Dark Matter and neutrino detection in nutshell

Mini-workshop: graphene technology in particle physics

Madrid November 13th, 2017

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Ciemat Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

EXCELENCIA MARÍA DE MAEZTU

cfp CIEMAT física de partículas

Underground laboratories

F: SNOLab
DEAPCLEAN
Picasso
COUPP
DAMIC

G: Soudan
SuperCDMS
CoGeNT

E: Homestake
LUX-LZ

C: Boulby
Drift

D: Canfranc
ArDM
Rosebud
ANAIS

A: GranSasso:
XENON
CRESST
DAMA/LIBRA
DarkSide

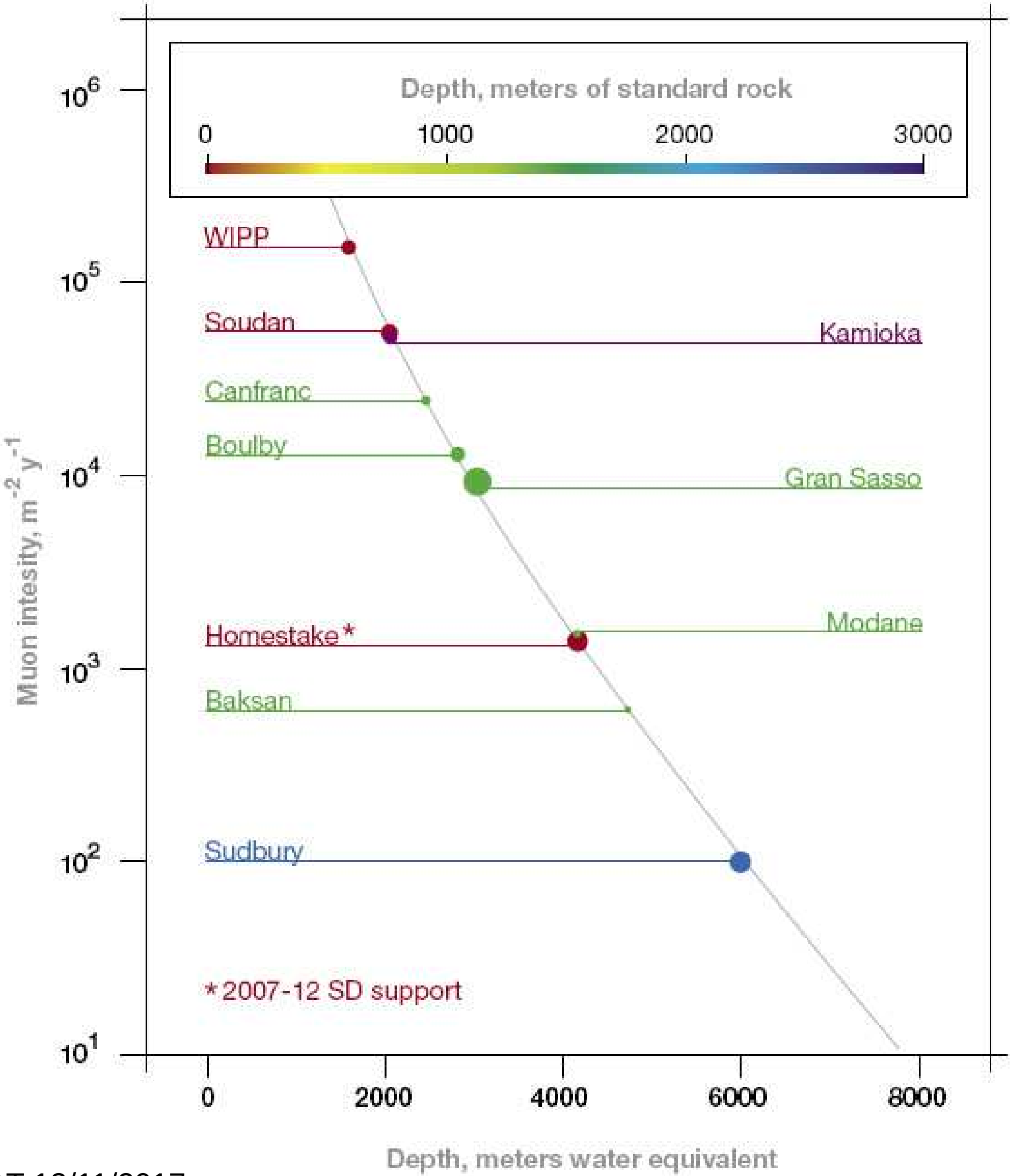
B: Modane
EDELWEISS
MIMAC

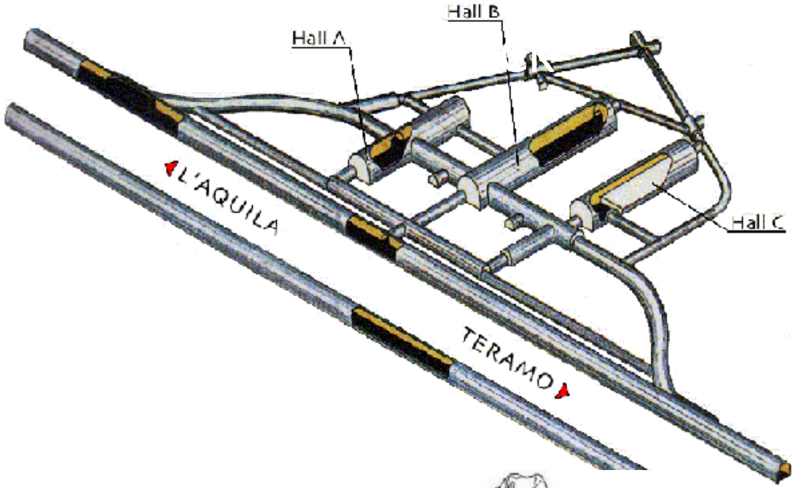
I: YangYang
KIMS

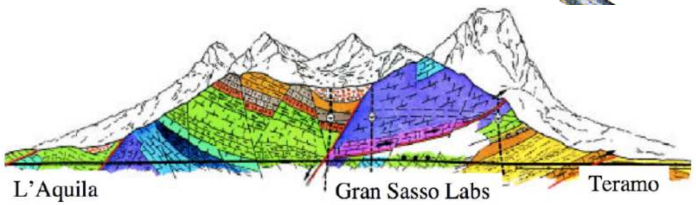
H: Kamioka
XMASS
Newage

J: Jinping
Panda-X
CDEX

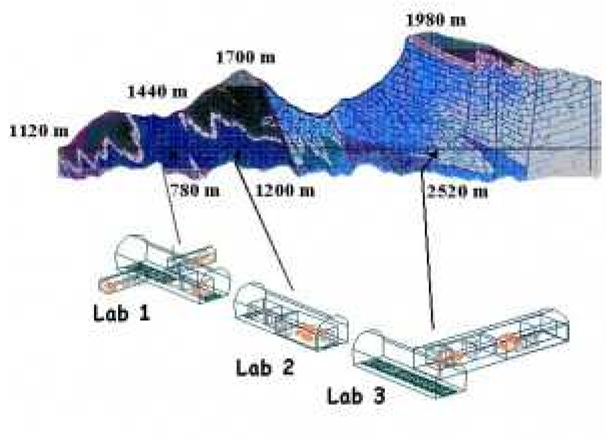
Underground laboratories



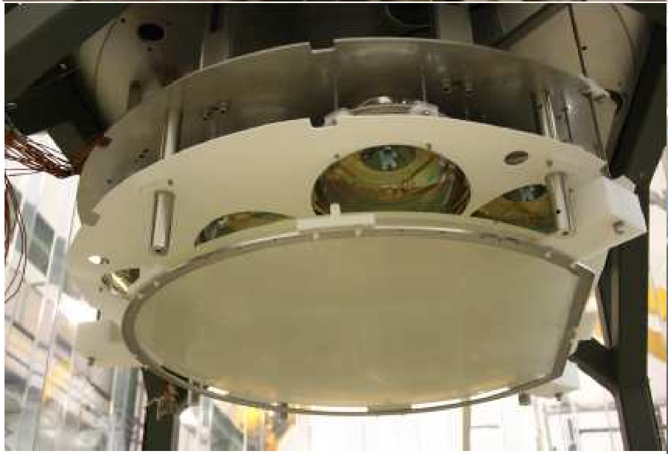




~3800 m.w.e



~2500 m.w.e

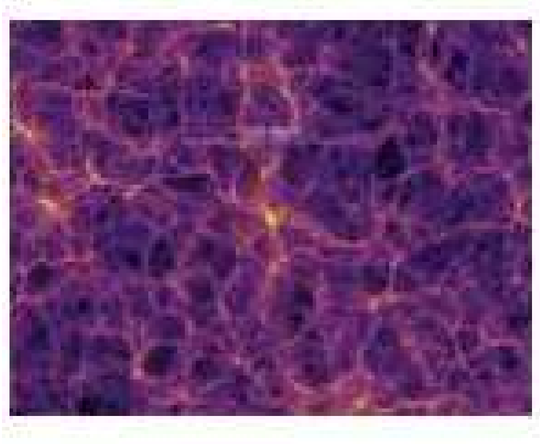


