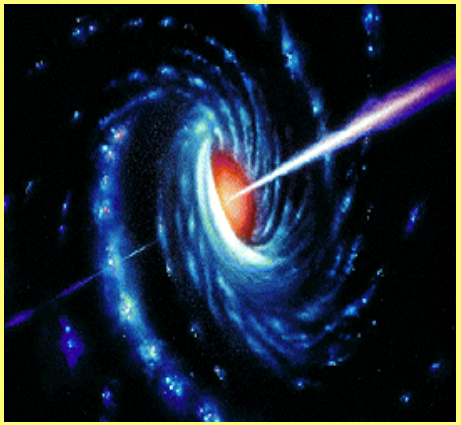


SUSY PHENOMENOLOGY & SUSY DARK MATTER

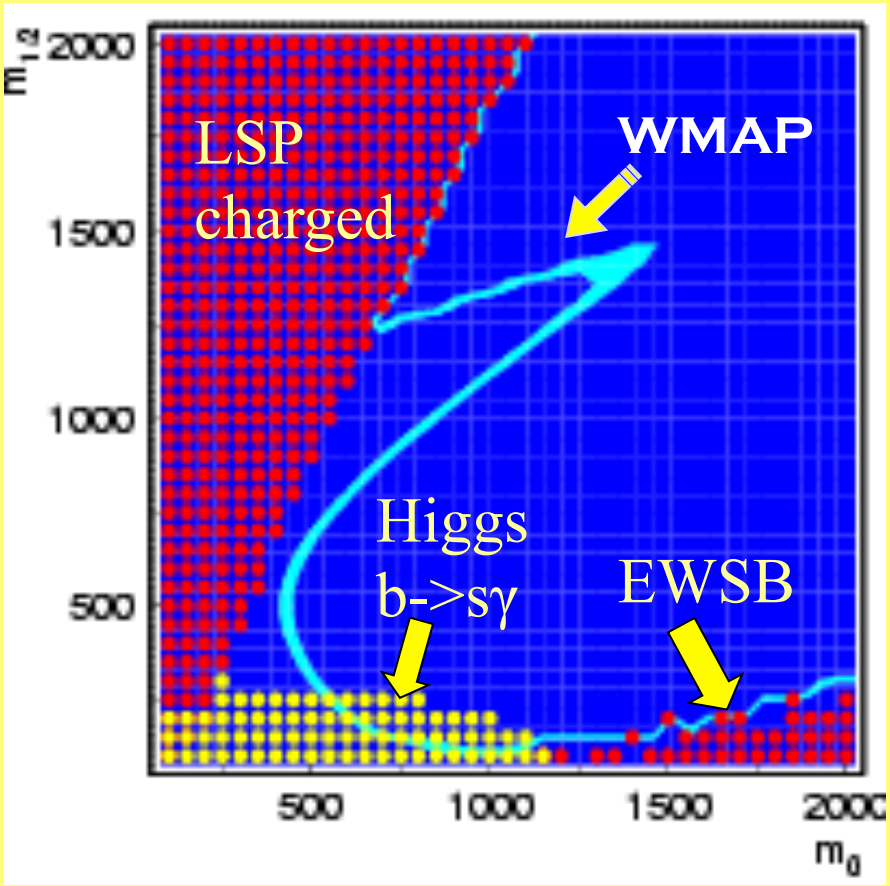
Dmitri Kazakov

JINR(Dubna) & ITEP(Moscow)

Outline

1. Allowed regions of SUSY parameter space
2. SUSY DM and excess of galactic gamma rays
3. DM annihilation in Galactic halo
4. Fit to WIMP mass -> neutralino mass
5. New constraint on SUSY parameter space
6. Prediction of SUSY mass spectrum
7. Search for SUSY at LHC

ALLOWED SUSY PARAMETER SPACE



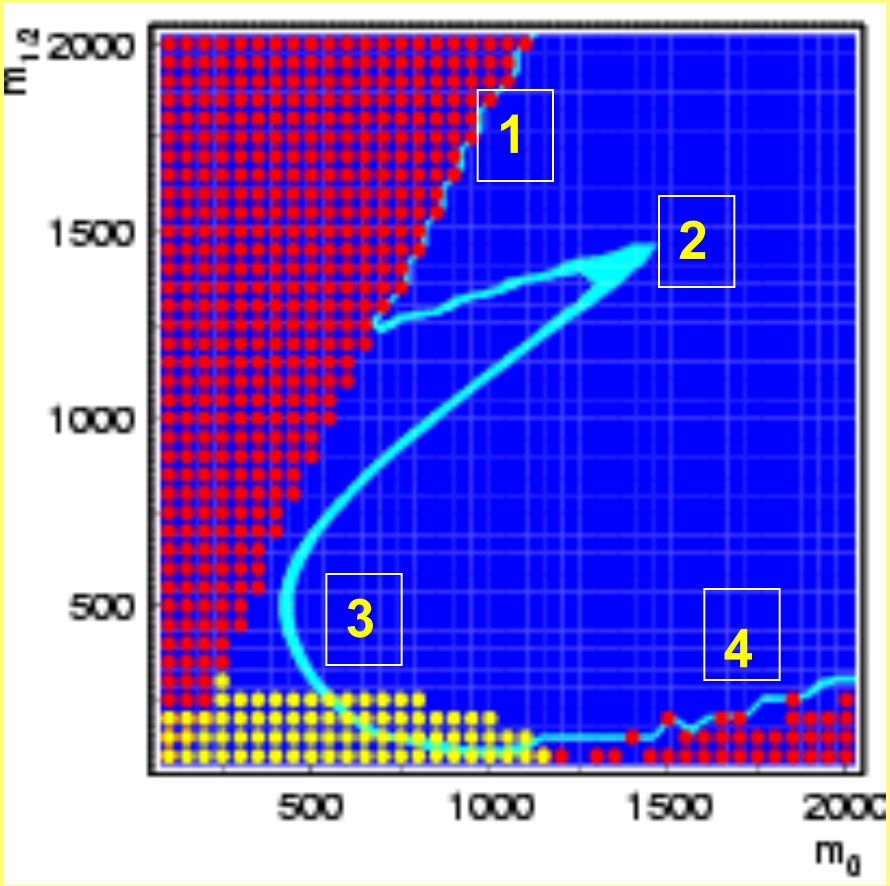
tan β =50

In allowed region one fulfills all the constraints simultaneously and has the suitable amount of the dark matter

Narrow allowed region enables one to predict the particle spectra and the main decay patterns

m_0 common spin 0 mass
$m_{1/2}$ common spin ½ mass
$\tan\beta = v_2/v_1$

REGIONS OF PARAMETER SPACE



Phenomenology essentially depends on the region of parameter space and has direct influence on the strategy of SUSY searches

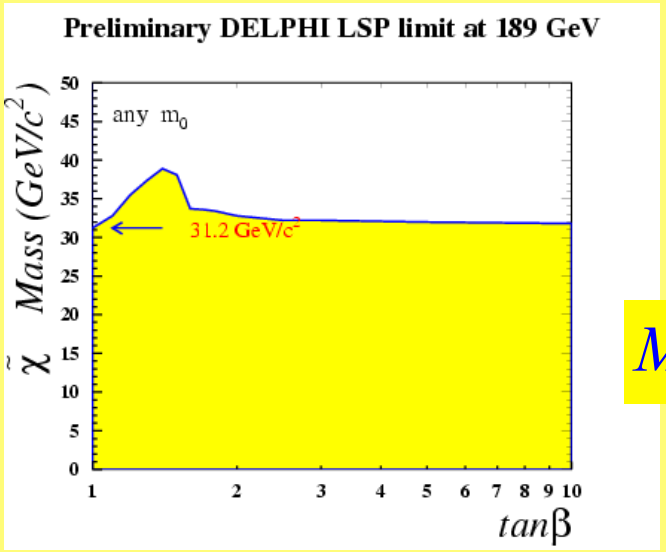
1. $\tilde{\chi}^0\tilde{\tau}$ - coannihilation region
2. *A*-annihilation funnel region
3. Bulk region
4. Focus point region

SUSY DARK MATTER

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

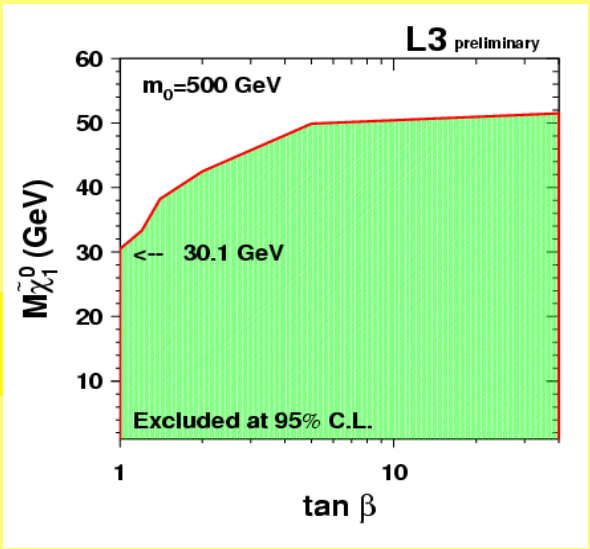
$$\tilde{\chi}^0 = N_1\tilde{\gamma} + N_2\tilde{z} + N_3\tilde{H}_1^0 + N_4\tilde{H}_2^0$$

