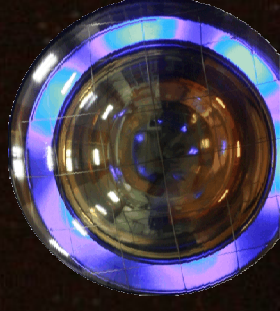


Antares, Premières vues du ciel

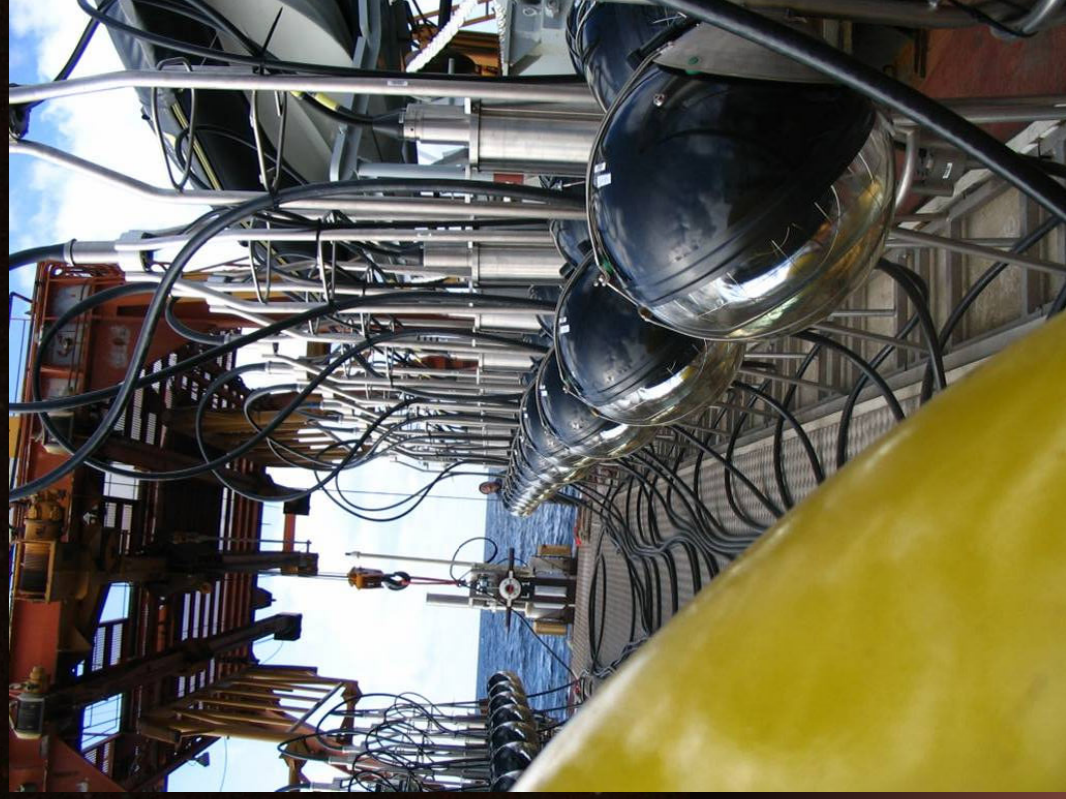


Th. Stolarczyk

CEA Irfu
Service de physique des particules

26 mai 2009

ANTARES



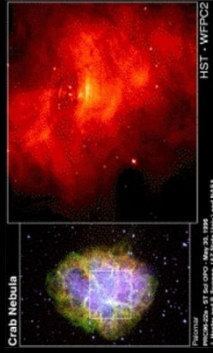
- Introduction
- Résultats
 - μ atmosphériques
 - Neutrinos
 - Recherche de sources
 - Matière noire
- Sciences environnementales
- KM3NeT

Galactique

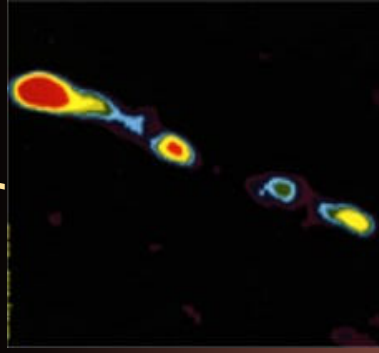
Restes de
Supernova



Pulsars

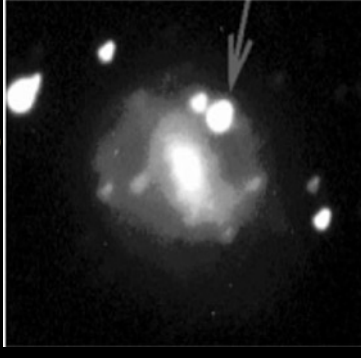


Microquasars

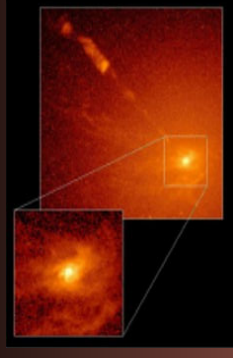


Extra-galactique

Sursauts gamma

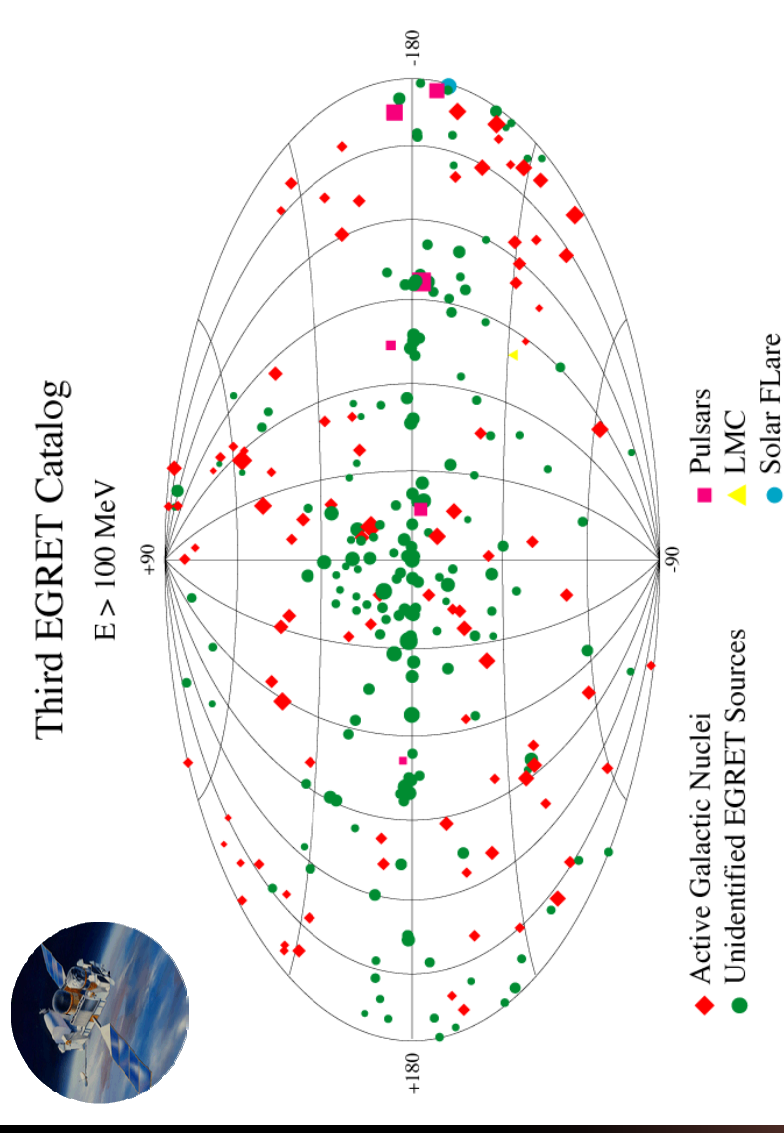


Noyaux actifs
de galaxie



Third EGRET Catalog

$E > 100 \text{ MeV}$

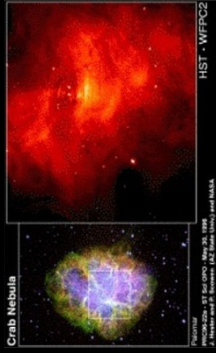


Galactique

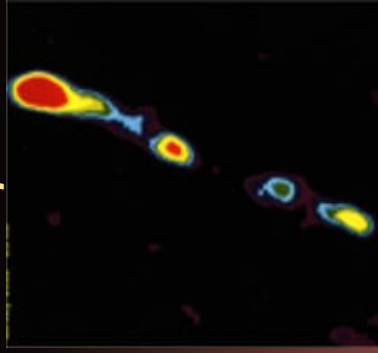
Restes de Supernova



Pulsars

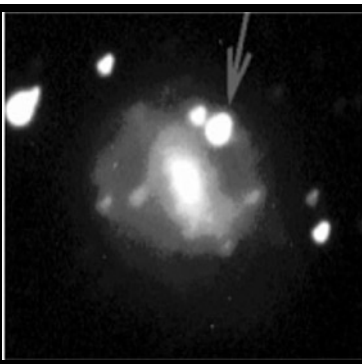


Microquasars

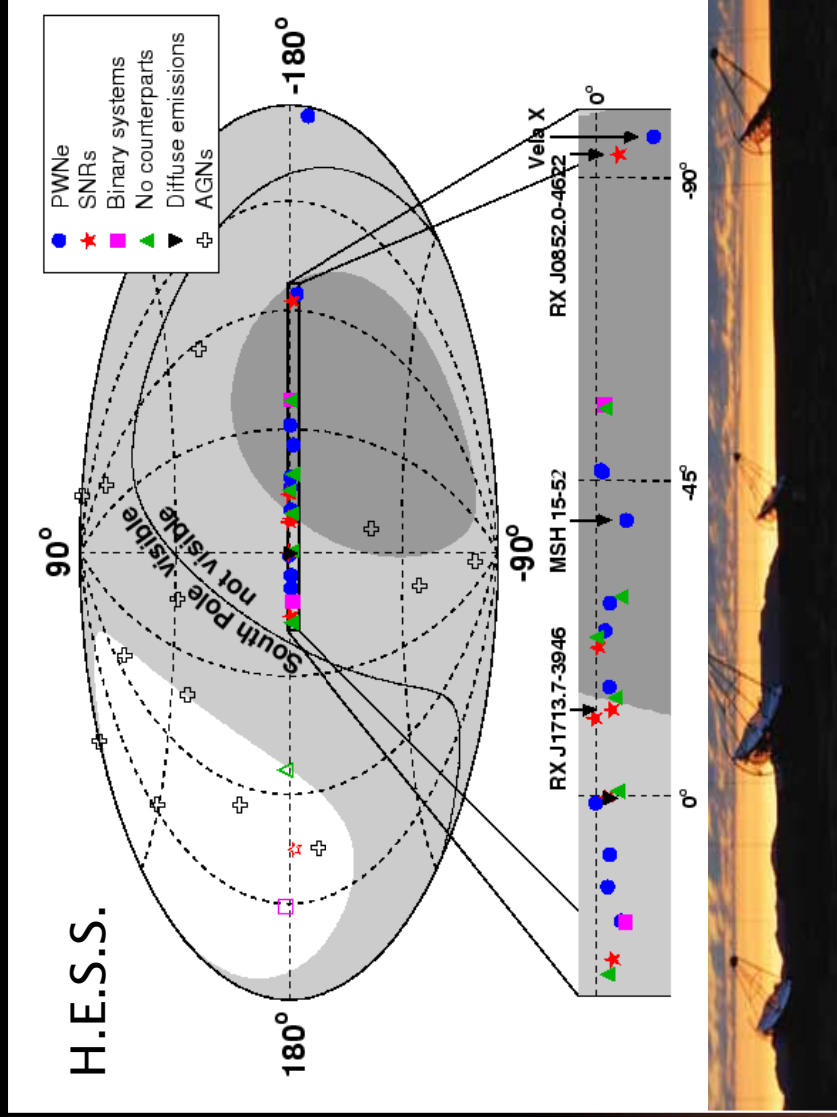
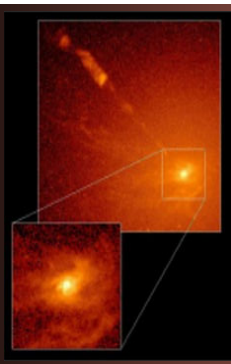


Extra-galactique

Sursauts gamma



Noyaux actifs de galaxie

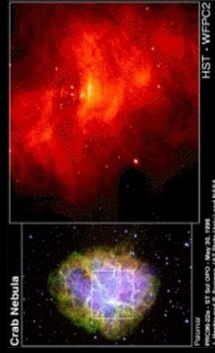


Galactique

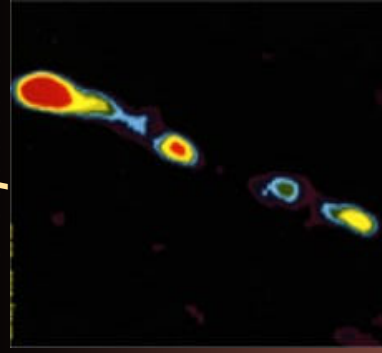
Restes de
Supernova



Pulsars

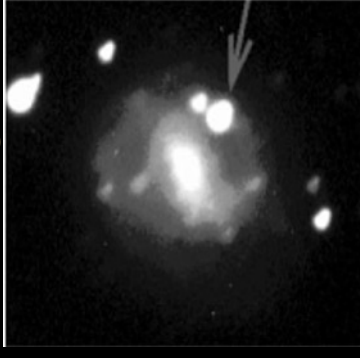


Microquasars

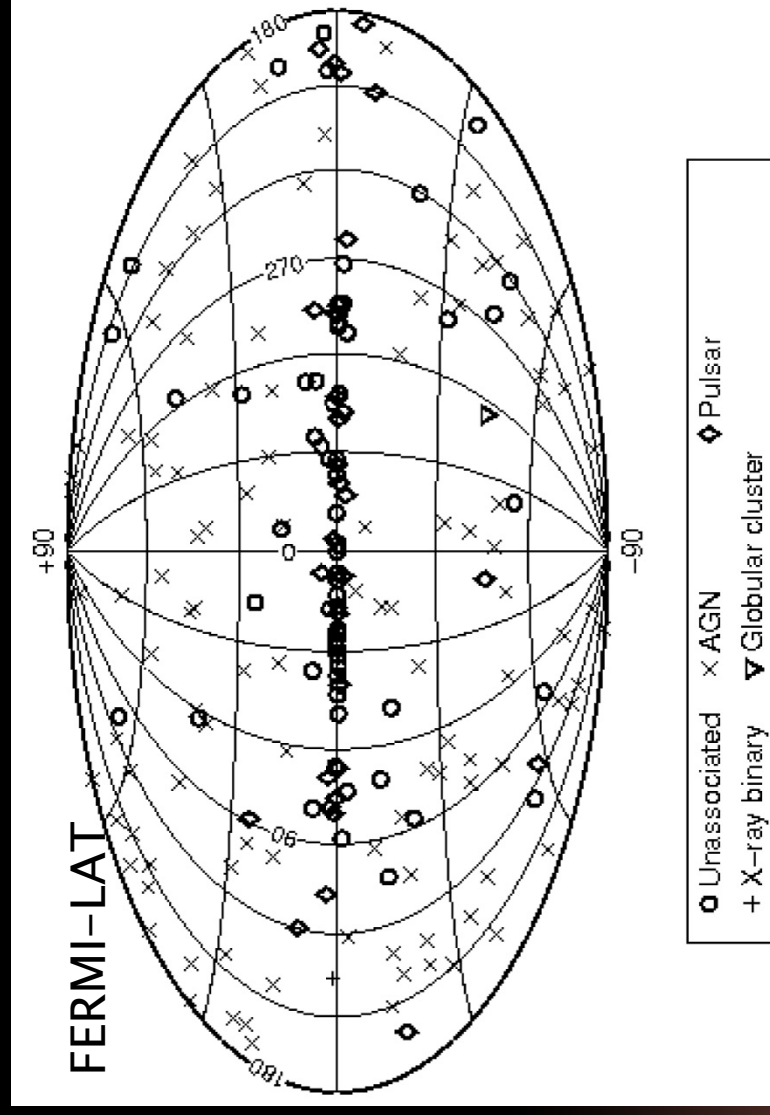
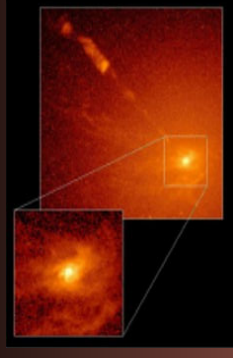


Extra-galactique

Sursauts gamma



Noyaux actifs
de galaxie

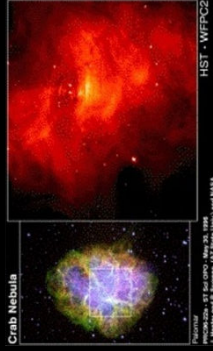


Galactique

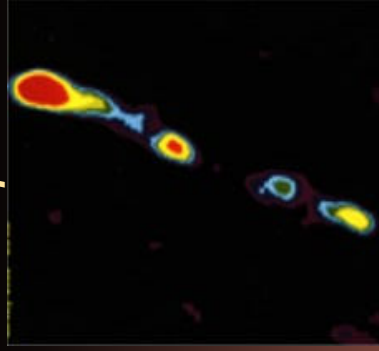
Restes de
Supernova



Pulsars

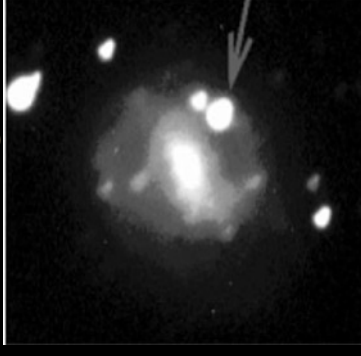


Microquasars

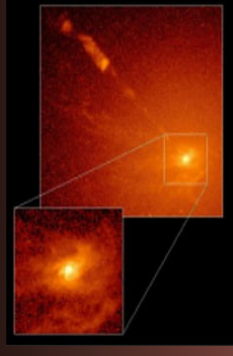


Extra-galactique

Sursauts gamma



Noyaux actifs
de galaxie



$e \rightarrow \gamma$ (inverse Compton)

