STACEE

The Solar Tower Atmospheric Cherenkov Effect Experiment

John Kildea
McGill University, Montréal,

on behalf of the STACEE collaboration

Overview

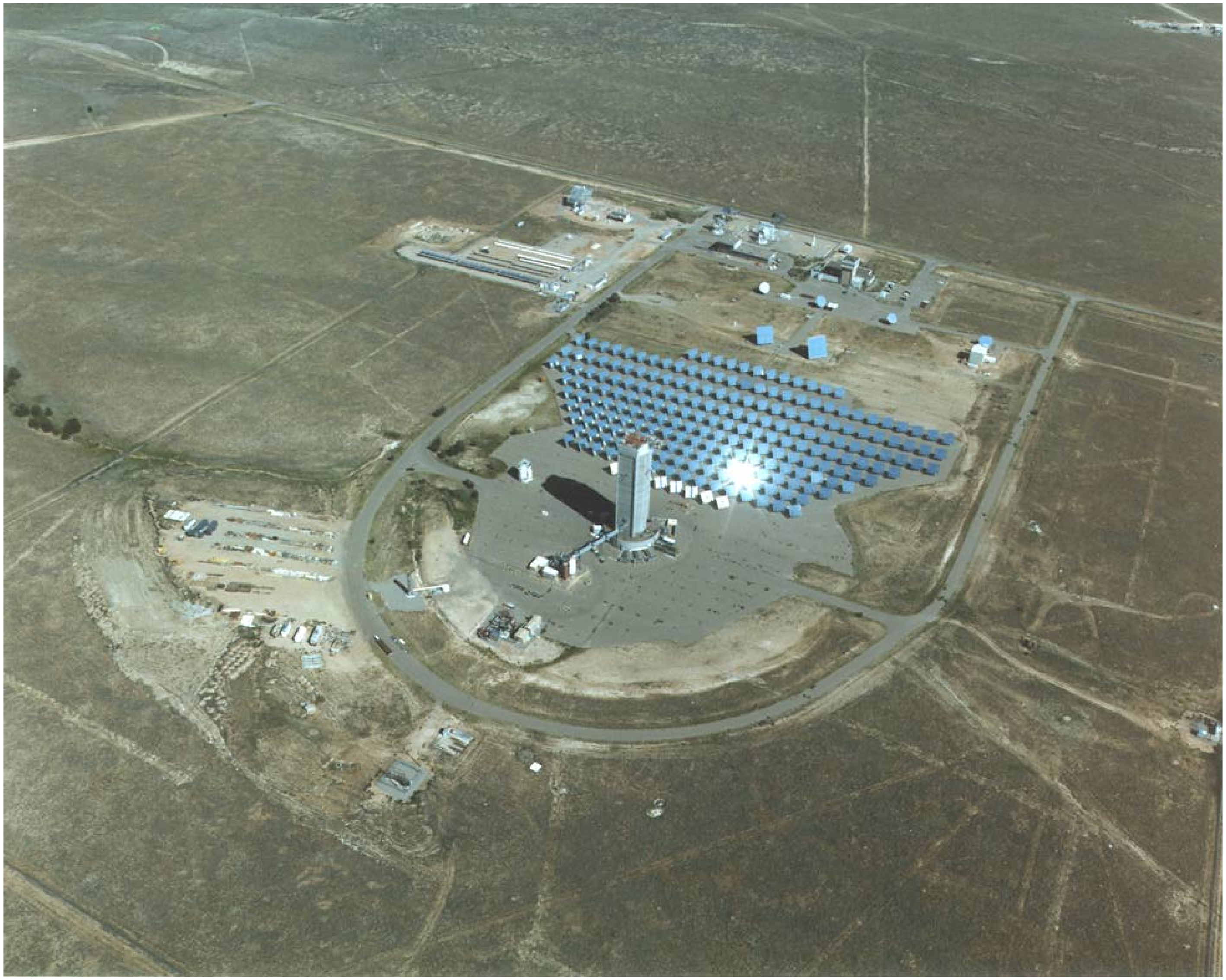
- Who, what, and where
  — all about the STACEE collaboration
- How and why
  — the solar tower γ-ray observatory concept
  — STACEE observations
- Detector and data analysis
  — a tour of STACEE
  — the nitty gritty of detecting γ-rays
- Results and Future
  — where now with STACEE

Who?

The STACEE collaboration

Case Western Reserve University
McGill University
University of California, Los Angeles
Columbia University
University of Alberta
University of California, Santa Cruz

The STACEE Experiment

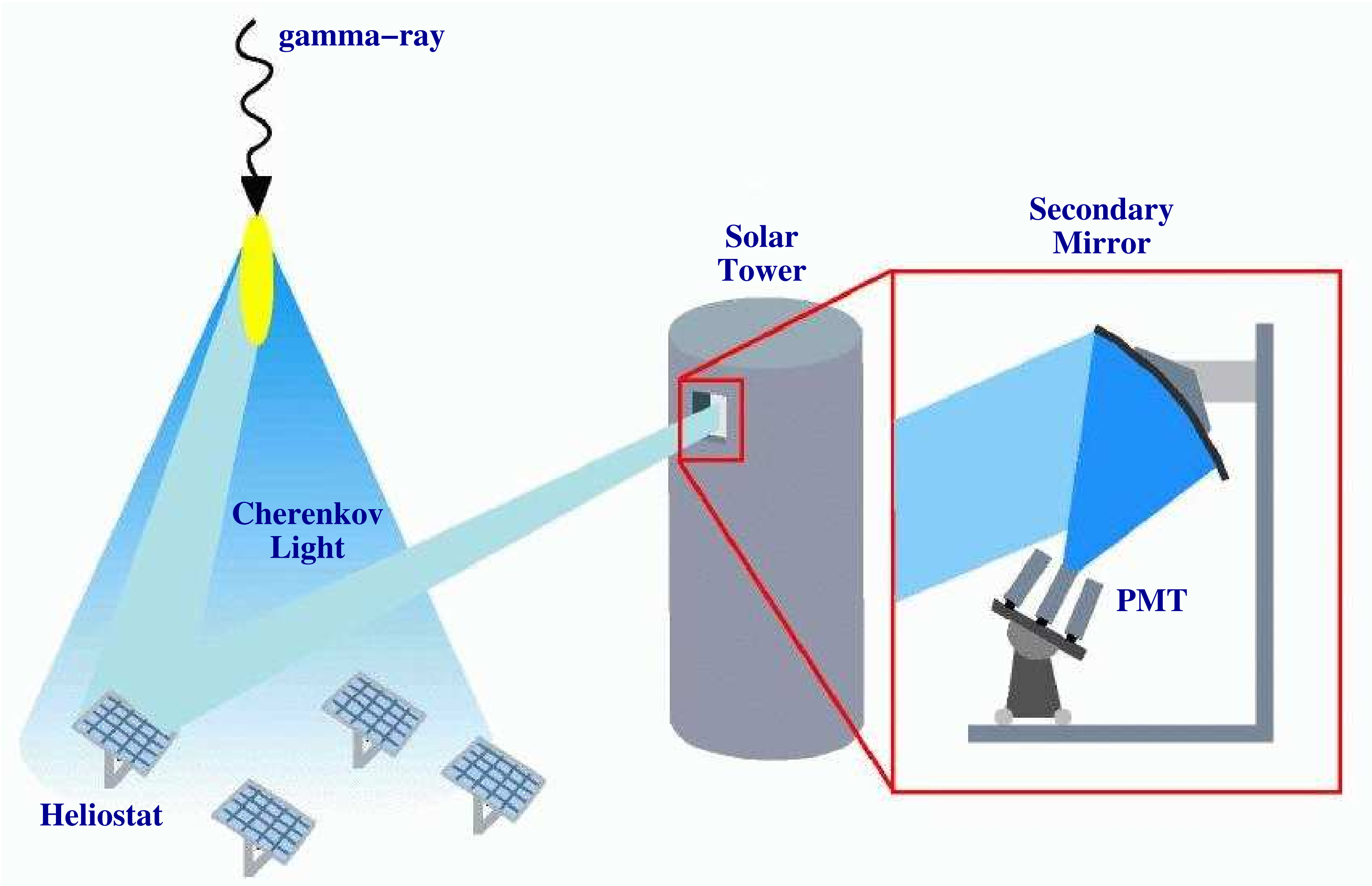


- National Solar Thermal Test Facility (NSTTF)
  — Sandia National laboratories, Albuquerque, New Mexico
  (US national facility for solar energy research)

The STACEE Experiment

- Central Receiver Test Facility (CRTF)
  — central tower (∼200 ft) and ∼200 steerable heliostat mirrors
- Purpose
  — research centre for solar thermal electric power (by day!)
  — detector for atmospheric Cherenkov flashes (by night!)

