Simulation setup for (top) physics at CMS and implications for measurements

- a somewhat personal view -

Part I: experiences beyond PYTHIA in the top sector

- introduction
- hard process generation
- generation setup for the CMS PTDR and beyond

Part II: thoughts on theory systematics (mostly top related)

- default parameters (AKA tunes): what and why?
- a long list of question marks…

Concluding: (my) desiderata for 2007

Roberto Chierici
IPN Lyon

CERN, Common tools and method meeting, March 2007

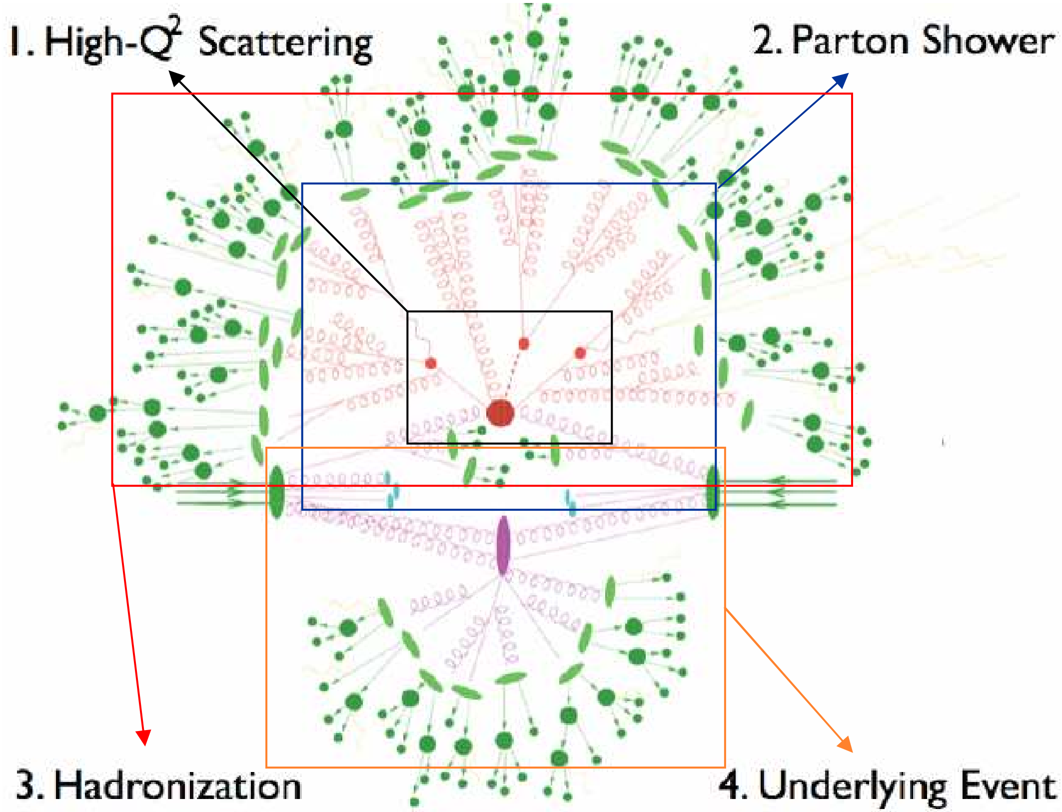
Part I: Simulate this !

- simulation setup so far
- CMS (little) experience with modern event generators

Our generation strategy (list of desiderata)

Possibility of extra partons generation at the highest possible order. Matching needed. Spin correlation in decays needed.

Interface to PYTHIA needed.
HERWIG very desirable.
Tuning will be needed.



Interface to PYTHIA needed.
HERWIG very desirable.
Tuning will be needed.

PYTHIA MPI. HERWIG/JIMMY desirable.
Tuning will be needed.

+ output in LH format, new physics in with minimum effort, support…

Modern event generation strategy

No generator adequately reproduces the physics processes for the whole CMS program

Essential to understand which techniques are applicable to which kinematic regime.

- Parton Shower: infinite serie in α_S keeping only singular terms (collinear approx.):
  - Excellent at low p_T, with emission at any order, simple interface with hadronization
  - Large uncertainties away from singular regions
  - To be used for soft (compared to signal scale) jets.
- Fixed order matrix elements: truncated expansion in α_S
  - Full helicity structure to the given order
  - To be used for hard (compared to signal scale) jets.

Modern event generators:

- Specialized tools for calculating higher fixed orders plus matching techniques
- Hard sub-process increasingly handled by separate ME codes (LO … N^nLO)
- Need universal interfaces and standards (e.g. the Les Houches (LH) Accords)

High jet multiplicity events are bound to be better described with ME.
For top physics at the LHC this choice is mandatory. Especially for backgrounds.

Event Generation is more complex and can become very time consuming
$\rightarrow$ think in advance
$\rightarrow$ adapt the production environment

Status in CMS so far

Completely new software architecture in CMS after the PTDR effort (1 year ago).

Already interfaced generators: 3 "general purpose" event generators:

- PYTHIA → direct interface exists
- HERWIG → direct interface exists
- SHERPA → indirect interface exists (through HepMC file)

And many others:

- ALPGEN (still via input files, full integration soon)
- MadGraph: need to port matching (soon)
- Phantom, via the common LH interface
- MC@NLO: special case.

  LO counter-terms only done with HERWIG. Cannot be interfaced with PYTHIA yet.
  On the other hand HERWIG needs JIMMY (MPI) for a decent UE description.
  → It will be difficult to interpret any study done after simulation

Structure of GeneratorInterface in CMSSW:

From F.Moortgat

GeneratorInterface /	Interface	Status
	Pythia6Interface	+
	Herwig6Interface	+
	Pythia8Interface	-
	Herwig++Interface	-
	HydjetInterface	-
	TopRexInterface	+
	MC@NLOInterface	+
	ALPGENInterface	+
	MadGraphInterface	+
	CompHEPInterface	+
	…	

All our practical experience in modern generation for the PTDR focused on ALPGEN.
(still the practice of using PS as representative in the multi-jet regime is hard to die)

Now we propose a more articulate plan for SM processes (Madgraph, MC@NLO,…)

ALPGEN

M.Mangano et al.

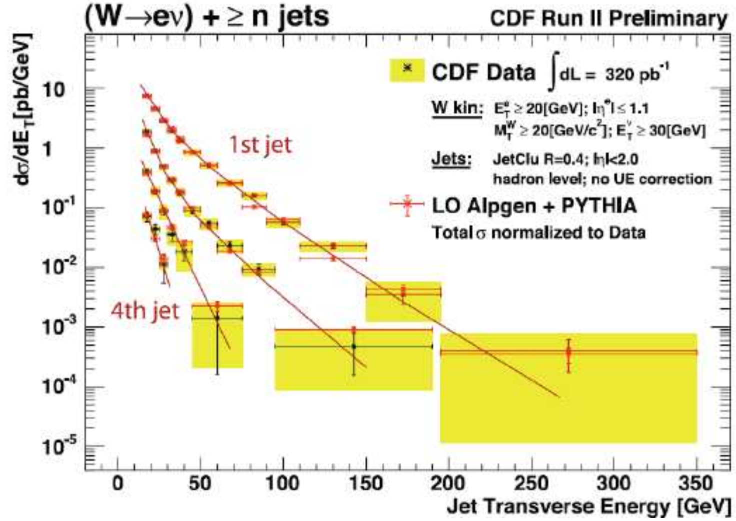
Fixed order matrix elements (tree level) for all SM processes we may need, up to 8 partons in the final state:

- ☞ bosons(W/Z/H/γ)+jets, multi-bosons+jets, heavy quarks(t,b,c)(+bosons)+jets
- ✥ ALPGEN does keep top spin correlations
- ✥ interfaced to PYTHIA

