Activities of the Monte Carlo Working Group (II)

Convenors: P. Bartalini, S. Gieseke, T. Kluge, F. Krauss

- Underlying Events (Joint Session with Multi-jet final states and energy flows)
- Validation

MC - tools: Underlying Events

(Joint Session with Multi-jet final states and energy flows)

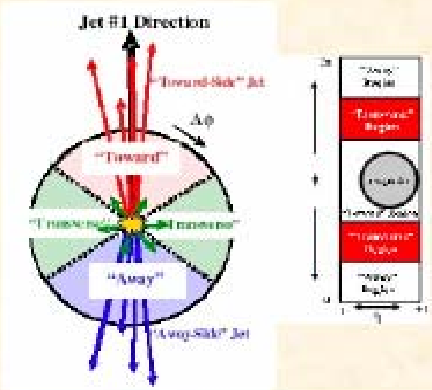
- The Underlying Event at the LHC (Livio Fano')
- The Underlying Event at ZEUS (Tim Namsoo)
- How to subtract the underlying event from jets? (Pavel Starovoitov)
- Sensitivity of the Muon Isolation Cut Efficiency to the Underlying Event Uncertainties (Alexey Drozdetskiy)

The measurement plan - UE

The Underlying Event at LHC
CMS-NOTE 2006/067
P-TDR vol.II, cap.7 section 3
(Florida, Perugia, CERN)

From charged jet

Topological structure of p-p collision from charged tracks
Charged jet definition -> ICA algorithm with massless charged tracks as input



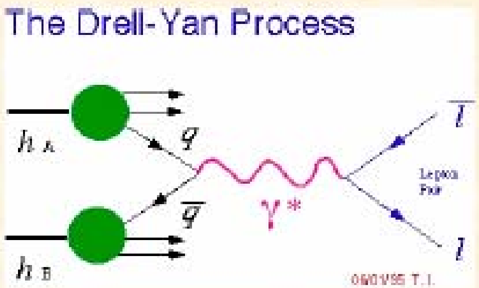
The leading Ch_jet1 defines a direction in the ϕ plane

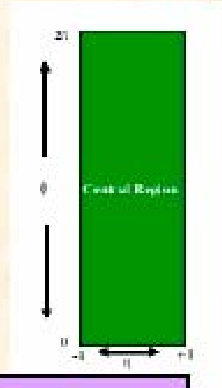
The transverse region is sensitive to the UE

Main observables:
- **+ $dN/d\eta d\phi$, charged density**
- **+ $d(PT_{sum})/d\eta d\phi$, energy density**

From D-Y muon pairs production

observables are the same but
defined in all the ϕ plane



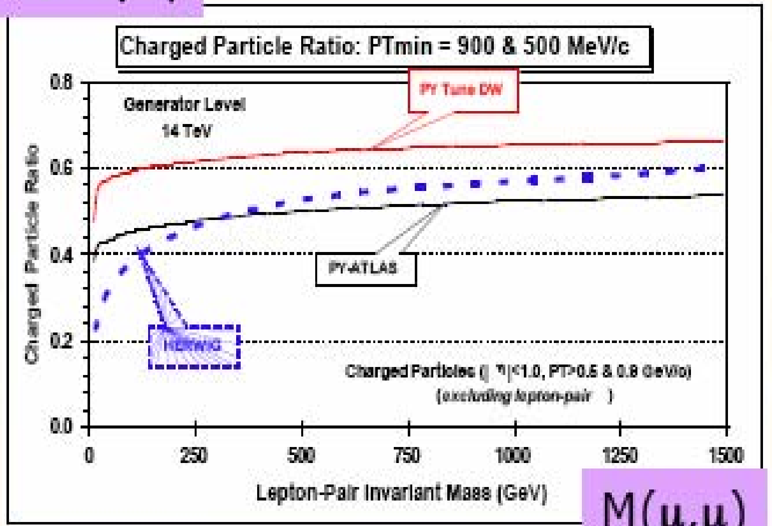


(after removing the μ pairs everything else is UE)

Idea from R. Field

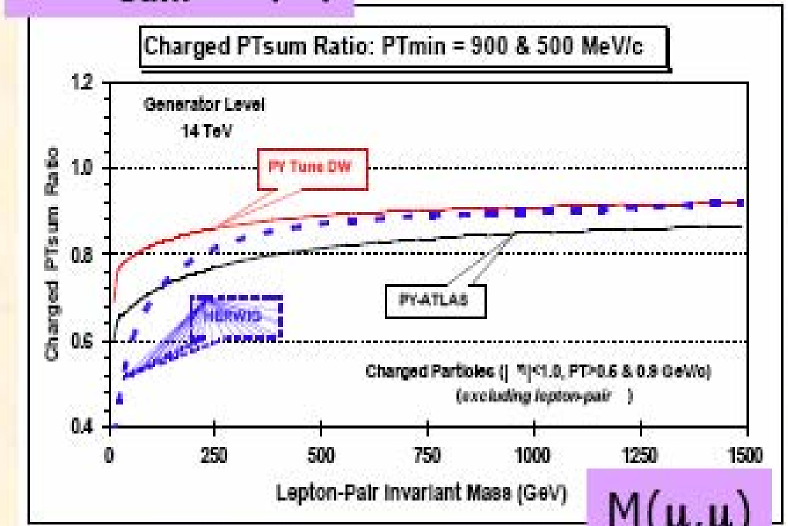
Generator level studies – DY – track PT sensitivity

dN/dηdφ



M(μ,μ)

dPT$_{sum}$/dηdφ



M(μ,μ)

