Qu'est-ce que la physique des particules ?
Où va-t-elle ?
Pourquoi ?
Comment ?

Est-ce réellement important ?

Etienne Augé
DAS IN2P3

des collisions:

- Mode opératoire
  - Peu raffiné
  - Toujours les mêmes ingrédients de départ
  - Inchangé depuis des décennies
- Et pourtant :
  - Accélérateurs et détecteurs toujours plus gros et plus chers
  - Ressources informatiques énormes
- **Ne manquerait-on pas d'imagination ?**

Physique des particules élémentaires

- Élémentaire ?
  - Atome ? Proton ? Quark ? Electron ?...
  - Particule élémentaire ultime ?
- Lois fondamentales ?
  - La découverte des quarks n'a révolutionné ni la Chimie ni la Biologie…
- **Il existe aussi une physique de la complexité**

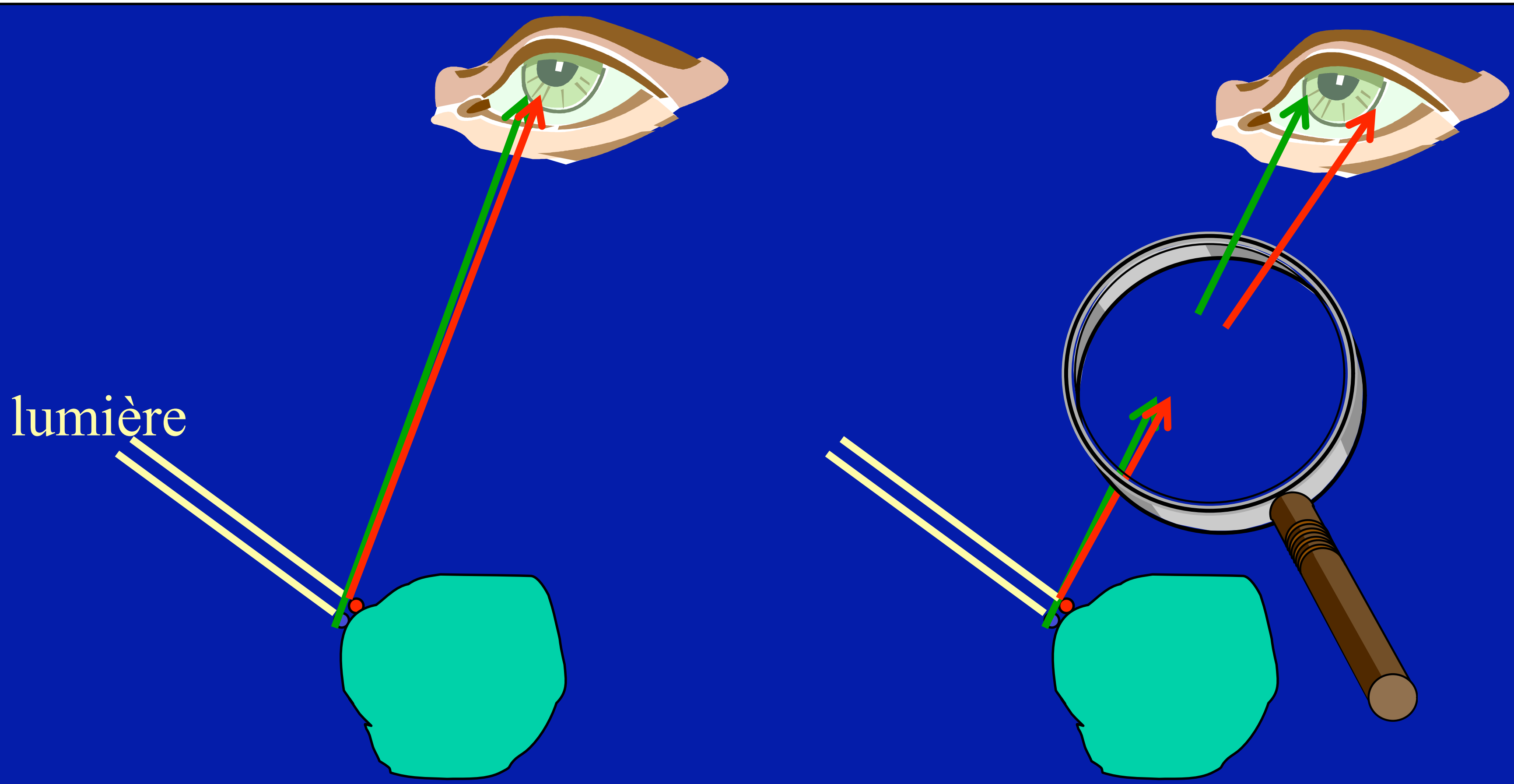
Et pourtant….

Une physique « des deux infinis »

- Modèle cosmologique du **big bang**
  - Très grande densité d'énergie aux premiers instants de l'Univers
    - Haute température ➔ Collisions violentes entre constituants de l'Univers
    - Comme ce qu'on provoque dans les laboratoires de physique des particules
- La connaissance des particules permet d'écrire des morceaux du scénario cosmologique
- Le scénario cosmologique permet de contraindre le comportement des particules dans des collisions beaucoup plus violentes que ce qu'on peut provoquer en laboratoire
- **Connaissance de l'univers**

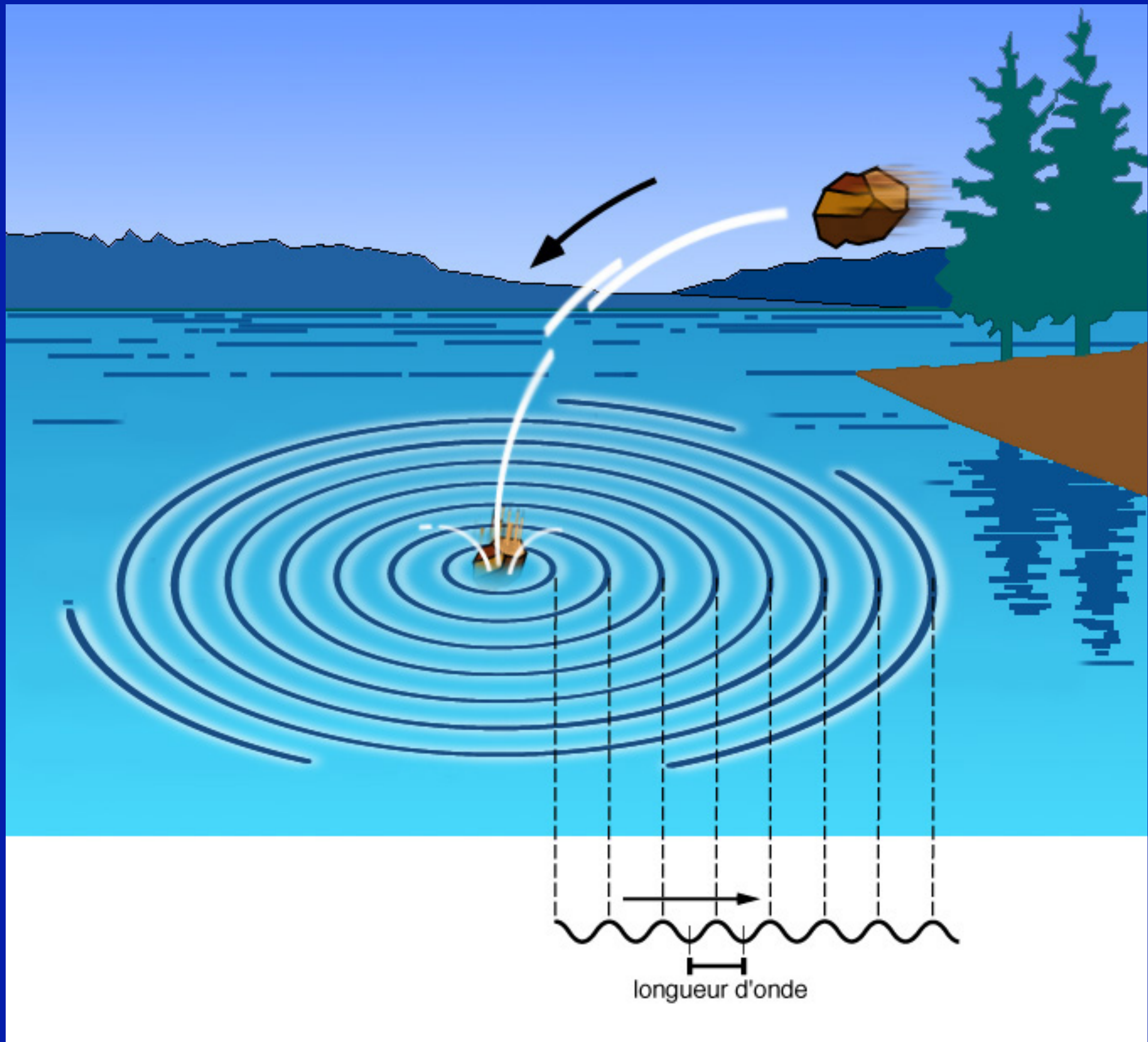
Collisions violentes : une nécessité

- Pour observer des détails fins (exemple H1)



Une loupe ou un microscope permettent de voir des détails plus petits que l'œil nu, mais pour des distances inférieures à la longueur d'onde…

Nature ondulatoire → diffraction



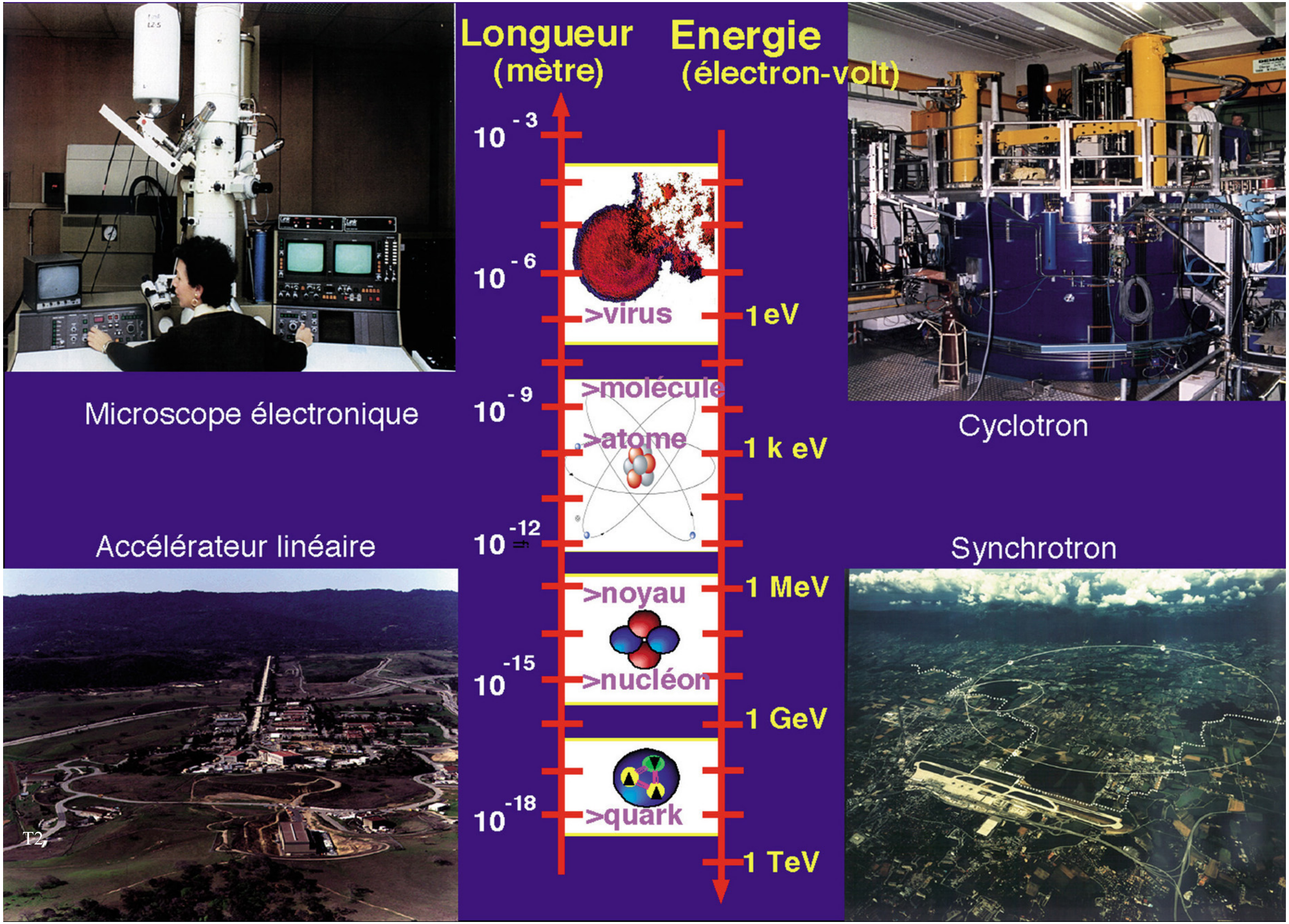
Pouvoir séparateur proportionnel à la longueur d’onde

Dualité onde-corpuscule

- Onde lumineuse ⇔ Faisceau de projectiles
  - Effet photo-électrique (A. Einstein)
  - photon = « grain de lumière »
- Faisceau de projectiles⇔ onde
  - microscopie électronique
  - imagerie par faisceau de neutrons
- Energie d'un corpuscule α inverse de la longueur d 'onde :
- finesse des détails ⇨λ petit⇨ E grand

$$E = \frac{hc}{\lambda}$$

- ⇨ Bombarder l'objet observé avec des projectiles énergiques
- ⇨ L'objet est cassé par le projectile


Longueur
(mètre)
Energie
(électron-volt)
10 - 3
10 - 6
>virus
1 eV
10 - 9
>molécule
>atome
1 k eV
10 -12
>noyau
1 MeV
10 -15
>nucléon
1 GeV
10 -18
>quark
1 TeV
Microscope électronique
Cyclotron
Accélérateur linéaire
Synchrotron

Collisions violentes : une nécessité

- Pour observer des détails fins (exemple H1)
- Pour concentrer de l'énergie en un point du vide
  - 1 TeV (LHC): soulever 1,6 grammes de 0,01 mm
  - Dans un cube de 10^{-45} m^3
  - Densité $1,6 \times 10^{38}$ Joule/m^3 : monstrueux…
- Faire apparaître de nouveaux phénomènes
  - Nouvelles particules élémentaires ➔ classification des particules élémentaires ➔ intuition de nouvelles lois plus fondamentales (classification de Mendeleiev)
- Produit tous les états finals possibles ➔ sélection a postériori, on-line et off-line

Les trois frontières

- Frontière de l'énergie
  (LEP➔Tevatron➔LHC➔sLHC ➔ILC➔????
- Frontière de l'intensité

  effet indirect des nouvelles particules ➔ déviations/prédictions ➔ mesures de précision

  LEP, LHCb ➔superB
- Frontière cosmique

  Matière noire, énergie noire

HEPAP (P5) Report
Major Findings

- **Progress in achieving the goals of particle physics requires advancements at the:**
  - **Energy Frontier**
  - **Intensity (or precision) Frontier**
  - **Cosmic (or particle astrophysics) Frontier**

  (each provides a unique window for insight about the fundamental forces/particles of nature)

- **LHC offers an outstanding opportunity for discoveries at the Energy Frontier**
  - Resources will be needed to support the extraction of the science by U.S. scientists
  - Resources will be needed for planned accelerator and detector upgrades

- **An opportunity exists for the U.S. to become a world leader at the Intensity Frontier**
  - Central is an intense neutrino beam and large underground long-based line detector
  - Building on infrastructure at Fermilab and partnering with NSF
  - Develops infrastructure that positions the U.S. to regain Energy Frontier (Muon Collider)

- **Promising opportunities for advancing particle physics identified at Cosmic Frontier**
  - Requires partnering with NASA, NSF, etc.

