Bo's contribution to experimental multiparticle production physics (an incomplete & biased selection)

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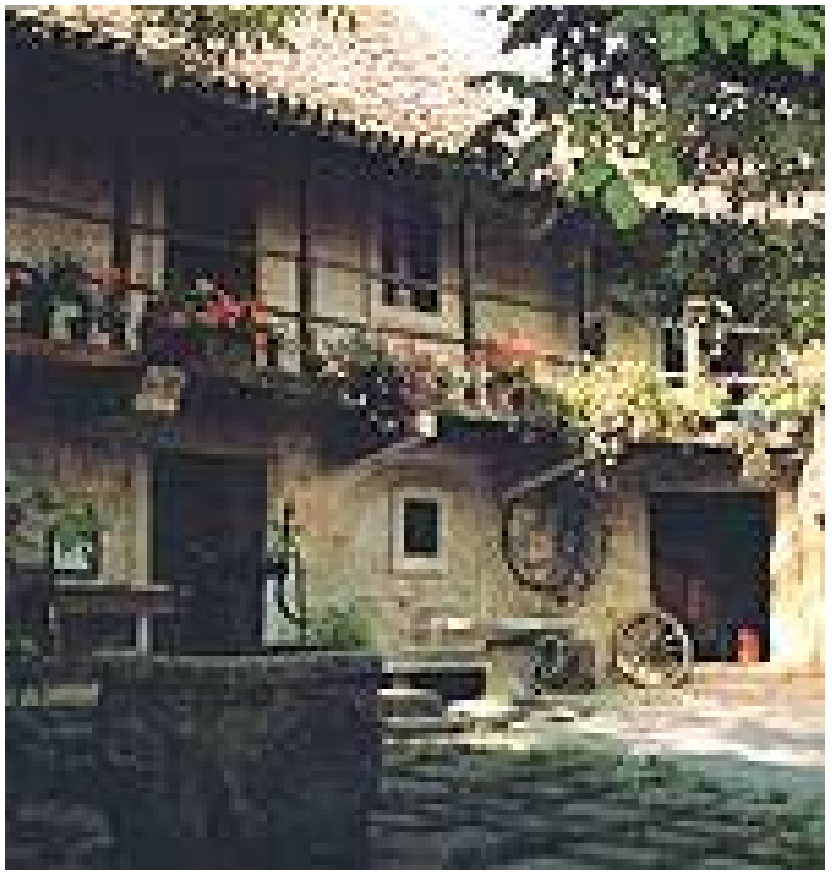
Preamble...

- Originality in the layout of transparencies
- Strict respect of the timetable for talks
- Capability of disappearing from a given place to reappear somewhere else

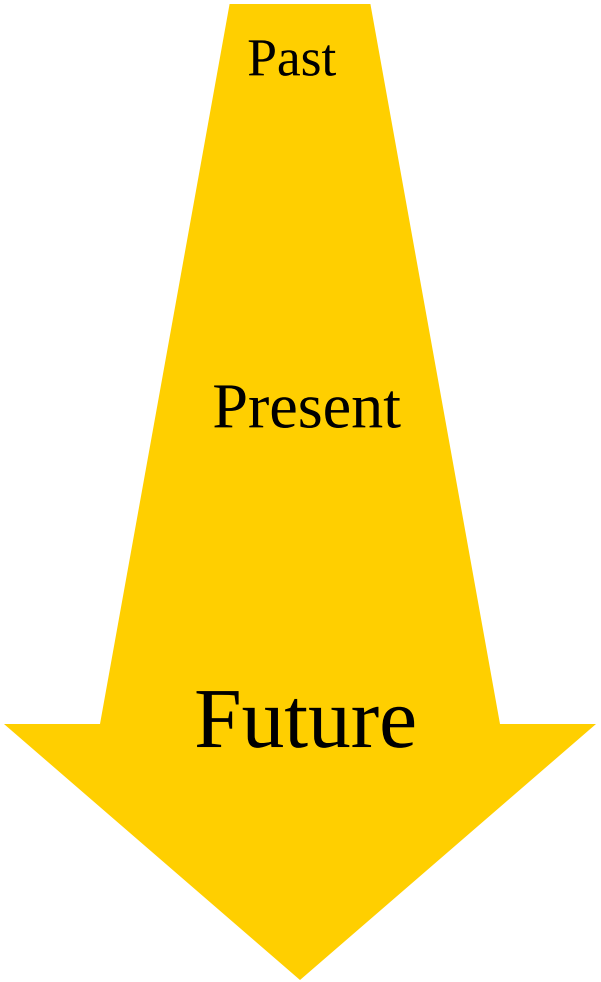
Preamble 2: my personal hit

- Know Bo since 1990, and shared a common hobby: wine
- My only paper with Bo is about BECs in quark and gluon jets from DELPHI
  - Is there any difference in strength ?
  - To my knowledge, the only paper in which an “osmizza” is acknowledged



