Exploitation of hard electro-magnetic probes and jets to study the QGP with LHC-ALICE

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2013 Joint Workshop of the France-Japan (TYL) and France-Korea (FKPPL) Particle Physics Laboratories

June 4, 2013

Yonsei University, Seoul,
Republic of South Korea

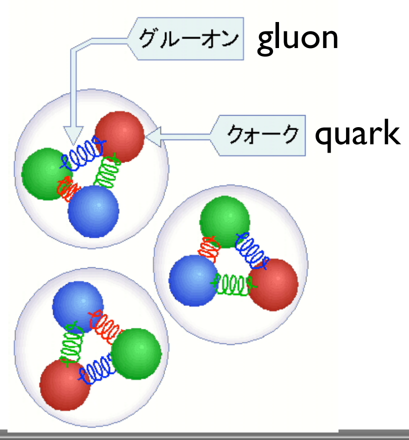
筑波大学
University of Tsukuba

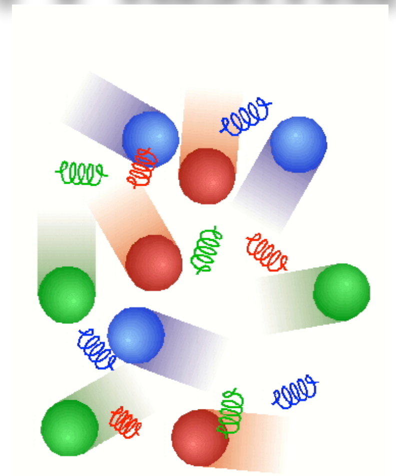
Outline

1. Introduction
2. What have we learned on QGP so far, and where we go?
3. ALICE experiment and Di-jet Calorimeter project
4. Proposal (LHC_05) in FY2013
5. Summary

1. Introduction

What is Quark Gluon Plasma (QGP)?





$$\mathcal{L} = -\frac{1}{4}G^a_{\mu\nu}G^{\mu\nu}_a + \bar{q}\gamma^\mu(i\partial_\mu - g t^a A^a_\mu)q - m\bar{q}q$$

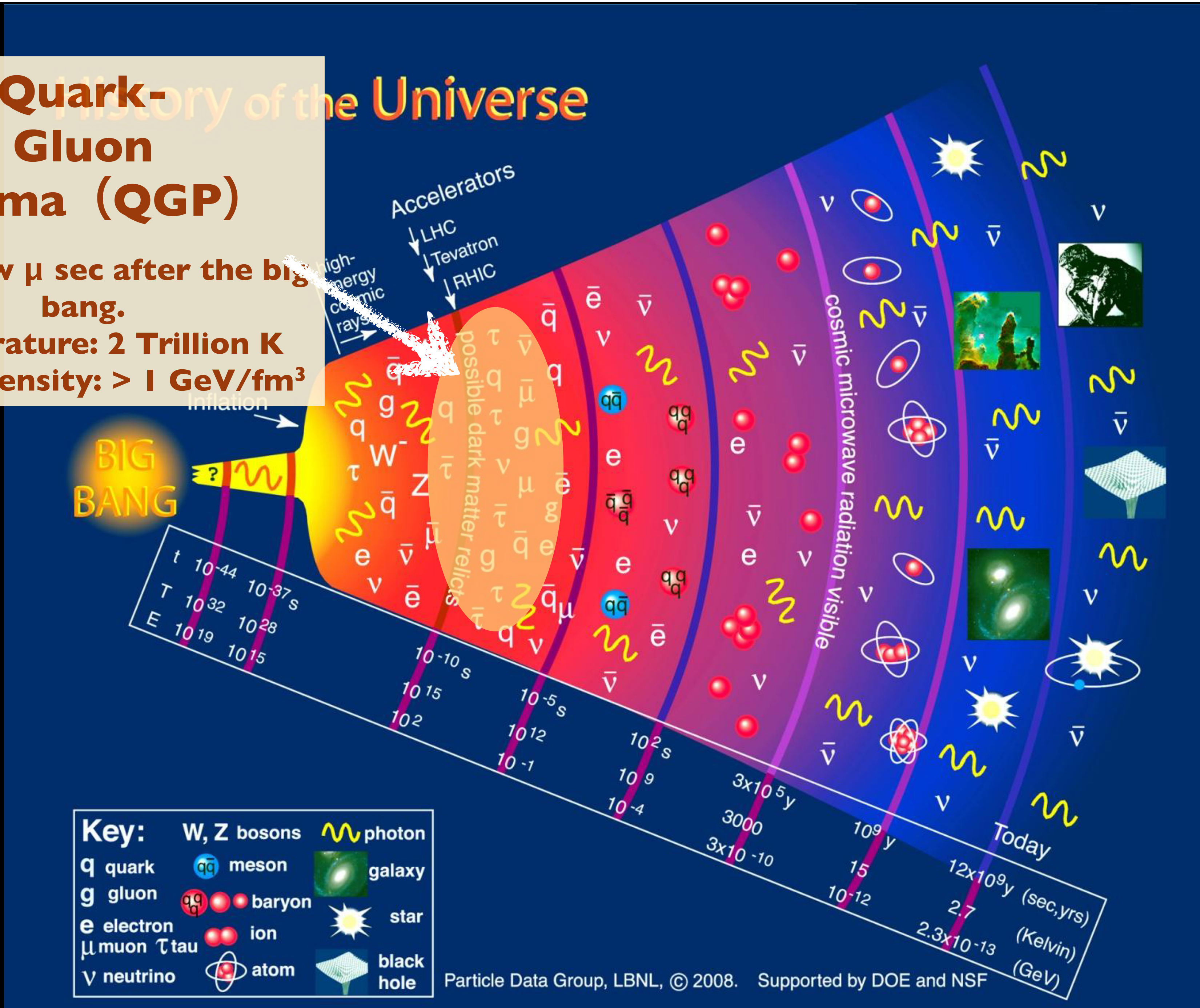
- De-confined state of quarks and gluon inside hadrons under the extremely high temperature and energy density
  - New and still unknown state of matter.
- Lattice QCD calculations:
  - Critical temperature: T_c = 150-200 MeV
  - Crossover phase transition from hadronic phase to parton phase.

Quark-Gluon Plasma（QGP）

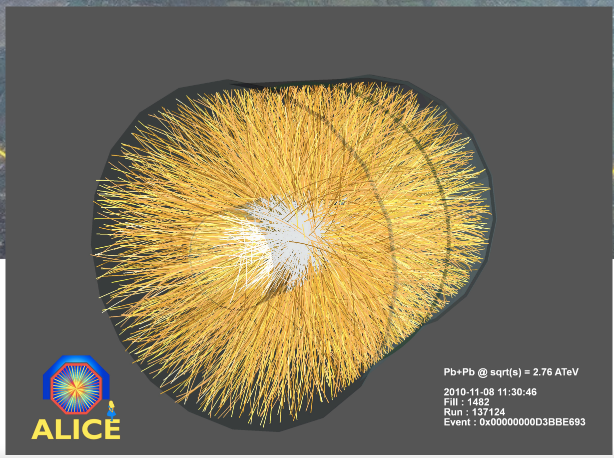
Time: few μ sec after the big bang.

