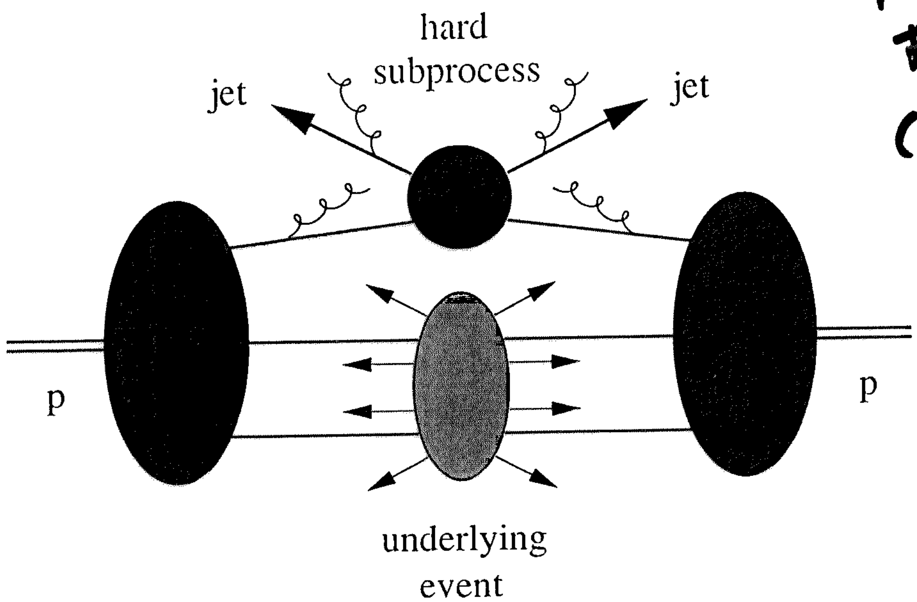
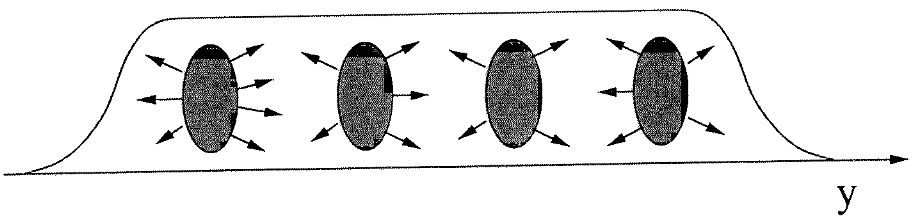
UNDERLYING EVENT について

Underlying Event



もっとくわしいトラペも持ってきています
(Webber WS on Theory of LHC processes, 13 Feb 98)

- HERWIG uses UA5 multi-cluster (min bias) model
  GJ Alner et al., Nucl Phys B291 (1987) 445

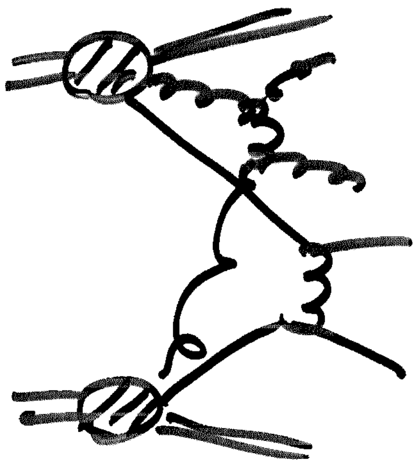


- ❖ Negative binomial distribution sampled for n_{ch}
- ❖ Clusters generated until preselected n_{ch} is reached

これでよいのか?

⟺

PYTHIAは
Multiple interaction

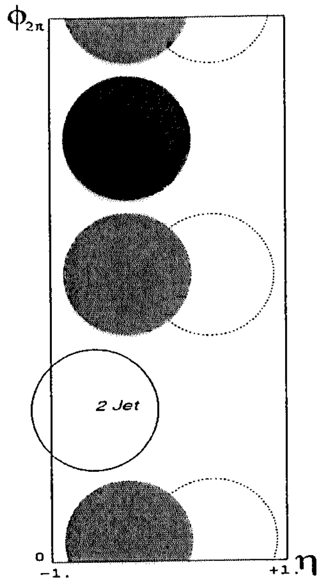


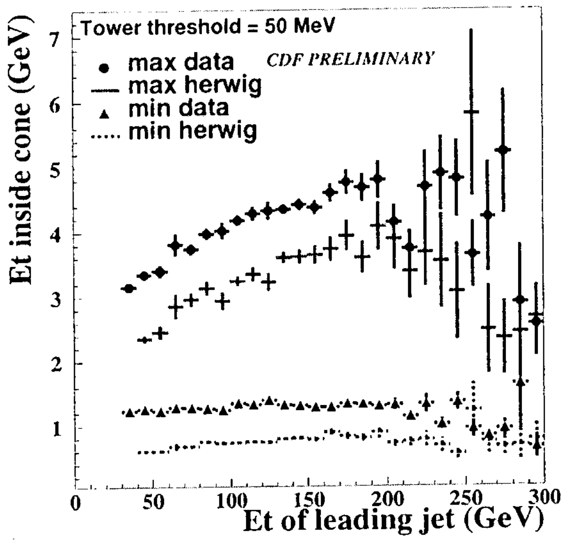
- Better understanding of underlying event is vital. Studying two regions away from jets can help

  G Marchesini & BRW, Phys Rev D38 (1988) 3419

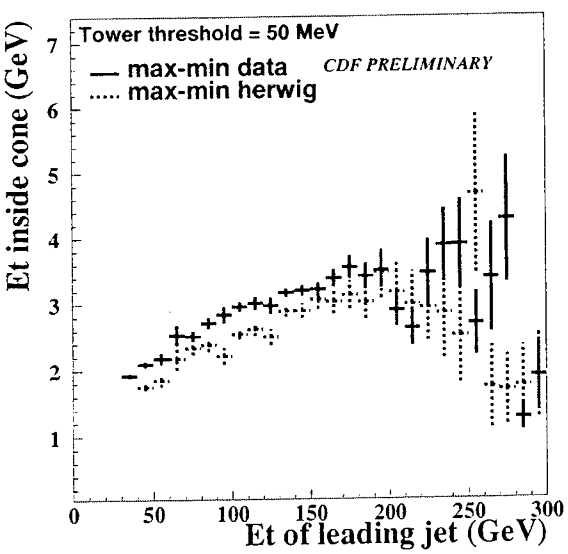
  - max has underlying event plus hard process activity
  - min has underlying event, less hard process activity

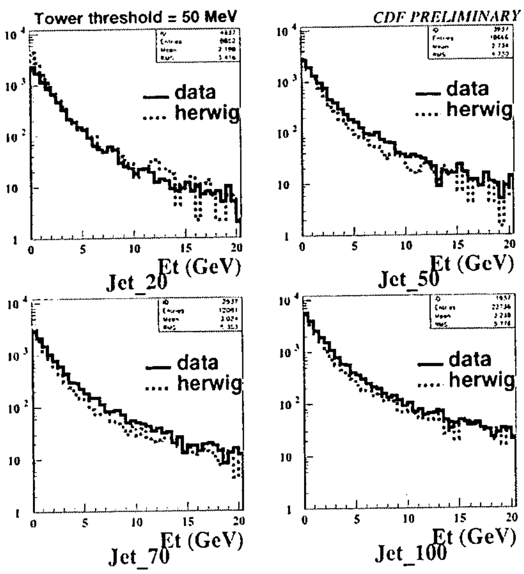
  J Huston & V Tano, in hep-ph/0005114





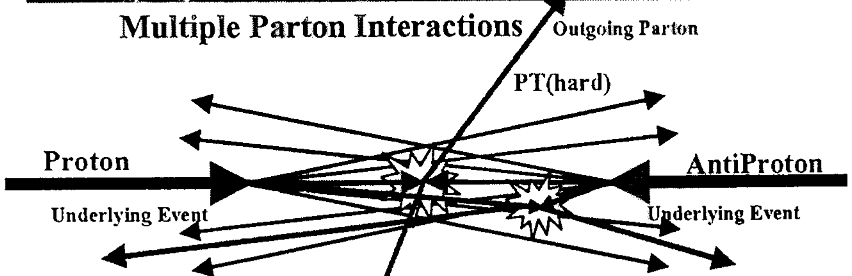
- min–max subtracts most of underlying event:





- HERWIG has right qualitative features but too little and/or too soft underlying event.

PYTHIA: Multiple Parton Interactions

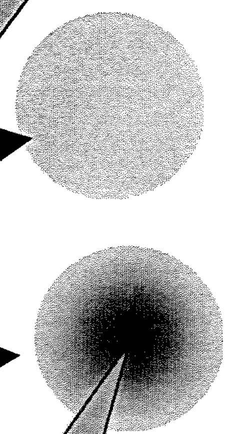


Pythia uses multiple parton interactions to enhace the underlying event.

and new HERWIG!

Parameter	Value	Description
MSTP(81)	0	Multiple-Parton Scattering off
	1	Multiple-Parton Scattering on
MSTP(82)	1	Multiple interactions assuming the same probability, with an abrupt cut-off $P_T$min=PARP(81)
	3	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a single Gaussian matter distribution, with a smooth turn-off P_{T0}=PARP(82)
	4	Multiple interactions assuming a varying impact parameter and a hadronic matter overlap consistent with a double Gaussian matter distribution (governed by PARP(83) and PARP(84)), with a smooth turn-off P_{T0}=PARP(82)

Multiple parton interaction more likely in a hard (central) collision!



