SEARCH FOR DILEPTON RESONANCES WITH ATLAS

IOP HEPP & APP MEETING 2013

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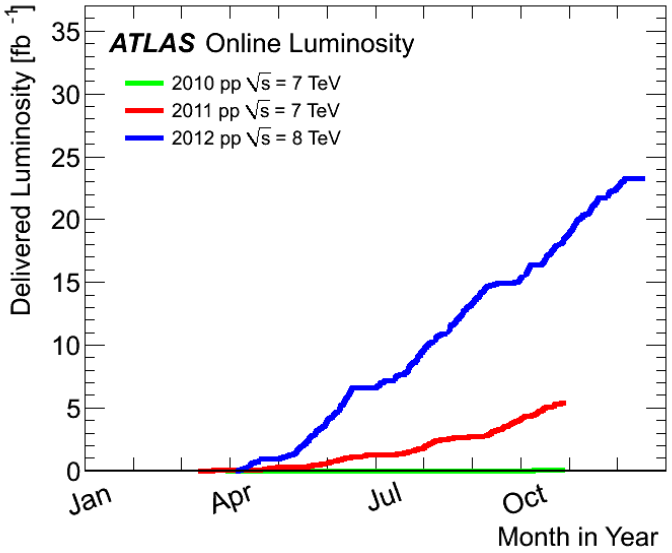
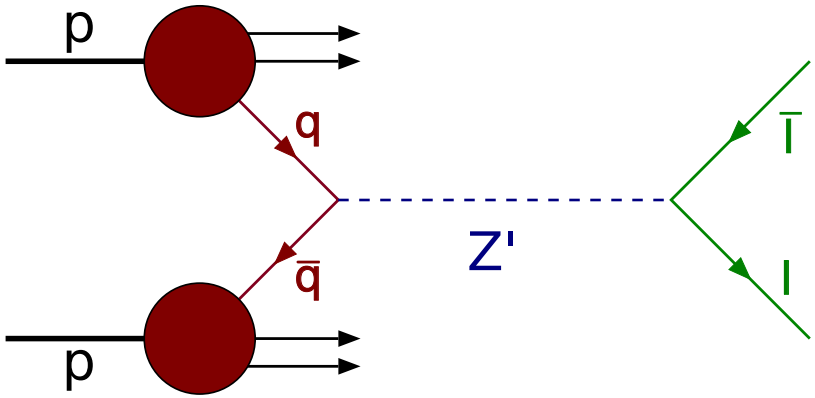
Motivation for Search

- LHC with 7/8 TeV centre-of-mass energy is a discovery machine: unprecedented c.o.m. energy & luminosity
- Extensions to standard model predict new heavy TeV-scale resonances decaying into two leptons, e.g.:
  - Extra dimensions
  - E6 GUTs
- Benchmark model here: Z'_{SSM} (sequential standard model)





