

3-Dimensional Statistical Analysis and effects of threshold and resolution

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Toy MC to Generate Events

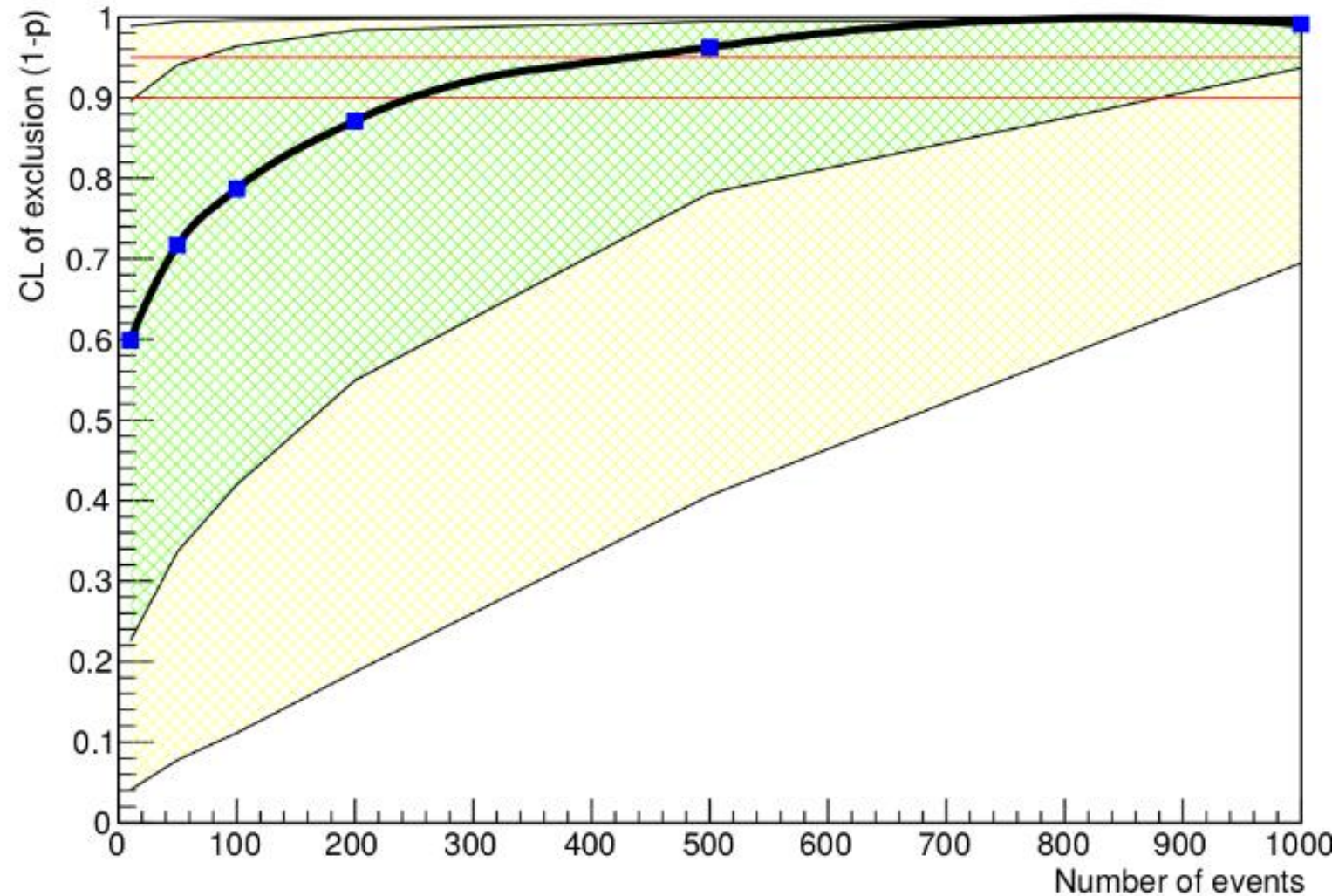
- Time is drawn from a uniform distribution from 0 to 24
- Cygnus angle is calculated
- Velocity components of the WIMP in the rest frame of the galaxy are chosen from a 3-dimensional Gaussian with $\sigma = 220,000/\sqrt{2}$ (while scalar velocity $< 560,000 \text{ km/s}$)
- The velocity of the SS motion through the galaxy is added to the z component to have the incident velocity components in a frame where the z-axis points in the direction of Cygnus (direction of SS motion)
- Coordinates are rotated to the detector frame
- A recoil energy is chosen from a uniform distribution from 0 to maximum possible recoil energy (rE_{WIMP} , where r is kinematic factor)
- The velocity of the recoiling nucleus, and $\sin(\alpha)$ and $\cos(\alpha)$ (where α = angle between incident WIMP and recoil track) are calculated. A vector is defined perpendicular to the WIMP vector and an algorithm is used to rotate it at random from 0 to 2π radians. This chooses a recoil vector in the detector frame. The cosine of the polar angle of the recoil in the detector frame can then be calculated.
- Absolute value of the $\text{Cos}(\Theta_r)$ is used to fold events at the same angle above and below the x-y plane of the detector

Process for Statistics

- A high statistics (10 million events right now) 2D histogram for Cygnus angle versus $\cos(\Theta_r)$, or 3D histogram (Cygnus, energy and polar angle) is created to be used as the signal probability density function (pdf).
- A histogram for a background pdf is created with the same number of events, but isotropic in $\cos(\Theta_r)$
- A 2D or 3D lambda histogram is made where the value in a bin is the log of the ratio signal/background for the same bin.
- 10,000 sets of N number of events are generated from the signal MC, and for each event the lambda value is retrieved from the corresponding bin of the lambda histogram. A new histogram of the lambda values of events is created.
- This is repeated using the background model to generate events, and a histogram is made of the lambda values of events.

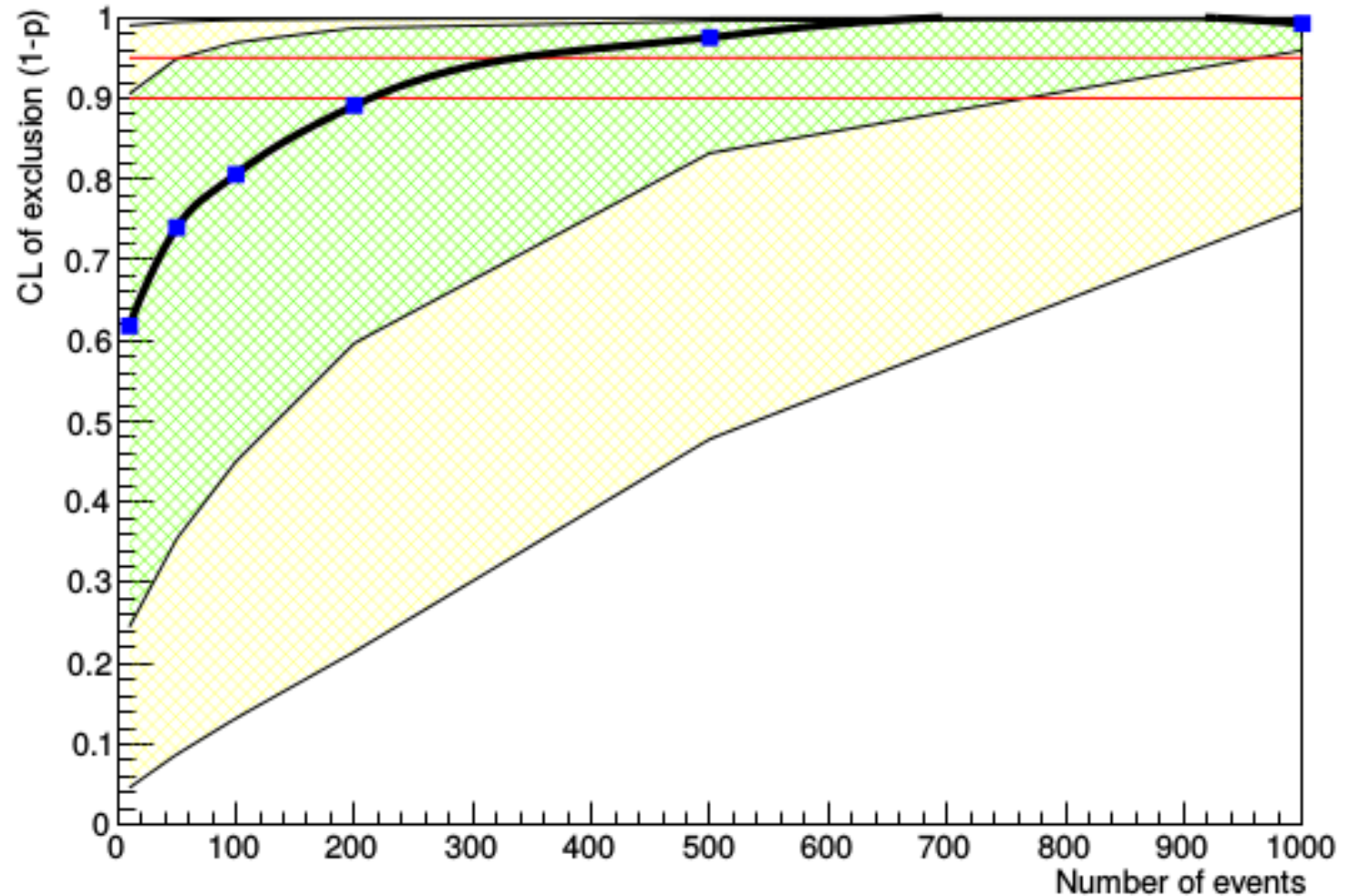
2D-isotropic: Confidence Level of Exclusion (1-p)

