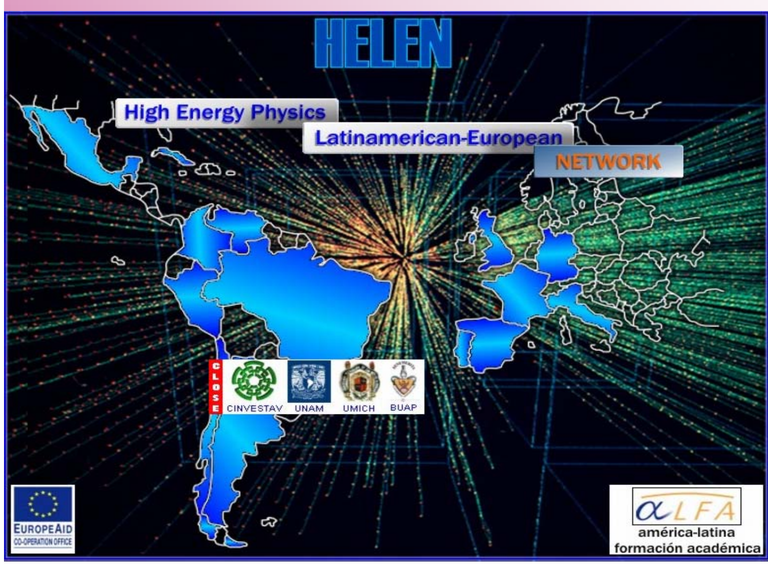
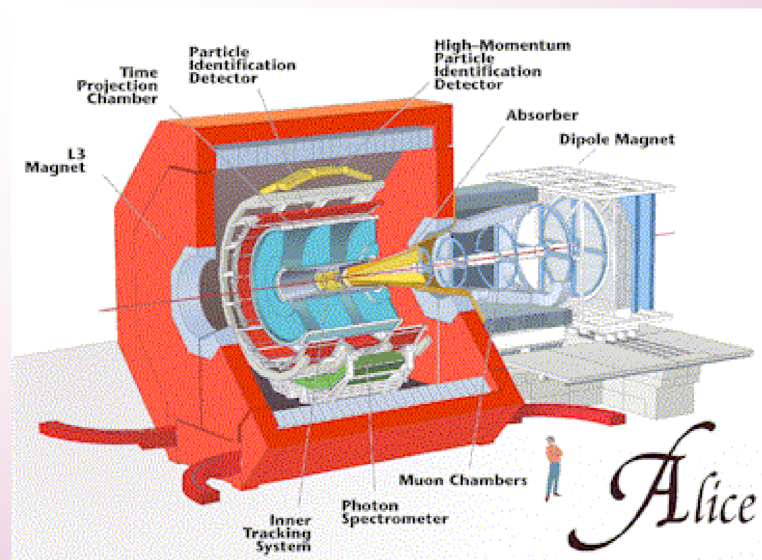
Jet Physics at ALICE:
Many Paradoxes, Many More Questions…

→ General introduction
→ Quark-Gluon Plasma and Jets
→ p-p collisions and AliRoot
→ Studying at CERN

