Dark Matter

Candidates and Detection

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  -Categories for Dark Matter
  -MACHO(MAssive compact Halo Object)
  -Axion
  -WIMP(Weakly Interacting Massive Particle)

- Detection

  -Direct detection of Dark Matter
  -Indirect detection of Dark Matter

- Overview

  There are several candidates for dark matter, the most reliable candidate is WIMP.
  Because of it‘s properties, detection of its existance is extremely difficult. Also there are several posibilities for other considerable matter.
  To detect the matters, Many of experiments are on progress with direct or indirect detection technologies.

Candidates for Dark matter

- Categories for Dark matter

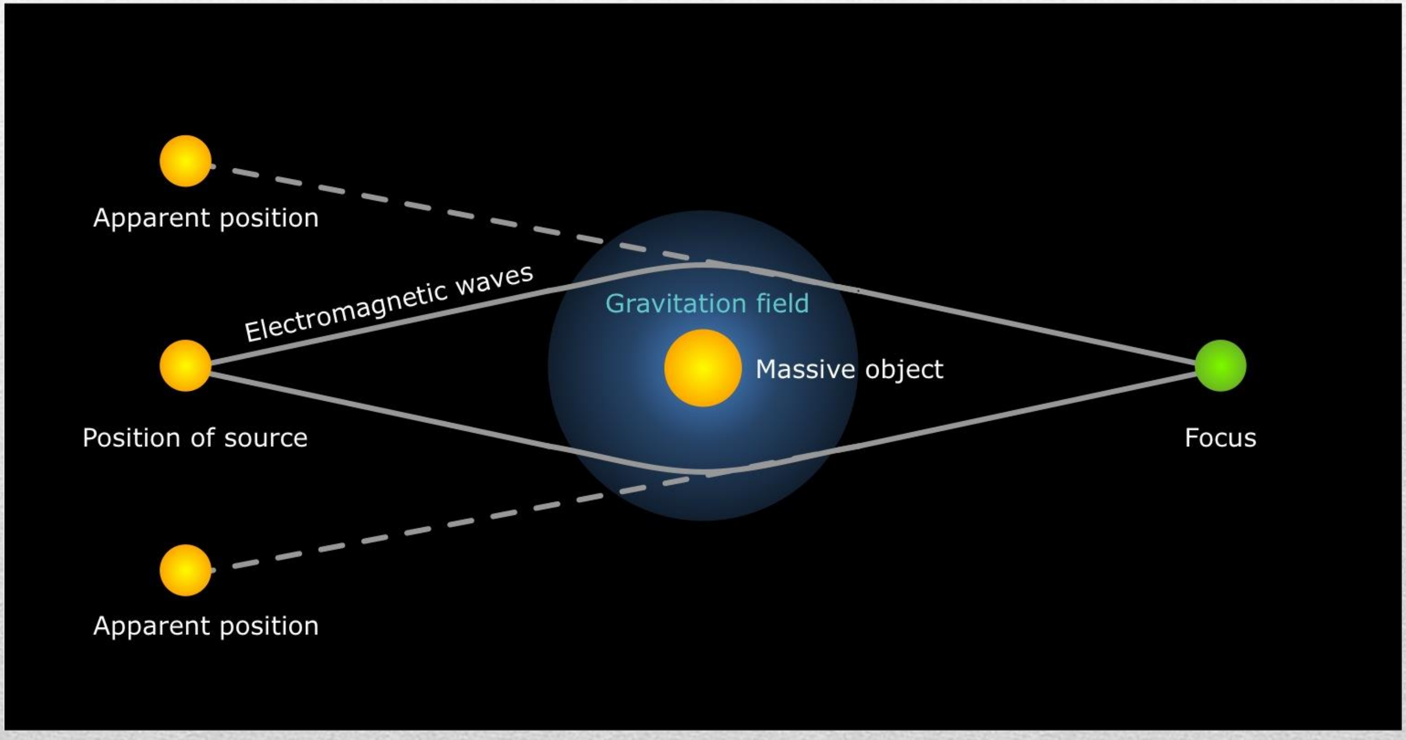
  -Hot Dark Matter
  Relativistic Neutrinos: not suit for Dark matter

  -Cold Dark Matter
  MACHO, Axion, WIMP

  -Warm Dark Matter & Mixed Dark Matter...

