

# MC for BSM at ATLAS

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# ATLAS CSC Exercise

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- For the last couple of years ATLAS is running the „Computing System Commissioning“ (CSC) exercise:
  - ▶ Large scale simulation of physics processes (60M+)
  - ▶ Over 1200 different samples.
  - ▶ Basically aiming to see the „last best guess“ before the data.
  - ▶ Alas, the results (notes) at this time still not public..

# ATLAS MC Setup

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- What we have available (i.e. stable/interfaced to ATLAS software etc):
  - Several parton level 'ME' MC generators,
  - Latest FORTRAN HERWIG and Pythia for the jet production in terms of QCD/QED parton showering/fragmentation..
  - Several 'addon'/decay packages are used.
  - ME and PS matching in several versions (MLM, CKKW).
- We try to use as many generators as reasonable:
  - The final answer which is best will be given only by the data.

# ME Level MC Tools

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- The list is 'longish' but we are still adding to it:
  - **AcerMC**: Zbb~, tt~, single top, tt~bb~, Wbb~
  - **Alpgen** (+ MLM matching): W+jets, Z+jets, QCD multijets
  - **Charbydis**: **Black holes..**
  - **CompHep**: Multijets, **some BSM**
  - **HERWIG**: QCD multijets, Drell-Yan, **SUSY (ISAWIG)...**
  - **Hijing**: Heavy Ions, Beam-gas..
  - **MadEvent**: Z/W+jets...
  - **MC@NLO**: tt~, Drell-Yan, boson pair production, W' etc..
  - **Pythia**: QCD multijets, B-physics, Higgs production, **BSM...**
  - **Sherpa**: W+jets/Z+jets...
  - **WINHAC**: W production and decay
- The MC base is **expanding**:
  - Pythia 8
  - HERWIG++
  - ???