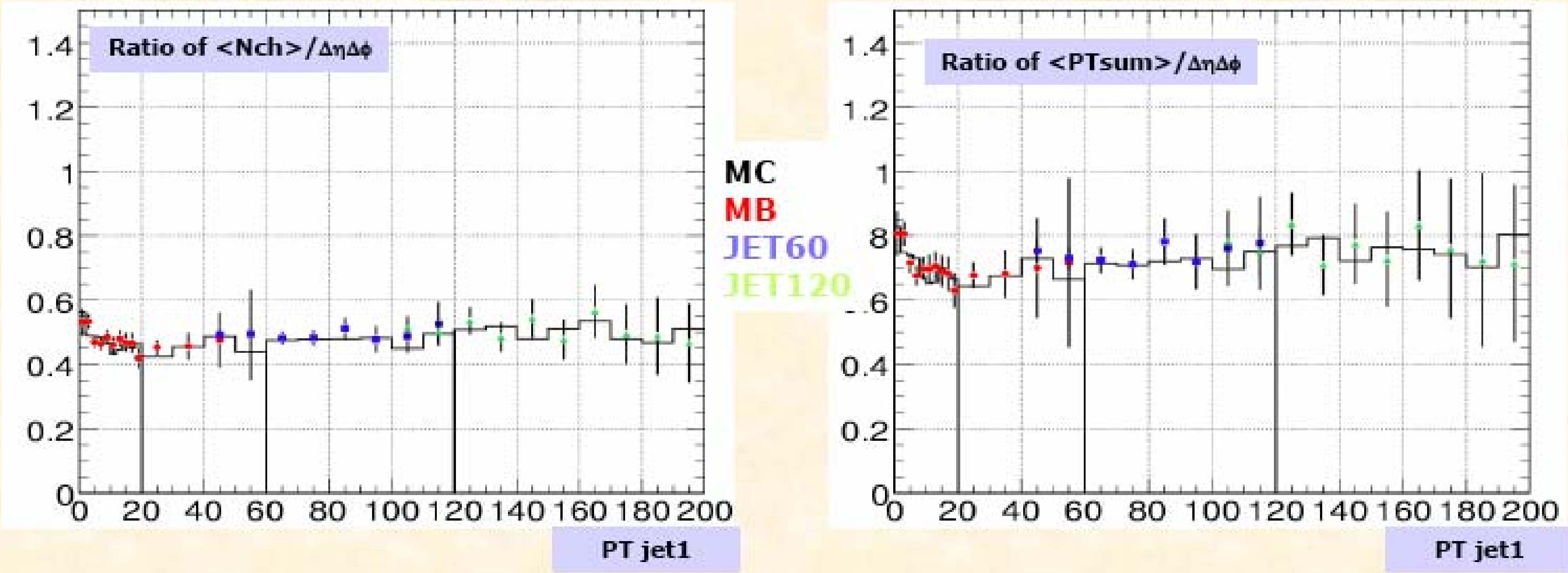
ratio 0.9/0.5 PT tracks threshold

A lot of emphasis on the reconstruction of soft tracks!

PY-Atlas Tune (-> optimized also for MB)
has a softer PT distribution than PY-DW **(done at CDF)** (-> optimized for UE)

Reconstruction studies – charged jet - transverse region

Ratio PT>0.9 / PT>0.5



Events re-weighted with corresponding x-sec.

(error bars dominated by MC statistics, arbitrary luminosity but scaling correctly)

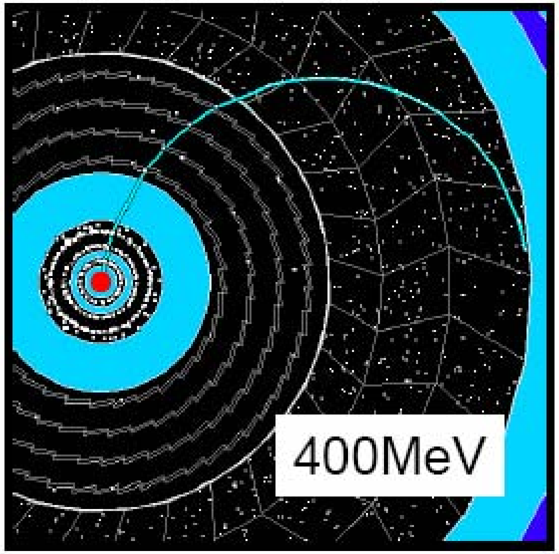
Really Good RECO/MC agreement.

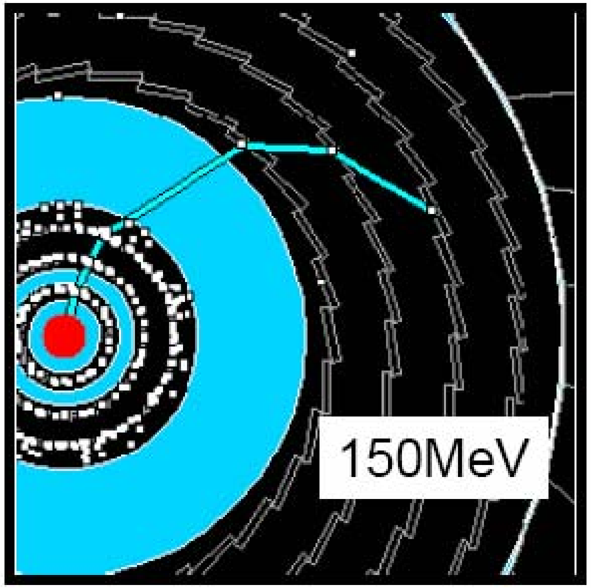
RECO/MC Differences absorb in the ratio, no need to apply corrections.

