The Exercises at the HAP Workshop 2014

Ulli Schwanke, Louise Oakes (HU Berlin)
Gernot Maier, Moritz Hütten, Rolf Bühler,
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HELMHOLTZ | ASSOCIATION
Alliance for Astroparticle Physics

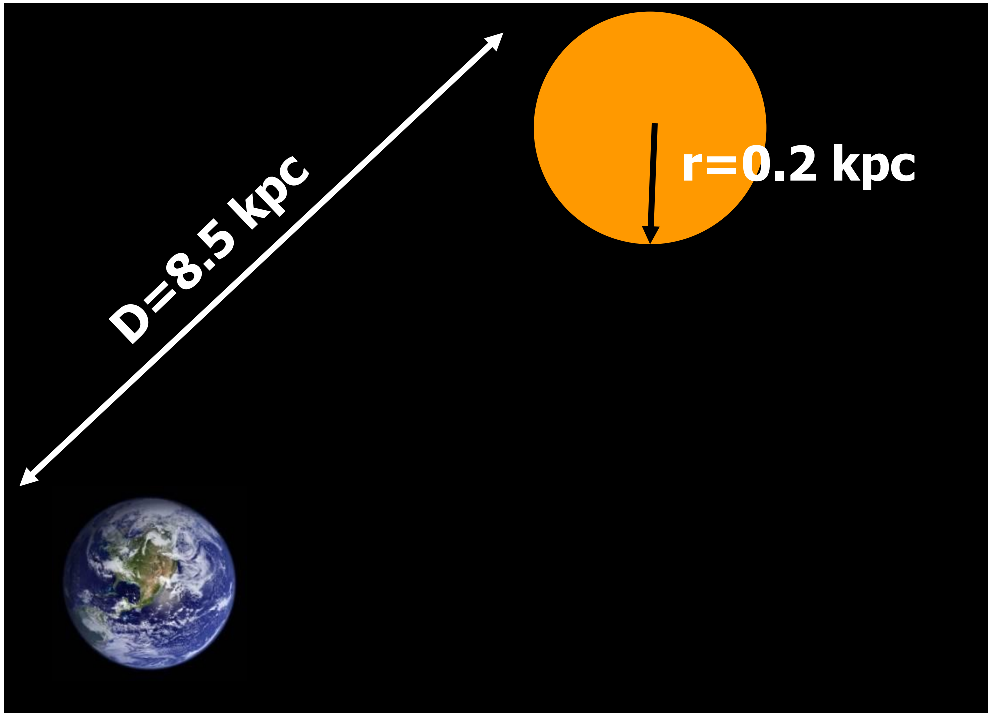
HUMBOLDT-UNIVERSITÄT · ZU BERLIN ·

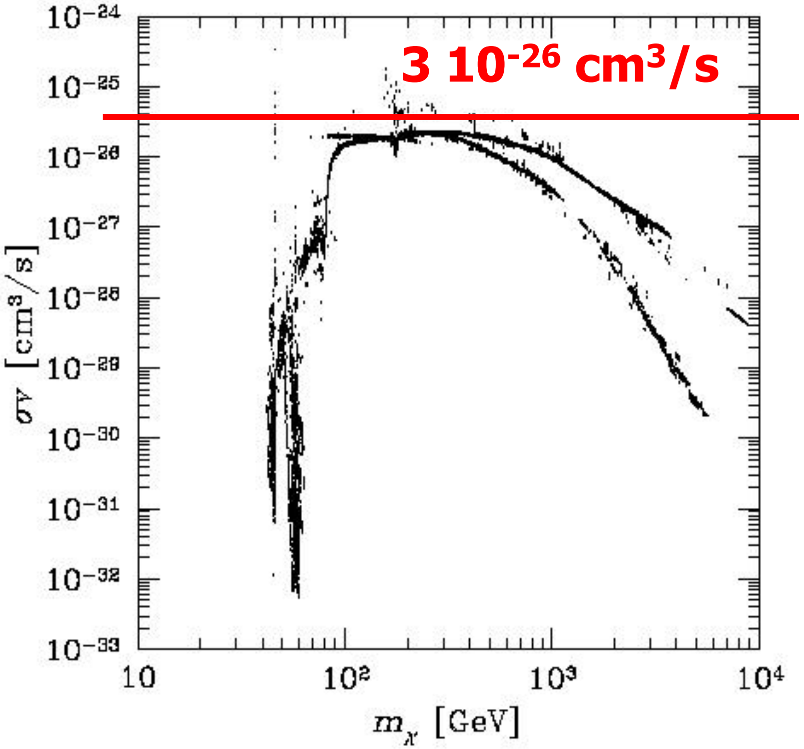
Overview: What we want (you) to do

1) Today (Mar 11)
   - Calculation of annihilation rates
   - Inspection of supersymmetric models and annihilation spectra
   - Responsible: Ulli Schwanke, Louise Oakes
2) Wednesday (Mar 12)
   - Calculation of astrophysical factors (analytically and using existing tools)
   - Calculation of fluxes
   - Responsible: Gernot Maier, Moritz Hütten
3) Thursday (Mar 13)
   - Calculation of event statistics, background rates
   - Statistical tests
   - Responsible: Rolf Bühler, Markus Ackermann

Note: The exercises of each day will use the same toy model and the same (not yet existing) detector

