
Fermi Gamma-ray Space Telescope

# Analysis Coordinators' Report
# April 2012, IFC Telecom

**Eric Charles & Luca Latronico**

# Introduction & Outline

## Outline

- **Recent Science Highlights**
- **Pass 7 Status & Improvements**
- **Pass 8 Overview and Status**
- **Analysis Organization, Working Groups, Shifters**
- **Publications**

The IFC requested an updated of the Pass 8 effort

Given the time available we will focus primarily on recent science highlights and the status of Pass 7 and Pass 8

We have included slides covering collaboration analysis efforts and publications at the end of the presentation and can answer questions about them if requested

Fermi Gamma-ray Space Telescope

# RECENT SCIENCE HIGHLIGHTS

# Extreme Solar Flare of March 7, 2012

X5.4 Class Solar Flare

Solar Flux > 1000x quiet Sun

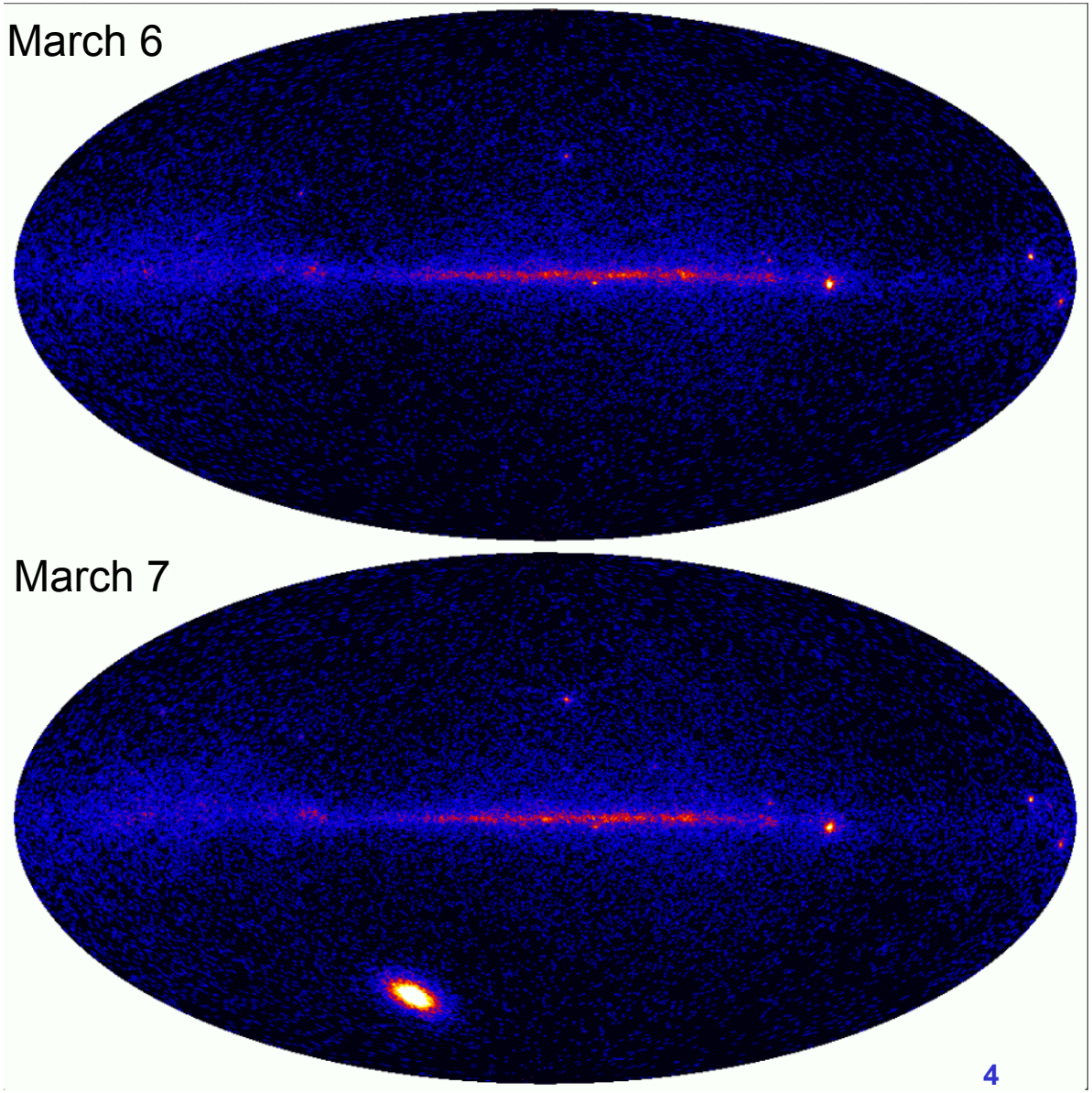
$10^4$ γ ray > 100 MeV

Bright enough to localize emission region to 2% radius of solar disk

ACD saturated for early phase of Flare (mitigated in pass 8)

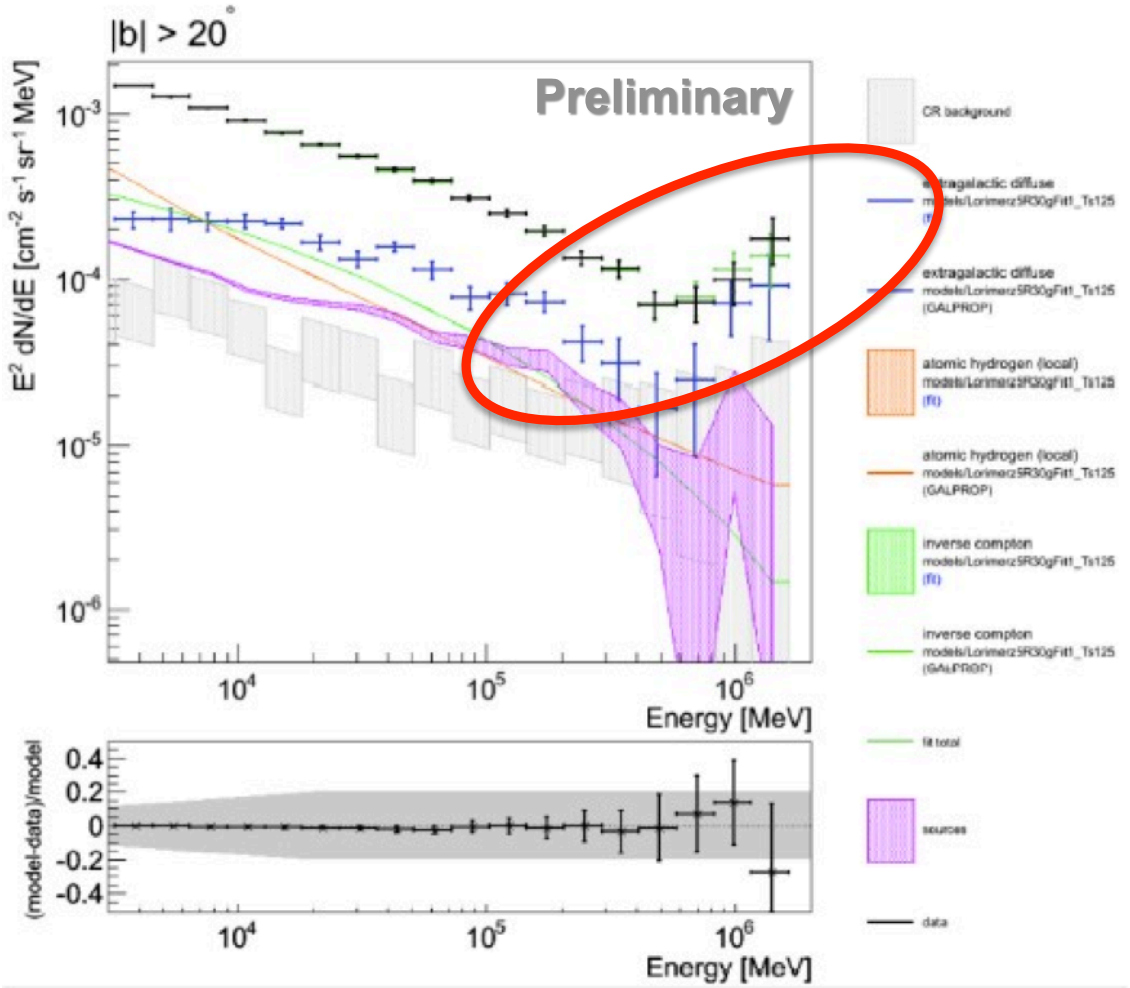
This is a "game-changing" data set for Solar physics in the γ-ray band

