Search of a dark photon A’ and an invisible dark Higgs h’

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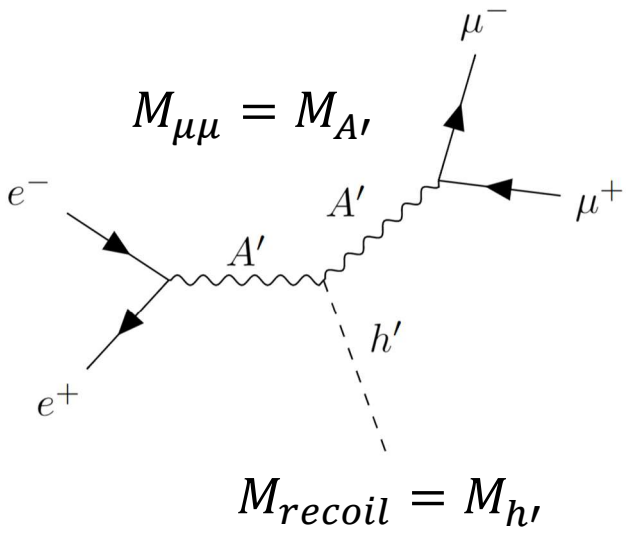
Brief introduction



Simultaneous search of a dark photon A' and dark higgs-like particle h'

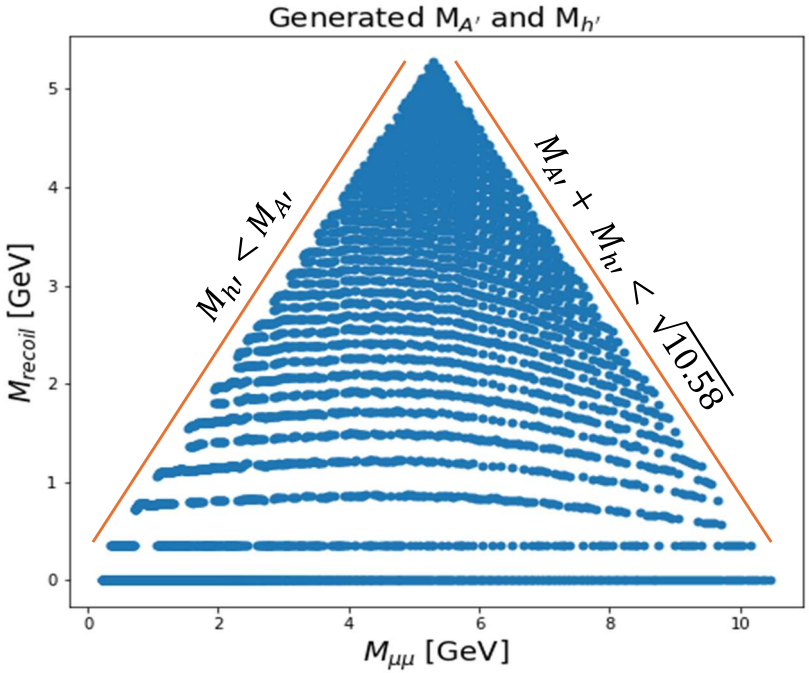
Final state:

- Two charged particles identified as muons from A' decay
- Missing energy due to h' escaping the detector

9k simulated signal distributions centered on the corresponding mass hypothesis. Use of elliptical signal windows (40k windows)