- **HEP at its core is an accelerator based experimental science**
  - Accelerator R&D develops technologies needed by the field and that benefit the nation

Un peu de sociologie

- Du résultat d'un doctorant à une recommandation de l'ICFA
- Filtre de la collaboration (working group, publications committee) ➔ publication
- Présentations en conférences, discussions dans la communauté : **très important**
- Emergence de nouveaux projets (processus collectif qui implique aussi les théoriciens)
- Eventuellement validés et soutenus par les tutelles
- Financement et construction planifiés à l'échelle mondiale : exemple ILC

2019 ?

International Linear Collider

Studies started 20 years ago

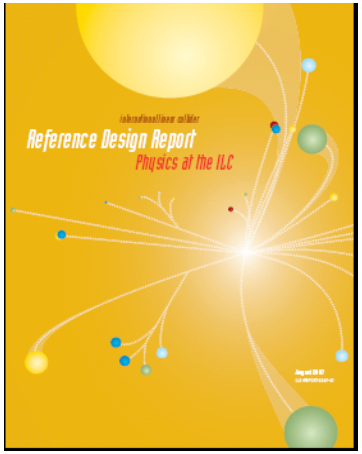
End of the project in 30 years

Organisation ILC

- ILC Steering Committee (E. Iarocci)
- Global Design Effort
  - B. Barish, chef du comité exécutif
- World-Wide Study (physique et détecteurs)
  - S. Yamada, directeur de la recherche
- International Detector Advisory Group
  - Nommé par l'ILCSC, M. Davier, président

- **Reference Design Report (4 volumes)**

Executive Summary



Physics at the ILC

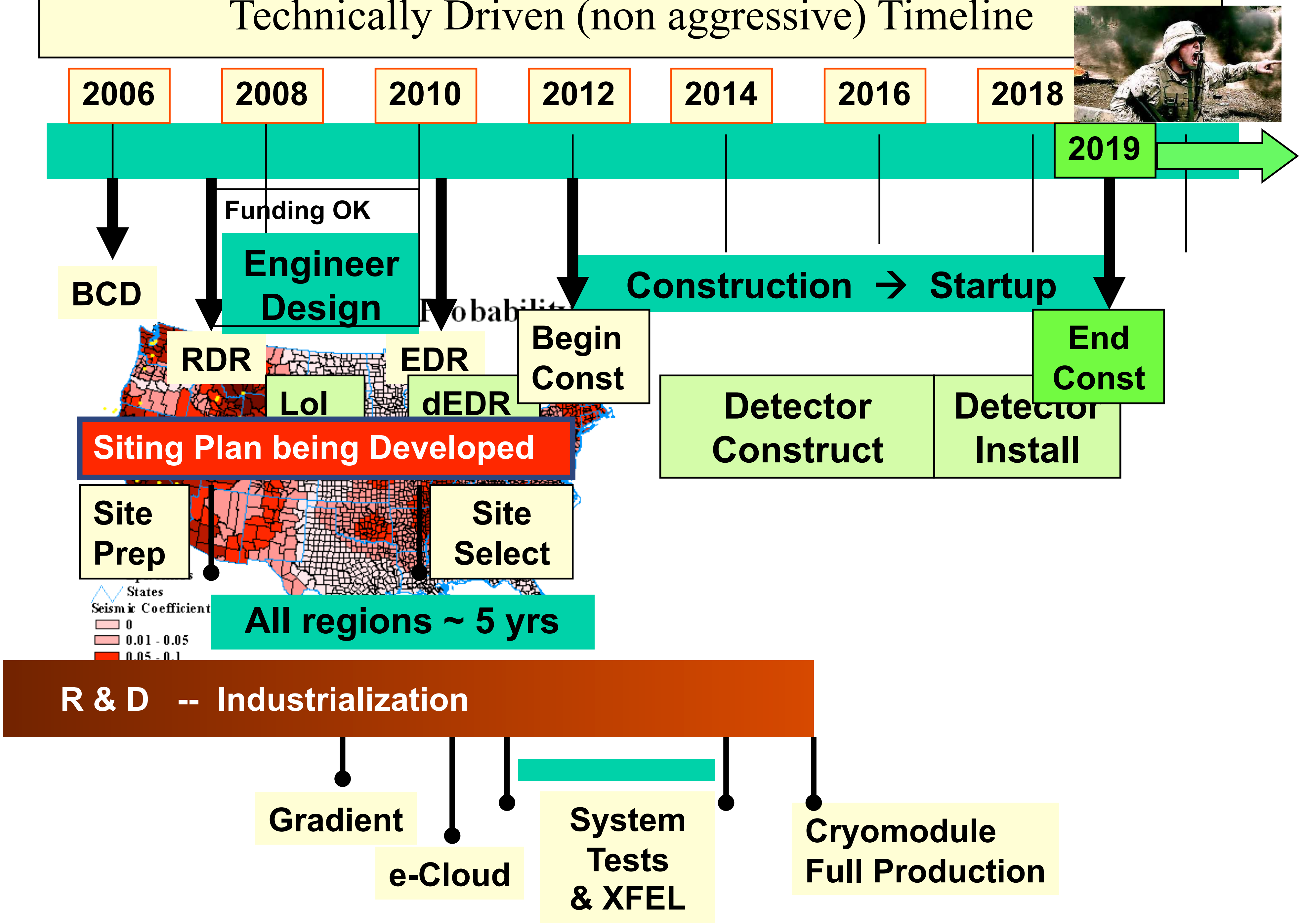
Accelerator

Detectors

LOI attendues en 2009

International Detector Advisory Group : présidé par M. Davier

Technically Driven (non aggressive) Timeline

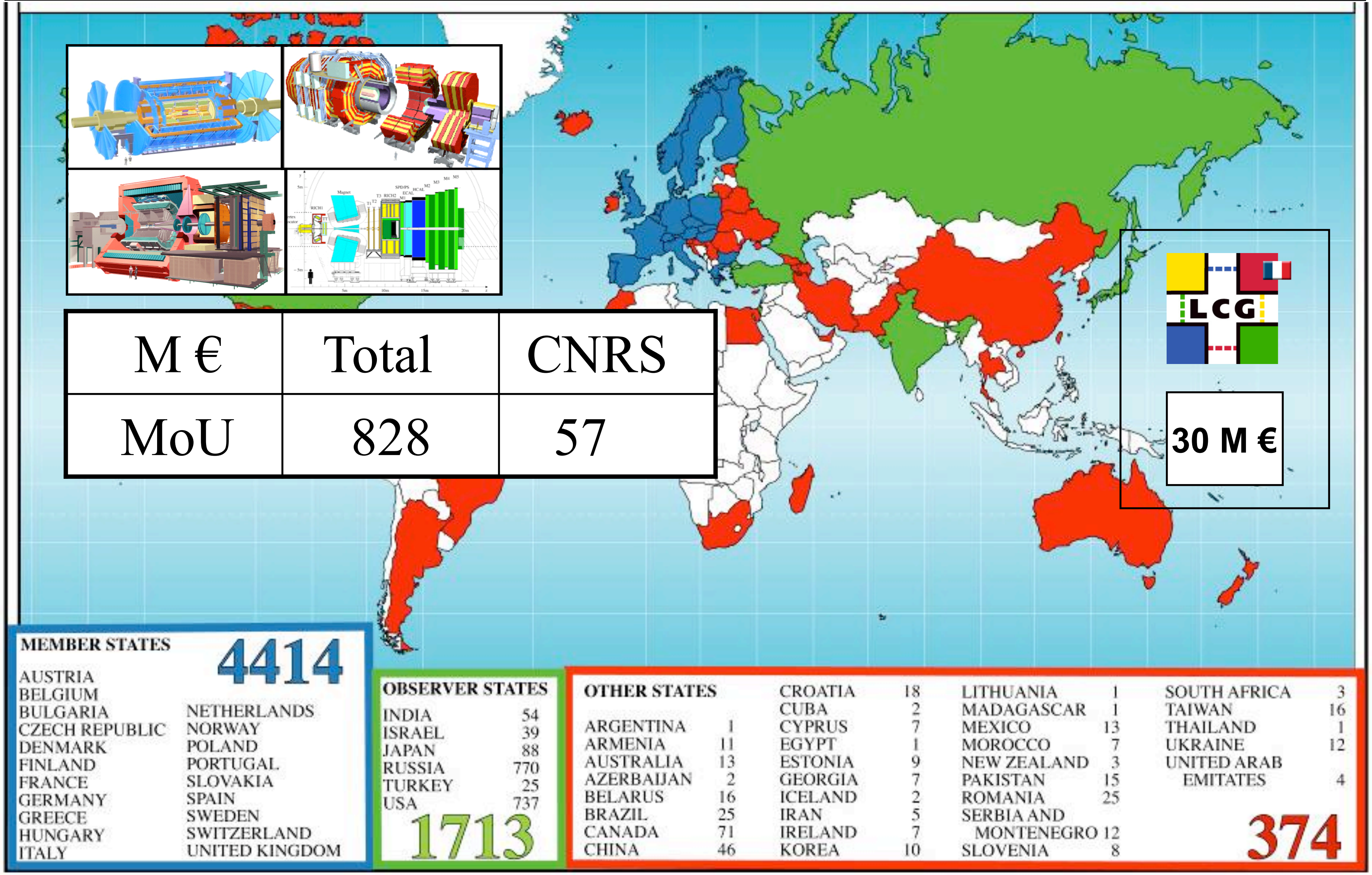


Un peu de géopolitique

- ATLAS: construit avec l'argent de 30 pays
  - Coordination des physiciens, des ingénieurs, des administrations ➔ liens forts.
- Opportunité pour que des pays développent leurs relations internationales à travers la Science

- Rôle du CERN – Roadmap ESFRI
- Rôle de l'OCDE (Open Science Forum)
- Réunions FALC

CERN 6500 users from institutes (+2500 from CERN)