Layout of this presentation

- The Lund model and its impact on experimental HEP
  - *Hadronic physics*
  - The LEP era
    - A few topics left for future analyses
- Miscellaneous topics where Bo's contribution is alive & kicking
  - BEC
  - Correlations in WW



QCD: theory vs. experiment

- *We have a theory … so why can't we test it right away to see if it's right or wrong? Because what we have to do is calculate the consequences of the theory to test it. This time,* ***the difficulty is this first step.***

  (Feynman)

- Quarks and gluons are not seen, only hadrons
  - How to quantify hadronization ?

    Lund string fragmentation model !

Lund model, MC implementation and impact on experimental HEP

- The Lund model: from the idea to the implementation
  - Bo, G. Gustafson and C. Peterson, ZP C1 (1979) 105;
  - Bo and G. Gustafson, ZP C3 (1980) 22;
  - Bo, G. Gustafson and T. Sjöstrand, ZP C6 (1980) 235; Z. Phys. C12 (1982) 49
  - **Bo, G. Gustafson, G. Ingelman and T. Sjöstrand, Phys. Rep. 97 (1983) 31**

Topcites 2001 Edition

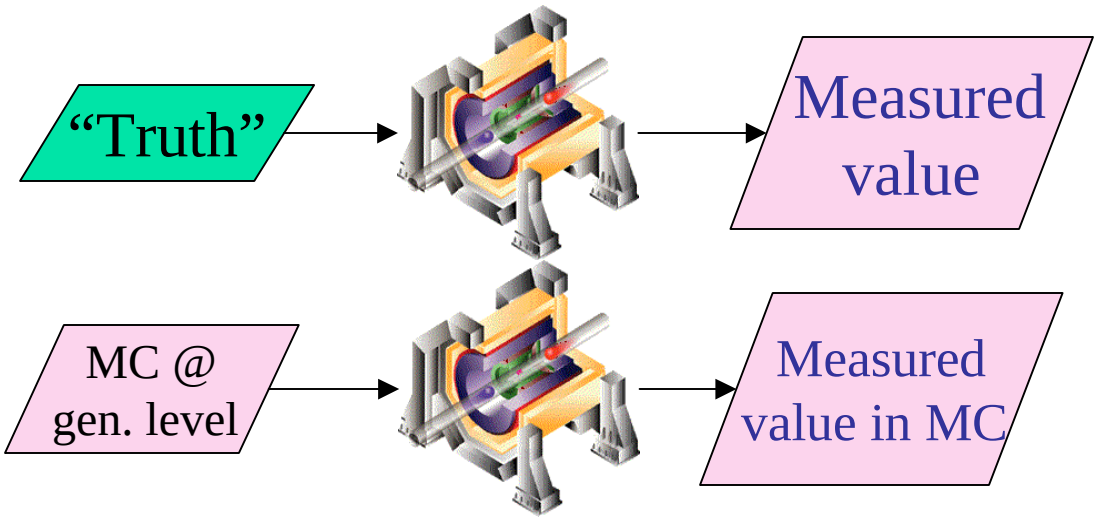
Top Cited HEP Articles
from SPIRES-HEP database, SLAC library

16. **HIGH-ENERGY PHYSICS EVENT GENERATION WITH PYTHIA 5.7 AND JETSET 7.4**
By Torbjorn Sjostrand (CERN).
Published in Comput.Phys.Commun.82:74-90,1994
[Total number of citations in HEP]

A large number of persons should be thanked for their contributions. Bo Andersson and Gösta Gustafson are the originators of the Lund model, and strongly influenced the early development of the programs. Hans-Uno Bengtsson is the originator of the PYTHIA

