Report on the 2003 Workshop on MC tools for the LHC*

CERN, July 7 - Aug 2, 2003

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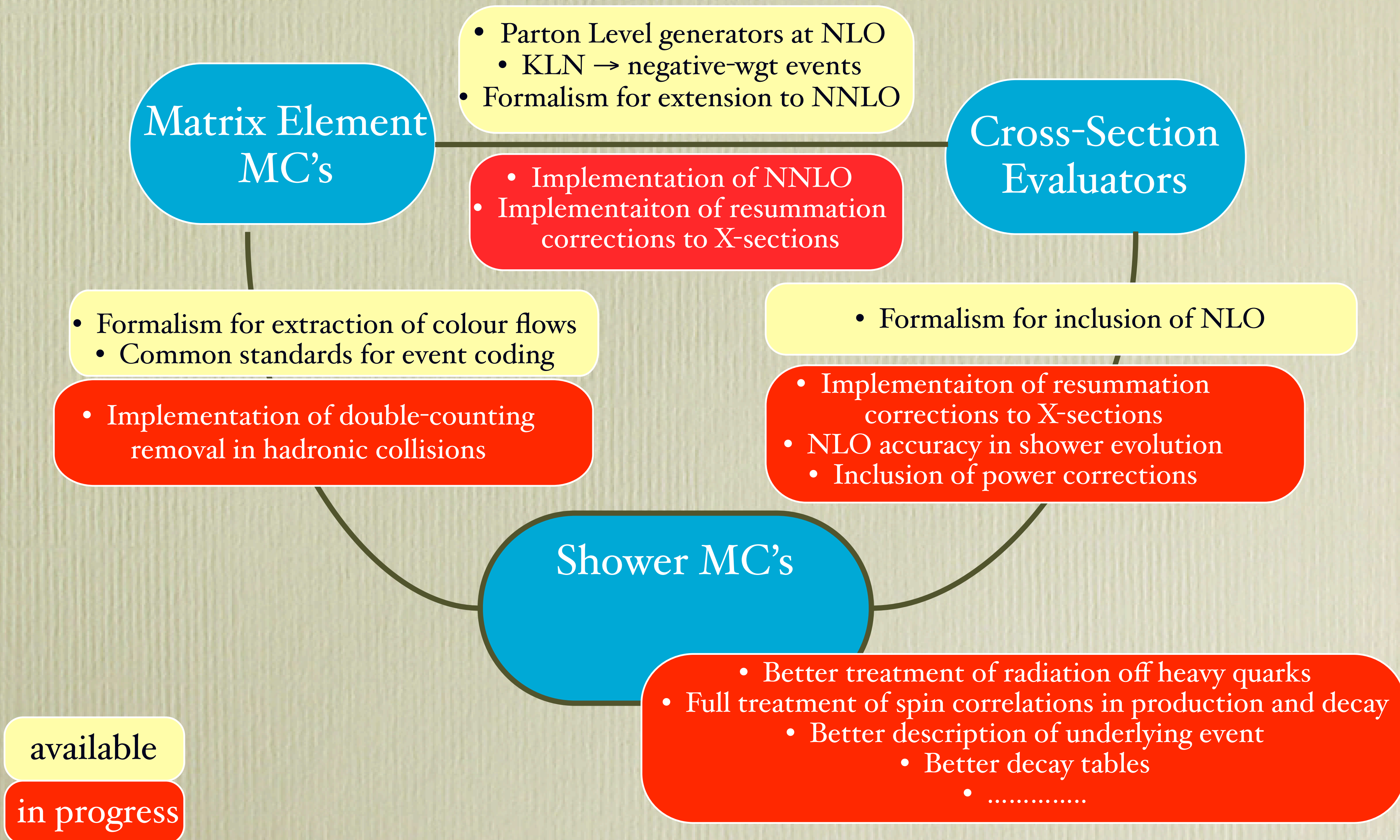
* http://mlm.home.cern.ch/mlm/mcwshop03/mcwshop.html

Goal of the WShop:
review status, assess readiness and outline needed progress of MC tools for the LHC

