QCD Monte Carlo

An incoherent talk on QCD coherence

Bryan Webber
Cavendish Laboratory
University of Cambridge

Welcome to INSPIRE! INSPIRE is out of beta and ready to replace SPIRES. SPIRES will be switched off soon. If you have questions, comments or concerns, please email us at feedback@inspirehep.net.

Marchesini, G. (188 papers)

This is me. Verify my publication list.

Name variants

Marchesini, G. (51)
Marchesini, Giuseppe (5)

Papers

All papers (188)
Published (122)
Review (6)
Lectures (1)
Book (1)

Frequent keywords

quantum chromodynamics: perturbation theory (43)
electron positron: annihilation (37)
PERTURBATION THEORY: HIGHER-ORDER (26)
quantum chromodynamics (25)
HADRON HADRON: INTERACTION (23)
jet: electroproduction (22)
heavy quark (17)
gluon: emission (16)
model: parton (16)
electron p: deep inelastic scattering (15)

Affiliations

Parma U. (88)
INFN, Milan (85)
Milan U. (42)
INFN, Parma (40)
Milan Bicocca U. (34)
CERN (13)
INFN, Milan Bicocca (8)
unknown affiliation (4)
Paris, LPTHE (4)
Naples U. (4)
UC, Berkeley (2)
Brookhaven (2)
Utah U. (2)
Orsay, LPT (1)
Cambridge U. (1)
Santa Barbara, KITP (1)
Fermilab (1)
Argonne (1)

Frequent co-authors

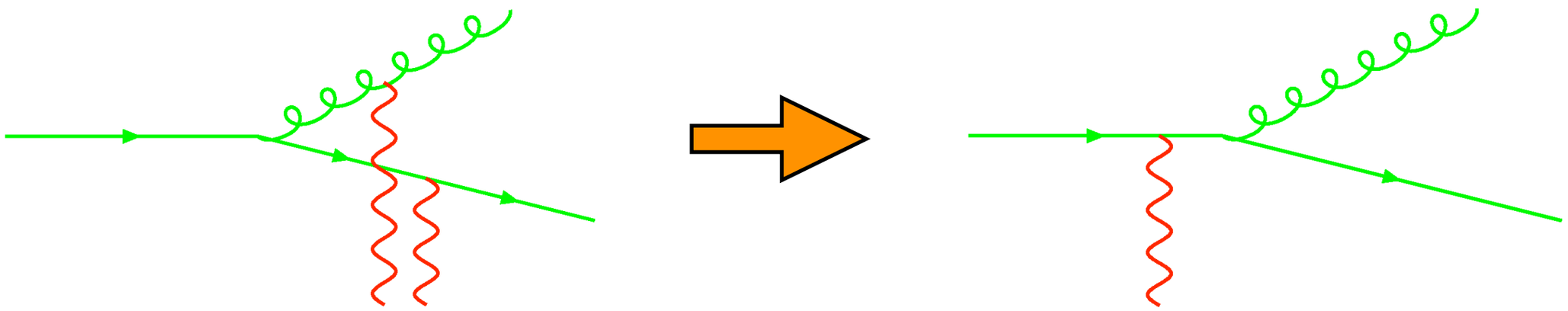
Webber, B.R. (26)
Ciafaloni, M. (20)
Onofri, E. (19)
Dokshitzer, Yuri L. (13)
Catani, S. (11)
Banfi, A. (10)
Bonini, M. (10)
Butera, P. (10)
Di Renzo, F. (9)

Topics

- History of a Monte Carlo
- QCD coherence
- Tevatron top quark asymmetry
- LHC top quark asymmetry
- Conclusions

History of a Monte Carlo

Angular Ordering



Mueller, PLB104(1981)161

Ermolaev, Fadin, JETP Lett33(1981)269

Bassetto, Ciafaloni, Marchesini, Mueller, NPB297(1982)189

- This led to ...

Ref.TH.3525-CERN

SIMULATION OF QCD JETS INCLUDING SOFT GLUON INTERFERENCE

G. Marchesini
Istituto di Fisica dell'Università di Parma
and
INFN, Sezione di Milano, Italy

and

B.R. Webber
CERN -- Geneva

ABSTRACT

We present a new Monte Carlo simulation scheme for jet evolution in perturbative QCD which takes into account the results of recent analyses of soft gluon interference. Therefore, this scheme accounts correctly not only for the leading collinear singularities, as in previous schemes, but also for leading infra-red singularities. In this first paper we study the basic features of gluon jet evolution such as: i) the interference effects and the corresponding depletion of the parton distributions in the soft region; ii) the approach to asymptopia; iii) the efficiency of colour screening (preconfinement), which has been questioned recently by Bjorken.

---

*) On leave from the Cavendish Laboratory, University of Cambridge and Emmanuel College, Cambridge, U.K.

Ref.TH.3525-CERN
February 1983

Nucl Phys B238(1984)1

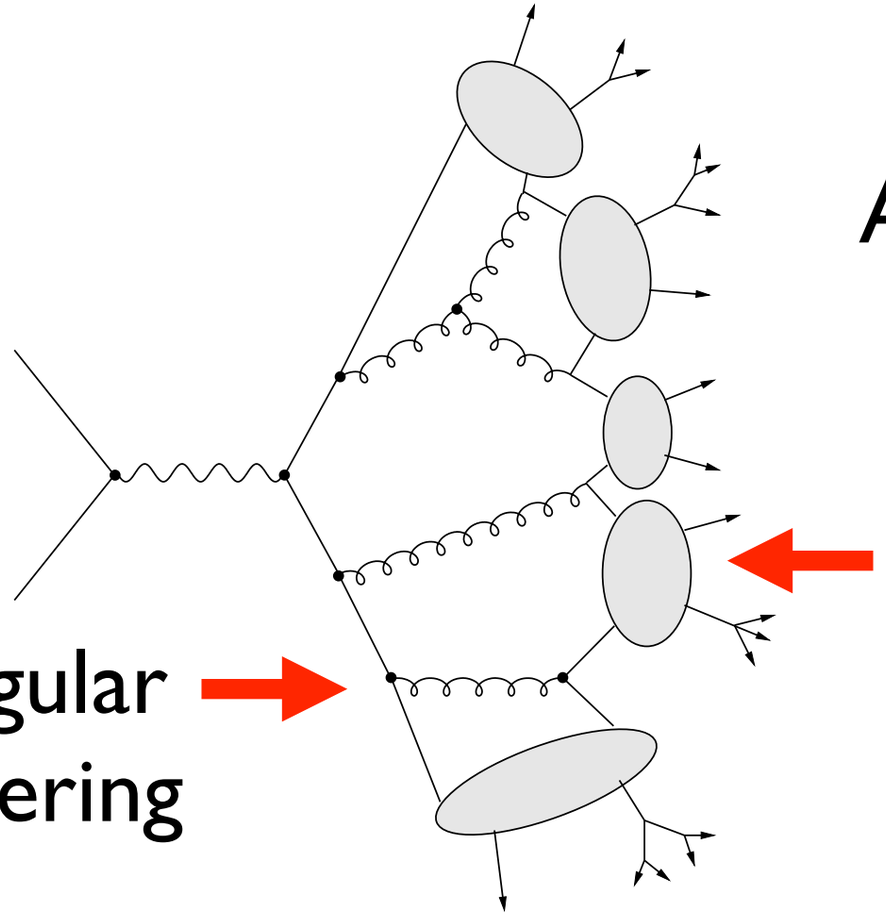
and so to ...

EARWIG

- Electron Annihilation Reactions With Interfering Gluons

QCD coherence

Angular ordering



Preconfinement: Amati & Veneziano

Cluster model: Wolfram

EARWIG

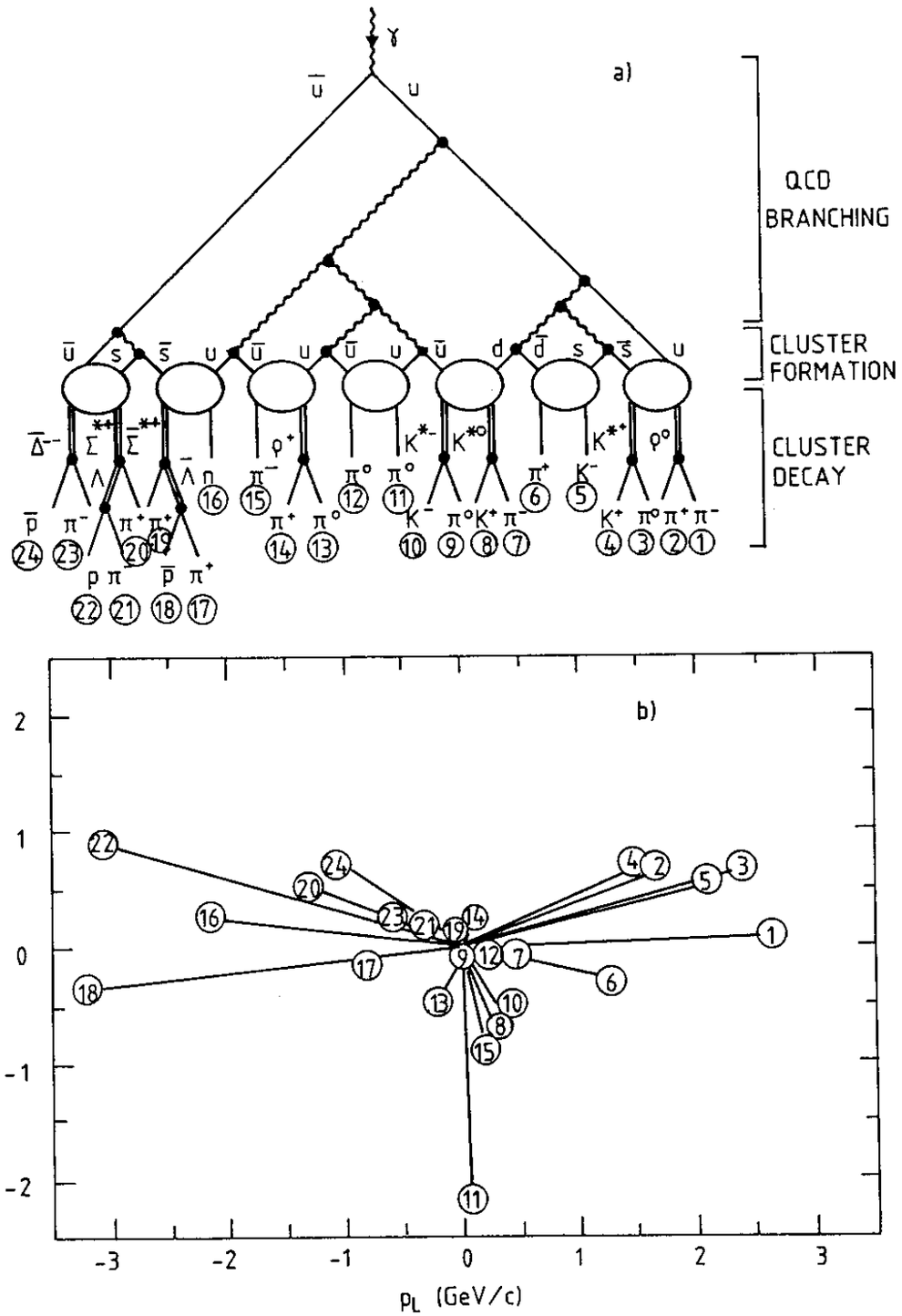
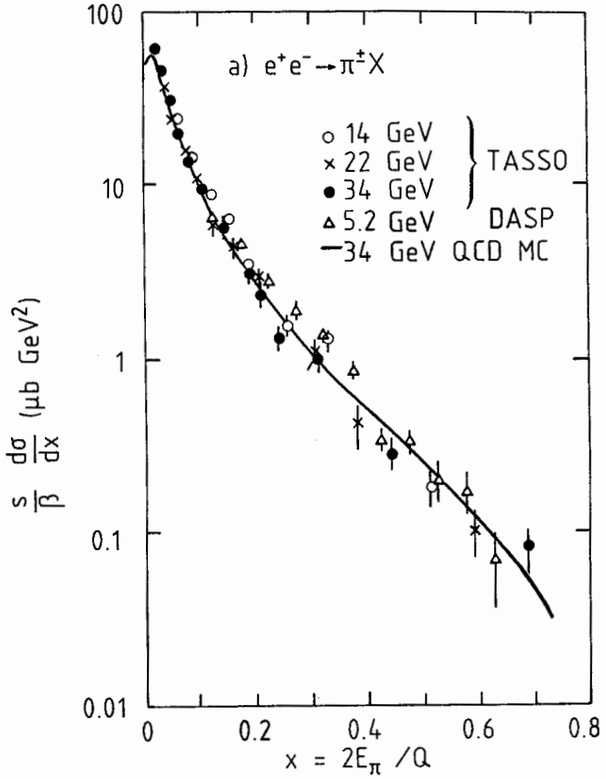

a)
QCD BRANCHING
CLUSTER FORMATION
CLUSTER DECAY
b)
p_{IN} (GeV/c)
p_L (GeV/c)

Fig. 6


a) e+e−→π±X
○ 14 GeV
× 22 GeV
● 34 GeV
TASSO
△ 5.2 GeV DASP
— 34 GeV QCD MC
s/β dσ/dx (μb GeV²)
x = 2Eπ/Q

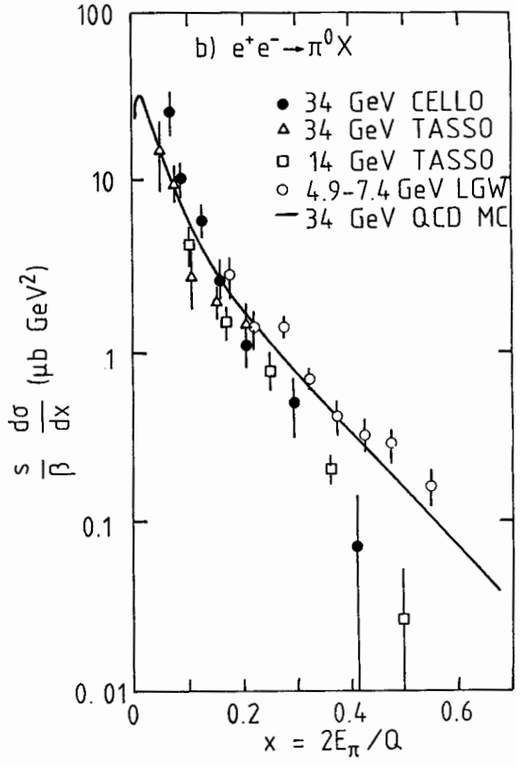
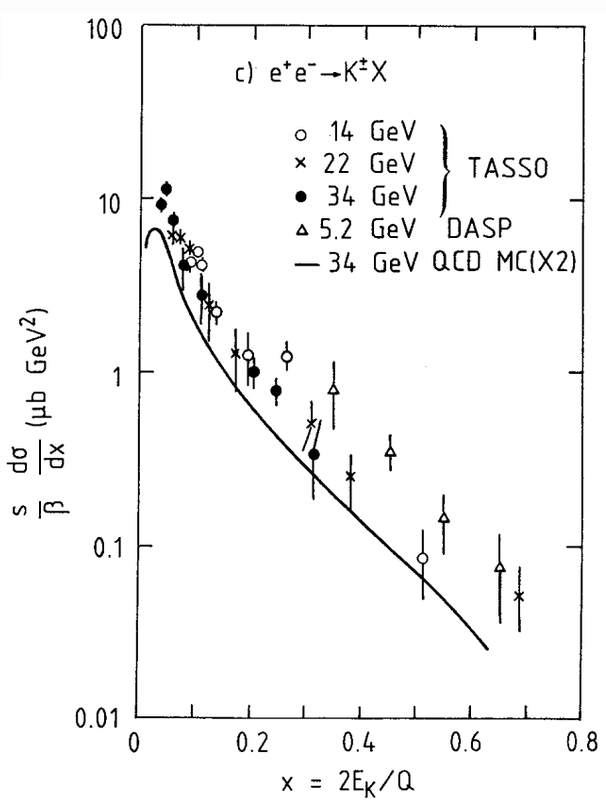
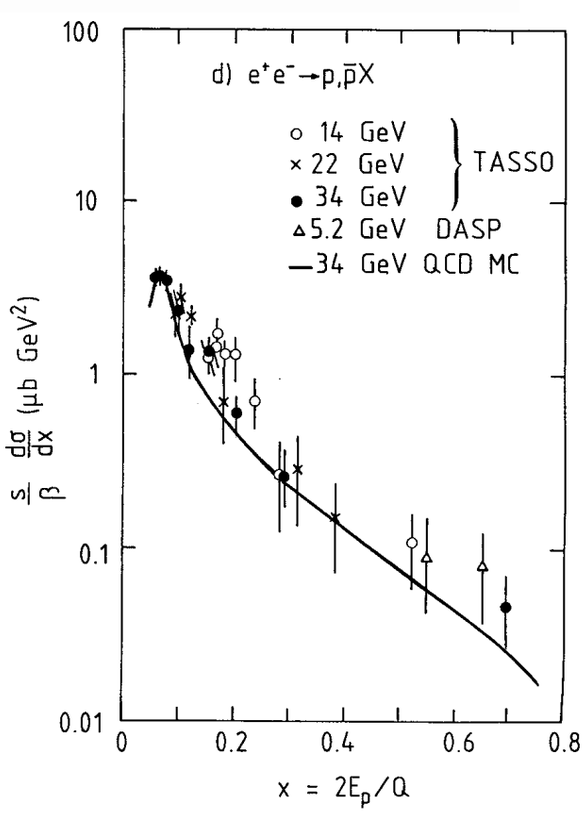
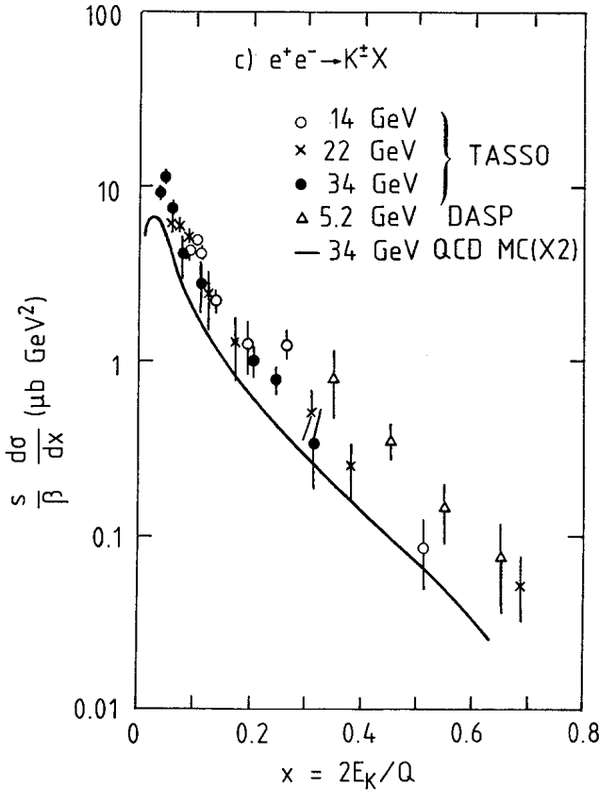

b) e+e−→π0X
● 34 GeV CELLO
△ 34 GeV TASSO
□ 14 GeV TASSO
○ 4.9-7.4 GeV LGW
— 34 GeV QCD MC
s/β dσ/dx (μb GeV²)
x = 2Eπ/Q

Fig. 7


c) e+e−→K±X
○ 14 GeV
× 22 GeV
● 34 GeV
TASSO
△ 5.2 GeV DASP
— 34 GeV QCD MC(X2)
s/β dσ/dx (μb GeV²)
x = 2EK/Q


d) e+e−→p,p̄X
○ 14 GeV
× 22 GeV
● 34 GeV
TASSO
△ 5.2 GeV DASP
— 34 GeV QCD MC
s/β dσ/dx (μb GeV²)
x = 2Ep/Q


c) e+e−→K±X
○ 14 GeV
× 22 GeV
● 34 GeV
TASSO
△ 5.2 GeV DASP
— 34 GeV QCD MC(X2)
s/β dσ/dx (μb GeV²)
x = 2EK/Q

