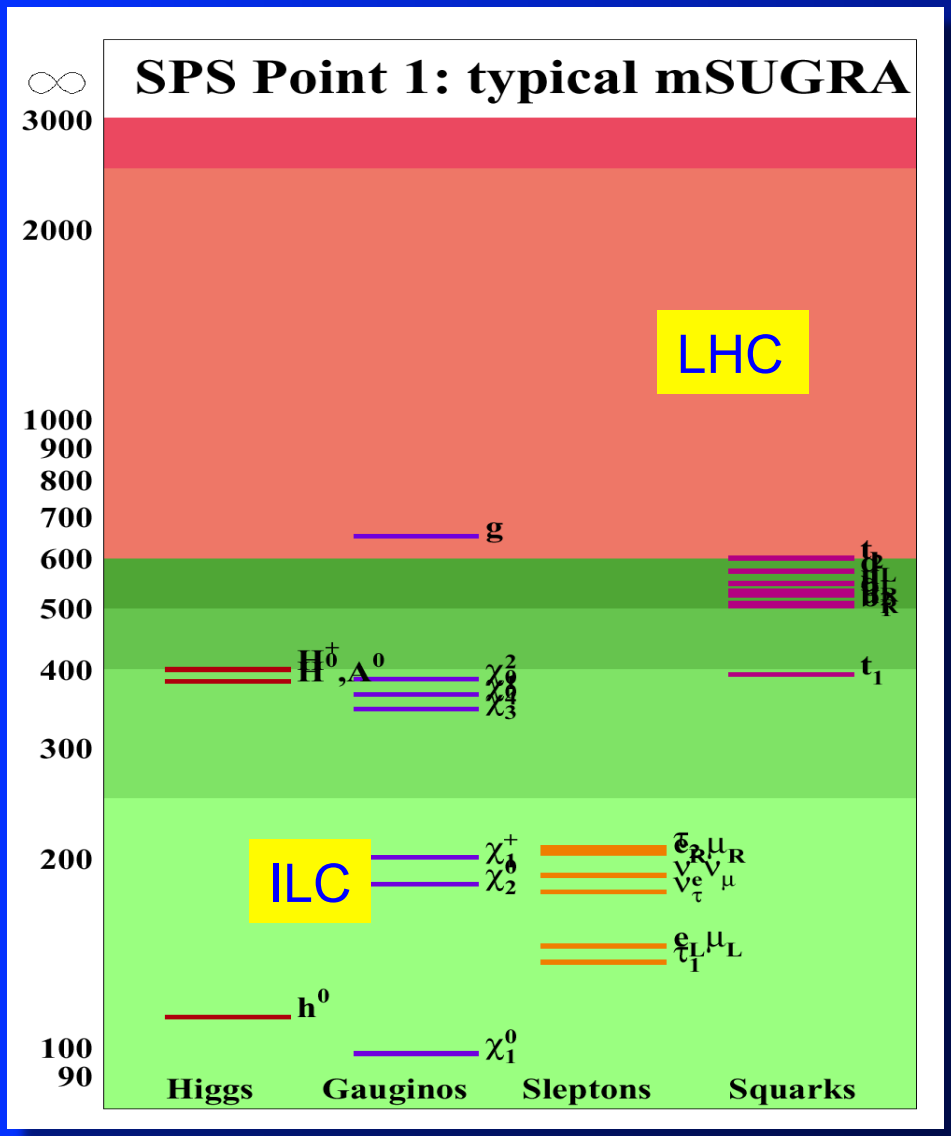
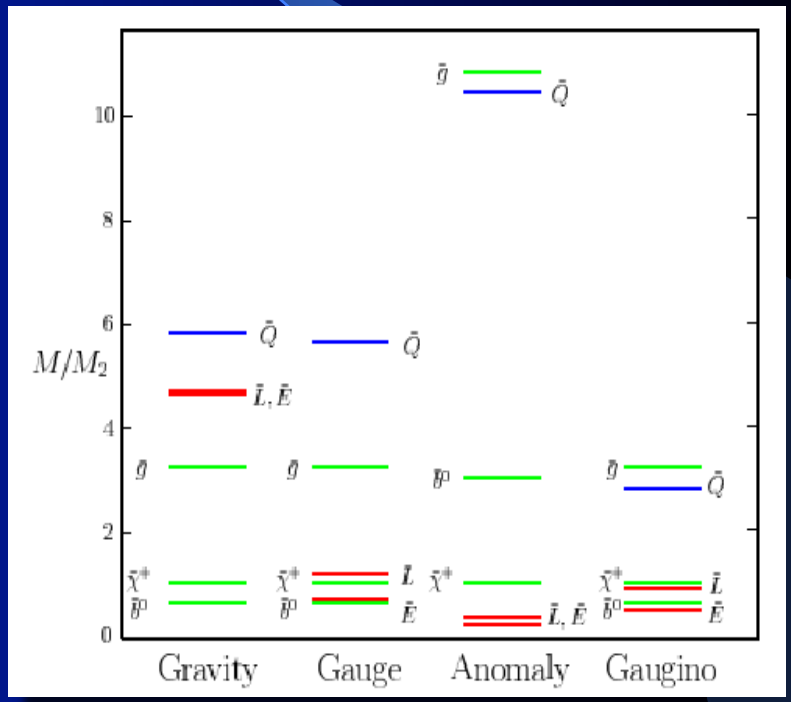
Search for Superpartners @ Colliders

