y = 22.1
Photometric calibration	< 1% repeatability, absolute, & colors
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	< 60 sec after last visit exposure
Data release	Full reprocessing of survey data annually

M1M3 Fabrication in Process

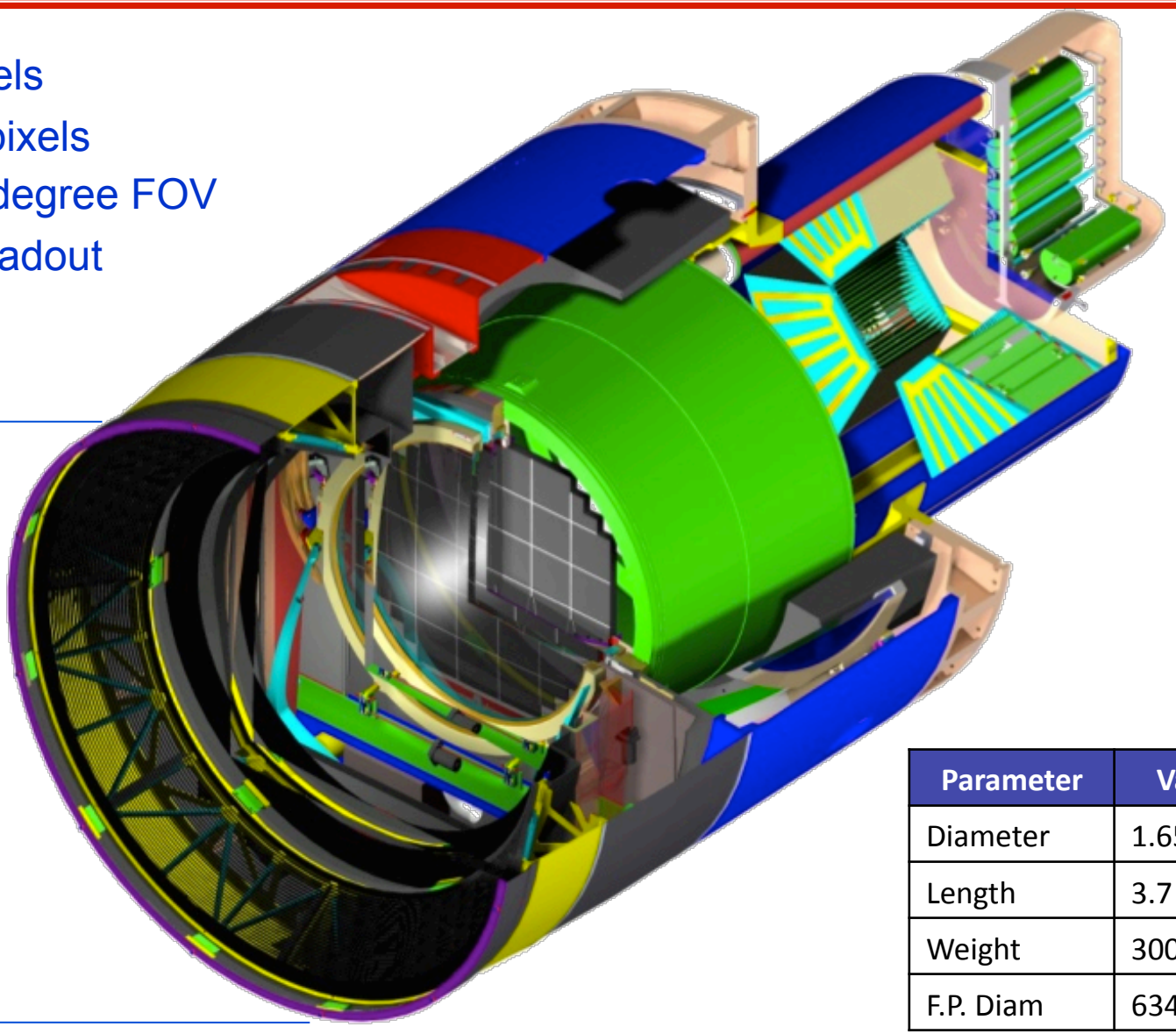


Camera Overview

- 3.2 Gigapixels
- 0.2 arcsec pixels
- 9.6 square degree FOV
- 2 second readout
- 6 filters



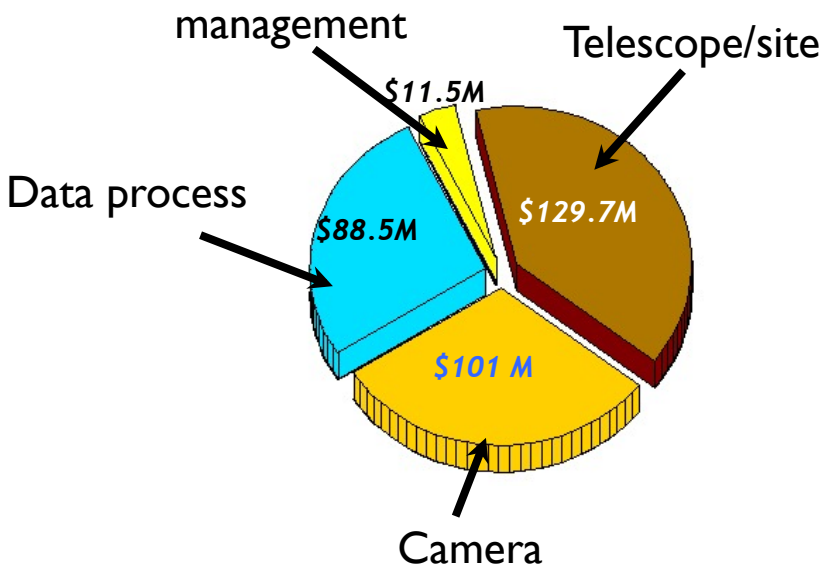
1.65 m
5’-5”



Parameter	Value
Diameter	1.65 m
Length	3.7 m
Weight	3000 kg
F.P. Diam	634 mm

LSST : Planning / coût

- 2008-2012: R&D
- 2012-2018 : Construction
- 2018-2028 : Observations
- Telescope/site : 130 M$
- Camera : 100 M$
- Data Proc : 88 M$
- Operation ~ 30 M$ / an



LSST collaboration

Brookhaven National Laboratory
California Institute of Technology
Google Corporation
Harvard-Smithsonian Center for Astrophysics
Johns Hopkins University
Las Cumbres Observatory
Lawrence Livermore National Laboratory
National Optical Astronomy Observatory
Ohio State University
Pennsylvania State University
Princeton University
Research Corporation
Stanford Linear Accelerator Center
Stanford University
University of Arizona
University of California, Davis
University of Illinois
University of Pennsylvania
University of Washington

