Bump Hunt on 2016 Dataset

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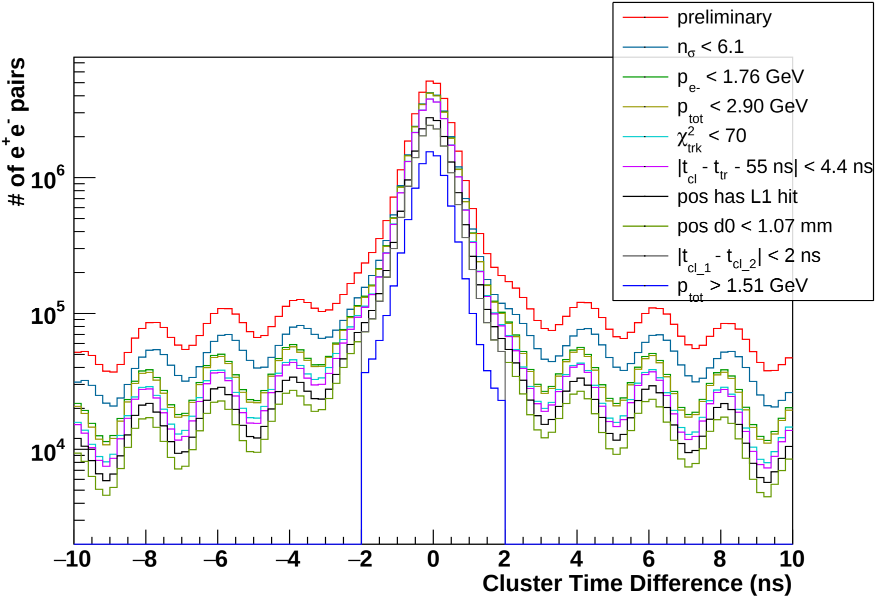
Outline

- Pre-Fitting
  - Event Selection
  - Mass Resolution & Signal Shape
  - Radiative Fraction
- Bump Hunt
  - Background & Signal Models
  - p-values
  - Look Elsewhere Effect
  - Exclusion Limits on Signal Yield & Coupling
- Conclusions & To Do List

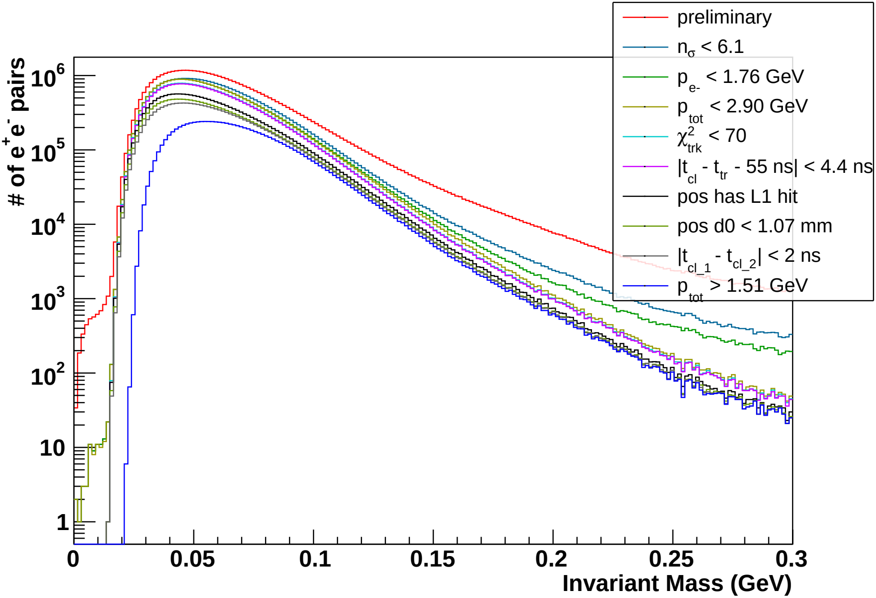
Event-Selection Cuts

- Preliminary cuts
  - SVT flags good.
  - e^+e^-
  - if tracks share ≥ 4 hits, use track with best χ^2
  - both tracks matched to a cluster
- Accidental reduction
  - $n_\sigma < 6.1$ both tracks
  - $|t_{\mathrm{trk}} - t_{\mathrm{clust}}| < 4.4$ ns for both tracks
  - $p_{e-} < 1.76$ GeV (≈76% E_{beam}, reduces FEEs)
  - $p_{\mathrm{tot}} < 2.9$ GeV (≈126% E_{beam}
  - $|t_{\mathrm{clust},1} - t_{\mathrm{clust},2}| < 2$ ns
  - track $\chi^2 < 70$
- Bethe-Heitler and WAB reduction
  - $p_{tot} > 1.51$ GeV (≈65% E_{beam})
  - $d_{0,e+} < 1.07$ mm
  - positron has L1 cut

Cutflows: Cluster-Time Difference



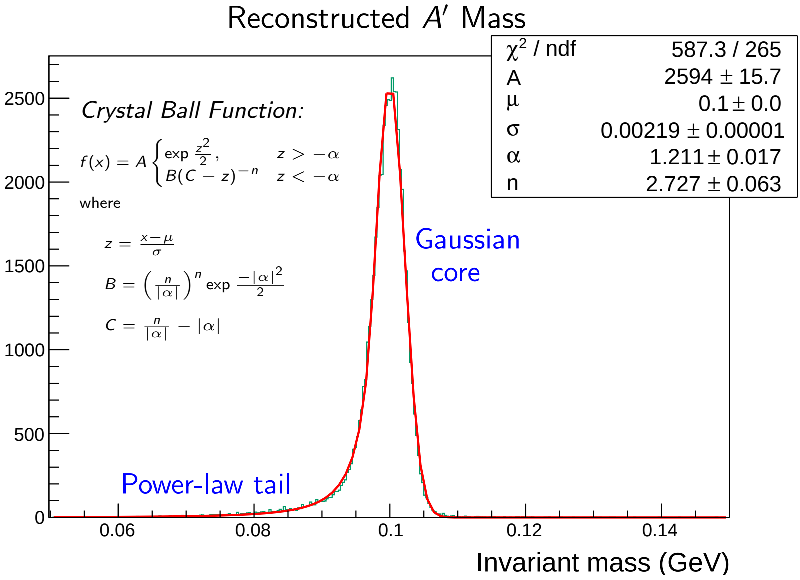
Cutflows: Invariant Mass



Mass Resolution & Signal Shape

- Use A' Monte Carlo at several mass hypotheses.
  - Included wab-beam-tri background
  - Same cuts as in data
  - Fit mass spectrum to Crystal-Ball function
- Use Møller pairs to correct for mismatch in mass resolution between data and MC.
  - See slide 8 for cuts
  - Fit to Crystal-Ball function
  - $\sigma_{A',\mathrm{corr}} = \sigma_{A',\mathrm{MC}} \left[\frac{\sigma_{\mathrm{Møl,data}}}{\sigma_{\mathrm{Møl,MC}}}\right]$

A' Signal Shape:



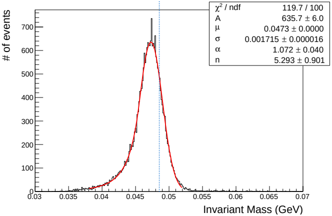
Møller Event Selection

- Event Samples used:
  - Carbon-target calibration run (8054)
  - MC: moller-WBT
- Selection Cuts
  - All flags good.
  - both tracks: fit $\chi^2/\mathrm{d.o.f.} < 7$
  - both tracks: $p < 1.75$ GeV
  - exactly one track matches to a cluster ($n_\sigma < 7$)
  - track time difference < 3 ns ($\approx 3\sigma_{t\_track}$)
  - 1.8 GeV $< p_{\mathrm{sum}} < 2.9$ GeV
  - Target-constrained vertex $\chi^2 < 100$
  - Single-0 trigger

Signal-Shape Correction

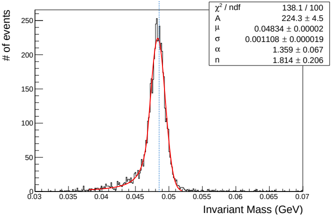
Moller Pairs in Data

$\sigma = 1.72$ MeV

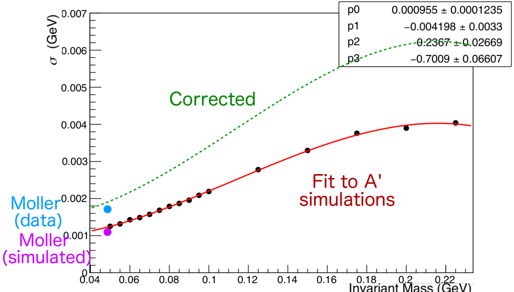


Moller Pairs in MC

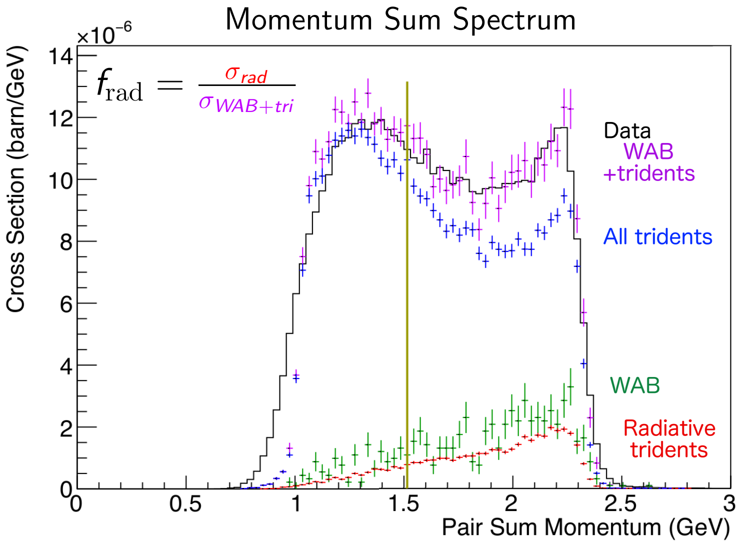
$\sigma = 1.11$ MeV



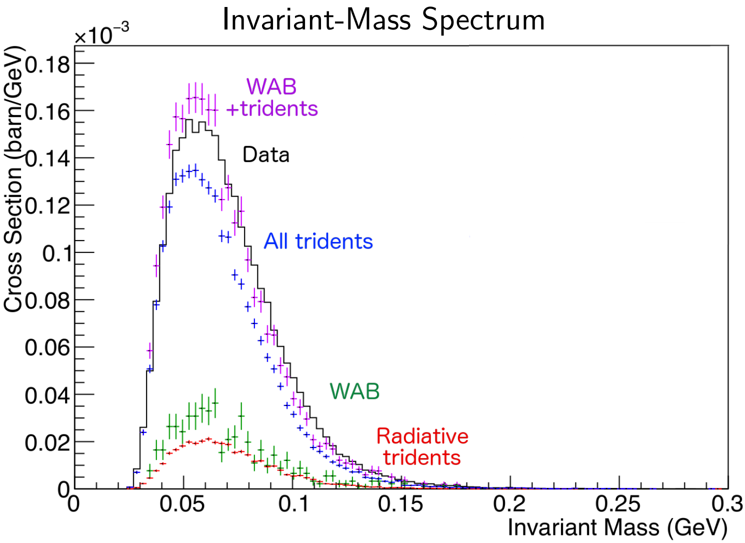
Corrected Width (55% increase)



