Excited Electron Search in ATLAS at 1 TeV

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Theory

Data Samples And Selection

Analysis:

Best Electron Selection Method
- demonstrates increased e* signal strength when applying new electron selection method
- Properly scaled backgrounds for “best electron selection” method. No dramatic increases in Z-ee background, therefore conclusion that the best electron selection, is an effective though more work intensive method (backgrounds calculated for each individual masspoint).

QCD Background Calculation
- QCD Background fitting using $p_0^*x^{p_1^*}x^{p_2^*\log(x)}$

Limit Setting
- Gage mass range at which analysis is sensitive, set a limit

Conclusions
**Composite model:** quarks and leptons may share common constituent particles and are just the ground state of excited Fermions. The discovery of an electron in an excited state will provide evidence for this model.

Electroweak decay process $e^* \rightarrow e\gamma$ is particularly worthwhile to study because decay products can be directly reconstructed in ATLAS.

![Gage Mediated Branching Ratio for $e^*$](image-url)
The Calorimeter is composed of multiple layers with varying sensitivities. Track matching is the primary means of distinguishing between photons and electrons.
Today we look at the 2011 data, periods A-H (skimmed by Ahmed - thanks!)

The QCD background is estimated using a method similar to the $Z'$ analysis

The method in brief:

Select events from the 2g20 trigger that pass the loose electron cut but fail the medium cut. Add a photon selection, use best distribution. Fit to a polynomial function and use as a template for modeling the QCD background
Data and MC

- Data set is skimmed di-electron 2011, period B-H, skimmed by Ahmed, tag p580.
- Using GRL: 
  `data11_7TeV.periodAllYear_DetStatus-v18-pro08-05_CoolRunQuery-00-03-98_Eg_standard.xml`
- 1.075/fb. Cutflow (e20_medium trigger):
MC background samples are the officially produced SMWZ ntuples, tag p591:

**Signal Distributions**
CompHEP: Lambda = 7000 GeV

- **Zee**
  mc10_7TeV.106046.PythiaZee_no_filter.merge.NTUP_SMWZ.e574_s933_s946_r2302_r2300_p591

- **Diboson**
  mc10_7TeV.105986.ZZ_Herwig.merge.NTUP_SMWZ.e598_s933_s946_r2302_r2300_p591
  mc10_7TeV.105985.WW_Herwig.merge.NTUP_SMWZ.e598_s933_s946_r2302_r2300_p591
  mc10_7TeV.105987.WZ_Herwig.merge.NTUP_SMWZ.e598_s933_s946_r2302_r2300_p591

- **ttbar**
  mc10_7TeV.105200.T1_McAtNlo_Jimmy.merge.NTUP_SMWZ.e598_s933_s946_r2302_r2300_p591

- **W+jets**
  mc10_7TeV.107681.AlpgenJimmyWenuNp1_pt20.merge.NTUP_SMWZ.e600_s933_s946_r2302_r2300_p591
  mc10_7TeV.107680.AlpgenJimmyWenuNp0_pt20.merge.NTUP_SMWZ.e600_s933_s946_r2302_r2300_p591
  mc10_7TeV.107682.AlpgenJimmyWenuNp2_pt20.merge.NTUP_SMWZ.e760_s933_s946_r2302_r2300_p591
  mc10_7TeV.107683.AlpgenJimmyWenuNp3_pt20.merge.NTUP_SMWZ.e760_s933_s946_r2302_r2300_p591
  mc10_7TeV.107684.AlpgenJimmyWenuNp4_pt20.merge.NTUP_SMWZ.e760_s933_s946_r2302_r2300_p591
  mc10_7TeV.107685.AlpgenJimmyWenuNp5_pt20.merge.NTUP_SMWZ.e760_s933_s946_r2302_r2300_p591
MC Corrections

