MCWS

Workshop sui Monte Carlo, la Fisica e le Simulazioni di LHC

- Organizers: V. del Duca, B. Mele, P. Nason, G. Polesello (ATLAS), R. Tenchini (CMS)
- Conveners: S. Frixione, F. Piccinini, B. Mele, P. Azzi, M. Cobal, G. Tartarelli, C. Mariotti, Livio Fanó, F. Fabbri, E. Migliore.
- Scientific Committee: V del Duca, G. Polesello, S. Frixione, A. Ballestrero, F. Piccinini, S. Catani, P. Marchesini, B. Mele, A. Romanino, R. Tenchini, C. Corianó, F. o Zwirner, M. Mangano, A. Strumia, G. Passarino, G. Altarelli, G. Giudice, R. Rattazzi, A. Vicini, G. Isidori, V. Vagnoni, P. Ciafaloni, P. Azzi, G. Graziani, G. Montagna, F. Fabbri, E. Migliore, M. Monteno.

- Scope: INFN (italian)
- Purpose: to bring together LHC experimental physicists, collider phenomenologists, BSM physicists, in order to
  - Promote better understanding of LHC physics problems
  - Favour better cohesion among the TH and EXP communities
  - Develop a common language in preparation of LHC physics
- 2006: 3 meetings
- Several presentations with introductory character
- Next goal: collect the presentation in a document, to be use as introductory reading for people interested into LHC physics.
  The document should be readable by LHC experimentalists, collider physics phenomenologists, and BSM phenomenologists (i.e. should be clear, avoid or explain acronyms, focus upon relevant issues, avoid technicalities: heavy internal refereeing). Useful also for students.

Highlights

See also:

→ http://www.le.infn.it/mcws (web page of the conference)

→ http://moby.mib.infn.it/~nason/mcws1(2,3) (transparencies)

Few comments and selected topics from

- Shower MC
- Matrix Elements
- Physics
- Experimental studies

plus some more comments on the workshop achievements

Shower Monte Carlo

Past Italian involvement in SMC's:

Odorico's COJETS, Marchesini and Webber's HERWIG

Today: some involvement in HERWIG (Corcella, S. Moretti)

However: important involvement in new development:

- Matching ME with Shower MC's: Catani, Krauss, Kühn, Webber (presented by S. Catani at the meeting), used in Sherpa
- The matching method used in ALPGEN (MLM matching)
- MC@NLO: Frixione, Webber; recent addition: single top production
- POWHEG: P.N. 2004, Ridolfi and P.N. for ZZ production

Besides these topics (and an elementary introduction, P.N.), at the workshop:

- Specific SMC issues: Minimum Bias, Underlying Event (P. Bartalini)
- Jet corrections (A.Giammanco, D.Benedetti,A.Santocchia)
- Jet definition (M. Cacciari, "Algoritmi di Cono e k_T, Fastjet, UE")

- Analysis using new tools:

Example: Simulating $H \to WW \to l\nu l\nu$ in CMS

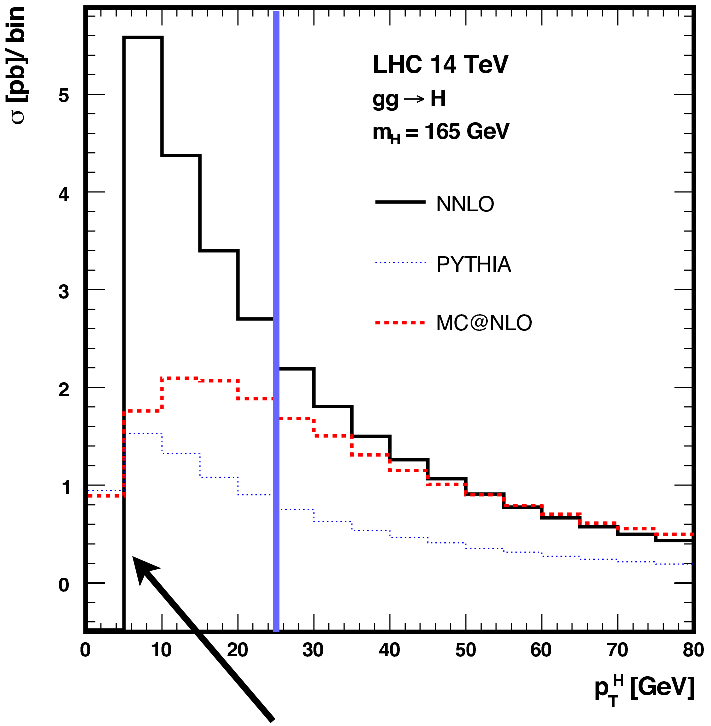
Including new theoretical developments into an experimental analysis

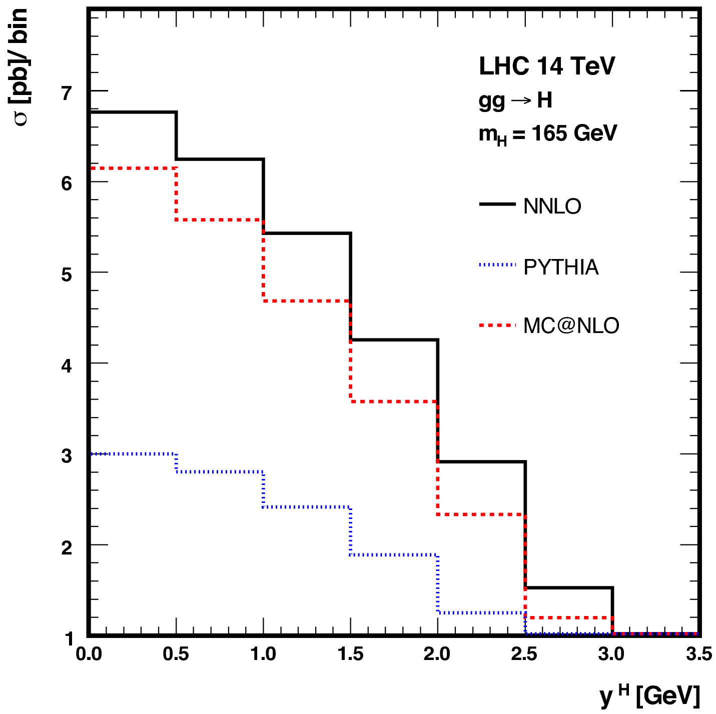
(Presented by A-S Giolo-Nicollerat, CMS, ETH group)

- Two leptons plus missing energy
- Main background: WW, $t\bar{t}$
- Selection based on spin correlations (reduce WW background) and jet veto (reduce $t\bar{t}$ background)

Because of the jet veto, the p_t of the Higgs must be described accurately. Comparison of PYTHIA, MC@NLO, NNLO calculations (Fehip) and NNLL calculation of the p_t spectrum (Grazzini) have been included in the study

Higgs transverse mass and rapidity

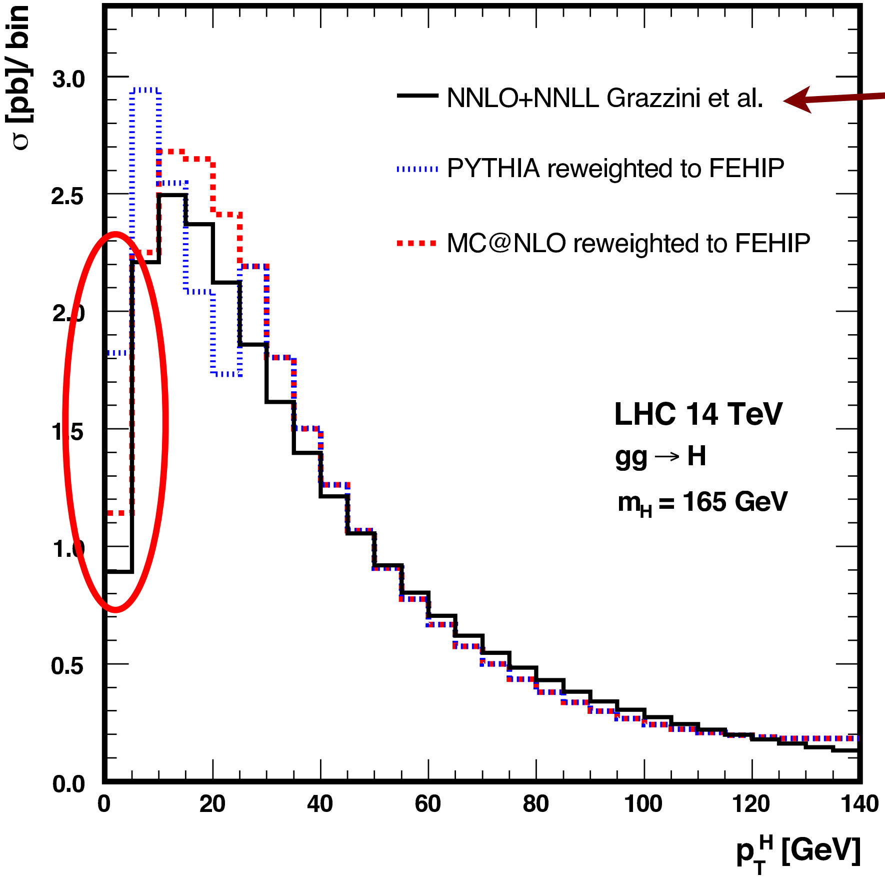




In Fehip, no log resummation
Reweighting: constant K-factor from 0 to 25GeV
rely on parton shower prediction for this region

