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Physics News in PYTHIA 6.3

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Part I:

- New underlying event framework
- New $p_\perp$-ordered parton showers
- Overview of relevant parameters

Part II:

- The SUSY Les Houches Accord

New UE Framework: WHY BOTHER?

- QCD point of view: hadron collisions are highly complex, while present descriptions are not.
  Should be possible to gain further physics insight.

- LHC point of view: any reliable extrapolation will require such insight.
  Simple parametrizations are not sufficient.

- New Physics and precision point of view: random and systematic fluctuations in the underlying activity can impact measurements:
  More reliable understanding is needed.

- Obvious point of view: Lots of fresh data from Tevatron:
  Great topic for phenomenology right now

New Parton Shower: WHY BOTHER?

- Some common approaches to showers:
  Parton Showers (e.g. HERWIG, PYTHIA)
  and Dipole Showers (e.g. ARIADNE).
  Each has pros and cons.
- Idea was to combine the virtues of each of these while avoiding the vices.

News in PYTHIA 6.3

PYTHIA 6.3 includes new ISR and FSR parton showers, based on a $p_\perp$-ordered sequence of $1 \to 2$ parton splittings.

It also includes a new model for multiple parton–parton interactions (for underlying events and min-bias).

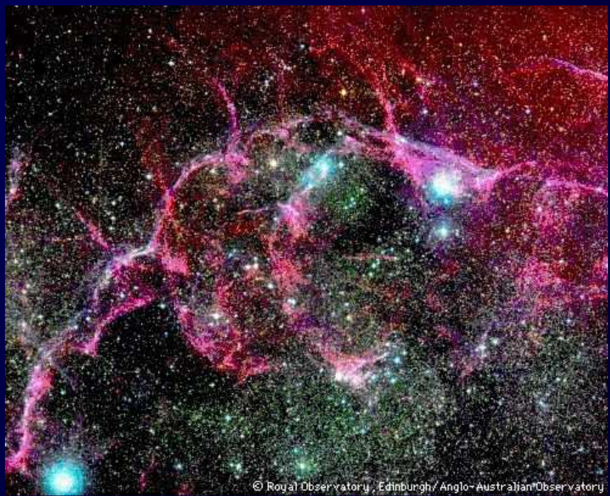
Further, the description of parton showers and the underlying event has been unified in a common $p_\perp$-ordered 'interleaved evolution' of the event as a whole.

(The PYTHIA 6.2 shower and underlying-event framework remains in `PYEVNT`, while the new options are obtained by using `PYEVNW` instead.)

THE NEW FRAMEWORK

Interactions

+ showers



+ remnants

New Multiple Interactions: Some Details

- Correlated PDF's:
  - Momentum and Energy in parent hadron conserved.
  - Sum rules for valence quarks respected. (Can't kick the same quark out twice!)
  - Sea quarks knocked out $\rightarrow$ 'companion quarks'.
- Hadronization:
  - Possible to have composite objects in the beam remnants, e.g. diquarks.
  - Addressing 'baryonic' colour topologies $\rightarrow$ 'string junctions' in the colour confinement field.
- Colour Correlations:
  - The big question! Seems Nature likes a *very* high degree of correlation (cf. 'Tune A' of old model!).
  - Several possibilities investigated, so far without success.

New $p_\perp$-ordered parton showers

- $p_\perp$ ordering $\Rightarrow$ coherence inherent, while kinematics still simple and Lorentz invariant
  (cf. quite messy kinematics and L/I in HERWIG, coherence not inherent and slightly messy kinematics in "old" PYTHIA).
- $p_\perp$ ordering $\Rightarrow$ Merging with Matrix Elements also simple
  (cf. complicated in HERWIG — "dead zone")
- It's still a parton shower, so $\mathrm{g} \to \mathrm{q\bar{q}}$ not principally different from other branchings and ISR no problem
  (cf. 'artificial' in ARIADNE)
- showers can be stopped and restarted at any $p_\perp$ scale
  ($\Rightarrow$ well suited for ME/PS matching)

