LSST

Téléscopes grand champ
Etude de l'Energie Noire

-Pour une Contribution de l'IN2P3 à la construction de LSST-

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(PI LSST-France)

Conseil Scientifique de l'IN2P3 , 25 Octobre 2012

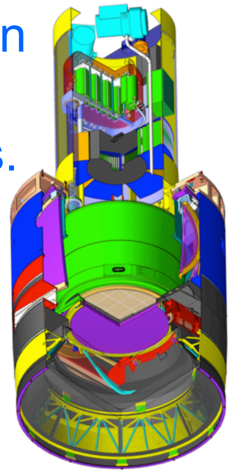
LSST Overview

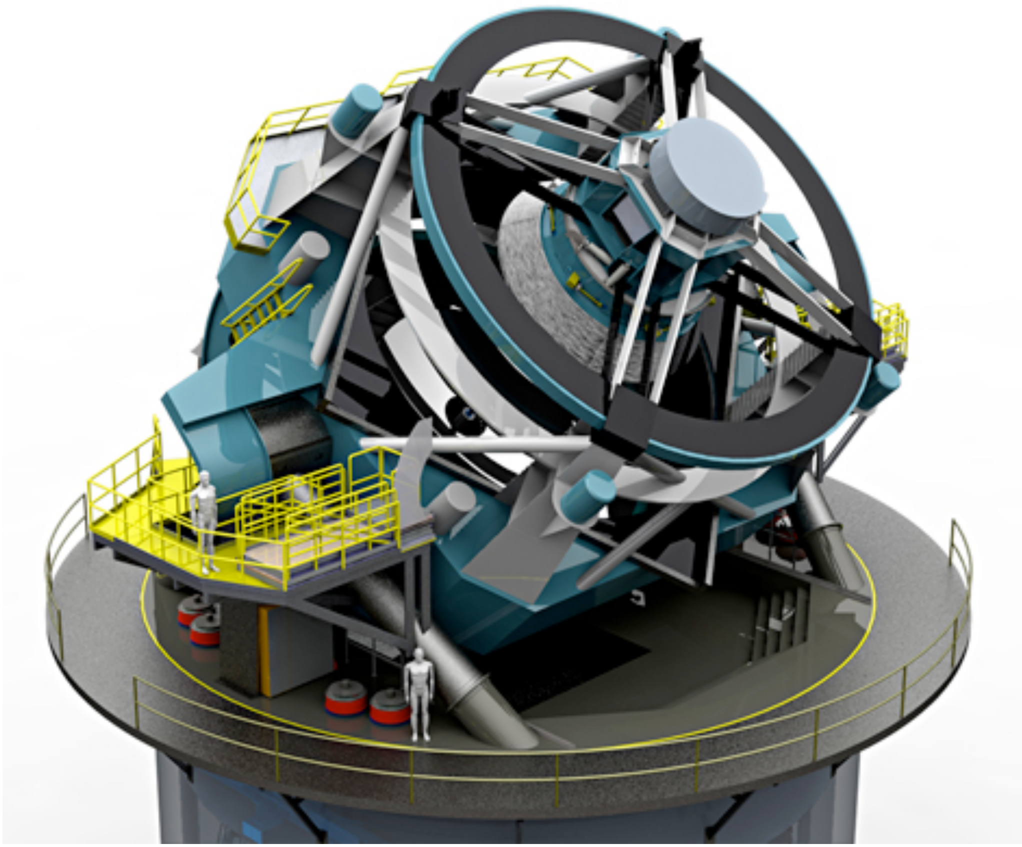
LSST = an instrument (=a Telescope + a Camera)

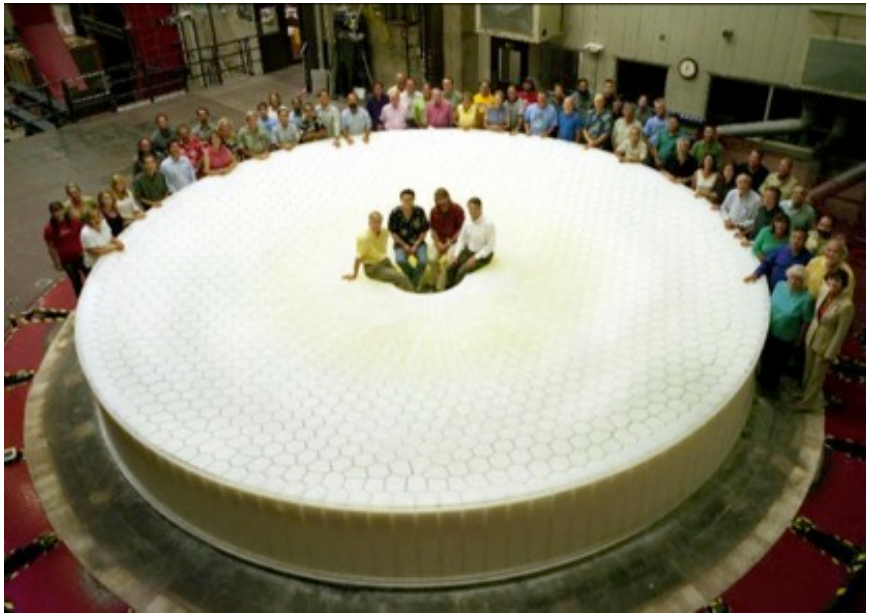
100% dedicated to a continuous ½ sky survey planned over 10 years

Large Synoptic Survey Telescope

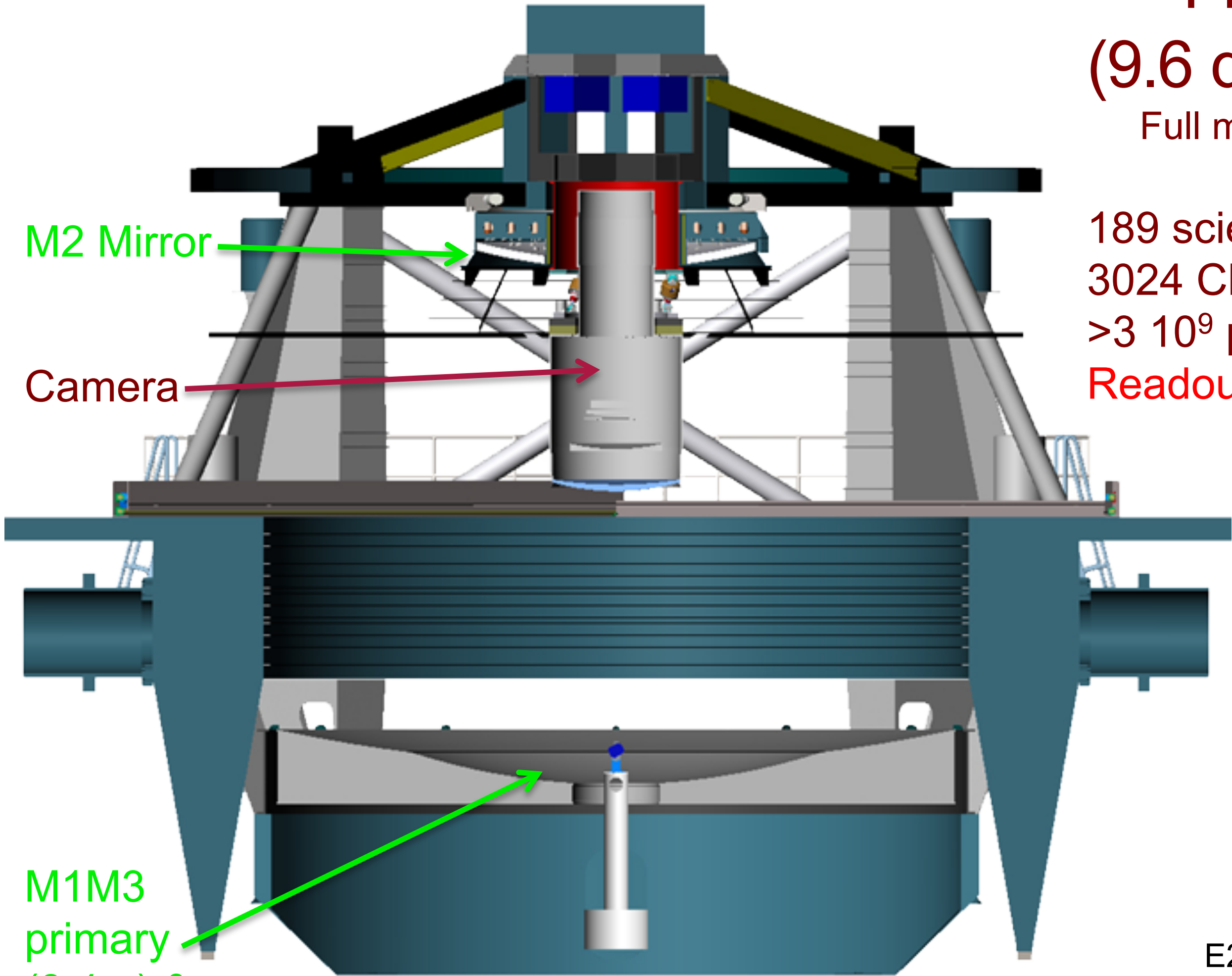
The LSST survey / data = enormous variety of complementary scientific investigations, based a common dataset / observation
An highlighted scientific domain :
the Dark Energy study through the access to the 4 DE probes.







LSST : Wide , Deep , Fast and Uniform sky survey



Moving Structure 350 tons
60 tons optical systems

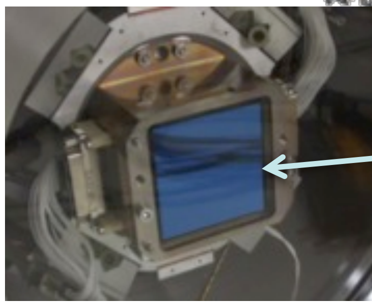
Field of view : 3.5 deg

($9.6\ deg^2$ =.023% sky sphere; all-sky= 44k deg^2)

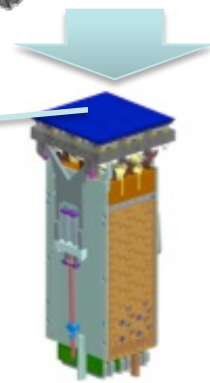
Full moon = 0.5 deg = $4.8\ 10^{-6}$ of sky sphere

Focal plane diameter : 64 cm

189 science CCD (21 rafts)
3024 Channels
>3 10^9 pixels
Readout: 2s



E2v CCD 250 ,
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed by Dedicated R&D for LSST



1 raft = 3x3 CCD
150 M pixels
(1/2 Megacam)

LSST concept : a single observation plan

6-band Survey:
ugrizy 320–1070 nm

Main Survey Area (Uniform Survey for DE study)
18,000 square degrees ~ ½ sky with 0.2 arcsec / pixel

Total Visits per unit area and Visits per filter :

	u	g	r	i	z	y
Nb Visit	70	100	230	230	200	200
1 visit mag	23.9	25.0	24.7	24.0	23.3	22.1
10 year	26.1	27.4	27.5	26.8	26.1	24.9

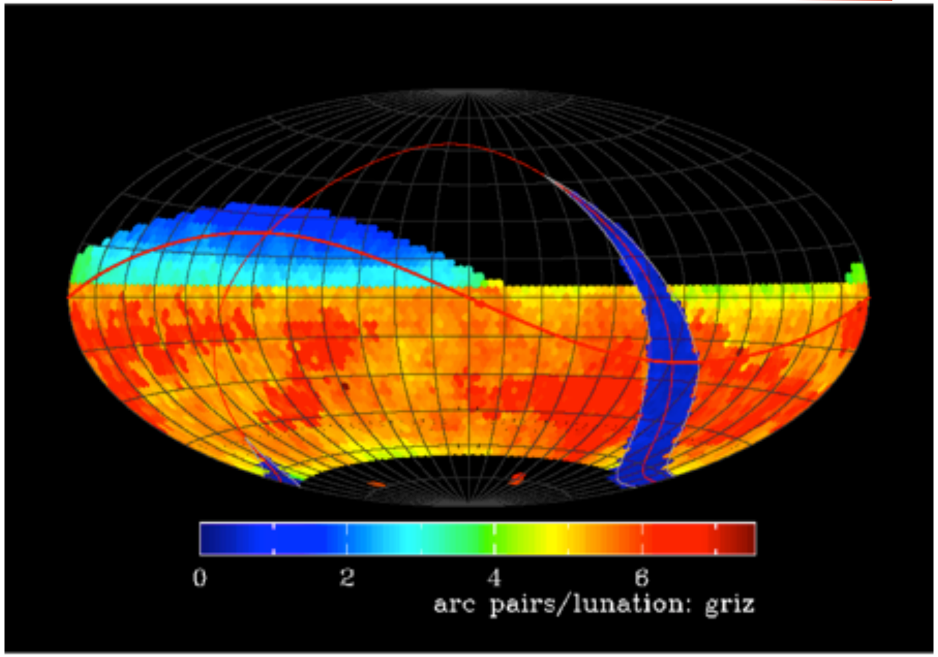
Deep drilling field (core of SNIa data for DE study) :
10% of the time / ~1h/night on 30 fields/300 deg sq

Total Survey Area : 27,000 square degrees

Image Quality
Median seeing at the site is ~ 0.6 arcsec
PSF FWHM < 0.4 arcsec (no atmospheric seeing).
PSF Ellipticity < 0.04
(referenced to 0.6 arcsec FWHM circular Gaussian)

Photometric precision:
0.01 mag absolute; 0.005 mag repeatability

Remark : calibration will be the key of the LSST success !