(No reweighting applied here)

Low p_t(H) description



Compare with calculation including **logarithm resummation** (NNLO+NNLL) Grazzini et al. [hep-ph/0302104] [hep-ph/0508068]

Low p_t region: Still some uncertainty due to different models used

New PS+NLO: POWHEG

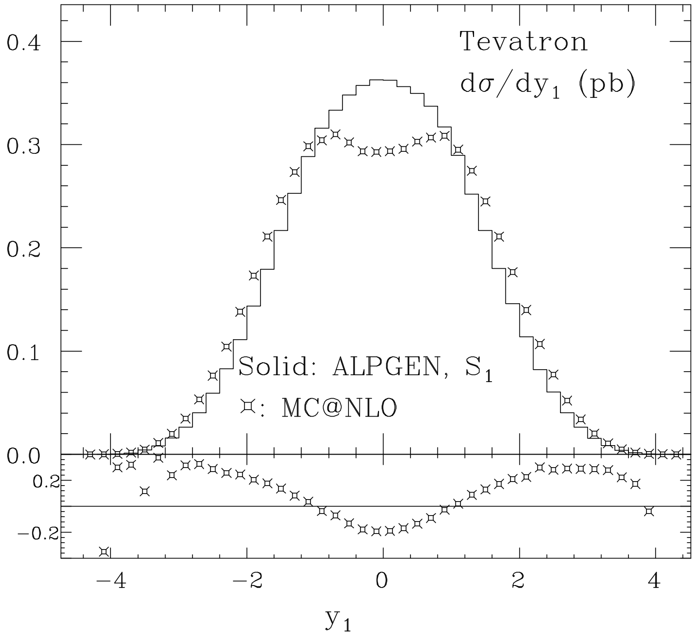
Positive Weight Hardest Emission Generator

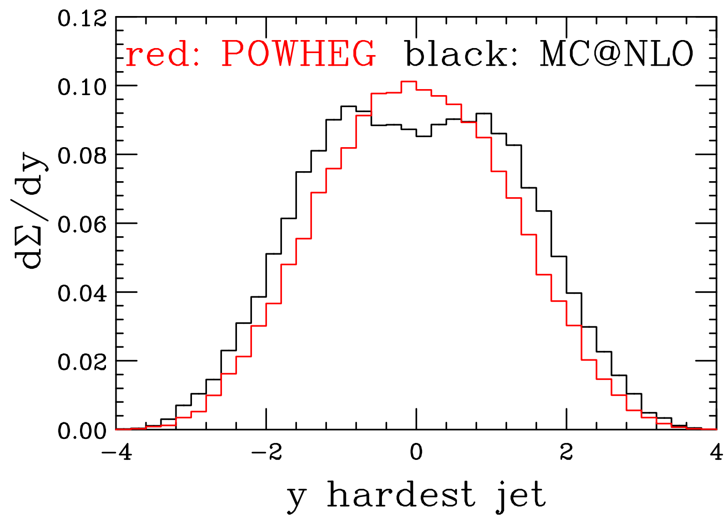
Method to generate the hardest emission first, with NLO accuracy, and independently of the SMC (P.N. 2004).

- SMC independent; no need of SMC expert; same calculation can be interfaced to several SMC programs with no extra effort
- SMC inaccuracies only affect next-to-hardest emissions; no matching problems
- As the name says, it generates events with positive weight

Implemented so far for: ZZ production (G. Ridolfi, P.N), heavy flavour production (Frixione, Mangano, Ridolfi, P.N).
Results: mostly compatible with MC@NLO. Differences seem to appear where SMC inaccuracies affect the matching in MC@NLO.

In a presentation by M. Treccani, a comparison between ALPGEN and MC@NLO was shown to yield discrepancies for the rapidity distribution of the first radiated jet (hep-ph/0611129).
Results from POWHEG support ALPGEN result.





Probable cause of the problem: HERWIG has an unphysical dip in the rapidity distribution of the hardest jet; The NLO correction from MC@NLO corrects it only partially: typical matching problem, absent in POWHEG

Jet Corrections

Animated discussions at the workshop, following presentations of Giammanco, Benedetti and Santocchia. Jet corrections:

- Particle level correction (Detector effects): $E_T^{\mathrm{raw}}/E_T^{\mathrm{MC}}$
- Parton level correction: $E_T^{\mathrm{MC}}/E_T^{\mathrm{PART}}$

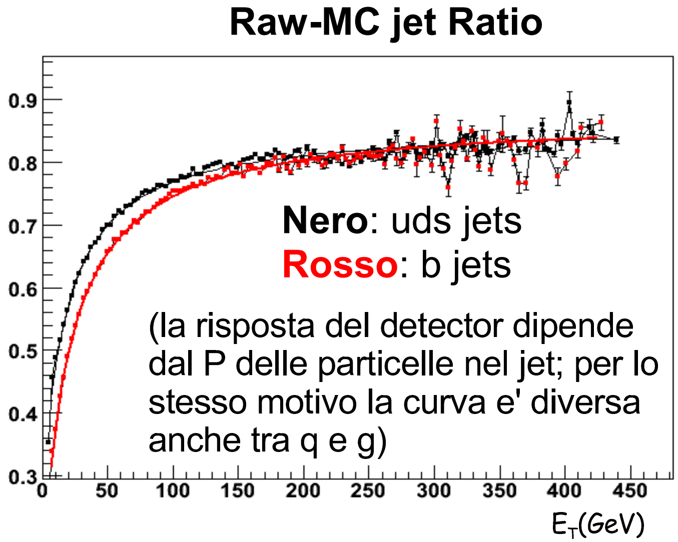
Particle level: with full simulation reconstruct calorimeter jets and particle (MC) jets, pair them up using ΔR distance, histogram $E_T^{\mathrm{raw}}/E_T^{\mathrm{MC}}$ as a function of η and E_T^{raw}.

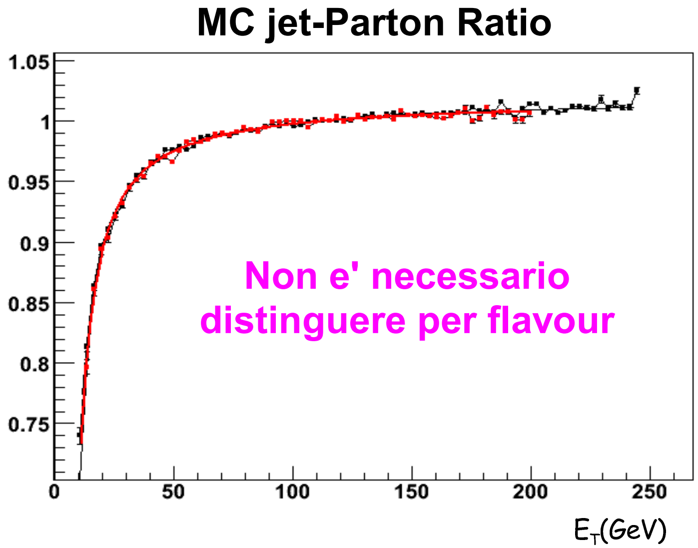
Parton level: reconstruct particle (MC) jets, pair them with primary partons using ΔR distance, histogram $E_T^{\mathrm{MC}}/E_T^{\mathrm{PART}}$ as a function of η and E_T^{MC}.