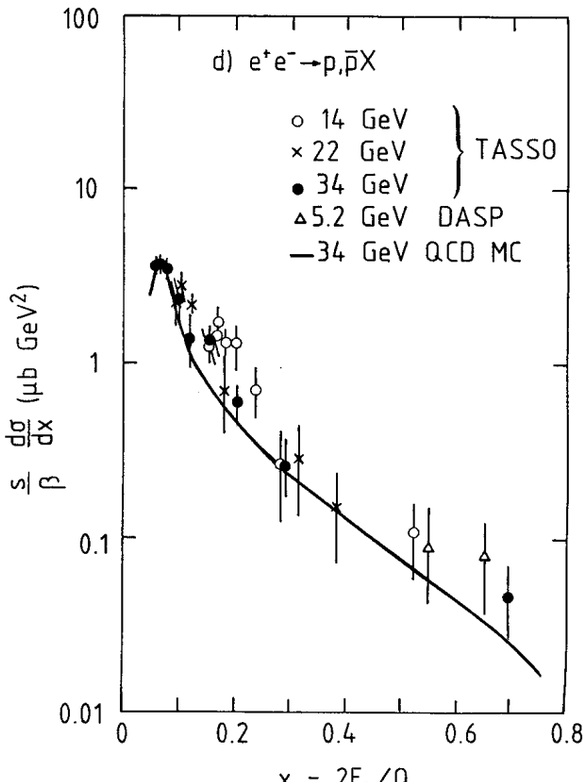
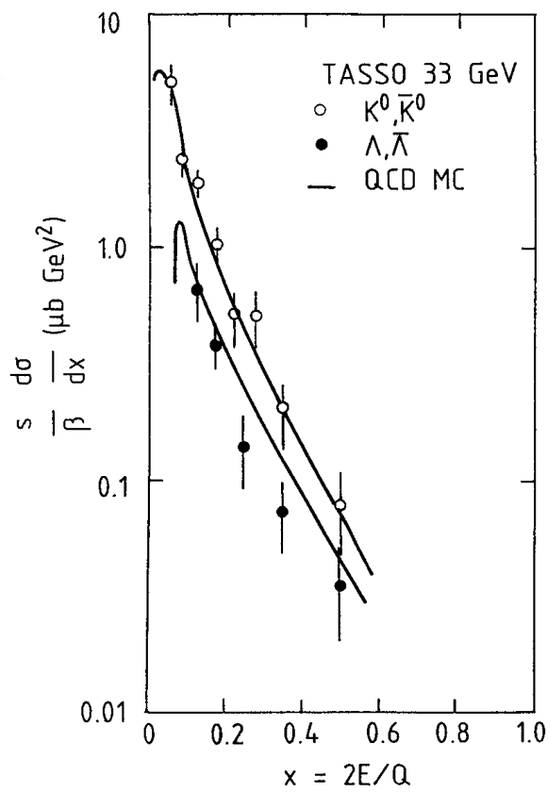
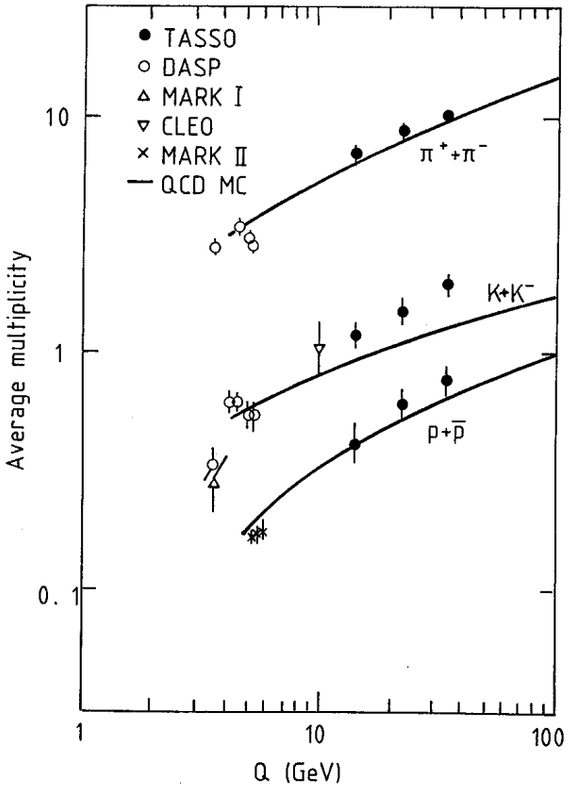

d) e+e−→p,p̄X
○ 14 GeV
× 22 GeV
● 34 GeV
TASSO
△ 5.2 GeV DASP
— 34 GeV QCD MC
s/β dσ/dx (μb GeV²)
x = 2Ep/Q

Fig. 7


TASSO 33 GeV
○ K0,K̄0
● Λ,Λ̄
— QCD MC
s/β dσ/dx (μb GeV²)
x = 2E/Q


● TASSO
○ DASP
△ MARK I
▽ CLEO
× MARK II
— QCD MC
π++π−
K+K−
p+p̄
Average multiplicity
Q (GeV)

HERWIG

- Hadron Emission Reactions With Interfering Gluons

MONTE CARLO SIMULATION OF GENERAL HARD PROCESSES WITH COHERENT QCD RADIATION*

G MARCHESINI

Dipartimento di Fisica, Università di Parma, INFN, Gruppo Collegato di Parma, Italy

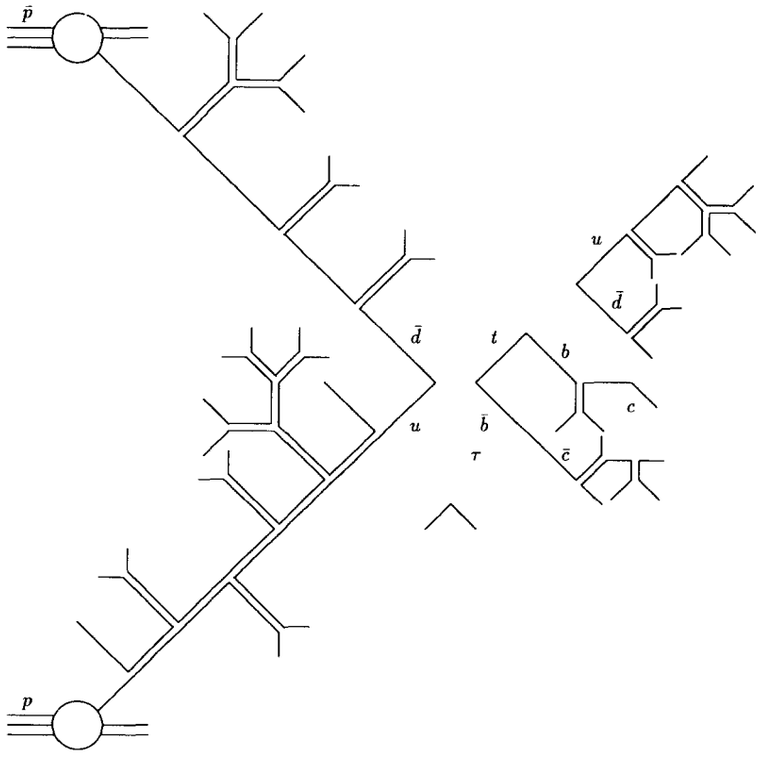
B R WEBBER

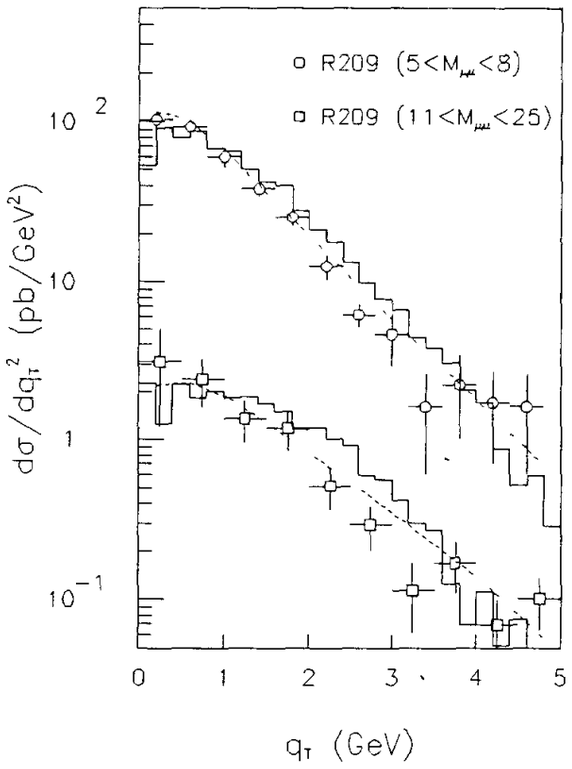
Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge CB3 0HE, UK

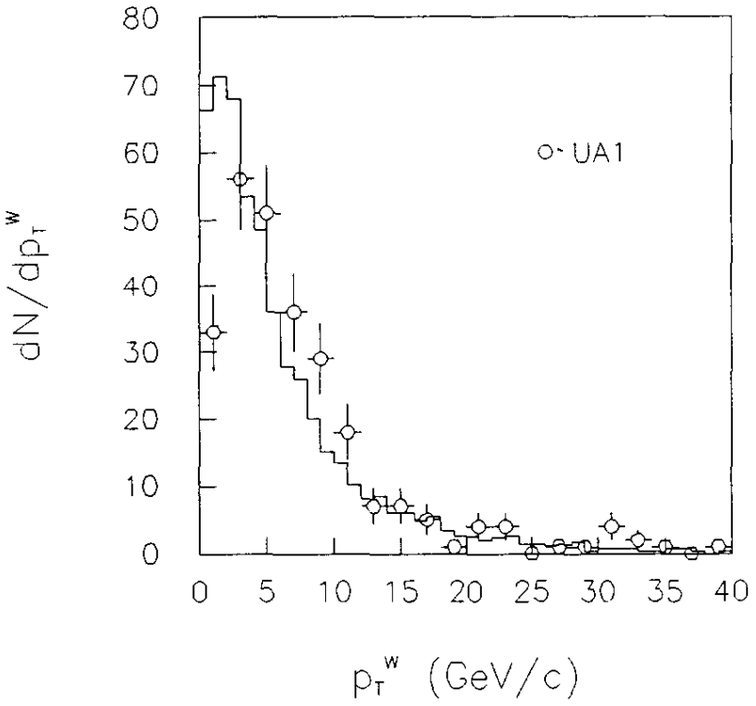
Received 8 February 1988

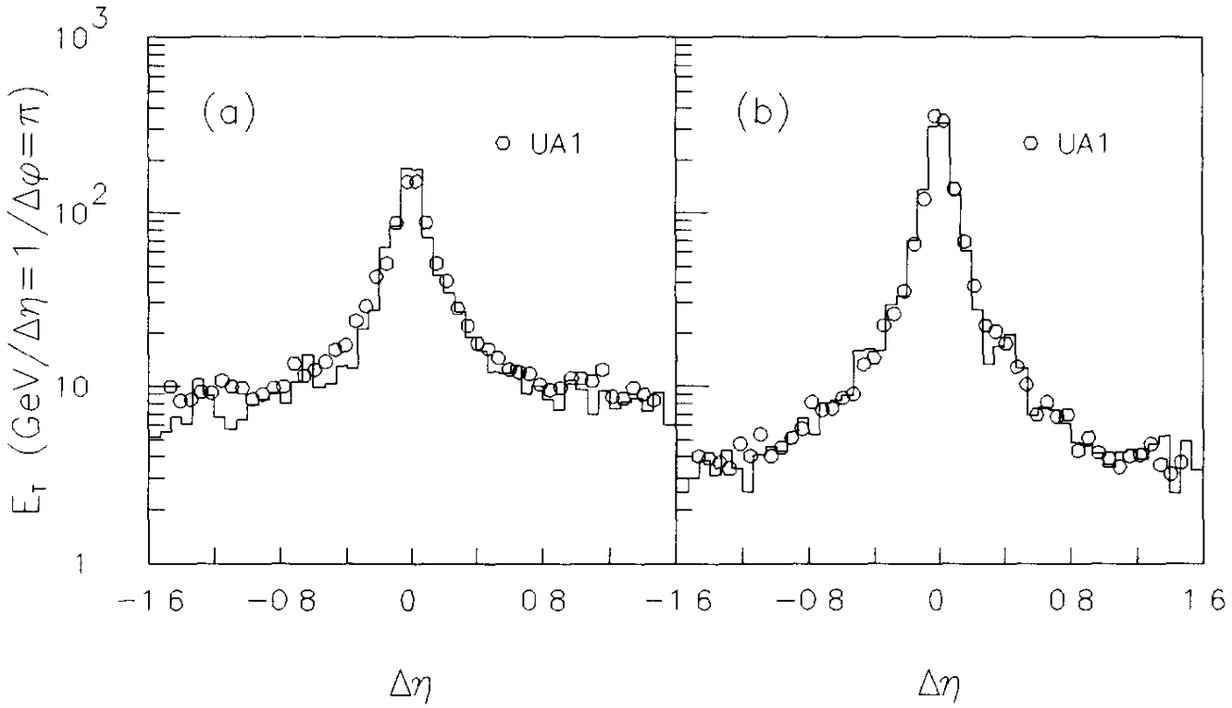
HERWIG

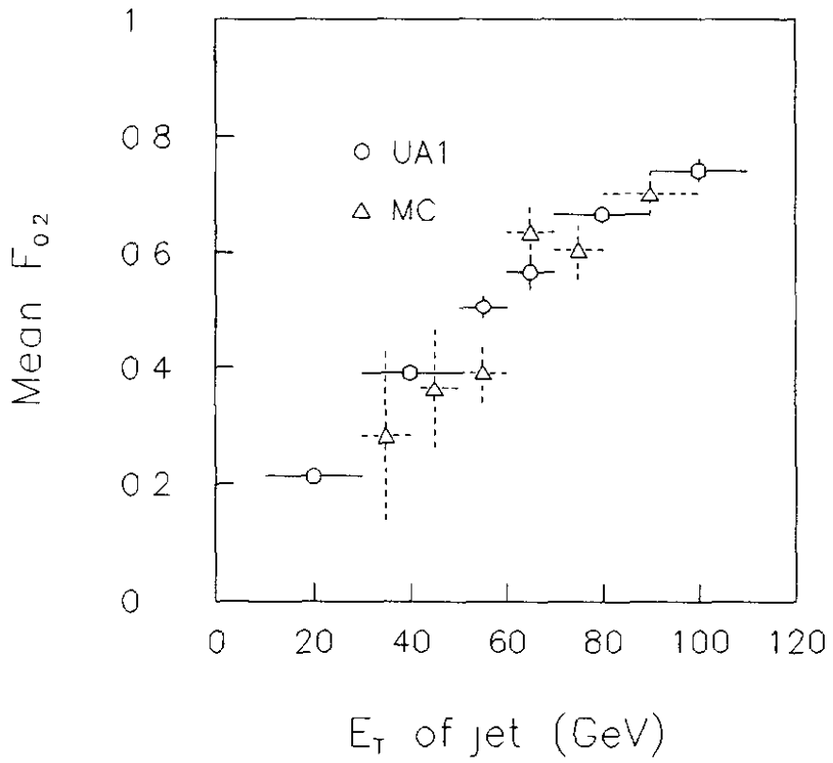
- Hadron Emission Reactions With Interfering Gluons


$\bar{p}$
$\bar{d}$
u
t
b
$\bar{b}$
τ
c
$\bar{c}$
u
$\bar{d}$
p


R209 (5<M$_{\mu\mu}$<8)
R209 (11<M$_{\mu\mu}$<25)
$d\sigma/dq_T^2$ (pb/GeV^2)
10^2
10
1
10^{-1}
0 1 2 3 4 5
q_T (GeV)

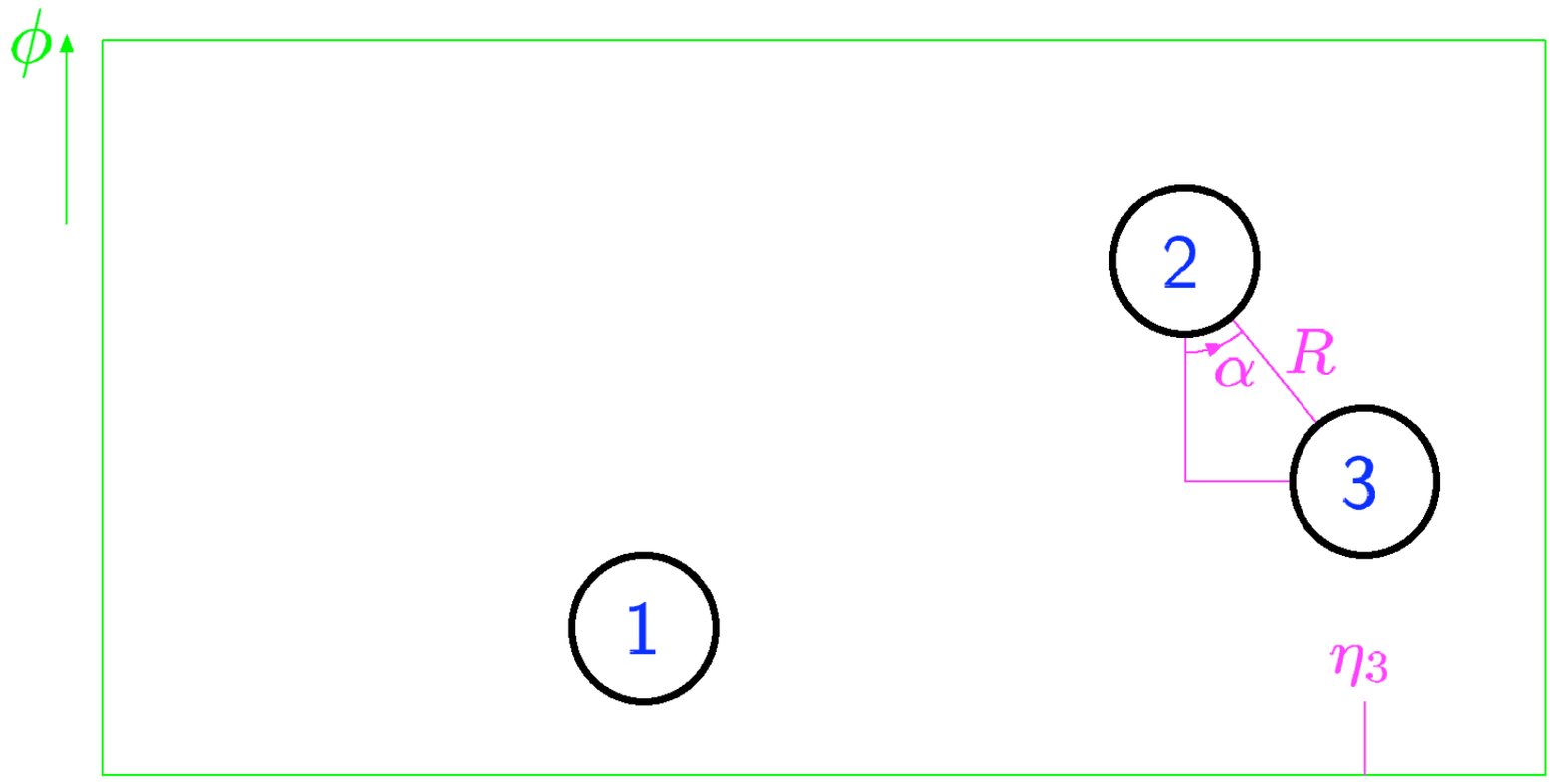

UA1
dN/dp_T^W
80
70
60
50
40
30
20
10
0
0 5 10 15 20 25 30 35 40
p_T^W (GeV/c)


(a)
(b)
UA1
UA1
E_T (GeV/$\Delta\eta$=1/$\Delta\varphi$=π)
10^3
10^2
10
1
−1 6 −0 8 0 0 8 1 6
$\Delta\eta$
$\Delta\eta$


UA1
MC
Mean F_{02}
1
0 8
0 6
0 4
0 2
0
0 20 40 60 80 100 120
E_T of jet (GeV)

