LHC, and the future of particle physics

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is electroweak symmetry broken as postulated in the Higgs mechanism of the SM?

- SM production and decay rates well known
- Detector performance for SM channels well understood
- $115 < m_H < 200$ from LEP and EW fits in the SM

Summary of SM Higgs discovery potential
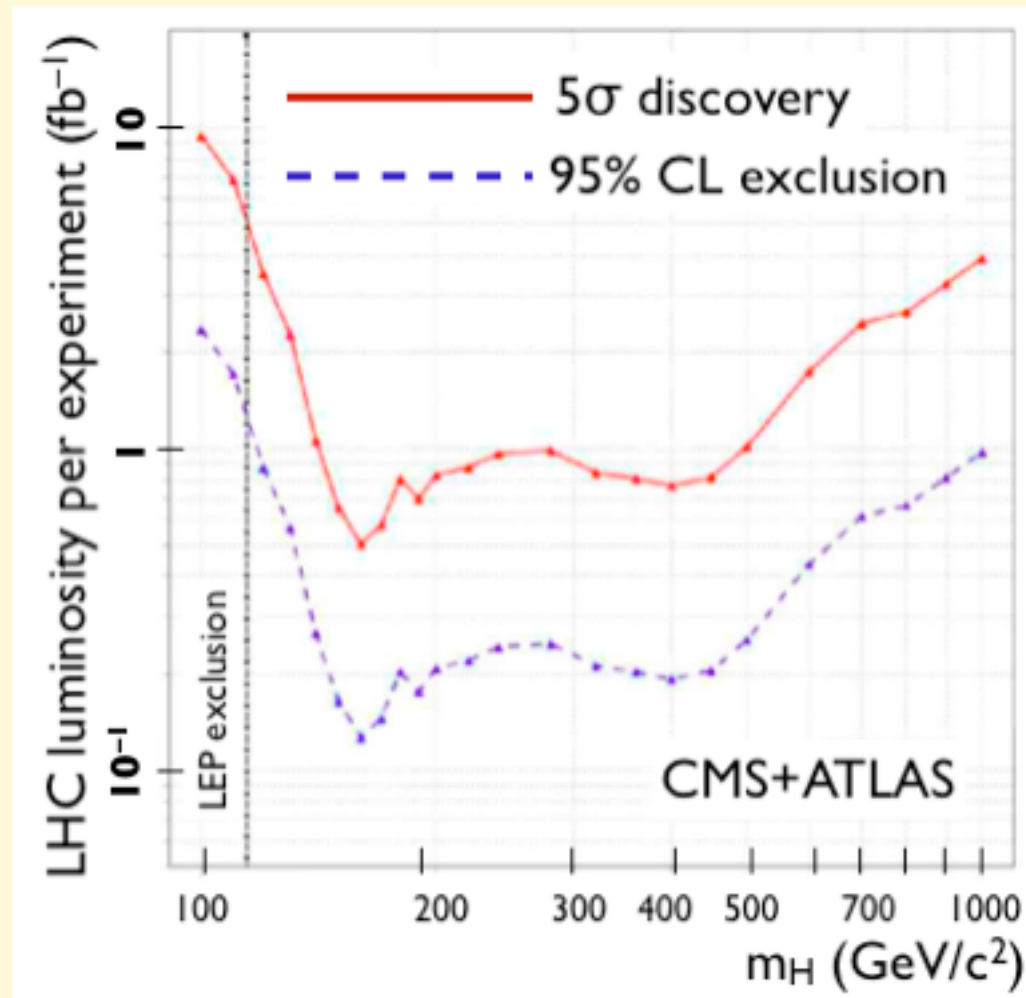
Within 2-3 yrs from startup we should have an answer

IF Higgs seen with SM production/decay rates, but outside SM mass range:

- new physics to explain EW fits, or
- problems with LEP/SLD data

In either case,

- easy prey with low luminosity up to ~ 800 GeV, but more lum is needed to understand why it does not fit in the SM mass range!

IF NOT SEEN UP TO m_H ~ 0.8-1 TeV GEV:

$\sigma < \sigma_{SM}$: $\Rightarrow$ **new physics**

or

BR(H→visible) < BR$_{SM}$: $\Rightarrow$ **new physics**

or

m_H>800 GeV: expect WW/ZZ resonances at $\sqrt{s}$ ~ TeV $\Rightarrow$ **new physics**

- Sorting out non-SM scenarios may take longer than the SM H observation, and may well require LHC luminosities upgrades and/or a LC, but the conclusion about the existence of BSM phenomena will come early and unequivocal

- Exposing the mechanism of EW symmetry breaking (EWSB) and identifying the Higgs boson or its alternatives is necessary to set the scene for what's next

We would also like the LHC to help us address the three key experimental shortcomings of the Standard Model:

- **Neutrino masses**

- **Dark matter**

- **Baryon asymmetry of the universe**

as well as its theoretical weakness, the **hierarchy problem**

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Will the answers to these questions be related to each other?

Which experimental programme, at the LHC and beyond, will allow us to address them?

Timeline for SUSY (MSSM) discovery potential
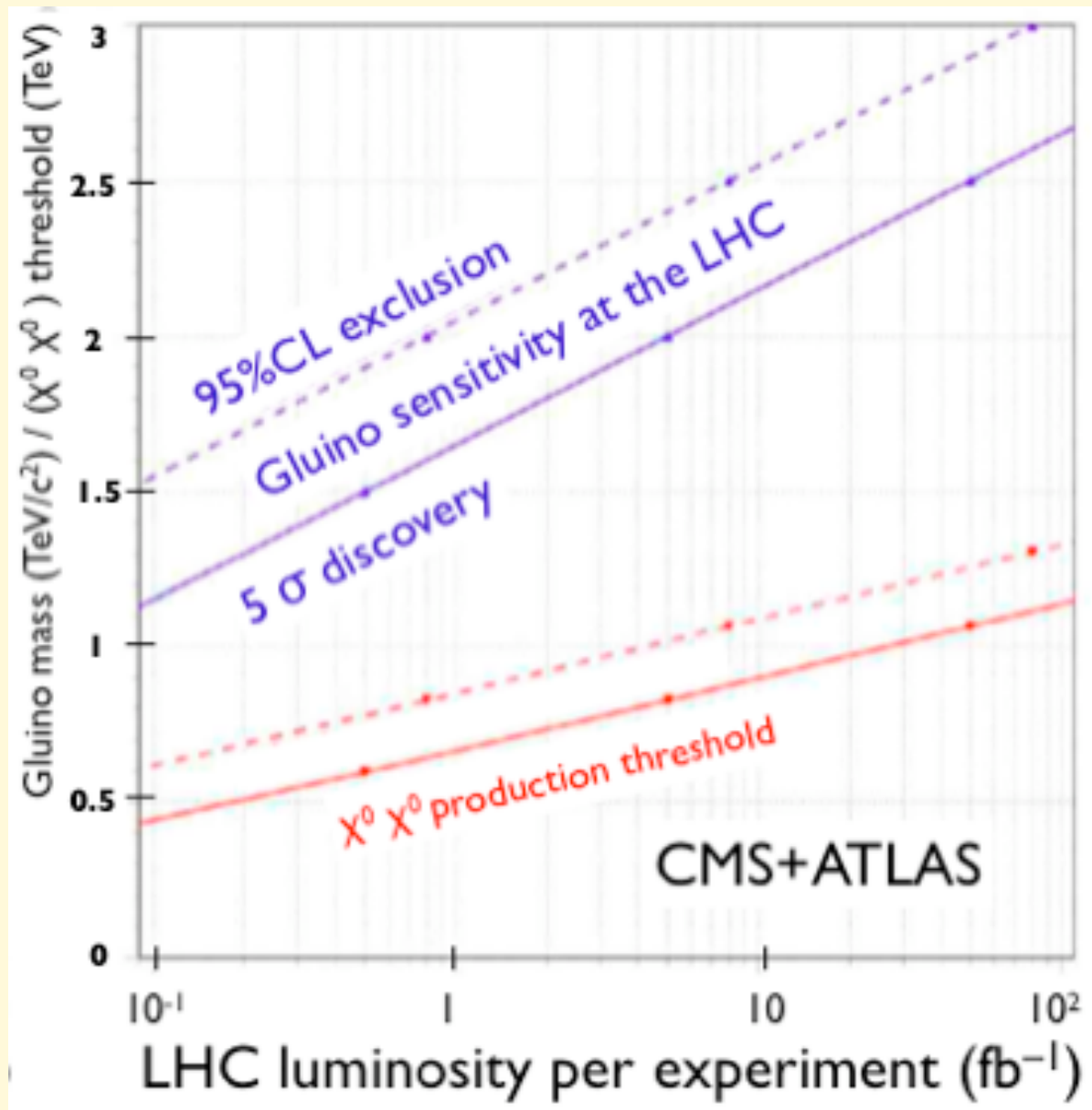
The discovery of SUSY (or whatever else) will only the beginning of a new era of exploration, dominated by questions like
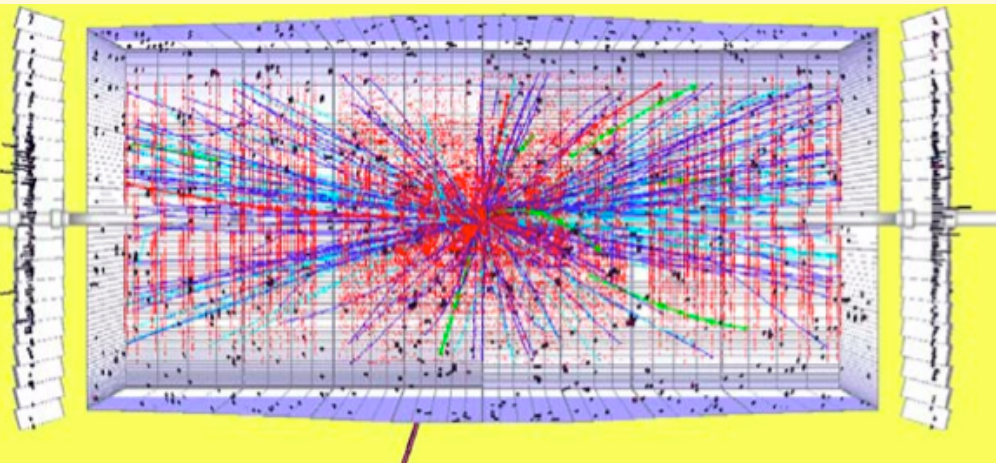
what is the mechanism of SUSY breaking?

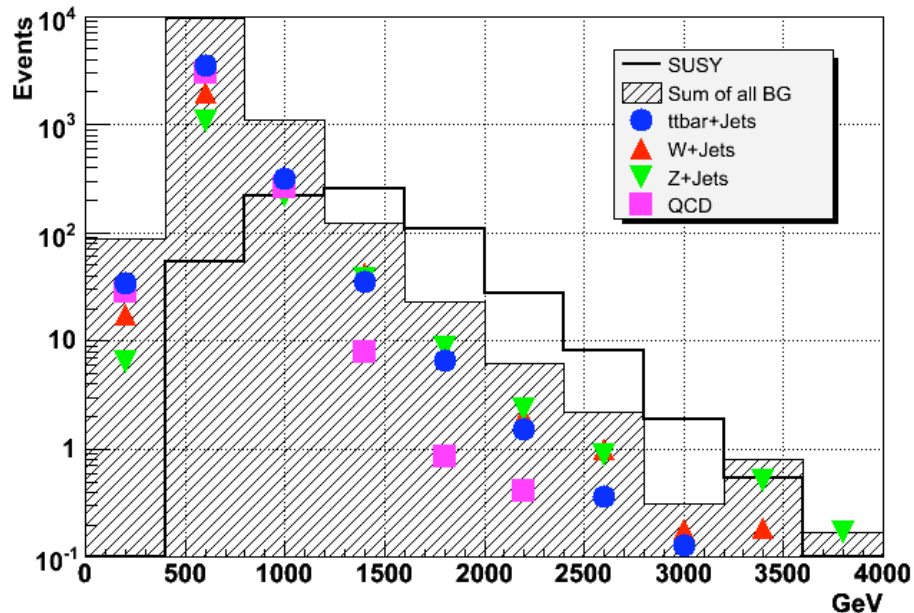**New exptl input will be needed to start addressing this issue:**

- Chargino/gluino mass spectrum

- Squarks and sleptons masses and mixings

- CP structure of SUSY couplings

- .....

The LHC inverse problem
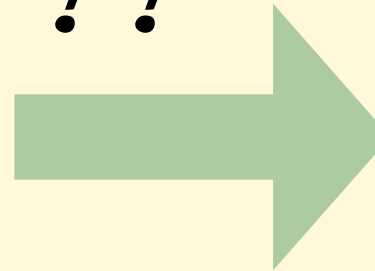
Reconstruct the Lagrangian of new physics from the LHC data

Effective Mass 0lepton SUSY

Legend:
— SUSY
▨ Sum of all BG
● ttbar+Jets
▲ W+Jets
▼ Z+Jets
■ QCD

$$M_{eff} (GeV) = \sum_{i=1,4} E_T (i) + E_T^{miss}$$

?? → extra dims? gluinos? Little Higgs?

$\mathcal{L}$

- I doubt the LHC inverse problem can be solved by global fits of many distributions from either LHC or ILC.

- More likely, the understanding of the new physics will emerge from a step-by-step consolidation of prominent features of the data, restricting more and more the class of models first, and their parameters later.

