

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)

2015 Joint Workshop of TYL/FJPPL and FKPPL
(Particle Physics Laboratories) @OIST

May20, 2015

OIST, Okinawa, Japan



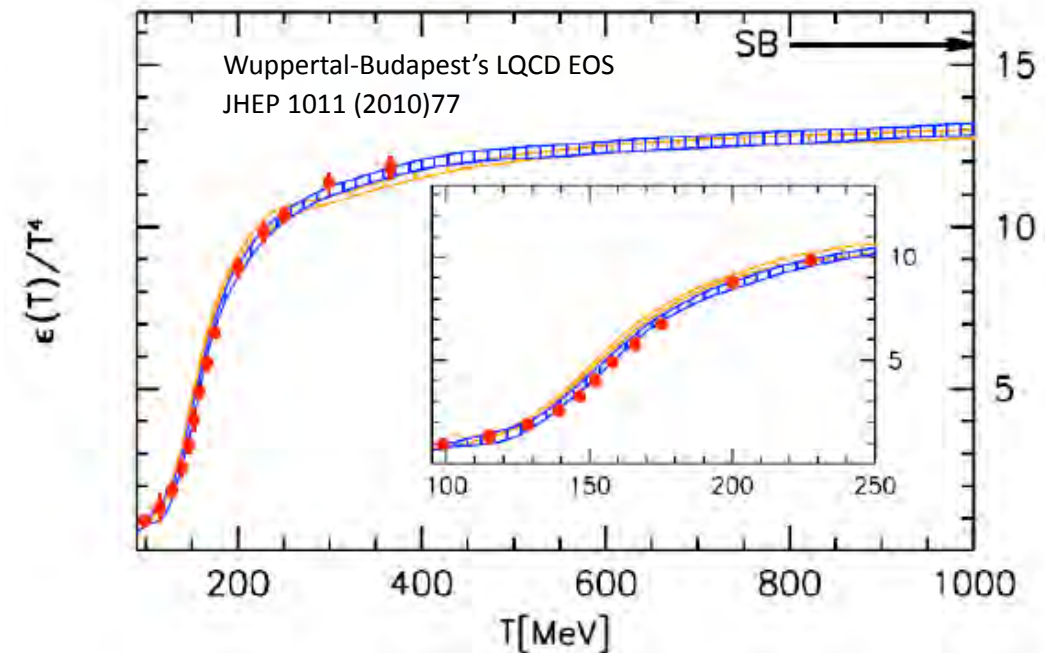
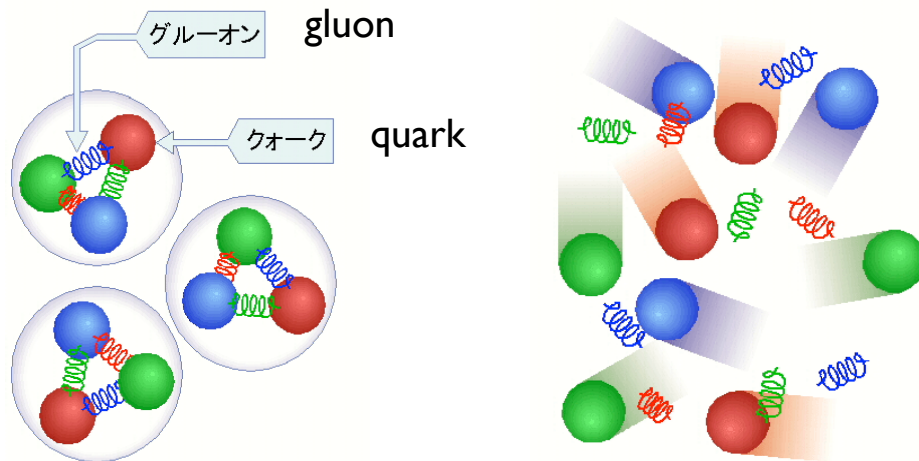
筑波大学
University of Tsukuba

Outline

1. Introduction
2. Project report (2014-2015)
3. Project proposal (2015-2016)
4. Summary

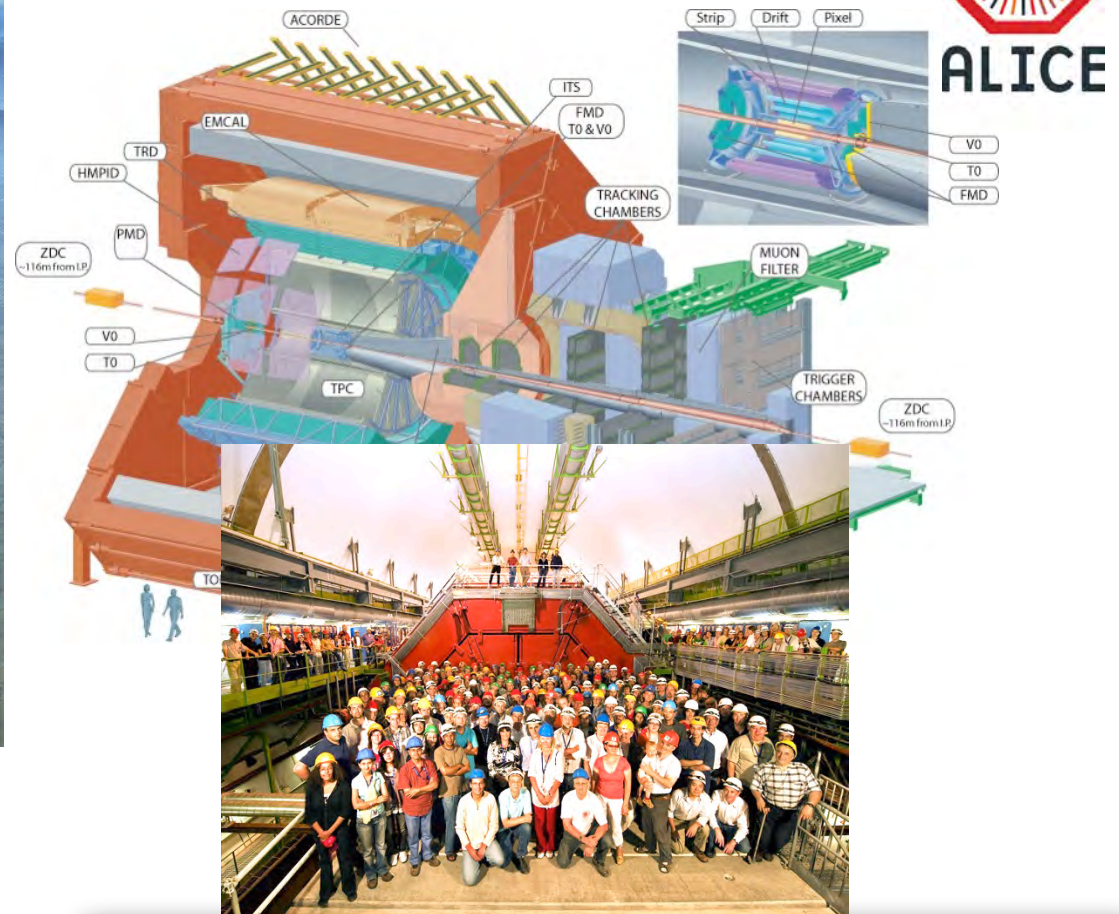
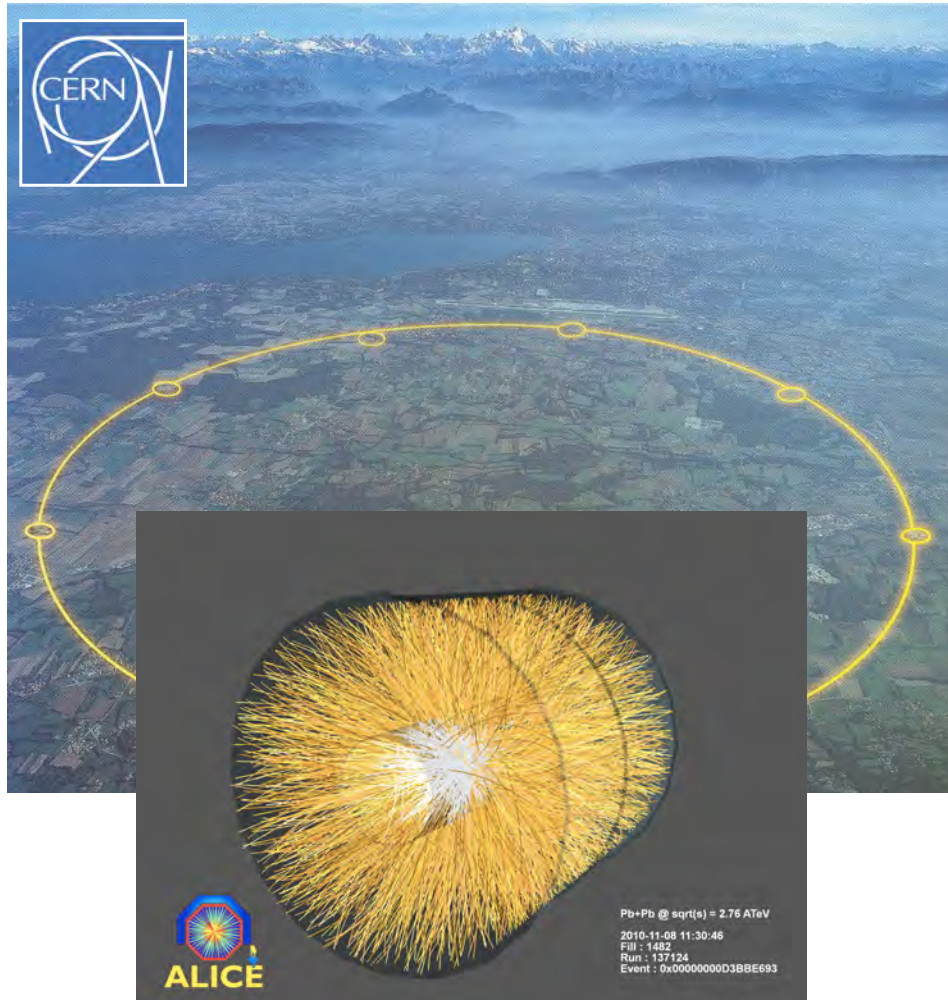
I.Introduction

Quark Gluon Plasma (QGP)



- De-confined state of quarks and gluon inside hadrons under the extremely high temperature and energy density
- Lattice QCD calculations:
 - Critical temperature: $T_c = 150\text{-}200 \text{ MeV}$
 - Crossover phase transition from hadronic phase to parton phase.
- **A primordial state of universe, after few micro second of Big Bang.**

