Report on The “Astroparticle Axis”

(I’ll be more specific in a moment!)

Pasquale D. Serpico
(with input/slides by A. Barrau, G. Lamanna, F. Marion, F. Mayet, L. Rolland...)

Scientific Council, Annecy-le-Vieux, 19/02/2013

Outline

1. Recap of the scientific goals & challenges (Extremely broad!!!)

2. (Necessarily incomplete) review of some of the ongoing projects/efforts, with some recap of the physics

3. Explicit examples of the role of Enigmass (PhD, Postdocs, Visitors...)

Driving Questions

Note: All labs involved to some extent (often large!) in this axis

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Driving Questions

➡ Origin of the microscopic mass (e.g. DM) and energy budget of universe (“cosmology”)
➡ Mechanisms for conversion of mass & gravitational energy into to e.m./kinetic energy in astrophysics (multiwavelength and multimessenger approach)
➡ Aspects related to fundamental understanding of gravity

Note: All labs involved to some extent (often large!) in this axis

lapp LAPTh Annecy-le-Vieux LPSC Grenoble lsm laboratoire souterrain de Modane

Subjects (wrt research lines in the proposal)

Of the 6 Major Scientific Objectives of the Grant, 4 involve "the Universe as a Lab"!!!

C. Indirect and Direct Dark Matter Searches, weighing the Universe at the Colliders

LAPP, LAPTh, LPSC, LSM involved: direct detection **MIMAC,** gamma-rays and antiparticles (**AMS, HESS, CREAM, CTA**) indirect cosmological probes **(e.g. PLANCK), Theory,** link with **LHC...**

D. Multi-messenger astrophysics, from gravitational waves to the high-energy universe

HESS/CTA, AMS, on longer terms **Virgo, LSST,** link with neutrinos...

E. Dark Energy Probes

Planck, of course... but also efforts in either precision standard candle determination (Baryon Acoustic Oscillations with **LSST**) or to look for new standard candles like GRBs (including PopIII ones?), e.g. via **HESS/CTA, LSST**, or standard sirens (**Virgo**)

F. The nature of Gravity

Quantum **Theory** of Gravity (Loop quantum gravity), tests of LIV (e.g. **HESS/CTA**), strong-gravity tests & cosmology (**VIRGO**). Study of quantum states of matter in the gravitational field (**GRANIT**)

Some Technical Challenges (see proposal for details)

MIMAC: Shares typical Challenges of Underground Physics (see neutrino presentation)

CTA: Mechatronic developments and a Science Gateway (Virtual Data Centers)

design of an architecture based on a mechatronic framework.
transition from scientific collaboration-led experiments to public observatories where astronomers will submit proposals and receive data, software or analysis services, and support (e-Science Environment for data storage, handling, processing, protocols, software libraries). Shared concern with other observatories

Gravitational Waves in Virgo

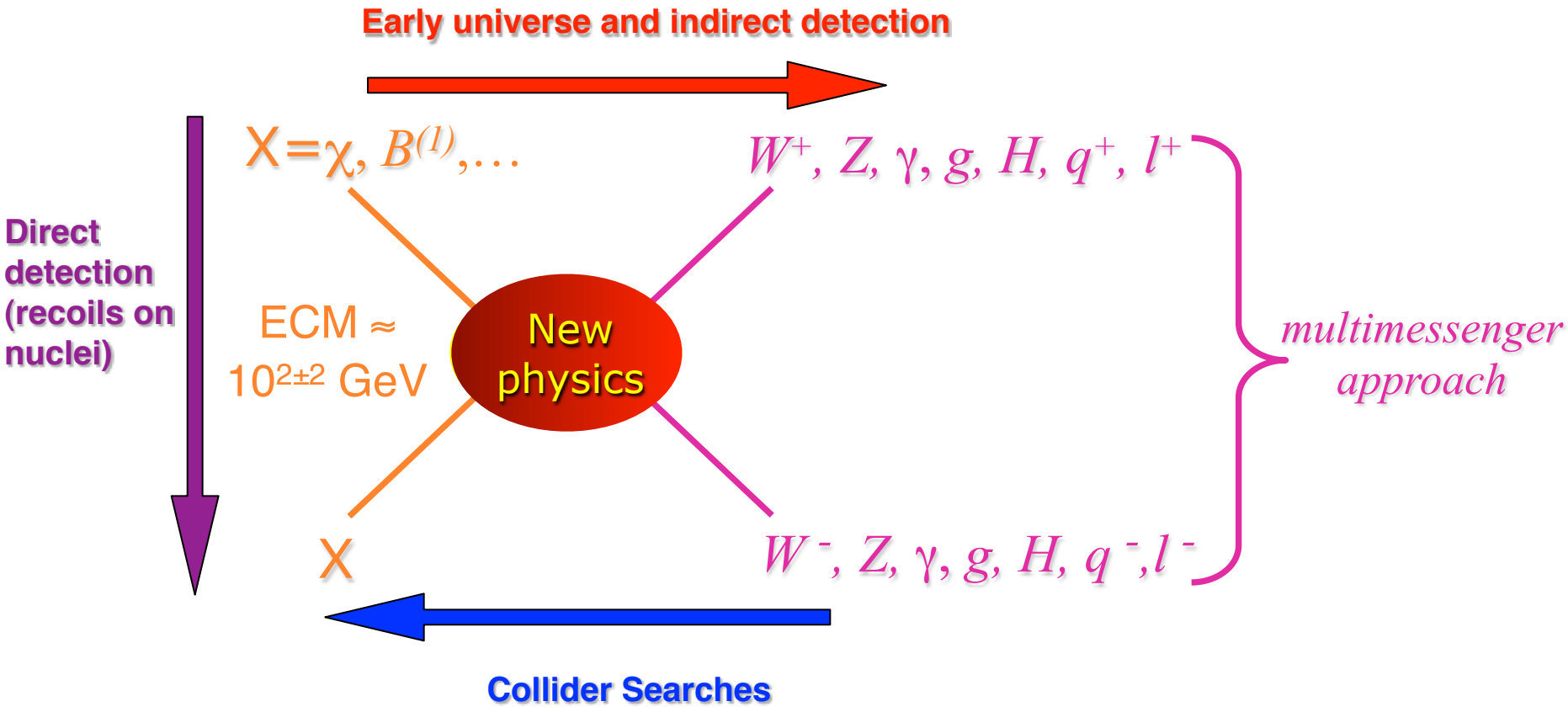
get to the point of **having Advanced Virgo operating** at improved sensitivity as quickly as possible, to join Advanced LIGO in taking data as soon as 2015. For LAPP this means completing successfully the detector upgrades under its responsibility, in particular that of the detection system.

LSST

8 meters class telescope especially dedicated to dark energy. It has been ranked as first priority by the American decadal survey. The IN2P3 is a major partner. Within this collaboration, the LPSC is in charge of the **calibration and commissioning of the LSST camera**

High-energy astroparticles & Dark Matter research

WIMP dark matter "discovery program"



- ✓ demonstrate that astrophysical DM is made of particles (locally, via DD; remotely, via ID)
- ✓ Possibly, create DM candidates in the controlled environments of accelerators
- ✓ Find a consistency between properties of the two classes of particles. Ideally, we would like to calculate abundance and DD/ID signatures → link with cosmology/test of production

WIMP miracle... and hard facts

A textbook calculation can prove that

$$\Omega_X h^2 \simeq \frac{0.1\,\mathrm{pb}}{\langle \sigma v \rangle}$$

dimensionally, for EW scale masses & couplings, one gets the right value!

$$\langle \sigma v \rangle \sim \frac{\alpha^2}{m^2} \simeq 1\,\mathrm{pb} \left(\frac{200\,\mathrm{GeV}}{m} \right)^2$$

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In practice, one has to take care of many effects (coannihilations, resonances,...)
Relic density calculations have reached a certain degree of sophistication and are often automatized with publicly available software.

Leading effort in this respect at **LAPTh** !

MicrOMEGAs: a code for the calculation
of Dark Matter Properties
including the **relic density**, direct and **indirect rates**
in a general supersymmetric model
and other models of New Physics

