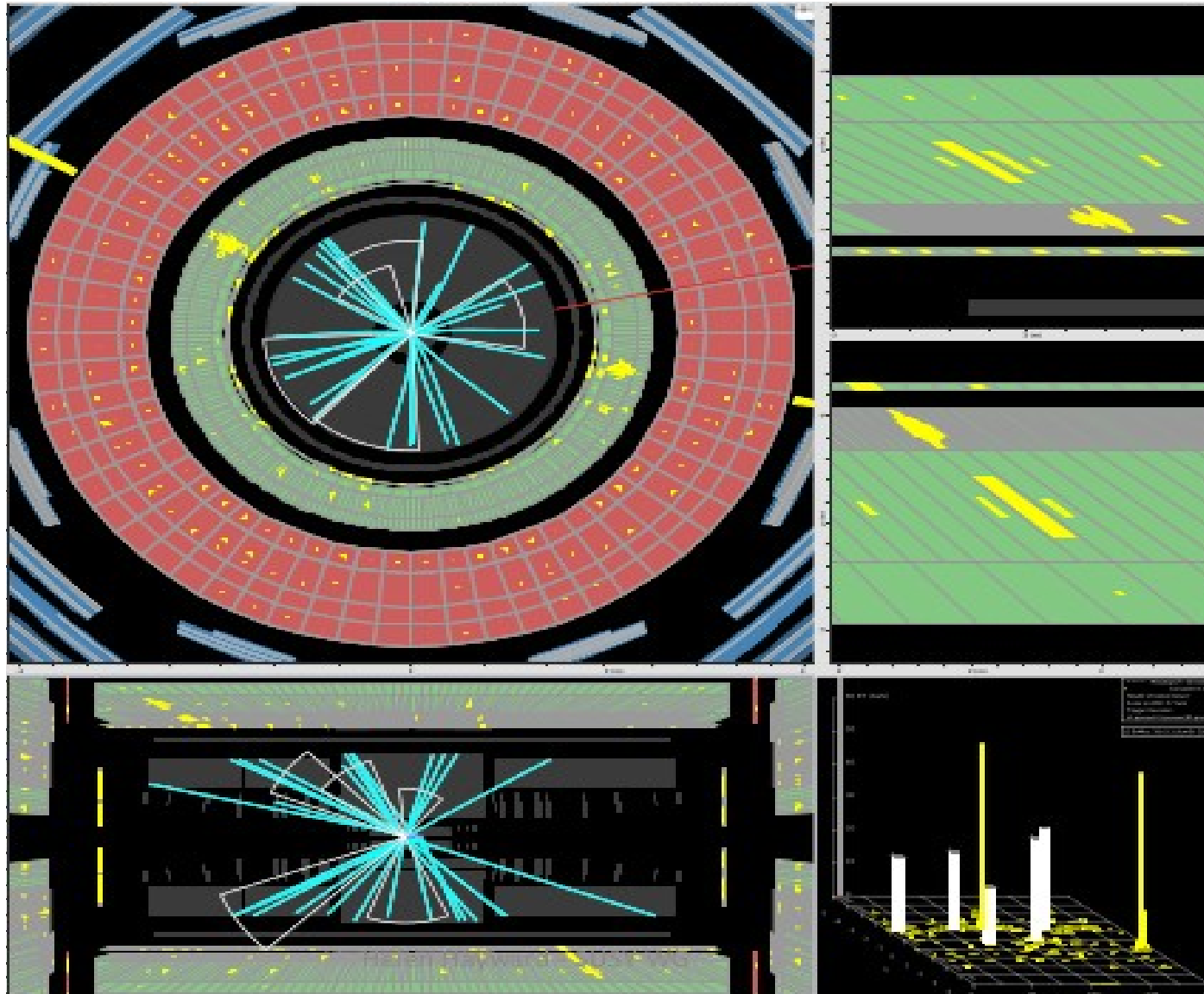


A Search For Long Lived Neutral Particles

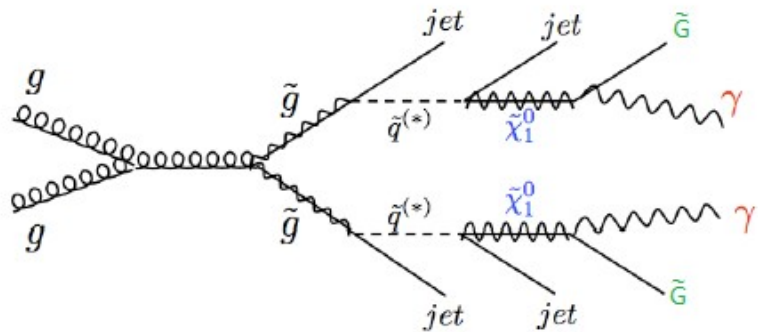
8/4/2014

Allan Lehan



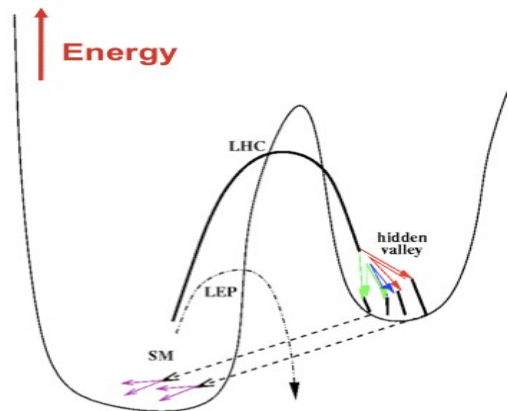
Motivation

Gauge Mediated Symmetry Breaking

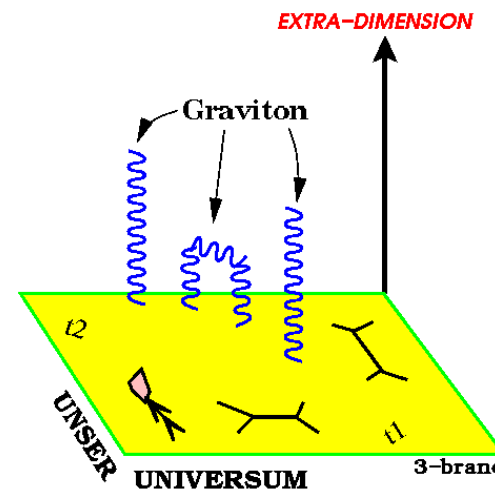


- The discovery of a long lived neutral particle would be a clear sign of new physics
- Exist in a number of beyond the Standard Model physics models
- In Gauge Mediated Symmetry Breaking the lightest neutralino can be **long lived**
- Search for **diphoton** events with a large amount of **missing transverse energy**

Hidden Valley Models

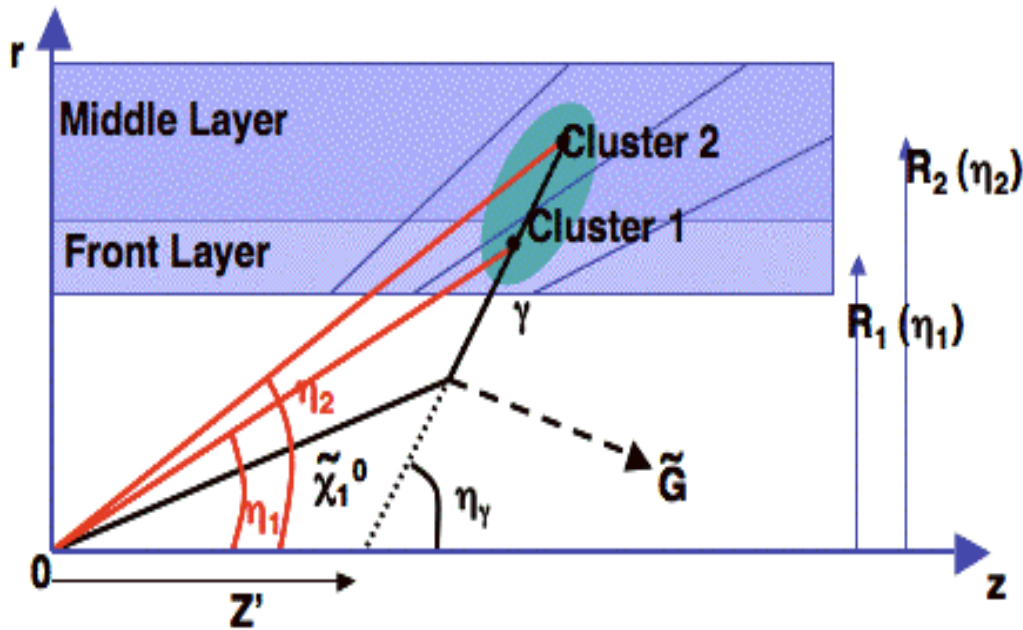


Extra Dimension Models

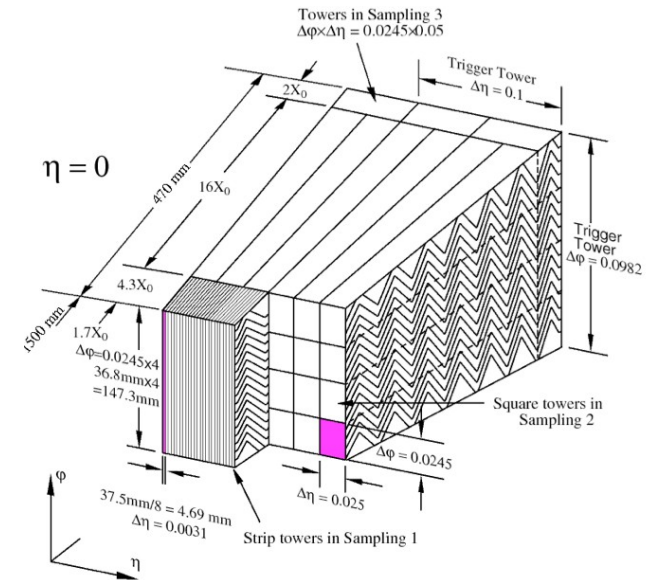


Non-Pointing Photons

- Electromagnetic calorimeter has 'accordion' geometry with each cell pointing back to center of detector
- Fine spacing in first layer allows excellent η resolution



$$z_{DCA} = z' - z_{PV}$$

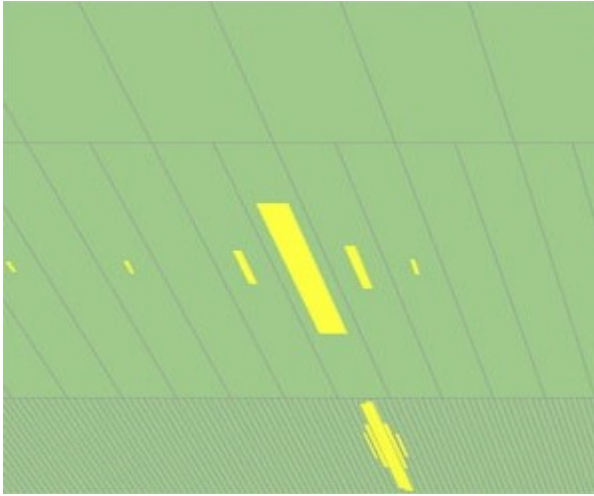


- Combine η information from first and second sampling layers to determine path of photon
- Photon will point back to decay vertex of neutralino not the primary decay vertex

