A Conditional Case for Extended Observations of the Galactic Center: Effects on Search for a Spectral Line at 130GeV

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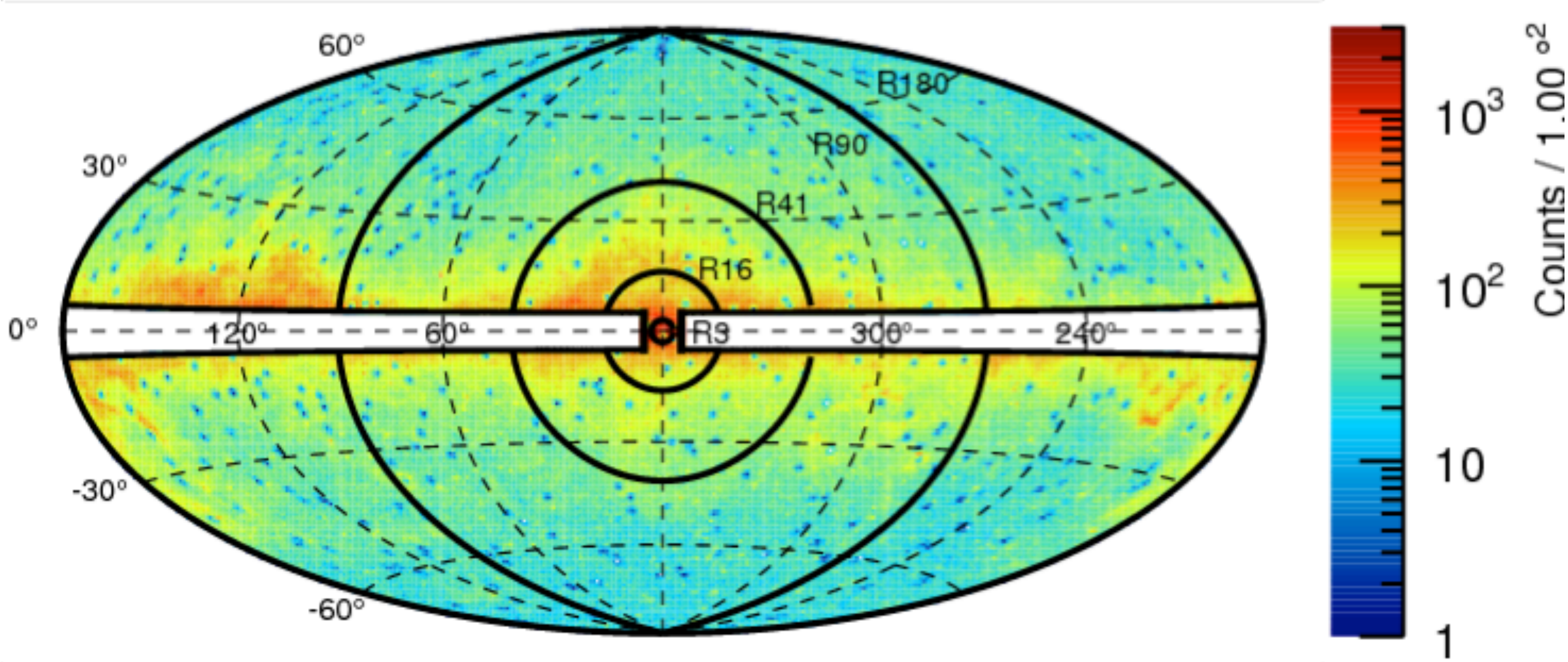
Outline

- Evolution of Feature near 130 GeV
- Dark Matter Signal Scenarios Considered & Considerations for Optimizing the Observing Strategy for Sensitivity to a 130 GeV Line
- Projected Increase in Sensitivity to a 130 GeV Line
- Extra Material

Evolution of Feature near 130 GeV

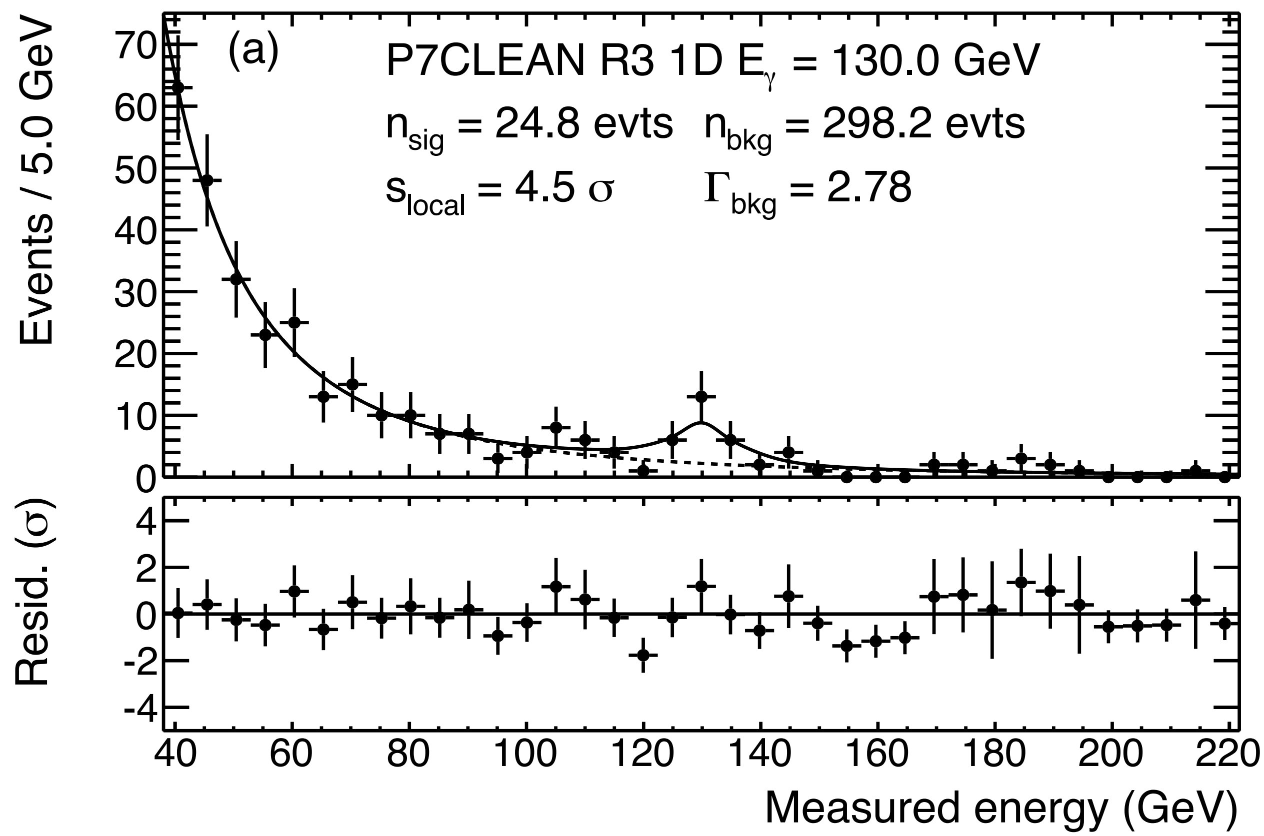
Region of Interest Definitions



•The LAT Collaboration search for lines in 5 nested regions of interest (ROIs) optimized for different DM models

