Search for SUperSYmmetry in hadronic channels with the CMS detector at the CERN LHC

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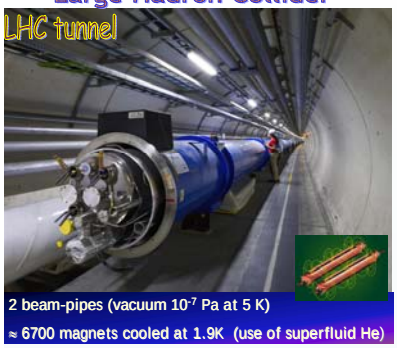
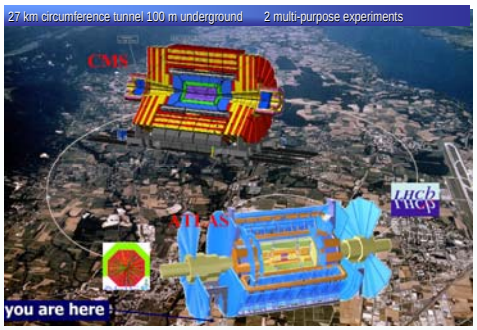
Sciences

CMS collaboration :38 nations - 155 institutes - 2000 physicists & engineers - ≈450 students

Large Hadron Collider

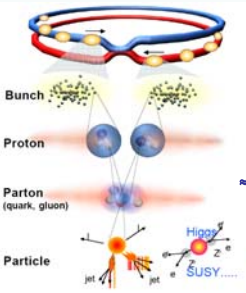




Compact Muon Solenoid

- cylinder 21 m long, 15 m high
- superconductor solenoid 13m long, 6 m ∅
- tracker based on Si strips and Si pixels
- 75 (66+9 tracker) millions of electronic readout channels

proton - proton collisions



Proton-Proton	2835 bunch/beam
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2}s^{-1} Design luminosity
Crossing rate	40 MHz

Beam collision every 25 ns !

Collisions rate ≈ 10^{7} - 10^{9} Hz

≈20 pp collisions per bunch crossing

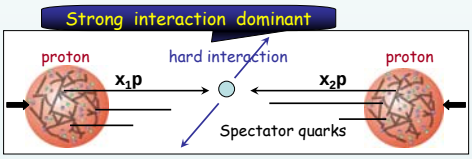
New physics rate ≈ .00001 Hz

Event selection: 1 in 10,000,000,000,000

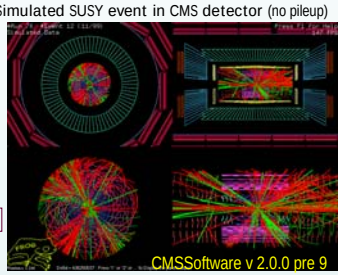
Hard p-p collision : *only a fraction of the proton energy available* for the hard parton interaction ⇨ rest = underlying event

Numerous soft (not interesting pp collisions) ⇨ minimum bias events

numerous tracks >1000



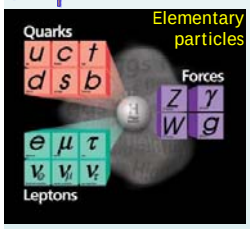
Simulated SUSY event in CMS detector (no pileup)



Our present understanding of particle physics : the Standard Model

SM explains present experimental results with agreement from 10^{-2} to 10^{-4}

One missing experimental piece : the Higgs-Brout-Englert boson !



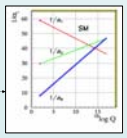
Theoretical framework : relativistic quantum field theory (Quantum Mechanics + Special Relativity)

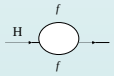
Local internal (gauge) symmetries, governed by a SU(3)xSU(2)xU(1) algebra leading to strong and electroweak interactions mediated by gluons, W/Z massive bosons and photons (QCD and electroweak theory)

3 families of matter particles, quarks and leptons, with diverse masse spectra : 10^{-8} GeV (ν) → 10^{2} GeV (top, W/Z)

SM limitations ...

- Many free parameters (18)
- Gravitation not included
- Interaction coupling constants not unified
- Higgs mechanism introduced by "hand "
- Instability of Higgs mass (quadratic divergences)





Open questions ...

Is the Higgs mechanism the right one for particle mass generation ?

Do quarks and leptons have a structure ?

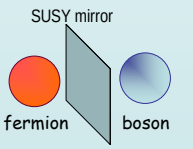
What 96% of the Universe made of ? Why is there no anti-matter ?

Extra - dimensions of the Universe ? Dark matter nature ?

Physics beyond the Standard Model

The most promising theoretical model based on : SUperSYmmetry

Symmetry between fermions and bosons

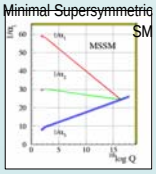


SUper SYmmetry can not be exact :
$m_{part} \neq m_{SUSYpartner}$
⇳ must be broken

