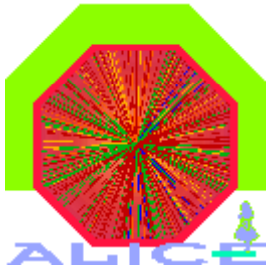
The ALICE PHOS Calorimeter

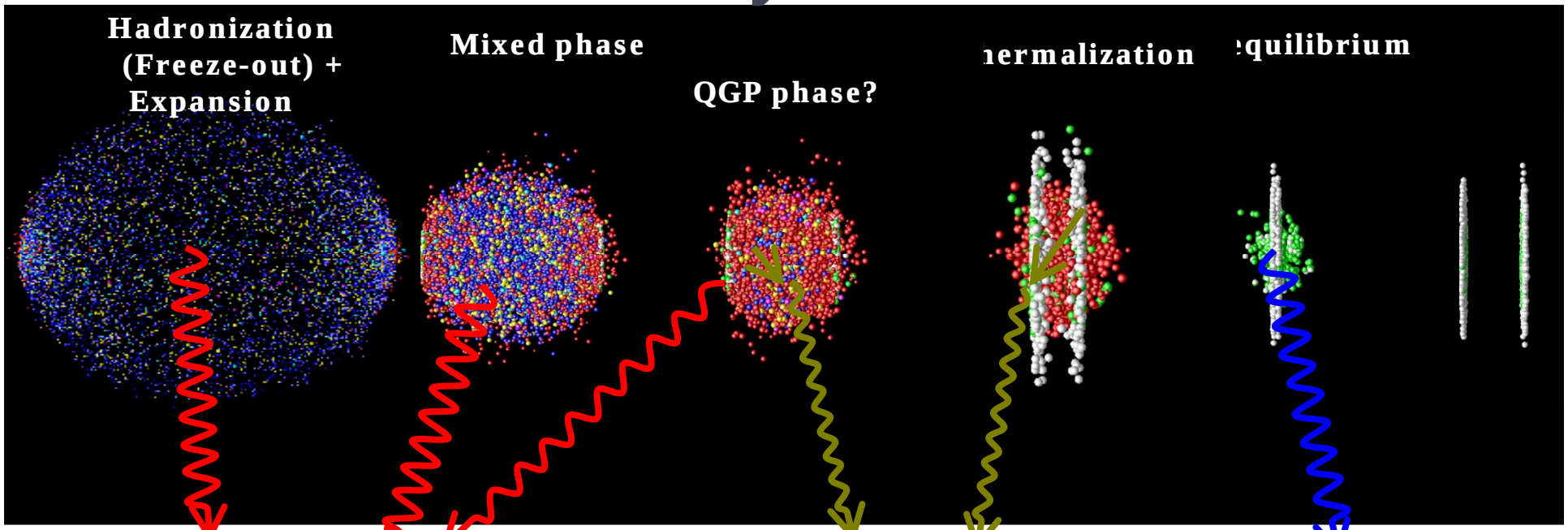
Hisayuki Torii for the ALICE-PHOS Collaborations

CALOR 2008, Pavia Italy



Quark Physics Laboratory
Hiroshima University, Japan

Photons from Heavy Ion Collisions



Thermal Photon

Thermal Photon (QGP)
Thermal Photon (HG)

Jet+Medium

Jet-Photon Conversion
Jet-Bremsstrahlung (QGP)

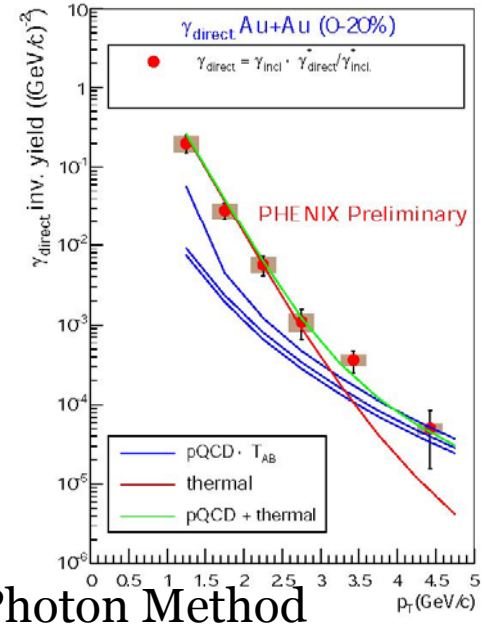
Prompt Photon

Compton/Annihillation
Fragmentation

Time Evolution

Requirement: Thermal Photon from QGP

RHIC

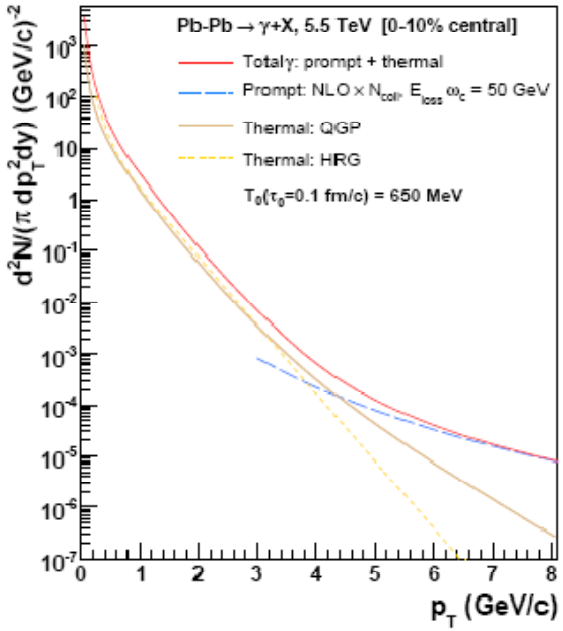


Indirect Photon Method

First Direct Photon Excess seen at low pT

Temperature from thermal photon measurement results in 300-500MeV

LHC Prediction



Photon excess is predicted at pT<10GeV

High Multiplicity (~12000 h±/η)
Wide Dynamic Range (0.1-80GeV)

