Search for SUSY dark matter in the first LHC run

Joakim Edsjö, Erik Lundström, Sara Rydbeck och Jörgen Sjölin
The Oskar Klein Centre for Cosmoparticle Physics, Stockholm University

Based on JHEP 1003:054, 2010 (arXiv e-Print 0910.1106). Results updated to a 7 TeV center-of-mass energy.

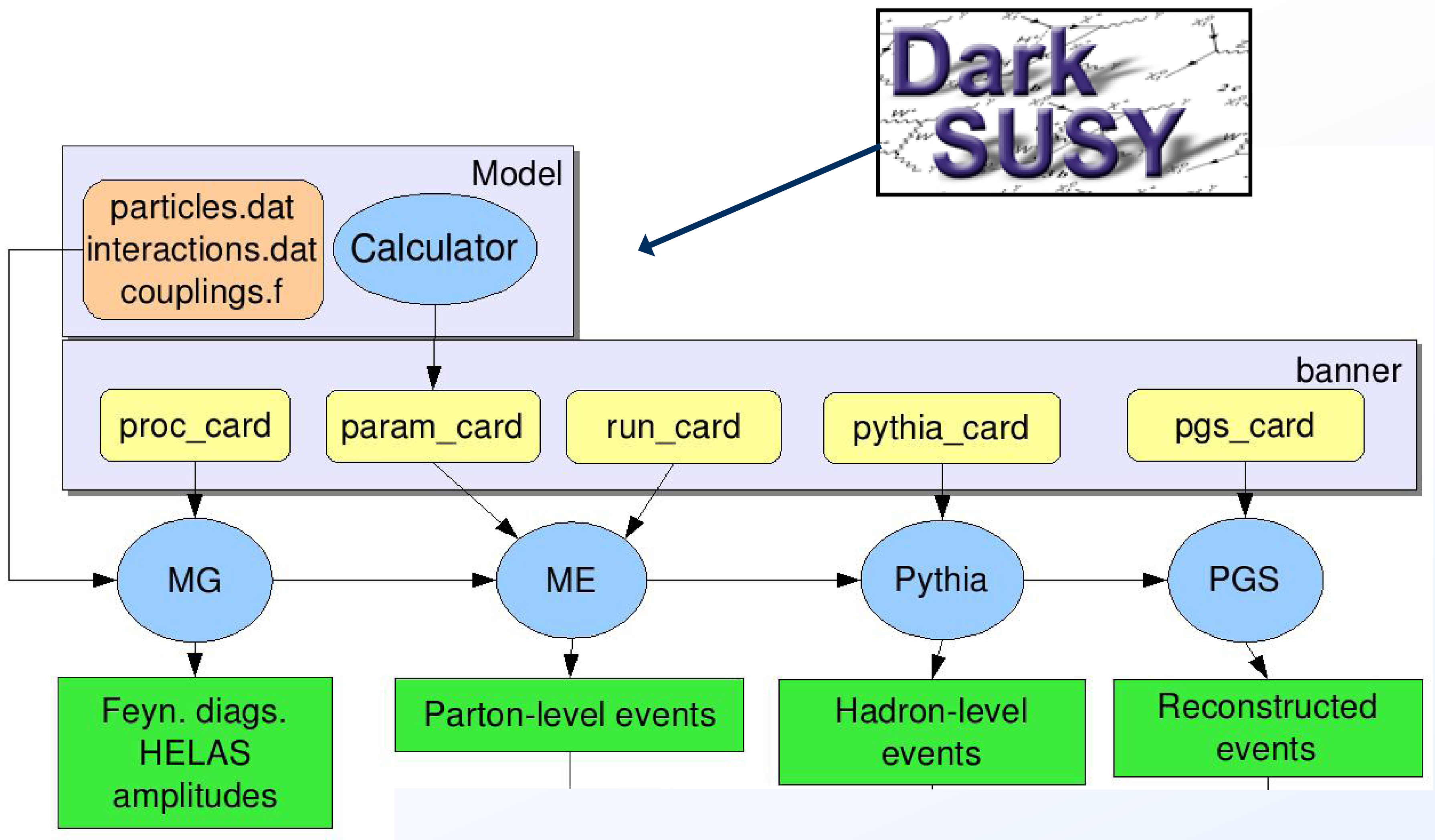
The evidence for dark matter coming from cosmological observations is overwhelming but its particle nature has yet to be established. Particle astrophysics is an active and exciting field but methods of indirect and direct detection of dark matter particles present in our surroundings suffer from uncertainties due to astrophysics and the unknown distribution of the dark matter.
In high energy collisions at particle accelerators we can hope to create the dark matter particles and in a more controlled environment determine its properties.