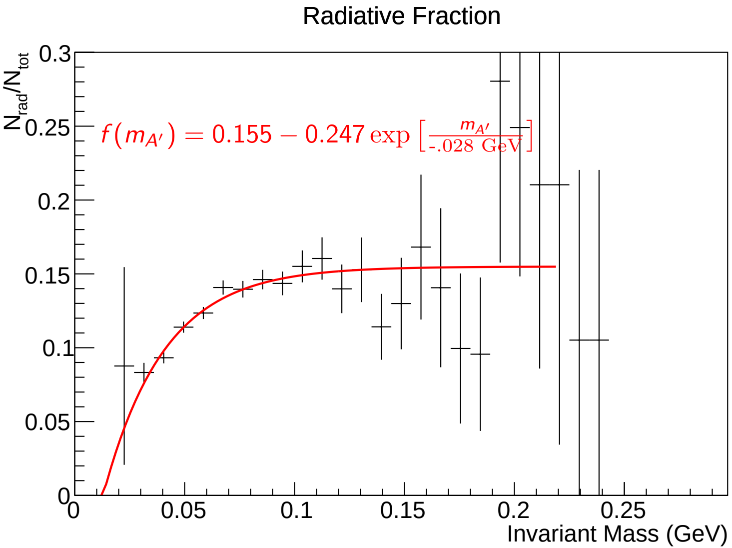
Radiative Fraction



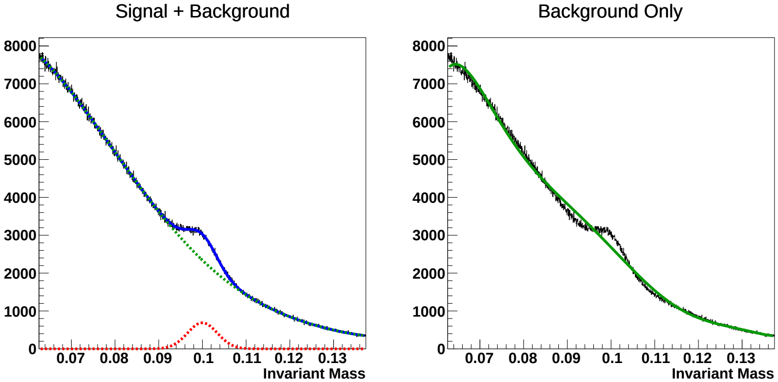
Radiative Fraction



Radiative Fraction

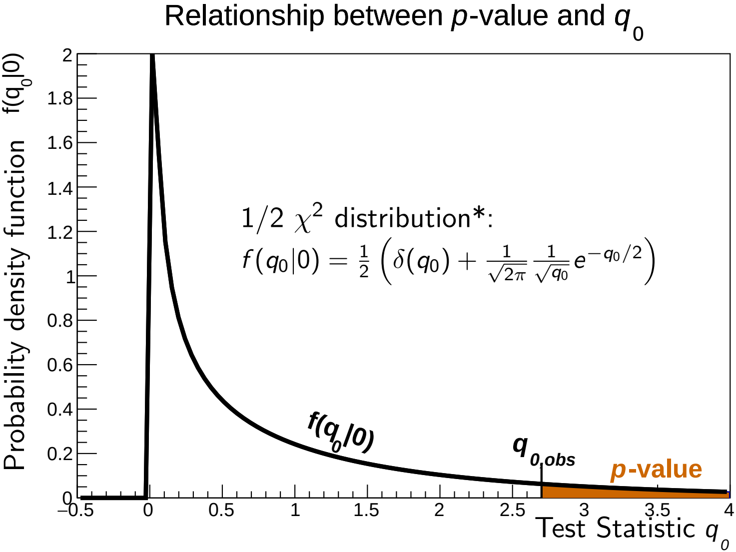


Formalism of a Bump Hunt Analysis: Log Likelihood Test



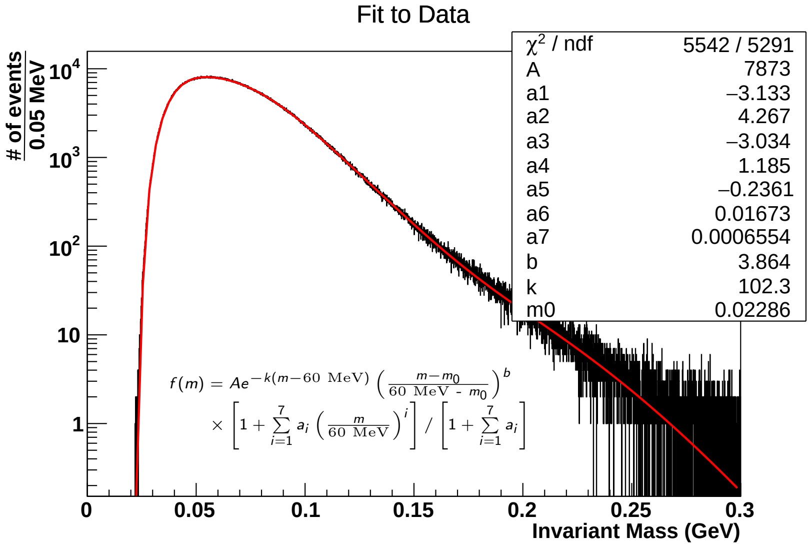
$$\text{Test statistic } q_0 = \begin{cases} 2\log\frac{\mathcal{L}(\hat{\mu},\hat{\theta})}{\mathcal{L}(0,\hat{\hat{\theta}})}, & \hat{\mu} > 0 \\ 0, & \text{else} \end{cases}$$