# Addon/Decay Packages

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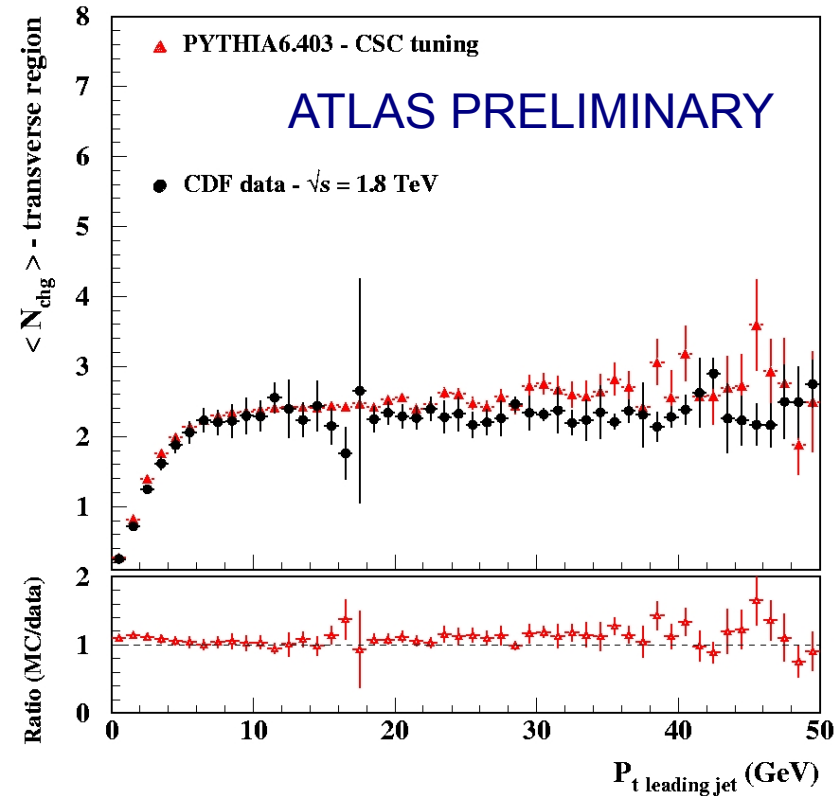
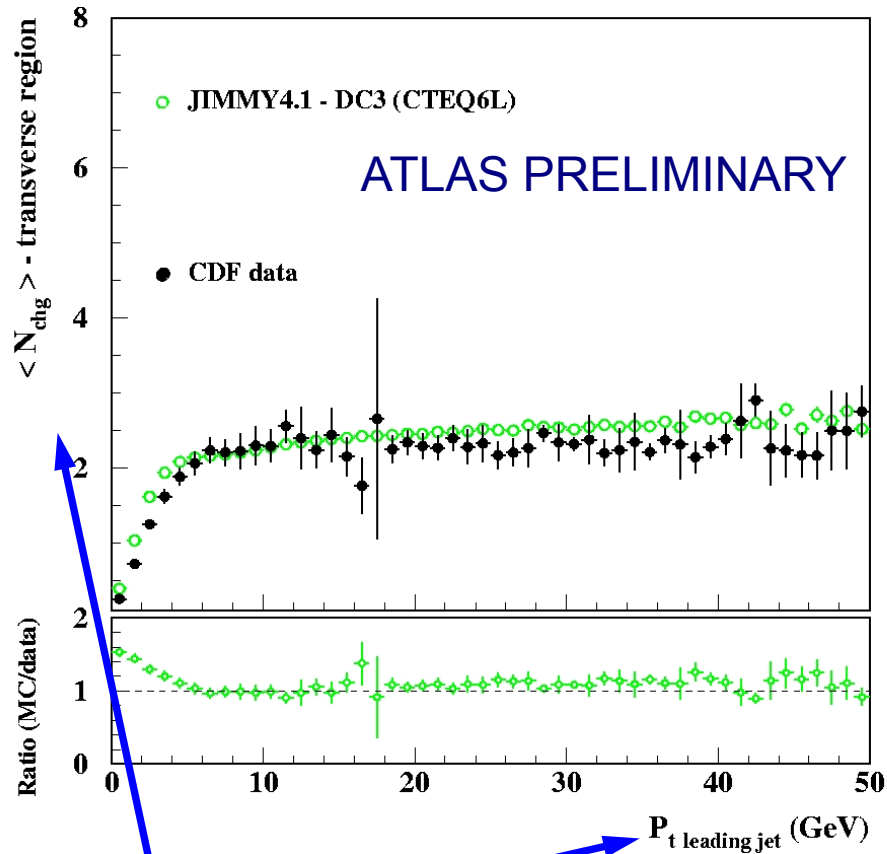
- **TAUOLA:**
  - Interfaced to work with Pythia, Herwig and Sherpa,
    - Native ATLAS effort/patches present..
- **PHOTOS:**
  - Interfaced to work with Pythia, Herwig and Sherpa,
    - Also native ATLAS effort present..
- **EvtGen:**
  - Used above all in B-physics channels.
    - An ongoing effort to validate it..



# Parton Showering and Underlying Event

- For Parton Showers we use:
  - The latest FORTRAN Herwig (6.510) with bugfixes.
  - Pythia from 6.323 to 6.411 and onwards with the pT ordered parton showers...
    - Moving versions primarily due to bug fixes and improvements.
  - Sherpa, the 1.0x batch (up to 1.0.11), incrementing versions due to bug fixes...
  - Jimmy 4.2 and new Pythia 6.4 (interleaved) models for multiple interactions/underlying event simulation.
    - Which we tuned on the published Tevatron data...