- Corrections applied to make the MC10b samples match the data:
  - PileUpReweighting
  - k-factor determined only for Z/gamma* sample using LO* to NNLO QCD and EW scaling
  - FEB acceptance loss - remove dead FEB’s after first 167/ pb - egamma method 3
  - energy scaling (data) and smearing, (MC) according to egamma EPS recommendation (electron and photon)
  - scale for trigger efficiency from Sarah’s macro
  - scale factors for electron reco/id/blayer/iso efficiency as a function of eta and pT from Sarah’s macro (none for photons)
  - Use PV corrected isolation for electrons, ED corrected isolation for photons

August 2nd, 2011
Events and Objects:

**Photon**:  
- author 4 or 16  
- etamax, crack  
- pt>20 GeV  
- OQ, larQuality=0  
- cleaning cuts  
- PhotonLooseAR  
- deltaR(e,ph) >0.7  
- Et cone 20 (ED cor.) isolation < 10 GeV

**Event**:  
- GRL  
- vertex cut ntracks>2  
- pass trigger e20_medium and matched to an offline electron.

**Electron**: (Z' selection)  
- author 1 or 3  
- etamax, crack  
- pt>25 GeV  
- OQ, larQuality=0  
- medium  
- blayer  
- Et cone 20 (PV cor.) isolation < 7 GeV

August 2nd, 2011
**Selection - continued**

<table>
<thead>
<tr>
<th>Z:</th>
<th>e*:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2 medium electrons</td>
<td>• 2 medium electrons</td>
</tr>
<tr>
<td>• Mz &gt; 70 GeV</td>
<td>• I loose photon</td>
</tr>
<tr>
<td></td>
<td>• Zveto - remove event 85 GeV &lt; M(ee) &lt; 95 GeV</td>
</tr>
<tr>
<td></td>
<td>• Check both el/ph combinations</td>
</tr>
<tr>
<td></td>
<td>• Lambda value: 7000 GeV</td>
</tr>
</tbody>
</table>

**Background “anti-cuts”:**

• for Electron only:

  • With trigger 2g20loose two electrons are loose, blayer + notMedium, leading electron is isolated.

  • require 1 loose photon

  • We have tried e60 trigger with same anti-cuts as above
Question: which final state electron is a decay product of The excited electron?

• Currently, we choose which electron to use to form the resonance by examining the pT of each electron. At each e* invariant mass value, either the highest pT electron or the second highest pT mass electron corresponds to the higher signal.

• Instead, select electron based on which e + γ combination has a resonance with a mass closest to the expected e* mass.

• In the data, think of it as say, 15 experiments for 15 different test masses in which each resulting analysis is compared with mc generated for the hypothesized e* mass.
For smaller $m(e^*)$, the 2nd highest $p_T$ electron dominates,
Whereas at higher $m(e^*)$ the highest $p_T$ electron dominates.
However, the best selection seems to always dominate
Best Selection 200 GeV
Best Selection 700 GeV

Events

Inva mass[GeV]

August 2nd, 2011
Best Selection 1500 GeV

Events

Inva mass[GeV]

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QCD Background Fitting
QCD Fit: M_log plot at 700 GeV

Selection: two loose electrons
Not medium, 1 loose photon
Select best electron photon pair and plot mass
(this is QCD background template)

Fitting function:

\[ p_0 x^{p_1} e^{p_2 \log(x)} \]

Fit Parameters at 700 GeV:

1. \( p_0 \): 1.24413e-06 ± 2.19540e-06
2. \( p_1 \): 6.92529e+00 ± 5.95201e-01
3. \( p_2 \): -8.30384e-01 ± 7.49177e-02
Add QCD background template to MC background and compare that using a fit to the data in the signal distribution.

Scale Factors:
MC: 1.0 (fixed)
m_QCDbkg: 0.36457
QCD Fitting Result: m_log

- Resulting mass plot for fitted QCD background at 700 GeV
- Data: 1 fb-1
- All backgrounds plotted, including fitted QCD background
Now, we test the method
And implementation
By replicating the
The procedure with $Z\rightarrow\gamma\gamma$
Resulting in an accurate
$Z'$ qcd fit. (no photon cut)
Validation of principle
10% more events at peak
Than predicted
We plot Signal Distributions. No Zveto cut.