Calibrazione “MC jet”→partone

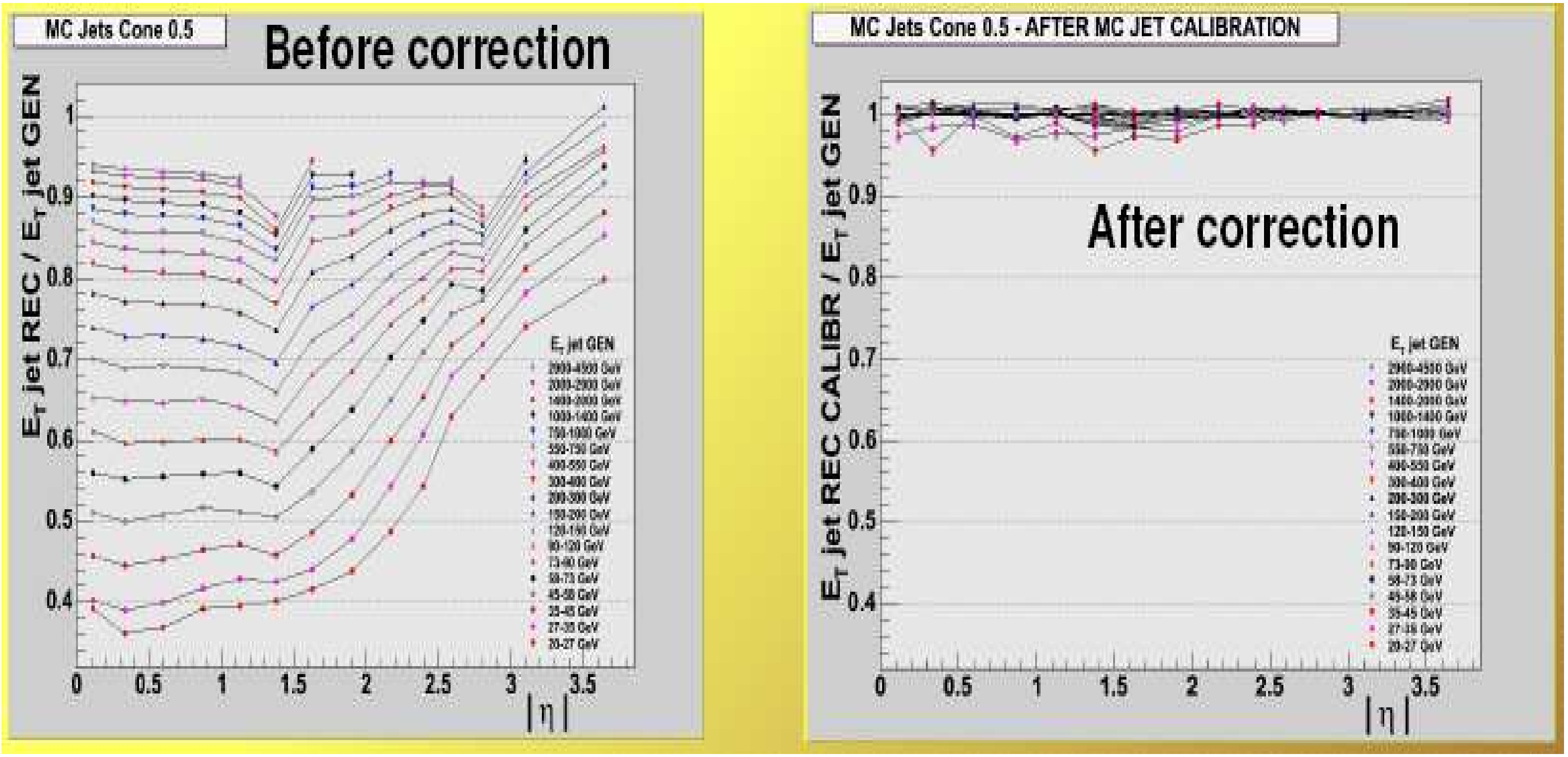
- Come prima, ma per i jet a livello generatore e per i partoni (<u>prima dello showering</u>): si minimizza la somma dei ΔR(MC jet – partone), e si fitta per ogni bin di η la funzione: $$\frac{E_T^{MC}}{E_T^{partone}} = \frac{1}{a + b\,E_T^{MC}} + c$$

A.Santocchia, CMS (preliminary)
eventi ttH, jet nel bin 0.6<η<0.7





Caveat: showering e frammentazione riguardano l'intero sistema partonico, non i singoli partoni! Qua abbiamo assunto che si possa approssimativamente parlare di effetto sul singolo partone, e applicare una correzione “universale”.



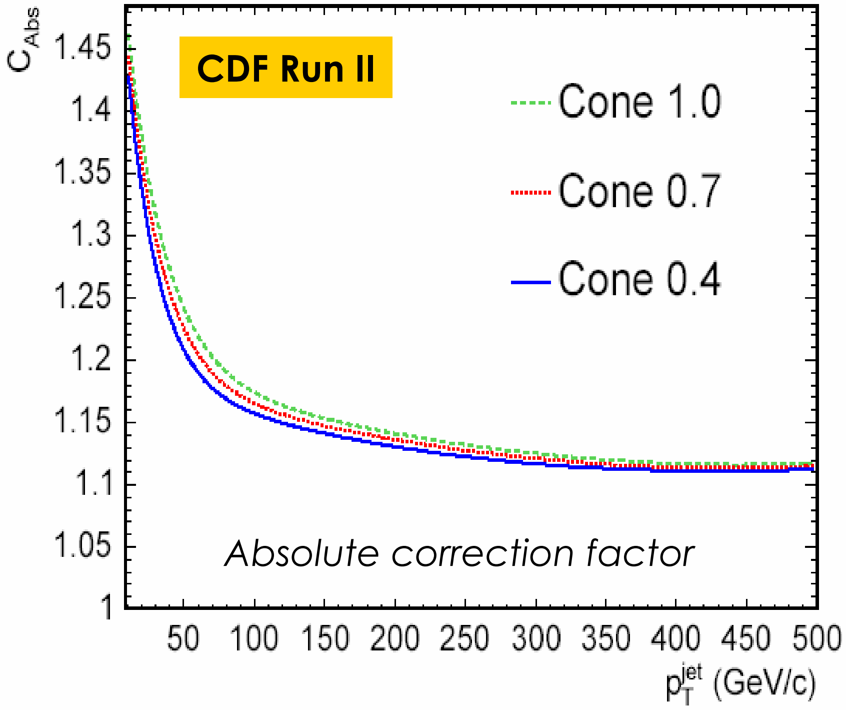
CMS, Physics-TDR Vol. I

(Jet energies from 20 to 4500 GeV)

CDF Jet Energy Scale Method

Different correction factors:

- (f_{rel}) Relative Corrections
  - → Make response uniform in η
- (MPI) Multiple Particle Interactions
  - → Energy from different ppbar interaction
- (f_{abs}) Absolute Corrections
  - → Calorimeter non-linear and non-compensating
- (UE) Underlying Event
  - → Energy associated with spectator partons in a hard collision



$$P_{T\,jet}(R) = [\, P_{T\,jet}^{raw}(R) \times f_{rel}(R) - MPI(R)] \times f_{abs}(R) - UE(R)$$

Total systematic uncertainties for JES → between 2% and 3%

Underlying event (UE)

What is the underlying event? Ambiguous definitions everywhere ...

Yet, (M. D'Onofrio), in CDF the UE is subtracted to correct for particle jet.

Furthermore:

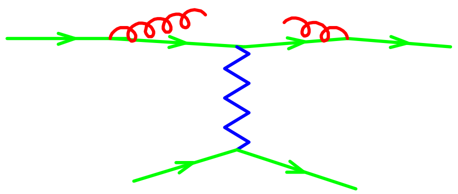
In CMS TDR: Pile up and UE subtracted in particle level correction

In Giammanco's talk: Pile up and UE subtraction in parton level correction

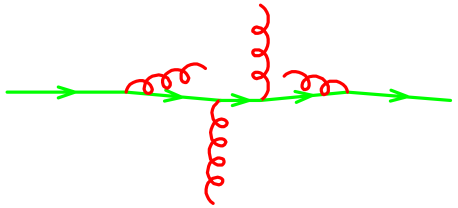
Should not one subtract Pile up in particle level, and UE in parton level?

Pile up is a well defined, measurable thing.

UE is: whatever you are not interested into in the case at hand. Example:



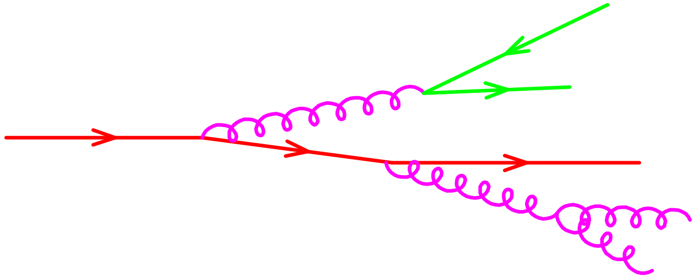
If you are interested in W production, the "interesting" jets are those from W decay; the UE is initial state radiation (also jets!), hadronization, etc.