# Underlying Event Tuning



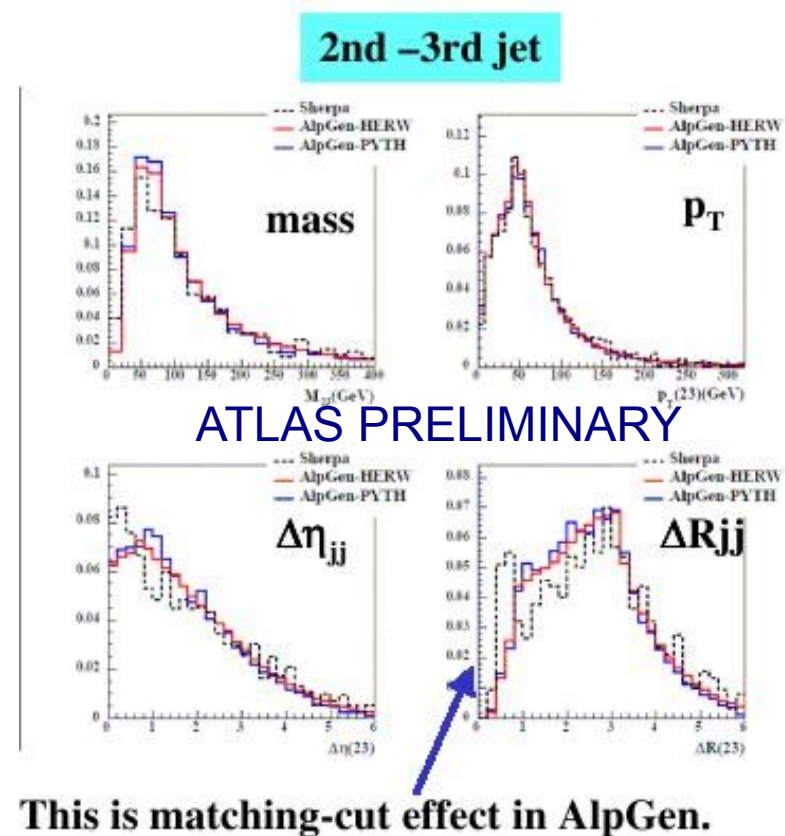
Average multiplicity of charged particles in the underlying event associated to a leading jet with  $P_{\text{t}}^{\text{lj}}(\text{GeV})$ .

Just to show that it works...

# ME + PS Matching



- At ATLAS we predominantly use:
  - ▶ The MLM matching implemented inside Alpgen MC generator
  - ▶ The L-CKKW matching implemented in the Sherpa MC generator.
  - ▶ Now also Madgraph/MadEvent is appearing sporadically...
- Quite a lot of effort went into setting up the system and validation.
  - ▶ Huge CPU requirements involved..





# BSM MC Signals

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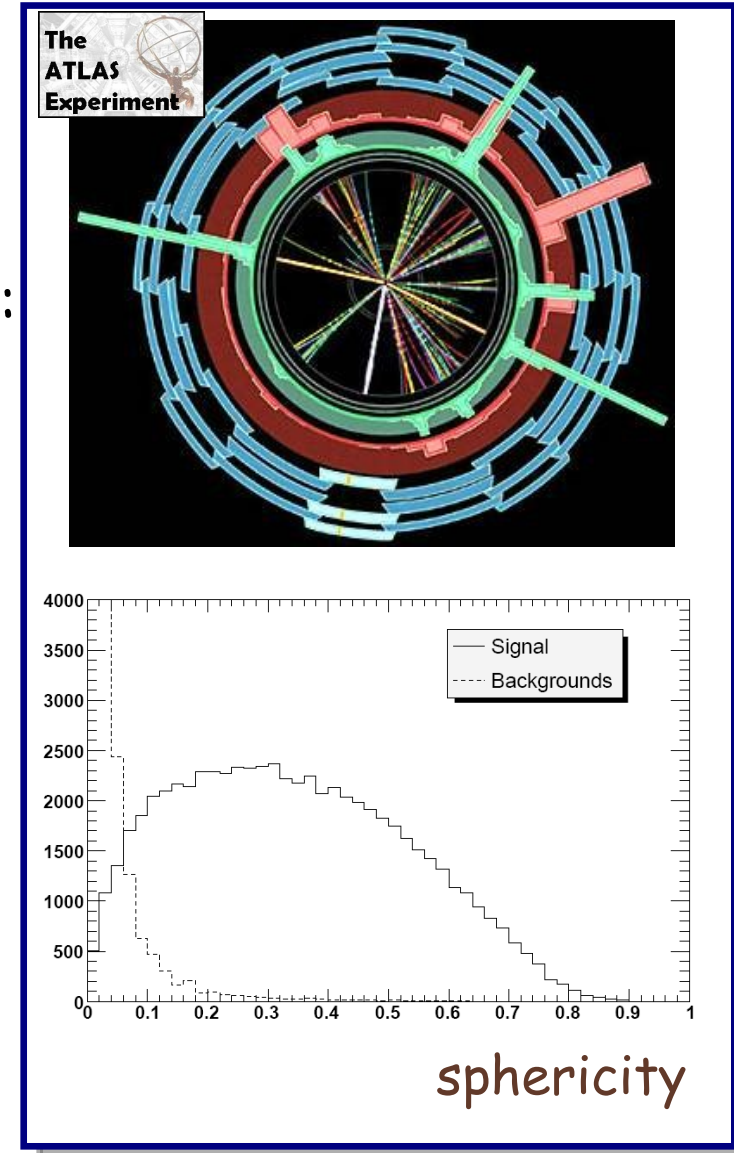


