Machine Learning for the Heavy Photon Search

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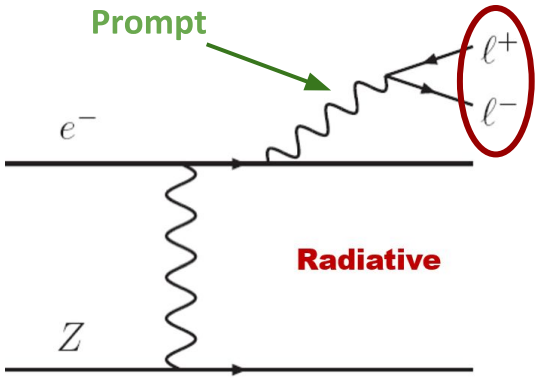
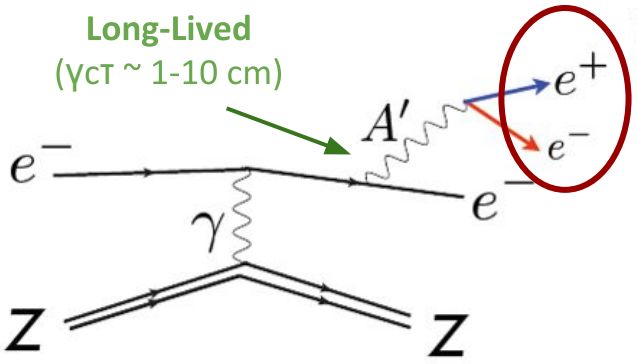
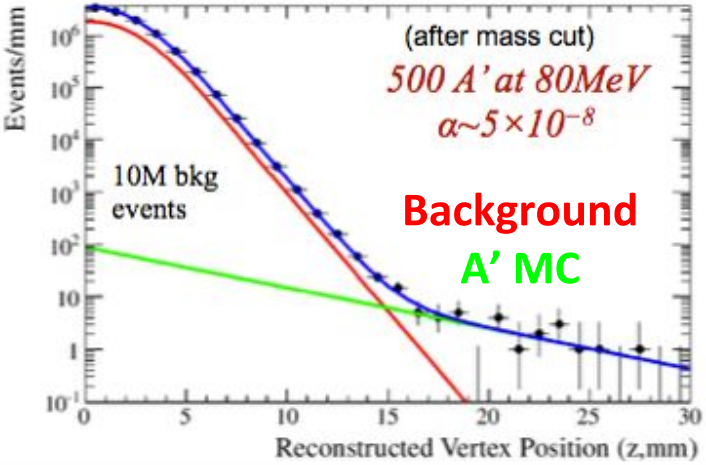
Introduction

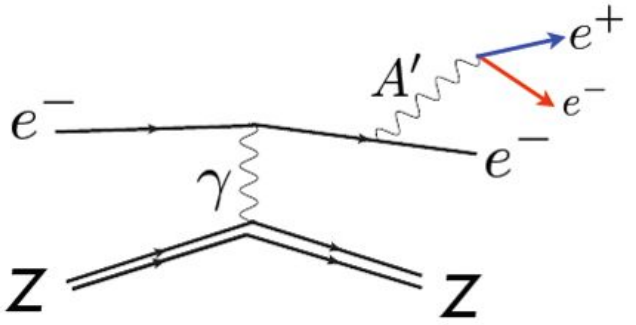
- The Heavy Photon Search (HPS) is a **fixed target experiment** at Jefferson Lab searches for a hypothetical vector boson, an A' (dark or heavy photon)
- HPS looks to distinguish between **displaced A's** ($\gamma c\tau$ ~ 1-10 cm) and **prompt trident backgrounds** that decay to e+e- pairs
- I show preliminary results using an MLP, and compare it to previous data analysis