+… french connection

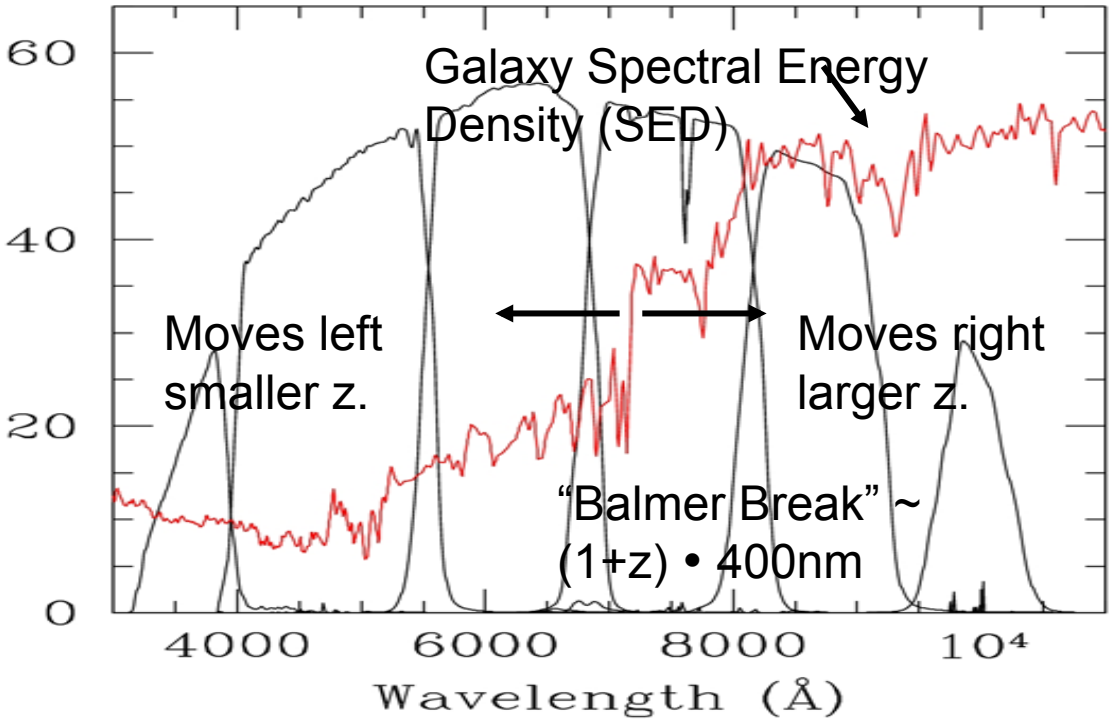
La France dans LSST (1er état non-US)

- **IN2P3: APC, LAL, LPNHE, LPSC, LMA, CC-IN2P3, CPPM**
- **INSU: APC**
- **Science**
  - **Oscillations acoustiques de Baryons (LAL, LPSC, APC)**
  - **Supernovæ (LPNHE, CPPM)**
  - **Weak lensing (APC)**
  - **Amas (APC)**
  - **Matière cachée (LAL) recherche de matière transparente par scintillation**
- **R&D**
  - **Electronique de lecture**
  - **senseurs (CCD)**
  - **filtres**
  - **systèmes de changement de filtres**
  - **calibration**
  - **slow control**
  - **organisation/traitement de données**

2 challenges

- **Redshifts photométriques**
-mesure du redshift avec un spectromètre à très basse résolution (6 pas)
    - Nécessite une excellente résolution photométrique (<1% à mag=27.7)
- **Corrections d'absorption atmosphérique**
- calibration

=> **Fil conducteur en France**: précision photométrique/calibration



R&D France (1)

Mécanique

- Dispositifs de changement de filtres

Filtres

- multicouches minces

Capteur CCD

- Participation à la définition des spécifications et aux tests de pré-prototypes

Electronique

- R&D du circuit de lecture (ASIC)
- Bancs de test à chaud et à froid

R&D France (2)

Calibration (APC, LPSC, APC)

- Calibration photométrique
- Calibration atmosphérique: mesure de la transmission atmosphérique $\tau[\lambda, t, (\alpha,\delta)]$
- Calibration optique + caméra (avec source)

Slow control (APC)

- commande opérations caméra

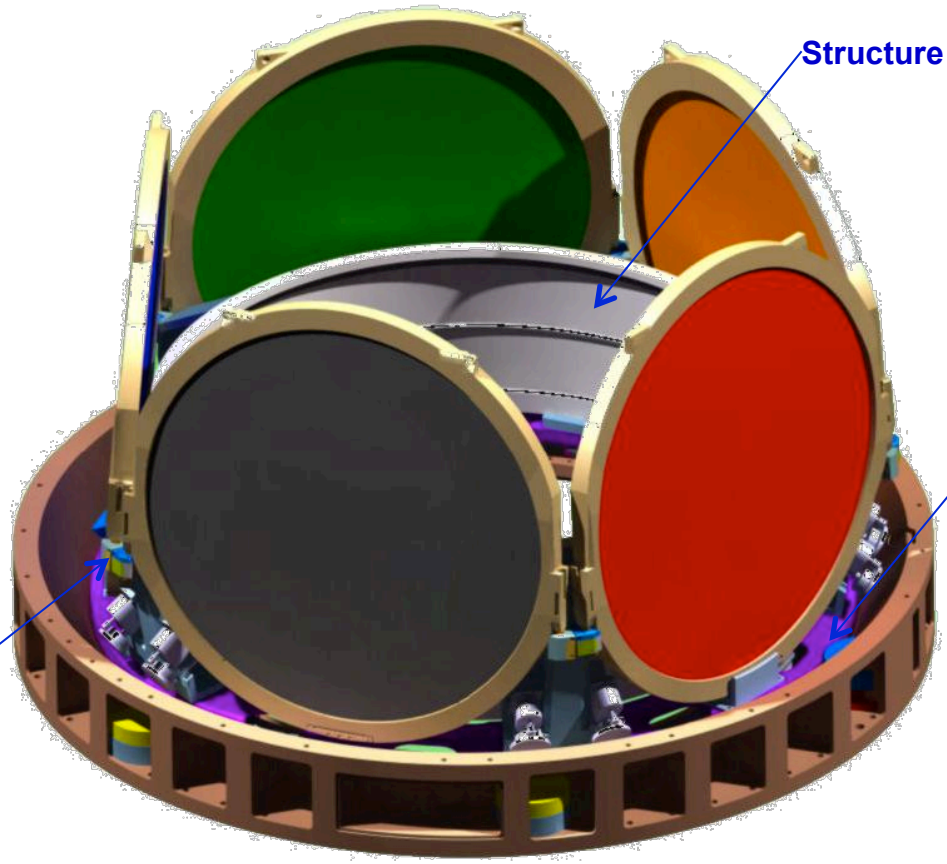
Traitement/manipulation de données (LAL, LPNHE, CC-IN2P3)