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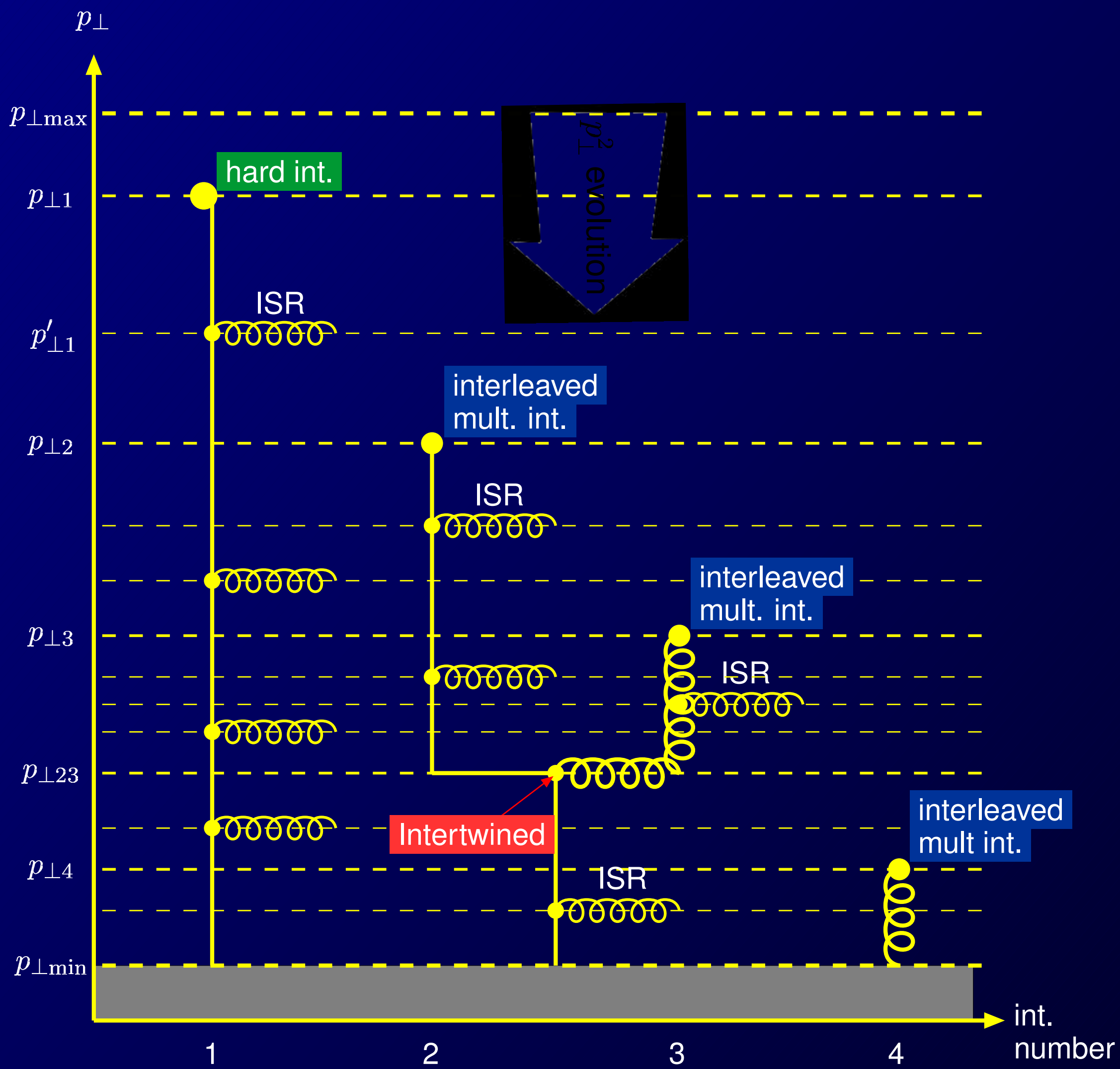
  ($\Rightarrow$ well suited for ME/PS matching)
- $p_\perp$ evolutions of showers and multiple interactions can be combined $\rightarrow$ *common* evolution of ISR, FSR, and MI!