- MACHO- MAssive Compact Halo Object

Evidence of existence:
Gravitational lensing



- Candidates for MACHO:

  Body composed of normal baryonic matter
  -Black holes
  -Neutron stars
  -Brown dwarfs
  -Unassociated planets
  -White dwarfs
  -Red dwarfs

- Experimental Detection

  -The MACHO, EROS, and OGLE collaborations have performed a program of observation

  -EROS concluded that MACHOs cannot contribute more than 8% to the mass of the galactic halo
  →Existance of non-baryonic matter

- Axion

  -A hypothetical elementary particle postulated by Peccei–Quinn theory in 1977 to resolve the strong CP problem in QCD.

  -axions with low mass within a specific range
  → Possible component of cold dark matter.

- Theoretical background of detection
  Primakoff Effect: Axions convert to photons & vice versa

- Experimental detection of Axion
  -CAST(CERN Axion Solar Telescope) Detection by converting axions from the sun's core to X-rays in strong magnetic field

  -ADMX(Axion Dark Matter eXperiment)
  Detection by using strong magnetic field and resonance cavities to convert into photons

  -Other experiments
  BFRS and PVLAS

- WIMP- Weakly Interacting Massive Particle

  -Particles with mass from roughly 10 GeV to few TeV with cross sections of approximately weak streanght.

  -No electromagnetic interaction

  -Considered as most reliable Dark Matter candidate

  -Supersymmetry particle

- Theoretical Condition

  -Predicted from R-parity conserving supersymmetry

- Candidates for WIMP

  -Lightest SuperPartner (LSP)
  zino: fermionic partner of the Z boson
  photino: the spin 1/2 partner of the photon
  higgsino: the partner of the Higgs boson

- SM particles and Superpartners

SM particle	Symbol	Spin	Superparticle	Symbol	Spin
electron	e	1/2	selectron	$\tilde{e}$	0
muon	μ	1/2	smuon	$\tilde{\mu}$	0
tau	τ	1/2	stau	$\tilde{\tau}$	0
neutrino	ν	1/2	sneutrino	$\tilde{\nu}$	0
quark	q	1/2	squark	$\tilde{q}$	0
photon	γ	1	photino	$\tilde{\gamma}$	1/2
W boson	$W^{\pm}$	1	Wino	$\tilde{W}^{\pm}$	1/2
Z boson	Z	1	Zino	$\tilde{Z}$	1/2
gluon	g	1	gluino	$\tilde{g}$	3/2
graviton	G	2	gravitino	$\tilde{G}$	3/2
Higgs boson	h	0	Higgsino	$\tilde{h}$	1/2

Identification of each SM particles and Superpartners

- WIMP existance history

  -Early universe with excess of TeV scale, $t < 10^{-6}s$:
  Normal abundance of WIMPs equal to normal SM particles

  -After the energy droped below 100 GeV:
  SUSY particles decay leaving normal SM particles.

  -The present density of WIMP is:

$$\Omega_W \approx \frac{10^{-37}cm^2}{\sigma_\alpha}$$

where σ_α is cross section.

- Detection of WIMPs

  According to detection method, detection is classified as two ways, direct and indirect way.

  -Direct detection is measure the interaction with detector nuclei by several technologies

  -Indirect detection is to search for consequant gamma ray or SM particles from annihilations

- Direct Detection

  -Detection technologies

  Cryogenic Detection: Detection the heat produced when a crystal absorber hit by a WIMP

  Cryogenic Detectors:
  CDMS, CRESST, EDELWEISS, EURECA, DAMA/NaI, DAMA/LIBRA

- -Noble Liquid Detection: detect the flash of scintillation light produced by a particle collision in liquid xenon or argon.

