ROUND TABLE ITALY-RUSSIA,
DUBNA, DECEMBER 19, 2009

On the DARK MATTER at the time of LHC

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Univ. of Padova
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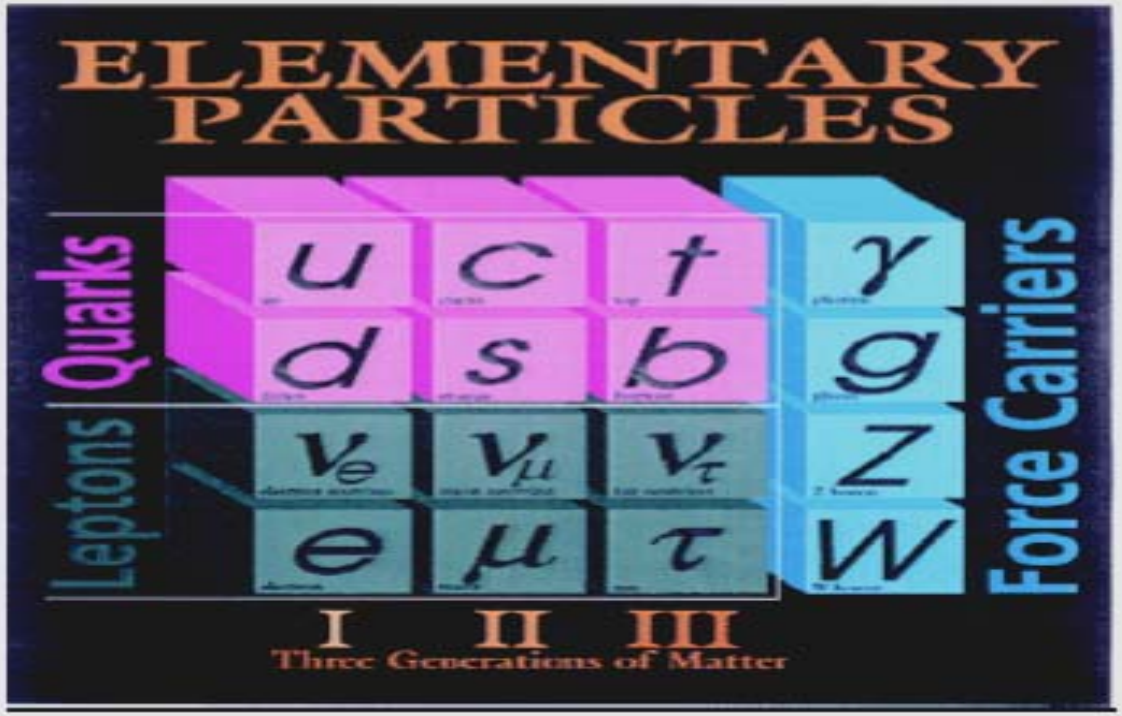
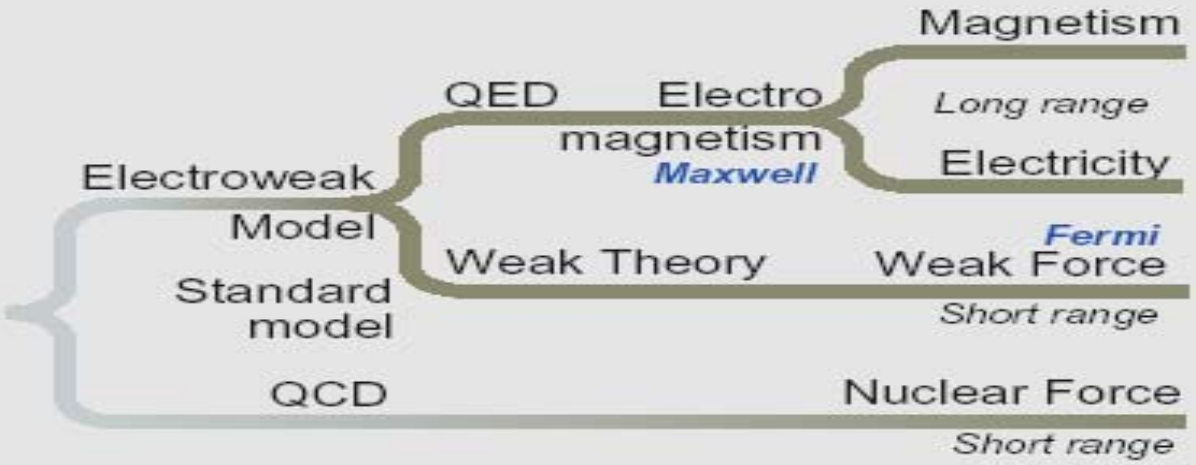
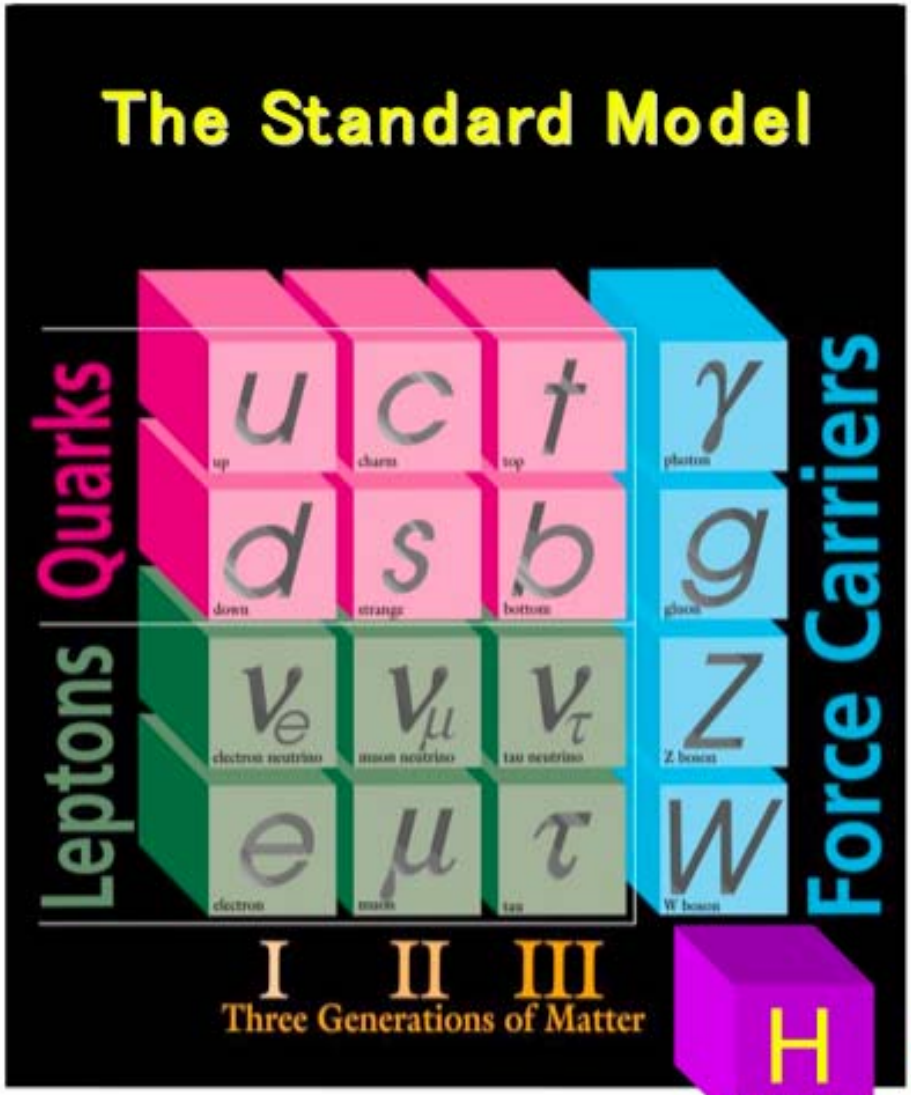
INFN, Padova