Toy Model

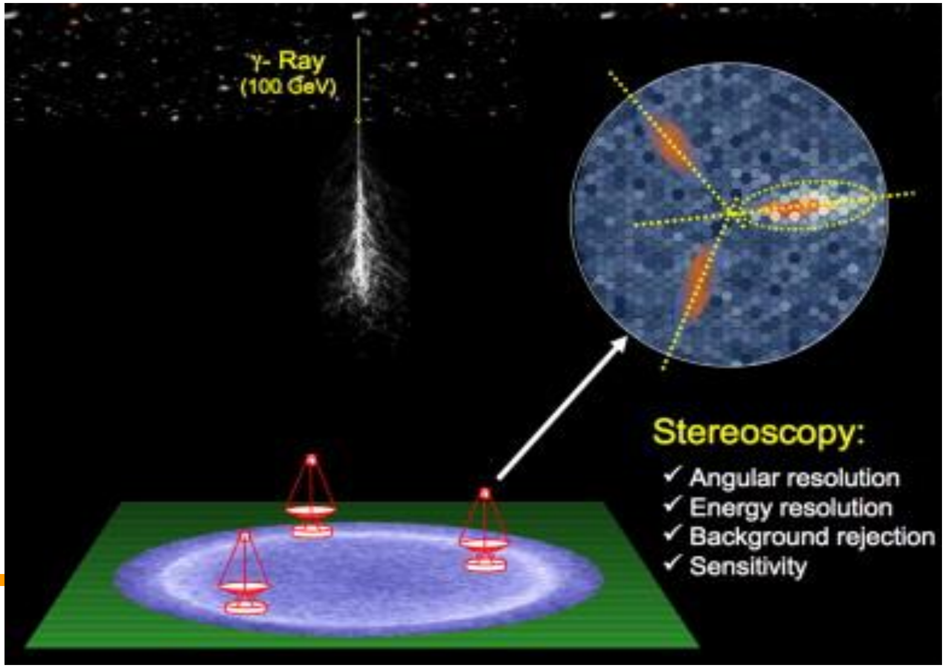




- A sphere of constant dark matter density (ρ=150 GeV cm^{-3}) at the distance of the galactic center (D=8.5 kpc) with radius r=0.2 kpc
- Annihilation cross-section for thermally produced DM ($\langle\sigma v\rangle = 3\ 10^{-26}\ cm^3/s$)

The Detector: CTA

- **The Cherenkov Telescope Array (CTA) is a future ground-based gamma-ray observatory**
- **Detection of photons with energies >30 GeV using arrays of Cherenkov Telescopes (>50 telescopes)**
- **Cherenkov telescopes detect the Cherenkov emission of electromagnetic and hadronic (background!) showers developing in the atmosphere**
- **Will use response files (effective area, angular resolution, background rates) from a Monte Carlo simulation – details later**



The Exercises at the HAP Workshop 2014 - Tuesday

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Louise Oakes (HU Berlin)

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Task 1 - Answers

$\rho = 150 \ \frac{GeV}{cm^3}$ (toy) ; $0{,}3 \ \frac{GeV}{cm^3}$ (Earth)

$\langle \sigma v \rangle = 3 \cdot 10^{-26} \ cm^3 \ s^{-1}$

$M = 500 \ GeV = 0{,}5 \ TeV$

R = Radius of sphere

- ▷ 6371 km for Earth
- ▷ $0{,}2 \ kpc = 0{,}2 \cdot 3{,}08 \cdot 10^{21} \ cm$ for toy model

1)

$$\Gamma = \frac{\langle \sigma v \rangle}{2} \frac{4}{3} \pi R^3 \left(\frac{\rho}{M} \right)^2$$

Units: $\frac{cm^3}{s} \cdot cm^3 \left(\frac{1}{cm^3} \right)^2 = \frac{1}{s}$

$= 0{,}5$ per day (Earth)

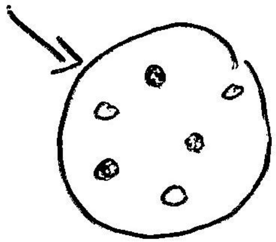
Task 1 - Answers

2) $\Gamma = 1{,}32 \cdot 10^{36}$ Hz (toy)

3)

Volume

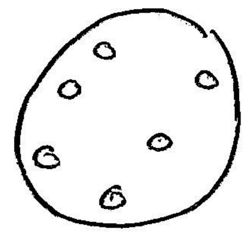
Dirac



$\frac{\langle \sigma v \rangle}{4}$

$\Gamma = 0{,}66 \cdot 10^{36}$ Hz

Majorana



$\frac{\langle \sigma v \rangle}{2}$

$\Gamma = 1{,}32 \cdot 10^{36}$ Hz

Task 1 - Answers

4) $B = 10^{-4}$ $E_\gamma = M = 0{,}5$ TeV

$D = 8{,}5$ kpc

point-like — Earth

$$\Phi = \Gamma \frac{B \cdot 2}{4\pi D^2}$$

(2 ← 2 photons per annihilation)

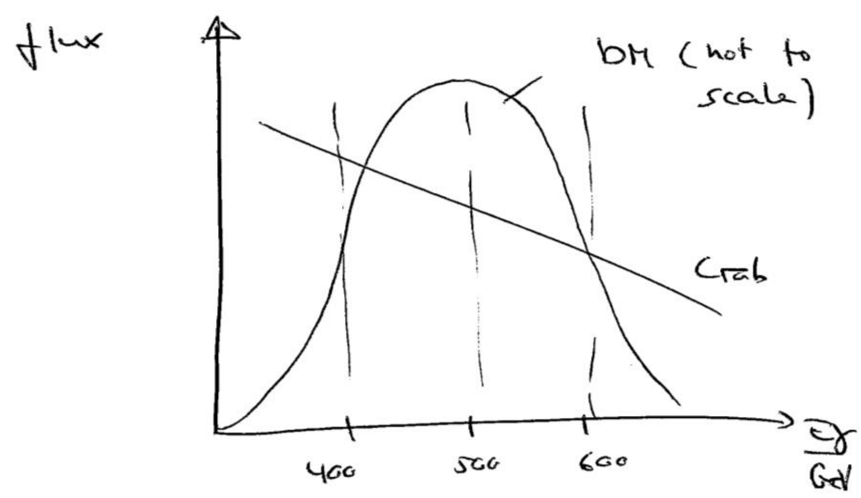
$= 3{,}1 \cdot 10^{-14}$ cm^{-5} s^{-1}

Crab flux $\left(400 \le \frac{E_\gamma}{\text{GeV}} \le 600 \right)$

is $1{,}74 \cdot 10^{-10} \frac{\text{cm}^{-2}\,\text{s}^{-1}}{\text{TeV}} \cdot 0{,}2$ TeV