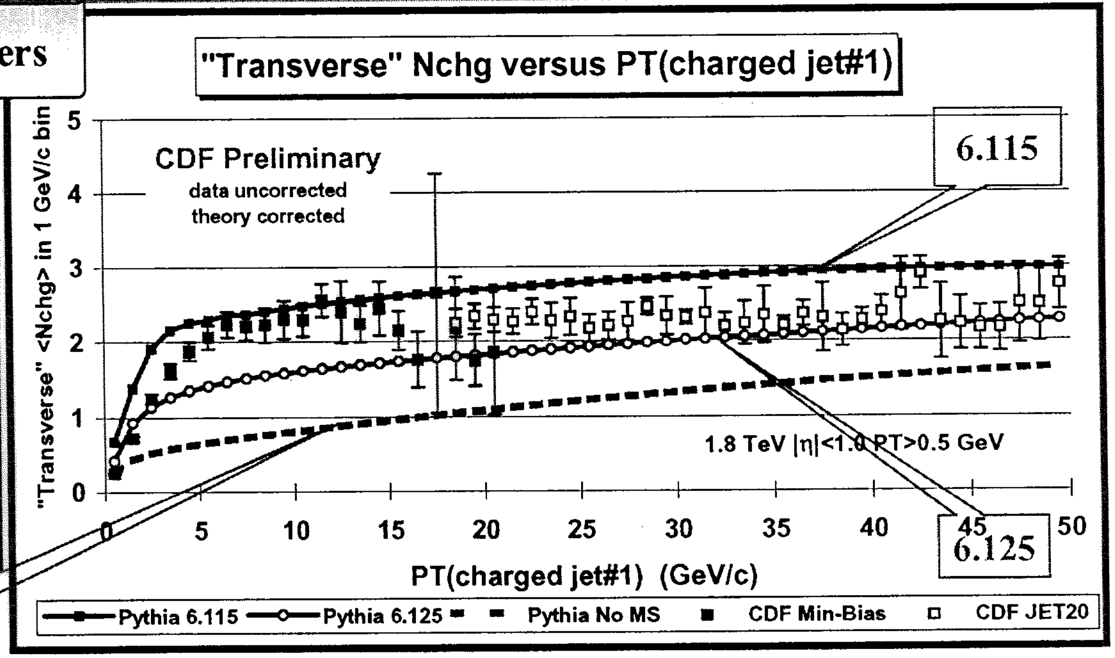
Hard Core

PYTHIA
Multiple Parton Interactions

PYTHIA default parameters

Parameter	6.115	6.125
MSTP(81)	1 MI on	1
MSTP(82)	1	1
PARP(81)	1.4 GeV/c	1.9 GeV/c
PARP(82)	1.55 GeV/c	2.1 GeV/c

1 – impact param. ind.
3 – matter がおける分布
4 – double gaussian.



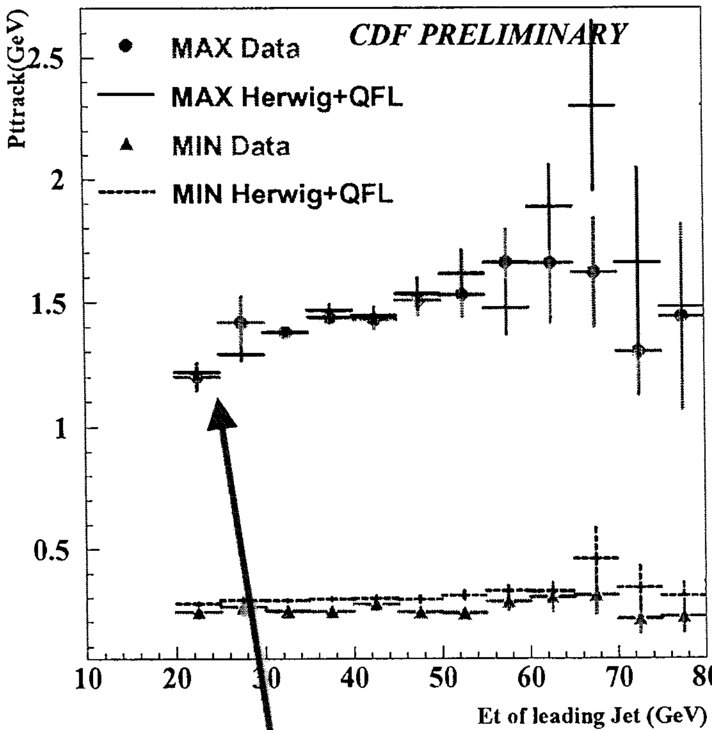
No multiple scattering

- Plot shows "Transverse" <Nchg> versus PT(chgjet#1) compared to the QCD hard scattering predictions of PYTHIA with P_T(hard) > 3 GeV.
- PYTHIA 6.115: GRV94L, MSTP(82)=1, $P_T$min=PARP(81)=1.4 GeV/c.
- PYTHIA 6.125: GRV94L, MSTP(82)=1, $P_T$min=PARP(81)=1.9 GeV/c.
- PYTHIA 6.115: GRV94L, MSTP(81)=0, no multiple parton interactions.

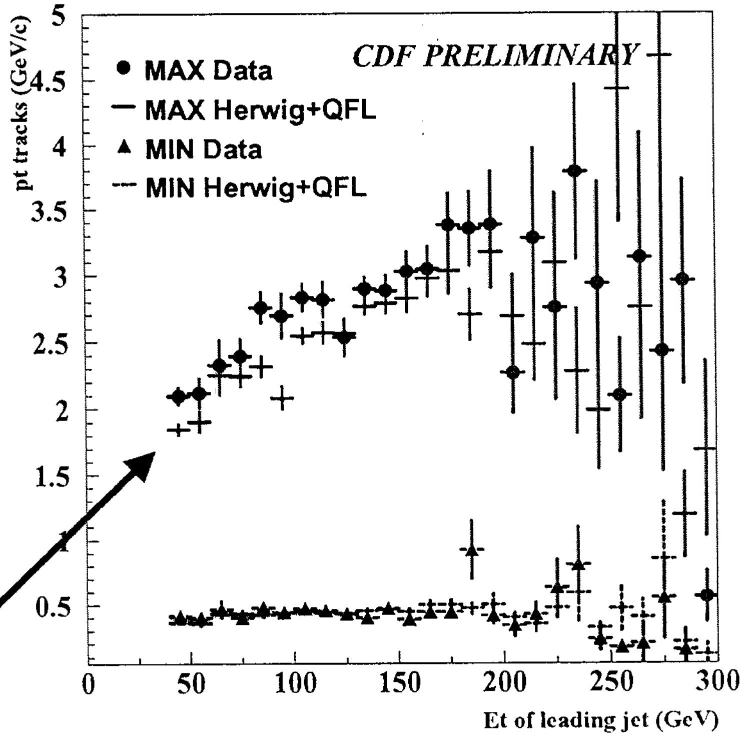
Constant Probability Scattering

Max/Min Cones at 630 GeV/c

Pt track in max and min cone at 630 GeV



Pt track in max and min cone

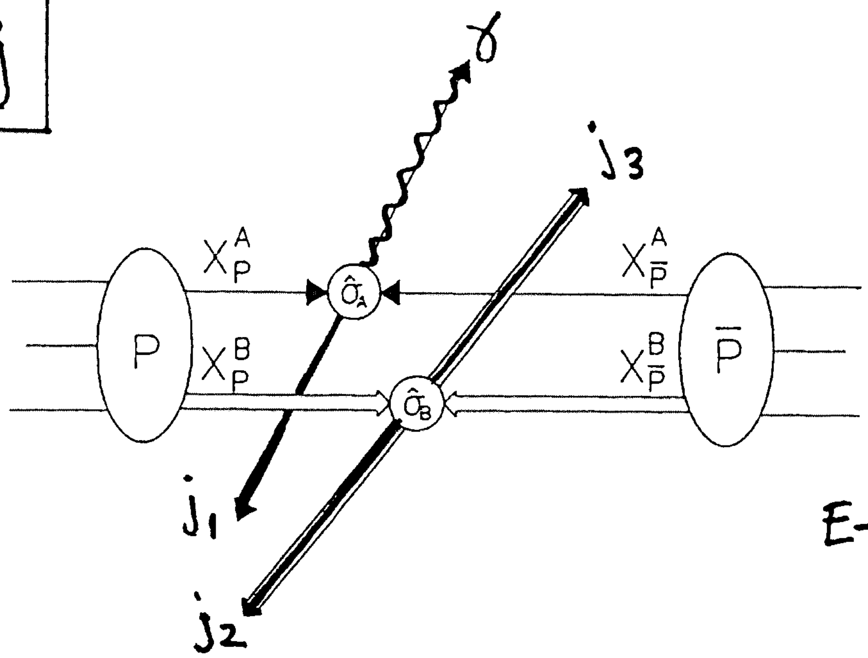


- HERWIG+QFL slightly lower at 1,800 GeV/c agrees at 630 GeV/c.

Tano-Kovacs-Huston-Bhatti

γ jjj

CDF
PRD56(97)3811



$E_{Tj} > 5$ GeV

FIG. 1 Schematic diagram of double parton scattering in $\bar{p}p$ collisions. Two pairs of partons undergo hard scatterings; the scatterings are labeled A and B, and the Feynman x's of the four initial state partons are labeled by the baryon from which they originate and the scattering to which they contribute.

- N.B. σ_B HARD $\propto 1/Q^2 \Rightarrow$ A 'HIGHER-TWIST' CONTRIB'N

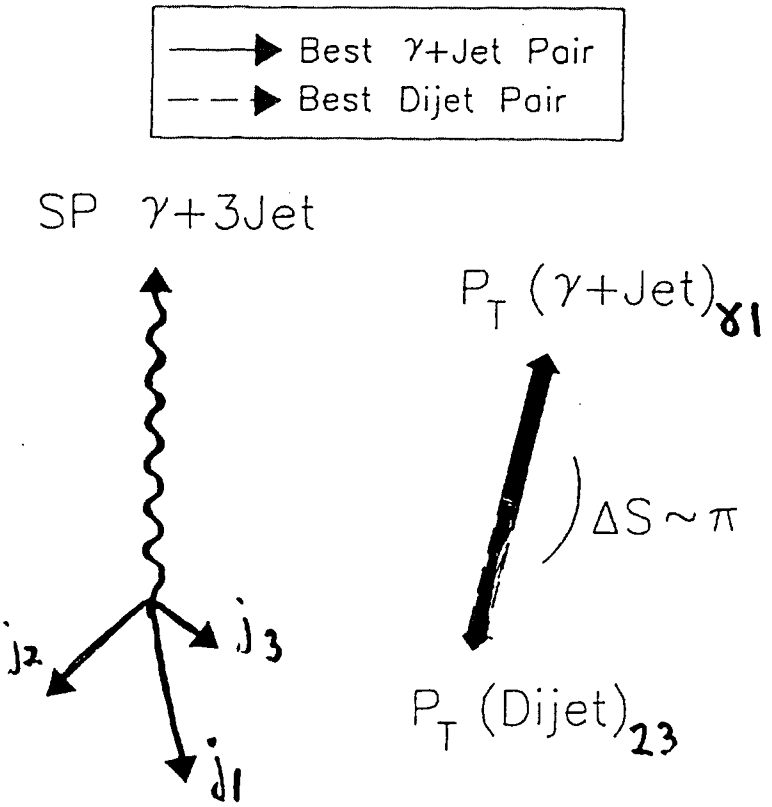


FIG. 5. Illustration of the definition of the ΔS variable, applied to a SP photon + 3 jet event. ΔS is the azimuthal angle between the p_T vectors of the two best-balancing pairs constructed from the photon + 3 jet system.