http://lapth.in2p3.fr/micromegas/

Where to look for Gamma rays

To first approximation — particle physics — astrophysics

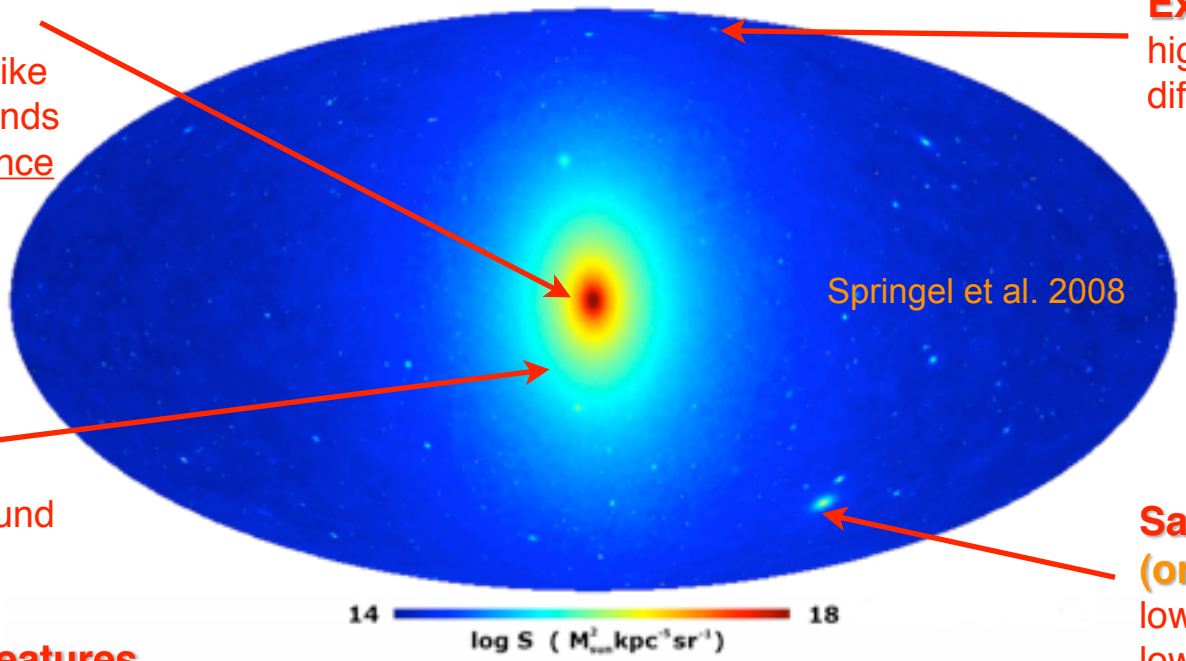
$$\Phi_\gamma(E_\gamma,\Omega) = \left[\frac{\mathrm{d}N_\gamma}{\mathrm{d}E_\gamma}(E_\gamma)\frac{\langle\sigma v\rangle}{8\pi m_X^2}\right]\int_{\mathrm{los}}\rho^2(\ell,\Omega)\,\mathrm{d}\ell$$

[particle] ⊗ (astro) factorization holds if $<\sigma\, v>$ is v-independent & if prompt emission dominates

What is the picture of the "DM - gamma sky" suggested by simulations?
(but the actual gamma-ray sky is astrophysically crowded and bright...)

Galactic Center
high statistics, point-like and diffuse backgrounds
halo-model dependence

Extragalactic
high statistics, lot of diffuse backgrounds



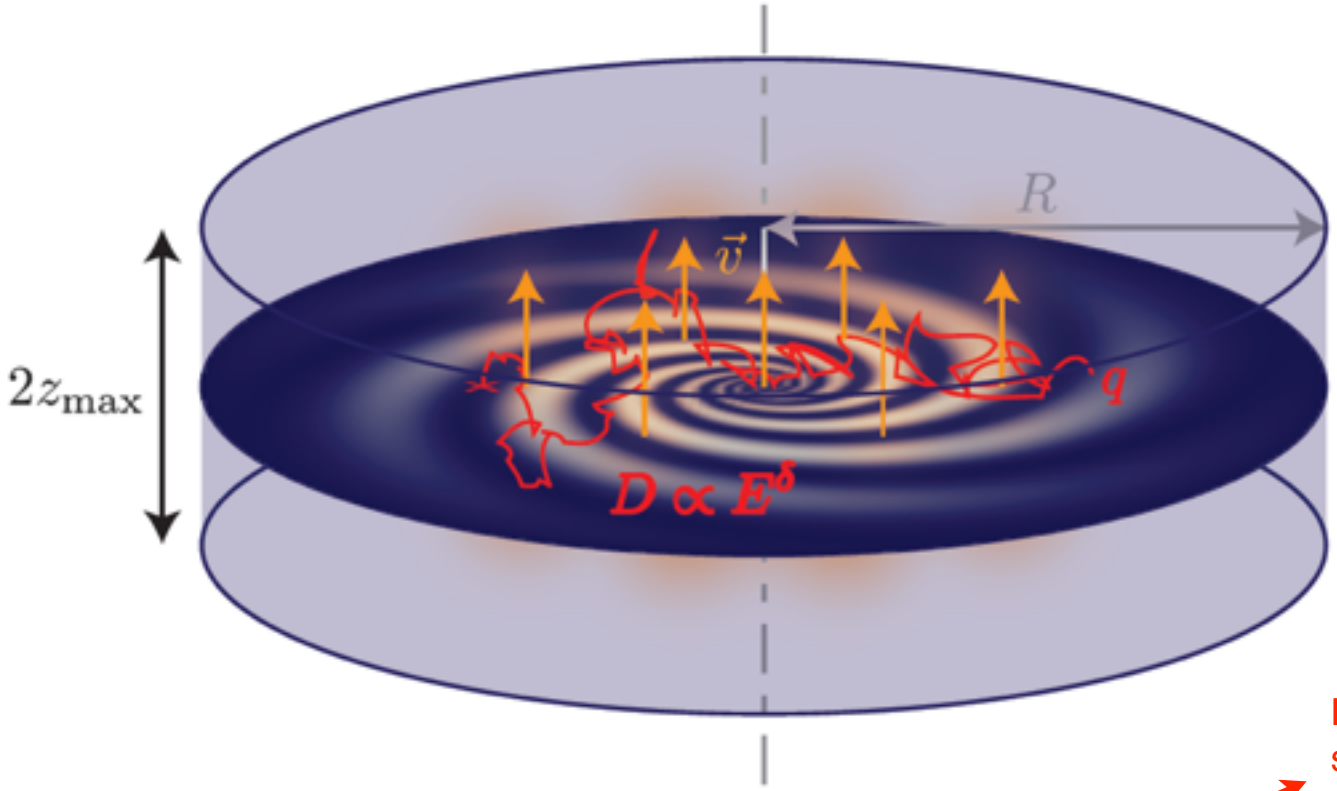
MW Halo
high statistics,
high diffuse background

Satellites (or Clusters)
low background (?),
low statistics

Lines/Spectral Features

What about charged particles?

Not only DM physics (sigma's, b.r.) and astrophysics (halo distribution) matter, but also plasma astrophysics (diffusion in the Galaxy)
Antimatter is preferred due to lower astro background

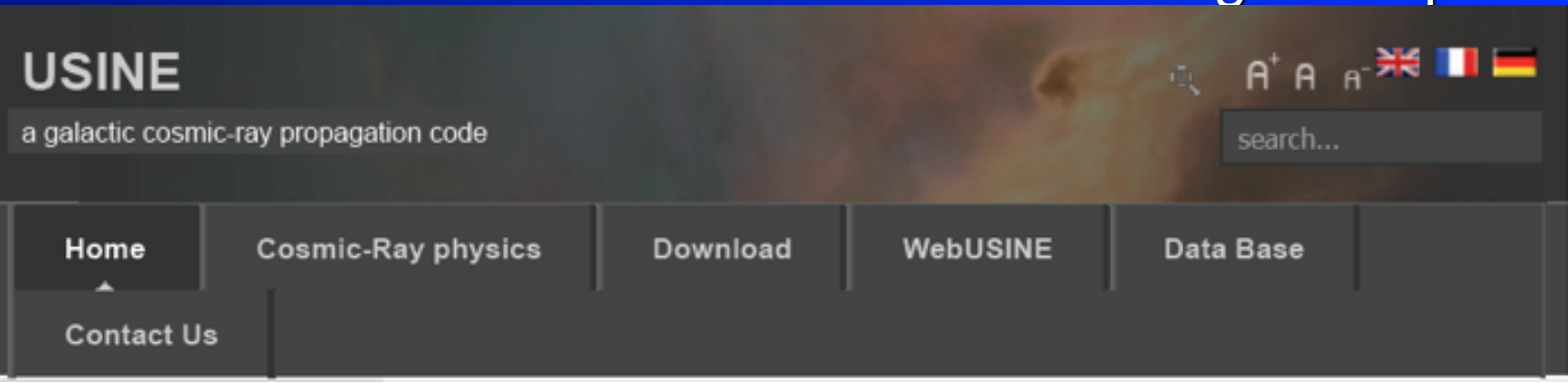


$$\Phi_a(E_a) = \left[\frac{dN_a}{dE_a}(E_a) \frac{\langle \sigma v \rangle}{8\pi m_X^2} \right] \mathcal{F}_a(E_a, \ldots)$$

Functional of the spectrum and astrophysics!

Additional complication for e+e-: relevant E-losses, local effects...

Different codes are available to solve for a given input



Currently LPSC (with contributions from LAPTh, LAPP & external labs) heavily involved in the **USINE** release, based on semi-analytic scheme (suitable for fast, large scans over parameter space).

Complementary to fully numerical codes like GALPROP or DRAGON

http://lpsc.in2p3.fr/usine/

For DM-substructure enhancement signal (in gammas) see also **CLUMPY** (line-of-sight integrator of DM^2 distribution)

http://lpsc.in2p3.fr/clumpy/

MIMAC

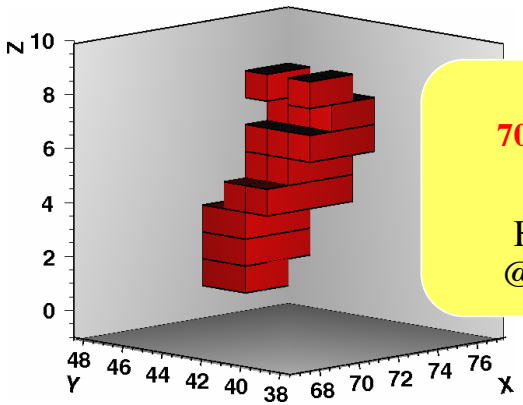
First step towards a large directional detector for dark matter ("wind" to Earth/Sun Motion in the DM halo) in the framework of European ASPERA program.

