



# Le Futur de la Physique des Particules

**Daniel Treille**

**Postdoc à l'ETHZ**

# la Physique des Particules

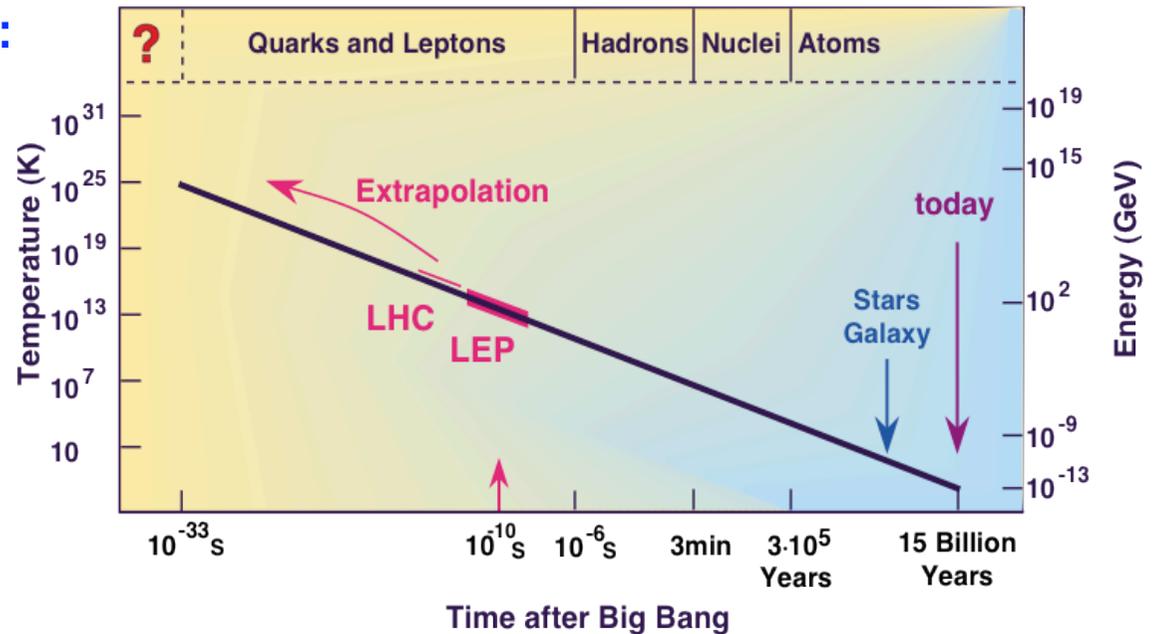
# Evolution of the Universe

D'abord la redéfinir simplement:  
étude des constituants et des  
forces s'exerçant entre eux  
avec accélérateurs, cosmiques,  
phénomènes naturels

immergée dans la cosmologie:  
raconter l'histoire de l'Univers,  
donc, d'abord, si possible,  
le comprendre...

la communication est vitale:  
parfois incorrecte, peu adroite  
Higgs Big Bang  
"Grand, fort et ... subtil"

spin off, accélérateurs,  
détecteurs, pour médecine, etc  
une réalité à bien conduire.  
Mais c'est la physique qu'il  
faut illustrer



FP\_79

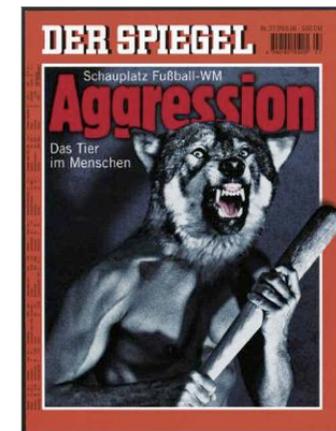
DER SPIEGEL 27/1998

PHYSIK

**Kathedralen für ein Phantom**

Von Klein, Stefan

DER SPIEGEL 27/1998



# Le Modèle Standard

terme modeste! construction de Yang-Mills grand succès: vérifié au pour mille

Electrofaible: OK,

mais secteur scalaire non testé

QCD: simple en principe, mais complexe dans sa dynamique

Les insuffisances du MS  
ce qu'il manque

ses problèmes conceptuels de hiérarchie, largement dus au secteur scalaire

la "petite" ou paradoxe du LEP compensation de l'effet du top?

la "grande", de 100 GeV à l'échelle de Planck

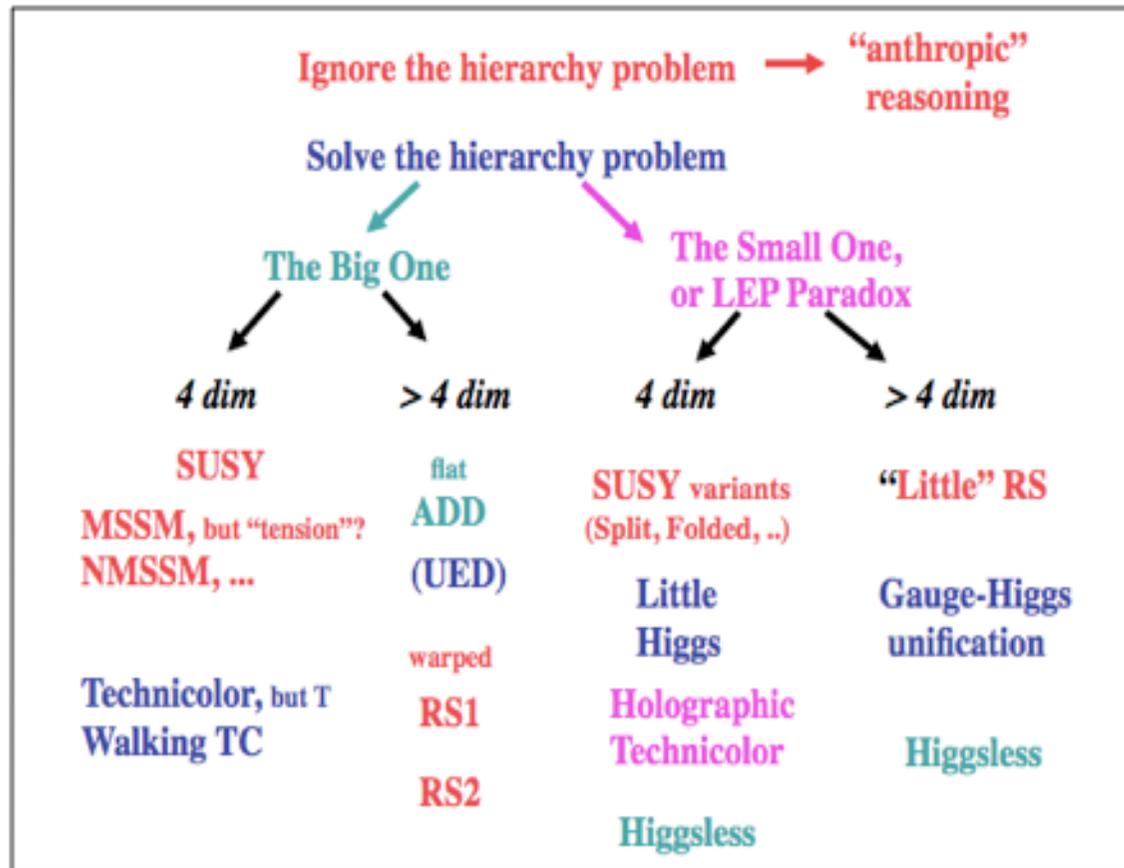
le problème de la saveur

Diverses solutions à l'étude.

Préjugé, motivé, en faveur de SUSY "légère" (hiérarchie, pourquoi du mécanisme de Higgs, unification des couplages, candidat matière noire). Retour à la mode de la Technicouleur?

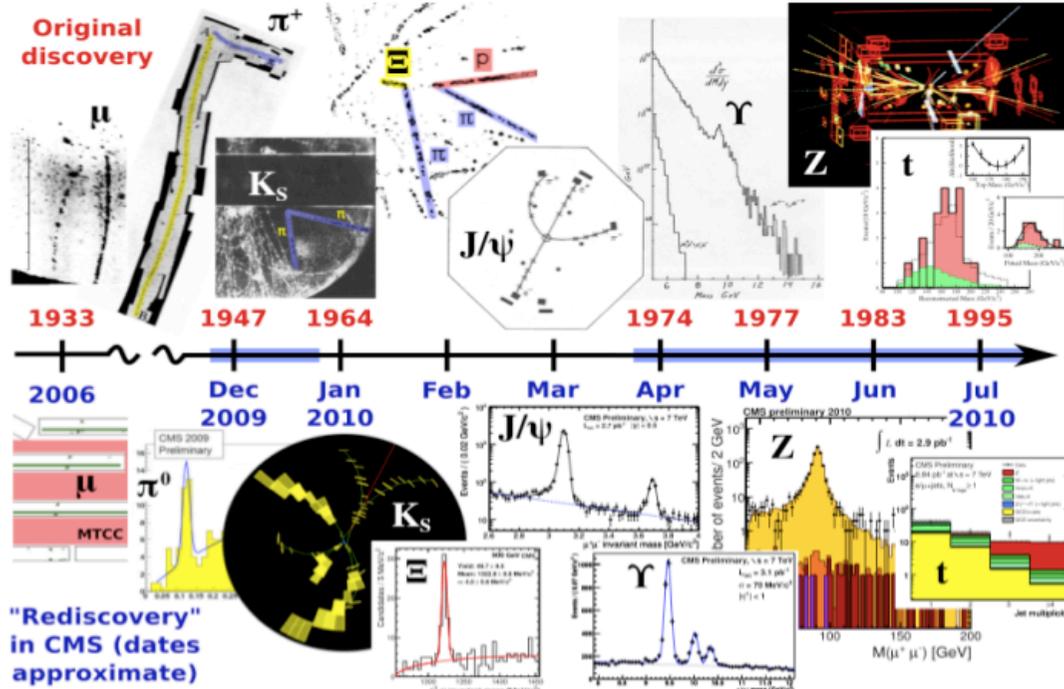
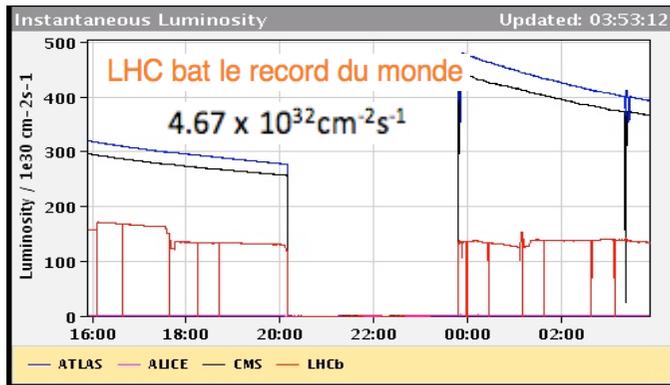
Le top détient-il l'une des clés?

Crucial de répondre. "Menace" du raisonnement anthropique



# LHC

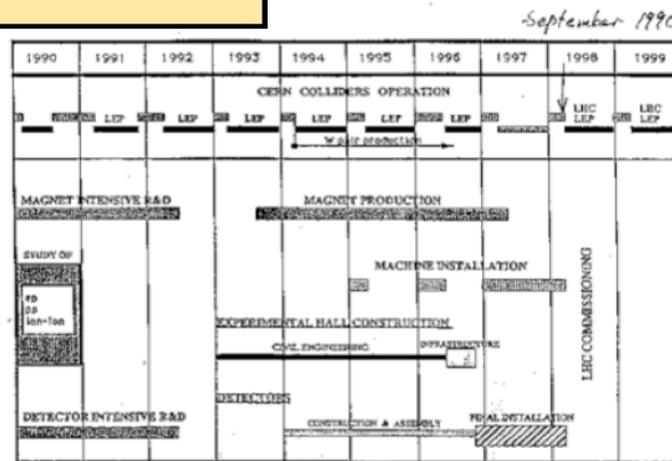
franc succès en 2010  
très bon début en 2011  
excellente machine  
excellents détecteurs



L'envers du décor  
retard, E/2, L/20.  
En son nom?  
LEP2 "bridé",  
Tevatron stoppé

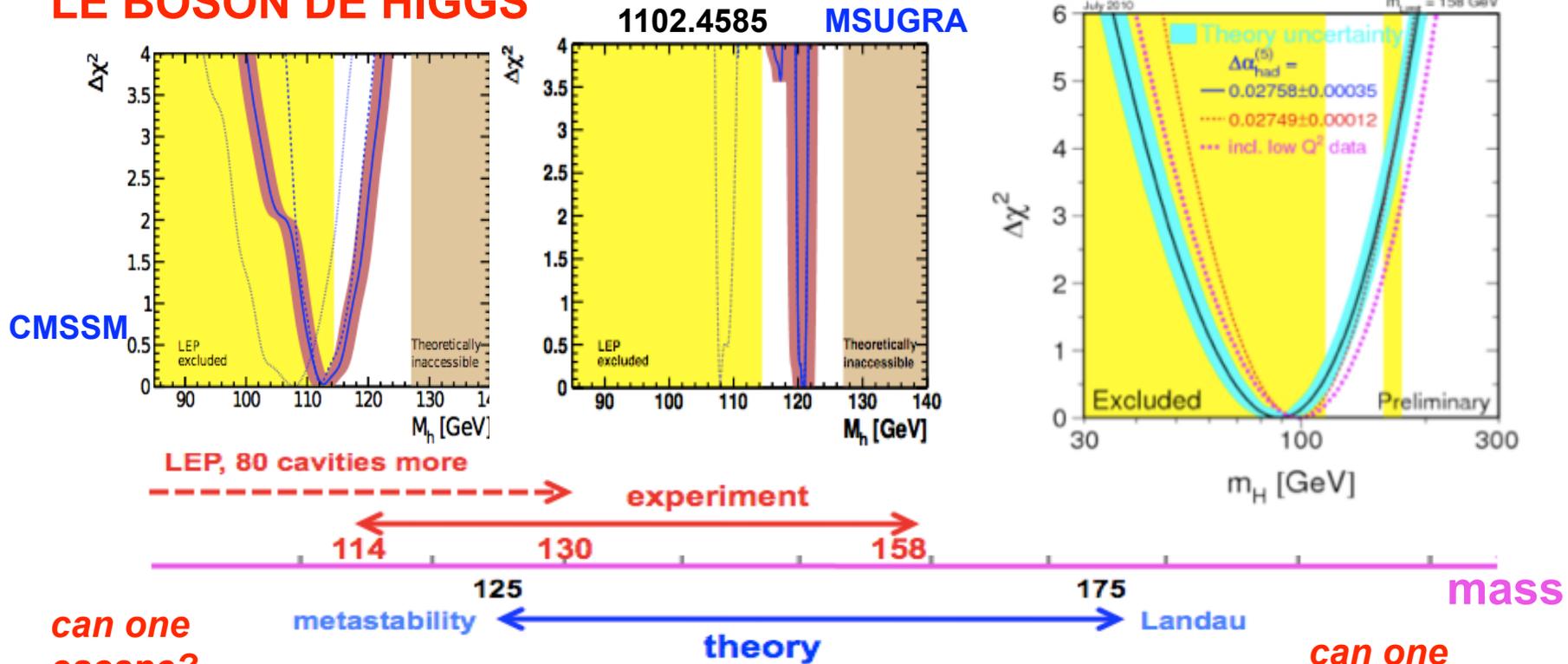
From a blog

I read in the CERN Courier that one of the reasons CERN couldn't pursue its Higgs boson candidates at LEP was that industrial production of its RF cavities (or magnets; my memory is as bad as it's always been) had already been shut down. I hope that every opportunity will be taken by Fermilab to focus on probing a narrow range around the statistically-preferred Higgs boson mass of 117 GeV, before the Tevatron is finally shut down after a very productive life. I would suggest that this might warrant a one-year extension, politically, for streamlined operation.