THE G-W-S STANDARD MODEL

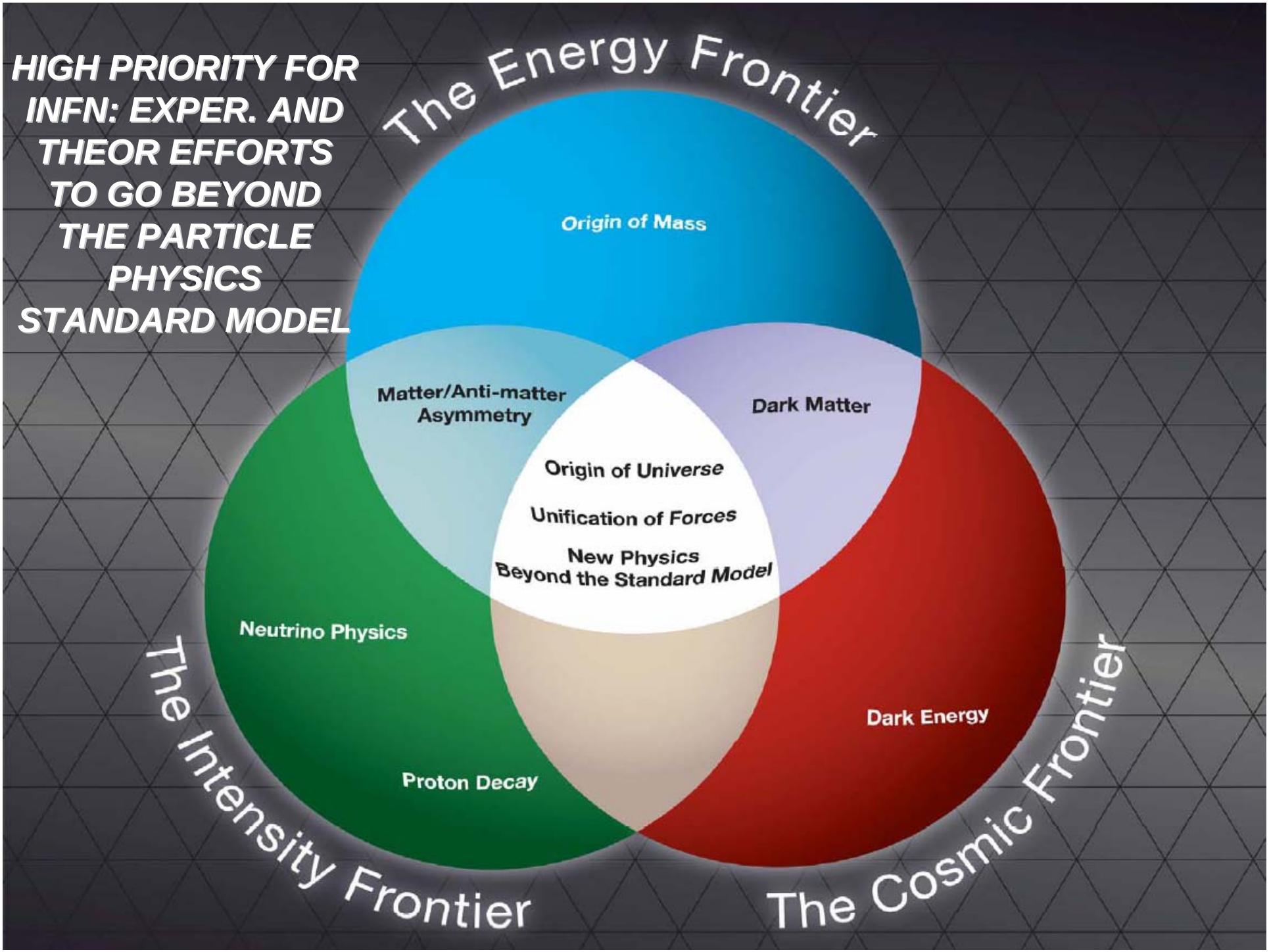




Gravity
?


The Standard Model
Quarks
Leptons
Force Carriers
u
c
t
d
s
b
up
charm
top
down
strange
bottom
ν_e
ν_μ
ν_τ
electron neutrino
muon neutrino
tau neutrino
e
μ
τ
electron
muon
tau
γ
photon
g
gluon
Z
Z boson
W
W boson
I
II
III
Three Generations of Matter
H
Higgs boson
?

HIGH PRIORITY FOR INFN: EXPER. AND THEOR EFFORTS TO GO BEYOND THE PARTICLE PHYSICS STANDARD MODEL



The muon g-2: Standard Model vs. Experiment

- Adding up all the above contribution we get the following SM predictions for a_μ and comparisons with the measured value:

	$a_\mu^{SM} \times 10^{11}$	$\Delta a_\mu \times 10^{11}$	σ
[1]	116 591 793 (60)	287 (87)	3.3
[2]	116 591 778 (61)	302 (88)	3.4
[3]	116 591 807 (72)	273 (96)	2.8
[4]	116 591 828 (63)	252 (89)	2.8
[5]	116 591 991 (70)	89 (95)	0.9

2

with $a_\mu^{HHO(lbl)} = 110\ (40) \times 10^{-11}$. $\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM}$.

[1] Eidelman at ICHEP06 & Davier at TAU06 (update of ref. [5]).
[2] Hagiwara, Martin, Nomura, Teubner, PLB649 (2007) 173.
[3] F. Jegerlehner, PhiPsi 08, Frascati, April 2008.
[4] J.F. de Troconiz and F.J. Yndurain, PRD71 (2005) 073008.
[5] Davier, Eidelman, Hoecker and Zhang, EPJC31 (2003) 503 (τ data).

- The th error is now the same (or even smaller) as the exp. one!
- If BaBar's prelim. results are used instead, Δa_μ drops to ~1.7σ.

