ISAPP 2004

LNGS - June 28 - July 9 2004

# DARK MATTER AND NEW PHYSICS BEYOND THE SM

A. MASIERO

UNIV. OF PADOVA,

INFN, PADOVA

# 1. THE STANDARD MODEL: A CRITICAL REAPPRAISAL

- SPONT. BROKEN GAUGE THEORY
  ⇓
  RENORMALIZABILITY

- EXTRAORDINARY **EXPER. SUCCESS**

- "UNIFICATION" OF ELM. + WEAK (1)

- GIM, FCNC SUPPRESSION
- CT ≠ (2)
- B and L **automatic** conservation at the perturbative level
- economy in the Higgs sector ('1 doublet → $M_W, M_Z, m_f$') (3)

(1) – **LACK OF "TRUE" UNIFICATION**

a) no Q quantization
b) elm-weak $G_F, e \Rightarrow g, g'$
c) $g_s, g, g'$ far apart
d) no gravity

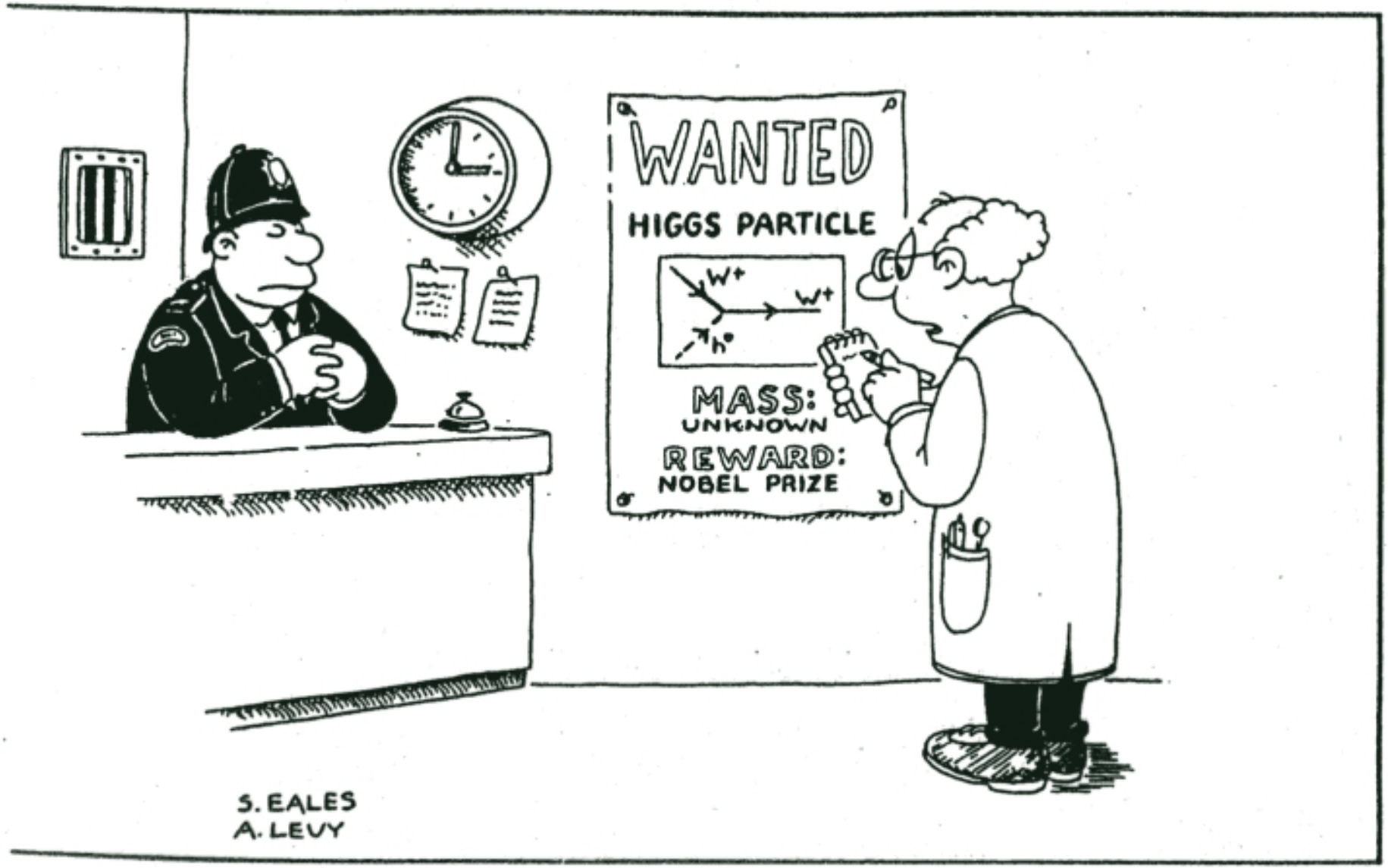
(2) – **FLAVOUR PROBLEM**

a) # of families
b) fermion masses
c) ν mass
d) CKM parameters

(3) **SCALAR PROBLEM**

a) arbitrariness in the scalar sector
b) gauge hierarchy ($G_F$, $M_{Pl}$)

$m_H > 113.5$ GeV




hint: "possible signal" corresponding to $m_H = 115^{+1.3}_{-0.7}$ GeV (2.9 $\sigma$ significance)

# WHY TO GO BEYOND THE SM

## OBSERVATIONAL MOTIVATIONS

- PARTICLE PHYSICS PHENOMENOLOGY

  → NO HINT FOR NEW PHYSICS

  * SM "COLDS": $a_\mu$, $A^b_{FB}$, $A_{CP}(B \to \phi K_S)$, NuTeV

- ASTROPARTICLE PHYSICS

  HINTS FOR NEW PHYSICS

  - $\nu$ MASSES AND MIXINGS (atm. and solar $\nu$)
  - DARK MATTER AND ENERGY
  - BARYOGENESIS
  - INFLATION

## THEORETICAL MOTIVATIONS

- SM → SPONT. BROKEN GAUGE THEORY WITHOUT ANOMALIES