Experimental study on QGP by Relativistic Heavy Ion collisions

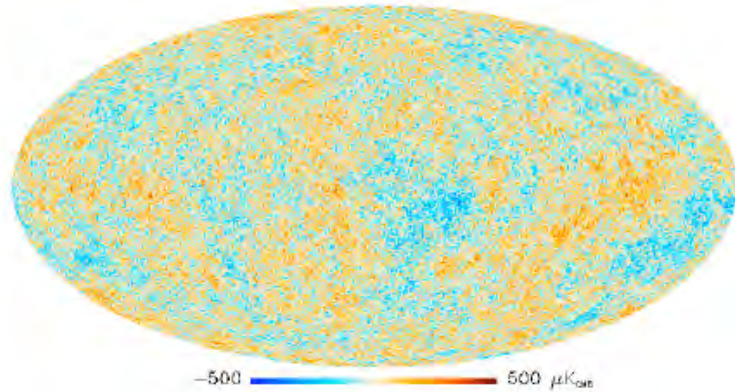


CERN-LHC (2009-)
 $\sqrt{s_{NN}} = 2.76$ (5.5 design) TeV Pb-Pb
2.76, 7.0, 8.0 TeV p-p
5.02 TeV p-Pb

LHC-ALICE experiment:
36 countries, 129 institutions,
~1,000 collaborators.
The dedicated experiment to HI program
and QGP study at LHC

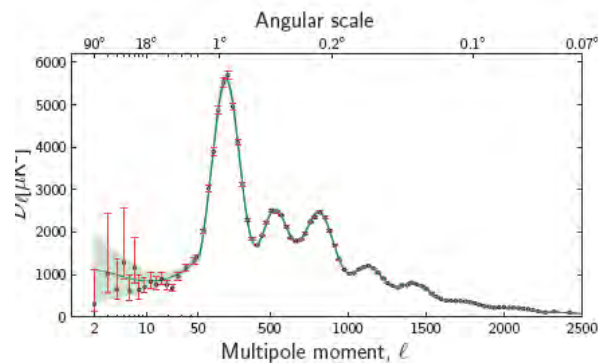
Probing QGP by Higher harmonics

Fluctuations of the Universe



Planck (2013)

Determination of cosmological parameters

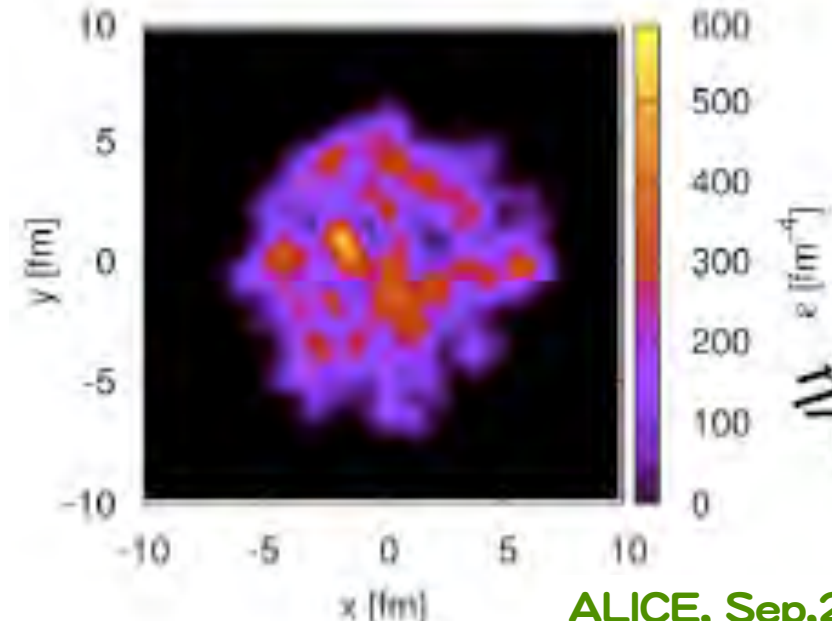


Power spectrum

Heavy Ion Collisions

Initial condition, QGP property (e.g. η/s)

Fluctuations of Little bang



ALICE, Sep, 2011

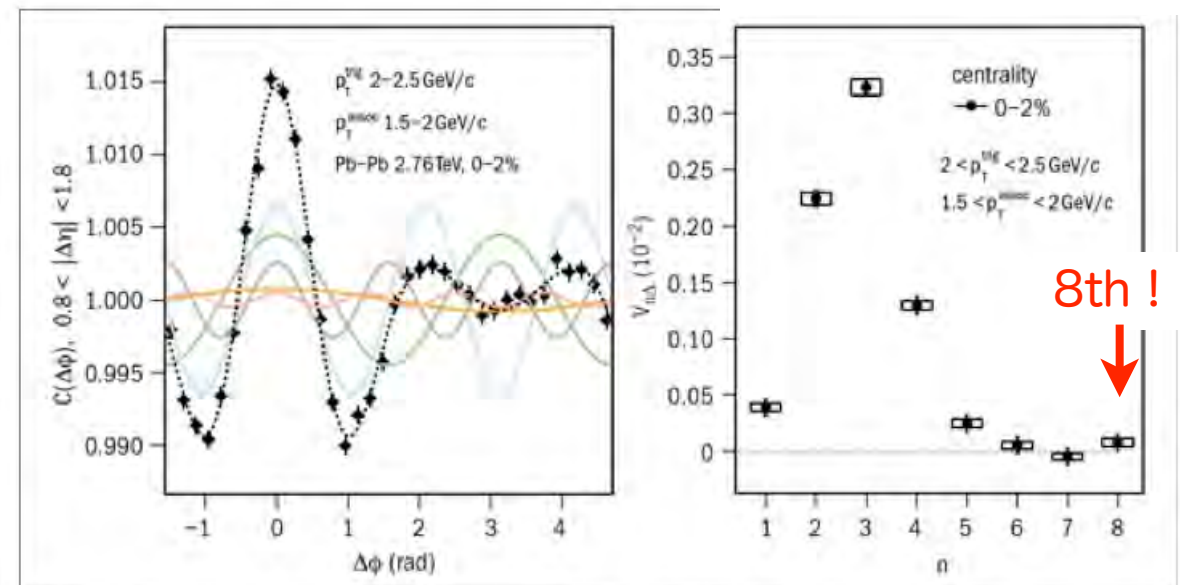
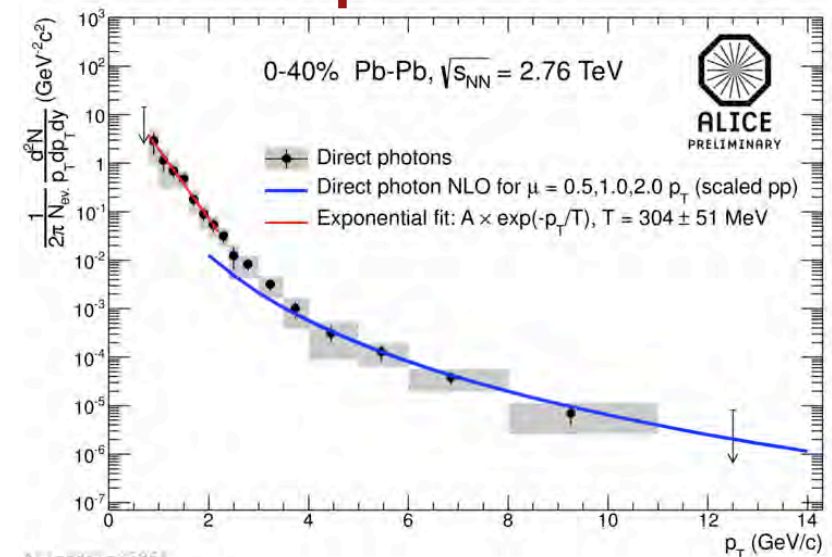


Fig. 1. Left: correlation function for charged hadron pairs from head-on Pb-Pb collisions. Right: corresponding spectrum of Fourier harmonic amplitudes vs n .

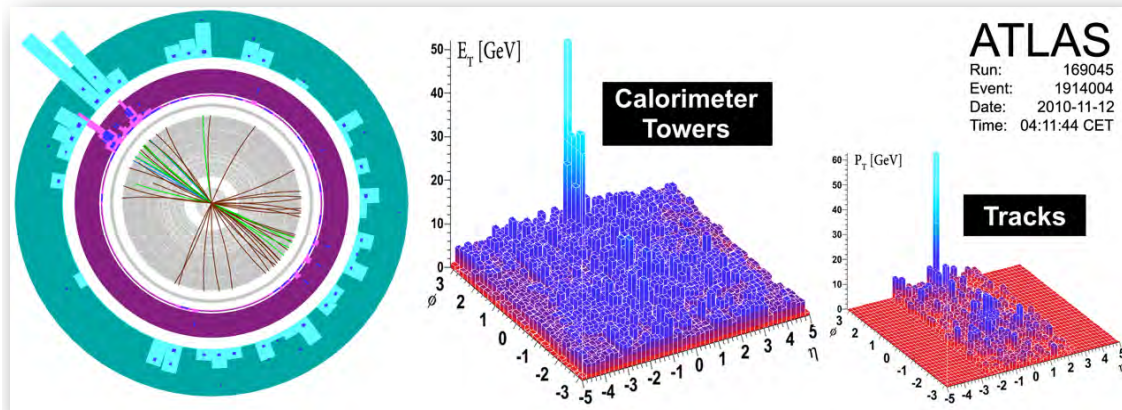
LHC Heavy Ion Physics Highlights (Run-1: 2009-2013)

- Initial temperature: $T_{\text{int}} \sim 304 \pm 51$ MeV
 - $\sim 1.4 \times T_{\text{int}}$ (RHIC).
- Denser ($\sim \times 2$) and longer lifetime w.r.t RHIC
- Strong collective flow, jet quenching.
- Disappearance of excited Y states, evidence for creation of high temperature matter
- Recombination of c-cbar pairs (J/ψ)
- Collectivity in small system p-Pb, p-p (high multip.)
- ...