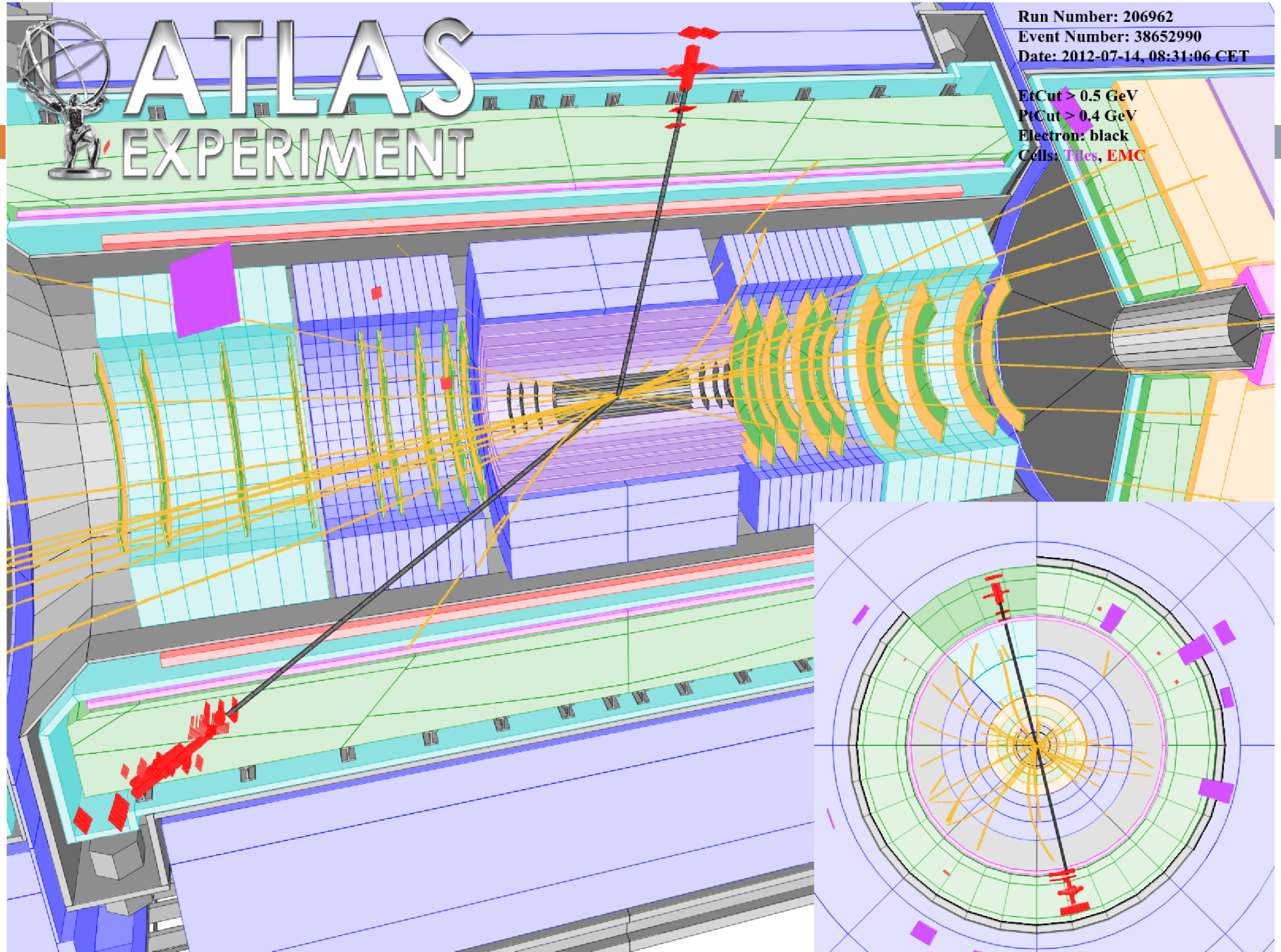
Overview

- Search with 2011 data (4.9 fb^{-1} at $\sqrt{s} = 7$ TeV) established limits on Z'_{SSM} mass at:
  - Di-electron: 2.07 TeV
  - Di-electron & di-muon: 2.22 TeV
  - Paper: *Search for high-mass resonances decaying to dilepton final states in pp collisions at a center-of-mass energy of 7 TeV with the ATLAS detector* (arXiv:1209.2535 [hep-ex])
- Follow-up standard model mass-differential cross-section measurement with 2011 data from 116 – 1500 GeV:
  - Established cross-checks and methods
  - Worked on electron channel
  - Conference note: *Measurement of the high-mass Drell-Yan differential cross-section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector* (http://cds.cern.ch/record/1493623)

Overview

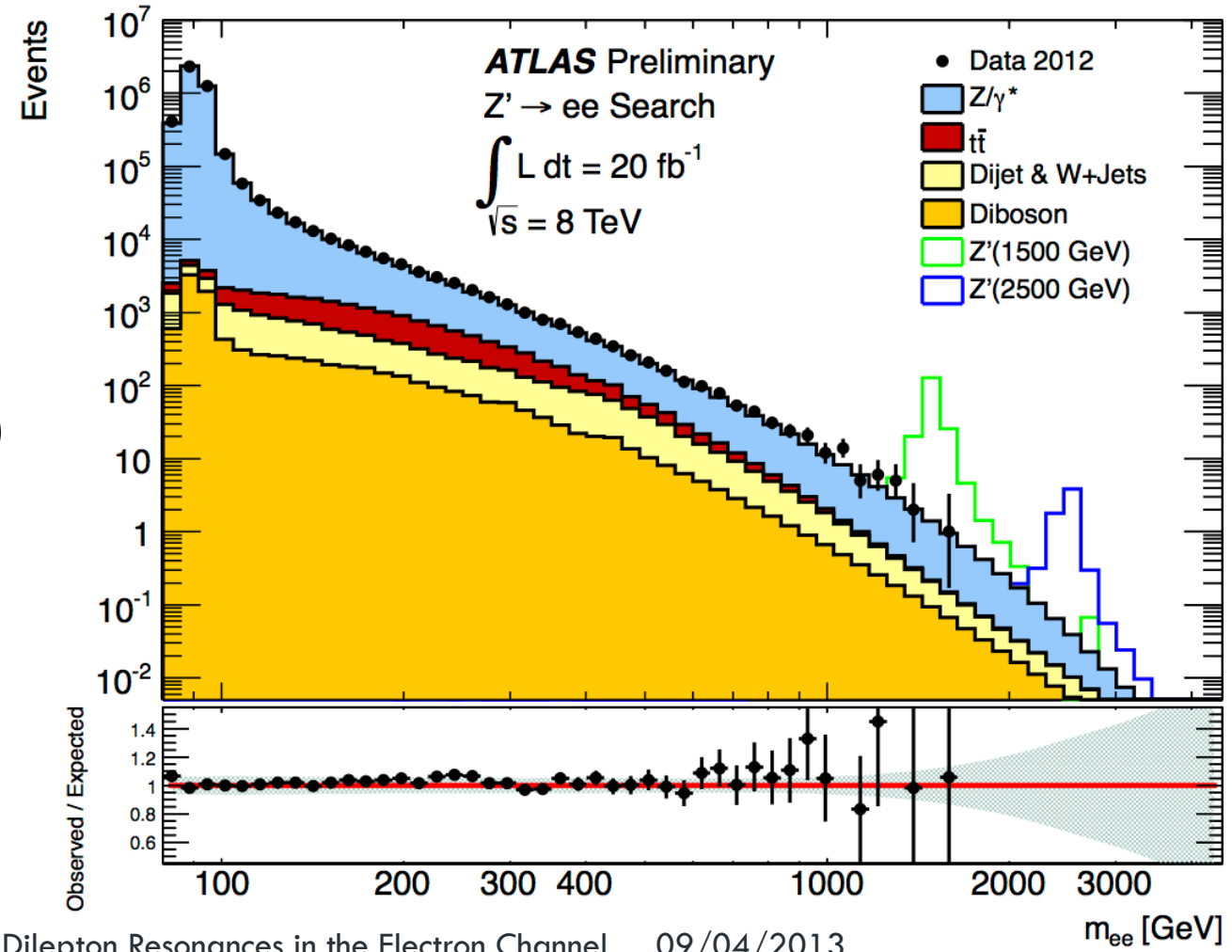
- Talk focuses on 2012 analysis with full data set (20 fb^{-1}) at $\sqrt{s} = 8$ TeV:
  - Search variable: Invariant mass of lepton pair, m_{ll}
  - Range: 120 – 4500 GeV
  - Focus on electron channel
  - Conference note: *Search for high-mass dilepton resonances in 20/fb of pp collisions at $\sqrt{s} = 8$ TeV with the ATLAS experiment* (http://cds.cern.ch/record/1525524)