Advantage at LHC

- Higher temperature, Longer QGP lifetime, Larger background photon suppression

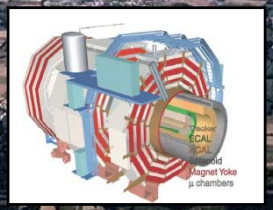
Heavy Ion Collisions at LHC

$p+p$ $\sqrt{s} = 14$ TeV

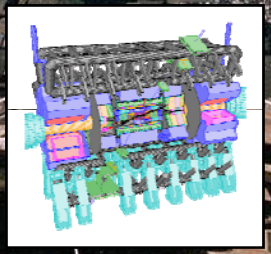
$Pb+Pb$ $\sqrt{s_{NN}} = 5.5$ TeV/A

Energy LHC = 28 x RHIC =320 x SPS = 1000 x AGS

CMS実験



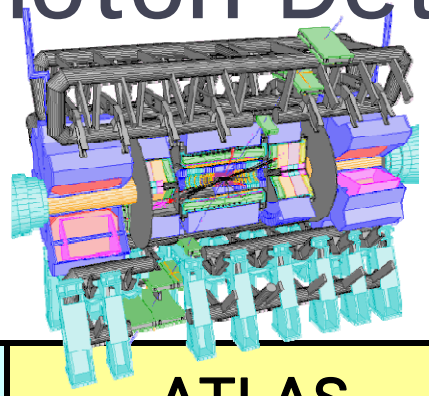
LHC-b実験

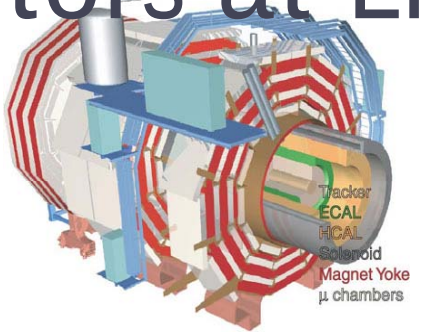


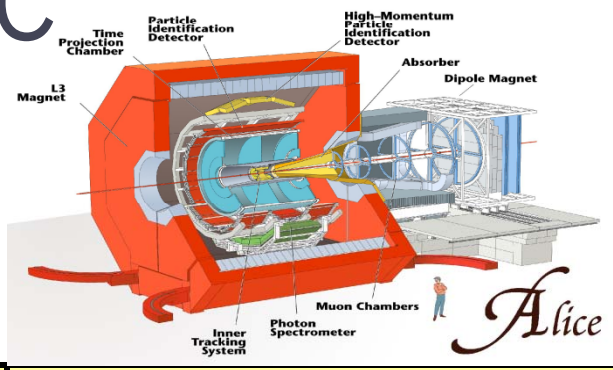
ATLAS実験

ALICE実験

Photon Detectors at LHC



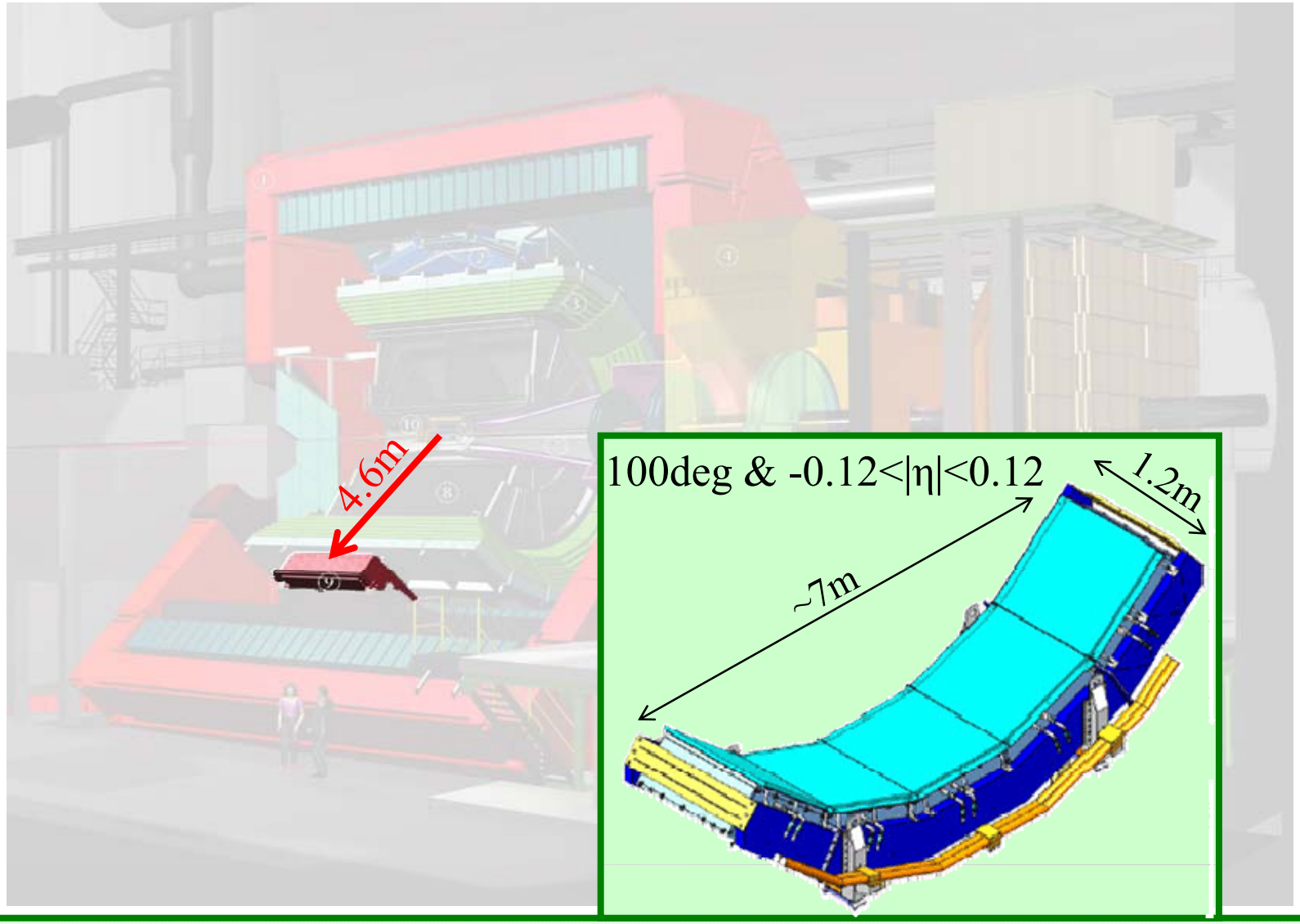




Exp.	ATLAS		CMS		ALICE	
Name	LAr Barrel	LAr Endcap	ECAL(EB)	ECAL(EE)	PHOS	EMCal
Structure	Liquid Ar		PWO + APD		PWO + APD	Pb + APD
Coverage	$0<\|\eta\|<1.4$, 2π	$1.4<\|\eta\|<3.2$, 2π	$0<\|\eta\|<1.5$, 2π	$1.5<\|\eta\|<3.0$, 2π	$0<\|\eta\|<0.12$, 0.6π	$0<\|\eta\|<0.7$, 0.6π
Granularity $\Delta\eta\times\Delta\varphi$	0.003x0.100 0.025x0.025 0.025x0.050	0.025x0.100 0.025x0.025 0.025x0.050	0.0174x0.0174	0.0174x0.0174 to 0.05x0.05	0.004x0.004	0.0143x0.0143
Res.	$10\%/\sqrt{E}\oplus 0.5\%$	$10\%/\sqrt{E}\oplus 0.5\%$	$2.7\%/\sqrt{E}\oplus 0.55\%$	$5.7\%/\sqrt{E}\oplus 0.55\%$	$3.3\%/\sqrt{E}\oplus 1.1\%$	$7\%/\sqrt{E}\oplus 1.5\%$