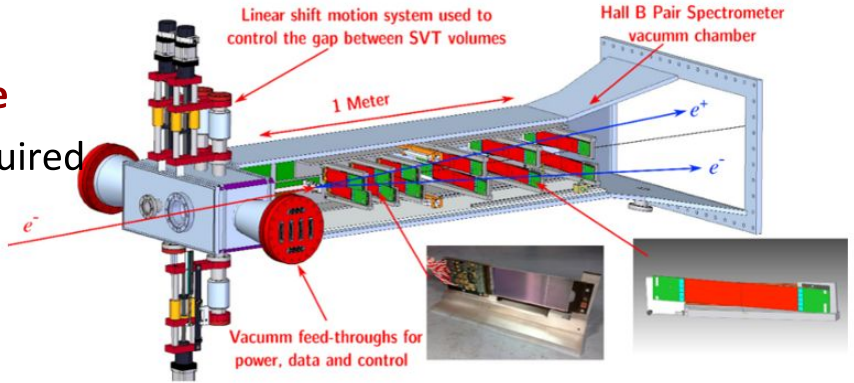


Radiative Background vs A' Signal



- Goal:
  - Distinguish between **prompt** trident backgrounds and **displaced** A' signal
- Challenges:
  - Both are **kinematically identical**, only separated by long-lived A's
  - **Multiple scattering** in the tracker is the main background (looks very signal-like)
  - Large background rate, **very low signal rate**
  - Precisely characterizing backgrounds is required
  - Other backgrounds (converted brems, bad tracks/vertices, etc.)

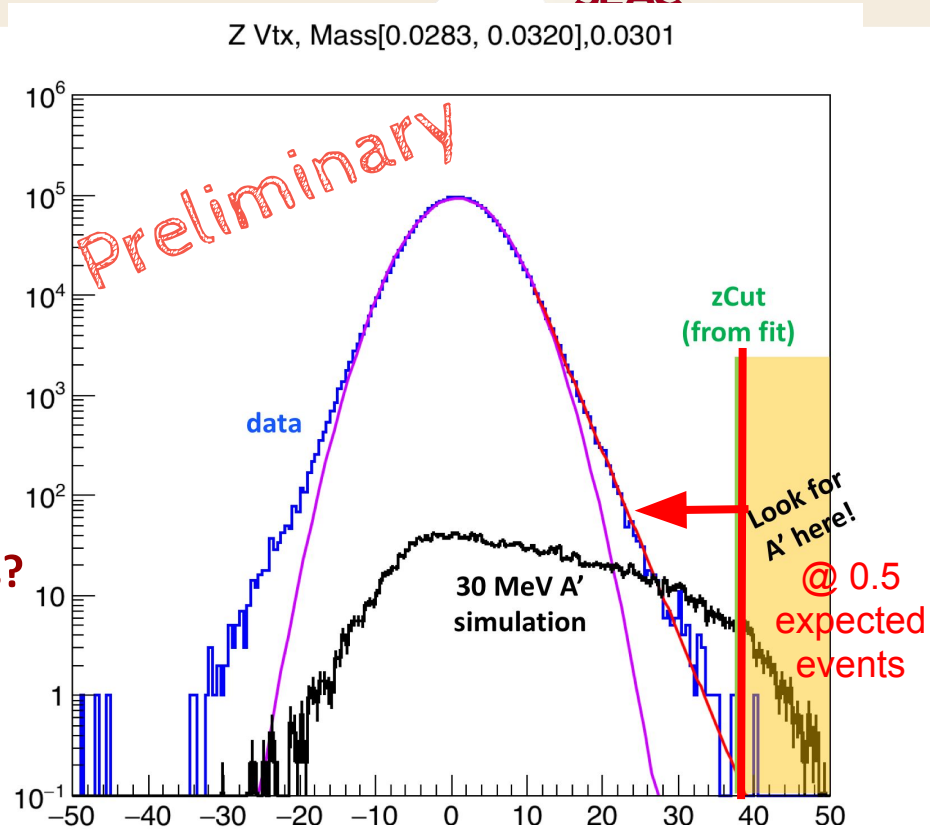
Silicon Vertex Tracker (SVT)
reconstructs mass and vertex positions