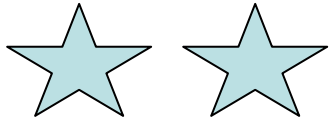
Courtesy of M. Passera

WG on Rad. Corrections and MC Generators for Low Energies

(coll. with Novosibirsk and Dubna)

Coll. Agreement INFN - Moscow State Univ. for theor, research in this field

Present "Observational" Evidence for New Physics

- **NEUTRINO MASSES** 
- **DARK MATTER** 
- **MATTER-ANTIMATTER ASYMMETRY** 
- **INFLATION** 

EVIDENCE FOR DM

Various astrophysical sources have confirmed the existence of Dark Matter (DM)

- Binding of Galaxies in Clusters (F. Zwicky, 1933)
- Rotation curves of Galaxies (V.C. Rubin and W.K. Ford, 1970)
- Bindings of hot gases in clusters
- Gravitational Lensing observations
- Large Scale Stucture simulations
- High z - Supernovae
- Observations of colliding clusters of Galaxies

The most direct and accurate evidence comes from WMAP by measuring anisotropies of the CMB power spectrum

~ 73% DarkEnergy, ~ 23% DarkMatter, 4% Baryons

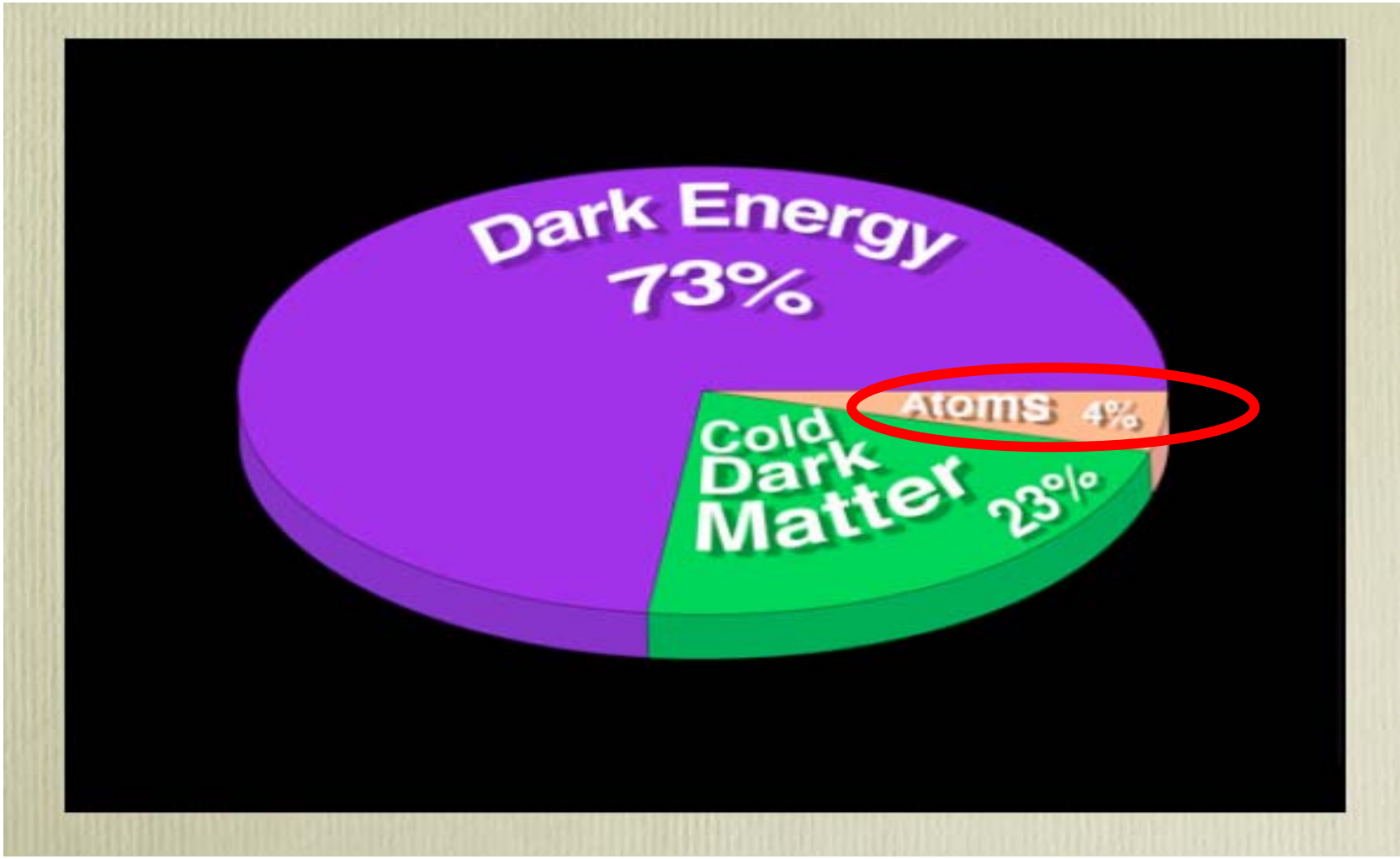
DM → NEW PHYSICS BEYOND THE (PARTICLE PHYSICS) SM - if Newton is right at scales>size of the Solar System

- $\Omega_{DM} = 0.233 \pm 0.013$ *
- $\Omega_{baryons} = 0.0462 \pm 0.0015$ **

*from CMB (5 yrs. of WMAP) + Type I Supernovae + Baryon Acoustic Oscillations (BAO)

**CMB + Typel SN + BAO in agreement with Nucleosynthesis (BBN)

In terms of energy content, the astonishing progress of human knowledge of the Universe has reached only 4% of its content!!



STABLE ELW. SCALE WIMPs
(Weakly Interactive Massive Particle)

1) **ENLARGEMENT OF THE SM**

SUSY	**EXTRA DIM.**	**LITTLE HIGGS.**
(x^μ, θ)	$(x^\mu, j^{i)}$	SM part + new part
Anticomm. Coord.	New bosonic Coord.	to cancel Λ^2 at 1-Loop

2) **SELECTION RULE**

→ **DISCRETE SYMM.**

→ **STABLE NEW PART.**

R-PARITY LSP	**KK-PARITY LKP**	**T-PARITY LTP**
Neutralino spin 1/2	spin1	spin0
m_{LSP} ~100 - 200 GeV *	m_{LKP} ~600 - 800 GeV	m_{LTP} ~400 - 800 GeV

3) FIND REGION (S) PARAM. SPACE WHERE THE "L" NEW PART. IS NEUTRAL + $\Omega_L h^2$ OK

* But abandoning gaugino-masss unif. → Possible to have m_{LSP} down to 7 GeV

Bottino, Donato, Fornengo, Scopel

HUMAN PRODUCTION OF WIMPs

WIMPS HYPOTHESIS

DM made of particles with mass 10Gev - 1Tev

ELW scale

With WEAK INTERACT.

