Trigger Rate Monitoring and a New Search for Dark Photons

USATLAS SUPER Symposium

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USATLAS → SUPER Symposium

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https://indico.cern.ch/event/1066365/

Overview

Project has two components

- **Monitoring:** Research and development for trigger monitoring tool xMon
- **Physics:** Determining feasibility of new trigger in the search for an exotic Higgs decay involving dark photons

Project status

- Start date was delayed one month due to contract processing
- Still have month remaining

Summary of work done

- **Monitoring:** Added functionality to xMon that allows for the detection of small deviations in groups of correlated triggers
- **Physics:** Found best cuts that most likely provide highest sensitivity to the signal

Overview: xMon

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Trigger rate prediction tool in operation at Point 1

Use prior data

- Make fits of cross section vs pileup for individual triggers
- Returns prediction parameters to be used by xMon Online

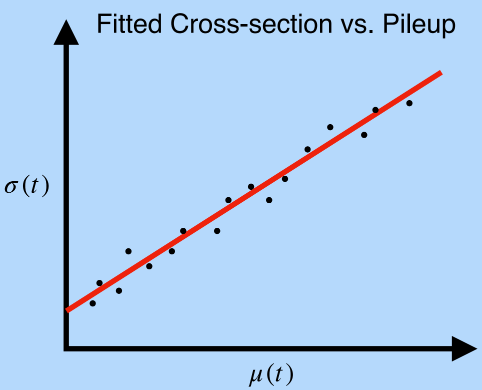
xMon at Point 1

- Uses prediction parameters and live luminosity and pileup to calculate predicted rate

History

- Andy Aukerman (2015-19)
  - D3PD -> xAOD, update to Run-2 TDAQ
- Nick Felice (2016-21), SUPER '20
  - Add HI, update to Run-3 data format
- CHM (2020-present)

Offline fits

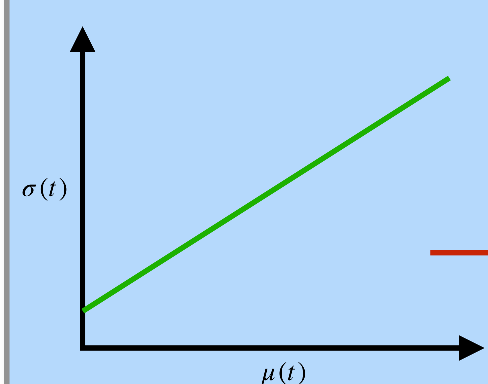


$$\sigma(t) = \frac{R(t)}{L(t)} = \frac{\text{rate}}{\text{lumi}}$$

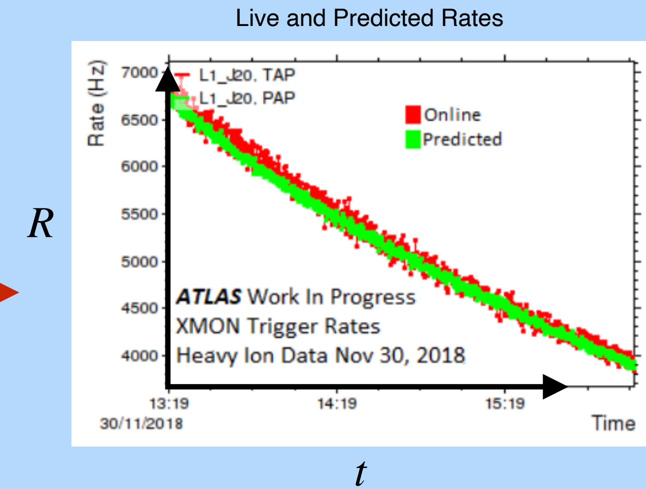
$$\mu(t) = \frac{\text{collisions}}{\text{bunch crossing}}$$