- While a lot of the listed tools is used for background predictions the 'signal' signatures are generated by:
  - Pythia (Technicolor,  $Z'$ ,  $W'$  ....)
  - Charybdis + Herwig ( Black Holes, of course)
  - Special implementations, e.g. :
    - Pythia UED
    - Pythia R-hadronsyou already heard about...
  - Pythia ChL with Chiral Lagrangian model
  - Some CompHEP use ( $Z'$ , excited leptons)
- In principle very particular things w.r.t. Bulk production.

# Black Hole Studies



- Charybdis (1.003) used with ATLAS default Herwig:
  - Fulfills the expectations...
  - Initially some hiccups in the ATLAS setup:
    - Persuading the system to keep the BH in the record (HepMC translation...)
- Another tool appearing on the market:
  - BlackMax: A black-hole event generator with rotation, recoil, split branes and brane tension.", arXiv:0711.3012 [hep-ph]

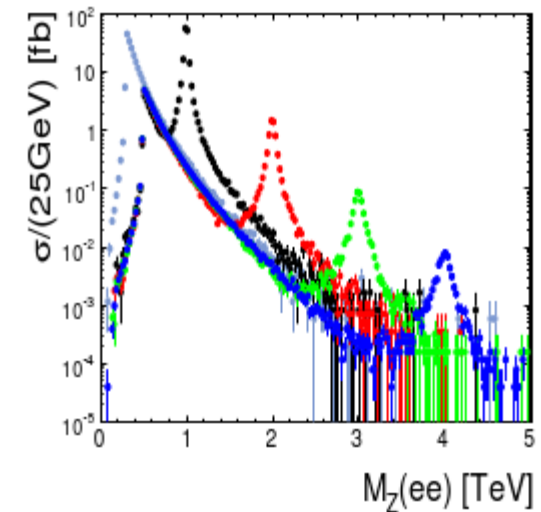


# Dileptons, Di-Photons, Leptons + MET



- Extensive use of Pythia (all those nice switches to toggle and set..):
  - ▶ *SSM*:  $Z' \rightarrow e^+e^-, \mu^+\mu^-$
  - ▶ *CDDT/E6*:  $Z' \rightarrow e^+e^-, \mu^+\mu^-$
  - ▶  $W' \rightarrow l \nu$
  - ▶ *Gravitons*  $\rightarrow e^+e^-, \gamma\gamma, \tau^+\tau^-$
  - ▶ *Technicolor*  $\rho_T/\omega_T \rightarrow \mu^+\mu^-$
  - ▶ *Technicolor (TCSM)*  $\rho_T \rightarrow ZW \rightarrow (ll) (l \nu)$
- **MC@NLO** Used for cross-checks (e.g. re-setting  $W$  mass)