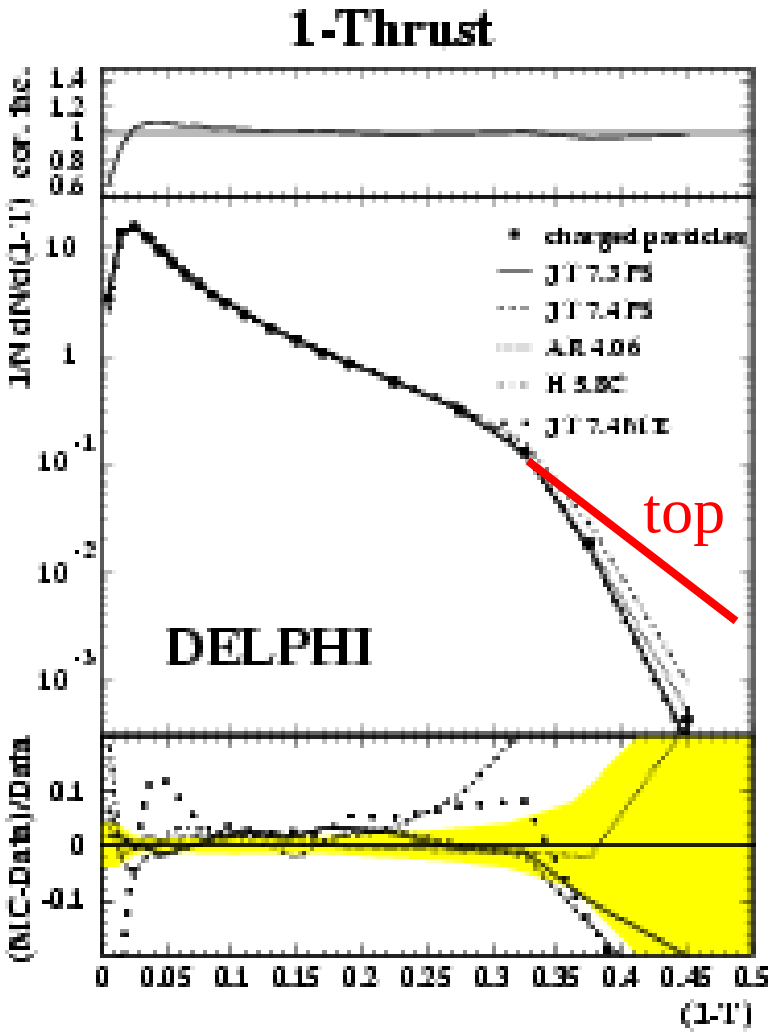
Additional (and crucial) contribution to the study of hadronic collisions

- In the first fixed target experiments, the only way of measuring quantities is the direct one
- From the EHS experiments, unfolding techniques become essential for hadronic final states
- Good modeling of the soft sector is the crucial point for the unfolding
  - and understanding what is “new physics”



The LEP era

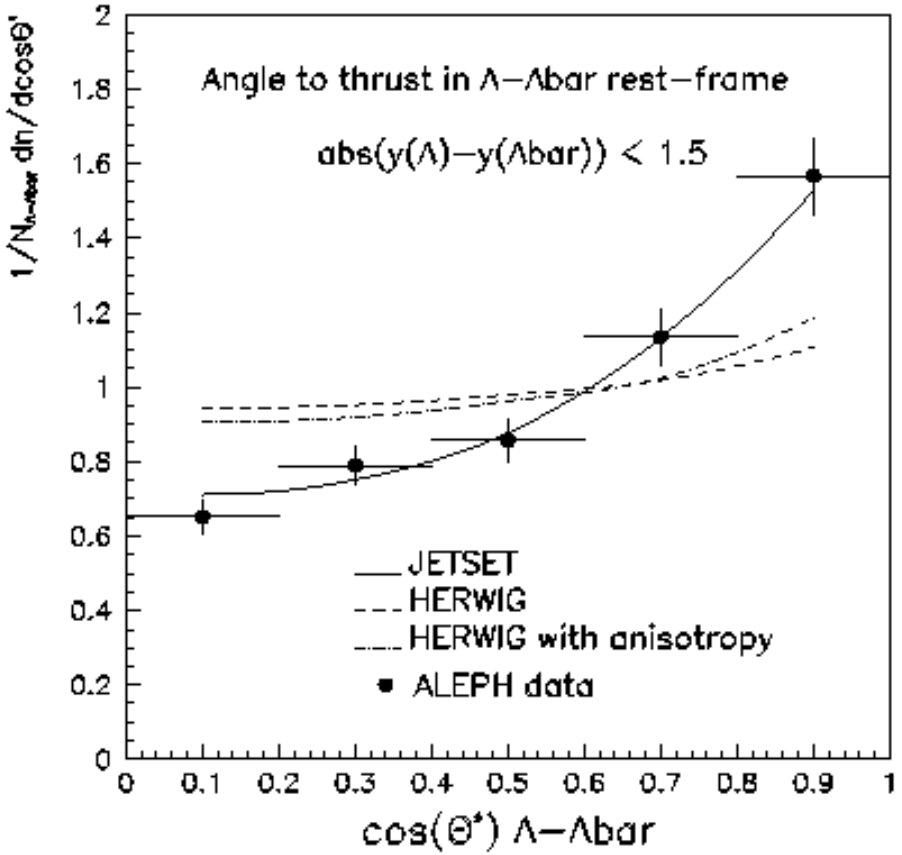
- First way of looking for new physics in 1990: compare inclusive distributions with MC
  - Check string- and cluster-based models
- But in case there is discrepancy, how to know if the model was wrong or if there is new physics ?
  - Was never a problem: string-based MC in excellent agreement with data
    - Large statistics needed to observe deviations



