



# GALACTIC DARK MATTER & SUSY PARAMETER SPACE

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In collaboration with W. de Boer, C. Sander, V. Zhukov (Uni Karlsruhe)  
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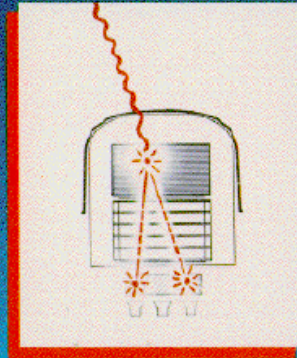
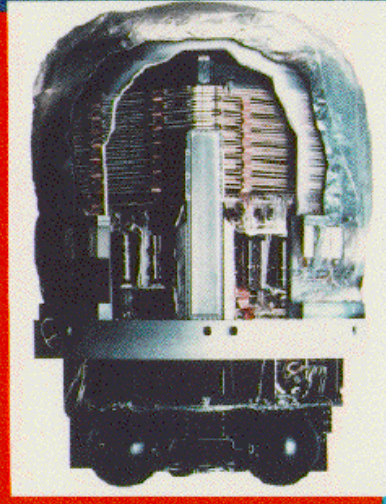
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PL B636 (2006)13  
PRL 95 (2005) 209001

## Outline

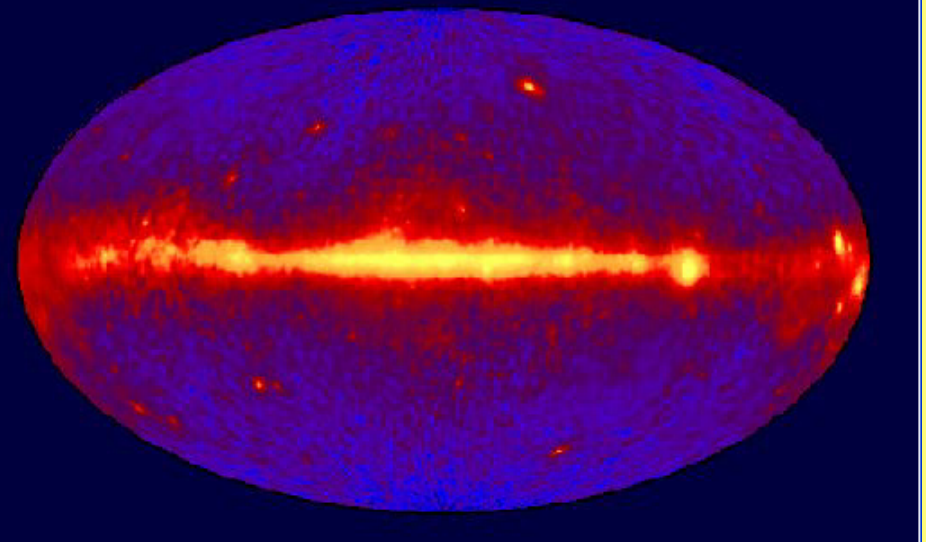
- Diffuse Galactic  $\gamma$  Rays from EGRET
- DM annihilation in the MSSM
- Restriction to SUSY Parameter Space
- SUSY Production at LHC in EGRET Region
- Conclusions

# DIFFUSE GAMMA RAYS FROM THE SKY

Energetic Gamma Ray Experiment  
Telescope (EGRET)



EGRET All-Sky Gamma-Ray Survey Above 100 MeV



## Instrumental parameters:

Energy range: 0.02–30 GeV

Energy resolution: ~20%

Effective area: 1500 cm<sup>2</sup>

Angular resol.: <math><0.5^\circ</math>

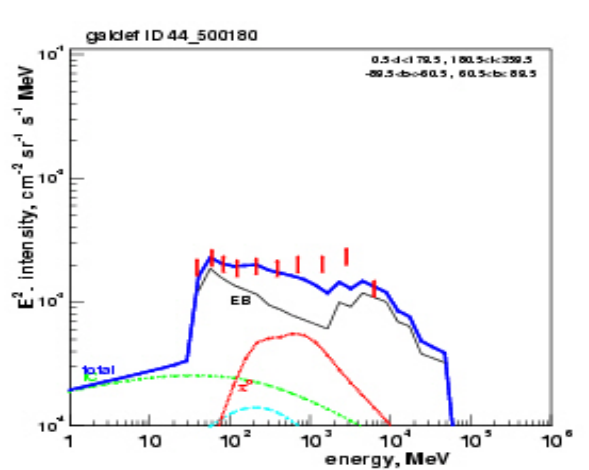
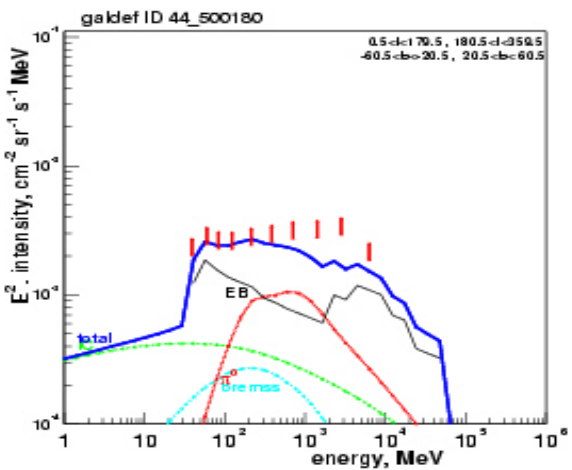
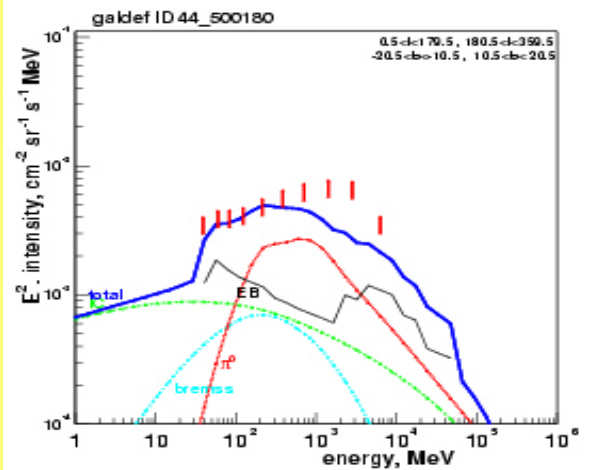
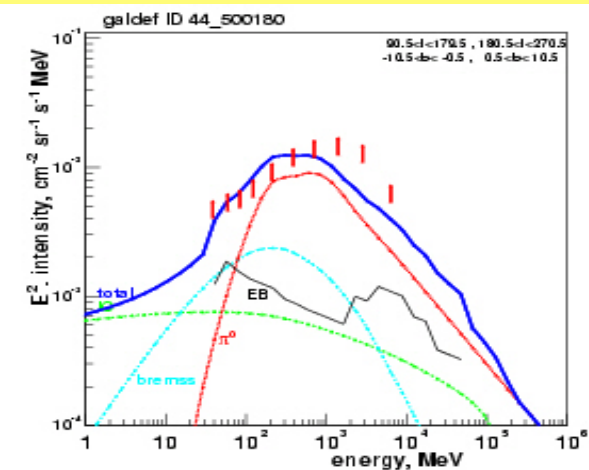
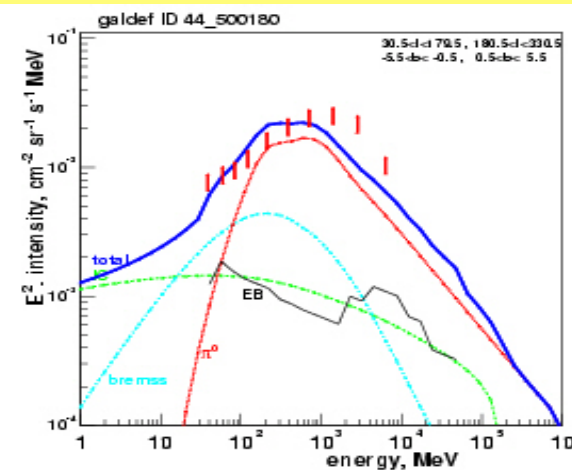
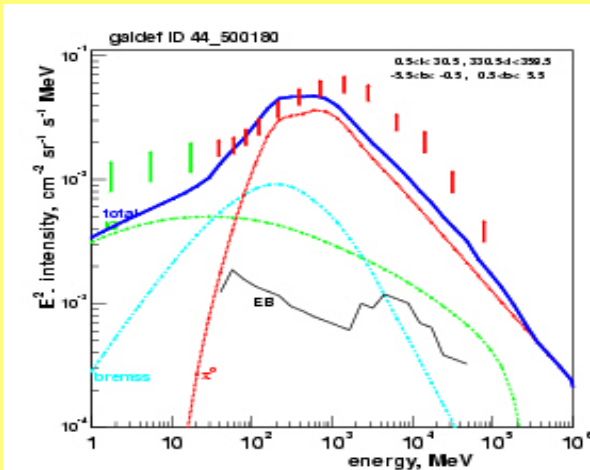
Data taking: 1991–2000