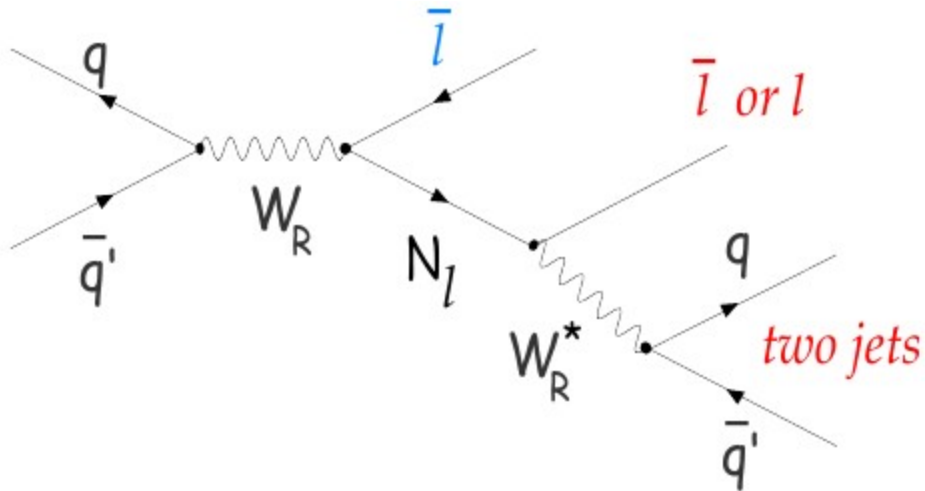
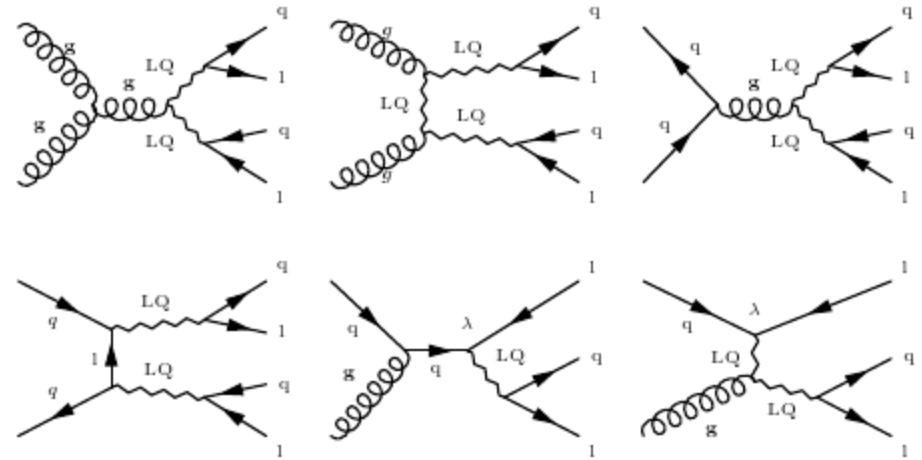
ATLAS PRELIMINARY