~ 20 Tbytes/jour pendant 10 ans

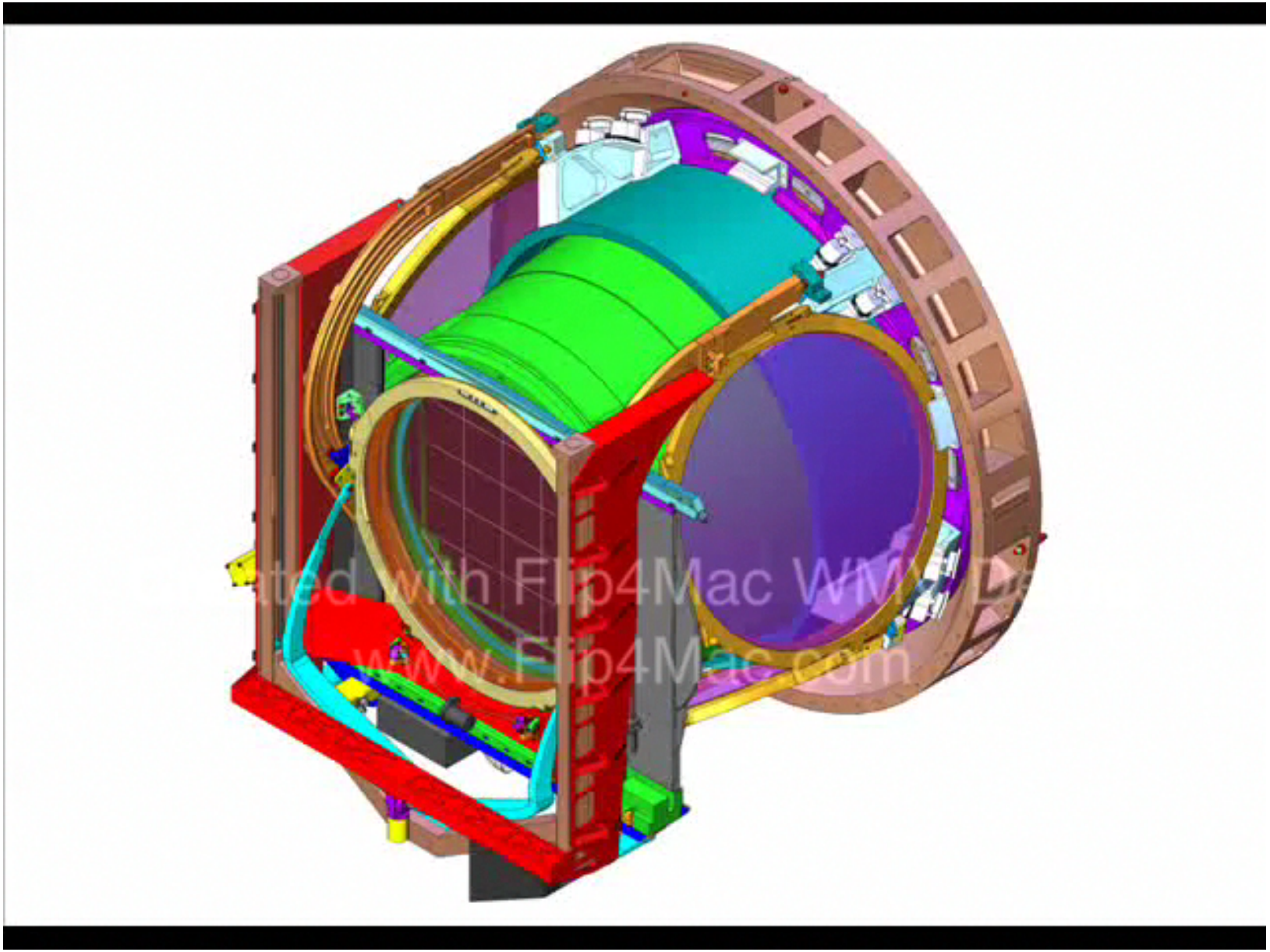
R&D Carousel

- **People Involved (Coordination : G. Daubard / P. Antilogus)**
  - **LPNHE Laboratory : Bertoli Walter, Daubard Guillaume, Evrard Christophe, Orain Yann, Vincent Daniel & « work shop »**
- **R&D goals : Provide a fully operational system for design validation and aging study.**