Temperature: 2 Trillion K

Energy density: > 1 GeV/fm³

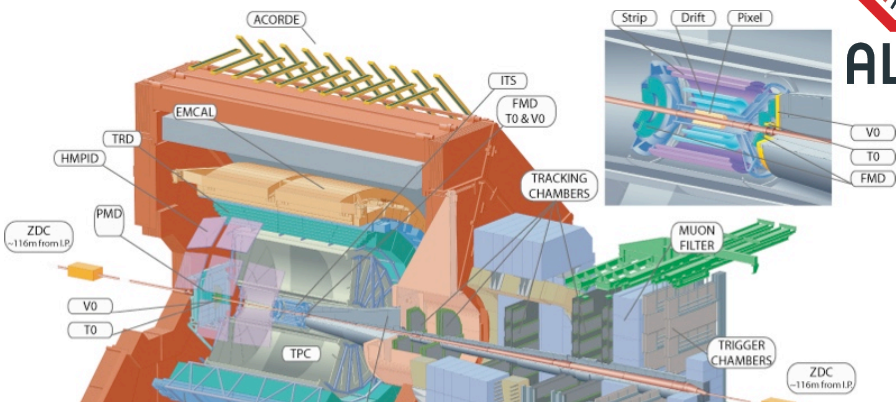


Experimental study on QGP by Relativistic Heavy Ion collisions



CERN-LHC (2009-), ring length ~27 km
$\sqrt{s_{NN}}$ = 2.76 (5.5 design) TeV Pb-Pb
2.76, 7.0, 8.0 TeV p-p
5.02 TeV p-Pb

ALICE

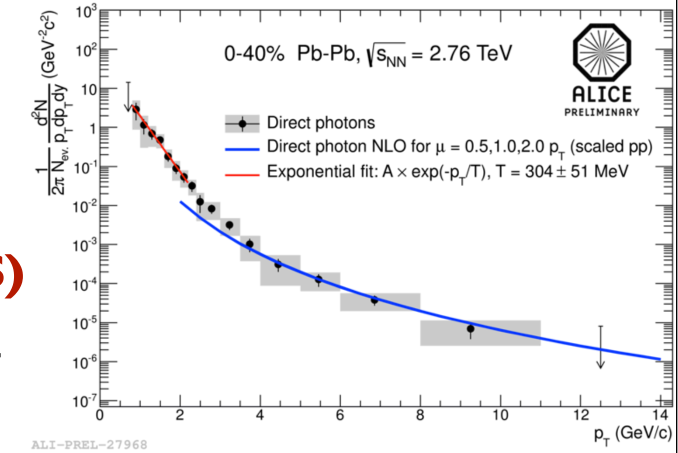


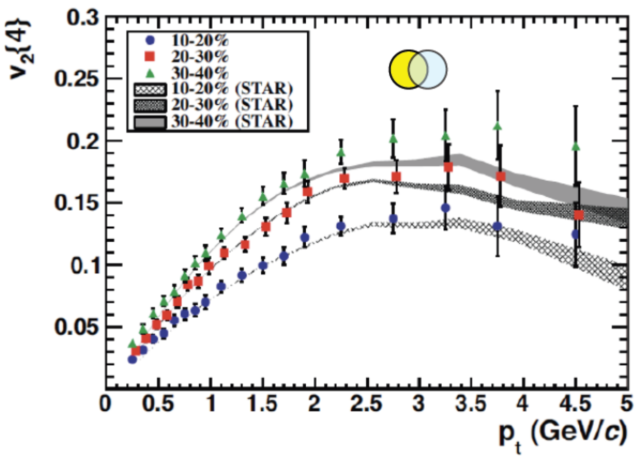
LHC-ALICE experiment:
36 countries, 129 institutions,
~1,000 collaborators.
The dedicated experiment to HI program
and QGP study at LHC

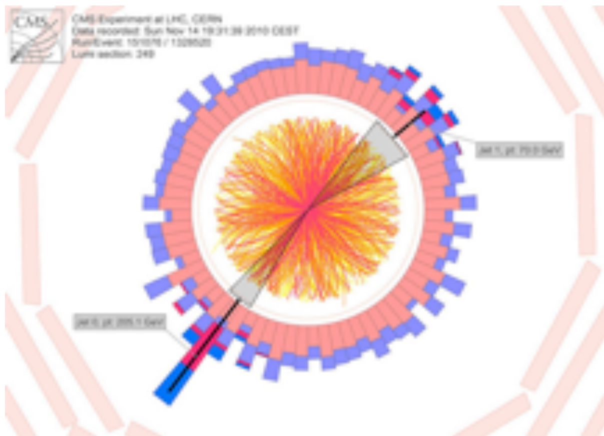
2. What have we learned on QGP so far, and where we go?

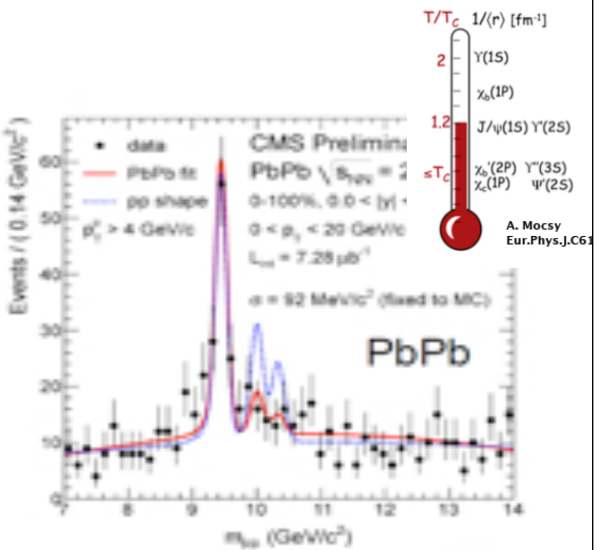
First three years of Heavy Ion Programs at LHC (Run-1 : 2009-2013)

- Initial temperature: T_{int} ~ 304 ± 51 MeV ~1.4 x T_{int} (RHIC).
- Large radial and elliptic flow (ALICE, ATLAS, CMS)
- **Large jet quenching effect (ALICE, ATLAS, CMS)**
- Disappearance of excited ϒ states (evidence for creation of high temperature matter, CMS)

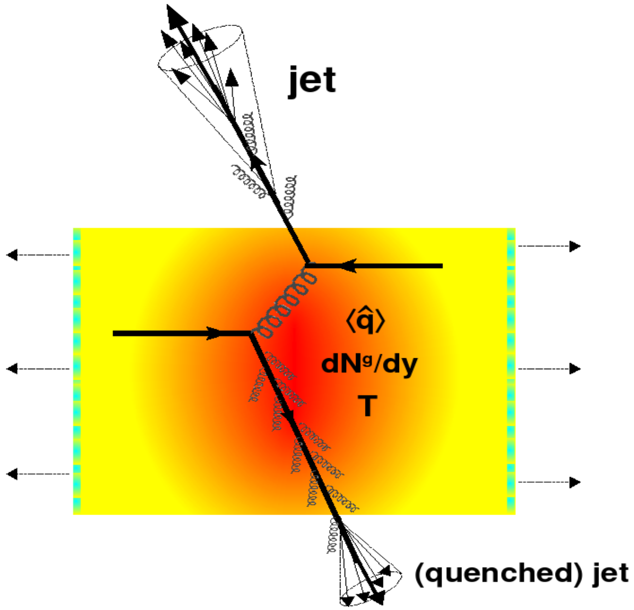




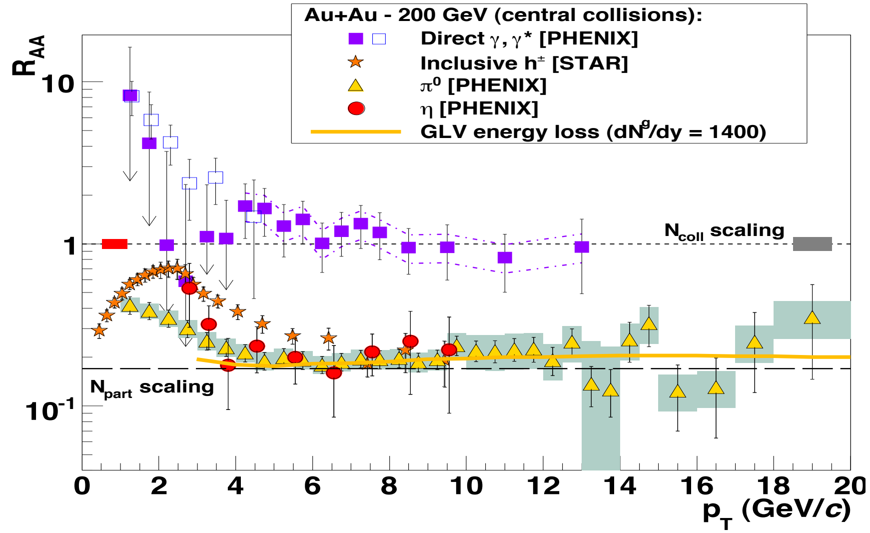


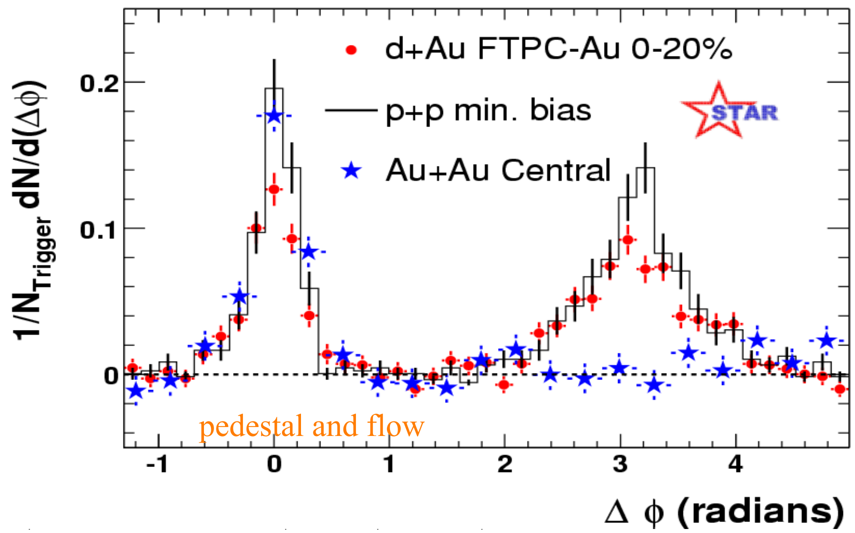


Jet quenching (energy loss of parton in QGP)