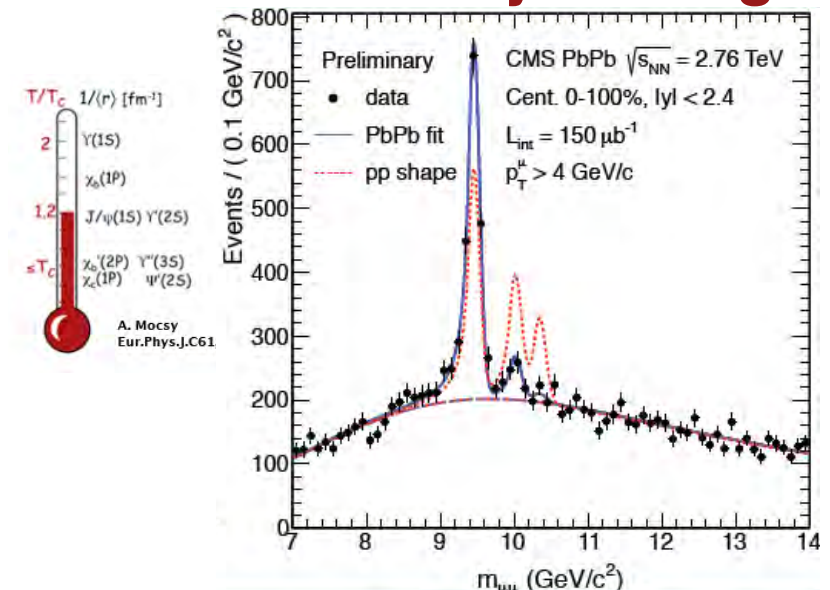
Thermal photon radiation



Jet quenching



Y family melting



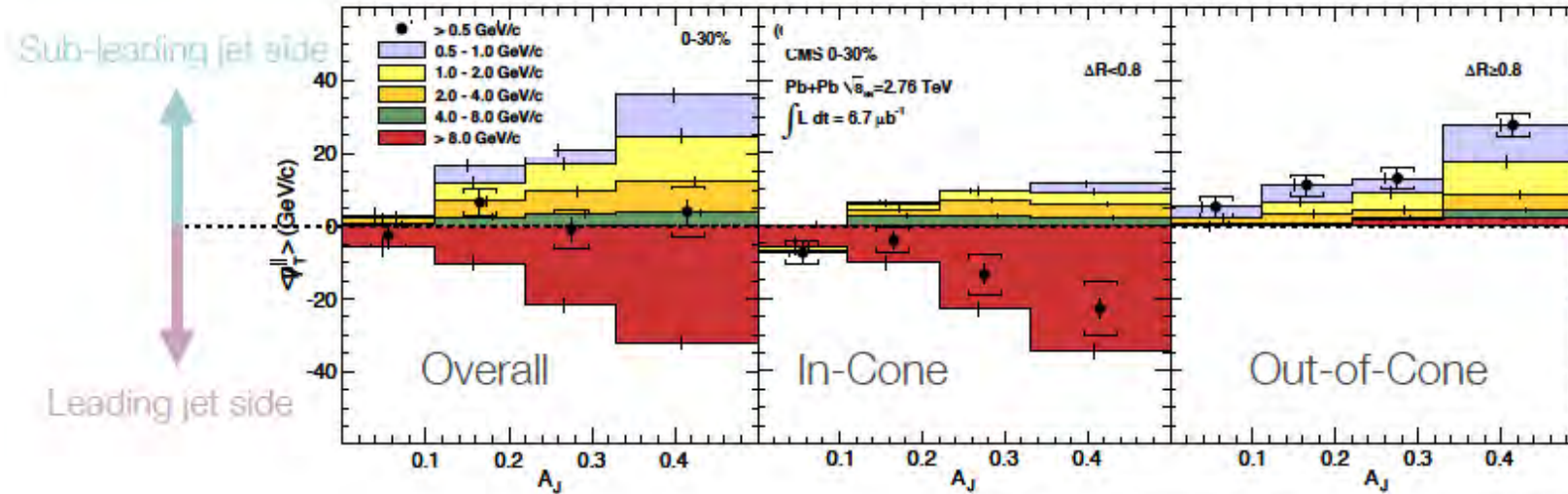
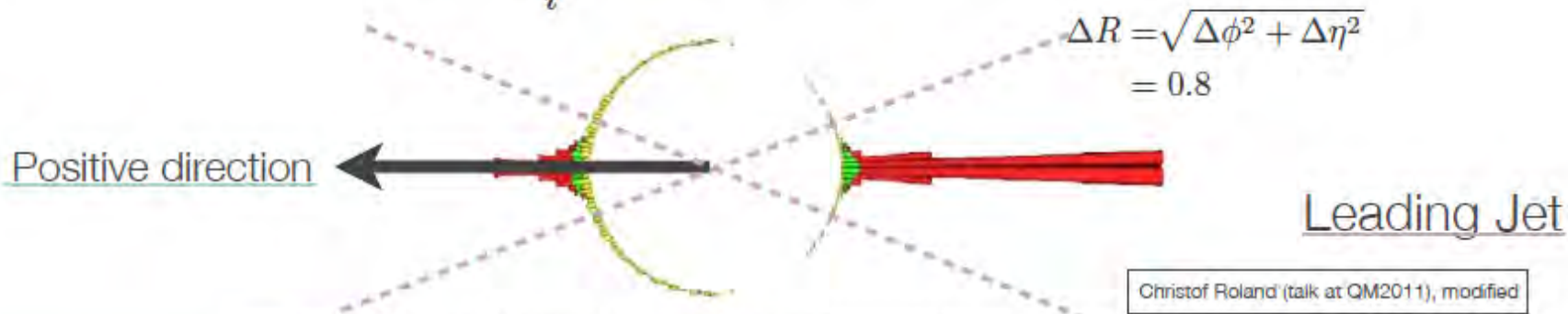
Energy balance by low p_T particle at large angle

Slide from Y. Tachibana (ATHIC 2014)

Net- p_T along the sub-leading jet

CMS (2011)

$$p_T^{\parallel} = \sum_i -p_T^i \cos(\phi_i - \phi_{\text{Leading Jet}})$$

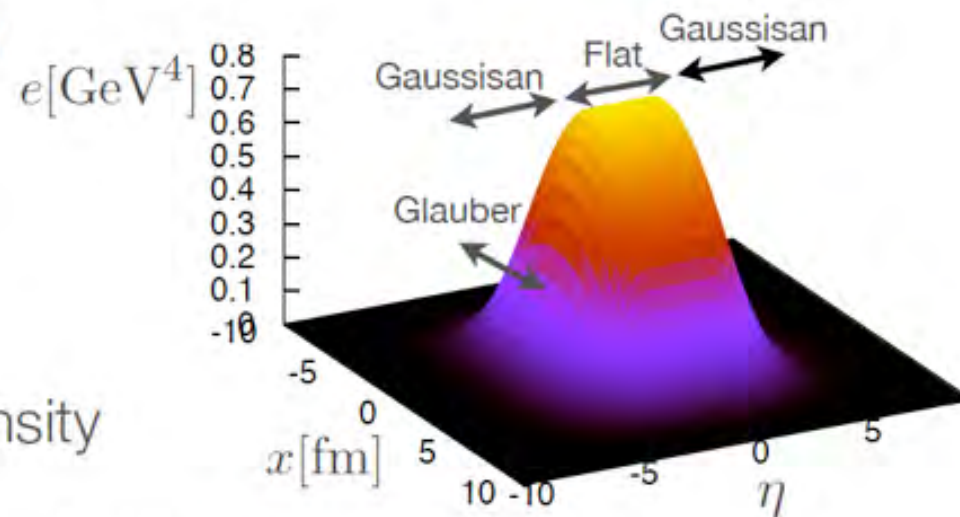


S. Chatrchyan et al. [CMS Collaboration], Phys. Rev. C 84, 024906, modified

$$A_J = \frac{p_{T,1} - p_{T,2}}{p_{T,1} + p_{T,2}}$$

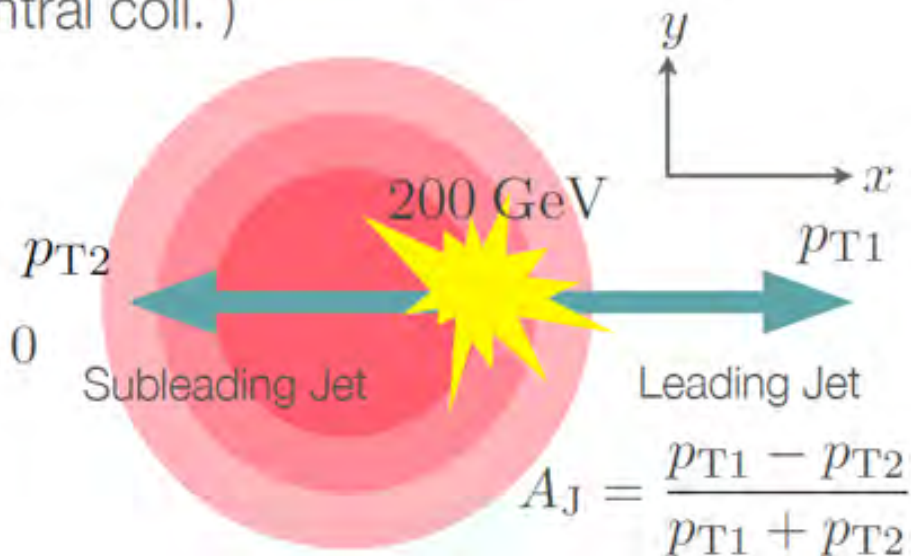
■ Fluid expanding strongly in the longitudinal direction

- (3+1)-D perfect QGP-fluid (PPM)
- Expanding coordinate system
 (τ, x, y, η)
- New scheme at high precision
- Initial condition of the energy density
 η : Flat + Gaussian
 x, y : Glauber model (Pb-Pb, central coll.)



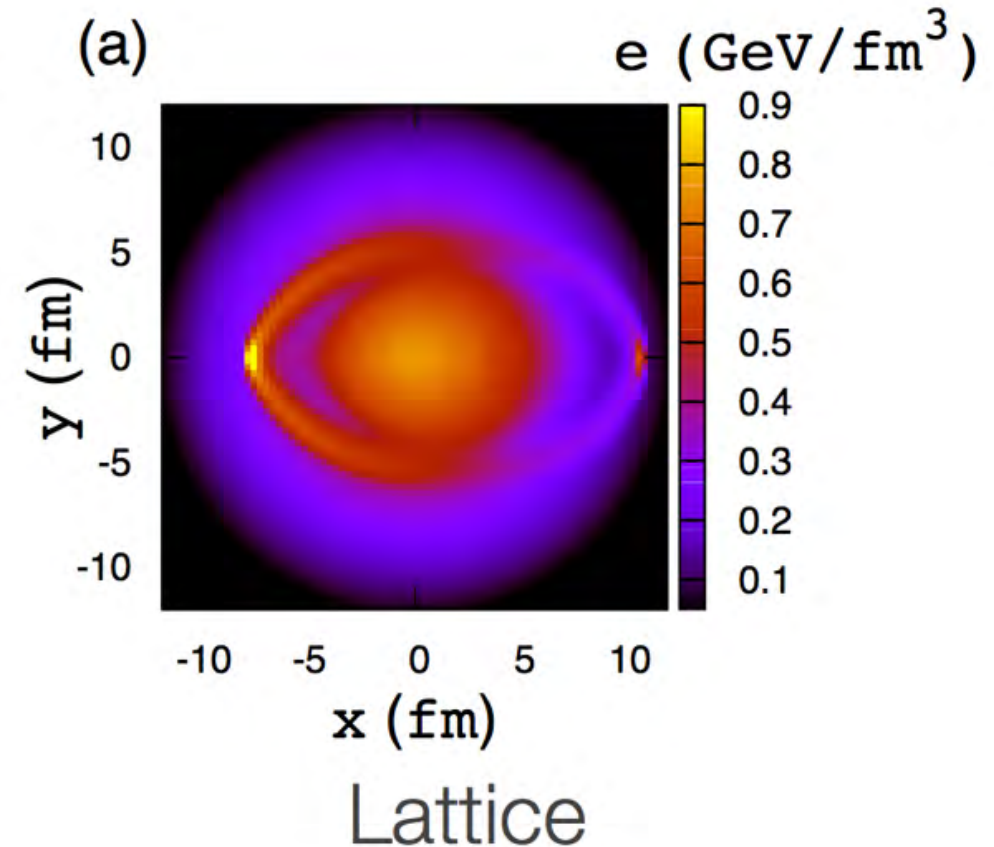
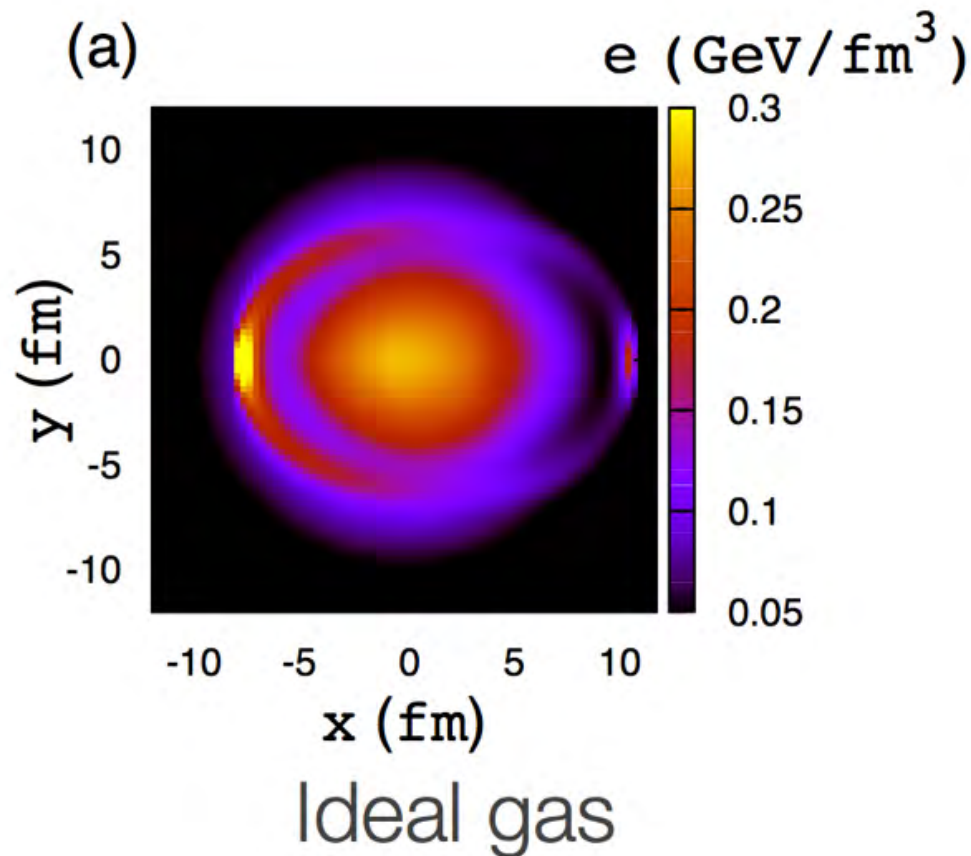
■ Di-jet