M €	Total	CNRS
MoU	828	57

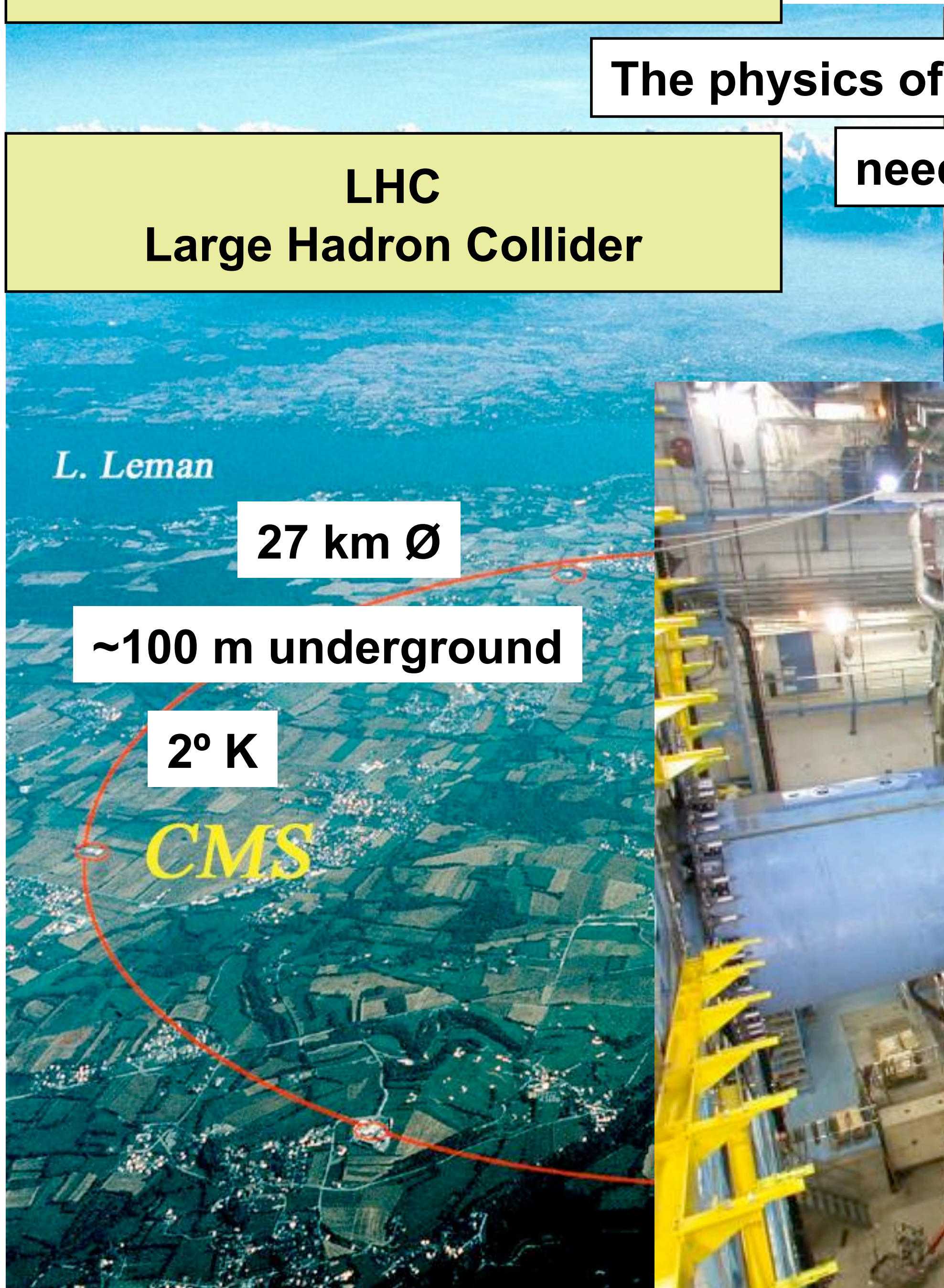
CERN: where the WeB was born

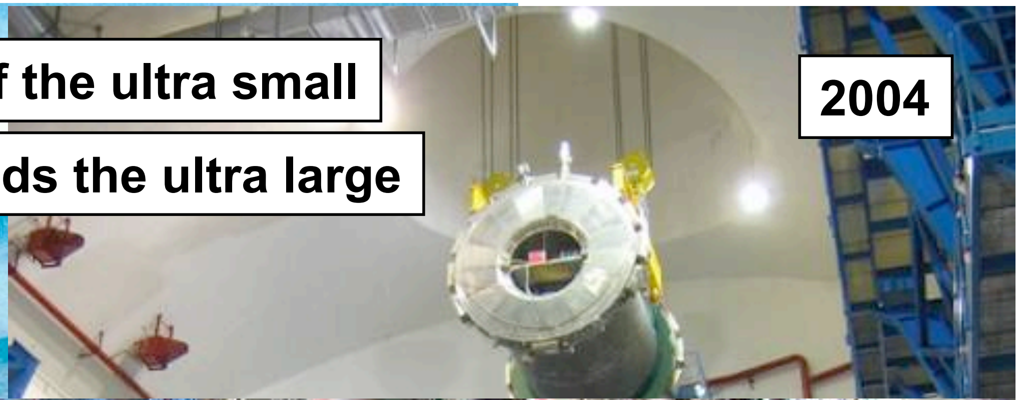
~2000 physicists/experiment

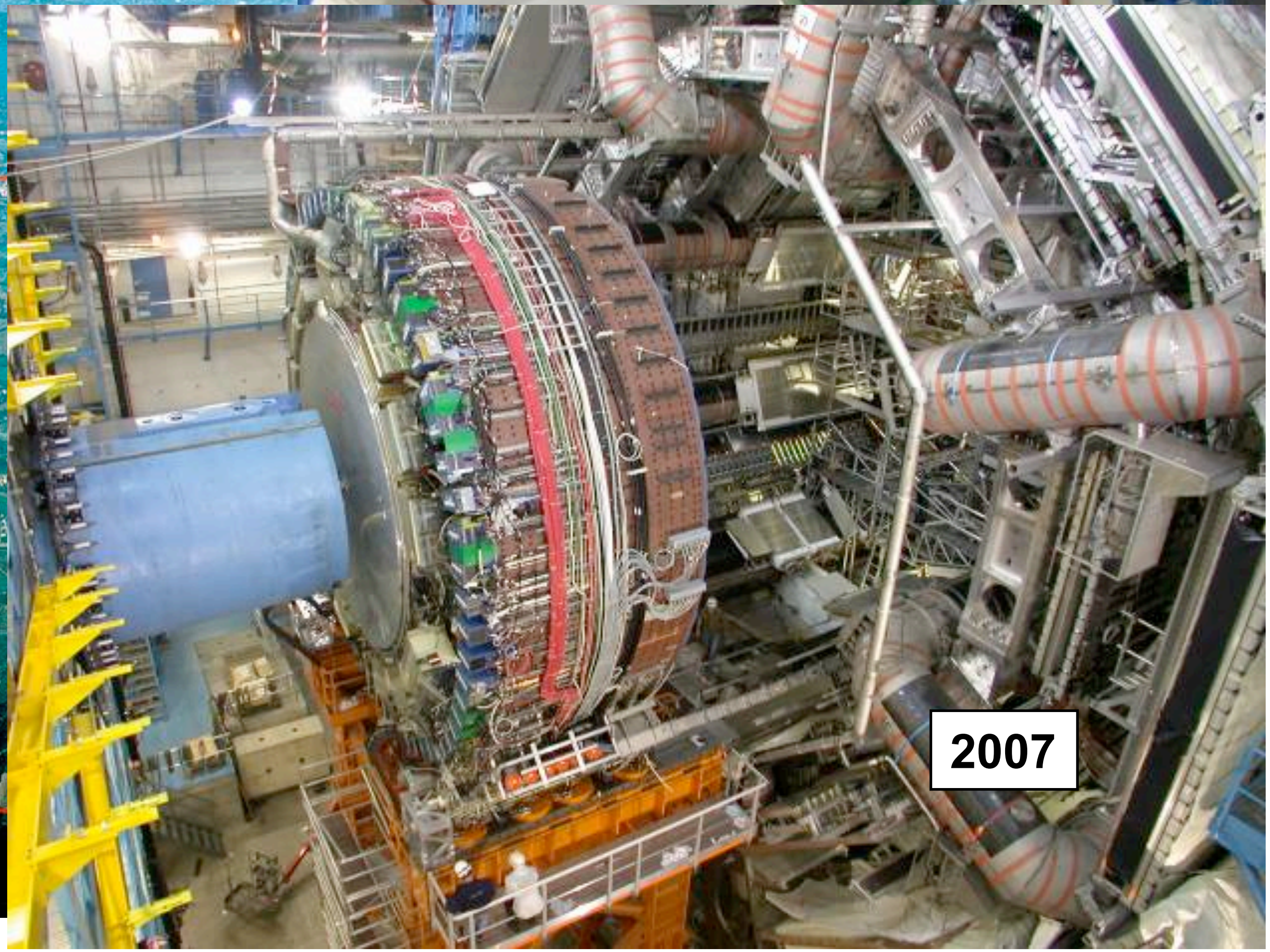
The physics of the ultra small

needs the ultra large

LHC
Large Hadron Collider



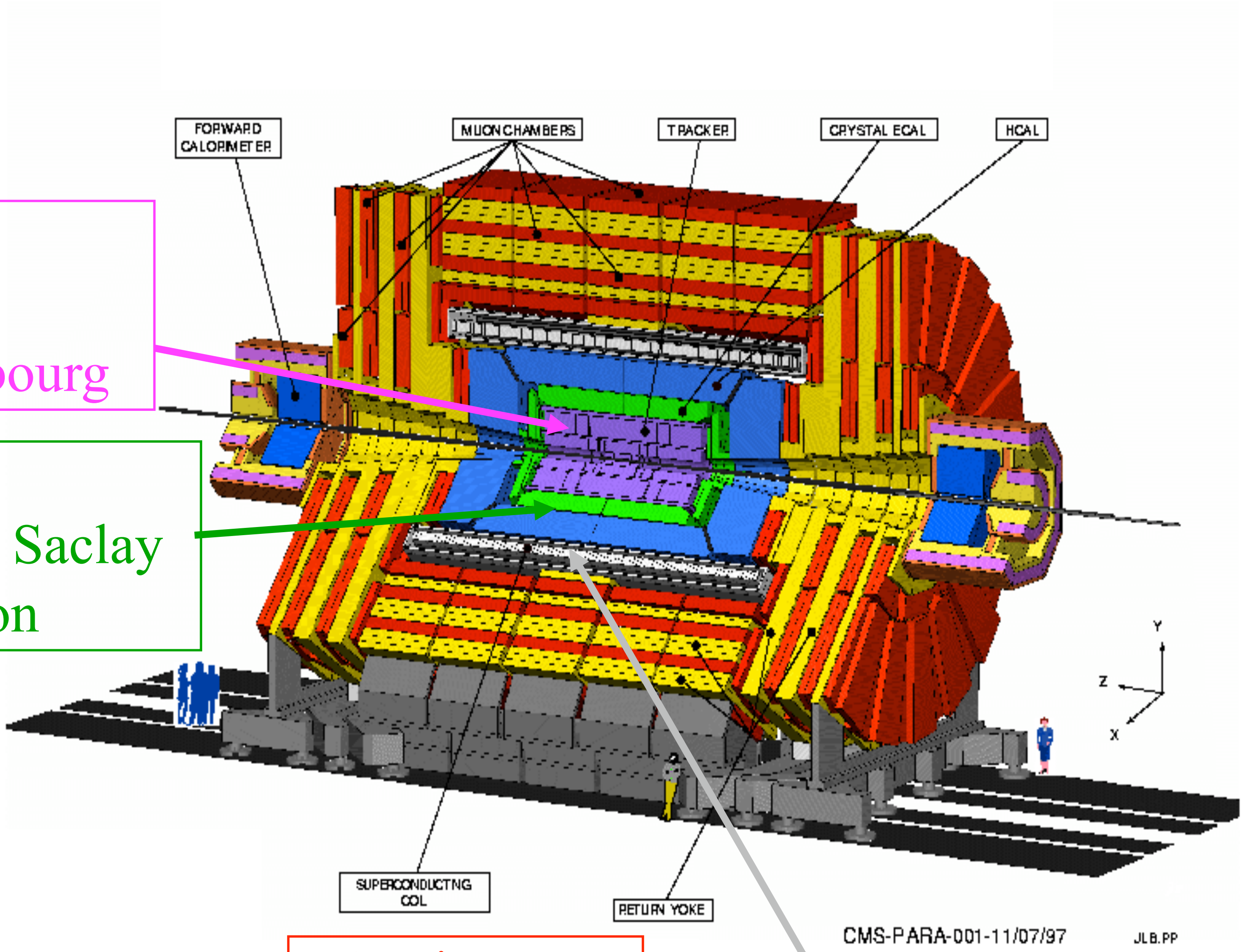




CMS

Si Tracker
End cap
Lyon-Strasbourg

EM Calo
Crystals test : Saclay
Readout : Lyon



Length : 20 m
Radius : 7 m
Weight : 14000 tonnes
Electronic channels : 10^8

L1 Trigger
Electronics
LLR

Solenoid : Saclay

A
T
L
A
S

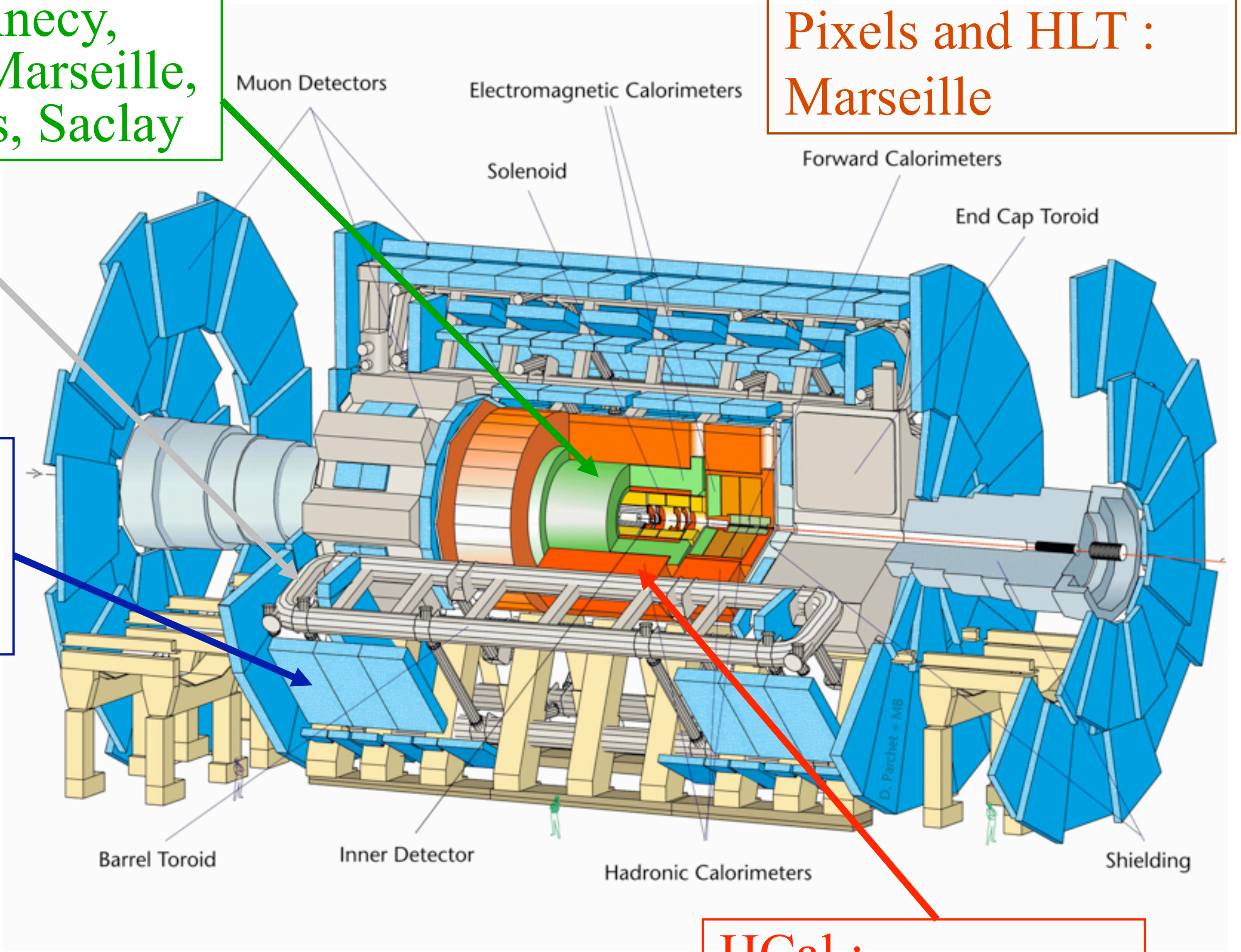
EmCal : Annecy, Grenoble, Marseille, Orsay, Paris, Saclay

