Z→ee Pythia studies in athena

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Outline

- Modern tools for HO calculations
- Pythia+Photos in athena
- Why Pythia output isn't LO
- Pseudo-HO effects in Pythia+Photos
  - ISR
  - Primordial k_T
  - Parton Shower
  - FSR
- LO $\longrightarrow$ NLO K-factors
- Acceptances with cuts
- Conclusions

Tools for HO calculations

Several tools now exist that allow accurate computation of cross sections in p-p collisions. Some examples:

- MCFM – NLO calculations with spin correlations
- MadGraph/MadEvent – LO calculations for (almost) arbitrary processes
- FEWZ – Fully Exclusive W,Z production (NNLO QCD)
- Horace – specialised program for O(α) electroweak corrections to W and Z production

These have been extensively tested and cross-normalised here at Liverpool

See T. Kluge's talk from January for more on this:
http://indico.cern.ch/getFile.py/access?contribId=5&resId=0&materialId=slides&confId=25354

Cross sections from HO tools

Many factors affect the cross section predictions from these tools

- HO settings
- PDF choice
- Kinematic selection
- Electroweak parameterisation

With consistent settings, the different tools agree. An example benchmark (LO cross section):

MCFM: 1713.3 ± 1.7 pb
FEWZ: 1712.3 ± 1.4 pb
Madgraph: 1713.9 ± 1.4 pb

pdf: CTEQ6L1
$M_Z > 60$ GeV only $G_F = 1.17\times10^{-5}$
$\alpha(Q^2{=}M_Z) = 1/132.5$ $\sin^2(\theta_W) = 0.2222$
$M_Z = 91.188$ GeV $\Gamma_Z = 2.49$ GeV
$M_W = 80.419$ GeV $\Gamma_W = 2.06$ GeV
Factorisation scale = Renormalisation scale = M_Z

So why bother with Pythia?

The motivation for looking at Pythia here is largely practical: Several large MC samples are generated with Pythia+Photos

- (SM): Minbias, QCD Dijets, Photon+Jet, W/Z, Drell-Yan, ...
- Most SM detector-level studies implicitly depend on Pythia's assumptions

But Pythia calculates Leading Order cross sections

- So NLO Result = Pythia * (NLO/LO) ??
- No!
- Pythia (+Photos) already emulate some aspects of higher-order behaviour
  - Subject of this talk

Running Pythia in athena

Official evgen “job transform” was designed to handle large-scale event generation. It's actually quite simple to use:

csc_evgen_trf.py	Job transform script
–test	Removes event number restriction
005144	Sample number
0	First event #
20000	Number of events
23040	Random seed
CSC.005144.PythiaZee.py	Job options file
005144.evgen.0.pool.root	Output POOL file
005144.histo.0.root	Output histogram file
005144.ntuple.0.root	Output ntuple file

20k events take 30 mins (LO) to 1h50 (ATLAS default) on Liverpool's 800 MHz batch nodes

Running Pythia in athena

```
#################################################################
#
# Job options file
# Everything I can find turned off - is it overkill?
# 27 Mar 08
# lepton filter removed
#
#================================================================

# ... Main generator : Pythia
from AthenaCommon.AlgSequence import AlgSequence
topAlg = AlgSequence("TopAlg")

from Pythia_i.Pythia_iConf import Pythia
topAlg += Pythia()

#----------------------------------------------------------------
# Algorithms Private Options
#----------------------------------------------------------------
Pythia = topAlg.Pythia
Pythia.PythiaCommand = [ "pysubs msel 0",          # Users decay choice.
                         "pydat1 parj 90 20000", # Turn off FSR.
#                         "pydat3 mdcy 15 1 0",     # Turn off tau decays.
#
                         "pypars mstp 81 20",      # Turns off multiple interactions
                         "pydat1 mstj 41 0",       # Turn off Parton Shower
                         "pypars mstp 61 0",       # Turn off ISR
                         "pypars mstp 91 0",       # Turn off primordial kT
                         "pypars mstp 71 0",       # Turn off FSR completely
                         "pypars mstp 111 0",      # Turn off hadronisation
# Z production:
                         "pysubs msub 1 1",        # Create Z bosons.
                         "pysubs ckin 1 60.0",     # Lower invariant mass.
                         "pydat3 mdme 174 1 0",
                         "pydat3 mdme 175 1 0",
                         "pydat3 mdme 176 1 0",
                         "pydat3 mdme 177 1 0",
                         "pydat3 mdme 178 1 0",
                         "pydat3 mdme 179 1 0",
                         "pydat3 mdme 182 1 1",    # Switch for Z->ee.
                         "pydat3 mdme 183 1 0",
                         "pydat3 mdme 184 1 0",    # Switch for Z->mumu.
                         "pydat3 mdme 185 1 0",
                         "pydat3 mdme 186 1 0",    # Switch for Z->tautau.
                         "pydat3 mdme 187 1 0"]

# ... Tauola
include ( "EvgenJobOptions/CSC_Tauola_Fragment.py" )

# ... Photos
#include ( "EvgenJobOptions/CSC_Photos_Fragment.py" )
```

