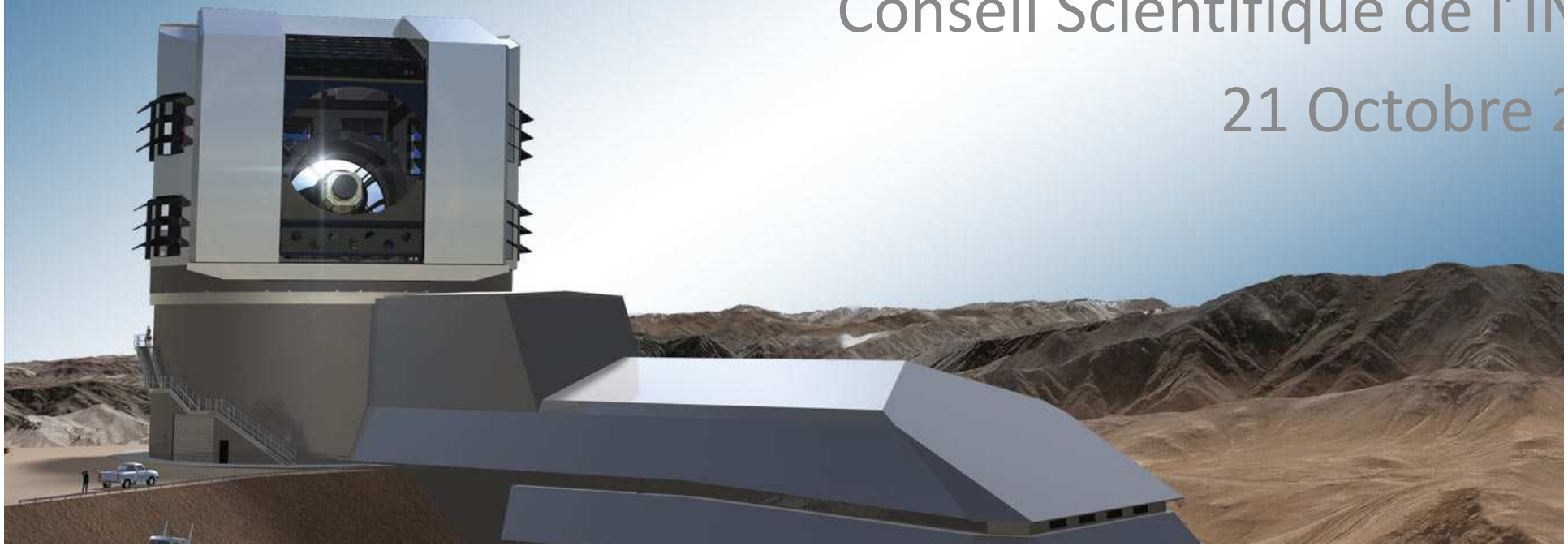
STATUS ON CONSTRUCTION AND SCIENTIFIC PREPARATION OF LSST AT

P.Ant

Conseil Scientifique de l'IN

21 Octobre 2



LSST in a Nutshell

- The LSST is an integrated survey system designed to conduct a decade-long, deep, wide, fast time-domain survey of the optical sky. LSST = 8-meter class wide-field ground based telescope

  + a 3.2 Gpix camera

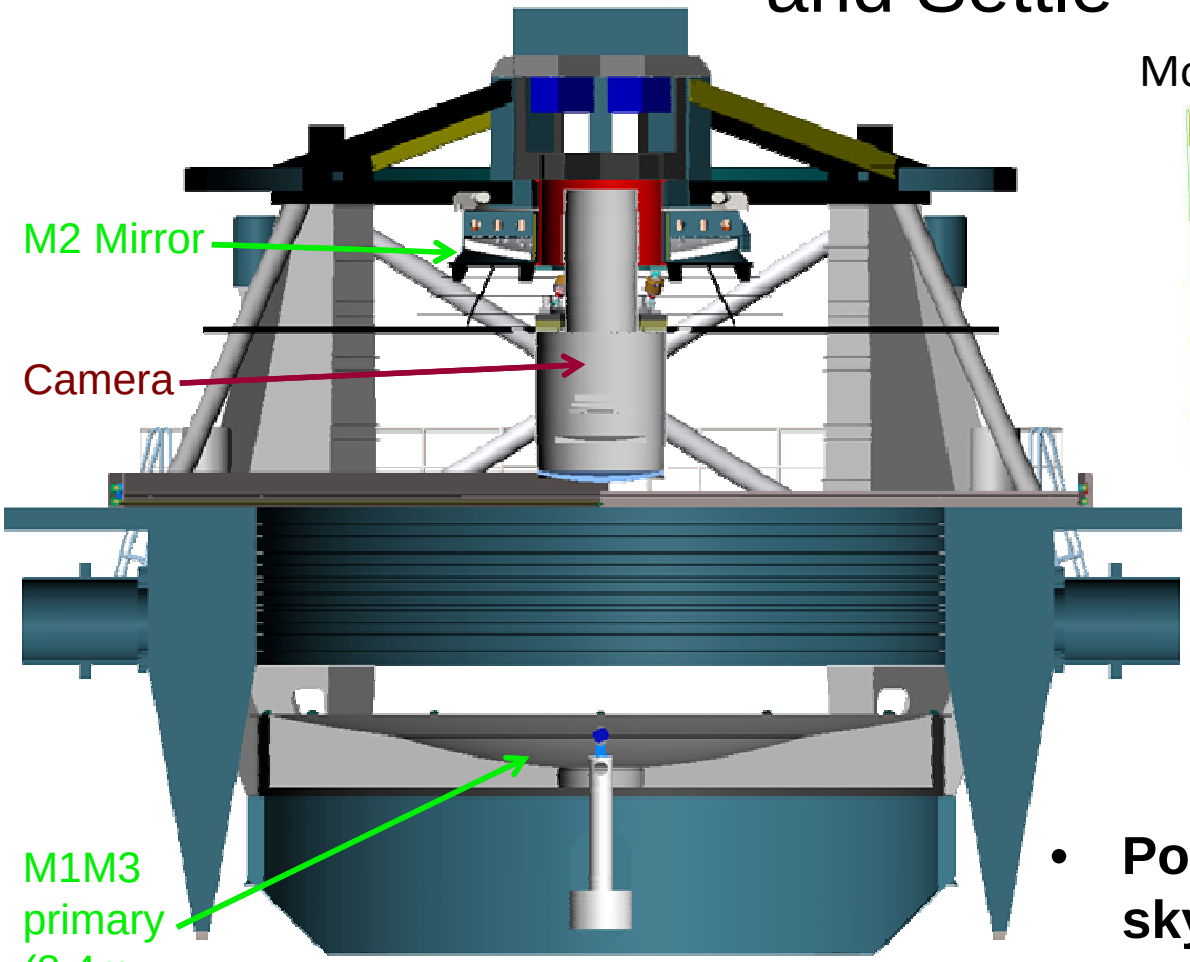
  + 10 year survey plan

- Over a decade of operations the LSST survey will acquire, process, and make available a collection of over 5 million images and catalogs with more than 37 billion objects . Tens of billions of time-domain events will be detect and alerted on in real-time.
- The LSST will enable a wide variety of complementary scientific investigations, utilizing a common database and alert stream. These range from searches for small bodies in the Solar System to precision astrometry of the outer regions of the Galaxy to systematic monitoring for transient phenomena in the optical sky. The main LSST science goal is to provide crucial constraints on dark matter and on the nature of dark energy ➔ IN2P3 science driver

LSST : Wide , Deep and Fast (1/2)