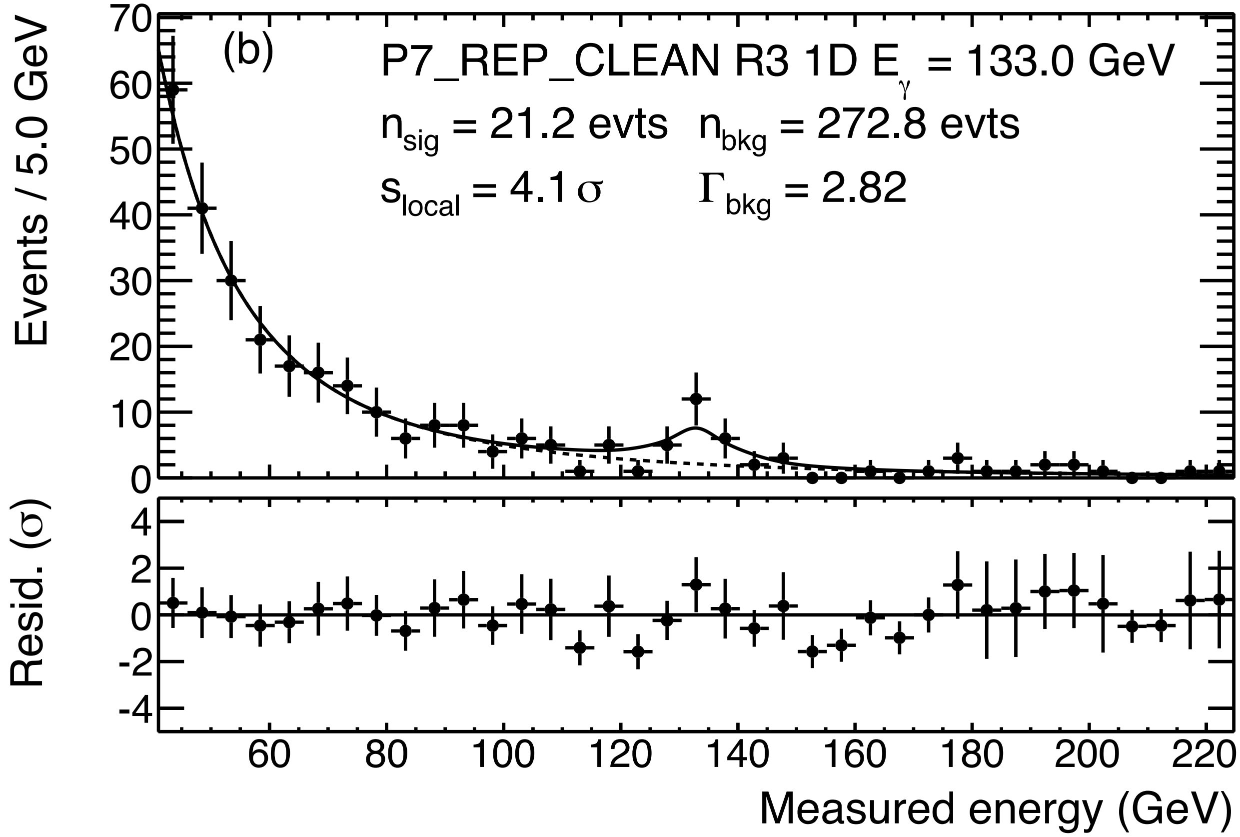
•ROI consist of a variable size circle centered at the GC, and exclude the Galactic Plane except for the central 12°

P7 Fit for R3, 3.7 Years of Data



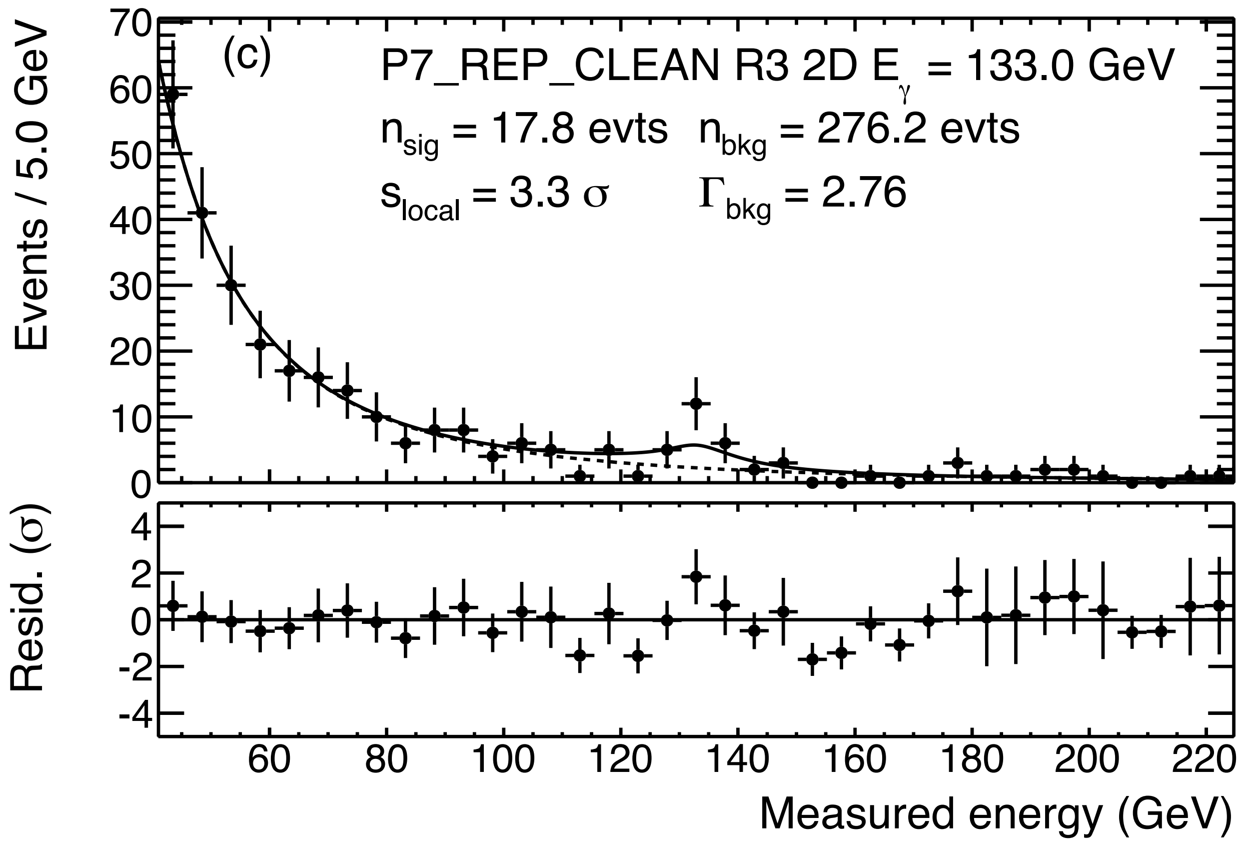
•P7 (original version) 3.7 years: s_{local} ~ 4.5 (3.9) σ in R3 (R16)