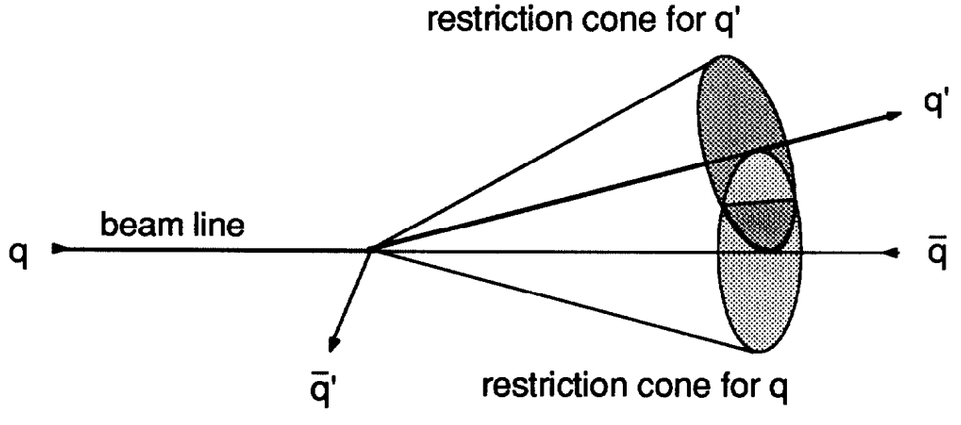
CDF 3-Jet Correlation

CDF, PRD50(1994)5562

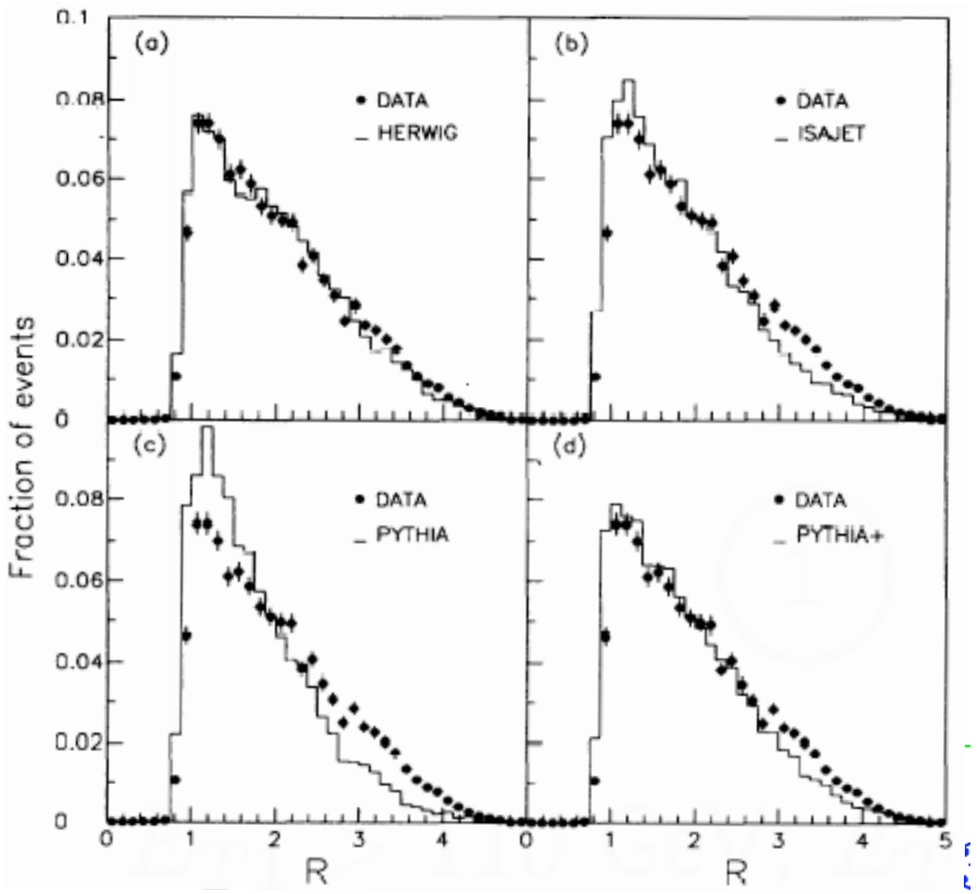


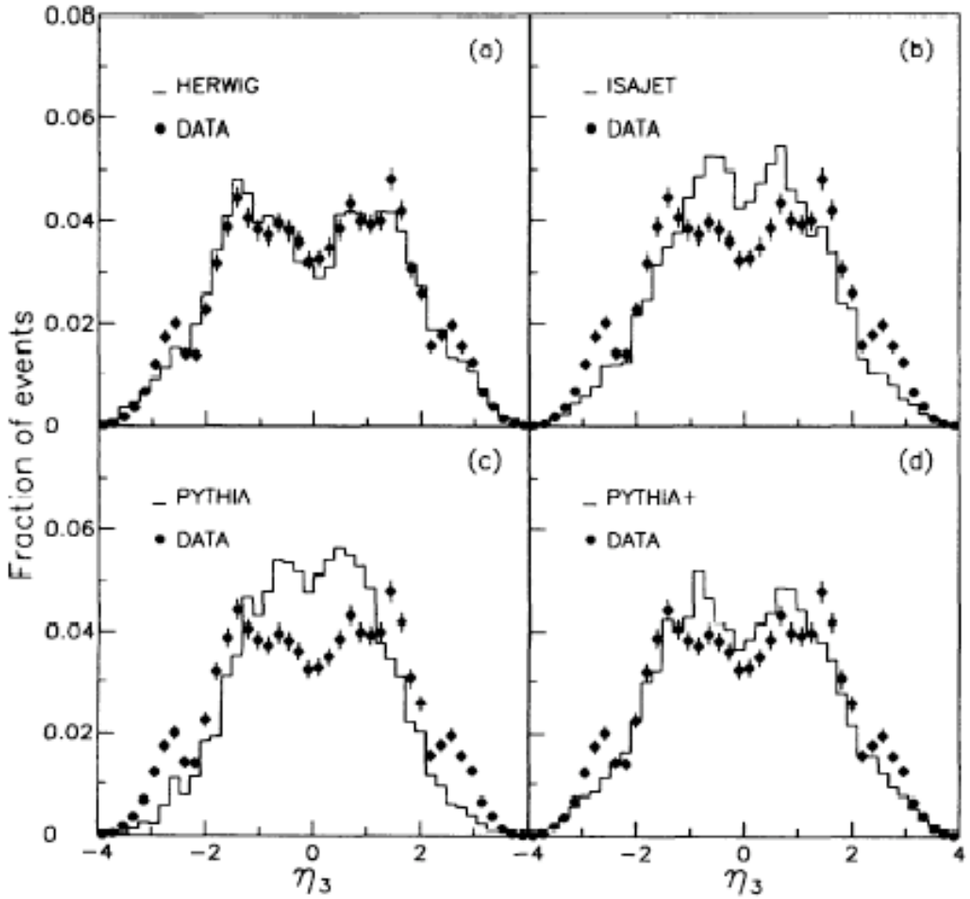
$E_{T1} > 110$ GeV, $E_{T3} > 10$ GeV.

- Test of QCD coherence



CDF 3-Jet Correlation

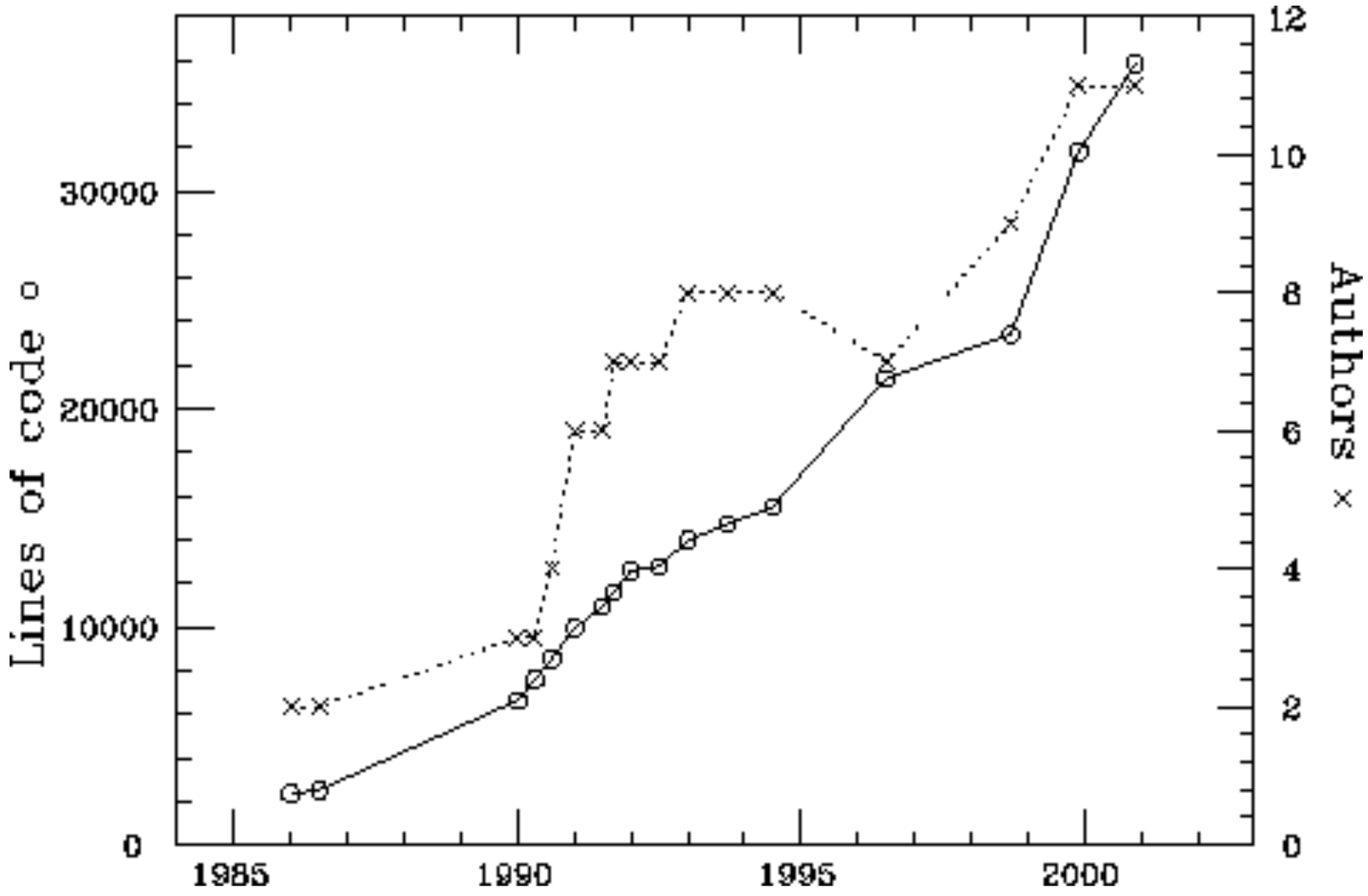




- ISAJET & PYTHIA (originally) incoherent

HERWIG

- Growth of the program and collaboration



Preprint typeset in JHEP style. - HYPER VERSION

Cavendish-HEP-99/03
CERN-TH/2000-284
RAL-TR-2000-048

HERWIG 6.5: an event generator for Hadron Emission Reactions With Interfering Gluons (including supersymmetric processes)*

Gennaro Corcella

Max-Planck-Institut für Physik, Werner-Heisenberg-Institut, Munich
E-mail: corcella@mppmu.mpg.de

Ian G. Knowles

Department of Physics and Astronomy, University of Edinburgh, UK
E-mail: knowles@supanet.com

Giuseppe Marchesini

Dipartimento di Fisica, Università di Milano-Bicocca, and
I.N.F.N., Sezione di Milano, Italy
E-mail: Giuseppe.Marchesini@mi.infn.it

Stefano Moretti

Theory Division, CERN, and IPPP, University of Durham, UK
E-mail: Stefano.Moretti@cern.ch

Kosuke Odagiri

Theory Group, KEK, Japan
E-mail: odagirik@post.kek.jp

Peter Richardson

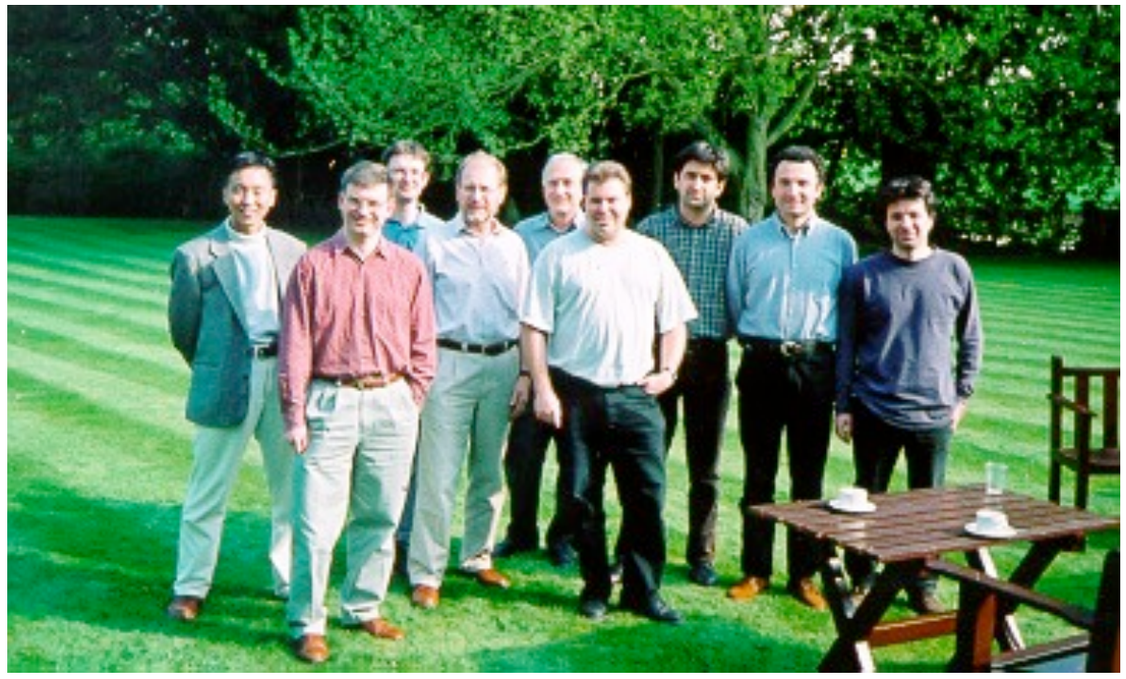
Department of Applied Mathematics and Theoretical Physics and
Cavendish Laboratory, University of Cambridge, UK
E-mail: richardn@hep.phy.cam.ac.uk

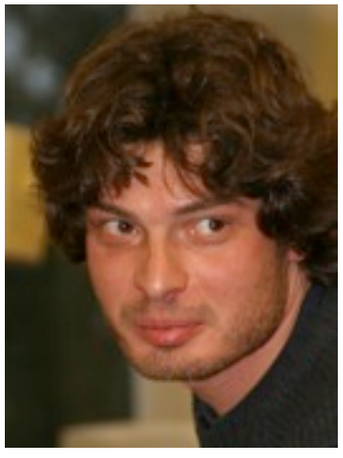
Michael H. Seymour

Department of Physics and Astronomy, University of Manchester, UK
E-mail: M.Seymour@rl.ac.uk

Bryan R. Webber

Cavendish Laboratory, University of Cambridge, UK
E-mail: webber@hep.phy.cam.ac.uk





LUDWIG

- LHC Ultimate Development With Interfering Gluons

~~LUDWIG~~

- ~~LHC Ultimate Development With Interfering Gluons~~

HERWIG++

HERWIG++

Eur. Phys. J. C
DOI 10.1140/epjc/s10052-008-0798-9

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

Herwig++ physics and manual

Manuel Bähr[1], Stefan Gieseke[1], Martyn A. Gigg[2], David Grellscheid[2], Keith Hamilton[3], Oluseyi Latunde-Dada[4], Simon Plätzer[1], Peter Richardson[2,5,a], Michael H. Seymour[5,6], Alexander Sherstnev[4], Bryan R. Webber[4]

[1]Institut für Theoretische Physik, Universität Karlsruhe, Karlsruhe, Germany
[2]IPPP, Department of Physics, Durham University, Durham, UK
[3]Centre for Particle Physics and Phenomenology, Université Catholique de Louvain, Louvain-la-Neuve, Belgium
[4]Cavendish Laboratory, University of Cambridge, Cambridge, UK
[5]Physics Department, CERN, Geneva, Switzerland
[6]School of Physics and Astronomy, University of Manchester, Manchester, UK

Received: 1 September 2008

- Pino left

HERWIG++

Herwig++ 2.5 Release Note

S. Gieseke[1], D. Grellscheid[2], K. Hamilton[3], A. Papaefstathiou[4], S. Plätzer[5], P. Richardson[2], C. A. Röhr[1], P. Ruzicka[6], A. Siódmok[1], L. Suter[7], D. Winn[2]
E-mail: herwig@projects.hepforge.org

[1] *Institut für Theoretische Physik, Karlsruhe Institute of Technology.*
[2] *IPPP, Department of Physics, Durham University.*
[3] *INFN, Sezione di Milano-Bicocca.*
[4] *Cavendish Laboratory, University of Cambridge.*
[5] *Theory Group, DESY Hamburg.*
[6] *Institute of Physics, Academy of Sciences of the Czech Republic.*
[7] *School of Physics and Astronomy, University of Manchester.*

- Bryan left

Herwig Collaboration Agreement

agreed version of 25/02/09

Preamble

The present agreement constitutes the first time the Herwig collaboration has tried to define its own existence in writing, after having existed for about eight years in its present form (and some 15 years before that). It may appear somewhat 'from one extreme to the other' to start with such a detailed document, but having started on this road, we tried to anticipate possible problems and ambiguities and to spell them out in as much detail as possible. Nevertheless it is clearly a framework around which the collaboration should work with flexibility and common sense, and should not be considered an over-prescriptive straitjacket to further development.

Executive Summary

Herwig is developed by a group of authors who take collective responsibility for the code and the physics simulation it provides. This document sets out the responsibilities of authors and the benefits they may derive from authorship.

The Herwig collaboration also has members who are not authors. They have fewer obligations, in particular ongoing obligations on their time. It would normally be expected that someone who plans to develop a specific small feature or enhancement and contribute it either to the main code or to the directory of separate code that is distributed together with Herwig, would become a member as soon as their plan becomes clear. This document also sets out the responsibility of members, the benefits they may derive from membership, and the circumstances under which they may become authors.

1 Purpose

The principle purposes of this agreement are:

1.1 To ensure that Herwig is maintained and supported in a professional manner.

1.2 To ensure that the external community, including but not restricted to users, give due respect to the program and its physics basis, and to the collaboration.

1.3 To ensure that credit for the program goes to those who contribute significantly to it and does not get diluted by those who do not.

1.4 To ensure that the collaboration is not over-reliant on the availability of any given member at any particular moment.

1.5 To ensure that all members of the collaboration have time to pursue non-Herwig-related physics interests and research projects.

In addition, by defining two levels of membership (member and author) and constituting *Herwig Notes*, we hope:

1.6 To provide a framework to encourage and reward non-authors for making contributions that are significant and important, but are not at a sufficient level to justify becoming full authors and taking on the corresponding responsibilities and obligations.

2 Membership

We define three (cummulative) levels of membership of the collaboration:

2.1 **member**

2.1.1 A member has the right to attend the weekly phone meetings, to access the development wiki, be listed in the `herwig-dev` mailing list and, upon request, have submission rights to an `svn` *branch*.

2.1.2 A member can request that the write-up of a piece of work be accepted as a *Herwig Note*, that code they have written be released as part of Herwig, or to give talks on behalf of the collaboration. The request will be granted if approved by the majority of the authorship.

2.1.3 Anyone may request to become a member, and will be accepted if the majority of the authorship believes that there is a reasonable expectation that they will contribute to the program, its physics basis, or in some other way benefit the collaboration, except:

2.1.4 Membership may be vetoed by majority vote of the authorship, for example if the proposed member is already a member of another event generator collaboration or similar and the majority of the authorship felt that their could be a conflict of interest, or they have previously written papers or given public presentations espousing an approach that the majority of the authorship does not consider compatible with that of Herwig.

