Le stelle e i neutrini

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NEMO
astronomia con neutrini
ovvero
guardare le stelle

Guardare le stelle

Strumenti

occhio buono



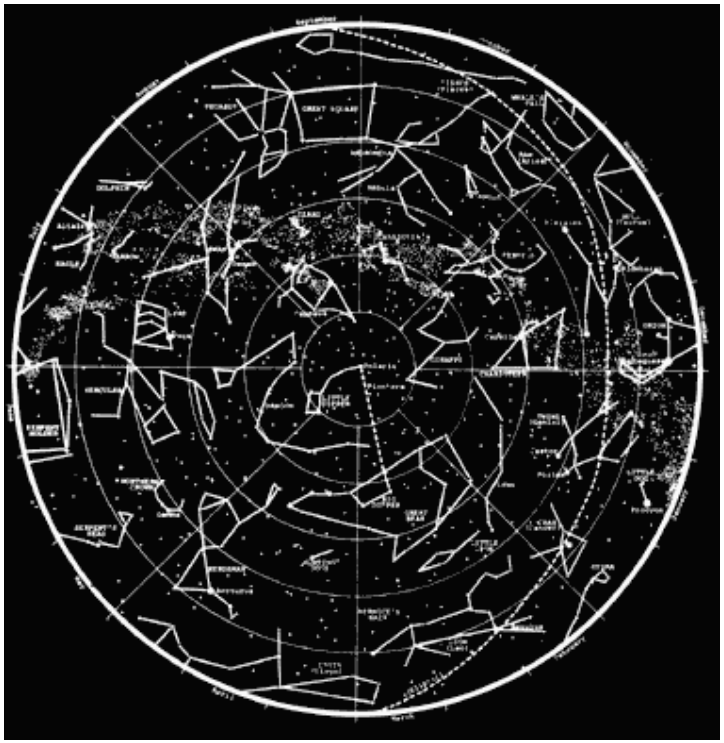


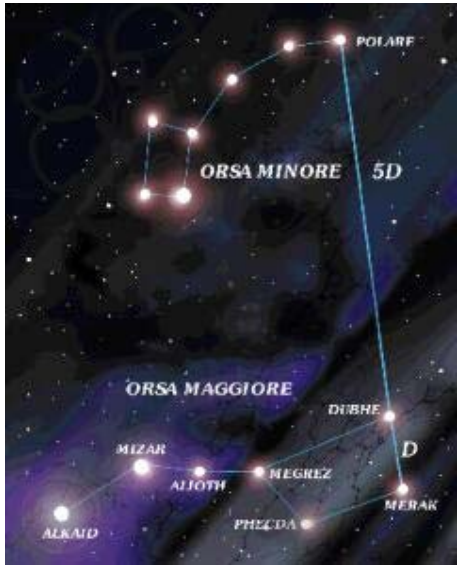




Guardare le stelle

Le costellazioni





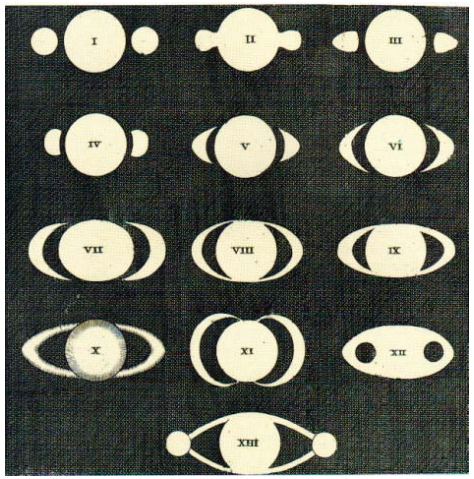
Le costellazioni

Luciano Trasatti, Napoli, 10/5/2007: Le stelle e i neutrini

Guardare le stelle

Strumenti

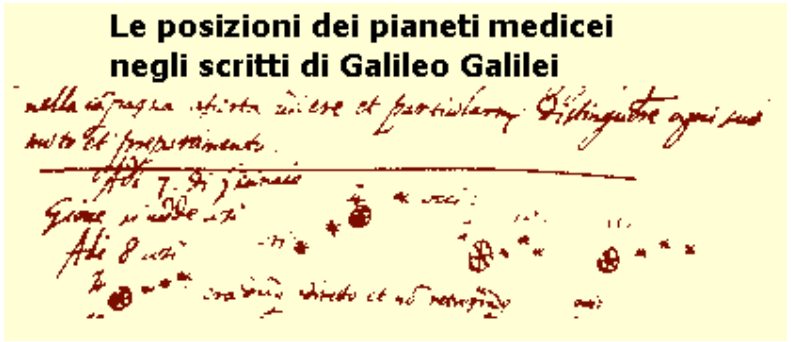
cannocchiale

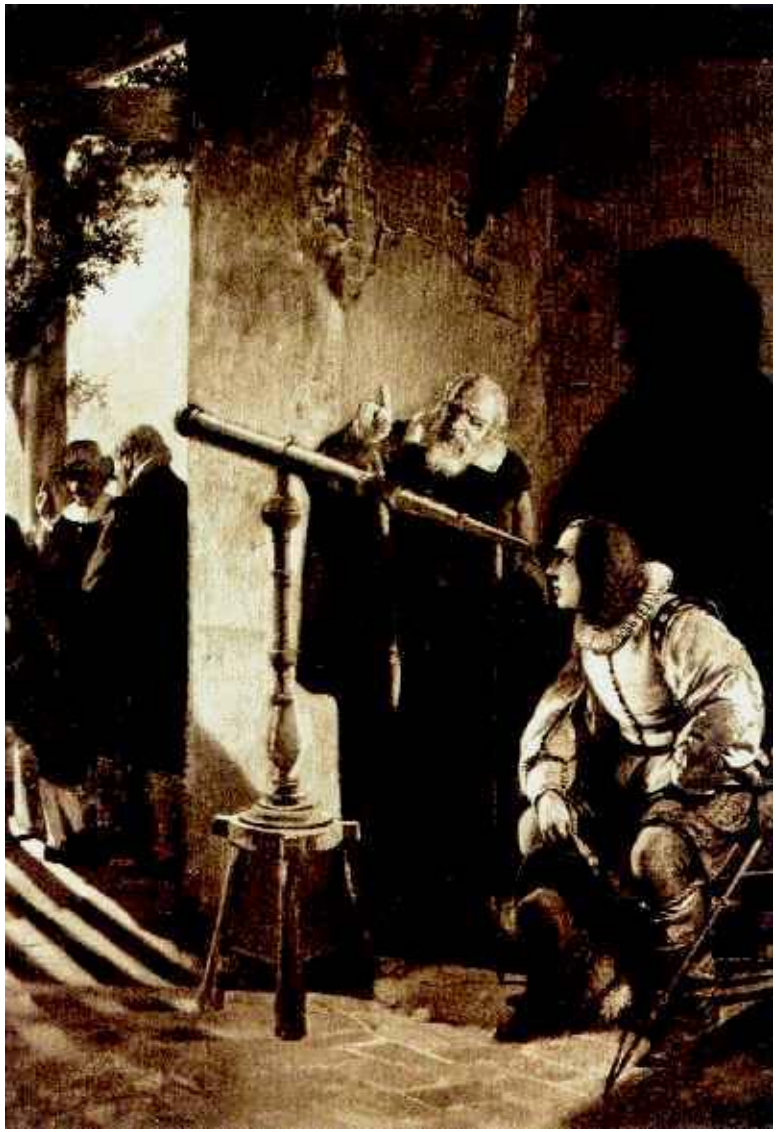


tricorporeita’

saturno

pianeti medicei

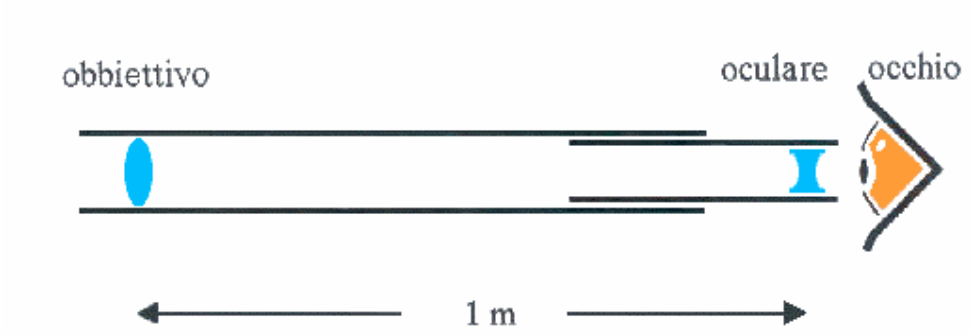




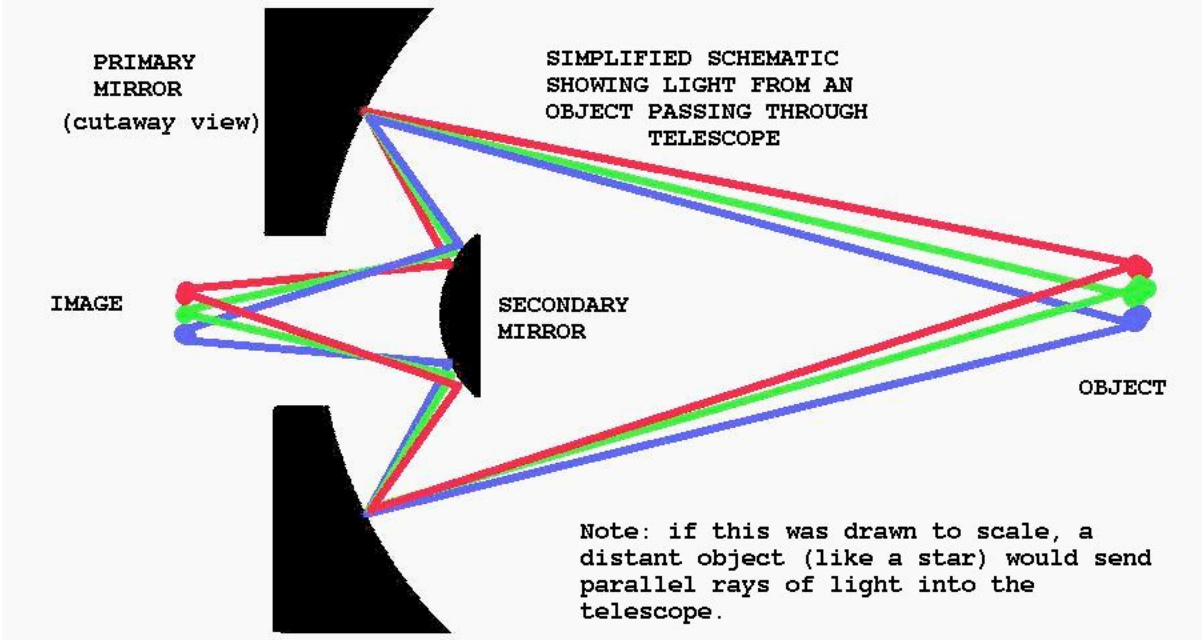
Guardare le stelle

Strumenti

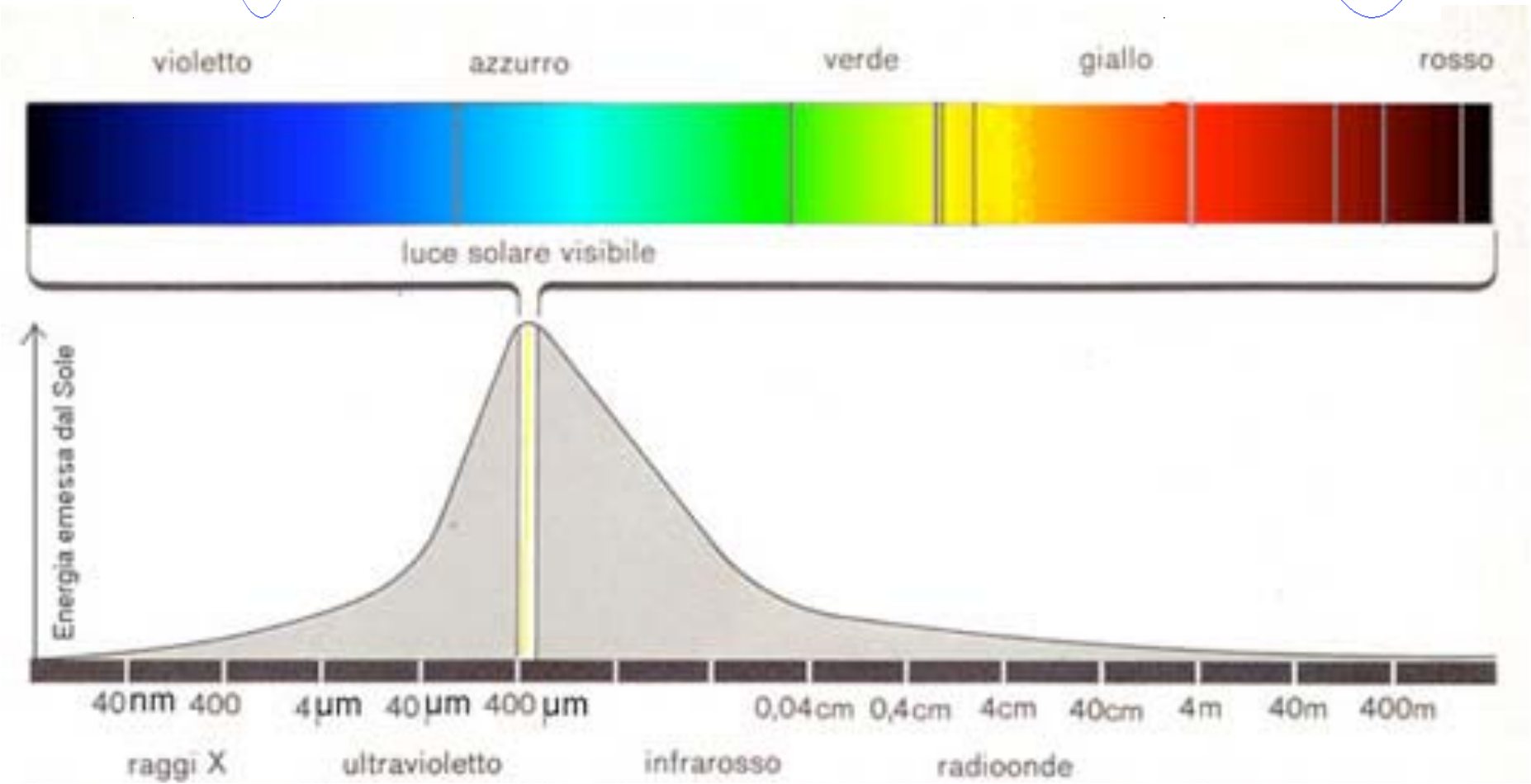
cannocchiale



telescopio



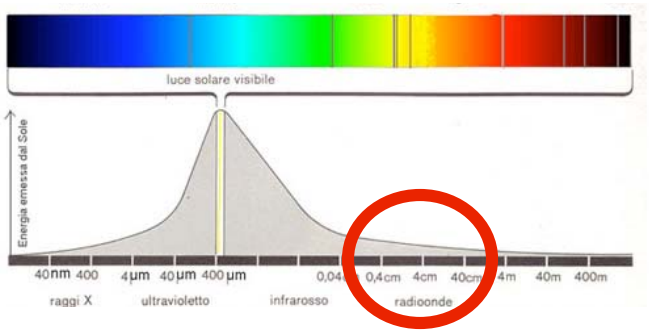
la luce


violetto
azzurro
verde
giallo
rosso
luce solare visibile
Energia emessa dal Sole
40 nm
400
4 µm
40 µm
400 µm
0,04 cm
0,4 cm
4 cm
40 cm
4 m
40 m
400 m
raggi X
ultravioletto
infrarosso
radioonde