The Mass Spectrum

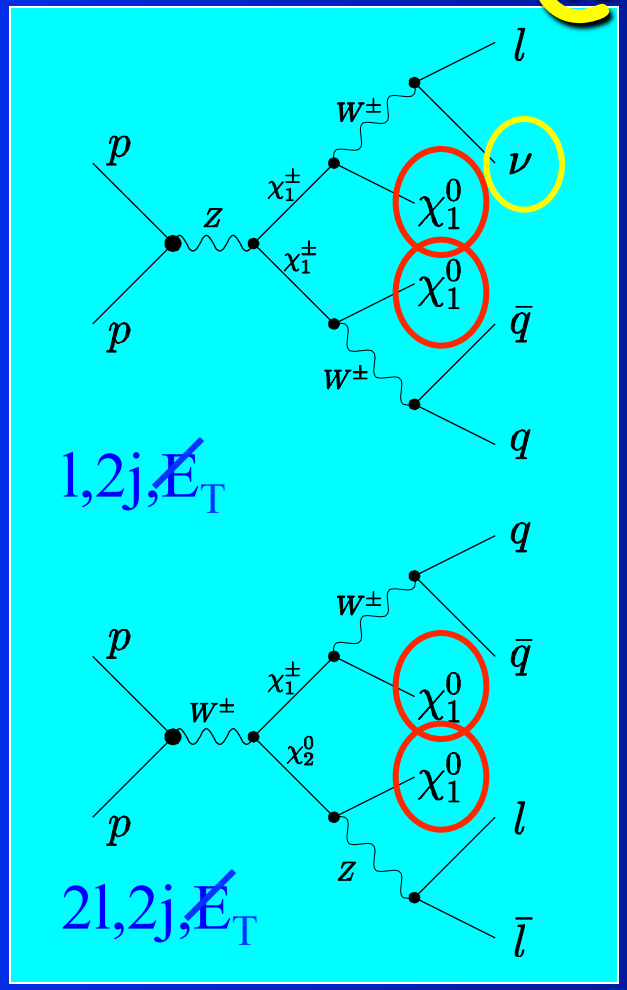


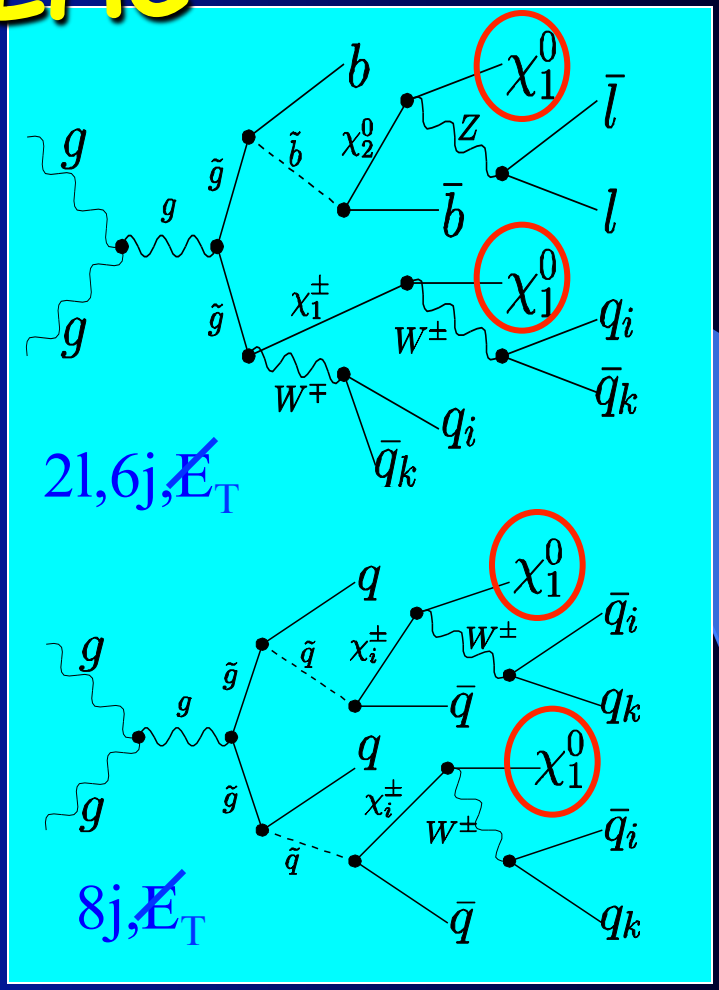
Model Dependent



Creation and Decay of Superpartners in Cascade Processes @ LHC

weak int.'s

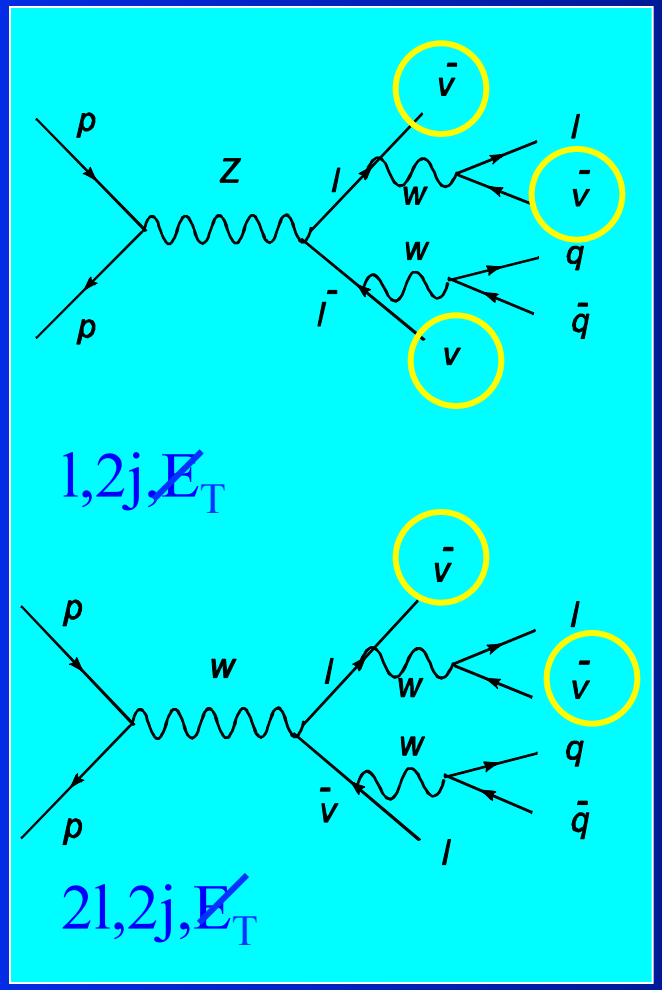


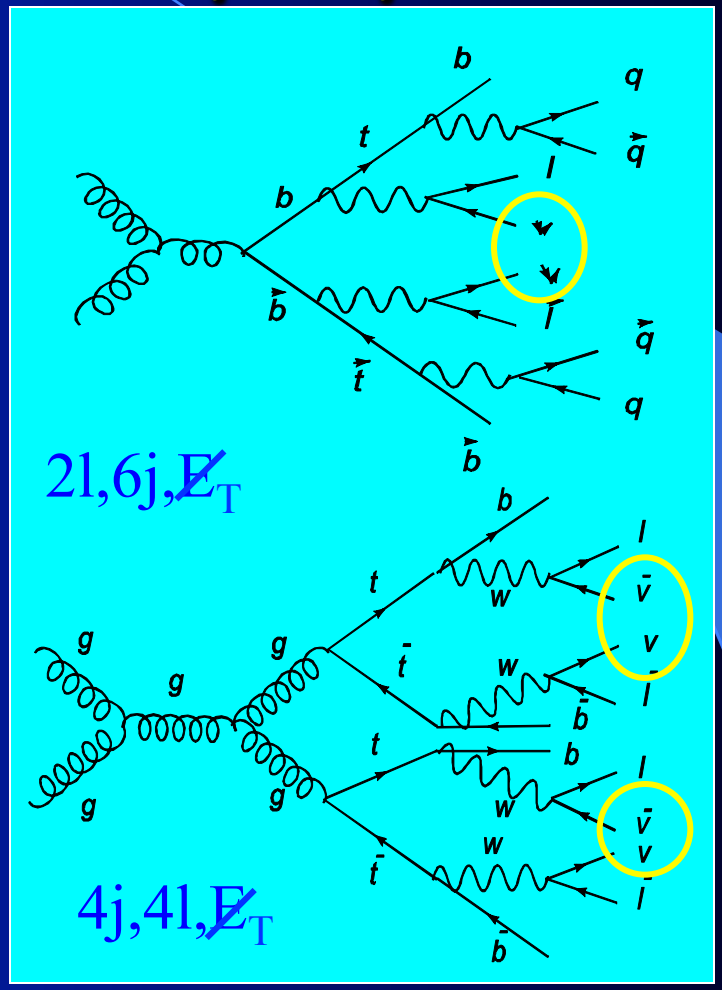


strong int.'s

Typical SUSY signature: Missing Energy and Transverse Momentum

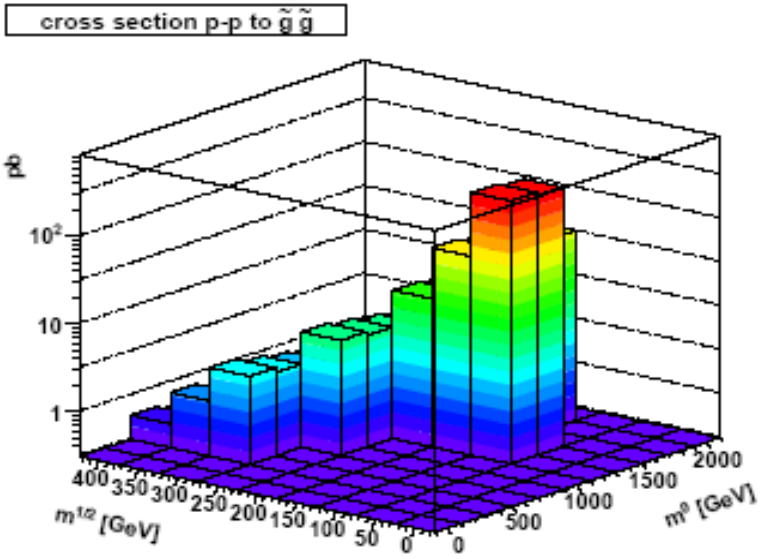
Background Processes of the SM for creation of Superpartners

