



Plateforme Éducative **Rayons cosmiques et muONs**

# **French Teacher Program** **22-26 octobre 2018** **CERN**



**Cyrille BAUDOUIN**  
**Coordinateur du projet e-PÉRON**

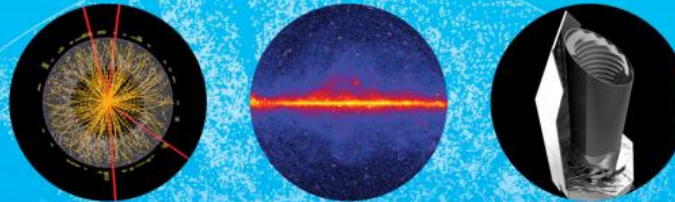
[\*\*baudouin.cyr@gmail.com\*\*](mailto:baudouin.cyr@gmail.com)





The academic community of the South belt of France on the Origins, Constituents and EVolution of the Universe

particle physics  
astroparticles  
cosmology



To find answers to the big questions of contemporary fundamental physics

- Origins of very high energy cosmic rays
- Formation of the first stars and galaxies
- Nature of dark energy and dark matter
- Exploration of new theories in particle physics and in cosmology

collaborative projects  
scientific research  
academic training  
technology transfer  
outreach

OCEVU Laboratory of Excellence - Fundings: 10 ME (2012 > 2020) within the Investissements d'Avenir  
Administrative coordination: Initiative d'Excellence A\*Midex of AMU - Staffs : 450 people from 6 laboratories



UNIVERSITÉ DE MONTPELLIER



# Culture scientifique

## / Plateformes pédagogiques



IRIS New Dome and Site, 30.3.2016

Peter Antol @ OHP



Télescope pilotable à distance @ Observatoire de Haute-Provence

<http://iris.lam.fr/>



Plateforme Éducative Rayons cosmiques et muONS

<https://eperon.omp.eu/>

# Culture scientifique

## / Plateformes pédagogiques / Ressources

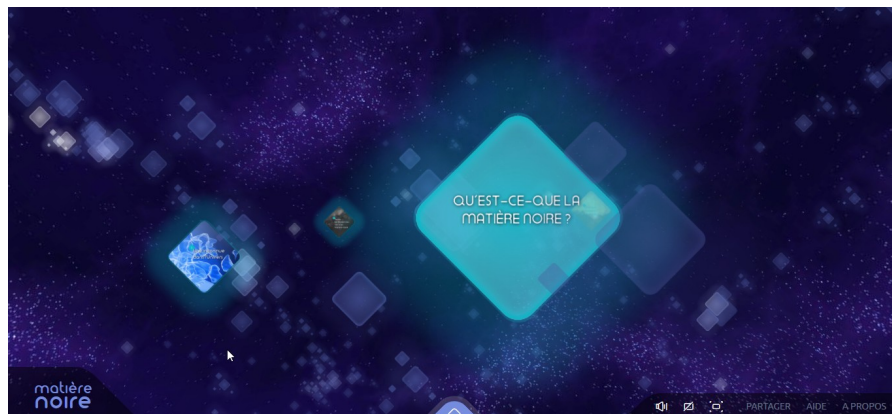


**WEB série Le saviez-vous ?**

**7 épisodes (4')**

**Matière noire, antimatière, gravité,**

**YouTube / *Le Saviez-Vous ? TV***



**Webdocumentaire sur la matière noire**

**[lamatierenoire.fr](http://lamatierenoire.fr)**



# Le projet en quelques mots

Plateforme Éducative Rayons cosmiques et muONs



**Apprendre la physique avec la physique contemporaine**

**Plusieurs expériences sur la physique des rayons cosmiques  
@ Observatoire du Pic du Midi**

**Accessibilité des données et des expériences en ligne  
*Laboratoire virtuel***

**Education / Formation :  
Du secondaire (Lycée) à  
l'enseignement supérieur**

**1/ Le rayonnement cosmique  
aujourd'hui : des sursauts gamma  
aux pyramides**

**2/ e-PERON**

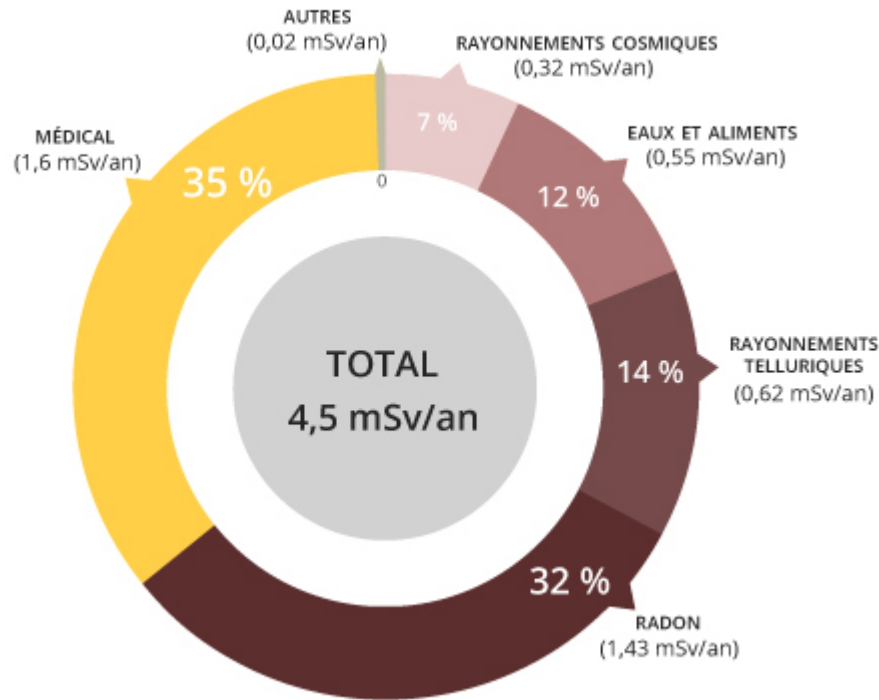
**3/ Les expériences**

**4/ Quoi en faire ?**

**5/ A vous de jouer**

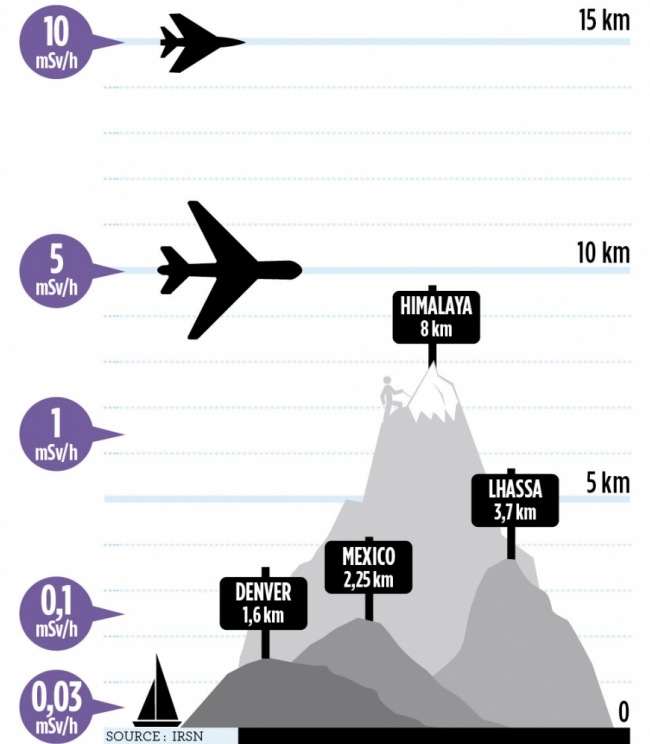
# **1/ Le rayonnement cosmique aujourd'hui : des sursauts gamma aux pyramides**

## Exposition moyenne de la population aux rayonnements ionisants Bilan IRSN 2015



## UN RISQUE EN ALTITUDE

Exposition aux rayons cosmiques en microsieverts par heure

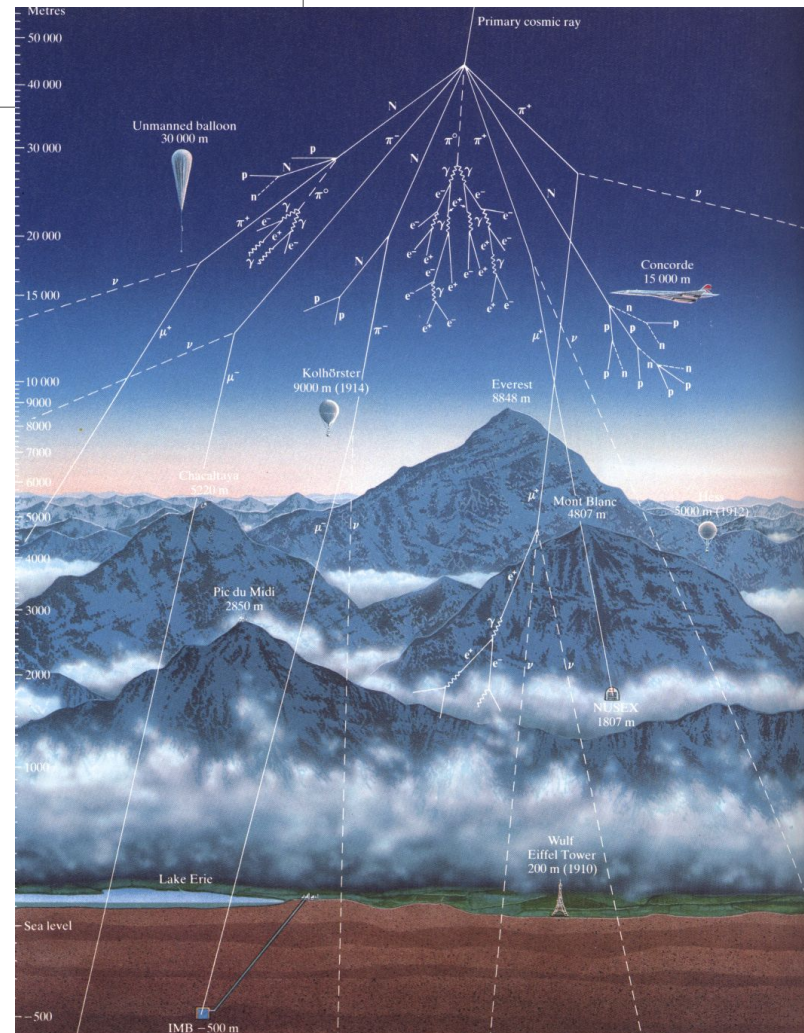
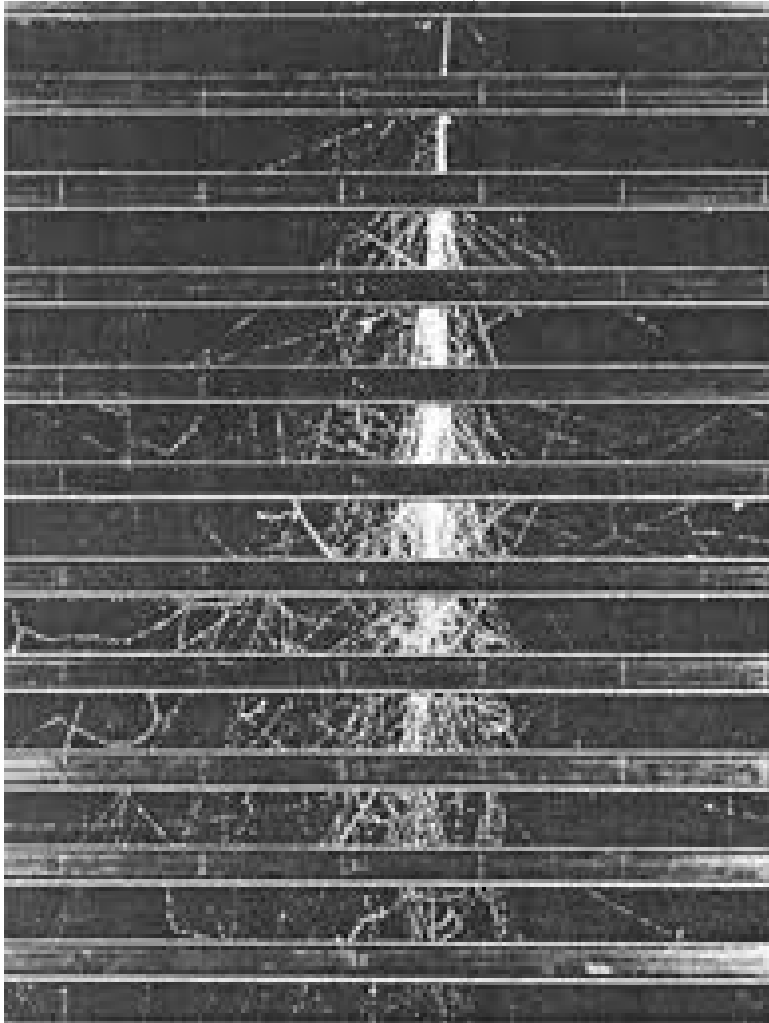
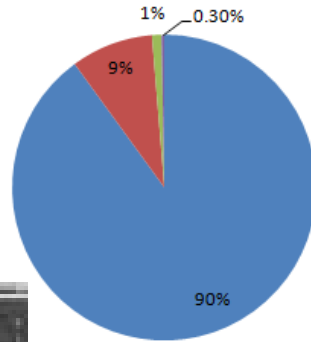


