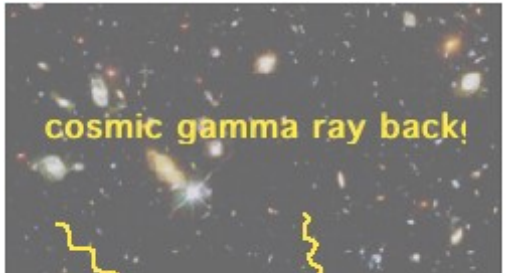
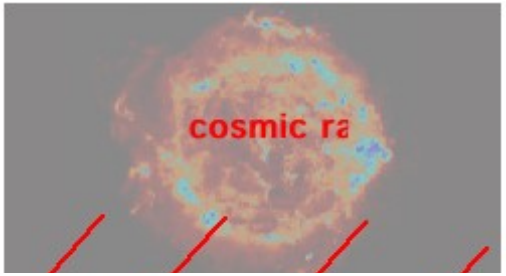
Spectrométrie Gamma

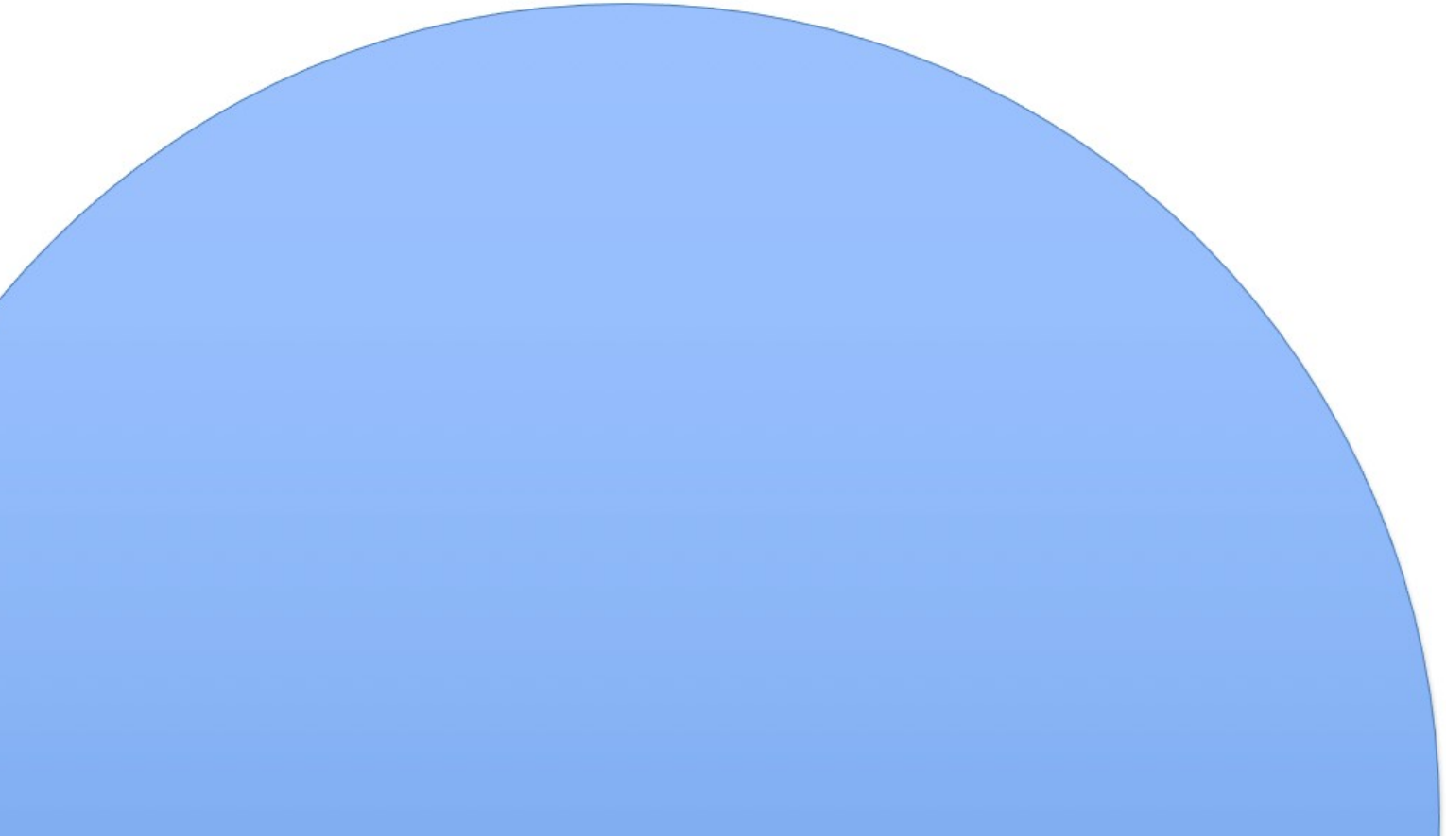
Peter von Ballmoos, IRAP

Astronomie Gamma

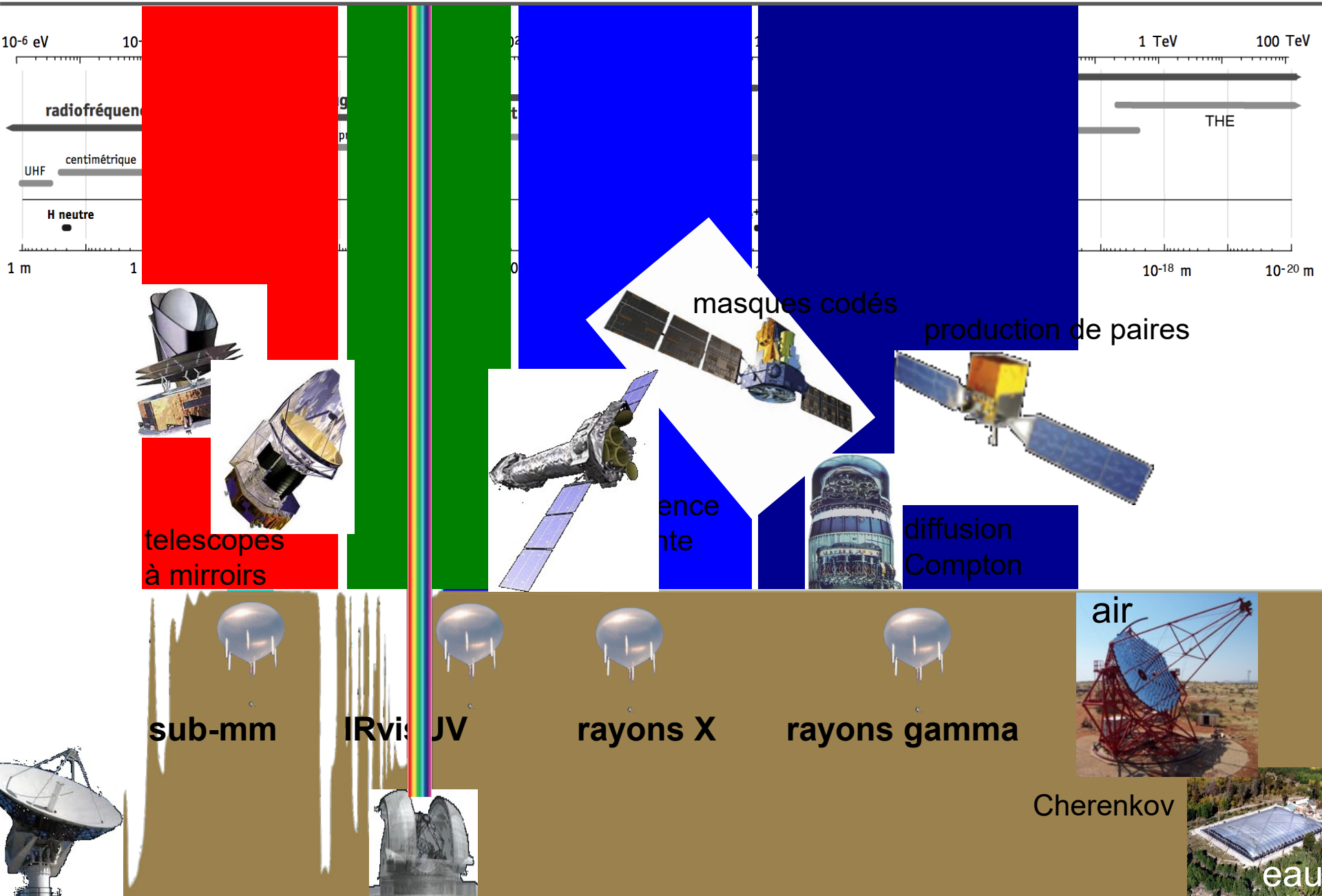




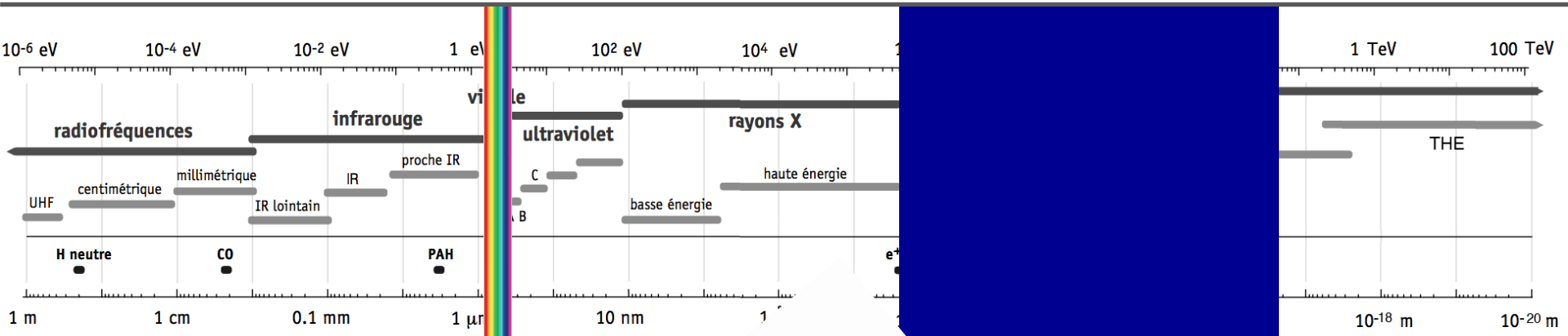
un environnement
radiatif atmosphérique
et instrumental
très *"riche"*