## Main EGRET results:

Catalogue of point sources

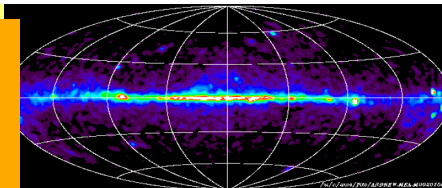
Excess in diffuse gamma rays

# EXCESS OF DIFFUSE GAMMA RAYS ABOVE 1 GEV



A: inner Galaxy ( $l = \pm 30^\circ, |b| < 5^\circ$ )  
 B: Galactic plane avoiding A  
 C: Outer Galaxy

D: low latitude ( $10-20^\circ$ )  
 E: intermediate lat. ( $20-60^\circ$ )  
 F: Galactic poles ( $60-90^\circ$ )



# PHYSICS PROBLEMS

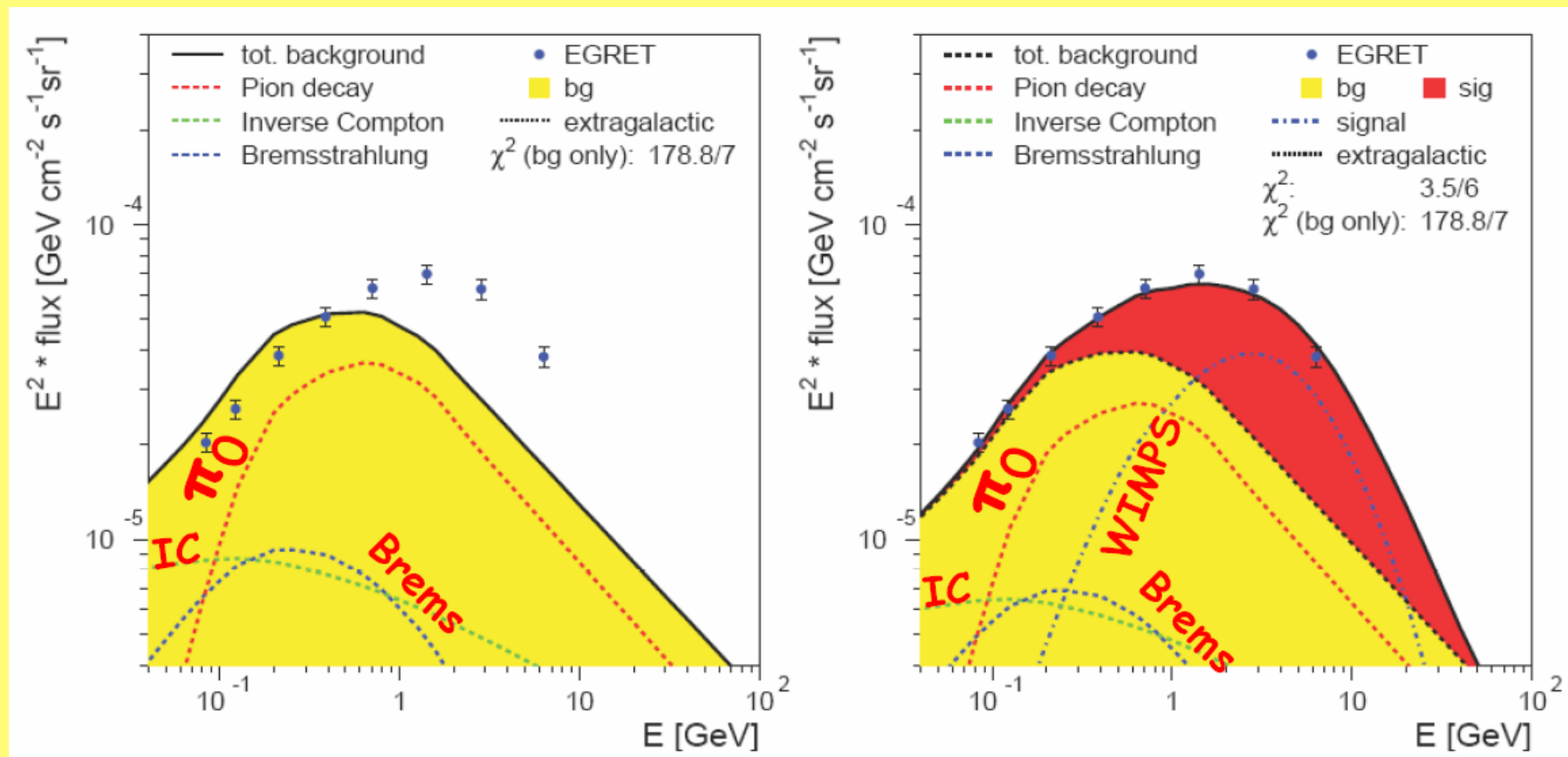
- **What is the origin of excess of diffuse Galactic Gamma Rays?**
- **What is Cold Dark Matter made of?**
- **Where are the Supersymmetric Particles?**