**4 RC / cm<sup>2</sup> / s => 1 kg/an**

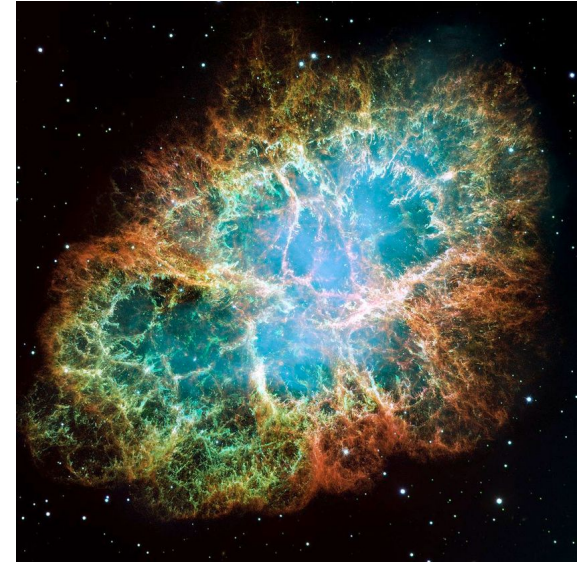
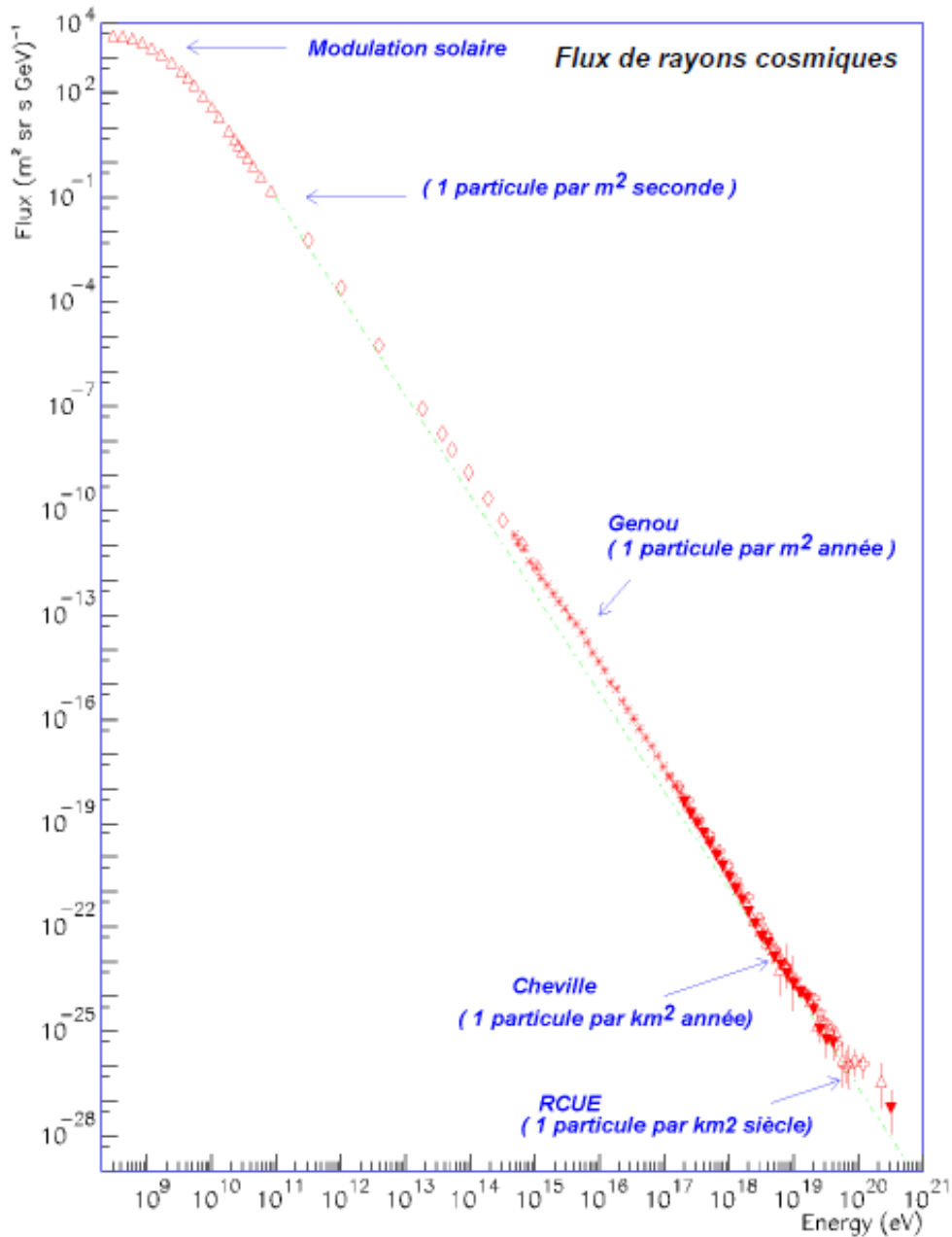


# Composition of Cosmic Rays

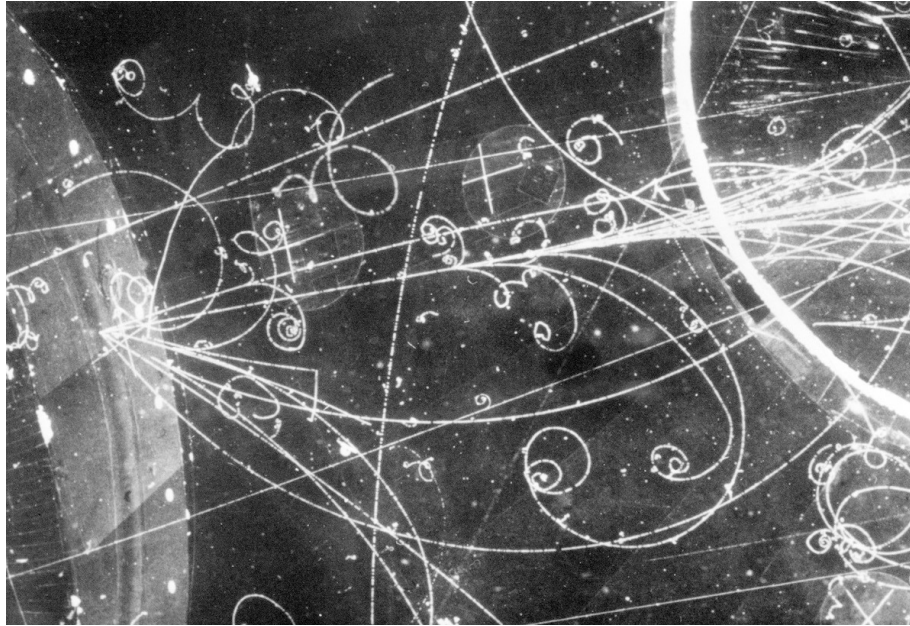
■ Hydrogen Nuclei (protons)   
 ■ Helium Nuclei (alpha particles)   
 ■ Electrons   
 ■ Other



# D'où vient le rayonnement cosmique ?



# Stratégies ?



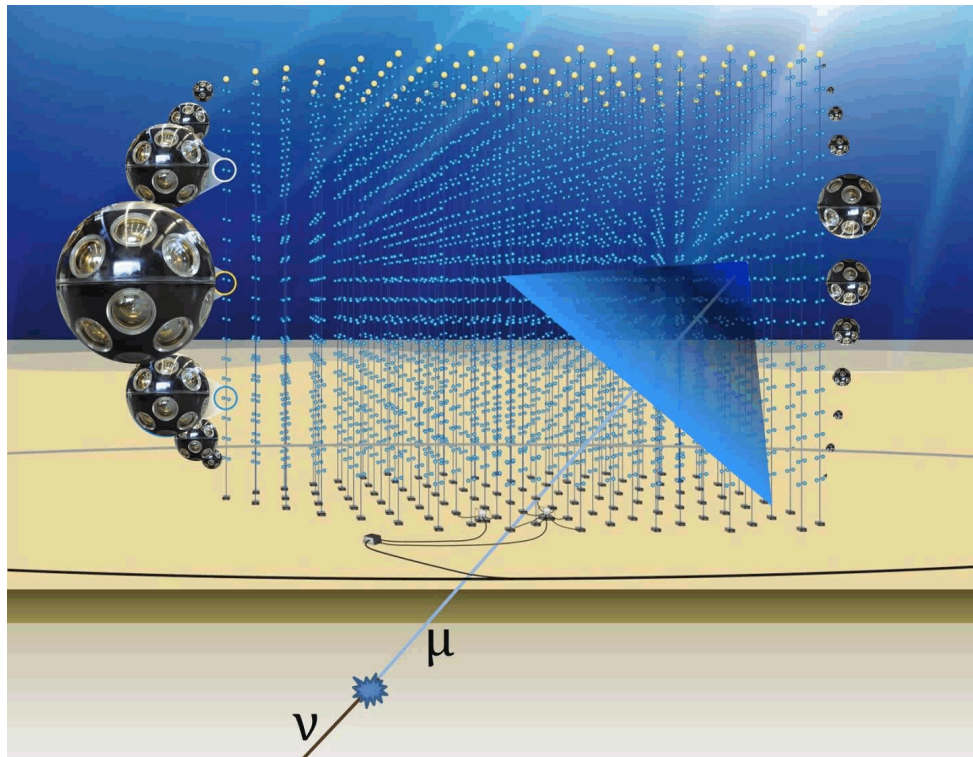
- > **Indirecte**
- > **Ultra haute énergie**
- > **Au-dessus de l'atmosphère**

# Stratégies ?

> Indirecte

Neutrinos → KM3NeT, Ice Cube

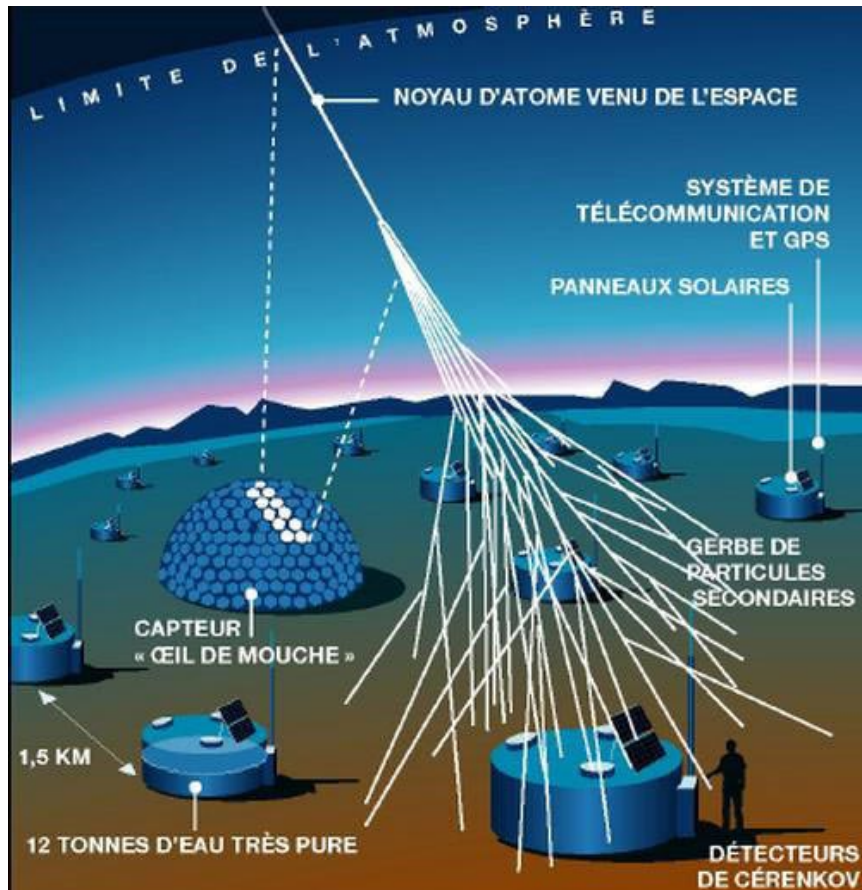
Gamma → HESS, CTA, HAWC...