Guardare le stelle

Strumenti

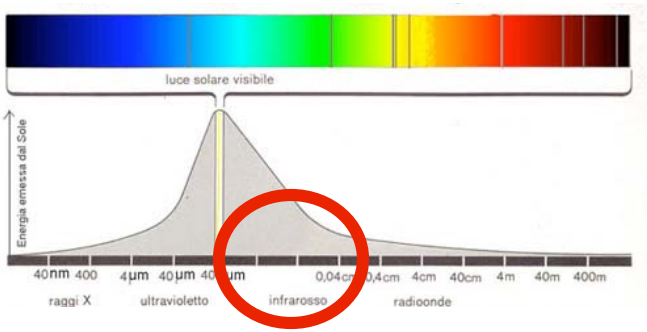
Radioastronomia



Guardare le stelle

Strumenti

Infrarosso

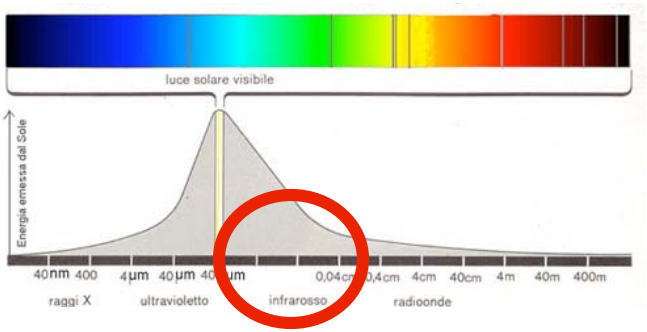


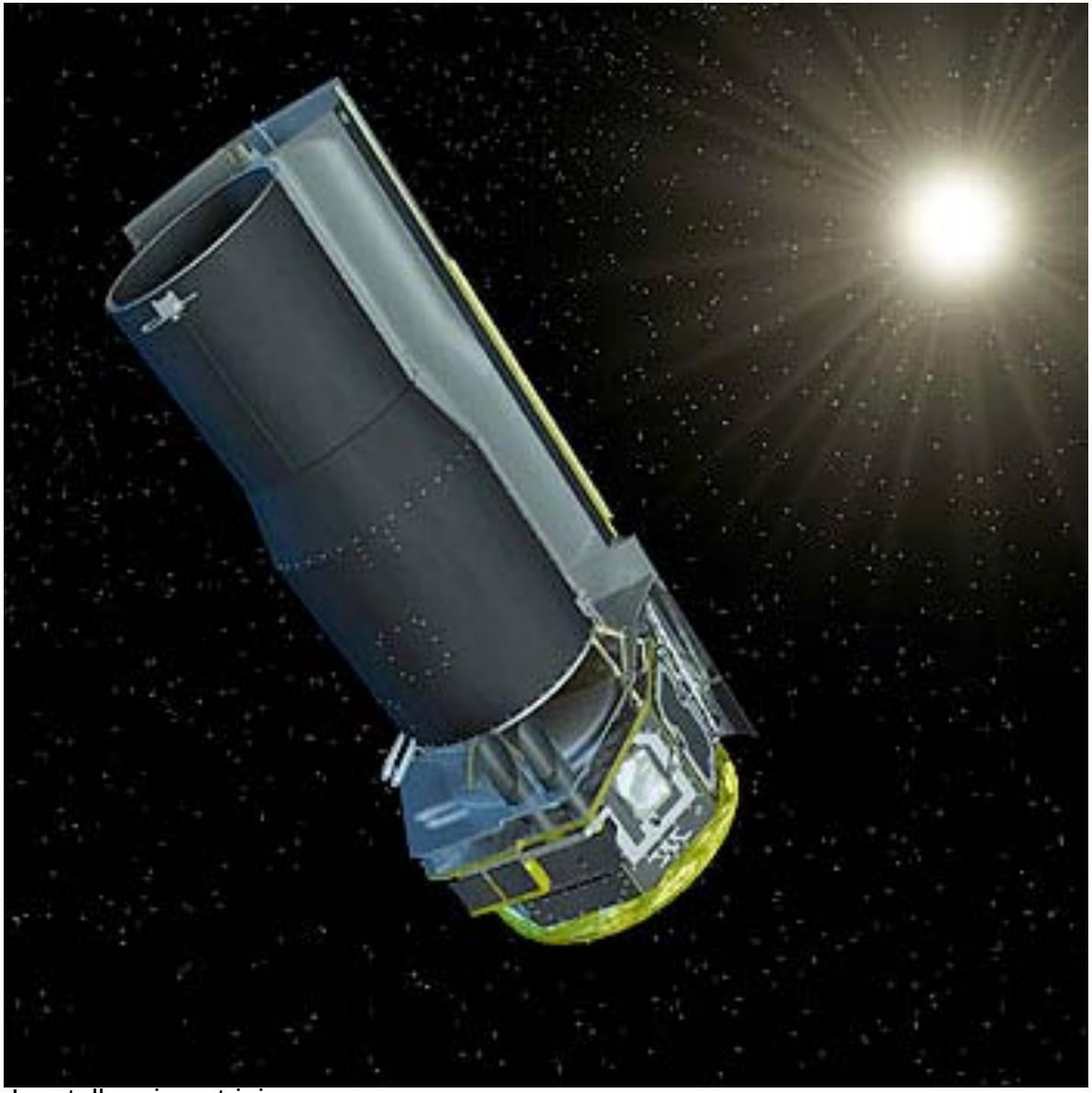
Guardare le stelle

Strumenti

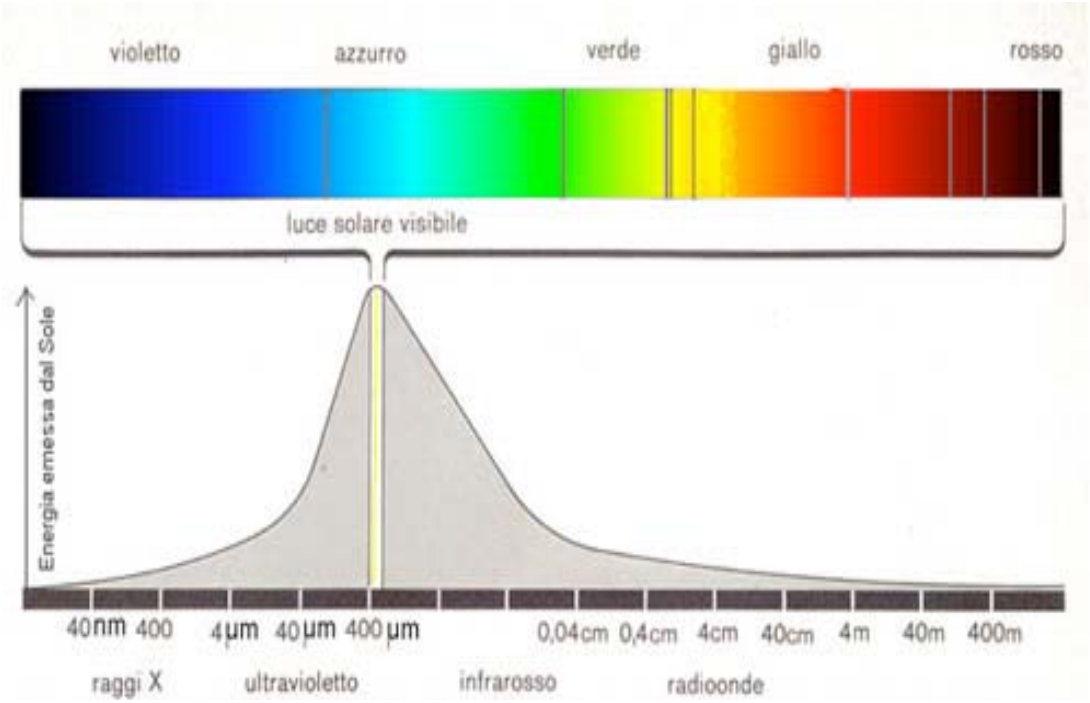
Infrarosso

spazio





la luce estrema

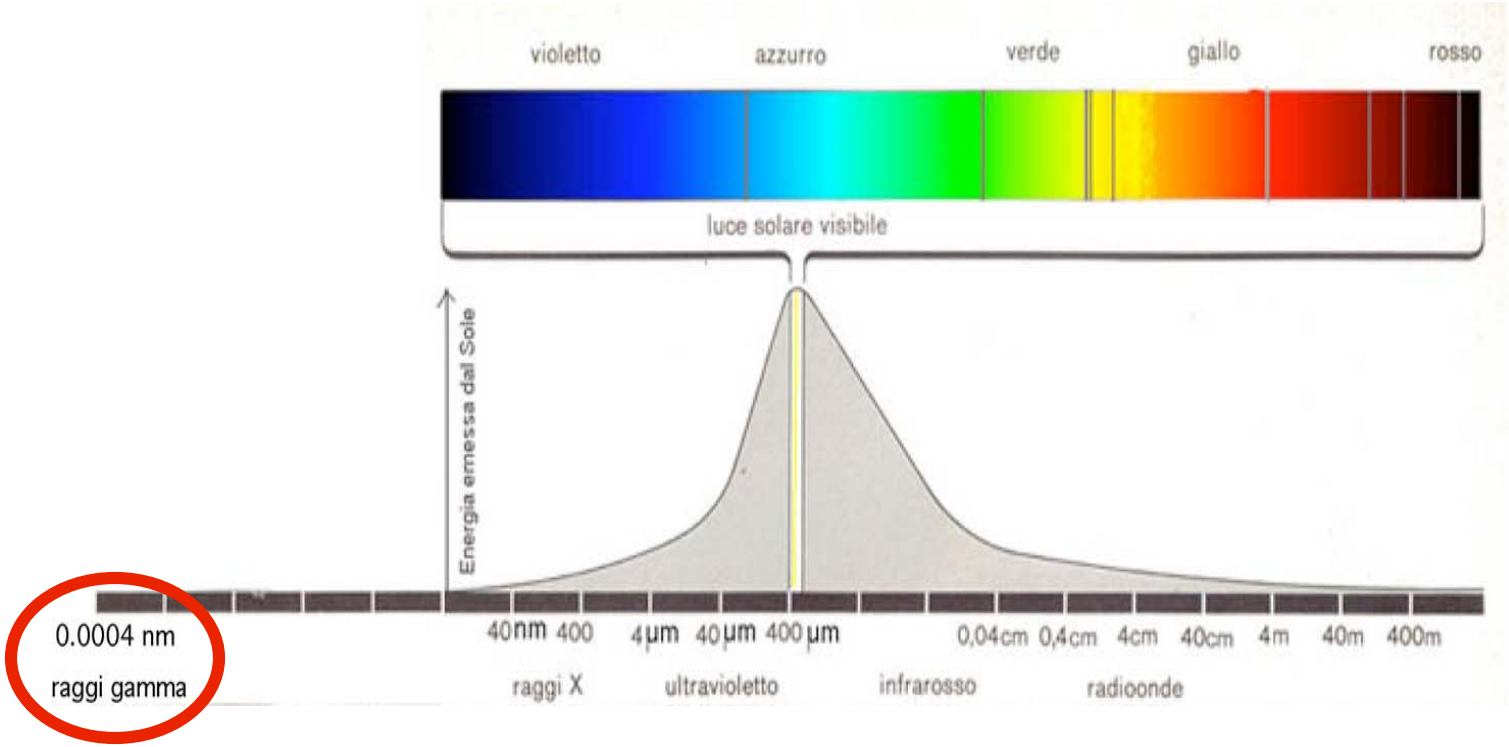


la luce estrema

raggi gamma

γ

10^{-10} lunghezza d'onda sole = 10^{10} energia



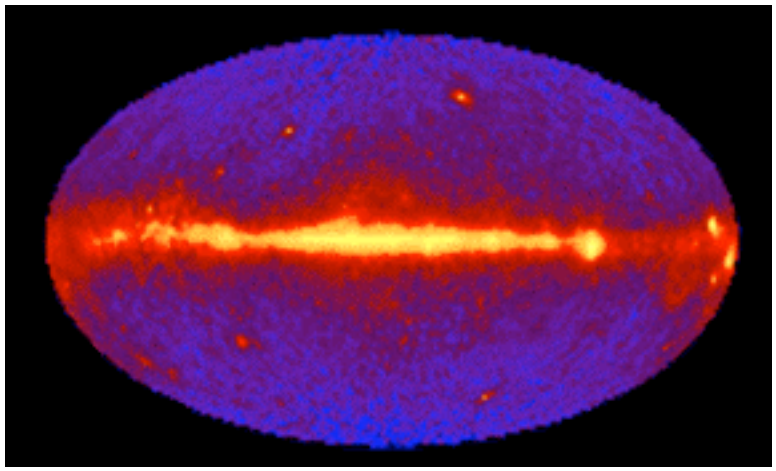
Guardare le stelle

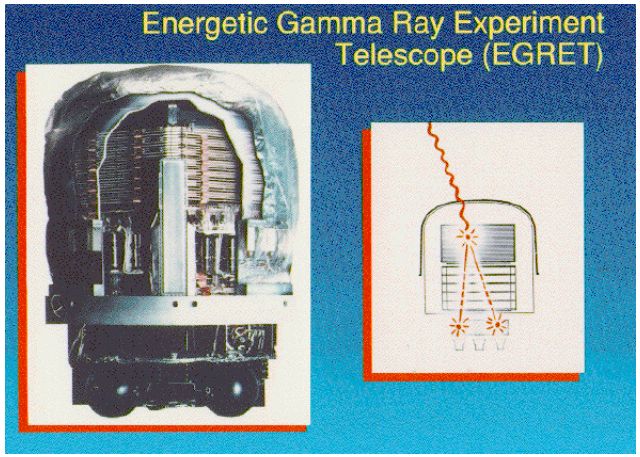
Strumenti

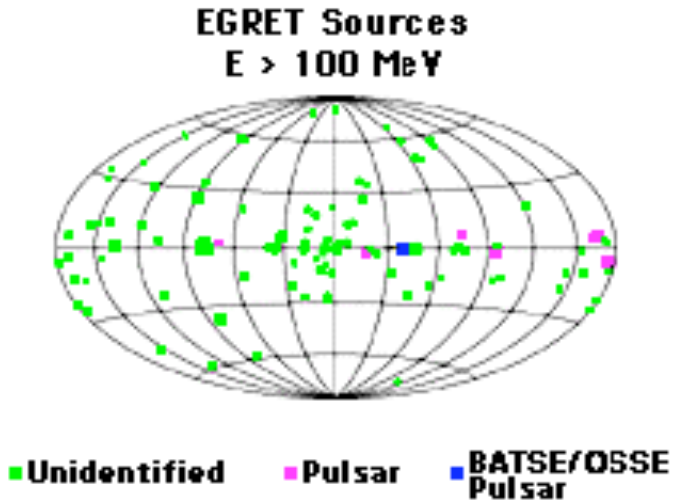
raggi gamma

solo spazio

EGRET







Guardare le stelle

Strumenti

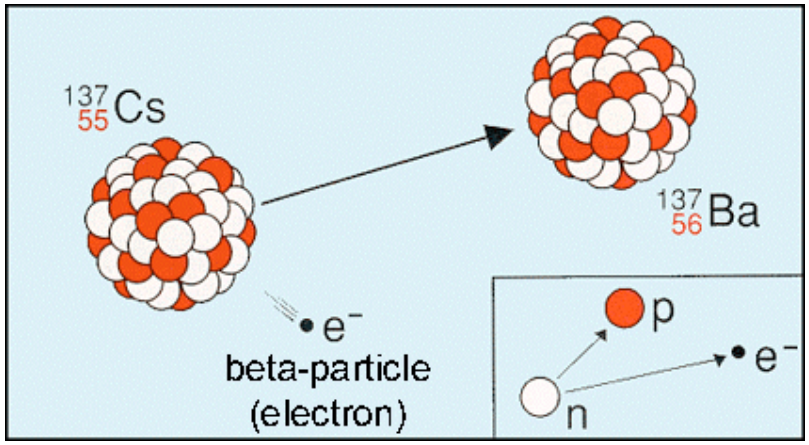
Cosa resta?

