Upgrade of the ALICE Experiment

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Outline

• Physics Motivation and Strategy
• Core Upgrade
  • ITS Upgrade
  • High Rate Capabilities
  • Physics Performance Examples
• Further Additions (under consideration)
  • VHMPID, MFT, FoCal
• Summary
Physics Motivation

- measurement of heavy-flavour transport parameters
  - study of QGP properties via transport coefficients
- charmonium states down to $p_T=0$
  - statistical hadronization vs. dissociation/recombination
- measurement of low-mass and low-$p_T$ dileptons
  - chiral symmetry restoration, thermal radiation
- jet quenching and fragmentation (with PID)
- heavy-nuclear states

- possible addition: measurement of large rapidity direct photons
  - low-$x$ structure and gluon saturation
Upgrade Strategy

• most physics signals are **rare**, but **untriggerable**

• increase rate capabilities for minimum bias heavy-ion collision
  • upgrade of TPC and ITS, all readout electronics, etc.
  • target: inspection of 50 kHz of minimum bias Pb+Pb
  • factor 100 increase in statistics (for untriggered probes)
  • collect $> 10 \, \text{nb}^{-1}$ of integrated luminosity
  • upgrade in LS2, implies running few years after LS3

• ALICE is **unique** in low-$p_T$/low-mass measurements and particle identification
  • further enhance capabilities, in particular with **upgraded ITS**
  • closer to beam, less material, better resolution
ITS Upgrade

factor 3 better secondary vertex resolution:
• inner layer as close as possible (R = 2.2 cm)
• less material budget
• thin sensors
• thinner beam pipe (ΔR = 800 µm)

fast readout
• allow 50 kHz rate in Pb+Pb

two technologies investigated
• hybrid pixels
• monolithic active pixels
to be used as all-pixel (7 layers) or pixel(3)+strip(4)
• possibly new Si-strip sensors

talk by R. Lemmon, this session, poster by G. Contin (ID 601)
Limits of Current TPC

- gating grid of readout chambers closed to avoid ion feedback
  - limit space charge to tolerable level
  - effective dead time $\approx 280 \, \mu s$, maximum readout rate: $\approx 3.5 \, \text{kHz}$
- alternative: gating grid always open
  - ion feedback $\approx 10^3 \times$ ions generated in drift volume
  - large space charge effects (of the order of electrical field)
    - space point distortions of order of 1 m - not tolerable!
TPC Upgrade

new readout chambers
• replace MWPC with GEMs
• no gating, small ion feedback
• usage of existing pad-planes possible
  • momentum resolution for constrained tracks not affected

continuous sampling at 10 MHz, ship data unsuppressed off detector
• needs new electronics

extensive R&D program ongoing with lab tests
• confirm low ion feedback
  • goal: 0.25% at gain of 2000
• gain stability?
  ... and in ALICE cavern (November)
• performance under LHC conditions?

poster by T. Gunji (ID 496)
Central Barrel: More Upgrades

- other detector systems under investigation
  - upgrade of PHOS calorimeter
    - better time resolution to reduce background
    - miscellaneous improvements
  - upgrade of trigger detectors (T0/V0)
- upgrade of all readout electronics
  - pipelined readout of major ALICE detectors
- new DAQ/HLT
  - data compression requires on-line calibration and tracking
- common computing framework (DAQ/HLT/Offline)
Event Size and Rates

- event size of major systems, I/O rates of online system
- assume average minbias rate to tape of 20 kHz

<table>
<thead>
<tr>
<th>Detector</th>
<th>Event Size (MByte)</th>
<th>Input to Online System (GByte/s)</th>
<th>Compressed Output to data storage (GByte/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>After Zero</td>
<td>After Data Compresssion</td>
<td>Peak</td>
</tr>
<tr>
<td>ITS</td>
<td>0.8</td>
<td>0.2</td>
<td>40</td>
</tr>
<tr>
<td>TPC</td>
<td>20.0</td>
<td>1.0</td>
<td>1000</td>
</tr>
<tr>
<td>TRD (20 kHz)</td>
<td>0.3</td>
<td>0.1</td>
<td>6</td>
</tr>
<tr>
<td>Others (1)</td>
<td>0.5</td>
<td>0.25</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>21.6</td>
<td>1.55</td>
<td>1071</td>
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</tbody>
</table>