N. Omodei & Solar Group
March Collaboration Meeting



# The extragalactic background

**Unexpected spectral hardening in EGB seen above 500 GeV**




Not seen in control samples (Earth limb, galactic plane)

Survives source masking and is not correlated with known AGN positions

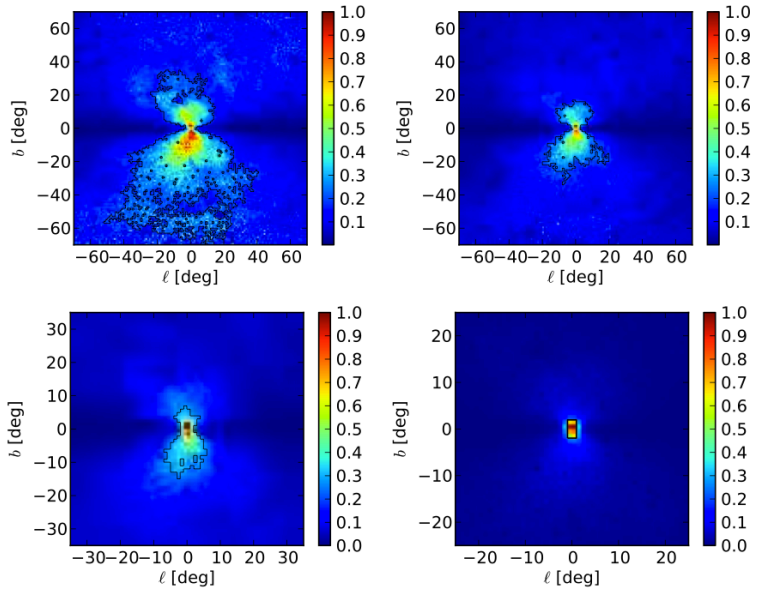
Current IRFs only go up to 560 GeV (Pass 8 ~ 2TeV)

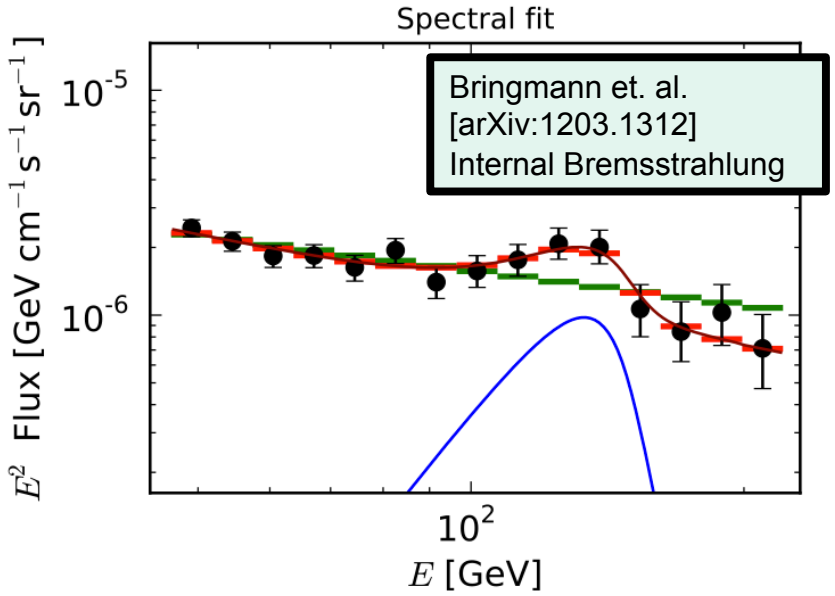
Also need to study possible CR $e^+e^-$ contamination (improved in Pass 8)

Pass 8 selection will improve statistics above 500 GeV

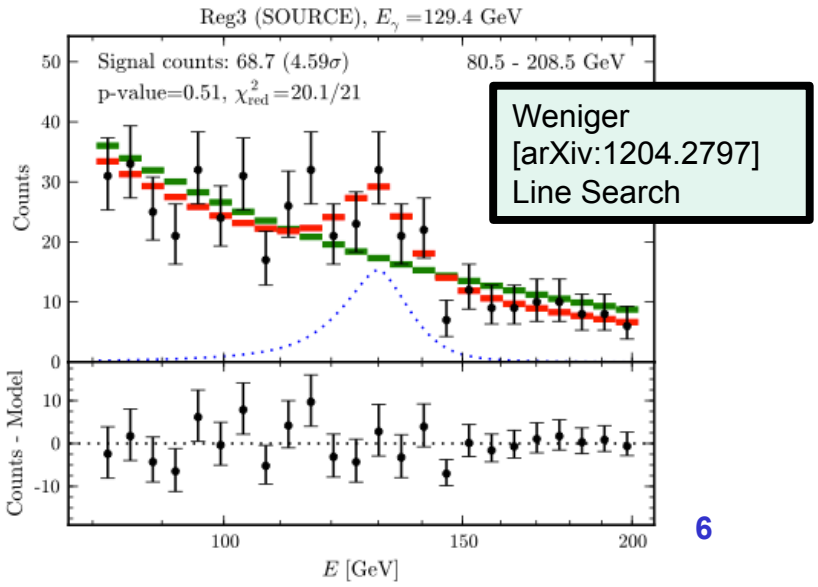
M. Ackermann & Diffuse Group
March Collaboration Meeting

# Recent External DM Results




Spectral feature at 130 GeV observed in ROI optimized for S/N under different models



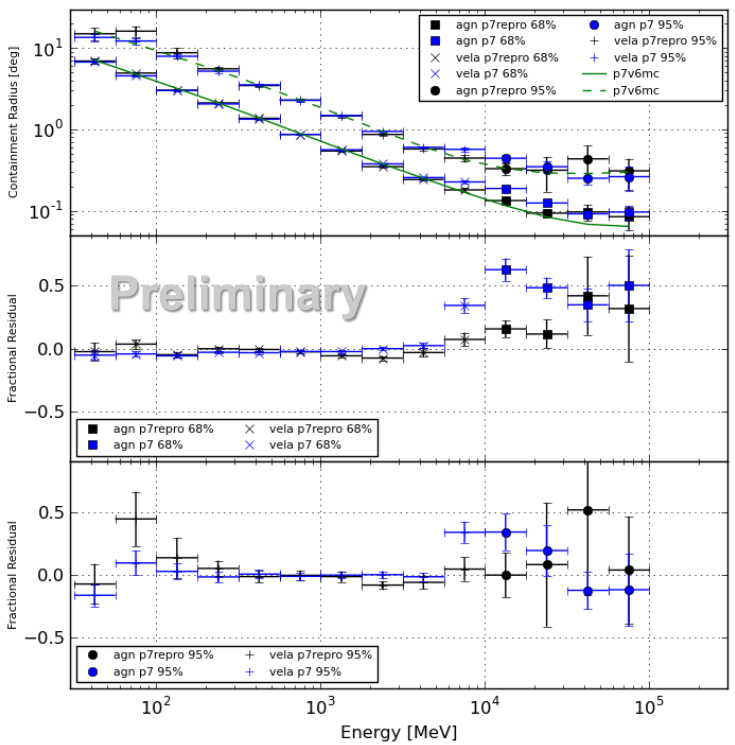

Not seen in control samples (Limb & Plane)