# Stratégies ?

## > Ultra Haute énergie

### Observatoire Pierre Auger (Argentine)



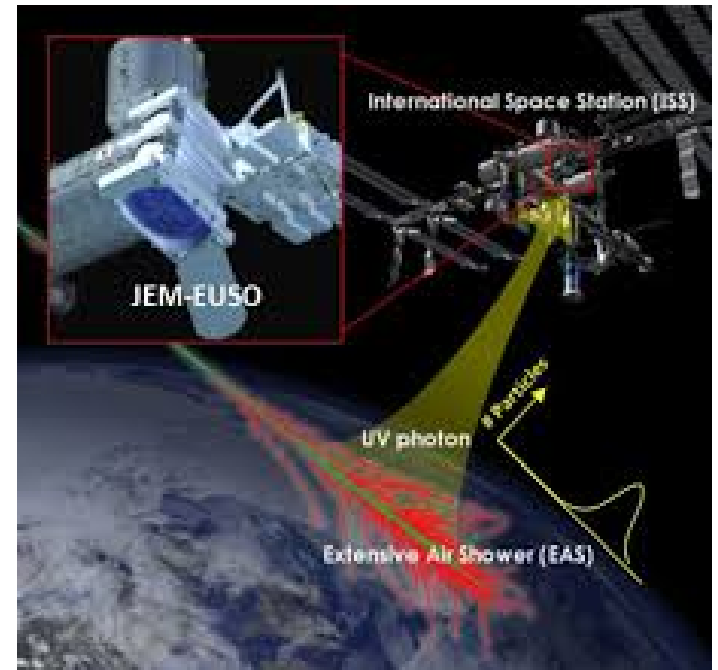
# Stratégies ?

> Au-dessus de l'atmosphère

**AMS**



**JEM-EUSO**



# Les retombées du rayonnement cosmique

## > Impact sur l'environnement terrestre

**Table 1** Cosmogenic isotopes for in-situ exposure age studies of terrestrial rocks

Isotope	Half-life (years)	Principal targets (lithosphere)
$^3\text{He}$	stable	O, Si, Al, Mg, etc
$^{10}\text{Be}$	$1.5 \times 10^6$	O, Si, Al
$^{14}\text{C}$	5730	C, O
$^{21}\text{Ne}$	stable	Mg, Na, Si, Al
$^{26}\text{Al}$	$0.71 \times 10^6$	Si, Al
$^{36}\text{Cl}$	$0.30 \times 10^6$	Cl, K, Ca
$^{53}\text{Mn}$	$3.7 \times 10^6$	Fe
$^{131}\text{Xe}$	stable	Ba



**Déclenchement de la foudre**  
**Physique atmosphère**



**Formation des nuages**  
**Cimatologie, physique**

**Cosmonucléides**  
**Géomorphologie**

# Les retombées du rayonnement cosmique

## > Impact sur les activités humaines

→ Santé des personnels navigants

*Cancers, cataracte*

→ Dommages neuronaux pendant vols spatiaux

*Problématique pour vol habité vers Mars*

→ Electronique

*Accidents auto et aérien recensés*

*Nanoélectronique*



# Les retombées du rayonnement cosmique

## > Le rayonnement cosmique comme sonde

→ Tomographie muonique

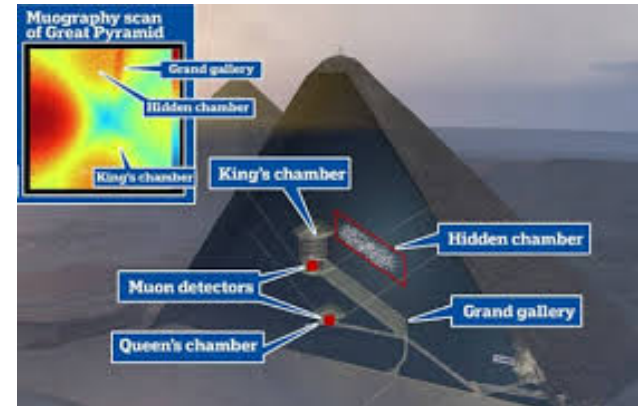
*Archéologie (pyramides)*

*Volcanologie*

*Géologie martienne*

*Industrie nucléaire*

→ *Nivologie*



## 2/ e-PERON

# Objectifs

→ **Faire rentrer la science contemporaine dans les classes**

→ **Mettre à disposition des données de qualité scientifique**

→ **Pas de matériel**

# Laboratoire virtuel

**Expériences / données**



**Base de données**



**Interface WEB**



# Pourquoi au Pic du Midi ?

**Altitude  
2877 m  
Flux x 4**

**Histoire scientifique  
Haut lieu de l'étude des RC**

**Infrastructure  
scientifique &  
technique**

**+  
liens avec  
science @ Pic du  
Midi (aerologie,  
physique solaire)**



# Organisation

**Financements OCEVU**

**2012 – 2018 : 65 k€**

**Coordination générale : Cyrille BAUDOUIN**

**Coordination scientifique : José BUSTO (CPPM) & Damien DORNIC (CPPM)**

**Soutien technique et scientifique (analyse des données, implémentation, maintenance, réseau, web) :**

**Guillaume Chamak (OMP), Olivier Espagnet (OMP), Alain Klotz (IRAP), Aurore Mathieu (CPPM), Damien Turpin (IRAP), Pierre Vert (OMP)**

**+Stagiaires : Antoine Auvity (L3/2016), Yannick Gosset (DUT, 2017), Lou Byrnes (DUT, 2018), Cécile Roques (ENS, 2018)**

**Équipes techniques (CPPM, OMP)**

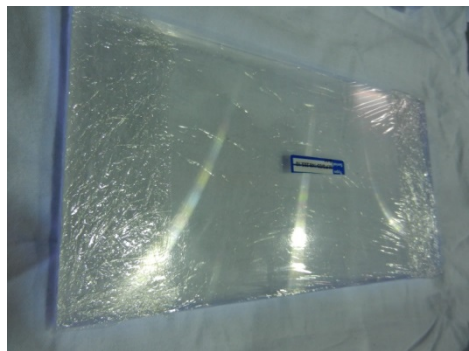


# Le principe



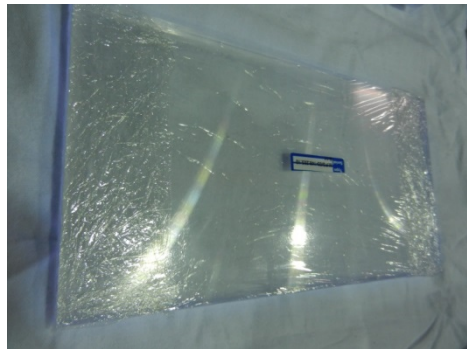
# Le principe

## Scintillation



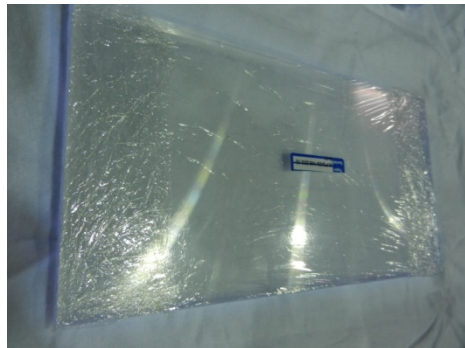
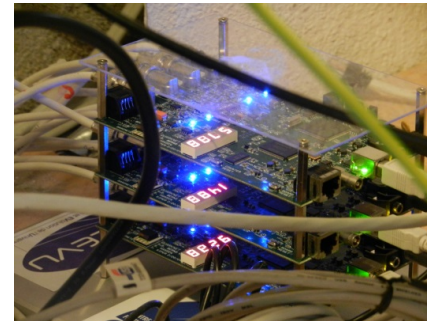
# Le principe

**Scintillation** → **Détection**



# Le principe

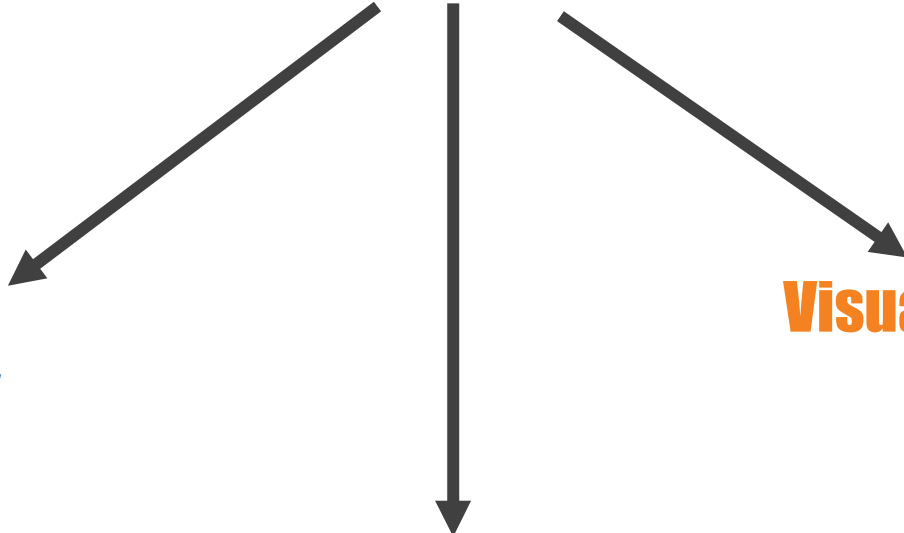
**Scintillation** → **Détection** → **Acquisition**





```
chan0 | chan1 | chan2 | chan3 | R0 | R1 | R2 | R3 | Trigger | Delta_time
6 376.000000 444.000000 448.000000 0.000000 74.700000 9.000000 75311 89.070584
415.000000 0.000000 91.599637 87.799653 82.950000 0.000000 0.000000 5.000
04287 90.404194 84.403916 0.000000 0.200000 0.000000 452.000000 464.00000
0 0.000000 0.200015 4.999620 424.000000 18.000000 0.000000 428.000000 0.000000 84
0252 406.000000 445.000000 451.000000 0.000000 0.000000 81.203330 89.003650 90.203
000 444.000000 0.000000 79.789000 87.777777 88.787853 0.000000 0.799891 5
91.639267 87.829320 82.010000 0.000000 0.000000 0.401047 4.986945 424.000000 460.0
01187 0.000000 1.200016 1.000000 0.000000 0.000000 452.000000 424.000000 0.00000
4.999738 477.000000 443.000000 431.000000 0.000000 95.398817 88.598902 86
```

**Données**



**Données brutes**  
*Universités*  
*(Licence, Master,*  
*DUT)*

**Visualisation graphique**  
*Lycées*

**Données prétraitées**  
*Lycées, DUT*

# 3/ Les expériences

# 3/ Les expériences

- > **Effets Est/Ouest**
- > **Expérience de Rossi**
- > **Vie moyenne du muon**
- > **Données environnementales**