## **Solution:**

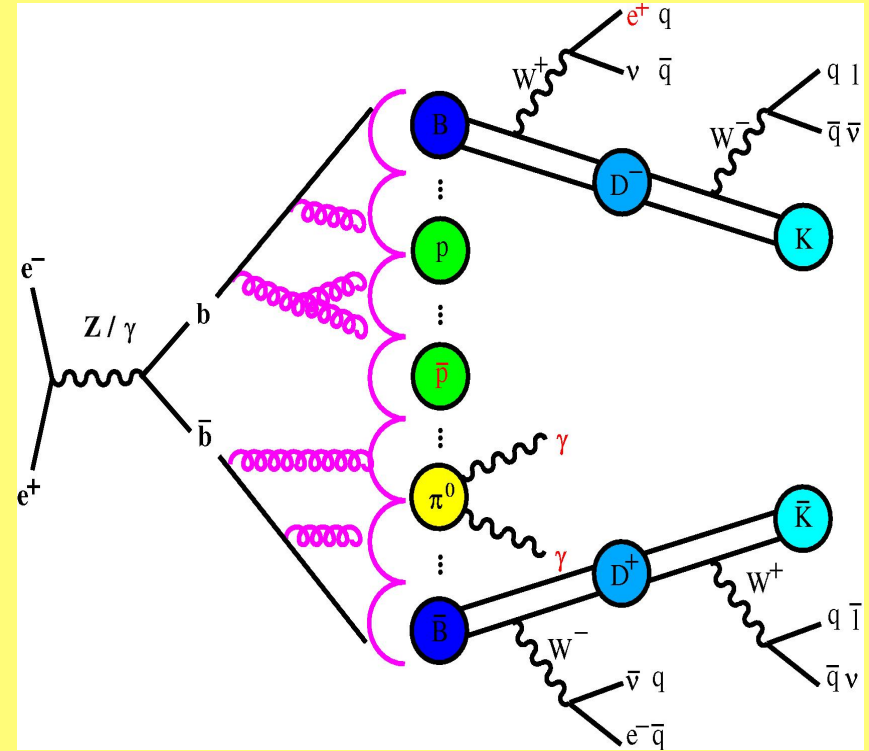
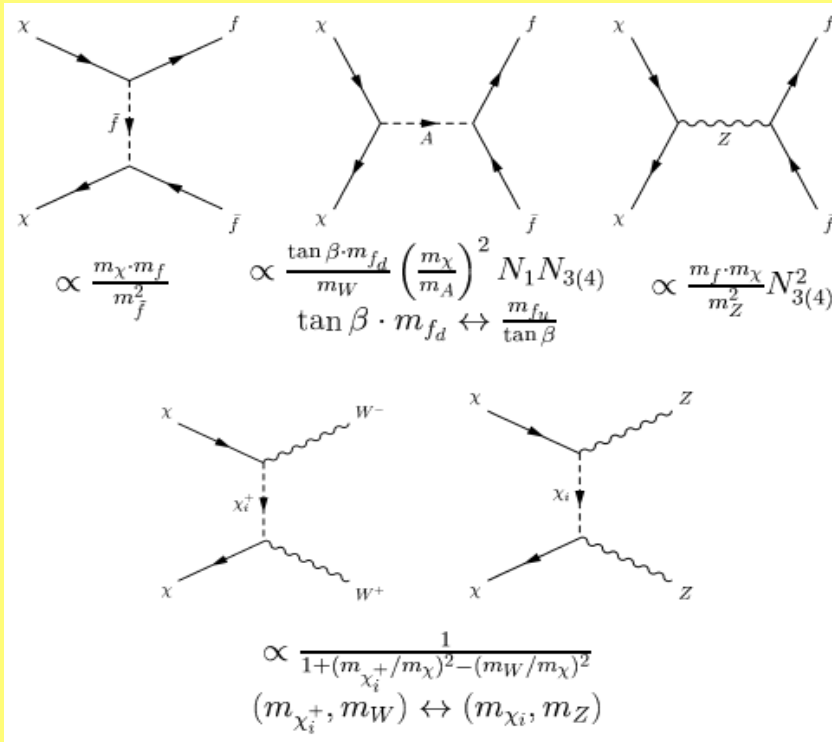
- **EGRET excess is due to DM annihilation**
- **DM is made of WIMPs which are SUSY particles distributed in Halo of our Galaxy**
- **SUSY Neutralinos have a mass around 60 GeV and should be observable at the LHC**



# EXCESS OF DIFFUSE GAMMA RAYS WITH AND WITHOUT DM ANNIHILATION



# DM NEUTRALINO ANNIHILATION FINAL STATES

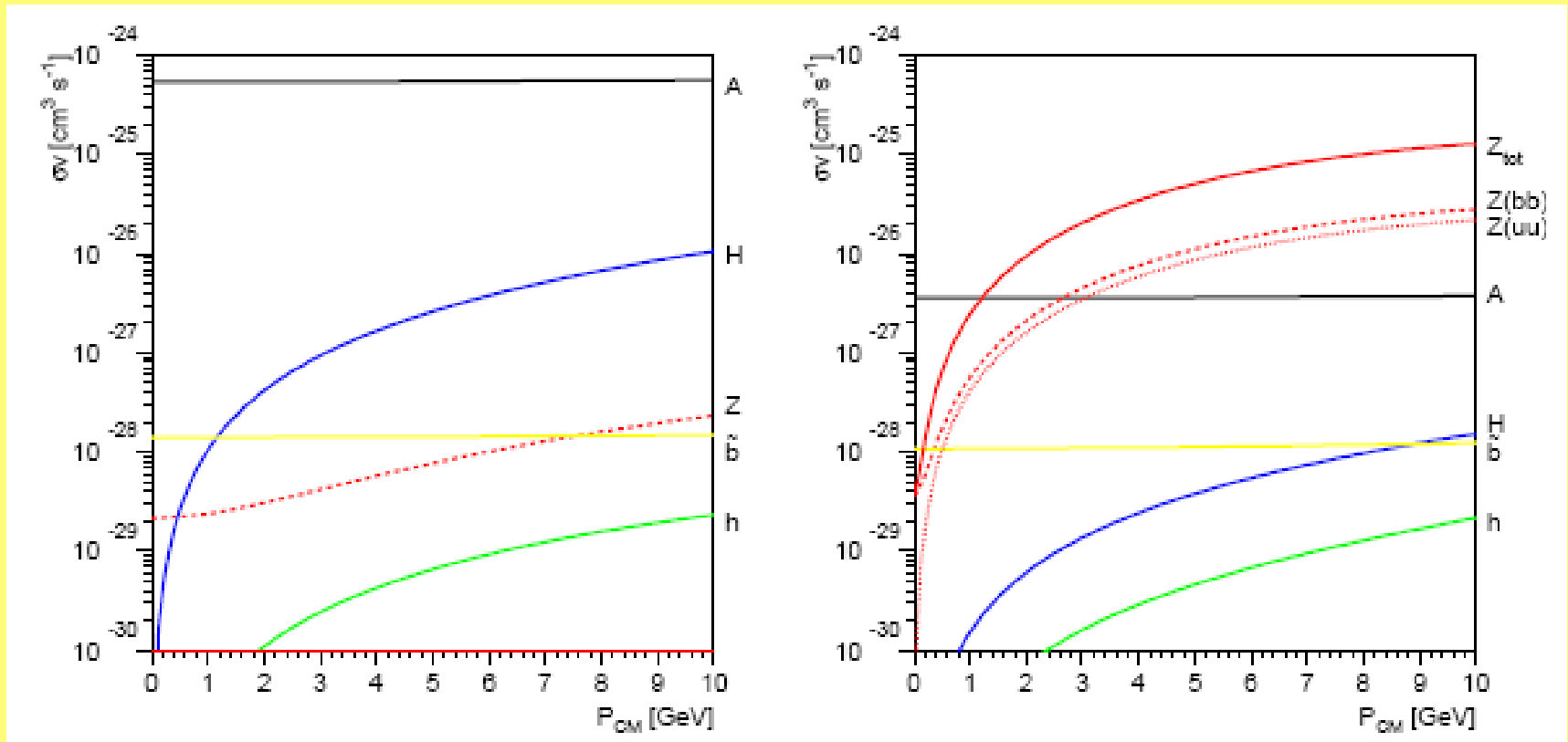


**Dominant annihilation  $\sigma$ -section:**  
 $\chi + \chi \rightarrow A \rightarrow b\bar{b}$  quark pair

Sum of diagrams should yield  
 $\langle \sigma v \rangle = 2 \cdot 10^{-26} \text{ cm}^3/\text{s}$  to get  
 correct relic density