I neutrini

ν

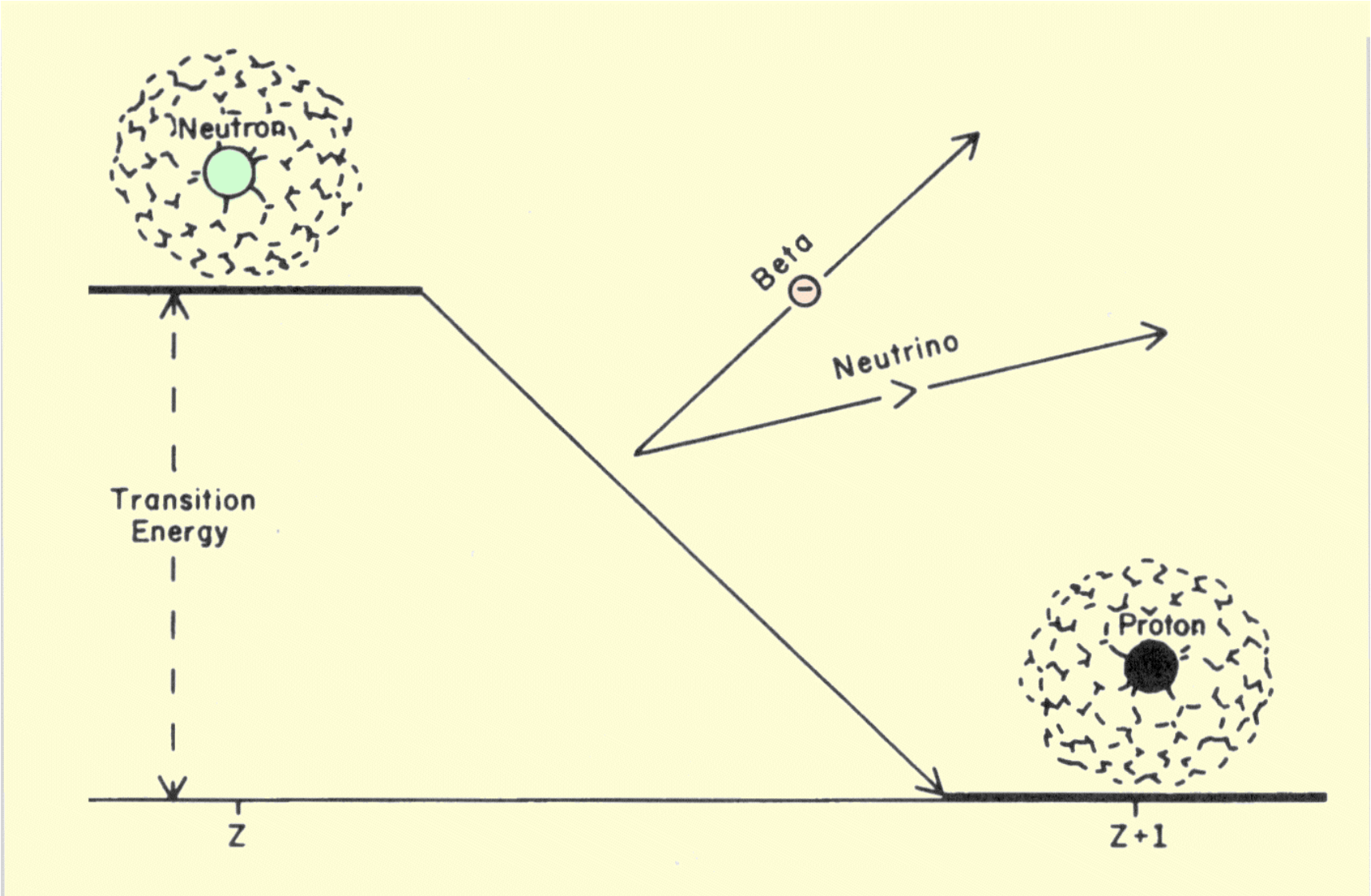
neutrini

Decadimento beta 1911

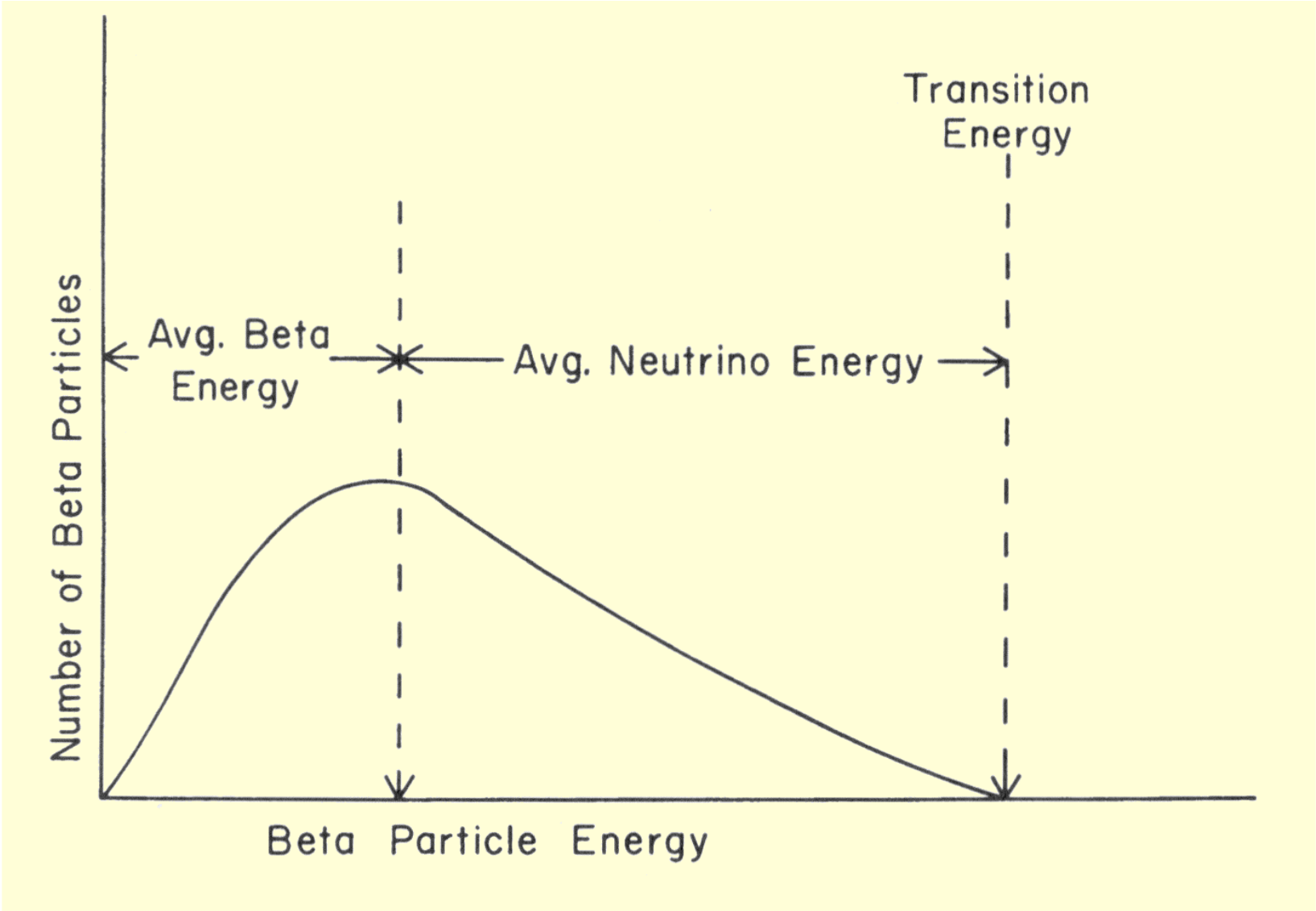


Manca qualcosa…

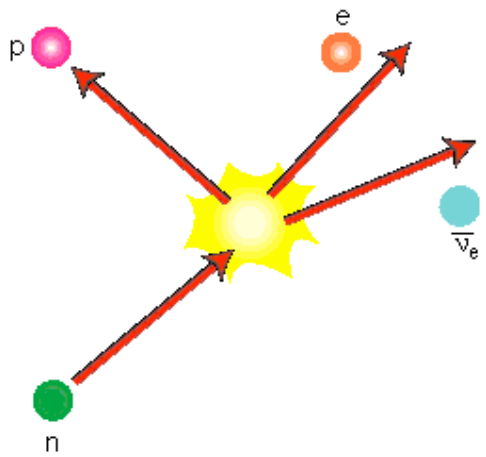
Decadimento beta



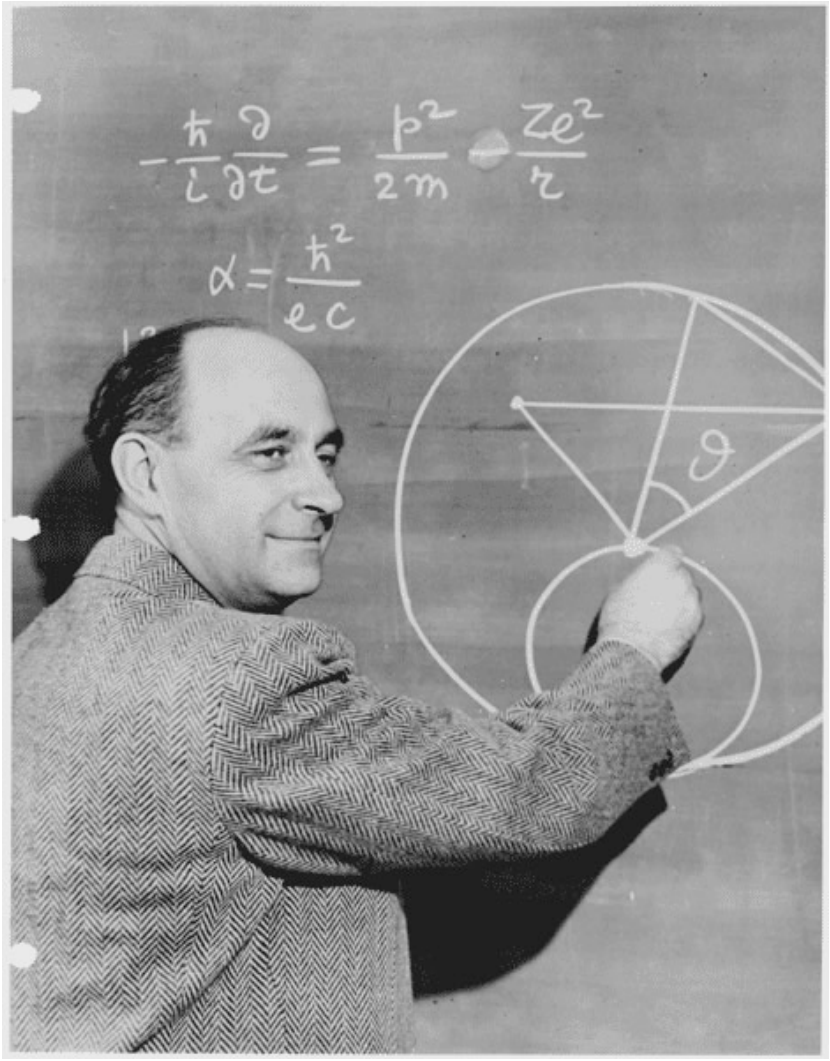
Decadimento beta



Decadimento beta

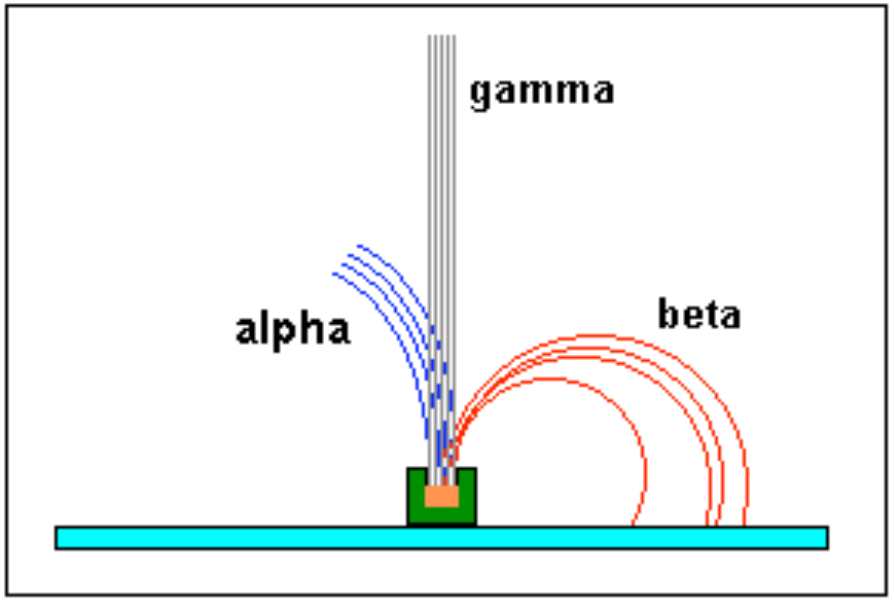


Enrico Fermi



Particelle “elementari”

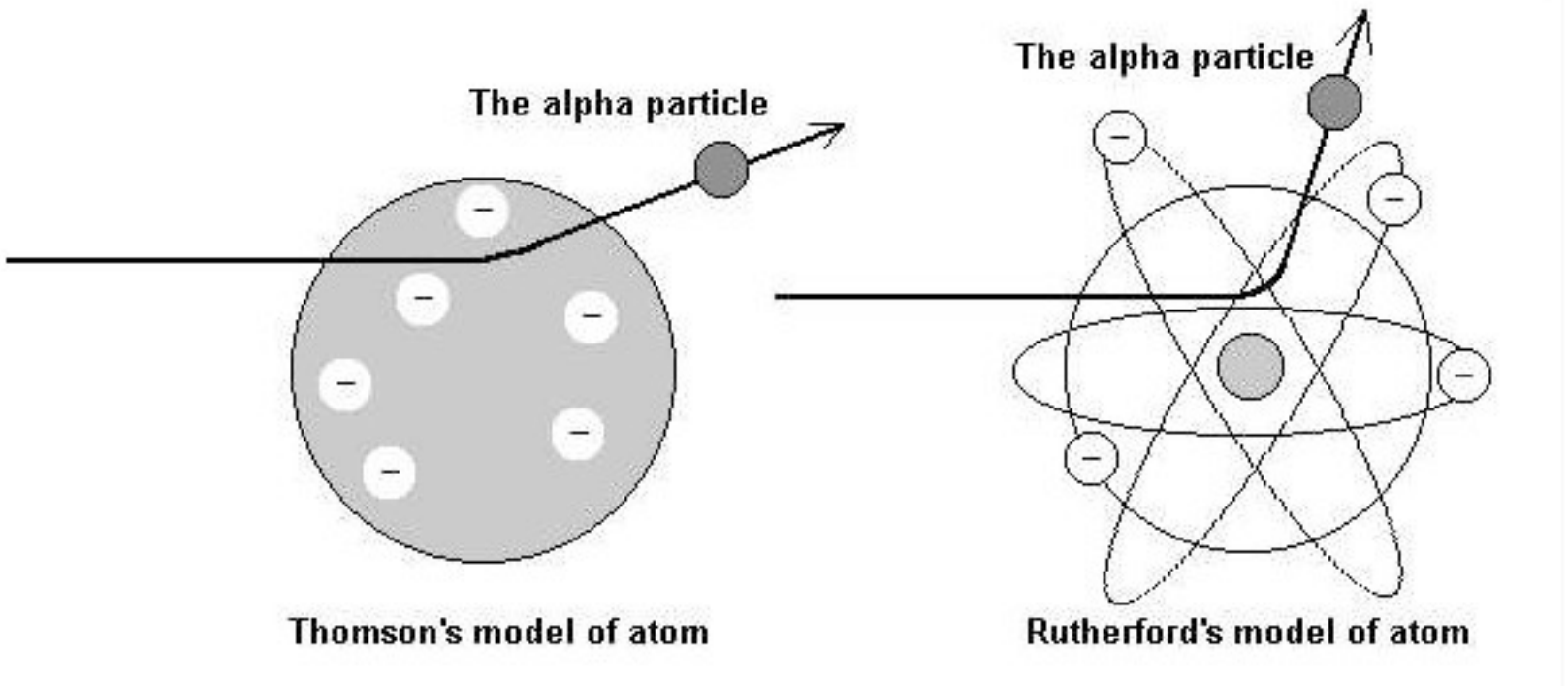
All’inizio



Particelle “elementari”

α

com’e’ fatto un atomo?
Ernest Rutherford, 1911



Particelle “elementari”

α

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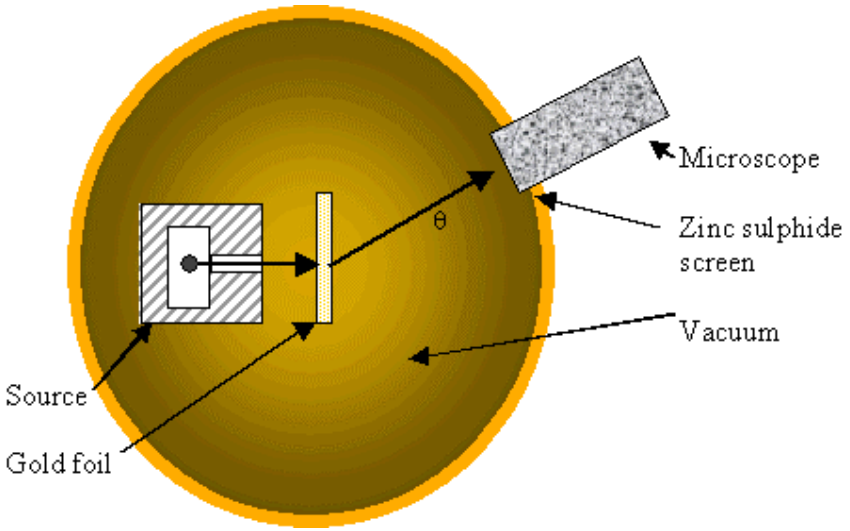
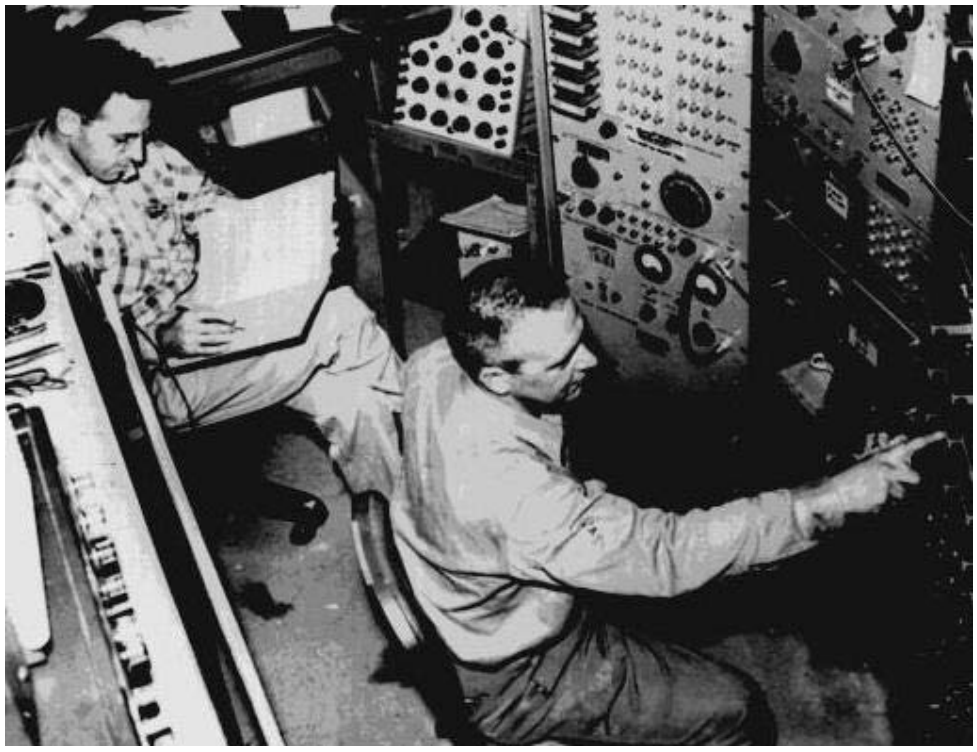


Particelle “elementari”

un esperimento anni ‘50

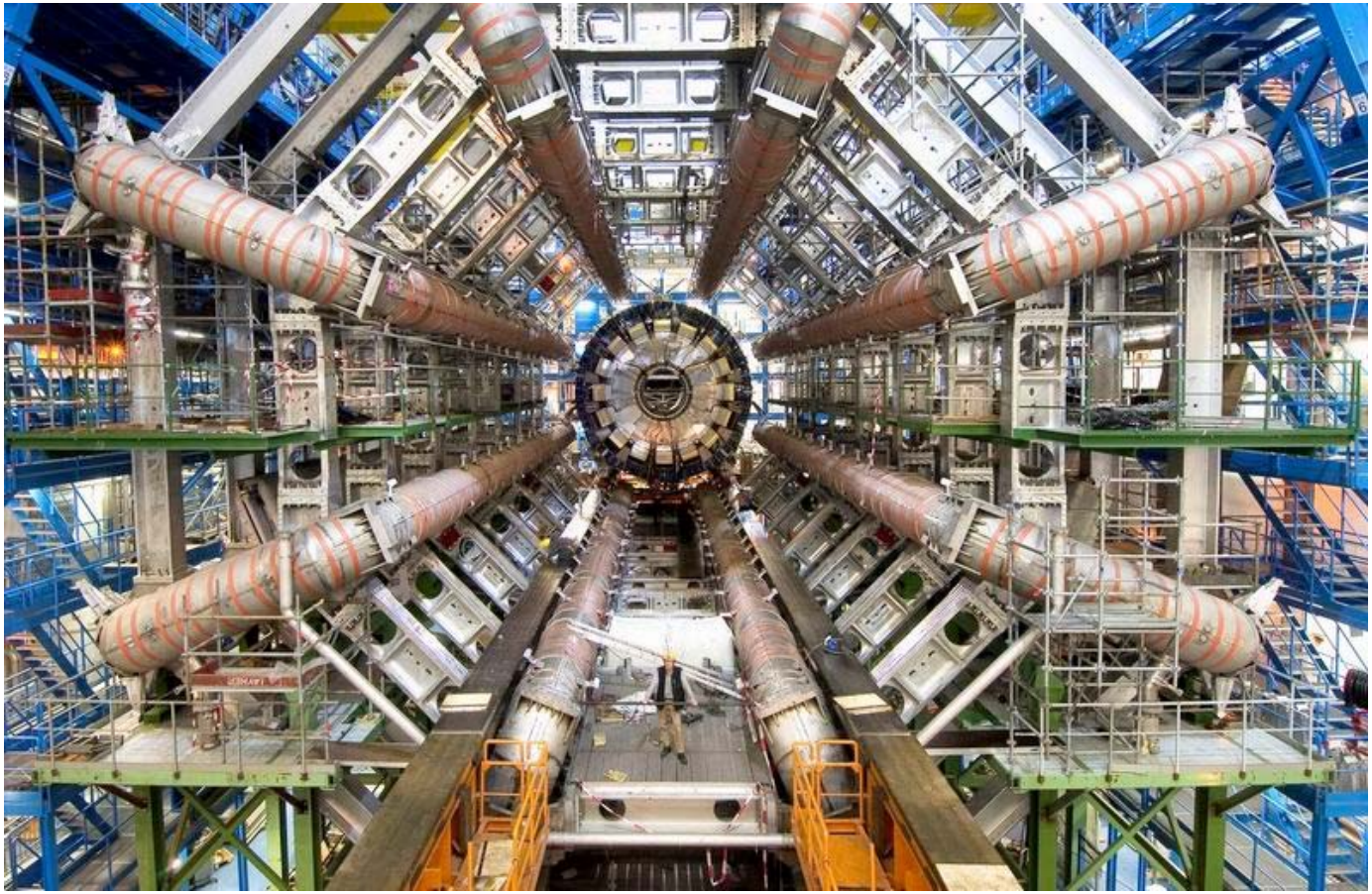


Particelle “elementari”

