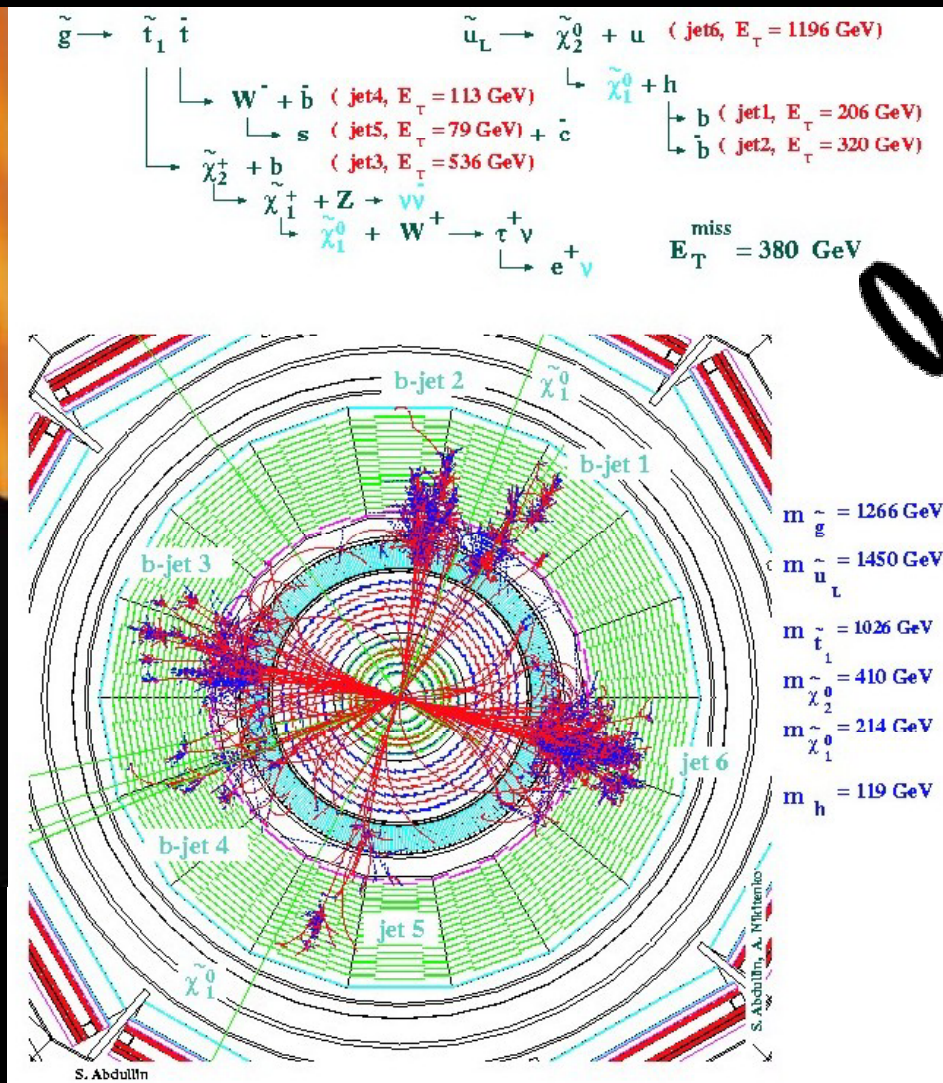


Collider Scene Investigation



Anwar Bhatti
Rockefeller
(bhatti@fnal.gov)

Teruki Kamon
Texas A&M/LPC
(t-kamon@tamu.edu)



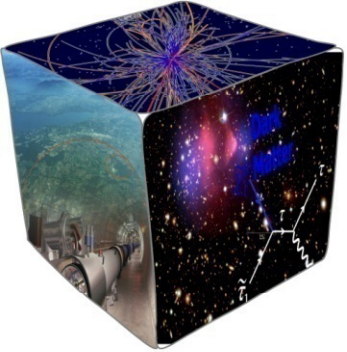
- Goal with CMS
- Why Jets+MET?
- $\sigma_{\text{BSM}} \sim 50$ pb
- Tasks at a Glance
- Sign-up!!!

Physics with Jets+MET Topology

Goals of Jets+MET Topology Group

http://uscms.org/uscms_at_work/physics/lpc/organization/topologies/jets_met/index.shtml

Nov. 18, 2007



The CMS SUSY and EXOTICA groups have a set of vigorous programs to discover new particle(s). The LPC Jets+MET topology group will help such CMS programs in the following final states:

$$E_T^{\text{miss}} + \text{Jets}$$

$$E_T^{\text{miss}} + \text{Jets} + \tau\text{'s}$$

$$E_T^{\text{miss}} + \text{Jets} + \text{b's (e.g., } h \rightarrow \text{bb)}$$

$$E_T^{\text{miss}} + \text{Jets} + \text{t's (e.g., gluino} \rightarrow \text{tt} + \text{neutralino)}$$

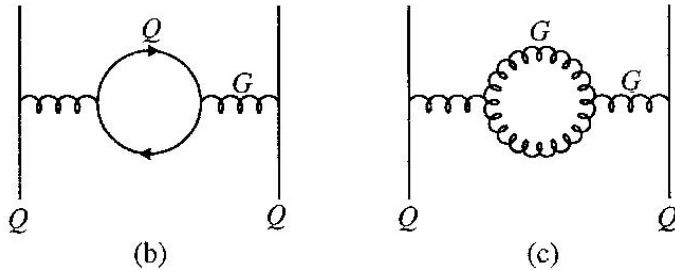
...

As a group, we will actively involved in various common tasks such as τ ID, b tagging, and missing E_T clean-up/calculation/correction in the CMS **SUSY** and **EXOTICA** groups to maximize the success of the CMS new particle hunting in the initial conditions up to 1 fb^{-1} for now. This obviously also leads us to make strong connections with **Dijet** topology group and τ /b object groups. ...