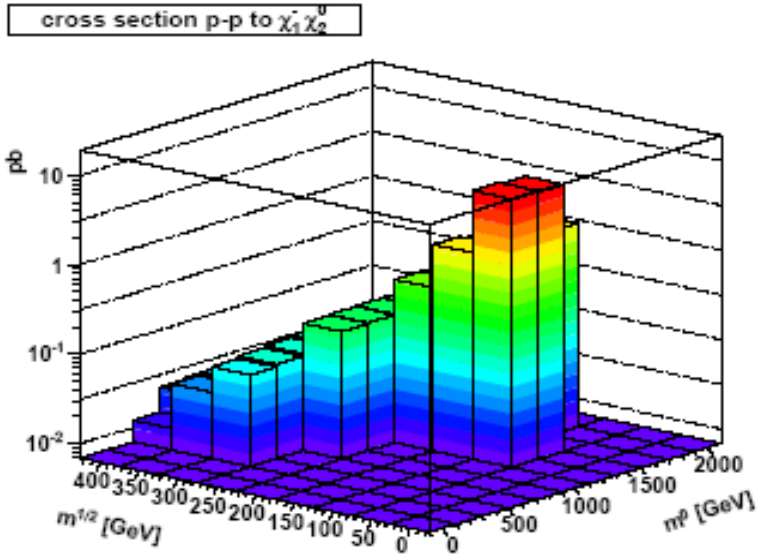


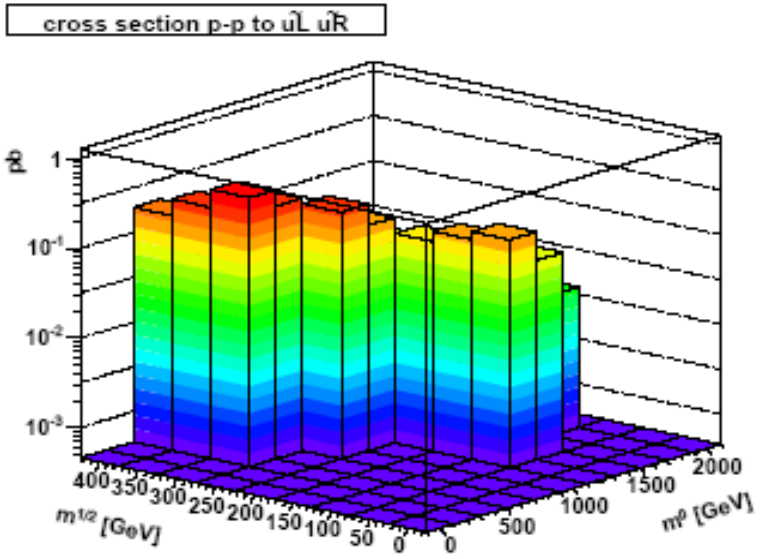


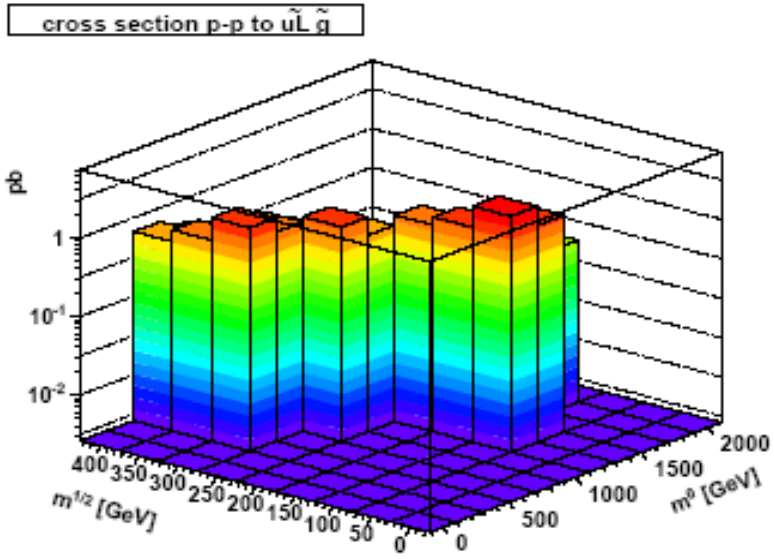
The x-sections are usually much smaller than for creation of SUSY