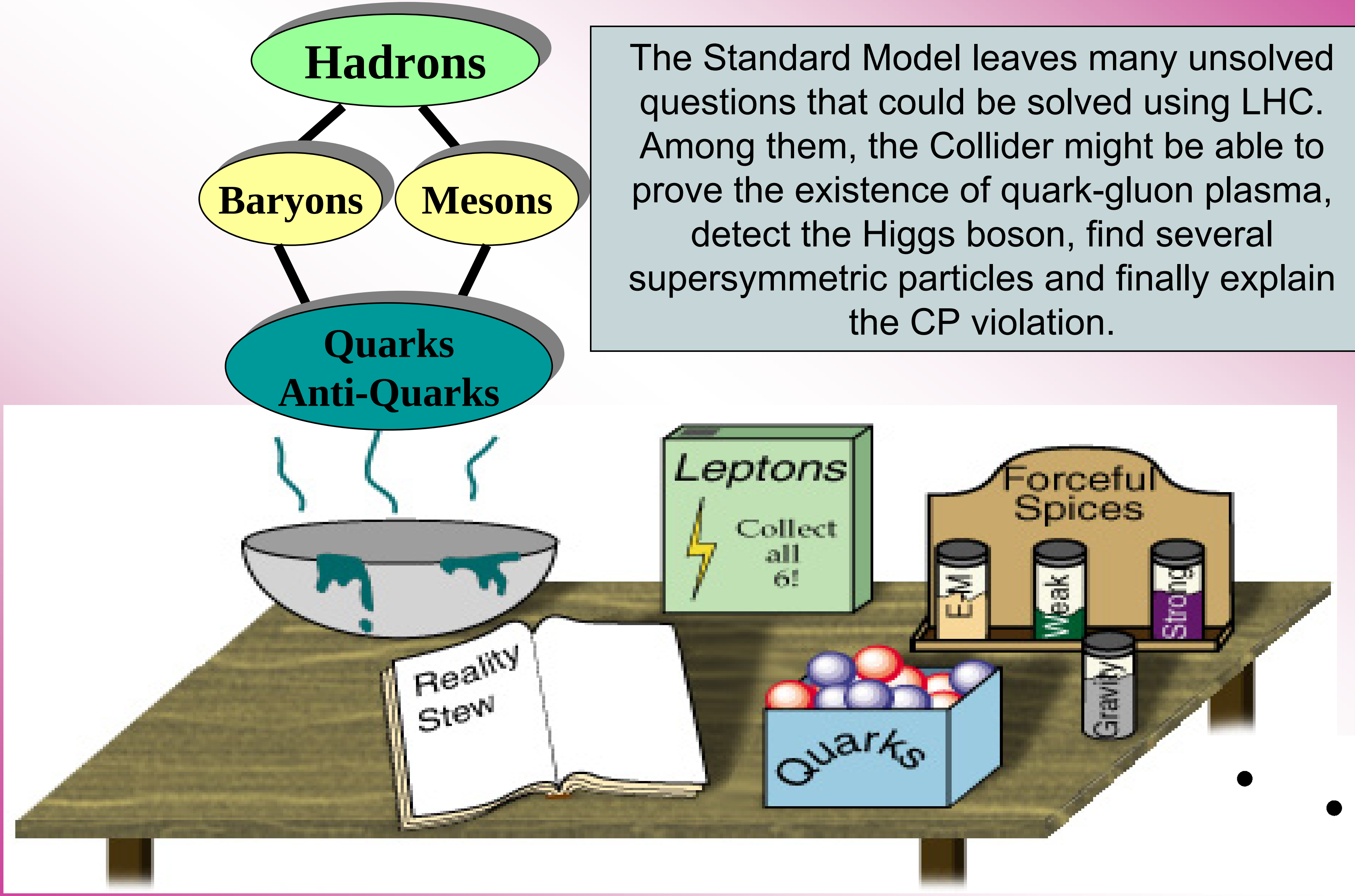


Leonid Serkin
(HELEN-ICN)



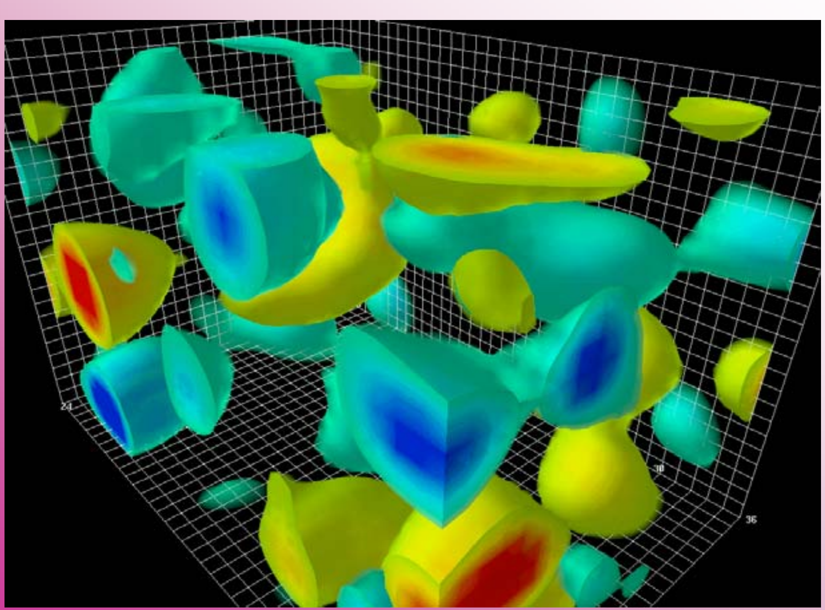
Quarks are born free, but everywhere they are in chains

The Standard Model leaves many unsolved questions that could be solved using LHC. Among them, the Collider might be able to prove the existence of quark-gluon plasma, detect the Higgs boson, find several supersymmetric particles and finally explain the CP violation.



Special Relativity and Quantum Mechanics both Work

The interactions of virtual particles are strongly constrained by the consistency of special relativity and quantum mechanics, creating spontaneous quantum fluctuations in the gluon field.



The ALICE detector at LHC is optimized for the reconstruction and analysis of heavy-ion collisions, particularly lead – lead collisions. In addition, ALICE has a broad physics program devoted to p – p and p – A interactions:

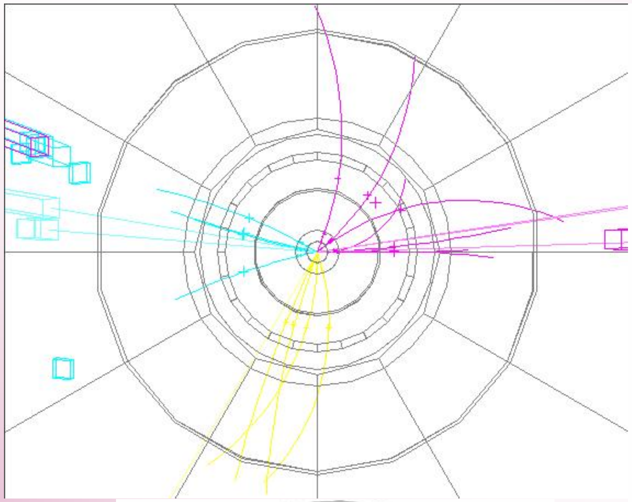
global event characteristics: particle multiplicity, centrality, energy density, nuclear stopping;

soft physics: particle and resonance production, particle ratios and spectra, strangeness enhancement, transverse and elliptic flow, event-by-event dynamical fluctuations;

hard probes: jets, direct photons;

heavy flavours: quarkonia, open charm and beauty production.

Asymptotic Freedom and Antiscreening



VOLUME 43, NUMBER 12 PHYSICAL REVIEW LETTERS 17 SEPTEMBER 1979

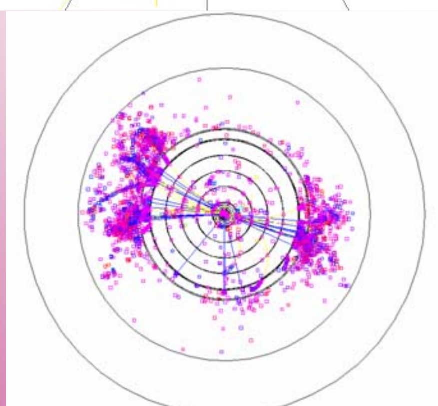
Discovery of Three-Jet Events and a Test of Quantum Chromodynamics at PETRA

