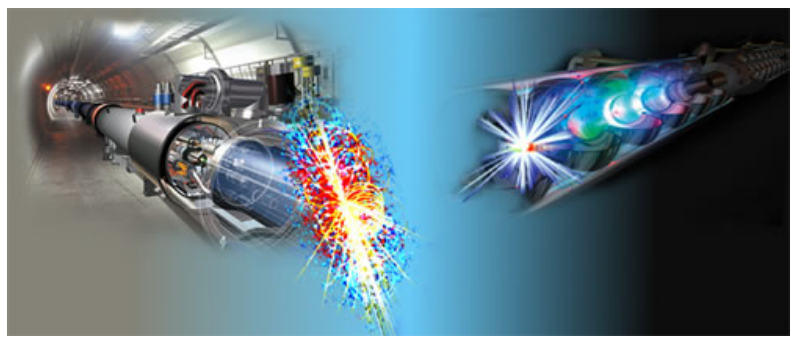
Leptonic Resonances and Multi Gauge Bosons, Theory

Doreen Wackeroth, *SUNY at Buffalo*

LHC Early Phase for the ILC
Fermilab, April 13, 2007

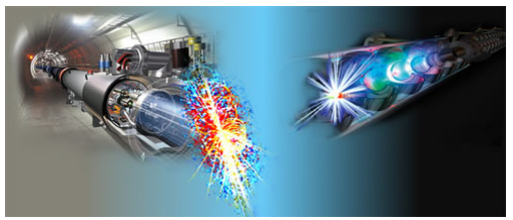


Resources

- ATLAS and CMS TDRs and Notes
  CDF Physics Results at www-cdf.fnal.gov/physics/physics.html
  D0 Physics Results at
  www-d0.fnal.gov/Run2Physics/WWW/results.htm
- TeV4LHC, LesHouches, LHC/ILC and HERALHC workshop reports:
  hep-ph/0608322, hep-ph/0602198, hep-ph/0410364,
  hep-ph/0601012

Many Thanks !

Please note: Experimental results have been chosen and are shown for illustration purposes only. For a detailed discussion please see the previous 2 talks in this session.



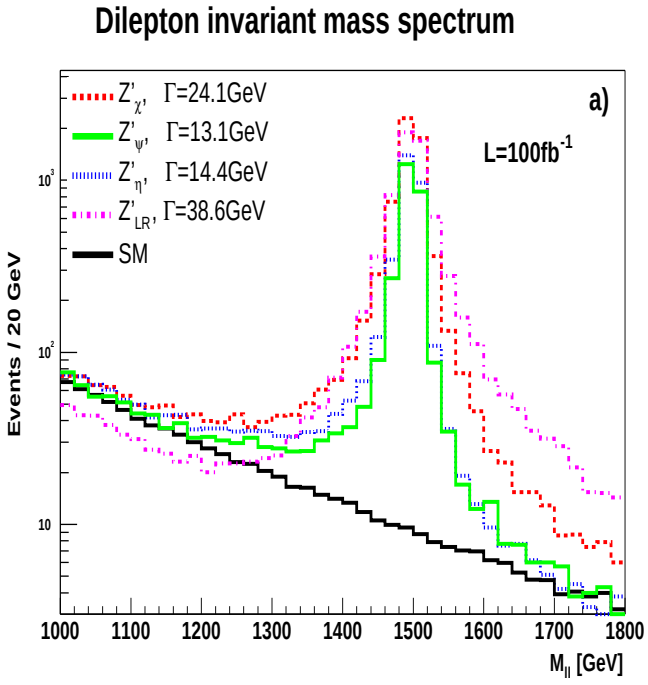
Resonances in Drell-Yan - one of the first physics results ?

And next: "Search for new high mass particles decaying to lepton pairs in pp collisions at $\sqrt{s} = 14$ TeV"

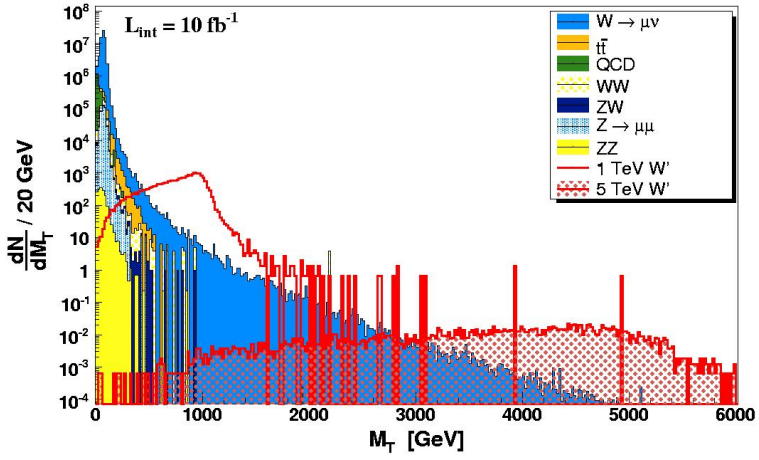
A search for new particles (X) that decay to electron or muon pairs has been performed using approximately 800 pb^{-1} of pp collision data at $\sqrt{s} = 14$ TeV collected by the CMS experiment at the LHC at CERN. Limits on $\sigma(pp \to X) \cdot BR(X \to \ell\ell)$ are presented as a function of dilepton invariant mass $m(\ell\ell) > 150$ GeV/c^2, for different spin hypotheses (0, 1, or 2). Lower mass bounds for X from representative models beyond the Standard Model including heavy neutral gauge bosons are presented.

Lassila-Perini, hep-ex/0605042

Extended gauge sector, Z', W'



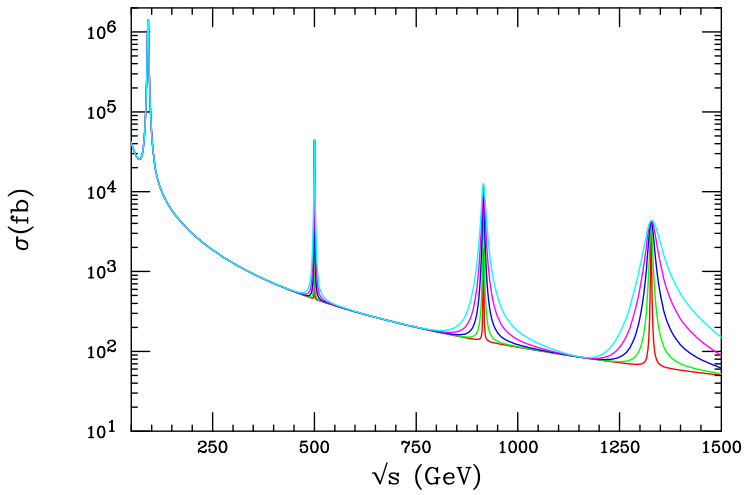
Dittmar, Nicollerat, Djouadi, hep-ph/0307020