Cross-sections for SUSY creation @ LHC

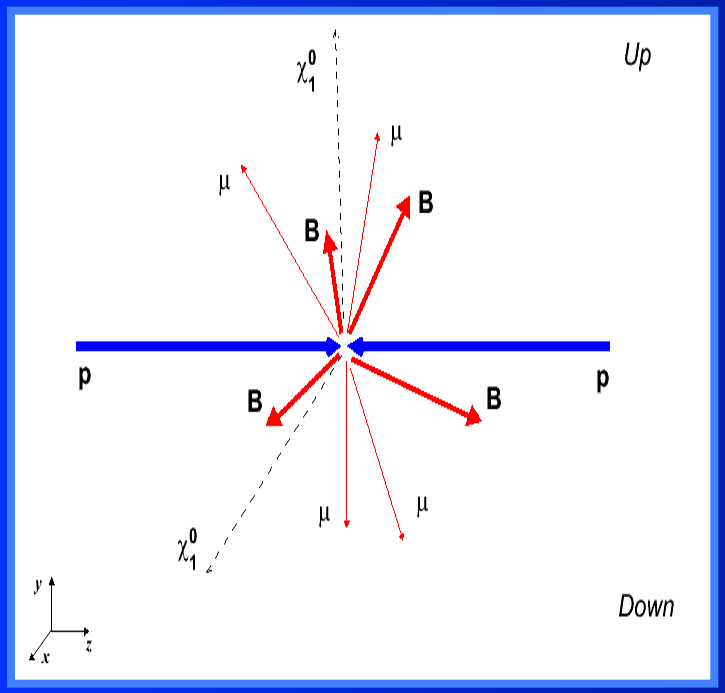


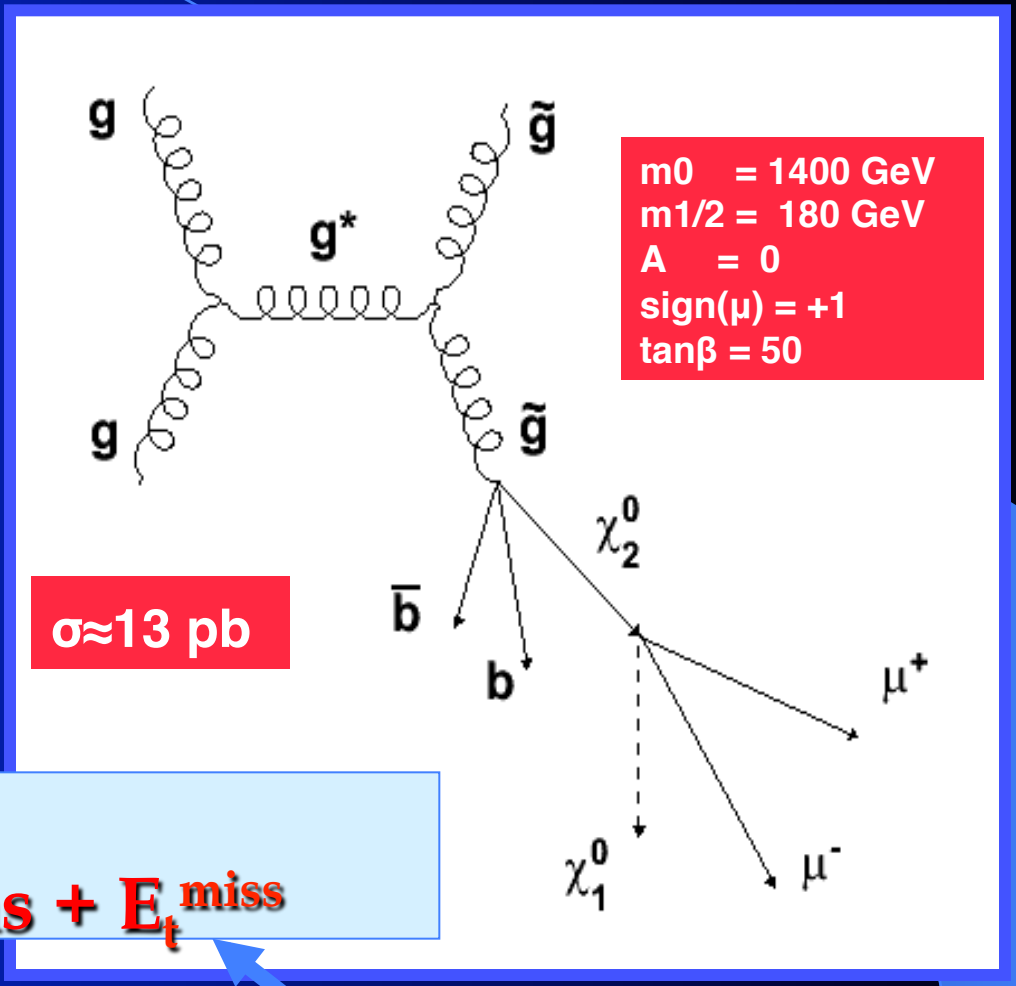






Creation of Gluino @ LHC

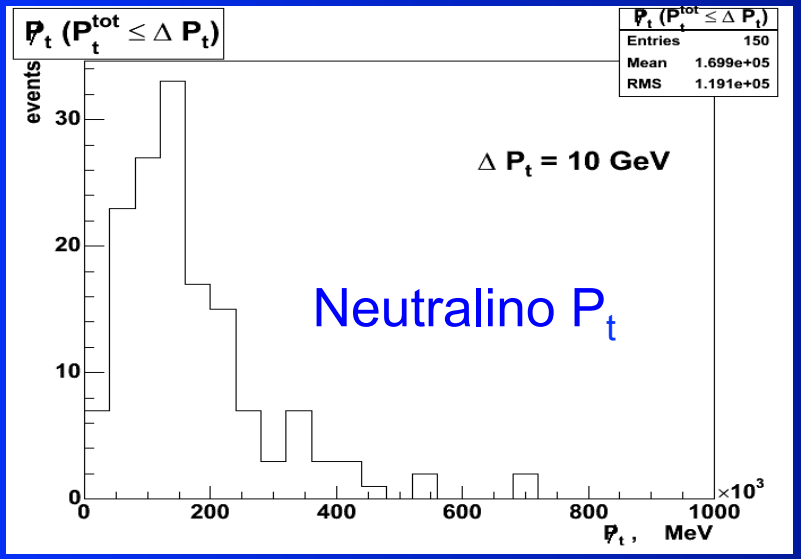


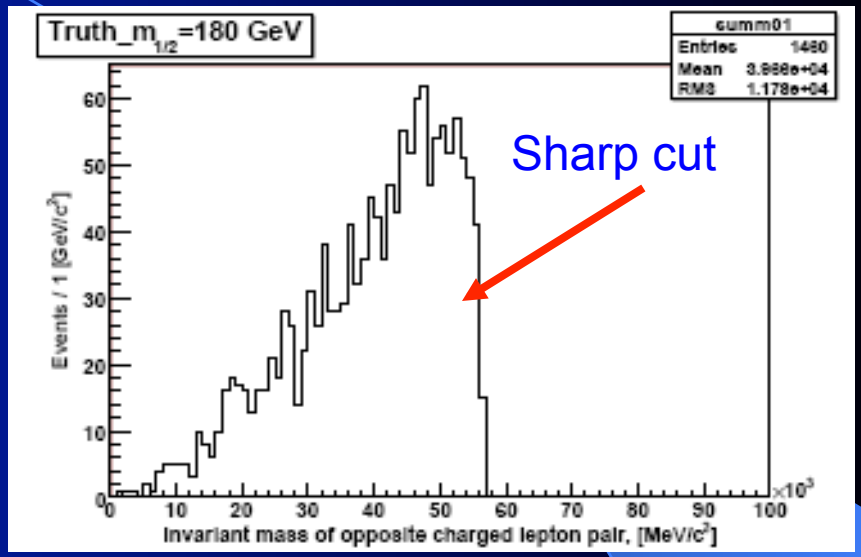


Signature:
4 b-jets + 4 muons + E_t^{miss}

Large!

SUSY Signal @ ATLAS





Missing Momentum

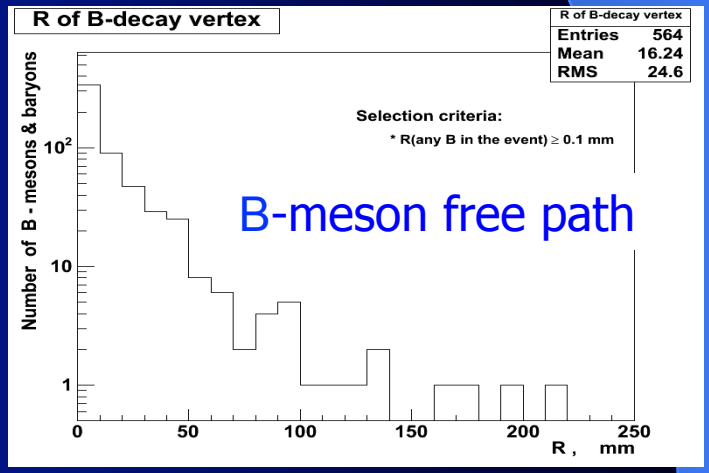
$$\Sigma P_t^{B,B,\mu,\mu}\,(\text{down}) \;-\; \Sigma P_t^{B,B,\mu,\mu}\,(\text{up}) \;=\; \not{P}_t \equiv \not{E}_t$$