photino zino higgsino higgsino



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

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

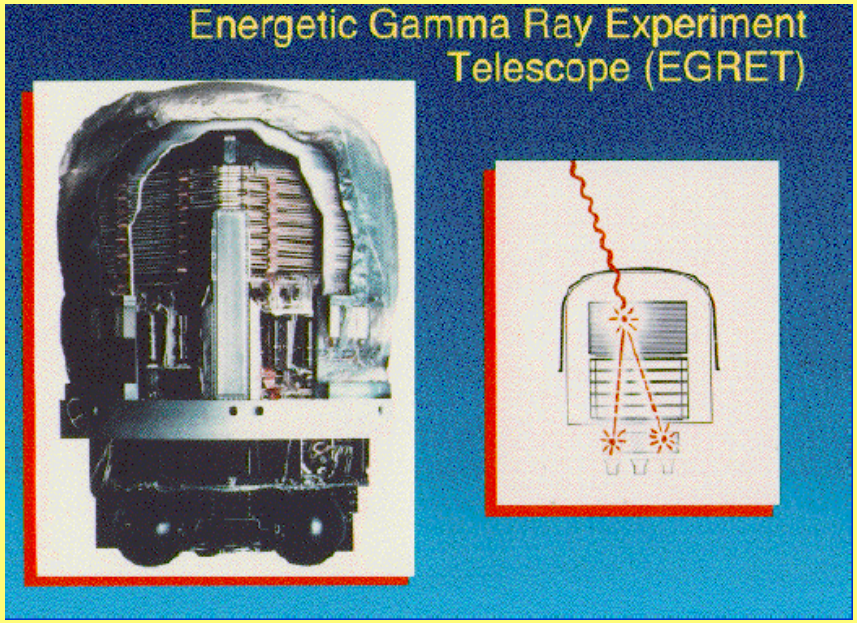


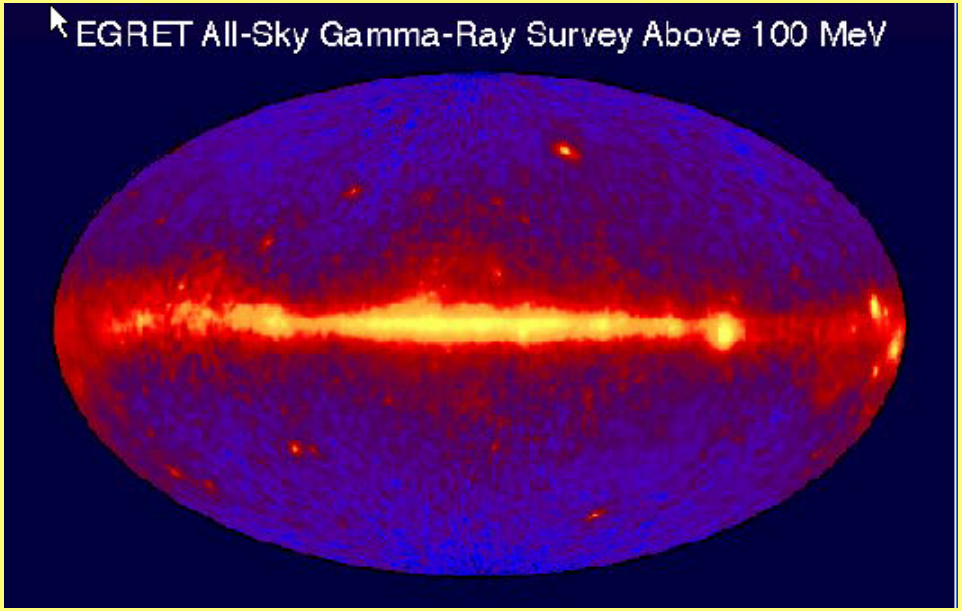
$$R = (-1)^{3(B-L)+2S}$$

$$R_p = +1,\ R_{\tilde{p}} = -1$$

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

DIFFUSE GAMMA RAYS FROM THE SKY





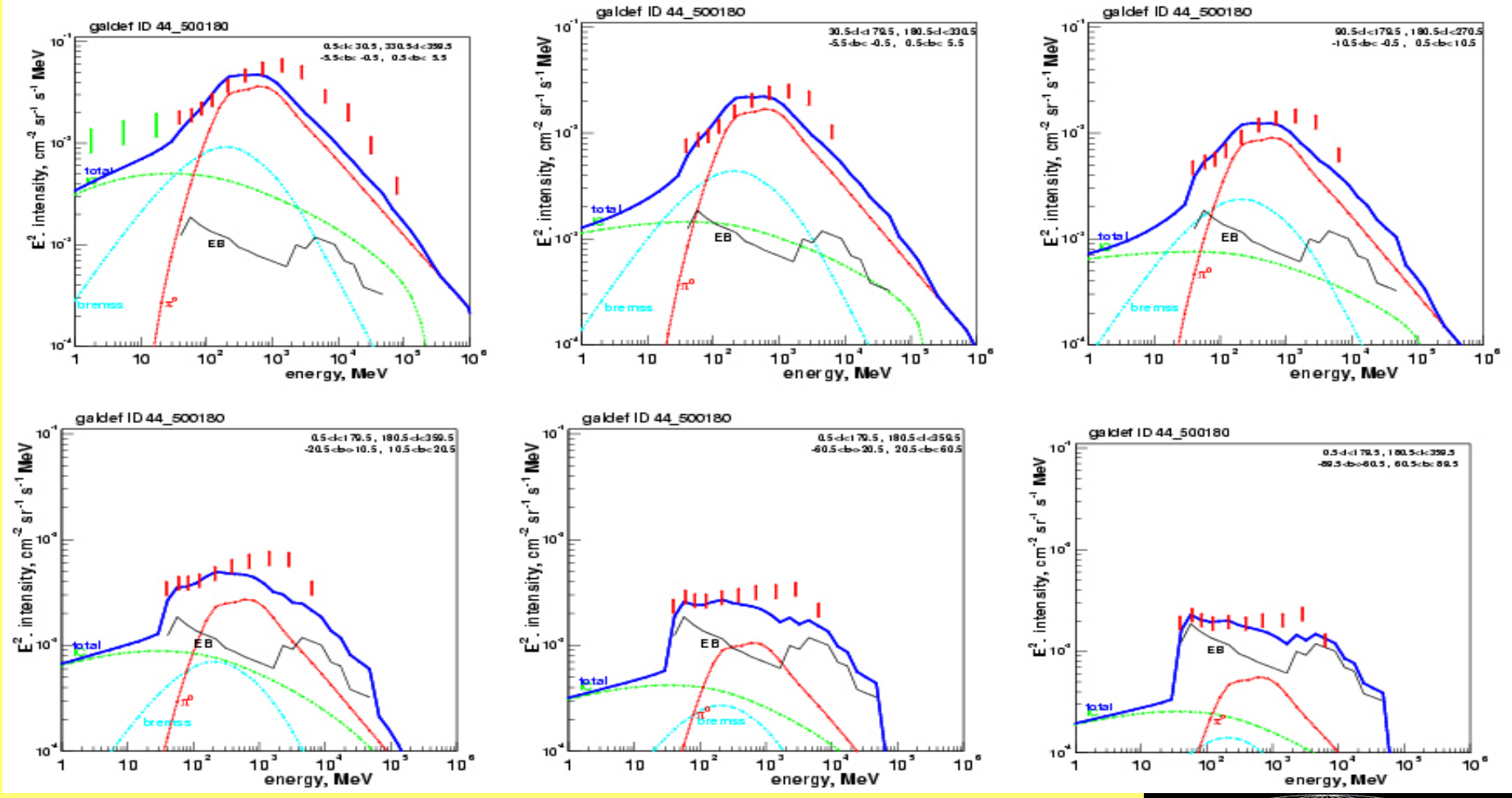
Instrumental parameters:

Energy range: 0.02-30 GeV
Energy resolution: ~20%
Effective area: 1500 cm^2
Angular resol.: $<0.5^0$

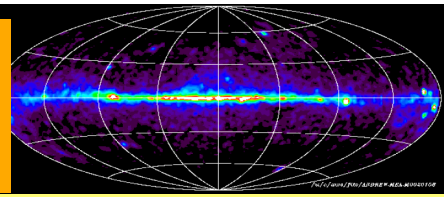
Data taking: 1991-2000

Main EGRET results:
Catalogue of point sources
Excess in diffuse gamma rays

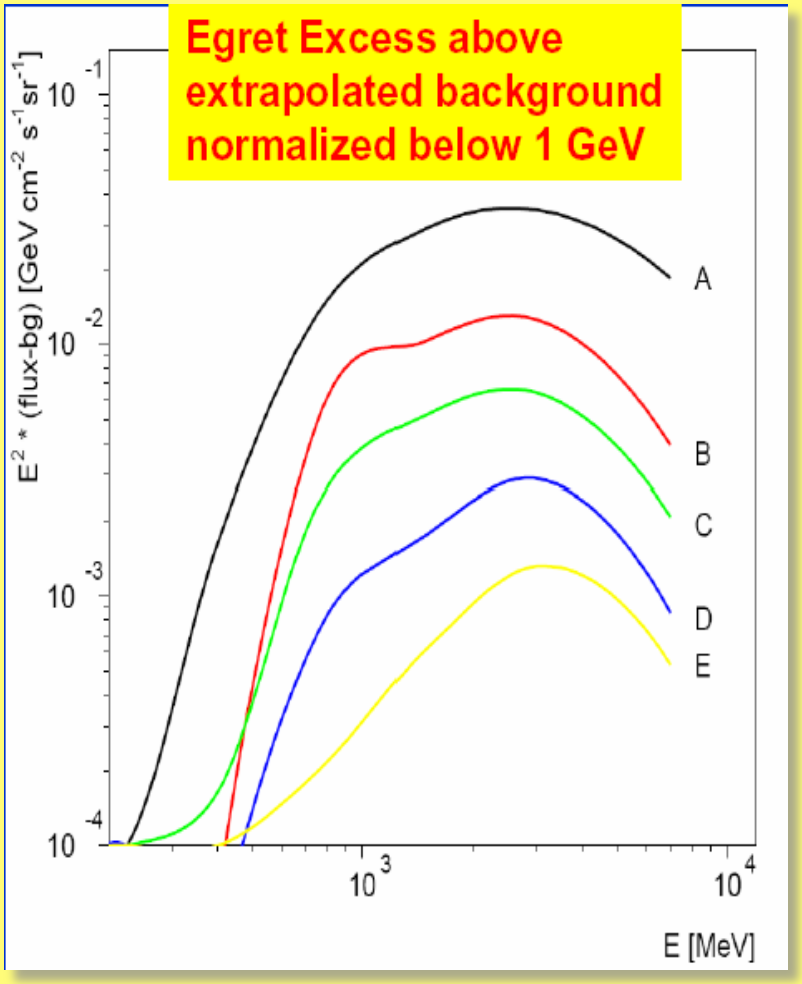
EXCESS OF DIFFUSE GAMMAY RAYS ABOVE 1 GEV