The data and the string model

- String effect

  (particle flow in 3-jet events)
- A MC-independent test: angle between the baryon and the evt axis in the B/antiB rest frame.
  - String model: baryon production is preferentially aligned to the event axis (pulled by the string tension)
  - Cluster model: isotropic
- Data favor the string model. Also measurements of B/antiB production in q/qbar jets favor the string model



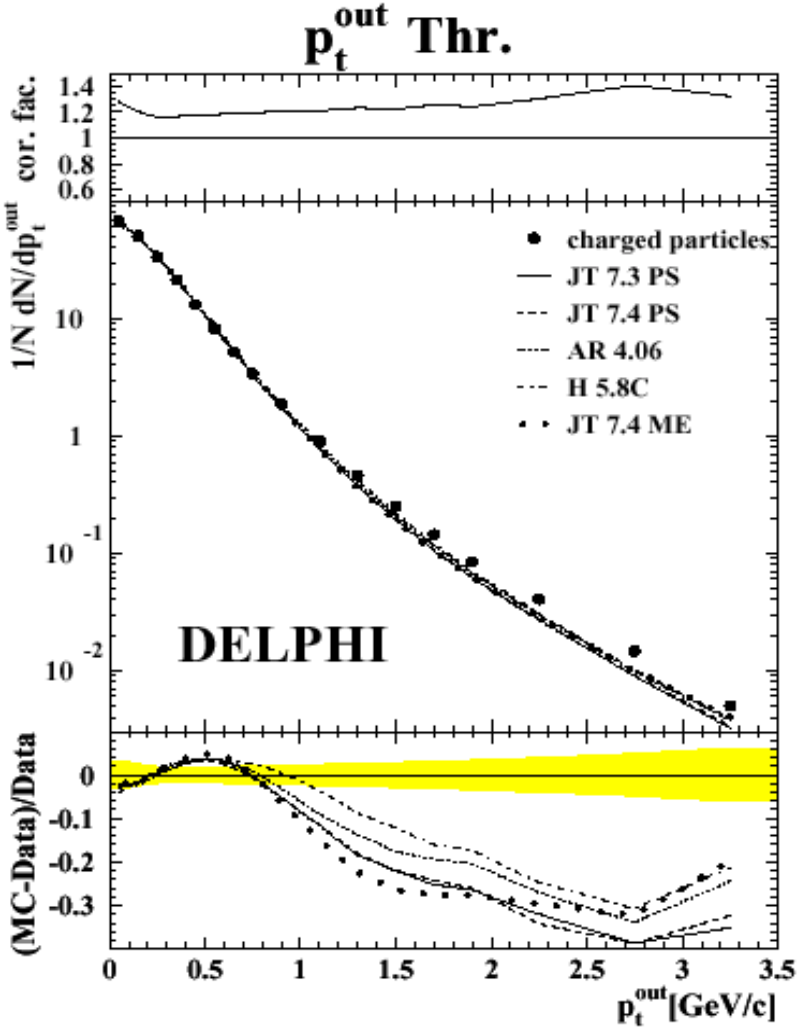
Lund as a standard “de facto” for hadronization

- The string-inspired MCs became a standard “de facto”
  - A joke: it would have been cheaper to run Lund...
  - A sentence from several papers:

    “The experimental data are in agreement with the simulation”
- Several physical quantities have been measured by using Lund as a function of the unknown parameter, and then minimizing the $\chi 2$
- As a standard “de facto”, Lund parameters were adjusted to the experimental data.
  - Huge computational program to tune the string parameters

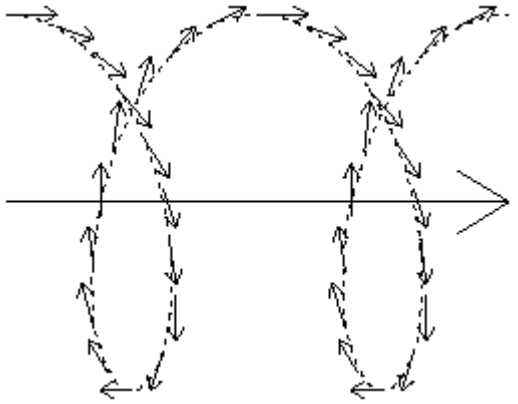
Bo was anyway always very attentive to the new...