  $\equiv$ **'Interleaved Multiple Interactions'**

Interleaved Evolution, what is that?

The new picture: start at the most inclusive level, $2 \to 2$.
Add exclusivity progressively by evolving *everything* downwards.



The New Framework

The building blocks:

- $p_\perp$–ordered multiple interactions. ✔
- $p_\perp$–ordered initial–state parton showers.✔
- $p_\perp$–ordered final–state parton showers.✔
- $p_\perp$ used as scale in α_s and in PDF's.✔
- (Model for) correlated multi–parton densities.✔
- Beam remnant hadronization model.✔
- Model for initial state colour correlations. (✔)
- Other phenomena? (e.g. colour reconnections (✔), ...)
- Realistic tunes to data (so far only for FSR...)

Model Tests: FSR

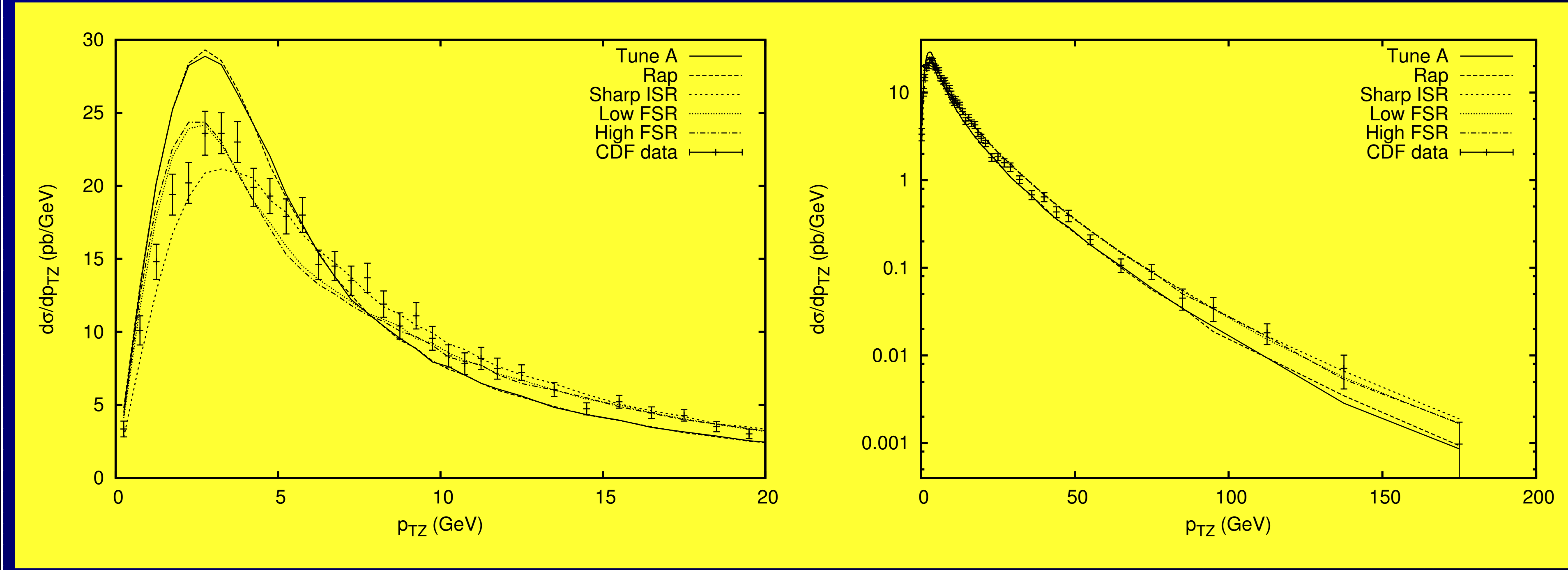
- FSR algorithm.
  - Tested on ALEPH data (G. Rudolph).