It aims to build a matrix of micro-Time Projection Chamber using Micromegas to reconstruct the kinematics of the WIMP-nucleus interaction (collecting both energy and 3D track)

Collaboration : LPSC Grenoble, CEA Saclay, CPMM Marseille, Tsinghua U.

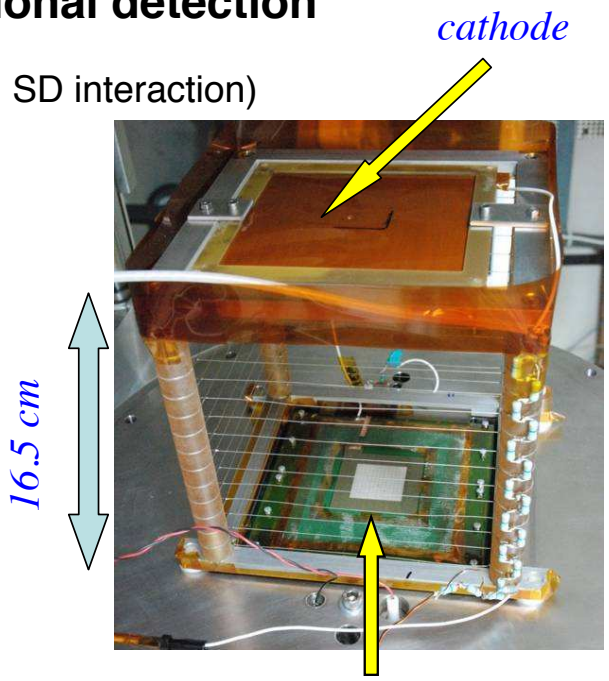
A matrix of *μ*TPC dedicated to directional detection

- Gaz Mixture : CF_4 + CHF_3 (Fluorine target → SD interaction)
- Low pressure operation : 50 mbar
- Micromegas technology
- Measurement of 3D track and energy
- Final goal : a 10 kg detector



DATA
70 % CF_4 + 30% CHF_3

50 mbar
Fluorine Candidate
@ 50 keV ionization



Micromegas & pixelized anode (x,y)
10 cm x 10 cm / Pixel = 350*μ*m
512 channels : 256 X + 256 Y
50 MHz sampling

MIMAC: status, challenges & goals

- **A large directional detector (30 kg.year) could lead either to a :**
  - **constraint on DM properties (halo and particle),** $\sim 10^{-3}$ *pb*
  - **conclusive discovery (with a high significance),** 10^{-4}-10^{-5} *pb*
  - **competitive exclusion,** 10^{-5}-10^{-6} *pb*

- **Experimental issues**
  - **major :**
    - **3D reconstruction**
    - **energy threshold**
    - **residual background**
  - **minor :**
    - **angular resolution**
    - **sense recognition**

- **MIMAC project**
  - **Dual-TPC. 5 liters. Underground in 2012**
  - **Next phase : m³ detector**

MIMAC first module

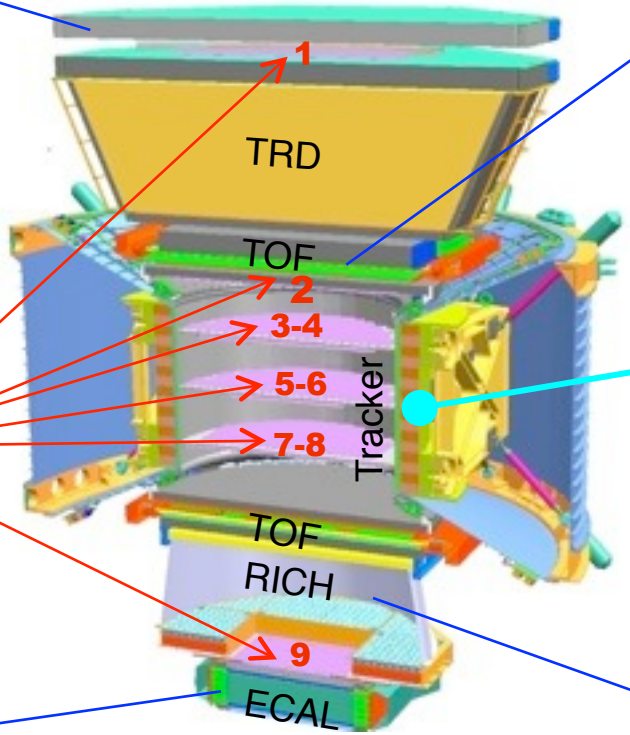
AMS: a TeV multipurpose spectrometer in space

TRD
Identify e^+, e^- , Z

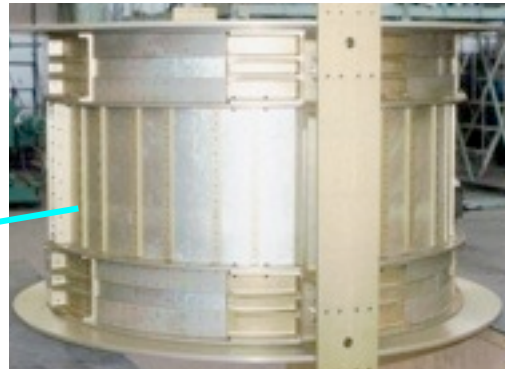
Particles and nuclei are defined by their
charge (Z) and energy (E ~ P)

TOF
Z, E

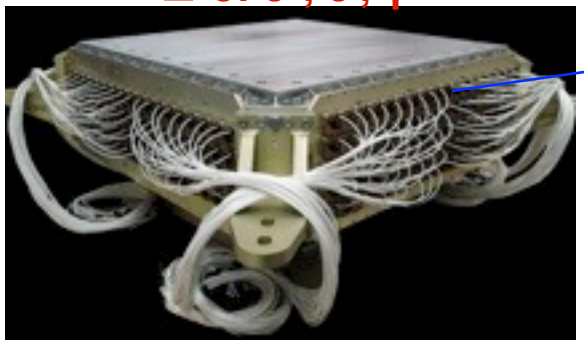
Silicon Tracker
Z, P



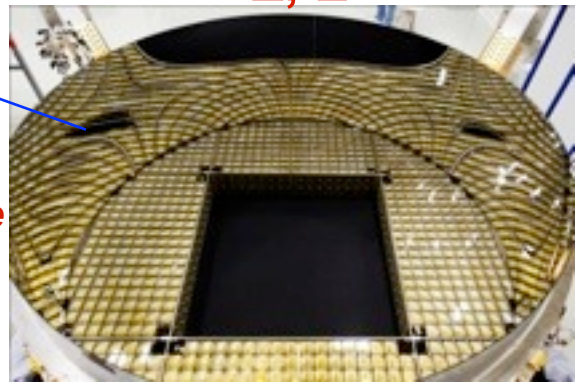
Magnet
±Z



ECAL
E of e^+, e^-, γ



RICH
Z, E



Z, P are measured independently by the Tracker, RICH, TOF and ECAL

AMS finally @ home, since almost 2 years

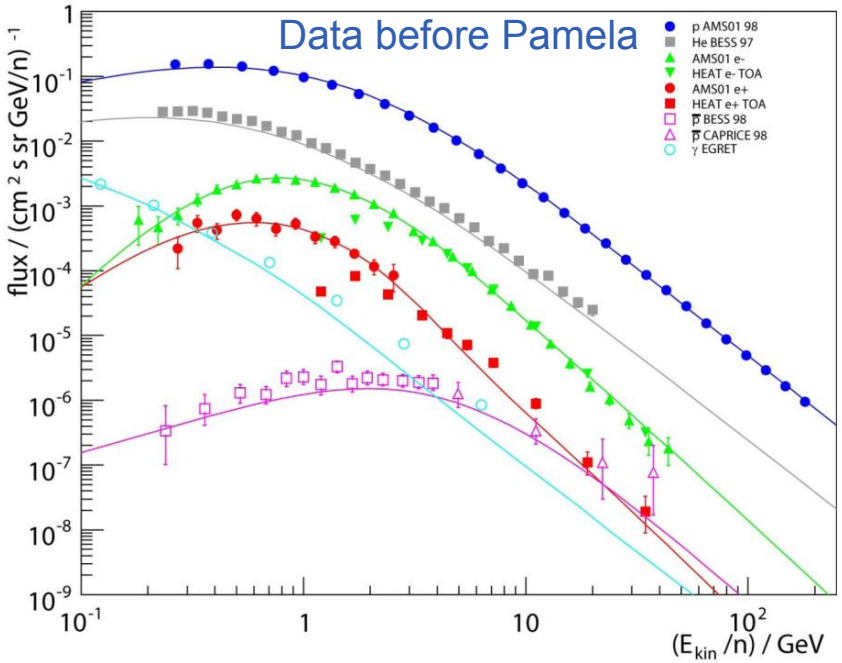
DOE led, international long duration (10-20 years) Experiment on the International Space Station

May 19, 2011: AMS installation completed at 5:15 AM.
Data taking started at 9:35 AM

The detectors function as designed and is routinely collecting events, at a rate of 1.6×10^{10} events/year

Some Scientific Goals

- Measuring with unprecedented precision several CR species spectra over a large dynamic range.
- Improving CR propagation parameters determination (and breaking some degeneracies)
- Looking for signatures of Dark Matter annihilation (anti-p, positrons, possibly anti-deuterons, perhaps gamma rays?).
- Reaching a sensitivity of 10^{-9} in the anti-He/He ratio (an improvement of three orders of magnitude over existing bounds)
- Of course, be ready for the unexpected...