2.1.5 Membership automatically lapses after three months of not attending the weekly phone meeting or making other useful input. It can be terminated earlier by majority vote of the authorship.

2.2 **author**

2.2.1 An author has the right to sign release notes and the latest version of the Physics and Manual, to accept invitations to give talks on behalf of the collaboration, to participate in collaboration decisions and planning, and to make check-ins to the `svn` *trunk* (under the conditions detailed below).

2.2.2 A member can become an author if:

2.2.2.1 They have delivered a significant piece of new development work towards Herwig, adding a new feature or significantly enhancing an existing one, considered by the majority of the senior authors to be equivalent to around six months of full-time work. Anticipated authorship is possible if a significant part of this development has been completed with the corresponding code ready for release and it is clear that the total investment will eventually reach six months. Accumulation of several smaller pieces of work totalling six months' worth may also be considered equivalent, but is not required to be.

2.2.2.2 The corresponding code has been checked by an existing author (in the case of student members this should be someone other than the supervisor) and both the code and the methodology by which it was tested are judged to be of sufficient quality.

2.2.2.3 The majority of senior authors accept them.

+ 6 more pages ...

HERWIG++

- The project is left in good hands:

Mike Seymour

David Grellscheid

Peter Richardson

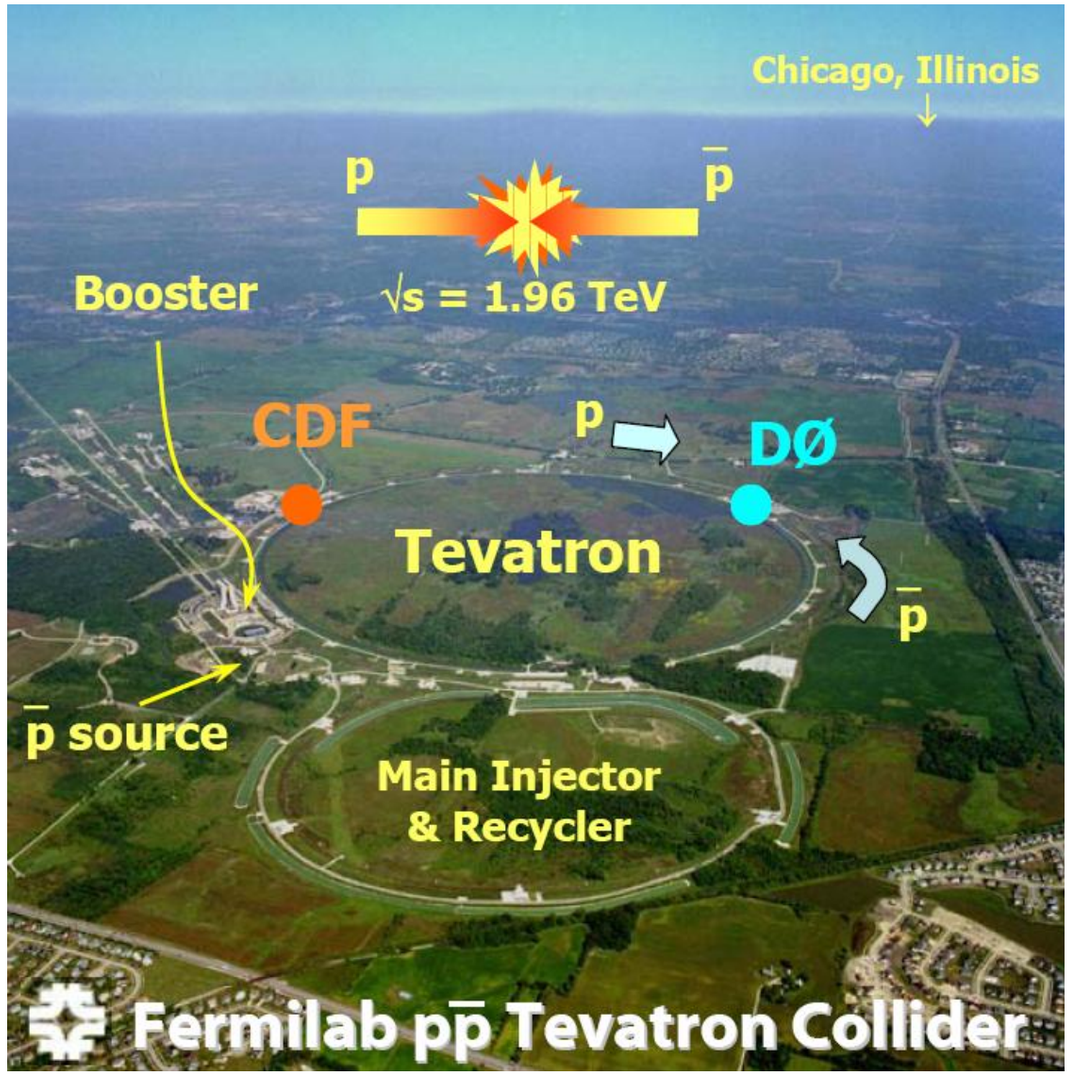
Stefan Gieseke

QCD Coherence and the Top Quark Asymmetry

Top Production at Tevatron

- $p\bar{p}$ at 1.96 TeV
- CDF & D0
- ~9 fb^{-1}/expt
- $\sigma_{t\bar{t}}$~8 pb

➡ ~70,000 $t\bar{t}$



$$t \to Wb$$

$$W \to e\nu_e, \mu\nu_\mu \to l + \not{E}$$

$$(W \to \tau\nu_\tau)$$

$$W \to u\bar{d}, c\bar{s} \to jj$$

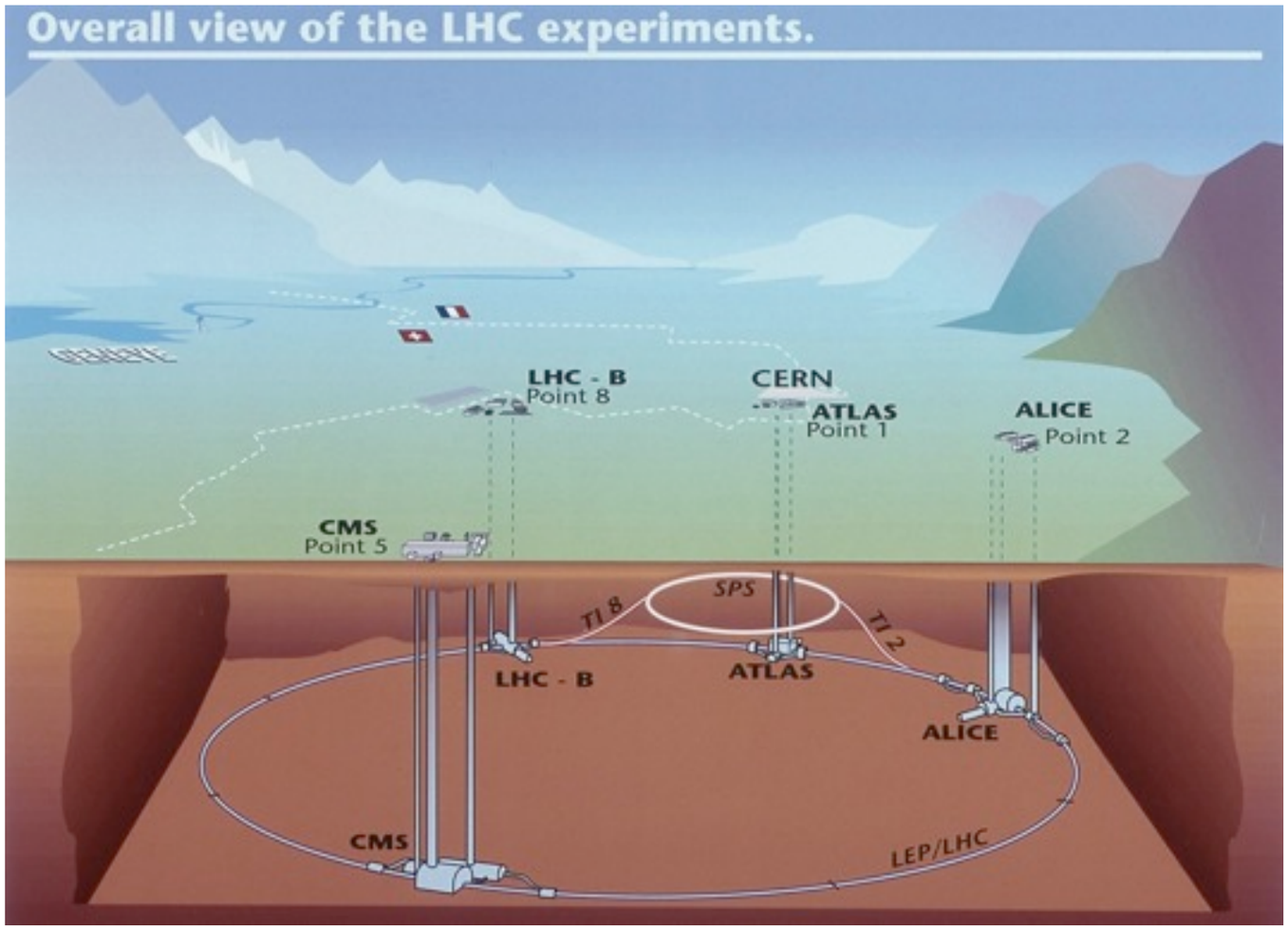
➡ $t\bar{t} \to b\bar{b}l\bar{l} + \not{E}\,(5\%),\ t\bar{t} \to b\bar{b}ljj + \not{E}\,(30\%)$

Top Production at LHC

- pp at 7 TeV
- ATLAS & CMS
- ~6 fb^{-1}/expt
- $\sigma_{t\bar{t}}$~160 pb

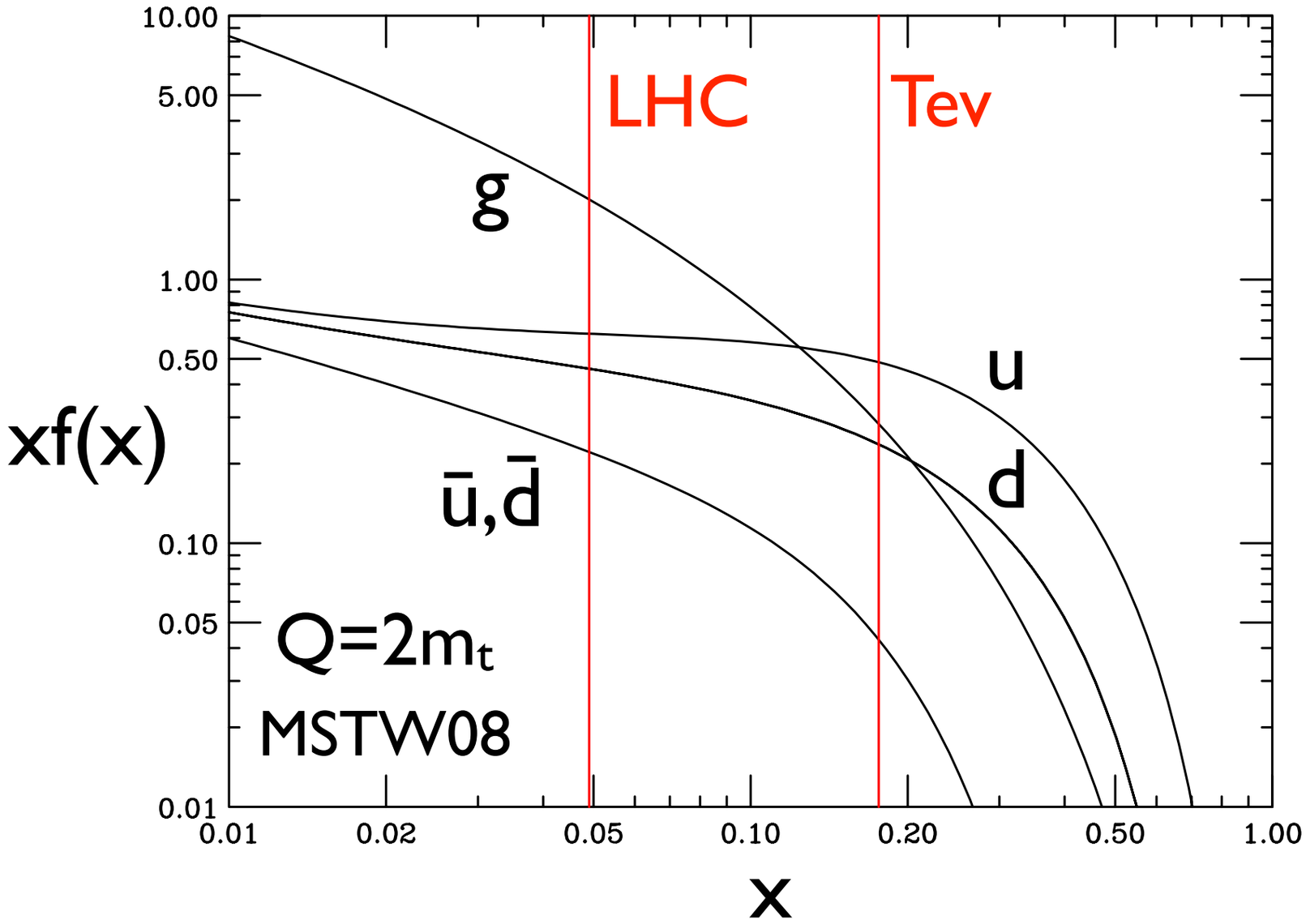
→ ~10^6 $t\bar{t}$

- Expect ~15 fb^{-1} this run (2012)



But dominated by gg rather than $q\bar{q}$ collisions

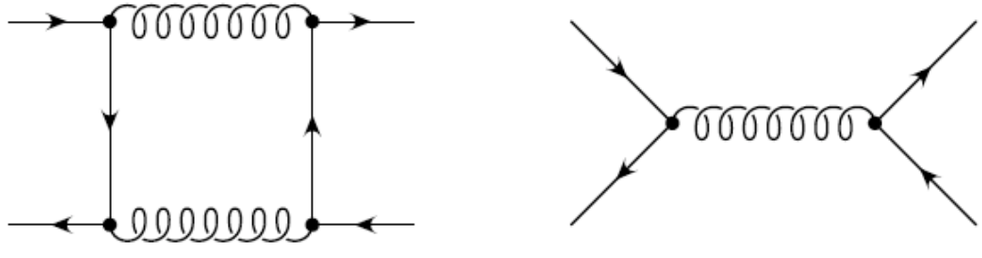
Parton distributions



- uū→tt̄ dominates at Tevatron, gg→tt̄ at LHC

Standard Model prediction

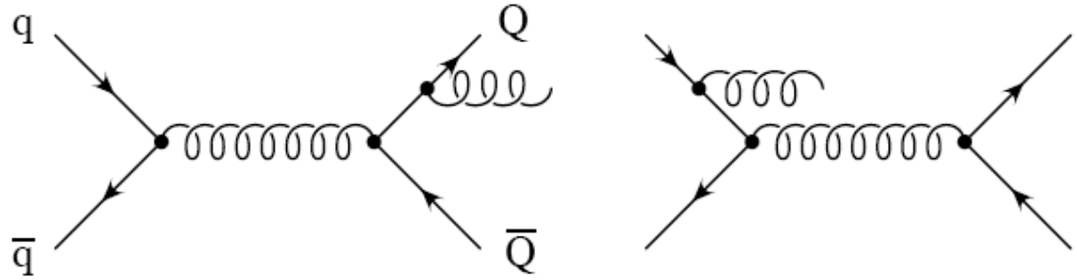
- Only $q\bar{q}$ asymmetric
- NLO effect ~5% at parton level



$A^{t\bar{t}} > 0$ dominant (low $p_T^{t\bar{t}}$)

- t prefers q direction

$$y \equiv \frac{1}{2} \ln \left(\frac{E + p_z}{E - p_z} \right)$$



$A^{t\bar{t}} < 0$ if extra jet or high $p_T^{t\bar{t}}$

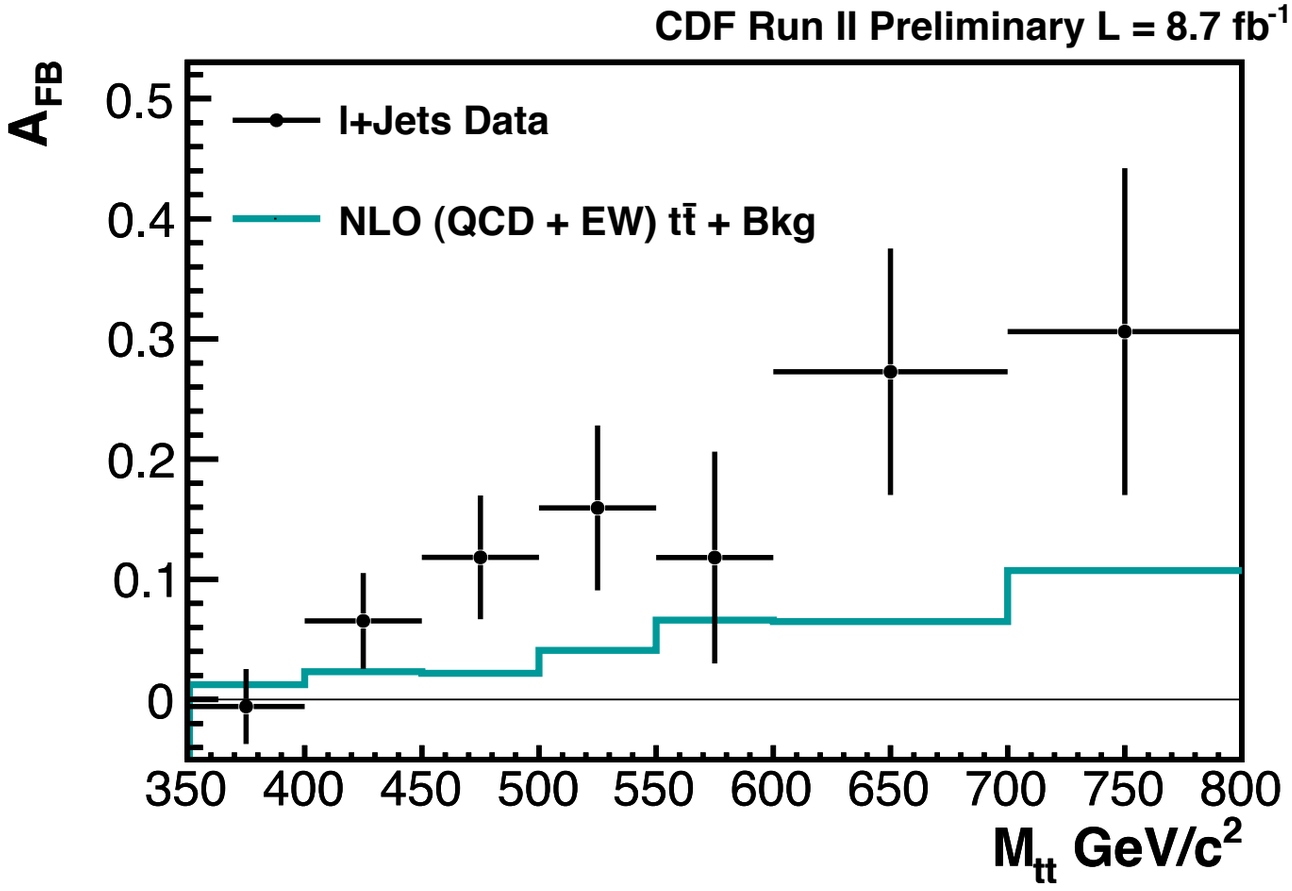
➡ Expect $y_t > y_{\bar{t}}$

$$\Delta y = y_t - y_{\bar{t}} \quad \Rightarrow \quad A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)} > 0$$

CDF Results

CDF Note 10807

- CDF report a large effect, increasing with $t\bar{t}$ invariant mass
- SM predicts a smaller NLO effect
- MC@NLO, MCFM and POWHEG in good agreement
- CDF claim P_{NLO}=0.0065