- Plot of the median expected exclusion confidence level (1-p-value) for the 2D-isotropic model.
- The solid line indicates the mean, while the green shaded area shows sigma of one around the mean, and the yellow shaded area a sigma of 2.



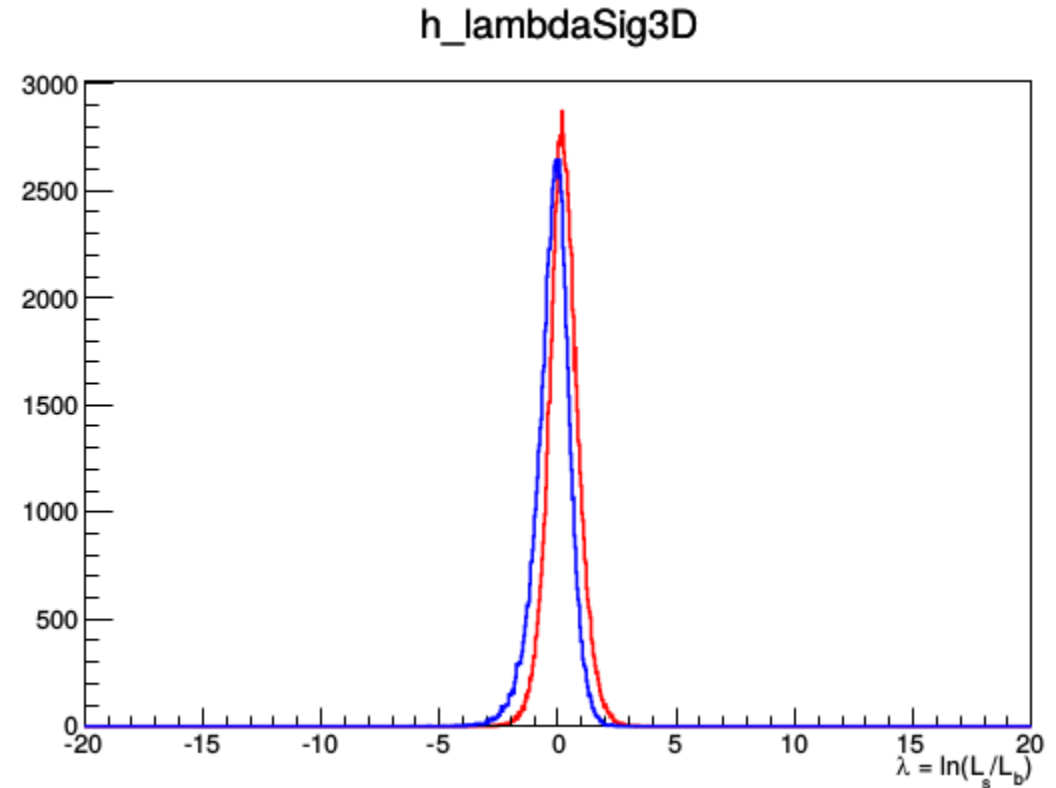
2D-co-rotating: Confidence Level of Exclusion (1-p)

- Plot of the median expected exclusion confidence level (1-p-value) for the 2D-co-rotating model.
- The solid line indicates the mean, while the green shaded area shows sigma of 1 around the mean, and the yellow shaded area a sigma of 2.

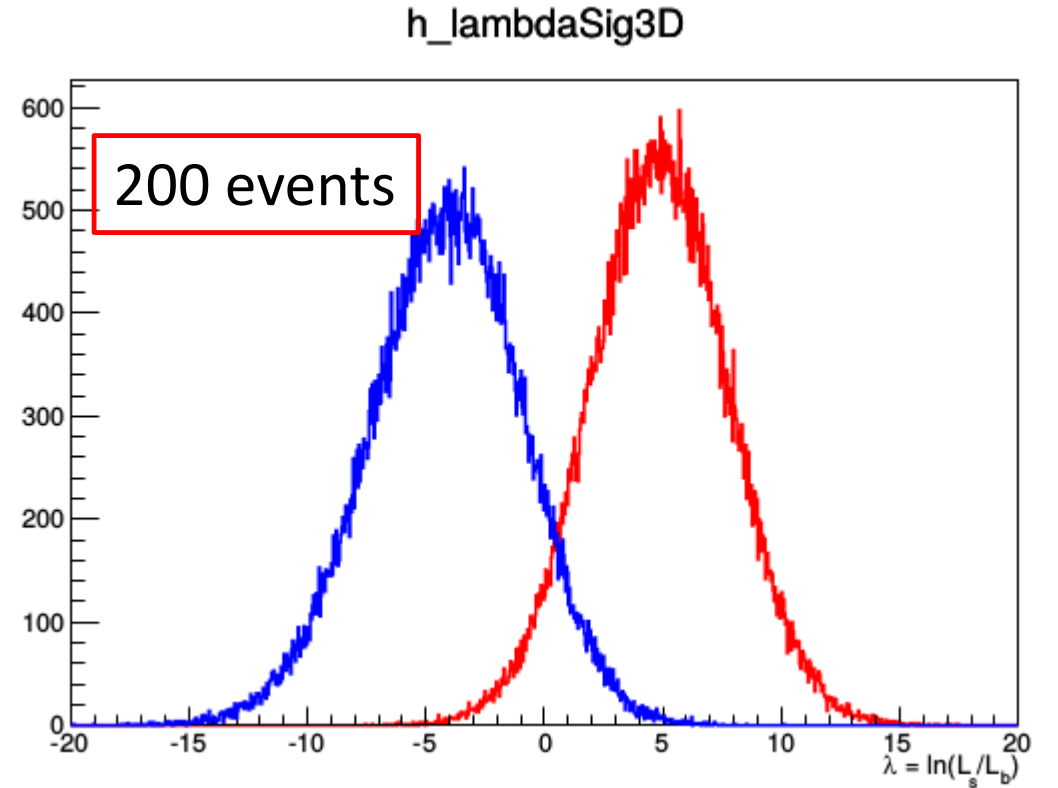
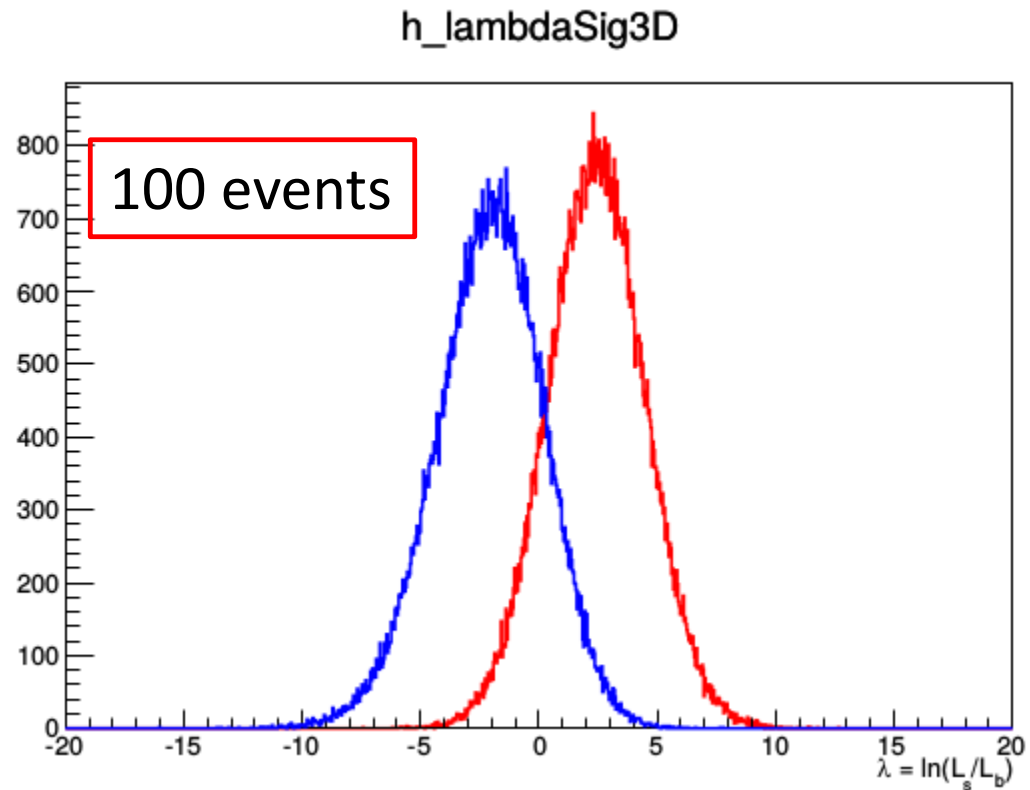