Top-level AlgSequence

Pythia added to AlgSequence

Pythia configuration

Additional Tauola/Photos programs

Job options based on Z→ee sample 5144 (in release)

evgen → AOD conversion

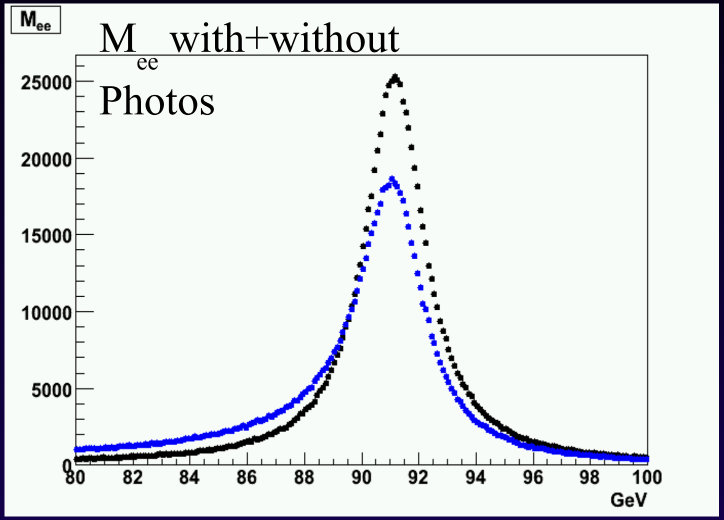
Custom AOD analysis algorithm

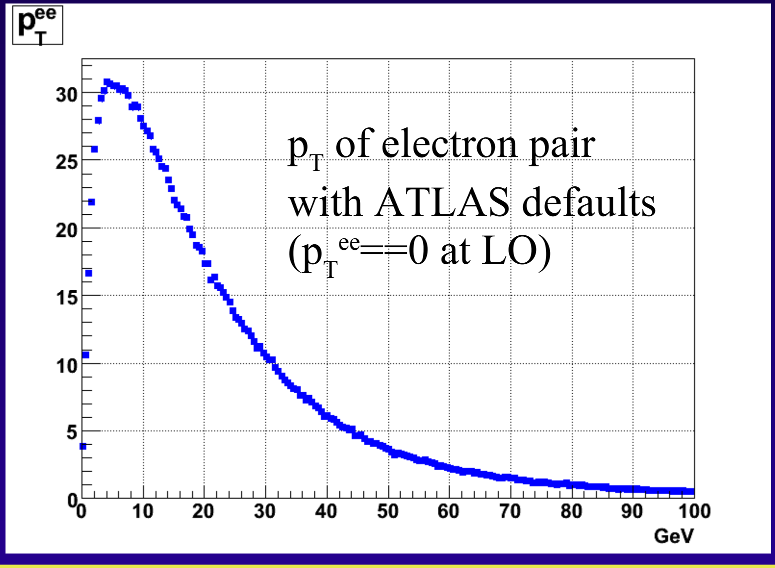
```
#----------------------------------------------------------------
# AOD production
#----------------------------------------------------------------

#import AthenaPoolCnvSvc.ReadAthenaPool
#include( "AthenaPoolCnvSvc/ReadAthenaPool_jobOptions.py" )
from McParticleAlgs.JobOptCfg import McAodBuilder
from McParticleTools.McParticleToolsConf import NoopFilterTool
from McParticleTools.McParticleToolsConf import TruthParticleCnvTool
topAlg += McAodBuilder(
    "McAodBuilder",
    OutputLevel = WARNING,
    FilterTool = NoopFilterTool(
    McEvents = "GEN_EVENT",
    DoEtIsolations = True
    ),
    CnvTool = TruthParticleCnvTool(
    McEvents = "GEN_AOD",
    TruthParticlesOutput = "SpclMC",
    DoEtIsolations = True
    )
    )
include( "ParticleBuilderOptions/McAOD_PoolCnv_jobOptions.py")

from AthenaPoolCnvSvc.WriteAthenaPool import AthenaPoolOutputStream
outStream = AthenaPoolOutputStream("Stream1")
outStream.ItemList  = [ "EventInfo#McEventInfo" ]
outStream.ItemList += [ "McEventCollection#GEN_EVENT" ]
outStream.ItemList += [ "McEventCollection#GEN_AOD" ]
outStream.ItemList += [ "TruthParticleContainer#SpclMC" ]
outStream.ItemList += [ "TruthEtIsolationsContainer#TruthEtIsol_GEN_EVENT" ]

outStream.OutputFile = "AOD.pool.root"
outStream.ForceRead  = True  #force read of output data objs

#### ElectronParameters algorithm
from MJFcode.MJFcodeConf import TruthZ
topAlg += TruthZ()

#### Configure the algorithms
truth = topAlg.TruthZ
truth.OutputLevel     = WARNING
truth.ElectronETCut   = 10*GeV
truth.ElectronMaxEta  = 2.7
truth.LowerZMassCut   = 60*GeV

truth.ResummationDR  = [0.05,0.1,0.2]

#----------------------------------------------------------------
# Configuration for EvgenJobTransforms
#----------------------------------------------------------------
from EvgenJobOptions.PythiaEvgenConfig import evgenConfig
#evgenConfig.efficiency = 0.75
evgenConfig.efficiency = 1.00

from AthenaCommon.AppMgr import ServiceMgr
ServiceMgr.OutputLevel = ERROR
```

