Study of di-jet properties in p+p collisions at $\sqrt{s} = 7$ TeV by the LHC-ALICE experiment

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Outline

• Physics motivation
• ALICE experiment and data set
• First look at (di-) jet in p+p $\sqrt{s} = 7$ TeV in ALICE
• Dijet Calorimeter project
• Summary and outlook
Why jets?

- Jet is a well defined object, and produced by the hard scattering of partons at the initial stage of the collision.
- Studied in many high energy experiments for many years.
- Jet provides a powerful probe to study the hot and dense QCD matter created in high energy heavy ion collisions.
- At LHC energy, jet production is dominant, compared to that in RHIC.
- Jet measurements in p+p at LHC provide an important baseline to heavy ion data, as well as the further understanding of QCD.

Jet quenching at RHIC

- Disappearance of away-side jet in Au+Au central at RHIC ($\sqrt{s_{NN}} = 200$ GeV).
- Jet quenching by hot and dense medium.
  - indicating energy density: $\varepsilon > 100 \varepsilon_0$
- First measurement of full jet reconstruction at RHIC (STAR).

Jet ID using TPC & ITS in ALICE

- **ITS (Inner Tracking System), TPC**
  - Charged particles reconstructed $\Delta \eta = 1.8$.
  - ITS: $\sigma_{r\phi} \sim \text{few 10 um}, \sigma_z \sim \text{few 100 um (SPD, SDD)}$
    - SPD: Silicon Pixel
    - SSD: Silicon Strip
    - SDD: Silicon Drift
    - Material budget: $\sim 1\% X/X_0$ per layer.
  - TPC: Excellent momentum resolution.
    - $\sim 7\%$ at 10 GeV.

Momentum resolution ($\Delta p_T/p_T$)
Analyzed data sample

• p+p at $\sqrt{s} = 7.0$ TeV, reconstructed data from LHC10c and LHC10d periods.

• Minimum bias trigger: 128 M events.
  – eliminating non-physics events, and requiring $z$-vertex $< \pm 10$ cm.
  – MB trigger: “SPD or V0-A or V0-C”
    • at least one charged particle in 8 pseudorapidity units

• $\eta$ cut:
  – single charged tracks within $|\eta| < 0.9$.
  – jets $|\eta| < 0.5$. 
Jet finding algorithms

1. Cone algorithm:
   - Simple geometric motivation.
   - Split/merging procedure for overlapping cone.
     - UA1
     - SIS cone
       - Seedless Infrared Safe Cone algorithm
       - Insensitive to soft radiation.

2. Sequential recombination algorithm:
   - Cluster pairs of objects close in relative $p_T$.
   - Define “distance” between pairs.
     - $k_T$ algorithm
       - Starting from low $p_T$ particle.
     - anti-$k_T$ algorithm
       - Starting from high $p_T$ particle.
Dijet event in p+p 7 TeV in ALICE

Reconstructed Jets UA1 Cone R = 0.4:
Jet 1: $\eta = 0.02$, $\phi = 306^\circ$, $p_T = 71$ GeV, Tracks 15
Jet 2: $\eta = 0.84$, $\phi = 132^\circ$, $p_T = 47$ GeV, Tracks 9
$\Delta\phi = 174^\circ$
Total Tracks 108
(Raw) single jet spectrum in p+p 7 TeV

Jet can be measured $p_T \sim 70$ GeV/c with current statistics.
Di-jet invariant mass plot

Di-jet mass can be measured $p_T \sim 50$ GeV with current statistics.
Leading and second jet $p_T$ raw spectrum and correlation (for T. Chujo, JPS2010 Fall meeting (Sep. 13, 2010)).

Leading jet $p_T$ spectrum is harder than that for 2nd jet.
Acoplanarity of jets (Raw)

- Azimuthal angle difference between 1\textsuperscript{st} (leading) jet and 2\textsuperscript{nd} jet.
- Leading jet $p_T$ cut: > 10 GeV/c
- Acoplanarity: $\phi_{Jet1} - \phi_{Jet2} + \pi$
- Next step:
  - Comparison with model.
  - \textit{Comparison to that in heavy ion}, which will start data taking in Nov. 2010, Pb+Pb 2.76 TeV.
ALICE Dijet Calorimeter (DCal) Project

**DCal:**
- Extend the acceptance of EMCal (Pb-Scinti. sampling).
  - EMCal: $\Delta \phi = 110^\circ$
  - DCal: $\Delta \phi = 60^\circ$ (on opposite side of EMCal)
  - $\Delta \eta = 0.7$ for both EMCal and DCal + PHOS
  - $\sim 10%/\sqrt{E}$
- Allow back-to-back hadron-jet, di-jet measurements in ALICE, with $R = 0.4$, up to $p_T \sim 150$ GeV/c.
- Enhance jet, $\gamma$ trigger capability.
  - Catania, CERN, Frascati, Grenoble, INFN, Jyväskylä, Nantes, Strasbourg, Tsukuba, ORNL, LBNL, Yale, Huston, LANL, Wuhan

- **To be installed in 2012.**
Summary and outlook

• First look at jet and dijet in p+p 7 TeV in ALICE.
• Using the 128 M MB statistics, ALICE can measure single jet up to $p_T \sim 70$ GeV/c, and dijet mass < 50 GeV/c$^2$.

• **Outlook:**
  – Analyze full statistics data sample (so far, 700 M MB data in p+p 7 TeV as of Sep. 2010).
  – Corrections to the raw (di-) jet spectra.
  – Acoplanarity:
    • Model comparison.
    • > 2 jets study.
  – Prepare for the first Pb+Pb run ($\sqrt{s_{NN}} = 2.76$ TeV, Nov. 2010)!
    • Any difference in $\phi$ balance, $p_T$ balance in Pb+Pb compared to p+p?
  – Use EMCal & PHOS info, to enhance di-jet measurement.