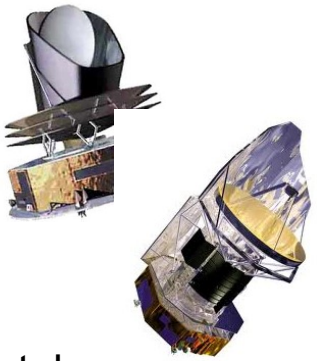


les ballons et l'astronomie spatiale



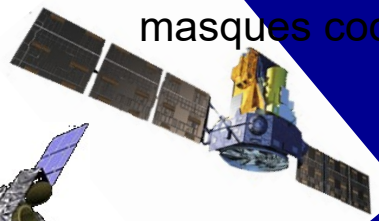
les ballons et l'astronomie spatiale

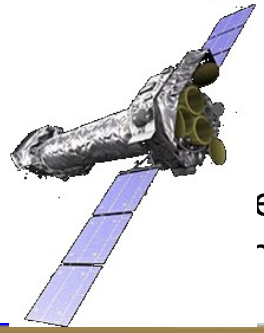




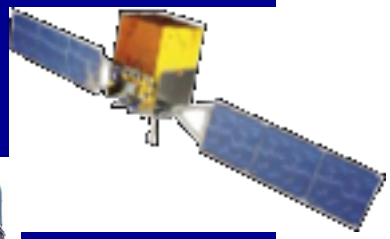
telescopes
à mirroirs

masques codés





production de paires

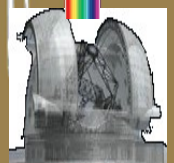


ence
nte

diffusion
Compton

sub-mm IRvis UV rayons X rayons gamma

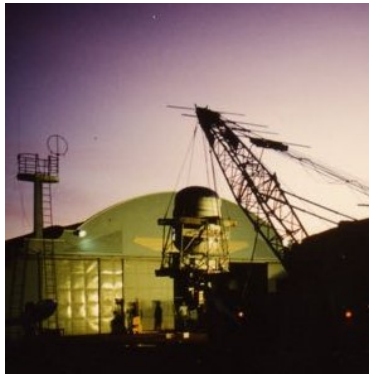
air



Cherenkov

eau

« mes » ballons

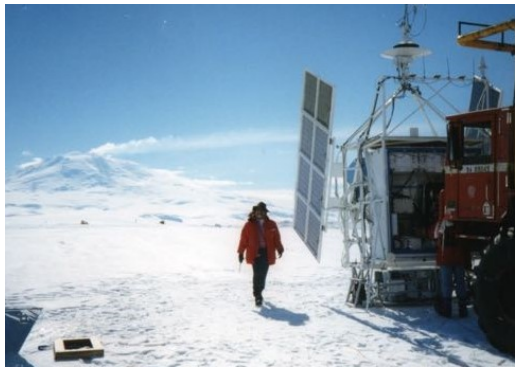


Compton balloon
1982

FIGARO II
1988

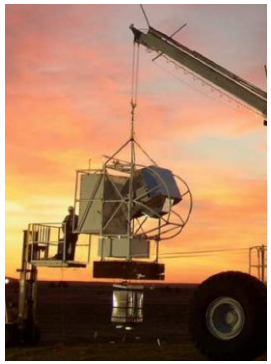
HEXAGONE
1989, 1992

CLAIRE
2000, 2001



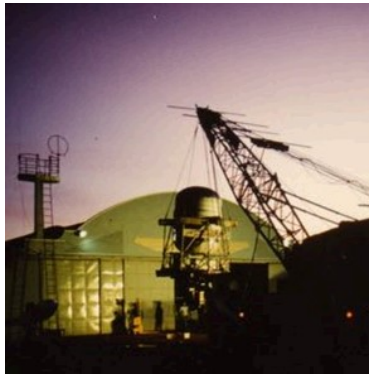
HIREGS
1999

eusoballoon
2014, 2017

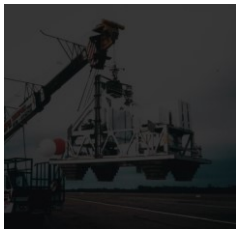


NCT
2005, 2009,
2010 …
COSI
2014, 2016

« mes » ballons



Compton balloon
1982



FIGARO II
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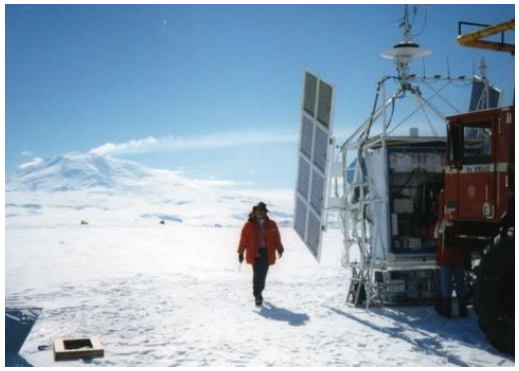
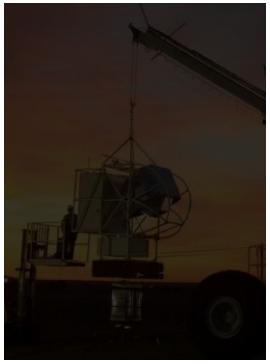


HIREGS
1999



NCT
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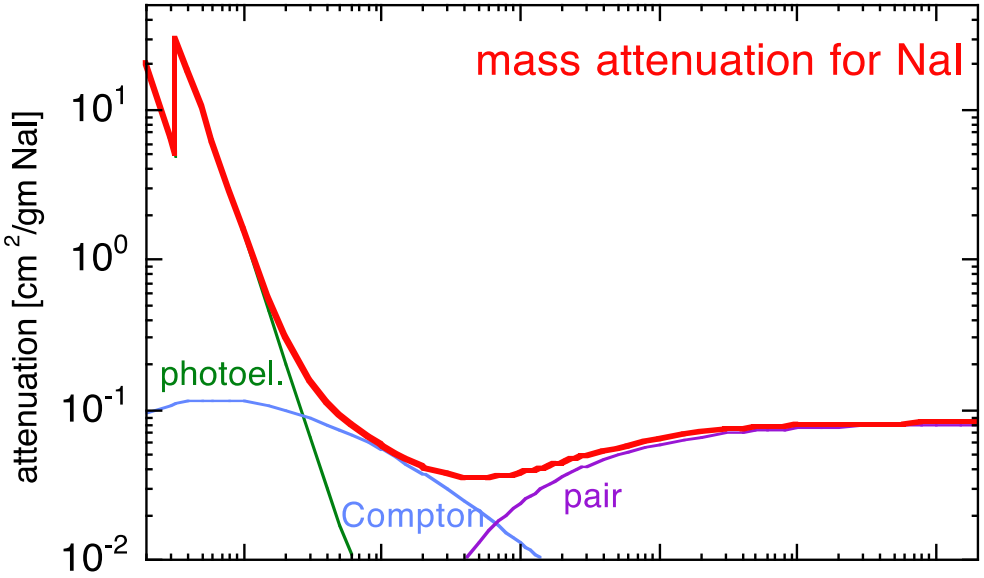
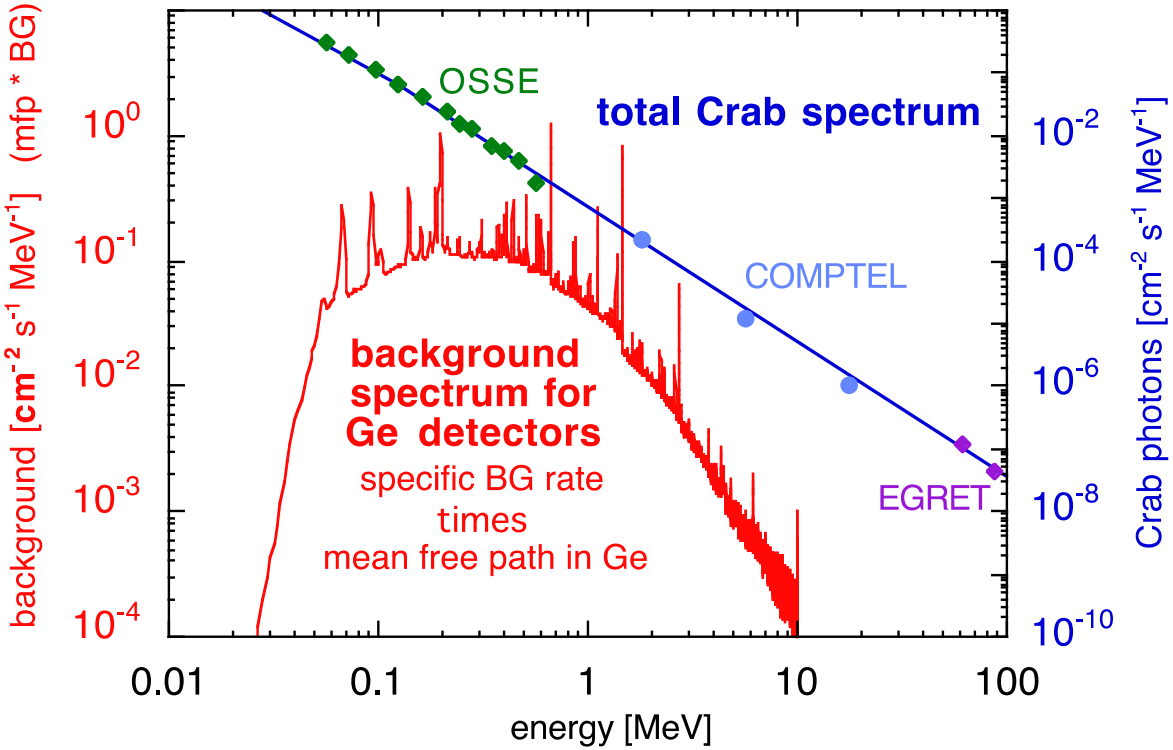


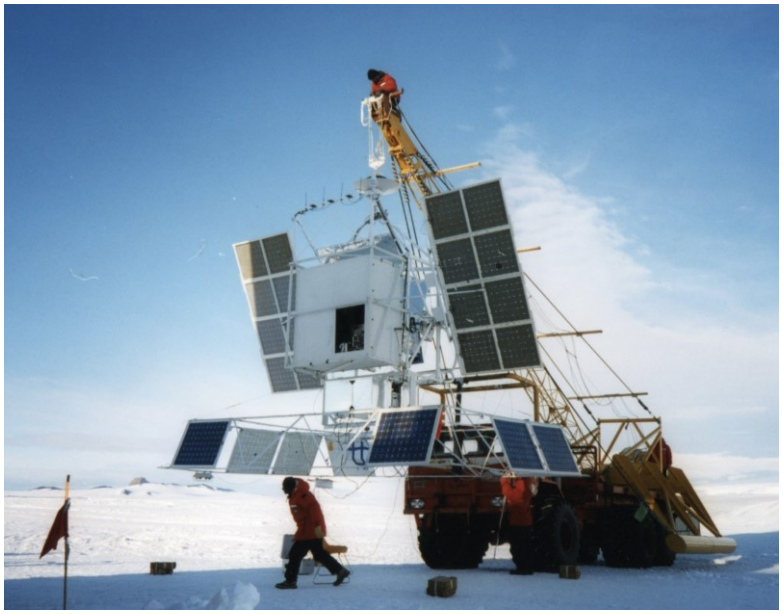


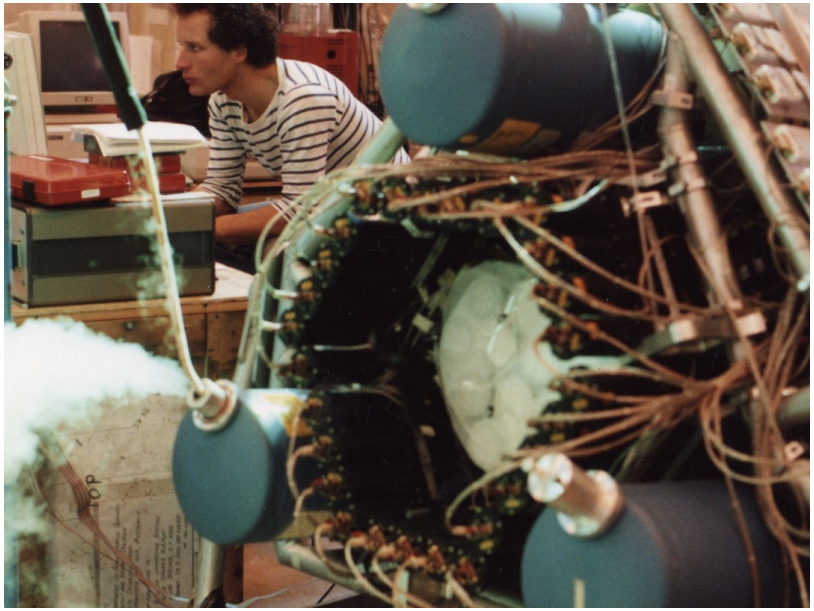
What made progress so slow ?

