From raw data to physics results with ALICE PHOS

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Calor 2010, May 10~14, 2010  Beijing, China
Outline

• LHC, ALICE, Photon Spectrometer (PHOS)
• Data processing from raw data to physics results
• Neutral pion measurement with proton-proton collisions from real data
• Conclusions and outlook
ALICE detectors

- Designed for heavy-ion collisions at $\sqrt{s_{NN}} = 5.5$ TeV
- pp runs as a reference for pA and AA
- Cope with high multiplicity $dN_{ch}/dy \sim 8000$
- Study the QGP and learn about the QCD matter
- Direct photon (prompt+thermal), and light neutral mesons
- Test the pQCD, $M_T$ scaling

PHOS parameters

<table>
<thead>
<tr>
<th>Coverage in pseudo-rapidity</th>
<th>$-0.12 \leq \eta \leq 0.12$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage in azimuthal angle</td>
<td>$\Delta\phi = 100^\circ$</td>
</tr>
<tr>
<td>Distance to interaction point</td>
<td>4600 mm</td>
</tr>
<tr>
<td>Modularity</td>
<td>Five modules of 3584 crystals</td>
</tr>
</tbody>
</table>

**EMCAL**
- Material: Lead-tungstate crystals (FWO)
- Crystal dimensions: $22 \times 22 \times 180$ mm$^3$
- Depth in radiation length: 20
- Number of crystals: 17,920
- Segmentation: 3584 crystals per module
- Total area: 8 m$^2$
- Crystal volume: 1.5 m$^3$
- Total crystal weight: 12.5 t
- Operating temperature: $-25 ^\circ C$

**CPV**
- Gas: 80% Ar/20% CO$_2$
- Thickness: 0.5X$_0$
- Active area: $1.8 \times 14$ mm per module
- Wire diameter: 30 $\mu$m
- Number of wires per module: 256
- Wire pitch: 5.65 mm
- Pad size: $22 \times 16.5$ mm$^2$
- Pad inter-distance: 0.6 mm
- Number of pads per module: 7168

**PHOS parameters**

- EM-Calorimeters: PHOS, EMCAL and DCAL (upgrade)
- Explore the hot medium
- Jet quenching
- Nuclear modification factor
- Photon-jet and azimuthal correlation
- Fragmentation function measurement
- ...

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|        | Material | $|\eta|/ | $\Delta \varphi$ | Granularity | Resolution |
|--------|----------|---|----------------|-------------|------------|
|        |          |   |                |             | Energy(GeV) | Position(mm) |
| PHENIX | EMCs     | PbSc | <0.35          | 135         | 0.011*0.011 | 8.1%/ $\sqrt{E} \oplus 2.1\%$ | 1.4 $\oplus$ 5.9/ $\sqrt{E}$ |
|        |          | PbGl | <0.35          | 45          | 0.008*0.008 | 5.9%/ $\sqrt{E} \oplus 0.8\%$ | 6.0/ $\sqrt{E}$ |
| STAR   | BEMC     | Pb   | <1             | 360         | 0.05*0.05   | 14%/ $\sqrt{E} \oplus 1.5\%$ | 3.2 $\oplus$ 5.8/ $\sqrt{E}$ |
|        |          |      |                |             |            |                                      |                 |
| ATLAS  |          |      |                |             |            |                                      |                 |
| Barrel LAr | Liquid Ar | <1.375 |            | 0.003*0.1  |            | 10%/ $\sqrt{E} \oplus 0.2\%$     |                 |
| Endcap LAr |       | >1.4 |            | 360         | 0.025*0.025 |                                      |                 |
|          |          | <3.2 |            |             | 0.05*0.025  |                                      |                 |
| CMS    |          |      |                |             |            |                                      |                 |
| EM-Barrel | PbWO4  | <1.479 |            | 360         | 0.0174*0.0174 | 2.8%/ $\sqrt{E} \oplus 0.3\%$     |                 |
| EM-Endcap |       | >1.479 |            |             | 0.0174*0.0174 | ~ 0.05*0.05                  |                 |
|          |          | <3.0 |            |             |            |                                      |                 |
| ALICE  |          |      |                |             |            |                                      |                 |
| PHOS   | PbWO4    | <0.12 |            | 100         | 0.004*0.004 | 3.3%/ $\sqrt{E} \oplus 1.1\%$ | 0.7 $\oplus$ 2.3/ $\sqrt{E}$ |
| EMCAL  | PbSc     | <0.7  |            | 110         | 0.0143*0.0143 |                                      |                 |
| DCAL   | PbSc     | >0.2 |            | 60          | 0.0143*0.0143 | 11%/ $\sqrt{E} \oplus 1.7\%$ | 1.5 $\oplus$ 5.3/ $\sqrt{E}$ |
| (upgrade)  |       | <0.7 |            |             |            |                                      |                 |