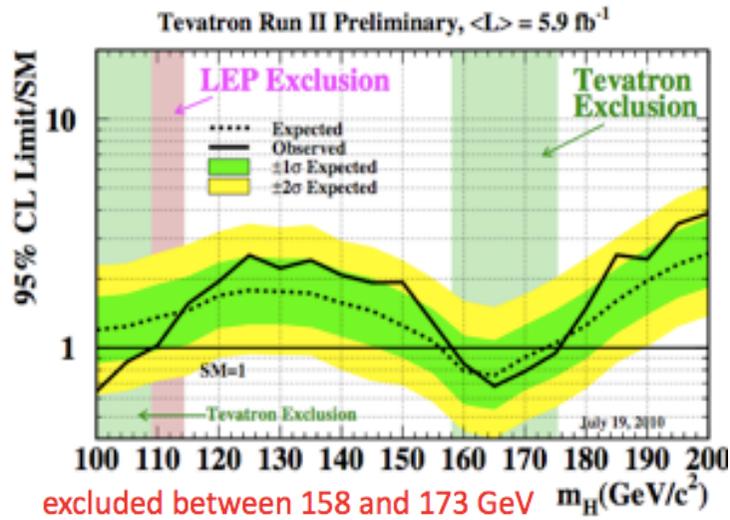
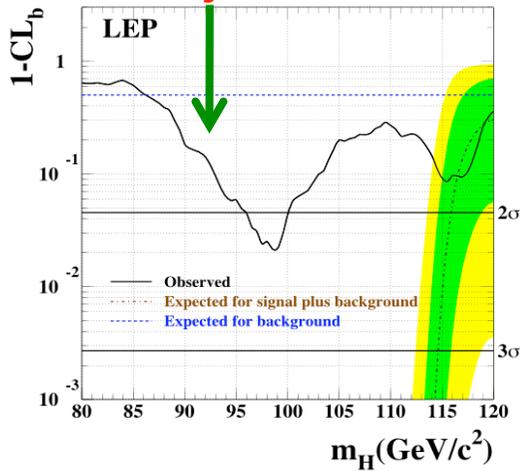


≥1 long(s) shut down(s) avant le nominal

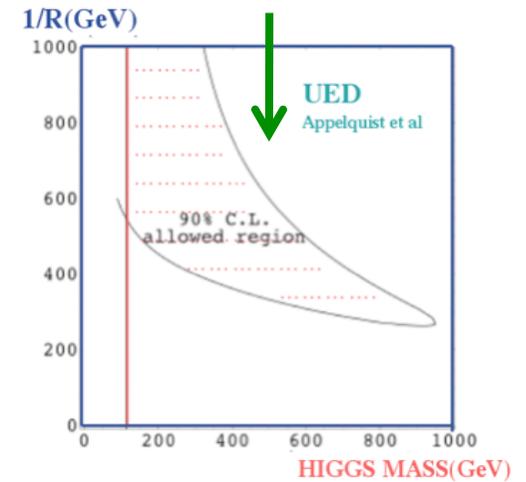
# LE BOSON DE HIGGS



can one escape? unlikely



can one escape?

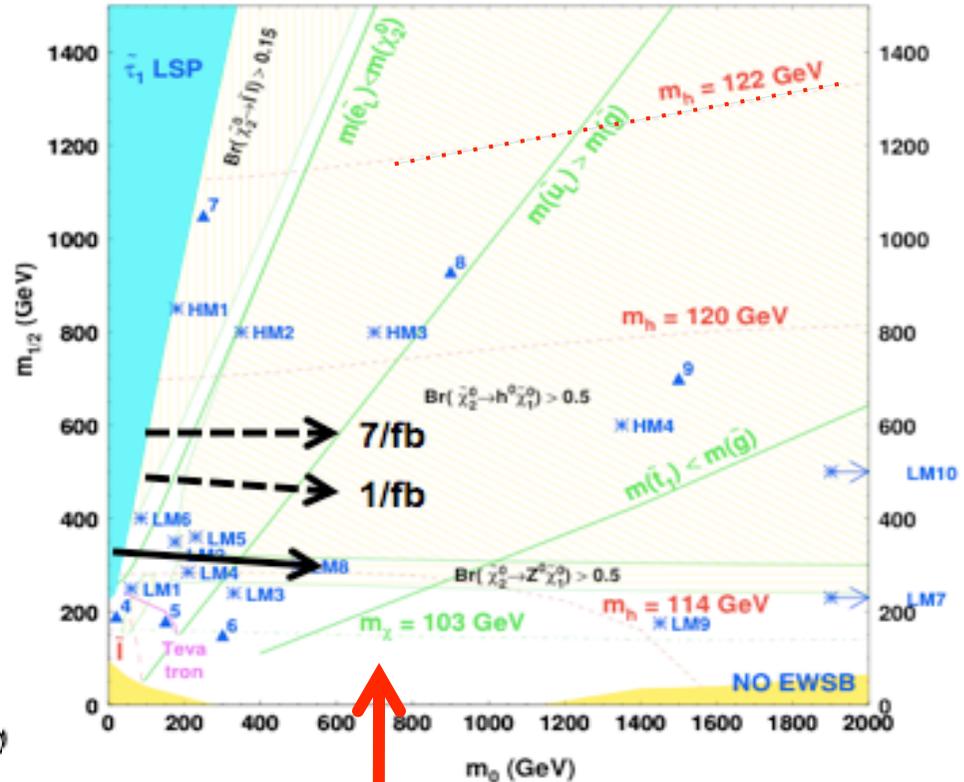
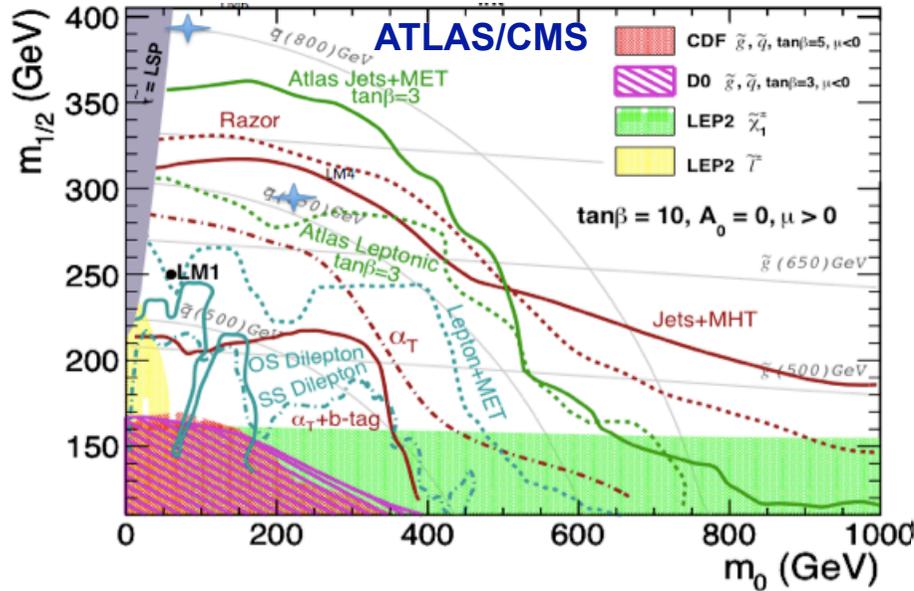


# SUSY

## LHCb

LHCb will either find signs of NP or exclude most of the  $\tan\beta$  vs  $M_A$  plane with the 2010/2011 data.

$\Delta m_s = 17.63 \pm 0.11(\text{stat}) \pm 0.04(\text{syst}) \text{ ps}^{-1}$   
 $\text{BR}(B_s \rightarrow \mu^+\mu^-) < 5.6 \times 10^{-8} @ 95\% \text{ CL}$   
 $\text{BR}(B^0 \rightarrow \mu^+\mu^-) < 1.5 \times 10^{-8} @ 95\% \text{ CL}$



lente montée lente descente

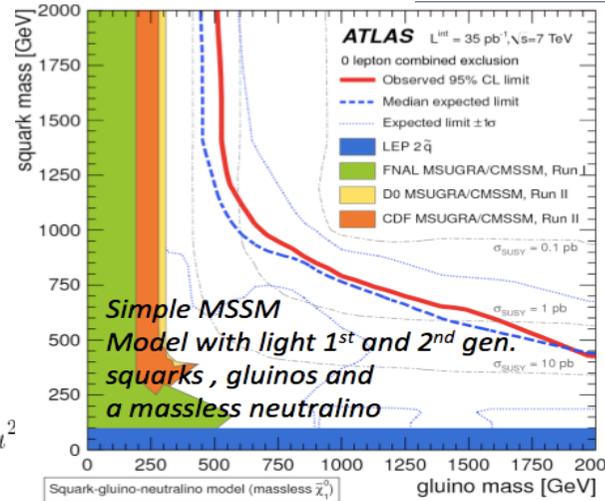
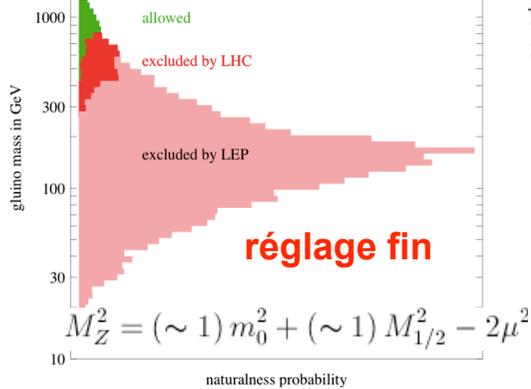


V.Sharma Higgs standard

ATLAS + CMS $\approx 2 \times \text{CMS}$	95% CL exclusion	$3\sigma$ sensitivity	$5\sigma$ sensitivity
1 fb <sup>-1</sup>	120 - 530	135 - 475	152 - 175
2 fb <sup>-1</sup>	114 - 585	120 - 545	140 - 200
5 fb <sup>-1</sup>	114 - 600	114 - 600	128 - 482
10 fb <sup>-1</sup>	114 - 600	114 - 600	117 - 535

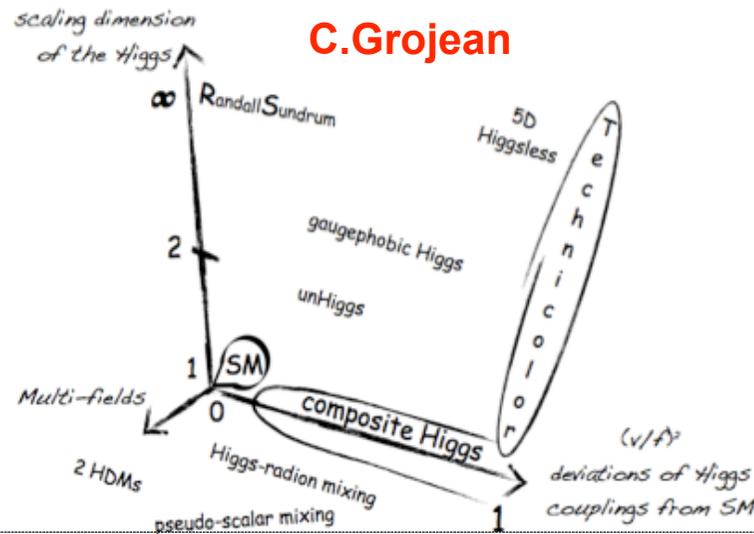
## masse du gluino Strumia

Beautiful theory collides with smashing particle data



**Higgs**  
**LHC "fait pour lui"**  
**Et s'il n'est pas là?**

**SUSY, etc**  
**on se focalise sur**  
**des benchmarks**  
**qui reflètent**  
**des préjugés**

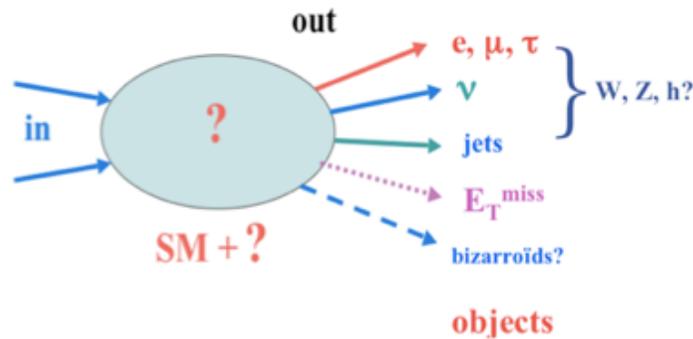


**An Emergency Tire Even Beyond the SM**

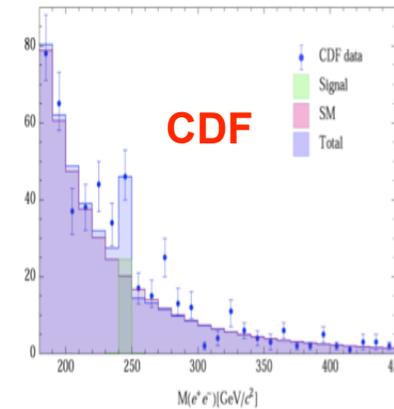
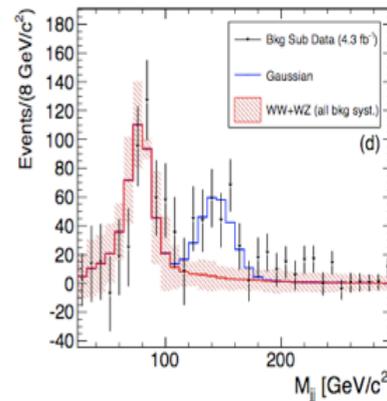
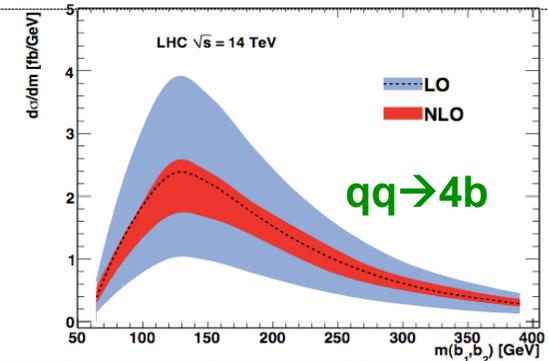


[picture courtesy to Andreas Weiler]

**Passer un jour**  
**à une analyse**  
**topologique**  
**systématique,**  
**sous le réverbère**  
**du LHC**



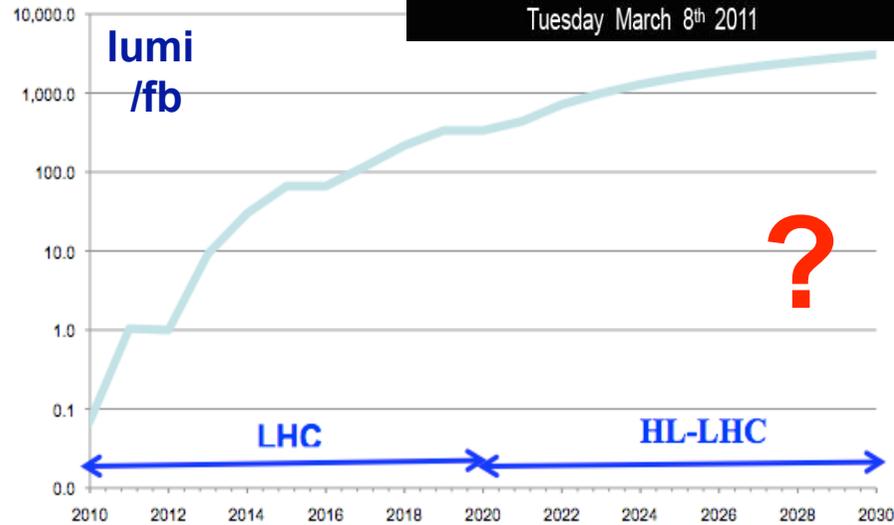
**maîtrise**  
**de QCD,**  
**GOLEM,**  
**etc**