$p/A + p/\gamma \rightarrow \pi^0 + \pi^\pm + \dots$

\rightarrow

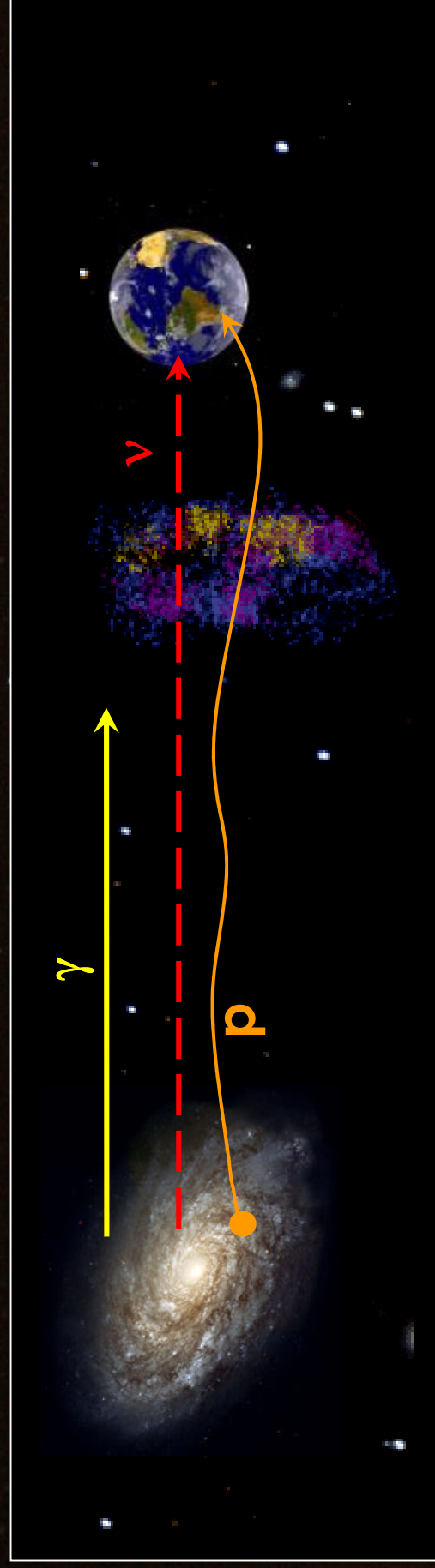
$\gamma \gamma$

$\nu_\mu \mu$

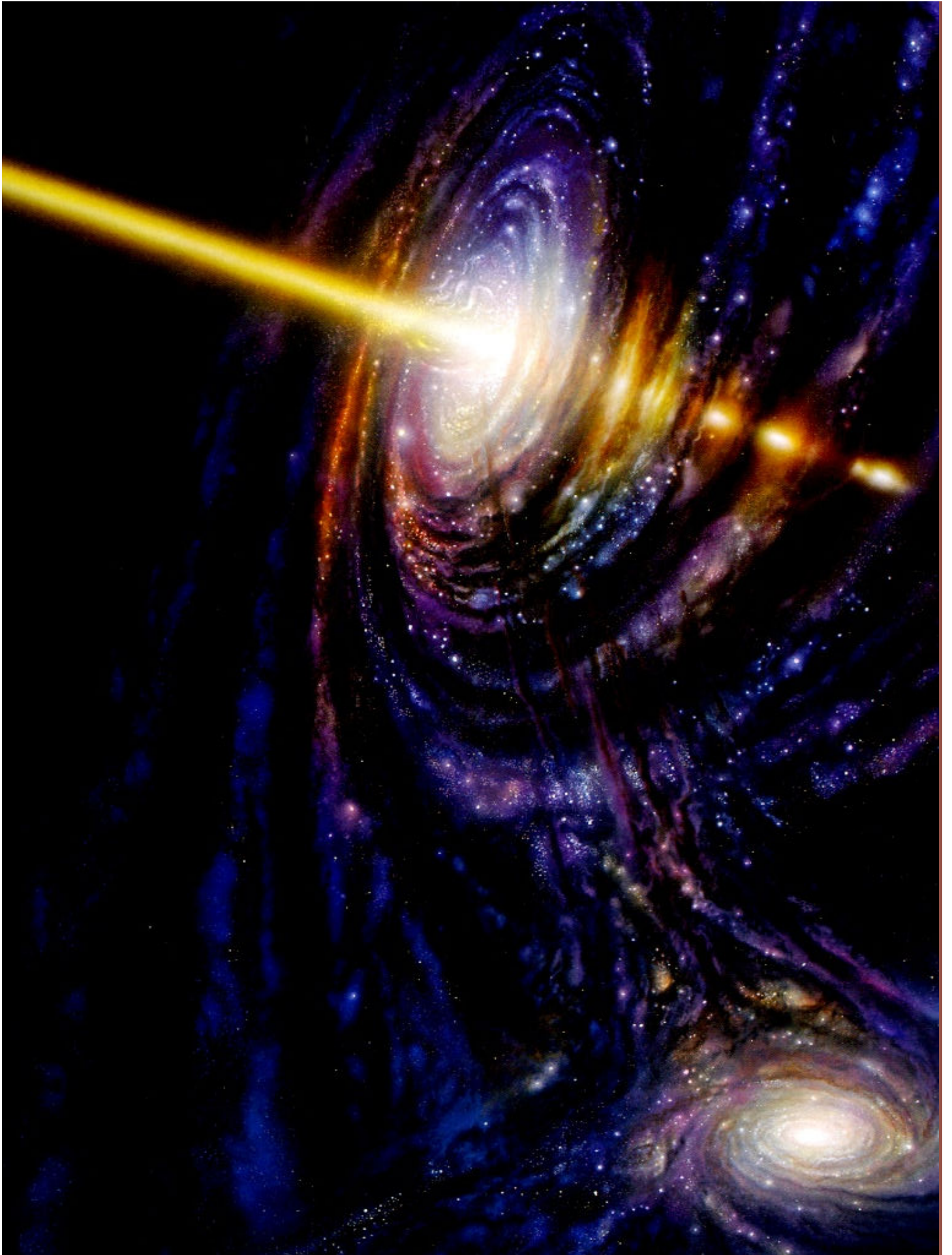
\rightarrow

$\nu_\mu \nu_e e$

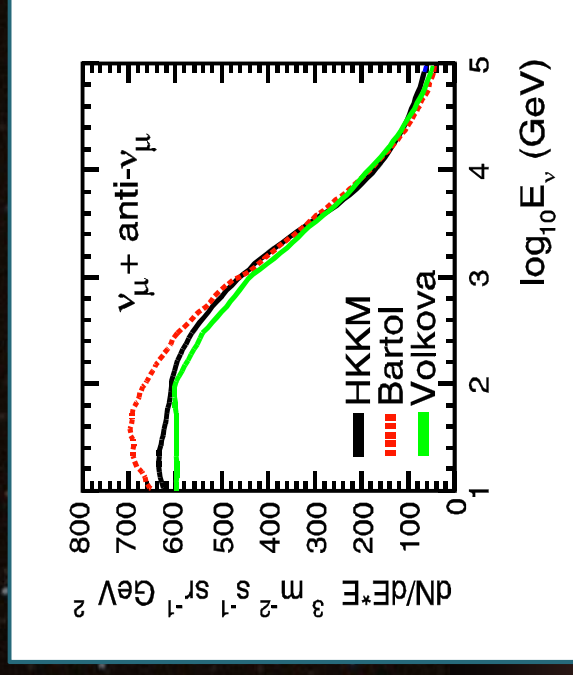
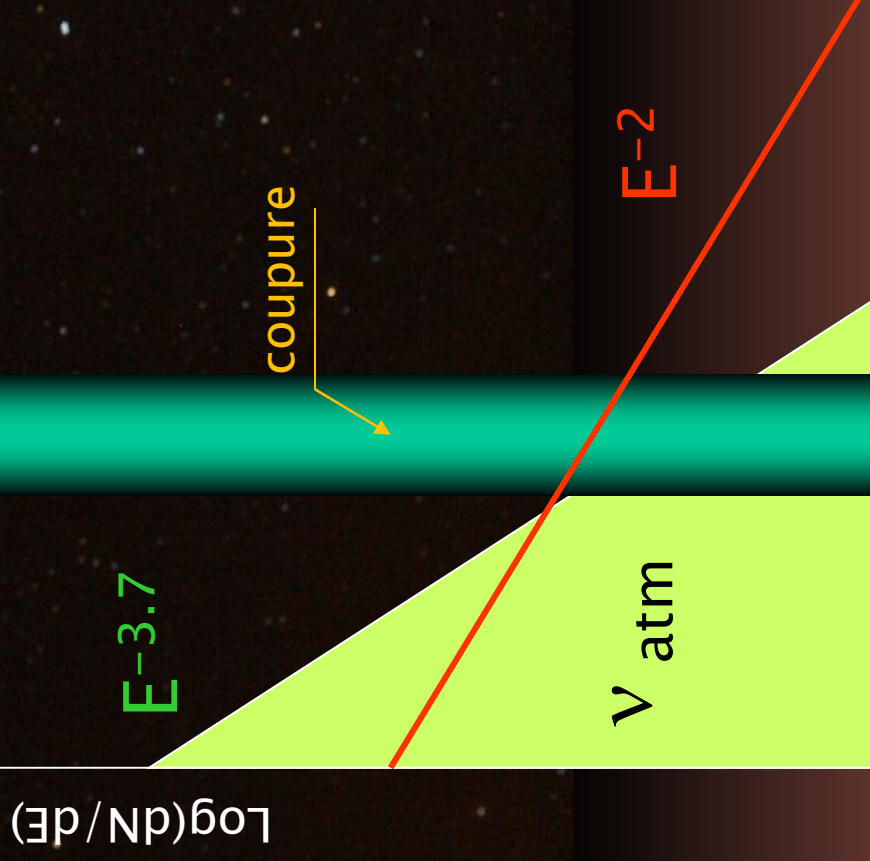
Le neutrino, nouveau messenger



γ	$< 2 \cdot 10^9$	a.l.	à 1 TeV	→ Amas local
	$< 30 \cdot 10^6$	a.l.	à 100 TeV	→ Galaxie
	$< 30 \cdot 10^3$	a.l.	à 1 PeV	



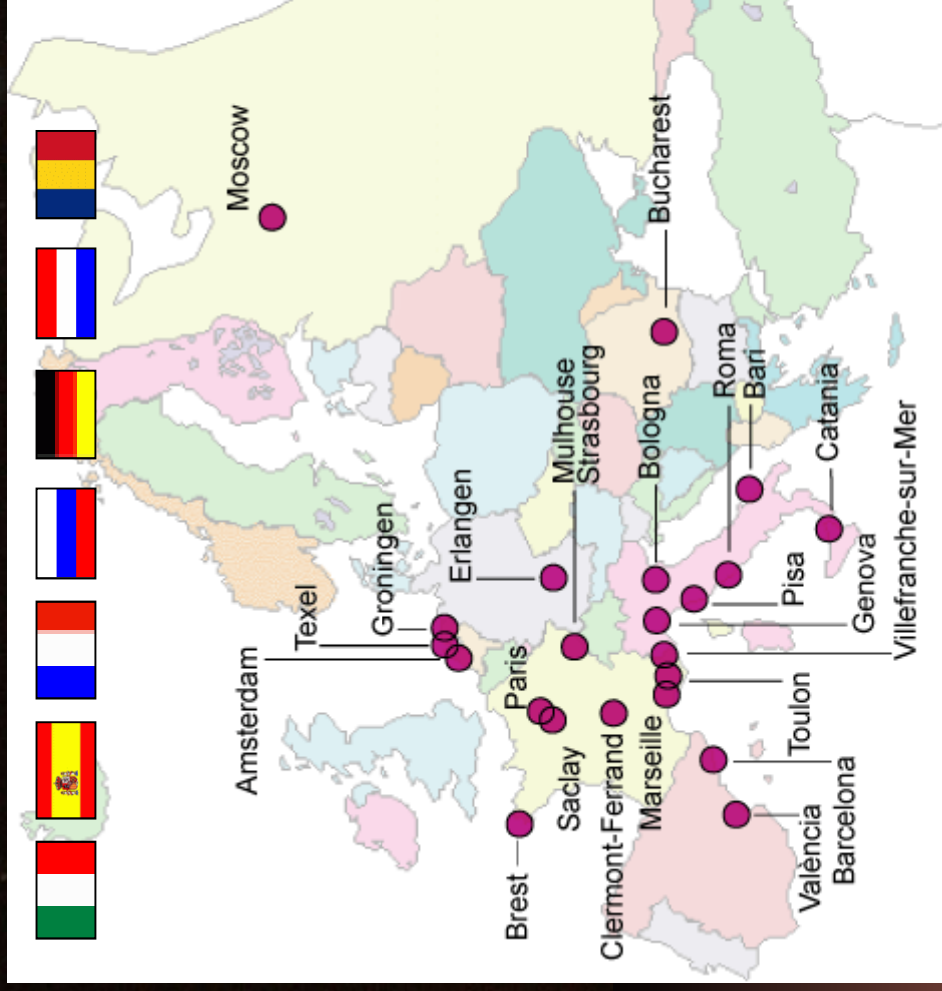
Sélection haute énergie



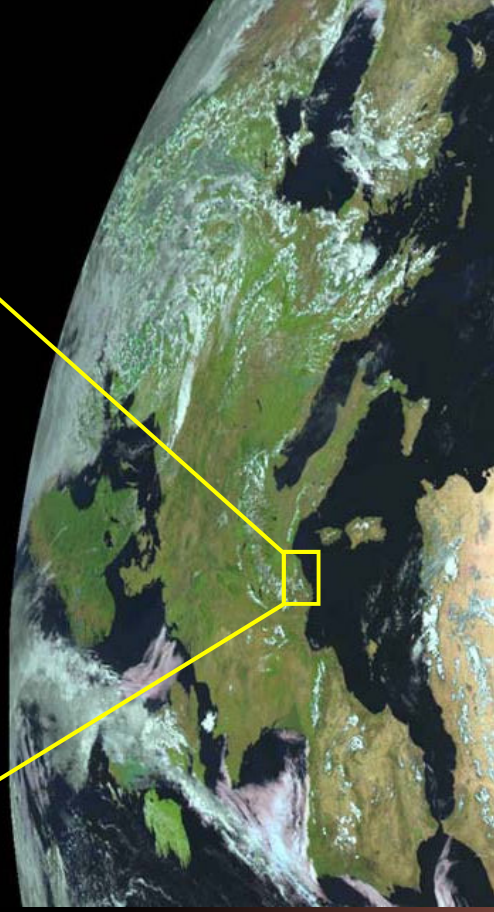
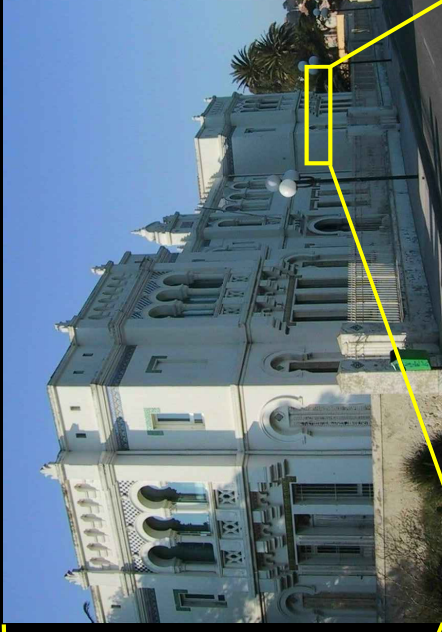
$$E^3 \times \frac{dn}{dE_{\text{atm}}}$$

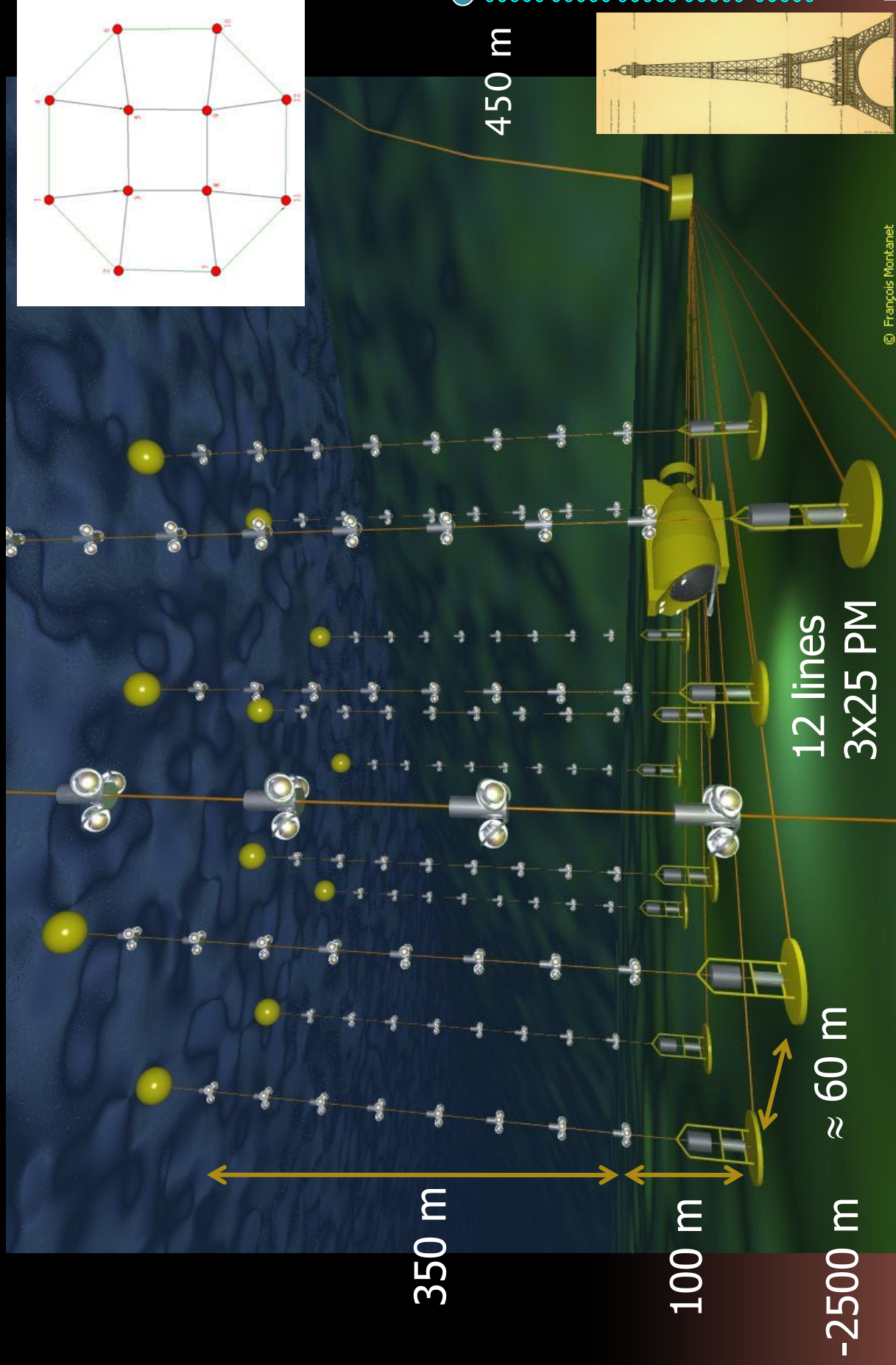
Log(E)

La collaboration



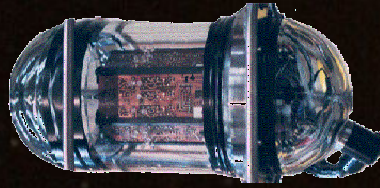
- Depuis 1996
- 7 pays
- 22 laboratoires
- ~150 ingénieurs et scientifiques







Etage de détection



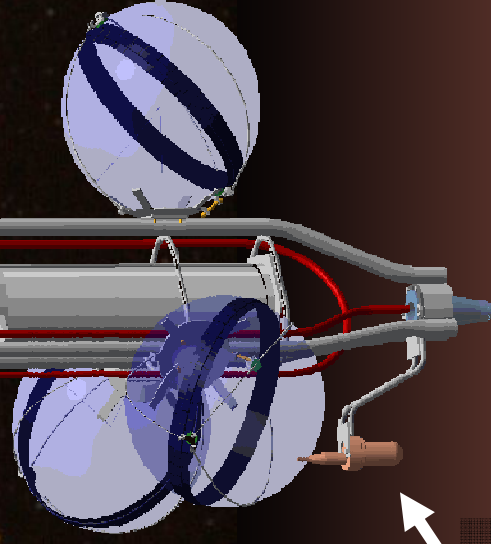
Balises optiques
Etalonnage en temps



DAQ
Slow Control
Cartes compas

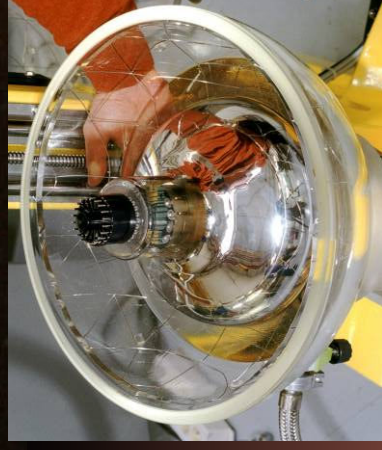


Hydrophone
Positionnement acoustique

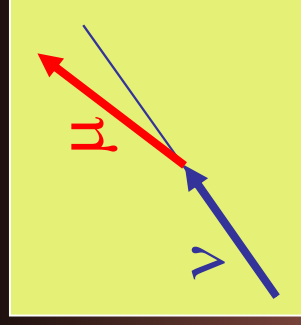
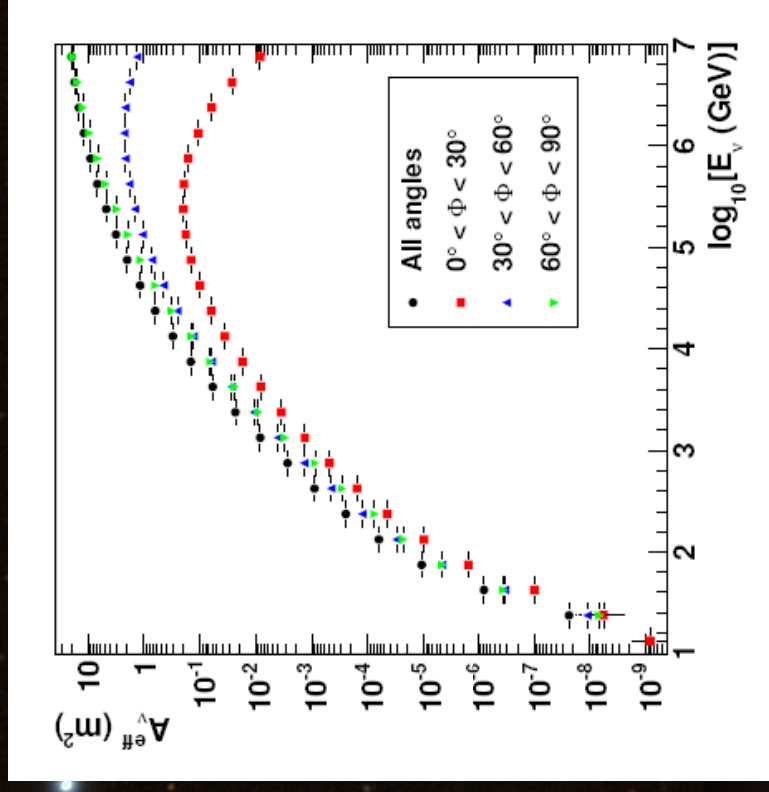
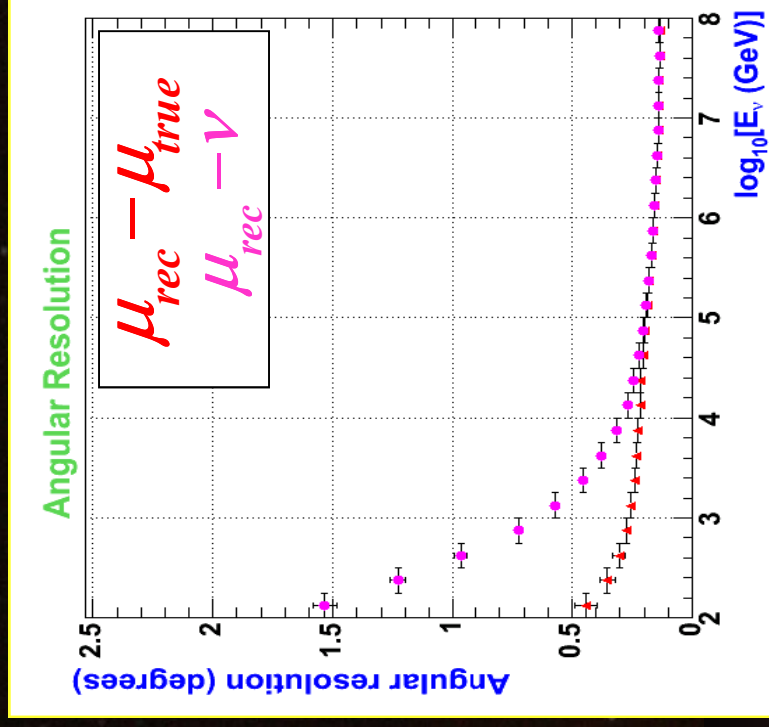


Structure titane

PMT 10" ($\sigma_{TTS} \approx 1,3 \text{ ns}$)
Sphere 17"



Performances attendues



- Volume instrumenté : 20 Mton (1/50 km³)
- Surface effective muon \approx 20000 m² ($E > 1$ TeV)