More than 2.5 10^6 visits & 5 x10^6 exposures
following the sequence:
15 s pose + 1 s shutter + 2 s read + 15 s pose
+ 1s shutter + 5s new pointing as reading
➔ **Points to new positions in sky every 39 seconds**

Temporal Visit Distribution in Main Survey Area
Revisit after 30-60 minutes
Visit pairs every 4 nights
3 pairs per lunation

LSST & Dark Energy

Goal → reduce by 1 order of magnitude the errors on DE equation of state.

Remark : give also constrain on modified gravity and neutrino mass

Method → Large sky Survey (1/2 of total sky) & deep (27.5 mag)

Statistic →

- at 27.5 Mag galaxy surface density ~ 40-50/sq. arcmin (~ ground limit) / 3 10^9 galaxies
- discovery > 10^7 SN over ten-year duration , > 10^5 good SNe Ia in the "deep drilling fields"

DE Observables : all of them within one survey, will minimize the impact of nuisance parameters

- Growth of structure : Weak Lensing & Galaxy Clustering
- Standard ruler : Baryon Acoustic Oscillations
- Standard candle : SuperNovae

Key issues

→ Systematic Errors :

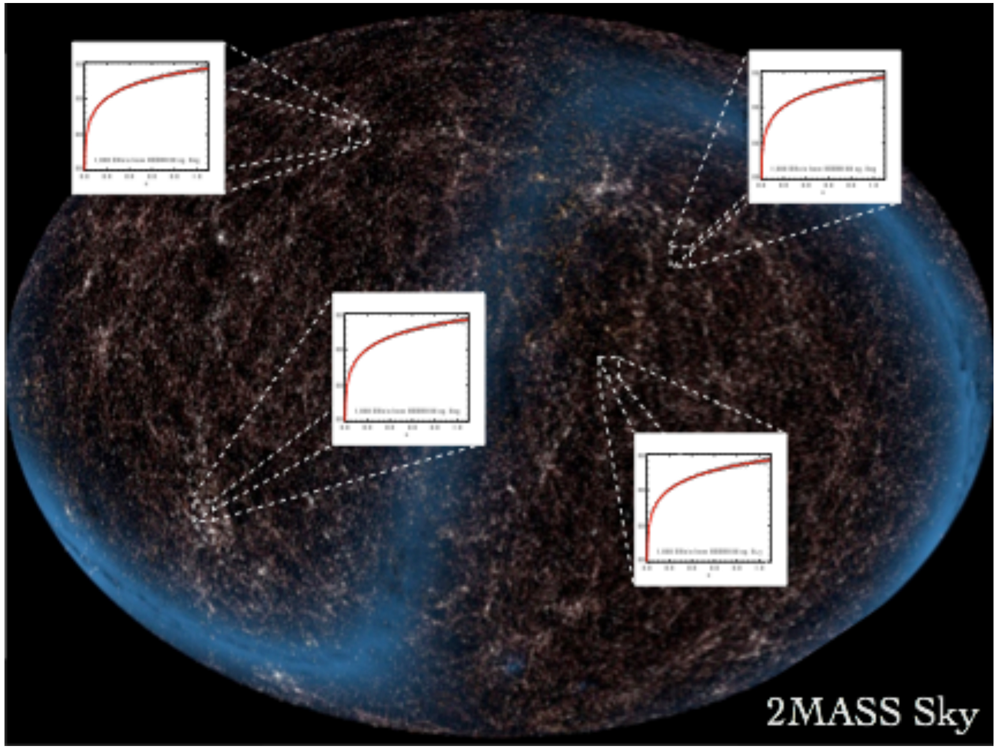
To control the weak-shear measure LSST plan to deconvolve the instrumental & atmospheric distortion by observing the same patch of sky ~1000 of time , each time with the same depth than Euclid .

→ Photometric red-shift :

The LSST multi-observation scheme is also a key in the survey photometric capability

LSST : examples of high statistic DE science with SN Ia

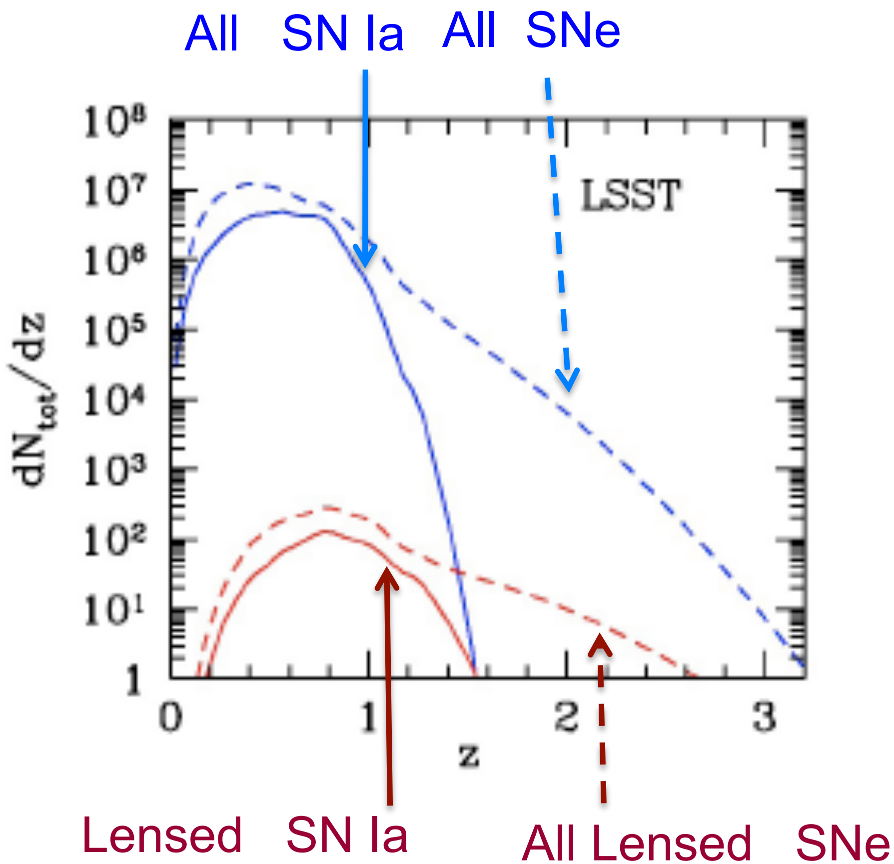
LSST will be able to probe the isotropy of the Dark Energy properties . For example the large SNIa statistic will allow to build SNIa hubble diagram for different directions in the sky…



LSST will provide time-dependent imaging of an unprecedented sample of rare strong gravitational lensing events.

➔Strong lensed SN Ia

= sensitive to H(z) at the lens location



LSST & IN2P3 :
Overview

LSST : Project & Collaboration

- 2003, LSST = international collaboration , multi-agencies :
  - NSF main agency : in charge of telescope , site & data management
  - DOE in charge of the camera (Leading lab : SLAC)

- August 2010, LSST selected by « Astro2010 » as THE ground project for next decade :
  - NSF & DOE in the US and IN2P3 in France moved on to include LSST in their programs
  - LSST passed with success major review in 2011 (PDR in August et CD-1 en November)
  - DOE (April 2012) and NSF (July 2012) signed to bring LSST to construction ; LSST has a calendar : start construction 2014 + first light 2019 + start science 2020

- IN2P3 , for its contribution to the camera, & Chile, for the site, are the only non-US among the 36 LSSTc core institutions . Some level of data access is also foreseen to a larger non-US community in 2021 , it will help to cover running cost : 67 letter of intent received for ~ 500 non-US scientists at 20 k$/year/scientist (total ~ 10 M$/year) , on top of the ~450 LSST core scientists from US, Chile & IN2P3 (≈10%) .
- In 2012 , a HEP like collaboration (detector & computing & data analysis tasks & science) has been put together under DOE request , LSST DESC (Dark Energy Science Collaboration) , IN2P3 is part of it.

CD-1 Approval

DOE HEP has determined that SLAC will manage the acquisition of the LSST Camera under the existing DOE M&O contract (DE-AC02-76-SF00515). Furthermore, SLAC will coordinate and manage the future "off-project" operations efforts required for the success of the LSST experiment.

Major collaborators include the Brookhaven National Laboratory (BNL), the Lawrence Livermore National Laboratory (LLNL), Fermi National Accelerator Laboratory (FNAL), and the Institute National de Physique Nucleaire and de Physique des Particules (IN2P3- several members of national science laboratories in France). SLAC will manage and coordinate the required efforts with the collaborators based on several task specific Memoranda of Understanding (MOU) that are in place.

LSST Camera Project CD-1 Decision Document

Approval

Based on the information presented above and at this review, Critical Decision-1, Approve Alternative Selection and Cost Range for the LSST Camera Project at SLAC National Accelerator Laboratory is approved. Therefore, the project is authorized to begin the Execution Phase.

William Brinkman
Director
Office of Science

4/12/12
Date

IN2P3 is on the same footing than DOE national laboratories

- -Our integration in the project if really good and acknowledged .
- -We are paid back of the risk taken/early investment in the project since 2007
- -The long standing relation DOE/IN2P3 & IN2P3 laboratories / SLAC (BABAR,FERMI,…) is a solid ground which allowed the construction of a good collaboration.

LSST collaboration and French contributions (1 / 2)

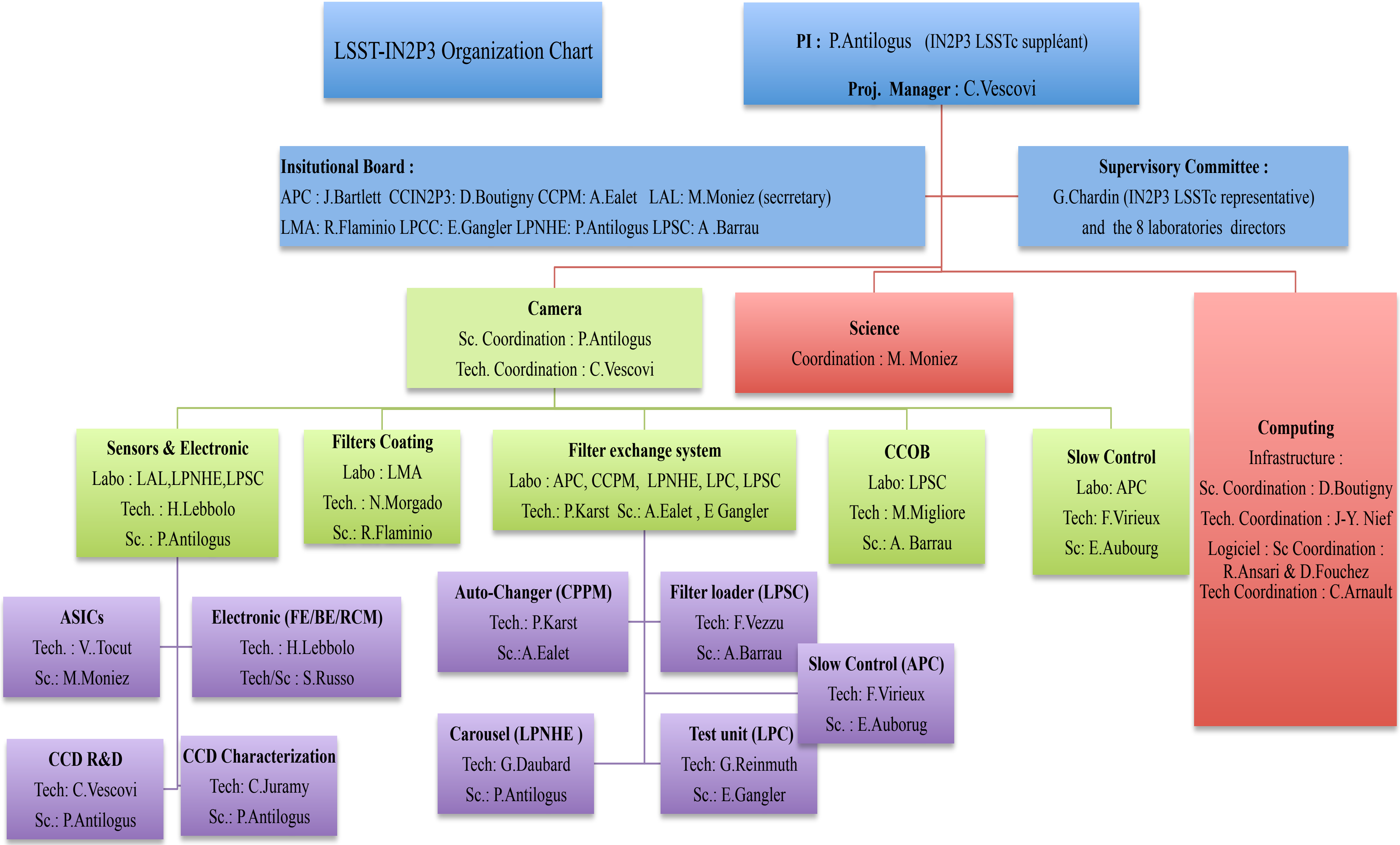
Large Synoptic Survey Telescope

- 2005 First contacts
- 4 IN2P3 & 3 INSU laboratories submitted a letter of intent to LSST in 2006
- Early 2007 , 3 IN2P3 laboratories (APC, LAL, LPNHE) joined the LSST camera R&D, followed in December 2007 by the support of the IN2P3 Scientific Council.
- Fall 2009 : MOU signed with the LSSTC. IN2P3-CNRS joined as full member of the LSSTC . This acknowledged the contribution of IN2P3 to the camera R&D.
- Today 8 IN2P3 laboratories (APC, CCIN2P3, CPPM , LAL , LMA , LPNHE , LPC, LPSC) are involved in LSST.
- LSST team at IN2P3 counts 46 scientists and 48 engineers and technical staffs, for an effort of 33 FTE on LSST, including 25 FTE on the camera construction alone. The LSST-IN2P3 group includes today ~ 95% of IN2P3 scientists working on Dark Energy.
- Remark : Discussions to have LSST open to some INSU scientists is underway.