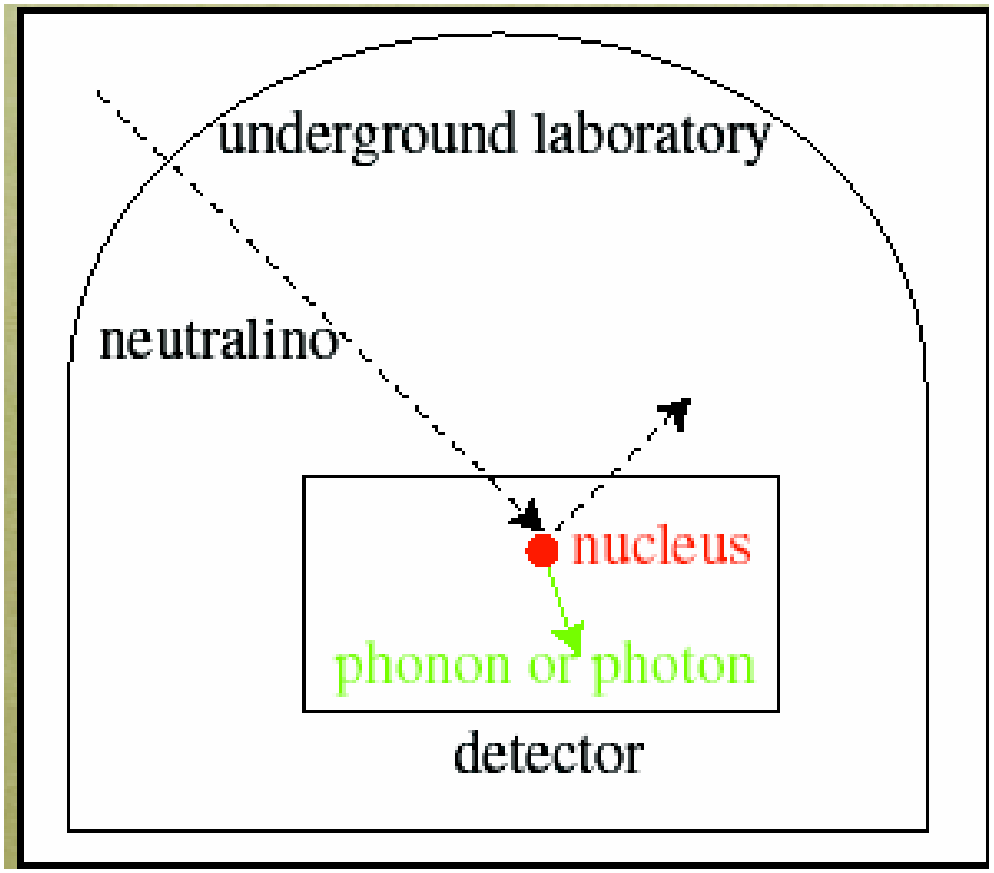
LHC, ILC may PRODUCE WIMPS

WIMPS escape the detector

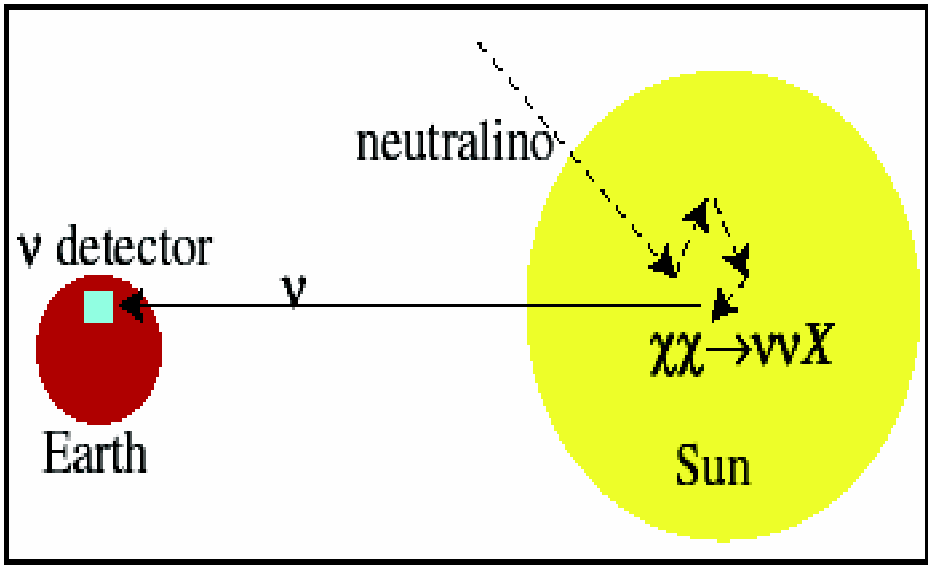
→ MISSING ENERGY SIGNATURE

POSSIBILITY TO CREATE OURSELVES IN OUR ACCELERATORS THOSE DM PARTICLES WHICH ARE PART OF THE RELICS OF THE PRIMORDIAL PLASMA AND CONSTITUTE 1/4 OF THE WHOLE ENERGY IN THE UNIVERSE

HUNTING FOR DARK MATTER



DIRECT DM SEARCHES



INDIRECT DM SEARCHES

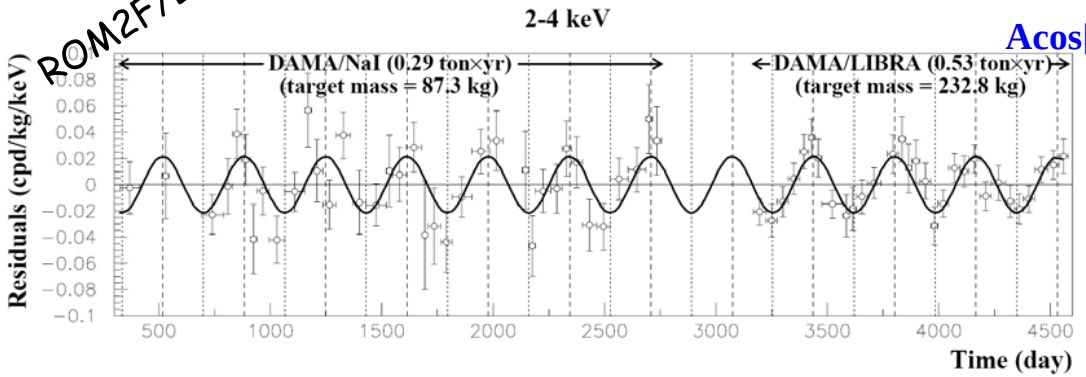
Model Independent Annual Modulation Result