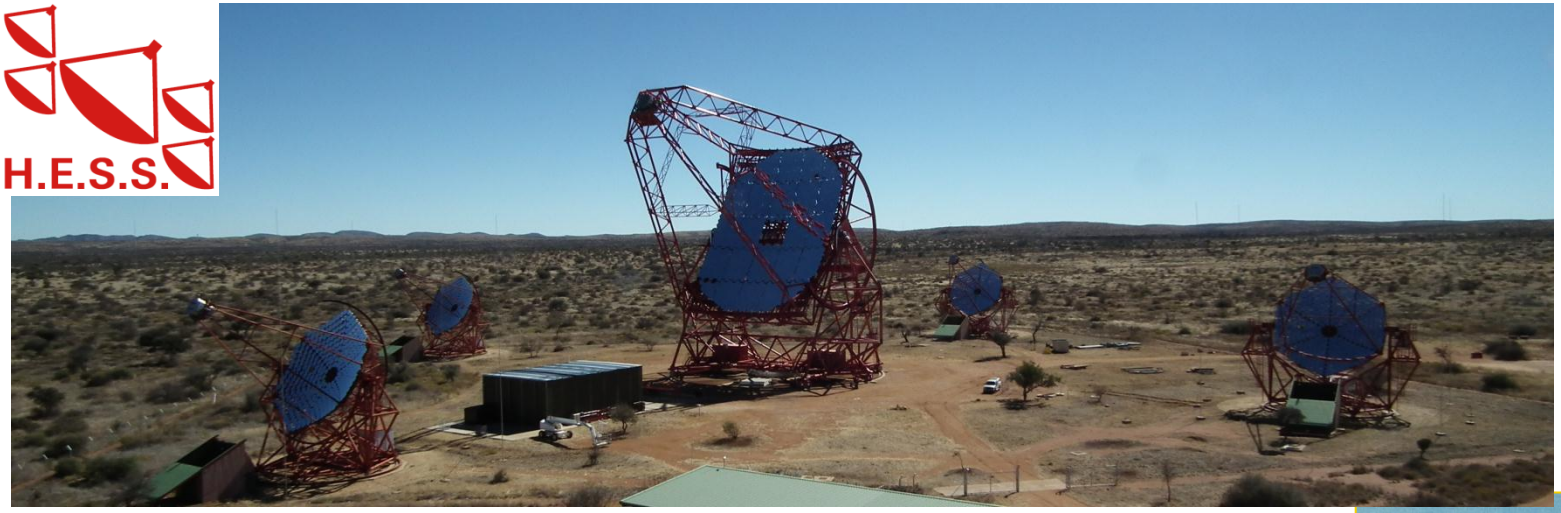
@ 10 GeV

88%	**Protons**
10%	Helium
++1%	**Electrons**
++0.1%	**Positrons**
++0.01%	**Gamma rays**
0.001%	**Antiprotons**

First results expected to be published soon!
(e+ fraction should be the first one)

Involvements: longstanding theory/experiment collaboration (LAPP, LAPTh,LPSC) especially on propagation issues.
Exp.: Lepton spectra reconstruction, t-dependence fluxes, (ECAL@LAPP, RICH@LPSC)...
Add.: Some LPSC involvement in **CREAM** (balloon-born CR experiment)

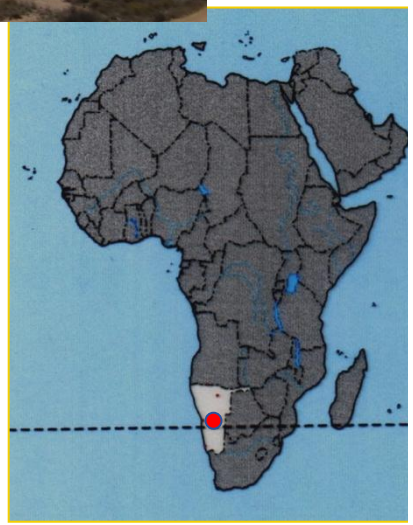
HESS: High Energy Stereoscopic System



A system of 4 (13 m diameter dish) telescopes (since 10 years)

and

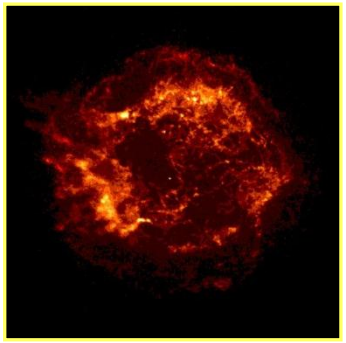
1 (30 m diameter dish) telescope (since September 2012) ***HESS-II***



In Namibia (1800 m)

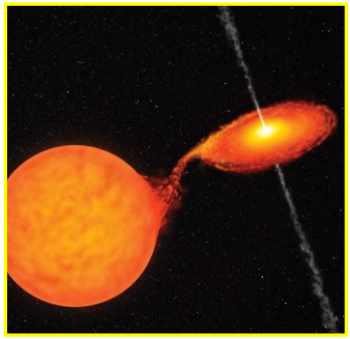
On moonless nights, imaging of the short flash of Cherenkov radiation generated by the cascade of relativistic charged particles produced when a very high-energy gamma ray strikes the atmosphere

Scientific Objectives

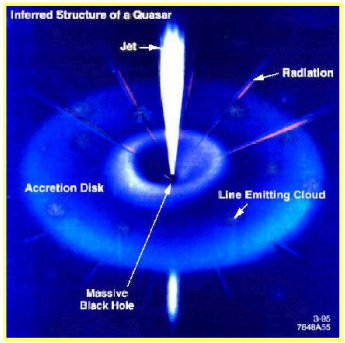


SNRs

Pulsars
and PWN

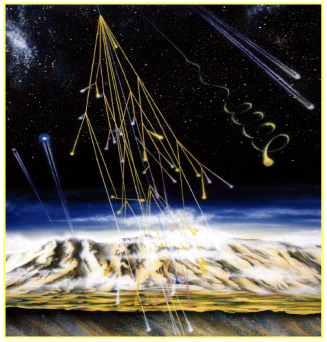


Micro quasars
X-ray binaries

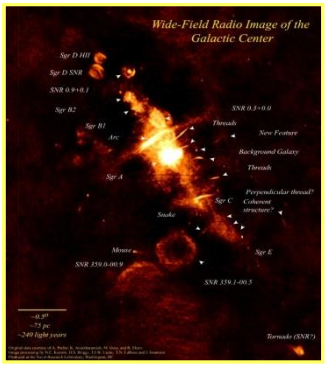


AGNs

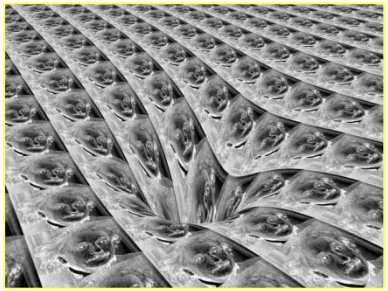
GRBs



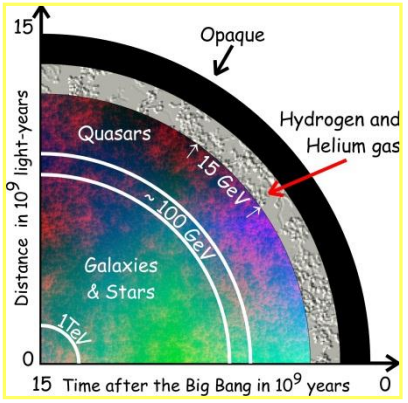
Origin of
cosmic rays



Dark matter



Space-time
& relativity



Cosmology

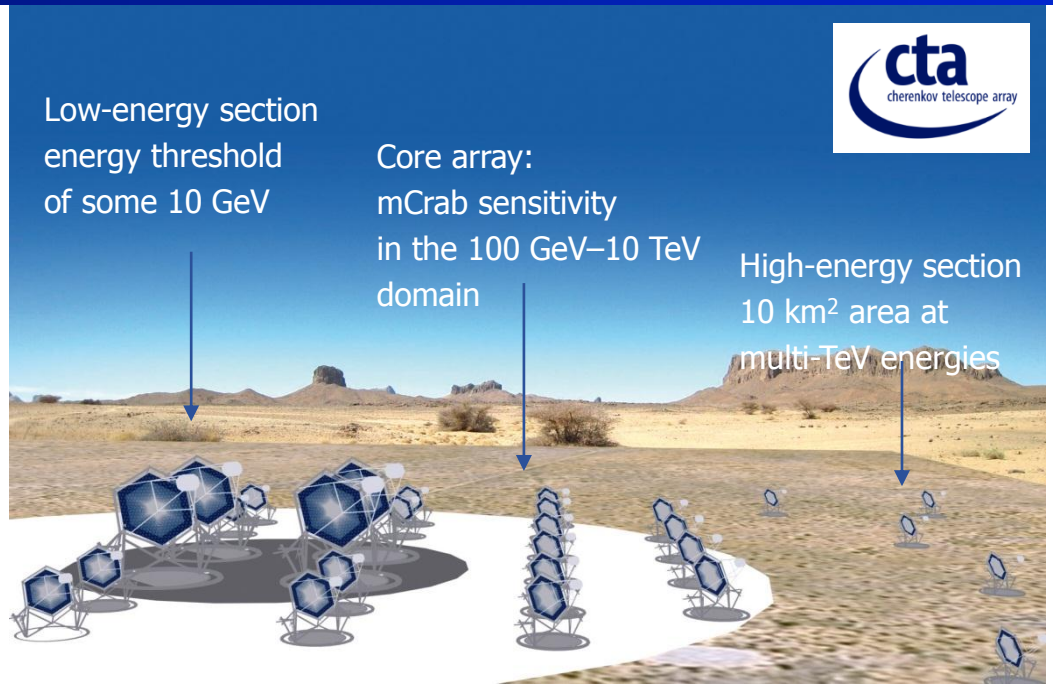
Starting collaboration on γ−rays Dark Matter