Fit to Reprocessed Data



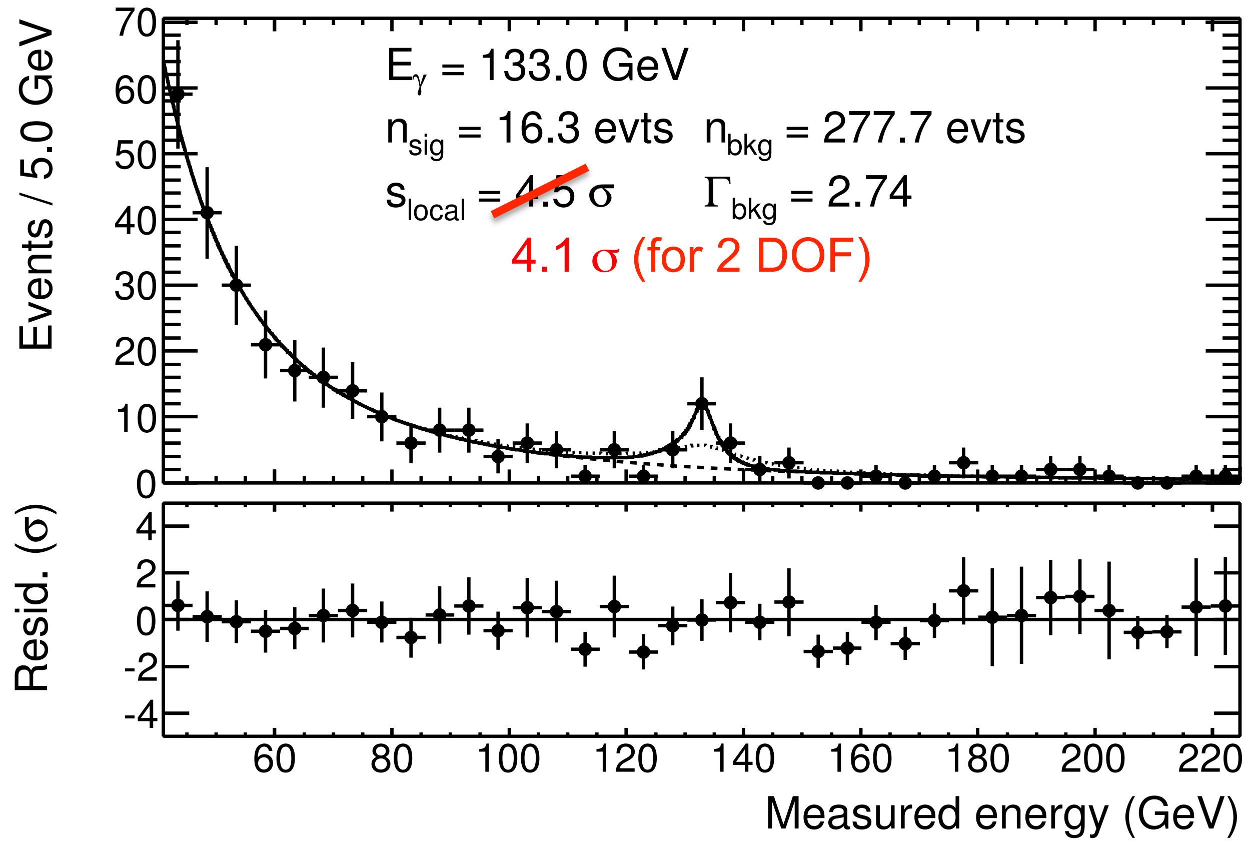
- P7 (original version) 3.7 years: s_{local} ~ 4.5 (3.9) σ in R3 (R16)
- P7REP (reprocessed) 3.7 years: s_{local} ~ 4.1 (2.2) σ in R3(R16)

Fit to Reprocessed Data with "2D PDF"



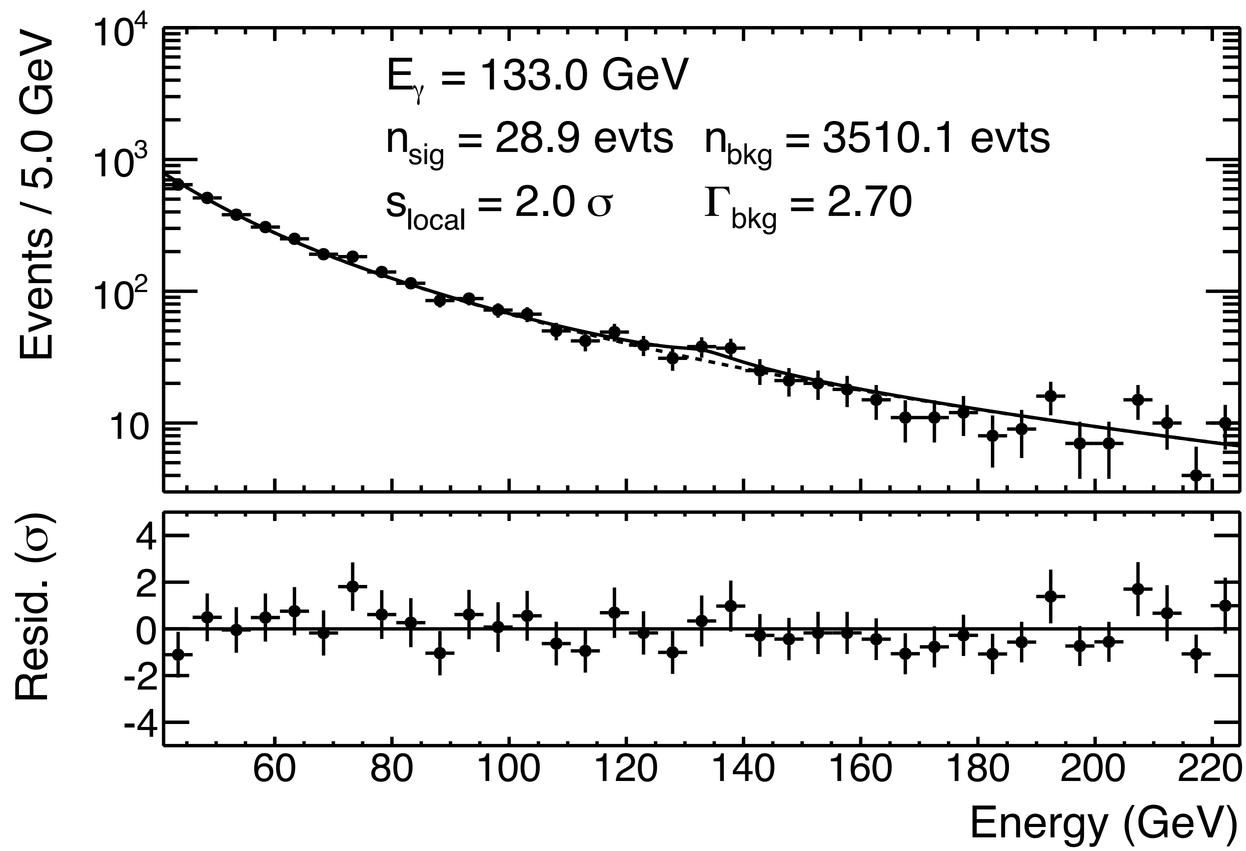
- P7 (original version) 3.7 years: s_{local} ~ 4.5 (3.9) σ in R3 (R16)
- P7REP (reprocessed) 3.7 years: s_{local} ~ 4.1 (2.2) σ in R3 (R16)
- P7REP "2D PDF" 3.7 years: s_{local} ~ 3.3 (1.6) σ in R3 (R16)