ALICE-PHOS aim at low energy photon meas.

ALICE-PHOS

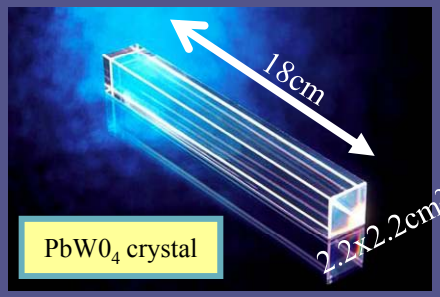


Photon Spectrometer (PHOS) Electro-Magnetic Calorimeter

PHOS Calorimeter

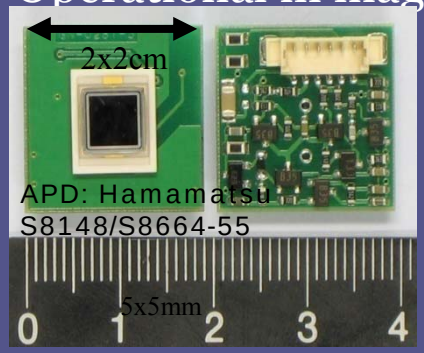
$PbWO_4$ Crystal

- Fast Signal (~nsec),
- Smaller Moliere Radius (2cm)
  ➔ Good 2 photon Separation



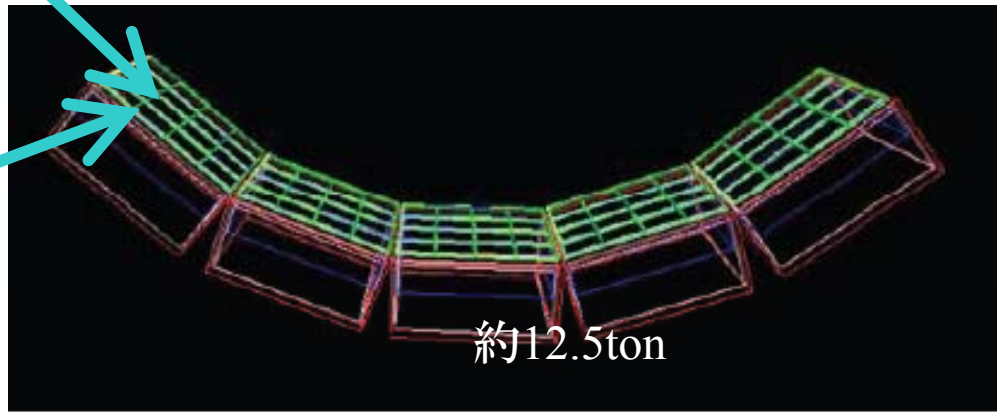
Avalanche Photo Diode (APD)

- High Q.E.(60%-80%)
- Thin photo-sensor
- Operational in magnetic



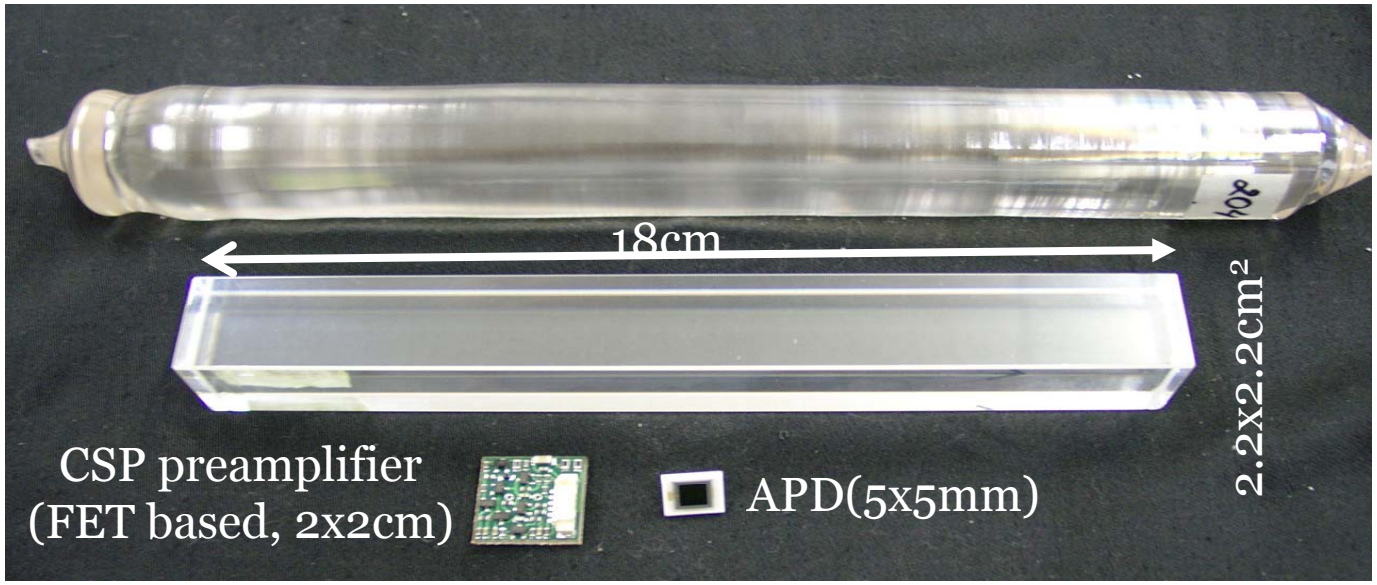
Combination of recent high technology.