- High granularity and high resolution with PHOS
- Larger acceptance of the ALICE EM-Calorimeters
- EMCAL and PHOS+DCAL are back to back dedicated on jet measurement
The course of analysis

**Simulation**
- Generator
- Hits
- SDigit
- Digits

**Data-taking**
- Experiment
- Raw data (ddl, date, root)
- Raw fitter

**Reconstruction**
- Cluster
- Track Segment
- PID
- ESD/AOD
- Analysis framework

**OCDB (eg. Phos)**
- Altro (mapping)
- Bad channel map
- HG/LG
- ADC to GeV
- Time shift
- Reco parameters
- Alignment

**Corrections**
- ACC*Rec
- Trigger efficiency
- Off-vertex
- Conversions
- Bin shift ...

**Systematic uncertainties**

**Track-match**
- SSA
- TOF
- Bayesian

**Others**
- Global run info
- Theoretical
- Other data point ...

**physics results**

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From raw data

- In simulation, three data formats (date, ddl and root) for DAQ
- The real data is reconstructed from raw data

- Zero and Non-Zero suppression
- Dual gain shaper, $HG/LG \sim 16$, for a 14 bits dynamic range between 5 MeV to 80 GeV
- calibrated cell by cell
- The shower and signal shape were observed in the first pp collisions
- The raw shape is fitted by Gamma2 to extract the amplitude and timing
PHOS calibration

- **Absolute calibration**
  - Scale the energy
  - Beam test
- **Relative calibration**
  - Unify the channels
  - $E/p$, MIP and $\pi^0$
  - LED
  - cosmic
  - physics data-taking

- The pre-calibration was based on the equalization of the APD gains
- Further calibration will be possible using the physics data from pp collisions at 7 TeV this year
**Clustering**

- Cluster is a group of adjacent digits
- Cluster finding and unfolding
- COG (central of gravity) algorithm to calculate the cluster energy and position
- Corrected for the incident angle
- Shower shape parameter (lateral dispersion, two major axes, sphericity parameter ... )

\[
\begin{align*}
\sum_{\text{digs}} w_i \left[ (x_i - x)^2 + (z_i - z)^2 \right] \\
\sqrt{\frac{\sum_{\text{digs}} w_i}{\sum_{\text{digs}} w_i}} \\
S = \begin{pmatrix} s_{xx} & s_{xz} \\ s_{xz} & s_{zz} \end{pmatrix} \\
S = \frac{|\lambda_1 - \lambda_2|}{\lambda_1 + \lambda_2}
\end{align*}
\]
Particle identification

- Time of flight to reject the slow particles
- Charged particle excluding, CPV-EMC or TPC-EMC position matching
- Shower shape analysis
- Isolation cut method
Bayesian PID