Interpretation relies on morphology

Improved high energy PSF in pass 8

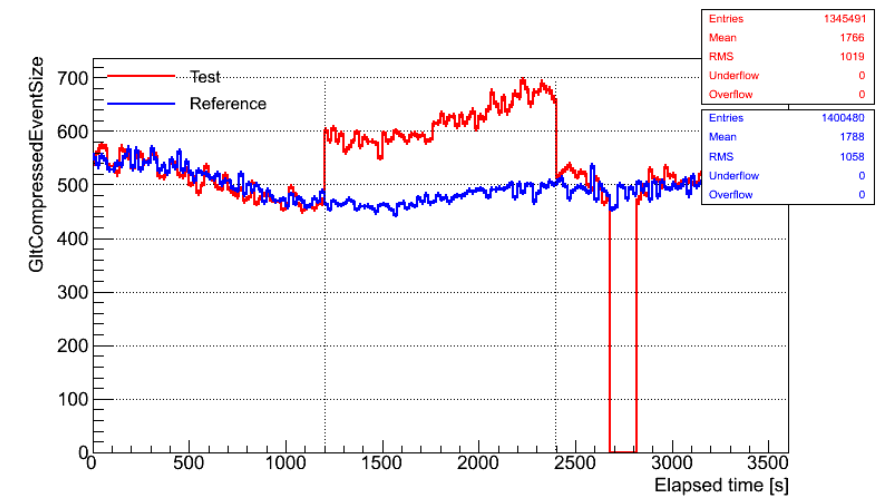
# PASS 7 DEVELOPMENTS

# Pass 7 Developments




PSF with reprocessed data and improved calibrations much closer to MC predictions

M. Wood, M. Roth, April 18th 2012



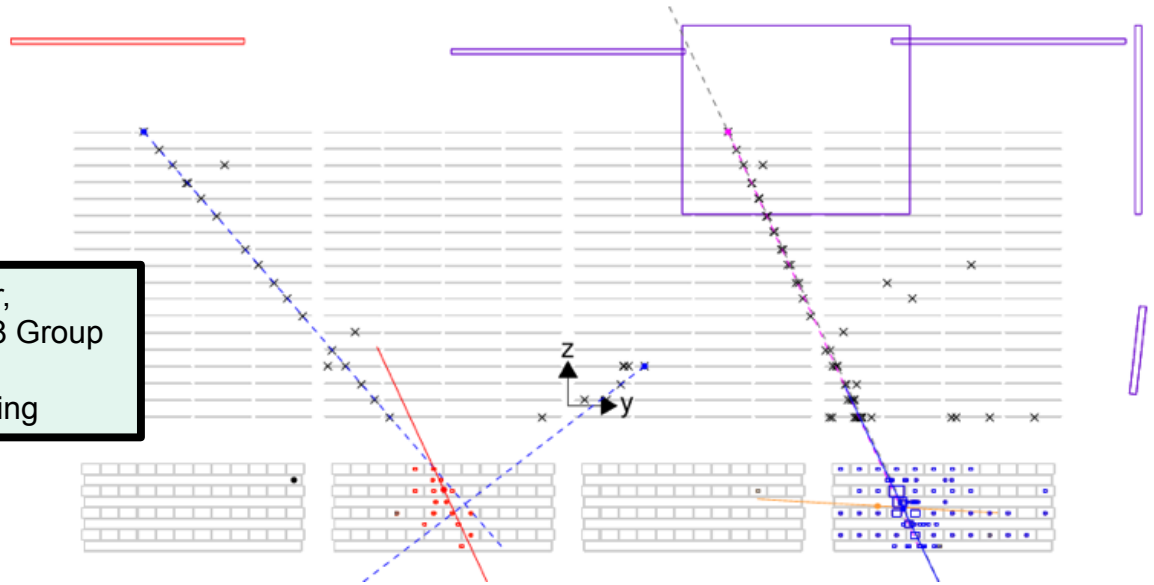

- New TKR readout configuration "trunc64" recovers many hits (recovers *all hits* in many events)
- Simulations show marked reduction of PSF tails above few GeV

Results of engineering runs are indicating that "trunc64" configuration will improve high-energy PSF

C & A Group & ISOC & Pass 8 Group
March Clb. Meeting

# PASS 8 STATUS

# Motivations for Pass 8




A. Drlica-Wagner,
C. Sgro & Pass 8 Group

March Clb. Meeting

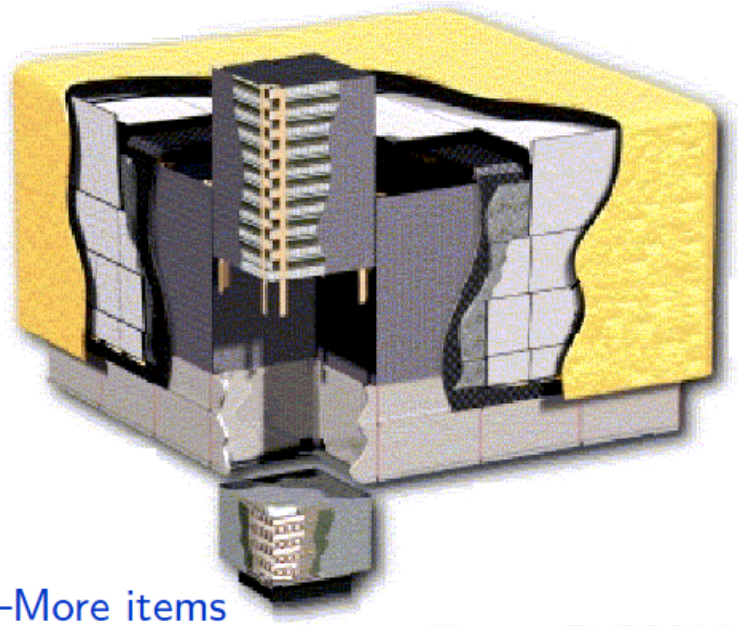
- **The LAT is complex particle detector**
- **LAT event-level analysis was largely developed before launch**
  - **We now have improved knowledge of the instrument and backgrounds**
    - **E.g., we found that many events are accompanied by GHOST signals...**
    - **These ghosts cause a significant losses in effective area**
- **Pass 8 uses this knowledge to improve data for science**

Pass 8 R&D started 3 years ago, now nearing completion

# Overview of Pass 8 Development Areas

## —Tracker

Kalman fit measurement errors, Point Spread function analysis, Tracker buffer truncation, tree-based pattern recognition, Cosmic-ray tracking, ghost tracking, neutral energy and vertexing...



## —Anti-Coincidence Detector

Error propagation, track-tile association finding and sorting...

## —Calorimeter

Crystal simulation and reconstruction, clustering, cluster classification, moments analysis and direction reconstruction, failure mitigation, crystal saturation and energy reconstruction beyond 1 TeV...

## —More items

periodic trigger event overlays, GEANT 4 update, background rejection, extended analysis classes, tools for analysis and validation...