Signal

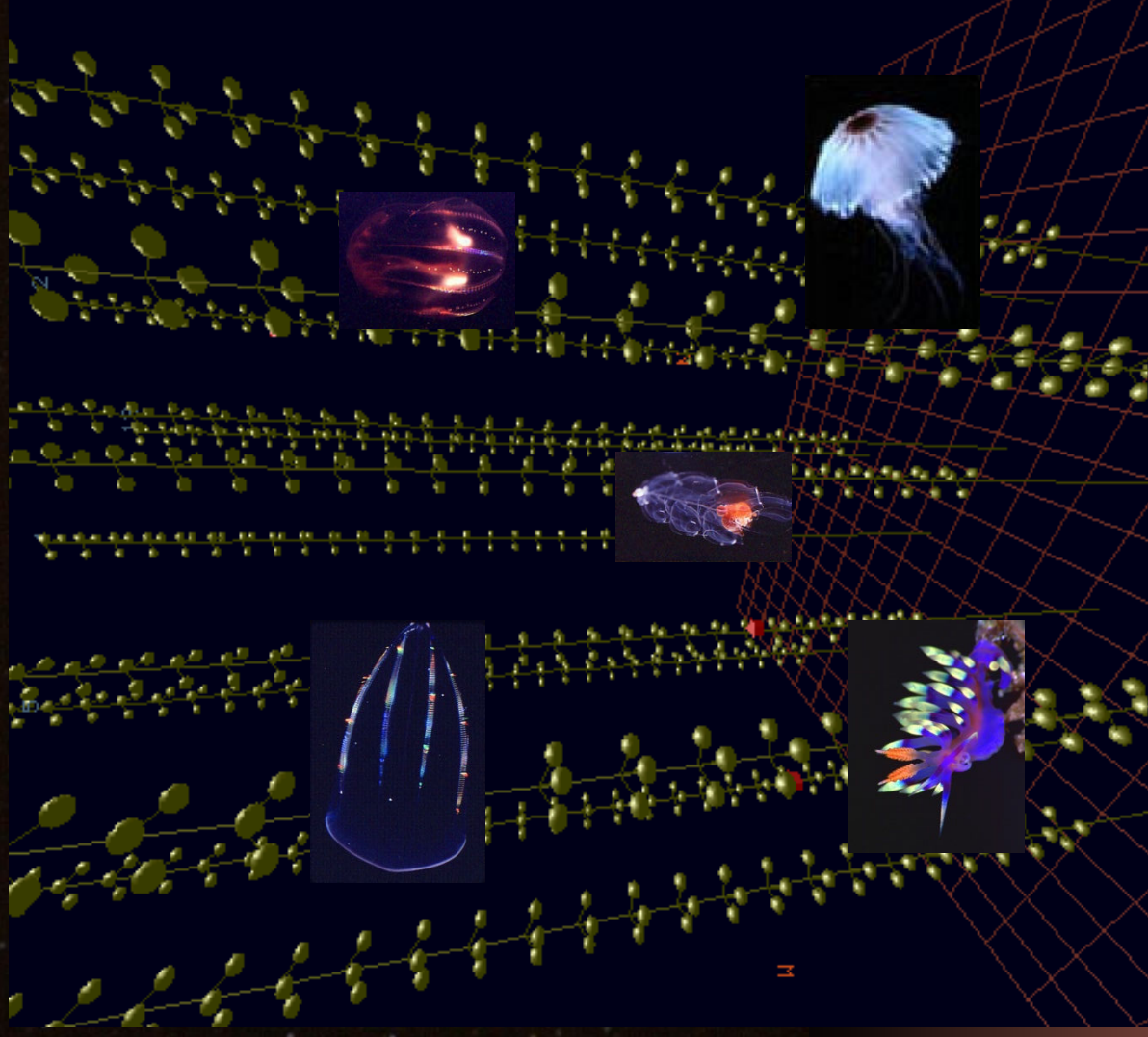
- Muon
 - Traverse en $2 \mu\text{s}$
 - ~ 100 modules touchés (Croît avec l'énergie)

- Désintégrations ^{40}K
 - Fond continu $\sim 30 \text{ kHz}^*$

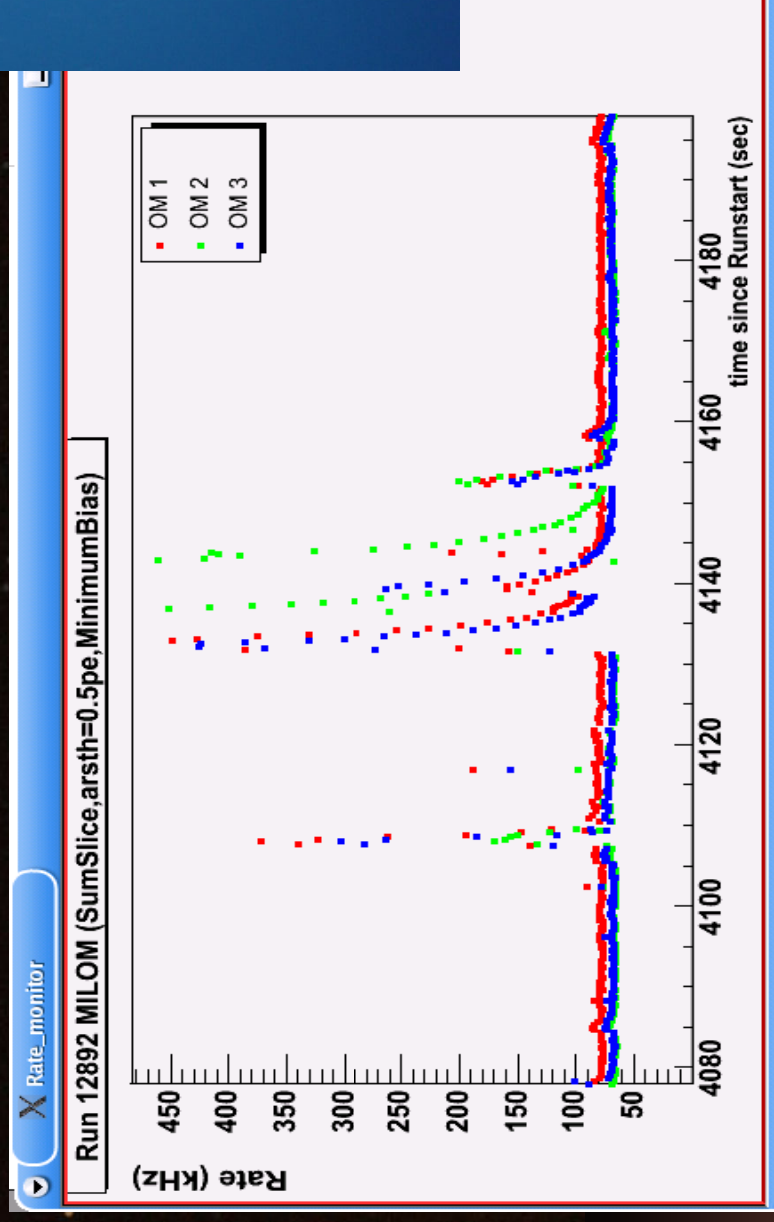
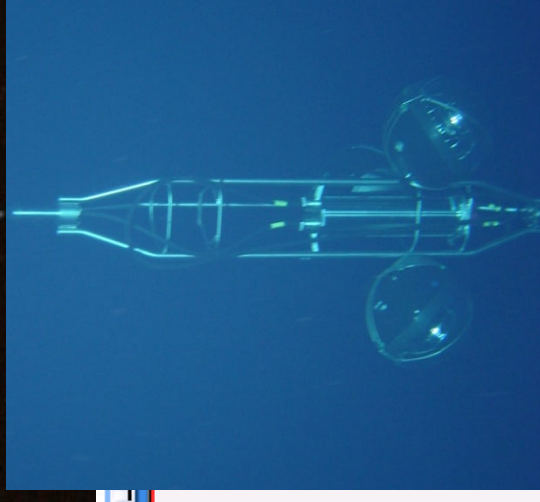
- Bioluminescence
 - fond continu $\sim 30 \text{ kHz}^*$
 - sursauts sporadiques
 - $> \text{MHz}$

- « all data to shore »
 - Plusieurs logiciels de déclenchement à Terre

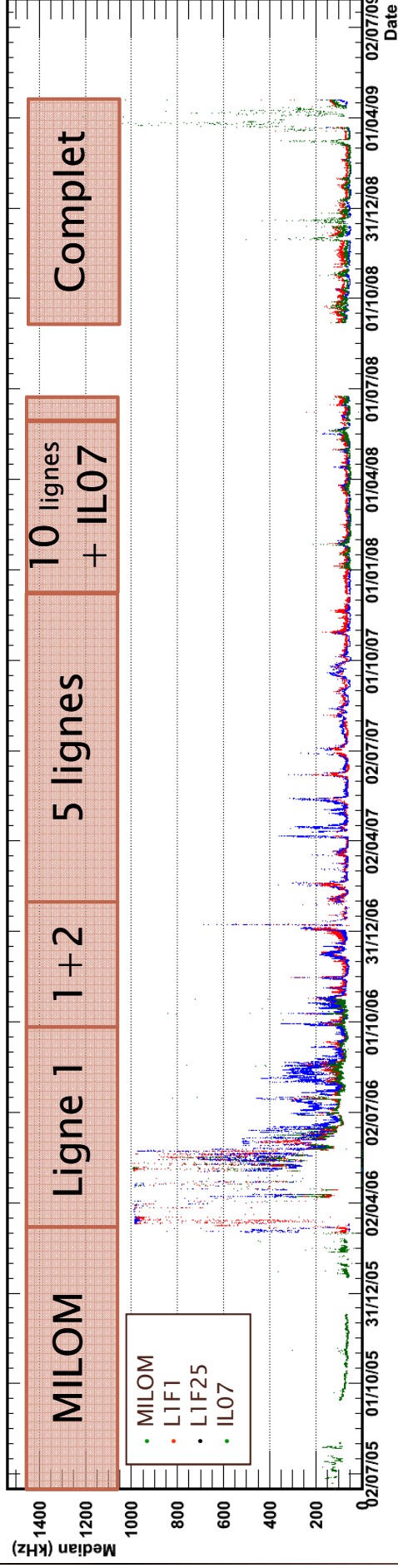
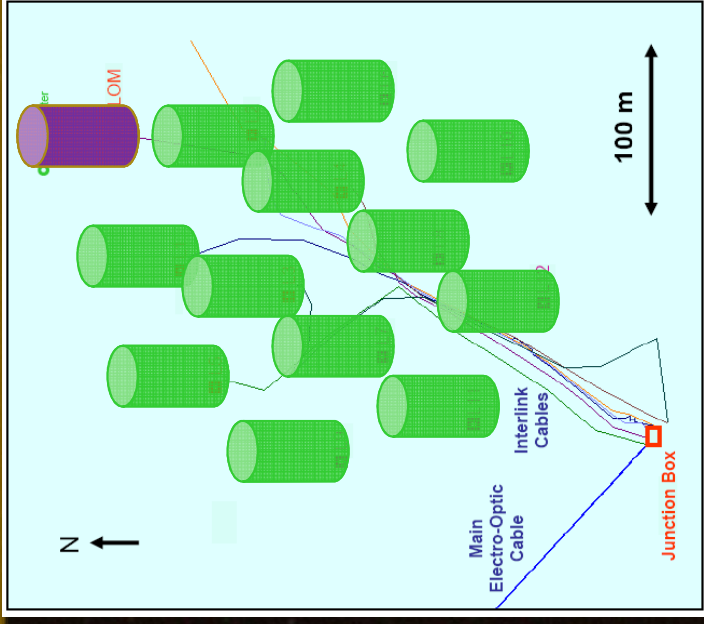
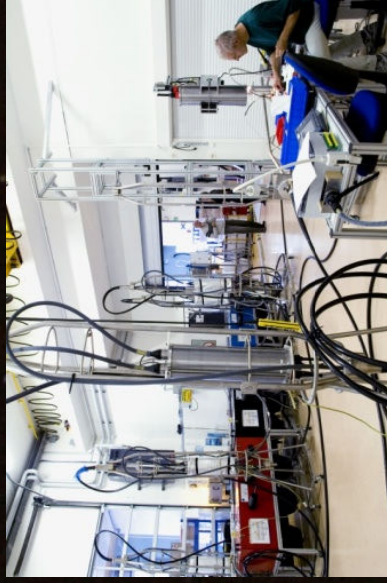
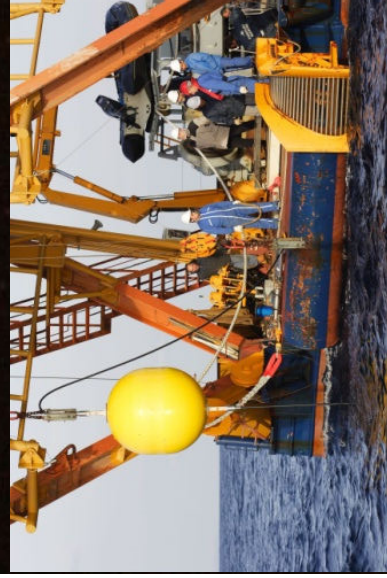
*PM 10'', seuil à 0,3 p.e.



Bioluminescence



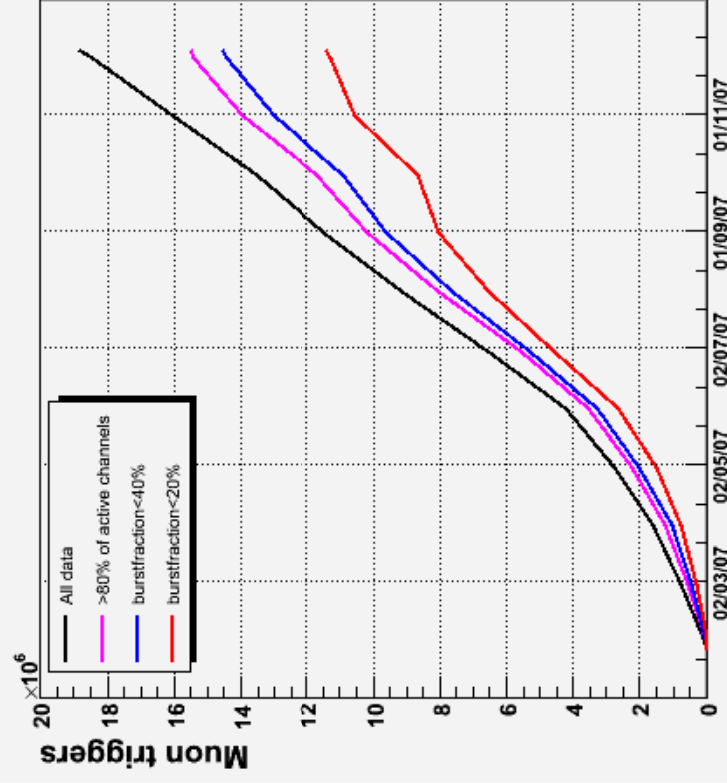
Historique



Statistique accumulée

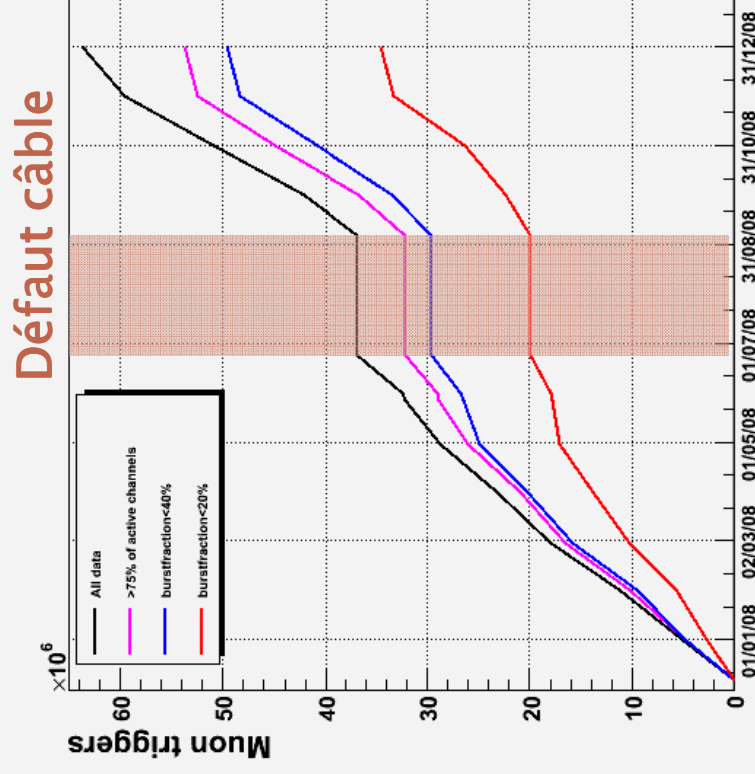
2007, 5 lignes : $19 \cdot 10^6$

2008, ≥ 10 lignes : $65 \cdot 10^6$



Total : 240 jours (80%)

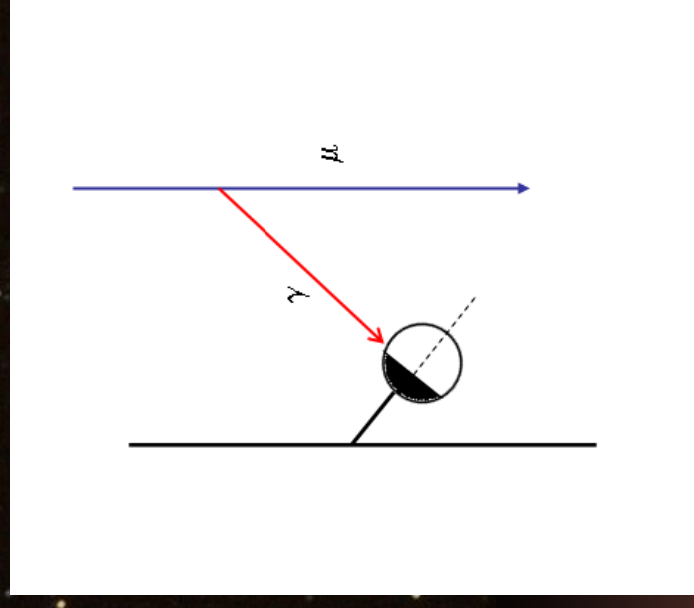
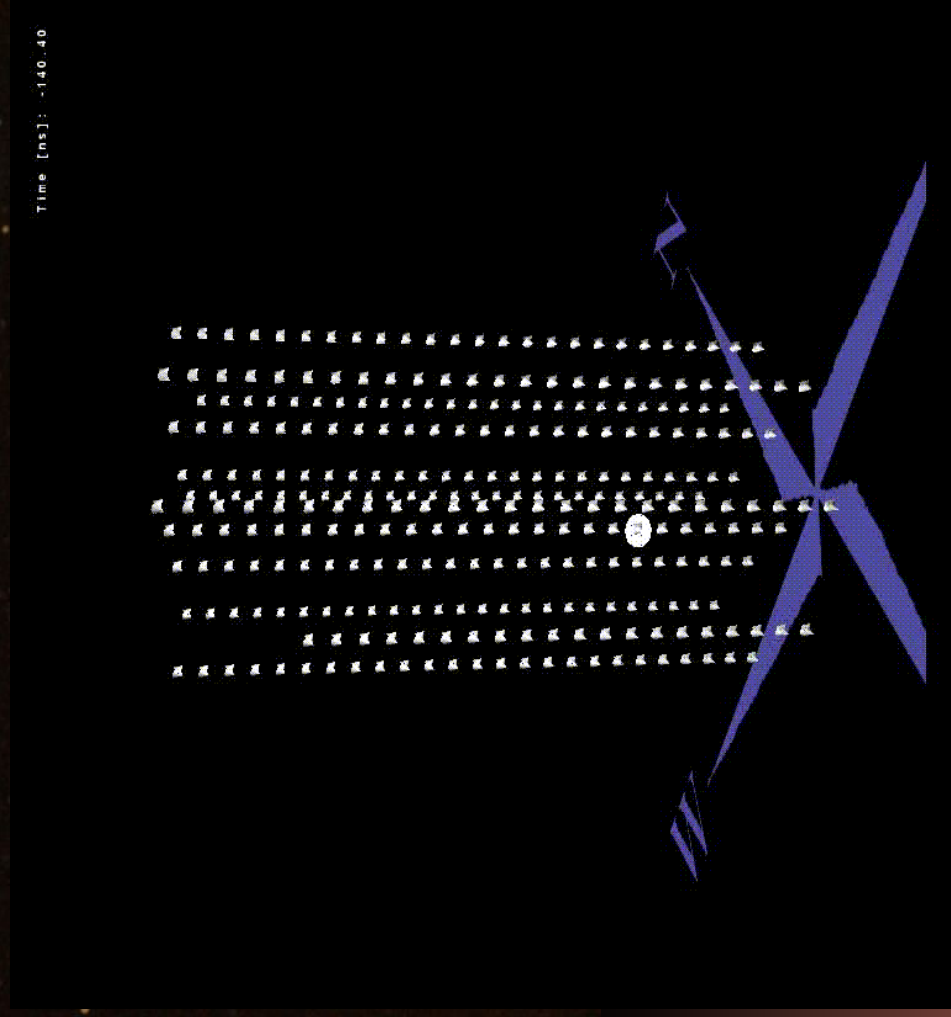
Selectionnés : 167 j (70% du total)



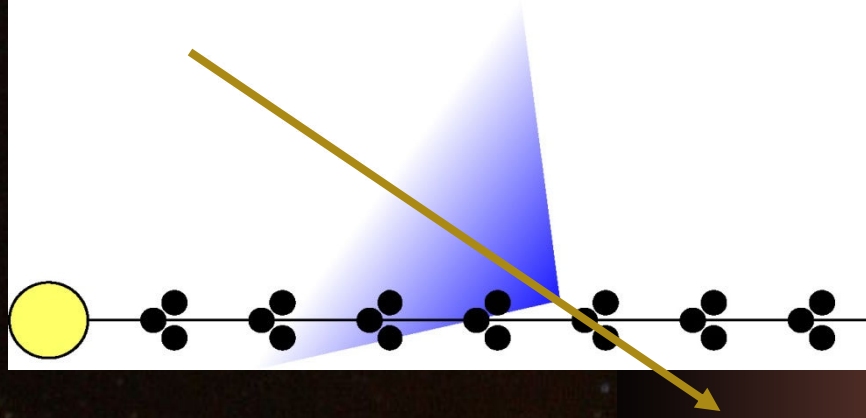
Total : 243 jours (83%)

Selectionnés : 173 j (71% du total)