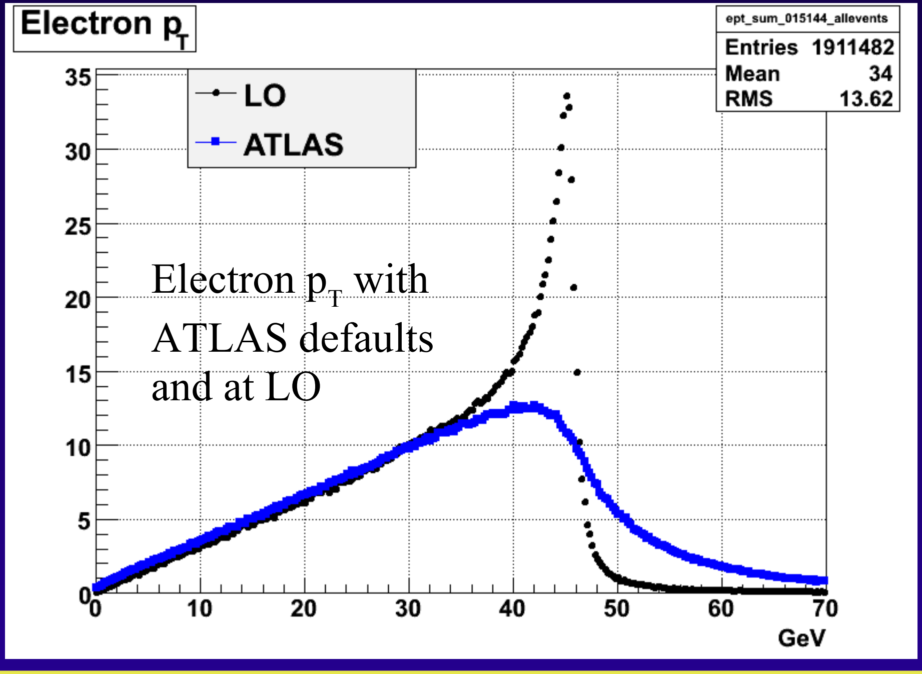
Comparison: LO vs ATLAS default

Pythia+Photos in athena by default looks very different from LO:

- M_{ee} is shifted from M_Z by Photos
- The Z is more central than in LO, and has non-zero p_T (from TeVatron results)
- The large peak in p_T^e at $M_Z/2$ (LO) is absent in ATLAS production







Discovering LO Pythia

Solution lies in all the other things that are in Pythia itself:

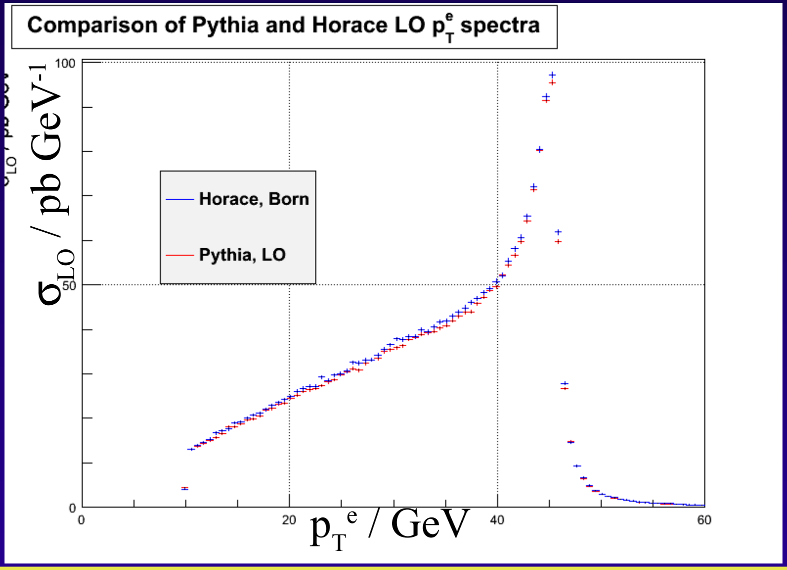
- Parametrised ISR/FSR
- Parton Shower (ie non-perturbative QCD)
- Multiple Interactions
- "Primordial" k_T of the incident partons

So, whatever the default Pythia is, it is not "Leading Order" in the Horace sense!