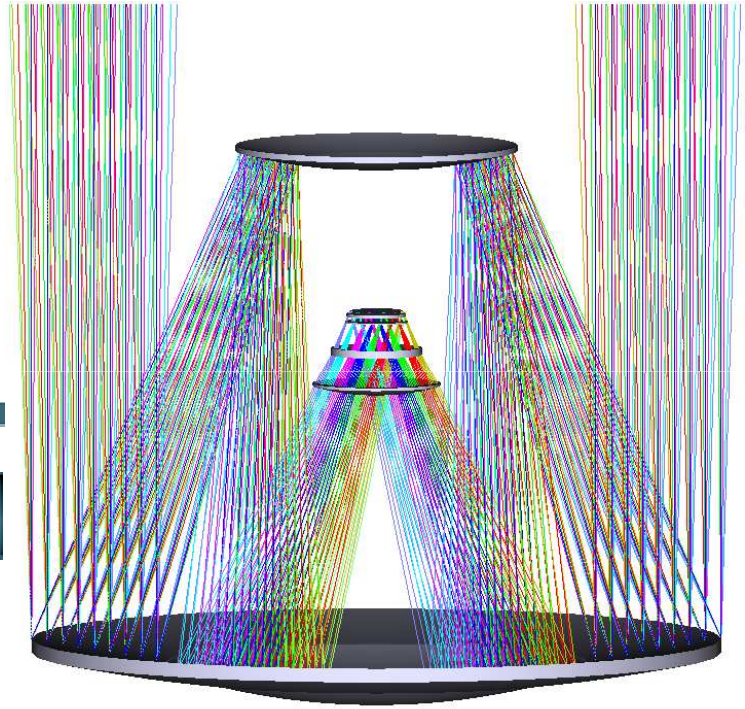
Telescope Mount Enables Fast Slew and Settle

LSST Etendue : 319 m^2 deg^2



Moving Structure 350 tons
60 tons optical systems

Modified Paul-Baker Optical Design



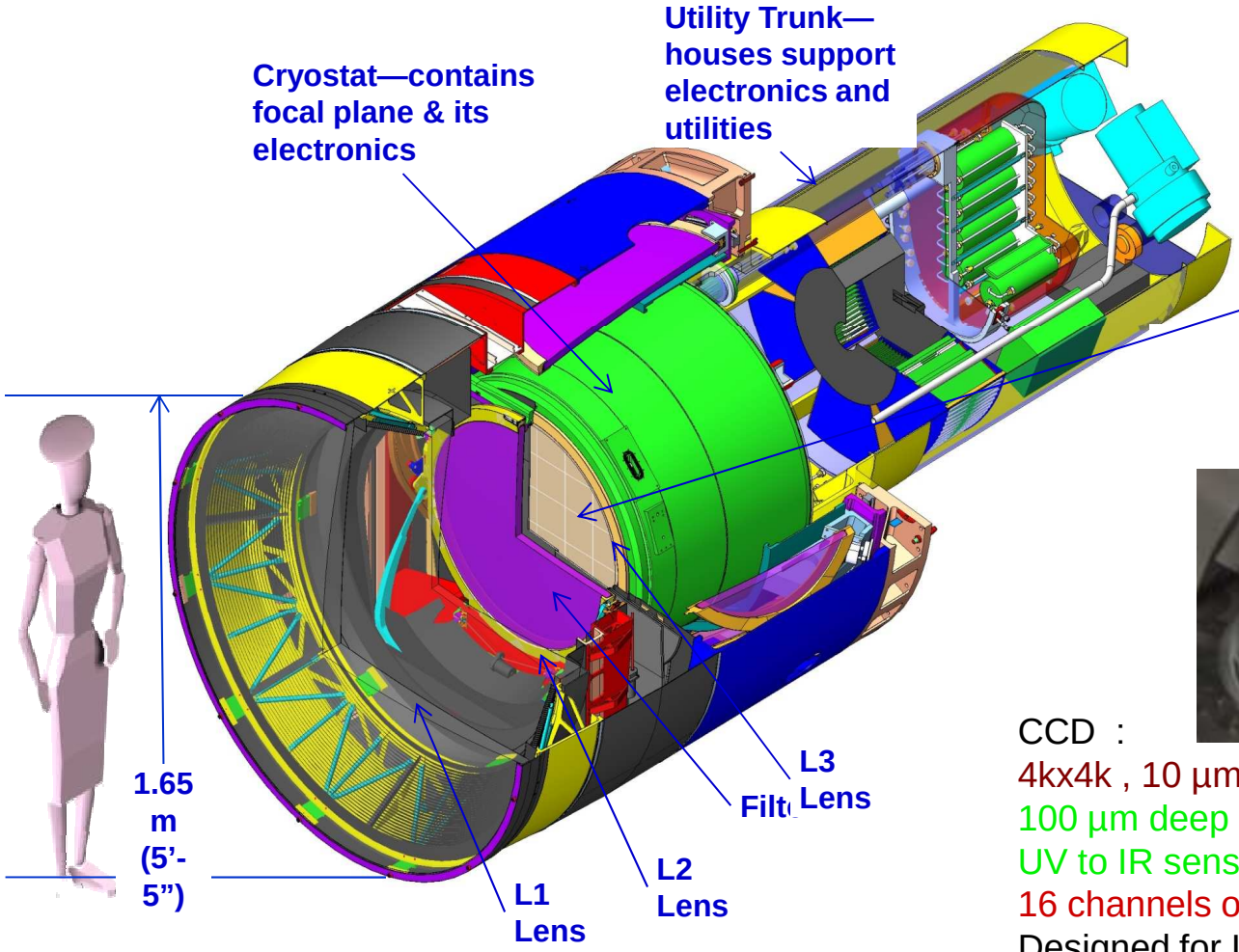
- **Points to new positions in the sky every 39 seconds**
- **Tracks during exposures and slews 3.5° to adjacent fields in ~ 4 seconds**

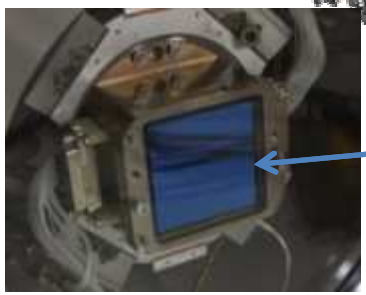
LSST : Wide , Deep and Fast (2/2)

Field of view : 3.5 deg (9.6 deg^2 =.023% sky sphere)

Focal plane diameter : 64 cm ; 189 science CCD (21 rafts)

3024 readout channels; >3 10^9 pixels ; Readout in 2s





CCD :
4kx4k , 10 µm pixels
100 µm deep depleted
UV to IR sensitive
16 channels output
Designed for LSST