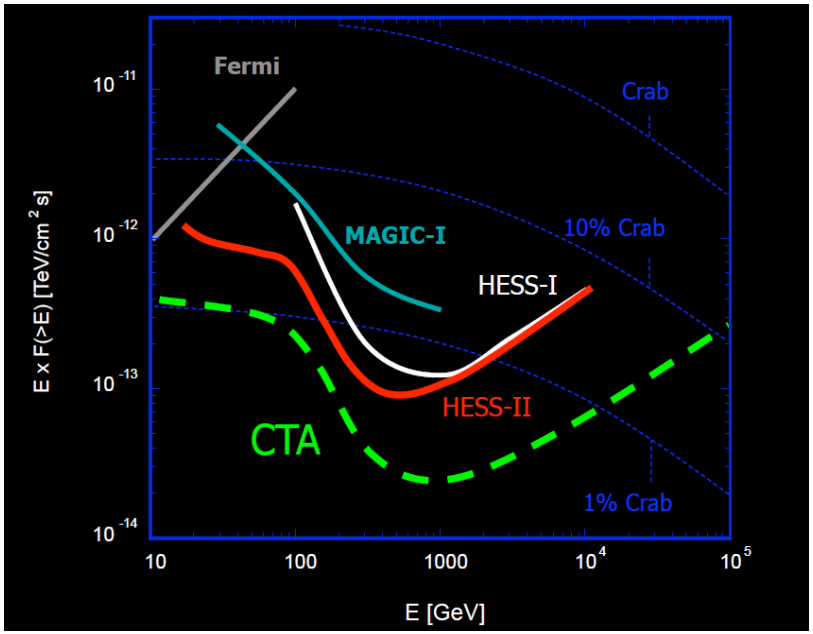
- Claimed line-like emission at ~130 GeV towards the Galactic Center detected in Fermi-LAT data: *Bringmann et al. 1203.1312, C. Weniger 1204.2797*
- It has been claimed that HESS-II can *at least* check if it is an instrumental effect (completely different systematics) *L. Bergstrom et al."Investigating Gamma-Ray Lines from Dark Matter with Future Observatories," arXiv:1207.6773*
- Is there a new type of astrophysical emission of which this represents the "first of its kind", just due to lack of sensitivity till now? *F. Aharonian, D. Khangulyan and D. Malyshev, "Cold ultrarelativistic pulsar winds as potential sources of galactic gamma-ray lines above 100 GeV," arXiv:1207.0458*

P. Serpico / G. Lamanna (LAPTh/LAPP) are studying **potential of HESS II for line searches** (together with *A. Goudelis & G. Belanger*, synergic with the DMastroLHC ANR project):

- cross-check claimed capabilities
- establish if internal cross-check of a potential signal is possible with "parasitic" extragalactic observation time
- in case of positive signal, explore if morphological studies are possible (help to discriminate between astro and DM origin)

Future: Cherenkov Telescope Array - CTA





- **Higher sensitivity at TeV energies (x 10)**
  more sources, details in extended sources
- **Lower threshold (some 10 GeV)**
  pulsars, distant AGN, source mechanisms
- **Higher energy reach (100s of TeV)**
  cutoff region of Galactic accelerators
- **Wider field of view**
  extended sources, surveys
- **Improved angular resolution**
  structure of extended sources
- **Higher detection rates**
  transient phenomena

Explore scientific objectives (and modes of operation) for this instruments

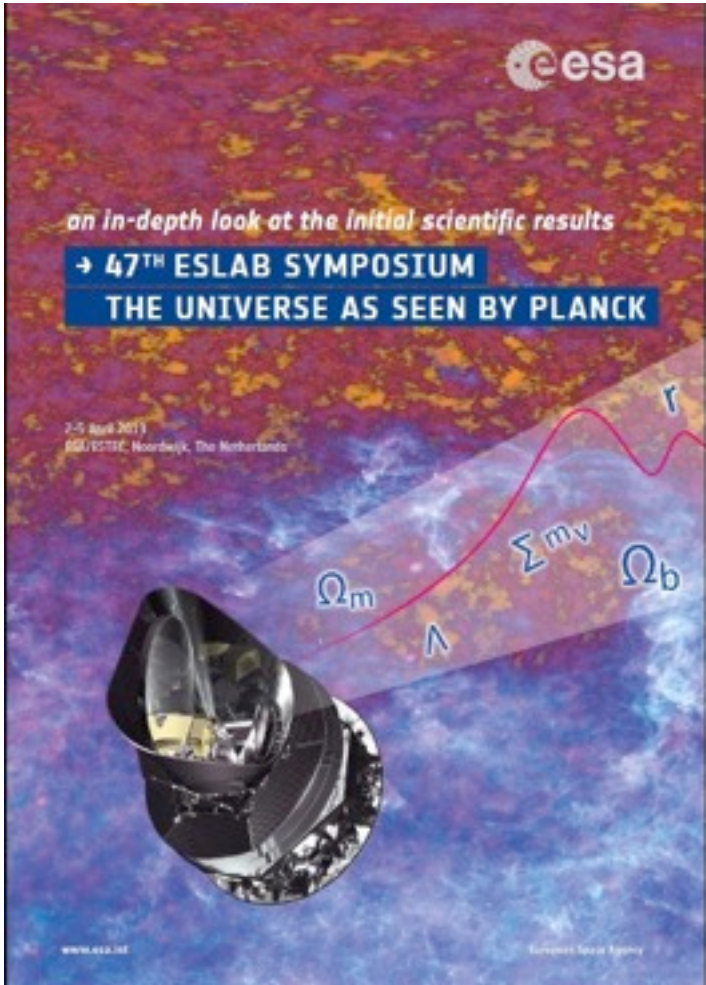
Cosmology and gravity

Planck & CMB studies

First cosmological maps (TT) publicly released in < 2 months! Implications for inflation, fundamental physics (neutrinos, DM, modified gravity...)

Several theoretical interests (e.g. neutrino cosmology at LAPTh, constraints to Loop Quantum Gravity at LPSC...) plus a group @ LPSC, formerly involved in Planck hardware aspects, at present of course on some data analysis topics, such as

- IR background
- primordial B-fields
- dark energy
- modeling of polarized galactic emission
- cluster studies (e.g. SZ effect)
- inflation
- weak lensing



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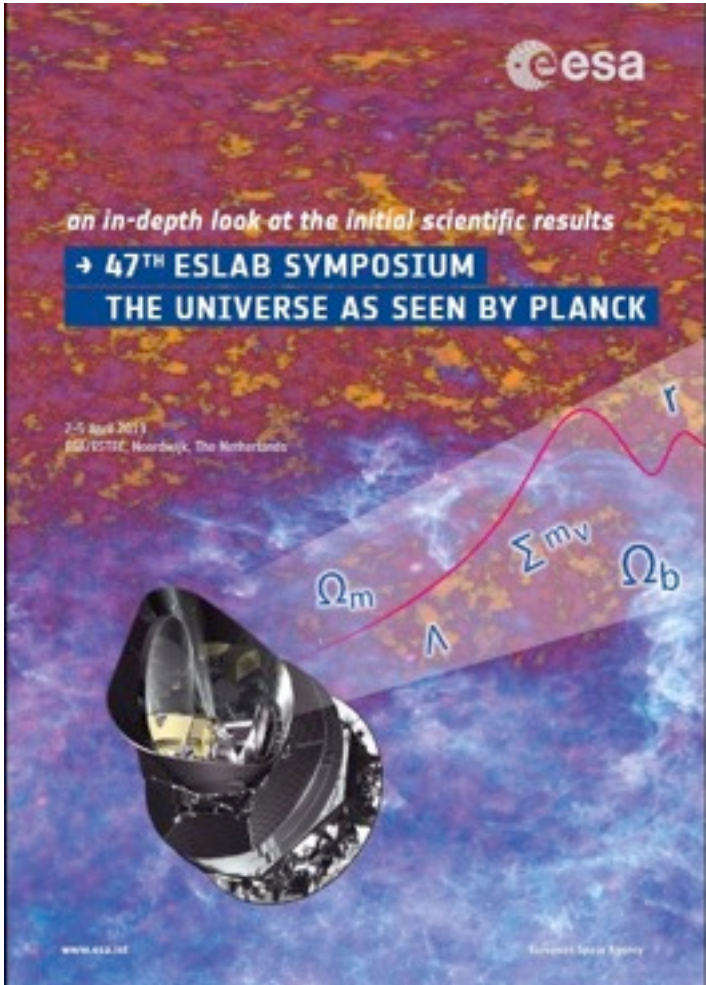


The LPSC group is now also involved in “NIKA”, an international collaboration lead by the Institut Neel in which the LPSC is strongly implicated both from the instrumental and scientific point of views. Aims e.g. at the new IRAM (30 m telescope at the millimeter frequency bands) KID Arrays cryogenic camera based on arrays of Kinetic Inductance Detectors (KID).