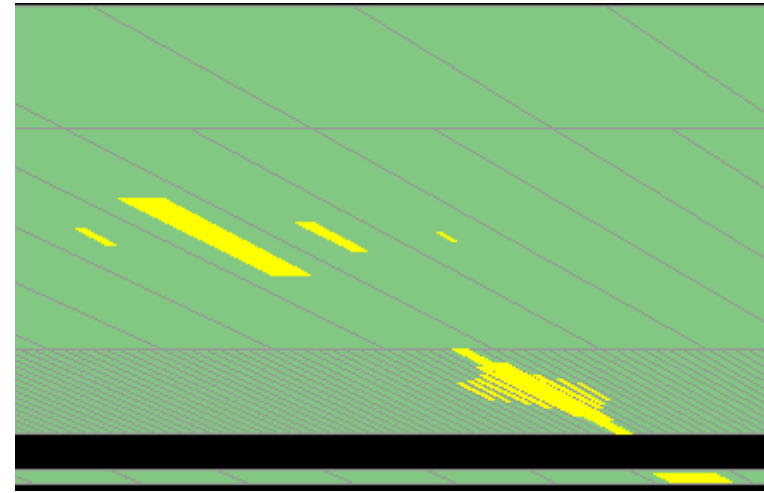


Electromagnetic Showers

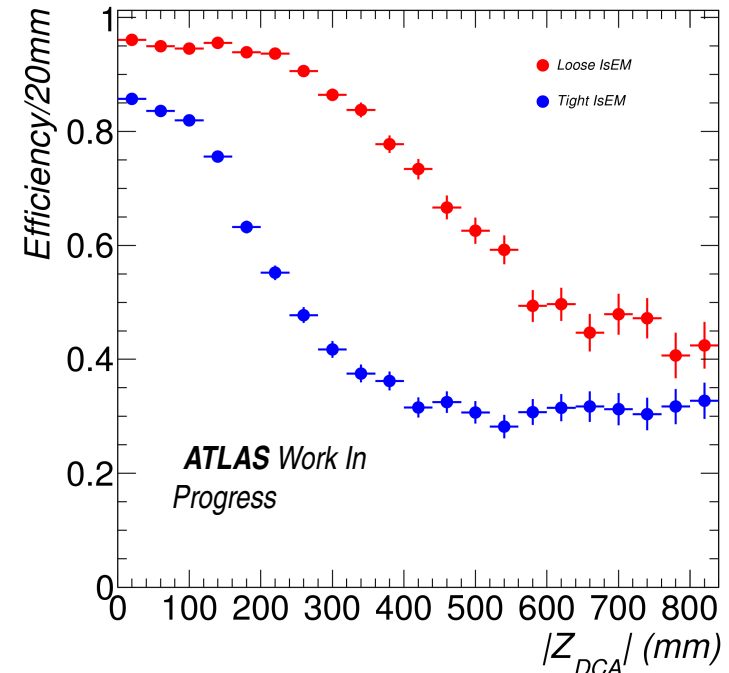
Photon Shower



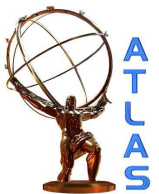
Jet Shower



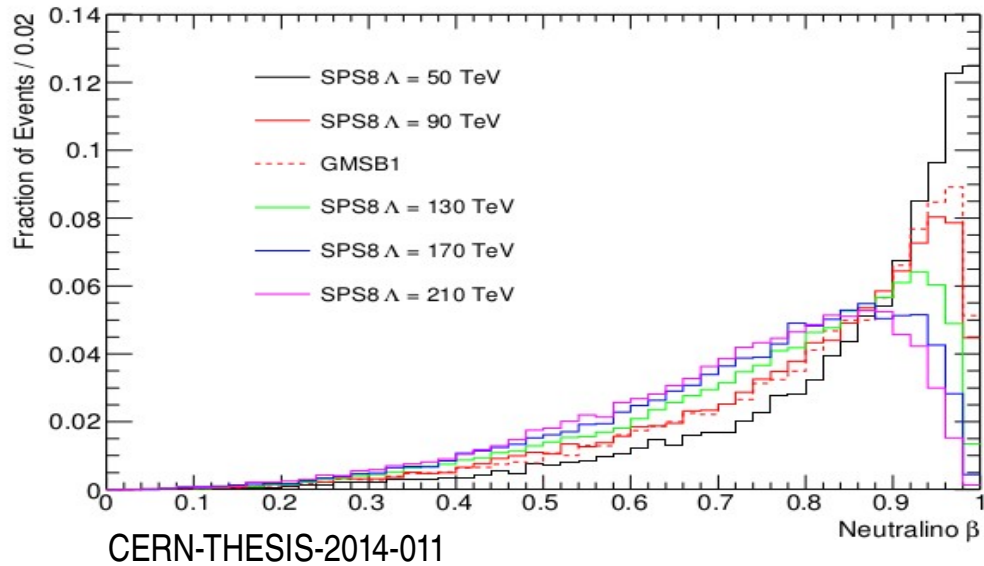
- Energy deposition in electromagnetic calorimeter used to distinguish between different objects
- A non-pointing photon can have a wider shower -> appear more 'jet-like'
- Drop in efficiency of non-pointing photons being identified as photons as z_{DCA} (i.e. 'non-pointingness') increases



• $Z_{DCA} = Z' - Z_{PV}$

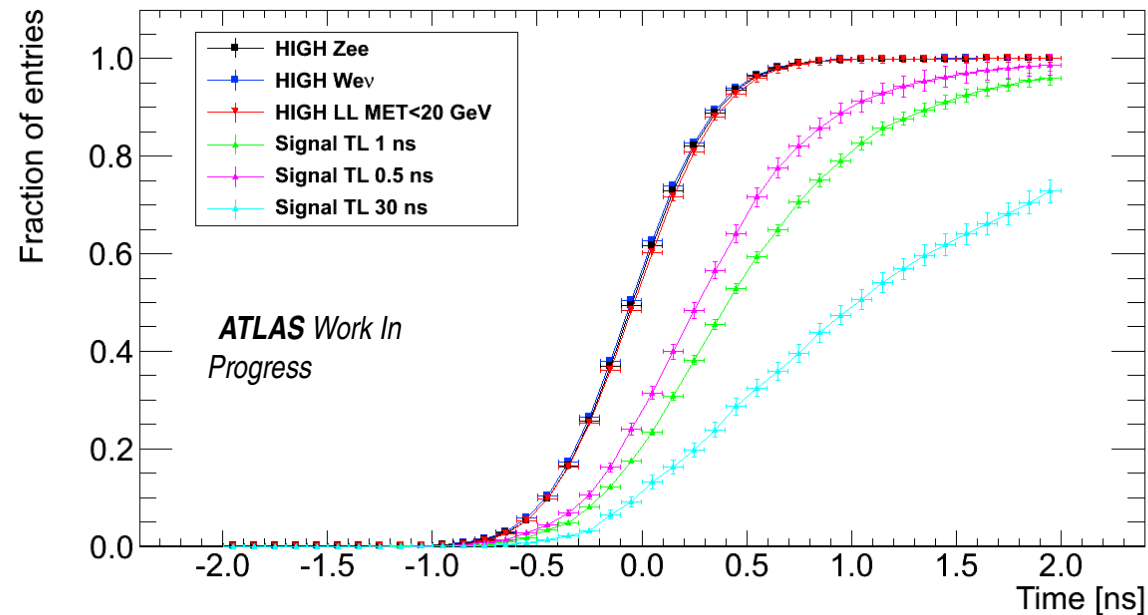


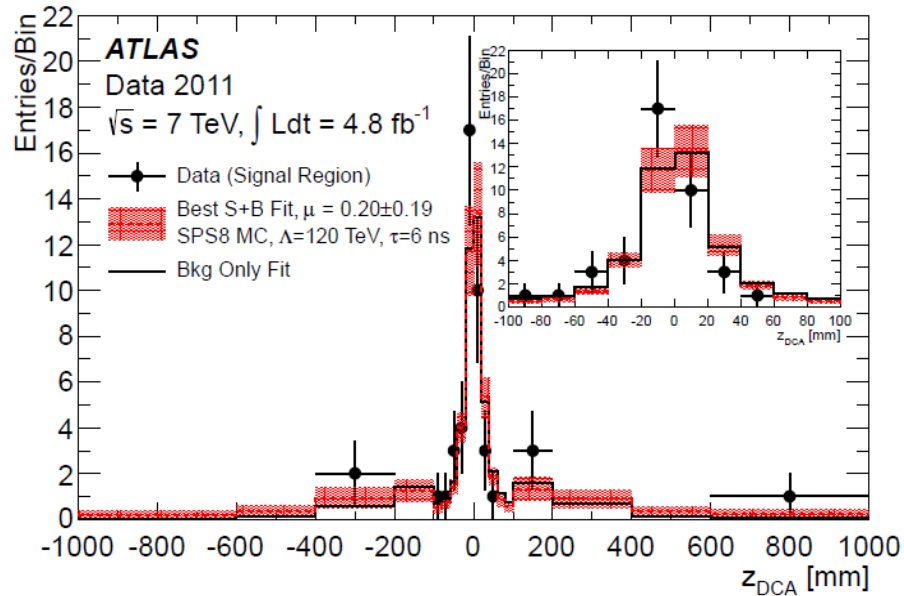
Time Delay of Non-Pointing Photons



- β of neutralino and extra path length results in non-pointing photons reaching calorimeter later than prompt photons

- Timing distribution of background samples very similar
- Signal samples have greater percentage of photons detected with large delays