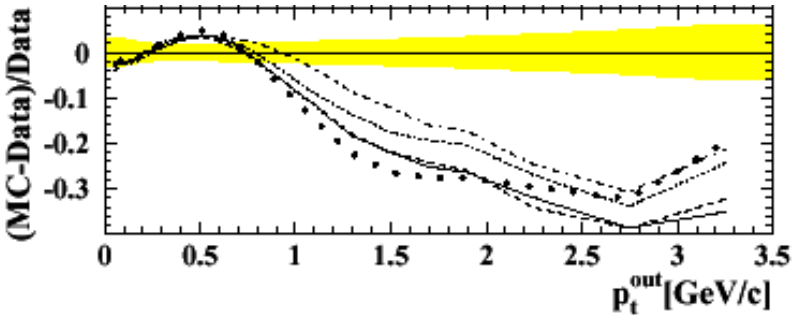
- If you are always right, there is little to learn...
  - Minor in e+e- $\rightarrow$ hadrons, thus
    - Lepton-hadron
    - Photoproduction
  - Special attention to discrepancies
    - Especially in the extreme nonperturbative sector



An example: screwiness

- Bo & al. (1998) show that the closest packing of gluons at the end of a QCD cascade can be obtained if gluons are arranged around a helix...
- This would contribute to a better modeling of p_T^{out}





Where, according to Bo, experiments could do a significant work - I

- The baryon sector
  - The extreme nonperturbative region might be a key for the understanding of the basics of multiparticle production
    - Fragmentation models contain many parameters which can be tuned according to data =>

      => A discrimination could be obtained by looking at

      spin and angular momentum generation

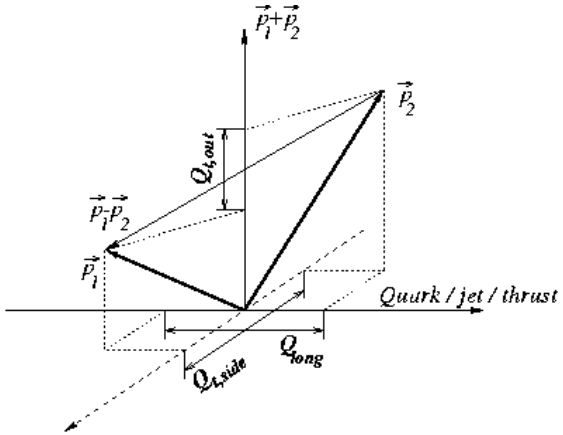
      correlations
    - Poor modeling of baryon correlations; S & L put in “by hand”;

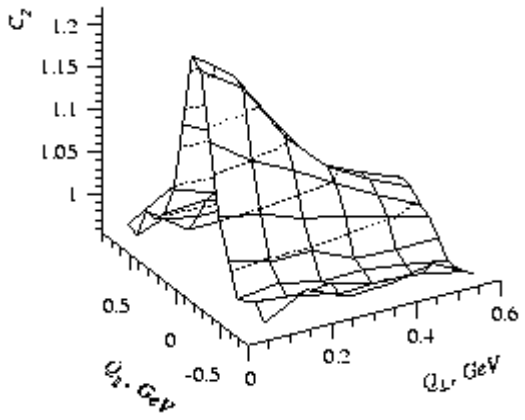
      in the string model => needs experimental studies
  - Use Λ polarization as a probe

Where, according to Bo, experiments could do a significant work - II

- Production of prompt photons
  - The decay of an unstable particle into charged particles can be thought as the sudden creation of rapidly moving charges. Such a variation of the electromagnetic field is accompanied by the emission of final state radiation.
  - WA91, NA22 and OMEGA measure an order of magnitude more radiation than predicted

Bo's BE





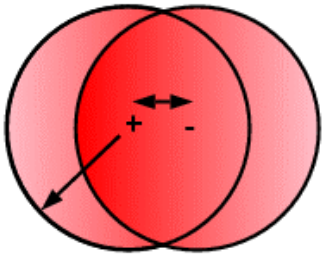
- Models assume in general a hadron source
  - spherically symmetric in space
- Also in the most fundamental process, ee, an ellipsoid seems more natural (string)
  - Bo & Ringnér 98

OPAL	$R_T/R_L = 0.77 \pm 0.02 \pm 0.07$
L3	$R_{out}/R_L = 0.71 \pm 0.02$ (+0.05-0.08) $R_{sid}/R_L = 0.80 \pm 0.02$ (+0.03-0.18)
DELPHI	$R_T/R_L = 0.64 \pm 0.09$