Formalism of a Bump-Hunt Analysis: *p*-Values

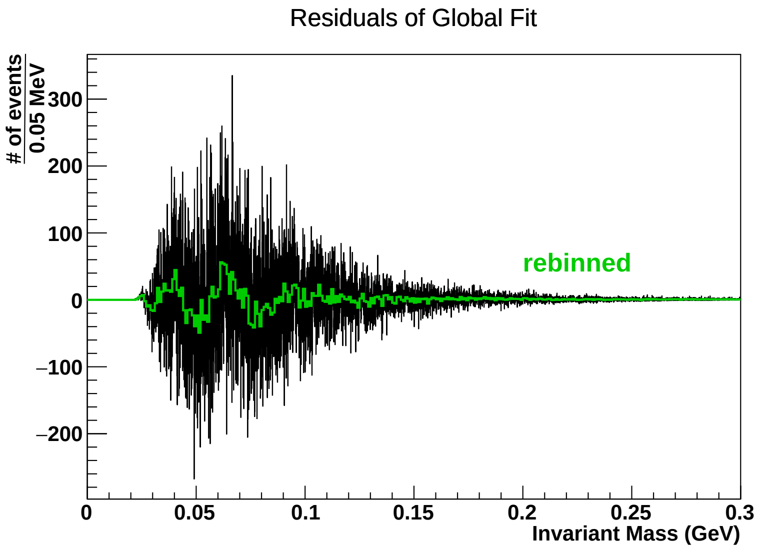


*Cowan et. al., 1007.1727

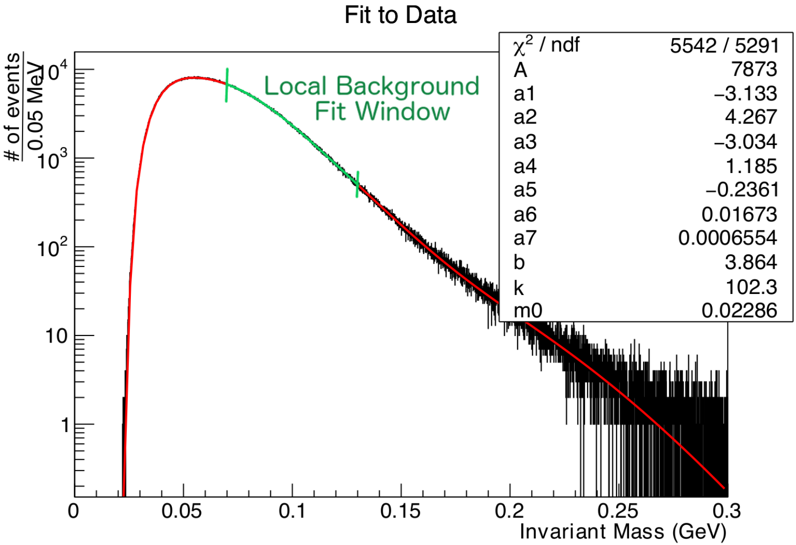
Global Background Model



Global Background Model

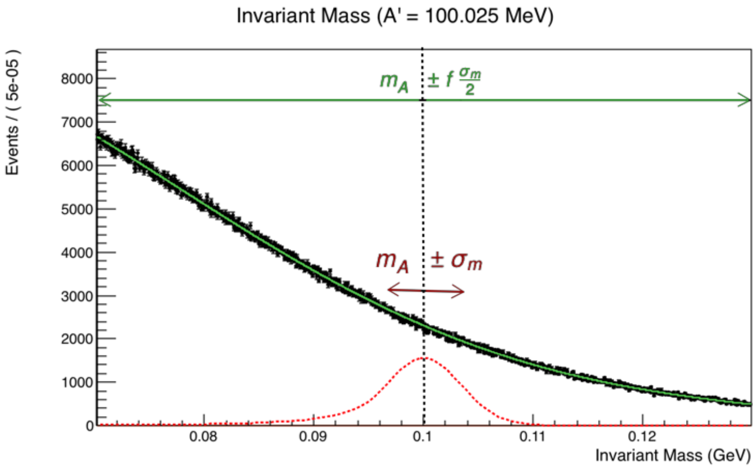


Global Fit$\rightarrow$ Local Fit

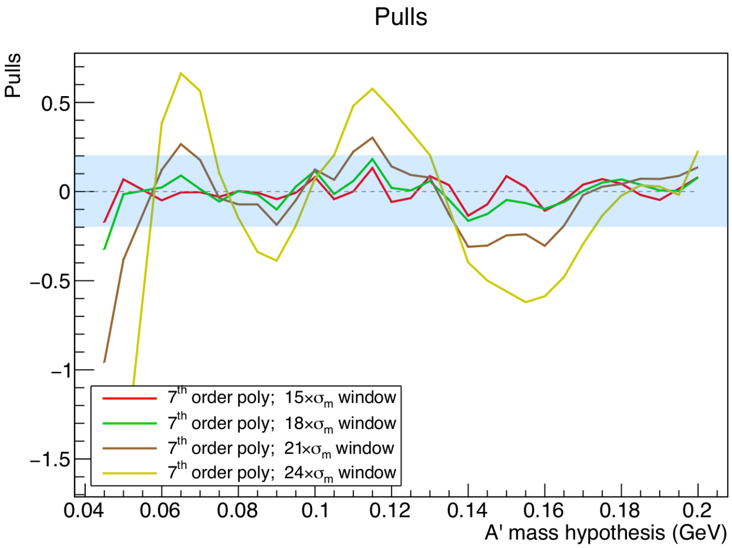


Local Background Model

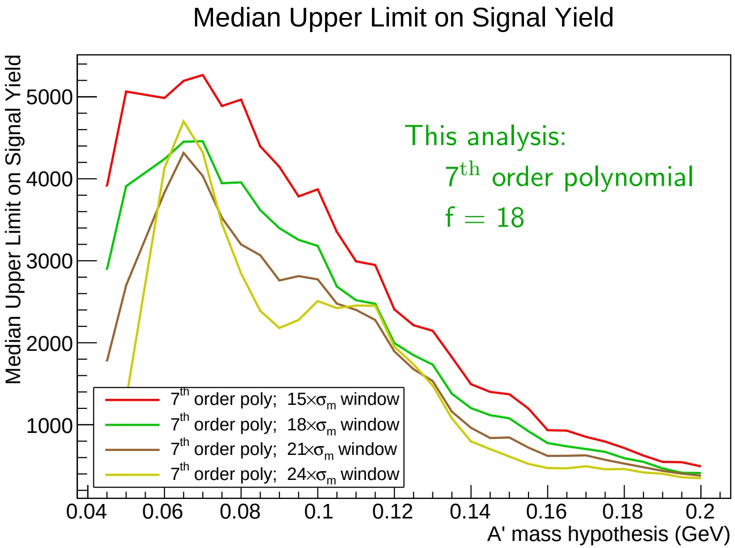
p^{th} order polynomial in a window $m \in [m_{A'} - \frac{f\sigma_m}{2}, m_{A'} + \frac{f\sigma_m}{2}]$



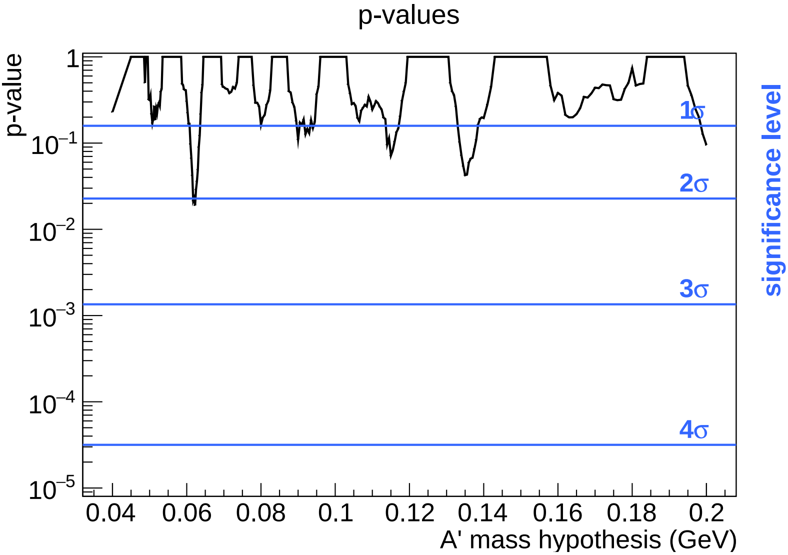
Local Background Model Comparison



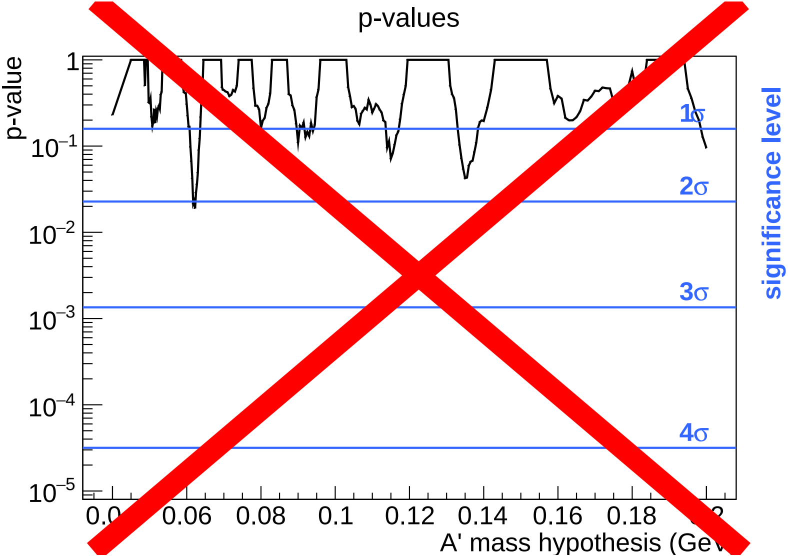
Local Background Model Comparison



p-Values

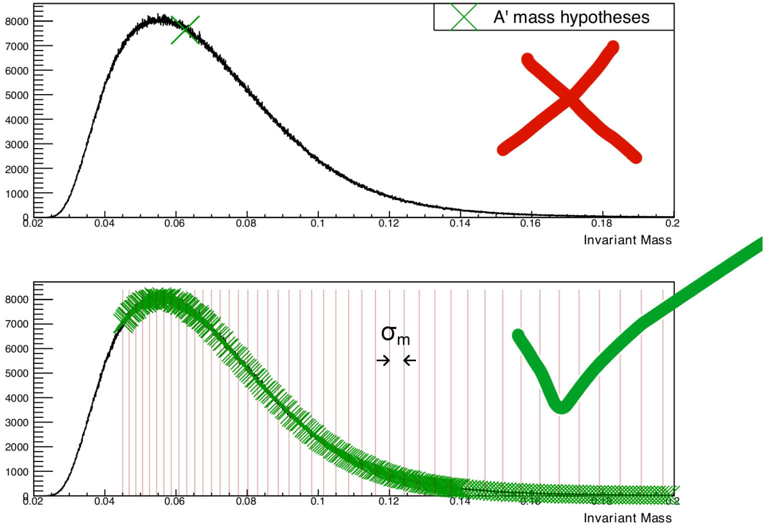

p-values
p-value
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
A' mass hypothesis (GeV)
1σ
2σ
3σ
4σ
significance level

