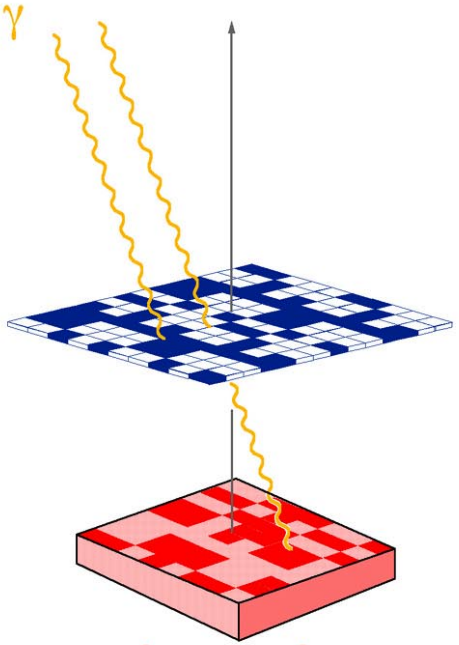
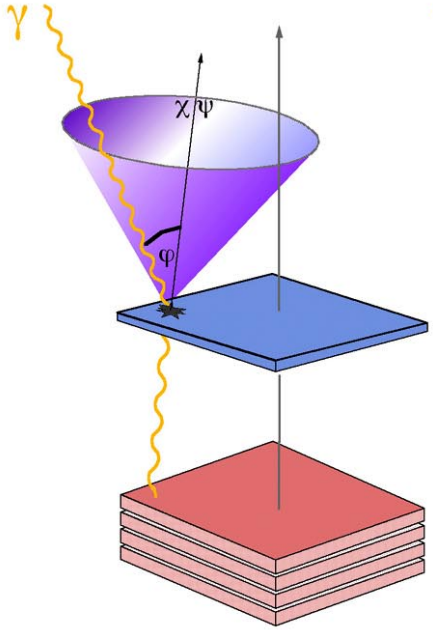
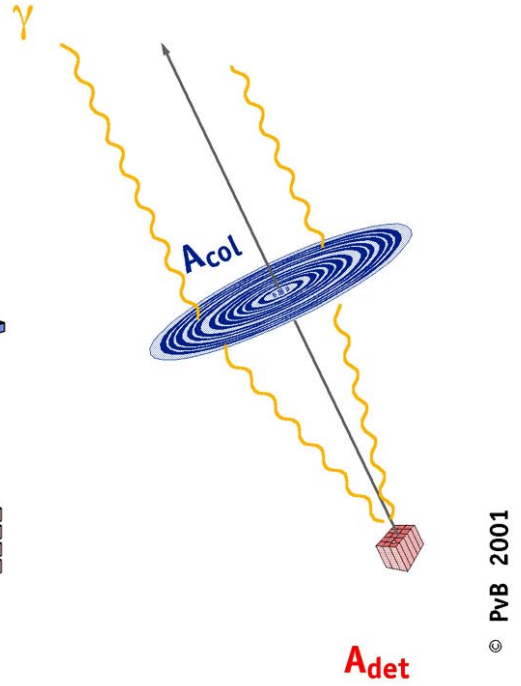
Focaliser des Rayons Gamma ? Pourquoi ?

aperture / effect	modulating aperture systems geometric optics absorption	Compton telescopes quantum optics incoherent scattering	crystal lens telescopes wave optics coherent scattering
aperture system / detector			
signal S ~	A_{col}	A_{col}	A_{col}
background B ~	$V_{det} \sim A_{det} = A_{col}$	$V_{det} \sim A_{det} = A_{col}$	$V_{det} \sim A_{det} << A_{co}$
S/B ≈	const (A)	const(A)	A_{col}/A_{det}

Focaliser des Rayons Gamma ?

... the inability to reflect or deflect individual photons makes the concentration of a gamma-ray beam impossible.

A. J. Dean, *Nuclear Instruments and Methods in Physics Research* **221**, 1984

Focusing gamma rays seems out of the question since their wavelengths (less than 0.01 angstrom) are smaller than the distance between atoms in solids.

Giovanni F. Bignami, *Sky & Telescope*, October 1985

Higher-energy X-ray photons can pas through a lens, but since they undergo no significant deflection, no focusing can take place.

Gerald K. Skinner, *Scientific American*, August 1988

... gamma-rays can not be focused. They are scattered incoherently and the direction of the scattered electrons are lost.

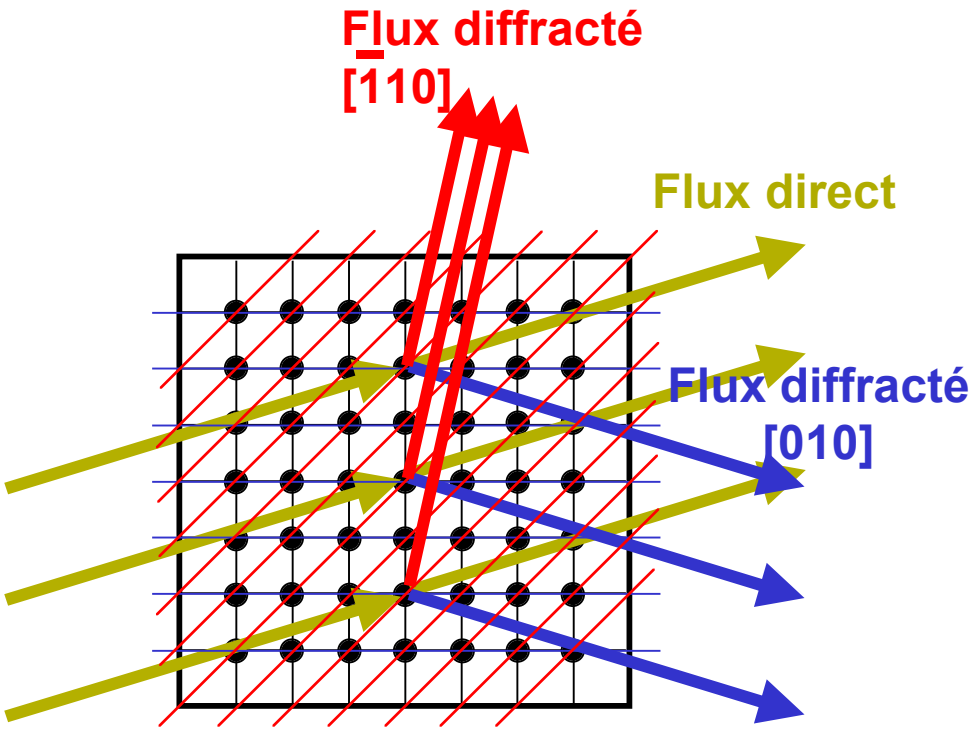
von Ballmoos et al., *Astron. Astrophys.* **221**, 396, 1989

Focaliser des Rayons Gamma !

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

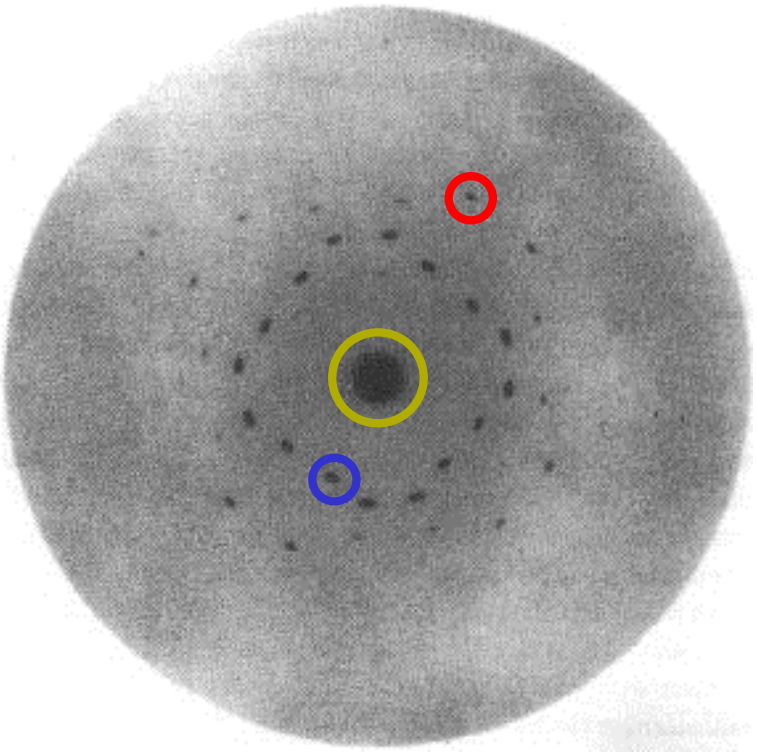
Marcel Pagnol, 1895-1974.

Focaliser les rayons gamma - comment ?