Start with "Running" Couplings

e.g., QCD

$$\alpha_s(Q^2) = \frac{12\pi}{(11n_{color} - 2n_{flavor}) \log(Q^2/\Lambda^2)}$$



$n_f = 6$ (quark flavors); $n_c = 3$ (colors)

The Nobel Prize in Physics 2004



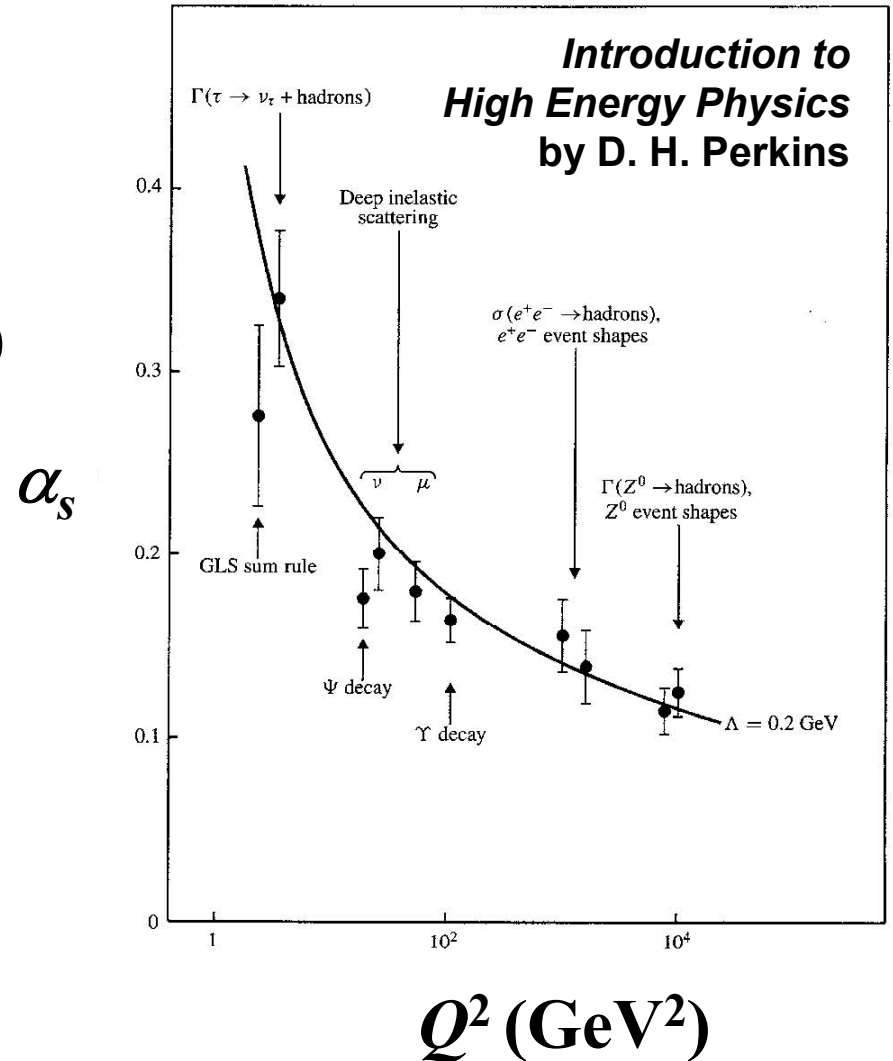
David J. Gross
Kavli Institute for
Theoretical
Physics
University of
California, Santa
Barbara, USA



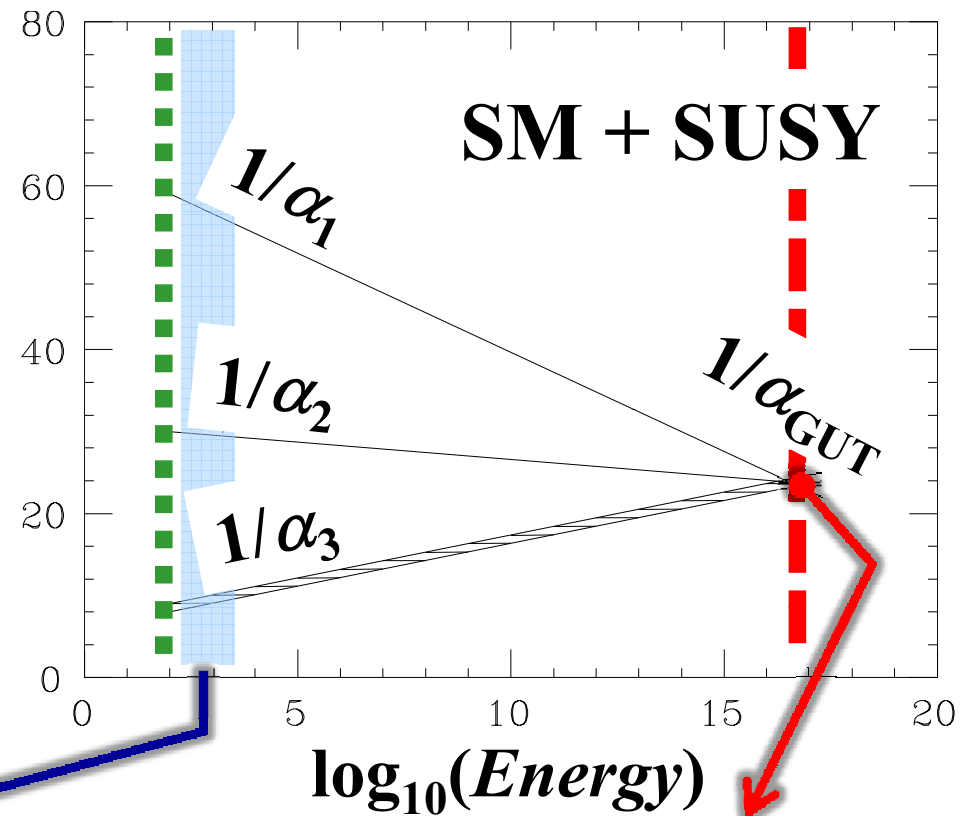
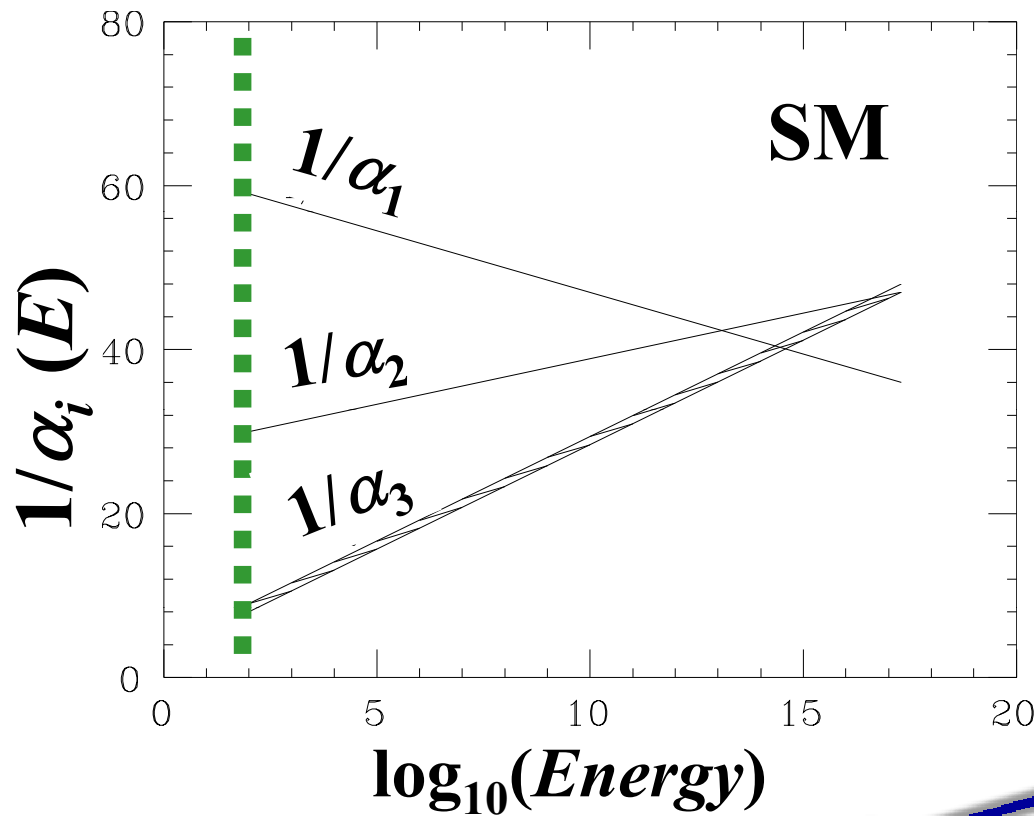
**H. David
Politzer**
California
Institute of
Technology
(Caltech),
Pasadena,
USA