		$\sum \chi^2$ of model	
Distribution	nb.of	PY6.3	PY6.1
of	interv.	$p_\perp$-ord.	mass-ord.
Sphericity	23	25	16
Aplanarity	16	23	168
$1-$Thrust	21	60	8
Thrust$_{\mathrm{minor}}$	18	26	139
jet res. y_3(D)	20	10	22
$x = 2p/E_{\mathrm{cm}}$	46	207	151
$p_{\perp \mathrm{in}}$	25	99	170
$p_{\perp \mathrm{out}} < 0.7$ GeV	7	29	24
$p_{\perp \mathrm{out}}$	(19)	(590)	(1560)
x(B)	19	20	68
sum $N_{\mathrm{dof}} =$	190	497	765

  - (Also, generator is not perfect. Adding 1% to errors $\Rightarrow$ $\sum \chi^2 = 234$. i.e. generator is 'correct' to $\sim$1%)

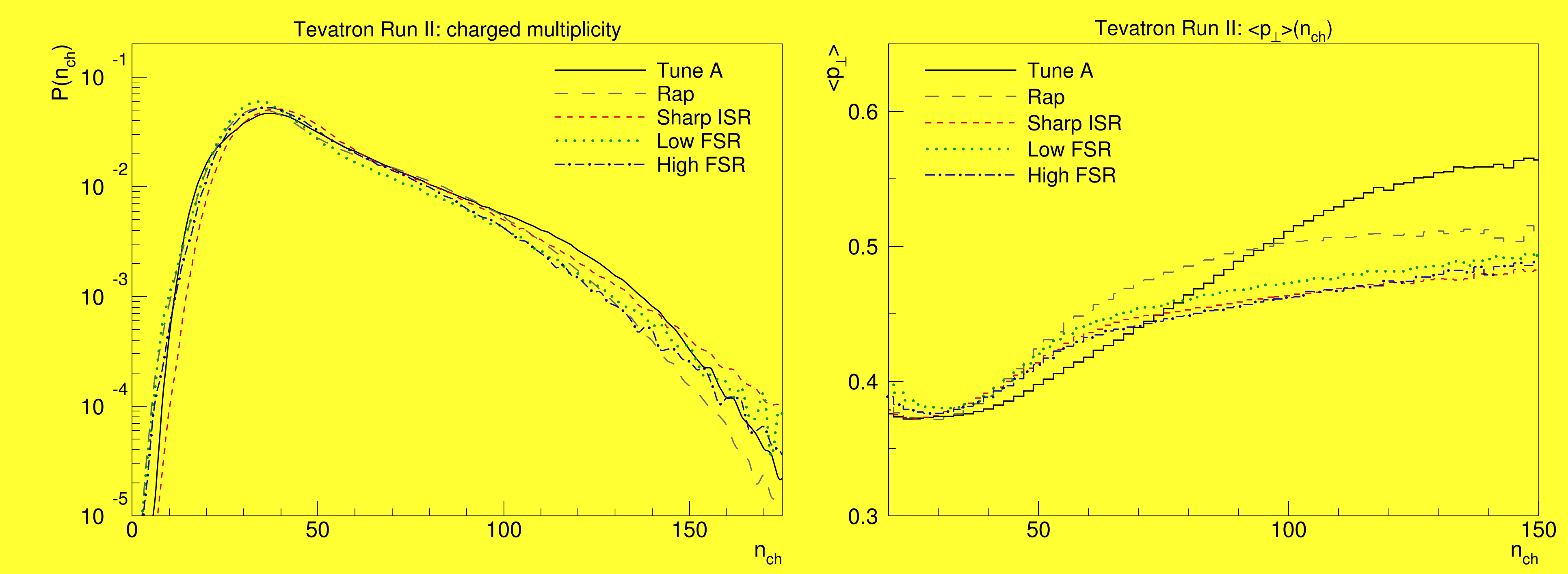
Model Tests: ISR

- ISR algorithm.
  - Less easy to test. We looked at $p_\perp$ of Z^0 at Tevatron.
  - Compared "Tune A" with an 'intermediate scenario' ("Rap"), and three rough tunes of the new framework.
  - Description is improved (but there is still a need for a large primordial $k_\perp$).