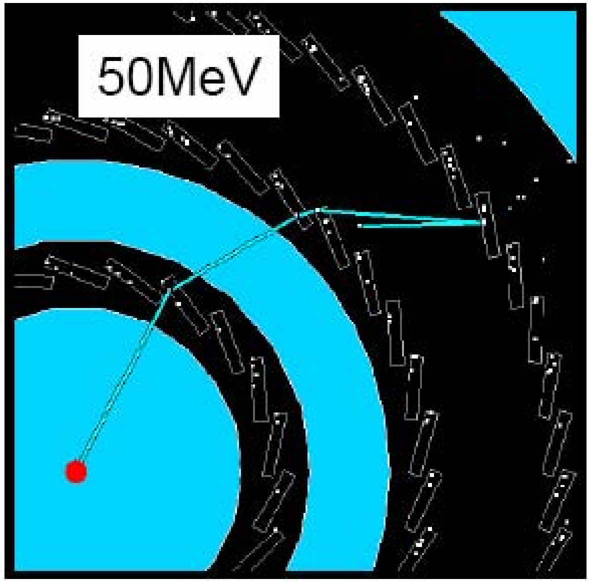
What is the momentum limit?

- Tracker is in principle sensitive to soft tracks
  P_T = 400 MeV - tracks reach end of TRT
  P_T = 150 MeV - tracks reach last SCT layer
  P_T = 50 MeV - tracks reach all Pixel layers

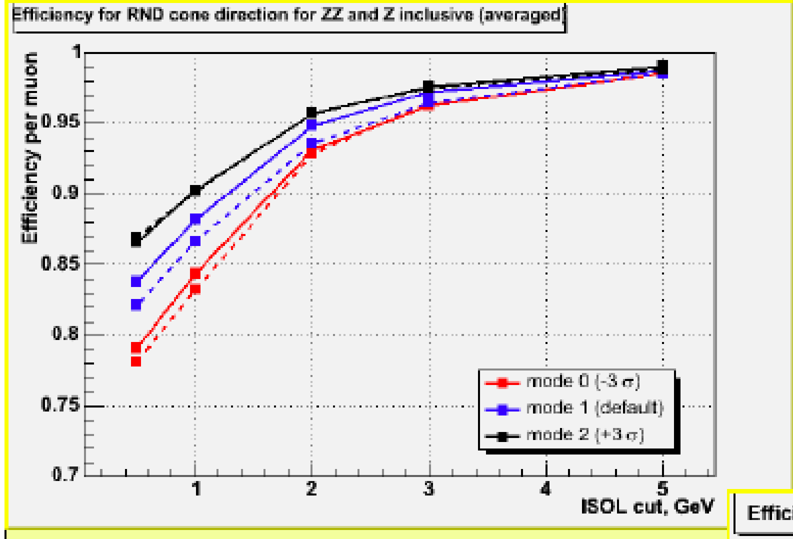
→ Do not need to run with low field







ISOL efficiency from data. (2)



Very close to ZZ "real" μ (dashed – Z-inclusive)

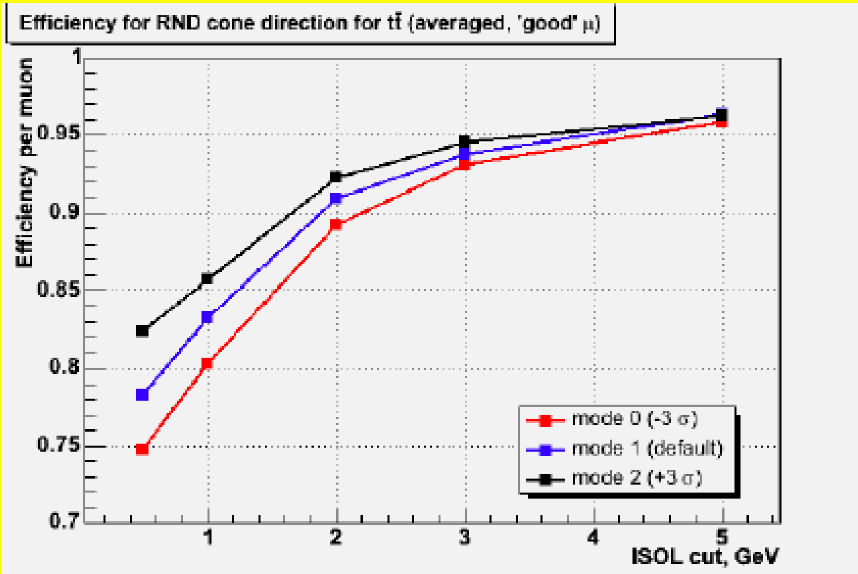


Illustration (not every sample is suitable): tt is too different.

ISOL efficiency from data. (3) Efficiency per event.

process/case	efficiency (default)	efficiency (-3σ)	efficiency ($+3\sigma$)
signal, $m_H = 150$ GeV	0.775 ± 0.004	0.707 ± 0.005	0.812 ± 0.004
ZZ background	0.780 ± 0.004	0.721 ± 0.005	0.838 ± 0.004
4 RND muons, Z-inclusive events	0.762 ± 0.007	0.706 ± 0.007	0.821 ± 0.006
$t\bar{t}$ background	0.016 ± 0.001	0.013 ± 0.001	0.015 ± 0.001