Di-electron event, invariant mass = 1541 GeV



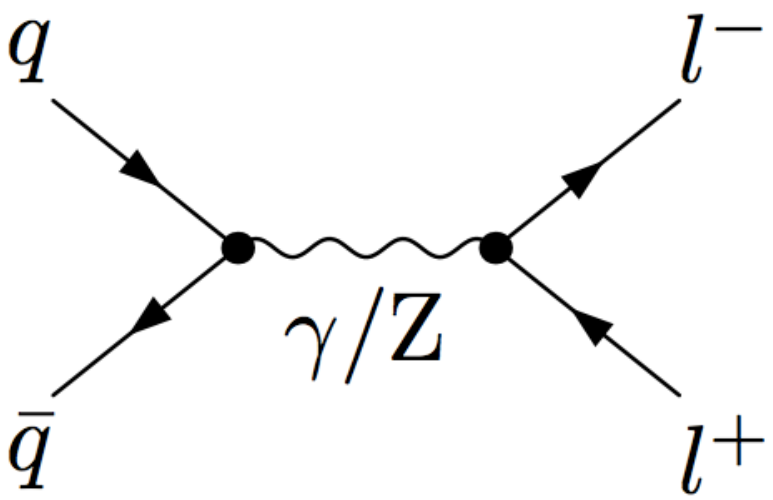
Data vs. Monte Carlo Comparison

- m_{ee} spectrum for 2012 data set
- SM backgrounds:
  - Drell-Yan (Powheg +Pythia 8)
  - Dileptonic top pair decays (MC@NLO)
  - Dijet + W+jets (data-driven)
  - Diboson (Herwig)
- Example signal shapes for Z'_{SSM}



Neutral Current Drell-Yan Background

- Largest SM background: Neutral current Drell-Yan production
- Should reflect current knowledge as accurately as possible



Monte Carlo:

QCD at next-to-leading order

EW at leading order

Theory:

QCD at next-to-next-to-leading order

EW at next-to-leading order

k-factor: General Method

- Mass-dependent k-factor to correct MC to latest theory knowledge
- Applicable to electrons & muons
- External calculations provides theory cross-sections
  - FEWZ 3.1b2[1]: QCD NNLO & EW NLO
  - MadGraph[2], Baur[3]: Real W/Z radiation
  - FEWZ[1]/SANC[4]: Photon-induced (PI) processes
- Complete k-factor for Drell-Yan:

$$k_{HO} = (\sigma_{FEWZ(QCD+EW)} / \sigma_{MC}) \times k_{W/Z} \times k_{PI}$$

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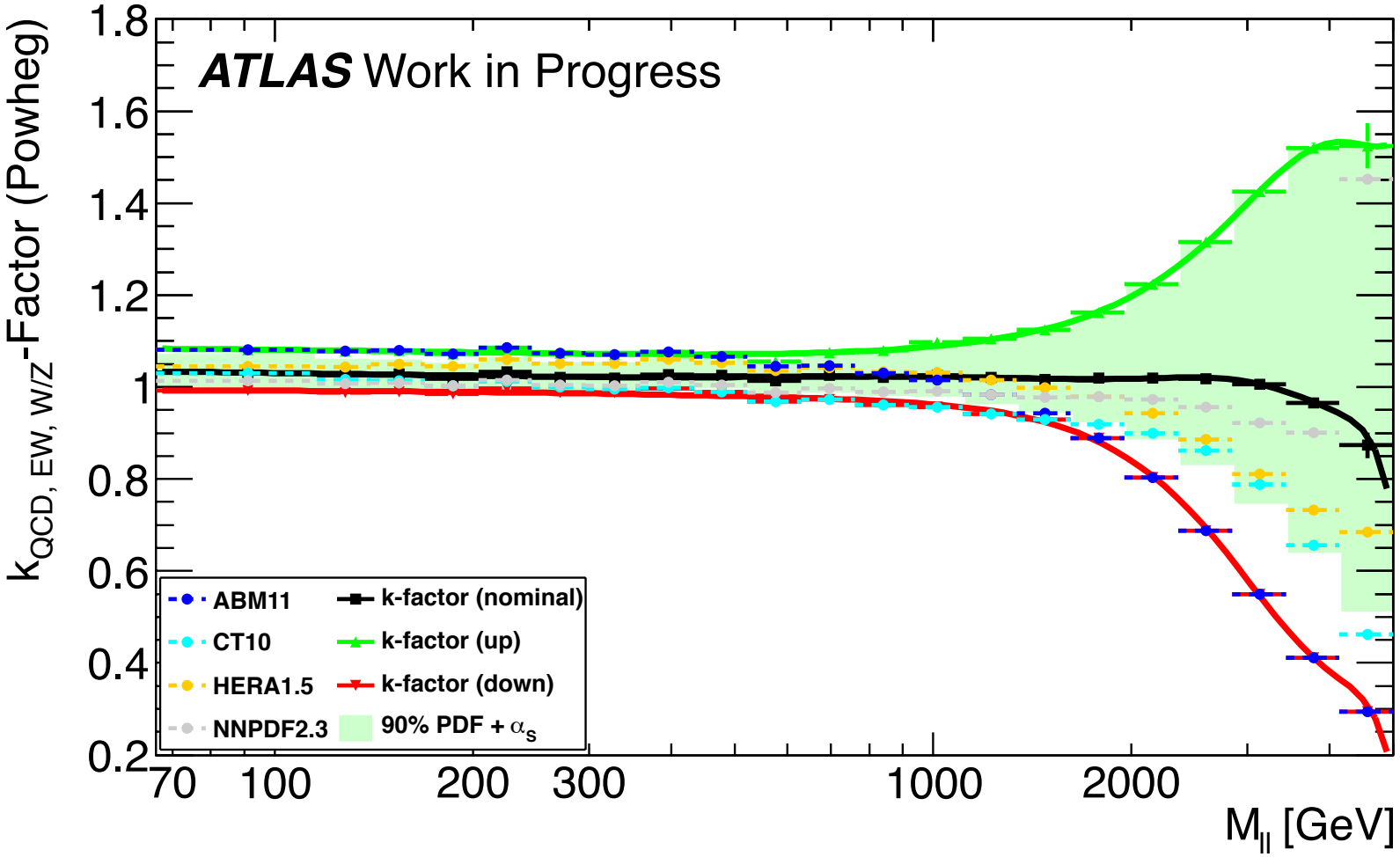
k-factor: Systematics

- Nominal PDF used: MSTWnnlo
- In addition, include theory systematics into k-factor:
  - PDF + α_s uncertainty (90% C.L.) for nominal PDF
  - PDF choice w.r.t nominal choice
- Systematics incorporated into uncertainty envelope
- PDF + α_s uncertainty calculated through FEWZ
- Additional uncertainty from higher-order EW:
  - ~1% up to 1000 GeV, <10% at 5000 GeV
  - Not shown in plots here