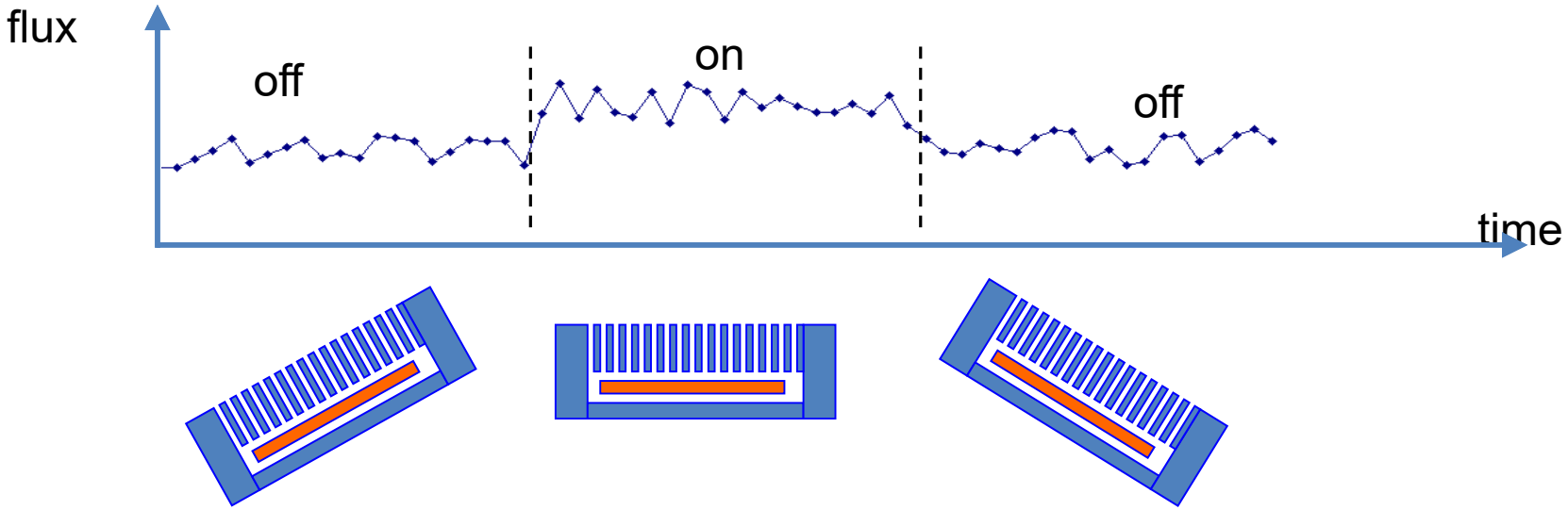
the "impossible" MeV range :

- three energy-loss processes plus coherent interactions ...
- minimum cross section
- **"rich" background !**

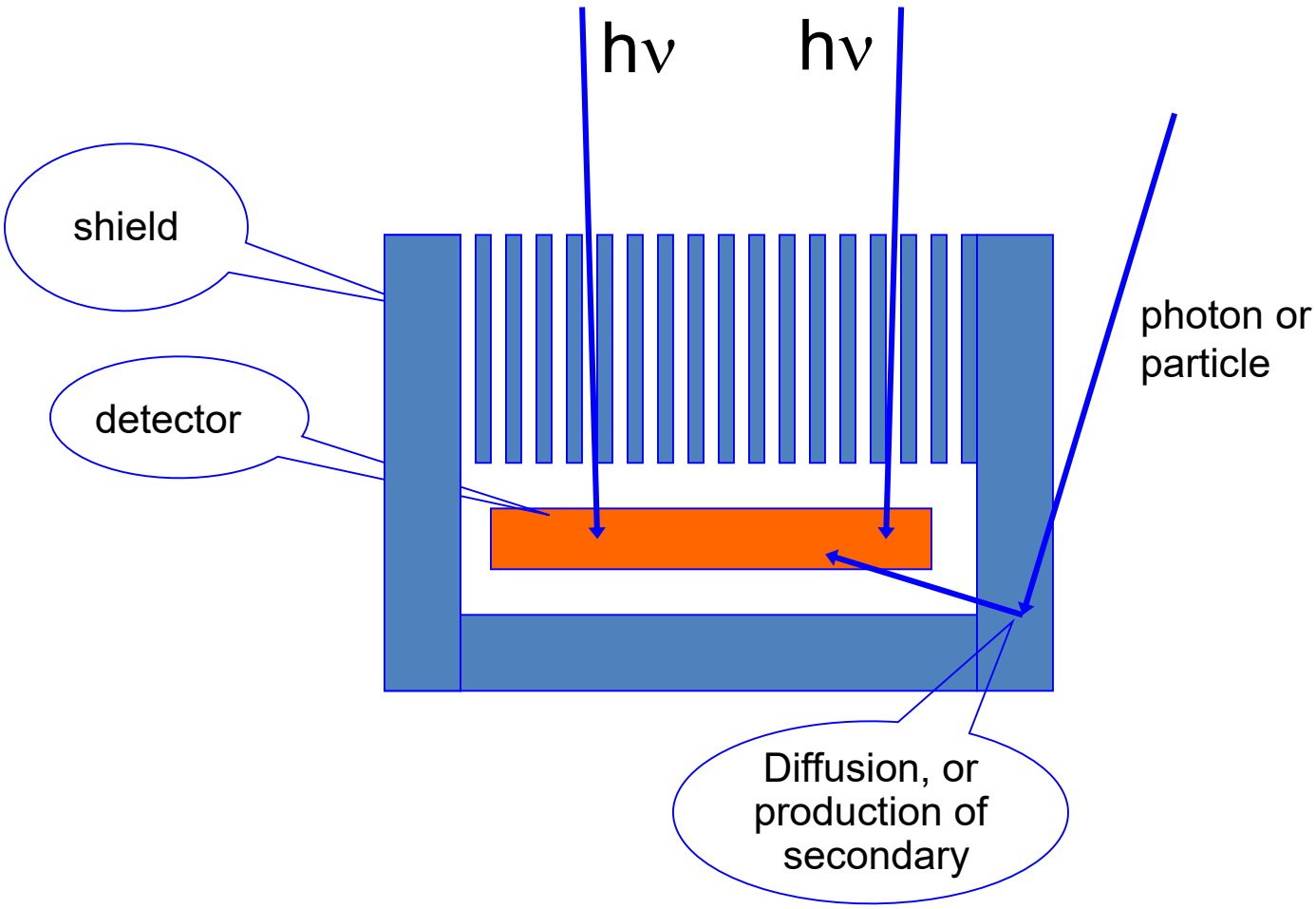
HIREGS and HEXAGONE : collimated Ge spectrometers