- Single key inputs, even if only partially accurate, can provide more valuable information than dozens of vaguely suggestive hints. For example, if SUSY:

  - the relation between gluino and chargino mass,

  - evidence for GMSB in the final states (prompt photons and MET),

  - the determination of the stop parameters and mH, etc.

NB

- **< 1973: theoretical foundations of the SM**

  - renormalizability of SU(2)xU(1) with Higgs mechanism for EWSB
  - asymptotic freedom, QCD as gauge theory of strong interactions
  - KM description of CP violation

- **Followed by 30 years of consolidation:**

  - **technical theoretical advances** (higher-order calculations, lattice QCD, ...)

  - **experimental** verification, via **discovery** of

    - **Fermions**: charm, 3rd family (USA)
    - **Bosons**: gluon, W and Z (Europe; .... waiting to add the Higgs ....)

  - **experimental** consolidation, via **measurement** of

    - EW radiative corrections
    - running of α_S
   - CKM parameters

It's unlikely it will take less than 30 yrs to clarify and consolidate the understanding of new phenomena to be unveiled by the LHC!

Notice that of the 3 empirical proofs that the SM in incomplete:

- **Neutrino masses**
- **Dark matter**
- **Baryon asymmetry of the universe**

at least **two** are directly related to flavour .....

Flavour phenomena have contributed shaping modern HEP as much as the gauge principle

μ   ν   **K**

$\varepsilon_K \Rightarrow$ **CP violation**

$K^0 - \bar{K}^0$ mixing/ FCNC $\Rightarrow$ **GIM, charm**
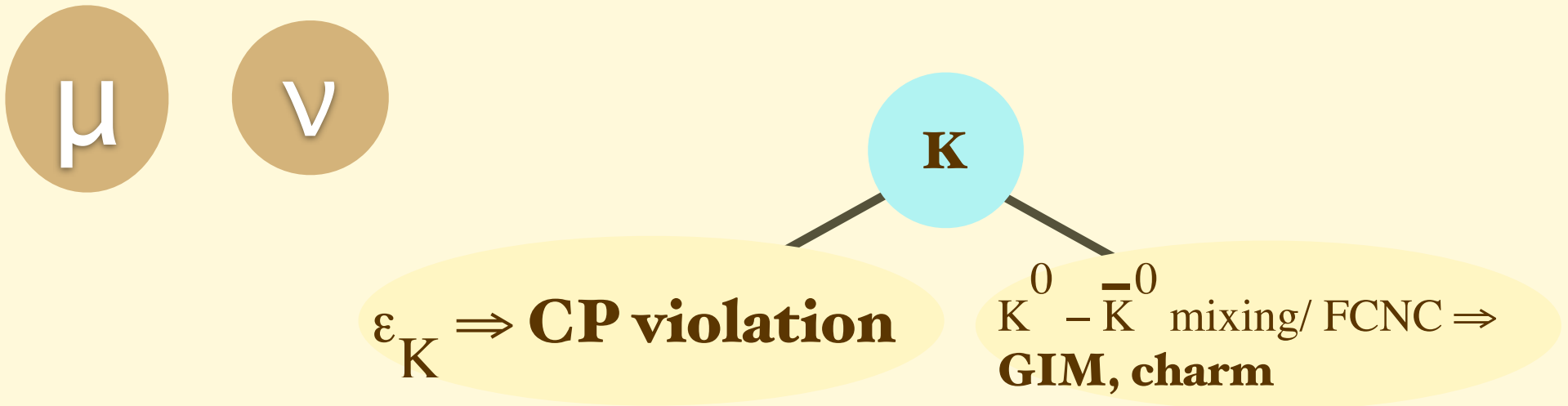
Large B$_d$ mixing (Argus/UA1) $\Rightarrow$ large m[top], well before EW tests

What is "flavour physics" ?

- In the SM, flavour is what deals with the fermion sector (family replicas, spectra and mixings):

  - all flavour phenomena are encoded in the fermion Yukawa matrices.

FCNC and CPV in the SM

- Suppression of FCNC and CPV are guaranteed in the SM by the following facts:

  - Quark sector:
    - unitarity of CKM (GIM mechanism)
    - small mixings between heavy and light generations
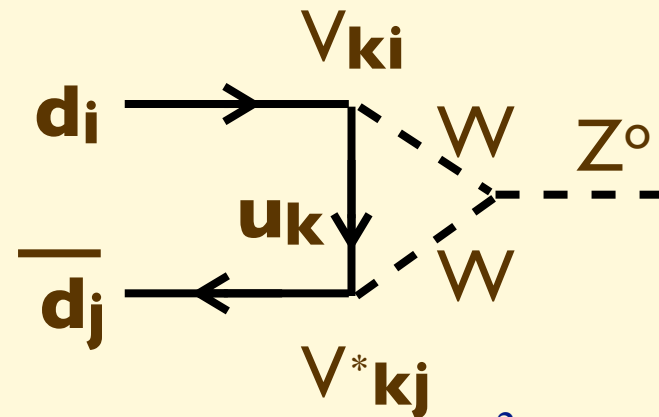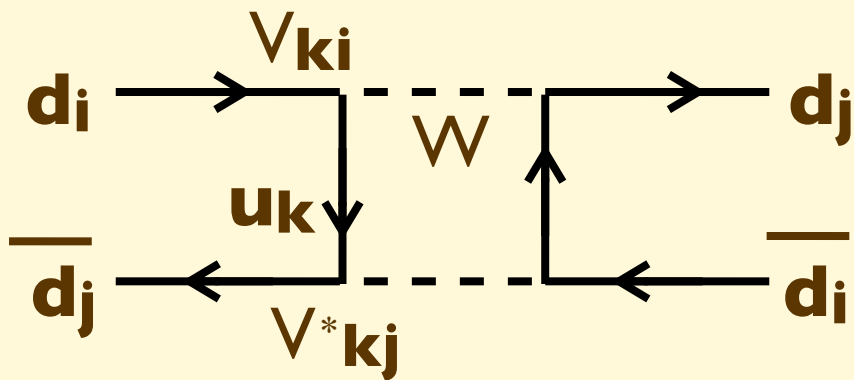
$$\Delta_{ij} \sim \sum_{k=u,c,t} V_{ki} V_{kj}^* \, f(m_k/m_W) \sim \sum_{k=c,t} V_{ki} V_{kj}^* \, m_k^2/m_W^2 \sim V_{ci} V_{cj}^* \frac{m_c^2}{m_W^2} + V_{ti} V_{tj}^*$$

  - Lepton sector:
    - mv=0 $\Rightarrow$ all phases and angles absorbed by field redefinitions, no mixings/CPV at all

What is "flavour physics" ?

- In the SM, flavour is what deals with the fermion sector (family replicas, spectra and mixings):
  - all flavour phenomena are encoded in the fermion Yukawa matrices.
- Beyond the SM, "flavour" phenomena cover a wider landscape. E.g.
  - FCNC can be mediated by
    - gauge-sector particles, like charged higgses, gauginos, new gauge bosons, or by
    - SUSY scalar partners
  - New flavours in the form of new generations, exotic partners of standard quarks (e.g. Kaluza Klein excitations, T' in LH), etc.
  - CP violation can reside in gauge/Higgs couplings

FCNC beyond the SM

S.Geer

- There is absolutely no guarantee that the suppression of FCNC and CPV is present in extensions of the SM

- As soon as these are released, effects are devastating!

Compare the to O(10 TeV) sensitivity w.r.t. modifications of the gauge/EW sector

$B(K_L \rightarrow \mu e) < 4.7 \times 10^{-12}$ $M_X > 150$ TeV/c^2

$B(K^+ \rightarrow \pi^+\mu^+e^-) < 4 \times 10^{-11}$ $M_X > 31$ TeV/c^2

$B(K_L \rightarrow \pi^0\mu^+e^-) < 3.2 \times 10^{-10}$ $M_X > 37$ TeV/c^2

$B(\mu^+ \rightarrow eee) < 1 \times 10^{-12}$ $M_X > 86$ TeV/c^2

$B(\mu^+ \rightarrow e^+\gamma) < 1.2 \times 10^{-11}$ $M_X > 21$ TeV/c^2

Normalized Rate $< 6.1 \times 10^{-13}$ $M_X > 365$ TeV/c^2

N.B. Once coupling constants – say of EW size – and O(θ_c) mixings, are included, these scales are not much bigger than the TeV scale accessible at the LHC ⇨

great potential synergy between LHC and flavour observables

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EWSB and flavour

- EWSB is intimately related to flavour:

  - No EWSB $\Rightarrow$ fermions degenerate $\Rightarrow$ no visible flavour effect

- In most EWSB models flavour plays a key role. E.g.:

  - Technicolor: tightly constrained by large FCNC

  - Supersymmetry: large value of top mass drives radiative EWSB

  - In several extra-dim models the structure of extra dimensions -- driven by the need to explain the hierarchy problem of EWSB -- determines the fermionic mass spectrum

  - Little Higgs theories $\Rightarrow$ top quark partners

- Why $m_{top} = g/\sqrt{2}\, m_W$ $(\Leftrightarrow y_{top} = 1)$?

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the gauge sector
(Higgs, EWSB)

The High Energy Frontier

LHC
SLHC
VLHC
ILC
CLIC
....

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the flavour sector (ν mixings, CPV, FCNC, EDM, LFV)

The High Energy Frontier

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The High Intensity Frontier

Neutrinos:	**Quarks:**	**Charged leptons:**
super beams	B factories	stopped μ
beta-beams	K factories	$\ell \rightarrow \ell'$ conversion
ν factory	n EDM	e/μ EDM

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+ Astrophysics and cosmology

What can we get from more integrated luminosity after LHC's first phase?

1. Improve measurements of new phenomena seen at the LHC. E.g.

   - Higgs couplings and self-couplings

   - Properties of SUSY particles (mass, decay BR's, etc)

   - Couplings of new Z' or W' gauge bosons (e.g. L-R symmetry restoration?)

2. Detect/search low-rate phenomena inaccessible at the LHC. E.g.:

   - $H \rightarrow \mu^+ \mu^-$, $H \rightarrow Z\gamma$

   - top quark FCNCs

3. Push sensitivity to new high-mass scales. E.g.

   - New forces (Z', W_R)

   - Quark substructure

   - ....

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Energies/masses in the few-100 GeV range. Detector performance at SLHC should equal (or improve) in absolute terms the one at LHC

Very high masses, energies, rather insensititive to high-lum environment.
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Slightly degraded detector performance tolerable

