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# Search for Dark Matter with H.E.S.S.

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# Content

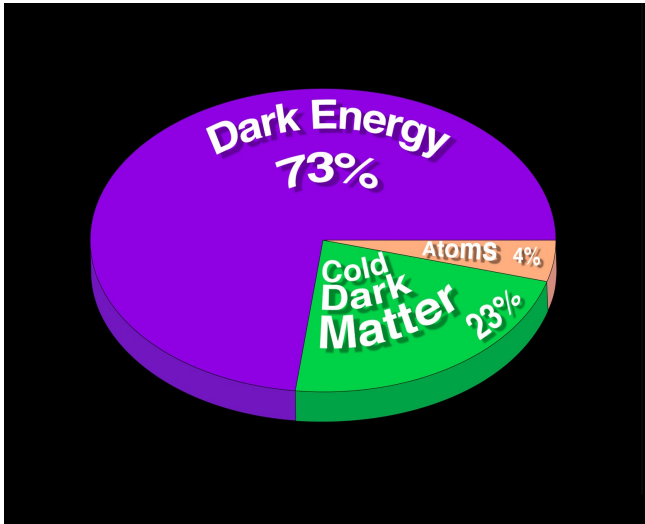
- Very brief introduction into Dark Matter
- General description of measurement
- Context

# Introduction
# - Summary of Empirical Evidences

Observation of large scale structure dynamics gives: (galactic, galaxy clusters)

Dynamics can only be explained with Newton's laws if there is non-luminous mass

Additionally: CMB acoustic peaks can be explained with DM



# Introduction

- What is the problem ?

  → The “MOND” approach:
  Modify Newtonian dynamics (Milgrom, 1983
  Bekenstein, 2004
  ...)

  → The particle Dark Matter approach:

  Plenty of candidates ...
  Most people believe in neutralino Dark Matter

# Experimental Approaches to Particle Dark Matter

•Direct detection in collisions:
Local DM density ~(0.2-0.4) GeV/cm³

→ F. i. heat production in crystals (sensitive thermometer)

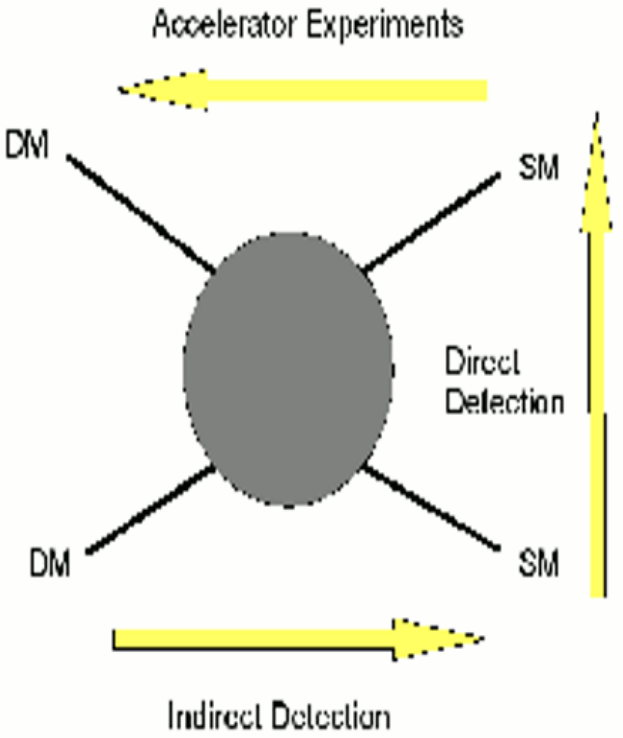
Volume V=(10 m)³
DM Mass M=500 GeV

N=6 Mega particles in V !

•Creation of DM: LHC

•Indirect detection of annihilation (or decay) products of astrophysical DM

→ Different channels (electrons, photons, neutrinos, ...)



# Experimental Approaches to Particle Dark Matter

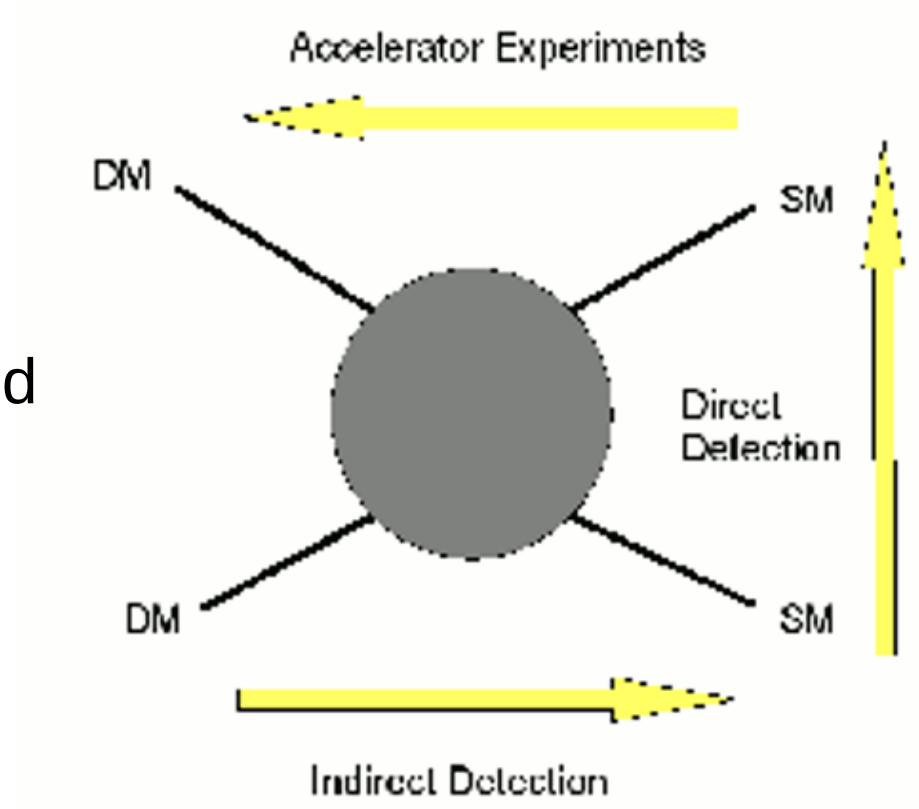
•Interdependence of approaches:

→ Origin of DM problem is in large scale (galaxy / galaxy cluster ) dynamics

→ Proposed solution is in SM extensions (particle physics)