Hof, Hebbeker, Höpfner, CMS-Note-2006-117

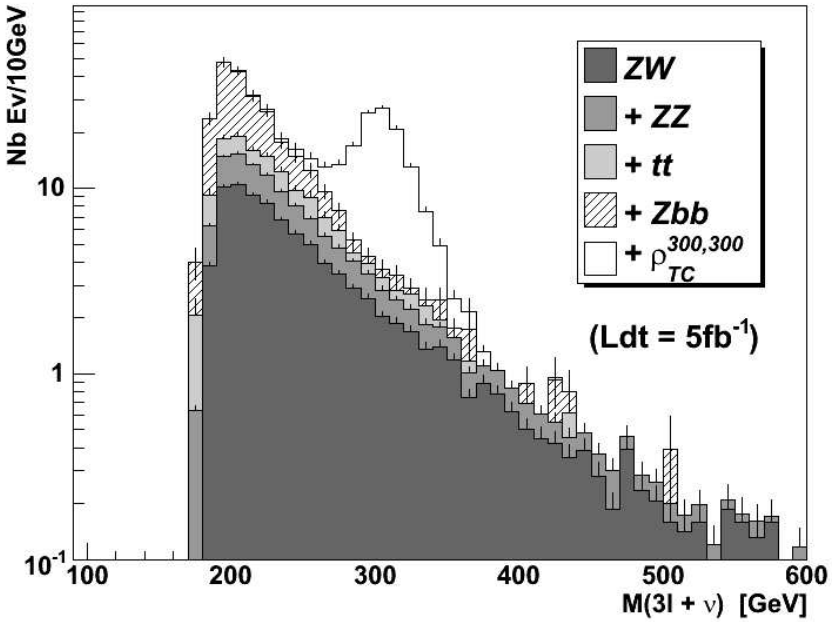
Resonances in Drell-Yan and di-boson production ?

Resonances in Drell-Yan:
Extra spatial dimensions (RS) (KK tower of gravitons)



Hewett, Spiropulu, hep-ph/0205106

Resonances in *WZ* production:
Technicolor



CMS TDR, CERN/LHCC 2006-021

Establishing deviations from SM predictions

Unless something really 'sticks out' or background can be modelled with data, we will need theory input both with early data and at high precision.

Are SM background predictions under theoretical control ?

Many accomplishments:

- most important $2 \to 2, 3$ processes at NLO QCD,
- some even at NNLO QCD (Higgs production, Drell-Yan),
- some $2 \to 2, 3, (4)$ processes at NLO electroweak and resummation of leading logarithms,
- interface between parton shower event generators and fixed order QCD calculations,
- NNLO PDFs and PDFs including NLO QED,
- leading logarithmic corrections to all orders.

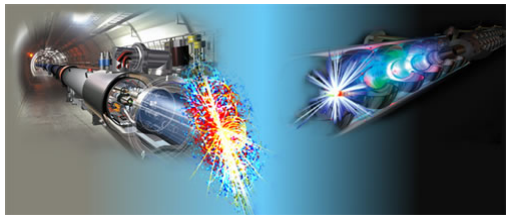
SM background predictions under theoretical control ?

But also many challenges:

- what are the theoretical uncertainties of existing predictions by event generators, NLO, NNLO QCD and 'all order' calculations ?
- need some $2 \to 4, 5, \ldots$ at NLO QCD, new methods needed (numerical, twistors, ...)
- improved electroweak predictions (Sudakov logarithms), combined QCD and electroweak calculations.

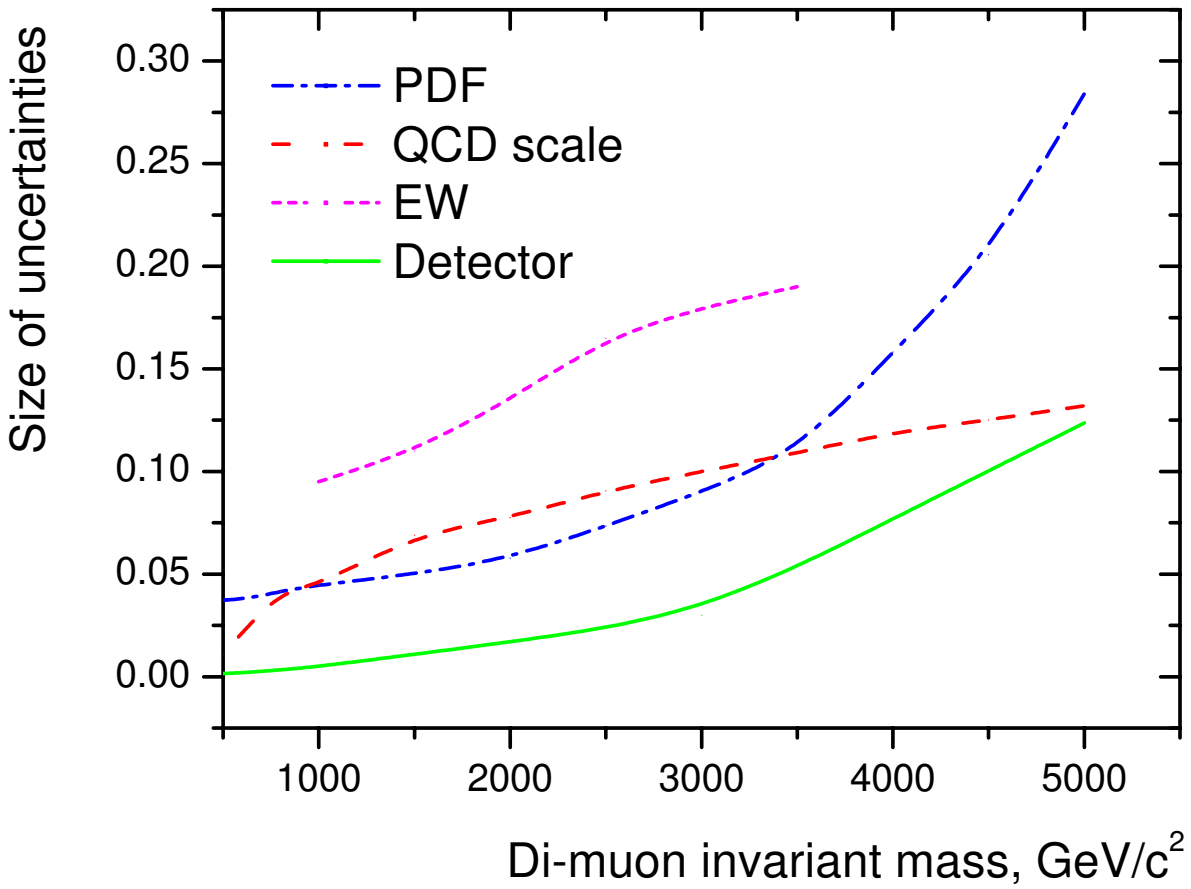
See, for example, review by Campbell, Huston, Stirling, Rept. Prog. Phys.70 (2007)

See also talks at LoopFest VI (4/16-4/18 at Fermilab).



