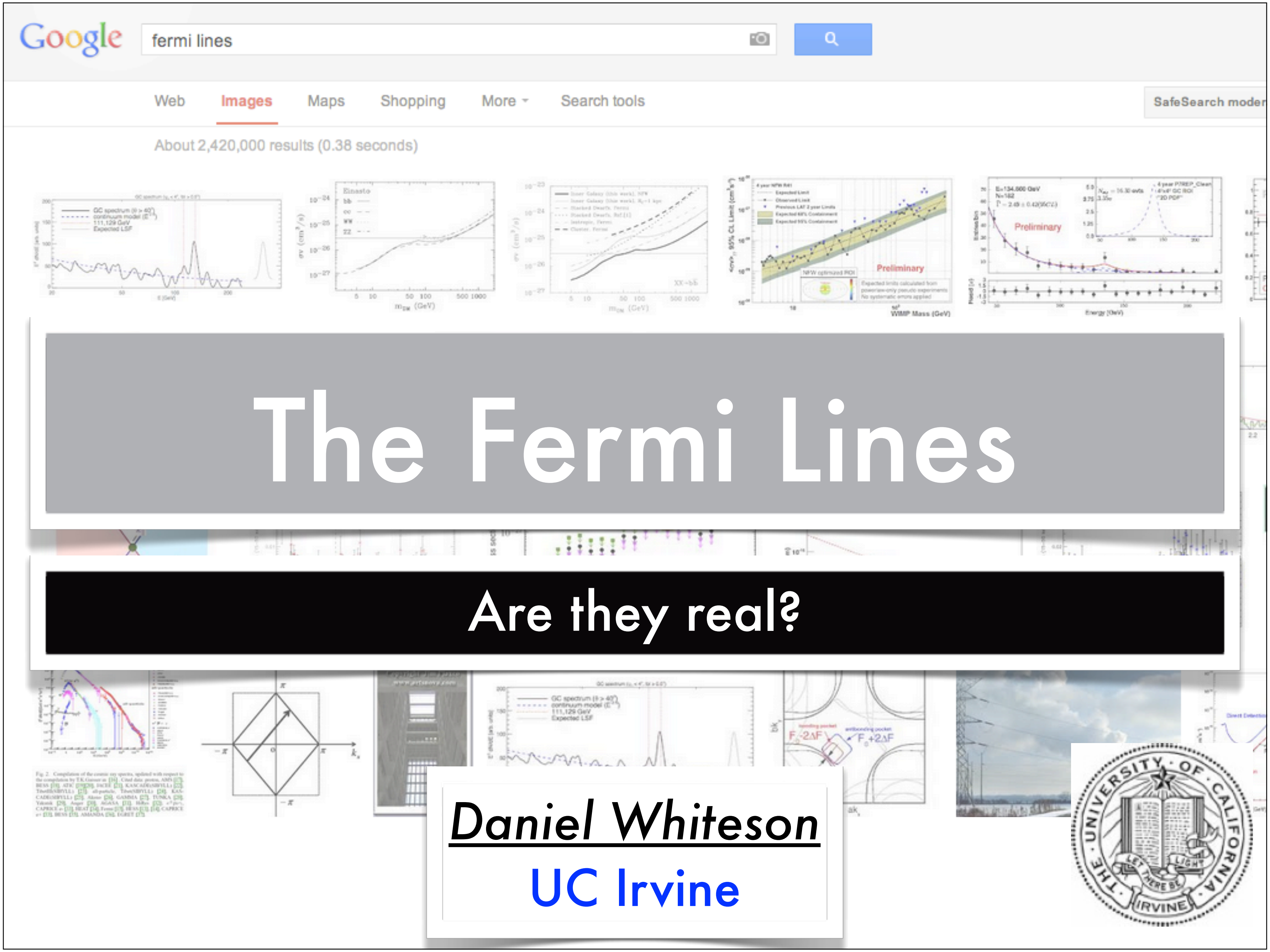


The Fermi Lines

Are they real?

Daniel Whiteson

UC Irvine

Disclaimer

I've been doing collider physics....

Search for resonant top plus jet production in $t\bar{t}$ + jets events with
detector in pp collisions at $\sqrt{s} = 7$ TeV

Measurement of ZZ production in pp collisions at
$\sqrt{s} = 7$ TeV and limits on anomalous ZZZ and ZZ
couplings with the ATLAS detector

Search for a heavy particle decaying to a
top quark and a light quark in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

Search for pair-produced heavy quarks decaying to Wq in the two-lepton channel at
$\sqrt{s} = 7$ TeV with the ATLAS detector

Search for same-sign top-quark production and
fourth-generation down-type quarks in pp collisions a
$\sqrt{s} = 7$ TeV with the ATLAS detector

Search for Dark Matter Candidates and Large Extra Dimensions in event
photon and missing transverse momentum in pp collision data at $\sqrt{s}$ =7 Te
ATLAS detector

Triangulating an exotic T quark

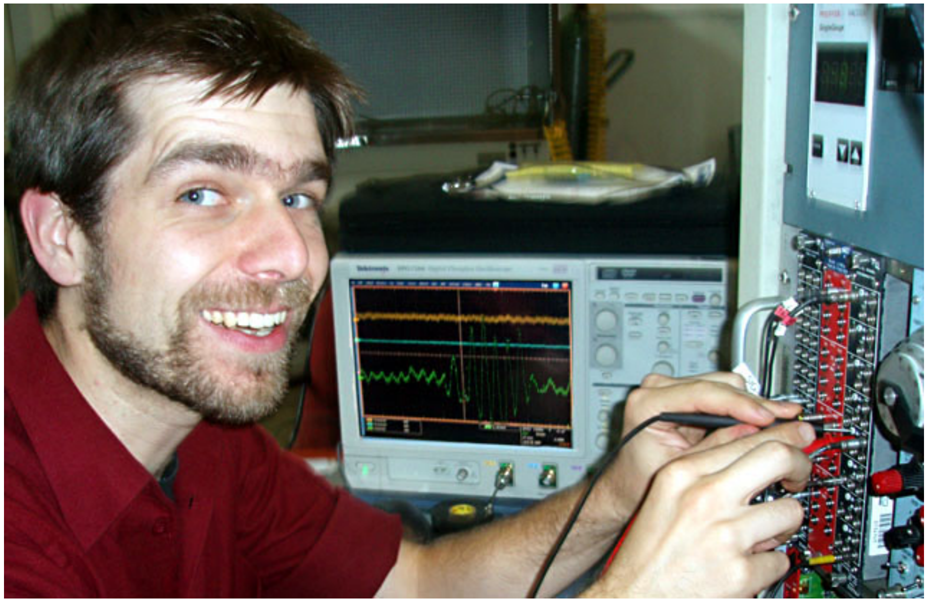
Search for a heavy vector boson decaying to two gluons
in $p\bar{p}$ collisions at $\sqrt{s} = 1.96$ TeV

Sul

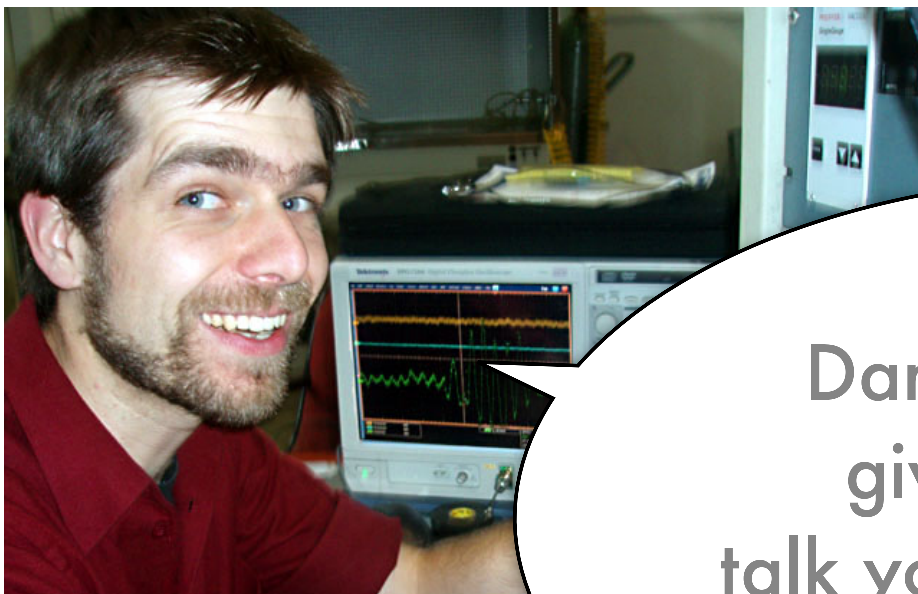
Search for down-type fourth generation quarks with the ATLAS detector in events
with one lepton and hadronically decaying W bosons

... I am not (yet) an astro-physicist!

8 AM Monday



8 AM Monday



Daniel, you’re not
giving the same
talk you gave at Aspen
.... are you?

Google fermi lines

Web Images Maps Shopping More Search tools SafeSearch moder

About 2,420,000 results (0.38 seconds)

The Fermi Lines

Are they real?

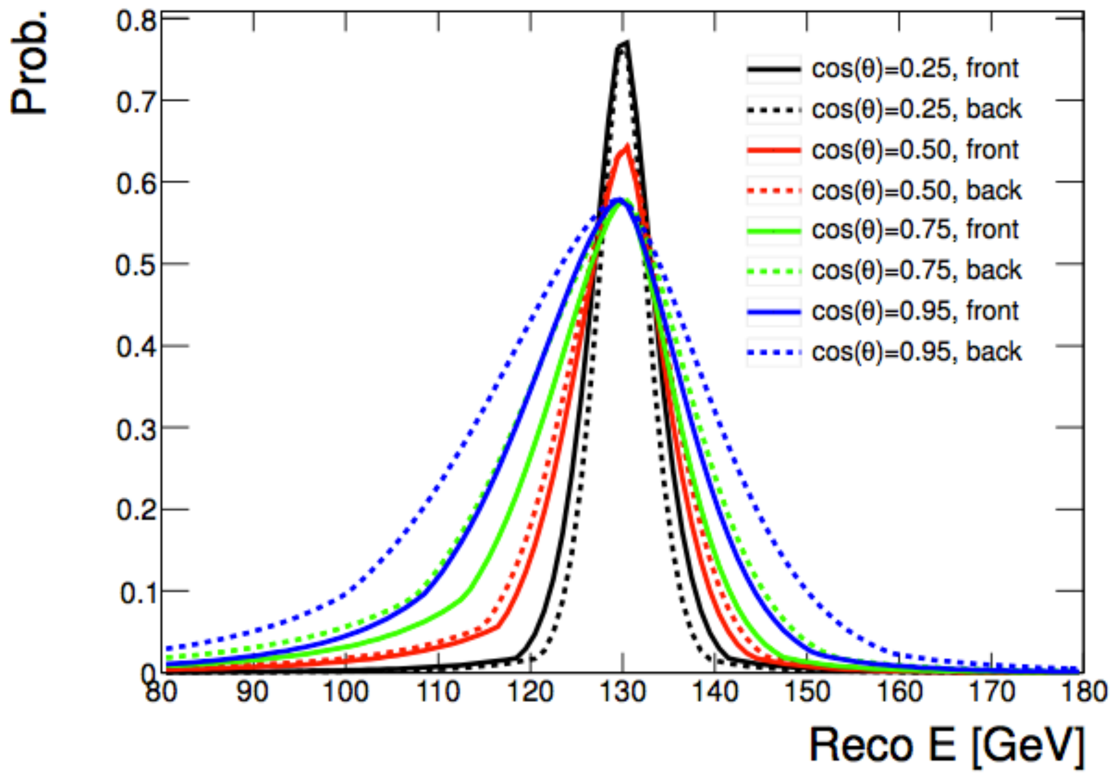
..and LHC mono-X

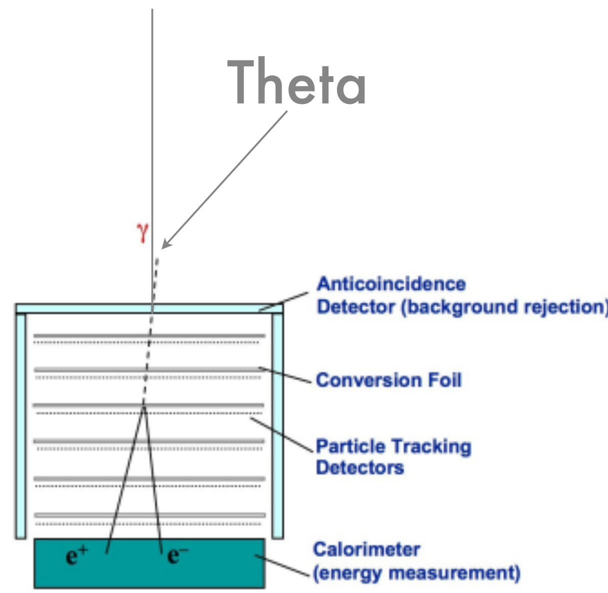
Daniel Whiteson

UC Irvine

Fermi

Performance



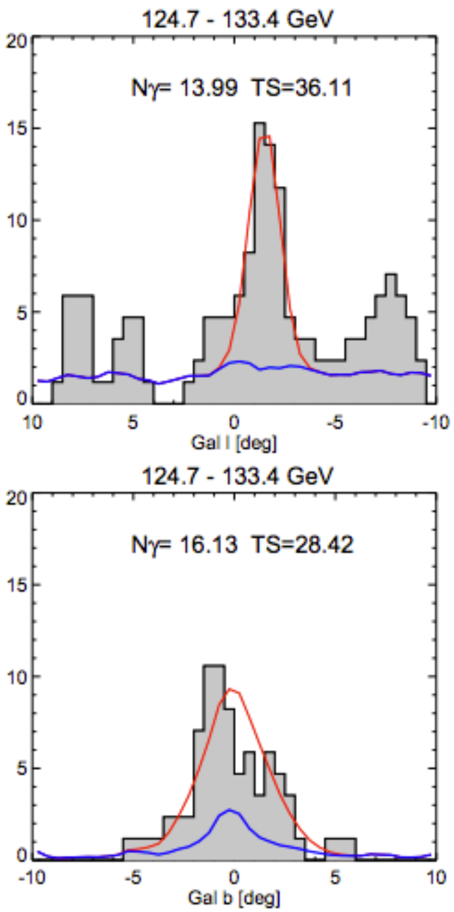


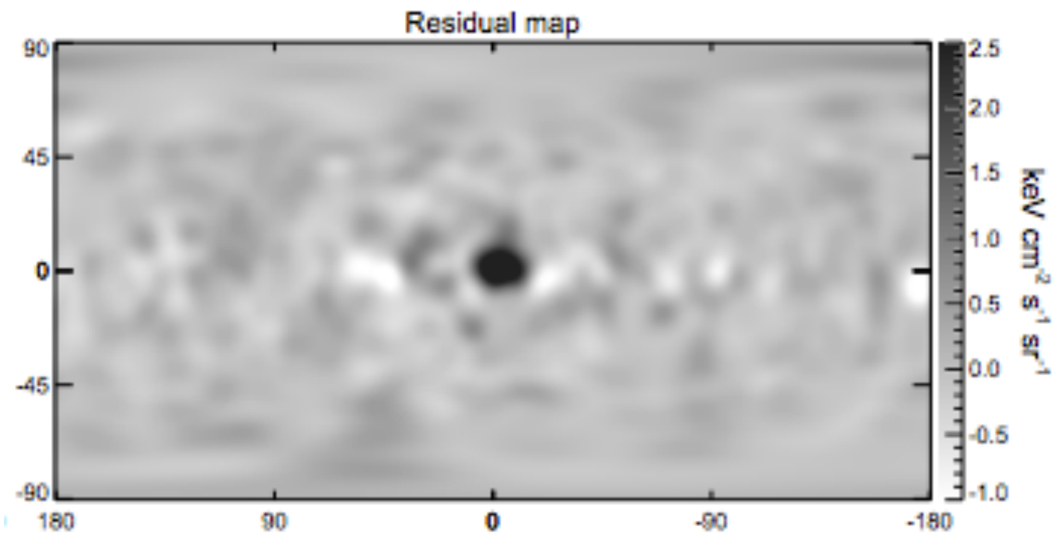
For simulated true photon energy of 130 GeV

Lines Outline

1. Where are the photons from?
2. Backgrounds
3. Instrumental effects
4. Tests of the instrument ← New
5. Discussion

Where are they from?