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

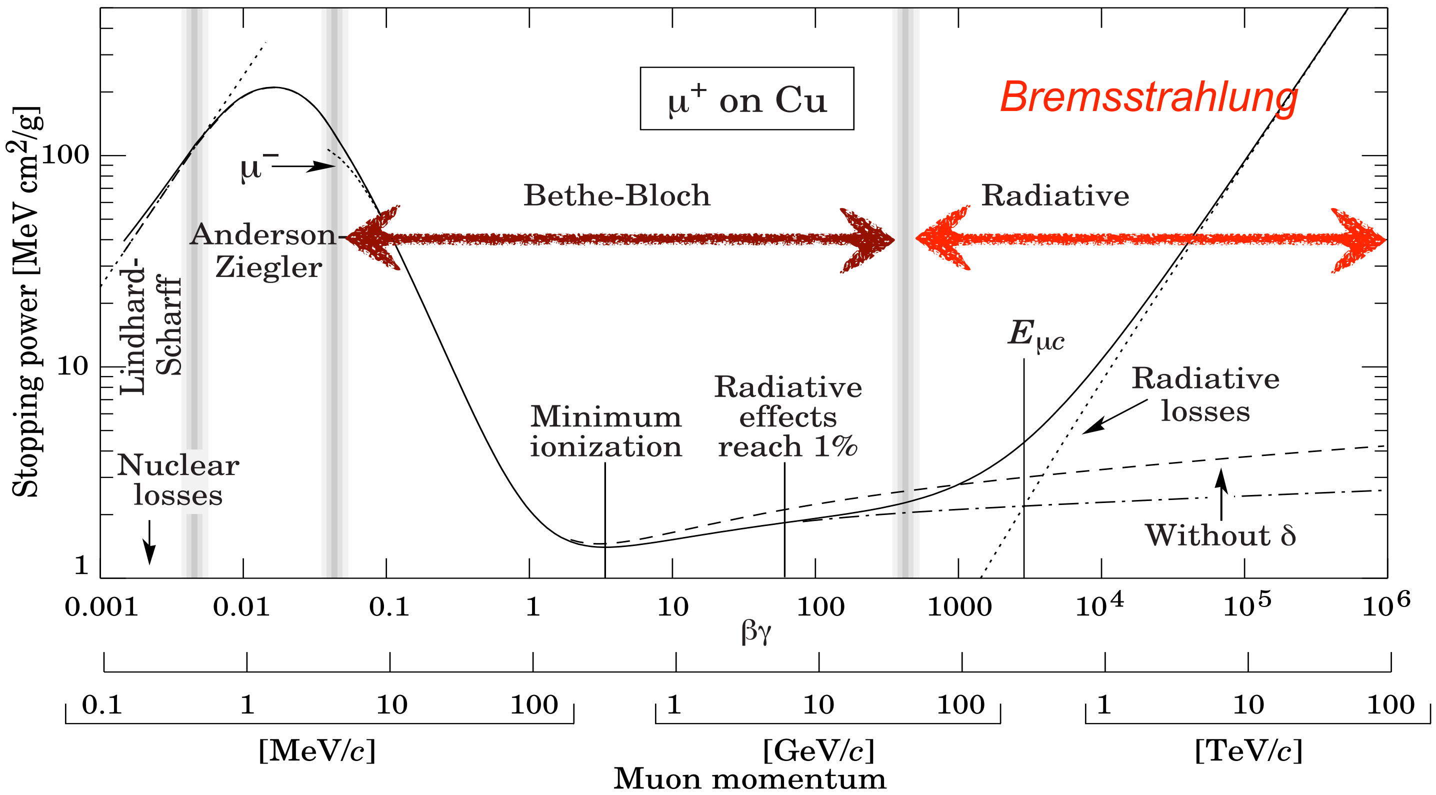




- ✓ 1) Decrease of high momentum particle yields
  - No observation at lower colliding beam energy (e.g. SPS)
- ✓ 2) Disappearance of back-to-back jets
- ✓ Energy loss ~ few GeV/fm
  - Cannot explained by hadron gas.
  - → One of the evidences of QGP formation

In case of QED...

Energy loss of charged particle in a matter



Collisional

- √ Bethe-Bloch

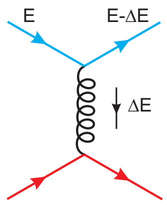
Radiative

- √ Bethe-Heitler (thin; L<<λ)
- √ Landau-Pomeranchuk-Migdal (thick; L>>λ)

√ **dE/dx measurement → determination of matter properties**

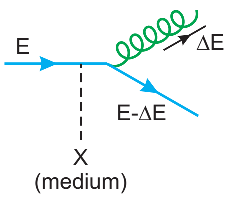
- **dE/dx in QED plasma → gives T & m_D**

In case of QCD:
Energy loss in QGP



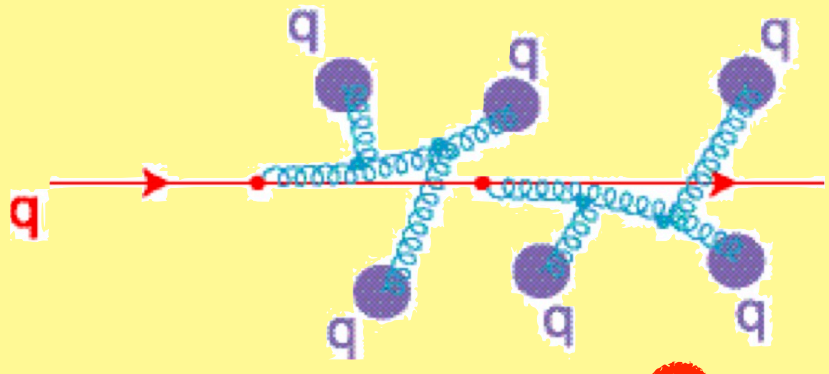
Collisional

$$\Delta E \propto \ell^1$$



Radiative

$$\Delta E \propto \ell^2$$



$$\Delta E \propto \alpha_S C_R \langle \hat{q} \rangle L^2$$

pQCD

- Dominant energy loss is gluon radiation

✓ **dE/dx meas. →Matter properties, jet tomography**

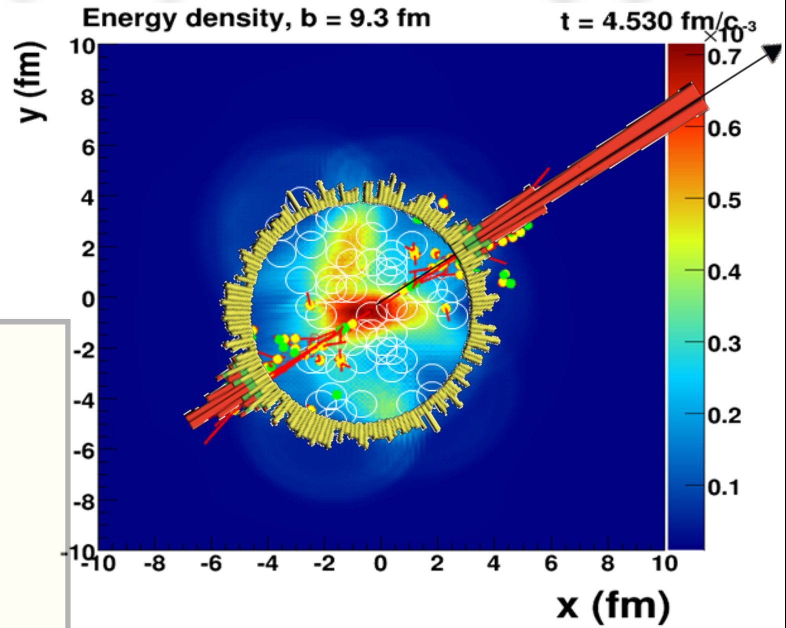
- **Jets and EM probes (photons):**

➡ **Powerful tools for the study of QGP's properties**

Revealing of **new** QGP properties by jet

At LHC energy:

- Hard processes dominant compared to that at RHIC.
- New measurements based on **jets**



1) QGP medium response by jet propagation.