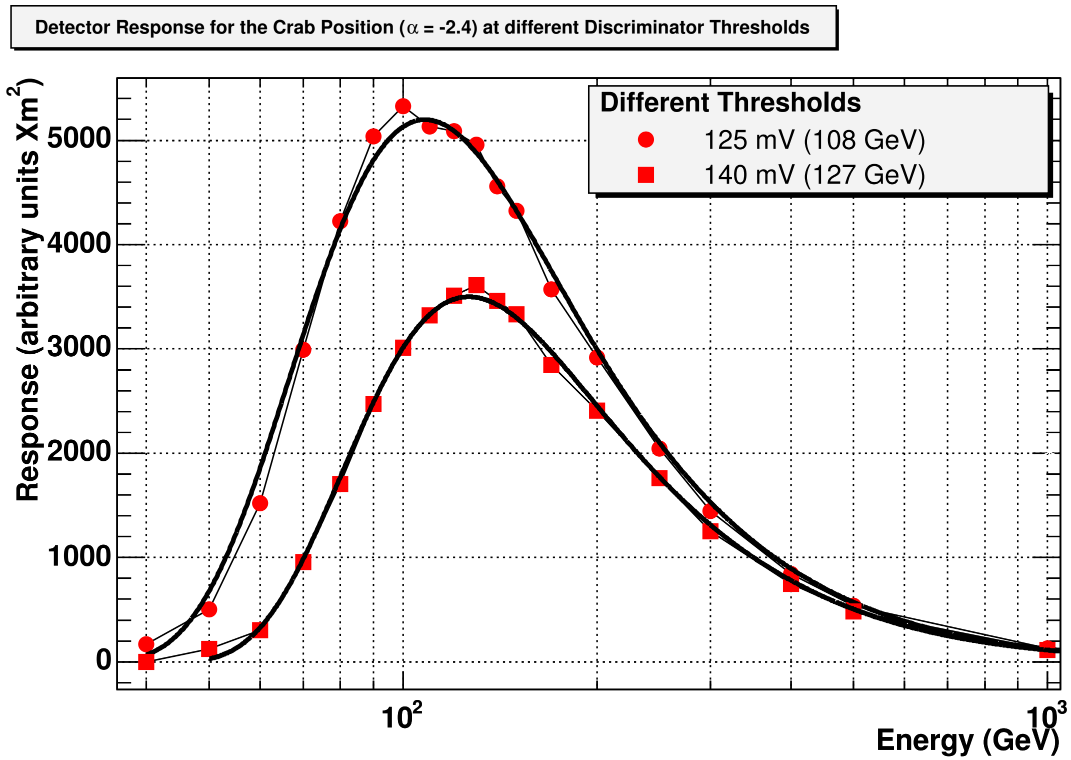
The Solar Tower Technique



- A Cherenkov light collector

  — detect γ-rays by sampling the Cherenkov wavefront

Why use a Solar Tower?



- Low energy threshold
  - $E_{threshold} \sim \frac{1}{\sqrt{Area_{mirror}}}$
  - heliostats provide mirror area
  - STACEE total mirror surface $\simeq$ 2400 m^2 ($\sim$ 100 m^2 for IACT)

Figure: P. Fortin, McGill

Where does STACEE fit in?

Space telescopes

(Below 50 GeV)

Atmospheric Cherenkov Detectors

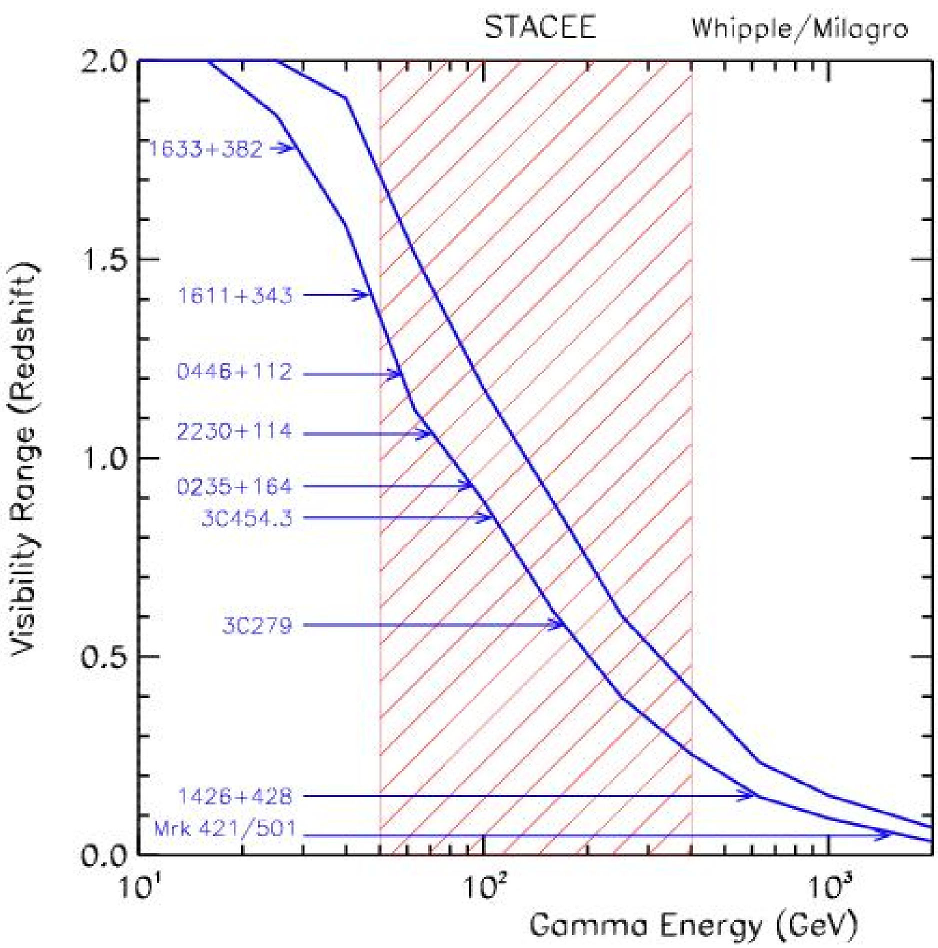
(50 GeV – 50 TeV)

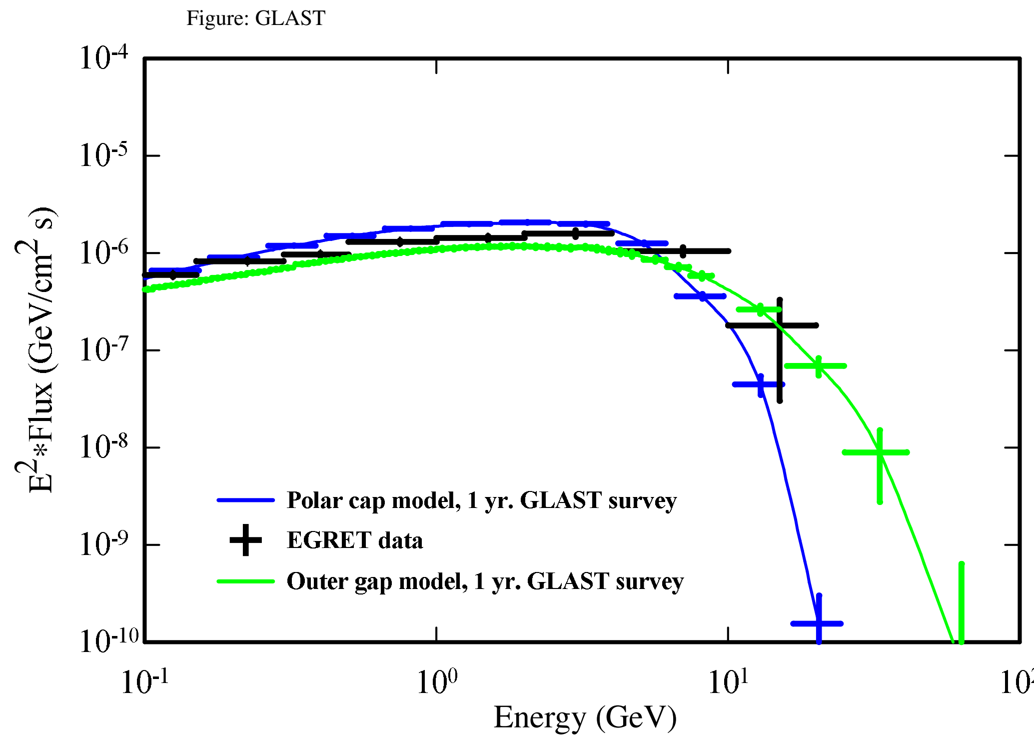
Air shower arrays

(Above 50 TeV)

- The open window (10–200 GeV)
  - — STACEE attempts to close the window between space telescopes and the IACTs
  - — GLAST and MAGIC will ultimately fill the gap