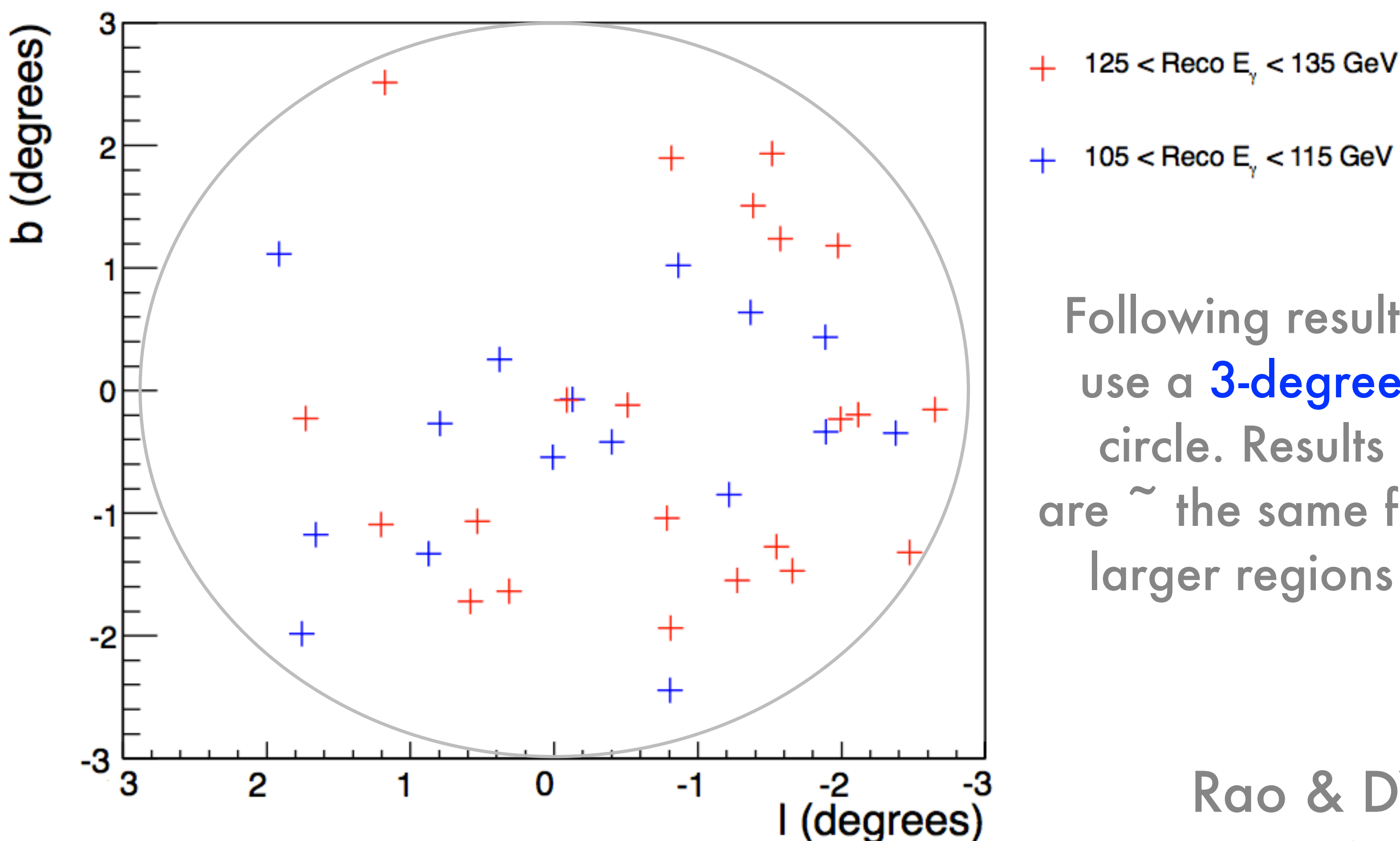




NFW density profile centered at $(\ell, b) = (-1.5°, 0°)$

Finkbiener&Su
1206.1616

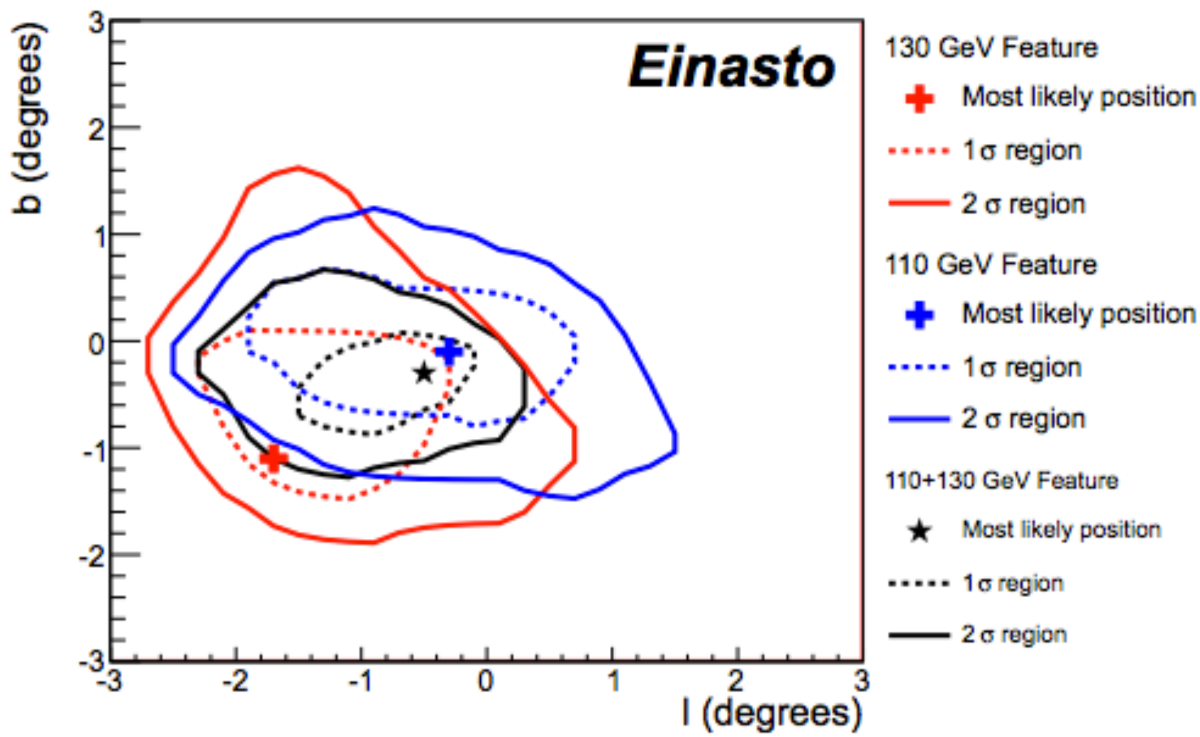
The photons



Following results use a **3-degree** circle. Results are ~ the same for larger regions

Rao & DW
1210.4934

Locations



Rao & DW
1210.4934

Hypothesis tests

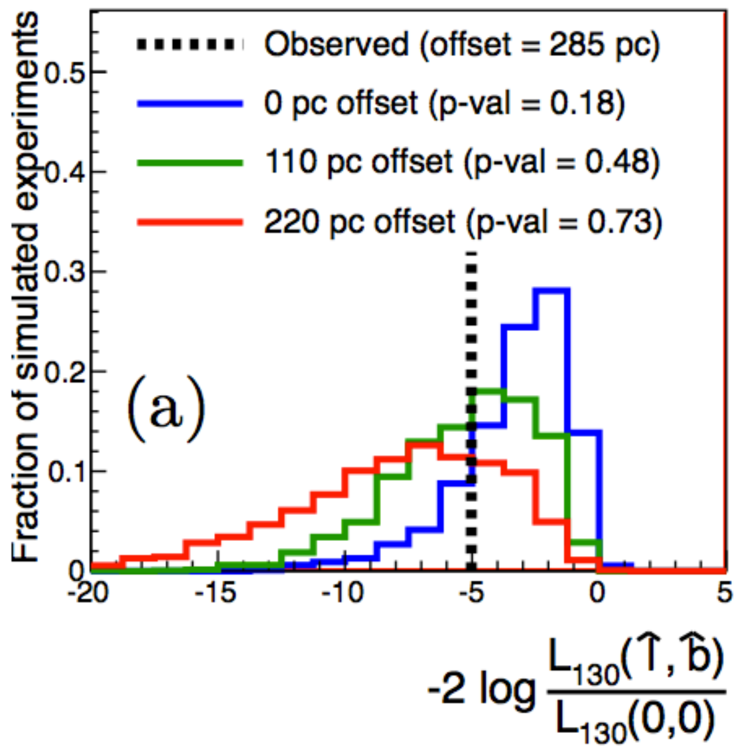
<u>(l,b) fit far from GC</u>

q → negative

$$q = -2\log\frac{L(l=\hat{l}, b=\hat{b})}{L(l=0, b=0)}$$

<u>(l,b) fit is close to 0,0</u>

q → zero



Lines Outline

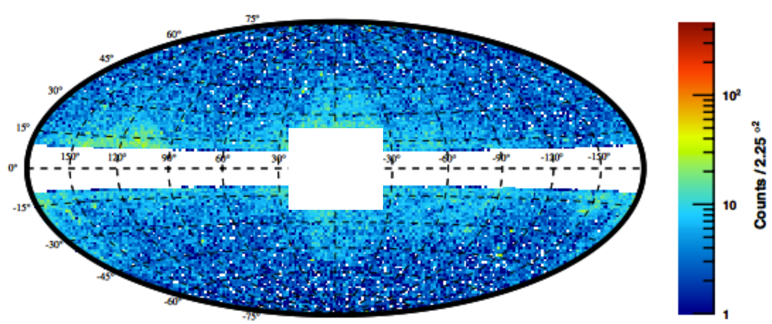
1. Where are the photons from?
2. Backgrounds
3. Instrumental effects
4. Tests of the instrument
5. Discussion

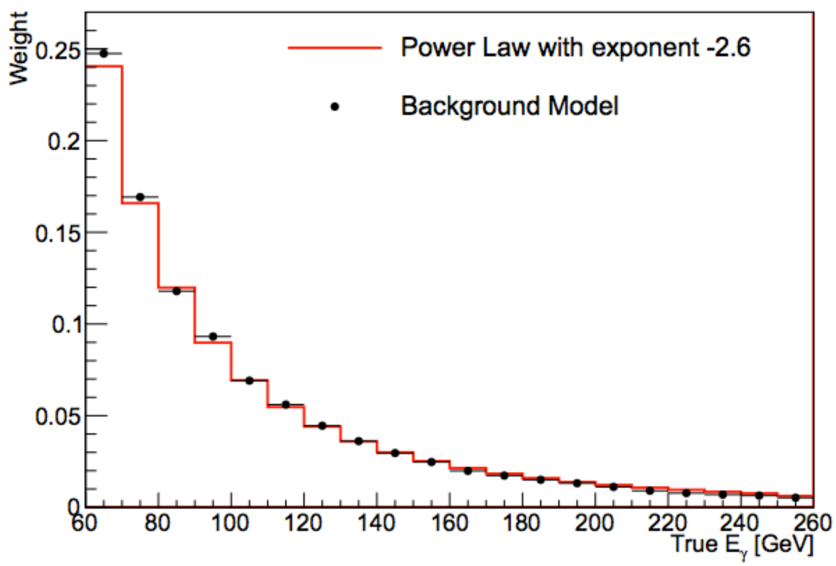
Background

Typical to assume a featureless power-law.

<u>One test</u>

Look away from DM density





<u>But</u>

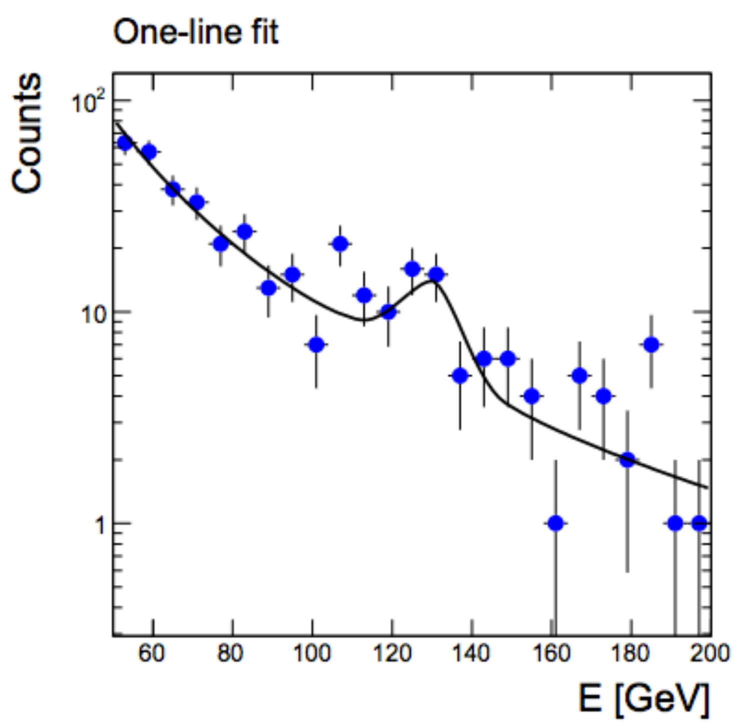
Can that describe the GC?

Rao & DW
1210.4934

Lines Outline

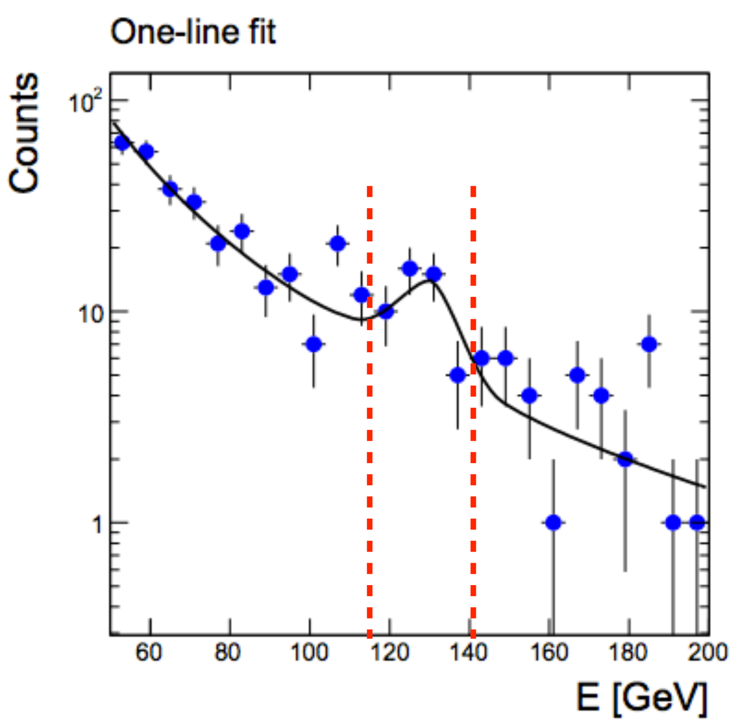
1. Where are the photons from?
2. Backgrounds
3. Instrumental effects
4. Tests of the instrument
5. Discussion

photons



Could the peak photons be spurious?
Are they different in some way?

First idea



<u>isolate signal photons</u>

Use energy cut

<u>But</u>

S/B is not large.

Few signal photons.

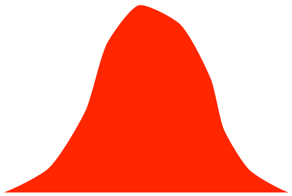
Can we do better?

sPlots

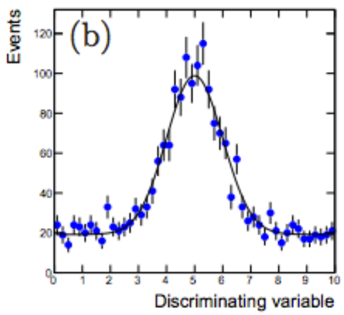
discriminating
variable

background

signal

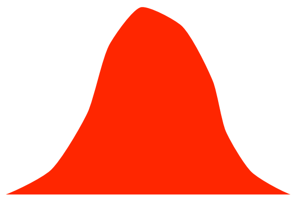
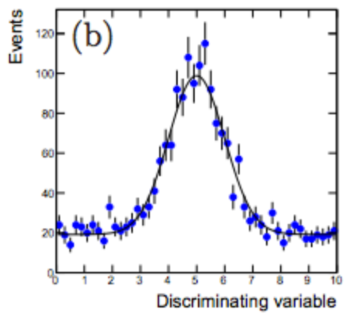


data



sPlots

(pdfs factorize)

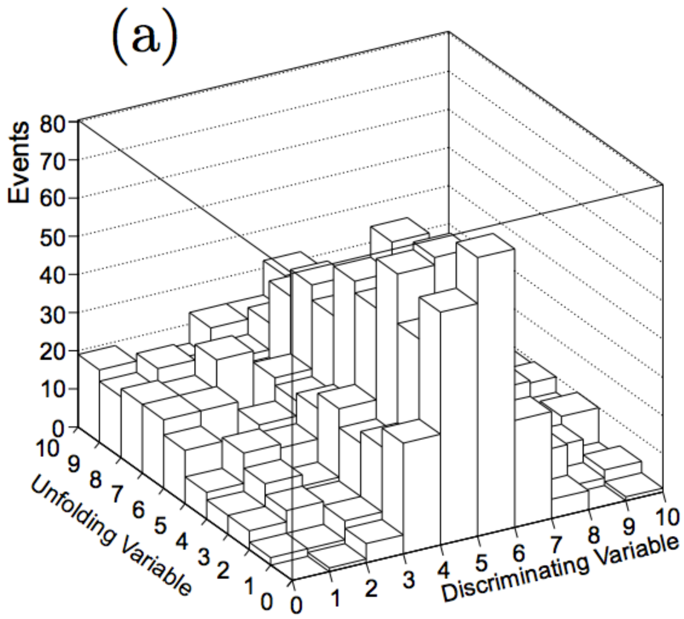
	discriminating variable	unfolding variable
background		
signal		
data		

sPlots

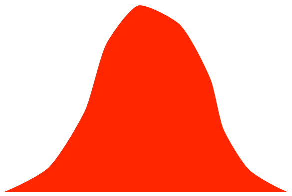
(pdfs factorize)

discriminating variable

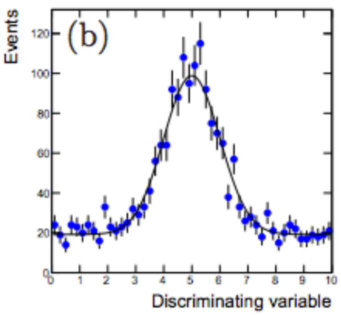
background



signal



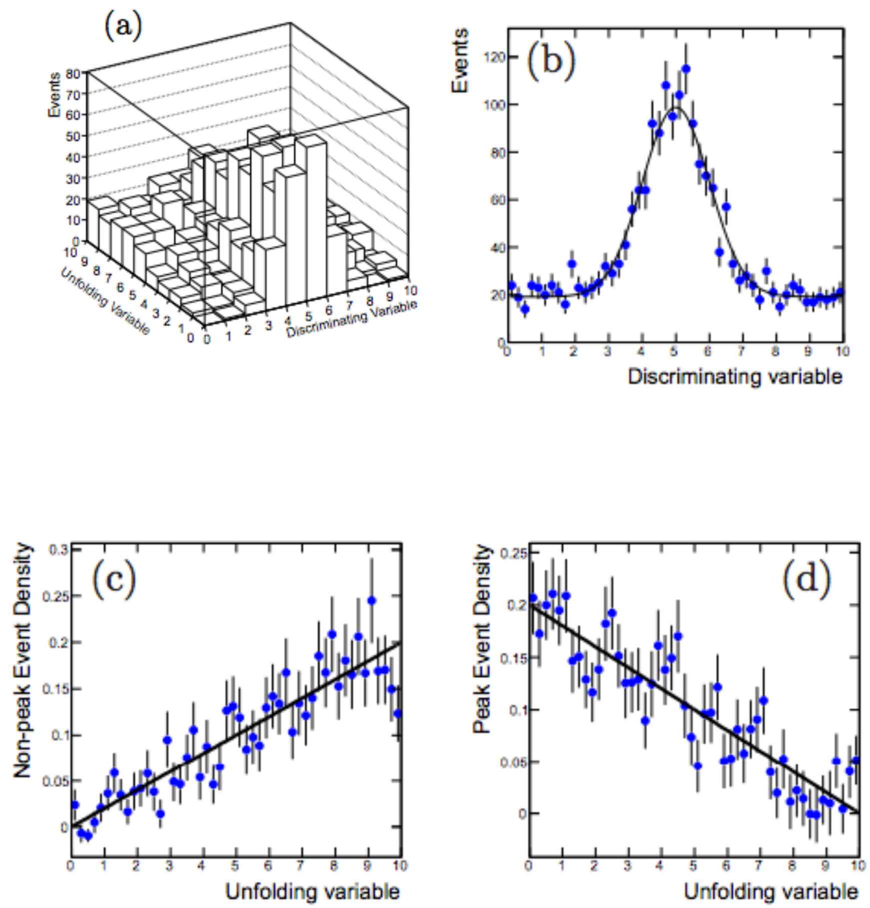
data



sPlots

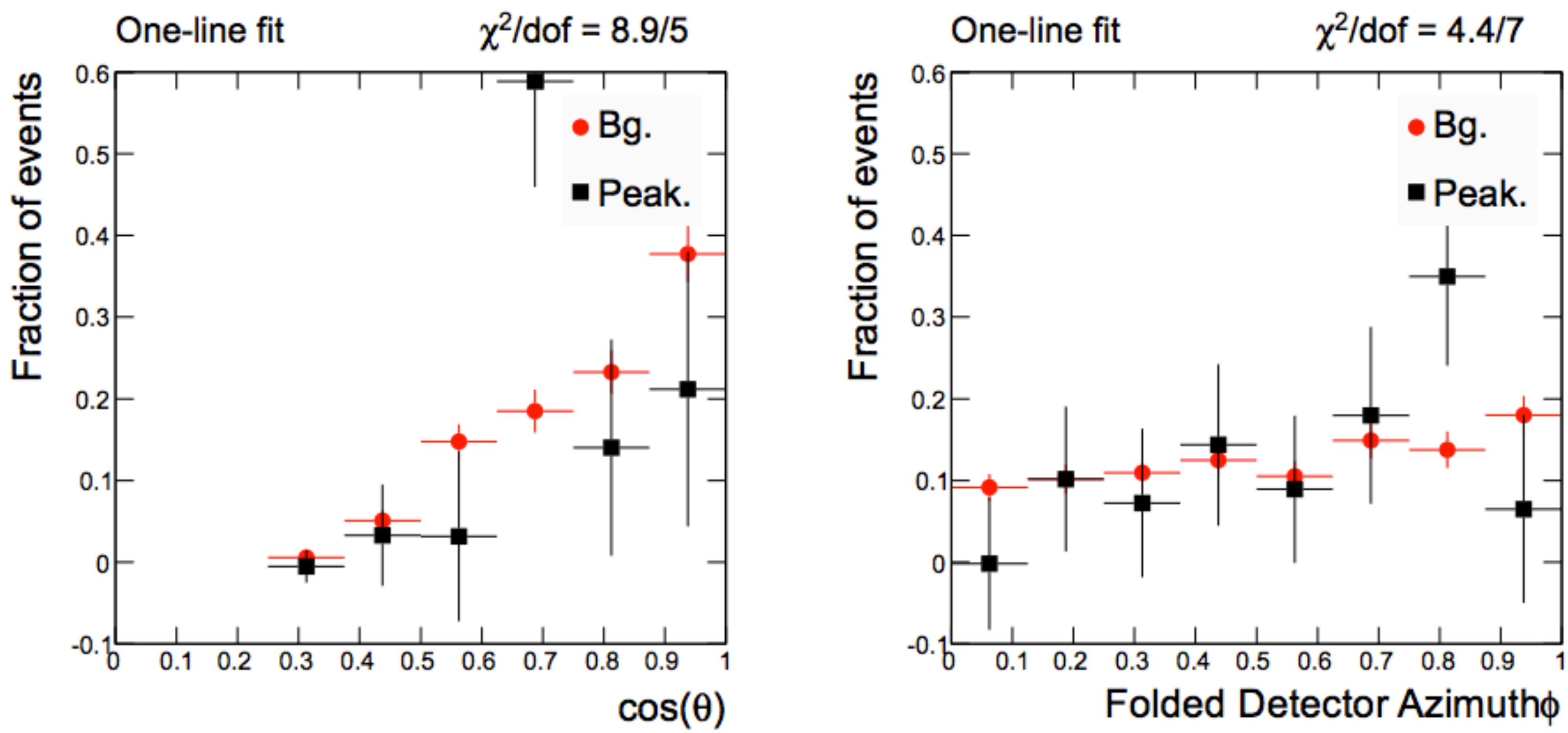
$$f_{\text{peak}}(x,y) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}(y-5)^2} \times \frac{10-x}{50}$$

