High Energy Astrophysics with stratospheric balloons

A short personal review on

- MPE Compton Balloon Telescope
- CLAIRE
- EUSO-BALLOON
- COSI

Peter von Ballmoos

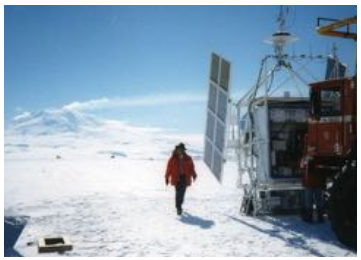
IRAP Toulouse

« my » balloons

Compton balloon
1982

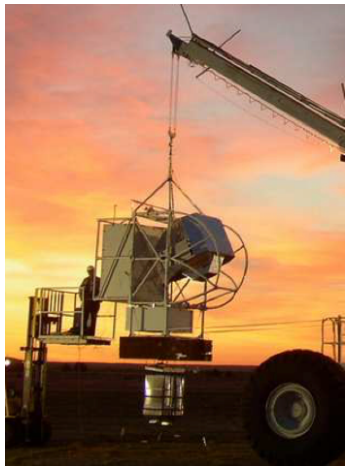
FIGARO II
1988

HEXAGONE
1989, 1992



HIREGS
1999

CLAIRE
2000, 2001



COSI (NCT)
2005,
2009,
2010 …
COSI
2014,
2016

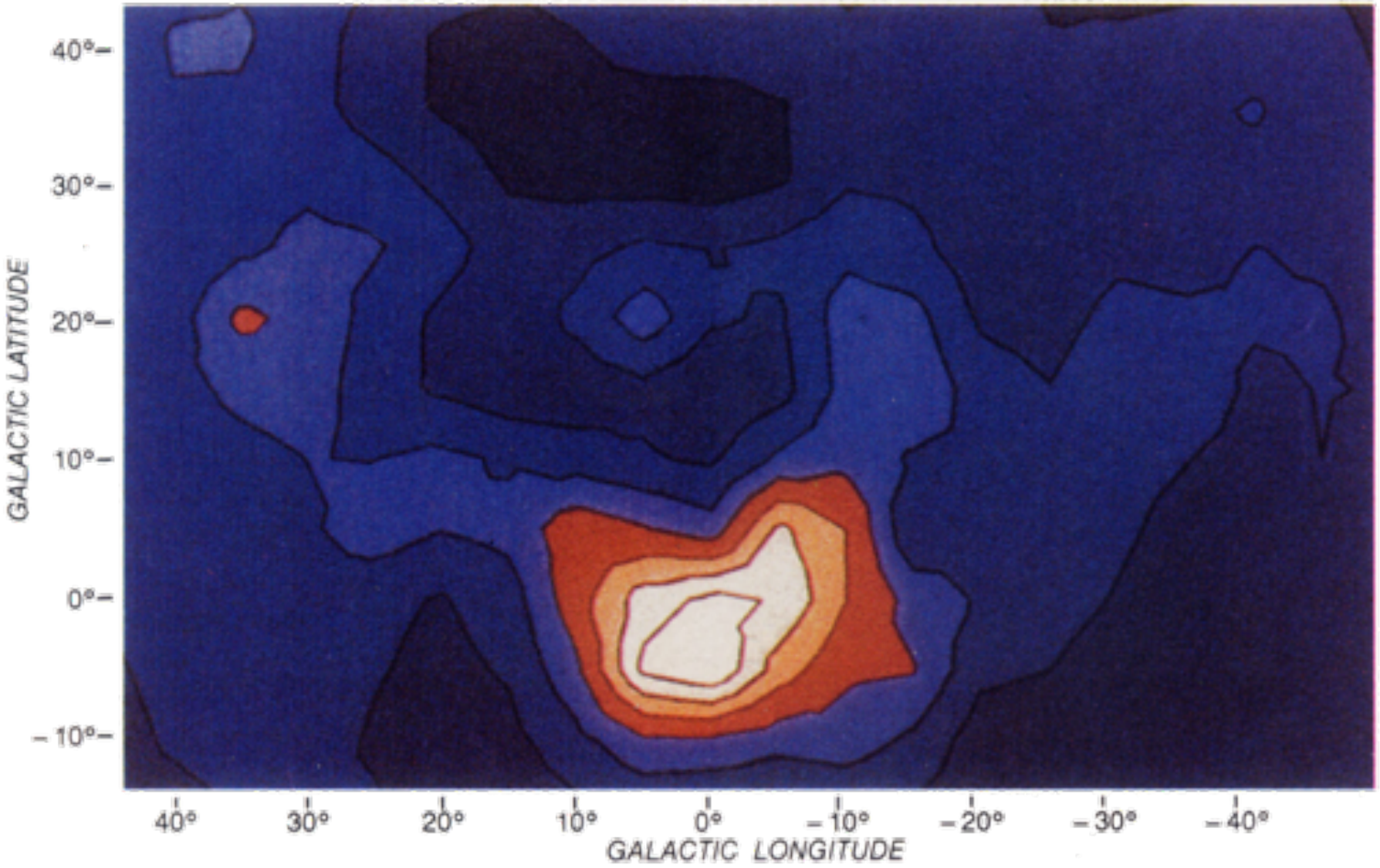
eusoballoon
2014, 2017


MPE Compton telescope
UBERABA October 31, 1982


the cleanroom

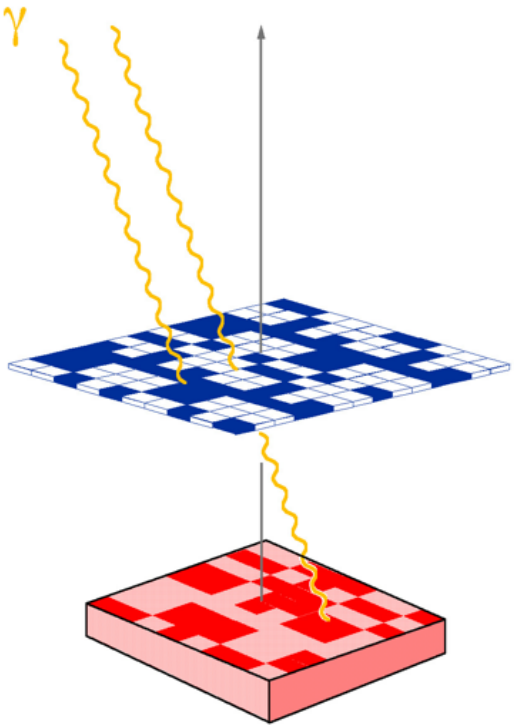
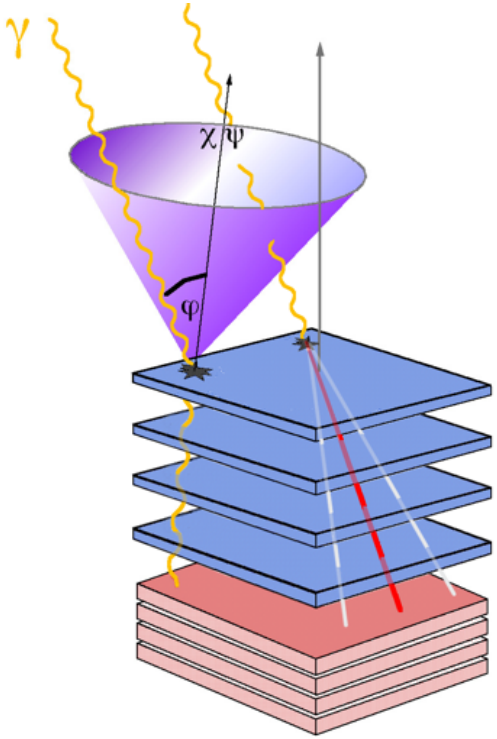
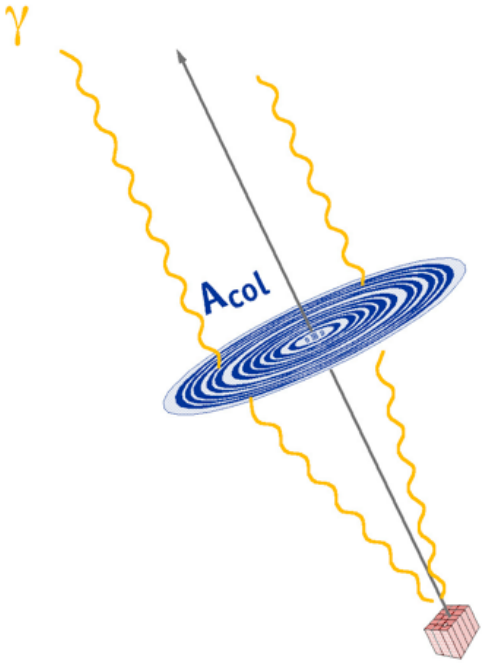
Mission Control Center