p-Values

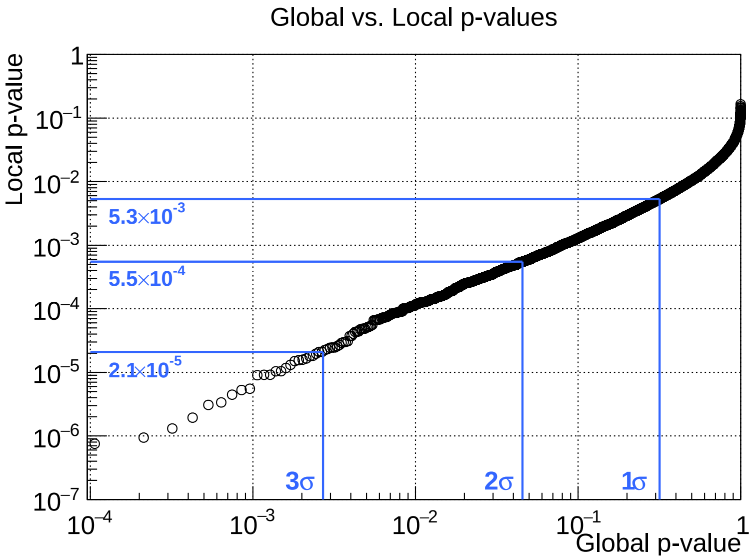


WARNING: DID NOT TAKE INTO ACCOUNT LOOK ELSEWHERE EFFECT

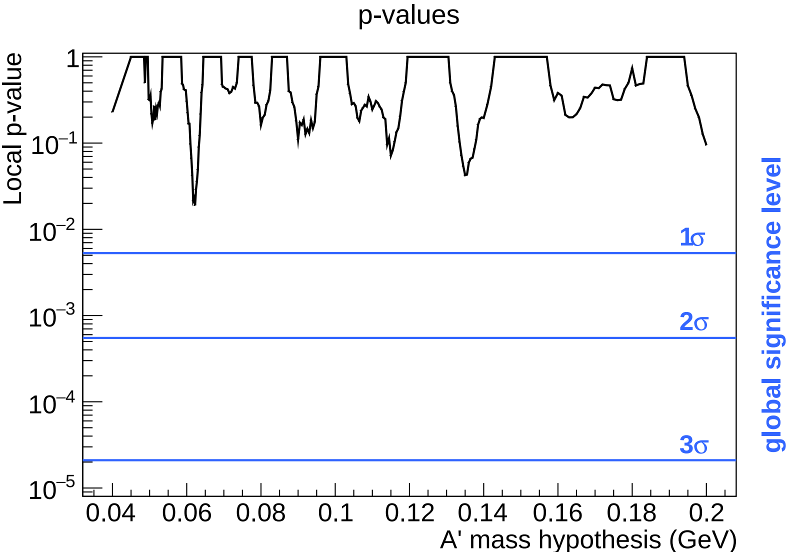
Look Elsewhere Effect



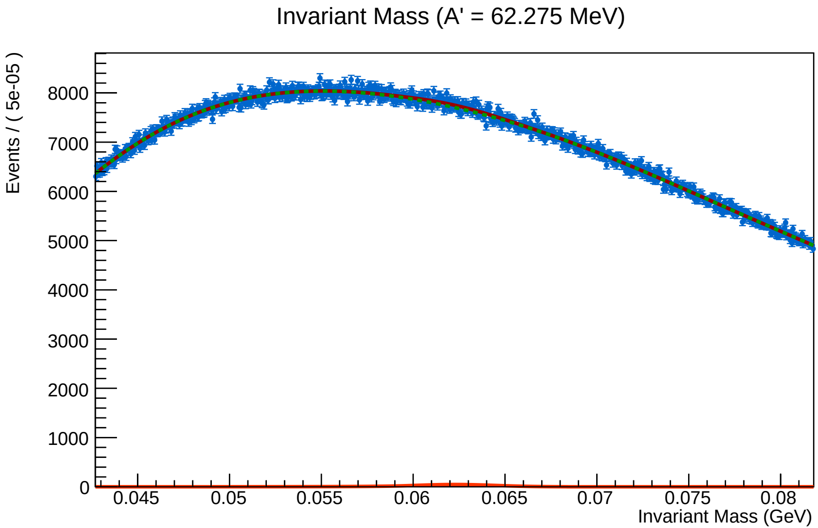
Look Elsewhere Effect



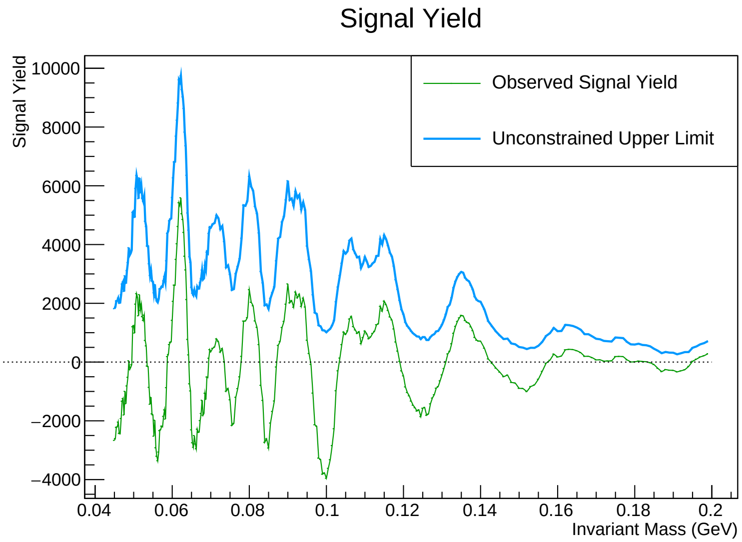
p-Values (Corrected for Look Elsewhere Effect)