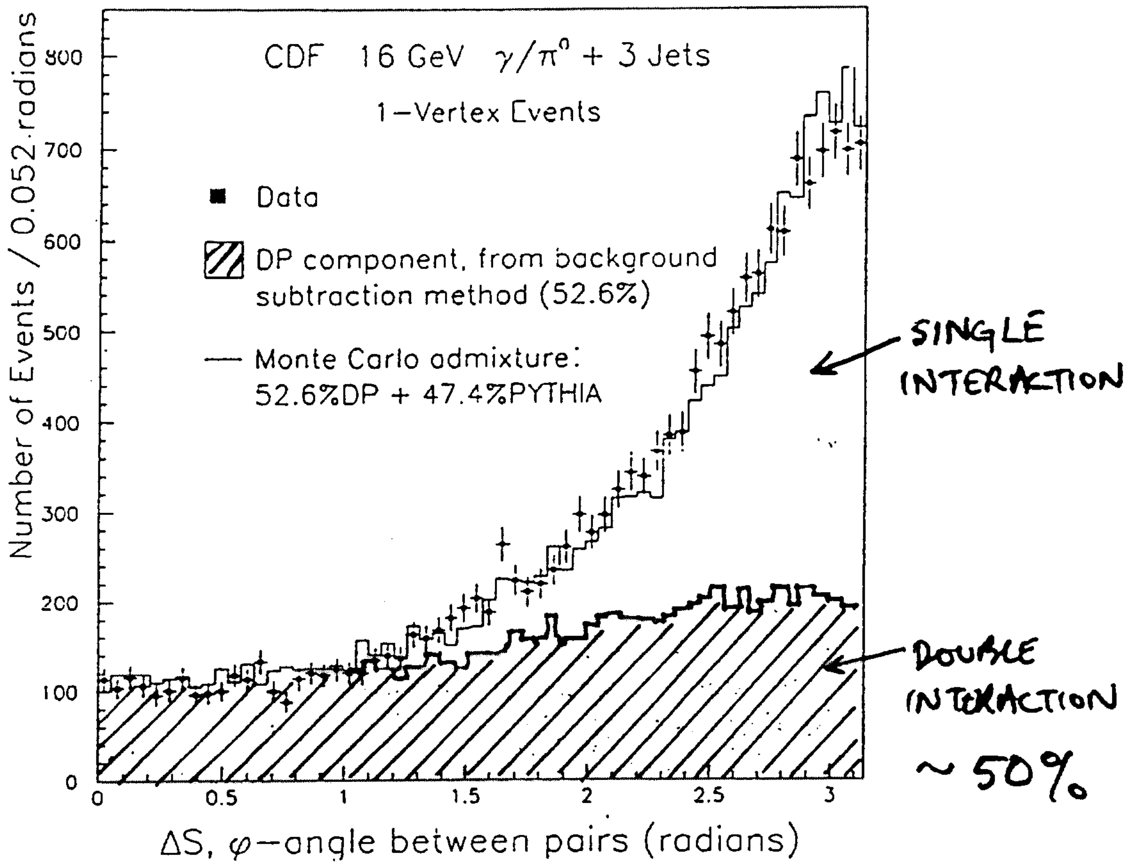


FIG. 15. ΔS distribution for 1VTX data (points). The DP component to the data, determined by the two-data-set background subtraction method to be 52.6% of the sample, is shown as the shaded region (the shape is taken from MIXDP). Also shown is the admixture 52.6% MIXDP+47.4% PYTHIA, normalized to the data (line).

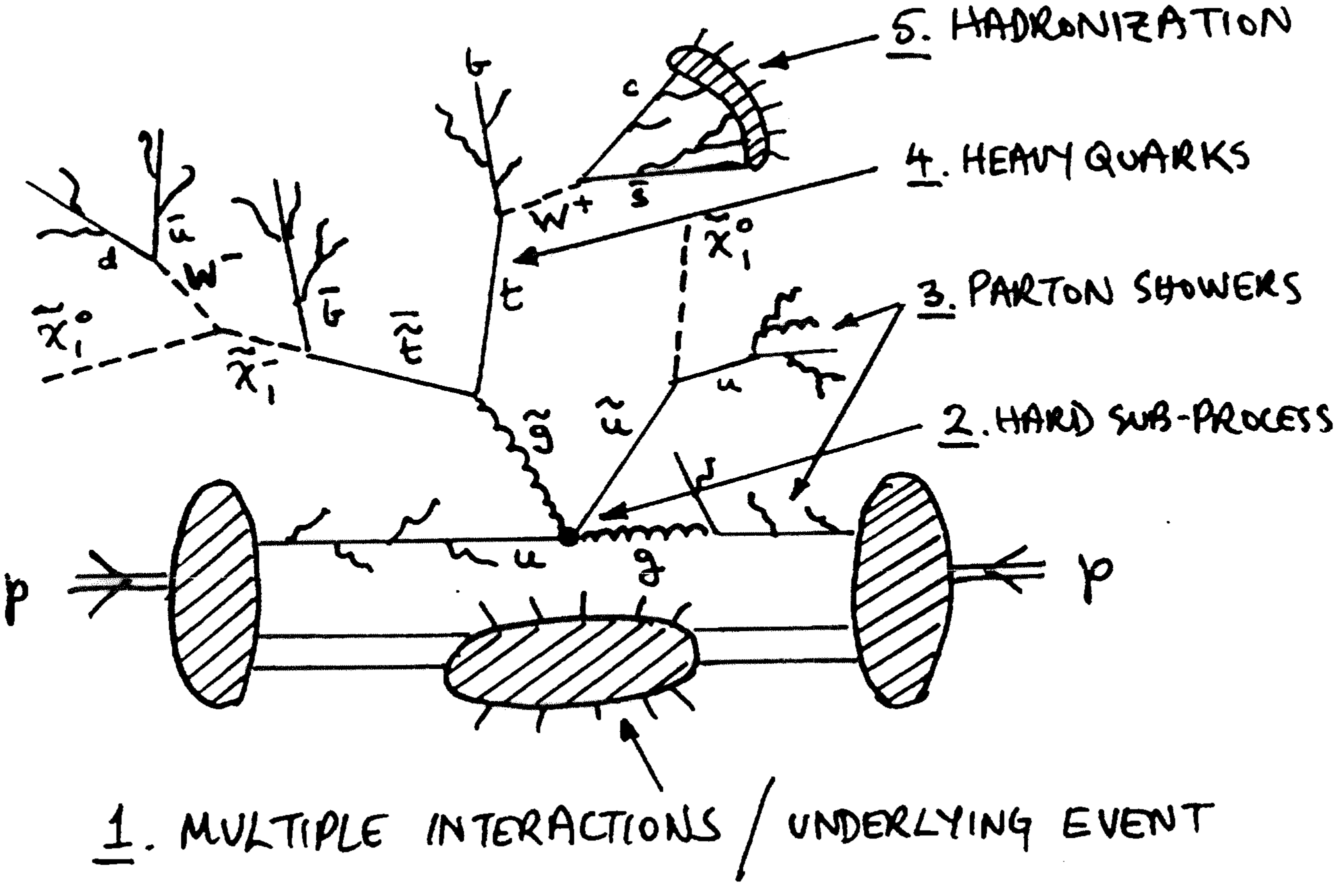
MONTE CARLOS FOR THE LHC

Bryan Webber

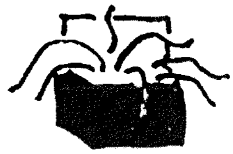
W/S on Theory of LHC Processes

13 February 1998

- A 'TYPICAL' LHC EVENT FROM A QCD EVENT GENERATOR (HERWIG 6.0)



- A SELECTION OF TOPICS



- APOLOGIES FOR HERWIG BIAS

MULTIPLE INTERACTIONS

$$\sigma_{AB} \simeq \sigma_A \sigma_B \left(\frac{1}{\pi R^2} + \frac{N_{int}}{\sigma_{inel}} \right)$$

SAME HADRONS ($\frac{1}{\pi R^2}$): $\pi R^2 \sim 15\,mb$ (CDF)

DIFFERENT HADRONS ($\frac{N_{int}}{\sigma_{inel}}$): $\sigma_{inel} \sim 70\,mb$

- N_{int} = no. of unresolved interactions per trigger event (+ PILEUP)

– $\Delta z \sim 5\,cm \Rightarrow 23$ at $\mathcal{L} = 10^{34}\,cm^{-2}s^{-1}$

– $\Delta z \lesssim 1\,mm \Rightarrow$ negligible

- Test case : W + 2 jets

– Prelim. studies suggest effect small at $(p_T)_{jet} \gtrsim 20$ GeV (Figs.)