LSST collaboration and French contributions (2 / 2)

- **LSST Cost (R&D + Construction + 10 year Running : $\$1.25\ 10^9$)**
  - **Construction cost : 625.9 M$**
    - DOE Camera : Base Budget 113 M$ + Contingency 47 M$
    - NSF/MREFC : Base Budget 380 M$ (174M$ telescope, 121M$ data management)+Contingency 86 M$
  - **Running cost , starting October 2020 : 37 M$/ year** (including 52 % in Data management)
    - Remark : The computing is a large effort/cost in the project :
      - 15 TB of raw science data / night , ~ 100 PB of total raw data in 10 years
      - Pixel access due to the "non-event" data structure is THE challenge
- **IN2P3 contributions :** **[in 2012]**
  - **Hardware cost & effort on the camera :** **[25 FTE]**
    - 2007-2012 : 75 FTE (5.2 M€) and 1.1 M€ invested (TGIR , P&U , IN2P3)
    - 2013-2018 plan : 110 FTE (7.7 M€) + 6.5 M€ hardware + 670 k€ travel (~ 20 M$ total)
  - **Software & Computing at CCIN2P3 :**
    - We plan to provide 50% of the computing needs for the level 1-2 processing (up to the filling of the LSST DB) , estimated cost during exploitation : ~ 2 M€ / year , for a significant effort starting in 2017
    - Contribution to the Dark Energy , 3rd level processing , not discussed/agreed yet
    - Started in 2012 a Software contribution / software expertise ramp-up **[2.5 FTE]**
  - **Science & Science preparation (including science tasks , like calibration)** **[5.5 FTE]**
    - Active participation to the LSST science / 23 IN2P3 scientist signed the DESC white paper which will be make public next week.

LSST-IN2P3 Organization Chart

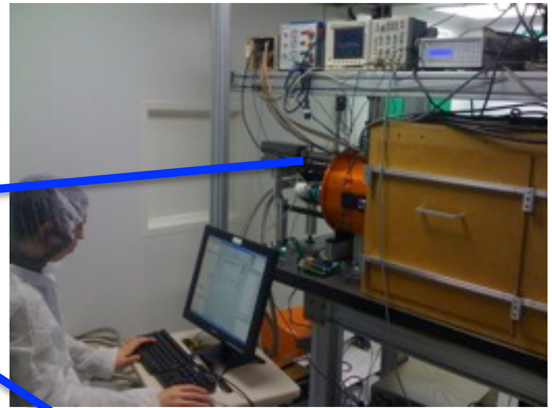


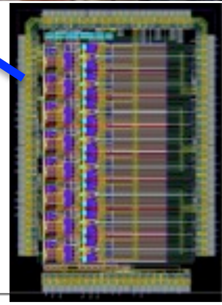
IN2P3 contribution to the LSST camera

Baseline of the IN2P3 contribution to the LSST camera
(As included in CD1)

LSST CCD and associated electronics :

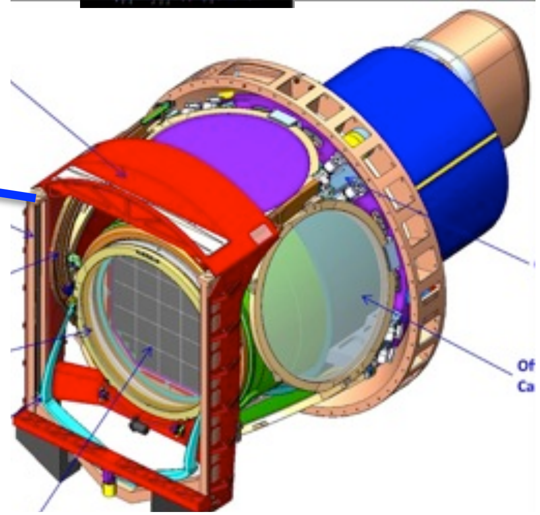
- Procurement of 25% of the LSST CCDs (~55 CCDs for a total of 225 CCDs foreseen by LSST), [4 M€ CCD]
- Initial testing of at least 25% of the CCD production,
- Design, qualification, production and testing of the ASPIC, ASIC for the CCD readout
- Design, qualification, production and testing of the CABAC, ASIC for CCD control, , [.8 M€ CCD test& elec]
- Responsibility for the design, implementation and qualification of the FPGA micro-code controlling the LSST Raft (a raft is an autonomous sub-system of 9 CCDs, with a total of 21 making up the LSST focal plane).





Filters & associated mechanical system & control :

- Contributions to LSST filters coating studies,
- Delivery of the *filter exchange system* [1.25 M€]
- Contribution to the core of the camera slow control , and provide the *filter exchange system* slow control. [0.15 M€]

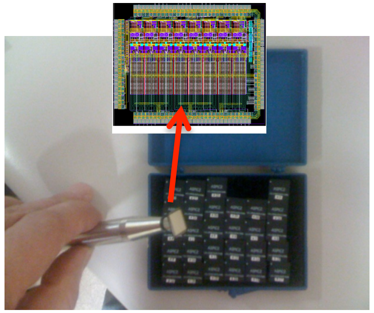


The hardware contribution associated with our calibration effort includes delivery of the CCOB, a system to characterize the LSST camera during its assembly at SLAC prior shipping to Chile. [0.3M€]

ASICs : A LAL (V.Tocut et al.) & LPNHE (H.Lebbolo et al.) team design , qualify and produce the 2 Front End ASICs of the LSST electronics

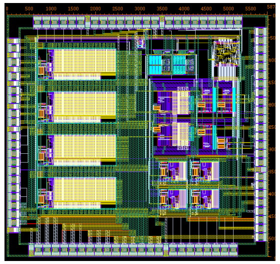
Large Synoptic Survey Telescope

ASPIC (Analog Signal Processing asIC), CMOS 0. 35µ (10.2 mm^2)

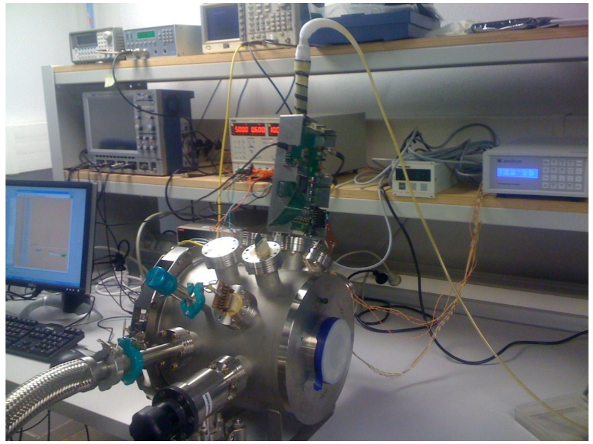


- It's a 8 Dual Slope Integration channels chip for CCD signal processing .
- R&D started in 2007
- ASPIC II is available and fulfill LSST requirement (Low Xtalk (<0.05%) , Low noise (< 2e-))
- ASPIC III , final design, with improved performances, optimized for LSST CCD (data from prototype CCD e2v 250 available since 2012) and with CCD and electronic diagnostic capabilities . Submission : Feb 2013.

CABAC (Clocks and Biases Asic for CCD) , CMOS 0.35µ HV (34.6 mm^2)



- Clocks, 8 bit programmable current, ΔV=20 volts max :
  - 4 // clocks (300mA each) & 4 serials clocks
- 6 Bias&OD 8 bits programmable level
- Multiplexer to monitor the delivered V&Clocks + diagnostic
- R&D started in spring 2011 (supersede an US R&D stopped)
- CABAC_0, 1st HV chip submitted at IN2P3 (April 2012), is under test now and is already qualified to run a CCD e2v 250.



The requirements & design of the ~3200 LSST CCD channels are a "premier" .

Our ASICs development has been/is an interplay between requirements, design and tests by a large integrated team (10 engineers / 7 FTE in 2012) . The performances of our prototypes attracted the attention of the CCD community: a good, compact and cheap electronic that can run close to the CCD , once it will exist , will have lots success / become a reference.

CCD R&D , CCD readout , CCD test/production

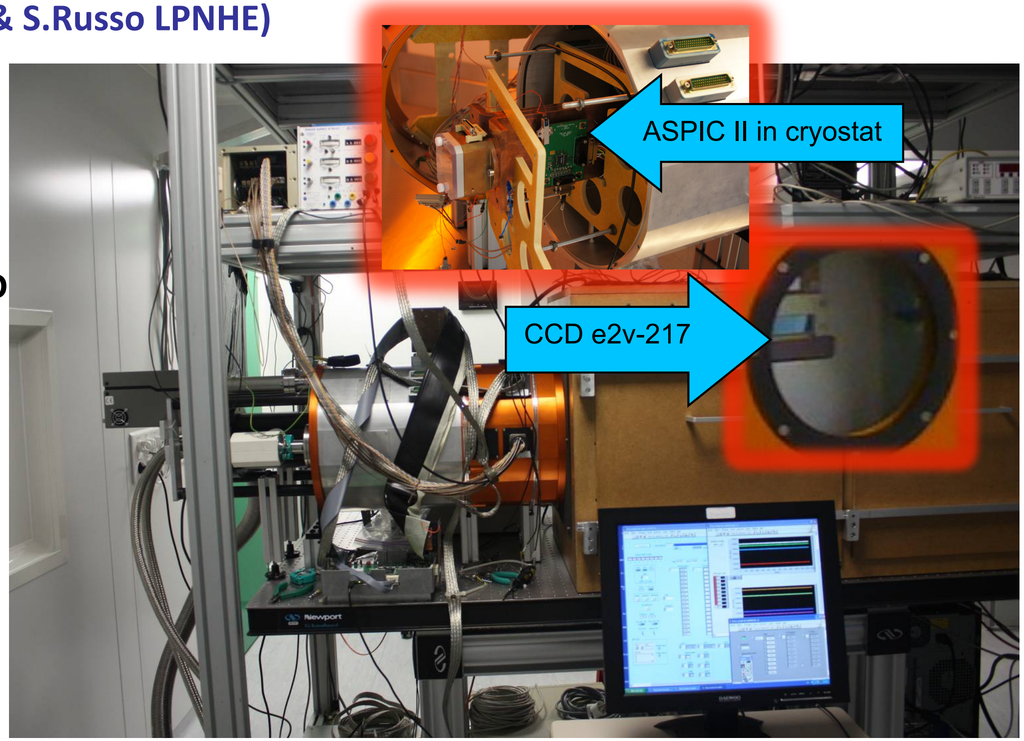
- **CCD R&D** (P.Antilogus LPNHE & C.Vescovi LPSC)

– IN2P3 contribute to the CCD R&D effort (2009-2011 : contribution for 340 k$ of contracts with e2v) :
  - Coating study in the UV (QE improved by 2- 1.5 in the U filter) & Contribution to the funding of a second prototyping iteration to overcome the CTE problem of the first prototypes produced by e2v in 2010
  - R&D contract with e2v completed in summer 2012 : the CCD e2v 250 fulfill the LSST requirements .

➔ Contributions to the CCD, key device, highly visible/acknowledged by LSST , long term impact on the core science .

- **CCD Readout with LSST electronic** (C.Juramy & S.Russo LPNHE)

- Leading the study to qualify the FE ASICs / core LSST electronic with a LSST CCD in a controlled/dedicated setup for performances (noise, Xtalk,…) analysis:
  - Completed with LSST pre-prototype e2v-217
  - Implementing test with ASPIC II + CABAC_0 + CCD e2v 250 for a qualification in February 2013.