**Frank
Wilczek**
Massachusetts
Institute of
Technology
(MIT),
Cambridge,
USA



A Hint of Beyond-SM at Tera-scale



$M_{\text{SUSY}} \sim 500\text{-}3000 \text{ GeV}/c^2$
and **two** (and only two)
Higgs doublets

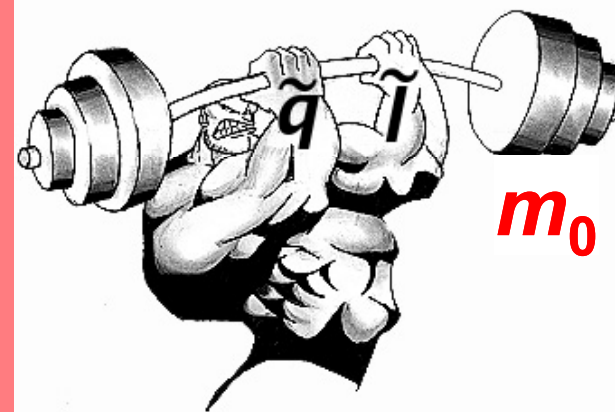
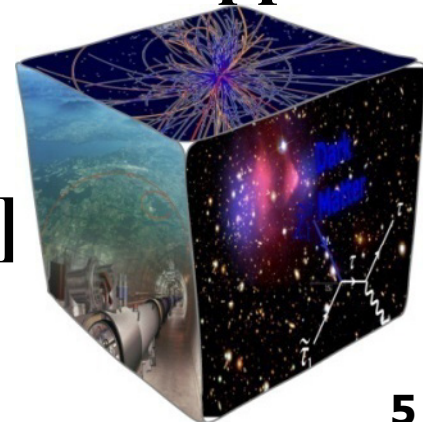


Image of a GUT world by Abram Krislock

Why Jets+MET at the LHC?

Example: SUSY with R-parity Conservation

- ⊕ $\tilde{g}\tilde{g}$, $\tilde{g}\tilde{q}$, or $\tilde{q}\tilde{q}$ production will be dominant, followed by their decays (e.g., $\tilde{q} \rightarrow q\tilde{\chi}_2^0$). → **Jets**
- ⊕ R parity conservation
 - Stable lightest supersymmetric particle (LSP)
 - If LSP is the lightest neutralino ($\tilde{\chi}_1^0$),
 - it will escape the detector → **MET** (E_T)
 - $\tilde{\chi}_1^0$ = Cold Dark Matter candidate → **Cosmology**
 - Thus, the evidence of SUSY-like new physics will appear in the Jets+MET final states.
- ⊕ **Cosmology** + **LHC**
= [Exciting Motivation] + [Right Place&Timing]