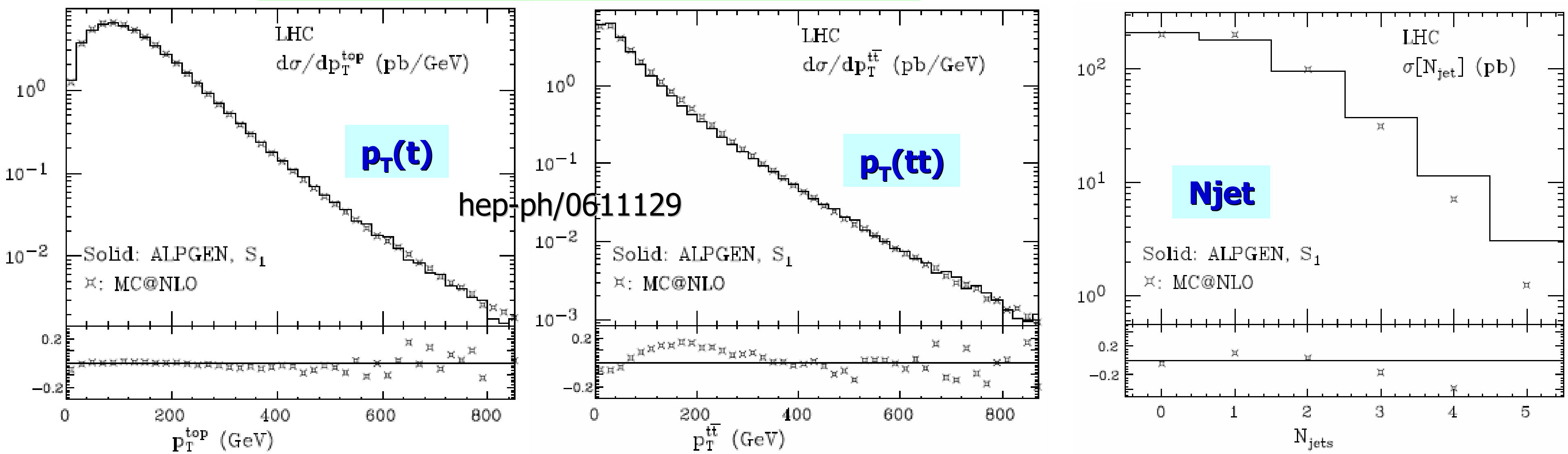
+Large-ish experience already in CMS

- Maybe the only modern generator in which there is experience in CMS
- Large full sim production never launched

Validation of ALPGEN with data



Validation of ALPGEN with MC@NLO (after PS)

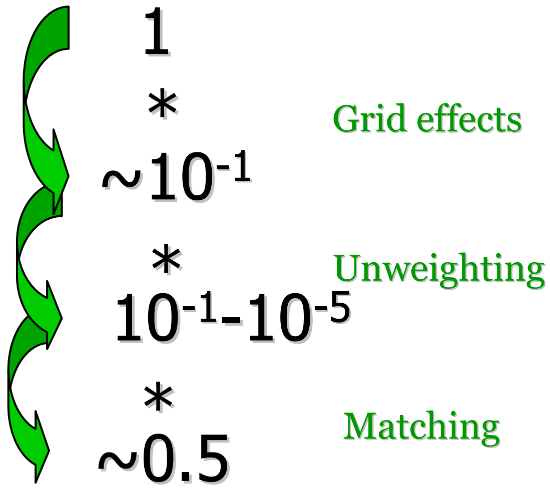


hep-ph/0611129

The ALPGEN generation

Big effort was needed to produce the ALPGEN samples

- sample the phase space for the individual hard process
  (create the so-called phase-space grid)
  do it once and for all for subsequent use in large production
- create weighted events
- un-weight the stored events
- process the events through shower evolution (PYTHIA)
  (needed for the shower evolution and hadronisation part)
- event matching



Adapted version of CRAB (CMS interface to GRID resources) has been developed for full production

- from overall efficiency get an idea of events required for the wanted
  event yield, as a function of the jet multiplicity bin
- get an idea of the CPU needed, split the jobs in a smart way over the grid
- generate remotely weighted, unweighted, matched events
- retrieve everything as a .tgz file on CASTOR

Using the events

ALPGEN v2.01+PYTHIA 6.227

Parton level cuts

- p_T>20 GeV/c, |η|<5, ΔR(parton-parton)<0.7

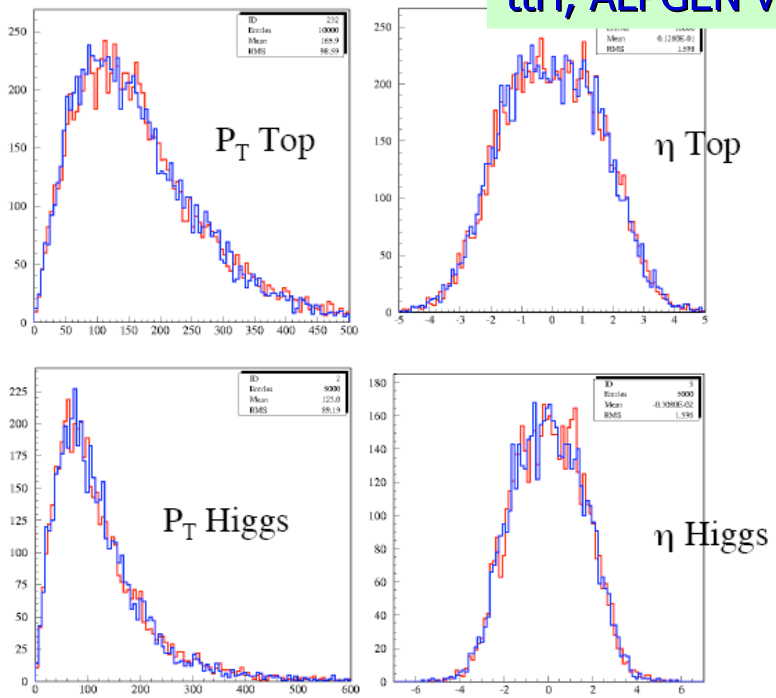
Normalization

- normalize each sample to the matched cross-section, add all samples
- normalize to best calculation of the process *with same cuts and definitions* (typically NLO)
- what about normalization to data?

Events were used in the PTDR for background and systematics studies at fastsim level

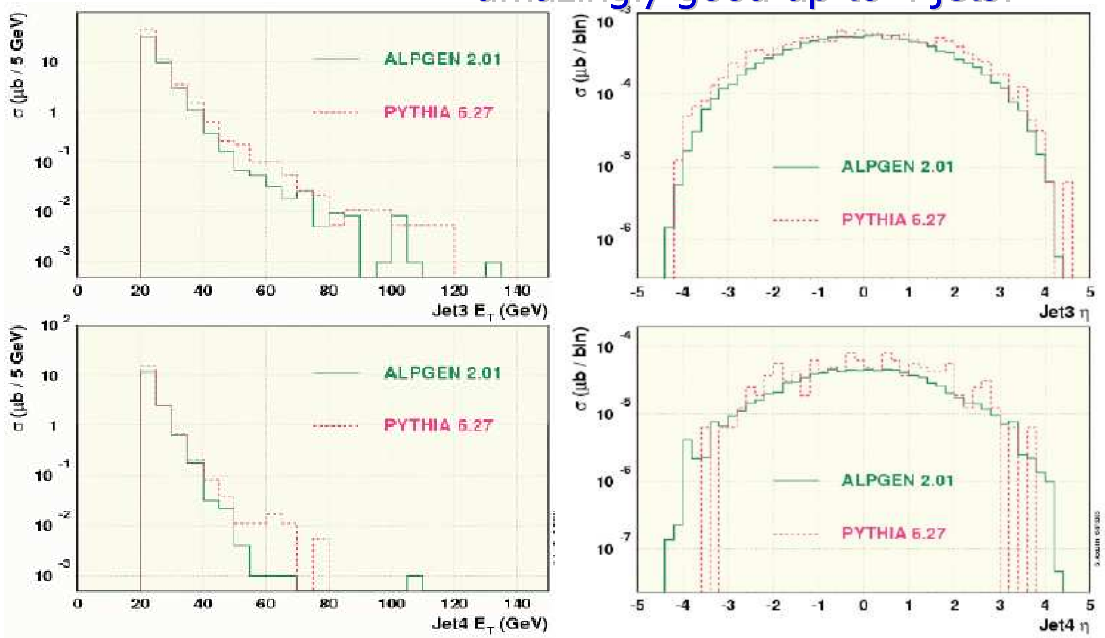
- not enough !

ttH, ALPGEN vs CompHEP fast sim.