# 3/ Les expériences

> Effets Est/Ouest

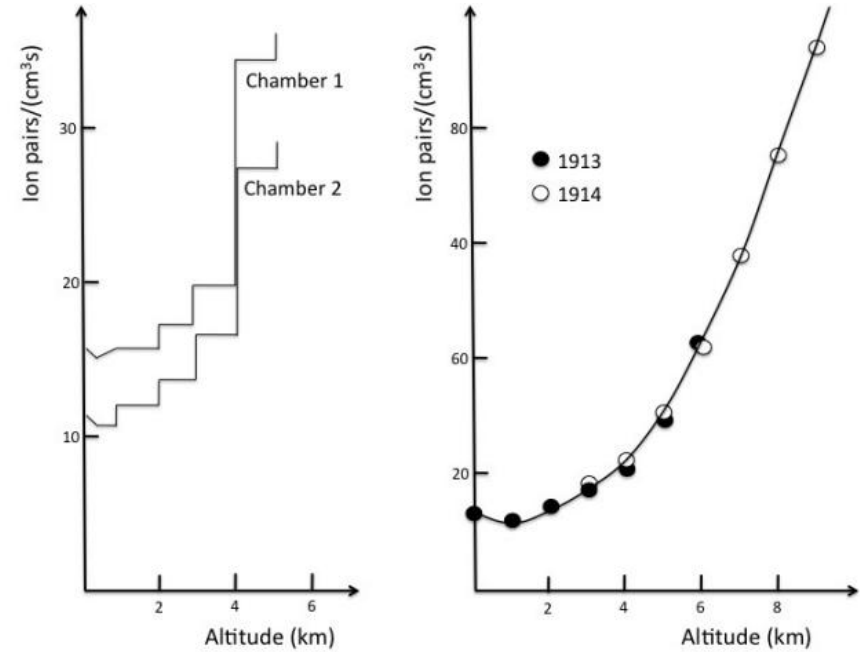
> Expérience de Rossi

> Vie moyenne du muon

> Données environnementales

**D'où vient notre connaissance du rayonnement ?**

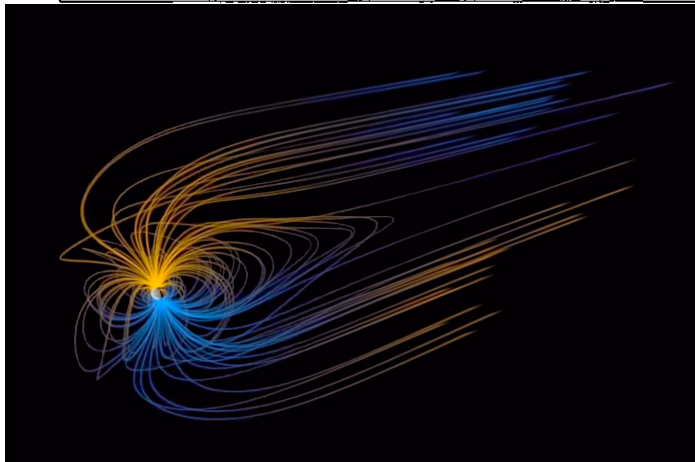
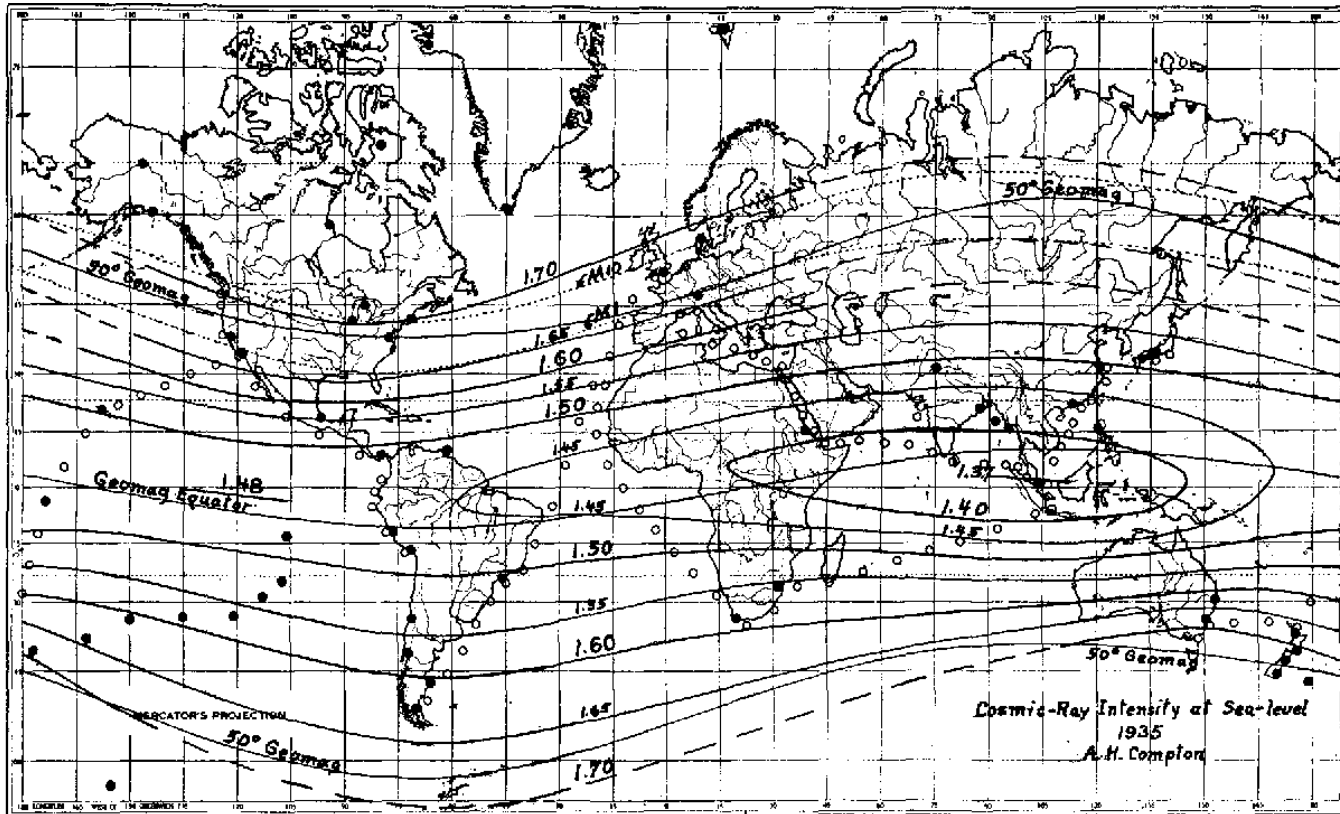




***Mesures effectuées par Viktor Hess et Werner Kohlhörster***

***« Les résultats de ces observations semblent pouvoir être interprétés simplement en assumant qu'une radiation de très haut pouvoir pénétrant provient d'en haut dans l'atmosphère », Viktor Hess (1912)***

# Particule chargée ou photon ?



THE  
PHYSICAL REVIEW  
A Journal of Experimental and Theoretical Physics  
VOL. 43, No. 2 JANUARY 15, 1933 SECOND SERIES

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On Compton's Latitude Effect of Cosmic Radiation  
G. LEMAITRE AND M. S. VALLARTA, *University of Louvain and Massachusetts Institute of Technology*  
(Received November 18, 1932)

# Une composante chargée positivement dans le RC

→ **Effet Est/Ouest**

→ **T. Johnson & J. Street (1932), A. Compton & L. Alvarez (1932),  
B. Rossi (1933)**

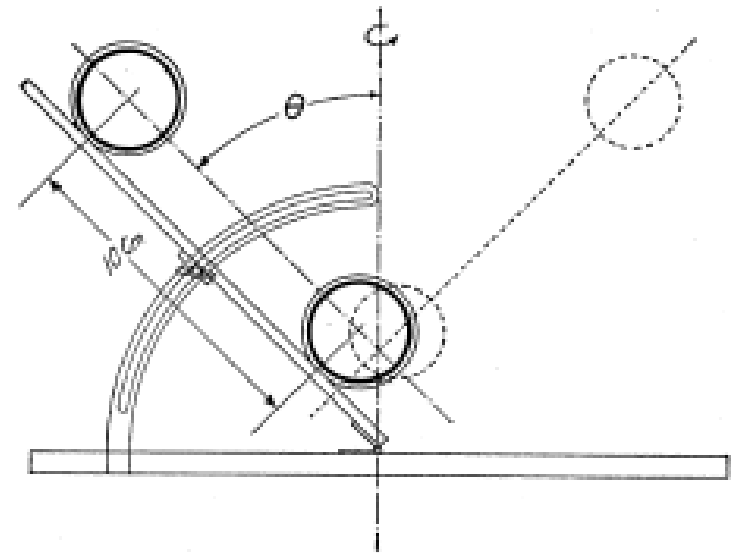
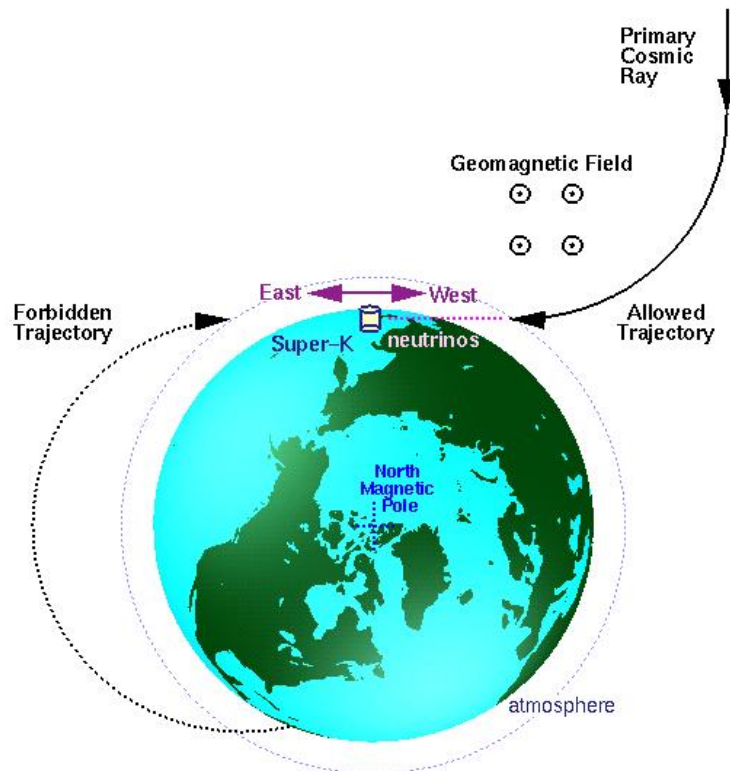
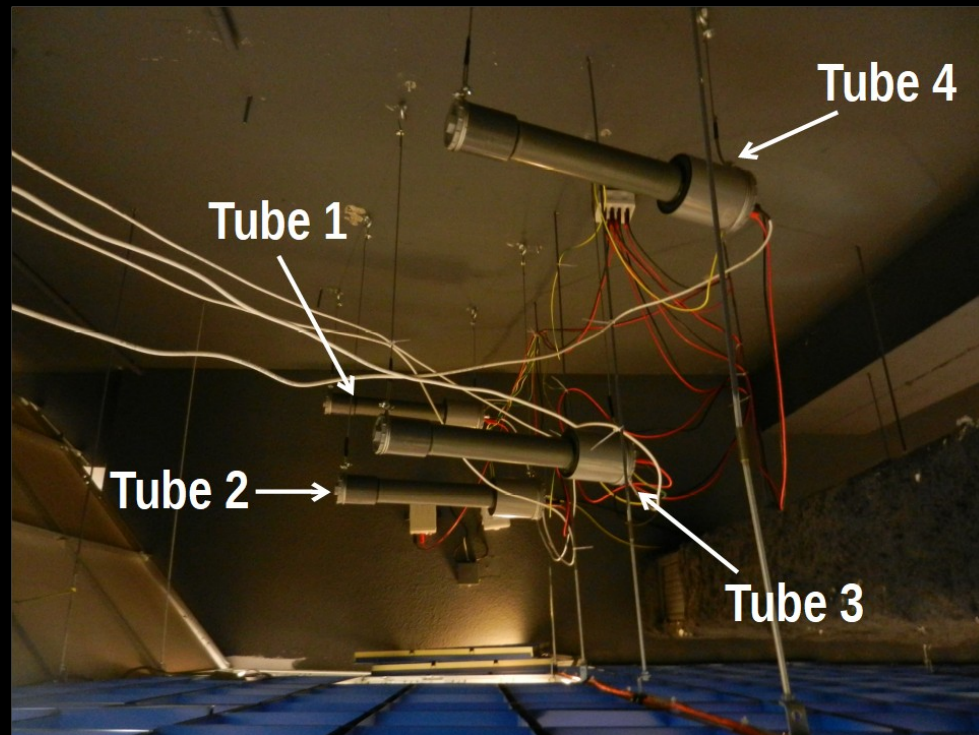
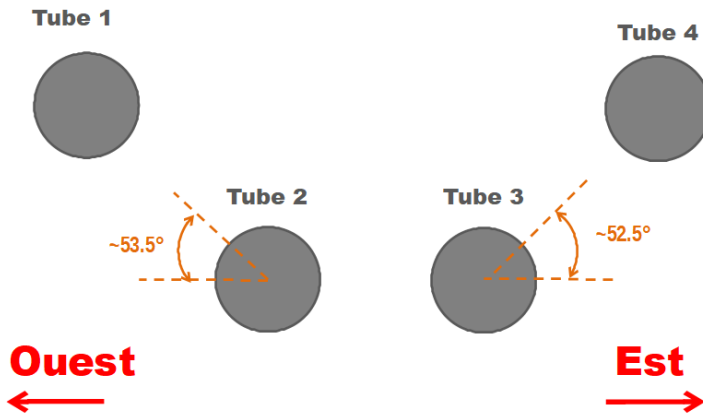


FIG. 1. Arrangement of coincidence counting tubes for studying East-West asymmetry of cosmic rays.