→ If given SM extension is approved by accelerator experiments

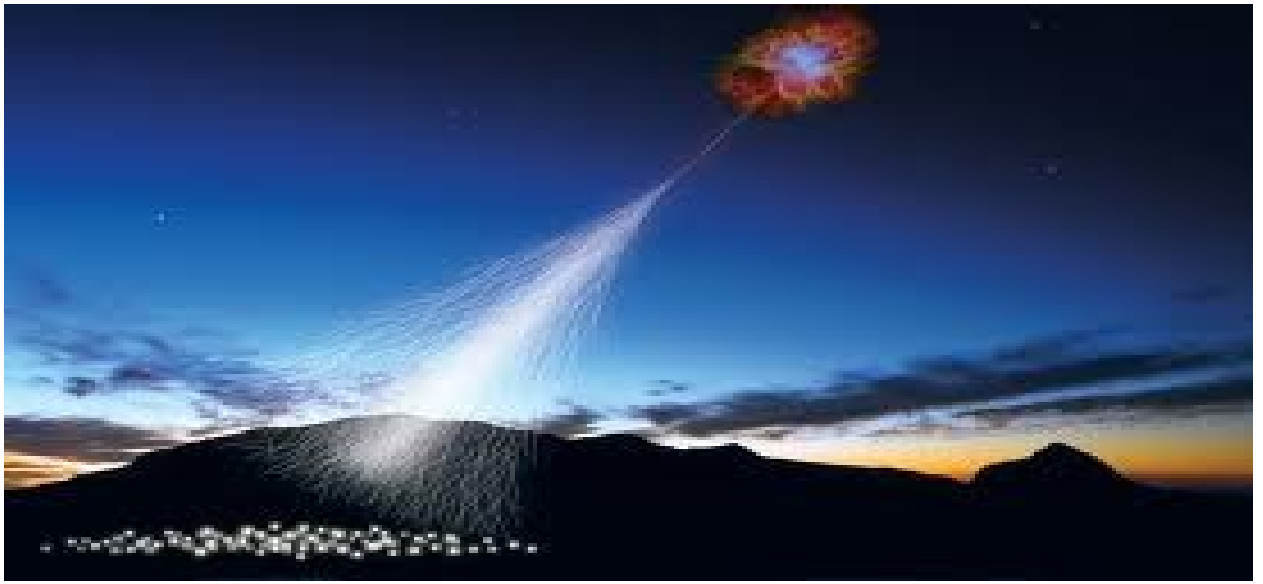
→ Have to prove that same mechanism is solution for DM problem



# Dark Matter Search with H.E.S.S. - The Experiment

- H.E.S.S.: High Energy Stereoscopic System, Namibia

- Strategy: Use atmosphere as homogeneous calorimeter for particles



- Cherenkov light from shower detected by telescopes
  = Function (Energy, distance, particle type, ...)

# Dark Matter Search with H.E.S.S. - The Experiment

- What H.E.S.S tries to measure (mostly):

  → VHE photons (100 GeV – 100 TeV) → Very interesting range for DM rest masses

- Main background for VHE photons:

  → Primary cosmic rays

  Sometimes f. i. proton showers look quite the same as a photon shower

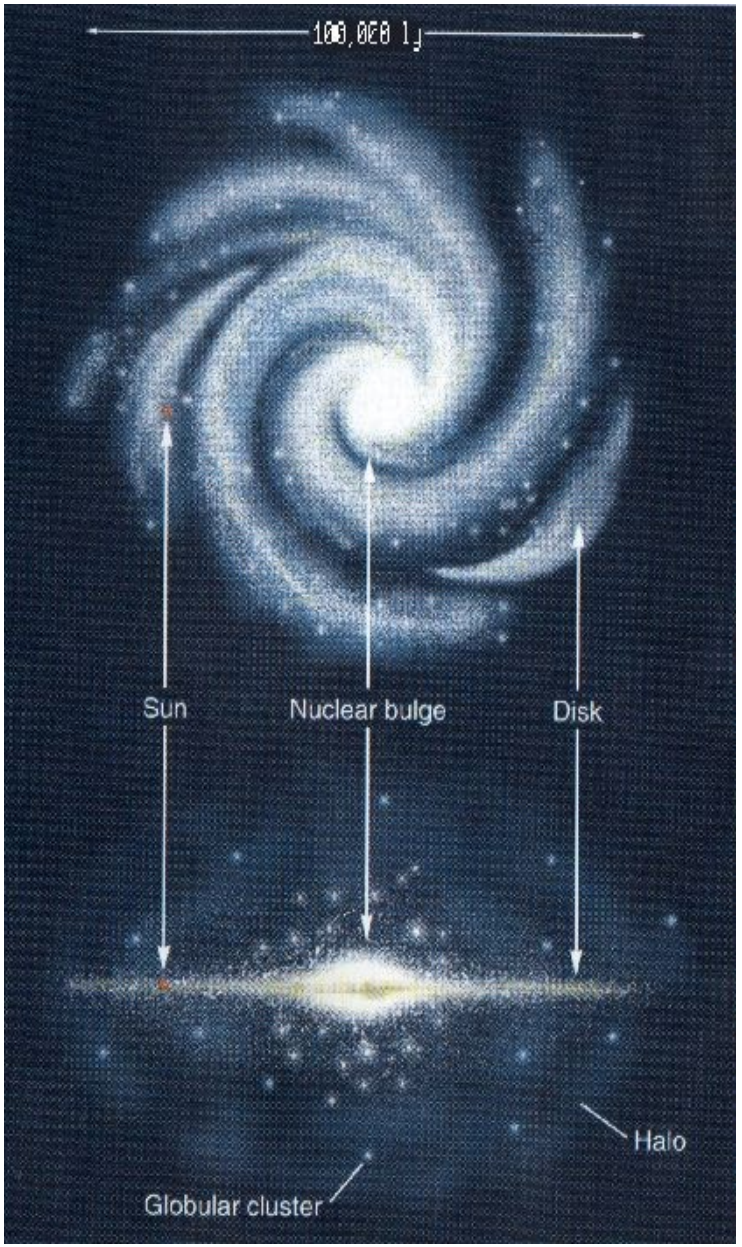
# DM & the GC-Region

- General idea:
  - → DM density in GC is high (Prediction of galaxy formation models)
  - → Many DM particles convert to photons in GC region (?)

- Measurement:
  - → Point telescopes to GC region

Measure:

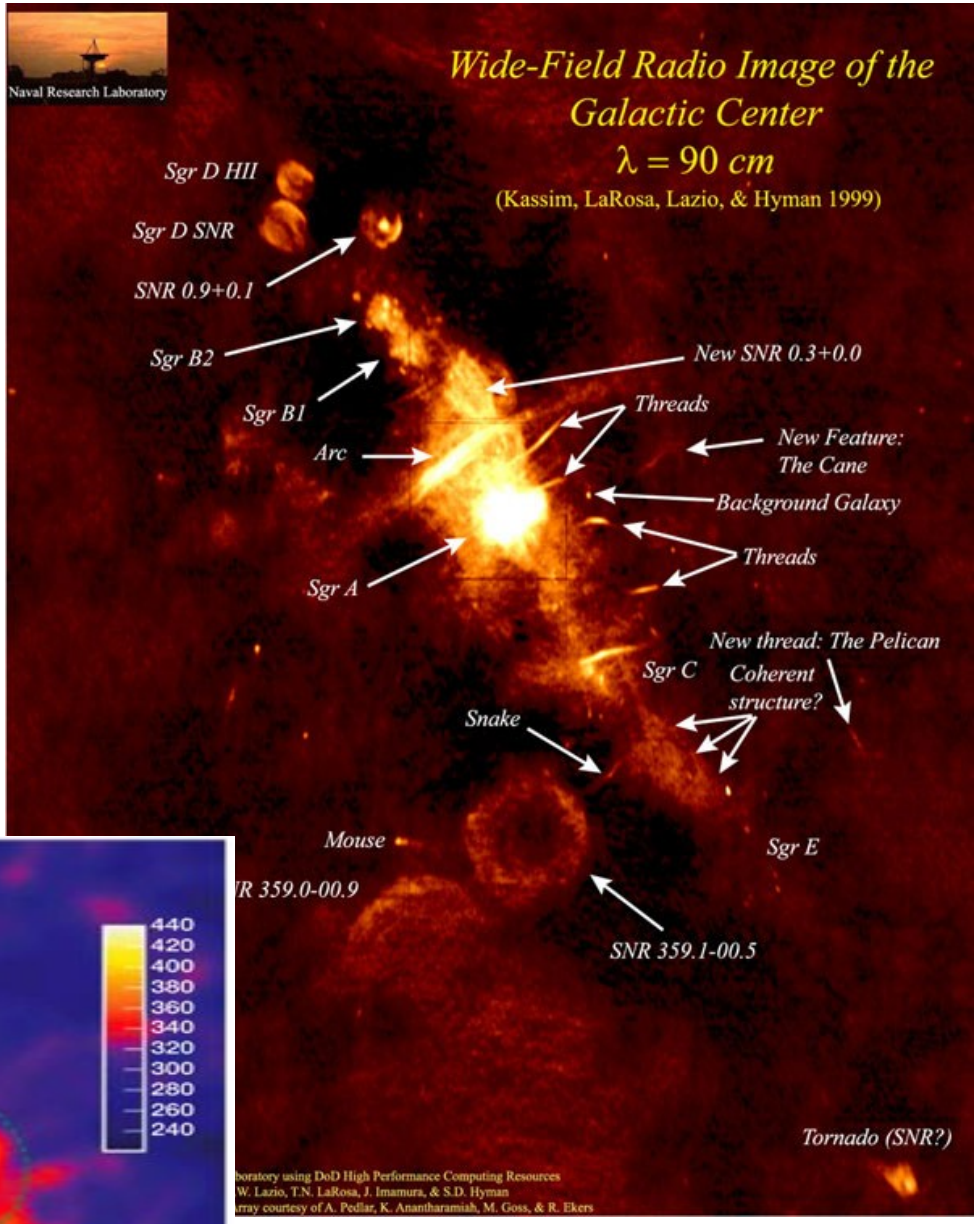
VHE photons from DM annihilation from galactic halo

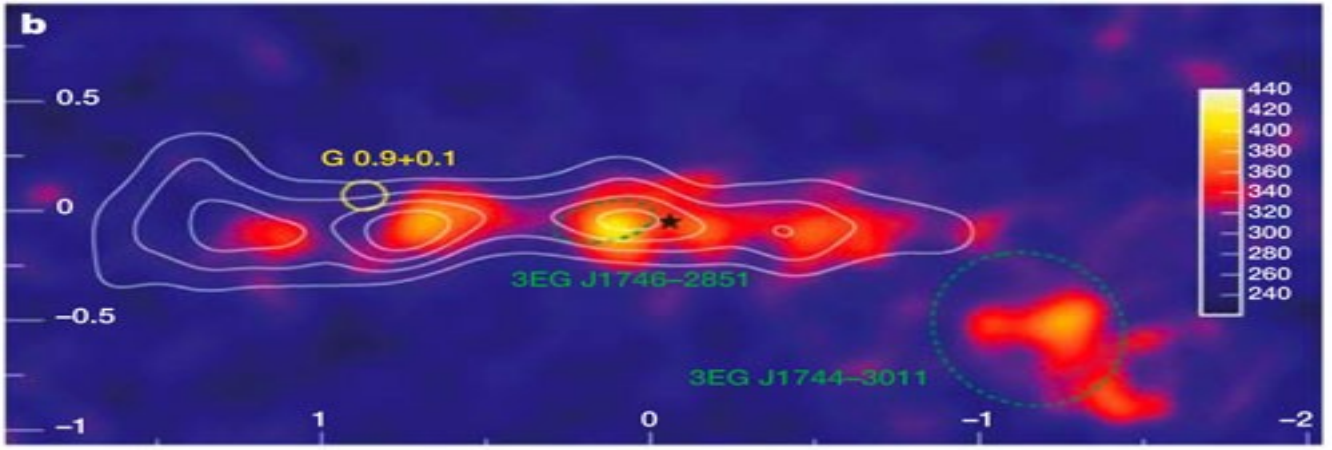


# Background
# - The GC Region

- Avoid observing regions with sources
- H.E.S.S. Field of view has ~2.5° opening angle

→ "See" only small fraction of GC region at same time



# Background

- Isotropic component:

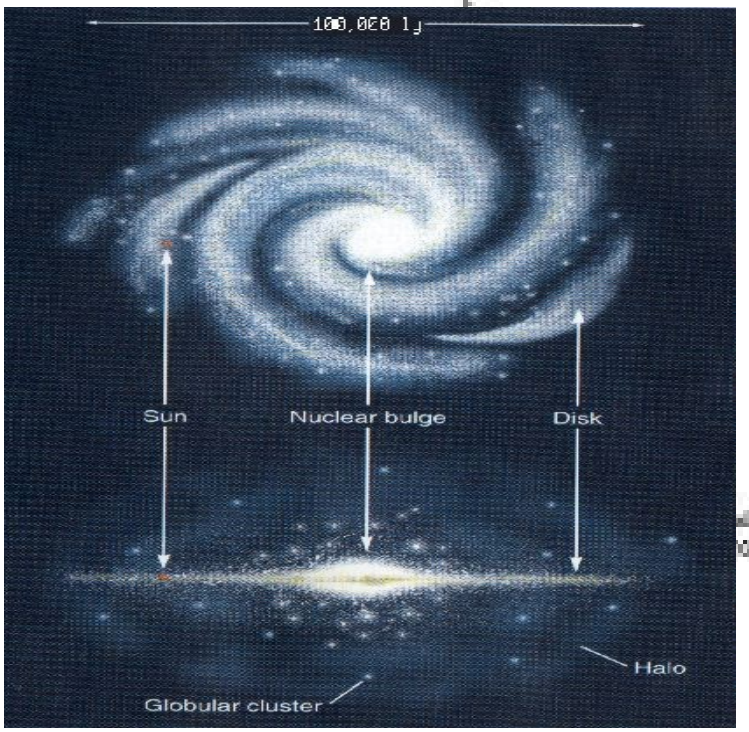
  CR's (protons, He, electrons, ...)