2) Heavy quark jet, di-jet, gamma-jet.
→jet tomography.

3) Redistribution of lost energy, EOS, velocity of sound.

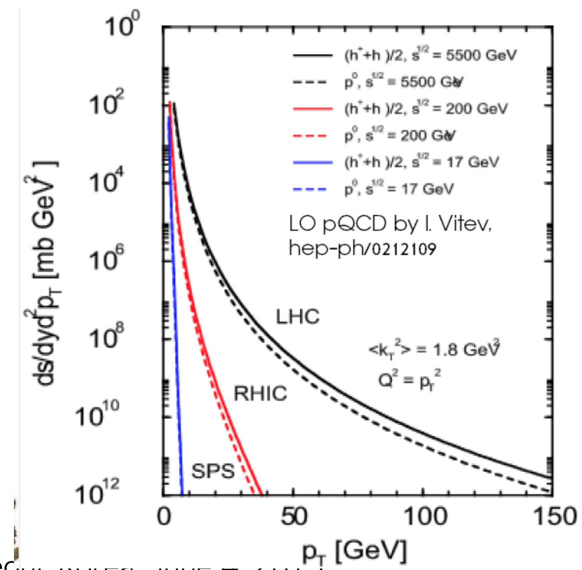
4) Interaction of heavy quark and strongly coupled QGP
→ (thermalization, interaction strength)

→ **ALICE Di-jet calorimeter (2015-)**

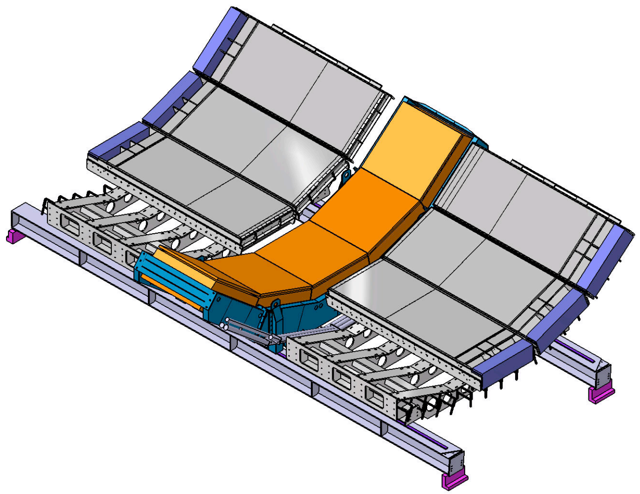
with soft particles

↓

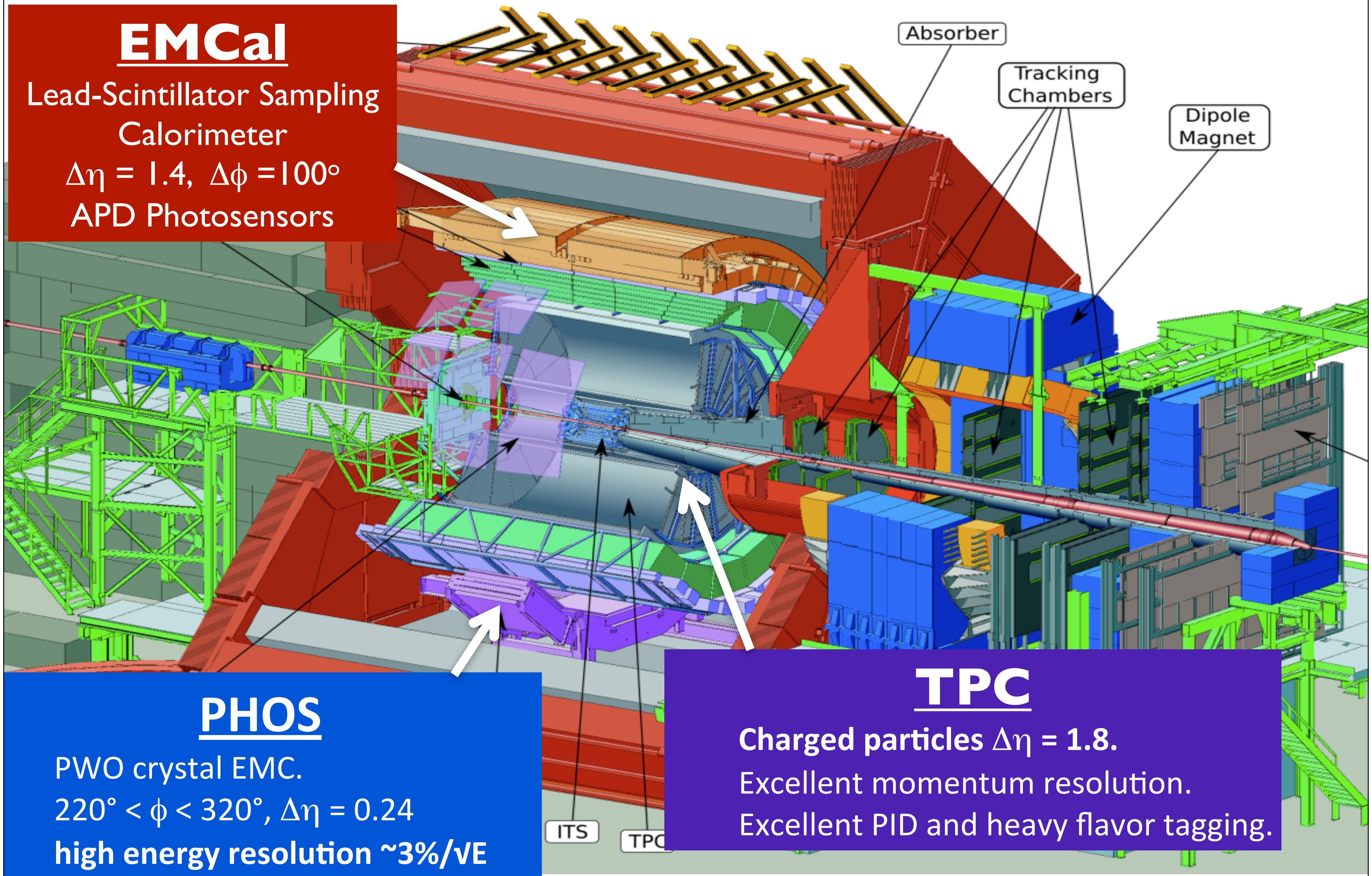
Unique measurements by LHC-ALICE



3. ALICE experiment and Di-jet calorimeter upgrade



ALICE experiment (Run-1, 2009-2013)



EMCal

Lead-Scintillator Sampling Calorimeter

$\Delta\eta$ = 1.4, $\Delta\phi$ =100°

APD Photosensors

PHOS

PWO crystal EMC.

220° < ϕ < 320°, $\Delta\eta$ = 0.24

high energy resolution ~3%/√E

γ trigger.

