Event Shape Analysis in ALICE at LHC.

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Abstract

The high energy hadron collisions are described by two components: a scattering with transfered momentum of $\mathcal{O} > 2$ GeV, which result is the production of high p_t particles and the other is what doesn't came of the hard scattering (final state radiation, beam remnants and multiple particle interactions(MPI)). It is interesting to develop an event shape analysis (ESA), which give us a phase space geometrical interpretation of the physical process in collisions. In this, poster contribution we discuss about Event Shape Analysis, some ALICE results are presented. We talk about the "sphericity", an event shape variable that allow us to determine if the event has an isotropic distribution or a dijet structure with collinear transverse axis.

Introduction

The Large Hadron Collider (LHC) has an interesting physics program on Standar Model (SM) and Beyond Standar Model (BSM). ALICE is one of the four main experiments of LHC, who has the important labor of study a physical state where the quarks and gluons are deconfined, the quark-gluon plasma (QGP)[1]. In particular the study of rare signals needs a perfect understanding of the collisions background between the hadrons components. This include the understanding of the transverse momentum and multiplicity spectra, particles abundance, thus like the correlations between observables. A lot of information is extracted from these and the contained in the event shape variables. The inelastic cross section of hadron collisions are dominated by a "soft" component however; some times a "hard" scattering can occur. These partons radiate soft gluons making the so called partonic showers. The probability that a gluon with momentum k and traverse momentum k_T is emitted by a quark with momentum p is:

$$dw^{q\to q+g} = 2C_F \frac{\alpha_s k_T}{4\pi}\left[1+\left(1-\frac{k}{p}\right)^2\right]\frac{dk}{k}\frac{dk_T^2}{k_T^2}, \qquad (1)$$

where $\alpha_s(k_T) = \frac{2\pi}{\beta_0} ln\left(\frac{k_T}{\Lambda}\right)$ and $C_F = 4/3$.

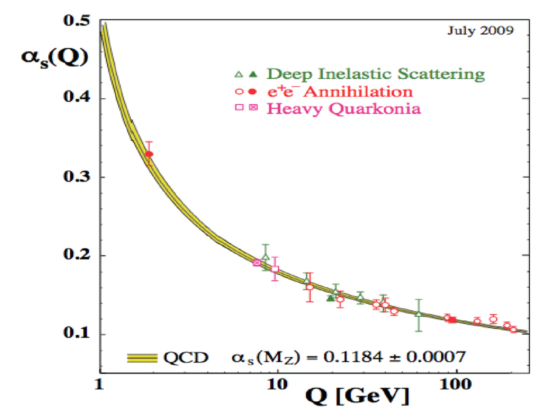

Fig 1. QCD coupling constant value vs four momentum transfer[2].

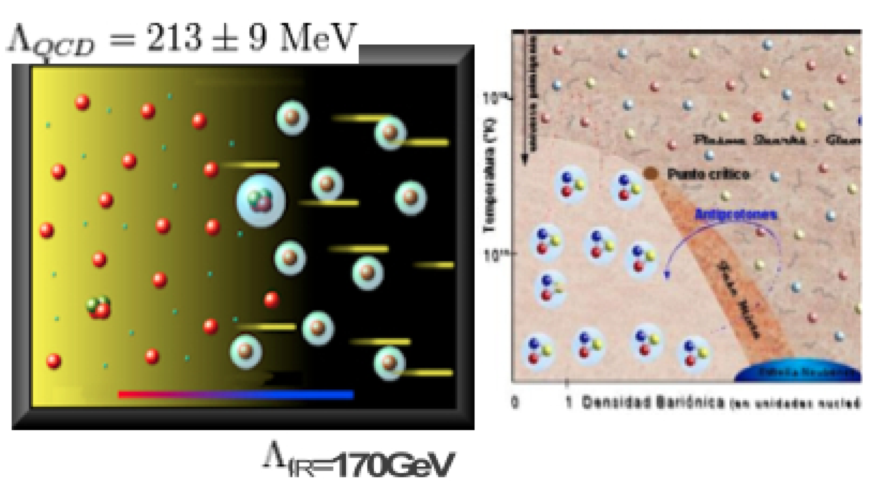

Fig 2. Left, Energy Scale; Right, ρ vs T phase diagram.