- **CCD test facility** (E.Sepulveda LPNHE)

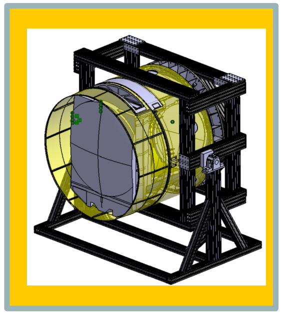
– 2 Clean rooms :
  - 1 for CCD handling (class 1000 + class 100 hood)
  - 1 with CCD optical test bench (class 10000

– Large cryostat (only one compatible with LSST electronic today)

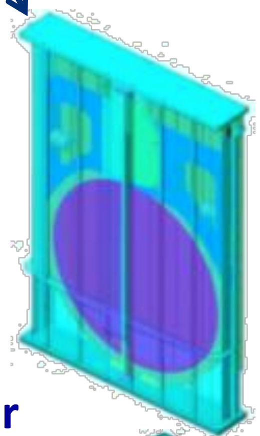
– fully equipped optical bench

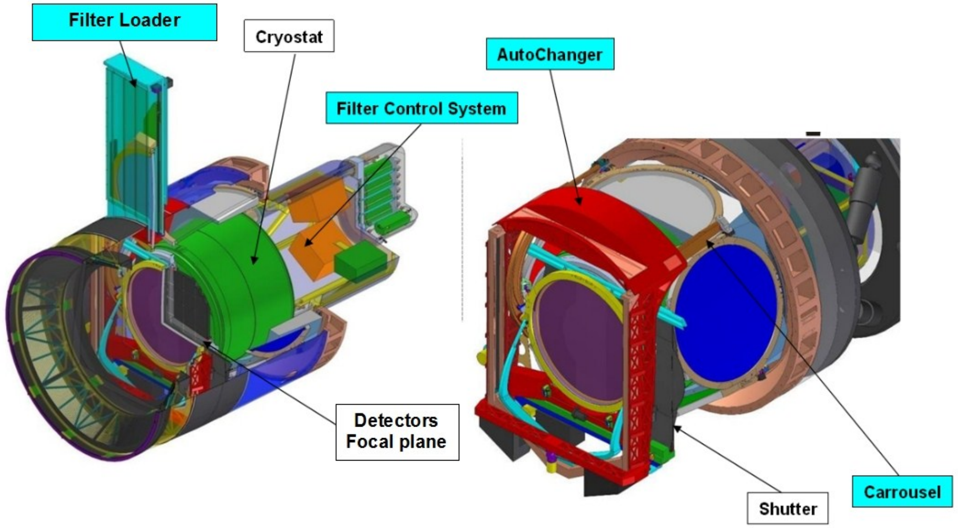
Filter Exchange system (1/2)

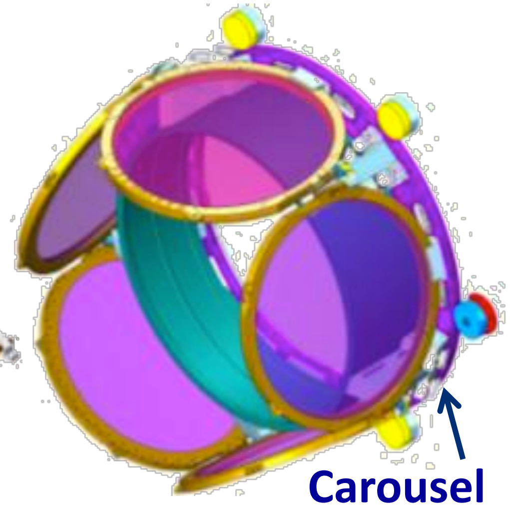
Test Bench
LPC,Clermont
G.Reimmuth



Filter Loader
LPSC,Grenoble
F.Vezzu

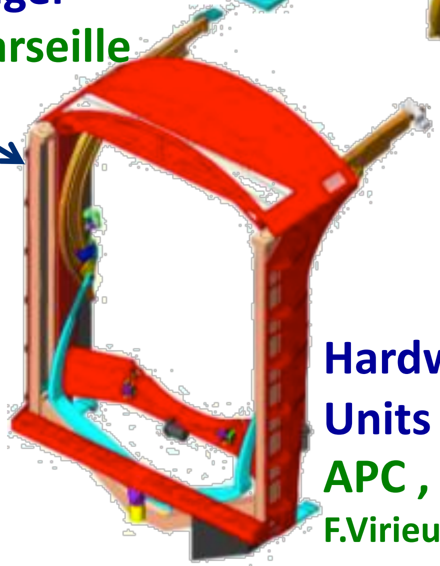






Carousel
LPNHE,Paris
G.Daubard

Autochanger
CPPM,Marseille
P.Karst

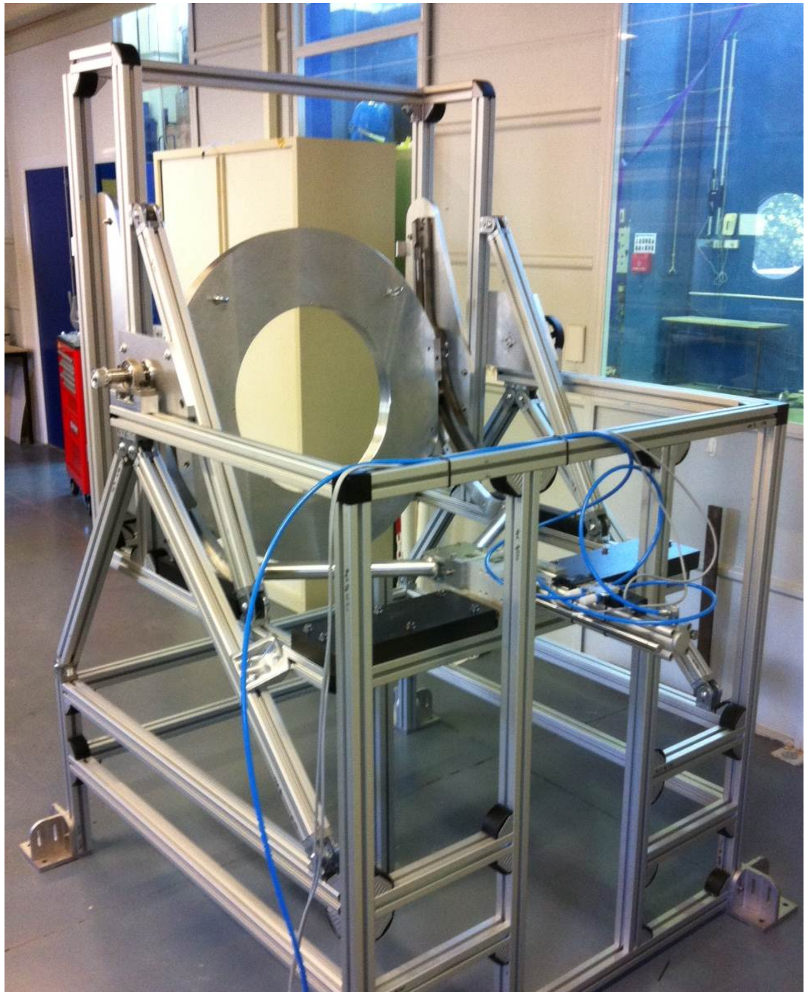


Hardware Control
Units & Slow control
APC , Paris
F.Virieux

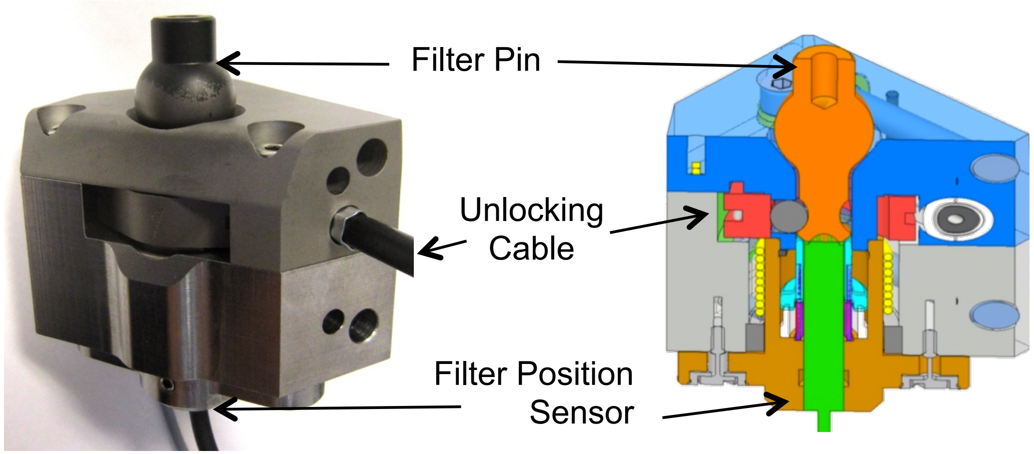
- 1 Filter : ~ 80 cm / 45 Kg
- Time to change 1 filter : 120 s
- Operating Lifetime : 15 Years
  - Number of Filter change: 100 000
  - Carousel full rotation : 30 000
- Limited maintenance over the 15 Years for the carousel (full access = 6 month stop)
- 1 spare for the AutoChanger
- Seismic risk (Chile)
- Many single point failures
- Breaking a filter : major issue for an uniform survey + 1 year to make a new one

➔ Demonstrator/Test/Qualification mandatory and part of the construction plan

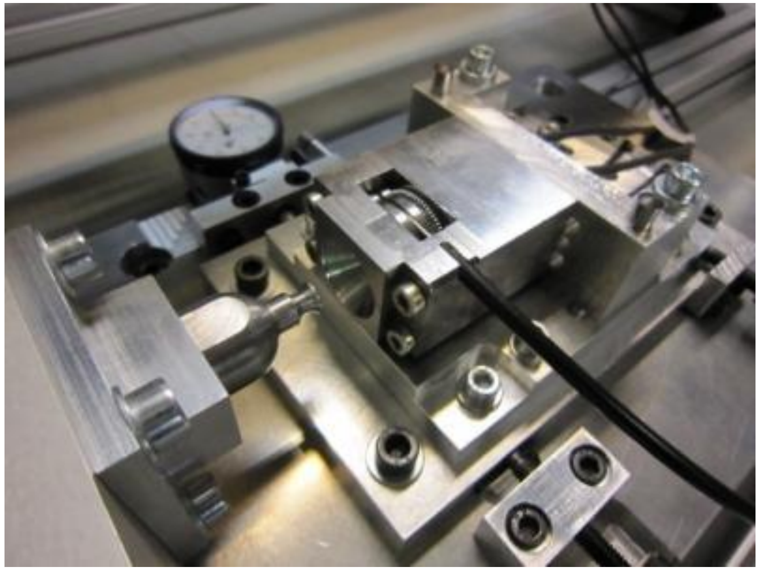
Filter Exchange system (2/2)
next ~2 ½ years pre-construcion / design qualification
(= main effort in € and in manpower)



AutoChanger Prototype with a filter model on its test bench



Filtre Clamp on Caroussel

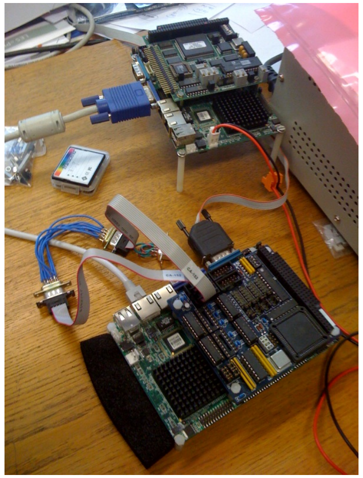


Automated setup to qualify clamps :
30 000 lock/unlock , traction of 50 kg

CCS (Control Command)

Contribution to the CCS core (B.Amade et al. APC) :

- The LSST CCS design is from IN2P3 (E.Aubourg 2008 proposal)
- Today delivery of software for the infrastructure and the consoles: communication busses, configuration data base, automatic tests, lock manager.
- delivery of support for the subsystems developers in France and in USA (there is 16 subsystems, 2 in France, 14 in USA)



Spring 2008 : CCS demonstrator using 2 PC104 under linux and Java

Responsible of the FCS, the Filter Control System the control software of the Exchanger Filters system (F.Virieux, APC et al.) :

- design of the FCS architecture
- delivery of control software for Filter Exchange System test benches for the actual Filter Exchange System

Spring 2012 : Control of the motor / magnetic transmission of the carousel-filter un-clamp system

Filters coating studies

Work Accomplished (Nazario Morgado, B.Sassolas LMA et al.) :

Coating design study & small filter coating at LMA

➔ **Underlined the difficulties and ramped-up the expertise inside the collaboration**

The LMA purchased, after a dedicated study/evaluation, a spectrophotometer with the capability of measuring filter with the precision required for LSST.

➔ **Out of band rejection of 10^{-4} difficult to do & to measure !**

Detailed design studies funded for 2 vendors (SAGEM in France by IN2P3 , JDSU in the US by DOE) , and completed in 2011.

➔ **Results still under evaluation.**

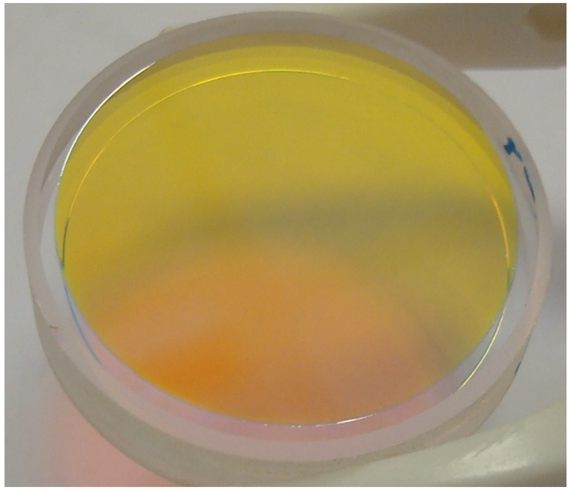
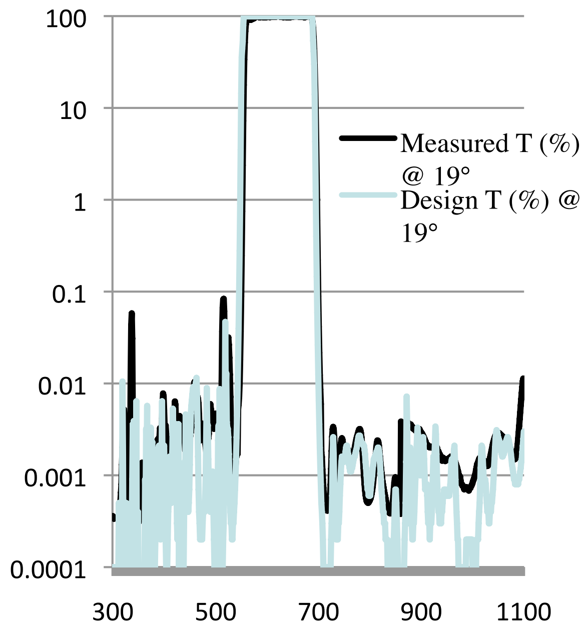


Photo of a 1"LMA R-band filter both side coated (Oct 2012)



What next :

- No further French funding foreseen, but LMA/IN2P3 expertise on filter is still provided to LSST
- Purchase of a 1st filter blank by LSST in 2013 + polish (JDSU like development plan)
- A SAGEM option for LSST is still discussed/alive , support from LMA in this case
- LMA proposed metrology / independent filter qualification to LSST
- LMA is still interested by developing LSST like filters . In home studies have been re-started in 2012 on proper fund at the moment.