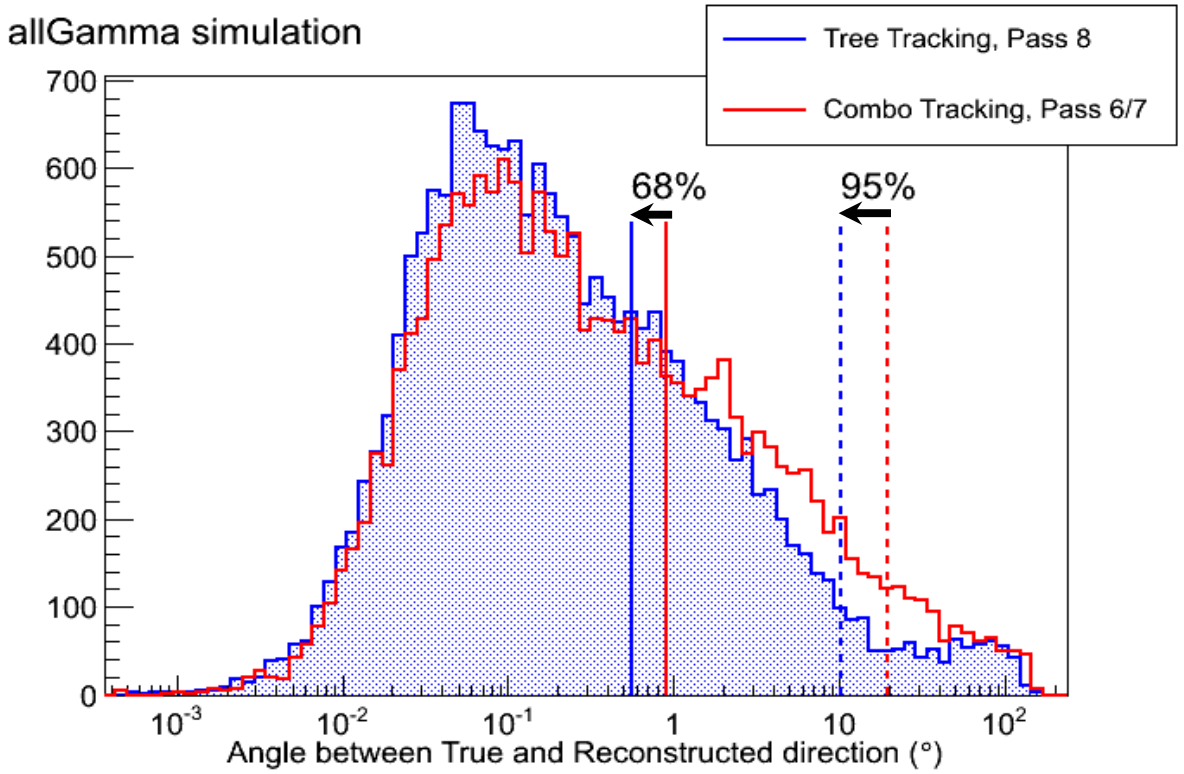
Pass 8 development group includes researchers from across the collaboration

# Completed Work: Tree-Based Tracking

- **Tree-based tracking follows the "flow of energy" in the tracker**
- **Code stable; nearing production**

T. Usher & Pass 8 Group

March Clb. Meeting



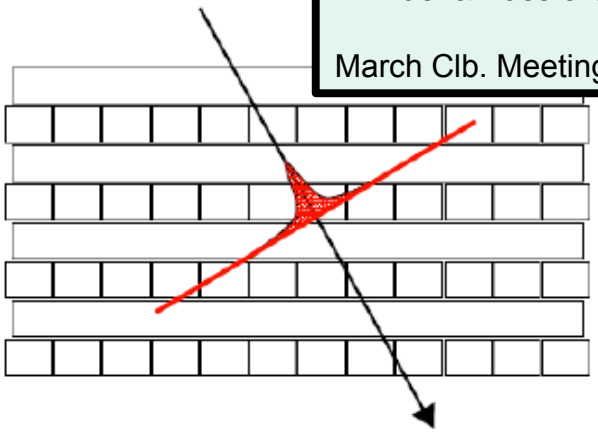

Better angular resolution, and decreased tails of PSF

# Completed Work: Improved Energy Estimate

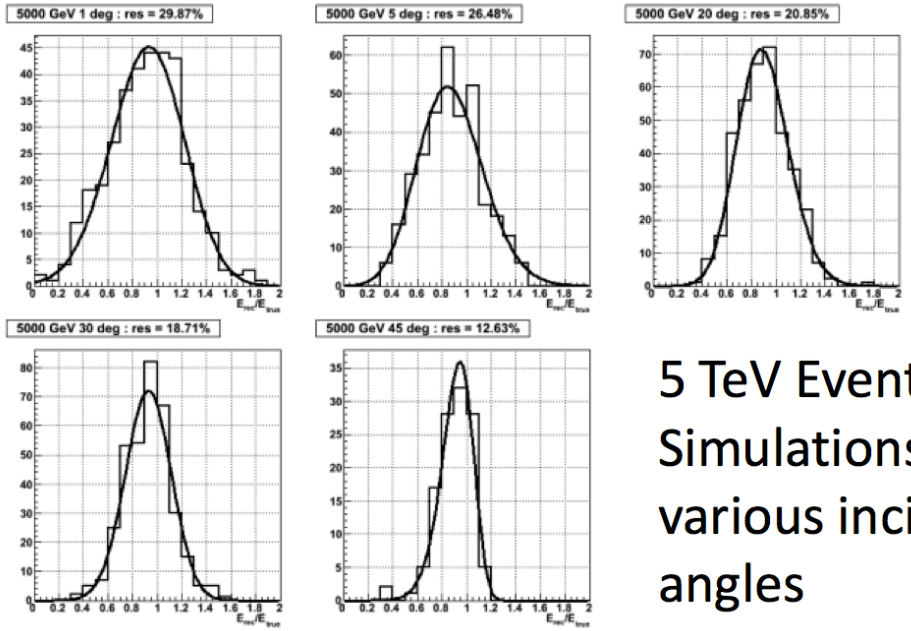
P. Bruel & Pass 8 Group

March Clb. Meeting

- **New full CAL profile energy analysis**
  - **Fit shower profile along shower axis**
  - **Better treatment of saturated crystals**
  - **Modify $\chi^2$ for saturated crystals**
- **Opens science window up to > 1 TeV**
  - **Recall EGB spectrum on slide 5**
- **$\chi^2$ useful for background rejection**



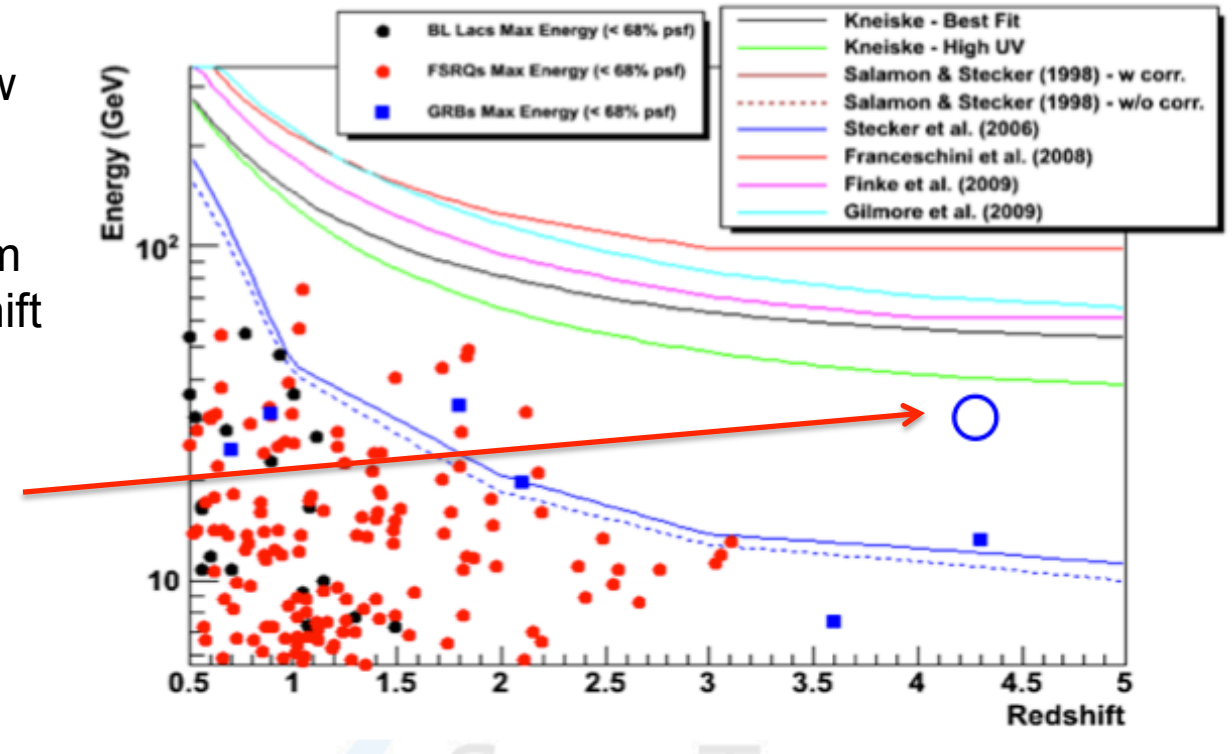
Simulations show ~20% energy resolution up to 5 TeV