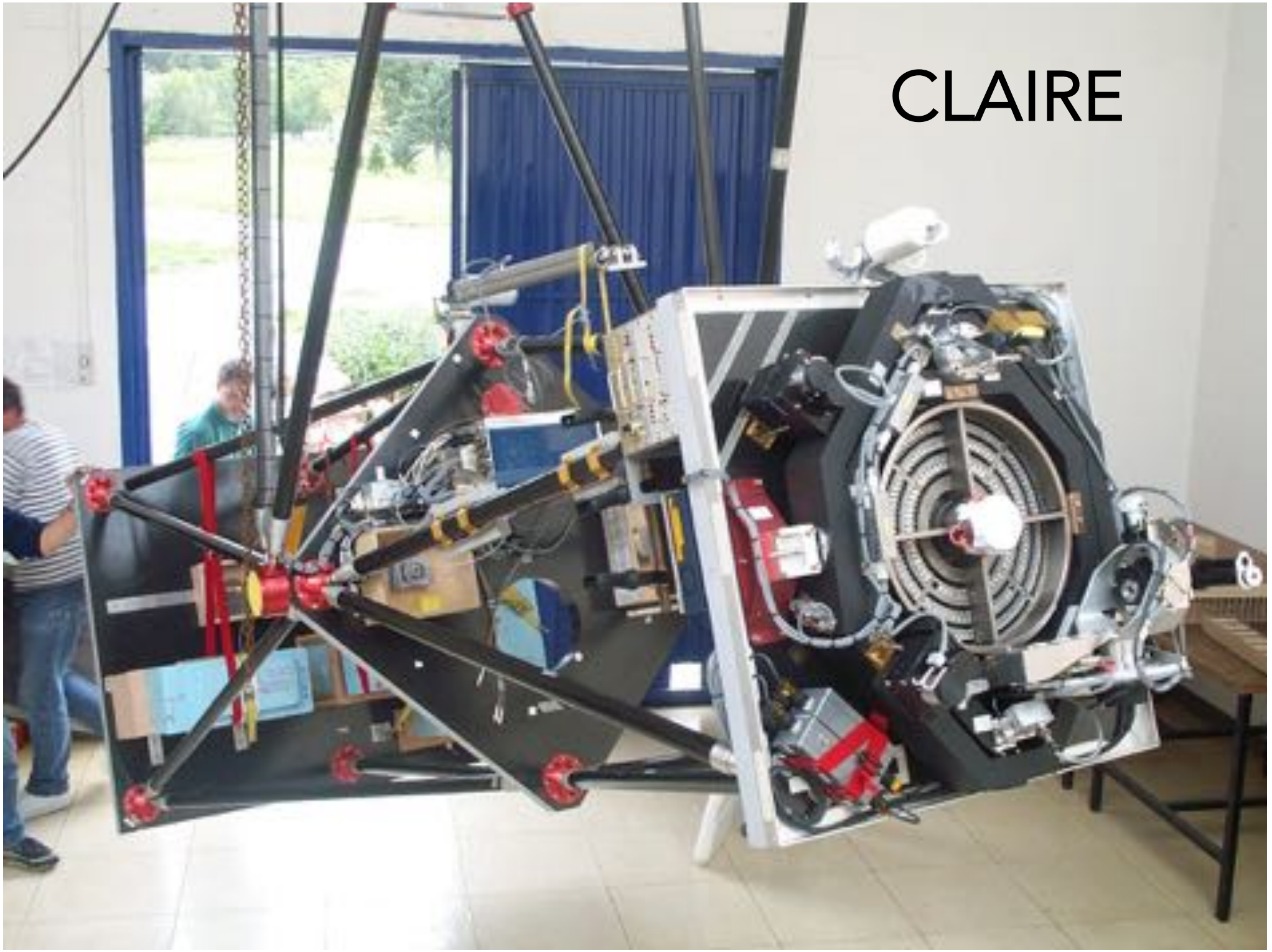
The Galactic Center Region in the light of ^{26}Al gamma-rays



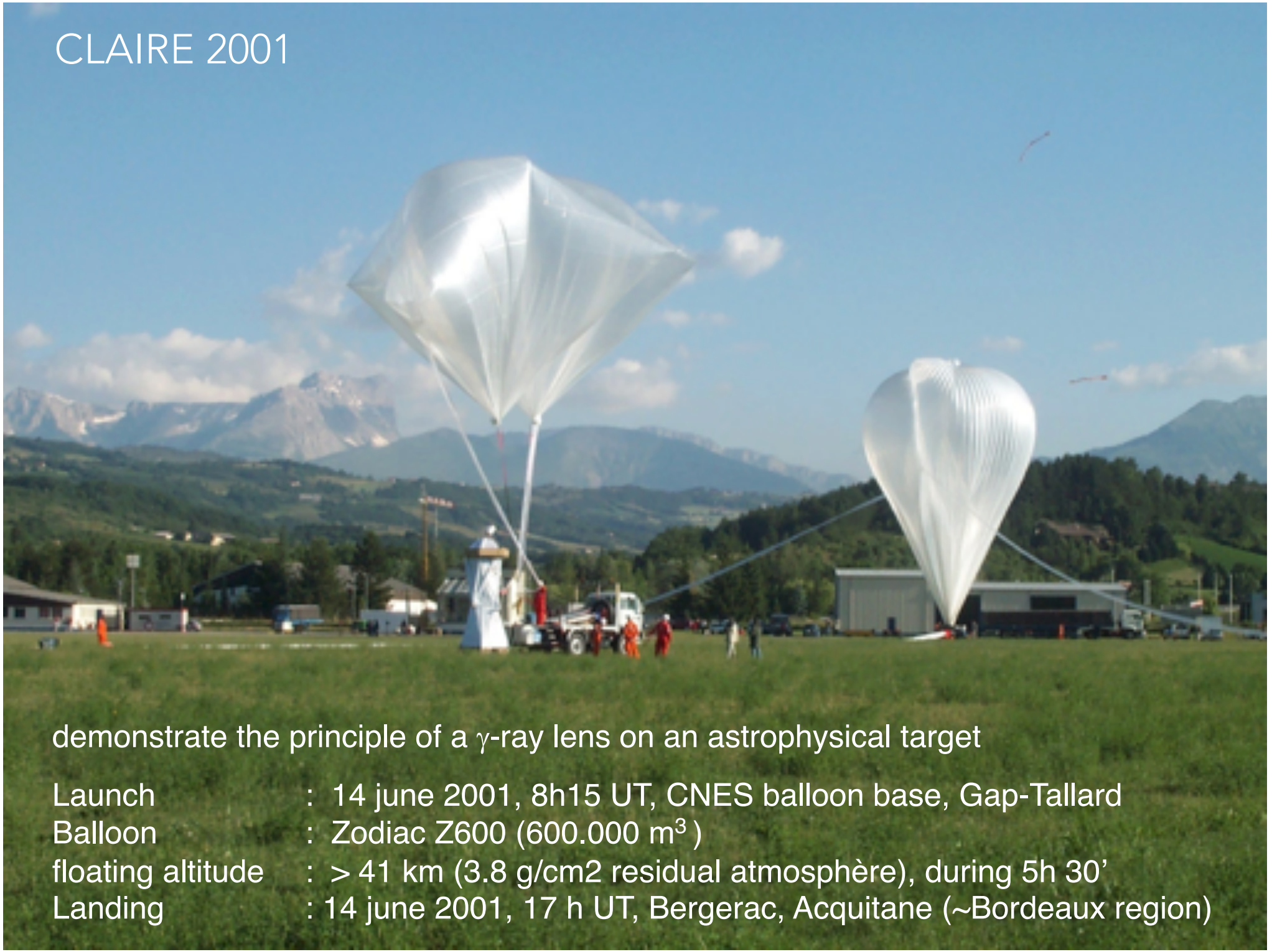
Instrument concepts in gamma-ray astronomy

The instrumental categories in nuclear astrophysics reflect our current perception of *light* itself.

	geometric optics absorption	**quantum optics** incoherent scattering	**wave optics** coherent scattering
detector aperture			
	ex. coded masks telesc. "on-off" collimators	ex. Compton telescopes tracking chambers	ex. Laue lenses Fresnel lenses


CLAIRE

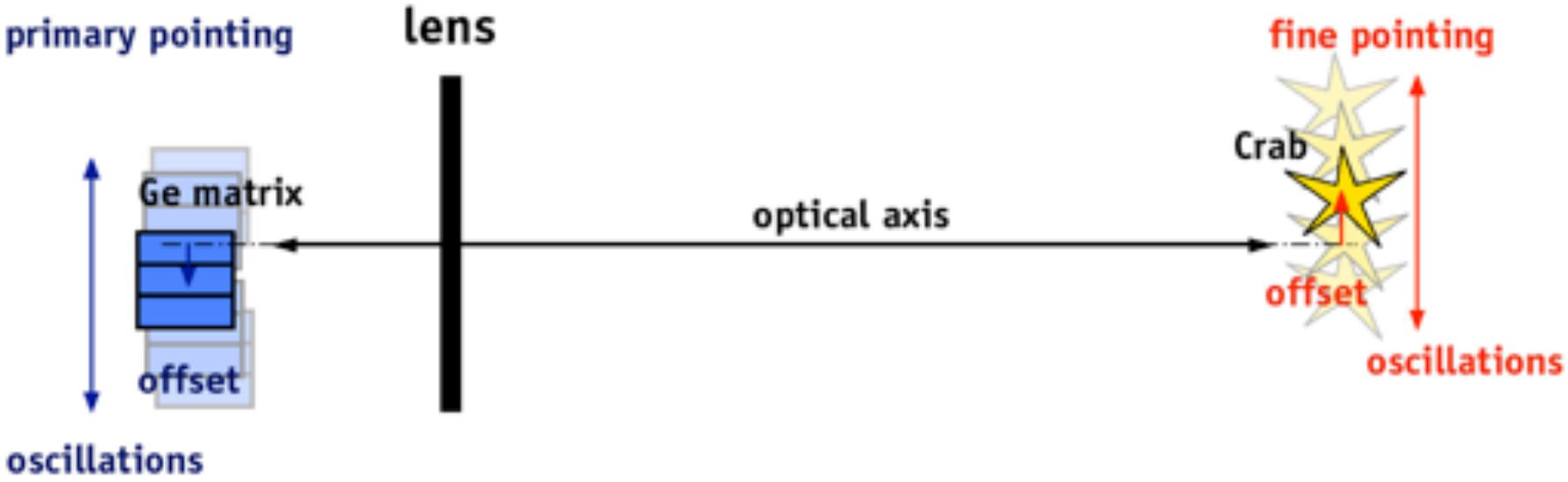
CLAIRE 2001

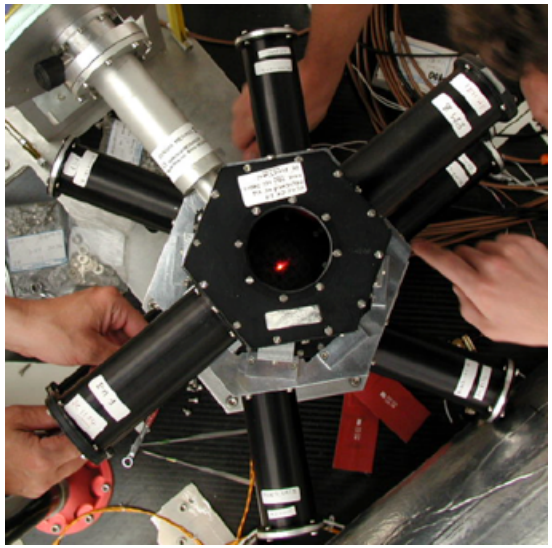


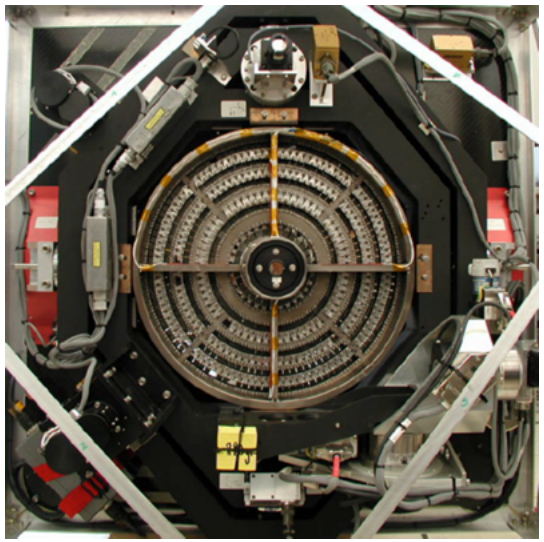
demonstrate the principle of a γ-ray lens on an astrophysical target