→ Prediction Parameters →

xMon at P1



$\mu, R, L, \ldots$ from live run



Idea: Global Offset Detection

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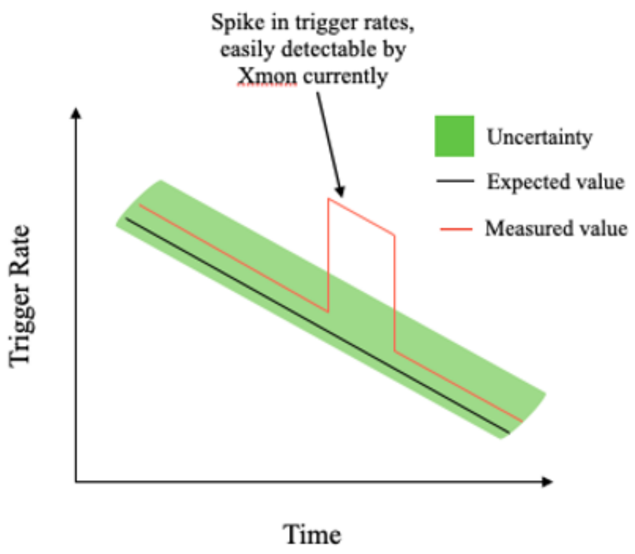
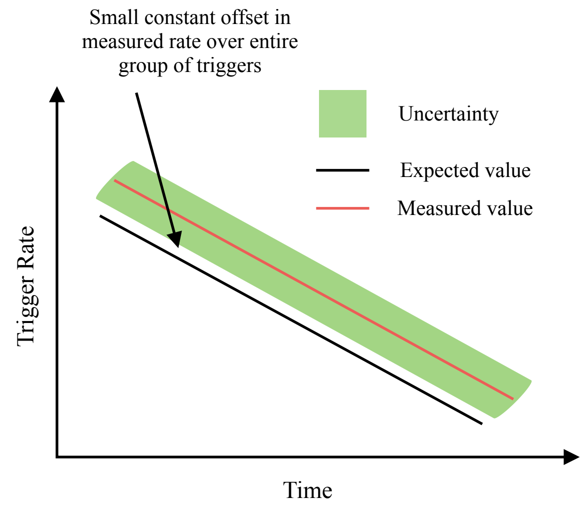
- xMon is great at detecting large deviations from predicted rates for individual triggers
    - Shifter needs to spot discrepancies by eye
- Groups of correlated triggers might be offset by some small percentage due to a systemic problem
    - i.e. one region of muon detector not triggering, no muons in that region detected
    - Other example: wrong calibration constants in some parts of detector for reconstruction with HLT
    - xMon **could not** detect these systemic offsets, but now it can!





Prototype: Global Offset

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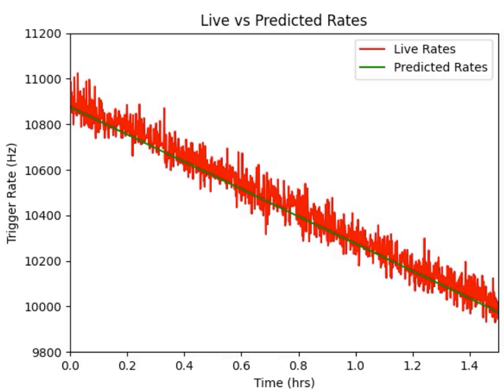
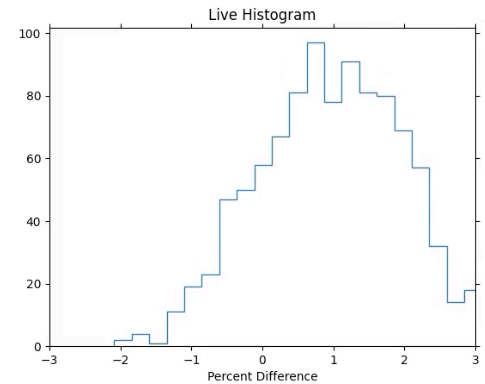
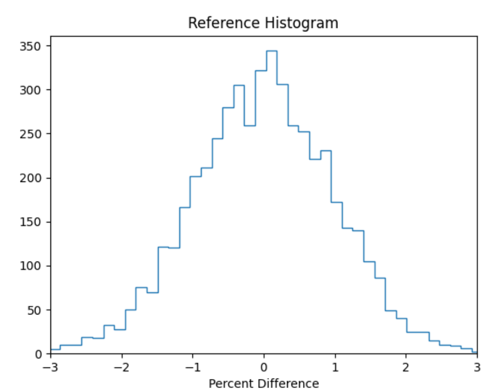
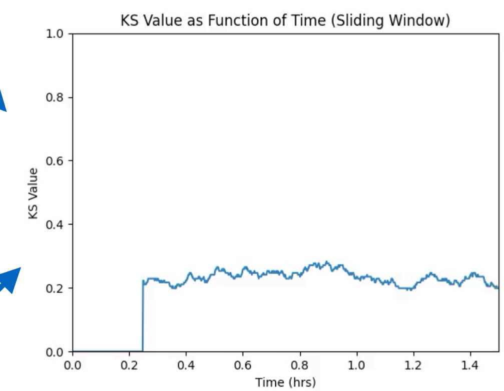
- Prototype the algorithm in standalone python
  - Goal: Compare the distributions of the live rate around the predicted rate
  - Steps
    1. Make reference histogram “offline”, storing the % difference between the live and predicted
    2. As data come in:
       i. Calculate the % difference between live and predicted rates and fill a new histogram
       ii. Compare these distributions with the Kolmogorov-Smirnov test to determine similarity
       iii. KS value is then averaged over the entire trigger group to get one value per group.