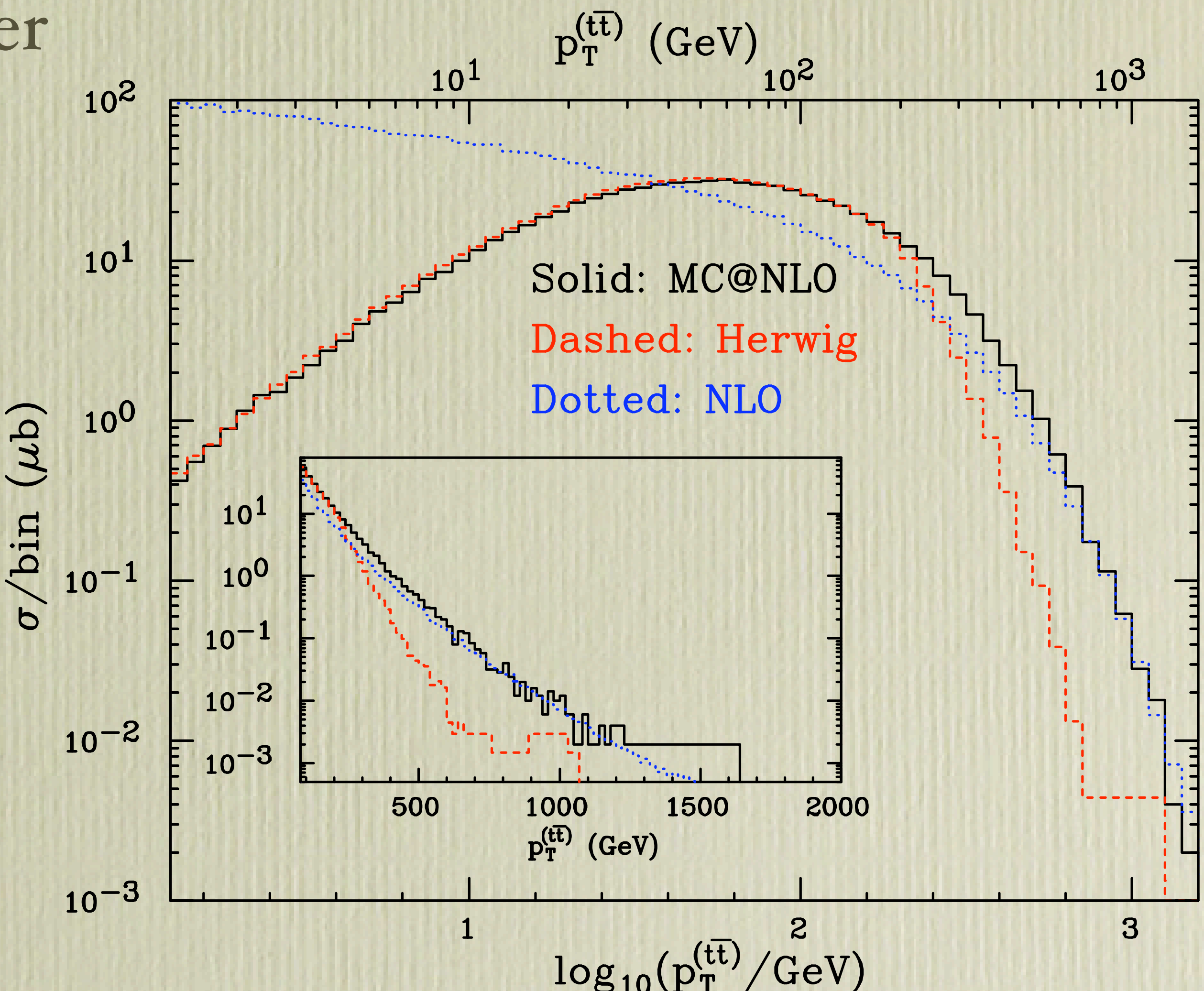
- **accuracy**: NLO, multijets, decays, PDFs, EW corrections, jet quenching, etc etc
- **completeness**: backgrounds and signals, SM & BSM
- **realism**: merging with shower/hadronization MC's
- **reliability**: cross-comparisons
- **validation**: comparison and tuning against existing (HERA, LEP, Tevatron) and LHC data
- **usability**: compliance with LHC software infrastructure requirements (C++, interfaces, MC datasets repositories)

M(*ontecarlo*) o(*f*) E(*verything*): integrating the best of all possible worlds



Example of NLO and shower integration

$t\bar{t}$ production with NLO accuracy in the Herwig shower MC (Frixione, Nason, Webber, Summer '03)