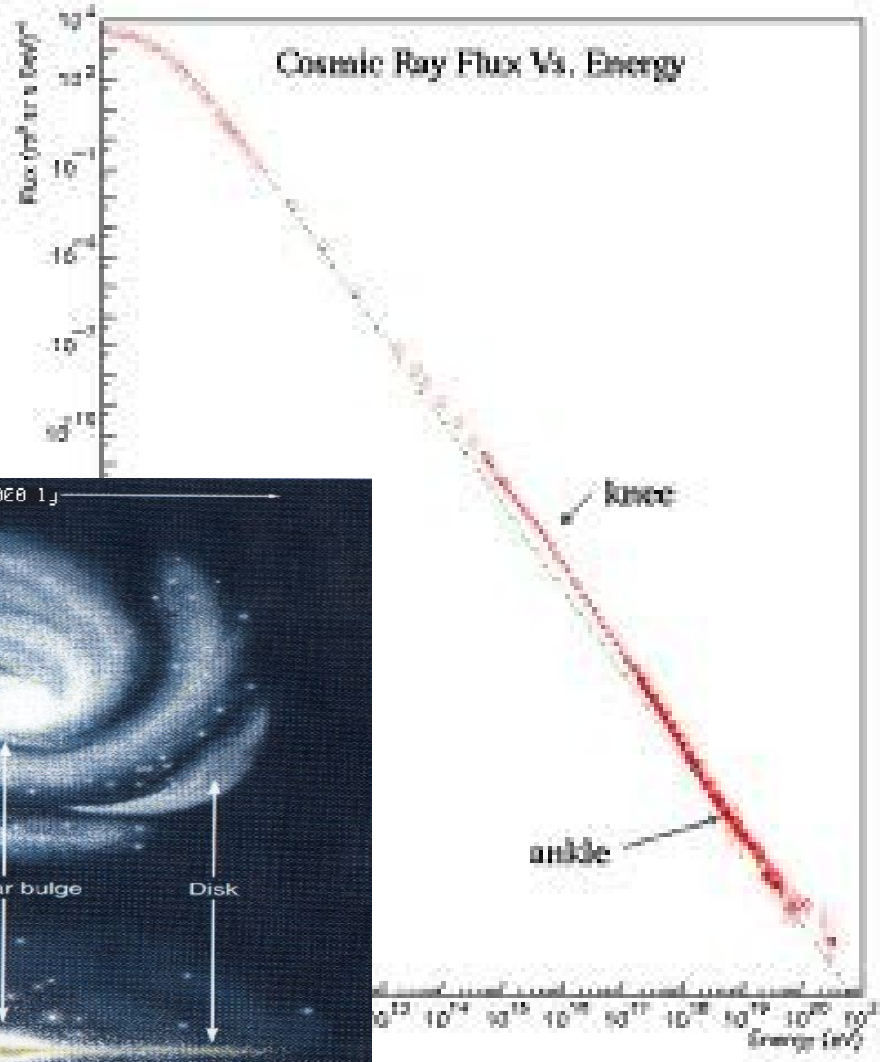
  ~5 Hz after cuts (sophisticated analysis)

- High energetic CR's not only on earth

  → In whole galaxy

- Particle reactions lead to




"Diffuse galactic VHE emission" (anisotropic)

# DM Signal

- Particle DM annihilation (no decay in this talk...):

  → How can DM particles annihilate to VHE photons ?

  → DM particles no electrical charge

    → No tree level production of photons

    → “Smoking gun” line signature loop suppressed

  → Tree level production of

    → Fermions (Quarks + Leptons)

      Helicicity suppressed for Majorana neutralinos
      (Possibly lifted by “Internal Bremsstrahlung”)

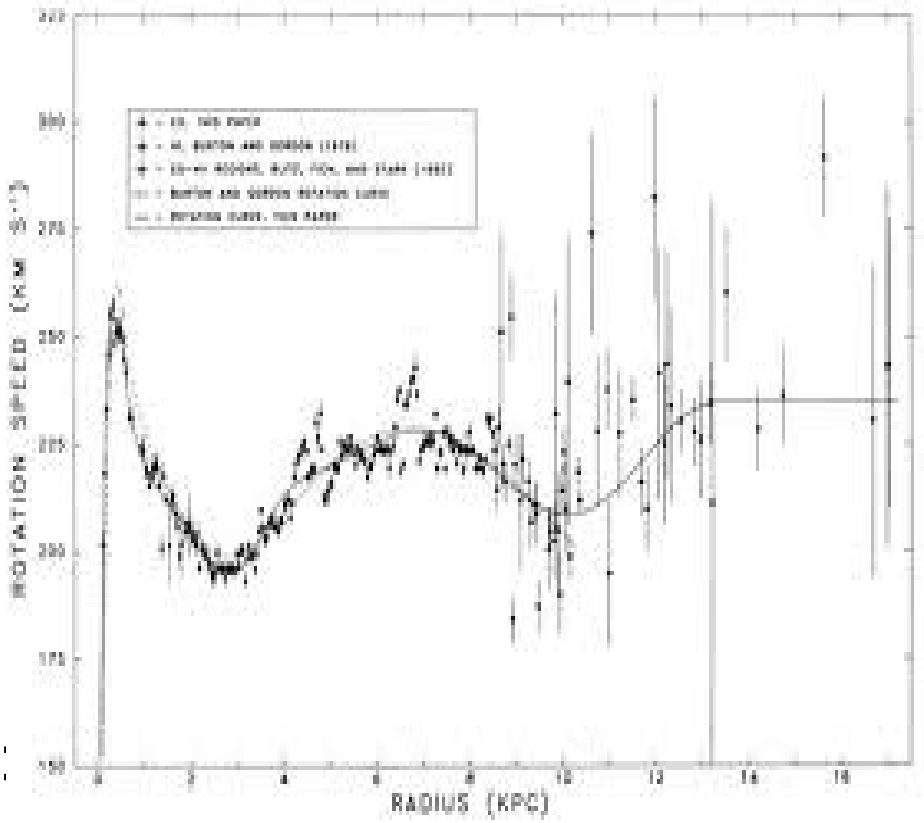
    → Gauge bosons

# DM Annihilation Signal

Particle physics (model dependent)

$$\left(\frac{d\Phi}{dE}\right)_{DM} \propto \frac{<\sigma v>}{m^2} \sum_i \Gamma_i \frac{dN_i^\gamma}{dE} \int_{LoS} ds\, \rho^2(s)$$