If you are interested in dijet production, ISR is not easily distinguishable from FSR, since they come from colour connected lines. UE very different here!

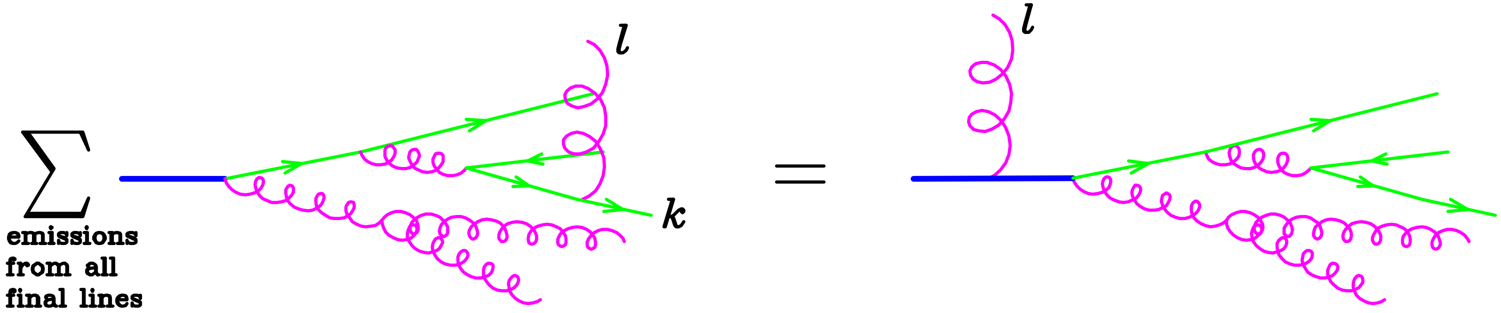
Yet, it is measured here, and used as universal!

Association jet-parton only valid in the leading log collinear approximation



In the small angle dominant region a jet has a single parton ancestor

Beyond the leading log approximation, and especially in the soft region, interference effects become important. Emissions at large angle add up coherently



If the jets arise from the same color neutral object (W,H) large angle radiation adds up to zero ...

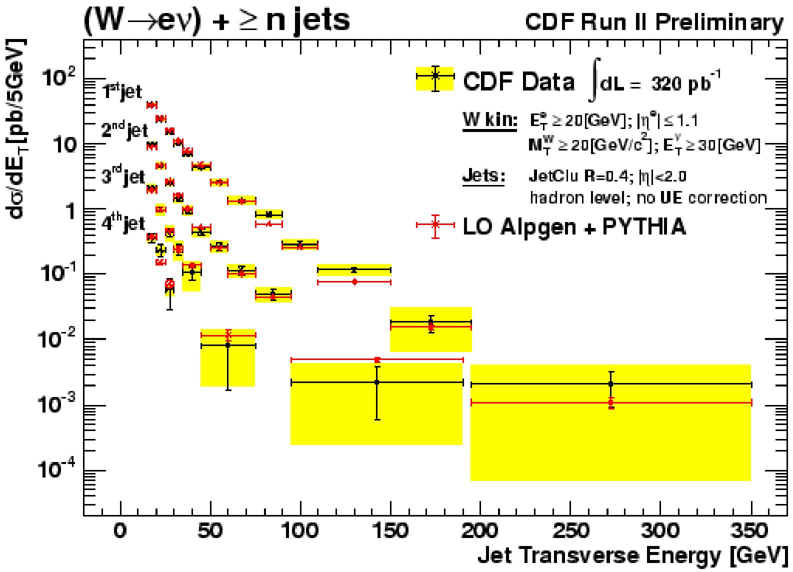
Can we avoid to correct to parton level?

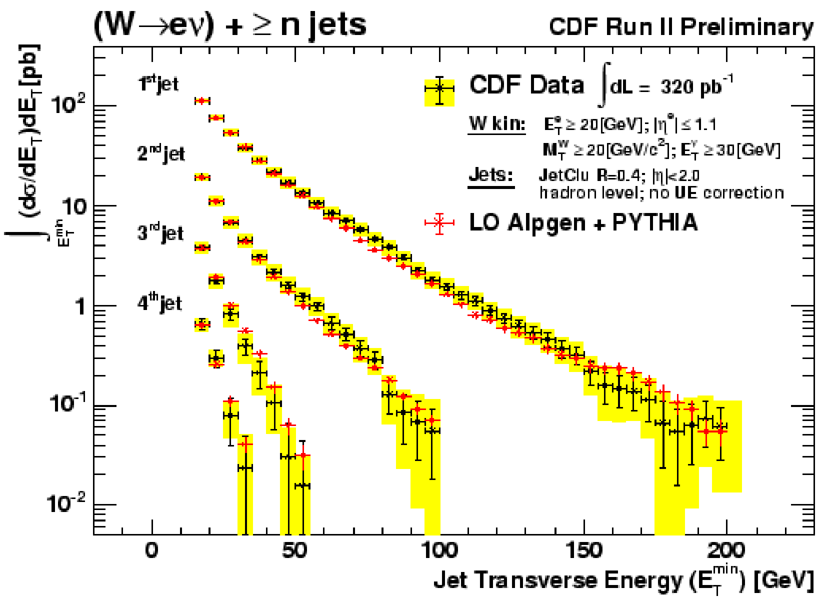
A. Messina

CDF Preliminary results

Differential xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples

Integrated xsec wrt jet E_T in each of the 4 W+ n jet inclusive samples





Only particle level corrections to jets

Caveat: this is not a full theory to data comparison. MC have been normalized to data inclusive cross section in each jet multiplicity sample!

When comparing and tuning calculations and models to real data, only particle level corrections are needed (not even Underlying Event corrections are applied in CDF case). What about looking for mass peaks?

- Parton level corrections: zero'th order approximation
- Account for colour of decaying object (next level of approximation)
  For example: a pair of jets coming from W decay:
  for a boosted W, jets are narrower: different "parton level" corrections
- Much room for improvement from theory: but needs very good understanding of experimental aspects

Very interesting and important problem to investigate in the future ...

Matrix Elements

MadGraph: Maltoni, Stelzer, etc.; general purpose ME generator

ALPGEN: Mangano, M.Moretti, Piccinini, Pittau, Polosa, Caravaglios:
basic processes + n jets

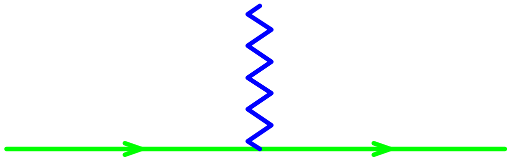
Phantom: Ballestrero, Belhouari, Bevilacqua, Maina: exact tree level
6 fermion processes

Horace: Carloni Calame, Montagna, Nicrosini, Treccani, Vicini
complete $O(\alpha_{\mathrm{em}})$ multi-photon corrections to W,
multi-photon corrections to Z production

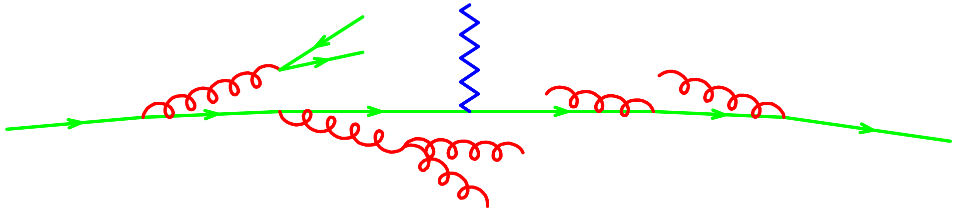
At the workshop:

- Reviews on LO ME generators (F. Maltoni) and N(N)LO (C. Oleari)
- Presentation of specific generators (Maina, M.Moretti, Montagna, etc.)

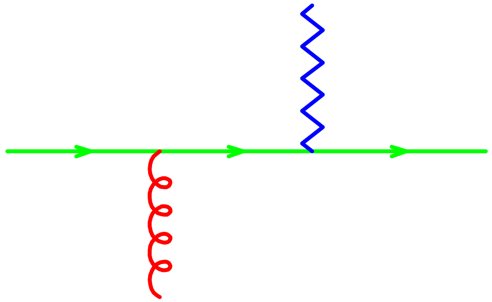
The ME-PS matching problem



A basic process cross section, computed to some level of accuracy (ME calculation)



QCD radiation at small angles is $O(1)$! Must be included to all orders (Shower MC's)



When the process involves extra radiation, adding the full MC shower is problematic. The shower algorithm adds extra radiation (but is inaccurate at large angle)

The same problem arises with virtual corrections: Shower MC's include all ($O(1)$) virtual corrections in the collinear approximation

Matching ME with Shower MC's: Catani, Krauss, Kühn, Webber (presented by S. Catani at the meeting), used in the Sherpa Shower MC.

