

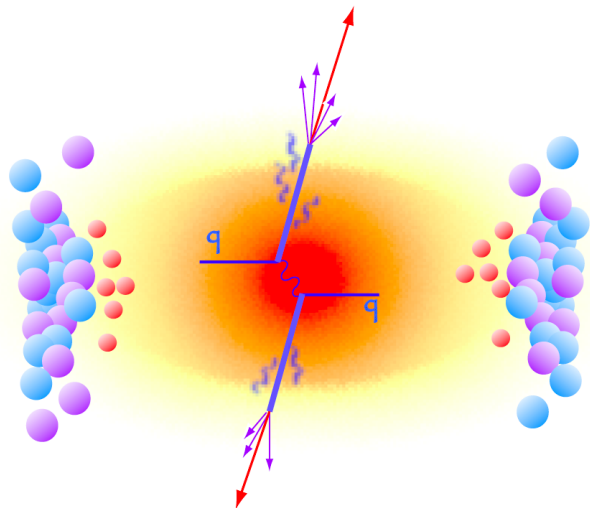
Electromagnetic calorimeter upgrade for the di-jet measurement in LHC-ALICE

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University of Tsukuba
(for the ALICE Collaboration)

Outline

- 1. Introduction (Physics motivation)**
- 2. Detector design**
- 3. Assembly procedure, status**
- 4. Detector performance**
 - PS/SPS beam test (2010)
 - LHC10/LHC11 data
- 5. Summary & Plan**

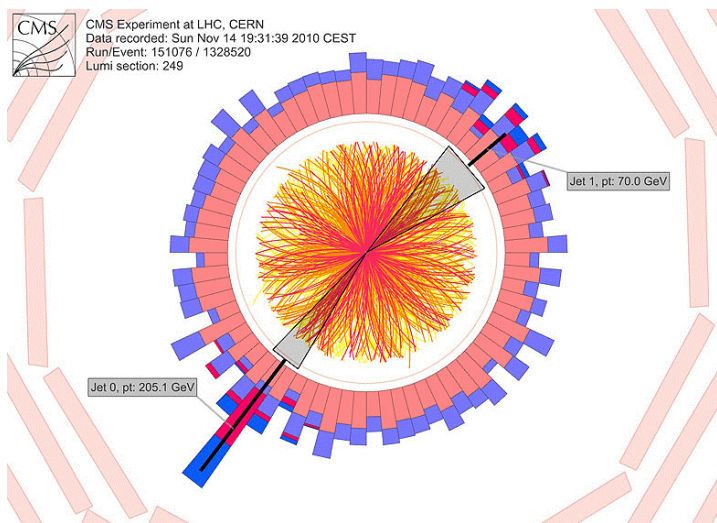
1. Introduction



- Primary Goal: To study and characterize the properties of hot, dense, deconfined matter (QGP) as produced in heavy ion collisions at LHC.
- Energy loss of parton (ΔE) in hot and dense medium.

Powerful probe: d-jets

- Importance of measurement of jet axis, and medium response by lost parton energy.
- Large acceptance EMCal to detect di-jet, with soft particle (<2 GeV/c) and PID.



di-jet (quenched) event in
Pb+Pb $\sqrt{s_{NN}} = 2.76$ TeV (CMS)

2. ALICE and DCal

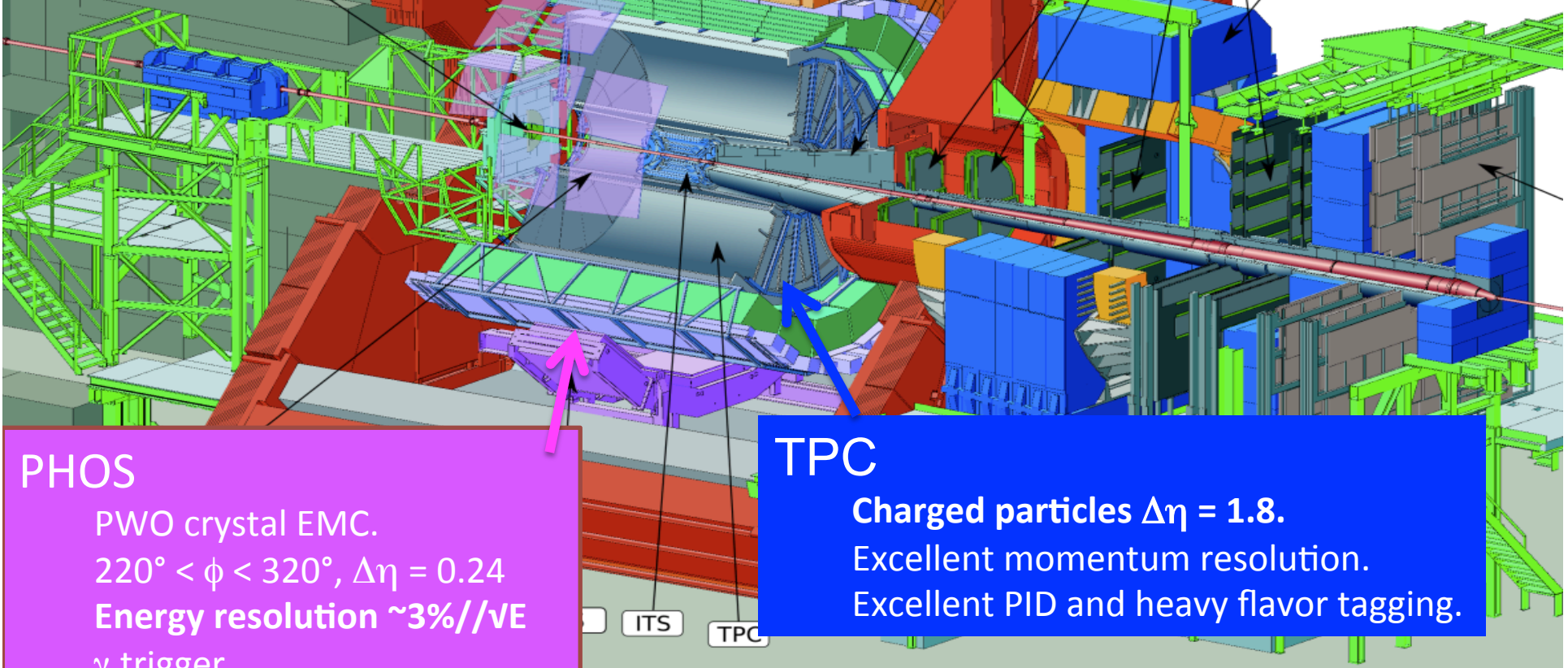
EMCal

Lead-Scintillator
Sampling Calorimeter
 $\Delta\eta = 1.4$, $\Delta\phi = 100^\circ$
APD Photosensor
11520 Towers