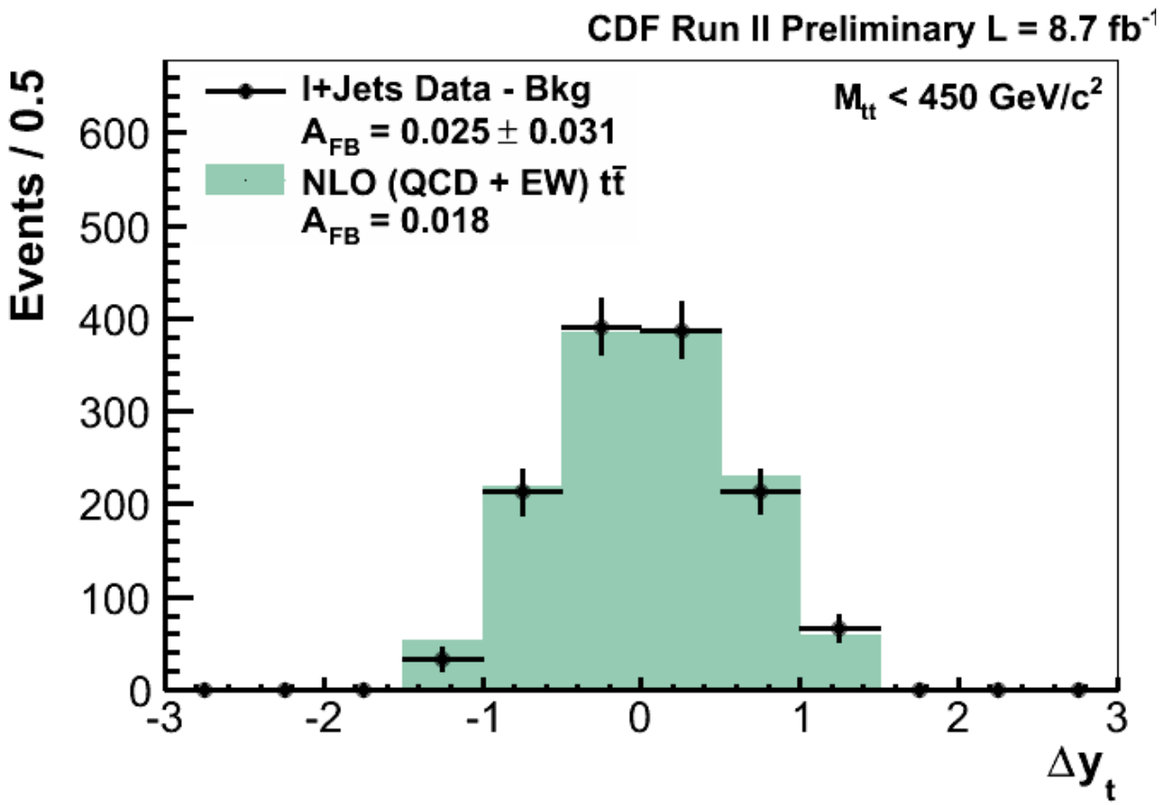


$$\Delta y = y_t - y_{\bar{t}} \ , \quad Y_{t\bar{t}} = \frac{1}{2}(y_t + y_{\bar{t}})$$

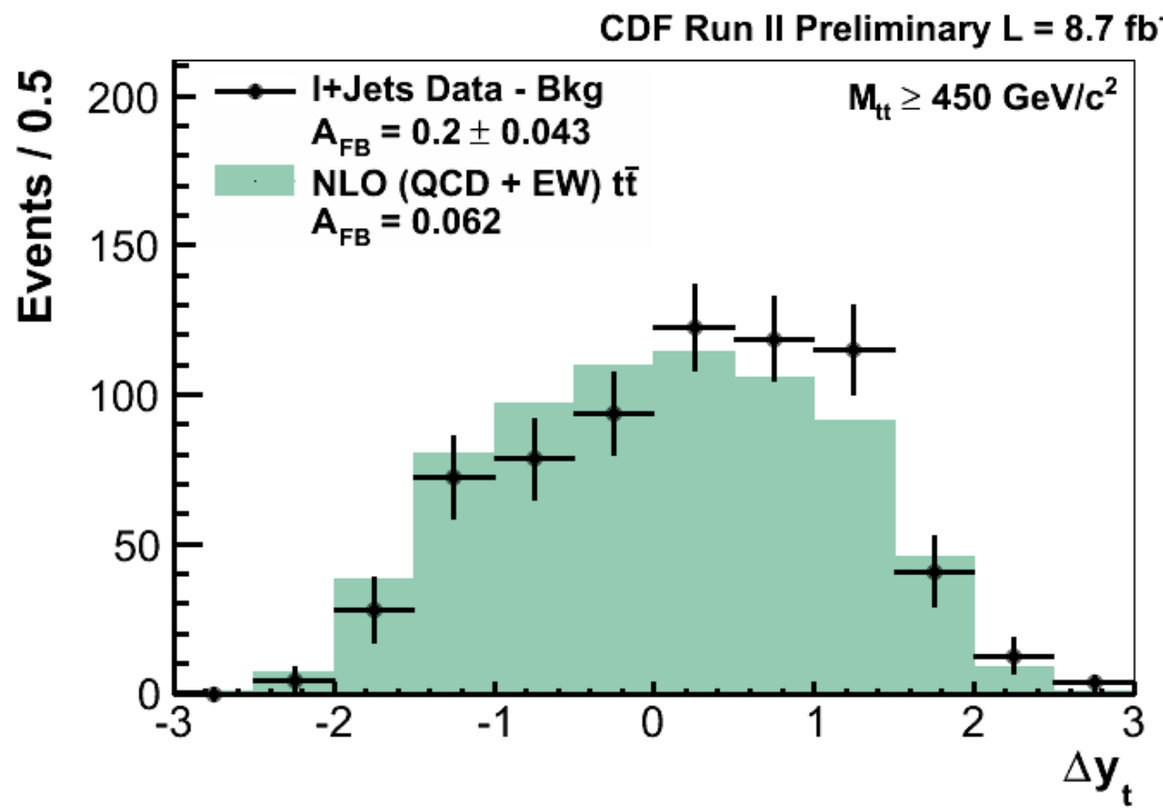
$$A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

CDF data: low vs high mass

$M_{tt} < 450$ GeV/c^2

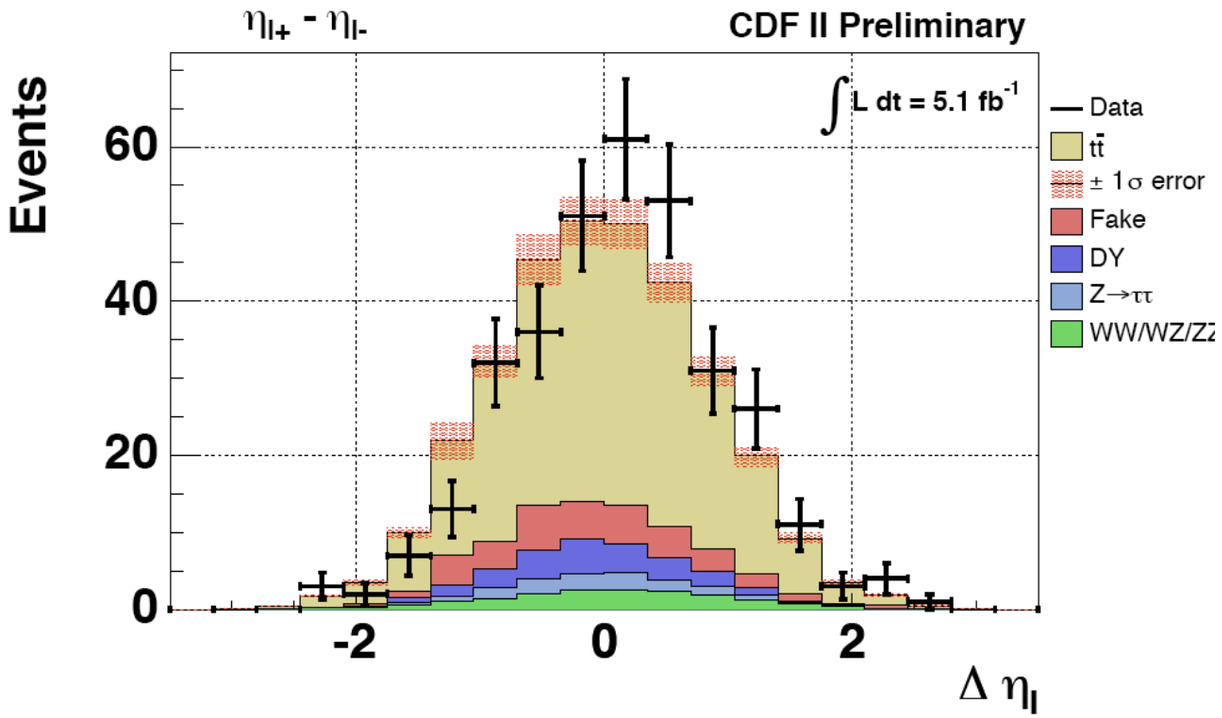


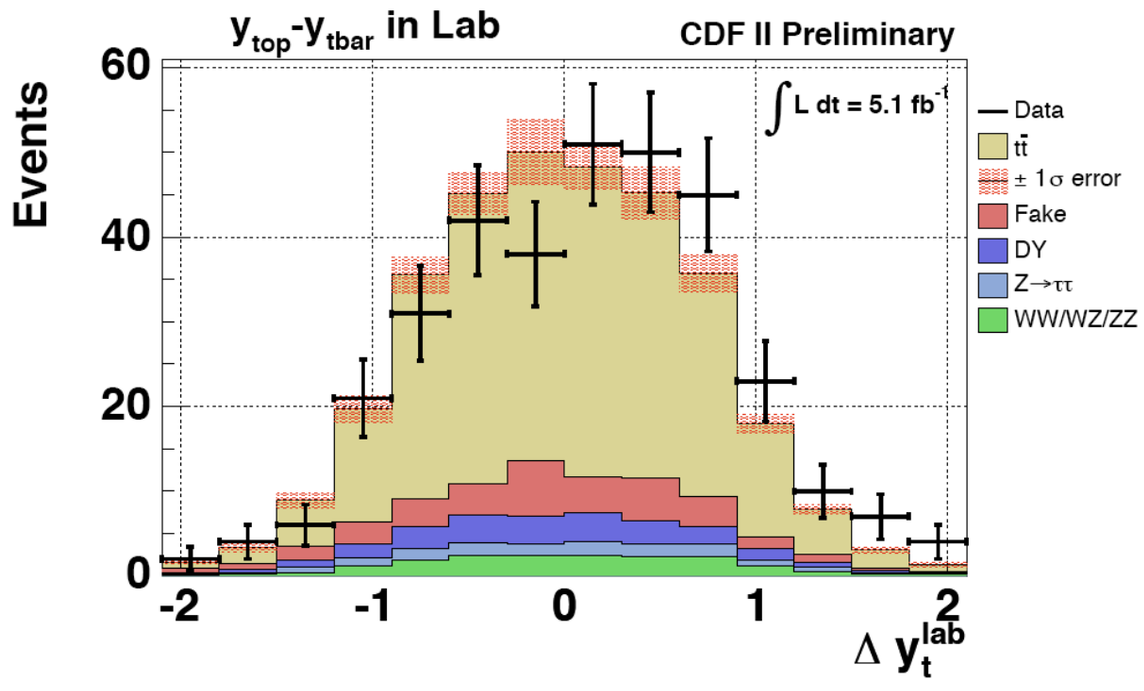
$M_{tt} > 450$ GeV/c^2



- No significant asymmetry below $M_{t\bar{t}} = 450$ GeV

Dilepton decay mode





$$A_{obs}^{\Delta\eta_l} = 0.138 \pm 0.054$$
$$A_{pred}^{\Delta\eta_l} = -0.022 \pm 0.022$$

$$A_{obs}^{\Delta y_t} = 0.138 \pm 0.054$$
$$A_{pred}^{\Delta\eta_l} = -0.015 \pm 0.023$$

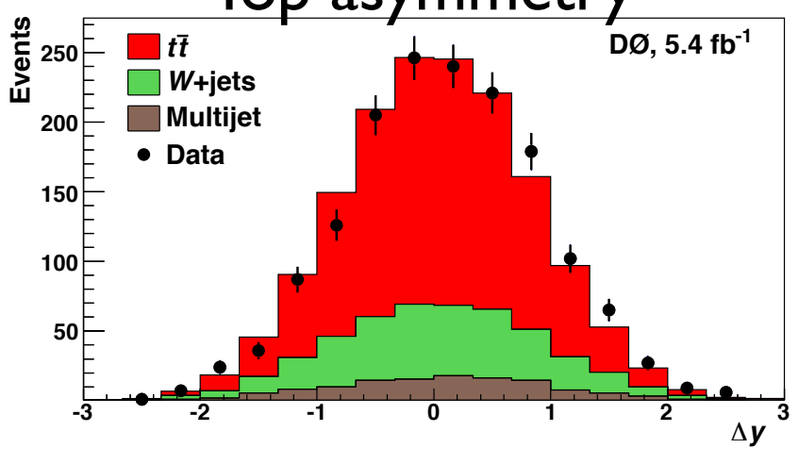
- Consistent with lepton+jets mode
- Results from 8.7 fb^{-1} coming soon

D0 Results

arXiv:1107.4995

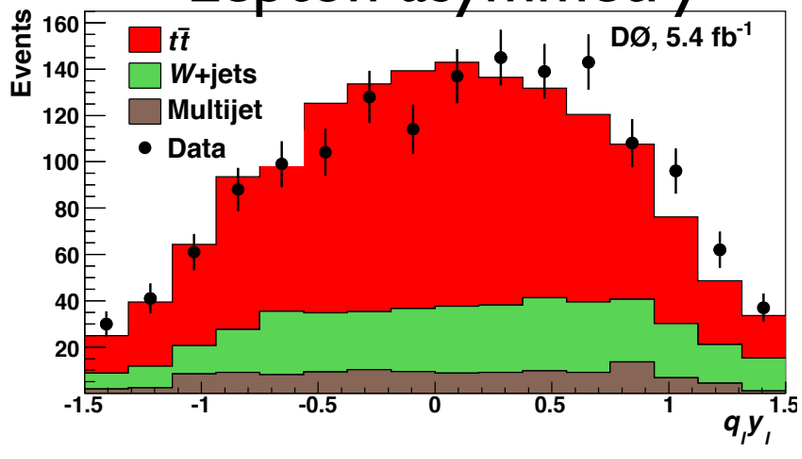
	l+≥4 jets	l+4 jets	l+≥5 jets
$A_{\rm FB}(\%)$	9.2±3.7	12.2±4.3	-3.0±7.9
MC@NLO $A_{\rm FB}$ (%)	2.4±0.7	3.9±0.8	-2.9±1.1

Top asymmetry



	l+≥4 jets	l+4 jets	l+≥5 jets
$A^l_{\rm FB}$ (%)	14.2± 3.8	15.9± 4.3	7.0± 8.0
MC@NLO $A^l_{\rm FB}$ (%)	0.8± 0.6	2.1± 0.6	-3.8± 1.2

Lepton asymmetry



- Disagreement with SM = 3.4 s.d.
- CDF $M_{t\bar{t}}$ dependence not confirmed (?)

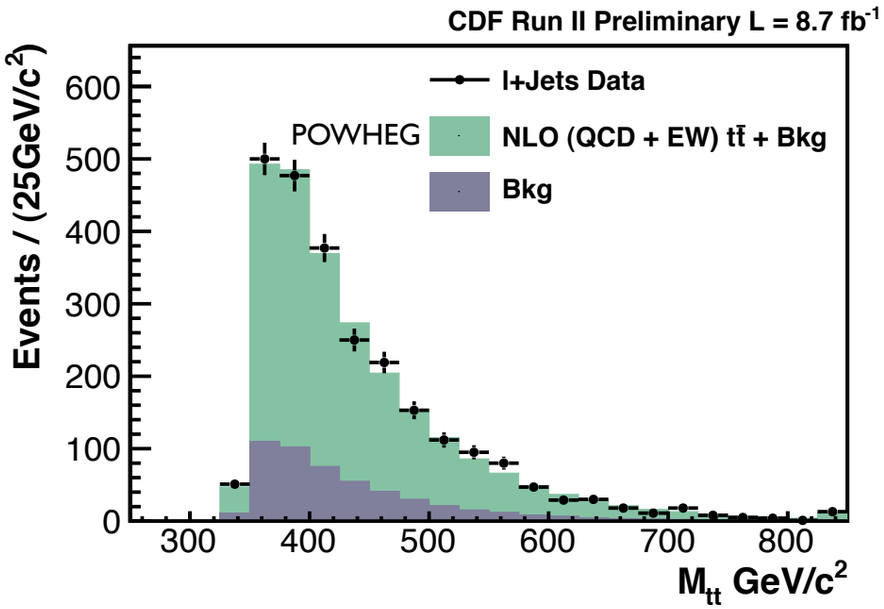
$t\bar{t}$ A_{FB} at Tevatron

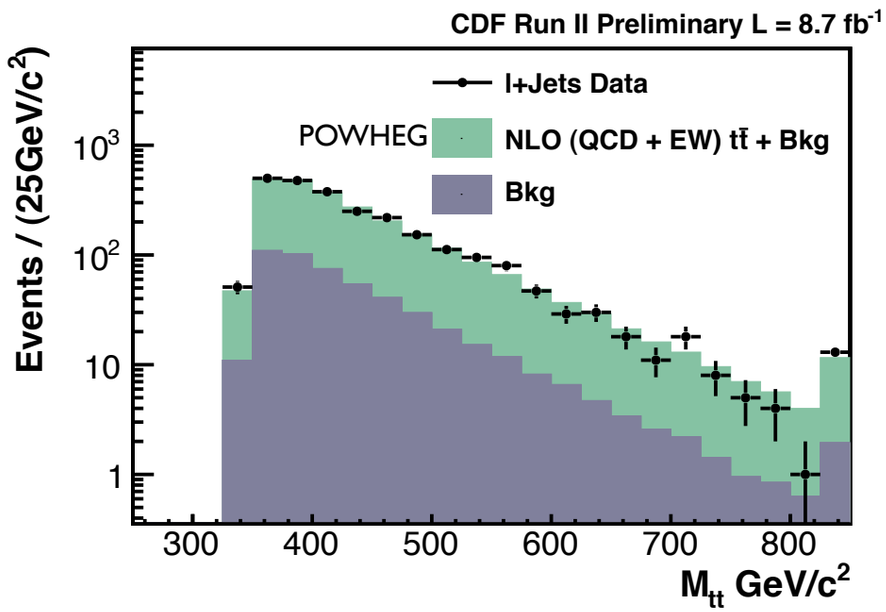
Selection	NLO (QCD+EW)	CDF, 5.3 fb^{-1}	D0, 5.4 fb^{-1}	CDF, 8.7 fb-1
Inclusive	6.6	15.8 ± 7.4	19.6 ± 6.5	16.2 ± 4.7
$M_{tt} < 450$ GeV/c^2	4.7	−11.6 ± 15.3	7.8 ± 4.8 (Bkg. Subtracted)	7.8 ± 5.4
$M_{tt} \geq 450$ GeV/c^2	10.0	47.5 ± 11.2	11.5 ± 6.0 (Bkg. Subtracted)	29.6 ± 6.7
$\|\Delta y\| < 1.0$	4.3	2.6 ± 11.8	6.1 ± 4.1 (Bkg. Subtracted)	8.8 ± 4.7
$\|\Delta y\| \geq 1.0$	13.9	61.1 ± 25.6	21.3 ± 9.7 (Bkg. Subtracted)	43.3 ± 10.9

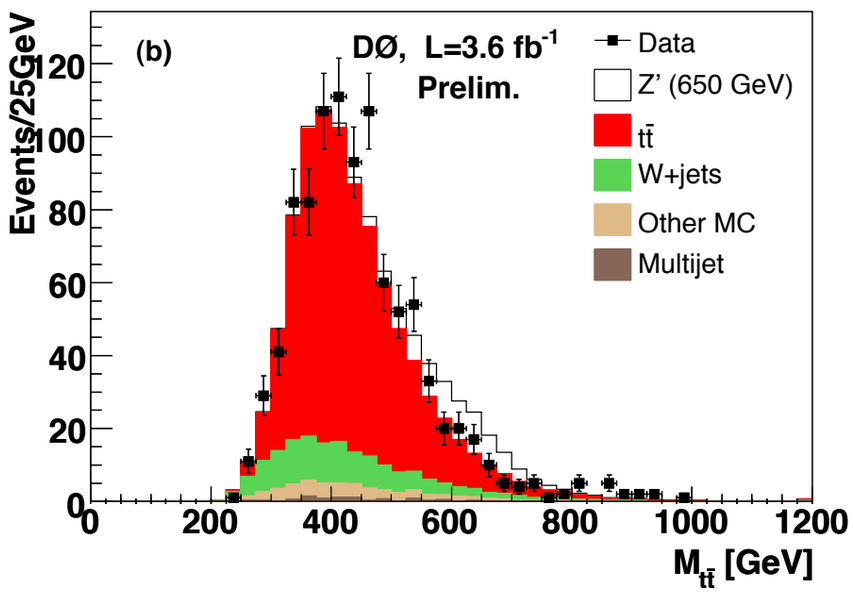
- CDF/D0 disagreement?

