Detection of Galactic Dark Matter by GLAST

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Introduction

- Dark Matter is introduced to resolve a conflict between observed (luminous) matter in the galaxy and that inferred from dynamical considerations

- One possible form of dark matter could be WIMPs (weakly interacting massive particles)

- There could be a way for WIMP to annihilate directly to photons through intermediate one-loop process; it would result in high energy (> 30 GeV) monochromatic gamma lines

- Gamma-line of such high energy cannot be misinterpreted. Since justified, it will be a solid signature of heavy particle annihilation.
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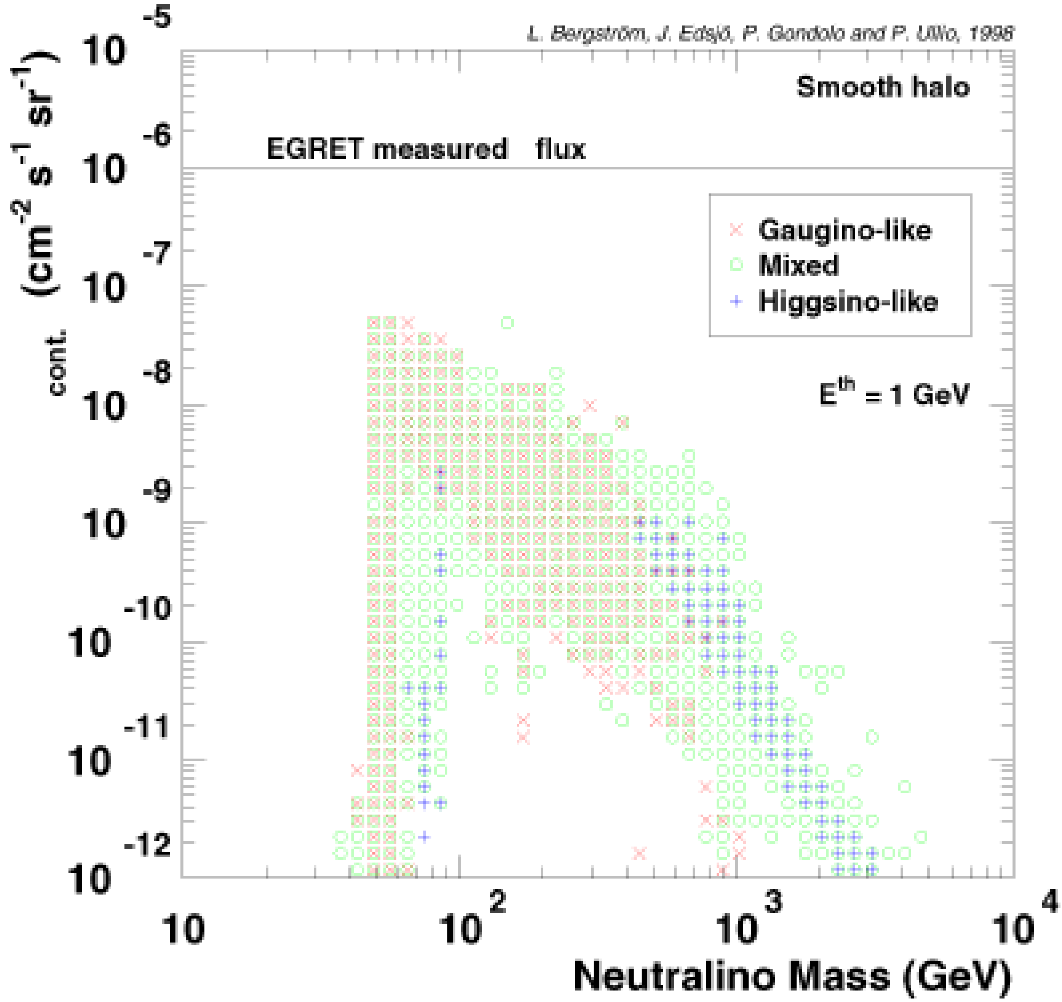
- Highest intensity of "dark matter" gamma-lines are predicted from the Galactic Center assuming clumpy dark matter distribution