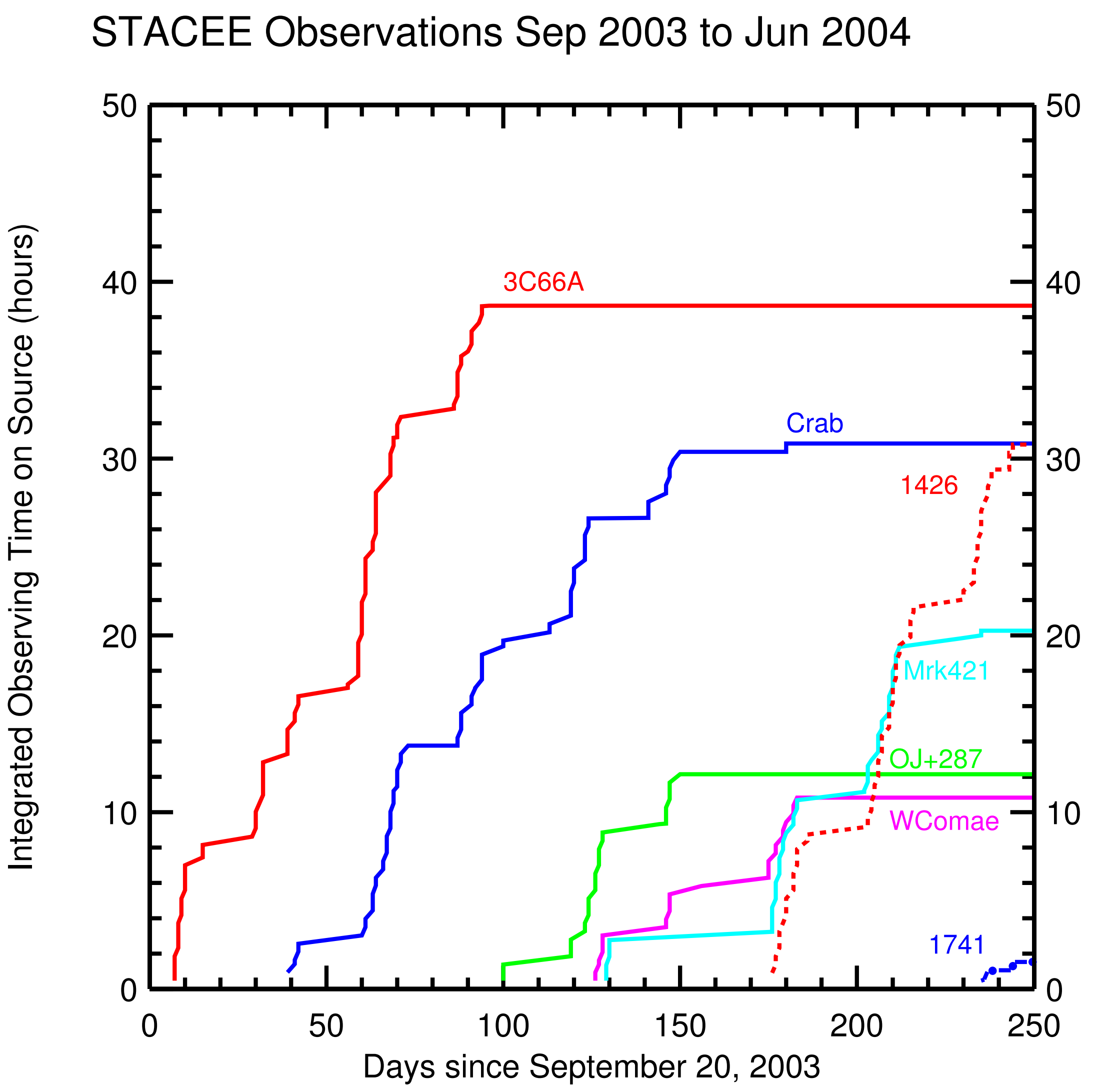
STACEE Observations





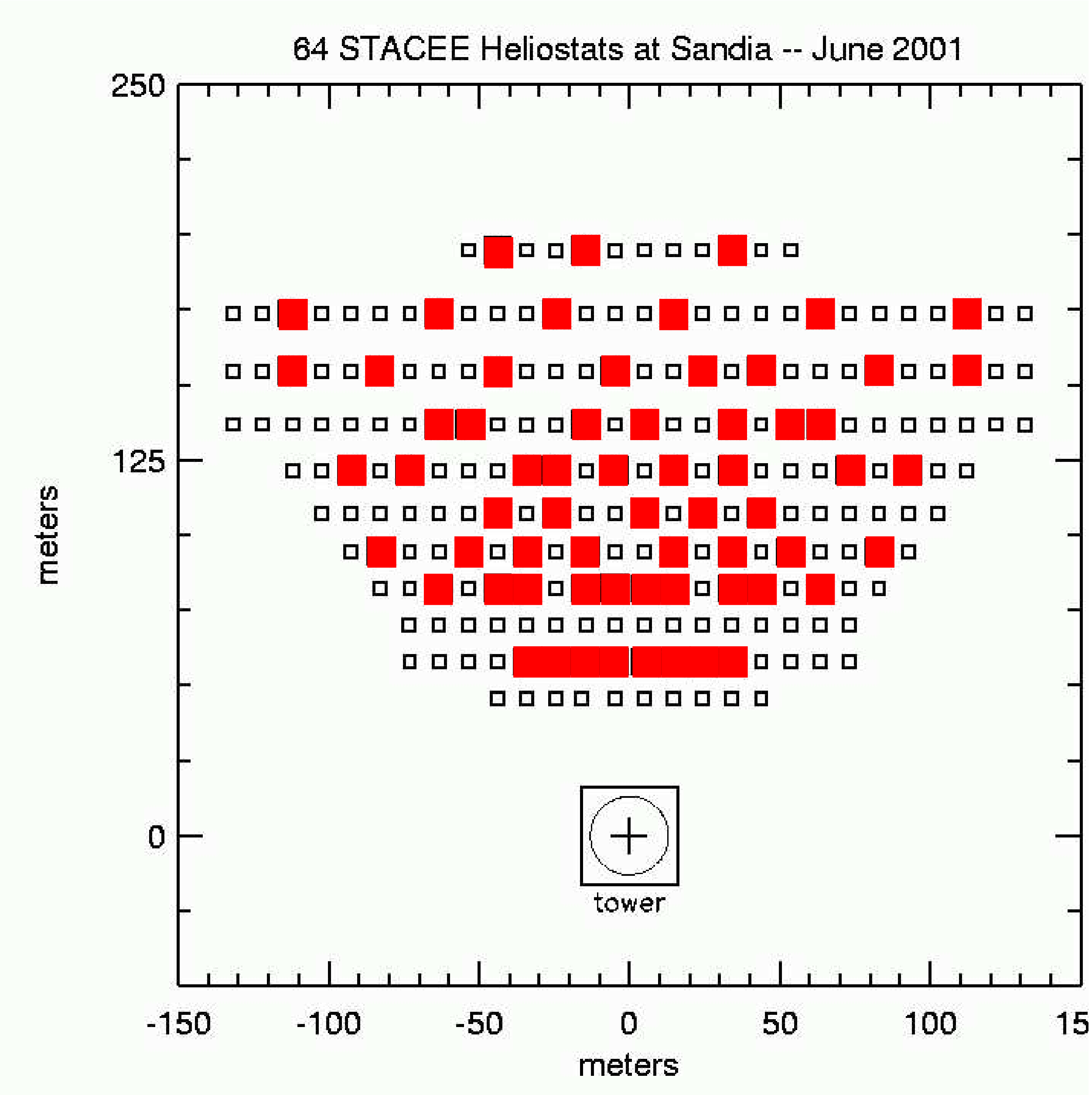
- Targets around 100 GeV
  - AGN: leptonic vs hadronic models, EBL absorption
  - Pulsars: outer gap model vs polar cap model
  - Gamma-ray bursts: high-energy component, STACEE is on GCN list, 2 GRBs observed in 2003/04, recent motor upgrade provides faster slewing – two minutes to GRB location

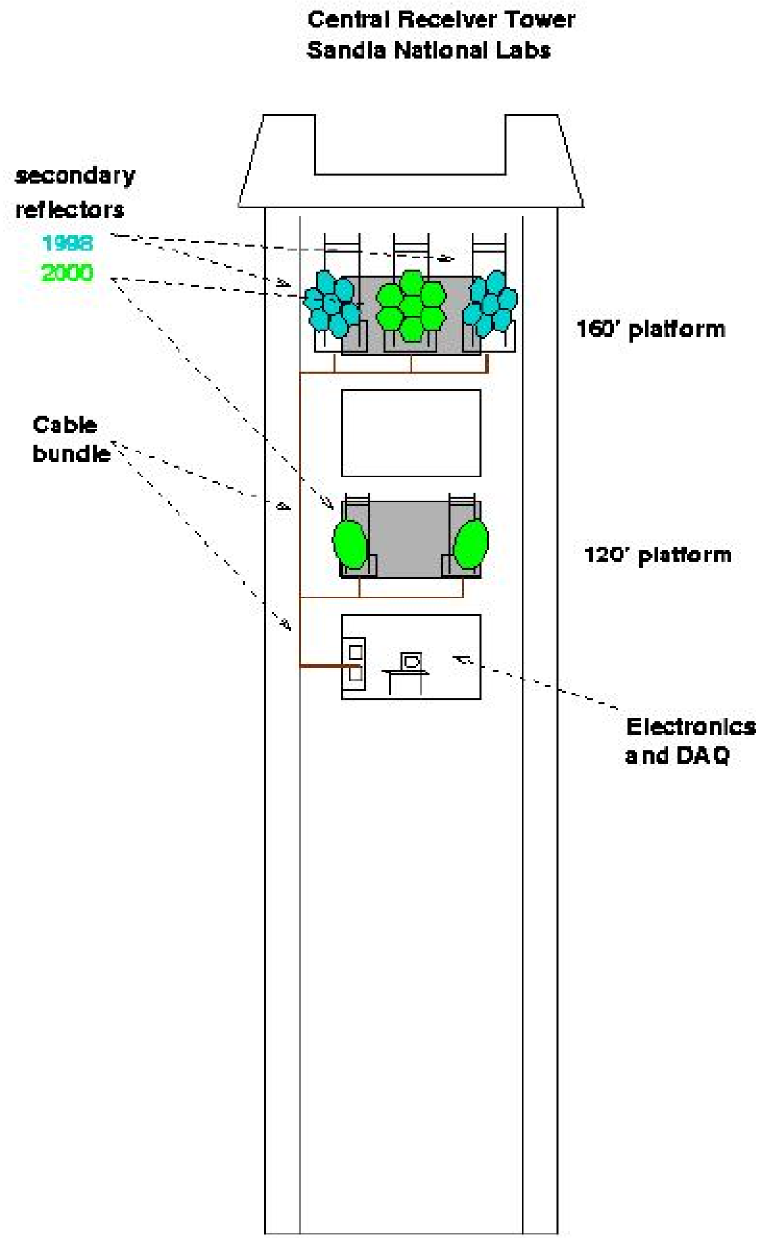
STACEE Observations



- STACEE observes in ON/OFF mode
  — typically 28 mins ON source followed by 28 mins OFF source
  — OFF-source data used for hadronic background quantification