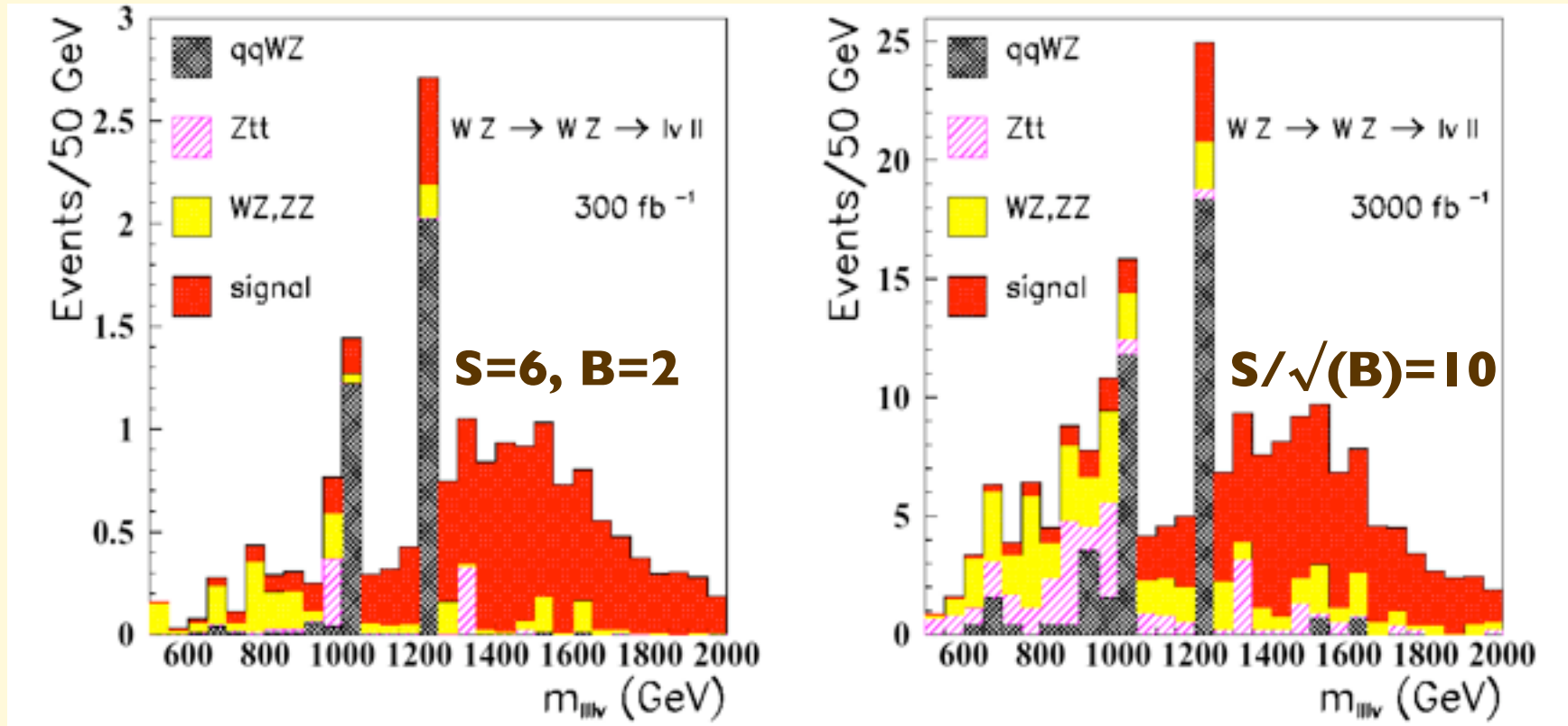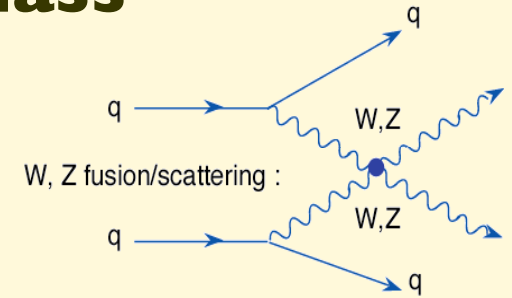# Measurement of Higgs couplings - Accuracy goal: 10-20%
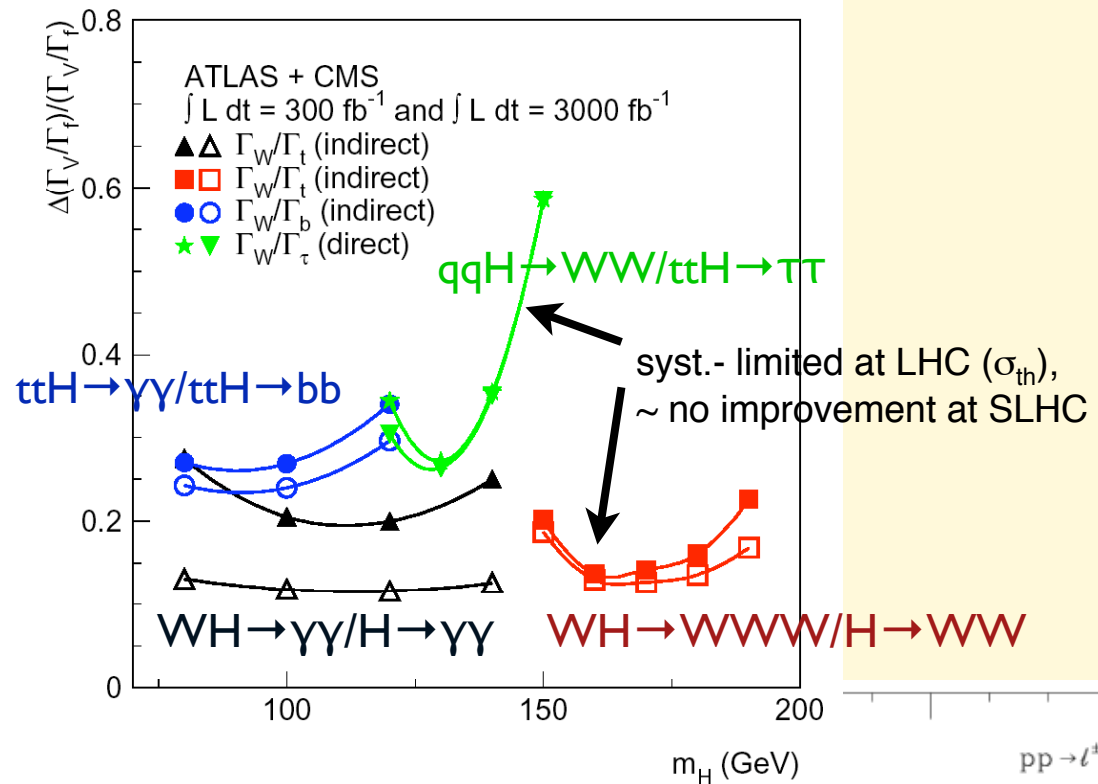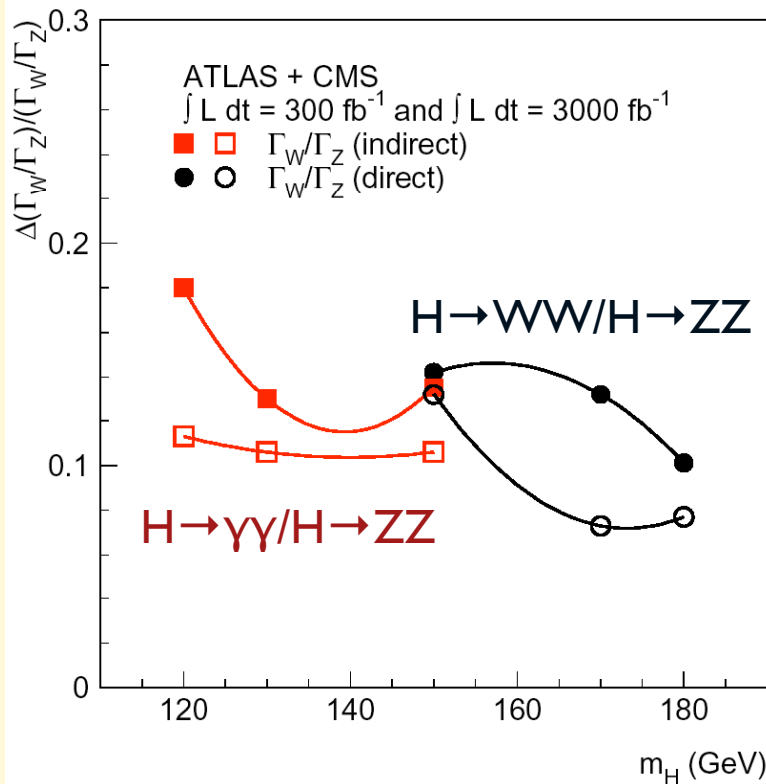
**Higgs boson couplings to fermions and gauge bosons**
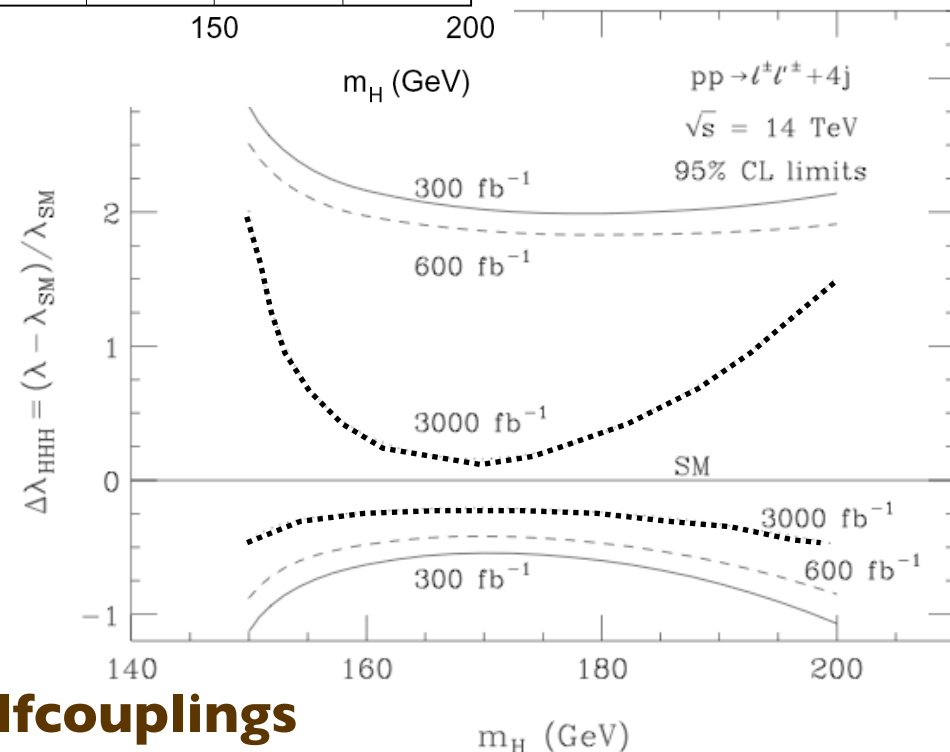
Higgs boson selfcouplings

Strong resonances in high-mass WW or WZ scattering

W, Z fusion/scattering :

S=6, B=2

$S/\sqrt{(B)}=10$

Vector resonance (ρ-like) in $W_L Z_L$ scattering from Chiral Lagrangian model
M = 1.5 TeV, leptonic final states, 300 fb^{-1} (LHC) vs 3000 fb^{-1} (SLHC)

Ex: Precise determinations of the self-couplings of EW gauge bosons

5 parameters describing weak and EM dipole and quadrupole moments of gauge bosons. The SM predicts their value with accuracies at the level of 10^{-3}, which is therefore the goal of the required experimental precision
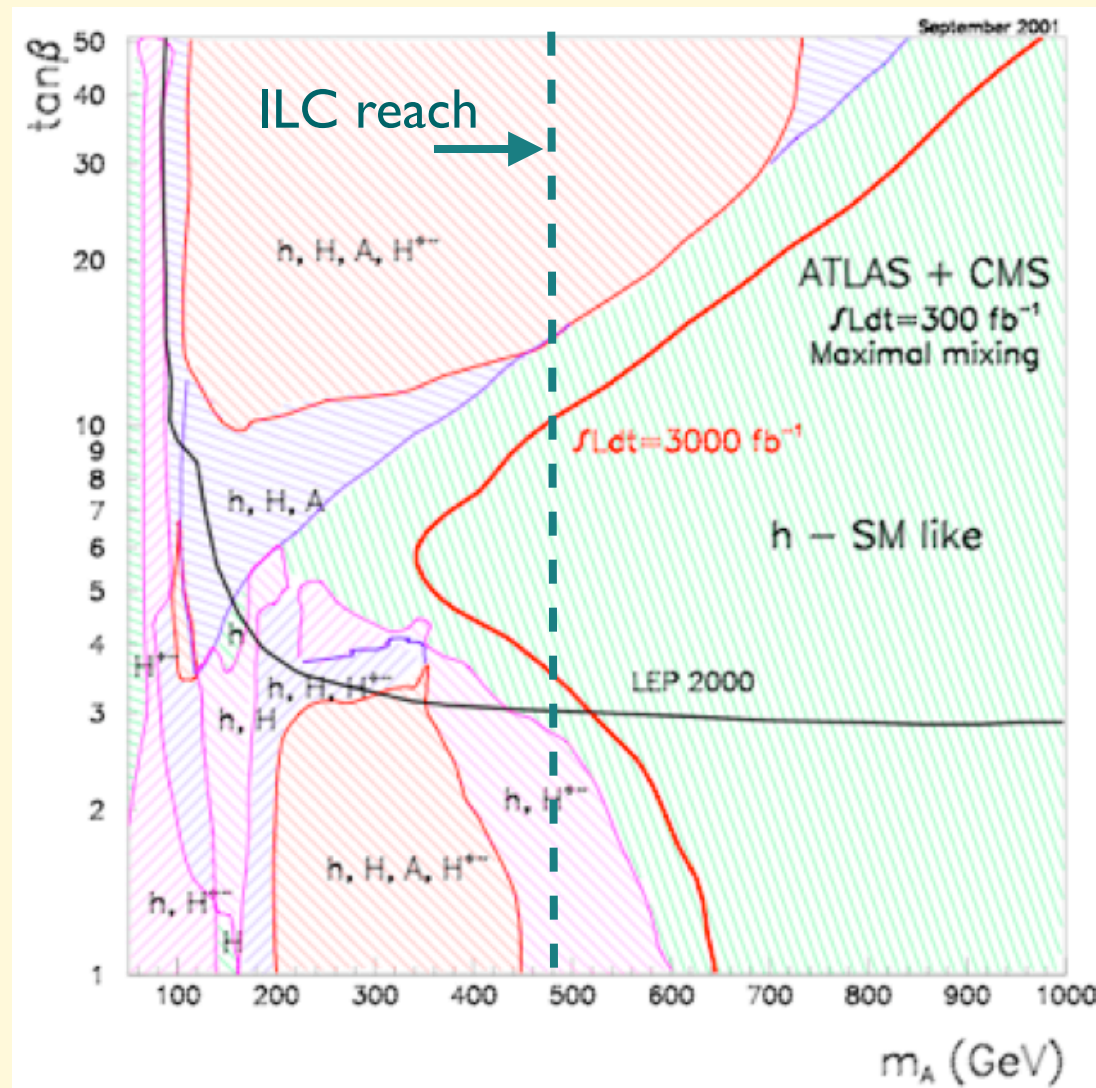

