

Final Remarks  
or, better,  
a couple of thoughts on TeVPA  
<1 year before the start of LHC

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# ON THE COMPLEMENTARITY OF DM and LFV SEARCHES to DIRECT LHC SEARCHES FOR NP

- Twofold meaning of such complementarity:
  - synergy in “reconstructing” the “fundamental theory”** staying behind the signatures of NP;
  - coverage of complementary areas of the NP parameter space** ( ex.: multi-TeV SUSY physics)

# WHY TO GO BEYOND THE SM

## “OBSERVATIONAL” REASONS

### •HIGH ENERGY PHYSICS

**NO** (but  $A_{FB}^{Z \rightarrow b\bar{b}}$ .....)

### •FCNC, $CP \neq$

**NO** (but  $b \rightarrow s\bar{q}q$  penguin ...)

### •HIGH PRECISION LOW-EN.

**NO** (but  $(g-2)_\mu$  ...)

### •NEUTRINO PHYSICS

**YES**  $m_\nu \neq 0, \theta_\nu \neq 0$

### •COSMO - PARTICLE PHYSICS

**YES** (DM,  $\Delta B_{\text{cosm}}$ , INFLAT., DE)

## THEORETICAL REASONS

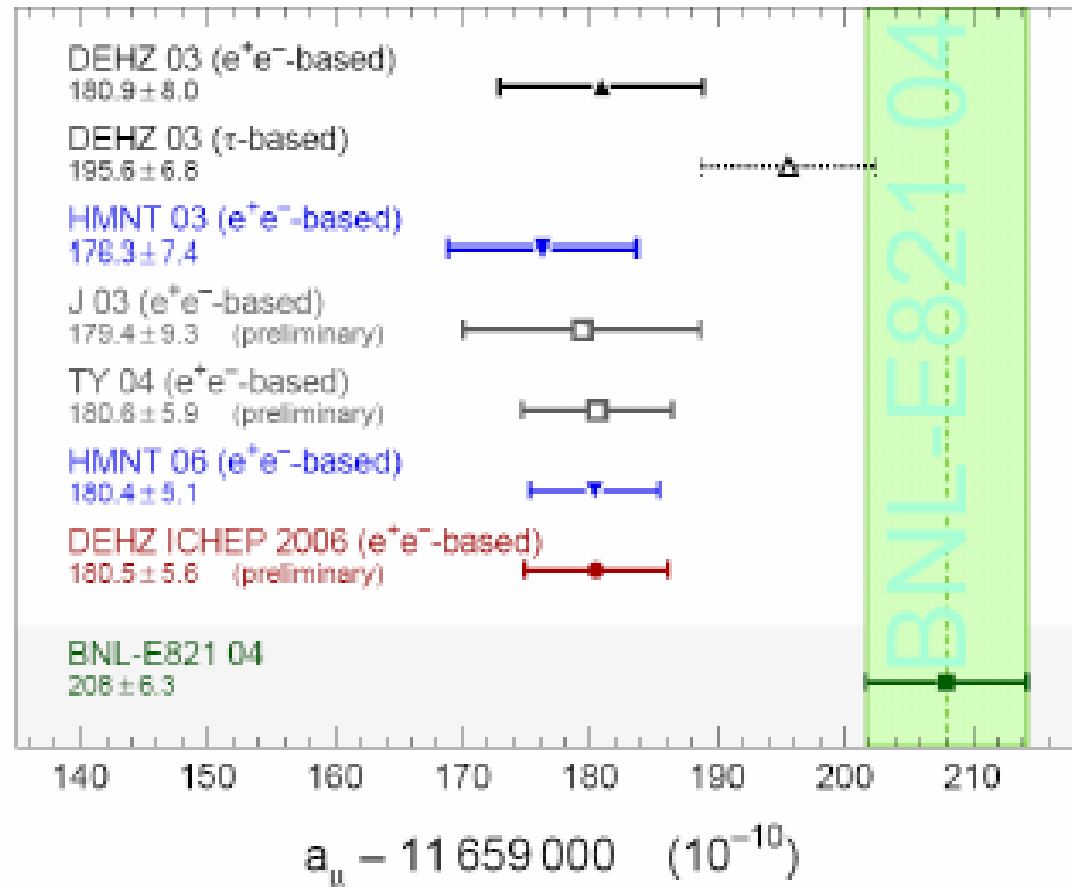
### •INTRINSIC INCONSISTENCY OF SM AS QFT

