Moriond 03
QCD + Hadronic Interactions
The Experimental Summary

Peter Mättig
University of Wuppertal
QCD: part of the SM

QCD: prototype of quantum corrections

1979 DESY: gluon discovery

Huge improvements, but levelling off
Directions of QCD experiments

- Fixing the one parameter
- Models for long – distance contributions
  (symmetries, universal parameters, ....)
- Deviations → 'New Physics' ?

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The experimental progress

Higher luminosity

Extended kinematic range

Higher density

New precision detectors

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Energy variation $\rightarrow \alpha_s$

3/2 Jet ratios

$\alpha_s = 0.1212 \pm 0.0032 \pm 0.0027$

expt. theo

Eventshapes

$\alpha_s = 0.1198 \pm 0.0009 \pm 0.0047$

expt. theo.

F2 Structurefunction

$\alpha_s = 0.1150 \pm 0.0017 \pm 0.0008$

, $0.1166 \pm 0.0048 \pm 0.0018$

Excellent agreement from completely different analyses!

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The error of $\alpha_s$

Sometimes rather different estimates of theoretical and model uncertainties $\rightarrow$ find a common procedure!

Procedure to estimate theory uncertainty (LEP QCD group)

- Scale uncertainty $x = \mu/Q$: $[0.5, 2]$
- Resummation uncertainties $x_L = [2/3, 3/2]$, alternative matching schemes, ....
- Maximum deviation

Note: Convention!

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estimate of theory uncertainty

Presentations yesterday: NLO outside LO uncertainty band

Crucial for believable QCD tests:

Reliable (! Not minimal) estimate of uncertainty

Follow LEP-QCD group and set up procedure also for other processes
Heavy Quark Production

first order: direct access to partons

- Rather firm theoretical prediction
- Deconvolution of hadronization effects
- Candidate for New Physics
Charm

A. Böhrer

A. Bertolin/J. Butterworth

Di-jet charm production

Good agreement with NLO prediction

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Top quark

<table>
<thead>
<tr>
<th>Channel</th>
<th>Xsec(pb)</th>
<th>Stat Err</th>
<th>Syst Err</th>
<th>Lumi</th>
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<tbody>
<tr>
<td>D0</td>
<td>all</td>
<td>8.4</td>
<td>(+4.5,-3.7)</td>
<td>(+5.3,-3.5)</td>
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<tr>
<td>CDF</td>
<td>lep/lep</td>
<td>13.2</td>
<td>5.9</td>
<td>1.5</td>
</tr>
<tr>
<td>CDF</td>
<td>lep + jets</td>
<td>5.3</td>
<td>1.9</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Agreement with theoretical expectations ....

more precise experimental tests soon!

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A beautiful (?) excess?

Known since several years → Motivating SUSY etc. searches

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Side remark: $pN \rightarrow B \rightarrow J/\Psi$

HERA-B:
Bottom production in nuclei: C, Ti
Agrees with NLLO calculation
Resolution ... at least for CDF?

Theory: Cacciari and Nason, hep-ph/0204025
Binnweiser et al. PR D58, 034016 (1998)

- Hardness of bottom hadronisation
- Shape of fragmentation function
- Proper inclusion of resummation

Disagreement: factor $2.9 \rightarrow 1.7$

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Ambiguities in MC

- INCLUSIVE measurement of $x(B)$, reference from LEP/SLC
- Convolution Parton splitting + B fragm. fct in colour neutral system
- Determine free parameter (e.g. $\varepsilon_b$ for Peterson shape)

$\varepsilon_b$ depends on many other parameters of model!

Affects shape and hardness at other energies

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Normalising B - fragmentation

Cleanest measurement at LEP, SLC

New average (preliminary) $0.715 \pm 0.003$

E. Ben-Haim

Lund & Bowler favoured
Some general comments

- Improvement from 2.9 → 1.7 great, but still not satisfactory?
- Remarkably little excitement .... typical for pure QCD deviations ?
- Very slow response of experiments: hardly any reanalysis in light of theoretical concerns

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Other News from inside the proton

Strange quark SF
$Q^2 = 4 \text{ GeV}^2$

Transverse spin asymmetry (RHIC)

Electro/photo production of VM

A. Tzanov

B. Surrow

K. Voss, D. Brown

Physics behind it?

pQCD works

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Diffraction

P. Van Mechelen

DIS diffraction @ HERA:
- Determination of the diffraction pdfs
- Application to Tevatron data not working!

Failure of Factorisation?

M. Gallinaro

Double diffraction

15 K events – opens up diffractive product of Higgs?

Opens up new Higgs signatures at LHC/Tevatron?
Colour flows

Experimental study based on LPHD

includes particles of very low energy

Very good understanding even to very low momenta!

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New tool: colour reconnection

M.Giunta

ARIADNE ruled out
RATHSMAN ruled out
HERWIG ok

Colour reconnection depends on environment?

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Hadronization models

Diquark model confirmed

Bose-Einstein at $Z^0$: $\pi^+/\pi^0$ different?
Kinematic dependence?

Bose Einstein between $W$'s?
DELPHI: $3\sigma$

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Glueballs in gluon ladders?

If you have one gluon .... good chance for a glueball?

~ 100 cand./2500 selected events
- yield similar to known $f_2$, $f_2$ (?)
ep not the only possibility ....

$K^0_sK^0_s$ mass spectra in gluon jets

No confirmation of L3, no signal at ZEUS candidate ......
Exciting ... but convincing?

Proper background shape?

- Reference $K^+K^-$ shape?

- $f_2 \rightarrow \pi\pi$ yield consistent?