Launch : 14 june 2001, 8h15 UT, CNES balloon base, Gap-Tallard
Balloon : Zodiac Z600 (600.000 m^3)
floating altitude : > 41 km (3.8 g/cm2 residual atmosphère), during 5h 30'
Landing : 14 june 2001, 17 h UT, Bergerac, Acquitane (~Bordeaux region)

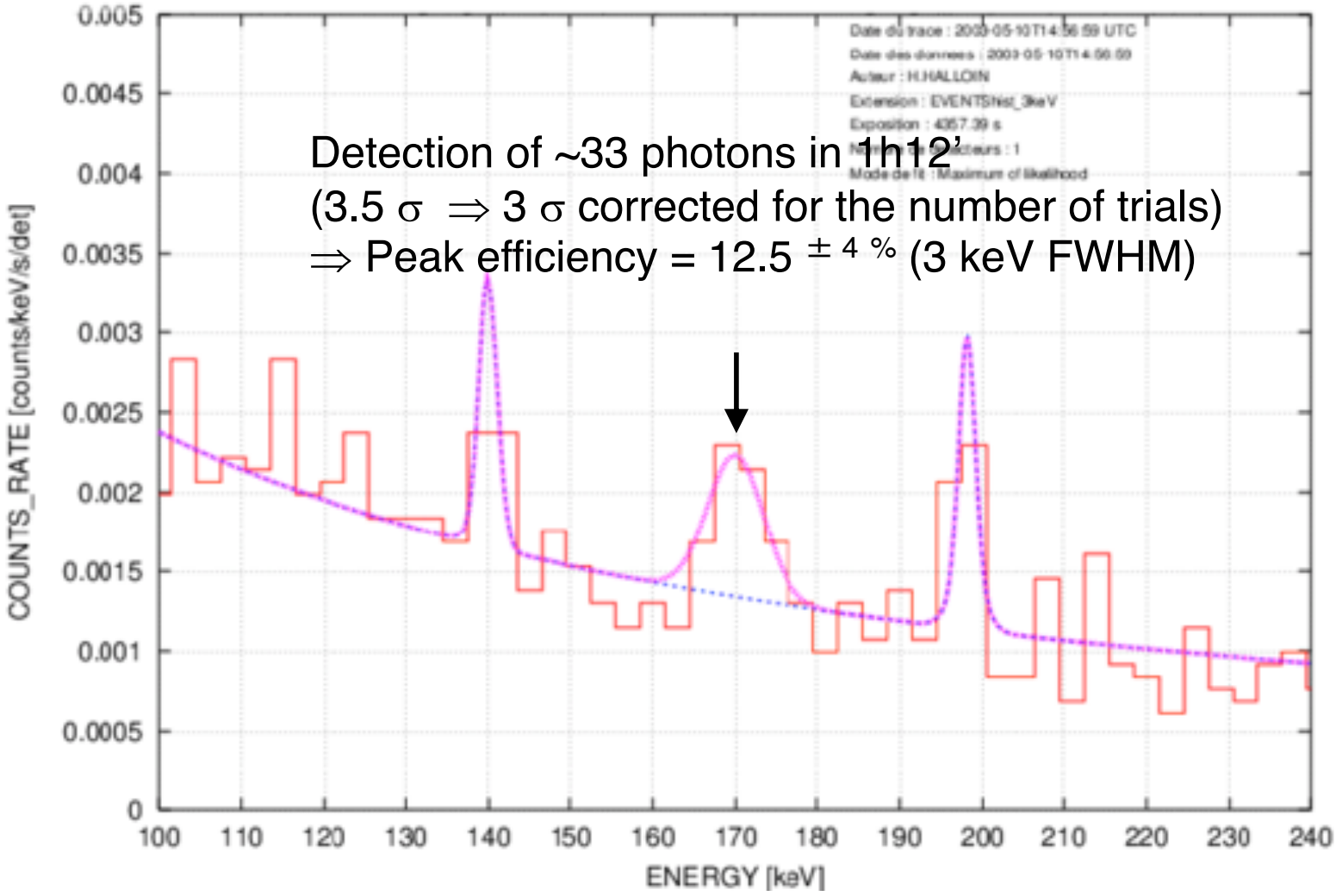
CLAIRE 2001 : pointing







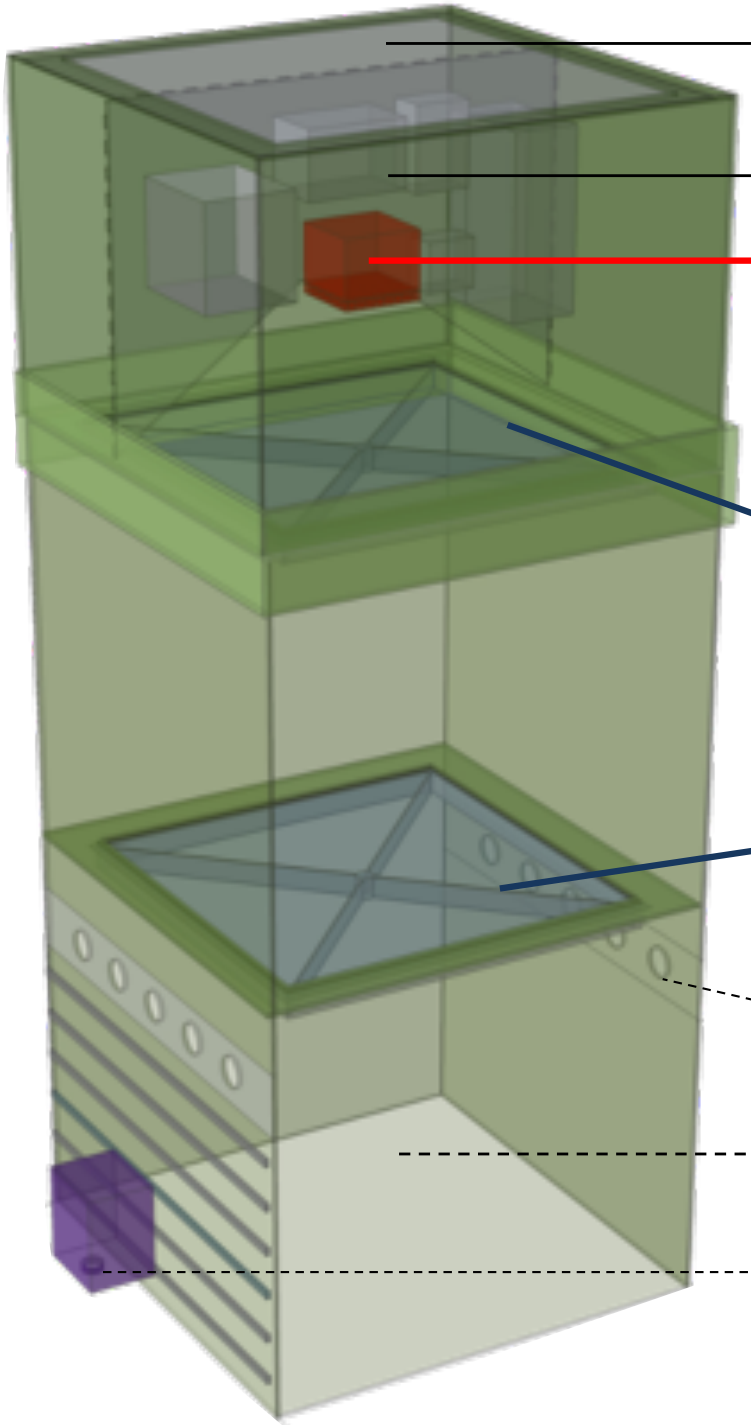
CLAIRE 2001 : first light of an astrophysical source



EUSO – Balloon 24.8.2014 20:53 LT

instrument booth

optical bench

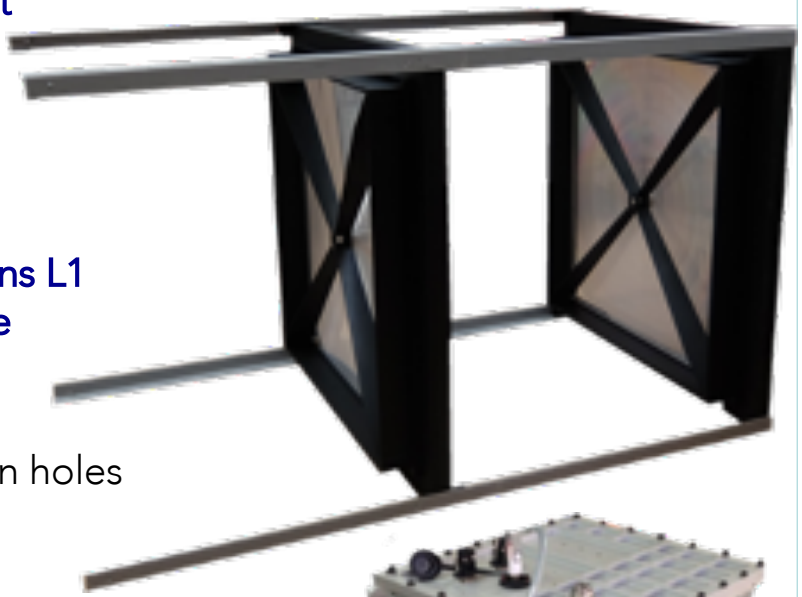


radiator

electronics (DP)
on "dry shelf"

PDM

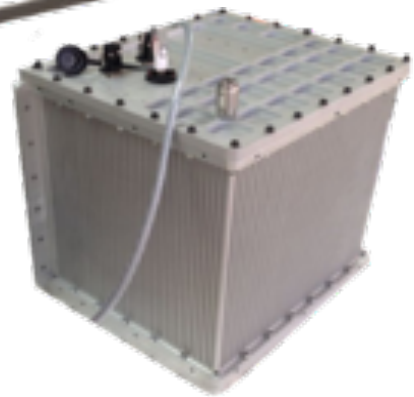
Fresnel lens L3
fixed/tight



Fresnel lens L1
adjustable

evacuation holes

Baffle &
"deceleration cylinder"