=> Evidence for an ellipsoidal structure

Bo's correlations in WW: a surprising prediction

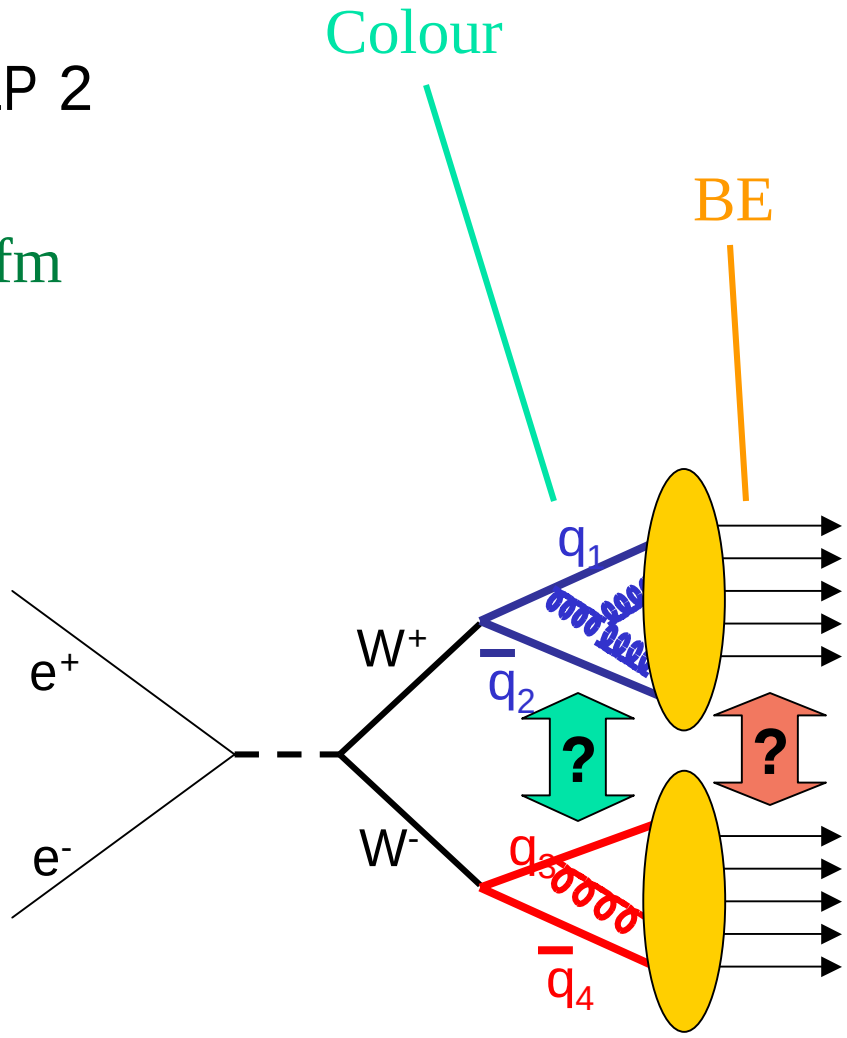
- Interconnection in W pairs at LEP 2



$$d_{WW} \approx \frac{\hbar}{\Gamma_W} \approx 0.1\text{fm}$$

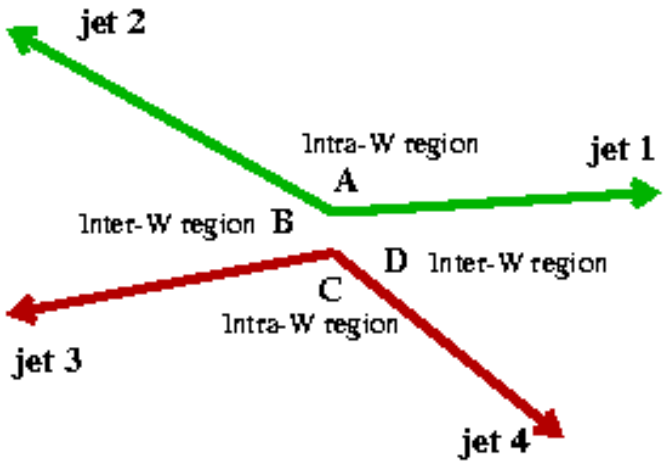
$$<< \frac{\tau_{had}}{c} \approx 1\text{fm}$$

- Hakkinen & Ringnér 98, Bo 98:
  - There could be little or no "exogamous" correlations after all
    - Kind of reality of the string concept