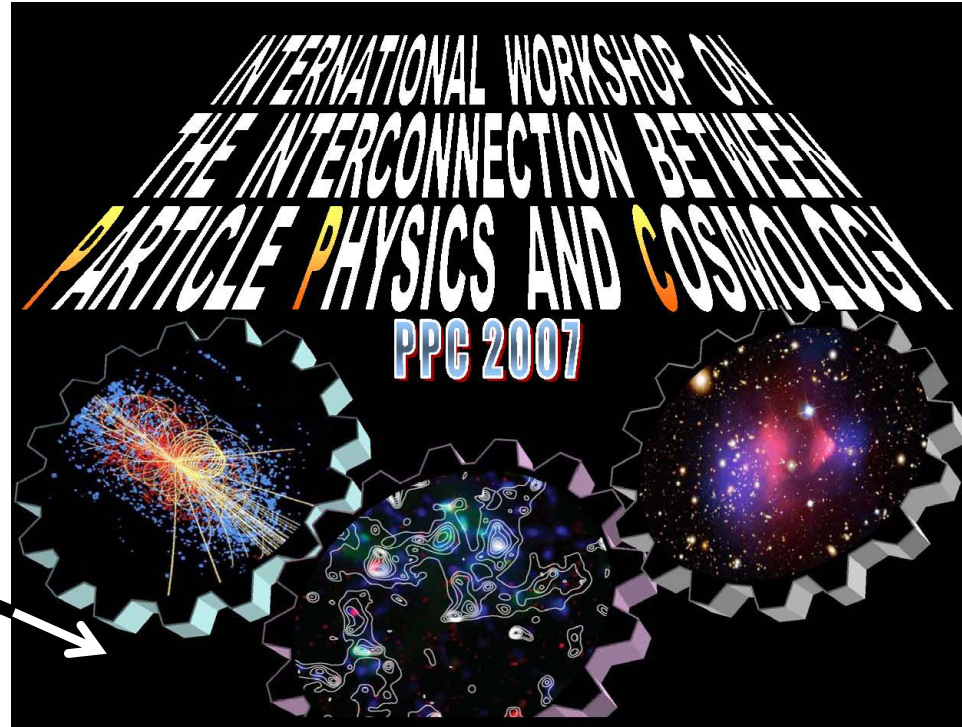




**CBS comedy “Big Bang Theory”
(Season 2 Episode 5, Oct 20, 2008)**



Particle Physics + Cosmology



SCIENTIFIC TOPICS

Dark Matter & Dark Energy - CMB Measurements - Supernovae, Weak Lensing & Large Scale Structure - Future Telescopes - Space Programs - Particle Cosmology - String Cosmology - Dark Matter Searches - Collider Searches - Future Accelerators

<http://ppc07.physics.tamu.edu>

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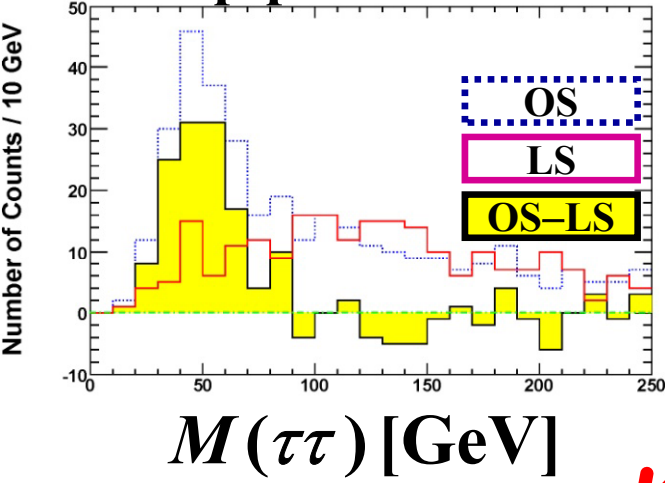
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- J. White (TAMU)
- *co-chairs

Cambridge-Mitchell (TAMU) Collaboration in Cosmology
Texas A&M University, College Station, TX, USA
May 14-18, 2007

Credit and Copyright [Left to Right]: CERN Photo (CMS), Richard Massey/Nature, NASA/ Chandra X-ray Center

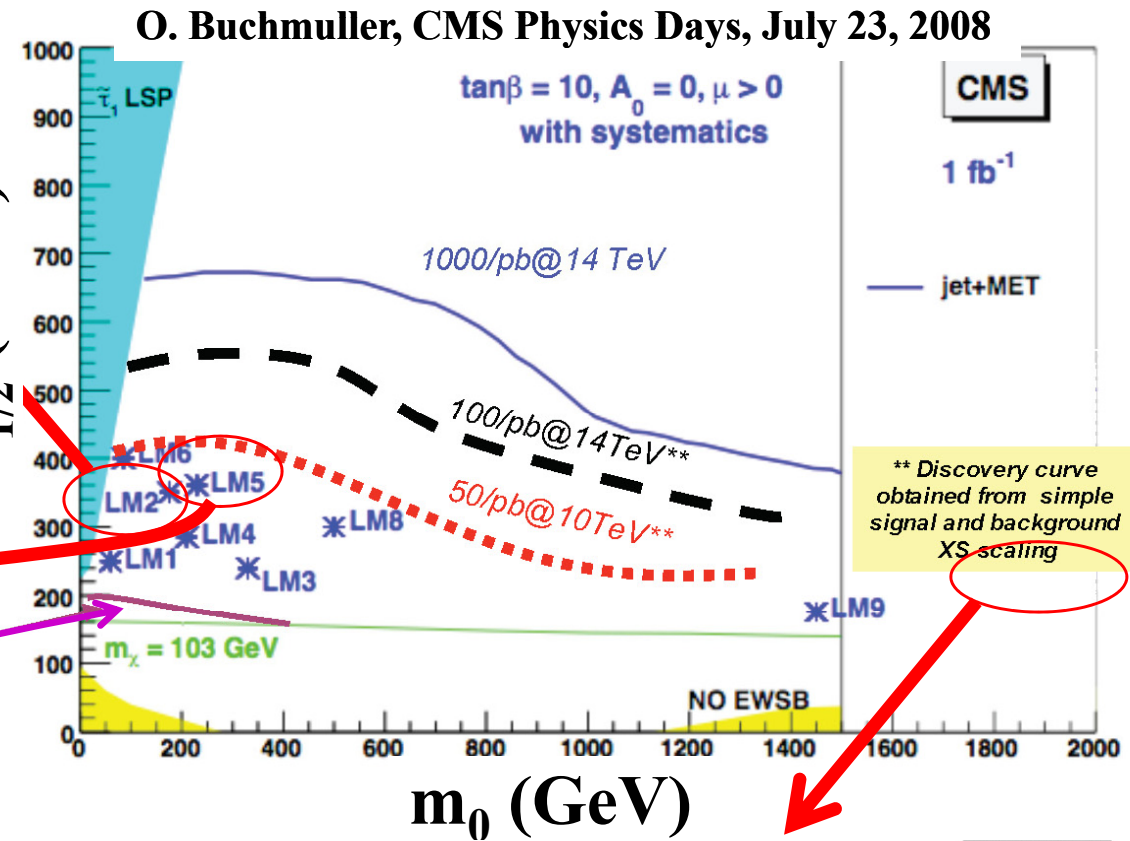
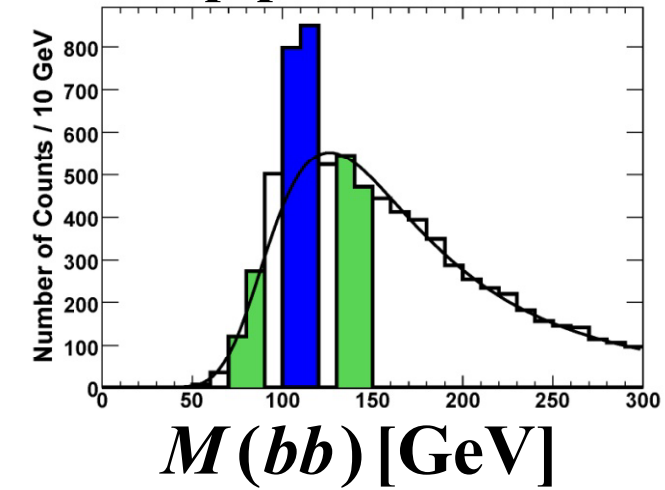
$$\tilde{\chi}_2^0 \rightarrow \tau^\pm \tilde{\tau}^\mp \rightarrow \tau^\pm \tau^\mp \tilde{\chi}_1^0$$