D. P. Barber, U. Becker, H. Benda, A. Boehm, J. G. Branson, J. Bron, D. Buikman, J. Burger, C. C. Chang, H. S. Chen, M. Chen, C. P. Cheng, Y. S. Chu, R. Clare, P. Duinker, G. Y. Fang, H. Fesefeldt, D. Fong, M. Fukushima, J. C. Guo, A. Hariri, G. Herten, M. C. Ho, H. K. Hsu, T. T. Hsu, R. W. Kadel, W. Krenz, J. Li, Q. Z. Li, M. Lu, D. Luckey, D. A. Ma, C. M. Ma, G. G. G. Massaro, T. Matsuda, H. Newman, J. Paradiso, F. P. Poschmann, J. P. Revol, M. Rohde, H. Rykaczewski, K. Sinram, H. W. Tang, L. G. Tang, Samuel C. C. Ting, K. L. Tung, F. Vannucci, X. R. Wang, P. S. Wei, M. White, G. H. Wu, T. W. Wu, J. P. Xi, P. C. Yang, X. H. Yu, N. L. Zhang, and R. Y. Zhu

III. Physikalisches Institut Technische Hochschule, Aachen, West Germany, and Deutsches Elektronen-Synchrotron (DESY), Hamburg, West Germany, and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts, and National Instituut voor Kernfysica en Hoge-Energiefysica (NIKHEF), Sectie H, Amsterdam, The Netherlands, and Institute of High Energy Physics, Chinese Academy of Science, Peking, People's Republic of China

(Received 31 August 1979)

We report the analysis of the spatial energy distribution of data for $e^+e^- \to$ hadrons obtained with the MARK-J detector at PETRA. We define the quantity "oblateness" to describe the flat shape of the energy configuration and the three-jet structure which is unambiguously observed for the first time. Our data can be explained by quantum chromodynamic predictions for the production of quark-antiquark pairs accompanied by hard noncollinear gluons.



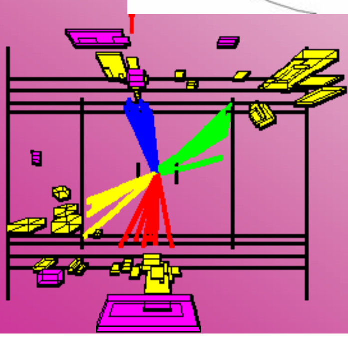
Evidence for Jet Structure in Hadron Production by e^+e^- Annihilation*

G. Hanson, G. S. Abrams, A. M. Boyarski, M. Breidenbach, F. Bulos, W. Chinowsky, G. J. Feldman, C. E. Friedberg, D. Fryberger, G. Goldhaber, D. L. Hartill,† B. Jean-Marie, J. A. Kadyk, R. R. Larsen, A. M. Litke, D. Lüke,‡ B. A. Lulu, V. Lüth, H. L. Lynch, C. C. Morehouse, J. M. Paterson, M. L. Perl, F. M. Pierre,§ T. P. Pun, P. A. Rapidis, B. Richter, B. Sadoulet, R. F. Schwitters, W. Tanenbaum, G. H. Trilling, F. Vannucci,‖ J. S. Whitaker, F. C. Winkelmann, and J. E. Wiss

Lawrence Berkeley Laboratory and Department of Physics, University of California, Berkeley, California 94720, and Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 8 October 1975)

We have found evidence for jet structure in $e^+e^- \to$ hadrons at center-of-mass energies of 6.2 and 7.4 GeV. At 7.4 GeV the jet-axis angular distribution integrated over azimuthal angle was determined to be proportional to $1+(0.78 \pm 0.12)\cos^2\theta$.



Three jets emerging from electron – positron annihilation at high energy are the materialization of a quark, antiquark and gluon

Early Universe explained ?

During a collision of two heavy ions at high energy, the resulting fireball and its subsequent expansion recreate, on a small scale and briefly, physical conditions that occurred during the Big Bang.

PHYSICS REPORTS (Review Section of Physics Letters) 88, No. 5 (1982) 331–347. North-Holland Publishing Company