~ 1% off





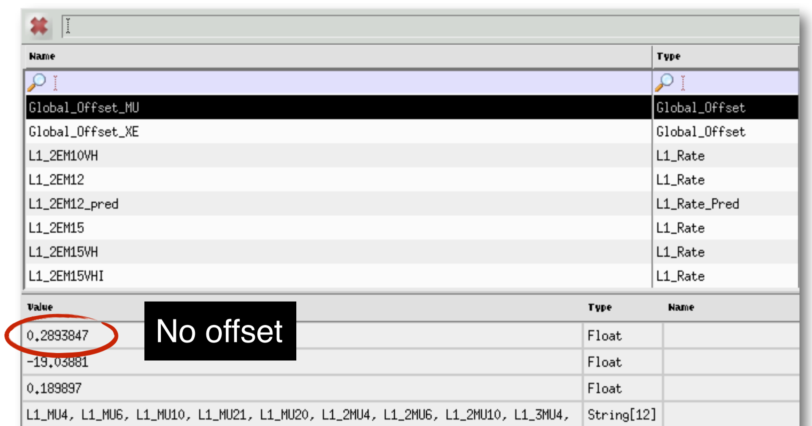


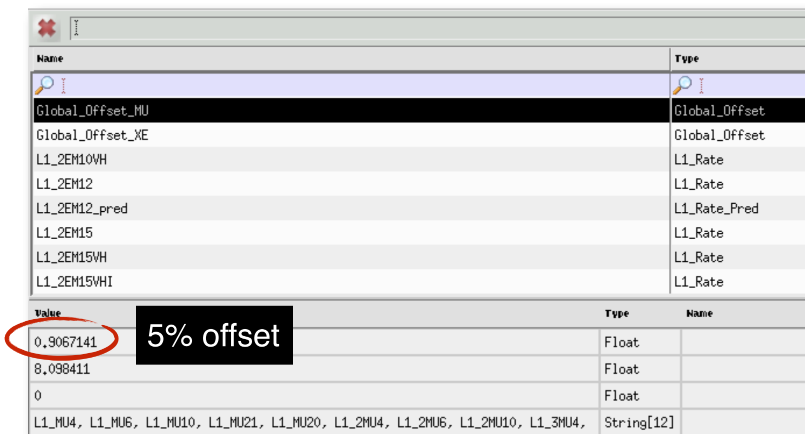
Implemented Global Offset (& other features) in c++ within TRP

Test adapter using testbed on lxplus

- Python playback script allows us to test locally without collecting data
- Tested functionality in a “test partition” using the IS monitor (below) on a special testbed server
    - Changed offset of trigger rates to see how KS value would change
    - Tested with XE and MU trigger groups
    - **Success!** See screenshots of the IS monitor