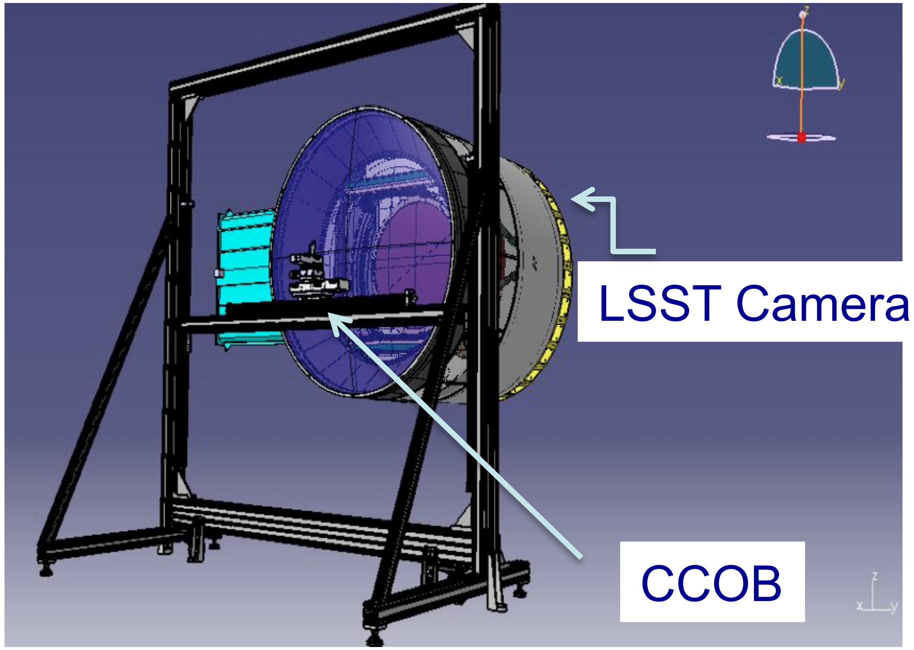
CCOB / Calibration

CCOB (M.Migliore LPSC) :

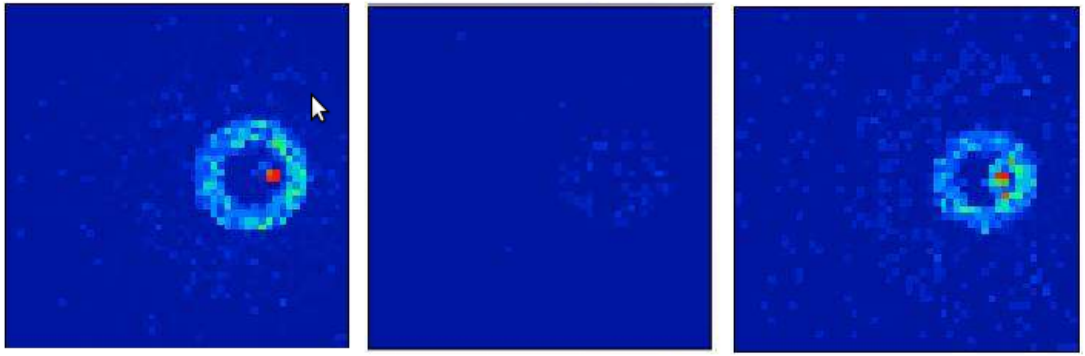
- **It's a French deliverable, it will allow a characterization of the camera optics & focal plan as it will be at SLAC prior to send it to Chile**

Calibration will be the key of the LSST success !

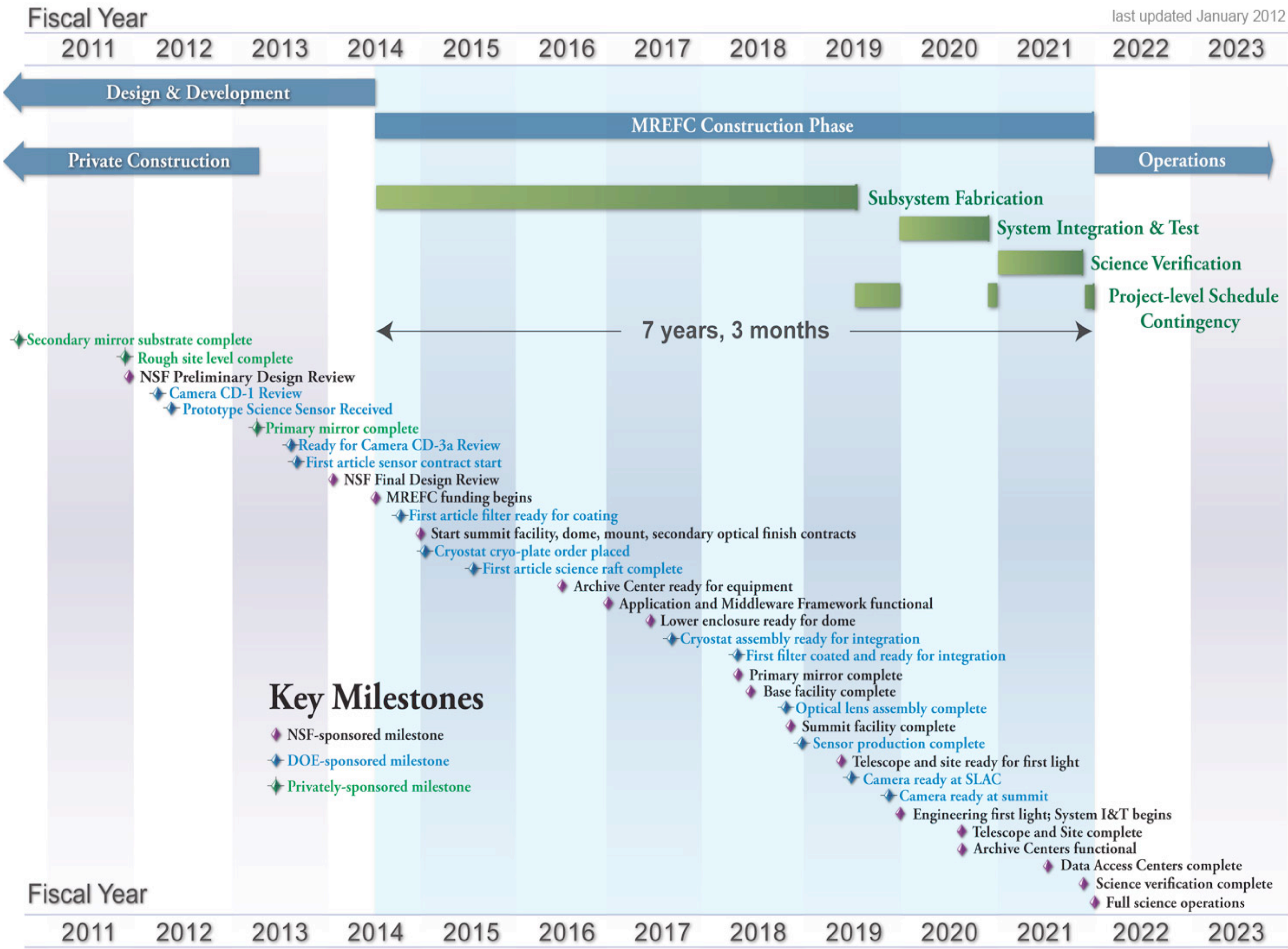
- **We contribute / will contribute to it**
- **Our hardware contribution (CCD ,elec, filter., CCOB) will provide a scientific return on the long term through the understanding of the instrument/calibration**



CCOB Simulations : Wavelength dependent ghosts generated by the edges of the filter pass-band

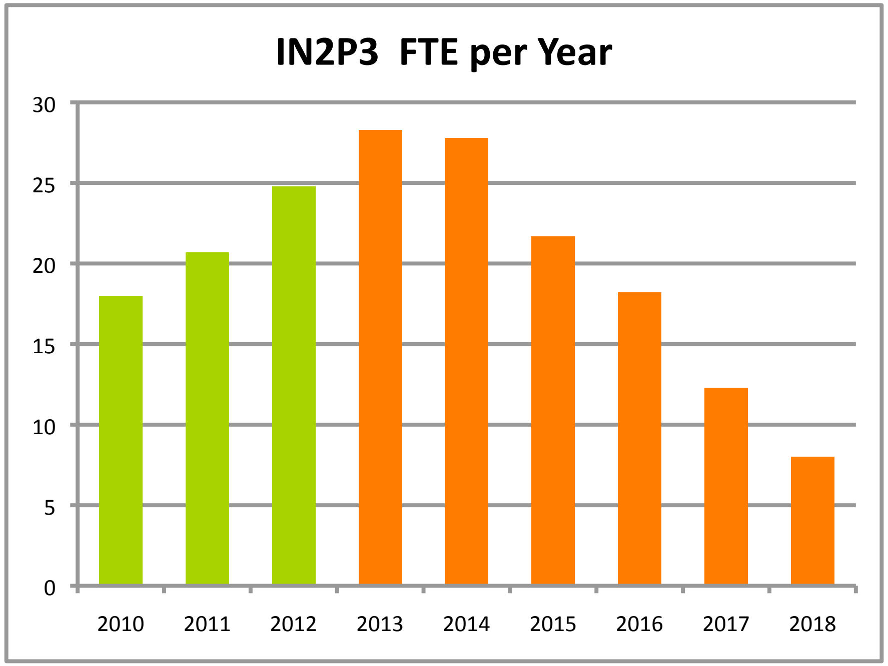


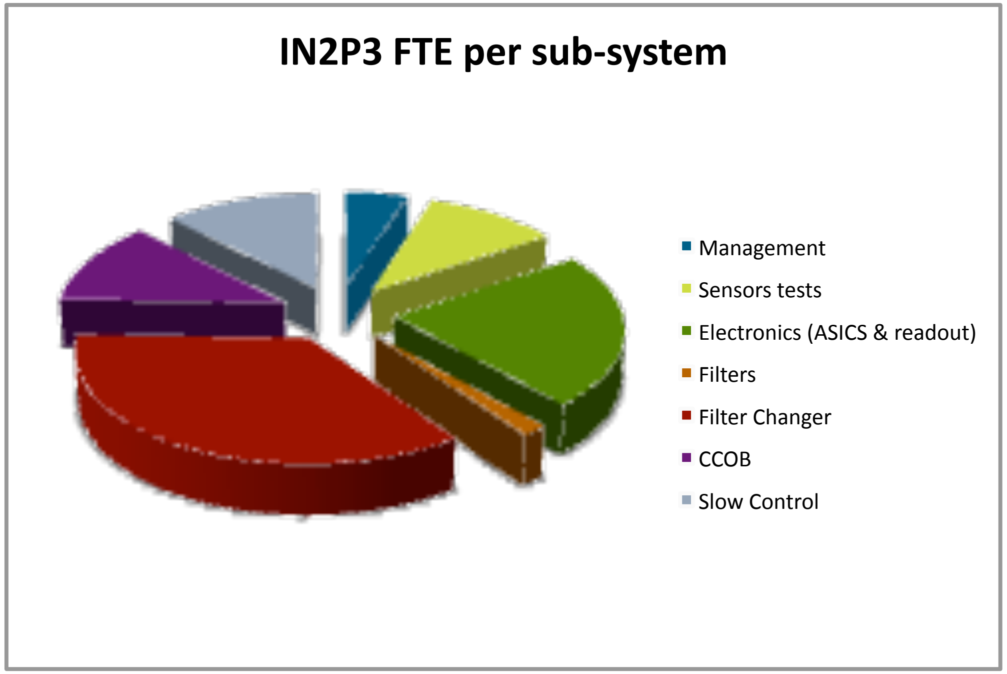
« blue » edge filter center « red » edge


Fiscal Year
last updated January 2012
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
Design & Development
MREFC Construction Phase
Private Construction
Operations
Subsystem Fabrication
System Integration & Test
Science Verification
Project-level Schedule Contingency
7 years, 3 months
Secondary mirror substrate complete
Rough site level complete
NSF Preliminary Design Review
Camera CD-1 Review
Prototype Science Sensor Received
Primary mirror complete
Ready for Camera CD-3a Review
First article sensor contract start
NSF Final Design Review
MREFC funding begins
First article filter ready for coating
Start summit facility, dome, mount, secondary optical finish contracts
Cryostat cryo-plate order placed
First article science raft complete
Archive Center ready for equipment
Application and Middleware Framework functional
Lower enclosure ready for dome
Cryostat assembly ready for integration
First filter coated and ready for integration
Primary mirror complete
Base facility complete
Optical lens assembly complete
Summit facility complete
Sensor production complete
Telescope and site ready for first light
Camera ready at SLAC
Camera ready at summit
Engineering first light; System I&T begins
Telescope and Site complete
Archive Centers functional
Data Access Centers complete
Science verification complete
Full science operations
Key Milestones
NSF-sponsored milestone
DOE-sponsored milestone
Privately-sponsored milestone
Fiscal Year
2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023

IN2P3 Manpower on the Camera

	2010	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL (FTE)
Management	1	1	1	1	1	1	1	1	1	9.0
Sensors tests	1.9	2	2.5	3	3	3	2	2	0	19.4
Electronics (ASICS & readout)	4.5	7	6.8	7	7	4	3	1	1	41.3
Filters	1.2	0.6	0.7	0.3	0.3	0	0	0	0	3.1
Filter Changer	5.9	5.7	9.4	10.5	10.5	8	7	5	2	64
CCOB	2.1	2.8	2	3.5	3	2.7	2.2	2	2	22.3
Slow Control	1.4	1.6	2.4	3	3	3	3	3	2	22.4
TOTAL	18	20.7	24.8	28.3	27.8	21.7	18.2	12.3	8	181.5