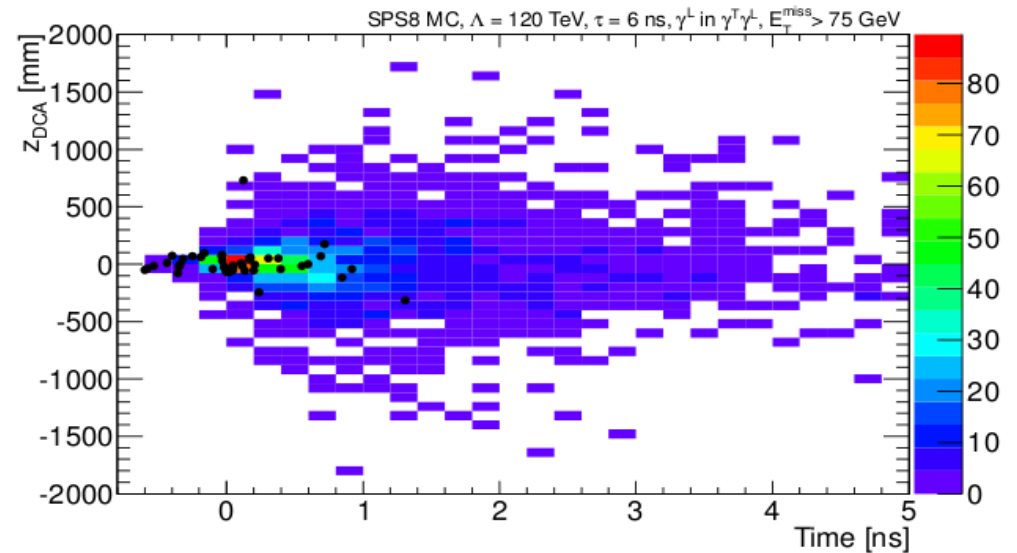




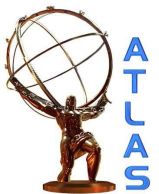
Phys. Rev. D 88 (2013) 012001

- Timing information only used as cross-check
- Shows that outlier in z_{DCA} is in time

- Require one high quality photon, analyse z_{DCA} distribution of second photon
- 46 events in signal region
- Good agreement with background only fit
- One outlier at large z_{DCA}

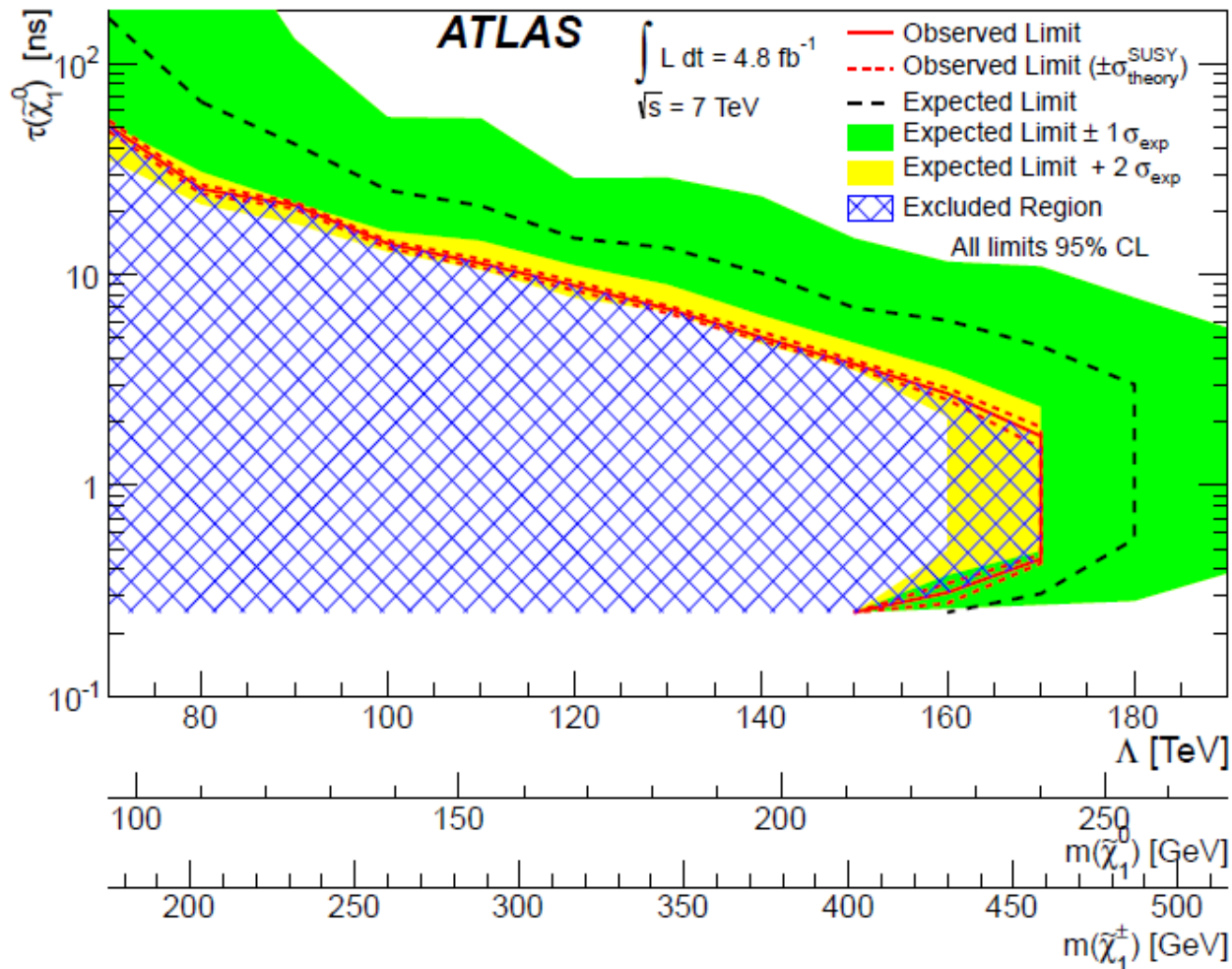


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2011 Exclusion Region

Phys. Rev. D 88 (2013) 012001

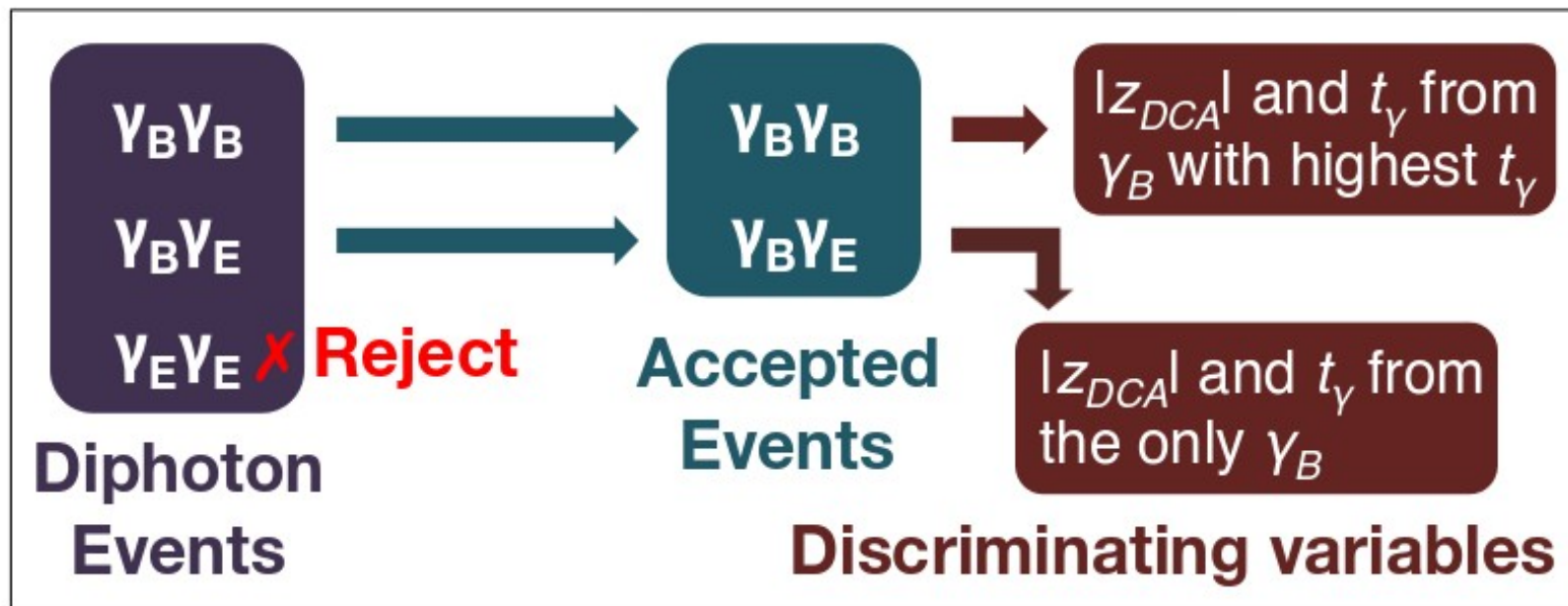


- Hatched region shows range of neutralino lifetimes excluded with 95% confidence level for neutralino masses between 95-235 GeV