Fit with Variable Line Width Scale Parameter



- Feature is notably narrower than the instrument resolution.
- We included a width scale parameter s_σ
  - Best fit value of $s_\sigma = 0.32^{+0.30}_{-0.13}$ (95% CL)
  - ΔTS w.r.t. $s_\sigma = 1.0$ is ~ 9

Fit for Signal in the Earth Limb



- The fractional size (f ~ TS/n_{sig}) of the feature in the limb is ~0.15
- Compare to f ~ 0.5 for R3 and ~ 0.36 for R16
    - Earth Limb feature can only account for 25%-40% of GC signals

Dark Matter Signal Scenarios Considered & Considerations for Optimizing the Observing Strategy for Sensitivity to a 130 GeV Line

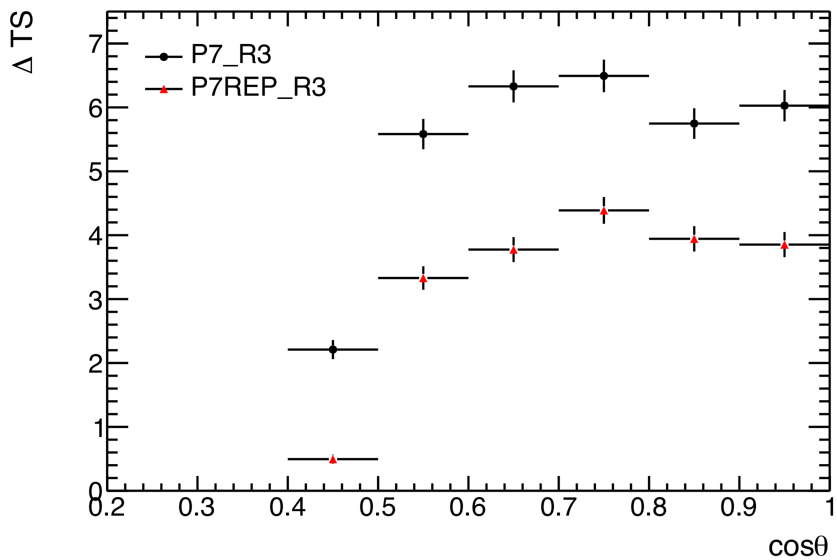
Scenarios Considered

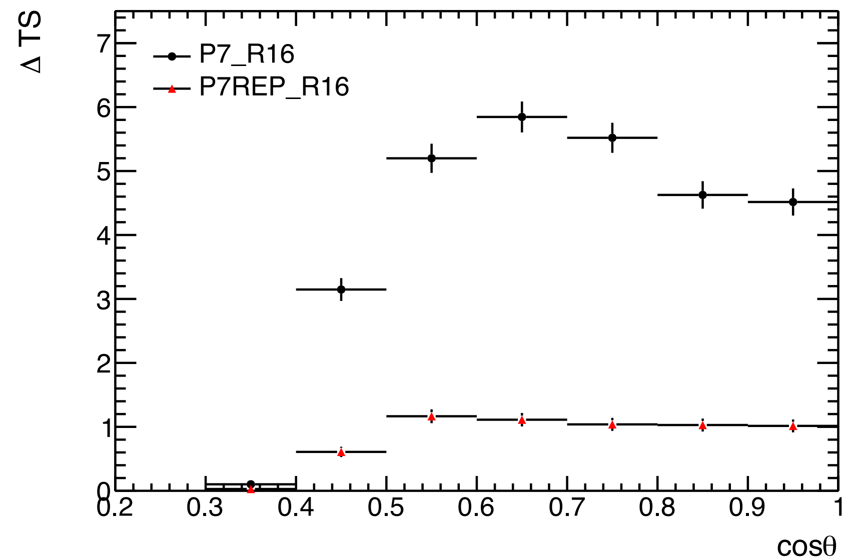
Scenario	$\Phi_{\gamma\gamma}$ $10^{-10}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	N_0 $10^{-14}\mathrm{cm}^{-2}\mathrm{s}^{-1}\mathrm{MeV}^{-1}$	Γ_{bkg}
P7_R3	2.4 ± 0.5	1.0	2.78
P7_R16	4.0 ± 1.0	4.1	2.68
P7REP_R3	1.7 ± 0.5	1.1	2.72
P7REP_R16	1.8 ± 1.1	4.9	2.55

Table 1: Scenarios for studies of projected sensitivity for modified observing strategies, showing the adopted signal fluxes ($\Phi_{\gamma\gamma}$) and background flux prefactors (N_0) and power law indices ($\Gamma_{\rm bkg}$) based on the best-fit results for a 130 GeV line in the R3 and R16 ROIs, with the **P7_CLEAN** and **P7REP_CLEAN** datasets. For sensitivity studies we modeled the background as a power law: $\frac{dN}{dE}(E) = N_0(\frac{E}{100\ \mathrm{GeV}})^{-\Gamma_{\rm bkg}}$.

- In white paper we considered 4 DM scenarios, corresponding to the best-fit signal and bkg. models found in R3 and R16 with P7 and P7REP data.
- Since then, we've added two new scenarios, corresponding to parameters from 54 months of data.