5 TeV Event Simulations at various incident angles

# Science Already in the Bag: Updated Selection of γ rays During GRBs

- Minimal analysis using new tracking and clustering
- 3 more γ rays > 5 GeV from GRBs with measured redshift (18 γ rays originally)
- Including a 29GeV photon from z = 4.35 GRB
- 14 more γ rays > 1 GeV from same GRBs

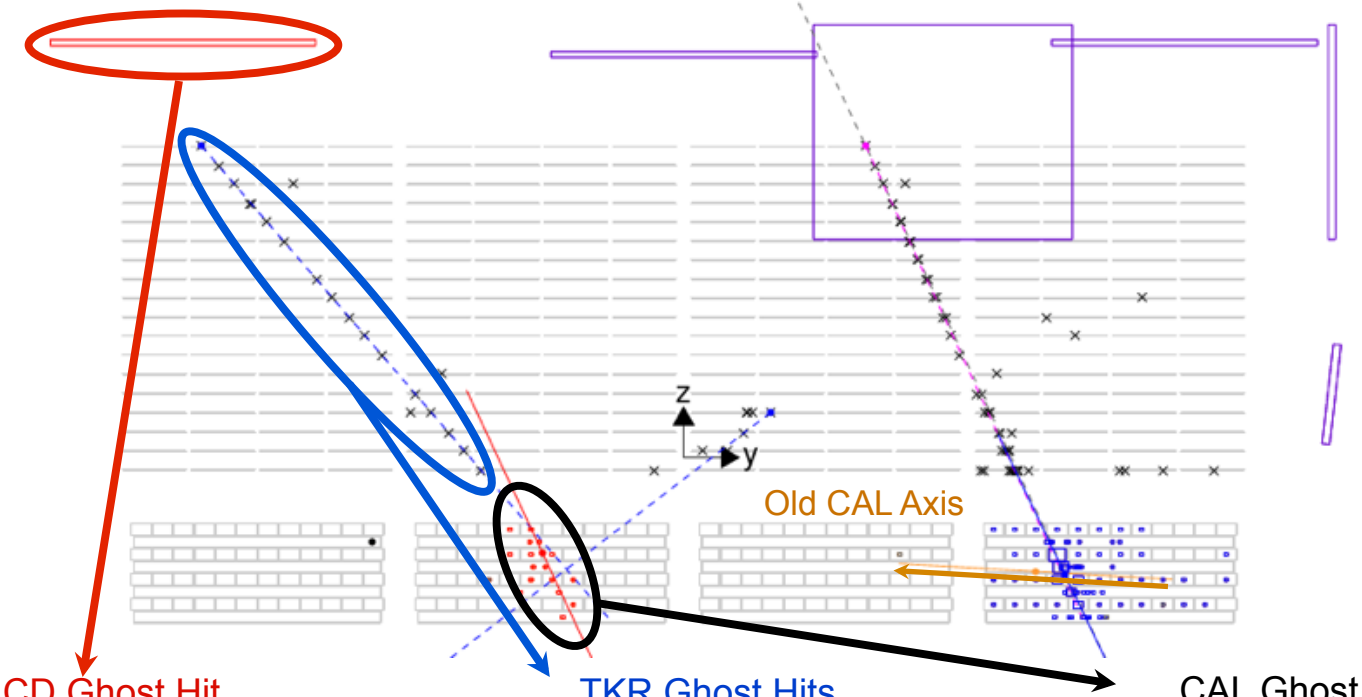



These high-energy, high-redshift γ rays allow us to probe the extra-galactic medium with unprecedented power

L. Baldini & J. Bregeon & Pass 8 Group

Nov. Clb. Mtg.

# Current Work: Putting the Event Together




ACD Ghost Hit

- Identify ACD tiles with ghost energy deposits using the fast ACD veto information.
- Can this be accomplished without sacrificing background rejection power?
- Needs more study

TKR Ghost Hits

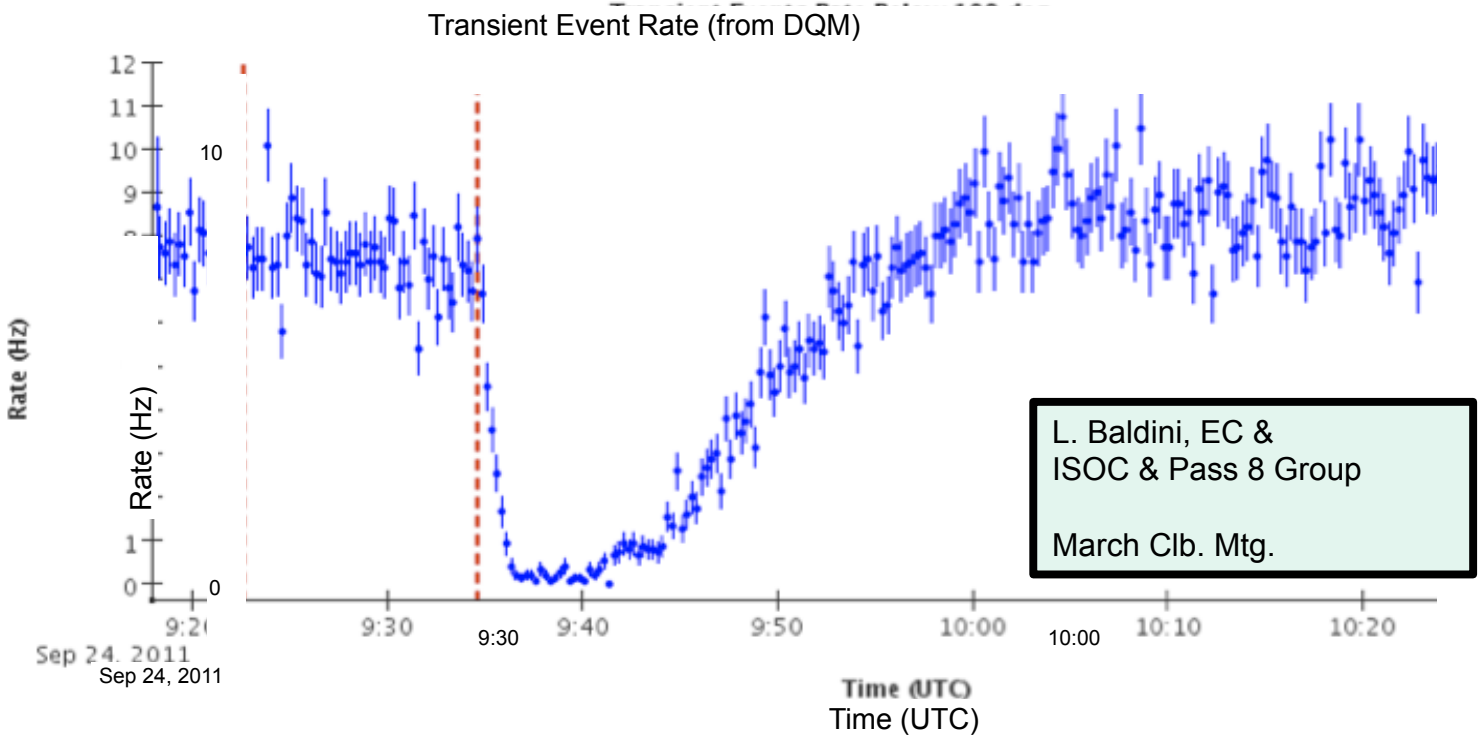
- Identify ghost energy in the TKR from TOT information and out-of-time hits.
- Remove tagged hits before running track finding.
- Could search for in-time hits on ghost tracks.

CAL Ghost Cluster

- Identify through CAL clustering and cluster classification.
- Work only with gamma cluster (effectively removing ghost) or remove ghost cluster and combine remaining crystals.