The jet evolution is determined by the soft and colinear gluon emission[3], ($w \sim \alpha_s ln^2 p$ for $k << p$, parton emited to a big angle suppressed when $k \sim p$). We can't see the parton showers, thus we say that is a process to "partonic level". Due to color confinement, the partons in the shower has to hadronize. The particle content of an event after hadronization is called as "hadronic level". Hadronization is described by the fragmentation functions (FF). The FFs include long range efects (low Q_2). The general description of final hadrons (X) given by QCD factorization theorem[4]:

$$\frac{d\sigma}{dX} = \sum_{j,k}\int_{\hat{X}} f_j(x_1, Q_i) f_k(x_2, Q_j) \cdot \left(\frac{d\hat{\sigma}_{j,k}(Q_i, Q_j)}{d\hat{X}}\right) F(\hat{X} \to X; Q_i, Q_j). \qquad (2)$$

1. $\frac{d\hat{\sigma}_{j,k}(Q_i,Q_j)}{d\hat{X}}$ short range, (partonic $\hat{\sigma}_{j,k}$) pQCD calculable
2. The universal functions (PDFs, FFs), no perturbative.

The event shape analysis (ESA)[5] is used to study the phase space geometrical properties of the energy flux in QCD.

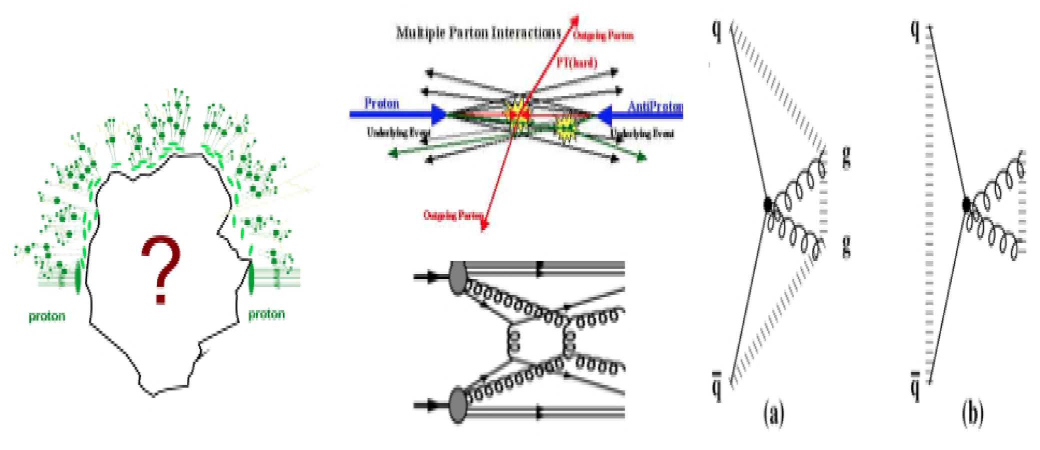

Fig 3. Other studies with ESA, (sensitive to the fragmentation and to the MPI) excellent tool to fit generators..

Some event shapes variables in hadronic collisions[5]: Transverse Sphericity (S_T), Thrust (T), Thrust-Minor (T_{min}), Recoil (r) and many others like aplanarity, circularity, etc. These are defined in the transverse plane of the phase space, in terms of p_T (Lorentz invariant), these are Infra Red Safe and Colinear Safe quantities.

Theoretical Model

TRANSVERSE SPHERICITY.