2. Formation and Observation of the Quark-Gluon Plasma*

J. RAFELSKI

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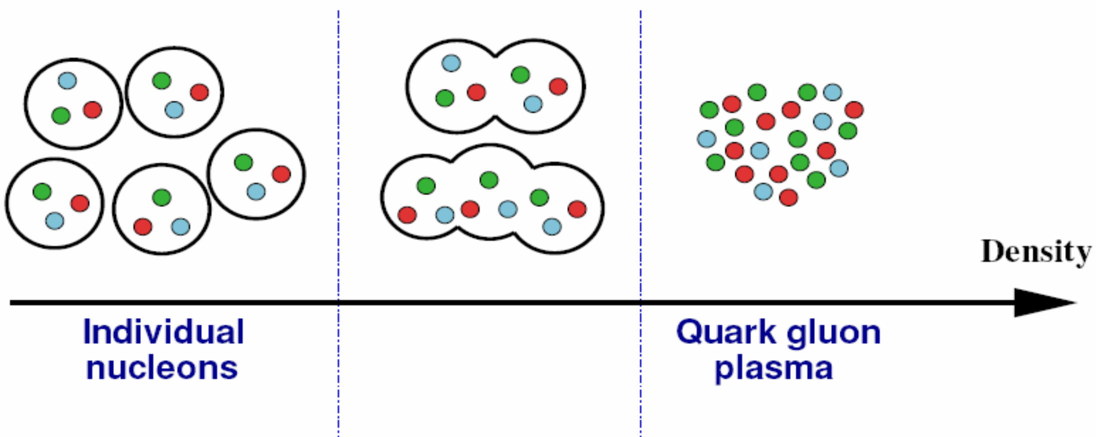
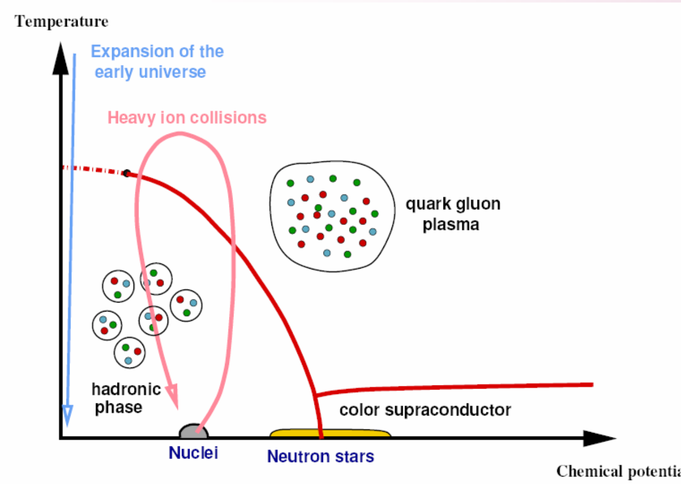
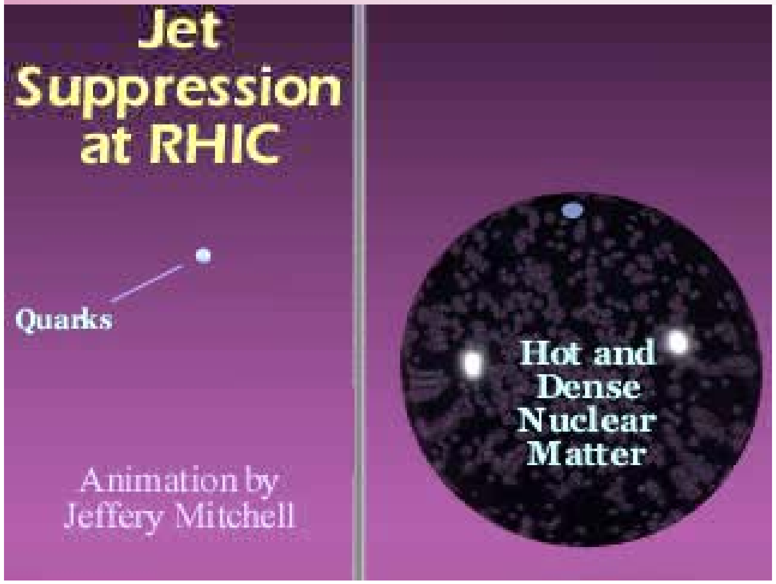
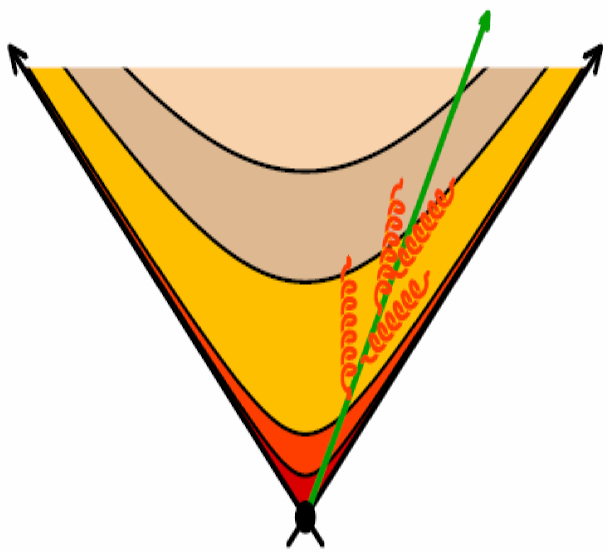




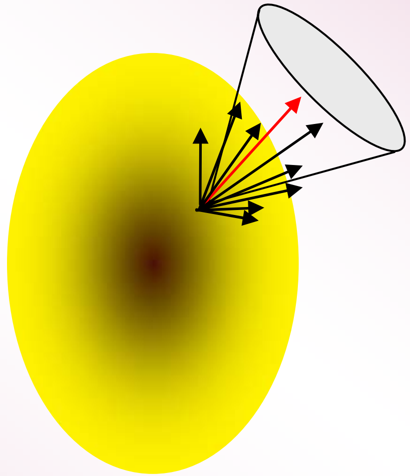
QCD, QGP and Jets

- Jets are produced at the initial impact
- Radiative energy loss when traveling through the plasma
- Important modifications of the azimuthal correlations
- Ideally, the analysis of reconstructed jets will allow us to measure the original parton 4-momentum and the jet structure.