Some of the Pheno/Theory expertise

CLASS

the Cosmic Linear Anisotropy Solving System

Especially @ LAPTh.
In recent years, mostly (but not only) applied to neutrino cosmology, such as number and masses of neutrinos, constraints and mechanism of production of sterile states, interplay with “hints” from the lab...

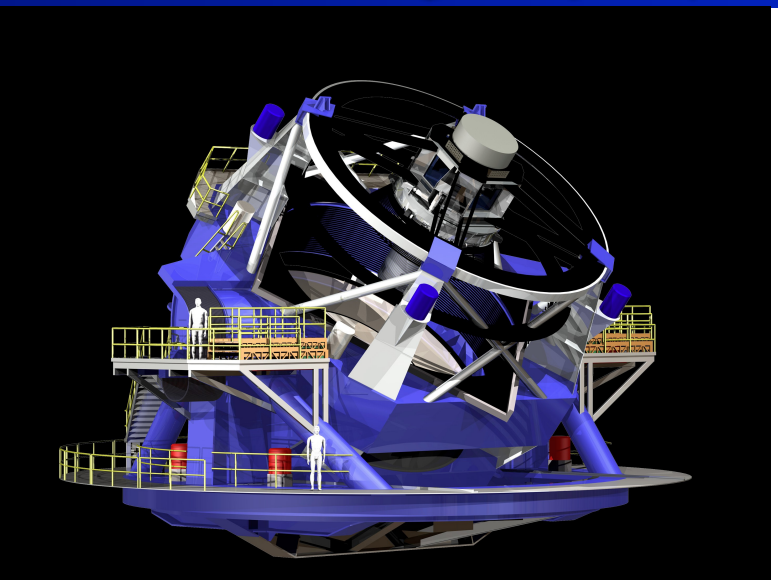
→ link with Neutrino axis

PArthENoPE

Public Algorithm Evaluating the Nucleosinthesis of Primordial Elements

Later I’ll mention some research path in (loop) quantum gravity phenomenology @ LPSC

Large Synoptic Survey Telescope LSST



Large Synoptic Survey Telescope

Location: Northern Chile (Cerro Pachon)
Optical telescope: 6 bands in 320 nm to 1050 nm
Large field of view: 3.5°
Large collection area: 8.4 m
→ detect faint objects up to magnitude 24 in 15 s
First light: 2020, for 10 years

The main "deep-wide-fast" survey

1 pair images of each sky field every 3 nights
→ 1000 images of each sky field in 10 years

Objectives

Cosmology

Dark matter: 3D mapping via strong gravitational lensing
Dark energy and accelerated expansion of the Universe with different independent observables: cosmic shear, BAO, supernovae

Transients

Supernovae, GRBs, AGNs, ..., new variable objects ?
→ *multi-messenger/wavelength observations with AdVirgo, CTA, ...*

Solar System

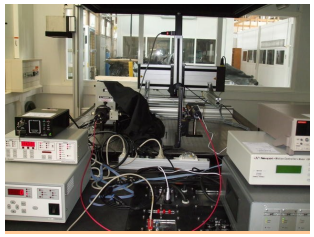
Asteroids, comets, ...

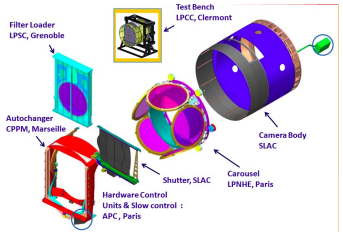
Milky Way studies

LSST: main LPSC involvement

Instrumentation

- Development of a bench for the calibration of the camera
- Conception and realization of the camera filter loader





Data Analysis and Simulation

- Galaxy redshift estimation (photometric reconstruction from the six optical bands of the telescope)

- Study of the baryonic acoustic oscillations (BAO) (simulation and reconstruction of the cosmological parameters)

Link Theory/Cosmological observables

A. Barrau's activity

Motivation for Gravity Wave research

Gravitation

Sources

Universe

- GW generated by powerful mass acceleration
  - Very energetic events in the Universe
  - GW probe event dynamics
- Gravitation is the only clue to 96% of matter in the Universe
  - GW probe gravitation in new regime

General Relativity

Astrophysics

Cosmology

Research path in ground-based interferometry

- 1st generation interferometric detectors
  - Initial LIGO, Virgo, GEO600

Unlikely detection

Science data taking
First rate upper limits
Set up network observation

  - Enhanced LIGO, Virgo+

Improved sensitivity

Lay ground for multi-messenger astronomy

- 2nd generation detectors
  - Advanced LIGO, Advanced Virgo, GEO-HF, KAGRA

2015-2020

Likely detection

Routine observation
➔ GW astronomy

Thorough observation of Universe with GW

- 3rd generation detectors
  - Einstein Telescope, US counterpart to ET

Goals of Advanced VIRGO

- Participate to the 1st direct detections of GW!

- General Relativity studies

Check the GW properties, study GR in strong fields

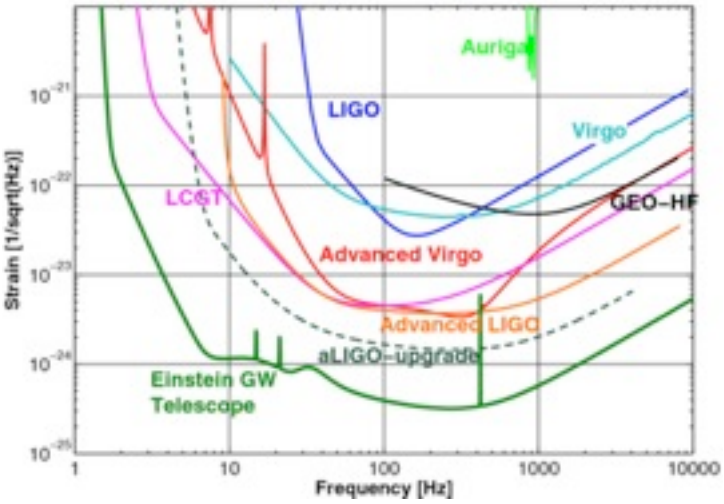
- Understand the GW source astrophysics

Link the short gamma-ray bursts (GRBs) to compact binary coalescences?
Observe the formation of black holes during supernovae

- Cosmology
- Compact coalescing binaries as *standard sirens* (measurement of Hubble constant independent of "astro" systematics)
- Search for the cosmic background of GW

- Preparation for multi-messenger astronomy studies (longer term)

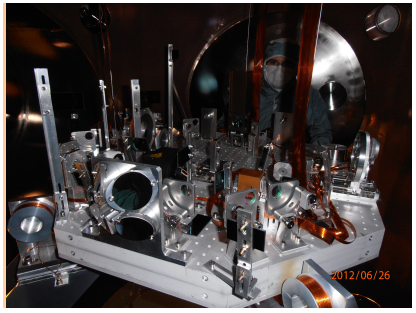
Coordination, alert and analysis tools

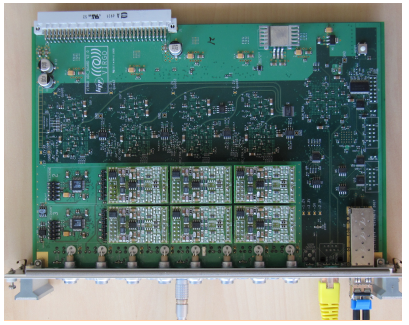


LAPP involvement

Instrumentation

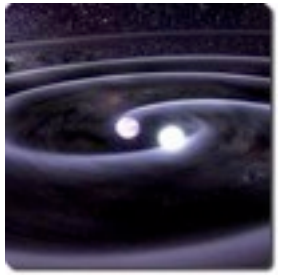
- Sensing of the power of laser beams of the interferometer (optical components and mounts, photodiodes, front-end electronics, vacuum tanks, suspended benches, in-vacuum compatibility)
- General digital electronics and data acquisition system (timing synchronization, ADC and DAC channels, cameras, online data collection/distribution, data visualization tools, ...)