hep-ph/0603128



$$\tilde{\chi}_2^0 \rightarrow h \tilde{\chi}_1^0 \rightarrow b\bar{b} \tilde{\chi}_1^0$$

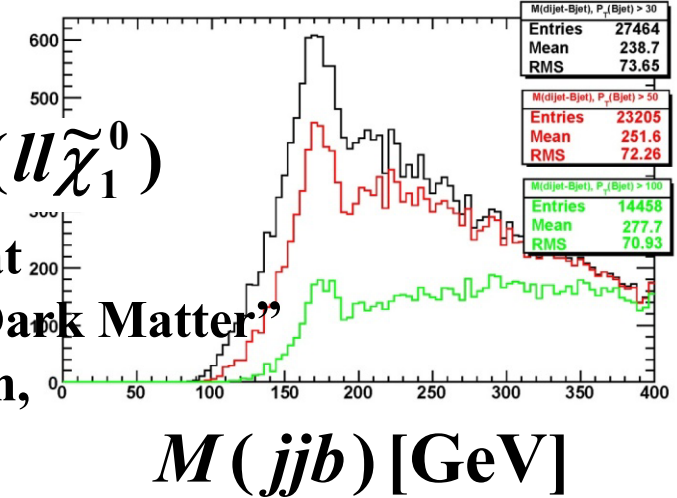
hep-ph/0808.1372



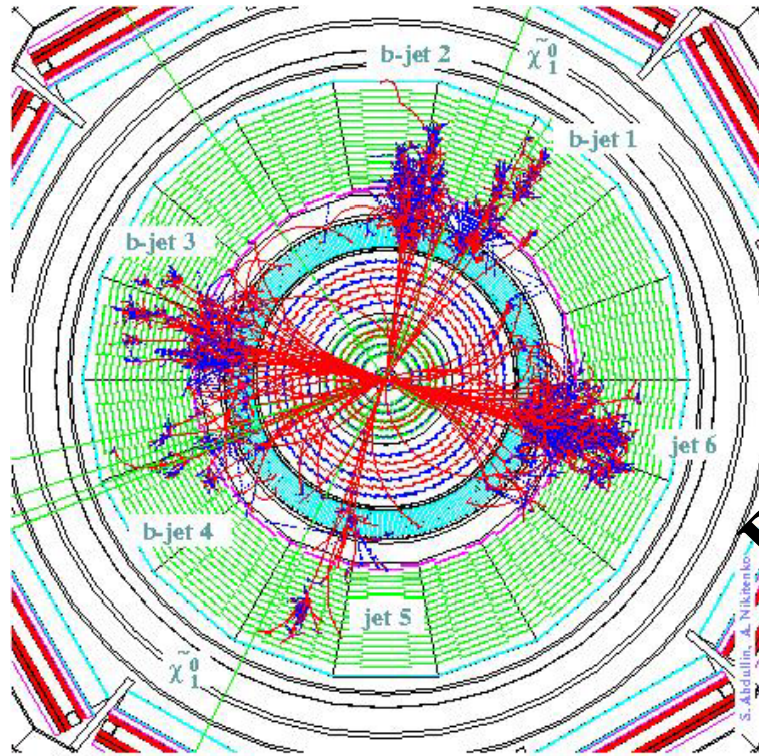
D0 collaboration (Tevatron)
Phys. Lett. B 660 (2008) 449

$$g\tilde{z} \rightarrow t\bar{t} \tilde{\chi}_2^0 \rightarrow (j\bar{j}b)(j\bar{j}b)(l\tilde{\chi}_1^0)$$

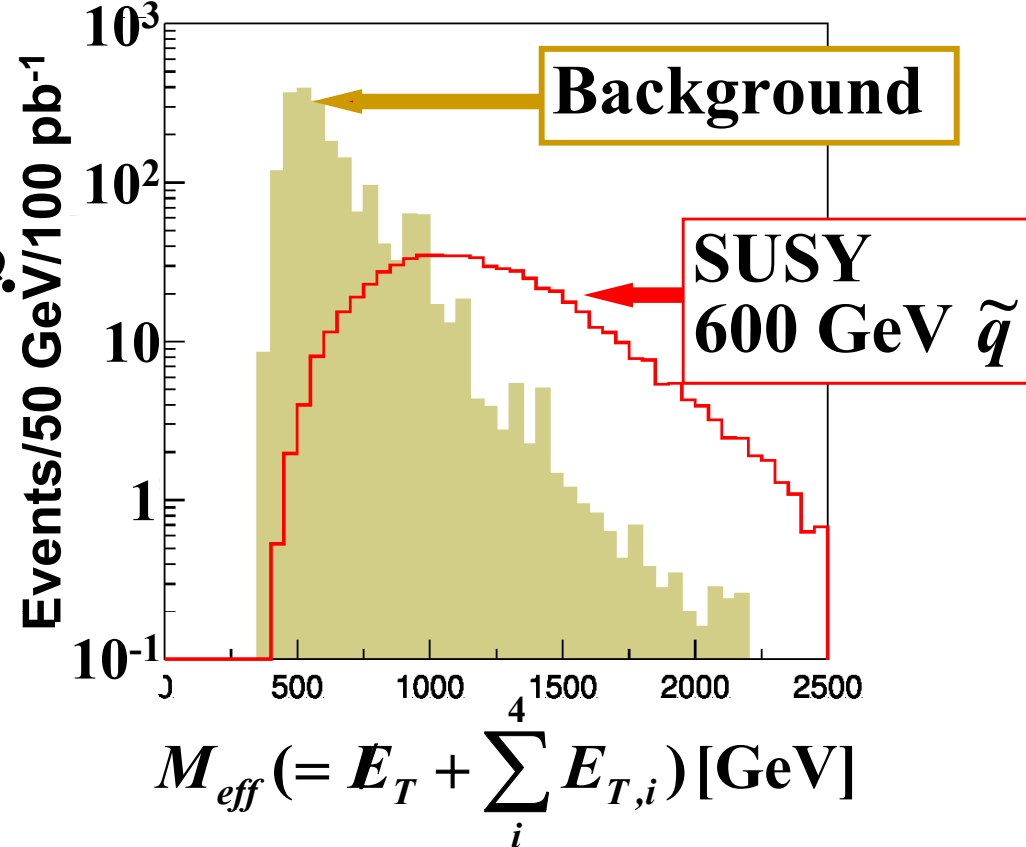
T. Kamon, Talk at
"The LHC and Dark Matter"
Univ. of Michigan,
Jan. 7, 2009