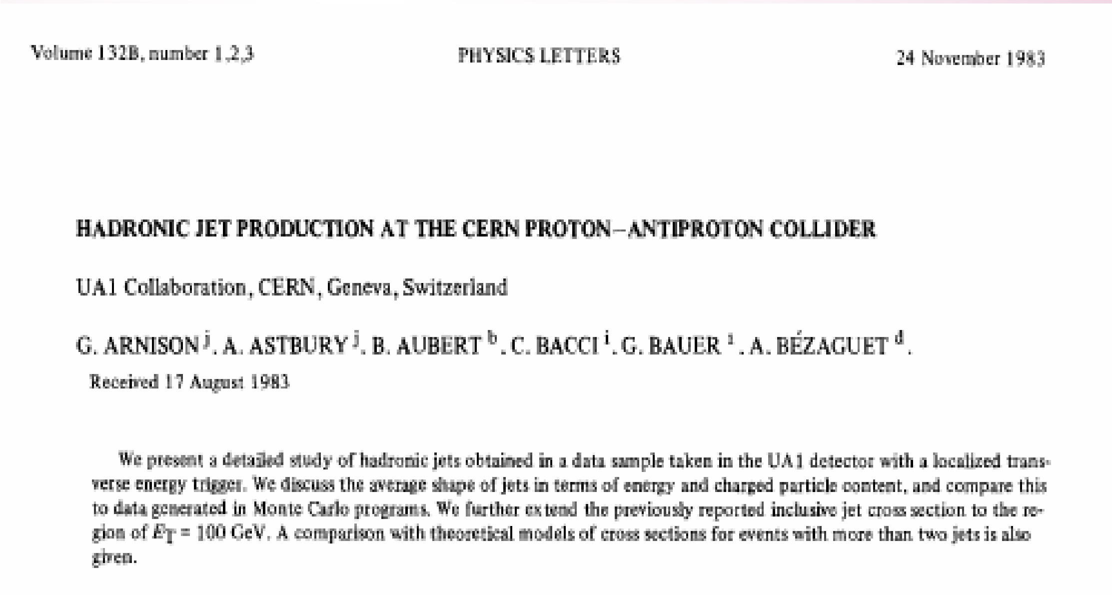




Reconstructed Jet



Searching for Jets at p-p collisions



Volume 132B, number 1,2,3 PHYSICS LETTERS 24 November 1983

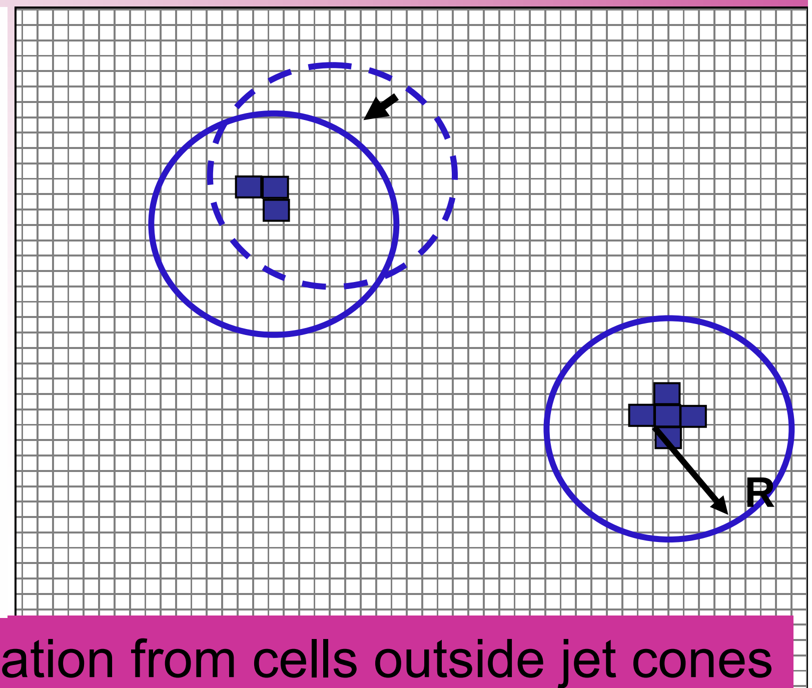
HADRONIC JET PRODUCTION AT THE CERN PROTON–ANTIPROTON COLLIDER

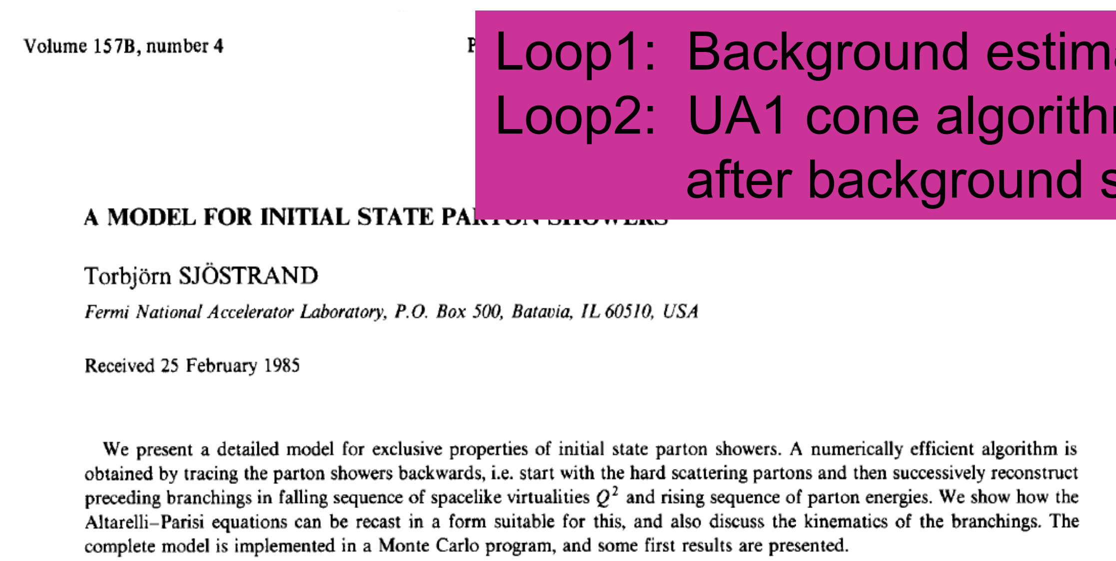
UA1 Collaboration, CERN, Geneva, Switzerland

G. ARNISON [j], A. ASTBURY [j], B. AUBERT [b], C. BACCI [i], G. BAUER [1], A. BÉZAGUET [d],

Received 17 August 1983

We present a detailed study of hadronic jets obtained in a data sample taken in the UA1 detector with a localized transverse energy trigger. We discuss the average shape of jets in terms of energy and charged particle content, and compare this to data generated in Monte Carlo programs. We further extend the previously reported inclusive jet cross section to the region of E_T = 100 GeV. A comparison with theoretical models of cross sections for events with more than two jets is also given.