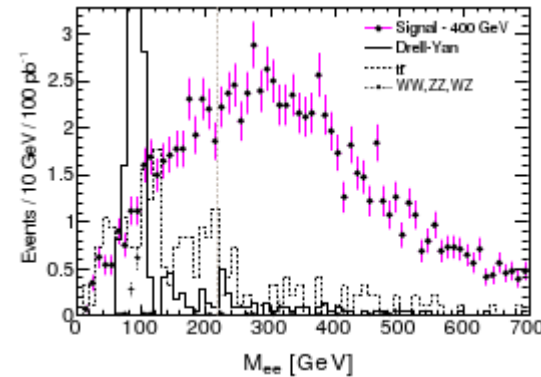
# Dileptons + jets



- Again Pythia used:
  - Leptoquarks (300 GeV - 1200 GeV)
  - LRSM:  $W_R, Z'$



ATLAS PRELIMINARY

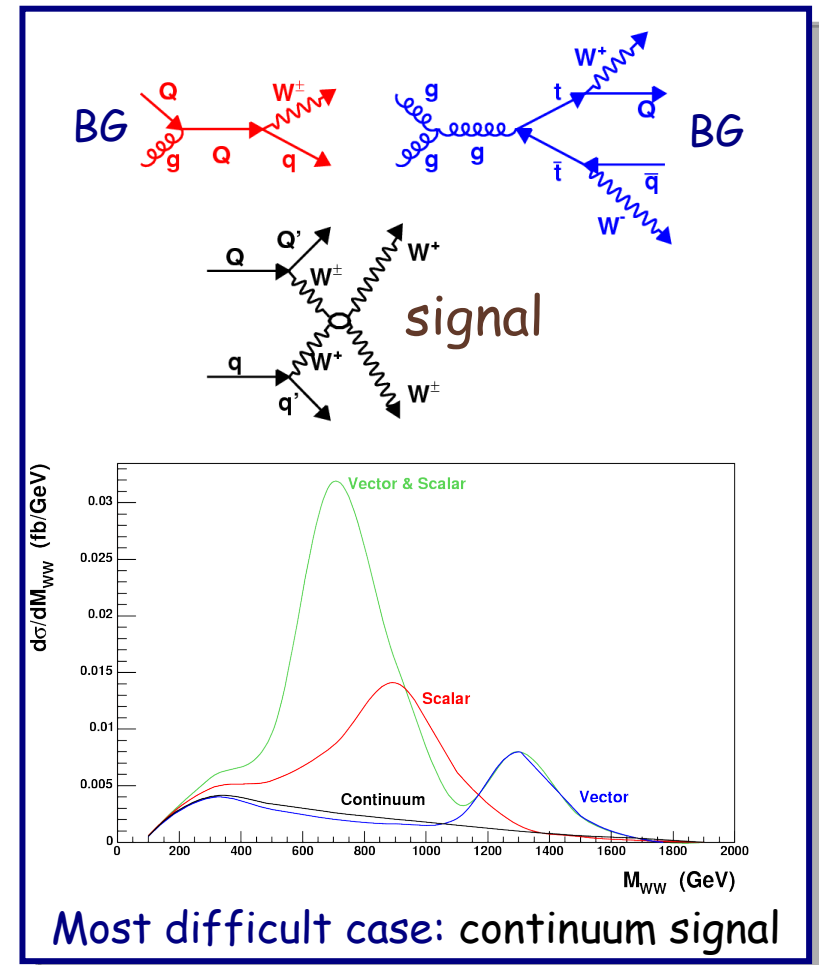


- CompHEP for E6 iso-singlet quarks  $DD \rightarrow hZjj, ZZjj$

# Vector Boson Pair Scattering



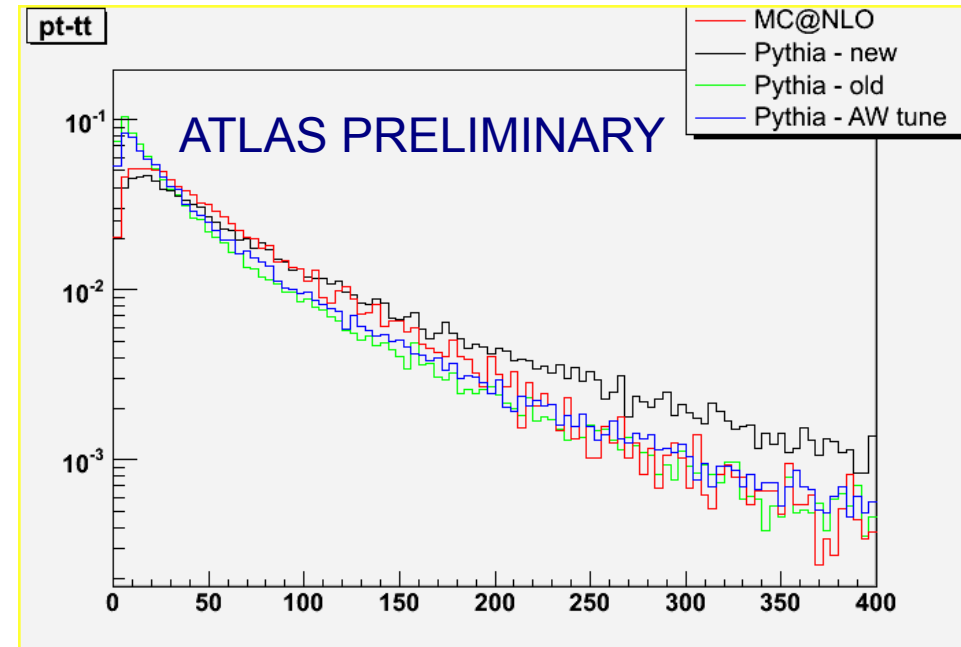
- Primarily use of Pythia:
  - with the Chiral Lagrangian interpretation: The scattering amplitudes calculated by Dobado *et al.* (hep-ph/9912224) with parameters  $a_4$  and  $a_5$ . These parameters were chosen so as to produce a vector or scalar resonance at the desired mass, or signal with no resonances at all. Only vector WZ and scalar ZZ resonances are possible, but both scalar and vector WW resonances can be produced. A continuum sample was also generated using this model.
  - Longitudinal WZ scattering with  $MSTP(46)=5$  (QCD-like model of with Pade unitarization - a generic narrow WZ resonance).
  - Some Whizard comparisons made.
- Heavy use of MadGraph/MadEvent+Pythia for background studies..



# A Note on Backgrounds



- Backgrounds in BSM are a difficult topic:
  - Looking into strange corners...
- Substantial use of MadGraph/MadEvent:
  - Exclusive  $WZ/WW/ZZ$  + jets
- Using the Standard Model signals:
  - MC@NLO  $t\bar{t}$
  - Alpgen  $W/Z$  + jets
  - AcerMC  $Zbb$
  - ....



- Often Rather different predictions due to parton showering models:
  - It seems we are much more affected than Tevatron..