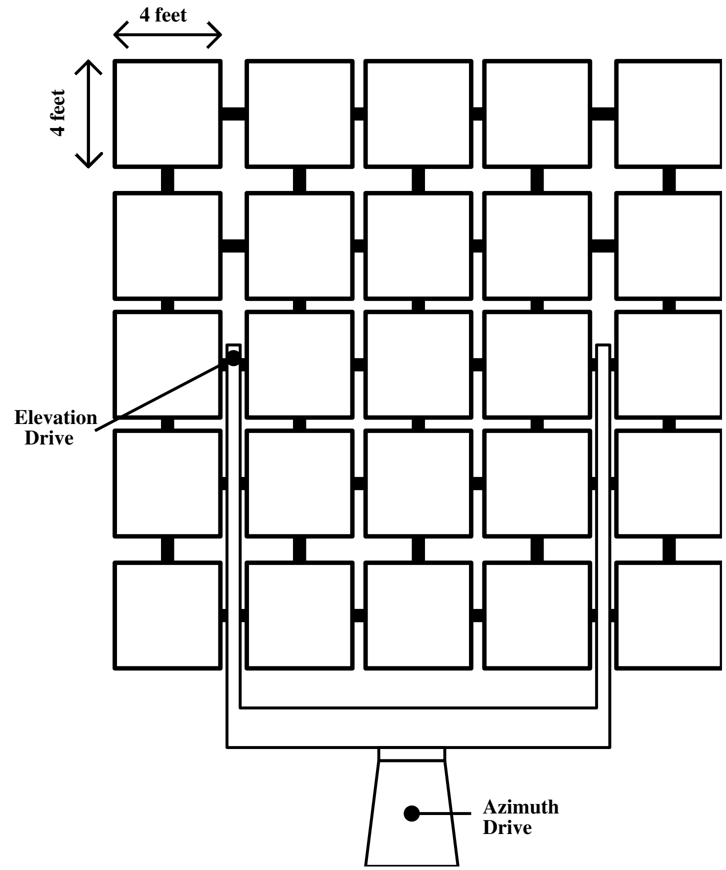
A Tour of STACEE





- 64 heliostats, 200 ft tower

STACEE Primary Optics

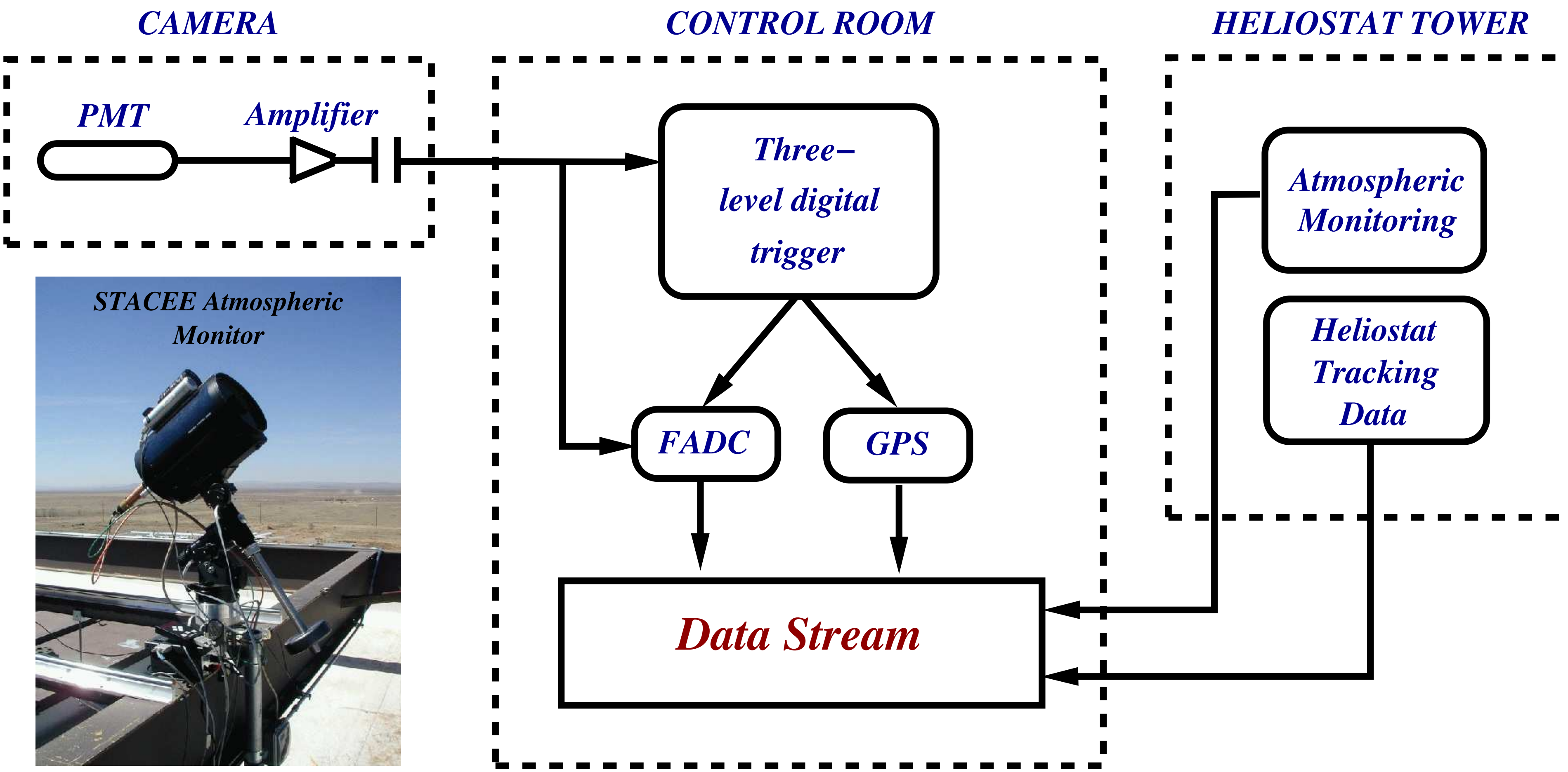


- Heliostat mirrors
  - — 37 m^2 (combined surface of 2400 m^2)
  - — back aluminized glass
  - — 25 segments, focused under tension onto central tower
  - — alt-azimuth mounts, recent motor upgrade

STACEE Secondary Optics

- Secondary optics
  - — 120-foot platform: 1-meter secondaries (2), 16 channels
  - — 160-foot platform: 2-meter secondaries (3), 48 channels
- Photomultiplier tubes
  - — each heliostat mapped onto one PMT
  - — 51 mm *Photonis* tubes