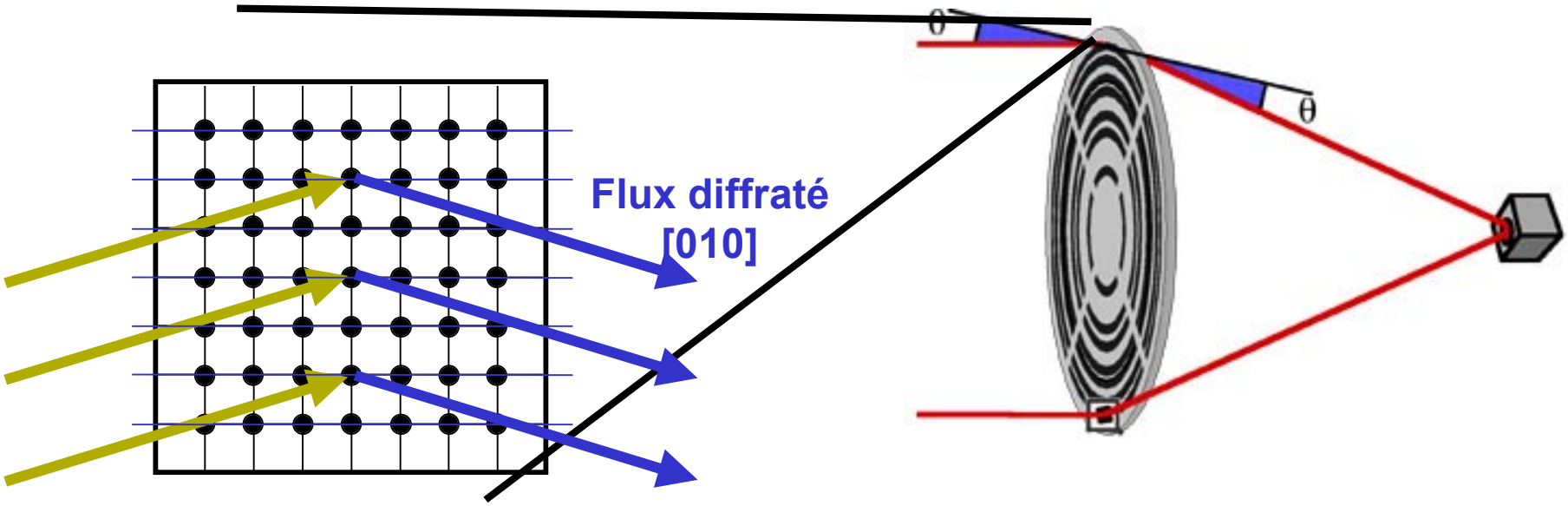
$$2d_{hkl} \sin\theta = n\lambda$$

Relation de Bragg



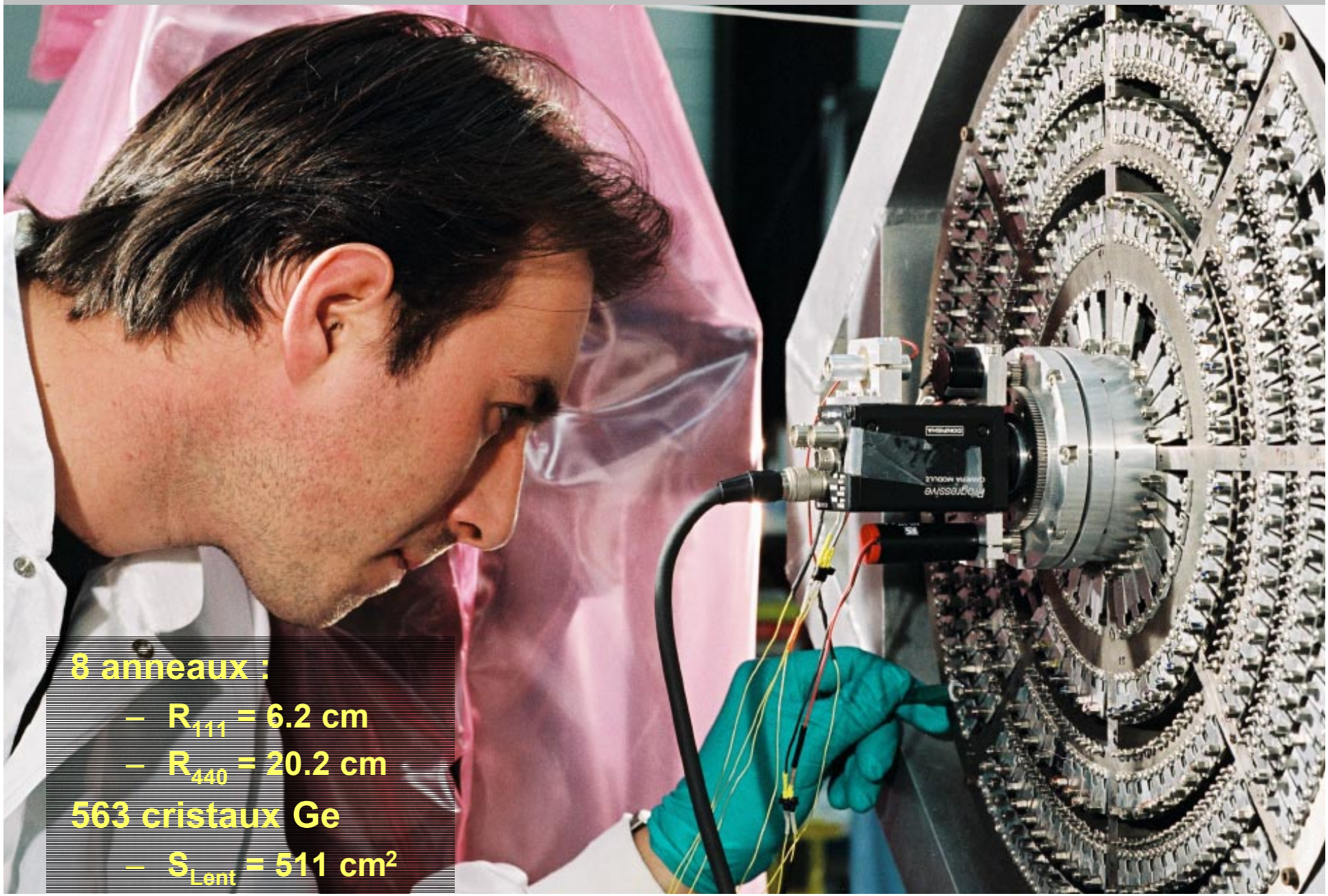
Laue, Friedrich et Knipping, 1912

Focaliser les rayons gamma - comment ?



$$2d_{hkl} \sin\theta = n\lambda$$

CLAIRE - première lumière d'une lentille gamma

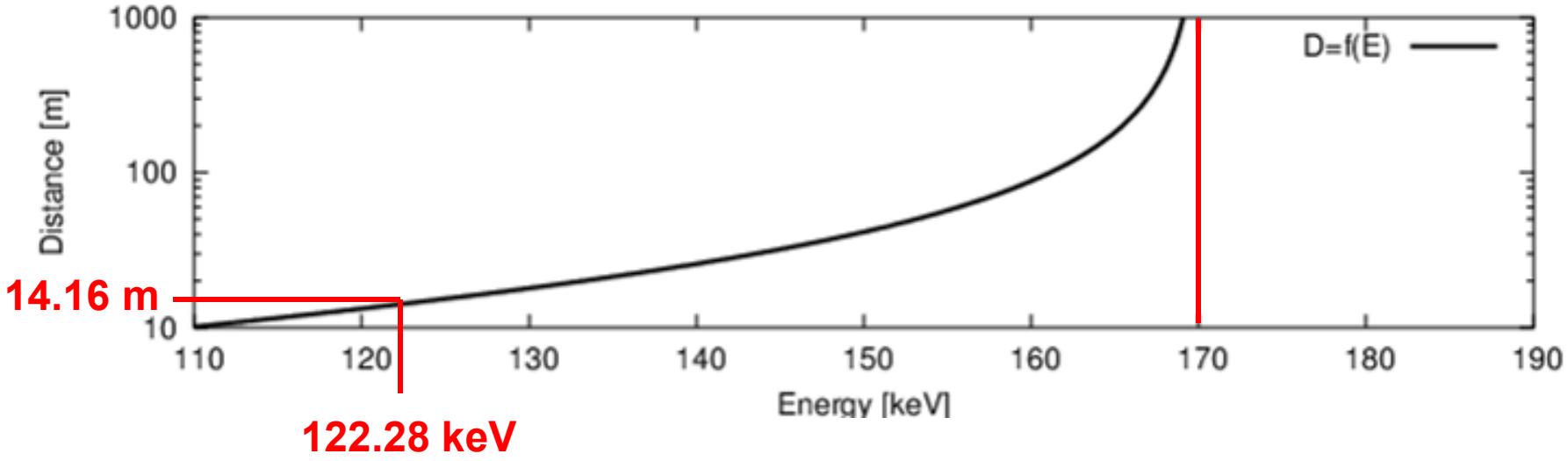


CLAIRE : principe de réglage de la lentille

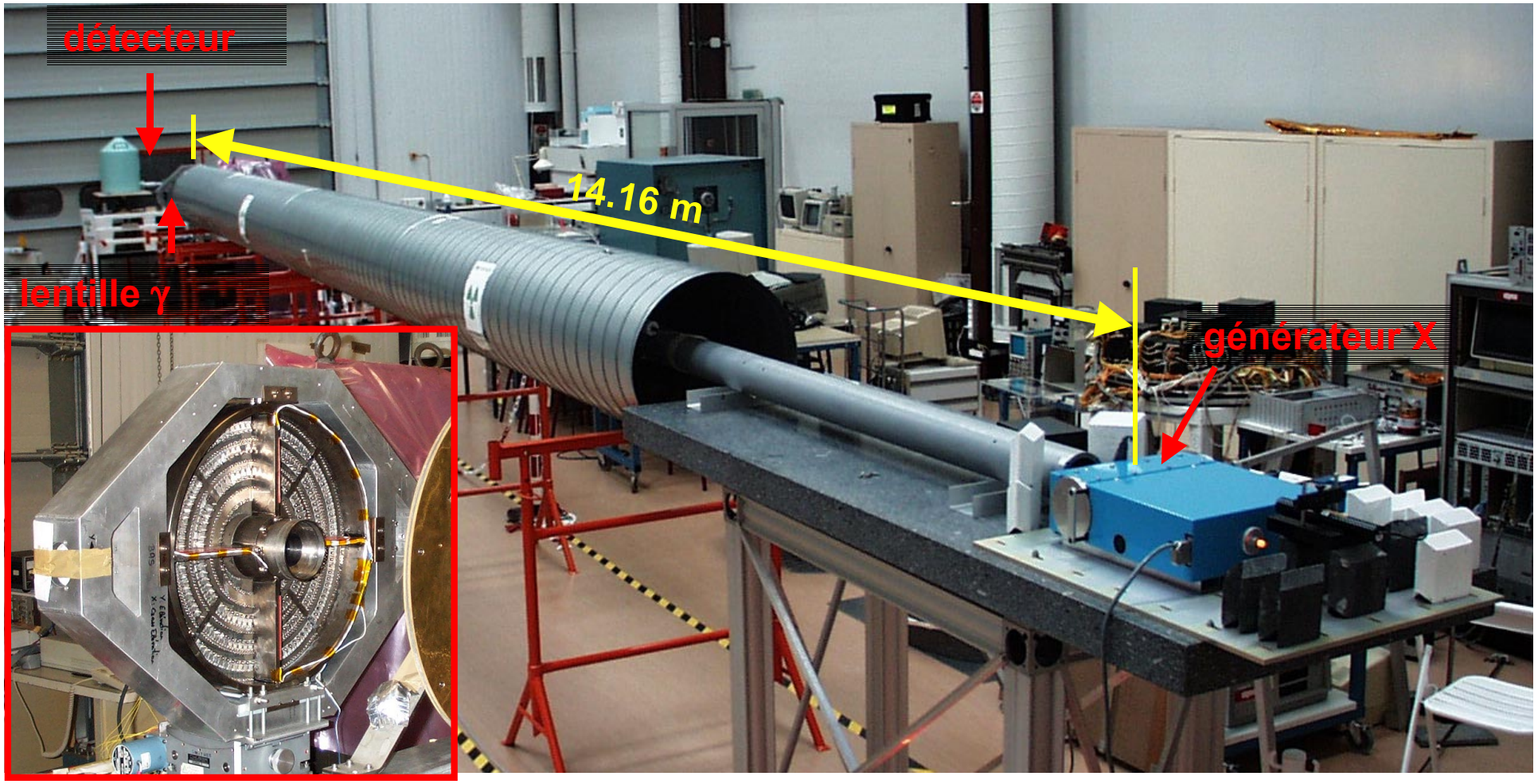
Relation entre distance de la source et énergie diffractée :