Absorber

Tracking
Chambers

Dipole
Magnet



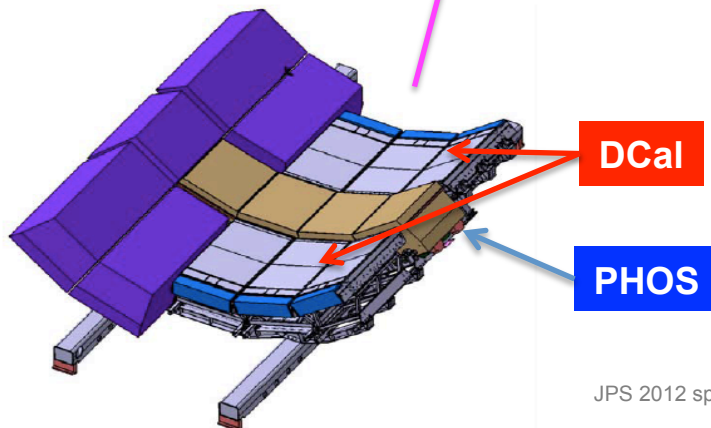
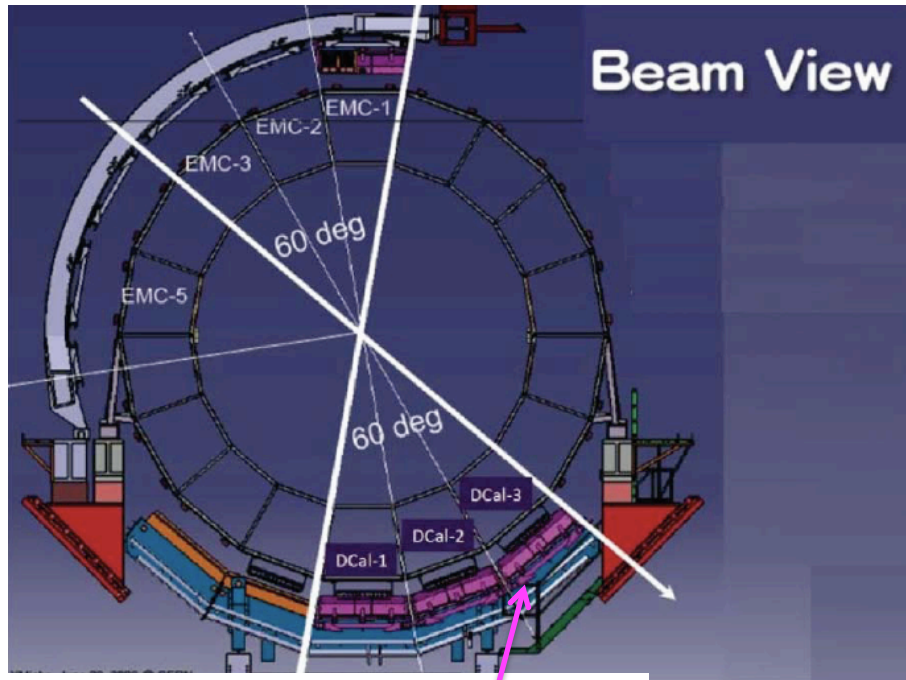
PHOS

PWO crystal EMC.
 $220^\circ < \phi < 320^\circ$, $\Delta\eta = 0.24$
Energy resolution $\sim 3\%/\sqrt{E}$
 γ trigger.

TPC

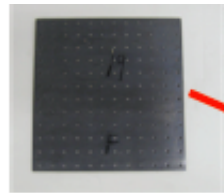
Charged particles $\Delta\eta = 1.8$.
Excellent momentum resolution.
Excellent PID and heavy flavor tagging.

ALICE Dijet Calorimeter (DCal)

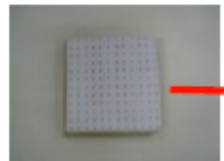


- **Extension of the acceptance of EMCal.**
- **Lead-scintillator sampling type EMC with APD readout.**
 - **EMCal: $\Delta\phi = 110^\circ$**
 - **DCal: $\Delta\phi = 60^\circ$ (on opposite side of EMCal \rightarrow good uniformity, less sys. uncertainty)**
 - **$\Delta\eta = 0.7$ for both EMCal and DCal + PHOS**
 - **Energy resolution: $\sim 10\%/\sqrt{E}$**
- **Allow back-to-back hadron-jet, di-jet measurements in ALICE, with $R = 0.4$ jet cone radius, up to $p_T \sim 150$ GeV/c.**
- **Enhance jet, γ trigger capability.**
- **Full energy scale for γ : 250 GeV.**