SM background predictions under theoretical control ?

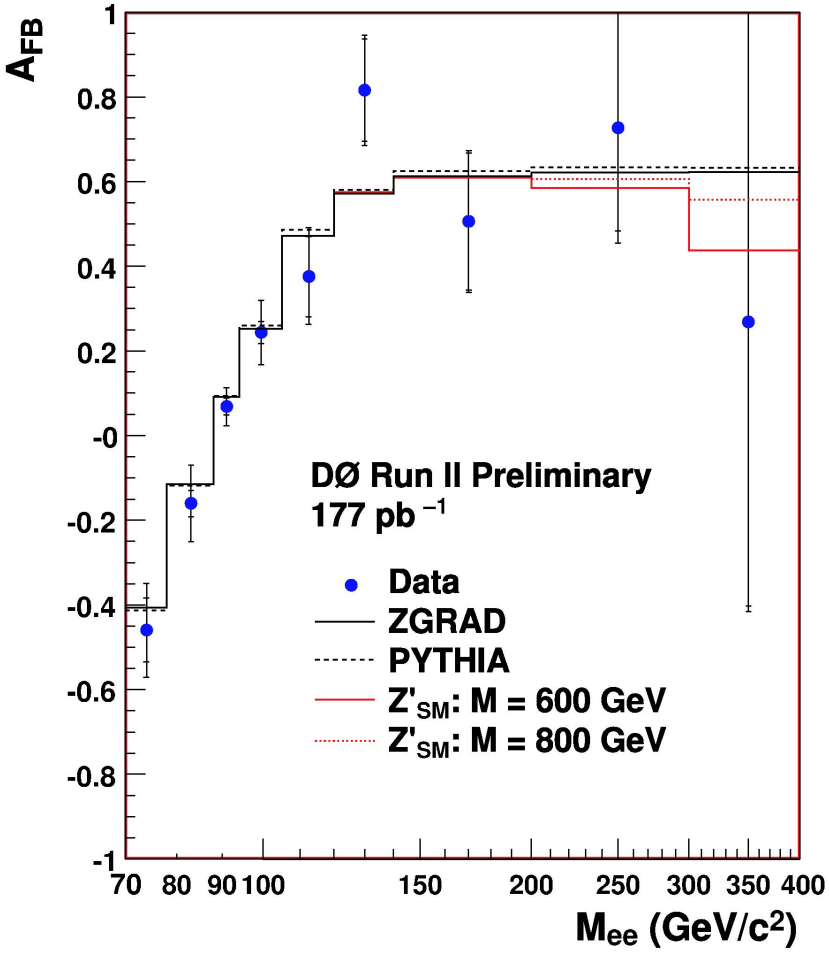
Which improvements have to be ready for the early LHC ?



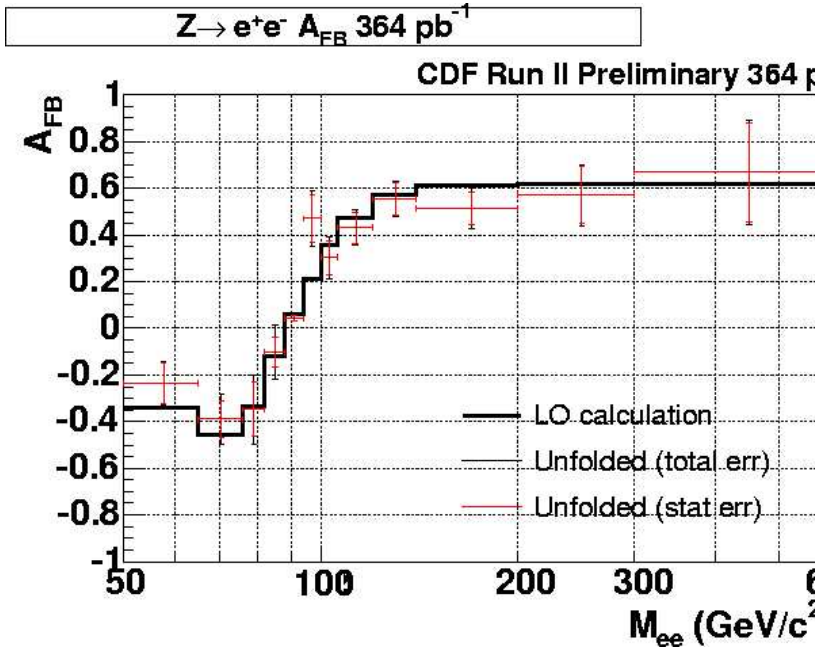
CMS TDR, CERN/LHCC 2006-021

SM background predictions under theoretical control ?

Can missing higher order corrections fake BSM signals ?