Astrophysics

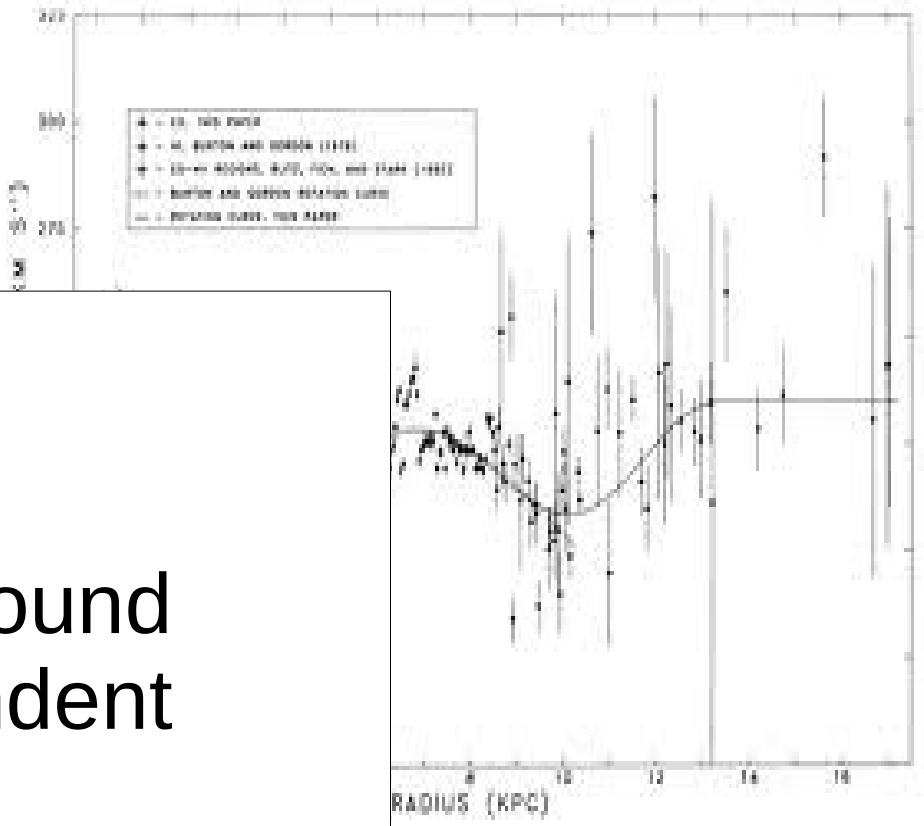



- Astrophysical factor:
  - → MW rotation curve compatible to different DM distributions
  - → From galaxy formation simulations: Profile for average galaxy ; But:
    - → N-body simulation without baryons, galaxy mergers ?
    - → Is the Milky Way an average galaxy ?

# DM Annihilation Signal

Particle physics (model dependent)

$$\left(\frac{d\Phi}{dE}\right)_{DM} \propto \frac{<\sigma v>}{m^2} \sum_i \Gamma_i \frac{dN_i^\gamma}{dE} \int_{LoS} ds\, \rho^2(s)$$




•Astroph

→ M
c

→ F
F

xy mergers ?

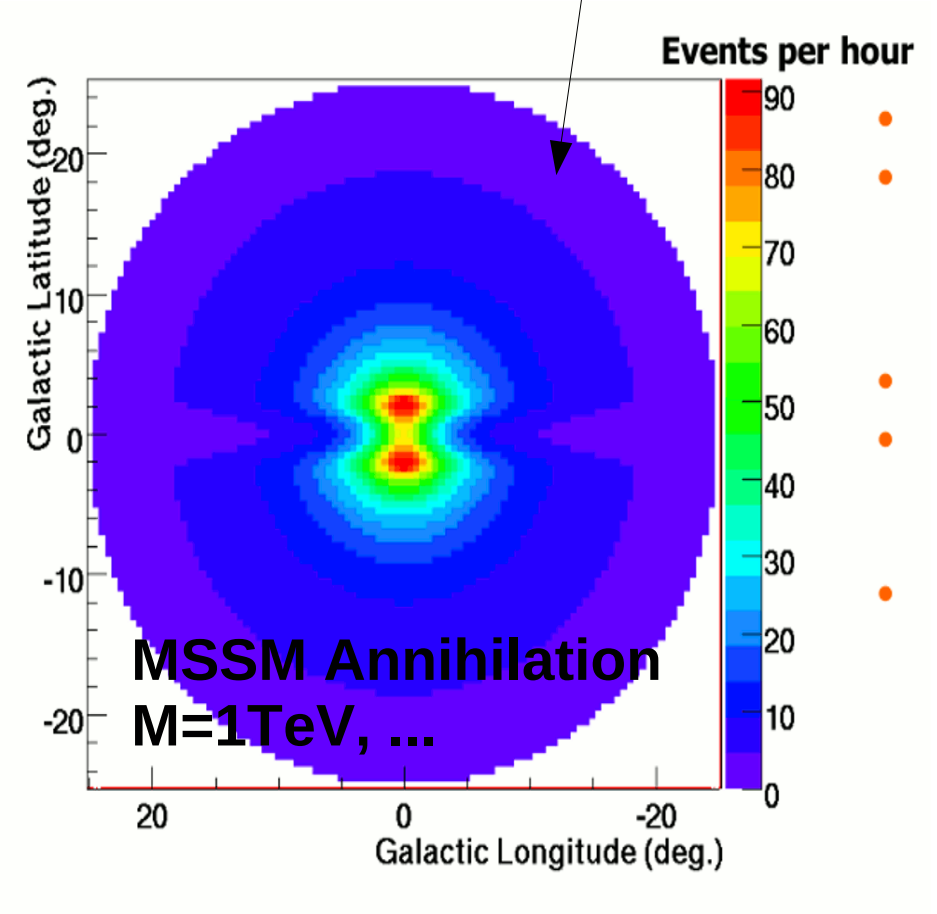
Summary:

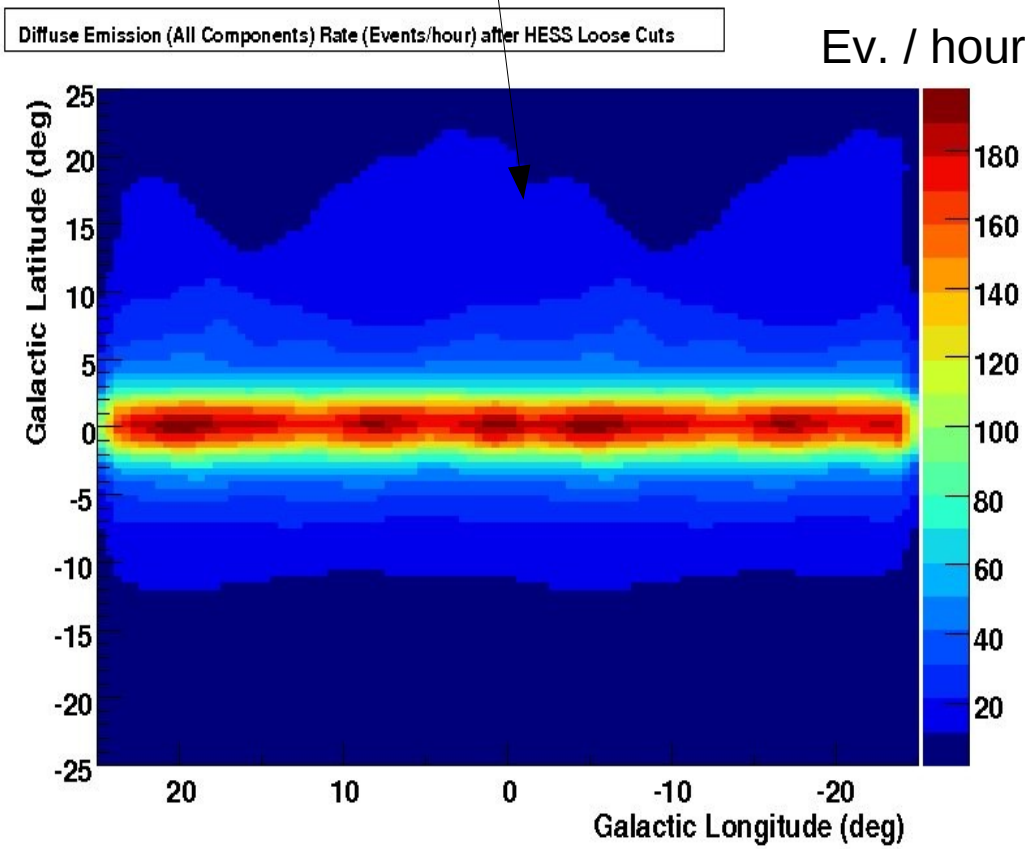
DM signal & background highly model dependent