KS Values





Next steps

- KS value seems to hover around 0.3-0.4 when there is no offset
    - Further testing required to determine why this is
- Commit code in git for the next TDAQ release

Next Steps for xMon

Regain operational experience with xMon during data taking

- Includes producing offline fits/references to install at P1
- Learn to monitor on new Grafana display (this is the “new” TRP web interface)

Implement automated warning system

- i.e. if KS value is greater than 0.6, a warning is thrown

Need to figure out most efficient way to determine trigger groups

- We could manually select trigger groups for full control
- We want to group triggers that have a common source so we have sensitivity to problems

Physics Motivation

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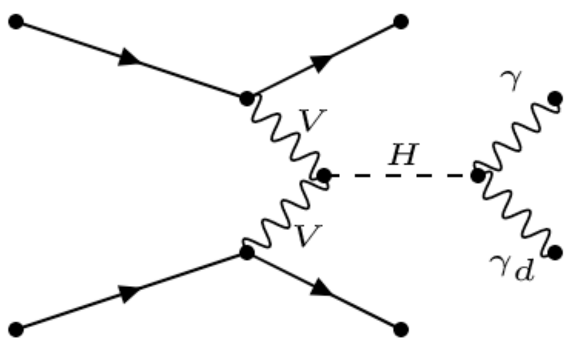
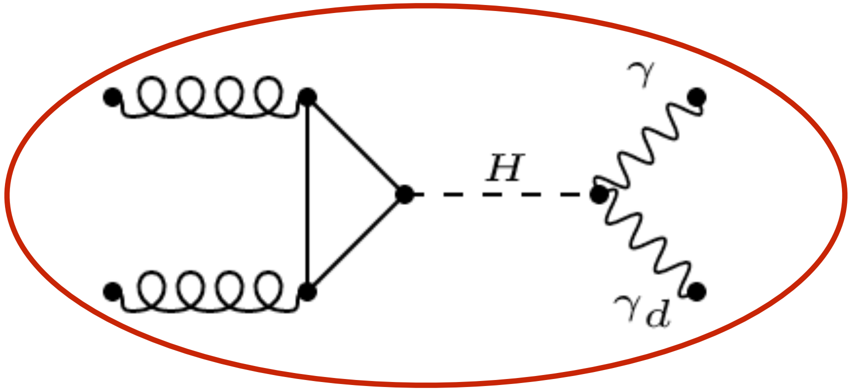
- We can use exotic Higgs decays to search for dark photons
  - Motivated partially by theory paper arXiv:2011.05259
- Previous work done by Nick Felice on vector boson fusion (VBF) production



VBF Production



ggF Production

- I am investigating gluon fusion (ggF) production
  - Signature is photon + MET
  - ggF has a much higher cross section (~10 times larger) than VBF
  - Typically a lot of background, makes it hard to find optimal cuts
  - Can ggF contribute to the VBF measurement?
- Looking into feasibility of new trigger to help search