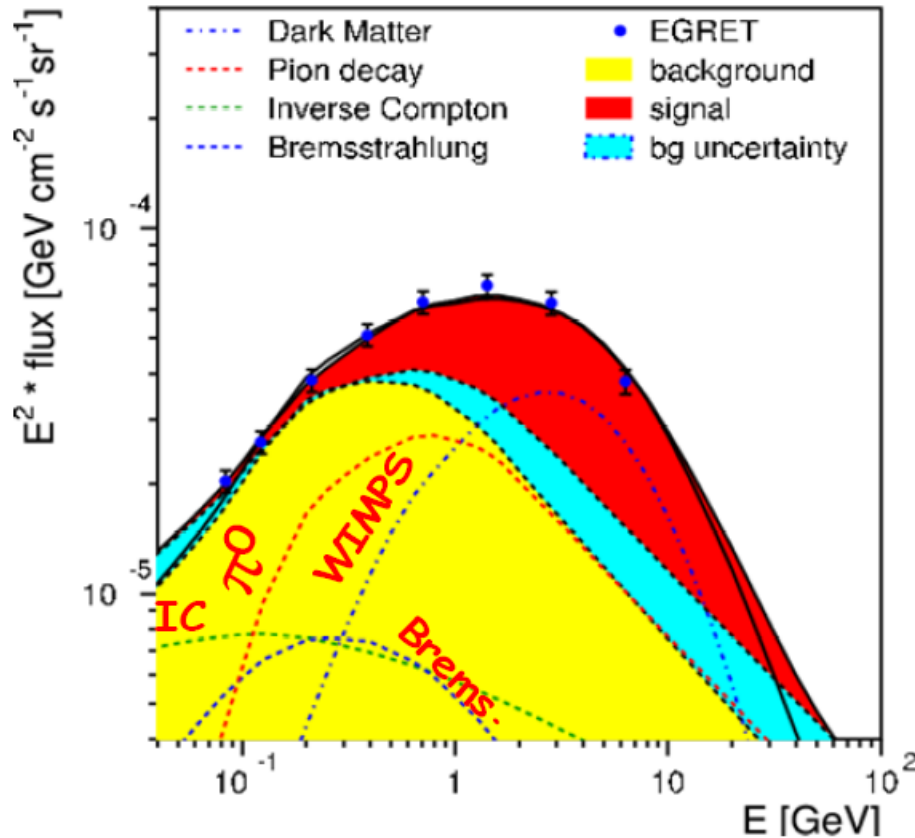
**B-fragmentation well studied at LEP!**  
 Yield and spectra of positrons,  
 gammas and antiprotons well known!

# DM NEUTRALINO ANNIHILATION CROSS-SECTION

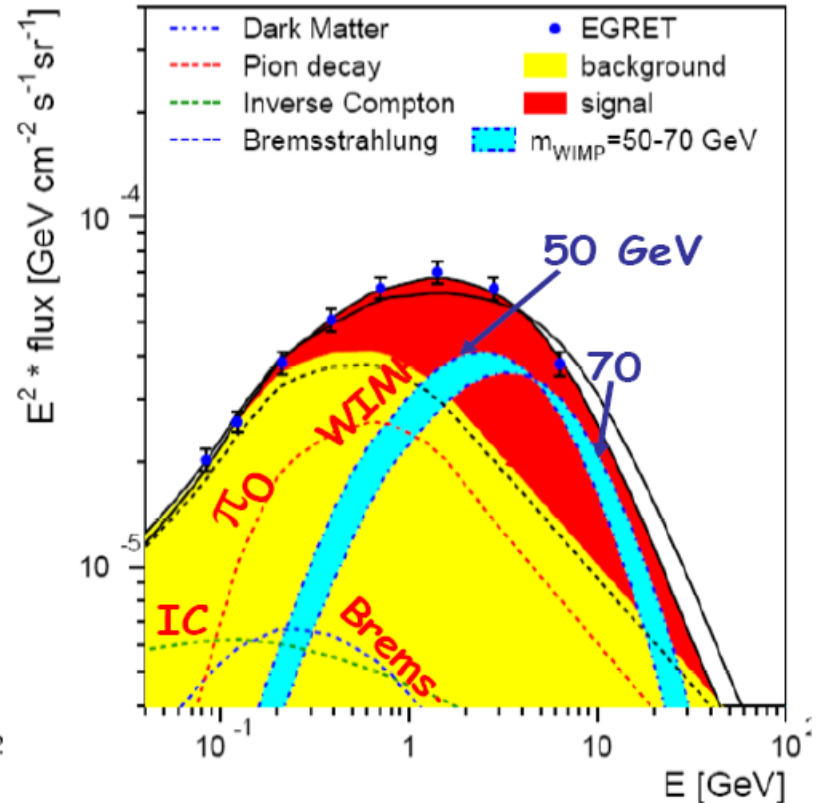


-  
**Dominant annihilation x-section:  
 $\chi + \chi \rightarrow A \rightarrow bb$  quark pair**