Main background contributions:
$\mu\mu(\gamma)$; $\tau\tau(\gamma)$; $ee\mu\mu$

Control samples:
$\mu\mu\gamma$ and eμ final states

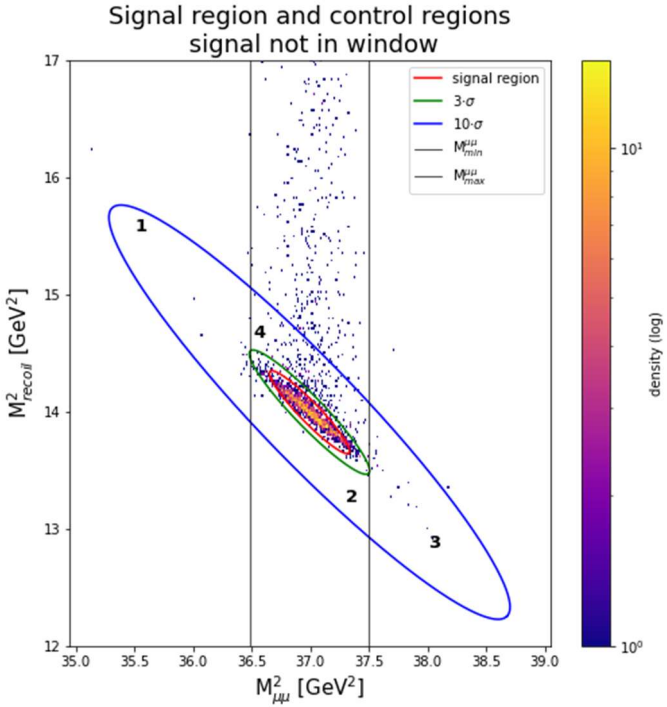


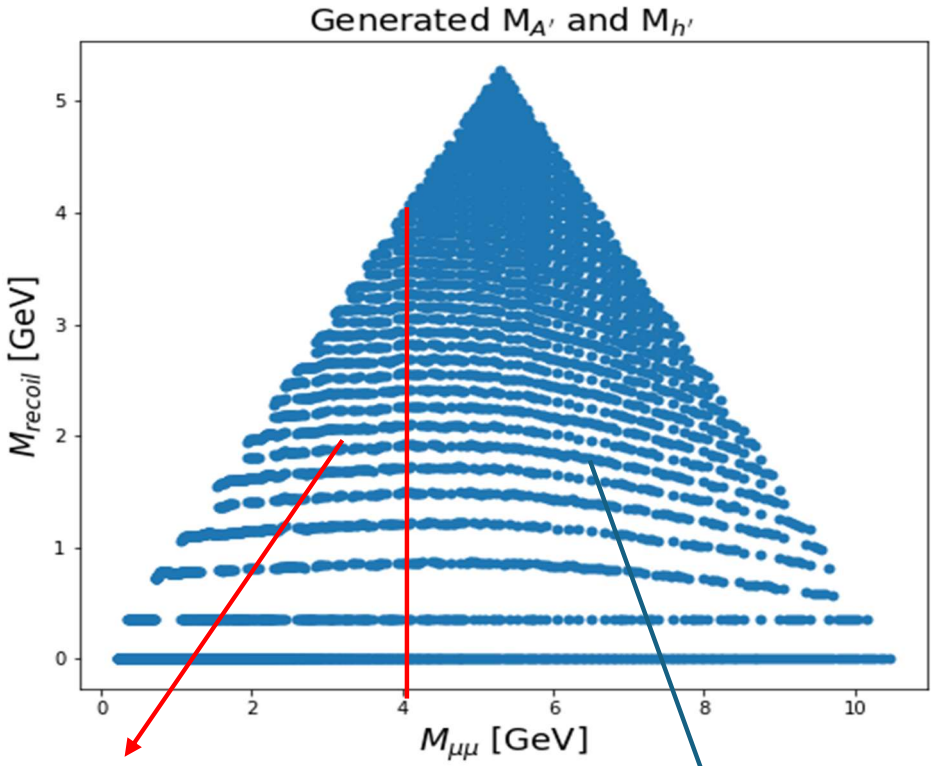
Overview of the analysis

- MC distributions for signal & bkg: cuts, mass windows, sidebands
- Control samples: check MC, compute some systematics
- Systematic uncertainties
- First UL estimate with BAT
- Significance with p-value & Toys
- Next steps

Approach: mass windows & sidebands

- Signal windows: tilted ellipses centered with the signal distribution
- Sidebands: bigger elliptical crown around signal windows, with vertical cut to exclude signal ISR