Volume 157B, number 4 P

A MODEL FOR INITIAL STATE PA

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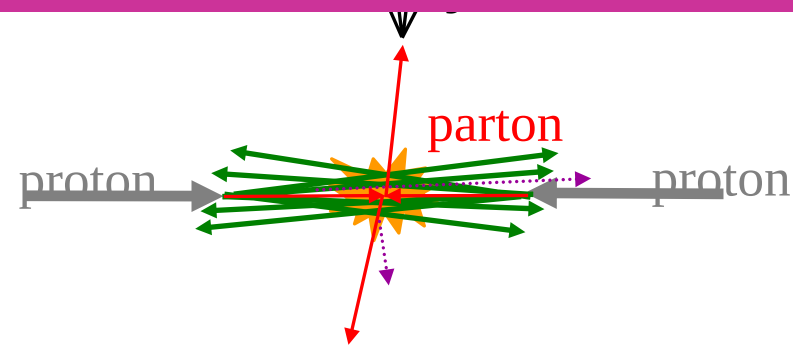
Received 25 February 1985

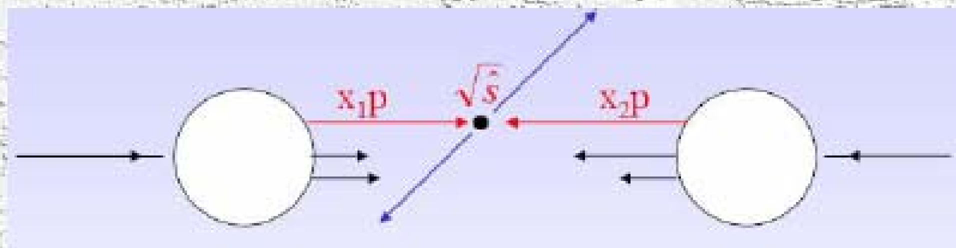
We present a detailed model for exclusive properties of initial state parton showers. A numerically efficient algorithm is obtained by tracing the parton showers backwards, i.e. start with the hard scattering partons and then successively reconstruct preceding branchings in falling sequence of spacelike virtualities Q^2 and rising sequence of parton energies. We show how the Altarelli–Parisi equations can be recast in a form suitable for this, and also discuss the kinematics of the branchings. The complete model is implemented in a Monte Carlo program, and some first results are presented.

Loop1: Background estimation from cells outside jet cones
Loop2: UA1 cone algorithm to find centroid using cells after background subtraction



Some properties of p-p collisions

- Proton beam can be seen as beam of quarks and gluons with a wide band of energies
- The proton constituents (partons) carry only a fraction $0 \leq x \leq 1$ of the proton momentum



- The effective centre-of-mass energy $\sqrt{\hat{s}}$ is smaller than $\sqrt{s}$ of the incoming protons

$$\left.\begin{aligned} p_1 &= x_1\, p_A \\ p_2 &= x_2\, p_B \\ p_A &= p_B = 7 \text{ TeV} \end{aligned}\right\} \quad \sqrt{\hat{s}} = \sqrt{x_1\, x_2\, s} = x\sqrt{s} \quad (\text{if } x_1 = x_2 = x)$$

Note:
- the component of the parton momentum parallel to the beam can vary from 0 to the proton momentum ($0 \leq x \leq 1$)
- the variation of the transverse component is much smaller (of order the proton mass)

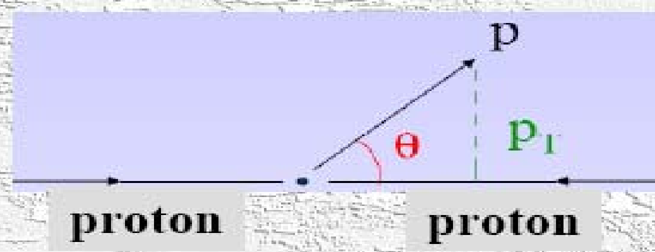
To produce a particle of mass		
mass	LHC	Tevatron
100 GeV	$x \approx 0.007$	$x \approx 0.05$
5 TeV	$x \approx 0.36$	---

Some variables in p-p collisions

Kinematics fully defined only in transverse plane

Transverse momentum p_T

$p_T = p \sin\theta$

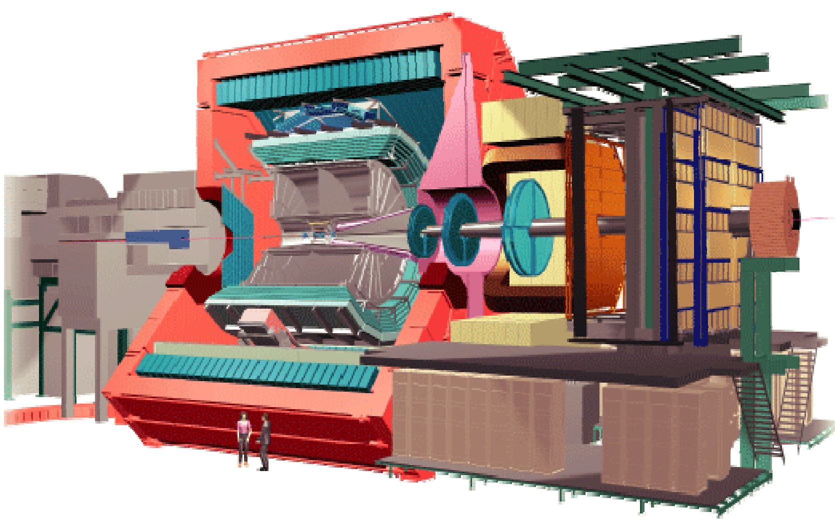


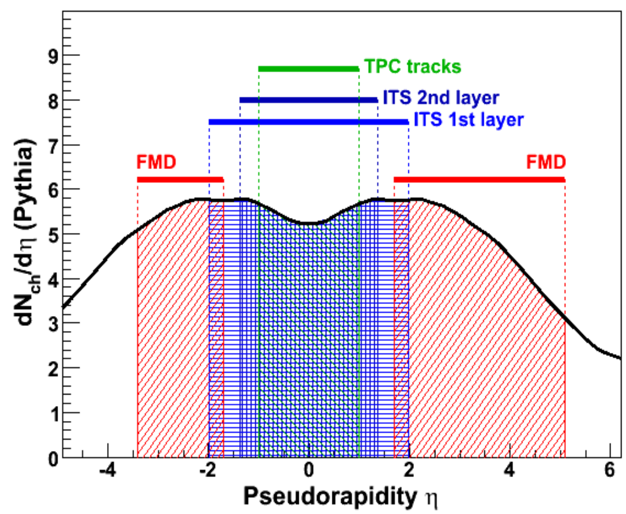
Rapidity: $y = \frac{1}{2}\ln\frac{E + p_L}{E - p_L}$