- Massless
- Back to back same energy jets
- Traveling straight in the plane $\eta = 0$



Mach cone; EOS dep.

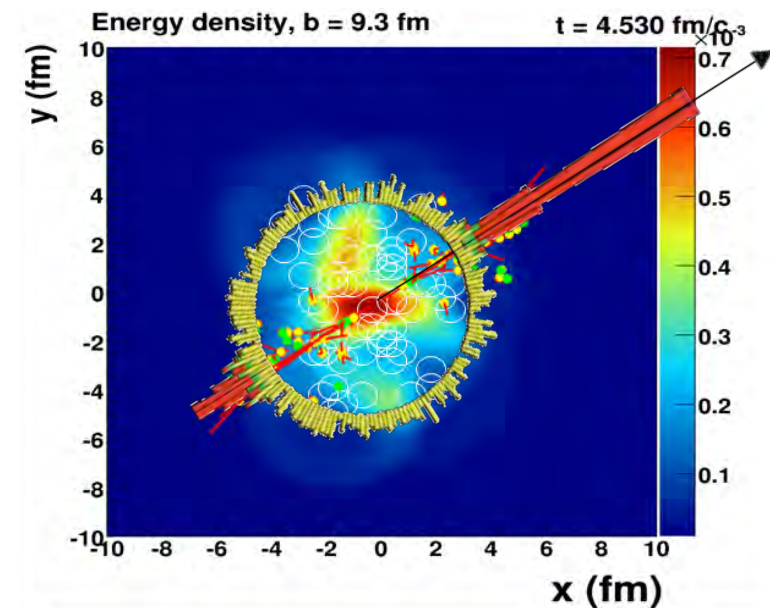
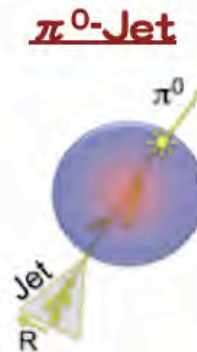
Y. Tachibana, T. Hirano,
PRC 90, 021902(R) (2014)



- Different c_s for Ideal and lattice, different angle.
- Possibility to measure c_s (EOS) by soft hadron angle.

Keys to understand dE/dx in QCD plasma

1. Control path length (parton scattering point)
2. Energy calibration (e.g. γ -jet)
3. Detection of medium response by jet (parton) propagation



Our project goals:

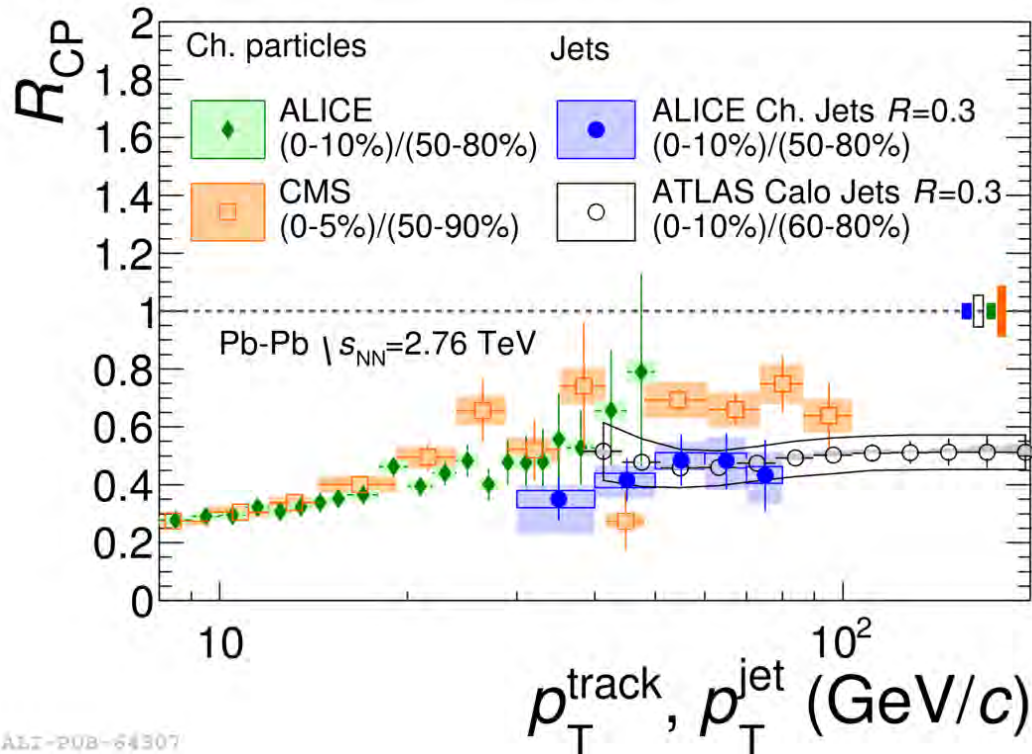
- To perform high precision measurements and to develop original physics data analysis during the LHC Run-2 (2015-2018) for the quantitative determination of QPG properties at the highest temperature.
- Particular emphasis on **jets and photons measurements**, Japan and France in ALICE, by EMCal/DCal detectors, which has been built within the framework of France-Japan collaboration.
- Participation of Japan in the French lead upgrade project MFT (Muon Forward Tracker) **NEW**

2. Project report (2014-2015)

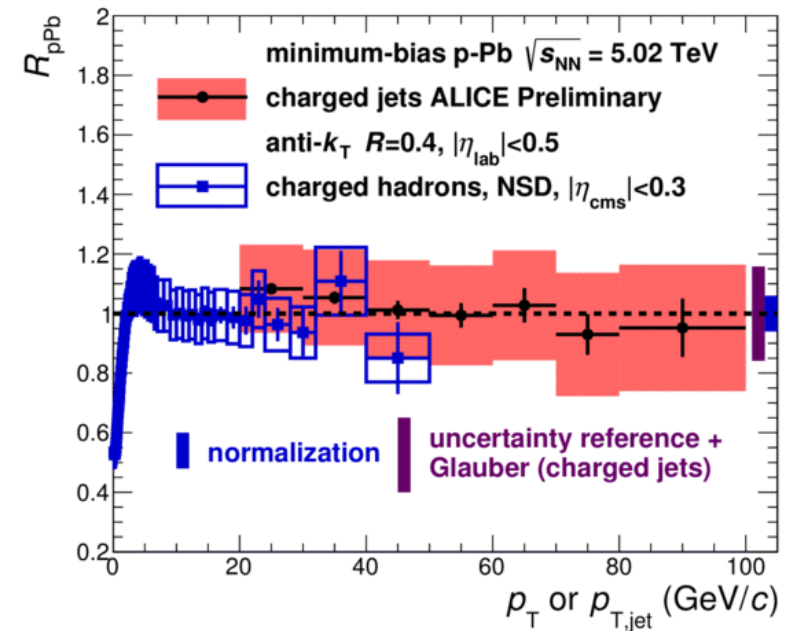
ALICE jet results (1)

$$R_{AA} = \frac{\text{"hot/dense QCDmedium"}}{\text{"QCD vacuum"}} = \frac{dn_{AA}/dp_T dy}{\langle N_{\text{binary}} \rangle \cdot dn_{pp}/dp_T dy}$$