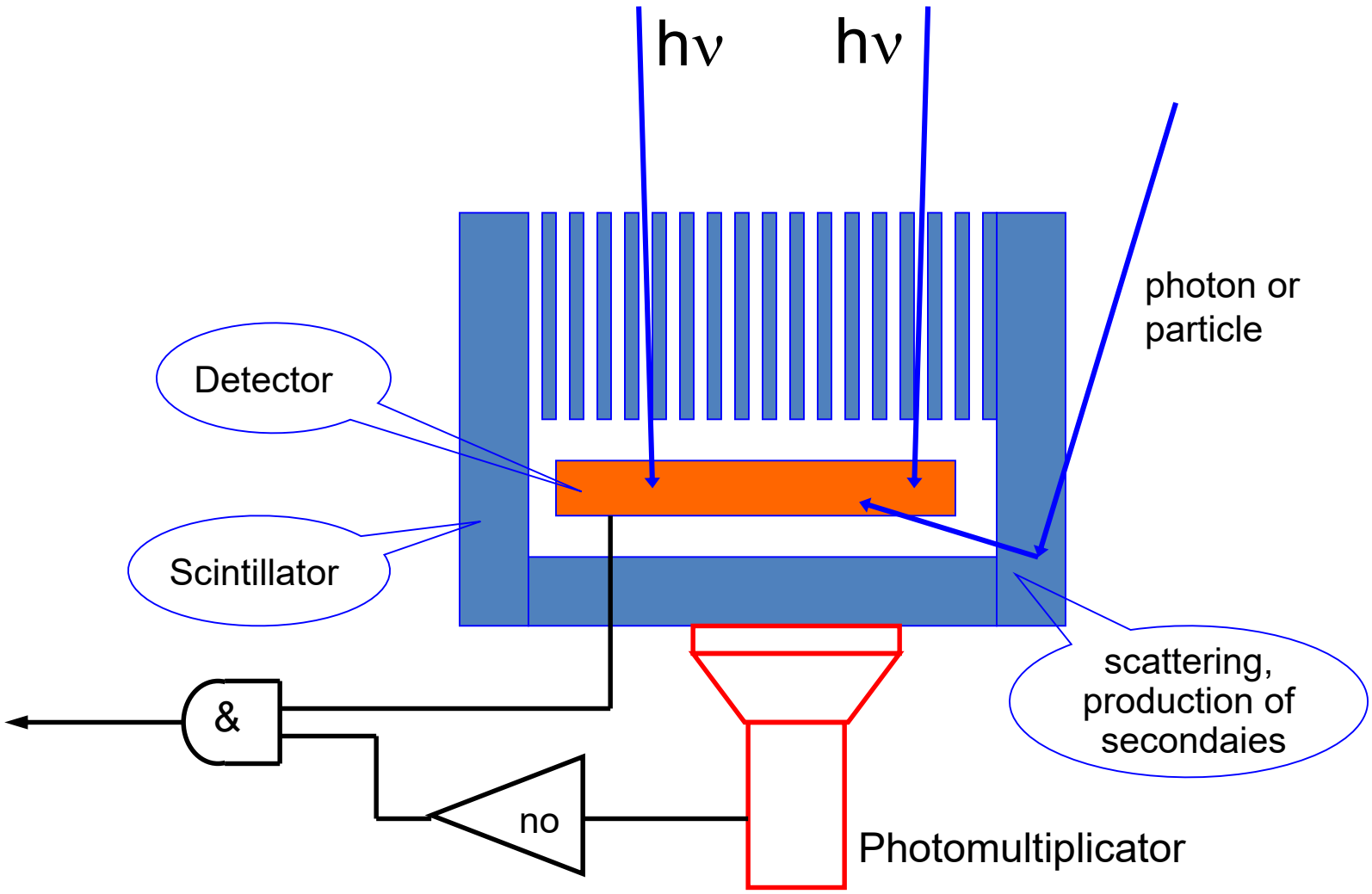


Passive shield

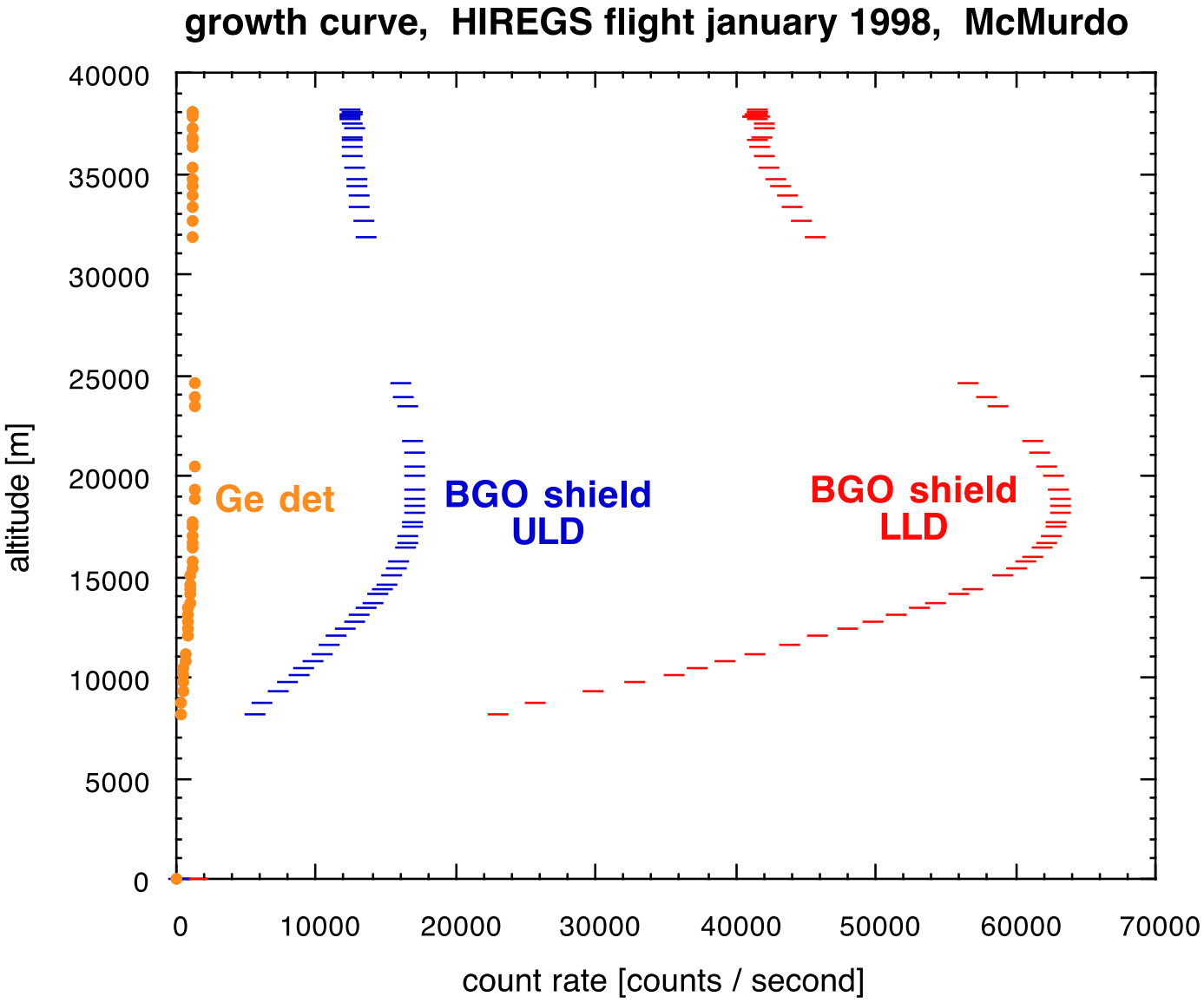


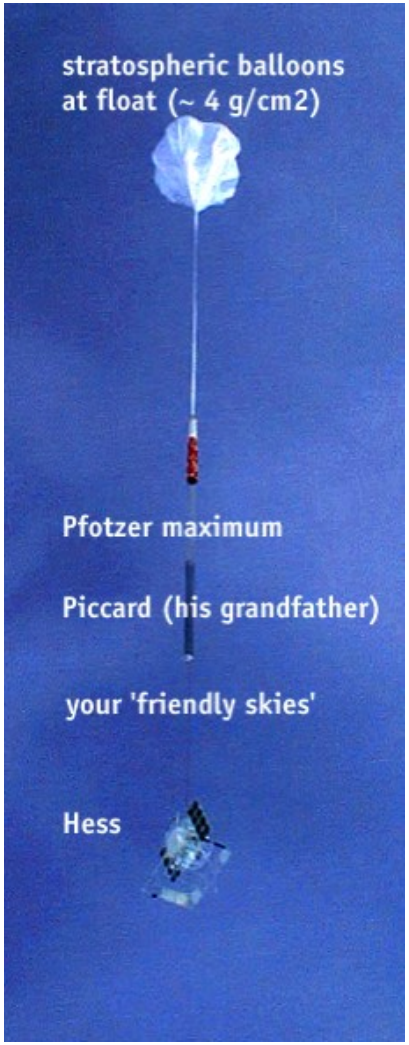
a few mm of W or Pb are sufficant to block
X-ray photons - but not gamma-rays …

Active - anticoincidence - shield

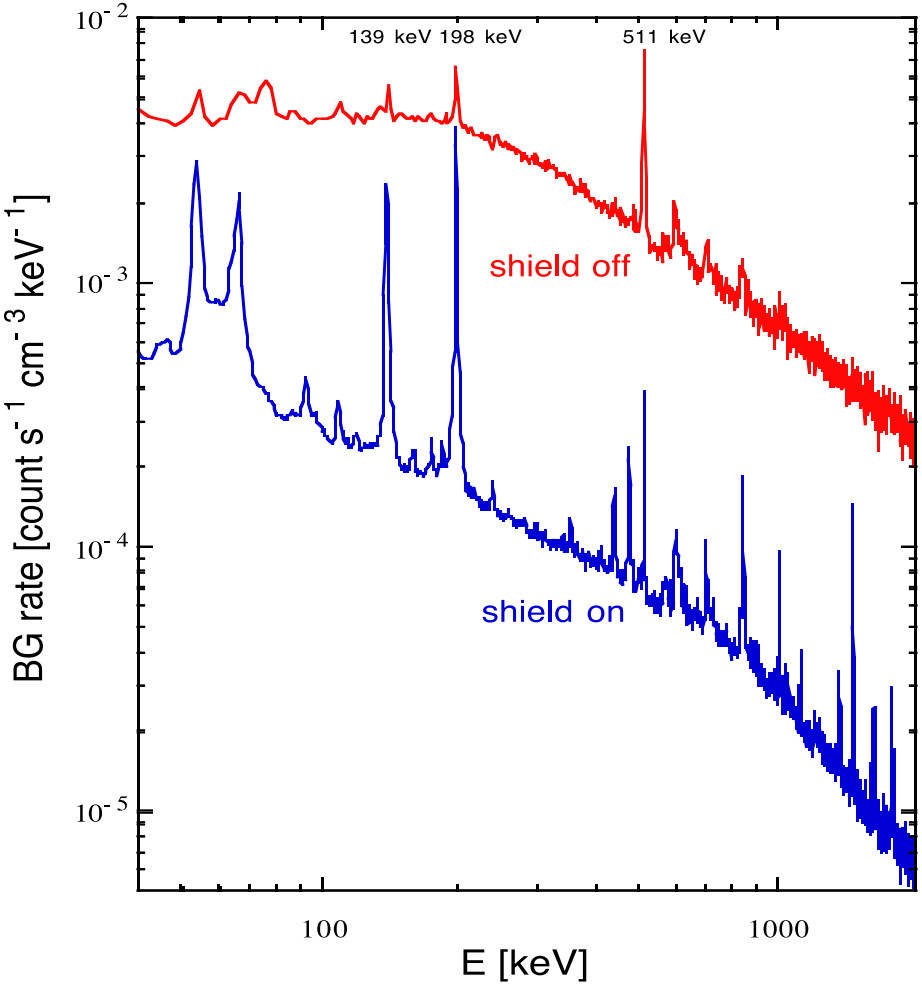


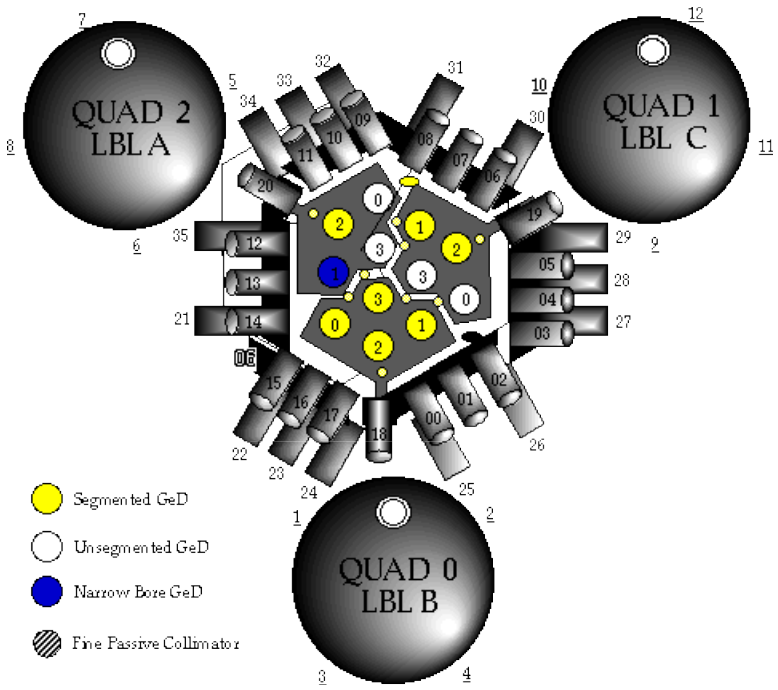
Background - γ-Ray production within the atmosphere