# BACKGROUND + SIGNAL DESCRIBE EGRET DATA



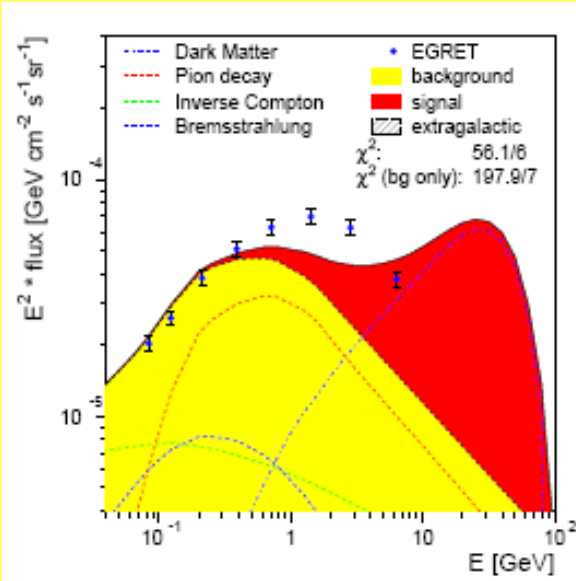
Blue: background uncertainty



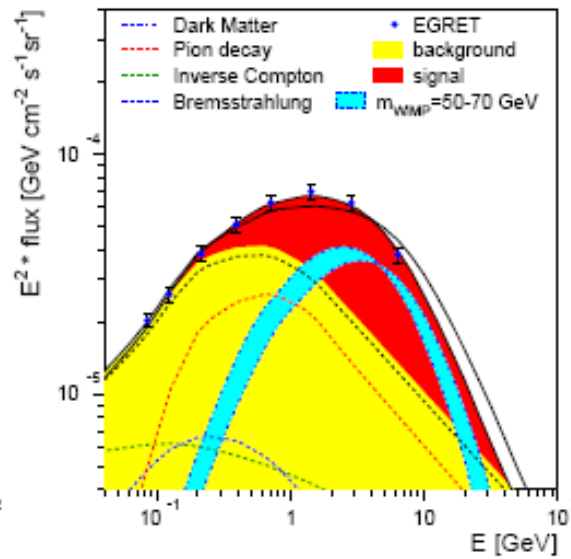
Blue: WIMP mass uncertainty



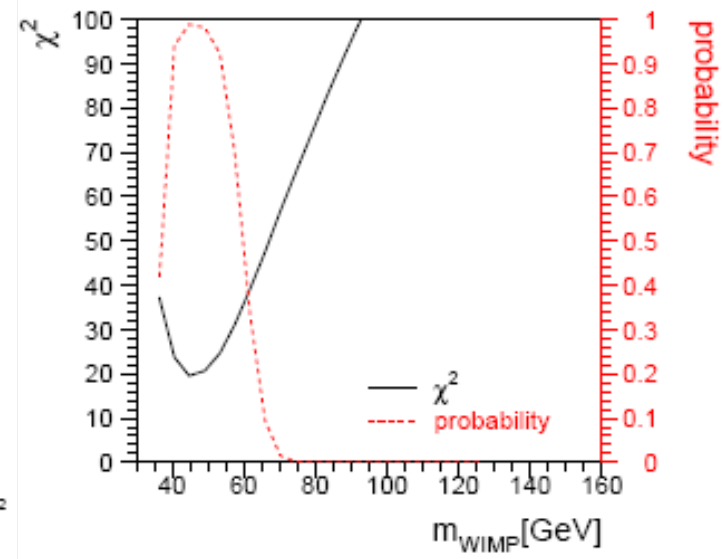
# FIT TO WIMP MASS



Heavy neutralino



$M_\chi \sim 50-80 \text{ GeV}$



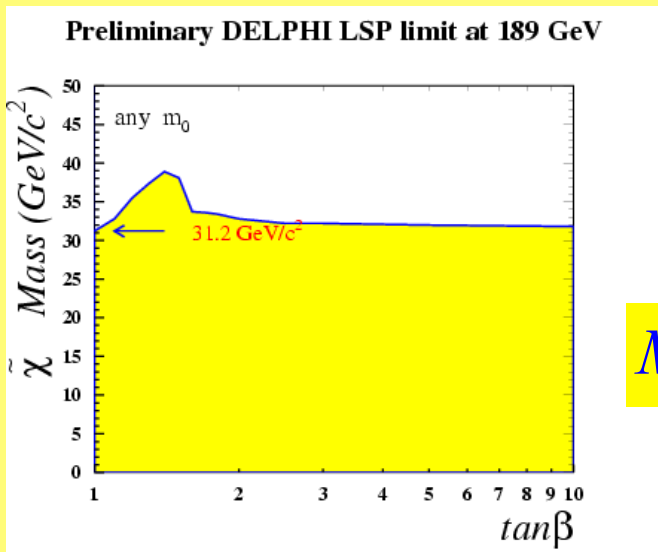
Heavy WIMP is excluded

# SUSY DARK MATTER

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

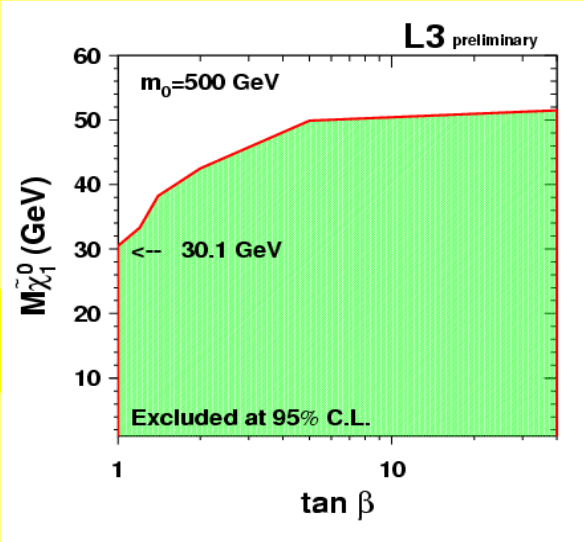
$$\tilde{\chi}^0 = N_1 \tilde{\gamma} + N_2 \tilde{z} + N_3 \tilde{H}_1^0 + N_4 \tilde{H}_2^0$$

photino                  zino                  higgsino                  higgsino