Base line
from LPNHE
for CoDR sept.
2010

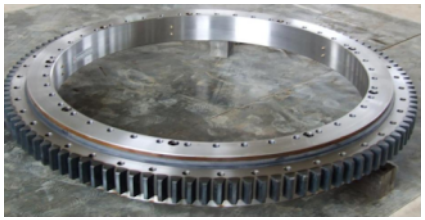


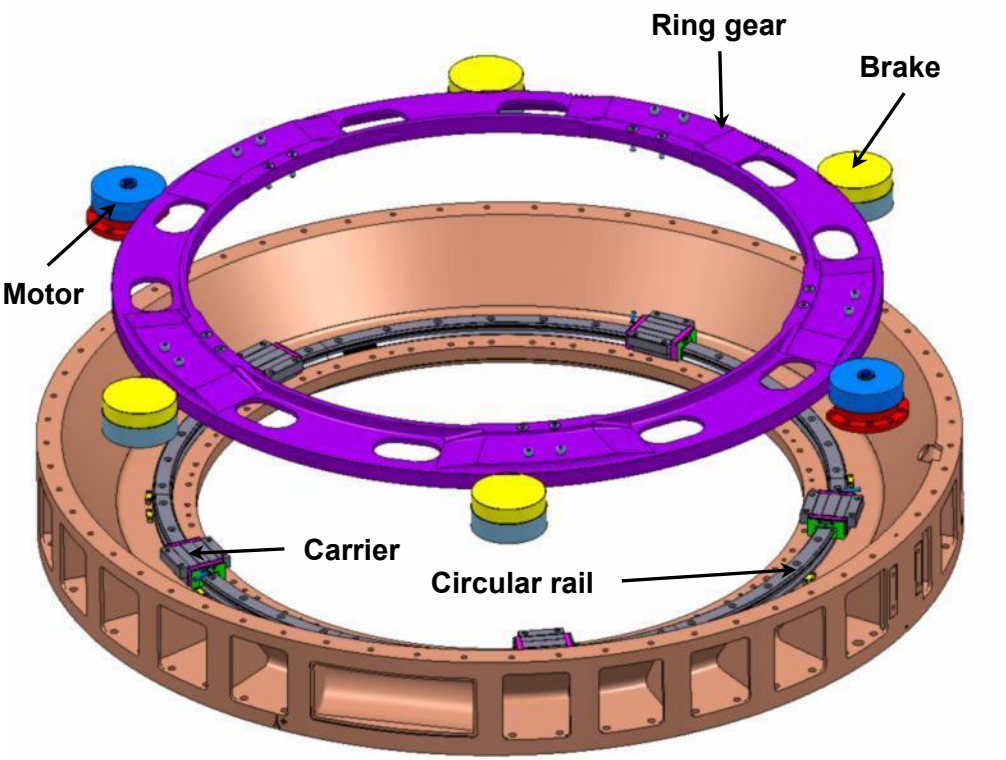
Changement de filtres



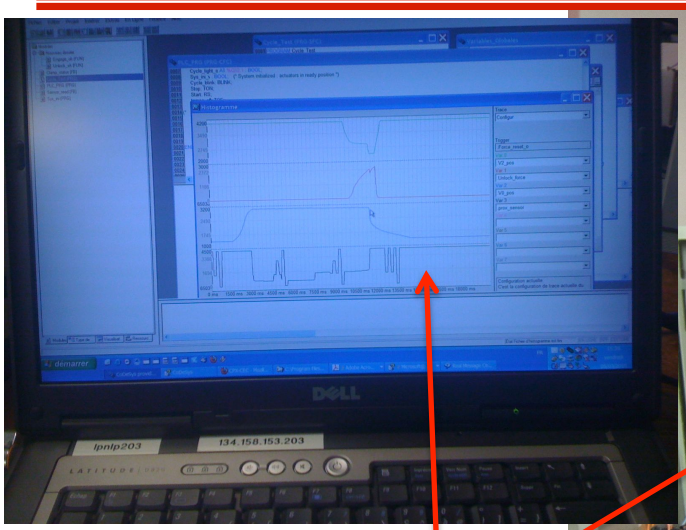
Guiding and Driving Systems

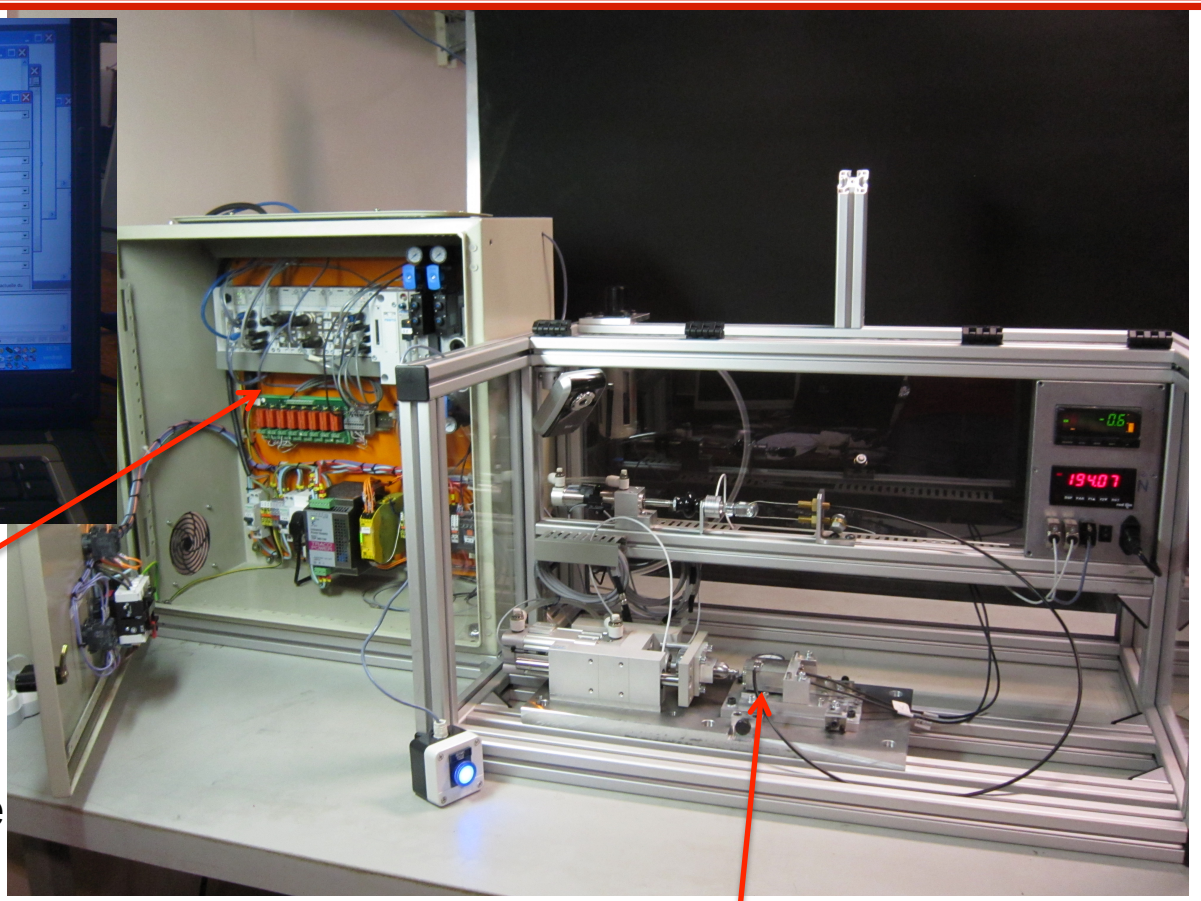
- **Design baseline**
  - **Circular rail fixed on camera flange + carriers as guiding system**
    - Ordered (Nov. 2008) and delivered (Feb. 2009)
  - **Ring gear fixed on the carriers for driving carousel**
    - **Gear teeth Validated (Jan 2011)**
  - **Driving mechanism**
    - **New baseline (Mar 2011)**
  - **Brake and blocking mechanism**
    - **New baseline (Mar 2011)**
  - **Encoder**
    - **Study need to be completed**





Clamp test bench & 3rd clamp generation





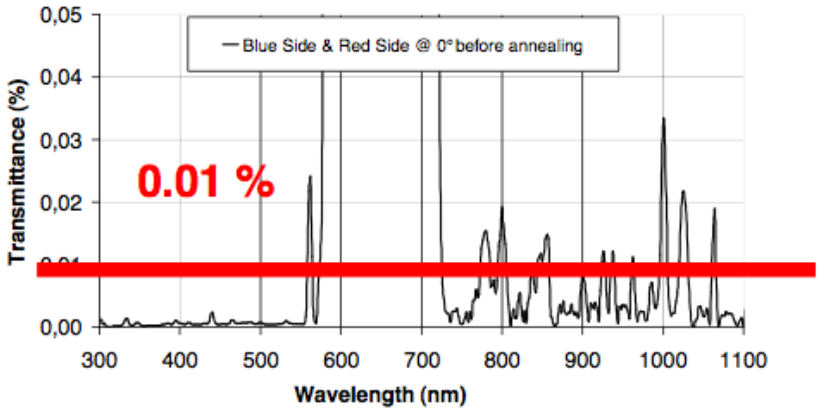
Control & measure :
-The Strength hold by the clamp
-The strength needed to unlock it
-The status of the clamp probes

Clamp system

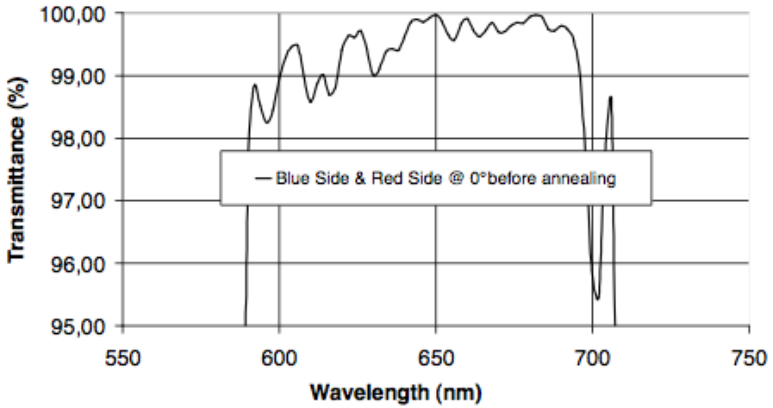
R&D Filters

- People Involved (Coordination: / R. Flaminio / N. Morgado)
  - Laboratory of Advanced Materials (LMA) : Flaminio Raffaele , Forest Danièle, Michel Christophe , Montorio Jean-Luc, Morgado Nazario , Pinard Laurent , Sassolas Benoît
  - Challenge: 76cm filters with >95% transmission in band; <0.01% out; ~6nm transition
  - Internal R&D at LMA on thin layers design : studies and production in small coating machine
- Three (small) filters studied at LMA (R, U, Y)
  - Requirements looks tough
  - Need to better understand impact on science and make compromises