Pythia within ATHENA,

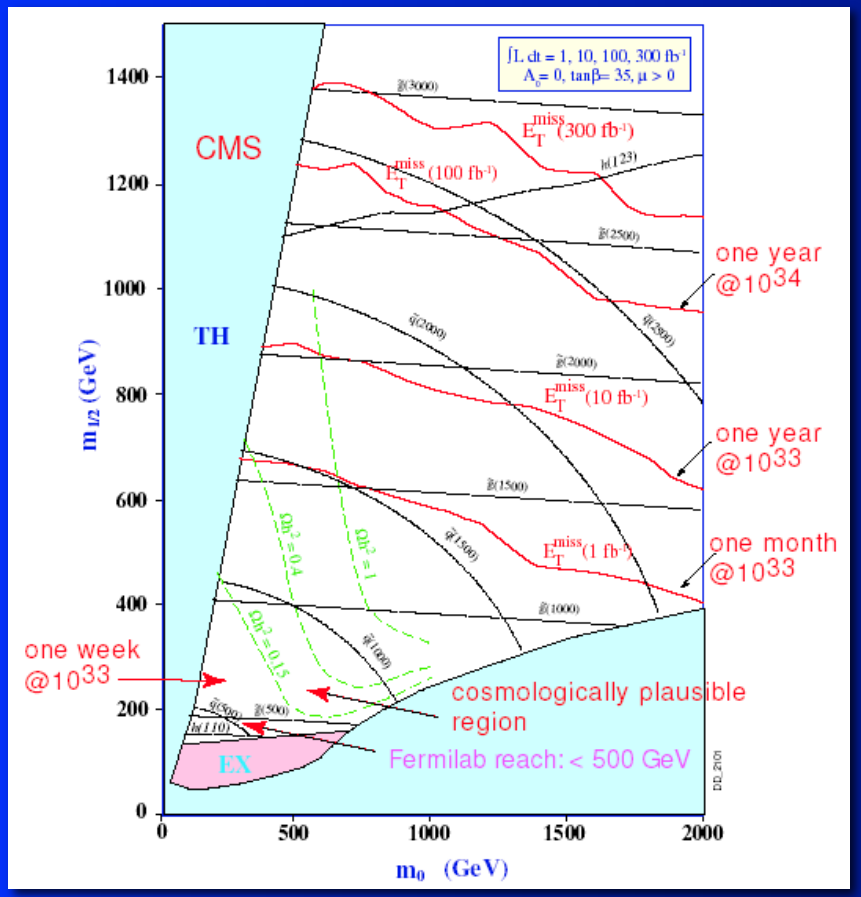
B-vertex taging

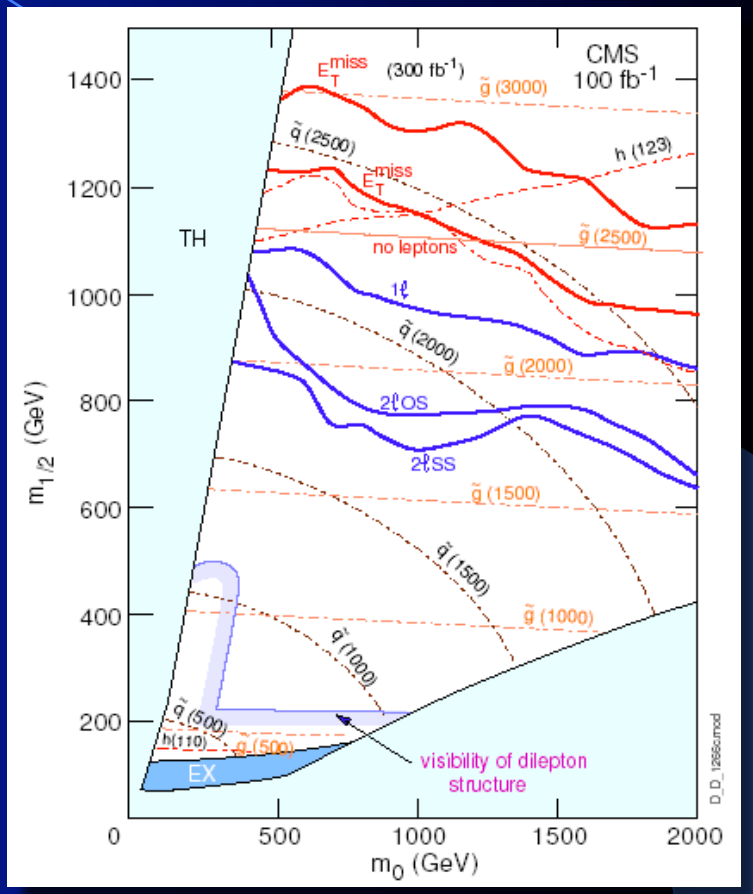
JINR ATLAS Group

Invariant Mass of lepton pair



Search for Supersymmetry @ LHC

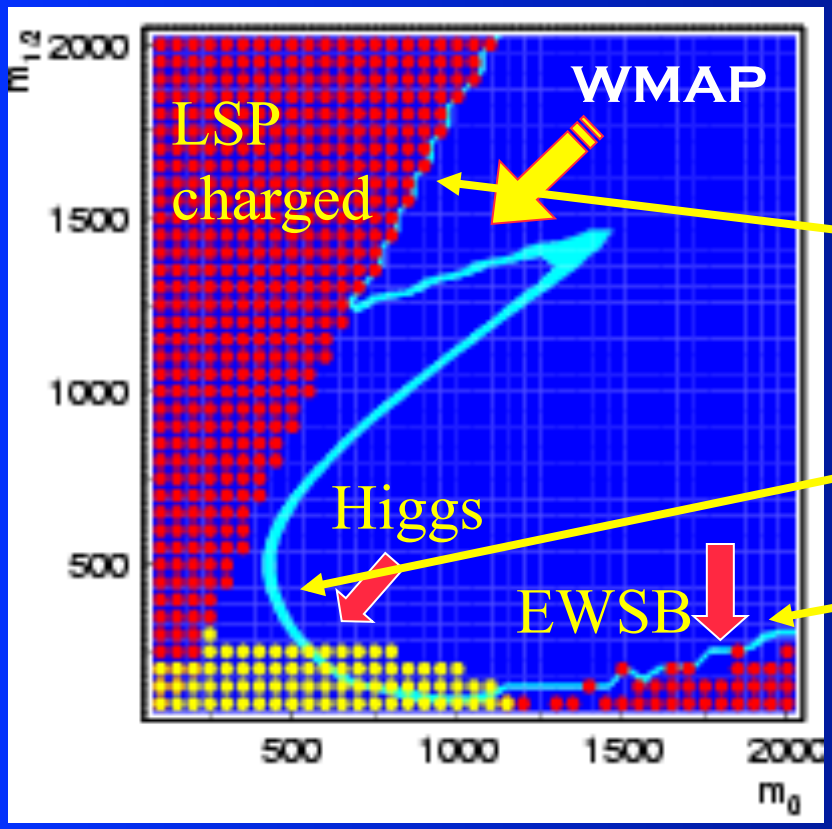




5 σ reach in jets + $\not{E}_T$ channel

Reach limits for various channels at 100 fb^{-1}

Long-Lived Superparticles



The MSSM parameter space

The reason for long-lived particles – mass degeneracy with the LSP

Long-lived $\tilde{\tau}^{\pm}$

Long-lived $\tilde{t}^{\pm}$

Long-lived $\tilde{\chi}_2^0, \tilde{\chi}_1^{\pm}$

Time of life > 10^{-10} сек, M ~ 100 ГэВ
Decay with creation of the secondary vertex or running through the detector

Needs the fine-tuning of parameters

Search for Dark Matter

The Origin of Dark Matter

The Dark Matter is made of:

- **Macro objects – Not seen**
- **New particles – axion (axino)**

Not from the SM

- **- neutralino**
- **- sneutrino**
- **- right neutrino**
- **- gravitino**
- **- heavy photon**
- **- heavy pseudo-goldstone**
- **- light sterile higgs**

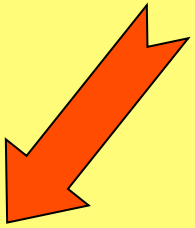
mSUGRA

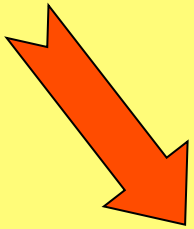
Gauge Mediation

Little Higgs Models

Inert Higgs Model

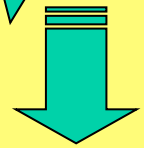
DM Detection





Direct detection

DAMA, Zeplin,
CDMS, Edelweiss



No convincing evidence so far
Hope for new results soon

Indirect detection

- EGRET -> GLAST
Diffuse Gamma Rays
- HEAT, AMS01 -> PAMELA
Positrons in Cosmic Rays
- BESS -> AMS02
Antiprotons in Cosmic Rays

First Evidence of DM annihilation!

The Lightest Superparticle

		property	signature
• Gravity mediation	LSP = $\tilde{\chi}_1^0$	stable	jets/leptons $+\not{E}_T$
• Gauge mediation	LSP = $\tilde{G}$	stable	$\not{E}_T$
	NLSP = $\tilde{\chi}_1^0$	$\tilde{\chi}_1^0 \to \gamma\tilde{G}, h\tilde{G}, Z\tilde{G}$	photons/jets $+\not{E}_T$
	NLSP = $\tilde{l}_R$	$\tilde{l}_R \to \tau\tilde{G}$	lepton $+\not{E}_T$
• Anomaly mediation	LSP = $\tilde{\chi}_1^0$	stable	lepton $+\not{E}_T$
	LSP = $\tilde{\nu}_L$	stable	

• R-parity violation — LSP is unstable ➔ SM particles

• Modern limit — $M_{LSP} \geq 40$ GeV

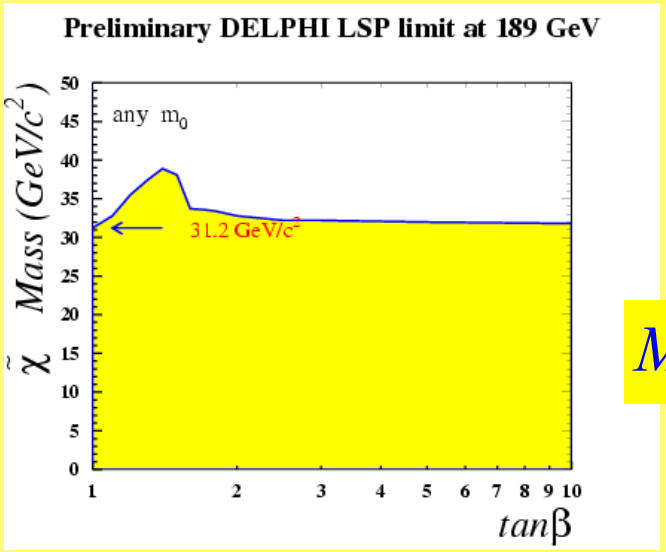
Rare decays
Neutrinoless double β decay

SUSY DARK MATTER

Neutralino = SUSY candidate for the cold Dark Matter
Neutralino = the Lightest Superparticle (LSP) = WIMP

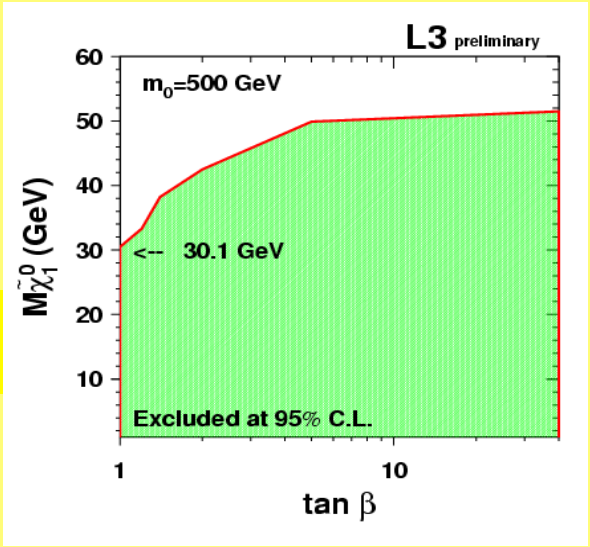
$$\tilde{\chi}^0 = N_1\tilde{\gamma} + N_2\tilde{z} + N_3\tilde{H}_1^0 + N_4\tilde{H}_2^0$$