DAMA/NaI (7 years) + DAMA/LIBRA (4 years) Total exposure: 300555 kg×day = 0.82 ton×yr

experimental single-hit residuals rate vs time and energy

ROM2F/2008/07

Acos[ω(t-t$_0$)] ; continuous lines: t$_0$ = 152.5 d, T = 1.00 y



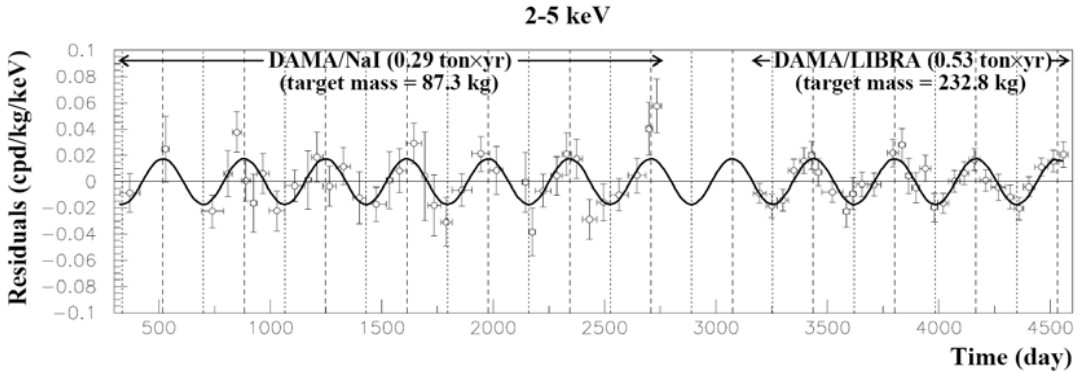
2-4 keV

A=(0.0215±0.0026) cpd/kg/keV

χ^2/dof = 51.9/66 **8.3 σ C.L.**

Absence of modulation? No

χ^2/dof=117.7/67 ⇒ P(A=0) = 1.3×10^{-4}



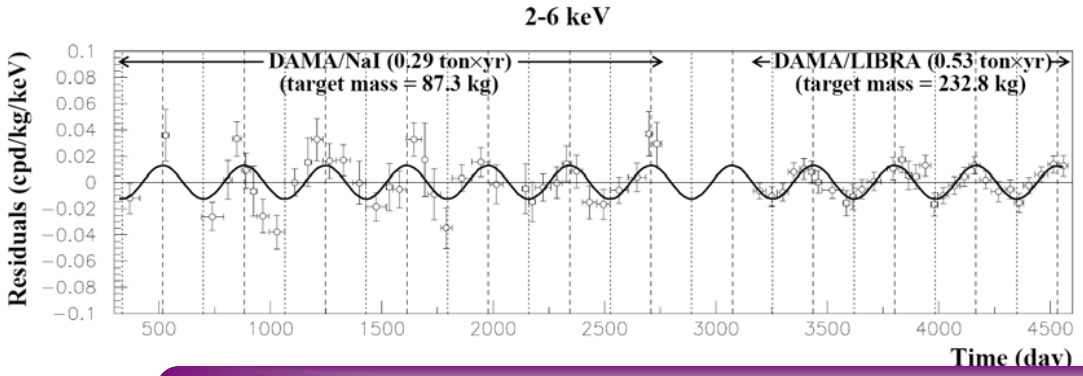
2-5 keV

A=(0.0176±0.0020) cpd/kg/keV

χ^2/dof = 39.6/66 **8.8 σ C.L.**

Absence of modulation? No

χ^2/dof=116.1/67 ⇒ P(A=0) = 1.9×10^{-4}



2-6 keV

A=(0.0129±0.0016) cpd/kg/keV

χ^2/dof = 54.3/66 **8.2 σ C.L.**

Absence of modulation? No

χ^2/dof=116.4/67 ⇒ P(A=0) = 1.8×10^{-4}

The data favor the presence of a modulated behavior with proper features at 8.2σ C.L.

The first glimpse of dark matter?

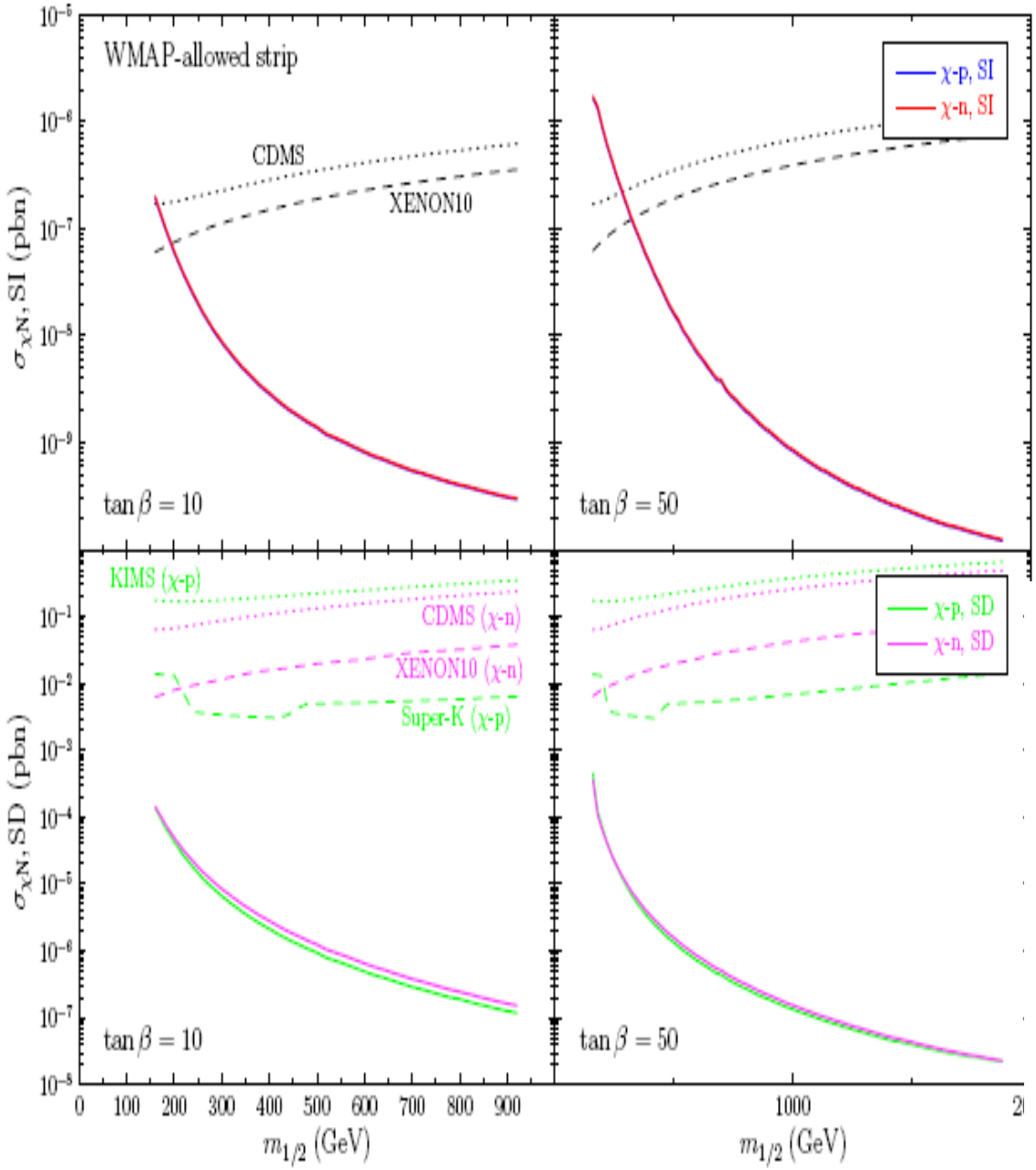
By Victoria Gill
Science reporter, BBC News
Story from BBC NEWS:
http://news.bbc.co.uk/go/pr/fr/-/2/hi/science/nature/8420089.stm

2009/12/18 11:52:13 GMT

arXiv astro-ph 0912.3592v1
CDMS EXP.