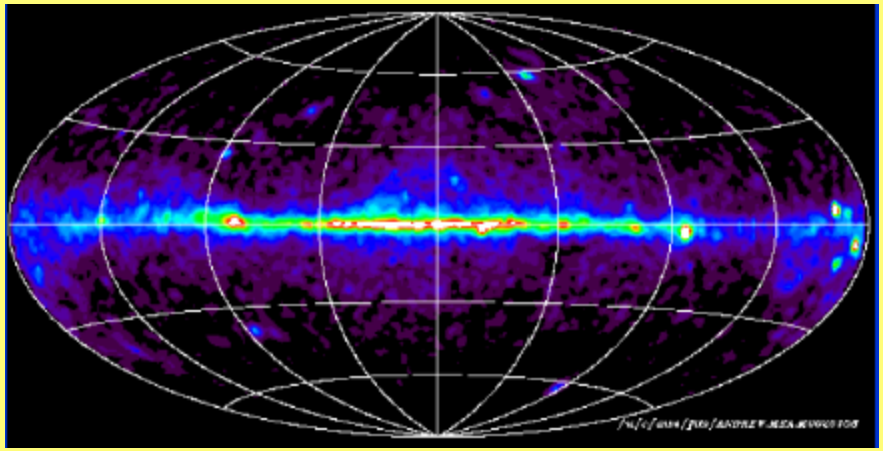


A: inner Galaxy (l=±30⁰, |b|<5⁰)
B: Galactic plane avoiding A
C: Outer Galaxy
D: low latitude (10-20⁰)
E: intermediate lat. (20-60⁰)
F: Galactic poles (60-90⁰)



DIFFUSE GAMMA RAYS IN EGRET ENERGY RANGE





A: inner Galactic plane (±30^0)
B: Galactic plane avoiding inner Galaxy (30-330^0)
C: Outer Galaxy (90-270^0)
D: low Latitude (10^0-20^0)
E: intermediate Latitude
F: galactic poles(60^0-90^0)

Excess same shape in all regions implying same source everywhere in galaxy

Physics Questions:

- **What is the origin of excess of diffuse Galactic Gamma Rays?**
- **What is Cold Dark Matter made of?**
- **Where are the Supersymmetric Particles?**

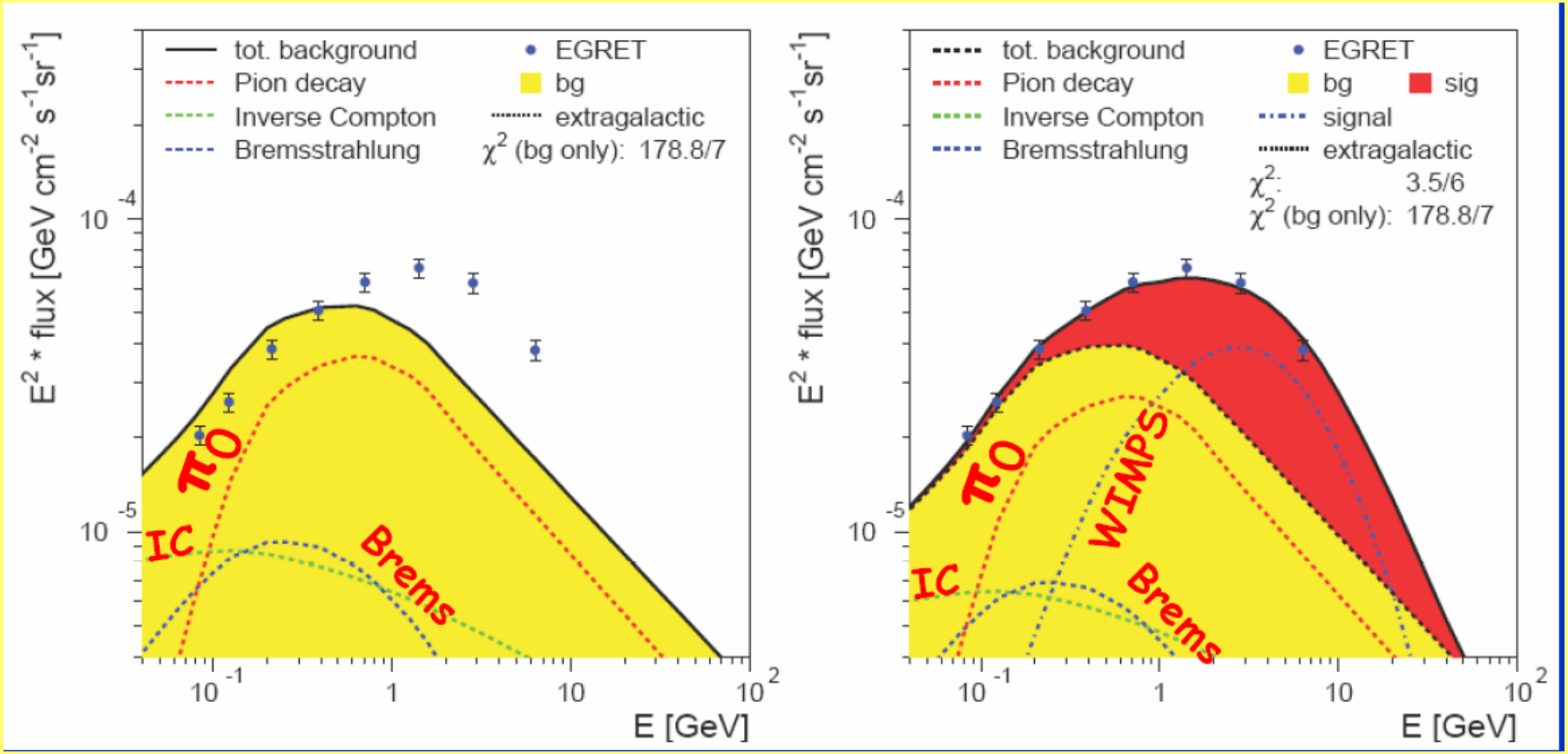
Solution:

In collaboration with W. de Boer, C. Sander, V. Zhukov (Uni Karlsruhe) and A. Gladyshev (JINR, Dubna)

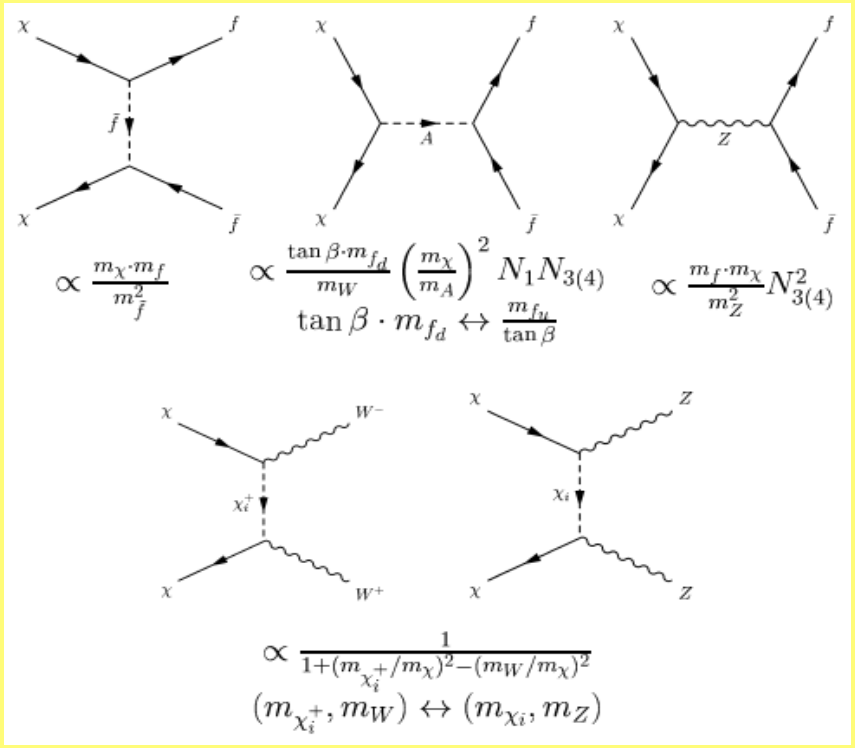
A&A 444 (2005)17
PL B636 (2006)13
PRL 95 (2005) 209001