Rejection Band



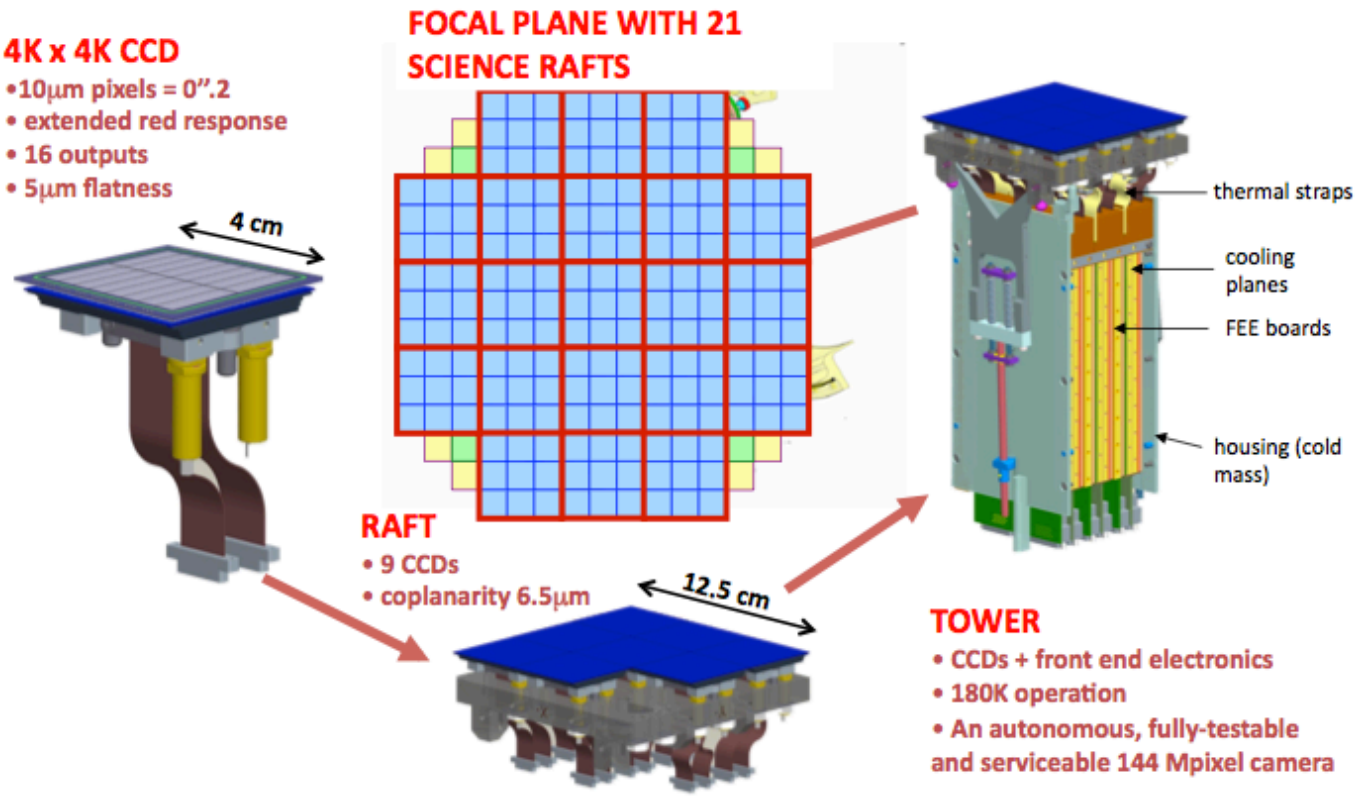
Pass-Band



CCD

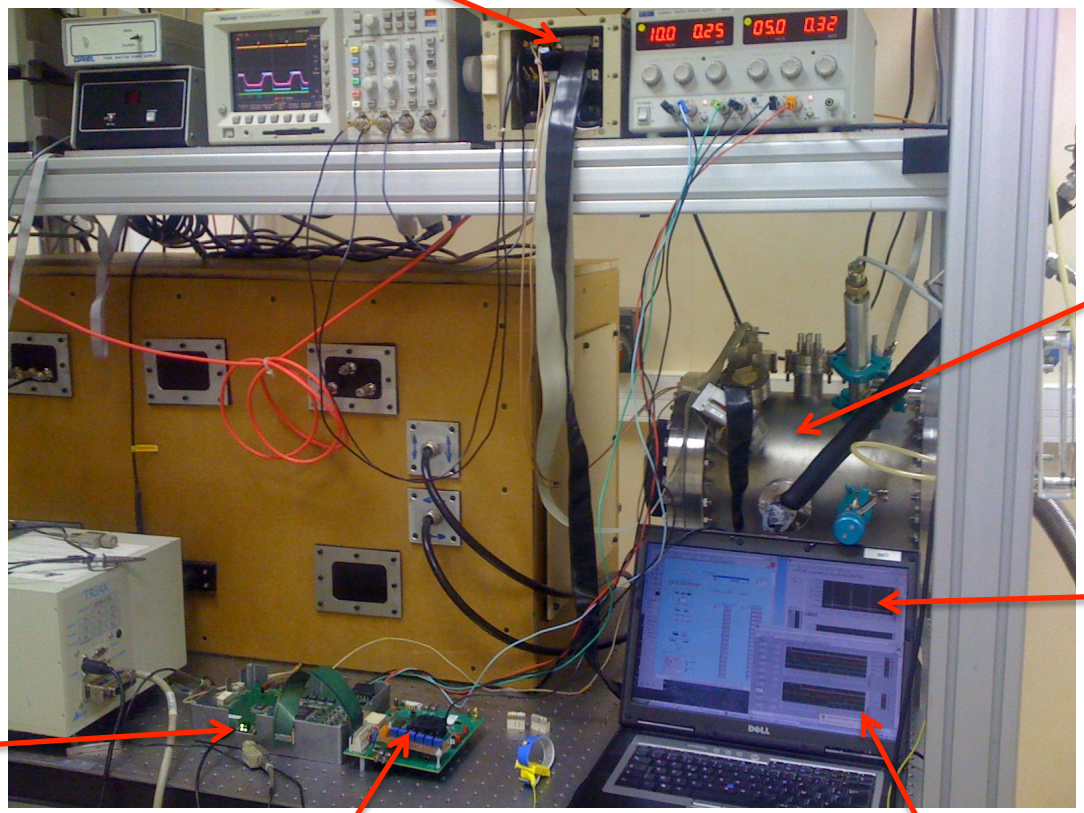
- **People Involved (Coordination : P. Antilogus / C. Vescovi)**
  - **CCD test bench/characterization at LPNHE : Antilogus Pierre, Bailey Stephen, Bertoli Walter, Hornero Emmanuel, Juramy Claire, Lebbolo Hervé,Martin David, Sefri Rachid, Vallereau Alain, Vincent Daniel**
  - **CCD R&D (E2V) : Antilogus Pierre (LPNHE) , Vescovi Christophe (LPSC)**

- **Goals :**
  - **Contribute to the e2v prototype studies/characterization**
  - **Study/design the CCD characterization/ manipulations plan in the labs during the construction phase (within the French contribution to the CCD for the LSST construction)**



CCD & LSST readout chain (room temperature and -100°C)

SDSU , used to clock the CCD (2.9 µs / pixel implemented for the moment to compare to LSST readout baseline 2 µs / pixel)



Cryostat with e2v CCD 47-10 (1k x 1k , 2 amps ccd)

Back End Control & Readout

Back End Card With ADC18 bits (AD7982)

ASPIC II (Warm card)