3D-isotropic: Separation of Signal and Background (10 events)

- Blue= background
- Red= signal
- Background pdf was created keeping the same energy distribution as that of the signal but with isotropic directional distribution.
- More difficult to separate than the co-rotating background

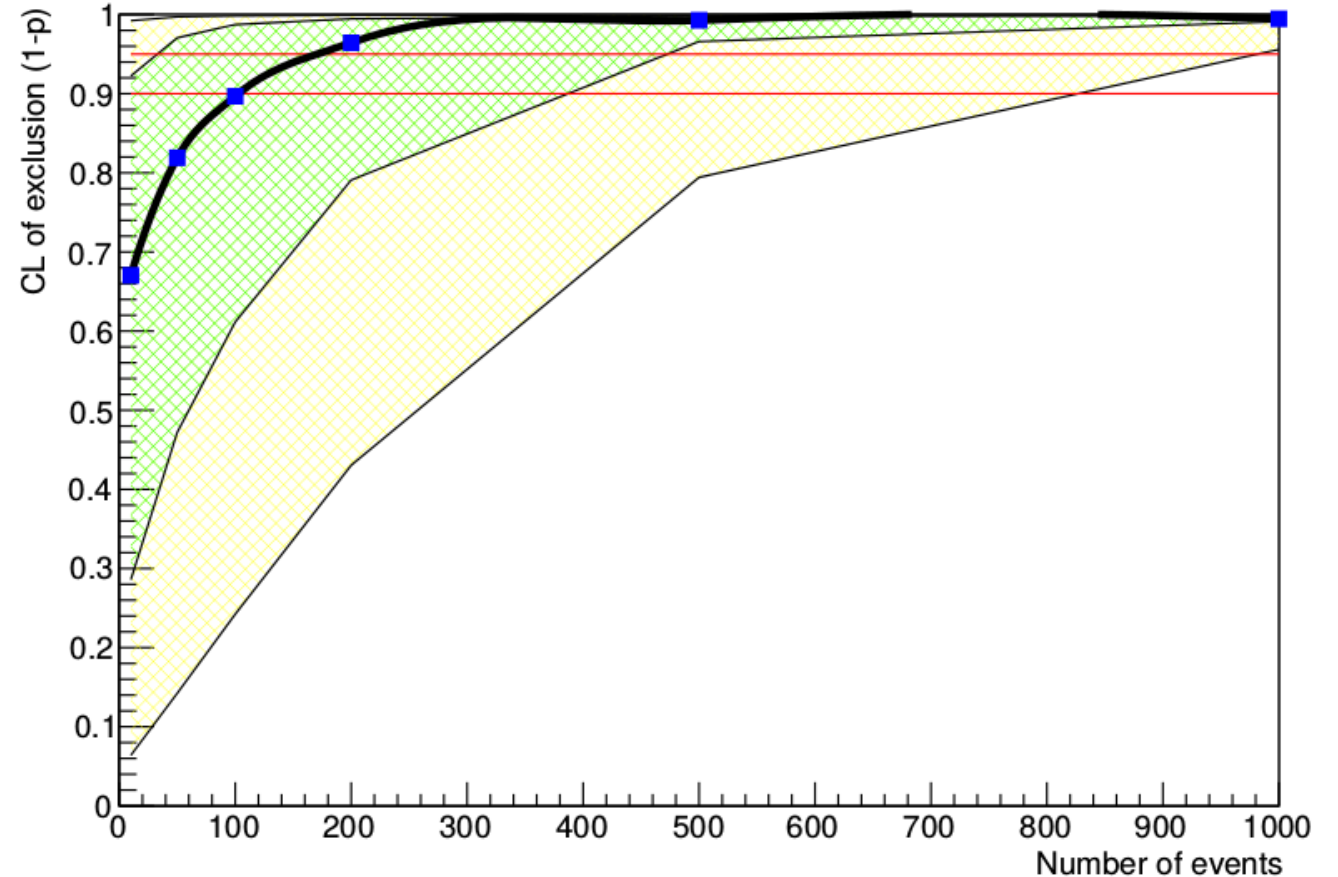


3D-isotropic: Separation of Signal and Background (10 events)



3D-isotropic: Confidence Level of Exclusion (1-p)