Sensitivity as a Function of Observing Angle (θ)



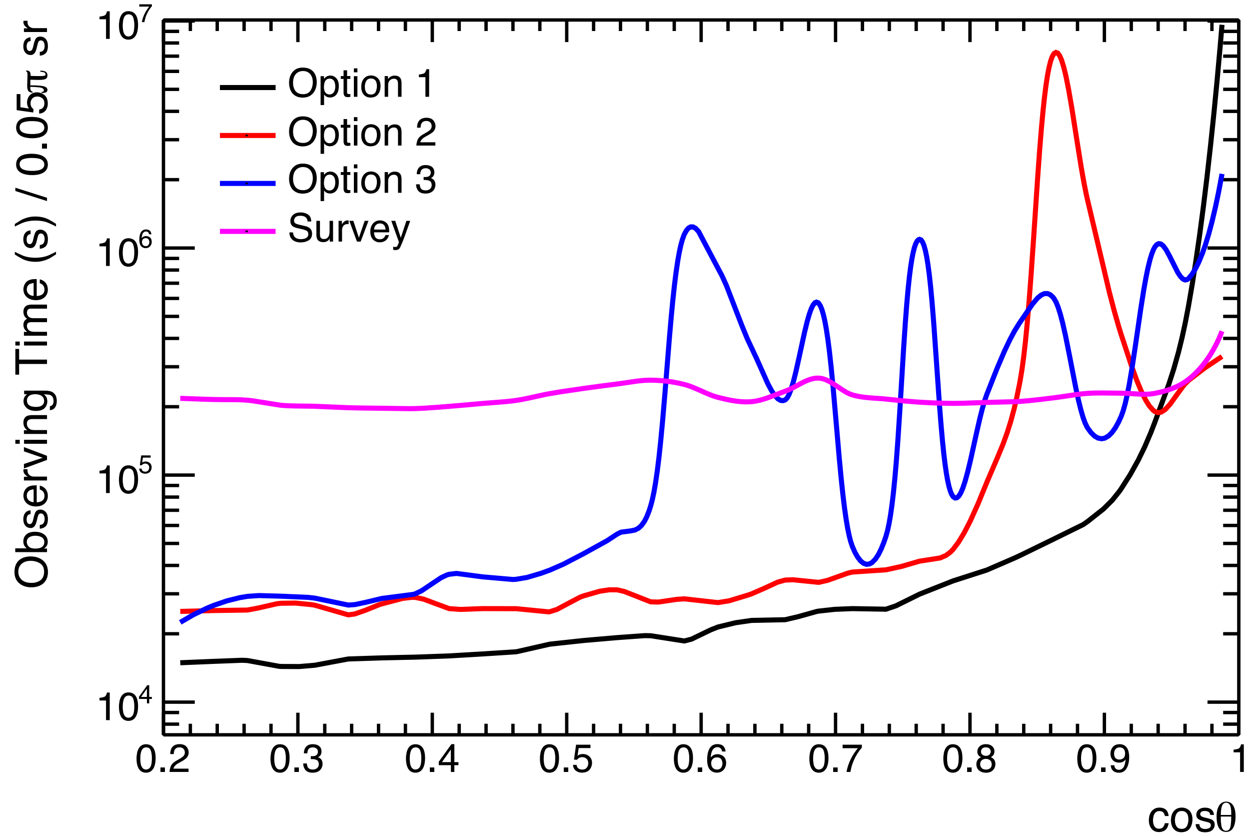


•Recall that the A_{eff} area decreases, but the Energy resolution improves as we move off-axis.

•These plots show the expected increase in TS for a 10^7 second exposure, if the exposure were taken entirely at a specific incidence angle, for each of the scenarios we considered.

•Changes in A_{eff} and energy resolution balance out for $\cos\theta \geq 0.55$.

Incidence Profiles for the Options Proposed



- All three options increase observing time with $\cos\theta \geq 0.55$
- Options 1 and 2 do so preferentially at particular incidence angles
- Options 3 adds observing time across the range $0.55 < \cos\theta < 1.0$.

Projected Increase in Sensitivity to a 130 GeV Line

Projected Improved Sensitivity

Mean ΔTS/ year

Scenario	Option 1	Option 2	Option 3	Survey
P7_R3	12.6 ± 0.5	11.4 ± 0.5	10.4 ± 0.5	5.5 ± 0.4
P7_R16	12.1 ± 0.5	10.1 ± 0.5	9.4 ± 0.4	5.1 ± 0.4
P7_REP_R3	9.1 ± 0.4	7.1 ± 0.4	7.0 ± 0.4	4.2 ± 0.3
P7_REP_R16	2.7 ± 0.2	2.3 ± 0.2	2.2 ± 0.2	1.1 ± 0.2
P7_REP_R3_54m	5.9 ± 0.4	5.4 ± 0.3	4.5 ± 0.3	3.1 ± 0.3
P7_REP_R16_54m	1.5 ± 0.2	1.4 ± 0.2	1.5 ± 0.2	0.9 ± 0.2

Note that this table has some changes w.r.t. what is in the white paper.

1) We use the mean of ΔTS instead the mean of sqrt(ΔTS)
2) We include scenarios based on 54 month status
3) We changed input flux values by ~10% to reproduce number of observed events in 3.7 years of data.

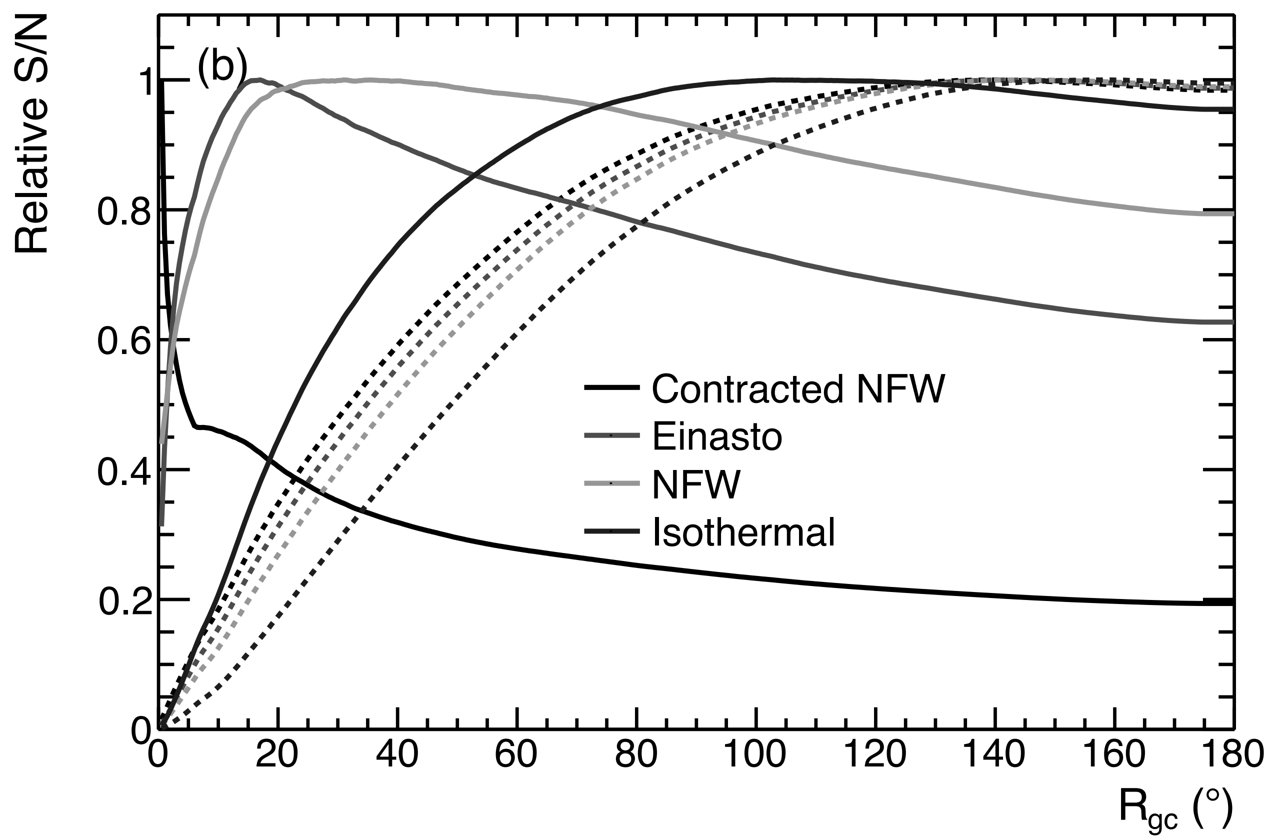
- Option 1 increases ΔTS by a factor of ~2.1 on average.
- Options 2 and 3 do slightly less well, but still close to 2.