# SUITE DU LHC

## SLHC, High-Luminosity Upgrade

Tuesday March 8<sup>th</sup> 2011

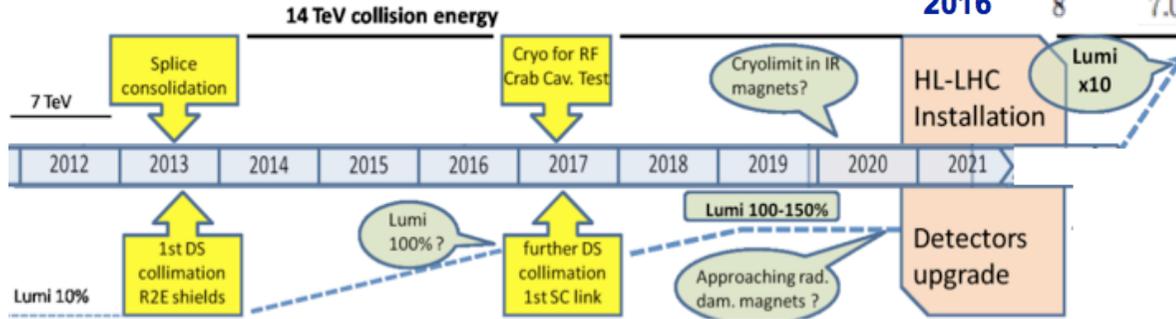


$\beta^* = 1.5m$

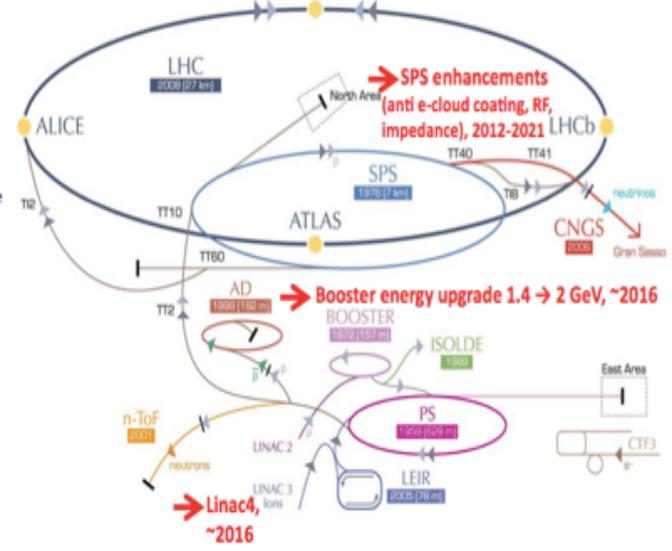
days	H.F	Comm with	Fills with	kb	Nb e11	$\epsilon$ $\mu m$	$\xi/IP$	L Hz/cm <sup>2</sup>	Stored energy MJ	L Int fb <sup>-1</sup> 4 TeV	L Int 3.5 TeV
160	0.3	150 ns	150 ns	368	1.2	2.5	0.006	~5.2e32	~30	~2.1	~1.9
135	0.2	75 ns	75 ns	936	1.2	2.5 2 1.8	0.006 0.007 0.008	~1.3e33 ~1.6e33 ~1.8e33	~75	~3 ~3.8 ~4.2	~2.7 ~3.3 ~3.7
125	0.15	50 ns	50 ns	1404	1.2	2.5	0.006	~2e33	~110	~3.2	~2.8



Year	Months	Energy [TeV]	$\beta^*$ [m]	$N_b$	Peak Luminosity [cm <sup>-2</sup> s <sup>-1</sup> ]	Int. Lumi per month [fb <sup>-1</sup> ]
2014	6 (+1)	6.5	1.0	720	$1.4 \times 10^{33}$	0.7
2015	9	6.5	1.0	1404	$2.8 \times 10^{33}$	1.3
2016	8	7.0	0.55	2808	$1 \times 10^{34}$	4.7



→ IR upgrade (detectors, low- $\beta$  quad's, crab cavities, etc) ~2020-21



- Machine: Splice Consolidation & Collimation in IR3**
- ALICE** - detector completion
- ATLAS** - Consolidation and new forward beam pipes
- CMS** - FWD muons upgrade + Consolidation
- LHCb** - consolidations

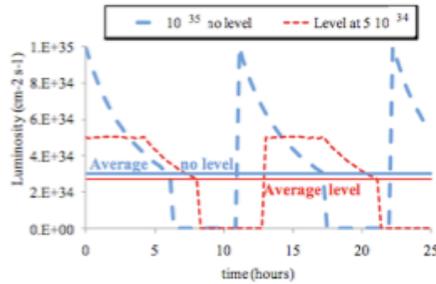
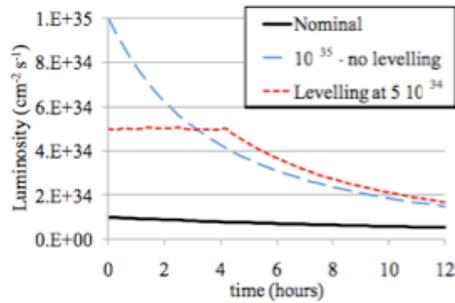
- Machine:** Collimation & prepare for crab cavities & RF cryo system
- ATLAS:** nw pixel detect. - detect. for ultimate luminosity.
- ALICE** - Inner vertex system upgrade
- CMS** - New Pixel. New HCAL Photodetectors. Completion of FWD muons upgrade
- LHCb** - full trigger upgrade, new vertex detector etc.

- Machine** - maintenance & Triplet upgrade
- ATLAS** - New inner detector
- ALICE** - Second vertex detector upgrade
- CMS** - New Tracker

? SPS - LINAC4 connection & ? PSB energy upgrade

The main objective of HL-LHC is to implement a hardware configuration and a set of beam parameters that will allow the LHC to reach the following targets:

- A peak luminosity of  $5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$  with levelling, allowing:
- An integrated luminosity of  $250 \text{ fb}^{-1}$  per year, enabling the goal of  $3000 \text{ fb}^{-1}$  twelve years after the upgrade. This luminosity is more than ten times the luminosity reach of the first 10 years of the LHC lifetime.



- allow design for lower peak L, less pile up
- less peak heat deposition ( a factor 2 may be the diff

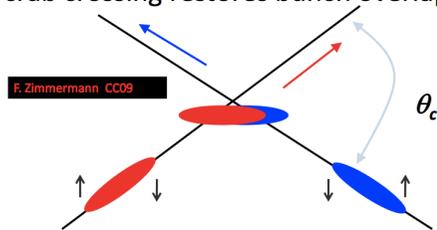
CERN-8March2011

Lucio Rossi @sLHC2011

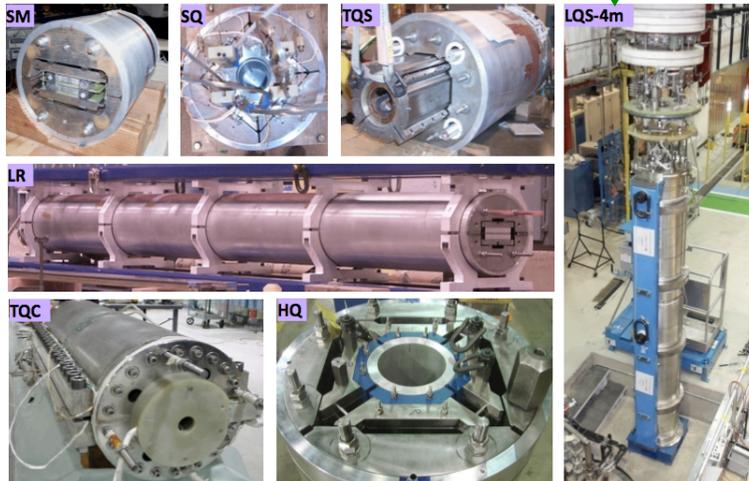


Raimondi - improving collider performance.

crab crossing restores bunch overlap



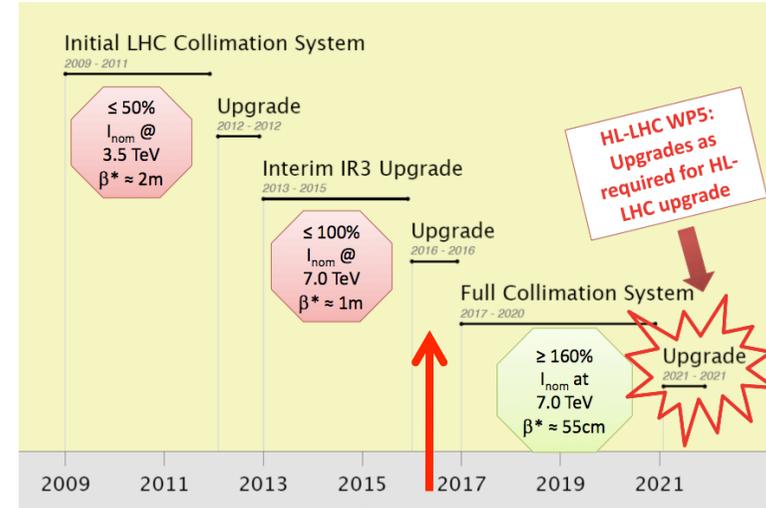
- RF crab cavity deflects head and tail in opposite direction so that collision is effectively "head on" for luminosity and tune shift
  - bunch centroids still cross at an angle (easy separation)
  - 1<sup>st</sup> proposed in 1988, in operation at KEKB since 2007
- world record luminosity!



CERN-8March2011

Lucio Rossi @sLHC2011

# vers le LHC Haute Luminosité



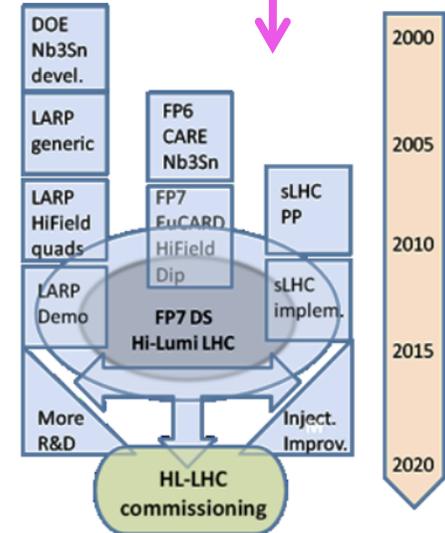
collimation

crab

champs élevés

organisation

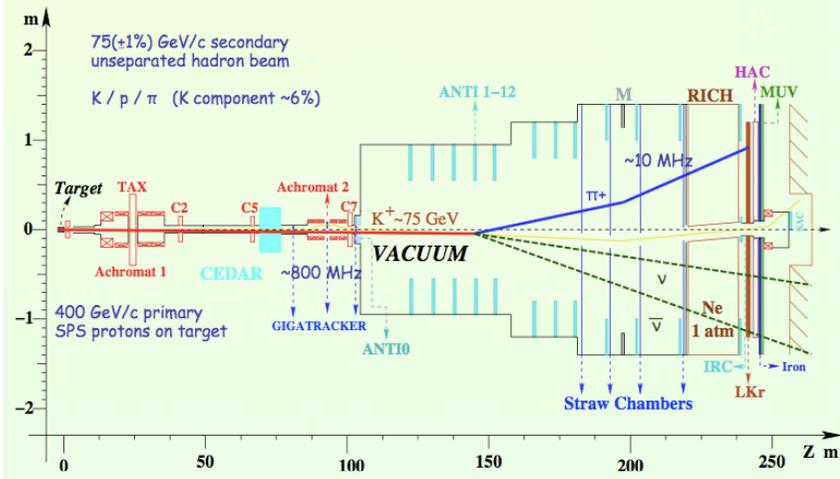
LARP Magnets



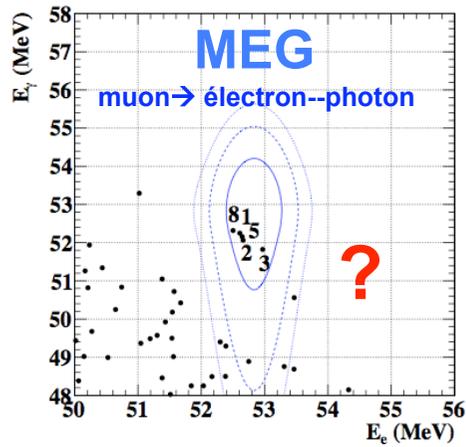
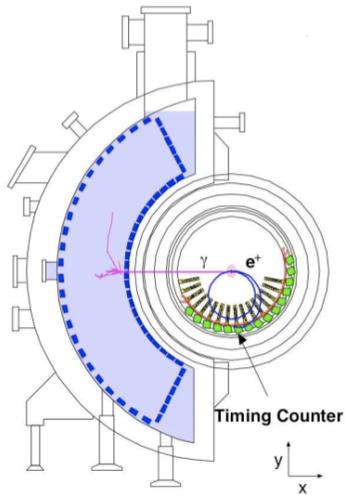
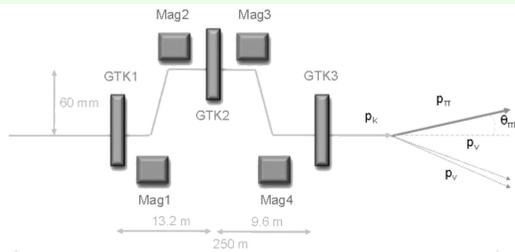


# Désintégrations rares

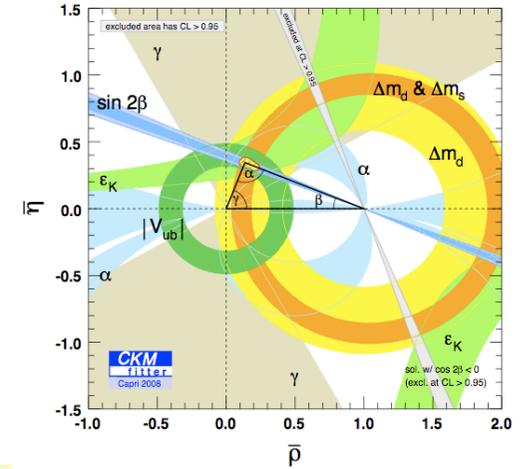
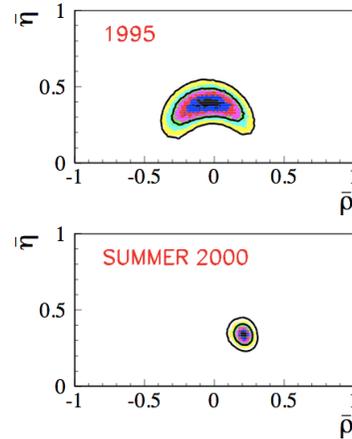
## The NA62 Experiment at the CERN SPS



## NA62 Gigatracker



## LES SUPER B



## KEKB to SuperKEKB: current status

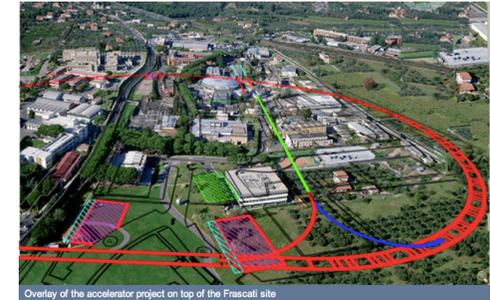
• KEBK operation finished at 9:00 am June 30, 2010