QCD, ALPGEN vs PYTHIA fast sim.

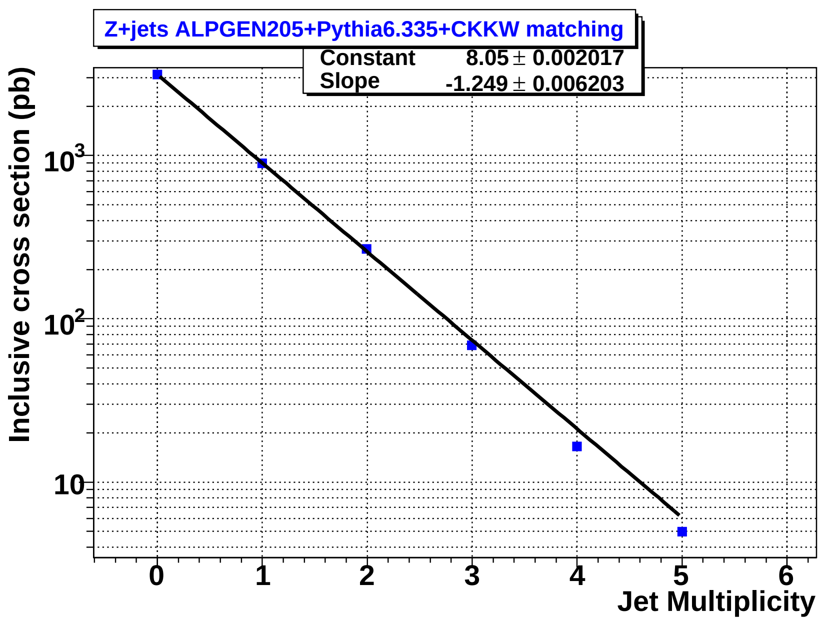
amazingly good up to 4 jets!

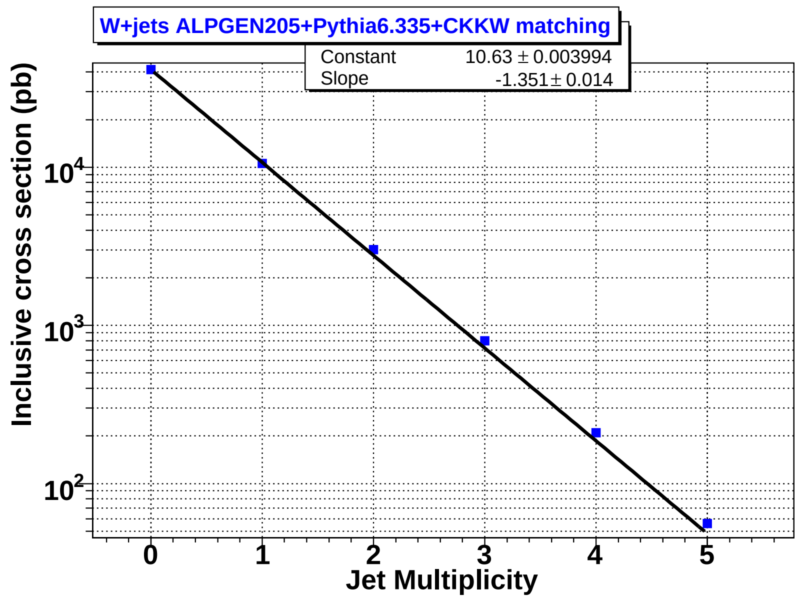


Status for the CMS PTDR (no fullsim)

Z + N jets	σ / [pb]	# of events	Lint / [fb^{-1}]
Z + 0 j (excl)	2436	3.300.000	1
Z + 1 j (excl)	670	2.900.000	4
Z + 2 j (excl)	230	2.300.000	10
Z + 3 j (excl)	66	643.000	10
Z + 4 j (excl)	17	170.000	10
Z + 5 j (excl)	4	40.000	10
Z + 6 j (incl)	3	50.000	16

W + N jets	σ / [pb]	# of events	Lint / [fb^{-1}]
W + 0 j (excl)	30000	3.500.000	0,1
W + 1 j (excl)	8000	incoming	
W + 2 j (excl)	2500	2.865.000	1,1
W + 3 j (excl)	722	523.500	0,7
W + 4 j (excl)	174	159.000	0,9
W + 5 j (excl)	45	incoming	
W + 6 j (incl)		incoming	





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Status for the CMS PTDR (cont)

Dibon + N jets	σ / [pb]	# of events	L_{int} / [fb^{-1}]
WW + 0 j (excl)	5,0	200.000	40
WW + 1 j (excl)	2,6	90.000	35
WW + 2 j (excl)	1,2	15.000	12
WW + 3 j (incl)	1,7	17.000	10
WZ + 0 j (excl)	1,1	40.000	36
WZ + 1 j (excl)	0,8	40.000	52
WZ + 2 j (excl)	0,4	20.000	49
WZ + 3 j (incl)	0,7	7.000	11
ZZ + 0 j (excl)	1,2	40.000	33
ZZ + 1 j (excl)	0,6	20.000	33
ZZ + 2 j (excl)	0,2	7.500	31
ZZ + 3 j (incl)	0,3	10.000	36

tt + N jets	σ / [pb]	# of events	L_{int} / [fb^{-1}]
tt + 0 j (excl)	190	3.356.000	18
tt + 1 j (excl)	170	3.259.500	19
tt + 2 j (excl)	100	331.500	3
tt + 3 j (excl)	40	125.000	3
tt + 4 j (incl)	61	186.000	3

WW + N jets
- both bosons decay leptonically

WZ/ZZ + N jets
- first boson decays inclusively, second one leptonically

tt + N jets
- top decays inclusively

cuts at generator level:
- jet $p_T > 20$ GeV
- $\Delta R_{jj} > 0.7$
- $|\eta| < 5.0$

25M events so far: 8 TB on castor

That is not enough: recent production request

Process	N	final state	σ (pb)
W+N jets	(N=0,1,2,3,4,5,6+)	W→ℓν	40000 [a]
Z+N jets	(N=0,1,2,3,4,5,6+)	Z→ℓℓ, νν	3500 [a]
WW/WZ/ZZ+N jets	(N=0,1,2,3+)	WW→ℓνℓν	11 [a]
		ZZ→ℓℓX	3 [a]
		ZW→ℓℓX	5 [a]
tt+N jets	(N=0,1,2,3,4+)	tt→X	560 [a]
Z+bb+N jets	(N=0,1,2,3,4+)	Z→ℓℓ, νν	9 [c]
W+bb+N jets	(N=0,1,2,3,4+)	W→ℓν	100 [a]
N jets	(N=4,5,6+)		5000000 [b]
bb+N jets	(N=1,2,3,4,5,6+)		600000 [b]
t+N jets	(N=0,1,2+)	t→bℓν	114
W+Mc+N jets	(N=0,1,2,3,4+; M=2)	W→ℓν	400?
Z+Mc+N jets	(N=0,1,2,3,4+; M=2)	Z→ℓℓ, νν	8 [c]
bbbb+N jets	(N=0,1,2,3,4+)		800 [b]
γ+N jets	(N=1,2,3,4,5,6+)		<200? [b]
γγ+N jets	(N=1,2,3,4,5,6+)		180 [a]
ttbb+N jets	(N=0,1,2,3,4+)	tt→ bℓνX	3 [b]
WWW(Z)/ ZZZ(W)+N jets	(N=0,1,2,3,4+)	WiWjWk→ℓℓX	?
W+Mc+N jets	(N=0,1,2,3,4,5+; M=1)		700 [b]