– But event topology different $\Rightarrow$ include in backgrounds

– Available in PYTHIA (m.i. ≡ underlying evt), not yet in HERWIG (multi-QCD in JIMMY)

Wjj

Eboli, Halzen + Mizukoshi
hep-ph/9710443

FIGURES

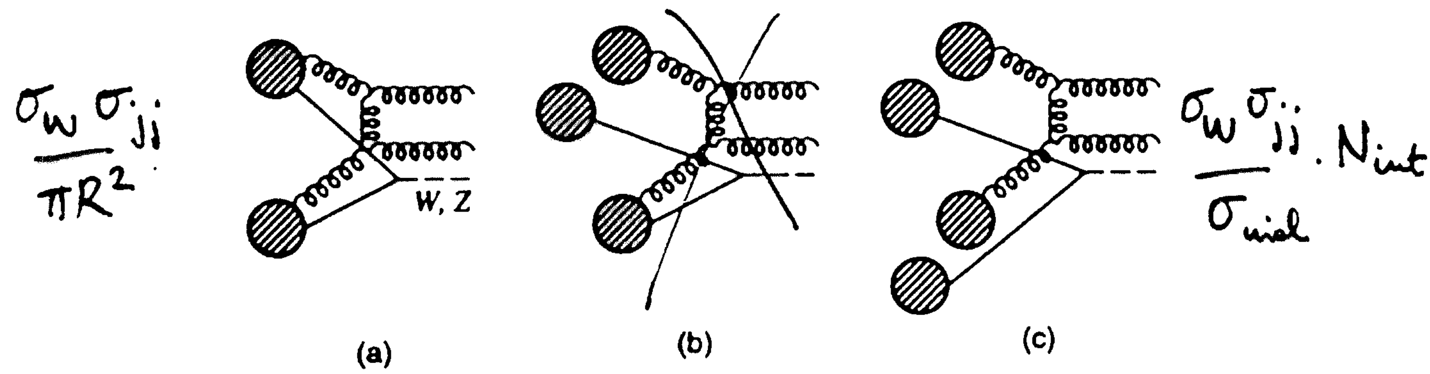


FIG. 1. $W, Z + 2$-jet multiple-parton scattering.

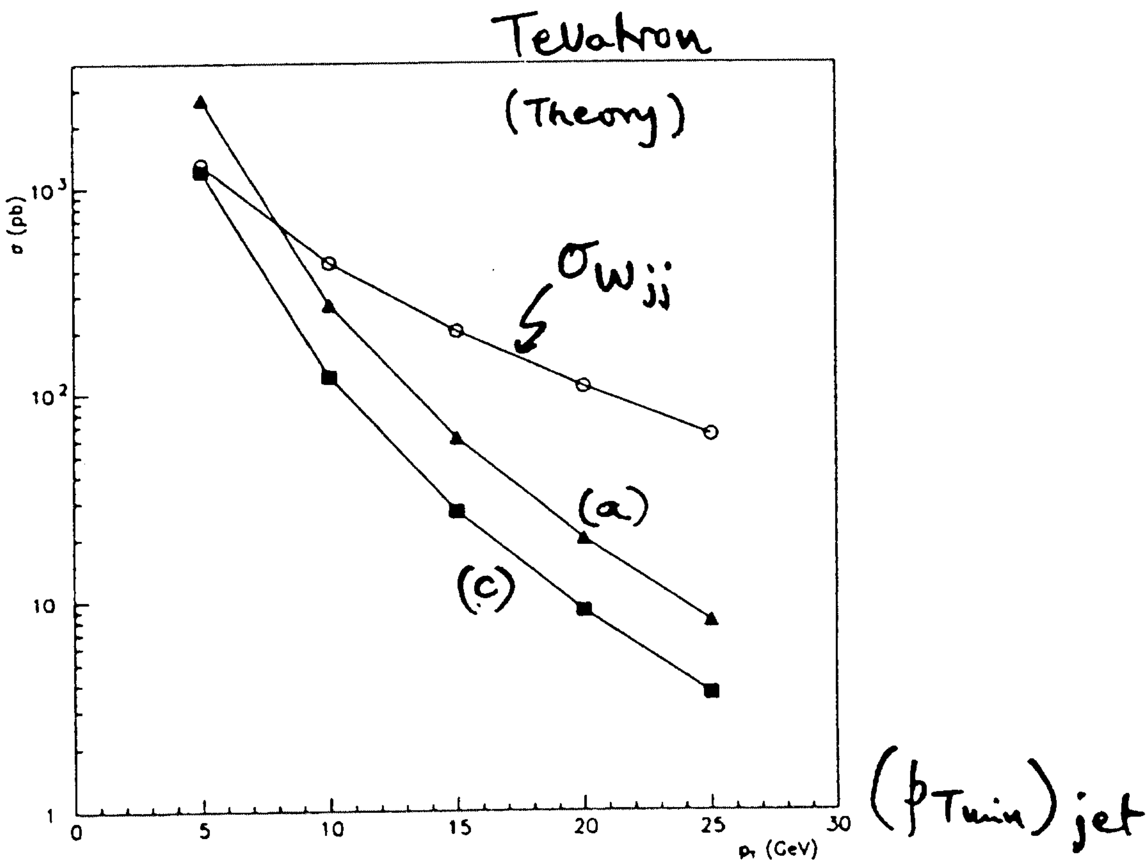
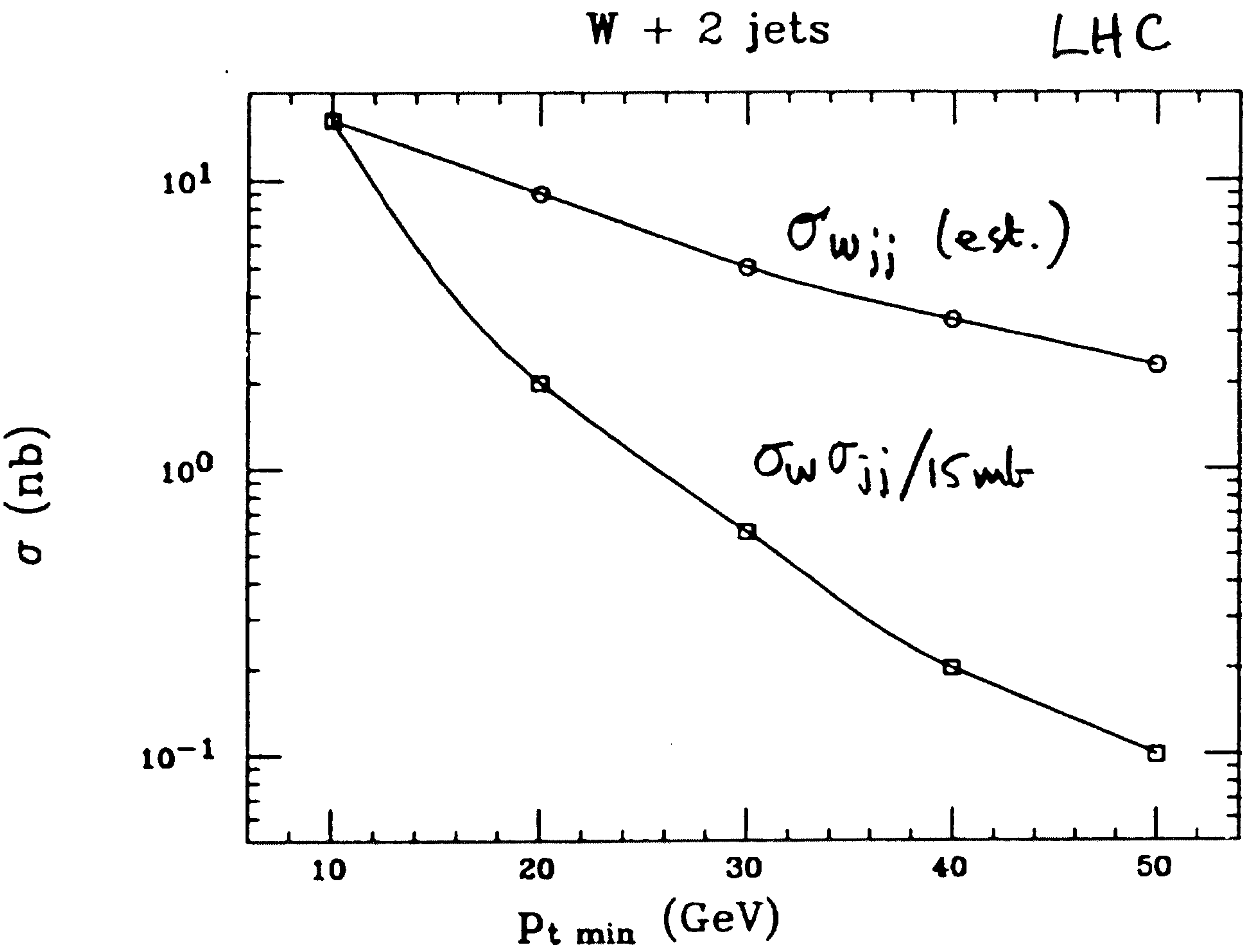


FIG. 2. Total cross section for the production of a W accompanied by 2 jets, as a function of the minimum-p_T cut, for: QCD processes (open circles), double-parton interactions (triangles), multiple interactions (squares).


W + 2 jets
LHC
σ (nb)
10¹
10⁰
10⁻¹
σ_Wjj (est.)
σ_W σ_jj/15mb
10
20
30
40
50
P_t min (GeV)