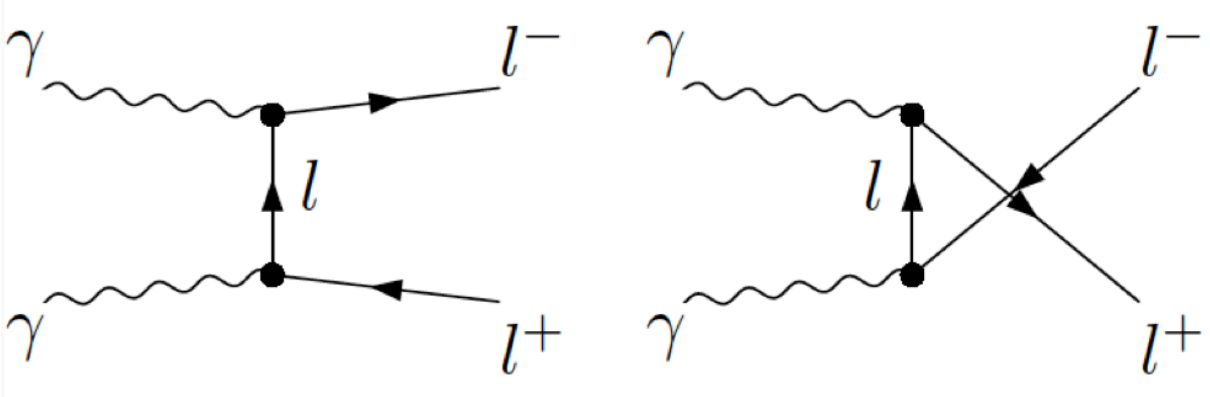
k-factor: Systematics

- Systematics due to PDF choice can be CPU-efficiently using VRAP[5]:
  - VRAP calculates cross-sections at certain mass points using $\alpha_S = 0.117$ of nominal PDF
  - Ratio of $\sigma_{\text{VRAP, alternative PDF}} / \sigma_{\text{VRAP, nominal PDF}}$ fitted over mass range & integrated over bin
  - Factor applied to FEWZ prediction to get cross-section of other PDF choices
  - Same procedure used as cross-check for α_S uncertainty (compared to FEWZ result)