$$f_{\text{non-peak}}(x,y) = \frac{x}{50}$$



Whiteson
1208.3677

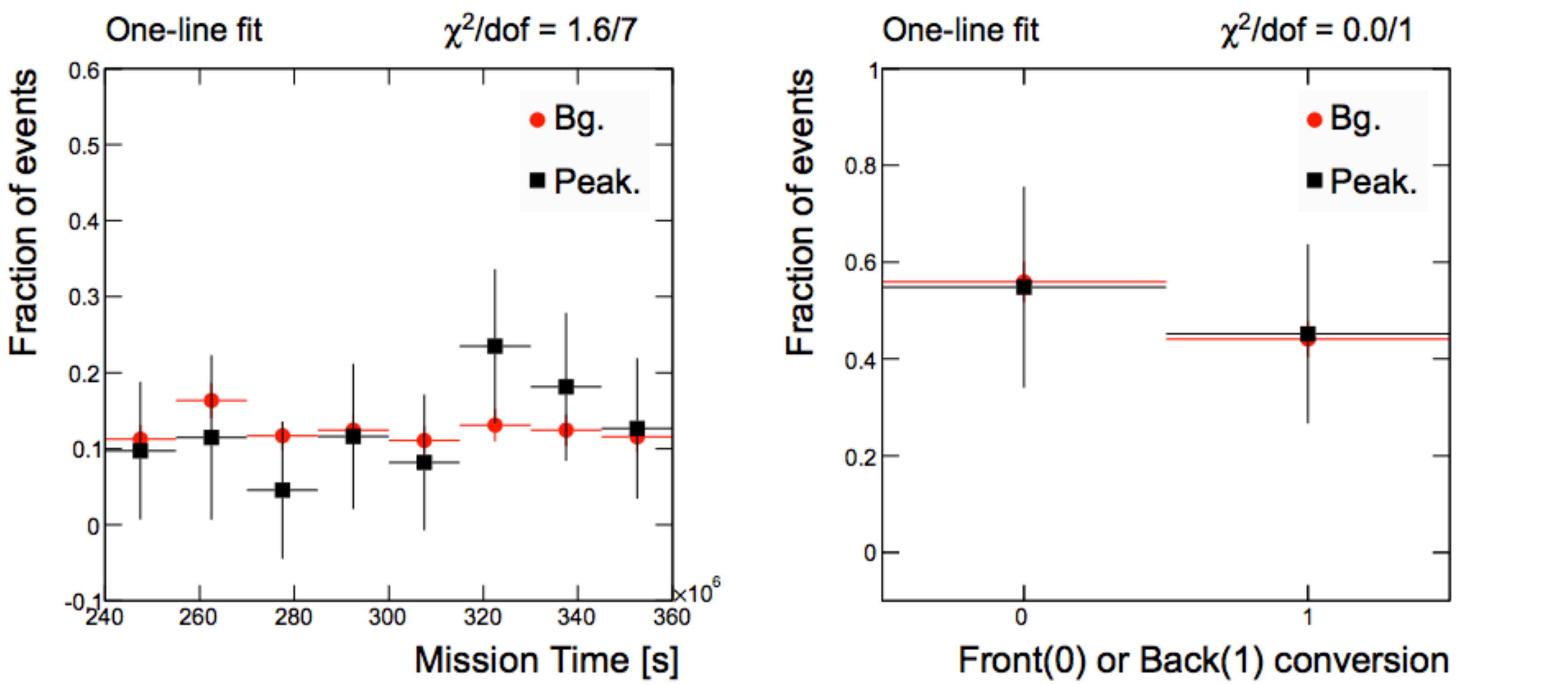
Results



- incident angle θ, measured with respect to the top-face normal of the LAT,
- azimuth angle ϕ, measured with respect to the top-face normal of the LAT, folded as described in Eq. (15) of Ref. [11].

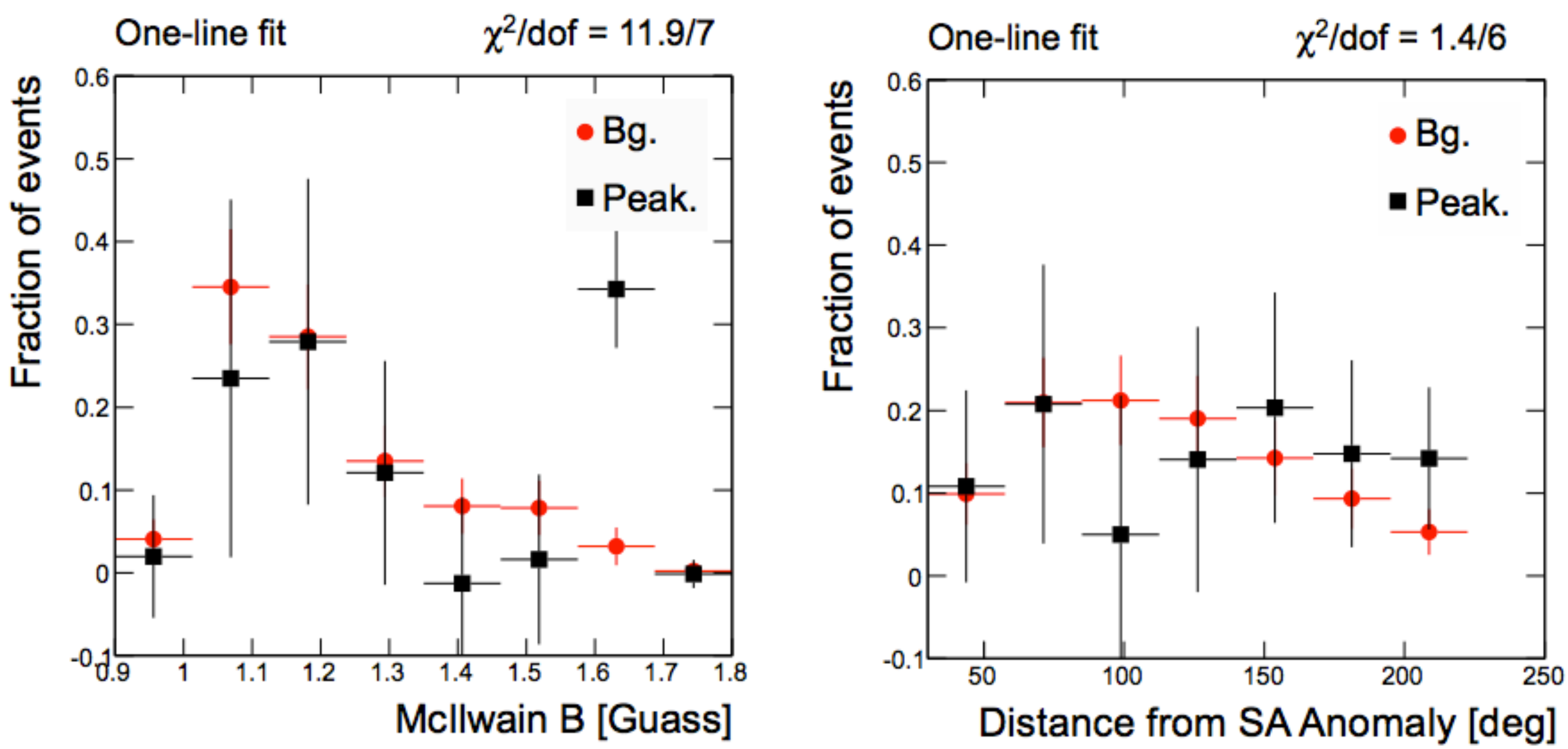
Whiteson
1208.3677

variables



Whiteson
1208.3677

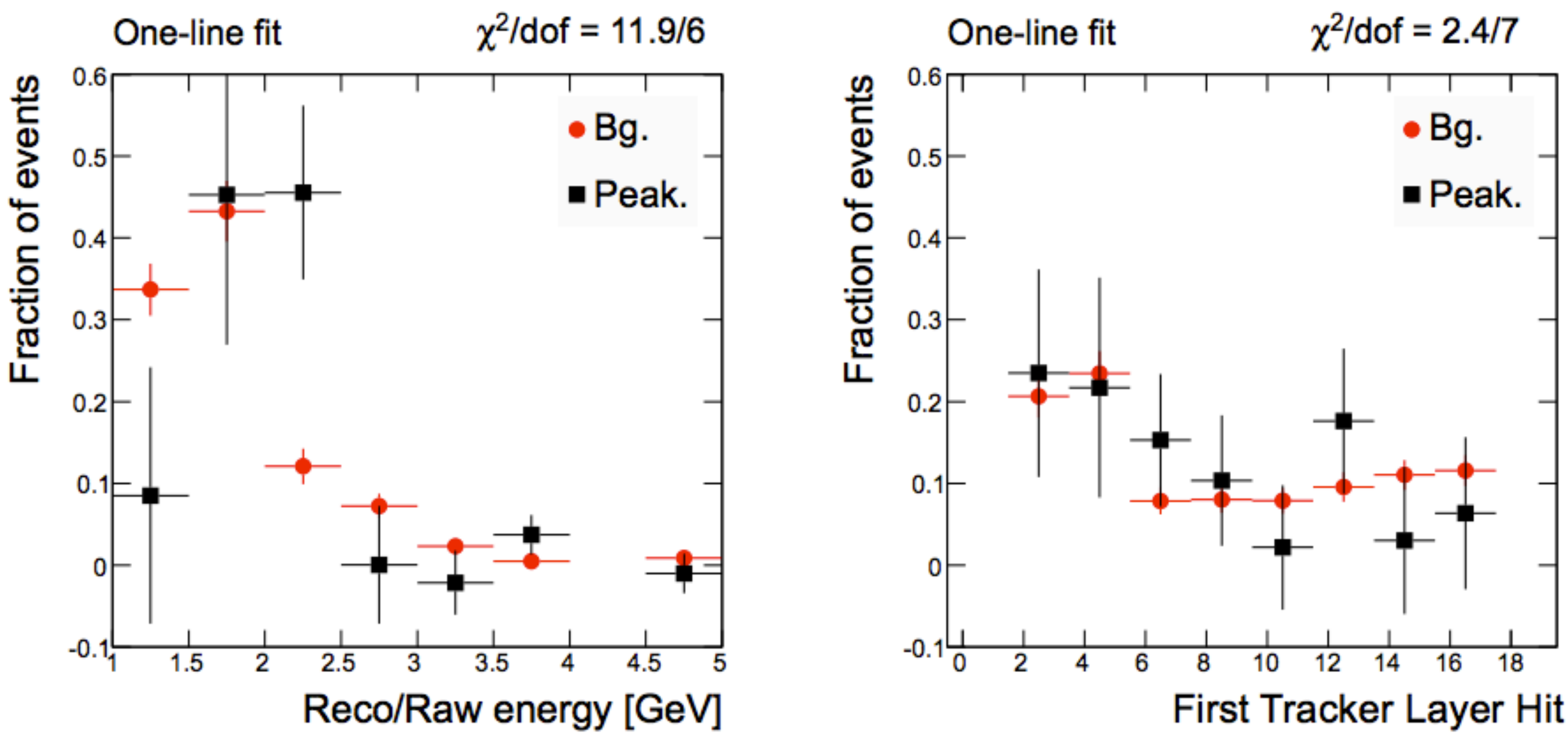
External issues?



Whiteson
1208.3677

- the magnetic field in which the LAT is immersed, as parameterized by the McIlwain B and L parameters [14],

