Analysis of ALICE data in dimuon low invariant mass region

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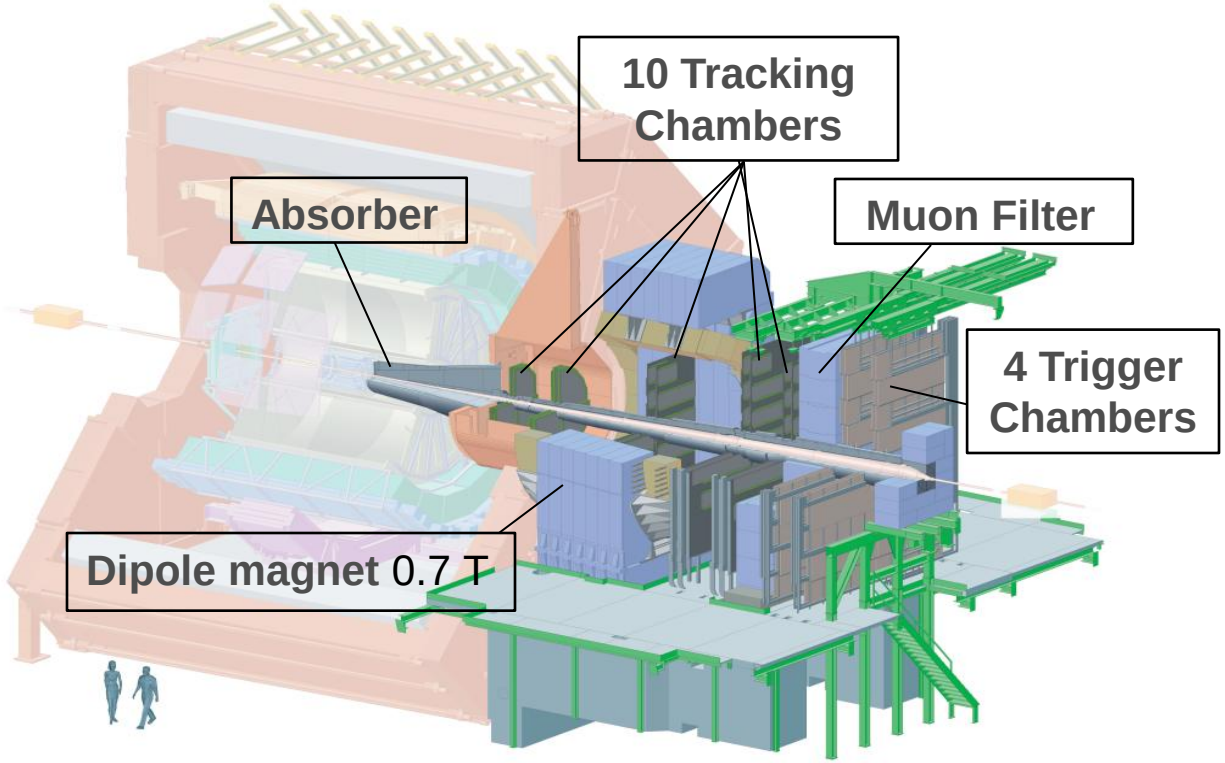
ALICE Experiment and Muon Spectrometer

The purpose of the ALICE (A Large Ion Collider Experiment) is the study of extremely hot and dense strongly interacting medium, including Quark Gluon Plasma (QGP), formed in the heavy-ion collisions at LHC energies.

In this study, a special role is played by pseudoscalar and vector mesons (η, ρ_0, ω, η', φ). Their production is analysed in ALICE in the dilepton channels ($\mu^+\mu^-$ and e^+e^-).

To study the dimuon channel, the ALICE collaboration has built a Muon Spectrometer.



Muons are detected in angular range 2˚- 9˚ around the beam.

Data analysis in ALICE

ALICE has several Physics Analysis Groups (PAG) studying different signals emanated by the matter formed in the collision processes.

The analysis of low-mass dimuon production is performed by the LMmumu (Low Mass mumu) PAG

Participants of LMmumu PAG are:

- ANSL (Yerevan, Armenia)
- INFN (Cagliari, Italy)
- IPNL (Lyon, France)

Within the LMmumu Work Programme, ANSL/ALICE team has undertaken analysis of 8 TeV data produced in *pp* collisions (accumulated in 2012).

In what follows, I will show my work on these data.

pp at 8 TeV

2012 data taking consisted of 9 periods: LHC12a,b,c,d,e,f,g,h and i. Because of high intensity of beams and not so big rate of data acquisition in ALICE experiment, in 2012 the ALICE detector was working in ***beam-satellite mode***. As a consequence, the analysis of these accumulated data requires “special” treatments!