Some Cases to Consider:

- Consider 3 possibilities after 5 years:
  - Case 1: TS > 20 (> 4.4σ)
    - If the signal is real, we are likely to reach TS = 25 in two years even without a change in observing strategy.
  - Case 2: 20 > TS > 15 (3.8σ – 4.4σ)
    - If this signal is real, we improve the chance of reaching TS = 25 in two years by changing the observing strategy
  - Case 3: TS < 15 (3.8σ)
    - There is a fair probability we won't reach TS = 25 even with a modified observing strategy
- We are either in case 2 or 3, depending of the ROI and if we consider the "1D PDF" or "2D PDF" fits

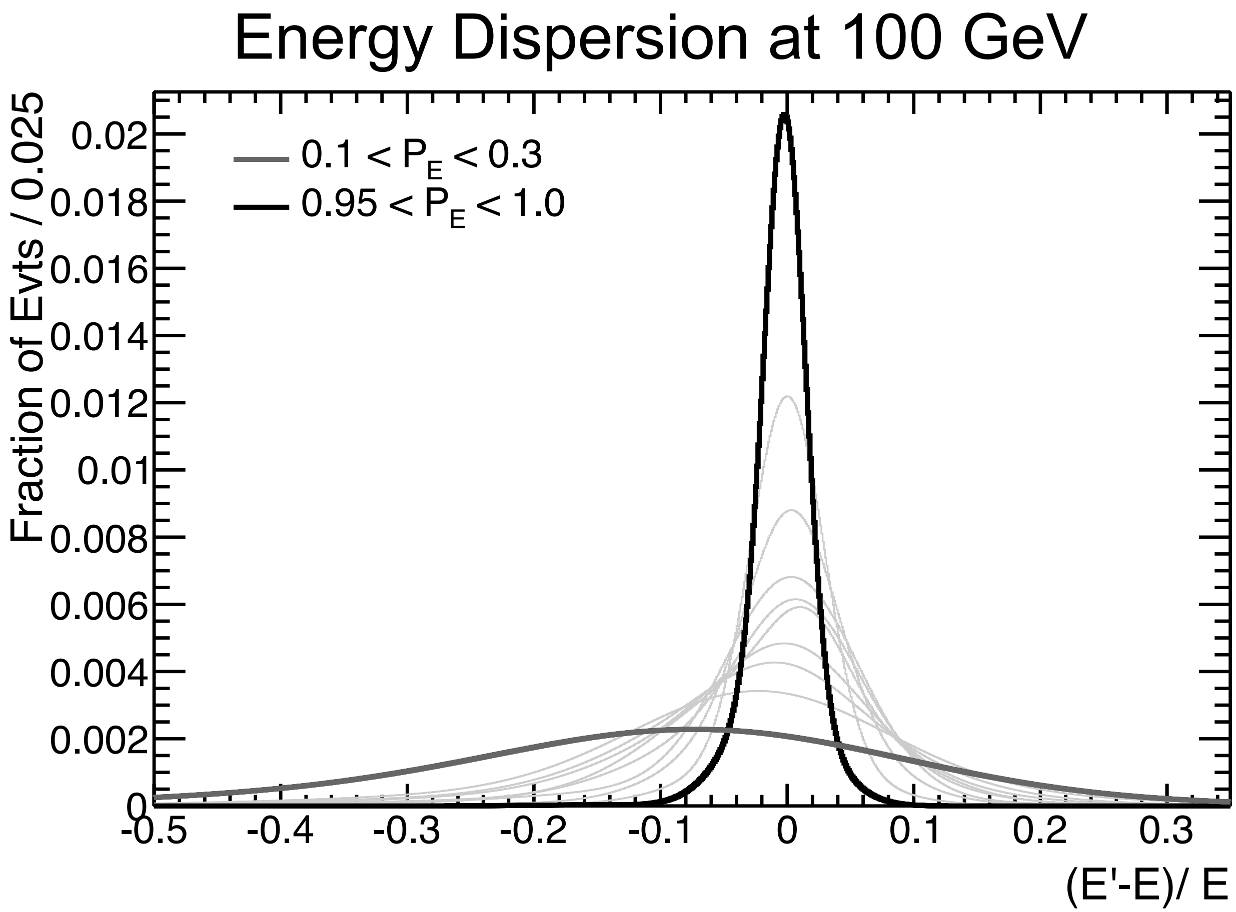