SM Spin 1/2	Susy Particle Spin 1
$\begin{pmatrix} e_{L,R} \\ \nu_{eL} \end{pmatrix}, \begin{pmatrix} \mu_{L,R} \\ \nu_{\mu L} \end{pmatrix}, \begin{pmatrix} \tau_{L,R} \\ \nu_{\tau L} \end{pmatrix}$	$\begin{pmatrix} \tilde{e}_{L,R} \\ \tilde{\nu}_{eL} \end{pmatrix}, \begin{pmatrix} \tilde{\mu}_{L,R} \\ \tilde{\nu}_{\mu L} \end{pmatrix}, \begin{pmatrix} \tilde{\tau}_{L,R} \\ \tilde{\nu}_{\tau L} \end{pmatrix}$
$\begin{pmatrix} u_{L,R} \\ d_{L,R} \end{pmatrix}, \begin{pmatrix} c_{L,R} \\ s_{L,R} \end{pmatrix}, \begin{pmatrix} t_{L,R} \\ b_{L,R} \end{pmatrix}$	$\begin{pmatrix} \tilde{u}_{L,R} \\ \tilde{d}_{L,R} \end{pmatrix}, \begin{pmatrix} \tilde{c}_{L,R} \\ \tilde{s}_{L,R} \end{pmatrix}, \begin{pmatrix} \tilde{t}_{L,R} \\ \tilde{b}_{L,R} \end{pmatrix}$
SM Spin 1,0	**Susy Particle Spin 1/2**
neutral bosons: γ, Z, h, H, A	neutralinos: $\tilde{\chi}_1^0$, $\tilde{\chi}_2^0$, $\tilde{\chi}_3^0$, $\tilde{\chi}_4^0$
charged bosons: $W^{\pm}$, $H^{\pm}$	charginos: $\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_2^{\pm}$, $\tilde{\chi}_3^{\pm}$, $\tilde{\chi}_4^{\pm}$
gluon: g	gluino: $\tilde{g}$

SUSY advantages ...

- SM reproduced at low energies
- Converging coupling constants
- Gravitation introduced **(certain models)**
  - *SUSY can be broken by gravitation*
- Quadratic divergences naturally suppressed
- Lightest Supersymmetric Particle (LSP) = stable ⇨cold dark matter candidate (certain models)
- Many new parameters introduced (105)



LHC physics aims

Test of the standard model at TeV scale.

Discovery of the Higgs boson ?

Discovery of new physics ? SUSY ?

Mons participation

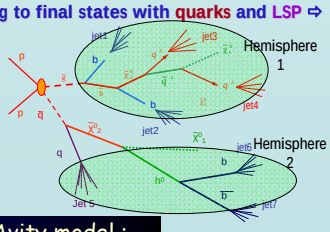
Inclusive search for SUSY in final states with hadronic jets and missing transverse energy

Expected SUSY event topology : 2 decay chains leading to final states with quarks and LSP ⇨ signature in the detector : hadronic jets & missing transverse energy (MET)

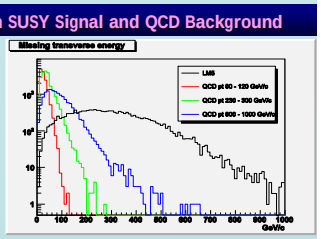
Example: $pp \to \tilde{g}\tilde{q} + \text{spectator quarks}$

∈ gluino decay: $\tilde{g} \to b\tilde{b} \to bb\tilde{\chi}_2^0 \to bbq\tilde{q} \to bbqq\tilde{\chi}_1^0$

∈ squark decay: $\tilde{q} \to q\tilde{\chi}_2^0 \to qh^0\tilde{\chi}_1^0 \to qb\bar{b}\tilde{\chi}_1^0$



MET = variable to distinguish between SUSY Signal and QCD Background



Need good detector calibration
Not usable in the beginning

In the framework of the minimal SUperGRAvity model : 5 free parameters

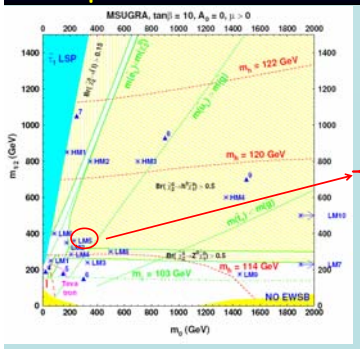


Table 1: Some sparticle masses at LM5.

Sparticle	Mass (GeV/c^2)
$\tilde{g}$	860
$\tilde{q}$	800
$\tilde{\chi}_2^0$	273
$\tilde{\chi}_1^0$	142
h^0	116

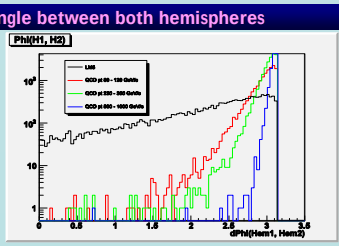
Table 2: Interesting branching ratios at LM5.

Decay	Branching ratio in %
$\tilde{g} \to \tilde{q} + q$	100
$\tilde{q} \to \tilde{\chi}_2^0 + q$	35
$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 + h^0$	85
$h^0 \to b\bar{b}$	72
$\tilde{q} \to \tilde{\chi}_2^0 + q$ and $\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 + h^0 \to \tilde{\chi}_1^0 + b\bar{b}$	21

Table 3: Cross section for the relevant processes.

Processes	Total cross section (pb)
All SUSY at LM5	1.5
$\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 + h^0 \to \tilde{\chi}_1^0 + b\bar{b}$	
$t\bar{t}$ inclusive	830
Z^0+jets	13 10^3
$W^{\pm}$+jets	41 10^3
inclusive QCD dijet	41 10^3

Another discriminating variable : angle between both hemispheres



No need for a good calibration
Need good reconstruction of jets
⇨ used at start of LHC data taking

Study of different variables or variable combinations (cut effects, correlations)
Aim : maximization of the ratio SUSY signal / QCD noise

Mars 2009