# Effets Est/Ouest





# Effets Est/Ouest

→ **Données prétraitées**

**Horodatage**



**R 12**



**R 34**



**R 13**



**R 24**



2457191.557210	0.083	0.057	0.033	0.0131	2457191.564170	0.091	0.060	0.038	0.0131	2457191.571118					
191.726849	0.110	0.080	0.060	0.0101	2457191.733796	0.100	0.070	0.042	0.0121	2457191.738783	0.0				
883934	0.078	0.047	0.033	0.0121	2457191.889899	0.102	0.033	0.025	0.0131	2457191.895862	0.055				
96	0.105	0.070	0.050	0.0321	2457192.058946	0.100	0.058	0.052	0.0221	2457192.064877	0.077	0.0			
0.120	0.055	0.042	0.0231		2457192.201072	0.098	0.058	0.045	0.0131	2457192.214991	0.122	0.038			
0	0.070	0.033	0.0121		2457192.408889	0.083	0.062	0.048	0.0081	2457192.421311	0.095	0.080	0.05		
0.043	0.033	0.0151			2457192.600739	0.107	0.047	0.043	0.0151	2457192.605724	0.088	0.030	0.027		
3	0.032	0.0081			2457192.773763	0.103	0.038	0.047	0.0071	2457192.780209	0.070	0.053	0.025	0.01	
0.028	0.0101				2457192.947751	0.130	0.047	0.033	0.0221	2457192.954705	0.090	0.062	0.047	0.0221	
2	0.0081				2457194.095893	0.128	0.035	0.058	0.0131	2457194.102826	0.063	0.035	0.025	0.0181	245
0.0221					2457194.283769	0.063	0.037	0.033	0.0131	2457194.290730	0.130	0.043	0.045	0.0131	2457194
71					2457194.438866	0.093	0.052	0.027	0.0101	2457194.452810	0.125	0.072	0.052	0.0201	2457194.458
					2457194.606914	0.073	0.067	0.042	0.0231	2457194.620835	0.122	0.052	0.030	0.0101	2457194.627762
7194	770438	0.118	0.047	0.045	0.0171	2457194.776899	0.045	0.047	0.025	0.0081	2457194.789843	0.			



Plateforme Éducative Rayons cosmiques et muONS

# Effets Est/Ouest

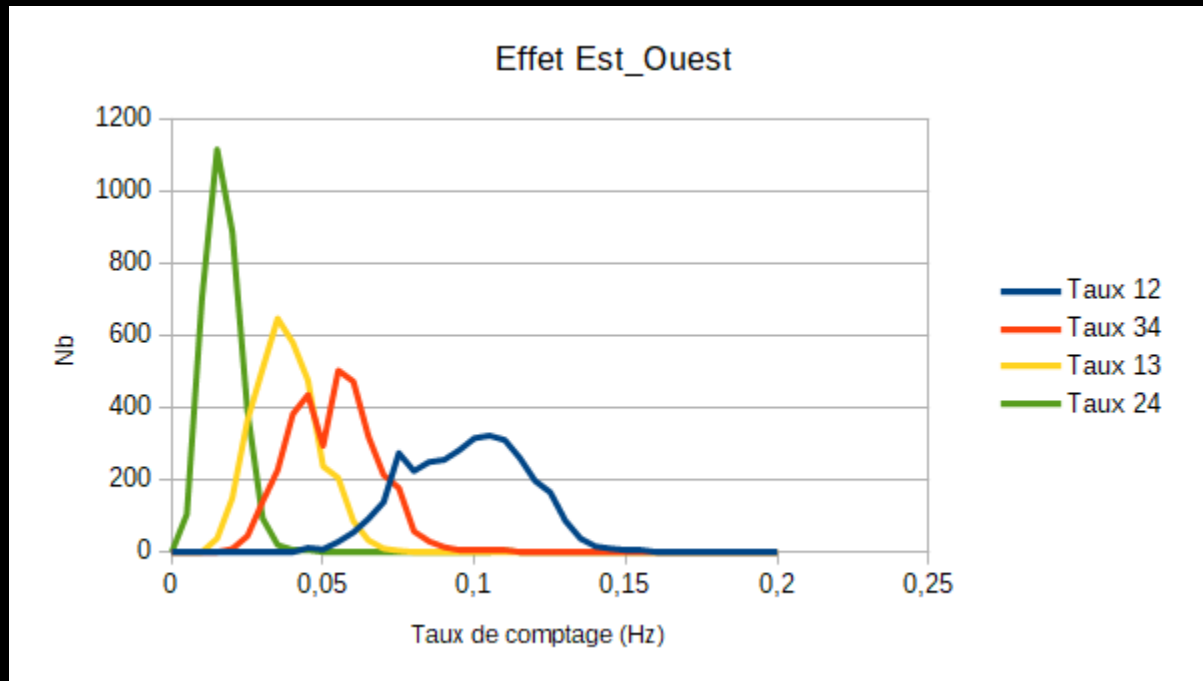
→ Données prétraitées

	A	B	C Ligne de saisie			F	G	H	I	J	K	L
			Nb12	Nb34	Nb13	Nb24		Répartition	Taux 12	Taux 34	Taux 13	Taux 24
1												
2												
3		Min	0,037	0,013	0,005	0,002						
4		Max	0,16	0,473	0,07	0,148						
5												
6	2457191,56417		0,091	0,06	0,038	0,013		0	0	0	0	0
7	2457191,571118		0,115	0,09	0,048	0,013		0,005	0	0	1	104
8	2457191,578069		0,095	0,038	0,032	0,022		0,01	0	0	1	702
9	2457191,585021		0,088	0,062	0,043	0,013		0,015	0	1	36	1115
10	2457191,598947		0,102	0,063	0,023	0,015		0,02	0	7	148	886
11	2457191,605892		0,107	0,06	0,035	0,013		0,025	0	43	363	389
12	2457191,611524		0,083	0,045	0,032	0,012		0,03	0	138	506	92
13	2457191,618476		0,13	0,075	0,032	0,01		0,035	0	226	646	18
14	2457191,623448		0,077	0,048	0,025	0,012		0,04	1	381	579	5
15	2457191,630397		0,112	0,052	0,038	0,017		0,045	10	434	474	2
16	2457191,644332		0,101	0,058	0,038	0,01		0,05	6	293	236	0
17	2457191,665223		0,12	0,065	0,047	0,02		0,055	27	502	204	0
18	2457191,672172		0,117	0,077	0,042	0,018		0,06	53	471	84	1
19	2457191,686102		0,127	0,057	0,045	0,012		0,065	91	318	31	0



# Effets Est/Ouest

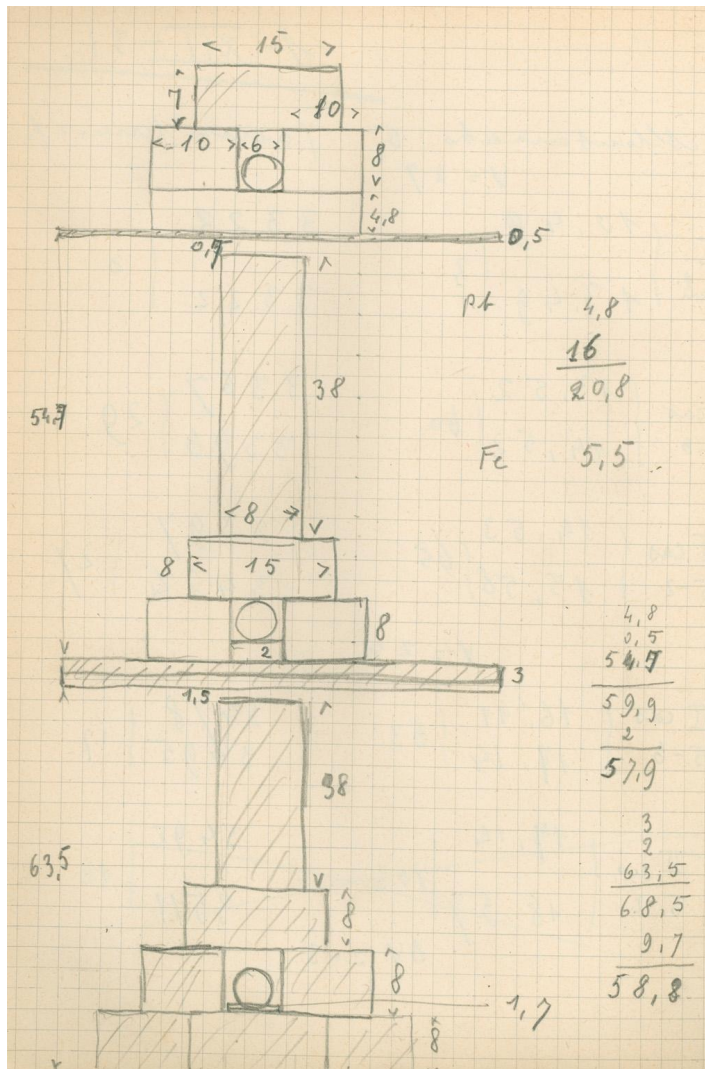
→ Données prétraitées



> + de flux de l'Ouest

> diminue avec  
l'angle zénital

# Etude systématique du RC



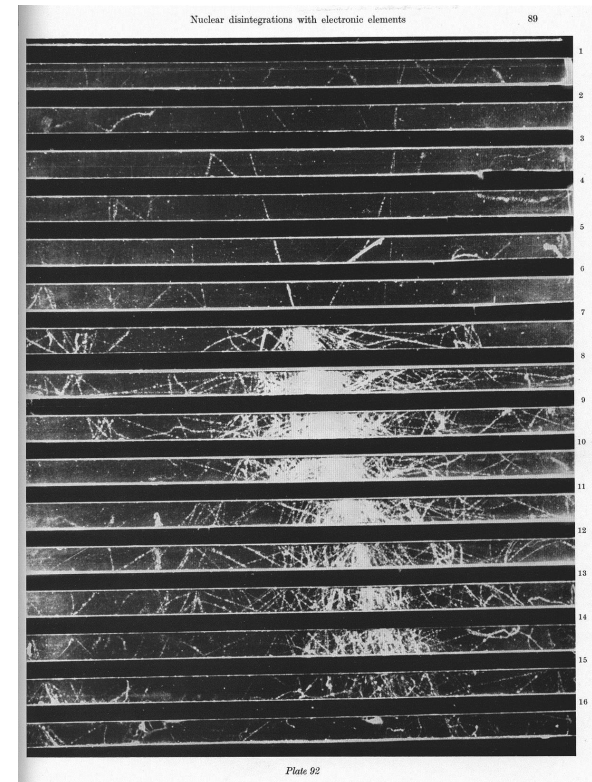
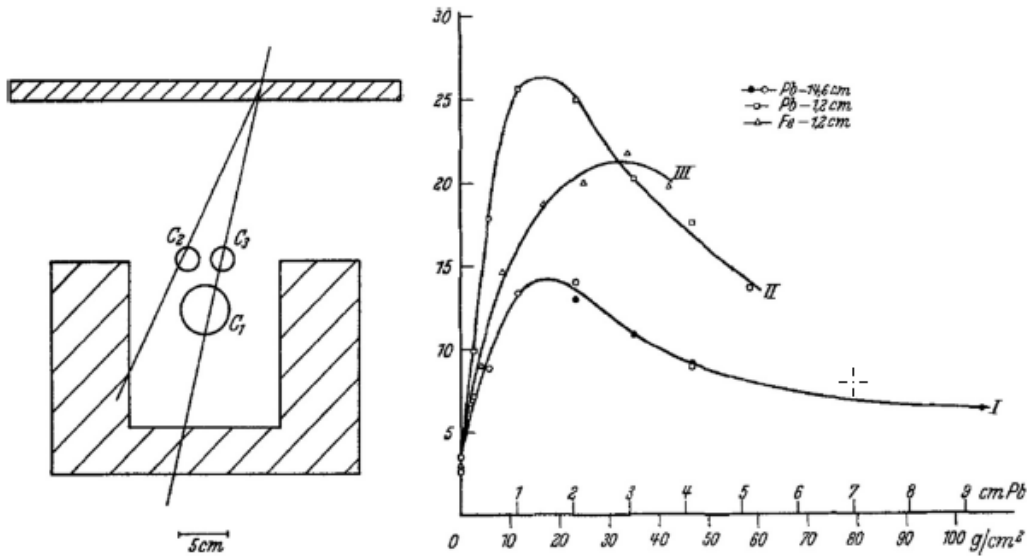
→ **B. Rossi**