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Hadron decays

Models required to include multi-gluon interactions

..... in the absence of lattice calculations

- top quark ..... easy: simple weak interactions (?),
  no top hadrons

- bottom (charm) quark \(\rightarrow\) Effective Heavy Quark Theory, ..

- up, down, strange \(\rightarrow\) mainly chiral pertubation theory

Experiments have reached outstanding precision !!!!!
Light quarks

Testing and constraining Chiral Perturbation Theory

D.Gotta

NA48: high precision $K^0_S$ decay

C.Cheskov

C.Schütz : Pionium

C.Petrasu : Kaonic atoms

.... a long way and lots of theory-experiments interactions!

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Charm

Huge charm samples

Tiny branching ratios explorable

Final aim: $D^0$ mixing, CP violation \(\rightarrow\) Beyond SM

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Key issue: CP violation – up to now in beautiful agreement with SM

CKM matrix
A. Warburton, A. Limousani,

Towards $B_S$ mixing
CDF/D0
L. Vacavant

BABAR, BELLE, CLEO:
Long list of $10^{-6}$ BR decays

QCD uncertainties often limiting factor!

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High density nuclear matter

Where to fit in in $Q^2$ ordering?

Checking signatures of nucleon/quark matter

<table>
<thead>
<tr>
<th>M. Van Leeuwen</th>
<th>H. Santos</th>
<th>G. Usai</th>
<th>H. Sako</th>
</tr>
</thead>
</table>

Saturated $K^+/\pi^+$ ratio  
$J/\Psi$ suppression  
NA60: Pixel detector  
Fluctuations

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Jets in Heavy Ion Interactions

Are jets observed?
Note: Jets ~ 6-8 GeV!

Comments from a High Energy Physicist:

Near side correlations
(\Delta \eta, \Delta \phi) correlations
Trigger bias?

History: jet evidence in e⁺e⁻ by distinguishing from random particle distribution!

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The amazing (?) baryon excess

J. Velkovsa

Central collisions:
$\pi^+/p \sim 1, \quad \pi^-/p^- \sim 1$

Completely in contrast to jets in ee, ep, pp collisions!

B. Hippolyte

Note: does not mean $p \sim p^-$!
Scaling with NN in collision

J. Velkovsa, P. Jacobs

Normalise to p – p combinatorics in peripheral/central collisions

Deviation from scaling for $p_t \sim 3$ GeV ?

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No clear picture!

A.Drees, U.Wiedemann, C.Salgado, T.Pierog, W.Busza, S.Panitkin

Jets have been swallowed within nuclei!?

..... but how, what is inside dense matter @ RHIC?

➢ purely hadronic interactions?
➢ signal of gluon/quark interactions?
➢ mixture ????

Complementary measurements required (d Au)
QCD processes to signal BSM?

In general:

Xsection alone difficult, at least without feel for uncertainties!

J.Hays

Uncertainties in pdf’s dilute sensitivity to possible signals

S.Ferrag

Hardly to be taken as signal

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Bump hunting

Huge mass span at Tevatron allow search for $X \rightarrow jj$

M. Begel

Jet – Jet Resonances in many models ..... Nothing found yet!

M. Gallinaro, J. Hays

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The other part of the SM

Constraints to SM: current main improvements from W, top

A. Straessner

Run I D0: better l+jets mass
Mt = 179.9+-3.6+-6.0 GeV

Run II: restarting top physics

S. Cabrera, R. Zitoun

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Extending SM probes

T. Dorigo

Testing the weak and strong top decays

R. Zitoun

Longterm: use for luminosity

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Setting the scale ……

Higgs still light!
… though gained some weight!

Standard model Higgs above 114.1 GeV at this stage out of reach

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Beyond the Standard Model Higgs

Quizhong Li

$H \rightarrow WW$

$H^{++}$

Tevatron detectors on guard, more luminosity needed!

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BSM: SUSY

S.Braibant-Giacomelli, A.Safanov

No signal observed:
Neither LEP nor Tevatron

Gravity mediated SUSY
MSSM dark matter candidate  $M > 46$ GeV

Gauge mediated SUSY:
CDF candidate interpretation excluded

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BSM: Non-SUSY

C. Goy, J. Hays

Z' search

Quark-electron compositeness

..... many other models + signatures

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Imminent Future

- RHIC coming into gear,
- PEPII, KEKB even more improving,
- Tevatron bound to select several fb⁻¹,
- HERAII, CESR-c starting

Possible highlights of Moriond 2006

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The near future: LHC

G. Bruno

Turn-on of LHC: dwarfing all existing data sets: per fb$^{-1}$

$W \to \mu \nu$ 7,000,000

$Z \to \mu \mu$ 1,100,000

$tt \to WbWb \to \mu \nu + X$ 80,000

K. Mazumder

LHC to solve the origin of mass

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ECFA, US-HEPAP, ACFA: a linear $e^+e^-$ collider next step

German government recent decision:

- A Free Electron Laser on SC – TESLA components

DESY will continue its research work on TESLA in the existing international framework, to facilitate German participation in a future global project

The next steps: international agreement on technology convince governments of this world – wide facility

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THANKS !!!!!!!

Technical help: Etienne Auge, Andreas Kootz

Physics advice:

John Butterworth, Susanna Cabrera, Peter Jacobs, Katharina Klimek, George Lafferty, Gavin Salam, Bernd Surrow ...... and Lynne Orr ..... and many others!

The excellent atmosphere and an exciting conference:

Jean Tran Than Van, Yuri Dokshitzer, Boaz Klima

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