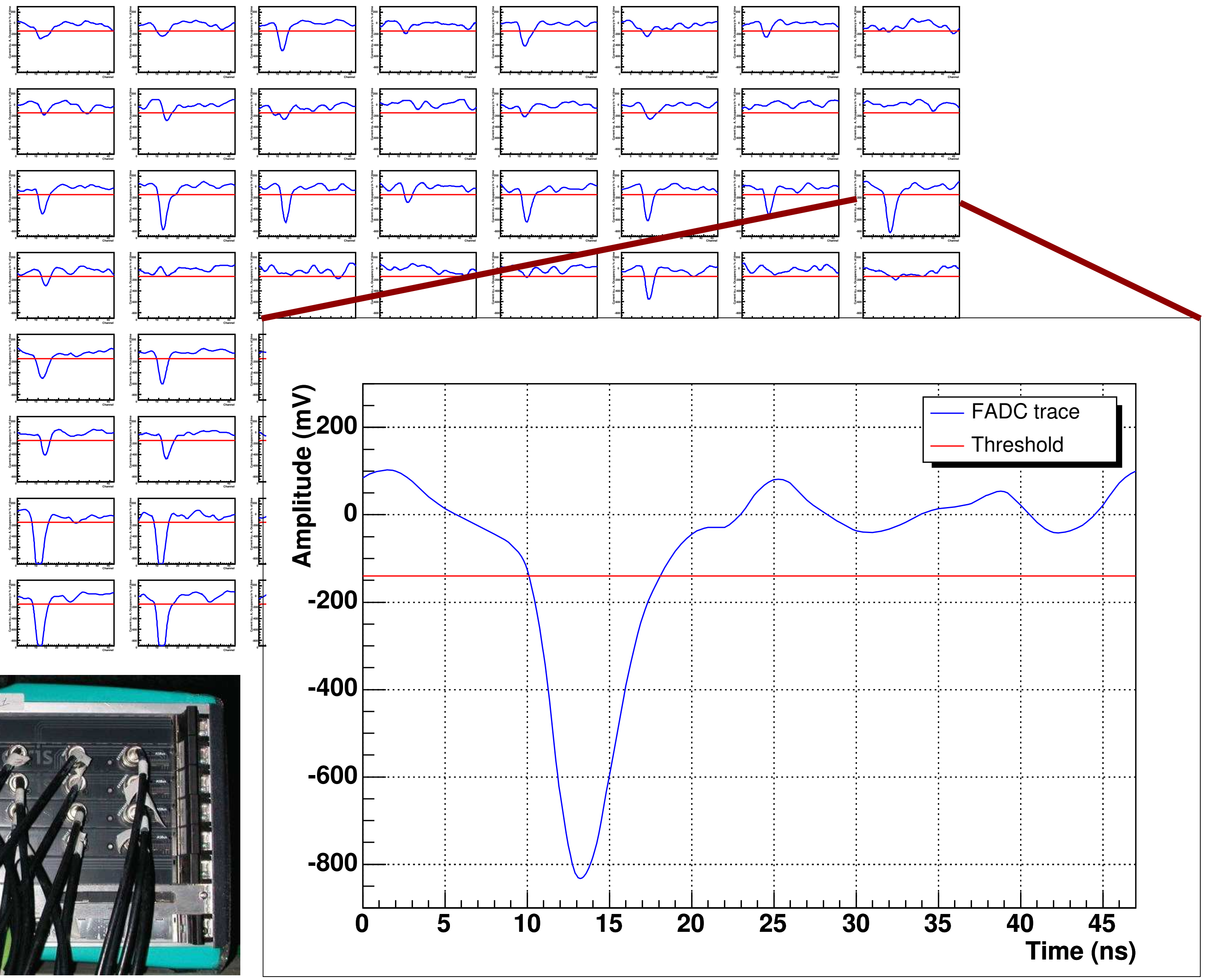
STACEE Electronics/Data Flow



— DAQ electronics in solar tower

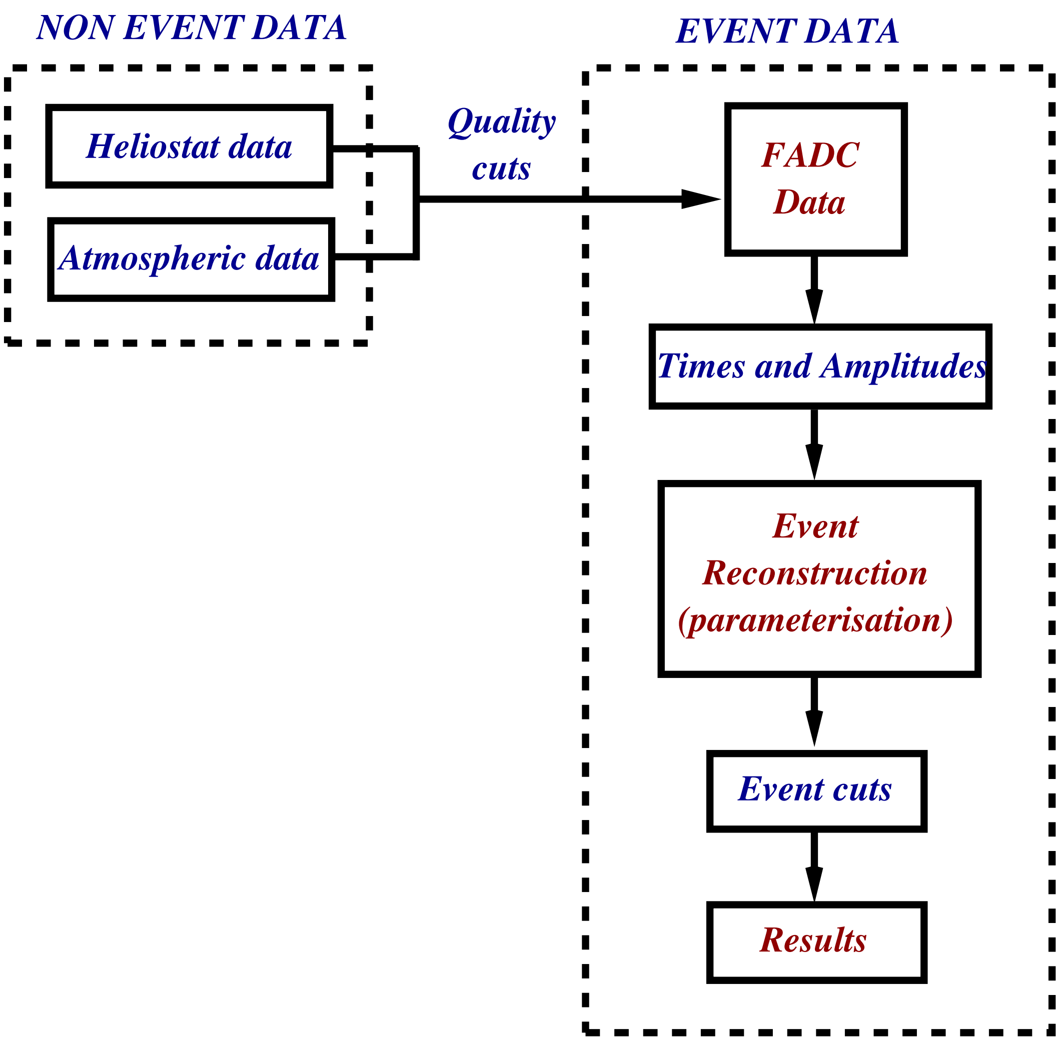
— heliostat control electronics in separate heliostat tower

STACEE FADCs



- 8 bit Flash ADCs, one per channel
  — commercial *Acqiris* boards under real-time linux
  — 1 GSample/second, 1 V dynamic range

STACEE Data Analysis



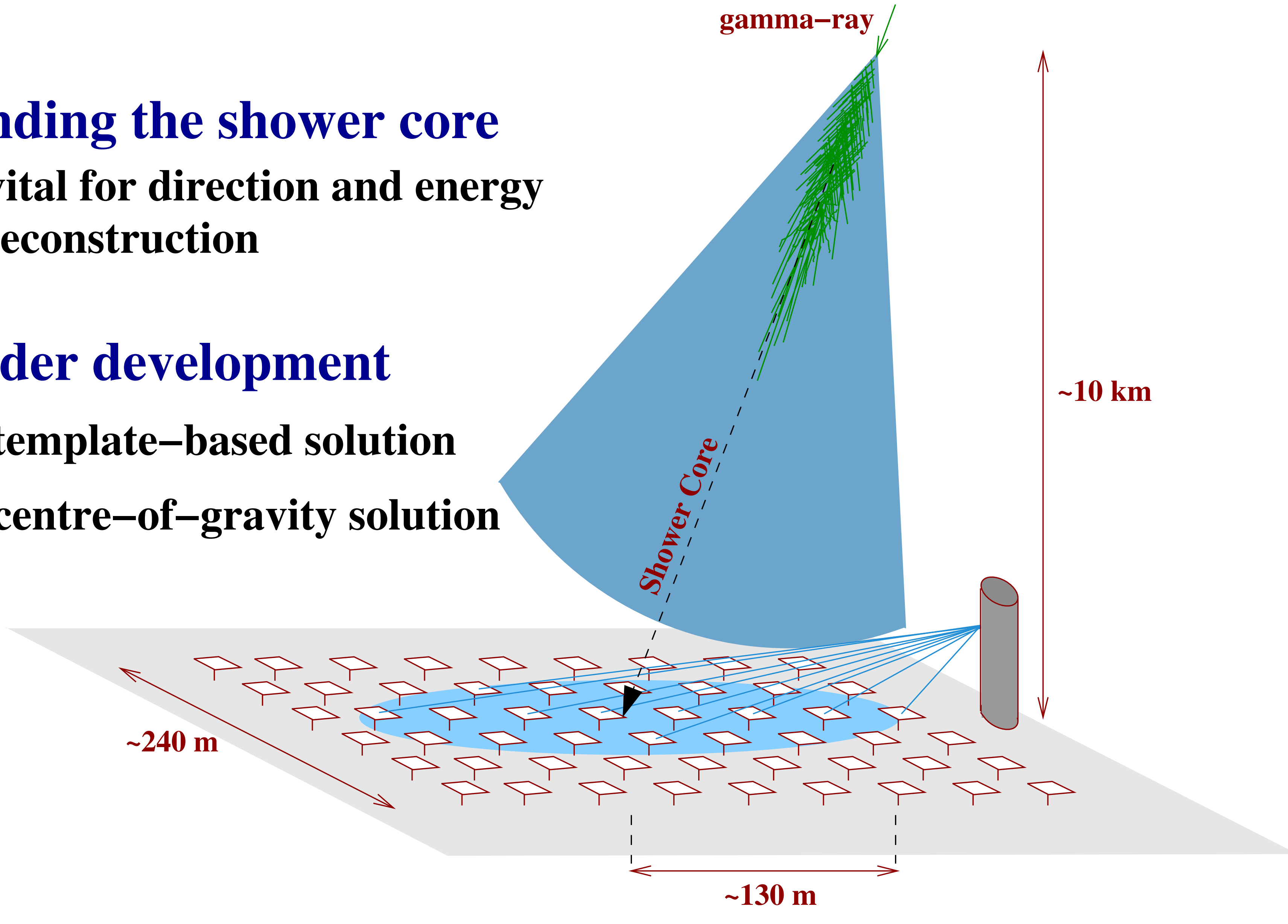
— significant advances in data analysis over the past year