Model Tests

- Whole framework.
  - The rough tunes were made to 'Tune A' at the Tevatron, using charged multiplicity distribution and $\langle p_\perp \rangle(n_{\rm ch})$, the latter being highly sensitive to the colour correlations.
  - Similar overall results are achieved (not shown here), but $\langle p_\perp \rangle(n_{\rm ch})$ still difficult.
  - Anyway, these were only *rough* tunes...



Outlook

- New complete framework for hadron collisions has been developed. Includes $p_\perp$–ordered *interleaved* parton showers and multiple interactions, correlated remnant parton distributions, impact parameter–dependence, extended (junction) string fragmentation model, etc.
- It's all in PYTHIA 6.316 (24 Nov 2004).
- Good overall performance, though still only primitive studies/tunes carried out, except for FSR.
- Colour correlations still a headache. Still unclear what role *intertwining* may play.

Outlook

- Conclusion: our picture of hadron collisions is becoming more complex...

PYTHIA 6.3

OVERVIEW OF RELEVANT PARAMETERS

PYTHIA 6.3 Parameter Overview: Switches

`MSTP(61)`	Master switch for initial–state radiation. Default is on.
`MSTP(71)`	Master switch for final–state radiation. Default is on.
`MSTP(81)`	Master switch for multiple interactions and beam remnant framework.

`MSTP(70)`	Selects regularization scheme for ISR when $p_\perp \to 0$. Default is sharp cutoff at the regularization scale used for MI.
`MSTP(72)`	Selects maximum scale for radiation off FSR dipoles stretched between ISR partons. Default is $p_\perp$ scale of radiating parton.
`MSTP(82)`	Selects which functional form to assume for the impact-parameter dependence of the matter overlap between two beam particles.
`MSTP(84)`	Selects whether initial–state radiation is turned on or off for subsequent interactions (i.e. interactions after the main one). Default is on.
`MSTP(85)`	Selects whether final–state radiation is turned on or off for subsequent interactions (i.e. interactions after the main one). Default is on.
`MSTP(89)`	Controls how initial–state parton shower initiators are colour–connected to each other. Default is to assume a rapidity ordering.
`MSTP(95)`	Selects whether colour reconnections are allowed or not. Default is on.

PYTHIA 6.3 Parameter Overview: Parameters

`PARP(82)`	Regularization scale, $p_{\perp 0}$, for multiple interactions, at reference energy `PARP(89)`. Default is 2 GeV.
`PARP(89)`	Reference energy for energy rescaling of $p_{\perp 0}$ cutoff, i.e. the energy scale at which $p_{\perp 0}$ is equal to `PARP(82)`. Default is 1800 GeV.
`PARP(90)`	Power of energy rescaling used to determine the value of $p_{\perp 0}$ at scales different from the reference scale `PARP(89)`.
`PARP(83:84)`	Shape parameters, controlling the assumed matter distribution or overlap profile, as applicable (i.e. depending on `MSTP(82)`).
`PARP(78)`	Controls the amount of colour reconnection in the final state.
`PARP(79)`	Enhancement factor for x values of composite systems (e.g. di-quarks) in the beam remnant.
`PARP(80)`	Suppression factor for initial–state colour connections that would break up the beam remnant.

More information on PYTHIA 6.3

- The PYTHIA 6.3 manual: hep-ph/0308153
- “Notes on using PYTHIA 6.3”: on my homepage: `http://home.fnal.gov/~skands/`
- Physics descriptions of the new ISR/FSR/MI framework:
  - TS+PS, “Transverse-Momentum-Ordered Showers and Interleaved Multiple Interactions”, hep-ph/0408302.
  - TS, “New Showers with transverse-momentum-ordering”, hep-ph/0401061.
  - TS+PS, “Multiple Interactions and the Structure of Beam Remnants”, JHEP 0403 (2004) 053.
- + Slides like these.

  (See “Slides/Talks” on my homepage for a complete list)