Pb-Pb 2.76 TeV



p-Pb 5.02 TeV

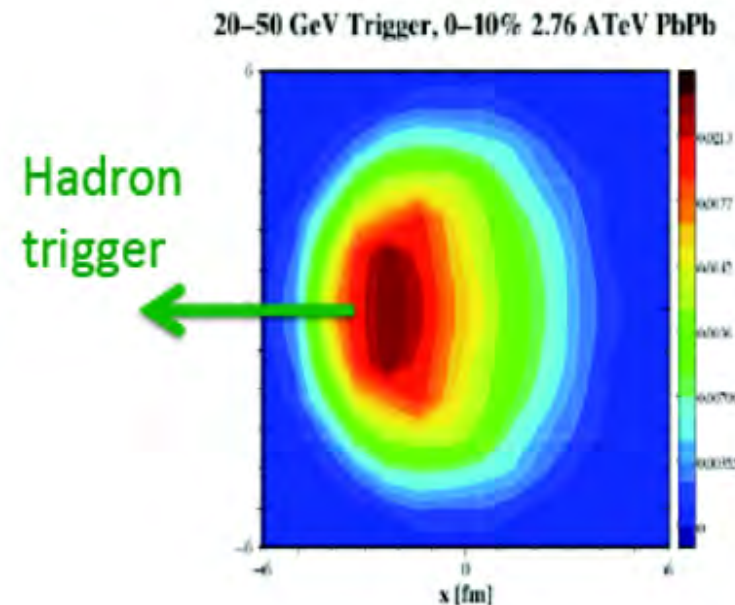
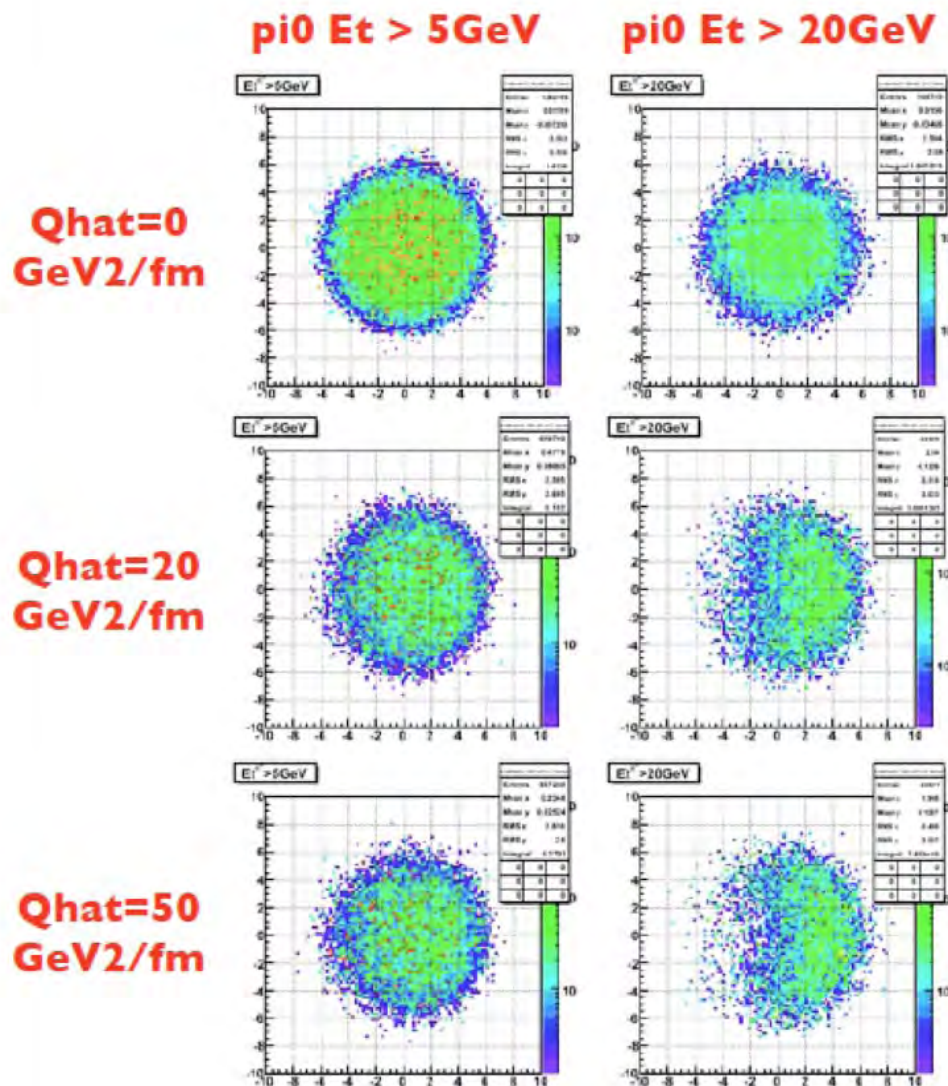


- Observed jet suppression in Pb-Pb, un-modified in p-Pb.

Path length “control” experiment

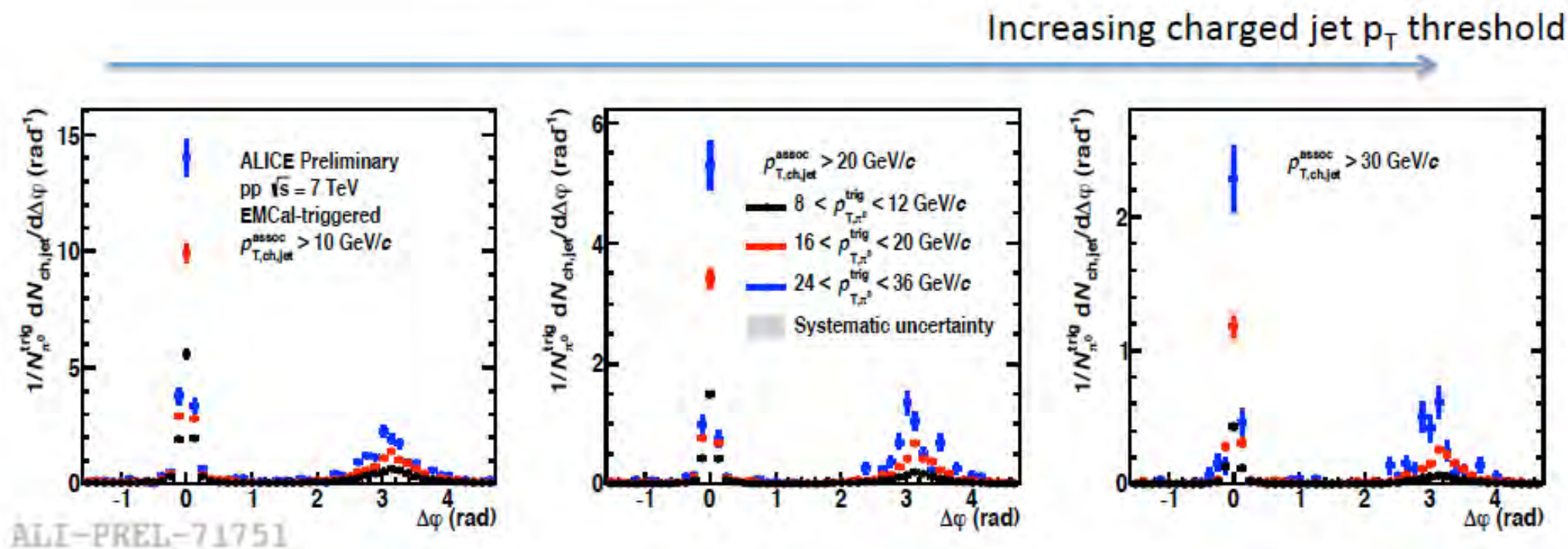
π^0 -jet correlations

From TDR ALCE-DCal
(work done by H.Yokoyama, M. Sano)



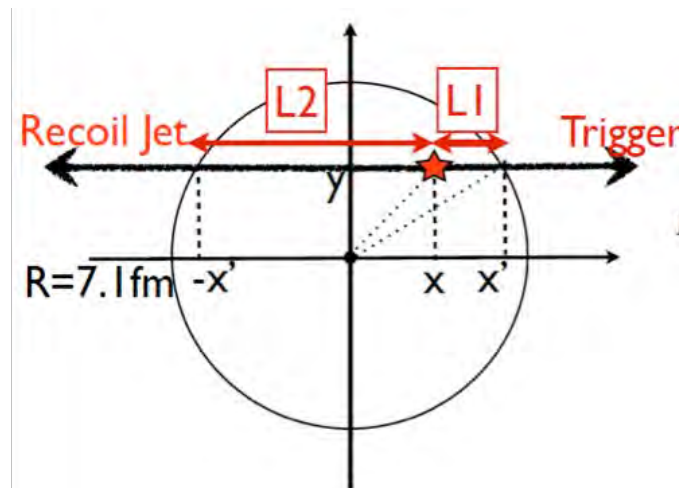
T.Renk, private com.

- Hard scattering point (in x-y plane) of trigger π^0 with associate recoil jet.
- **The higher $E_T \pi^0$, the stronger surface bias.**
- $\langle q\text{-hat} \rangle = 20 \text{ \& } 50 \text{ GeV}^2/\text{fm}$
 - small difference.
 - can be used as geometry measure of emission point, without knowing the quench parameters.



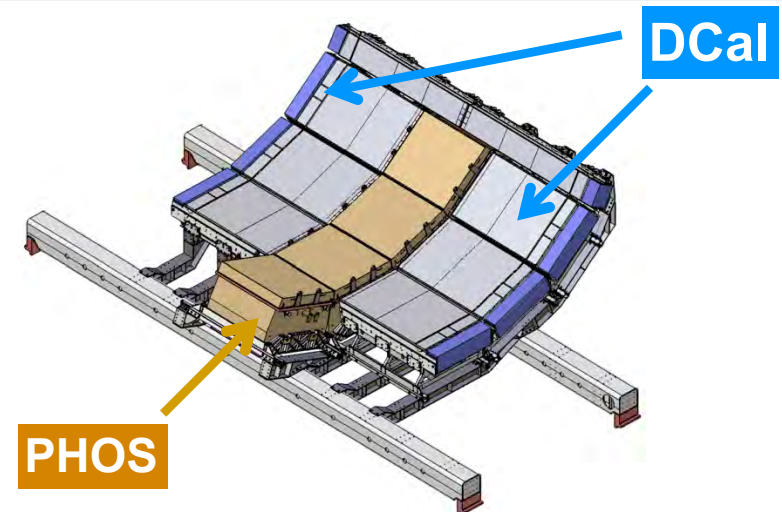
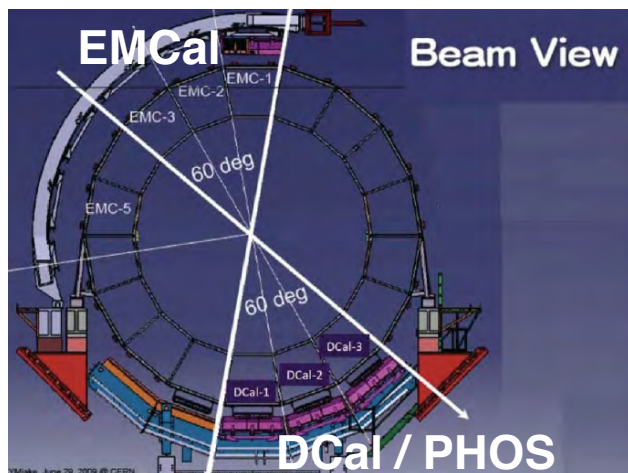
π^0 -jet correlations in pp (7TeV)

- Provide an important baseline data for Pb-Pb.
- Clear back-to-back jet peak is seen, and narrower width with increasing jet p_T and trigger π^0 p_T .
- Now analyzing Pb-Pb data.