DCal components



Lead



Paper

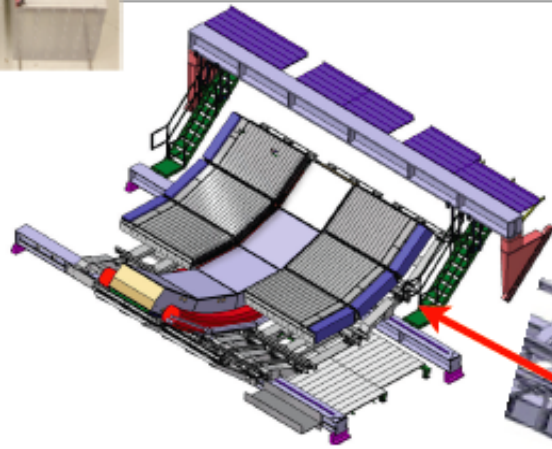
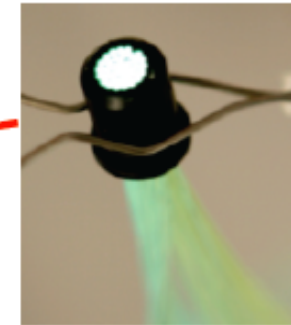
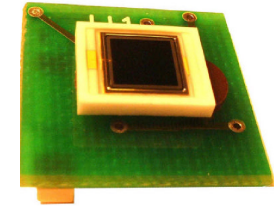
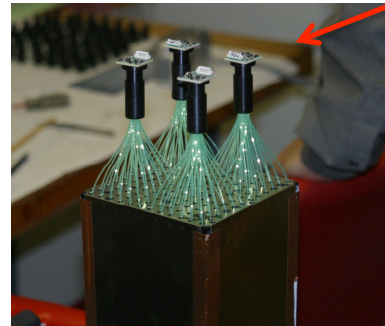


Scint.

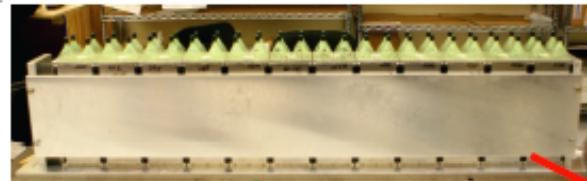


Module (77 layers)

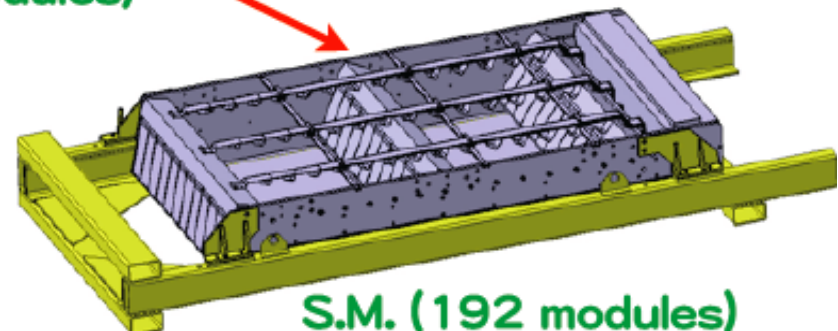
4 APD/module



DCal (6 S.M.)



Strip (12 modules)

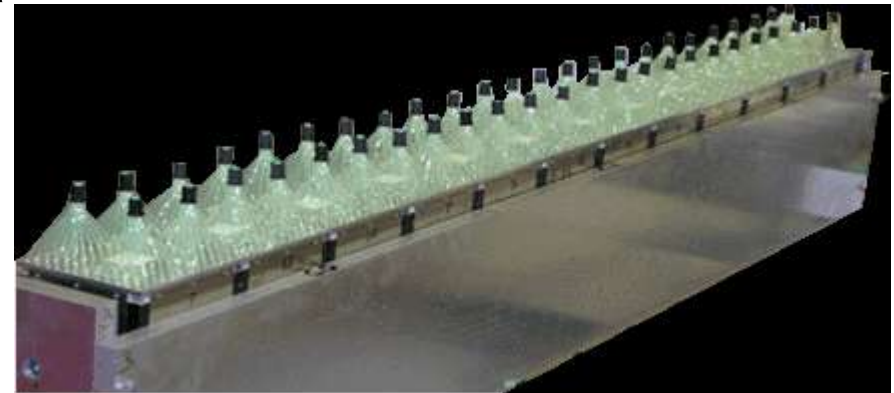
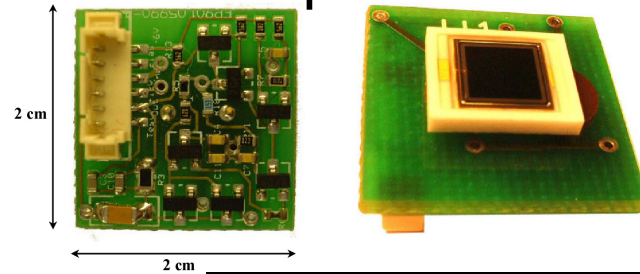


S.M. (192 modules)

Quantity	Value
Tower Size (at $\eta=0$)	$\sim 6.0 \times \sim 6.0 \times 24.6 \text{ cm}^3$ (active)
Tower Size	$\Delta\phi \times \Delta\eta = 0.0143 \times 0.0143$
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