- Total 17920 channel
  100deg -0.12<η<0.12



Operation at -25deg

PbWO4 Crystal + APD

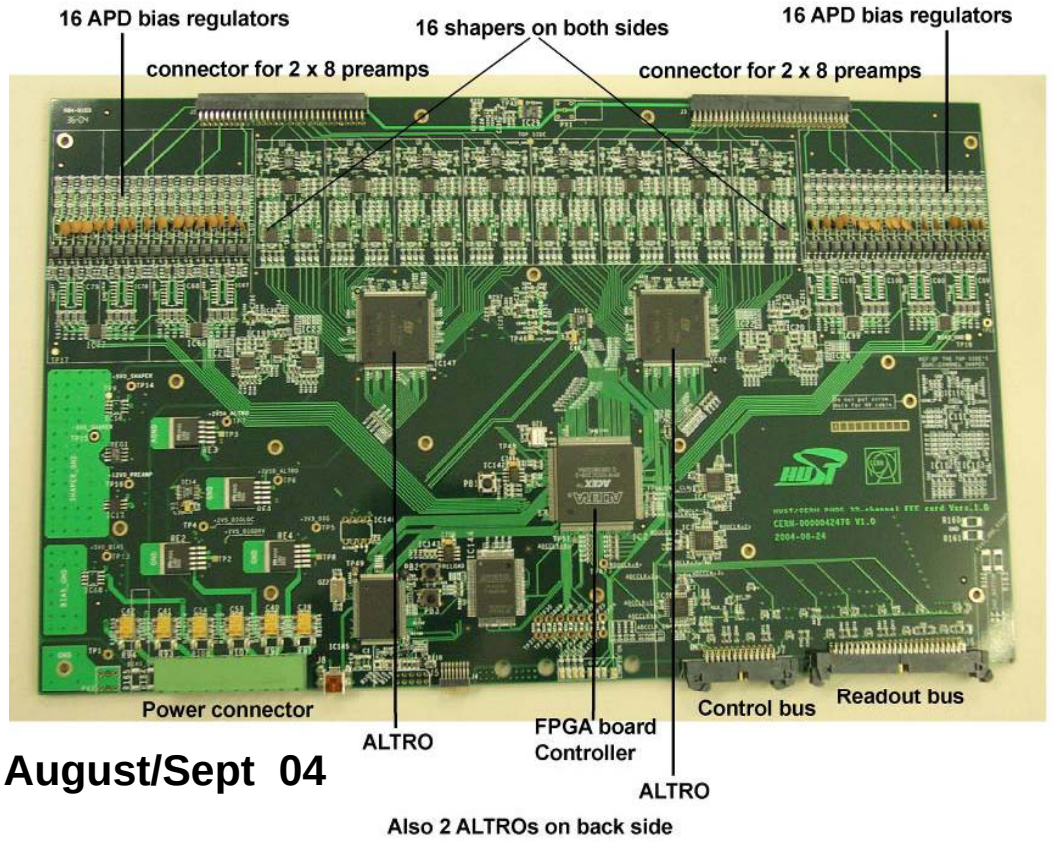


- $PbWO_4$ Crystal
  - 22 x 22 x 180 mm^3, ~20,000yen/crystal
  - ~2cm Moliere Radius, $20X_0$, 8.2g/cm^3
  - Scintillation light (400nm-500nm)
  - Operation at -25deg → 25ns decay,230pe/MeV
  - With APD acceptance: 4.5pe/MeV@-25deg, 1.45pe/MeV@+20deg
  - North Crystal Co. Apatity in Russia

- Avalanche Photo Diode (APD) + Preamp
  - Hamamatsu Co., ~7,000yen/APD+~8,000yen/Preamp
  - S8148/S8664-55
  - High Q.E.(60%-80%)
  - Low noise and capacitance
  - Thin photo-sensor
  - Operational at low temperature and in magnetic field

Front-End Electronics

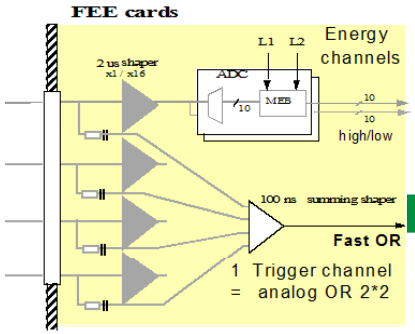
- Basic Properties
  - 349x210mm2, 5.5Watt
  - 32ch dual gain shapers (2usec)
  - Noise 615e- (=3.1MeV)
  - 14bit dynamic range 5MeV-80GeV
  - 32APD bias regulators
  - Fast 2x2 OR outputs
  - Board controller FPGA



⇧**R&D CERN April-June 04**
⇧**Cadence Schematics: CERN June 04**
⇧**10 layer Layout & mounting : Wuhan August/Sept 04**
⇧**Prototypes in Testbeam: October 04**
⇧**Evaluation: CERN Nov-Dec 04**
⇧**Revision: Jan 05**
⇧**Review and final testing: Mai-Sept 05**
⇧**130 card production Wuhan by end 2005 for first module**
⇧**250 card production Wuhan by end 2007 for second/third module**

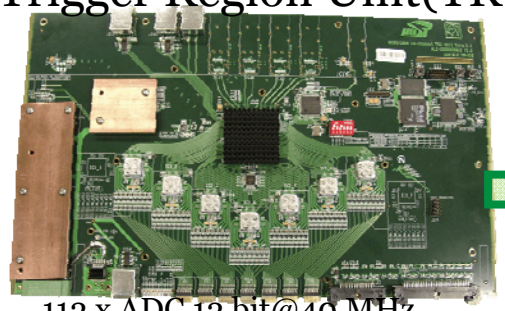
FEE mass production for first 3 modules was done

PHOTON Trigger Feasibility



2x2 Analog Sum

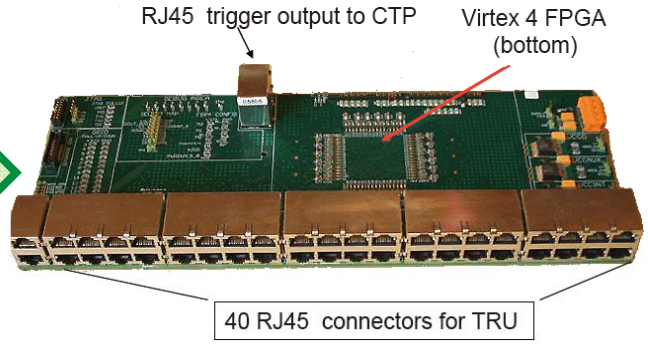
Trigger Region Unit(TRU)