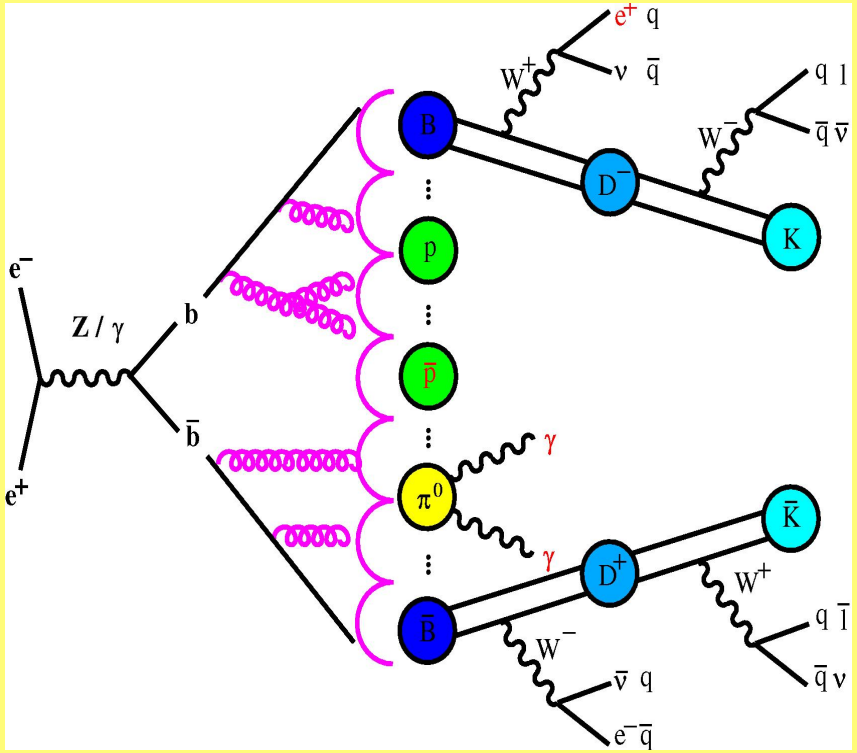
- **EGRET excess is due to DM annihilation**
- **DM is made of WIMPs which are SUSY particles distributed in Halo of our Galaxy**
- **SUSY Neutralinos have a mass around 60 GeV and should be observable at the LHC**

EXCESS OF DIFFUSE GAMMAY RAYS WITH AND WITHOUT DM ANNIHILATION



DM NEUTRALINO ANNIHILATION FINAL STATES



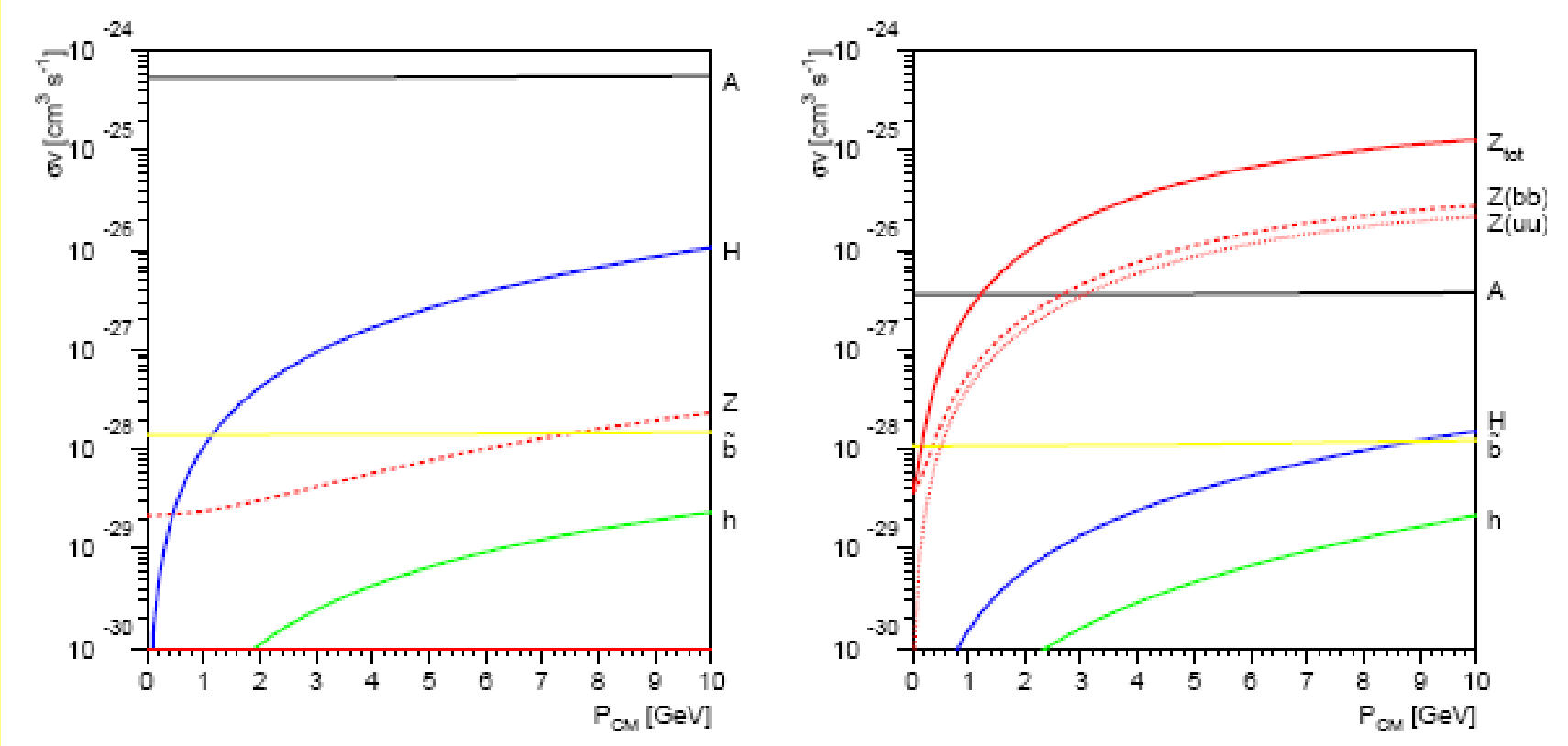


Dominant annihilation x-section:
X + X ➔ A ➔ $b\bar{b}$ quark pair

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

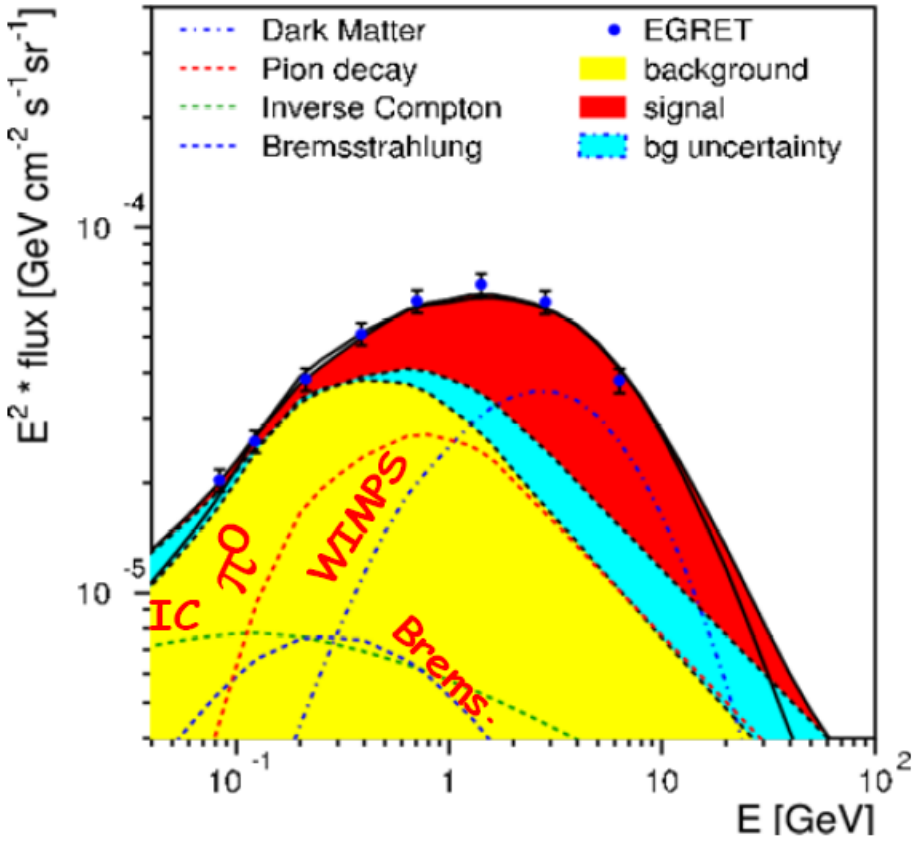
B-fragmentation well studied at LEP! Yield and spectra of positrons, gammas and antiprotons well known!