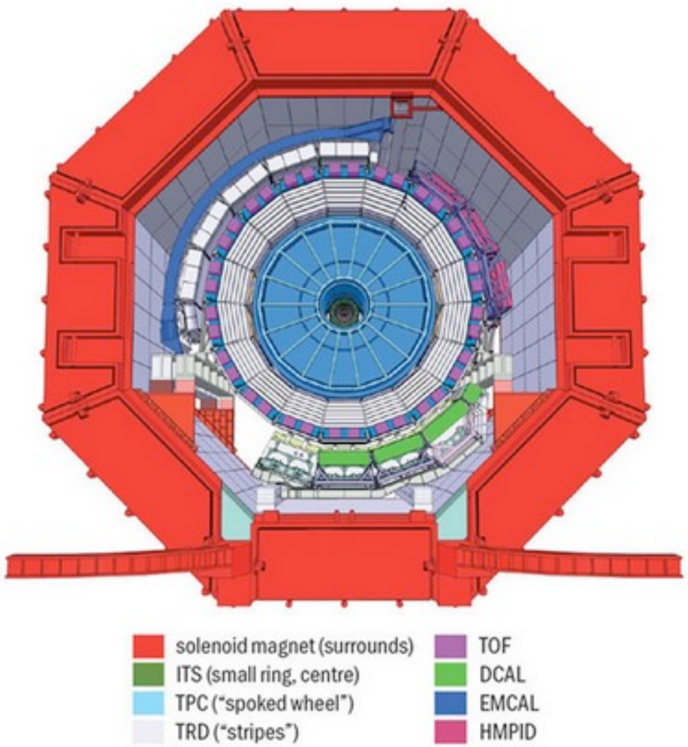
TPC

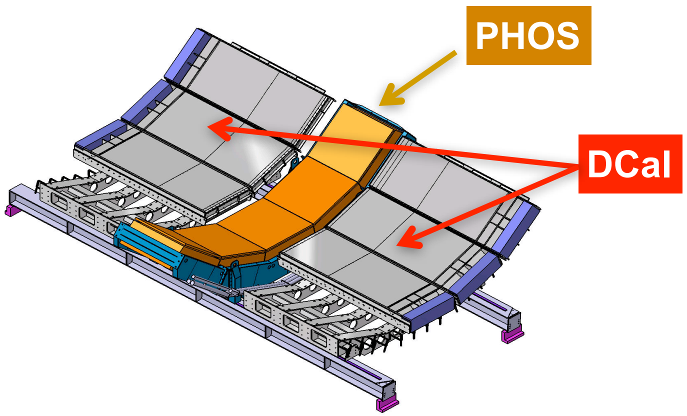
Charged particles $\Delta\eta$ = 1.8.

Excellent momentum resolution.

Excellent PID and heavy flavor tagging.

ALICE Dijet Calorimeter (DCal)





- Extension of the acceptance of EMCal .
- Lead-scintillator sampling type EMC with APD readout.
  - EMCal: $\Delta\phi$ = 113°
  - DCal: $\Delta\phi$ = 66° (on opposite side of EMCal→good uniformity, less sys. uncertainty)
  - $\Delta\eta$ = 0.7 for both EMCal and DCal + PHOS
  - Energy resolution: ~10%/$\sqrt{E}$
- Allow back-to-back hadron-jet, di-jet measurements in ALICE, with R = 0.4 jet cone radius, up to p_T ~ 150 GeV/c.
- Enhance jet, γ trigger capability.
- Full energy scale for γ: 250 GeV.

ALICE-DCal Collaboration

China
Huazhong Normal University (CCNU), Wuhan

Finland
University of Jyvaskyla

France
LPSC Grenoble, Subatech Nantes, IPHC Strasbourg

Italy
INFN Catania (Armando Palmeri, Angela Badala), LNF Frascati (Alessandra Fantoni)

Japan
Hiroshima University, University of Tokyo, University of Tsukuba

Switzerland
CERN

USA
Lawrence Berkeley National Laboratory, Wayne State University, University of Houston, University of Tennessee, Lawrence Livermore National Laboratory, Yale University, Oak Ridge National Laboratory, Creighton University, Cal Poly San Luis Obispo, Purdue University

France-Japan collaboration for ALICE-DCal (2008-)

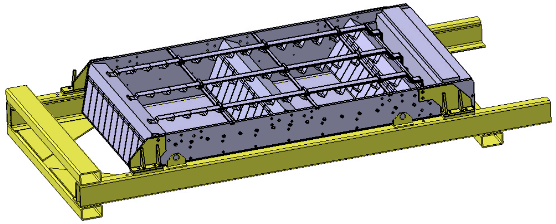
Institute & People

LPSC Grenoble (FR)
- Christophe Furget
- Jean-François Muraz

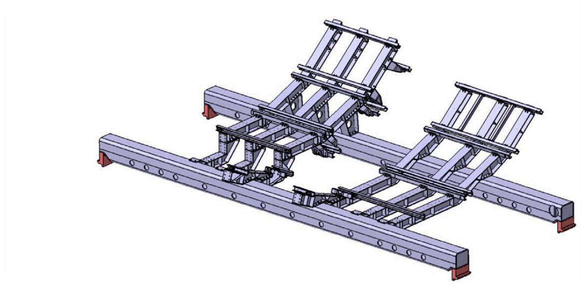
Subatech Nantes (FR)
- Manoel Dialinas
- Magali Estienne

IPHC Strasbourg (FR)
- Christelle Roy

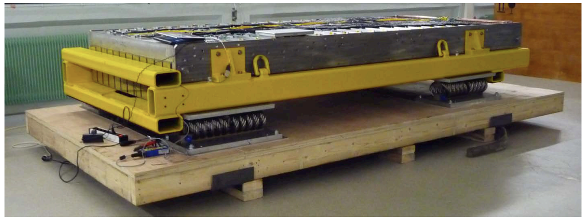
Tsukuba (JP)
- Y. Miake, S. Esumi, M. Inaba, T. Chujo



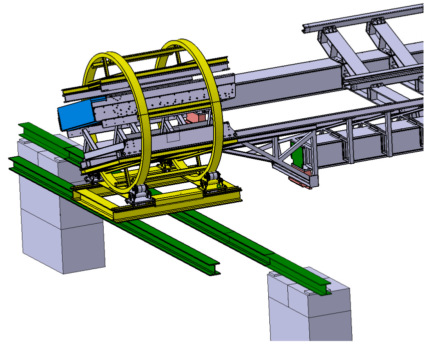
DCal SM platform (LPSC)



DCal support structure (Subatech)



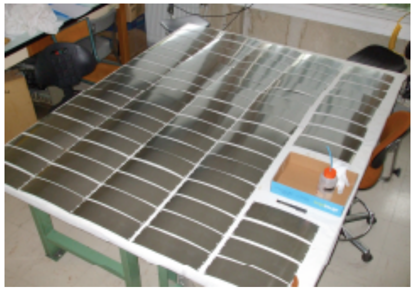
DCal SM shipping crate (LPSC)



DCal installation tool (Subatech

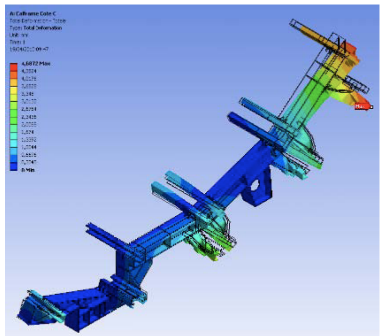
Contributions to DCal

LPCS Grenoble:
- module straps, SM cables, platform,
- shipping boxes, SM assembly, Calibration



DCal straps (LPSC)

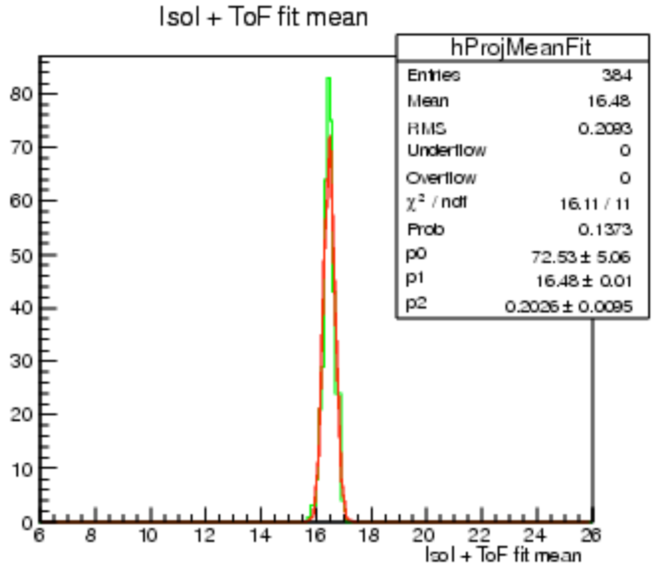
Subatech Nantes:
- DCal SM installation tool, support structure, integration
- DCal strip module production, DCal strong back