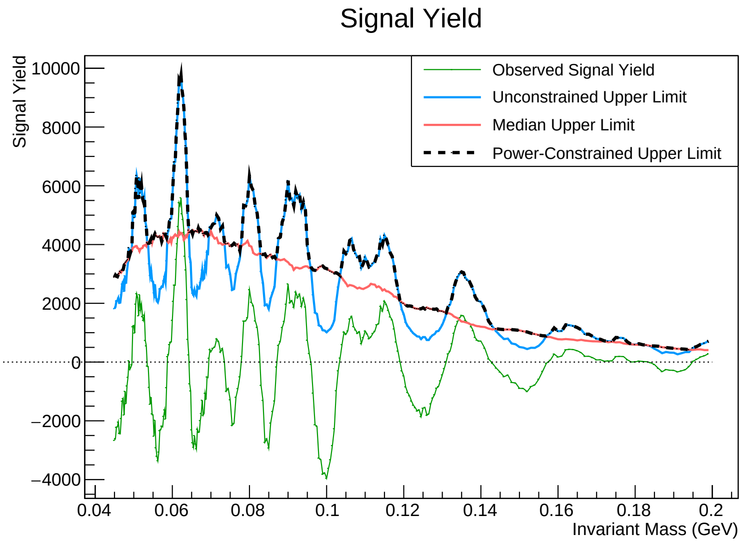
Most Significant Bump-Candidate



Upper Limits on Signal Yield



Upper Limits on Signal Yield: Power Constraint



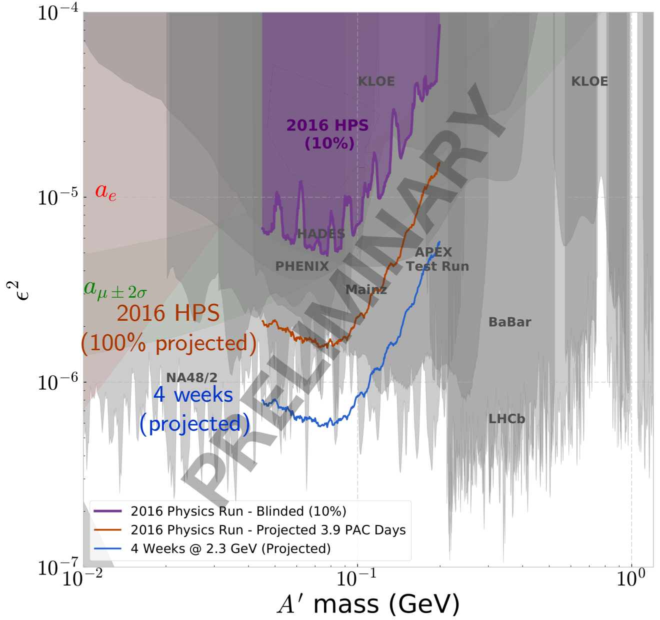
Convert These to Upper Limits on Coupling ...

$$\epsilon_{\mathrm{ul}}^2 = \frac{\mu_{pc}}{f_{rad}[\Delta B/\Delta m]} \frac{2N_{\mathrm{eff}}\alpha}{3\pi m_{A'}}$$

where

- μ_{pc} = power-constrained upper limit on signal yield.
- f_{rad} = fraction of events in sample that are radiative tridents
- $\Delta B/\Delta m$ = number of background events per mass in a mass window
- $N_{\mathrm{eff}} = 1$, for $m_{A'} < 2m_{\mu}$

Upper Limits on Coupling (Preliminary)

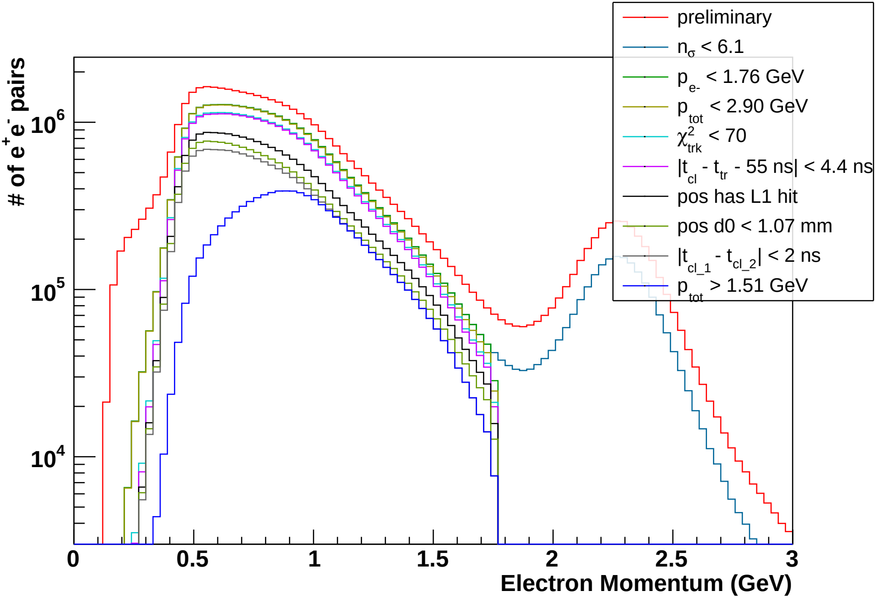


Conclusions & To Do List

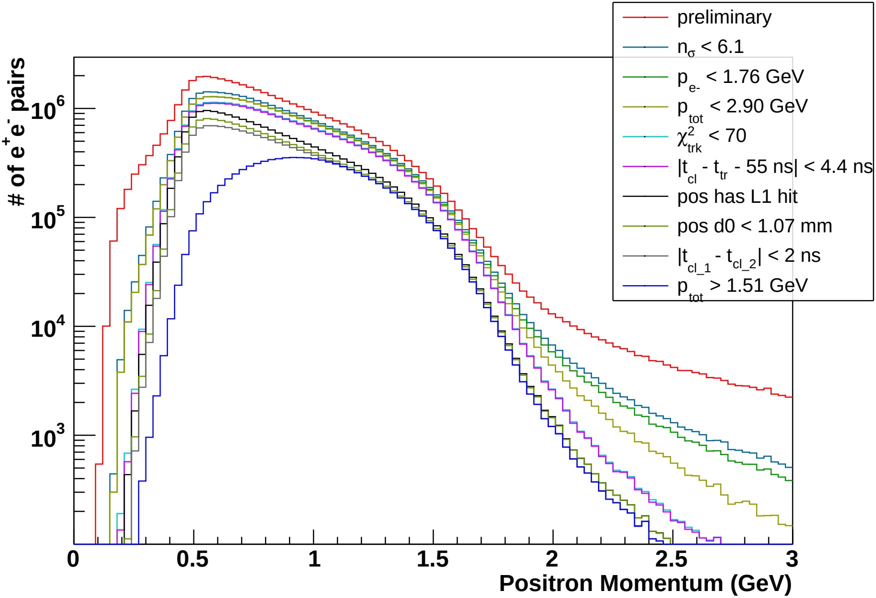
- We expect tiny reach from 2016 dataset after unblinding.
- Improved alignments $\rightarrow$ Improved resolutions (hopefully) $\rightarrow$ better reach.
- Improved fits could be done with exp(poly) background model (as Omar talked about)
- When the alignments are ready, I can rerun the bump hunt on the blinded 2016 datasets, and then unblinded