LHC options
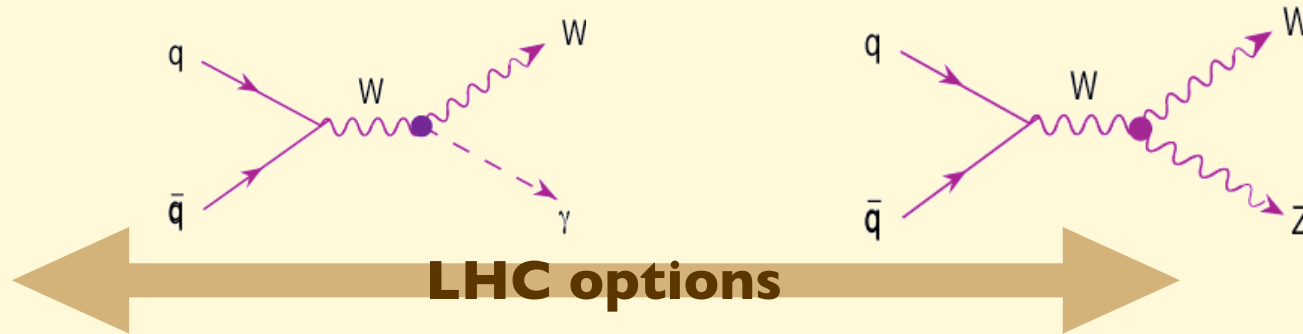
Coupling	14 TeV 100 fb^{-1}	14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}	28 TeV 1000 fb^{-1}	LC 500 fb$^{-1,}$ 500 GeV
λ_γ	0.0014	0.0006	0.0008	0.0002	0.0014
λ_Z	0.0028	0.0018	0.0023	0.009	0.0013
$\Delta\kappa_\gamma$	0.034	0.020	0.027	0.013	0.0010
$\Delta\kappa_Z$	0.040	0.034	0.036	0.013	0.0016
g^Z_1	0.0038	0.0024	0.0023	0.0007	0.0050

W, Z fusion/scattering :
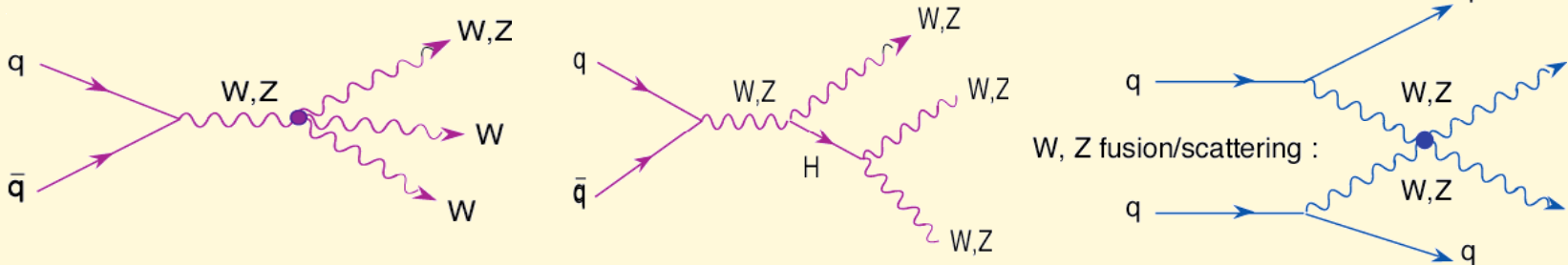
(LO rates, CTEQ5M, $k \sim 1.5$ expected for these final states)						
Process	*WWW*	*WWZ*	*ZZW*	*ZZZ*	*WWWW*	*WWWZ*
N(m_H = 120 GeV)	2600	1100	36	7	5	0.8
N(m_H = 200GeV)	7100	2000	130	33	20	1.6

Detecting the presence of extra H particles (as expected in SUSY)

SUSY reach and studies

Squark / gluino reach

CMS
E_t^{miss} + jets

Theorically excluded: $m(\tilde{\tau}_1) < m(\tilde{\chi}_1^0)$

$\sqrt{s}$ = 28 TeV: 100 fb^{-1}

$\tilde{q}(4000)$
$\tilde{g}(4000)$

$\sqrt{s}$ = 14 TeV: 1000 fb^{-1}, 2000 fb^{-1}

$\tilde{g}(3000)$

$\tilde{q}(3000)$

$\tilde{g}(2500)$

$\sqrt{s}$ = 14 TeV: 100 fb^{-1}, 200 fb^{-1}

$\tilde{q}(2500)$

$A_0 = 0$. $\tan\beta = 10$, $\mu > 0$

m_0 (GeV)

DD_3030

SLHC

LHC

Maintain excellent MET resolution

Maintain excellent bb mass resolution

Maintain excellent lept ID

Maintain excellent b tagging eff
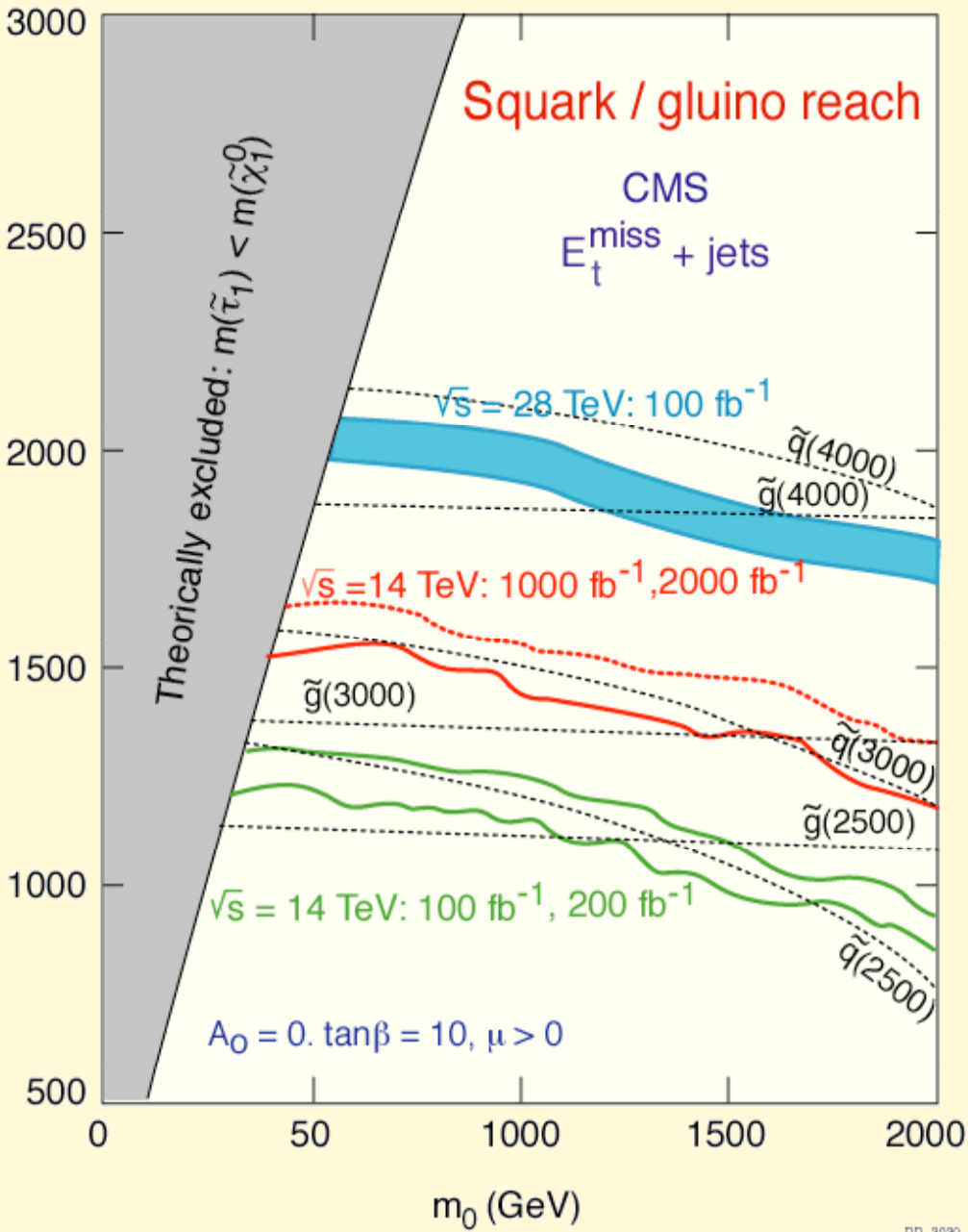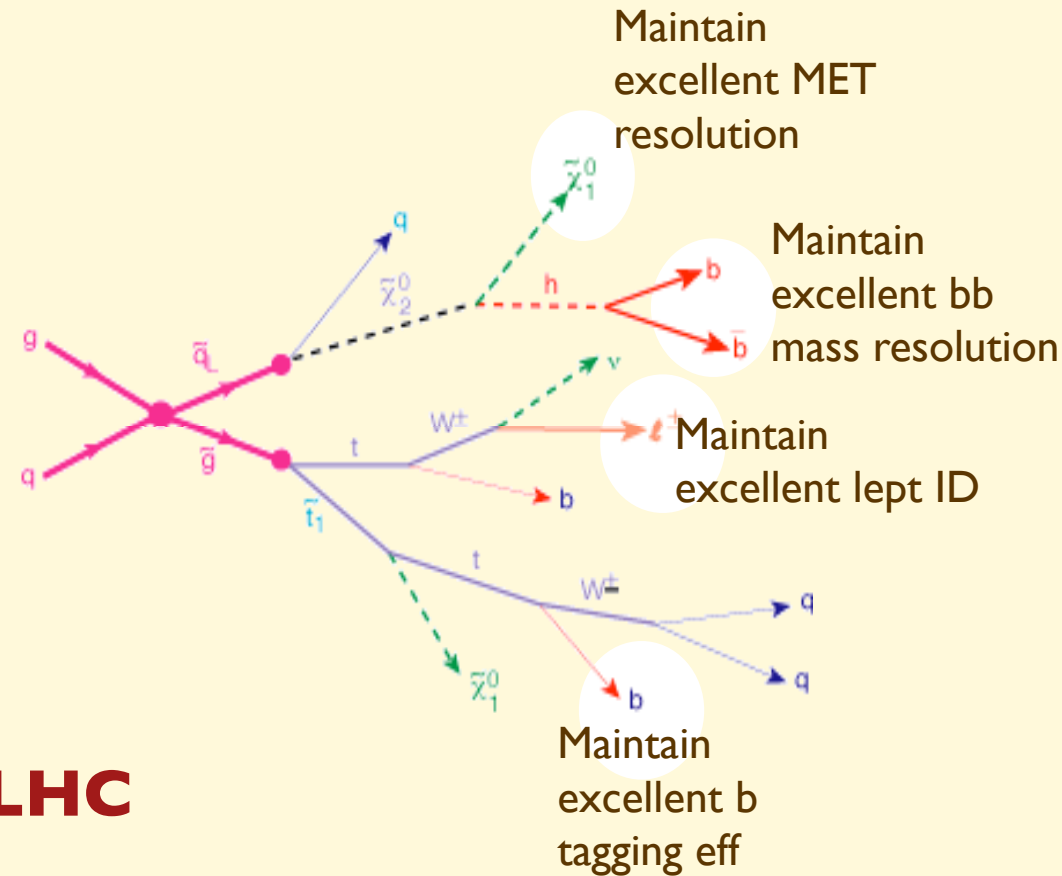
Mass reach: squarks and gluinos up to 2.5-3 TeV

Searching new forces: W', Z'

E.g. a W' coupling to R-handed fermions, to reestablish at high energy the R/L symmetry
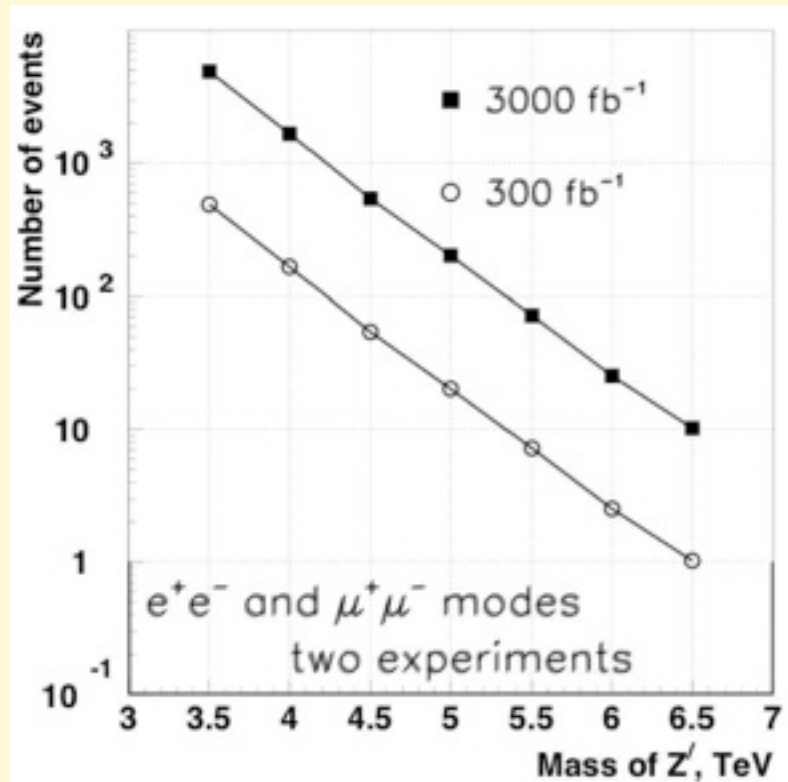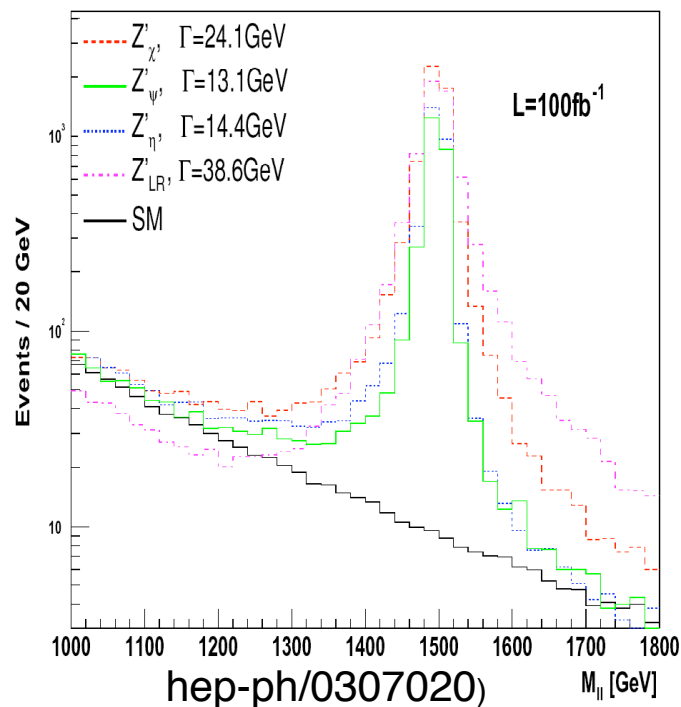

100 fb⁻¹ discovery reach up to ~ 5.5 TeV

but ....