Very low bkg MC statistics → derive bkg in window from data in SB

Sufficient bkg MC statistics → correct bkg in window with data/MC in SB

Systematic uncertainties: total summary

Uncertainties related to the efficiency

source	value (%)
PID,tracking,luminosity, cr. section (bkg only)	3 - 5.5
final selections	1
mass resolution	3
dependency from run conditions	2.3 - 4
mass dependency	2 - 9
interpolation	4.4
total	5.3 - 12.5

Uncertainties related to background

source	value (%)
PID,tracking,luminosity, cr. section (bkg only)	2.3
final selections	1
photon veto corrections	6.7
sideband related	1 - 8
total	7.2 - 10.7

100% correlated uncertainties, evaluated from CS

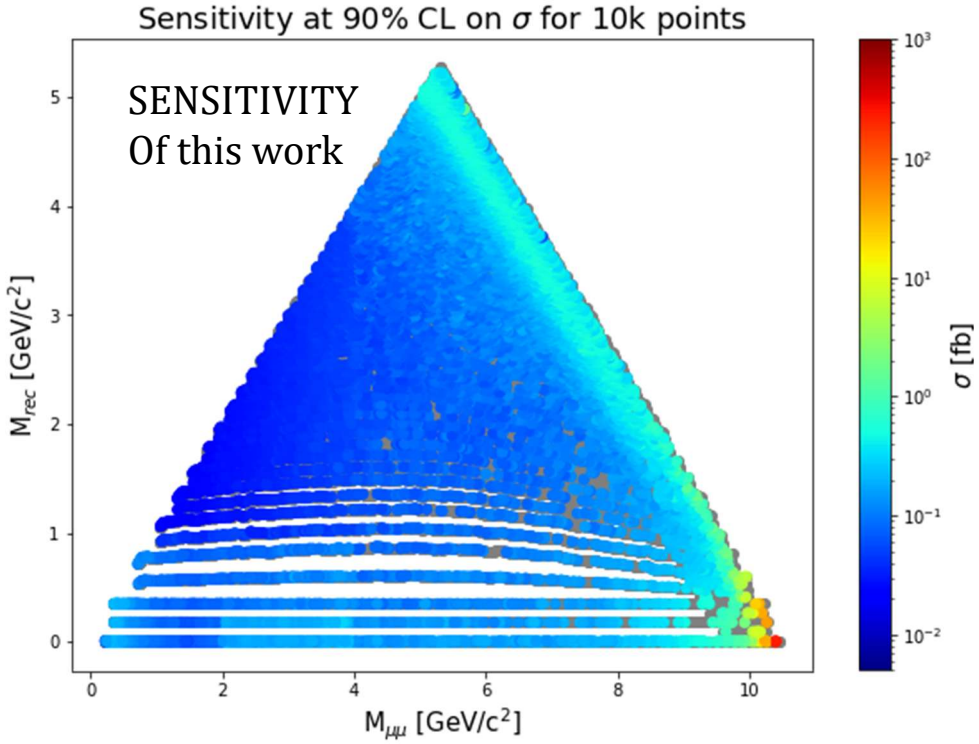