Progress

Preselection cuts

- Began by implementing simple cuts on MC ntuples to eliminate background

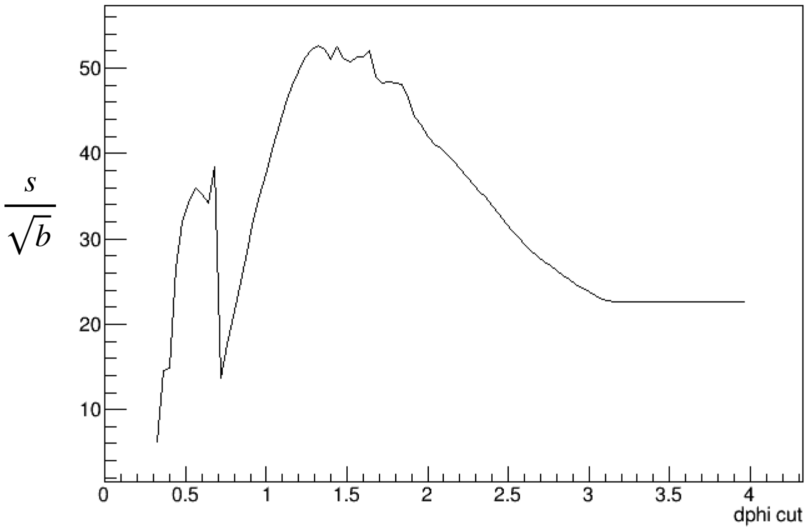
$p_T^{\gamma} > 25$ GeV

$|\eta| < 1.37$ or $1.52 < |\eta| < 2.37$

$E_T^{miss} > 100$ GeV

$\Delta\phi(\gamma, E_T^{miss}) < 1.5$

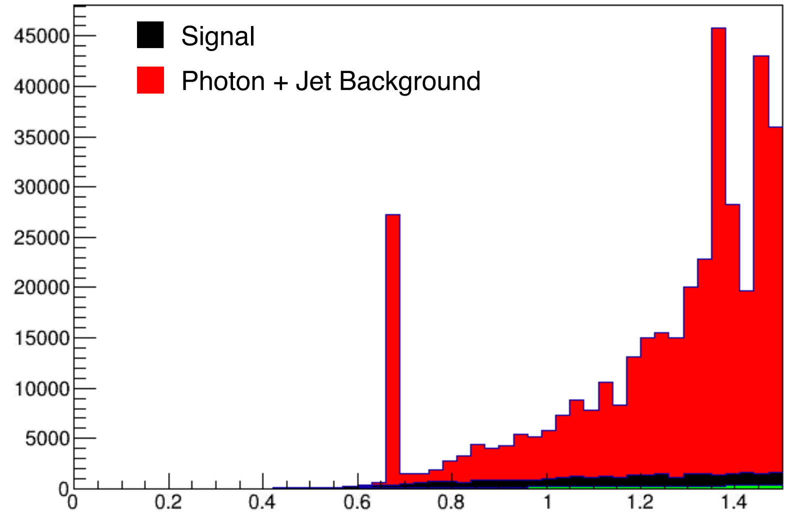
Sensitivity vs dphi for MET > 100GeV



Observations

- Most γ+jet backgrounds have large $\Delta\phi$
- These cuts are not sensitive enough
- Increase sensitivity against photon + jet by increasing MET cut and decreasing dphi cut
- Increase sensitivity against other background by decreasing MET cut and increasing dphi cut

Stack of Signal and Backgrounds



Next steps

- Realized that we need more information in the ntuple: MET significance, Truth and primary vertex positions, Event weights, Photon pointing $|\Delta z_{\gamma}|$

Progress (cont.)

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Recreated ntuples to use the new information

1. Changed the ntuple production code to include the new necessary algorithms
2. Figured out how to successfully run this code as a job on the grid
3. Recently finished this process only to find out that the original MC datasets moved
4. Now we either need to recreate these datasets or we try to run with AOD samples instead of DAOD
    - Not ideal, but the source code did not run successfully on the AOD datasets
    - Requested DAOD samples, now waiting

Event cleaning	Detector quality conditions and primary vertex						
Leading γ	$E_{\mathrm{T}}^{\gamma} > 150$ GeV, $\lvert\eta\rvert < 1.37$ or $1.52 < \lvert\eta\rvert < 2.37$, tight, isolated, $\lvert\Delta z_{\gamma}\rvert < 250$ mm, $\Delta\phi(\gamma, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}) > 0.4$						
$E_{\mathrm{T}}^{\mathrm{miss}}$ significance	> 8.5						
Jets	0 or 1 with $p_{\mathrm{T}} > 30$ GeV, $\lvert\eta\rvert < 4.5$ and $\Delta\phi(\mathrm{jet}, \boldsymbol{E}_{\mathrm{T}}^{\mathrm{miss}}) > 0.4$						
Leptons	veto on e, μ and τ						
	SRI1	SRI2	SRI3	SRI4	SRE1	SRE2	SRE3
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 200	> 250	> 300	> 375	200–250	250–300	300–375

Proposed cuts for this search for dark matter, from theory paper arXiv:2011.05259

Next Steps for Physics

Need to implement cuts once we get new ntuples to determine sensitivity

- Right now, it seems like high MET cut with a low dphi cut is the way to go
  - i.e. events have large MET and small dphi
  - Provides sensitivity against photon + jet background
- More information will come with the new ntuples since there is more information to work with
- Work will continue into the Fall

Questions?