Working groups (conveners)

1. **NLO & NNLO tools** (Krauss, Glover, Carli)
2. **MC's for new physics** (Richardson, Skands)
3. **Tools for heavy ion physics** (Morsch)
4. **C++ codes** (Pythia7, Herwig++, Sherpa) (Ribon)
5. **CLHEP, HepMC,** MC truth, etc (Hinchliffe, de Roeck)
6. **Matrix elements, shower MC's merging** (Mangano, Richter-Was)
7. **Tools for EW physics** (Jadach)
8. **Heavy quark and tau decay packages** (Pokorski, Brook)
9. **Parton Distribution Functions** (Giele)
10. **MB and MC tuning tools** (de Roeck, Brook)

NLO, NNLO WG

- 1 week of intense activity, lots of seminars, discussions
- Directions:
  - evaluation of NNLO corrections to more processes (only DY and H available so far)
  - inclusion of results in event generators (so far only total X-sections or inclusive spectra available)
  - automatization of calculations
- Started studies trying to define what is the level of accuracy needed for different measurements, and to identify the areas where the tools require improvement: for each observable, need to define a hierarchy of theoretical systematic uncertainties to be addressed
- Example: experimental extraction of W cross section from the counting of lepton events passing a given set of experimental cuts (Frixione MLM)

	LO (MLM)	LO+HW	NLO	MC@NLO
LHC cut 1	0.5237	0.4843	0.4771	0.4845
(no spin)	0.5520		0.5104	0.5151
LHC cut 2	0.0576	0.1218	0.1292	0.1329
(no spin)			0.1504	0.1570

?? → **NNLO**

Estimated cut efficiency

Cut 1: $|\eta(e)|<2.5$, $pt(e)>20$GeV   Cut 2: $pt(e)>40$

MC comparisons*, examples

W+multijet cross-sections

X-sects (pb)	Number of jets						
$e^- \bar{\nu}_e + n$ QCD jets	0	1	2	3	4	5	6
ALPGEN	3904(6)	1013(2)	364(2)	136(1)	53.6(6)	21.6(2)	8.7(1)
AMEGIC++	3905(4)	1014(3)	370(2)				
CompHEP	3947.4(3)	1022.4(5)	364.4(4)				
GR@PPA	3906.37 (4)	1046.85 (5)					
HELAC/PHEGAS/JetI	3786(81)	1021(8)	361(4)	157(1)	46(1)		
MadEvent	3902(5)	1012(2)	361(1)	135.5(3)	53.6(2)		

W+bb +multijets

X-sects (pb)	Number of jets				
$e^- \bar{\nu}_e + b\bar{b} + n$ QCD jets	0	1	2	3	4
ALPGEN	9.34(4)	9.85(6)	6.82(6)	4.18(7)	2.39(5)
AMEGIC++	9.42(5)	9.92(10)			
CompHEP	9.415(5)	9.91(2)			
HELAC/PHEGAS/JetI	9.88(11)	12.68(9)			
MadEvent	9.32(3)	9.74(1)	6.80(2)		

* Dozens of bugs found and fixed, in the process!