— now using full power of FADCs

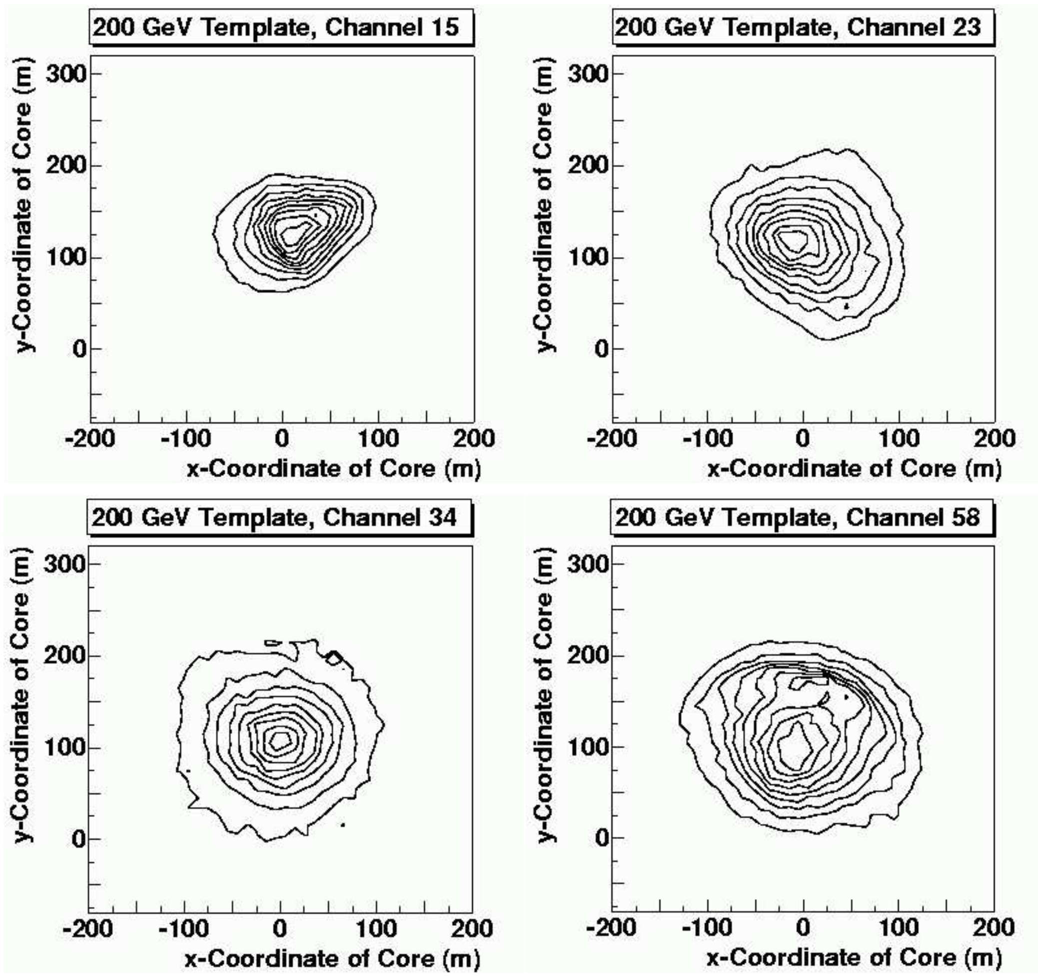
STACEE Event Reconstruction

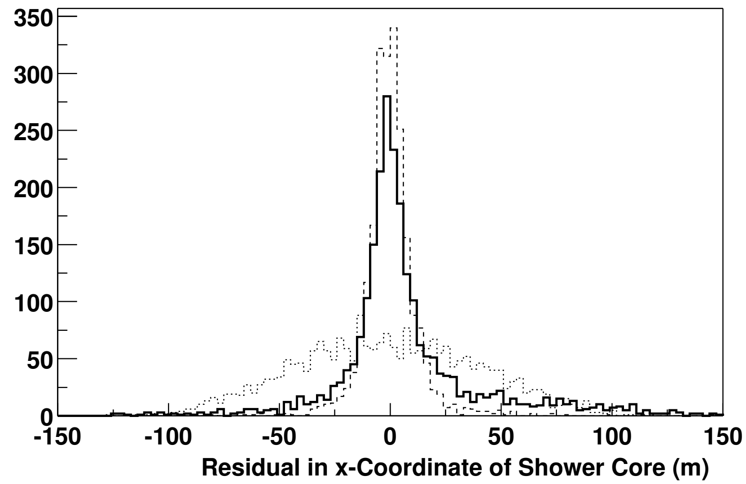
- **Finding the shower core**
  - vital for direction and energy reconstruction

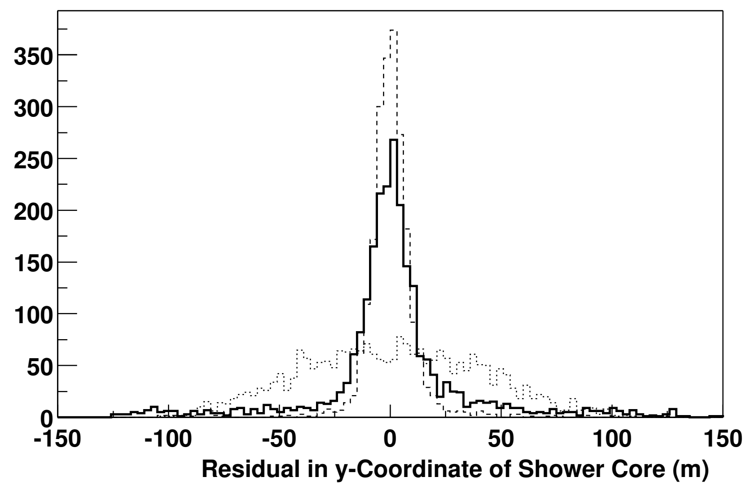
- **Under development**
  - template–based solution
  - centre–of–gravity solution



Event Reconstruction – Template Fitting



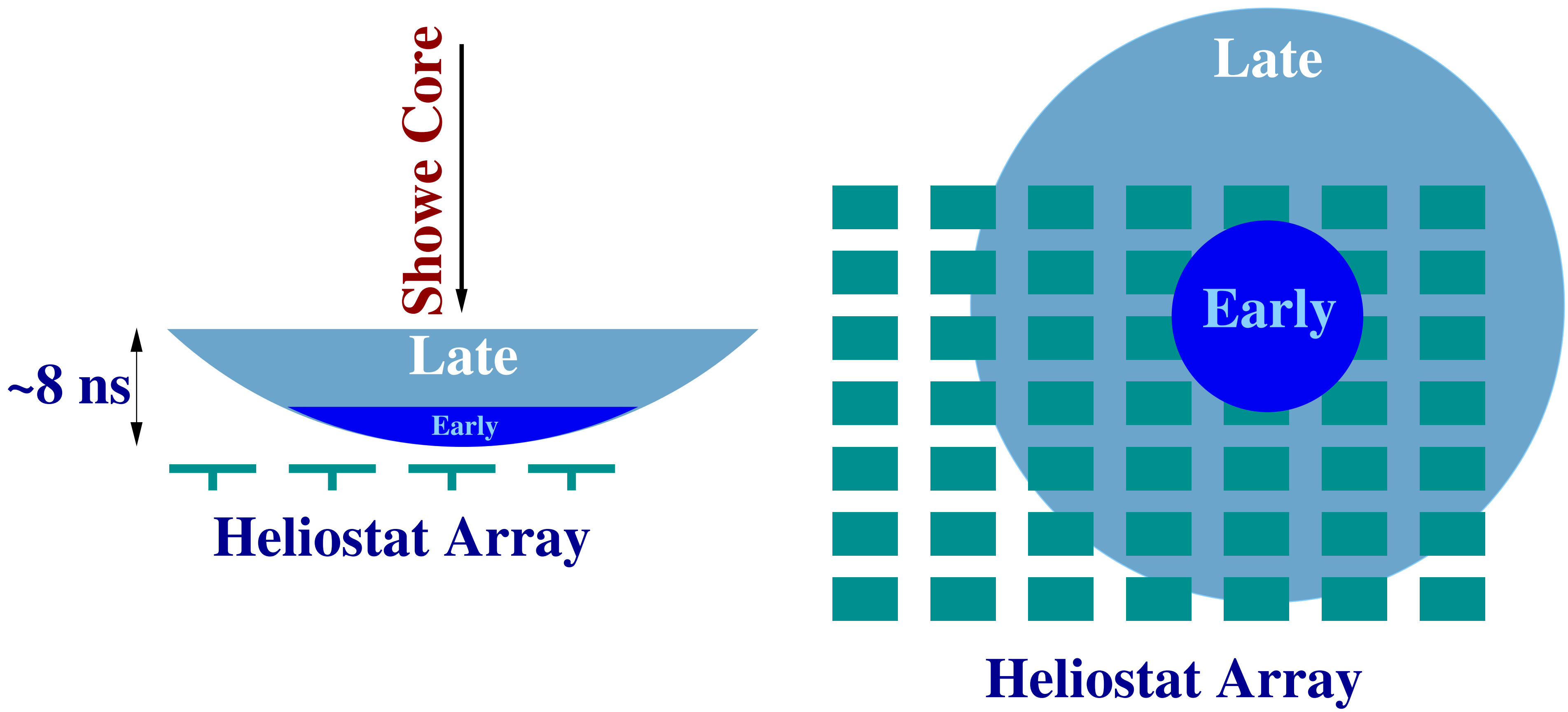




- Compare data with simulations
  - — directly compare measured FADC pulse charges with simulated templates
  - — templates compiled over wide range of energies and core locations