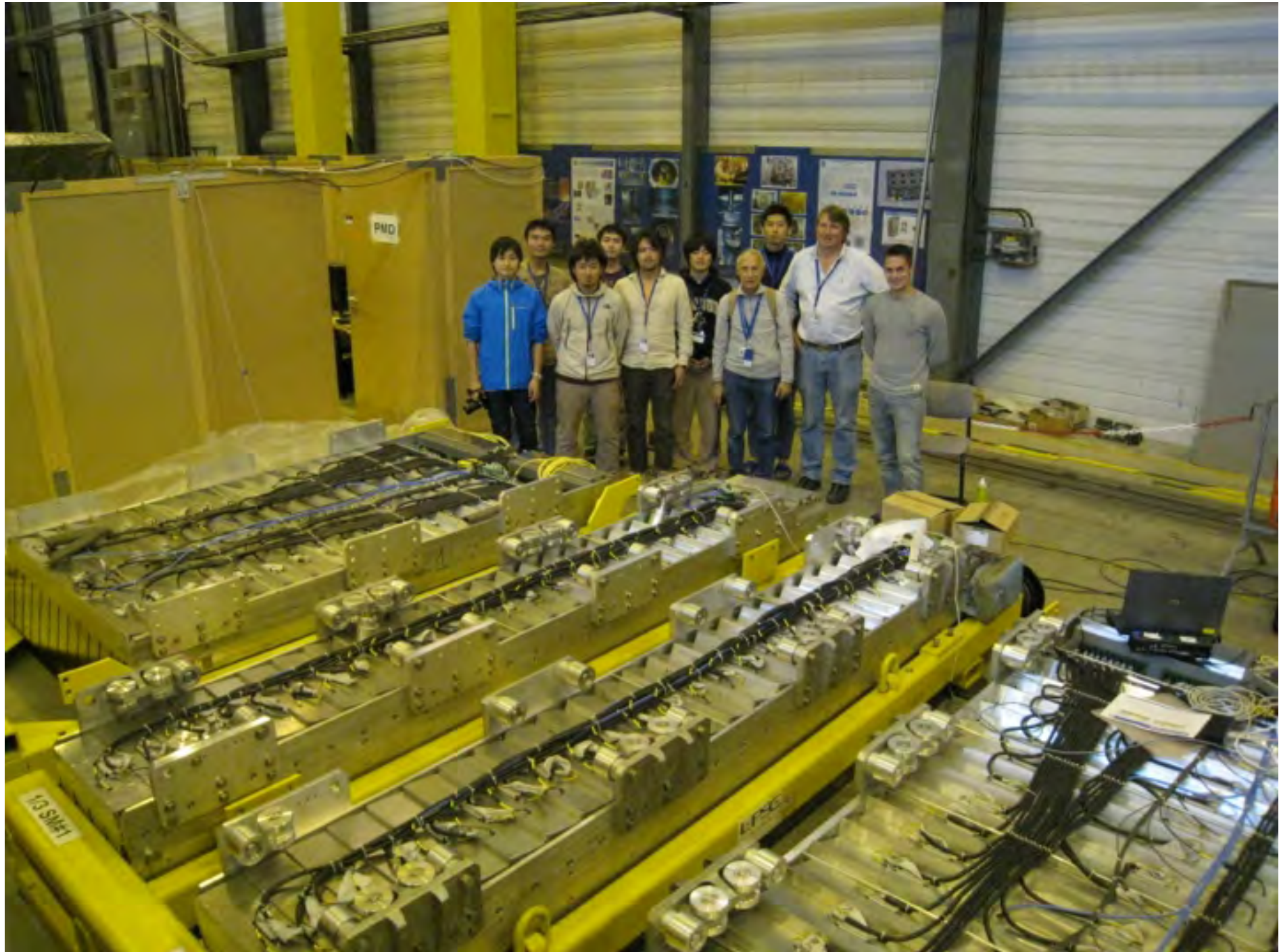


DCal (Di-jet Calorimeter) in ALICE

- Jet measurement including neutral particles, Electromagnetic Calorimeter for jet trigger, DCal.
- **Japan-France-US-Italy-China** collaboration in ALICE
- 2009: ALICE approval. supported by FJPPL.
- 2011: Finished all module production in Tsukuba and shipped them to France
- 2013/2014: all SM tested at CERN (D. Watanabe, N. Tanaka, et al.)
- 2013-2015: EMCal/DCal/PHOS L1 jet trigger development (H. Yokoyama, R. Hosokawa, R. Guernane)
 - Tsukuba-Grenoble collaboration for jet trigger.
- **2014 Nov.: Installation completed in ALICE P2**
- EMCal/ DCal detector, deputy project leader: T. Chujo (2013.11-)

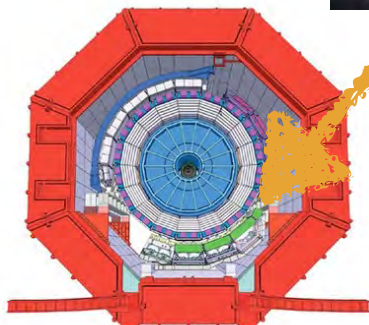


**DCal detector modules before installation
(Sep. 2013 @ CERN, ALICE assembly area)**





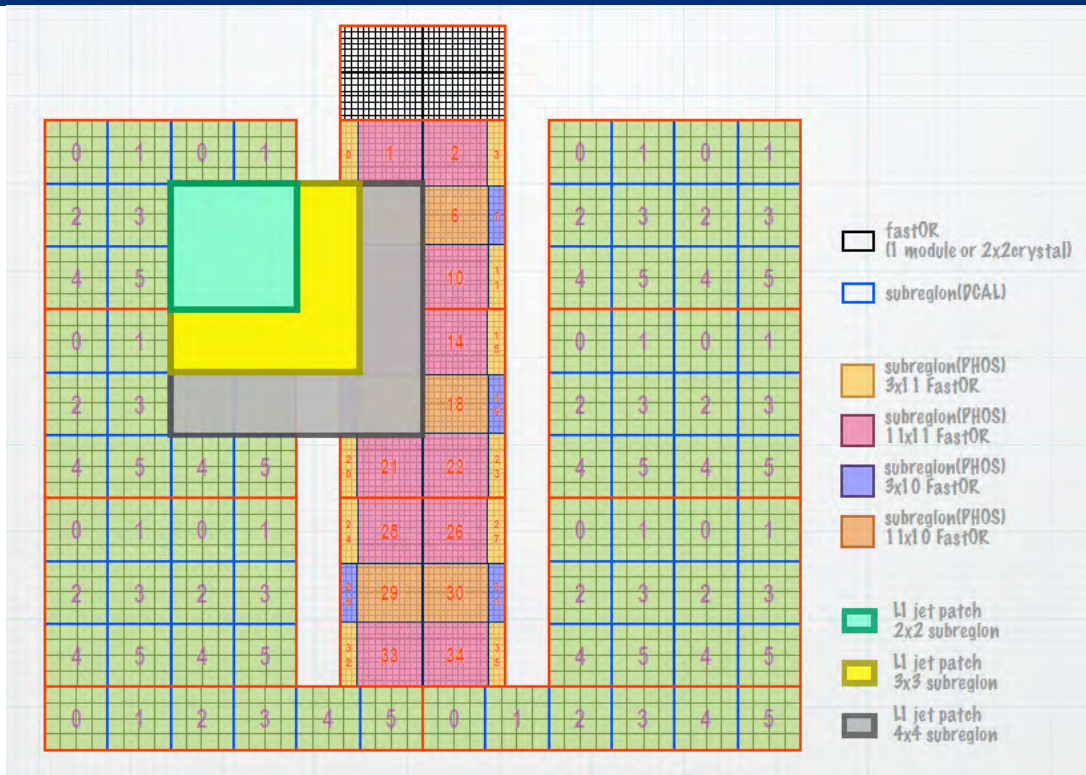
**DCal detector modules after installation
(Nov. 2014 @ CERN, ALICE)**



We ARE HERE

- solenoid magnet (surrounds)
- ITS (small ring, centre)
- TPC ("spoked wheel")
- TRD ("stripes")
- TOF
- DCal
- EMCAL
- HMPID

EMCal/ DCal/ PHOS Jet L1 trigger



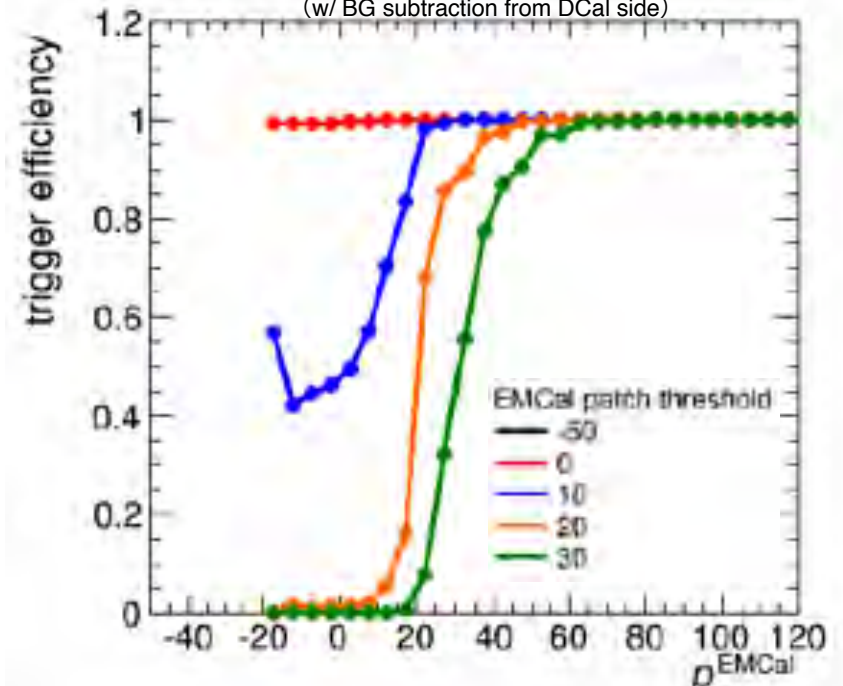
↑ DCal + PHOS trigger patch (H. Yokoyama)

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

- 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.

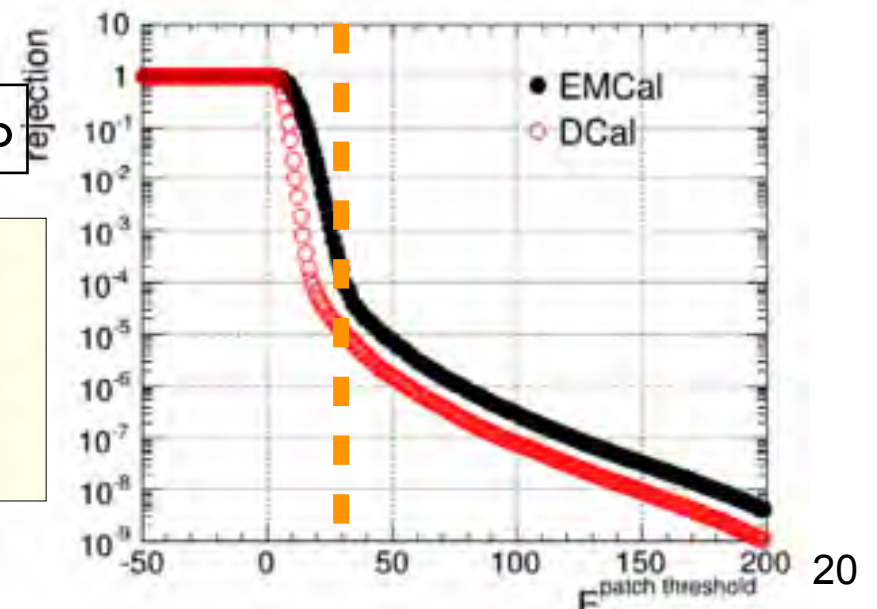
Jet trigger efficiency

(w/ BG subtraction from DCal side)



Rejection factor $R_{T,jet}$

(w/ BG subtraction from DCal side)