LHC, CERN, 2011

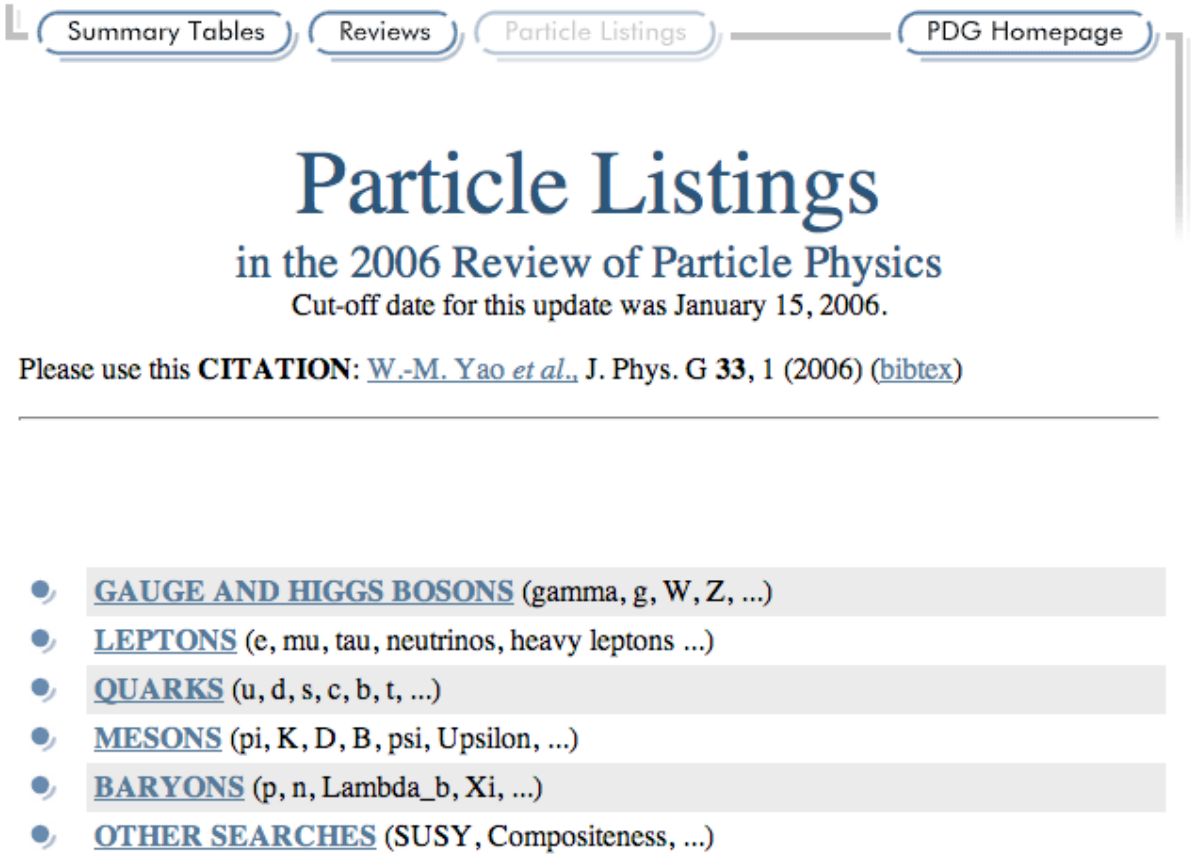
Particelle “elementari”

ATLAS, LHC, CERN, 2011



Particelle “elementari”

ora



288 pagine

neutrino

ν (MEAN LIFE) / MASS

Measures $\left[\sum |U_{\ell j}|^2 \, \Gamma_j \, m_j\right]^{-1}$, where the sum is over mass eigenstates which cannot be resolved experimentally. Some of the limits constrain the radiative decay and are based on the limit of the corresponding photon flux. Other apply to the decay of a heavier neutrino into the lighter one and a Majoron or other invisible particle. Many of these limits apply to any ν within the indicated mass range.

VALUE (s/eV)	CL%	DOCUMENT ID		TECN	COMMENT
> 15.4	90	[72] KRAKAUER	91	CNTR	ν_μ, $\overline{\nu}_\mu$ at LAMPF
> 7 $\times 10^9$		[73] RAFFELT	85	ASTR	
> 300	90	[74] REINES	74	CNTR	$\overline{\nu}_e$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
> 0.004	90	[75] AHARMIM	04	SNO	quasidegen. ν masses
> 4.4 $\times 10^{-5}$	90	[75] AHARMIM	04	SNO	hierarchical ν masses
$\gtrsim$ 100	95	[76] CECCHINI	04	ASTR	Radiative decay for ν mass > 0.01 eV
> 0.067	90	[77] EGUCHI	04	KLND	quasidegen. ν masses
> 1.1 $\times 10^{-3}$	90	[77] EGUCHI	04	KLND	hierarchical ν masses
> 8.7 $\times 10^{-5}$	99	[78] BANDYOPA...	03	FIT	nonradiative decay
$\geq$ 4200	90	[79] DERBIN	02B	CNTR	Solar pp and Be ν
> 2.8 $\times 10^{-5}$	99	[80] JOSHIPURA	02B	FIT	nonradiative decay
		[81] DOLGOV	99	COSM	
		[82] BILLER	98	ASTR	m_ν= 0.05–1 eV
> 2.8 $\times 10^{15}$		[83,84] BLUDMAN	92	ASTR	$m_\nu < 50$ eV
none 10^{-12} – 5×10^4		[85] DODELSON	92	ASTR	m_ν=1–300 keV
$< 10^{-12}$ or > 5×10^4		[85] DODELSON	92	ASTR	m_ν=1–300 keV
		[86] GRANEK	91	COSM	Decaying L^0
> 6.4	90	[87] KRAKAUER	91	CNTR	ν_e at LAMPF
> 1.1 $\times 10^{15}$		[88] WALKER	90	ASTR	m_ν= 0.03 – ~ 2 MeV
> 6.3 $\times 10^{15}$		[84,89] CHUPP	89	ASTR	$m_\nu < 20$ eV
> 1.7 $\times 10^{15}$		[84] KOLB	89	ASTR	$m_\nu < 20$ eV
		[90] RAFFELT	89	RVUE	$\overline{\nu}$ (Dirac, Majorana)
		[91] RAFFELT	89B	ASTR	
> 8.3 $\times 10^{14}$		[92] VONFEILIT...	88	ASTR	
> 22	68	[93] OBERAUER	87		$\overline{\nu}_R$ (Dirac)
> 38	68	[93] OBERAUER	87		$\overline{\nu}$ (Majorana)
> 59	68	[93] OBERAUER	87		$\overline{\nu}_L$ (Dirac)
> 30	68	KETOV	86	CNTR	$\overline{\nu}$ (Dirac)
> 20	68	KETOV	86	CNTR	$\overline{\nu}$ (Majorana)

particelle elementari

piccole

massa protone

$m_p = 1.67 \times 10^{-27}$ kg

particelle elementari

piccole

massa protone

$m_p = 1.67 \times 10^{-27}$ kg

0.000000000000000000000000167 kg

particelle elementari

piccole

massa protone

$m_p = 1.67 \times 10^{-27}$ kg

0.000000000000000000000000167 kg

ma: $e=mc^2$ $m_p = 938$ MeV

particelle elementari

piccole

massa protone = 938 MeV

massa elettrone = .5 MeV

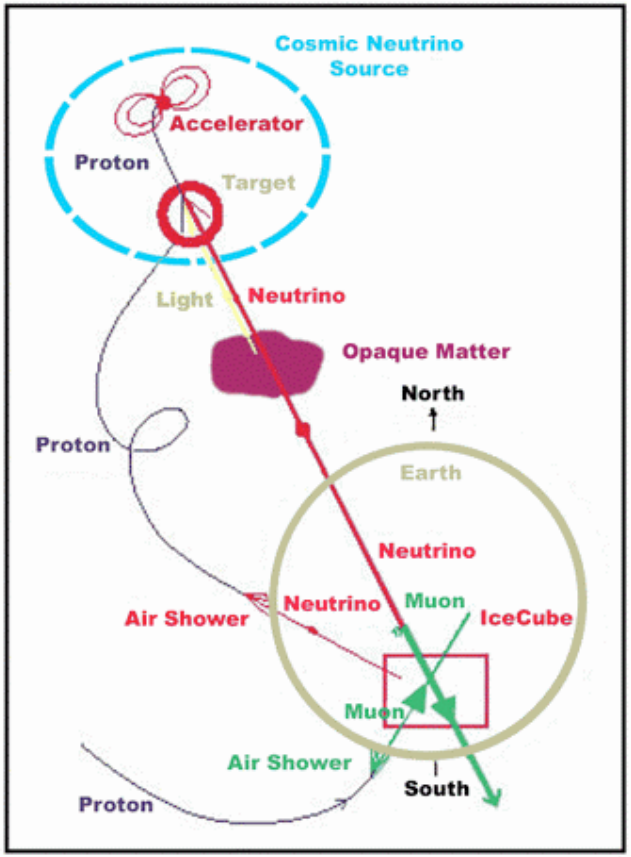
massa neutrino = .1 eV

neutrini e stelle

usare i neutrini, non studiarli

energia
molto alta

solo da stelle



guardare piu' lontano
indietro nel tempo
verso le origini

neutrini e stelle

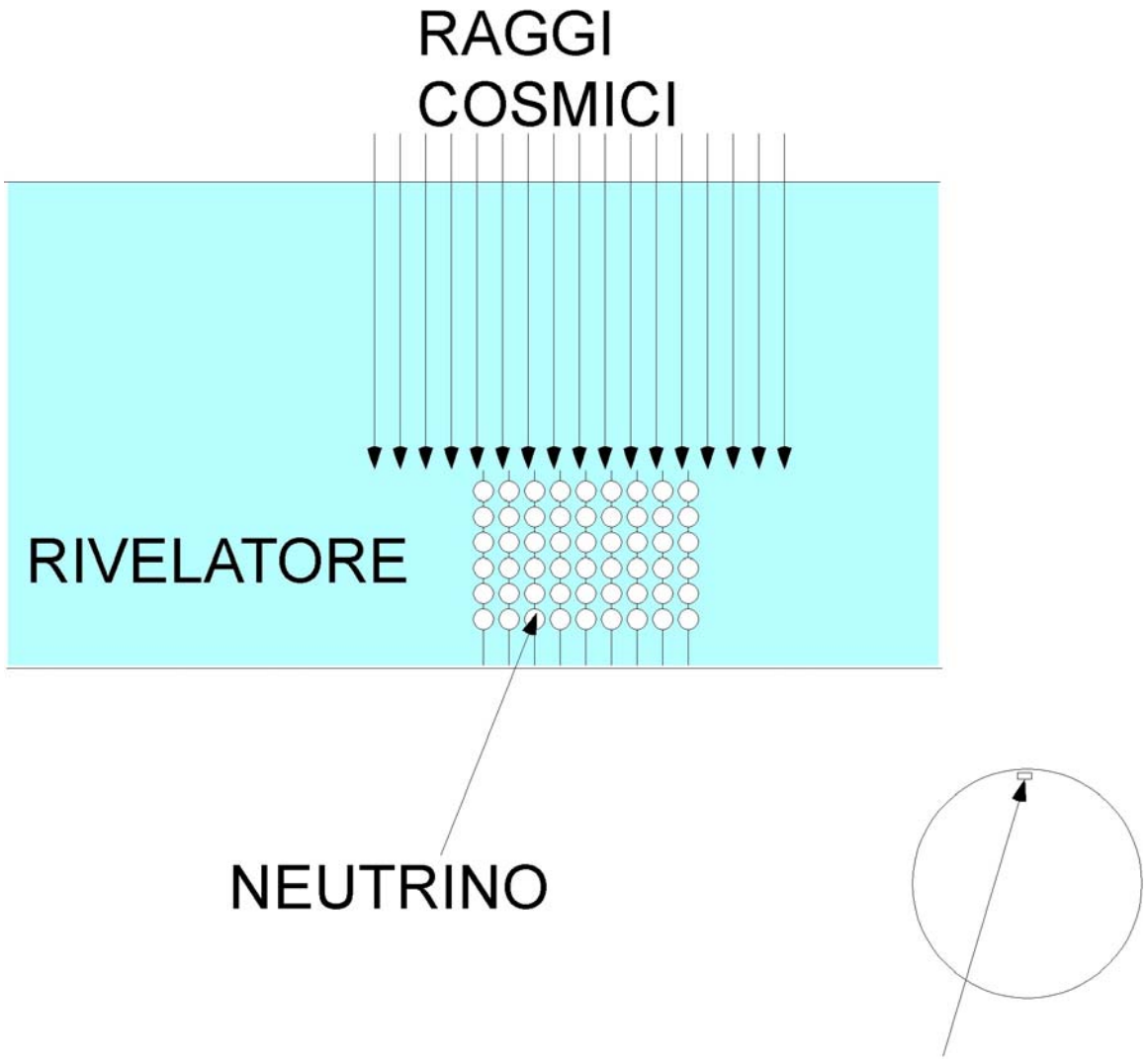
ma...

poche interazioni
poche rivelazioni

1 km cubo a 3 km di profondita' in mare

km3

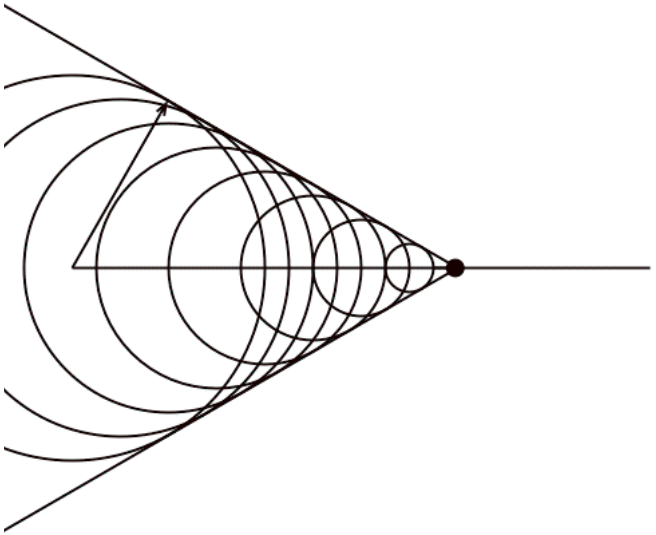
- 3 km profondita’



km3

perche’ in acqua?

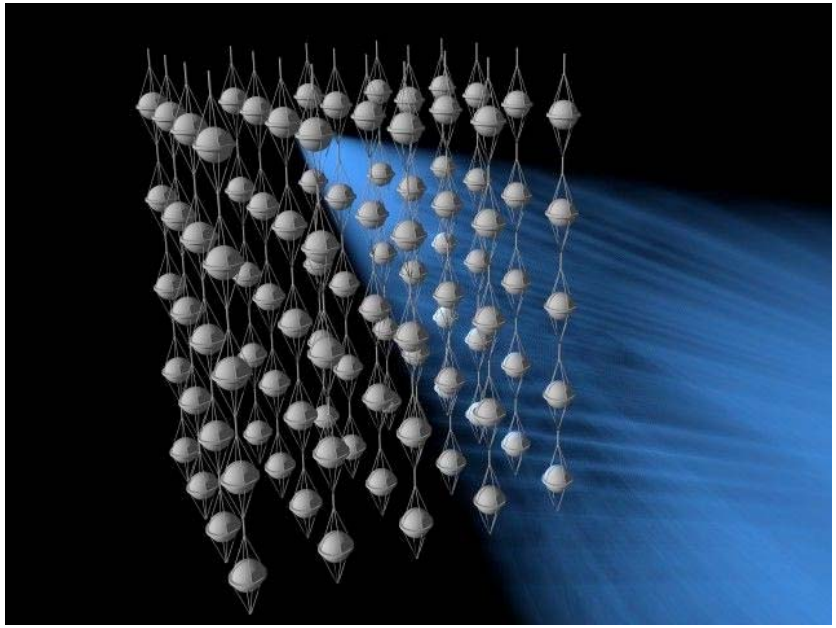
effetto Cerenkov



km3

perche' in acqua?