$$\frac{100\,\mathrm{keV}}{E} = \frac{100\,\mathrm{keV}}{E_\infty} + 0.3251\left(\frac{10\,\mathrm{m}}{D}\right)$$

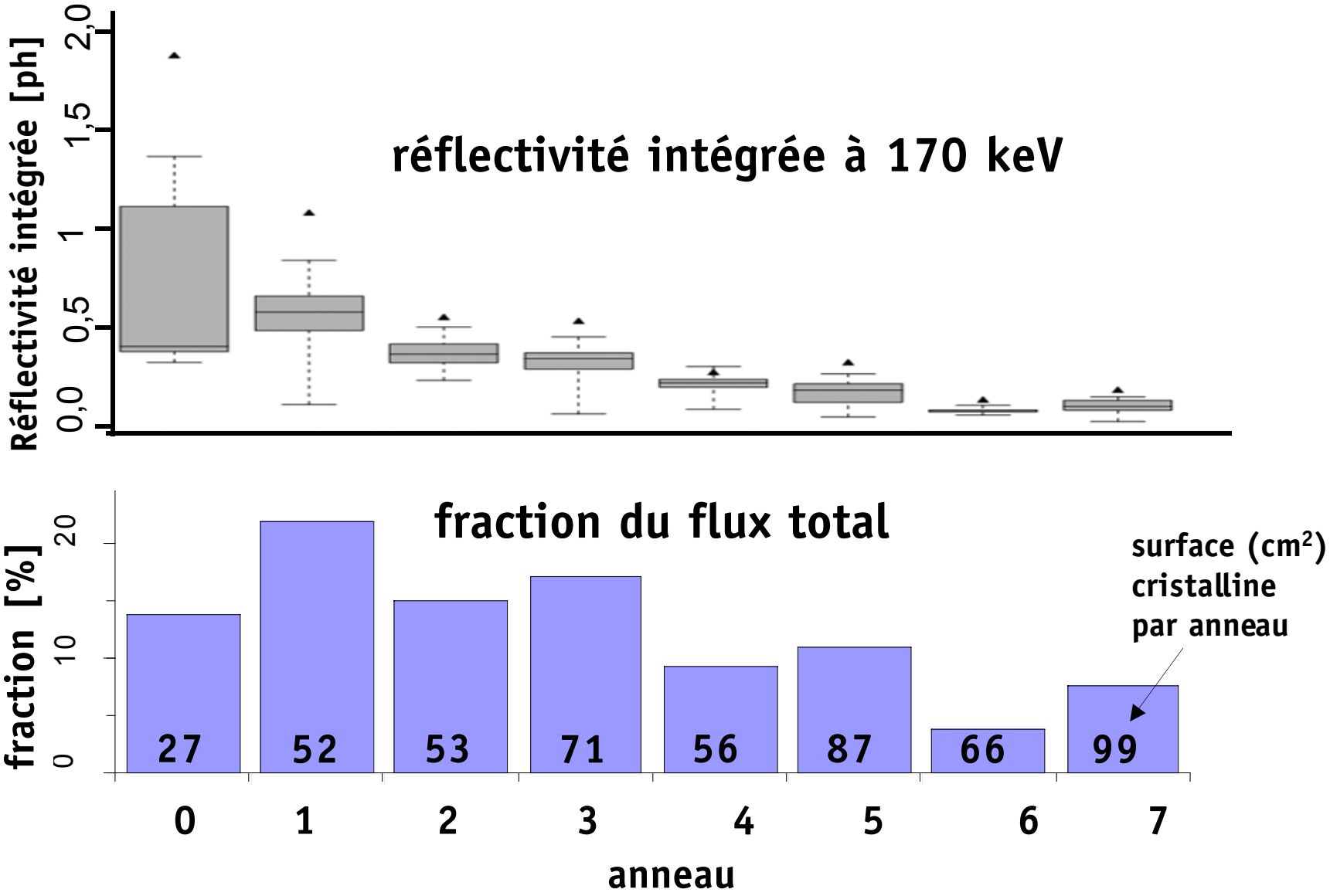
avec E_∞ = 170 keV



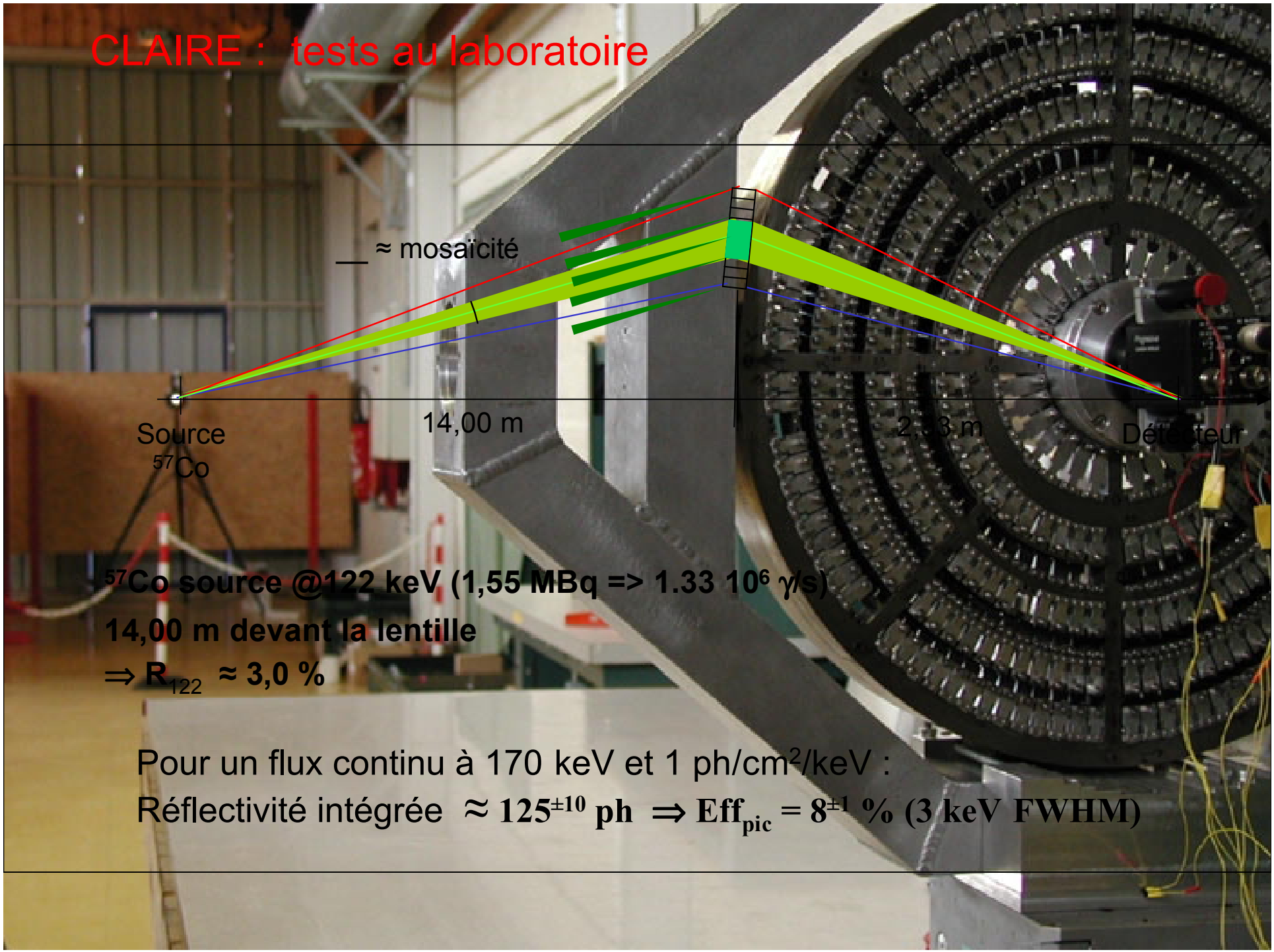
CLAIRE : le banc optique gamma au CESR



CLAIRE : qualité des cristaux individuels



CLAIRE : tests au laboratoire



^{57}Co source @122 keV (1,55 MBq => 1.33 10^6 γ/s)