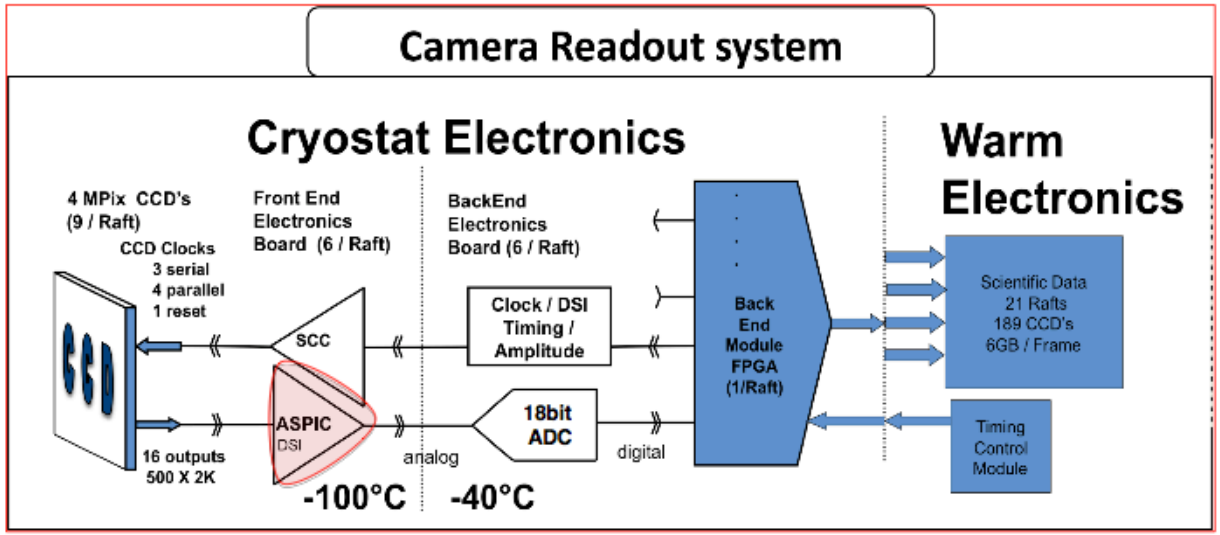
ASPIC clocking

ASIC for CCD readout : ASPIC (Analog Signal Processing asIC)

- People Involved in Orsay (LAL) and Paris (LPNHE) (Coordination : V. Tocut / M. Moniez)
  - Micro-Electronics : V.Tocut , H. Lebbolo, R.Sefri
  - ASPIC Tests : P. Antilogus, S. Bailey, J. Jeglot, C.Juramy, D. Martin ,M. Moniez ,F. Wicek
- Construction goal: ~500 low-noise (1e-), fast circuits (500 KHz) of 8 channels for parallel readout of CCDs, fully tested

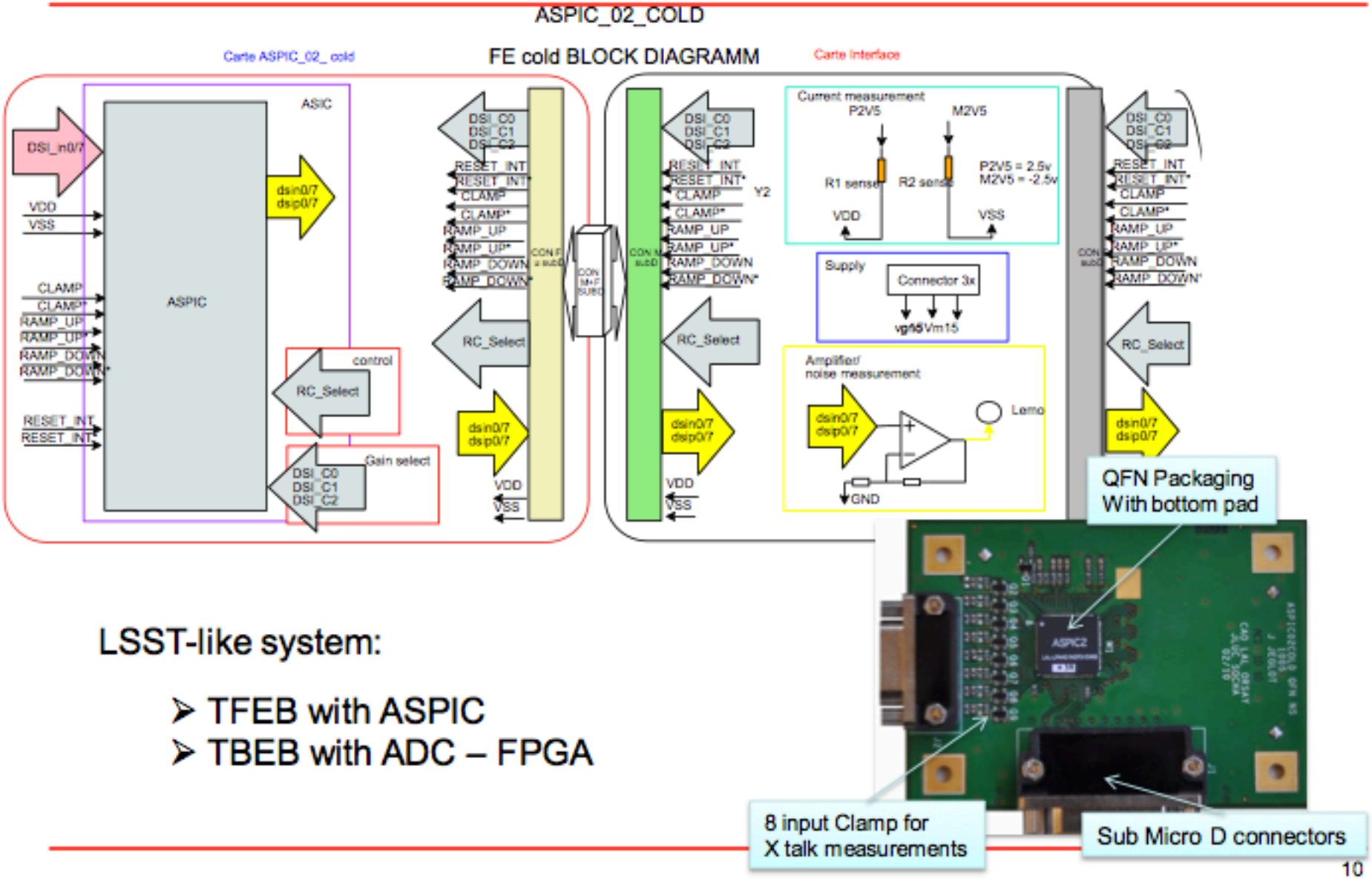
- **Achieved** :
  - **2 ASIC prototypes**, requirements satisfied by ASPICII (end 2009)
  - Test bench to qualify / study ASPIC channels at room temperature and at -100°C
- **2011- further developments** :
  - Plans to extensively test the ASPIC with a CCD.
  - Possibly build a prototype camera mounted on a telescope
  - An ASPIC III will be designed and build , with a working nap mode and a few changes (fine tuning from properties of CCD prototypes).