=

Very high dimensional parameter space for signal as well for background

# DM Signal vs. Background for H.E.S.S. (simplified !)



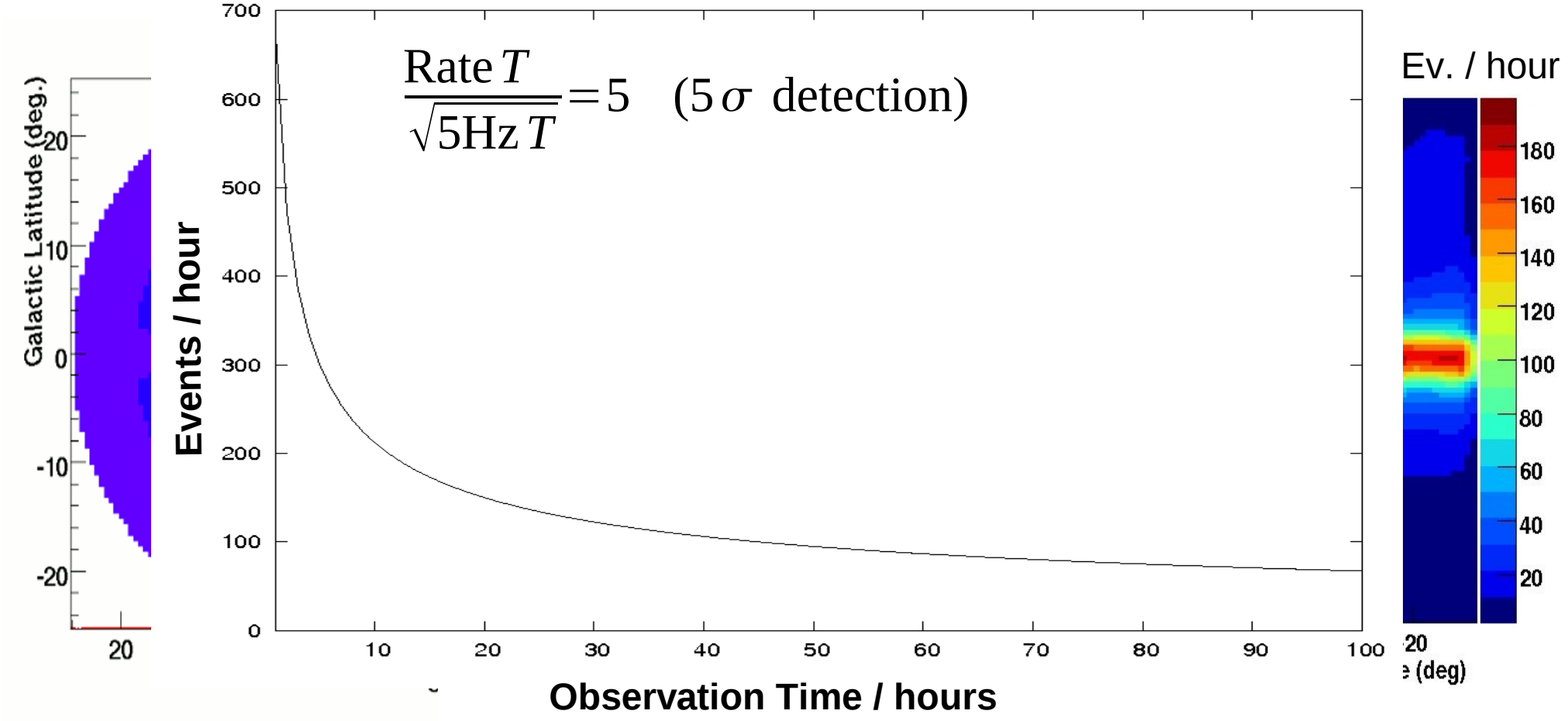




+5Hz isotropic background

Signal ON-OFF: ~60 Ev./h

Diffuse Background
ON-OFF: ~100 Ev./h

# DM Signal vs. Background for H.E.S.S. (simplified !)




+5Hz isotropic background

Signal ON-OFF: ~60 Ev./h

Diffuse Background
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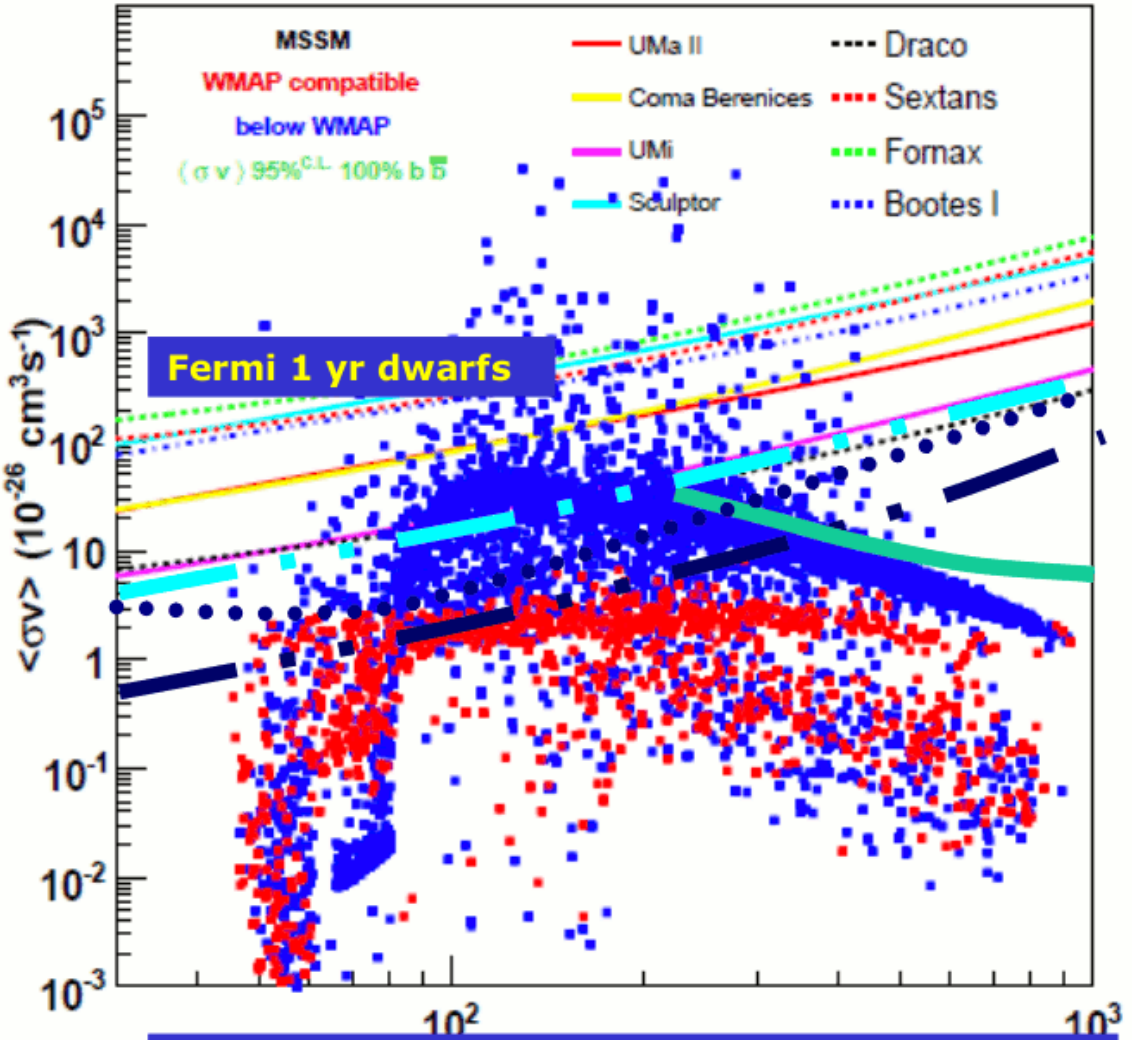
# Conservative speculation: 2013

Stockholms universitet




+ energy range, event selection (Fermi) + news from other exps. AMS,LHC(?) + HESSII,MAGICII

Fermi 5 yr combined dwarfs

Fermi 5 yr halo, no substructure

Grey: indicating diffuse bg range.