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

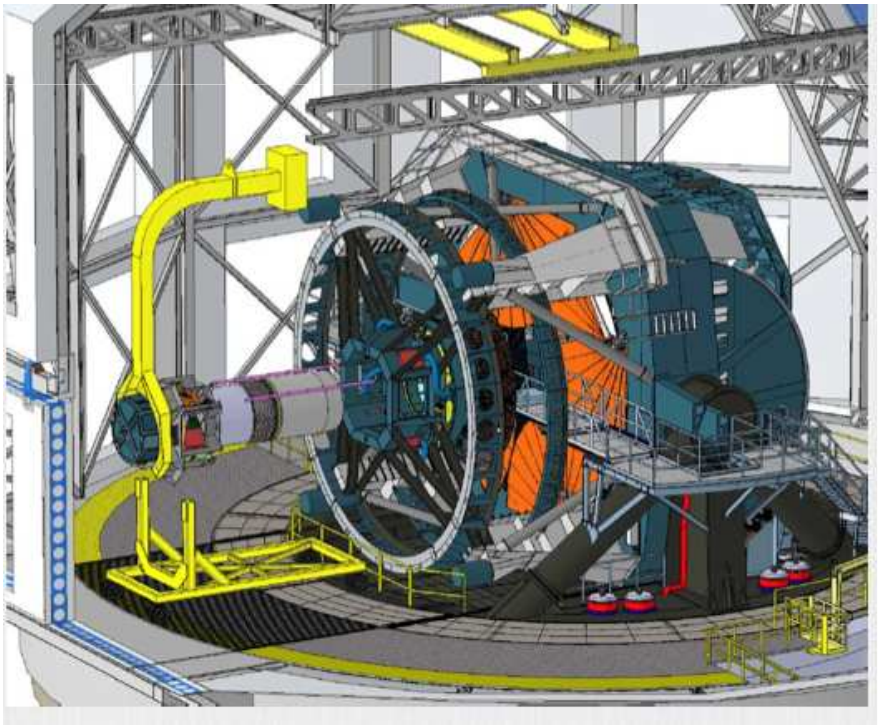
LSST data volume: 1 night ~ 15 TB …
and in 10 years :

Number of objects	~37 10^9 (20 10^9 galaxies /17 10^9 stars)
Number of forced measurements	~37 10^9 * 825 ~ 30 10^{12}
Average number of alerts per night	2 10^6 (10 ^{7} including galactic plane)
Number of data collected per 24 hr period	~ 15 TB
Final Raw image	24 PB
Final Disk Storage	0.4 EB (400 PetaBytes)
Final database size	15 PB

LSST : Cost & Timeline

- LSST cost :
  - Total cost ~ 1 B$, Construction + 10 years running included
  - Telescope & Data Management :$473M(NSF)
  - Camera : $168M (DOE) (+ France-IN2P3 in kind for ~10% camera cost)
  - Private Funds : $40M (early mirrors contribution & site preparation,…)

- LSST Timeline
  - Camera assembly at SLAC : 2017-2019
  - First telescope light with comcam : 2019
  - LSST camera at summit : spring 2020
  - Data management ready : end 2020
  - End of scientific validation : end 2021
  - Start of 10 years survey : 2023



LSST : 2015 highlight

MOAs IN2P3 – LSST (LSSTc , LSSTPO , NCSA)

5 Mars 2015 : final agreement on construction, running, computing, and scientific exploitation

14 Avril 2015 : LSST first stone

at the summit of the Cerro Pachón, Chili

6-8 aout 2015 :
LSST Camera Team passes DOE CD-3 Review

the committee found the project team to be "expert and very capable. The team is well managed and can effectively deliver on the construction phase tasks, manage the procurements, interfaces, and risks. The management structure and resources are in place to successfully deliver the project within the cost and schedule."

LSST & IN2P3 (1/2)

already a 10 years story

- 2005: First contacts (ex: Kirk Gilmore invited at the “EDEN” workshop at LPNHE)
- 2006: 4 IN2P3 & 3 INSU laboratories submitted a letter of intent to LSST
- Dec 2006: 3 IN2P3 laboratories (APC, LAL, LPNHE) joined the LSST camera R&D.

- 2007: CC-IN2P3 first contribution to a LSST data challenge with NCSA&SDSC
- Dec 2007: support of the IN2P3 Scientific Council & IN2P3 to the camera R&D.
- Fall 2009 : MOU on R&D between IN2P3 & LSSTC. IN2P3 is a LSSTc member.
- August 2010: LSST ranked as the highest priority large ground-based facility for the next decade ➔ DOE , NSF & IN2P3 endorsed this choice.

- Nov 2011: Camera CD1 , Baseline of IN2P3 contribution agreed, MoA draft
- Dec 2011: Letter of interest for a contribution of IN2P3 to the LSST computing(50%).
- 2012 : Creation of the LSST-Dark Energy Science Collaboration
- Fall 2012: The IN2P3 Scientific Council endorsed the IN2P3 participation to LSST
- 2014 : Start of the LSST construction

LSST & IN2P3 (2/2)

already a 10 years story

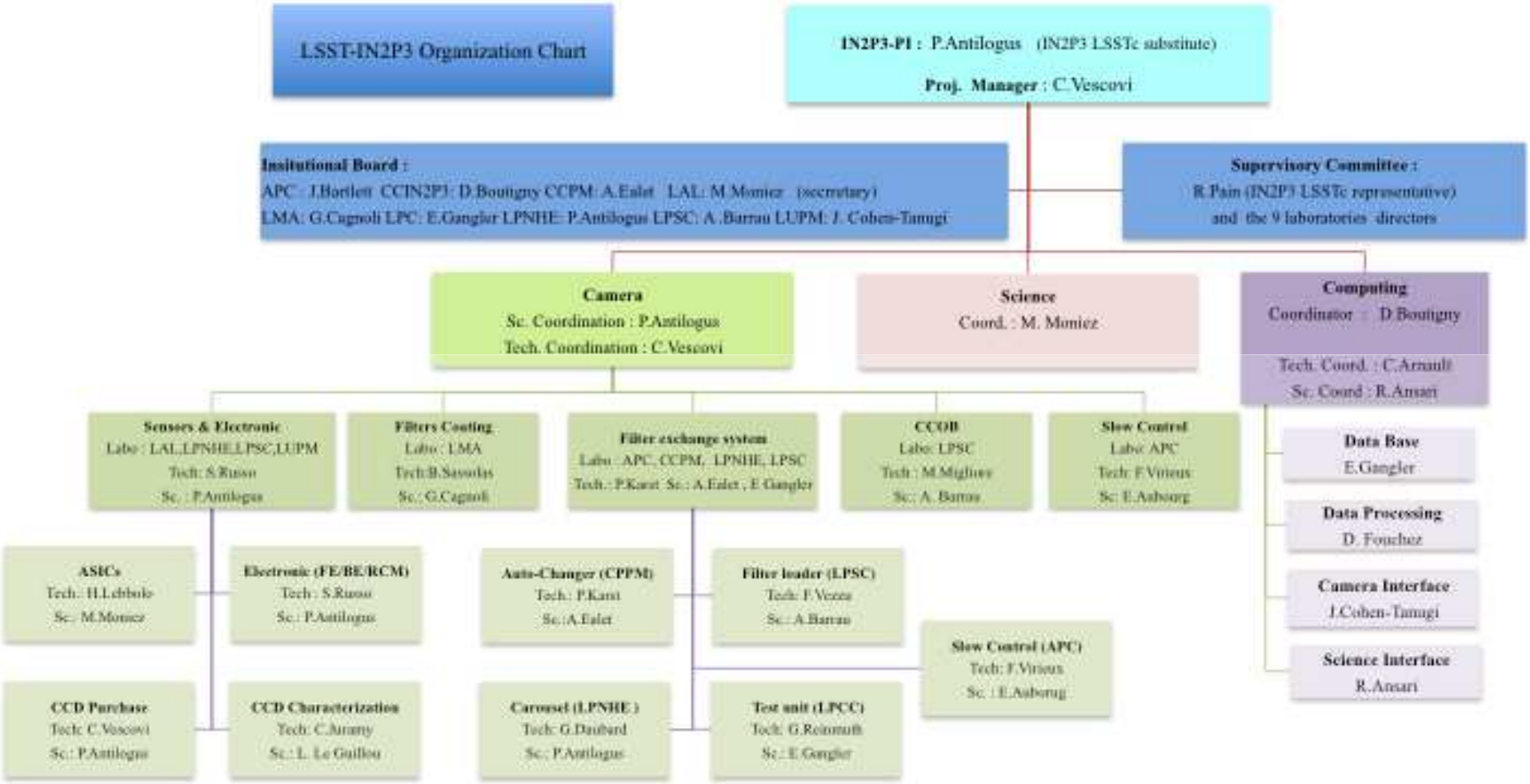
- March 2015 : IN2P3-LSST MOAs final agreement on construction, running, computing, and scientific exploitation .
  - IN2P3 scientists from the 9 IN2P3 laboratories contributing to the camera construction have full access to LSST (no numerus clausus)
  - +45 data access for French Staff scientist (+ up to 4 students and postdocs per Staff scientist) that will be open to French scientists from other IN2P3 laboratories or other French institution (CEA or INSU) under a formal agreement between them and the IN2P3 direction (to be implemented).
  - IN2P3 contribution to LSST is unique : it's the only non-US partner with only in-kind contribution to the construction and the exploitation (computing) . LSST will count ~ 1000 scientists, with ~ 50% non US. Except for Chile and France, non-US scientist will have to contribute 20 k$ / year for 10 years to have access to LSST data.
  - CC-IN2P3 will be the only non-US data center to host the full raw data , processed data and Data Base, the other foreign institution will only host the Data Base. This will be extremely valuable for the Dark Energy science in particular in the first years of the project.
  - ➔ Unique IN2P3 status in LSST is due to our early participation in the project and the great work that has bean achieved by the technical and scientific staff inside the IN2P3 contributing laboratories over the years all working as an IN2P3 team !