Background rejection goes hand-in-hand building the event into a coherent whole, including ghost removal

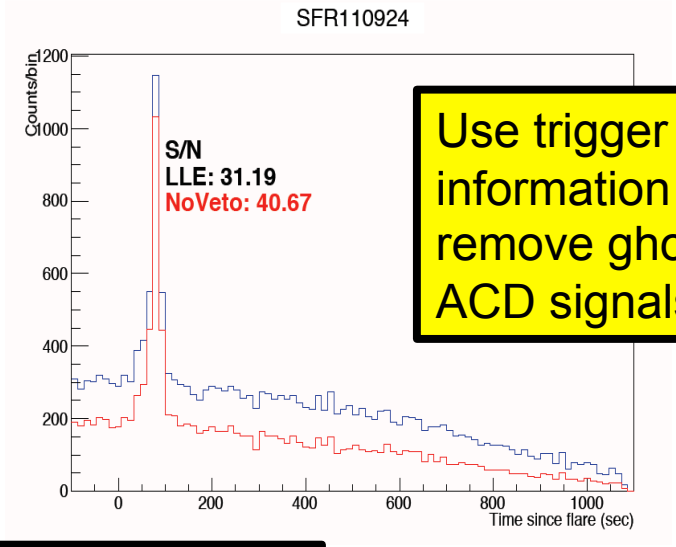
# Current Work: ACD Saturation and Solar Flares




- **High X-ray flux during solar flares saturates ACD**
  - **Loss of events in standard events classes**
  - **Currently requires use of LLE selection**
  - **Recall March 7, 2012 Solar Flare (slide 4)**

# Current Work: Improved ACD Selection for Transients

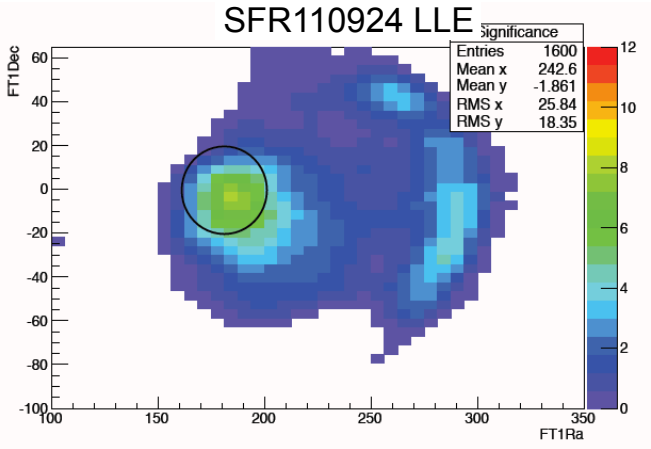
- **Solar Flare 110924**
  - **Class X2 solar flare**
  - **44 deg. from LAT boresight**
- **Overall S/N increase of ~30%**
- **Increase in S/N correlated with Sun position**
- **Also improve S/N over LLE for several GRBs**



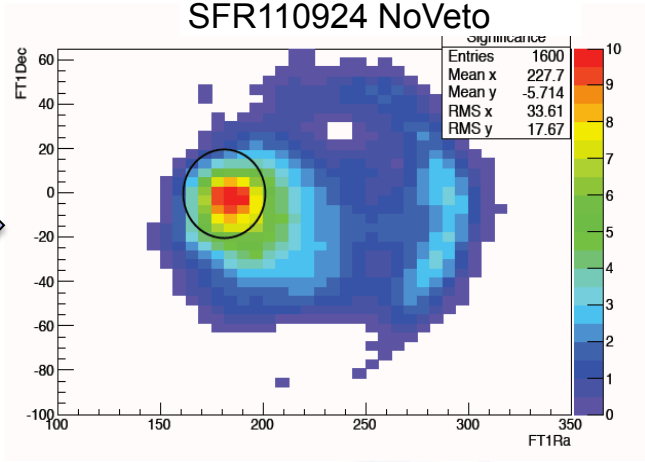

Use trigger information to remove ghost ACD signals

M. Pesce-Rollins & Pass 8 Group

March Clb. Mtg.




Include ACD veto information



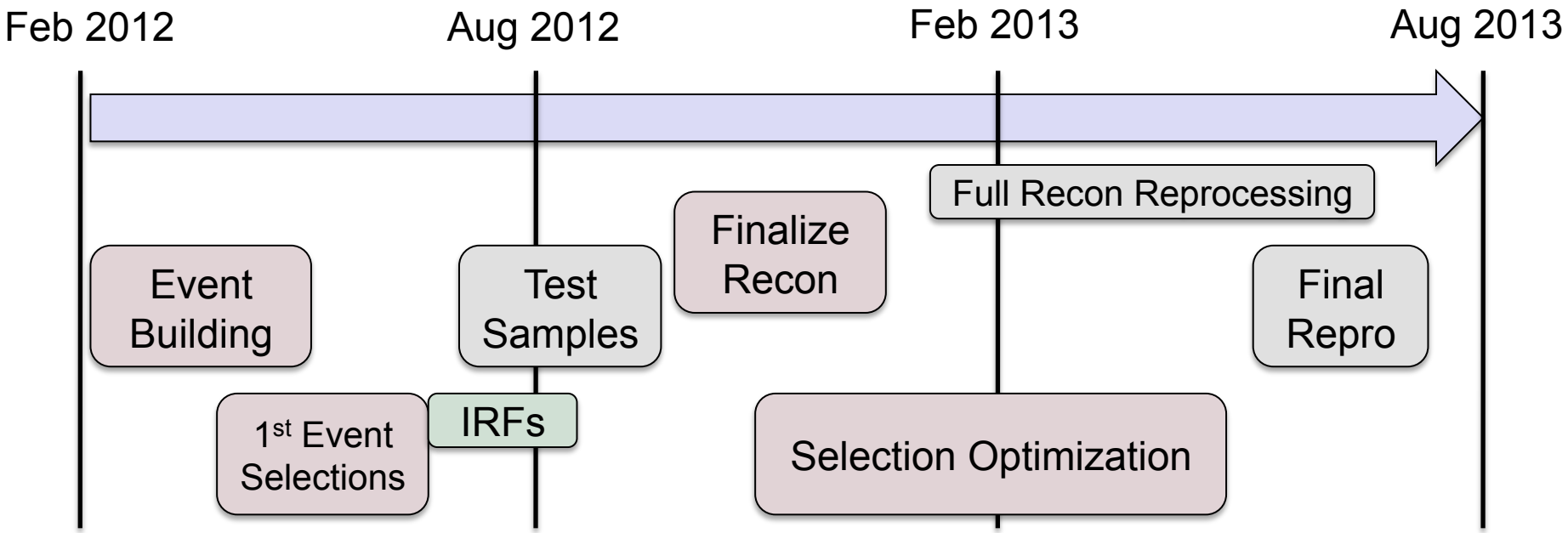
# Selected Science Highlights and Pass 8

| Pass 7 Science Highlight | Pass 8 Developments |
|---|---|
| Extragalactic Background | Energy Estimation > 1 TeV |
| Inner Galaxy / DM Searches | Improved PSF & Bkg Rejection<br>TKR Truncations |
| March 7, 2012 Solar Flare | ACD de-ghosting<br>Extending analysis < 100 MeV |