  Noble Liquid Detectors:
  ZEPLIN, XENON, DEAP, ArDM, WARP, DarkSide and LUX

  And also many other techniques
  SMILE and PICASSO

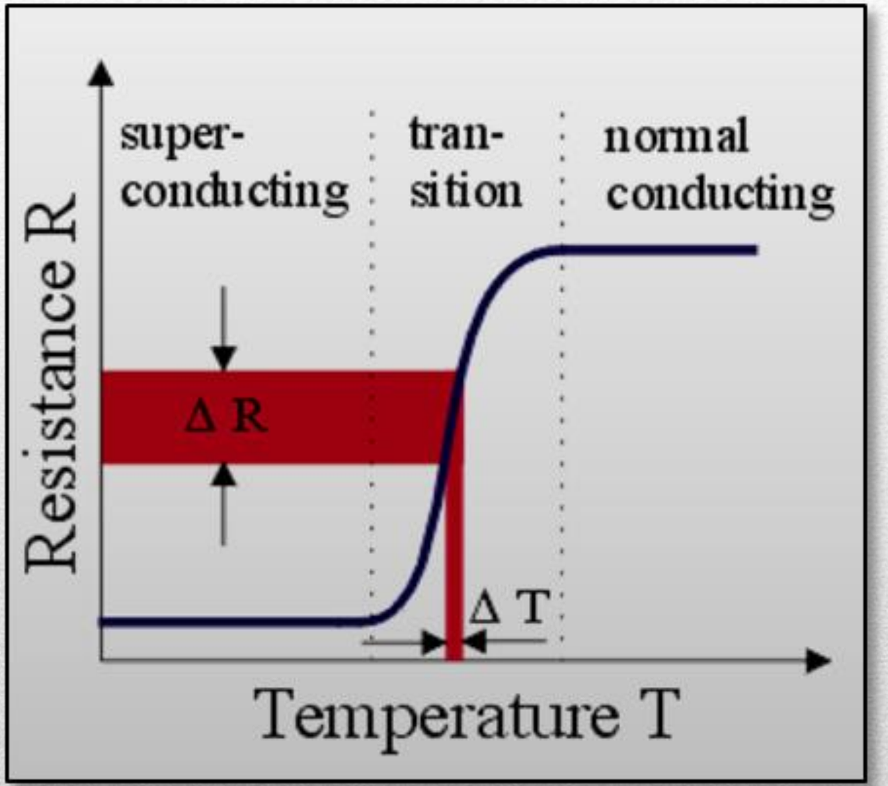
- A case of CDMS(Cryogenic Dark Matter Search): One of the Cryogenic Detectors at Sudan Mine

CDMS Detector Located in Soudan Mine Lab(http://www.sudan.umn.edu/cdms/index4.shtml)

- CDMS consists of very cold germanium and silicon crystals(appox. 50 mK), the layer is tungsten(TES) being maintained as between normal and superconductor states

- Detection of interaction
  -Measurement of heat
  -Ionization energy yield
  →Determination the kind of particle caused the event