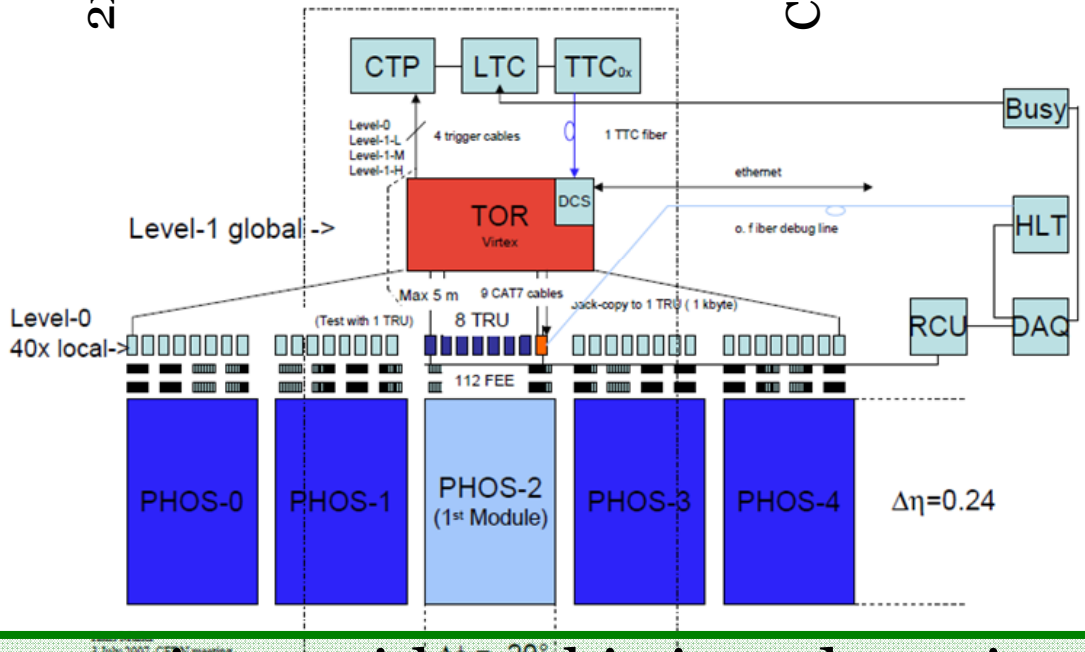


112 x ADC 12 bit@40 MHz

Collect all Digital

Trigger OR (TOR)

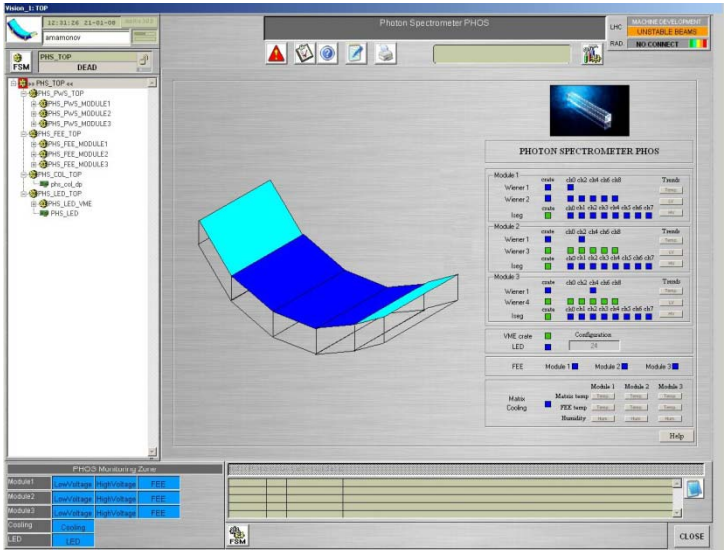




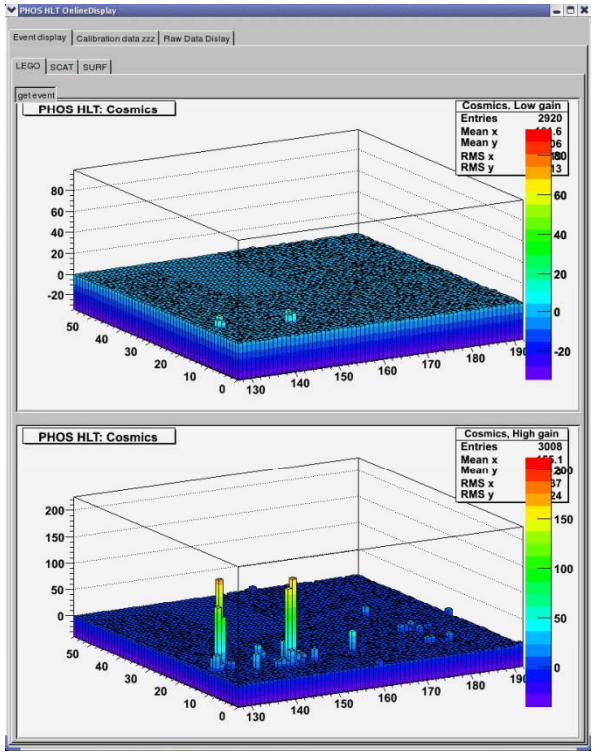
Photon trigger with sophisticated requirement is capable by programmable FPGA

Control and Monitoring

- Detector Control System (DCS)
  - Control and Monitoring
    - Cooling System
      - Cooling plant and temperature and humidity monitoring.
    - Power Supply (HV, LV)
    - LED System
      - LED operation
    - FEE
      - Configuration.
      - LV and temperature monitoring.