LET'S BUILD IT

LSST @ IN2P3 Today

- Today: 9 IN2P3 laboratories are directly involved in LSST (APC, CCIN2P3, CPPM , LAL , LMA , LPNHE , LPC, LPSC, LUPM)
- LSST team at IN2P3 counts ~ 110 active people :
  - 17 FTE for 38 active scientists in LSST
  - 28 FTE for 64 engineers and technical staff
  - 4 PostDoc + 6 PhD
- Its dominated by 31 FTE on the camera construction
- Ramping contribution on:
  - Algorithm , DB data processing preparation (~10 FTE)
  - Preparation of the Dark Energy science (~ 9 FTE) related to calibration , CCD signature removal, photo-z , supernovae , BAO , lensing , cluster

LSST @ IN2P3 : chart

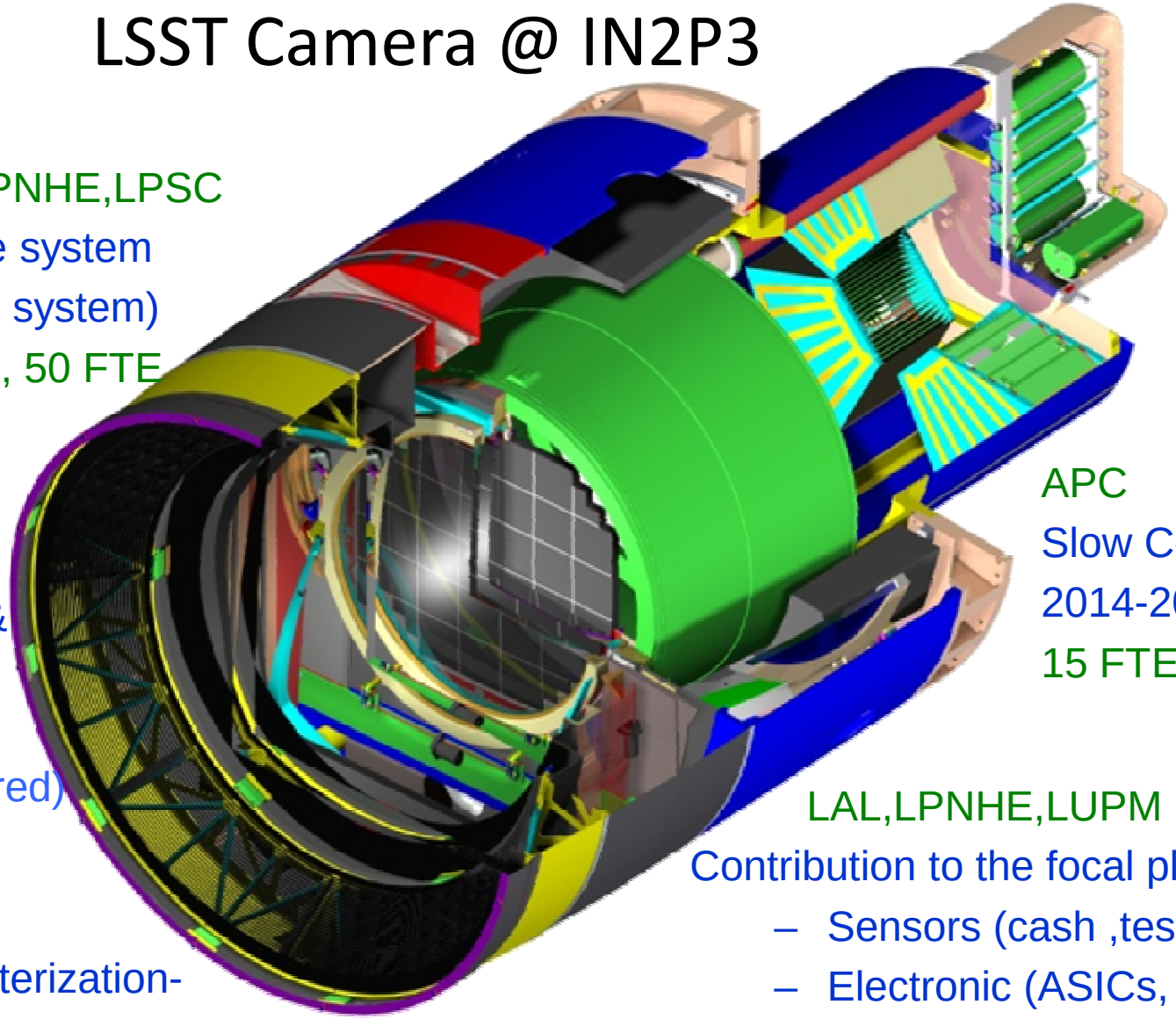


LSST Camera @ IN2P3

APC,CPPM,LPC,LPNHE,LPSC
Full Filter Exchange system
(robotic mechanical system)
2014-2020: 1.4 M€ , 50 FTE

LMA
Filter/optics
(coating expertise & characterization)
2014-2020: 3 FTE
(Extension considered)

LPSC
Stand alone characterization-illumination system (CCOB)
2014-2020: 300 k€ , 15 FTE