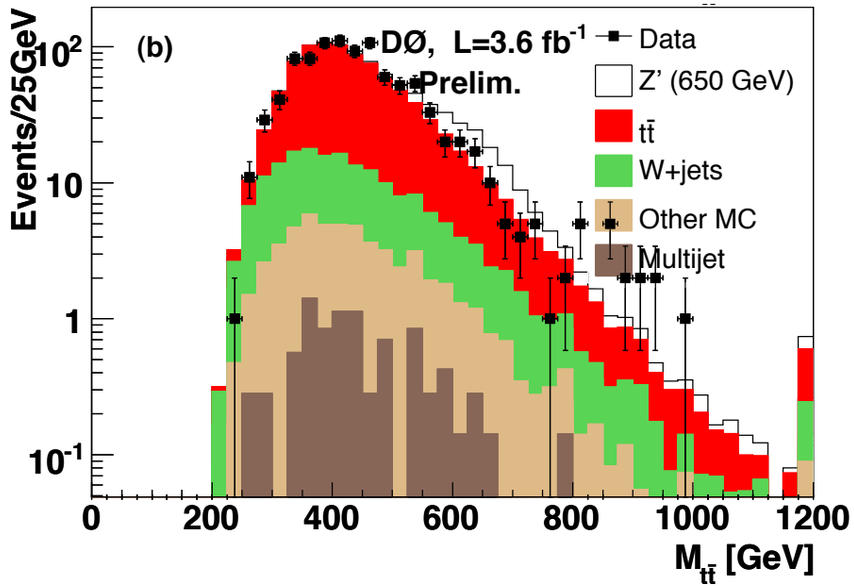
D. Mietlicki, Moriond, 2012

$t\bar{t}$ inv. mass at Tevatron





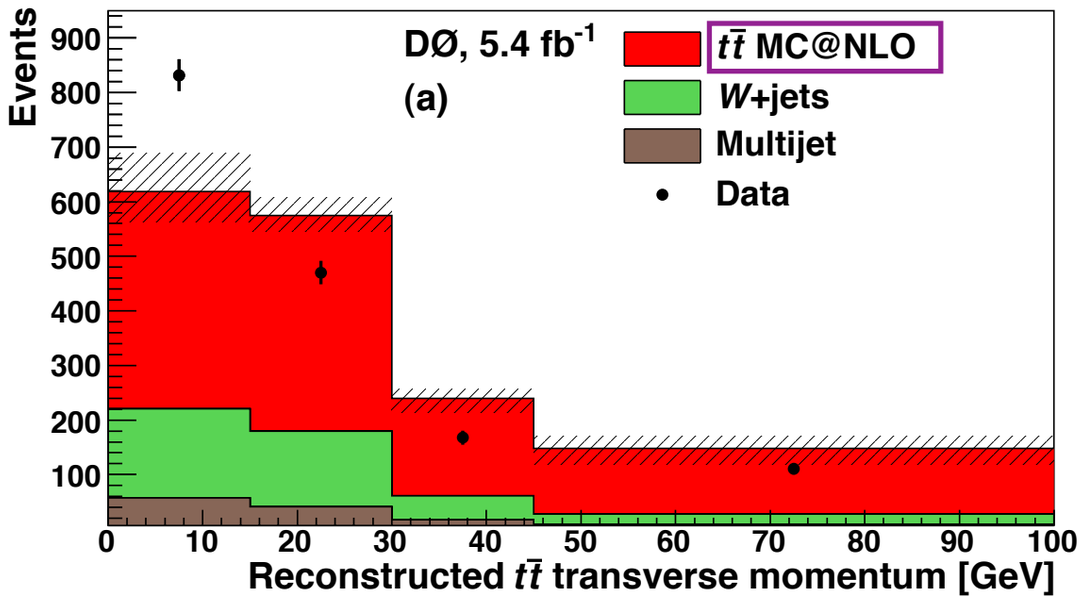


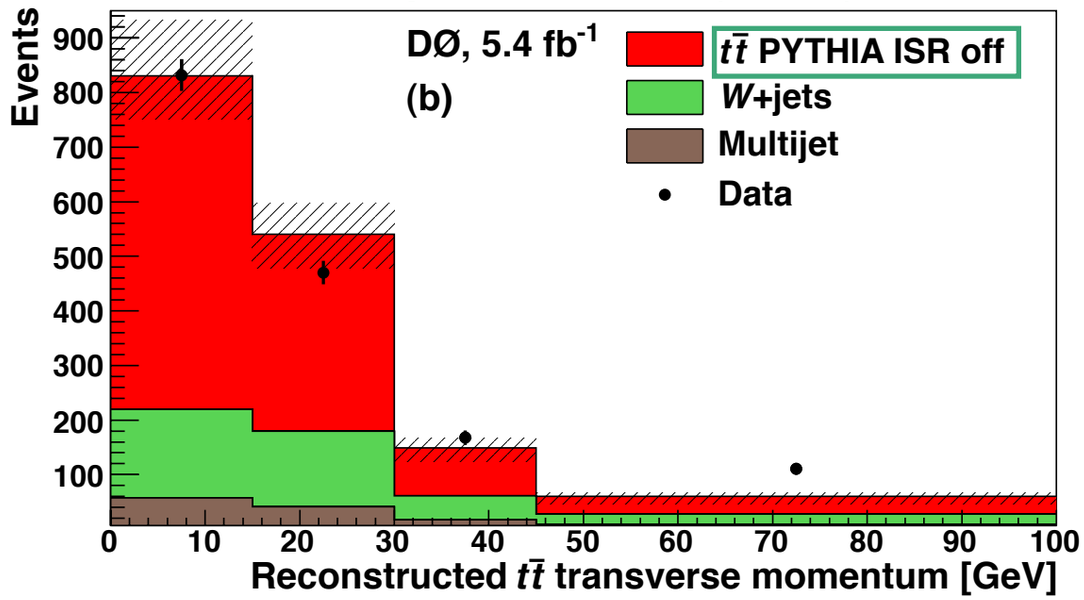


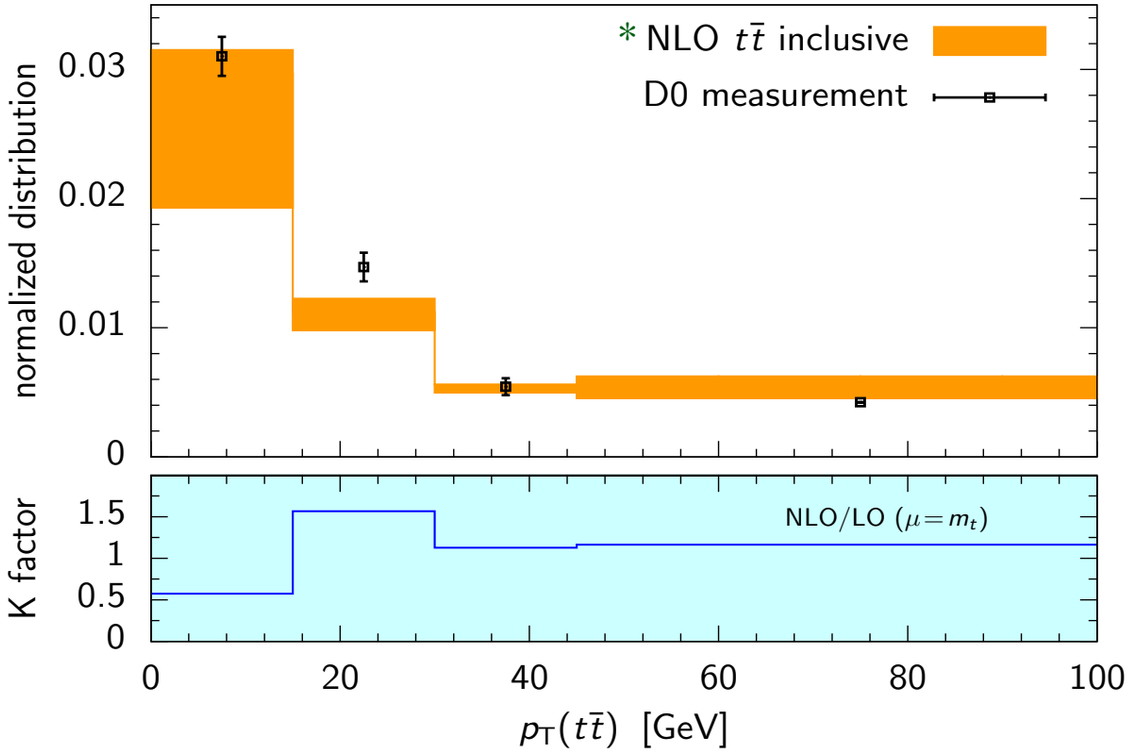
- CDF/D0 in agreement with SM

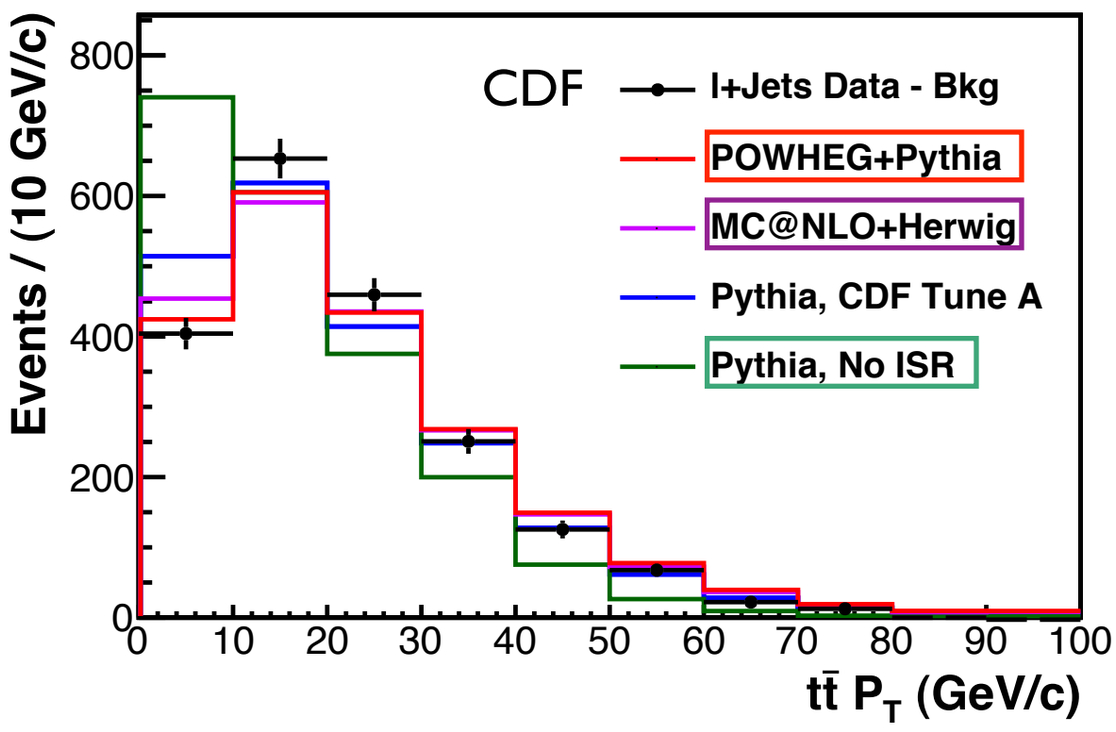
$t\bar{t}$ p_T at Tevatron

D0, Phys Rev D84 (2011) 112005





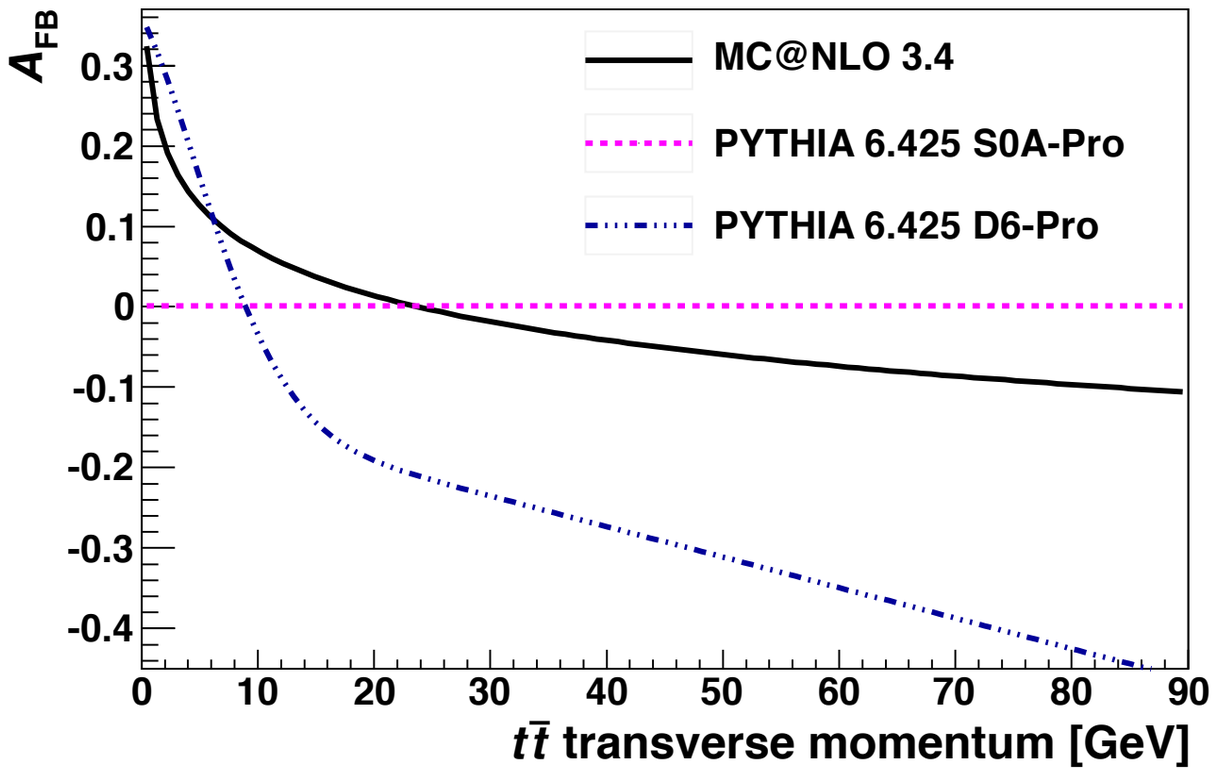


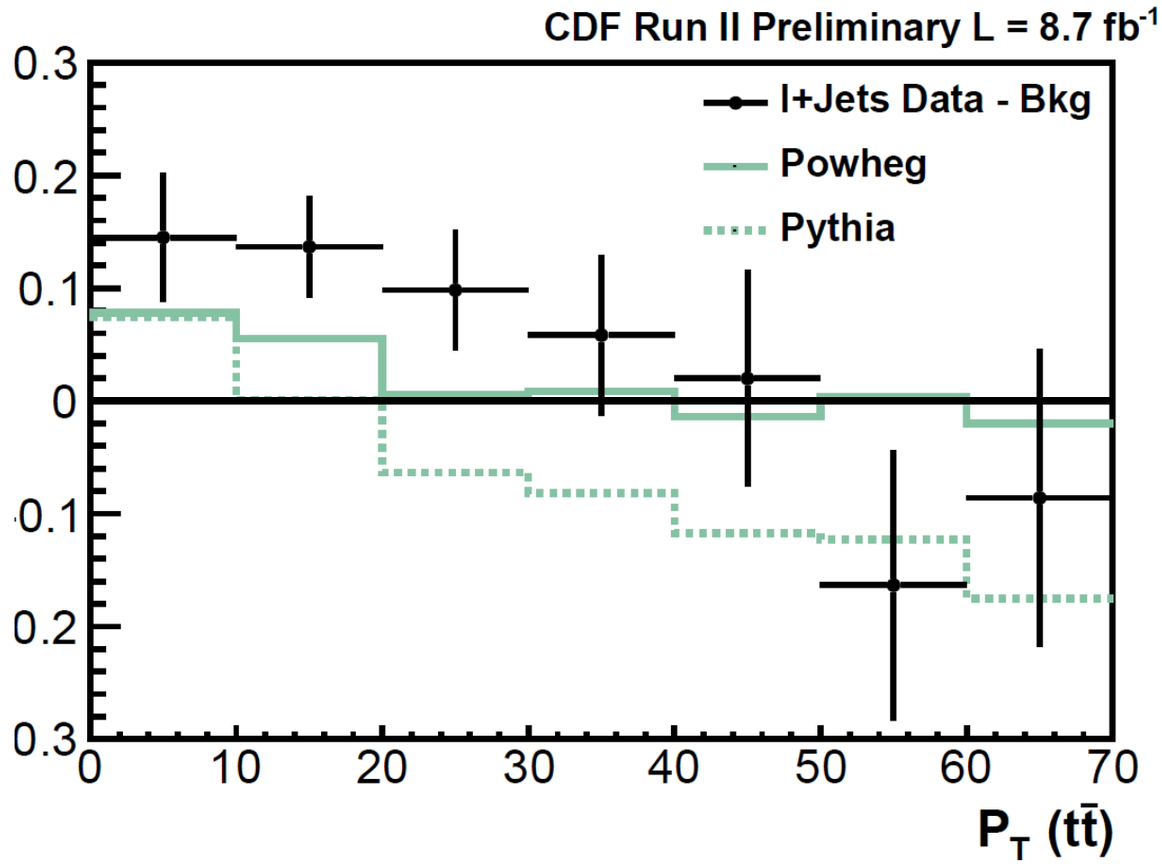


* Melnikov, Scharf, Schulze, arXiv:1111.4991

- CDF/D0 disagreement

p_T^{tt} dependence of asymmetry





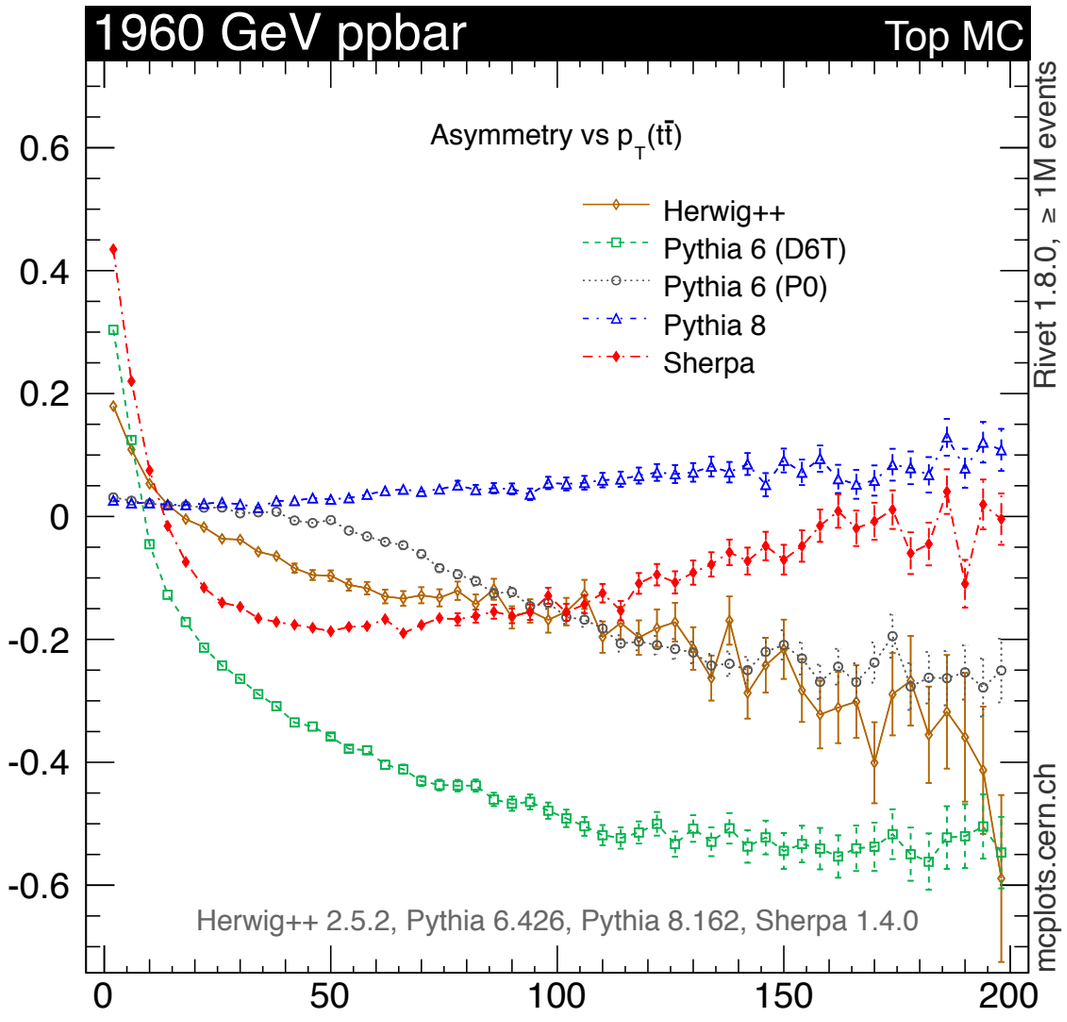
- CDF data disagree with POWHEG
- Asymmetry should change sign at ~20 GeV
- Loss at high p_T would enhance asymmetry