ℓ=e,μ,τ

Need, for SM processes, of a complete (all main processes) and coherent (same cuts and IPS) production

Huge cross-sections: need dedicated biasing studies first... (N jets, bb+N jets)

(a) approximate, our biasing from ALPGEN runs
(b) approximate, ALPGEN manual with ALPGEN biasing
(c) from NLO calculations

Comments on biasing and cuts

Biasing important for all our samples

- uniformity among different samples

Make sure we do not leave out important parts of the detected phase space

- having inclusive cuts – all partons/jets with $p_T > p_{Tcut}$ or $|\eta| < |\eta|_{cut}$ – does not make any good
- serious risk of not simulating large part of the acceptance
- can we reproduce the trigger thresholds? Looser to account for resolutions…

Biasing becomes crucial for high cross-section ones.
For top, and many jet physics in general, QCD background is essential:

- Njets, N>3
- bbNjets, N>0 (comparable to tt semileptonic if fake lepton rate from b = 0.1%)
- bbbbNjets (larger than tt itself !)

This is exactly the kind of background where we need ALPGEN or equivalent

MadGraph/MadEvent

F.Maltoni, T.Stelzer et al.
CMS interface: D.Kcira

MadGraph: multipurpose tree-level matrix element creator

- Given any process, automatically generate amplitudes and mappings for integration over PS

MadEvent: multipurpose tree level event generator

- Process dependent information from MG is packaged into ME and code is produced that can calculate cross sections and generate unweighted events
- Outputs events in the LH format

Can do any SM or BSM model up to 6 partons, together with the backgrounds

Very easy to plug in new models in the infrastructure. Need to know Feynman rules, couplings, estimates for masses

Same framework (cards / interfaces) for BSM physics and SM backgrounds

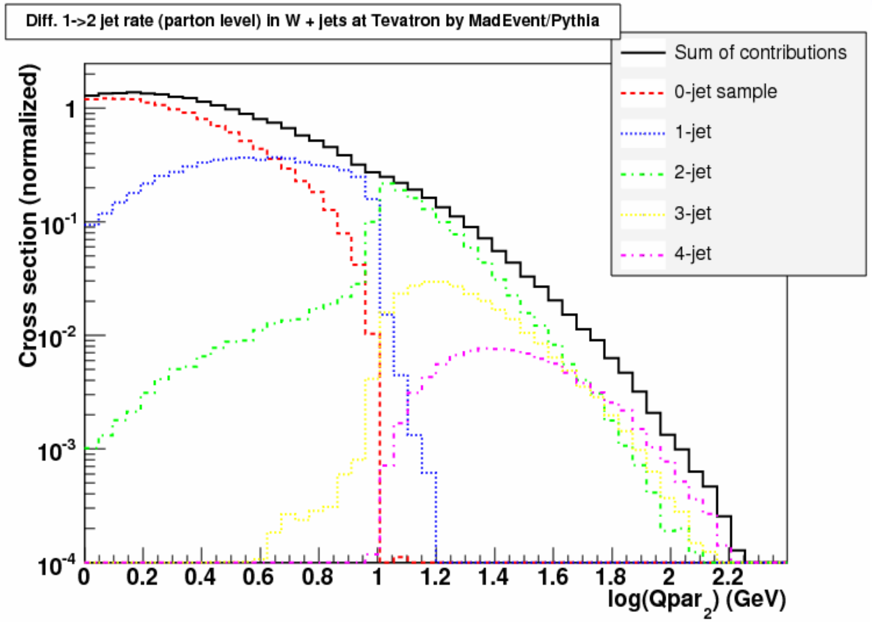
What is nicely in:

- All SM, Higgs included (all spin correlations accounted for)
- CP and R conserving SUSY
- General 2HDM, with FCNC and CP violation
- User defined models ! (already available: technicolour, HET, heavy resonances, ED)
- Interface with PYTHIA. HERWIG interface exists.

Web server oriented interface available

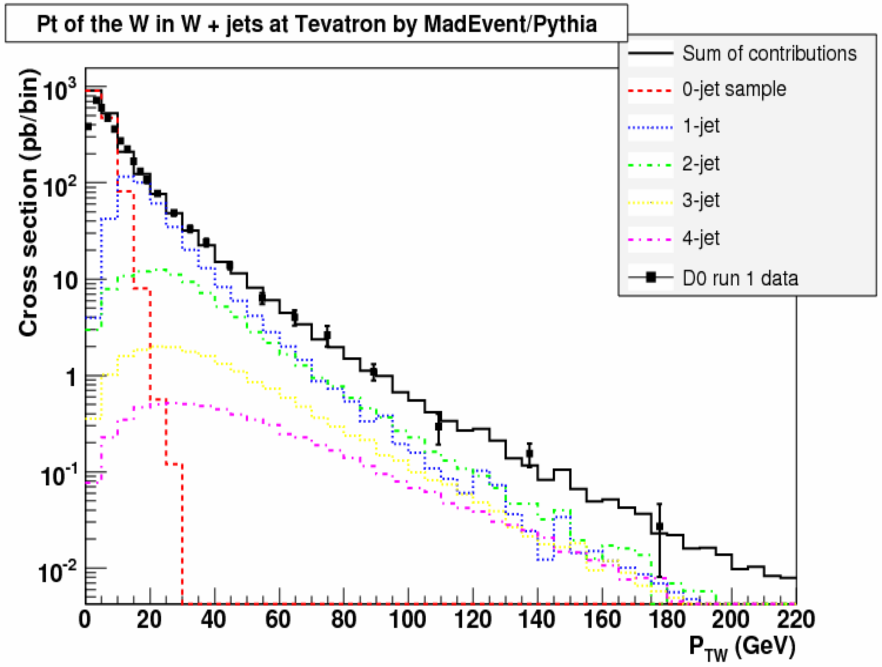
- Can perform the code generation or even the event generation remotely

Madgraph vs data



- Madgraph matching almost there:
  - Hybrid between CKKW and MLM
  - (W+)1->2 jet rates transition for W+jets at Tevatron shows smooth behaviour.
  - Different diagrams dominant in different regions of Qpar2 (k_T algorithm distance)
  - Clear cut around 10 GeV between 1 and 2 jet final states (Tevatron definition)

- Transverse momentum of W in W+jets at Tevatron (D0)
- MadGraph + parton showers and hadronization of Pythia gives very good description of data



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Thanks to J.Alwall, D.Kcira

Other tools:

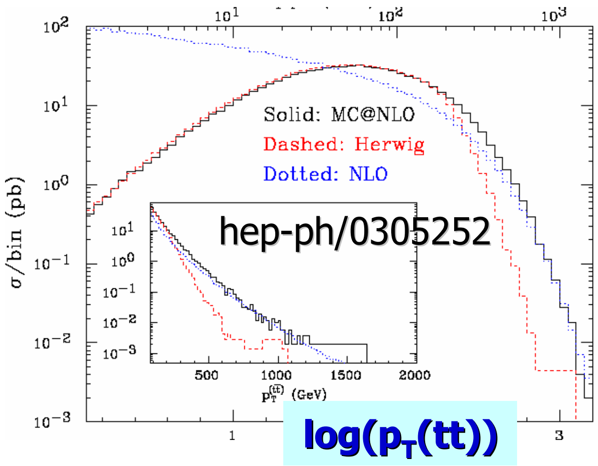
CompHEP

E. Boos et al.

- Generates code on the basis of symbolic calculations
- Specialized generations like single top tq with automatic matching 2→2 2→3
- Interfaced with CMSSW
- Cannot handle large hard emissions (max 2→5?)
- No helicity method (slower)
- Valid alternative to crosscheck ALPGEN…

MC@NLO

S.Frixione, B. Webber



- First hard emission correct.
- Best tool to use if not sensitive to many jets topologies.
- Right tool for calculating NLO cross-section with cuts (analytical ways sometime harder)
- It misses important leading terms in many hard emission topologies
- Only with HERWIG (so far…)
- We should use it, at least once in our (CMS) life. The sooner the better.