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

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



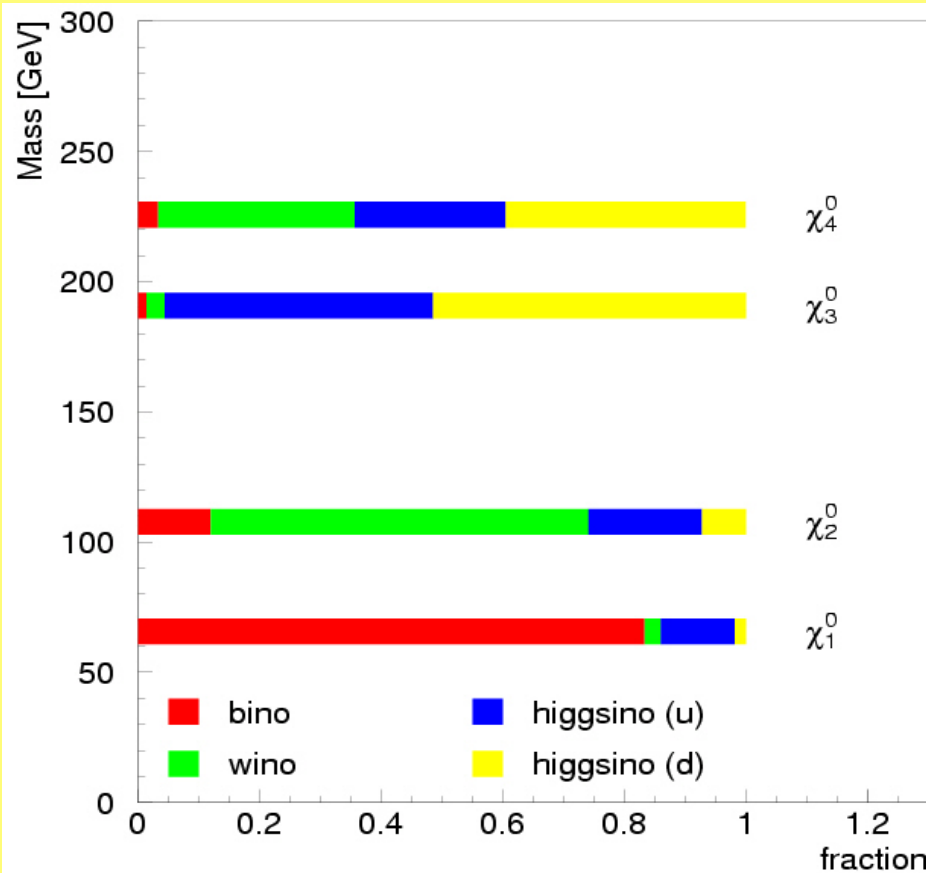
$$R = (-1)^{3(B-L)+2S}$$

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



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

# GAUGINO CONTENT OF THE LIGHTEST NEUTRALINO

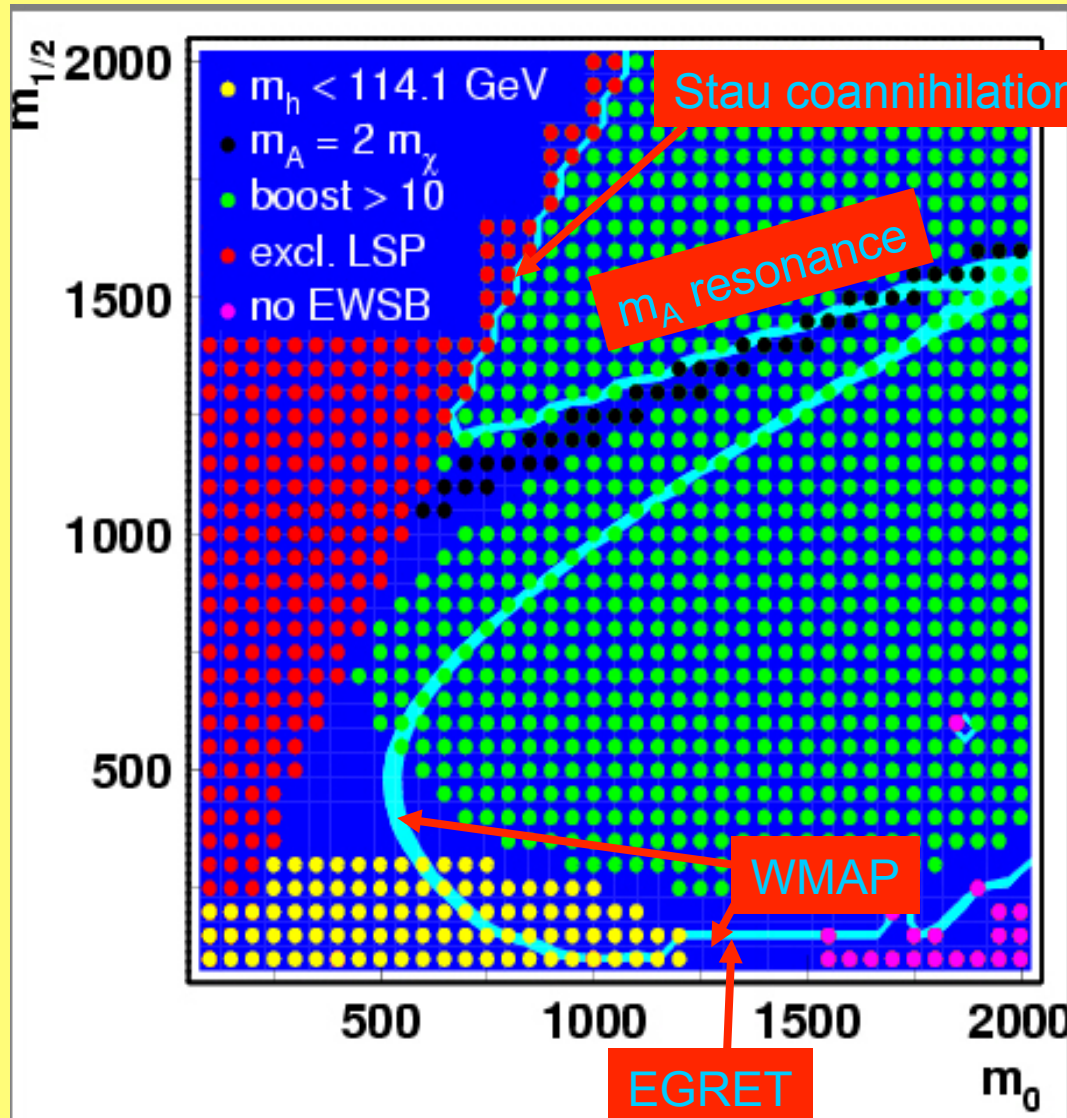


	$\tilde{b}^0$	$\tilde{w}^0$	$\tilde{h}_1^0$	$\tilde{h}_2^0$
$\tilde{\chi}_1^0$	0.833	0.026	0.122	0.018
$\tilde{\chi}_2^0$	0.119	0.621	0.187	0.072
$\tilde{\chi}_3^0$	0.014	0.030	0.442	0.515
$\tilde{\chi}_4^0$	0.033	0.323	0.249	0.395

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

DM = superpartner of the CMB

# ALLOWED SUSY PARAMETER SPACE



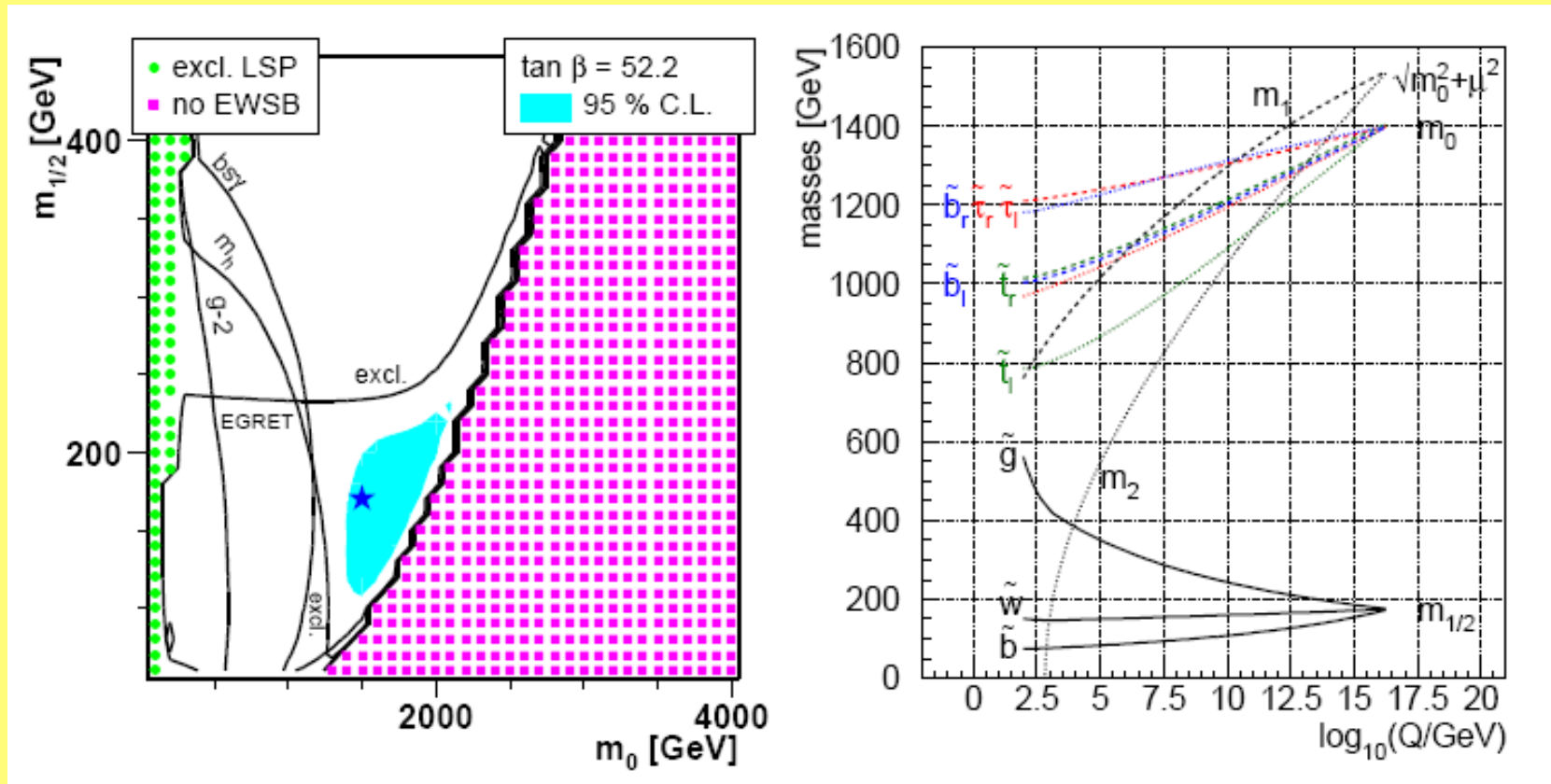
MSUGRA can fulfill all constraints from WMAP, LEP,  $b \rightarrow s\gamma$ ,  $g-2$  and EGRET

simultaneously, if DM is neutralino with mass in range 50-100 GeV and squarks and sleptons are  $O(1$  TeV)

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

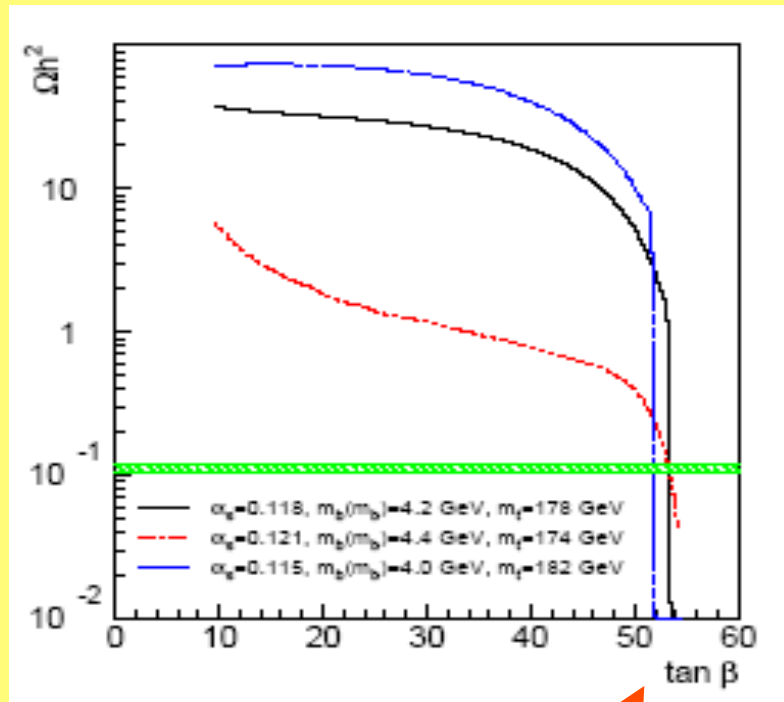
High  $\tan\beta$  solution  
 $\tan\beta = 50$