The CERN Large Hadron Collider (LHC) started up in November 2009 and will be collecting data from proton-proton collisions at a center-of-mass energy of 7 TeV during 2010-2011. A luminosity of $1\ \mathrm{fb}^{-1}$ is expected to be reach during this first run.

Supersymmetric particles could be produced at the LHC dominantly through processes

$$gg, q\bar{q}, qq, qg \to \tilde{g}\tilde{g}, \tilde{q}\tilde{q}, \tilde{q}\tilde{g}$$

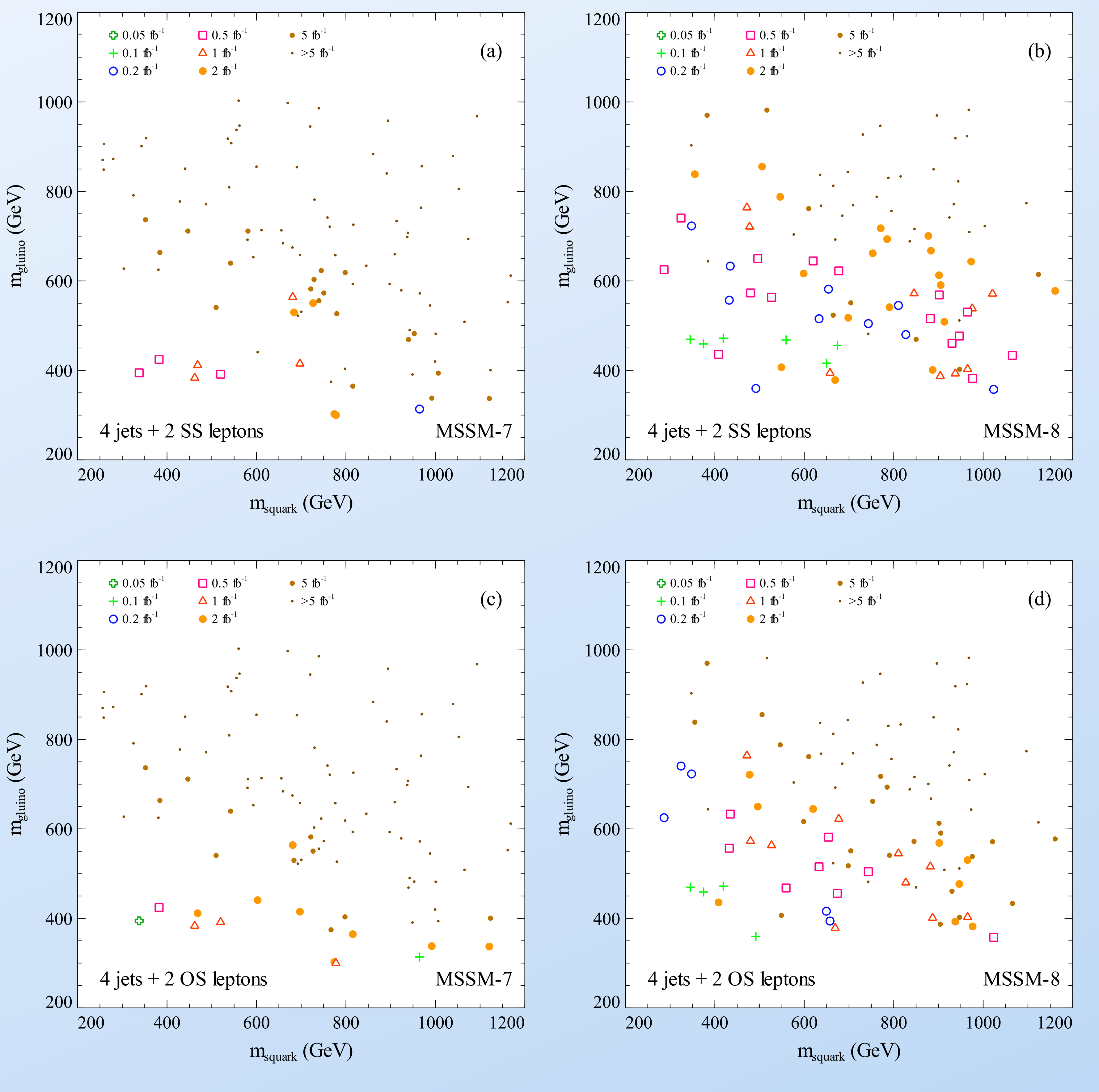
and decay into lighter states via cascade decay chains. At every step of the decay chain ordinary standard model particles will be produced and give rise to reconstructed jets and leptons in the data. In order to discriminate a signal of new physics from the large hadronic standard model background, hard cuts need to be imposed on the final state.
The dark matter particle would show up as missing transverse energy (MET).