- Thanks to Marc Goulette for help in finding all these!

Side note: from now on, the MC filter has been removed

- 1 lepton with $p_T > 10$ GeV and $|\eta| < 2.7$ ($\varepsilon = 85.5\%$)



Comparing LO calculations

To fully integrate Pythia predictions with those of HO tools, we'd like to compare the total LO cross section too

- σ_{tot} is independent of all the pseudo-HO effects
- Large dependence on EW parameters
  - M_Z , Γ_Z , M_W , Γ_W , $\sin^2(\theta_W)$, $\alpha(Q^2)$, M_t , G_F, ...
  - and which are independent?
- Ongoing study to align Pythia with the HO tools

MCFM, MadEvent, FEWZ concordance:	1713(1) pb
Pythia, ATLAS defaults:	1680(1) pb
Pythia, new EW values and EW scheme 0:	1809(1) pb
Pythia, new EW values and EW scheme 1:	1700(1) pb
Pythia, new EW values and EW scheme 2:	1698(1) pb

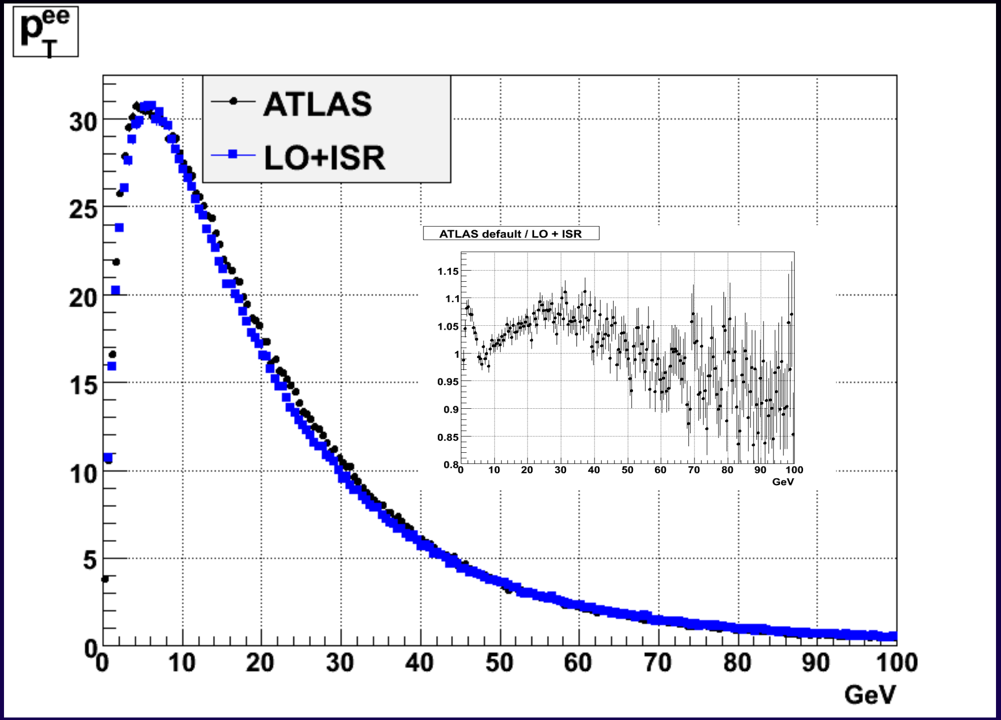
QCD effects: ISR

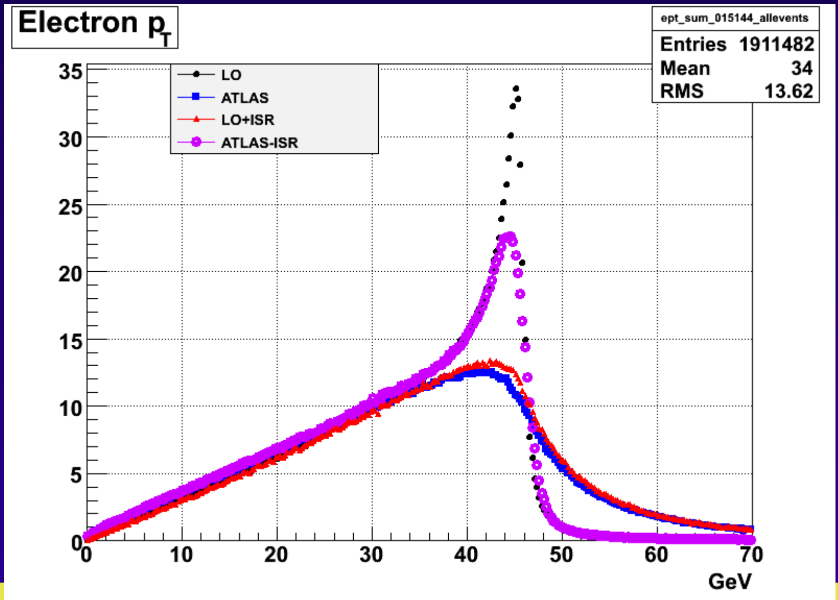
ISR is the radiation of partons in the initial state. By default, both QCD and QED radiation is accounted for in Pythia.