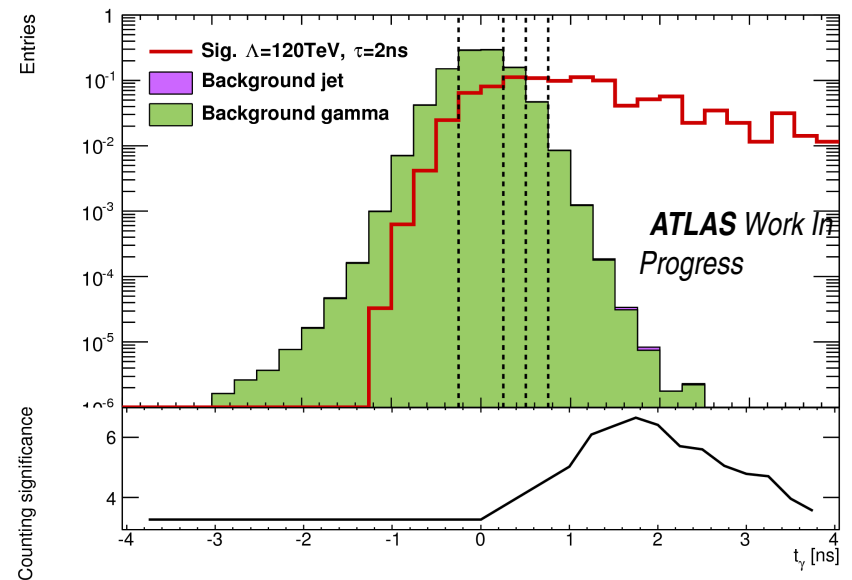
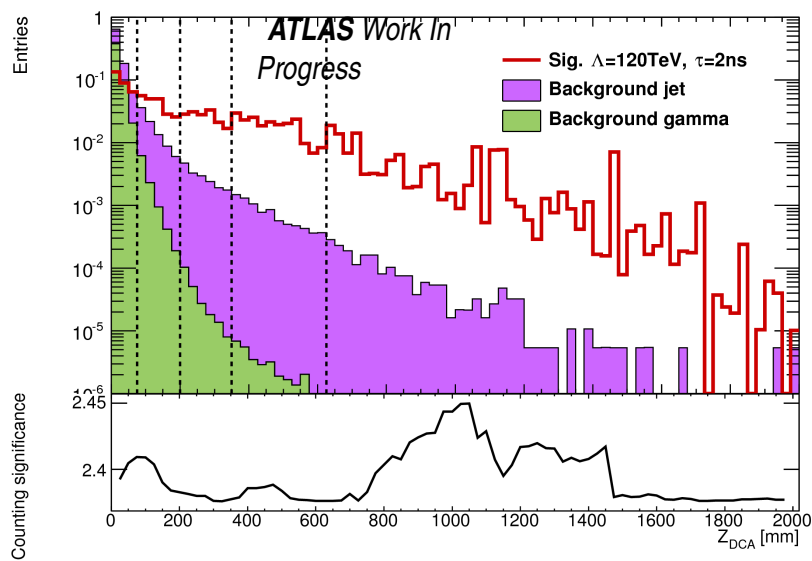
Event based variables

- Continue to use timing and $|z_{DCA}|$ variables for discriminating variables
- Consider $|z_{DCA}|$ and timing (t_γ) variables from photon with the largest delay
- Events with two loose photons in the end-caps have too much background so are rejected.



2012 Analysis Strategy - Outline

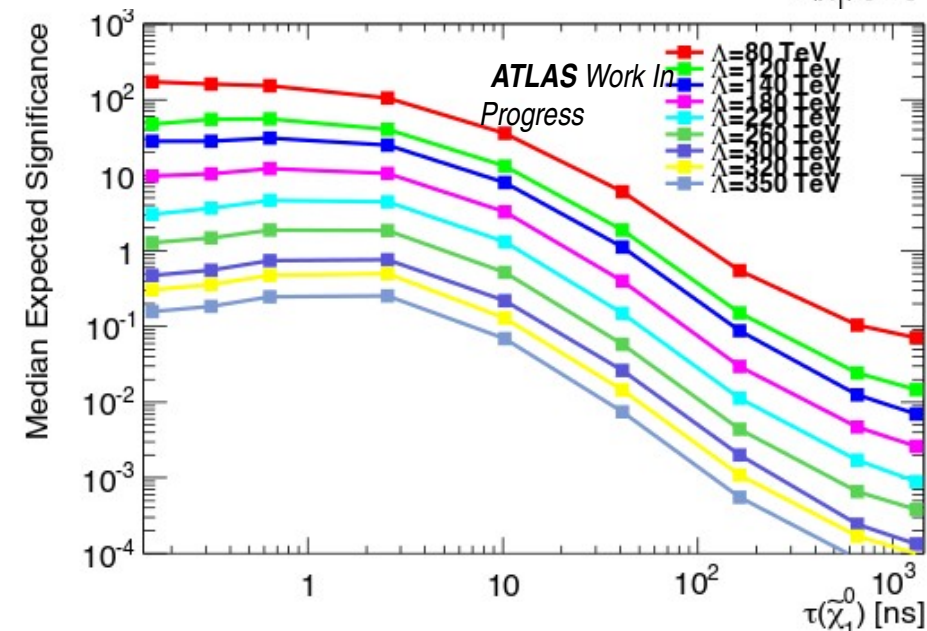
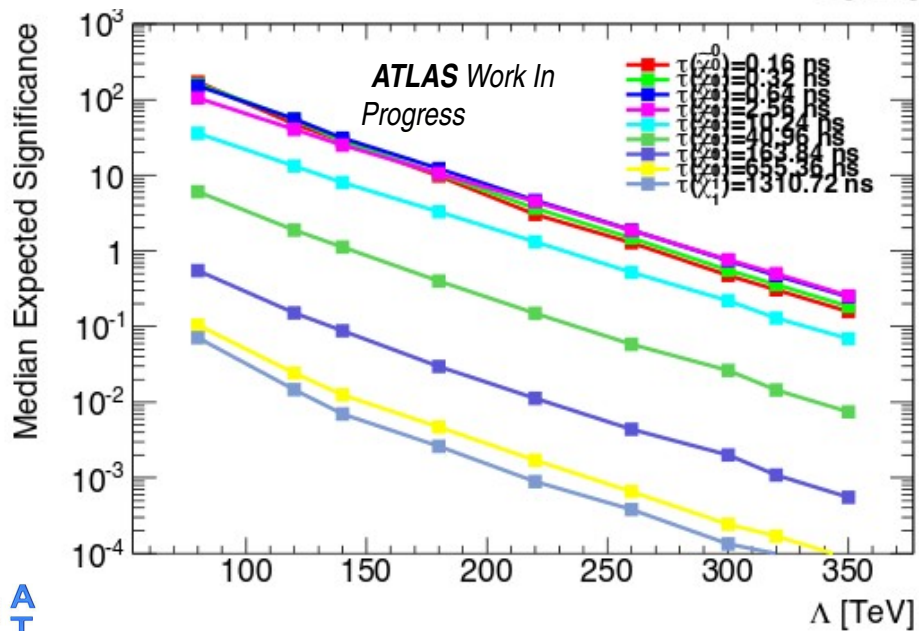
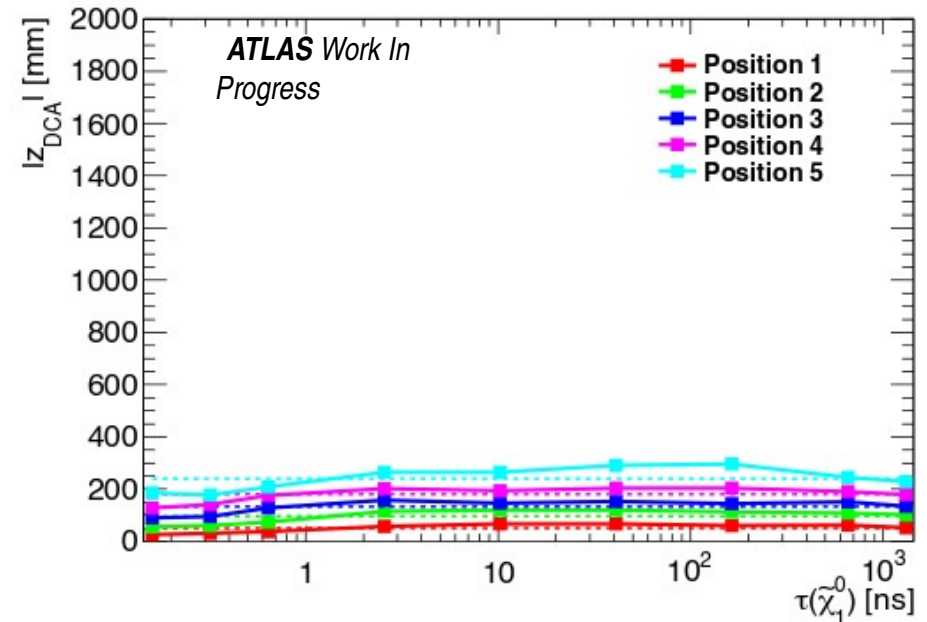
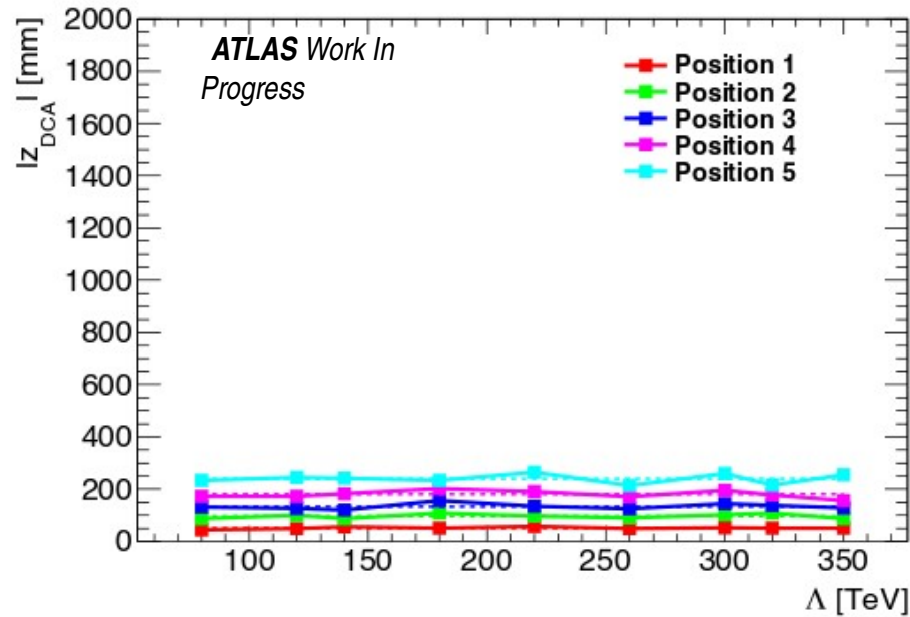
- Timing distribution of Jet & electron/photon background distributions very similar
- Timing distribution independent of z_{DCA} range
- Separate photons into different z_{DCA} regions and fit timing distribution
- Use same z_{DCA} and timing bins across entire signal region