RELEVANT MATERIAL FROM THE LAT LINE-SEARCH PAPER

Region of Interest Optimization



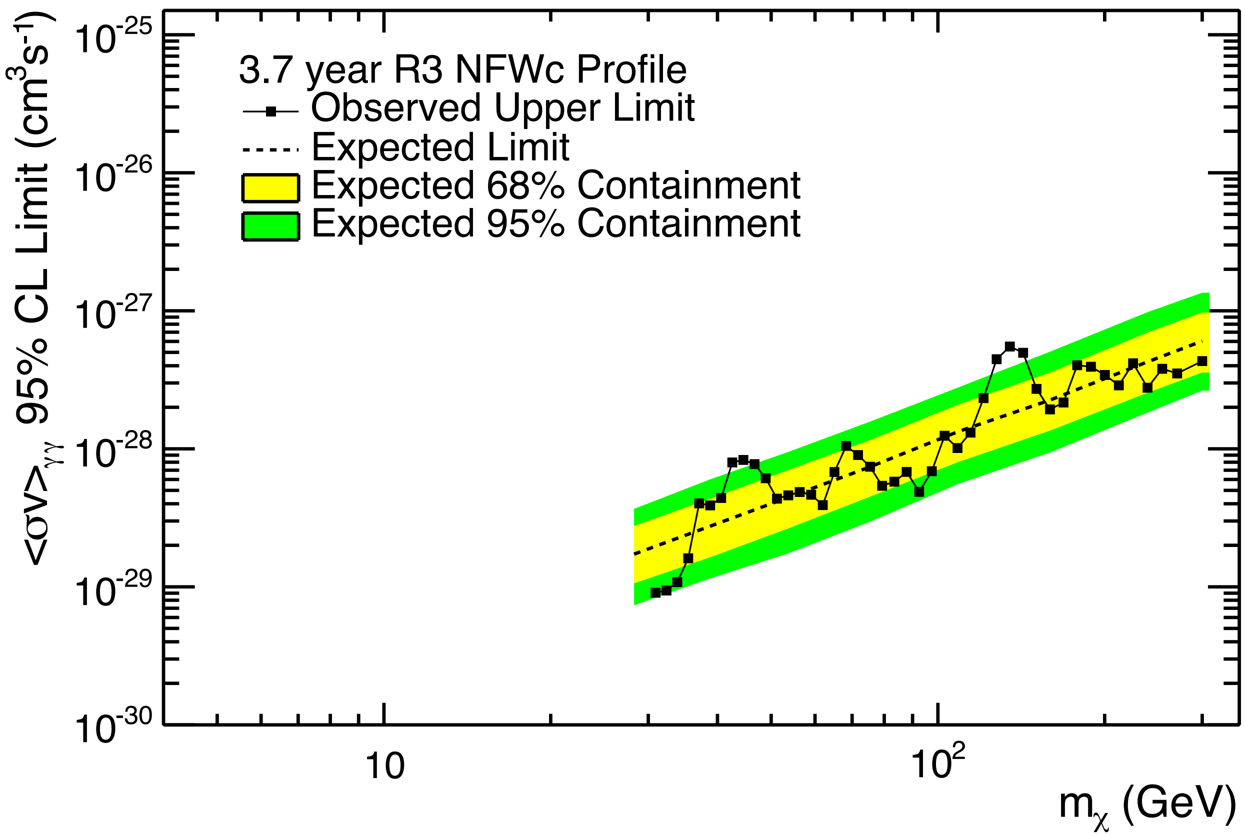
- This plot shows the signal-to-noise as a function of the ROI size for different DM models.
- We chose R = 3°, 16°, 41°, 90° for annihilation models (solid lines)
    - 180° for decay models (dotted lines)

Energy Quality Estimator: P_E



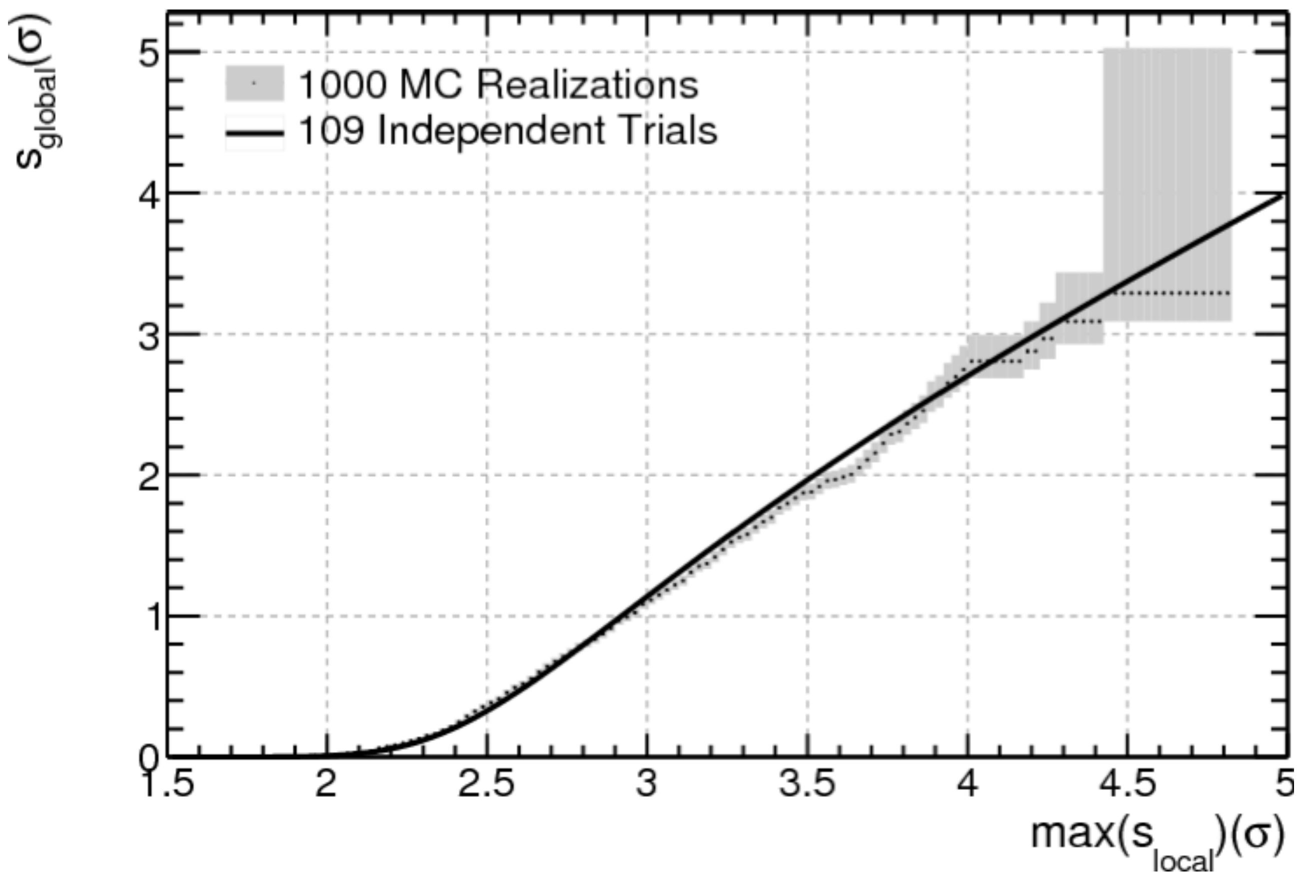
•The energy quality estimator P_E is a output of a Classification Tree analysis trained to predict if an event is inside the 68% energy containment window
•Larger P_E implies better energy resolution