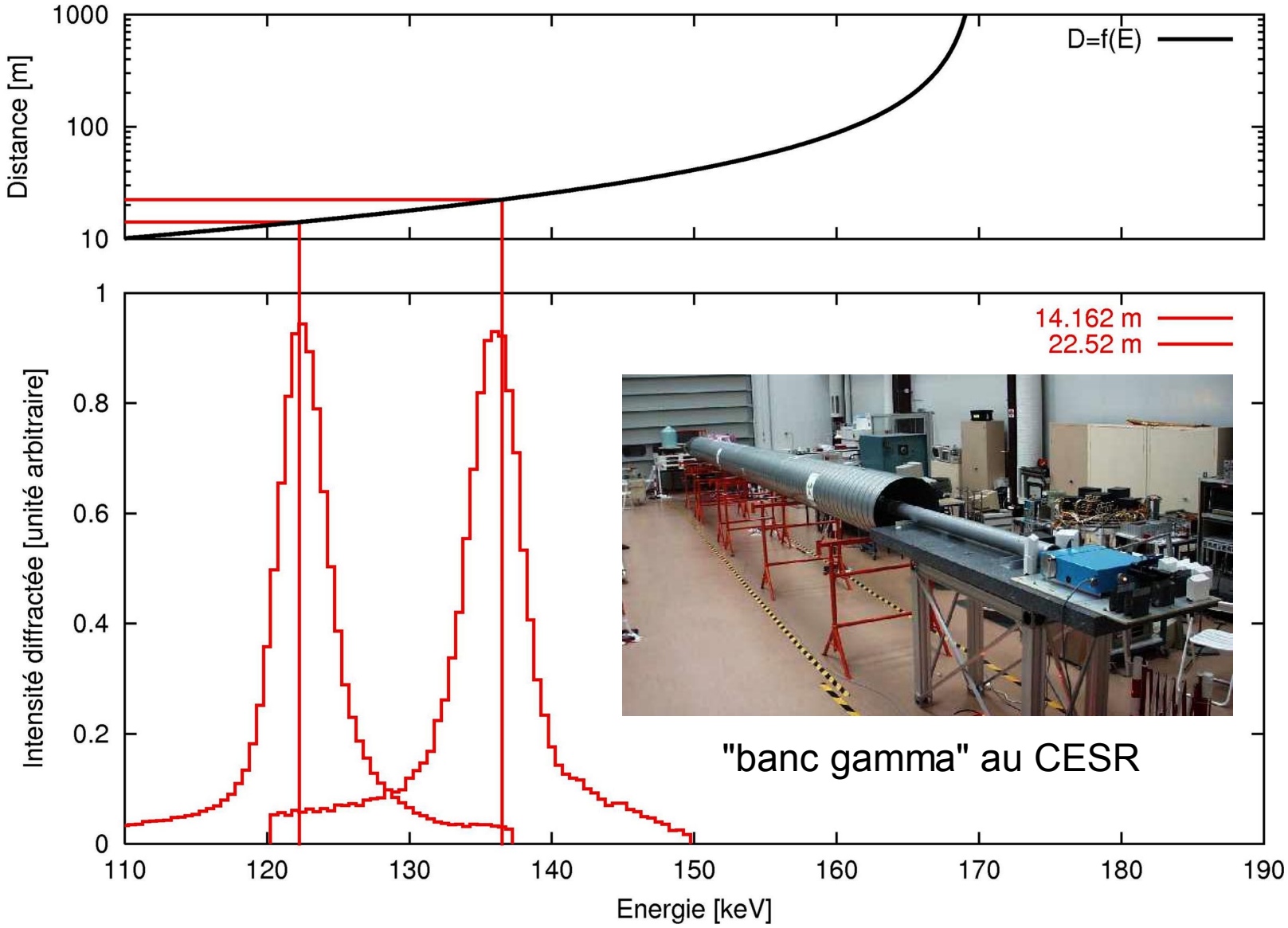
14,00 m devant la lentille

⇒ R_{122} ≈ 3,0 %

Pour un flux continu à 170 keV et 1 ph/cm²/keV :

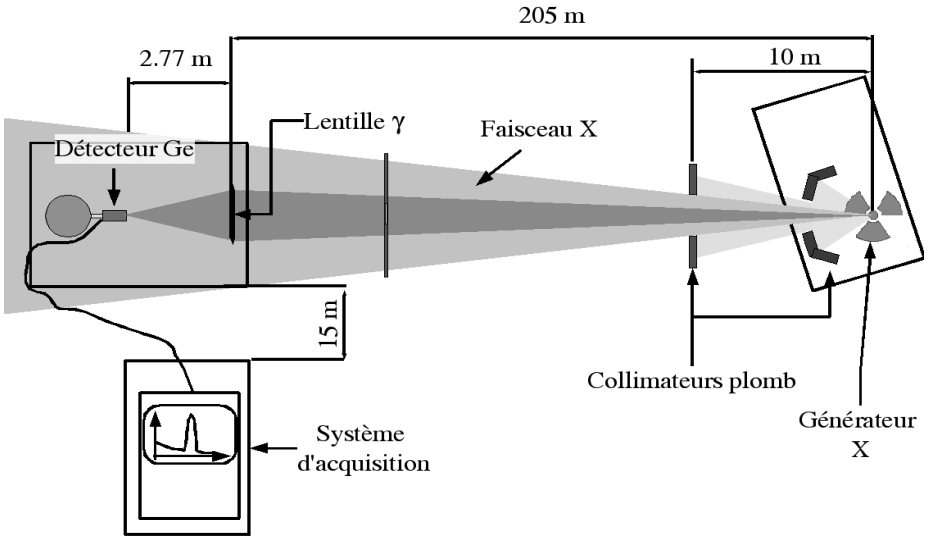
Réflectivité intégrée ≈ $125^{\pm 10}$ ph ⇒ $Eff_{pic} = 8^{\pm 1}$ % (3 keV FWHM)

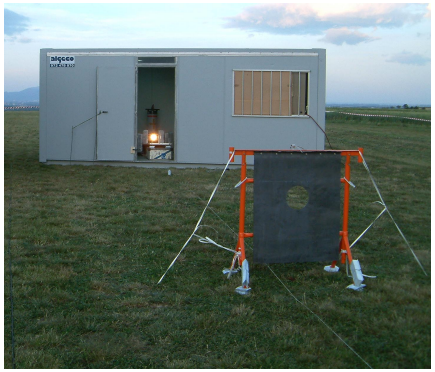
CLAIRE : tests au laboratoire ... et au delà



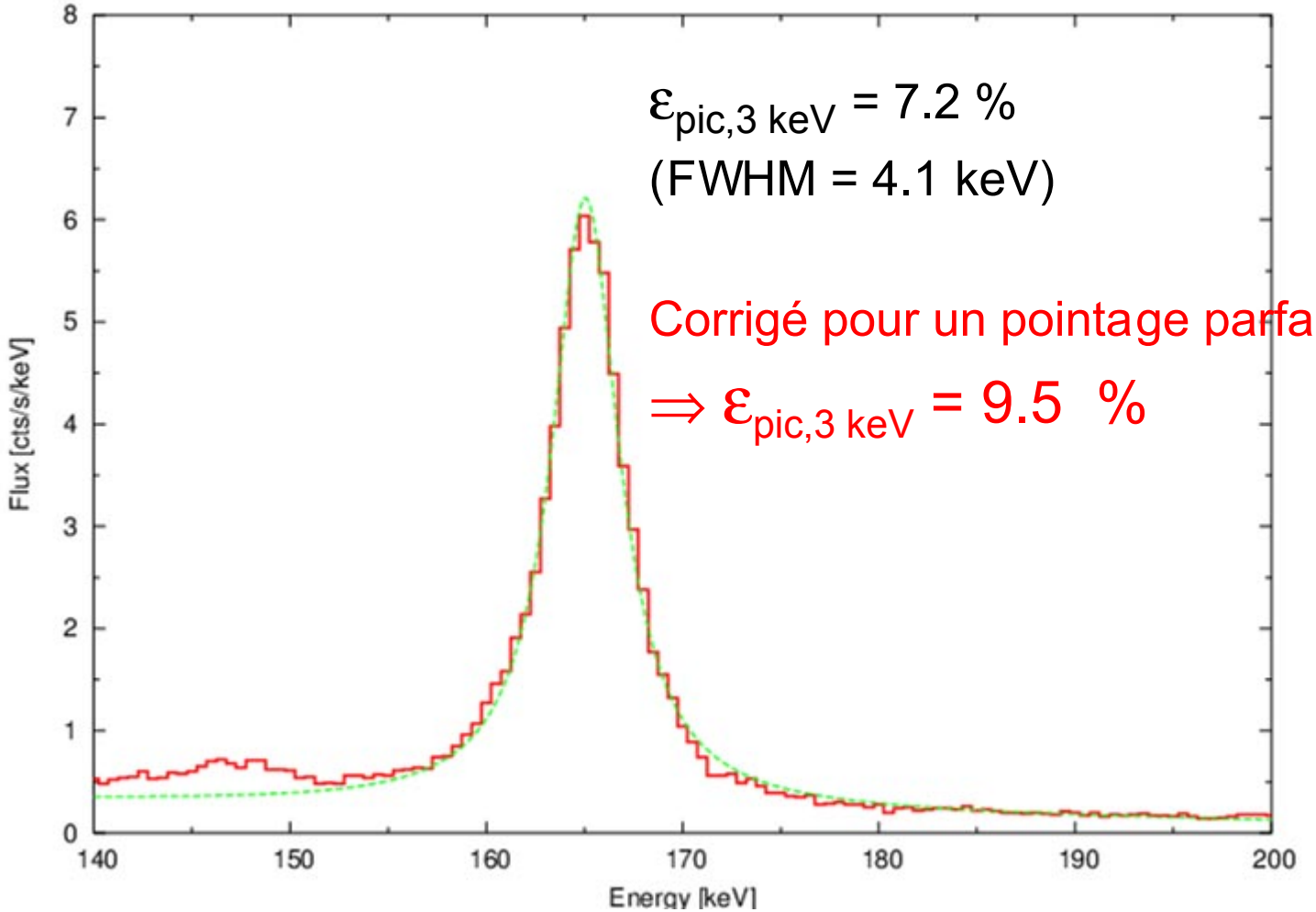
"banc gamma" au CESR

CLAIRE TGD : une source proche de l'"infini" ...