Upper Limit and sensitivity estimate

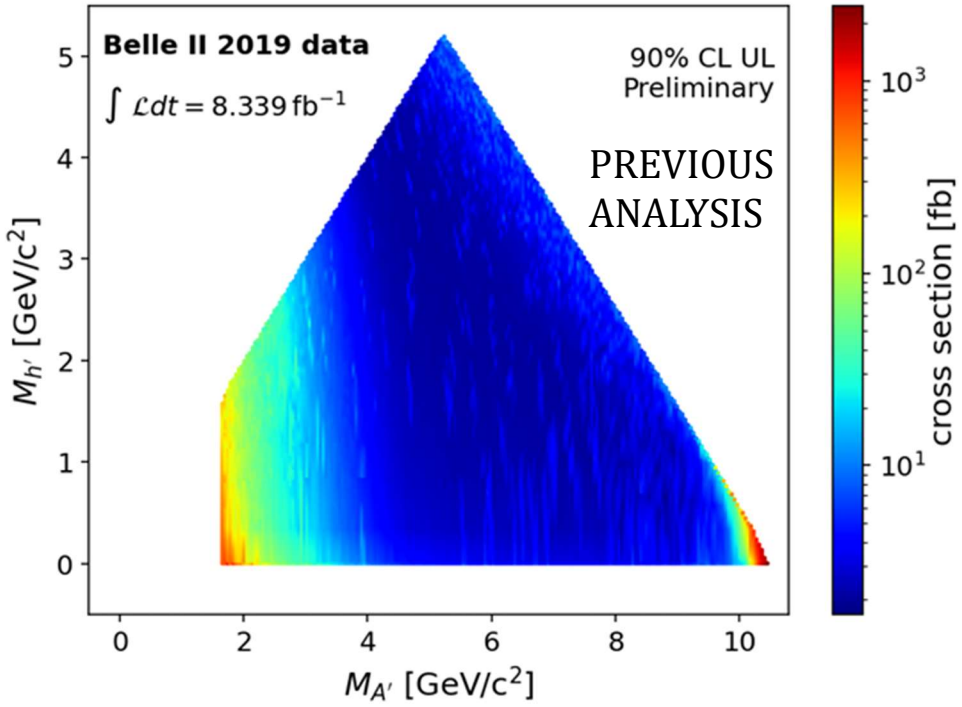
- Use BAT to estimate the 90% CL. Upper limit on the cross section
- The signal significance will be evaluated with the p-value (as in IDM+DH analysis)

Upper Limit and sensitivity for 10k mass points

With data still blinded, we choose two options for n_o:

- A **single n_o per mass window** is drawn from a Poisson distribution, with bkg yield in mass window as expected value; to compute UL faster and have results closer to what we expect from data
- Use **multiple n_o per mass window,** allowed by the Poisson distribution. The Poisson-weighted average of the corresponding ULs is the **sensitivity**