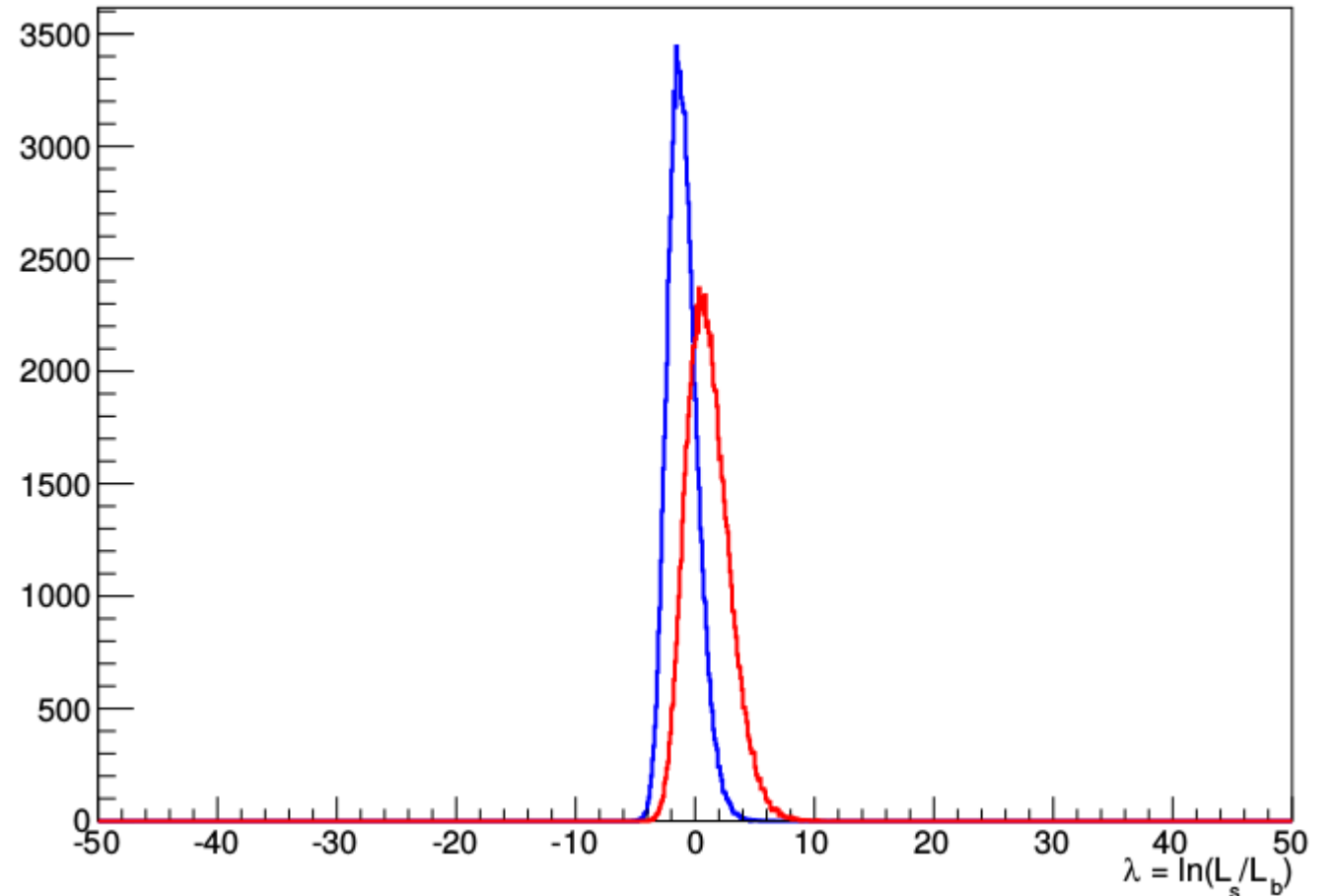
- Plot of the median expected exclusion confidence level (1-p-value) for the 3D-isotropic model.
- The solid line indicates the mean, while the green shaded area shows sigma of 1 around the mean, and the yellow shaded area a sigma of 2.



3D-co-rotating 10 events

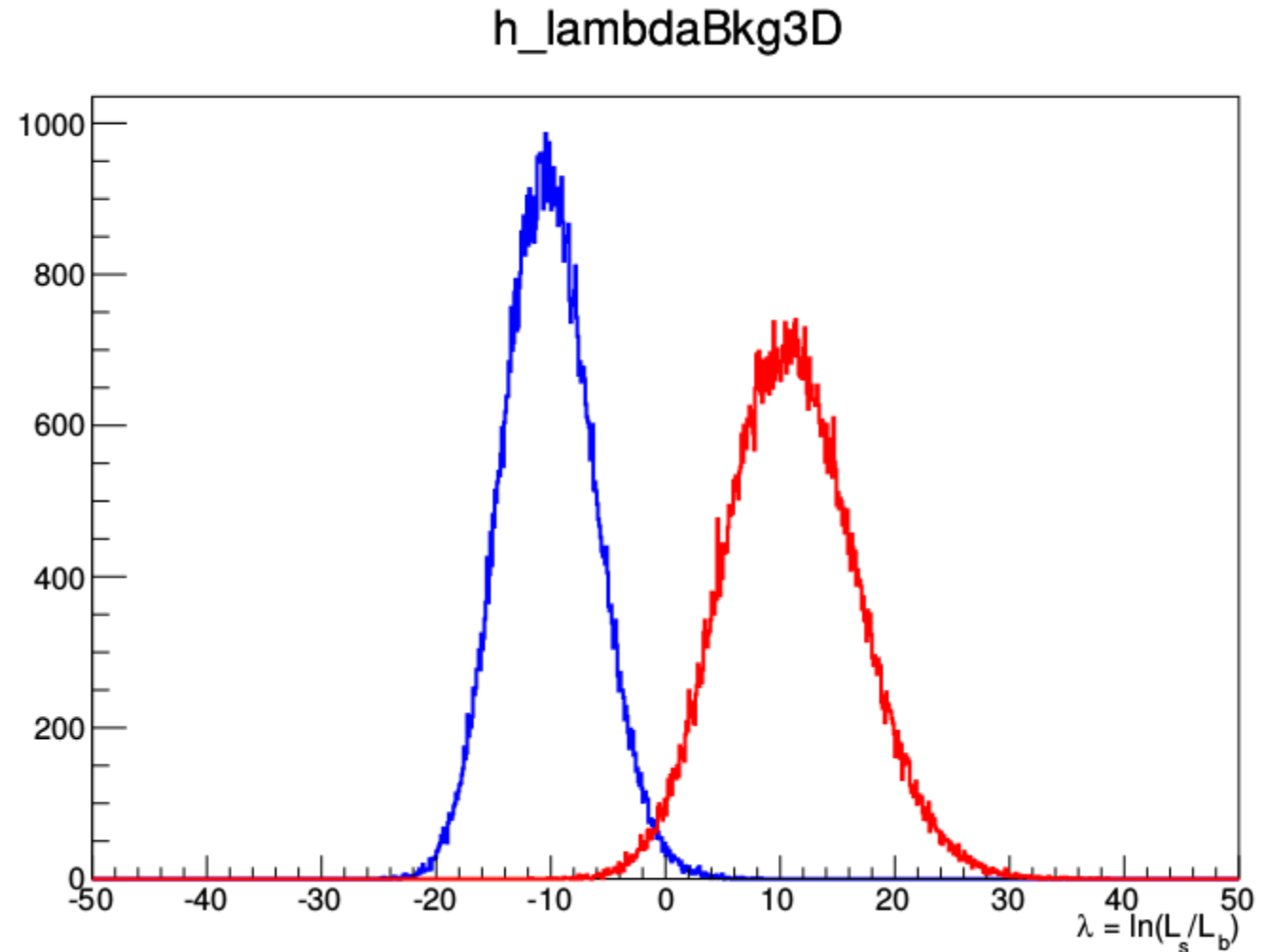
- Blue= background
- Red= signal
- Background pdf was created similarly to the signal pdf, except that the vector of earth motion was not added to the WIMP vector in the frame of the WIMP gas. This leads to a different energy distribution as well as a different polar angle distribution