$= 3{,}5 \cdot 10^{-11}$ cm^{-2} s^{-1}, so

10^3 x bigger



Task 2 - Benchmark Models

New Gamma-Ray Contributions to Supersymmetric Dark Matter Annihilation

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Department of Physics, Stockholm University, AlbaNova University Center, SE - 106 91 Stockholm, Sweden
(Dated: January 25, 2008)

We compute the electromagnetic radiative corrections to all leading annihilation processes which may occur in the Galactic dark matter halo, for dark matter in the framework of supersymmetric extensions of the Standard Model (MSSM and mSUGRA), and present the results of scans over the parameter space that is consistent with present observational bounds on the dark matter density of the Universe. Although these processes have previously been considered in some special cases by various authors, our new general analysis shows novel interesting results with large corrections that may be of importance, e.g., for searches at the soon to be launched GLAST gamma-ray space telescope. In particular, it is pointed out that regions of parameter space where there is a near degeneracy between the dark matter neutralino and the tau sleptons, radiative corrections may boost the gamma-ray yield by up to three or four orders of magnitude, even for neutralino masses considerably below the TeV scale, and will enhance the very characteristic signature of dark matter annihilations, namely a sharp step at the mass of the dark matter particle. Since this is a particularly interesting region for more constrained mSUGRA models of supersymmetry, we use an extensive scan over this parameter space to verify the significance of our findings. We also re-visit the direct annihilation of neutralinos into photons and point out that, for a considerable part of the parameter space, internal bremsstrahlung is more important for indirect dark matter searches than line signals.

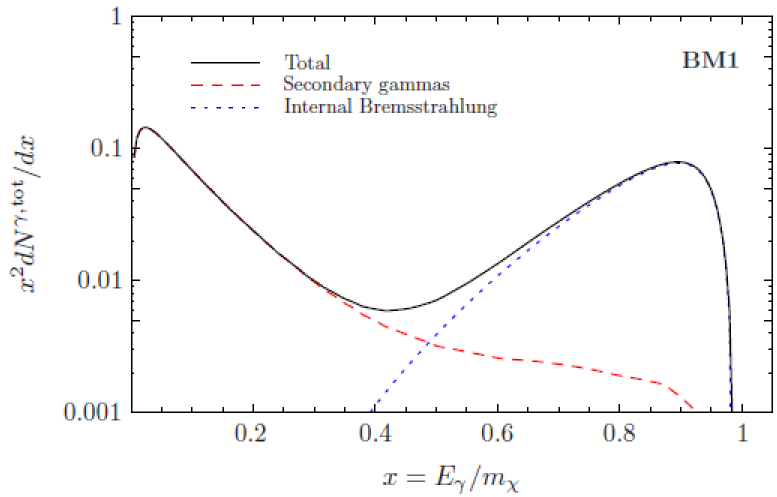
PACS numbers: 13.40.Ks,95.35.+d, 11.30.Pb, 98.70.Rz