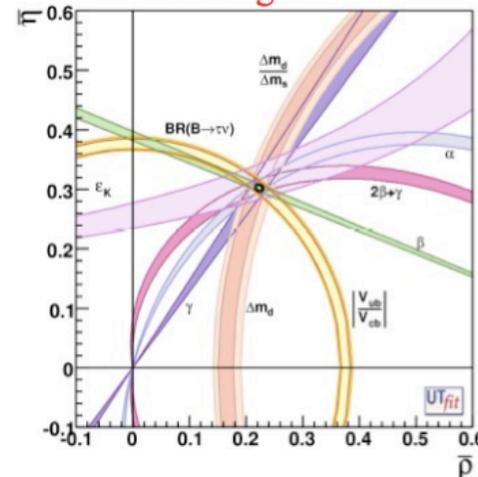
• SuperKEKB budget is partially approved

- Damping ring: 580M yen (~5.8MS) (FY2010)
- Special budget "Very Advanced Research Support Program" 1B yen (~100MS) (FY2010-2012)

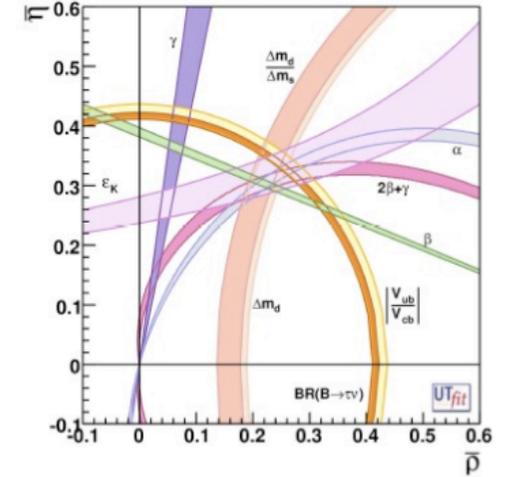
→ Start construction (FY2010-2013)

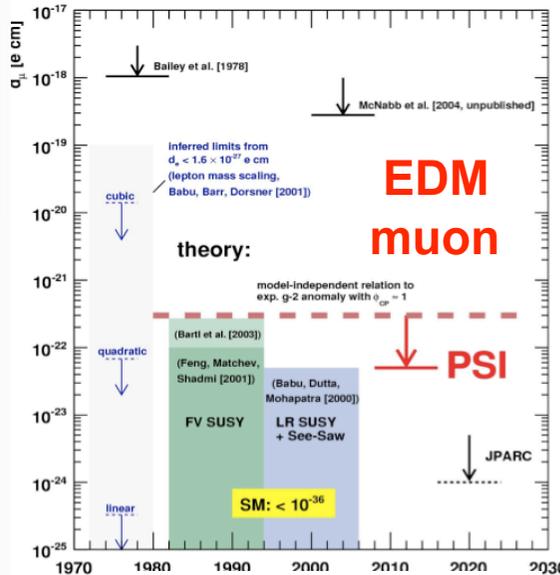
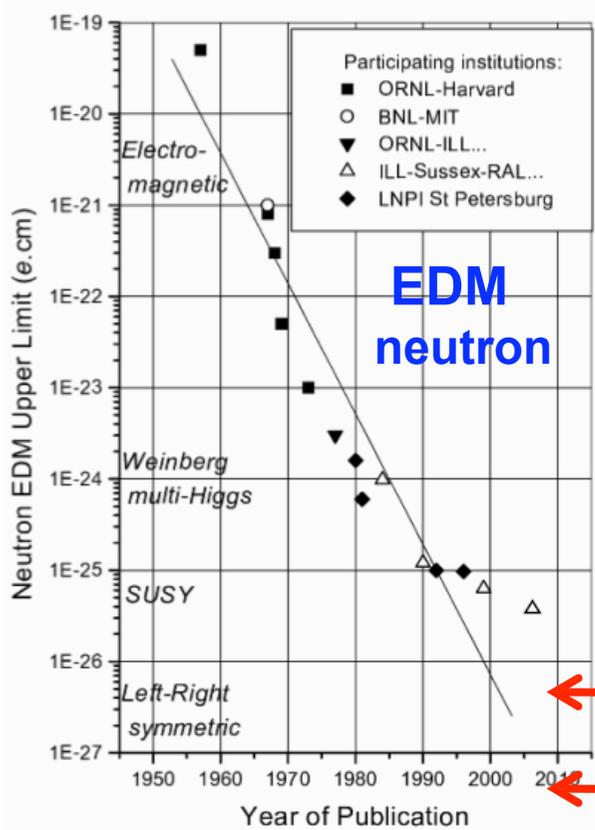


## The nightmare?



## ... or the dream?

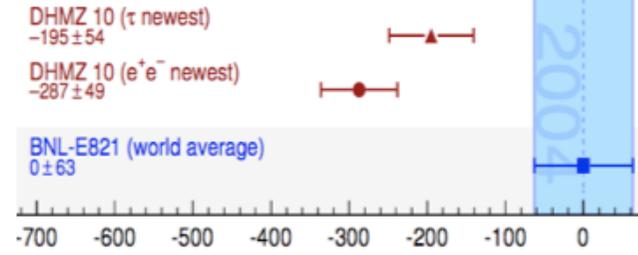




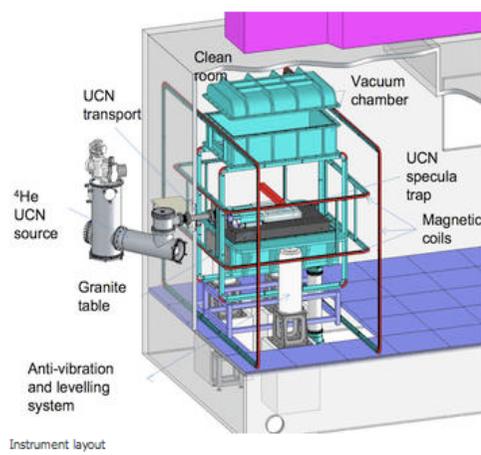
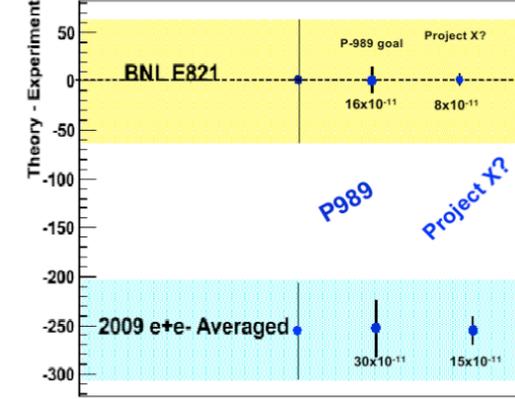
- Getting ready for new nEDM measurement 2011/12 aiming at  $5 \times 10^{-27}$  ecm sensitivity
- Designing n2EDM experiment to improve sensitivity to  $5 \times 10^{-28}$  ecm (2012+)

g-2

*"g-2 is not an experiment: it is a way of life."* John Adams

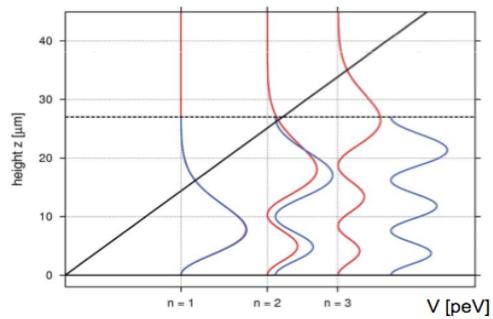


Muon Anomaly: Experiment and Theory

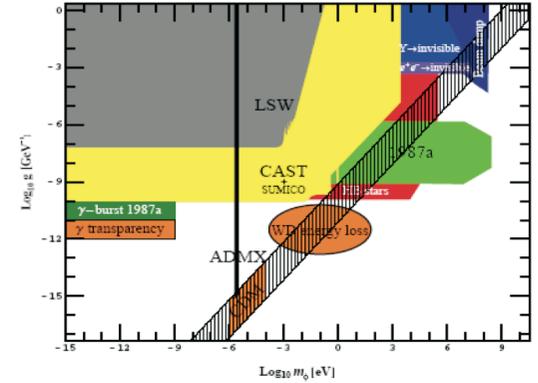


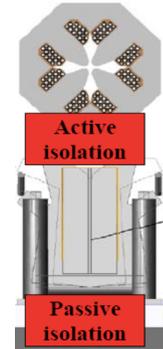
GRANIT

	$E_n$	$E_n$
1 <sup>st</sup> state	1.41peV	1.41peV
2 <sup>nd</sup> state	2.46peV	2.56peV
3 <sup>rd</sup> state	3.32peV	3.97peV

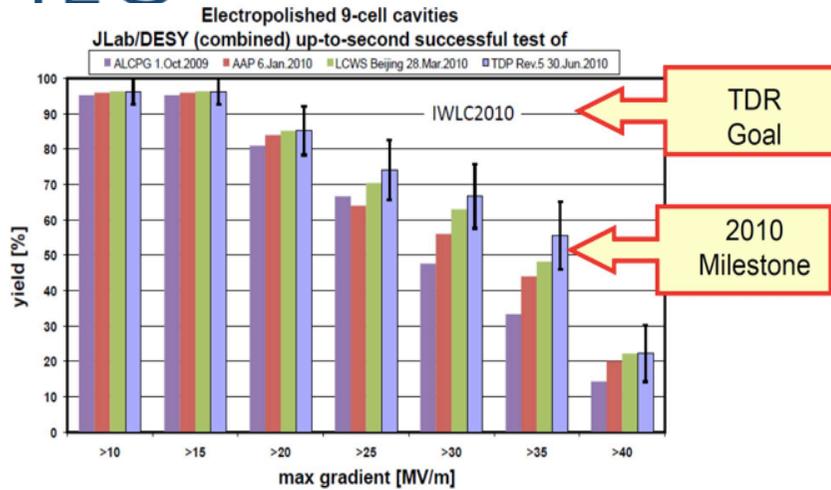
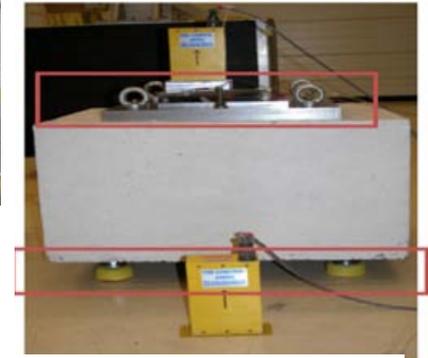
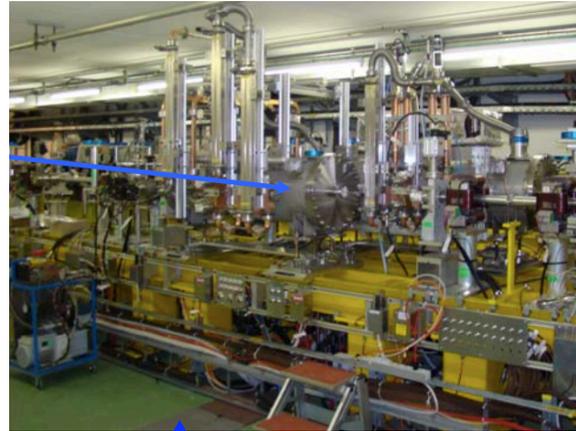


axion mur brillant 1009.4875

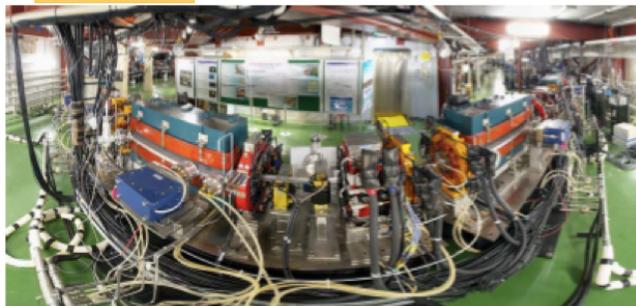




LAPP  
LAViSta



ATF/KEK ultra low emittance



## 10 CLIC Feasibility Issues

### Two Beam Acceleration:

- Drive beam generation
- Beam Driven RF power generation
- Two Beam Module

### RF Structures:

- Accelerating Structures (CAS)
- Power Production Structures (PETS)

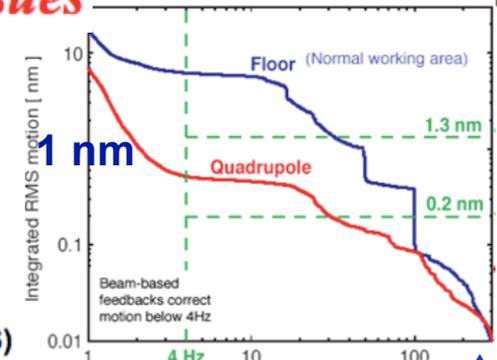
### Ultra low beam emittance and beam sizes

- Emittance generation & preservation during acceleration and focusing
- Alignment and stabilisation

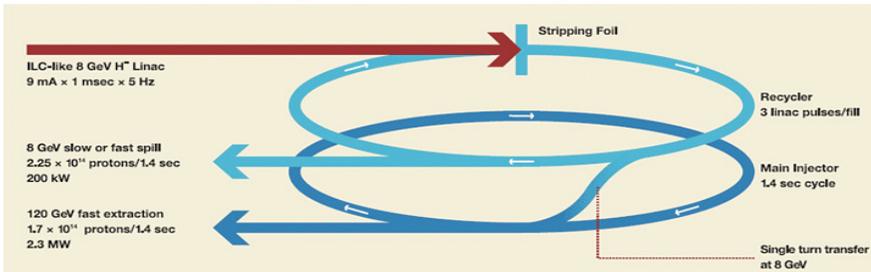
### Detector

- Adaptation to short interval between bunches
- Adaptation to large background at high beam collision energy

### Operation and Machine Protection System (MPS)



# LE PROGRAMME US



- The Flagship of the Intensity Program at Fermilab, the Long Baseline Neutrino Experiment (LBNE) with neutrino beams to DUSEL must not be impacted in any way by the Tevatron run extension

## Jobs at Fermilab

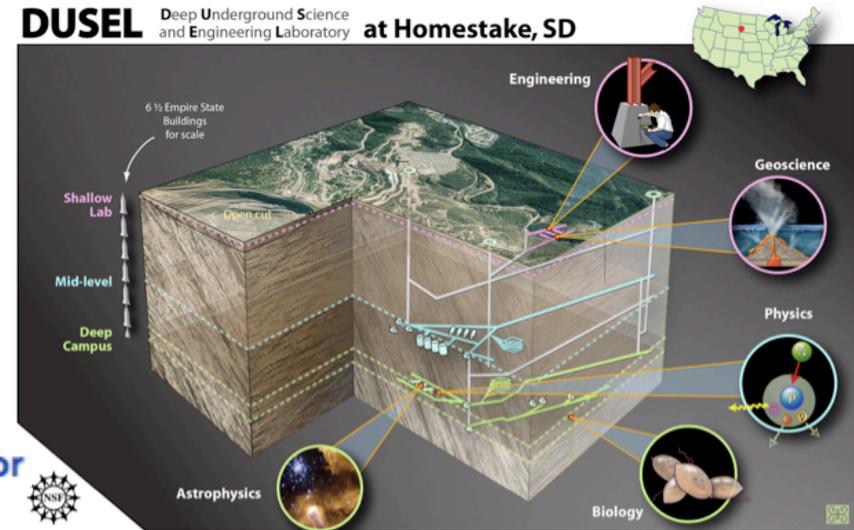
U.S. Muon Accelerator Program Director  
M.S.Zisman, Eugene, march 2011