Pixels and HLT : Marseille

Toroids : Saclay

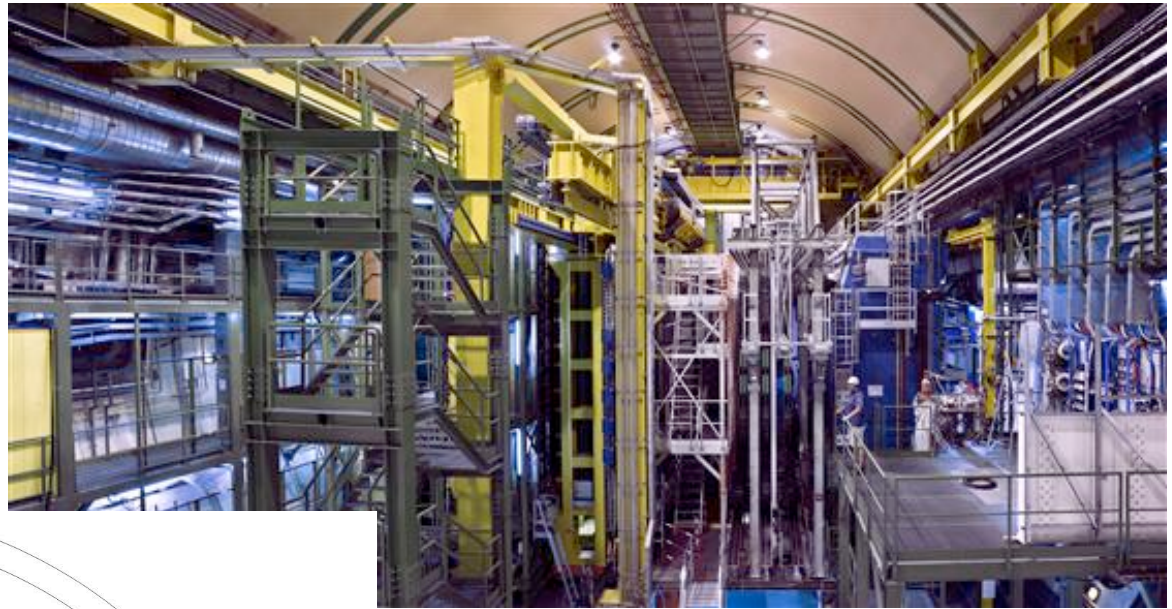
Muon chambers: Saclay

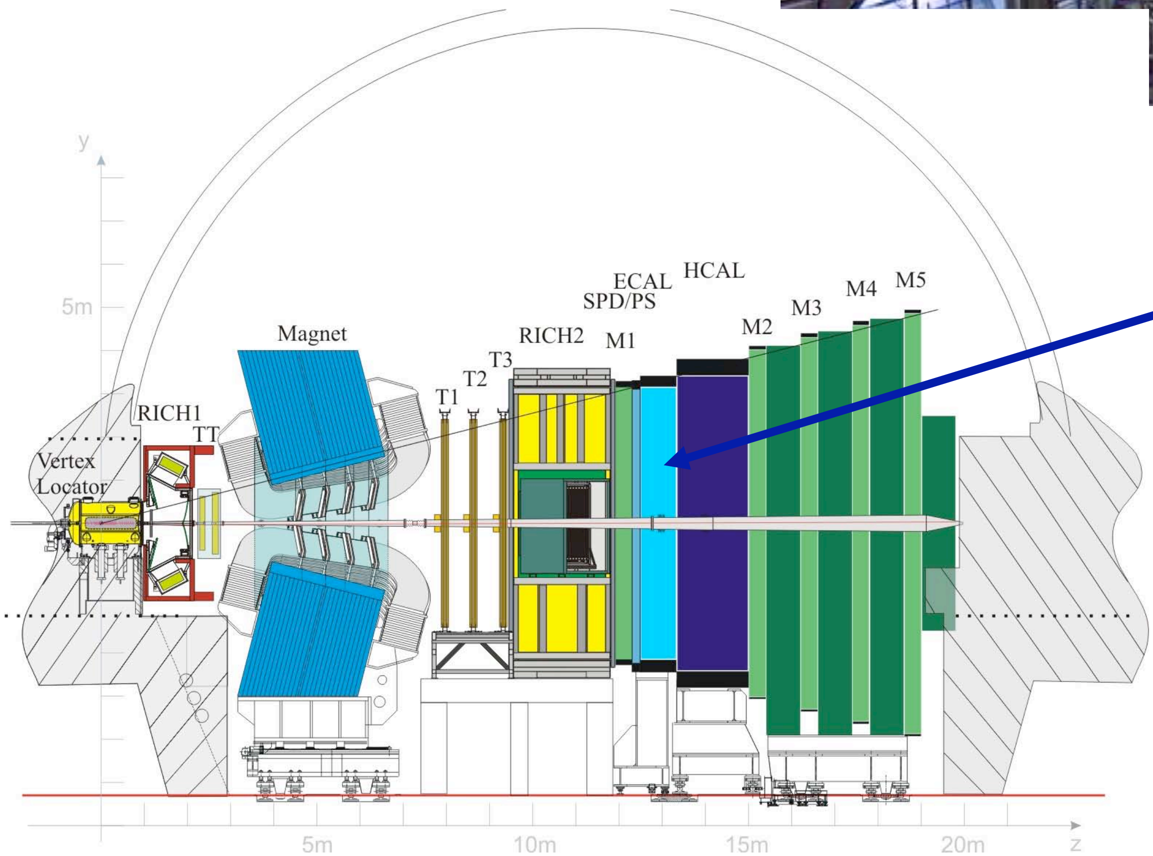
HCal : Clermont-Ferrand



Length : 40 m
Radius : 10 m
Weight : 7000 tonnes
Electronic channels : 10^8

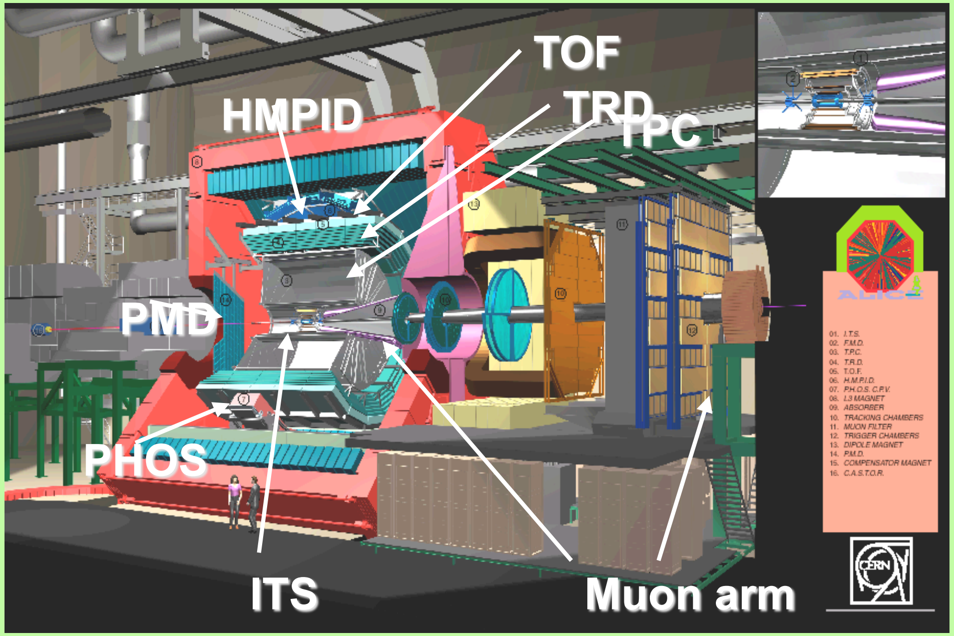
LHCb





Calorimètres :
Structure/électronique
Trigger L0
Annecy, Clermont-Ferrand, Marseille, Paris, Orsay

Nature of the confinement of quarks and gluons



ALICE (CERN)

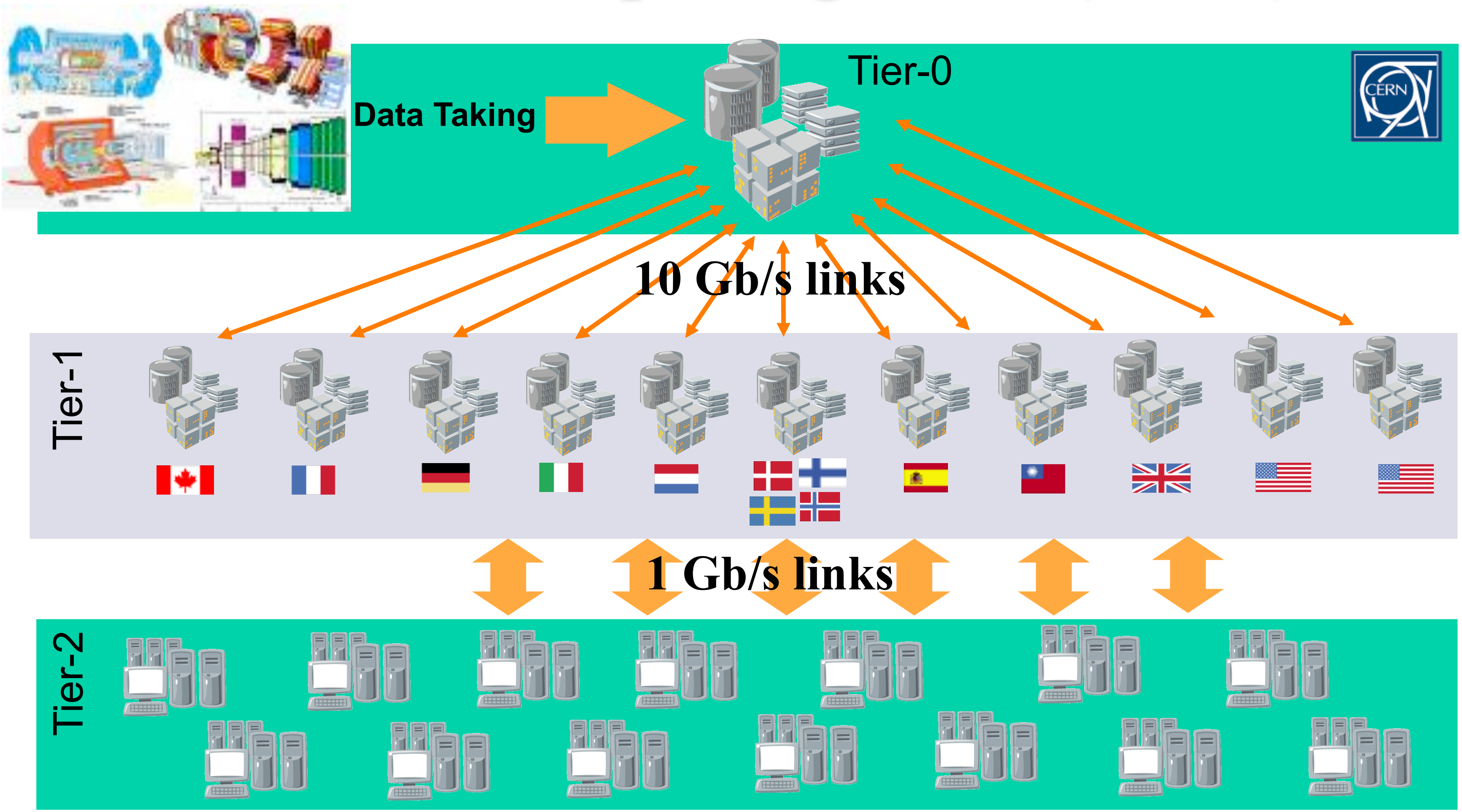
IN2P3 6 laboratories

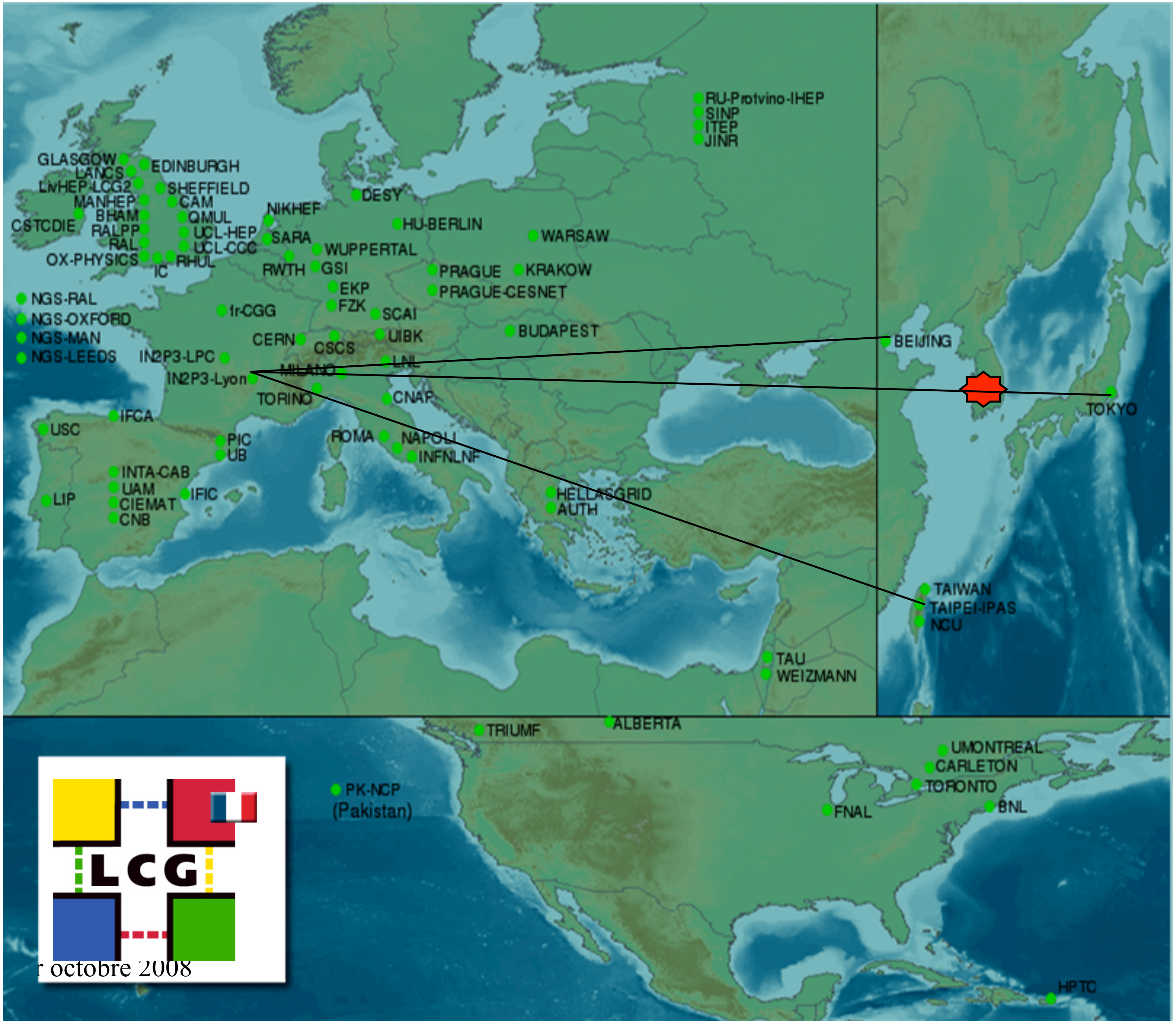
- Dimuon arm
- Internal tracking system (ITS)

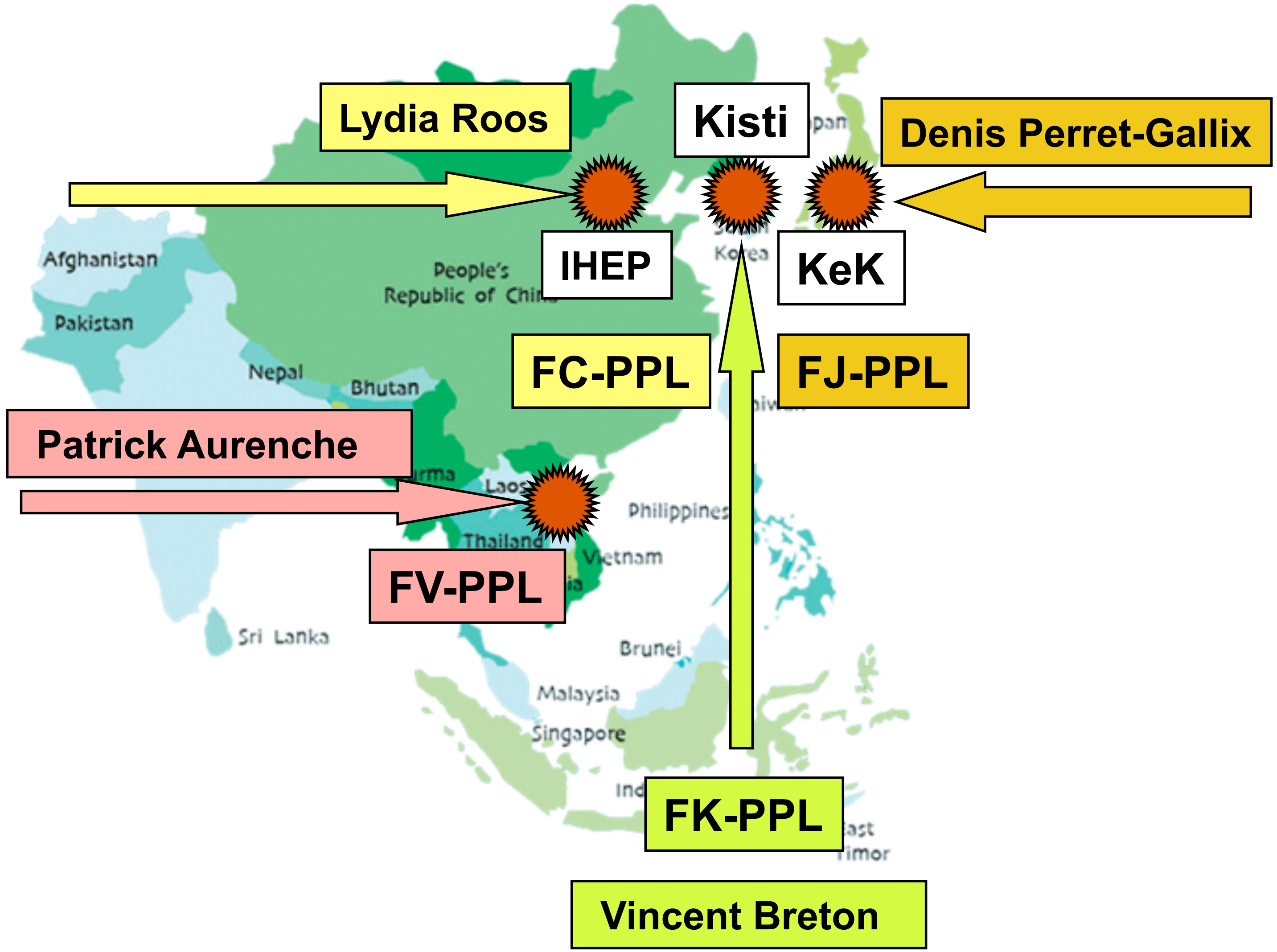
Investment: 6.6 M€

+ electromagnetic calorimeter

LHC Computing Grid (LCG)