DCal Readout

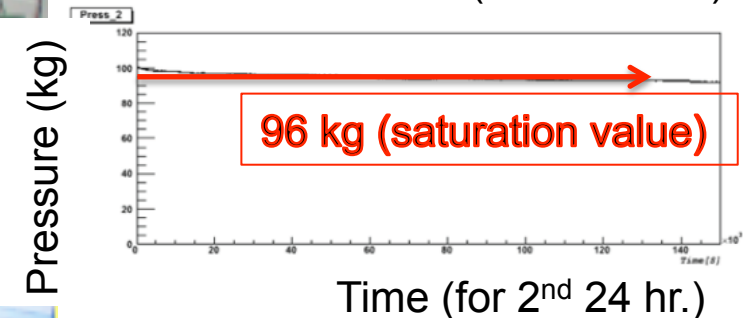
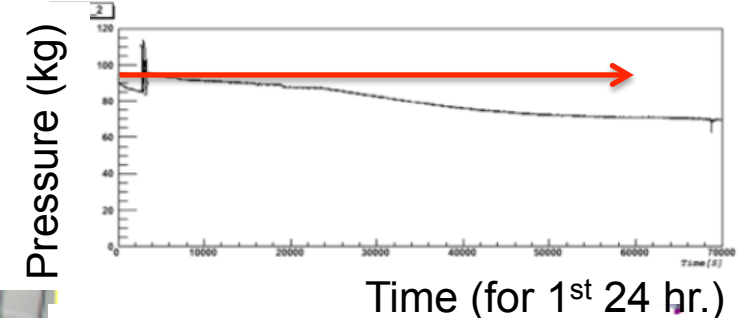
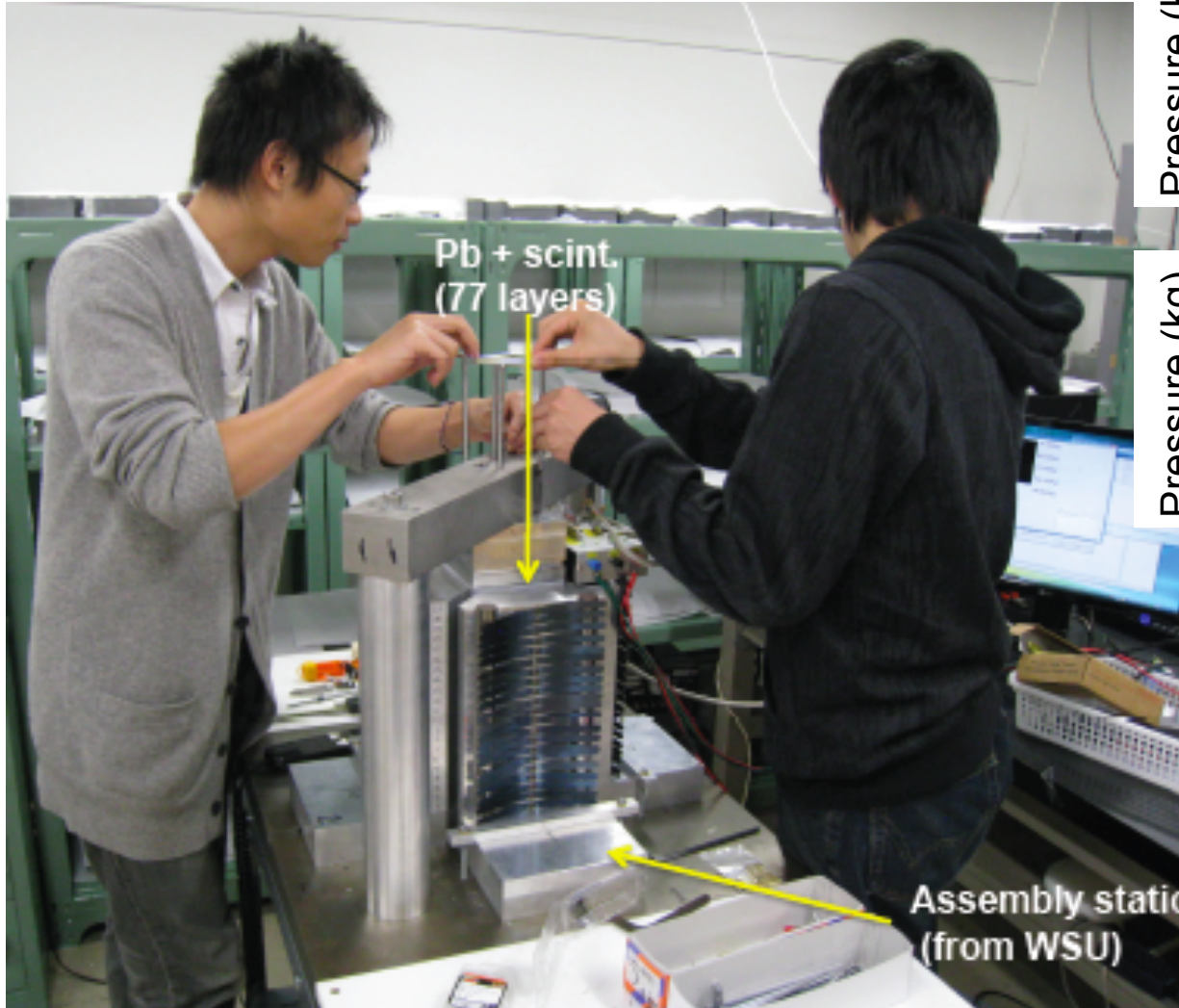
Preamplifier+APD



- 4 6x6 cm² towers/module
- WLS fiber readout on 1cm grid
- 5x5 mm² Hamamatsu and Perkin Elmer APDs
- ~4.5 photo-electrons/MeV at gain M=1
- Operated at nominal gain M=30
- Full scale Energy = 250 GeV

3. Assembly procedure

Press station with pressure monitoring system



Module check before shipping
(Feb. 2011, Tsukuba)