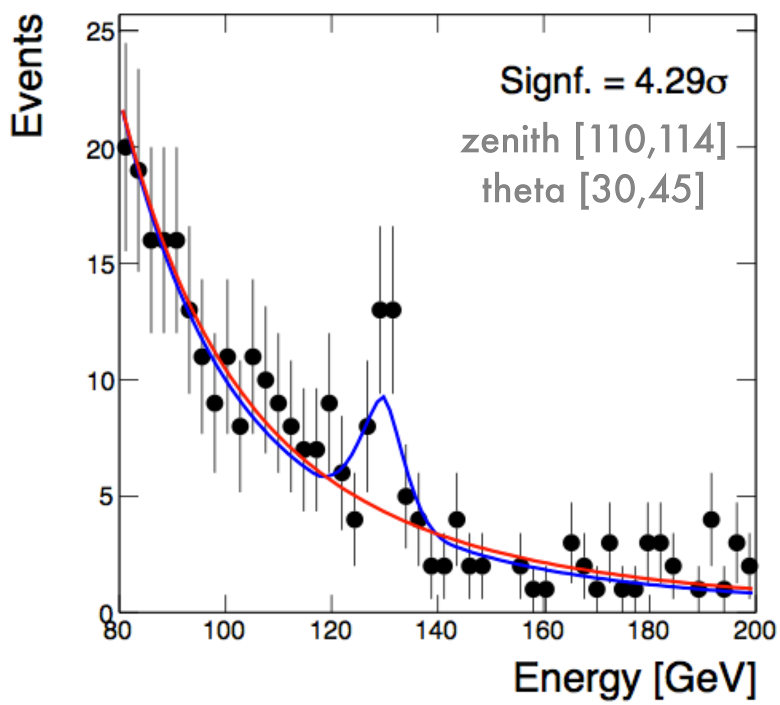
Reconstruction

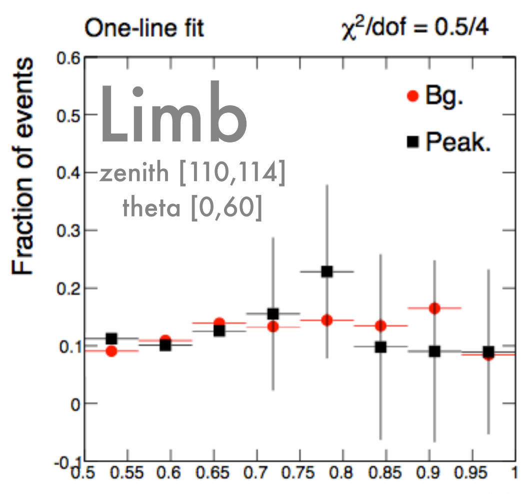


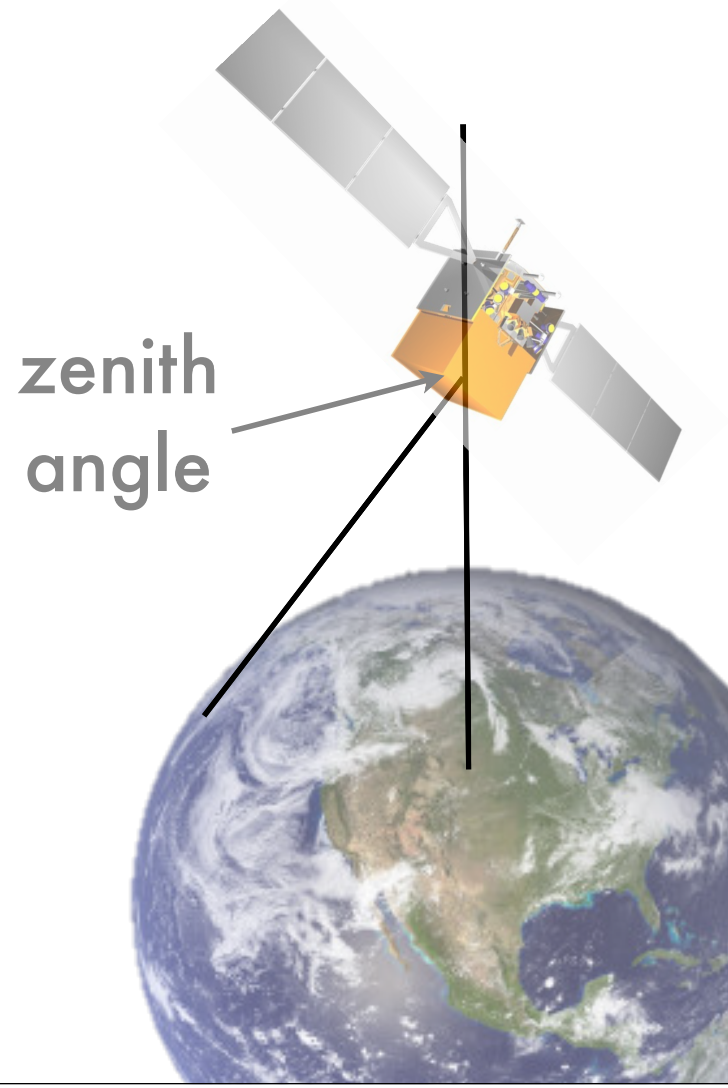
Whiteson
1208.3677

Limb

1st reported:
Finkbiener, et al
1209.4562

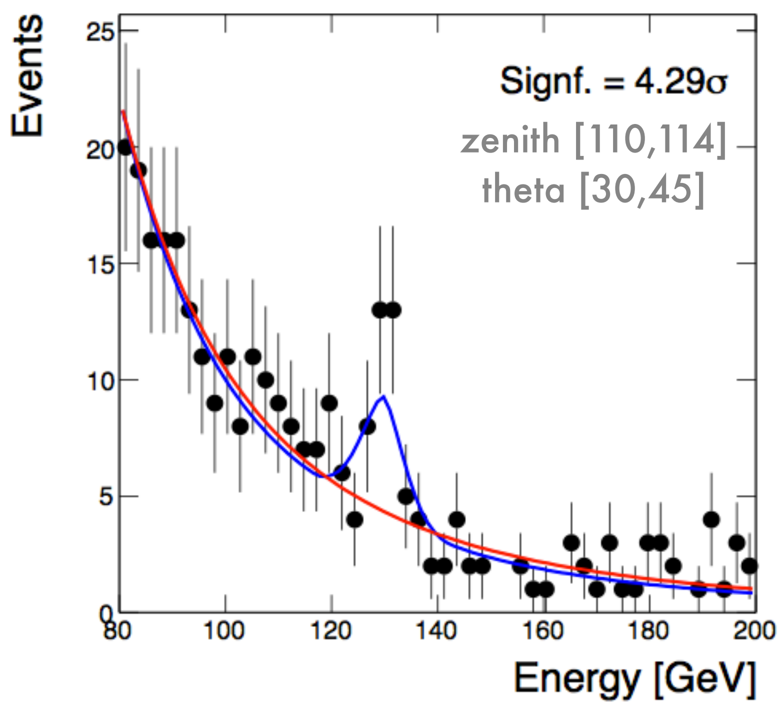


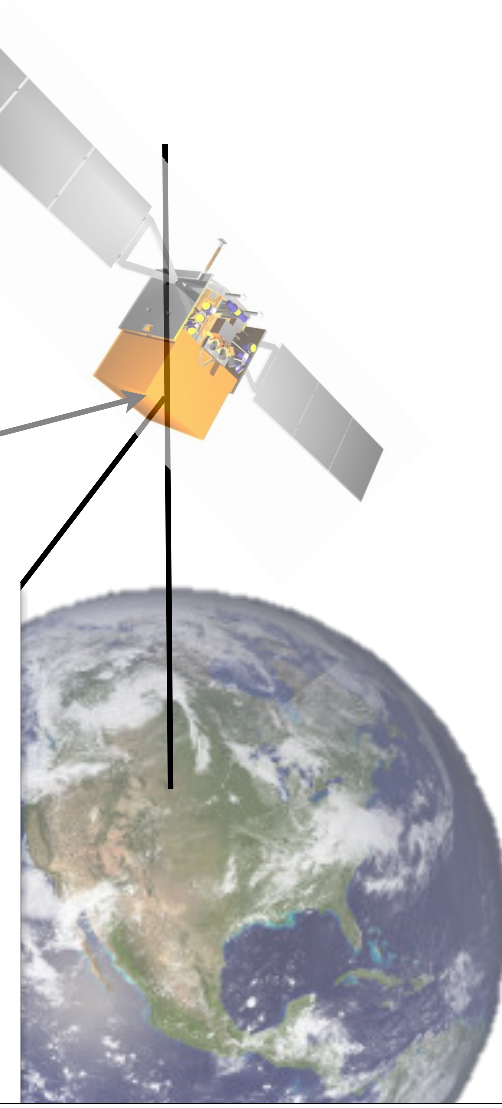


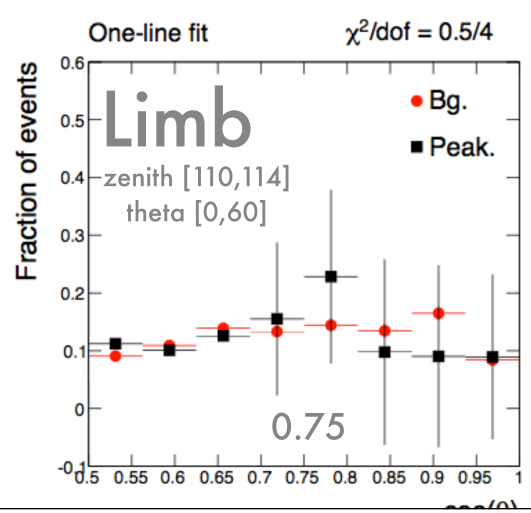


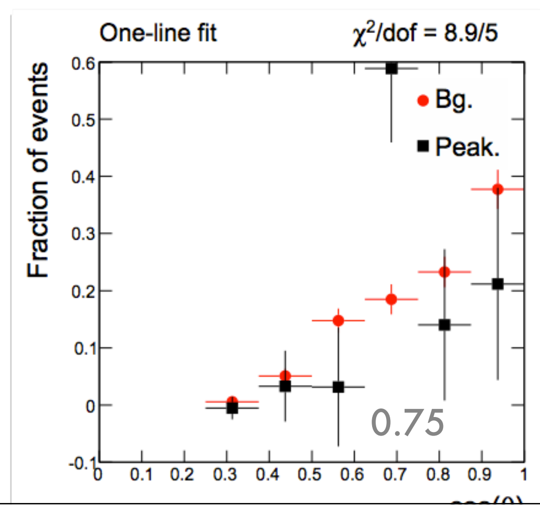
Limb

Whiteson
1302.0427







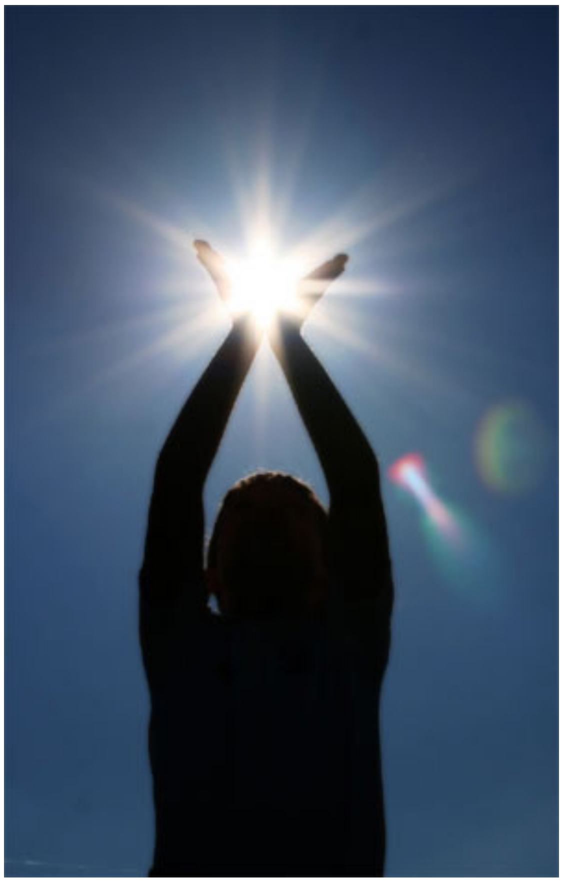


Other sources

Earth's limb is a powerful control region.

Are there other regions?

Other sources



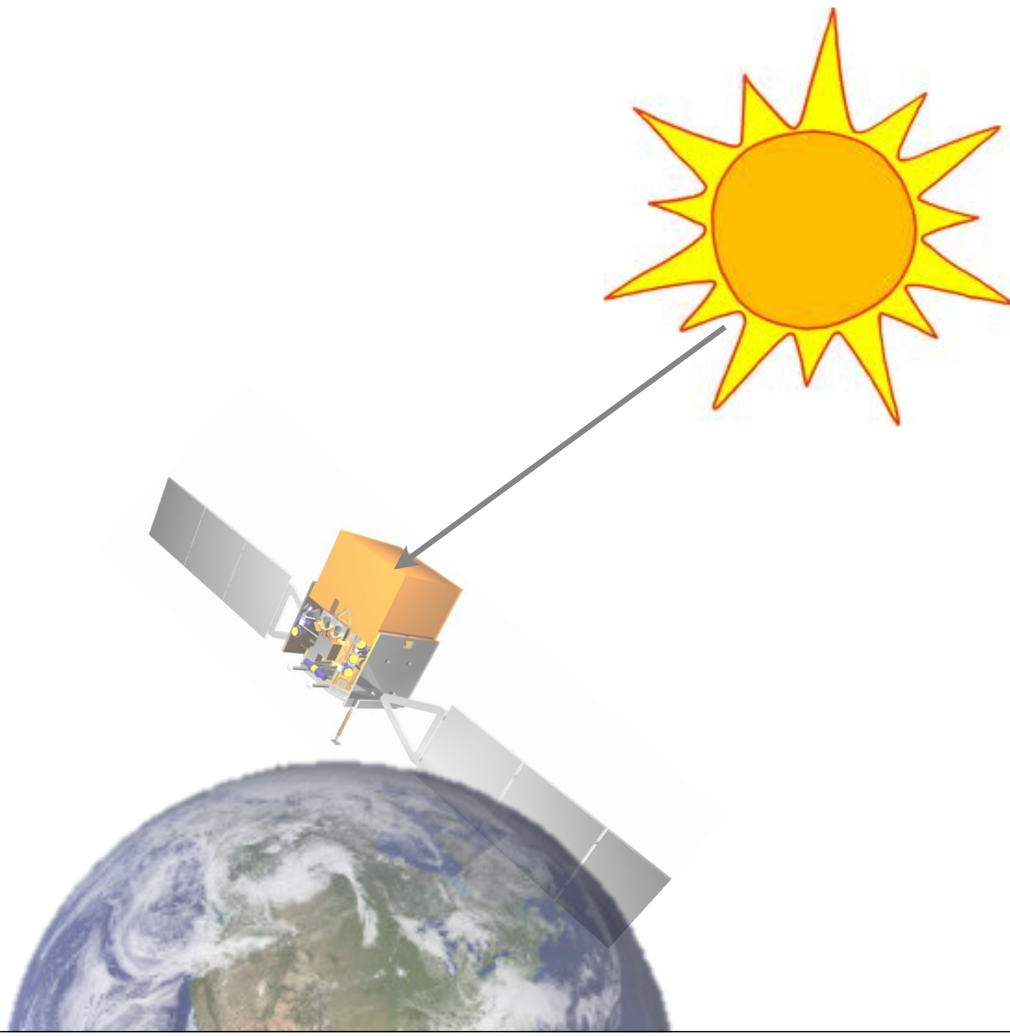
Earth's limb is a powerful control region.

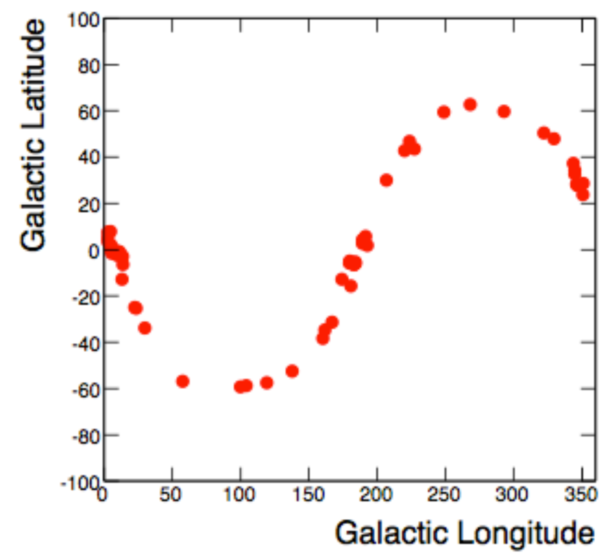
Are there other regions?

The Sun!