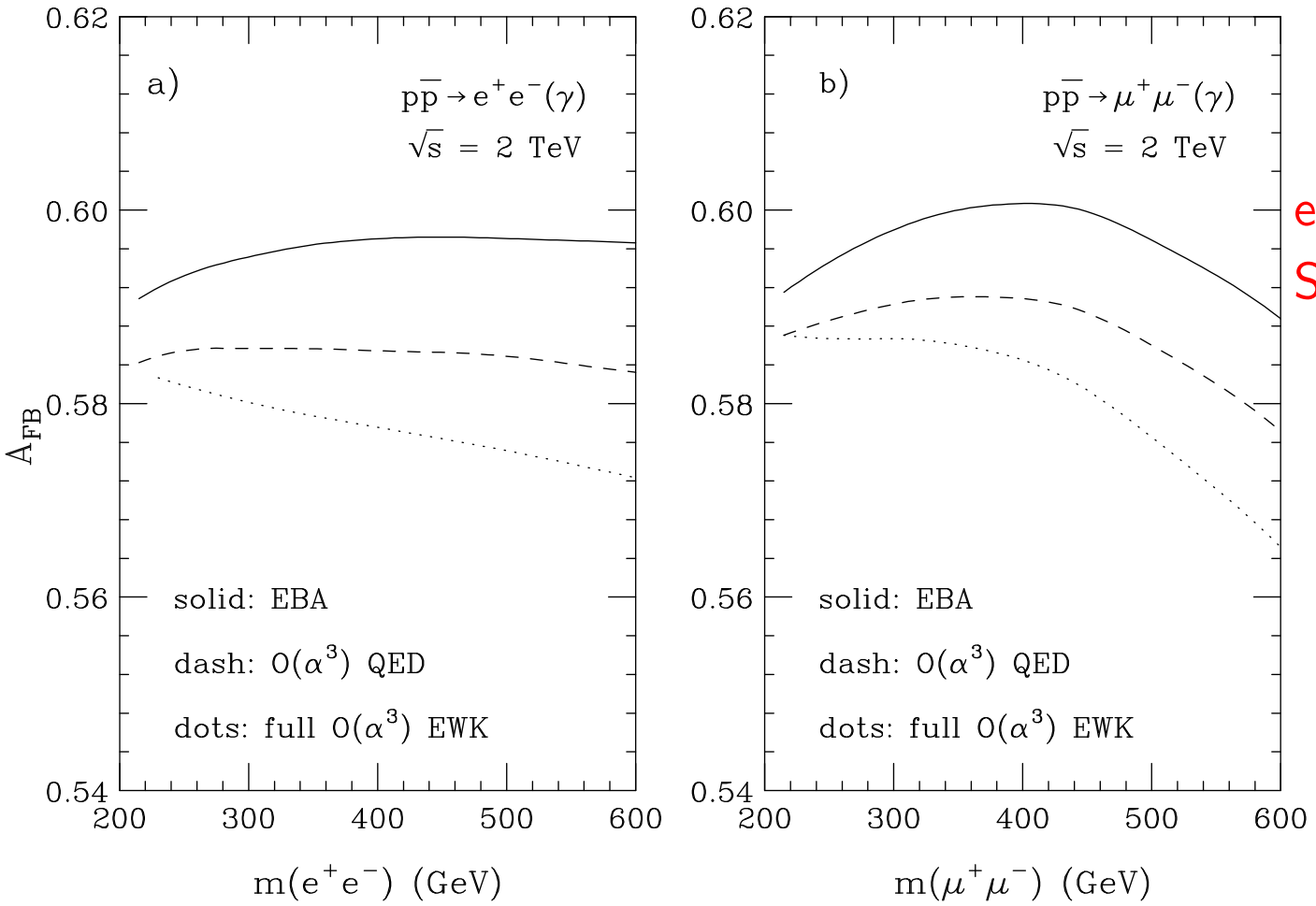


D0note 4757-CONF



CDFnote 8398

Impact of NLO EW corrections on A_{FB} at the Tevatron

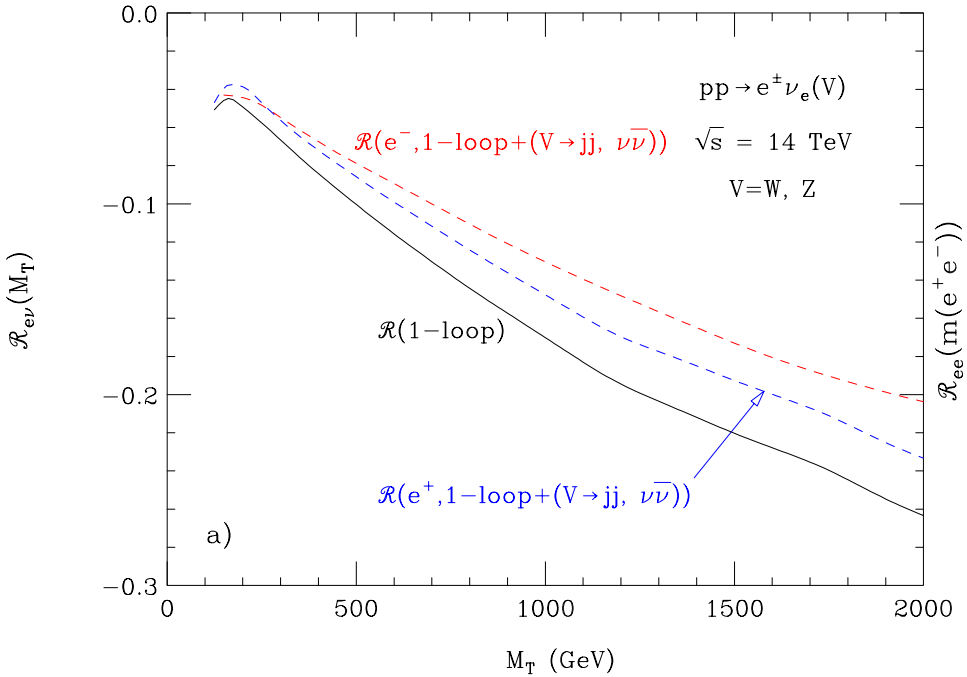


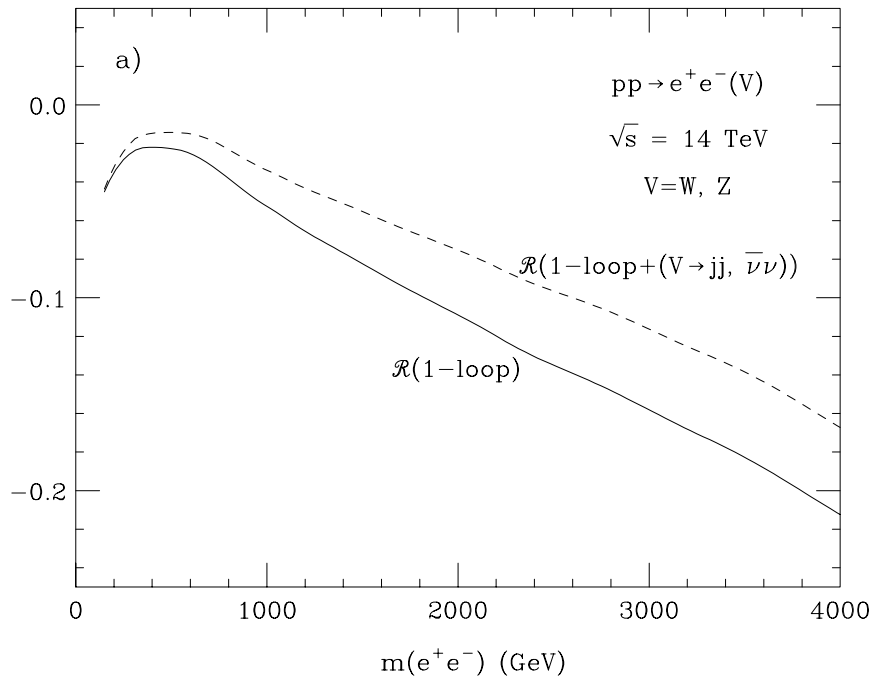
effect of EW Sudakov-like logs

from U.Baur *et al*, PRD65 (2002)

SM background predictions under theoretical control ?