Backup Slides

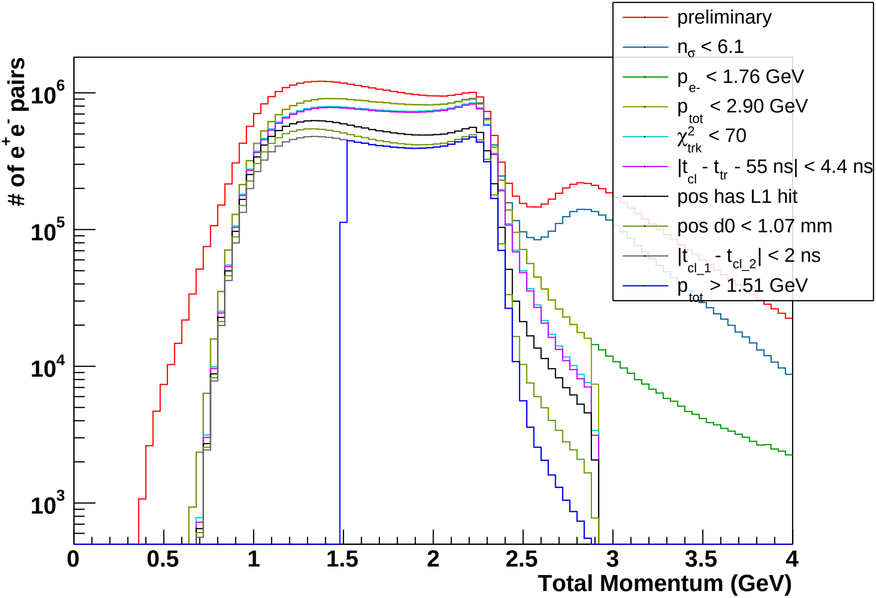
Cutflows: Electron Momentum



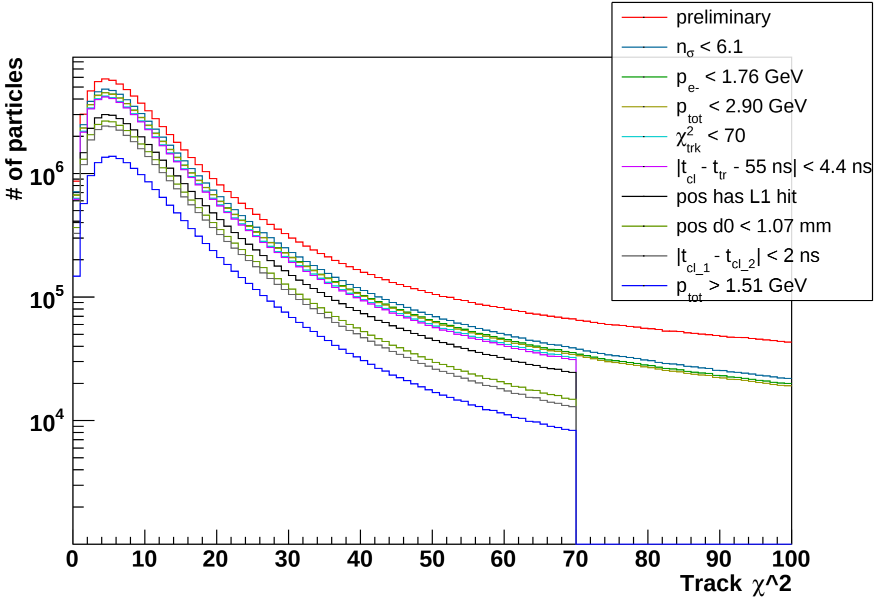
Cutflows: Positron Momentum



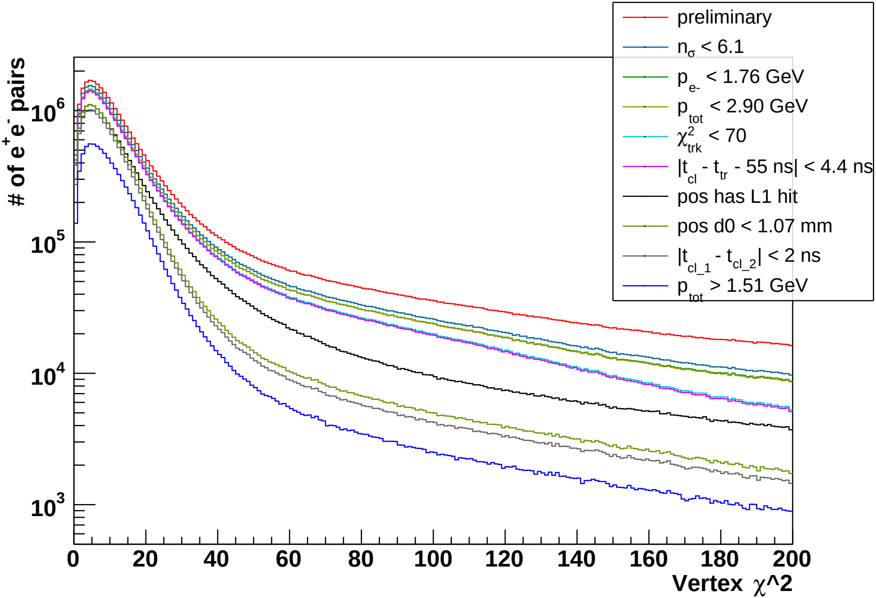
Cutflows: Total Momentum



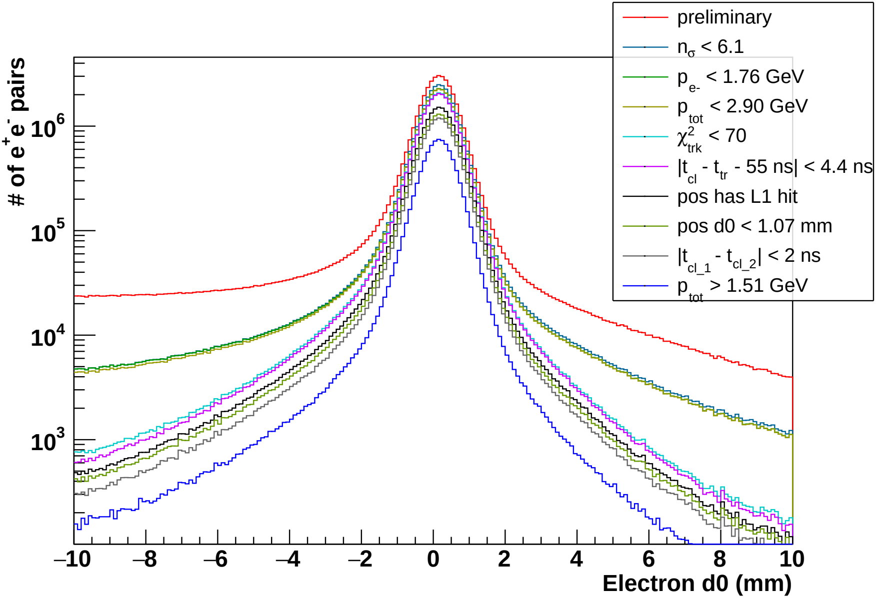
Cutflows: Track χ^2



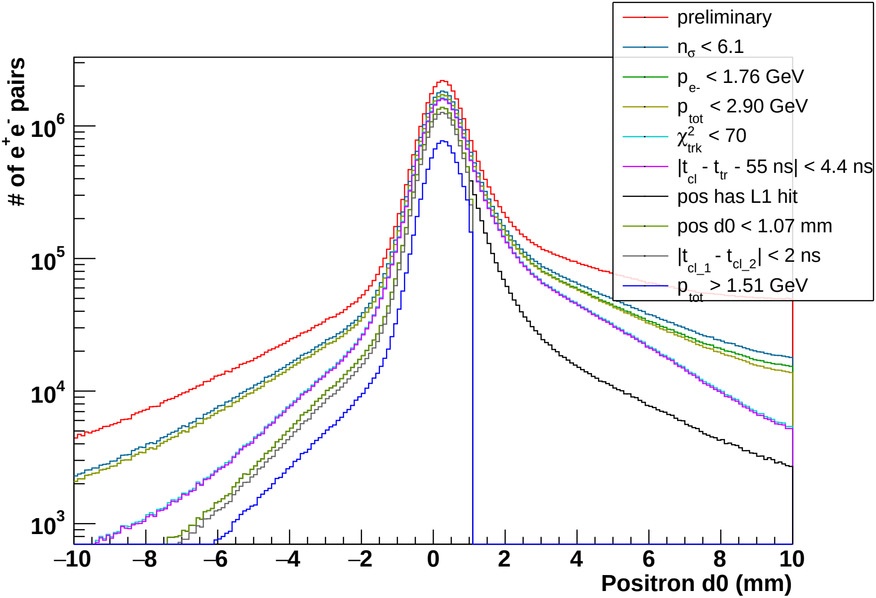