Alternative method: MLM matching, in ALPGEN (presented by M. Moretti)

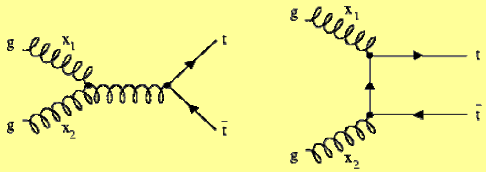
Generation of MC samples using ME programs is typically more involved than standard MC generation.

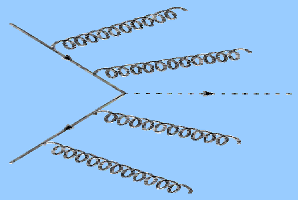
- Tevatron studies in W, $Z + \mathrm{jets}$ (A. Messina, M. D'Onofrio)
- Prospects for LHC (P. Azzi)
- Studies of $t\bar{t}H$ (fully hadronic) with $t\bar{t}$ + n jets background (A.Santocchia, A. Giammanco)
- $W + \mathrm{jets}$ background to $t\bar{t}$ signal (M.Cobal)

It appears that use of multijet samples (of the kind that ALPGEN provides), and dealing with the matching problem will turn out to be a typical need of LHC physics.

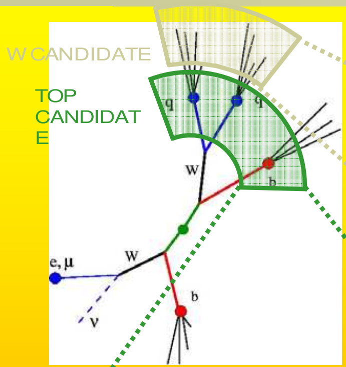
MC samples

	ttbar (signal)	W+jets (background)
Hard Process	• Generator: MC@NLO • Includes all LO + NLO m.e.	• Dedicated Generator: AlpGen • Includes all LO W + 4 parton m.e. *CPU intensive!*
Fragmentation, Hadronization & Underlying event	Herwig (Jimmy) [no pileup]	
Atlas Detector Simulation	ATLAS Full Simulation 10.0.2 (30 min/ ev)	
	'T1' Sample 175K event = 300 pb^{-1}	'A7' Sample 145K event = 61 pb^{-1}

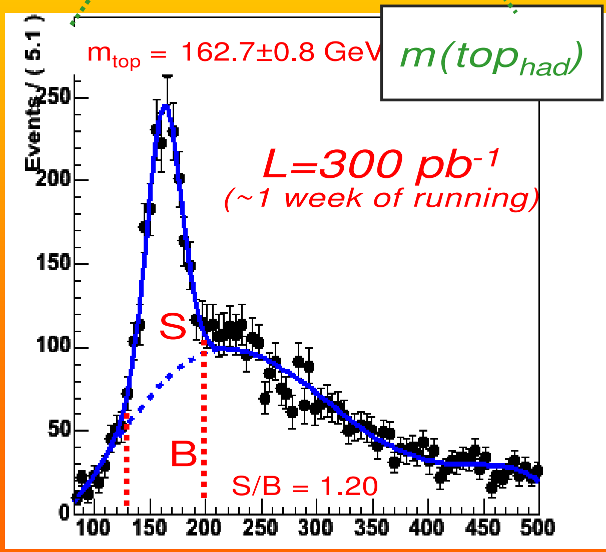


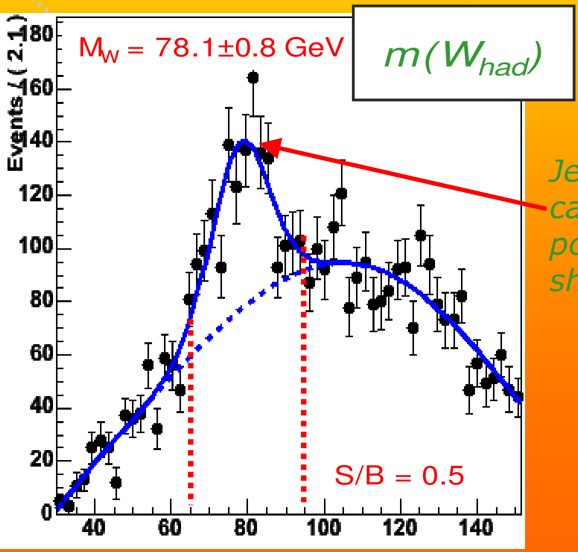


Signal-only distributions (Full Sim)



- Clear top, W mass peaks visible
- Background due to mis-assignment of jets
  - Easier to get top assignment right than to get W assignment right
- Masses shifted somewhat low
  - Effect of (imperfect) energy calibration

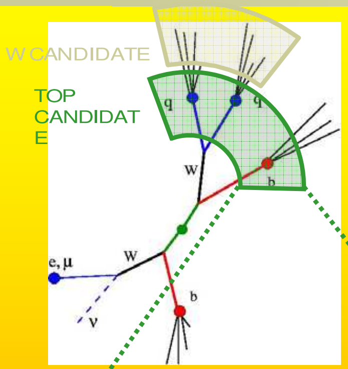


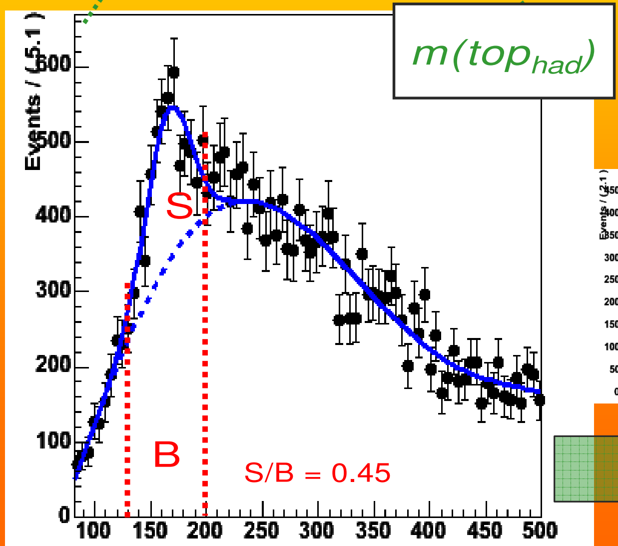


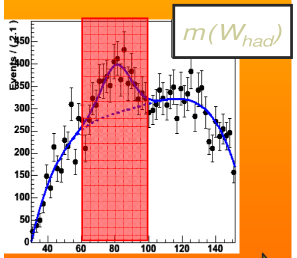
Jet energy scale calibration possible from shift in m(W)

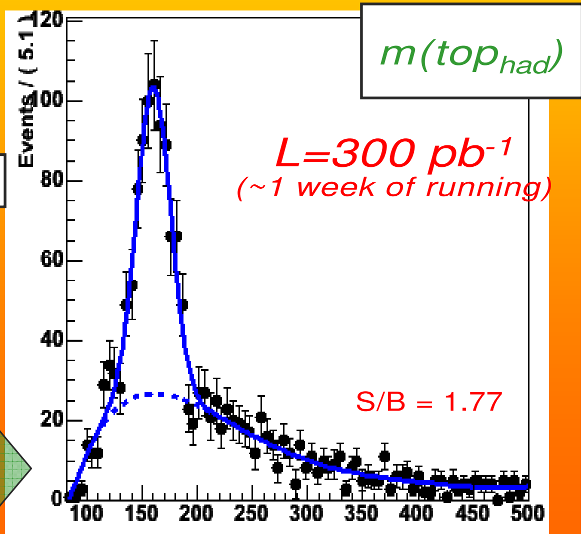
Signal + Wjets background (Full Sim)

- Now also exploit correlation between M_{top}(had) and M_W(had)
  - Show M_{top}(had) only for events with |m(jj)-m(W)|<10 GeV









New Physics

Presentations on simulations for BSM physics, especially SUSY (T. Lari), MSSM higgs (G. Masetti), Standard Higgs (M. Zanetti).
Revival of composite models (F.Sannino, R.Contino).