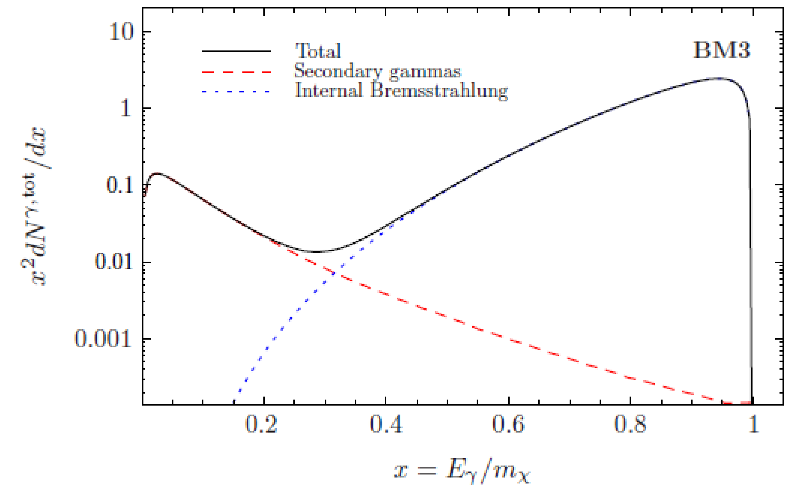
Task 2 - Benchmark Models

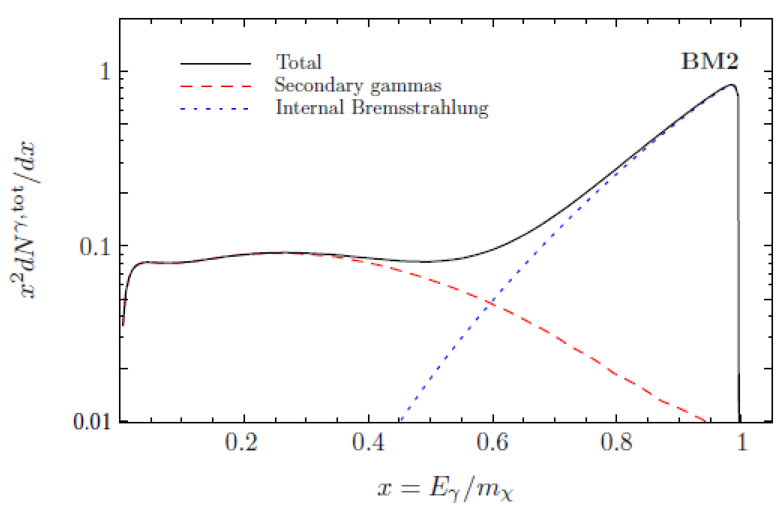
	m_0 [GeV]	$m_{1/2}$ [GeV]	$\tan\beta$	A_0 [GeV]	sgn (μ)	m_χ [GeV]	$Z_g/(1-Z_g)$	Ωh^2	t-channel	$\mathcal{S}$	IB/ sec.	IB/ lines
BM1	3700	3060	5.65	$-1.39\cdot10^4$	-1	1396	$3.0\cdot10^4$	0.082	$\tilde{t}(1406)$	$8\cdot10^{-5}$	19.2	4.5
BM2	801	1046	30.2	$-3.04\cdot10^3$	-1	446.9	1611	0.110	$\tilde{\tau}(447.5)$	0.044	10.6	8.5
BM3	107.5	576.4	3.90	28.3	$+1$	233.3	220	0.084	$\tilde{\tau}(238.9)$	1.19	$2.3\cdot10^3$	5.0
BM4	$2.2\cdot10^4$	7792	24.1	17.7	$+1$	1926	$1.2\cdot10^{-4}$	0.11	$\tilde{\chi}_1^+(1996)$	0.012	10.8	2.1

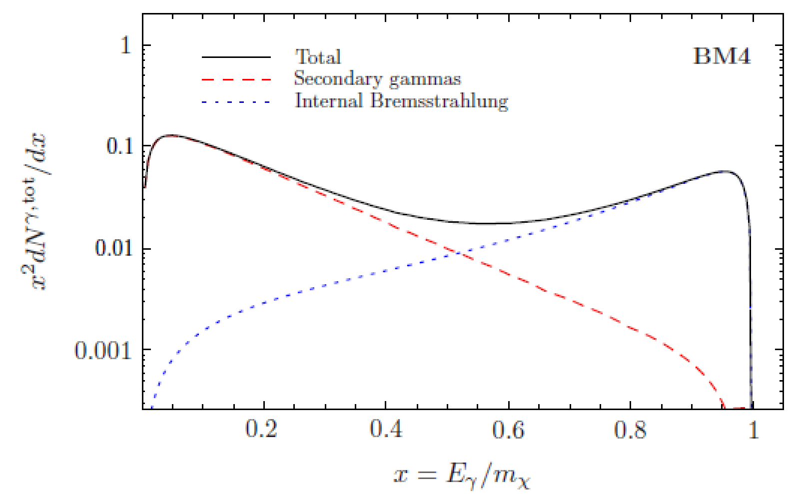
TABLE I: Benchmark models that represent typical regions in the supersymmetric parameter space where IB becomes important. The "t-channel" entry indicates the main contributing t-channel diagram, with the corresponding sparticle and its mass (all masses are given in GeV). $\mathcal{S} \equiv N_\gamma \frac{\langle\sigma v\rangle}{10^{-29}\mathrm{cm}^3\mathrm{s}^{-1}} \left(\frac{m_\chi}{100\mathrm{GeV}}\right)^{-2}$ is the rescaled flux from IB alone and the last two columns give the ratio of the integrated flux, all above $0.6\,m_\chi$, between the new IB contribution and secondary photons as well as the line signals. The main difference between BM2 and BM3 is that in the former neutralinos mainly annihilate into τ leptons, while in the latter mainly into t quarks. Also, for BM2 only the τ final states give an important contribution, while in the second case, even the other leptonic final states contribute considerably (due to near-degenerate slepton masses). For the BM4 model, the IB contribution from the W^+W^- state dominates.