→ **Méthode physique des particules**

→ **Amélioration des techniques de détection (triple coïncidences)**



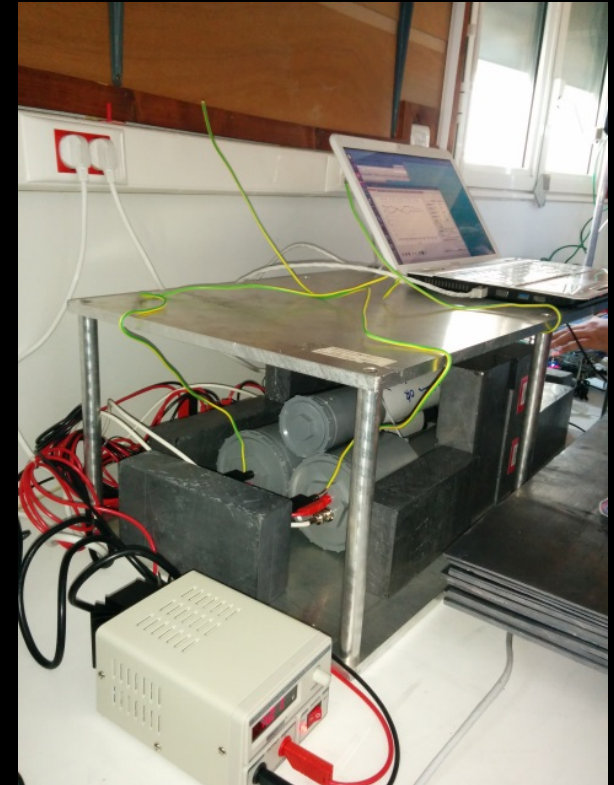
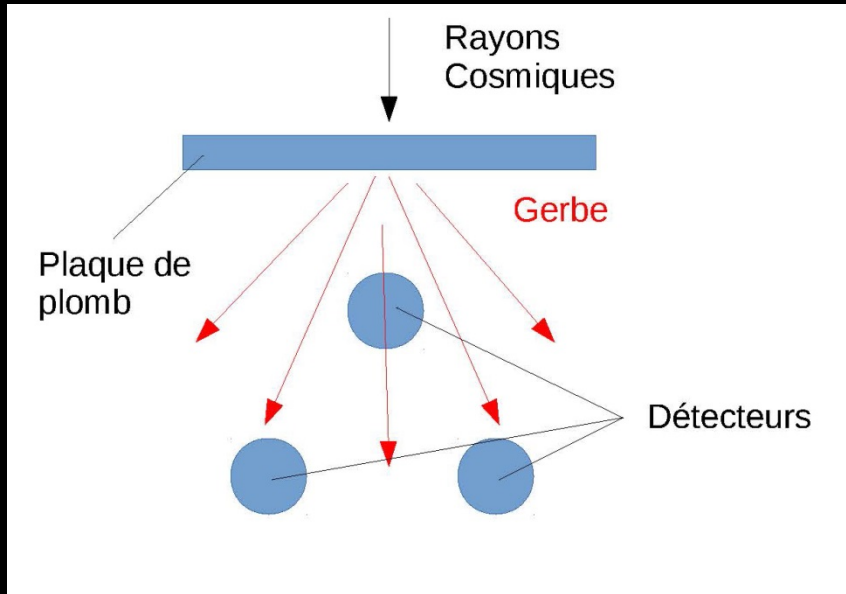
# Mise en évidence des gerbes de particules



- 1 composante « molle » et une composante « dure »
- Création d'une gerbe par particules secondaires
- Image des gerbes (P. Blackett & G. Occhialini)



# Expérience Rossi





# Expérience Rossi

- Données prétraitées
- 2 fichiers

Horodatage

Triple  
coincidence

2016-01-29	01:13:20	0.0277397
2016-01-29	01:13:20	0.0398011
2016-01-29	01:13:20	0.0331345
2016-01-29	01:13:20	0.0255205
2016-01-29	01:13:20	0.0387274
2016-01-29	01:13:20	0.0276902
2016-01-29	01:13:20	0.036108
2016-01-29	01:13:20	0.0349108
2016-01-29	01:13:20	0.031957
2016-01-29	01:13:20	0.0320285
2016-01-29	01:13:20	0.0365992
2016-01-29	04:00:00	0.0354166
2016-01-29	04:00:00	0.0355173
2016-01-29	04:00:00	0.0287716
2016-01-29	04:00:00	0.0288668
2016-01-29	04:00:00	0.0350562

Horodatage

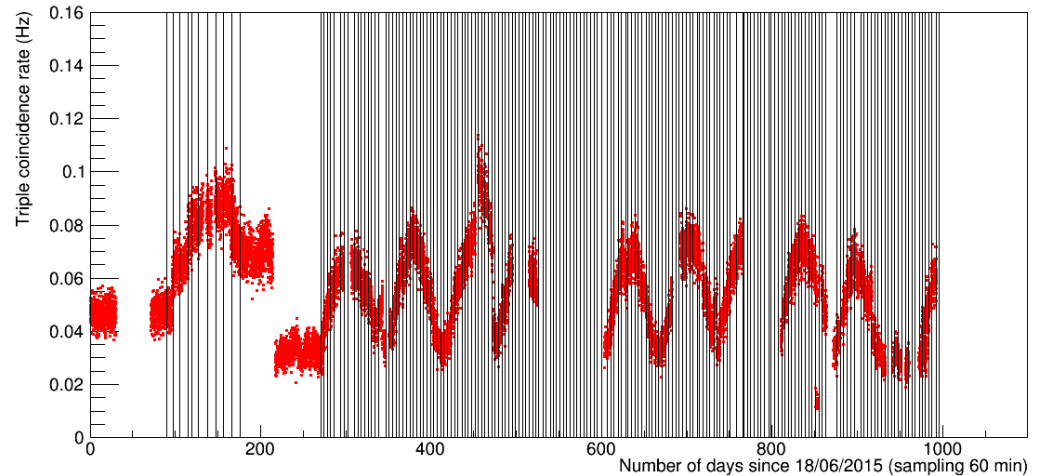
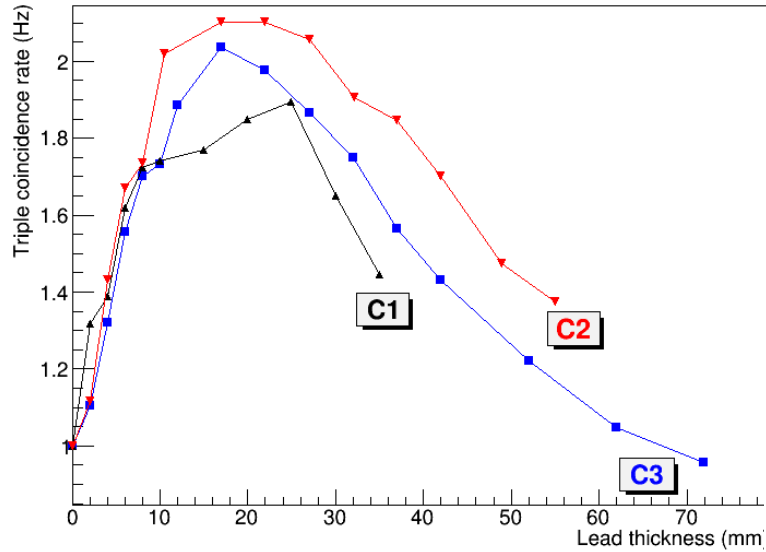
Epaisseur Pb (cm)

2016-04-07	09:30:00	10
2016-04-11	11:30:00	12
2016-04-15	11:30:00	17
2016-04-23	15:42:00	22
2016-04-27	10:46:00	27
2016-05-01	08:55:00	32
2016-05-05	10:00:00	37
2016-05-09	14:45:00	42
2016-05-13	09:08:00	48.8
2016-05-17	12:08:00	54.8
2016-05-21	10:47:00	48.8
2016-05-30	19:21:00	0
2016-06-03	08:57:00	2
2016-06-07	17:41:00	4
2016-06-11	14:41:00	6
2016-06-15	08:40:00	8
2016-06-19	11:52:00	10
2016-06-23	08:44:00	12

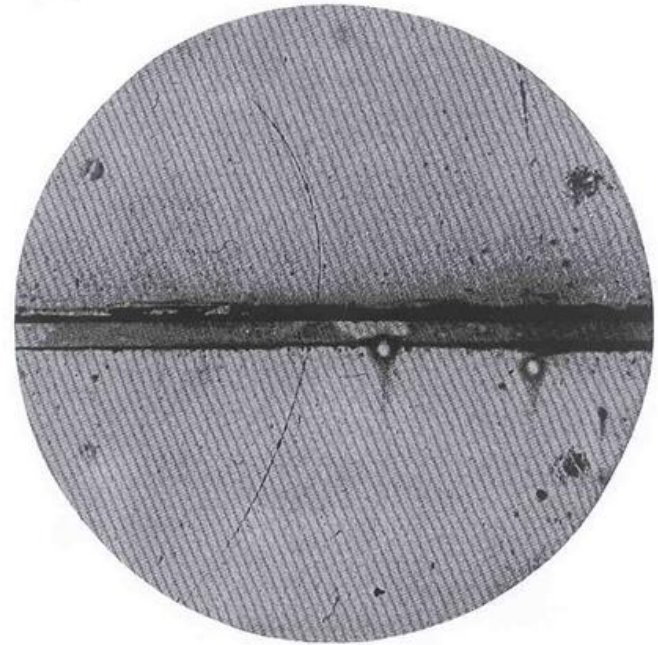
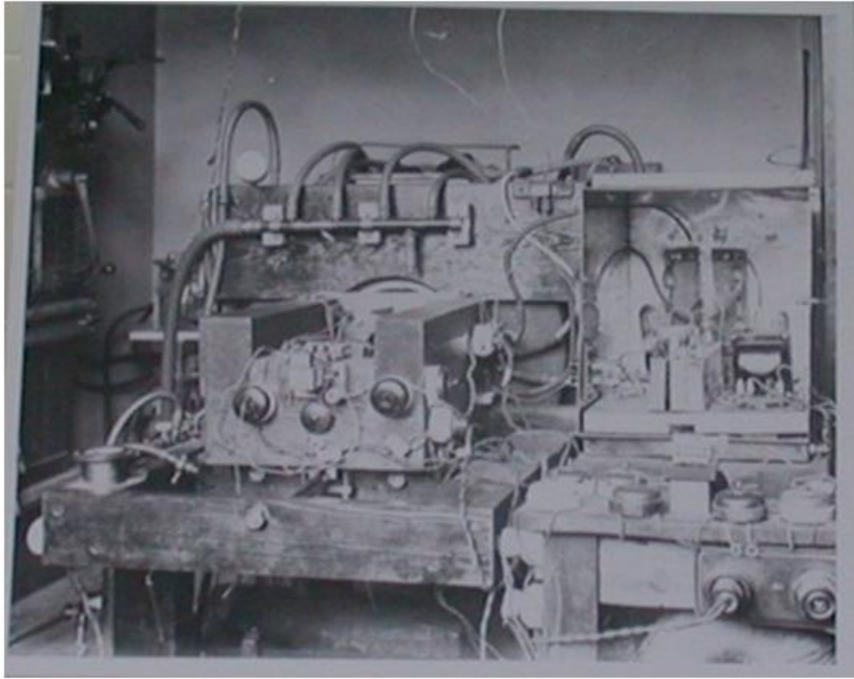