h_lambdaBkg3D



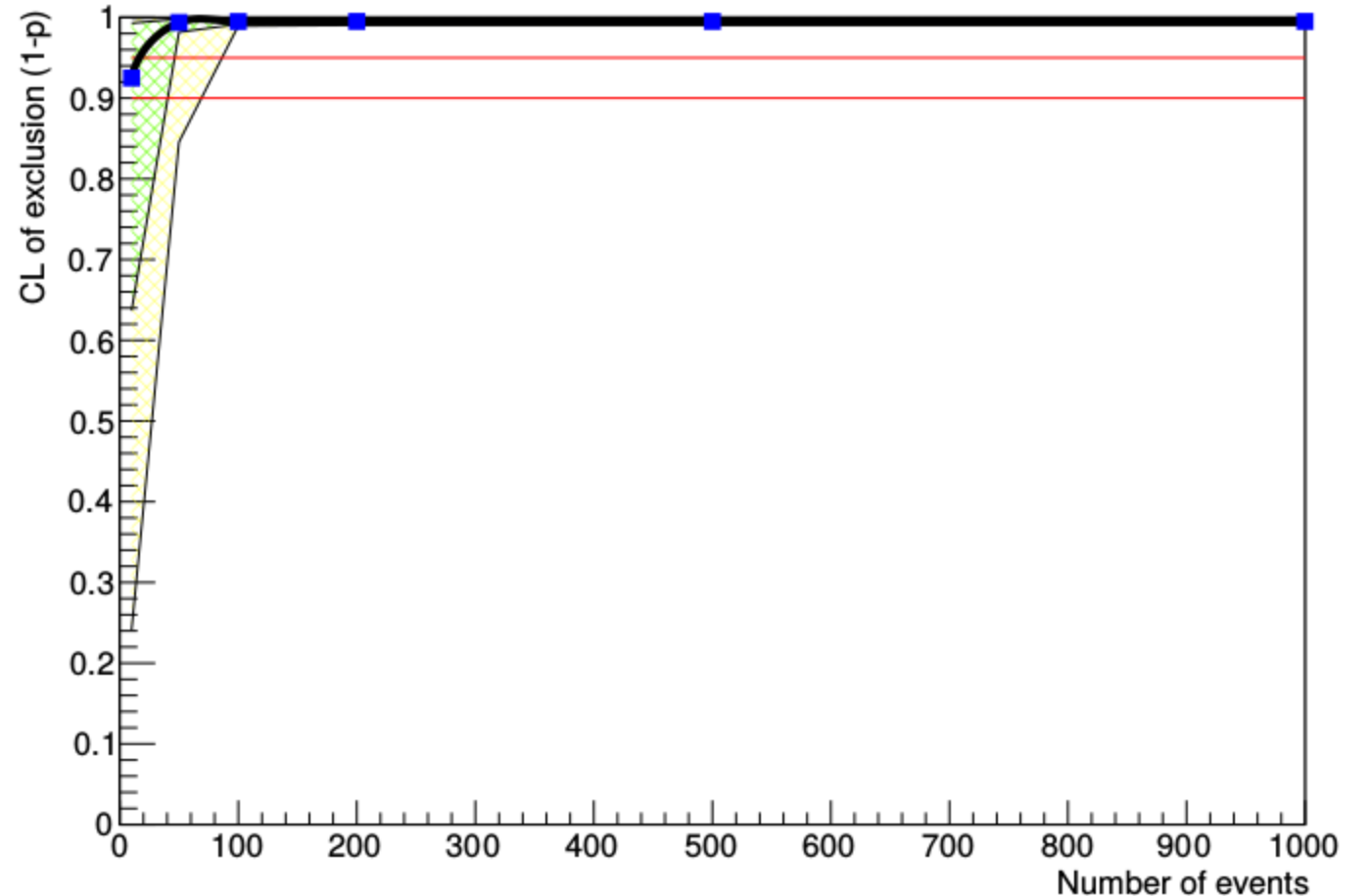
3D-co-rotating 100 events

- Separation at 100 events is excellent



3D-co-rotating: Confidence Level of Exclusion (1-p)

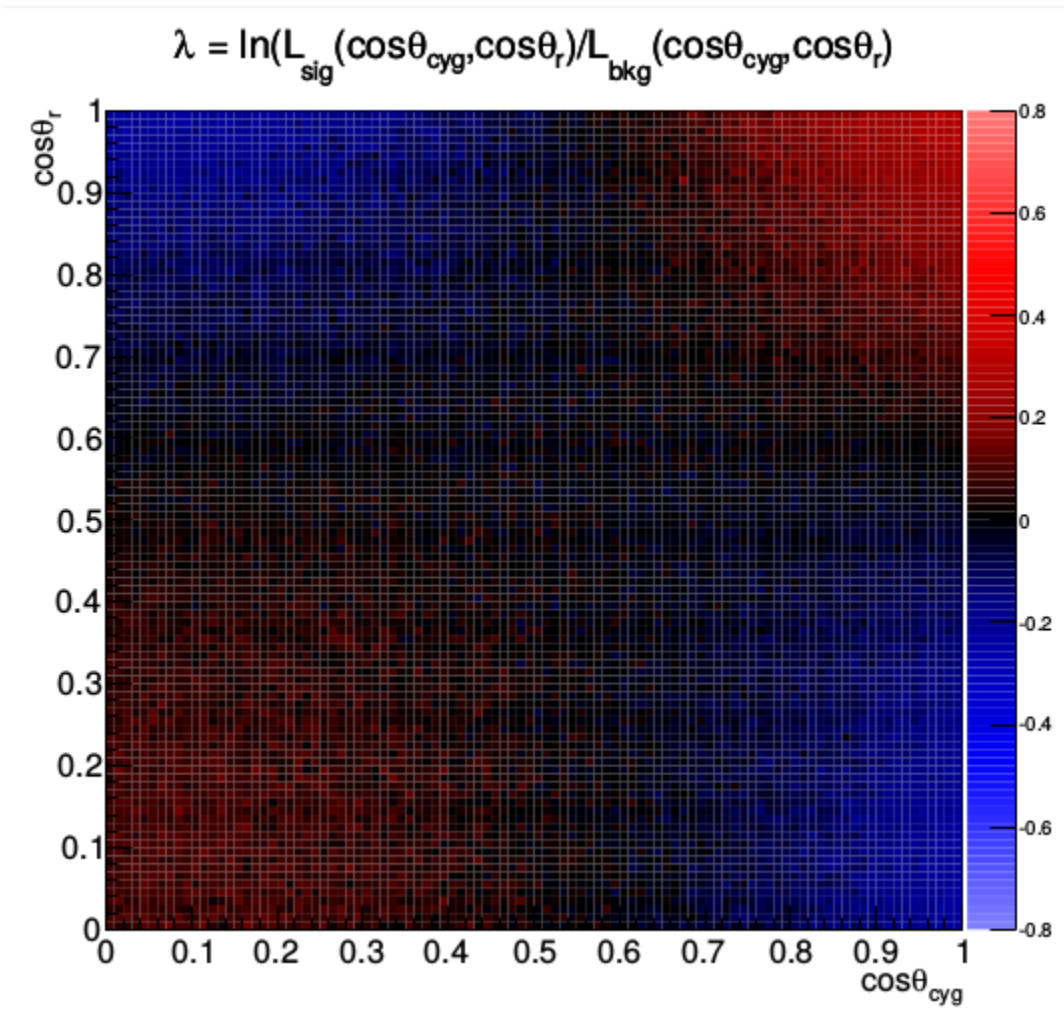
- Plot of the median expected exclusion confidence level (1-p-value) for the 3D-co-rotating model.
- The solid line indicates the mean, while the green shaded area shows sigma of 1 around the mean, and the yellow shaded area a sigma of 2.