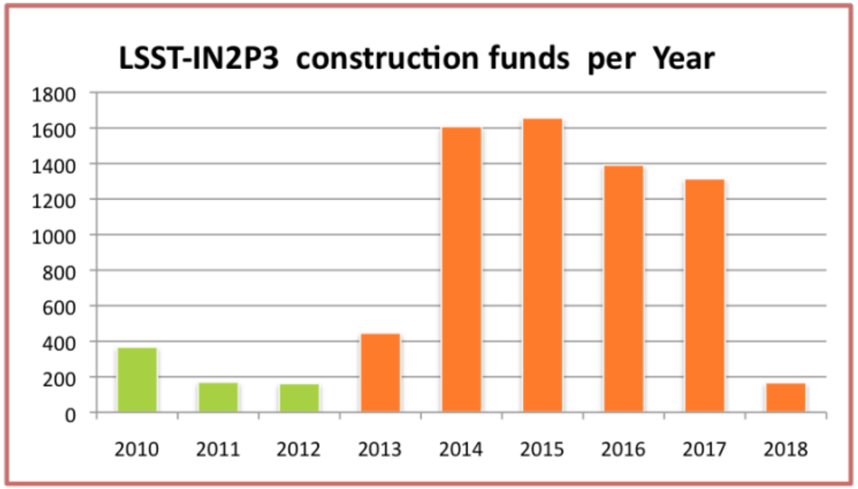


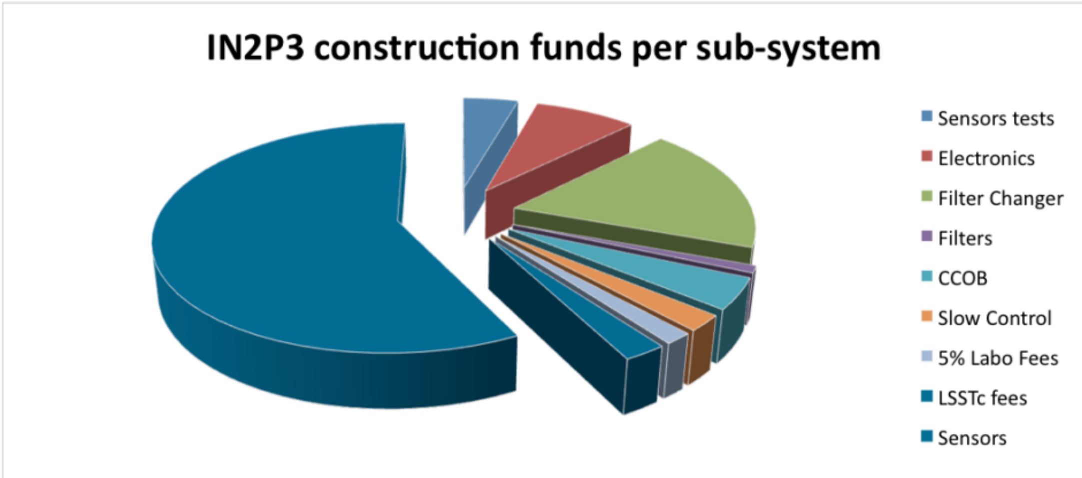


Hardware cost of the IN2P3 contribution to the LSST camera

LSST-IN2P3 investment profile (travel money not included)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	TOTAL (k€)	2013-2018
Sensors tests	30	30	10	70	75	40	35	30	0	320	250
Electronics	8	20	70	83.5	160	195	35	20	0	592	493.5
Filter Changer	32	75	52	217.5	265	261	194	130	90	1316.5	1157.5
Filters	62	10	0	0	0	0	0	0	0	72	0
CCOB	10	10	5	25	50	100	70	50	0	320	295
Slow Control	5	5	5	10	10	10	20	50	50	165	150
5% Labo Fees	0	0	0	20.3	28	30.3	17.7	14	7	117.3	117.3
Sub-Total	147	150	142	426.3	588	636.3	371.7	294	147	2902.3	2463.3
LSSTc fees	20	20	20	20	20	20	20	20	20	180	120
Sensors	200	0	0	0	1000	1000	1000	1000	0	4200	4000
TOTAL	367	170	162	446.3	1608	1656.3	1391.7	1314	167	7282	6583.3





LSST computing at IN2P3

LSST computing at IN2P3 (1/2)

- The LSST running cost (37M$/Year) is high / LSST data reduction is one reason
- In the present agreement : the French scientific community involved in LSST will not rely on computing facilities in the US for science analysis.
- Efficient access to the very large LSST dataset will be one of the primary challenges for scientific exploitation, and most particularly for dark energy science
- To support running costs/share of the low level computing effort and to ensure competitive data access in France – a letter of intent was sent by the IN2P3 director to the LSSTc in December 2011 :
  - The CC-IN2P3 will provide CPU and storage resources corresponding to 50% of the LSST needs for the Data Release Processing (level 2)
  - The full LSST dataset will be resident at the CC-IN2P3.

This proposal has been elaborated with a strong support from all parties (LSST , IN2P3 , CCIN2P3 , LSST-France).

CC-IN2P3 new data center

This in-kind contribution is evaluated by LSST to be equivalent to a cash contribution of 2 M$/year. At the same time, the hardware and software investment at the CC-IN2P3 over the project lifetime is estimated at 17.5 M€, the operations cost at around 3.5 M€ and the manpower cost at around 11 M€. Significant investment at CCIN2P3 should start in 2017.

LSST computing at IN2P3 (2/2)

Associated to the processing plan at CCIN2P3 , a computing activity with contribution from different LSST IN2P3 laboratories has been ramping up in 2012 (C.Arnault & R.Ansari LAL , D.Fouchez CCPM , E.Gangler LPC)

• The LSST software stack is under deployment at CC-IN2P3 : the CC-IN2P3 will contribute to the LSST data challenge in 2013 : given the existing expertise within the French team on CFHTLS images, we are in line to adapt the LSST software stack and process the CFHTLS images.

• Evaluation of Qserv / LSST database work has been initiated in 2012 with a grant to our PetaSky project (E.Gangler et al.) within the MASTODONS call .

• Other planed contributions :

  - • Testing the scalability of the LSST software and its ability to use available CPU power in multicore machines.
  - • usage of the LSST software to process the data from CCD/readout test bench.

➔LSST will produce 15 TB / night , 7 PB of archive / year , 70 PB total at the end
➔11 PB of storage space on disk (image access /processing cache) at the start of the project , reaching 22-25 PB at the end of the survey
➔~ 100 TF (10^{12} FLOPS) sustained computing power at the start of the survey, which should reach ~ 900 TF in 2029 (dominated by the object measurement step)

Dark Energy Science Collaboration

DESC (1/2)

Until 2012 the organization of the science in LSST was focused on 11 autonomous "LSST Science Collaborations" covering the different science topics of LSST, including at least 4 collaborations concerning Dark Energy probes.

In 2012, the DOE urged LSST to set up a collaboration "à la" High Energy Physics. As a consequence, the Dark Energy Science Collaboration (DESC) has been created in June 2012. This collaboration explicitly manages all the aspects of the project, including the technical tasks. It is open to all US scientists, DOE or NSF funded, and to all IN2P3 scientists involved in LSST.

Although the "LSST Science Collaborations" have been successful in producing the LSST Science Book in 2009, we see the DESC as the correct collaboration structure to face the complex challenges of the Dark Energy science

We/IN2P3 actively contributed to the DESC creation:

- The French-PI was involved in the initial process (P.Antiliogus)
- 3 of us attended the founding meeting last June (P.Antilogus, E.Aubourg, M.Moniez)
- One of us sits on the newly created DESC executive committee. (R.Pain)
- Over the Summer 2012 as the collaboration took shape with production of a white paper, 23 French members joined DESC working groups with dark energy science tasks involving all major probes, as well as strategic activities in calibration and photometric redshift determination. .

DESC (2/2)

- IN2P3 scientist are involved in all the faces of the LSST multi-probe cosmology, from the calibration aspect to the metrology with each DE probe.
- 46 IN2P3 scientists in LSST-France , 23 already joined DESC working group with unequal but increasing participations
  - Traveling funds in adequacy needed
- Many scientists active in other surveys (Planck, SNLS...) and will transfer progressively their activity to LSST
  - Expect a natural transfer of science budget within the next years
- Today age and rank distributions plead for the participation of younger scientists (considering the calendar)
  - PhD, postdocs and CR/MCF positions

SN (LPNHE, CPPM, LPC – 10 scientists)
- observing strategies
- Synergies with IR observations (EUCLID)
- Imroving image subtraction technique

Weak lensing (APC – 3 scientists)
- Cosmic magnification
- Cluster mass measurements
- Weak lensing analysis algorithm

Large scale structures incl. BAO (APC, LAL, LPSC – 9 scientists)
- Simulation

Galaxy clusters (APC -1 scientist)
- Detection and mass determination techniques

Combination of probes (LAL, CPPM – 4 scientists)
- Combine CMB+LSST -> neutrino mass contraint
- Statistical analysis (compare bayesian/ frequentist...)

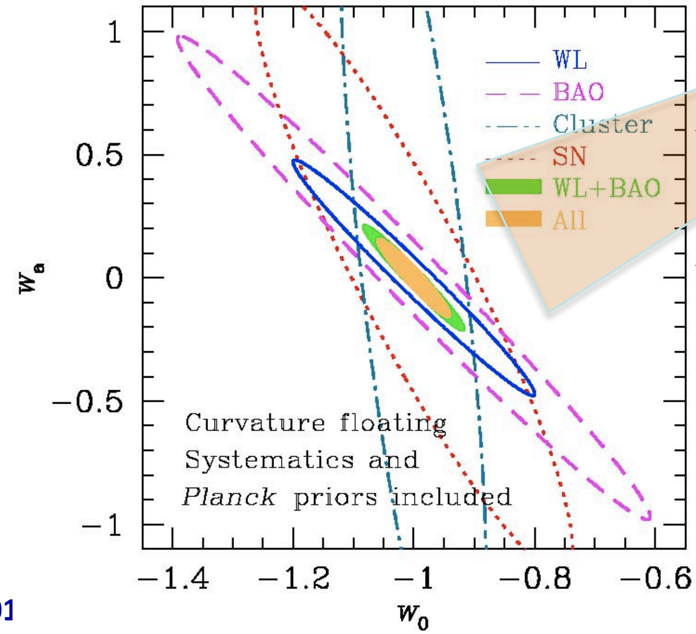
Transverse tasks (APC, LAL, LPNHE, LPSC - 12 scientists)
- Photometric calibration
- Determination of redshifts through photometry
- Complementary observations: follow-up

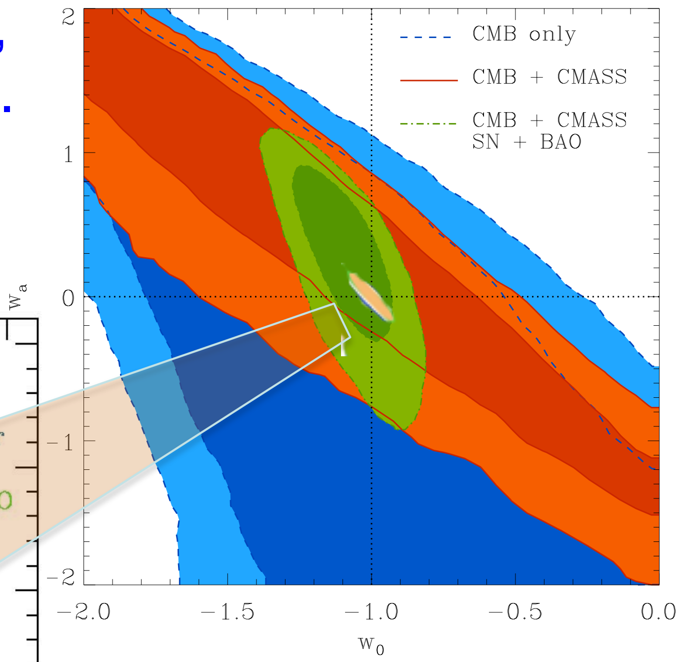
Conclusion

Observational cosmology / Dark Energy :

- extremely active field
- …for an extremely hard problem
- With a long term observational program :
    - LSST is a breakthrough program
    - and, today, as its construction start, we are and can stay at the core of it.