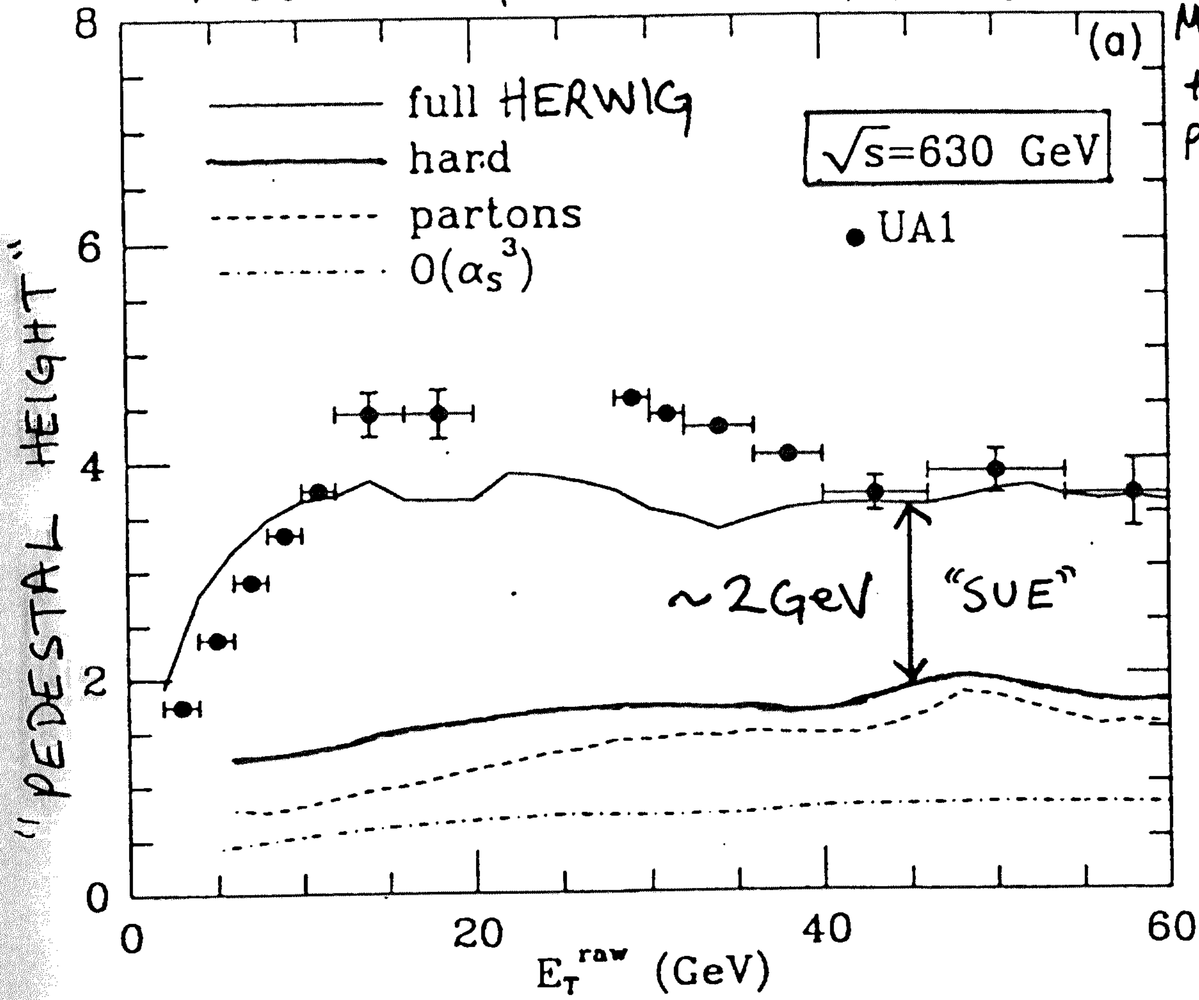
UNDERLYING EVENT

- Studies of jet production at $Sp\bar{p}S$ + Tevatron Collider energies suggest ~ 50% of E_T is associated with hard sub-process (QCD ISR) Figs.
- Is the rest due to multiple interactions (PYTHIA, ISAJET)?
- Or is there a distinct mechanism ≈ min. bias (GENCL, HERWIG)?

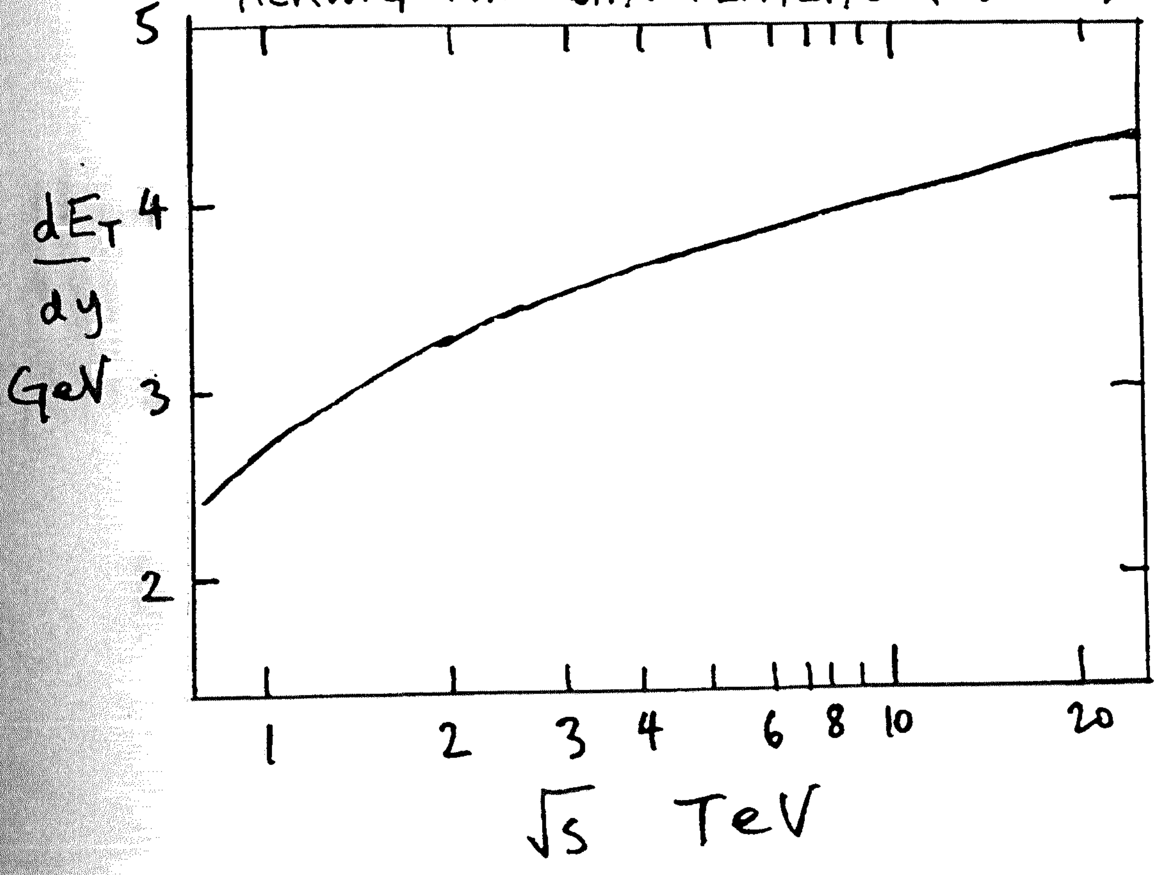
— A possible way to isolate and study the underlying event is to look for long-range rapidity correlations, e.g. by comparing 'pedestal heights' on each side of jet. Fig.

UNDERLYING EVENT IN $\bar{p}p \to$ jet X

Marchesini + BRW PRD38 (88) 3419



HERWIG MIN BIAS PLATEAU (|y|<2)



Marchesini + W

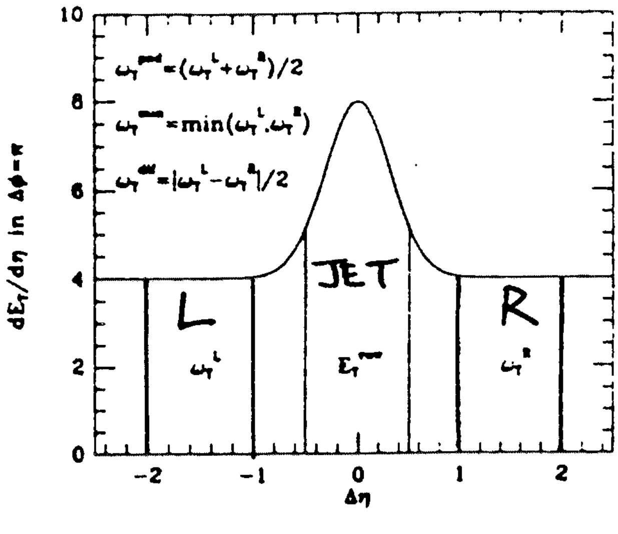
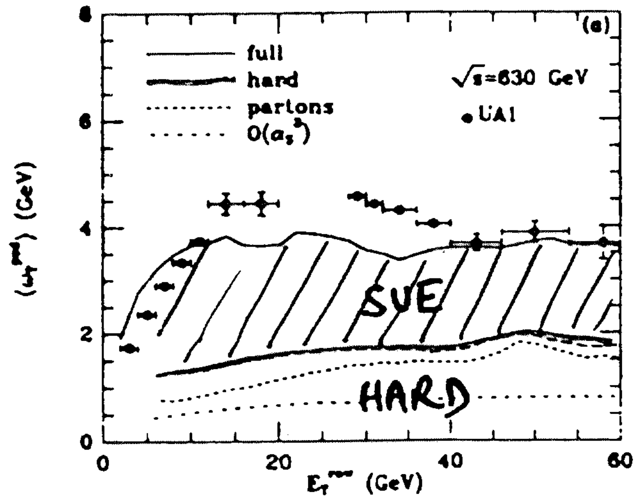
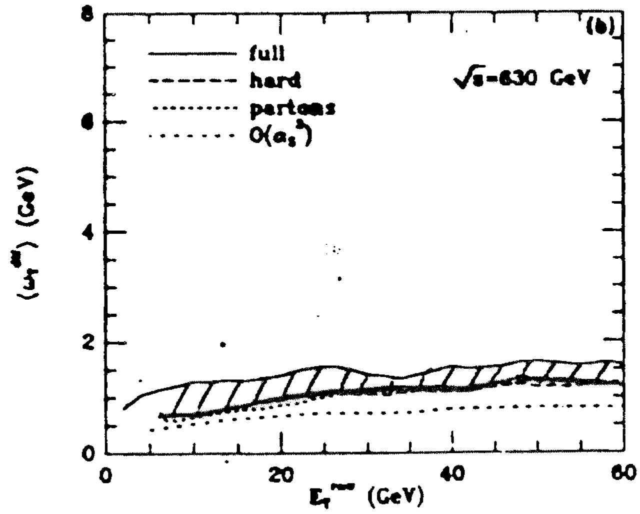


FIG. 1. Definition of the pedestal height and related quantities.