Summarizing: SM very healthy, but:

- Fine tuning problem (EW scale needs fine tuning to be $\ll M_{\rm GUT}$)
- Begs for unification (but proton does not decay)
- No dark matter candidate

SUSY solves these problems, but some fine tuning remains after LEP:

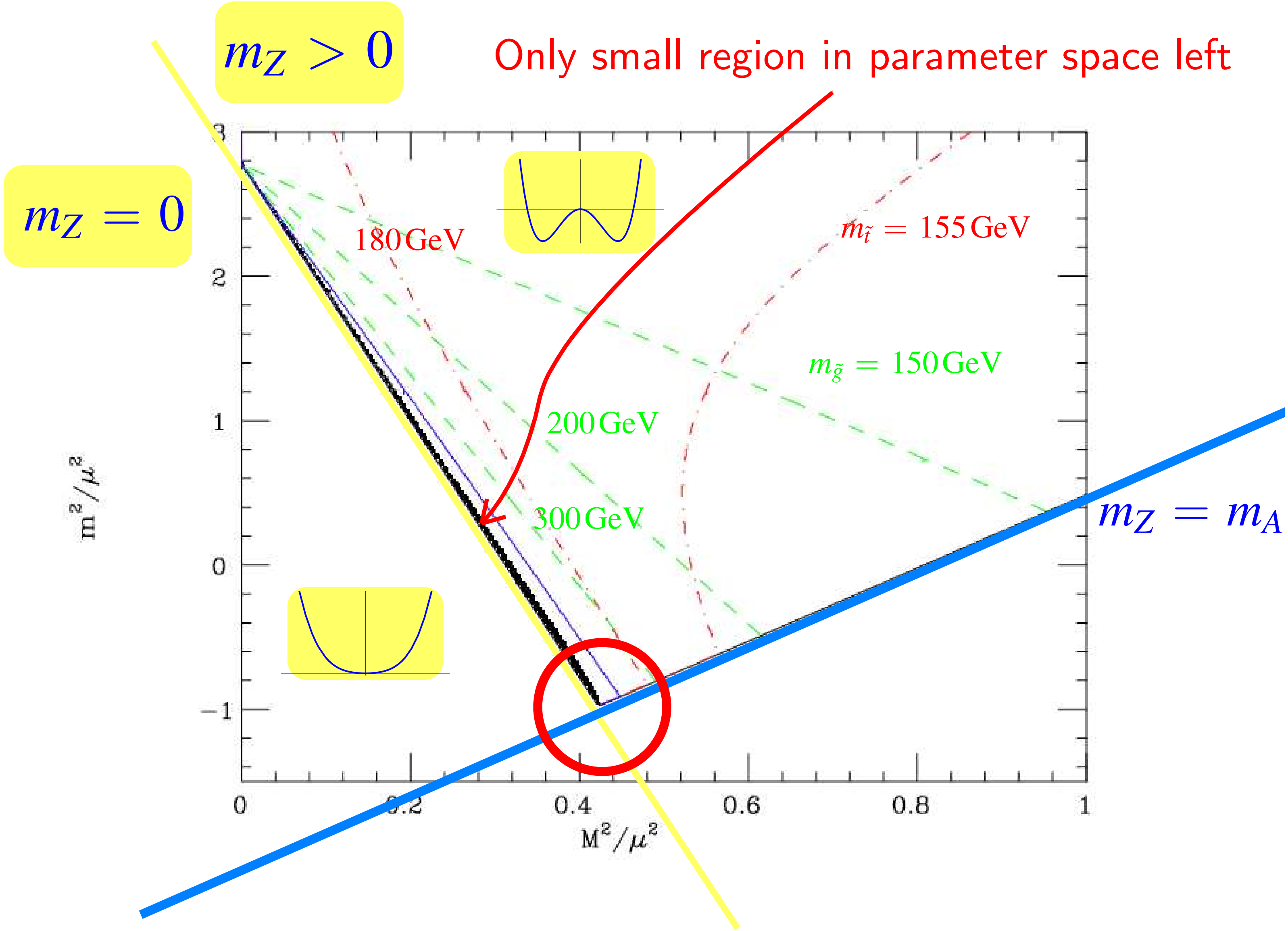
$$m_h^2 < m_Z^2 + m_t^2 \frac{3\lambda_t^2}{2\pi^2} \log \frac{m_{\tilde{t}}}{m_t}, \qquad m_Z^2 \simeq 2\mu^2 + \frac{3}{2\pi^2}\lambda_t^2\, m_{\tilde{t}}^2 \log \frac{M_{\rm Plank}}{m_{\tilde{t}}^2}$$

requires $m_{\tilde{t}} \gtrsim 500 \div 1000\,\mathrm{GeV} \implies$ 1 to 5% cancellation in m_Z^2

Talk by Rattazzi

Arkani-Hamed,Giudice,Rattazzi ‘06

Only small region in parameter space left



If some fine tuning is acceptable, composite models also become more acceptable. However, calculability, and thus even trying to answer fine tuning problems in the composite model framework, is a real drawback.

The messages at the workshop:

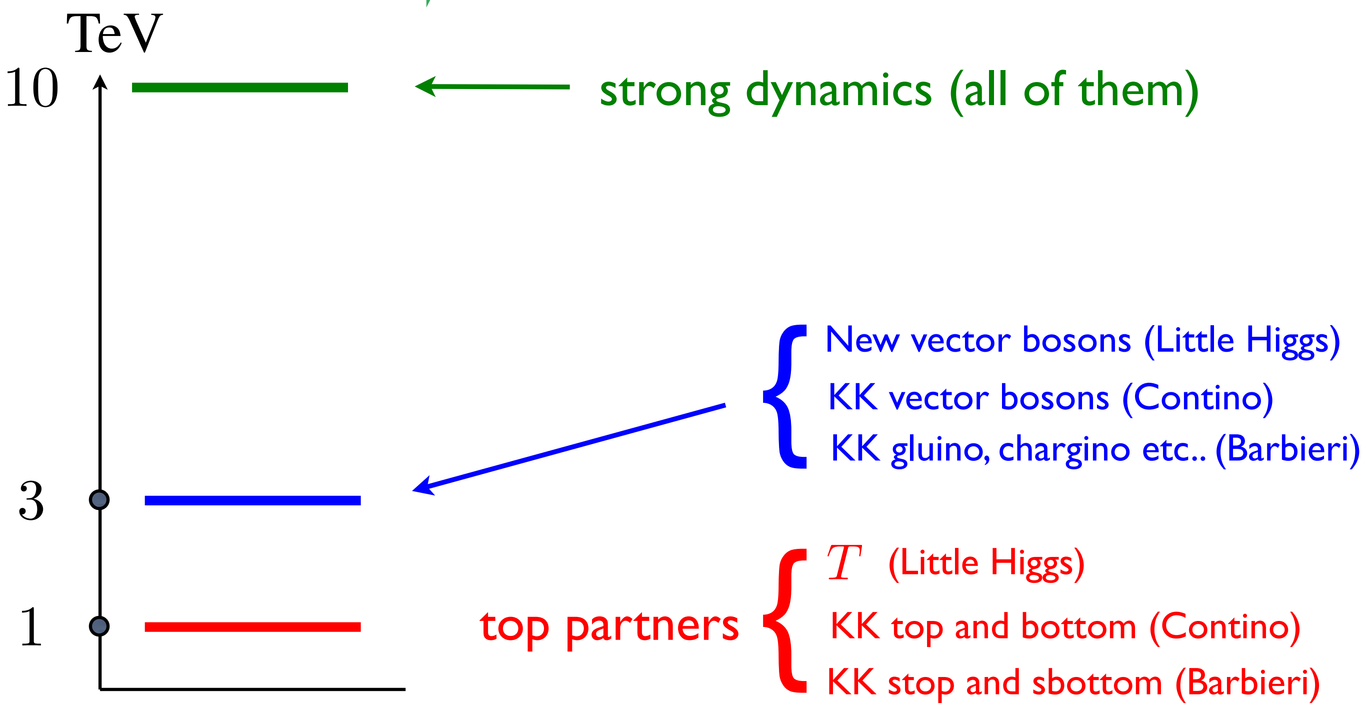
- Some Lattice gauge theory wisdom can be used to address the fine tuning problem in composite models (F. Sannino)
- Recent progress in field theory (what goes under the name of AdS5-CFT correspondence) allow to compute properties of certain strong interacting theories. R. Contino has illustrated models that are in correspondence with traditional composite models (namely models where the composite Higgs field is a pseudo Goldstone bosons) and that are calculable in this framework. In this context, even questions having to do with unification can be addressed.

Signals with: composite (or Kalutza-Klein) excitations, top partners, etc.

Rattazzi's talk

Summary

- LEP/SLC data → many new proposals for calculable EW breaking



- Some tension with EWPT data exists already, but not dramatic yet
- Models are not significantly worse than MSSM (secondo me)
- Wonderful playground to sharpen our ability to do physics with the LHC

SM Physics: EW corrections

One has to worry about EW corrections when precision is important. HORACE collaboration (Carloni Calame, Montagna, Nicrosini, Vicini) presents a study on effect of photon emission and EW corrections on W mass measurement. They find relevant shifts ($\approx 10 - 100\,\mathrm{MeV}$) in some cases.