- Based on Bayes’s theory of probabilities
- Assign a PID weigh to a reconstructed particle on an E-b-E bias
- TOF, track-matching and shower shape probability density distribution

\[
W(i) = \frac{P(tof \mid i) \cdot P(d_{CE}^{XZ} \mid i) \cdot P(dis \mid i) \cdot P(rec \mid i)}{\sum_s [P(tof \mid s) \cdot P(d_{CE}^{XZ} \mid s) \cdot P(dis \mid s) \cdot P(rec \mid s)]}
\]

\[\begin{align*}
&\text{γ PID as γ} \\
&\gamma_{\text{PID as γ}} \\
&\bullet W^{\gamma}(i) = 0.05 \\
&\triangle W^{\gamma}(i) = 0.95 \\
&\text{Merged γ PID as γ} \\
&\gamma_{\text{Merged PID as γ}} \\
&\bullet W^{\gamma}(i) = 0.05 \\
&\triangle W^{\gamma}(i) = 0.95
\end{align*}\]

\[\begin{align*}
&\text{e° PID as e°} \\
&e_{\text{PID as e°}} \\
&\bullet W^{e°}(i) = 0.05 \\
&\triangle W^{e°}(i) = 0.95 \\
&\text{Merged e° PID as e°} \\
&e_{\text{Merged PID as e°}} \\
&\bullet W^{e°}(i) = 0.05 \\
&\triangle W^{e°}(i) = 0.95
\end{align*}\]
$\gamma / \pi^0$ discrimination

- $\pi^0$ and its decay are the main background for photon detection
- Lower pt, $\pi^0$ is reconstructed by invariant mass
- Higher pt (>20 GeV/c), the two photon merged and misidentified as photon
- Based on the eccentricity of the shower: a photon develops a shower with axial symmetry, while the pi0 produces a elliptic shape
- Bayesian method
Physics analysis

- **AliRoot**, within the analysis framework
- Flexible to handle Monte Carlo and real data
- **π^0** are important for tuning and calibrate the detector in the early stage
- We can ...

<table>
<thead>
<tr>
<th>Decay channel</th>
<th>Branch ratio(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>π^0 -&gt; 2γ</td>
<td>99.98</td>
</tr>
<tr>
<td>η -&gt; 2γ</td>
<td>39.38</td>
</tr>
<tr>
<td>ω(782) -&gt; π^0 γ&gt;3γ</td>
<td>8.9</td>
</tr>
<tr>
<td>η -&gt; π^0 π^+ π^-</td>
<td>28.0</td>
</tr>
<tr>
<td>ω(782) -&gt; π^0 π^+ π^-</td>
<td>89.1</td>
</tr>
<tr>
<td>K_s^0 -&gt; π^0 π^0</td>
<td>30.69</td>
</tr>
</tbody>
</table>

Pythia MB 10TeV, simulation with detectors
How far we can reach?

Acceptance in PHOS 3mods

\[
\frac{dN}{dp_T} = \frac{d\sigma}{dp_T} \cdot \mathcal{L} \cdot T \cdot A \cdot \varepsilon
\]

\[\mathcal{L} = 5 \cdot 10^{28} \text{ cm}^{-2}\text{s}^{-1}\]

- Direct photons at \(p_T < 10 - 20\) GeV/c
- \(\pi^0\) at \(p_T < 25 - 50\) GeV/c
- \(\eta\) at \(p_T < 20 - 40\) GeV/c
- \(\omega(782)\) at \(p_T < 15 - 30\) GeV/c
Enter the real world ...

In 2009, Dec. 6 ~ Dec. 16

- 20 hours data-taking
- ~316k events
- Integrated luminosity: 10.2 $\mu b^{-1}$

Since 2010 Mar. 30

- New TeV era --- 7 TeV proton-proton collisions
- PHOS runs smoothly
- ~40M events (April 26)
- $\pi^0$ pt spectra can reach 10 GeV/c
ALICE detectors in run 2009~2010

ITS, TPC, TOF
7/18 TRD
3/5 PHOS
4/10 EMCAL
7/7 HMPID
\( \pi^0 \) invariant mass spectra (PHOS)

- pp collisions at 7 TeV
- Measure the \( \pi^0 \) pt reach from 1 to 10 GeV/c
- Optimize the cuts to minimize the combinational background
Conclusion and outlook

• The analysis chain from raw data to physics results was presented
• PHOS is on the right track
• More statistics are being collected in the following long run
• We are ready ...
• Expecting the physics at the new TeV era

Thanks for your attention!