# (Almost) Not Pursued in CSC

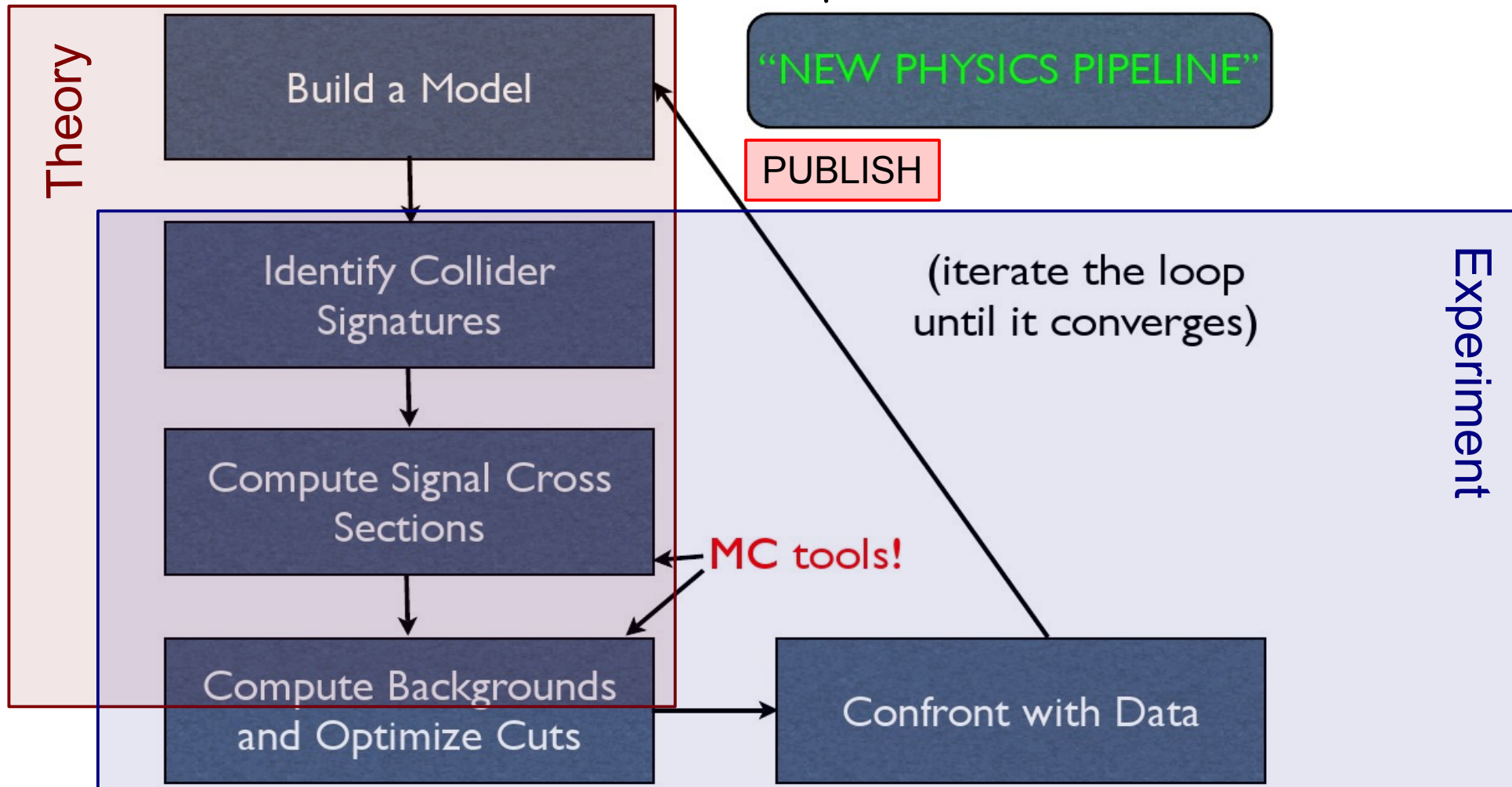


- Some models and tools not pursued (enough/yet):
  - ▶ **Extra dimensions:** virtual graviton; KK excitations of  $Z$ ,  $W$ ,  $g$ ,  $q$ ;  $G^*$  in Randall-Sundrum models; Higgsless models  $Z_{kk} \rightarrow WW$  and  $W_{kk} \rightarrow WZ$ , black holes, transPlanckian model;  $Z'$  with localized fermions; gauge-Higgs unification.
  - ▶ **Compositeness:** excited quarks and leptons; heavy quarks and leptons including isosinglet quarks; leptoquarks. (These exist in CalcHep/CompHep).
  - ▶ **Symmetry breaking:** new technicolor models (as shown by Foadi, being implemented in Sherpa), Chiral Lagrangian (easy to implement in Pythia) and  $WW$  scattering at high mass in exact calculation (not using effective  $W$  approximation), as in Whizard.
  - ▶ ADD model: monojet, single photon signatures.
  - ▶ Randall-Sundrum  $Z'$ , RS radion and RS KK gluons (we have gravitons).
  - ▶ Gauge excitations in  $\text{TeV}^{-1}$  scale models ( $Z'$ ,  $W'$ , gluon).
  - ▶ The  $Z'$  implementation in modified [MC@NLO](#).
  - ▶ ...
- Mainly due to lack of available tools and/or manpower to implement them inside the ATLAS setup.



# The „Small Divide“

- It is indeed very useful that new tools like e.g. MadGraph/MadEvent facilitate fast model implementations.
  - It is however still not trivial for an experimentalist to do it...





# Summary

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- At ATLAS people are looking at a lot of things and models.
  - Many more could probably be considered.
- In order to be useful to experimentalists, new models need to be given to us in form of MC generators.
  - We will give theorists due credit but **we won't give you the data to play with. ( before it is published )**
- It is clear that in order to get to grips with the possible new signals a good cooperation between the experimentalists and theorists is of the essence!
  - Workshops as this always a good starting point.