photino zino higgsino higgsino



$$M_\chi^{exp} \geq 40 \text{ GeV}$$

$$M_\chi^{theor} = 40 \div 400 \text{ GeV}$$

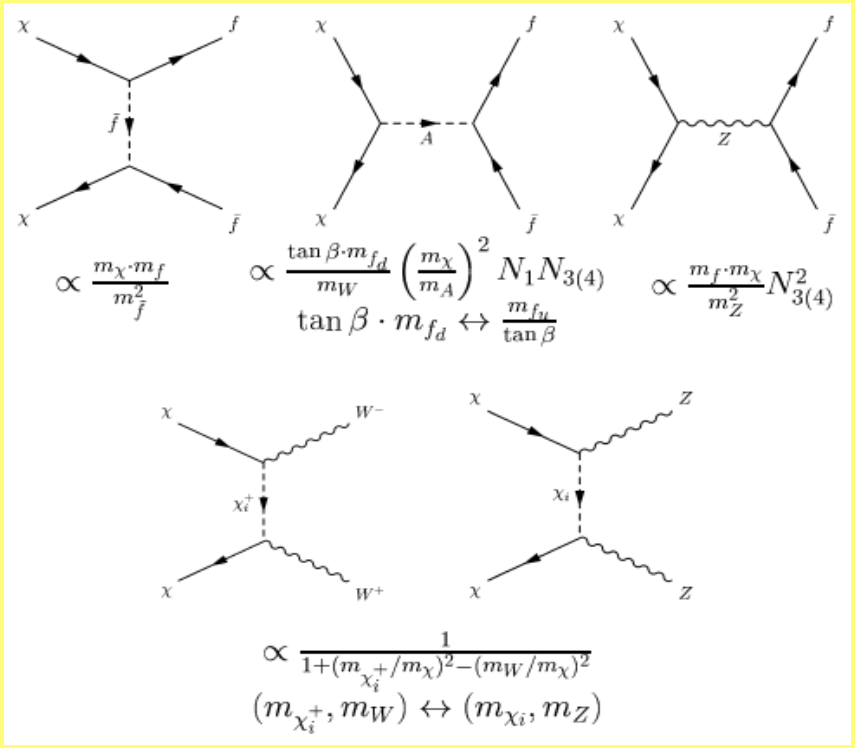


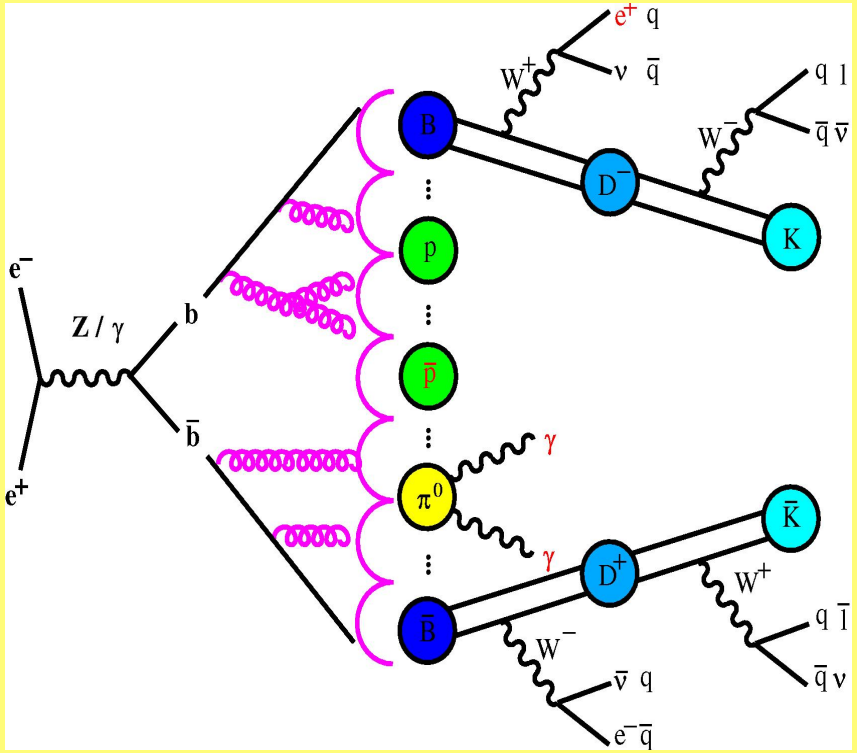
$$R = (-1)^{3(B-L)+2S}$$

$$R_p = +1,\ R_{\not p} = -1$$

- **Superparticles are created in pairs**
- **The lightest superparticle is stable**

DM NEUTRALINO ANNIHILATION FINAL STATES



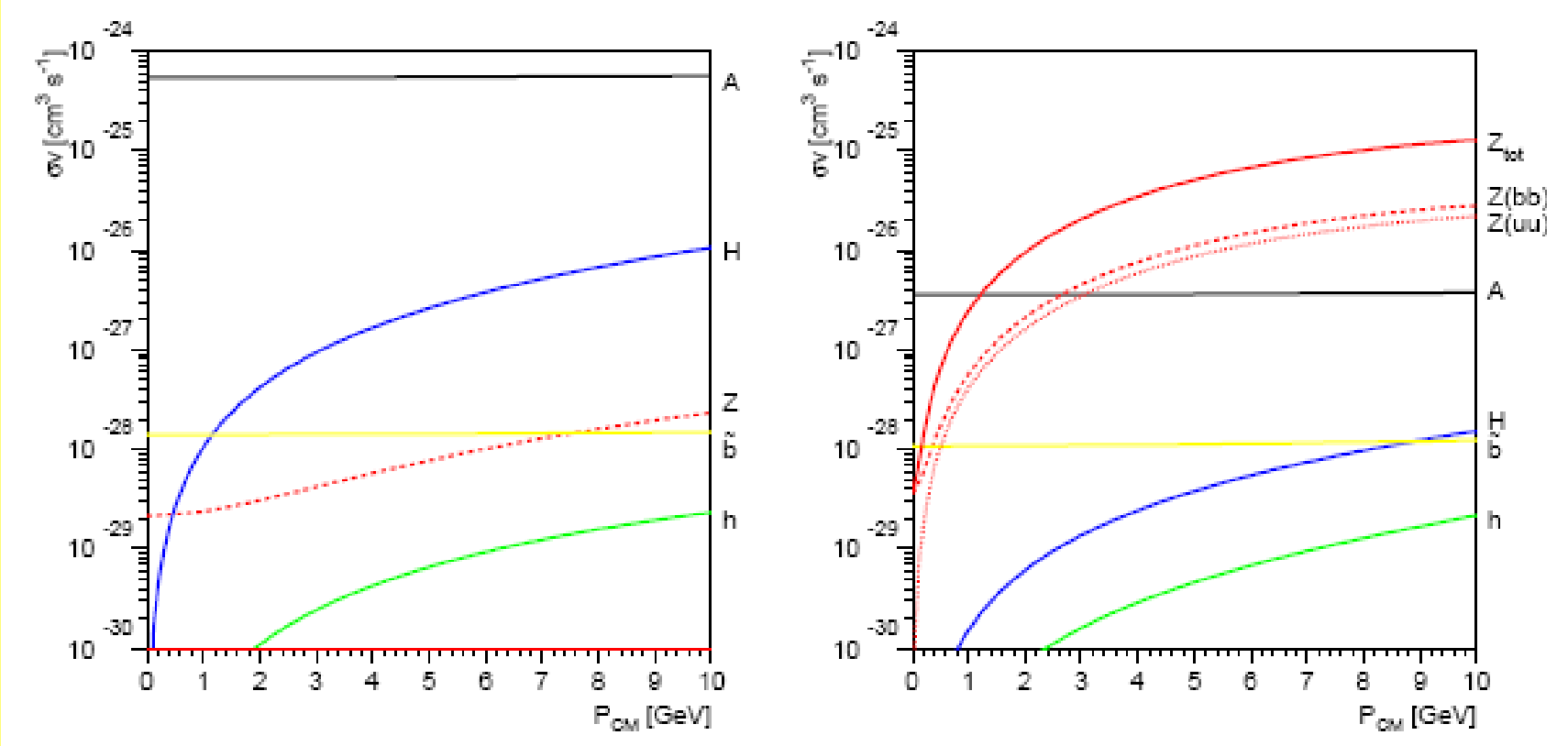


Dominant annihilation x-section: X + X ➔ A ➔ b̄b quark pair

Sum of diagrams should yield $\langle\sigma v\rangle = 2.10^{-26}$ cm³/s to get correct relic density