  ↓

  no intrinsic inconsistencies

- FAILURE TO ANSWER "FUNDAMENTAL" QUESTIONS

  ↓

  - FLAVOR ISSUE
  - UNIF. ISSUE
  - HIERARCHY ISSUE

# SM FAILURE TO ORIGINATE COSMIC MATTER-ANTIMATTER ASYMMETRY

**Sacharov's NECESSARY INGREDIENTS**

- $B \neq$ → QUANTUM EFFECTS (sphalerons) — SM
- $CP \neq$ → CKM PHASE
- OUT OF EQUILIBRIUM → ELW PHASE TRANSITION; NEED 1st ORDER PHASE TRANSITION

↓

**SM QUANTITATIVE FAILURE**

- $B \neq$ ✓
- $CP \neq$ ⇒ need to involve all 3 generations ⇒ 12 Yukawa couplings ⇒ CKM $CP \neq \propto 10^{-20}$
- for $m_H > 80$ GeV phase transition in the SM ⇒ smooth crossover

↓

**NEED NEW PHYSICS BEYOND GWS STANDARD MODEL**

- PLANCK PHYS. - GUT

BARYOGENESIS

inflation? reheating temp.?

⇓ ΔB erasement

⇓ not enough for superheavy part.

LEPTOGENESIS

↓ "BONUS" of SEE-SAW MECH.

⇓ $m_{\nu_R} > 10^9$ GeV gravitino problem?

AFFLECK-DINE MECH.

↓ $\langle \tilde{\ell} \rangle$ $\langle \tilde{q} \rangle$

⇓ model implementation?

# WHAT IS THE DM MADE OF ?

$\Omega$ — $\Omega_{MATTER}$ at least 0.2

$\Omega$ — $\Omega_\Lambda$ $\Lambda$ cosm. const.

$\Omega_\gamma h^2 = 2.48 \times 10^{-5}$ with $m_\nu = 0$ $\Omega_\nu = \frac{7}{8}\left(\frac{4}{11}\right)^{4/3}\Omega_\gamma$

SM : relics $\gamma$, $\nu$, baryons $\Omega_{SM} < 0.1$

$\Omega_B < 0.1$

(MACHOS only small fart of galactic halo)