The main effect is to impart p_T to the boson (right), which has knock-on effects on several distributions.

- The resulting bosons and leptons are more central
- The peak in the LO p_T^e distribution is washed out

Despite the size of these effects, there is clearly something else too...



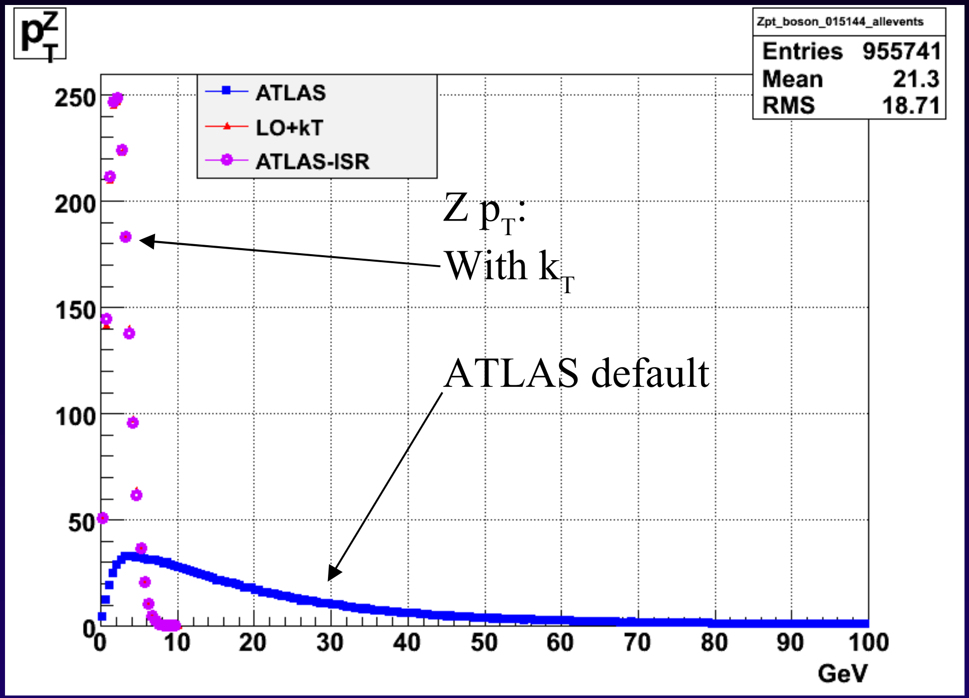


QCD effects: k_T

Pythia parameterises the "primordial" k_T of the incoming partons as Gaussian

This contributes ~2-3 GeV to the boson pT, appearing to be the sub-dominant contribution here

- Test (to do): What does p_T^Z look like for LO+ISR+k_T?