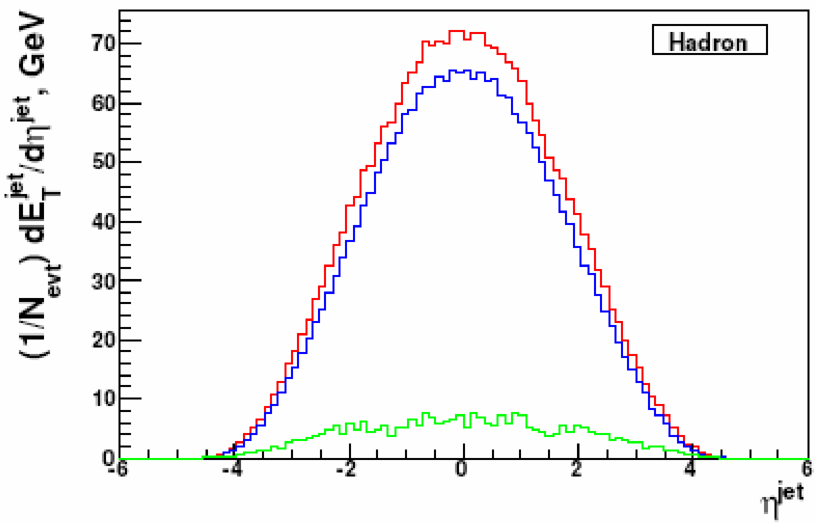
- numbers for Signal, ZZ and Z-inclusive samples are in agreement with each other for all the three different tested UE scenarios
- range of efficiencies for the ZZ spans from ~0.72 to ~0.84
    - prediction uncertainties!!! (from theoretical uncertainties in the UE physics)
- from data: shift is ~2% and not dependant on UE scenario
    - smaller than other known uncertainties

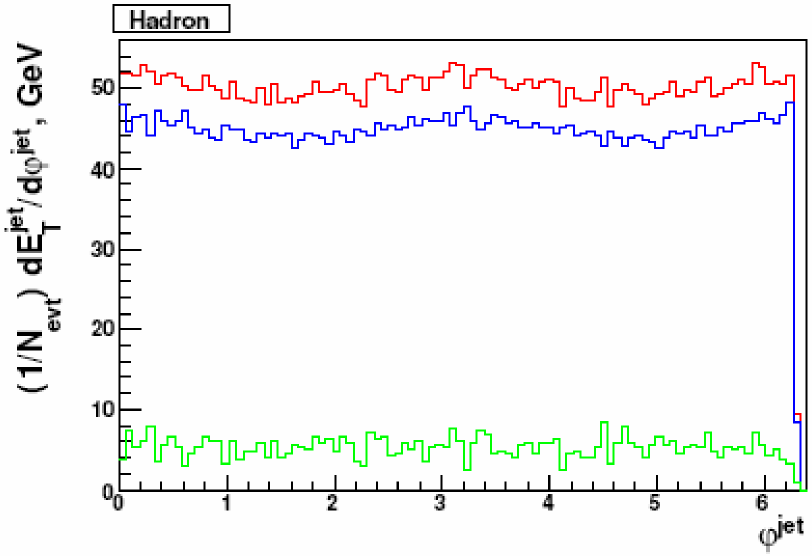
$$\frac{1}{N}\frac{dE_T^{jet}}{d\eta^{jet}} \quad \frac{1}{N}\frac{dE_T^{jet}}{d\varphi^{jet}}$$

Conclusions

Generator: Sherpa-1.0.8
Jet cut: $E_T^{jet} > 100\ GeV;\ |\eta^{jet}| \leq 5$
Jet Algorithm: MidPoint

- Jets at HS+UE becomes broader
- Jet axis in HS+UE is not the same as in HS.
- UE changes the response of the jet algorithm
  - UE produce a bias to the Jet Algorithms



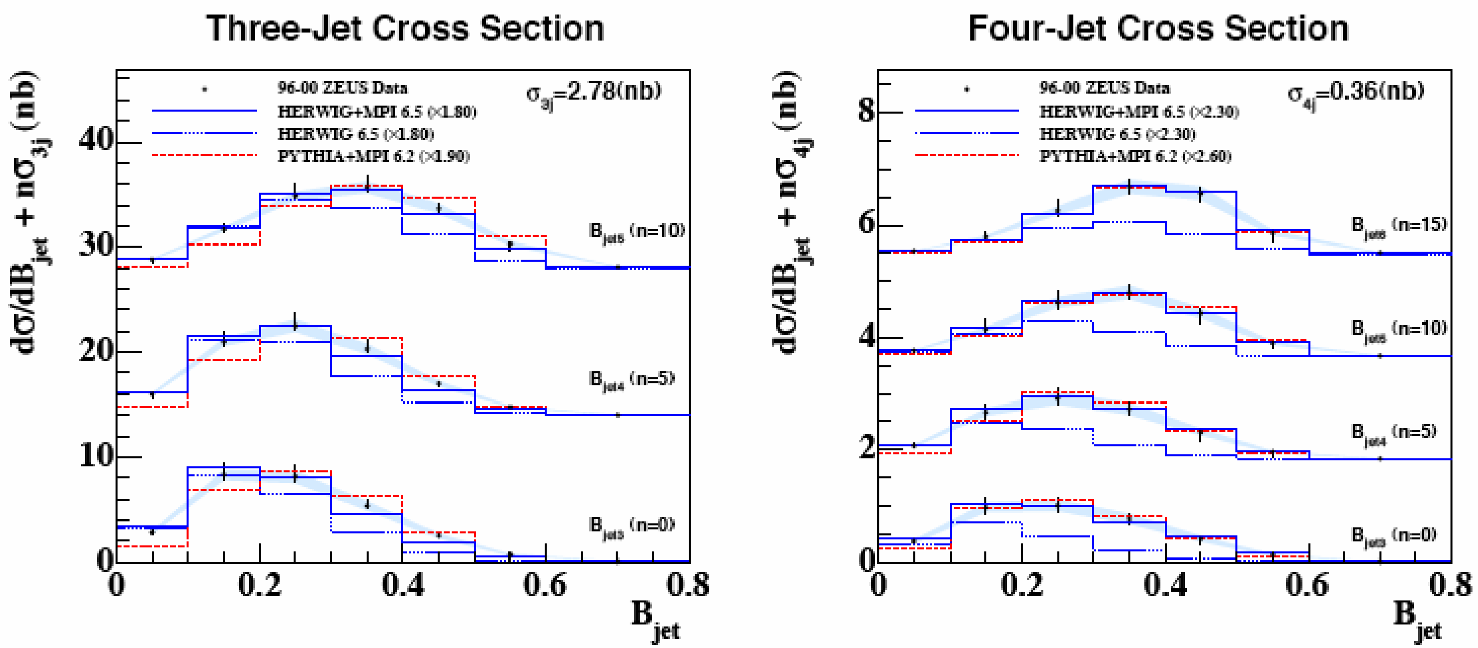


Hard Scale HS+UE Difference

Plan

- Future: We want to study uncertainties for different Jet Algorithms: Cone & K_T