- The ENERGY FRONTIER**
  - The Tevatron
  - The LHC
  - ILC and Accelerator R&D
- The INTENSITY FRONTIER**
  - MINOS, MiniBOONE -> NOvA, MicroBOONE -> LBNE, DUSEL
  - Reactor neutrino expts DoubleCHOOZ, DayaBay
  - Precision Meas: Mu-to-e conversion
  - Proton Decay Searches
- The COSMIC FRONTIER**
  - Direct Dark Matter Searches
  - Dark Energy from Ground and Space

## The P5 Roadmap

## DUSEL Deep Underground Science and Engineering Laboratory at Homestake, SD

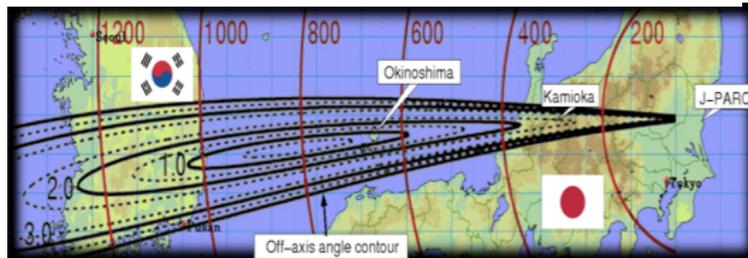


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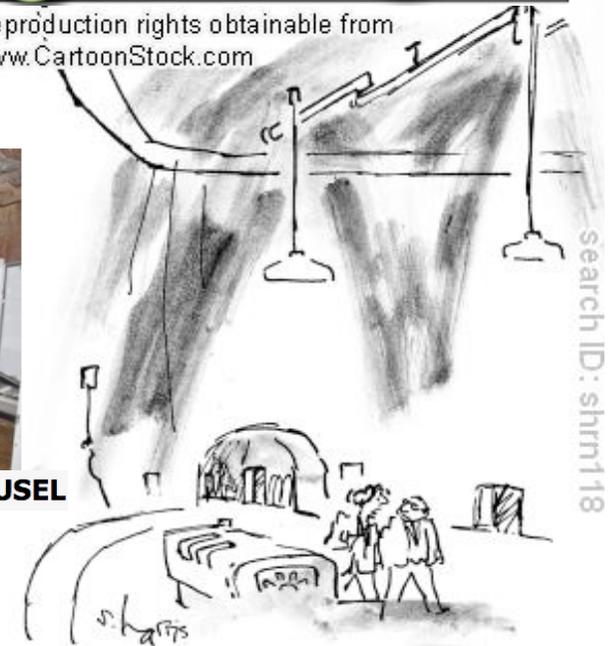
Water level stable in 2010



NSF TO AWARD UP TO \$4 MILLION TO DUSEL



DUSEL  
J-PARK?  
LAGUNA?



"THIS UNDERGROUND FACILITY ALLOWS US TO BE CLOSELY INVOLVED WITH PROTON DECAY, GRAVITY WAVES, NEUTRINOS AND THE GROWING AND SELLING OF MUSHROOMS."

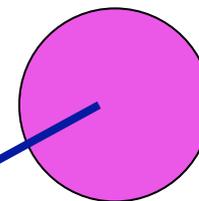
search ID: shrn118

**CvB**  
 1.945K  
 112/cm<sup>3</sup>

impact of neutrinos on cosmology

cosmic  
 p or N

150M km



**SUN**

$\nu_e$

0.2-20 MeV

accelerator



$\nu_\mu$   
 1-20 GeV  
 0.1-700 km



$\nu_\mu$   $\nu_e$   
 15 km

from Supernova

100 km

reactor

1 km

$\bar{\nu}_e$  2-6 MeV

$\nu_\mu$   $\nu_e$   
 10<sup>4</sup> km  
 0.1-10 GeV

$\bar{\nu}_e$

radiogenic

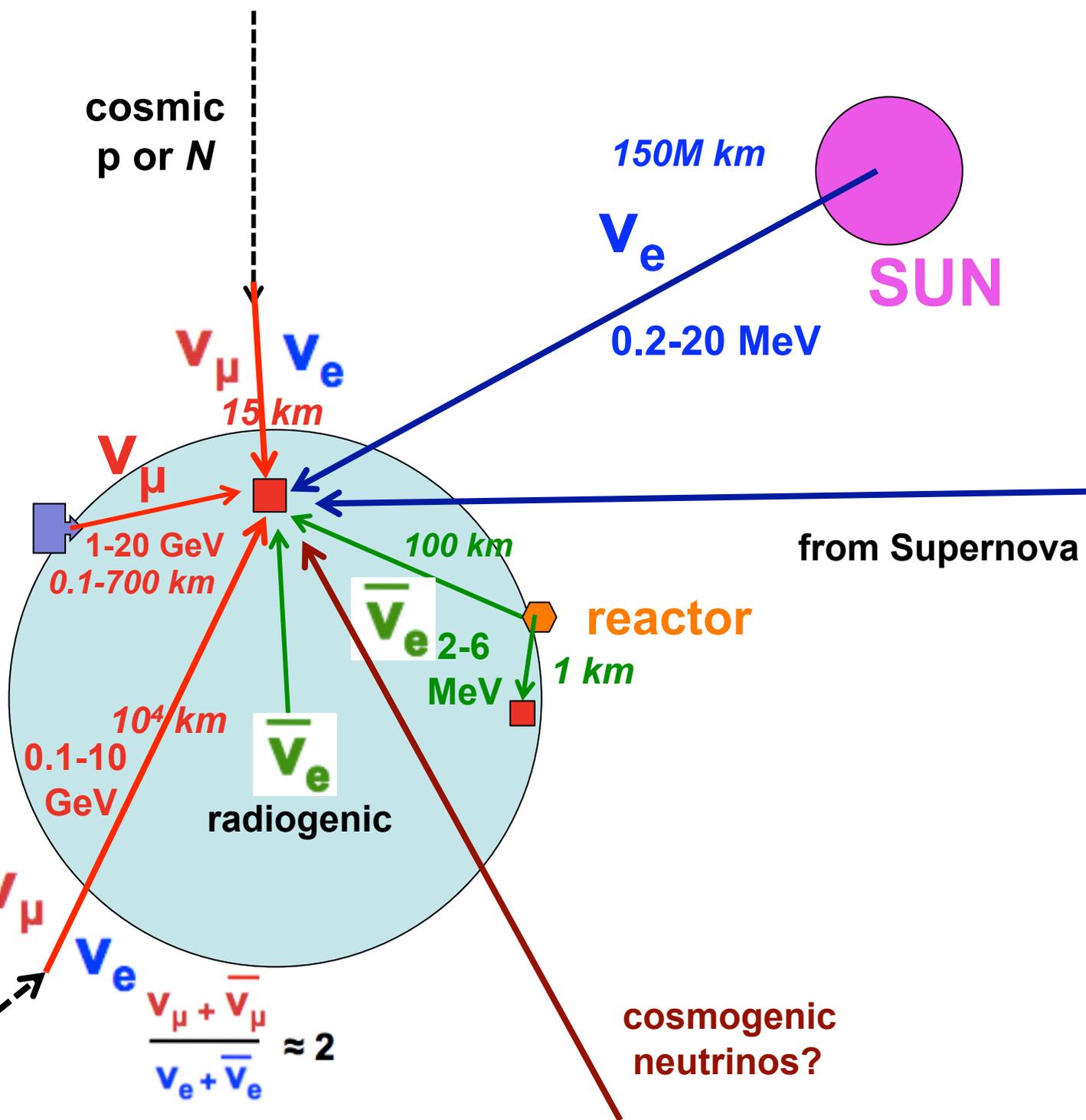
cosmic  
 p or N

$\nu_\mu$

$\nu_e$

$$\frac{\nu_\mu + \bar{\nu}_\mu}{\nu_e + \bar{\nu}_e} \approx 2$$

cosmogenic  
 neutrinos?



# neutrinos

masse absolue? KATRIN

nature?

Beta double sans neutrino

SuperNEMO, etc

$$\begin{pmatrix}
 \boxed{V_{ud}} & \boxed{V_{us}} & V_{ub} \\
 \boxed{V_{cd}} & \boxed{V_{cs}} & \boxed{V_{cb}} \\
 V_{td} & V_{ts} & \boxed{V_{tb}}
 \end{pmatrix}$$

$$\sin^2 \theta_{12} = 1/3, \sin^2 \theta_{23} = 1/2, \sin^2 \theta_{13} = 0$$

$$U_{\text{tri-bimaximal}} = \begin{pmatrix}
 \sqrt{2/3} & \sqrt{1/3} & 0 \\
 -\sqrt{1/6} & \sqrt{1/3} & -\sqrt{1/2} \\
 -\sqrt{1/6} & \sqrt{1/3} & \sqrt{1/2}
 \end{pmatrix}$$

Non-Abelian Flavor Symmetry ?

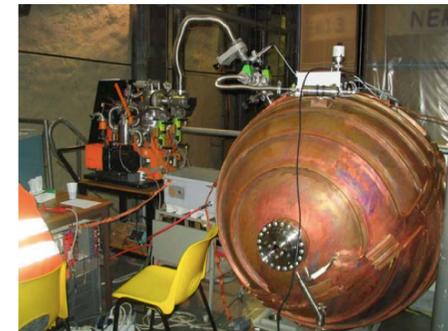
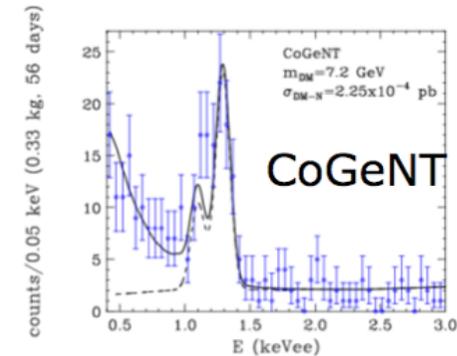
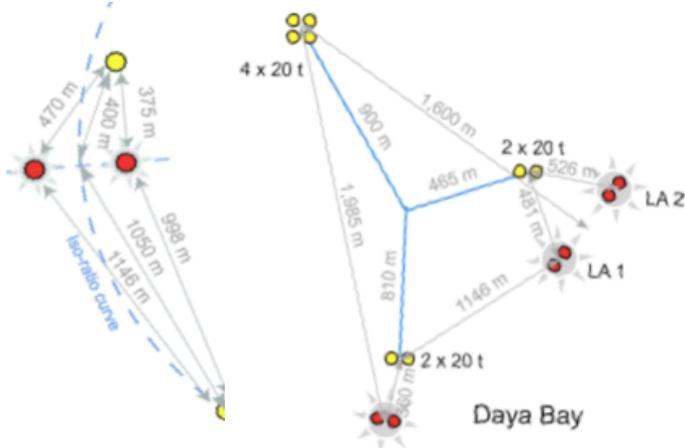


→ la quête de  $\theta_{13}$  Frontière haute luminosité: OPERA, MINOS T2K

Réacteurs: Daya Bay, Double Chooz, RENO

Aucun n'atteindra  $10^{-3}$

Win-win! Si rien vu, Super beam, Beta beam, Usine à neutrinos, Hyper détecteur



→ La course aux seuils de détection très bas

→ L'anomalie réacteur? stérile?  $1\text{eV}^2$  Cosmologie?

$1\text{ MeV} \leftrightarrow 1\text{ m}$  Faisceau neutrino PS? Sources?

Vérifications préliminaires? (Y.Declais)

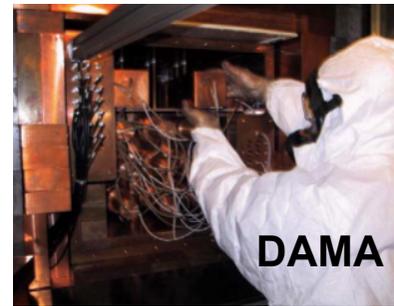
I.Giomataris

# LA MATIERE NOIRE

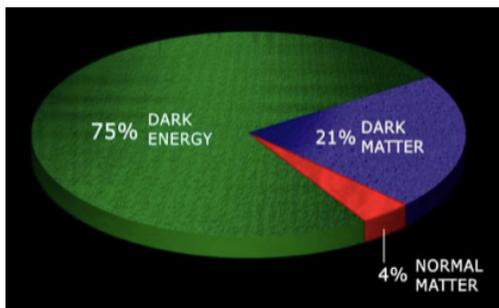
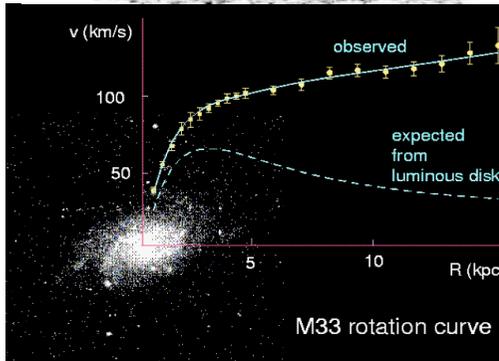


*S'il s'agit d'une particule (par exemple la plus légère de la Supersymétrie) on peut la rechercher par:*

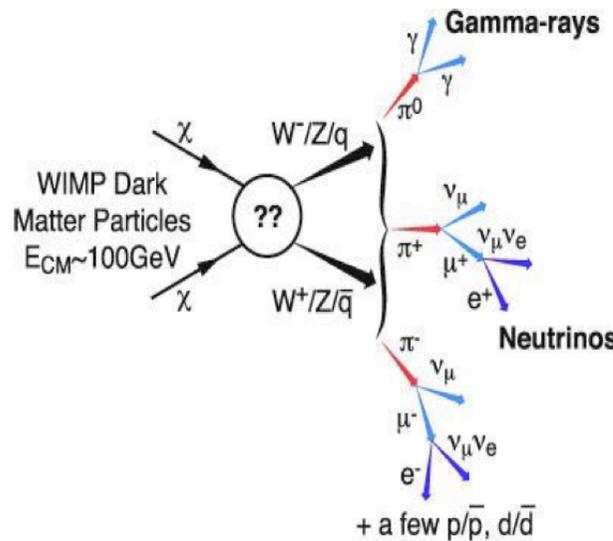
*sa production par accélérateur*



*sa détection directe comme particule fossile du Big Bang*



*sa détection indirecte*



*veillée d'armes*



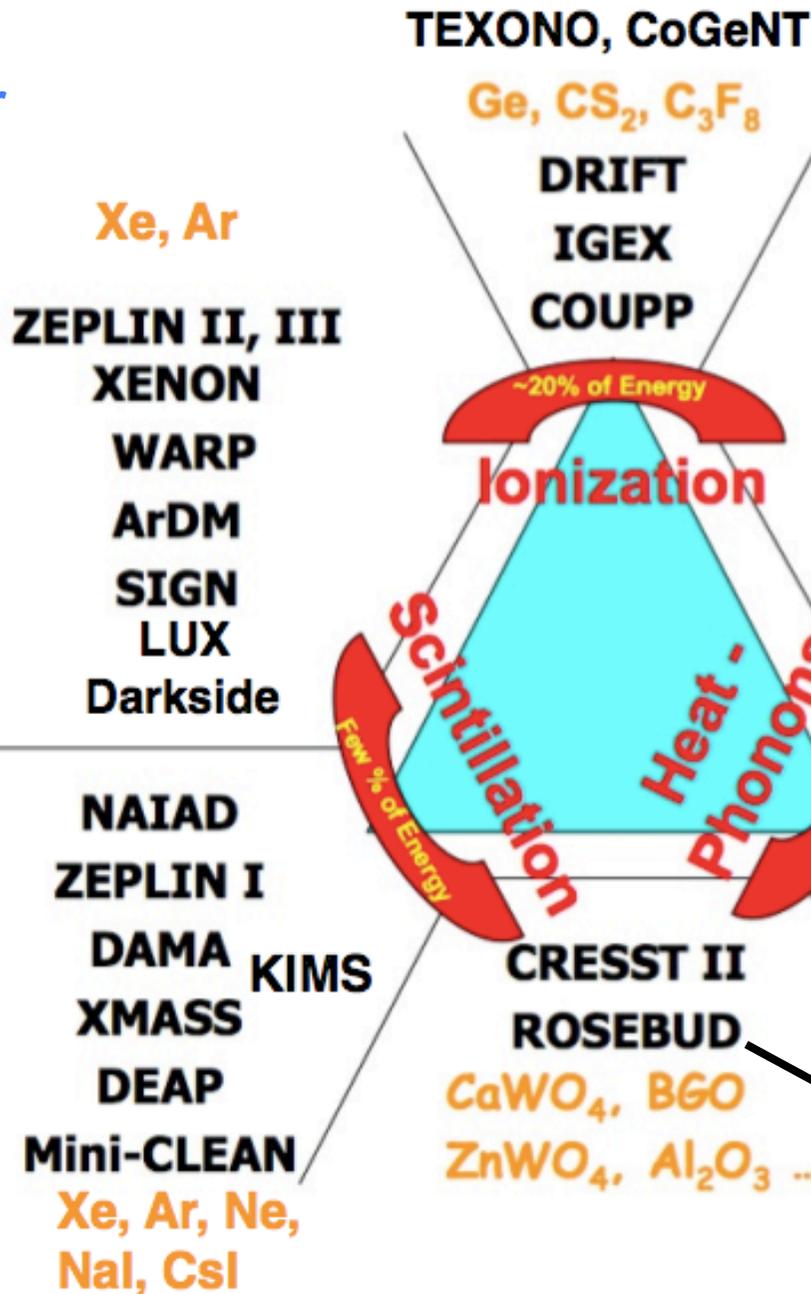
# Xe:

- + high nuclear mass, high scintillation efficiency
- limited drift length, knowledge of quench factor

# Ar:

- + cost, drift length, temporal analysis
- isotope <sup>39</sup>Ar

G.Chardin  
J.Gascon



Main challenge:  
*extreme suppression of background from natural radioactivity at low energy*  
(ex.: people = 10<sup>10</sup> decay/kg/year)

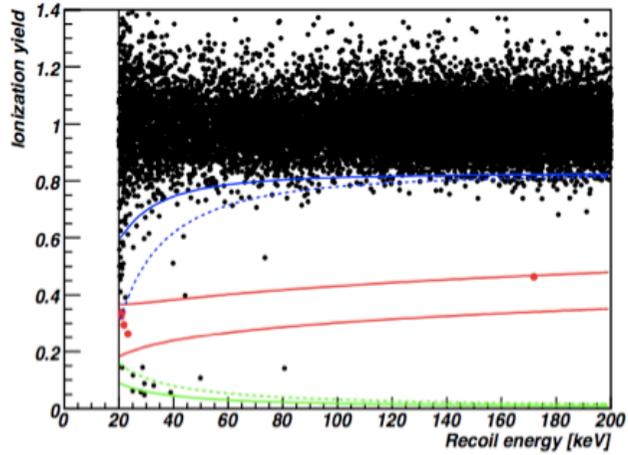
- + identification, energy resolution
- complexity, cost challenge of surface interactions

Get together?

- + excellent separation above 20 keV, no surface effect
- small light yield, natural source of background (through alpha)

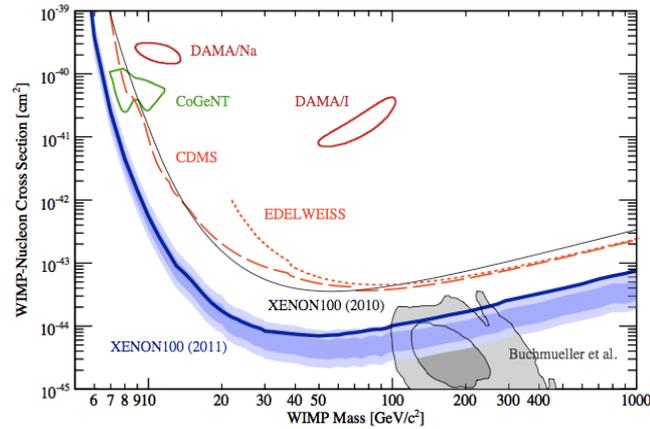
# Brèves du cosmos

**EDELWEISS-2**



**Xenon100**

1103.4070



**?**

**One Model Explains**

**DAMA/LIBRA,  
CoGENT, CDMS, and XENON.**

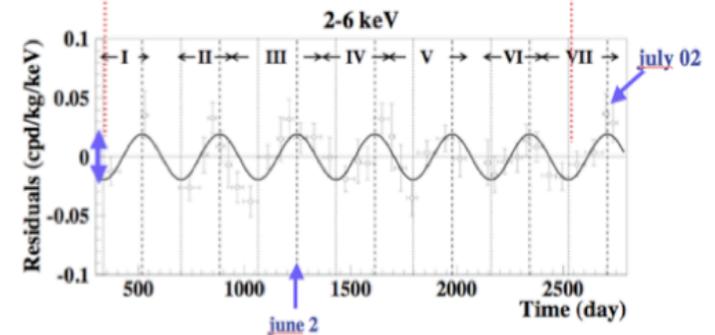
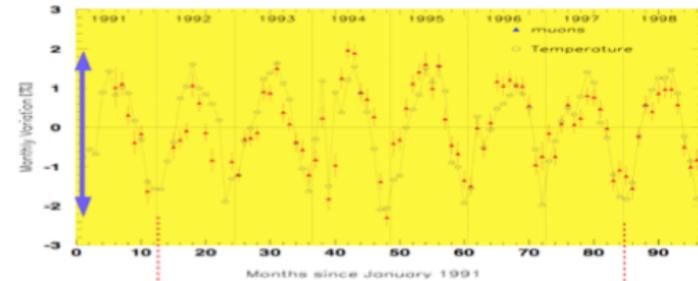
**neutron background**

1006.5255

1102.0815

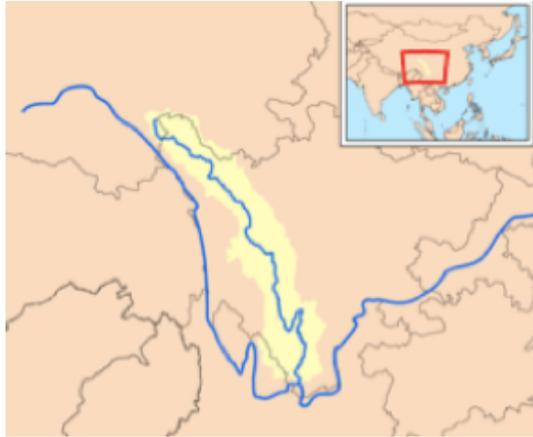
**DAMA and MACRO: similar in amplitude, identical in phase**

	Gen 1 /1'	Gen 2	Gen 3
<b>DOUBLE BETA</b>	10kg Nemo3 Cuoricino GERDA 1 /2	100kg SuperNemo Cuore, etc /3	1 ton ?
<b>DARK MATTER</b>	1kg-100kg EDELWEISS 1, 2, 3 CDMS, SUPERCDMS 1 /2 XENON 10 /100	10kg-1ton ?	100kg -10t EURECA? GEODM? DARWIN?
<b>neutrino proton lifetime</b>	SOUDAN	SUPERK	MegaTon DUSEL LAGUNA HyperK
<b>cosmic neutrino</b>	AMANDA ANTARES	ICECube KM3net	?



**perform DAMA in South Hemisphere...**

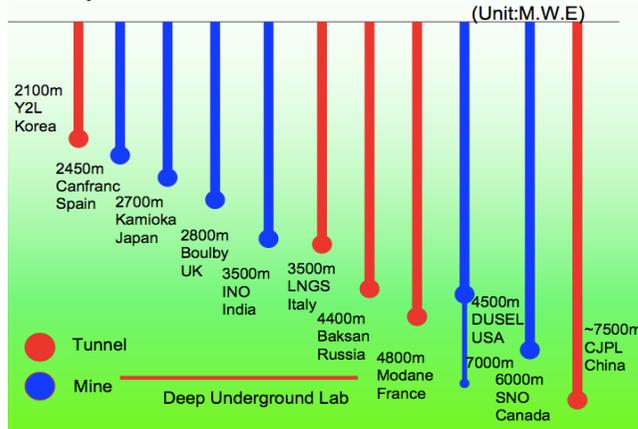
# Jinping



gorge of Yalong River



Comparison of main ULs in the world



## CDEX schedule

### Phase-I (2010.9-2011.3)

- 20g ULE-HPGe detector @ CDUL
- Shielding system construction
- HPGe detector for radioactive measurement
- Radon monitor system

### Phase-II (2010.12-2011.12)

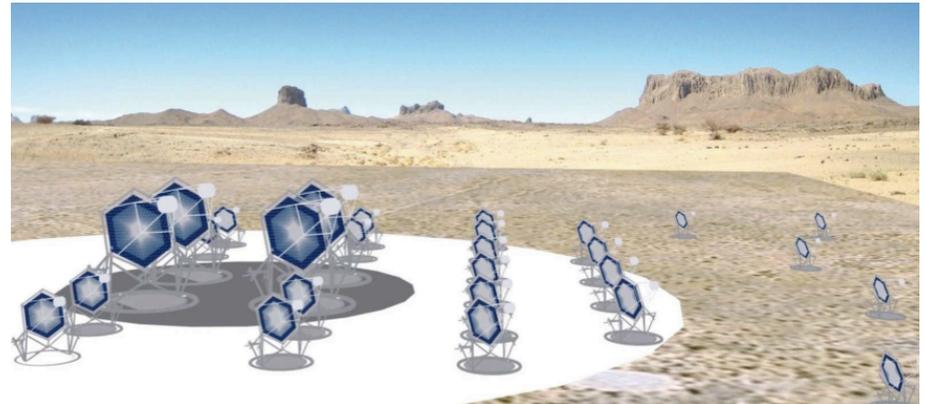
- ULE-HPGe detector (~1500g)

### Phase-III (2012-)

- ULE-HPGe detector (~10kg scale)



# Astronomie gamma: HESS, MAGIC,..



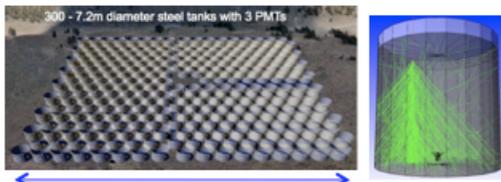
CTA: It is one of the “Magnificent Seven”

## FACT First GAPD Cherenkov Telescope

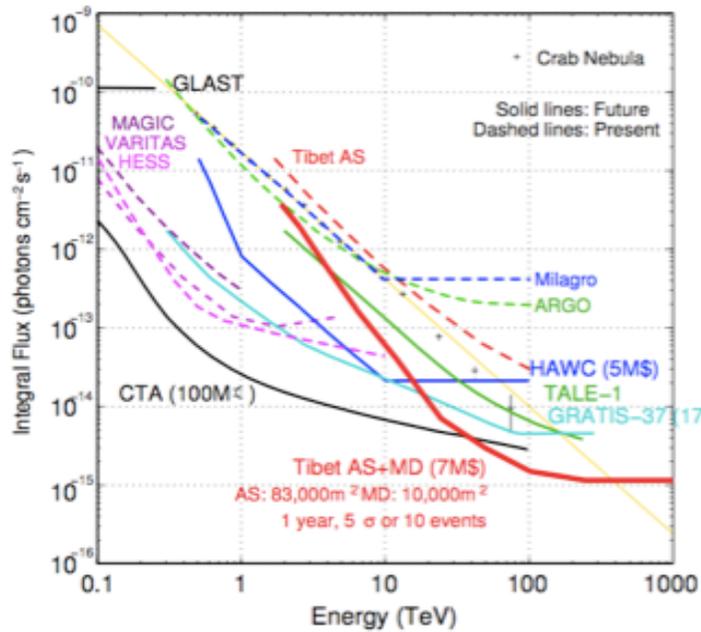
Former HEGRA CT3 telescope  
La Palma, Canary Islands