DM NEUTRALINO ANNIHILATION CROSS-SECTION

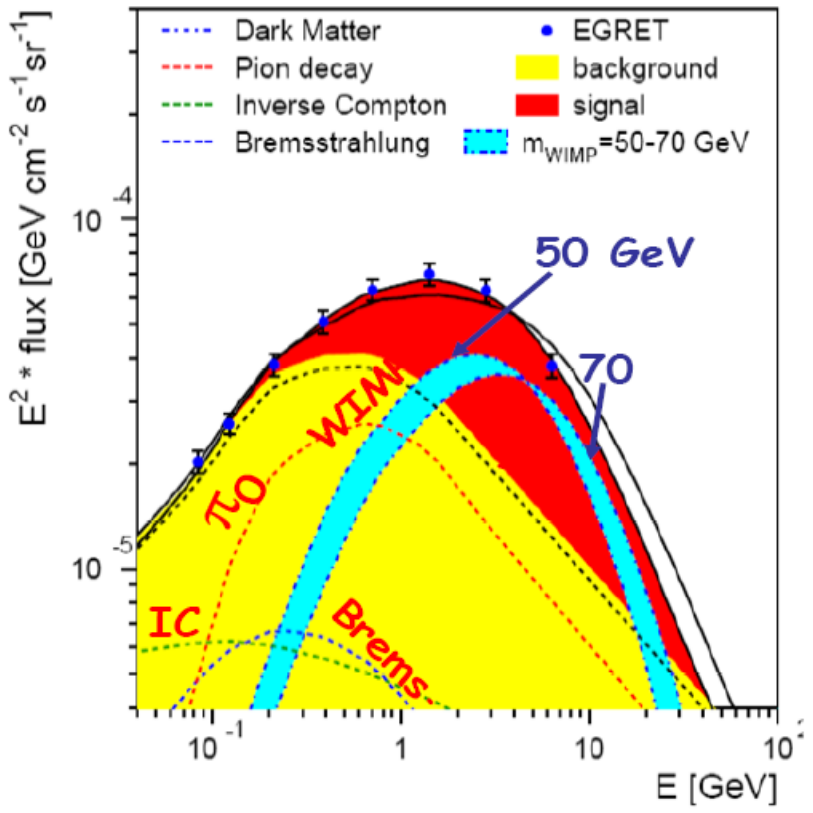


Dominant annihilation x-section:
X + X → A → bb quark pair

BACKGROUND + SIGNAL DESCRIBE EGRET DATA

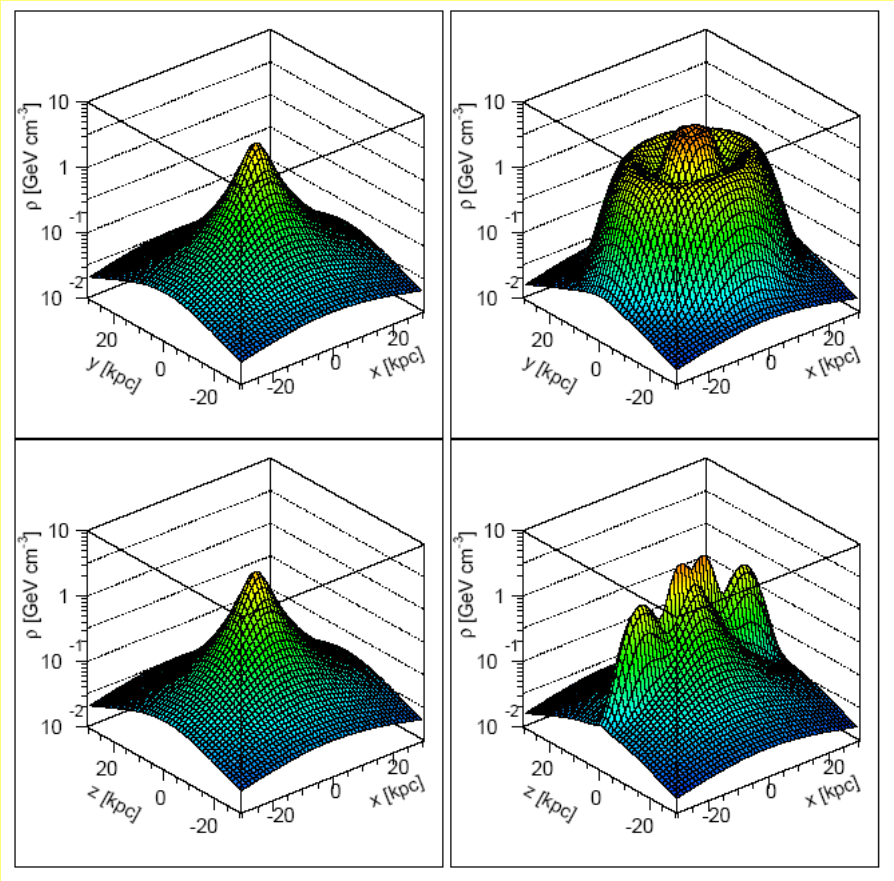


Blue: background uncertainty

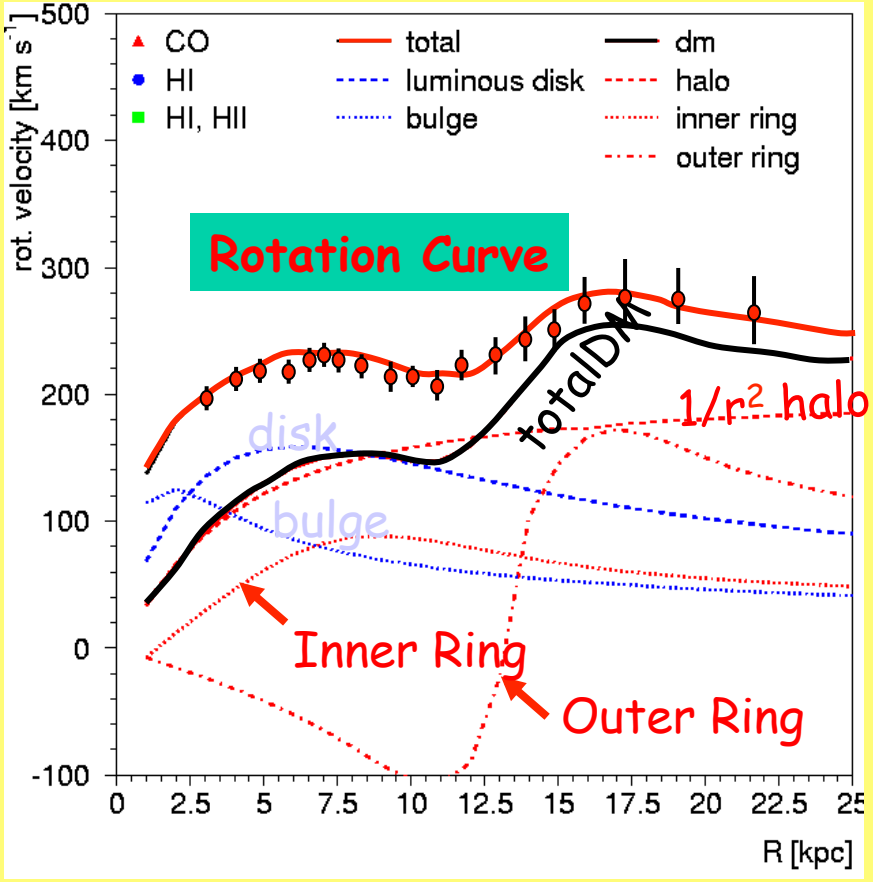


Blue: WIMP mass uncertainty

HALO PROFILE AND ROTATION CURVE

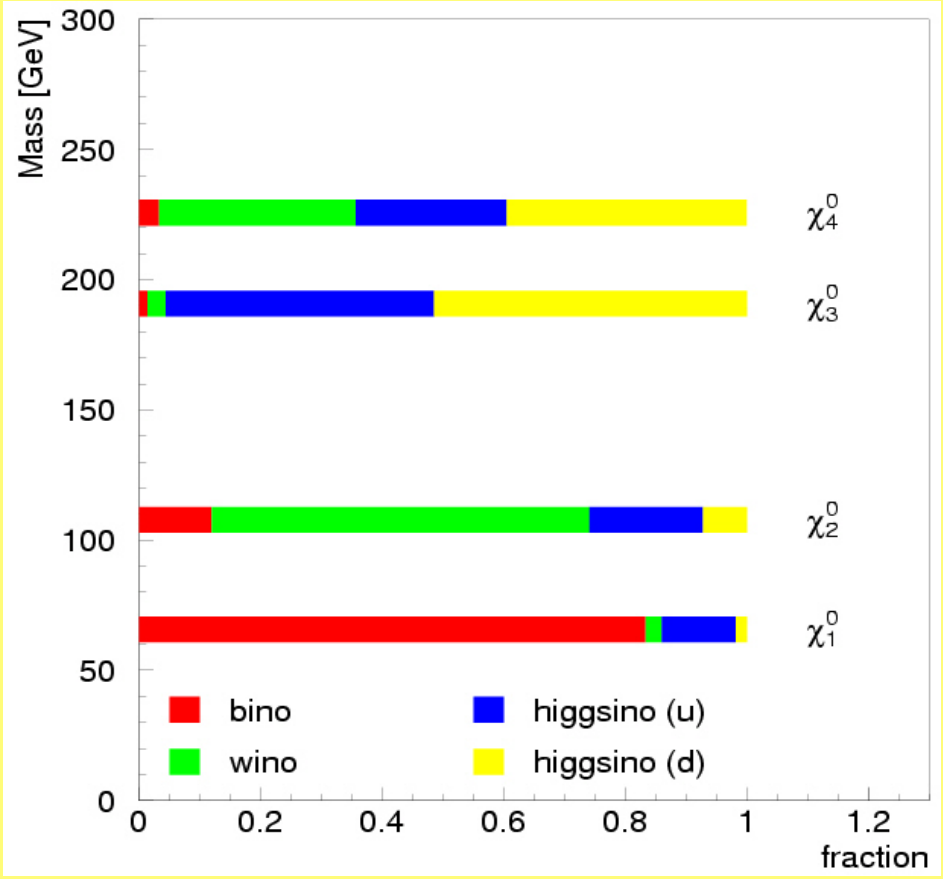


Halo profile with rings of DM



Rotation curve of the Milky Way

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

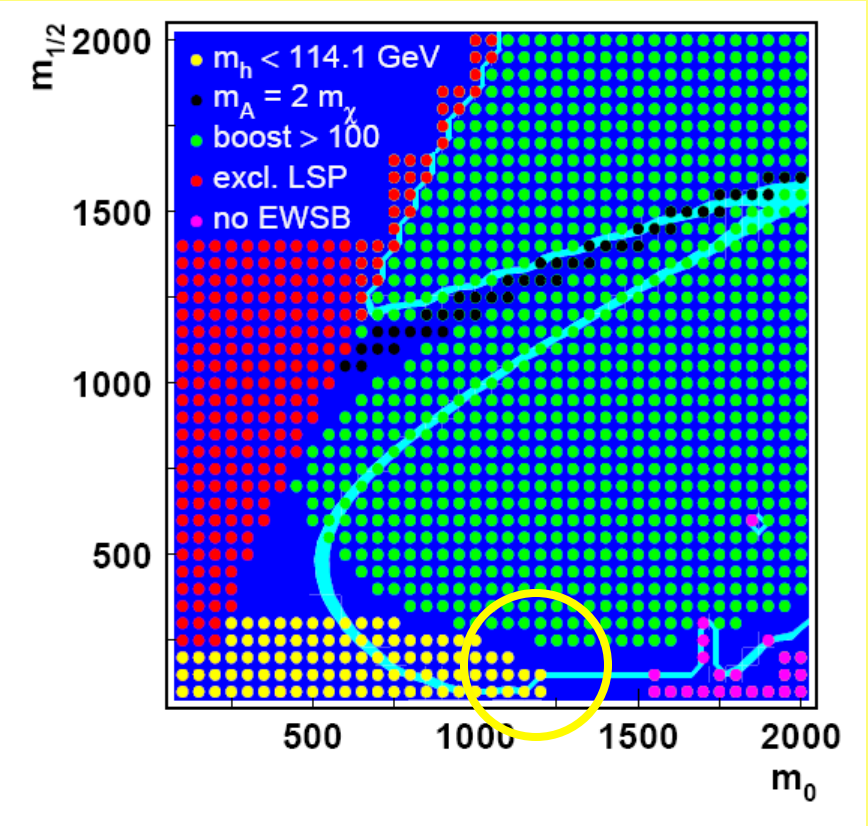
The region is compatible with diffuse gamma ray flux from the DM annihilation