Muons atmosphériques

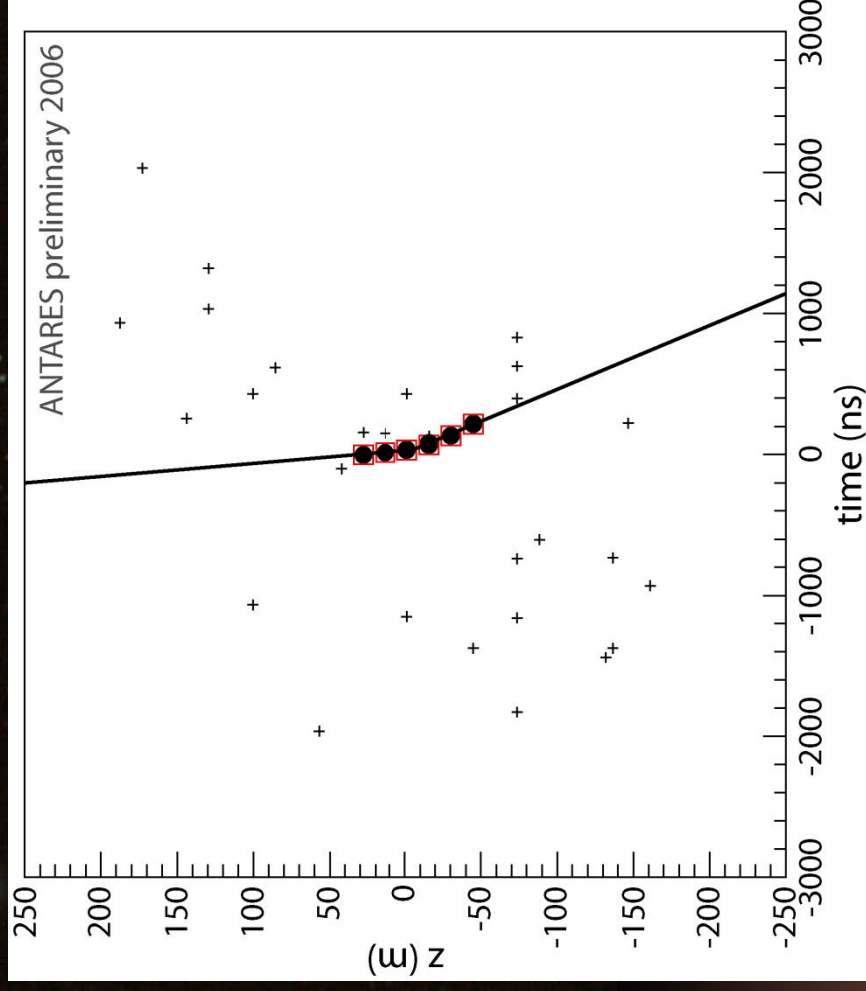


z (m)



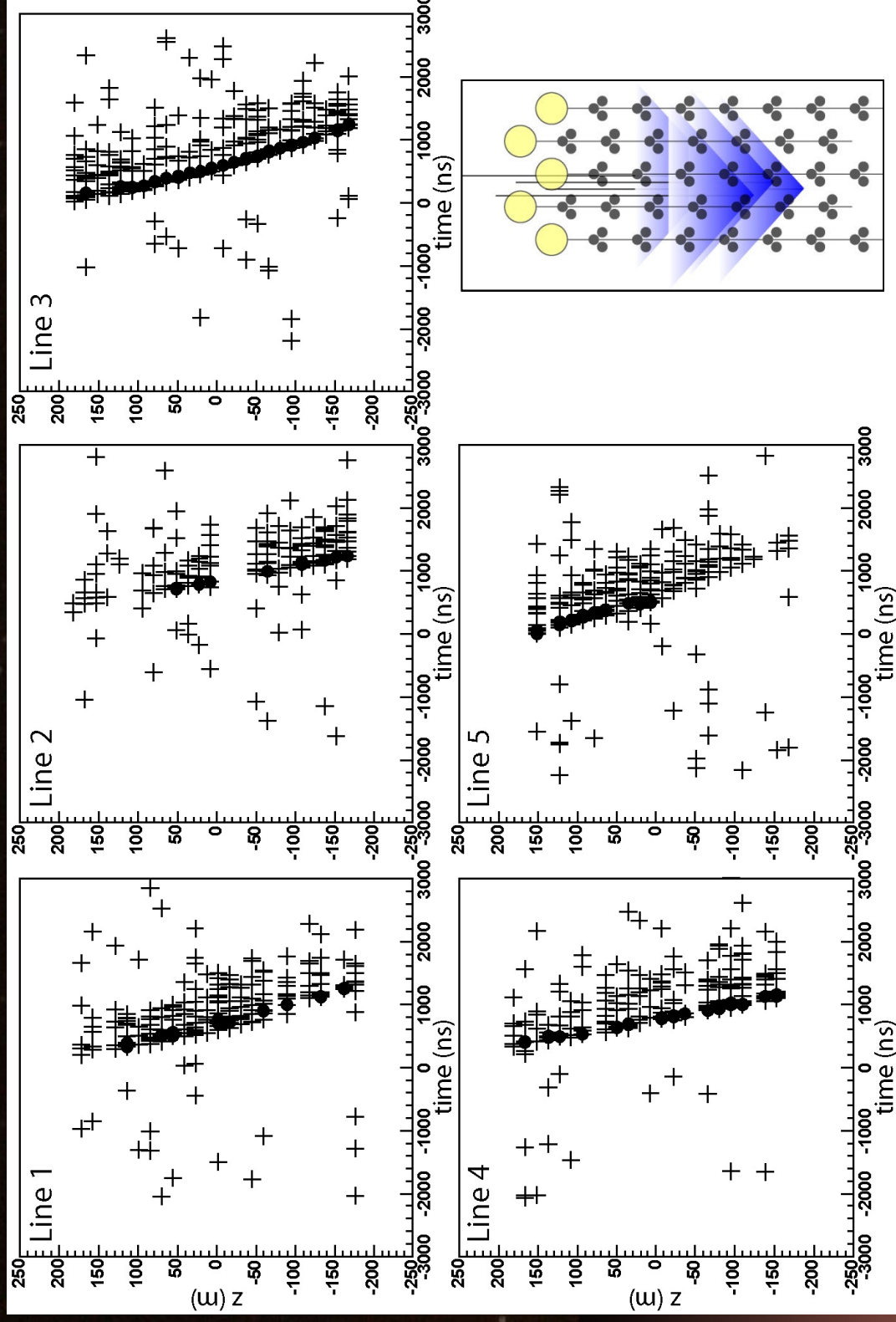
r (m)

z (m)

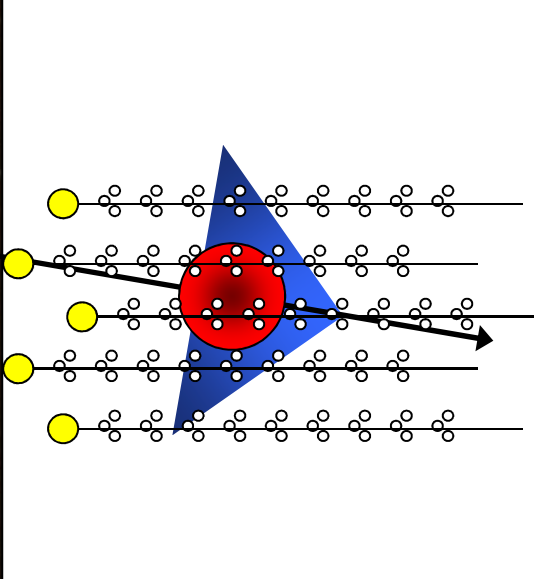
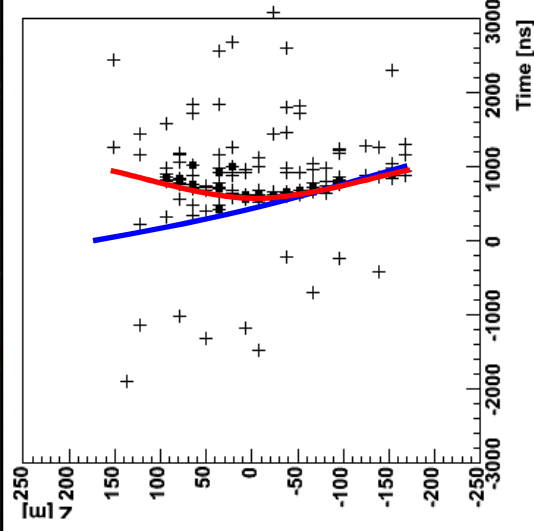
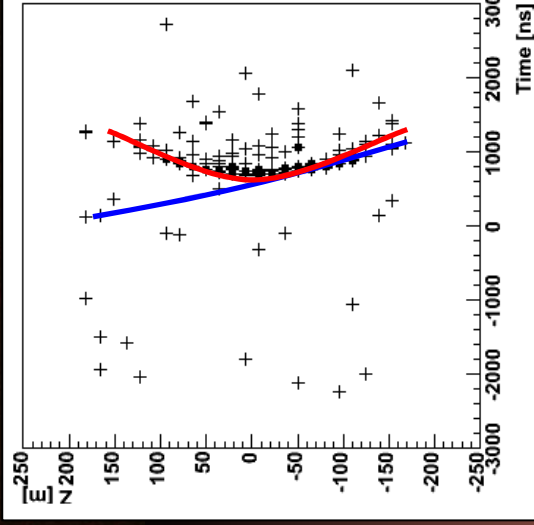
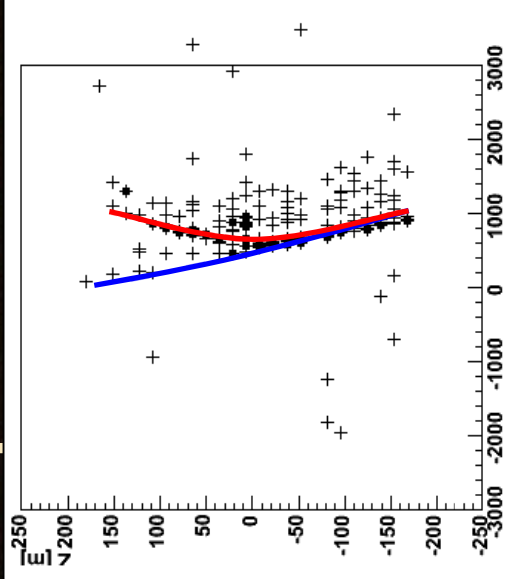
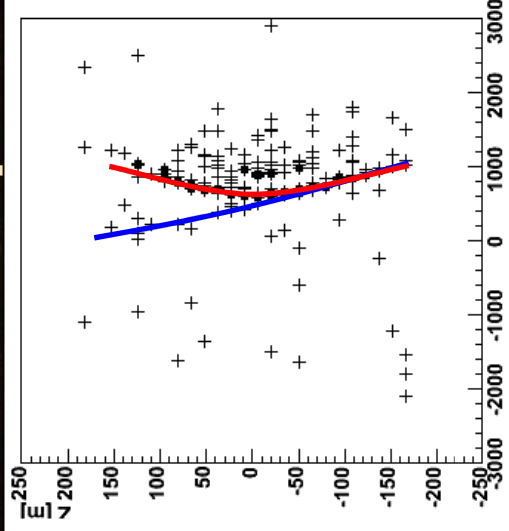
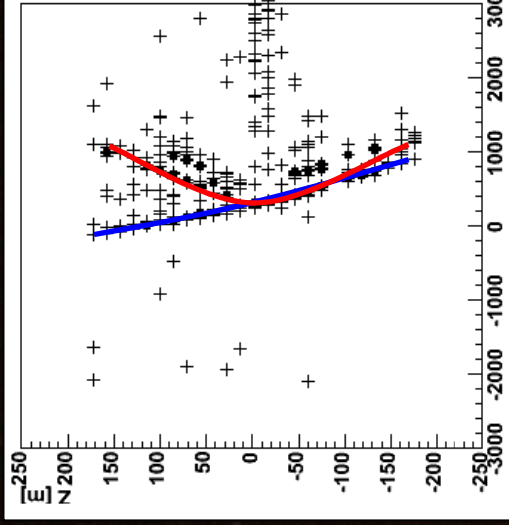


t (ns)

Multi-muons

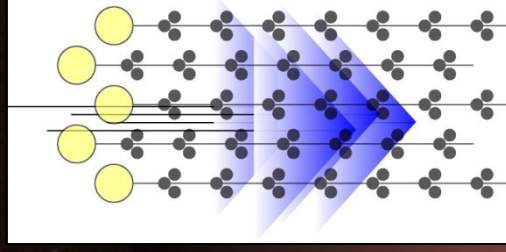
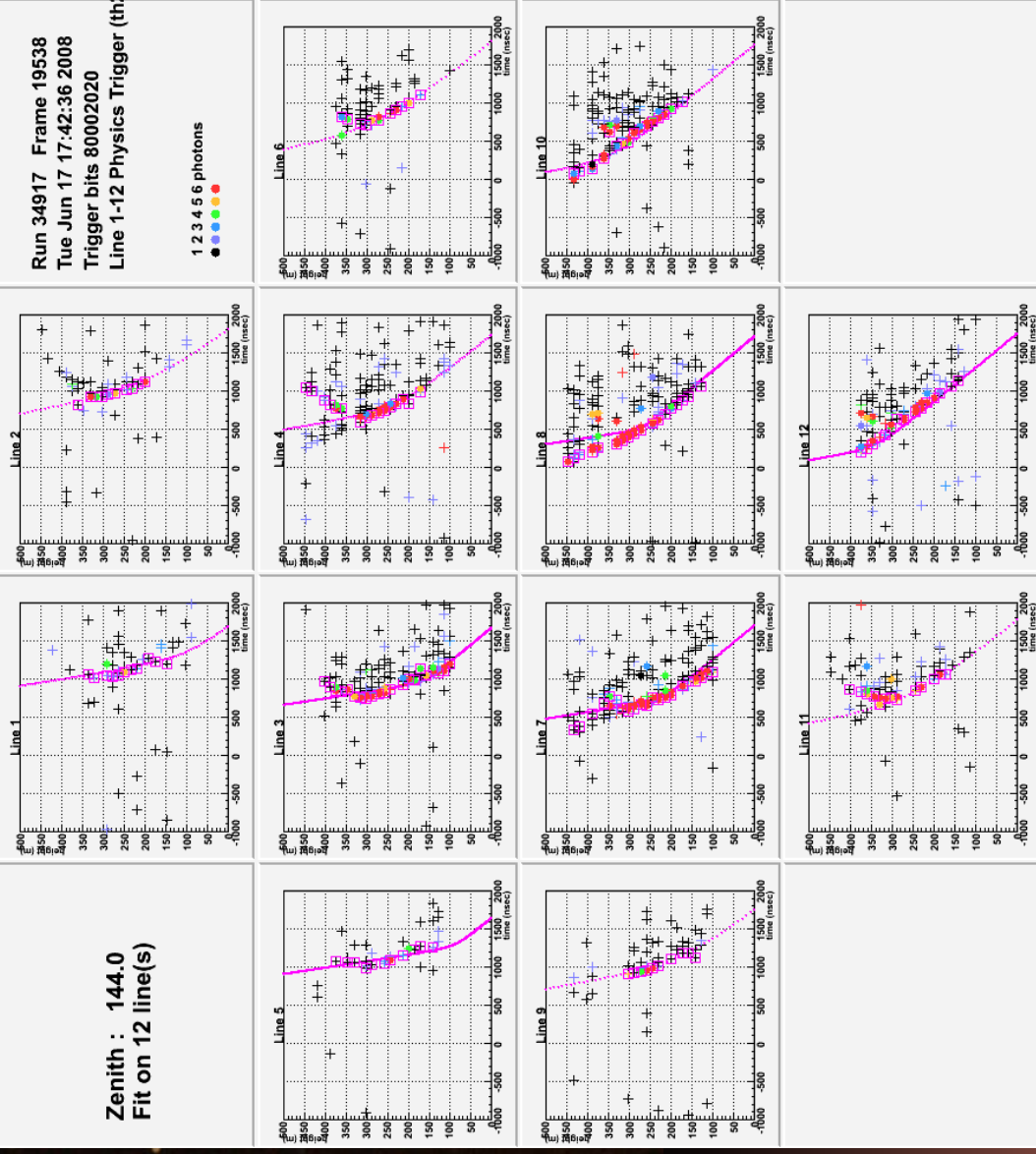


Gerbes induites par les μ



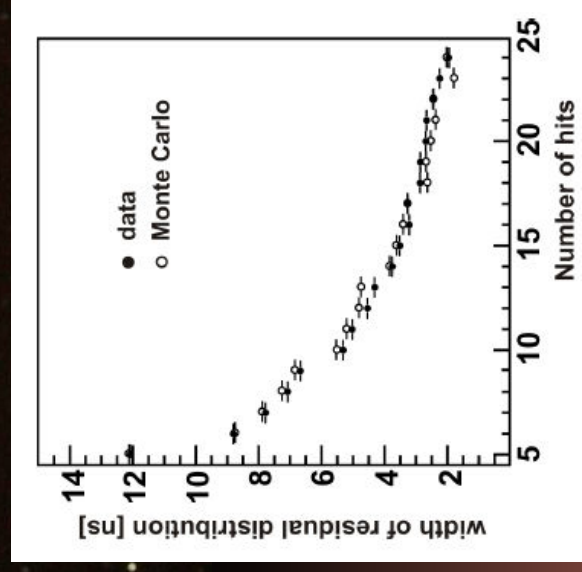
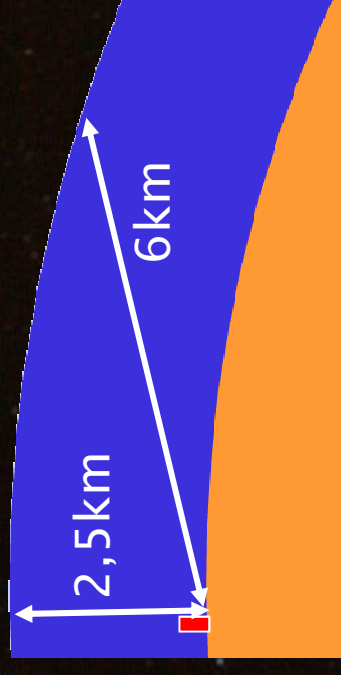
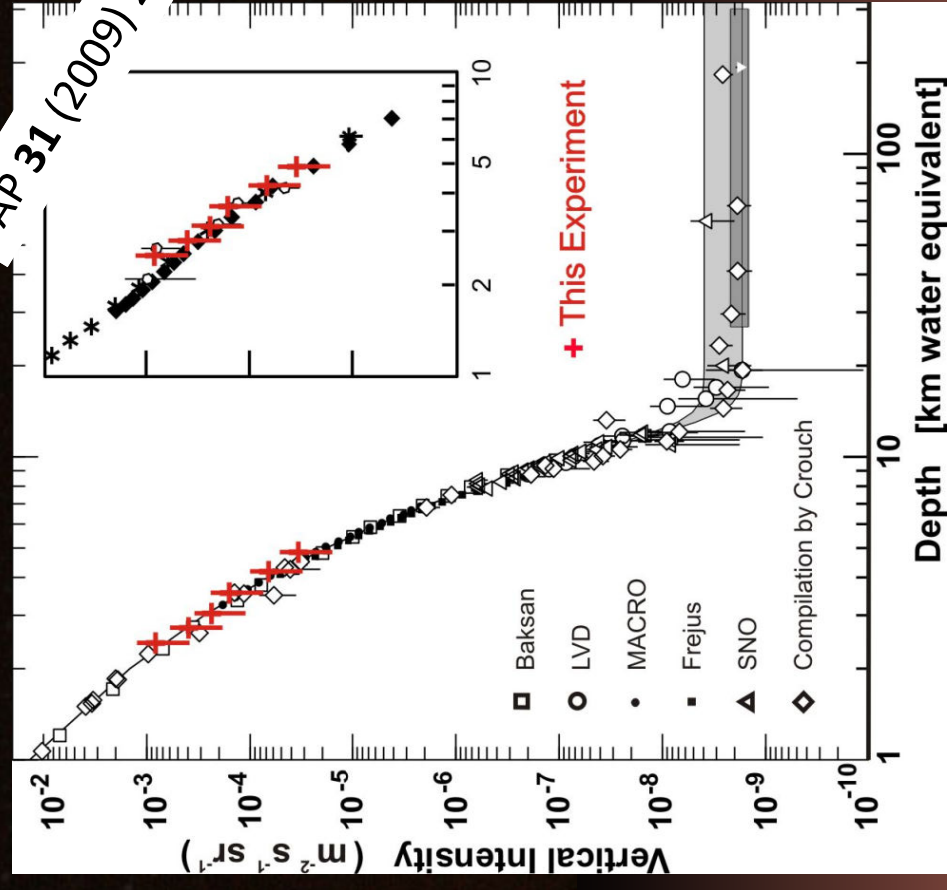
Multi-muons

Zenith : 144.0
Fit on 12 line(s)



Ligne 1

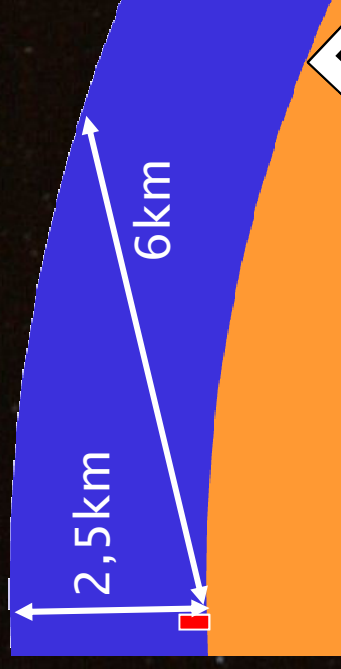
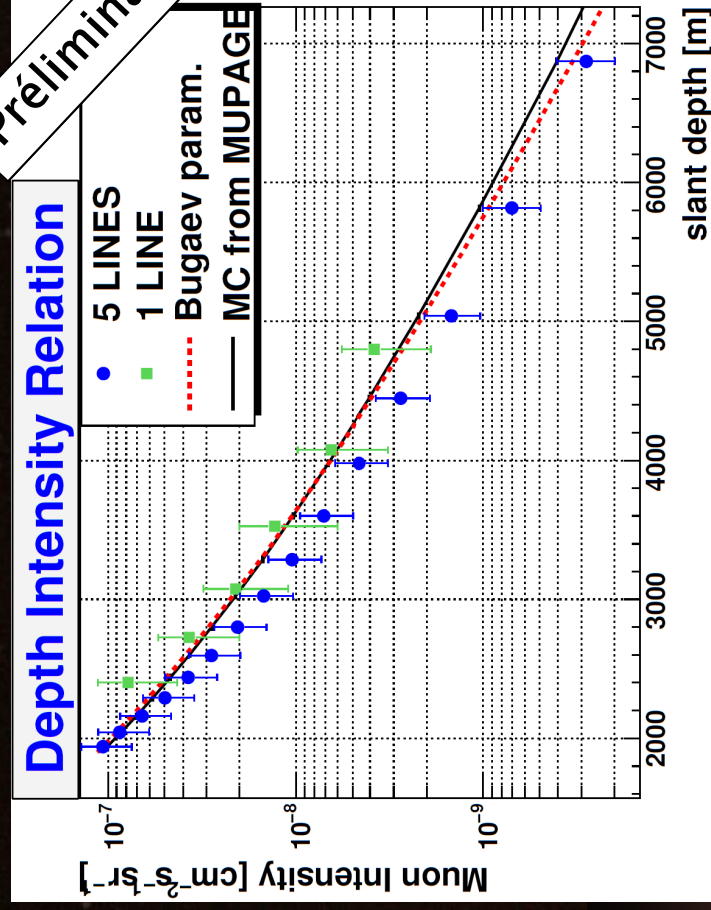
Relation intensité-profondeur