Pass 8 makes improvements in many areas directly related to exciting new science

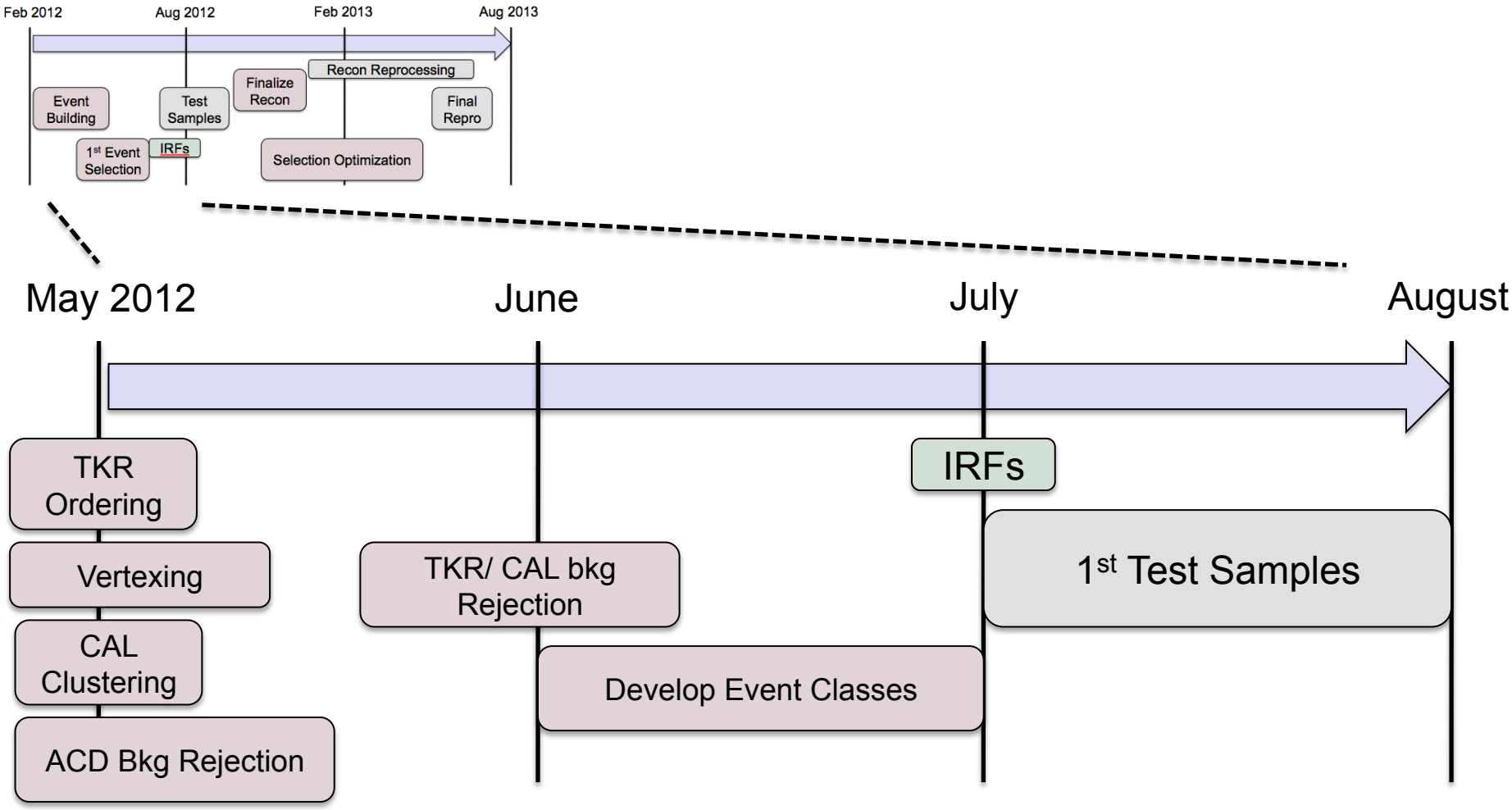
# Pass 8 Timeline

- **Baseline: have Pass 8 ready for 5 year Catalog (Aug 2013)**



# Pass 8 Near Term Timeline

- **Baseline: IRFs and first test samples for Clb. Mtg. (Aug 2012)**



# ADDITIONAL SLIDES

# ANALYSIS ORGANIZATION

# Science Group Coordination

| Group | Leads (Nov. 2011) | Leads (Apr. 2012) |
|---|---|---|
| Calibration & Analysis | Luca Baldini<br>Leon Rochester | **Johan Bregeon**<br>Leon Rochester |
| Dark Matter & New Physics | **Jennifer Siegal-Gaskins**<br>Luca Latronico | Jennifer Siegal-Gaskins<br>**Nicola Mazziota** |
| Diffuse | **Luigi Tibaldo**<br>Gulli Johannessen | Luigi Tibaldo<br>Gulli Johannessen |
| Catalog | Elizabeth Ferrara<br>Isabelle Grenier | Elizabeth Ferrara<br>Isabelle Grenier |
| Solar System | **Nicola Omodei**<br>Nicola Giglietto | Nicola Omodei<br>Nicola Giglietto |
| AGN | **Marco Ajello**<br>Justin Finke | Marco Ajello<br>Justin Finke |
| Galactic Sources | **Paul Ray**<br>Francesco Giordano | Paul Ray<br>**Liz Hays** |
| GRB (LAT members) | Vlasios Vasileiou<br>Judith Racusin | **Giacomo Vianello**<br>Judith Racusin |

**Huge amount of organizational work is done by group leaders**
**We are lucky to have so many skilled people willing to step up**

# Analysis Procedures & Developments

- **Several Active WG to address specific analysis issues**
  - **All are very productive, seems like a good model for addressing specific, well defined, problems and issues**
  - **IRFs (Riccardo Rando)**
  - **Binned v. Unbinned (Elizabeth Ferarra)**
  - **Low energy systematics (Largely Front/Back) (Steve Fegan)**
  - **Solar Template Tool (Elena Orlando)**
  - **Earth Emission (Keith Bechtol)**
  - **Routine Science Processing (Benoit Lott & Tom Glanzman)**
  - **All sky simulations with *gtobsim* (Max Razzano)**
- **List will need to evolve**
  - **e.g., Binned v. Unbinned is effectively completed**
  - **Proposals for some new groups…**