CLAIRE TGD - efficacité de diffraction



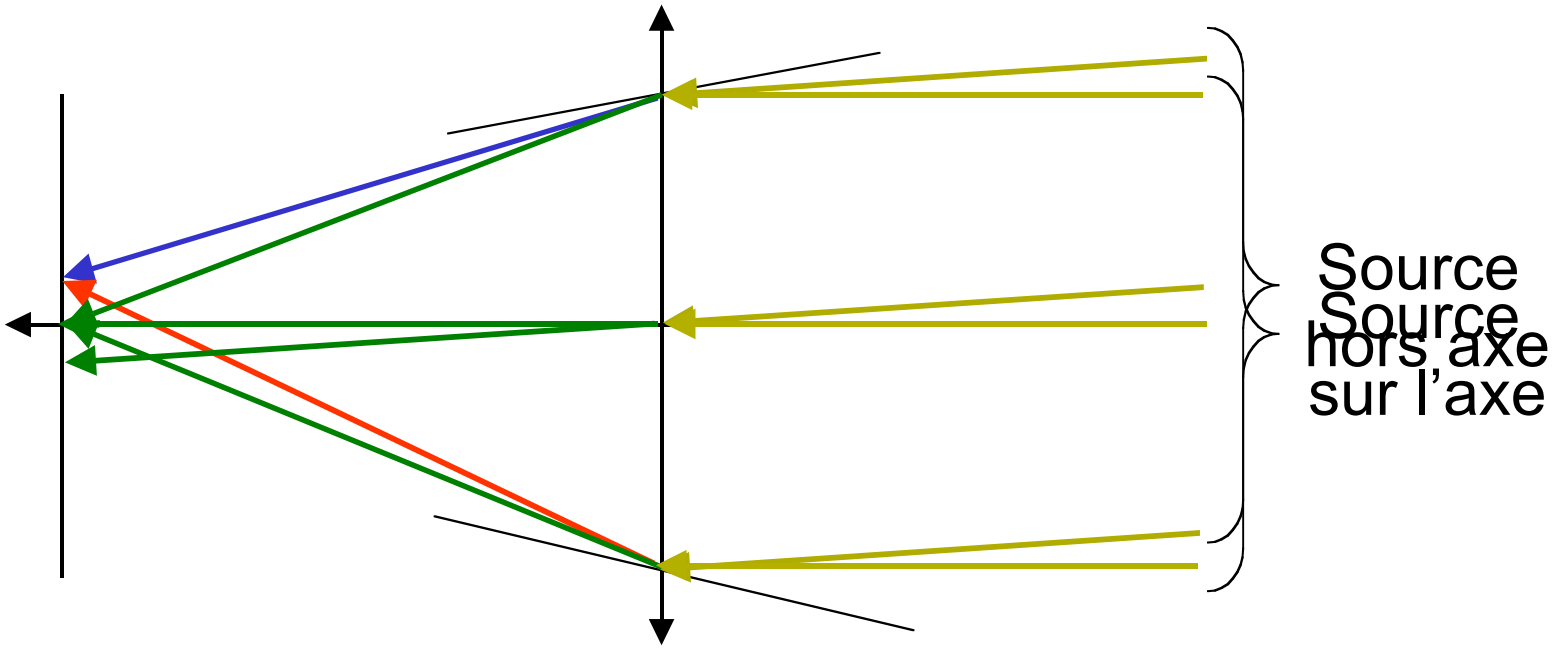
$\varepsilon_{pic,3\ keV}$ = 7.2 %

(FWHM = 4.1 keV)

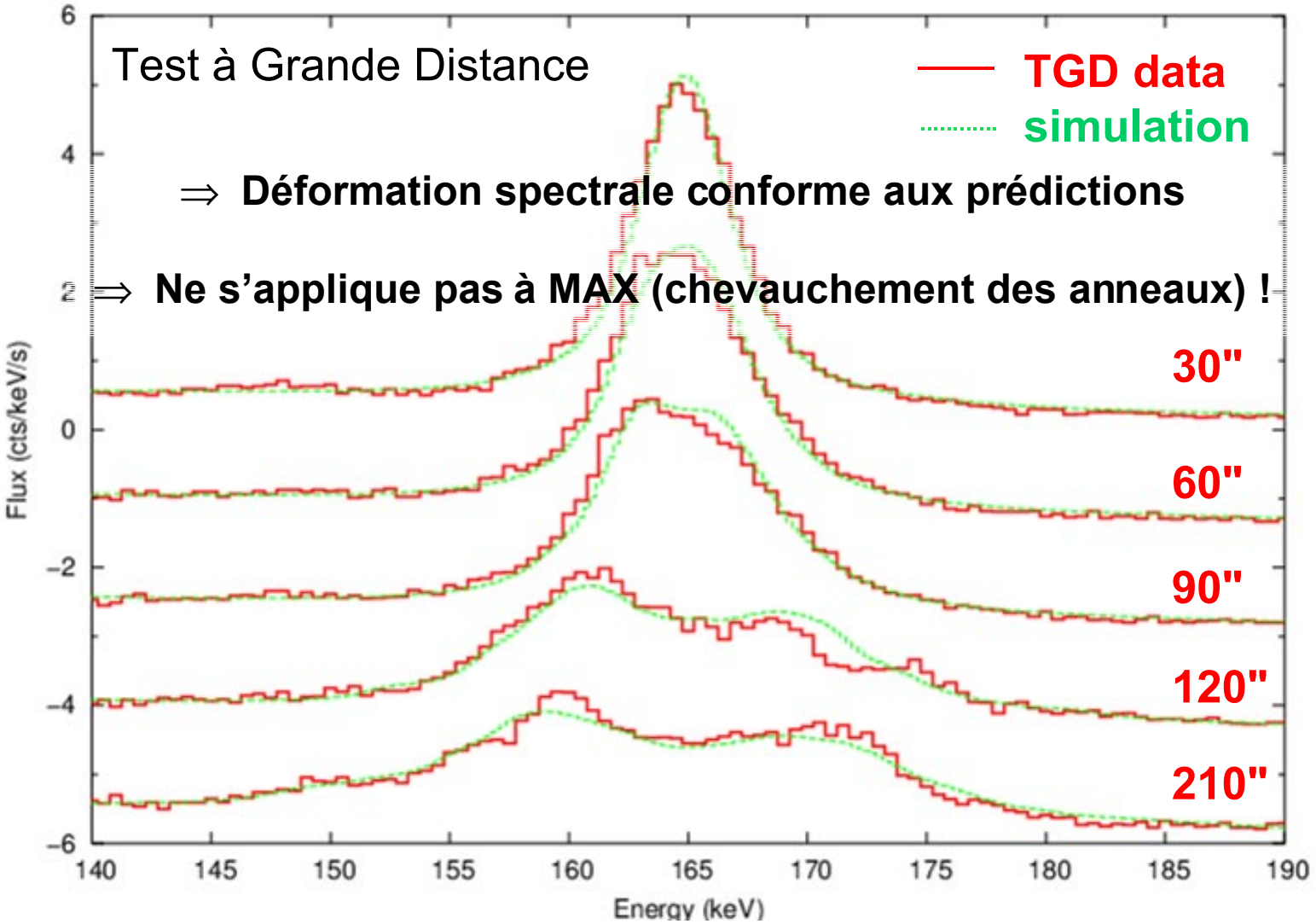
Corrigé pour un pointage parfait :

$\Rightarrow \varepsilon_{pic,3\ keV}$ = 9.5 %

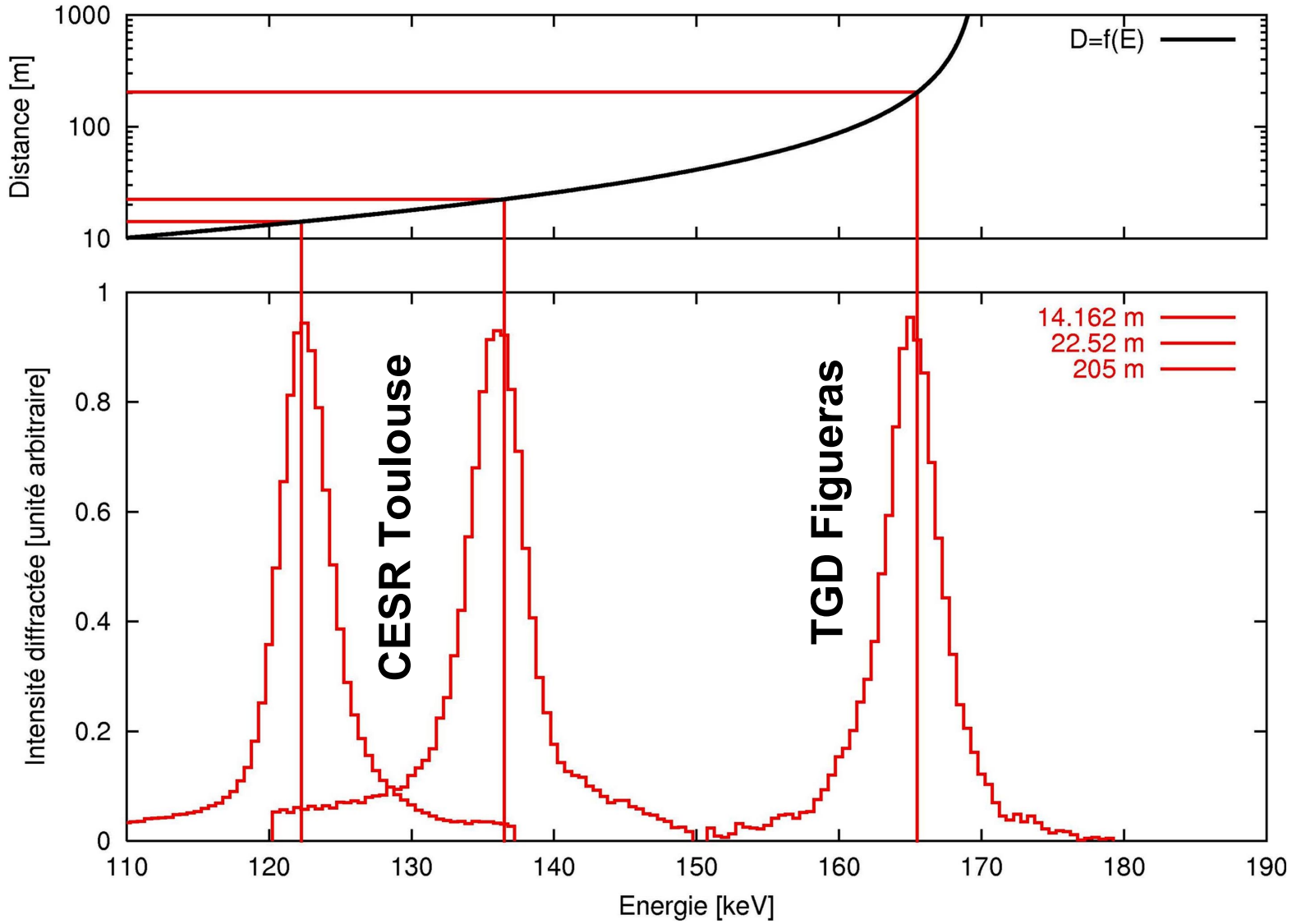
Réponse instrumentale de la lentille - principe