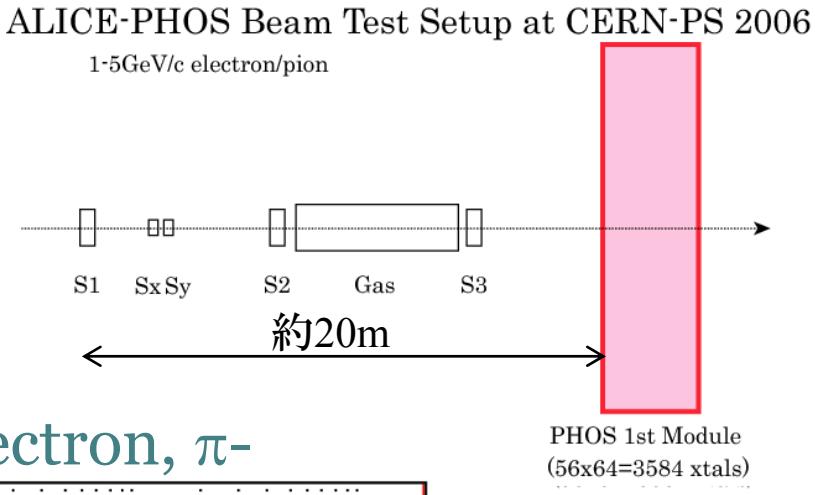
- High Level Trigger (HLT)
  - Online Data Monitoring
  - Online Calibration
  - Data Reconstruction and Compression
  - Event Selection

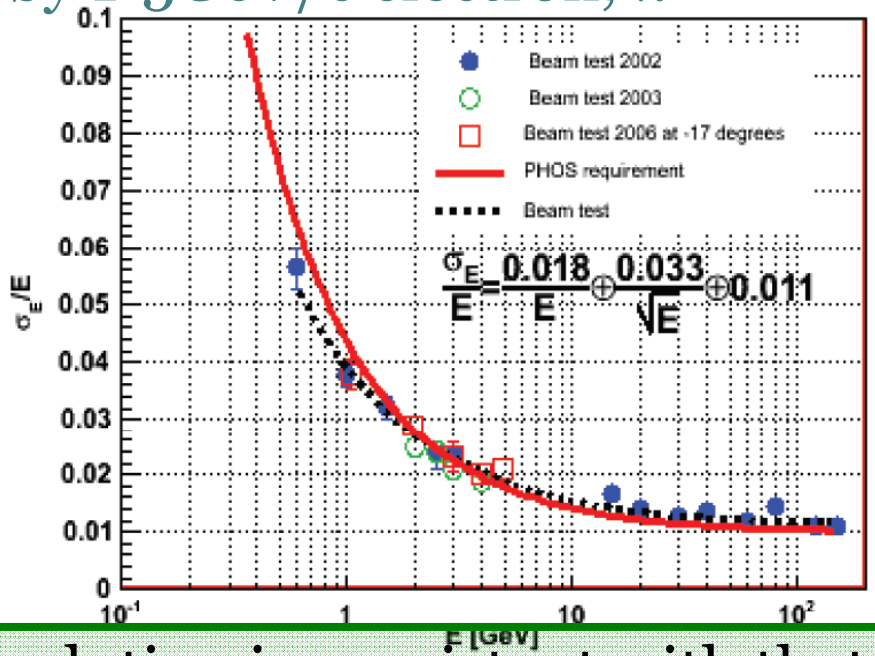


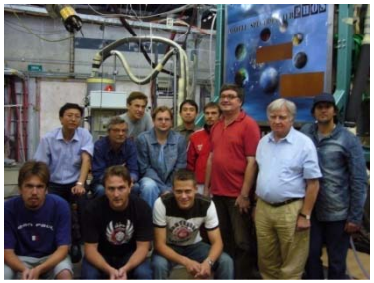
Cosmic Ray Event in 2007

Test Beam in 2006

- First Module Test
  - 2006/6月～8月
  - CERN/PS T10 Beam line
  - Operated at about -17deg
  - Irradiated by 1-5GeV/c electron, π-





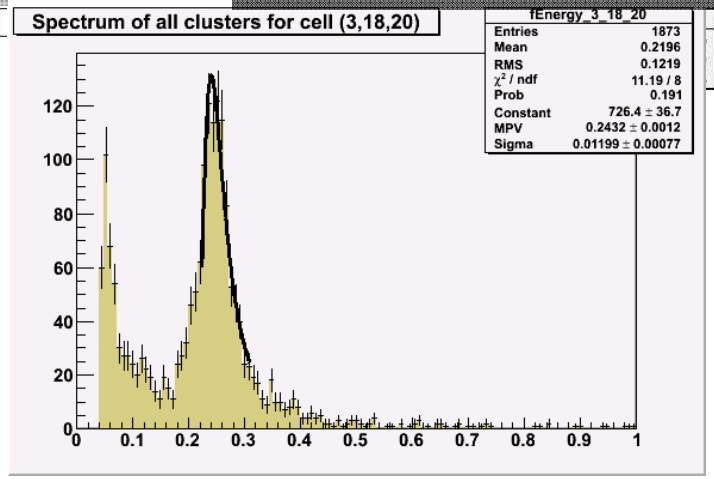


The energy resolution is consistent with that of a prototype.
Operation by ALICE Standard DAQ system

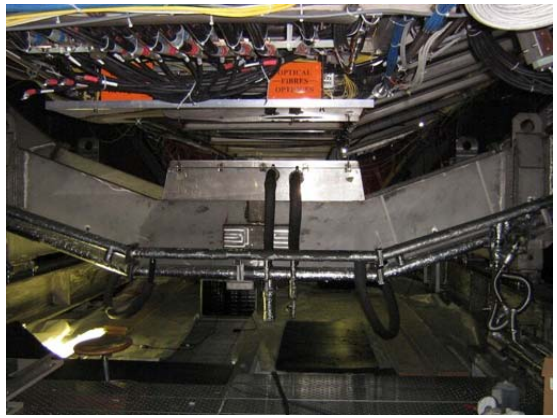
Cosmic Ray in 2007 & Installation in 2008

- First module test in 2007
  - Irradiate cosmic-ray on all xtals.