Anticoincidence Shields - HIREGS / Antarctica 1994

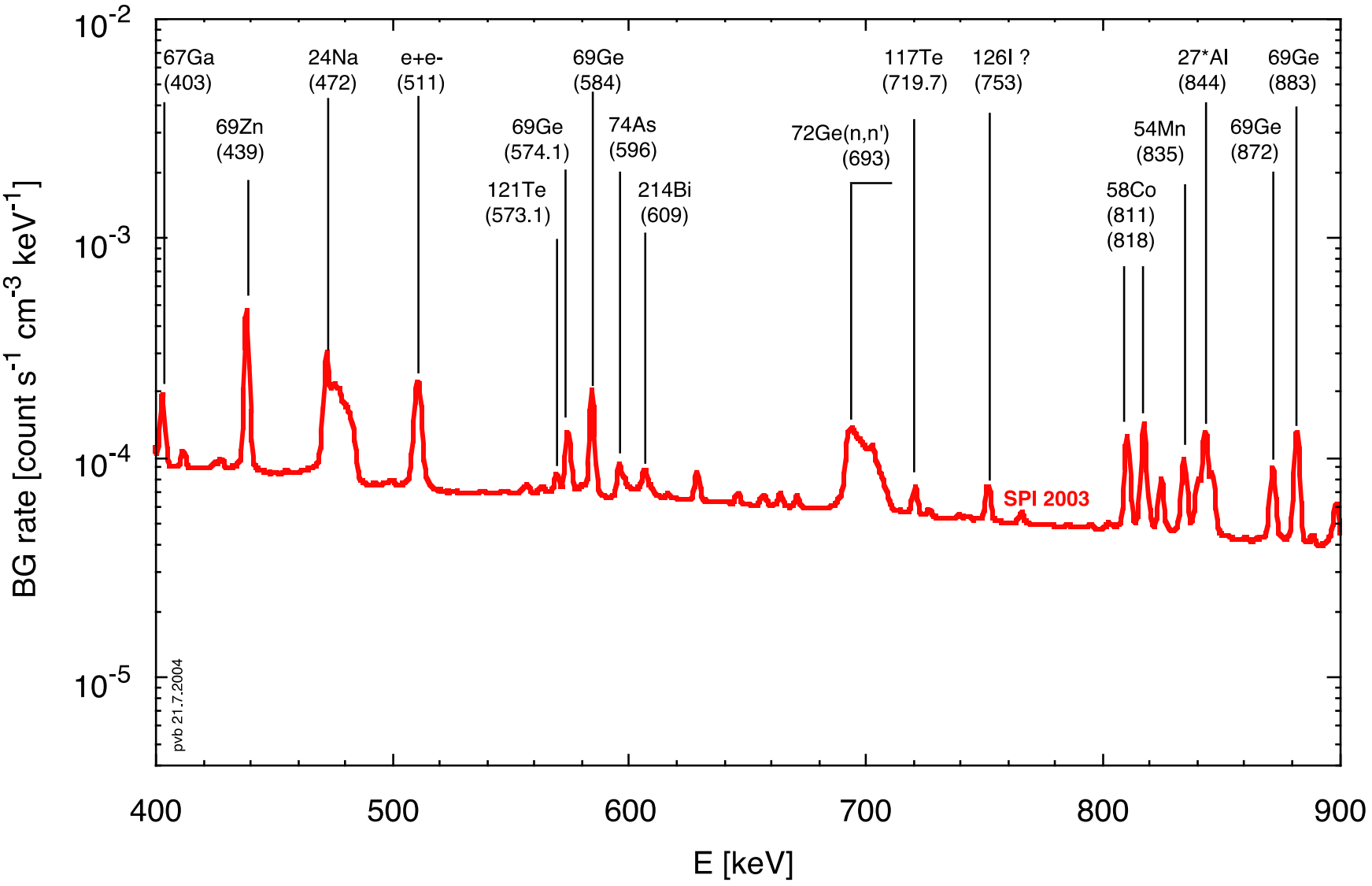




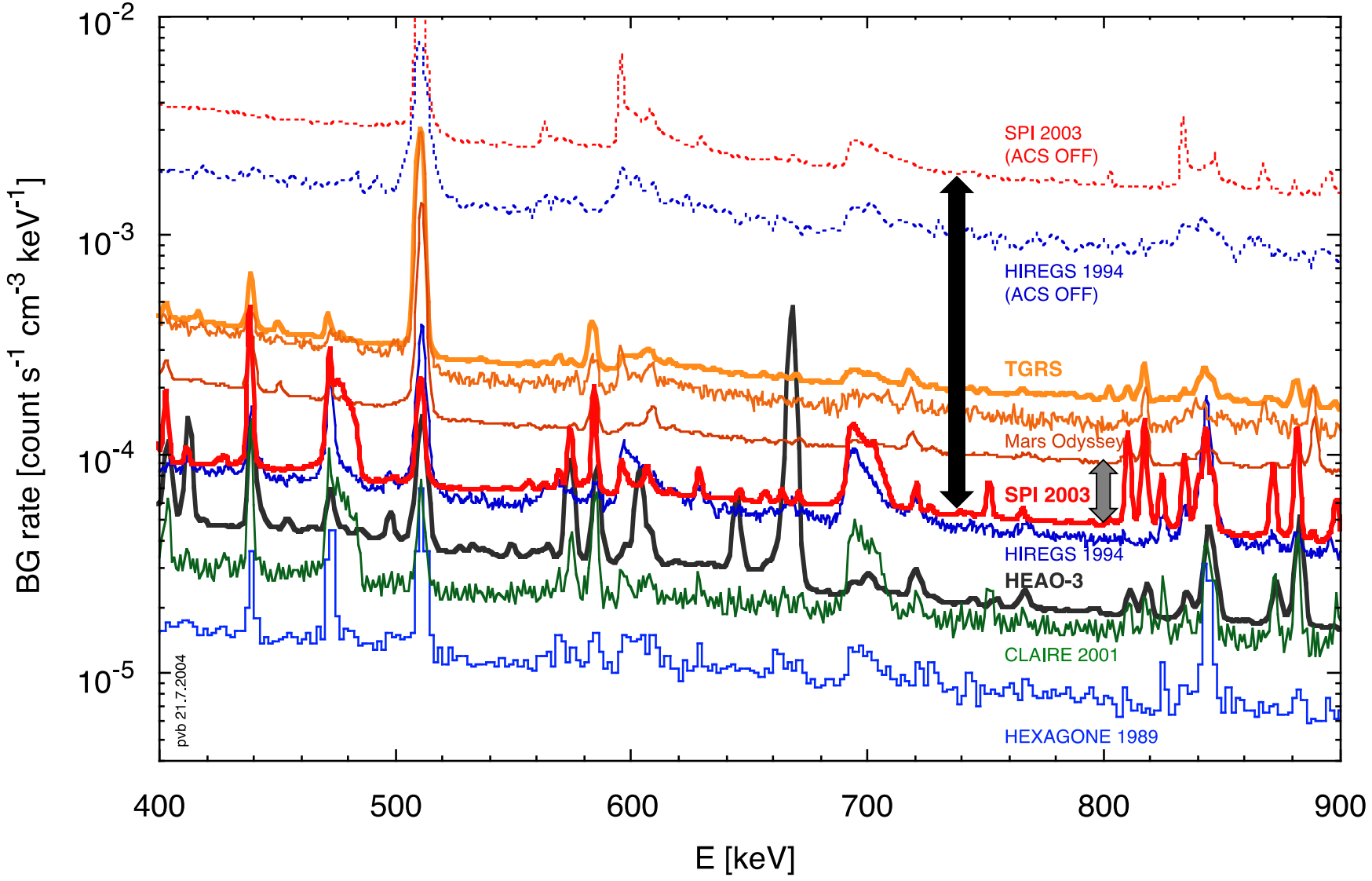
HIREGS detector and
AC shield at float altitude

detectors : 12 coax - HPGe
shield : 5 cm BGO

Ge detector background : SPI



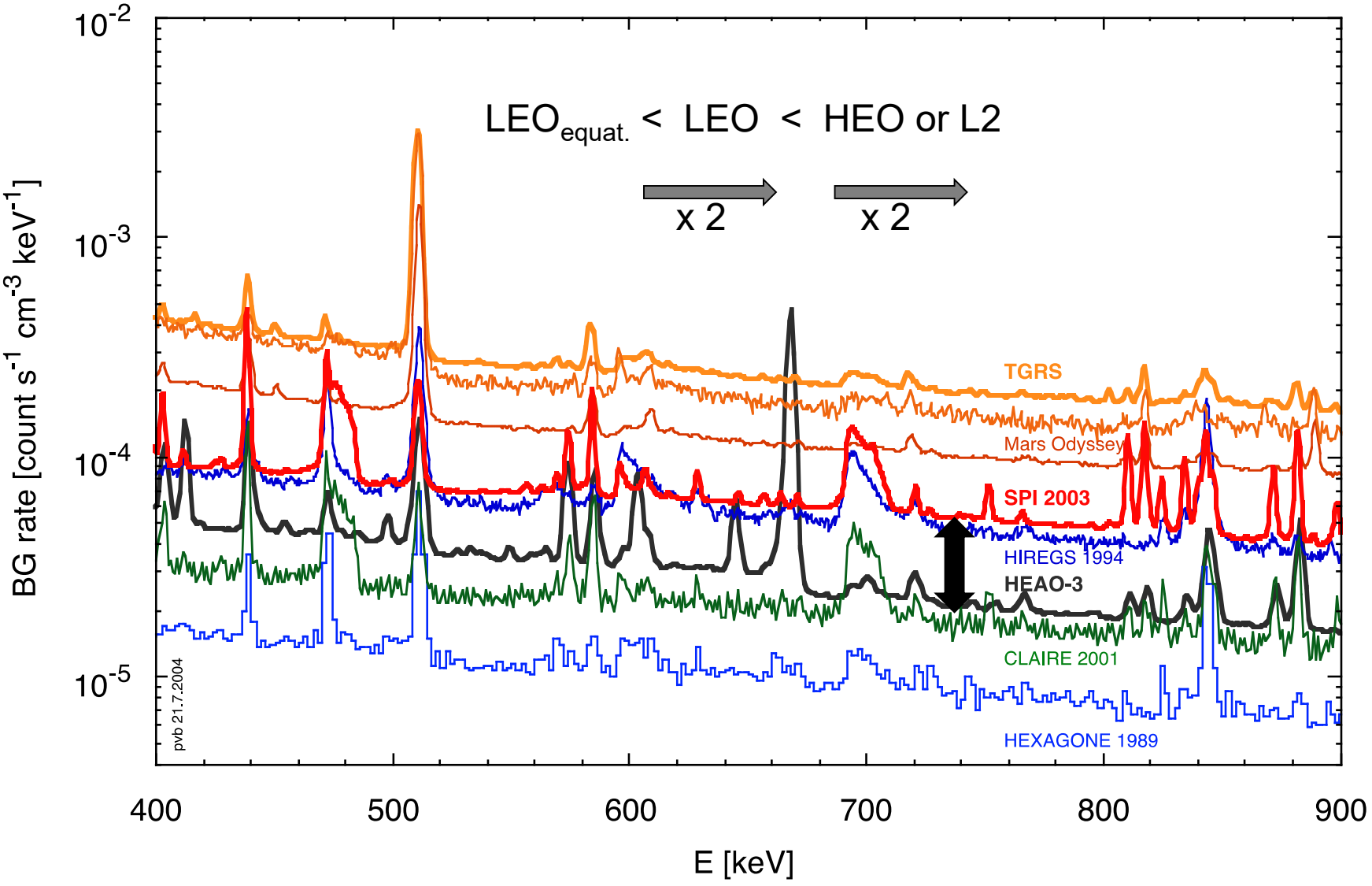
Ge detector background : impact of shield



shield on/off : x 300

shield / no shield : x 2

Ge detector background : impact of orbit



Living with background - you either :

fight

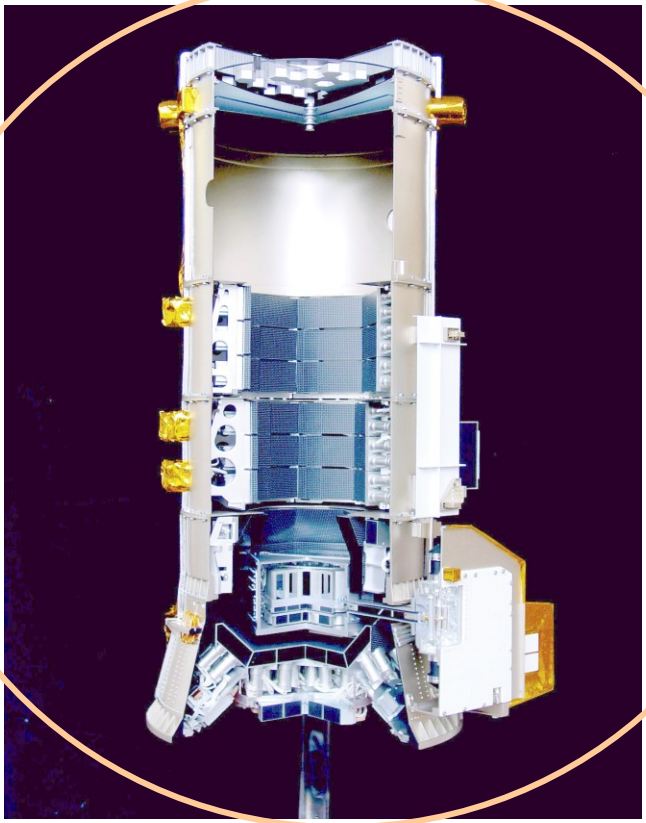
passive shielding
active anticoincidence shields
supershields
discrimination of BG-event signatures e.g.