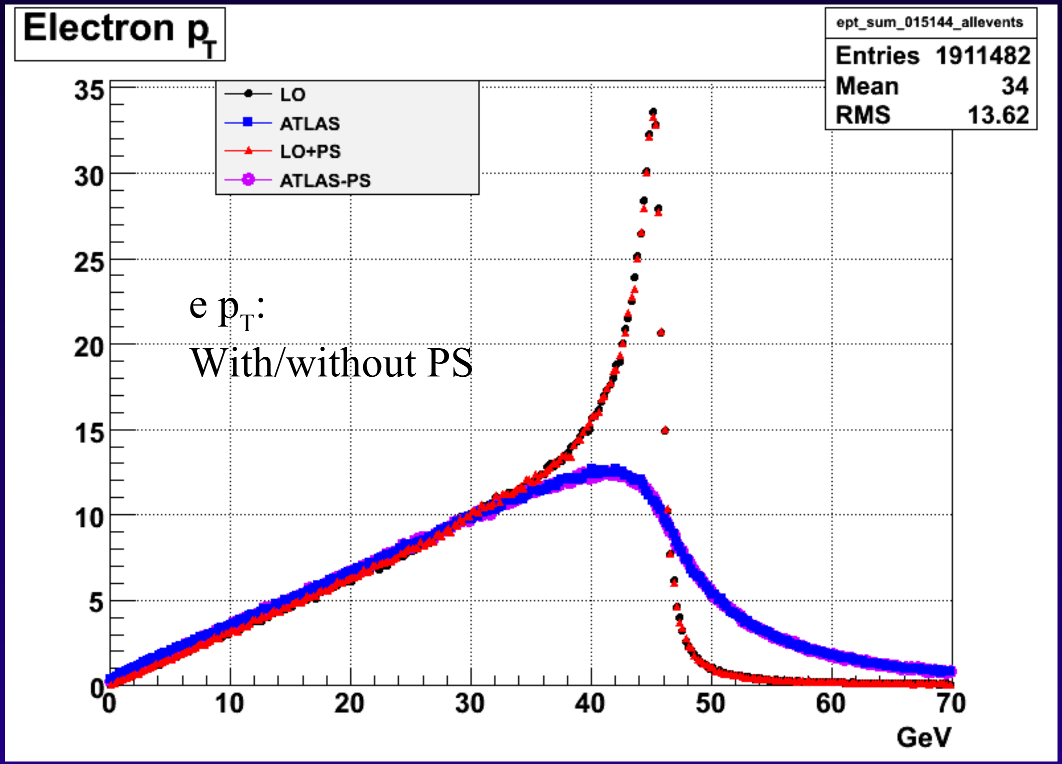


QCD effects: Parton Shower

Parton Shower has negligible effect

- K-factors are 1 within stat. errors

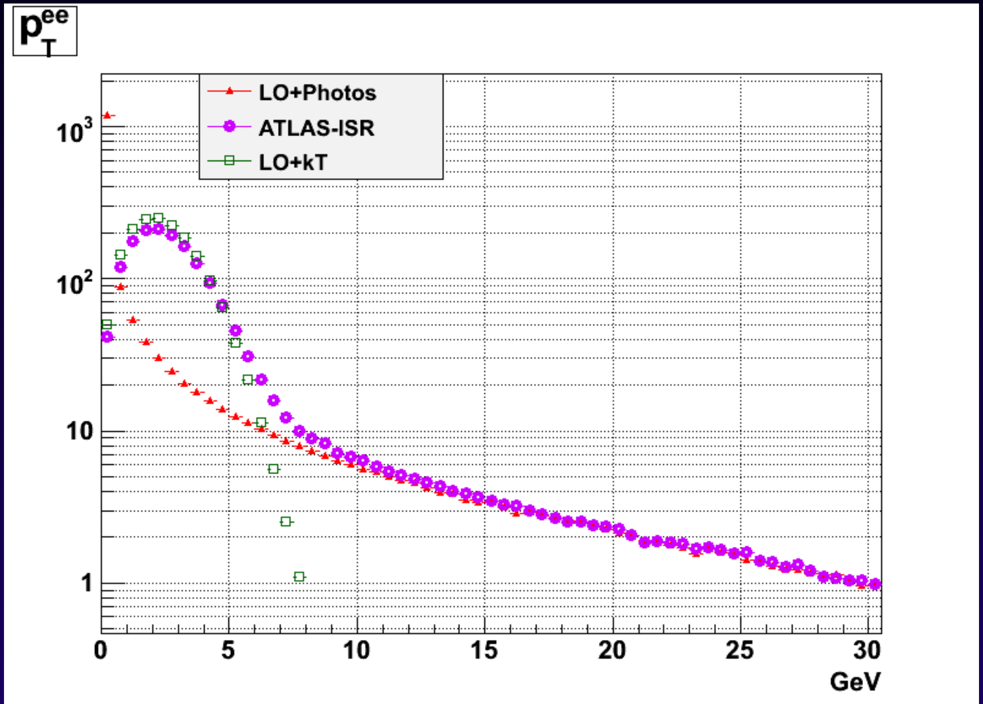
What's left? FSR...



QED effects: FSR

In ATLAS MC, QED FSR is managed by Photos, not Pythia

- For leptonic final states, QCD FSR expected to have a tiny residual effect



We've already seen its effect on M_{ee}

- Together with ISR and primordial k_T, QED FSR also contributes significantly to p_T^{ee} (note: not p_T^Z)