Cutflows: Target Constrained Vertex χ^2



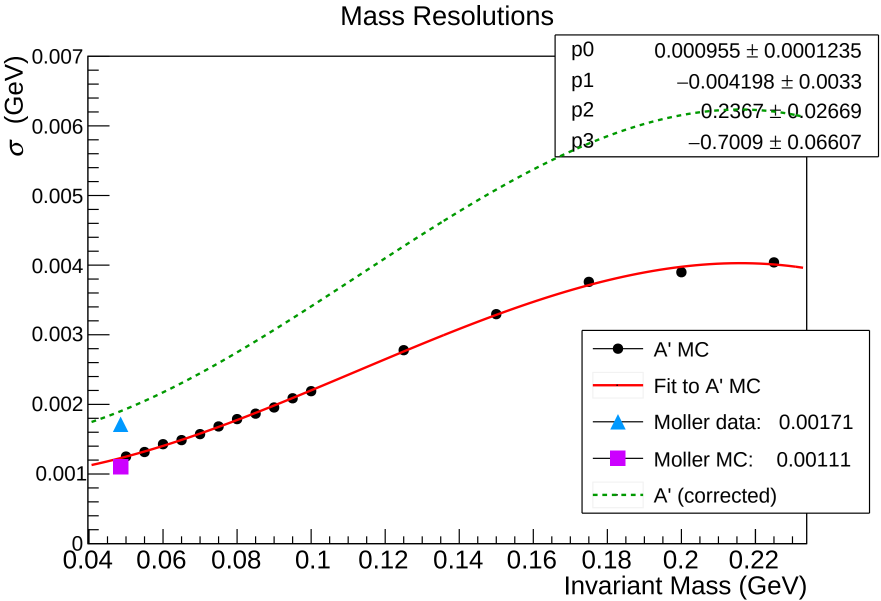
Cutflows: Electron d0



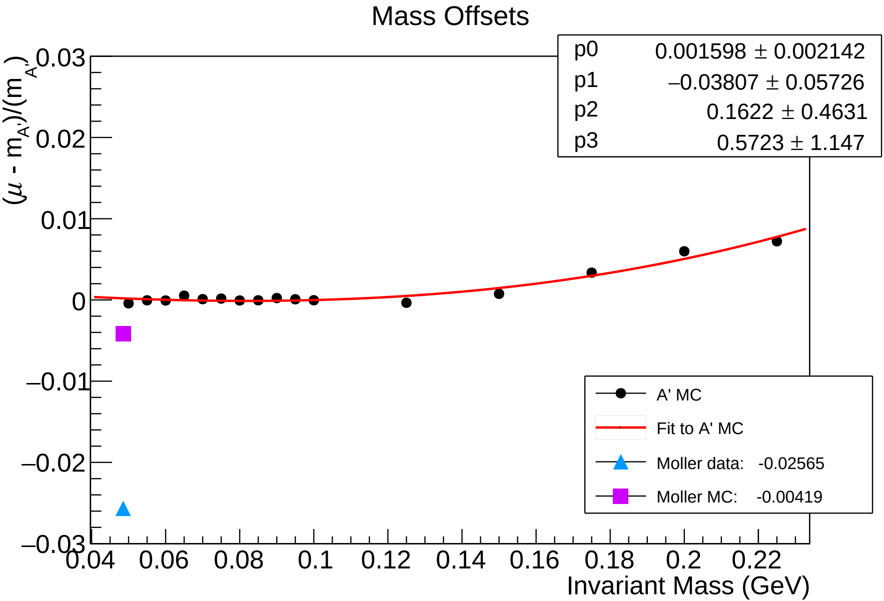
Cutflows: Positron d0



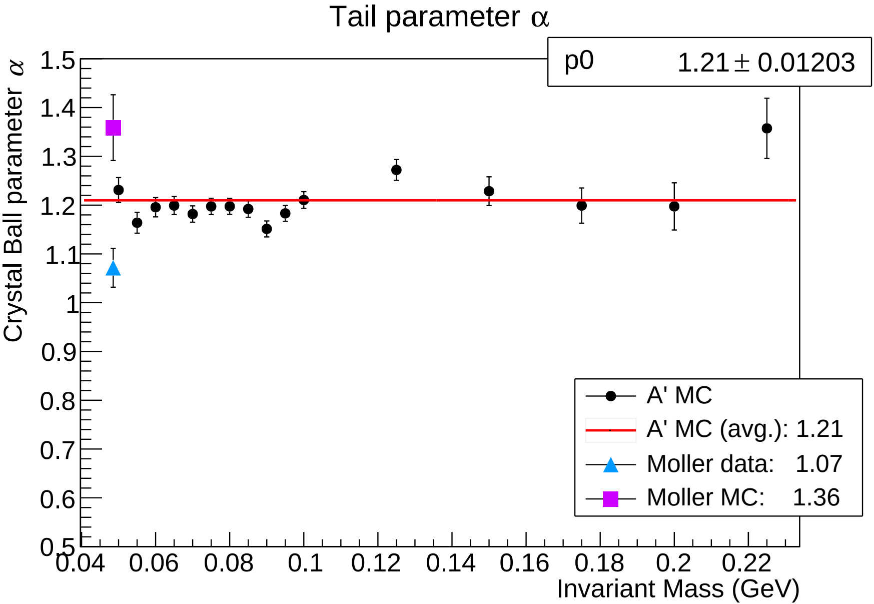
Signal Shape: Sigma



Signal Shape: Mass Offset



Signal Shape: Crystal Ball Parameter α



Signal Shape: Crystal Ball Parameter n