Material budget with the displaced vertex technique using VZERO

Maxime Guilbaud (m.guilbaud@ipnl.in2p3.fr),
for the ALICE collaboration,
Université de Lyon, Université Lyon1, CNRS/IN2P3, Institut de Physique Nucléaire de Lyon

Abstract

The LHC already provided a large amount of Pb-Pb collisions analyzed by the ALICE Collaboration [1]. The beam tuning has continuously improved but in 2010, some collisions took place at different vertex location regarding the nominal one: a non-negligible number of satellite collisions have been recorded. These were easily removed by the ALICE physics selection for most of the physics analyses. Nevertheless, these satellite vertices were used to measure the primary charged particle density in a large pseudo-rapidity range using the VZERO and FMD detector. These measurements were also done using the Forward Multiplicty Detector at the nominal vertex. The comparison between both VZERO and FMD measurements highlighted the need for adjusting the material budget in the Monte Carlo which simulated the ALICE apparatus. The displaced vertex technique can be used to scan the ALICE detector geometry and locate these materiel budget discrepancies between reality and Monte Carlo. In this poster, the origin of satellite vertices and the principle of the displaced vertices technique are explained.

Satellite vertex origin

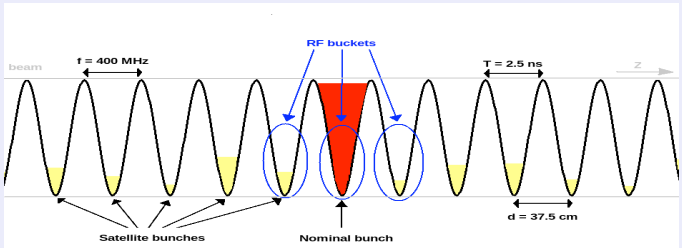

Fig 1: Bunch distribution in one beam at LHC after all injections.

Before injection into the main accelerator, the ions are "produced" and then prepared by a series of systems that successively increase their energy. Thanks to 400 MHz RF accelerating system bunches are filled in RF buckets separated by a multiple of 25 ns in the LHC rings. Due to LHC frequency, there is one RF bucket every 2.5 ns. Nevertheless, during the beam injection and transfer from one machine to the next, part of the beam can be un-captured at the beginning of the acceleration and lost. In addition, an other fraction of the beam can be captured inadvertently in an unwanted RF bucket and creates satellites bunches spaced by 2.5 ns (**Fig 1.**). This de-bunching effect occurs for both beam injections (PS/SPS, SPS/LHC). Satellite bunches present in the SPS are likely to create satellite in LHC. Crossings of the satellite bunches of one beam with the nominal bunches of the other beam produce satellite interaction vertices spaced by 37.5 cm along the Z axis. Regarding statistics, satellite interactions are less likely than nominal interactions (a probability around 10^3 smaller). Finally, satellite collisions are clearly seen in ALICE and can be easily removed in the physics selection using the Zero Degree Calorimeter (ZDC) [2].

VZERO detector

The VZERO detector [3] is made of two scintillator hodoscopes on both sides of the IP. The VZERO-A (**Fig 2a.**) is located 330 cm away from the IP on the side opposite to the muon spectrometer. The VZERO-C is fixed at the front face of the hadronic absorber, 90 cm from the IP position. They cover the pseudo-rapidity ranges $2.8 < \eta < 5.1$ (VZERO-A) and $-3.7 < \eta < -1.7$ (VZERO-C). These pseudo-rapidity ranges rely on the nominal interaction point position. They are segmented into 64 channels distributed in four rings and eight sectors. In the following, only the VZERO-A is used because its surrounding material budget is smaller than the VZERO-C one.

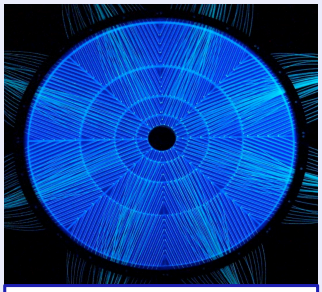

Fig 2a: Picture of the VZERO-A array.

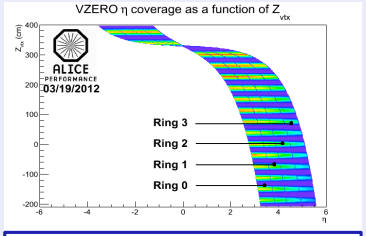

Fig 2b: VZERO-A rings η coverage as a function of Z-vertex position.

Thanks to the de-bunching effect of the LHC's lead ion beam, the VZERO-A extends its pseudo-rapidity coverage ($-2.81 < \eta < 5.22$). In fact, the angular acceptance of forward detectors, including VZERO-A, and thus their pseudo-rapidity coverage change for satellite collisions as the interaction point position is not the same (**Fig 2b.**). Consequently, this effect is used to perform measurements in a larger pseudo-rapidity range.

Displaced vertex technique

Using de-bunching implies development of an event selection and a centrality estimator for satellite collisions. The ZDC is far from the interaction point (ZDC-N/P~114 m, ZEM~7.5 m) and therefore is weakly sensitive to the interaction vertex position.