Phantom

A. Ballestrero et al.

- 6f generator. All diagrams in.
- Top width effect fully included. All 6f interference terms included.
- Useful when off-resonance, as a crosscheck and maybe more?
- Output in LH format, interfaced in CMSSW already (I believe)
- Cannot handle more than 6f
- I believe some analyses (especially those cutting away top) should really keep an eye on it and use it !

Part II:
The realm of systematic errors

- systematics due to modeling
- how to best use data
- questions, questions, questions…

Systematics

Most of SM measurements will be assessments of systematic errors…

Instrumental:

- luminosity, energy calibrations (scale, resolution), alignment, amount of material…

Modelling:

- that is what I will be talking about

Most dangerous if correlated in channels and experiments

- all theory and modeling systematics will

Do not believe this is just a problem for those performing SM physics !

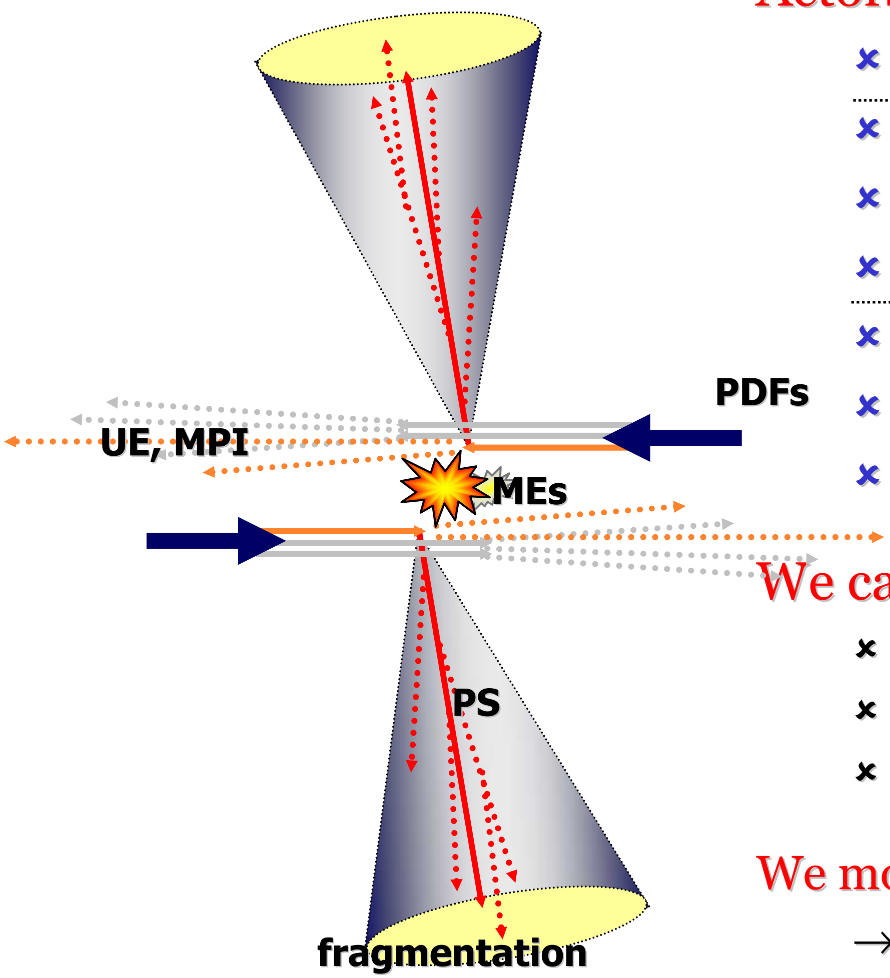
☞ spoil measurements
☞ spoil limits on new physics
☞ fake new physics

The correct (to me) approach:

⌘ aim at common strategies for constraining physics with data, and start preparing them now
- different analyses use same MC and recipes to assess systematics
- different experiments also use same recipes (combinations ahead of us!)

⌘ talk whenever necessary to the other experiment
⌘ talk whenever necessary to theorists

Modeling our ignorance



Actors and their role:

- pdfs
- hard scattered partons
- final state radiation
- hadronization

Jets

- initial state radiation
- multi-parton interactions
- proton/antiproton remnants

UE

We call them differently because of convenience:

- radiation connected to UE and fragmentation
- ISR and FSR interfere
- color connections…

We model most of our description of reality:

$\rightarrow$ Need to quote a confidence on the description of our simulations (systematics)

$\rightarrow$ Avoid non realistic scenarios (ex: FSR OFF)

$\rightarrow$ Avoid to double count errors

PDF tuning $\leftrightarrow$ UE tuning $\leftrightarrow$ radiation tuning $\leftrightarrow$ fragmentation tuning

The top mass case

Errors per experiment* (in GeV)

10 fb^{-1}, low lumi (columns qqbblν, qqbblν (high p_T), bblνlν, σ_{tt})

50 fb^{-1}, high lumi (column qqbblν (+J/ψ))

	qqbbqq	qqbblν	qqbblν (high p_T)	bblνlν	σ_{tt}	qqbblν (+J/ψ)
statistical	0.2	0.1	0.3	0.5	<0.05	0.5
light jet E scale/res	2.0	0.8	<1.0?	-	1.0	negl.
b-jet E scale/res	0.8	0.8	0.6	0.7	1.0	negl.
Lepton E scale/res	-	negl.	?	negl	0.5	0.4
b-tagging	0.3	0	?	0.3?	1.3	-
background	2.0	0.1	0.1	0.1?	negl.	0.2
ISR/FSR	2.3	<1.0?	0.2?	1.0	0.8	0.6
b/q-fragmentation	0.9	0.3	0.1	0.7	1.6	0.7
Underlying Event	0.6	0.3	1.3	?	2.0	0.6
pdfs uncertainty	1.4	0.1	negl.	negl.	3.5	0.3
Total	<3.0?	<2.0?	<2.0?	<2.0?	<4.0?	<1.5?

(*) From the ATLAS PTDR
and the CMS PTDR

Systematics will dominate our measurements
The ones from theory/modelling are very important

Mere comments... and questions

- Description of radiation
- Fragmentation
- Description of UE/MB
- PDFs
- Others

Today: sensitivity to the description of radiation (parton showering):

- vary the parton shower parameters in a sound way instead of switching radiation ON/OFF
- vary Λ_{QCD} consistently in the initial and final state
- vary consistently (initial and final state) the Q^2_{max} for the emission
- sound variations of the corresponding parameters are suggested by the author(s) and by common sense

Warning: changing the radiation will have an effect on the UE as well... try to disentangle the two effects...

Beware: at e+e- PS radiation is fitted with fragmentation, at hadron colliders part of it enters directly in the UE description

→ finding the right balance to use LEP experience at LHC is not easy

Tomorrow: fit radiation to data

- how to disentangle just radiation issues? Which observables?
- Top physics: extrapolating from DY will not work (different initial state, different scale, different color flow)
- Use tt for tt. Same channel or not? How do we treat the fragmentation part? And the UE? Keep it fixed?