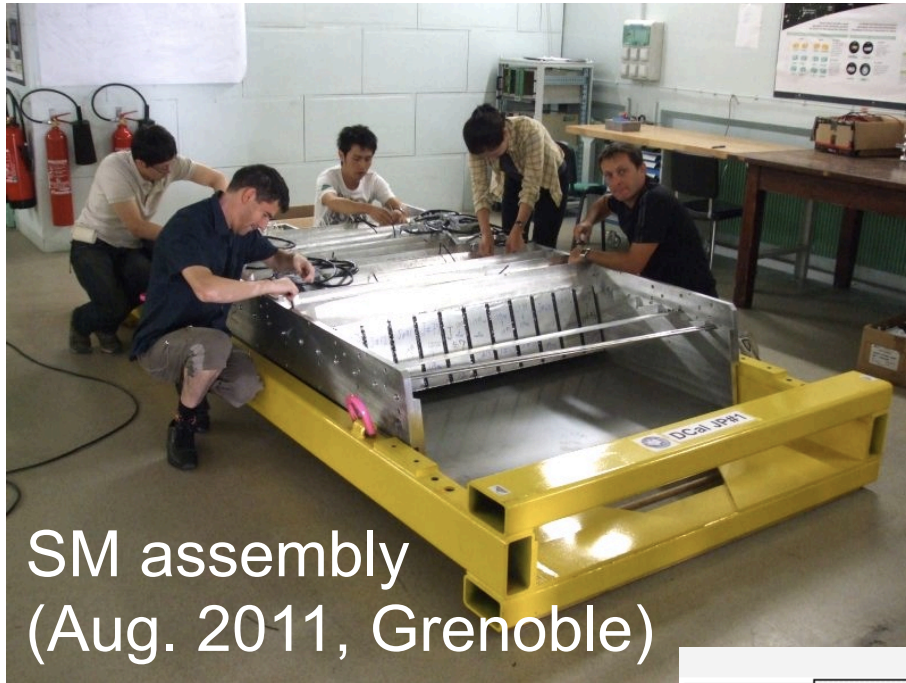


Shipping prep. completed
(Jul. 2011, Tsukuba)



Shipped to Nantes, France
(Jul. 2011, Tsukuba)

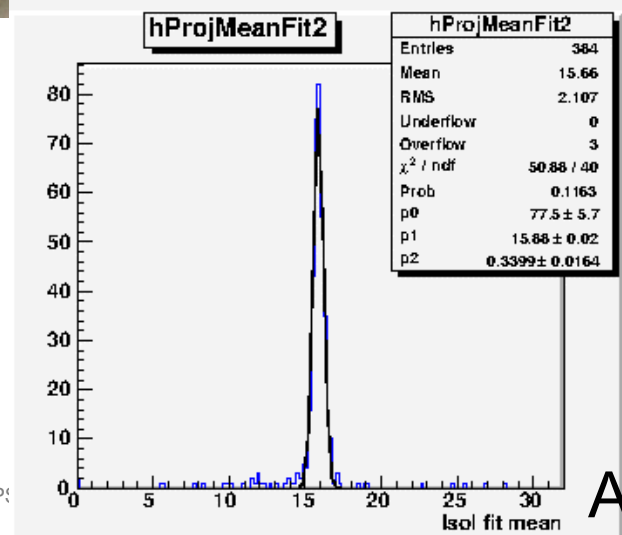
SM assembly, APD gain calibration @ LPSC Grenoble, France



SM assembly
(Aug. 2011, Grenoble)



APD gain calibration
(Aug. 2011, Grenoble)

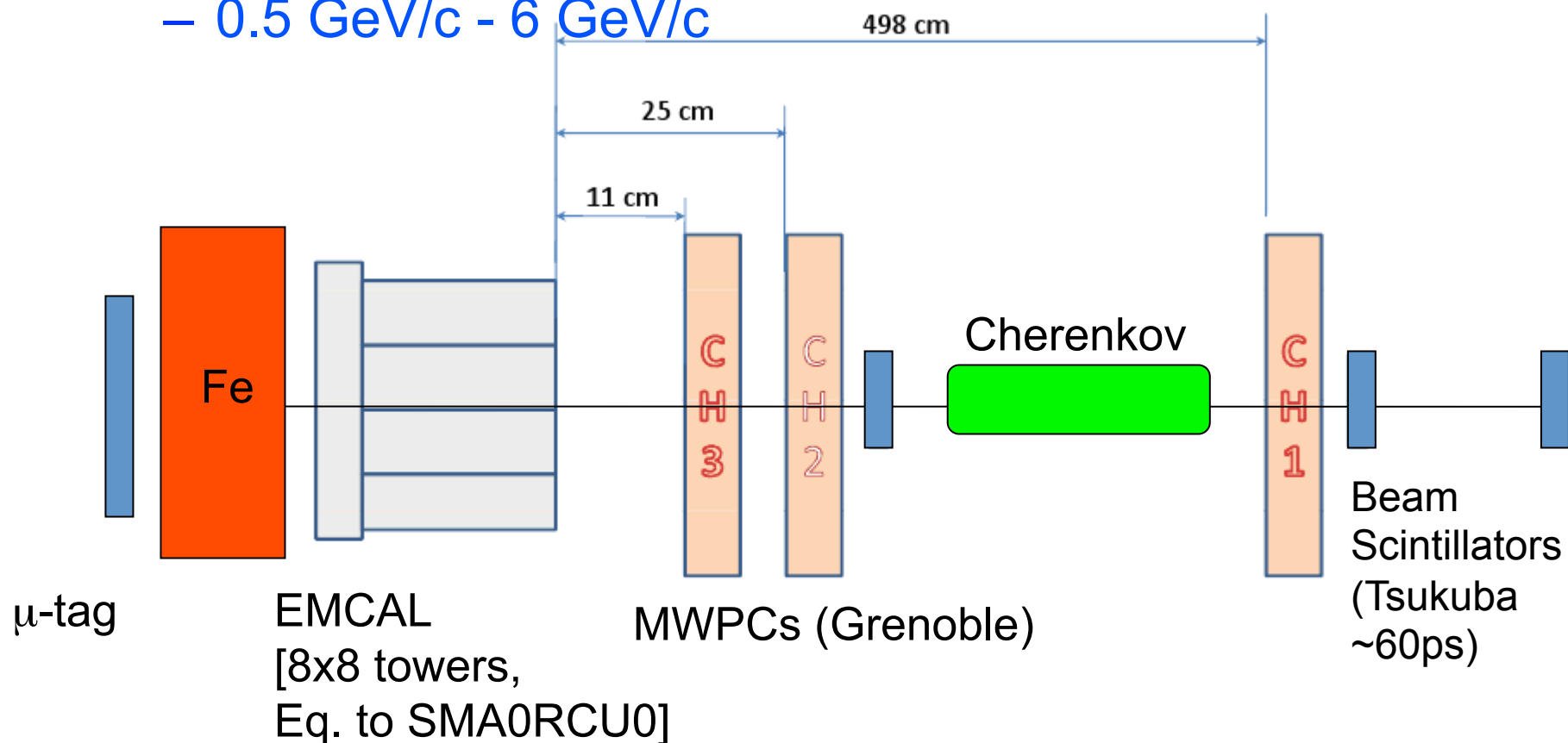


APD Gain dispersion
w/ cosmic ray (MIP):
~ 2% for 384 ch.