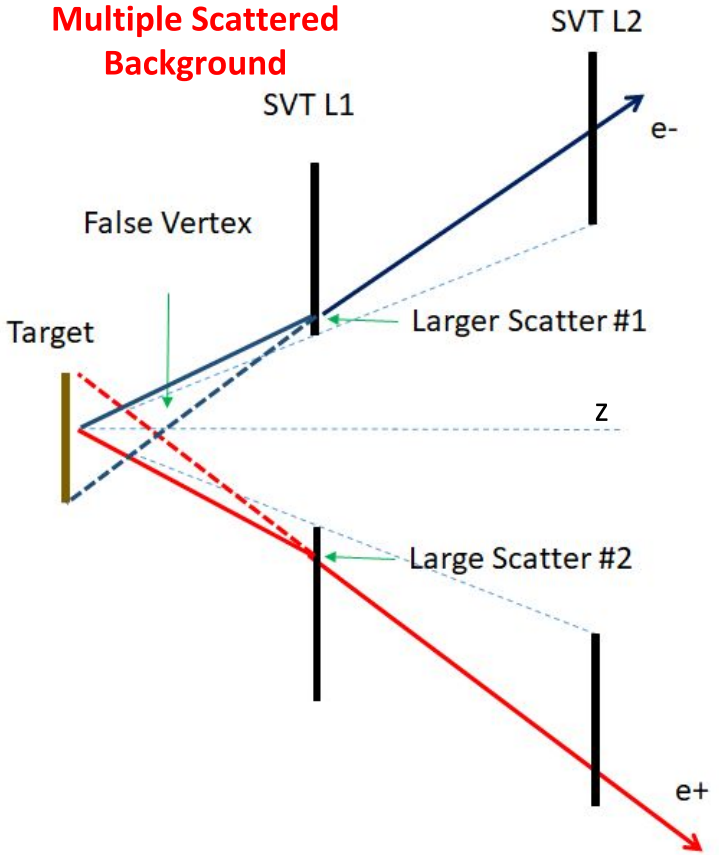
Previous Analysis

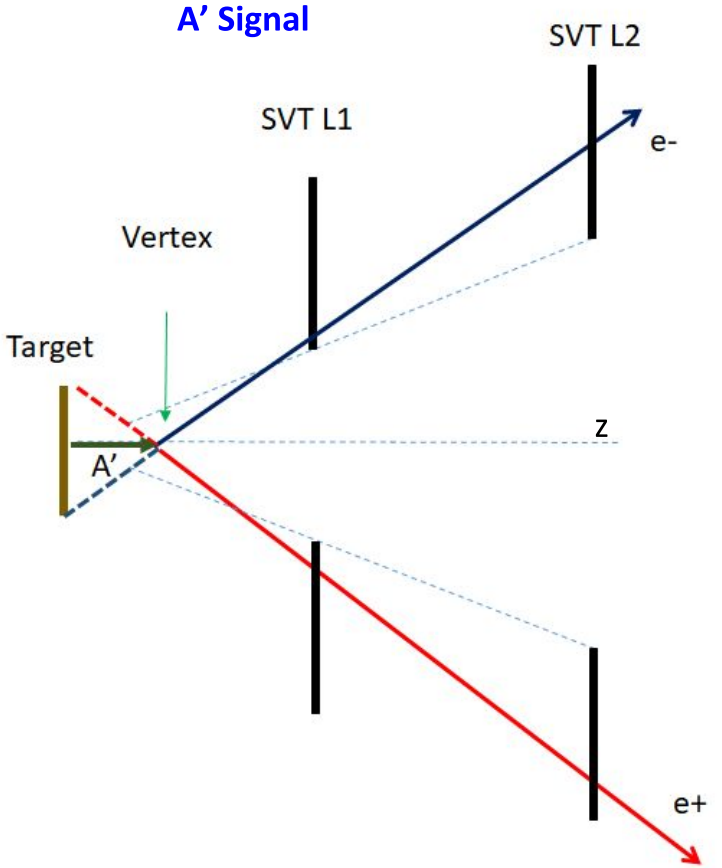
Looking at data/MC for a 1.05 GeV electron beam with 1.7 days of data

- Current analysis approach **only uses reconstructed z position** (after a series of square cuts)
- Dominant background (at large z) is due to multiple scattering in Layer 1 of SVT
- **Can we use ML to improve this analysis?**
- (Start with MLP, very open to other methods and suggestions)