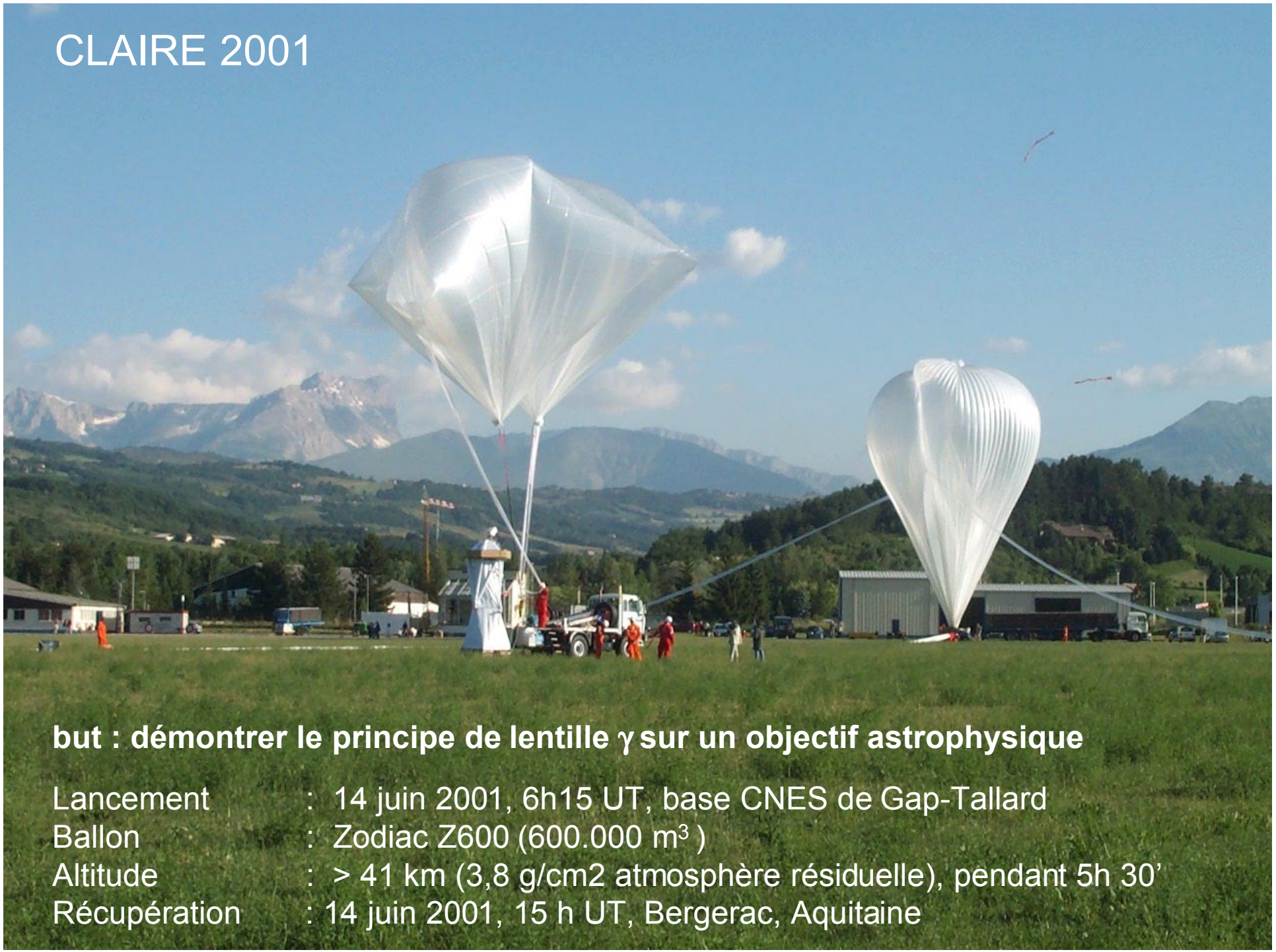
CLAIRE TGD : réponse hors axe



CLAIRE TGD : 14 m, 22.5 m ... et 205 m



CLAIRE 2001

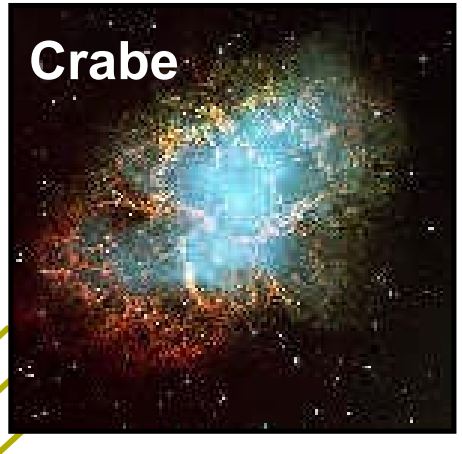


but : démontrer le principe de lentille γ sur un objectif astrophysique

Lancement : 14 juin 2001, 6h15 UT, base CNES de Gap-Tallard
Ballon : Zodiac Z600 (600.000 m^3)
Altitude : > 41 km (3,8 g/cm2 atmosphère résiduelle), pendant 5h 30'
Récupération : 14 juin 2001, 15 h UT, Bergerac, Aquitaine

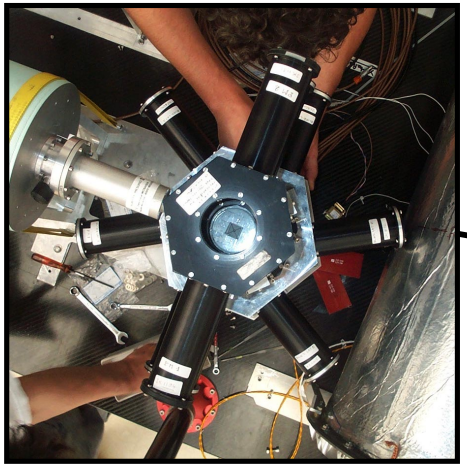
CLAIRE 2001 : la nacelle

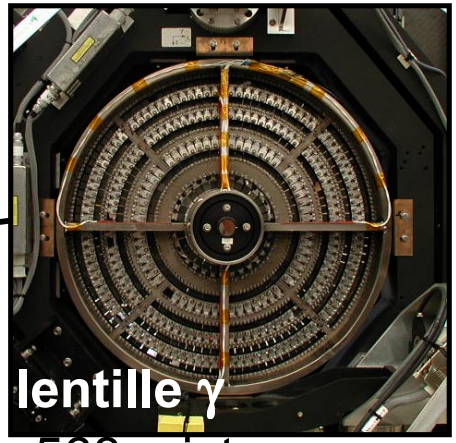
chandelle standard, polychromatique
proche du Soleil (~1° le 15 Juin)