Solar region

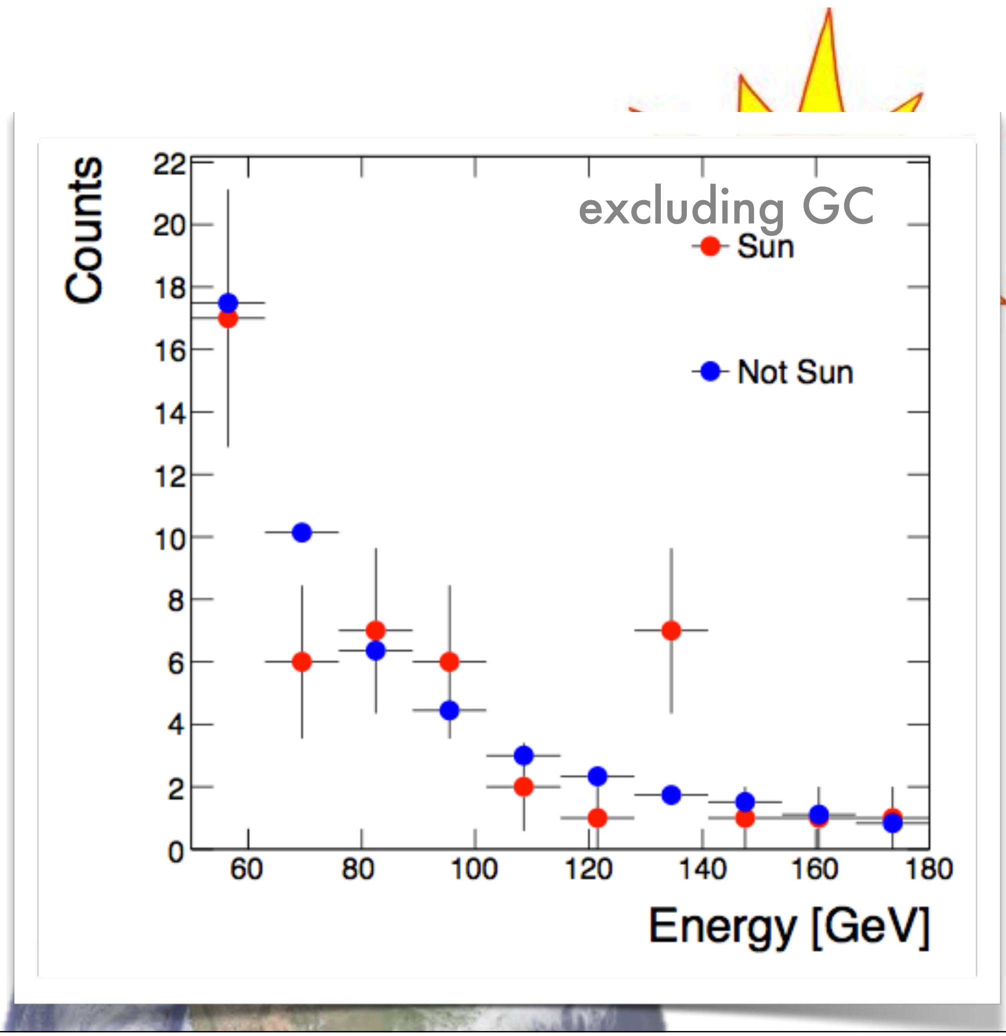
Find galactic coord of solar photons



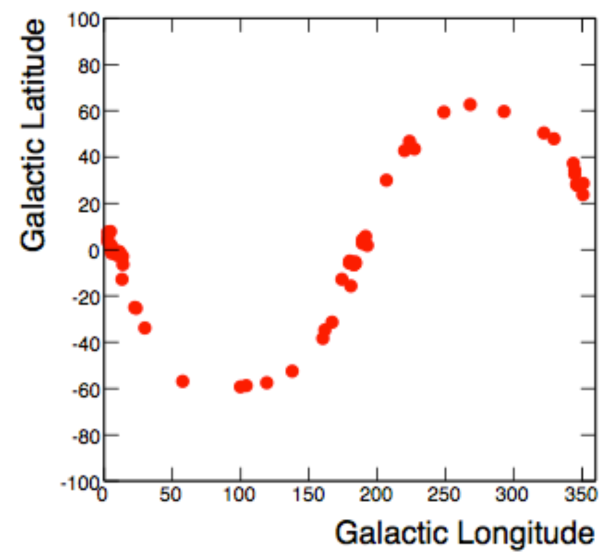


Solar region

Whiteson
1302.0427



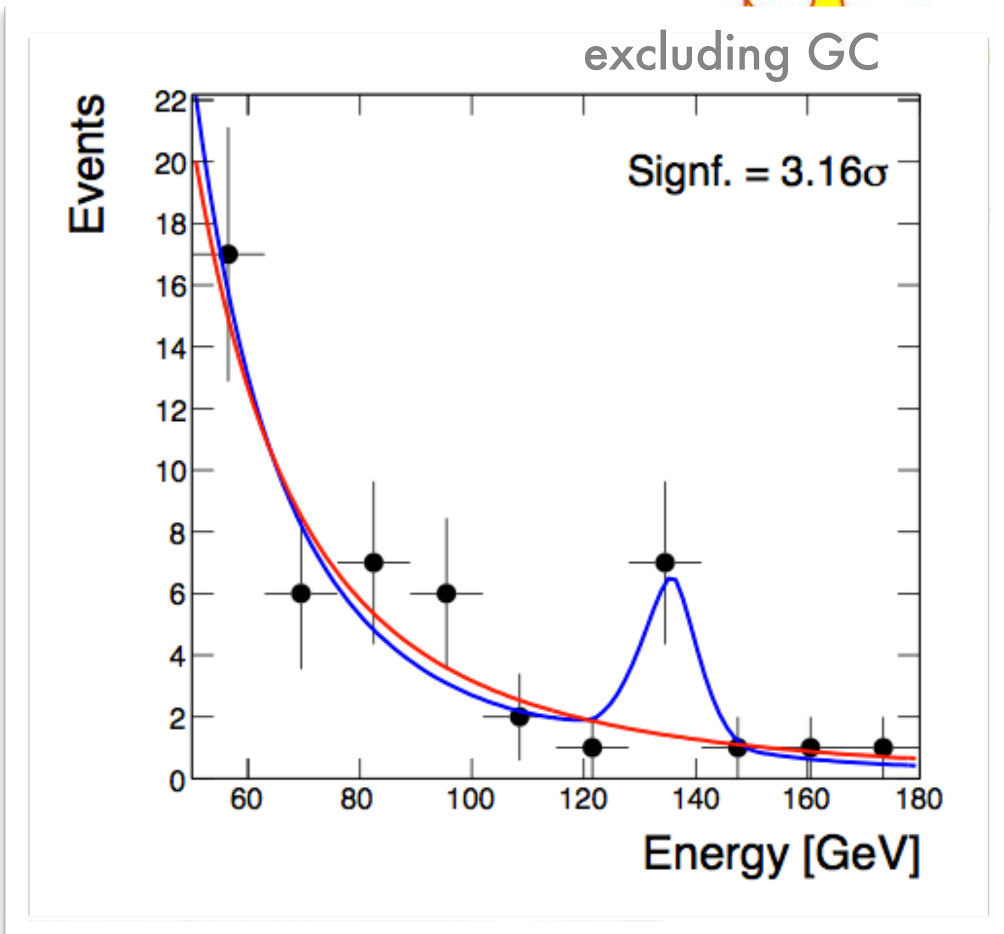
Find galactic coord of solar photons

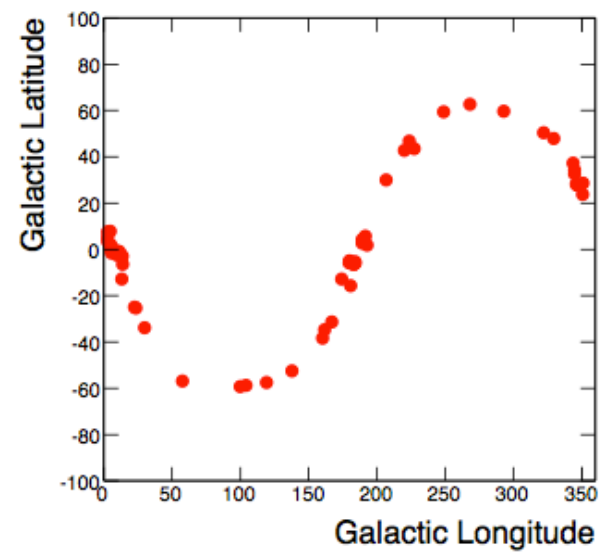


Solar region

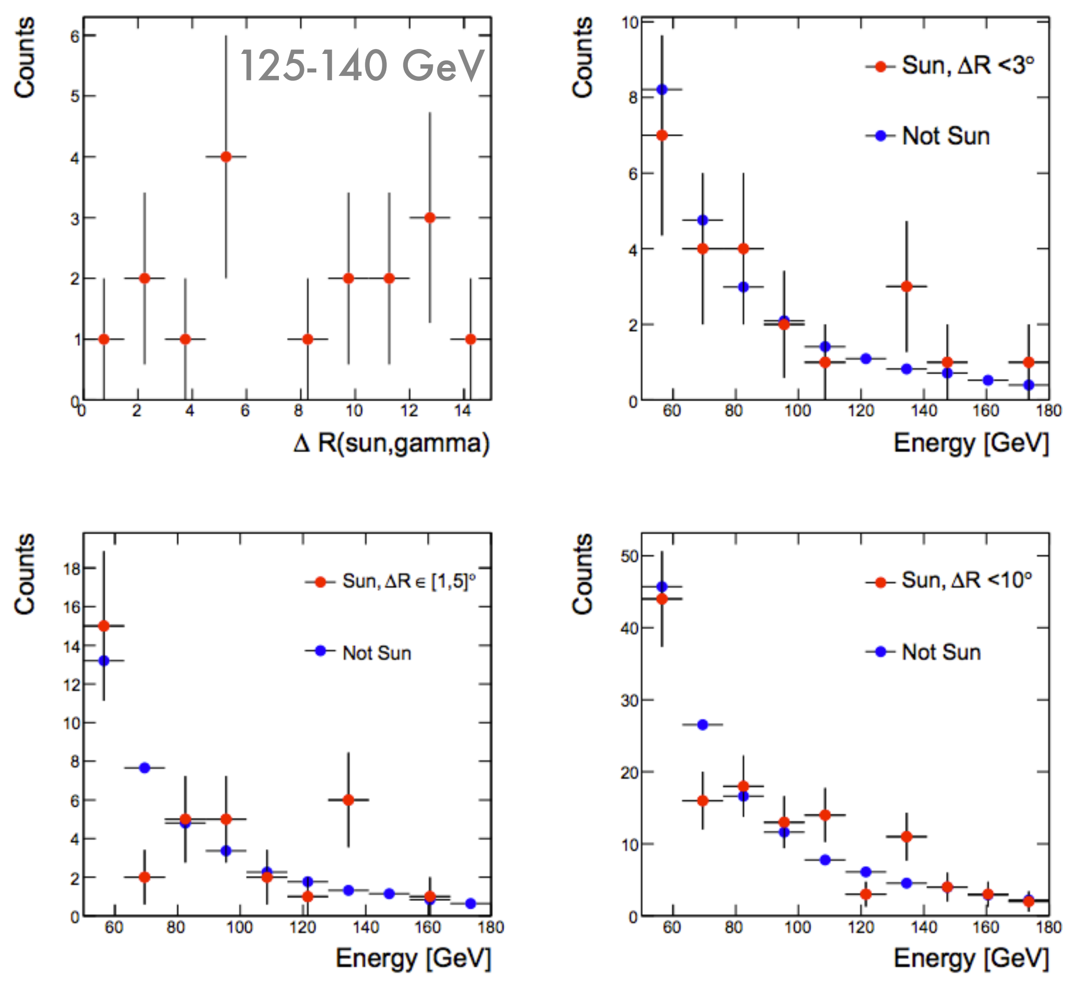
Whiteson
1302.0427

Find galactic coord of solar photons





Ring around the Sun



Lines Outline

1. Where are the photons from?
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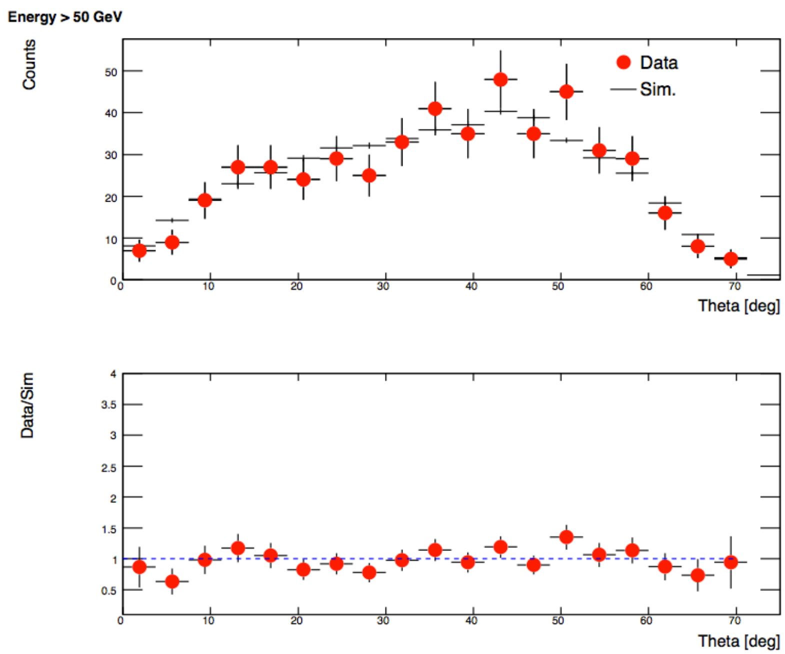
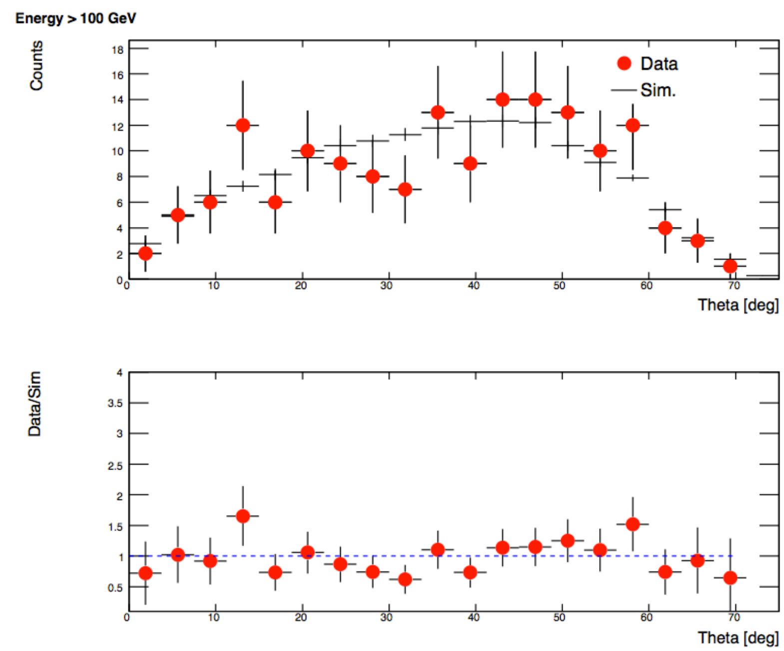
Simulation: GC

E>50

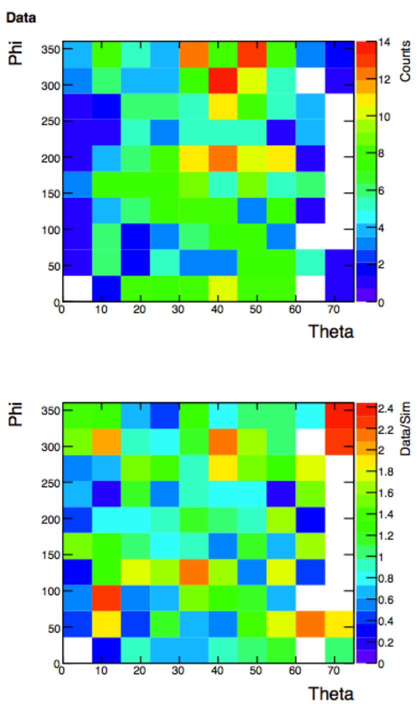


E>100

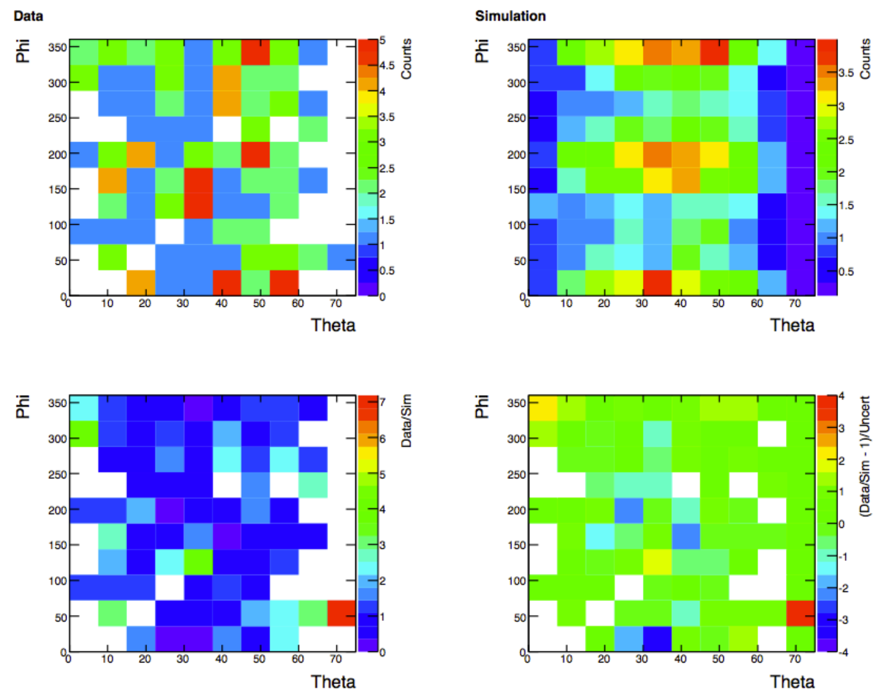


Simulation: GC

E>50



E>100



Lines Outline

1. Where are the photons from?
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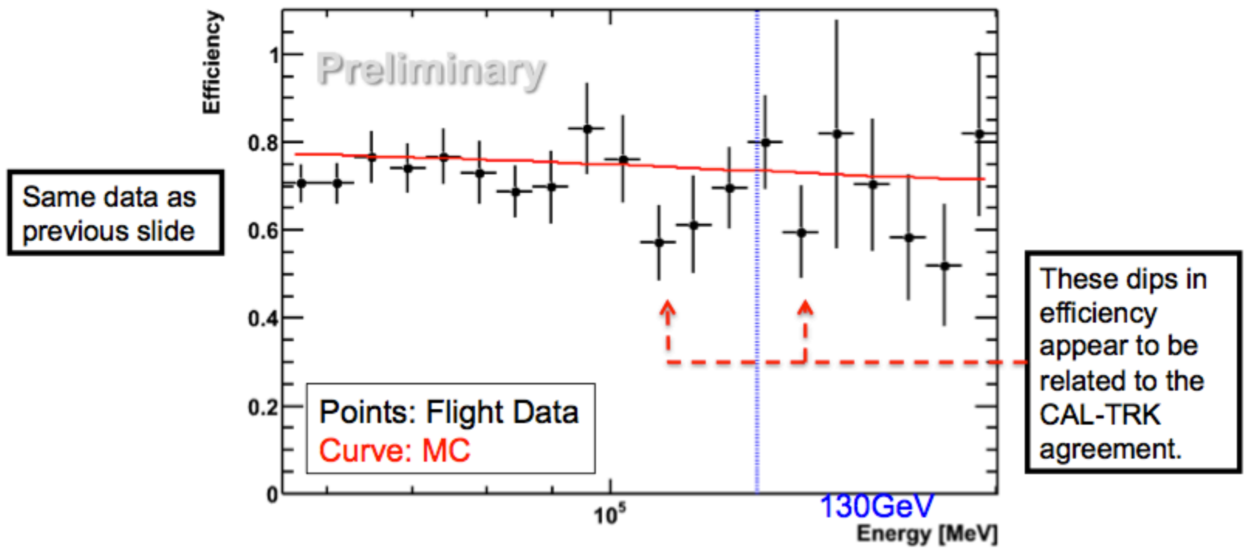
Symposium

P7TRANSIENT to P7CLEAN Efficiency

15



The efficiency at ~115Gev is 0.57/0.75 = 75% of the MC prediction. This would imply a 30% boost in signal at 130 GeV relative to the prediction from nearby energy bins.

Eric Charles

Simple explanation?

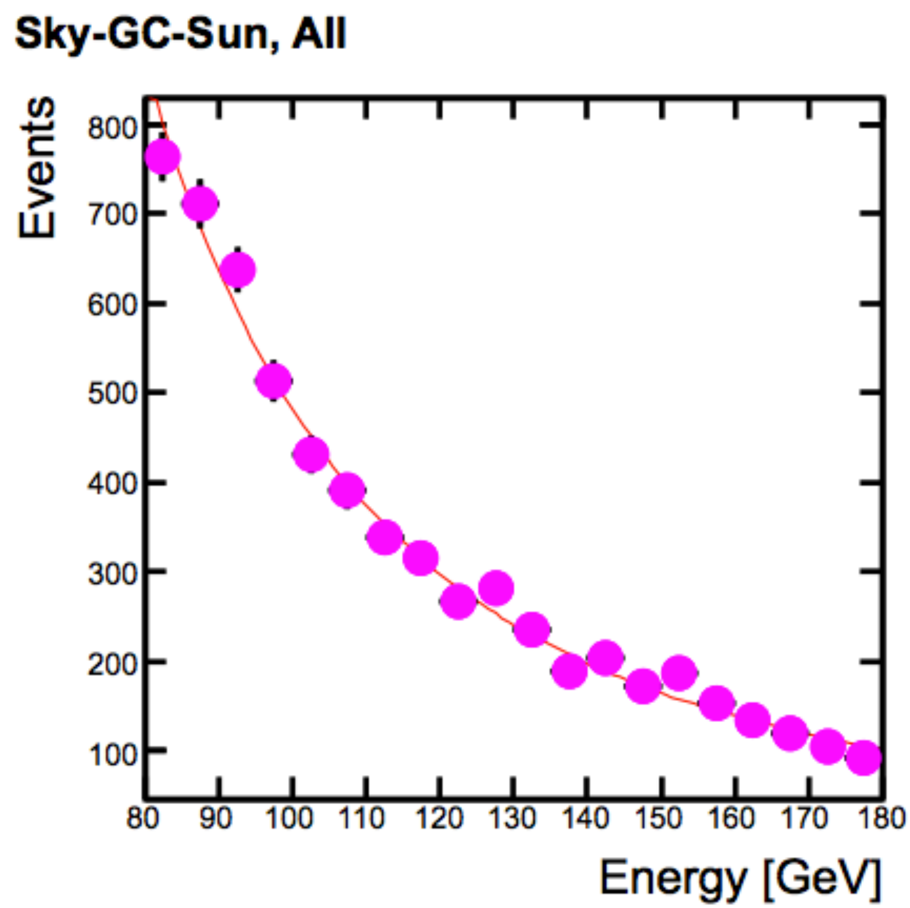
Is there a simple energy-dependent efficiency?

Simple explanation?

Is there a simple energy-dependent efficiency?

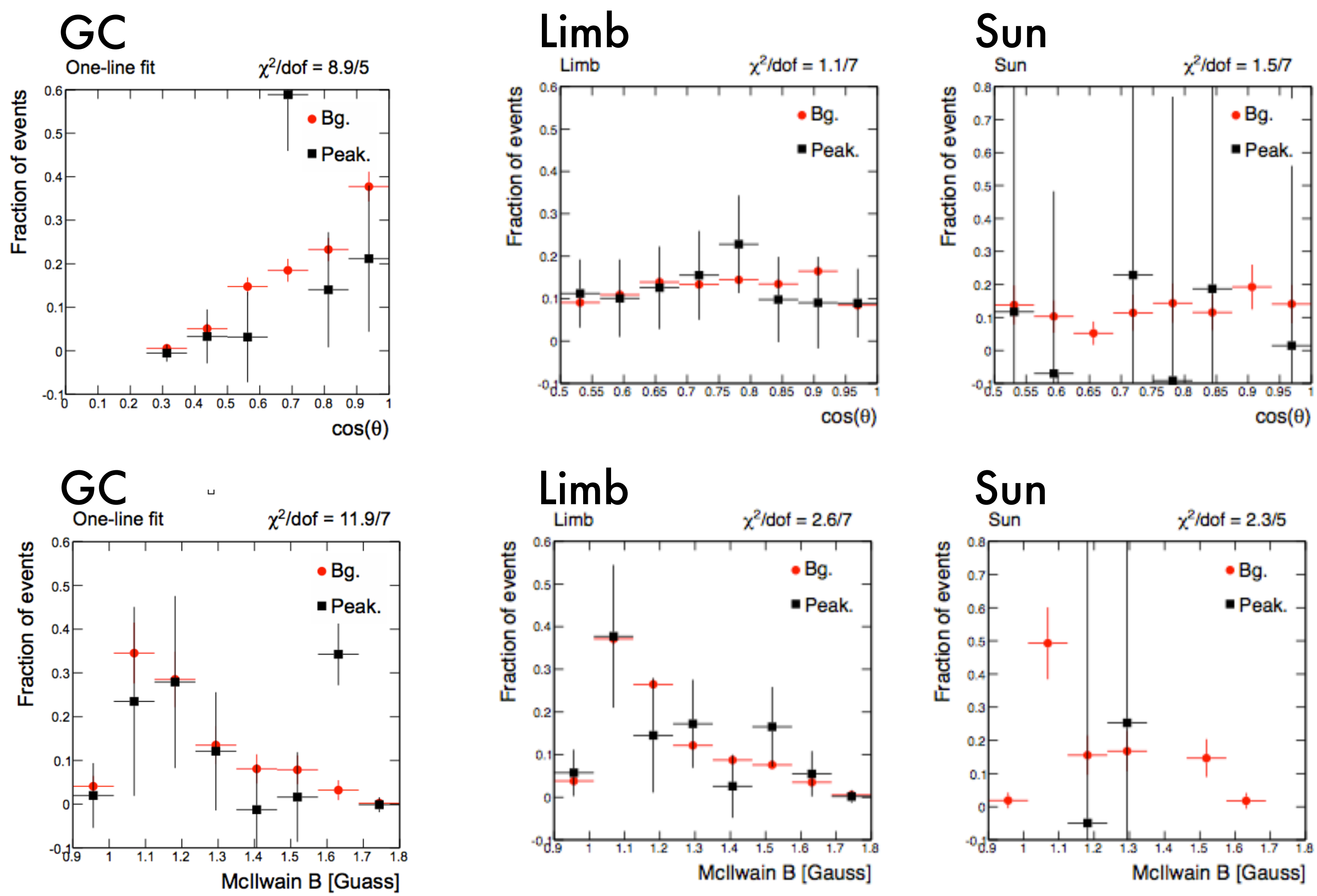
<u>Fails to explain</u>

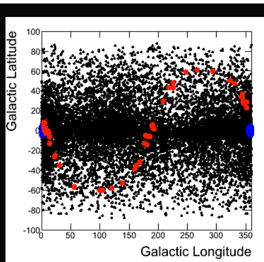
- localization of peak near GC, Limb
- theta-dependence of Limb peak
- lack of feature in remainder of Sky



Common features?

Whiteson
1302.0427

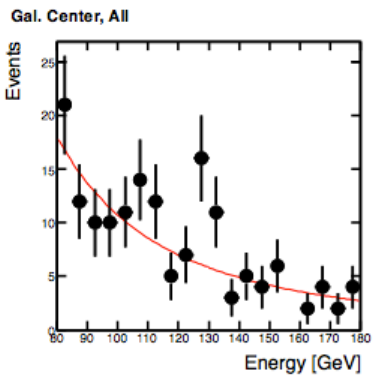
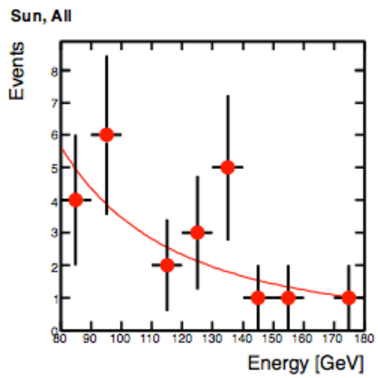
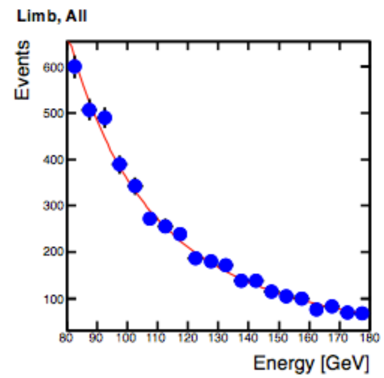
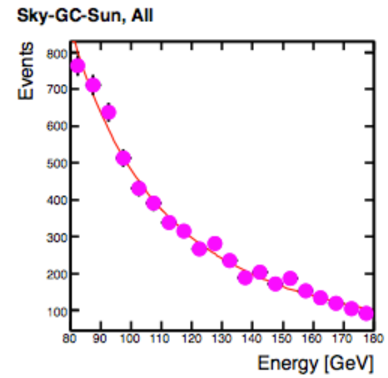