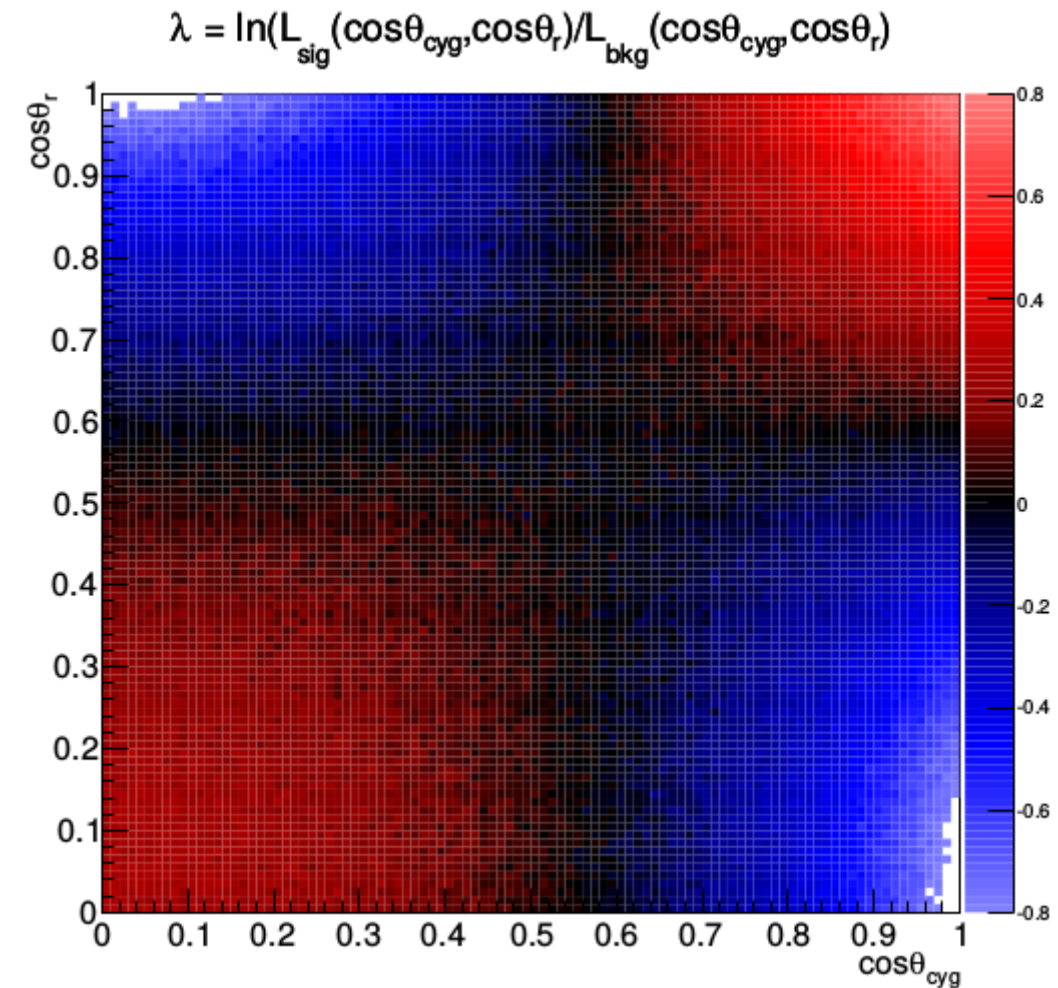
Threshold and Resolution

- The effects of threshold and resolution were studied
- The energy threshold used was 50 keV as lower energy recoil events will not be long enough to use columnar recombination
- The energy resolution used was 10 keV
- Angular resolutions of 100 , 200, and 400 mrad were explored. (5.7, 11.5, and 22.9 degrees)
- For now, the resolutions were treated constant numbers, not dependent on the energy or angle of the event in question.

2D-co-rotating: Effect of Threshold

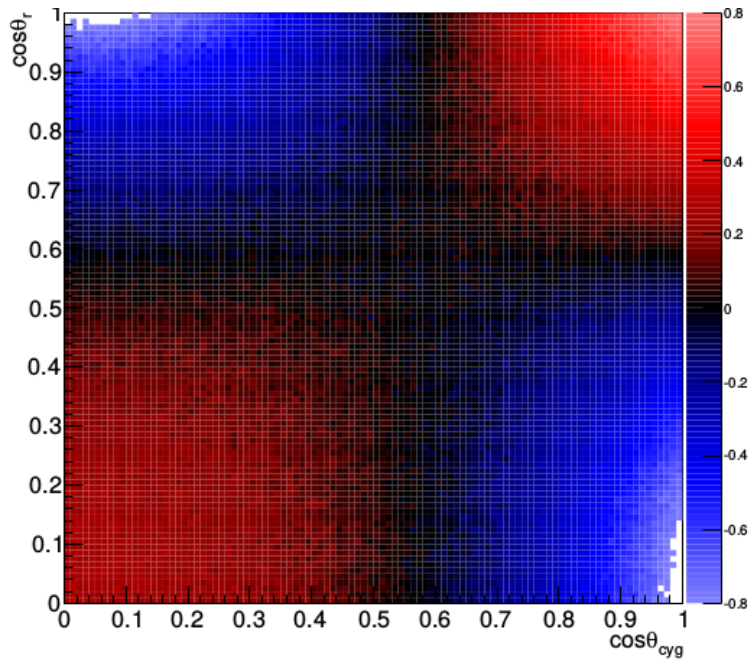


Threshold = 0 keV, Energy resolution 0 keV,
Angular resolution = 0 mrad



Threshold = 50 keV, Energy resolution 10 keV,
Angular resolution = 100 mrad

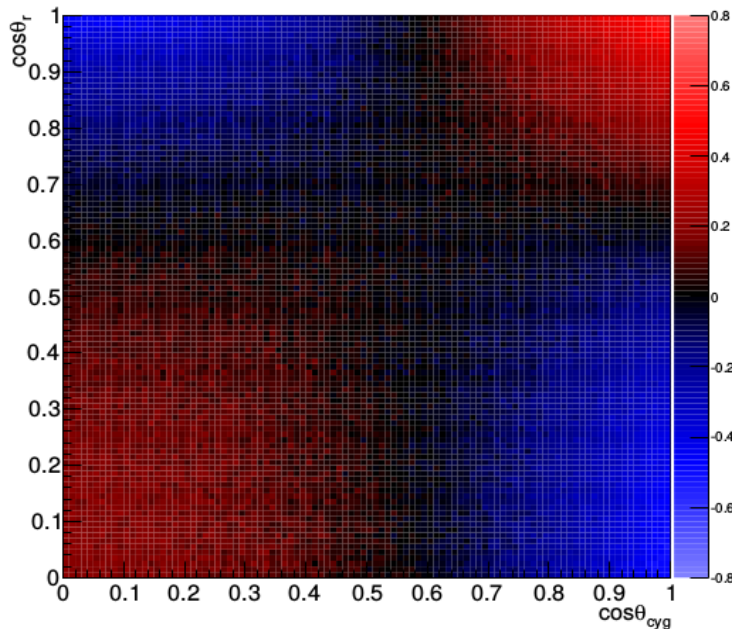
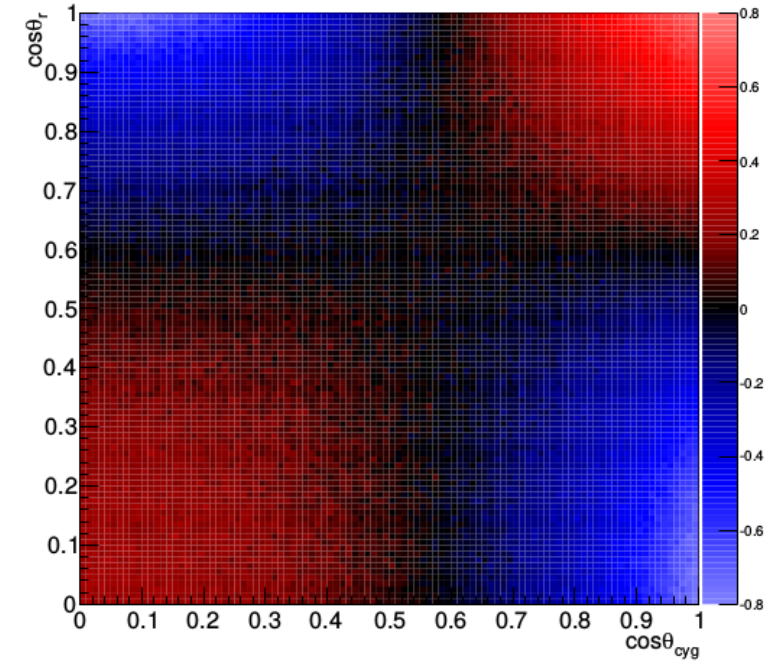
Angular resolution = 100 mrad (5.7 deg)