- effetto Cerenkov
- assorbitore ν+N-> μ
  e rivelatore
- costo



km3

moduli ottici

fotomoltiplicatori

sfere Benthos

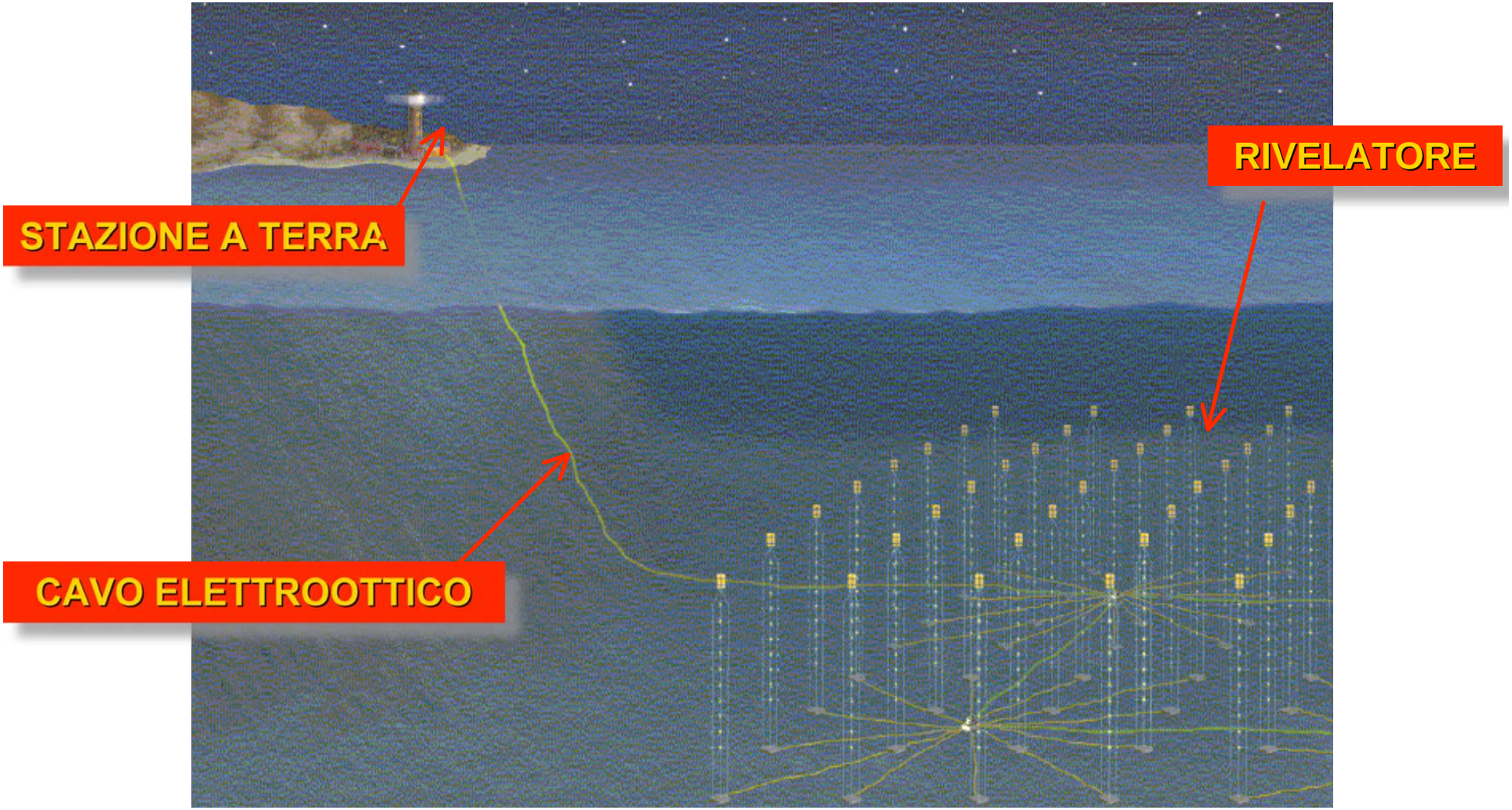
km3

costo in mare

~ 100 volte di piu’ che a terra

km3

- 3 km profondita’

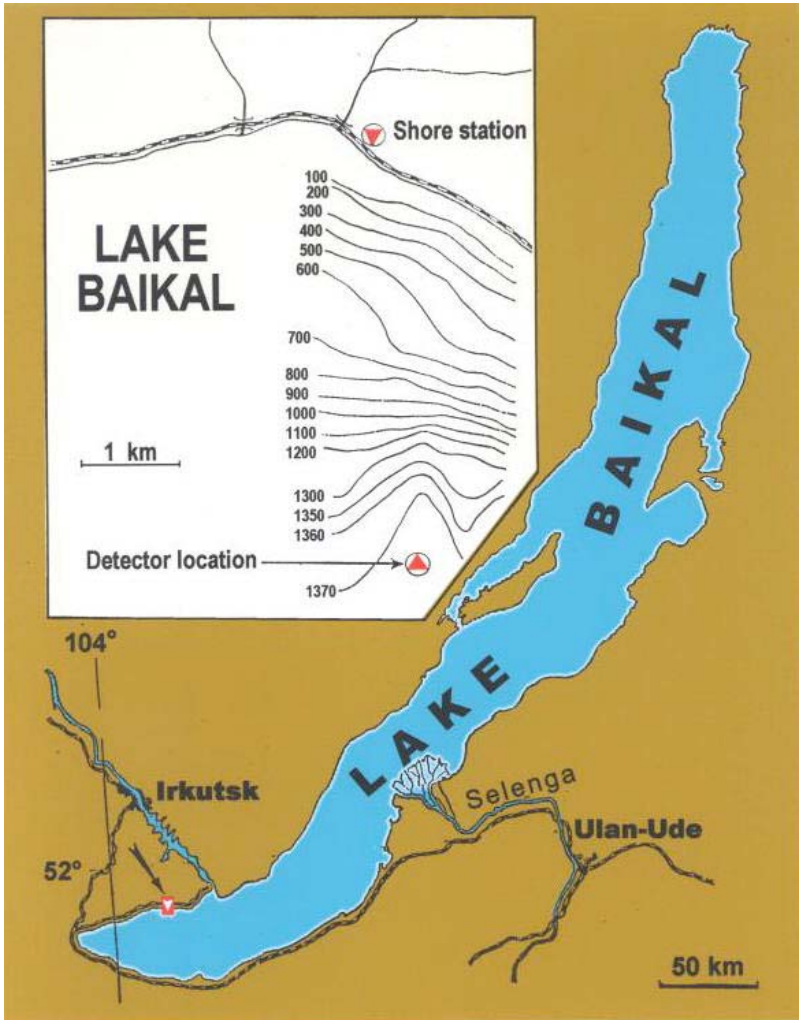


km3 - storia - DUMAND (1976...)

Hawaii

US Navy

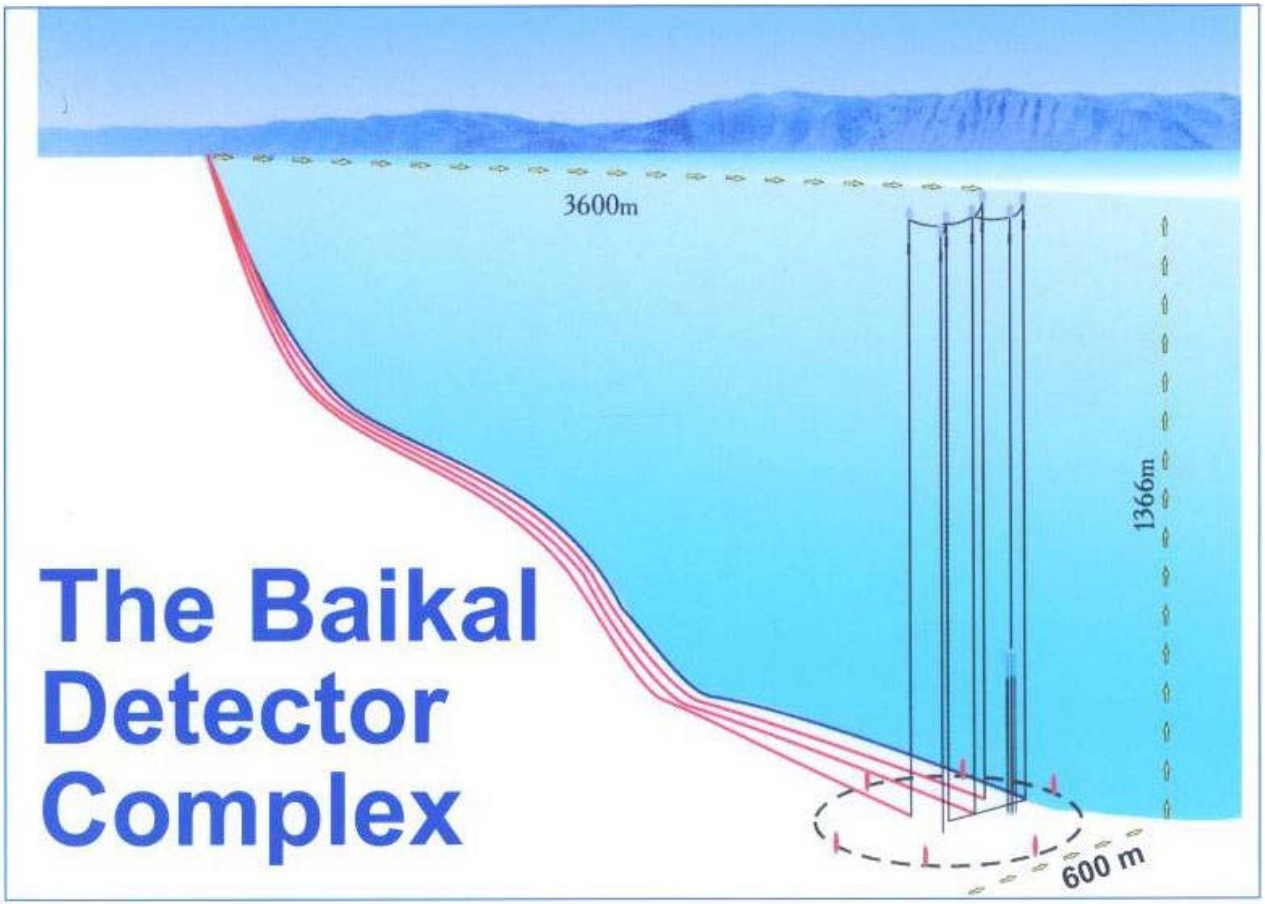
km3 - storia - Lago Baikal (1982...)



km3 - storia - Lago Baikal (1982...)

km3 - storia - Lago Baikal (1982...)

Lago Baikal

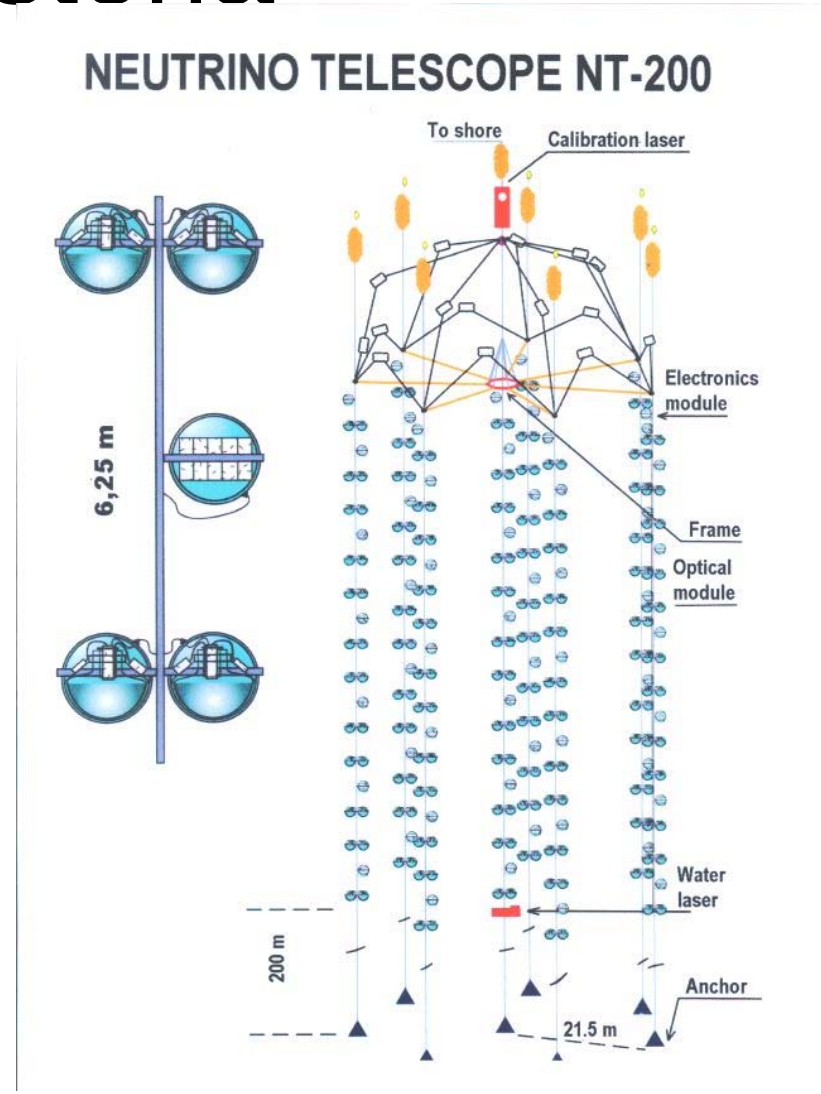


km3 - storia - Lago Baikal (1982...)

km3 - storia

ghiaccio
poca profondita’

esprimenti
tecnologici



km3 - storia - NESTOR (1989...)

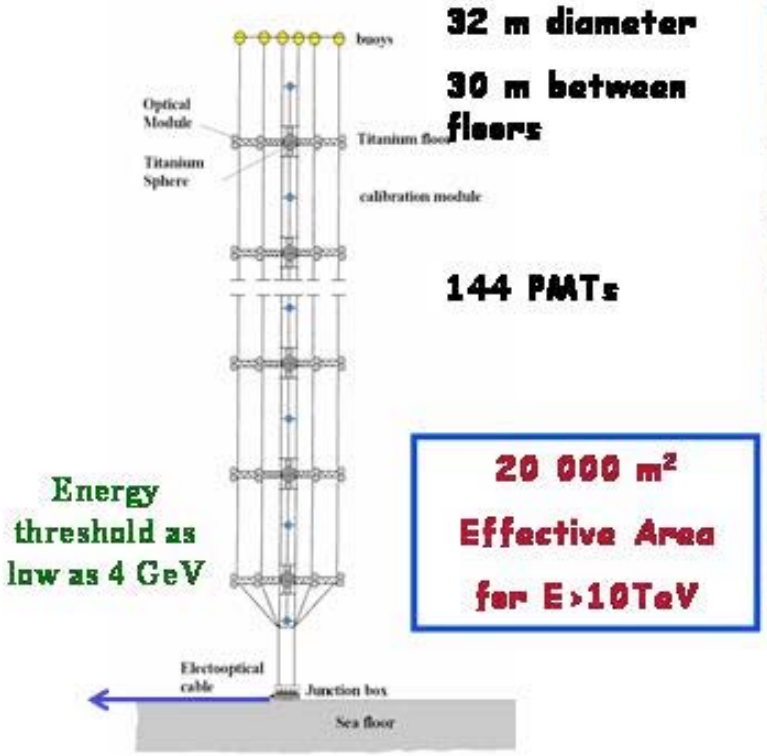
Luciano Trasatti, Napoli, 10/5/2007: Le stelle e i neutrini

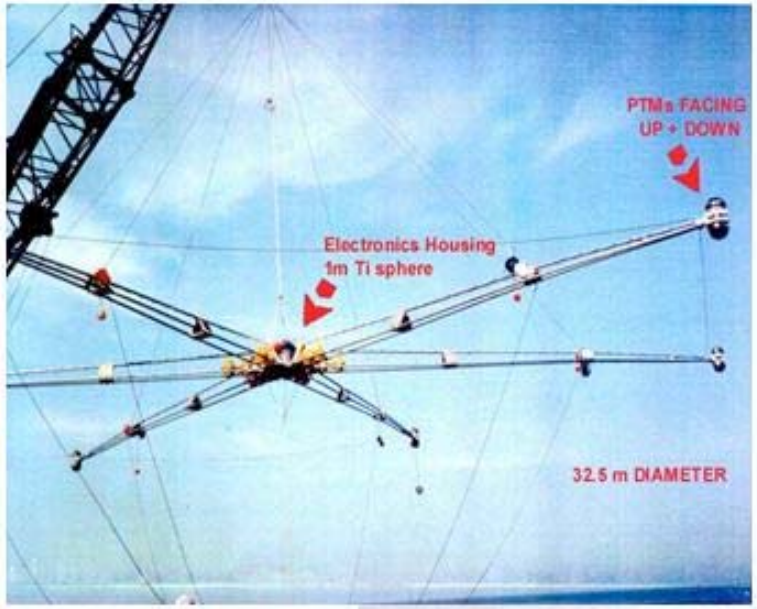
km3 - storia - NESTOR (1989...)

km3 - storia - NESTOR (1989...)

NESTOR TOWER

connessioni
in aria





km3 - storia - NESTOR (1989...)

2003
una stella
a 3000 m

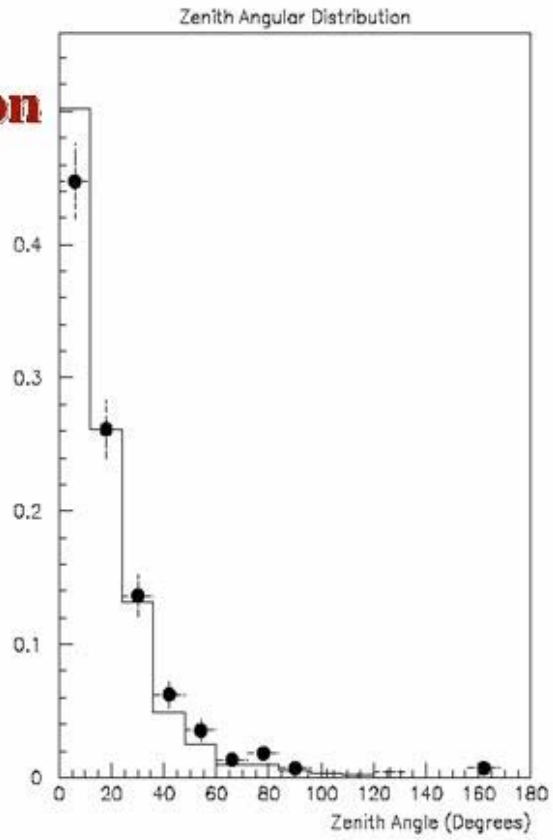
Preliminary

Zenith Angular Distribution

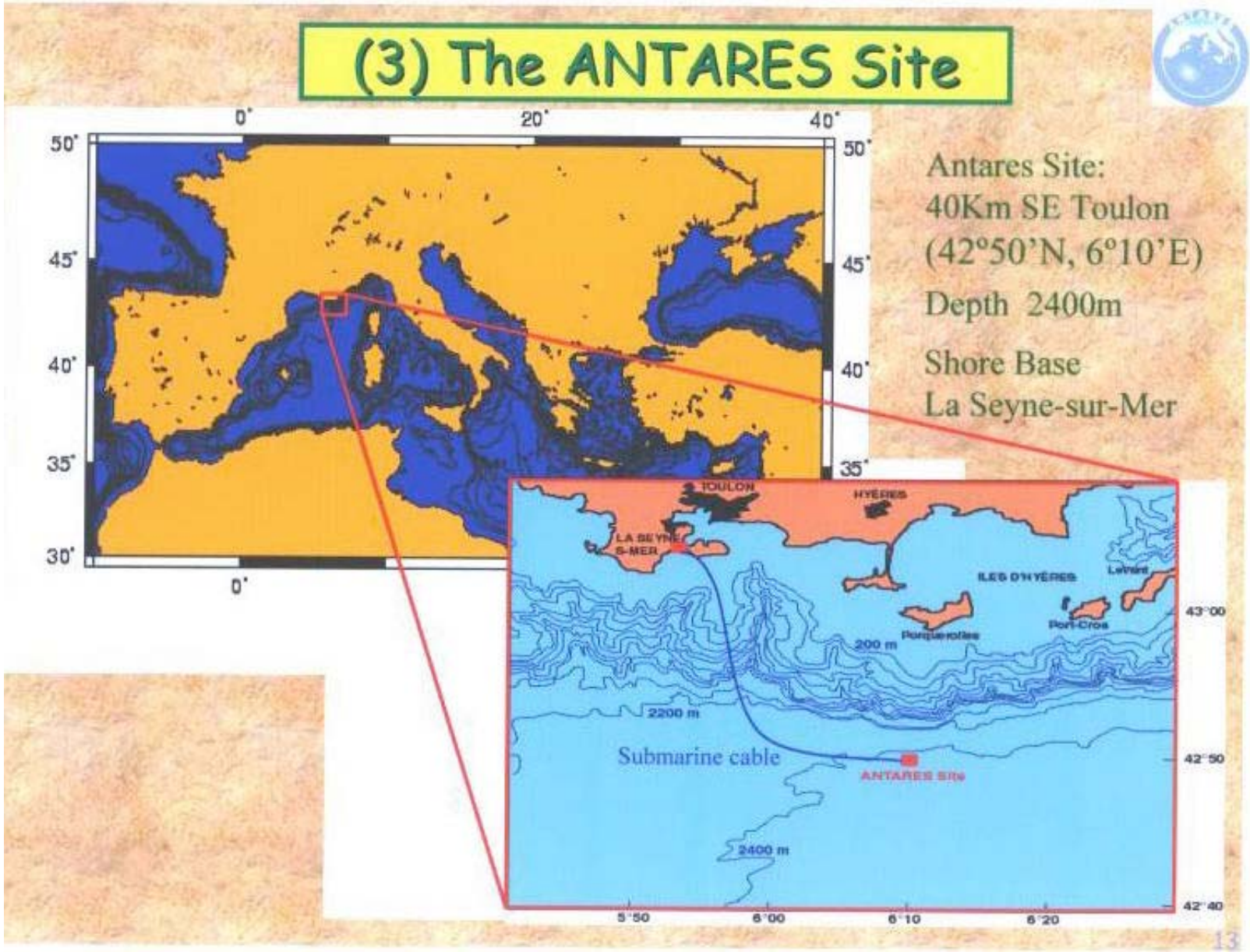
- χ^2 probability > 0.1
- track selection according to the charge-likelihood
- more than 4.5 p.e.s per hit per track