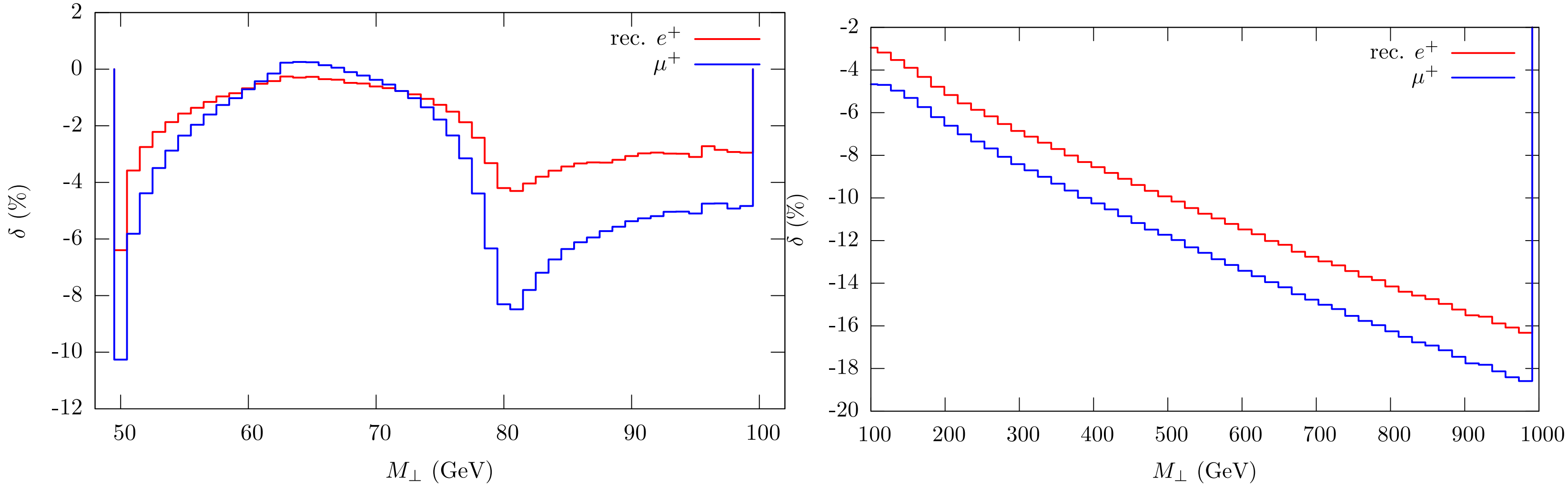
$\mathcal{O}(\alpha)$ EW results

Notice: e is inclusive in γ

Large γ corrections for μ near peak

C.C., Montagna, Nicrosini, Vicini, `hep-ph/0609170`

- LHC, $pp \to W^+ \to \ell^+\nu_\ell$, $p_{\perp,\ell}$ and $p_{\perp,\nu} > 25$ GeV, $|\eta_\ell| < 2.5$
- $\mathcal{O}(\alpha)$ EW corrections to the M_T distribution

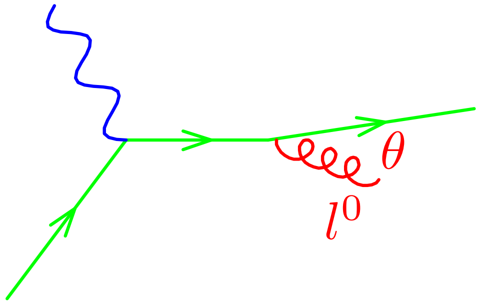


- $\mathcal{O}(\alpha)$ corrections at 5% - 10% level around the peak and increasingly large in the M_T tail due to the presence of the EW Sudakov (logs)^2, $\alpha_W \log^2 \frac{s}{M_Z^2}$

- Near the peak, collinear photon emissions dominate
- Far of shell, pure EW dominates via Sudakov logs

Electroweak Sudakov

$\alpha_{\text{ew}} = \alpha_{\text{em}}/\sin^2\theta_W \approx 1/34$ at high energy (1/3 of strong coupling constant).
Further enhancement arises at high energies: Sudakov EW logs
(P. Ciafaloni, E. Accomando e G. Montagna, Carloni Calame).
In gauge theories:



$$= \frac{C_F\alpha}{2\pi}\int\frac{dl^0}{l^0}\int\frac{d\cos\theta}{1-\cos^2\theta} \propto \frac{C_F\alpha}{2\pi}\log^2\frac{Q^2}{\lambda^2}$$

In QCD, Sudakov double logs cancel in inclusive quantities,
if one mediates/sums over the colour of the initial and final particles.
In QCD this is always the case: incoming and final particles are colour neutral.
Not so in EW interaction: an incoming proton is not an EW singlet, and neither is a final state μ or e. Diagrams with W emission instead of gluon emission, or with W virtual exchange, may carry Sudakov enhancement.

When are EW Sudakov important?

A guess: when large virtualities in the EW process are present; thus

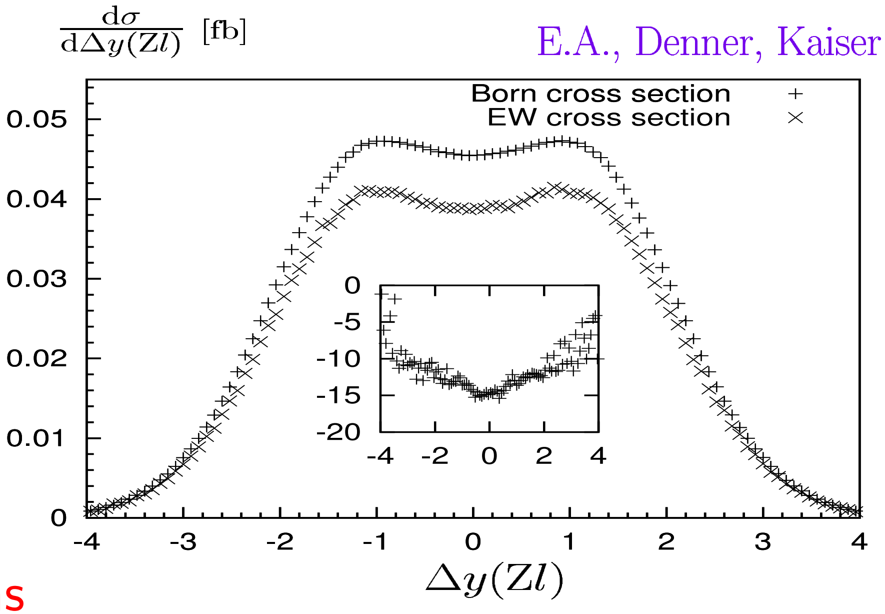
- In e^+e^- collision at very high energy (ILC). The annihilation process has high virtuality and the incoming beams are not $\mathrm{SU}(2)_{\mathrm{weak}}$ singlets
- In hadronic collisions, when some final state constrain forces large EW virtuality (as in the example of large M_T in $e\nu$ Drell-Yan)

Some (still ongoing) debate at the workshop about other cases.

WZ production
EW corrections

E.A., Denner, Kaiser

E. Accomando

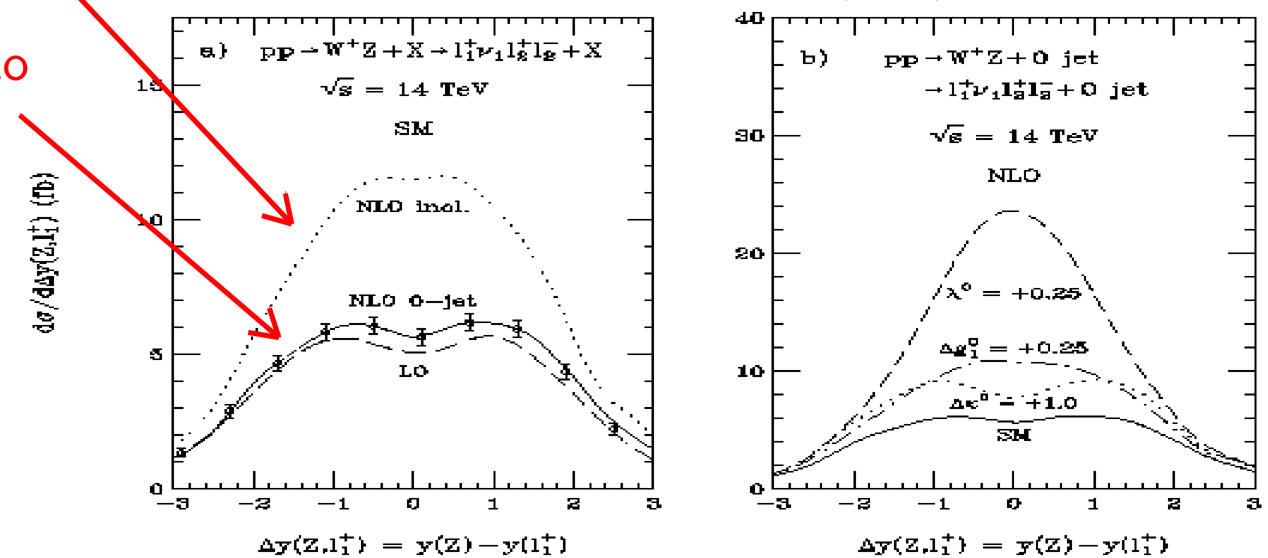


With jet veto NLO effects are smaller but uncertainties are larger ...