APD gain (ch)

EMCal/DCal PS Beam Config.

- PS beam period in T10 beamline August 2-16, 2010
 - 0.5 GeV/c - 6 GeV/c



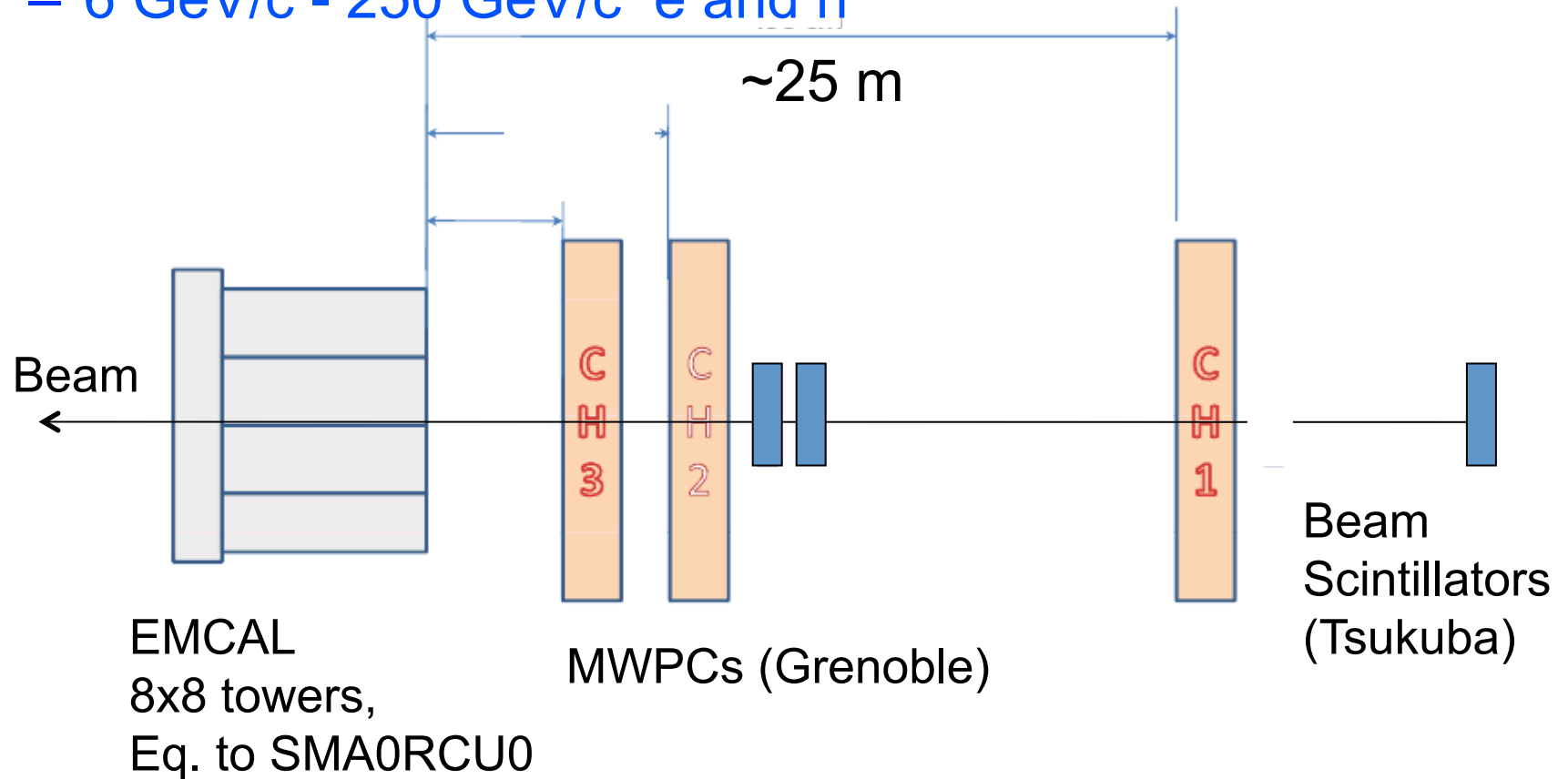
January 27, 2011

JPS 2012 spring meeting, Kwansai Gakuin Univ., March 26, 2012 (T. Chujo)

Beam Test, T.Awes

EMCal/DCal SPS Beam Config.

- SPS beam period in H4 beamline August 23-30, 2010
 - 6 GeV/c - 250 GeV/c e and h