# EGRET POINT AND MASS SPECTRUM





# FIT TO $\tan \beta$



$\tan \beta \sim 50$

# SUSY MASS SPECTRUM

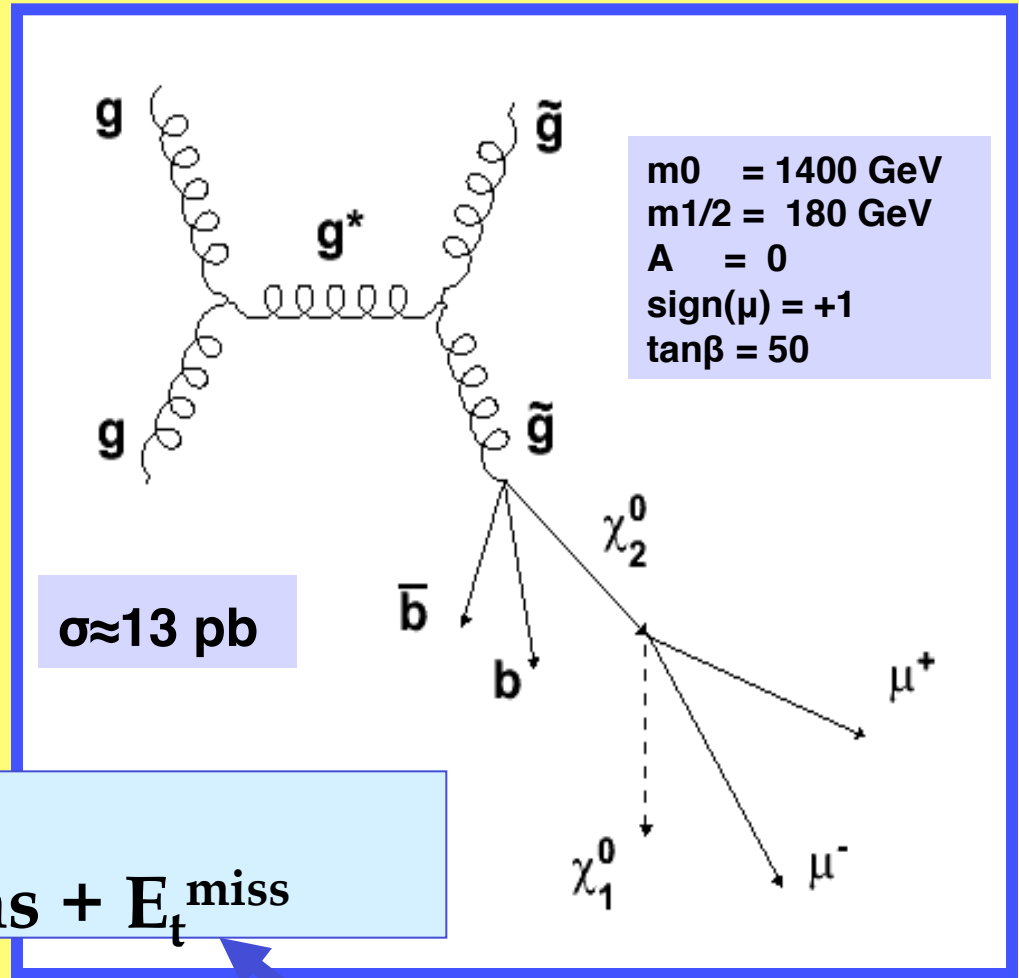
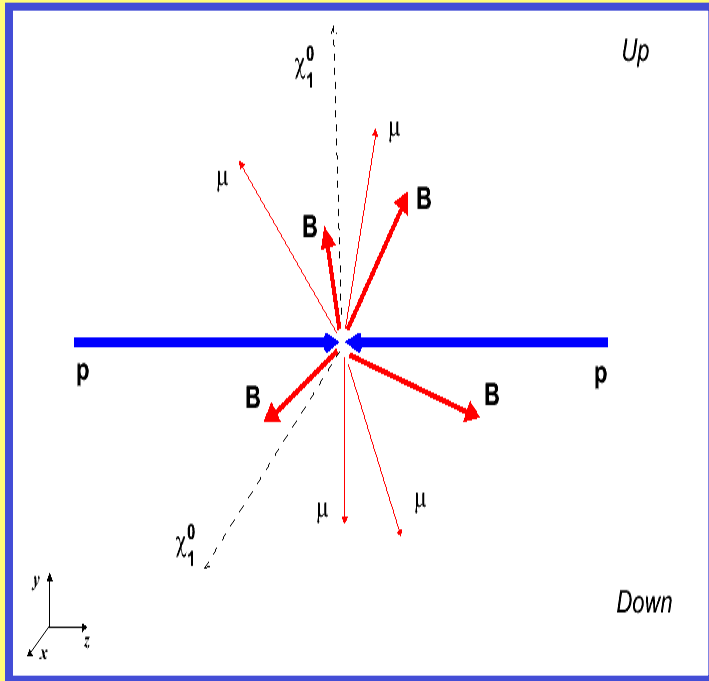
## Fitted SUSY Parameters

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

## SUSY Masses in GeV

Particle	Mass
$\tilde{\chi}_{1,2,3,4}^0$ →	64, 113, 194, 229
$\tilde{\chi}_{1,2}^\pm, \tilde{g}$ →	110, 130, 516
$u_{1,2} = c_{1,2}$	1519, 1523
$\tilde{d}_{1,2} = \tilde{s}_{1,2}$	1522, 1524
$\tilde{t}_{1,2}$	906, 1046
$b_{1,2}$	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

# SUSY PRODUCTION AT LHC



**SIGNATURE:**  
**4 b-jets + 4 muons +  $E_t^{\text{miss}}$**

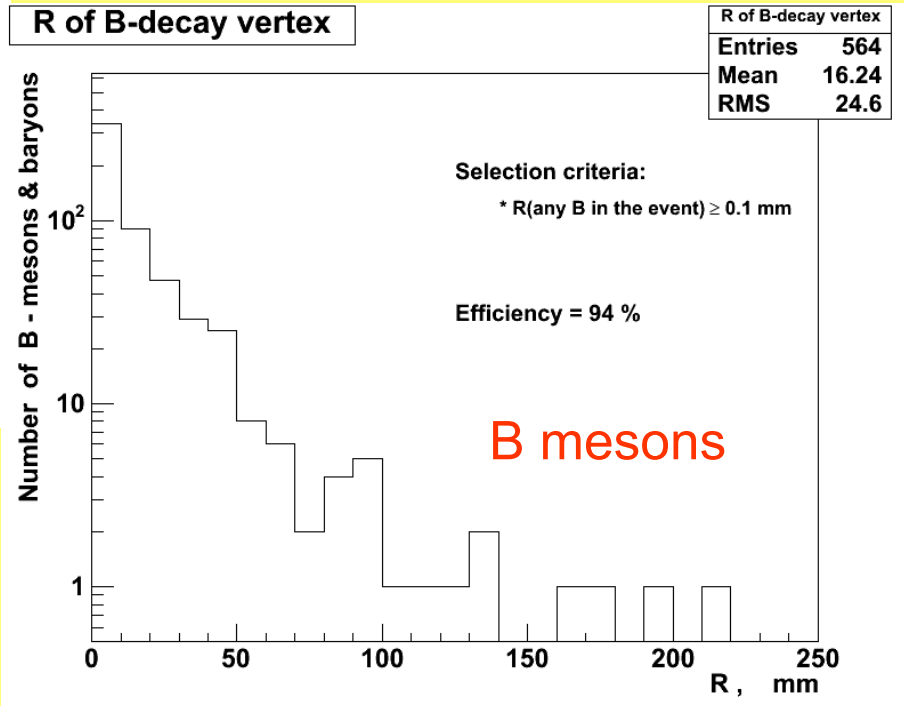
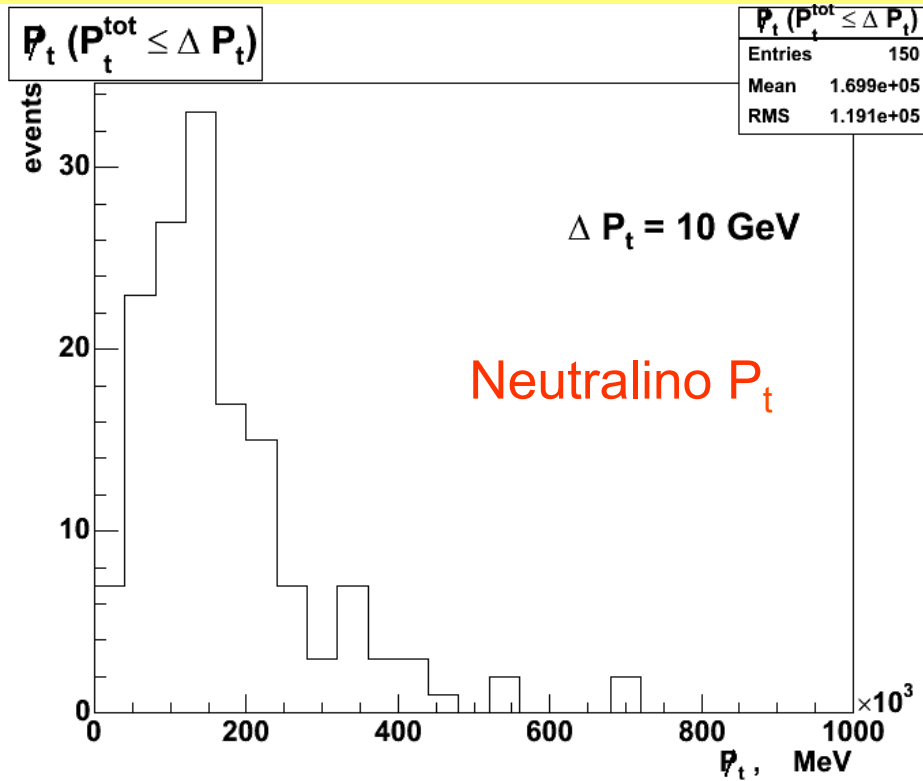
**LARGE!**