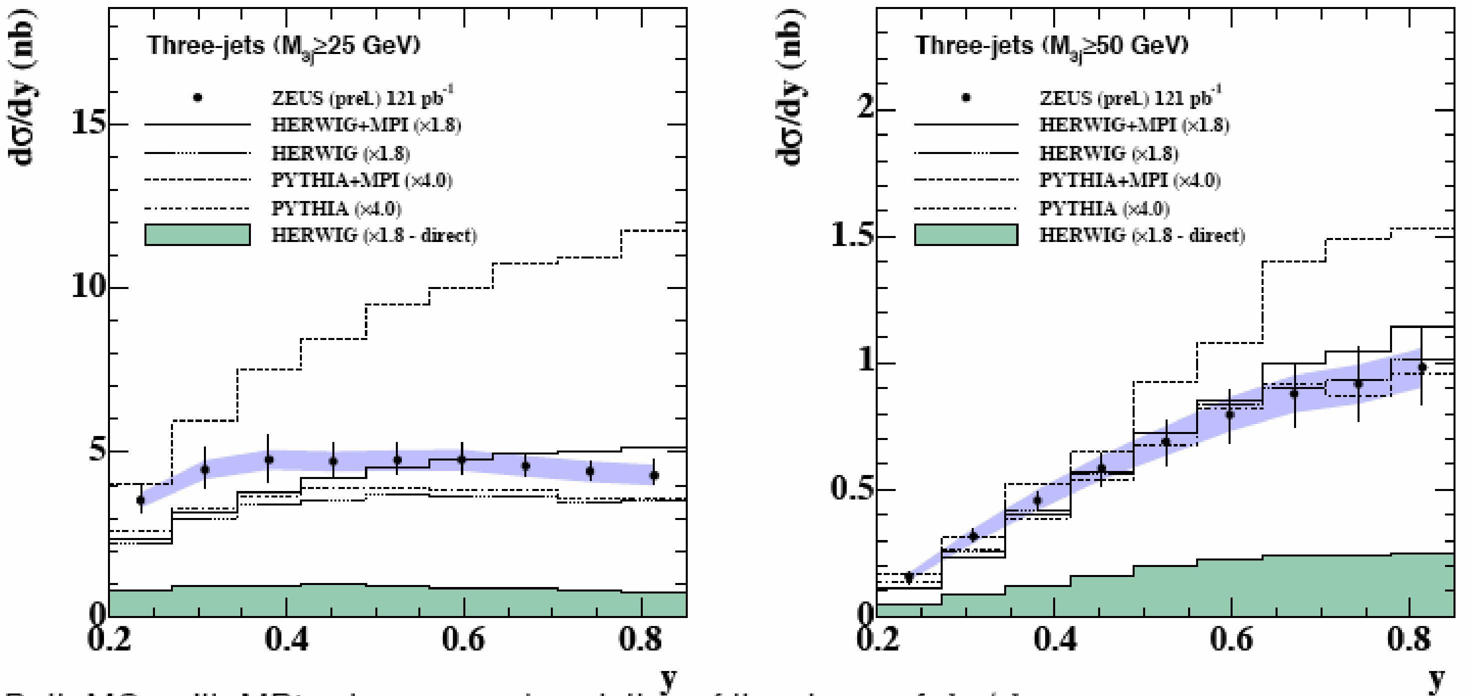
ZEUS



$M_{3j} \geq 25.0$ GeV | *$M_{4j} \geq 25.0$ GeV*

- jet broadness: $B_j = \left(\sum_i |\mathbf{h}_i \times \mathbf{p}_j|\right)/\left(\sum_i |\mathbf{h}_i||\mathbf{p}_j|\right)$ (sensitive to transverse energy flow in jet)
- note: different PYTHIA k-factors - want to observe how each model affects the jet shape.
- clearly the MC without MPIs predicts too narrow jets - MPIs could account for the broadening
- PYTHIA simple model and JIMMY predictions very similar in 4-jet case but less so in 3-jet.

ZEUS



- Both MCs with MPIs give a poor description of the shape of $d\sigma/dy$...
- ...but MCs without MPIs describe shape well. MPI models causing the problem?
- if so, $d\sigma/dy$ good for tuning/testing models but hard not to imagine MPIs not (slightly) y dependent.
- suggests MPIs not the only problem?
- same observations made in the 4-jet $d\sigma/dy$ distributions.

Underlying Events Bottom Line

- Experimental methodologies
  - Extension to DY
  - New observables (ratios)
  - Emphasis on reconstruction of soft tracks
- Tuning of the Models
  - Still painful to achieve a global picture
    - Describing UE and MB with the same settings
    - Common Tevatron + LHC (+HERA) tuning ???
  - Having the best parameters is not enough we also need the errors!
- Spin offs of UE comprehension
  - New methodologies to calibrate lepton isolation

MC - Tools: Fragmentation and hadron decays (CERN(40-S2-A01))

❖ Heavy Quarkonia sector in PYTHIA 6.324: test and validation (Marianne Bargiotti)
❖ EvtGen at the LHC (Maria Smizanska)

MC - Tools: Validation of Monte Carlos

❖ MC validation in ATLAS (Borut Paul Kersevan)
❖ Validation of simulation packages in LCG (Mikhail Kirsanov)
❖ MC validation, HZtool (Christiane Risler)
❖ CEDAR & HZTool (Jon Butterworth)
❖ CEDAR: HepData, HepML and HepForge (Andy Buckley)