Strong corrections

With jet veto

Baur, Han, Ohnemus



If we try to limit strong effects using cuts, in order to expose EW effects, we reduce the size of strong corrections, but increase the uncertainty.

The fact remain that at the LHC we must keep an eye on EW corrections. Open questions:

- Which processes need EW Monte Carlo's? To what accuracy?
- Do we need to incorporate EW Sudakov in Shower Monte Carlo's?

Experimental Studies

Our conveners (F. Tartarelli (ATLAS), C. Mariotti and E. Migliore (CMS)) have organized their sessions according to "themes":

- First meeting: Experimental Objects
  muons (S.Rosati), e/γ (P.Meridiani), jets/Eflow (I.Vivarelli), missing E_T,τ (M.Heldmann), b tag (A.Rizzi)
- Second meeting: Fast simulation (A.Perrotta and A.Giammanco)
- Third meeting: Trigger (A.Nisati, F.Parodi, N.Amapane, F.Sarri)

Aim: to give a non-technical view of the detector capabilities,
especially for theorists.

They succeeded very well in their objectives. The collection of the presentation will be written in the form of an introduction to the detectors of LHC, that is accessible to theorists willing to work in the field, students, etc.
Notice: something like this is normally missing in conferences, lectures, etc.

The PGS (John Conway)

In the framework of the LHC Olympics, the Pretty Good Simulator is used by theorists to mock detector response to events simulated with a standard SMC. The rôle that the PGS may play in the future was discussed in the workshop:

- Overview of PGS by E. Migliore.
- The experiments are unwilling to support it: no extra work to tune it or compare it to CMS/ATLAS fast simulation
- Theorists see it as a toy to get an idea of detector effects, that is freely accessible without any commitment to an experiment
- General agreement: it is an interesting pedagogical tool to learn the basis of how detectors work.

Perspective

In this first year, the objective was: to make the three physicists communities (experimentalists, collider phenomenologists, BSM theorists) explain to each other their respective activity. The aim was to form a common language to discuss issues relevant to LHC physics, and in the long run, to form collaborations with theorists and experimentalists working together.

Examples of this kind of collaboration were presented at the workshop:

- Phantom in the Turin CMS group
- Collaboration of G. Corcella with the ATLAS group in Rome (workshop induced collaboration)

L'interfaccia di **Phantom** con **CMS**

S.Bolognesi per il gruppo di Torino
(N.Amapane, A.Ballestrero, A.Belhouari, R.Bellan, G.Bevilacqua, G.Cerminara, E.Maina, C.Mariotti, G.Mila)

- **Technicalities:**

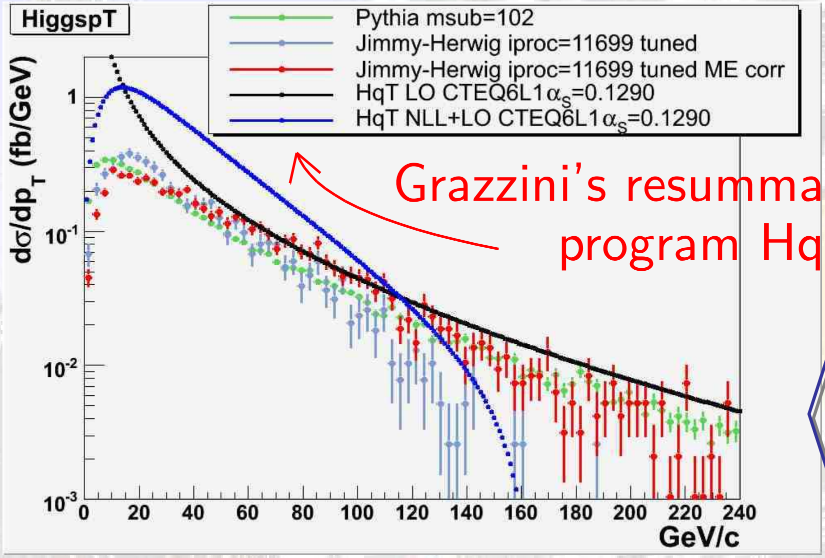
  come un MC viene integrato nel framework di un esperimento

- **Esperienza scientifica e umana a Torino di forte interazione teorici - sperimentali:**

  sviluppo e studio di un nuovo MC per la Vector Boson Fusion

MCWS - Frascati 24/05/2006

Higgs transverse momentum distribution
© G. Corcella, D. Rebuzzi



Logarithmic contributions to the Higgs p_T

LL	$\alpha_s^n \log^{n+1}(m_H^2/p_T^2)$
NLL	$\alpha_s^n \log^{n}(m_H^2/p_T^2)$
NNLL	$\alpha_s^n \log^{n-1}(m_H^2/p_T^2)$

HqT, PY and HW tuned with the same input parameters, to get a reliable comparison

HW and MC@NLO	$\sqrt{m_H^2+p_T^2}$
HqT	m_H
PY	p_T

Discrepancies at high p_T: the programs use different scale in α_S to generate events with $p_T > m_H$ through the fixed order calculation

Integral of the resummed calculation

σ (pb)	HqT	HIGLU	FEHiP*
NLL+LO	30.4	30.2	33.3
NNLL+LO	40.5		39.2

[*C. Anastasiou, K. Melnikov, F. Petriello, hep-ph/0501130]

B. Acharya (ICTP, Trieste) is a string theorist, that became interested into LHC physics, and presented work of the LHC Olympics in our workshop

Theory Space, LHC and the Inverse Problem

Bobby Acharya (ICTP, Trieste)
INFN Monte Carlo Workshop, Frascati
28th February, 2006

The LHC Olympics

- **Many theorists are NOT ready for the experiment which will dominate high energy physics for some years to come**
- **The LHC Olympics is a series of meetings which offers an opportunity to resolve this issue.**

The LHC Olympics Format

- **http://wwwth.cern.ch/lhcOlympics/lhcolympicsII.html - online info and discussion**
- **Blackboxes - simulated data samples which participants can study as if real data**
- **Biannual meetings with talks and discussions.**
- **Hopefully this will help prepare us for the inverse problem…**

In occasion of the Workshop, B. Acharya met the people of the Udine ATLAS group. He is now a 100% ATLAS member, and is following (with M.Cobal) two students, one on SUSY and one on top Physics.

Besides collaborations theorists-experimentalists, there are also examples of theorists-theorists collaborations, namely collider phenomenologists and BSM phenomenologists.

PHANTOM (Ballestrero, Belhouari, Bevilacqua, Maina):

- Dedicated event generator $O(\alpha^6) + O(\alpha^4 \alpha_s^2)$
- All $q_1 q_2, gg, qg \to f_1 f_2 f_3 f_4 f_5 f_6$
- Suitable to study vector boson scattering in the Standard Model

BSM: the high energy scattering of the longitudinal component of the vector bosons probes directly the structure of the Higgs sector.

With Rattazzi, they are interested in studying signals in cases when there is a light Higgs, that is a pseudo-goldstone boson. In spite of the presence of the light Higgs, these models exhibit a behaviour intermediate between a very heavy Higgs scenario and the (pointlike) light Higgs.
There is ongoing progress on this issue.

Summary

- In essence, MCWS has been a meeting of physics communities that normally do not talk enough to each other
- The rule of the game has been: plenary talks, encourage people to listen to all of them, encourage speakers to make non-technical presentations
- Outcome:
  - We have learned a lot
  - We have spotted new problems to work on
  - Hybrid collaborations have started to spawn
- Next step: write up things
- Outlook: from the learning phase to a more active collaborating phase.