LSST (in > 12 years)





Today :
Sanchez *et al.* 2012
w_0 =−1.08±0.11
w_a = 0.23±0.42

Backup Slides

Lastname	Firstname	FTE	Technical activity (Camera,soft)
APC → 2.2FTE = 1.2 FTE (Perm) + 1 FTE (CDD)			
Amade (CDD)	Bernard	100	Control
Collet	Jean-Marc	20	Control
Virieux	Françoise	100	Control - Filters Exchange
CCIN2P3			
Lemrani	Rachid		Computing
CPPM → 2.8 FTE (Perm)			
Breugnon	Patrick	20	Filters Exchange
Karst	Pierre	100	Filters Exchange
Labat	Daniel	80	Filters Exchange
Rivière	Françoise	80	Filters Exchange
LAL → 2.05 FTE (Perm)			
Christian	Arnault	50	Software Offline
Jeglot	Jimmy	100	electronics
Tocut	Vanessa	40	electronics
François	Wicek	15	electronics
LMA → 0.7 FTE (Perm)			
Forest	Daniele	5	Filters
Morgado	Nazario	30	Filters
Pinard	Laurent	5	Filters
Sassolas	Benoit	30	Filters
LPCC → 2.1 FTE (Perm)			
Bonnefoy	Roméo	5	Filters Exchange
Chandez	Fredéric	20	Software Offline
Chassagny	Philippe	10	Software/Filter Exchange
Jammes	Fabrice	40	Software Offline
Lafarguette	Patrick	10	Filters Exchange
Medernach	Emmanuel	25	Software Offline
Reinmuth	Guy	100	Filters Exchange
LPNHE → 9.63 FTE = 8.63 FTE (Perm) + 1 FTE (CDD)			
Baillly	Philippe	25	Sensors/electronics
Coridian	Julien	-	Support (cabling)
Daubard	Guillaume	100	Filters Exchange
De Matos	Felipe	75	Filters Exchange
Dhellot	Marc	67	Sensors/electronics
Evrard	Christophe	100	Filters Exchange
Goffin	Colette	-	Support (Board routing)
Imbault	Didier	10	Filters Exchange
Juramy (CDD)	Claire	100	Sensors/Electronics
Lebbolo	Hervé	80	Sensors/Electronics
Martin	David	80	Sensors/Electronics
Orain	Yann	75	Filters Exchange
Repain	Philippe	10	Filters Exchange – Sensors/Electronics
Sepulveda	Eduardo	100	Sensors/Electronics
Terront	Diego	100	Filters Exchange - Sensors/Electronics
Vallereau	Alain	25	Sensors/electronics
Vincent	Daniel	16	Filters Exchange– Sensors/Electronics
LPSC → 2.30 FTE (Perm)			
Carcagno	Yves	5	Filters Exchange
Faure	Rémi	30	Calibration/CCOB & Filters Changer
Giraud	Julien	5	Filters Exchange
Lagorio	Eric	10	Filters Exchange
Migliore	Myriam	70	Calibration/CCOB
Perbet	Eric	20	Filters Exchange
Vescovi	Christophe	60	Technical Manager
Vezzu	Francis	30	Filters Echange

LSST France ITA

Lastname	Firstname	FTE %	Technical activity (Camera, computing) & science
APC → 3.04 FTE = 2.19 FTE (Perm) + 0.85 FTE (Thes)			**FTE/NbPhys = 30%**
Aubourg	Eric	35	control/ DESC(LSS – BAO)
Bartlett	James	25	calibration/ DESC(LSS/Clusters/Lensing)
Blanc	Guillaume	67	calibration/DESC (Lensing- magnification)
Boucaud (Thèse)	Allexandre	85	calibration/magnification
Bouquet	Alain		
Busca	Nicolas	10	LSS
Creze	Michel	25	Calibration
Giraud-Heraud	Yannick		
Hamilton	Jean-Christophe		
Roucelle	Cécile	57	calibration/DESC(Lensing, photo-z)
CCIN2P3			
Boutigny	Dominique		Computing
CPPM → 0.6 FTE (Perm)			**FTE/NbPhys= 10%**
Blondin	Stephane		
Fouchez	Dominique	10	Computing, DESC(SNIa)
Ealet	Anne	10	Filters Changer, DESC
Escoffier	Stephanie		DESC
Tao	Charling		DESC
Tilquin	André	20	DESC(Fit cosmo)
LAL → 1.6 FTE (Perm)			**FTE/NbPhys= 27%**
Ansari	Réza	50	Computing – DESC (Photo-z,LSS)
Campagne	Jean-Eric	20	DESC(LSS)
Moniez	Marc	60	Sensors/electronics / DESC (Photo-z,LSS)
Perdereau	Olivier	10	DESC(Param cosmo)
Plaszczynski	Stefane	10	DESC(Param cosmo)
Tristram	Mathieu	10	DESC(Param cosmo)
LMA → 0.05 FTE			**FTE/NbPhys= 5%**
Flaminio	Raffaele	5	Filters
LPCC → 0.70 FTE **FTE/NbPhys= 23%**			
Gangler	Emmanuel	50	Filters Changer, computing , DESC(SN Ia)
Gris	Philippe	20	Computing, SN Ia , DESC
Says	Louis-Pierre		
LPNHE → 3.15 FTE = 2.15 FTE (Perm) + 1 FTE (PDoc)			**FTE/NbPhys= 23%**
Antilogus	Pierre	90	Sensors/electronics & Filters Changer, DESC(SN Ia)
Astier	Pierre	10	Calibration/ DESC (SN Ia)
Barrelet	Etienne		
Balland	Christophe		
Beaumont	Sylvain	75	Sensors/Electronics / SN Ia / follow up
Bongard	Sébastien	10	DESC(SNIa / follow up)
Guy	Julien	10	DESC (SNIa)
Hardin	Delphine		
Joyce	Michael		
Le Guillou	Laurent		
Pain	Reynald	10	DESC (SNIa)
Regnault	Nicolas	10	Calibration/ DESC(SN Ia)
Russo (PostDoc)	Stefano	100	Sensors/Electronics , DESC
Schahmaneche	Kyan		
LPSC → 3.10 FTE = 1.1 FTE (Perm) + 1 FTE (ATER) + 1 FTE (Thes)			**FTE/NbPhys= 62%**
Barrau	Aurelien	50	CCOB & Filters Changer / Photo-z,LSS
Choyer	Adeline	100	Calibration/LSS/Photo z
Derome	Laurent	10	
Ricol	Jean-Stéphane	50	Calibration/CCOB / DESC (Photo-z,LSS)
Villa (ATER 2012-13)	Francesca	100	Calibration/CCOB

LSST France Scientists

LSST Computing at IN2P3 (2/2)

We foresee to share the data management between NCSA and CC-IN2P3 for

- The full dataset available at CCIN2P3
- A 50% share of the data processing at CCIN2P3

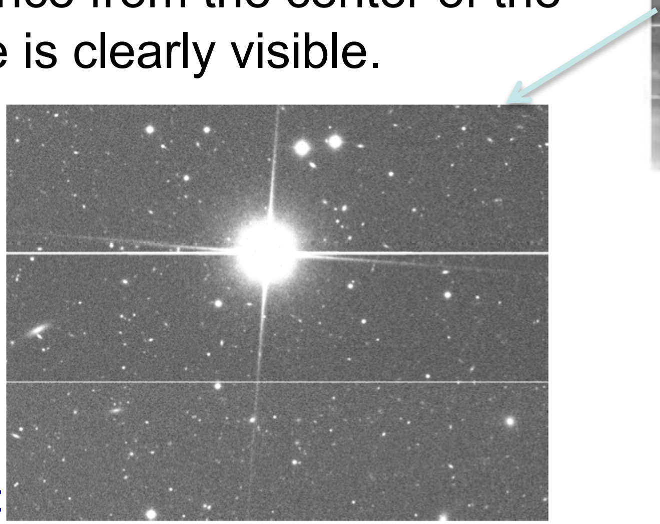
The following preliminary budget will serve as a basis for further discussions with LSST management :

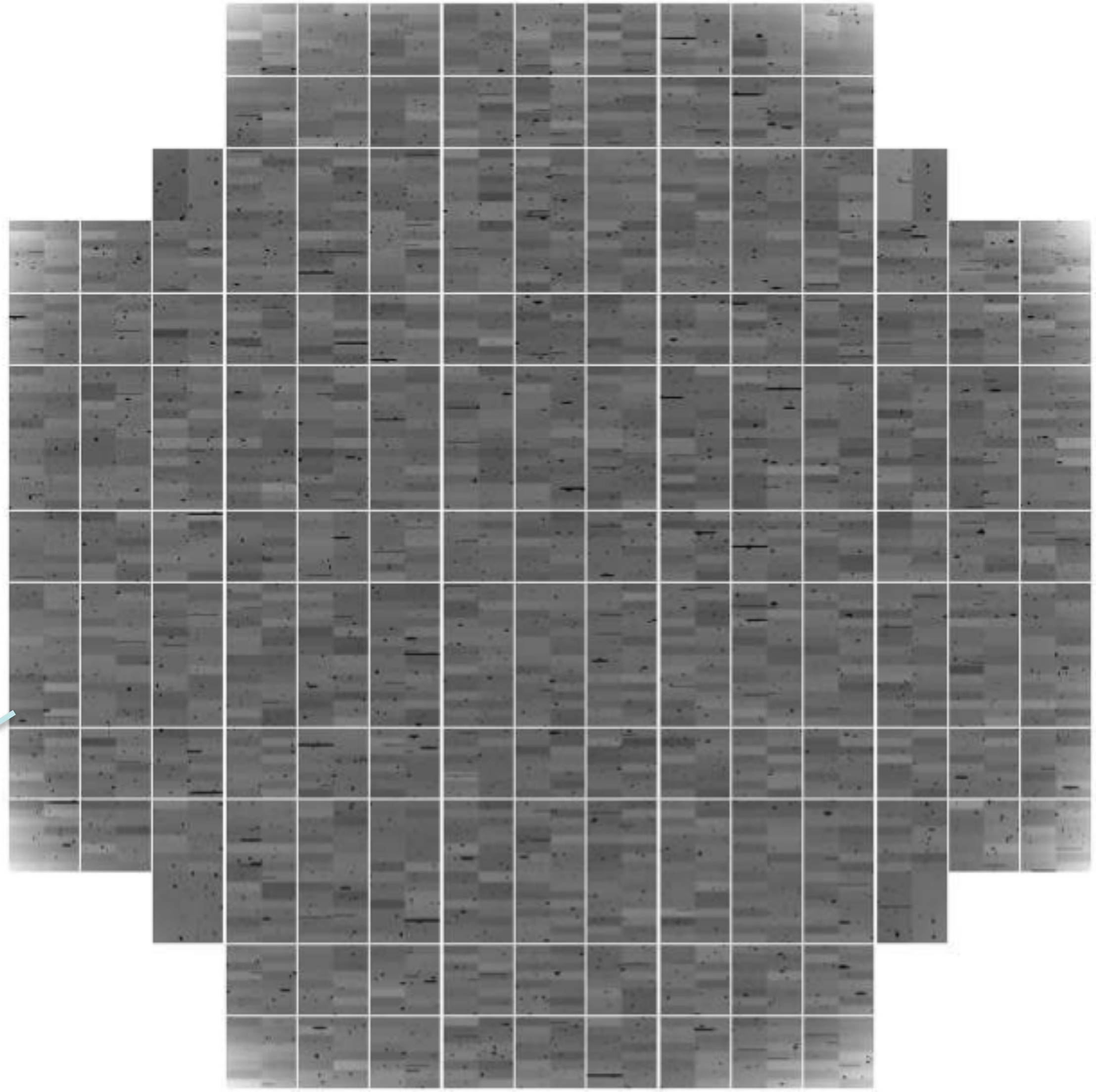
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Number of cores (in 2012 technology)	100	350	1000	1 500	2 000	7 500	18 500	30 00	43 000	55 000
Disk storage (TB)	50	100	150	200	250	1 200	3 150	5 100	9 000	14 000
Mass Storage (TB)	50	50	50	50	100	1 000	2 000	2 000	4 000	6 000
Manpower (FTE)	1	1	2	2	2	5	7	10	10	10
Hardware investment (k€)	113	53	166	81	153	1 108	1 259	1 081	1 305	1 493
Operation cost (k€)	13	9	25	20	29	154	217	242	311	356
Manpower cost (k€)	68	70	142	145	148	378	539	786	801	817
Annual cost (k€)	**194**	**132**	**333**	**247**	**330**	**1 640**	**2 015**	**2 108**	**2 417**	**2 666**

Total CC-IN2P3 budget integrated over 2012 – 2016 : 1,2 M€ (1,6 M$ for 1,35$/€)
Total CC-IN2P3 budget integrated over 2017 – 2021 : 10,9M€ (14,6 M$)
The equivalent of 3 M$/year (subject to exchange rates and other uncertainties)

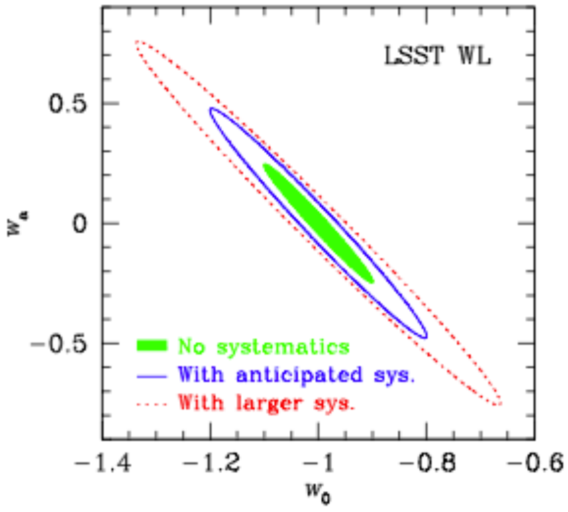
Example of computing activity in LSST today : Full image simulation

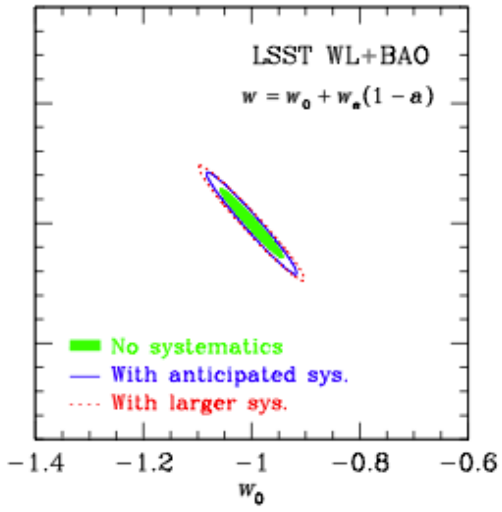
- LSST simulation : full photon tracking from the sources (star/ Galaxy/sky) to the sensor + all readout effect implemented .
- Here , a LSST simulation of an entire focal plane : CCDs (squares) , and the rectangular individual amplifiers (16 per chip) are visible.. At this resolution, only the hot columns, and an occasional bright star can be seen. The vignetting of the light at the outer edge of the eight chips that are most distance from the center of the focal plane is clearly visible.