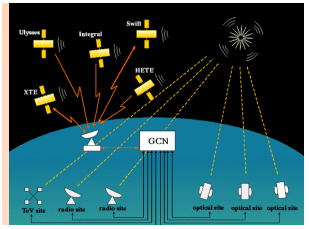


Data Analysis

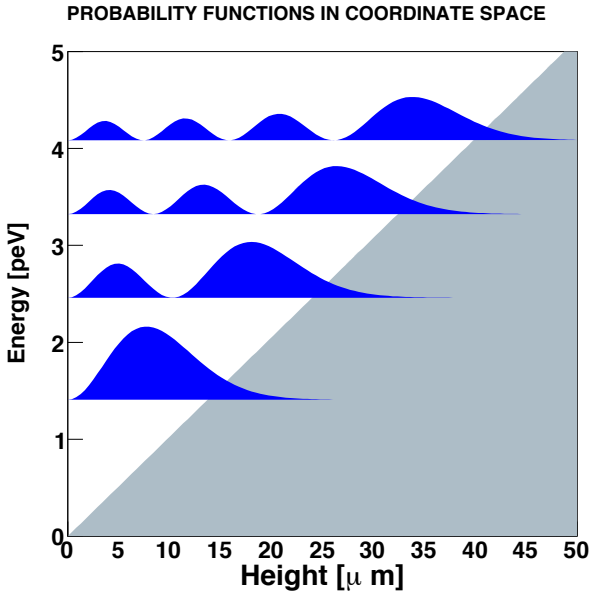
- Interferometer calibration and GW signal reconstruction (search for coalescence of binary compact objects)

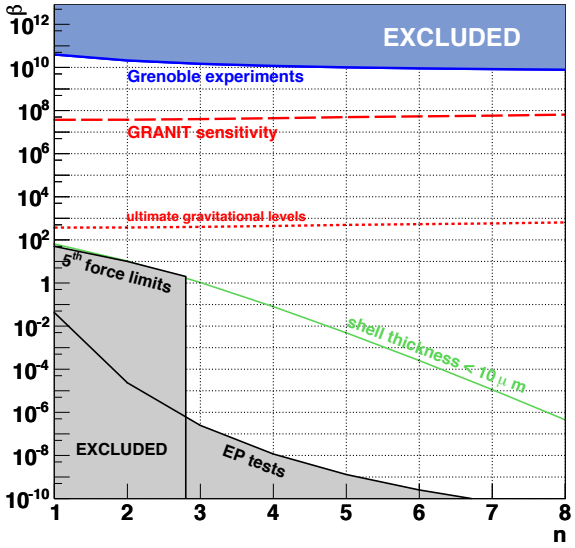


- Data Quality LIGO-Virgo online data analysis to provide alerts for other observatories



GRANIT: Gravitational Neutron Induced Transitions





GRAvitational Neutron Induced Transition

→ follow-up of the pioneering experiments at ILL that first observed the quantum states of neutrons trapped in the earth's gravitational field bouncing above a mirror...

GRANIT will induce resonant transitions between states thus accessing to spectroscopic measurements and precision tests

$$-\frac{\hbar^2}{2m}\frac{d^2\psi}{dz^2} + mgz\,\psi = E\,\psi$$

Probing Dark Energy models

(Chameleons) by searching for a new force close to the mirror.

$$\Phi(z) = mgz + \beta\frac{m}{M_{\mathrm{Pl}}}\phi(z)$$

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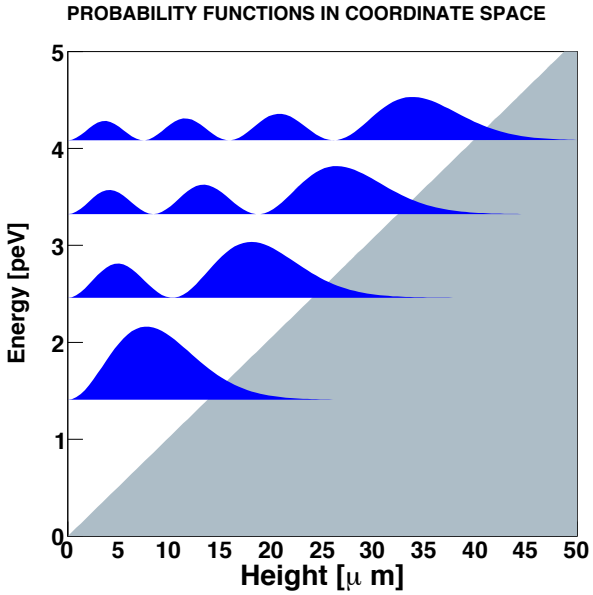

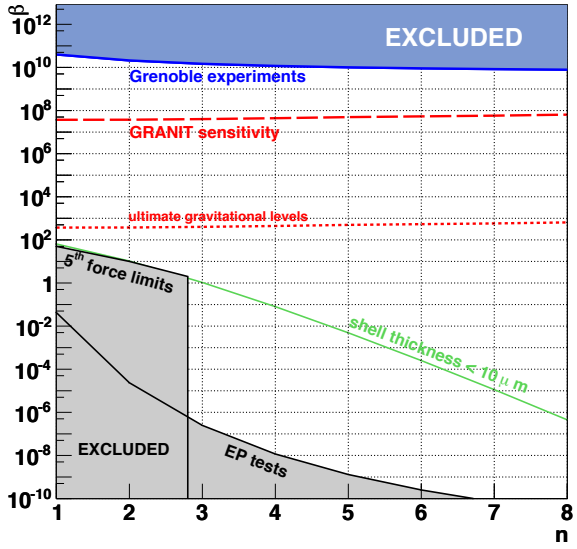

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rich program within ~3 year timescale, see 1202.2784

News from GRANIT

16 November, delivery of the GRANIT mirror

After many years of tremendous efforts of so many people, a unique GRANIT mirror has been completed and delivered to Grenoble on Friday 16 November.

Some initiatives, grants, etc.

Involvement in some training initiatives (sketch)

The 45th edition of the **Ecole de Gif** (oldest thematic school of IN2P3) is currently organized in Annecy le Vieux on the Astroparticle topic, with LAPP & LAPTh members involved in the organization (some members of LPSC, LAPP, LAPTh also in giving courses)

Rayonnement cosmique de haute énergie: Astroparticules comme messagers du cosmos

16-20 September 2012

http://ecole-de-gif.in2p3.fr/une.htm

ENIGMASS is also exploring the possibility to organize and coordinate doctoral or post-doctoral lectures which could be linked to different laboratories or universities worldwide.

An **Erasmus Mundus Joint Doctoral** (EMJD) **IRAP** program on astrophysics, led by one of our members, might provide the needed know-how acting as a seed of such an initiative.

PhD, last round: a success!

14 subjects proposed in Astroparticle+Cosmology+Gravity **over 27** total: Large participation of "Enigmass physicists" to the call!

Deep Interest from highly qualified applicants! In fact, **majority of bourses** selected **in astroparticle**

- Rémy Adam *Reconstruction de la masse dans l'univers : de Planck à NIKA* (Planck, LPSC)
- Linda Linsefors *Phénoménologie de la cosmologie quantique à boucles* (avec A. Barrau, LPSC)
- Li Tao *Measurement of the electron flux with AMS. Implications on propagation models and acceleration mechanisms.*(AMS, avec C. Goy, LAPP)

Since they recently started, no "formal" reports available yet.
First overview expected in ~1 year. Nonetheless...

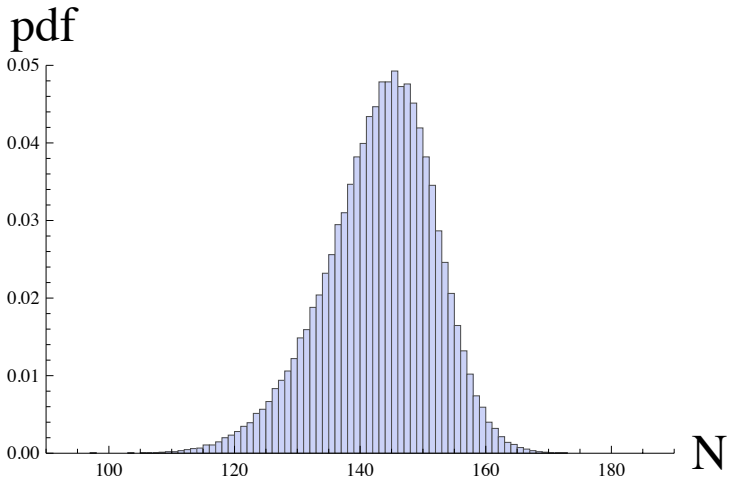
Some recent works of a PhD student!

Linda Linsefors with A. Barrau @ LPSC, on loop quantum gravity/cosmology

- **Primordial tensor power spectrum** derived with a fully closed algebra of constraints. Specific features allowing possible observational tests. (submitted to PRD, 2013)

- **Inflation as a prediction of loop quantum gravity.** Not only should inflation occur but the probability distribution for the number of efolds can be calculated and is in agreement with data. (Submitted to PRL, 2013)

Preprints available on-line respectively at
arXiv:1212.2852
arXiv:1301.1264



PhD: new proposals

- P. Ghez / Lees : Observation of the B0 → J/ψ π0 and B0 → J/ψ η decays in the LHCb experiment
- P. Salati (LAPTh) Dark matter, cosmic rays and LHC
- P. Serpico / G. Lammana (LAPTh/LAPP) Deciphering extragalactic gamma-ray sources
- M. Brinet / I. Schienben : High precision QCD
- R. Gouaty / B. Mours (LAPP) Preparation of Advanced Virgo: upgrade of the detection system
- H. Przysiezniak Frey : Search for new phenomena at the LHC, in the context of Extra Dimensional models and SUSY, with high momentum photons and/or leptons associated to missing transverse energy
- I. Wingerter-Seez : Measure of parameters of X(126) at ATLAS Calorimeter
- V.Poireau (LAPP) Indirect search for dark matter and study of primary sources of positrons and electrons coming from astrophysical sources
- L. Derome (LPSC) Galactic Cosmic Rays with AMS-02
- D. Guadagnoli : Interrogating the “brothers of the Higgs”
- E. Ragoucy : Quantum spin chains in integrable systems
- E. Sokatchev : Amplitudes and Integrability
- D. Maurin (LPSC) Cosmic-ray propagation and dark matter indirect detection with AMS-02
- A. Lucotte / Lleres : ATLAS/LPS/top
- E. Tournefier / Guadagnoli / Minard : Study of Radiative decays of beautiful hadrons with the LHCb detector
- S: Kraml : Implications of the 126 GeV Higgs boson for physics beyond the Standard Model
- D. Duchesneau/Del Amo Sanchez : Experimental Neutrino physics