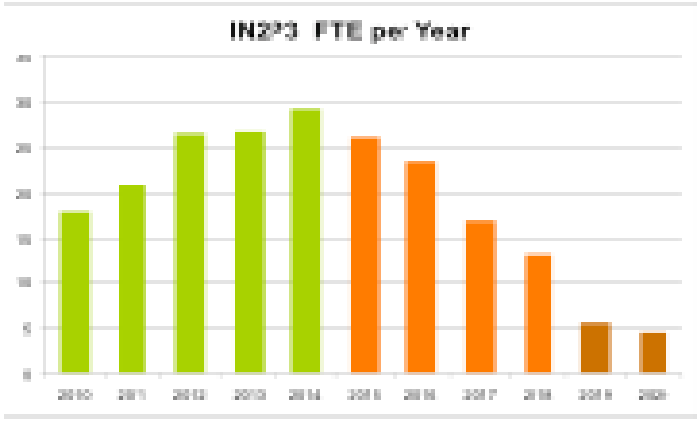
APC
Slow Control
2014-2020:
15 FTE

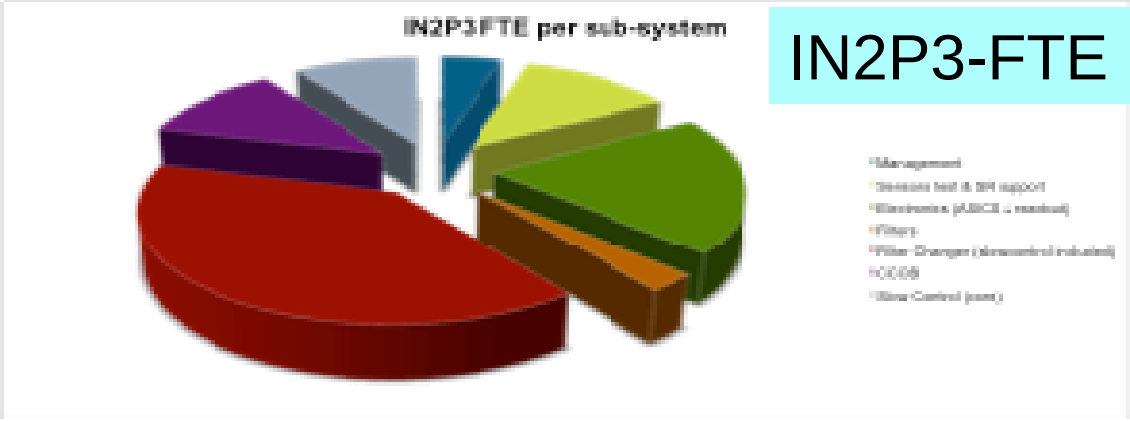
LAL,LPNHE,LUPM
Contribution to the focal plane :
- Sensors (cash ,tests)
- Electronic (ASICs, design
- "Brain" (FPGA)

2014-2020: 2.5 M€ , 30 FTE

LSST Camera@IN2P3 Resources

2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total 2014-20
1	1	1	1	1	1	1	1	1	0.5	0.5	6
3.6	4	4.5	4	4.4	4.6	4	4.5	4.5	0.5	0.5	26.8
4.5	7	8.1	8.5	7.5	6.5	7	5	0	0	0	34.1
1.2	2.6	3.6	3.3	0.5	0.5	0.5	0.5	0.5	0.5	0	7
5.5	14	18.1	19.4	11.5	12	12	8	5	1	0.5	58
4.1	1.8	4.1	4.5	4.5	2.1	3	3	2	1	1	14.6
1.4	1.1	2.1	1.6	2.5	1.5	2	2	2	2	2	14
19	31.5	41.5	42.7	32.2	28.7	29.5	24	15	5.5	4.5	160.5

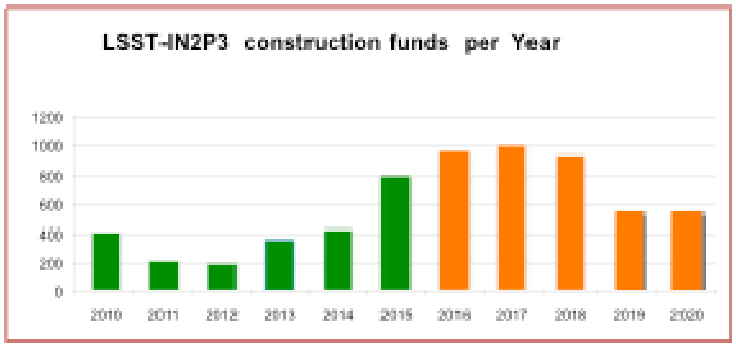


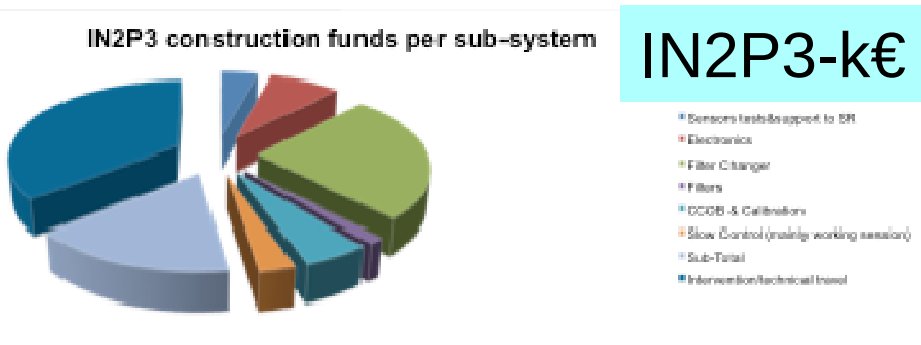


IN2P3-FTE

LSST Work breakdown profile

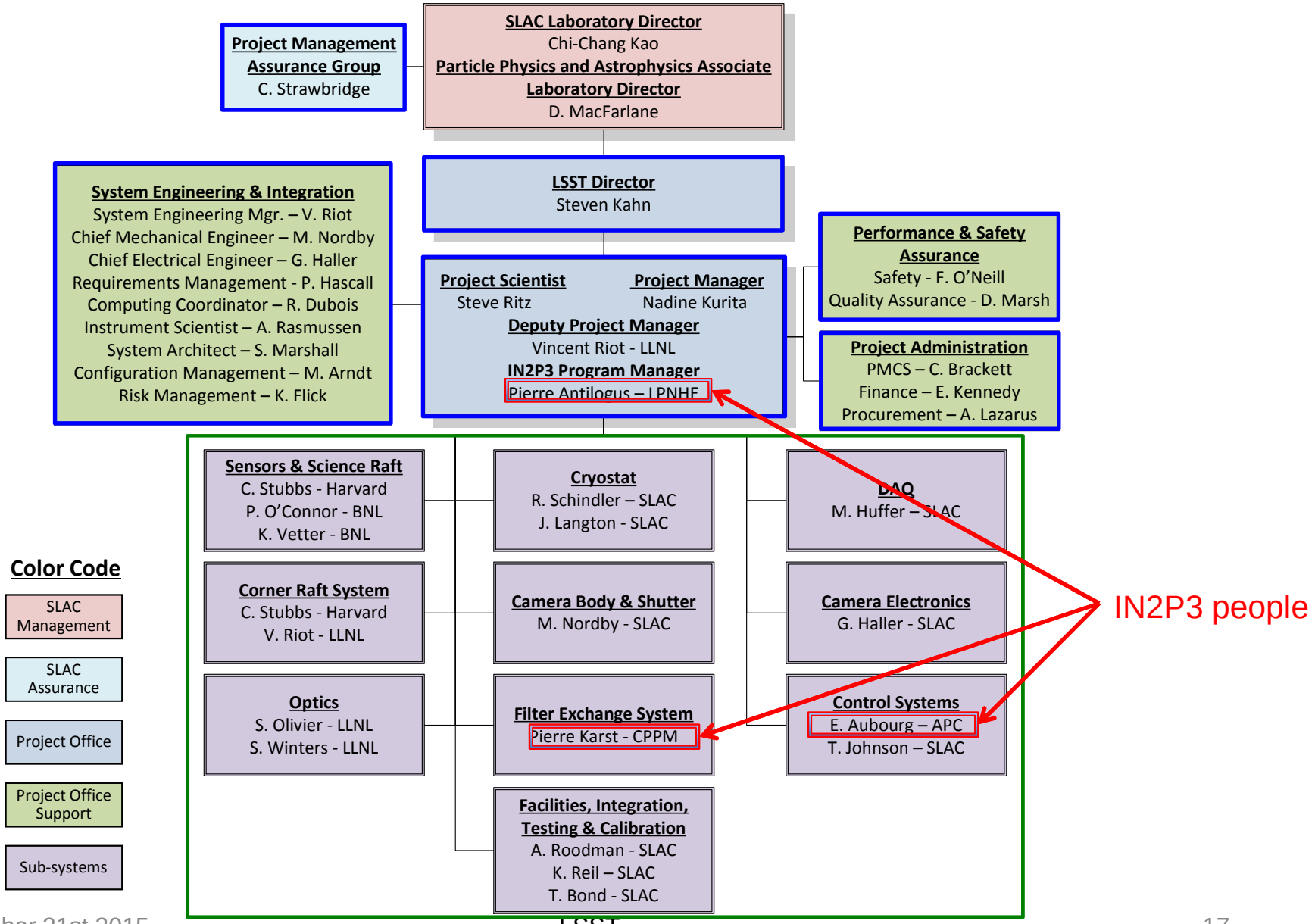
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	N.A. (k€)	2014-2020
[illegible]	30	30	10	75	29	35	50	50	25	0	0	[illegible]	189
[illegible]	8	20	70	30	101	258	10	10	10	0	0	[illegible]	389
[illegible]	32	75	52	155	201	381	310	285	200	25	25	[illegible]	1427
[illegible]	62	10	0	0	0	6	0	0	0	0	0	[illegible]	6
[illegible]	10	10	5	15	10	38	75	100	75	0	0	[illegible]	298
[illegible]	5	5	5	10	15	22	20	25	25	25	25	[illegible]	157
Sub-Total	147	150	142	285	356	740	465	470	335	50	50	2905	2466
Intervention/technical travel	60	60	50	70	70	60	100	130	200	100	100	1000	760
Sensors	200	0	0	0	0	0	400	400	400	400	400	2200	2000
[illegible]	407	210	192	355	426	800	965	1000	935	550	550	[illegible]	5226





