The ALICE PHOS Calorimeter

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Photons from Heavy Ion Collisions

- **Hadronization (Freeze-out) + Expansion**
- **Mixed phase**
- **QGP phase?**
- **Thermalization + Equilibrium**

**Thermal Photon**
- Thermal Photon (QGP)
- Thermal Photon (HG)

**Jet+Medium**
- Jet-Photon Conversion
- Jet-Bremsstrahlung (QGP)

**Prompt Photon**
- Compton/Annihilation
- Fragmentation
Indirect Photon Method
First Direct Photon Excess seen at low pT
Temperature from thermal photon measurement results in 300-500 MeV

Photon excess is predicted at pT<10 GeV

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

Advantage at LHC
• Higher temperature, Longer QGP lifetime, Larger background photon suppression
Heavy Ion Collisions at LHC

\[ p+p \quad \sqrt{s} = 14 \text{ TeV} \]
\[ \text{Pb}+\text{Pb} \quad \sqrt{s_{\text{NN}}} = 5.5 \text{ TeV/A} \]

Energy

\[ \text{LHC} = 28 \times \text{RHIC} = 320 \times \text{SPS} = 1000 \times \text{AGS} \]
### Photon Detectors at LHC

<table>
<thead>
<tr>
<th>Exp.</th>
<th>ATLAS</th>
<th>CMS</th>
<th>ALICE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name</strong></td>
<td>LAr Barrel</td>
<td>LAr Endcap</td>
<td>ECAL(EB)</td>
</tr>
<tr>
<td><strong>Structure</strong></td>
<td>Liquid Ar</td>
<td>PWO + APD</td>
<td>PWO + APD</td>
</tr>
<tr>
<td><strong>Coverage</strong></td>
<td>0&lt;</td>
<td>η</td>
<td>&lt;1.4, 2π</td>
</tr>
<tr>
<td><strong>Granularity</strong></td>
<td>0.003x0.0100</td>
<td>0.0025x0.1000</td>
<td>0.025x0.025</td>
</tr>
<tr>
<td><strong>Res.</strong></td>
<td>10%/√E⊕0.5%</td>
<td>10%/√E⊕0.5%</td>
<td><strong>2.7%/√E⊕0.55%</strong></td>
</tr>
</tbody>
</table>

ALICE-PHOS aim at low energy photon meas.
Photon Spectrometer (PHOS) Electro-Magnetic Calorimeter
PHOS Calorimeter

PbWO₄ 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 field

Combination of recent high technology.

- Total 17920 channel
  100deg  -0.12<\(\eta\)<0.12

Operation at -25deg

About 12.5 ton
**PbWO₄ Crystal + APD**

**PbWO₄ Crystal**
- 22 x 22 x 180 mm³, ~20,000yen/crystal
- ~2cm Moliere Radius, 20X₀, 8.2g/cm³
- 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

**APD**
- 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

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.

- **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**: LHC Close 08/June
- **2008**: 10TeV p+p
- **2009**: 14TeV p+p
  - 5.5TeV Pb+Pb?
  - 5.5TeV Pb+Pb
  - 1/20 luminosity (5x10^25)
  - Designed luminosity (10^27)
- **2010**: p+Pb

**First Module**
- Const.
- Adjustment
- Air tight

**Second Module**
- Const.
- Installed

**Third Module**
- Const.

**Modification for**
- Air tight second module

**During a shutdown after first p+p runs,**
- 2 modules will be installed.
- Ready for first Pb+Pb runs.

**Forth/Fifth Modules**
- Const.

**All five modules will be installed**
- before full luminosity Pb+Pb runs.
PHOS Potential (1) : Neutral Pion

**WA98** (CERN)  

**PHENIX** (BNL)  

**ALICE** (CERN)

Pb+Pb 13GeV  

**p+p 200GeV run2**  

**p+p 14TeV**  

GEANT simulation

\[ m_{\pi^-} - m_0 \in 0.9 - 1.0 \text{ GeV/c}^2 \]

\[ m_{\text{inv}} \text{ (GeV/c}^2) \]

\[ \pi^0 (E=5-6\text{GeV}) \]

\[ (\pi^- + ^{12}\text{C} \rightarrow \pi^0 + X) \]

13MeV width of \( \pi^0 \)@1GeV/c  

5-6MeV

Improvement of particle identification compared to the other HI exp.
PHOS Potential (2) : Thermal Photon

Without Jet Quenching

With Jet Quenching

Systematic error in thermal photon measurement is well smaller than statistic error at the pT > 3 GeV/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 (π⁰, 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