LSST camera readout system



189 Science CCD x 16 outputs = 3024 readout channels
→ compact readout chain inside the cryostat

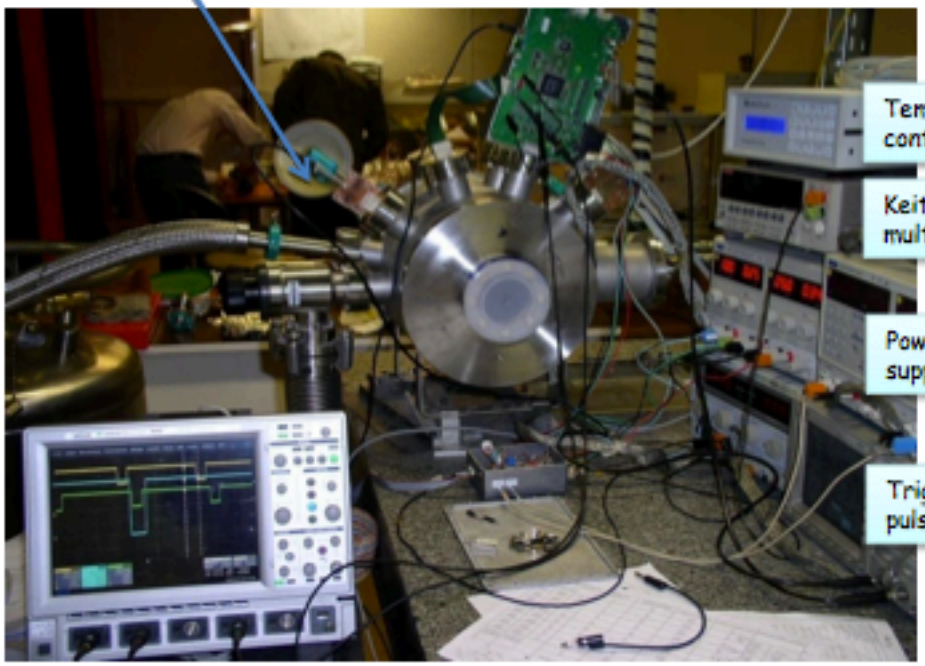
ASPIC test bench



LSST-like system:

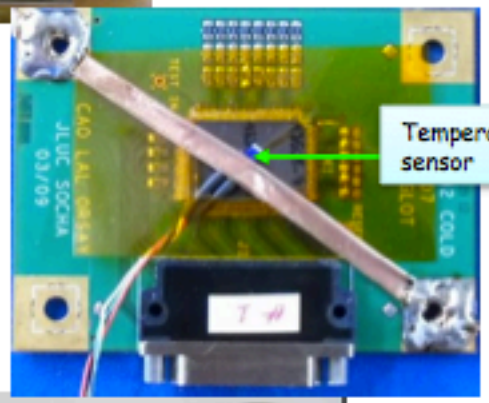
- TFEB with ASPIC
- TBEB with ADC – FPGA

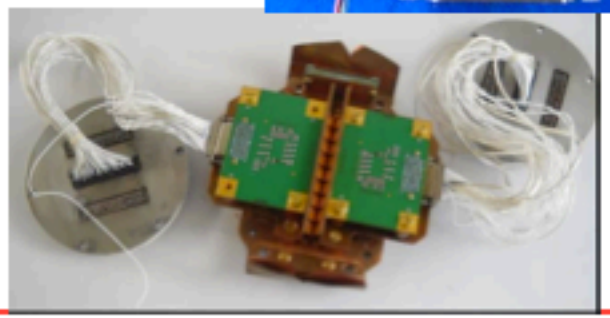
ASPIC test bench



LPNHE

LAL



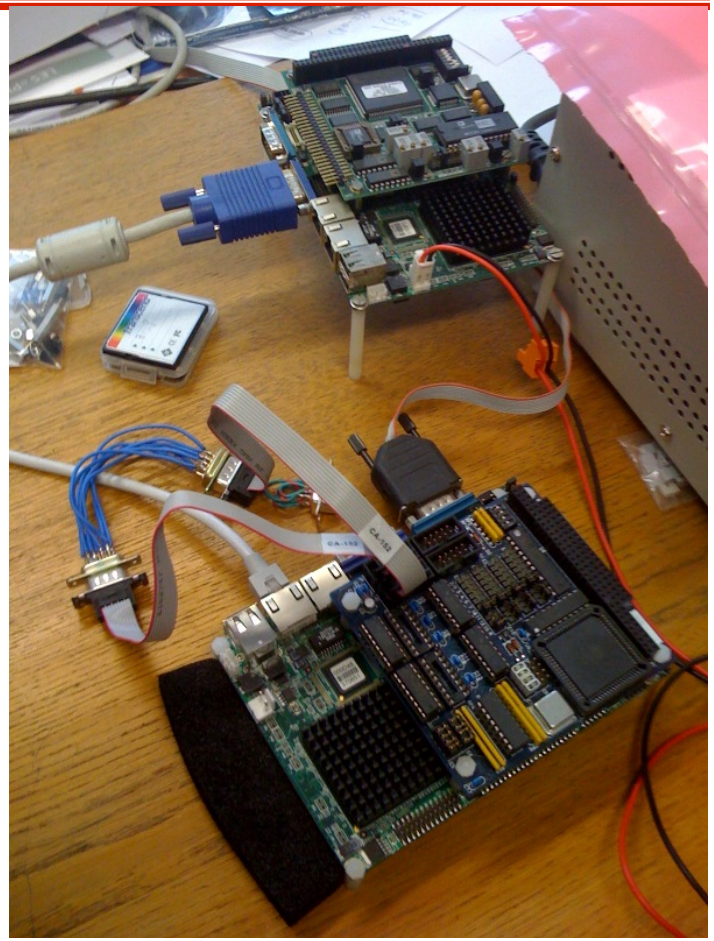


ASPIC results summary

	Nominal Specs	Results
Power dissipation @ 173K	25mW	25mW (2mW in idle mode)
Gain	5	6
Linearity (full well scale)	0.5%	0.3%
Noise @ 173K – Gain 5	7µv	4.8µV (5.9µV @ 296k)
Noise @ 173K – Gain 2.5	No Specs	6µV (8.8µV @ 296k)
Crosstalk	0.05% max (0.01% goal)	0.02%

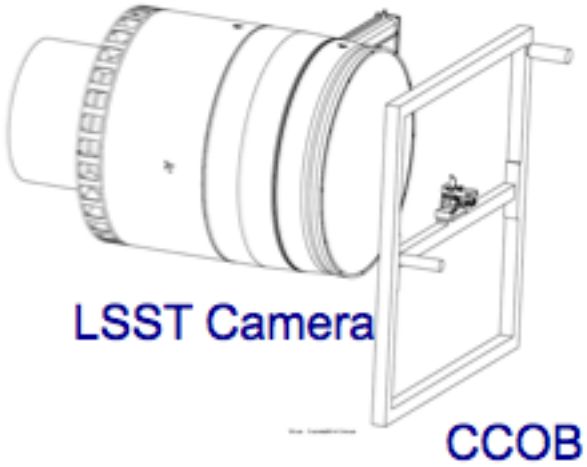
CCS (Control Command)

- **People Involved (Coordination : E. Aubourg)**
  - **APC Laboratory : Aubourg Eric, Guglielmi Laurent, Virieux Françoise, 1 CDD starting in July 201**
- **Achieved with P2I support :**
  - **Spring 2008 : implemented a demonstrator using 2 PC104 under linux and Java**
- **R&D goals :**
  - **CCS (Camera Control System) :**
    - Defined/finalized the architecture / communication frame work
    - Design a Skeleton for the subsystems
  - **FCS (Filter Changer System) :**
    - Use the FCS as a R&D/example for the subsystems (Collaboration in Paris APC/LPNHE)
    - Implement a carousel simulator to feed the FCS in a first stage
  - **CCOB (Camera calibration Optical Bench) :**
    - **Provide support to LPSC/Grenoble to implement this subsystem**