Dashed line shows position of optimised bin positions

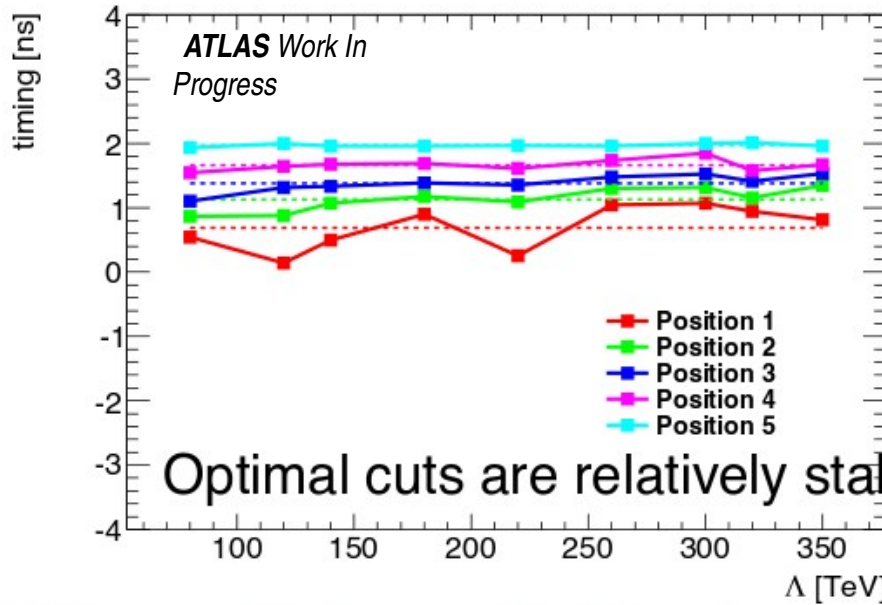
Optimising Position of $l_{z_{DCA}}$ Bins For Entire Signal Grid

- Same bin positions will be used for entire signal grid, shown as dashed lines in top two plots

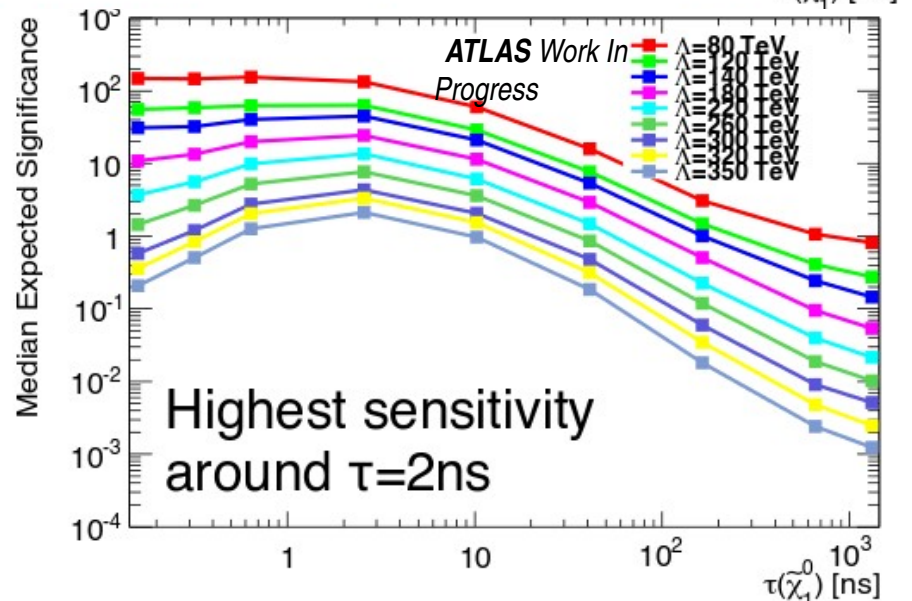
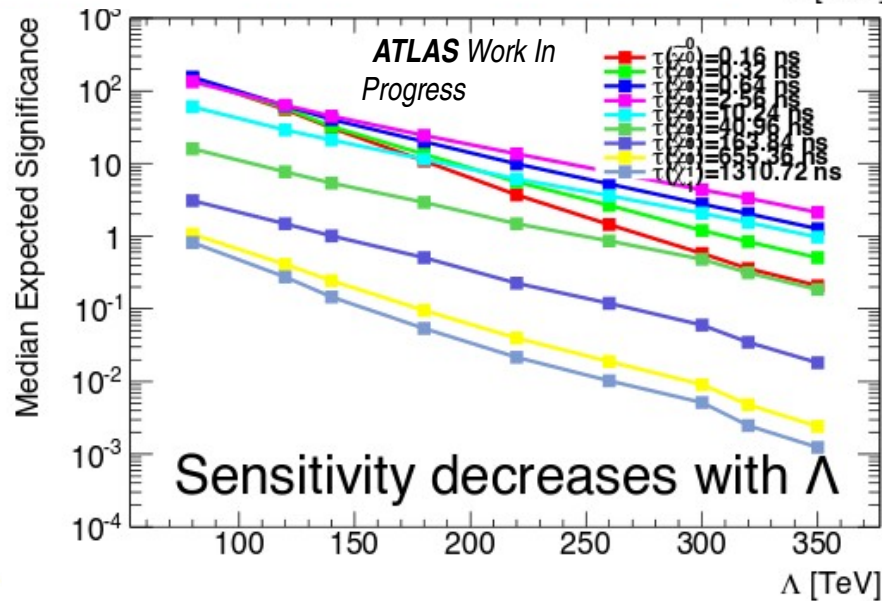
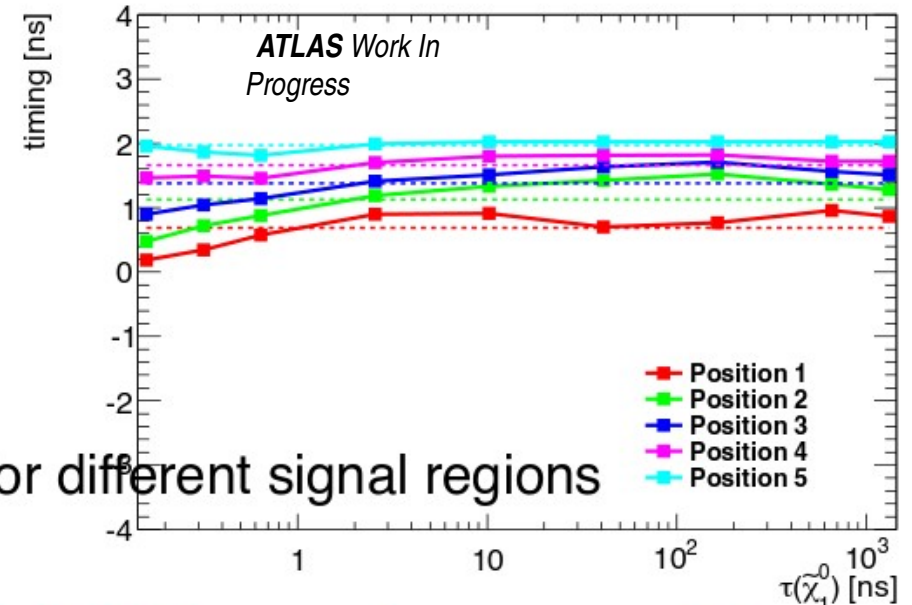


Optimising Position of Timing Bins For Entire Signal Grid

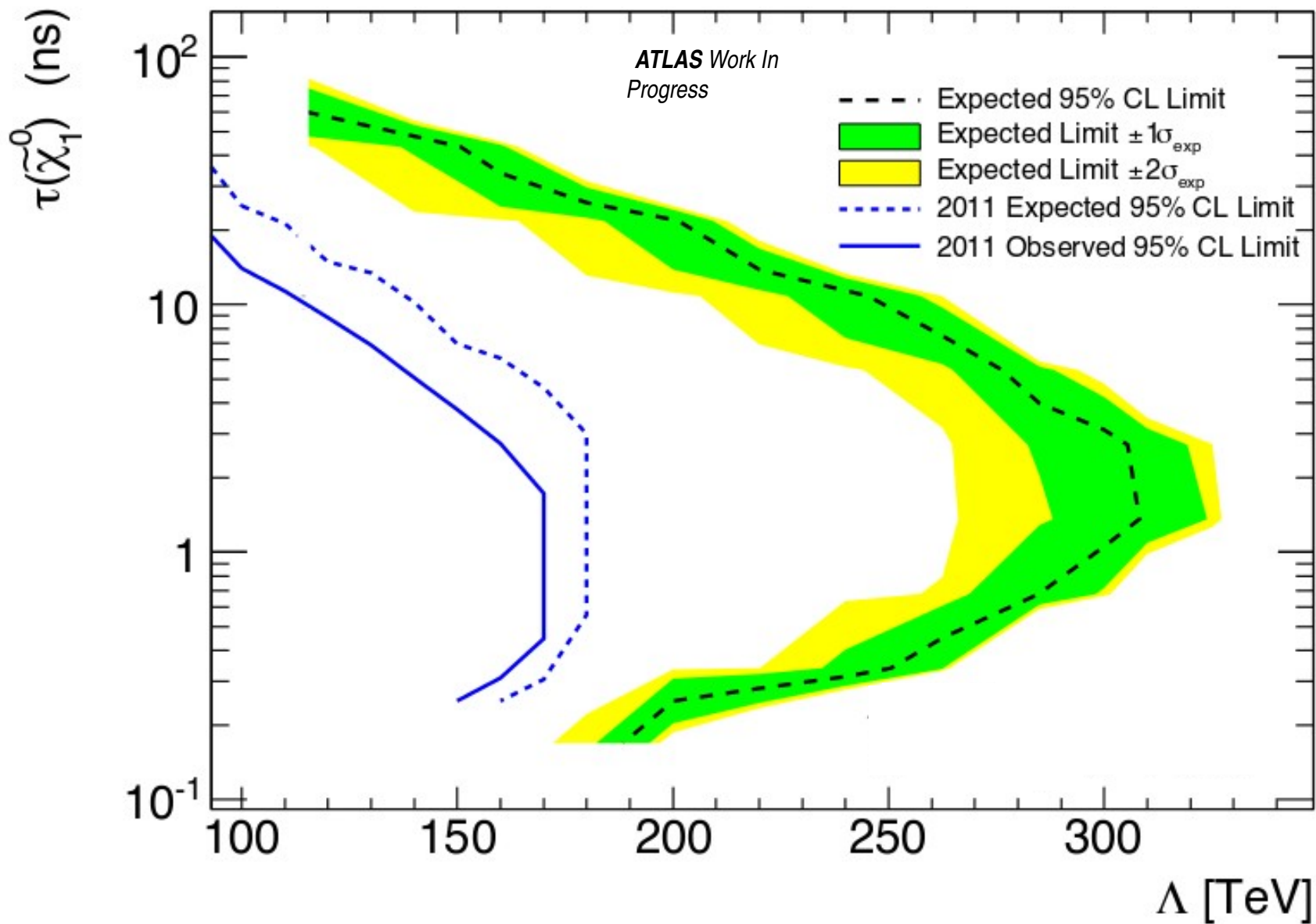
- Same bin positions will be used for entire signal grid, shown as dashed lines in top two plots