- Measurement of heat



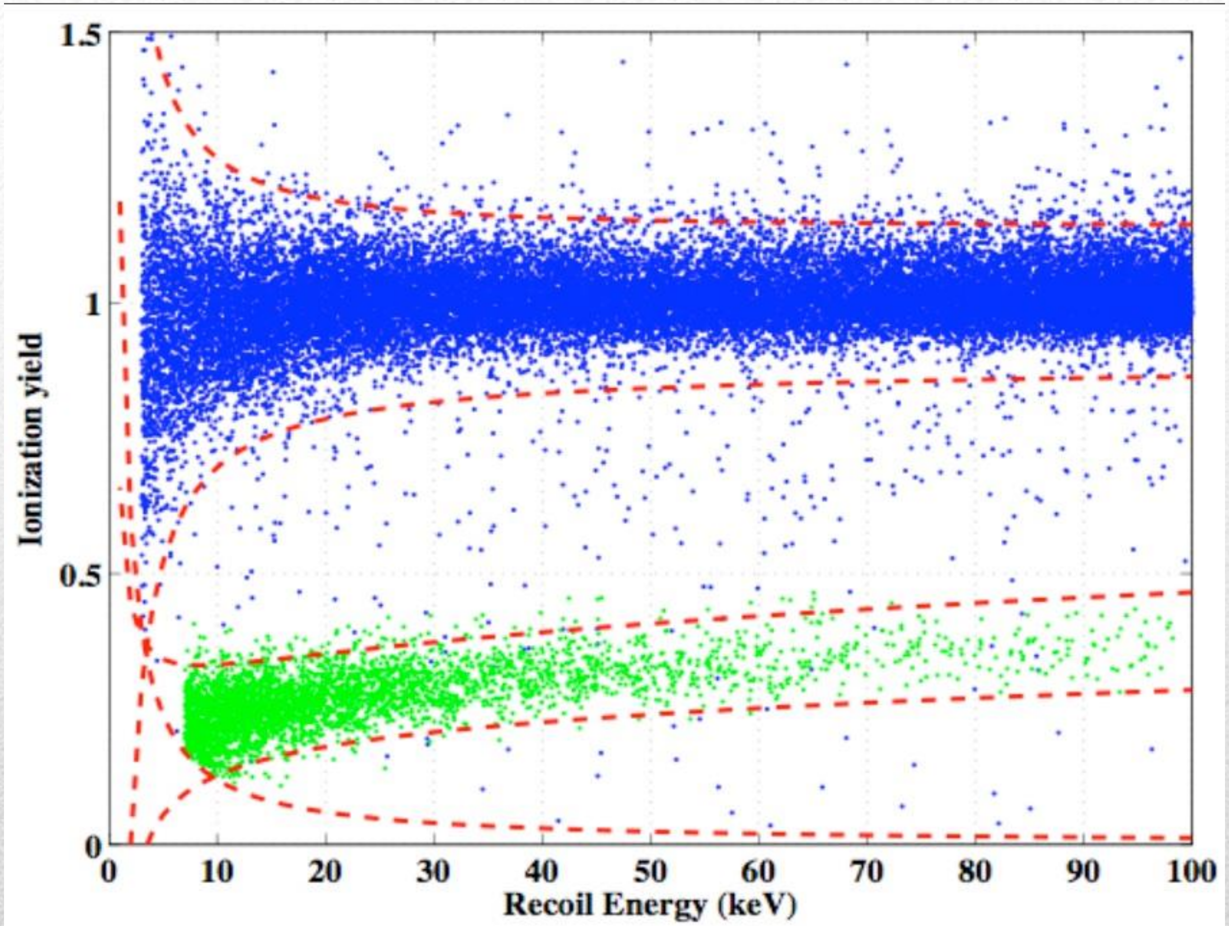
A small temperature changes in temperature lead to large changes in resistivity

- Ionization Energy

  -The ratio between ionization energy and total energy

  Electronic recoil: the ratio ≈ 1 (full energy is converted to ioniziation)
  Hadronic recoil: the ratio < 1