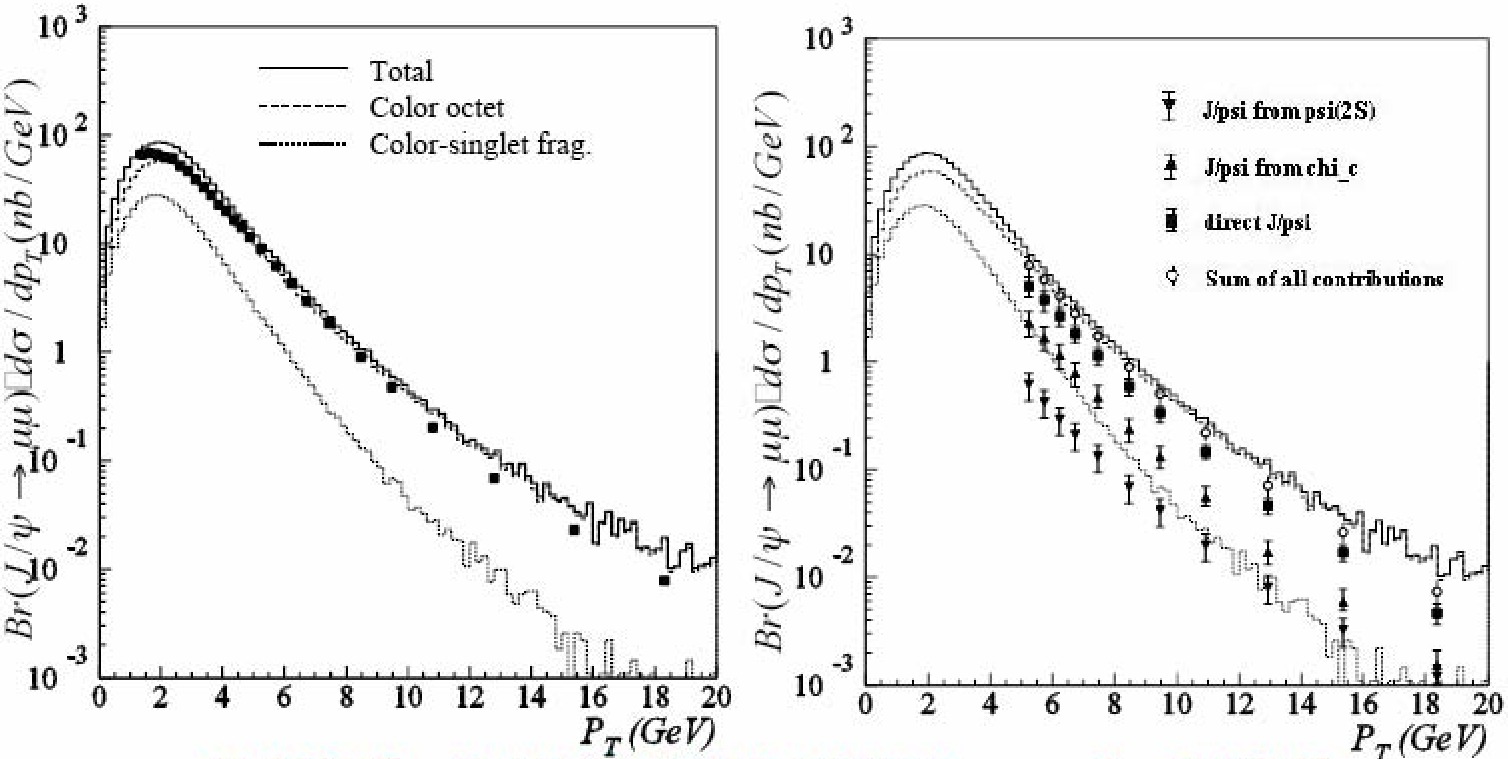
CURRENT STATUS

- Integration of the original code (by Stefan Wolf) made by T. Sjostrand in PYTHIA 6.324.
  - This PYTHIA implementation for NRQCD already existed since a few years, but it was not validated and never included in official releases.
  - PYTHIA 6.324 now relays **both to charmonia and bottomonia sector**
  - The code is now under validation;
  - Realistic parameter values (e.g. NRQCD MEs) have to be fixed.

→ OTHER VISIBLE IMPLICATIONS:

- **Possibility to produce simultaneously J/ψ and Υ (introduced as different processes)**
- **is still not possible to generate Υ' and ψ' simultaneously, but can be implemented 'in locum'**

Preliminary Results using PYEVWT for event-by-event reweighting



WEIGHT = (P_T2/(P_{T0}**2+P_T**2))**2** **P_{T0}=2.5 GeV**

HERA-LHC Workshop, CERN
6-8 June 2006

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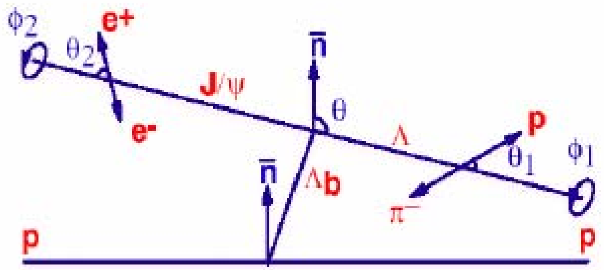
Inspired by the running of the PT-cut-off in the Multiple Interactions Framework --> Extrapo

Lambda_b polarization and decay

Use of EvtGen to generate polarized Lambda $_b$ in the cascade decay :

$\Lambda_b \rightarrow J/\psi\ \Lambda_0$

$J/\psi \rightarrow \mu\mu$, $\Lambda_0 \rightarrow \pi p$



Angular distribution $\Lambda_b \rightarrow J/\psi(\mu\mu)\Lambda(\pi p)$ depends on 5 angles + 6 parameters of the 4 complex helicity amplitudes + polarization P_b. Helicity amplitudes and P_b have to be simultaneously determined.