**Frist workshop in Tsukuba (March 3-7, 2014)
within the framework of France-Japan ALICE collaboration.
@ Univ. of Tsukuba, ~80 participants [FJPPL supported]**



2nd workshop in Sante-Maxime (March 15-16, 2015)
“ALICE physics analysis workshop”
~30 participants [FJPPL supported]

Dual Degree Program (Ph.D) Grenoble U. - U. of Tsukuba

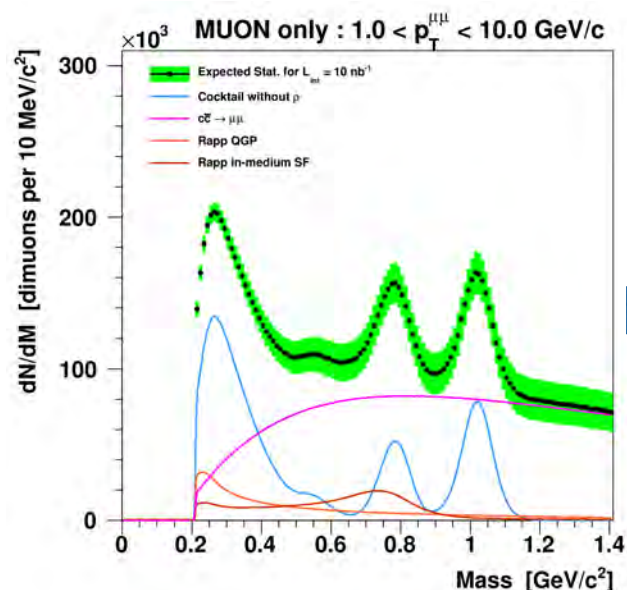
- Grenoble University (Joseph Fourier) and University of Tsukuba, agreed to start the joint double degree program (Ph.D) in 2015.
- Supervised by two institutes (Grenoble and Tsukuba) on same thesis topics.
- Ph.D degrees will be obtained from both Grenoble and Tsukuba after successful defense.
 - **Hiroki Yokoyama** (U. Tsukuba): started April 2015.
 - “pi0-jet correlations in p-Pb”, jet trigger
 - **Ritsuya Hosokawa** (U. Tsukuba): will start Sep. 2015.
 - “Full jet pT spectra in 13 TeV p-p and 5.1 TeV Pb-Pb”, jet trigger
 - They are the first students for this program, both worked on ALICE.

MFT: Muon Forward Tracker, proposed in ALICE ($-4.0 < \eta < -2.5$)

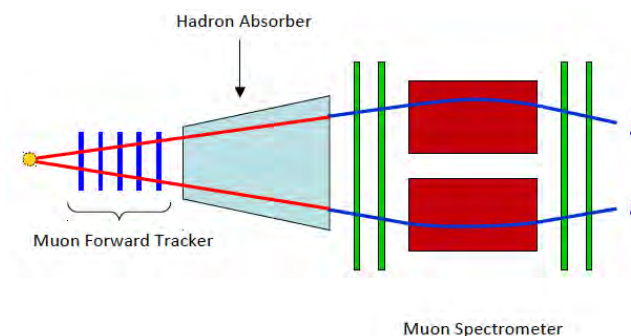
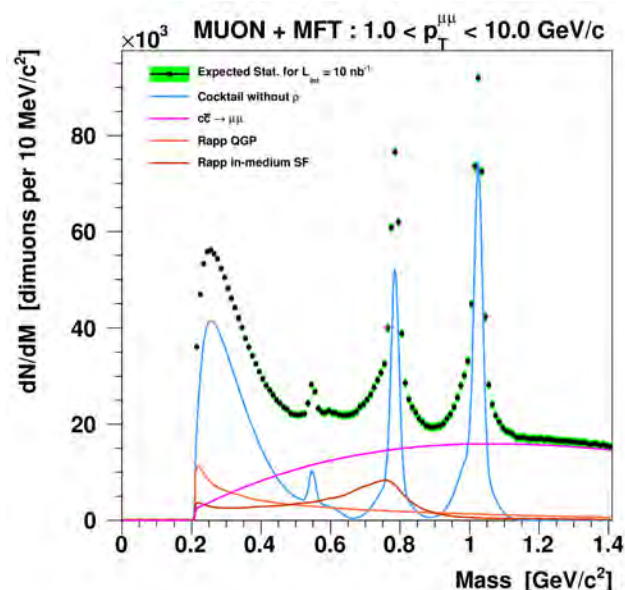
- Silicon pixel tracker in Muon Spectrometer
- Separation of charm/beauty down to very low p_T
- Precise $\psi(2s)$ measurement even in central Pb-Pb
- Prompt and non-prompt J/ψ separation
- Improve S/B ratio and mass resolution for **Low Mass di-muons**

The MFT project has been approved by the ALICE Collaboration to be part of the ALICE upgrade planned for the LHC LS 2017/2018

Hiroshima G. joined for this project in 2014.



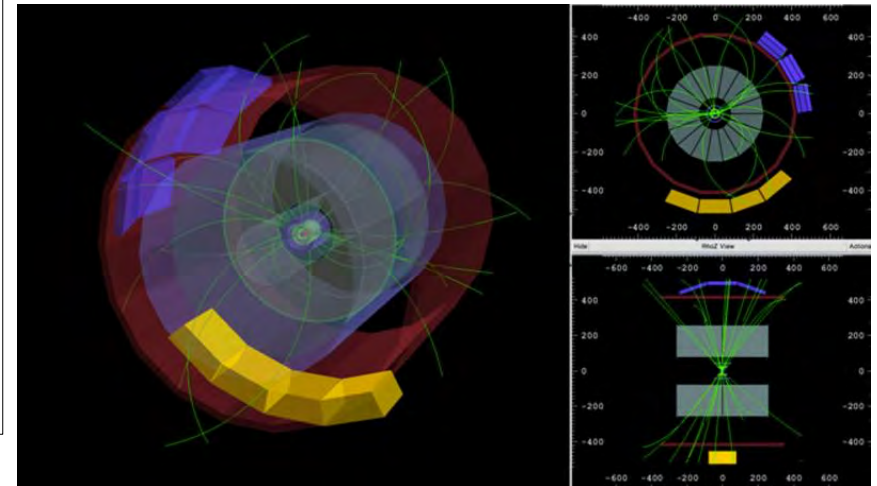
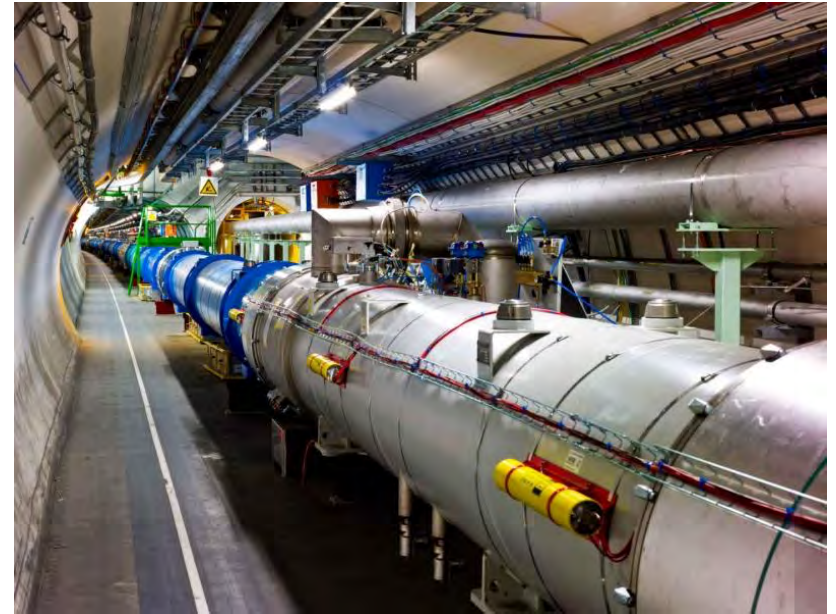
**MUON
+ MFT**



3. Project Proposal (2015-2016)

ALICE Run-2 (2015-2018) and DCal, jet physics

- Highest beam energy ever at LHC in Run-2 (2015-2018)
 - pp ($\sqrt{s} = 13$ TeV)
 - Pb-Pb ($\sqrt{s_{NN}} = 5.1$ TeV)
 - p-Pb ($\sqrt{s_{NN}} = 5.1$ TeV?)
- Longest, hottest, and largest QGP creation at LHC
- 2015 plan:
 - Run-2 start in pp (13 TeV) in June, PbPb (Nov.) 2015.

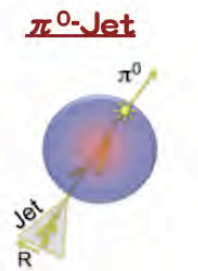
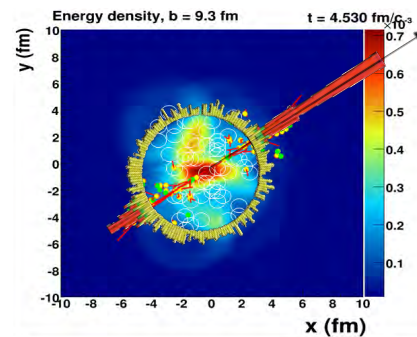
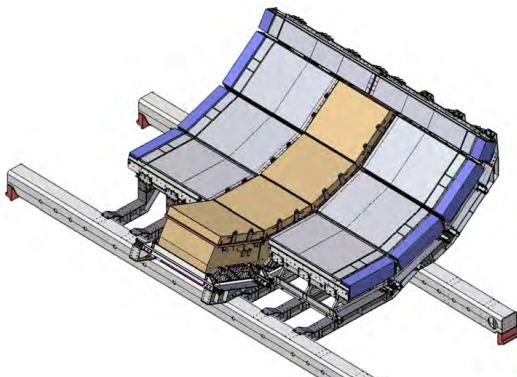


Proton-proton collision at 900 GeV as determined by the inner silicon trackers in the ALICE detector (Image: ALICE/CERN)

Our proposal (2015-2016)

- Run-2 start-up, and first physics data taking by **DCal**.
- Successful operation of EMCal/ DCal operation, jet trigger
- Physics outputs from EMCal/DCal.
- Data analysis in Run-1 and new Run-2, will be presented at **Quark Matter 2015** international conference, Kobe, Sep-Oct, 2015, Japan (French collaborators will be invited).
 - H. Hamagaki (chair)
- **Double degree PhD program for two students.**
- Further involvement of MFT project.

qm2015.riken.jp





QUARK MATTER 2015

The XXVth International Conference on Ultrarelativistic Nucleus-Nucleus Collisions

HOME

INDICO HOME

SCIENTIFIC TOPICS

IMPORTANT DATES

ANNOUNCEMENTS

REGISTRATION ▶

YOUNG PARTICIPANTS ▶

VISA

ABSTRACTS

AGENDA ▶

PROCEEDINGS



QUARK MATTER 2015

XXV INTERNATIONAL CONFERENCE ON
ULTRARELATIVISTIC NUCLEUS-NUCLEUS COLLISIONS

SEPTEMBER 27 – OCTOBER 3, 2015
KOBE FASHION MART, KOBE, JAPAN

The Quark Matter 2015 is the XXV international conference on ultrarelativistic heavy-ion collisions. The aim of this conference is to unravel mystery of strongly interacting matter