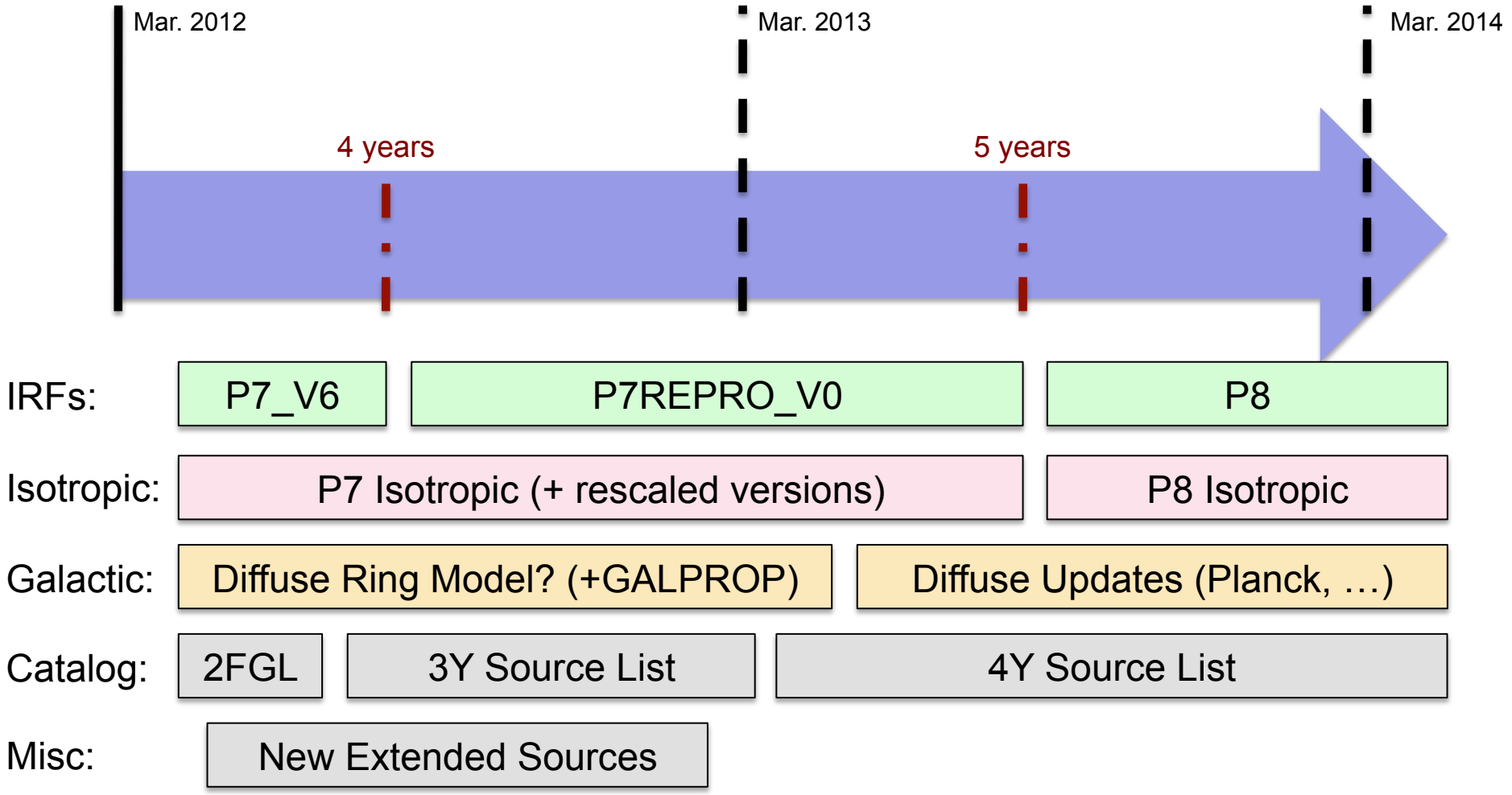
# Looking back: shifter shortage

- **Continued actively recruiting Data Quality Shifters**
  - **Requires about 1 hour /day for 1 week / year**
  - **Good response (shifts filled through July 30)**
  - **Now people at most institutions who have taken shifts & can help others get involved**
    - **Much easier to get started**
  - **Documentation is much improved**
- **We will continue to monitor shifter situation to ensure things continue smoothly**

# Looking Forward: detector/ reconstruction expertise

- March pass 8 meeting made it clear LAT team is running low on detector & reconstruction expertise. Many experts moving on to other things
- Few people actively working on reconstruction / event classification full time:
  - TKR (~2-3 FTE)
  - CAL (~5 FTE)
  - ACD (~1 FTE)
- Even fewer people working on sub-system calibrations:
  - TKR(<1 FTE)
  - CAL(<1 FTE)
  - ACD(<1 FTE)
- We are making active efforts to involve students & post-docs in these areas

# Looking towards the 5 Year source catalog



# STATUS OF THE PUBLICATIONS

# Continued High Level of Paper Production

**18 April 2012**

**Category I and II papers in refereed journals**

| Journal | Published | In press | Total |
|---|---|---|---|
| Astronomical Journal | 1+0=1 | - | 1 |
| Astronomy and Astrophysics | 6+9=15 | 0+1=1 | 16 |
| Astroparticle Physics | 2+2=4 | - | 4 |
| Astrophysical Journal | 62+30=92 | 1+0=1 | 93 |
| Astrophysical Journal Letters | 20+10=30 | - | 30 |
| Astrophysical Journal Supplement | 4+1=5 | - | 5 |
| Journal of Cosmology and Astroparticle Physics | 3+2=5 | 0+1=1 | 6 |
| Monthly Notices of the RAS | 0+9=9 | 0+1=1 | 10 |
| Nature | 2+1=3 | - | 3 |
| Physical Review D | 4+0=4 | 1+0=1 | 5 |
| Physical Review Letters | 6+0=6 | - | 6 |
| Science | 13+0=13 | - | 13 |
| **Total** | 123+64=187 | 2+3=5 | 192 |

Number of Cat III papers published = 86
Number of Astronomer's Telegrams = 191 (~1 / week)
Number of GCN notices = 40

**+MW follow ups**

# Papers Published Since Nov. 2011

| | | | | | |
|---|---|---|---|---|---|
| 2011 | Dec | I | AGN | ApJ | 2LAC |
| 2011 | Dec | II | AGN | A&A | Planck, Swift, and Fermi radio selected |
| 2011 | Dec | I | darkmat | Phys. Rev. Lett. | Dwarf stacking for DM |
| 2011 | Dec | II | galactic | ApJ | Blind Search Sensitivity |
| 2011 | Dec | II | galactic | ApJ | High-B pulsars |
| 2011 | Dec | II | galactic | ApJ | The X-ray counterpart of PSR J2021+4026 |
| 2012 | Jan | III | AGN | A&A | Radio/Gamma Connection of 3C345 |
| 2012 | Jan | III | AGN | A&A | MOJAVE properties of LAT AGN |
| 2012 | Jan | I | calibration | Astropart. Phys. | Absolute CAL scale |
| 2012 | Jan | I | diffuse | Phys. Rev. Lett. | Positron paper for PRL |
| 2012 | Jan | I | galactic | ApJ | SNR G8.7-0.1 |
| 2012 | Jan | I | galactic | Science | The Gamma-ray Binary 1FGL J1018.6-5856 |
| 2012 | Jan | II | galactic | ApJ | Nine new gamma-ray pulsars |
| 2012 | Jan | II | galactic | ApJ | J1939+2134 & J1959+2048 |
| 2012 | Jan | II | galactic | ApJ | The Gamma-Ray Pulsar in the CTA1 |
| 2012 | Jan | II | galactic | ApJ | Modeling of phase-aligned MSP profiles |
| 2012 | Jan | II | galactic | ApJL | Tycho SNR Paper |
| 2012 | Jan | II | galactic | MNRAS | HTRU Survey IV |
| 2012 | Feb | I | AGN | ApJ | LAT Seyfert |
| 2012 | Feb | II | AGN | A&A | VHE gamma-ray emission of 1ES 0414+009 |
| 2012 | Feb | II | AGN | ApJ | Two Gamma-ray Blazars Behind the Plane |
| 2012 | Feb | II | AGN | ApJ | M87 Joint TeV Paper on 2010 Flaring |
| 2012 | Feb | III | AGN | ApJ | VLBA monitoring of 3C84 at 43 GHz |
| 2012 | Feb | I | darkmat | ApJ | Unassociated DM Satellites |
| 2012 | Feb | I | darkmat | JCAP | LED Limits from Neutron Stars |
| 2012 | Feb | III | darkmat | JCAP | Gravitino DM prospect of detection |
| 2012 | Feb | I | diffuse | A&A | Interstellar emission in Cygnus |
| 2012 | Feb | II | galactic | ApJ | PSR J2030+3641 |
| 2012 | Feb | II | galactic | ApJL | PSR J0101-6422 |
| 2012 | Feb | II | galactic | MNRAS | March 2011 flaring episode of Cygnus X-3 |
| 2012 | Feb | III | galactic | ApJ | Suzaku unid paper |
| 2012 | Feb | III | galactic | ApJL | UnID Fermi source as BW-like MSP |
| 2012 | Feb | III | GRBs | MNRAS | Thermal and non-thermal in GRB090902B |
| 2012 | Feb | I | solar | AJ | Solar Flare June 12 2010 |
| 2012 | Mar | II | AGN | A&A | VHE discovery of B3 2247+381 |
| 2012 | Mar | II | AGN | ApJ | MAGIC: 5 years of PG 1553+113 |
| 2012 | Mar | II | AGN | MNRAS | IGR J22517+2217 |
| 2012 | Mar | II | galactic | ApJ | The gamma-ray binaries after 2.5 years |
| 2012 | Mar | II | galactic | ApJ | Crab paper 3 |
| 2012 | Apr | I | catalogs | ApJS | 2FGL Catalog Paper |
| 2012 | Apr | II | galactic | ApJL | SNR W44 at High Energies |

# Status of Major Papers for 2011-2012

- 2nd Fermi LAT AGN Catalog -> Published!
- 2nd Fermi LAT Source Catalog -> Published!
- Galactic Diffuse Model -> Published!
- **Instrument Performance -> Collaboration Review**
- **2nd Fermi LAT Pulsar Catalog -> Under review in Gal. Group**
- **Fermi GRB Catalog -> Under review in GRB Group**
- **Inner Galaxy Paper -> Analysis finishing, draft in preparation**
- **SNR and PWNe Catalogs -> In preparation in Gal. Group**

# Summary

- Many exciting and high profile results are coming in
- Pass 8 is coming together
  - Work on event level analysis is progress
  - Seeing first signs of improved science yield
- Collaboration is doing well
  - Extremely productive
  - Work and responsibilities being shared
- Take advantage of gap in scheduled deliverables to put things in order for the future
  - Develop new analysis techniques
  - Planning for 5 year source catalog and associated analyses
    - Working to make analysis cycle routine