Probability function

$$w(\Omega, \Omega_1, \Omega_2) = \frac{1}{(4\pi)^3} \sum_{i=0}^{i=19} f_{1i} f_{2i}(P_b, \alpha_\Lambda) F_i(\theta, \theta_1, \theta_2, \phi_1, \phi_2)$$

i	f_{1i}	f_{2i}	F_i
0	$a_+a_+^* + a_-a_-^* + b_+b_+^* + b_-b_-^*$	1	1
1	$a_+a_+^* - a_-a_-^* + b_+b_+^* - b_-b_-^*$	P_b	$\cos\theta$
2	$a_+a_+^* - a_-a_-^* - b_+b_+^* + b_-b_-^*$	α_Λ	$\cos\theta_1$
3	$a_+a_+^* + a_-a_-^* - b_+b_+^* - b_-b_-^*$	$P_b\alpha_\Lambda$	$\cos\theta\cos\theta_1$
4	$-a_+a_+^* - a_-a_-^* + \frac{1}{2}b_+b_+^* + \frac{1}{2}b_-b_-^*$	1	$d^2_{00}(\theta_2)$
5	$-a_+a_+^* + a_-a_-^* + \frac{1}{2}b_+b_+^* - \frac{1}{2}b_-b_-^*$	P_b	$d^2_{00}(\theta_2)\cos\theta$
6	$-a_+a_+^* + a_-a_-^* - \frac{1}{2}b_+b_+^* + \frac{1}{2}b_-b_-^*$	α_Λ	$d^2_{00}(\theta_2)\cos\theta_1$
7	$-a_+a_+^* - a_-a_-^* - \frac{1}{2}b_+b_+^* - \frac{1}{2}b_-b_-^*$	$P_b\alpha_\Lambda$	$d^2_{00}(\theta_2)\cos\theta\cos\theta_1$
8	$-3Re(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\cos\phi_1$
9	$3Im(a_+a_-^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2\sin\phi_1$
10	$-\frac{3}{2}Re(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 cos(\phi_1+2\phi_2)$
11	$\frac{3}{2}Im(b_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\sin\theta_1\sin^2\theta_2 sin(\phi_1+2\phi_2)$
12	$-\frac{3}{\sqrt{2}}Re(b_-a_+^* + a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\cos\phi_2$
13	$\frac{3}{\sqrt{2}}Im(b_-a_+^* + a_-b_+^*)$	$P_b\alpha_\Lambda$	$\sin\theta\cos\theta_1\sin\theta_2\cos\theta_2\sin\phi_2$
14	$-\frac{3}{\sqrt{2}}Re(b_-a_-^* + a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
15	$\frac{3}{\sqrt{2}}Im(b_-a_-^* + a_+b_+^*)$	$P_b\alpha_\Lambda$	$\cos\theta\sin\theta_1\sin\theta_2\cos\theta_2\sin(\phi_1+\phi_2)$
16	$\frac{3}{\sqrt{2}}Re(a_-b_+^* - b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\cos\phi_2$
17	$-\frac{3}{\sqrt{2}}Im(a_-b_+^* - b_-a_+^*)$	P_b	$\sin\theta\sin\theta_2\cos\theta_2\sin\phi_2$
18	$\frac{3}{\sqrt{2}}Re(b_-a_-^* - a_+b_+^*)$	α_Λ	$\sin\theta_1\sin\theta_2\cos\theta_2\cos(\phi_1+\phi_2)$
19	[illegible]	[illegible]	[illegible]

- *see ATLAS Note* ATL-PHYS-94-036

Generators used at ATLAS

- We try to use as many generators as reasonable:
  - The final answer which is best will be given only by the data.
  - Need some overlap: different generators for the same processes.
- So far tried:
  - AcerMC
  - Alpgen (+ MLM matching)
  - Charbydis
  - CompHEP
  - Hijing
  - HERWIG (+ Jimmy)
  - MadEvent
  - MC@NLO
  - Phojet
  - Photos (both with HERWIG and Pythia)
  - Pythia (old and new showering and UE algorithms)
  - Tauola (both with HERWIG and Pythia)
  - Sherpa
  - TopReX

2

B. Kersevan

Common validation procedures at ATLAS

- There are in general two approaches:
  - We take into account the experience and results at the Tevatron (tunings) and/or we try to tune/check the generators using available Tevatron information ourselves.
  - We compare the results of different MC generators in the quantities where they should match (to a certain precision) either at the generator level or by performing full analysis studies.
- In all cases we of course check the obvious parameters (masses, resonance shapes, angular (a)symmetries etc.)
- We also check the stability of the algorithms and their sensitivity to parameter changes (e.g. cutoff parameters in MLM matching algorithm etc..).
- Detailed checks when switching versions of the same MC tool.

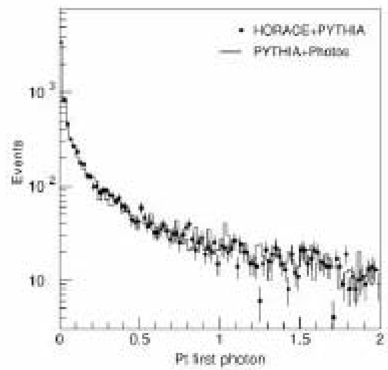
Validation using generator comparisons

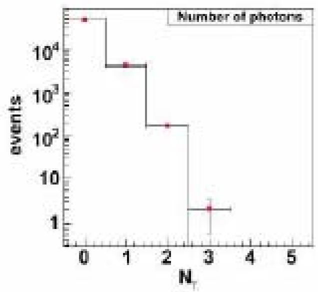
- Comparison between PHOTOS (supposed to be an approximate algorithm in principle) and HORACE (exact QED DGLAP solution):
  - Turns out that PHOTOS is doing an excellent job!