Mere comments…

- Description of radiation
- **Fragmentation**
- Description of UE/MB
- PDFs
- Others

(Light jets) fragmentation:

- always said to be universal (use LEP tunings), but:
  1. it depends on the factorization scale (i.e. cutoff of parton showering)
  2. its description depends on the description of the perturbative part (i.e. NLO calculations should imply a new tuning)
  3. Radiation and fragmentation are tuned together at LEP !
- ☆ fragmentation should not be an issue… ? (T. Sjostrand)

  true if jet universality is assumed. But jets are not experimentally universal

Tomorrow's tunings:

- use, as Tevatron does, particle density and multiplicity in QCD events, and transverse fractional momentum in QCD jets.
- is it portable to different event topologies (eg tt??). Detector effects?
- the use of both PYTHIA and HERWIG tunes will help understand systematics

b-fragmentation (particularly relevant for exclusive channels):

- in PYTHIA the easiest is to use 'standard' Peterson tunings to evaluate systematic errors (but Bowler or Khartvelishvili are known to be better)
- carefully use LEP tunings !

  SLD: $\varepsilon_b = 55\ 10^{-4}$ **(with no error)**
  ALEPH: $\varepsilon_b = (31 \pm 3 \pm 5)\ 10^{-4}$
  OPAL: $\varepsilon_b = (41 \pm 1 \pm 4)\ 10^{-4}$

  taking the minimum and the maximum of these numbers is not correct

- more precise (analytic) calculations of the perturbative part (re-summation of large logs) are not part of our MC generation.

Mere comments…

- ✦ Description of radiation
- ✦ Fragmentation
- ✦ **Description of UE/MB**
- ✦ PDFs
- ✦ Others

MB = generic single particle-particle interaction
UE = everything in the collision except the hard process (MB+ISR+FSR+MPI+B.R.).

The physics of the underlying event is poorly understood:

- ✦ It pollutes all the analyses
  - important for the tuning of the selection (especially isolation criteria)
  - the UE event is correlated with the interesting high p_T event
- ✦ switching ON/OFF MPI is not motivated
- ✦ CDF PYTHIA tune A (like any other UE tuning at Tevatron) should (must) not be used, the parameters strongly depend on energy
- ✦ the evolved tunings at the LHC (Jimmy/PYTHIA) differ by factors !

UE/MB tunings today:

- ✦ Use dedicated ATLAS tuning, also with UA5, and dedicated Rick's tunes (DWT or DKT)
- ✦ Only vary the main p_T cutoff for studying the sensitivity to the UE.

UE/MB tunings tomorrow: (Bartalini, Field, Ambroglini, Fano, et al.)

- ☞ MB studies: charged particle distributions and correlations
- ☞ UE studies: charged densities in transverse regions from leading jet and back-to-back jet production. Central region in DY production.

Mere comments...

- Description of radiation
- Fragmentation
- Description of UE/MB
- PDFs
- Others

PDFs today:

- with the Les Houches accord we now can have PDF errors easily without regenerating events
  - vector of weight can be used for reweighing events
  - caution: only NLO PDF have errors, compare them consistently !
- for PTDR: use CTEQxL with PYTHIA for our central measurement, use CTEQxM (NLO) only for our error assessment.
- different PDFs do not even overlap in some regions of the phase space

compare CTEQ vs MRST in analyses expected to be very sensitive to PDFs

PDFs tomorrow:

- use NLO LHAPDF in PYTHIA (controversial now) and consistent tunings
- use data to improve fit. For gluon PDFs top-pair is again essential

Mere comments…

- Description of radiation
- Fragmentation
- Description of UE/MB
- PDFs
- **Others**

Scale

- dependence of the hard process to Q^2 is unphysical
  - don't forget this dependency is also in the PDFs
  - systematic to be assessed ad hoc via different trials
  - sensitivity decreases with HO calculations/generators

b fragmentation again

- b in top decays are colour-connected to the beam remnant
  - beam drag (shift in η of hadrons) and cluster collapse
  - modeling maybe slightly different than a simple adoption of the LEP tunings? By a negligible amount?

Electroweak uncertainties can sneak in

- Thumb rule: NNLO QCD ~ NLO EW

W(+γ)+X: $|\delta_{weak}|$=5% (p_T=50 GeV) - 25% (p_T=500 GeV)

W(+γ)+jet+X: $|\delta_{weak}|$=5-15%

WW(+γ)+X: $|\delta_{weak}|$=5-25%

tt+X: $|\delta_{weak}|$< 10%

bb+X: $|\delta_{weak}|$< 2%

How do we put all together? Thinking loud…

I am confused. Looking for convincing answers…

- most probably it is better if LHC uses its own data for tunings. How?
- let us start from UE and MB. Part of the radiation parameters will be fitted together.
- how do we tune the rest of radiation?
  - → is this universal (ie can we take some other's tunings)? Detectors effects?
  - → radiation tuning dependent of the physics channel we are interested in. Awkward.
  - → is there a way to perform an inclusive tuning UE+radiation(+fragmentation)
  - → is there any automatic(ed) fitting procedure in place?
- fragmentation. Is factorization universal?
  - → at first order don't take LEP tunes. Tune it ourselves. Just simple QCD?
  - → same comments as for radiation. Dependence on the jet multiplicity?
  - → can LHC contribute to the b fragmentation tuning? It probably should
- general: we tune plain PYTHIA, do we? If so, how does this apply to PYTHIA as a PS on top of something else?
  - → a tuning for every kind of hard process generator?
- PDF. Top-pair very useful for constraining the gluon pdfs.
  - → is any dependence on all above a second order effect?
- go back to the beginning, in case we suspect there is new physics behind
  - → what are the best obervables?

Desiderata (somewhat personal)

1. Converge soon on solid MC choices

Spend 2007 in (among many other things) preparing the generation and analyses setup to understand physics as soon as data will arrive.

Desiderata – a personal view

Start focusing on a modern event generation for everything concerning hard process ALPGEN and MadGraph to start with in CMS

Learn about missing tools (MC@NLO, JIMMY for HERWIG) and new ones (power showers in PYTHIA, SHERPA...)

2. Converge on a detailed strategy for MC tuning in a wide sense

Answer to most important questions about the best use of data in tuning MC+models
- ☞ which data, which observable, which parameter, which tuning sequence

3. Learn and talk. More learn than talk.

The Tevatron experience is invaluable. Let us learn from them.
Build a cooperative TH-EXP community on these subjects
Cooperate between experiments (ATLAS and CMS). We should not feel in competition for what concerns the understanding of physics.

UE tunes

PYTHIA 6.2 CTEQ6L

Fits run I CDF UE
Fits run II CDF UE

Fits run I CDF UE
Fits run II CDF UE
Fits run I Z pT

As DW, use the same MPI s dependence as the ATLAS tune

UE Parameters

ISR Parameters

Intrensic KT

Parameter	Tune A	Tune DW	Tune DWT	ATLAS
MSTP(81)	1	1	1	1
MSTP(82)	4	4	4	4
PARP(82)	2.0 GeV	1.9 GeV	1.9409 GeV	1.8 GeV
PARP(83)	0.5	0.5	0.5	0.5
PARP(84)	0.4	0.4	0.4	0.5
PARP(85)	0.9	1.0	1.0	0.33
PARP(86)	0.95	1.0	1.0	0.66
PARP(89)	1.8 TeV	1.8 TeV	1.96 TeV	1.0 TeV
PARP(90)	0.25	0.25	0.16	0.16
PARP(62)	1.0	1.25	1.25	1.0
PARP(64)	1.0	0.2	0.2	1.0
PARP(67)	4.0	2.5	2.5	1.0
MSTP(91)	1	1	1	1
PARP(91)	1.0	2.1	2.1	1.0
PARP(93)	5.0	15.0	15.0	5.0

Tune to:

- N(ch)
- <Pt(ch)>
- PtSum(ch)
- Z-boson Pt
- ...