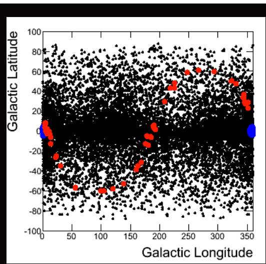


GC
Sun
Sky-GC-Sun

theta

Whiteson
1302.0427

	GC	Sun	Limb	Sky-GC-Sun
All				



GC
Sun
Sky-GC-Sun

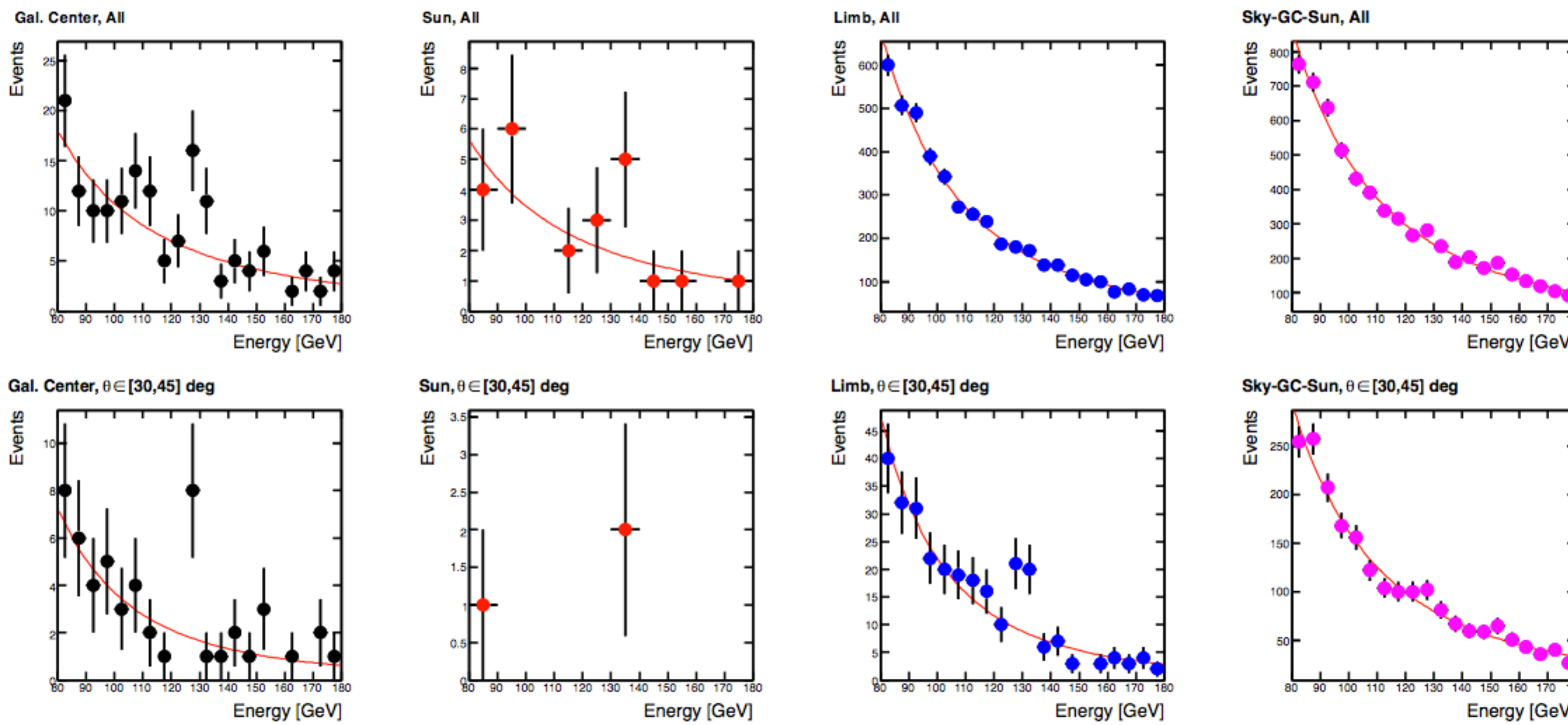
theta

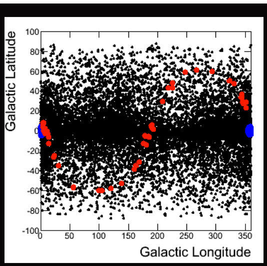
Whiteson
1302.0427

GC | Sun | Limb | Sky-GC-Sun

All

Theta [30,45]





GC
Sun
Sky-GC-Sun

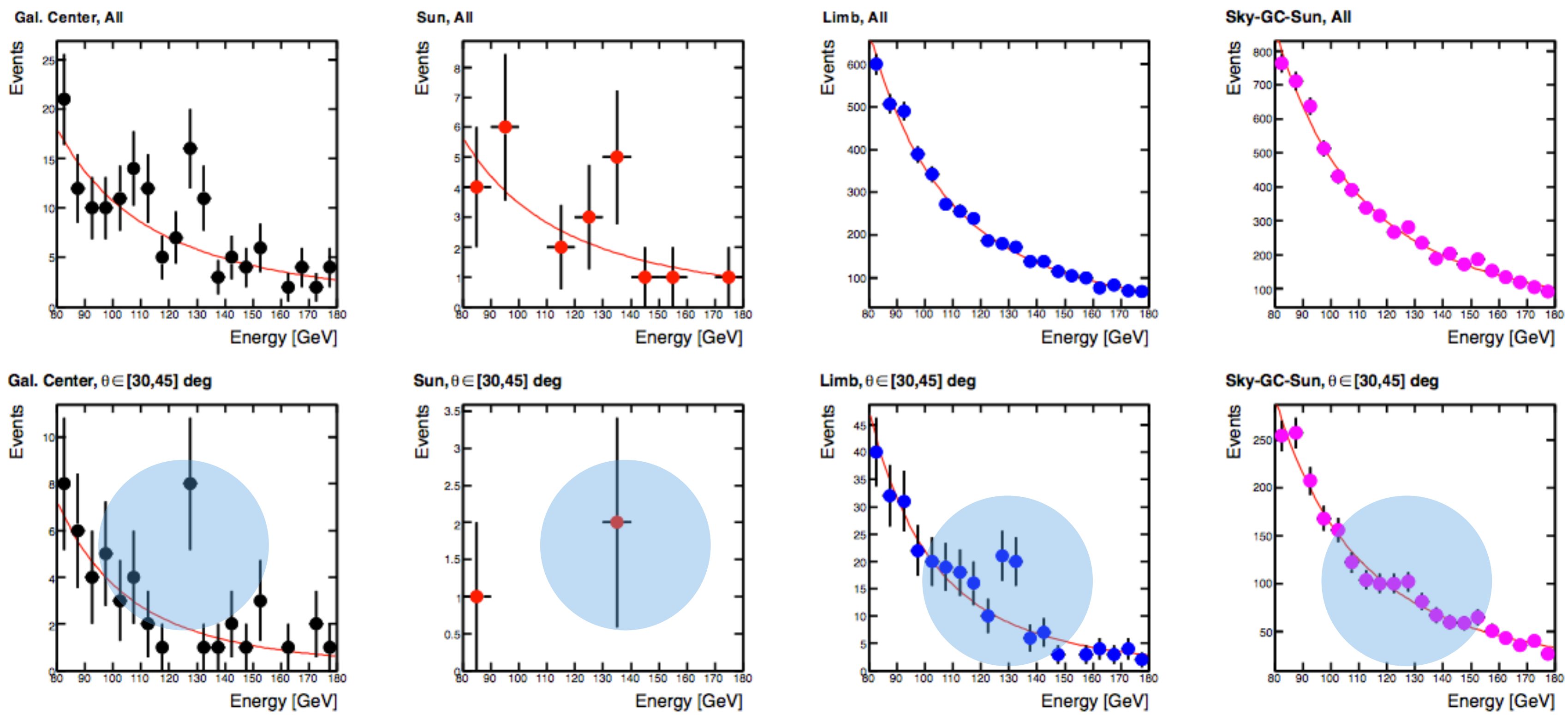
theta

Whiteson
1302.0427

GC | Sun | Limb | Sky-GC-Sun

All

Theta [30,45]



Discussion

Not a simple energy-dependent efficiency

- Not seen in full sky

Not a energy-and-theta-dependent efficiency

- GC peak not isolated to theta [30,45]
- Not seen in full sky with theta restriction (but a hint?)

More complex efficiency dependence?

- Sun/Limb/GC sweep out different paths across detector
- No clues seen in efficiency checks

The Fermi Lines

Are they real?

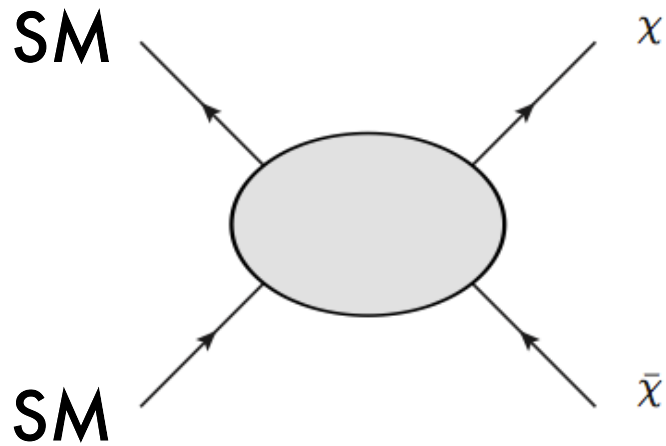
..and LHC mono-X

Daniel Whiteson

UC Irvine

DM at LHC

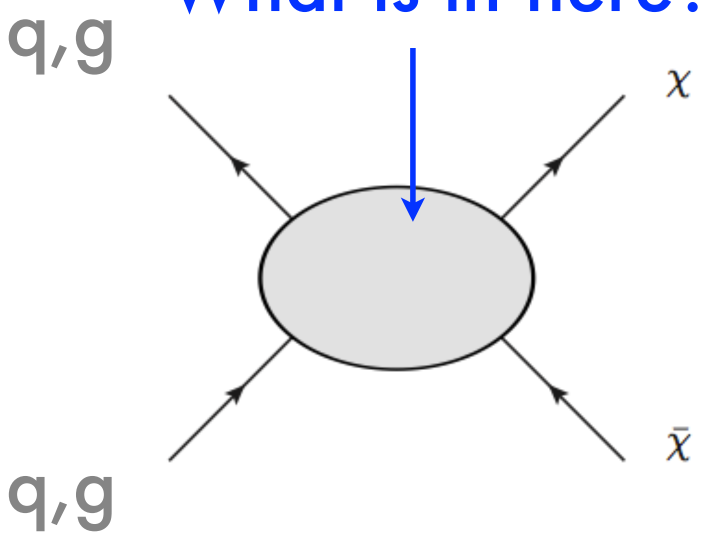
Direct weak production...



..via intermediate heavy particle

Effective field theories

What is in here?



Allows connections to direct, indirect exp.

$$\sigma_0^{D1} = 1.60 \times 10^{-37}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{20\mathrm{GeV}}{M_*}\right)^6,$$

$$\sigma_0^{D5,C3} = 1.38 \times 10^{-37}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{300\mathrm{GeV}}{M_*}\right)^4,$$

$$\sigma_0^{D8,D9} = 9.18 \times 10^{-40}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{300\mathrm{GeV}}{M_*}\right)^4,$$

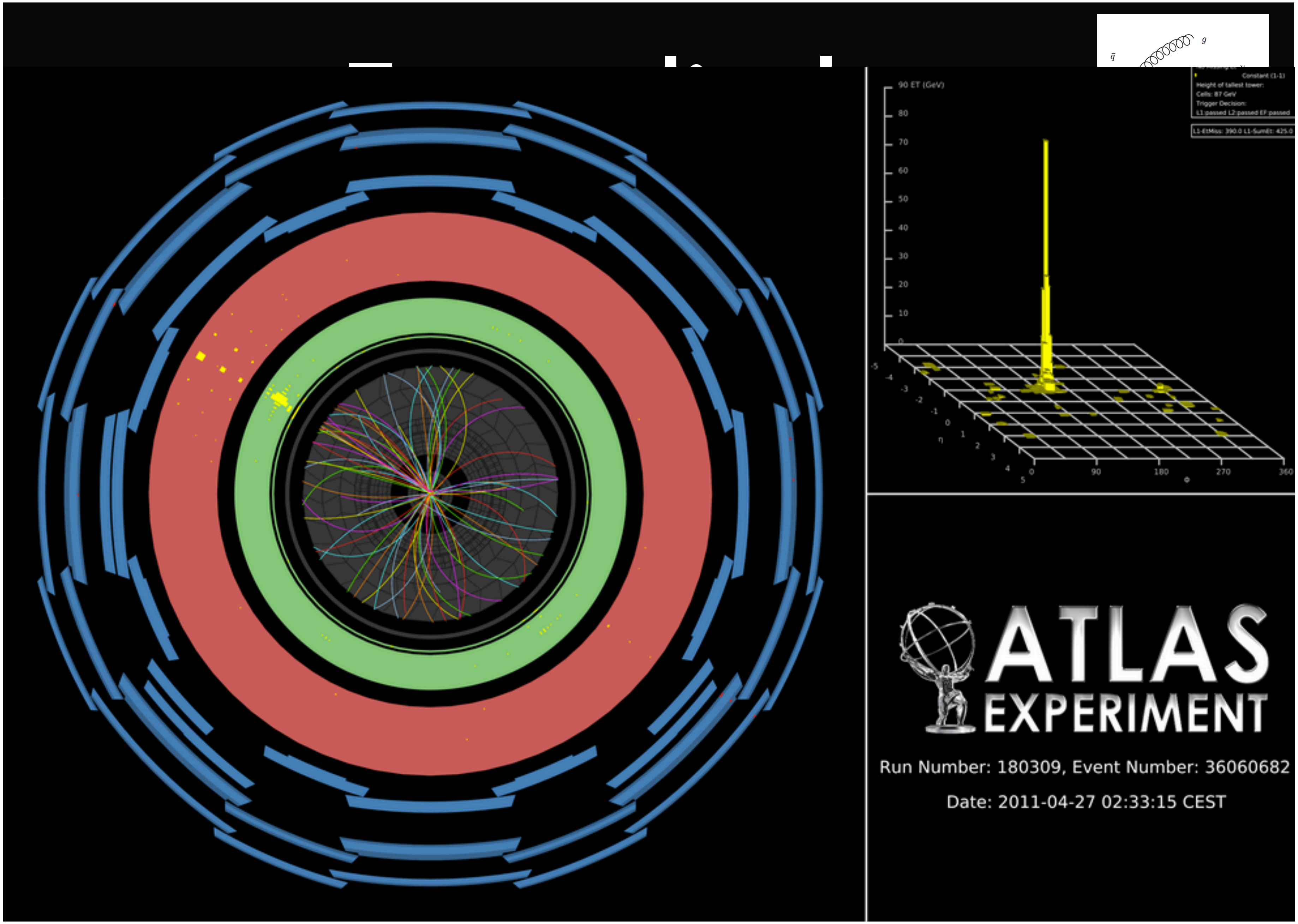
$$\sigma_0^{D11} = 3.83 \times 10^{-41}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{100\mathrm{GeV}}{M_*}\right)^6,$$

$$\sigma_0^{C1,R1} = 2.56 \times 10^{-36}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{10\mathrm{GeV}}{m_\chi}\right)^2 \left(\frac{10\mathrm{GeV}}{M_*}\right)^4,$$

$$\sigma_0^{C5,R3} = 7.40 \times 10^{-39}\mathrm{cm}^2 \left(\frac{\mu_\chi}{1\mathrm{GeV}}\right)^2 \left(\frac{10\mathrm{GeV}}{m_\chi}\right)^2 \left(\frac{60\mathrm{GeV}}{M_*}\right)^4.$$

A few possibilities

Name	Operator	Coefficient
D1	$\bar{\chi}\chi\bar{q}q$	m_q/M_*^3
D2	$\bar{\chi}\gamma^5\chi\bar{q}q$	im_q/M_*^3
D3	$\bar{\chi}\chi\bar{q}\gamma^5 q$	im_q/M_*^3
D4	$\bar{\chi}\gamma^5\chi\bar{q}\gamma^5 q$	m_q/M_*^3
D5	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D6	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu q$	$1/M_*^2$
D7	$\bar{\chi}\gamma^\mu\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D8	$\bar{\chi}\gamma^\mu\gamma^5\chi\bar{q}\gamma_\mu\gamma^5 q$	$1/M_*^2$
D9	$\bar{\chi}\sigma^{\mu\nu}\chi\bar{q}\sigma_{\mu\nu}q$	$1/M_*^2$
D10	$\bar{\chi}\sigma_{\mu\nu}\gamma^5\chi\bar{q}\sigma_{\alpha\beta}q$	i/M_*^2
D11	$\bar{\chi}\chi G_{\mu\nu}G^{\mu\nu}$	$\alpha_s/4M_*^3$
D12	$\bar{\chi}\gamma^5\chi G_{\mu\nu}G^{\mu\nu}$	$i\alpha_s/4M_*^3$
D13	$\bar{\chi}\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$i\alpha_s/4M_*^3$
D14	$\bar{\chi}\gamma^5\chi G_{\mu\nu}\tilde{G}^{\mu\nu}$	$\alpha_s/4M_*^3$


ATLAS
EXPERIMENT
Run Number: 180309, Event Number: 36060682
Date: 2011-04-27 02:33:15 CEST
90 ET (GeV)
η
φ

8 TeV Preliminary

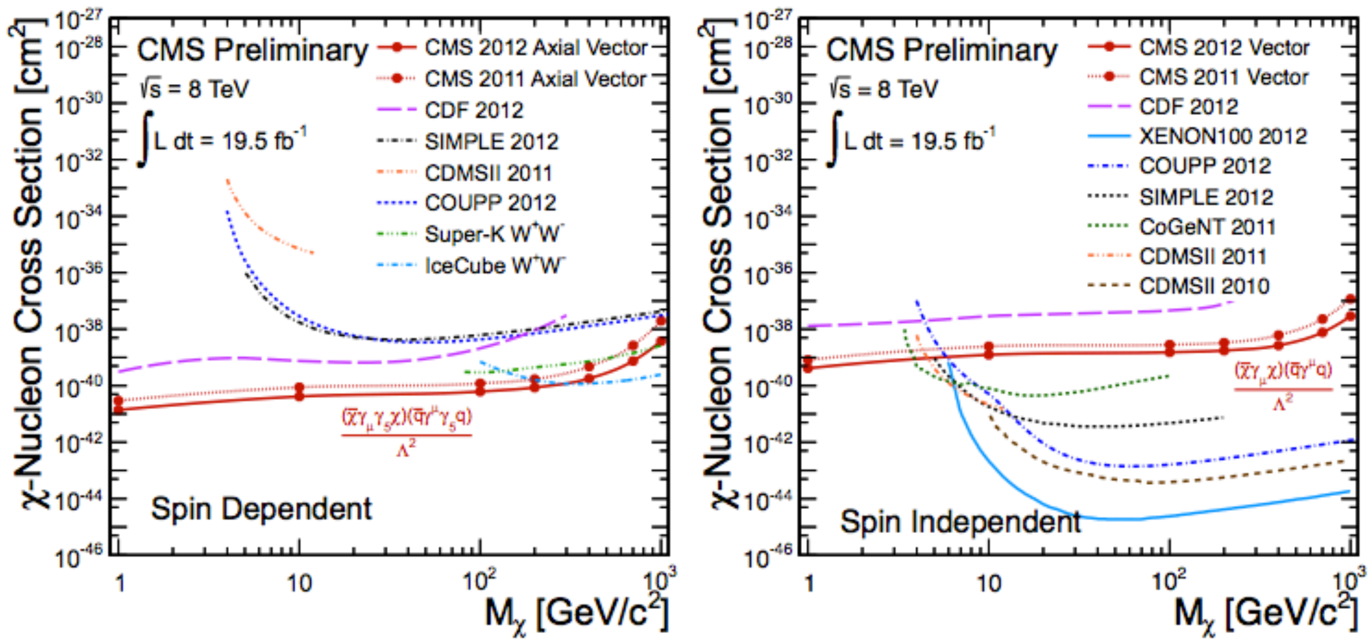
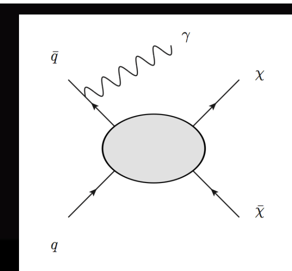
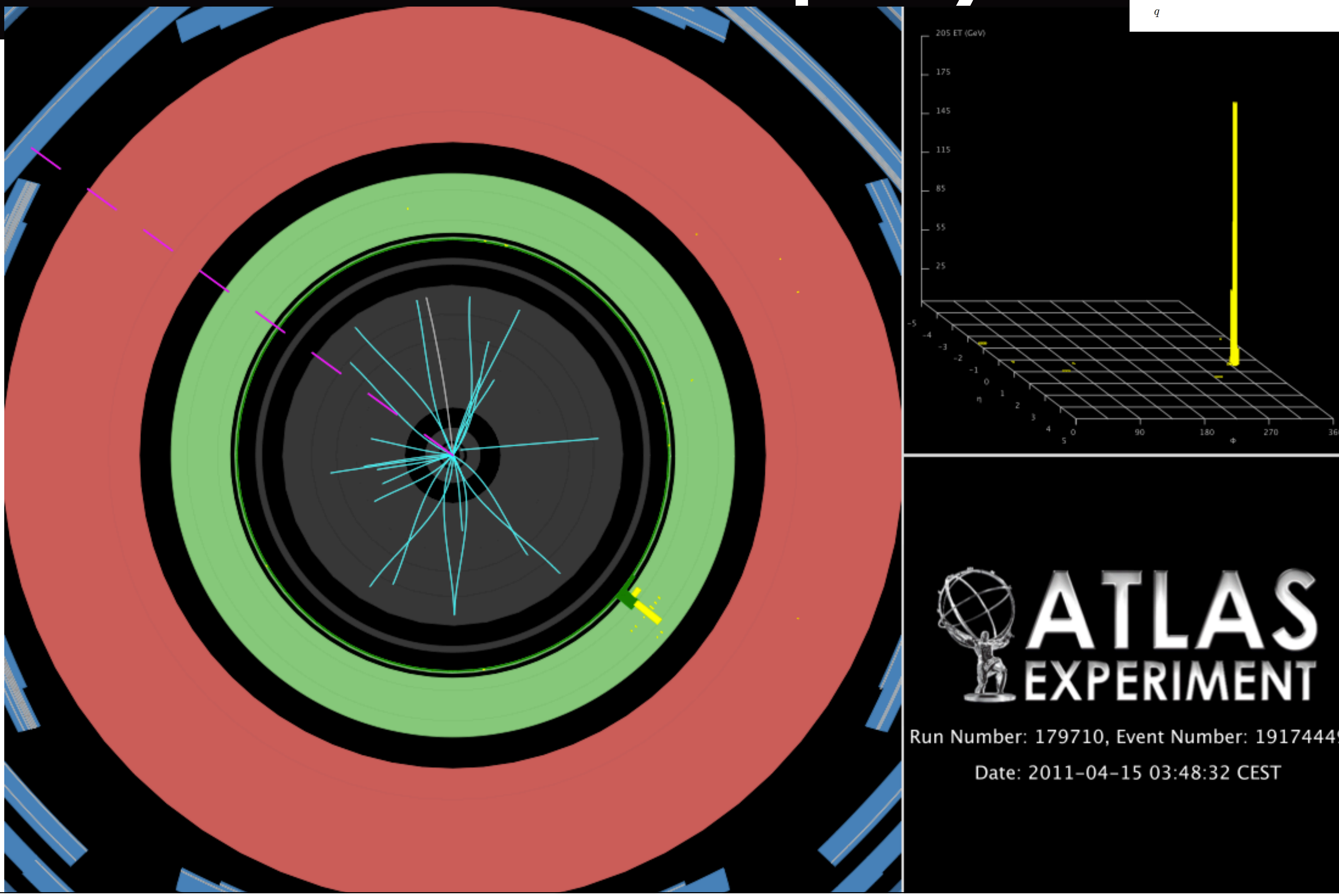