## HAWC



160m



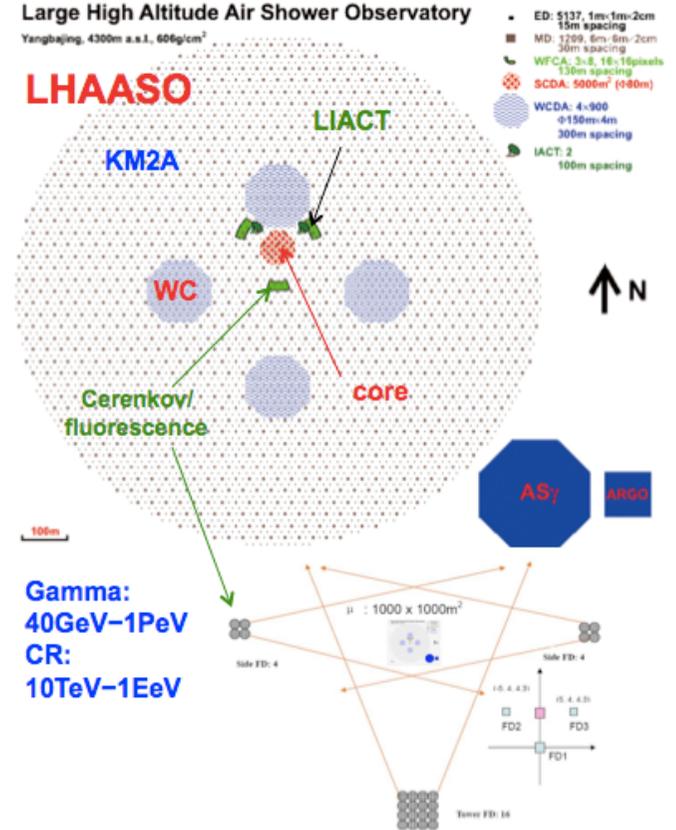
## Yangbajing



## Large High Altitude Air Shower Observatory

Yangbajing, 4300m a.s.l., 600g/cm²

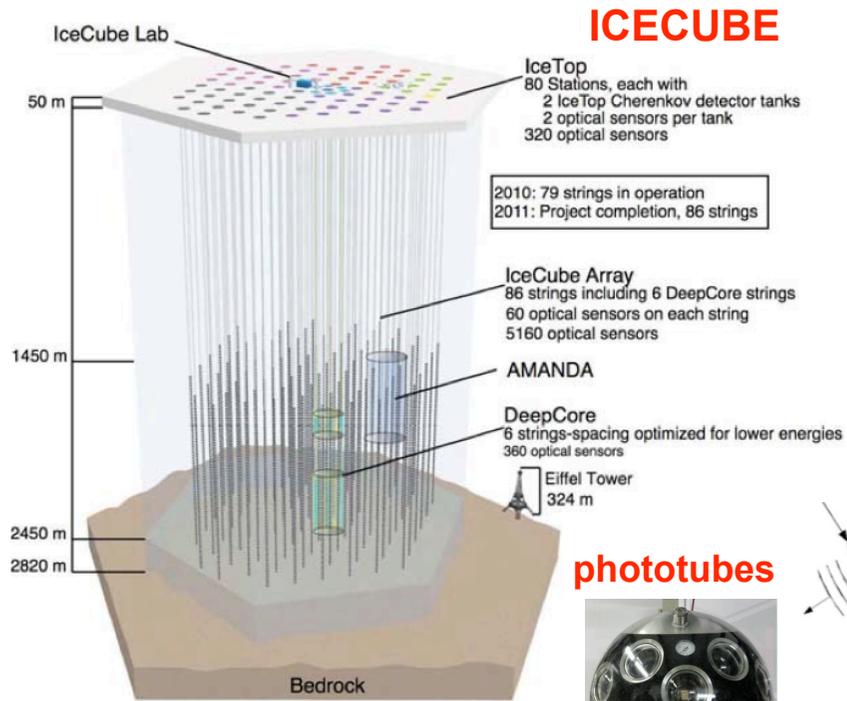
## LHAASO



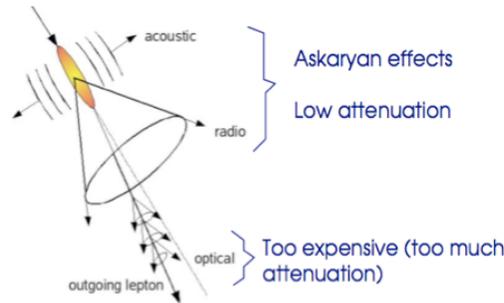
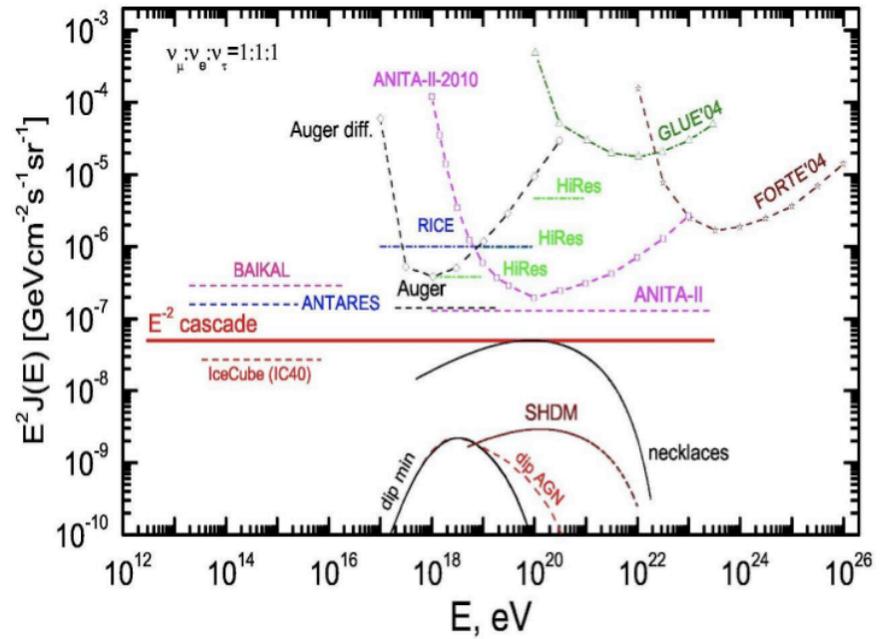
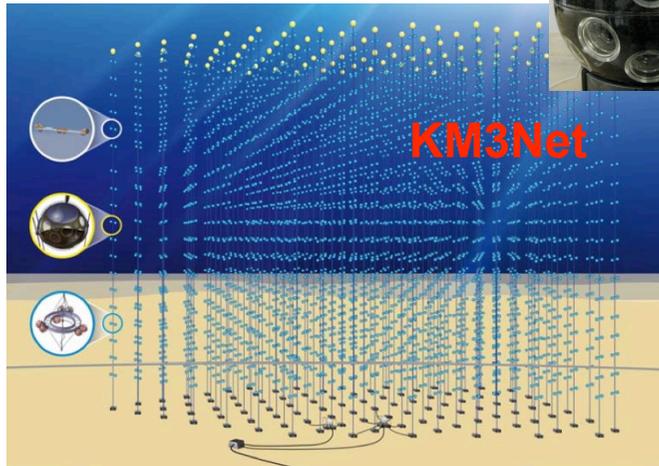
Gamma:  
40GeV-1PeV  
CR:  
10TeV-1EeV

# ASTROPHYSIQUE DES NEUTRINOS

## AMANDA, ANTARES: prototypes...

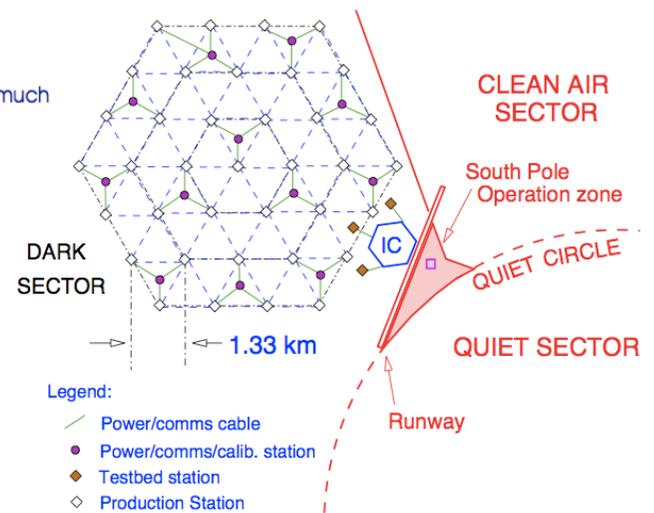
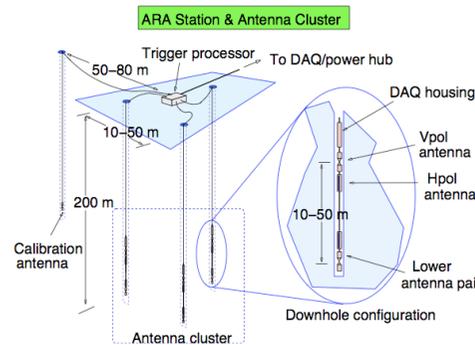


phototubes



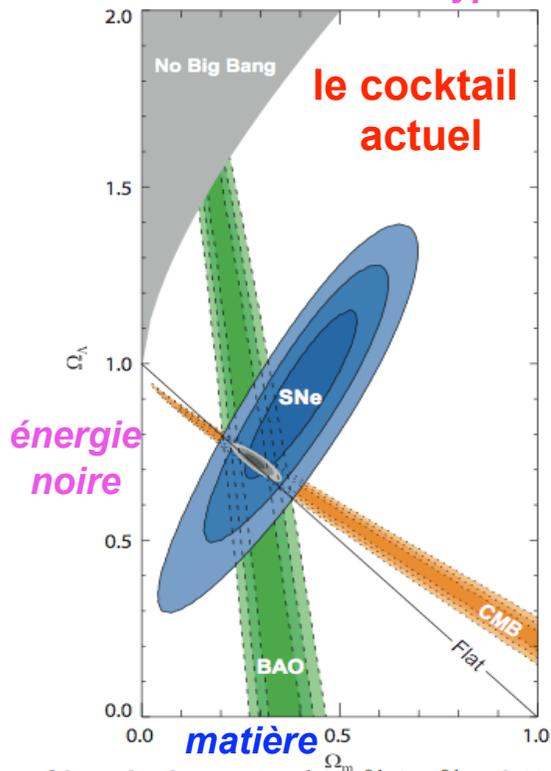
km3 trop petit, en viser 100,...  
changer de technique

Askaryan Radio Array

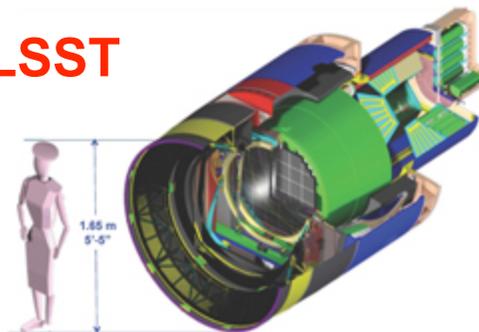


# cosmologie

*garder en tête les hypothèses iconoclastes!*

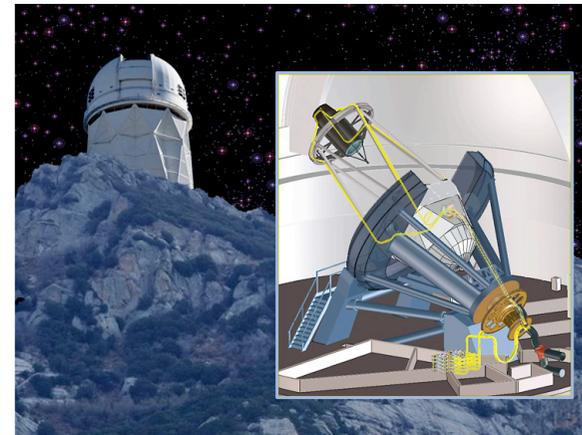


## LSST



**Euclid will challenge all sectors of the cosmological model:**

- **Dark Energy:**  $w_p$  and  $w_a$  with an error of 2% and 13% respectively (no priors)
- **Dark Matter:** test of CDM paradigm, precision of 0.04eV on sum of neutrino masses
- **Primordial Initial Conditions:** constrain amplitude, slope and higher order parameters of primordial power spectrum, constrain primordial non-gaussianity
- **Gravity:** Distinguish GR from simplest modified Gravity theories

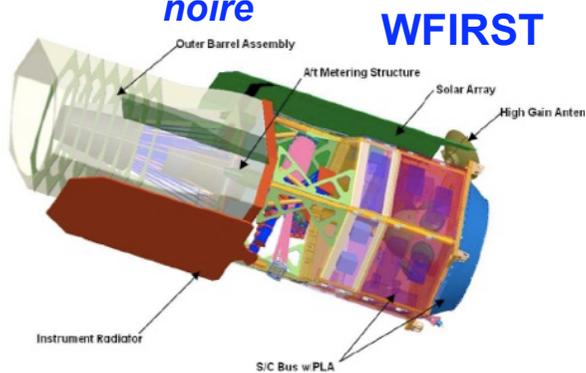
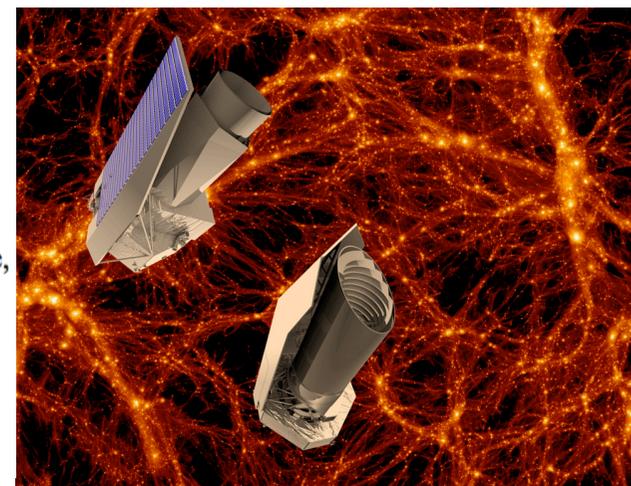


## BigBOSS

**BigBOSS receives favorable review from the National Optical Astronomy Observatory**  
*A plan to build the biggest galaxy-redshift map of the universe at Kitt Peak National Observatory*

## EUCLID

**SPACE + DUNE spectro + imaging**



## WFIRST

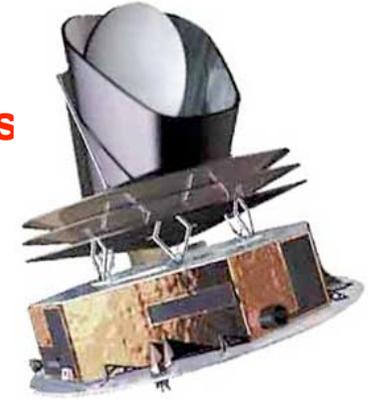
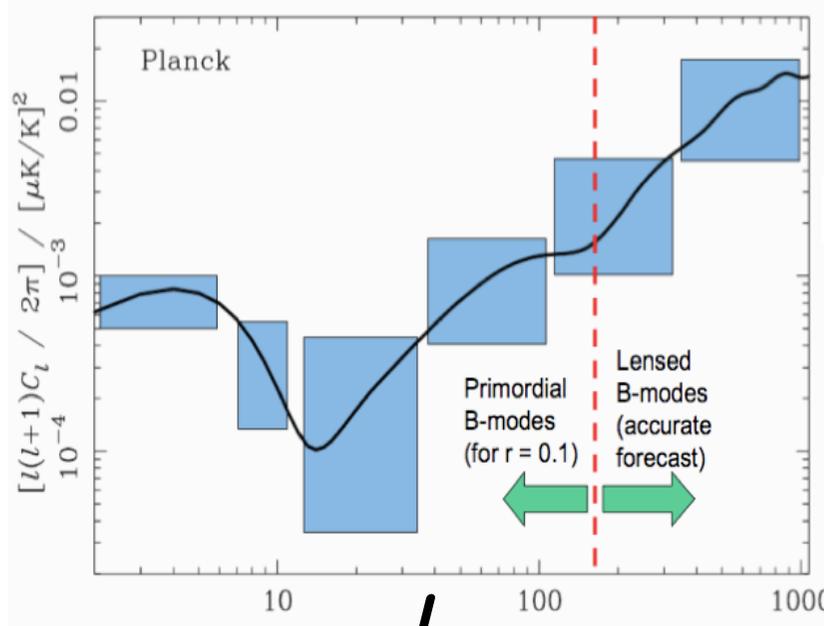
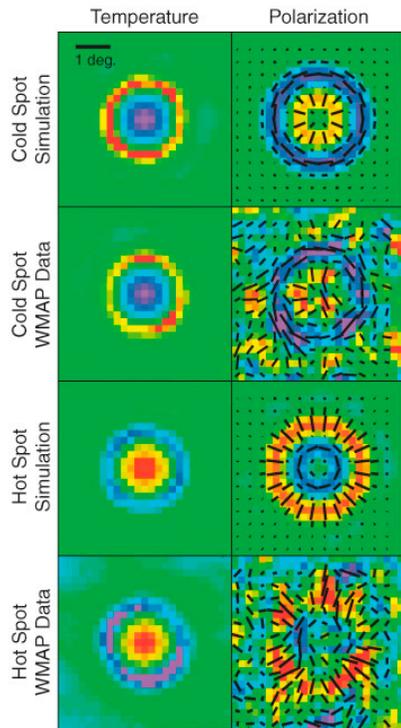
**Europe makes do without NASA**

US budget crisis forces European Space Agency to abandon plans for joint mission.

# Le rayonnement fossile:

polarisation B, fluctuations non gaussiennes

## PLANCK



Herschel and Planck win the French Grand Prix



espace

ballons

sol

**B-Pol**  
(www.b-pol.org)

- European proposal recently submitted to ESA (Cosmic Vision).
- ESA encourages the development of technology and resubmission for next round
- Detector Arrays development activities (KIDS in Rome, TES in Oxford, Genova etc.)
- A balloon-borne payload being developed with ASI (LSPE).