# Expérience Rossi

→ courbe de transition de Rossi

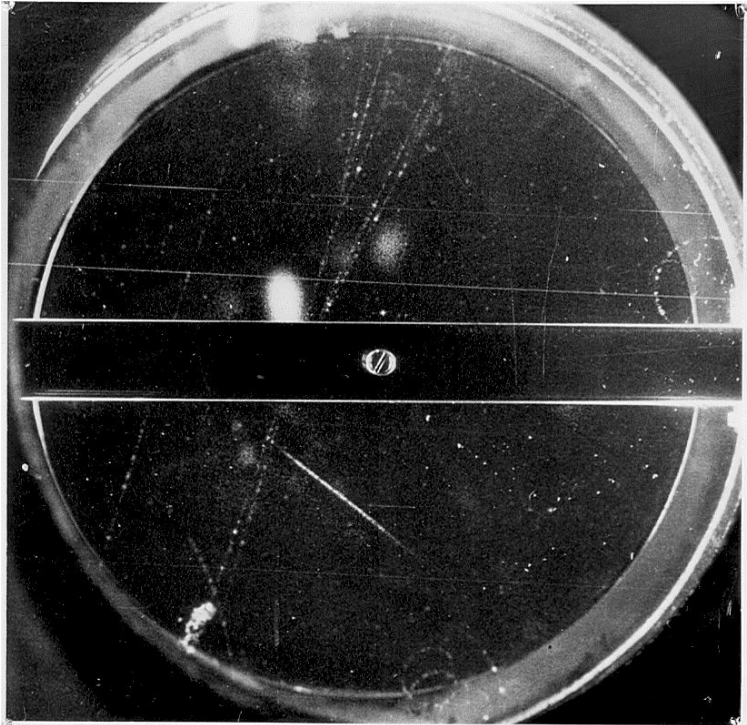


# Découverte de nouvelles particules



- **Chambre à brouillard à déclenchement (Blackett et Occhialini)**
- **Interface physique nucléaire / physique quantique / rayons cosmiques**
- **positron (1932), muon (1936...), pions (1947), kaons (1949), ...**

# L'étude des RC au Pic du Midi

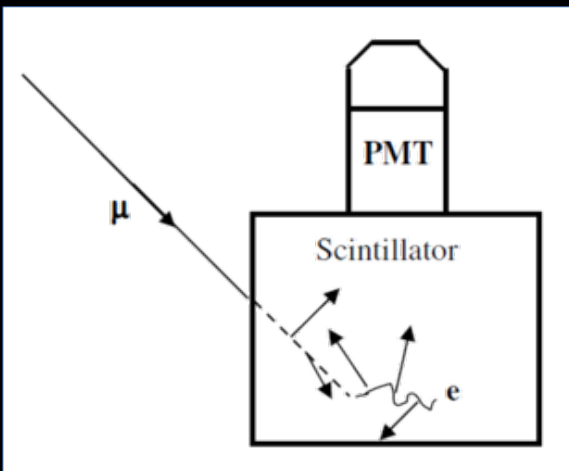
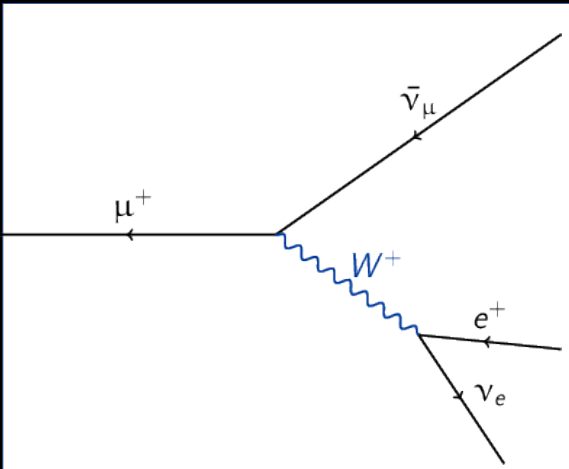


- **1937 – 1938 : étude des grandes gerbes (Auger et al)**
- **1949 – 1956 : l'équipe de Manchester (Blackett et al)**
- **1953 : Congrès Bagnères de Bigorre**



# Vie moyenne du muon

# Vie moyenne du muon







# Vie moyenne du muon

→ Données prétraitées

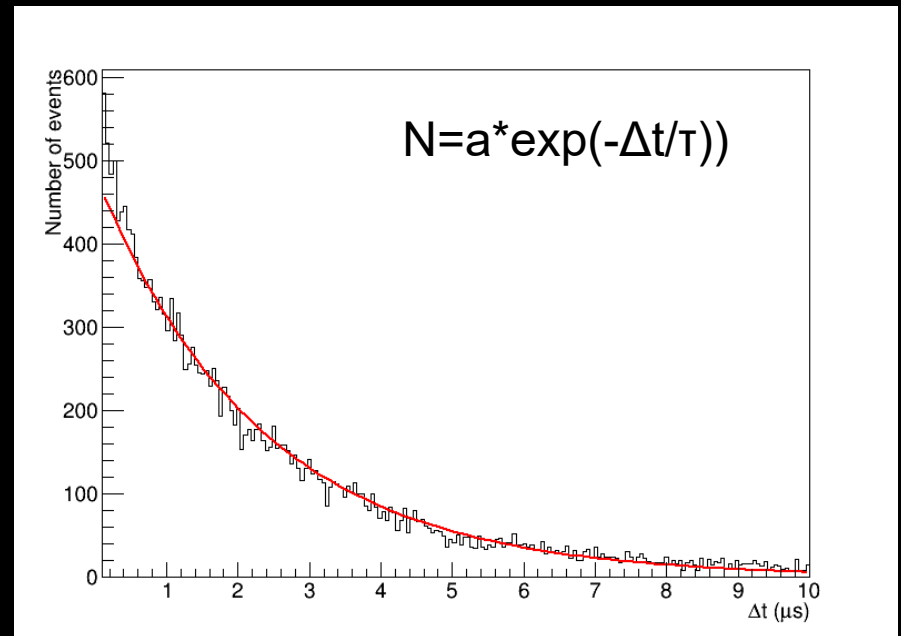
**Horodatage**      **Temps de vie du muon (microsec)**

9	2458184.930191	1.0439	2458184.930316	1.6999	2458184.930341
69	2458184.936292	0.5519	2458184.936345	5.0669	2458184.936460
2689	2458184.941713	0.8799	2458184.941922	2.7579	2458184.94211
1.1779	2458184.949868	0.9549	2458184.949930	7.0049	2458184.950
8.0329	2458184.958117	6.2739	2458184.958204	0.4629	2458184.95
9.7169	2458184.966139	0.3589	2458184.966438	1.3569	2458184.9
3	2.5939	2458184.974572	5.1869	2458184.974711	2.4149
2458184	638	9.2249	2458184.980667	2.1019	2458184.981168
1.8039	24581	88159	1.7589	2458184.988187	0.5969
2458184.988204	0.1199	245	.993621	0.9099	2458184.993708
7.6749	2458184.993732	0.4329	2	85.000465	1.8929
2458185.000533	1.1329	2458185.000640	1.5059	8185.007943	6.2299
2458185.008201	2.3109	2458185.008279	0.5229	458185.014761	2.2509
2458185.014820	0.7609	2458185.014842	2.28	2458185.020818	3.1149
2458185.020904	3.0999	2458185.020918	2.6	2458185.026448	1.4459
2458185.026469	4.0089	2458185.026834	3.	2458185.032308	0.6719
2458185.032392	2.2959	2458185.032486	0	9	2458185.040013
2.8169	2458185.040030	7.9139	2458185.040031	49	2458185.046869
1.1929	2458185.046872	1.2529	2458185.047239		



# Vie moyenne du muon

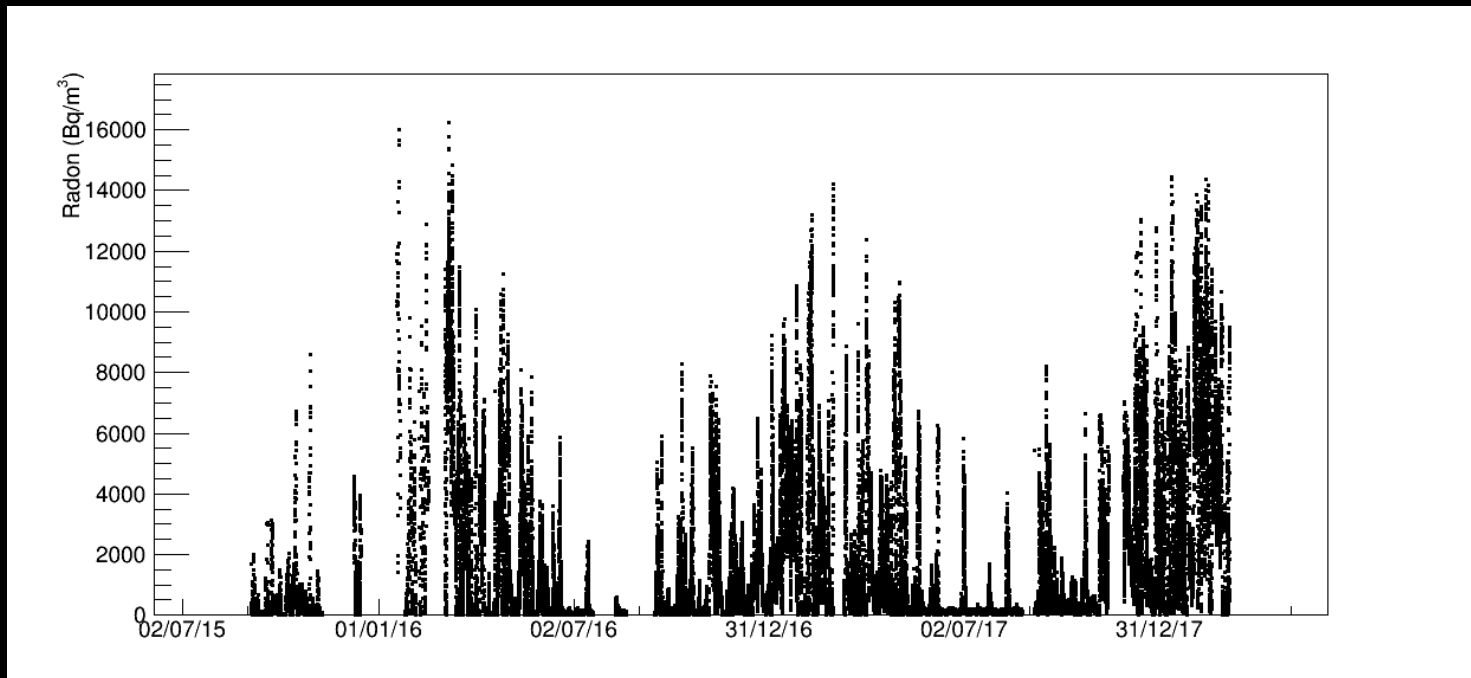
- Données prétraitées
- Relativité restreinte





# Compléments

→ **Données environnementales :  
radon, aérologie, activité solaire**





# Compléments

→ **Données environnementales :  
radon, aérologie, activité solaire**

→ **Télescope à muons**





# Compléments

→ **Données environnementales :  
radon, aérologie, activité solaire**

→ **Télescope à muons**

→ **Expérience Auger**



# **4/ Comment exploiter les expériences ?**

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Plateforme Éducative **Rayons cosmiques et muONS**

**Site web**

**<https://eperon.omp.eu>**

**/**

**→ Accès aux données**

**→ Ressources : fiche d'activité,  
protocole expérimental, sciences**

# Plusieurs modes d'implication possibles

→ « Clé en main » de type TP : 2h



Plateforme Éducative **Rayons cosmiques et muONS**

## **Expérience: Vie moyenne du muon** Activité-type

*Niveau : Terminale S*

*Durée : 2 heures*

*Logiciels utilisés : Libre Office Calc 5, Regressi 4.0*

*Prérequis :*

- *Rayonnements dans l'Univers*
- *Notions de durée propre*

**1) Contexte de l'expérience**

**2/ Représentation graphique des données expérimentales, modélisation et détermination de la vie moyenne du muon**

**3/ Analyse des données**

**4) Interprétation de l'expérience**

**Annexes :**

**A.1/ Récupération et mise en forme des données dans un tableur (pour les enseignants en amont de l'activité)**

**A.2/ Aide pour la modélisation avec Regressi (pour les élèves)**



# Plusieurs modes d'implication possibles

→ « Clé en main » de type TP : 2h

→ Mode plus libre : interdisciplinarité

Encadré ou en autonomie

Ateliers scientifique, TPE...