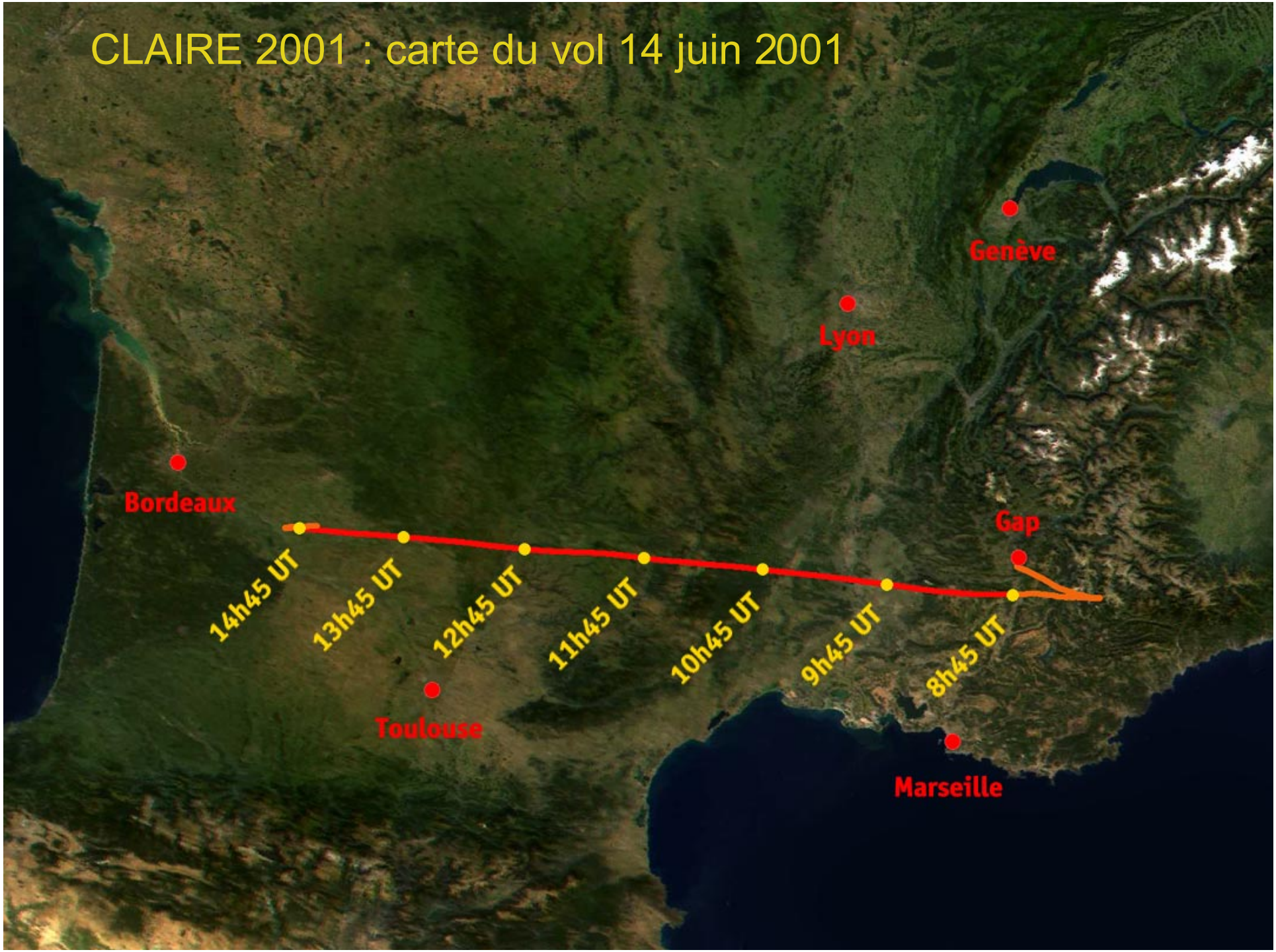
Détecteur
- matrice 3x3
- Ge haute pureté
  1,5*1,5*4 cm

Blindage actif
- CsI
- BGO

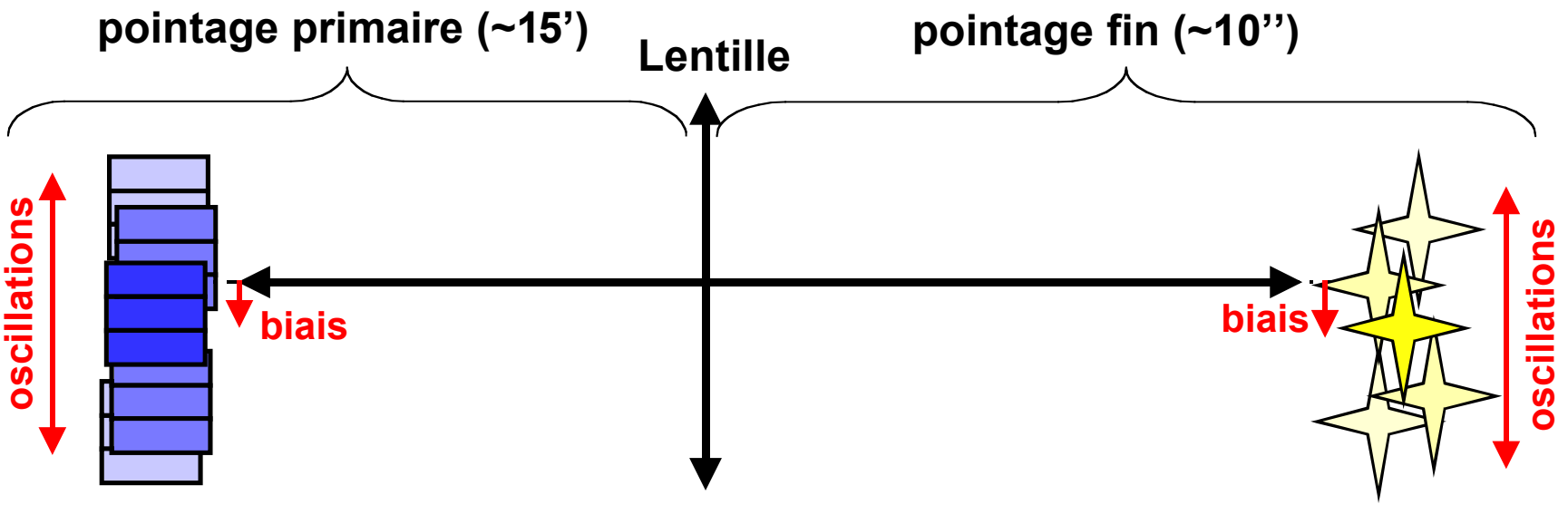


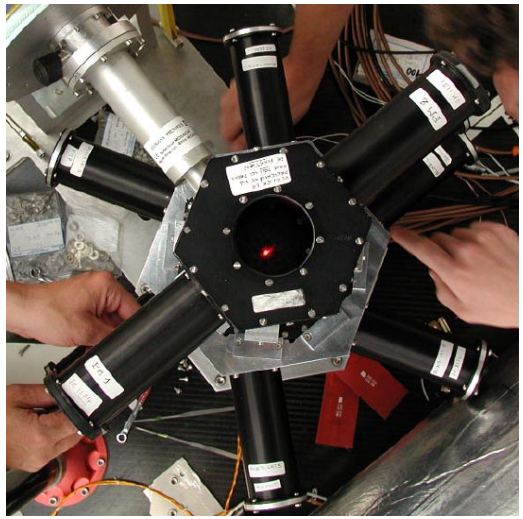


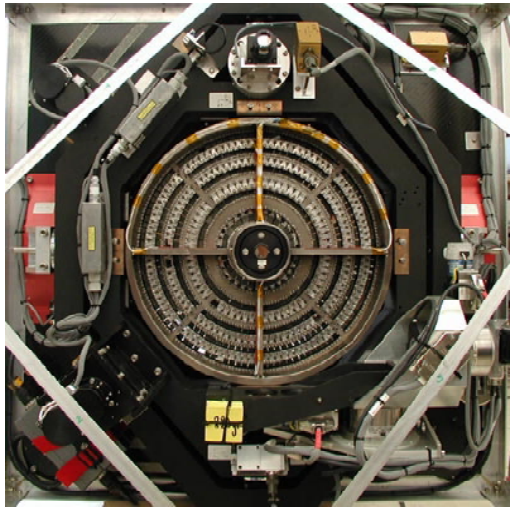
- 563 cristaux
- E = 170 keV
- FWHM ~ 3 keV

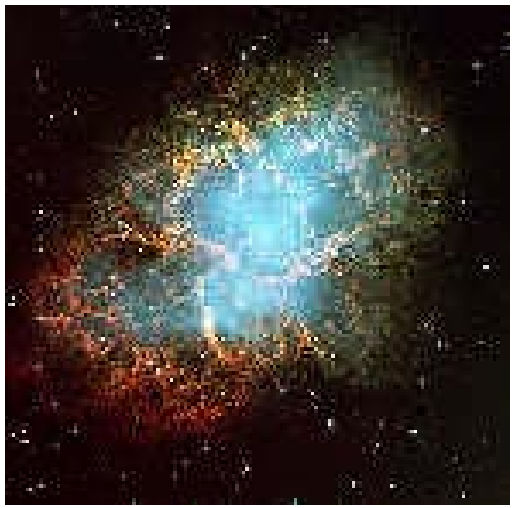

CLAIRE 2001 : carte du vol 14 juin 2001
Genève
Lyon
Bordeaux
Gap
14h45 UT
13h45 UT
12h45 UT
11h45 UT
10h45 UT
9h45 UT
8h45 UT
Toulouse
Marseille