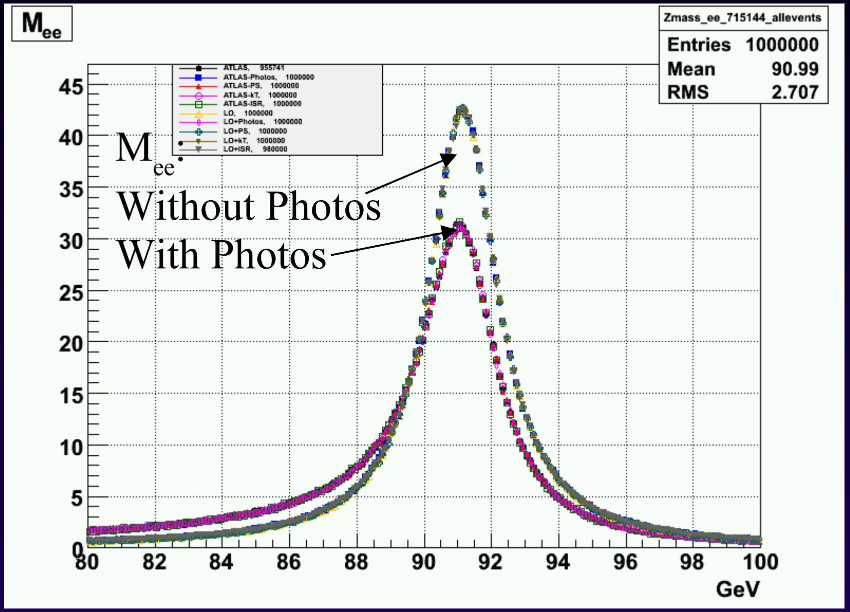
Defining LO → NLO K-factors

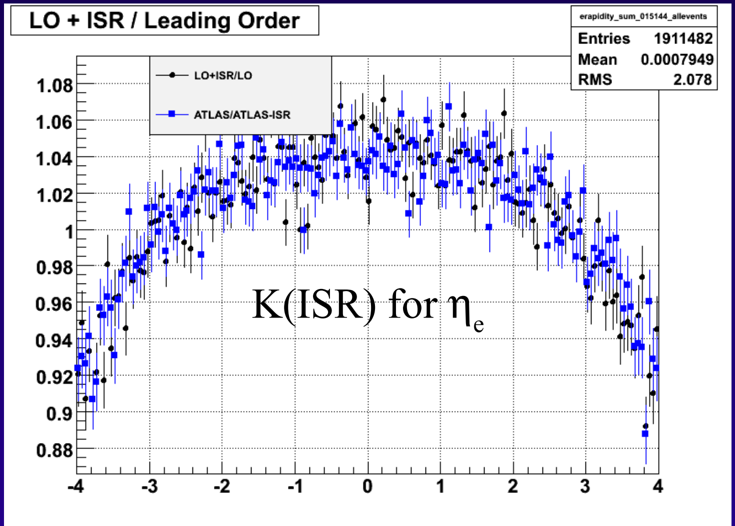
A final goal of this study is to enable K factors calculated for (N)NLO to be used with the Pythia MC production. As this is not LO, can this be done consistently?

One solution: Find distributions where one factor dominates, or are otherwise “simple”, ie

$$\frac{ATLAS}{ATLAS-X}=\frac{LO+X}{LO}$$

In these cases, K-factors from LO can be used



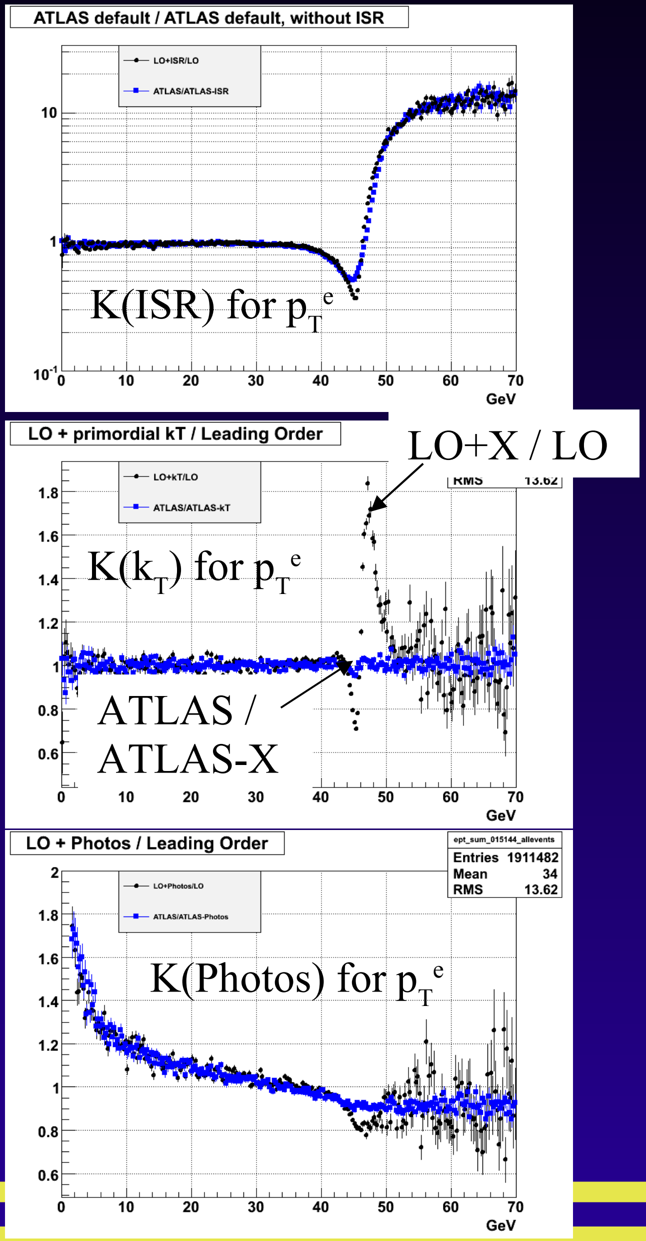


Defining LO → NLO K-factors

Some distributions are simply too quickly changing at LO to do this. Most notably:

- p_T^Z (=0 at LO)
  - Need to correct using ResBos anyway
- p_T^e (spike at $M_Z/2$)
  - K-factors from LO and from ATLAS defaults show large differences (left)

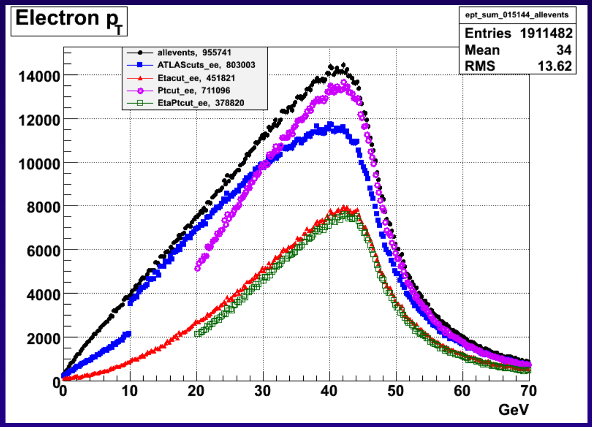
In these cases, we will probably have to relate the HO tool predictions directly to Pythia, "bypassing" LO



Acceptances with kinematic cuts

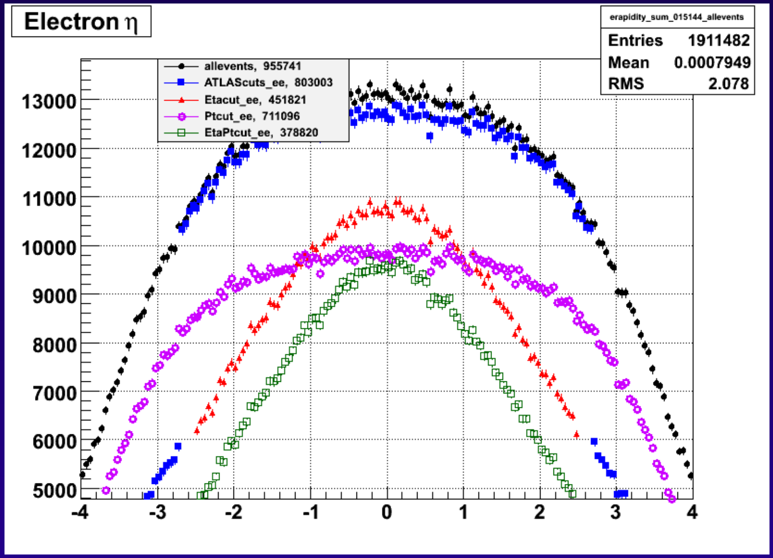
Most plots so far show "inclusive" distributions, ie without cuts
Acceptance factors with realistic cuts need not be flat or independent of the physics considered
Some benchmark cuts have been chosen:

- ATLAS filter: at least 1 e with $p_T > 10$ GeV, $|\eta| < 2.7$
- Eta cut: both e with $|\eta| < 2.5$
- Pt cut: both e with $p_T > 20$ GeV
- Pt&Eta cut: Simply Pt cut ∩ Eta cut



Electron p_T (ATLAS)

Electron η (LO)



"Global" Acceptances

Generator settings	ATLAS filter	Eta cut	pT cut	Eta&pT cuts
Leading Order	82.12%	44.43%	85.20%	42.11%
LO + Photos	81.57%	44.55%	80.31%	40.10%
LO + Parton Shower	82.13%	44.52%	85.20%	42.18%
LO + primodial kT	82.24%	44.52%	84.06%	41.82%
LO + ISR	84.59%	47.26%	78.60%	41.72%
ATLAS default	84.02%	47.27%	74.40%	39.64%
ATLAS - Photos	84.56%	47.34%	78.62%	41.73%
ATLAS - PS	84.08%	47.28%	74.42%	39.71%
ATLAS - primordial kT	84.02%	47.29%	74.44%	39.69%
ATLAS - ISR	81.66%	44.60%	79.37%	39.81%

$|\eta|<2.5$ (Eta cut) $p_T>20GeV$ (pT cut)

ISR and Photos have the greatest impact on *A*, up to ~5%

- Checks done "from both ends" (LO and ATLAS defaults)
- Correlations (eg between p_T and η cuts) as yet uninvestigated

Typical uncertainty ~0.05%

Conclusions and future plans

Understanding Pythia and its physics content is essential for relating ATLAS simulation to more up-to-date theoretical models

- Pythia + Photos is not just LO!
- Some of the work of HO corrections seems to already be done (Photos vs Horace?)
- Other distributions (p_T^Z?) will be difficult to match to NLO, NNLO calculations

To avoid (near-)singularities, we hope to use (N)NLO/{Pythia+Photos} to form effective K-factors

Some cross-checks (eg overall normalisation, sensitivity to event selection) are yet to be completed