RU-Protvino-IHEP
SINP
ITEP
JINR
GLASGOW
EDINBURGH
LANCS
LivHEP-LCG2
SHEFFIELD
MANHEP
CAM
CSTCDIE
BHAM
QMUL
RALPP
UCL-HEP
RAL
UCL-CCC
OX-PHYSICS
RHUL
IC
NIKHEF
SARA
DESY
HU-BERLIN
WARSAW
WUPPERTAL
RWTH
GSI
PRAGUE
KRAKOW
PRAGUE-CESNET
EKP
FZK
SCAI
NGS-RAL
NGS-OXFORD
NGS-MAN
NGS-LEEDS
fr-CGG
CERN
CSCS
UIBK
BUDAPEST
IN2P3-LPC
IN2P3-Lyon
MILANO
LNL
TORINO
CNAF
BEIJING
TOKYO
IFCA
USC
PIC
UB
ROMA
NAPOLI
INFNLNF
INTA-CAB
UAM
CIEMAT
CNB
IFIC
LIP
HELLASGRID
AUTH
TAIWAN
TAIPEI-IPAS
NCU
TAU
WEIZMANN
TRIUMF
ALBERTA
UMONTREAL
CARLETON
TORONTO
PK-NCP
(Pakistan)
FNAL
BNL
HPTC
LCG


Lydia Roos
Kisti
Denis Perret-Gallix
IHEP
KeK
FC-PPL
FJ-PPL
Patrick Aurenche
FV-PPL
FK-PPL
Vincent Breton
Afghanistan
Pakistan
Nepal
Bhutan
People's
Republic of Chin
Laos
Philippines
Thailand
Vietnam
Sri Lanka
Brunei
Malaysia
Singapore

CALICE at IN2P3

Jan. 2009

80 phys/IR/IE
70 Phys/IR
45.4 FTEs

Laboratoire Annecy de Physique des Particules

C. Adloff, Y. Karyotakis, A. Espargilière, R.Hermel, J.Prast, N.Geffroy, P.Delbecque, C.Girard

Laboratoire de l'Accélérateur Linéaire

B.Bouquet ,R.Poeschl , F.Richard , H. Li ,Ph. Doublet , Ch. De la Taille, J.Fleury , S.Callier, N.Seguin-Moreau ,F.Dulucq , L.Raux ,G.Martin-Chassard ,F.Wicek ,A.Faloud

Laboratoire Leprince Ringuet

V.Boudry, J-C.Brient, A.Rougé, M.Ruan, H.Videau, M.Reinhard , M.Anduze , C.Clerc, G.Musat, P.Mora de Freitas, R.Cornat ,J-Ch. Vanel , F.Gastaldi

Institut de physique Nucléaire de Lyon

I.Laktineh, M.Bedjidian , E.Latour, M.Vander Donckt , R.Kieffer, G.Grenier, P.Lebrun J.Fay, N.Lumb, H.Mathez , R.Gaglione, Ch. Combaret, E.Schibler, J.-C Ianigro

Laboratoire de physique subatomique et corpusculaire

J-Y Hostachy, L.Morin , D.Grondin , D.Zahini ,O. Rosetto, C. Vescovi , F.-E Rarbi

Laboratoire de physique Corpusculaire de Clermont

F.Badaud, M.Benyamna, C.Carloganu, P.Gay , Ph.Gris , G.Blanchar, N .Brun , M.Crouau , S.Manen , L.Royer

Conclusions

- La physique des particules a de beaux jours devant elle
  - LHC, sLHC, ILC
  - OPERA, T2K, … Mégatonnes
  - SuperNEMO
- Des projets mondiaux très lourds
  - R&D Instrumentation (et informatique)
  - Gros détecteurs, Grosses collaborations

Backup slides

Particle Physics at IN2P3

400 permanent scientists (FTE) / 10 Laboratories / 7 Experiments

Experiments		Data taking
Ongoing Experiments		
H1	(10/3)	ended in **2007**
BaBar	(20/5)	ended in **2008**
D0	(30/8)	ends ni **2009** (2010?)
Next Experiments		
ATLAS	(60/7)	starts in **2008**
CMS	(30/4)	starts in **2008**
LHCb	(20/6)	starts in **2008**
ALICE	(38/6)	starts in **2008**
LCG (LHC computing grid)	*all*	ready
Future Experiments		
ILC	(30/9)	starts > 2020

Structure and the dynamics of nuclei.
Nature of the nucleonic matter

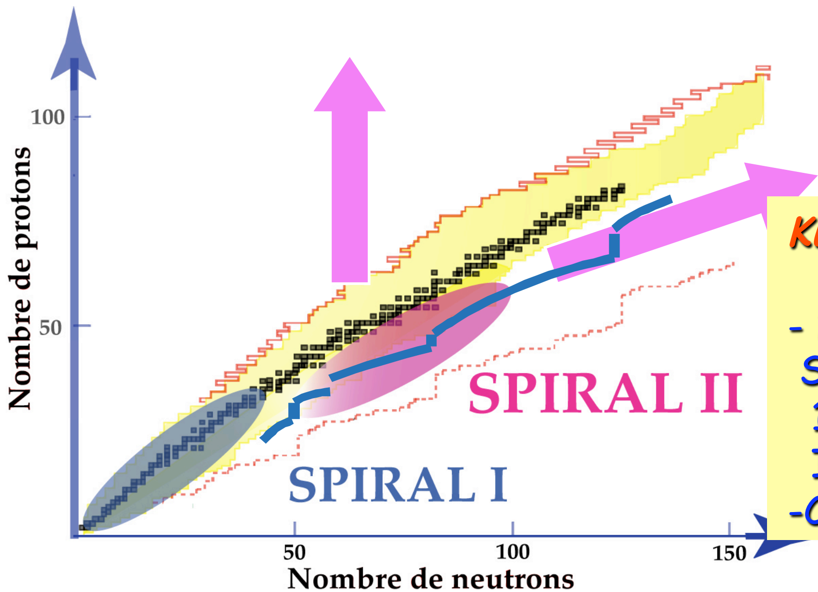
- Origin of nuclear binding
- Limits of nuclear stability
- Heavy and super-heavy elements

- Formation of elements in the universe (nucléosynthesis)

GANIL
SPIRAL
CAEN

Some key facts:
New limits of stability (37Ne)
Discovery of 48Ni
2p radioactivity
New deformations, New magicity
Nuclear molecules
New detectors (EXOGAM, VAMOS)

R&D for SPIRAL2: ALTO (agreementDUBNA-IPNO)
R&D future detectors: AGATA



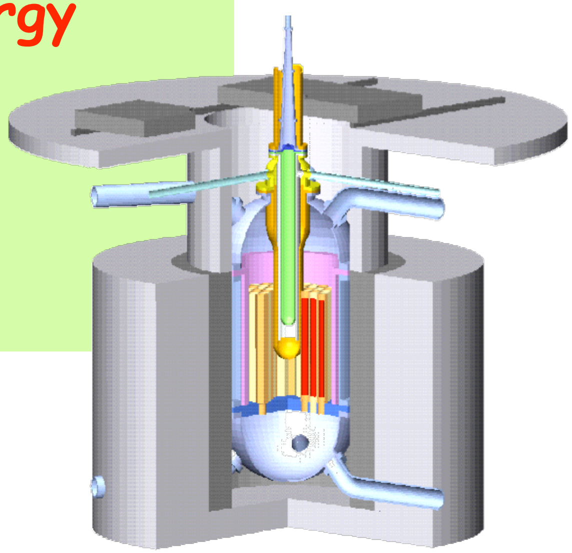
KEEP THE INTERNATIONAL COMPETITIVITY OF GANIL
SPIRAL2 project
- 2002-2008 experiments with SPIRAL I
SPIRAL II , a priority stated by NuPECC
118M€ (full cost) - cofinanced by Region (33%)
Into operation: 2012-2015
-Complementarity with GSI/FAIR - Future with EURISOL…

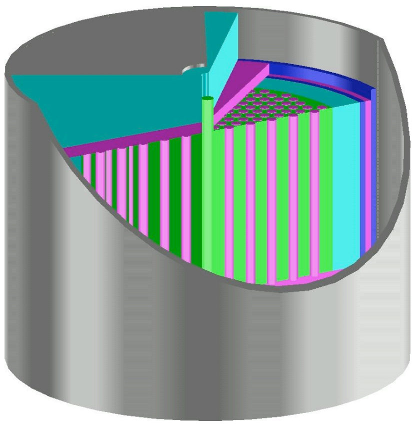
Pluridisciplinary Program PACE

Back-end of electronuclear cycle

IN2P3 focused on transmutation of nuclear wastes and innovative systems for the future of nuclear Energy

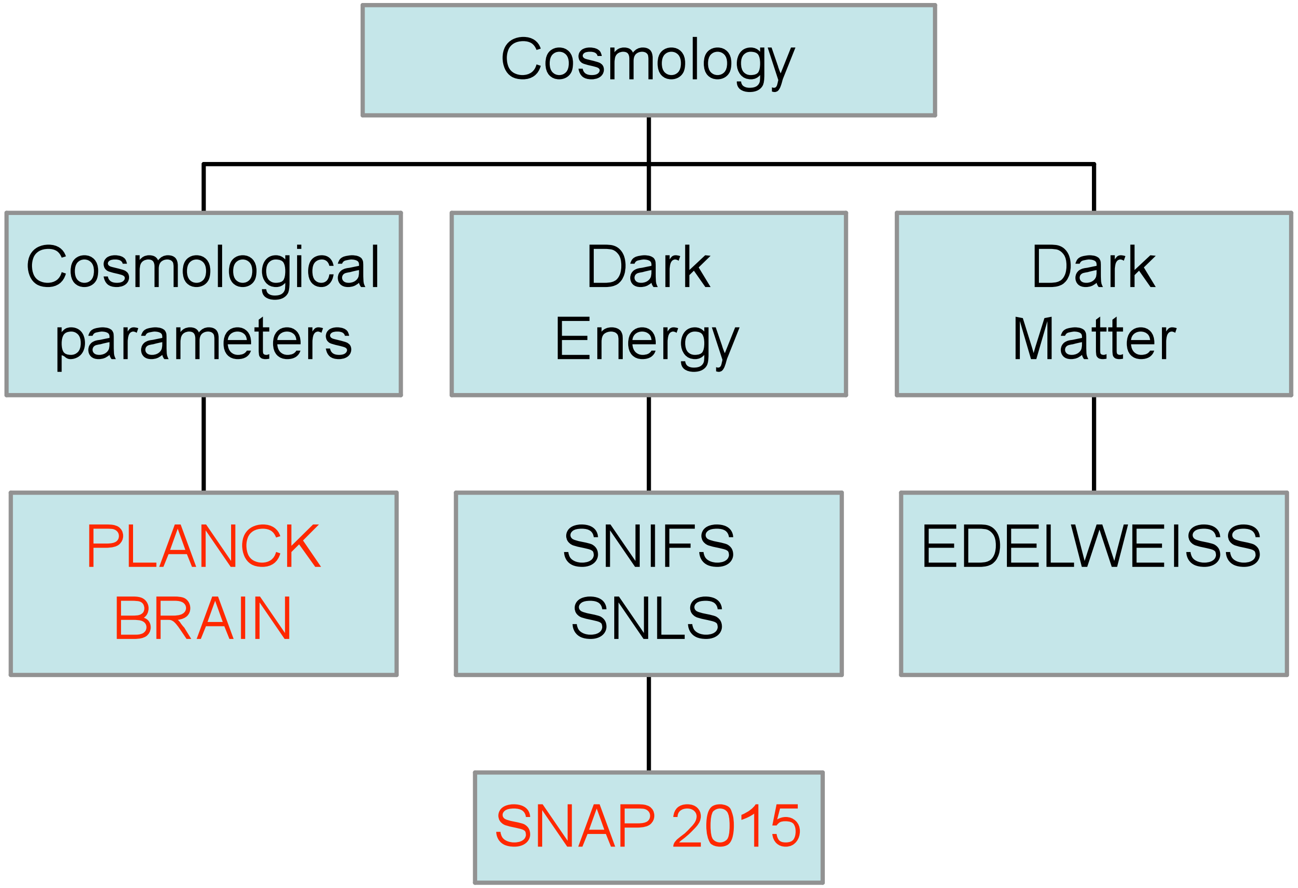
- Experimental validation of Accelerator Driven Systems (ADS)
    R&D European programs
    (MEGAPIE, n-TOF, MUSE, PDS-XADS, EUROTRANS)
    - High intensity accelerator developments (IPHI)





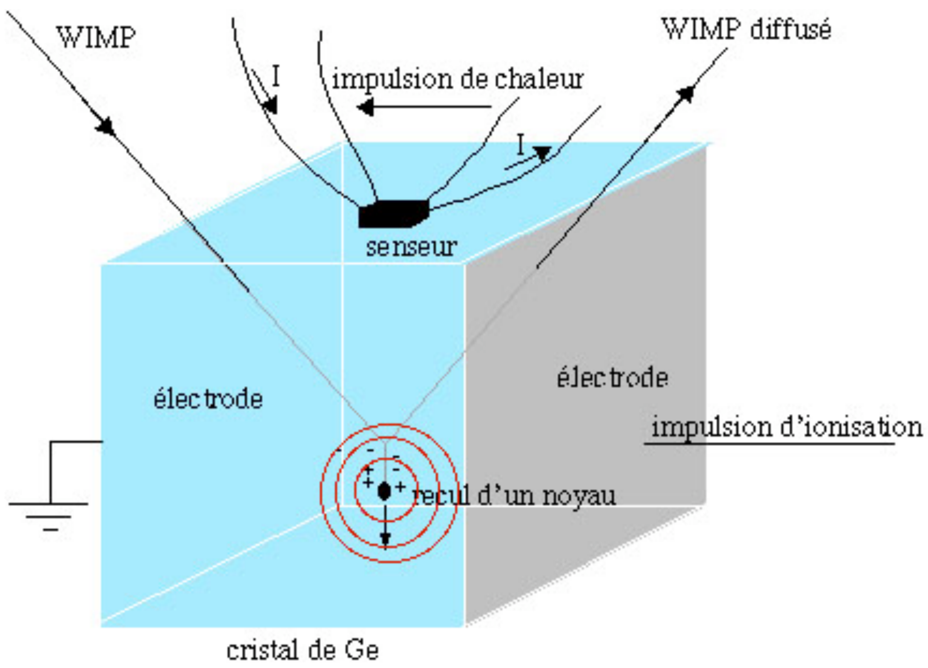
Innovative systems for Nuclear Energy based on the Th cycle
Scenarios, focused on the concept of a molten salt reactor