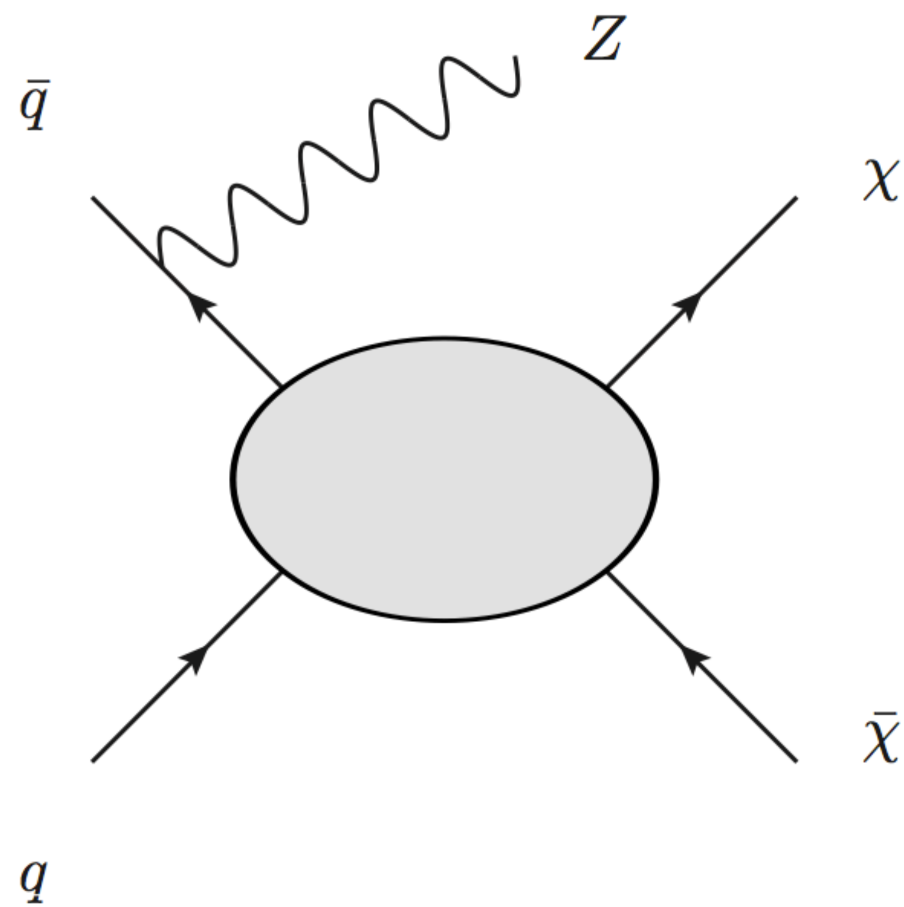
Figure 7: Comparison of CMS 90% CL upper limits on the dark matter-nucleon cross section versus dark matter mass for the vector operator with CDF [54], SIMPLE [55], CDMS [21], COUPP [56], Super-K [26] and IceCube [25] and for the axial-vector operator with CDF [54], XENON100 [18], CoGeNT [19] and CDMS [21, 22]

Event display





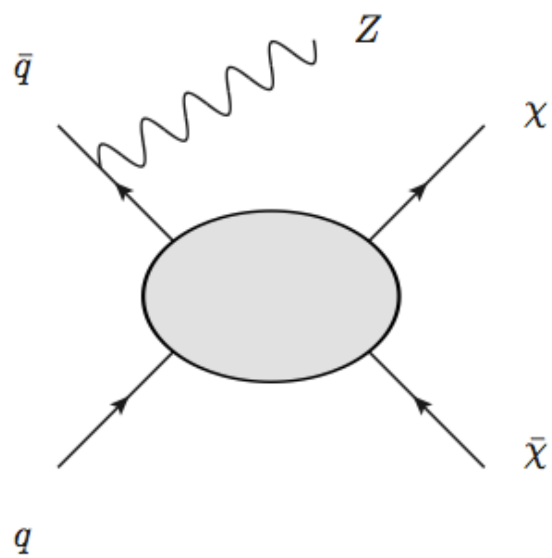
Mono-Z

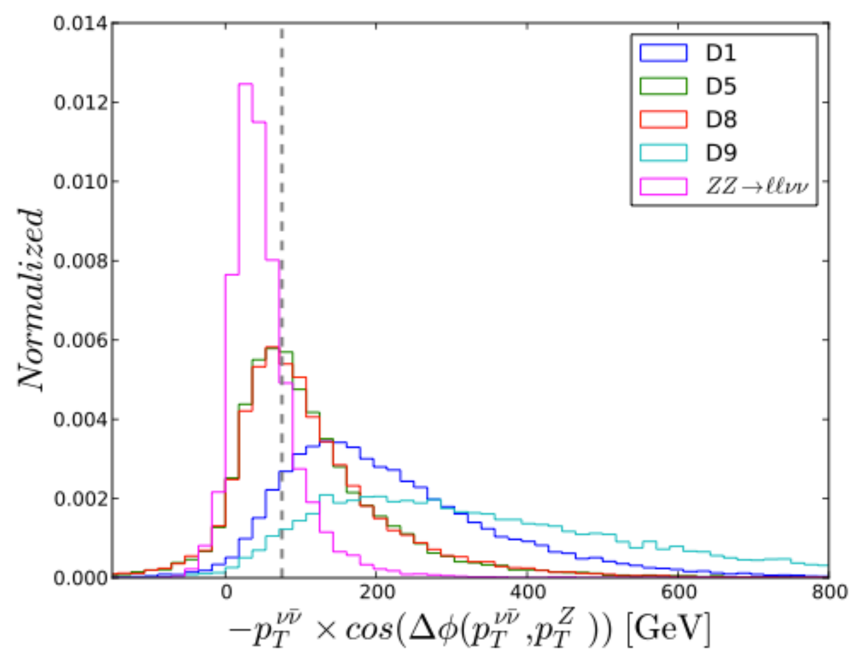


Mono-Z

TABLE II: Expected backgrounds and observed data in the ATLAS $ZZ \to \ell\ell\nu\nu$ analysis [8] in pp collisions at $\sqrt{s} = 7$ TeV with integrated luminosity of 4.6 fb^{-1}. The first uncertainty is statistical and systematic and the second uncertainty is luminosity.

	$ee\nu\nu$	$\mu\mu\nu\nu$	$\ell\ell\nu\nu$
Background	20.8 ± 2.7	26.1 ± 3.3	46.9 ± 5.5
SM $ZZ \to \ell\ell\nu\nu$	17.8 ± 1.8	21.6 ± 2.2	39.3 ± 4.0
Total	38.6 ± 3.8	47.7 ± 4.6	86.2 ± 7.2
Data	35	52	87

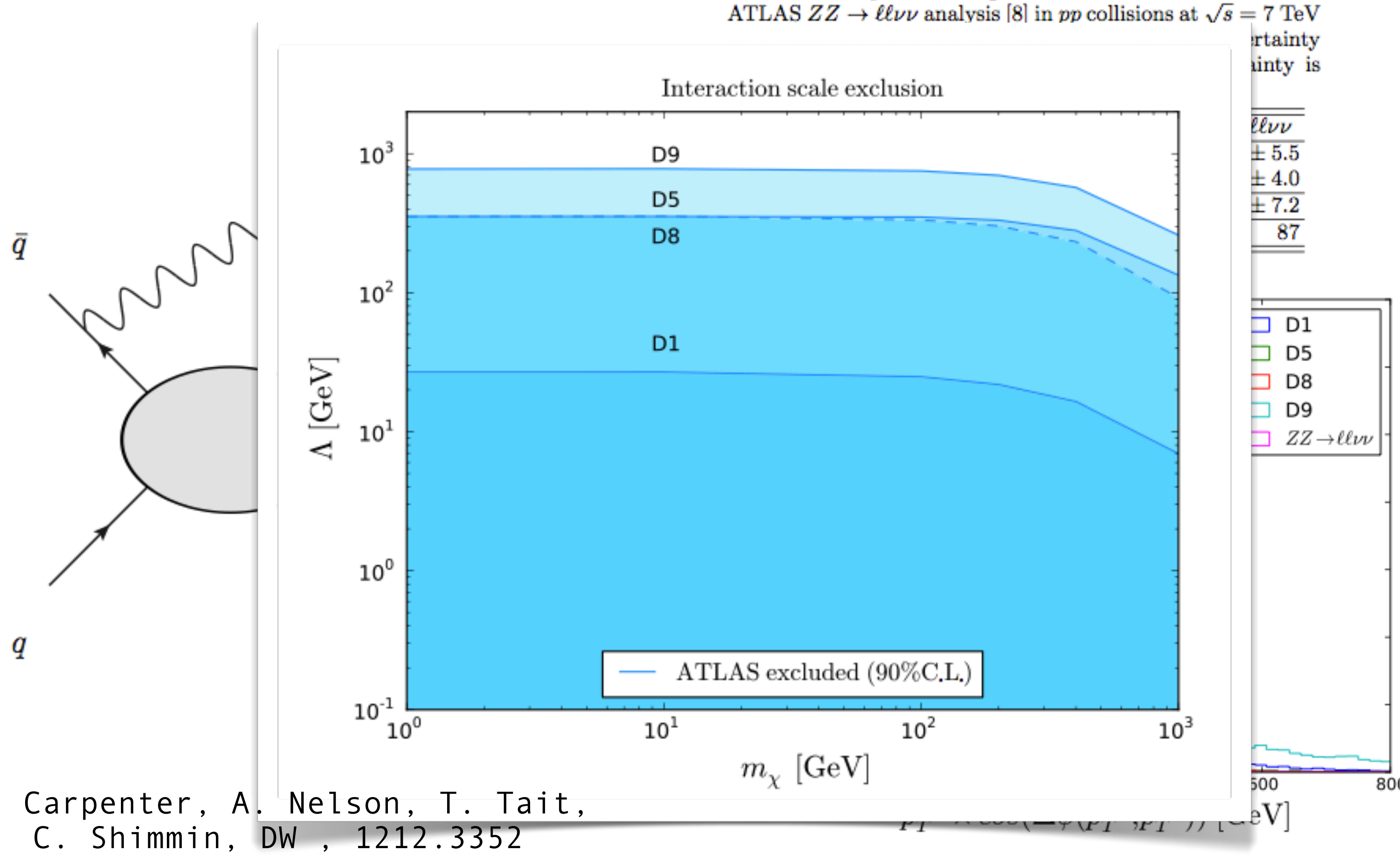




L. Carpenter, A. Nelson, T. Tait, C. Shimmin, DW , 1212.3352

Mono-Z

TABLE II: Expected backgrounds and observed data in the ATLAS $ZZ \to \ell\ell\nu\nu$ analysis [8] in pp collisions at $\sqrt{s} = 7$ TeV



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C. Shimmin, DW , 1212.3352

Mono-Z

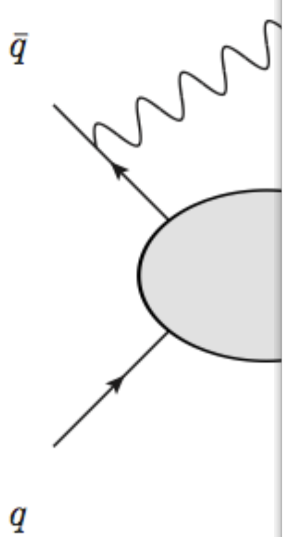
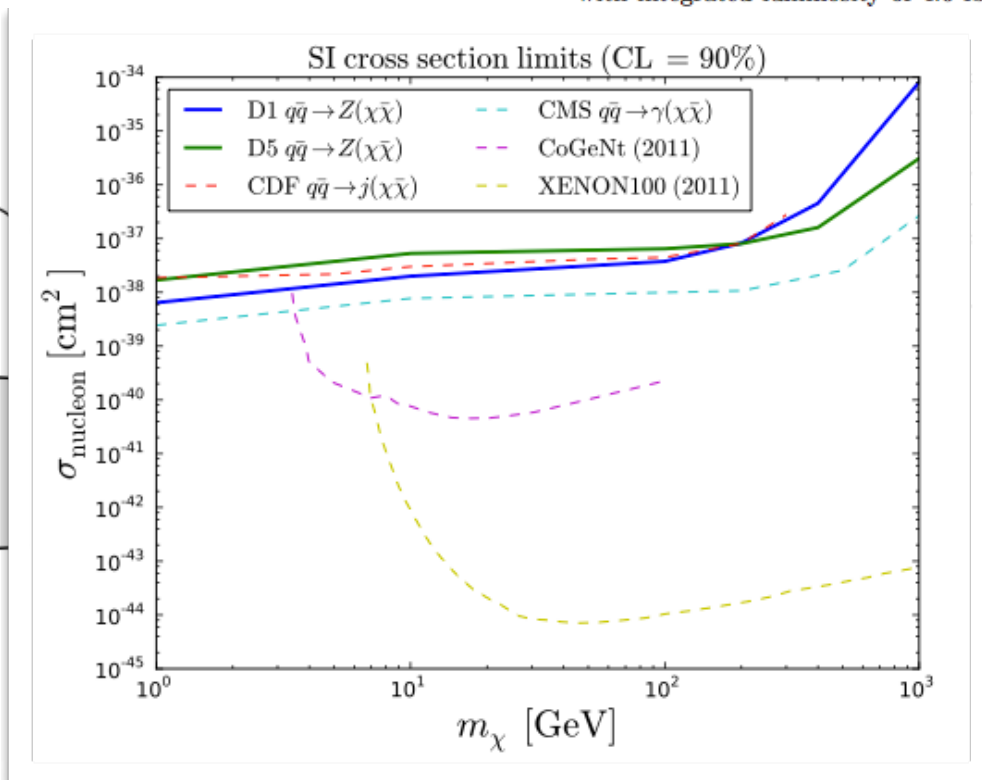
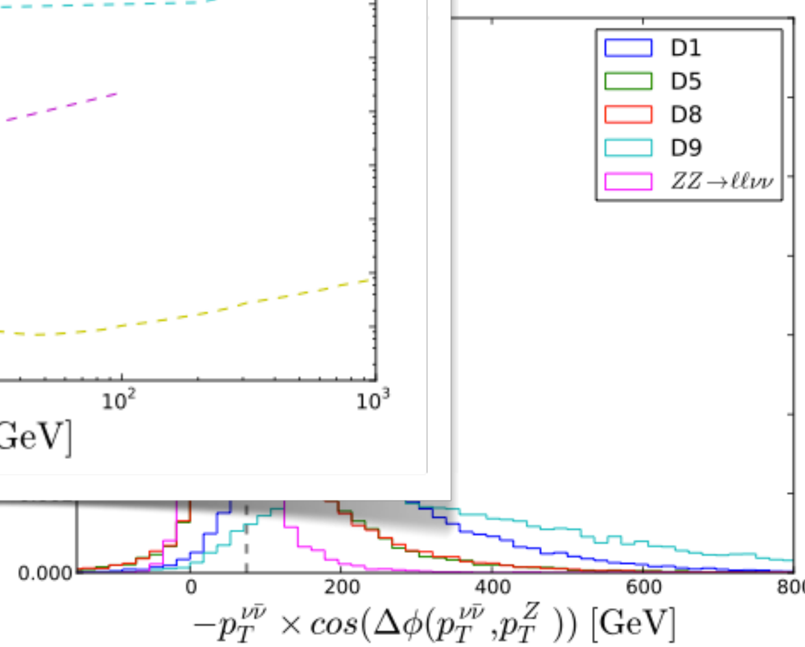


TABLE II: Expected backgrounds and observed data in the ATLAS $ZZ \to \ell\ell\nu\nu$ analysis [8] in pp collisions at $\sqrt{s} = 7$ TeV with integrated luminosity of 4.6 fb^{-1}. The first uncertainty ... ne second uncertainty is

$\mu\mu\nu\nu$	$\ell\ell\nu\nu$
6.1 ± 3.3	46.9 ± 5.5
1.6 ± 2.2	39.3 ± 4.0
7.7 ± 4.6	86.2 ± 7.2
52	87