MC's for new physics

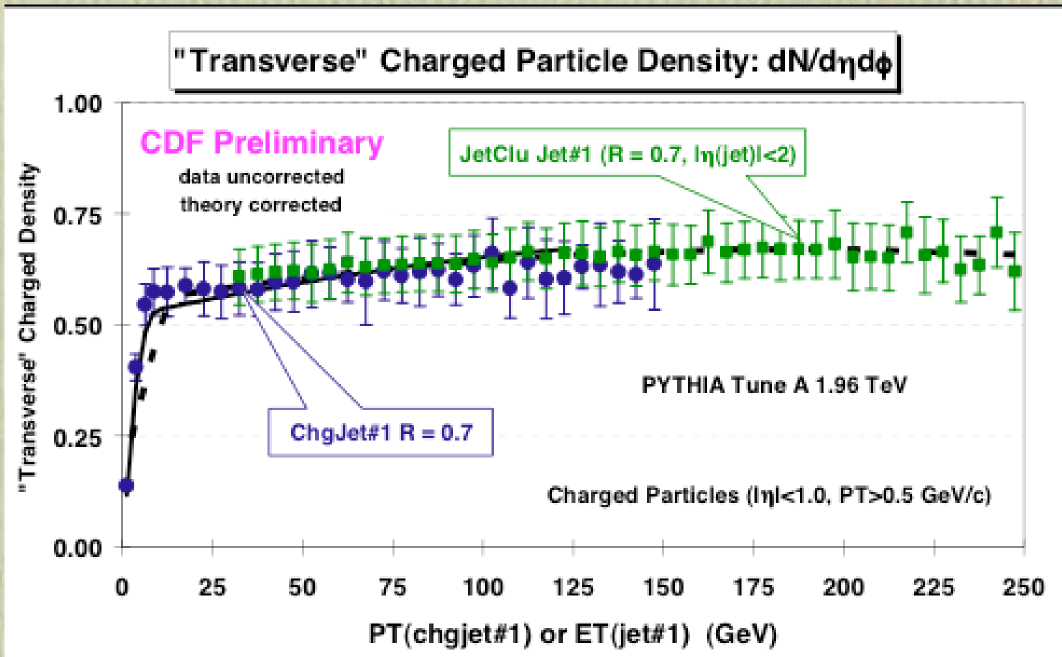
- New physics models typically developed by non-MC physicists => new ideas can't be tested through detector simulations right away.
- Inclusion in MC's typically less complex than description of bg's, but still someone has to do it, and typically it is not the proponents of the new-physics models.
- **Outcome (P.Skands et al, hep-ph/0311123):**
  - An accord specifying generic file structures for 1) supersymmetric model specifications and input parameters, 2) electroweak scale supersymmetric mass and coupling spectra, and 3) decay tables is defined, to provide a universal interface between spectrum calculation programs, decay packages, and high energy physics event generators.