H.E.S.S. 50 h halo, (Aquarius substructure) or Dwarf stacking?


$10^{-27}$ .... with some work and ideas ....



Slide from Jan Conrad, 2010

# What can CTA do - conservatively

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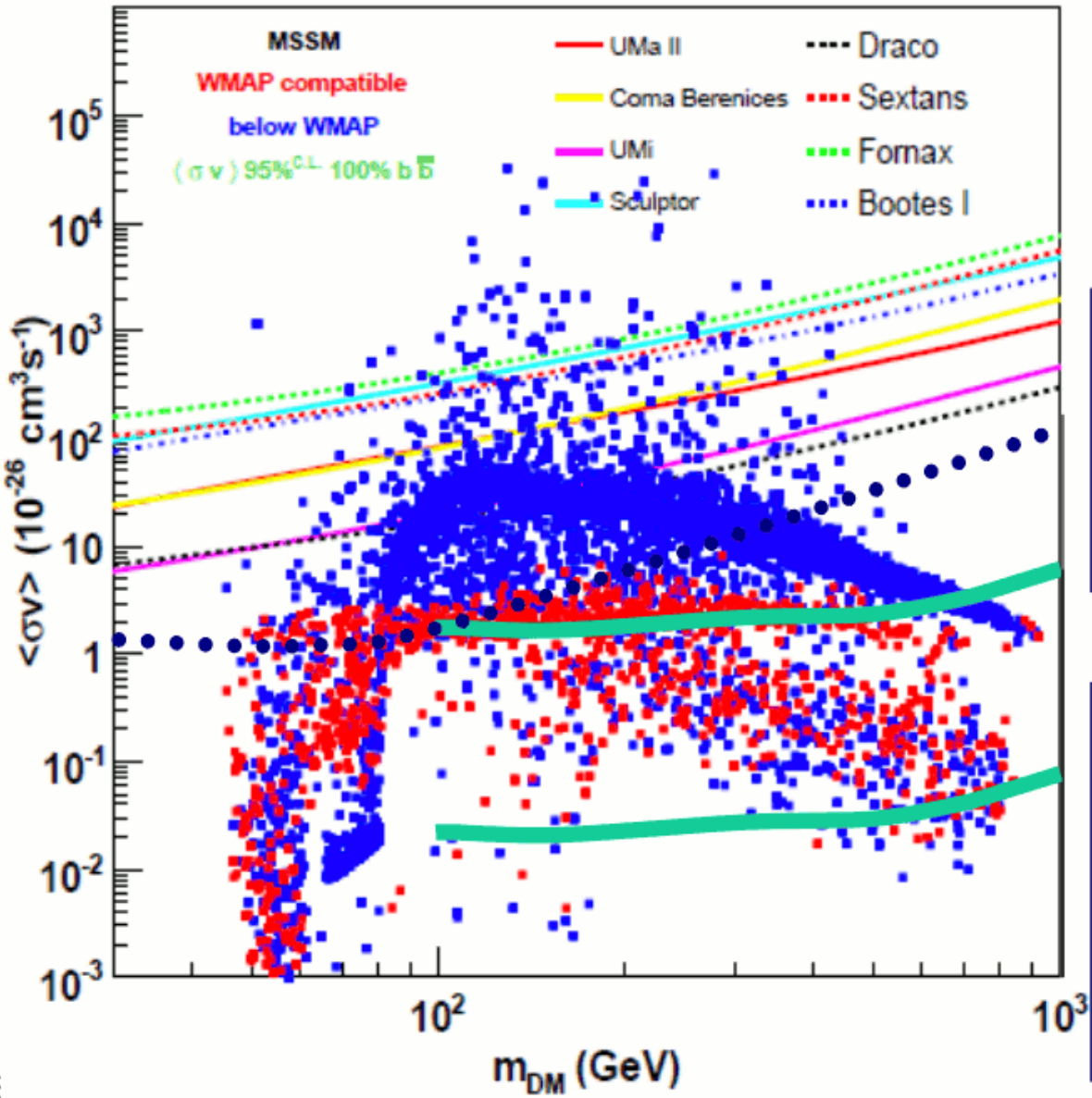



**CTA Sag, NFW, 20 h (based on CTA Design study simulations). NB: 5 σ**

***PRELIMINARY!***

**CTA halo (~100h)**

**(if halo sensitivity improvment comparable to Sag dwarf improvement)**

**Aquarius**

09-08



Slide from Jan Conrad, 2010

# Context

- No single measurement for solution of DM problem
- Instead: Interdependence of experimental approaches (->Introduction)

- Indirect detection:

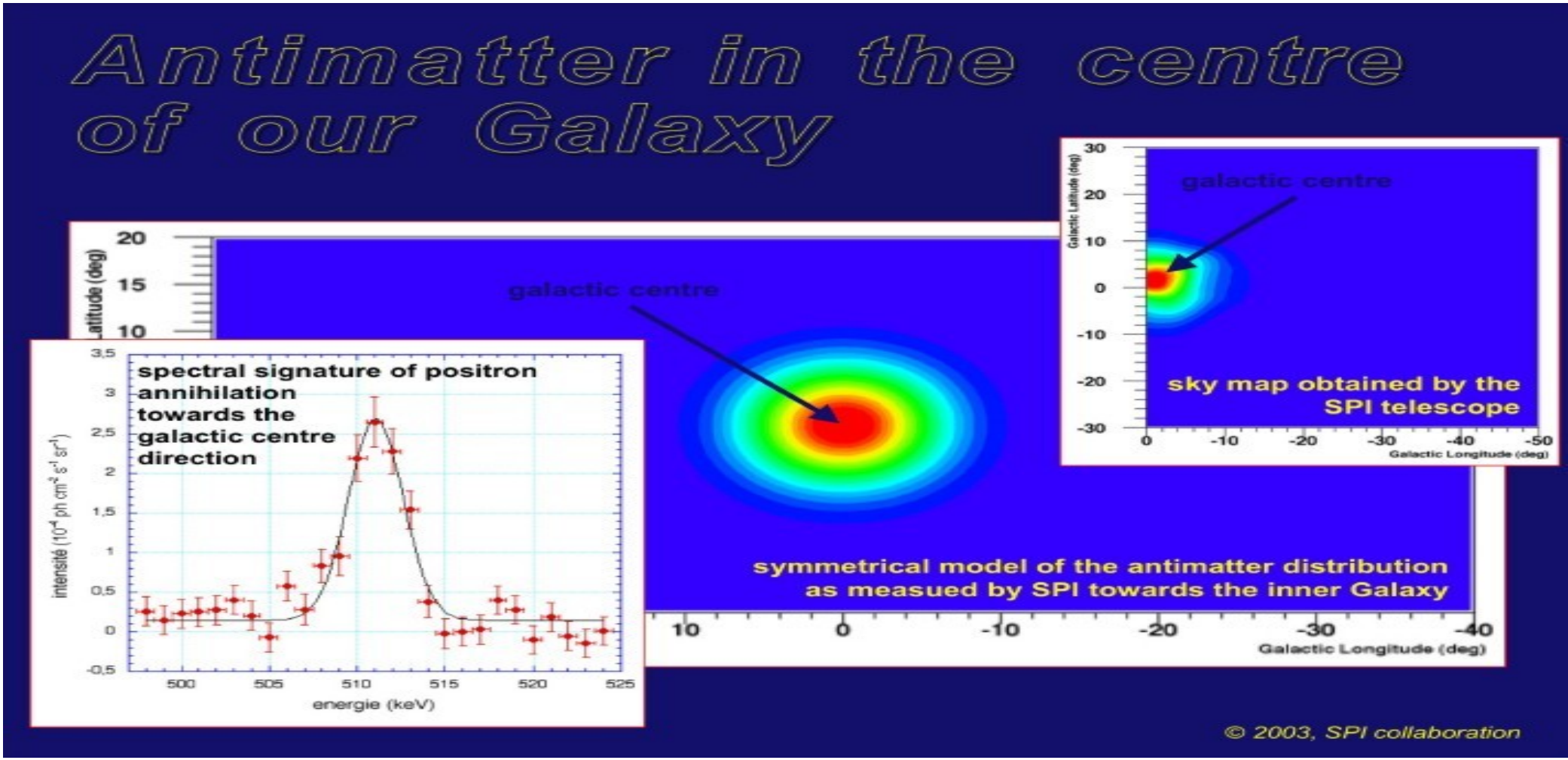
  → Astrophysical DM signals strongly model dependent

  → For DM detection:
  Measured signal must be compatible with other indirect DM signals

  + Accelerator measurements (LHC)

  + Direct earth measurements (DAMA, ...)

# Context

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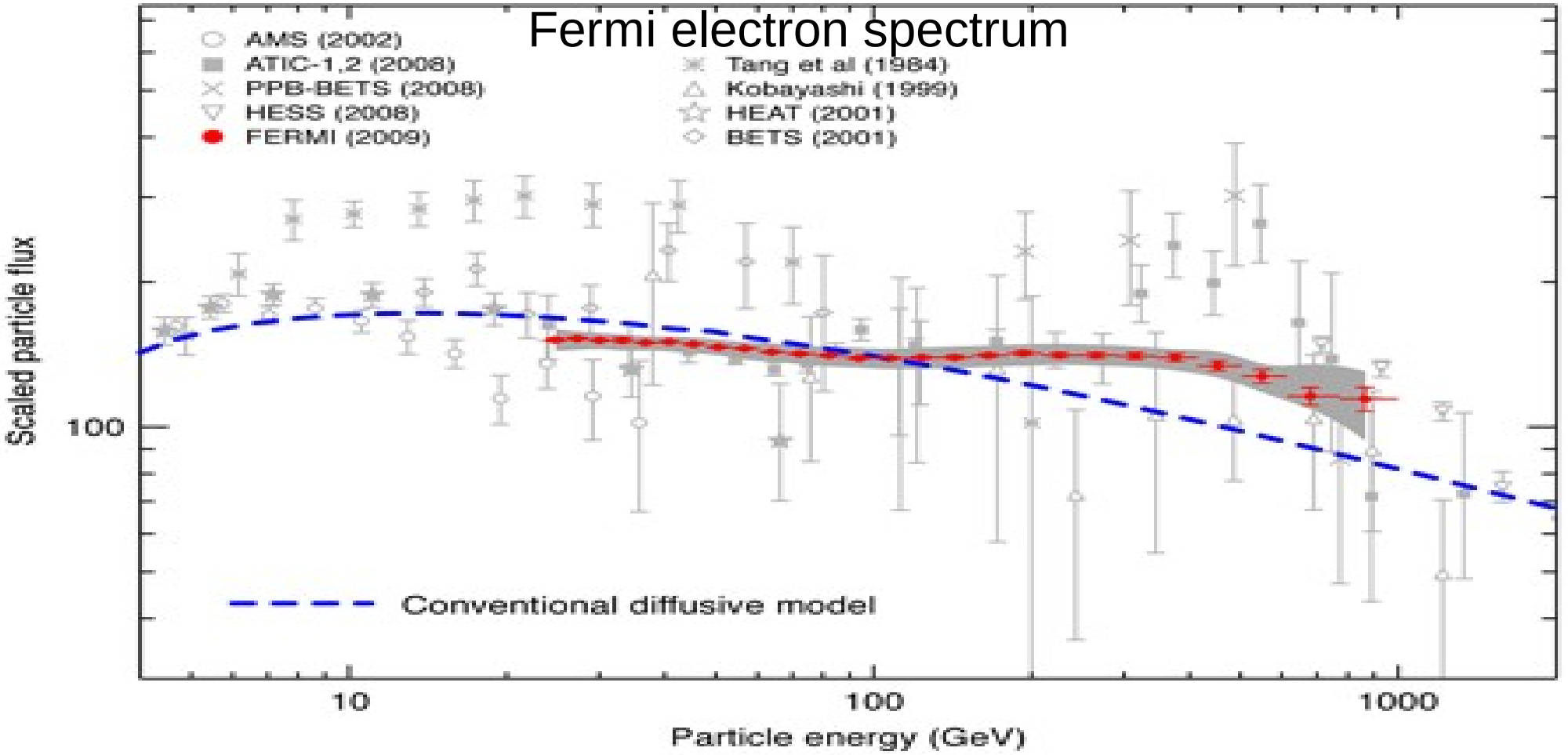


+ Accelerator measurements (LHC)

+ Indirect earth measurements (DAMA, ...)

# Context

- Further possible hints:

  → "WMAP haze, (2004)" (Hard component in CMB, maybe connected to synchrotron emission of electrons produced by DM ?)

  → "Fermi haze, (2010)"
  (IC counterpart of synchrotron WMAP haze ?)

  → PAMELA positron fraction

- But: All individual signals can also be explained by special non-DM models

- Some signals go away with time:

  → EGRET MeV excess (not seen by Fermi)

  → Attic peak (not seen by H.E.S.S.)

# Summary

- 
  - → Search for DM signal in photon channel from GC region
  - → Status: Took data in July, analysis in progress ...

- If all goes well:
  - → 2013 limits on DM that start to constrain MSSM parameter space

- Outlook:
  - → Same analysis with CTA/AGIS (~2018?) will cover large parts of MSSM parameters space

- Solution for DM problem will only be possible by performing many independent measurements and combining the informations ...