$\frac{L+R}{2}$



$\frac{|L-R|}{2} \Rightarrow$ SUE SUPPRESSED

PYTHIA

Sjostrand + van Zijl PRD36(87)2019

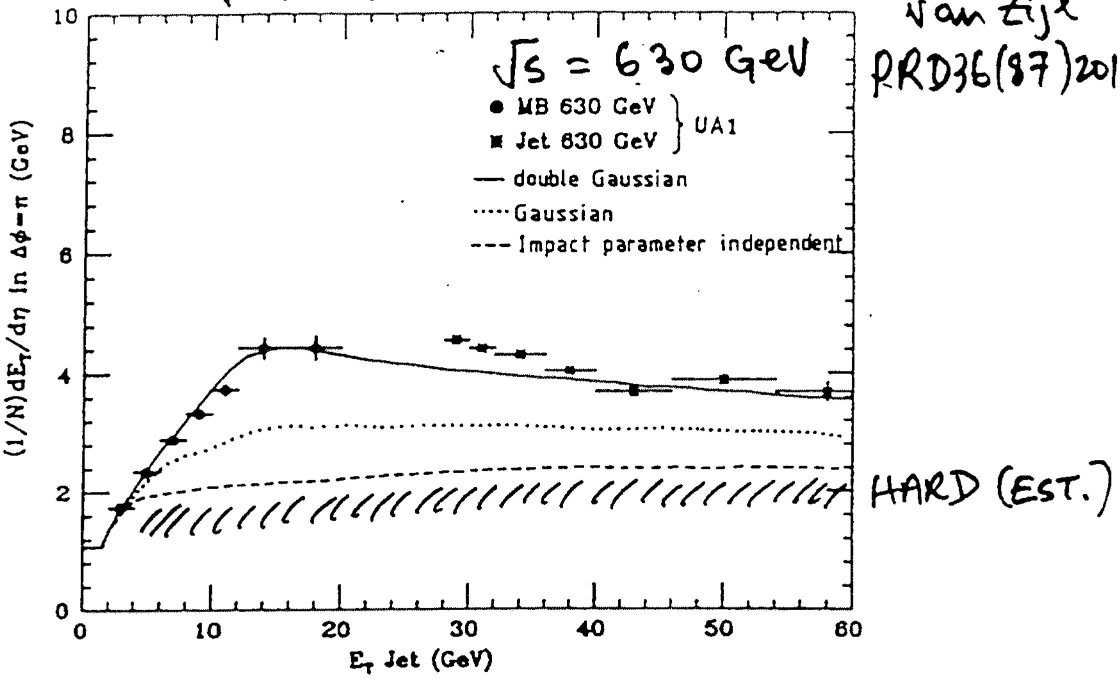


FIG. 32. Average transverse energy $\langle dE_T/d\eta \rangle$ in $1 \leq |\eta - \eta_{jet}| \leq 2$, $|\phi - \phi_{jet}| < 90°$ as a function of the $E_{T jet}$ trigger. Data points UA1 at 630 GeV (Ref. 50), dashed curve represents the impact-parameter-independent model, dotted curve represents Gaussian, and solid curve represents double-Gaussian matter distribution.

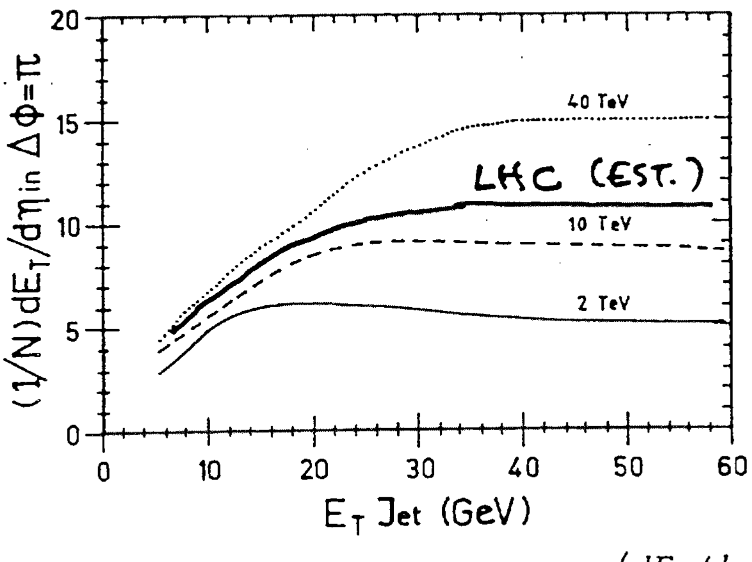


FIG. 34. Average transverse energy $\langle dE_T/d\eta \rangle$ in $1 \leq |\eta - \eta_{jet}| \leq 2$, $|\phi - \phi_{jet}| < 90°$ as a function of the $E_{T jet}$ trigger (UA1-inspired jet algorithm). Solid curve, results at 2 TeV; dashed curve, results at 10 TeV; and dotted curve, results at 40 TeV.

- HERWIG + PYTHIA ⇒ LHC "PEDESTAL" ~ 10±3 GeV
- REALLY MORE UNCERTAIN

HERWIG 現状と今後

HERWIG 6.3 (6.301) RELEASED
9 JULY 2001

- ☆ DEFAULT PDF CHANGED TO MRST
- ☆ DI GAUGE BOSON PRODUCTION
  QQZ PRODN. (WW, ZZ, ZW, Zγ, γW, etc)
- ☆ 2→3 MSSM HIGGS
- ☆ NEGATIVE WEIGHTS OPTION
- ☆ CIRCE BEAMSTRAHLUNG PROGRAM INTERFACE

HERWIG 6.4 TO BE RELEASED
"REAL SOON"

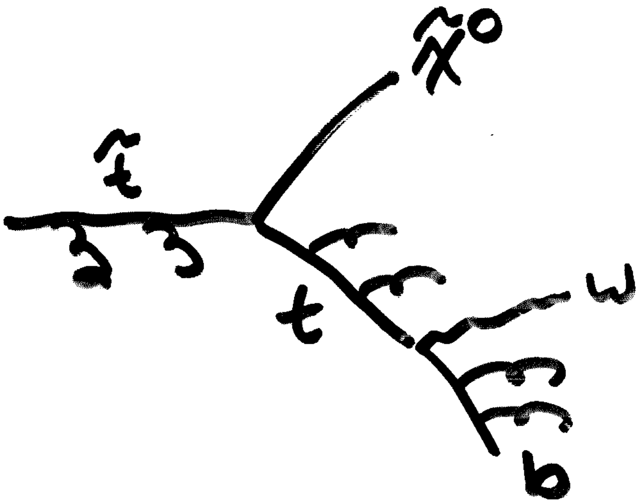
最強の SUSY generator?

- ☆ SPIN CORRELATION IN CASCADE DECAY
- ☆ SUSY 3 BODY ME DECAY
- ☆ SUSY LEPTON BEAM POLARISATION
- ☆ $e^+e^- \to$ MSSM HIGGS

HERWIG++ BEFORE LHC – 2008?

NEW PHYSICS INCLUDES

(例)

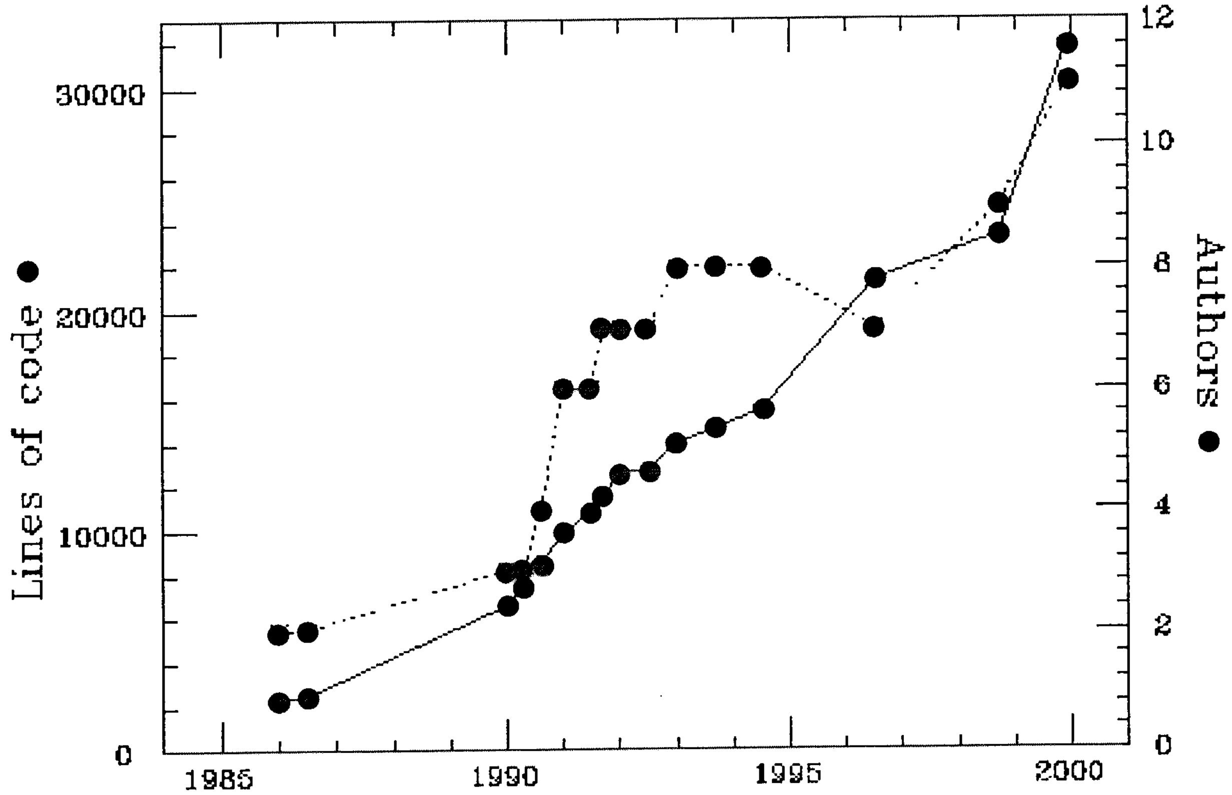


MORE CONSISTENT TREATMENT OF SUSY SHOWERING.