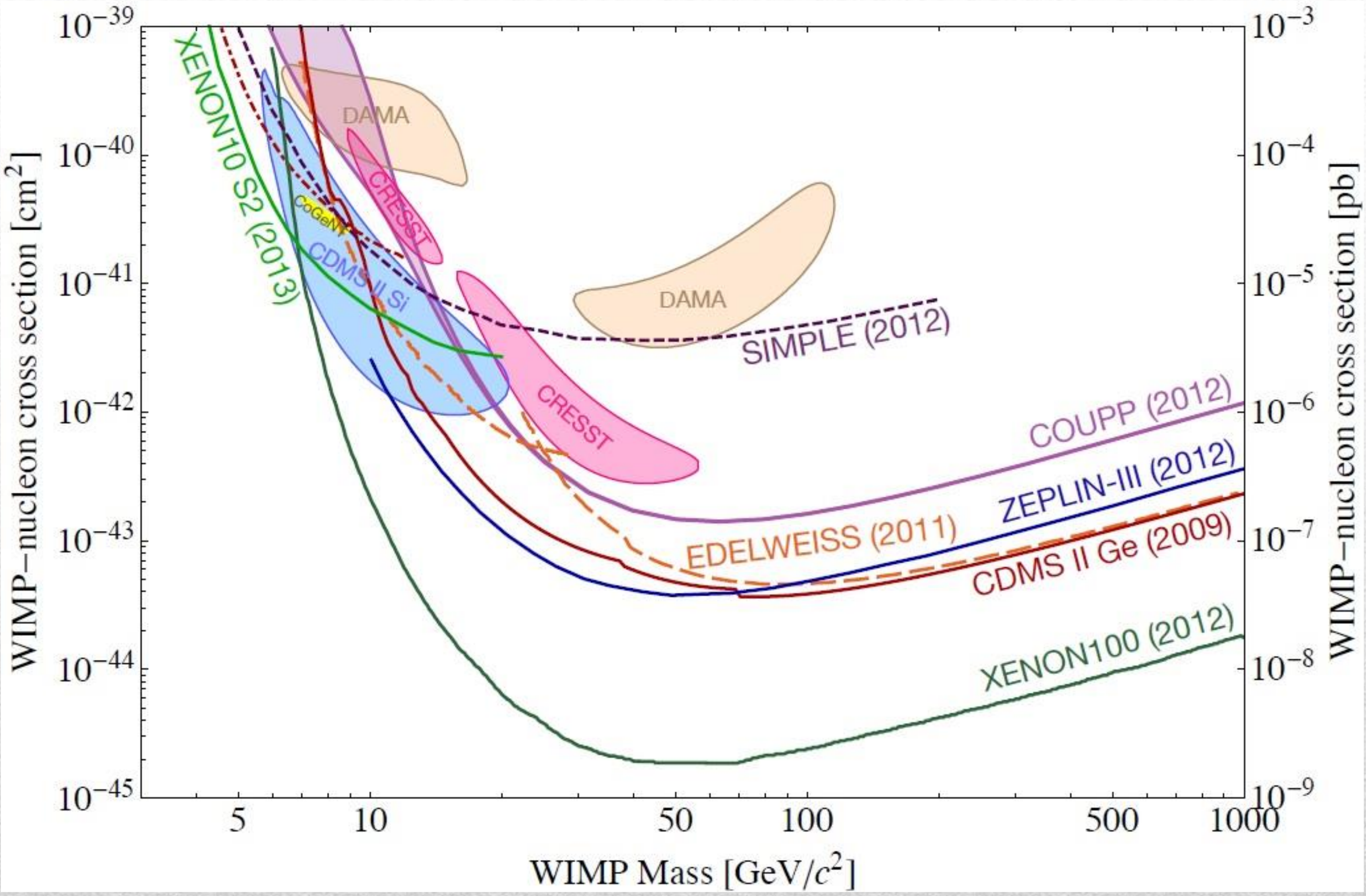
  -This result make the energy distinguishable