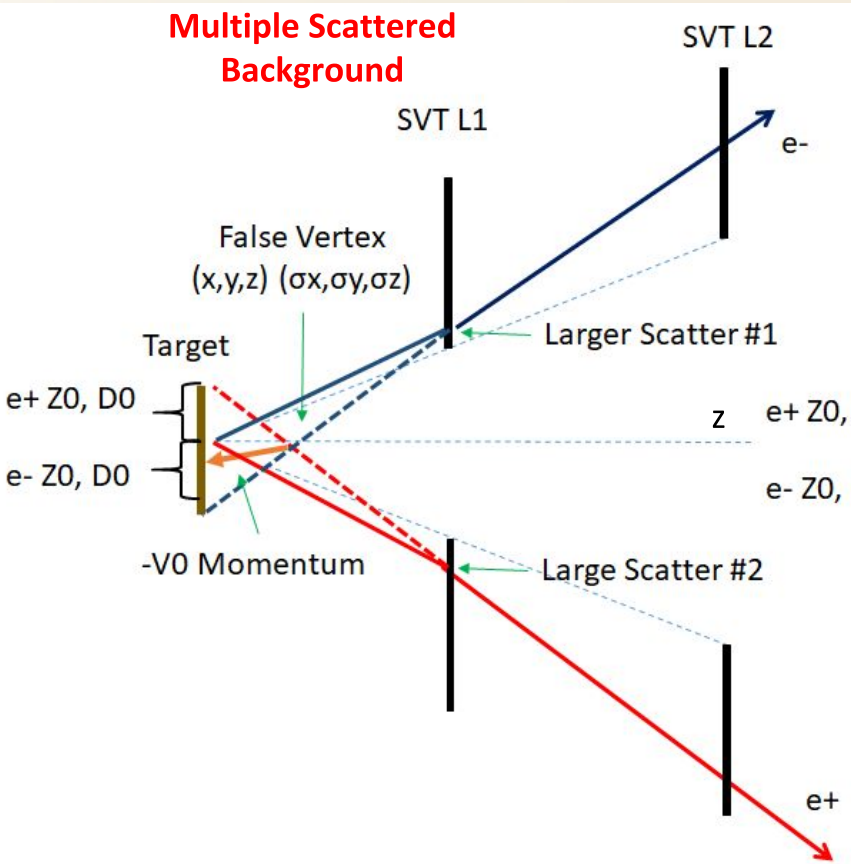
Signal vs Scattered Background

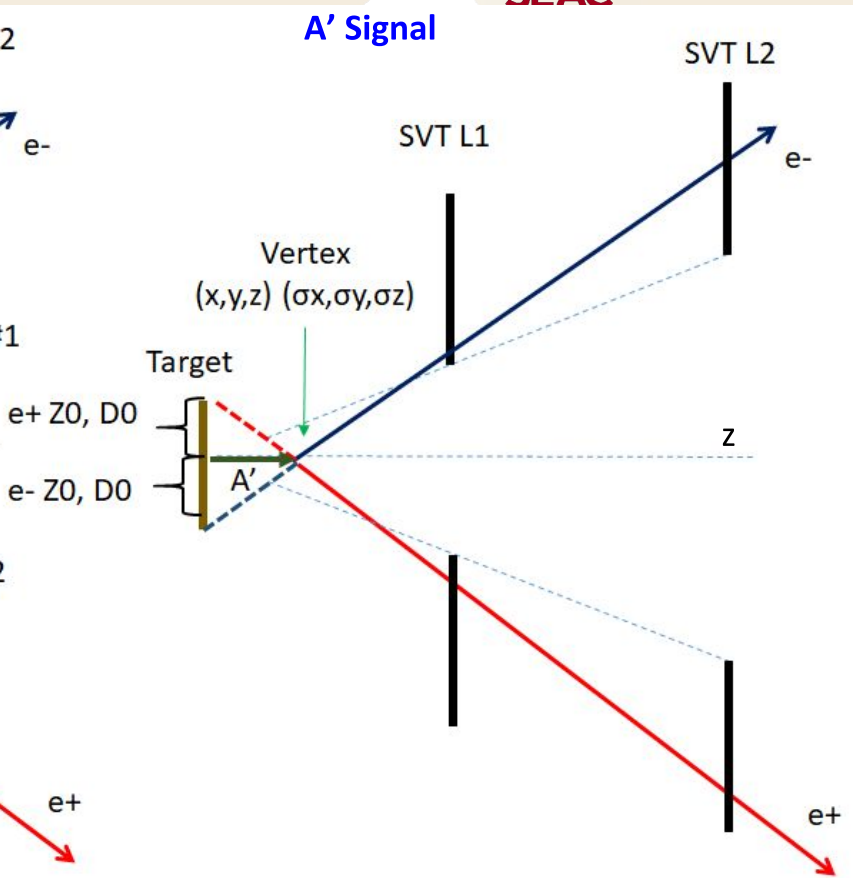




Signal vs Scattered Background

Variables of Interest
Track Quality
Vertex Quality
Vertex Positions
Vertex Errors
V0 Projection to Beamspot
Track Projection to target