(現状では $\tilde{t}$ からの EMISSION はない)

Future Plans

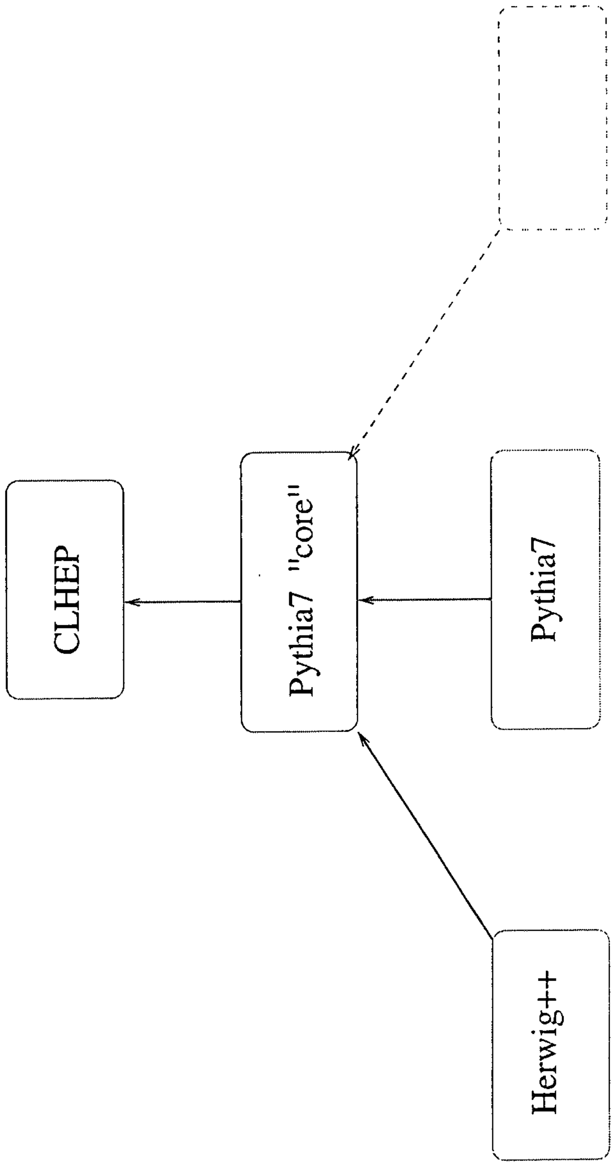
- Program has expanded $\times 10$ over 15 years

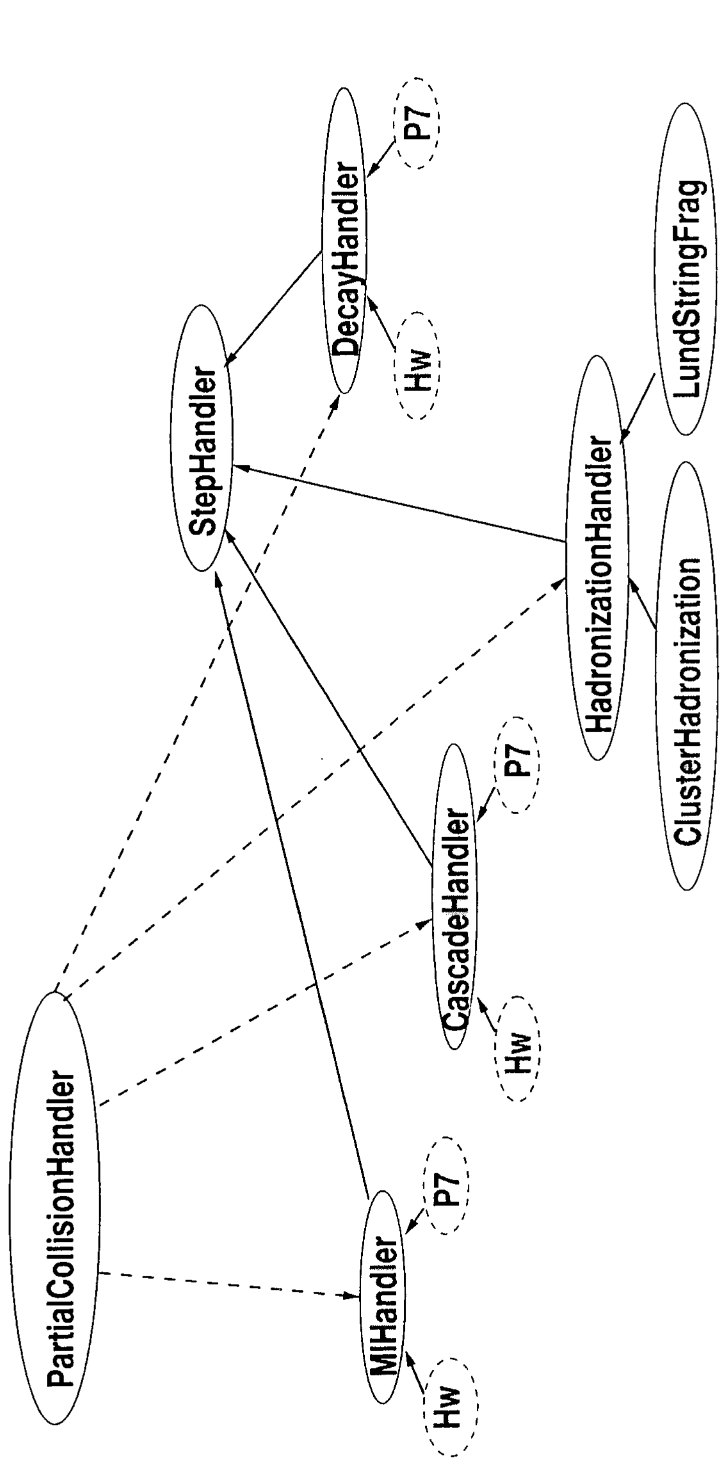


- Software maintenance and development becoming impossible (and students don't learn Fortran . . .)

- New Object Oriented Program HERWIG++ under construction (talk by Alberto Ribon)
  - ❖ Standard class structure and interfaces (CLHEP, PYTHIA7, . . .)
  - ❖ New physics (multijets, SUSY showering, . . .)

A Ribon, MH Seymour, AN Other & BRW, 2003?


CLHEP
Pythia7 "core"
Pythia7
Herwig++


StepHandler
DecayHandler
P7
Hw
LundStringFrag
HadronizationHandler
ClusterHadronization
CascadeHandler
P7
Hw
PartialCollisionHandler
MIHandler
P7
Hw

Advantages of using "Pythia7 core"

For the developers:

- Code reuse: avoid to "reinvent the wheel".
- Sharing (partial or total?) of the subprocess matrix elements.

For the users:

- Same (graphical) user interface for both generators.
- Intermix the two generators:
  Herwig showering + Pythia string fragmentation

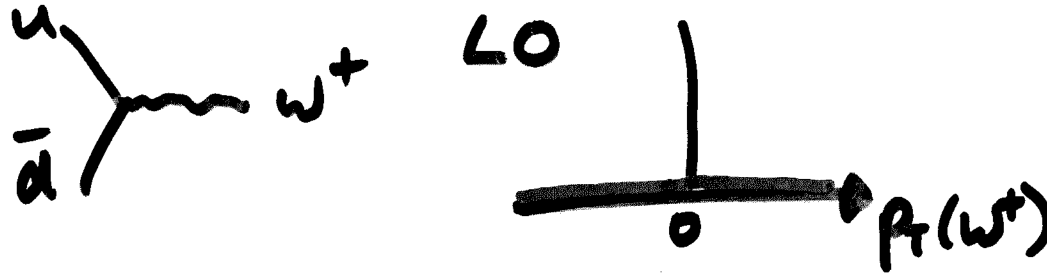
Possible disadvantages

- Inherit specific Pythia7' physics model assumptions that do not match with Herwig++' ones.
- Bugs would spread in both generators rather than compare them to debug each other.
- (general possibilities of large C++ program) large executable size and/or slow performance.

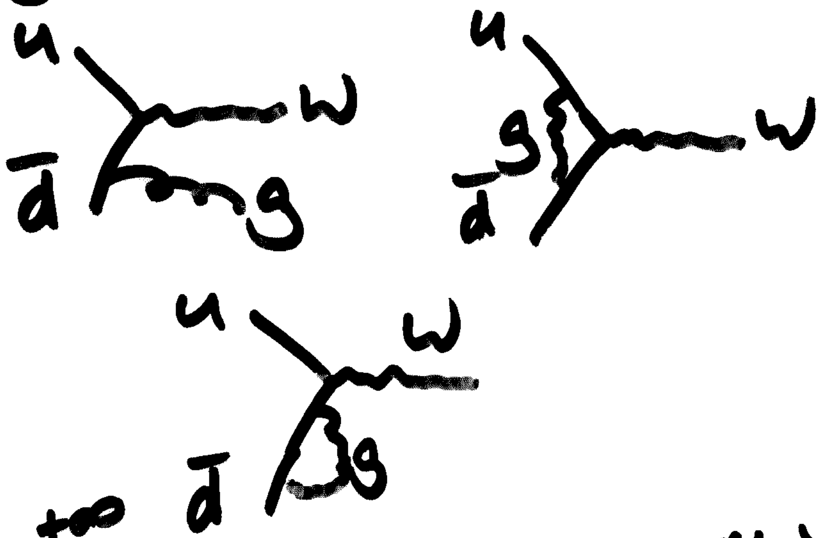
⇒ We will be wary!

NEGATIVE WEIGHTS OPTION について

例えば $u\bar{d} \to W^+$ を考える

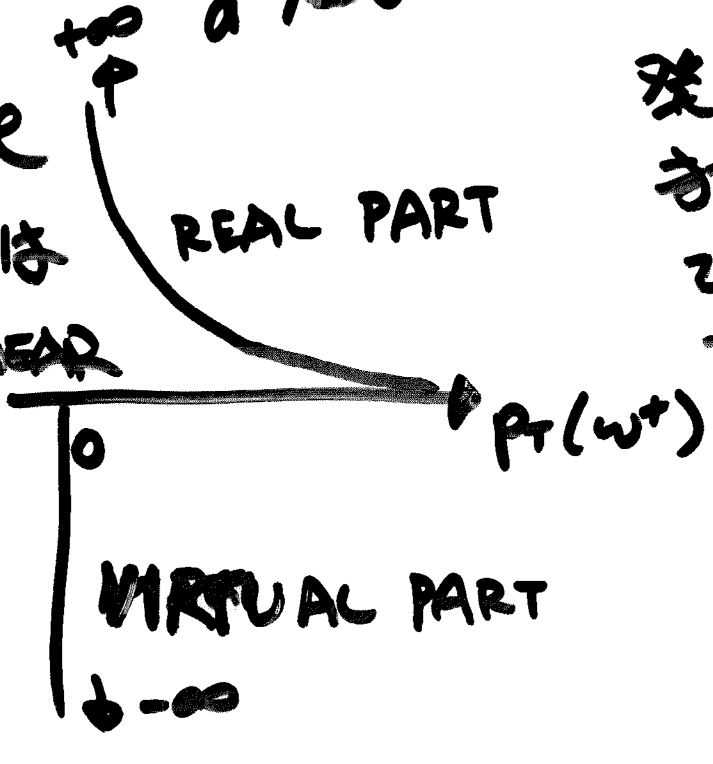


NLOを考える



和はfinite

発散するのは SOFT/COLLINEAR PART.