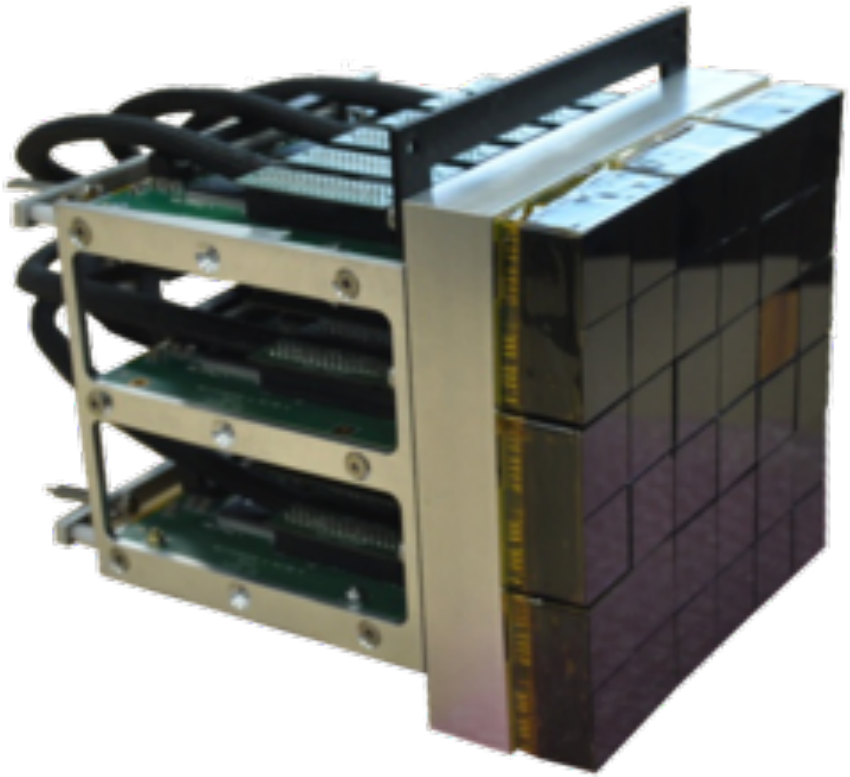


IR Camera

mounting the Fresnel Lenses

The Photo Detection Module (PDM)

The PDM consists in a focal surface and electronics.
It has to detect the UV photons coming from the optics, digitalize the data and perform the level 1 triggers.



2304 pixels (48 x 48)

36 Multi-Anode Photomultipliers
9 Elementary Cell front units
9 High Voltage Power Supplies
6 ASIC boards
1 FPGA board

quantum efficiency ~ 25 %
frame rate : 400'000 per sec

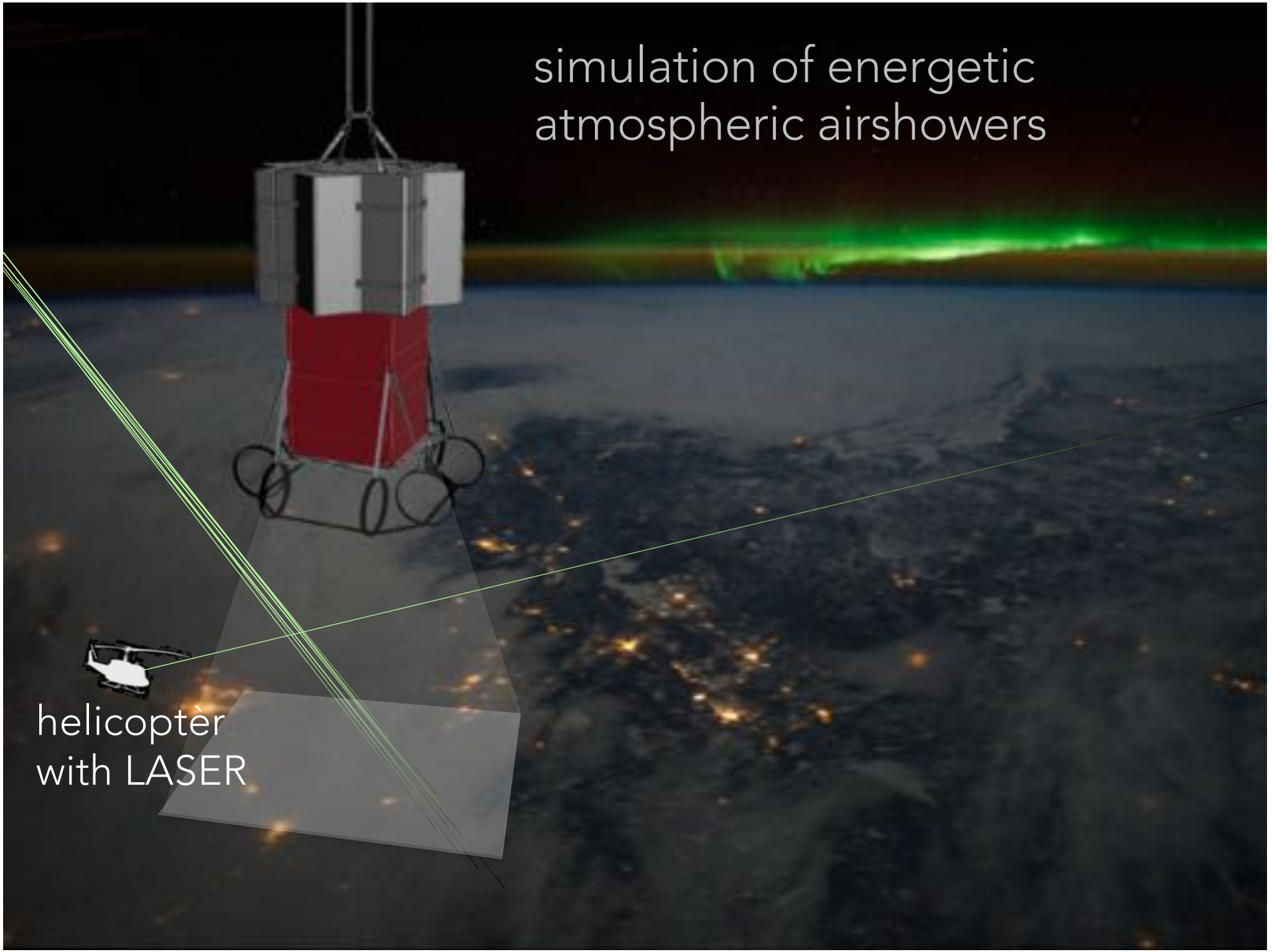
EUSO-BALLOON descent

over one of the "dryest" zones in Canada (country of 3 million lakes)