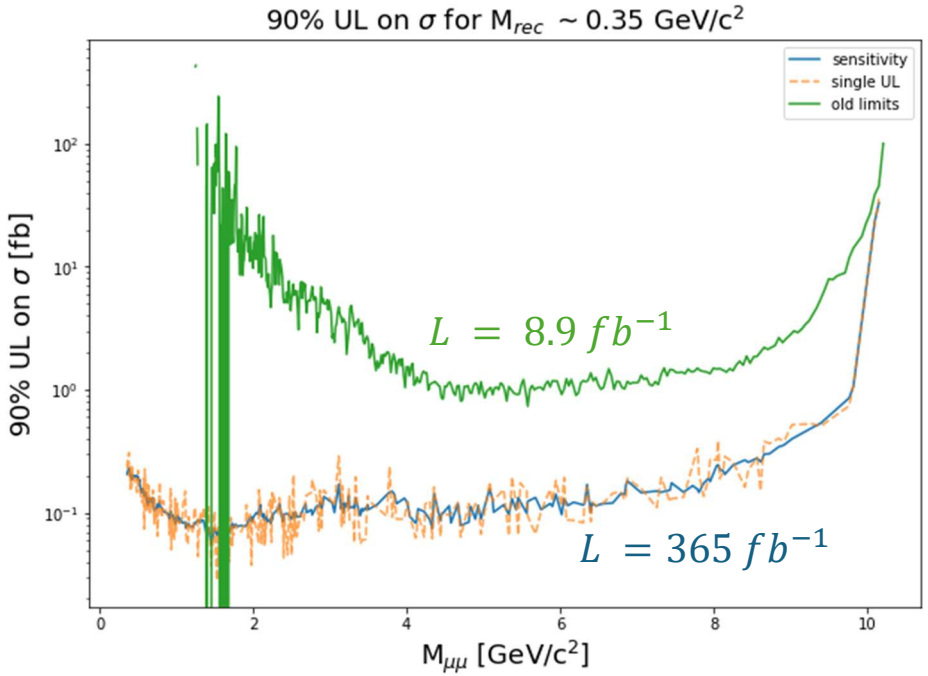
Sensitivity

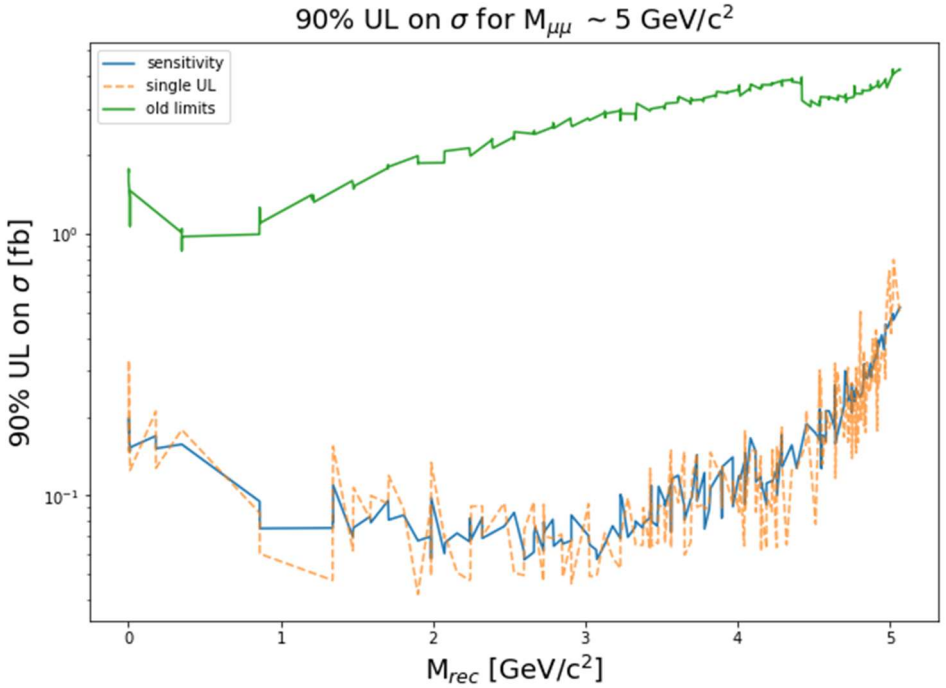
Sensitivity shown as a function of the masses:

- **Blue line: sensitivity** (weighted UL)
- **Orange line**: UL from **single n_o**
- **Green lines**: limits from **previous analysis**

Comparison with older limits:

- Single objects trigger lines available in this analysis allow for a better sensitivity in the $M_{\mu\mu}$ <4 GeV region
- From luminosities considerations, expect a factor 7 gain
- Many point exhibit also factor 10 of gain





Playing with toys

Goal:

- Estimate p-value and significance
- Account for look eslewhere effect

Must include statistical fluctuations of signal and bkg

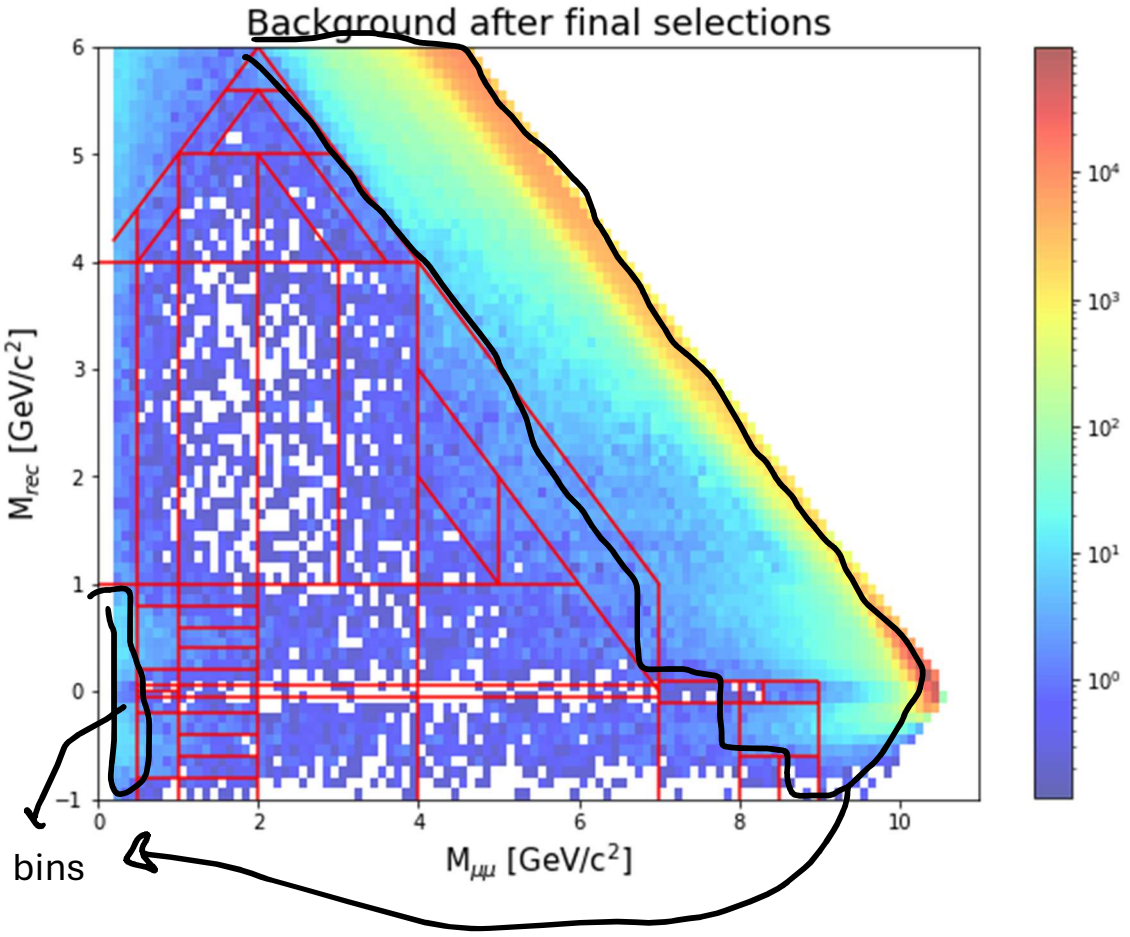
- Signal → effectively unlimited numebr of evts in each mass windos
- Background → only one MC realization
  - need toys to model statistical fluctuation

Toys

Create toys for background events and consider them as «data»

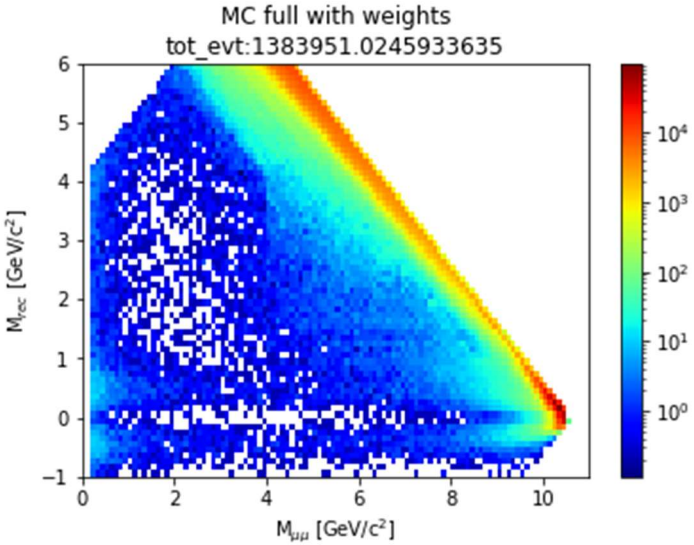
How to:

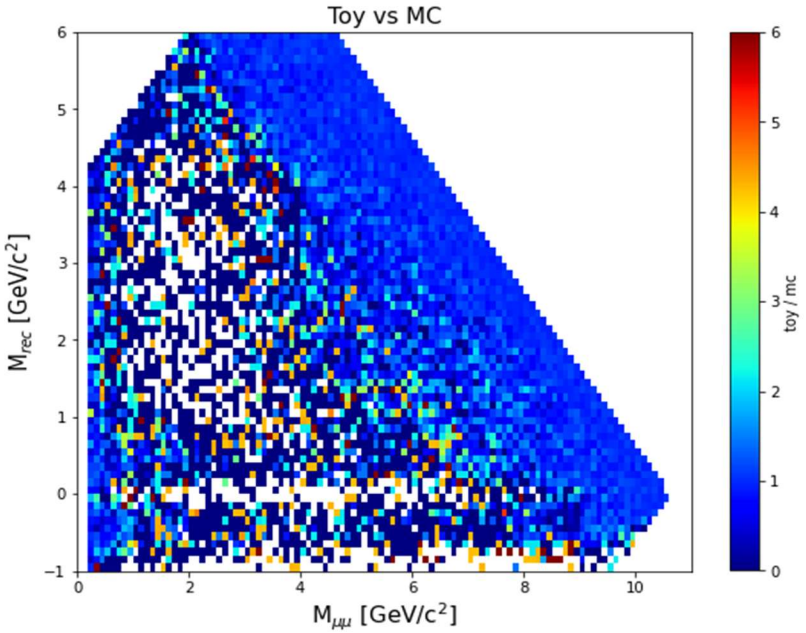
- Isolate bkg MC counts in given region
  - Using 100x100MeV bins if there is statistics (counts !=0)
  - Or bigger regions if there is low stastistics.
  - Important: bkg MC is uniform in bin/region
- Add gaussian noise to bkg MC counts to mimick systematic uncertainties
- Extract number of events form poissonian distribution with expected value
- Distribuite uniformly in the region/bin → toy!