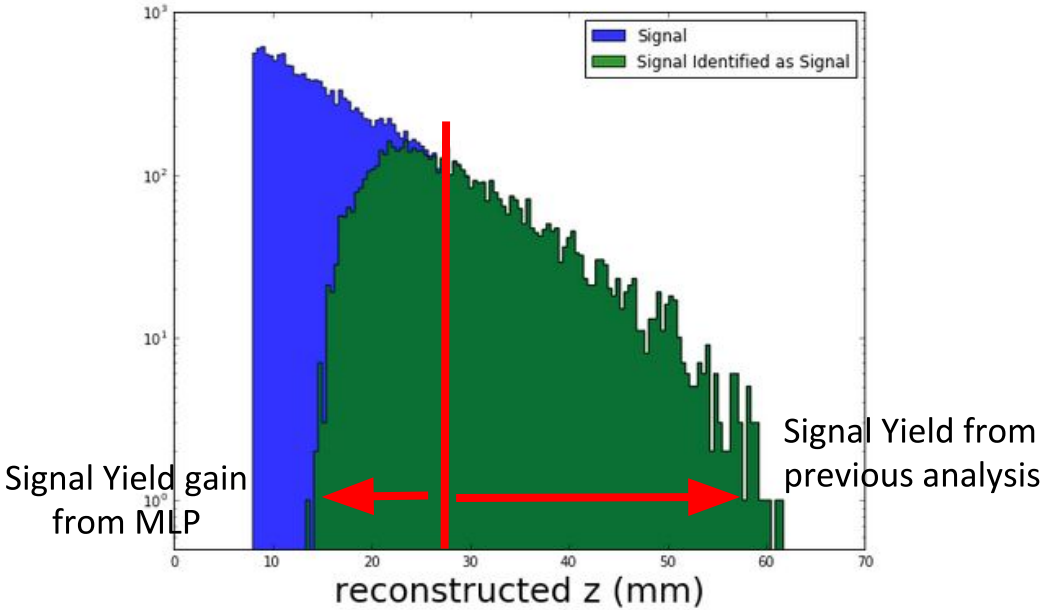


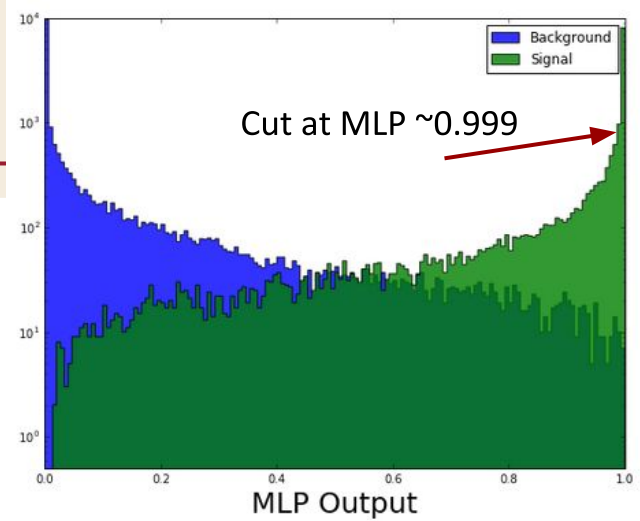


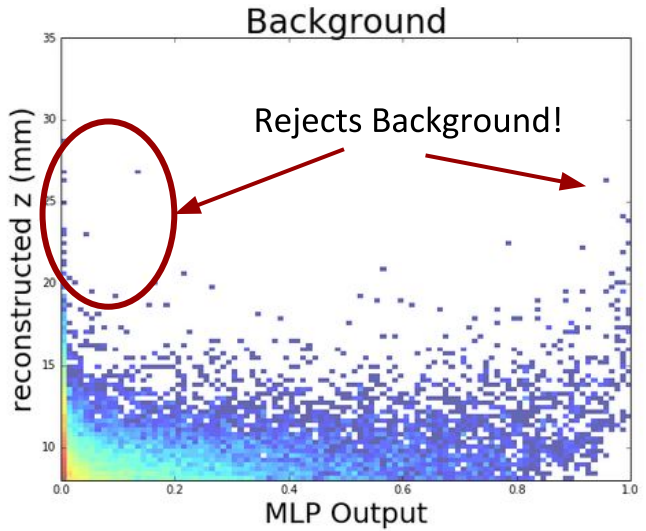
Preliminary Results

- Preliminary results using an MLP show rejection of high z backgrounds and a factor of ~2 signal yield!