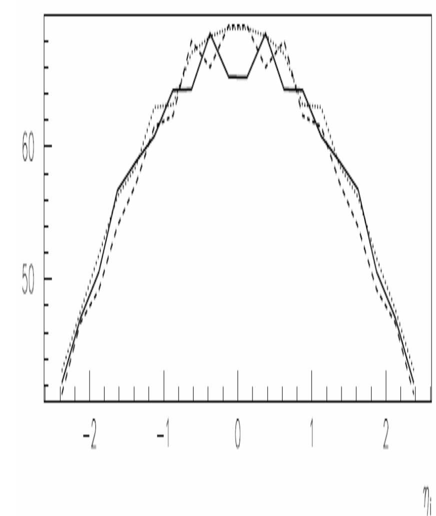
Differences in y are invariant under Lorentz boosts

Pseudo-rapidity: $\eta = -\ln\frac{\theta}{2}$

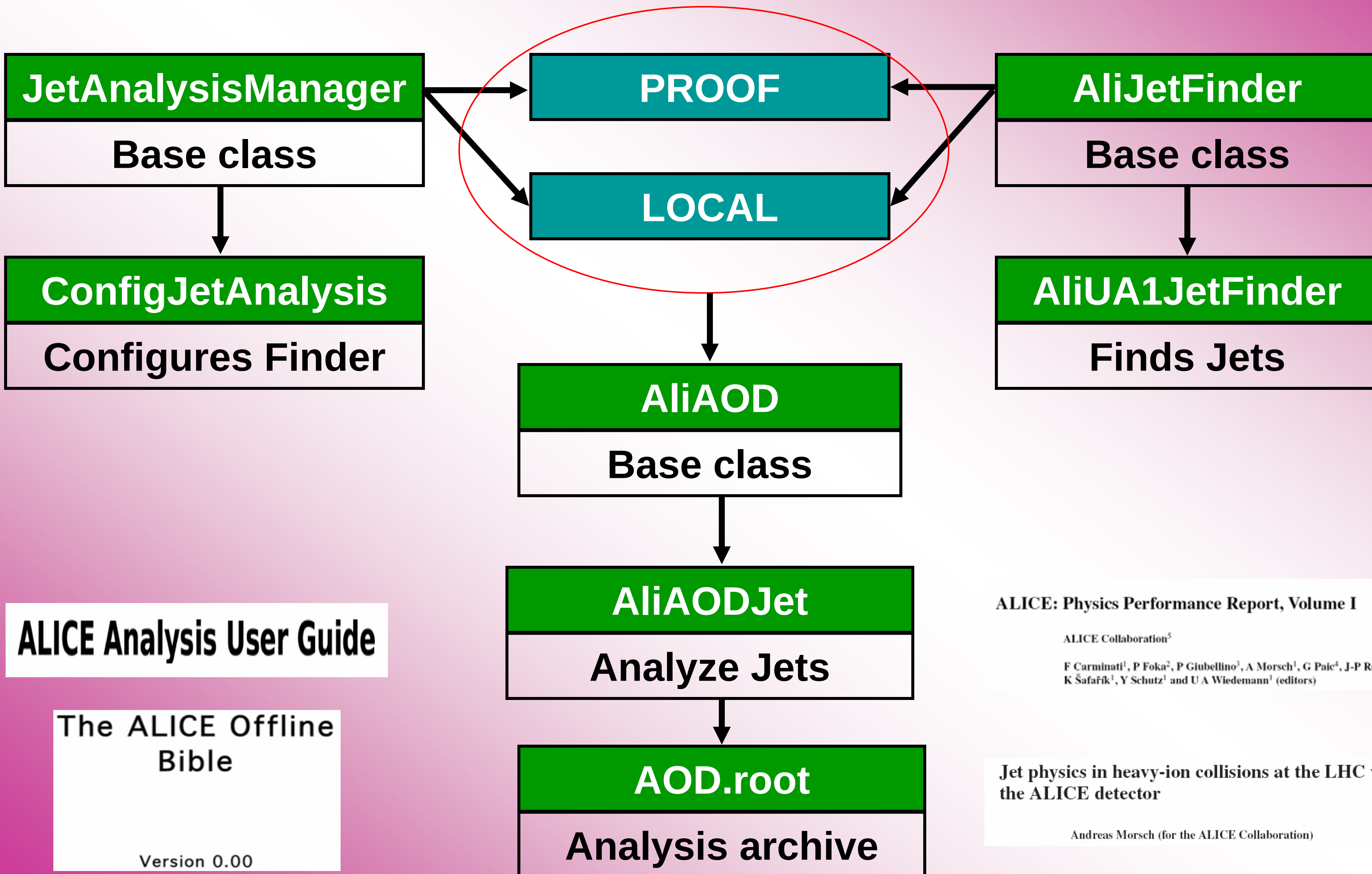
handy approximation, do not need to know the particle mass







AliRoot Classes for Jet Finding and Analysis



ALICE Analysis User Guide

The ALICE Offline Bible

Version 0.00

ALICE: Physics Performance Report, Volume I

ALICE Collaboration[5]

F Carminati[1], P Foka[2], P Giubellino[3], A Morsch[1], G Paic[4], J-P Revol[1], K Šafařík[1], Y Schutz[1] and U A Wiedemann[1] (editors)

Jet physics in heavy-ion collisions at the LHC with the ALICE detector

Andreas Morsch (for the ALICE Collaboration)

Trying to study at CERN

The analysis of experimental data is the final stage of event processing and it is usually repeated many times. In the ALICE Computing Model the analysis starts from the Event Summary Data (ESD). These are produced during the reconstruction step and contain all the information for the analysis. The analysis tasks produce Analysis Object Data (AOD) specific to a given set of physics objectives.