Bergström et al. prediction for the continuum γ-flux



Conditions of the experiment

- **Gamma-lines should be seen above a continuum of galactic gamma rays**

  - large geometry factor / sensitive area of detector to collect enough events

  - high energy resolution

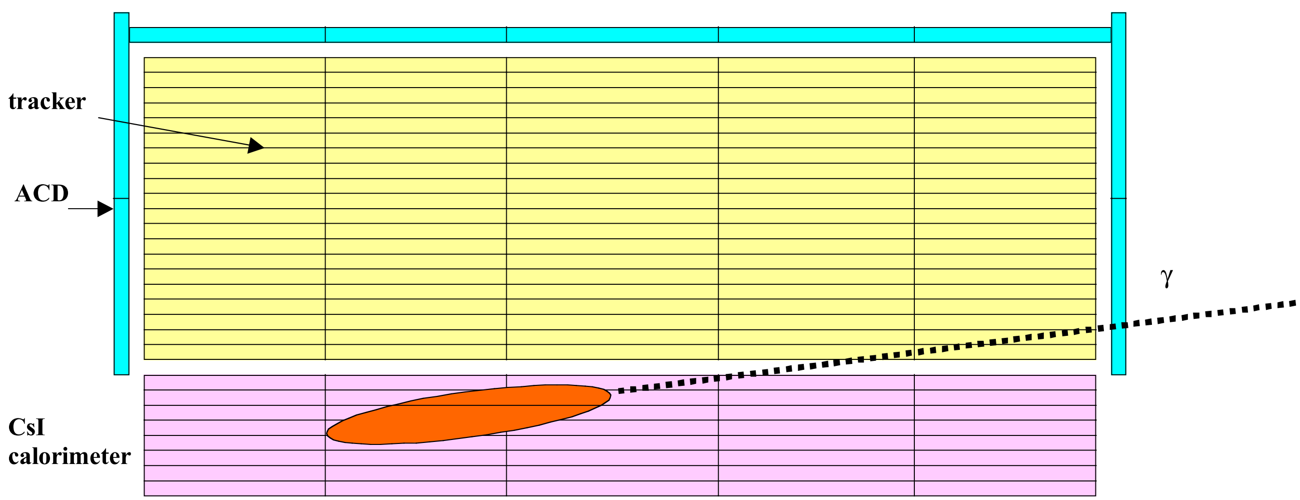
  - long observation time

  are the critical factors of the instrument / experiment to be optimized

- **Residual contamination from cosmic rays, misidentified in the detector, should be negligible - powerful photon/charge particles separation is required**

Silicon GLAST instrument

- GLAST is a gamma-ray mission scheduled for launch in 2005
- Consists of 18-layer silicon-strip tracker, 10 X_0 CsI calorimeter and anticoincidence detector
- The energy resolution is ~ 15% at 30 GeV
- Time of operation more than 5 years



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Idea - use of off-axis events with longer paths in the calorimeter (> 20 X_0) to reach 1-2% of energy resolution

Cosmic Ray background rejection

Requirements:

- **Cosmic ray protons and helium**

  - their sum differential flux is up to 5 orders of magnitude higher than the high latitude diffuse gamma radiation at 30 GeV

- **cosmic ray electrons**

  ~1000 times more abundant

- we need 3×10^6 against protons and 3×10^4 against electrons to have cleanest measurements

Rejection:

- calorimeter provides at least 10^3 rejection against protons and helium; ACD should recognize remaining 3×10^3
- calorimeter does not help much against electrons because their showers are identical to showers from gammas; ACD rejects 3000; remaining factor of 10 should come from the tracker

Specifics of the off-angle events:

- off-angle events have longer paths in a calorimeter, but fewer (or none) hits in the tracker. Only events passed at least two tracker planes are accepted for the analysis

- first we reconstruct the trajectory using imaging capability of the calorimeter, with the precision of 2-3 degrees

- further we reject events if there is at least one hit in the tracker along the reconstructed trajectory or a hit in the ACD tile crossed by this trajectory

- preliminary Monte Carlo results show that the calorimeter alone provides a good pointing of electron showers to the ACD; such good as none of ~500 reconstructed trajectories pointed far than 5cm from the entry point to the ACD. This is an additional information for choosing the segmentation of ACD

Backsplash

- Use of ACD creates a problem of backsplash which mainly is a soft radiation from the shower in a calorimeter.
- Backsplash can create a veto-signal in ACD, dramatically reducing efficiency to photons.
- Efficiency of EGRET degraded by 50% at 10 GeV already
- Segmented ACD is a way to minimize this effect.
- Beam test at SLAC and Monte Carlo simulations demonstrate that segmentation of ~1000 cm^2 at the top of GLAST is sufficient to maintain >90% efficiency up to 300 GeV
- For off-axis events the ACD is closer to the "source" of backsplash; finer segmentation on the sides of ACD is required