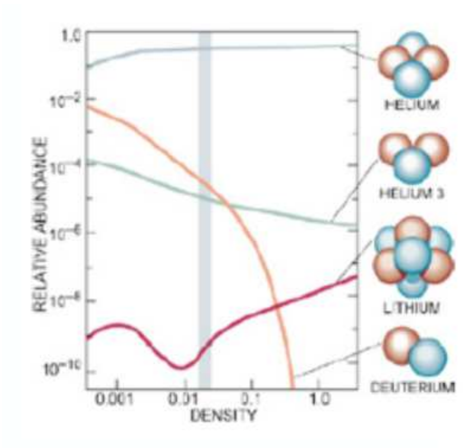
LSC

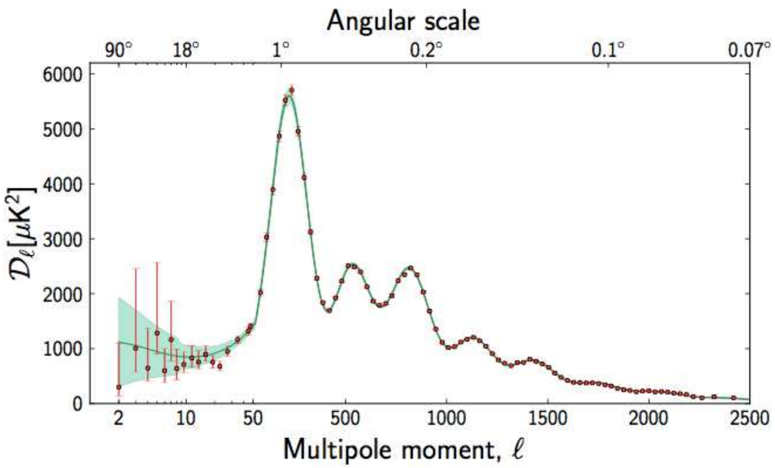
Laboratorio Subterráneo de Canfranc

The Dark Matter problem

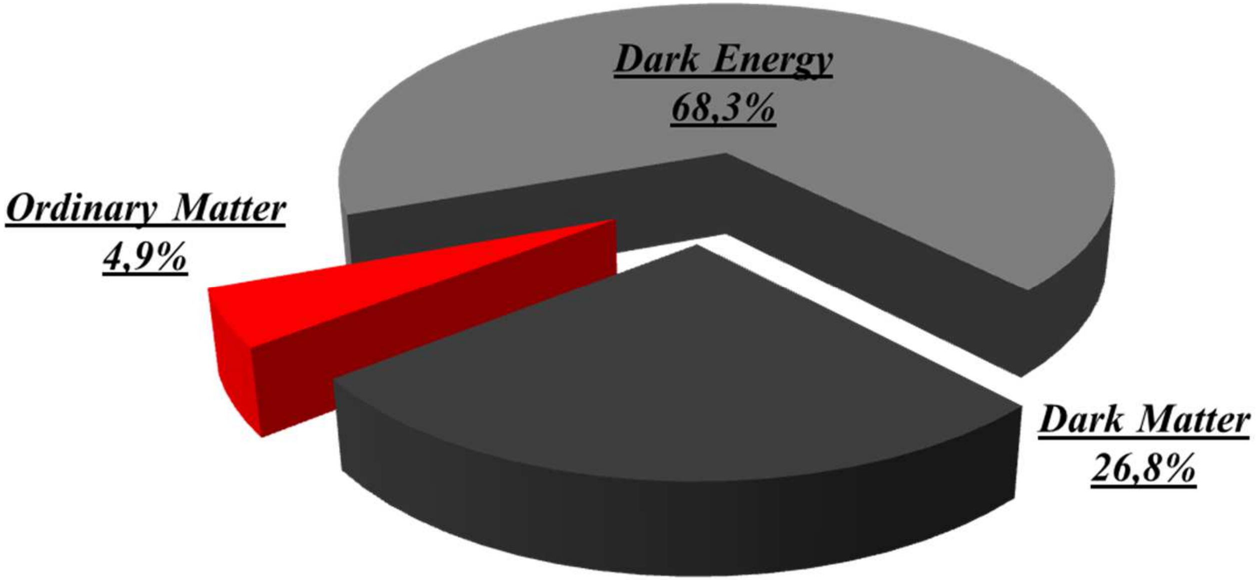
- The ΛCDM model has been successful explaining CMB, large scale structure etc..
- It fits all the observations with only 6 parameters
- A Cold Dark Matter model is necessary for the formation of structure and galaxies in the universe