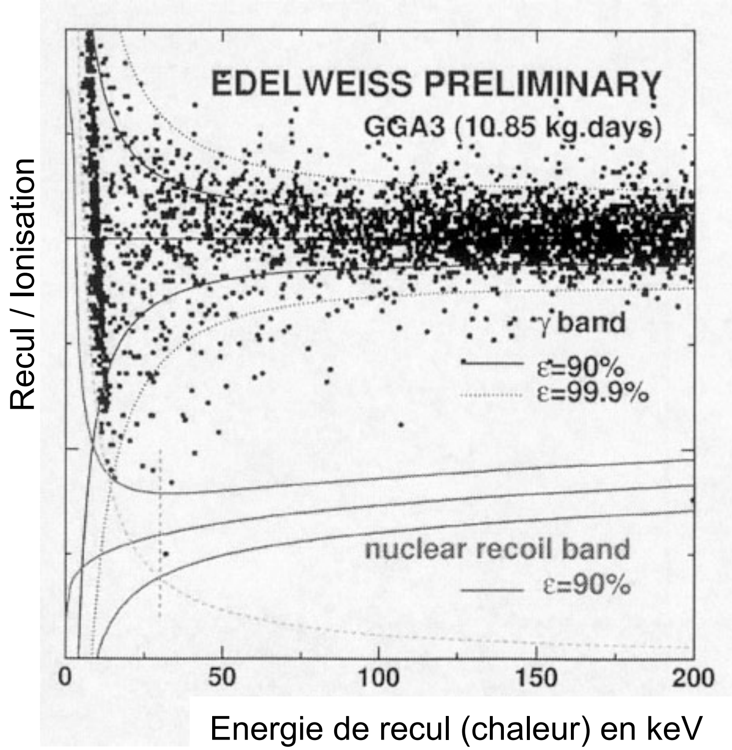
Current IN2P3/IRFU program in Cosmology



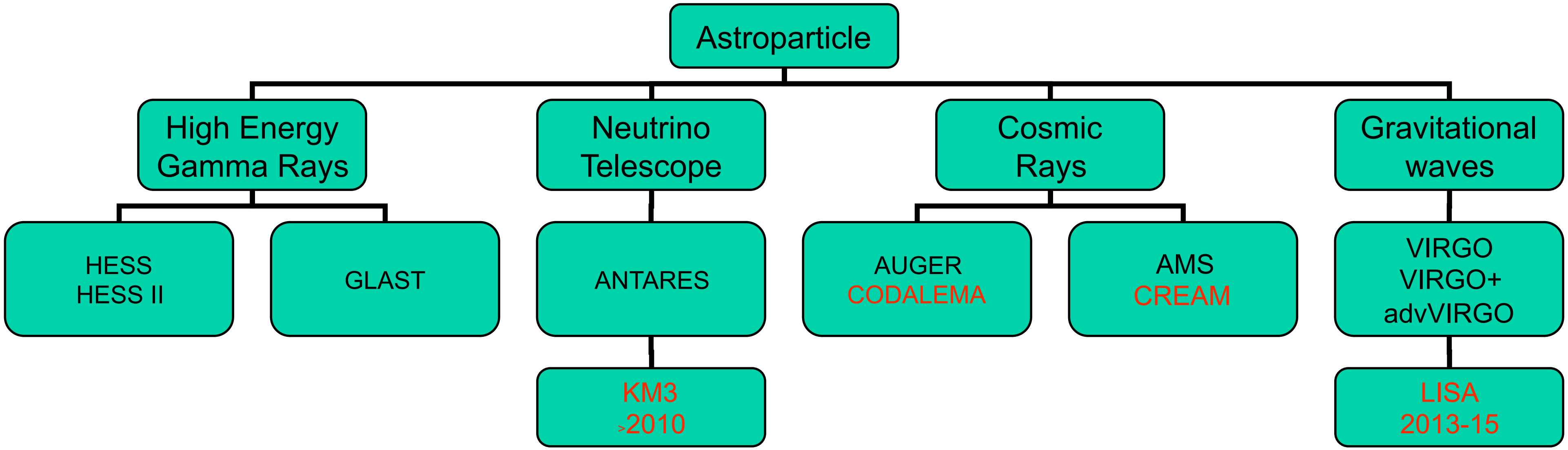
EDELWEISS searches for WIMPS

- **Technological challenge :**
  - **Big monocristals (Germanium)**
    - **Few grams ➔ kilograms ➔ 100 kilograms** **now 28 cristals = 10 kg**
    - **Température close to absolute zéro : 10 mK**
    - **Protected from ordinary cosmic rays ➔ Underground laboratory in Modane**
      archelogic lead protection
- CRTBT Grenoble, IPN Lyon, LSM Modane, CSNSM Orsay, IAP Paris, CEA/DAPNIA et CEA/DRECAM Saclay, Karlsruhe

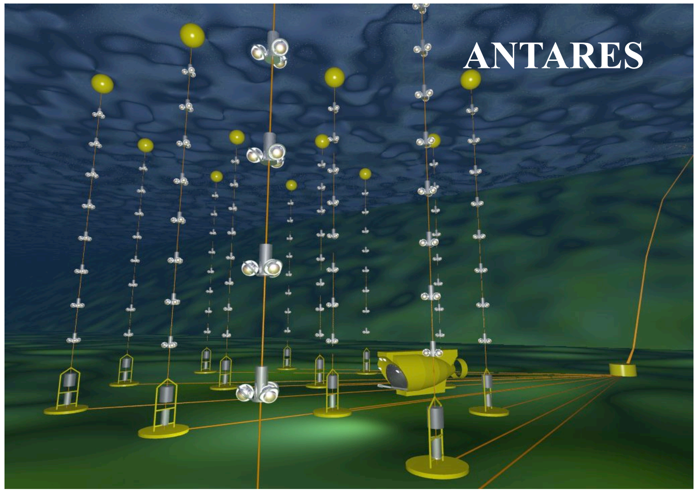




Current IN2P3/IRFU program in Cosmic Rays

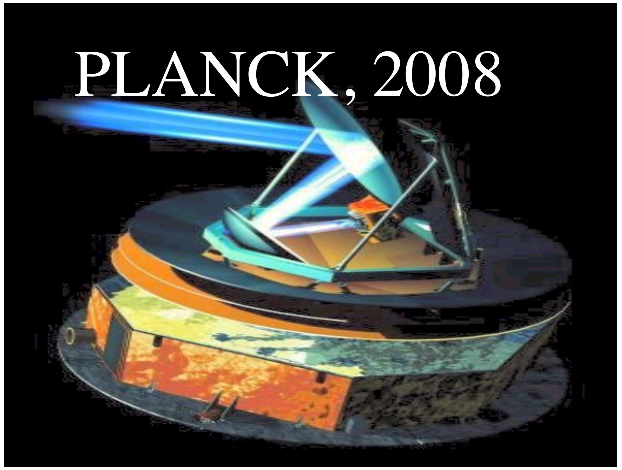


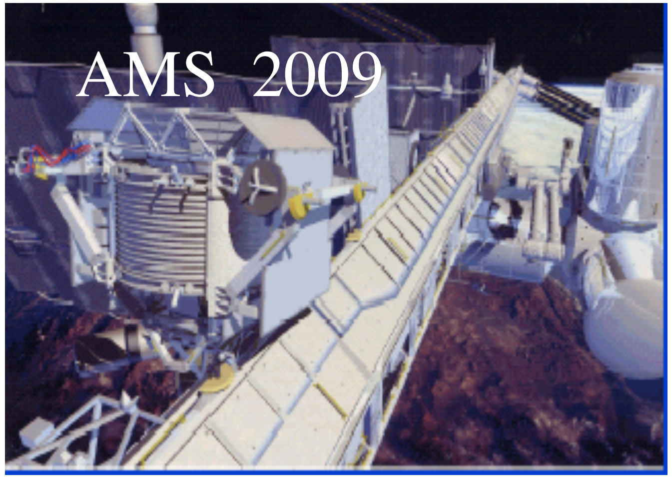
A cosmic ray program

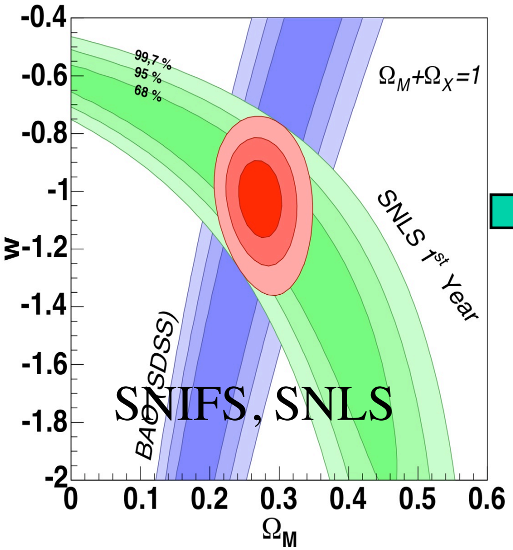


In the near future
Cosmic rays and cosmology in space

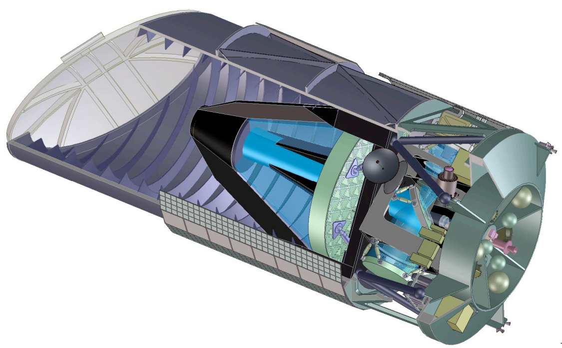
High energy gamma rays, antimatter, CMB, Dark Energy