**EBEX**

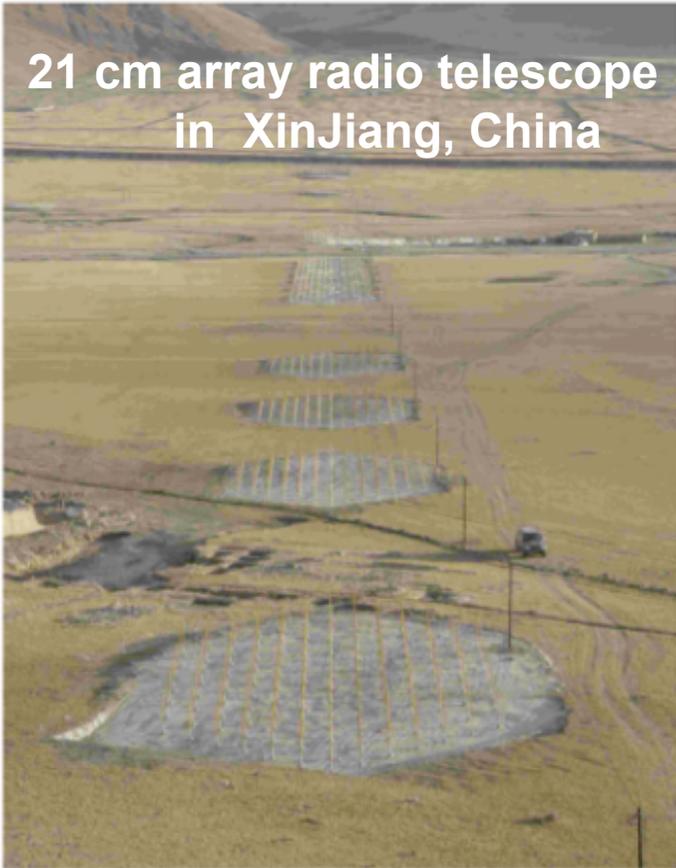
- Secondary Mirror
- Star Camera
- Primary Mirror
- Cryostat
- ACS Crate
- Reaction Wheel
- Magnetometer
- Battery Table
- pivot
- dGPS, Sun sensor (not installed)
- Suspension Cables (4)
- Bolometer readout crate (2)
- Elevation Actuator
- Flight Computer Crate



compétition en Antartique?  
Dome C, Dome A



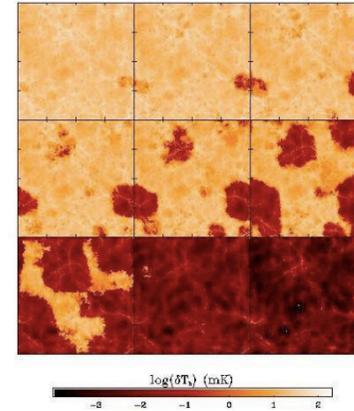
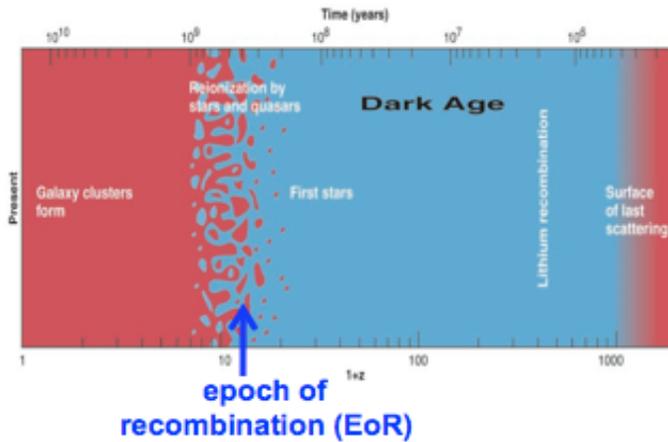
21 cm array radio telescope in XinJiang, China



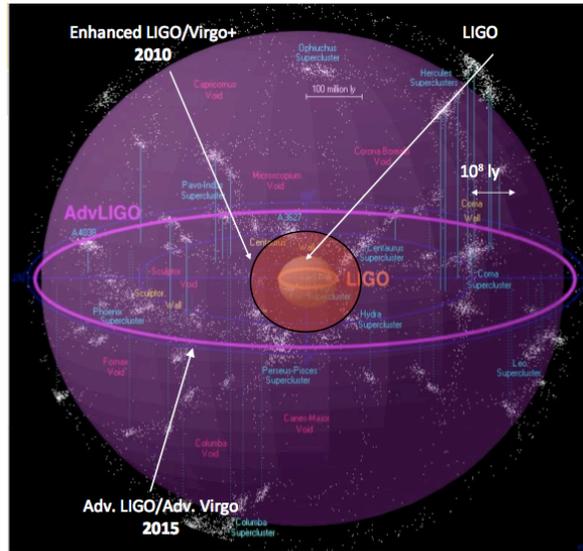
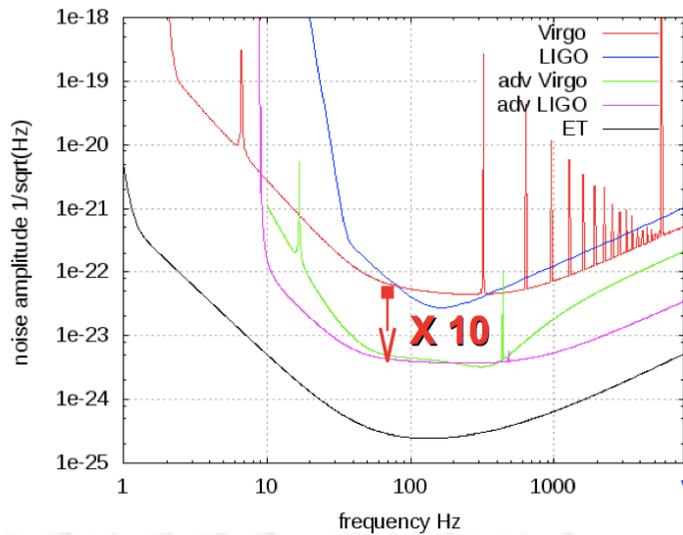
## 21cm Cosmology



Lofar,  
SKA, etc

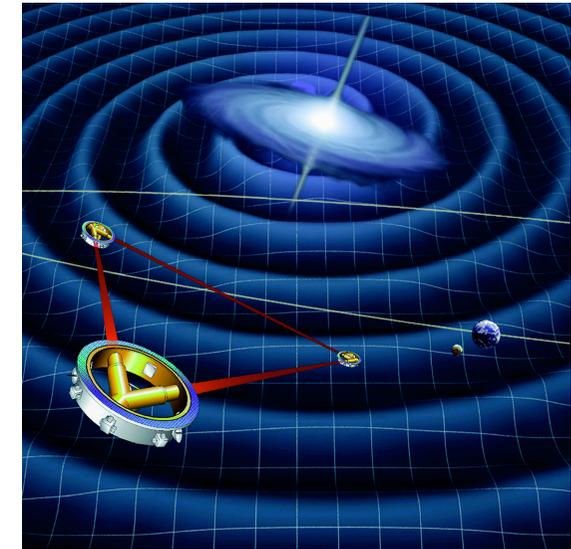


# ONDES GRAVITATIONNELLES



Credit: R.Powell, B.Berger

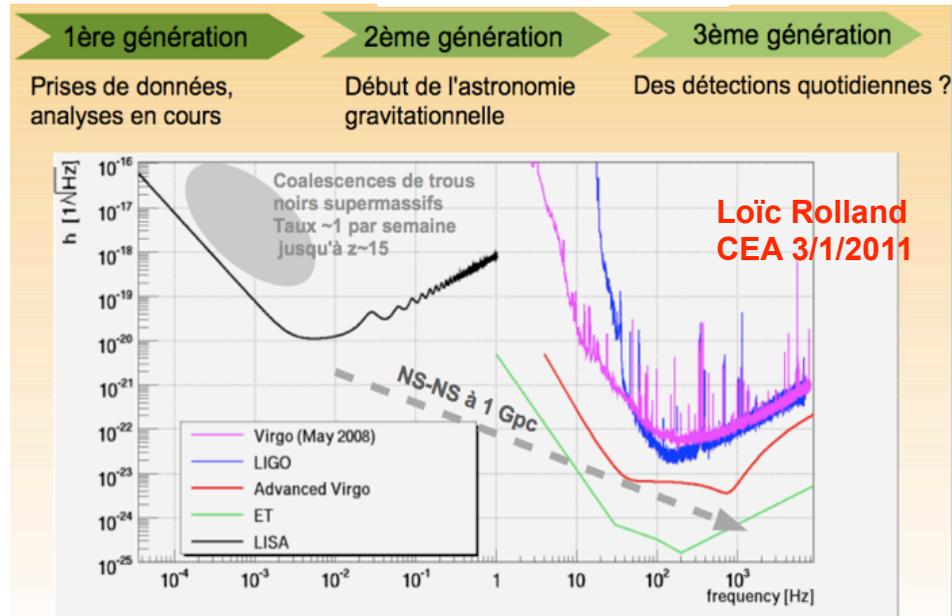
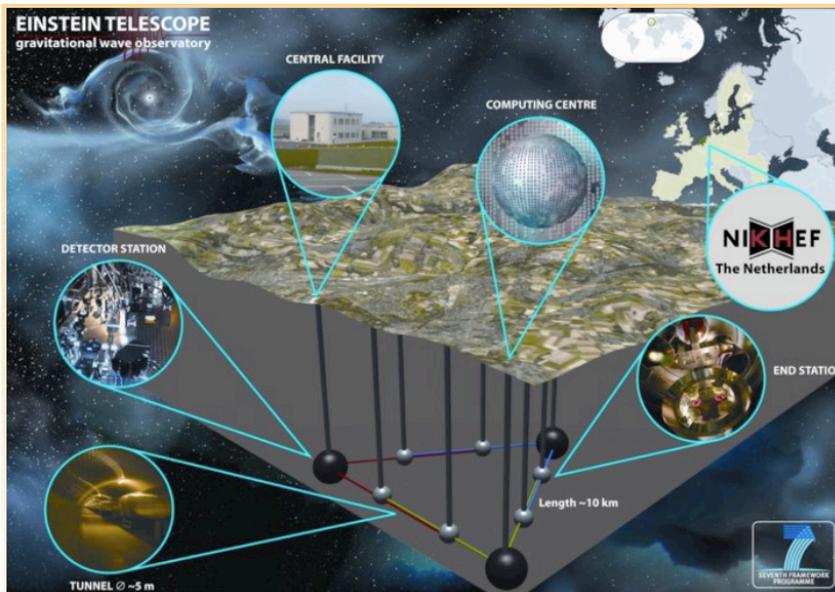
**VIRGO, LIGO:**  
advanced set up



**LISA**  
**LISA Pathfinder**  
**2013**

**Compétition:**  
**EJSM-Laplace**  
**IXO**

**Einstein Telescope**



# LES TRÈS GRANDES INFRASTRUCTURES DE RECHERCHE

La feuille de route : les TGIR existantes, décidées et en projet

Flotte océanographique française	VLT// (ESO)	CERN, LHC, détectel.	ESRF	GENCI	INSTRUCT - Biologie Structurale
GODAE / MERCATOR	CFHT	VIRGO / EGO	SOLEIL	CINES	IEHS - P4
EURO-ARGO	HESS/HESS II	ANTARES	LULI	IDRIS	CRB
SAFIRE	IRAM	GANIL	LIL	CCRT	NeuroSpin
CEPMMT (ECMWF)	ALMA	JET	LLB	CC-IN2P3	EMBL
CONCORDIA	LOFAR	TORE SUPRA	ILL	RENATER	IdG (CNS-CNG)
ECORD / IODP	CDS		LCMI		
EGS-Soultz			LNCMP		
RESIF			Centrales nanos		
ECOTRONS			RMN à très hauts champs		
			Souffleries		

**LES TGIR  
EXISTANTES**

## Les TGIR décidées

Particules noyaux énergie	RJH	SHS	ADONIS
Particules noyaux énergie	ITER	SHS	PROGEDO
Particules noyaux énergie	IFMIF/EVEDA		
Particules noyaux énergie	SPIRAL 2	SHS	CORPUS
Particules noyaux énergie	FAIR		
La matière	XFEL	SHS	BSN
La matière	ILE	Biologie santé	CELPEDIA
La matière	PETAL	Biologie santé	RIEHS - A3
La matière	ILL upgrade 1		
La matière	ESRF upgrade 1	Biologie santé	PREDECOB
Données, Calcul, services	Grille de production	Biologie santé	CIC

## Les TGIR hautement prioritaires

La planète	Navire polyvalent régional
La planète	ICOS
La planète	SOERE
L'Univers vu de la terre	E-ELT
L'Univers vu de la terre	CTA
La matière	ESRF upgrade 2
La matière	ILL upgrade 2
La matière	Magnétisme
Données, Calcul, services	Grille de recherche
Données, Calcul, services	PRACE
Biologie santé	LIFEWATCH
Biologie santé	Recherche translationnelle

## Les TGIR prioritaires

La planète	IAGOS-ERI	Particules noyaux énergie	Super LHC
La planète	COPAL	Particules noyaux énergie	ILC ou CLIC
		Particules noyaux énergie	ULISSE/LSM
La planète	EMSO	Particules noyaux énergie	Eurisol
L'Univers vu de la terre	LSST	Particules noyaux énergie	MYRRHA
L'Univers vu de la terre	SKA	Particules noyaux énergie	IFMIF
L'Univers vu de la terre	Km3Net	La matière	ELI
		La matière	ESS
		La matière	EMFL

# Et la théorie de haut vol? Supercordes, Gravité Quantique

*(Je connais l'air, pas les paroles...)*

Jonction avec la phénoménologie?

Supersymétrie! Mais la faut-il légère?

Le Landscape des Supercordes

*Un nombre quasi infini d'univers possibles*

*Par l'inflation éternelle, tous sont essayés*

*Un, au moins, a "réussi"*

Comment infirmer cette possibilité?

*Falsifier l'idée d'inflation éternelle?*

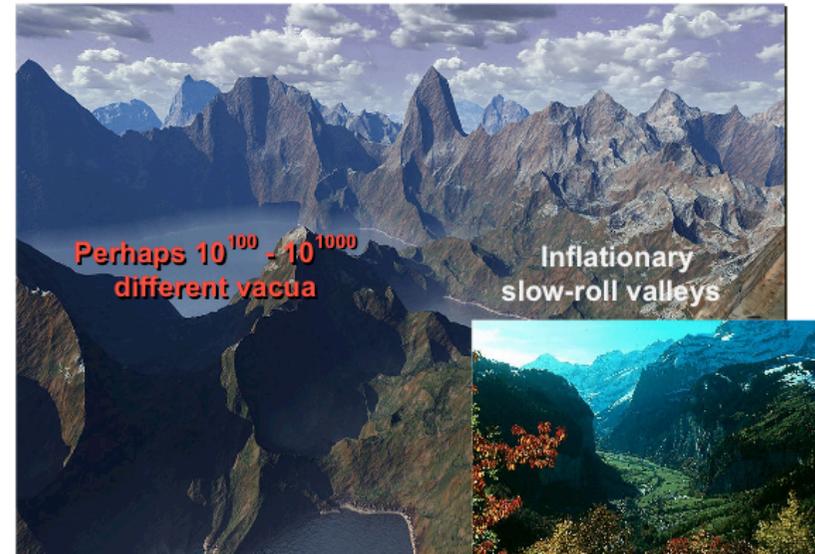
*Contraindre le Landscape?*

*Grande Unification supersymétrique?*

Et si l'argumentation anthropique l'emportait?

Darwinisme cosmologique? Une défaite?

## String Theory Landscape



math/0105155

	$\mathbb{K}' = \mathbb{R}$	$\mathbb{K}' = \mathbb{C}$	$\mathbb{K}' = \mathbb{H}$	$\mathbb{K}' = \mathbb{O}$
$\mathbb{K} = \mathbb{R}$	$\mathfrak{so}(3)$	$\mathfrak{su}(3)$	$\mathfrak{sp}(3)$	$\mathfrak{f}_4$
$\mathbb{K} = \mathbb{C}$	$\mathfrak{su}(3)$	$\mathfrak{su}(3) \oplus \mathfrak{su}(3)$	$\mathfrak{su}(6)$	$\mathfrak{e}_6$
$\mathbb{K} = \mathbb{H}$	$\mathfrak{sp}(3)$	$\mathfrak{su}(6)$	$\mathfrak{so}(12)$	$\mathfrak{e}_7$
$\mathbb{K} = \mathbb{O}$	$\mathfrak{f}_4$	$\mathfrak{e}_6$	$\mathfrak{e}_7$	$\mathfrak{e}_8$

Table 5 — Magic Square Lie Algebras  $M(\mathbb{K}, \mathbb{K}')$