Equilibrated among labs, “healthy” ratio of 6 over total of 17 proposals

2 Postdocs (2+1 year) on Labex funding

Activities yet to start (May-June their expected arrival dates). Here is the overview of their profiles:

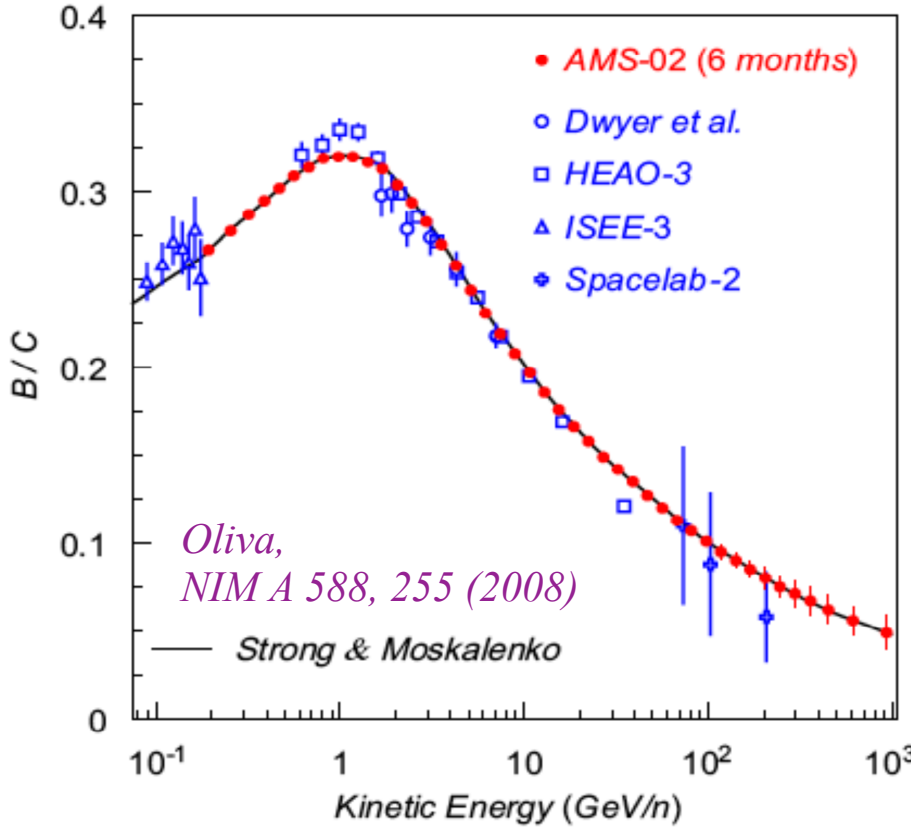
I. Cosmic Ray Physics (AMS group at LPSC)

Selected candidate: Nicola Tomassetti, INFN Perugia, Italy

He will work on the crucial B/C analysis and its interpretation (expertise on similar work on AMS-01)

This observable is one of the cornerstones for the inference of propagation parameters and the predictions for many other observables (e.g. related to DM searches)

Of course, he will also contribute to other ongoing AMS activities and possibly collaborate on phenomenological research projects (he wrote recently papers of this kind both alone and with F. Donato, Univ. Torino, regular visitor of our Labs)



Postdocs Gamma-ray astrophysics

II. Gamma-Ray astrophysics (HESS/CTA group at LAPP)

Selected candidate: David Sanchez, MPIK Heidelberg, Germany

Goal: first step in starting a joined expertise theory/experiment on a relatively new pheno sector ("cosmological studies with extragalactic gamma-sources"), stimulated by the Enigmass Labex.

The hired candidate has expertise on AGN, modeling and analysis, EBL signatures, excellent match of the **required profile (mix of data analysis skills and phenomenological interests)**

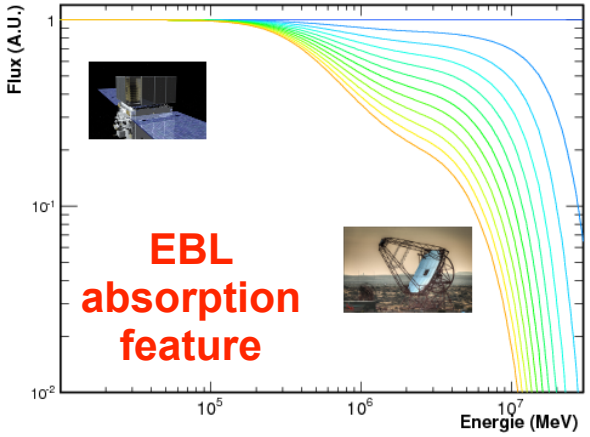
Enrico 0.1 documentation »

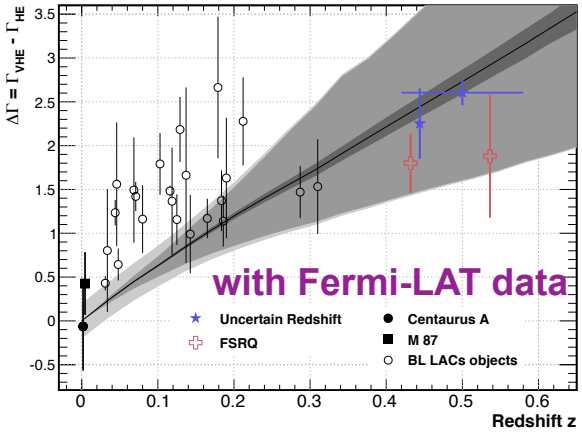
python package

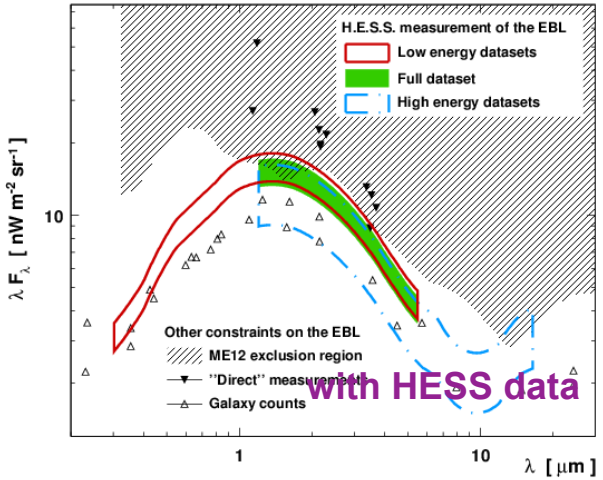
Welcome

https://github.com/gammapy/enrico

Hi, I am Enrico, and I will help you run your Fermi data analysis!







Visitors, expected demands...

➡ Started “more slowly”, but today we are getting a more **regular rate of requests**, e.g.

- 2 months Matt Walker to work on dwarf Galaxies at LPSC
- expected M. Regis at LPSC end of 2013 (Monte Carlo techniques in CR transport)
- 1 week request of visiting from High energy astrophysicist from Bangalore at LAPTh (Gamma-ray lines and Gal. Center activity),
- Possibly international visitors in September at LAPP (for Ecole de Gif), etc.

➡ We anticipate **further postdoctoral requests**, e.g.:

VIRGO needs expert manpower to help commission the detection system towards 2015, possibly AMS, etc

➡ At a later stage, would be interesting to see the **interplay of the Labex Initiative** with:

- other grant initiatives (ERC, ANR...). Does it stimulate them?
- the hiring policies within labs (via CNRS, Univ...): is there a positive feedback e.g. from the profiles of people hired and the actions of the program? Impact of international visibility, etc.

Key Point & Personal Comments/suggestions

Main advantage of this branch: **its breadth**, which naturally leads to cross-disciplinary expertise and research, within the perimeter of the Enigmass activities, all over the sites of the consortium.

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Suggestions:

➡ to identify a few sub-axes, like

Charged Cosmic Rays (AMS, CREAM, UHECRs, Theory)
Gamma Rays/Multimessenger probes (HESS II, CTA, Theory...)
Gravity (Theory, VIRGO, Granit)
Cosmology (Planck, MIMAC, NIKA, LSST, Theory)

Each one with a competent expert coordinator/rapporteur.

➡ to automatize the system of “collecting feedback” from grant beneficiaries (e.g. periodical reports to coordinators)

Conclusions

✓ The “Universe as a Lab” axis is a crucial one of the Enigmass project (in terms of # goals and experiments involved, it is the largest!)

✓ It is healthy, with lot of activities on-going and lot of projects.

✓ Some collaborations already existed (most notably LAPP-LPSC-LAPTh on charged cosmic rays) and are further stimulated by Enigmass. New collaborations (e.g. gamma rays) are beginning.

✓ Many collaborative ideas “in the spirit” of Enigmass are also shared by researches in the field of Gravity/Cosmology and will probably develop further as the program develops (certainly different timescales for different project is a factor to take into account)

✓ Good response to 2012 PhD and postdoctoral to Enigmass funding calls: already “too successful” (e.g. 3 granted out of 14 PhD requests), in a sense! Visitors’ funding starts to be demanded, too; for the moment no mismatch demand/offer is present.

✓ Advice for the future scientific management of the branch: Each sub-branch needs closer coordination, probably demanding sub-task coordinators. “Feedback” from grant beneficiaries would benefit from “automatization” (e.g. periodical reports to coordinators)