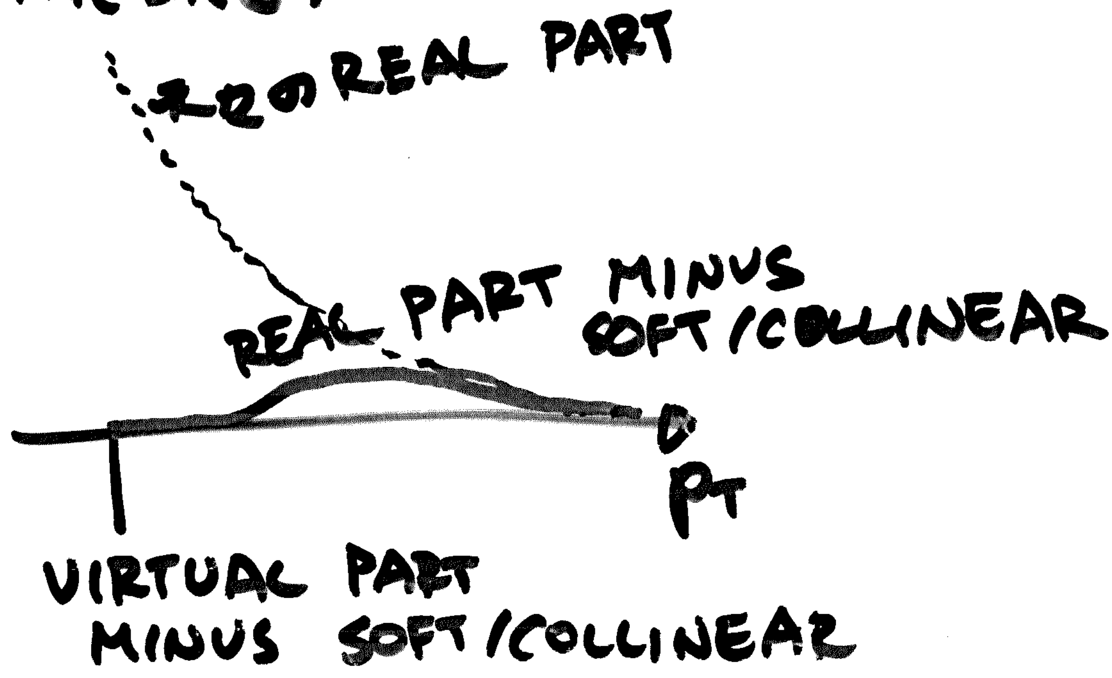


発散するのは まさに MC で ALL ORDER で足し上げる 部分.

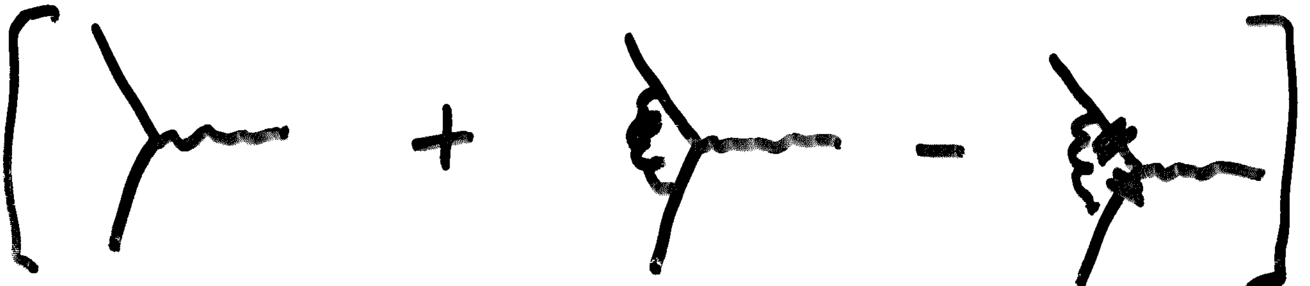
$N^{\infty}LO$ (ALL ORDER SUM) では

となるはず。

では NLO から PARTON SHOWER に含まれる部分を引けば NLO と LOG RESUMMATION の両方を取り入れられる?

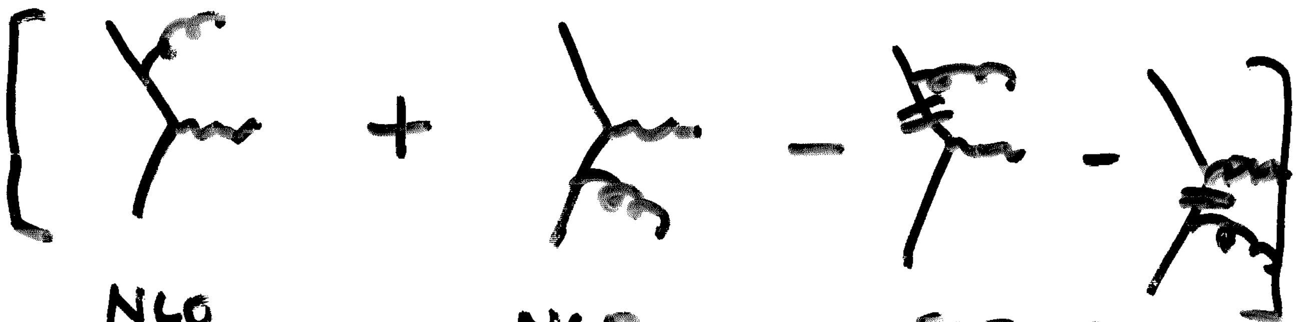


という事は



LO　　NLO VIRTUAL　　SOFT/COLLINEAR PART

× PARTON SHOWER +



NLO REAL　　NLO REAL　　SOFT/COLLINEAR PART

× PARTON SHOWER

で NLO &

LOG RESUMMED

GENERATOR が出来る?

(NLL ではなく) → NLL の意味に注意。

問題は

REAL PART MINUS
SOFT / COLLINEAR PART は

必ずしも POSITIVE DEFINITE
ではない。

ただ それに 目を つぶってしまえば
上記の 手法 で (EXPERIMENTAL CUT
後の) 分布が 正である 様にする事は
できる。

⇒ 負の EVENT WEIGHT を
許容する OPTION が 便利

HERWIGにはすでにEMISSIONを
NLOのREAL PARTのMATRIX ELEMENT
とPARTON SHOWERとでMATCHする

"MATRIX ELEMENT CORRECTION"
(WEBBER, SEYMOUR, CORCELLA)
の手法がある (例, top DECAY,
DRELL-YANなど)

- PSでは埋まらないPHASE SPACE
の部分をMATRIX ELEMENTで
行なう
- PSの存在する部分では
"HARDEST SO FAR"の
EMISSIONに関して補正する。

NLOではない

→ FRIXIONE-WEBBERの
NEGATIVE WEIGHTSに基づいた
手法と比較?

SUB SUMMARY 2

- ☆ UNDERLYING EVENT に関しては理論及び実験の立場からの更なる解析が望まれる
- ☆ HERWIG 6.4 では SUSY SIMULATION がさらに改善する
- ☆ HERWIG ++ 計画進行中

尾高さんから問い合わせのあった 'negative weights??' の話です.

Negative Weights Option

- Monte Carlo generates weights

$$\sigma = \frac{1}{N_w}\sum_{i=1}^{N_w} w_i \equiv \overline{w}$$

- Error depends on width of weight distribution

$$\frac{\delta\sigma}{\sigma} = \frac{1}{\sqrt{N_w}}\frac{\delta w_{\rm rms}}{\overline{w}}$$

- If $w_i > 0$, unweighted events can be generated by 'hit and miss': $w'_i = 0$ or 1 with $P(w'_i = 1) = w_i/w_{\rm max}$. Then

$$\frac{\delta\sigma}{\sigma} = \sqrt{\frac{w_{\rm max} - \overline{w}}{N_w \overline{w}}} = \sqrt{\frac{w_{\rm max} - \overline{w}}{N_e w_{\rm max}}} \sim \frac{1}{\sqrt{N_e}}$$

where $N_e = N_w\overline{w}/w_{\rm max}$ is number of events generated. Time needed (especially for detector simulation) depends mainly on number of events. Hence inefficiency of 'hit and miss' is not a disaster.

- Negative weights can be generated by subtraction procedure for matrix element corrections. These are not a problem of principle but prevent naive 'hit and miss'.

- To generalize 'hit and miss', consider generating unweighted events ($w'_i = 1$) and antievents ($w'_i = -1$) with

$$\begin{aligned} \text{sign}(w'_i) &= \text{sign}(w_i) \\ P(w'_i = \pm 1) &= |w_i| / |w|_{\text{max}} \end{aligned}$$

- Then

$$\frac{\delta\sigma}{\sigma} = \sqrt{\frac{\overline{|w|}|w|_{\text{max}} - \overline{w}^2}{N_w \overline{w}^2}} \sim \frac{1}{\sqrt{N_e}} \frac{\overline{|w|}}{\overline{w}}$$

where $N_e = N_w \overline{|w|} / |w|_{\text{max}}$ is now the total number of events+antievents generated.

- Again, time $\propto N_e$, so this is tolerable as long as $\overline{|w|} \sim \overline{w}$.

- Cross section after cuts is

$$\sigma_c = \frac{\overline{|w|}}{N_e} (N_+ - N_-)$$

where N_+ events and N_- antievents pass cuts.

Title — 'NLO W boson production using a subtraction method' — Frixione & Webber.