A SUSY Excess – Not Discovery



Reversible?



[Stage 1] Is this a real excess? We need to understand MET.

- Detector Performance Group or DPG (especially, HCAL)
- Physics Object Group or POG (especially, jets, MET, tau, b)
- Physics Analysis Group or PAG (especially, SUSY and EXOTICA)

[Stage 2] What kind of excess? We need to identify e , μ , τ , b , t .

- POG
- PAG (especially, Kinematical reconstructions)

"Supersymmetrists, Beware!" (J. Ellis, SUSY07)

EUROPEAN ORGANISATION FOR NUCLEAR RESEARCH

CERN-EP/84-42
29 March 1984

Zoom To Fit (1)

Experimental Observation of Events with **Large Missing Transverse Energy** Accompanied By a Jet or Photon(s) in $p\bar{p}$ Collisions at $\sqrt{s} = 540$ GeV

UAI Collaboration, CERN, Geneva, Switzerland

Aachen¹ -Annecy(LAPP)² -Birmingham³ -CERN⁴ -Harvard⁵ -Helsinki⁶ -Kiel⁷
Queen Mary College, London⁸ -NIKHEF, Amsterdam⁹ -Paris(Coll.de France)¹⁰ -Riverside¹¹
Roma¹² -Rutherford Appleton Lab.¹³ -Saclay(CEN)¹⁴
Vienna¹⁵ -Wisconsin¹⁶ Collaboration

Abstract

We report the observation of five events in which a missing transverse energy larger than 40 GeV is associated with a narrow hadronic jet and of two similar events with a neutral electromagnetic cluster (either one or more closely spaced photons). We cannot find an explanation for such events in terms of backgrounds or within the expectations of the Standard Model.

(submitted to Phys. Lett. B)



CERN-TH.3968/84

IS SUPERSYMMETRY FOUND?

John Ellis
CERN — Geneva

and

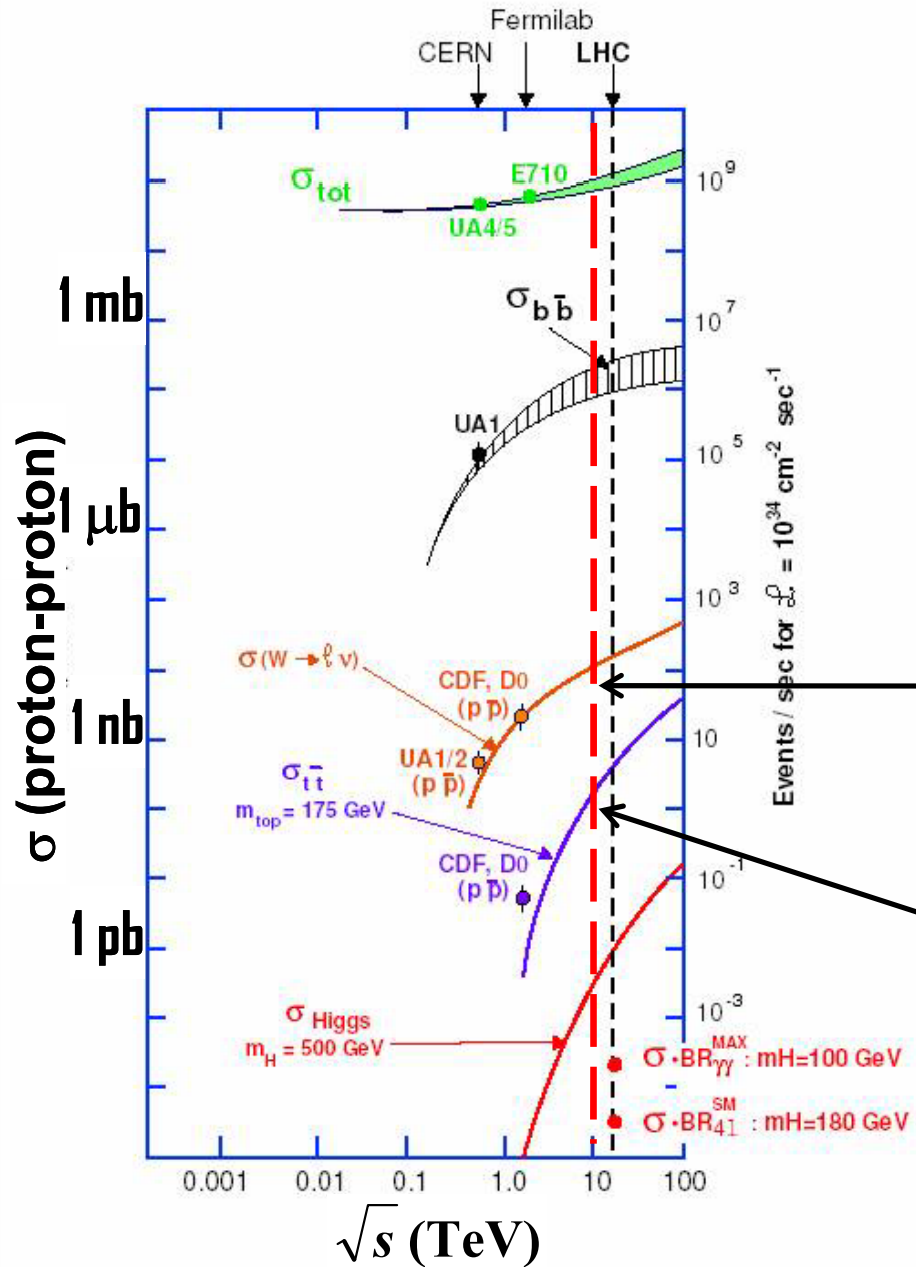
Marc Sher **)
University of California, Irvine