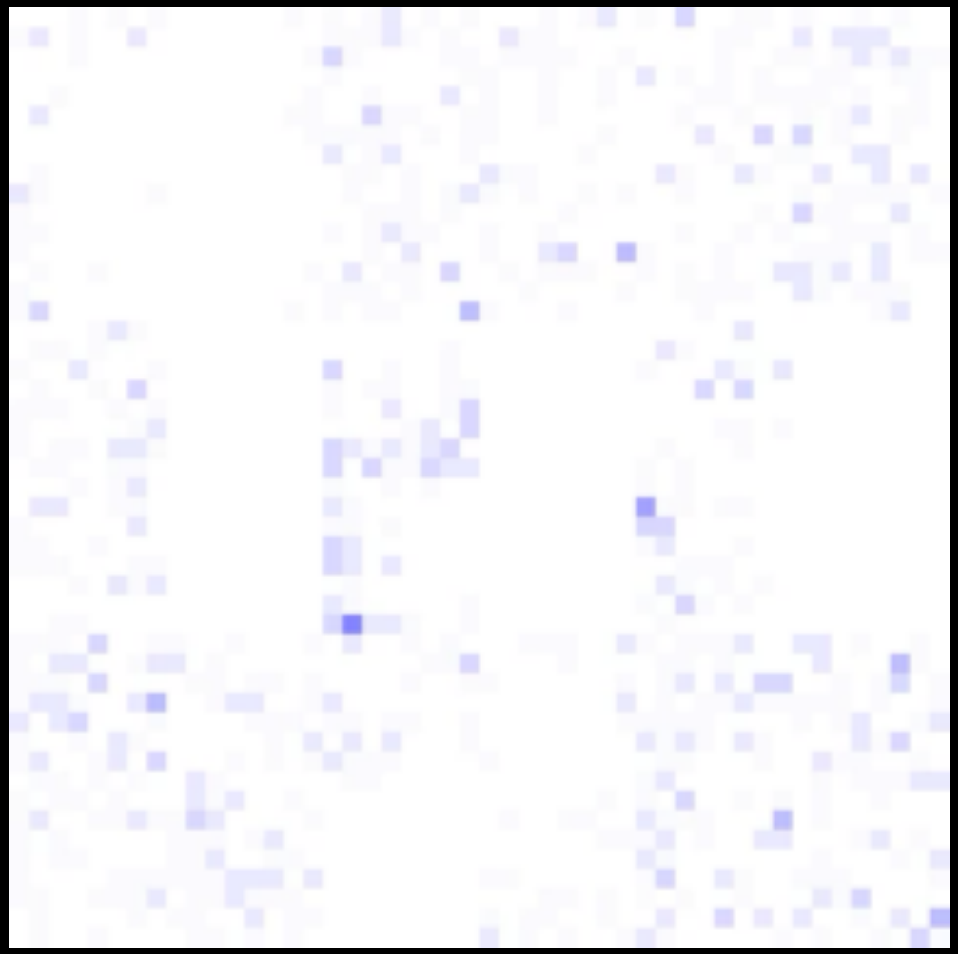
simulated landing sit

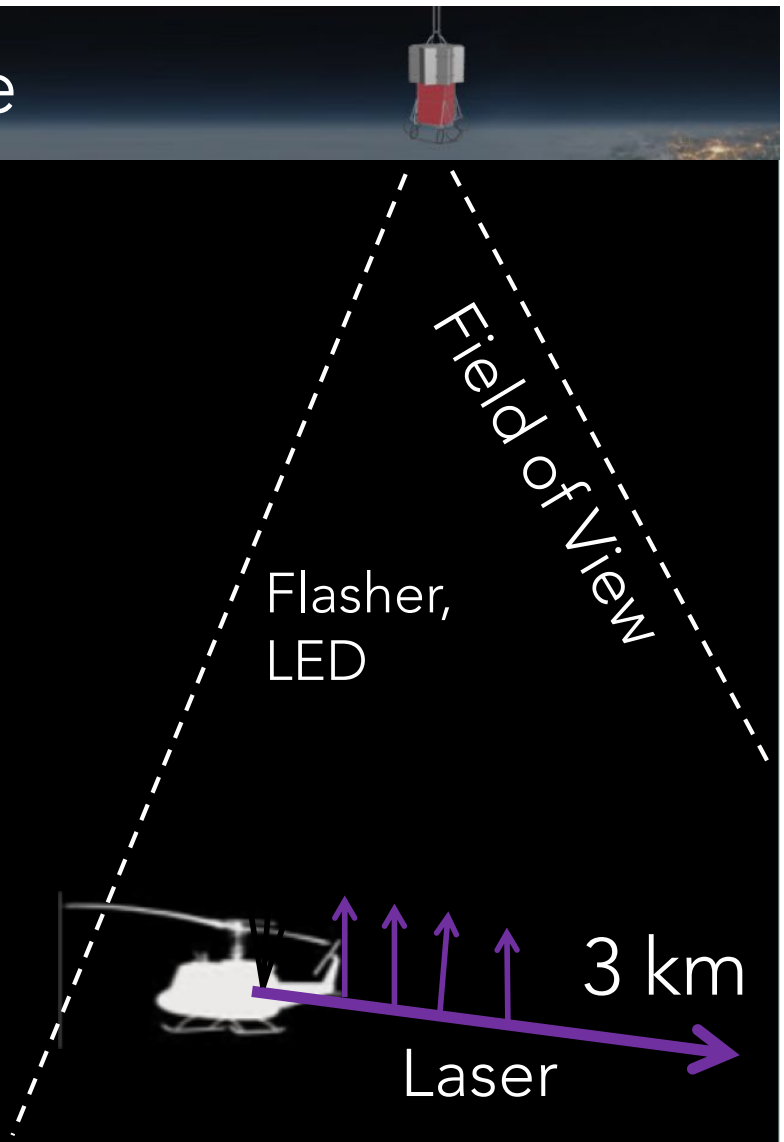
10 km


from the recovery helicopter above … "Lake Euso"
A Balloon-gondola for Waterlanding
presentation by Jean Evrard (CNES) on Tuesday - [A-169]


simulation of energetic
atmospheric airshowers
helicoptèr
with LASER

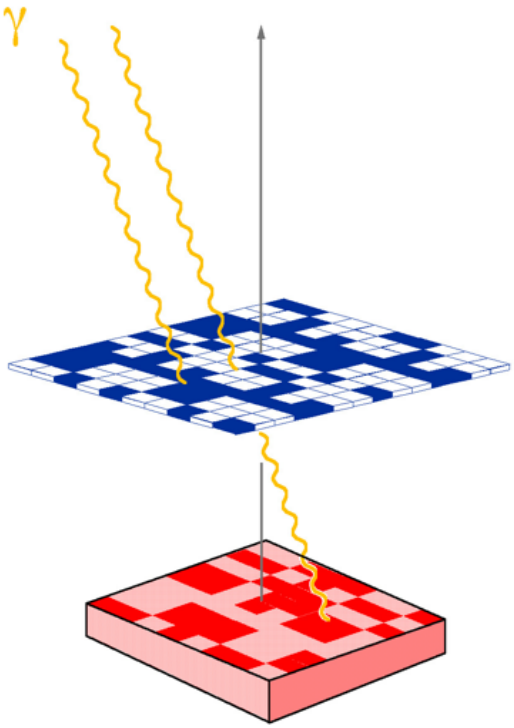
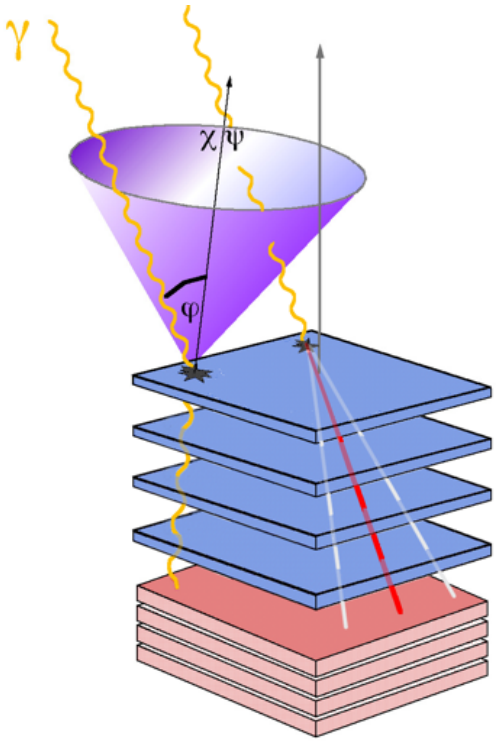
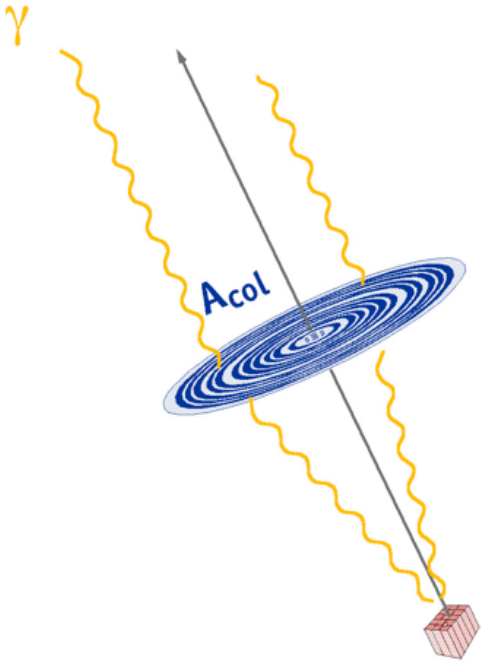
a LED-LASER-XENON sequence





Concepts instrumentaux en astronomie gamma

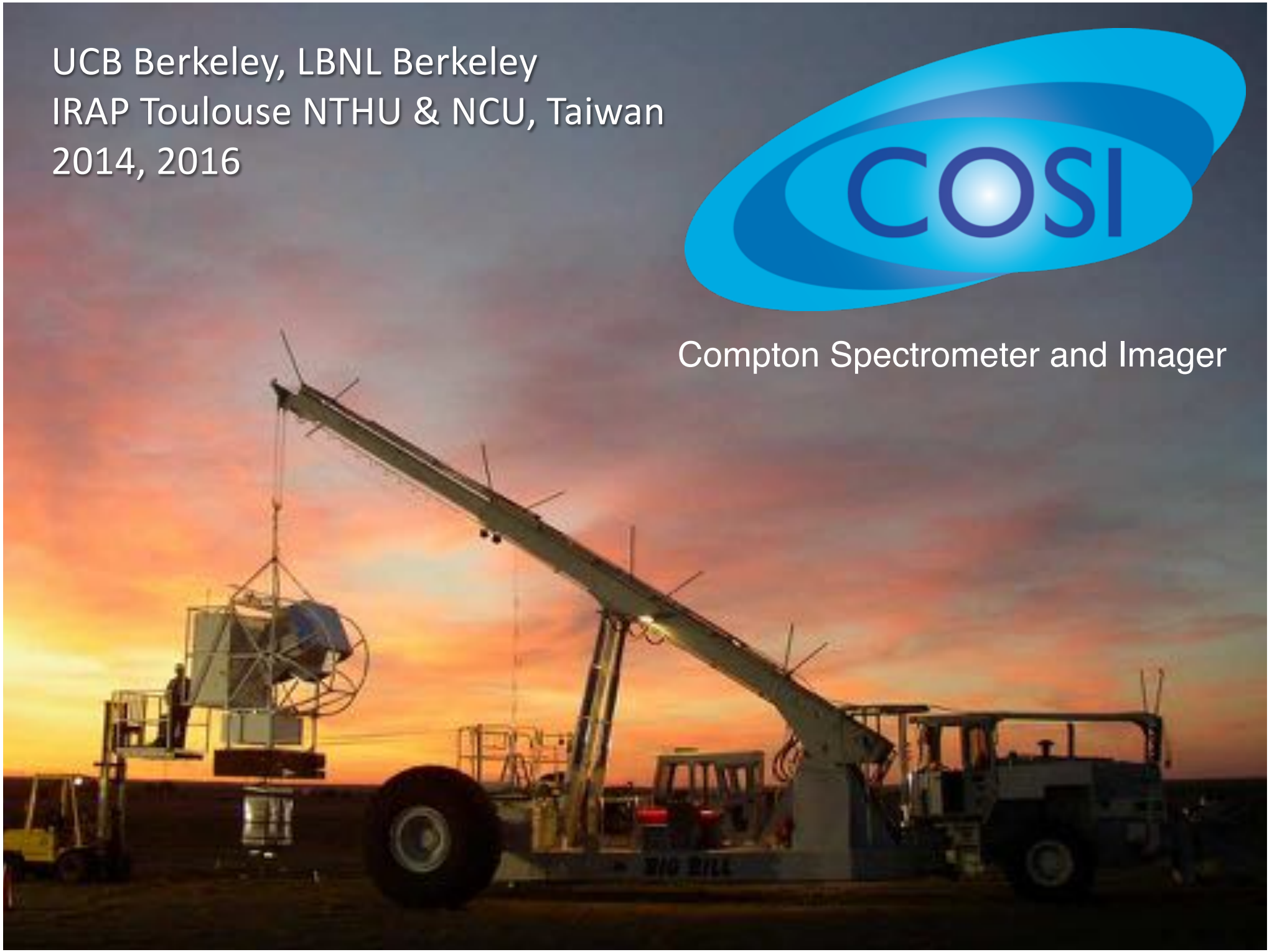
Les catégories instrumentales de l'astrophysique nucléaire reflètent notre perception de la lumière elle-même.

	optique géométrique Absorption	**optique quantique** diffusion incohérente	**optique onulatoire** diffusion cohérente
detecteur ouverture			
	ex. masques codés telesc. Colimateurs « on-off »	ex. Télescopes Compton trajectographes	ex. Lentilles de Laue Lentilles de Fresnel