We report results from a blind analysis of the nal data taken with the Cryogenic Dark Matter Search experiment (CDMS II) at the Soudan Underground Laboratory, Minnesota, USA. A total raw exposure of 612 kg-days was analyzed for this work. We observed two events in the signal region; based on our background estimate, the probability of observing two or more background events is 23%.

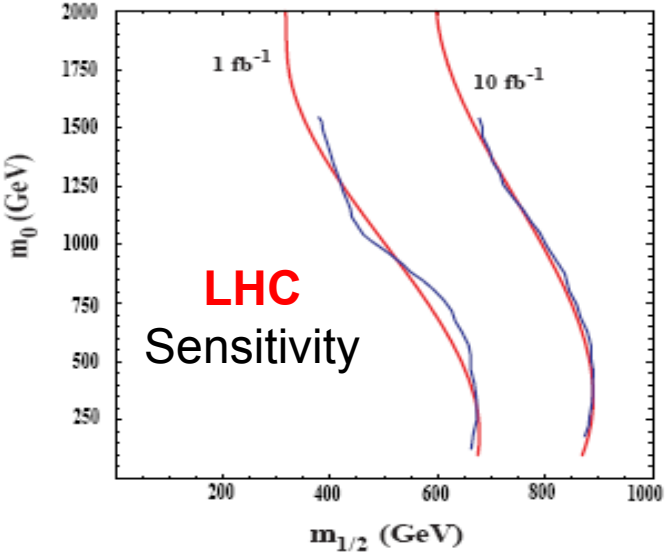
Neutralino-nucleon scattering cross sections along the WMAP-allowed coannihilation strip for tanbeta=10 and coannihilation/funnel strip for tanbeta=50 using the hadronic parameters



ELLIS. OLIVE. SAVAGE

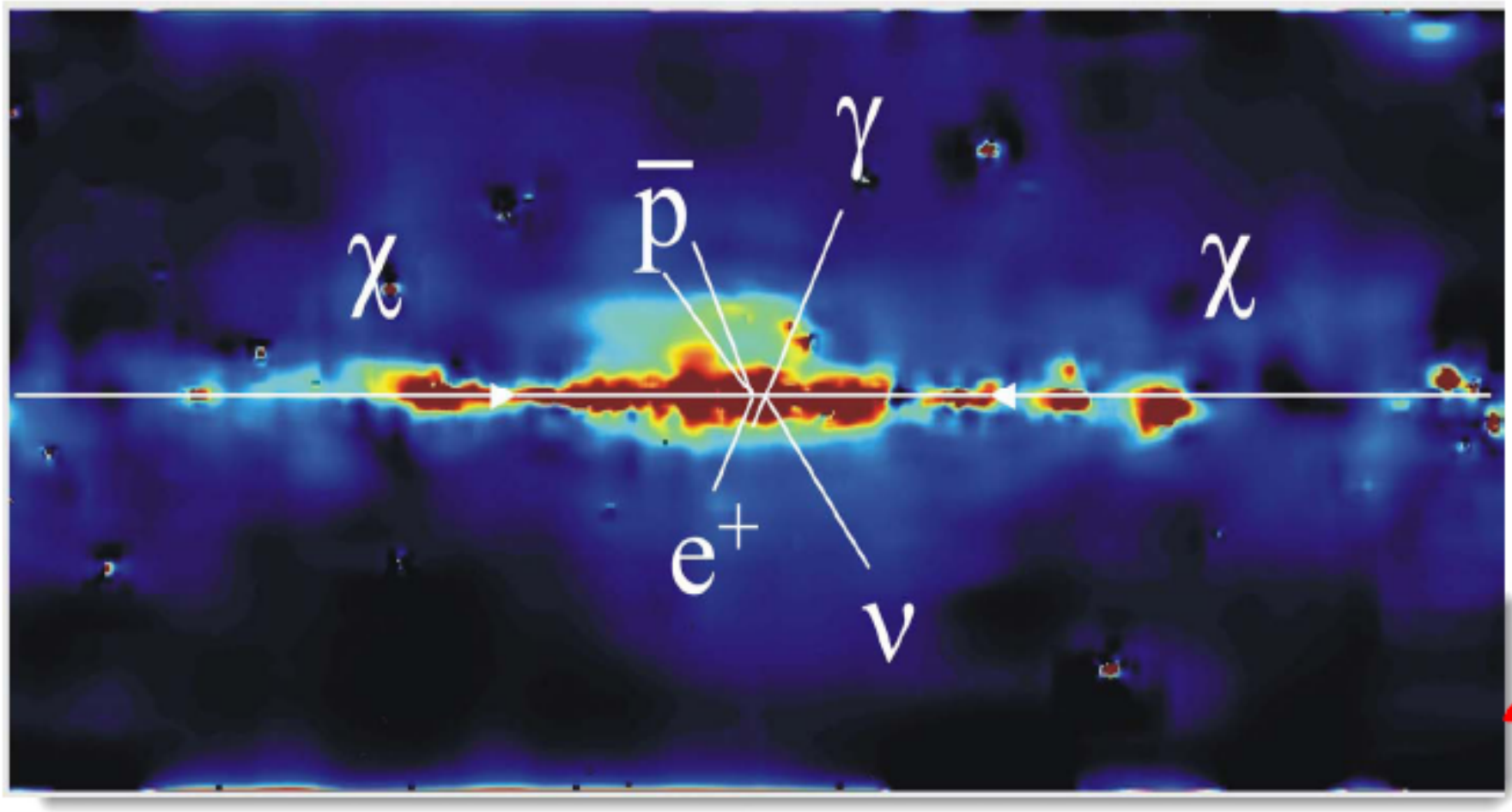
m_u/m_d	0.553	± 0.043
m_d	5	± 2 MeV
m_s/m_d	18.9	± 0.8
m_c	1.25	± 0.09 GeV
m_b	4.20	± 0.07 GeV
m_t	171.4	± 2.1 GeV
σ_0	36	± 7 MeV
$\Sigma_{\pi N}$	64	± 8 MeV
$a_3^{(p)}$	1.2695	± 0.0029
$a_8^{(p)}$	0.585	± 0.025
$\Delta_s^{(p)}$	-0.09	± 0.03

Ellis, Olive, Sandick



DM INDIRECT DETECTION

■ WIMP-WIMP annihilation in the galactic halos may be detected through production of γ, neutrinos, anti-matter.