Differentiating among different Z' models:

hep-ph/0307020)

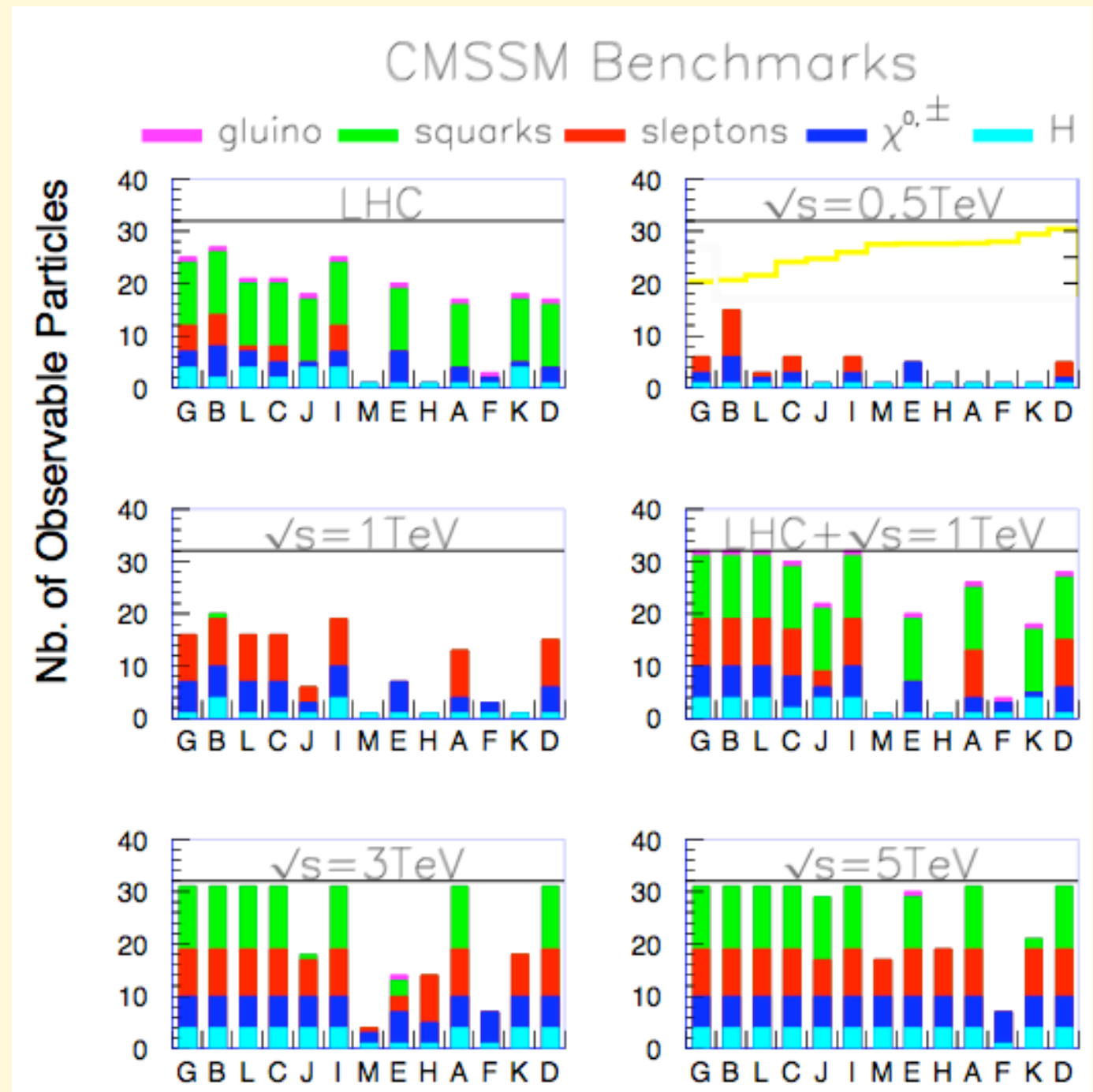**100 fb⁻¹ model discrimination up to 2.5 TeV**

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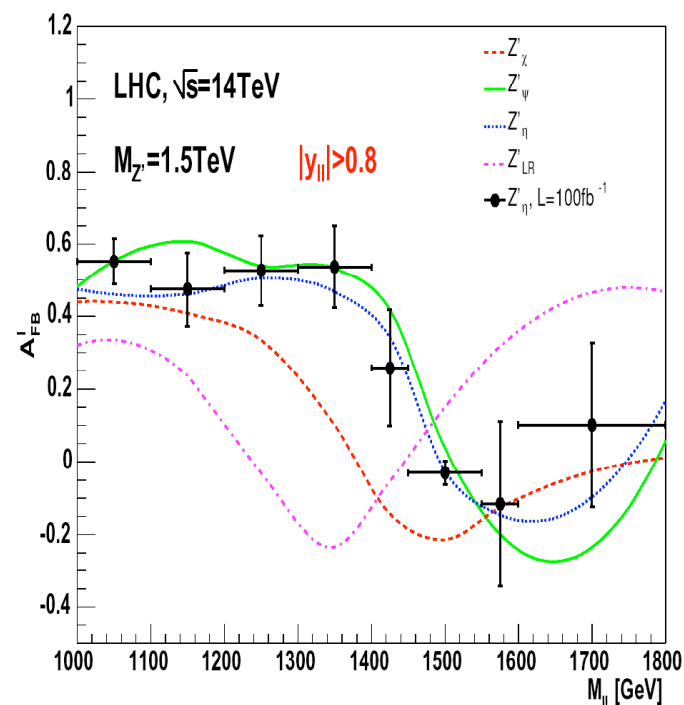
SUSY Beyond the LHC: ILC/CLIC

Example:
Exploration of the Supersymmetric particle spectrum, for 10 different SUSY models

Reference: Physics at CLIC, Battaglia, De Roeck, Ellis, Schulte eds., hep-ph/0412251

Neutrinos

- LEP: 3 weakly interacting neutrinos with $m < M_Z/2$

- 2 relative masses, one absolute mass scale, 3 mixing angles, 1 CKM phase δ, 2 extra relative phases if Majorana

$|\Delta m^2_{23}|$	Δm^2_{12}	m_1	$\sin^2\theta_{12}$	$\sin^2\theta_{23}$	$\sin^2\theta_{13}$	δ_i
$\sim 2.6 \times 10^{-3}$	$\sim 7 \times 10^{-5}$	?	0.2–0.4	0.3–0.7	<0.05	?

- Iff all $\theta_{ij} \neq 0$ and at least one phase $\delta \neq 0$, then CPV

  - Leptogenesis (lepton-driven B asymmetry of the Universe)

- Dark Matter: WMAP $\Rightarrow \Omega_\nu < 0.015$, $m_\nu < 0.23$ eV

The completion of the neutrino programme, with the full determination of

mass hierarchy

majorana vs dirac nature

full spectrum of masses and mixing angles

CPV phase(s)

will "just" put us in the position we are today in the quark sector: we know masses and mixings, but have no idea where they come from.

This is not enough.

- To interpret these parameters we need to establish a **connection with the other sectors of the theory**

- We need a **redundancy of inputs** to expose deviations from the simple mixing picture. The equivalent of all redundant measurements of CKM offered by the many channels where we measure CKM angles and phases
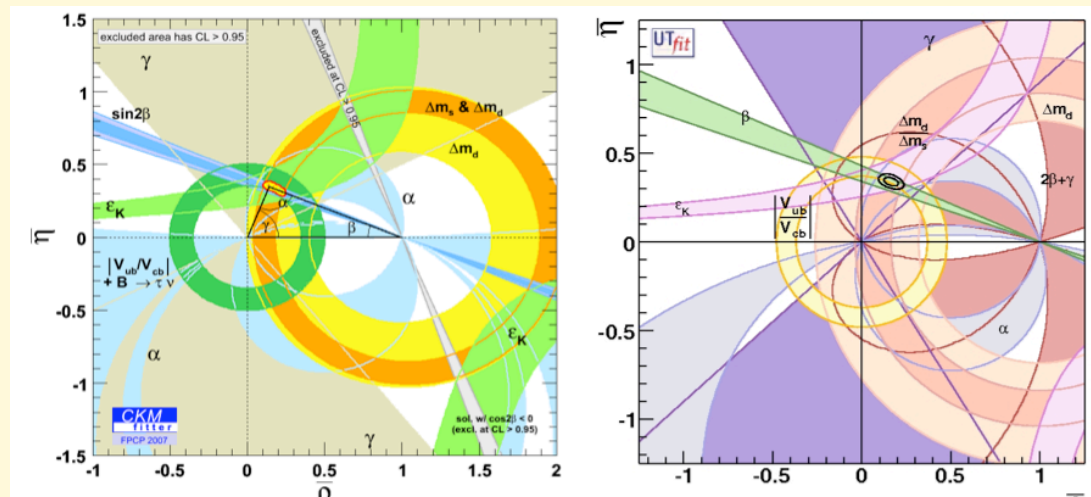
Neutrinos and SUSY

The merging of neutrino masses, SUSY and GUT leads to very interesting constraints and consequences:

SUSY $\Rightarrow$ Higgs field giving Dirac υ mass = Higgs field giving up-quark masses

$$L_m \propto y_\ell H_d L_i L_i^c + y_\nu^{ij} H_u L_i N_j + M_N^{ij} N_i N_j$$

GUT (e.g. SO(10)) $\Rightarrow$ Yukawa ν-mass matrix = Up-quark Yukawa matrix

$$L_m \propto y_{i,j}^{d,\ell} \mathbf{16}_i \mathbf{16}_j H_d + y_{i,j}^{u,\nu} \mathbf{16}_i \mathbf{16}_j H_u + y_{i,j}^{R} \mathbf{16}_i \mathbf{16}_j H_R^{126}$$

where $\quad \mathbf{16} = (u_L, d_L, u^c, e^c)_{10} + (d^c, L)_5 + N^c$

$\Rightarrow$ one entry in the neutrino Yukawa matrix is of order of the top Yukawa coupling!

$\Rightarrow$ m(N_R) = f(m_{up}, m_ν) $\approx$ (m_t^2 / m_ν, m_c^2 / m_ν, m_u^2 / m_ν)

$\Rightarrow$ $m_\nu > m_t^2 / M_{GUT}$ to ensure that m(N_R) < M_{GUT}

Even more interestingly, quark mixings induce charged **slepton** mixing via RG evolution from M_{GUT} to $m(N_R)$:
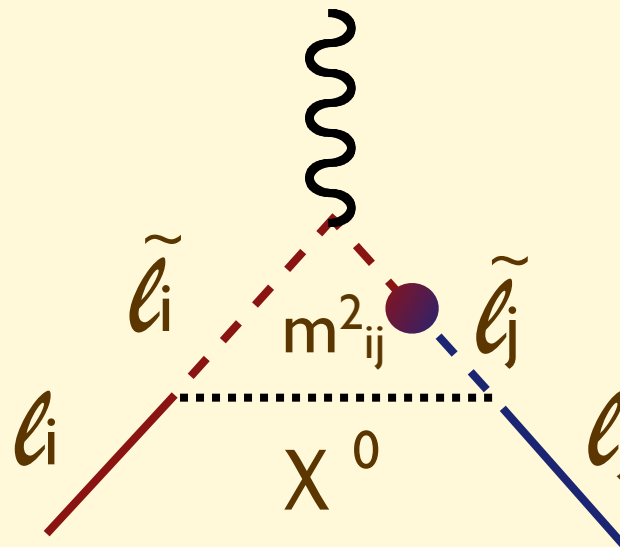
$$(m_{\tilde{L}}^2)_{ij} \sim -\frac{3m_0^2 + A_0^2}{8\pi^2} y_t^2 \, O_{ij} \log \frac{M_{GUT}}{M_{N_R}}$$

SUSY breaking param's

nu mixing param's

$$y_t^2 \, O_{ij} = \sum_k y_{ik}^\nu \, y_{jk}^{\nu*}$$

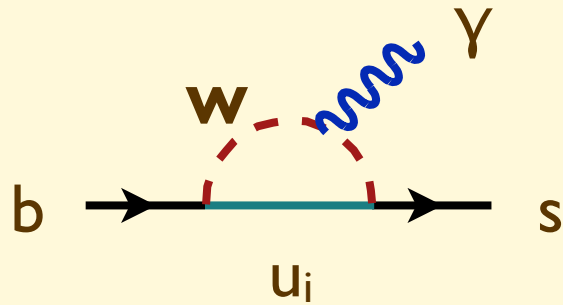$\ell_i \rightarrow \ell_j \, \gamma$ transitions:

Possible scenarios:

$O_{\mu e} = V_{td} \, V_{ts}$ "CKM
$O_{\tau\mu} = V_{tb} \, V_{ts}$ scenario"

$O_{\mu e} = U_{e3} \, U_{\mu 3}$ "MNS
$O_{\tau\mu} = U_{\tau 3} \, U_{\mu 3}$ scenario"

In the SM

GIM

$$\propto \left| \frac{m_c^2 - m_u^2}{m_W^2} V_{cb}V_{cs}^* + \frac{m_t^2 - m_u^2}{m_W^2} V_{tb}V_{ts}^* \right|^2 \sim \frac{m_t^4}{m_W^4} |V_{tb}V_{ts}^*|^2$$
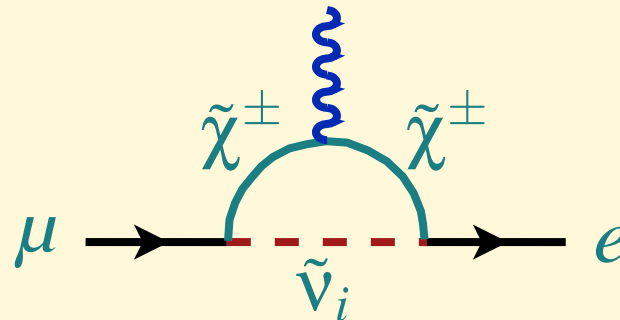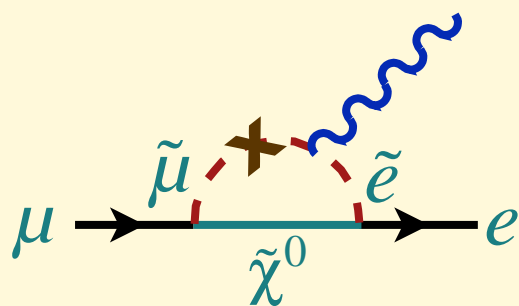
O(1)
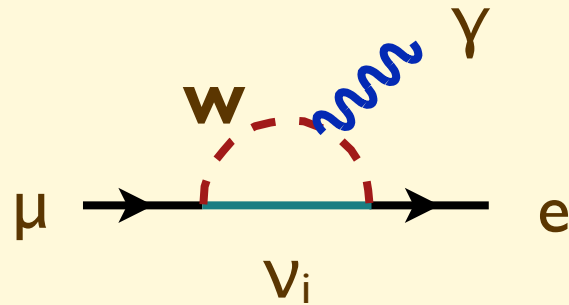
$$\propto \left| \frac{m_1^2 - m_2^2}{m_W^2} M_{12}M_{11}^* + \frac{m_3^2 - m_2^2}{m_W^2} M_{32}M_{31}^* \right|^2 \sim \frac{\Delta m_{23}^4}{m_W^4} s_{23}^2 c_{31}^2 s_{31}^2$$

O(10⁻⁴⁹)

The smallness of B($\mu \to e\gamma$) is entirely due to the smallness of ν masses (and splittings)

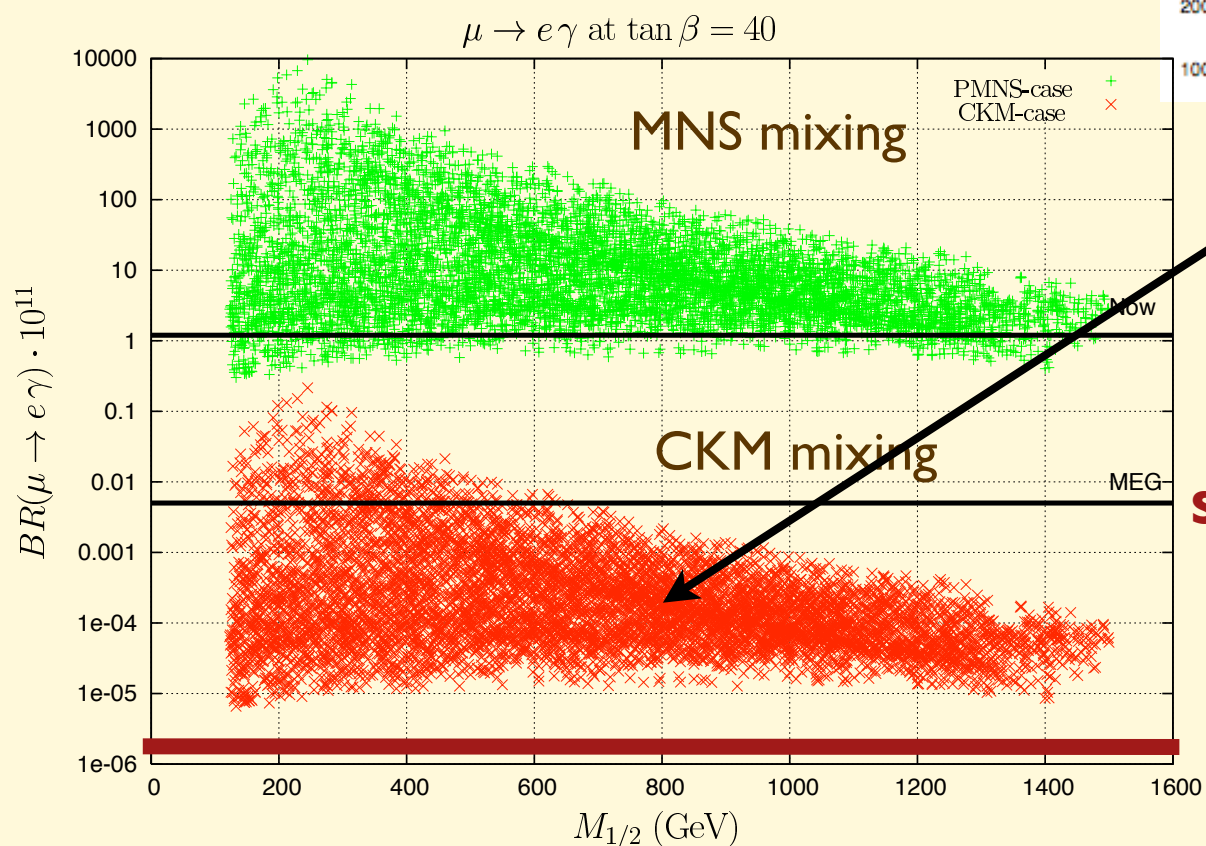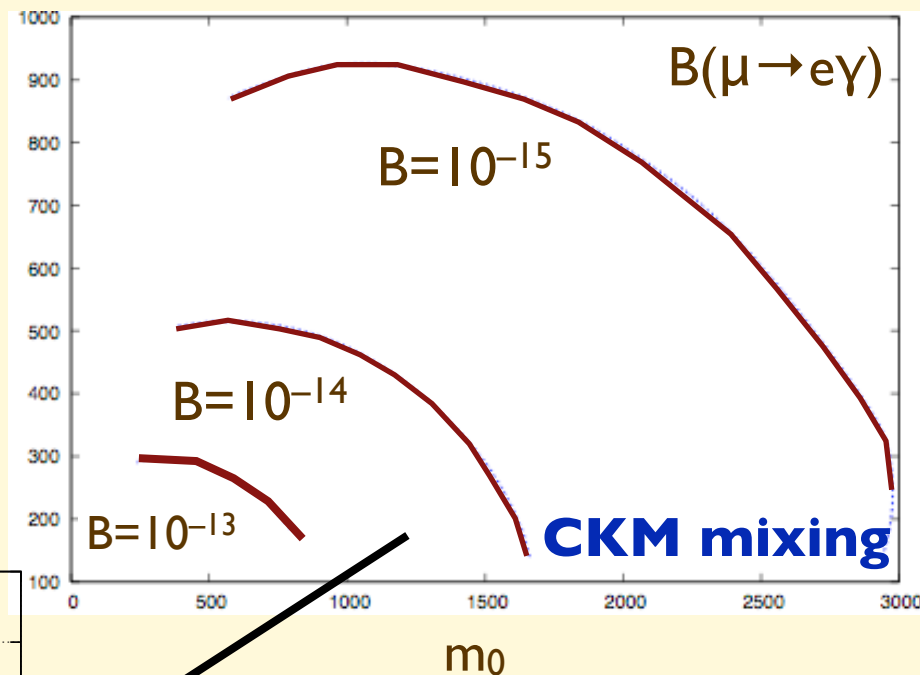The moment we have new states in the loop, the rates goes up!

Example: SUSY

$$B \propto \left| \frac{\Delta m^2(\tilde{\nu})}{m_{\tilde{\chi}}^2} \times \varepsilon_{12}^2 \right|^2$$

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Examples of LHC-(μ→eγ) sinergy:

SO(10) GUT scenario, slepton mixign induced by RG evolution

To push to the ultimate LHC squark reach (m~2.5–3 TeV) may require sensitivity to B(μ→eγ) ~ 10^{-15}

$m_{1/2}$

B(μ→eγ)

B=10^{-15}

B=10^{-14}

B=10^{-13}

CKM mixing

m_0

$\mu \rightarrow e\gamma$ at $\tan\beta = 40$

MNS mixing

PMNS-case +
CKM-case ×

Now

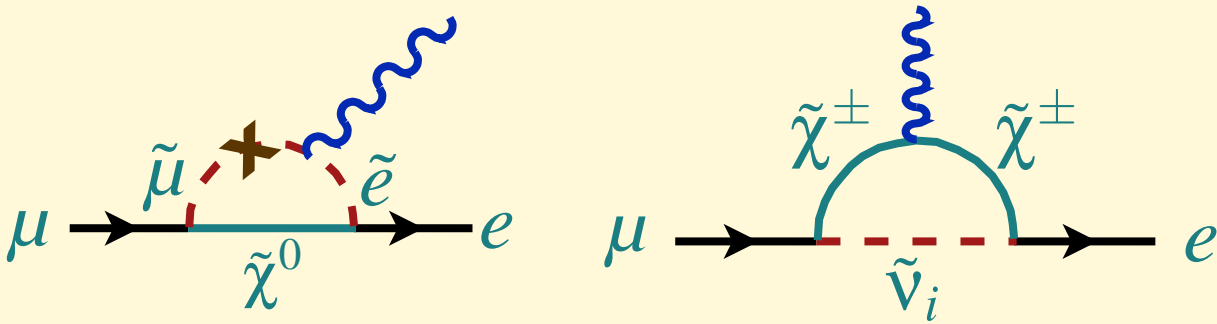CKM mixing

MEG

$BR(\mu \rightarrow e\gamma) \cdot 10^{11}$

$M_{1/2}$ (GeV)

SO(10) mSUGRA scan
with m(squark)<2.5 TeV
Calibbi et al, hep-ph/0605139

Sensitivity of MEG experiment

**Sensitivity of
Project-X mu2e conversion**

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Neglecting mixing, these diagrams are also responsible for (g-2)$_\mu$
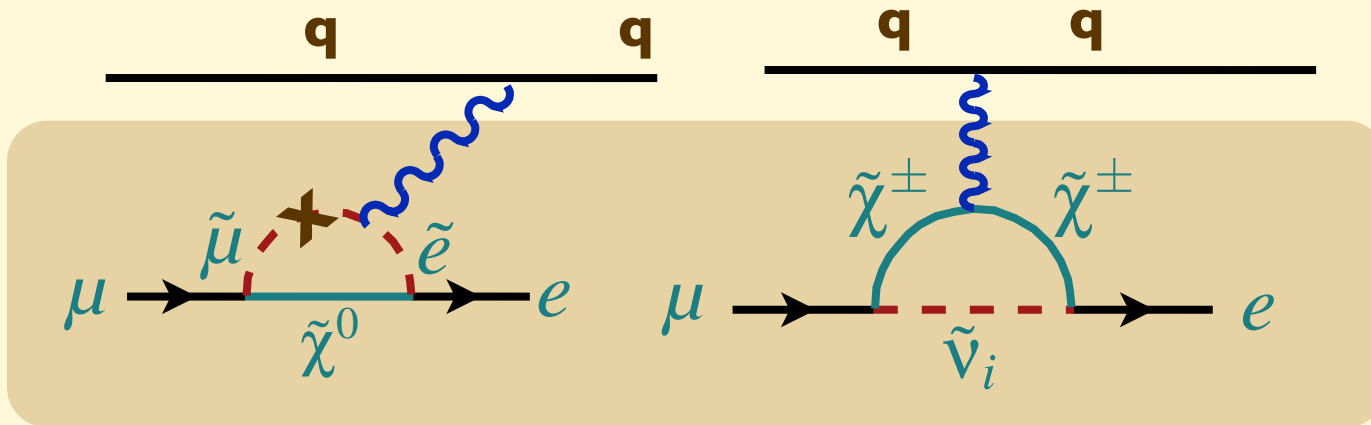
Assuming that the BNL data are explained by SUSY,

$$\text{(g-2)}_\mu{}^{\text{data}} - \text{(g-2)}_\mu{}^{\text{SM}} = \text{(g-2)}_\mu{}^{\text{SUSY}}$$
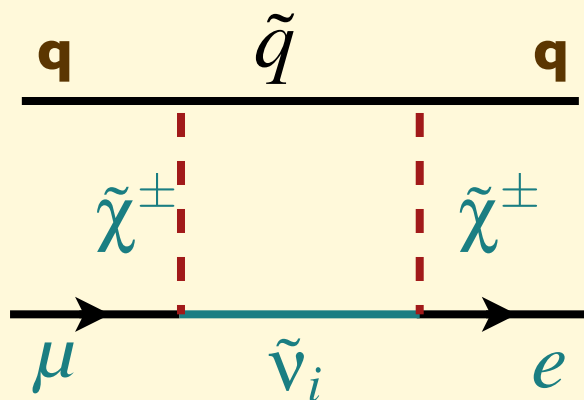
sets a scale for m(SUSY) ~ 100 GeV

Current B($\mu \to e\gamma$) limits then indicate mass splittings in the slepton sector of few 10s MeV !!