# Plusieurs modes d'implication possibles

→ **« Clé en main » de type TP : 2h**

→ **Mode plus libre : interdisciplinarité**

**Encadré ou en autonomie**

**Ateliers scientifique, TPE...**

→ **Récupération des données en amont, formatage des données**

# Plusieurs modes d'implication possibles

→ « Clé en main » de type TP : 2h

→ Mode plus libre : interdisciplinarité

Encadré ou en autonomie

Ateliers scientifique, TPE...

→ Récupération des données en amont, formatage des données

→ Exploitation des contenus

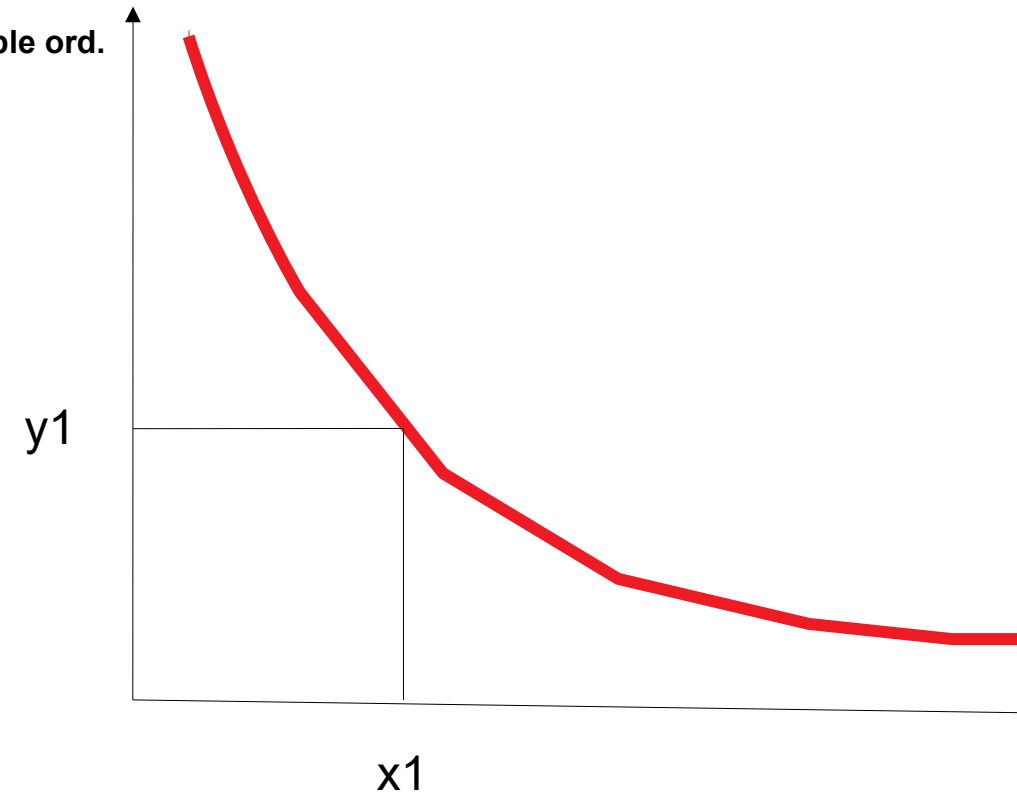
**5/ A vous de jouer !**

# Etat des lieux aujourd'hui

- **Fonctionnement des expériences depuis 2015**
- **Base de données en cours de remplissage**
- **Données brutes + données prétraitées**
- **Tutoriels en cours**
- **Visualisation graphique : en cours**

# Expérience

Du jj/mm/aa, hh.min  
au jj/mm/aa, hh.min  
Xx j



## Représentation des données

	Abcisses	Ordonnées
Variables	<input type="text" value="Menu déroulant"/>	<input type="text" value="Menu déroulant"/>
Echelle	<input type="text" value="Menu déroulant"/>	<input type="text" value="Menu déroulant"/>
Couleur	<input type="text" value="Menu déroulant"/>	
Type	<input type="text" value="Menu déroulant"/>	
Incertitude	<input type="checkbox"/>	Affichage

## Modélisation des données

Type de modèles	<input type="text" value="Menu déroulant"/>
Intervalle	<input type="text"/>
<b>Résultats</b>	
Equation	<input type="text"/>
Chi2	<input type="text"/>

## Paramétrage

Echantillonnage	<input type="text"/>
-----------------	----------------------

# Pourquoi utiliser e-PERON ?

## Pour vous :

- ✓ **Acquisitions sur des temps longs**
- ✓ **Pas de matériel, juste des données**
- ✓ **Plusieurs expériences**
- ⇒ **Complémentaire du cosmodétecteur**

## Pour nous

- ✓ **Retours/améliorations de l'offre (données, ressources)**
- ✓ **Construction participative**

# Vers un réseau international

## Global Cosmic Ray Studies

### Projects for High School Students

There are several projects around the world opportunity to explore cosmic particles. The the web pages.

#### FINLAND



**Callio Lab:** Doing are really interest Callio Lab, in Fir 2010, is based on the cosmic ray experimen exercises with simple data and detectors. Th taken out into the community by participatir and organizing theme weeks on physics topi

[Lab](#)

#### FRANCE

Sciences à l'École



**Cosmos à l'École** "Institut National the CNRS and "S which is promoti detectors called "

(CPPM) and given to high school teachers s receiving the detector – a one week-long se technical course in Marseille to learn how to through a dedicated internet forum and pres Cosmodéteur. There are currently 30 sud Website: [Sciences à l'École](#)



**e-PÉRON:** a vi research labori Midi-Pyrénées school to unive platform onlin

several ones (muon lifetime, East/West effec download the data during a choosen period French Pyrenees and are running continuou Website: [e-PÉRON](#) (the official website is u

#### GERMANY



**Cosmic@V** different ex data on the research ps



**Netzwerk Teilchenwelt:** On the track of the Big B Teilchenwelt" one can enjoy particle physics and workshops in schools, student labs or museums, yc the whole of Germany experience the world of Q from science or their own experiments. If you want to know more, join the net and participate in workshops at CERN in Geneva. Website: [Netzwerk Teilchen](#)

#### POLAND



**Cosmic-Ray Extremely Distributed Observato** wide network of cosmic ray detectors, utilising b public mobile devices such as smart phones. Tl look for cosmic ray events which are extended in both time and space and th detectors to identify. Such events have interdisciplinary applications in areas : weather as well as astrophysics. The involvement of non-professional science by Dark Universe Welcome where citizen scientists are invited to explore the c the world, classify them and identify patterns. Website: [CREDO, Dark Universe](#)

#### RUSSIA

**Showers of Knowledge** is an open outreach educational project that aims to an analysis of data of the real online cosmic-rays experiment. It is developi Research (Dubna, Russia). The project consists of the distributed setup for rese ("mermaid"), comprising 11 stations located in the area of about 0.5 km in dia portal livni.jinr.ru, where users can run a variety of pre-made data analysis scri Our feature is the possibility for users to communicate with real particle physic Website: [Showers of Knowledge](#)

#### SPAIN



**Cazadores de Rayos Gamma** is a high energy astrophysics web s analyse data from the MAGIC telescopes using a python program application combines a storytelling approach with science and pr users. 4 PhD students introduce the user into high energy astrphys and analysis done with the MAGIC telescopes. The user will learn related to Super Nova Remnants, Black Holes, Dark Matter,... and also about : as Casiopea A or the Crab Pulsar. The project was developed at the Institut di Barcelona. At the moment only a spanish version is available. But soon it will Website: [Cosmic@Web](#)

#### SWEDEN



**Cosmic ray outreach in Stockholm:** The Royal Institute of Ted House of Science offer high school projects on cosmic rays to S high school. Muon detectors of different sizes are available for s research labs. The participating students pose their own resear with one or more of our muon detectors. As part of this project a weather balloon once a year to measure the cosmic ray flux at altitudes up to 30000m and the data from this flight is collected in a database which is freely available to anyone interested in collaborating with us. Website: [Info kosmisk strålning](#)

#### TAIWAN



**QuarkNet-TW** started in 2006. While we have worked with both high school and university students, most participants have been university students. We have prepared full usage of raspberry pi and python programs. (Using the QuarkNet detector is included in the senior course "Experiment for Modern Physics" by the Physics Department of National Cheng Kung University) However, we are moving QuarkNet-TW to the Taipei Astronomical Museum (TAM) which is more practical for high school students. In addition to uploading data to e-Lab, students can analyze and view their data in real time. Extensions to astronomy become possible at TAM, and interested students can do some hands-on experiments related to electrical engineering.

#### UK



**UNIVERSITY OF BIRMINGHAM**

**Detecting Cosmic Rays – possible student projects:** Three portable scintillation telescopes, each comprising a pair of scintillators, have been constructed, following the QuarkNet design, in the School of Physics and Astronomy at the University of Birmingham. These telescopes can be set up and used conveniently by students to measure the flux of cosmic rays; its dependence on distance between the scintillators, on zenith angle and on height (e.g. on the successive floors of a building). Results can also be stored and analysed using standard QuarkNet software. These telescopes, with worksheets outlining possible investigations, can be borrowed by schools and colleges for student projects. For more information, please contact : Website: Login as a guest to view [Birmingham QuarkNet Project](#)



**High School Project on Astrophysics Research with Cosmics (HiSPARC)** is a project in which secondary schools and academic institutions join forces and form a network to measure cosmic rays with extremely high energy. HiSPARC offers students the opportunity to participate in real research, with the purpose of finding out more about these mysterious and rare cosmic particles. Schools purchase HiSPARC detectors and students install these on the roofs of their school. The HiSPARC project started in the Netherlands in 2002. The HiSPARC detectors are connected to a central computer at the scientific institute Nikhef in Amsterdam through the internet, forming a large network. The project is coordinated from Nikhef in Amsterdam. The project spread to the UK in 2012 with first the Universities of Bristol, Bath and Birmingham. The project has recently spread to the Universities of Cardiff and Sussex. Website: [HiSPARC](#)

**QuarkNet Cymru** builds on existing STEM programmes linked with HiSPARC and QuarkNet and a programme to pilot the use of cosmic ray detectors in schools across South Wales. Since January 2016, the project has tried to entuse secondary school students in STEM activities through engagement in real hands-on astrophysics experiments — measuring cosmic rays using detectors based in schools. Equipment is available for loan to those schools that need A level particle physics laboratory equipment. A website will eventually act as a repository of the resources for using the detectors in the classroom, and as a collaborative learning space where schools can upload their data and work together to analyse their results. Website: [QuarkNet Cymru](#)

#### USA



**Cosmic Ray e-Lab Studies:** provide opportunities for high school students to conduct their own scientific investigations either with data they collected themselves or with data from their peers. QuarkNet teachers receive a kit to build a portable, configurable classroom detector; non-QuarkNet educators can purchase the DAQ with GPS, antenna and temperature and pressure sensors. They can buy the rest of the parts commercially. The



# Merci pour votre attention



Plateforme Éducative **Rayons cosmiques et muONS**

<https://eperon.omp.eu/>

Contact: [baudouin.cyr@gmail.com](mailto:baudouin.cyr@gmail.com)