Physics performance of the ATLAS Pixel Detector

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On behalf of ATLAS Collaboration
Introduction

ATLAS Physics results:  https://twiki.cern.ch/twiki/bin/view/AtlasPublic

ICHEP2016 Conference Notes:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/Summer2016-13TeV

54 physics conference notes + 13 supportive notes

In this talk, I will discuss what is the impact of the Pixel to the physics analysis.
Application to the physics analysis

Most powerful measure of impact parameter.

=> Good separation of the interaction vertex
- better performance for b-jet tagging,
- pileup suppression, well-control of the Object identification (e / µ / τ / MET)

IBL is the new detector in Run-2

![Graph showing the rejection of light-flavour jet rejection](image)

ATLAS Simulation Preliminary

~5 times better rejection

\[ \sqrt{s} = 8, 13 \text{ TeV}, \, |\eta| < 2.5 \]

\[ p_T^{jet} > 25 \text{ GeV}, \, |\eta^{jet}| < 2.5 \]
IBL tracking performance

Data Z→μμ events are compared with MC.

The separation power of the merged cluster is ~0.75mm.
(50 x 250μm pixel)

The Neural Network additionally resolves cluster splitting.

(Talk is given by MANSOUR, Jason Tue. 9am)

Slight degradation is due to non-primary track from vertex.

pion mostly, track from muon

ATLAS Preliminary

Slight degradation is due to non-primary track from vertex.

Z→μμ Events
- Data 2015
  - Simulation

ATLAS Preliminary

Simulation, ρ→ππ

• Ideal
  • TIDE
  • Baseline

ρ ρ_T [GeV]

Pixel Clusters

2 2.5 3 3.5 4 4.5
0 200 400 600 800 1000

I.B. Efficiency

0.8 0.85 0.9 0.95 1
1 10 100 1000

ρ_T [GeV]
ICHEP 2016 – ATLAS physics results

65% of the analysis uses the b-jet!!!
b-jet is dominant systematic uncertainty

This is natural, increasing the b-jet multiplicity, increase the systematics...

In most of the analyses, the systematics on b-jet efficiency is **DOMINANT systematics**.

1. Jet energy scale (JES) , 2. b-jet efficiency, 3. MET (through propagation from them)

At low pT, JES is dominant, while at high pT, b-jet systematics is dominant.

**Typical order of uncertainty**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>JES</th>
<th>b-jet</th>
</tr>
</thead>
<tbody>
<tr>
<td>$N_{bjet} &gt; 2$</td>
<td>13-25%</td>
<td>10-30%</td>
</tr>
<tr>
<td>$N_{bjet} = 2$</td>
<td>4-10%</td>
<td>1-15%</td>
</tr>
<tr>
<td>$N_{bjet} = 1$</td>
<td>2-20%</td>
<td>2-10%</td>
</tr>
<tr>
<td>b-veto</td>
<td>1-20%</td>
<td>~3%</td>
</tr>
<tr>
<td>top CR</td>
<td>12-33%</td>
<td>7-16%</td>
</tr>
</tbody>
</table>

**Example, top pair xsec measurement**

![Graph showing fractional uncertainty for different sources: Stat. Unc., Syst. Unc., Flavour Tagging, Backgrounds, Hadronisation, JES/JER, IFSR, PDF, MC Stat., Hard Scattering. JES is dominant at low pT, ~10% at high pT.](image)
Search for SUSY in events with multiple b-jets

Run-1 Limit (8TeV):  
\[ \text{JHEP10(2014)024} \]  
\[ \text{m}(g^\sim) < 1350\text{GeV} \text{ @95\% C.L.} \]

Run-2 Limit (13TeV):  
\[ \text{ATLAS-CONF-2016-052} \]  
\[ \text{m}(g^\sim) < 1900\text{GeV} \text{ @95\% C.L.} \]

If Run-1 result is “scaled” to 13TeV collisions (that is, no IBL),

Simple scaling: \[ \sigma_{13\text{TeV}} \sim 8 \times \sigma_{8\text{TeV}} \]

Scaled Run-1 limit (no IBL) reaches:  
\[ \text{m}(g^\sim) = \sim 1600\text{GeV} \text{ @95\% C.L.} \]  
(without IBL)

Big impact on introducing IBL (Run-2):

\[ \text{m}(g^\sim) : 1900\text{GeV} \text{ v.s. } 1600\text{GeV} \text{ (%)} \]  
(plus analysis improvement)

(\%) this scaling is more or less consistent with \[ \text{ATL-PHYS-PUB-2015-005} \]
Search for Standard Model $t\bar{t}H \rightarrow b\bar{b}$

More complex situation:

$\rightarrow$ background also scales as same order of signal...

<table>
<thead>
<tr>
<th></th>
<th>$\sigma_{\text{exp}}$ [pb]</th>
<th>$\mu$</th>
<th>stat</th>
<th>syst</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Run-1 (8TeV)</strong> EPJC.75(2015)349</td>
<td>0.133</td>
<td>1.2</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Run-2 (13TeV)</strong> ATLAS-CONF-2016-080</td>
<td>0.507</td>
<td>1.6</td>
<td>0.5</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Cross section scaling, $\sim 2.5$

$\rightarrow$ Stat. error scales by $\sim 1.6$.

Same systematic uncertainty.

So far, impact on IBL is not visible, simply because of statistics dominant uncertainty.

... but will be more visible in future.
Search for long-lived SUSY using Pixel dE/dx

Heavy (new) particle may decay in (or outside) Pixel envelop.

**Run-1 Limit (8TeV):**

m(R-hadron) < 1185GeV
@lifetime = 10ns

**Run-2 Limit (13TeV):**

m(R-hadron) < 1570GeV
@lifetime = 10ns

With IBL, signal yield increases by ~15%.

IBL helps dE/dx measurements

\[ \tilde{g} \rightarrow q\bar{q} \tilde{\chi}^0, \ m(\tilde{\chi}^0) = 100 \text{ GeV} \]
IBL/Pixel performance and MC simulation

Understanding Pixel:

IBL is a new detector:
- Validation (MC) is not completed yet...
- Prompt (~hour order) alignment correction.
- Study new charge collection model (Bichsel model).
- 3D sensor is also interesting subject.

Other Pixel detector:
- Continuous monitoring
- Run-dependent MC
- Radiation damage simulation

September.05.2016

Poster, JIMENEZ PENA, Javier
Summary

- The Pixel detector is the core of ATLAS detector.
- The Pixel detector is used not only just for tracking/vertexing but also object identification, pileup suppression.
- Now, ~65% physics analysis uses b-jet in their analyses.
- In some area (multiple-b-jet final state), significant improvement is seen by new Pixel detector, IBL (and improved analysis method).
- Need further improvement of the systematic uncertainty (direct connect to the object identification)

More ATLAS talks is coming for more detail aspect.
  - Track reconstruction in dense environment and dE/dx measurement.
  - Vertex reconstruction, future Pixel layout design for HL-LHC etc..