— M.C. Prediction (atmospheric muons)

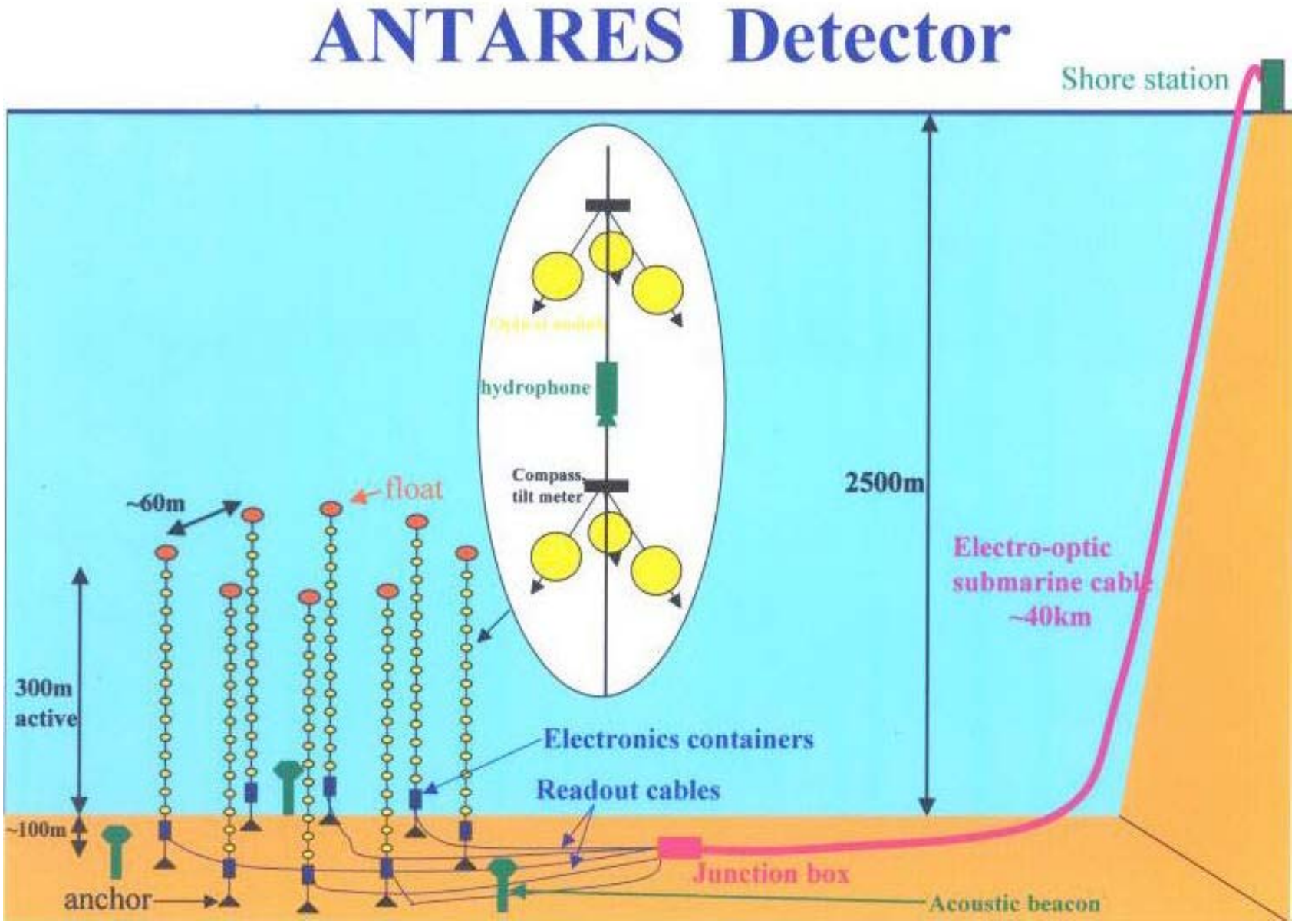
● Data Points



km3 - storia - Antares (1999...)

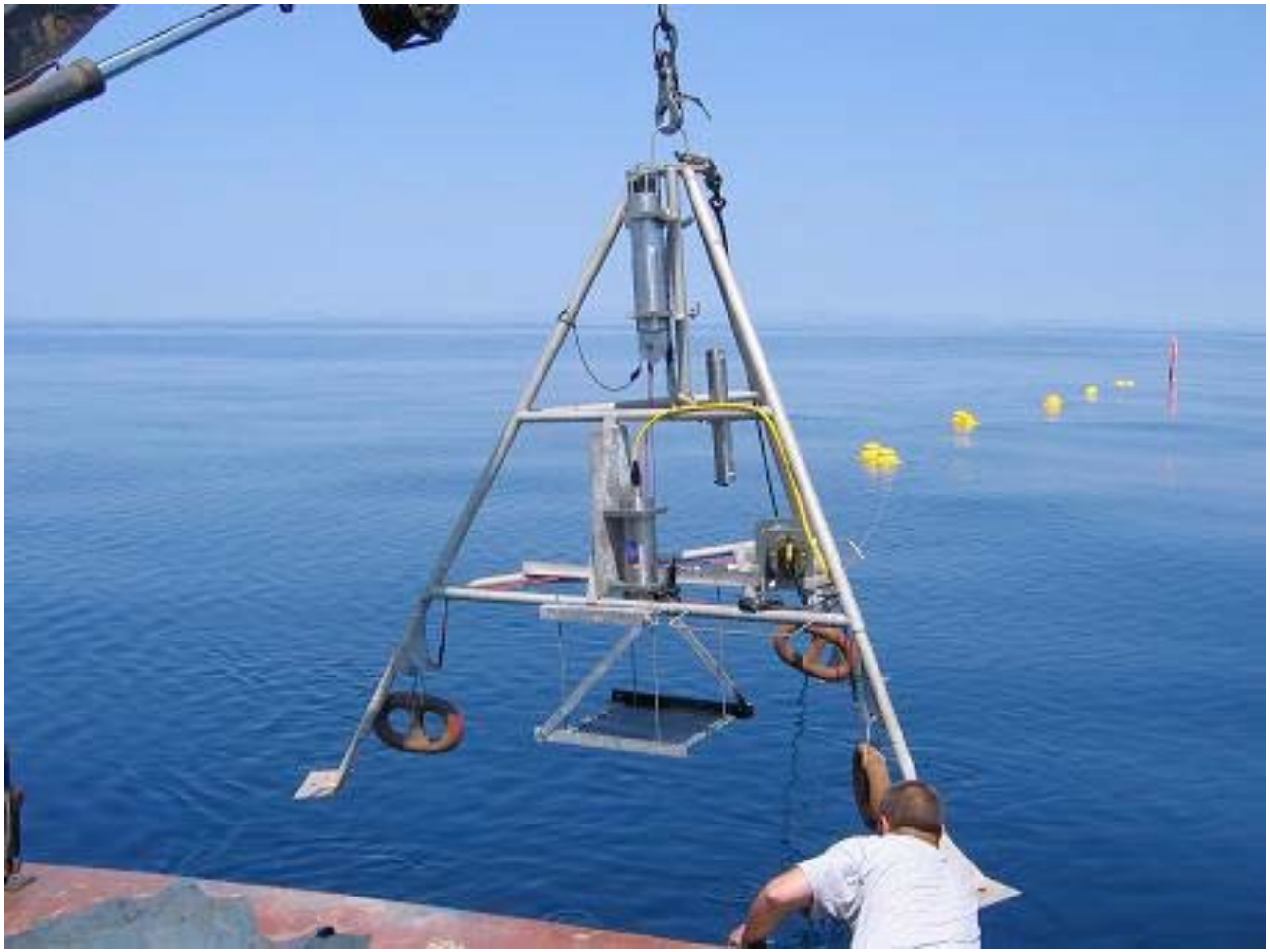


km3 - storia - Antares (1999...)



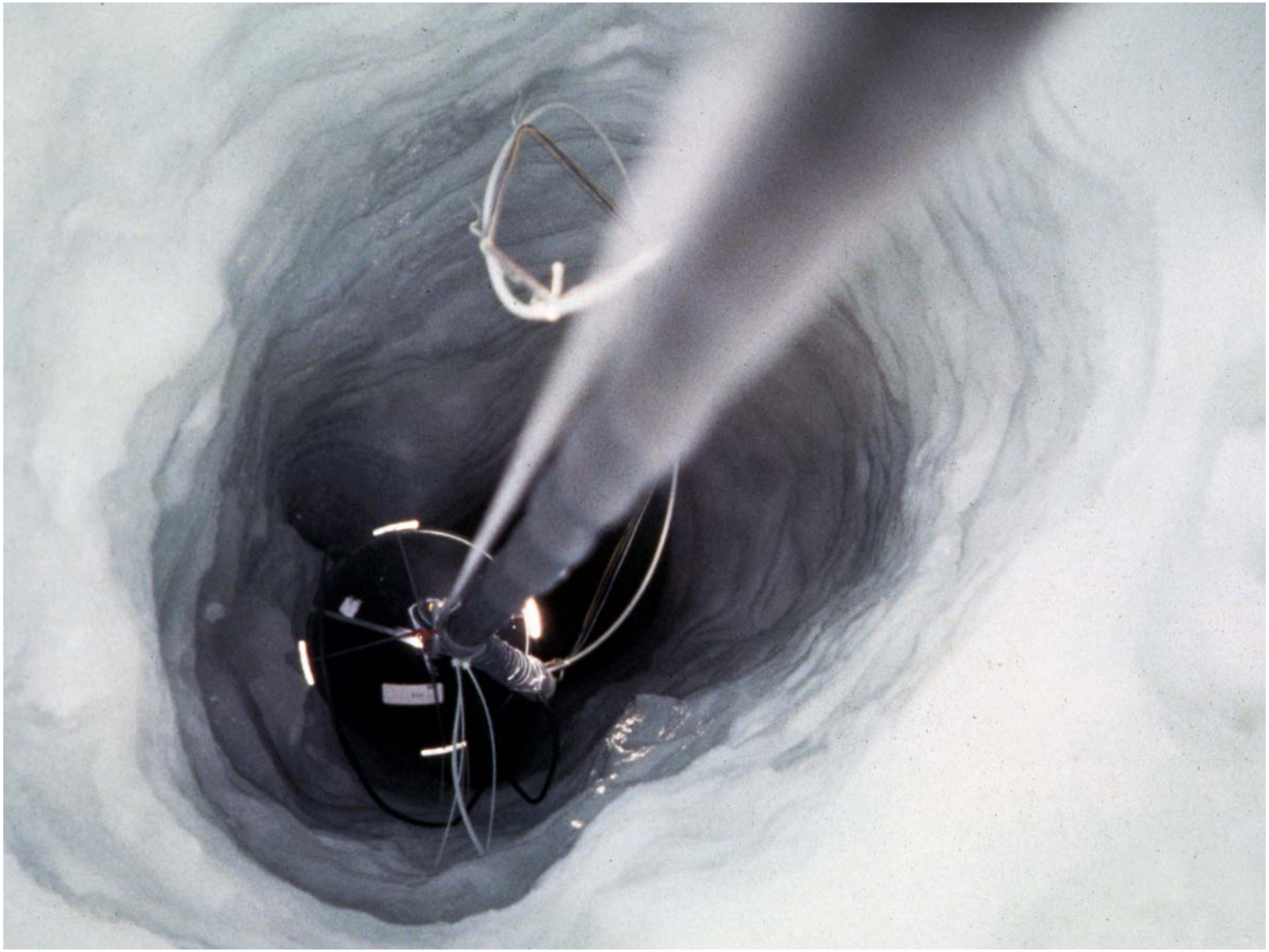
km3 - storia - Antares (1999...)

poca profondita’
acqua sporca

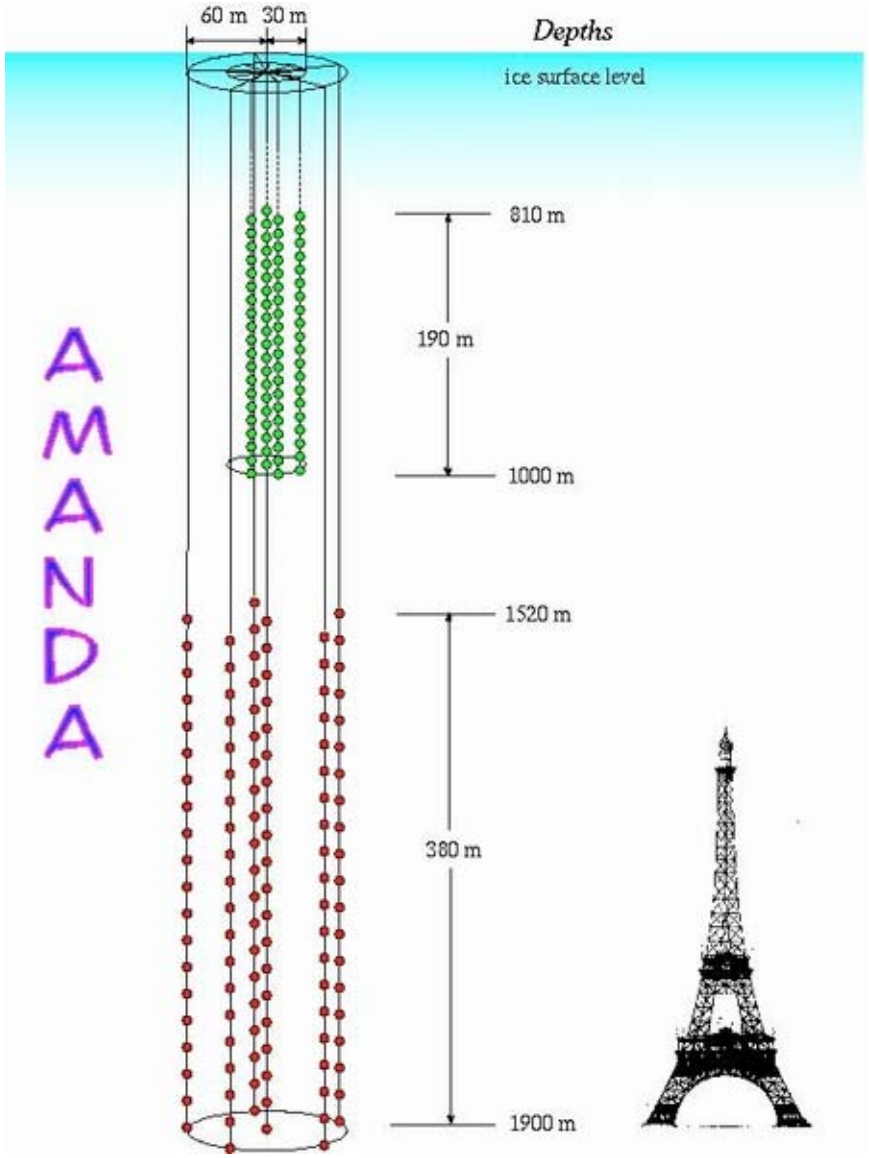


km3 - storia - Amanda (1993...)