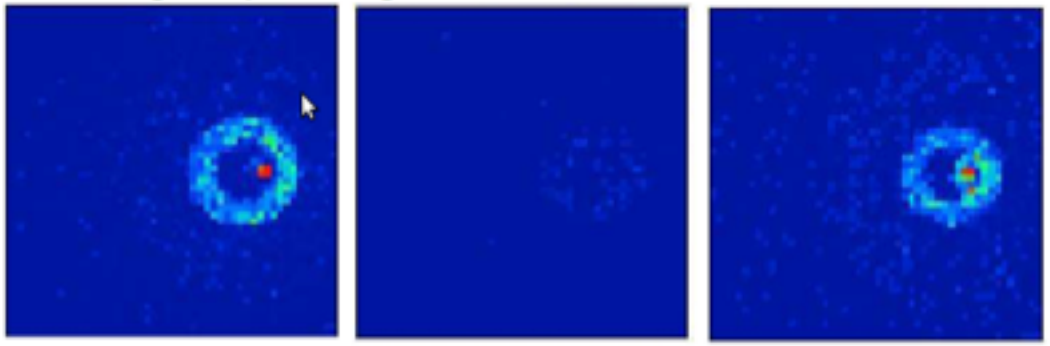


CCOB : LSST Camera Calibration Optical Bench

- **People Involved** (Coordination : A.Barrau /M.Migliore)
  - LPSC Laboratory : Barrau Aurélien, Beaumont Sylvain, Derome Laurent, Migliore Myriam, Gorecki Alexia, Perbet Eric , Vescovi Christophe
- **Function** : The function of the Camera Calibration Optical Bench (CCOB) is to provide "first light" for the LSST camera, to perform a global commissioning of the camera and to calibrate the response of the focal plane array (FPA) and refractive optics system while the camera is dismounted from the telescope.
- **Achieved :**
  - Implementation of optical test bench facilities to validate the proposed CCOB design
  - A first version of the PDR for the CCOB has been submitted to the camera calibration team summer 2009
  - A complete analysis (analytical and simulation with zemax) has been implemented to study the images ghost generated in the camera



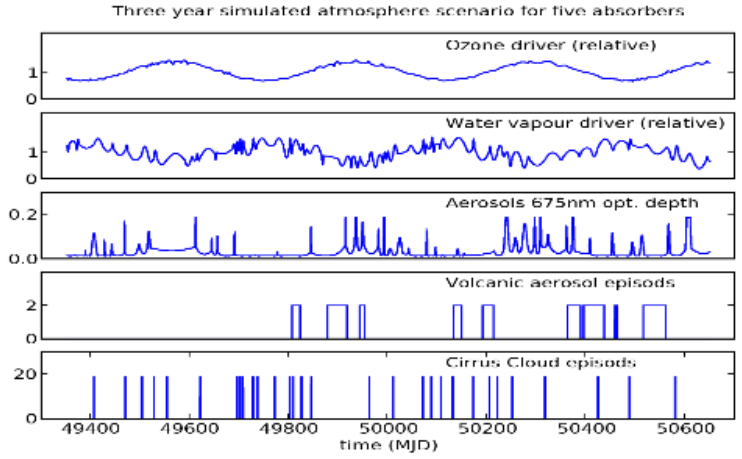
CCOB performances simulations
Ghost Simulations
Wavelength dependent ghosts

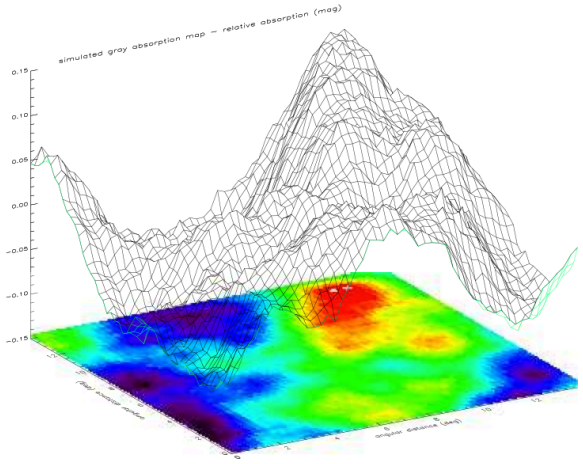


« blue » edge | filter center | « red » edge

R&D LSST : Photometric Calibration

- **APC: J.G. Bartlett, G. Bazin, G. Blanc, A. Boucaud, M. Crézé , Y. Giraud-Héraud , C. Portello-Roucelle .**
- **Lead on WP4 for the Calibration Simulation**
  - **Atmospheric modeling**
    - Atmospheric extinction spectra for LSST pointings. Simulated spectra, first code and documentation elements delivered:
      - 2 atmospheric scenarios for 3 years of LSST operations
    - Gray (cloud) extinction effects
      - In progress. Crucial for auto-calibration studies
  - **Auxiliary Telescope (AT) operations simulator**
    - Elements of AT simulator in place
- **Participation in Auto-Calibration studies and algorithmic development and evaluation**





LSST Will Produce an Enormous Data Volume – Challenging Current Database Technologies

- **The raw data from the camera will comprise ~ 30 Terabytes per night.**
- **Over ten years, the database will grow to ~ 200 Petabytes.**
- **The catalogue alone will be trillions of lines long!**

R&D LSST-France : Computing

- **CCIN2P3 D.Boutigny / J-Y Nief**
  - **Follow-up of the computing activities in connection with SLAC – NCSA – SDSC etc.**
  - **Contribution to the working group on data transfer**
  - **Contribution to the data challenge in 2007**
  - **Contribution to a large challenge at Super Computing 2008 (Austin / Tx) → Final !**
    - Simulation of the data management of LSST between multi-site . The CC-IN2P3 was the «telescope »
    - Demonstrated than the LSST infrastructure proposed is able to handle 9.10^{18} files with hierarchical rules .
  - **Contribution to the data challenge in 2010 (100 TB of disk on the network using iRods)**

- **The CC-IN2P3 is highly interested to contribute to the challenge related to the LSST data management . It's willing to be highly involved at this level.**
- **The design of the new computer room at ccin2p3 take into account LSST storage need at the horizon 2015. The « first stone » ceremony for this building was last Tuesday (June 8th 2010) .**

Illustration : Cabinet Unanime Architectes
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Rapport qualité/prix

- ~ 20 FTE dont 5 FTE physiciens engagés dans les actions de R&D en 2010
- Dépenses du budget P2I par poste / résultats
  - **Mécanique filtres: 25 K€ / la France livrera le système changeur de filtres**
  - **Electronique: 35 K€ / l'ASIC sera livré par la France et nous sommes sollicités pour d'autres éléments (commande CCD)**
  - **CCD: 25 K€ / la France devrait contribuer à 25% aux tests des CCD**
  - **Slow-control: 15 K€ / design français adopté, co-responsabilité**
    - Total P2I: **100 K€** attribués à un moment critique pour LSST-France (pour mémoire, total dépensé de 2008 à 2011: 1.06 M€)
- Opérations couronnées de succès
  - **reconnues au niveau de LSST-corp.**
  - **« récompensées » par 30 accès IN2P3**
  - **Un représentant au board directorial**
- **Suite des opérations: construction -> 2018, puis récolte scientifique de 2018 à 2028. Préparation de la science en parallèle (1 postdoc P2I en 2008-2010)**