HAD_01: Project Members

FJPPL (TYL) application 2015-2016

Fiscal year April 1st 2015 – March 31st 2016

Please replace the red examples by the appropriate data in black

ID¹ : LHC_8	Title: Measurements of Jets and Photons in Heavy Ion Collisions at the Highest Beam Energy during the LHC-Run 2 by ALICE					
Leader Members	French Group			Japanese Group		
	Name	Title	Lab./Organis.²	Name	Title	Lab./Organis.³
	<u>Leader:</u> Yves Schutz	DR1	SUBATECH	<u>Leader:</u> Tatsuya Chujo	Dr	U. Tsukuba
	<u>Deputy leader:</u> Christophe Furget	Pr	LPSC	Yasuo Miake	Pr	U. Tsukuba
	Gustavo Conesa Balbastre	CR2	LPSC	Shinichi Esumi	Dr	U. Tsukuba
	Renaud Vernet	IR	CCIN2P3	Toru Sugitate	Pr	U. Hiroshima
	Magali Estienne	CR1	SUBATECH	Kenta Shigaki	Pr	U. Hiroshima
	Marie Germain	CR1	SUBATECH	Hideki Hamagaki	Pr	U. Tokyo
	Rachid Guernane	CR1	LPSC	Taku Gunji	Dr	U. Tokyo
	Julien Faivre	MC	LPSC	Motoi Inaba	Pr	U. Tsukuba Tech.
	Gines Martinez	DR2	SUBATECH	Hiroshi Masui	Dr	U. Tsukuba
				Ken Oyama	Pr	NiAS
				Yosuke Watanabe	Dr	U. Tokyo
				Oliver Busch	Dr	U. Tsukuba

HAD_01: Funding request (2015-2016)

France

Funding Request from France				
Description	€/unit	Nb of units	Total (€)	Requested to ⁴ :
Visit to Japan (Travels)	1200	4 travels	4800	
Stay in Japan (local expense)	90/day	40 days	3600	
Stay in France	90/day	20 days	1800	
Total			10200	
Funding Request from KEK				
Description	¥/Unit	Nb of units	Total (¥)	Requested to:
Travels (students, for the double degree program)	150	4 travels (Round trip)	600	KEK
Stay in France (students, for the double degree program)	10/day	60 days	600	KEK
Total			1,200	

Japan

*** In addition to a support from France, we would like to ask a support from KEK for to conduct PhD double degree program for 2 students (Grenoble-Tsukuba)**

4. Summary

✓ 2014-2015:

- ALICE DCal has been finally installed to ALICE experimental area successfully.
- Jet Level 1 trigger development has been completed within the FJPPL framework.
- Ready for the physics data taking in Run-2.
- Grenoble-Tsukuba PhD double degree program has been newly launched in 2015.
- Newly involved in the MFT project in 2014 (Hiroshima).

✓ 2015-2016:

- **DCal first data, physics outputs on jet from ALICE w/ DCal.**
 - (1) Develop double degree program
 - (2) QM 2015 international conference in Kobe, Sep-Oct, 2015, French collaborators will be invited.
- Asked TYL-FJPPL support for both (1) and (2).

Backup slides

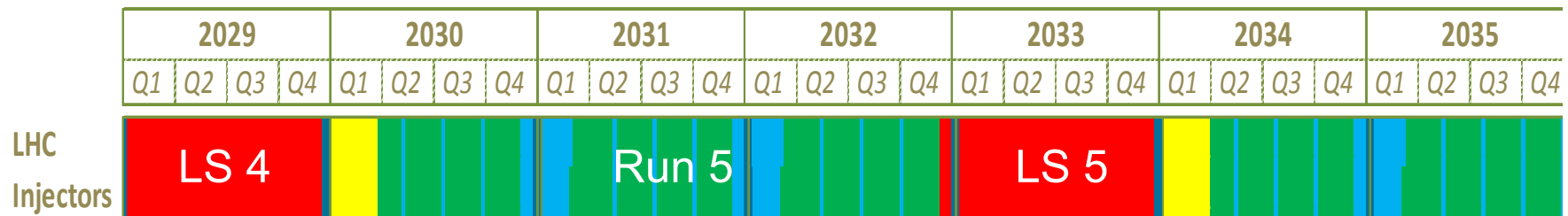
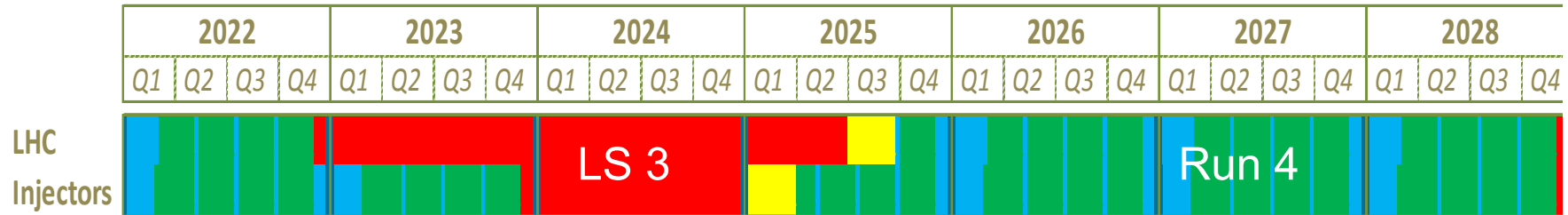
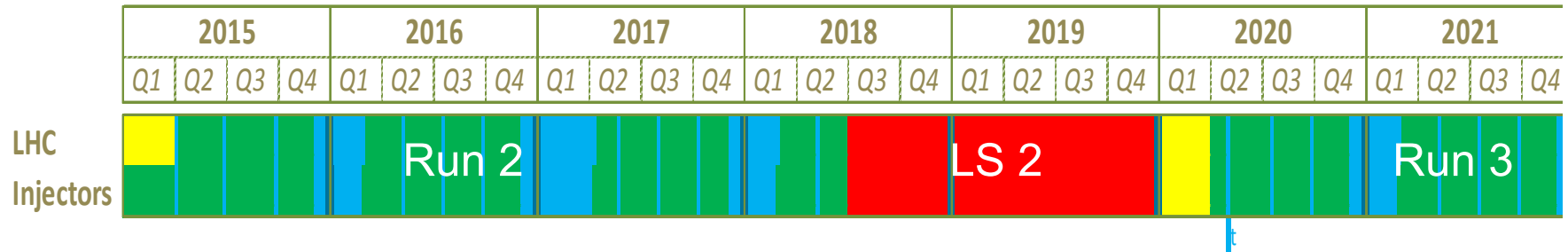
LHC schedule beyond LS1

Only EYETS (19 weeks) (no Linac4 connection during Run2)

LS2 starting in **2018 (July)** **18 months** + 3months BC (Beam Commissioning)

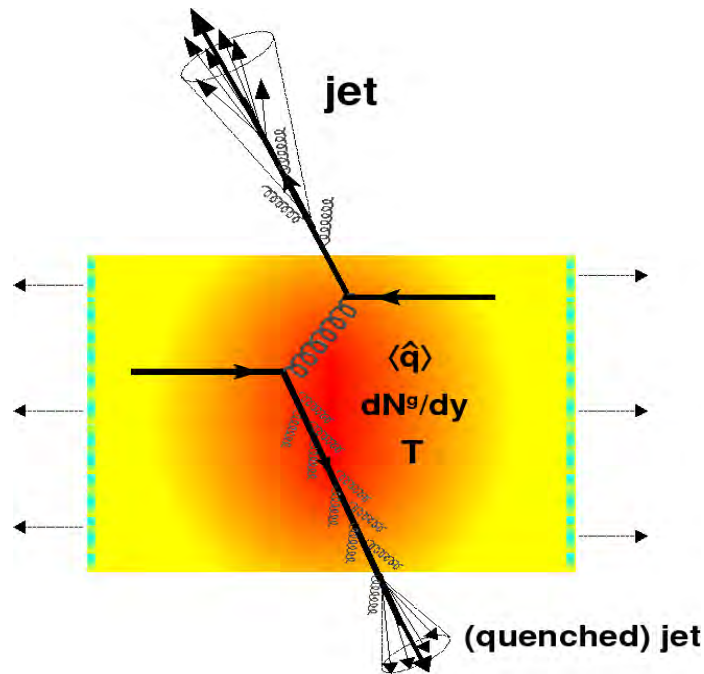
LS3 LHC: starting in 2023 => **30 months** + 3 BC

injectors: in 2024 => **13 months** + 3 BC

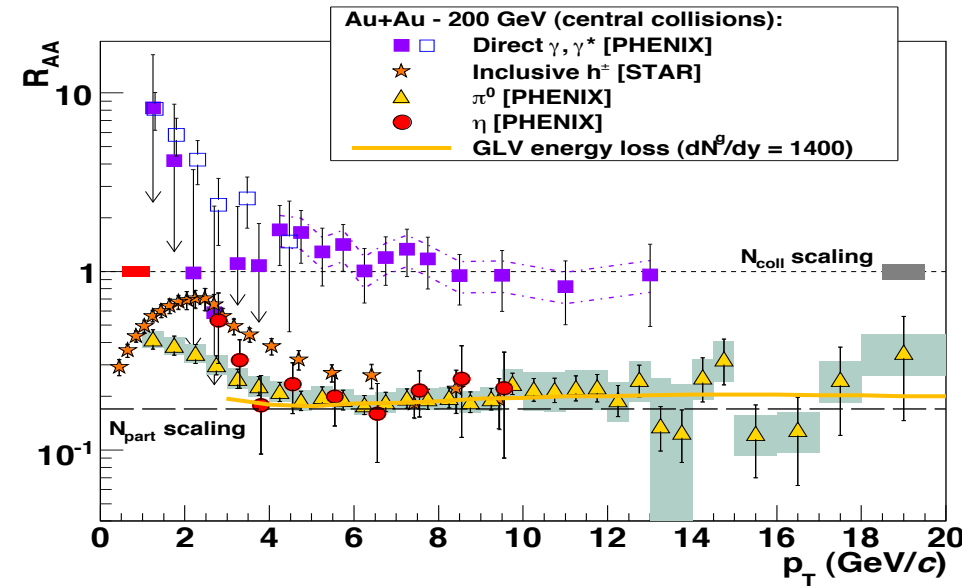


LHC schedule approved by CERN management and LHC experiments spokespersons and technical coordinators
Monday 2nd December 2013

Jet quenching (energy loss of parton in QGP)



$$R_{AA} = \frac{\text{"hot/dense QCD medium"}}{\text{"QCD vacuum"}} = \frac{dn_{AA}/dp_T dy}{\langle N_{\text{binary}} \rangle \cdot dn_{pp}/dp_T dy}$$



✓ 1) Decrease of high momentum particle yields

- No observation at lower colliding beam energy (e.g. SPS)

✓ 2) Disappearance of back-to-back jets

✓ Energy loss \sim few GeV/fm

- Cannot explained by hadron gas.

• → One of the evidences of QGP formation