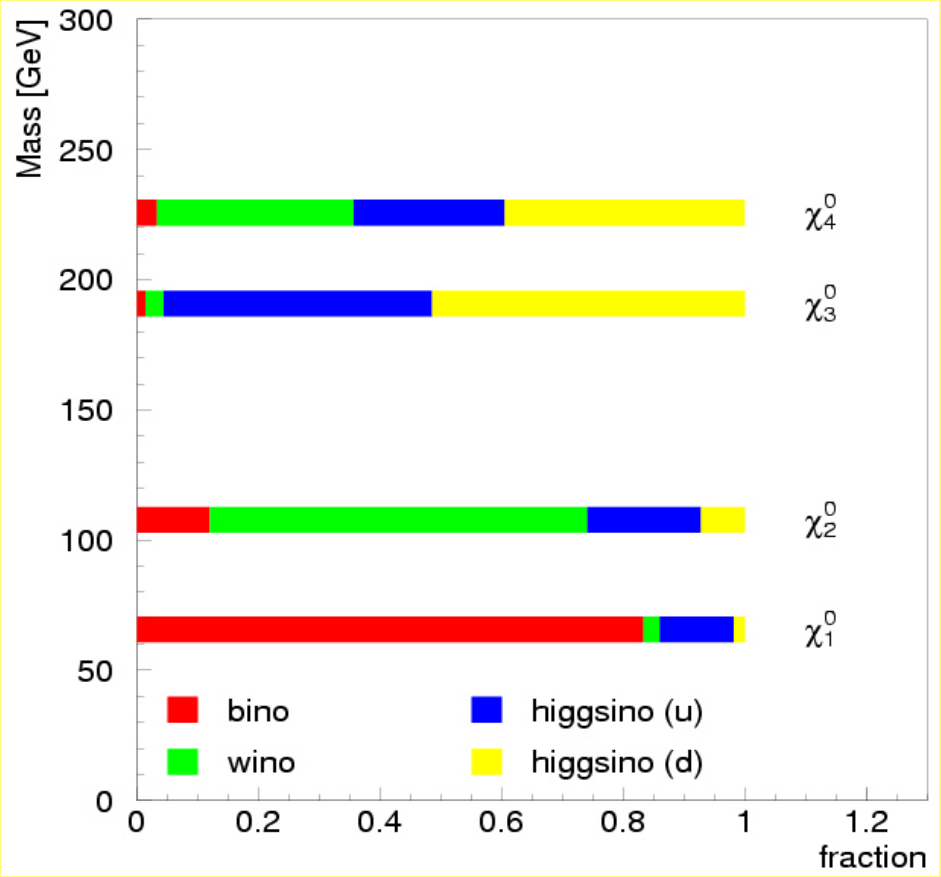
B-fragmentation well studied at LEP! Yield and spectra of positrons, gammas and antiprotons well known!

DM NEUTRALINO ANNIHILATION CROSS-SECTION



Dominant annihilation x-section:
X + X → A → bb quark pair

GAUGINO CONTENT OF THE LIGHTEST NEUTRALINO



	$\tilde{b}^0$	$\tilde{w}^0$	$\tilde{h}_1^0$	$\tilde{h}_2^0$
$\tilde{\chi}_1^0$	0.833	0.026	0.122	0.018
$\tilde{\chi}_2^0$	0.119	0.621	0.187	0.072
$\tilde{\chi}_3^0$	0.014	0.030	0.442	0.515
$\tilde{\chi}_4^0$	0.033	0.323	0.249	0.395

The lightest neutralino is almost bino – the superpartner of a photon

DM = superpartner of the CMB

Favoured regions of parameter space

EGRET region

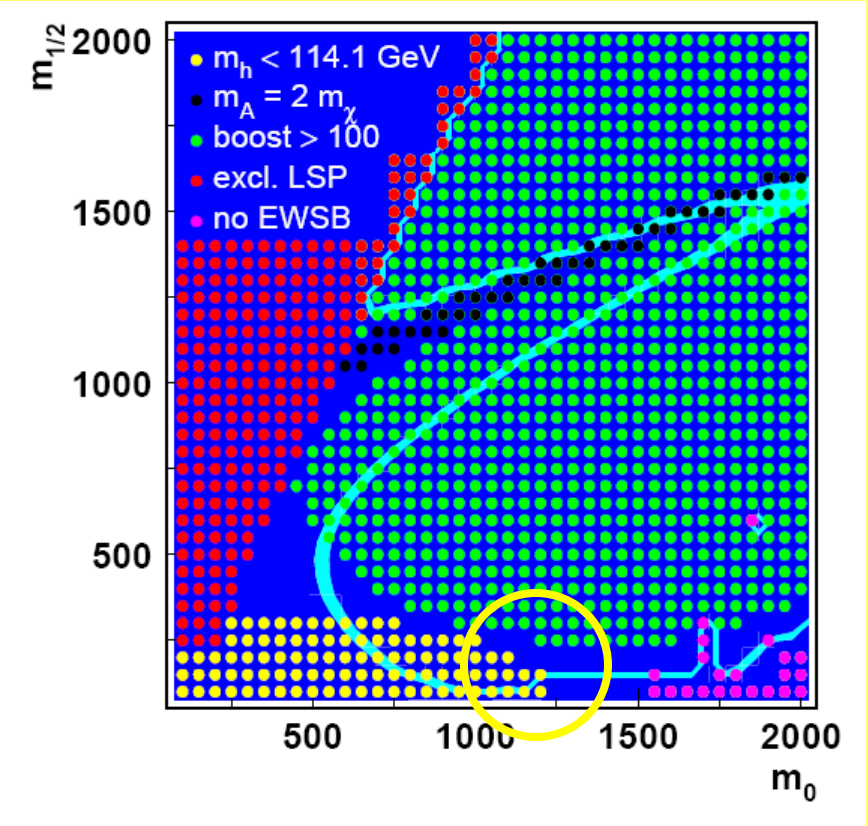
The region is compatible with diffuse gamma ray flux from the DM annihilation