R. Field

The matching: a main actor

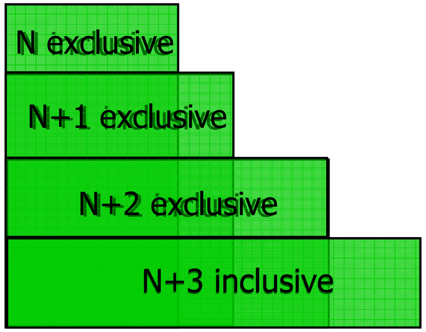
A long-standing problem in MC generation: how to match PS and ME?

- Cutoff? How? Where?
- How to avoid double counting? (ME_N+PS has parts of ME_{N+1}+PS)

Techniques to match up to one additional hard jet exist in PYTHIA, HERWIG, MC@NLO, still this does not solve the problem in a general problem for multi-jet topologies

MLM

1. ME_N+PS
2. ME_{N+1}+PS
3. ME_{N+2}+PS
4. ME_{N+3}+PS



- (cone-)cluster showered event → njets
  - match partons from the ME to the clustered jets
  - if all partons are matched, keep event. Else discard it.

☞ Works independent of the generation procedure…

CKKW

ME for $p_T > p_{Tcut}$, PS for $p_T < p_{Tcut}$

$[ME_N | p_T > p_{Tcut}] * W_{veto}(p_{Tcut}) + PS(p_T < p_{Tcut})$

$[ME_{N+1} | p_T > p_{Tcut}] * W_{veto}(p_{Tcut}) + PS(p_T < p_{Tcut})$

…

$[ME_{Nmax} | p_T > p_{Tcut}] * W_{veto}(p_{Tcut}) + PS(p_T < p_{Tcut})$

- W_{veto} (<1) is the probability that no parton shower emission happened above p_{Tcut}.
- Computed using clustered 'parton shower histories' on the ME final states
- Gets rid of double counting…

Beware: PS(today) ≠ PS(yesterday). Tunings need to adapt to the choice of the matching

Constraining pdfs at the LHC

How? For an s-channel process (W, Z, W/ZW/Z, tt) $m^2 = s x_1 x_2$ and $y = 1/2 \ln(x_1/x_2)$

$$\frac{dN_X}{dy} = \frac{d\sigma_{qq,gg\to X}}{dy} \bullet L \bullet pdf_{qq,gg}(x_1, x_2; Q^2)$$

$\Rightarrow x_{1/2} = e^{\pm y}\, m/\sqrt{s}$

From the shape of y differential cross-sections we can constraint different pdfs

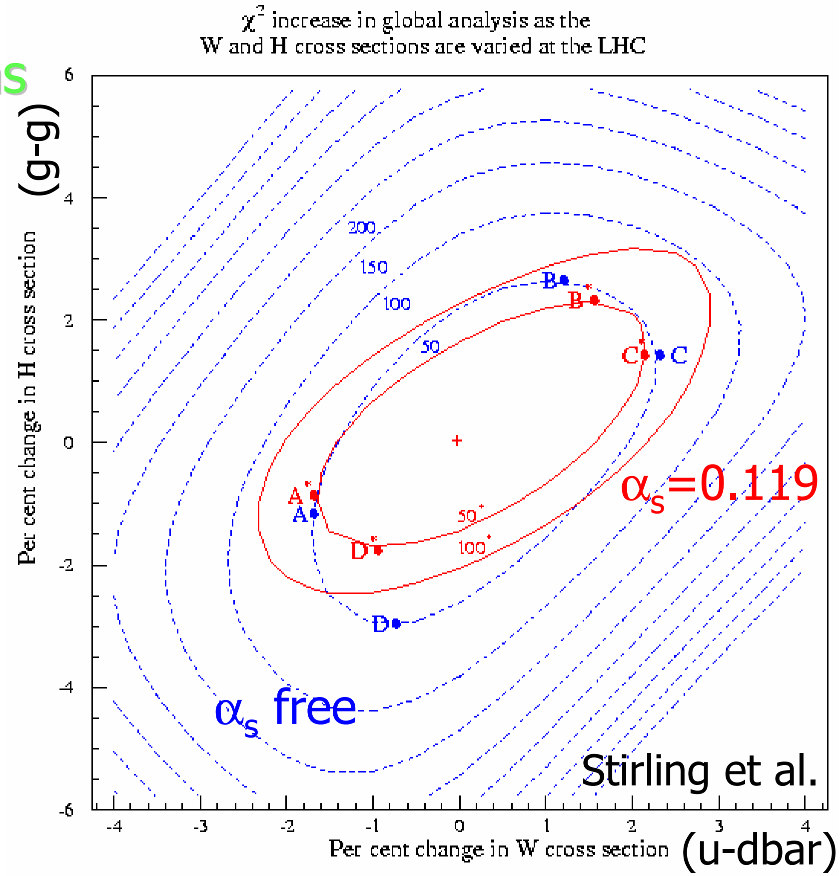
(one can measure L•pdf)

⇒ Single W, Z, W/ZW/Z can bring info on regions of x close to tt production
  (q-antiq x range between 3 10^{-4} and 0.1)

⇒ γ or Z+jet can help in the q-g case
  (g x range between 5 10^{-4} and 0.2)
  ($x_{b,c}$ range between 10^{-3} and 0.1)

⇒ W+jet can help for x_s

⇒ $d\sigma/dy(W^-)/d\sigma/dy(W^+) \approx d(x_1)/u(x_1)$ at large y



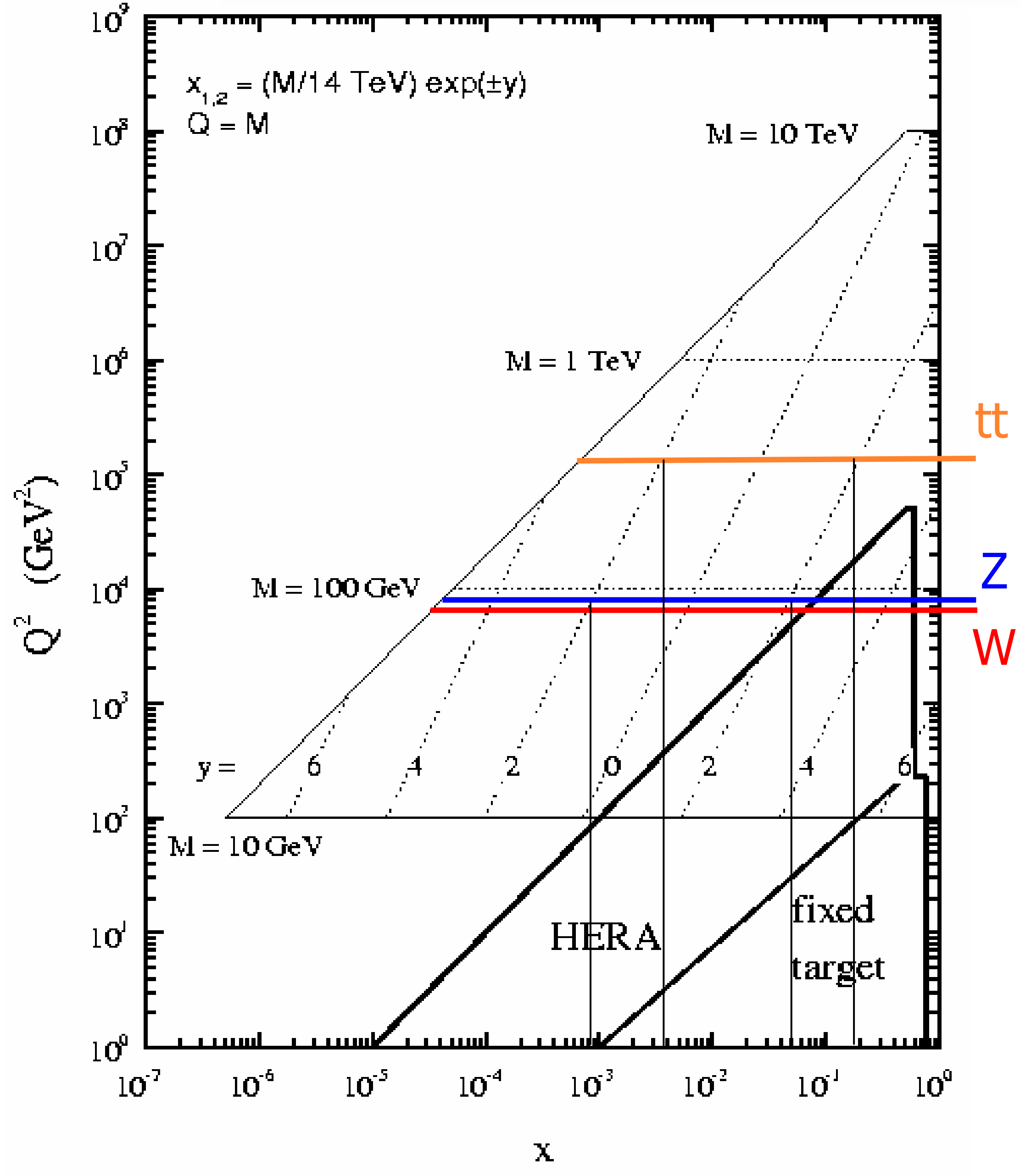
⇒ All the high Q^2 region is covered !