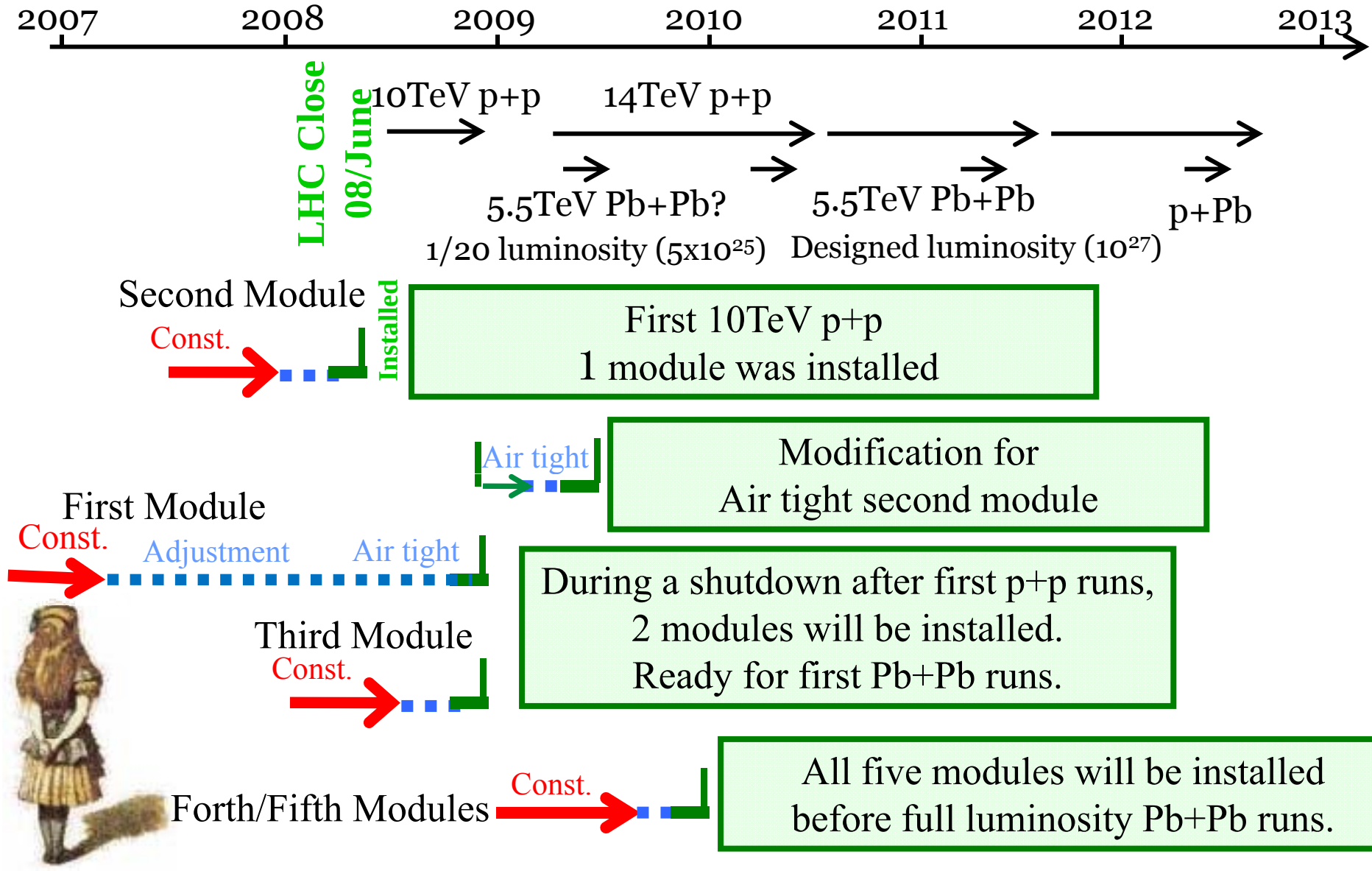
Cluster Energy Distribution



- Installation in 2008
  - Second Module was installed on May/2008.
  - Will be operated at +18deg temperature during the first pp run at LHC.
  - First and third modules are basically ready and they are under mechanical upgrade now to fulfill the air-tightness requirement. They will be tested in the lab in 2008 with cosmic and/or electron beam and will be installed in ALICE during shutdown after first LHC beam.

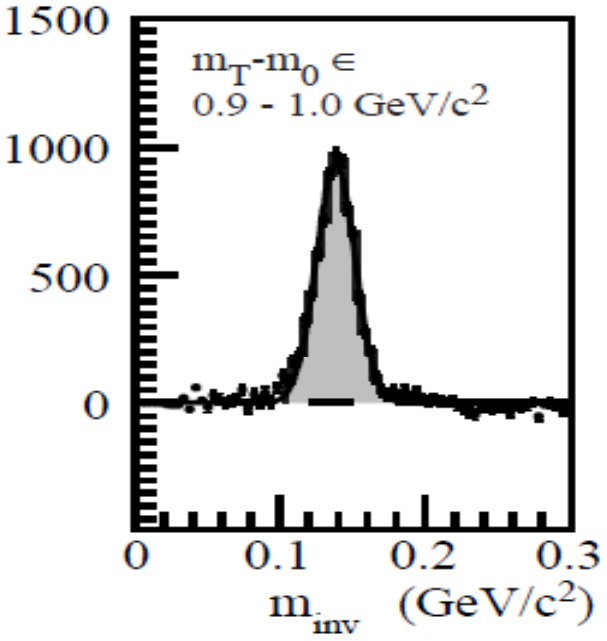


Future Plan


2007
2008
2009
2010
2011
2012
2013
LHC Close
08/June
10TeV p+p
14TeV p+p
5.5TeV Pb+Pb?
1/20 luminosity (5x10²⁵)
5.5TeV Pb+Pb
Designed luminosity (10²⁷)
p+Pb
Second Module
Const.
Installed
First 10TeV p+p
1 module was installed
Air tight
Modification for
Air tight second module
First Module
Const.
Adjustment
Air tight
During a shutdown after first p+p runs,
2 modules will be installed.
Ready for first Pb+Pb runs.
Third Module
Const.
Forth/Fifth Modules
Const.
All five modules will be installed
before full luminosity Pb+Pb runs.

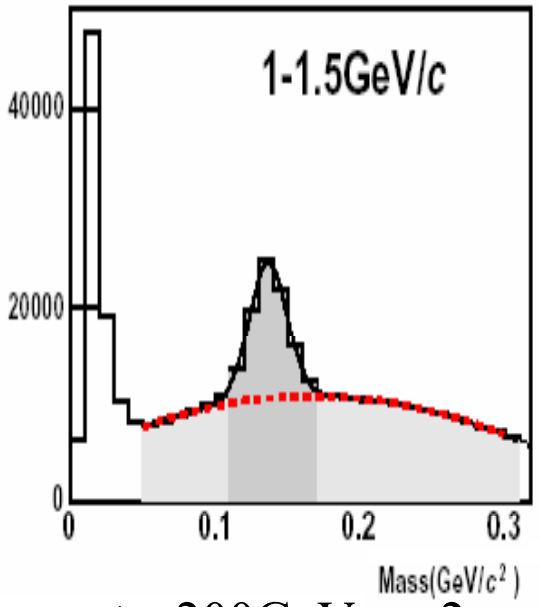
PHOS Potential (1) : Neutral Pion

WA98(CERN)