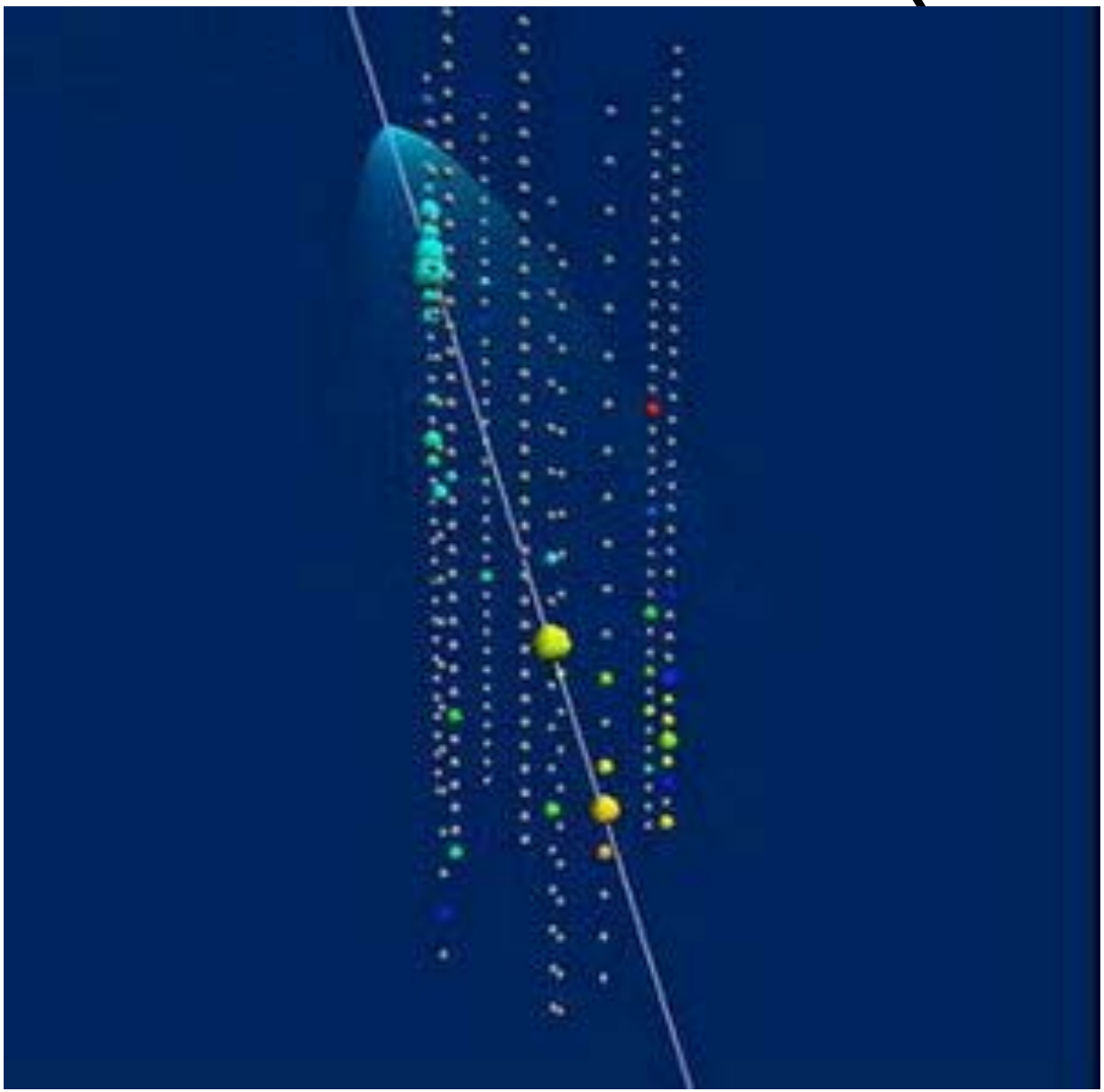
km3 - storia - Amanda (1993...)



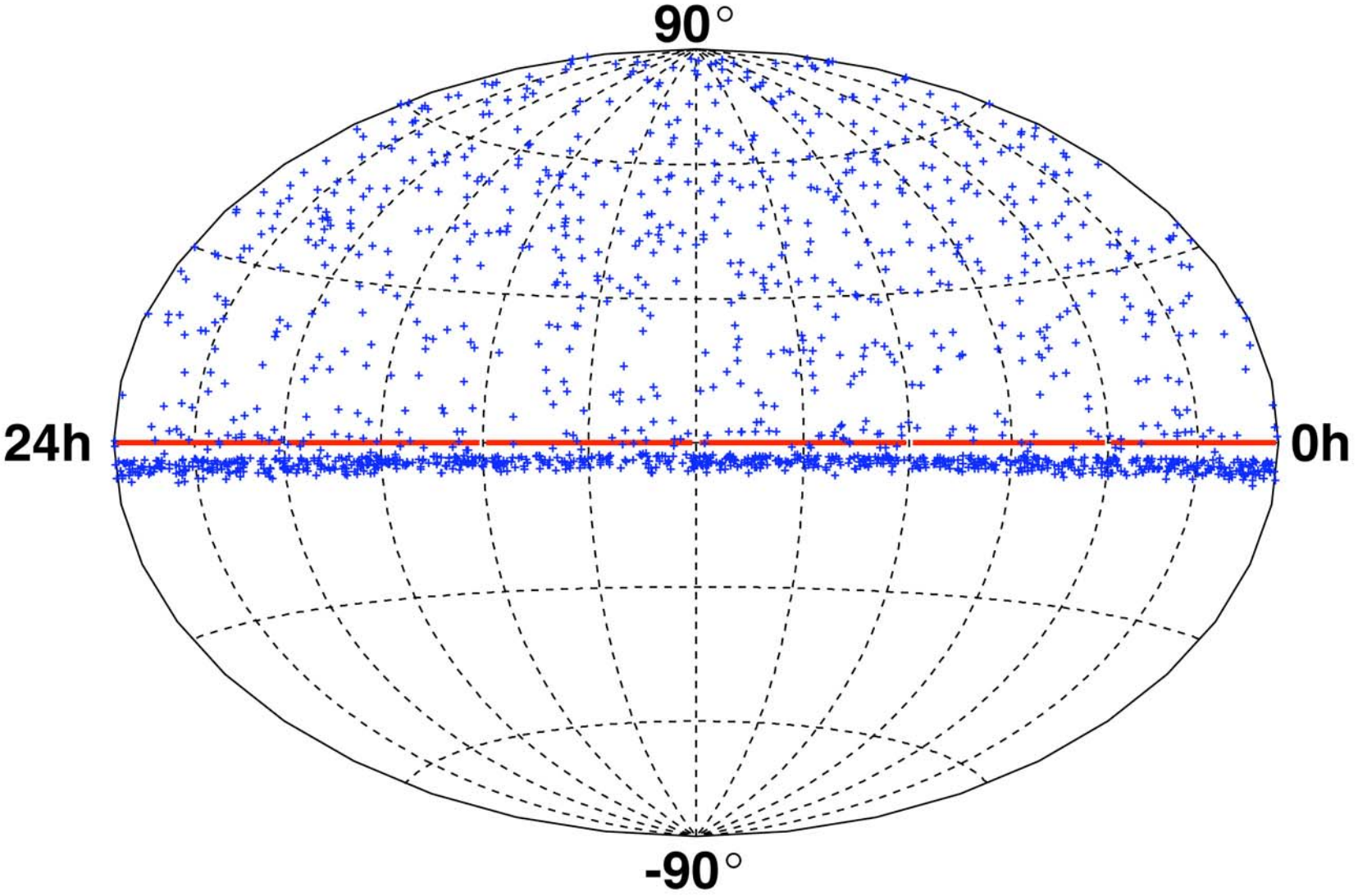
km3 - storia - Amanda (1993...)



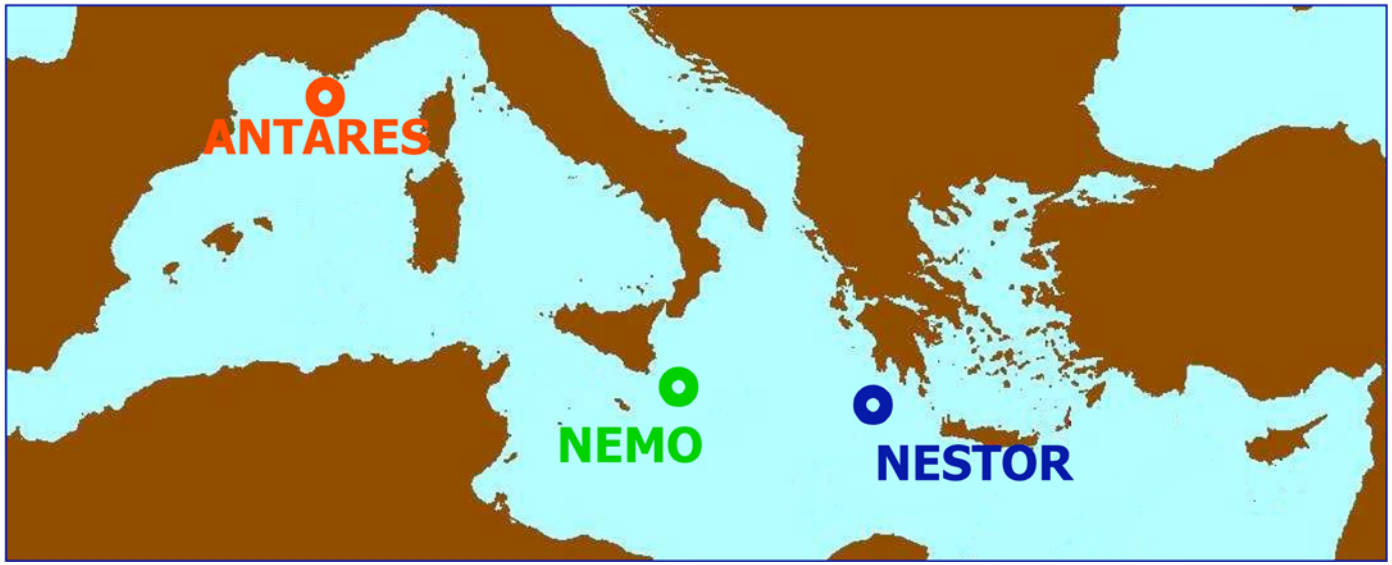
km3 - storia - Amanda (1993...)



km3 - storia - Amanda (1993...)



km3 - storia - NEMO (1996...)



km3 - storia - NEMO (1996...)

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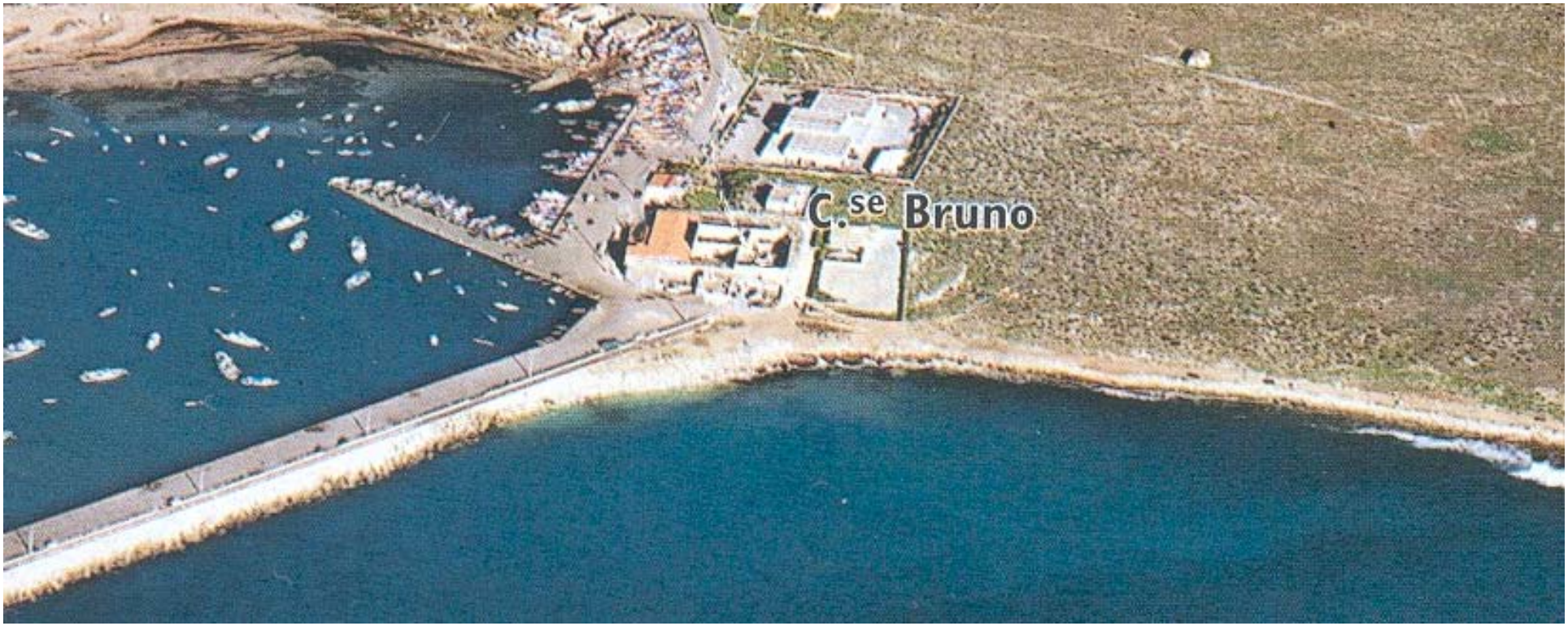


km3 - storia - NEMO (1996...)

Cavo elettro ottico Sottomarino

Dati di progetto

Fibre Ottiche: 48 fibre ottiche standard ITUT G-655.

Potenza al carico: 30kW.

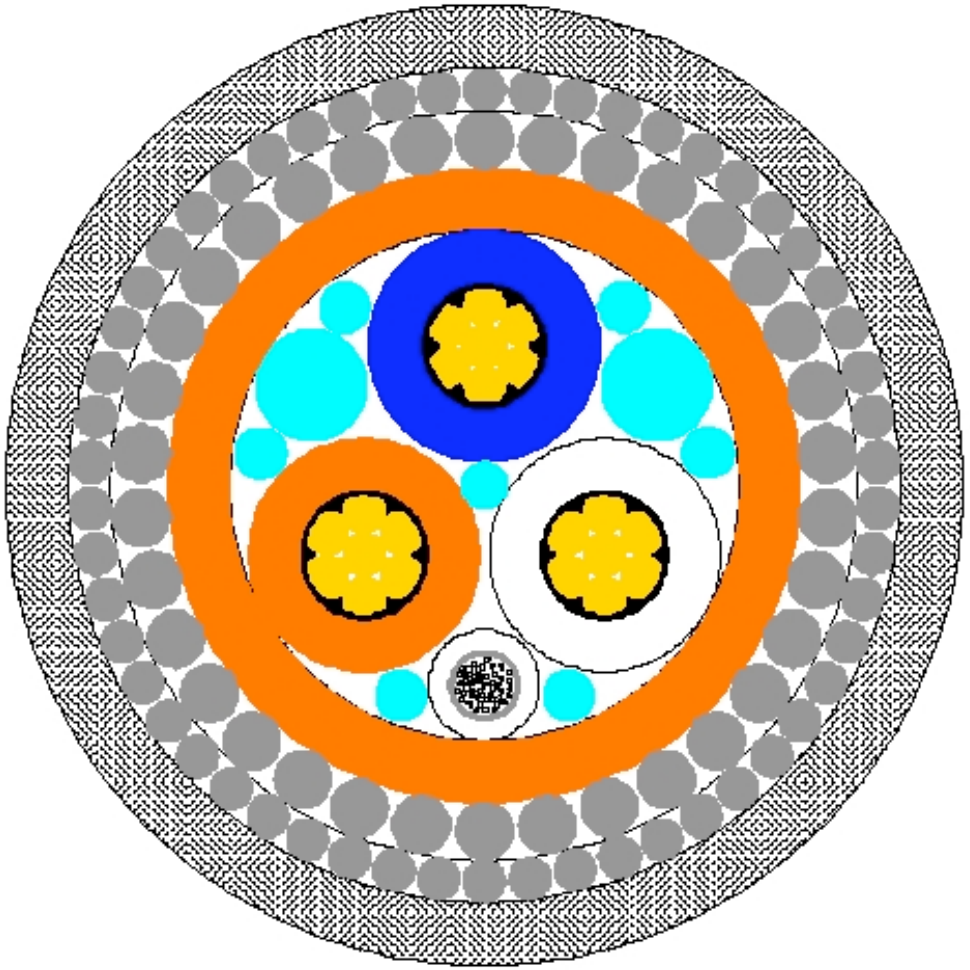
Tensione Massima: 6kV AC Trifase.

Lunghezza del Cavo: 100km (approx.).

Profondità: 3.500m.

km3 - storia - NEMO (1996...)

Cavo elettroottico



km3 - storia - NEMO (1996...)