Defined in terms of the eigenvalues $\lambda_1 \geq \lambda_2$ of the linearized transverse momentum tensor[5]:

$$S^L_{x,y} = \frac{1}{\sum_i p_{Ti}}\sum_i \frac{1}{p_{Ti}}\begin{pmatrix} p_{xi}^2 & p_{xi}p_{yi} \\ p_{xi}p_{yi} & p_{xi}^2 \end{pmatrix} \qquad (3)$$

as $S_T = \frac{2\lambda_2}{\lambda_1+\lambda_2}$. So then the extreme values are:

$$S_T = \begin{cases} 1 = \text{isotropic structure} \\ 0 = \text{dijets structure} \end{cases} \qquad (4)$$

Experiment and simulation

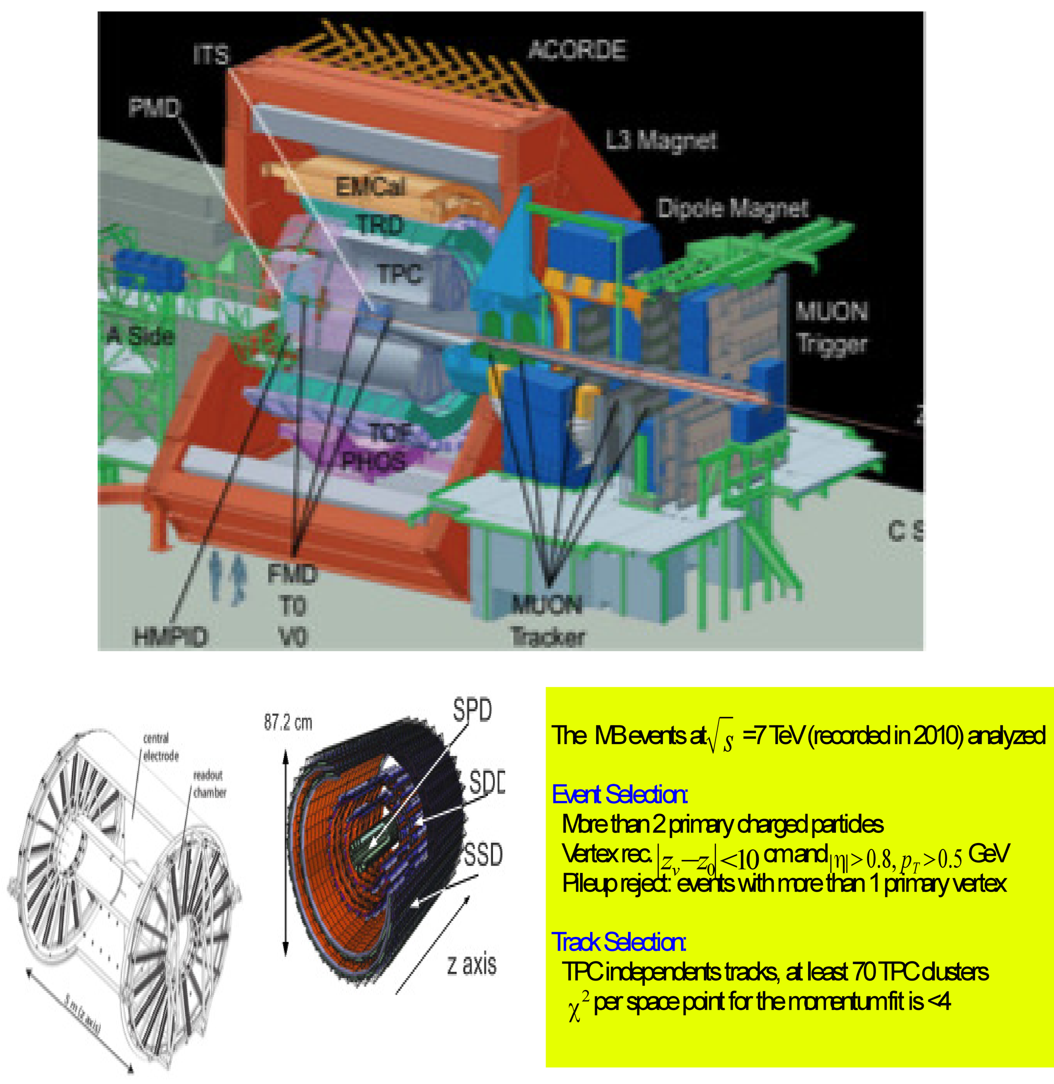

Fig 4. ALICE detectors used in the present analysis (TPC and ITS), located in the central barrel inside a large solenoidal magnet (uniform 0.5 T field).