- phoswhich
- pulse shape discrimination (PSD)
- time of flight measurements (TOF)

avoid

choice of orbit (e.g. high cutoff rigidity, avoiding radiation belts)
minimize passive mass
choice of low BG materials (e.g. ^{70}Ge)
solid angle effects (earth -> high orbit, spacecraft -> mast)
coincidence techniques (Compton telescopes, TPC's)
small detectors (focusing)
resolution (spectral-, angular-, timing)

SPI : example of a massive anticoincidence shield

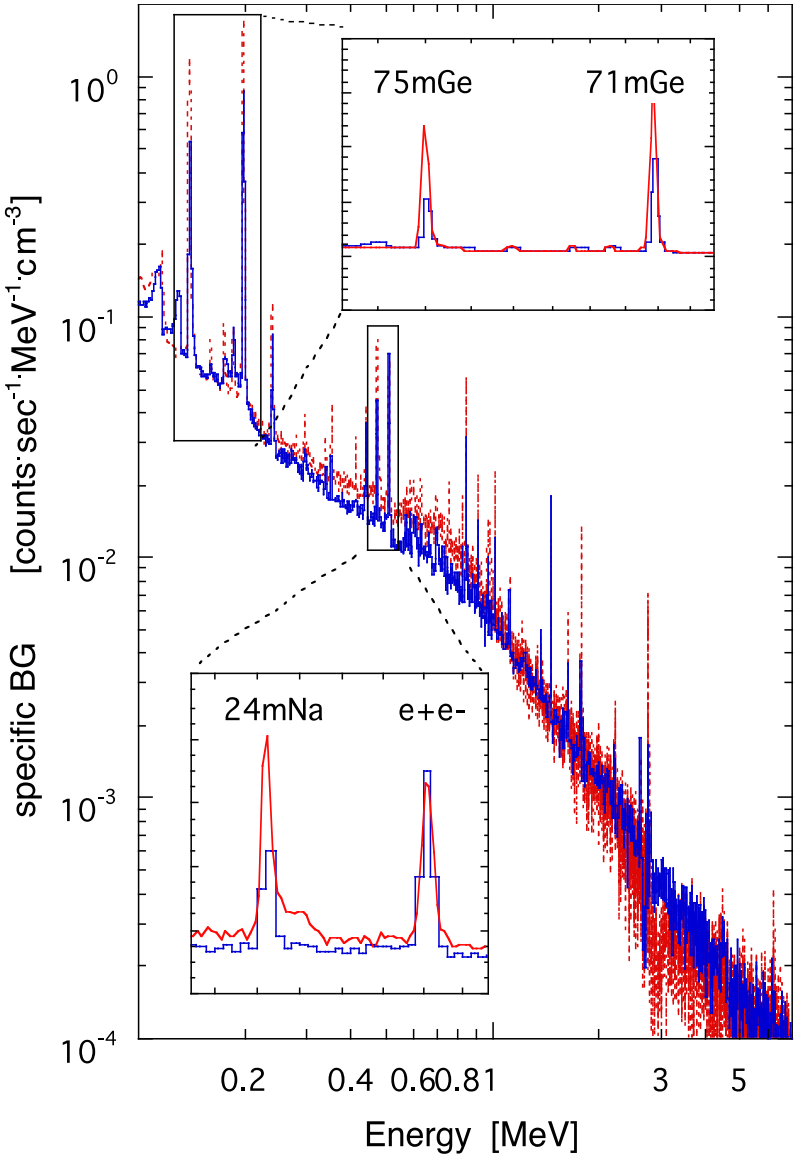


shield
detector

ACS : 856 kg
Ge camera : 141 kg

BGO alone : 504 kg
Ge alone : 19 kg

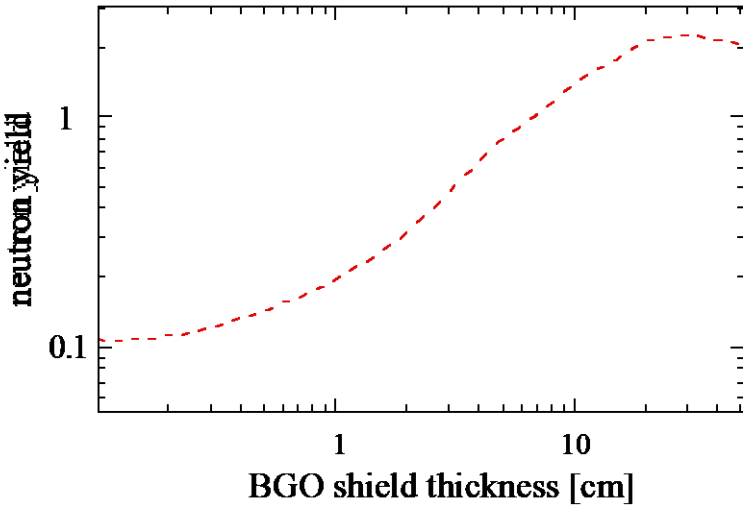
shield thickness and neutron activation



HEXAGONE 89 :
5 cm BGO anticoincidendce shield

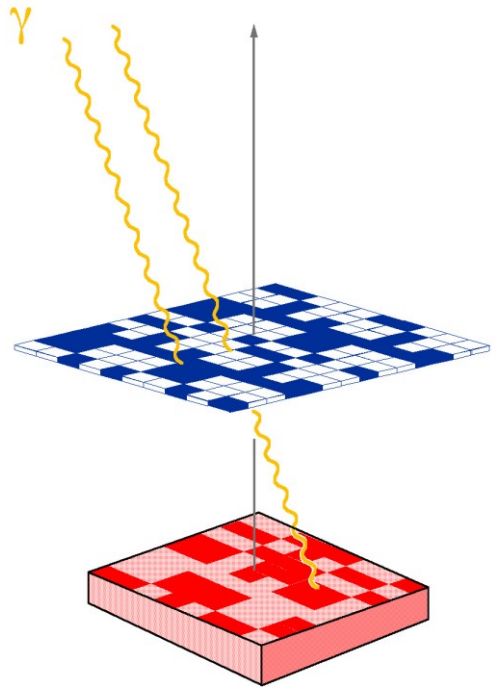
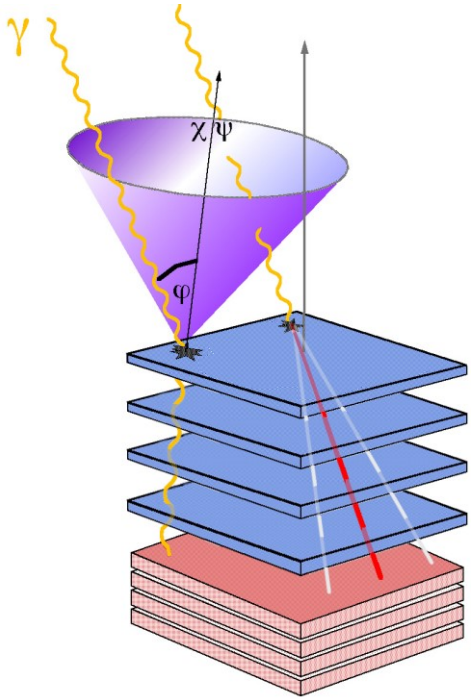
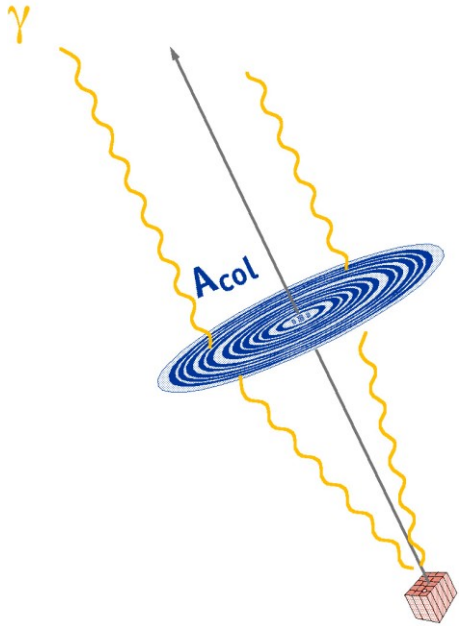
HEXAGONE 92 :
10 cm BGO anticoincidendce shield

neutron flux versus shield thickness (Naya 1995)



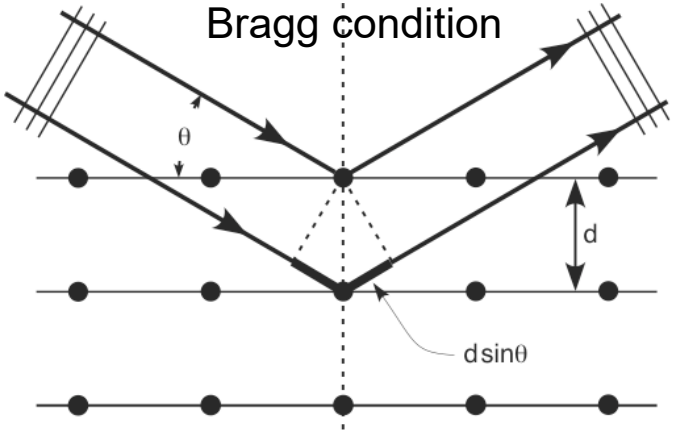
Instrument concepts in gamma-ray astronomy

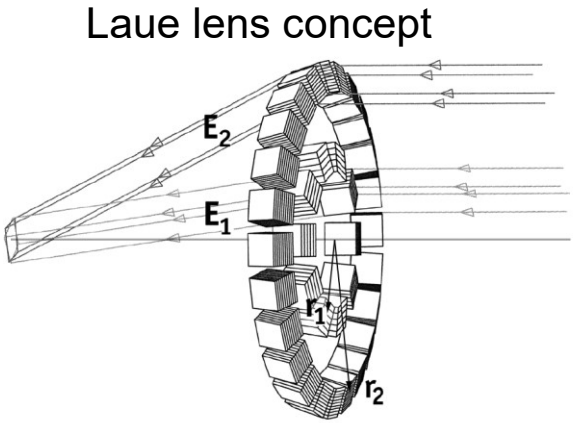
The instrumental categories in nuclear astrophysics reflect our current perception of *light* itself.