Optimal cuts are relatively stable for different signal regions



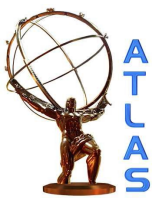
Comparison of Expected Limits to 2011 Result



Conclusion

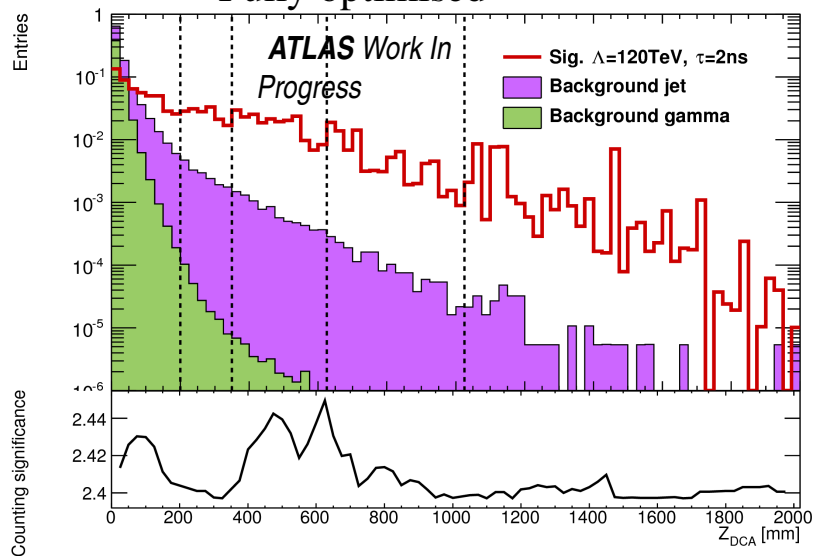
- The discovery of a long lived neutral particle that decays to photons would be a clear sign of beyond the Standard Model physics
- Utilising the excellent η resolution of the ATLAS electromagnetic calorimeter allows us to determine if photons have come from displaced vertices
- A novel technique for calibrating data from electrons allows us to accurately determine if a photon has arrived at the electromagnetic calorimeter later than expected
- An analysis of data collected in 2011 showed no signal events but set competitive limits on possible mass and lifetime ranges of neutralinos
- Analysis of the 2012 data is ongoing. Improvements to the analysis method & extra statistics mean we expect to greatly increase the mass and lifetime ranges of neutralinos that are excluded



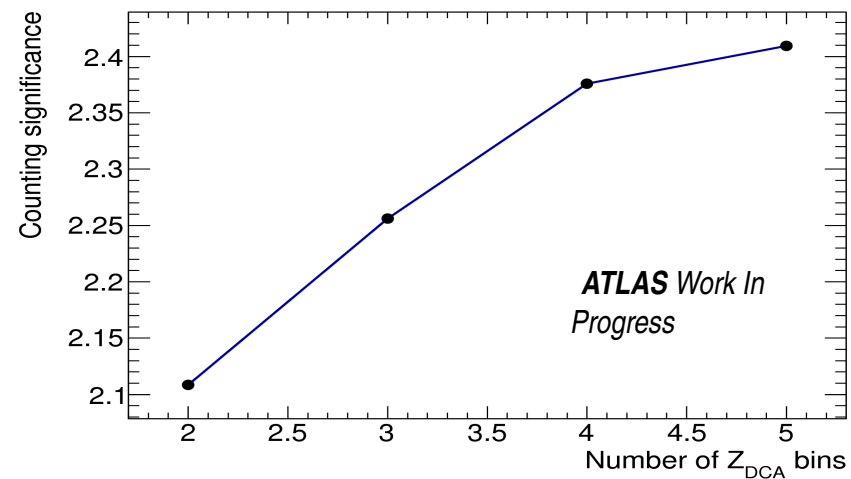
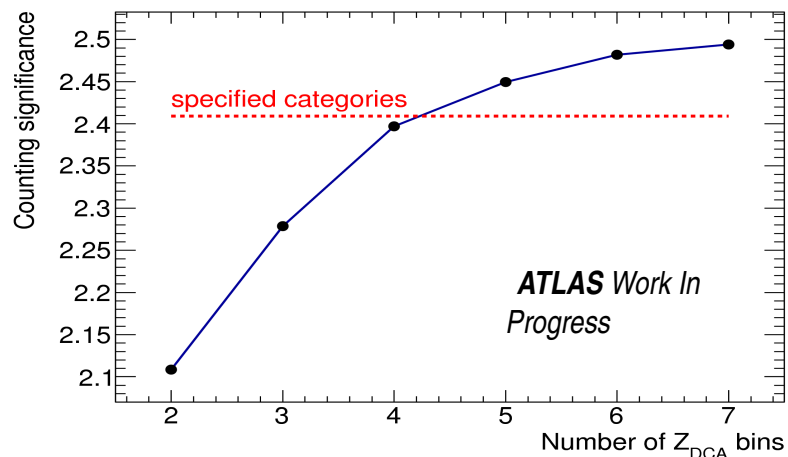
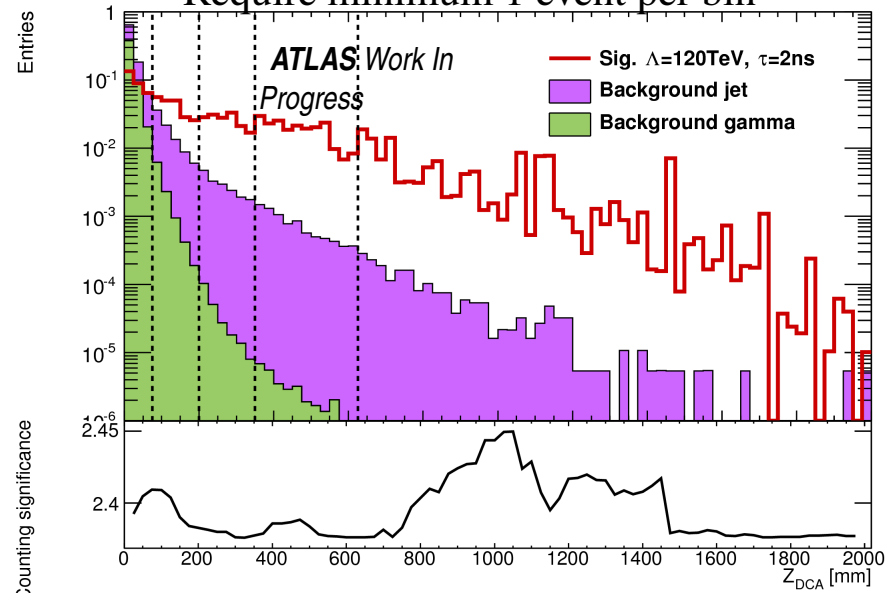


Optimise Binning in $|z_{DCA}|$

Fully optimised



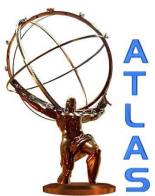
Require minimum 1 event per bin



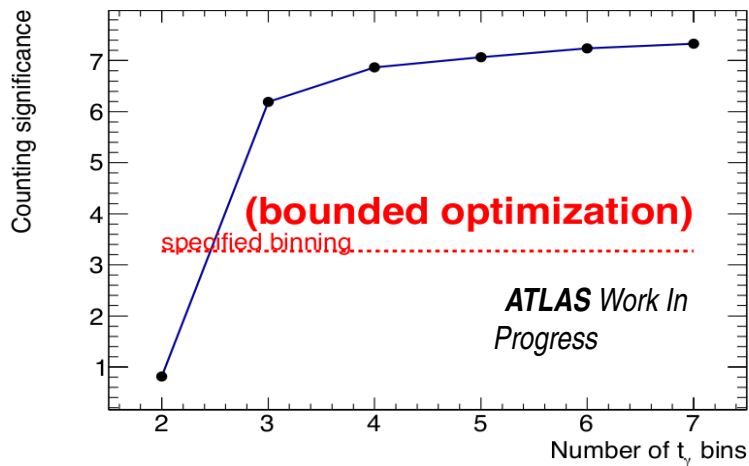
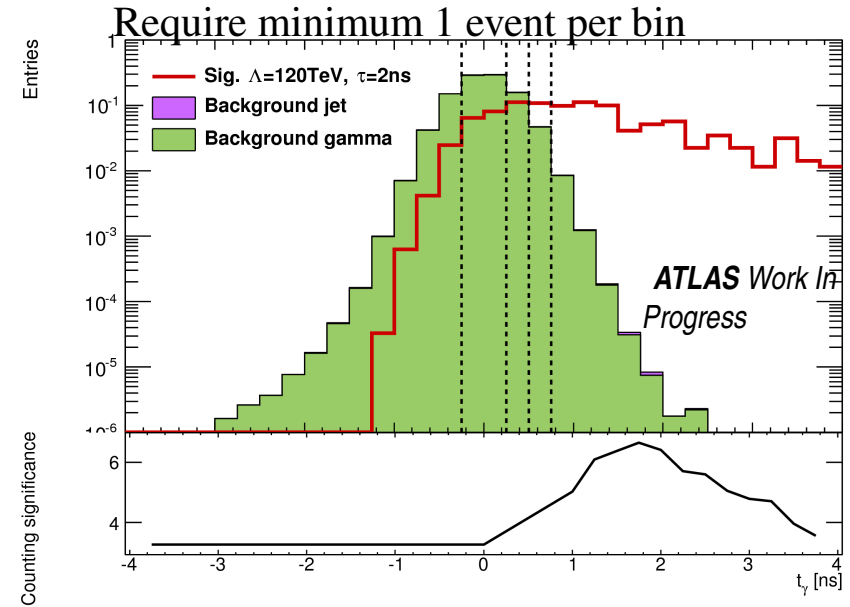
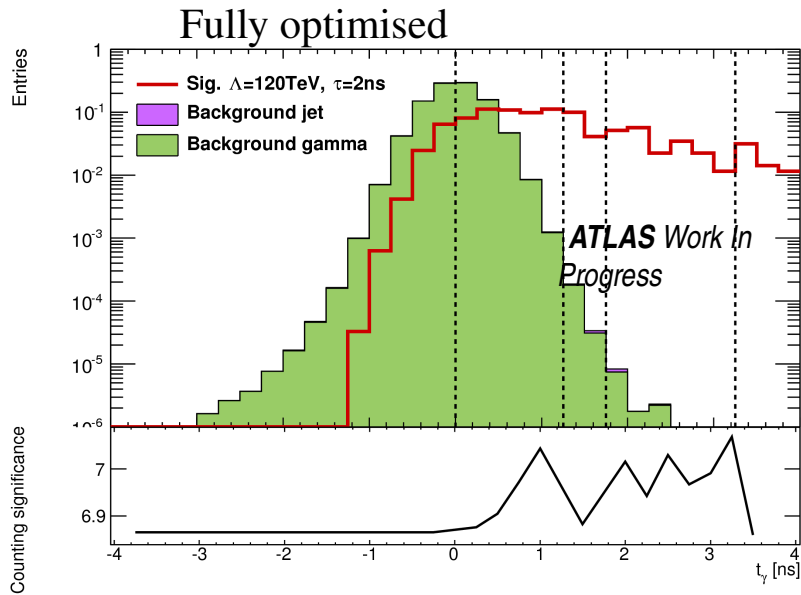
Bins={0,200,350,625,1025,2000}[mm]