# SUSY $gg \rightarrow \tilde{g}\tilde{g}$ IN ATLAS

JINR(Dubna) ATLAS Group

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

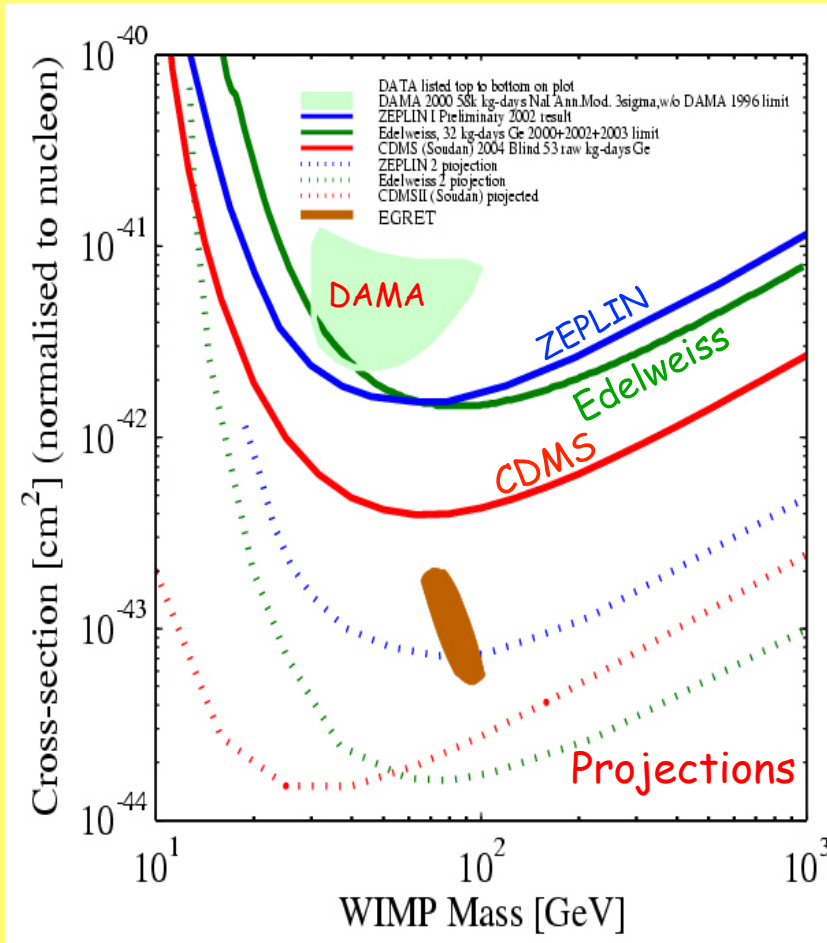
Pythia within ATHENA,  
B-vertex tagging



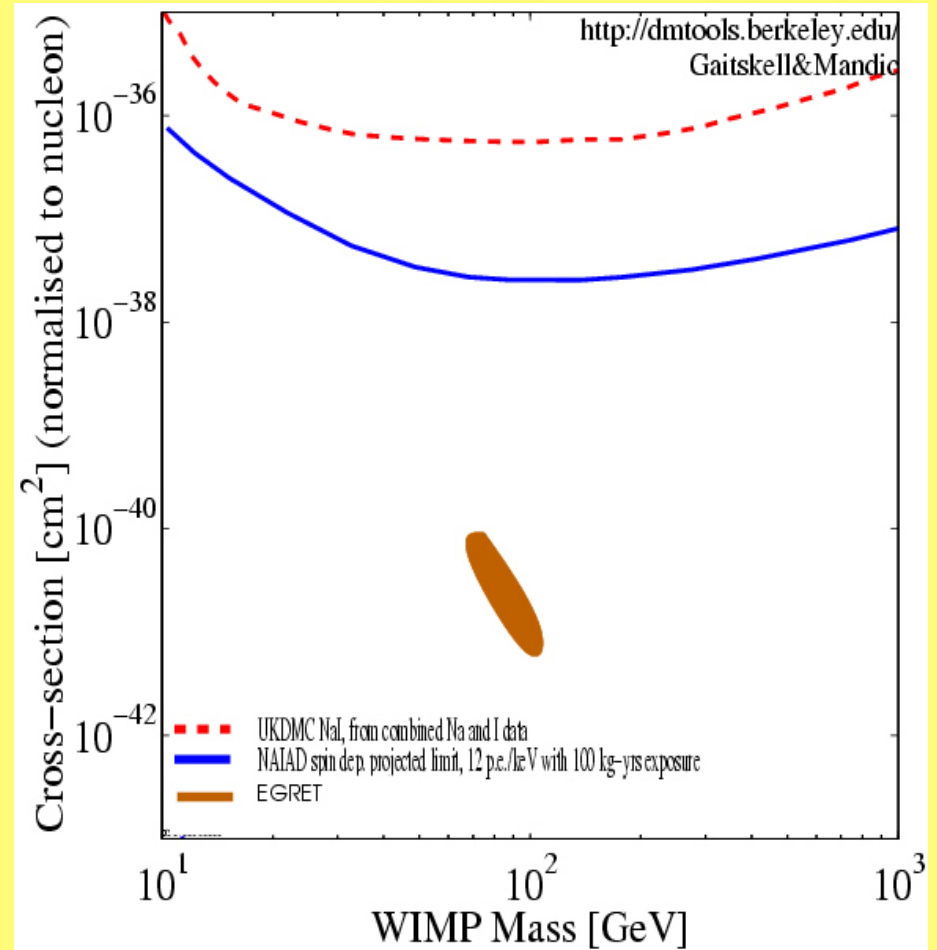
$$\sum P_t^{B,B,\mu,\mu} (\text{down}) - \sum P_t^{B,B,\mu,\mu} (\text{up}) = P_t \equiv E_t$$

# 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**