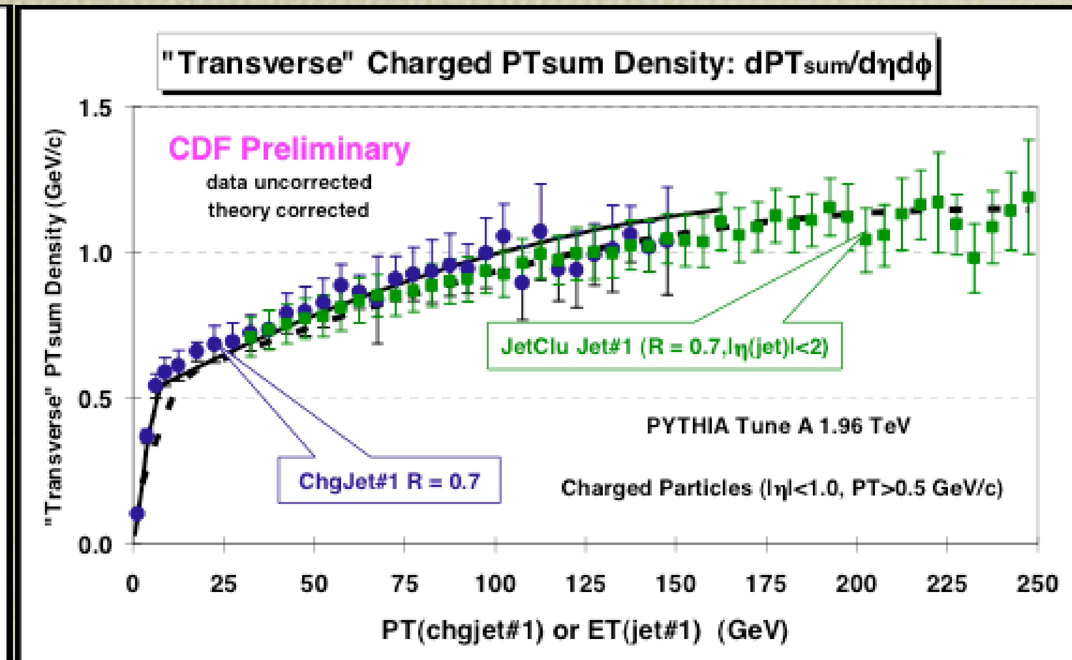
Underlying event and MC tunings

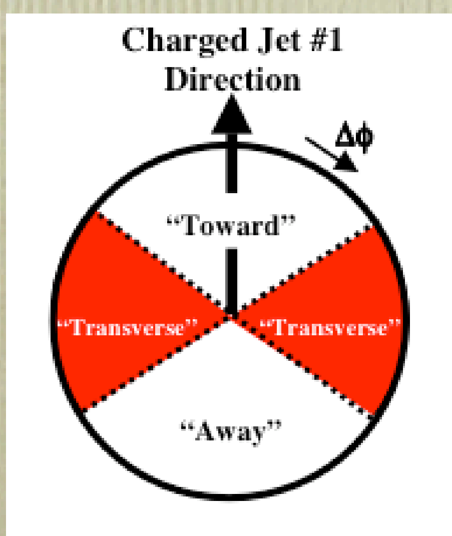
- New models for UE description presented and discussed
- Discussion of validation and tuning studies based on HERA and Tevatron data
- Discussion of automatic validation (MCtester) and tuning/fitting tools (HZtool, JetWeb)
- Consolidated link with Tevatron people, established benchmark studies and observables to be used for MC evaluation and tuning:

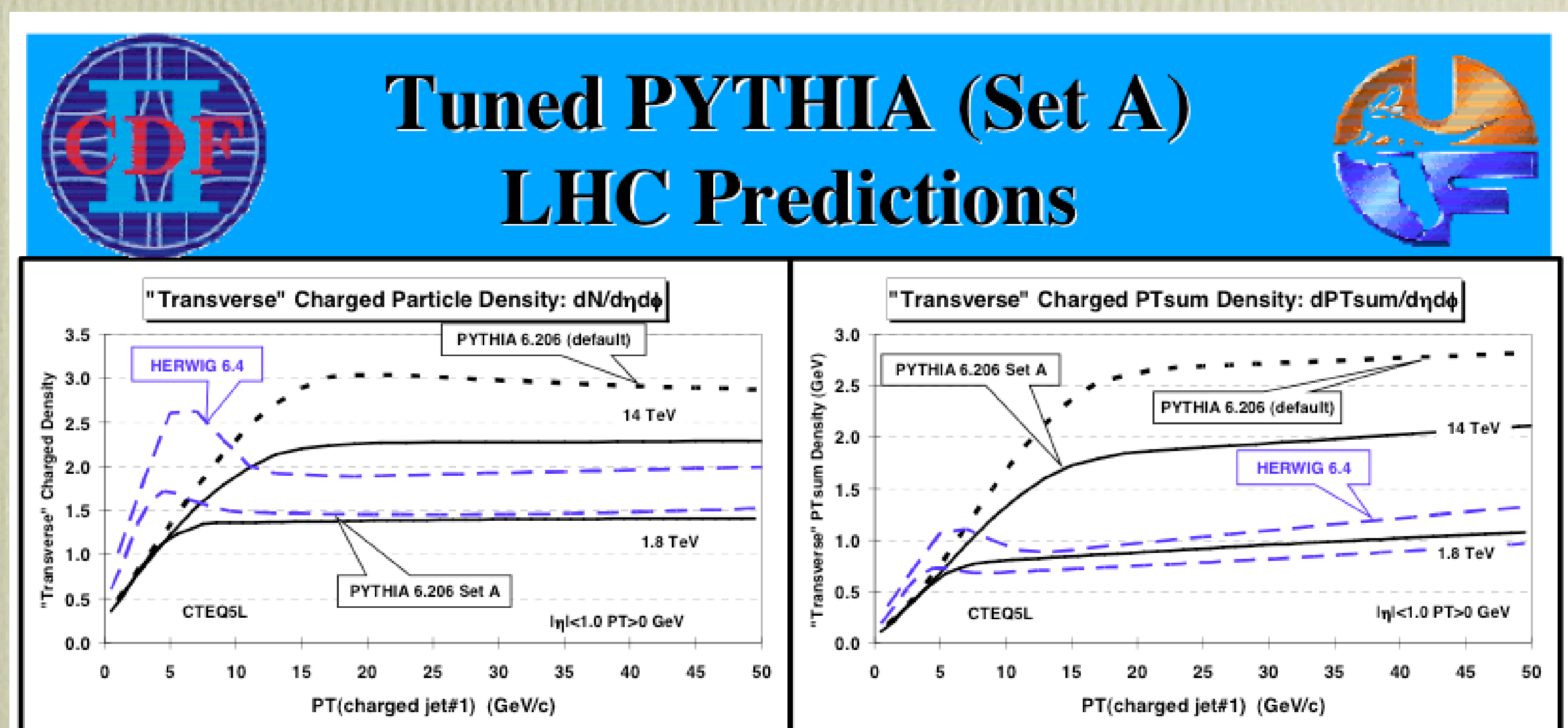
http://agenda.cern.ch/fullAgenda.php?ida=a031541