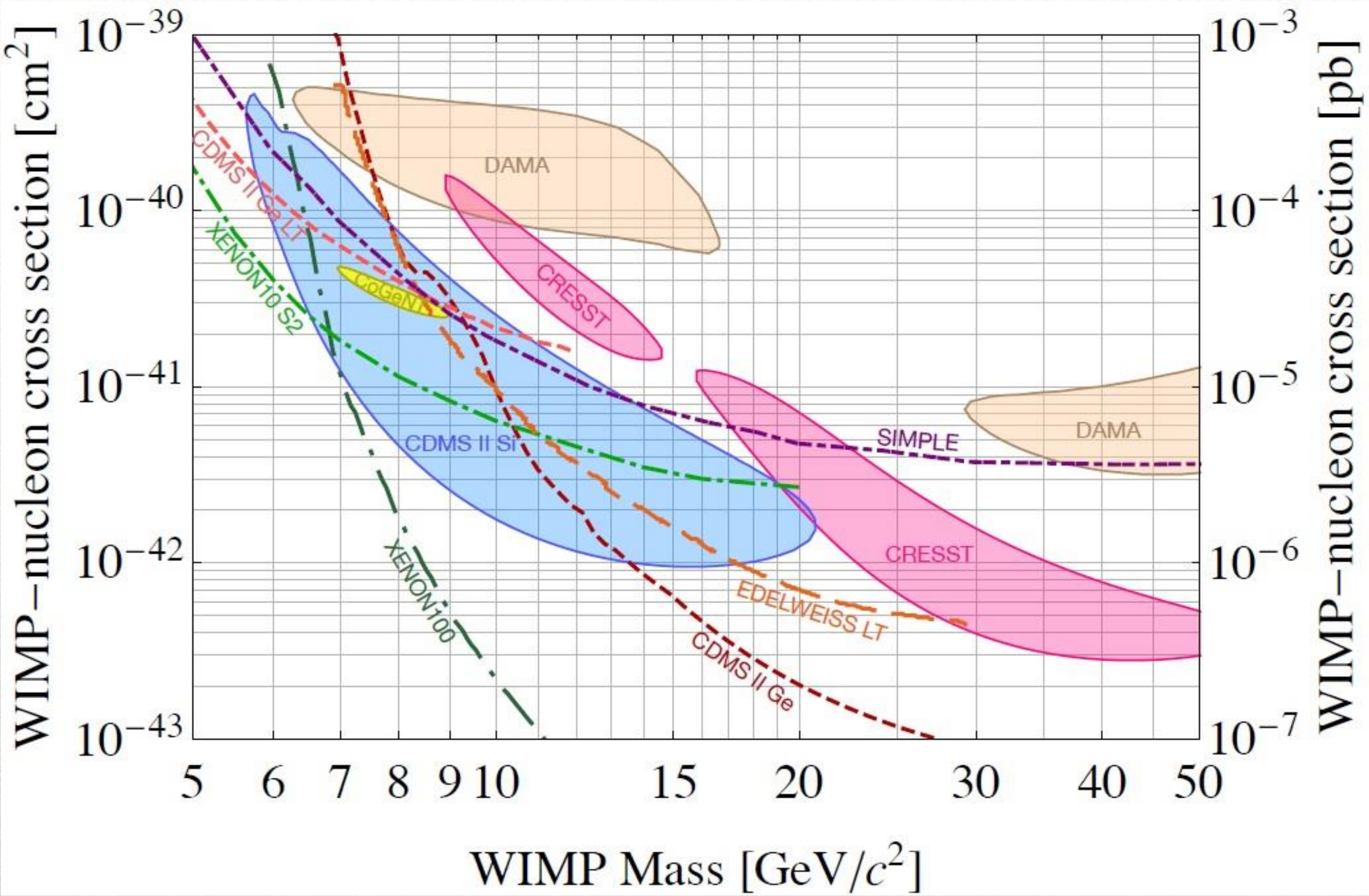
Ratio between total energy and converted ionization energy (Blue dots: electronic recoils, green dots: hadronic recoils)

- Background suppression
  Since # of Expected WIMP interaction << # of SM particle interaction →Background suppression is needed.

  -very pure materials with low intrinsic radioactivity
  -underground laboratory
  -absorber material around the detector
  -a veto detector
  -discard "multi site" events
  -use ionization yield



WIMP Mass-Cross section



WIMP Mass-Cross section

- - CDMS II found three events consistent with WIMP interactions in the Silicon data (probability for this being background is around 5%)

- - CoGent, DAMA and CRESST have also seen hints (similar significance)

- - XENON100 has excluded the area where the hints were found

- Indirect Detection

  -The technique of observing the radiation produced in dark matter annihilations

  Process 1. if WIMPs have own antiparticles,
  WIMP + anti WIMP $\rightarrow \gamma$ or SM particles

  Process 2. if WIMPs are not stable,
  WIMPs decay into SM particles

  Process 1,2 reproduce γ rays or proton and positrion

- The flux of such radiation is proportional to the annihilation rate, which in turn depends on the square of the dark matter density

$$\Gamma \propto \rho_{DM}^2$$

→Considerable area where large dark matter densities accumulate, refer to the area as "amplifier"