Bins={0,75,200,350,625,2000}[mm]

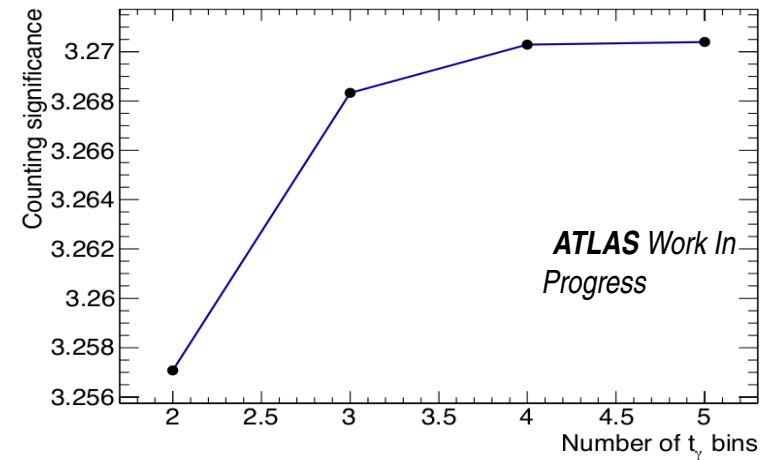
- Requiring minimum of 1 bin per event only results in 4% drop in significance
- > use this 'bounded' binning in limit setting



Optimise Binning in Timing



Bins={-4,0,1.25,1.75,3.75,4}[ns]



—Bins={-4,-0.25,0.25,0.5,0.75,4}[ns]

- Requiring minimum of 1 bin per event results in ~50% drop in significance -> use fully optimised binning in limit setting

Loose-Loose ph selection

We compare the selected EVENT yield after our standard diphoton selection and MET cut

Λ (TeV)	τ (ns)	TOTAL EVENTS	TL (2011)		L (barrel) + L (all)		LL (All)	
			Yield	Efficiency	Yield	Efficiency	Yield	Efficiency
70	2	40000	2191.98	5.5%	2422.94	6.1%	2463.64	6.2%
120	2	39999	6503.19	16.3%	7365.88	18.4%	7557.94	18.9%
120	6	40000	2143.22	5.4%	2598.4	6.7%	2681.59	6.7%
150	2	40000	9246.72	23.1%	10464.3	26.8%	10721.3	26.8%

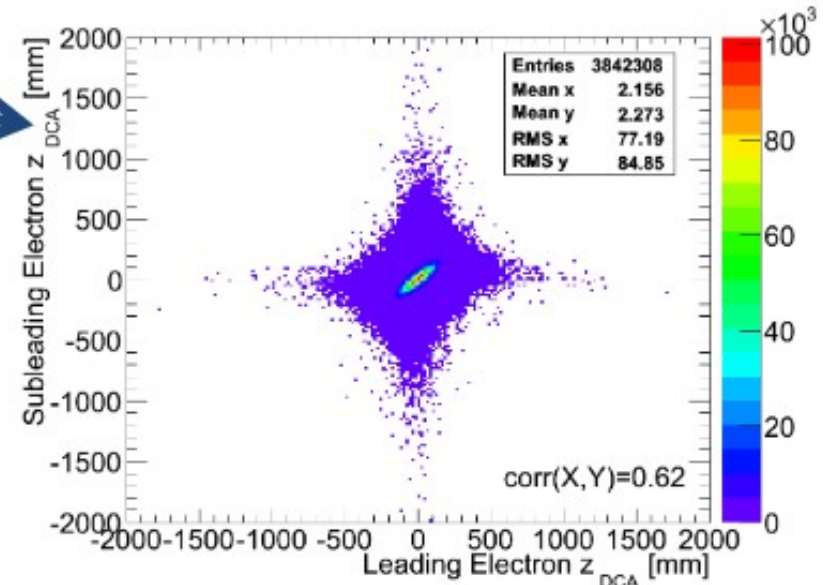
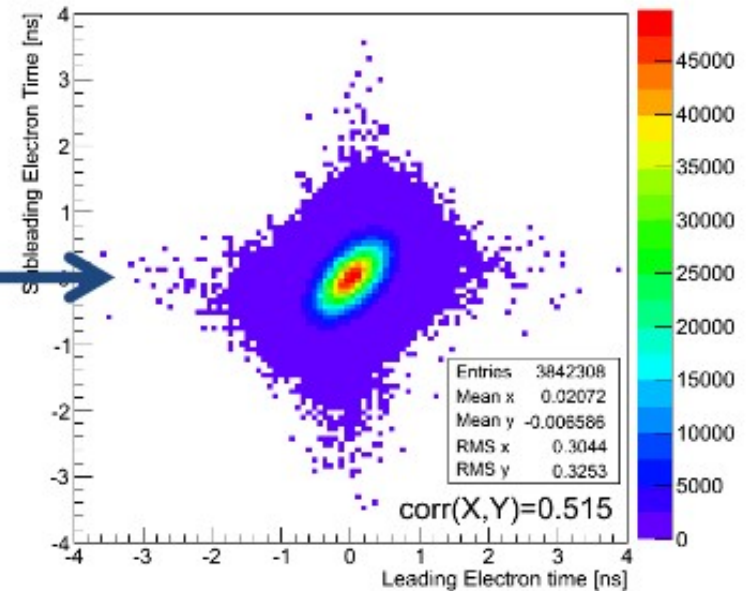


Correlations

Looked at correlations between kinematic variables in $Z \rightarrow ee$ events

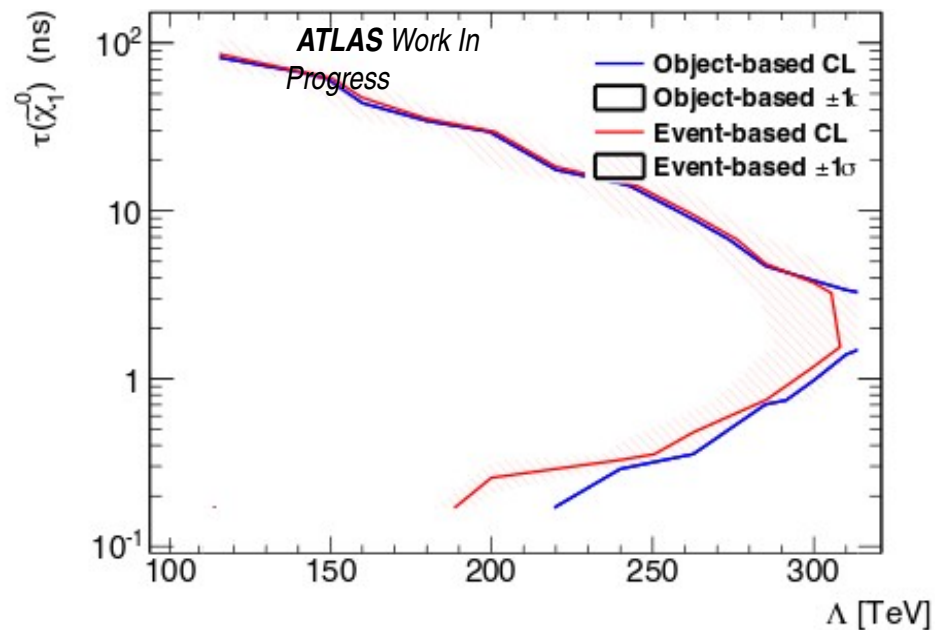
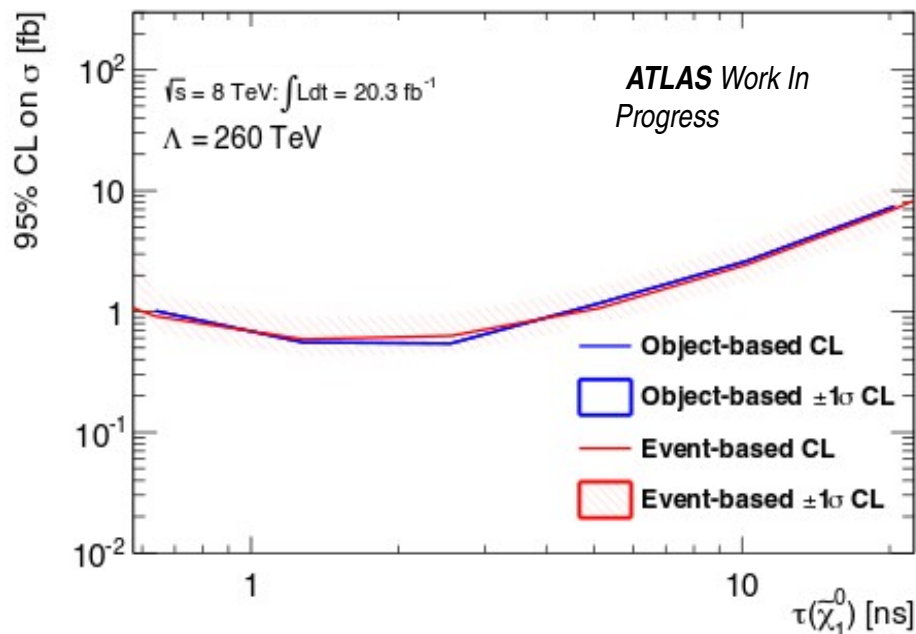
- 220 ps beam spread, which introduces a $\sim 50\%$ correlation between *prompt* EM object timings in the same event
- Less correlation for delayed signals
- Affects only timing (unless wrong PV is chosen)
- Selection of incorrect PV also introduces correlations in $|z_{DCA}|$ variables

Do 50% correlations between the timing variables bias the test statistic if the photons are counted independently?