ABSTRACT

Monojet events seen recently by the UAI collaboration at the CERN $p\bar{p}$ Collider may be due to squarks or gluinos with masses $O(40)$ GeV. The thinness of the observed jets favours the squark interpretation. In this case, we predict that sleptons should have masses between 20 and 30 GeV and that the photino should have a mass between 5 and 10 GeV. Such masses are close to the experimental lower limits and sparticles could soon be detectable in $e^+e^- + (\gamma\gamma)\gamma$ experiments and W^\pm and Z^0 decay. We demonstrate that such light sparticle masses are consistent with models whose weak gauge symmetry breaking is driven by a t quark weighing $O(40)$ GeV as recently reported, and even with no-scale models in which the supersymmetry breaking scale is also determined dynamically.

CERN-TH.3968/84
July 1984

Typical Statistics at 10 TeV / $\mathcal{L} = 10 \text{ pb}^{-1}$



(*Assume $\mathcal{L} = 10 \text{ pb}^{-1}$, include acceptance, initial reconstruction and ID efficiency

Minimum bias

10^{12}

Jet, $E_T > 25 \text{ GeV}$

3×10^{10}

Jet, $E_T > 140 \text{ GeV}$

3×10^6

γ +Jet, $E_T > 20 \text{ GeV}$

3×10^6

$W \rightarrow \ell \nu$

30,000

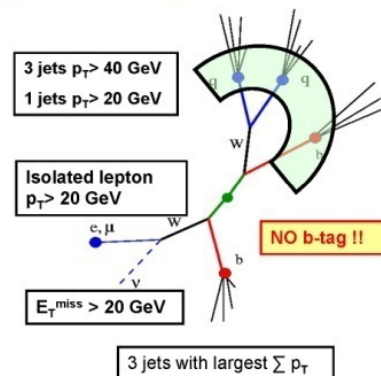
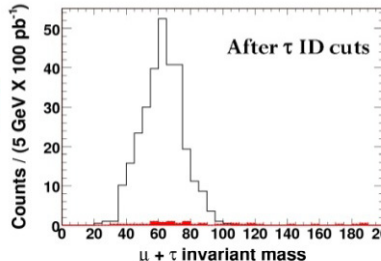
$Z \rightarrow \ell \ell$

3,000

$t\bar{t} \rightarrow \ell \nu 4q$

100

Nailing Down $\sigma_{\text{BSM}} = 50 \text{ pb}$ in $1 \sim 1000 \text{ pb}^{-1}$

\mathcal{L}	N_{prod} (events)	$A_{\text{total}} \sim 10\%$... Many people are working on Detectors & Physics Objects.	
			Major Effort & Papers	Trigger/DPG/POG/Topology
1 pb⁻¹	50	5	Commissioning α_T , MET, and M_{eff} using QCD events	HCAL operation Trigger menu
10 pb⁻¹	500	50	Understanding α_T , MET, and M_{eff} using $Z(\rightarrow ll)+\text{jets}$, $W(\rightarrow lv)+\text{jets}$, $\gamma+\text{jet}$ & tt (*) α_T in QCD events (*) W+jets, Z+jets, tt+jets (*) Search for SUSY ...	High-quality jet objects High-quality e/ μ rejection High-quality τ ID High-quality b tagging High-quality γ ID High-quality MET/Cleanup Basic selection cuts & SUSY-PAT
100 pb⁻¹	5,000	500	Retuning α_T , MET, and M_{eff} using $Z+\text{jets}$, $W+\text{jets}$, $\gamma+\text{jet}$ & $tt+\text{jets}$ MET scale using $Z \rightarrow \tau\tau$, $W \rightarrow lv$ (*) W+jets, Z+jets, tt+jet (*) Evidence for SUSY ...	<div style="border: 1px solid black; padding: 5px; margin-bottom: 10px;"> $\sigma_{tt} \approx 250 \text{ pb}$ for $tt \rightarrow bW bW \rightarrow blv bjj$ Note: $\sigma_{tt}(\text{LHC})/\sigma_{tt}(\text{Tevatron}) \sim 100$ </div>  <div style="text-align: right;">  <p>$Z \rightarrow \tau\tau \rightarrow \mu\tau_h$ After τ ID cuts</p> </div>
1 fb⁻¹	50,000	5,000	(*) Observation of SUSY ...	

Tasks at a Glance

(1) QCD & EWK – dominant backgrounds for new physics

- ✓ QCD smearing function (**Elif**, Taylan, ...)
- ✓ α_T for QCD rejection (Mehmet, Taylan, ...)
- ✓ MET using $W/Z/\gamma$ +jets (**Sue Ann**, ...)
- ✓ MET using $Z(\rightarrow \nu\nu)$ + jets (**Jim**, ...)
- ✓ MET using tt + jets (**Duong**, ...)
- ✓ Tau ID using $Z \rightarrow \tau\tau$ (**Alfredo**, ...)

Names in **red** are speakers in our parallel session

(2) Detector commissioning effort from SUSY view point

- ✓ MET DQM (Ken, ...)
- ✓ MET cleanup (Alfredo, Ming, Michael, ... by HCAL ROC team)
- ✓ MET monitoring trigger for HPD noise study (Alfredo at HCAL-DPG)
- ✓ MET Triggers (**Jim**, ...)
- ✓ MET in CRAFT (**Mehmet**, ...)

(3) Preparing analysis tool for all-hadronic final states

- ✓ SUSY b 's (**Harold**, ...), τ 's (**Jonathan**, ...), W 's (...)
- ✓ Black Hole High multiplicity high- E_T jets (Romulus, ...)