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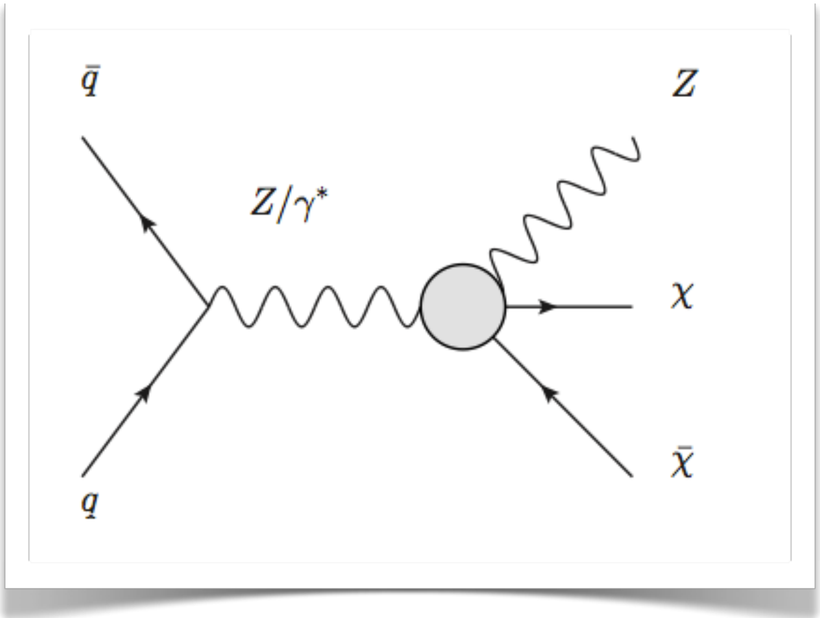
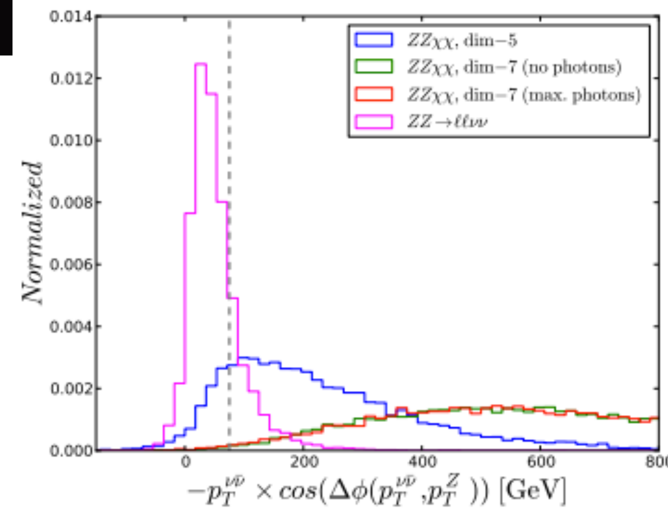
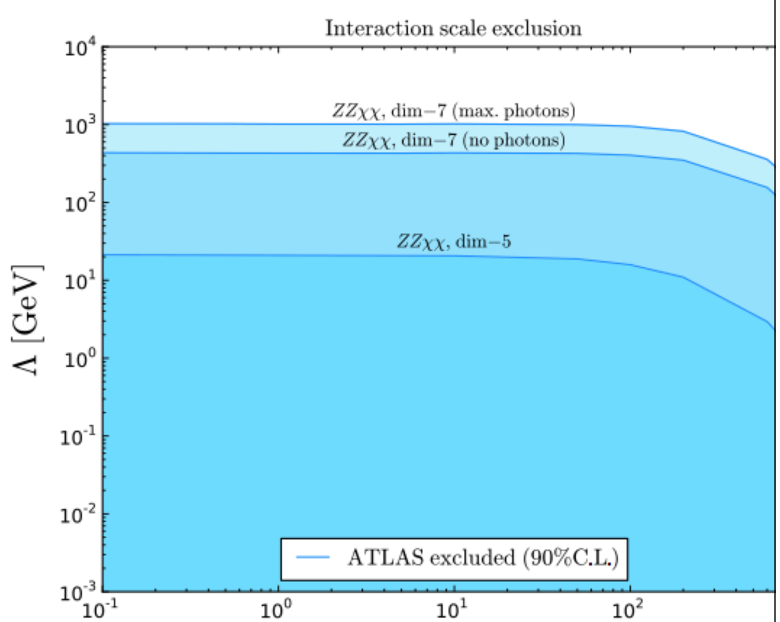
Mono-Z







L. Carpenter, A. Nelson, T. Tait,
C. Shimmin, DW , 1212.3352

Combination

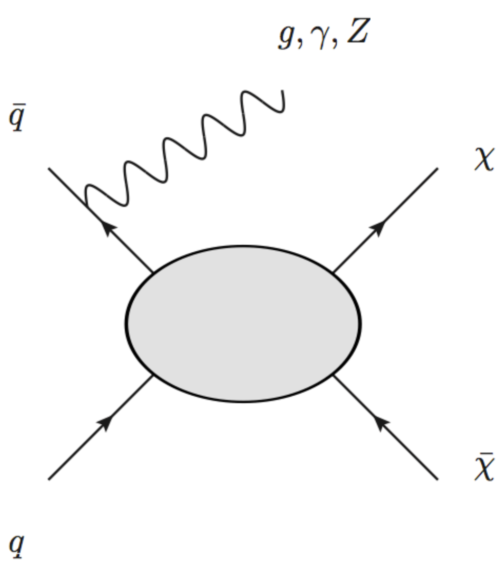
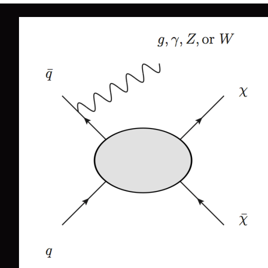


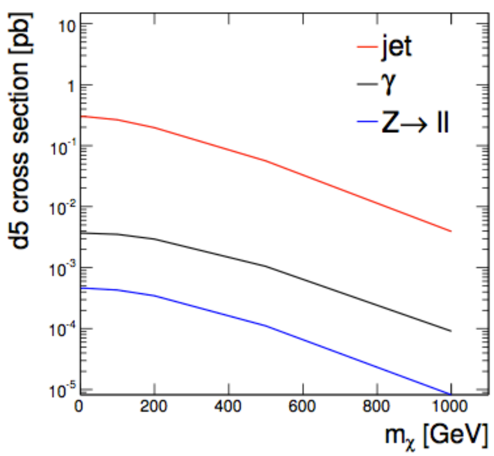
TABLE III: 90% CL limits on N_{events}, efficiencies for $m_\chi = 10$ GeV, and limits on $\sigma(pp \to \chi\bar{\chi} + X)$ using the D5 operator. In the case of the $Z + \not{E}_T$ final state, the efficiency is relative to $Z \to \ell\ell$ decays only.

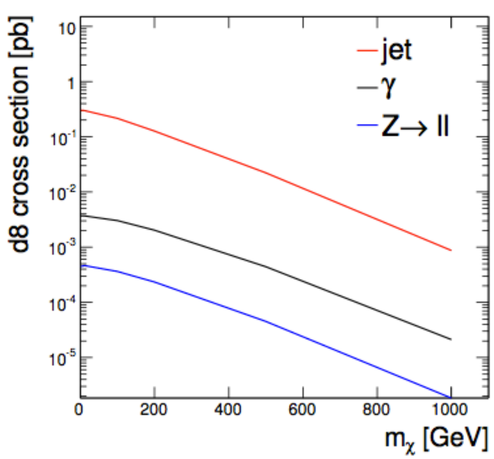
Channel	Bg.	Obs	Limit N	Eff.	Lumi. (fb^{-1})	Limit σ (fb)
ATLAS jet+$\not{E}_T$	750 ± 60	785	139.3	1.7%	4.8	1,700
CMS jet+$\not{E}_T$	1225 ± 101	1142	125.2	2.2%	5.0	1,140
ATLAS $\gamma + \not{E}_T$	137 ± 20	116	27.4	18%	4.6	33
CMS $\gamma + \not{E}_T$	75.1 ± 9.4	73	19.3	11%	5.0	35
ATLAS $Z + \not{E}_T$	86.2 ± 7.2	87	21.7	13%	4.6	36

N. Zhou, D. Berge, DW

Combination







D5, WIMP mass of 10 GeV

TABLE V: 90% CL limits on $\sigma(pp \to \chi\chi + X)$ for $m_\chi = 10$ GeV, theory prediction for $M_\star = 1$ TeV, and limits on $M_\star$ using the D5 operator. In the case of the $Z + \not\!\!E_T$ final state, the prections include the $Z \to \ell\ell$ branching fraction.

Channel	Limit σ (fb)	Pred. ($M_\star = 1$ TeV)	Limit $M_\star$ (GeV)		
ATLAS jet+$\not\!\!E_T$	1,700	370	685	785	795
CMS jet+$\not\!\!E_T$	1,140	370	750		
ATLAS $\gamma + \not\!\!E_T$	33	3.7	580	645	
CMS $\gamma + \not\!\!E_T$	35	3.7	570		
ATLAS $Z + \not\!\!E_T$	36	0.5	340		

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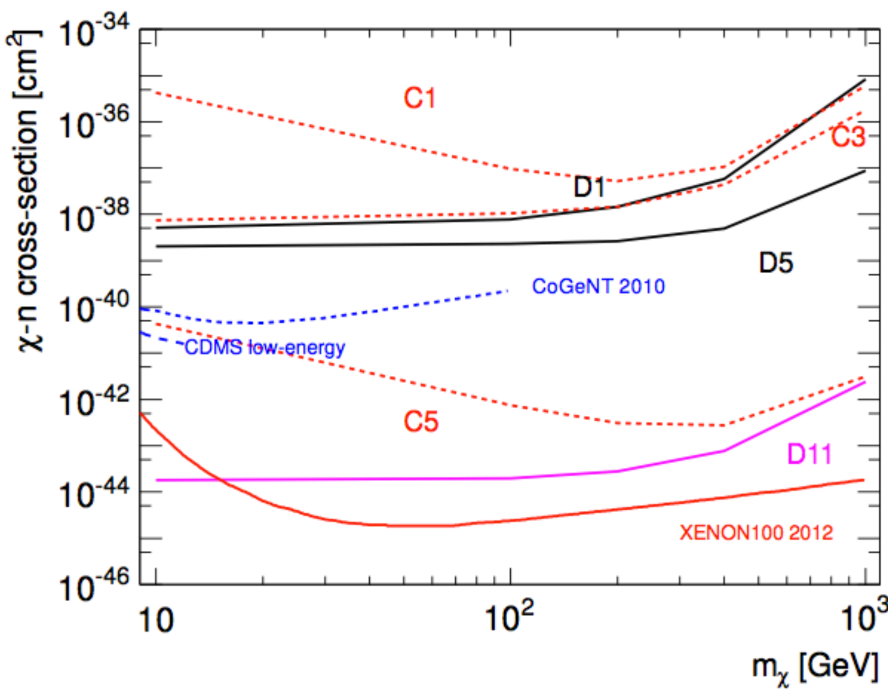
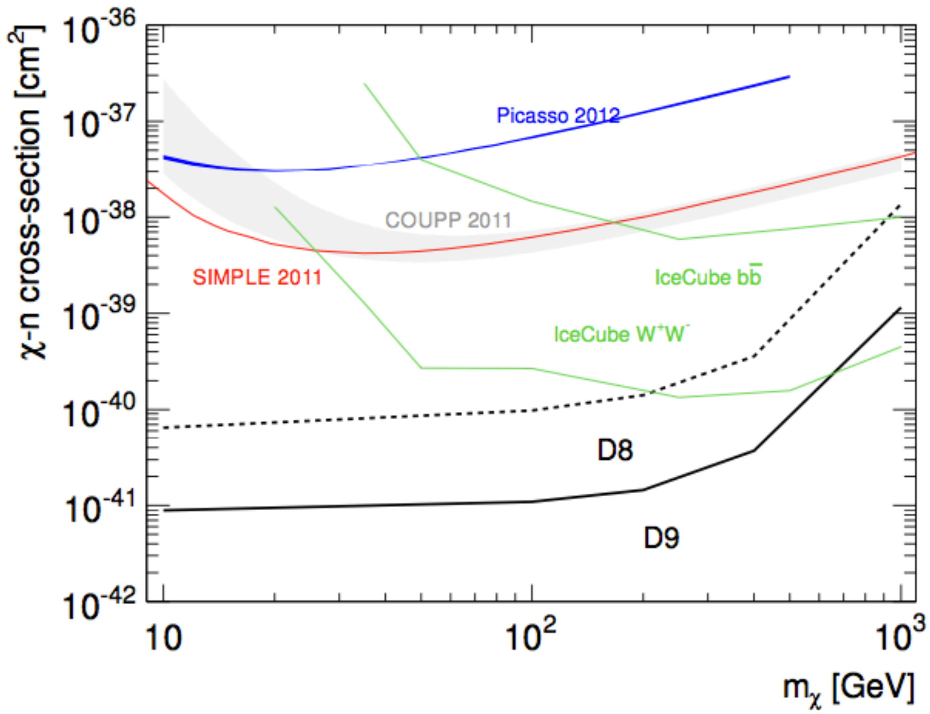
Combined



χ-n cross-section [cm²]
10⁻³⁴
10⁻³⁶
10⁻³⁸
10⁻⁴⁰
10⁻⁴²
10⁻⁴⁴
10⁻⁴⁶
C1
D1
C3
D5
CoGeNT 2010
CDMS low-energy
C5
D11
XENON100 2012
10
10²
10³
m_χ [GeV]



χ-n cross-section [cm²]
10⁻³⁶
10⁻³⁷
10⁻³⁸
10⁻³⁹
10⁻⁴⁰
10⁻⁴¹
10⁻⁴²
Picasso 2012
COUPP 2011
SIMPLE 2011
IceCube bb̄
IceCube W⁺W⁻
D8
D9
10
10²
10³
m_χ [GeV]

The future

$$\frac{\Delta N_{bg}}{N_{bg}}(\mathcal{L}) = f_0$$

$$\frac{\Delta N_{bg}}{N_{bg}}(\mathcal{L}) = \frac{f_0}{2} + \frac{f_0}{2} \times \sqrt{\frac{\mathcal{L}=5}{\mathcal{L}}}$$

$$\frac{\Delta N_{bg}}{N_{bg}}(\mathcal{L}) = f_0 \times \sqrt{\frac{\mathcal{L}=5}{\mathcal{L}}}$$

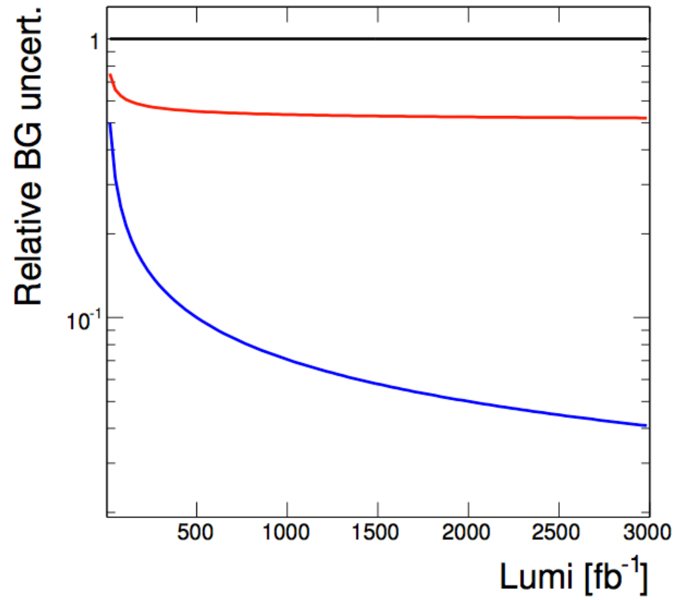
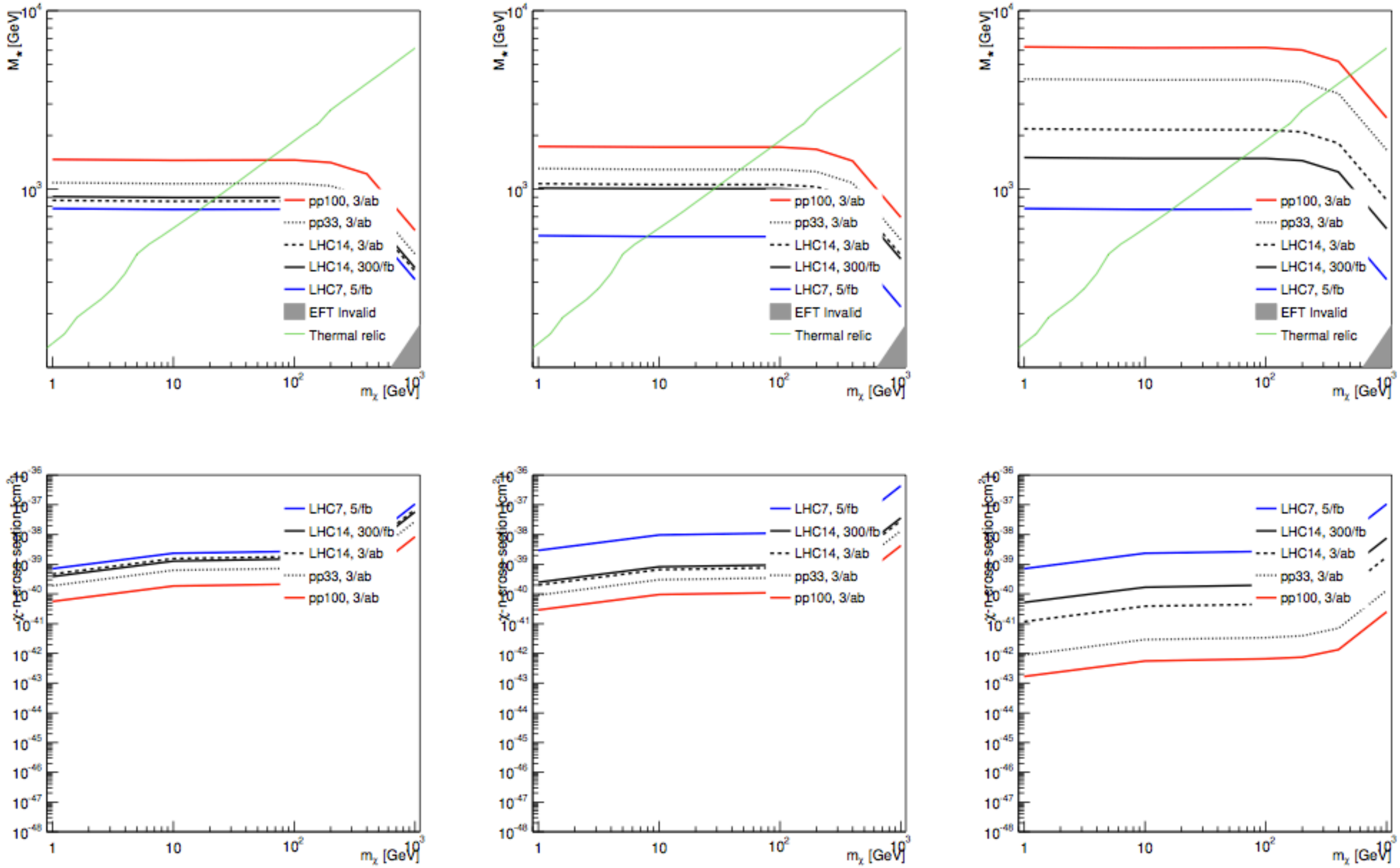


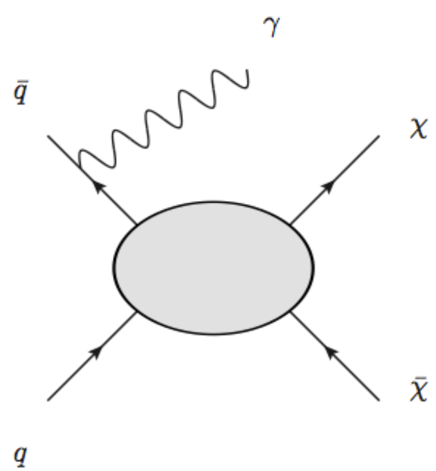
FIG. 1: Relative background uncertainties versus integrated luminosity for three assumptions: no improvement (black), statistical improvement for 50% (red), statistical improvement for full uncertainty (blue).

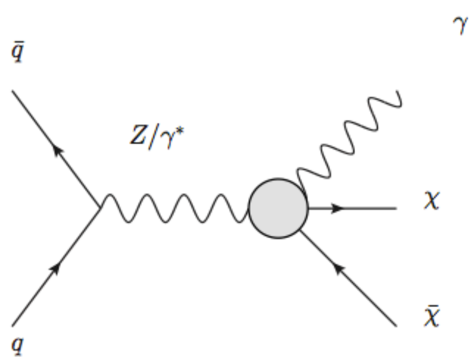
The future:D5 operator

Conserv. Medium Aggressive



Photons





LHC mono-photon results

Same final state can probe
quark-WIMP effective ops.
photon-WIMP effective ops.

Same diagram as Fermi line
feature... results soon.

Fermi: Conclusions

Supporting evidence

Features
- strong stat power

Locations
- consistent with GC

Concerns

Background assumptions
- fair to assume featureless?

No Continuum
- requires some theory gymnastics

Limb, solar signals

Hints in theta
- need resolution