IN2P3-k€

LSST camera chart



LSST Camera@IN2P3: time line

- Key dates for the Focal Plane (CCD & Electronics) :
  - Sensor Final Design Review May 2013
  - CABAC 2 final design review March 2015
  - Science Raft Final Design Review (FDR) May 2015
  - ASPIC Manufacturing Readiness Review October 2015
  - Start reception of pre-production CCD: fall 2015
  - Delivery of readout ASIC (ASPIC) : Jan 2016
  - Start of REB production (Focal Plane readout board) : Spring 2016
  - End CCD production / testing: summer 2018

- Key Dates for the Filter Exchange system :
  - Filter exchange system FDR : April 2015 , Delta-FDR for carousel : October 2015
  - Filter exchange demonstrator operational : summer 2016
  - Integration of the filter exchange system at SLAC : spring 2018

- Key Dates for the Camera Characterization Optical bench (CCOB)
  - Delivery of the wide beam system : mid-2016
  - Delivery of the thin beam system : mid-2018

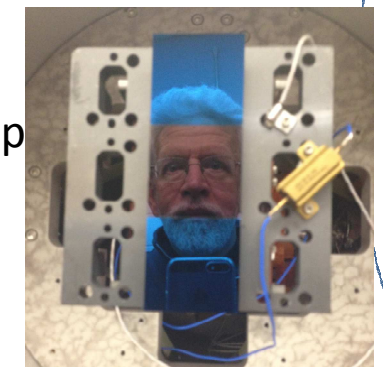
- The Slow Control (CCS) successfully passed its FDR in June 2015 (many deliveries during the construction)

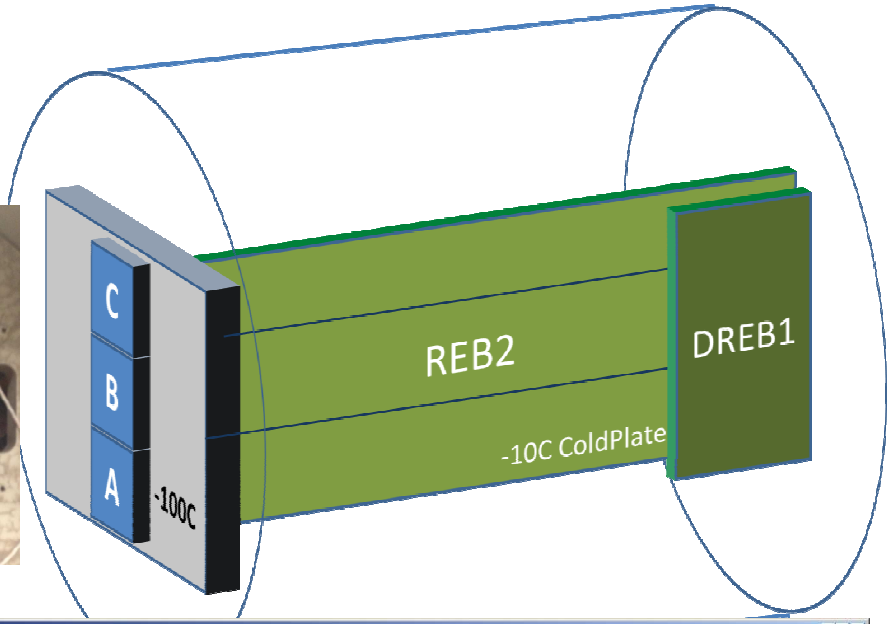
- Qualification of the optical test samples (at LMA) : 2016

- Camera assembly at SLAC : 2017-2019

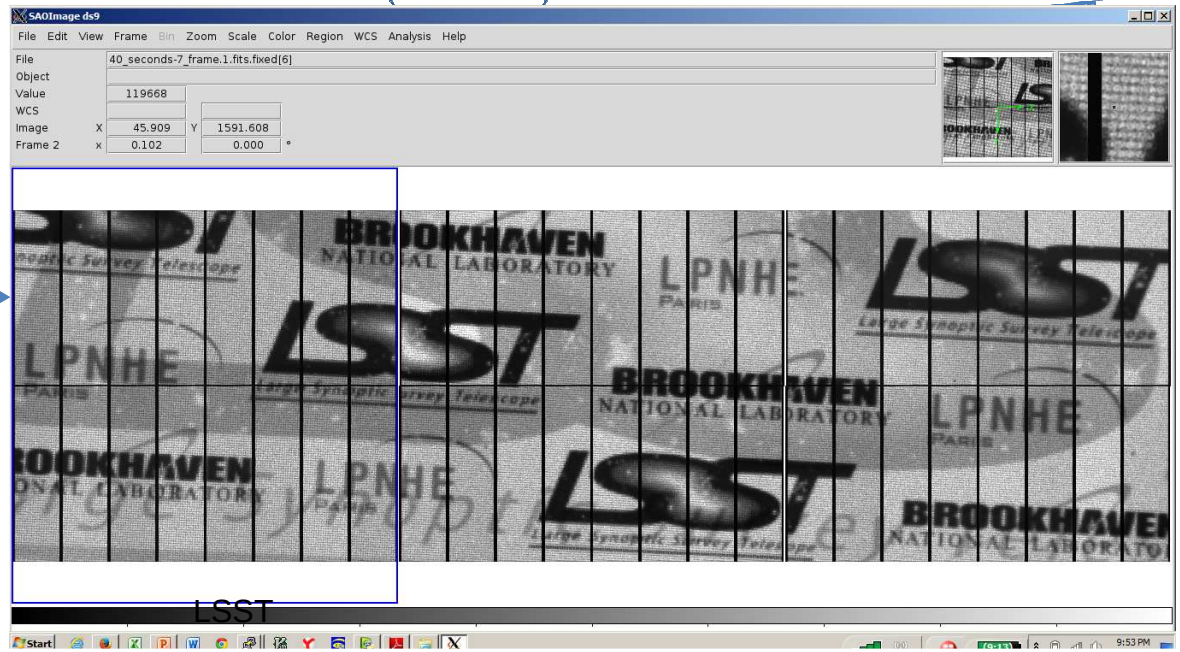
Feb 2015 : 3 CCD readout at BNL by a BNL & LPNHE team