The analysis is presented for two categories of events defined by the charged-particle $max(p_T)$ in each event: a) dominantly events without any hard scattering ("soft" events) and b) events dominantly with at least one hard scattering ("hard" events). Analysis results are presented with different model predictions: PHOJET, PYTHIA(8 y 6 (Tunes[7] ATLAS-CSC,PERUGIA-0, PERUGIA-2011)).

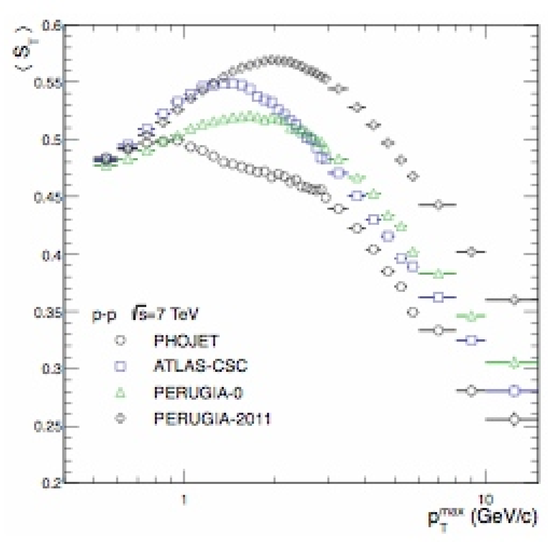

Fig 5. $< S_T >$ vs $max(p_T)$ of the event selection for MC simulations.

Results

The mean transverse momentum as a function of Nch at $\sqrt{s} = 7$ TeV is shown (Fig 6). As seen in left panel, PERUGIA-0, PERUGIA-2011 and PYTHIA8 curves are within the systematic uncertainty bands of the data for soft events, though PYTHIA8 has a different functional form than the data. In "hard" events there is a significant difference between data and generators above $Nch \sim 20$. For lower multiplicities, ATLAS-CSC has an overall different shape than other generators. For "all" events, the calculations exhibit a change in the slope for $Nch \sim 30$.