CLAIRE 2001 : pointages primaire et fin

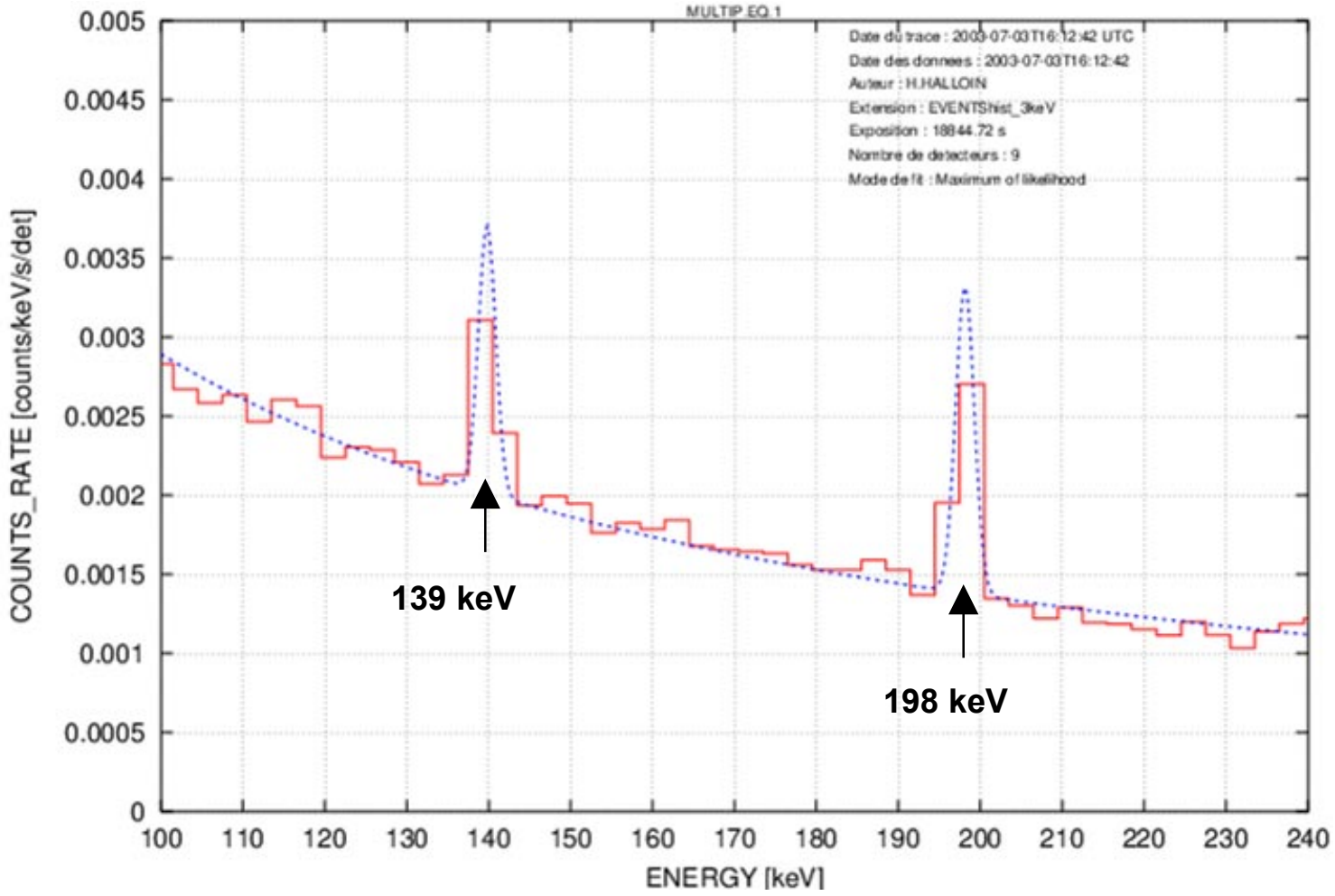




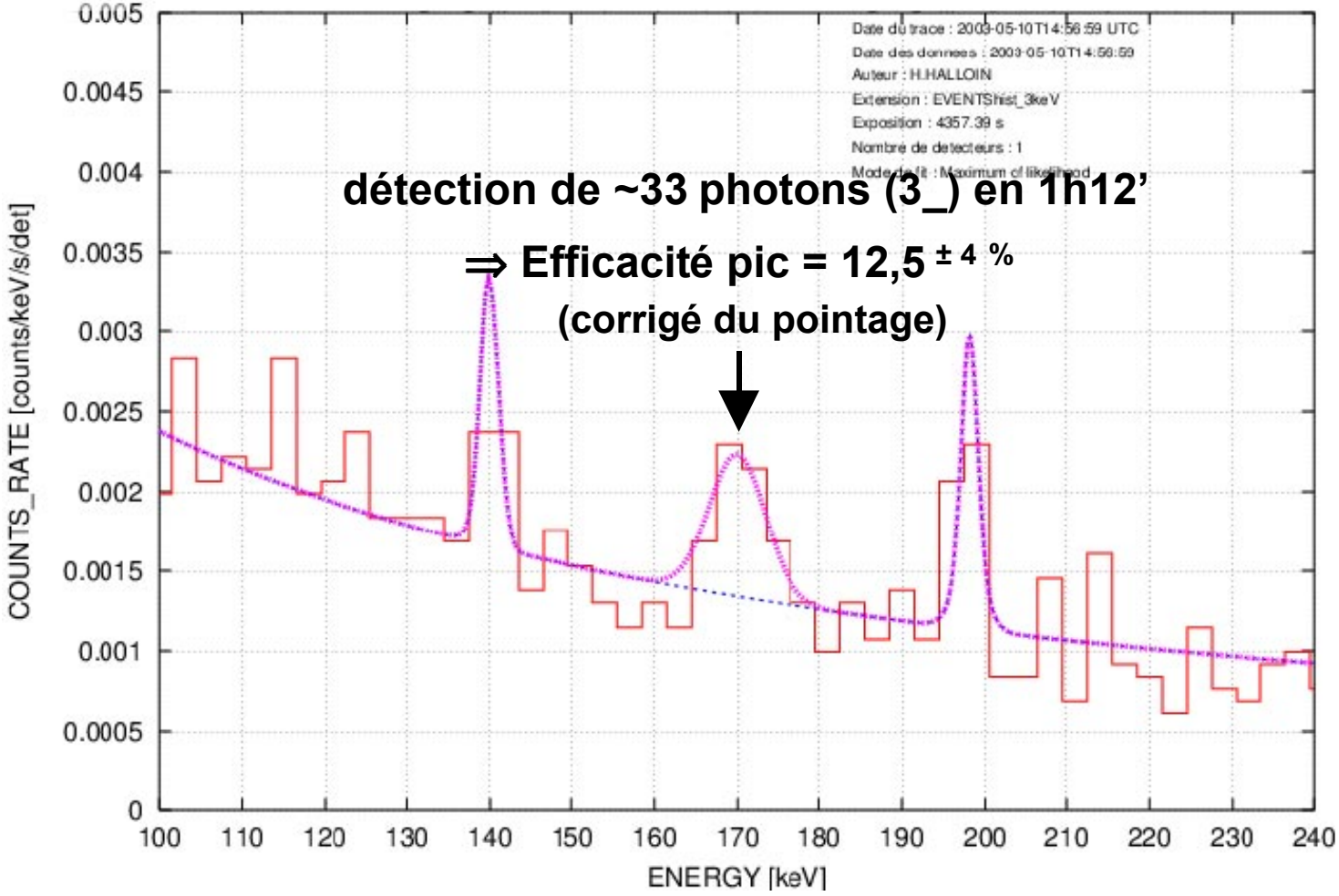




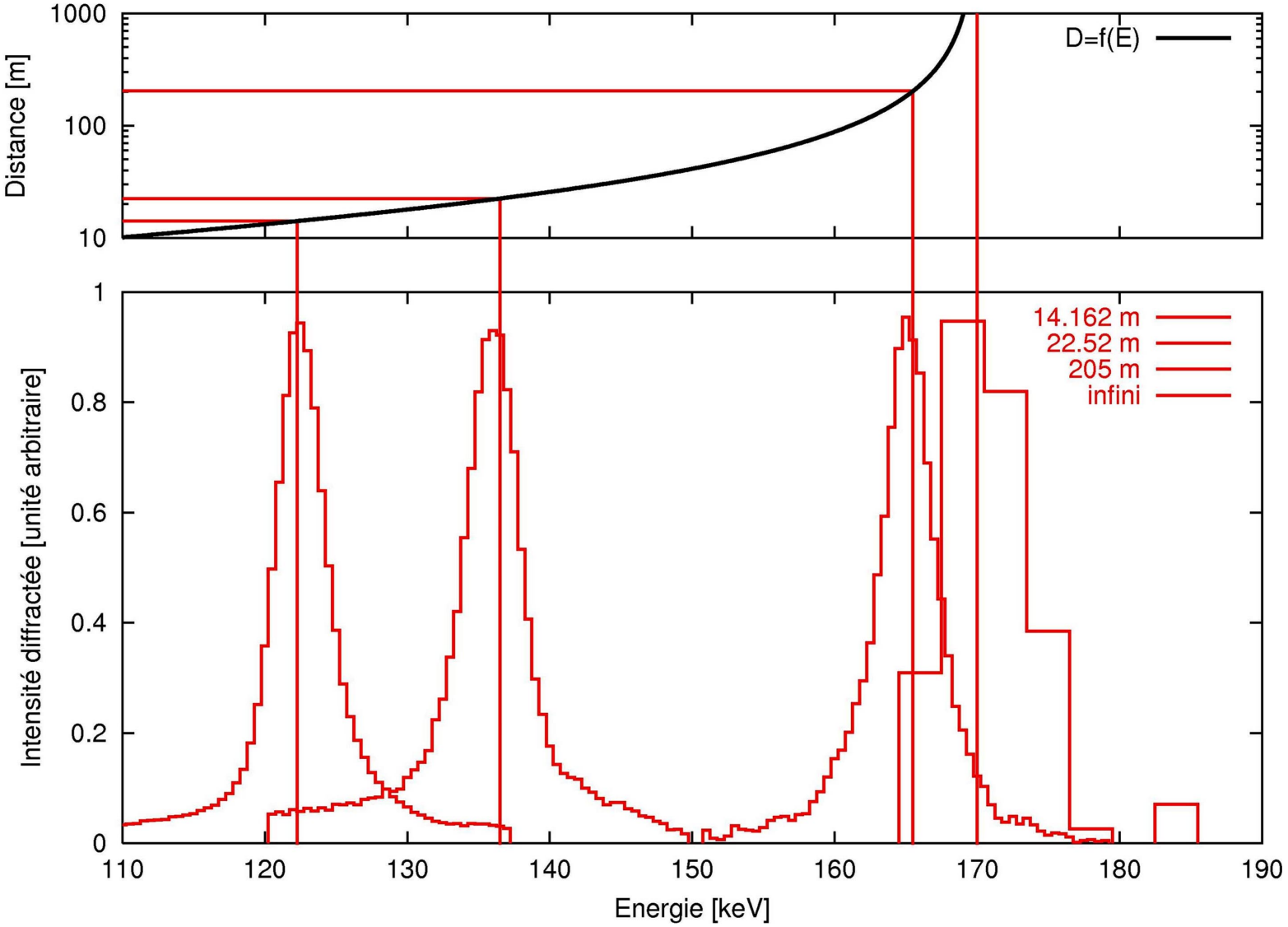
CLAIRE 2001 : bruit de fond au plafond (évts simples)



CLAIRE 2001 : première lumière d'une source astrophysique



CLAIRE 2001 : 14 m, 22.5 m, 205 m ... infini !



l'astronomie gamma
commence à voir

CLAIRE