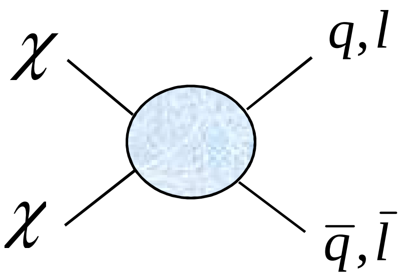


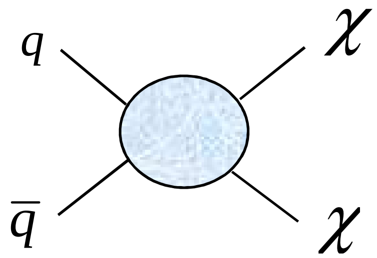
The Dark Matter problem

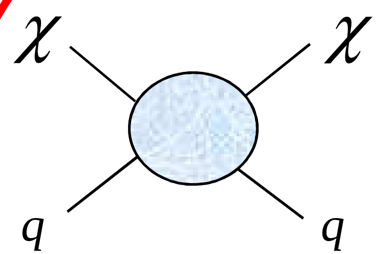


- Invisible dark matter makes up most of the universe – but we can only detect it from its gravitational effects
- The nature of dark matter is one of the most fundamental problems in modern physics and cosmology