**NO** (spont. broken gauge theory without anomalies)

•NO ANSWER TO QUESTIONS THAT “WE” CONSIDER “FUNDAMENTAL” QUESTIONS TO BE ANSWERED BY “FUNDAMENTAL” THEORY

**YES** (hierarchy, unification, flavor)

# Status of $g_{\mu}-2$



Whereas  $\tau$  based prediction agrees with the measurement within  $1\sigma$   
all recent  $e+e-$  based predictions have a deviation with data at over  $3\sigma$

# Bright prospects for the experimental sensitivity to LFV

*Experiments:*

Running: **BaBar**, **Belle**

Upcoming: **MEG** (2006)

Future: **SuperKEKB** (2011)

**PRISM/PRIME** (next decade)

**Super Flavour factory** (?)

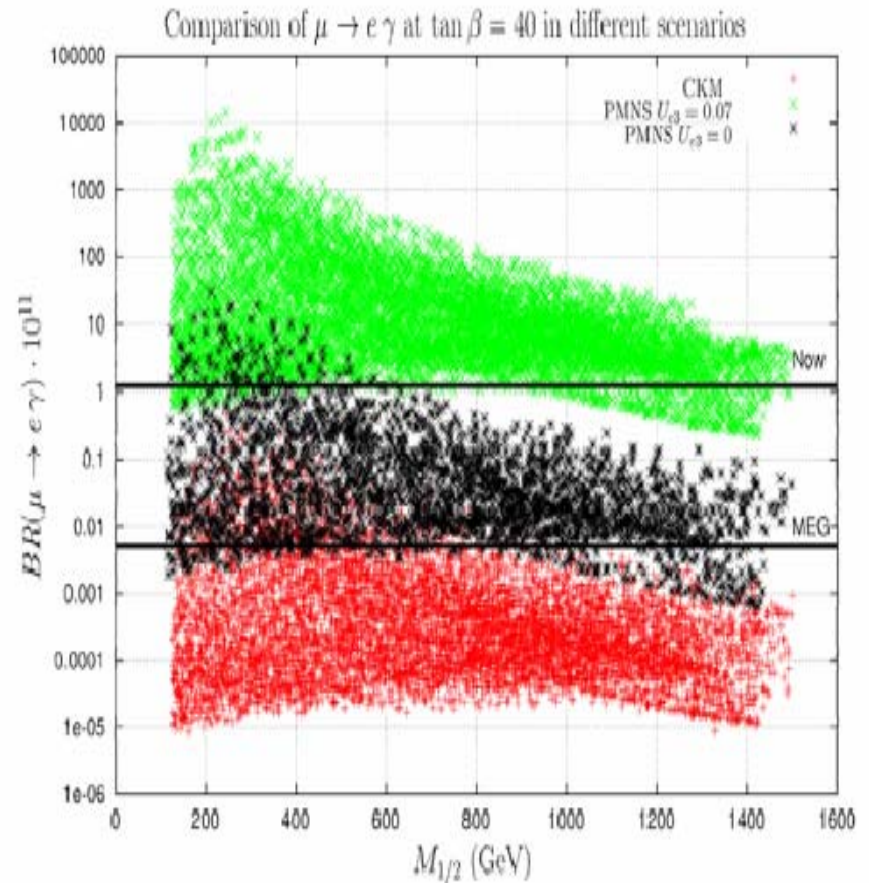
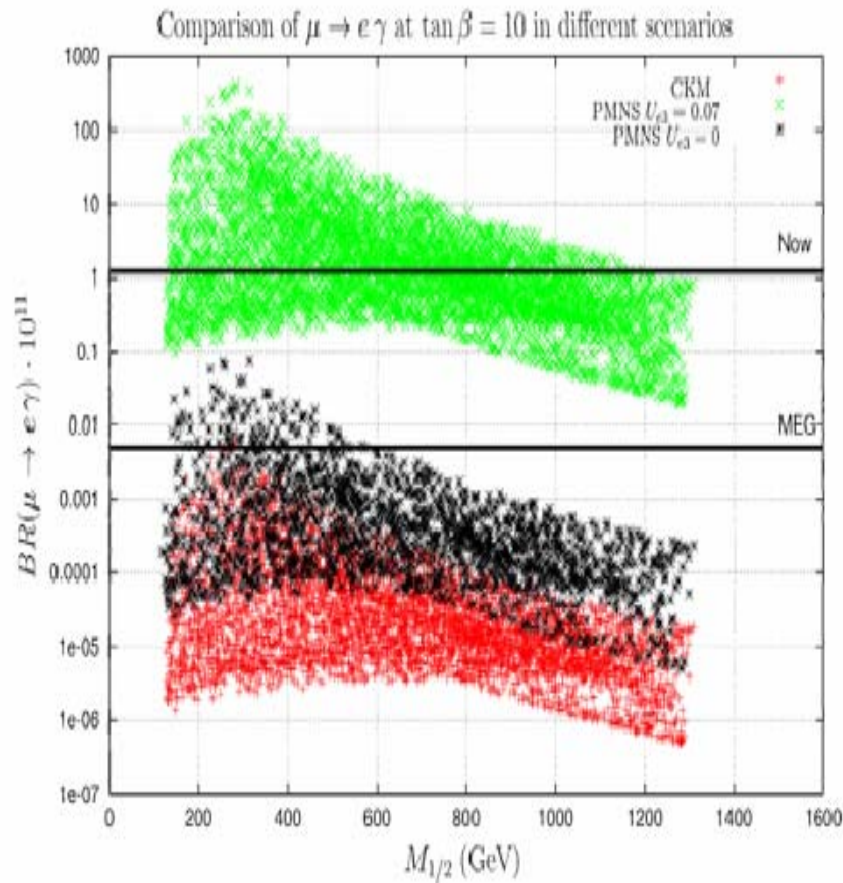
TABLE I: Present bounds and expected experimental sensitivities on LFV processes