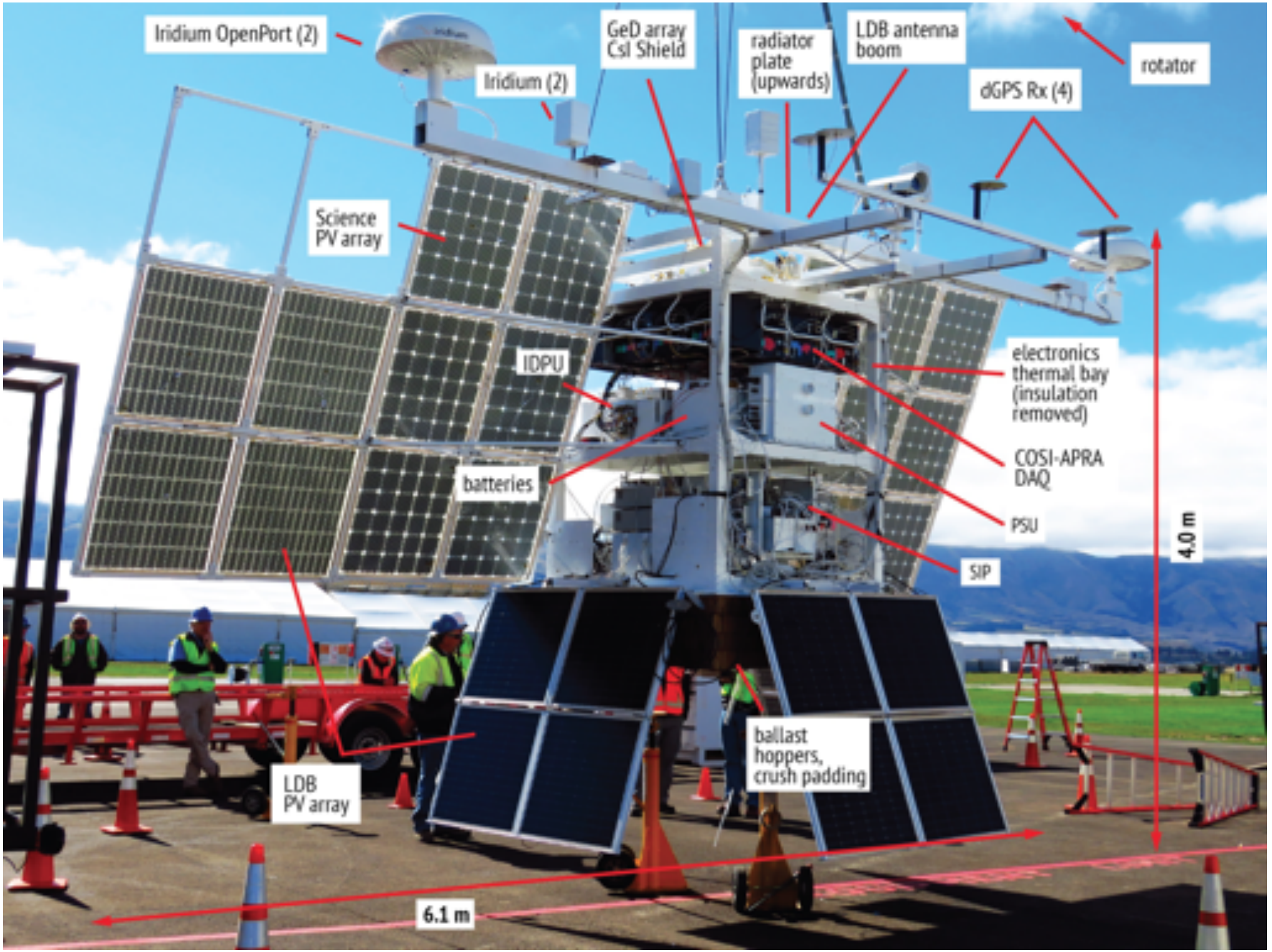
UCB Berkeley, LBNL Berkeley
IRAP Toulouse NTHU & NCU, Taiwan
2014, 2016

COSI

Compton Spectrometer and Imager



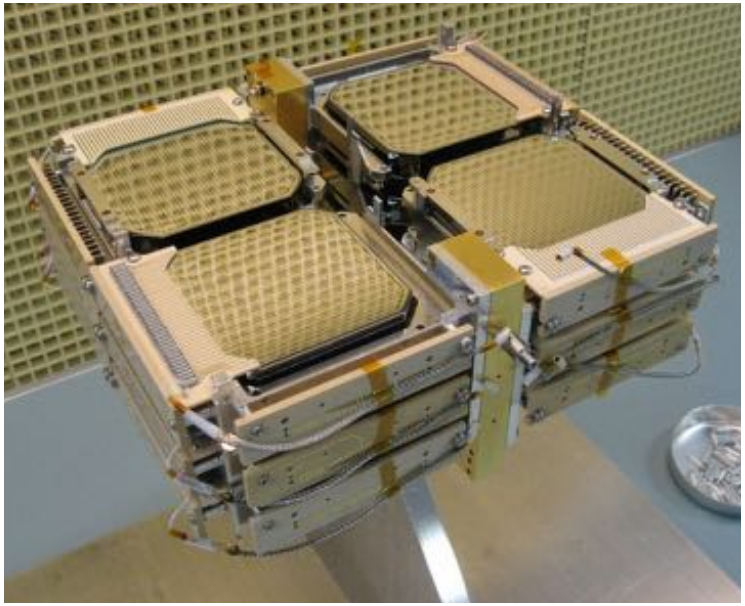
NCT launch "mishap" Alice Springs 28 april 2010


Iridium OpenPort (2)
Iridium (2)
GeD array
CsI Shield
radiator
plate
(upwards)
LDB antenna
boom
rotator
dGPS Rx (4)
Science
PV array
IDPU
batteries
electronics
thermal bay
(insulation
removed)
COSI-APRA
DAQ
PSU
SIP
4.0 m
LDB
PV array
ballast
hoppers,
crush padding
6.1 m

Overview: Instrument & Campaigns

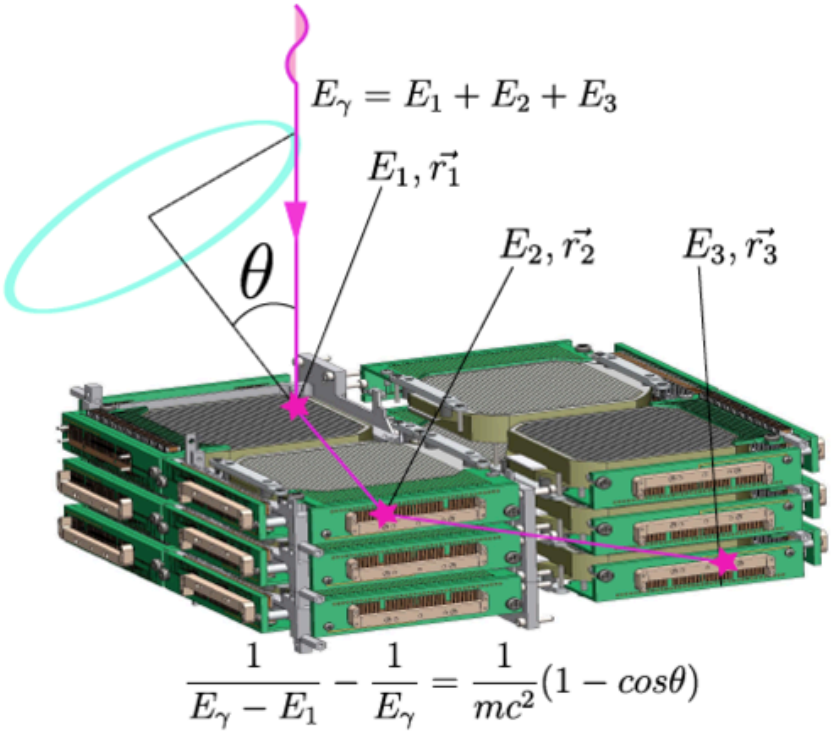
Instrument:

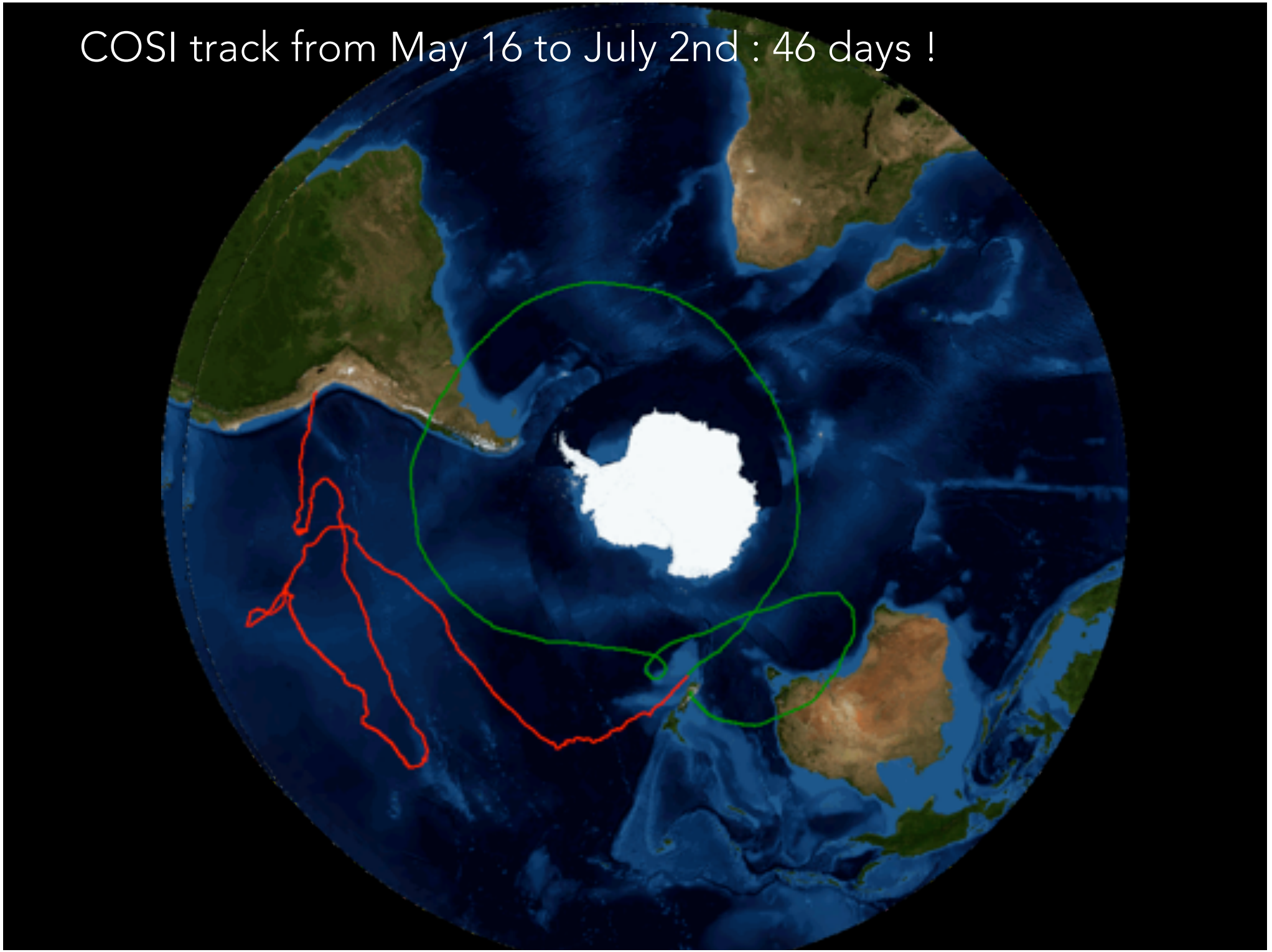
- Balloon-borne Compton telescope
- Energy range: 0.2 – several MeV
- 12 high-purity Ge double-sided strip detectors , 2 mm strip pitch
- Energy resolution: 1.5-3.0 keV FWHM
- Depth resolution: ~0.5 mm FWHM
- Angular resolution: up to ~4° FWHM
- Large field-of-view: almost 1/4 of sky