k-factor: QCD & EW & Real W/Z

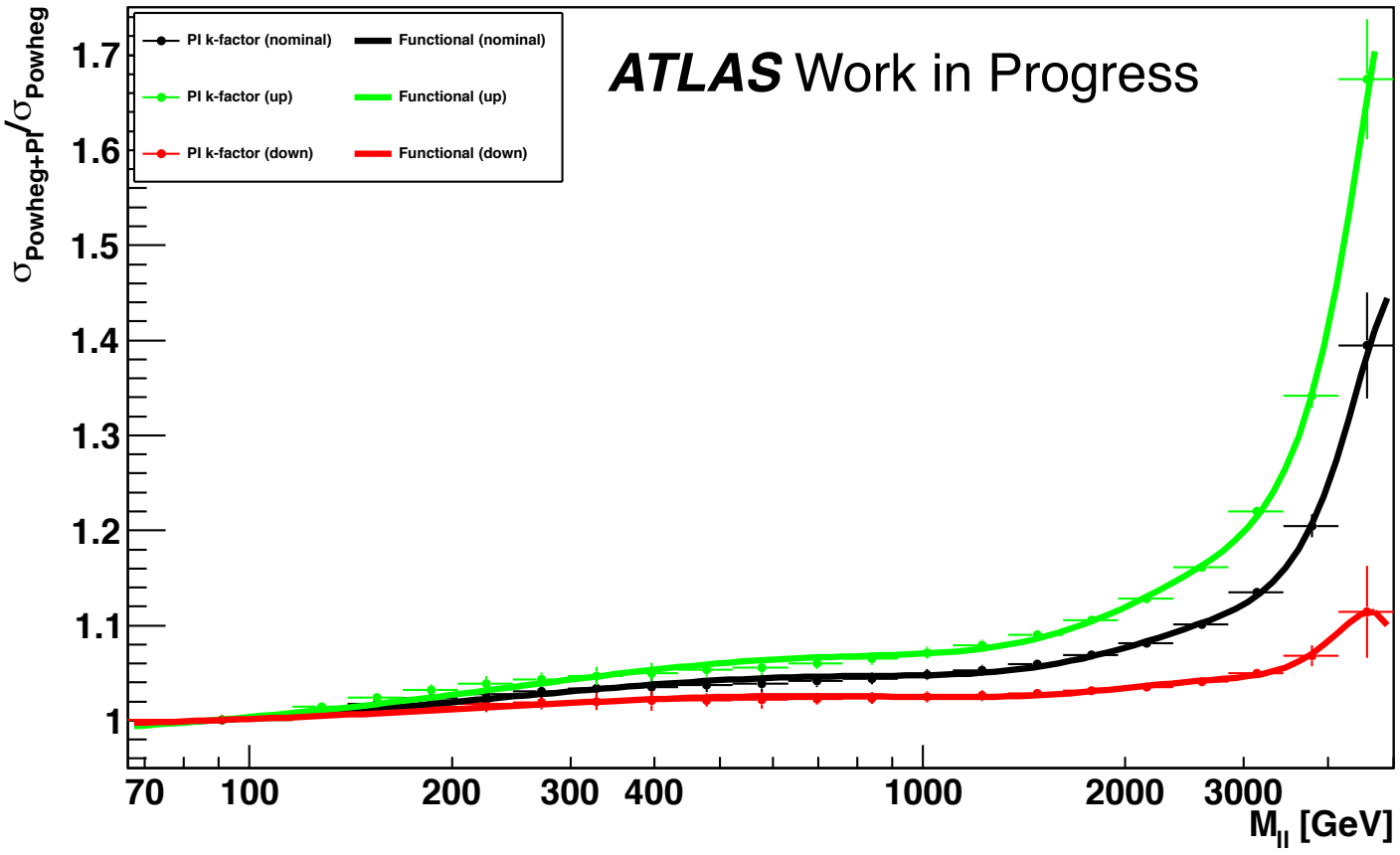


k-factor: Photon-induced Contribution



- On top of Z/γ*, additional process: non-resonant di-lepton production
- Additional process – hence, cross-section of PI purely additive!
- Calculated with MRST2004QED PDF in fiducial region ($|\eta_l| < 2.5$, $p_t^l > 25$ GeV)

k-factor: Photon-induced Contribution



- $k_{QCD,\ EW,\ W/Z}$-factor applied to MC with fiducial cuts
- Determine & fit additional k_{PI}-factor
- PI contribution significant at high masses

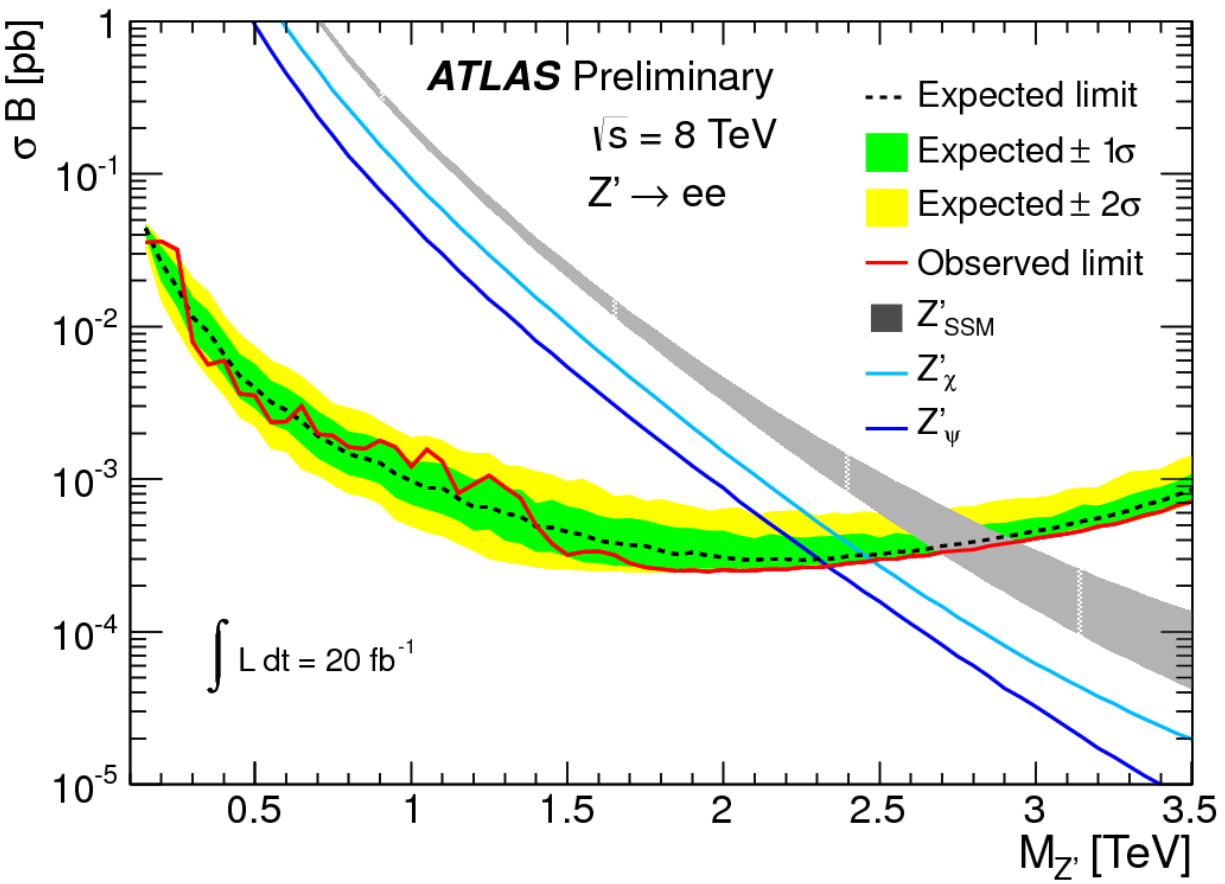
k-factor: Application

- All fits & envelopes are described via a set of C functions (usable in ROOT)