194 events ->108 Events (only removed Z->ee background)

No QCD included, but still useful for understanding the Zveto cut, which in the previous plots removed events with two electrons whose resonant mass is near that of a Z.

The low mass region is removed by cutting +5 GeV around Z peak (Zveto cut)
Dielectron Mass Plot Two Medium Electrons
One Loose photon Best Selection

- Signal Distribution, no Zveto cut
- Again, no QCD included, but another m_log plot for Z->ee useful in understanding the effect of the Zveto cut
Final Result: 700 GeV

Resulting mass: Final Plot
Plot at 700 GeV
Including Zveto cut
Diagnostic: Worst Electron Selection

Resulting m_log (Worst Selection)
Plot at 700 GeV
Including Zveto cut:

bestE events count: 194
bestE w/Zveto count: 108
Diagnostic Distributions: Electron0

No QCD yet
Diagnostic Distributions: Electron1

No QCD yet

August 2nd, 2011
Diagnostic Distributions: Photon

No QCD yet
Power-constrained one-sided 95% frequentist limits using standard ATLAS tool

Counting experiment (not taking into account shape)

Including systematic uncertainties may not give as strong a limit, might point to overestimate of QCD at higher mass regions, not including photon jet-photon fake rate

Excludes mass range <1248 GeV
Final Remarks

• “best” electron procedure effective in increasing signal strength,
  But now must run analysis independently for each individual mass point

• Fitting QCD to function used by Z' group effective,
  But may still try alternative fit functions. Also will run analysis for each individual mass point

• Result of other attempts: ex combined 2g20 + e60 trigger fitting, possibly unnecessary as of now due to low number of events that pass e60 but not 2g20 triggers. We set up analysis for this process in certain circumstances, but may not be so useful:
  • 2g20 trigger, z' selection: 257429
  • e60 trigger (not 2g20) z' selection: 220
    (not high mass, didn’t make 2g20 cut)

ATLAS is very sensitive to excited electron physics, strong case for exclusion of lower mass points and lambda values
### Backup: QCD Fit Parameters

$p_0 x^{p_1} x^{p_2 \log(x)}$

<table>
<thead>
<tr>
<th>Mass Range</th>
<th>p0</th>
<th>p1</th>
<th>p2</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 GeV</td>
<td>4.65097e-08</td>
<td>7.25397e+00</td>
<td>-7.52764e-01</td>
</tr>
<tr>
<td>400 GeV</td>
<td>3.62320e-05</td>
<td>4.56098e+00</td>
<td>-4.83553e-01</td>
</tr>
<tr>
<td>500 GeV</td>
<td>3.50168e-02</td>
<td>1.77300e+00</td>
<td>-2.06052e-01</td>
</tr>
<tr>
<td>600 GeV-1500 GeV</td>
<td>2.09704e-02</td>
<td>1.98733e+00</td>
<td>-2.28336e-01</td>
</tr>
</tbody>
</table>

Fit becomes constant due to lack of statistics at higher mass values.
Backup: Cutflow for e20 trigger (Z’ Selection)

<table>
<thead>
<tr>
<th>Selection</th>
<th>Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Cut</td>
<td>14515104</td>
</tr>
<tr>
<td>GRL</td>
<td>12543511</td>
</tr>
<tr>
<td>Trigger</td>
<td>3882366</td>
</tr>
<tr>
<td>&gt;2e crack</td>
<td>3564974</td>
</tr>
<tr>
<td>&gt;=2e pt</td>
<td>1664963</td>
</tr>
<tr>
<td>&gt;=2e otx</td>
<td>1664958</td>
</tr>
<tr>
<td>&gt;=2e loose</td>
<td>386905</td>
</tr>
<tr>
<td>&gt;=2e medium</td>
<td>291726</td>
</tr>
<tr>
<td>&lt;7GeV corrected npv isolation</td>
<td>266036</td>
</tr>
<tr>
<td>m&gt;=70GeV (for Z)</td>
<td>259856</td>
</tr>
</tbody>
</table>

After Photon cut, 108 events
Acknowledgements

John Parsons
Tim Andeen
Columbia ATLAS Group