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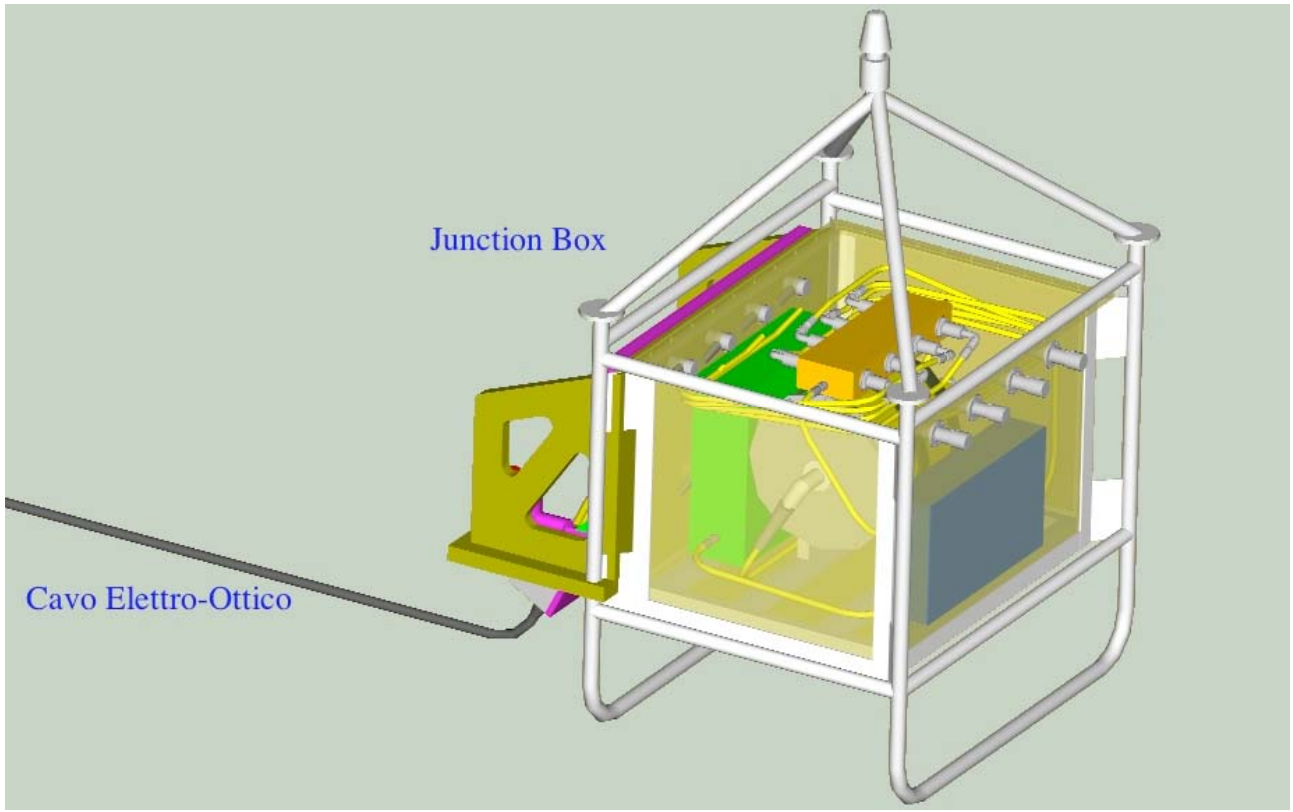
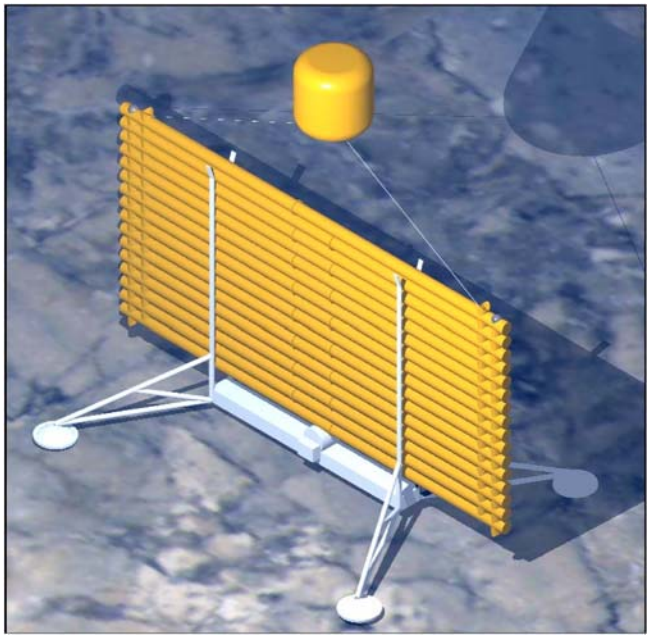
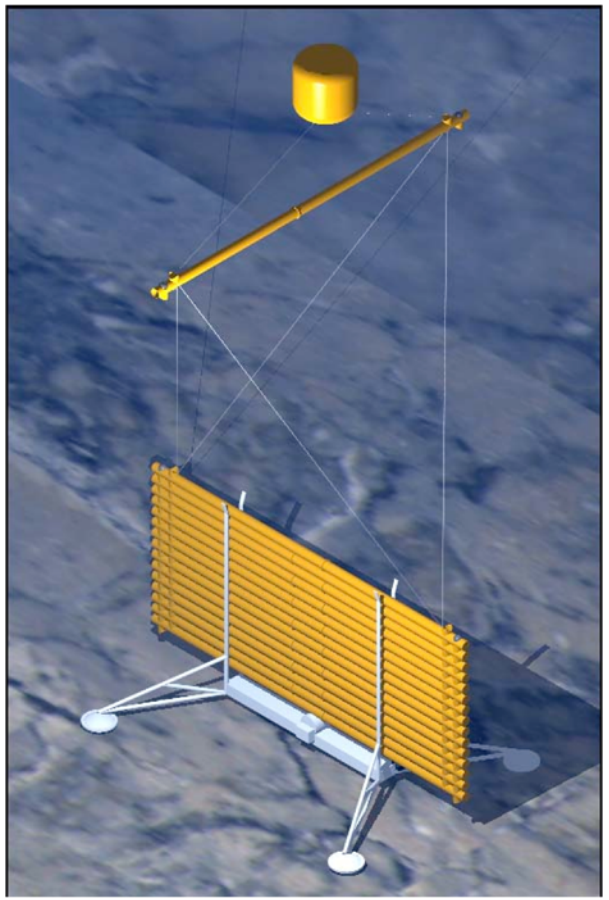
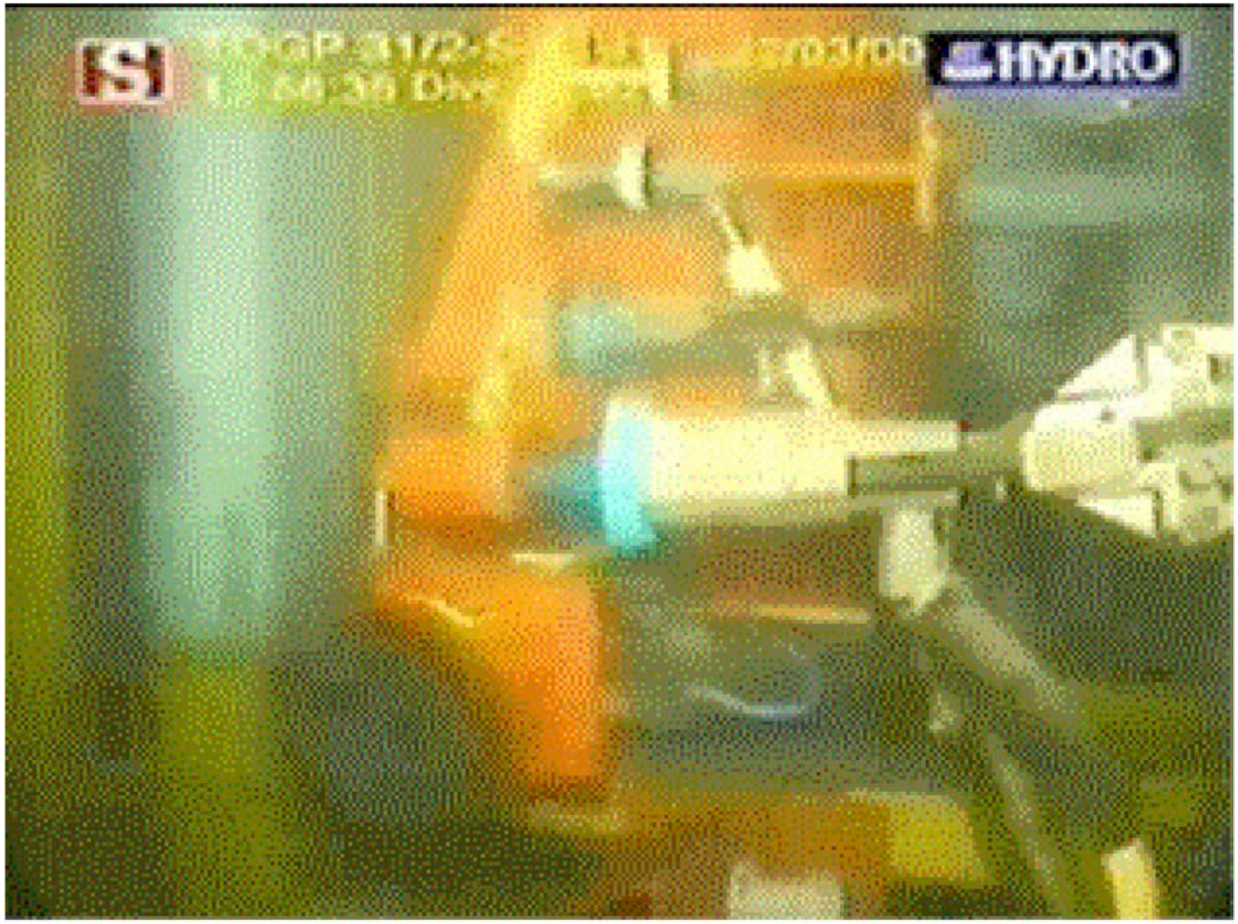


km3 - storia - NEMO (1996...)





km3 - storia - NEMO (1996...)



km3Net

progetto europeo

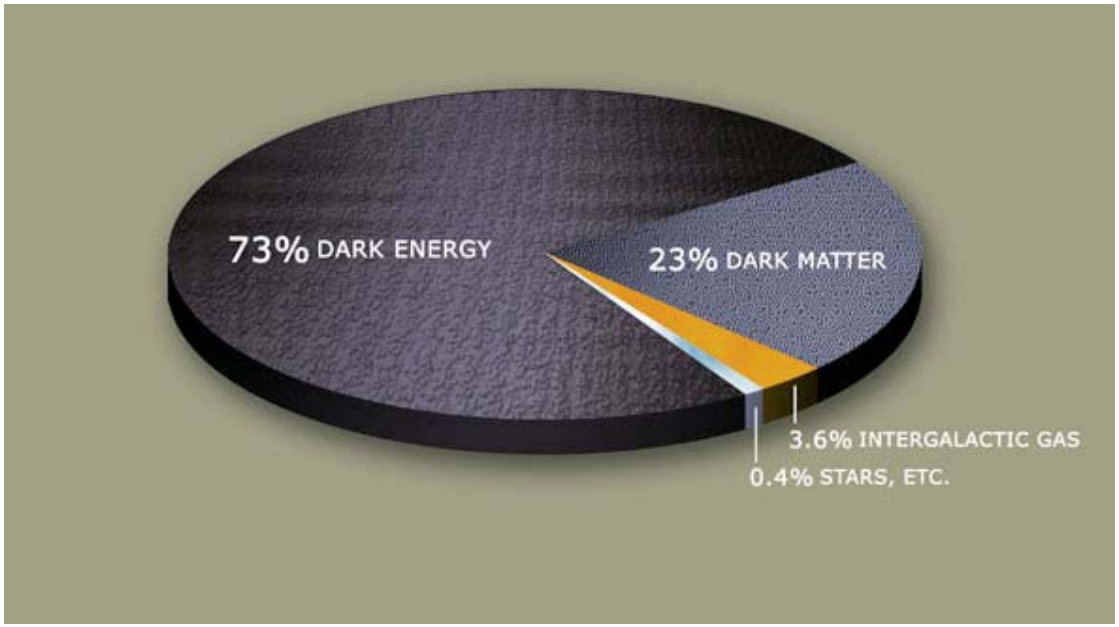
scelta sito

R&D per km cubo

Perche' l'astrofisica?

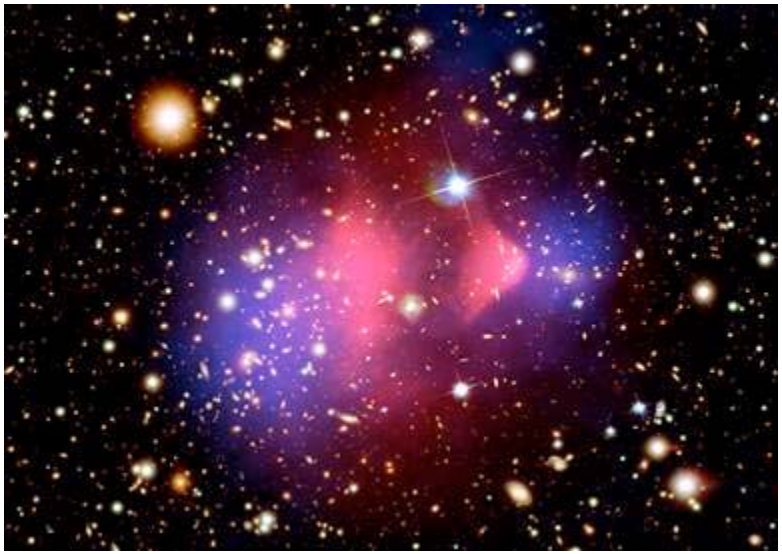
materia oscura

energia oscura



materia oscura

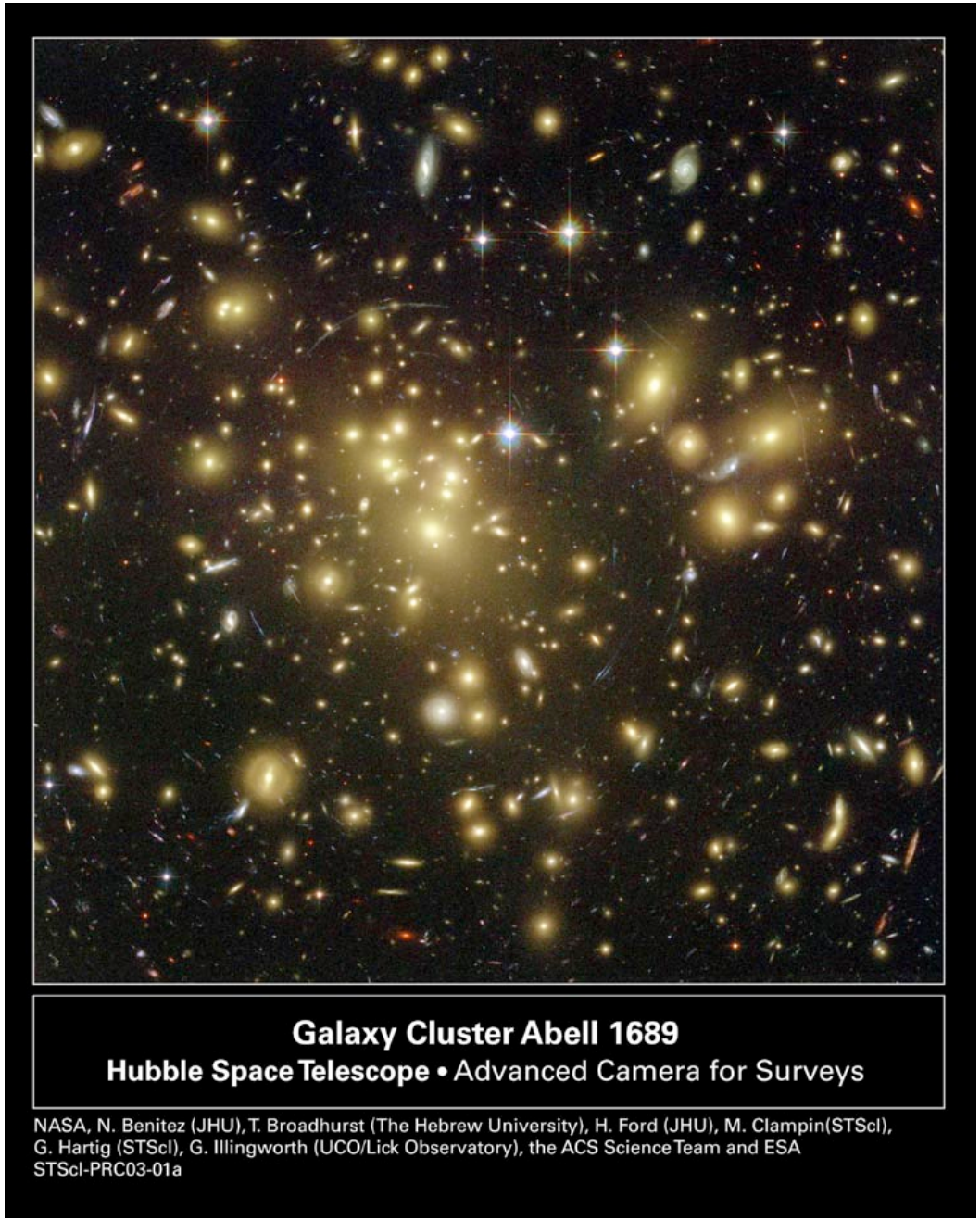
moto delle galassie



bullet cluster

materia oscura

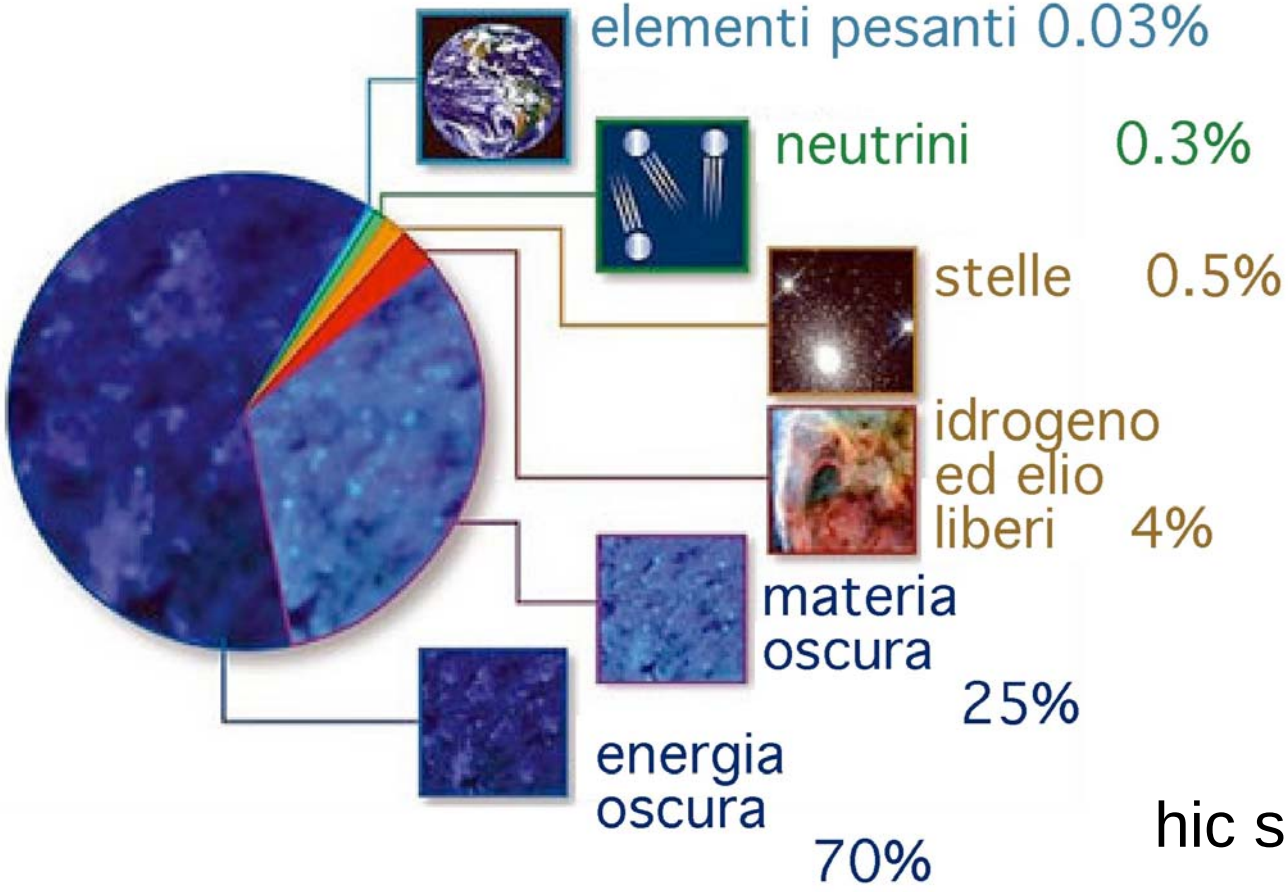
effetto lente



energia oscura

velocita’ di espansione dell’universo

a che punto e' la nostra conoscenza del mondo?



hic sunt leones