My work on these data (started at the end of 2012):

Study of the muon-related statistics in these data has been done. 2 periods having sufficient statistics, **LHC12h** and **LHC12i** have been chosen for further analysis.

The work on these 2 periods consisted of two part:

- Assessment of Muon data (Quality Assurance, QA)
- Physics analysis of QA-ed data

Muon QA

QA is a central service in ALICE. Data can be used for the physics analysis only after the QA check.

The steps in my work on Muon QA for **LHC12h** and **LHC12i** periods :

- Check of the hardware functioning in each run. This information is got from the detector experts.
- Check of the quality of reconstructed data. Run-by-run study of numerous characteristics: *efficiency of trigger chambers*, *charge asymmetry*, *tracking quality*, *number of tracks per trigger class*, *average number of clusters per chamber*, *etc.*

(The work has been done with Muon QA experts Diego Stocco and Cynthia Hadjidakis)

Finally an 'official' list of runs to be used for analysis has been produced for ALICE collaboration.

The work was presented by me in:

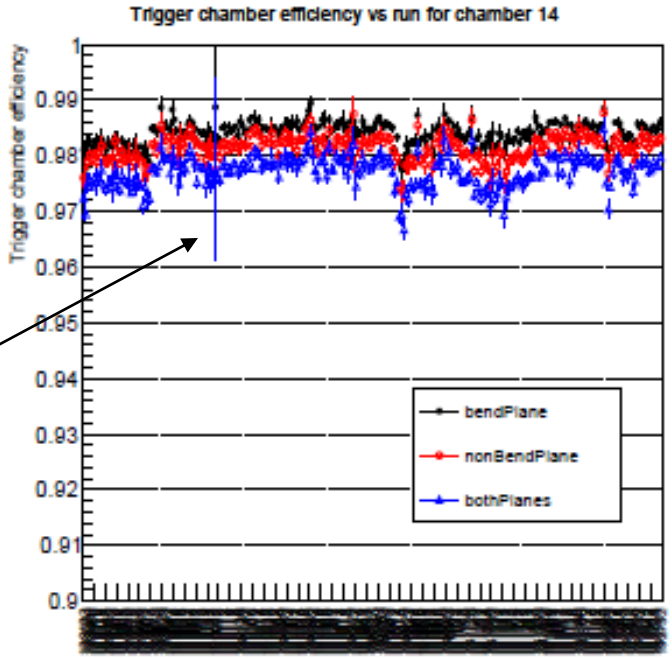
- "QA meeting" on December 10, 2013 (https://indico.cern.ch/event/287244/)
- "Muon Plenary meeting" on January 20, 2014 (https://indico.cern.ch/event/293161/)

Muon QA results for LHC12h

LHC12h	# of runs	MSH7-S / MSH8-S	MUL7-S / MUL8-S
ALICE logbook	295	21 / 44.7 M	2.7 / 6.8 M
V0 problem	21	1.7 / -	- / -
not rec.	15	0.3 / 0.2 M	0.04 / -
MTRG bad	6	0.3 / 0.2 M	0.05 / 0.03 M
Good from QA	225	18.5 / 33 M	2.5 / 5 M

An example: *the check of the efficiency of the trigger chamber #14*

One (#190055) of 6 runs was marked as “MTRG bad”. The reason- muon trigger was in ‘Busy’ state.



Physics Analysis

Construction of Physics Analysis set of events:

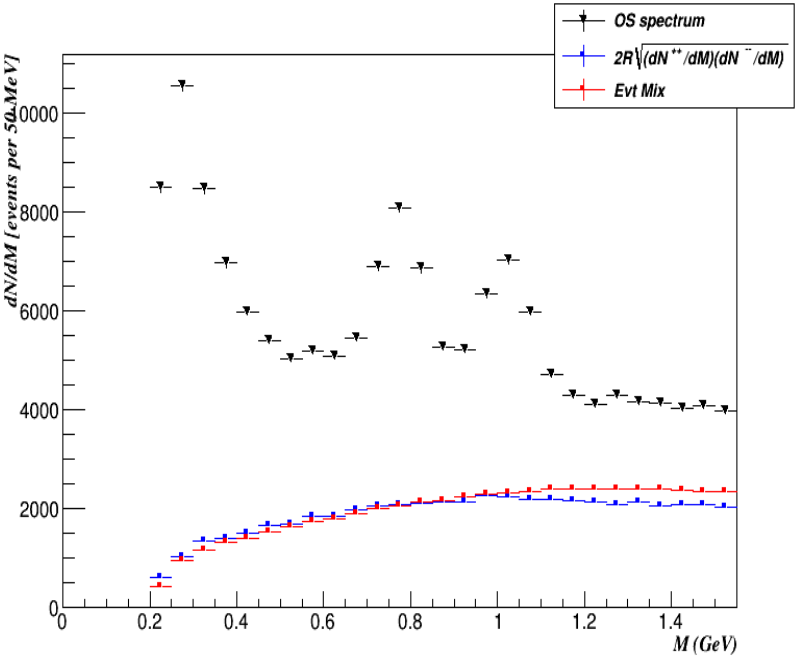
- **The events registered by 'dimuon' triggers have been selected**
  - Muon Unlike Low Pt: events containing "+ –" muon pairs, each of muon having p_t >1GeV.
  - Muon Like Low Pt: events containing "++" and "– –" muon pairs, each of muon having p_t >1GeV.
- **Physics Selection cut:** removal of the events resulting from beam-gas interactions.
- **Matching** of the tracks observed in the tracking chambers with the tracklets observed in the trigger chambers: removes particles (in particular hadrons), which do not cross the Muon Filter.
- **Selection of events that have been registered in the fiducial volume of detector**. Single muon pseudorapidity cut (-4< η_μ< -2.5).

Experimental $\mu^+\mu^-$ mass spectra in LMR

The mass spectra consist of correlated and uncorrelated μ^+ and μ^- leptons:

- the main sources of the correlated $\mu^+\mu^-$ pairs are the processes of the ***decays of mesons*** *(see slide #9)*.
- The (combinatorial) **background** is filled by the pairs of uncorrelated μ^+ and μ^- leptons which originate from the independent decays of ***pions*** and ***kaons:***

$$\pi^{\pm} \to \mu^{\pm}\nu_{\mu}, \quad K^{\pm} \to \mu^{\pm}\nu_{\mu}$$



The **background** is constructed by 2 methods:

1. **Using the like sign dimuon spectra:**

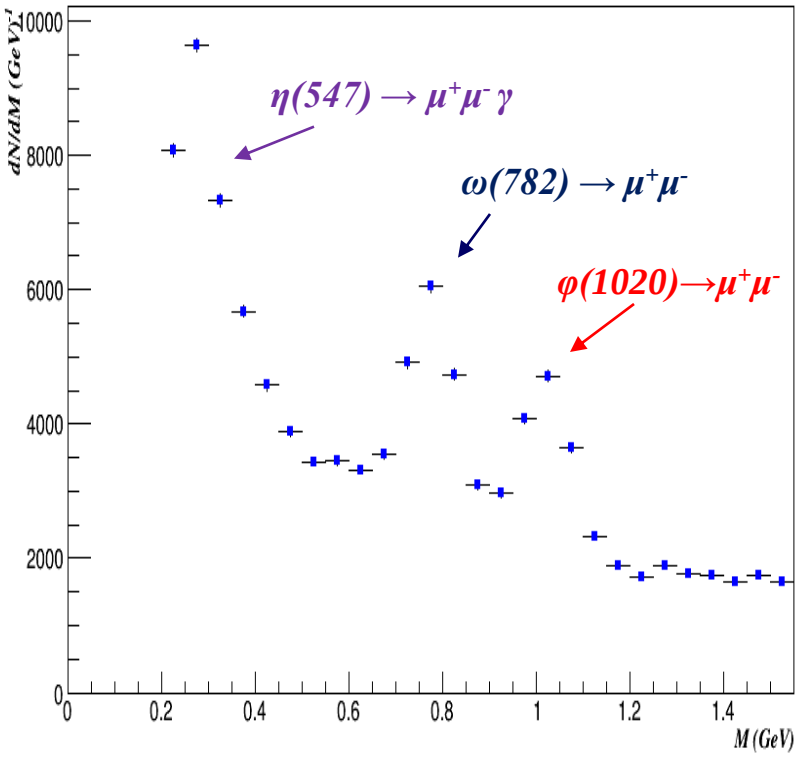
$$B^{+-}(M) = 2R(M)\sqrt{N^{++}(M)N^{--}(M)}$$

where $R = \frac{A^{+-}}{\sqrt{A^{++}A^{--}}}$ takes into account the possible correlation between the detection efficiency of two muons in a pair (A^{+-}, A^{++} and A^{--} are respectively the acceptances for “+-”, “++” and ”--“ pairs).