Detection



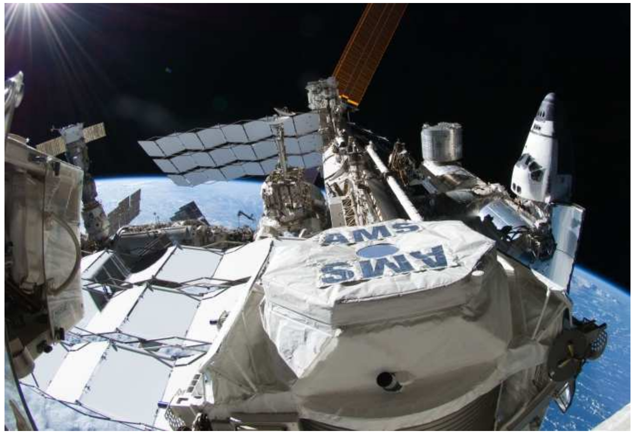


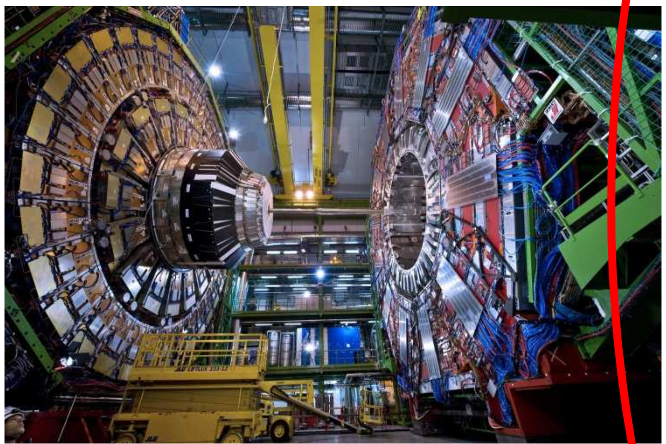


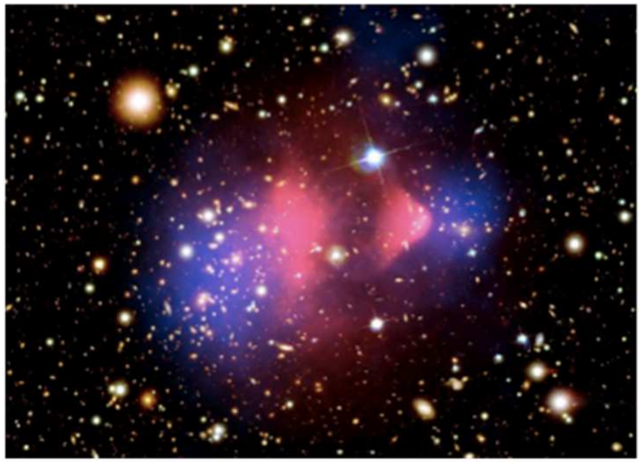
Above ground

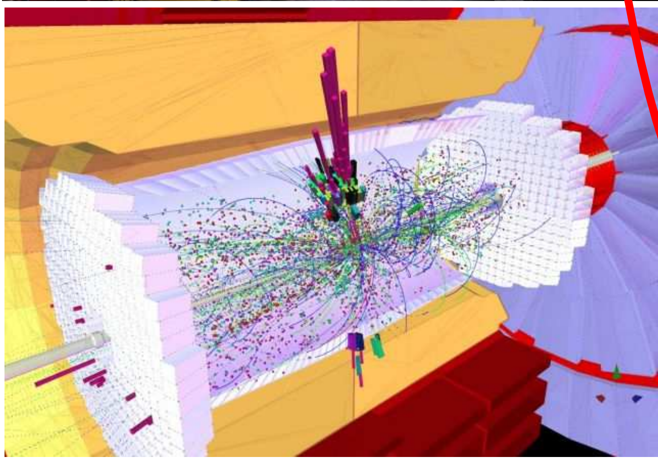
Collider

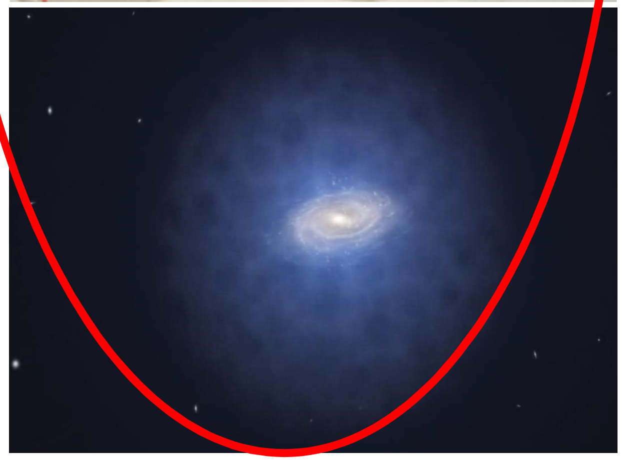
Underground









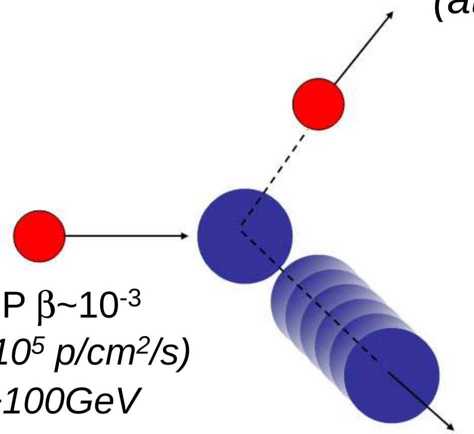


Dark Matter direct detection

GOAL: Detection of the WIMP collisions with atomic nuclei

***W**eakly*
***I**nteractive*
***M**assive*
***P**article*

- stable
- slow
- relic from the Bing Bang
- with the "right" mass and abundance



Scattering non relativistic :
coupling spin-dependent / spin-independent

Possible scalar (coupling to the mass of the nucleus)
and spin-spin interactions (coupling to the nuclear spin)

$$R_0 = \frac{2}{\sqrt{\pi}} \frac{N_0}{A} \frac{\rho_W}{m_W} \sigma_N v_0 \qquad \sigma_N = \frac{\mu^2{}_N}{\mu^2{}_n} A^2 \sigma_n$$

N_0 = Avogadro number
A= atomic mass
m_W = WIMP mass
ρ_0 = local WIMP density *(ρ_0~0.3GeV/cm^3$\rightarrow$3000 wimp/m^3 , m_W=100GeV)*
σ = WIMP-nucleus and WIMP-nucleon scattering cross section ($\leq 10^7$pb)