- data reduction for TPC: clustering, reconstruction

<table>
<thead>
<tr>
<th>Data Format</th>
<th>Data Reduction Factor</th>
<th>Event Size (MB Pb-Pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw data</td>
<td>1</td>
<td>700</td>
</tr>
<tr>
<td>Zero suppression (FEE)</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>Clustering (HLT)</td>
<td>5-7</td>
<td>~3</td>
</tr>
<tr>
<td>Remove clusters not associated to relevant tracks (HLT)</td>
<td>2</td>
<td>~1.5</td>
</tr>
<tr>
<td>Data format optimization (HLT)</td>
<td>2-3</td>
<td>&lt; 1</td>
</tr>
</tbody>
</table>
Performance: Open Charm

- strong reduction of background with new ITS
  - improved S/B and significance
- with high rate should make possible for the first time:
  - $D^0$ measurement at low $p_T$ (0-2 GeV/c) in Pb+Pb
  - $\Lambda_c$ measurement in Pb+Pb
  - ...

- precision measurements of open charm transport
Dielectron Measurement

- uncertainties with current ITS
  - limited by background subtraction and statistics
- high rate measurement with new ITS
  - more efficient cuts to reduce background, high statistics: allows detailed measurement of low mass dielectrons
Muon Forward Tracker

- 5 circular Si-pixel planes covering muon arm acceptance
- Pixel size ≈ 25 µm x 25 µm
- Technology of choice: monolithic active pixels

Complement muon arm with tracking in front of absorber:
- Secondary vertex measurement
- Better background rejection
- Improved mass resolution

Access prompt vs. secondary J/ψ, possible sensitivity to chiral symmetry via low-mass dileptons
VHMPID

focusing RICH
C$_4$F$_8$O radiator, pressurized
CsI photocathode with MWPC
readout: HMPID FEE (Gassiplex)
possibly dedicated trigger
detector

combine VHMPID with DCAL in
the same acceptance

<table>
<thead>
<tr>
<th>radiator pressure (atm)</th>
<th>1</th>
<th>2.5</th>
<th>3</th>
<th>3.5</th>
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</thead>
<tbody>
<tr>
<td>π threshold (GeV/c)</td>
<td>2.5</td>
<td>1.6</td>
<td>1.5</td>
<td>1.3</td>
</tr>
<tr>
<td>K threshold (GeV/c)</td>
<td>9</td>
<td>5.6</td>
<td>5.1</td>
<td>4.8</td>
</tr>
<tr>
<td>p threshold (GeV/c)</td>
<td>17</td>
<td>11</td>
<td>9.8</td>
<td>9.1</td>
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</tbody>
</table>

study hadron PID in jets!
e.g. nuclear modification of
proton fragmentation

poster by A. Harton (ID 499)
Small-x Physics

- enters new regime at LHC
  - larger phase space than at RHIC
- unique opportunity for ALICE
  - use highest rapidity possible ($\eta > 3$), with significant $p_T$ range
  - direct photon measurement cleanest!
    - $x$-sensitivity, no final state effects
- studies of gluon saturation
  - expect transition from pQCD to CGC
    - $p_T$ and $y$ not precisely known
    - requires significant $p_T$ coverage for direct photons at large $y$
FoCal

- SiW electromagnetic calorimeter
  - two options for location
    - 3.5 m from IP, $2.5 < \eta < 4.2$
    - 8 m from IP, $3.3 < \eta < 5.0$
  - optional hadronic calorimeter

- 2 technologies
  - low-granularity conventional Si-pads
  - high-granularity $\approx 1 \text{ mm}^2$
    - needed for $\pi^0/\gamma$ discrimination
    - likely using MAPS
  - also allows studies of $\gamma$-jet correlations

posters by T. Gunji (ID 498, 143), N. Poljak (ID 118)
Summary

• ALICE has strong physics program for precision QGP studies

  • unique in rare low-\(p_T\) probes
  
  • requires ITS upgrade, enhanced rate capabilities + running beyond LS3
    
    • significant R&D program for upgrades

• further enhancement of the ALICE setup under investigation, possibly

  • strengthening muon measurement and high \(p_T\) hadron ID

• exploring forward physics
Backup Slides
The ALICE Setup
Kinematic Constraints

• large $y$ prompt photons effective to constrain kinematics to low $x$
  
  • obvious in LO (PYTHIA)

• NLO studies in JETPHOX:
  
  • indicate clear sensitivity of isolated photons, dedicated calculations under way

from D. d’Enterria and J. Rojo, arXiv:1202.1762
Saturation at RHIC and LHC

larger phase space for saturation effects at LHC