HORACE vs Photos (3)

- Photon multiplicity and transverse momentum spectrum done with standalone generators (outside Athena)

perfect agreement for all p_T range





with cut $p_T(\gamma)$ > 500 MeV perfect agreement also in Athena iterfaced version to third hard photon

Pythia + HORACE

Pythia + Photos

The LCG Generator Library (status and plans 2006)

- GENSER_1_3_0 – last major release, March 2006. 27 packages.
  - Pythia8 and Herwig++ inside GENSER (M.Kirsanov)
  - Two levels of release tests, development of level 1 (M.Kirsanov, O.Zenin)
  - Heavy ions generators: HIJING, PYQUEN, HYDJET
  - Release policy and tools (A.Pfeiffer)

Number of generators starts to saturate; accent being shifted towards

convenience, tests, validation

- Further development of procedures for Light Bug Fix Releases
- Develop the package TESTS
- User support (versions 1_3_0 – 1_4_0)
- Increase support for Makefiles
- Continue testing with gcc 4
- Migrate to HepMC in the package TESTS to provide a general approach to c++ and Fortran generators.
- Update of already introduced Sub-package versions
  - Requests from the LHC experiments are welcome

HZTOOL - routines

Future routines: new analyses / wishlist for new routines

Heavy flavors:

DESY-05-147, ZEUS, *Measurement of Charm Fragmentation Ratios and Fractions in Photoproduction at HERA*

DESY-05-132, ZEUS, *Inclusive Jet Cross Sections and Dijet Correlations in D* Photoproduction at HERA*

DESY-04-070, ZEUS, *Measurement of beauty production in deep inelasti*

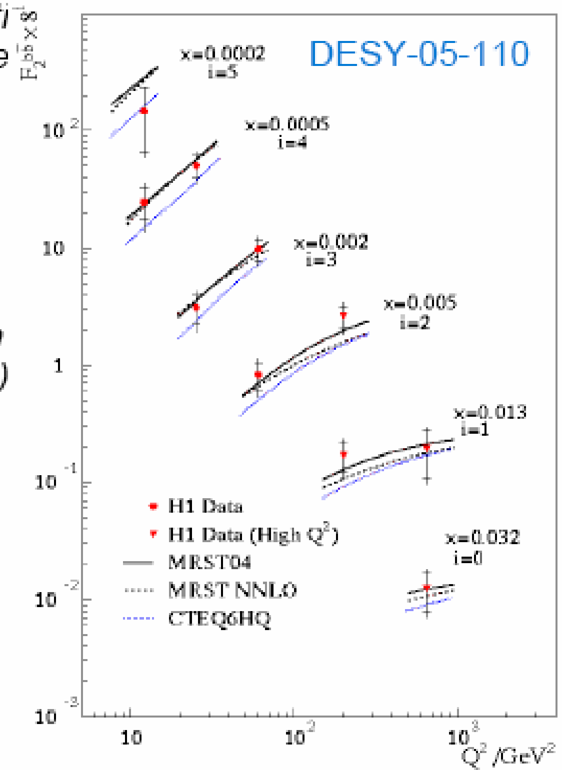
DESY-03-115, ZEUS, *Measurement of D*+ production in deep inelastic e*

DESY-06-039, H1, *Measurement of Charm and Beauty Dijet Cross Sections in Photoproduction at HERA using the H1 Vertex Detector*

DESY-05-110, H1, *Measurement of F_2^{c\bar{c}} and F_2^{b\bar{b}} at Low Q^2 and x using the H1 Vertex Detector at HERA (hep-ex/0507081)*

DESY-05-040, H1, *Measurement of Charm and Beauty Photoproduction at HERA using D* mu Correlations (hep-ex/0503038)*

DESY-04-209, H1, *Measurement of F_2^{c\bar{c}} and F_2^{b\bar{b}} at High Q^2 using the H1 Vertex Detector at HERA (hep-ex/0411046)*



CEDAR

Rivet and RivetGun

- Robust Independent Validation of Experiment & Theory
- Approximately equivalent to a C++ replacement of HZTool (Rivet) and HZSteer (RivetGun).
  - Will make greater use of existing external libraries (CLHEP, KtJet etc)
  - Rivet is generator independent.
  - RivetGun must interface to ThePEG, Sherpa, Pythia8 and existing Fortran generators.
  - Generators to be configured using HepML.

CEDAR **JetWeb**

- Goals
  - Build up database of validated models using wide range of existing data
  - Running HZSteer and RivetGun on LCG
    - CEDAR now a registered VO
    - would like to use GENSER distribution of generators
    - would like HZSteer (and eventually RivetGun) supported in GENSER – discussion with/request to LCG team.
  - Add new generators and data rapidly as they appear
  - Add more user front-end facilities for interactive tuning and analysis
- See http://jetweb.cedar.ac.uk

CEDAR: Collaborative e-Science Data Analysis Resource

I expect Jon Butterworth will have already said this, but. . .
CEDAR is an e-Science project with several sub-projects:

- JetWeb: Monte Carlo generator tuning
- HepData: archival of published experimental data
- HepML: XML formats for data sets and MC config
- HepForge: development environment for HEP software
- HepCode: centralised repository of pheno code/programs

www.cedar.ac.uk

Durham University

MC Validation Bottom Line

- Software frameworks for MC certification and validation are growing well
  - LCG Generator <--> CEDAR
- However, physics validation is still a very complex problem that needs some actions in our working group and in the context of the forthcoming MC4LHC
  - MC authors suffer from a reduced access to the "fresh" data
  - There should be a general agreement on observables and tuning parameters
  - Some work needed to recover recent but not systematically organized information
    - Fragmentation measurements at LEP