?

INDIRECT SEARCHES OF DM

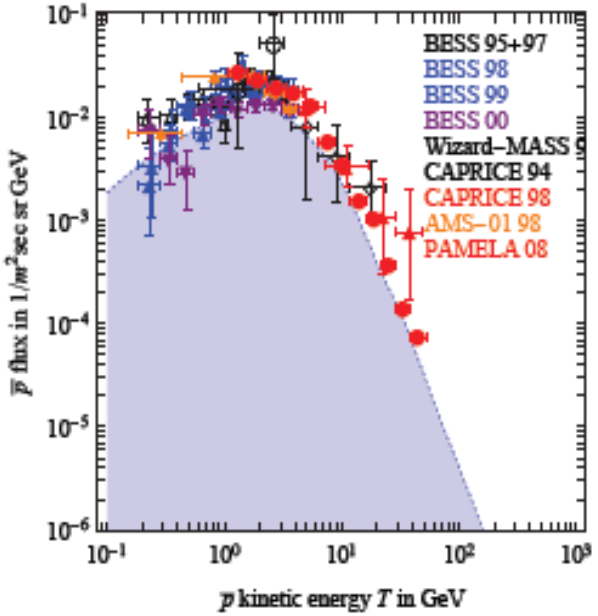
- **WIMPs collected inside celestial bodies** (Earth, Sun): their annihilations produce energetic neutrinos
- **WIMPs in the DM halo**: WIMP annihilations can take place (in particular, their rate can be enhanced with there exists a CLUMPY distribution of DM as computer simulations of the DM distribution in the galaxies seem to suggest. From the WIMP annihilation:

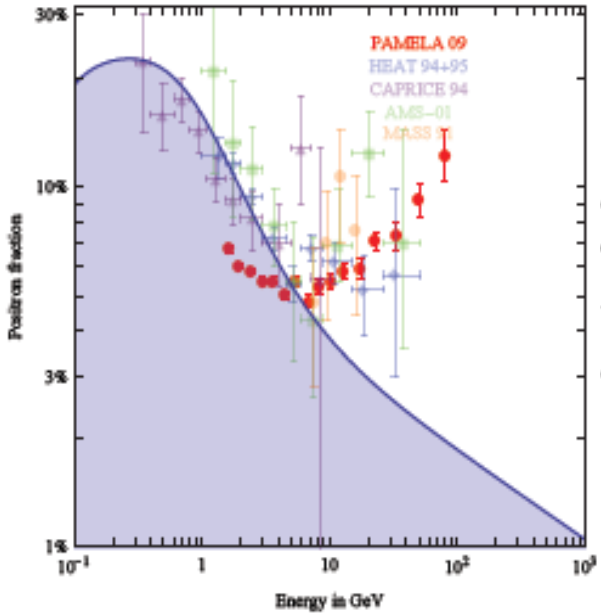
-- **energetic neutrinos** (under-ice, under-water exps Amanda, Antares, Nemo, Nestor, …)

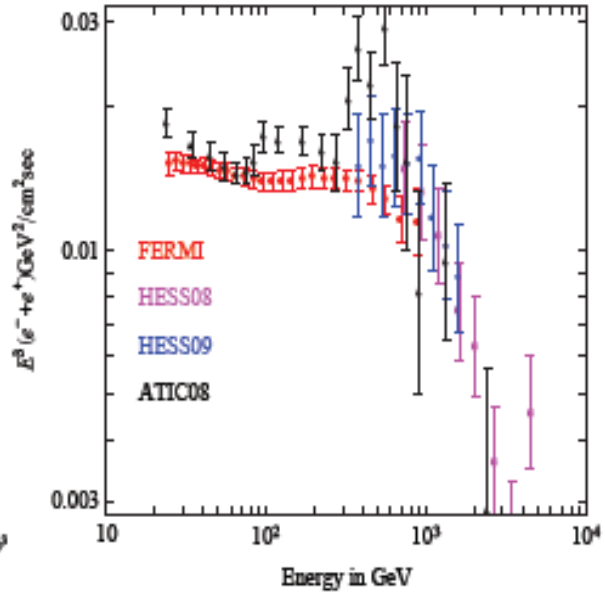
--photons in tens of GeV range (gamma astronomy on ground Magic, Hess, … or in space Agile, Glast…)

--antimatter: look for an excess of antimatter w.r.t. what is expected in cosmic rays (space exps. Pamela, AMS, …)

PAMELA, FERMI/ATIC, HESS







$\bar{p}$: consistent with bck

e^+/e^-: excess

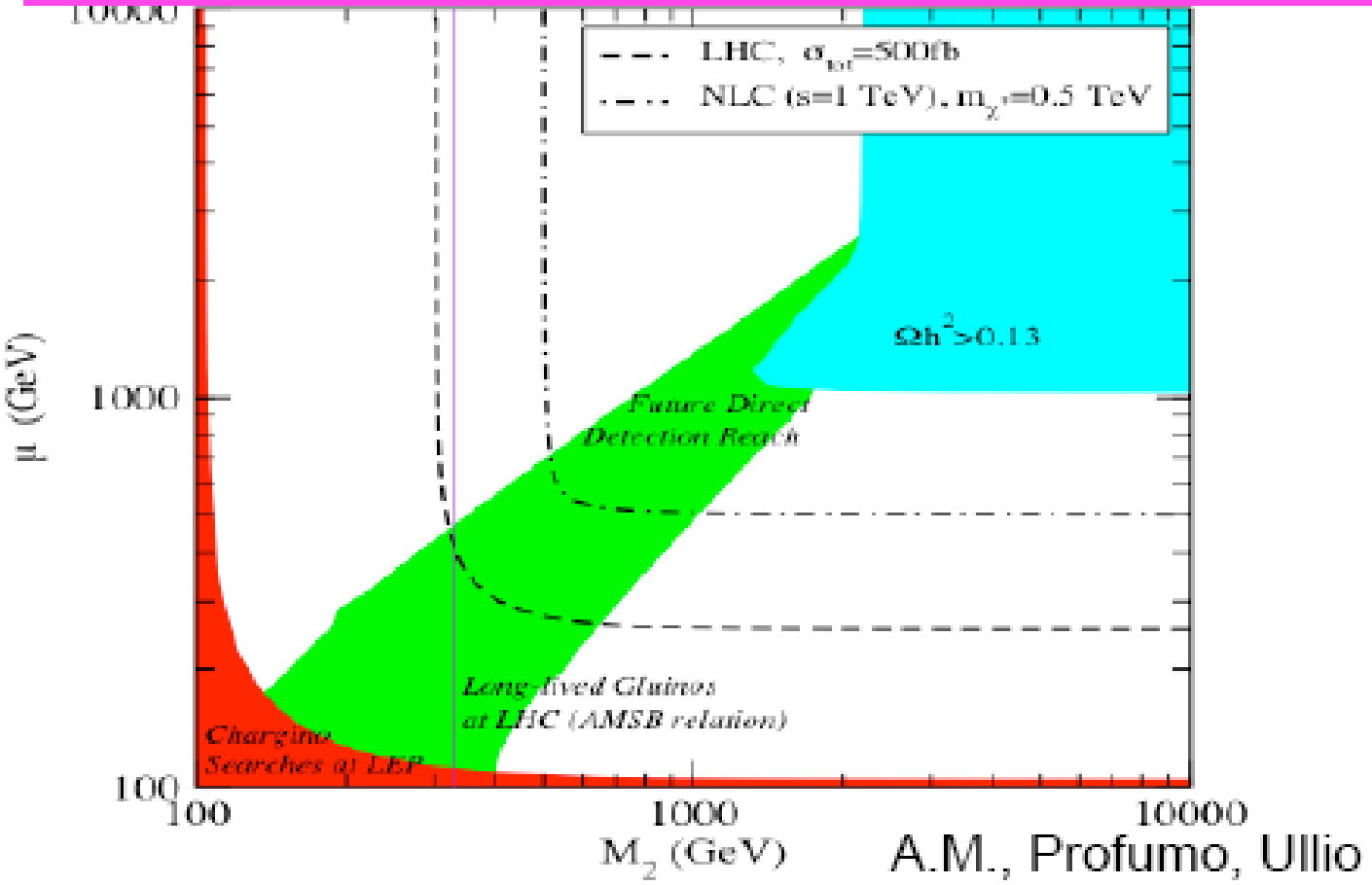
$e^- + e^+$: feature?