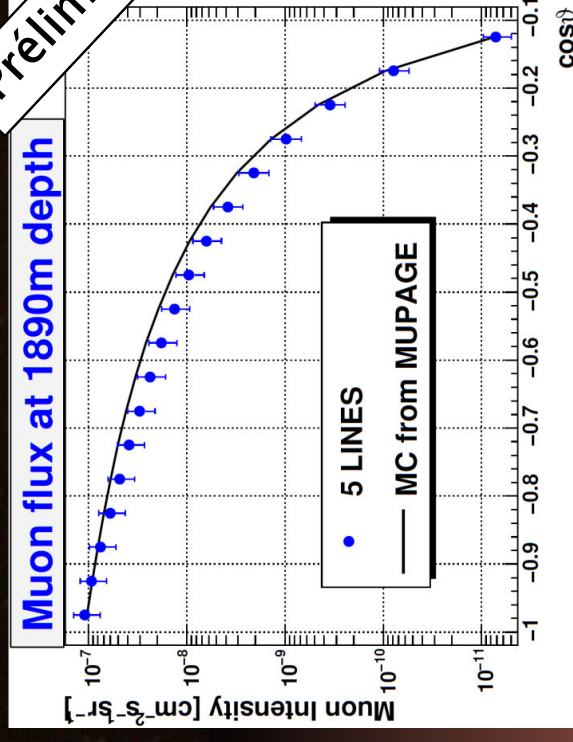
5 lignes (2007)

Relation intensité-profondeur

Préliminaire



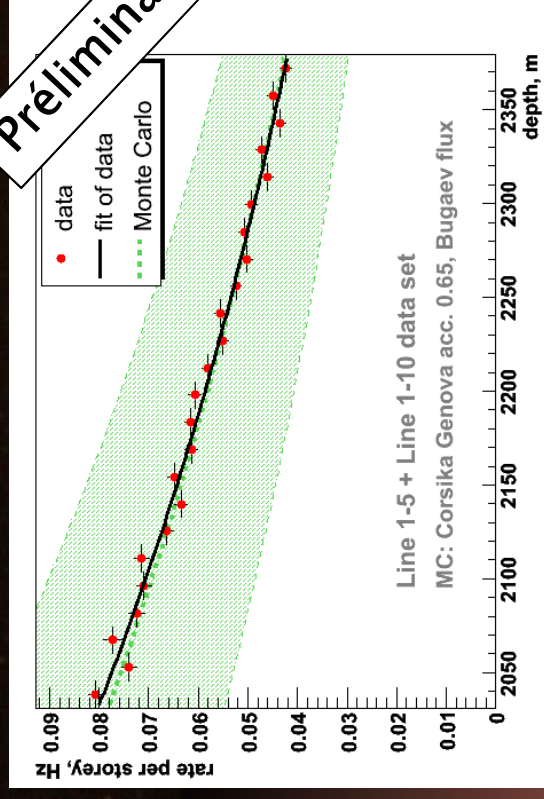
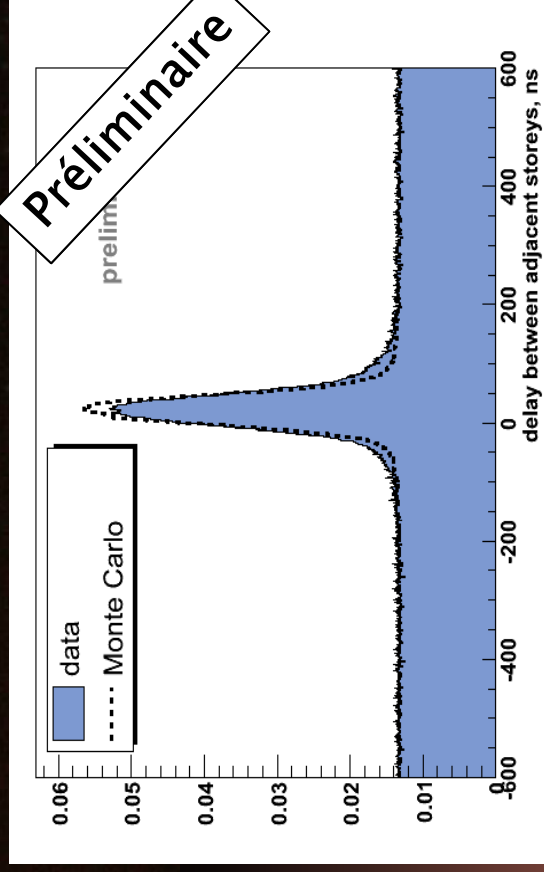
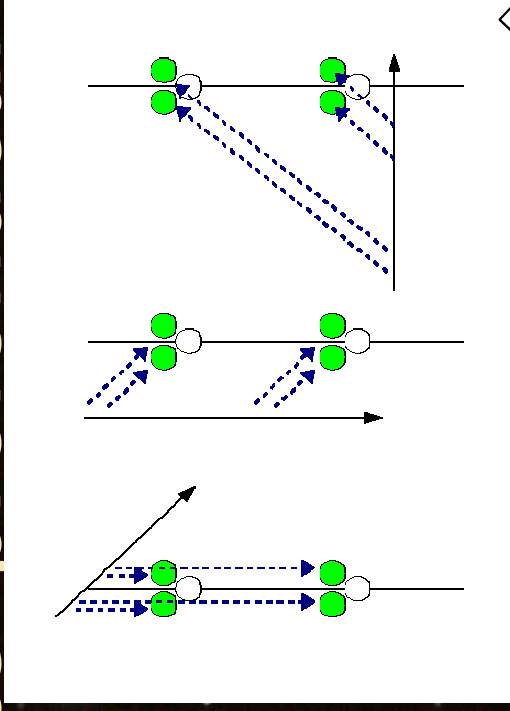
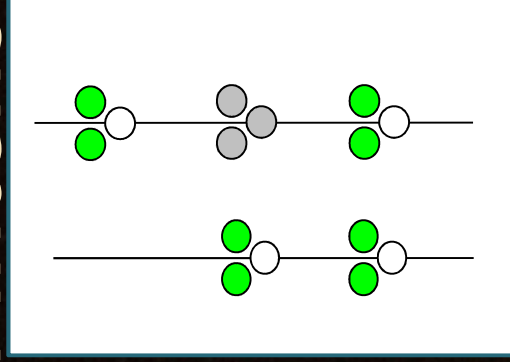
Préliminaire



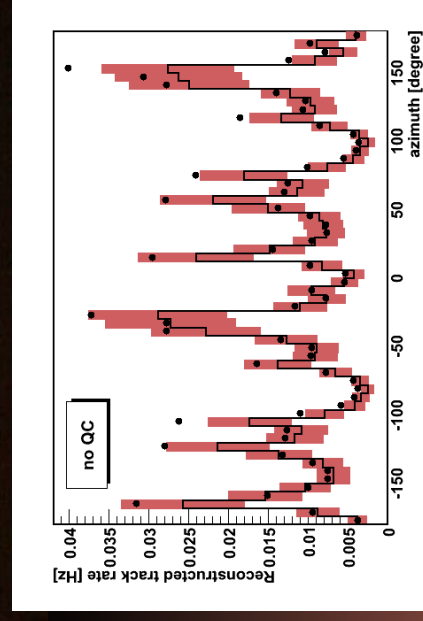
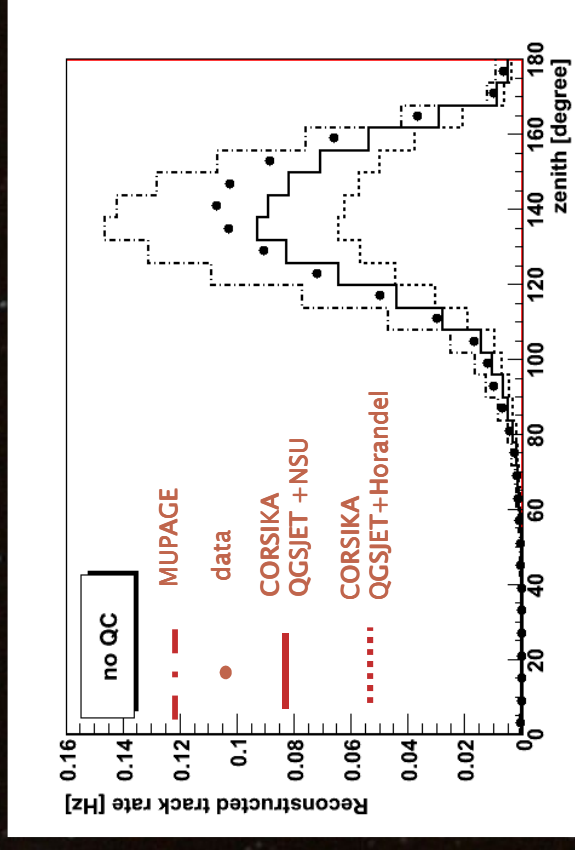
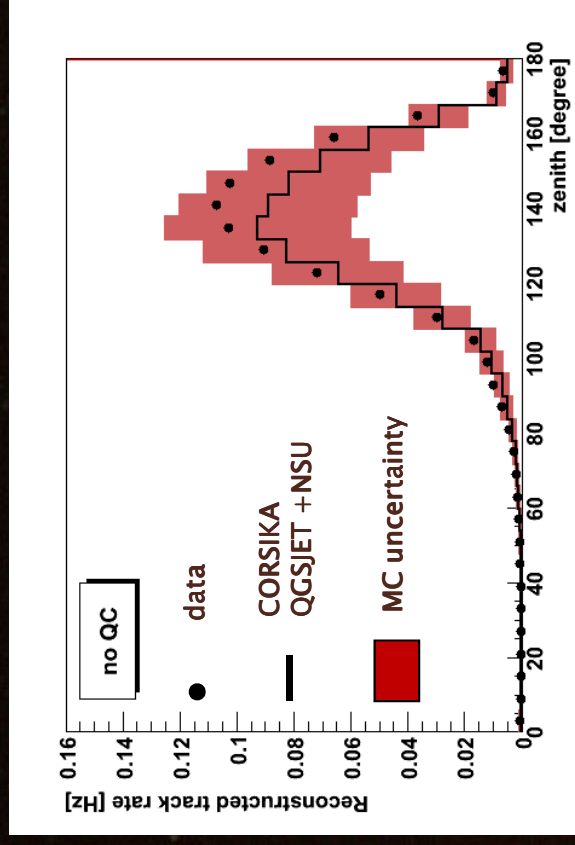
Cf. Thèse Claire Picq
18 juin 2009 – 14 h
APC – Salle Klee

Relation intensité-profondeur

- Pas de reconstruction
- Coïncidences entre étages contigus

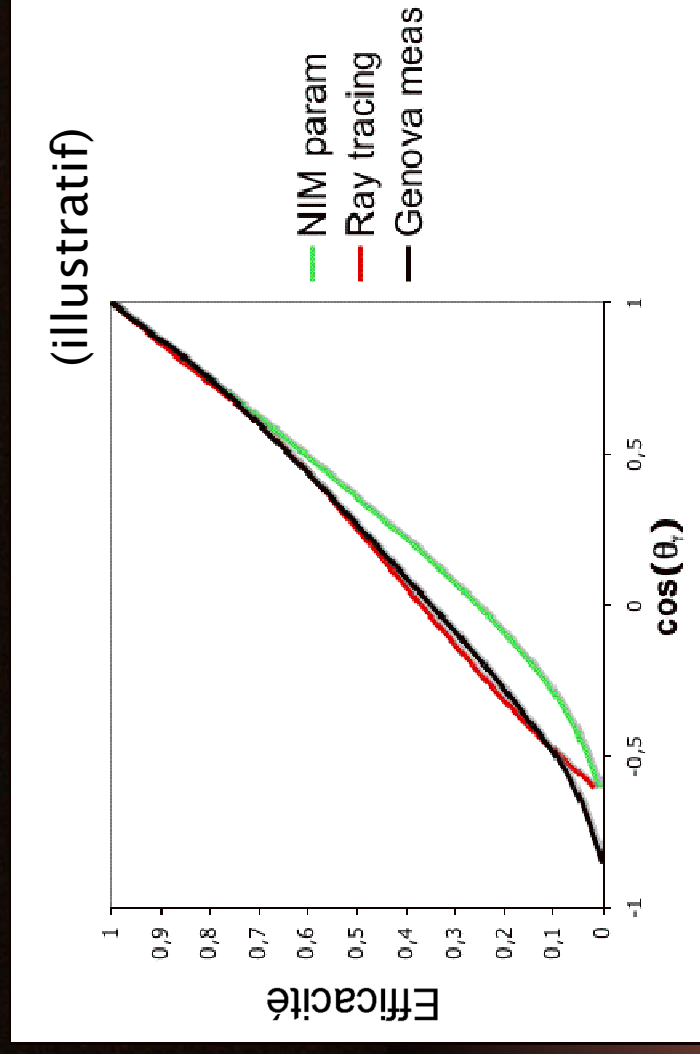
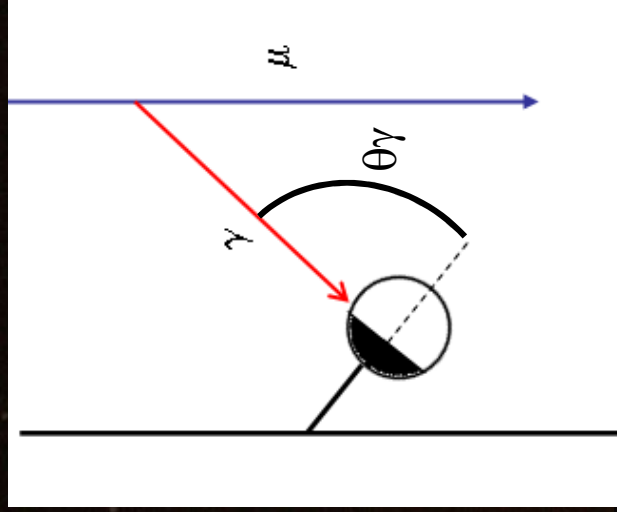


Etude du flux de μ atm.



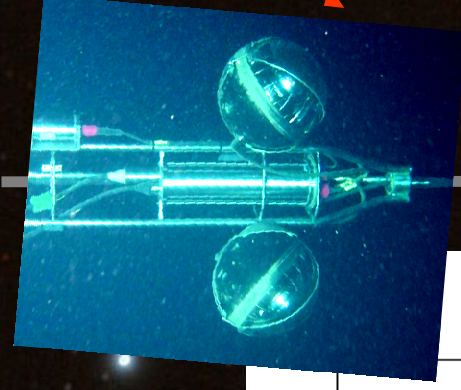
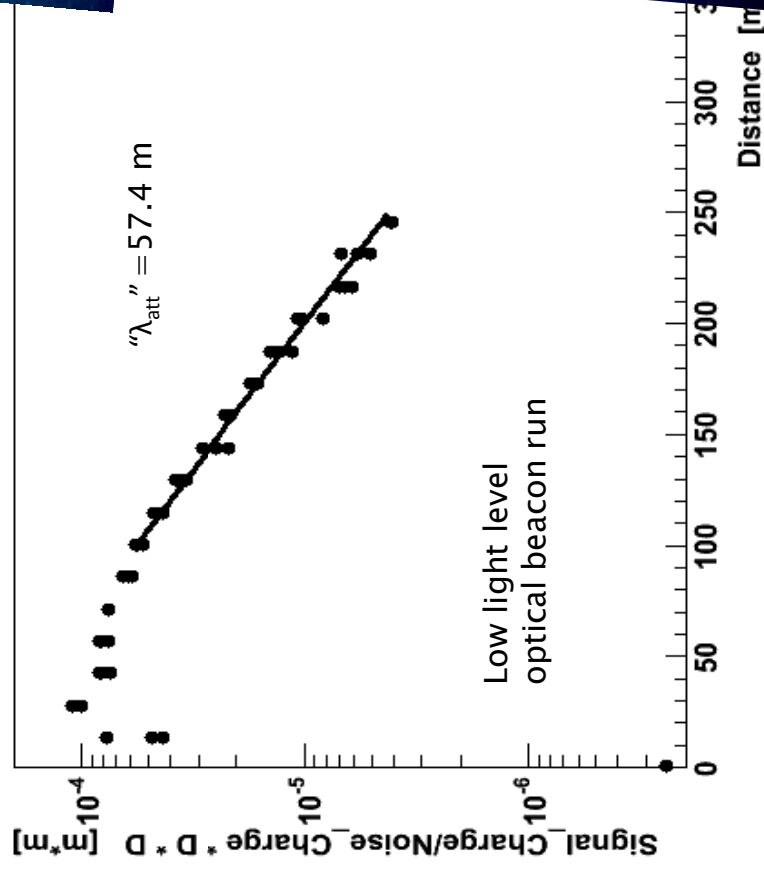
- Accord obtenu sans coupures
- Erreurs expérimentales :
 - acceptance angulaire OM
 - propriétés optiques de l'eau (λ_{abs} λ_{scatt})

Acceptance angulaire

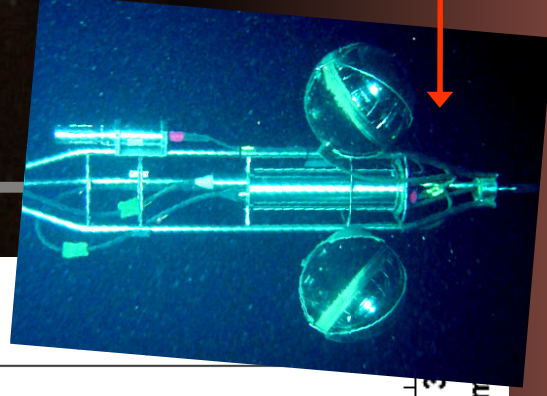


Attenuation

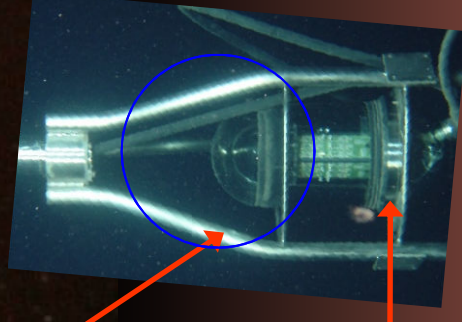
(absorption \otimes diffusion)