  (results for a 50 MeV A’ with cτ = 0.8 mm)

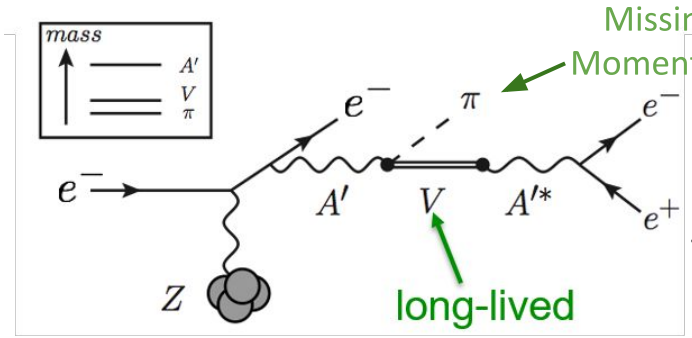




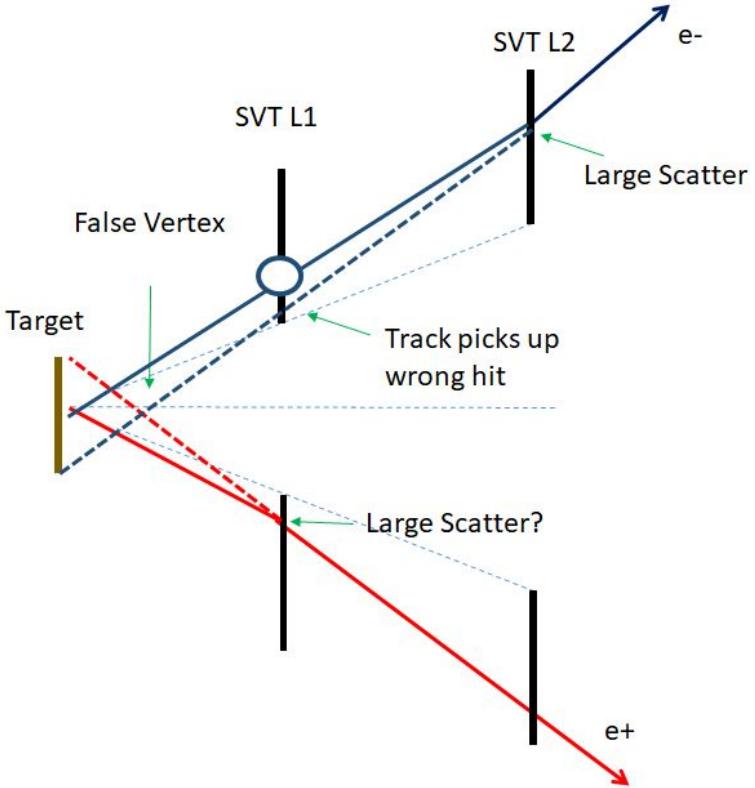


Future Work

- A second major source of large z background are **tracks picking up the wrong hit** in L1 (right)
- HPS can probe an interesting region of parameter space for a wide variety of models (very short lifetime particles). Can we distinguish between MS and a displaced vertex in a **model-independent way**? (example below)