It corresponds to the best fit values of parameters

tan β= 51

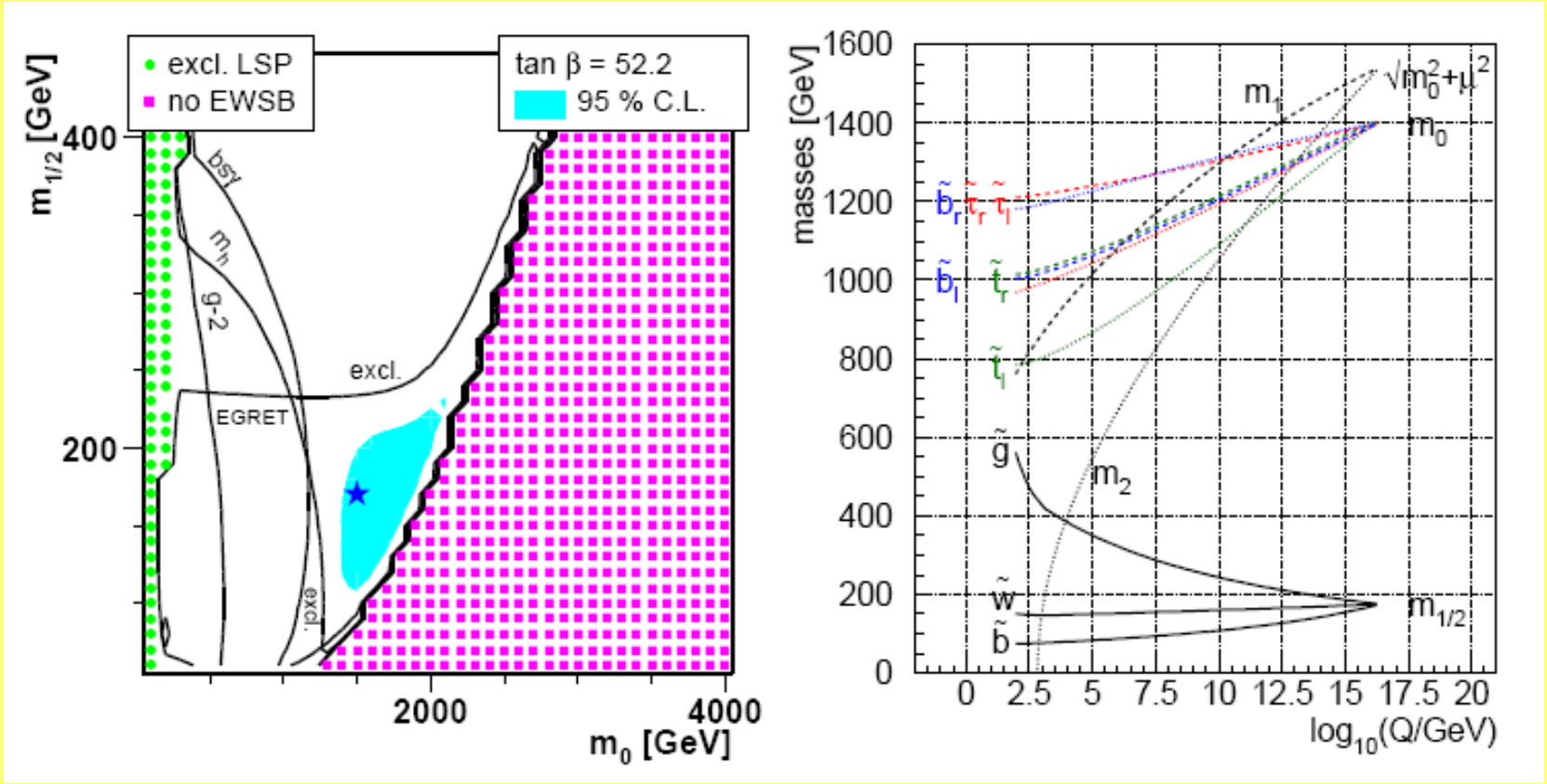
m0 = 1400 GeV

m1/2 = 180 GeV



SUSY DM: $m_{\chi^0} \sim 65$ GeV ⇒ $m_{\chi^\pm} \sim 115$ GeV

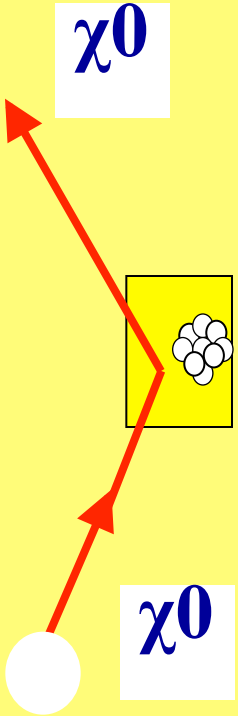
EGRET POINT AND MASS SPECTRUM

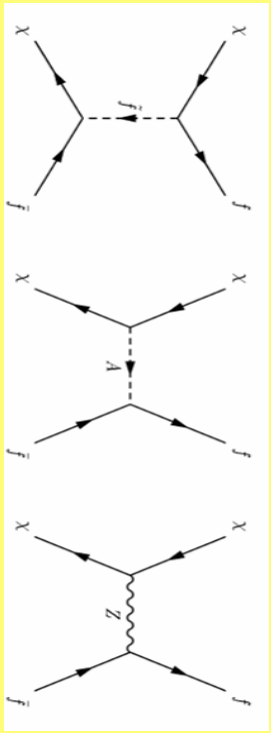


Direct Detection of WIMPs

WIMPs elastically scatter off nuclei => nuclear recoils

Measure recoil energy spectrum in target





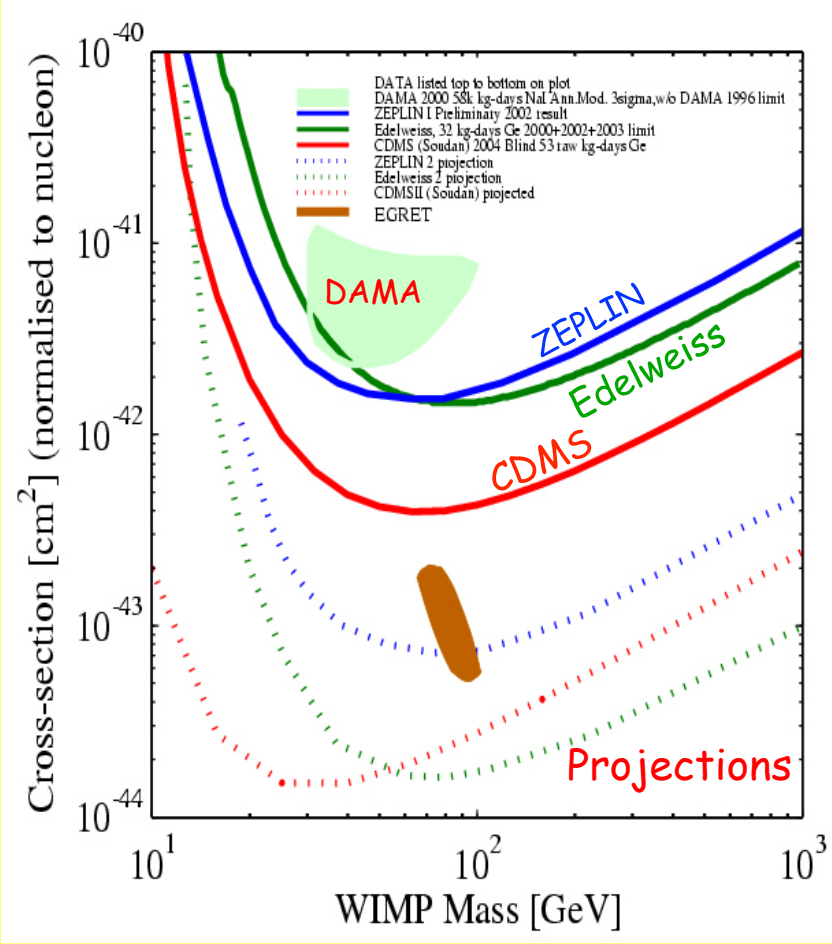
Spin dependent and indep.

Spin independent ~ Number of nuclei^2
(coherent scattering on all nuclei!)

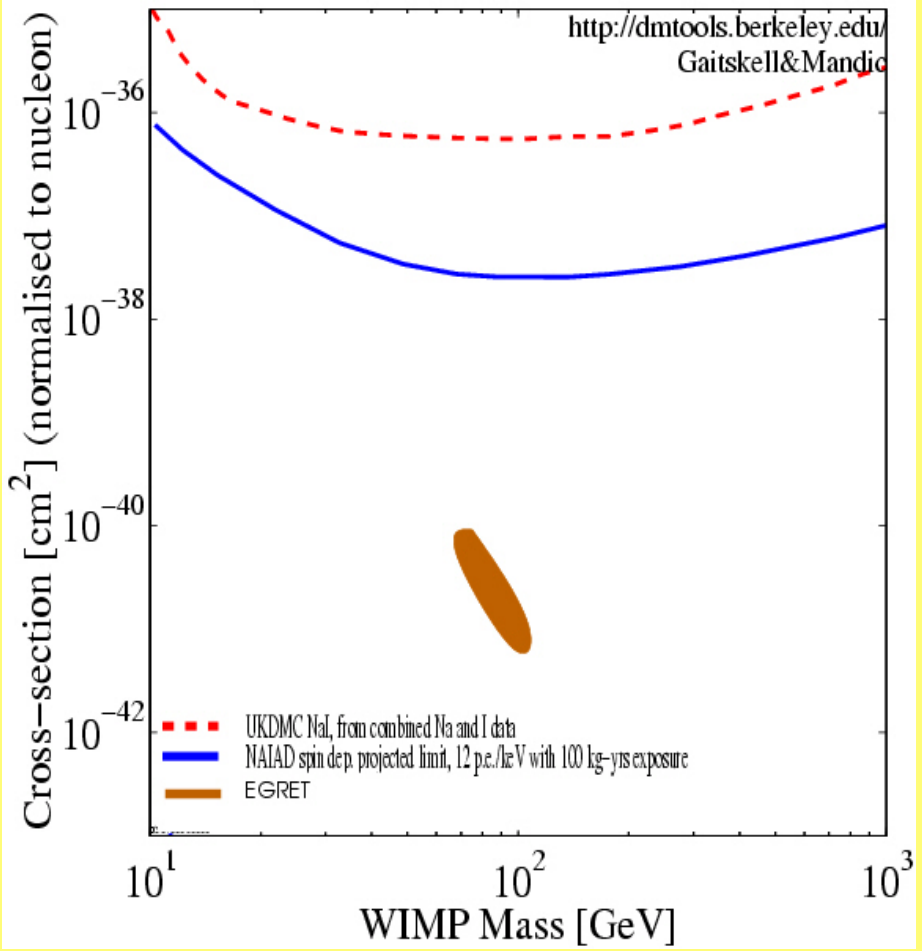
Spin dependent

DIRECT DM SEARCHES

Spin-independent



Spin-dependent



Predictions from EGRET data assuming Supersymmetry