The model - a phenomenological MSSM

An R-parity conserving minimal supersymmetric standard model (MSSM) gives a weakly interacting cold dark matter candidate in the form of the lightest neutralino . Since supersymmetry has to be broken, this model has more than a hundred free parameters. To make phenomenological studies feasible, some simplifying assumptions and approximations have to be made.
In the MSSM-7, the number of free parameters has been reduced to the third genereration trilinear couplings A_t and A_b, a common soft sfermion mass parameter m_0 , one of the gaugino mass parameters M_2 , the Higgsino mass parameter μ, the ratio between the two Higgs vevs $\tan\beta$ and the mass of the neutral CP-odd one of the physical Higgs bosons m_A. Since we in this work are interested in lepton signatures, we also define an MSSM-8 model where m_0 is broken up inte two; a common soft squark mass parameter $m_{\tilde{q}}$ and a common soft slepton mass parameter $m_{\tilde{l}}$.
To be consistent with neutralinos making up the dark matter in the universe, we require that the lightest neutralino has a relic density within 2σ of the measured WMAP range:

$$\Omega_\chi h^2 = 0.1099 \pm 0.0062\ (1\sigma)$$



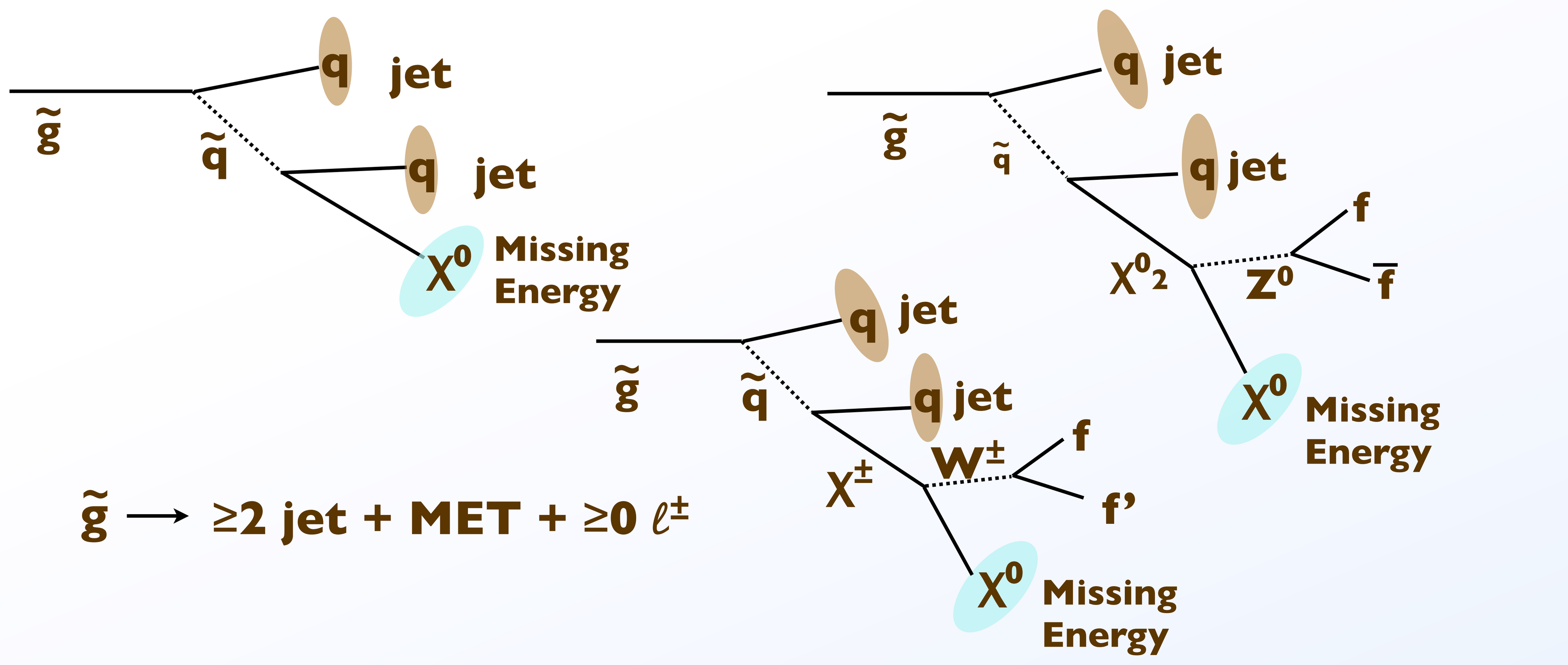


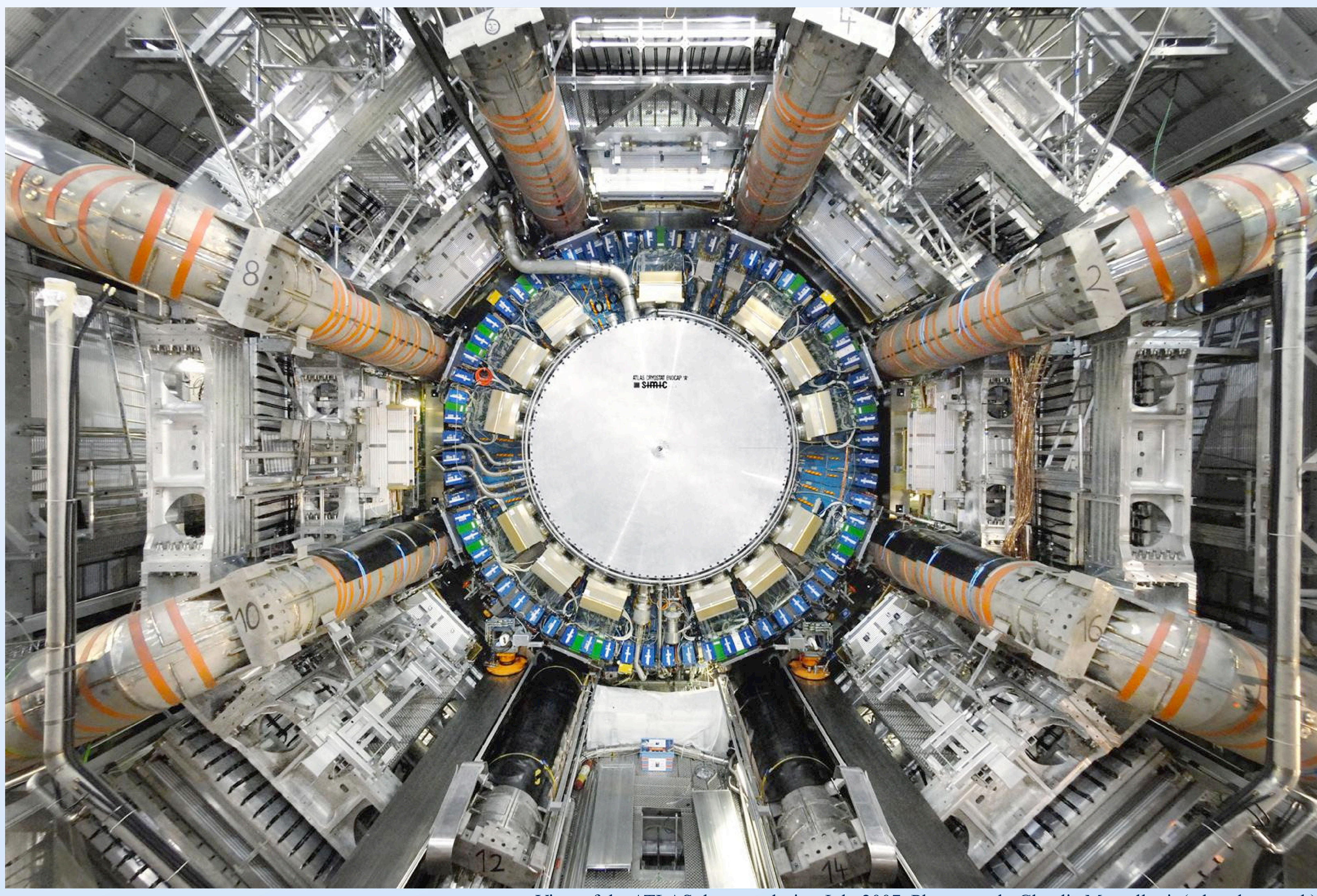
Figure from M. L. Mangano, arXiv:0809.1567, Eur.Phys.J.C59:373-387, 2009

Early searches without missing energy - the role of isolated leptons

MET requires perfect knowledge of the detector and is not the most reliable signature in early data. Fake contributions could come from dead and noisy channels in the calorimeters, beam-gas interactions, and pure mis-measurements in cracks, inactive material and escaping muons. A strategy for early searches could be to make use only of locally measured objects such as muons, electrons and jets.