Task 2 - Benchmark Models

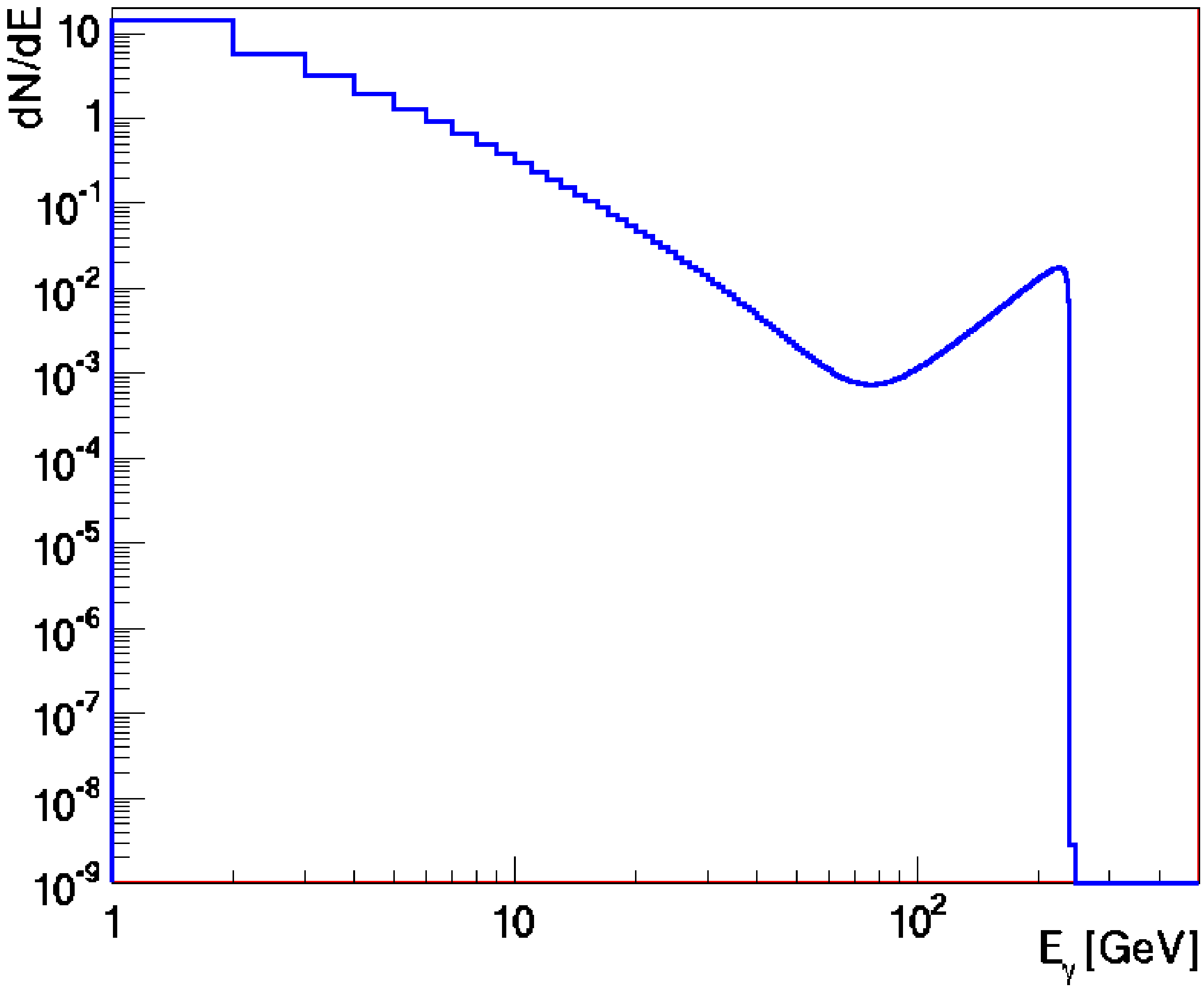






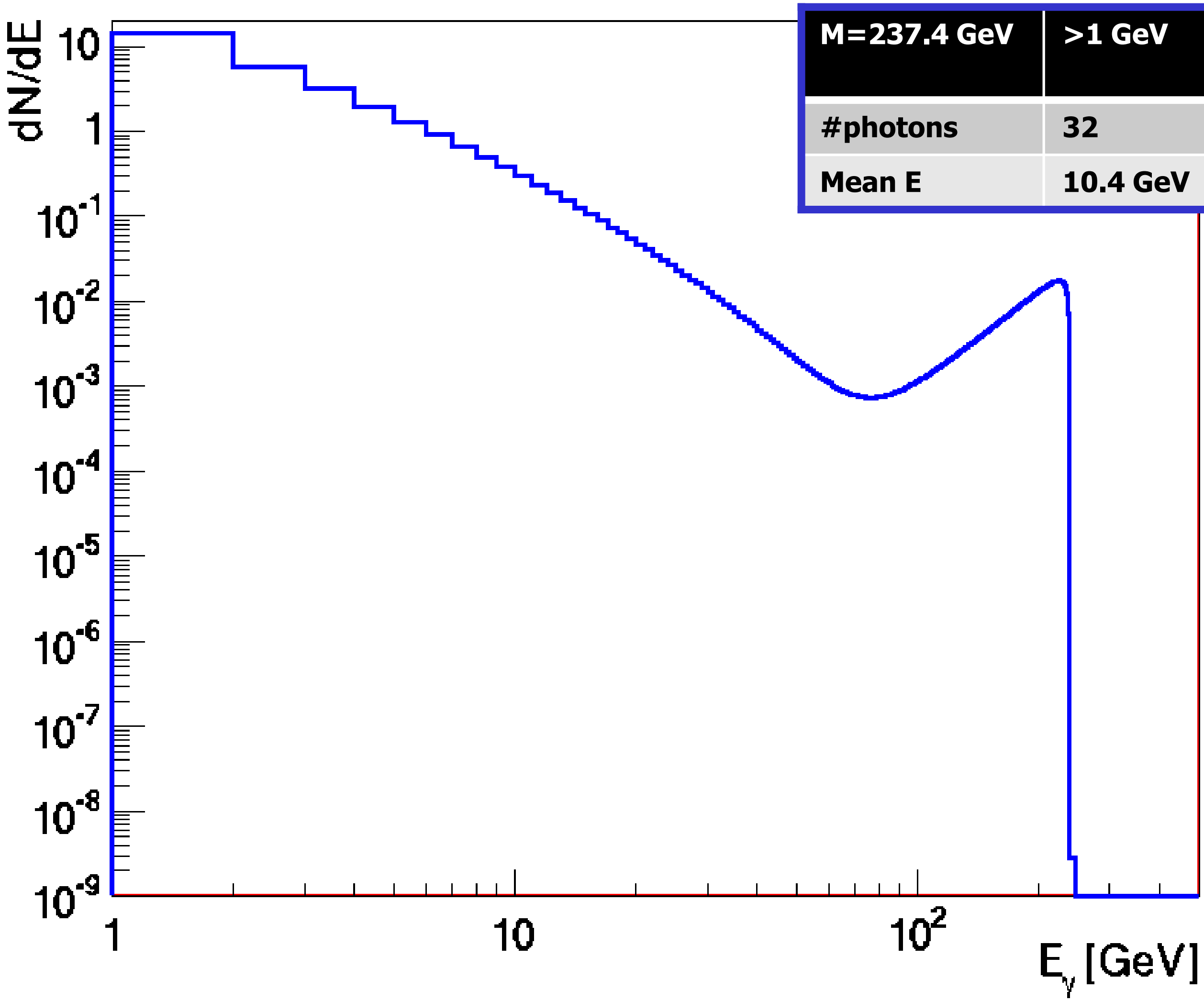


Photon Spectra



Photon Spectra

M=237.4 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	32	2.9	1.1
Mean E	10.4 GeV	84.7 GeV	194 GeV