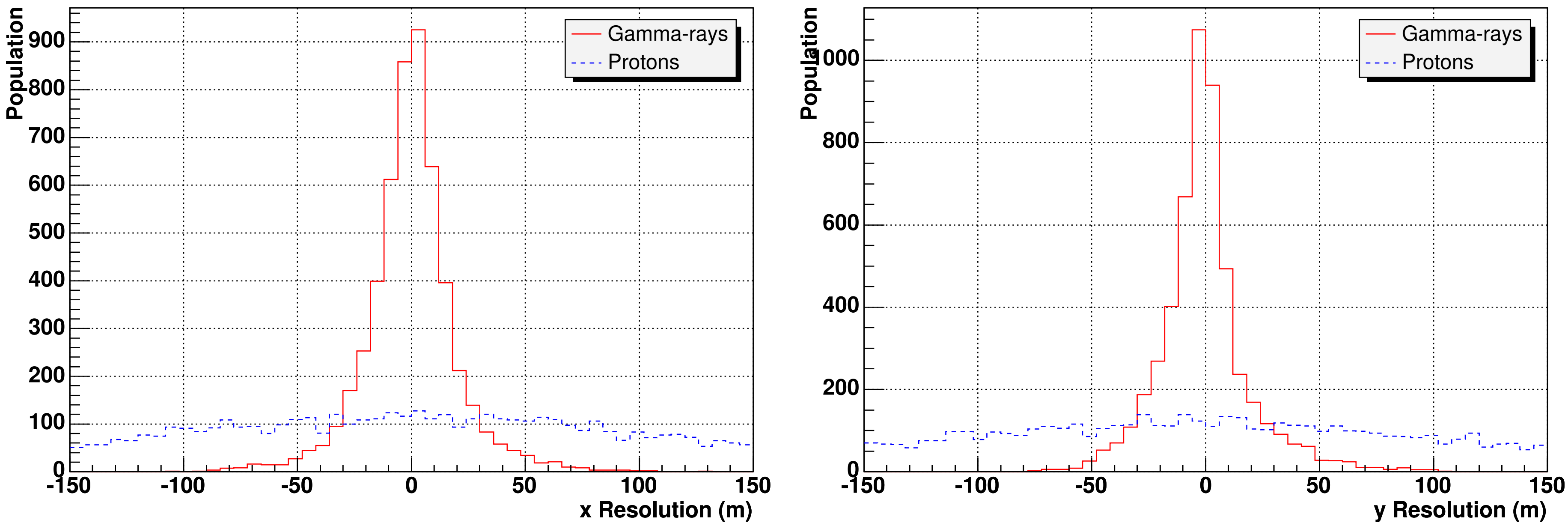
Figures from Scalzo 2004, PhD thesis

Event Reconstruction – Centre of Gravity



- Centre-of-gravity of first few nanoseconds
  - — γ-ray air showers around 100 GeV are spherical or conical
  - — examining early part of shower avoids confusion from shower truncation
  - — treat FADC data as matrix of times and amplitudes, re-apply trigger, obtain shower begin and end
  - — method not dependent on simulations

Event Reconstruction – Centre of Gravity



- Development continuing
  — early work is encouraging, study ongoing using simulations and real data

STACEE Milestones

- 2000: Crab nebula detection
  — 190 GeV, 32-channel detector (Oser et al., 2001, ApJ, 547:949)
  — Crab pulsar upper limit–constraint on outer gap model
- 2001: Detection of Mrk 421 flares
  — (Boone et al., 2002, ApJ, 579:L5)
- 2002: STACEE-64 commissioned
  — 64 heliostats, 64 FADCs
- 2003: WComae (ON+231) upper limits
  — Scalzo et al., ApJ, 607:778-787 (2004)
  — an EGRET blazar, hard (α = 1.73) spectrum (undetected by IACTs)
  — 10.5 hours of ON-source data
  — flux upper limits above 100 GeV for leptonic models,
  above 150 GeV for hadronic models (lowest yet for WComae)
  — strongly constrain EGRET power law extrapolation
  — upper limit below SPB 2 hadronic model prediction

SPB model: Mücke & Protheroe 2000; Aharonian 2000; Mücke et al., 2003

WComae Upper Limits

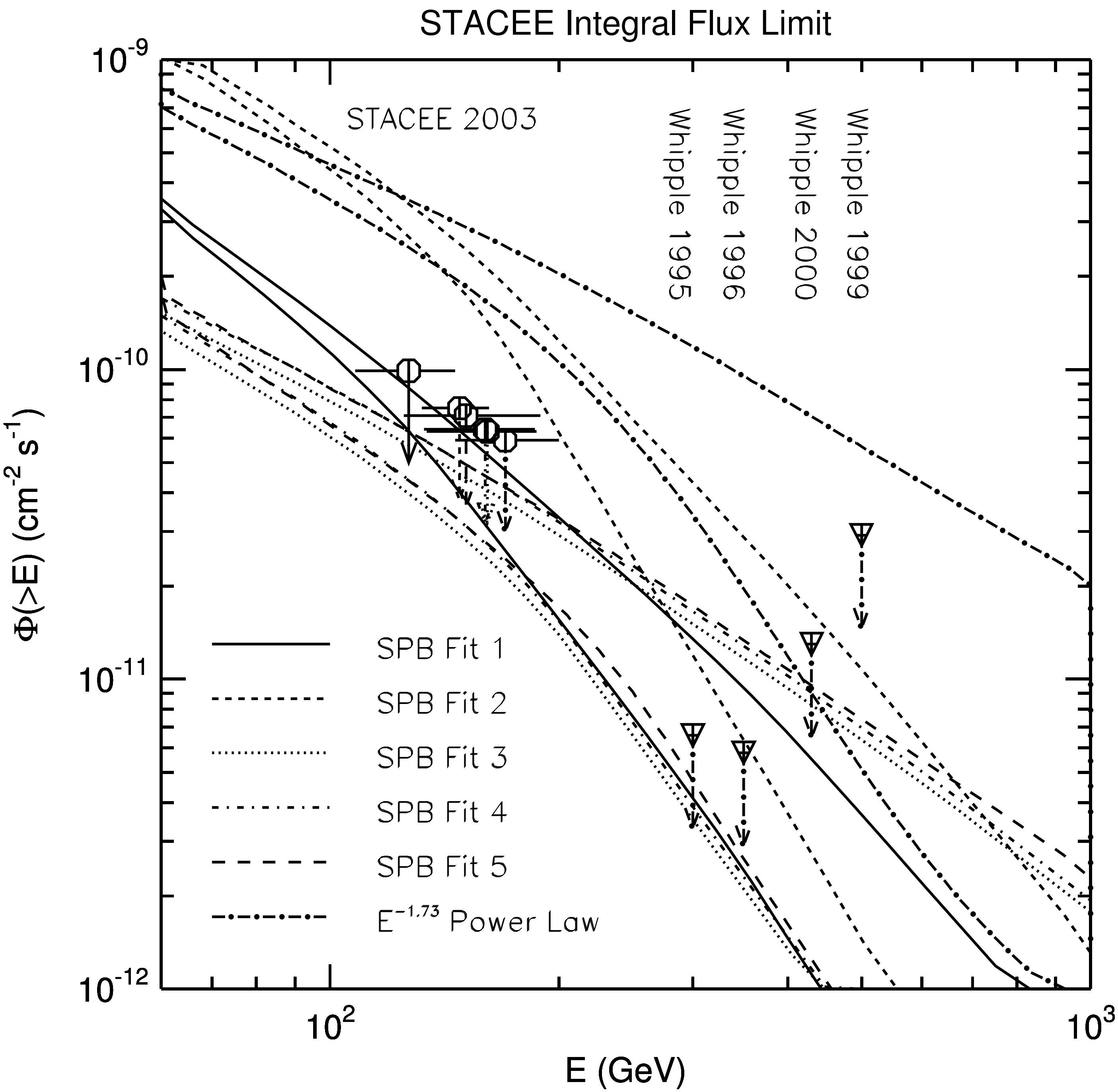
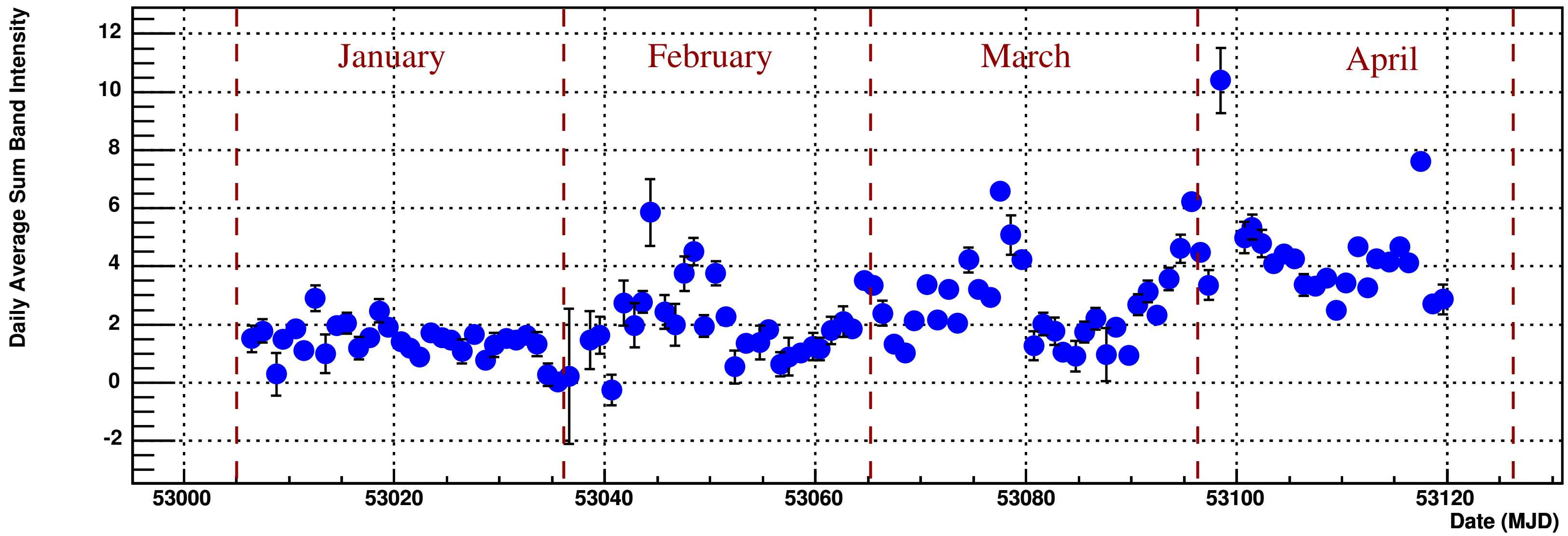