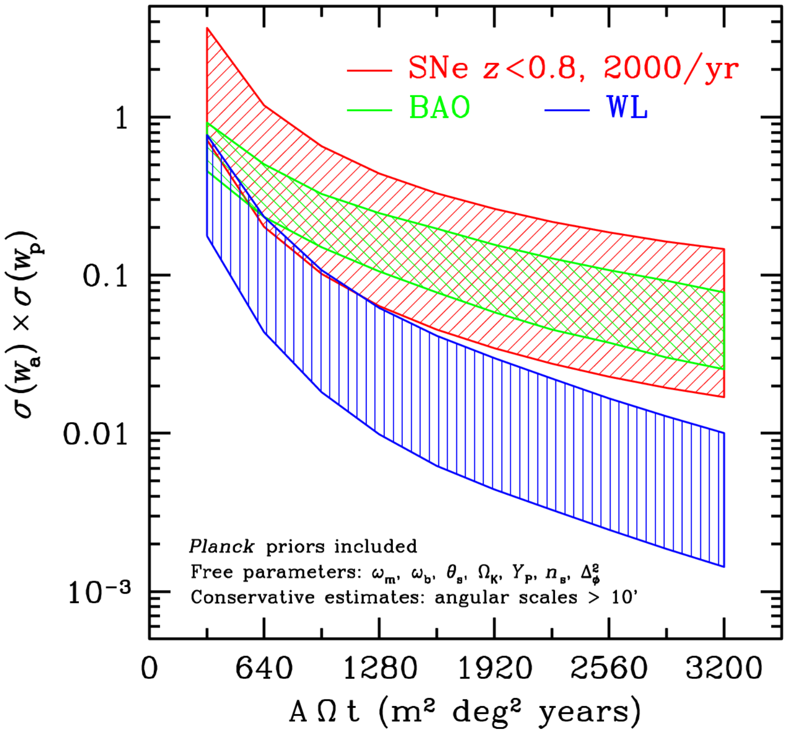


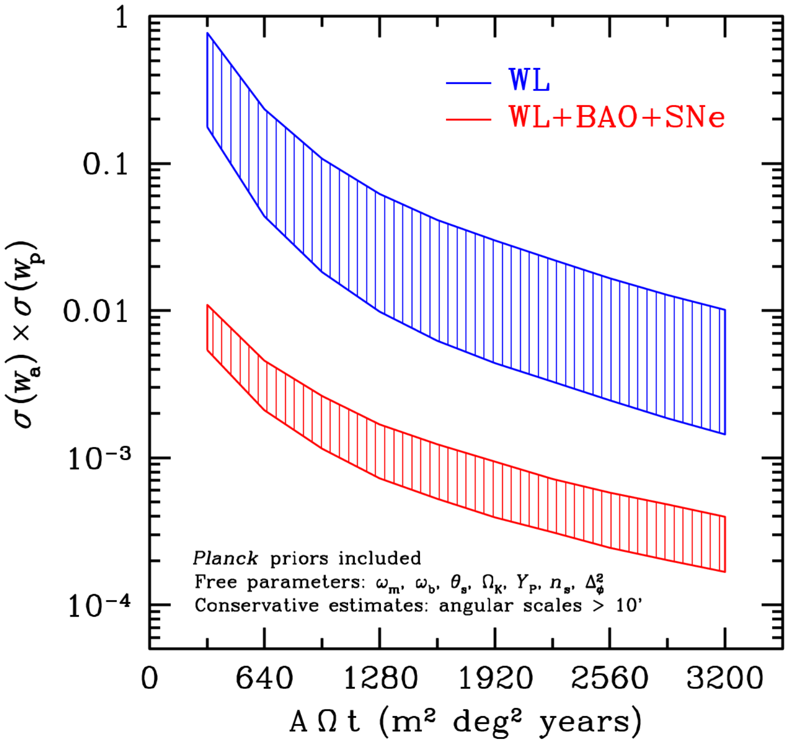


Complementarity between Dark Energy probe









Euclid & LSST : 2 complementary paths for the same scientific goal(s)

LSST
Large Synoptic Survey Telescope
Euclid

Goal ➔ **reduce** by **1 order of magnitude the errors on DE equation of state.**

Remark : give also constrain on modified gravity and neutrino mass

Method ➔ **Large sky Survey (1/2-1/3 of total sky) & deep (24-27 mag)**

Observables ➔

- **Weak Lensing : growth of structure**
- **Galaxy Clustering : growth of structure**
- **Baryon Acoustic Oscillations : standard ruler**
- **SuperNovae : standard candle**

Key issue ➔ **Systematic Errors :**

LSST & Euclid have different and complementary approach to address the systematic error issues. For example , to control the weak-shear measure :

- **LSST plan to deconvolve the instrumental & atmospheric distortion by observing the same patch of sky ~1000 of time , each time with the same sensitivity than Euclid**
- **Euclid ,in space, will avoid the atmospheric distortion and plan a stable instrument.**

Euclid & LSST

Euclid

FoM ~ 1500(WL&Galaxie)-4000 (all)

~ 900 members

European lead project / ESA

Space telescope / 1.2 m mirror

Launch : 2019

Mission length : 6 years

1 exposure depth : 24 mag

Survey Area : 15 000 square degrees (.36 sky)

Filters : 1 Visible(550-900nm)+ 3 IR(920-2000 nm)

+ NIR spectroscopy (1100 – 2000 nm)

LSST

FoM > 800 (WL,BAO, SN)

~ 450 Core members + 450 to come

US lead project / NSF-DOE

Ground Telescope / 6.5 m effective mirror

1^{st} light : 2019

Observation length : 10 years

1 exposure depth : 24 mag (i) (~27 in 10 years)

Survey Area : 20 000 square degrees (.48 sky)

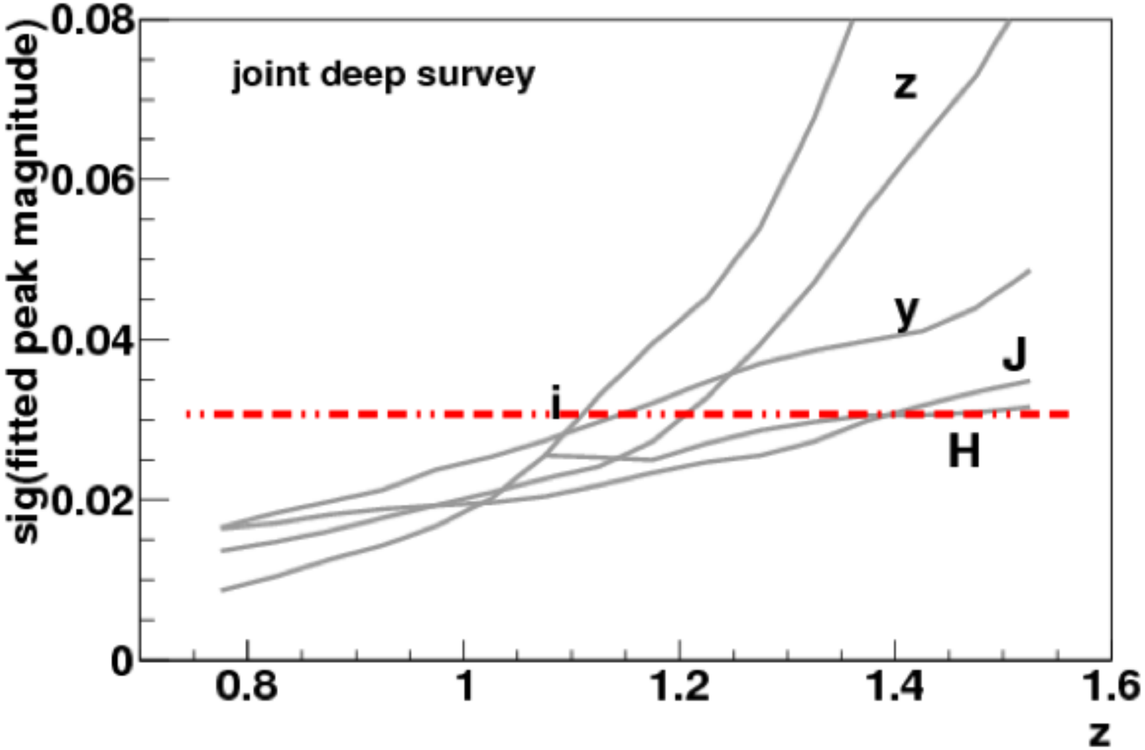
Filters : 6 filters (320-1070 nm)

→2 complementary approaches to address the question of the acceleration of the Universe and the nature of the Dark Energy in the next decade.

Major contributions to both projects from French teams

Measuring Ia at high z with Euclid + X

We need visible photometry → consider e.g. LSST



Hypotheses :

4-day cadence

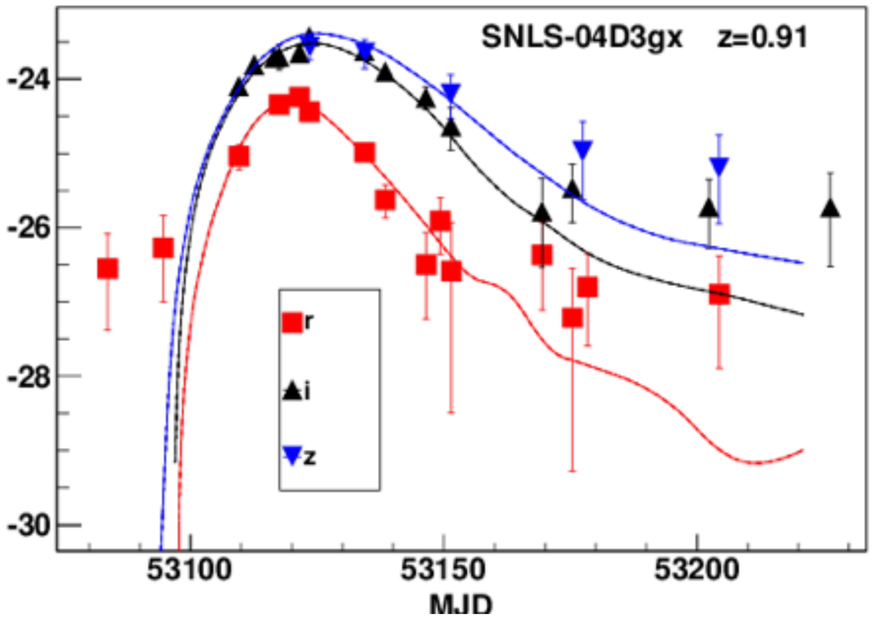
Joint LSST – Euclid survey

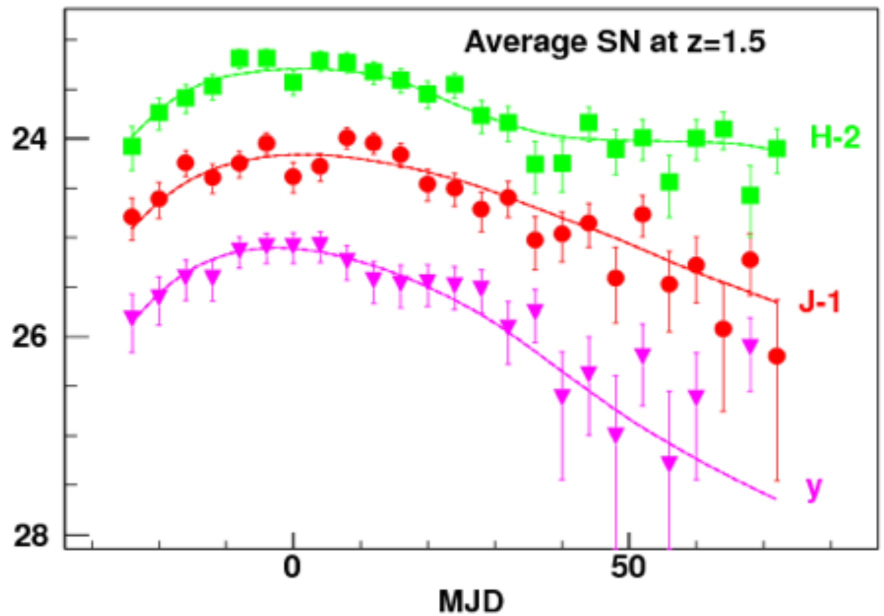
LSST	i	700 s
LSST	z	1000 s
Euclid	Y	1200 s
Euclid	J	2100 s
Euclid	H	2100 s

- The wavelength coverage is larger than the redshift coverage :
  i at z=0.8 → 420 nm H at z=1.5 → 660 nm
- LSST integration times are moderate : going deeper is conceivable
- LSST is just an example. HSC/Subaru would do as well.

Euclid & LSST

LSST wide Survey	LSST Deep fields	Euclid IR Photometry
↓	↓ ↘	↙
0.05<z<0.35 (~8000)	0.15<z<0.95 (8800)	0.75<z<1.55 (1750)





Simulation Results

Summary :

	z min	z max	area	duration	statistics
Hi-z	0.75	1.55	20	6	1740
Mid-z	0.15	1.05	50	18	8800
Low-z	0.05	0.35	3000	6	8000

All surveys are redshift limited !

Cosmological constraints with "geometrical" Planck priors + flatness.

	sig(w_0)	sig(w_a)	FOM
3 surveys	0.022	0.25	204
low+mid	0.026	0.22	137
mid+high	0.030	0.40	82

$s(w_0) = 0.022$

- Euclid's contribution is sizable although not dominant.
  Can be made larger with more observing time …
- Final Euclid stack reaches ~28^{th} mag (point-source, 5 sigma)