Real and virtual NLO EW corrections at the LHC:





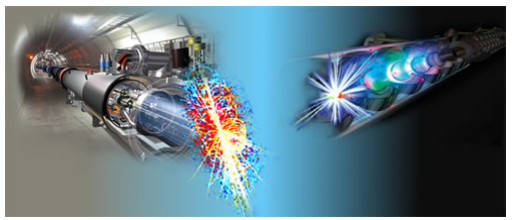
Baur, PRD75 (2007)

EW logarithmic corrections to 4-fermion processes are known up to 2-loop N^3LL order and are available in form of compact analytical formula. For a review see, e.g., J.Kühn's talk at Radcor 2005: `www-conf.kek.jp/radcor05`

Possible BSM physics scenarios in di-lepton and di-boson production

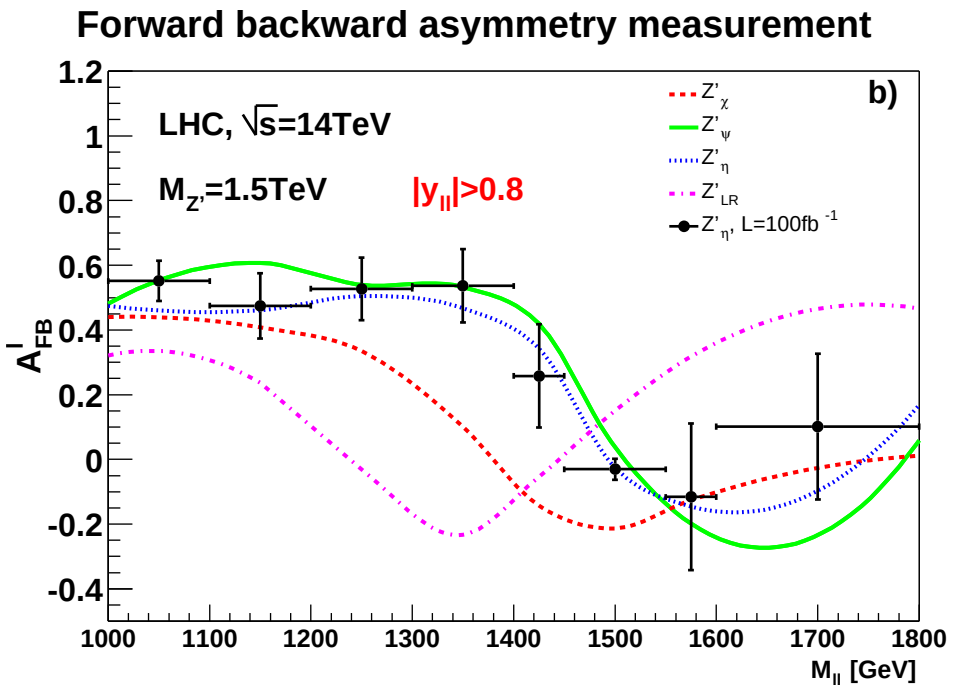
- New, heavy gauge bosons, Z', W':
  $SO(10)$, $E(6)$, Left-Right symmetric models, extra dimensions, Little Higgs, extended MSSM, string theory inspired,...
- Technicolor
- Higgsless models
- Leptoquarks
- KK gravitons
- contact interactions (compositeness, new heavy particles)
- ...

For prospects of searches at the LHC see previous two talks.



Identification of BSM signals

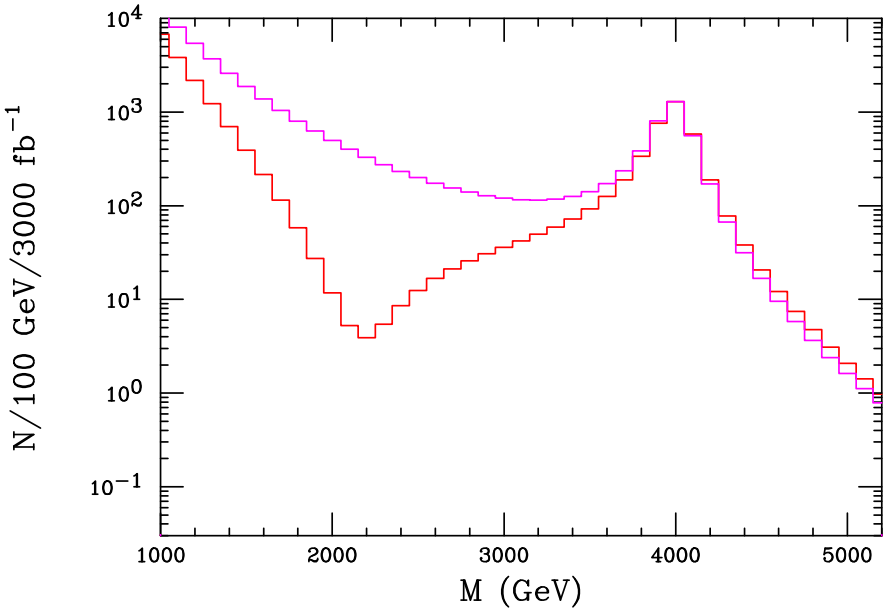
Measurements of total cross section, resonance shapes (mass and width), angular distributions, asymmetries, spin correlations, will help to identify BSM model candidates.
Most likely there will be not just one model candidate for the same BSM signal: Z's scenarios, UED vs MSSM, KK excitations vs Z'

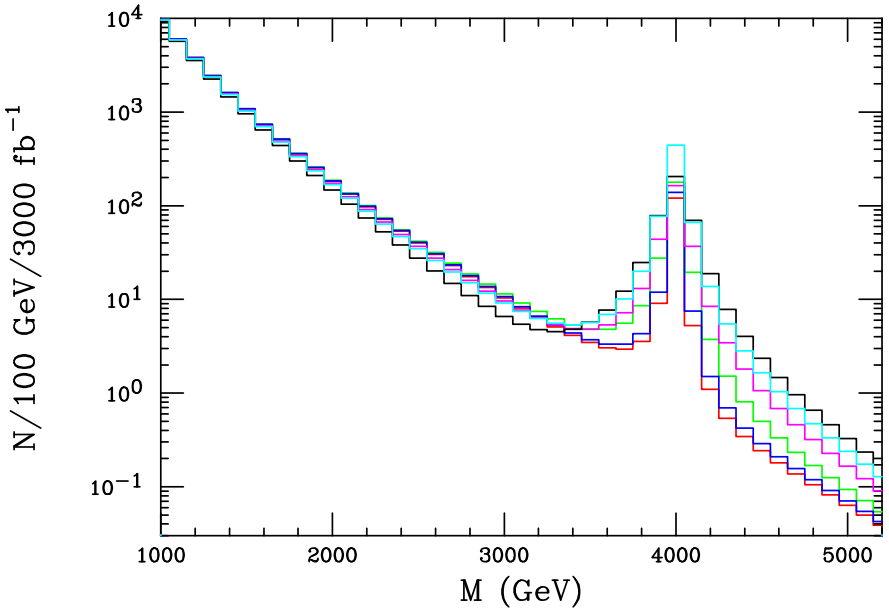


Dittmar *et al*, PLB 583 (2004)

Identification of BSM signals

Z' resonance vs KK excitations in $pp \to \mu^+\mu^-$:





Rizzo, hep-ph/0305077

Identification of BSM signals

Descriminating power of observables with early data ?