Capability of GLAST to detect gamma lines

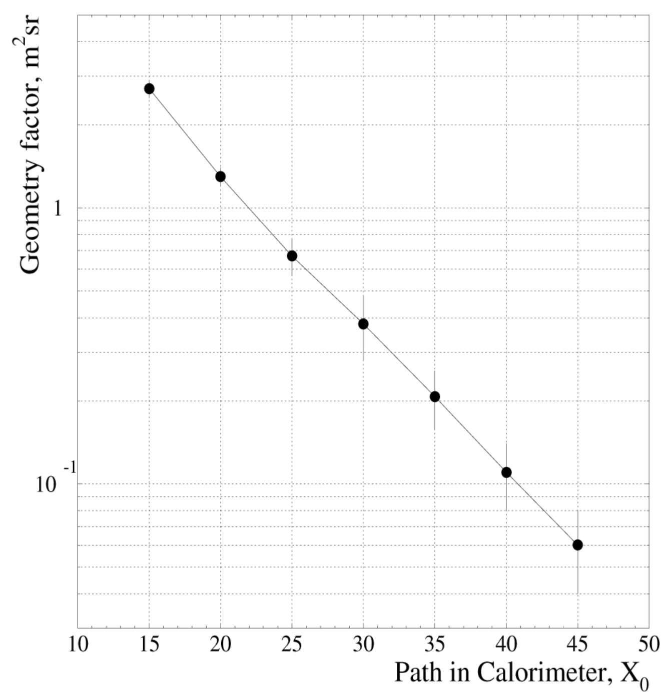
- Energy resolution for 50-300 GeV photons approaches 1-2% for path lengths in CsI more than 20 X_0.
- Effective area of GLAST calorimeter for such trajectories is 2×10^4 cm^2, geometry factor for isotropic flux is 1.3 m^2 (accounting for the Earth obscuration)
- Monte Carlo simulation (Glastsim event generator)

  - set of selections was developed to achieve the best energy resolution while maximizing the fraction of retained photons

  - minimization of the required path length was critical

  - 1-2% energy resolution was achieved, retaining ~50% of all events which have a path length in a calorimeter longer than 20 X_0

  - gain variation from crystal (CsI) to crystal was assumed to be <1% including flight calibration on heavy nuclei



Sensitivity of GLAST

GLAST sensitivity for the "dark matter point source"

$$I_\gamma = \frac{n_\sigma}{0.68\sqrt{A\, f_t T}} \sqrt{2\eta E_\gamma \left(F_{GC} + F_b \Delta\Omega\right)}$$

and for the high latitude model

$$I_\gamma = \frac{n_\sigma}{0.68} \sqrt{\frac{2\, F_b \eta\, E_\gamma}{A \Omega\, T}}$$

where I_γ and E_γ are the intensity and the energy of the line, n_σ is the significance (in σ), F_b is the background flux, F_{GC} is the differential gamma-radiation from the Galactic Center, A◇ is the instrument geometrical factor, A is the sensitive area, η is the relative energy resolution (half width containing 68% of events), T is the observation time, $2\eta E_\gamma$ is the binning width, $\Delta\Omega=10^{-3}$ sr is the point-spread function for the calorimeter, and f_t (0.25) is the fraction of time during which the Galactic Center lies in a direction that provides a path length in a calorimeter of more than 20 X_0 .

Summary

Flux to be measured by GLAST on the level of 3σ:

Energy of the line I_γ	High Latitude Model Source $[cm^2\ s\ sr]^{-1}$	Galactic Center Model Source $[cm^2\ s]^{-1}$
50 GeV	1.8×10^{-10}	1.2×10^{-10}
100 GeV	1.2×10^{-10}	8×10^{-11}
500 GeV	5×10^{-11}	3×10^{-11}

Assumed parameters:

- Energy resolution 2%
- Effective geometry factor 0.5 m^2 (reduced for the event selection efficiency)
- Effective sensitive area 6000 cm^2 (includes requirement for the >20X path length and event selection efficiency)
- Observation time 3 years
- Galactic Center radiation from Hunter et al. 1997, Mayer-Hasselwander et al. 1998
- High latitude gamma radiation from Sreekumar et al. 1998