Amplifiers such as center of galaxy, sun and other astrophysical objects

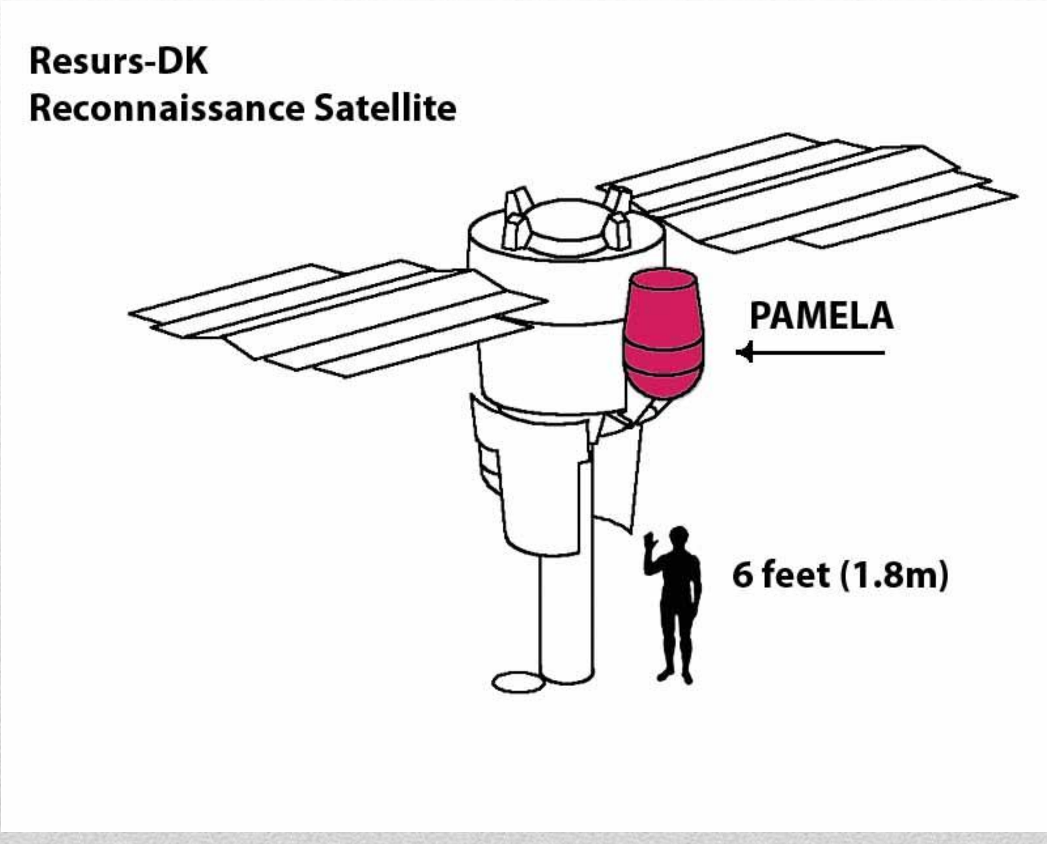
- Detectors

  -Gamma ray detection
  EGRET gamma ray telescope,
  Fermi Gamma-ray Space Telescope,
  Large Area Telescope

  -Positron detection
  PAMELA experiment,
  Alpha Magnetic Spectrometer

  -High-energy neutrino detection
  AMANDA, IceCube and ANTARES

- A case of PAMELA (Payload for Antimatter Matter Exploration and Light-nuclei Astrophysics)