A_{FB} in Monte Carlos

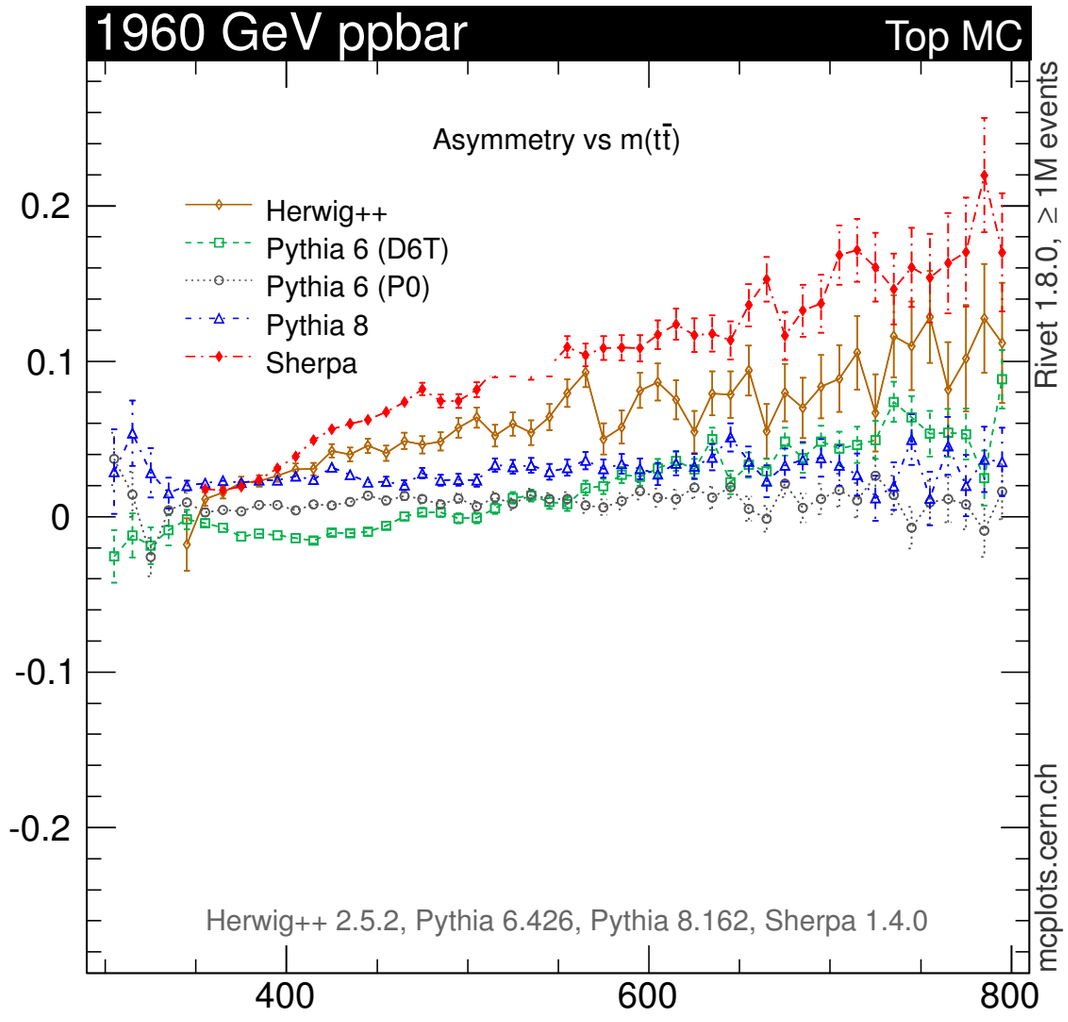
- Leading-order Monte Carlo = Born process + parton showers
- Born process has no asymmetry
- Hence MC has no asymmetry?

Peter Skands, Jan Winter, BW, arXiv:0512:1466

Wrong!



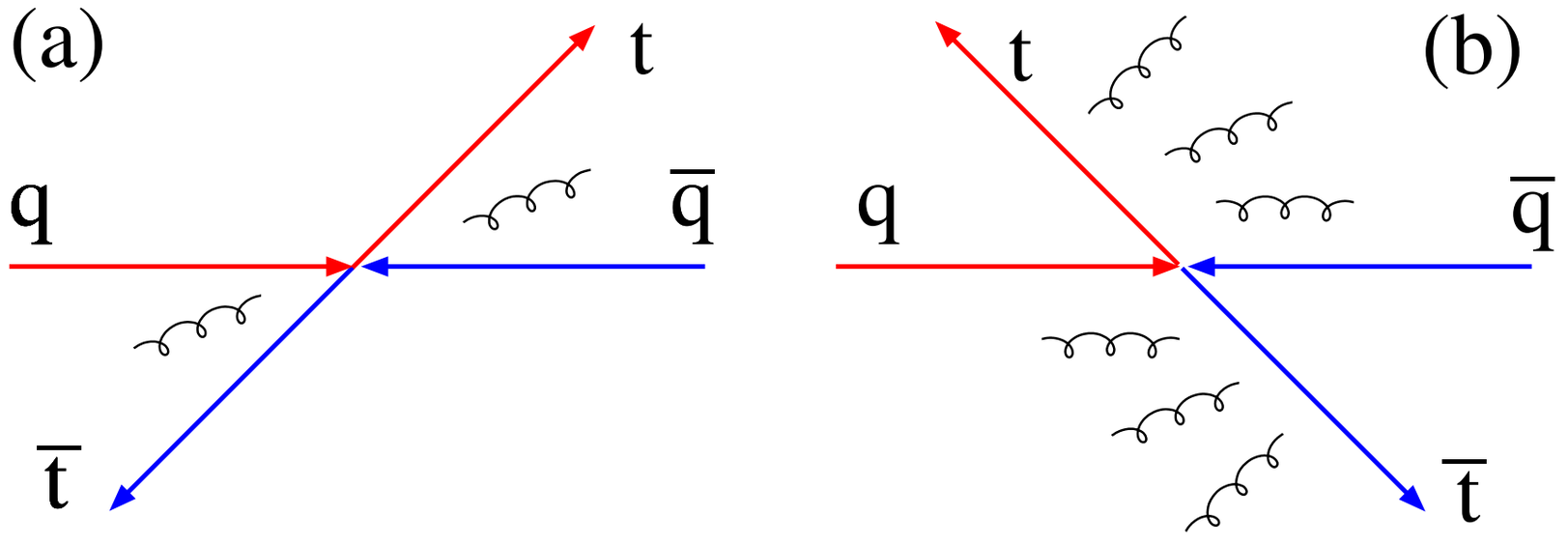
$p_T(t\bar{t})$



$m(t\bar{t})$

- MCs with coherent showering do!

What's going on?



- QCD coherence!
- Backward top → more radiation
- More radiation → bigger recoils

  → bigger $p_T(t\bar{t})$

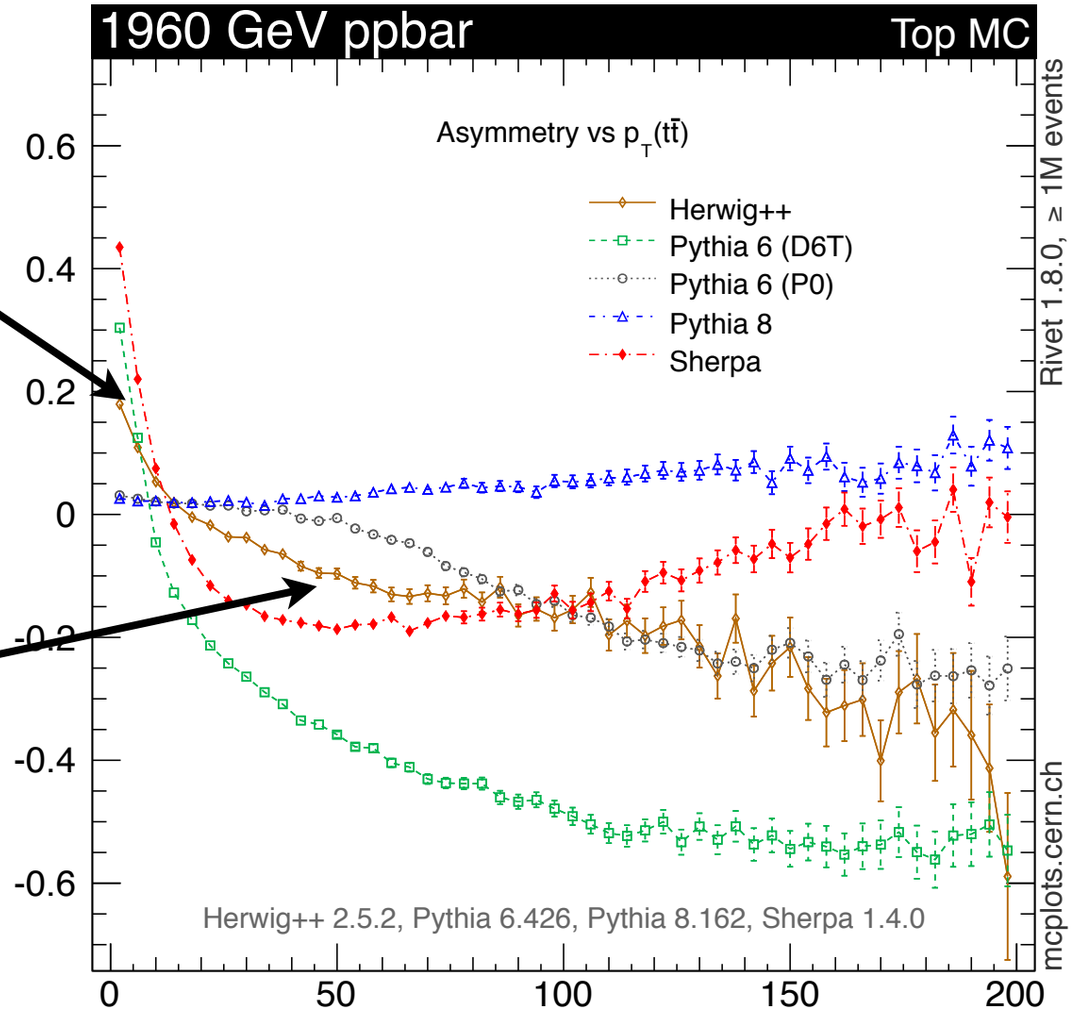
A_{FB} vs $p_T(t\bar{t})$

Forward tops left at low p_T

→ $A_{FB}>0$

Backward tops moved to high p_T

→ $A_{FB}<0$



Inclusive A_{FB} vs m(tt)

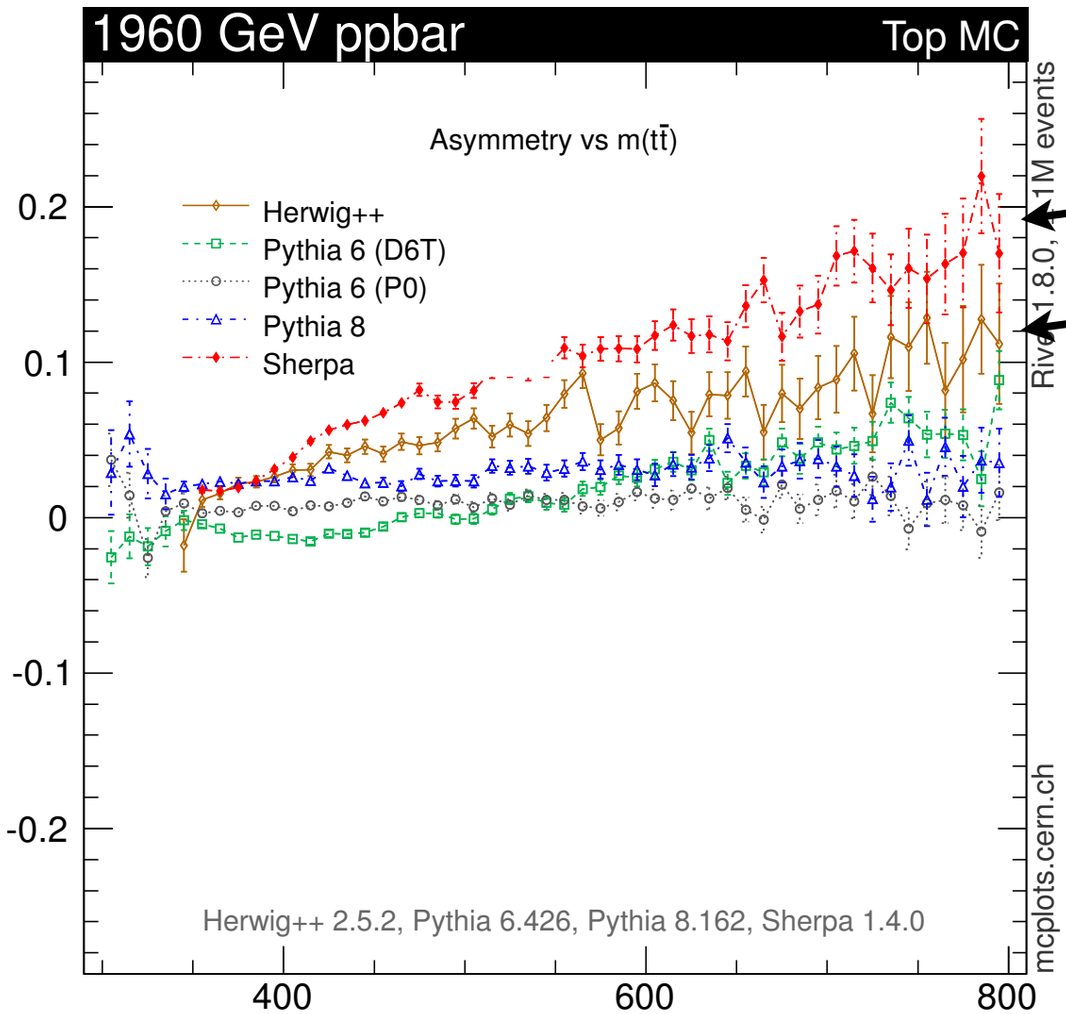
- Less radiation from forward tops
- Sudakov factor is larger: $\Delta_+ > \Delta_-$
- Migration from F to B is smaller: $P_{+-} < P_{-+}$

$$\Delta\sigma_{+-} = \int d\sigma^{\rm LO}\big]_{\Delta y>0} \left[\Delta_+ + (1-\Delta_+)(P_{++} - P_{+-})\right]$$

$$- \int d\sigma^{\rm LO}\big]_{\Delta y<0} \left[\Delta_- + (1-\Delta_-)(P_{--} - P_{-+})\right]$$

$$= -2\int d\sigma^{\rm LO}\big]_{\Delta y>0} (1-\Delta_+)P_{+-} + 2\int d\sigma^{\rm LO}\big]_{\Delta y<0} (1-\Delta_-)P_{-+} \quad \textbf{>0}$$

Inclusive A_{FB} vs m(tt)



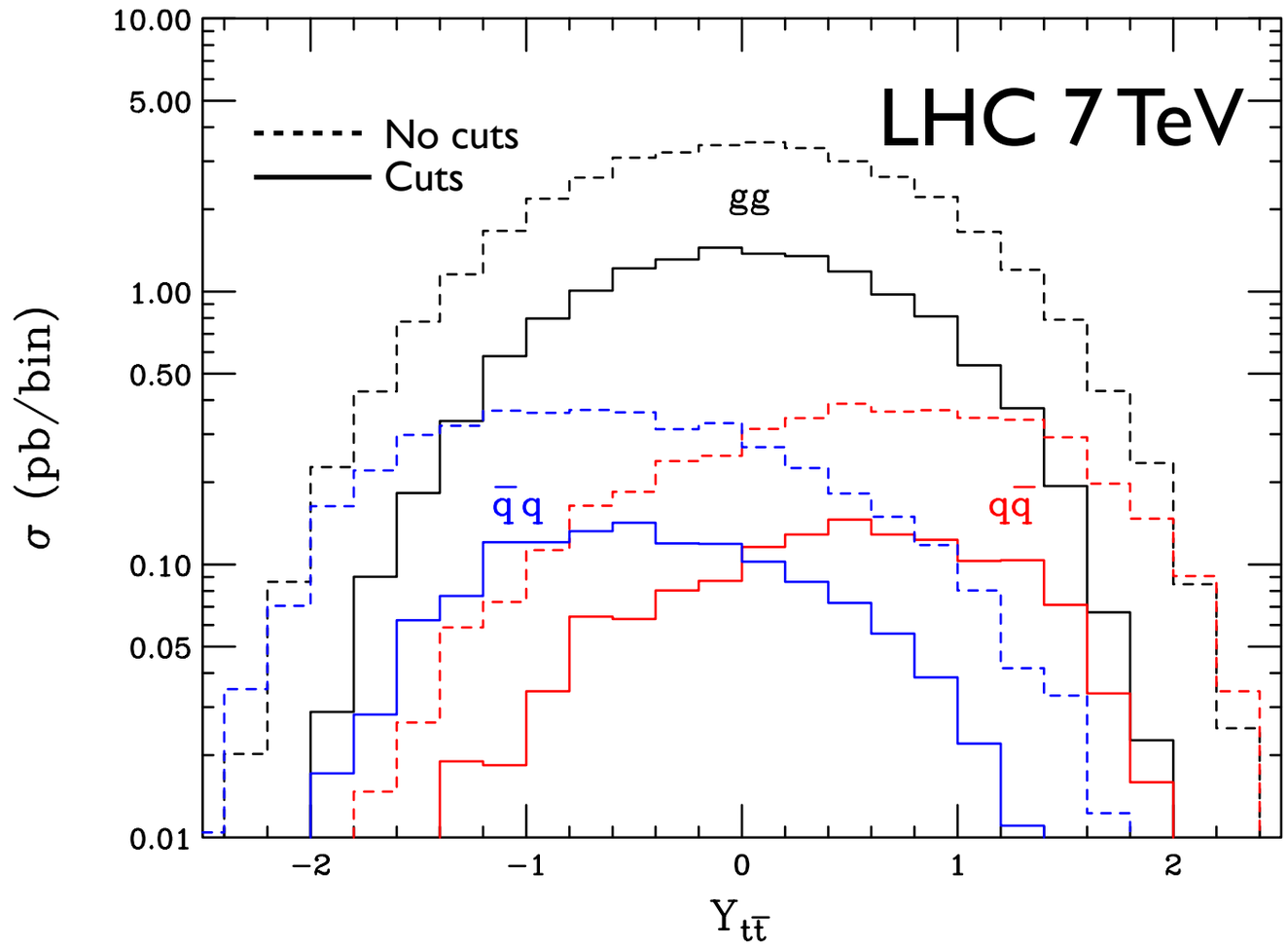
Sherpa coherent dipole shower

Herwig++ coherent parton shower

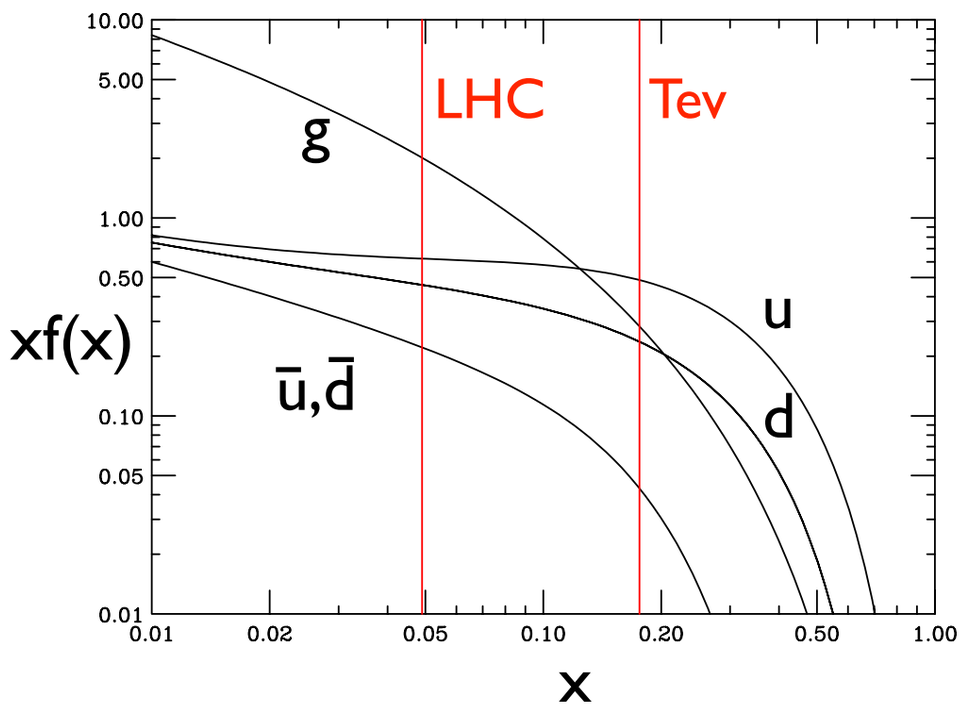
- QCD loop effect reproduced (approximately) by Sudakov factors in coherent showering