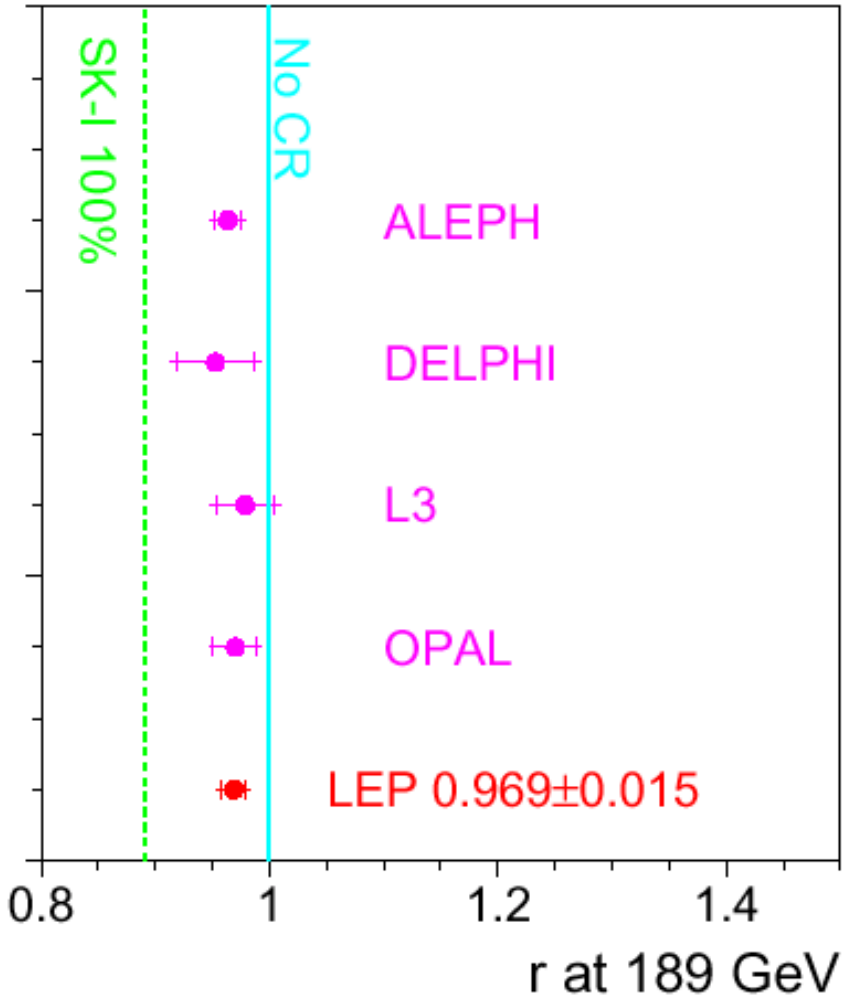


As a matter of fact, Bo could still be right for CR...