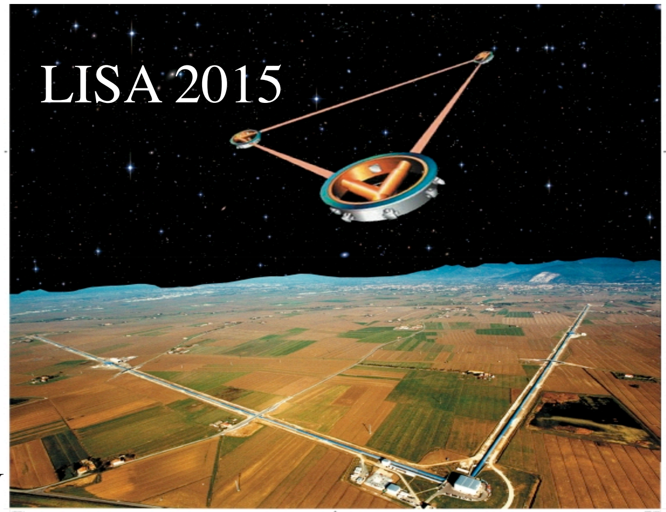




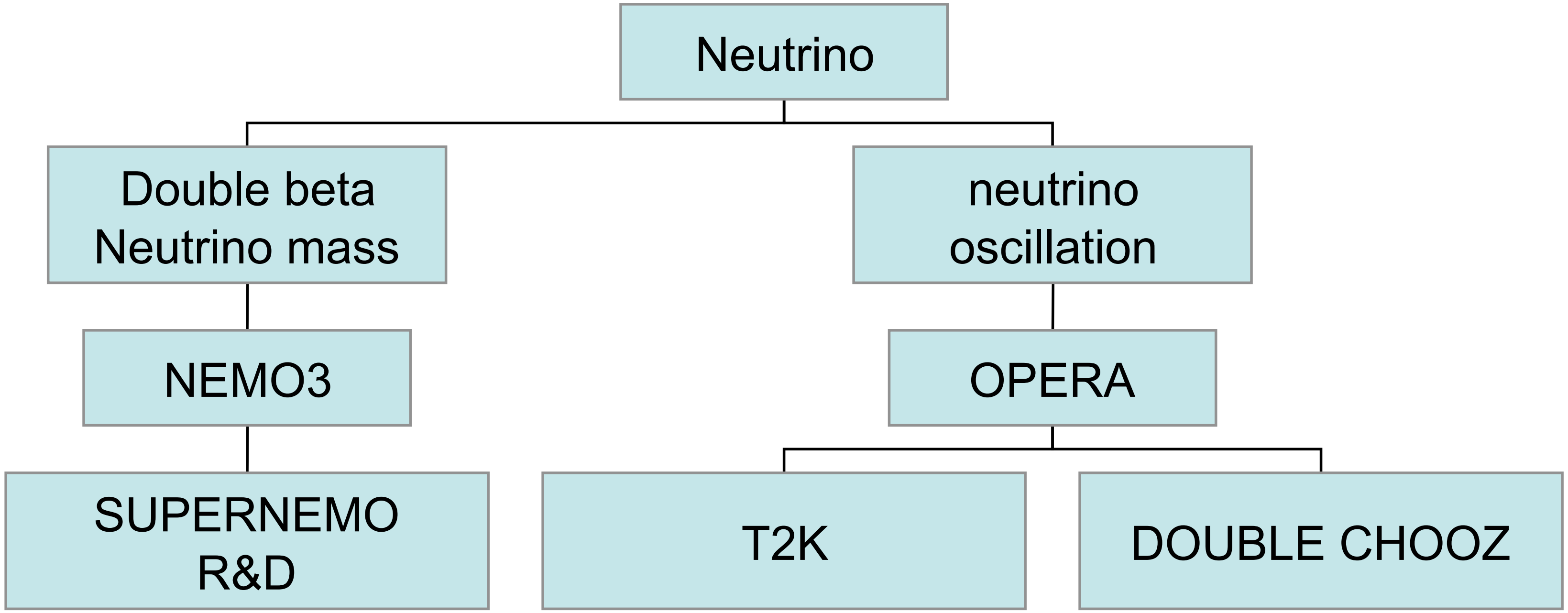


SNAP/JDEM 2015

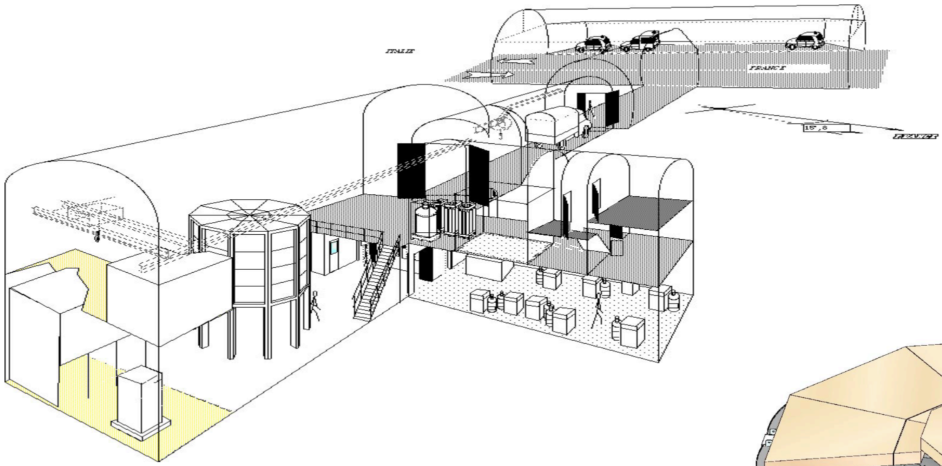


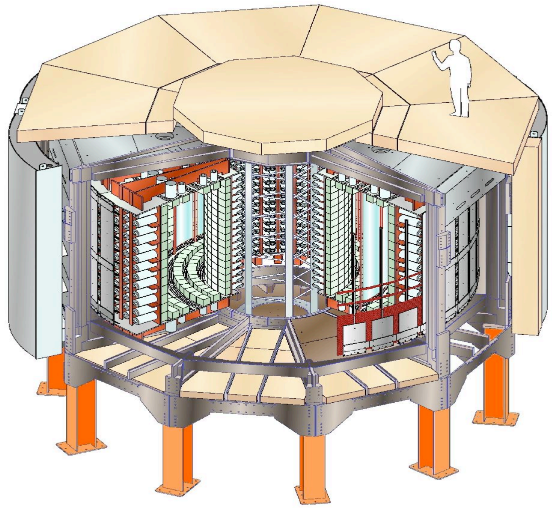


Current IN2P3/IRFU program in Neutrino physics

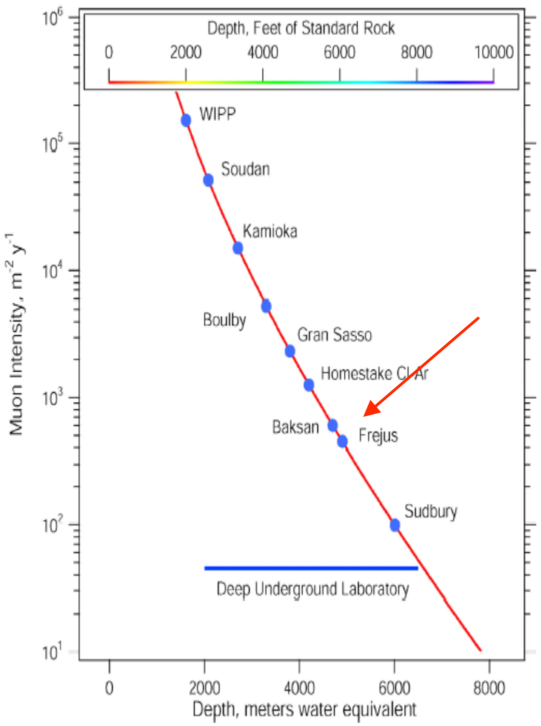


Laboratoire Souterrain de Modane, France

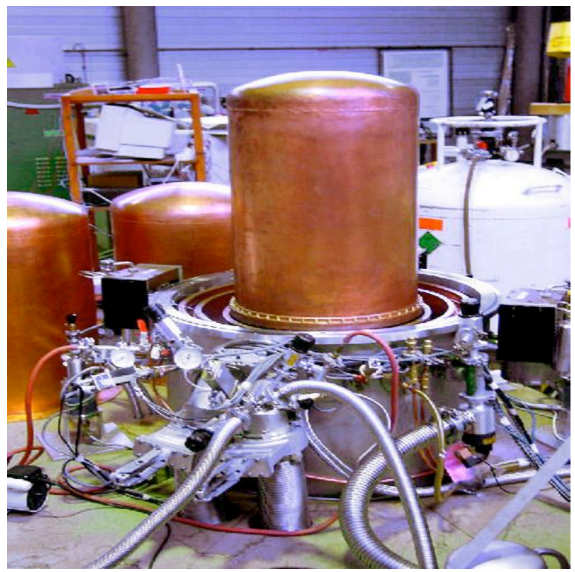




LSM in Fréjus

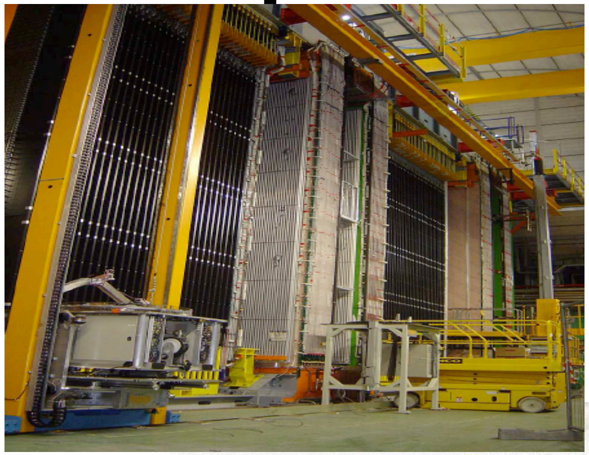


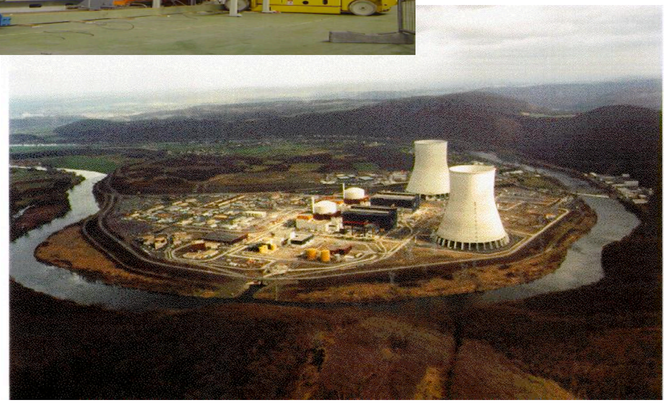
- NEMO3, double beta decay (2003-)
- EDELWEISS II, dark matter (2006)
- Low radioactivity studies (ILIAS)
- Search for SHE in nature

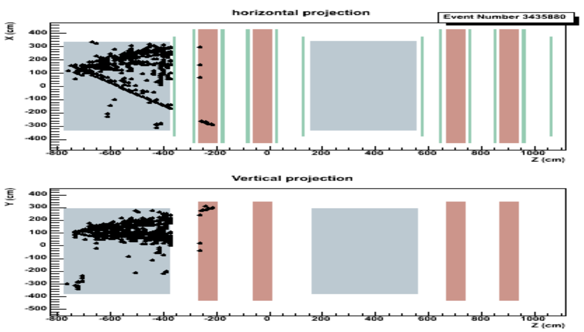


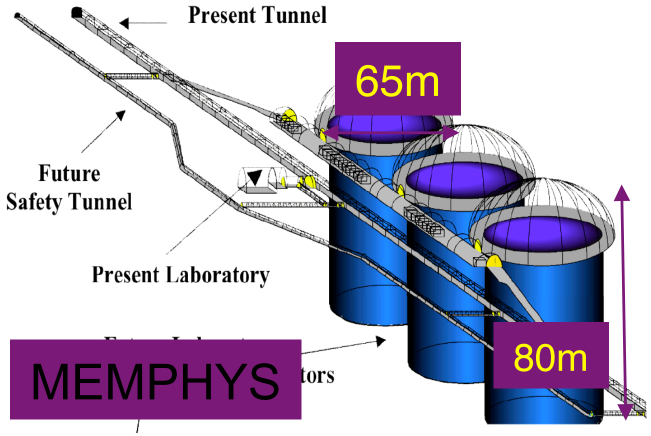
Neutrino roadmap

- OPERA(2006)
- In the next few years:
  - DOUBLECHOOZ (2008-2009)
  - T2K (2009-2013)
- R&D for SuperNEMO, double beta decay (>2010)
- At the horizon of 2015-18
  - Megatonne detector in Fréjus in relation to super and beta beam from CERN?



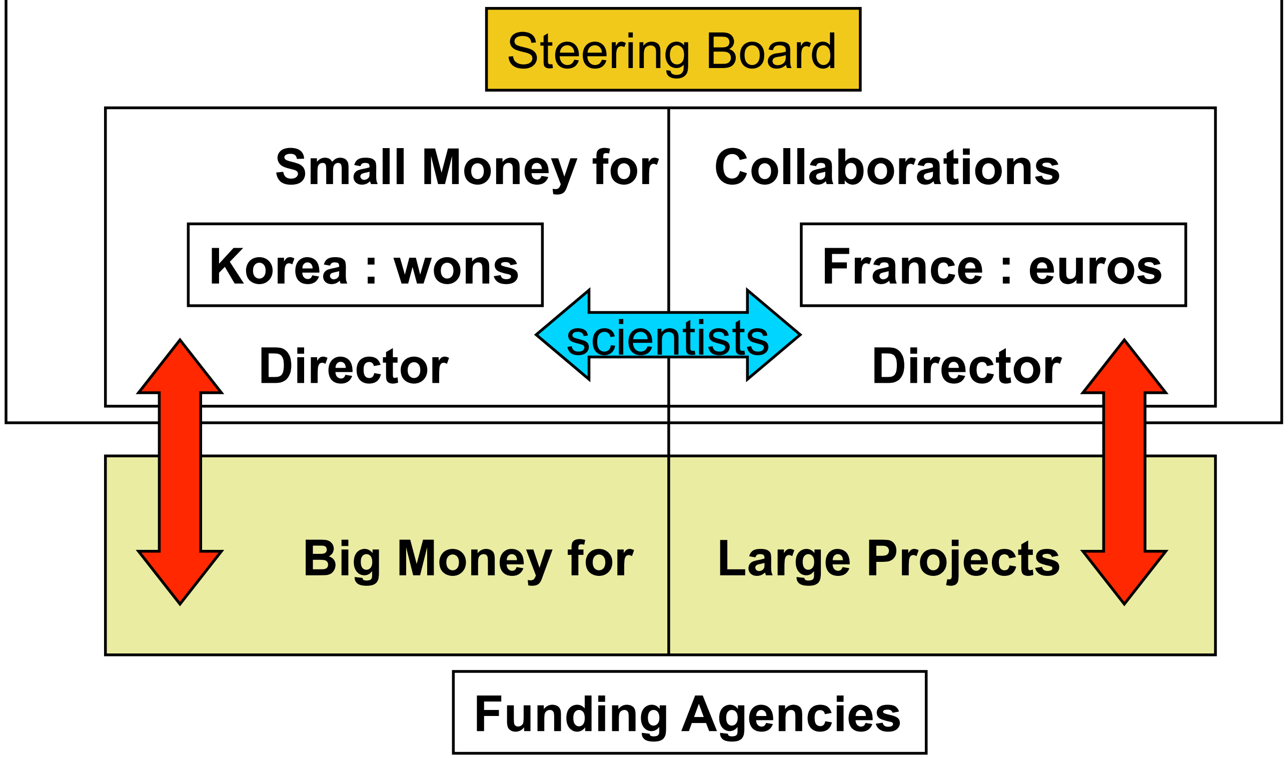






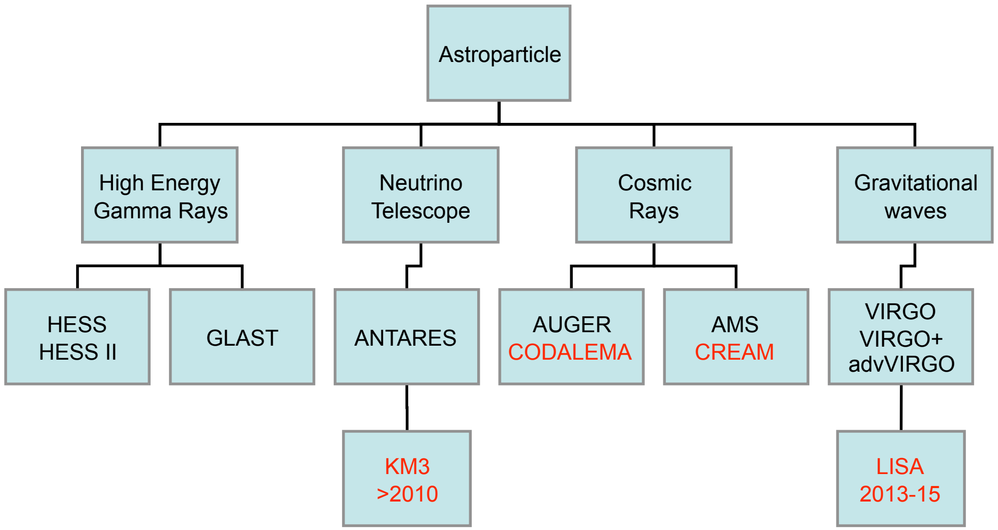
LIA :

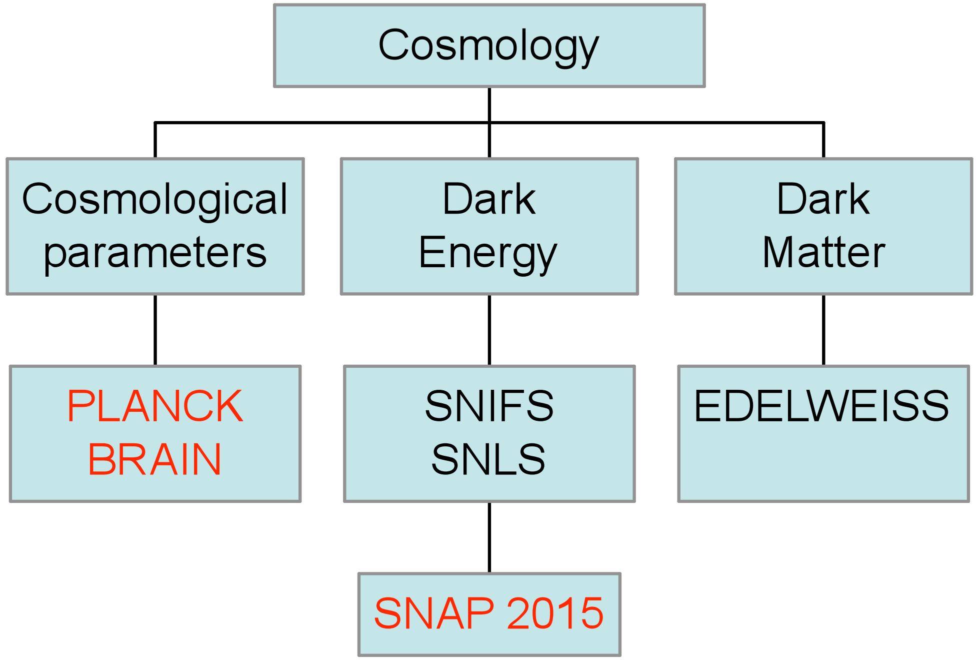
International Associated Laboratory

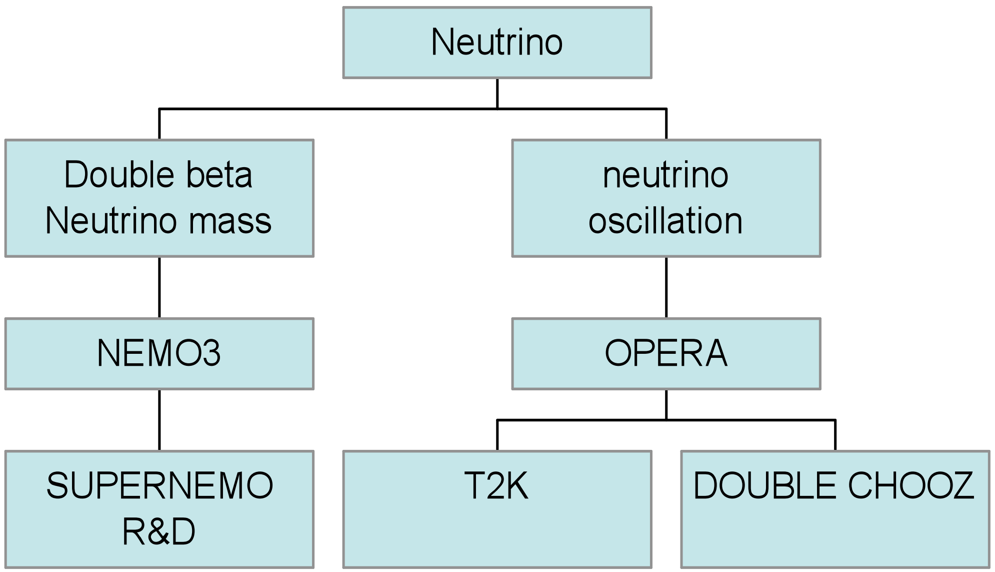


IN2P3 is a NETWORK of 20 large laboratories

	BaBar	D0	H1	ATLAS	CMS	LHCb	LCG	ILC
CPPM		DØ	H1			LHCb	LCG	
LPSC		DØ					LCG	ilc
IPNL		DØ			CMS		LCG	ilc
LPC Cl		DØ				LHCb	LCG	ilc
LAPP						LHCb	LCG	ilc
IReS		DØ			CMS		LCG	ilc
LPNHE		DØ				LHCb	LCG	ilc
LLR			H1		CMS		LCG	ilc
LAL		DØ	H1			LHCb	LCG	ilc
CC-IN2P3		DØ			CMS	LHCb	LCG	ilc