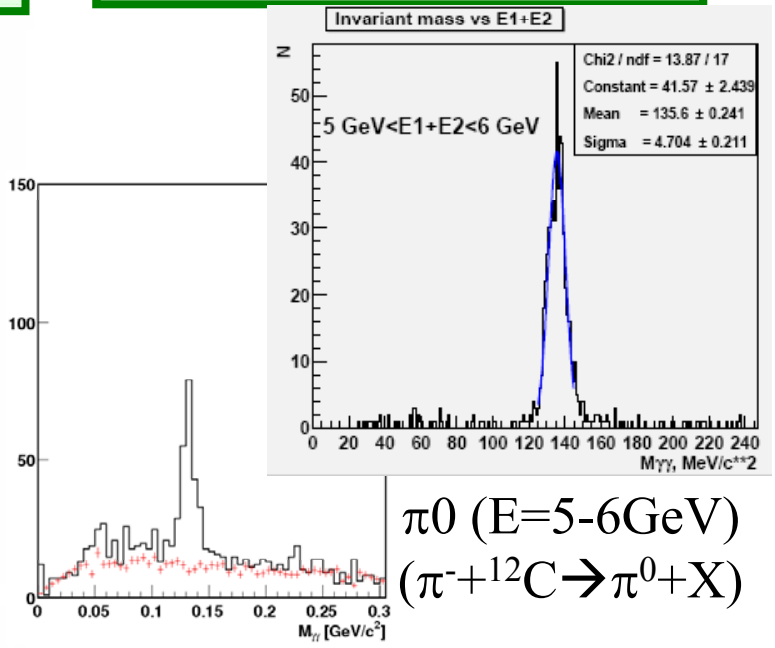
Pb+Pb 13GeV
nucl-ex/0108006

PHENIX(BNL)



p+p 200GeV run2

ALICE(CERN)



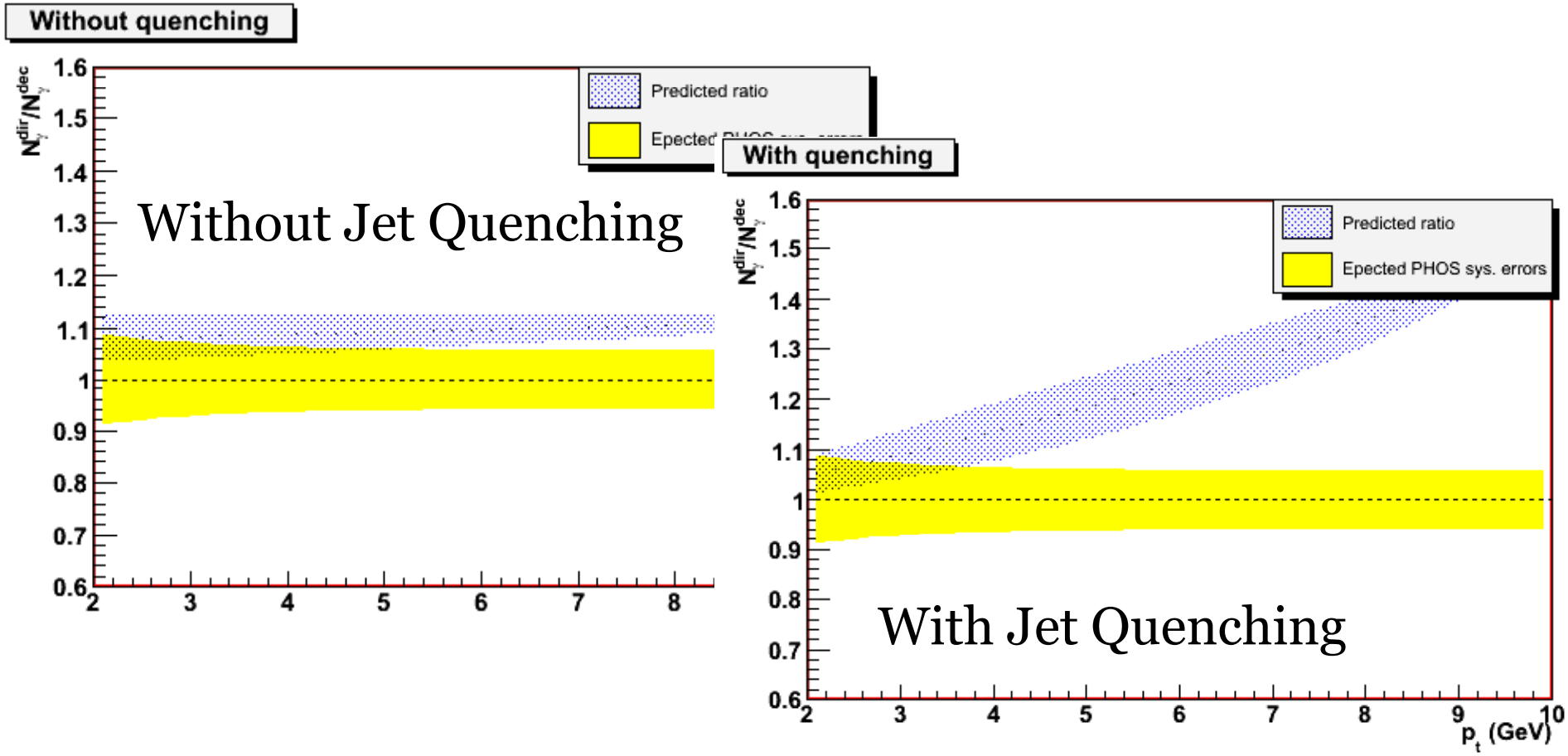
π0 (E=5-6GeV)
(π^-+^{12}C→π^0+X)

p+p 14TeV
GEANT simulation

13MeV width of π^0@1GeV/c → 5-6MeV

Improvement of particle identification compared to the other HI exp.

PHOS Potential (2) :Thermal Photon



Systematic error in thermal photon measurement is well smaller than statistic error at the pT>3GeV/c

Summary

- Physics requirement.
  - Thermal photon measurement requires wide dynamic range 0.1-100GeV. High energy resolution. High granularity for high multiplicity events.
- PHOS Structure
  - PbWO4 Crystals + APD
    - Operated at -25deg and at magnetic field
  - Front-End Electronics with wide dynamic range
  - Photon trigger with sophisticated algorithm is feasible
- Production Status
  - First module was tested by electron beam and cosmic-ray
  - Second module was installed and will be operated controlled temperature +18deg.
  - After a first shutdown in the end of 2008, three air-tight modules will be ready for installation.
- PHOS potential
  - Several physics measurement (π^0, direct photon, direct photon-jet correlation) in first p+p collisions at s=10TeV is feasible.
  - Enough systematic error for identifying thermal photon production in heavy ion collisions. Waiting for Pb+Pb beams