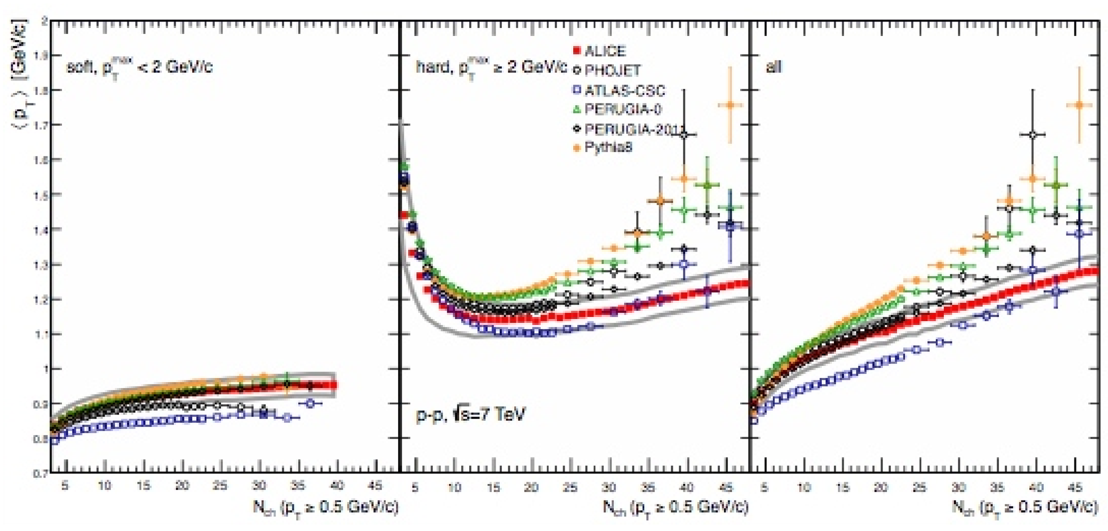

Fig 6. P_T vs Nch for events a) bulk b) hard c) soft.

The mean transverse sphericity as a function of Nch at $\sqrt{s} = 7$ TeV is shown (Fig 7) for the different event classes. The mean sphericity increases up to $Nch \sim 15$, however, for larger multiplicities the ALICE data exhibit an almost constant or slightly rising behavior. The differences between models and data are below 10% for "soft" events. For the "hard" events, PHOJET, ATLAS-CSC, PERUGIA-0 and PYTHIA8 predict a lower $< S_T >$ than observed in data, actually the differences between models and data are larger than 10% for $Nch < 10$ and $Nch > 40$.

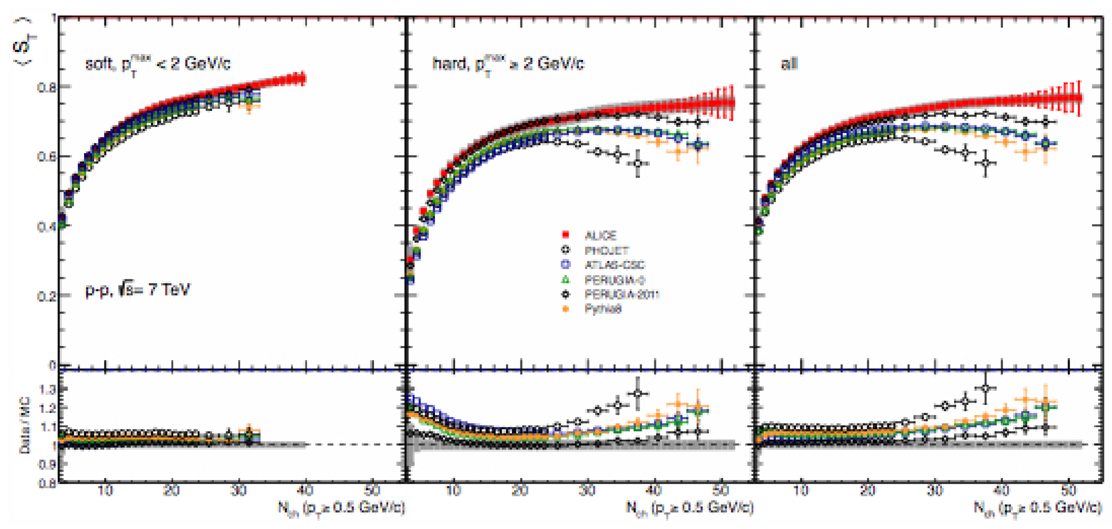

Fig 7. S_T vs Nch for events a) bulk b) hard c) soft.

Conclusions

ALICE data is compared with calculations of standard Monte Carlo event generators: PHOJET, PYTHIA6 and PYTHIA8. The MC generators exhibit a decrease of $< S_T >$ at high multiplicity with a simultaneous steep rise of $< p_T >$. On the contrary, in this data set, $< S_T >$ stays approximately constant or slightly rising accompanied with a mild increase in $< p_T >$. The level of disagreement between data and generators is markedly different for "soft" and "hard" events, being much larger for the latter. It is worthwhile to point out that PERUGIA-2011 describes the various aspects of the data generally quite well, except for the $< p_T >$, which is overestimated at high multiplicities.

Greatings

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