Top quark asymmetry at LHC

- LHC is a pp collider ➡ no effect??
- No! Effect should increase with $Y_{t\bar{t}}$ (q vs $\bar{q}$)
- SM effect is small (plots show MC truth for 2 fb^{-1})

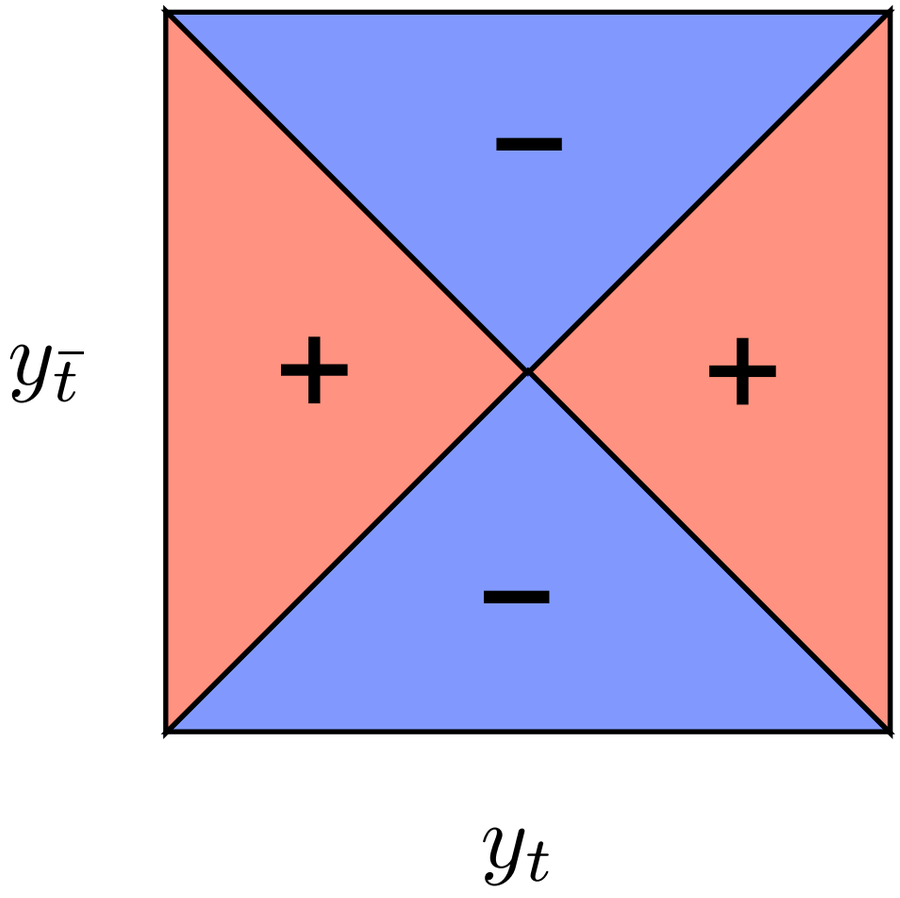


$$\Delta y = y_t - y_{\bar{t}}\ , \quad Y_{t\bar{t}} = \frac{1}{2}(y_t + y_{\bar{t}})$$



Top quark asymmetry at LHC

- LHC is a pp collider → no effect??
- No! Effect should increase with $Y_{t\bar{t}}$ (q vs $\bar{q}$)
- Rapidity correlation should be as shown below
- Top rapidity distribution should be wider



$$\Delta y = y_t - y_{\bar{t}}\ , \quad Y_{t\bar{t}} = \frac{1}{2}(y_t + y_{\bar{t}})$$

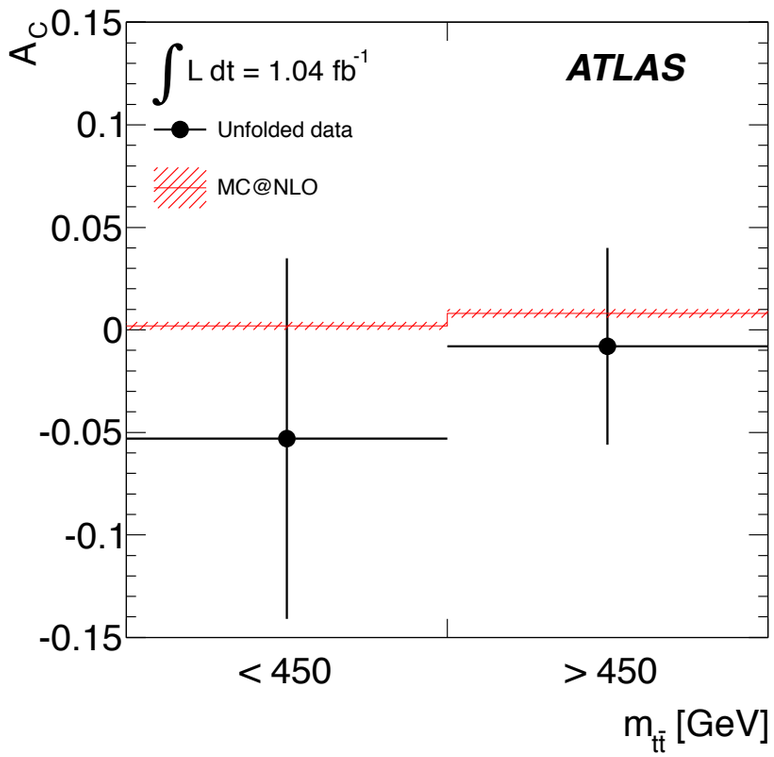
$$A^{t\bar{t}} = \frac{N(\Delta y > 0) - N(\Delta y < 0)}{N(\Delta y > 0) + N(\Delta y < 0)}$$

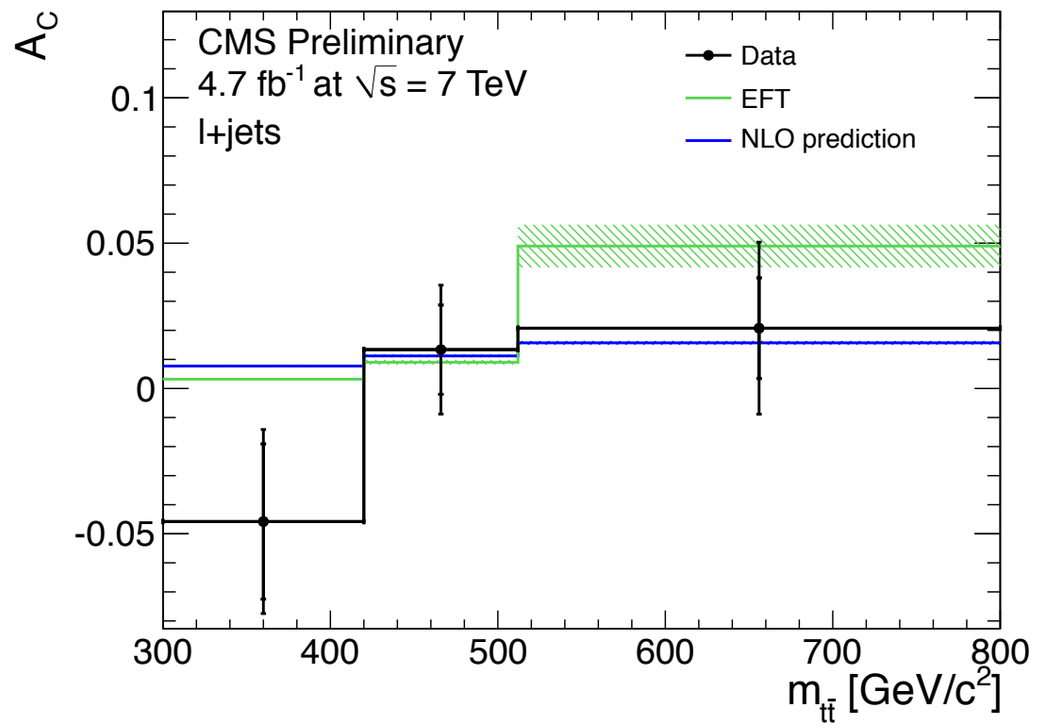
$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)}$$

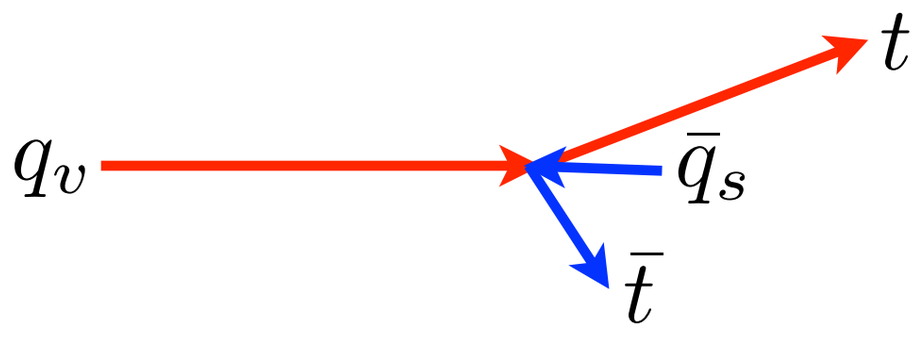
$$\Delta|y| \equiv |y_t| - |y_{\bar{t}}| > 0 \quad \Leftrightarrow \quad \Delta y \cdot Y_{t\bar{t}} > 0$$

$t\bar{t}$ A_C at LHC

$$A_C = \frac{N(\Delta|y| > 0) - N(\Delta|y| < 0)}{N(\Delta|y| > 0) + N(\Delta|y| < 0)} \qquad \Delta|y| \equiv |y_t| - |y_{\bar{t}}|$$



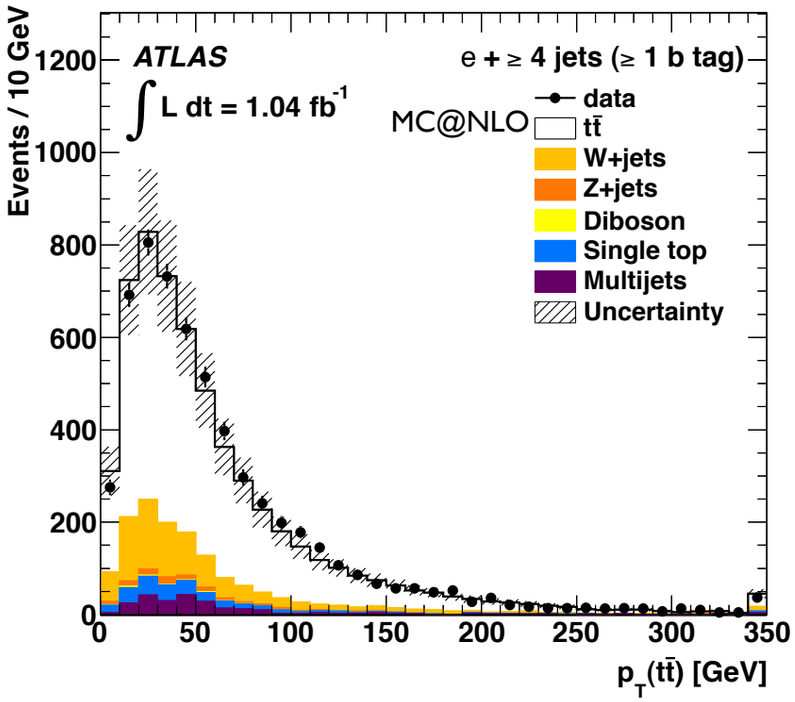


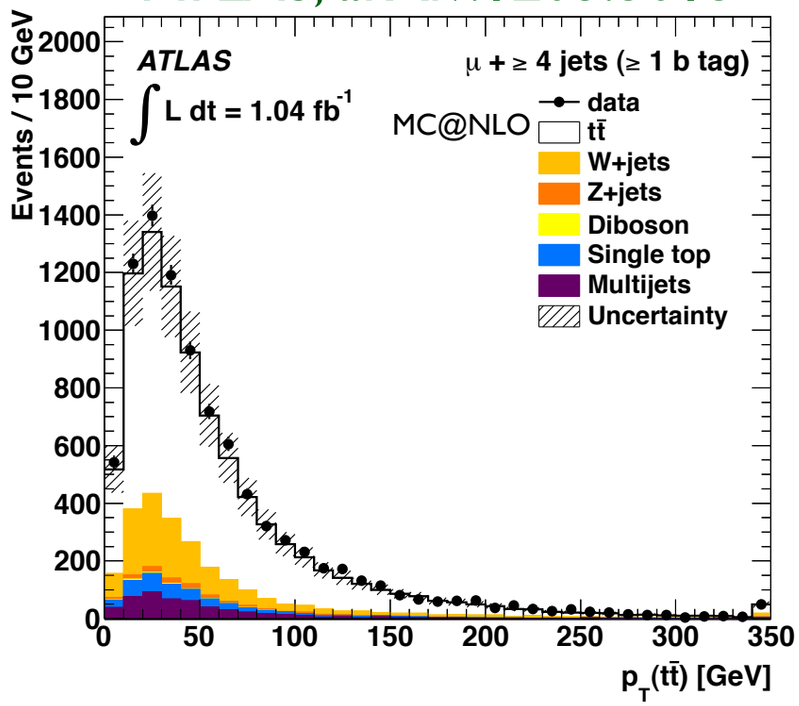


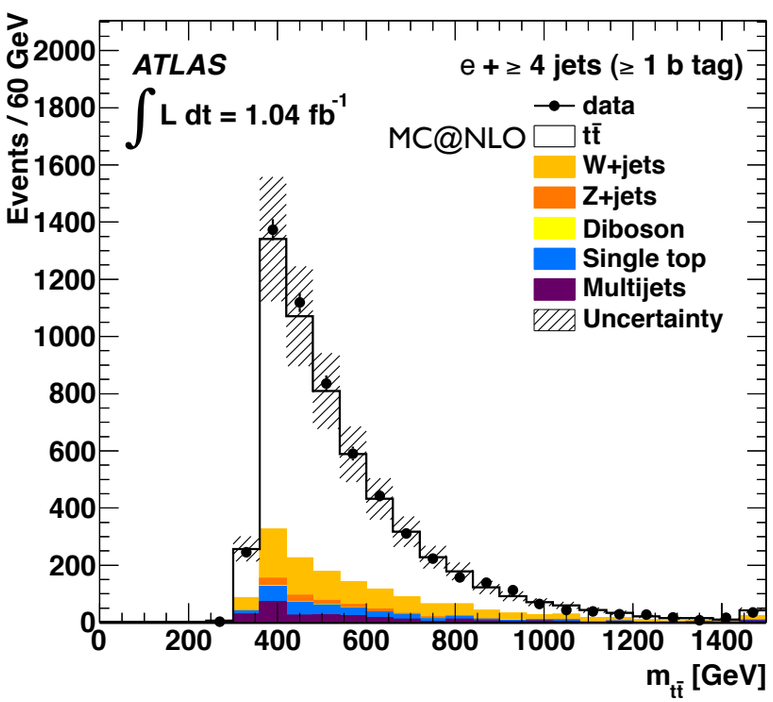
- Much smaller than A_{FB}
- Good SM agreement (so far)

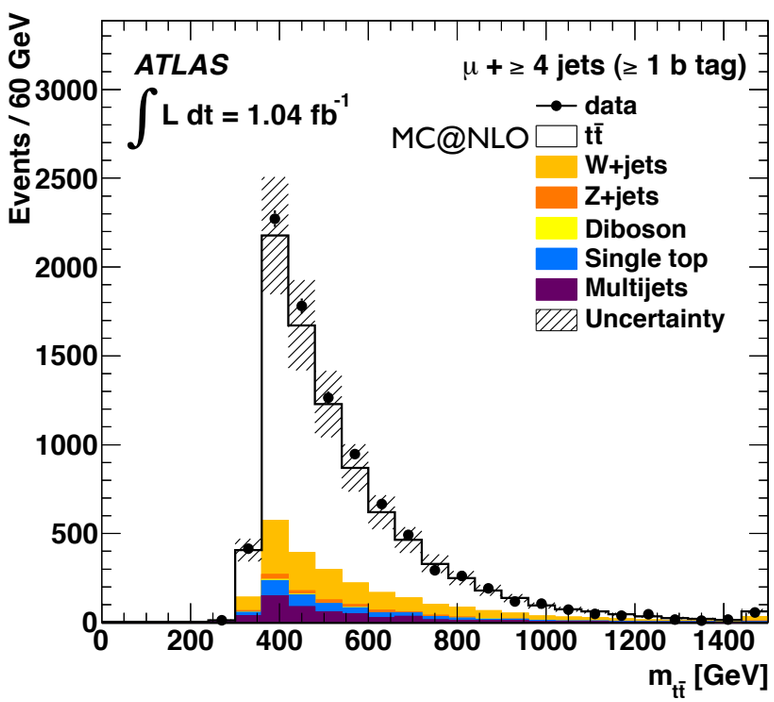
$t\bar{t}$ p_T & m_{tt} at LHC

ATLAS, arXiv:1203.5015









- Good agreement with MC@NLO

Conclusions on A_{FB}

- Asymmetry larger than SM seen by CDF in several independent data sets
- D0 also see this but no mass dependence
- SM asymmetry is due to QCD coherence
- Asymmetry at CDF (not SM) level could be seen at LHC in this run
- So far no sign of it

Finally ...

- Thanks to Pino for
  - introducing me to QCD coherence
  - many happy & fruitful collaborations
  - education in art, music, food, politics, ...