Process	Present bound	Future sensitivity
$\text{BR}(\mu \rightarrow e \gamma)$	$1.2 \times 10^{-11}$	$\mathcal{O}(10^{-13} - 10^{-14})$
$\text{BR}(\mu \rightarrow e e e)$	$1.1 \times 10^{-12}$	$\mathcal{O}(10^{-13} - 10^{-14})$
$\text{CR}(\mu \rightarrow e \text{ in Ti})$	$4.3 \times 10^{-12}$	$\mathcal{O}(10^{-18})^a$
$\text{BR}(\tau \rightarrow e \gamma)$	$3.1 \times 10^{-7}$	$\mathcal{O}(10^{-8})$
$\text{BR}(\tau \rightarrow e e e)$	$2.7 \times 10^{-7}$	$\mathcal{O}(10^{-8})$
$\text{BR}(\tau \rightarrow \mu \gamma)$	$6.8 \times 10^{-8}$	$\mathcal{O}(10^{-8}) - \mathcal{O}(10^{-9})^a$
$\text{BR}(\tau \rightarrow \mu \mu \mu)$	$2 \times 10^{-7}$	$\mathcal{O}(10^{-8})$

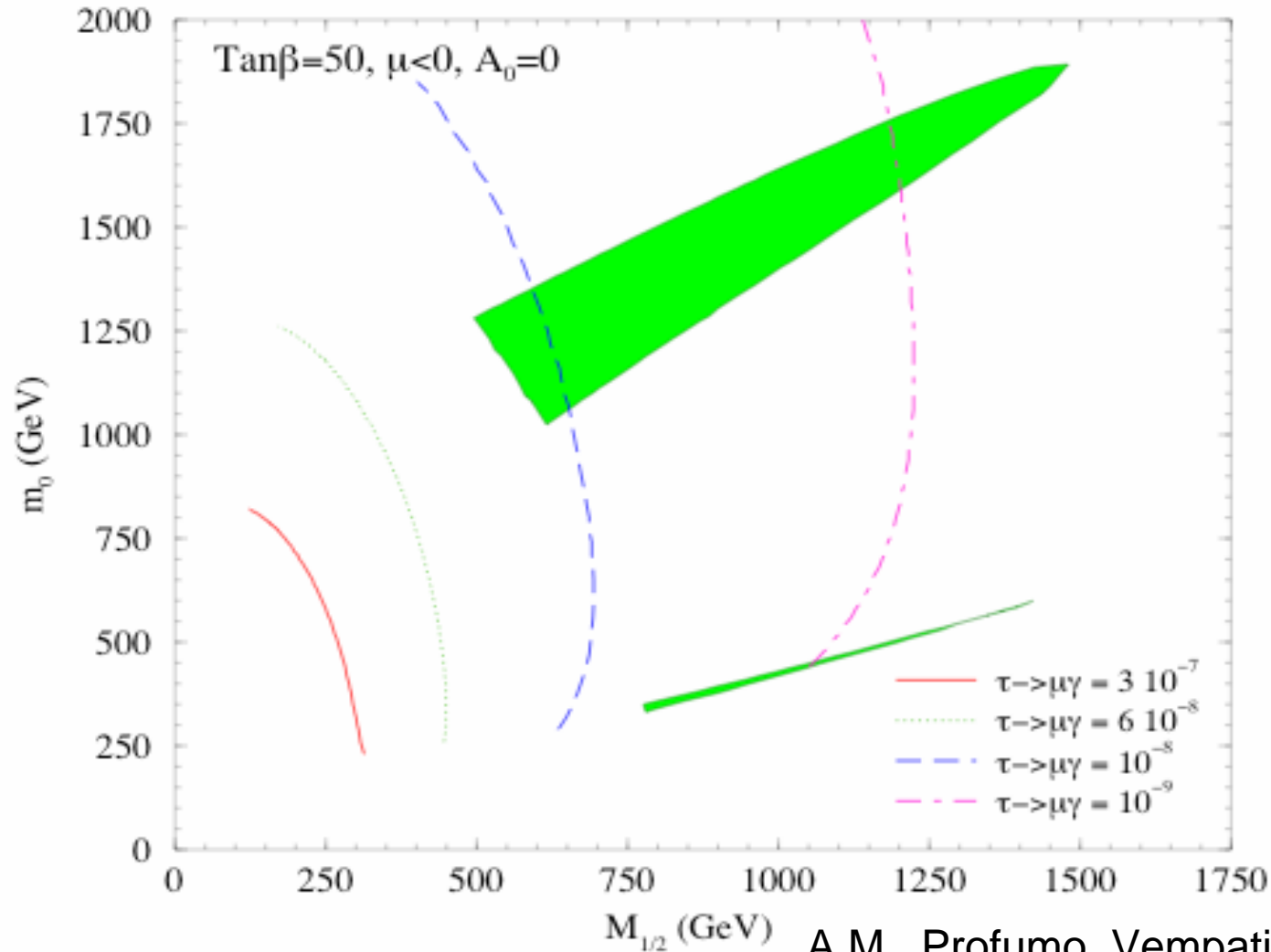
<sup>a</sup>Planned or discussed experiment, not yet under construction