- 3 CCD250 prototype sensors on CeSiC raft baseplate
- One REB2 + DREB1 in vertical slice (TS7) cryostat
  - 6X ASPIC3
  - 6X CABAC0
- 480kpix/s, no serials during exp fast clear once on startup
- Setpoints:
  - RSA -100C
  - coldplate -10C





48 M pixels image !
1/63 LSST focal plane

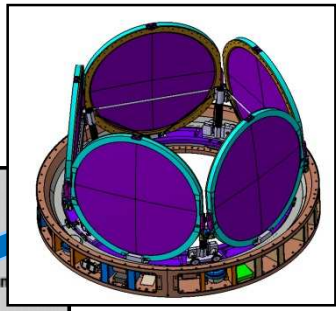


Filter Exchange system & IN2P3 labs

Total Manpower 2015
22 people – 12 ETP

Filter Control System
FCS (APC)
PARIS

Françoise Virieux, et al.

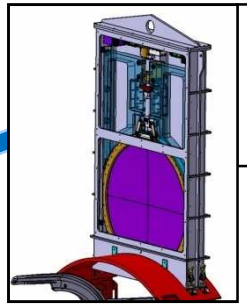


Carousel (LPNHE)
PARIS

Guillaume Daubard, et al.

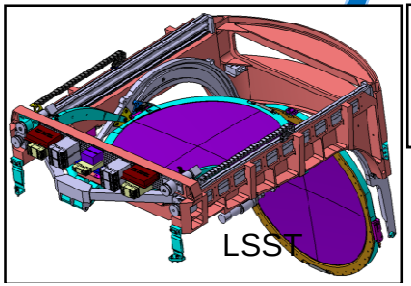
Full Scale Prototype
Test Bench (LPC)
Clermont Ferrand

Guy Reinmuth et al.



Loader (LPSC)
GRENOBLE

Francis Vezzu, et al.

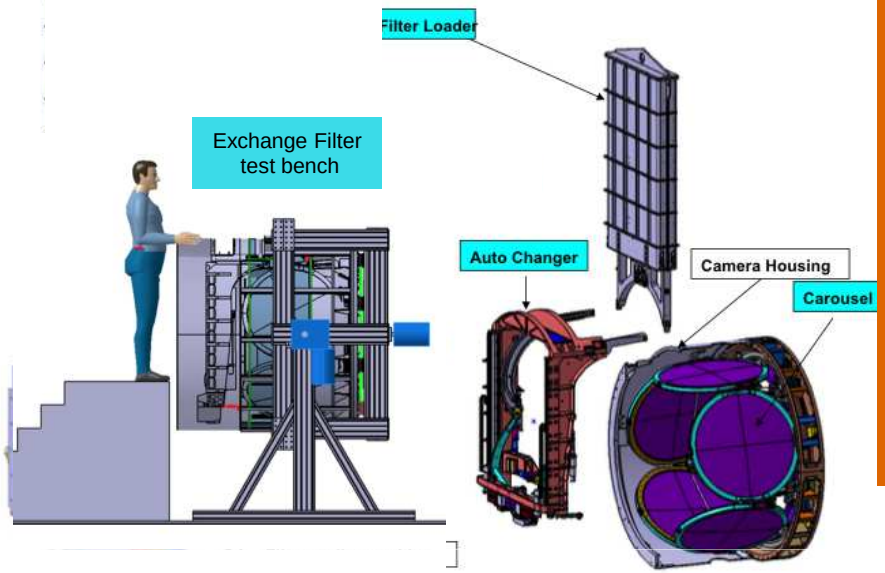


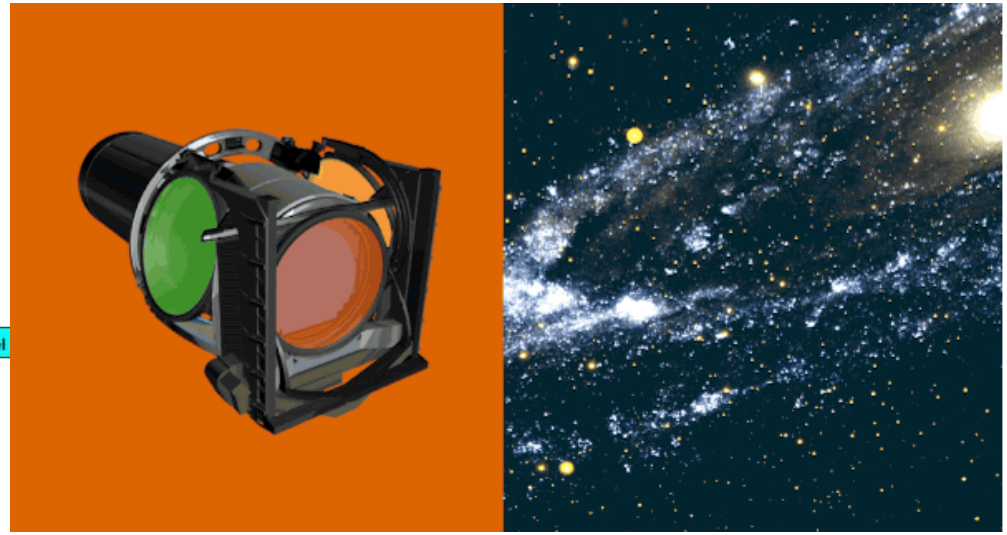
Auto-Changer (CPPM)
MARSEILLE

Pierre Karst et al.

LSST

Filter Exchange system & IN2P3 labs





The LSST Filter exchange system is a complex robotic system, with highly constraining requirements:

- 5+1 Filters to handle : ~ 40 Kg - diam 70 cm each
- Total weight of the system (with filters) ~ 600 kg
- 89s to change the on beam filter
- life time : 100000 filter exchanges during the LSST life
- Compatible with the Chili seismic condition
- High rigidity : in carousel filter holder moves by < 0.1 mm between extreme camera positions
- Dust free environment (avoid filter contamination)

LSST
Computing @ IN2P3

LSST computing at IN2P3: CCIN2P3

• 25%/~10M$ of the LSST running cost will be covered by international contribution.
• In all international agreement : the non-US scientific community involved in LSST will have to rely on its own computing facilities 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 effort and to ensure competitive data access in France – an unique in-kind contribution has been agreed with LSST:

- 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.

The collaboration between CC-IN2P3 and LSST/NCSA is running since spring 2015 :

- A coordination committee between LSST, NCSA and CC-IN2P3 is in place.
- CC-IN2P3 has setup a dedicated internal organization to proceed with LSST.
- CC-IN2P3 started an innovative study on computing infrastructure for LSST.
- The platform to distribute the LSST binaries is operated by CC-IN2P3
- Underway Discussion with RENATER on the CC-IN2P3-NCSA network
- F. Hernandez (CCIN2P3) gave a key talk at the annual main 2015 LSST meeting

➔ CC-IN2P3 is now fully part of the LSST landscape data processing.