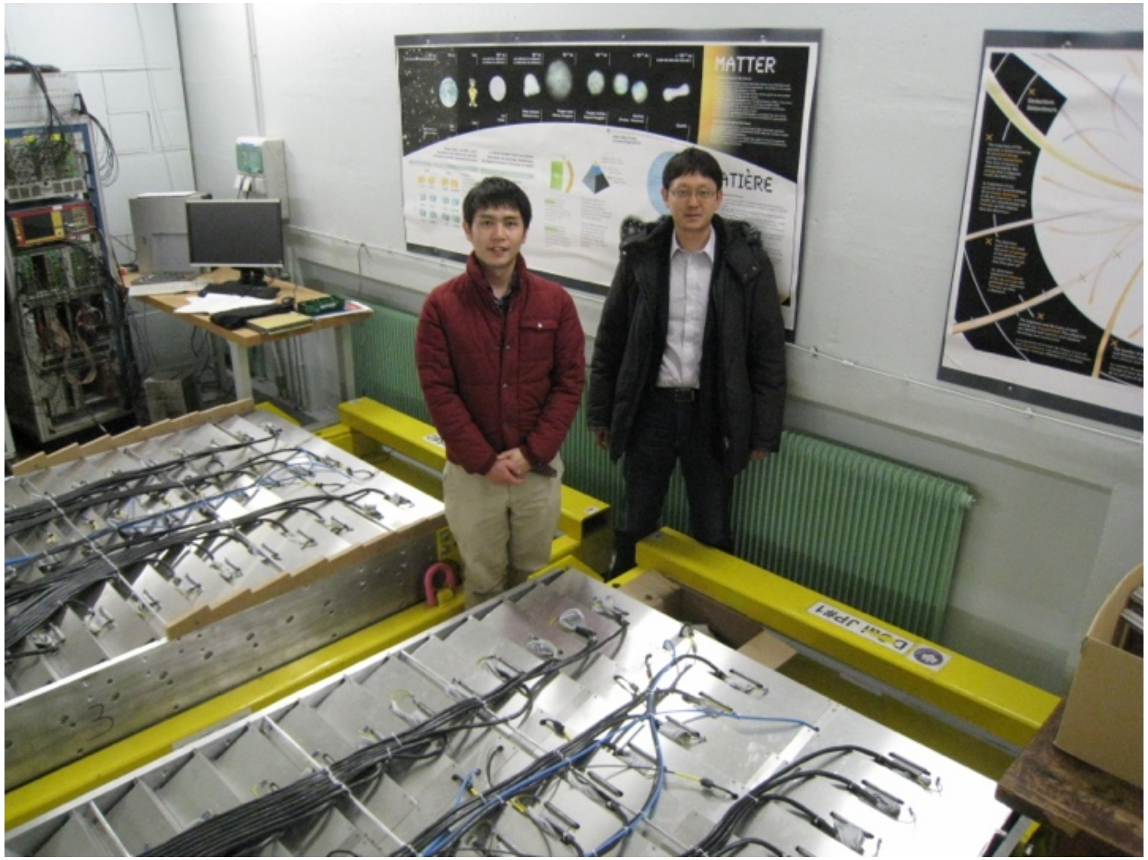
DCal weight cal. (Subatech)

Tsukuba:
- DCal module production (1 1/3 SM out of 6 + 2/3 SM)

All modules are stored in Grenoble & CERN.



←2012.12 (done by LPSC, Grenoble)
APD gain calibration (dispersion <1.2%)

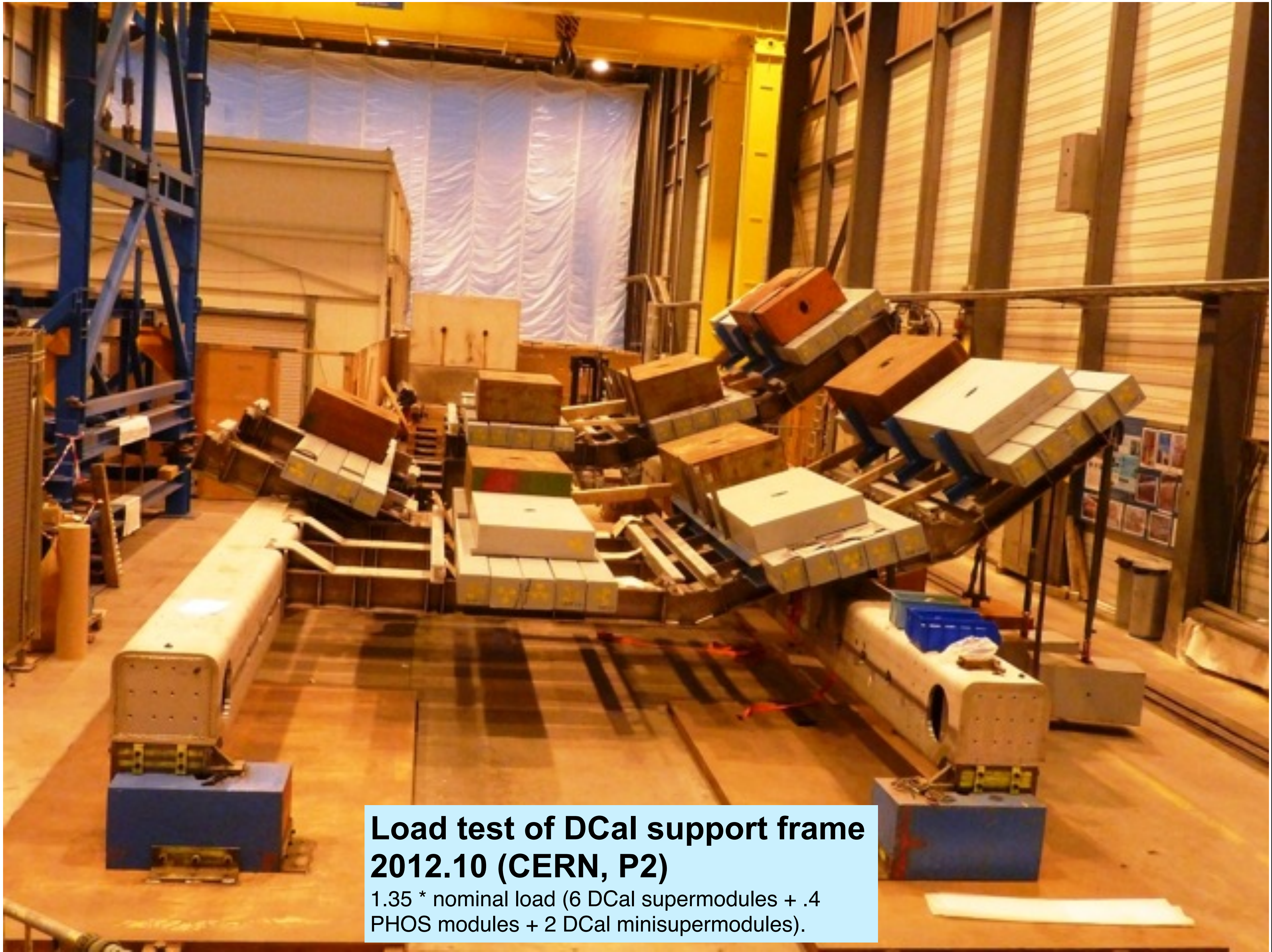


←2011.07 (@ Univ. of Tsukuba, final shipping prep.)