It corresponds to the best fit values of parameters

tan β= 51

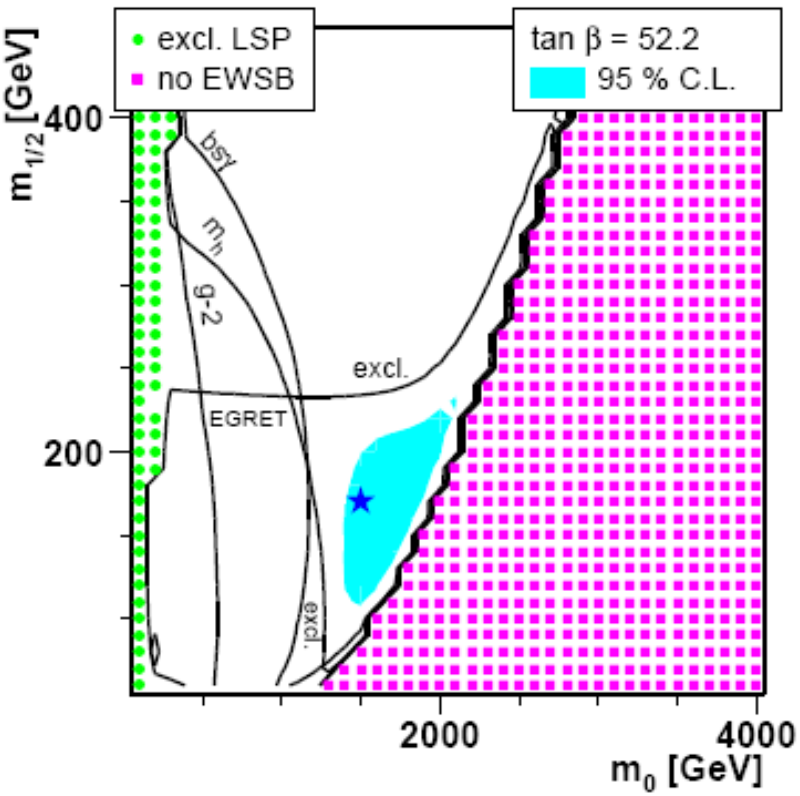
m0 = 1400 GeV

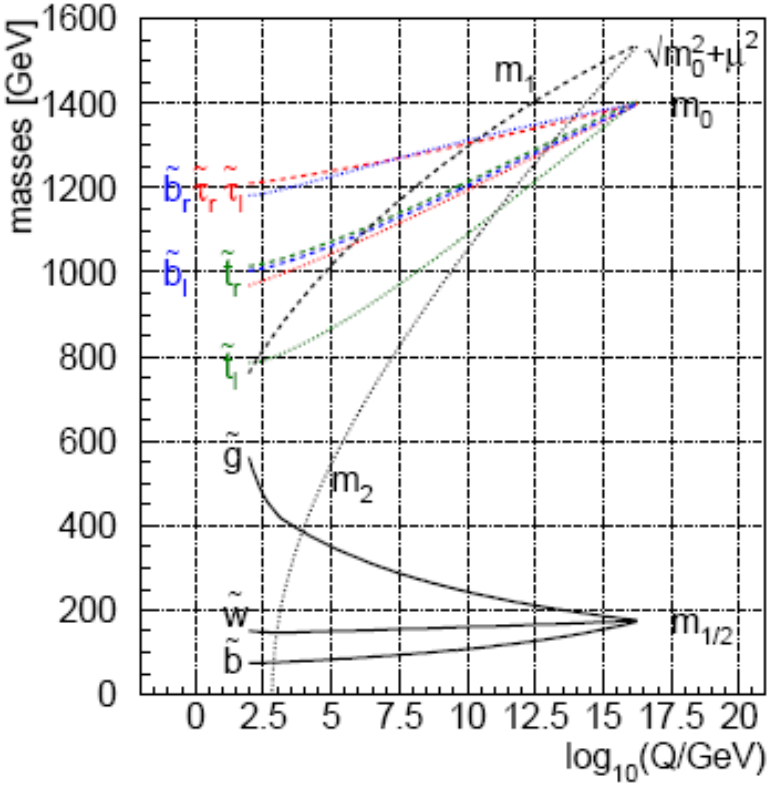
m1/2 = 180 GeV



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

EGRET POINT AND MASS SPECTRUM





SUSY MASS SPECTRUM

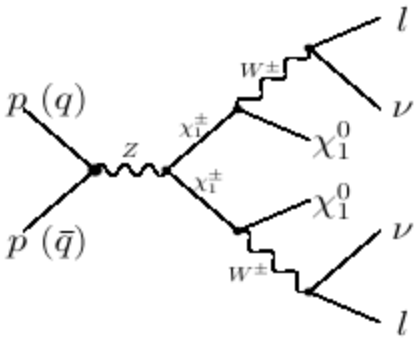
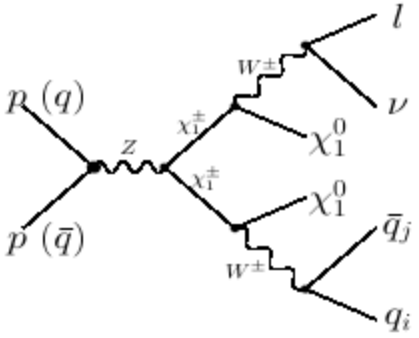
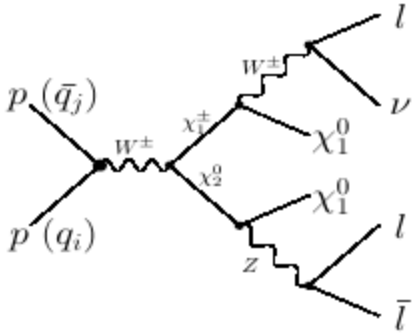
Fitted SUSY Parameters

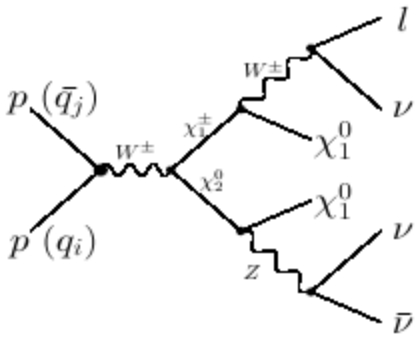
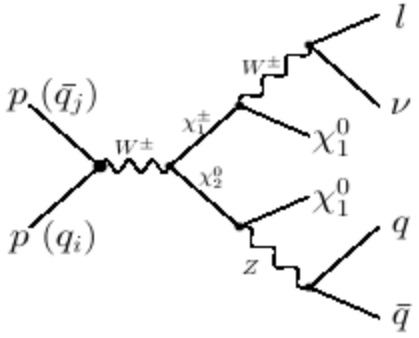
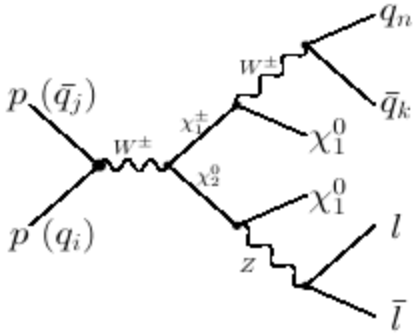
Parameter	Value
Tan β	52.2
m_0	1500
$m_{1/2}$	170
Sign μ	+
A(0)	0
$\alpha_s(M_Z)$	0.122
$\alpha_{em}(M_Z)$	0.0078153697
$Sin^2\theta_W\|_{\overline{MS}}$	0.2314
m_t	175 GeV
m_b	4.214 GeV