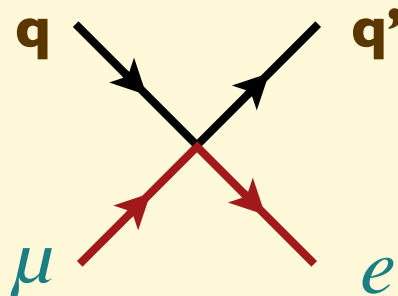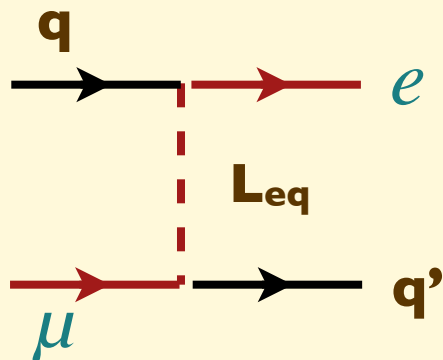**Sensitive to natural mass splittings m($\tilde\mu$)-m($\tilde e$) ~ O(m$_\mu$)**
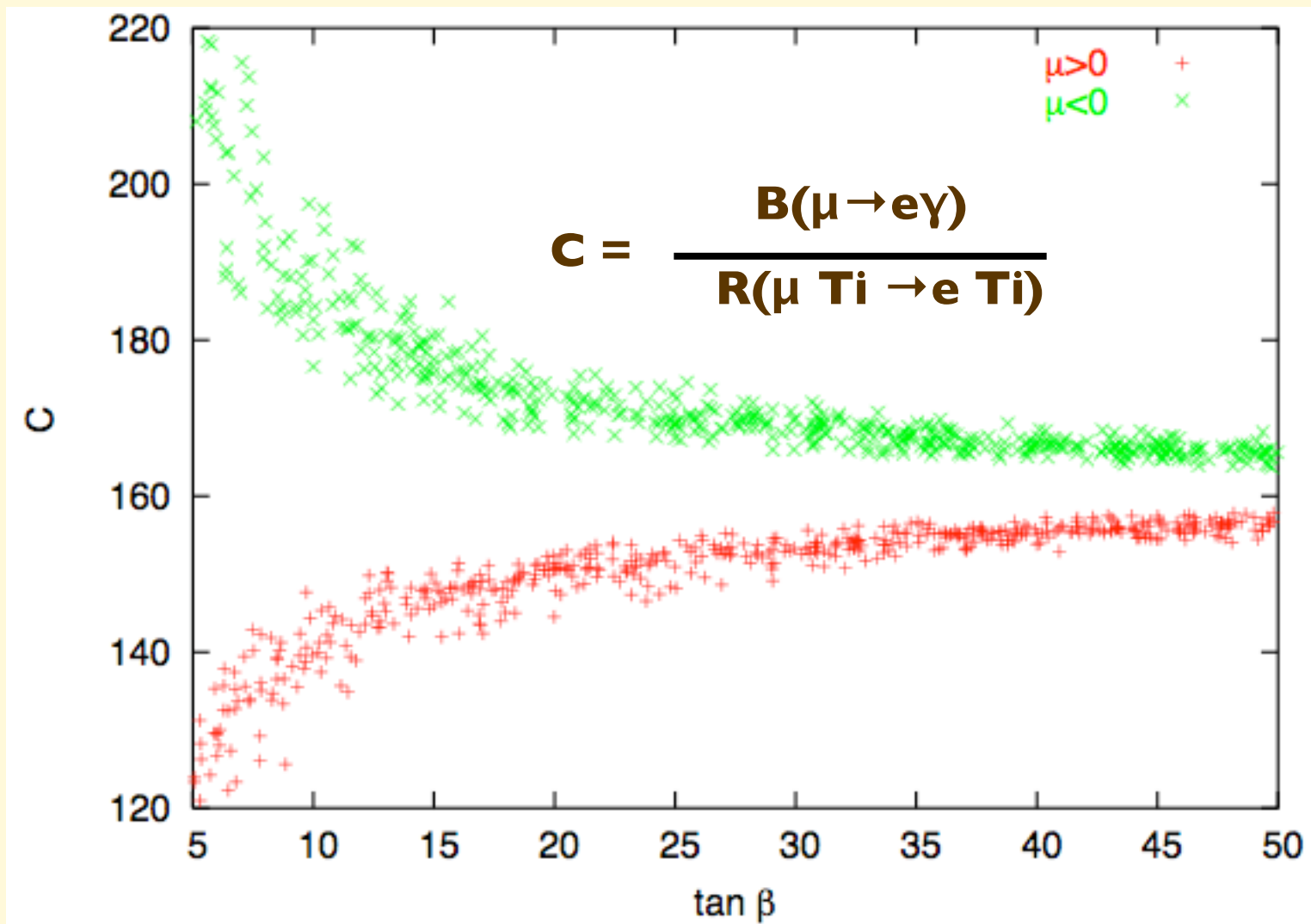
μ→eγ vs μN→eN complementarity

μ→eγ diagrams

extra contributions,
sensitive to additional
model parameters

extra contributions,
sensitive to other
underlying dynamics

K→eμ?

$$C = \frac{B(\mu \rightarrow e\gamma)}{R(\mu\ Ti \rightarrow e\ Ti)}$$

C Yagouna, hep-ph/0502014

More physics with charged leptons

- μ→eee (typically $O(\alpha)$, but $O(1)$ in LH models)

- τ →μ γ τ→e γ : model-dependent correlations with μ →eγ

- τ →μμμ (LHCb ?)

- CP violation in SM-allowed τ decays?

  - $O(10^{-3})$ CP asymmetry in τ →νKπ ⇨ B(τ →μ γ) ~ $O(10^{-9})$

- .....

# Example of correlations between ν and quark-sector observables

$$L_m \propto y_{i,j}^{d,\ell} \mathbf{16}_i \mathbf{16}_j H_d + y_{i,j}^{u,\nu} \mathbf{16}_i \mathbf{16}_j H_u + y_{i,j}^{R} \mathbf{16}_i \mathbf{16}_j H_R^{126}$$

$$\mathbf{16} = (u_L, d_L, u^c, e^c)_{10} + (d^c, L)_5 + N^c$$

A large mixing between ν_μ and ν_τ implies a large mixing between

$$(b_R , \bar{\nu}_\tau , \tau^+) \qquad (s_R , \bar{\nu}_\mu , \mu^+)$$

This has no impact on phenomenology, since right-handed quarks do not couple to weak interactions. However it leads to a large mixing between the scalar partners of R-handed squarks, and to interactions like
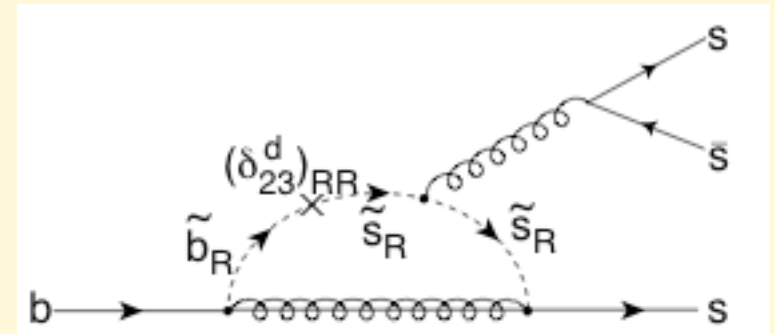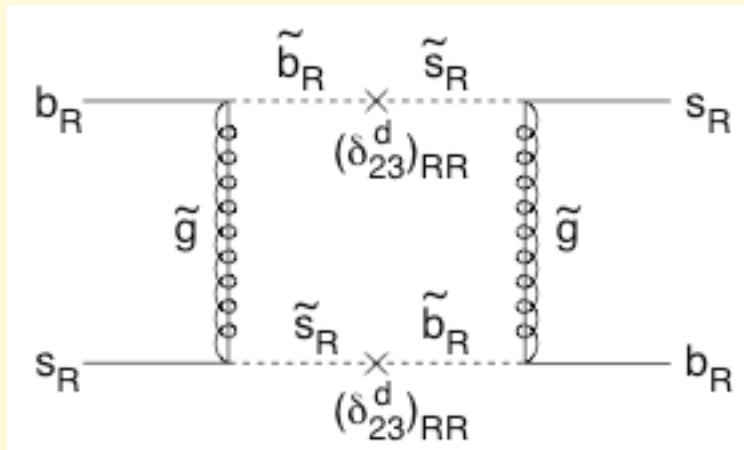
with potentially large contributions to:

Bs mixing, CP violation in Bs→φψ (~0 in the SM)

$$\sin 2\beta(B \to \phi K_s)$$
$$\neq \sin 2\beta(B \to \psi K_s)$$

μ → e γ

Current limits on B(μ → e γ)

mode	upper limit (90% C.L.)	year	Exp./Lab.
$\mu^+ \to e^+\gamma$	1.2×10^{-11}	2002	MEGA / LAMPF
$\mu^+ \to e^+e^+e^-$	1.0×10^{-12}	1988	SINDRUM I/ PSI
$\mu^+e^- \leftrightarrow \mu^-e^+$	8.3×10^{-11}	1999	PSI
$\mu^- \text{Ti} \to e^-\text{Ti}$	6.1×10^{-13}	1998	SINDRUM II / PSI
$\mu^- \text{Ti} \to e^+\text{Ca}^*$	3.6×10^{-11}	1998	SINDRUM II / PSI
$\mu^- \text{Pb} \to e^-\text{Pb}$	4.6×10^{-11}	1996	SINDRUM II / PSI
$\mu^- \text{Au} \to e^-\text{Au}$	7×10^{-13}	2006	SINDRUM II / PSI

Future:

near: μ → e γ

MEG at PSI http://meg.web.psi.ch/

o First data taking 2008, single-event sensitivity at BR<**5x10⁻¹²**

o New run Oct 2009, single-event sensitivity at BR<**5x10⁻¹³**

o ultimate sensitivity: BR<**1x10⁻¹⁴** at 90%CL by 2011
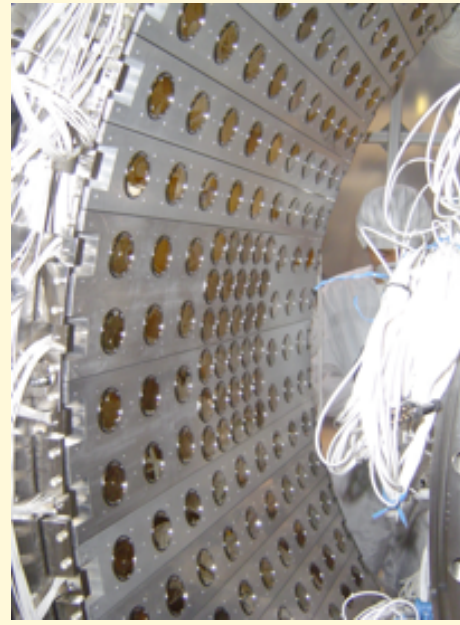
far: μ → e conv

MU2e at Fermilab

o Up for 1st stage DoE approval this Summer, could be taking data by 2016

o sensitivity: R(μ → e) < **6x10⁻¹⁷** @90%CL →**10⁻¹⁸** with Project-X

(i.e. BR< **~10⁻¹⁴** if only (μ → e γ) diagrams contribute)

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EDMs

● **Flavour-conserving CPV**

● **Sensitive probes of CPV in extended gauge sectors (e.g. SUSY gluinos, gauginos, higgsinos)**
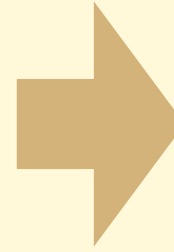
➡ **Probes of mechanisms to generate the antimatter asymmetry of the universe**

d_e / d_n correlations:

SUSY: d_e / $d_n \sim m_e/m_q \sim 0.1$

mSUGRA

no gaugino unification at GUT

large gluino CPV phases

Extra-dim, 2HDM: d_e / $d_n \ll 1$

40

Atoms:

    paramagnetic (Tl):   – **fundamental electron EDM**

                                   – **CPV eeqq interactions**
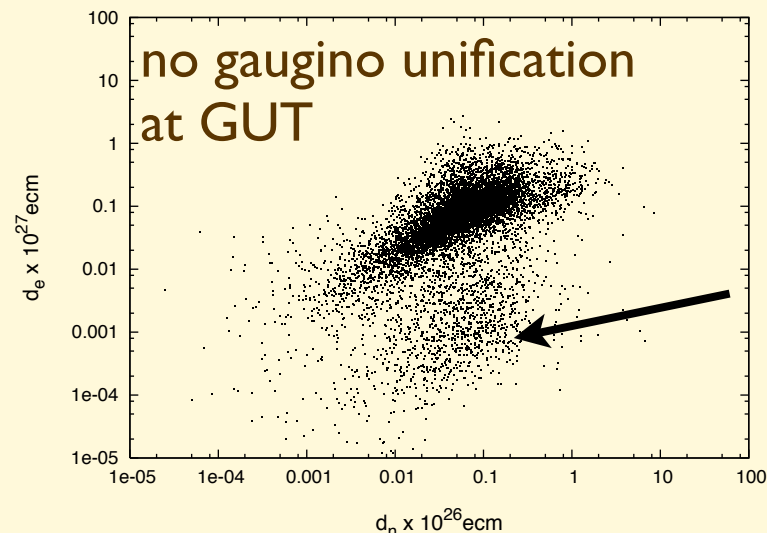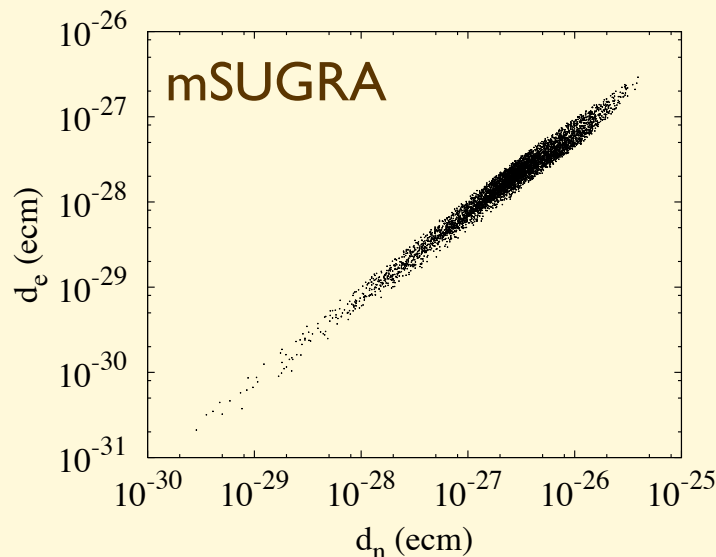
    diamagnetic (Hg):   – **fundamental electron EDM**

                                   – **fundamental quark EDM and θ_{QCD}**

                                   – **CPV eeqq interactions**

**heavy molecules
with unpaired**   – **fundamental electron EDM**
electrons (YbF):

Neutron:

          – **fundamental quark EDM and θ_{QCD}**
          – **higher-dim CPV qq operators (int^{ns} with
gluinos, etc)**

Neutron EDM

Current limit: $d_{neutron} = 3 \times 10^{-26}$ e cm

C.A. Baker et al, (RAL, Sussex, ILL Grenoble)
http://arxiv.org/pdf/hep-ex/0602020

Forthcoming experiments with ultracold neutrons:

ILL (Grenoble) and **PSI**

o R&D and construction of new detectors/beamline

o new runs 2009-2011 (ILL) and 2011-2014 (PSI)

o Goal: $d_{neutron} < \sim 2 \times 10^{-28}$ e cm/yr

⇨ **probe SUSY CPV phase of O(10^{-4})**

Deuteron EDM in a storage ring

Orlov, Morse, Semertzidis,
http://arxiv.org/pdf/hep-ex/0605022

o Inject deuterons from LEIR, CERN's low-energy ion ring used to prepare heavy ion beams for the LHC

o Sensitivity: $\sigma_d = 2.5 \times 10^{-29}$ e cm/yr

1.5 GeV

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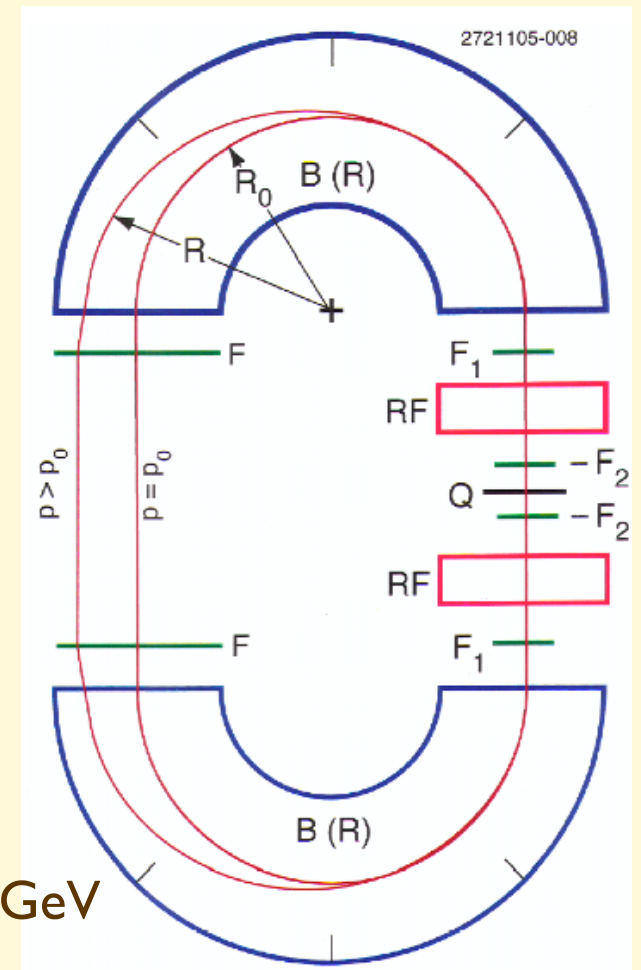
Rare K decays

$K_L^0 \to \pi^0 \nu \nu$ $B(K_L^0 \to \pi^0 \nu \nu)_{SM} = \mathbf{2.8 \pm 0.4 \times 10^{-11}}$

E391 at KEK, ongoing

E14 at JPARC
http://www-ps.kek.jp/jhf-np/NuclPart/0701/
Day2_AM/E14.ppt.pdf

o Being reviewed for approval by JPARC PAC

o Detector completion: 2008-09

o Beam survey: 2008-09

o Data: 2010-20

o Goal: $O(10^{-13})$, $\Delta BR \sim 10\%$
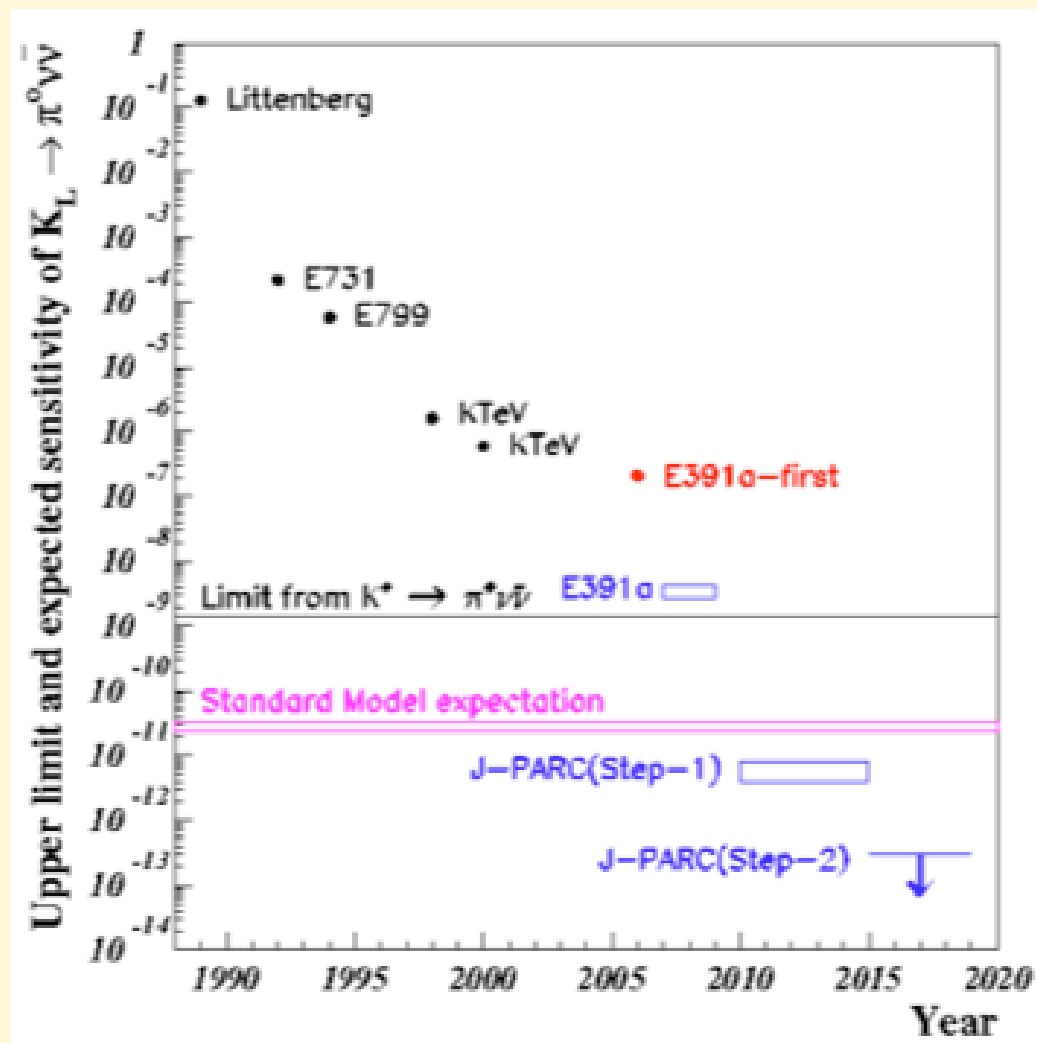
$K^+ \to \pi^+ \nu \nu$ $B(K^+ \to \pi^+ \nu \nu)_{E787/949\ BNL} = $ **$1.5 \pm 1 \times 10^{-10}$** (3 events, hep-ex/0403036)
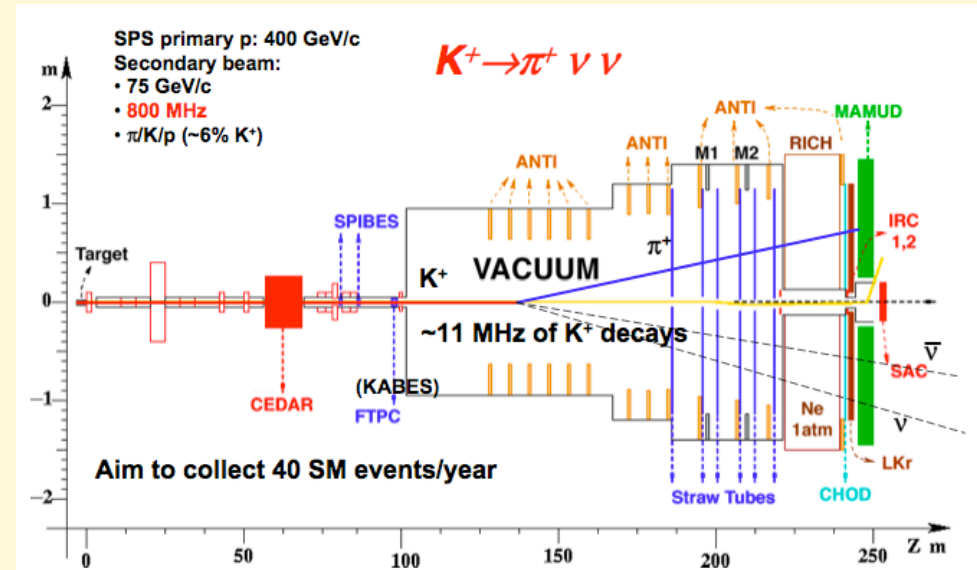
$B(K^+ \to \pi^+ \nu \nu)_{SM} = $ **$8.0 \pm 1.1 \times 10^{-11}$**   Expected reduction to 4% error via NNLO +better input parameters (m_{top}, etc)

NA62, a.k.a. NA48/3 or P-326

http://na48.web.cern.ch/NA48/NA48-3/

o R&D ongoing, with 2007 run for
$R_{e/\mu} = \Gamma(K \to e\ \nu) / \Gamma(K \to \mu\ \nu)$ to 0.3%

o Construction (once approved): ~2 yrs

o Goal: 80 events (@SM rate) in 2 yrs of run, S/B=10/1 $\Rightarrow \delta|V_{td}|$=10%

SPS primary p: 400 GeV/c
Secondary beam:
- 75 GeV/c
- 800 MHz
- π/K/p (~6% K⁺)

$K^+ \to \pi^+ \nu \nu$

~11 MHz of K⁺ decays

Aim to collect 40 SM events/year

$K_L^0 \to \pi^0 e^+ e^-$ $K_L^0 \to \pi^0 \mu^+ \mu^-$ NA48/4

$K_L^0 \to \pi^0 \nu \nu$ NA48/5

Require more protons than available from the SPS today

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It's a dream, but not an impossible one !

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Conclusions

- **Progress in the field will be 100% driven by new and better experimental data.** We are running out of ideas and tools to make progress based on first principles only.

- Nevertheless, we created scenarios for BSM physics which, in addition to addressing the most outstanding **theoretical puzzles** and the **established deviations** from the SM (DM, BAU, nu mixing), predict galore of new phenomena at energy and accuracy scales just behind the corner

- Maintaining **diversity** in the exp'l programme is our best investment for HEP.