2. **Using the event mixing technique**

Creating the muon pairs from the muons from different events.

Mass spectra after background subtraction



The list of the processes contributing to the LMR:

- **Two-body decays:** $\rho(770) \rightarrow \mu^+\mu^-$, $\omega(782) \rightarrow \mu^+\mu^-$, $\varphi(1020) \rightarrow \mu^+\mu^-$
- **Dalitz decays:** $\eta(547) \rightarrow \mu^+\mu^-\gamma$, $\omega(782) \rightarrow \mu^+\mu^-\pi^0$, $\eta'(958) \rightarrow \mu^+\mu^-\gamma$

→ **AliGenMUONLMR** cocktail generator

- **Semi-leptonic decays of open charm and open beauty:**

$D^{\pm} \rightarrow \mu^{\pm} X$, $B^{\pm} \rightarrow \mu^{\pm} X$

→ **AliGenCorrHF** generator

These processes are simulated and their summary contribution is fitted to the observed spectra.

Upgrade of AliGenMUONLMR fast generator

Parameterisation in AligenMUONLMR of **multiplicity**, **rapidity** and $\boldsymbol{p_t}$ distributions of the production of the resonances (η, ρ_0, ω, η', φ) using the corresponding spectra obtained with different 'tunes' of **Pythia** generator:

- ✓ ATLAS-CSC
- ✓ D6T
- ✓ Perugia0
- ✓ Perugia11

for *pp* collisions at 2.76, 7 and 8 TeV.

The **parameterizations for *pp* collisions at 8 TeV** have been included in official generator: **AliGenMUONLMR** on July, 2013.

Further work

- Massive Monte Carlo simulations in Grid
- Calculation of acceptance × efficiency in the detection of the muon pairs
- Extraction of individual contributions (φ, ω, η, …)
- Calculation of the corresponding cross sections
- Preparation of the Official Analysis Note

Presentation of my work at the LMmumu PAG meetings

- '***Multiplicities of "cocktail" resonances at 2.76, 7 and 8 TeV in PYTHIA tunes'*** (17.12.2012)
- '***ALICE pp @ 8 TeV. Study of data quality'*** (29.01.2013)
- '***ALICE pp @ 8 TeV. Study of data quality'*** (08.02.2013)
- '***First look at the pp @ 8 TeV LHC12c data'*** (22.02.2013)
- '***In-depth look #1 at pp @ 8 TeV LHC12c data'*** (08.03.2013)
- '***Muon multiplicities in pp @ 8 TeV LHC12c data'*** (15.03.2013)
- '***LS combinatorial background in pp @ 8 TeV LHC12c data'*** (28.03.2013)
- '***Upgrade of LHC12c data analysis'*** (19.04.2013)
- '***Refined analysis of LHC12c'*** (17.05.2013)
- '***Structure of data in LHC12h and LHC12i'*** (07.06.2013)
- '***Structure of data in LHC12d, e, f and g'*** (28.06.2013)
- '***Analysis of LHC12h and i data'*** (19.07.2013)
- '***Status of LHC12i and h muon_calo_pass2 data***' (29.11.2013)
- '***Problems with kinematics of generated events***' (24.01.2014)
- '***Low mass dimuon CMUL and CMLL statistics in muon_calo_pass2 of LHC12h and i***' (12.02.2014)
- '***Status of LHC12h and i (muon_calo_pass2) data analysis***' (21.03.2014)
- '***On the combinatorial background in LHC12h TO data***' (02.04.2014)

Participation in ALICE shifts

Within the obligations of ANSL in the ALICE experiment I have participated:

- **6 day** shifts for the Data Acquisition System (DAQ) in 2011.
- **6 day** and **5 night** shifts for the DAQ in 2012 (accumulation of **LHC12h** data).

Thanks

My activity before 2013

Dimuon analysis of 2.76 TeV data produced in *pp* collisions.

This analysis was the check of analysis previously done by *Cagliari* and *Lyon* teams. The repetition has a educational aim: understanding the complex data structure, analysis tools and methods in ALICE collaboration.

This work was done in close collaboration with Lyon team within the scope of grant: ***CNRS-IPNL*** and ***CSC-ANSL*** (2012). Within the scope of this grant I have visited IPNL in 2012 and 2013.

Student activity:

2010	Bachelor degree, "*Creation of repository of data on the nucleon charge-exchange reactions for data mining, presentation and analysis*".
2011	Studentship in the CERN Summer Student Programme with supervision of Dr. Andreas Morcsh.
2012	Master degree, "*Applying modern information technologies to the analysis of data of ALICE experiment at CERN*".