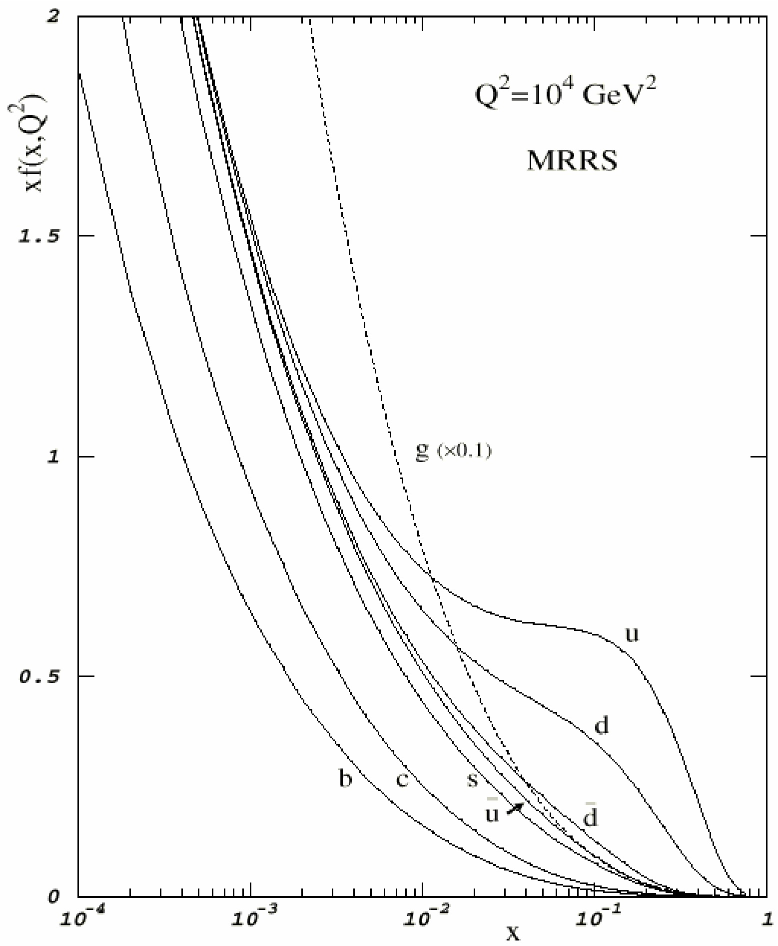
A few % on g and light quarks -syst. » stat.

And 5-10% on s, c, b might be reached

To which extent can we extrapolate from q-q ↔ g-g?

LHC parton kinematics





Mere comments...

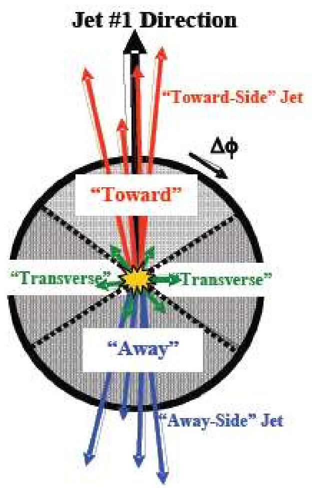
(Bartalini, Field, Ambroglini, Fano, et al.)

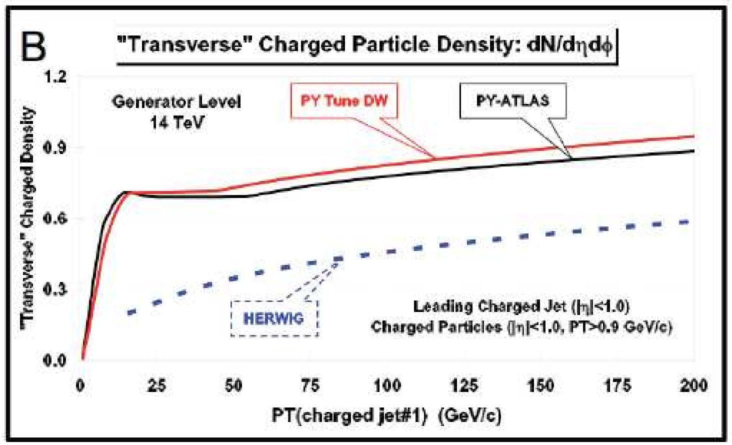
- Description of radiation
- Fragmentation
- **Description of UE/MB**
- PDFs
- Others

Strategy for tuning in place and established at Tevatron:

☞ Min-Bias Studies: Charged particle distributions and correlations. Construct "charged particle jets" and look at "mini-jet" structure and the onset of the "underlying event". (requires only charged tracks)

☞ "Underlying Event" Studies: The "transverse region" in "leading Jet" and "back-to-back" jet production. The "central region" in Drell-Yan production. (requires charged tracks and calorimeter and muons for Drell-Yan)





☞ Drell-Yan Studies: Transverse momentum distribution of the lepton-pair versus the mass of the lepton-pair, $<p_T(\text{pair})>$, $<p_T^2(\text{pair})>$, $ds/dp_T(\text{pair})$ (only requires muons).

Settings

'PMAS(5,1)=4.8 ! b quark mass`
'PMAS(6,1)=172.3 ! t quark mass',
'MSTJ(11)=3 ! Choice of the fragmentation function',
'MSTJ(22)=2 ! Decay those unstable particles‘
'PARJ(71)=10 . ! for which ctau 10 mm‘
'MSTP(2)=1 ! which order running alphaS‘
'MSTP(33)=0 ! no K factors in hard cross sections‘
'MSTP(51)=7 ! structure function chosen CTEQ5L‘
'MSTP(81)=1 ! multiple parton interactions 1 is Pythia default‘
'MSTP(82)=4 ! Defines the multi-parton model‘
'MSTU(21)=1 ! Check on possible errors‘
'PARP(82)=1.9 ! pt cutoff for multiparton interactions‘
'PARP(89)=1000. ! sqrts for which PARP82 is set‘
'PARP(83)=0.5 ! Multiple interactions: matter distrbn parameter‘
'PARP(84)=0.4 ! Multiple interactions: matter distribution parameter‘
'PARP(90)=0.16 ! Multiple interactions: rescaling power‘
'PARP(67)=1. ! amount of initial-state radiation‘
'PARP(85)=0.33 ! gluon prod. mechanism in MI‘
'PARP(86)=0.66 ! gluon prod. mechanism in MI‘
'PARP(87)=0.7 ! ‘
'PARP(88)=0.5 ! ‘
'PARP(91)=1.0 ! kt distribution'