SUSY Masses in GeV

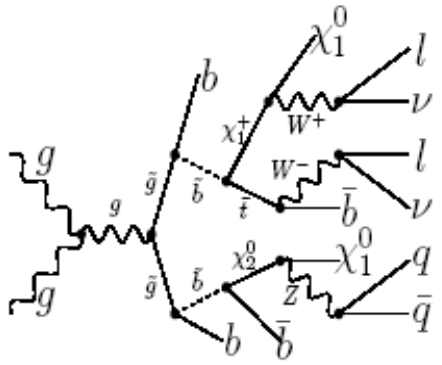
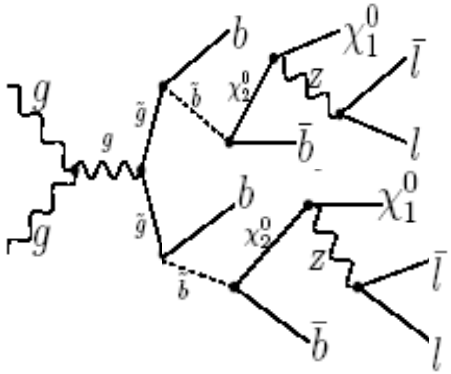
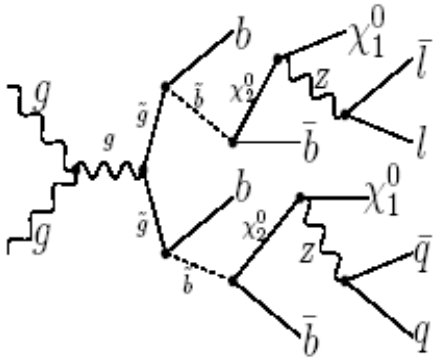
Particle	Mass
$\tilde{\chi}^0_{1,2,3,4}$ →	64, 113, 194, 229
$\tilde{\chi}^{\pm}_{1,2}$, $\tilde{g}$ →	110, 130, 516
$\tilde{u}_{1,2} = \tilde{c}_{1,2}$	1519, 1523
$\tilde{d}_{1,2} = \tilde{s}_{1,2}$	1522, 1524
$\tilde{t}_{1,2}$	906, 1046
$\tilde{b}_{1,2}$	1309, 1152
$\tilde{e}_{1,2} = \tilde{\mu}_{1,2}$	1497, 1499
$\tilde{\tau}_{1,2}$	1305, 1288
$\tilde{\nu}_e, \tilde{\nu}_\mu, \tilde{\nu}_\tau$	1495, 1495, 1286
h, H, A, $H^{\pm}$ →	115, 372, 372, 383

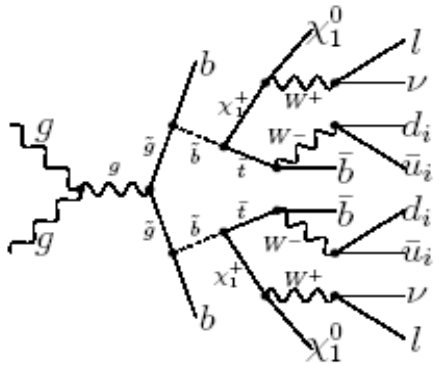
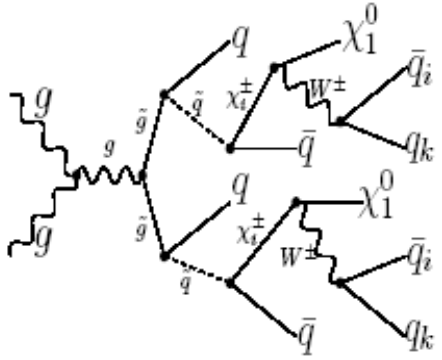
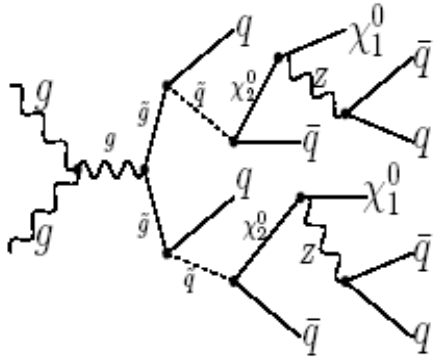
Cascade Processes (weak int's)

process	final states
	2ℓ 2ν $\not{E}_T$
	1ℓ $2j$ ν $\not{E}_T$
	3ℓ ν $\not{E}_T$

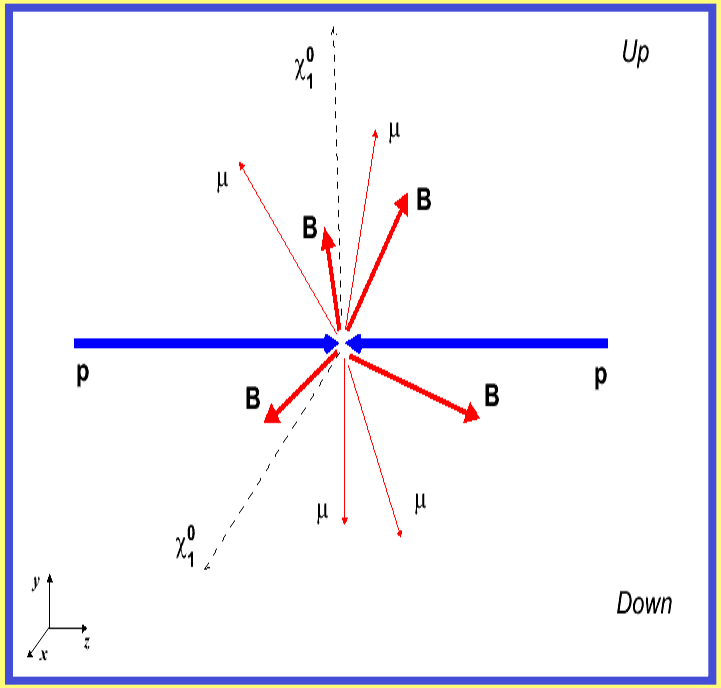
process	final states
	ℓ 3ν $\not{E}_T$
	ℓ ν $2j$ $\not{E}_T$
	2ℓ $2j$ $\not{E}_T$

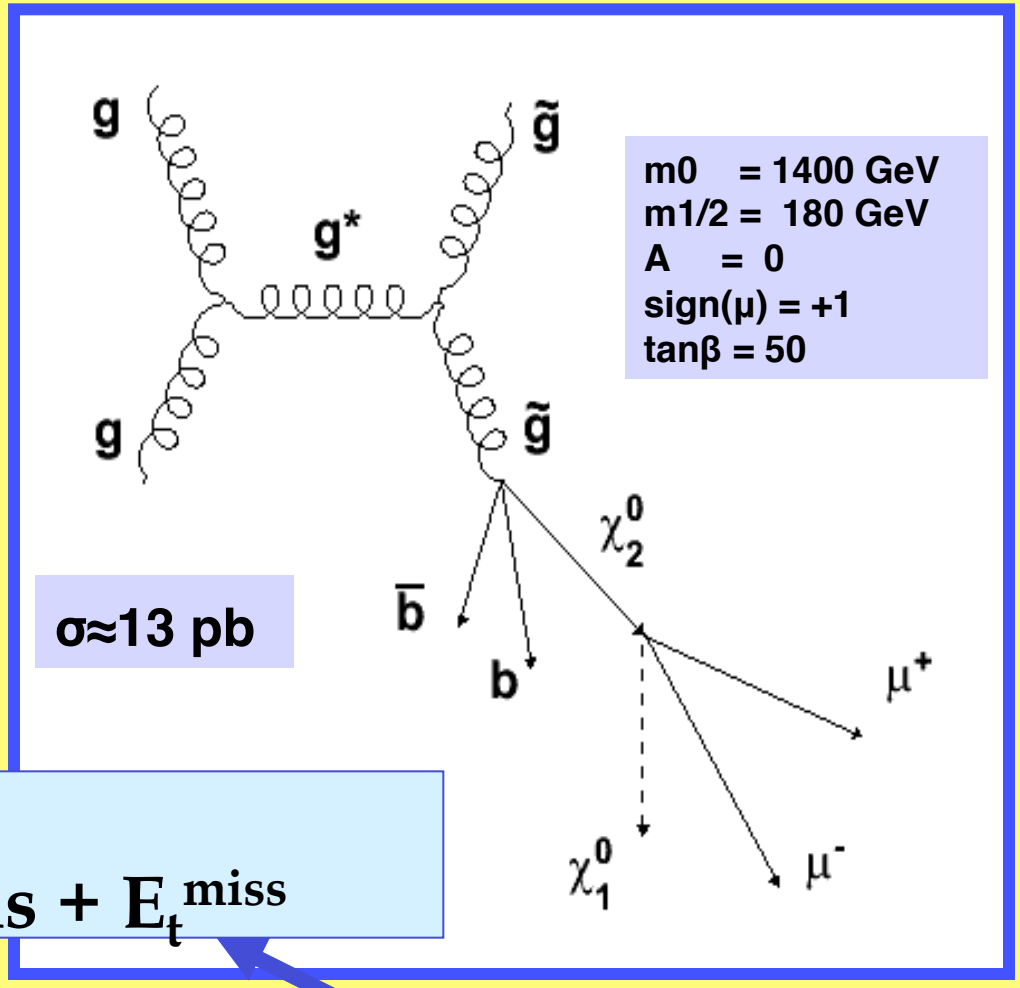
Cascade Processes (strong int's)

process	final states
	2ℓ 2ν $6j$ $\not{E}_T$
	$4l$ $4j$ $\not{E}_T$
	2ℓ $6j$ $\not{E}_T$

process	final states
	2ℓ 2ν $8j$ $\not{E}_T$
	$8j$ $\not{E}_T$
	$8j$ $\not{E}_T$

SUSY PRODUCTION AT LHC





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

LARGE!