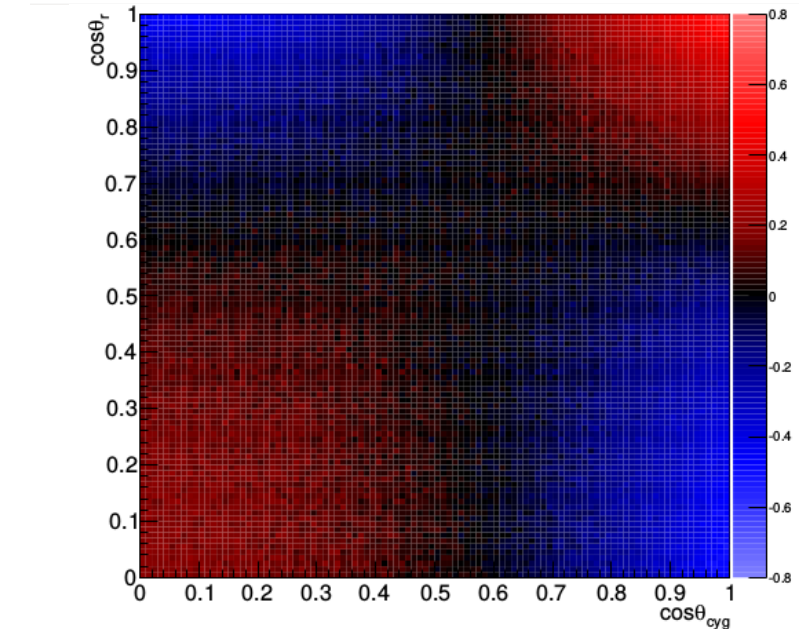
2D-co-rotating:
Effect of Resolution

- $\lambda=0$ indicates a ratio of 1, meaning that the probability of events at that $\cos(\Theta_r)$, $\cos(\Theta_{\text{cyg}})$ is equal for signal and background, as represented by black in the histogram. For red bins, events from signal have a higher probability of occurring than in background, while in blue bins it is the opposite.

Angular resolution = 200 mrad (11.5 deg)



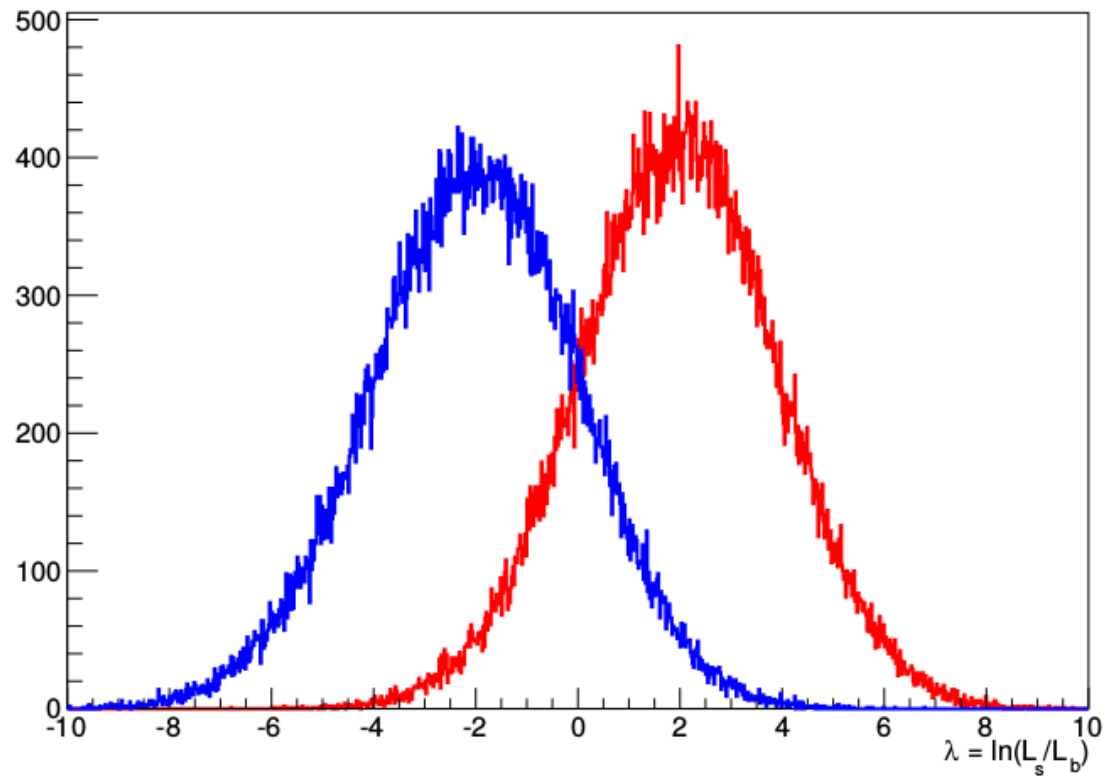
Angular resolution = 400 mrad (22.9 deg)



Angular resolution = 800 mrad (45.8 deg)