# $\mu \rightarrow e\gamma$ in SUSYGUT: past and future

$\mu \rightarrow e\gamma$  in the  $U_{e3} = 0$  PMNS case



# LFV - DM CONSTRAINTS IN MINIMAL SUPERGRAVITY



# Present “Observational” Evidence for New Physics

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



**MICRO**

**PARTICLE PHYSICS**

**GWS STANDARD MODEL**

**MACRO**

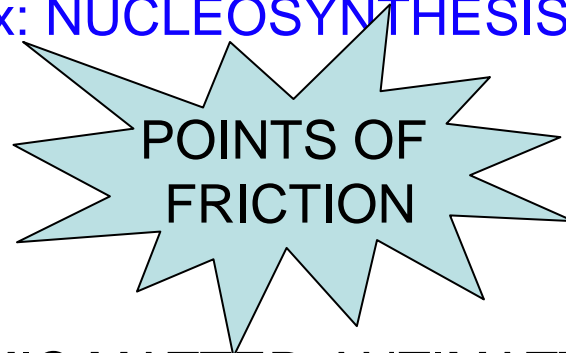
**COSMOLOGY**

**HOT BIG BANG  
STANDARD MODEL**

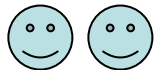


**HAPPY MARRIAGE**  
**Ex: NUCLEOSYNTHESIS**

**BUT ALSO**





**POINTS OF  
FRICTION**



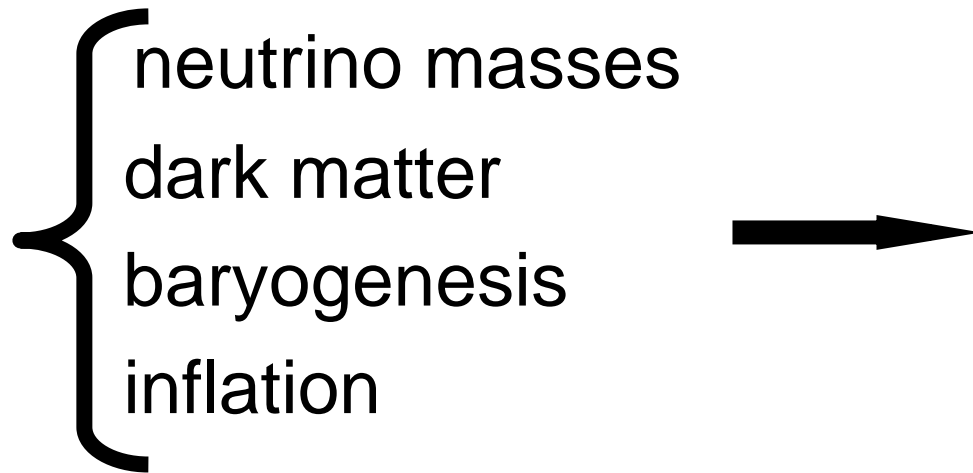
- COSMIC MATTER-ANTIMATTER ASYMMETRY
- INFLATION
- DARK MATTER + DARK ENERGY

**“OBSERVATIONAL” EVIDENCE FOR NEW PHYSICS BEYOND  
THE (PARTICLE PHYSICS) STANDARD MODEL**

# DM: the most impressive evidence at the “quantitative” and “qualitative” levels of New Physics beyond SM

- **QUANTITATIVE:** Taking into account the latest WMAP data which in combination with LSS data provide stringent bounds on  $\Omega_{\text{DM}}$  and  $\Omega_{\text{B}}$   **EVIDENCE FOR NON-BARYONIC DM AT MORE THAN 10 STANDARD DEVIATIONS!!** THE SM DOES NOT PROVIDE ANY CANDIDATE FOR SUCH NON-BARYONIC DM
- **QUALITATIVE:** it is NOT enough to provide a mass to neutrinos to obtain a valid DM candidate; LSS formation requires DM to be COLD  **NEW PARTICLES NOT INCLUDED IN THE SPECTRUM OF THE FUNDAMENTAL BUILDING BLOCKS OF THE SM !**