DCal Super modules 2013.03 (LPSC, Grenoble)

← DCal SM insertion test

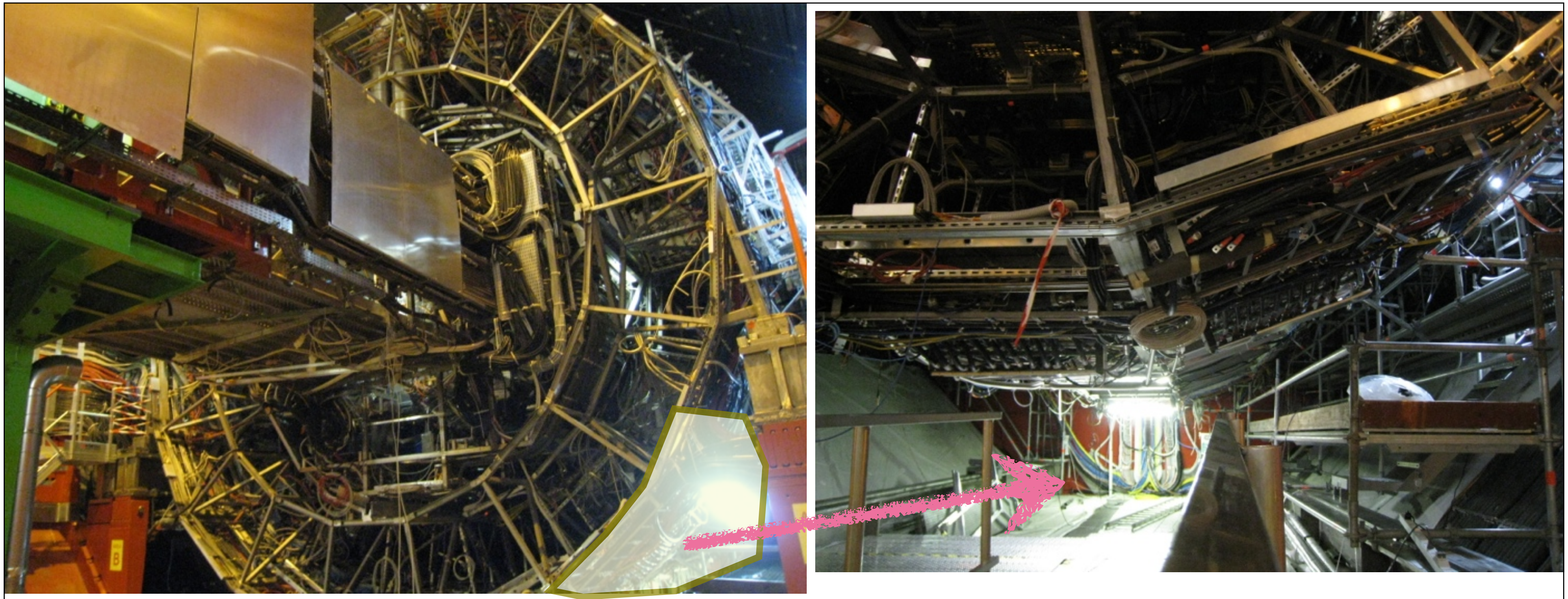
2013.05 (CERN, P2)



Load test of DCal support frame 2012.10 (CERN, P2)

1.35 * nominal load (6 DCal supermodules + .4 PHOS modules + 2 DCal minisupermodules).

DCal support frame
2013.05 (CERN, P2)
SM insertion test is underway.



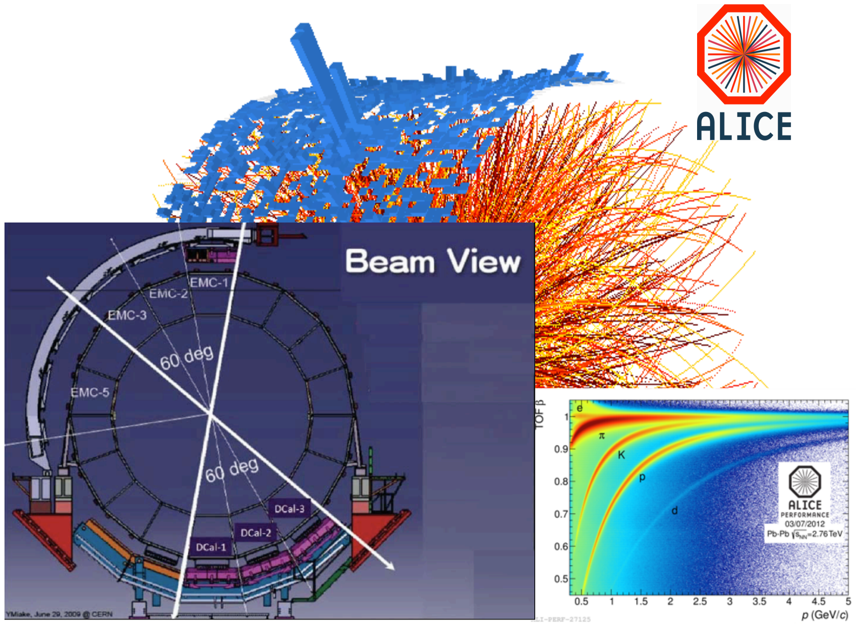
Space for DCal (and PHOS)

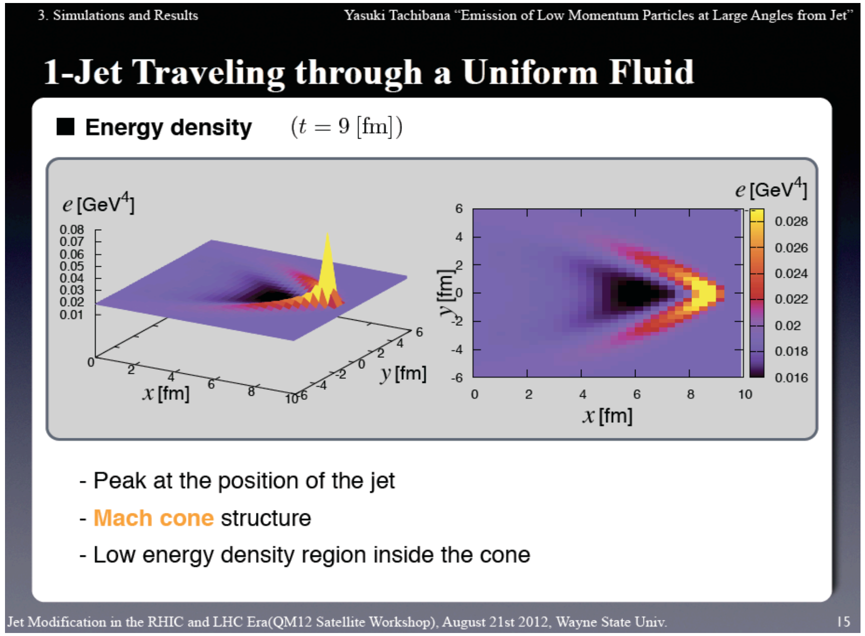
DCal installation schedule:

- Sep. - Oct. 2013: installation of 1st 3 SM + 1/3 SM (C-side).
- Dec. 2014 (TBD): installation of 2nd 3 SM +1/3 SM (A-side).
- **Physics data taking will start from LHC Run-2 (2015-).**

Perspective of physics with DCal:

Medium response with jets





3+1 hydro + jet (Tachibana, Hirano) QM2012

- Excellent **hadron PID** (0.15 – 20 GeV/c) and **photon ID**, suitable detector to measure the medium response with **jet ID triggered by EMCal**.
- Bulk properties (PID spectra, v_n, HBT, etc.) with a large **jet energy imbalance**.
- Key to access **c_s, EOS**?

4. Proposal (LHC_05) in FY2013

LHC_05 Members

FJPPL (TYL) application 2013-2014

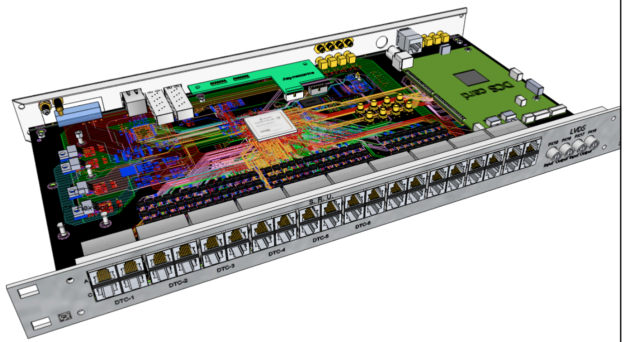
Fiscal year april 1st 2013 – March 31st 2014

In red are example to be replaced by the appropriate data in black

ID: LHC_05	Title: EXPLOITATION OF HARD EM PROBES AND JETS TO STUDY THE QGP WITH LHC-ALICE					
	French Group			**Japanese Group**		
	Name	**Title**	**Lab./Organis.** [2]	**Name**	**Title**	**Lab/Organis.** [3]
Leader Members	Leader: .Yves Schutz	DR1	SUBATECH	Leader: Yasuo Miake	Pr	U. Tsukuba
	Christelle Roy	DR2	IPHC	ShinIchi Esumi	Pr	U. Tsukuba
	Deputy leader. : Christophe Furget	Pr	LPSC	Tatsuya Chujo	Dr	U. Tsukuba
	Renaud Vernet	Dr	CCIN2P3	Deputy leader. : Toru Sugitate	Pr	U. Hiroshima
	Manoel Dialinas	IR	SUBATECH	Kenta Shigaki	Pr	U. Hiroshima
	Magali Estienne	CR1	SUBATECH	Hideki Hamagaki	Pr	U. Tokyo
	Gustavo Conesa	DR	LPSC	Taku Gunji	Dr	U. Tokyo
	Rachid Guernane	CR1	LPSC	Hisayuki Torii	Dr	U. Tokyo
	Julien Faivre	MC	LPSC	Motoi Inaba	Pro	U. Tsukuba Tech.