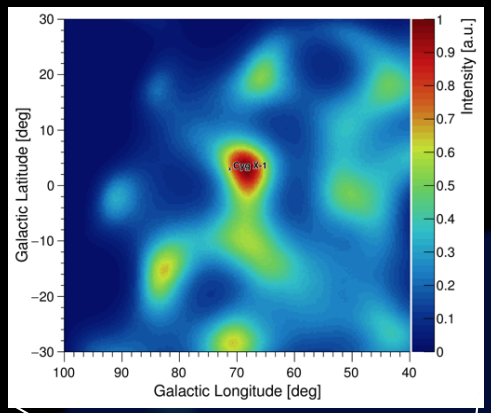


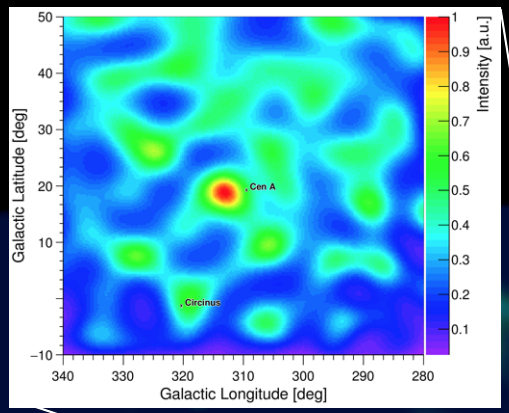
Balloon campaigns:

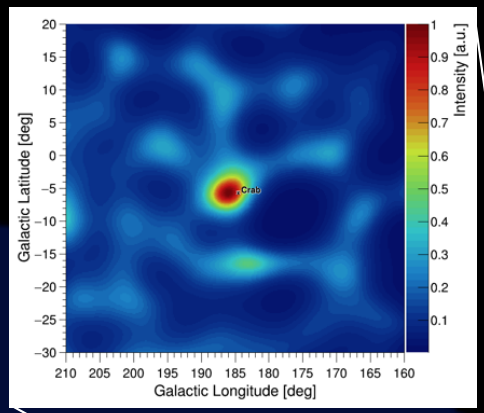
- NCT: 2 GeD prototype flew from Ft. Sumner, NM on June 1st, 2005
- NCT: 10 GeD instrument flew from Ft. Sumner, NM on May 17th, 2009
- NCT: Failed launch from Alice Springs, Australia on April 29th, 2010
- COSI: 2014 Antarctica campaign
- COSI: 2016 campaign …

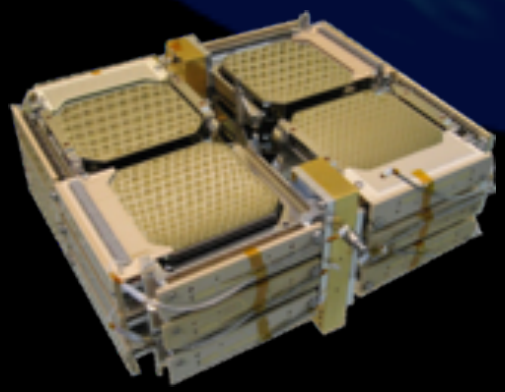



COSI track from May 16 to July 2nd : 46 days !







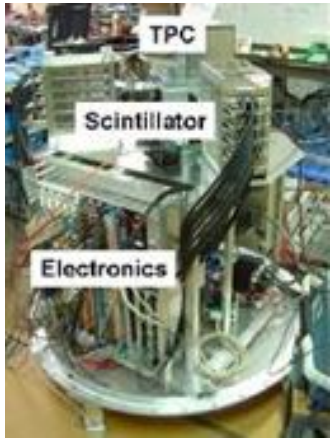


+ gamma-ray bursts

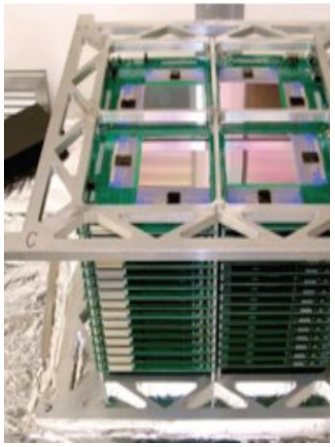
+ $e^{-}e^{+}$ annihilation

Compton / Pair Telescopes

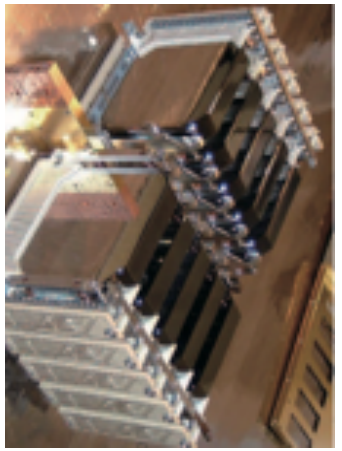
LXeGRIT
liquid Xe TPC



SMILE I / II
Xe 80%, Ar, C_2H_6
@1atm



TIGRE
D1 : DSSD
D2 : NaI &CsI



NCT -> COSI
Ge strip detectors

Columbia, Rice ..
flights
1997,1999, 2000

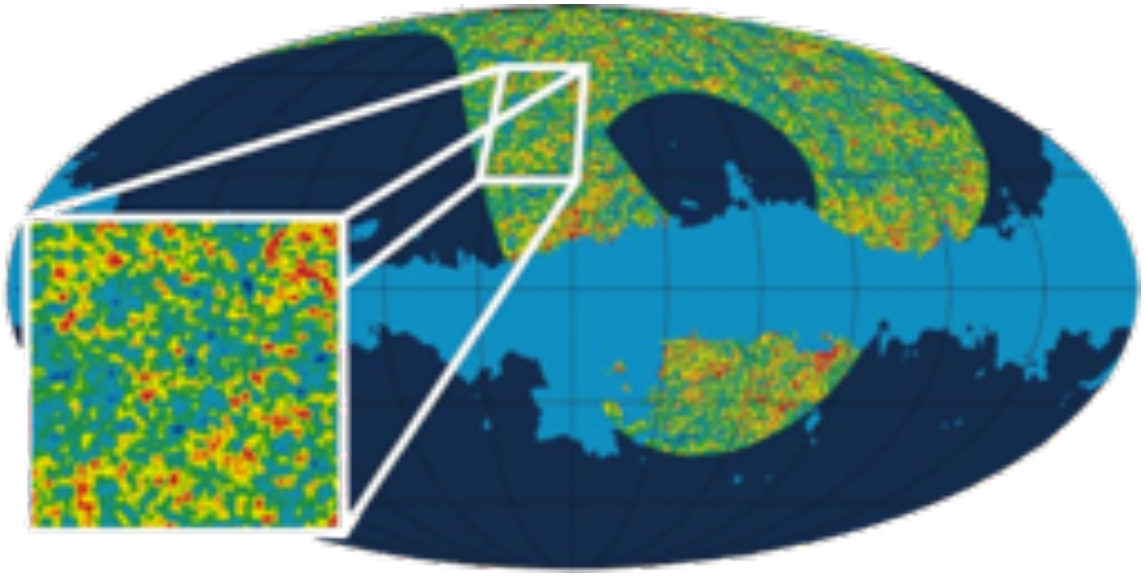
Kyoto U. Riken ...
flight
2006

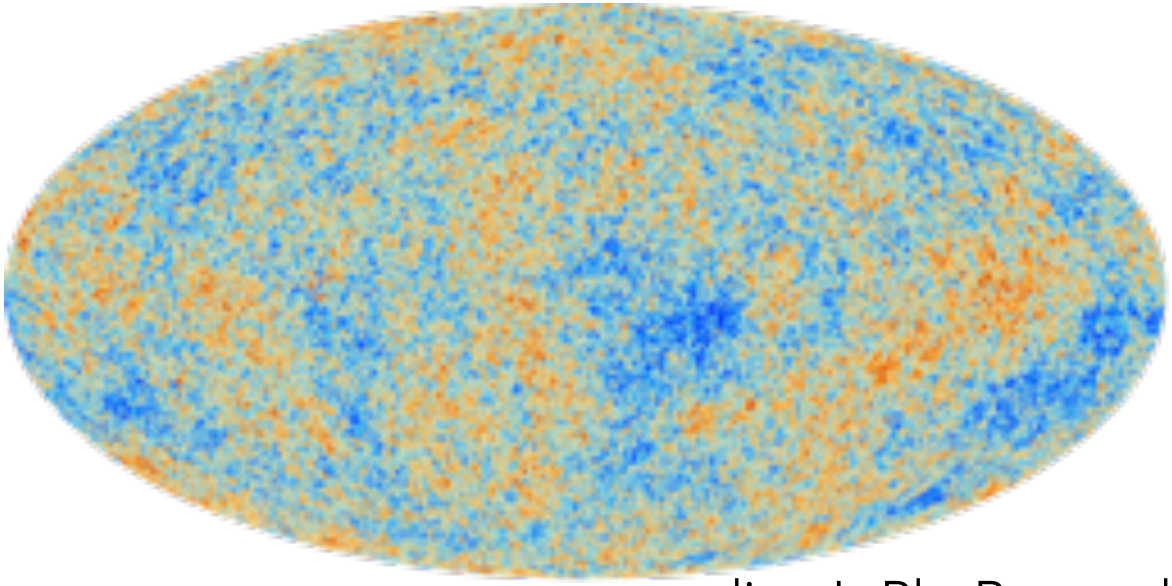
U. Riverside
flights
2007, 2010 (48 h !)