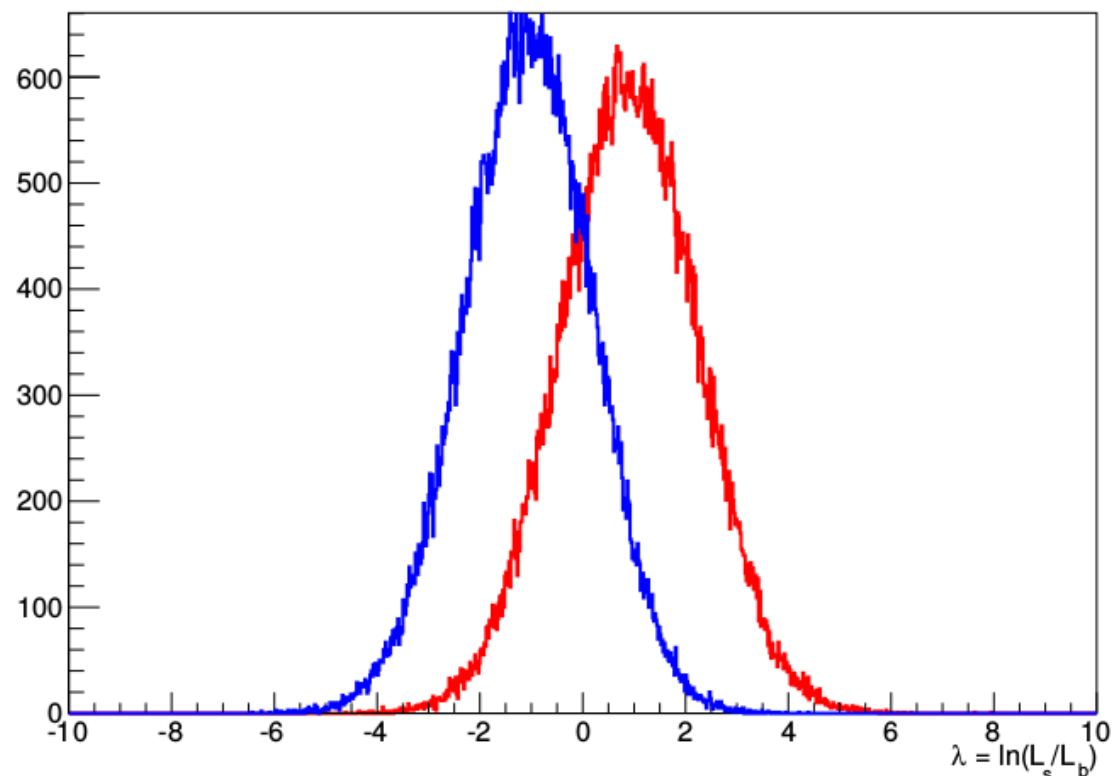
2D-co-rotating: Effect of Resolution

λ , directional vs flat



Angular resolution = 100 mrad

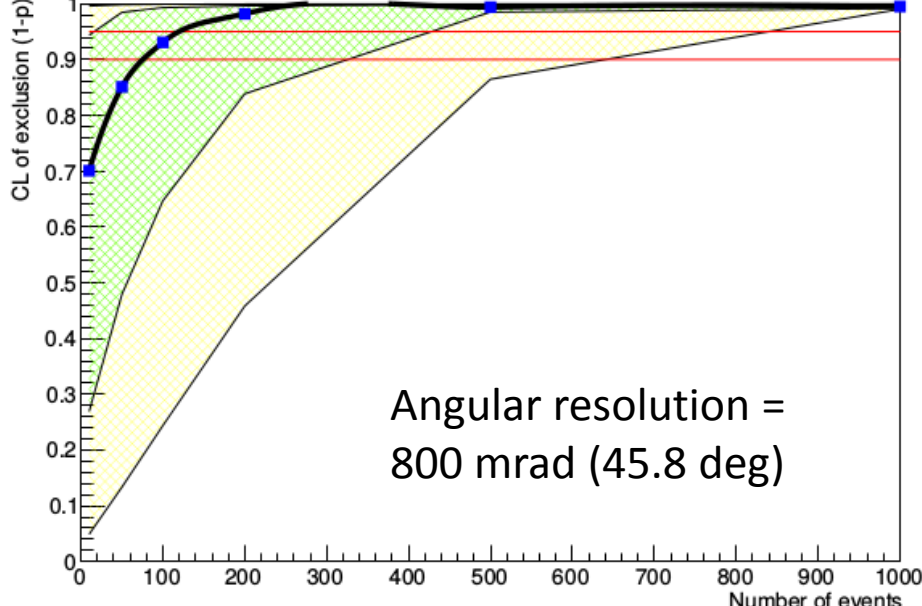
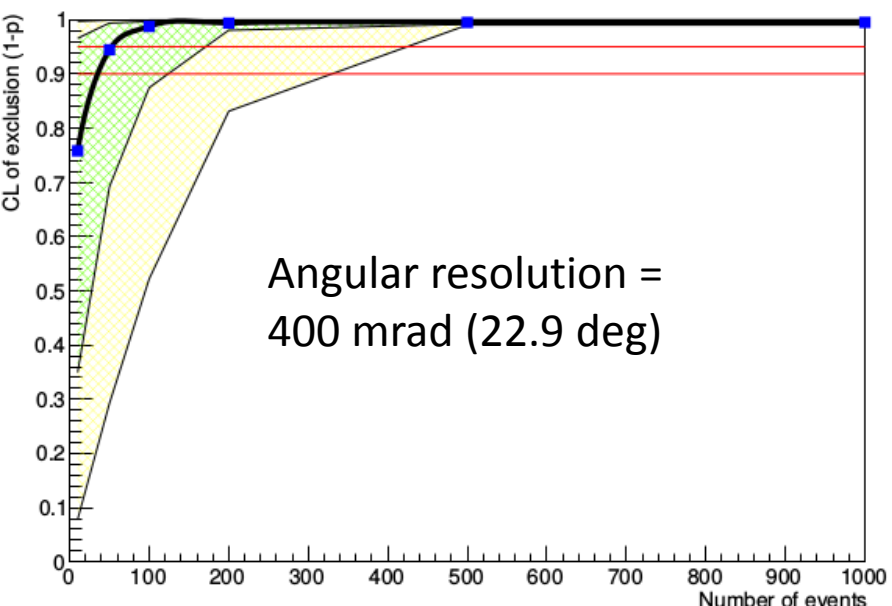
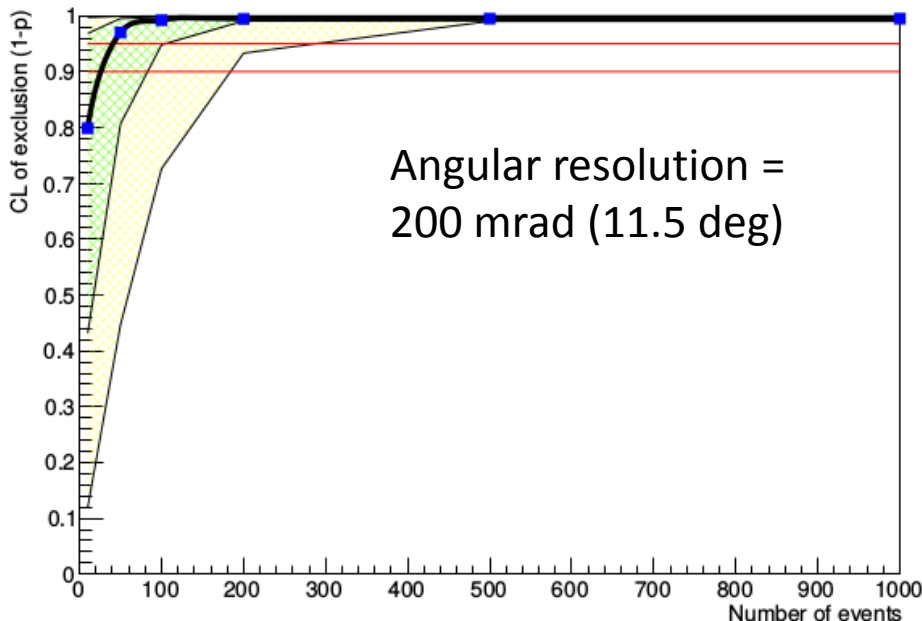
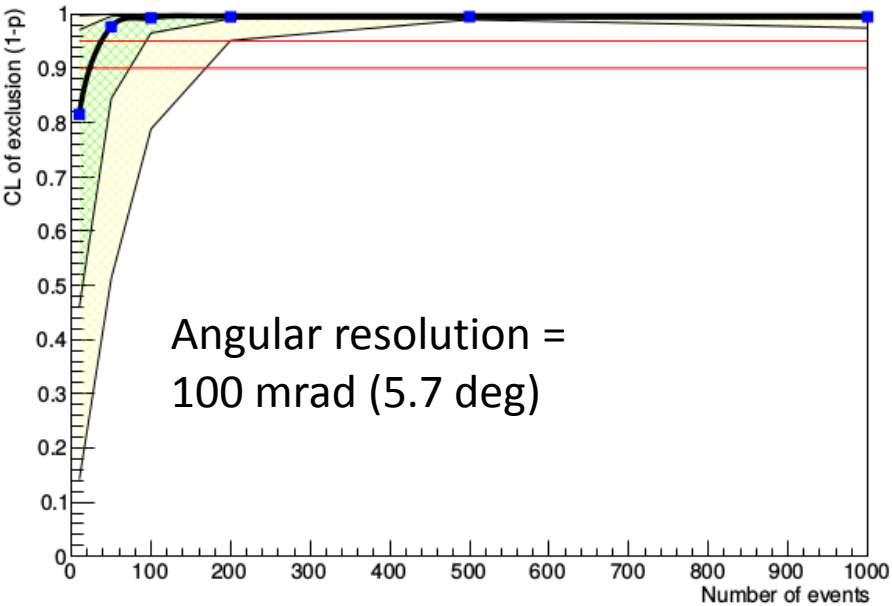
λ , directional vs flat



Angular resolution = 400 mrad

2D-co-rotating:
Effect of Resolution

- CL is clearly impacted by the angular resolution as expected



Next Steps

- Likelihood analysis including energy needs to consider *specific* isotropic models. Same energy distributions? Co-rotating? Contamination in detector?
- With real data sets the best approach would be to try to extract information on the WIMP mass/velocity distribution from the recoil energy distribution. This information can then be used to decide parameters used for the 3D pdfs.
- Smoother pdf and larger numbers of MCs are needed for final plots
- Which energy resolution should be used?
- Add annual modulation
- Add form factor

