**HAD_01:**
Measurements of Jets and Photons in Heavy Ion Collisions at the Highest Beam Energy during the LHC-Run 2 by ALICE

Tatsuya Chujo (Univ. of Tsukuba)

2016 Joint Workshop of FKPPL and TYL/FJPPL (Particle Physics Laboratories) @ KIAS

May 18, 2016
KIAS, Seoul,
Had_01: project goals

- LHC heavy ion physics at **ALICE experiment**.
- Perform high precision measurements for the quantitative determination of QPG properties at the highest temperature.
- **Jets and photons measurements**, Japan and France in ALICE, by EMCal/DCal detectors, which has been built within the framework of France-Japan collaboration.
Relativistic Heavy-Ion Collisions

made by Chun Shen

Initial energy density

QGP phase

Hadron gas phase

Hadronization

Kinetic freeze-out

final detected particle distributions

Collision overlap zone

pre-equilibrium dynamics

viscous hydrodynamics

free streaming

$\tau \sim 0 \text{ fm/c}$ $\tau \sim 1 \text{ fm/c}$ $\tau \sim 10 \text{ fm/c}$ $\tau \sim 10^{15} \text{ fm/c}$

Courtesy of Paul Sorensen and Chun Shen
Probing new physics by ALICE-DCal

ALICE DCal
New electromagnetic calorimeter for jet and photon physics, by
US, Japan, France, China, Italy
· T. Chujo : EMCal · DCal deputy project leader

From discovery to determination of properties
Quark Gluon Plasma (QGP) by using jets and photons

Search for the gluon radiation, Equation of state of QGP
Overview of ALICE 2015 data taking

- **p-p @ 13 TeV**
- **Pb-Pb @ 5.02 TeV**

- high multiplicity
- central Pb-Pb collision
- calo jets (DCAL)
ALICE data taking profile: Run-2 vs. Run-1

RUN1::2010/13

7.3PB (one replica)

RUN2: first year

7.2PB (one replica)

- 60% (4.5 PB) during pp
- 40% (2.7 PB) during HIL (+pp-ref)
First year of DCal, jet/photon L1 trigger

• DCal and L1 trigger: Operational in 2015, first year of physics data taking.
• Grenoble LPSC - Tsukuba- Jyvaskyla team for L0/L1 trigger
  • Tsukuba: EMCal/ DCal /PHOS Level-1 jet & photon trigger, FPGA firmware development.
• Reasonable turn-on curve on jet trigger.
• Rejection factor $10^4$ at 30 GeV jet.
• Physics data analysis is on-going.

H. Yokoyama, R. Hosokawa, R. Guernane, J. Kral, T. Chujo

Jet trigger efficiency

DCal + PHOS trigger patch (H. Yokoyama)
**π⁰-jet correlations to determine path length dep. of energy loss**

Increasing charged jet $p_T$ threshold

**π⁰-jet correlations in pp and PbPb**

- **Daisuke Watanabe (Tsukuba), obtained PhD in 2016, March.**
- Developed by FJPPL, presented at QM2015 (Kobe)
- Study of jet structure by triggering high $p_T$ π⁰ hadrons.
- pp 7 TeV finished, and Pb-Pb 2.76 TeV finalizing for the publication.

**ALI-PREL-71751**

T. Renk, private comm.
Dual Degree Program (Ph.D) 
Grenoble U. - U. of Tsukuba

- Grenoble University (Joseph Fourier) and University of Tsukuba, agreed to start the joint double degree program (Ph.D) in 2015.
- Supervised by two institutes (Grenoble and Tsukuba) on same thesis topics.
- Ph.D from both Grenoble and Tsukuba after successful defense.
- Two students in this program within the framework of FJPPL:
  - Hiroki Yokoyama (U. Tsukuba): started April 2015.
    - “Jet spectra at 5.02 TeV in Pb-Pb (ALICE)”
    - Defence expected Sep. 2017
    - “Full jet pT spectra in 13 TeV p-p” and “jet-hadron correlations in PbPb(future)”
ALICE Calo meeting in Osaka (2015)

- Discussed EMCal/DCal/PHOS, jet and photon physics, within FJPPL, including Russian collaboration.
- 2.5 days, around 30 participants.
  - https://indico.cern.ch/event/439906/

- Next meeting in Tokyo 2016, May-June.
  - https://indico.cern.ch/event/506125/
Project proposal (FY2016)
1. Control path length (parton scattering point)
2. Energy calibration (e.g. γ-jet)
3. Detection of medium response by jet (parton) propagation

• Within the framework of FJPPL and FCPPL, we developed the new analysis team in ALICE, called **AAF (ALICE Asian France) collaboration**.
• First results on jet at “Hard Probe 2016 (Wuhan)”, and continue for the future jet/ photon analysis.
QGP fluid + jet model

1. Mach cone as a hydrodynamic response
   • Fluidity of the bulk medium
   • Properties of QGP e.g. sound velocity, viscosity, stopping power, etc.

2. Bulk dynamics of the QGP in jet events in HIC
   • Hydrodynamic response to jets in the expanding QGP
   • Consequent spectra of particles from the bulk medium

Hydrodynamic equations with source terms
\[ \partial_{\mu} T^{\mu \nu} = J^{\nu} \]

- Energy-momentum tensor of the QGP fluid
- Energy and momentum deposited from the jets

\[ \theta_M = \arcsin \frac{c_s}{v}, \quad v > c_s \]

Y. Tachibana, T. Hirano (QM2015)
### FJPPL (TYL) application 2016-2017

**Fiscal year April 1st 2016 – March 31st 2017**

Please replace the red examples by the appropriate data in black

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<tr>
<td></td>
<td>Name</td>
</tr>
<tr>
<td>Leader:</td>
<td>Yves Schutz</td>
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<td>Deputy leader:</td>
<td>Christophe Furget</td>
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<tr>
<td>Members:</td>
<td>Gustavo Conesa</td>
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<td>Balbastre</td>
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**HAD_01: Funding request (2015-2016)**

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* Requested same amount as last year for the travel support in France and Japan, most for the students and young researchers.
✓ **2015:**
- Successful first ALICE DCal data taking with L1, developed by FJPPL
- Started double degree PhD program between Grenoble - Tsukuba, two students enrolled.
- Presented jet results (Run-1) developed by FJPPL at QM2015
- Held “ALICE Calo meeting in Osaka (2015)” within FJPPL
- New “AAF analysis team” formed by FJPPL, FCPPL, work on Run-2 data.
- D. Watanabe obtained Ph.D (2016, March, Tsukuba U.)
- Two master students in Tsukuba have been supported by “TYL-FJPPL Student or Early Stage Researcher Secondment" ). Thank you!

✓ **2016:**
- Continue 2015 activities:
  - Data analysis (Run-2 jet and photon results) → physics outputs & publications (by FJPPL, AAF)
  - Double degree program, EMCal/DCal and L1 trigger

**Thank you for the continuous and strong support by TYL/FJPPL!**