~ 150 m



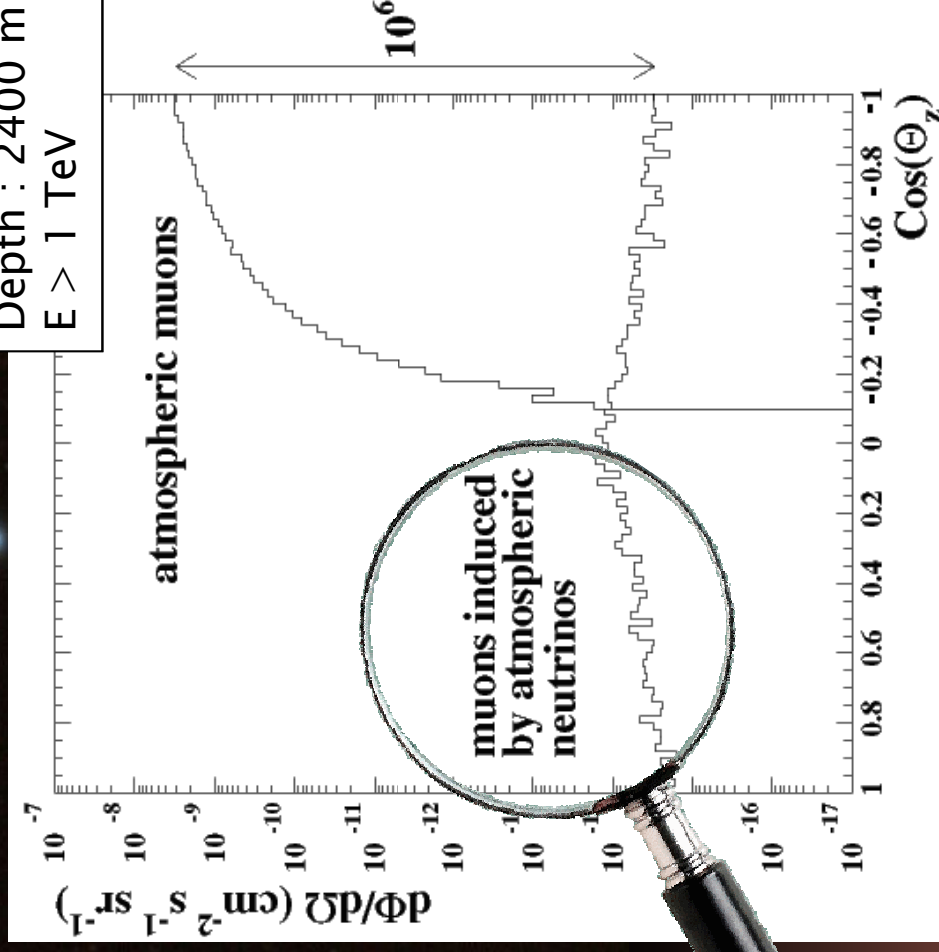
~ 70 m



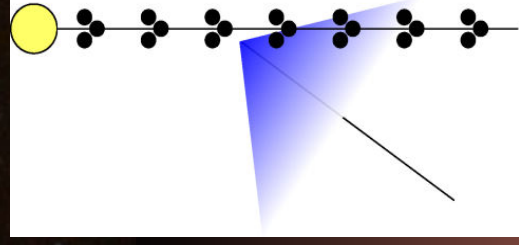
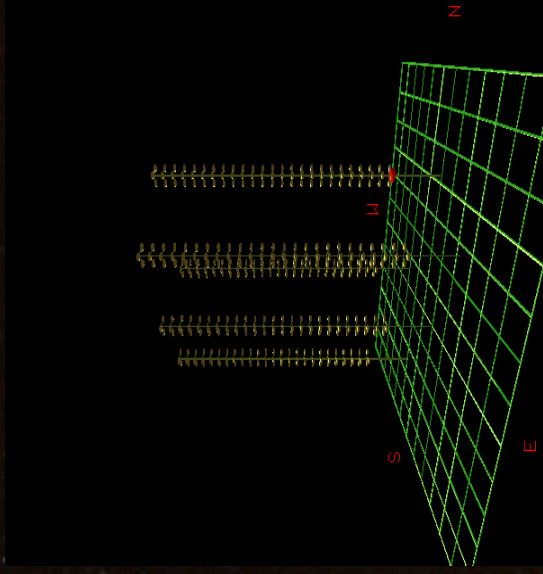
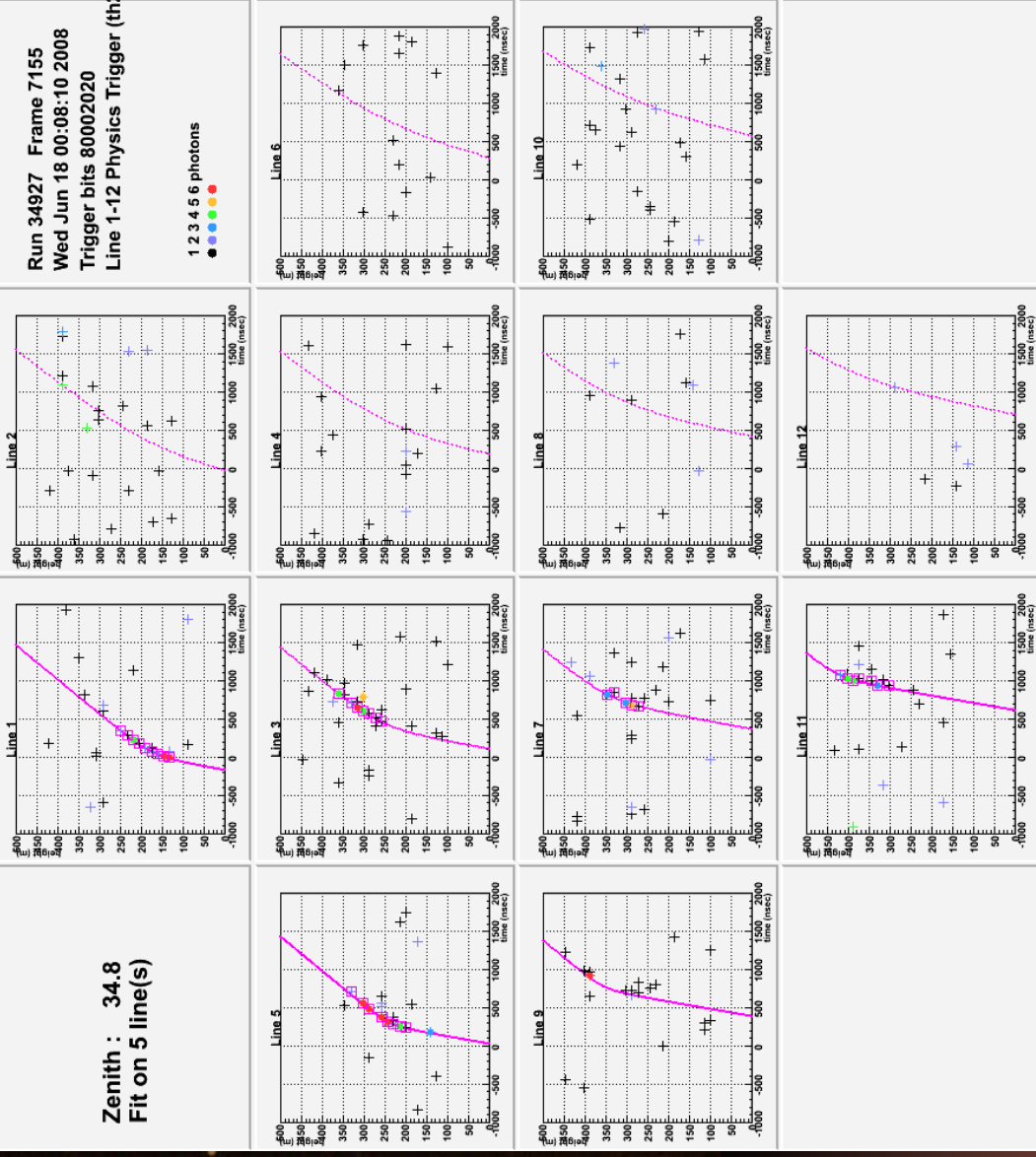
Neutrinos atmosphériques

Depth : 2400 m

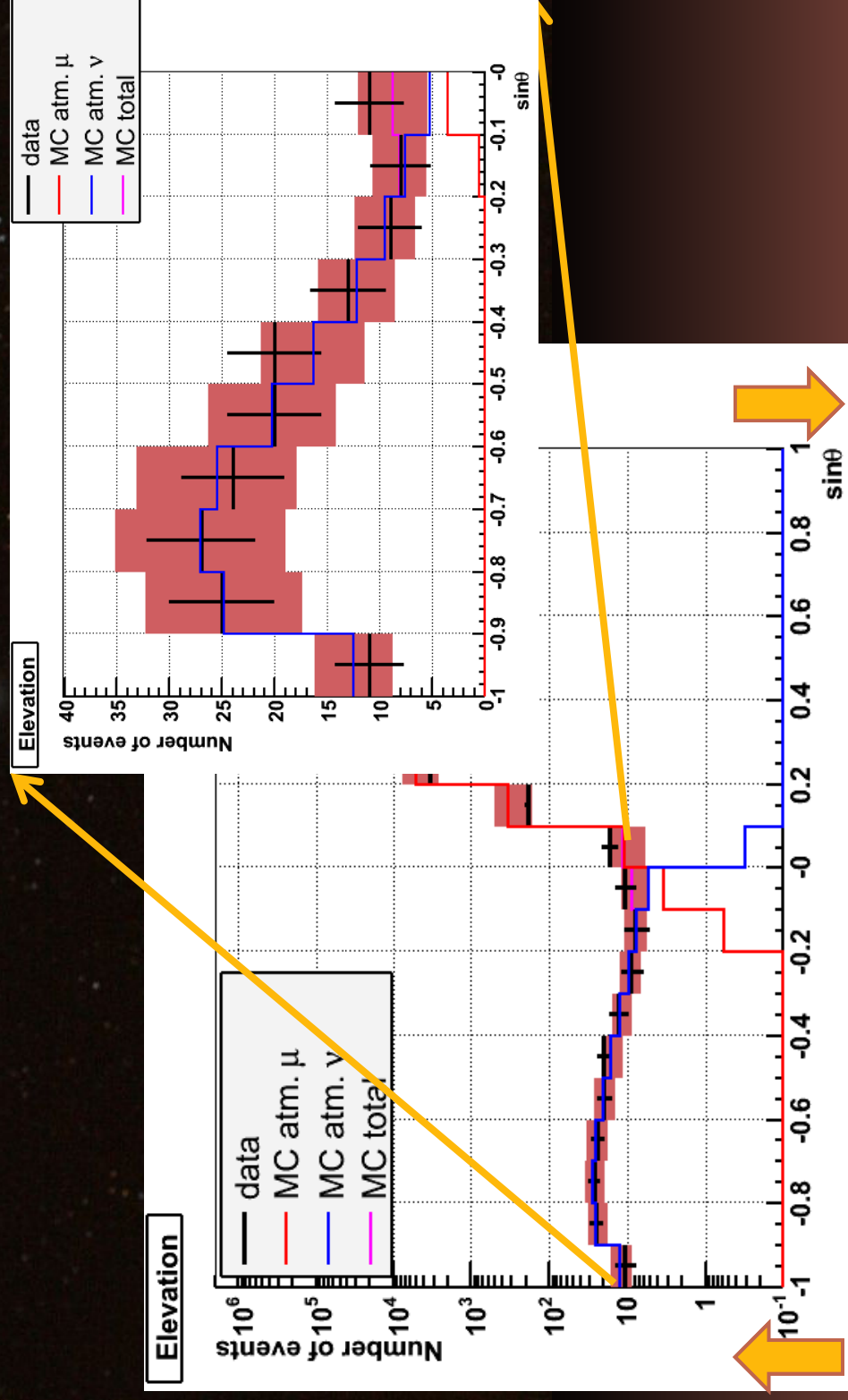
$E > 1 \text{ TeV}$



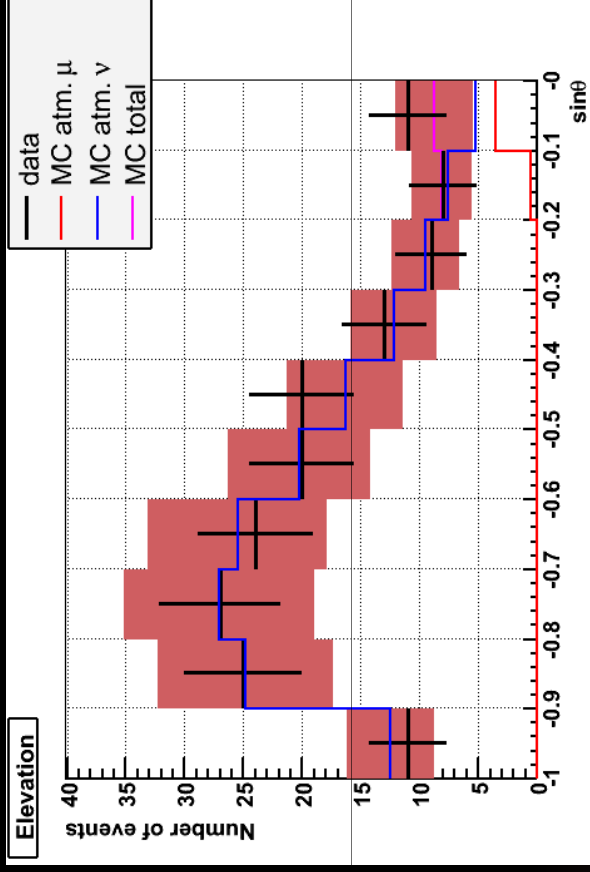
Zenith : 34.8
Fit on 5 line(s)



Données 2007 (5 lignes)

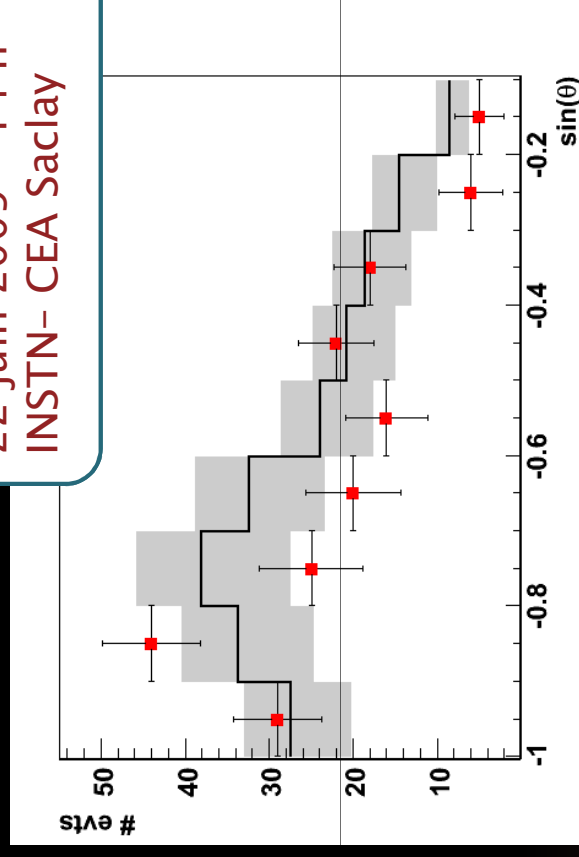


Deux méthodes indépendantes



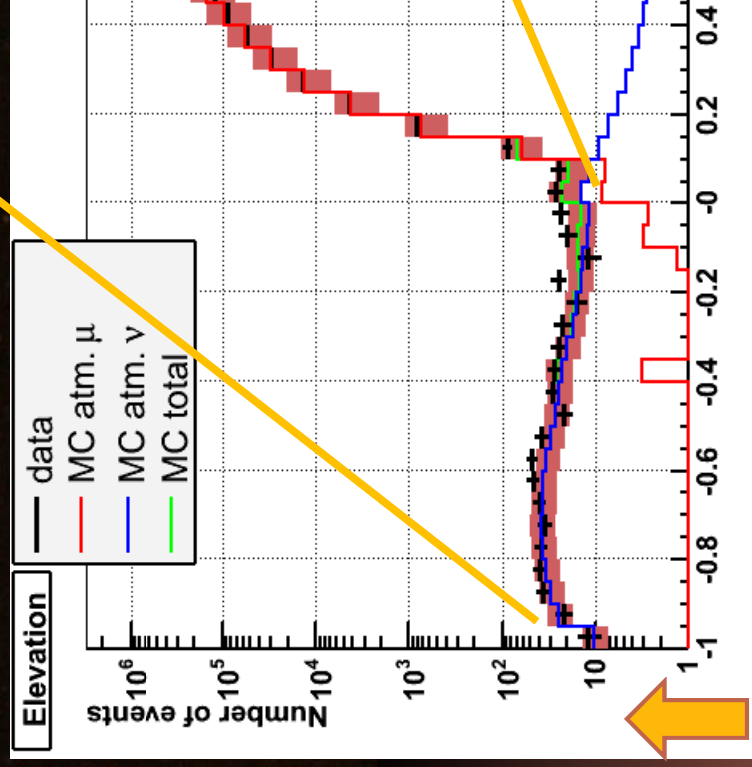
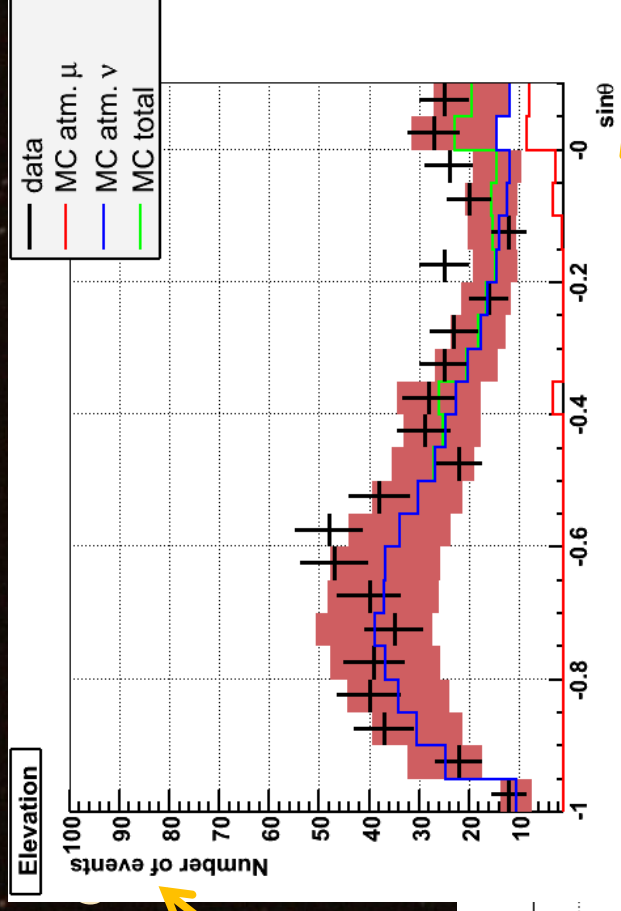
- Observés : 168
- MC : 164
 - ± 3 (stat)
 - ± 33 (théor)
 - ± 16 (syst)

Cf. Thèse N. Cottini
22 juin 2009 – 14 h
INSTN- CEA Saclay



- Observés : 185
- MC : 218
 - ± 4 (stat)
 - ± 41 (théor)
 - $+3$ -42 (syst)

Données 200



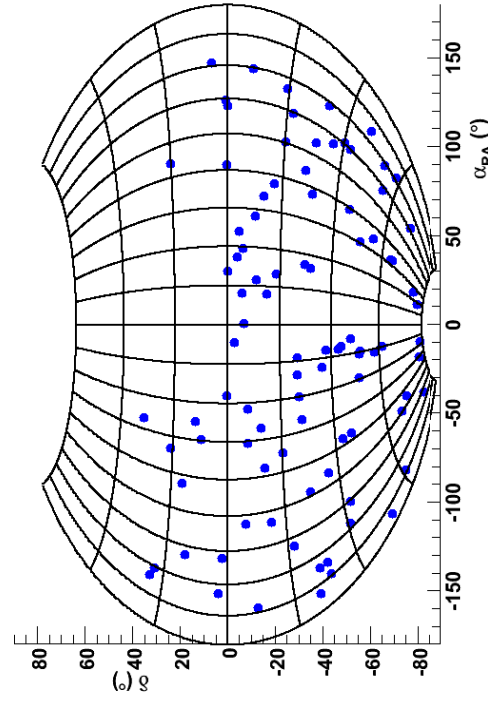
- 174 jours
- 582 μ montants
(> 1 ligne)

Recherche de sources (2007)

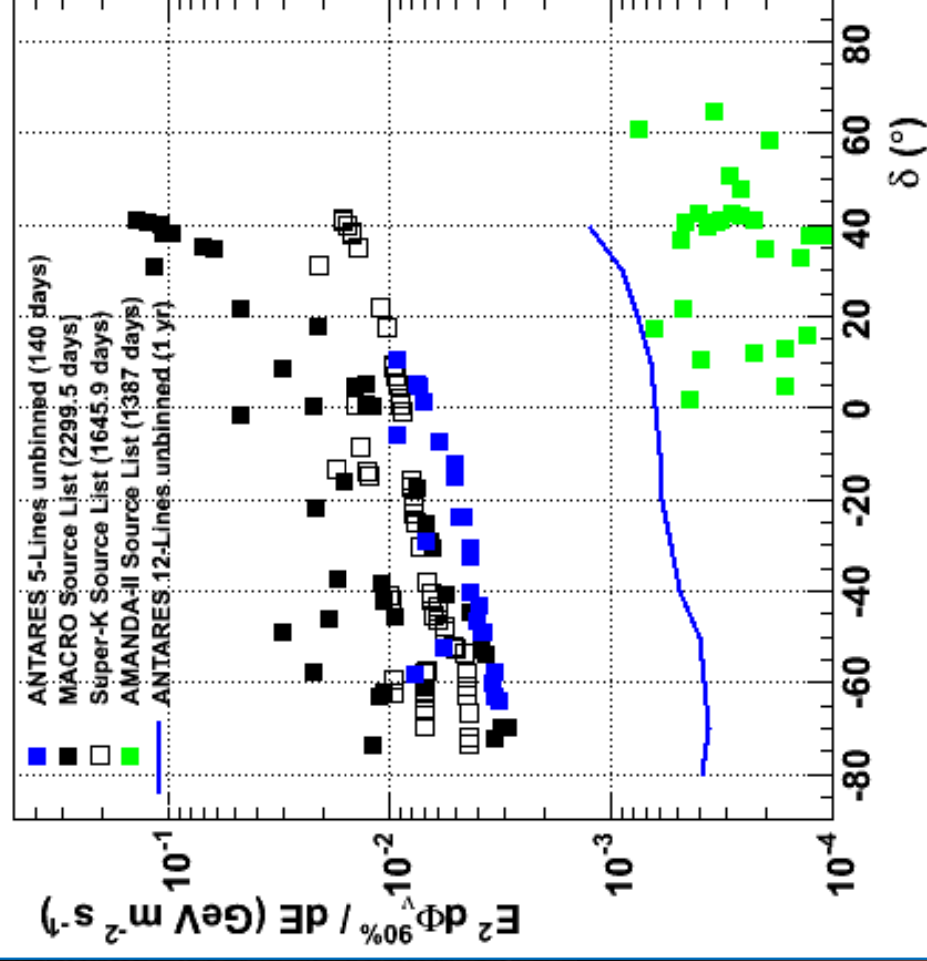
- Analyse en aveugle
 - Coupures strictes
 - Etudes sur données « floutées »
 - Résultats finals sur vraies données
- 94 ev^{ts} candidats
- Recherche appliquée à 25 sources

Source	DECL	AR	Nevents
PSR B1259-63	-63.8339	195.703	0
RCW 86	-62.4833	220.679	0
ESO 139-G12	-59.9414	264.414	0
HESS J1023-575	-57.7639	155.825	1
Cir X-1	-57.1667	230.171	0
HESS J1614-518	-51.82	243.579	1
PKS 2005-489	-48.8219	302.372	0
GX 339	-48.7897	255.704	0
RX J0852.0-4622	-46.3667	133	0
Centaurus A	-43.0191	201.364	0
RX J1713.7-3946	-39.75	258.25	0
PKS 0548-322	-32.2712	87.6692	0
H 2356-309	-30.6275	359.784	0
PKS 2155-304	-30.2217	329.721	0
Galactic Center	-29.0061	266.421	1
1ES 1101-232	-23.4919	165.909	0
W28	-23.335	270.425	0
LS 5039	-14.825	276.562	0
1ES 0347-121	-11.9908	57.3459	0
HESS J1837-069	-6.95	279.408	0
3C 279	-5.78917	194.046	1
RGB J0152+017	1.78861	28.1667	0
SS 433	4.98278	287.958	0
HESS J0632+057	5.80556	98.2416	0
IceCube HotSpot	11	153	0