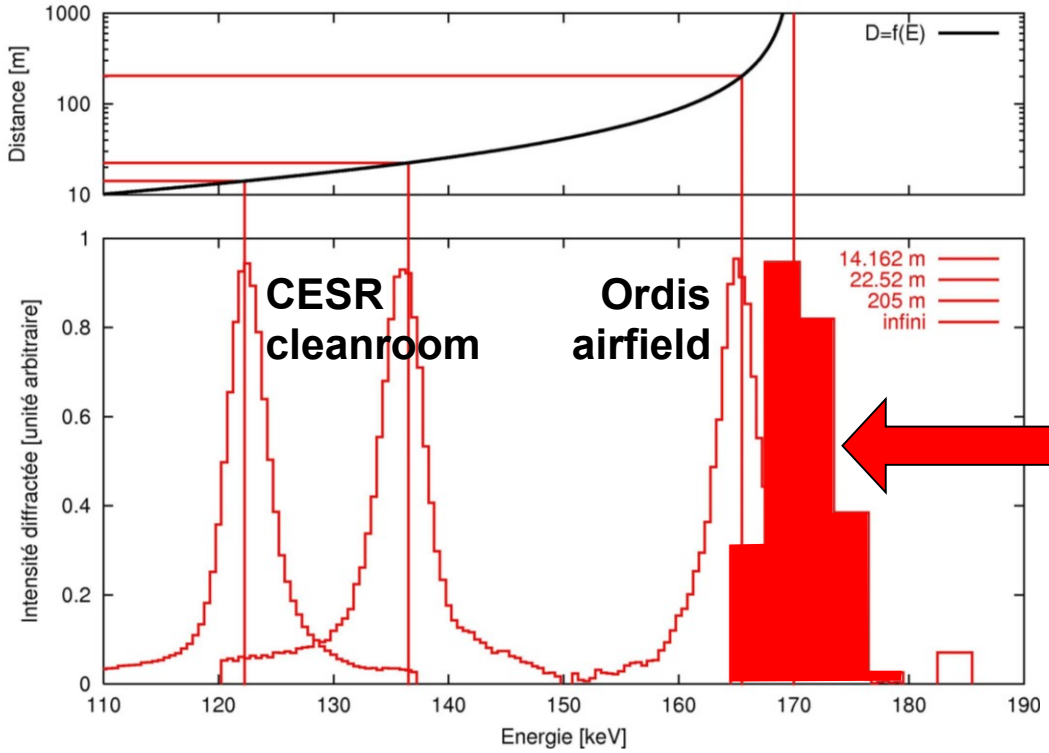
	geometric optics absorption	**quantum optics** incoherent scattering	**wave optics** coherent scattering
aperture / detector			
	ex. coded masks "on-off" collimators	ex. Compton telescopes tracking chambers	ex. Laue lenses Fresnel lenses

Laue lens

CLAIRE



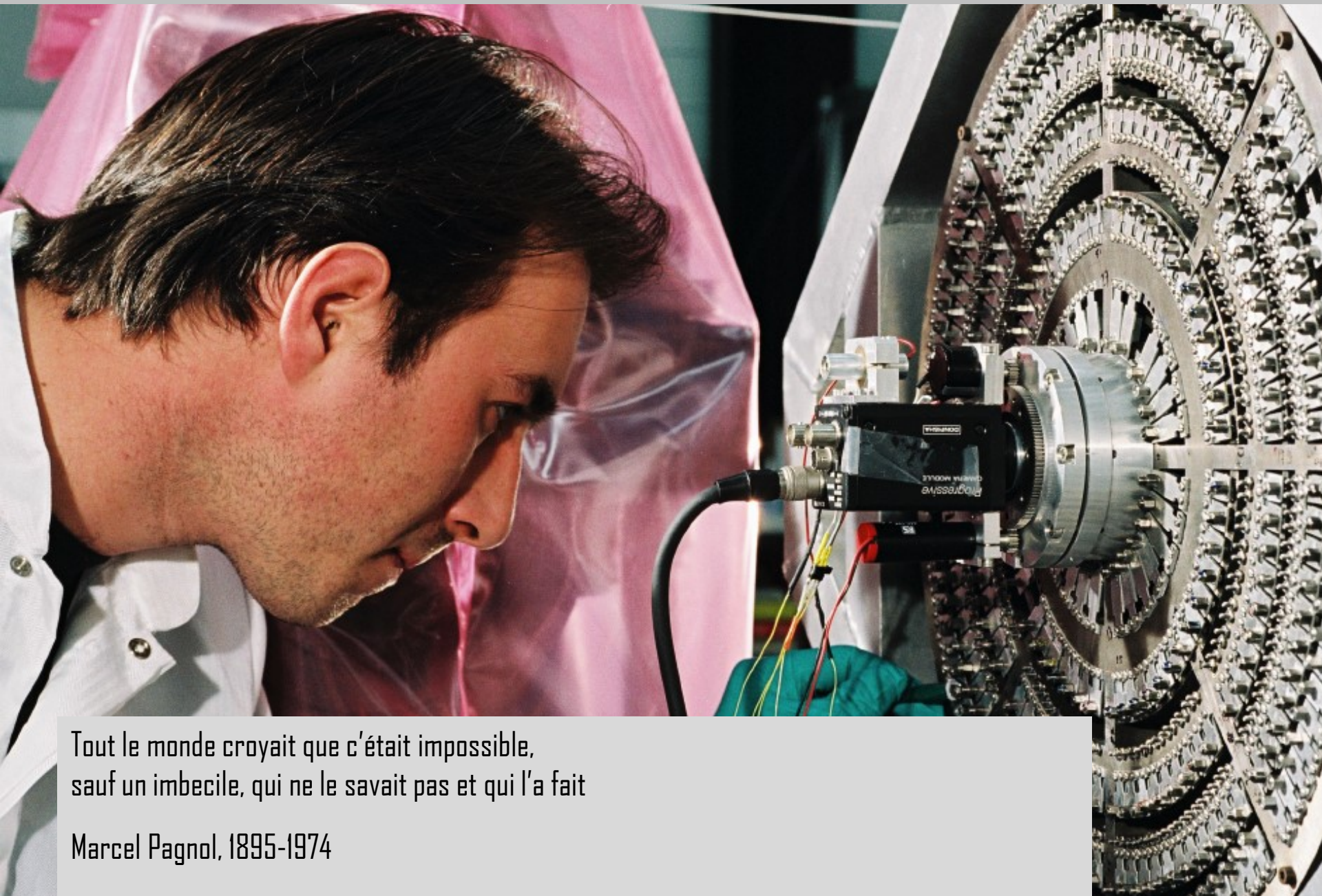




diffraction peaks

Crab detection 2001

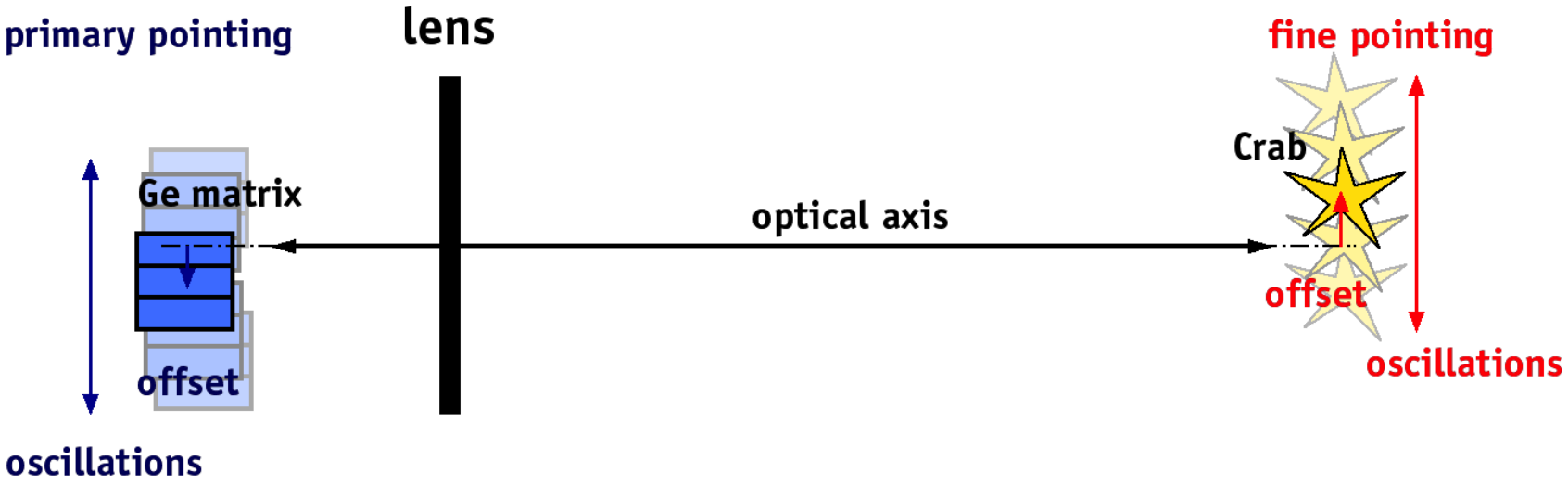
La lentille gamma de CLAIRE

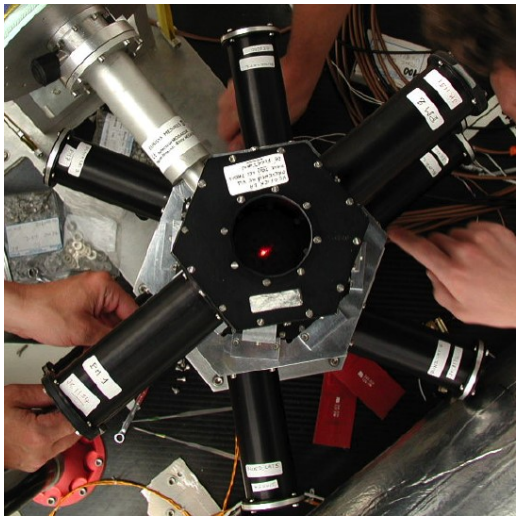


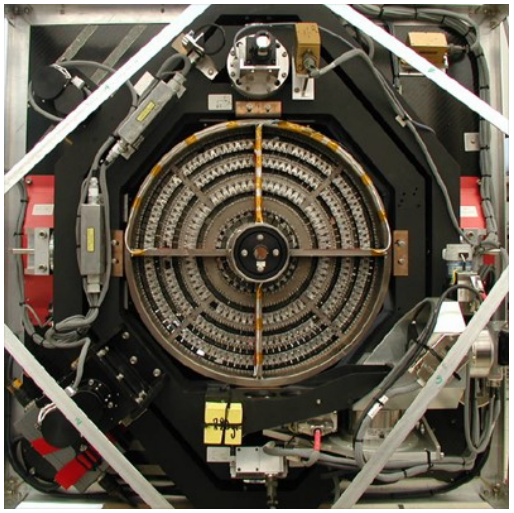
Tout le monde croyait que c'était impossible,
sauf un imbecile, qui ne le savait pas et qui l'a fait