- These functions…
  - Take the invariant mass of boson (Born-level)
  - Produce an event weight that is applied to the event

Analysis Result: Exclusion Limit

- Exclusion at 95% C.L (Bayesian approach using BAT)
- Limit produced as σ B
- Limits (e^+e^-):
  - Observed: 2.79 TeV
  - Expected: 2.76 TeV
- Limits (e^+e^- & $\mu^+\mu^-$):
  - Observed: 2.86 TeV
  - Expected: 2.85 TeV



Summary

- Involvement in implementing k-factors for Drell-Yan background to take QCD NNLO, EW NLO, real W/Z and PI corrections into account
- k-factor includes set of systematic theory uncertainties
- 2012 data excludes Z'_{SSM}-like di-electron resonances up to 2.79 TeV (di-electron & di-muon up to 2.86 TeV)

Backup Slides

Citations

- [1] Y. Li and F. Petriello, *Combining QCD and electroweak corrections to dilepton production in FEWZ*, Phys. Rev. **D86** (2012) 094034.
- [2] J. Alwall et al., *MadGraph 5: Going Beyond,* JHEP **128** (2011) 1106.
- [3] U. Baur, *Weak Boson Emission in Hadron Collider Processes,* Phys. Rev. **D75** (2007) 013005, arXiv:hep-ph/0611241.
- [4] D. Bardin, S. Bondarenko, P. Christova, L. Kalinovskaya, L. Rumyantsev, et al., *SANC integrator in the progress: QCD and EW contributions,* JETP Lett. **96** (2012) 285–289, arXiv:1207.4400 [hep-ph].
- [5] C. Anastasiou, L. Dixon, K. Melnikov, F. Petriello, *High-precision QCD at hadron colliders: electroweak gauge boson rapidity distributions at NNLO*, Phys. Rev. **D69** (2004) 094008, arXiv:hep-ph/0312266.

Event Selection & Backgrounds

Electron Event Selection

- Di-photon trigger
- Standard data quality cuts
- Fiducial cuts

  ($|\eta_e| < 2.47$, excluding calorimeter crack region $1.37 < |\eta_e| < 1.52$)
- Transverse momentum

  ($p_{t,\,leading} > 40$ GeV, $p_{t,\,subleading} > 30$ GeV)
- "Medium++" identification criterion
- Electron isolation

  E_t in $\Delta R < 0.1$ cone, mass-dependent

Standard Model Backgrounds

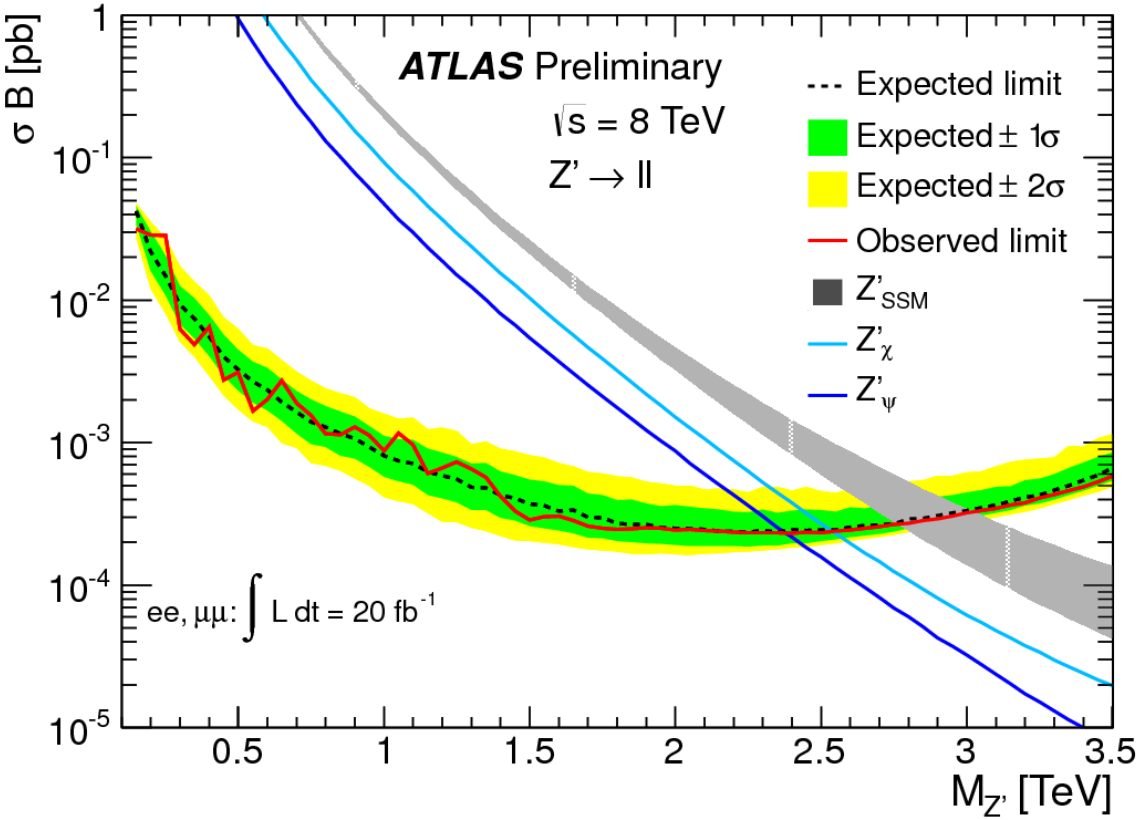
- Drell-Yan: Powheg+PYTHIA 8 (CT10)
- Dileptonic top pairs: MC@NLO (CT10)
- Dijet & W+jets: Data-driven
- Diboson: Herwig (CTEQ 6L1)