UCB, IRAP …
2005, 2009 :
Crab detection

ESUO-Ballon tests, IRAP, May 2014

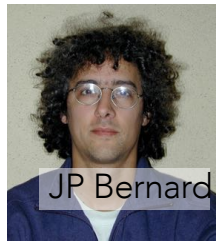
Preparing space missions : the example of Archeops / Planck





credit : J.-Ph. Bernard

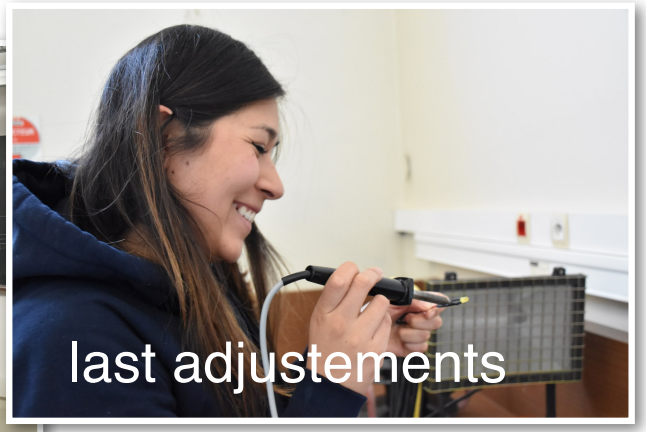
Preparing people : the example of Archeops / Planck

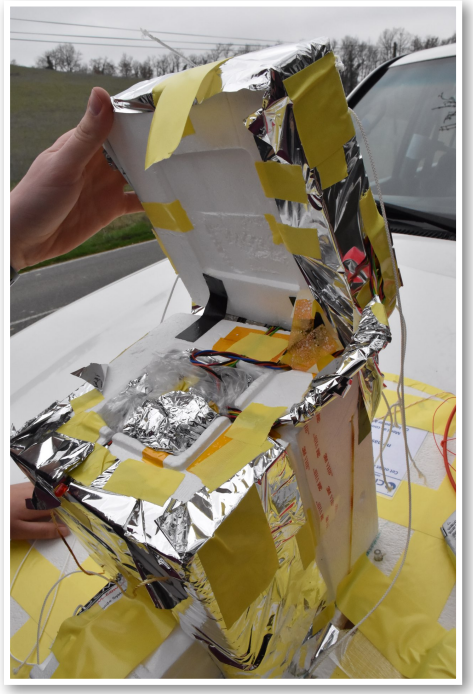


credit : J.-Ph. Bernard

master TSI Toulouse


thermal vacuum test at UPS


last adjustements


recovered payload


the 2016/17 payload


launch at the CNES balloon base of Aire-sur-l'Adour

the 2017 flight track

balloons are ideal means for R&D and training

- ideal R&D testbed
- niche science !
- training of future PI's, mission scientist and project managers

and if you're quick (and lucky), you may snatch a mayor result before the satellite with your new technology is ready to fly

altough payloads can be >> 1 T
possibility of "light" projects – i.e.
- timescale ≈ PhD thesis
- paper mass << payload mass

=> quick, cheap and …
not without risk ….

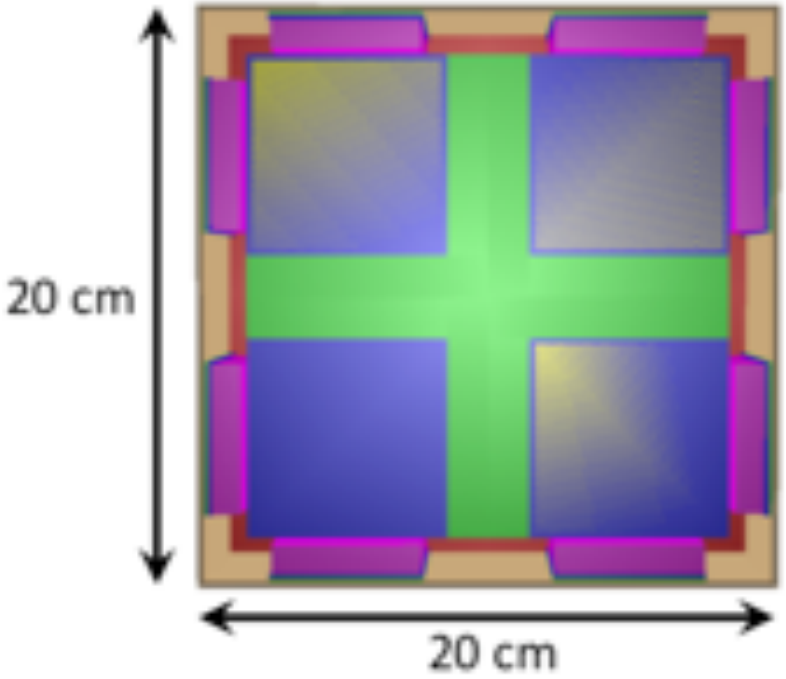
enthusiasm

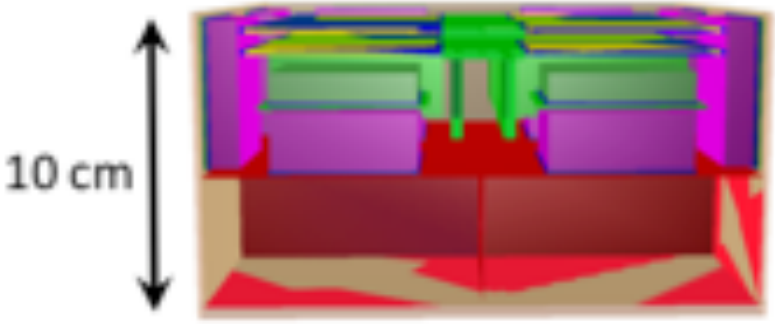
experience

ideas

Cocotte – June 2016 – Aire sur l'Adour

COMCUBE makes an ideal "nano-balloon" payload

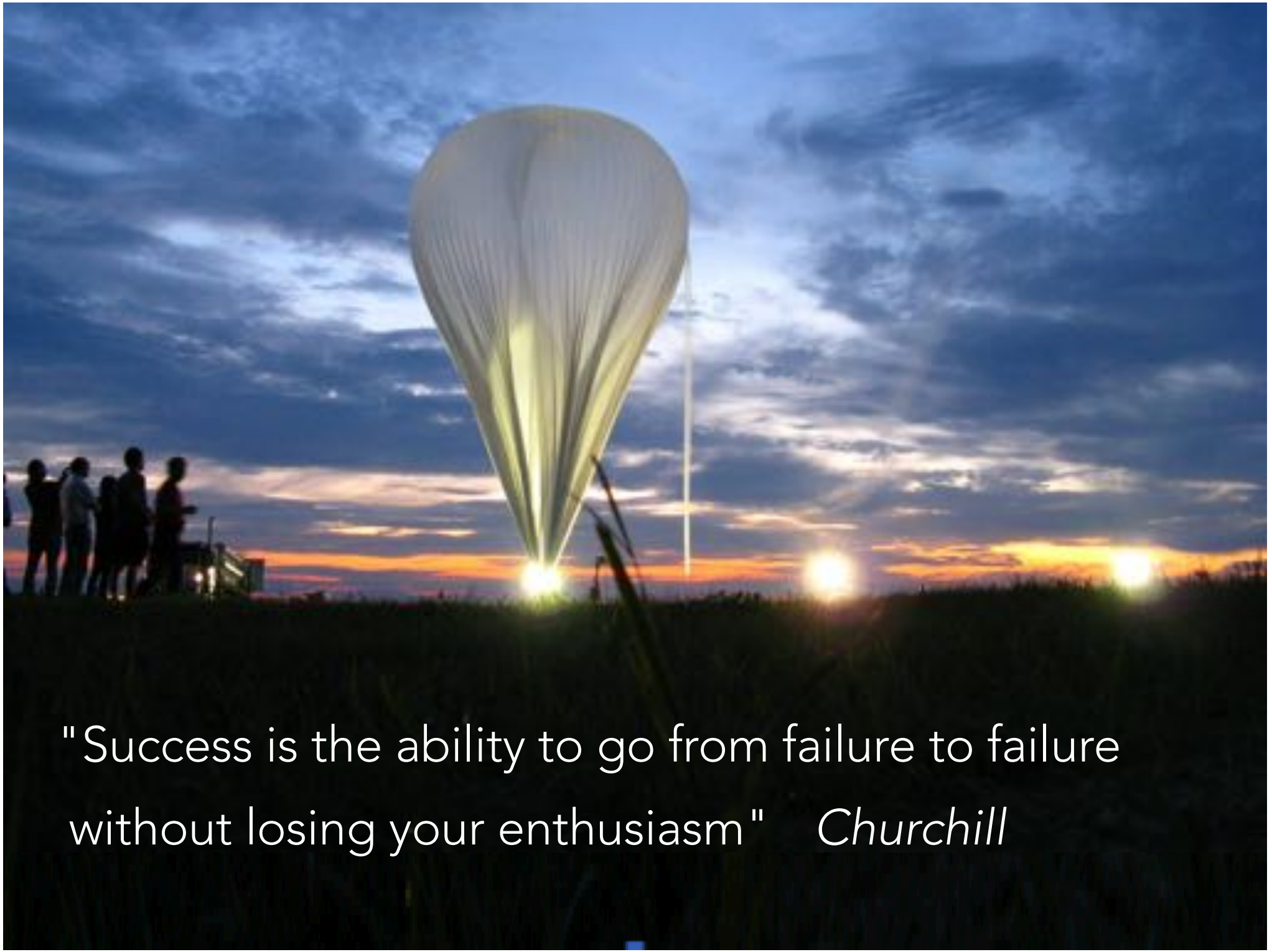




Mass of active material: $CeBr_3$ 2.1 kg,
p-T 120 g, DSSD 130 g, total **2.4 kg**

Numbers of channels: $CeBr_3$ 64 (x12),
p-T 64 (x4), DSSD 2x32 (x8)

- test hardware under (worse than) space conditions
- measure real BG (cutoff-rigidity ~ latitude)
- balloon launch bases in Europe (according to launch mass)
- multiple flights : rapid turnover for debugging/updates
- quick & cheap
- not without risk


"Success is the ability to go from failure to failure
without losing your enthusiasm" *Churchill*