# The Energy Scale from the “Observational” New Physics

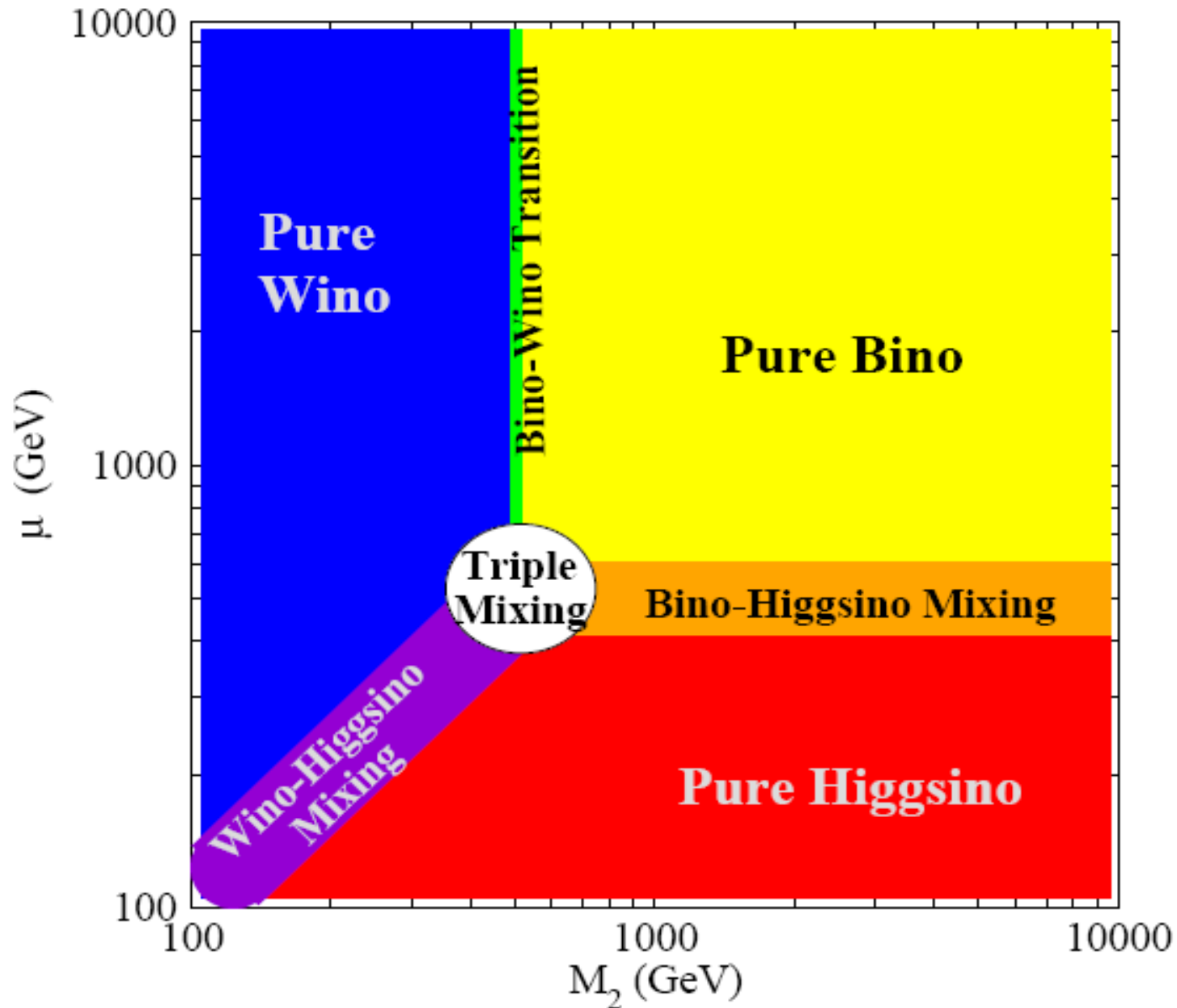


NO NEED FOR THE  
NP SCALE TO BE  
CLOSE TO THE  
ELW. SCALE

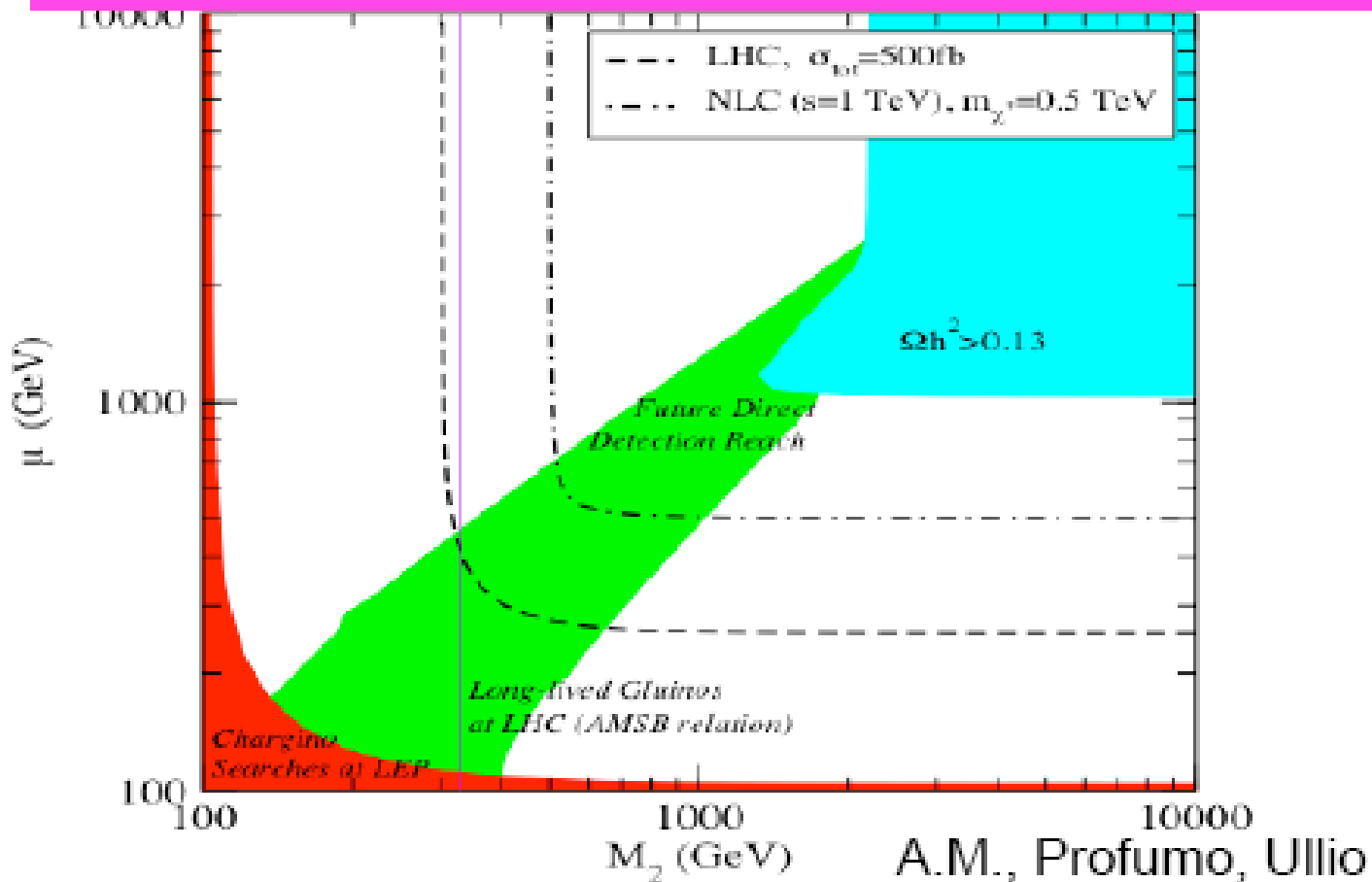
# The Energy Scale from the “Theoretical” New Physics

★ ★ ★ Stabilization of the electroweak symmetry breaking at  $M_W$  calls for an **ULTRAVIOLET COMPLETION** of the SM already at the TeV scale +

★ CORRECT GRAND UNIFICATION “CALLS” FOR NEW PARTICLES AT THE ELW. SCALE



# LHC, ILC, DM SEARCHES SENSITIVITIES



TEVATRON → LHC → ILC

DM - FLAVOR  
for DISCOVERY  
and/or FUND. TH.  
RECONSTRUCTION

A MAJOR  
LEAP AHEAD  
IS NEEDED

NEW  
PHYSICS AT  
THE ELW  
SCALE

DARK MATTER

"LOW ENERGY"

PRECISION PHYSICS

$m_\chi, n_\chi, \sigma_\chi, \dots$

FCNC, CP ≠, (g-2),  $(\beta\beta)_{0\nu\nu}$

LINKED TO COSMOLOGICAL EVOLUTION

→ Possible interplay with dynamical DE

LFV

LEPTOGENESIS

NEUTRINO PHYSICS