Baer, Prosper and Summy (arXiv:0801.3799) showed that without relying on MET, LHC can discover mSUGRA in the trilepton channel, and also Baer, Lessa and Summy (arXiv:0809.4719) found that early discovery can be made with only muons.

What does this mean for dark matter models?



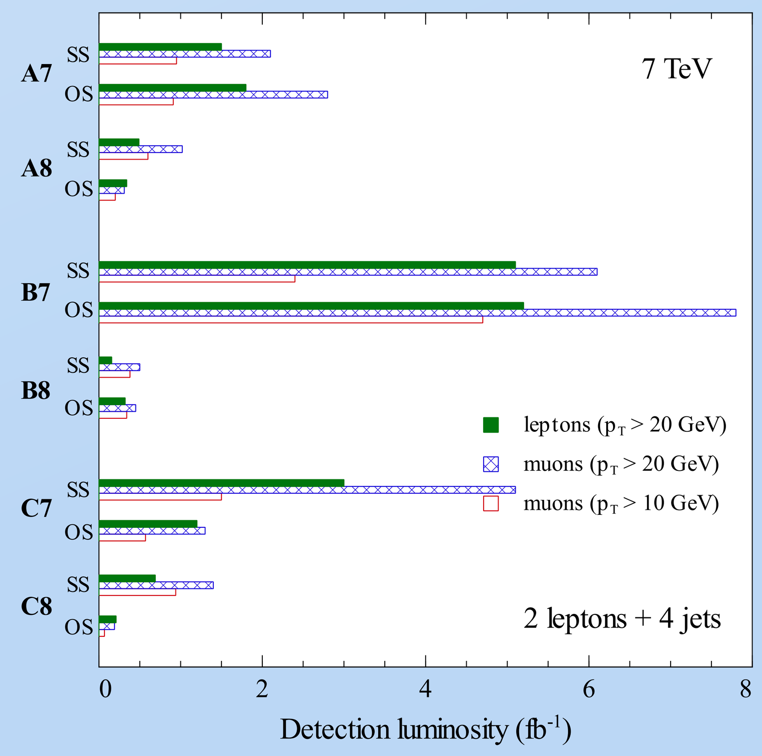
View of the ATLAS detector during July 2007. Photograph: Claudia Marcelloni. (cdsweb.cern.ch)

Tools, cuts and results

We scan 100 MSSM-7 and 100 MSSM-8 models. The particle spectrum and relic density for each model is calculated using DarkSUSY. For the event generation of the standard model background as well as the supersymmetry signal we use MadGraph/MadEvent, making use of its interfaces to Pythia for showering and hadronization, and the PGS detector simulation. We tune our settings to agree with the results presented by the ATLAS collaboration.
We cut on four high energetic jets of $p_T > 100, 50, 50, 50$ GeV and two isolated leptons (electrons and/or muons). The standard model background of this signal consists of the processes $t\bar{t}$ and Z.

Light sleptons significantly improve detectability in early LHC data. At 7 TeV, we can probe gluino masses up to ~700 GeV at integrated luminosities of 0.5-2 pb-1.

Model	A7	A8	B7	B8	C7	C8
μ	130		290		360	
m_A	700		1000		600	
$\tan\beta$	15		5		50	
M_2	190		170		115	
$m_{\tilde{q}}$	380		650		660	
$m_{\tilde{l}}$	380	180	650	110	660	260
$A_b/m_{\tilde{q}}$	2.5		−1.5		0	
$A_t/m_{\tilde{q}}$	0		2.5		0.9	
$m_{\tilde{g}}$	658		589		399	
$m_{\tilde{u}_L}$	376		648		658	
$m_{\tilde{b}_1}$	376		642		591	
$m_{\tilde{t}_1}$	413		424		602	
$m_{\tilde{e}_L}$	382	185	651	118	661	264
$m_{\tilde{\mu}_L}$	382	185	651	117	660	260
$m_{\tilde{\tau}_1}$	378	176	649	107	637	194
$m_{\chi^0_1}$	71		80		57	
$m_{\chi^0_2}$	120		147		109	
$m_{\chi^0_3}$	143		294		368	
$m_{\chi^0_4}$	236		327		377	
$m_{\chi^\pm_1}$	101		144		108	
$m_{\chi^\pm_2}$	236		324		379	
$\Omega_\chi h^2$	0.12	0.10	3.8	0.11	0.11	0.10



Contact: Sara Rydbeck, sararyd@fysik.su.se