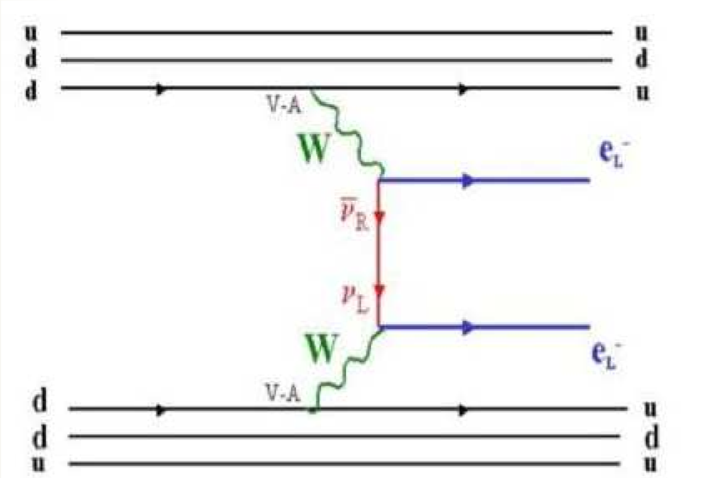
Neutrinos

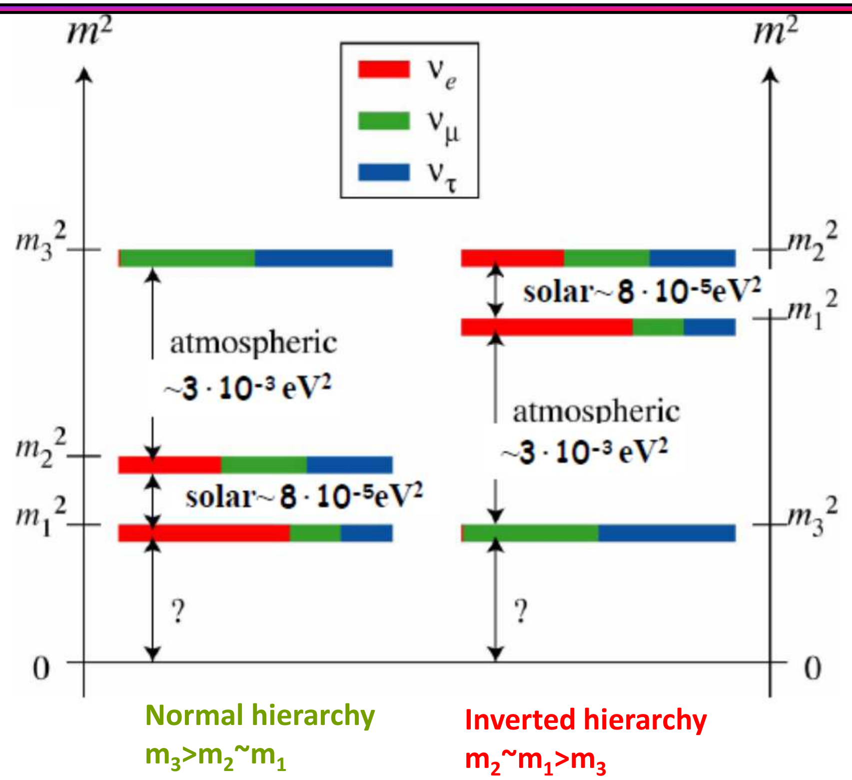
Neutrinos mixing matrix Uij characterized by:

Three mixing angles θ_{12} θ_{23} θ_{13}
One Dirac phase δ
Two Majorana phases $\phi_2\phi_3$

θ_{12} θ_{23} measured – more recently θ_{13}

Mass scale Δm^2_{12} $|\Delta m^2_{13}|$

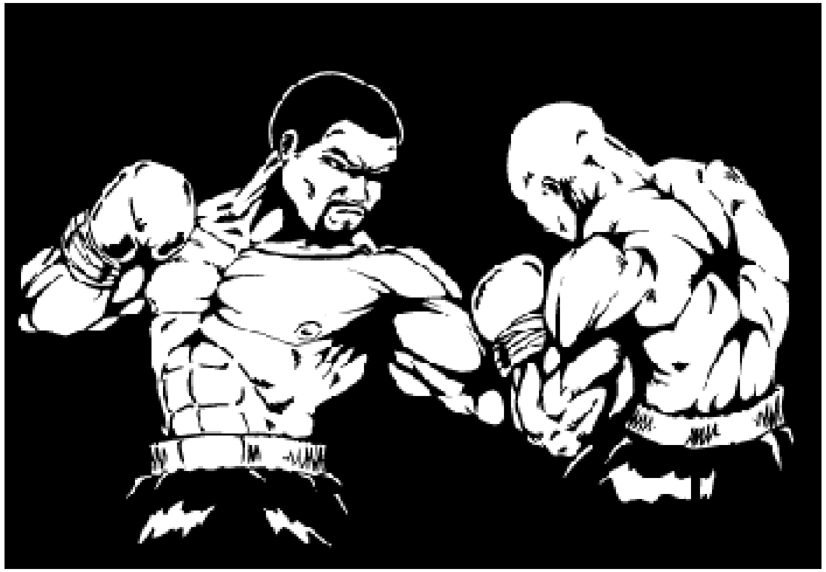




Next challenges in neutrino physics:

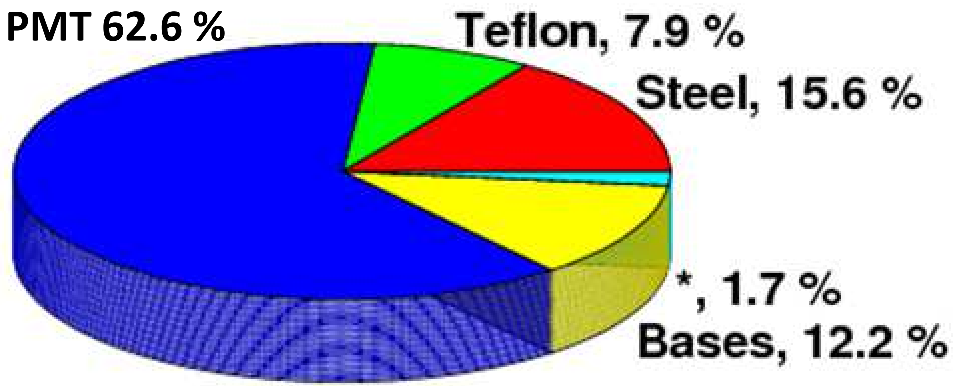
- Majorana or Dirac nature of the particle
- Mass hierarchy
- Absolute mass scale