MC UE tuning with CDF data (R.Field, CDF)









PDF's

- Until recently, a CERN Library product (PDFLIB) provided standardized access to up-to-date compilations of PDF parameterizations.
- PDFLIB not supported any longer, candidate for replacement is LHAPDF, a code developed by W. Giele at FNAL.
- Leading issue for the future: suitable framework for support of large sets of PDF used to assess systematic uncertainties
  - technical challenge (definition of "systematics")
  - architectural challenge (can't afford running 40 times the same MC to get the systematics from PDF)
- Work done to define more precisely the LHAPDF framework, definition of specs, etc.
- Involvement of M.Whalley (Durham HEP database, future repository of the code)

EW effects and observables

With the level of accuracy reached in the QCD part of the W cross-section calculations, EW effects start becoming important. Full inclusion of EW effects will require inclusion of QED effects in the PDF.

Does HERA have any sensitivity to these effects?

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Comparisons of the Monte Carlo programs HORACE and WINHAC for single-W-boson production at hadron colliders*

C.M. Carloni Calame[a,b], S. Jadach[c,d], G. Montagna[b,a], O. Nicrosini[a,b] *and* W. Płaczek[e,d]

Program	σ^{tot} [nb]: WITH CUTS		
	Born	$\mathcal{O}(\alpha)$	Best
$W^- \longrightarrow e^- \bar{\nu}_e$			
HORACE	3.23633 (12)	3.18707 (13)	3.18696 (13)
WINHAC	3.23629 (09)	3.18779 (07)	3.18765 (06)
δ = (W − H)/W	$-1.2\,(4.6) \times 10^{-5}$	$2.3\,(0.5) \times 10^{-4}$	$2.2\,(0.5) \times 10^{-4}$
$W^- \longrightarrow \mu^- \bar{\nu}_\mu$			
HORACE	3.23632 (12)	3.15990 (12)	3.16013 (13)
WINHAC	3.23630 (07)	3.16418 (06)	3.16409 (05)
δ = (W − H)/W	$-0.6\,(4.3) \times 10^{-5}$	$1.35\,(0.05) \times 10^{-3}$	$1.25\,(0.05) \times 10^{-3}$
$W^+ \longrightarrow e^+ \nu_e$			
HORACE	4.39341 (16)	4.32186 (17)	4.32187 (18)
WINHAC	4.39328 (13)	4.32286 (10)	4.32273 (08)
δ = (W − H)/W	$-3.0\,(4.7) \times 10^{-5}$	$2.3\,(0.5) \times 10^{-4}$	$2.0\,(0.5) \times 10^{-4}$
$W^+ \longrightarrow \mu^+ \nu_\mu$			
HORACE	4.39340 (16)	4.28255 (16)	4.28326 (16)
WINHAC	4.39336 (10)	4.28837 (08)	4.28848 (08)
δ = (W − H)/W	$-0.9\,(4.3) \times 10^{-5}$	$1.36\,(0.05) \times 10^{-3}$	$1.22\,(0.05) \times 10^{-3}$

C++ Shower-MC Codes

- F77 to C++ transition started 10yrs ago (L.Lonnblad), with infrastructure/tools: **CLHEP, ThePEG**
- **Pythia7** (L.Lonnblad, Sjostrand, M.Bertini)
- **Herwig++** (Gieseke, Stephens, Ribon, Richardson, Seymour, Webber)
- **Sherpa** (Gleisberg, Hoeche, Krauss, Schaelicke, Schumann, Winter)
- First versions (e+e- reactions) released for evaluation for the first time during the Workshop:
  - 1 day of hands-on tutorial for each code

very poor (~0) attendance by "users"

- In any case, this is more than just C++:
  - new shower development algorithms
  - new hadronization models
  - better QCD, better selection of parameters for tuning
  - ThePEG-driven modularity of tools, models, approx's
- These tutorials are documented and accessible via the WG Agenda page