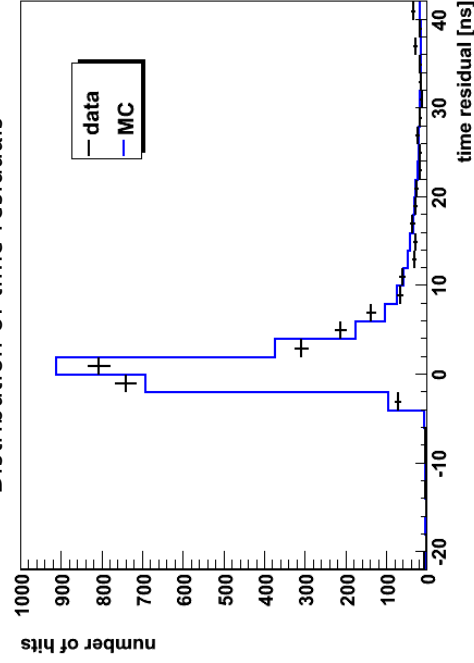
Recherche de sources cosmiques



Spectre en E^{-2}

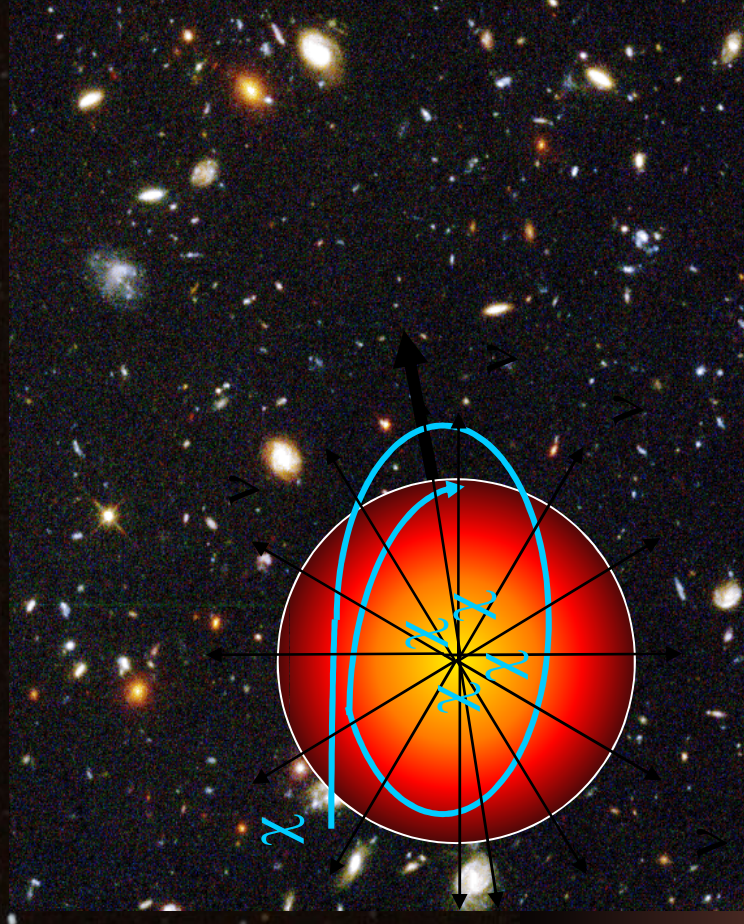


Distribution of time residuals



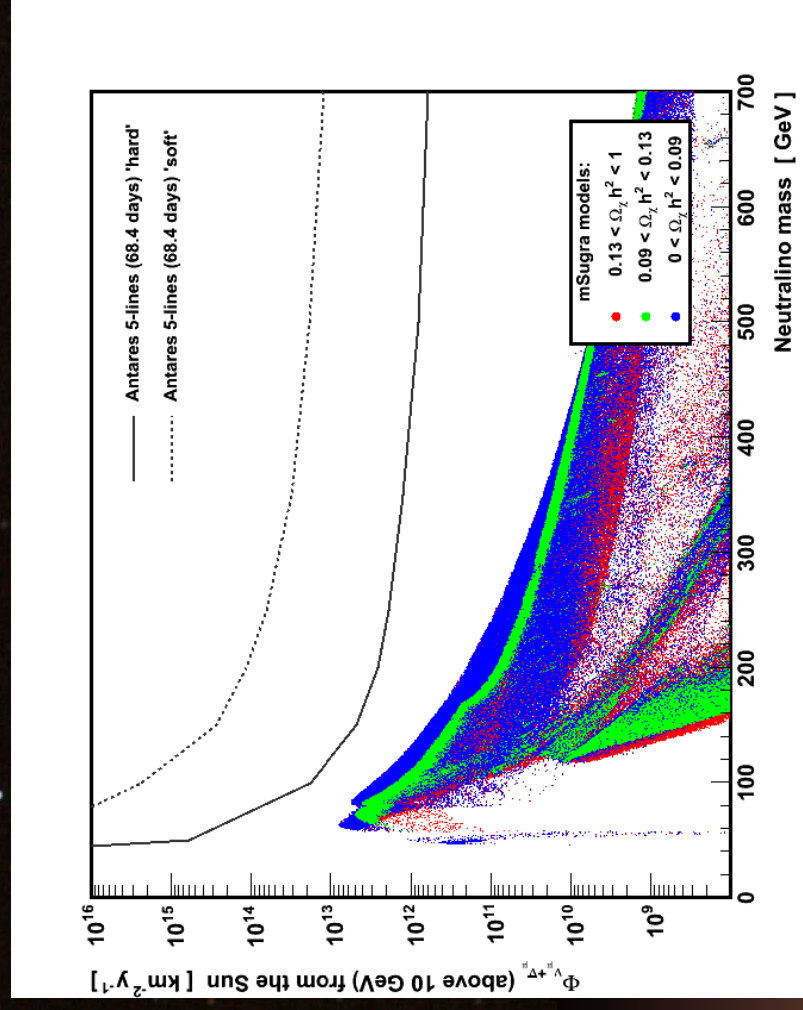
Recherche (indirecte) de matière noire

- WIMPs (χ) piégés par gravitation
 - Terre
 - Soleil
 - Centre de la Galaxie
- Annihilation $\chi\chi$
 - Quarks c,b,t, ou τ
 - Bosons W,Z,H
 - neutrinos

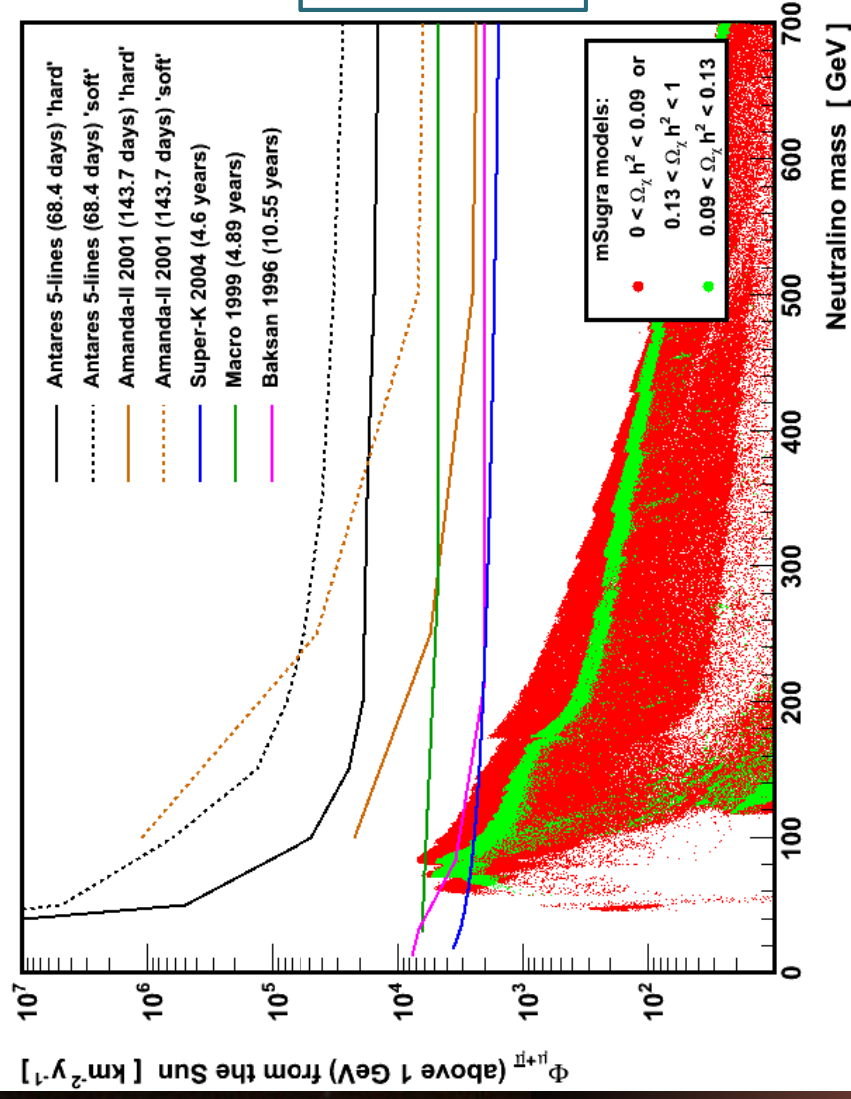


Recherche (indirecte) de matière noire

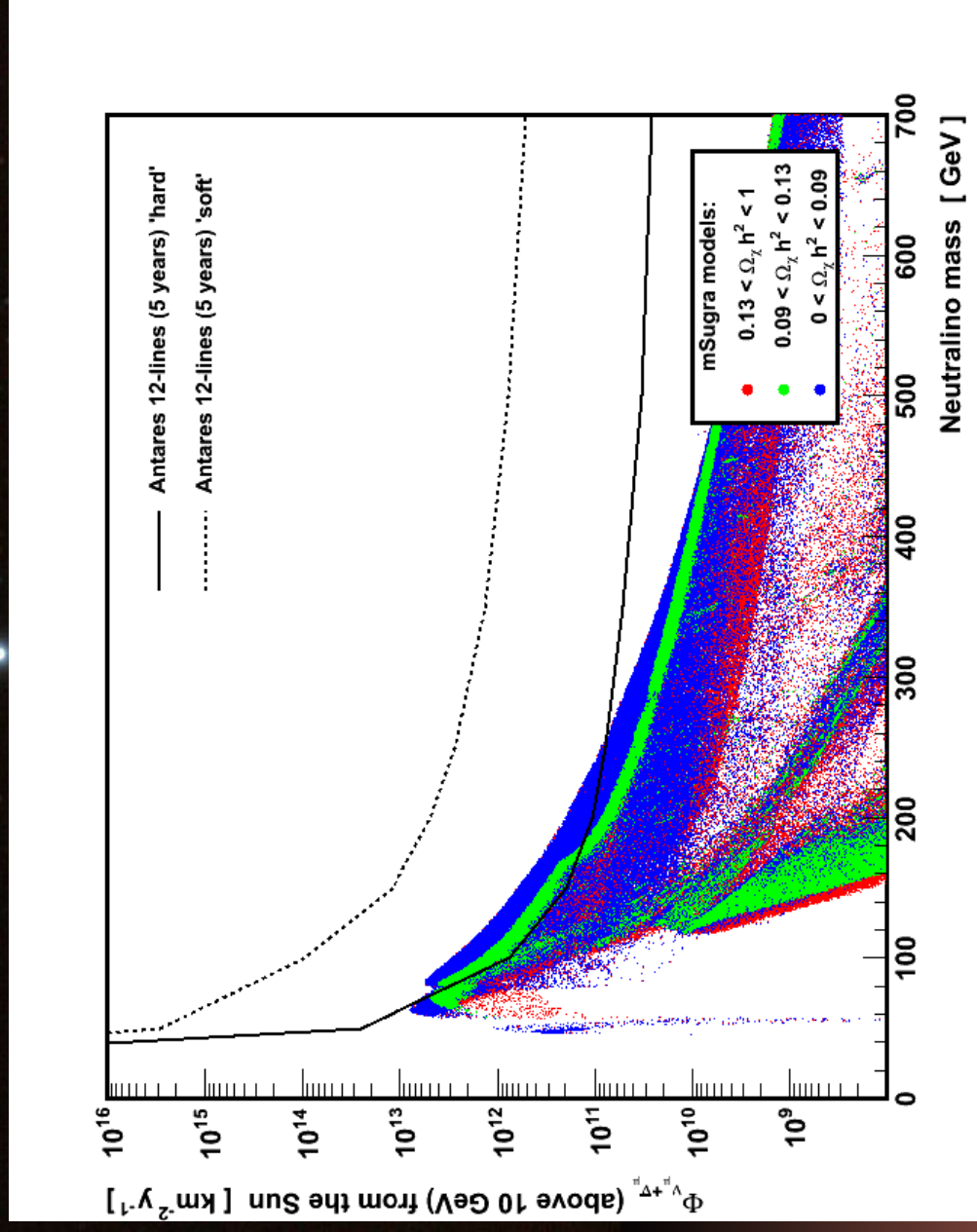
- $\phi(\nu_\mu + \bar{\nu}_\mu)$ du Soleil
- 68,4 jours eff.
 - 168 j
 - 51% Soleil non visible
- Aucun excès
 - 90% C.L. (F.C.)
- Prédiction mSugra
 - Densité relique
 - Favorisé WMAP
 - > WMAP
 - < WMAP



Φ_{μ} du Soleil

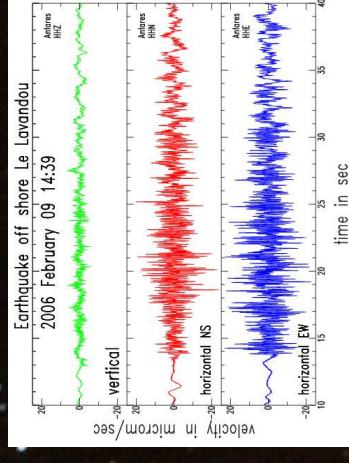
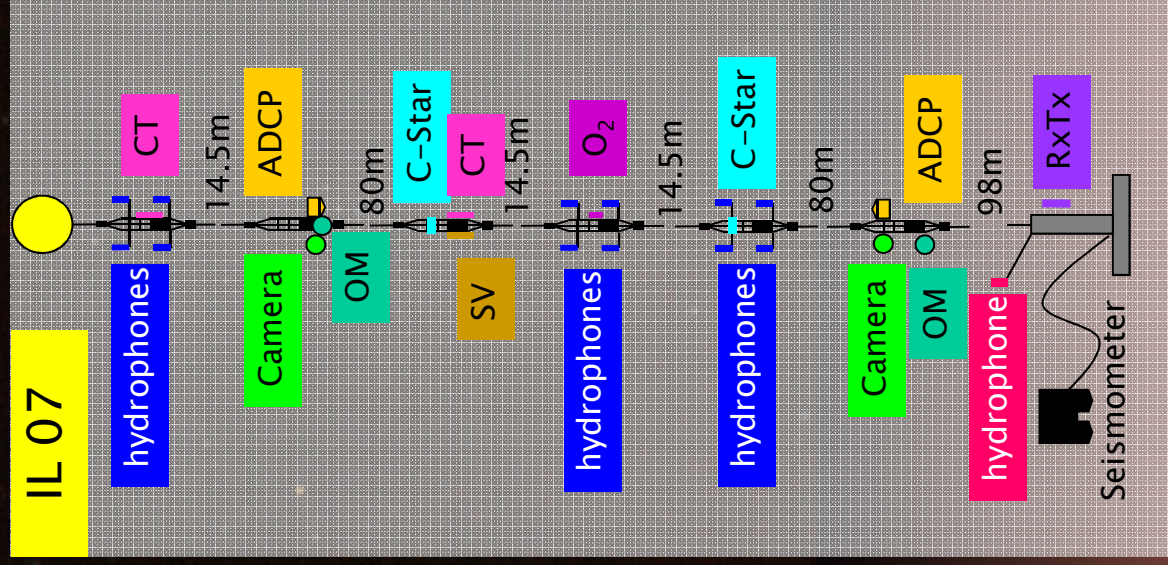


12 lignes, 5 ans, flux ν



Les autres sciences

- Sismologie
- Détection acoustique
- Océanographie
- Climatologie

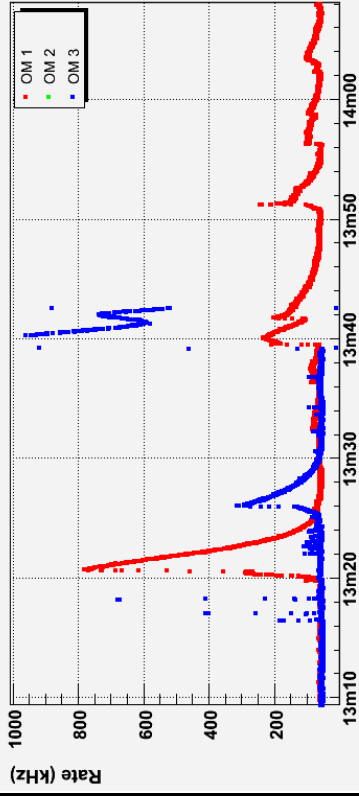


Premières vues des abysses...

2008-01-14 09:14:53



Run 30572 Biocam DAQ SCAN Line 14 Floor 1 Mon Dec 10 08:13:37 2007



2007-12-10 08:18:01



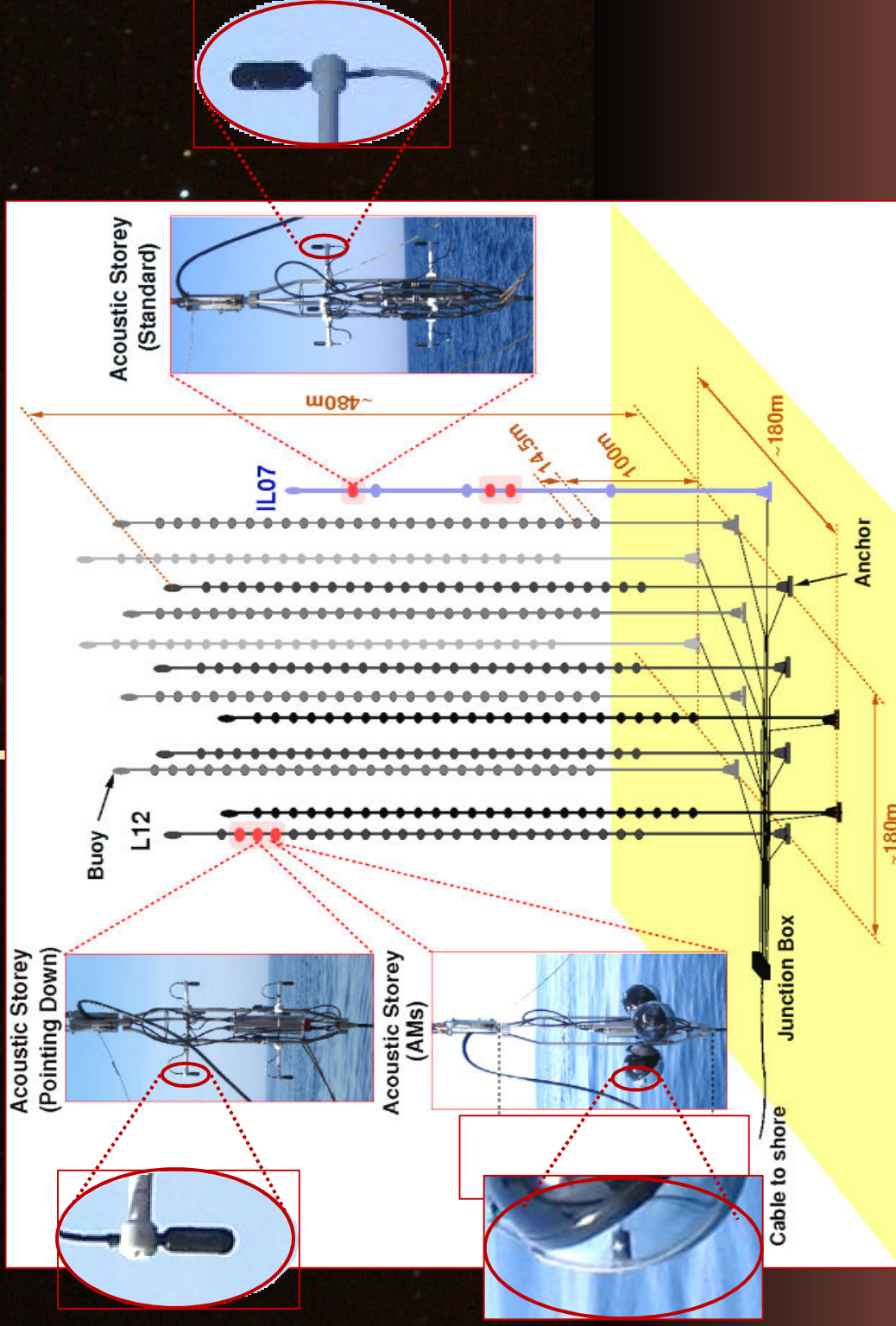
2007-12-10 floor5

2007-12-10 08:18:04

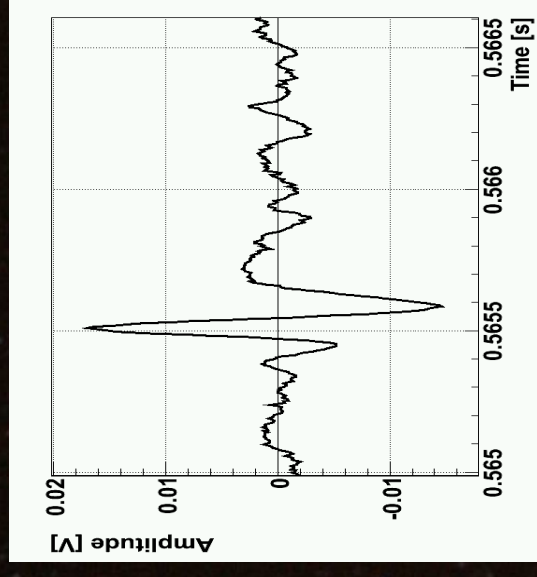
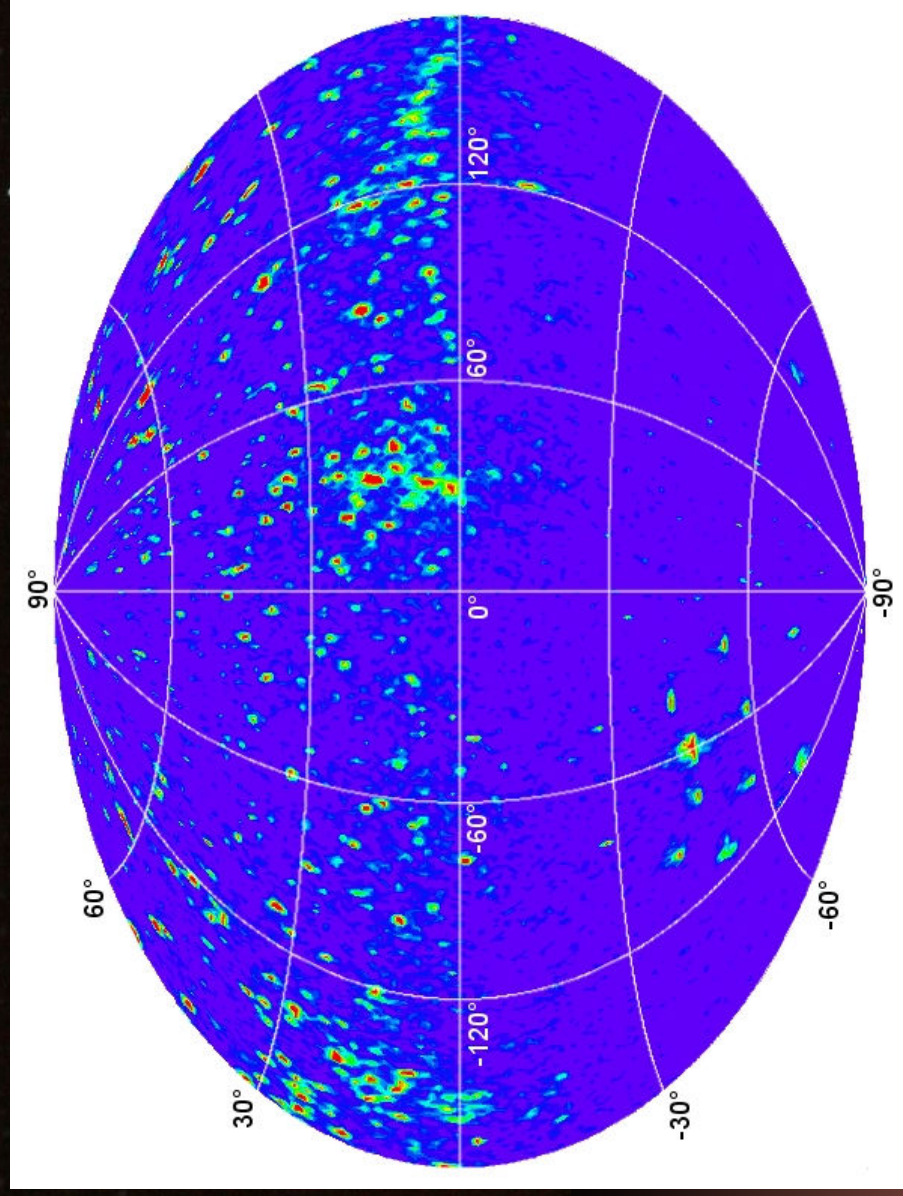
2007-12-10 08:18:03