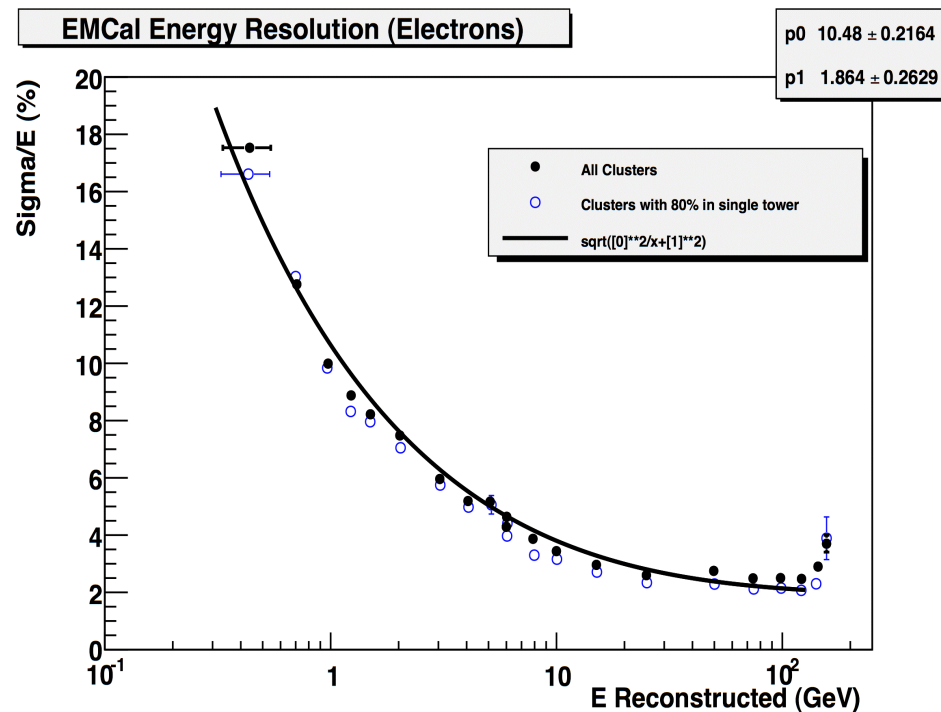


January 27, 2011

JPS 2012 spring meeting, Kwansai Gakuin Univ., March 26, 2012 (T. Chujo)

Beam Test, T.Awes

4. Detector Performance

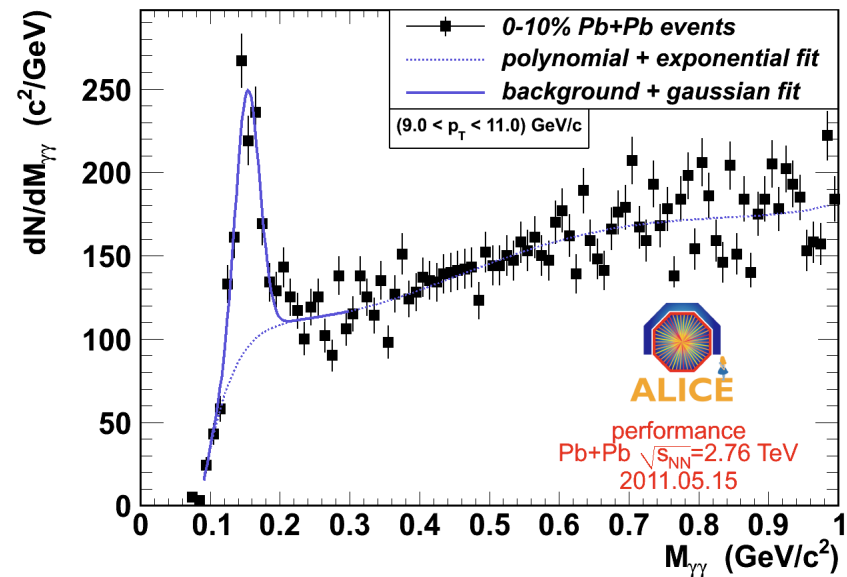
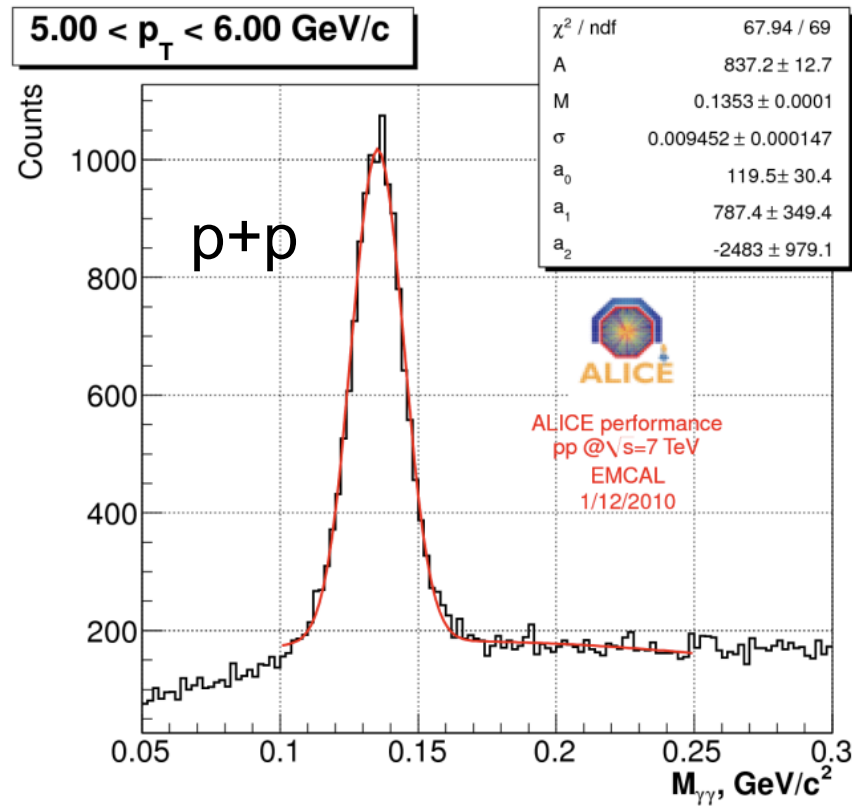