Strumia

EPS09

PAMELA excess: October 2008, stimulated enormous theoretical activity; note: statistical errors only! Fermi: feature observed by ATIC not confirmed

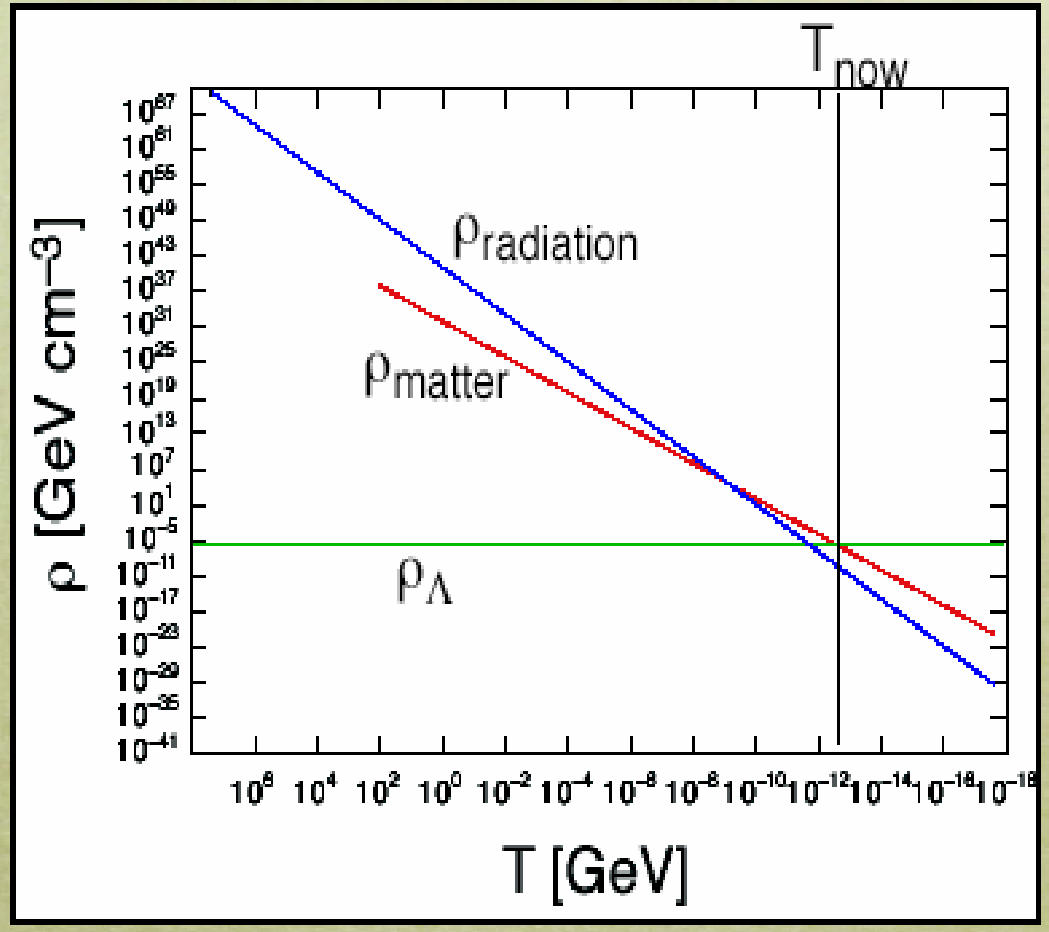
LHC, ILC, DM SEARCHES SENSITIVITIES



A.M., Profumo, Ullio

THE "WHY NOW" PROBLEM

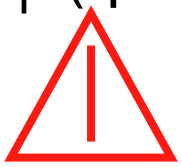
- *Why do we see matter and cosmological constant almost equal in amount?*
- *"Why Now" problem*
- *Actually a triple coincidence problem including the radiation*
- *If there is a deep reason for* $\rho_\Lambda \sim ((\mathrm{TeV})^2/M_{Pl})^4$, *coincidence natural*



Arkani-Hamed, Hall, Kolda, HM

DO THEY "KNOW" EACH OTHER?

- DIRECT INTERACTION ϕ (quintessence) WITH DARK MATTER



DANGER:
ϕ Very LIGHT
$m\phi \sim H_0^{-1} \sim 10^{-33}$ eV

→ Threat of violation of the equivalence principle
constancy of the fundamental "constants",…

- **INFLUENCE OF ϕ ON THE NATURE AND THE ABUNDANCE OF CDM**

Modifications of the standard picture of
WIMPs FREEZE - OUT

CDM CANDIDATES

CATENA, FORNENGO, A.M., PIETRONI, SCHELKE


THE MAGNIFICENT SEVEN
S. Katsanevas
ASPERA
ET
AUGER
North
CTA
KM3
1 ton
DM
1 ton
NM
Megaton
scale
NNN
Common with
Astrophysics
ASTRONET
Common with
Particle Physics
CERN SG

MICRO

STANDARD MODEL of PARTICLE PHYSICS

G-W-S MODEL

MACRO

***MODELLO STANDARD* of COSMOLOGY**

HOT BIG BANG

HAPPY MARRIAGE

EX: **NUCLEOSYNTHESIS**

BUT ALSO

FRICTION POINTS

DARK MATTER AND DARK ENERGY

LHC → AN EXCEPTIONAL WINDOW TO EXPLORE THE UNIVERSE AND ITS ORIGIN