LSST computing at IN2P3: Software

In Parallel to the work related to processing at CCIN2P3 , LSST software activities with contribution from different LSST IN2P3 laboratories are ramping up since 2012.
In particular there is 3 fronts active/ramping up in :

LSST DATABASE / BIG DATA (LPC,CC-IN2P3)

-LSST database work initiated in 2012 with a grant within the MASTODONS call
- F. Jammes (LPC) spent 6 months at SLAC in 2014, he is now a key LSST DB expert
-Dell provided (2015) to the CC-IN2P3 a platform of 50 nodes with 400 processors & 0.5 Po to deploy and test the LSST database : ongoing test / exceed expectation

VERIFICATION DATASETS (CC-IN2P3, CCPM,LPC)

-To test its software suite, LSST has recently embarked upon a project to reprocess DES, HSC and CFHTLS datasets with the LSST software. Using the IN2P3 expertise from SNLS, LSST-France fully responsible of the CFHTLS reprocessing at CC-IN2P3.

CONTRIBUTION TO DATA REDUCTION SOFTWARE

-Next generation of simultaneous astrometry solver (LPNHE,LPC,CC-IN2P3)
-PhD thesis (CCPM) on image subtraction software to extract SN Ia light curve in LSST.

LSST
Dark Energy Science Collaboration
@ IN2P3

IN2P3 science team in DESC

Dark Energy Science ➔ the horizon of the LSST IN2P3 team

~50 staff IN2P3 scientists have identified LSST as their future,
38 have already non-0 contribution to LSST today.

- Following the DOE request to set up a collaboration "à la" High Energy Physics, 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, international LSST partner and on the French side to all scientists from the IN2P3 laboratories involved in the camera construction + 45 “tickets” that will be open to French scientists from other IN2P3 laboratories or other French institution (CEA or INSU) under a formal agreement between them and IN2P3 direction that has still to be implemented.

- Today 24 scientists among the 152 DESC full members are from IN2P3 (~15%) .

- IN2P3 scientists between 2012 and 2014 helped to build the DESC and today IN2P3 members are part of the DESC management:
  - 1 member of the DESC Advisory board (D.Boutigny among 5 scientists)
  - 2 DESC board members (P.Antilogus, D.Boutigny among 15 elected members)
  - 1 working group co-coordination (P.Astier , DESC Sensor Anomaly Working Group)
  - 1 member of the Membership committee (E.Aubourg)

IN2P3 @ DESC

- IN2P3 scientists are involved in the DESC working groups associated to the 4 dark energy probes accessible to LSST. Two publications related to these studies have been produced (SN , Shear)
- Still today the work on these probes is on real dataset, like the one collected by DES (with a participation from US, Germany UK and Spain) or HSC (with a participation from Japan and US). It's mandatory for the LSST IN2P3 team to work on real dataset to prepare the LSST science:
  - To be at the state of the art in 2022 for LSST analysis
  - For the training of young scientists and new comers to the field
  - To keep ramping the dynamic inside/among the LSST science team

  ➔ see in particular N.Regnault talk today

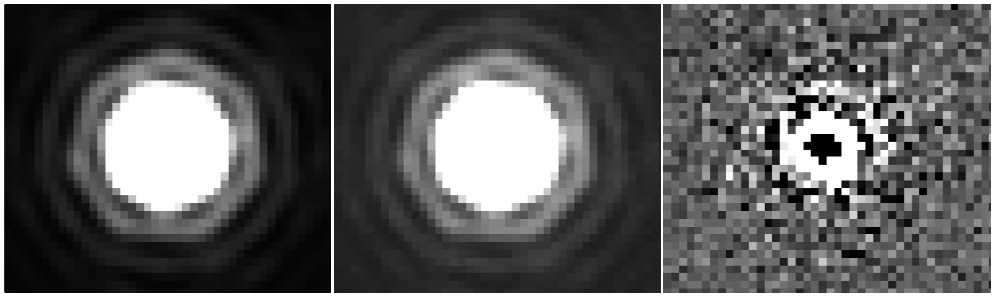
IN2P3 @ DESC

To prepare the scientific return our calibrations related activities are ramping :

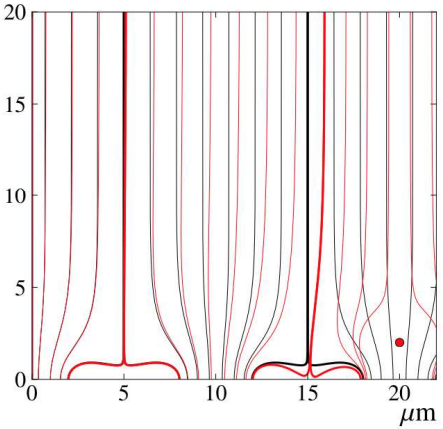
- There is a large Photometric LSST_France red-shift team, which has published in 2014 the first LSST internally reviewed paper. (APC,LAL,LPSC,LUPM)
- We launched last spring the LSST-France “Calibration studies” group (coordinated by M.Betoule & F.Feinstein) , its first goal is to address the usage of the Gaia survey as a “frame” (Astrometric & photometric) for the LSST survey data reduction. (CPPM,LPNHE,LUPM)
- The sensor signature removal studies (3 papers published), had a rocket start in 2013 with the discovery of the brighter-fatter effect (see next slide) (LPNHE)

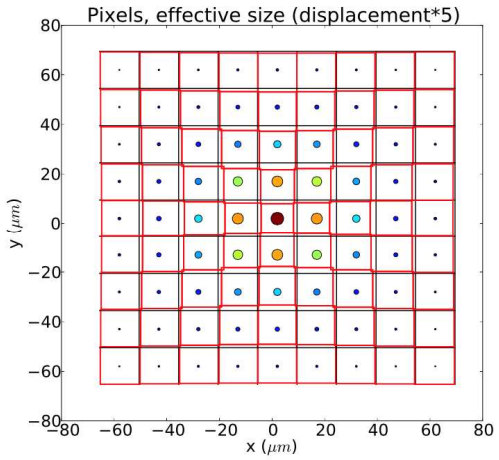
Brighter-Fatter effect

a recent (2013) finding in CCD properties (LPNHE)



spot shape / psf changes with flux ➔
Left : 200-s spot; middle : sum of ten 20-s spots; right : difference. ➔ Brighter spot is « fatter »





On top of the discovery and understanding of the effect a correction method, with parameters extracted from flats has been developed and already used by running project (DES) : correction mandatory for lensing studies .

Remark : The IN2P3 early hardware contribution to the project will end to a future better science ! This is not just words !

the cause of the effect : electrostatic distortion of the pixels boundaries by the charge collected

Conclusion : LSST@IN2P3

- LSST Camera construction started in late 2014. It was associated to a peak in the ITA FTE @ IN2P3. To succeed in our contribution to the camera construction, we have to face key milestones in the next 3 years. To sustain our effort will request the expected funds, stable manpower and overall strong laboratories-IN2P3 support in particular for the next 18 months.
- After ~ 3 years of preparation, IN2P3 is fully part of the LSST data processing . CC-IN2P3 is THE partner of the NCSA for the LSST data processing , the highly visible big-data challenge of the next decade. The IN2P3 team activities in Data management is unique, this put the IN2P3 team in good position for the scientific return,
- Over the last 3 years, IN2P3 scientists activities strongly raised with the take-off of DESC and Computing activities. The contribution to Calibration studies & Algorithm in LSST may further rise in the (close) future. Still LSST@IN2P3 need today that some of its members contribute to “top of the art” Dark Energy science (SN, lensing , phot-redshift …) in project(s) with real data now.