Constraining BSM:

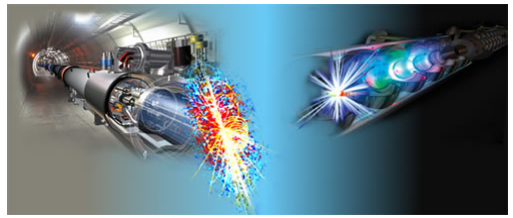
- MARMOSET: A Monte Carlo tool that tries to find an effective field theory description of data based on mass, production cross sections and decays of new particles.

  Arkani-Hamed *et al*, hep-ph/0703088

- Constraints from electroweak precision data:
  One-loop corrections to T parameter and $Zb\bar{b}$ in RS model.

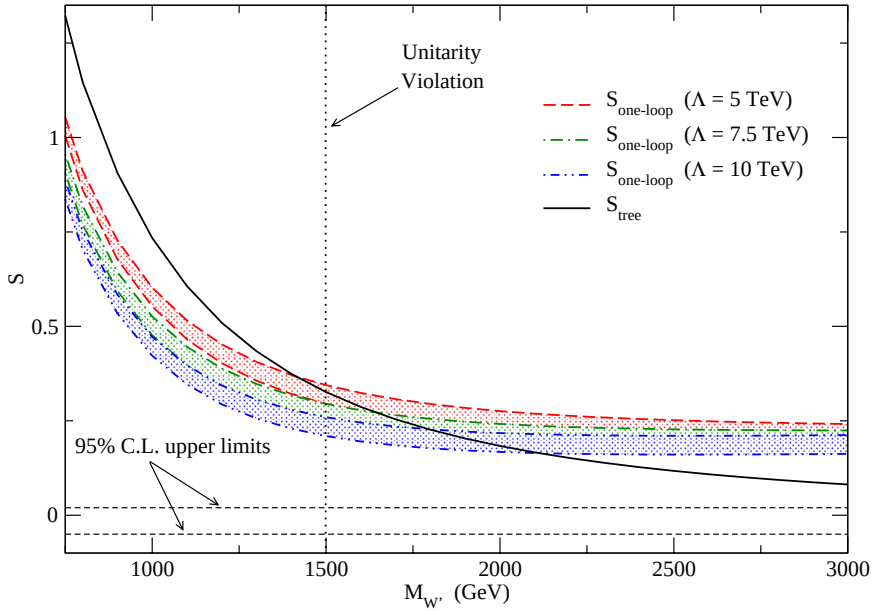
  Carena, Ponton, Santigo, Wagner, hep-ph/0701055 Global fit with Higgs triplets (Little Higgs models).

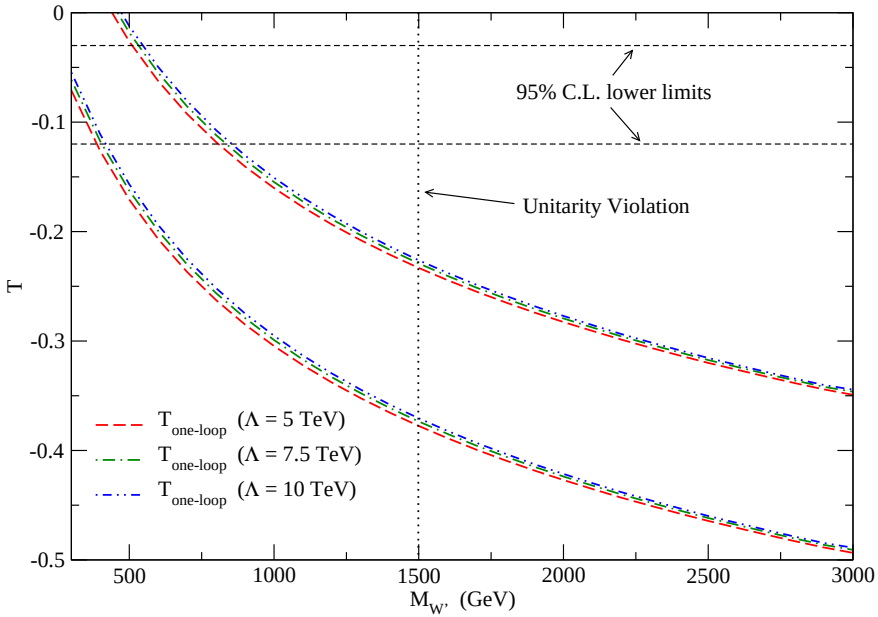
  Chen, Dawson, hep-ph/0604102



BSM and electroweak precision data

S, T parameters in Higgsless models with new, heavy gauge bosons:





Dawson, Jackson, hep-ph/0703299

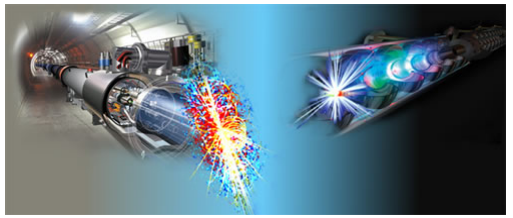
See also, Chivukula *et al*, hep-ph/0702218

BSM predictions under theoretical control ?

Many BSM tools are available in form of event generators and some NLO calculations (MSSM, Z's, ED).