Task 2 – Overplotting dN/dx

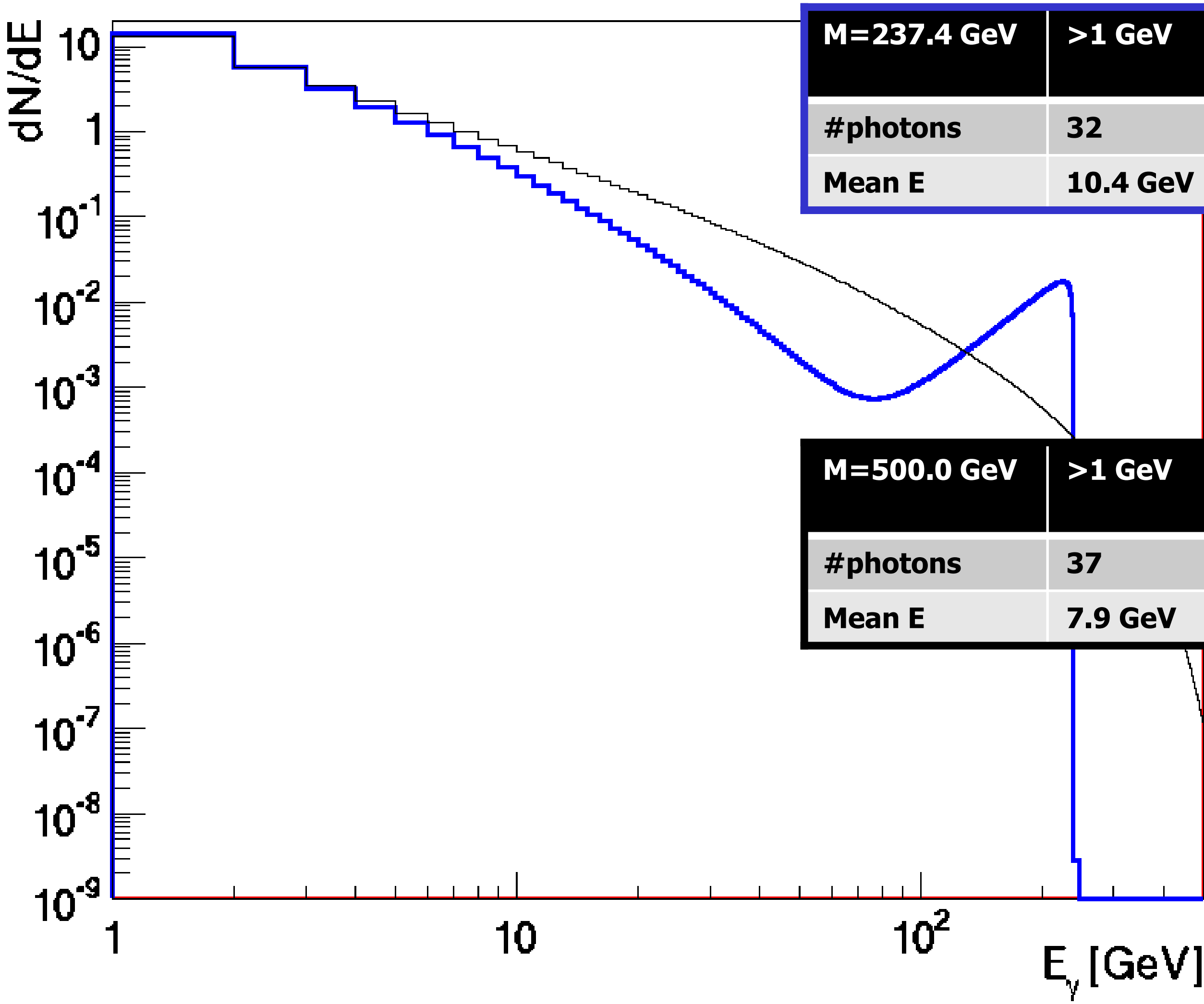
$$\frac{dN_\gamma}{dx} = x^a e^{b + cx + dx^2 + ex^3}$$

$$x = \frac{E_\gamma}{M}$$

$$\frac{dN}{d(E_\gamma/M)} = M \frac{dN_\gamma}{dE_\gamma} \Longrightarrow$$

$$\boxed{\frac{dN_\gamma}{dE_\gamma}(E) = \frac{1}{M}\frac{dN_\gamma}{dx}\left(x = \frac{E_\gamma}{M}\right)}$$