Activities in FY2012 (+FY2013)

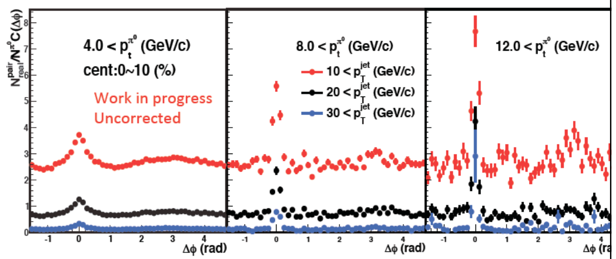
- DCal:
  - EMCal (DCal) new readout electronics, SRU (Scalable Readout Unit, SRU), tested at CERN and Tsukuba.
  - Installation and test of SRU at P2 (EMCal) (Apr-May, 2013).



SRU board for ALICE-EMCal/DCal

- Data analysis:
  - π^0-jet, hadron-jet correlations in p-p, Pb-Pb.
  - Developed analysis with Grenoble group.
    - One M2 student (Tsukuba) and a staff (TC) stayed at LPSC Grenoble (2 weeks, Mar. 2013)

➡ **FJPPL support in 2012**



π^0-jet correlations in p-p (D. Watanabe)

Our proposal in FY2013

Funding Request from France				
Description	€/unit	Nb of units	Total (€)	Requested to[4]:
Student stay in France	50/day	60 days	3000	
Visit to Japan	100/day	10 days	1000	
Travels	1500	1 travel	1500	
Total			5500	

Funding Request from KEK				
Description	k¥/Unit	Nb of units	Total (k¥)	Requested to:
Visit to France	10/day	30 days	300	KEK
Travels	150	4 travels	600	KEK
Total			900	

1) DCal installation and commissioning (including SRU readout) at CERN.

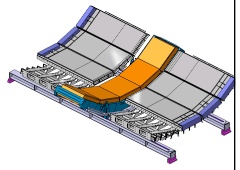
2)Collaboration with French Groups for jet/ direct photon analysis.

➡ FJPPL + JSPS-CRS bilateral research program (2013-2015, rep.TC)

➡ Plan to have a France-Japan mini-workshop on ALICE data analysis in Japan in this fall or winter.

✓ Request for funding for travels (Japan ⇔ France) and staying cost (both Japan, France)

Summary



✓ **ALICE Di-jet calorimeter (DCal) project is well proceeded, France-Japan collaboration keeps playing an important role in this project.**

- ✓ DCal will be installed during LS1 (2013-2014), and start physics data taking from LHC Run-2 (2015-).
- ✓ Expected unique physics programs using di-jet and photons with soft particles.
  - QGP medium response by jets, jet tomography, EOS etc..

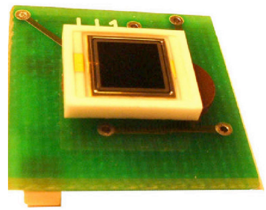
✓ **Requested travel support in FY2013 to keep this strong and excellent collaboration between France and Japan for both detector and data analysis in ALICE.**

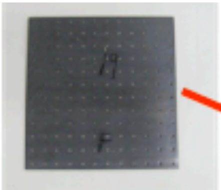
Back up slides

DCal Activities at Tsukuba (History, 2008-)

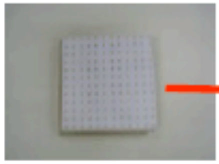
- Dec. 2008: Visited Wayne State Univ., and leaned how to build EMCal.
- Feb. 2009: DCal presentation to the ALICE Upgrade management.
- Mar. 2009: DCal presentation to the ALICE MB (also at ALICE upgrade forum).
- Jun. 2009: Official proposal submitted to ALICE MB/CB, **one SM approved.**
- Oct. 2009: ALICE MB/CB **approved 6B configuration.** The orders of the major components have been completed.
- Aug. 2010: All components delivered (delayed due to Scint. production).
- Oct. 2010: Started mass production at Tsukuba.
- Nov. 2010: Send materials to Catania, and assemble (2 people from Tsukuba)
- Nov. 2010: Catania team visited Tsukuba
- Feb. 2011: First shipping.
- (Mar. 2011): Earthquake
- May 2011: Restarted module assembly
- Jul. 2011: finished module assembly in Tsukuba, and shipped to Nantes.
- Aug.-Sep. 2011: Tsukuba people worked at Grenoble and Nantes.
- Feb. 2012: First Japanese DCal super module has been fully calibrated at Grenoble.

DCal components





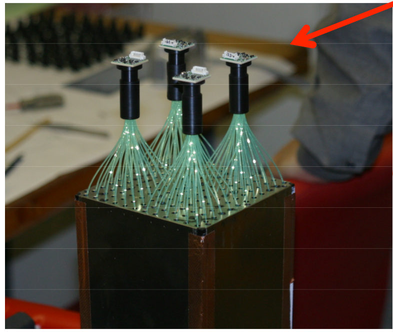
Lead



Paper

Scint.

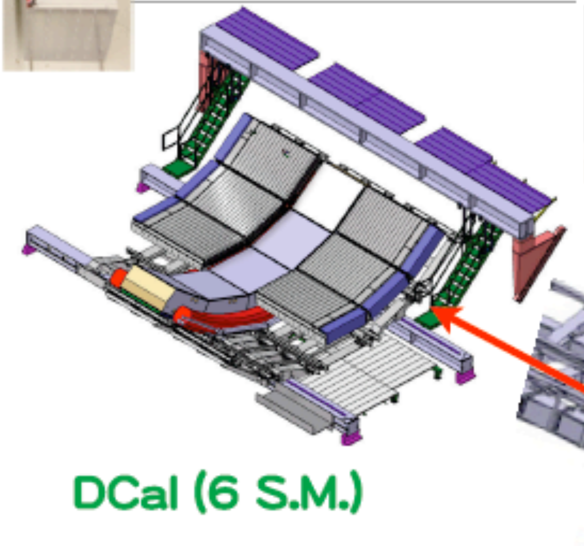
Module (77 layers)



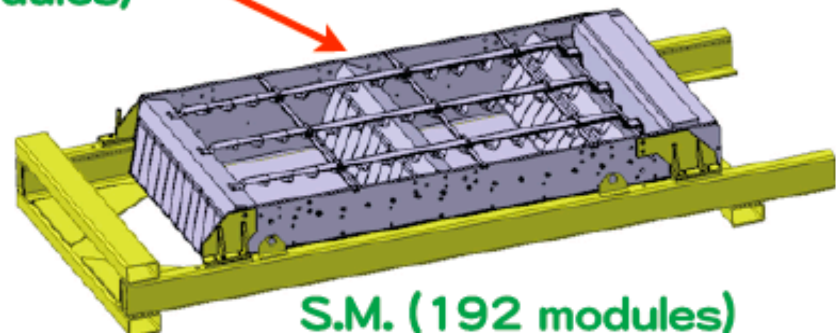
4 APD/module

Quantity	Value
Tower Size (at η=0)	~6.0 x ~6.0 x 24.6 cm^3 (active)
Tower Size	$\Delta\phi$ x $\Delta\eta$ = 0.0143 x 0.0143
Sampling Ratio	1.44 mm Pb / 1.76 mm Scintillator
Number of Layers	77
Effective Radiation Length X_0	12.3 mm
Effective Moliere Radius R_M	3.20 cm
Effective Density	5.68 g/cm^3
Sampling Fraction	10.5
Number of Radiation Lengths	20.1

Strip (12 modules)



DCal (6 S.M.)



S.M. (192 modules)