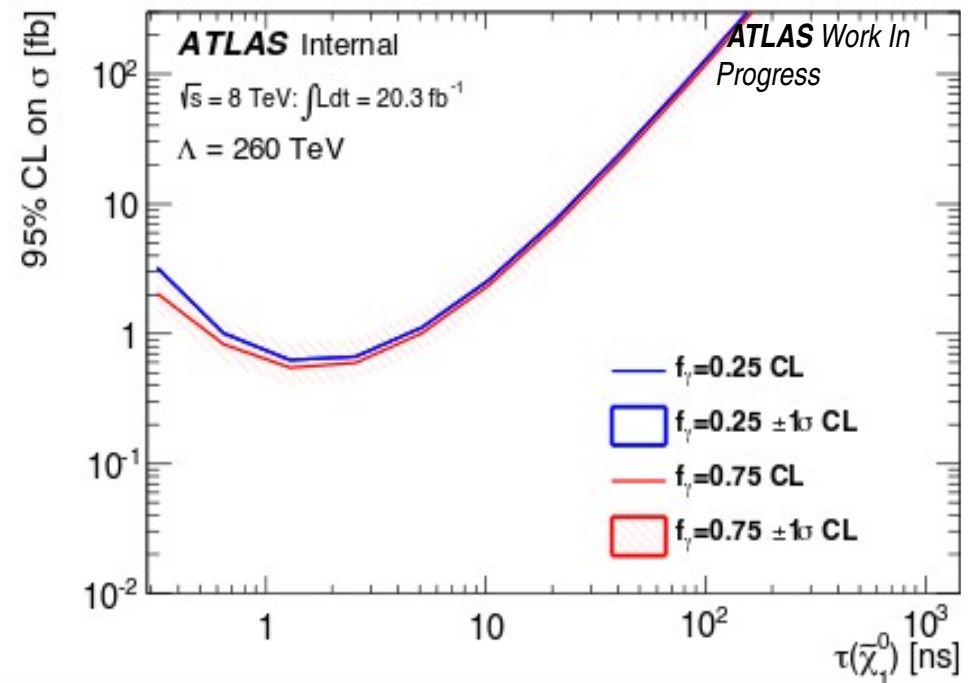
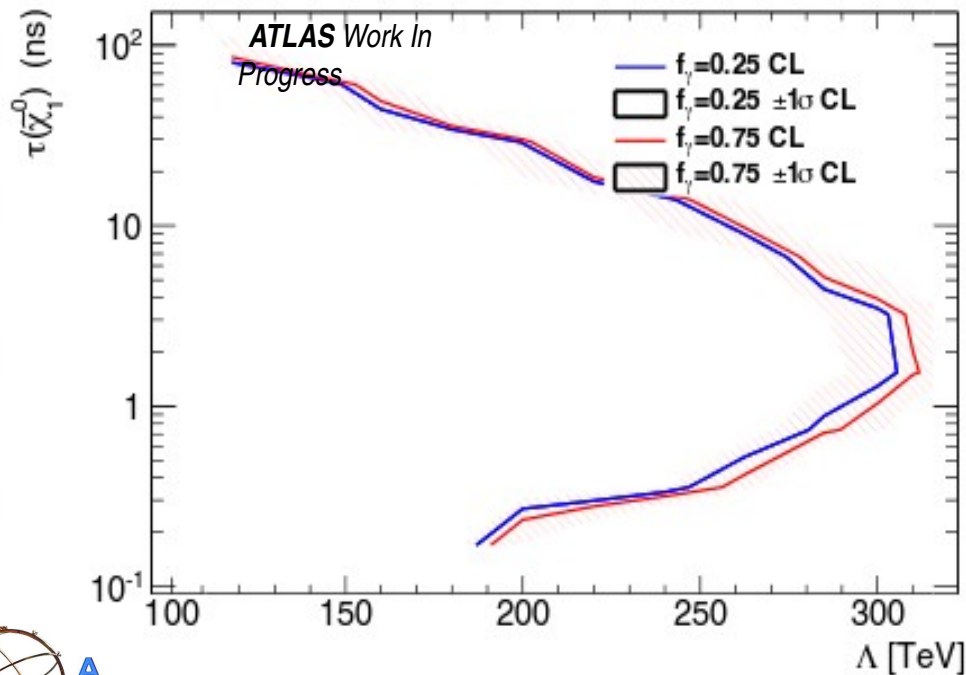
Comparison of event based and object based limits

- Loss in sensitivity when moving from object -> event based analysis is small
- Object based would also require additional systematic uncertainties to cover correlation issue

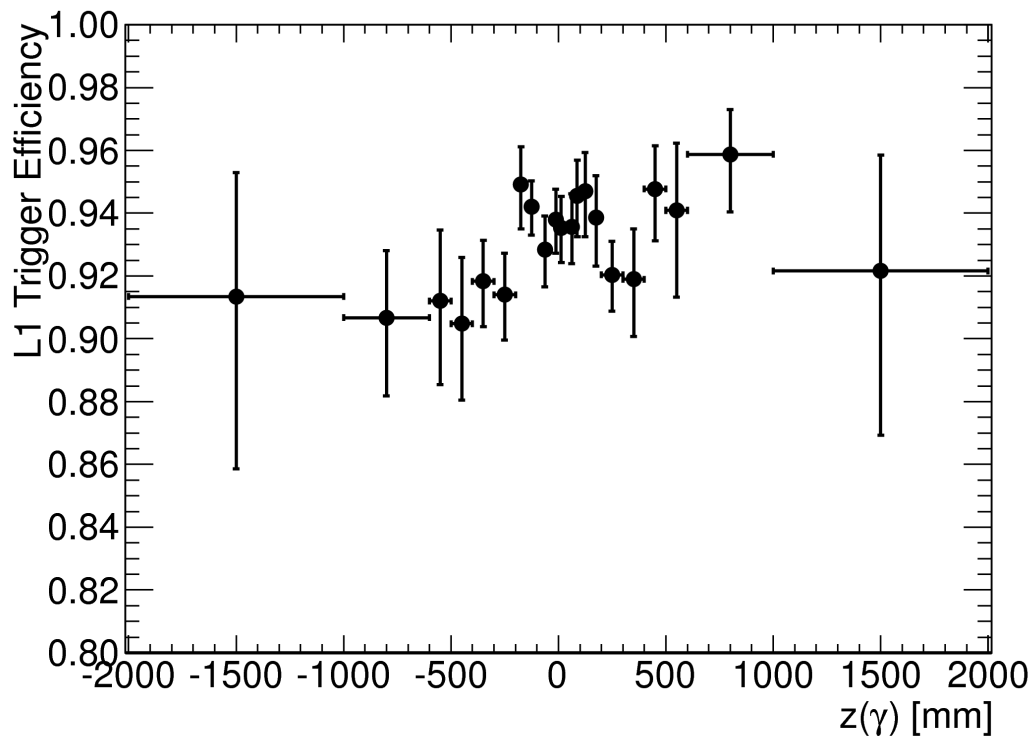


Background Composition

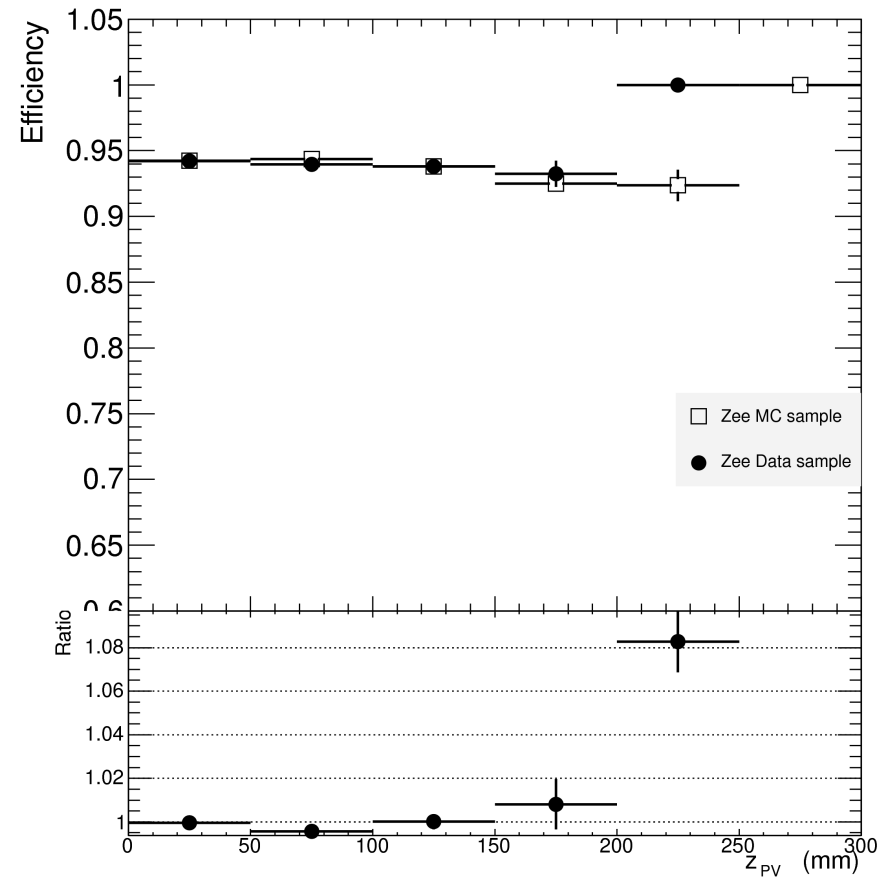
- Background in signal region ratio of electron/photons : jets unknown
- Assumed to be 50/50 in all studies
- If fraction due to egamma (f_γ) is varied between 25% and 75% very little variation in limits is observed



Efficiency of Passing Trigger



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- Efficiency of non-pointing photon events passing trigger is flat with zDCA (top left)
- Electrons used to model photon showers also show very little z_{DCA} dependence