R&D acoustique

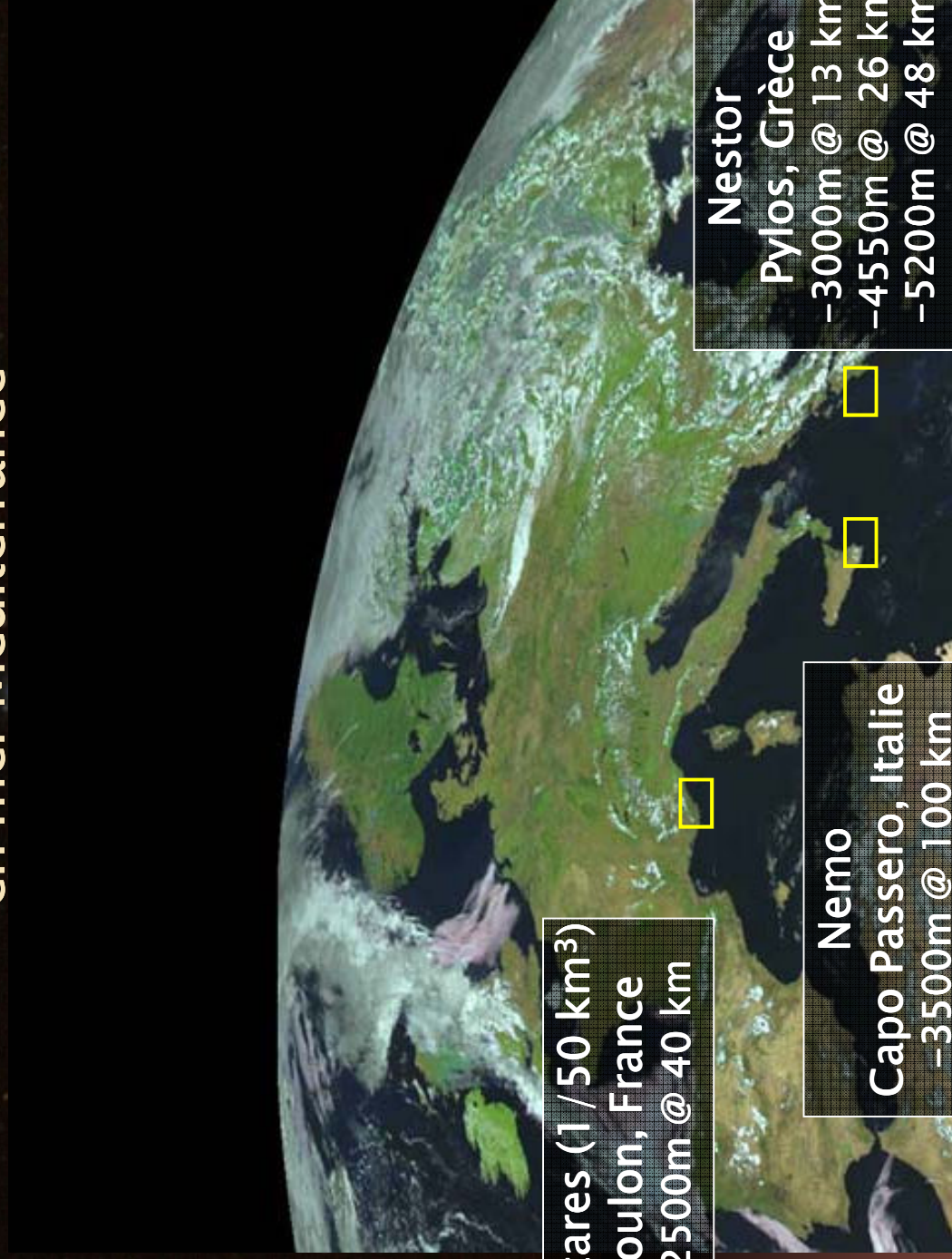


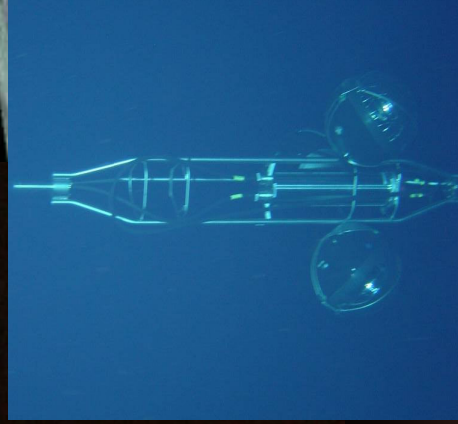
R&D acoustique



Détection de cétacés

Vers un détecteur km³ en mer Méditerranée

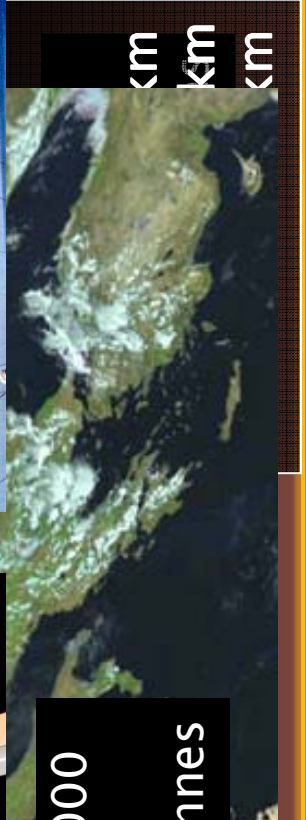
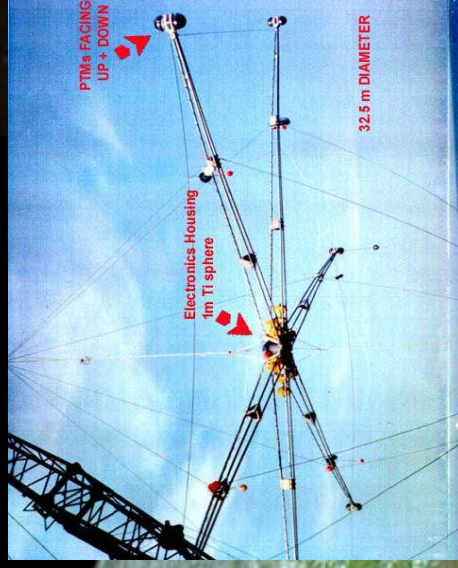




Depuis 1996
Neutrinos
~150 personnes



Depuis 2000
R&D
Nemo
Capo Passero, Italie
-3500m @ 100 km



Le consortium KM3NeT



- 10 pays, ~ 40 laboratoires, ~ 200 scientifiques



Cyprus: Univ. Cyprus, Nikosia



France

- CEA Saclay
- CNRS/IN2P3
 - APC, CPPM, IPHC
- GRPHE/Univ. Mulhouse
- Ifremer



Germany

- Univ. Erlangen
- MPIK-Heidelberg
- Univ. Kiel
- Univ. Tuebingen



Greece

- HCMR
- Hellenic Open Univ.
- NCSR Democritos
- NOA/Nestor
- Univ. Athens



Ireland :

- Institute for advanced studies, Dublin



Italy

- **CNR/ISMAR**
- INFN (Univ. Bari, Bologna, Catania, Genova, Pisa, Roma-1, LNS Catania, **Frascati**)
- **INGV**
- **Tecnomare SpA**



The Netherlands

- NIKHEF/FOM
- Univ. Amsterdam
- Univ. Utrecht
- KVI / Univ. Groningen
- NIOZ



Romania : ISS Bucharest



Spain

- **IFIC/CSIC Valencia**
- Univ. Valencia
- UP Valencia



UK

- Univ. Aberdeen
- Univ. Leeds
- Univ. Liverpool
- Univ. Sheffield

Pas dans Antares

KM3NeT (vue d'artiste)

~ 100–200 “lignes”

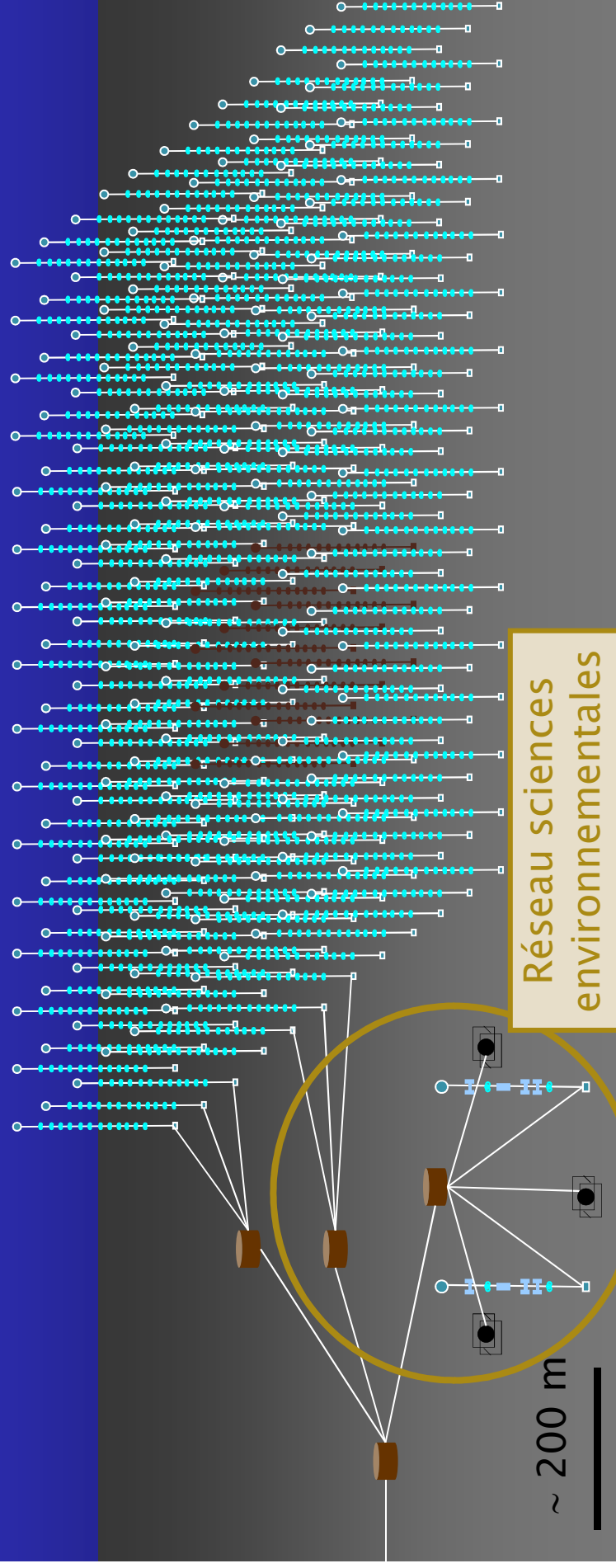
Hauteur : ~ 500 m

Espacement ~ 150 m

~ 20 étages à 25 m

~ 5000–10000 PM

Volume instrumenté
~ 1 km³
(ou plus)



- « **Design study** » – **FP6 - 2006 - 2009**

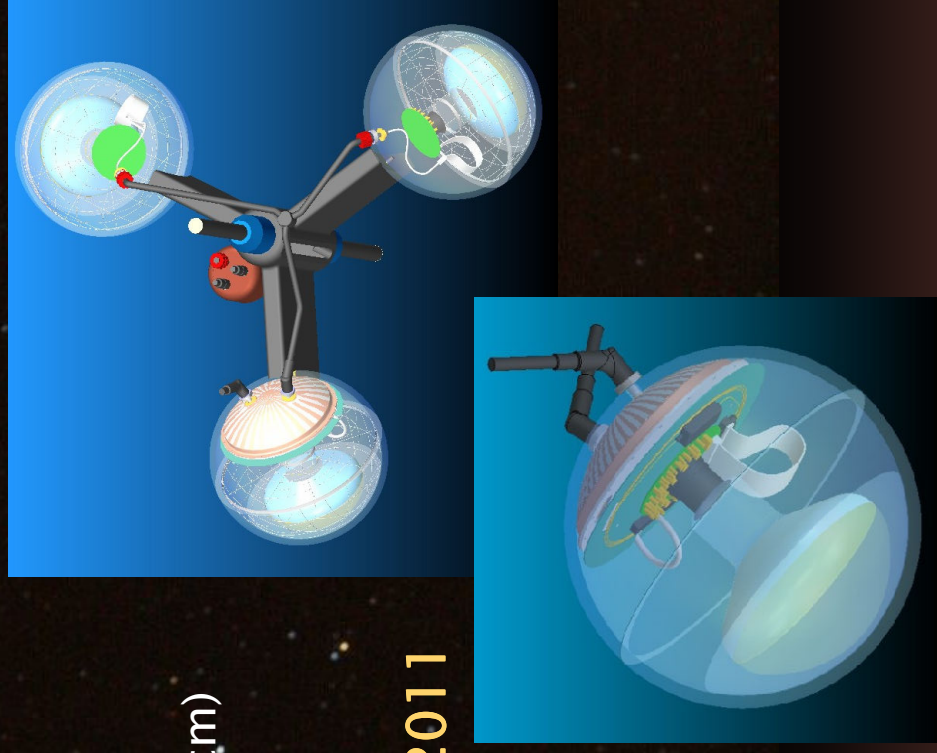
- CDR publié (Avril 2008)
- TDR pour l'automne
- Résolution : $0,1^\circ$ ($\delta t < 2$ ns, $\delta x < 40$ cm)
- Construction et Déploiement 4 ans
- Maintenance limitée

- **Phase préparatoire - FP7 - 2008-2011**

- Préparer la future collaboration
 - Structure légale et gouvernance
 - Scénario de financement
 - Relations avec EMSO
- **Stratégie**
 - Un site ou plusieurs sites ?
 - Extension du détecteur
 - Élargir le nombre de partenaires
- Définir le mode de production
 - Prototypes

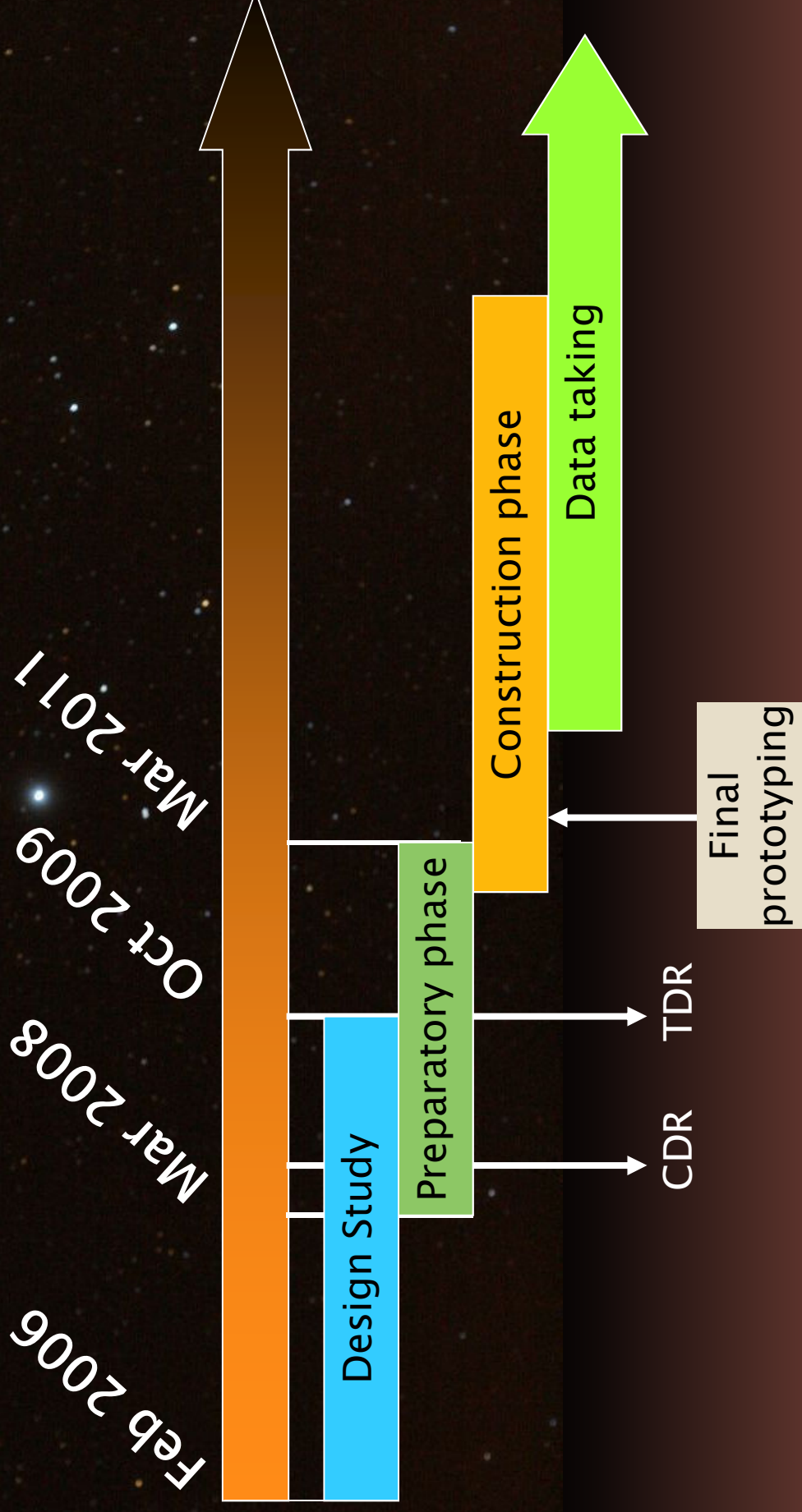
- Depuis sept. 2006 dans l' « ESFRI roadmap »

Exemple de solution proposée



(ESFRI = European Strategy Forum on Research Infrastructures)

Timeline towards construction



Note: "Construction" includes the final prototyping stage

Premières vues du ciel

- **Détecteur complet depuis fin mai 2008**
 - Données depuis 2006
 - Infrastructure sous-marine temps réel unique en Méditerranée
 - Opérations de déploiement/connexion/maintenance maîtrisées
 - Système d'étalonnage opérationnel, progrès notables sur les systématiques

Physique

- Exploration de l'hémisphère Sud
- Déjà le record de sensibilité (données 2007)

- Oscillations de neutrinos
- Matière noire
- Monopoles, physique des hautes énergies

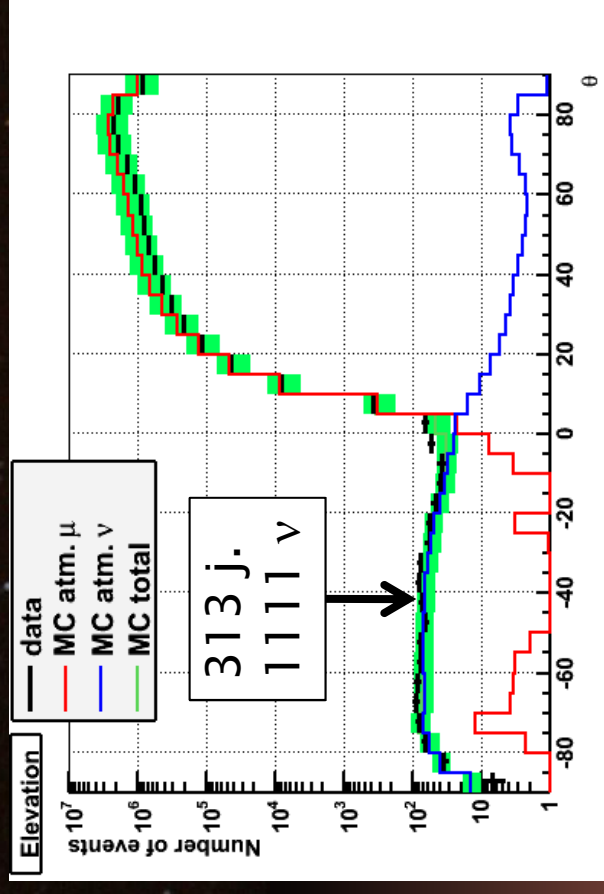
Physique multi-messenger

- Accord en cours LIGO / VIRGO
- Alerte GCN, TAROT (collab. Tatum)
- Auger ?

KM3NeT

- X 50 Antares
- Infrastructure sous-marine

Données 2007 + 2008



Première vue du ciel