$$\frac{\sigma}{E} = \frac{10.5\%}{\sqrt{E}} \oplus 1.9\%$$

$$\sigma_x = \frac{5.3}{\sqrt{E}} \oplus 1.5\text{mm}$$

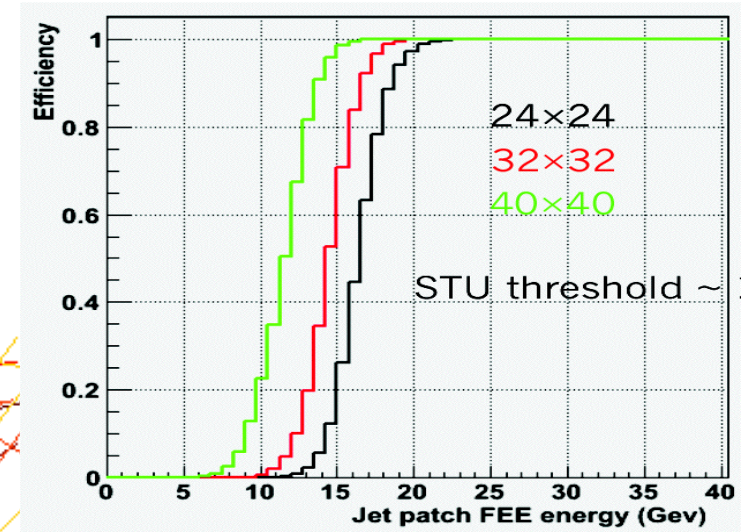
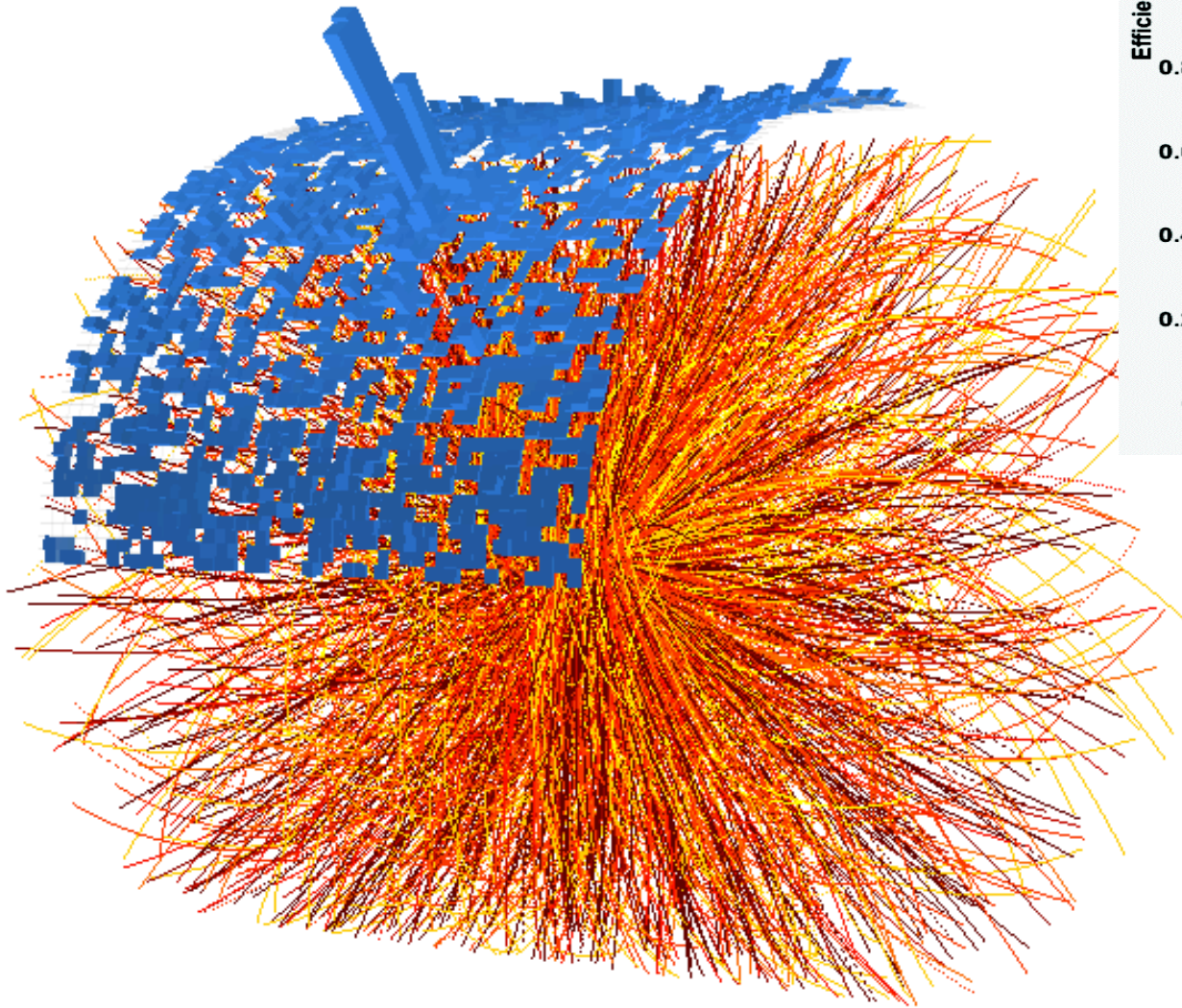
- PS beam period in T10 beamline August 2-16, 2010
 - 0.5 GeV/c - 6 GeV/c
- SPS beam period in T2-H4 beam for 7 days August 23-30, 2010
 - 6 GeV/c - 250GeV/c

Invariant mass for π^0 in p+p 7.0 TeV p+p and Pb+Pb 2.76 TeV Pb+Pb



10% most central Pb+Pb
 $dN_{ch}/d\eta \sim 1600$

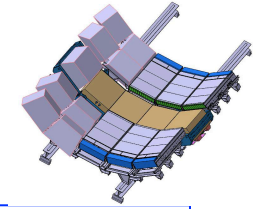
Jet Measurements in 2.76 TeV Pb+Pb (LHC11)



L1 jet trigger

Jet energy with
EMCal + TPC
tracking

- For 2011 run, all of EMCal is installed and trigger was in use.



5. Summary and plan

- **DCal in ALICE provides a powerful tool to investigate QGP through dijet and photon.**
- **All module production for DCal has been completed (1,344 modules).**
- **SM assembly is on going at Grenoble, France.**
- **DCal will be installed in ALICE during the LHC long shutdown (2012-2014), will be ready to take full energy 5.5 TeV Pb+Pb run.**
- **Detector performance for jet and gamma is promising.**

ALICE-DCal Collaboration



China

Huazhong Normal University (CCNU), Wuhan



Finland

University of Jyvaskyla



France

LPSC Grenoble, Subatech Nantes, IPHC Strasbourg



Italy

INFN Catania, LNF Frascati,



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