Marcel Pagnol, 1895-1974

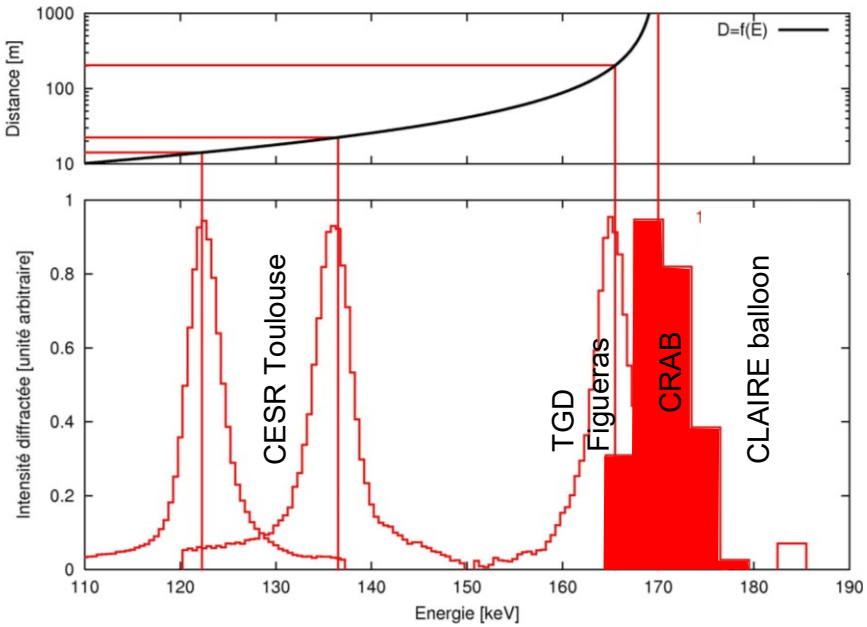
CLAIRE 2001 : pointer la nébuleuse du Crab … précisement







CLAIRE : rendement scientifique et technologique



première lumière
pour une lentille gamma

25 papiers "à referee"
47 papiers conference

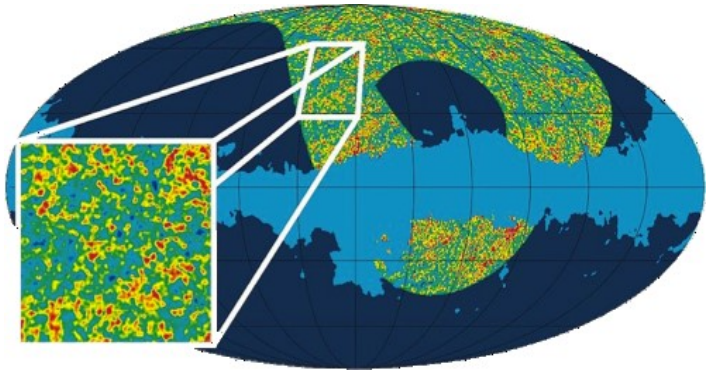
CLAIRE : tenue du calendrier et du budget

kick-off meeting : Nov 1997
1er vol: Juin 2000
2eme vol: Juin 2001

} < 3 ans

les Ballons pour l'Astronomie

un formidable moyen de test pour des nouvelles technologies

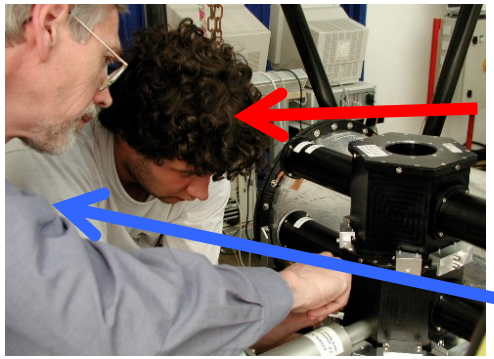


découvertes, grandes questions

si on est rapide (et chanceux) il est possible "d'arracher" un résultat clef avant que le satellite avec la nouvelle technologie est prête

la formation des futurs acteurs

instrumentalistes, chef de projet , " PI's"

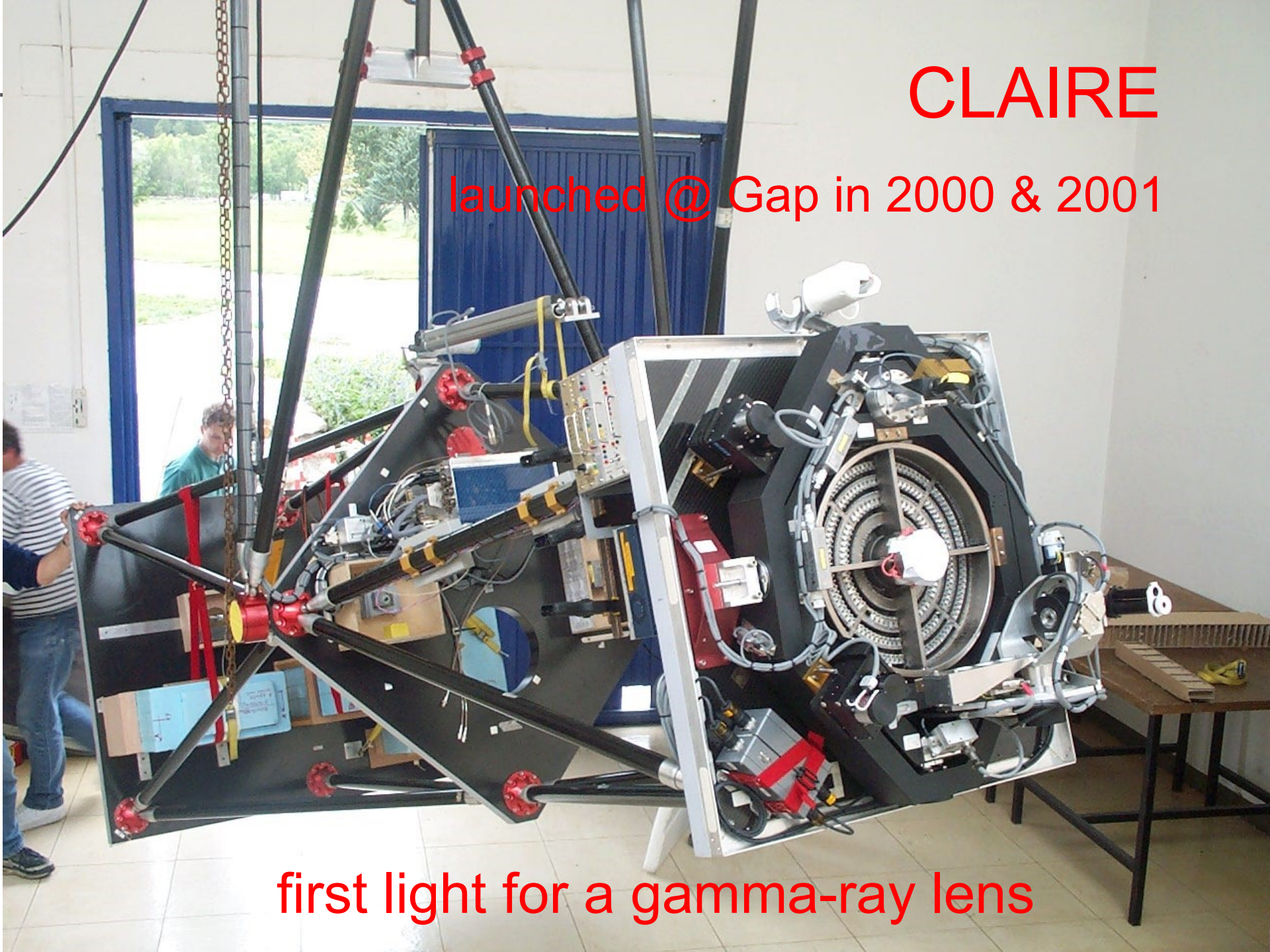


un accès rapide à l'espace

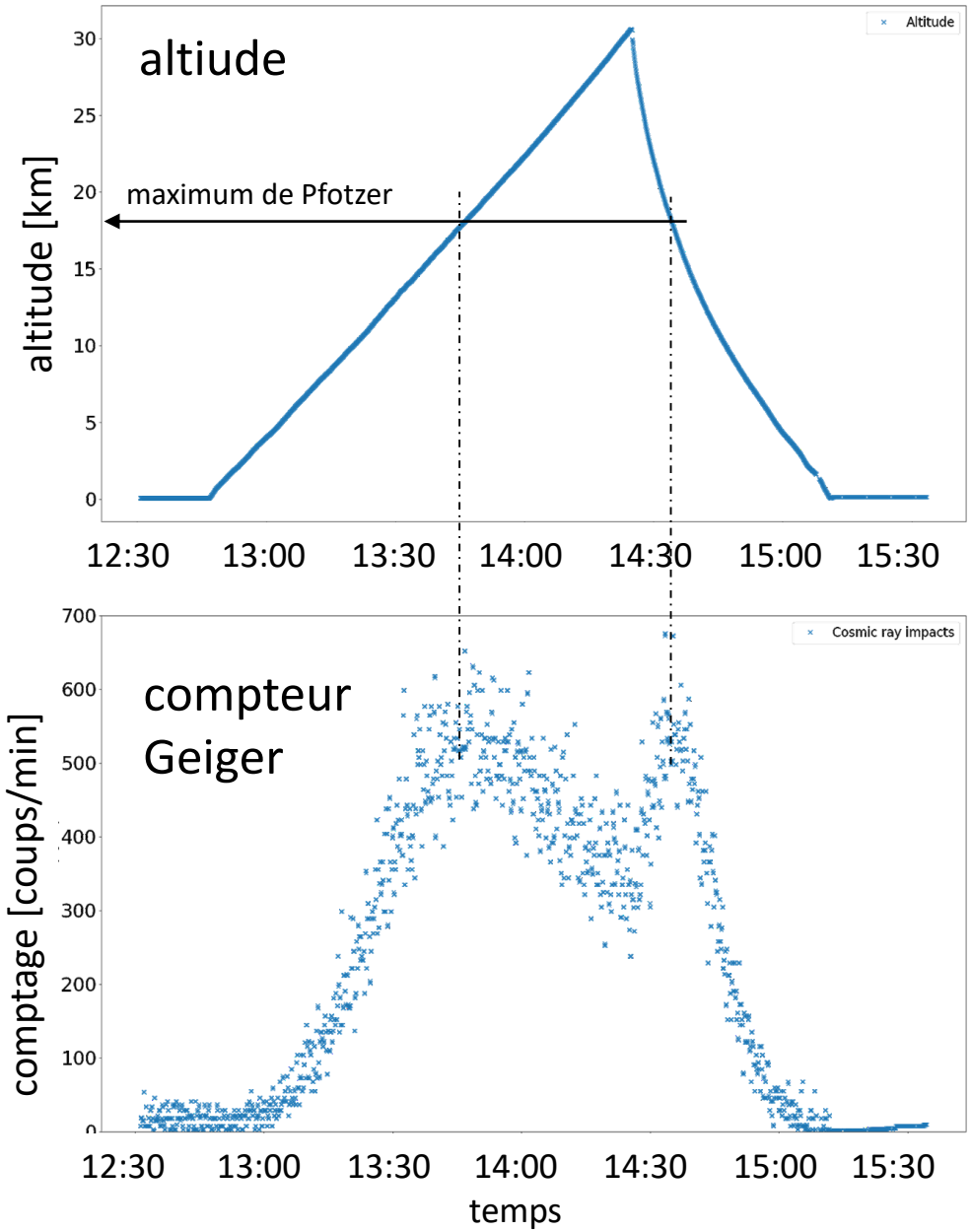
durée d'une thèse de doctorat
≈ durée d'un projet ballon

des projets "light"

$masse_{papier} < masse_{instrument}$


CLAIRE
launched @ Gap in 2000 & 2001
first light for a gamma-ray lens

Ballon Astro-Jeunes 2019



donnes du vol du ballon "L'Hermès"

lâché par les enfants du festival Astro-Jeunes
le 8 Août 2019