$$r = \frac{R_N}{R_N^{No-CR}}$$

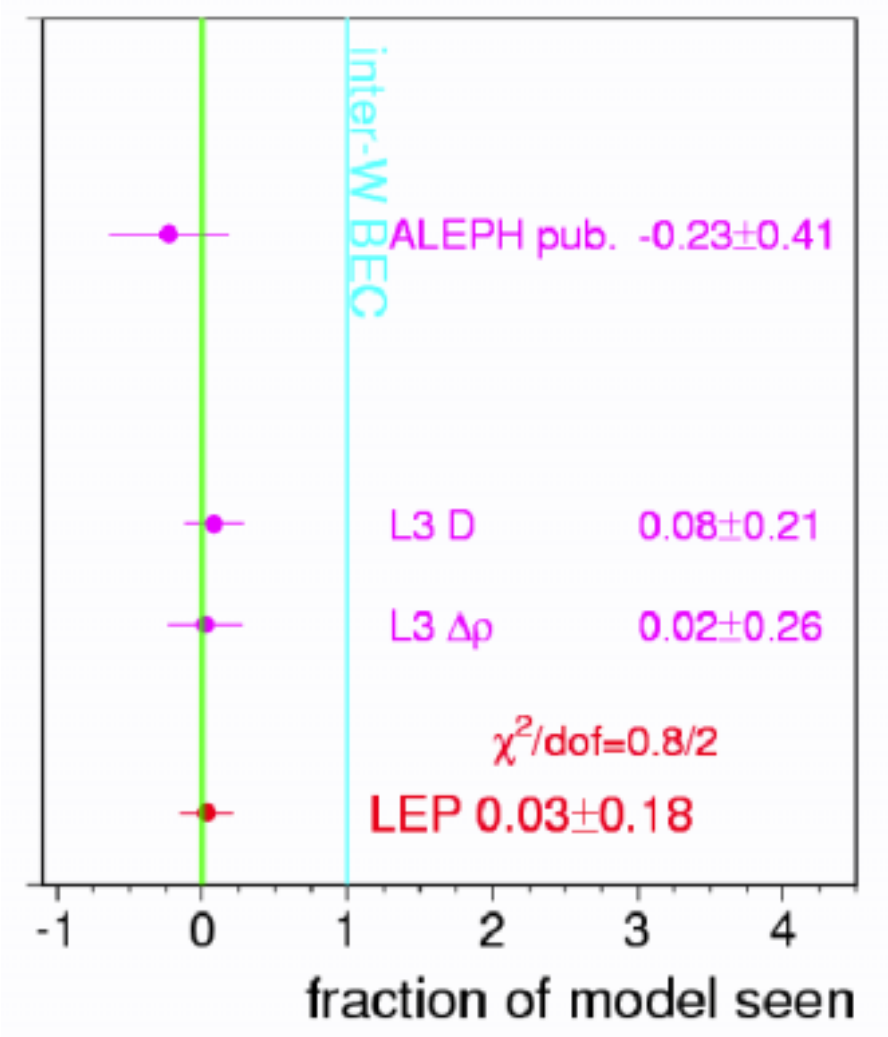


$$R = \frac{1/N_{evt} \cdot dn/d\phi(A+B)}{1/N_{evt} \cdot dn/d\phi(C+D)}$$



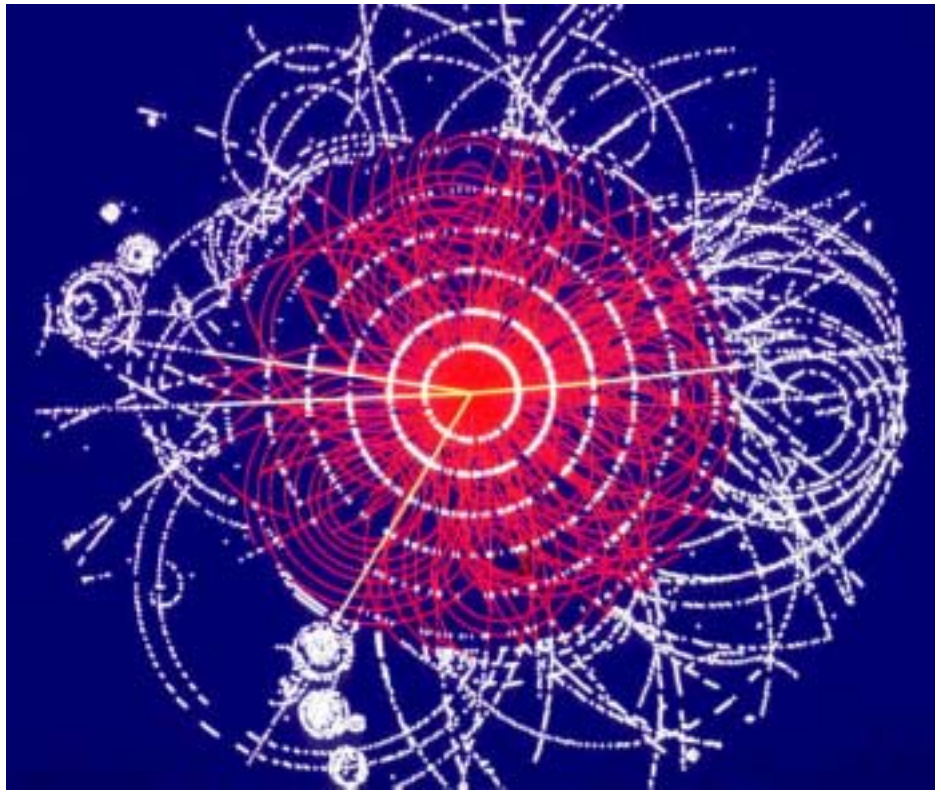
...and for BE as well

- Warning: very hot topic !
  - The different experiments give different indications



A key role in the design of future experiments

- For the next generation of experiments (LHC), when going to multiparticle Lund is the key
  - Hadronization of very complex systems, as a field of study in itself and as a tool for modeling the background to Higgs and new particles



Summary (in progress)

- All experiments in the QCD sector in the last 20 years profited in an essential way of Bo's ideas
- Without Bo's ideas, soft QCD would be completely different today
- Theorists are so fast, that experiments are often late
  - Much of Bo's contribution to experimental multiparticle dynamics is still to come