Current IN2P3 program

On Astroparticle, Cosmology and Neutrino

SPIRAL II project

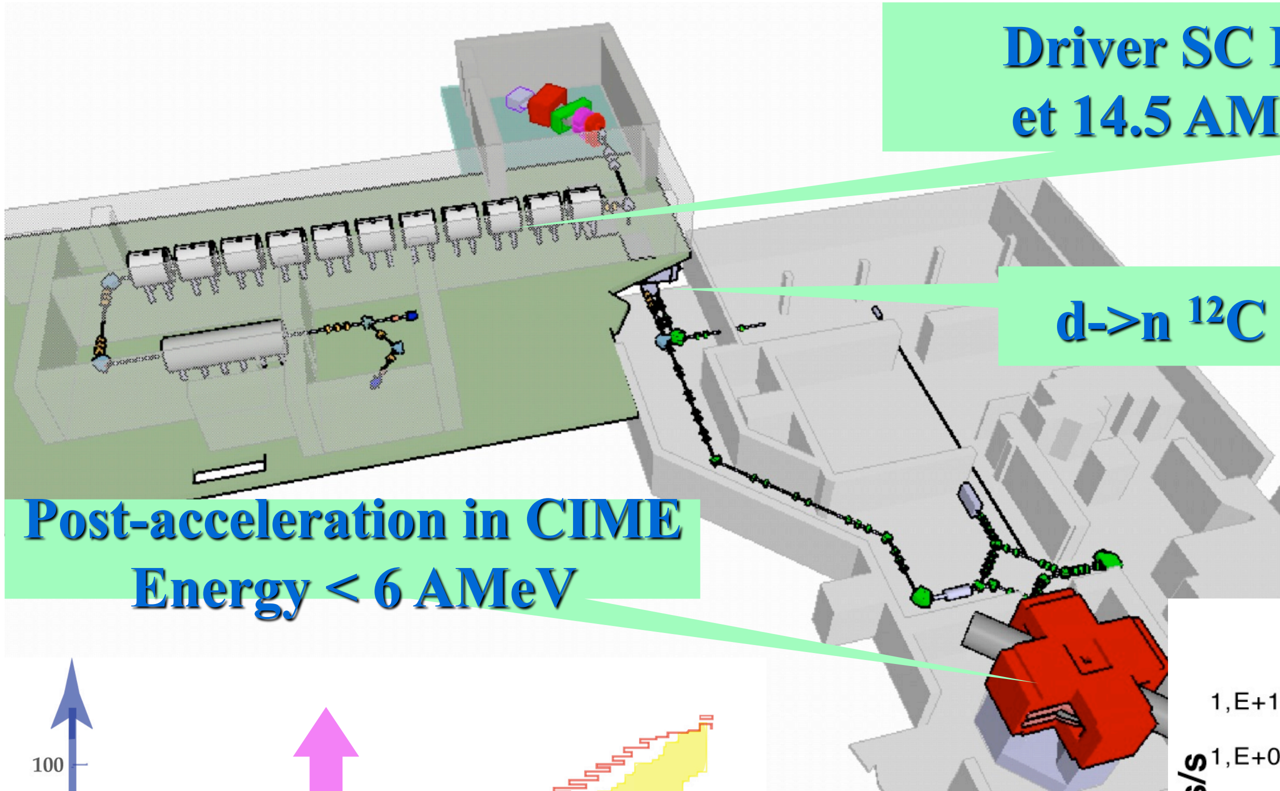
Driver SC Linac: 40MeV, 5mA d et 14.5 AMeV, 1pmA heavy-ions

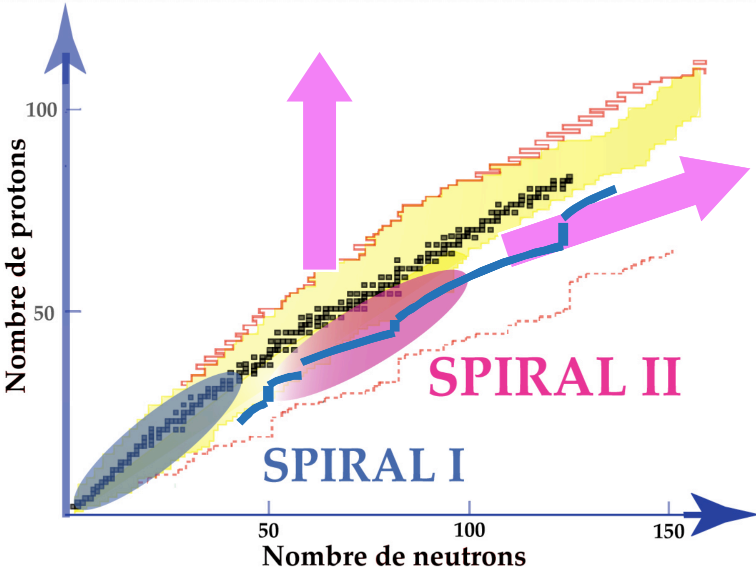
>10^{13} fissions/sec.

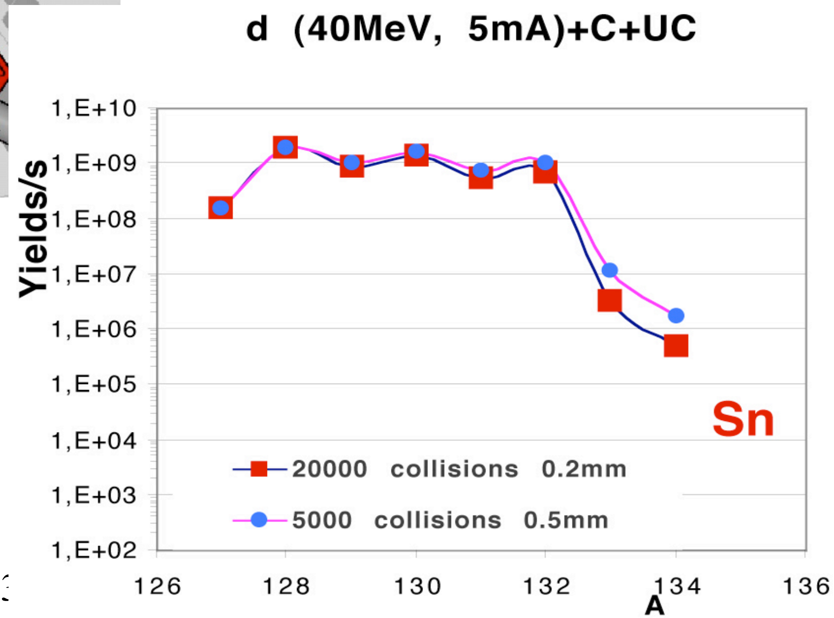
d->n ^{12}C converter + ^{238}UC$_x$ target

- **Multi-beams (up to 5)**
- **Into operation: 2009**

Post-acceleration in CIME Energy < 6 AMeV

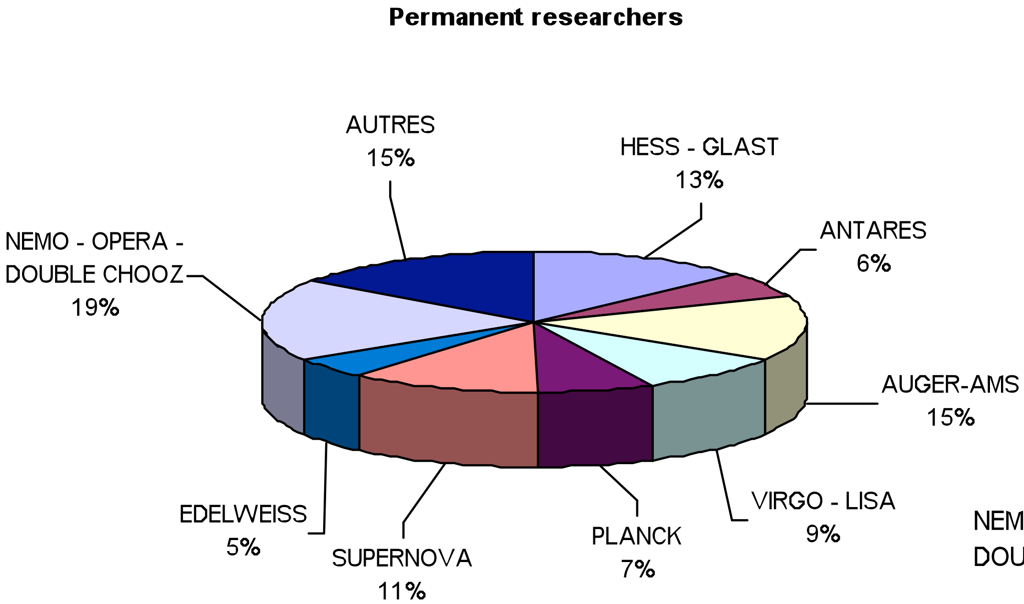


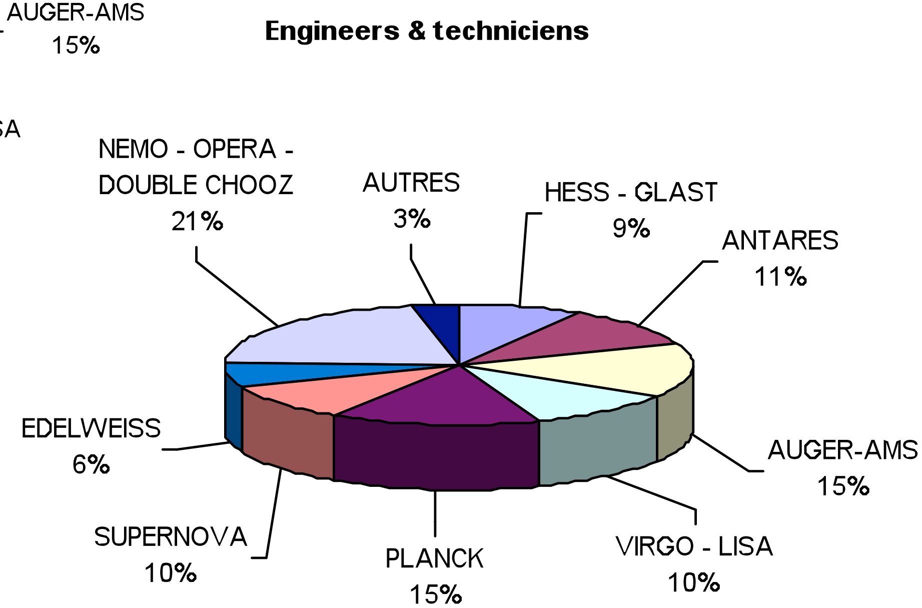




ASTROPARTICLE PHYSICS & NEUTRINO

200 researchers, 154 engineers, 70 non permanent staff

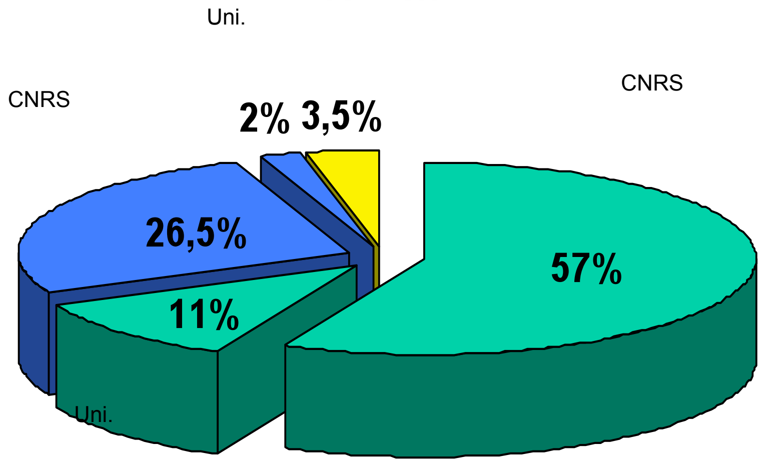




Space programs 25 %

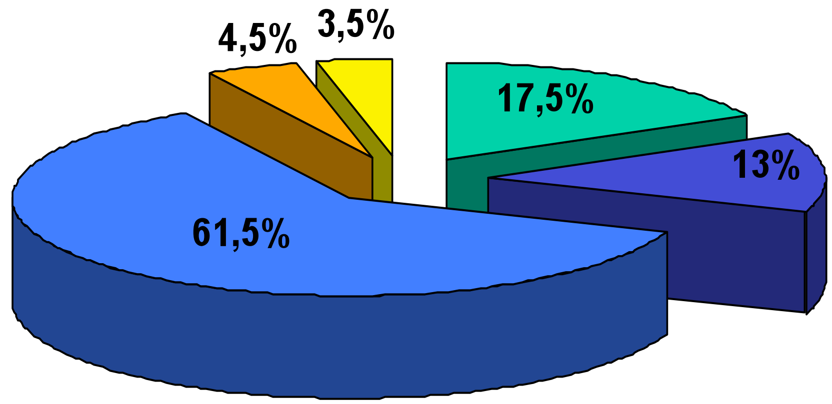
IN2P3/CNRS: 20 labs

BUDGET
170 M€



■ CNRS Staff + University
■ Investment + running CNRS + University
■ Others ressources

STAFF
2500



■ CNRS Researchers
■ University Researchers
■ CNRS Technical Staff
■ None permanents
■ University Technical