Signal Sample

- Z'_{SSM} template: PYTHIA 8

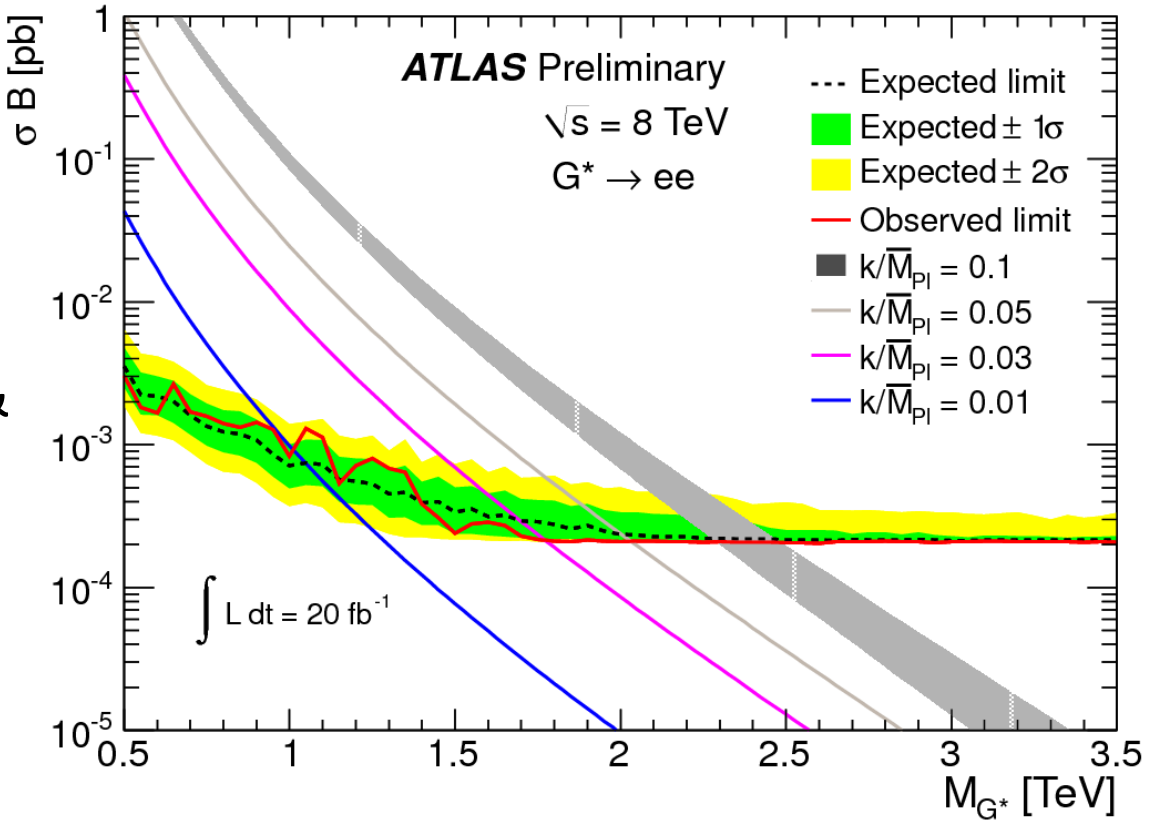
Z'_{SSM} Limit (di-lepton plot)

- Z'_{SSM} limit (e^+e^-):
  - Expected: 2.79 GeV
  - Observed: 2.76 GeV
- Z'_{SSM} limit (e^+e^- & $\mu^+\mu^-$):
  - Expected: 2.86 GeV
  - Observed: 2.85 GeV



Graviton Limit (di-electron plot)

- Graviton limit (e^+e^-):
  - Expected: 2.40 GeV
  - Observed: 2.40 GeV
- Graviton limit (e^+e^- & $\mu^+\mu^-$):
  - Expected: 2.47 GeV
  - Observed: 2.47 GeV



Graviton Limit (di-lepton plot)

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