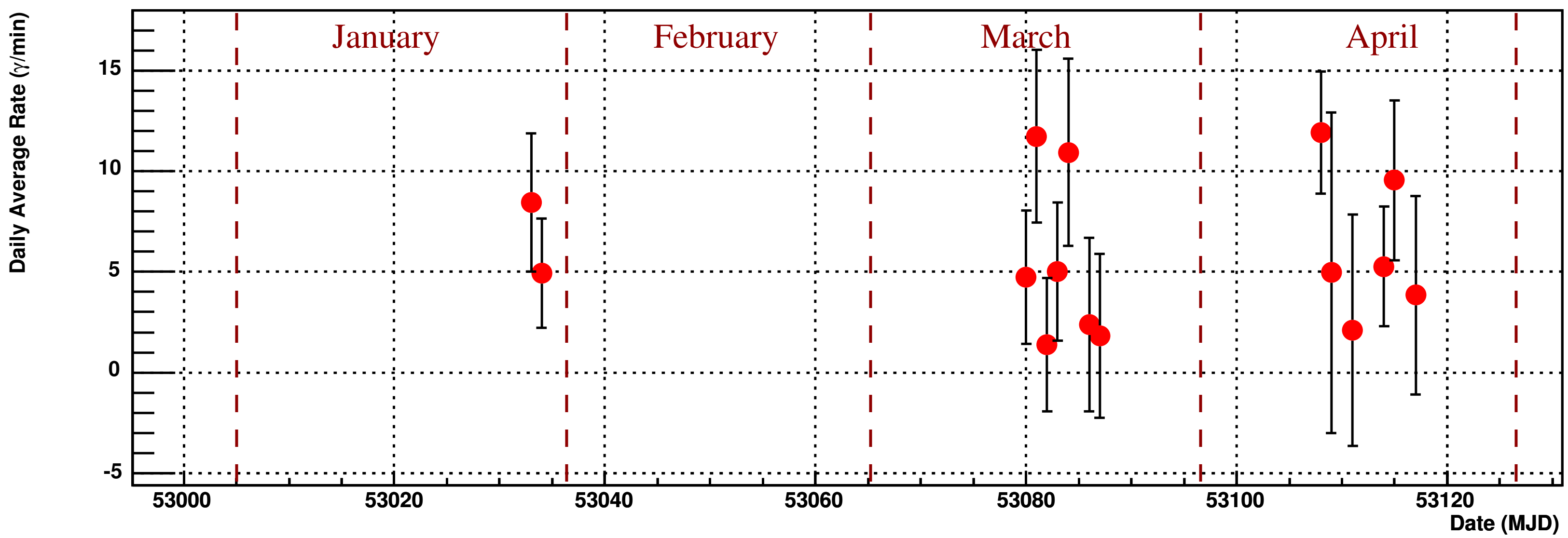
Figure: Scalzo et al. 2004

Markarian 421 – Preliminary Results

RXTE ASM Lightcurve



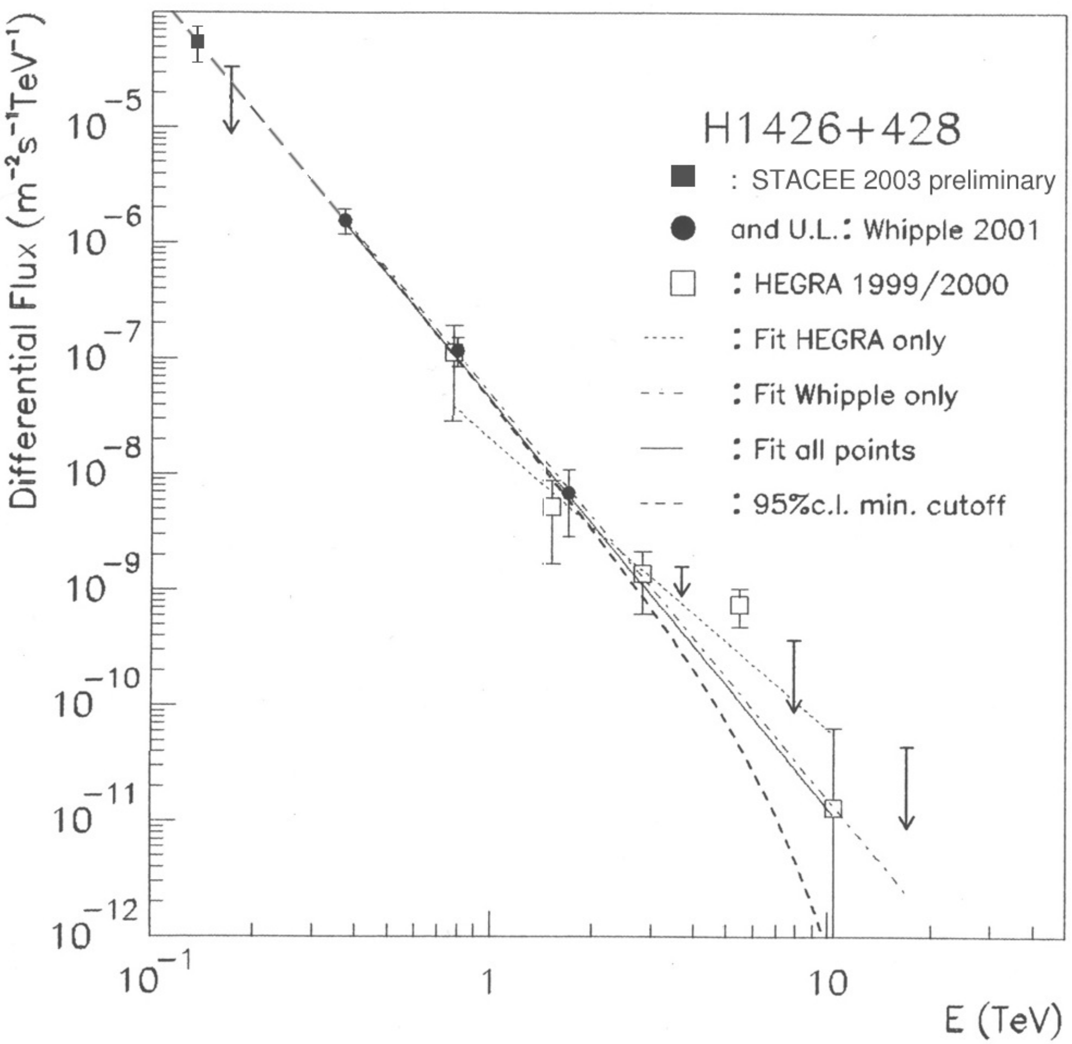
STACEE Lightcurve



— high state according to RXTE ASM during spring 2004

— 7.9 hours on source, combined significance of 5.9σ

H 1426+428 – Preliminary Results



— 7.5 hours ON-source data (after quality cuts) during 2003

— excess of 2.9 sigma, currently adding to dataset

Figure: Petry et al., 2002

Status/Future of STACEE

- Experiment status
  - STACEE fully operational, stable, and taking data
- Analysis status
  - continued improvements in data analysis methods, particularly advanced event reconstruction using FADCs and padding analysis (ON/OFF brightness equalisation)
  - advanced reconstruction to be applied in analysis of recent and future data with an improvement in sensitivity expected
  - Spectral analyses under development
- Observations
  - STACEE will continue to take data on known and potential γ-ray until mid-2006