NON-BARYONIC DM

CALLS FOR NEW PHYSICS BEYOND SM

DM RELIC PARTICLES

THERMAL — NON-THERMAL (ex. axions) Mass

ex.: $m_\nu \sim 10\,eV$, $T^\nu_{decoupl} \sim MeV$

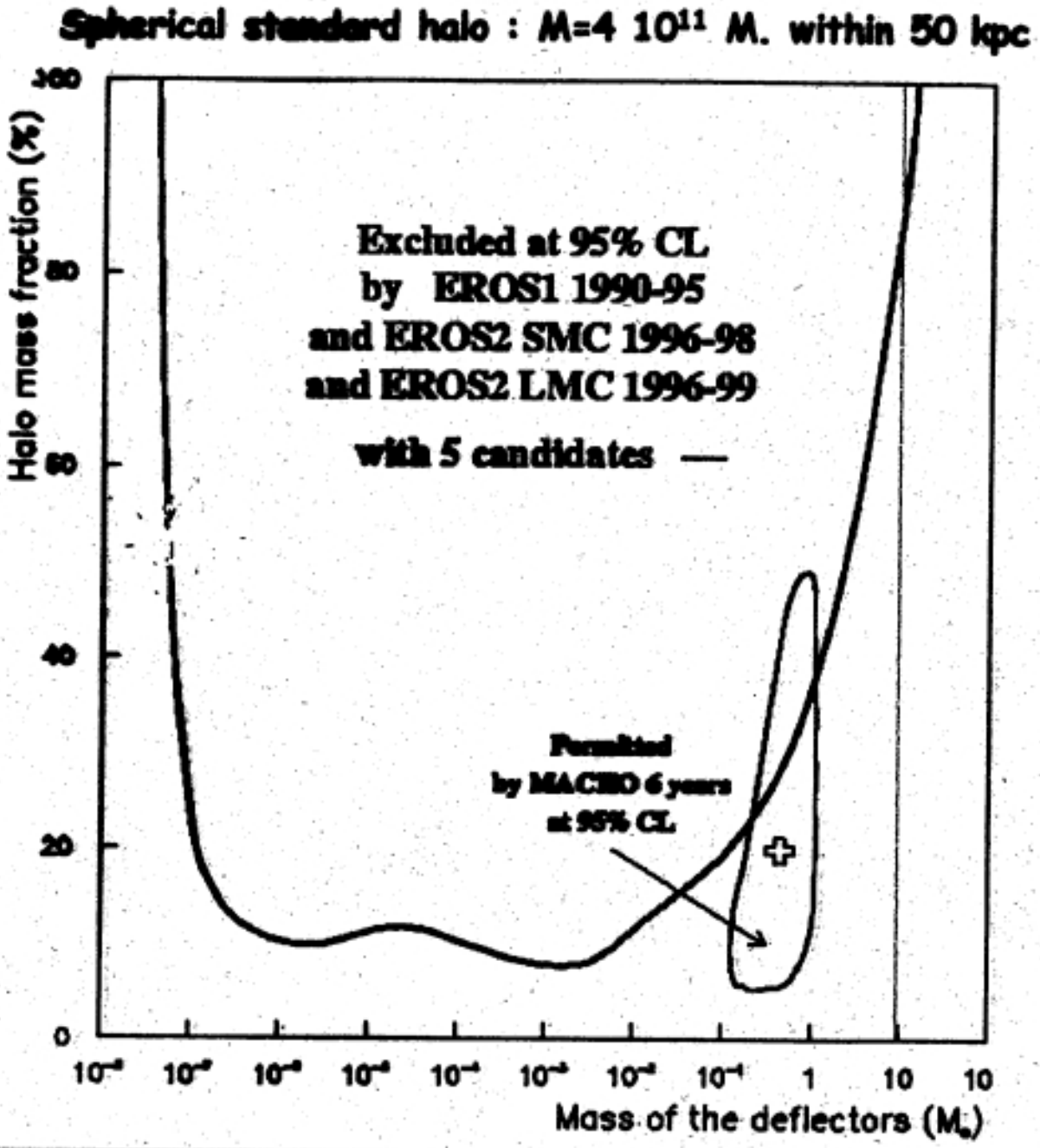
HOT — COLD

ex: $m_{\chi^0} \sim 100\,GeV$, $T^{\chi^0}_{decoupl} \sim 10\,GeV$

$m \ll T_{decoupl}$ relativistic at time structure formation starts

$m \gg T_{decoupl.}$ non relativistic when galaxies start forming

# Combined limit LMC/SMC EROS 1990-99




**1996/98 Limit confirmed and improved**

**Standard Halo fully comprised of MACHOs excluded à 95% C.L. for $M_{LENS}$ < 10 $M_\odot$**