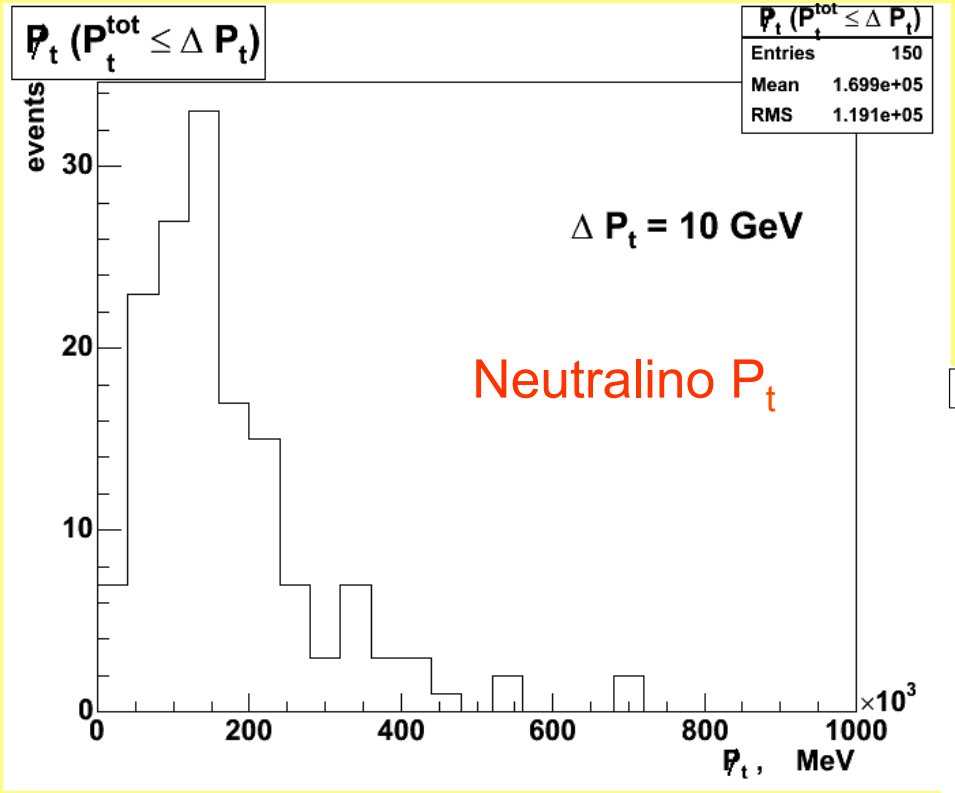
SUSY $gg \to \tilde{g}\tilde{g}$ AT LHC

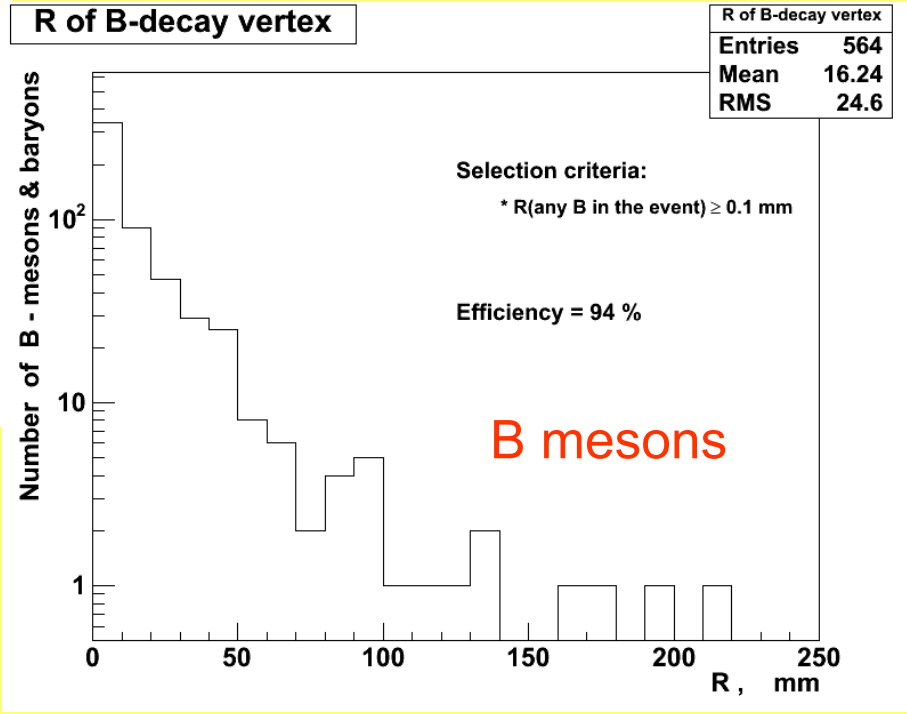
JINR(Dubna) ATLAS Group

V. Bednyakov, Y.Budagov, G. Khoriauli, J.Khubua

Pythia within ATHENA,

B-vertex taging

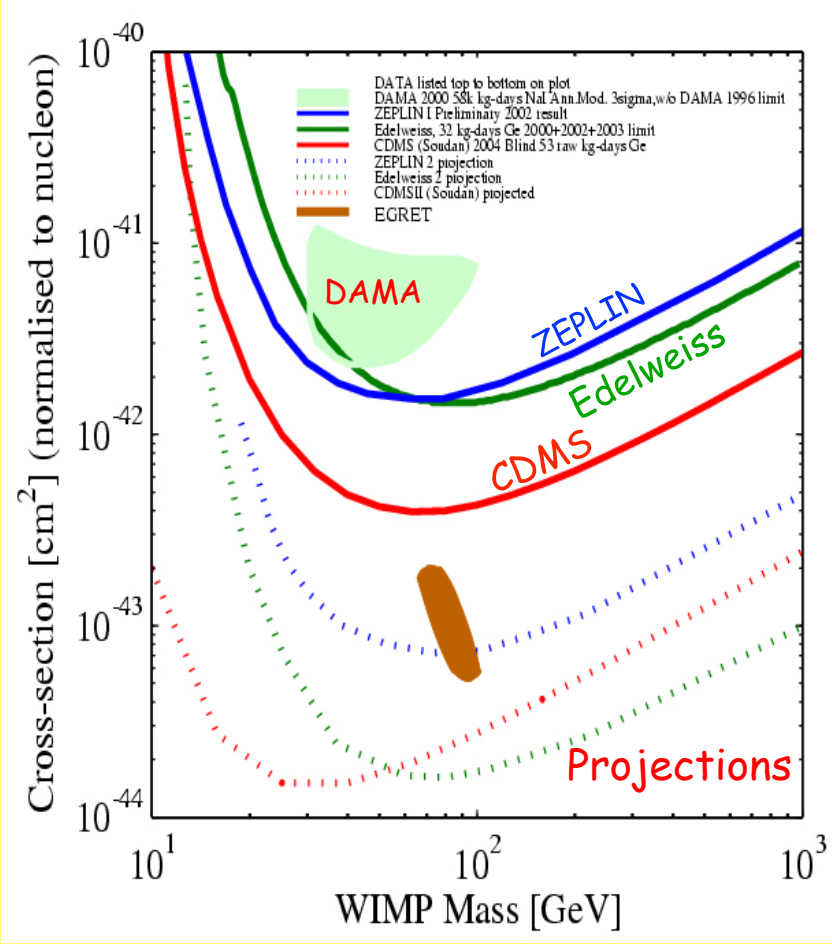




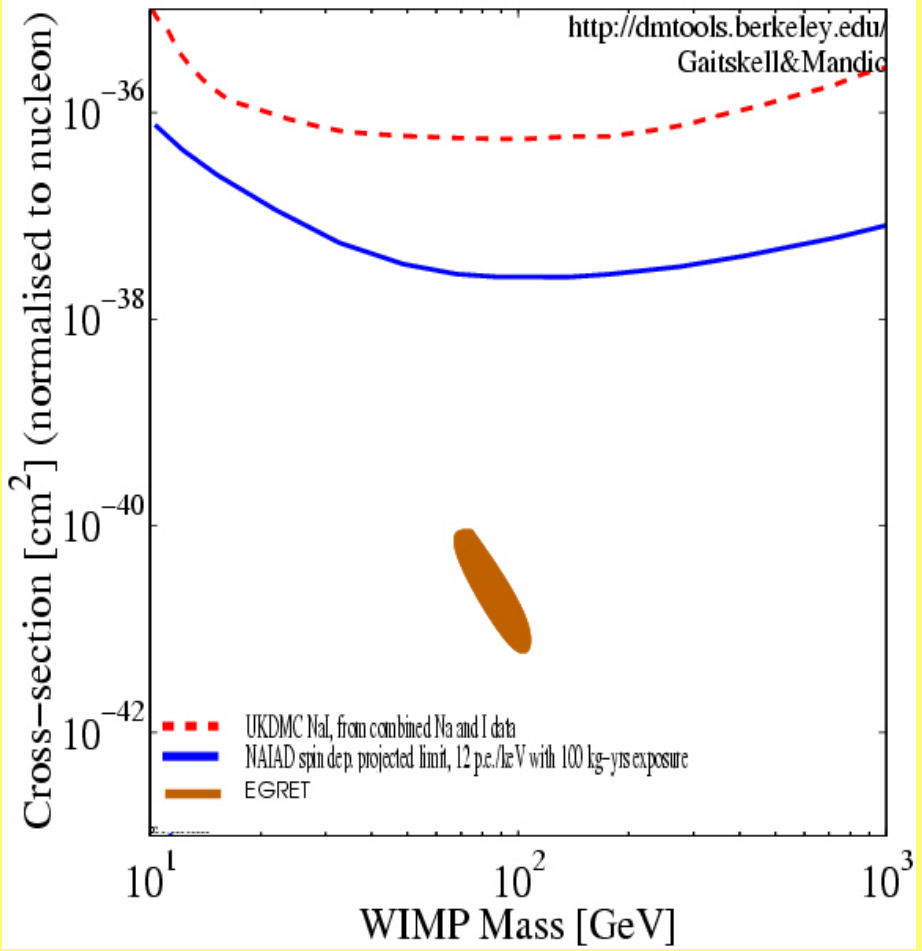
$$\Sigma P_t^{B,B,\mu,\mu}(\text{down}) - \Sigma P_t^{B,B,\mu,\mu}(\text{up}) = \not{P}_t \equiv \not{E}_t$$

DIRECT DM SEARCHES

Spin-independent



Spin-dependent



Predictions from EGRET data assuming Supersymmetry

CONCLUSIONS

If one accepts:

- **the interpretation of excess in diffuse galactic gamma rays as a signal of the DM annihilation**
- **the interpretation of the Cold Dark Matter as SUSY neutralino particles**

Then:

- **SUSY provides simultaneous consistent description of all observable data including astrophysics**
- **Parameter space of SUSY is highly restricted**
- **In the narrow allowed region the SUSY mass spectrum may be predicted**
- **Light superpartners are observable at the LHC**