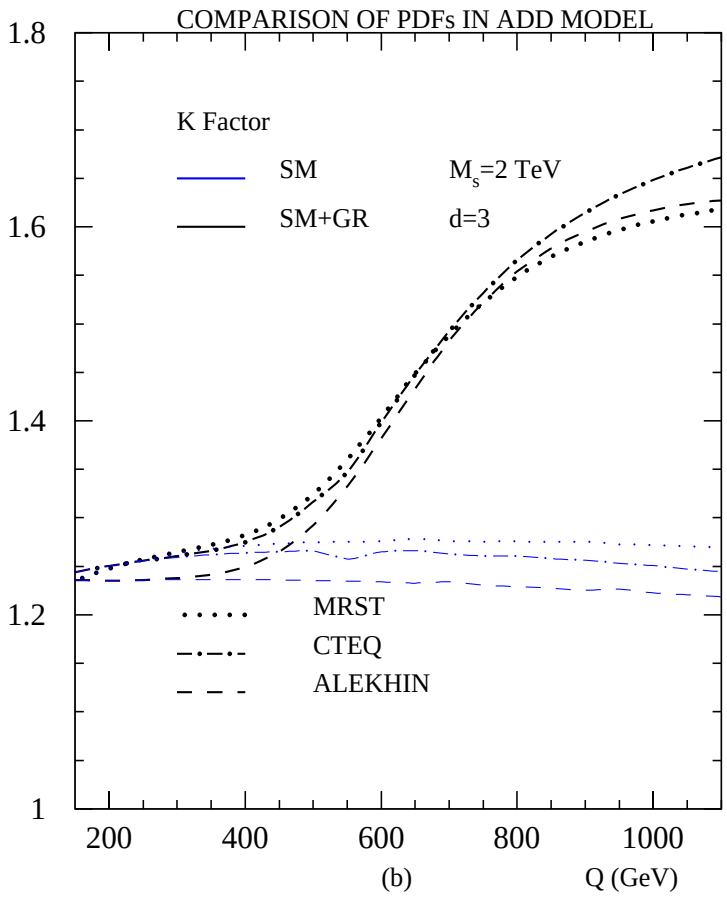
See, e.g., *A Repository for BSM tools* at www.ippp.dur.ac.uk/montecarlo/BSM

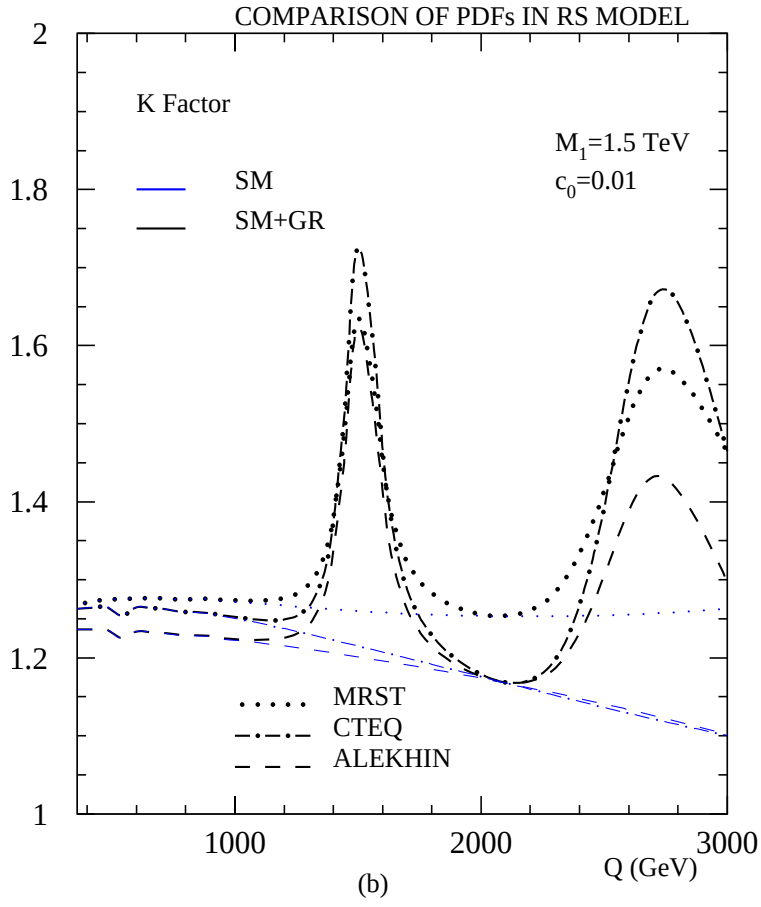
- Theoretical uncertainties of BSM predictions ?
- Consistent treatment beyond leading order (if not MSSM) ?



BSM predictions under theoretical control ?

SM experience not necessarily applicable to BSM predictions - there may be surprises.
QCD K-factors in the SM, ADD and RS models:

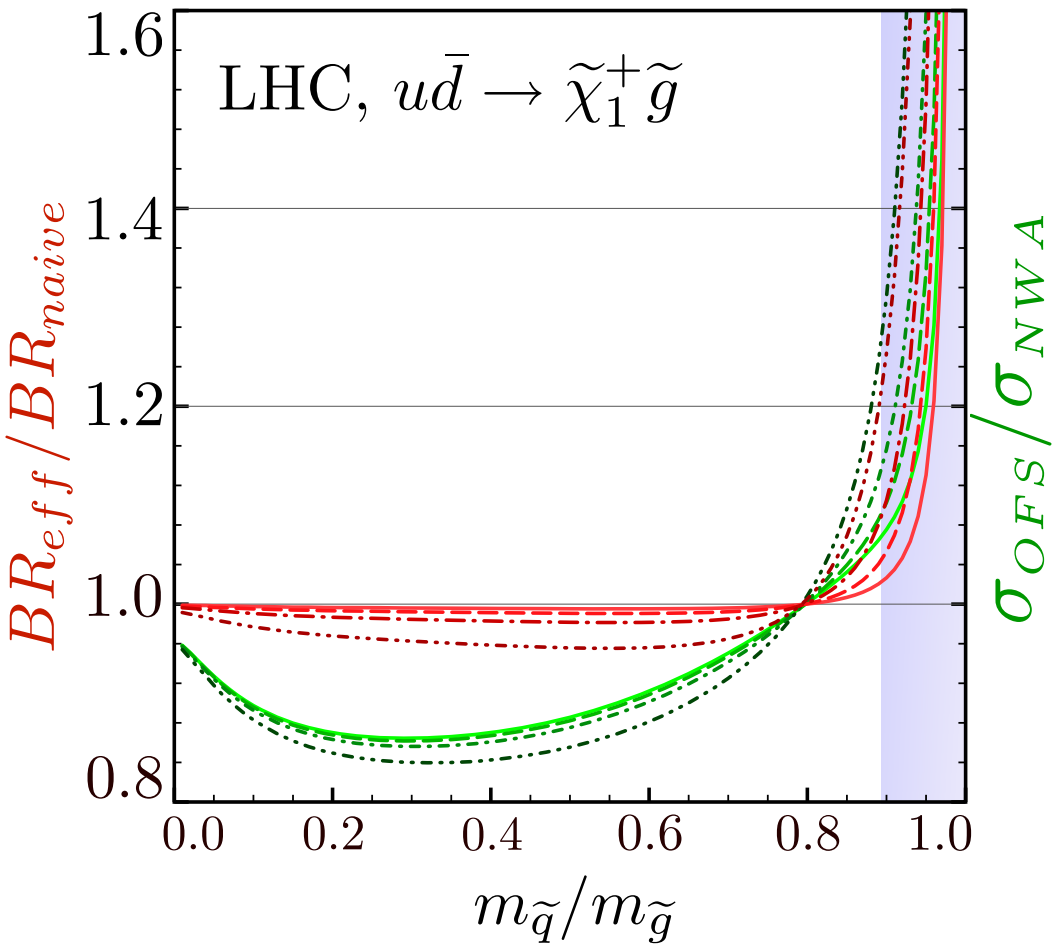




Kumar, Mathews, Ravindran, hep-ph/0604135

BSM predictions under theoretical control ?