Upper Limits on <σv> for R3 ROI



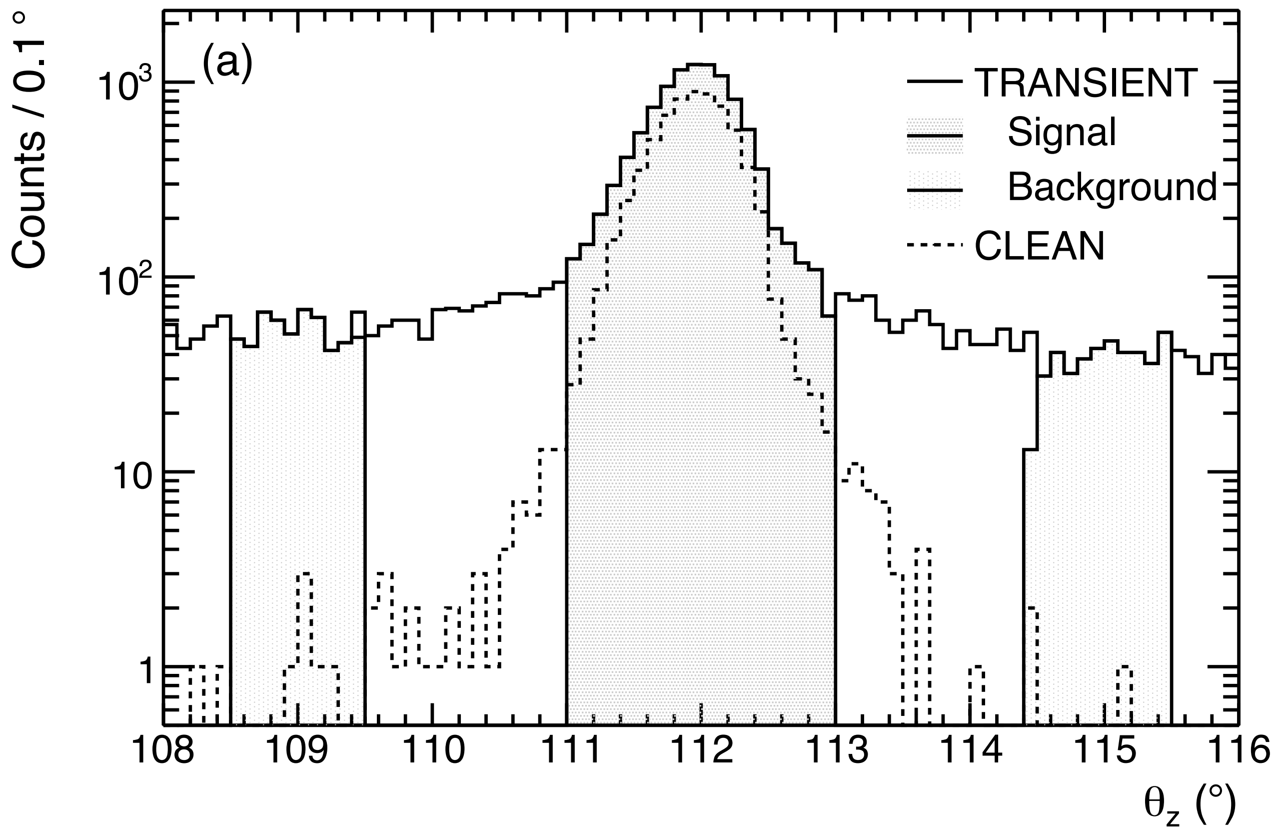
•“Brazil” plot showing the Upper Limits on <σv> assuming the “Contracted NFW” profile for which R3 was optimized.

Trials Factor Estimation



- With our energy scan we performed 396 (4*88 + 44) fits
- With simulations we find that the max(s_{local}) distribution is well-modeled as coming from 109 independent trials

Earth Limb Sample Definition



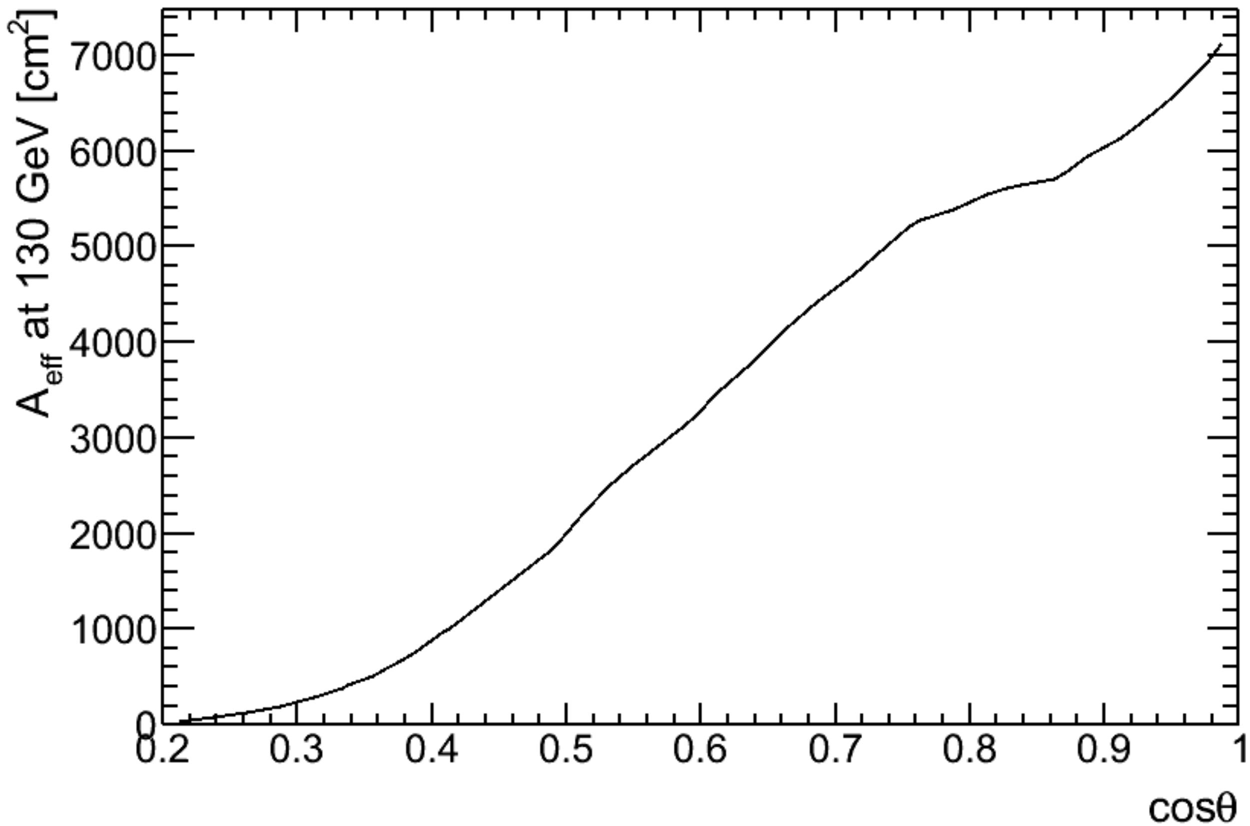
•Select only time ranges with rocking angle $\theta_r > 52°$

•We define signal and background regions for the Earth Limb in terms of the zenith angle θ_z

•In P7REP_CLEAN, we only see a handful of events “background”

OTHER USEFUL FIGURES

Effective Area vs. θ



Energy Dispersion PDF in θ slices