PAMELA

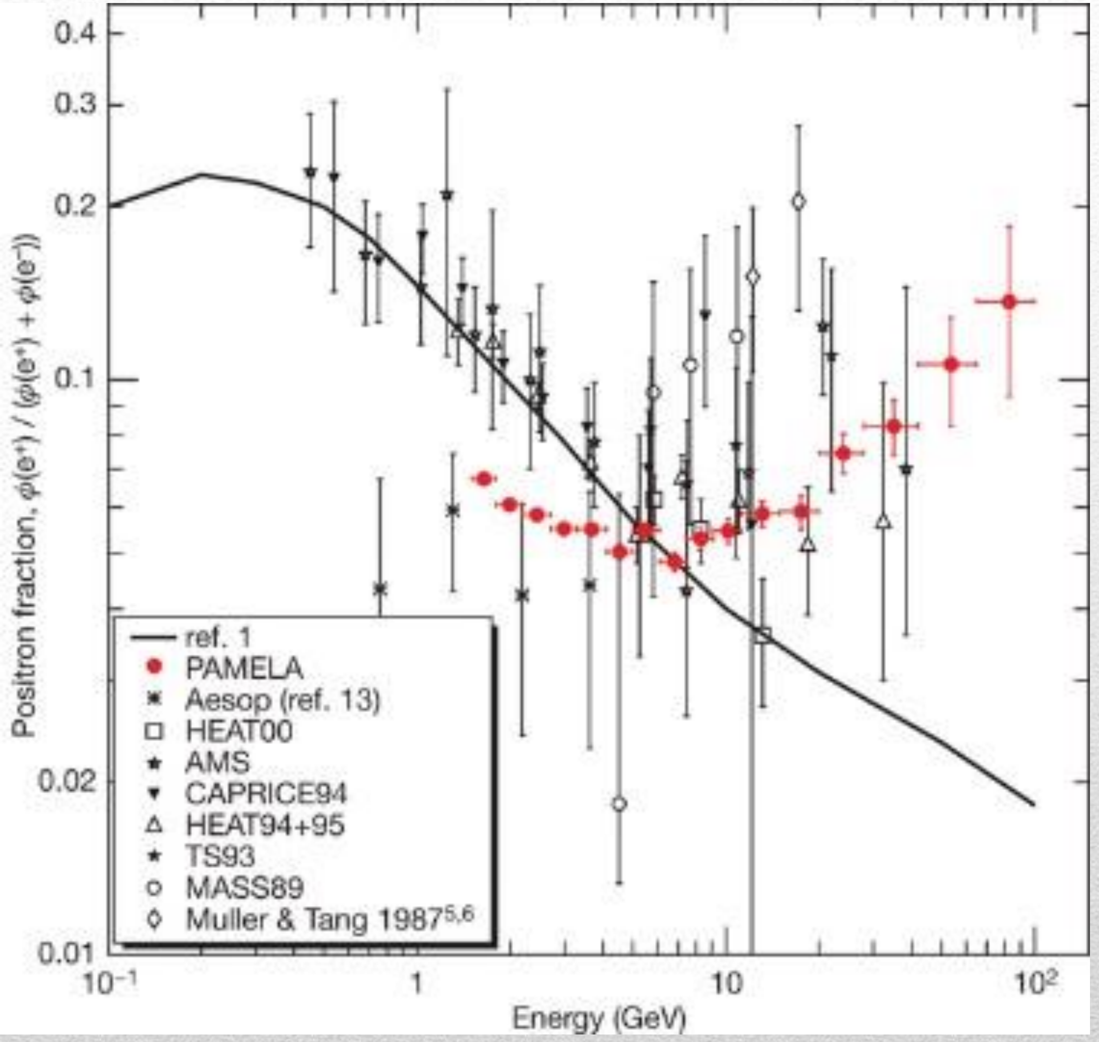
- PAMELA - cosmic ray research module

- Detection Process

  - measurement the number of cosmic electrons and positrons and their respective energy

  -distinction between positrons and protons.

  - comparison the result to theoretical predictions for the energy spectrum from SM processes



PAMELA positron fraction with other experimental data

- Result of Detection by PAMELA

  Preliminary data indicate an excess of positrons in the range 10–60 GeV thought to be a possible sign of dark matter annihilation
  But the production of electron-positron pairs on pulsars with subsequent acceleration in the vicinity of the pulsar should be also considered.

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