Narrow width approximation vs. full calculation:

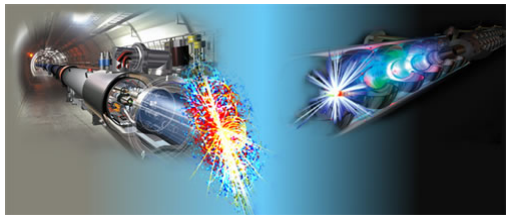


Berdine, Kauer, Rainwater, hep-ph/0703058

Anomalous Gauge Boson Couplings in WZ/WW production

No direct BSM signal in Drell-Yan and WW, ZW production:
What can we learn from measurements of SM particle properties with early data ?
Precision measurement of TGCs $(\Delta\kappa_Z, \lambda_Z)$ possible at the LHC already with $30 fb^{-1}$ in WW production.

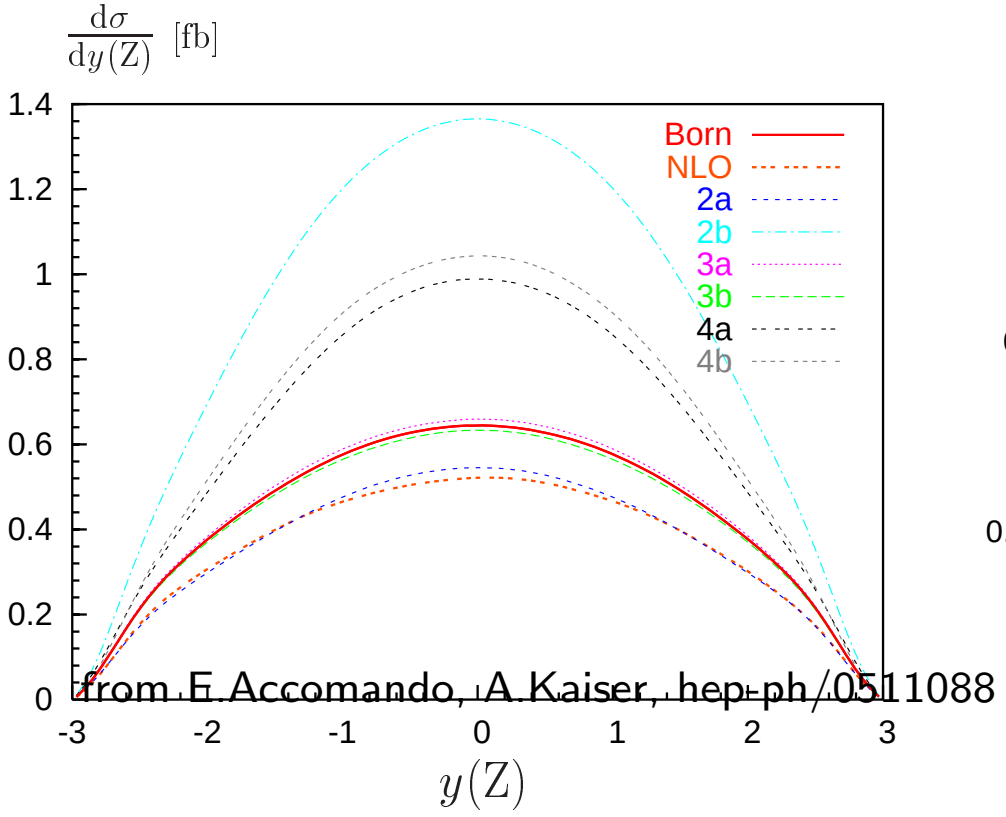
See, e.g., Simic *et al*, ATLAS phys-pub-2006011



Anomalous Gauge Boson Couplings in WZ/WW production

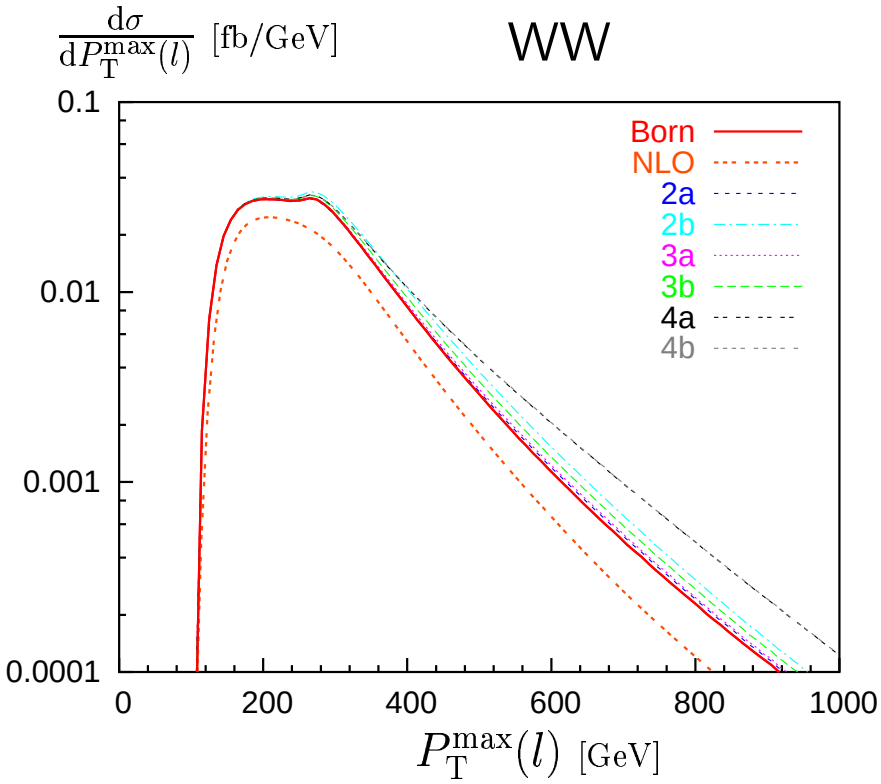
SM LO, NLO predictions vs. anomalous couplings scenarios:

WZ



from F. Accomando, A. Kaiser, hep-ph/0511088

WW



Implications of early LHC data for the ILC ?

BSM signal at the early LHC:
most likly the physics case for the ILC will be even stronger.
No BSM signal in di-muon, multiple gauge boson production processes:
How much can the ILC tell us about the BSM models that are now much more constrained ?
But first:

- Predictions for both SM and BSM cross sections need to be under control.
- Tools for identifying and descrminating BSM signals need to be in place.
- Necessary improvements of predictions need to be identified soon.