The Parallel ROOT Facility, PROOF has been specially designed and developed to allow the analysis and mining of very large data sets, minimizing response time. It makes use of the inherent parallelism in event data and implements an architecture that optimizes I/O and CPU utilization in heterogeneous clusters with distributed storage.

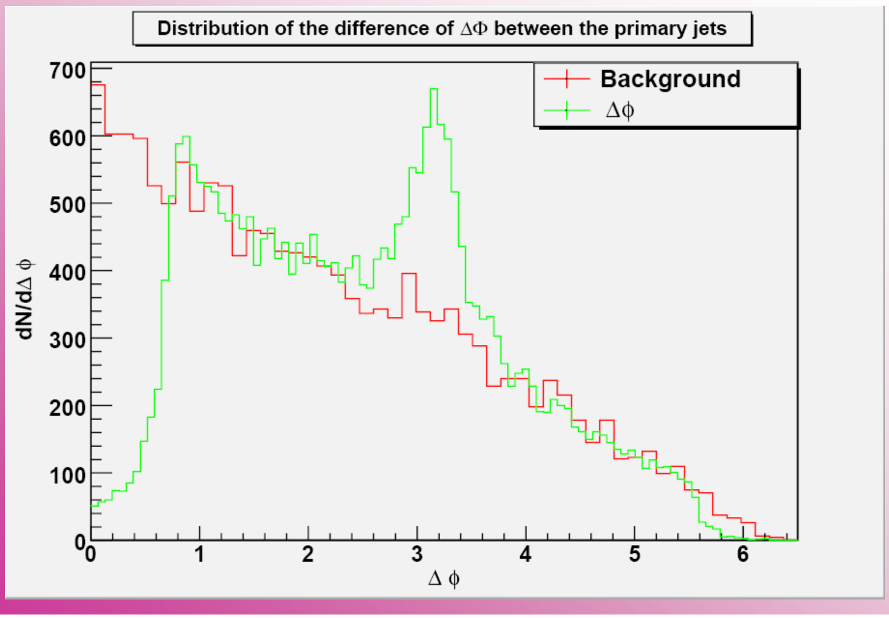
The main aim of the Training was to learn the LHC and the ALICE detector simulations algorithms and the theory upon them. First, the event simulation and reconstruction using Root and AliRoot environments via usual examples. A precise analysis of the available module JETAN of AliRoot was the second step in the creation of the necessary AOD objects. The particles were selected using a cut on the minimal-allowed transverse momentum and the jet finding was performed with the usual cone algorithm. The CERN Analysis Facility (CAF), a cluster at CERN running PROOF, was prompt for analysis of 2×10^6 p – p reconstructed events. A search for di - jets and their properties using different radii of the jet finding algorithm was performed, mixing it with event–by–event correlations based on jet transverse energy distributions.

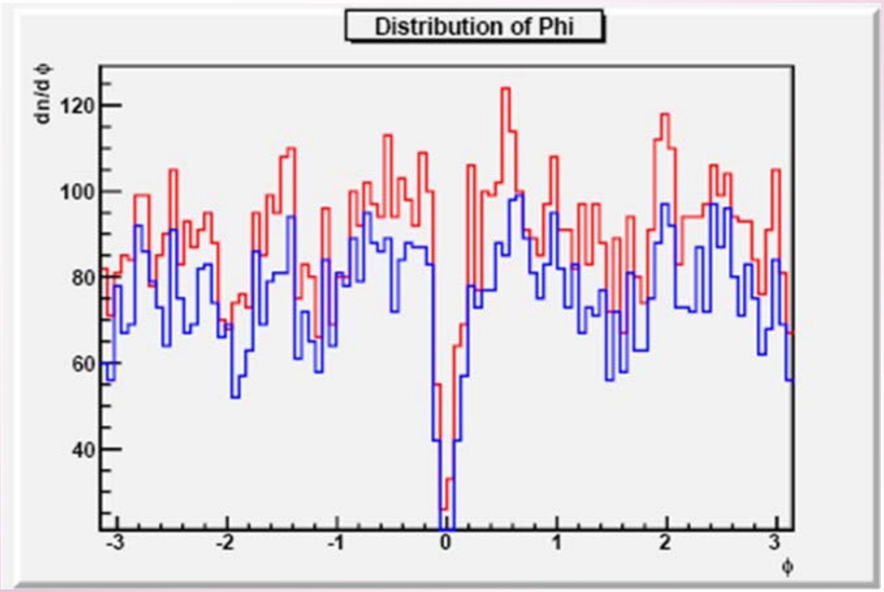
Advantages of Reconstructed Jets

- Since more of the original parton energy is collected:

  → Reduced bias on parton energy

  - Makes measurement of the fragmentation function possible
- Possibility to observe directly the quenched jet and the particles from gluon radiation.
- Increases statistics at high E_T
- Increased sensitivity to medium parameters





CERN

Not even close to the final...

Beyond the outstanding first class scientific value of the stay, participation in specialized courses related to the investigation done by diverse groups at CERN, visits of the incredible experiments and enormous detectors, and working in a multidisciplinary and multicultural group, made of this stay an extremely enriching personal experience.

Sincere gratitude to Dr. Guy Paic who appointed me to this program and to Dr. Andreas Morsch, who helped me in both personal and scientific sides. The everyday computer work was much easier due to help of Pedro, Isabel, Enrique and Antonio.

The support for traveling and stay at CERN was provided by the HELEN network, which I believe is essential to integrate and consolidate the collaboration in the field of High Energy physics between Latin America and Europe.