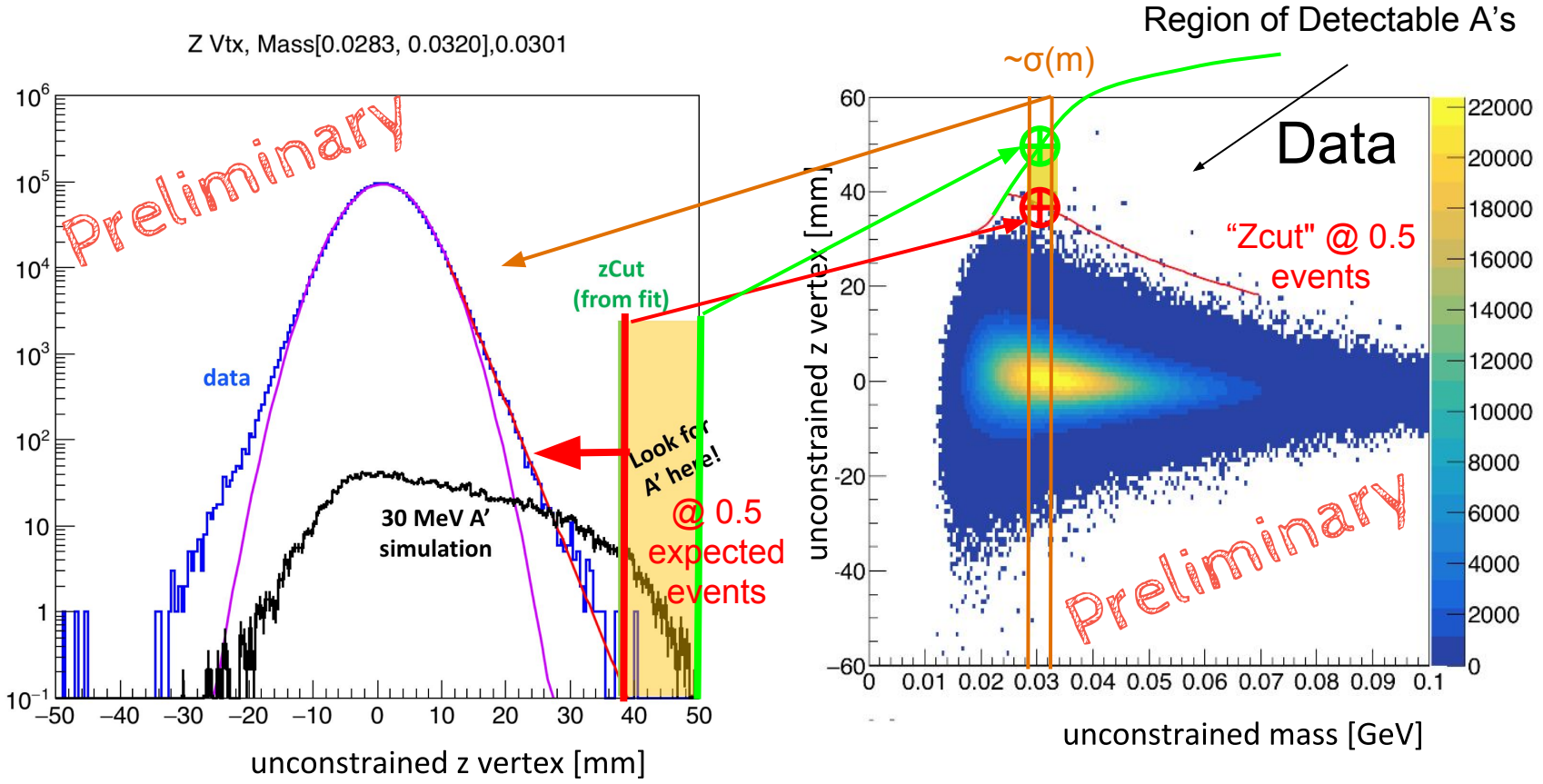
Strongly Interacting Massive Particles (SIMPs)



Conclusion

- **Previous analysis** on 1.7 days of 1.05 GeV electron beam (currently testing ML performance against this)
- **Current analysis** is on ~5 days of 2.3 GeV electron beam (the goal of this approach)
  - We are right on the edge of being able to set a limit in this dataset, incorporating an ML method could be the difference for the minimal A' model
- Resources needed
  - Understanding backgrounds takes several large MC samples (sometimes x10 data equivalent) to characterize the tails of distributions. More computing power
- This is preliminary work, I'm very open to ideas and feedback

Backup


Z Vtx, Mass[0.0283, 0.0320],0.0301
Preliminary
data
30 MeV A'
simulation
zCut
(from fit)
Look for
A' here!
@ 0.5
expected
events
unconstrained z vertex [mm]
Region of Detectable A's
~σ(m)
Data
"Zcut" @ 0.5
events
Preliminary
unconstrained z vertex [mm]
unconstrained mass [GeV]