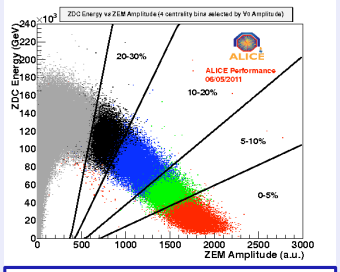

Fig 3a: Centrality selection with ZDC vs ZEM signal.

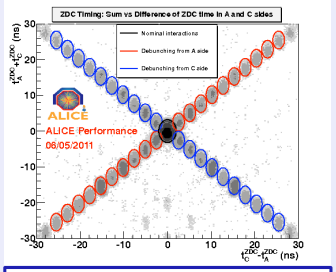

Fig 3b: Event selection with ZDC .

The ZDC centrality estimator works well for the most central events (0 to 40 %). The cut on centrality bins is applied to the correlation between ZEM signal and ZDC energy (**Fig 3a**).

Thanks to the good time resolution of the ZDC, we are able to separate collisions coming from different satellite bunches (**Fig 3b**).

Hints for missing material in ALICE

The first measurement performed with the displaced vertex technique is the dN/dη with the VZERO. The FMD detector [3] provided the same measurement with nominal vertex collisions. The comparison between both analyses (**Fig 4**) showed discrepancies around $2 < |\eta| < 4$. Systematic errors on this figure are a quadratic mean of both FMD and VZERO systematic errors. FMD values are higher which can be attributed to missing material in the simulation of the ALICE apparatus. The material budget has to be adjusted in the Monte Carlo.

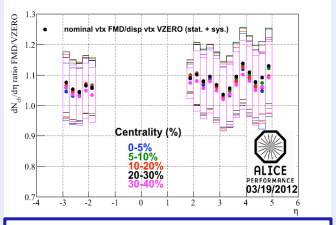

Fig 4: Disp. Vtx VZERO/FMD nominal

Material budget study

VZERO-A is able to measure dN/dη at some η using different vertices (**Fig 2b**). For some vertices, higher values for $2<|\eta|<4$ have been observed. Knowing the VZERO ring acceptances and their overlaps for these vertices (**Fig 5a**), it is possible to locate missing material in R and Z (dark red circled area). For these vertices, particles go trough the ITS (Inner Tracking System) [4] and its services before hitting FMD and VZERO-A. No discrepancy is are observed at Z_{vtx} = 37.5 cm (yellow on **Fig 5a**). Studies to adjust the material description are in progress. This technique can also be used to check symmetries and material description in most of the ALICE apparatus.

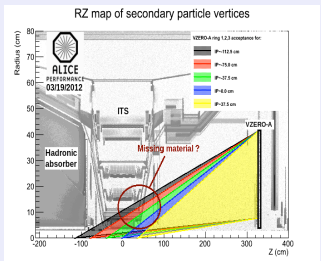

Fig 5a: Possible missing material location.

The interaction point position can be chosen to perform measurement in a low material budget region. **Fig 5b** shows that between FMD2 and FMD1+VZERO-A (i.e. 70 cm < Z < 100 cm), the environment is cleaner since the main contribution to the material budget is the beam pipe. Consequently, we are able to perform properly our analysis thanks to displaced vertex technique in this region.

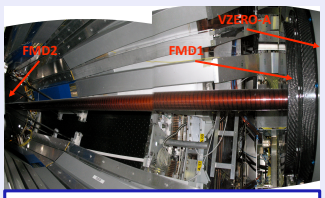

Fig 5b: Low material budget between FMD1,2 and VZERO-A

Using this technique in the region mentioned above, FMD performs again the dN/dη analysis. **Fig 5c** shows the ratio between both detectors VZERO-A and FMD using the displaced vertices technique. The measurements are consistent within error bars and no discrepancies around $2 < |\eta| < 3$ are observed any more. To conclude, the displaced vertex technique shows that most of the discrepancies between FMD measurement at nominal vertex and VZERO with the displaced vertices are due to missing material.

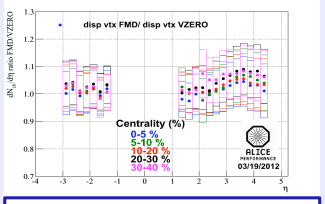

Fig 5c: Disp. Vtx FMD/VZERO

Conclusion

The displaced vertices technique is very useful to check and adjust material budget in ALICE. This technique can also be used to extend the η coverage of the VZERO detector. Studies on ϕ anisotropy are in progress with the same technique to increase our knowledge of material budget and therefore improve the precision of the results.

References

[1] The ALICE Collaboration, The ALICE experiment at the CERN LHC , JINST 3 (2008) S08002.
[2] The ALICE Collaboration, ZDC Technical Design Report,CERN-LHCC-1999-5.
[3] The ALICE Collaboration, Forward Detectors: FMD, T0,V0 Technical Design Report, CERN-LHCC-2004-025.
[4] The ALICE Collaboration, ITS Technical Design Report,CERN-LHCC-1999-12.