(4) Early SUSY-related paper(s) using α_T in n -jet final states

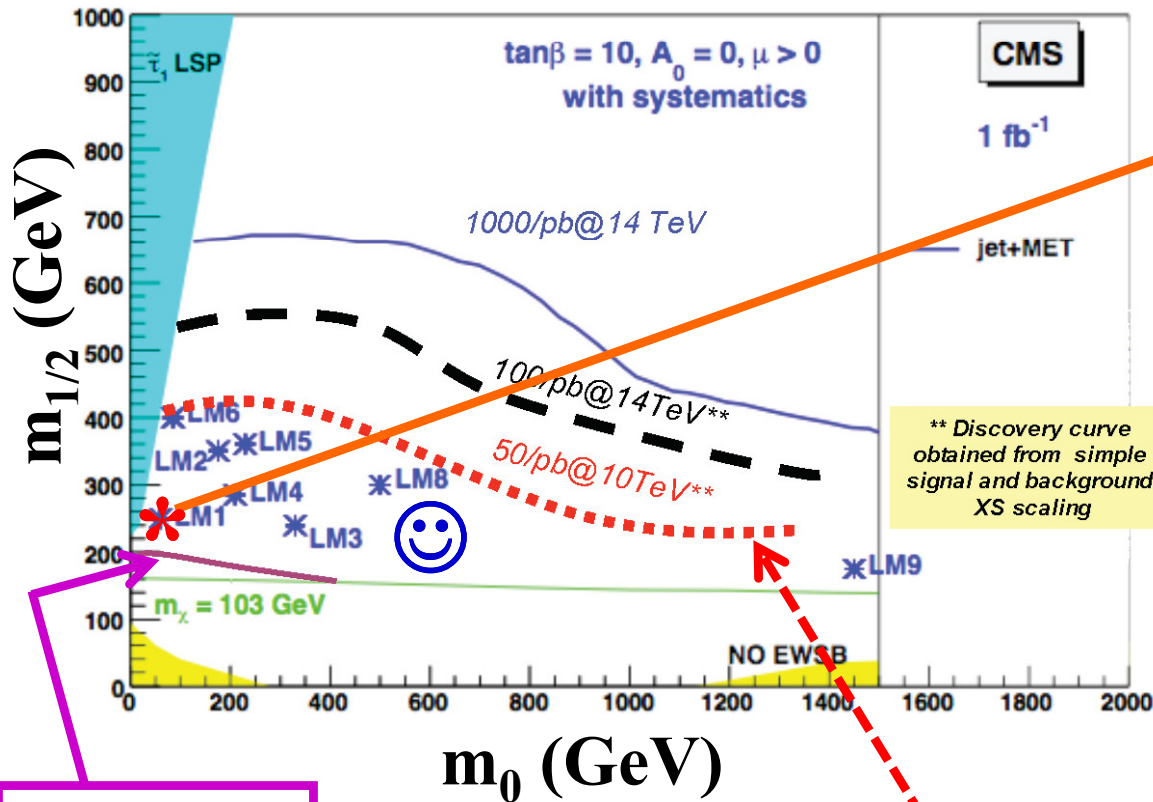
(5) More ...

Summary : $E = MC^2$

Effort = **M**anpower \times **C**hallenge \times **C**reativity

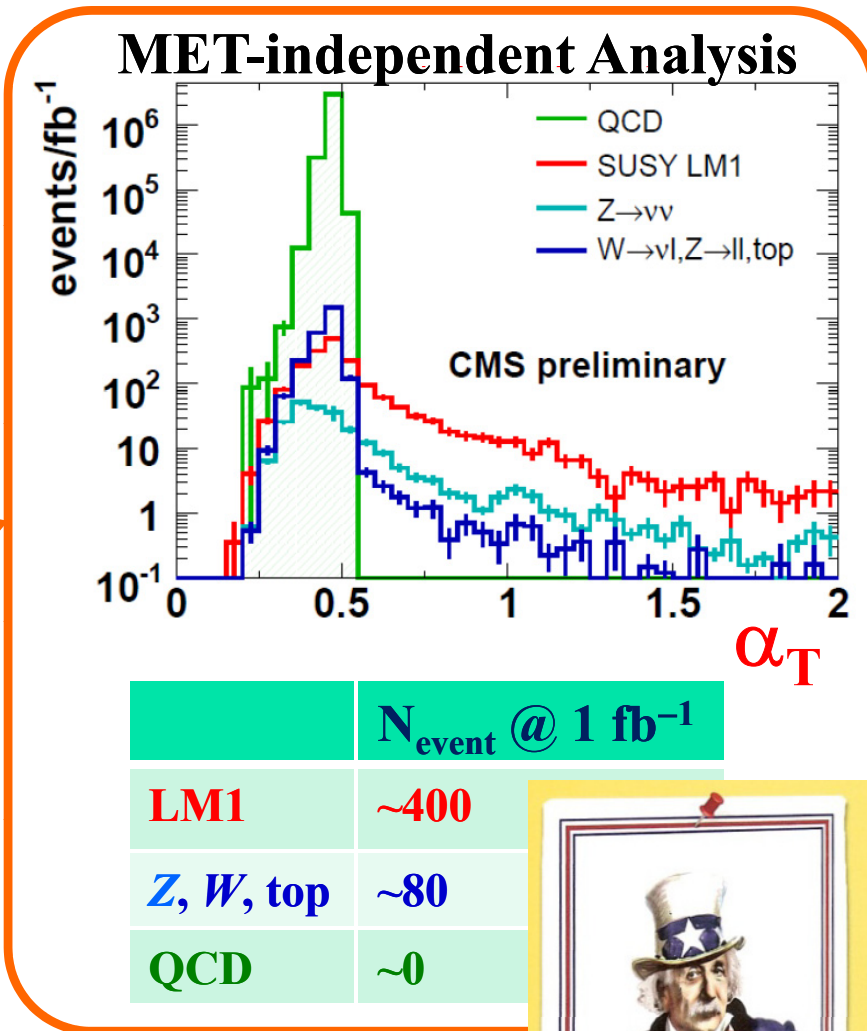
$\sqrt{s} = 10 \text{ TeV}$ & $\mathcal{L} = 50 \text{ pb}^{-1}$

– still powerful for BSM searches –



Tevatron

LHC 2009 (50 pb⁻¹ @ 10 TeV)



	$N_{\text{event}} @ 1 \text{ fb}^{-1}$
LM1	~400
Z, W, top	~80
QCD	~0