Rate vs Background

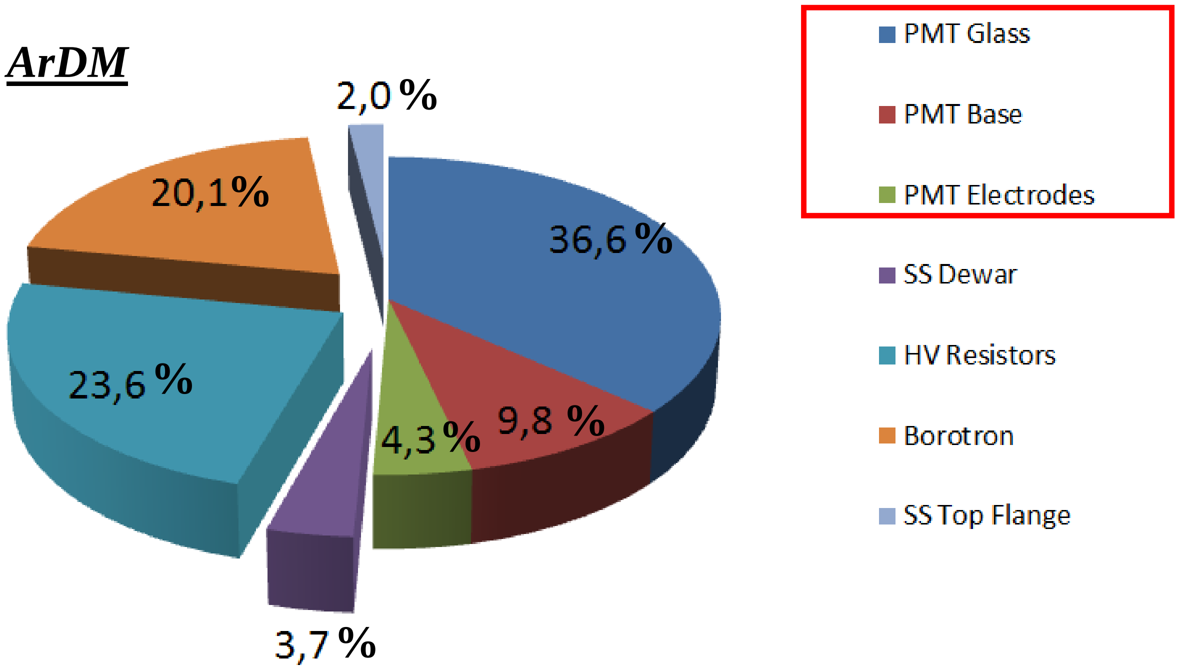


Background budget

XENON100



ArDM

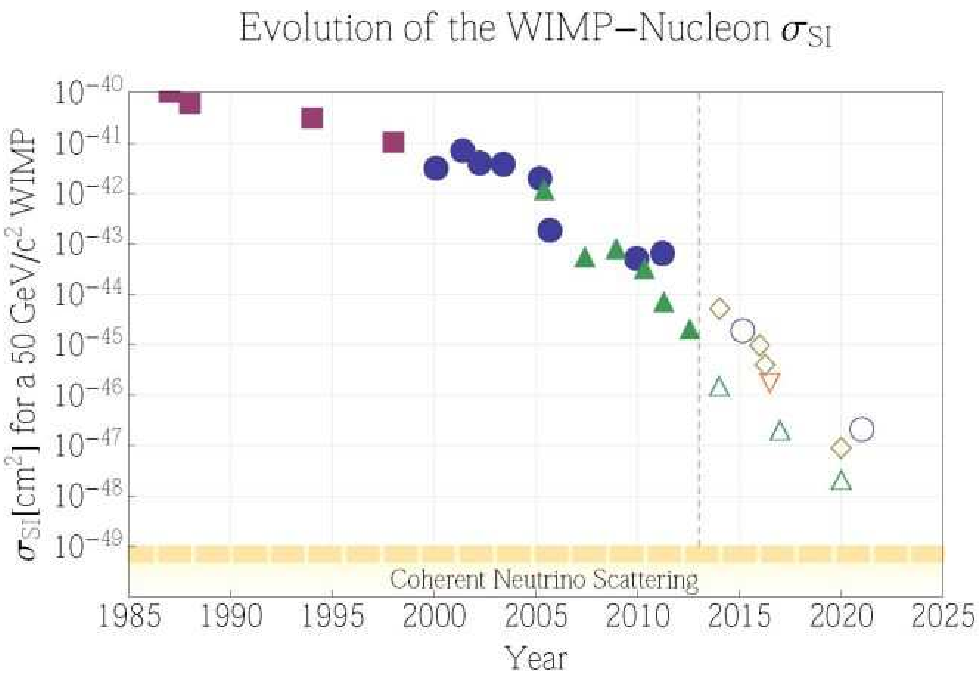


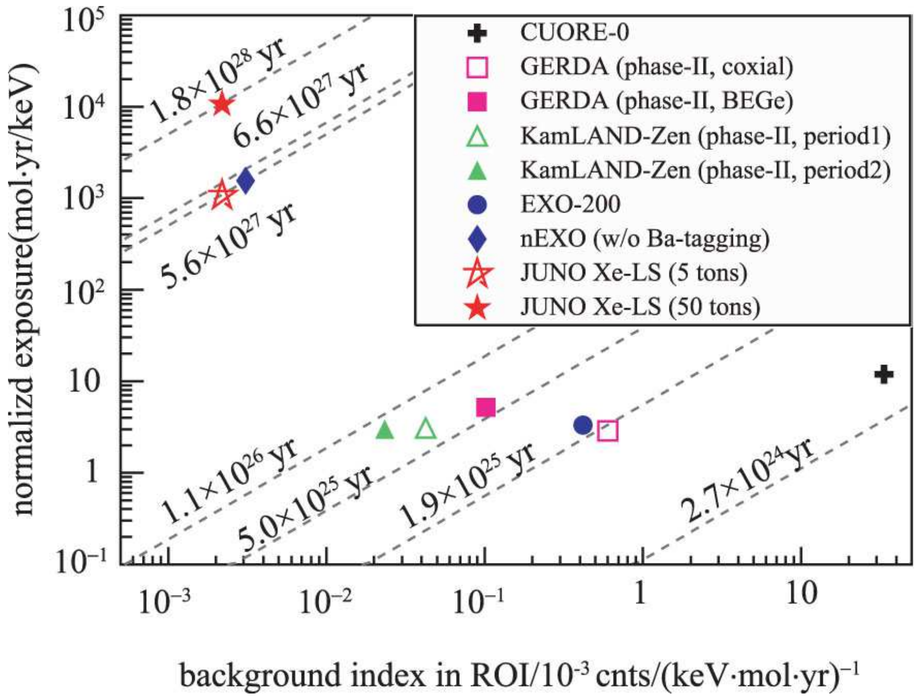
Background typically dominated by the detector materials

A difficult task

- Large Exposure (Mass $\times$ Time)
- Low Energy Threshold
- Event topology
- 3D Event Reconstruction
- Minimal Background Rate
- Discrimination between Signal and Backgrounds
- and directionality, energy resolution…. etc

Achievements





Conclusions

- Challenging investigations in terms of physics and technology
- …..but big risk, big reward!