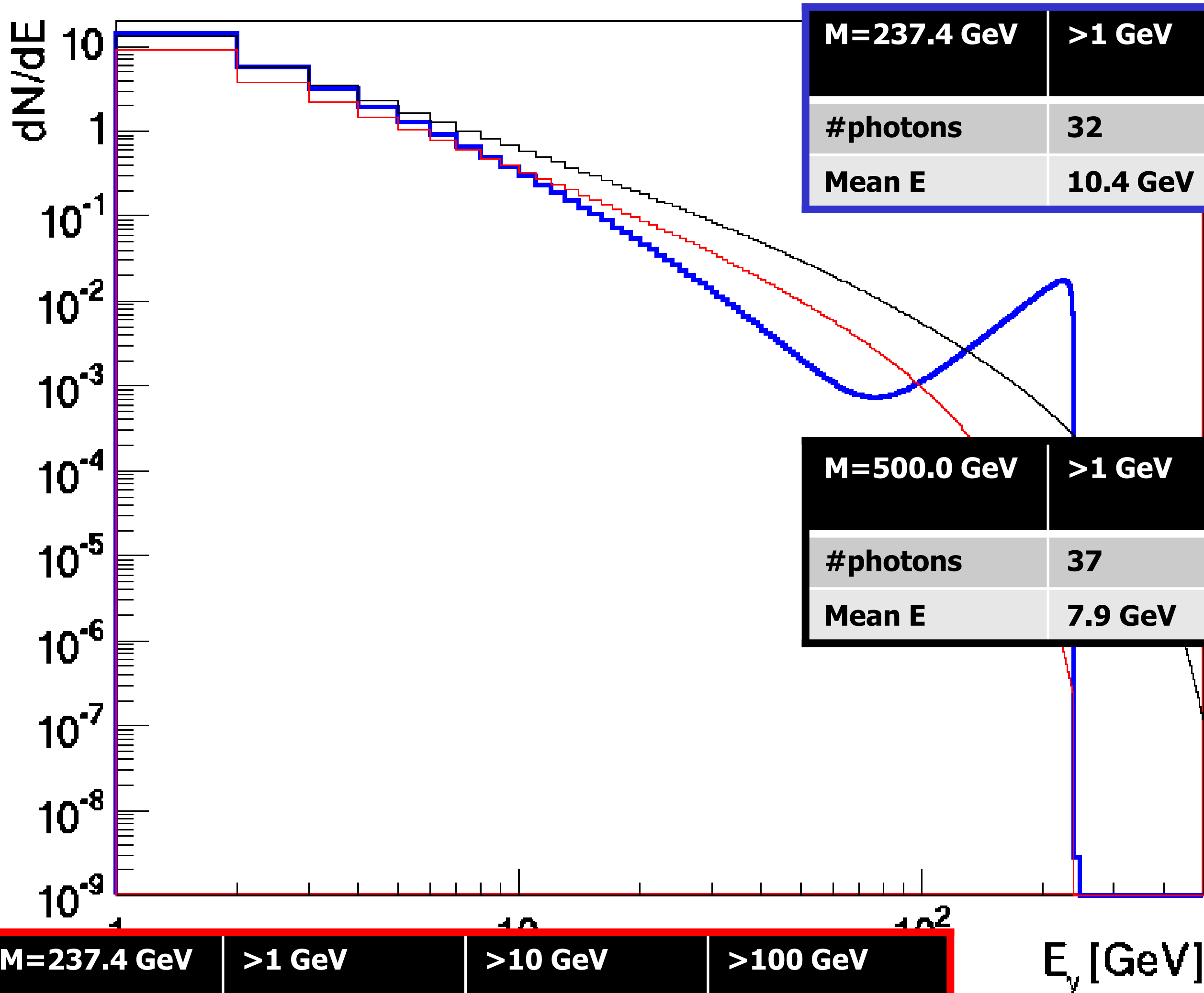
Photon Spectra



M=237.4 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	32	2.9	1.1
Mean E	10.4 GeV	84.7 GeV	194 GeV

M=500.0 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	37	6.6	0.2
Mean E	7.9 GeV	29.9 GeV	145 GeV