Backup

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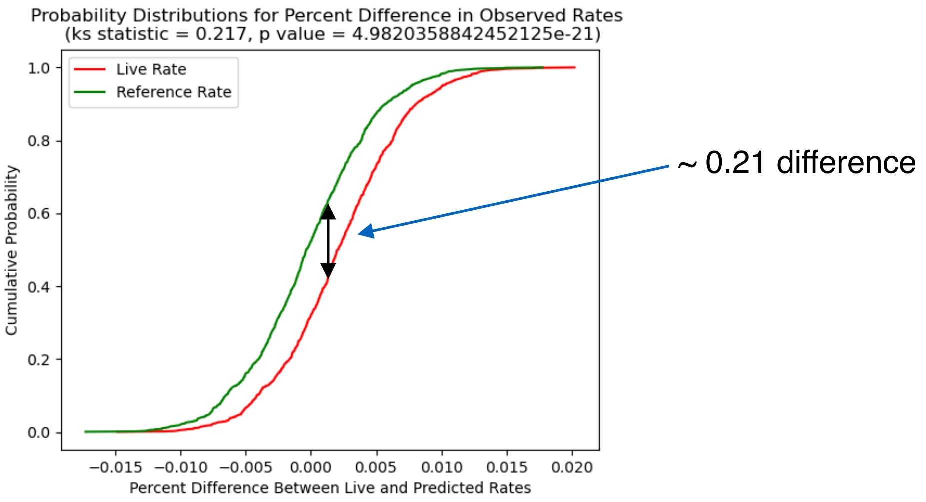
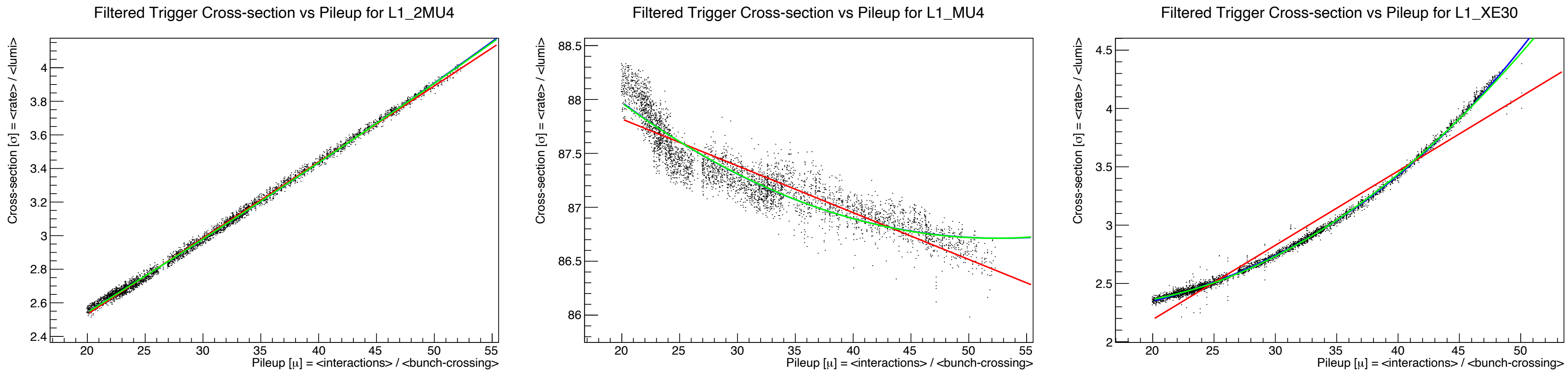
Kolmogorov-Smirnov Test:

- Measures maximum distance between two cumulative probability distributions

$$D_{ks} = \sup_{x} \{F_1(x) - F_2(x)\}$$



xMon Fitting Example:



Backup

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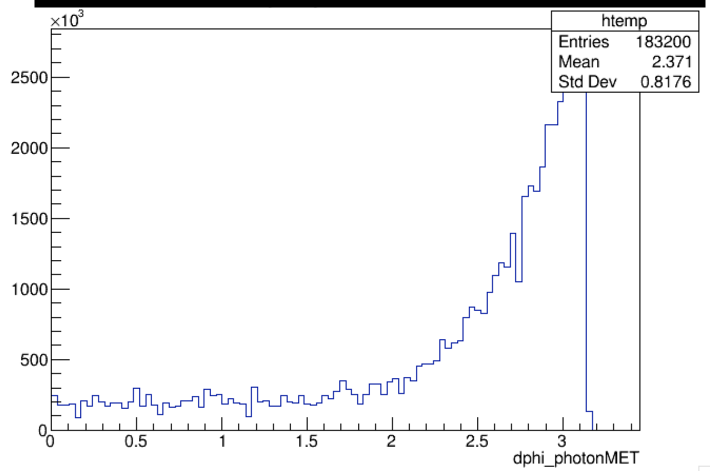
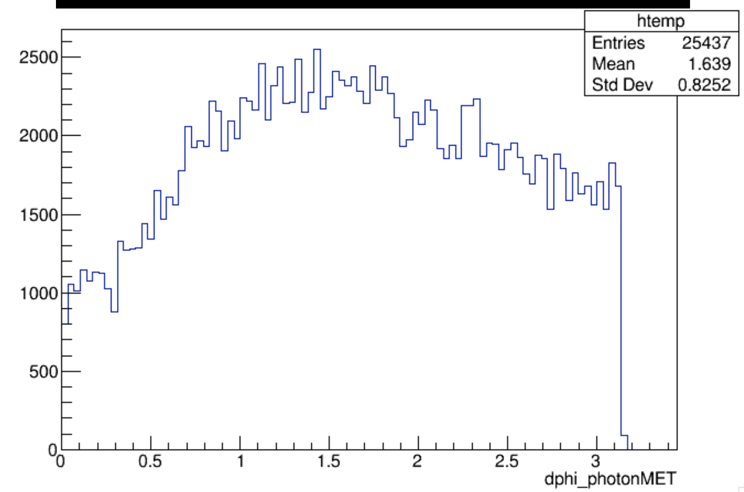
dphi(photon, MET) for photon+jet background

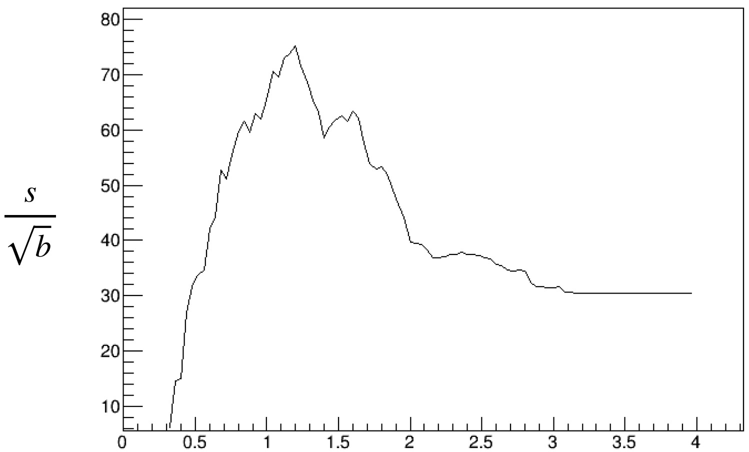


dphi(photon, MET) for all other background



- Many photon+jet events have large dphi
- Other backgrounds have large spread

Sensitivity vs dphi for MET > 150GeV



References

[1] The ATLAS collaboration., Aad, G., Abbott, B. *et al.* Search for dark matter in association with an energetic photon in *pp* collisions at $\sqrt{s} = 13$ TeV with the ATLAS detector. *J. High Energ. Phys.* 2021, 226 (2021). https://doi.org/10.1007/JHEP02(2021)226

[2] Chakravarti, Laha, and Roy, (1967). Handbook of Methods of Applied Statistics, Volume I, John Wiley and Sons, pp. 392-394.