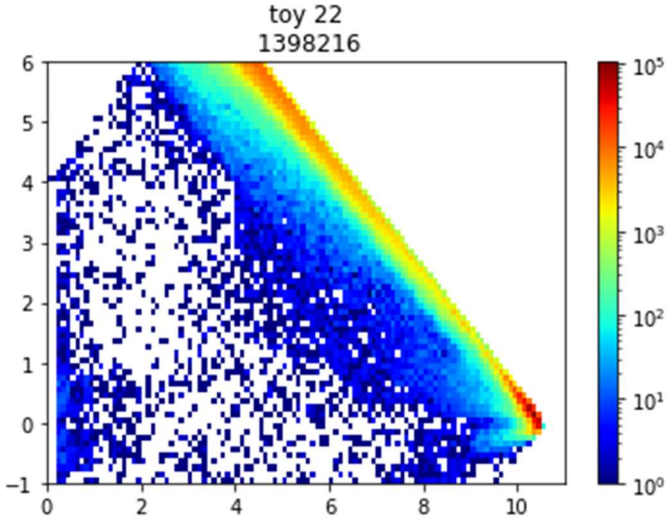


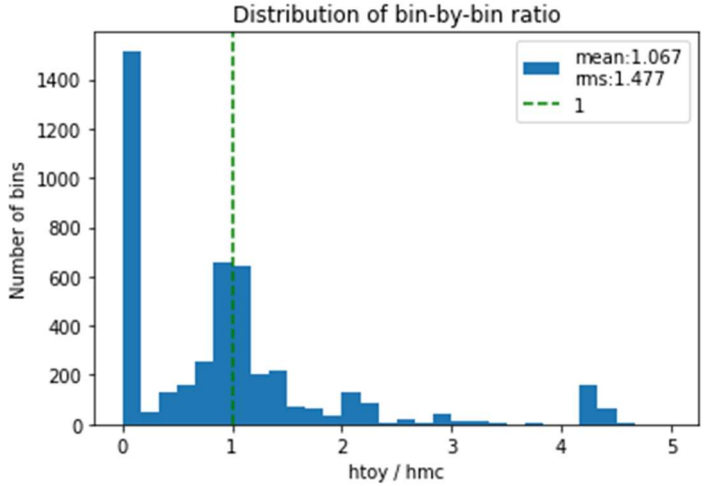
Toys

- Example of toy compared to bkg MC and agreement checks
- Created 1000 toys







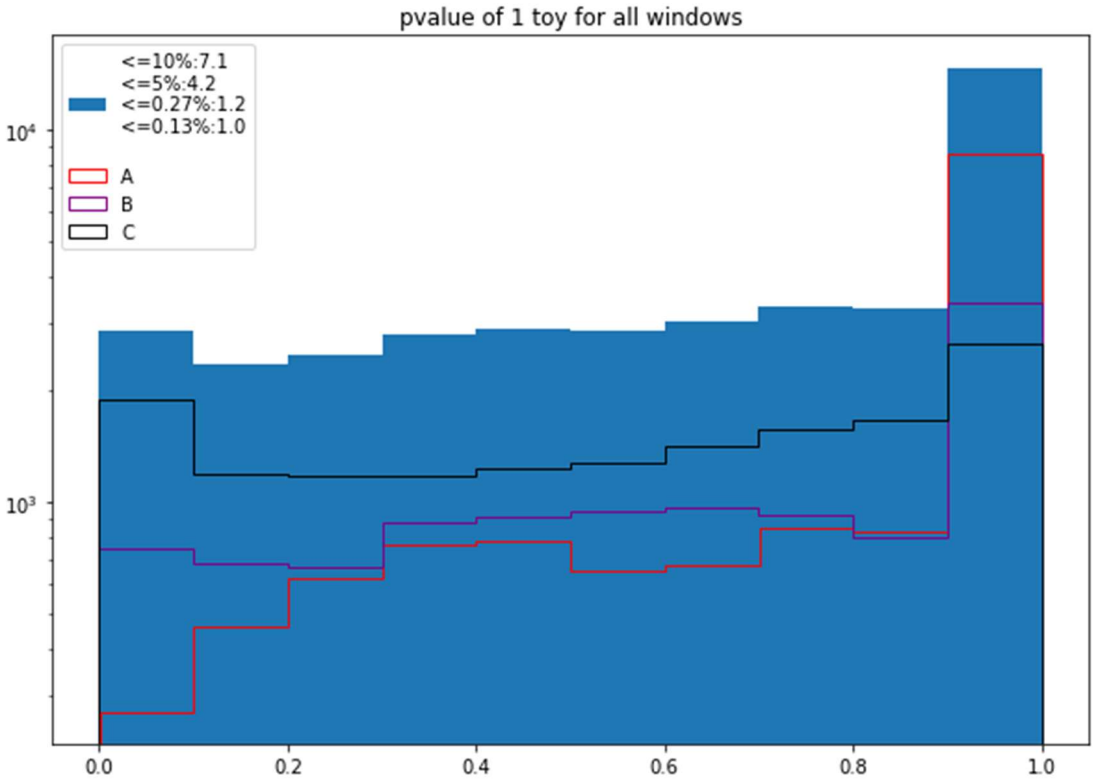


Compute pvalues with toys

- Count toy evts in signal windows & sideband
- **Use as data**
- Compute pvalue in the bkg only hypothesis
- Showing p-value for one toy

Need some checks/fixing:

- Where window statistic is very low (red line in plot) we see very few low pvalues → is this correct?
- For some cases (black line) we see even too much low pvalue events → have to check again the pvalue computation code



Next steps

Technical steps:

- Finish the pvalue with toys
- Check signal injection
- Compute the look elsewhere effect

General steps:

- Analysis entered WG review → waiting for comments
- Thesis on the way → hand in by the middle of june