Photon Spectra

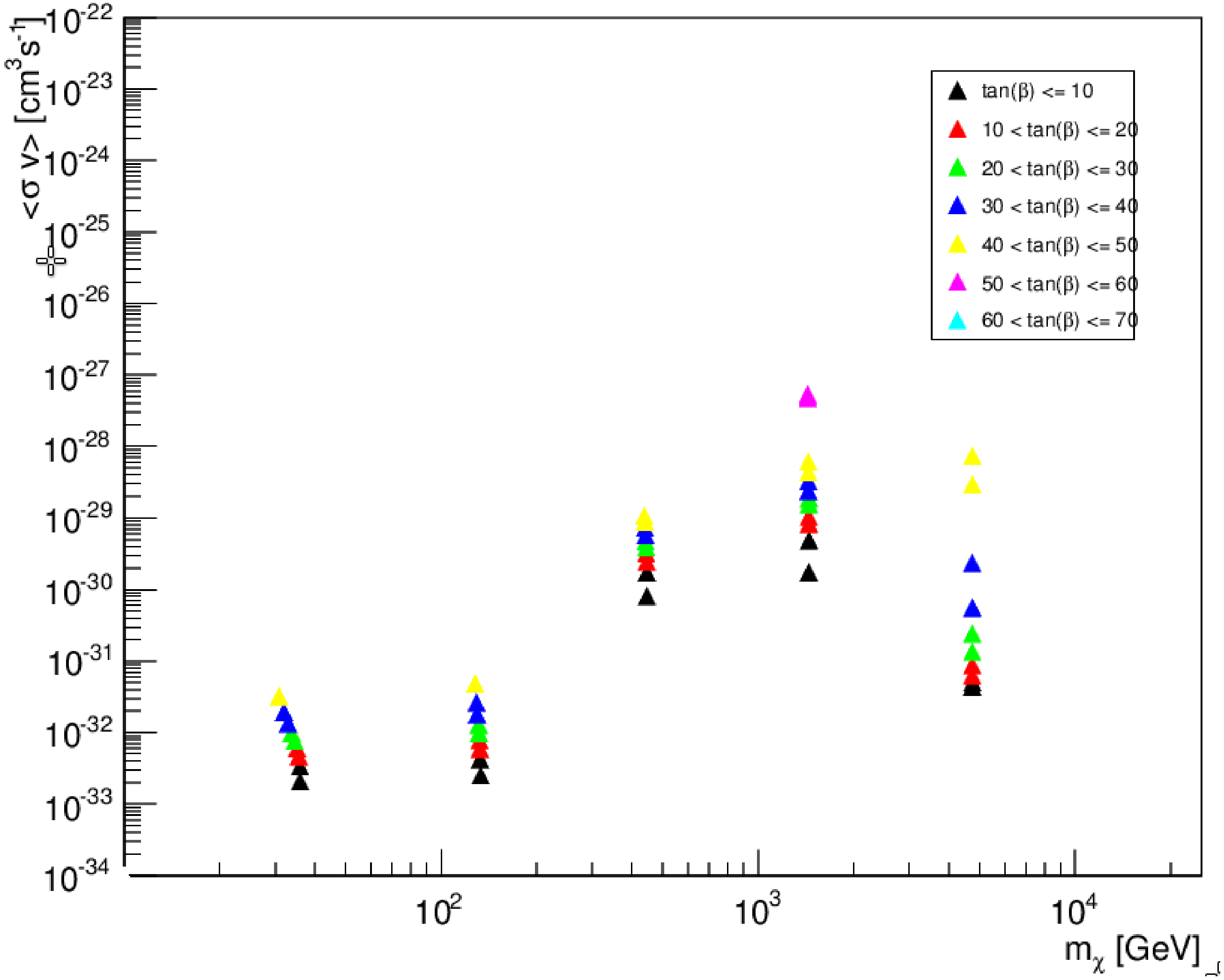


M=237.4 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	32	2.9	1.1
Mean E	10.4 GeV	84.7 GeV	194 GeV

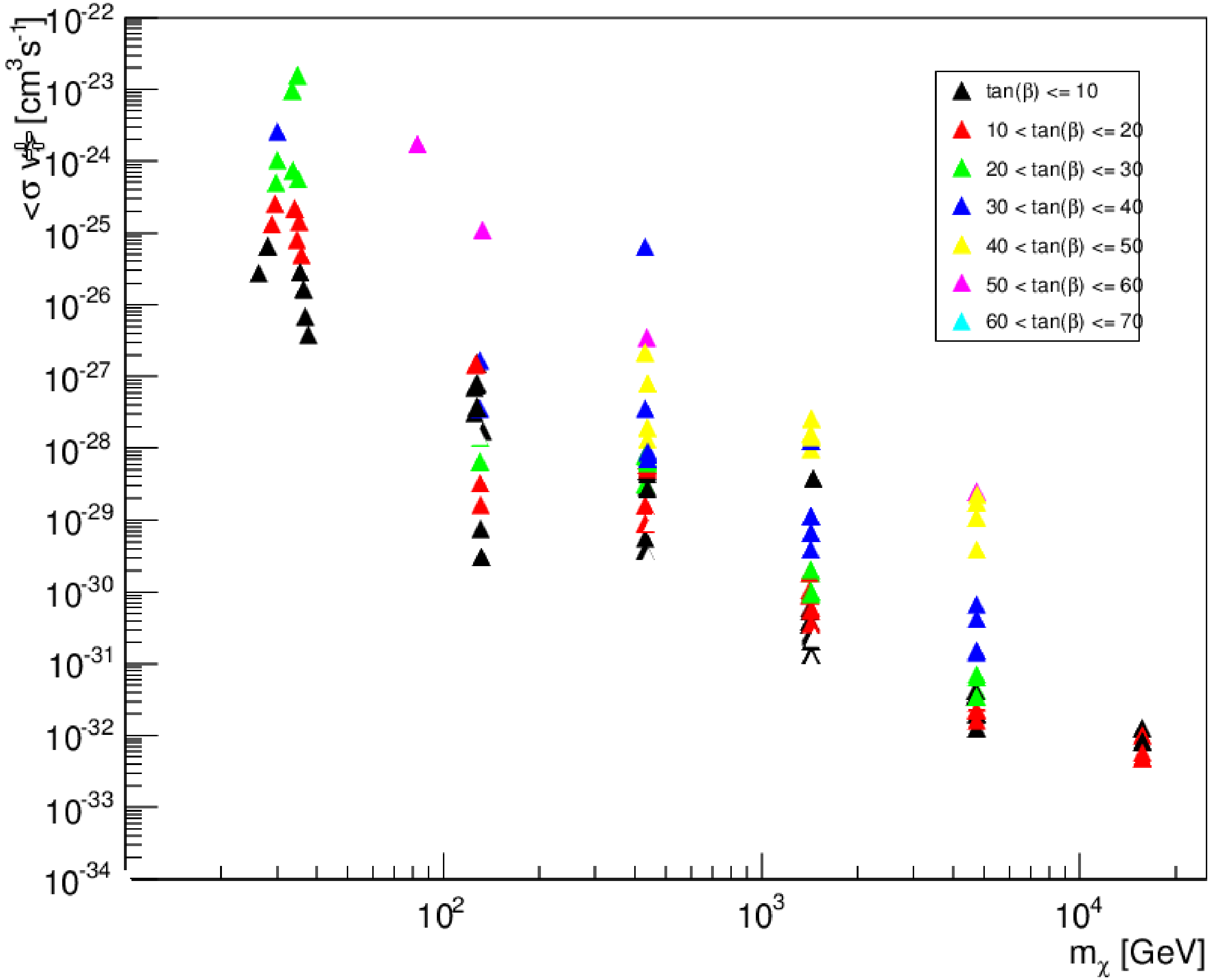
M=500.0 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	37	6.6	0.2
Mean E	7.9 GeV	29.9 GeV	145 GeV

M=237.4 GeV	>1 GeV	>10 GeV	>100 GeV
#photons	23	3.0	0.02
Mean E	5.7 GeV	22.9 GeV	121 GeV

Scan (923 models)



Scan



$<\sigma v>$ [cm^{3}s^{-1}]
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
10^{-29}
10^{-30}
10^{-31}
10^{-32}
10^{-33}
10^{-34}
tan(β) <= 10
10 < tan(β) <= 20
20 < tan(β) <= 30
30 < tan(β) <= 40
40 < tan(β) <= 50
50 < tan(β) <= 60
60 < tan(β) <= 70
10^2
10^3
10^4
m_χ [GeV]

The End

That`s it.