Satellite population measurements in Pb-Pb collisions with the ALICE ZDCs

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Motivation and outline

- Motivation

- Provide a cross check of the LHC LDM satellite charge measurements

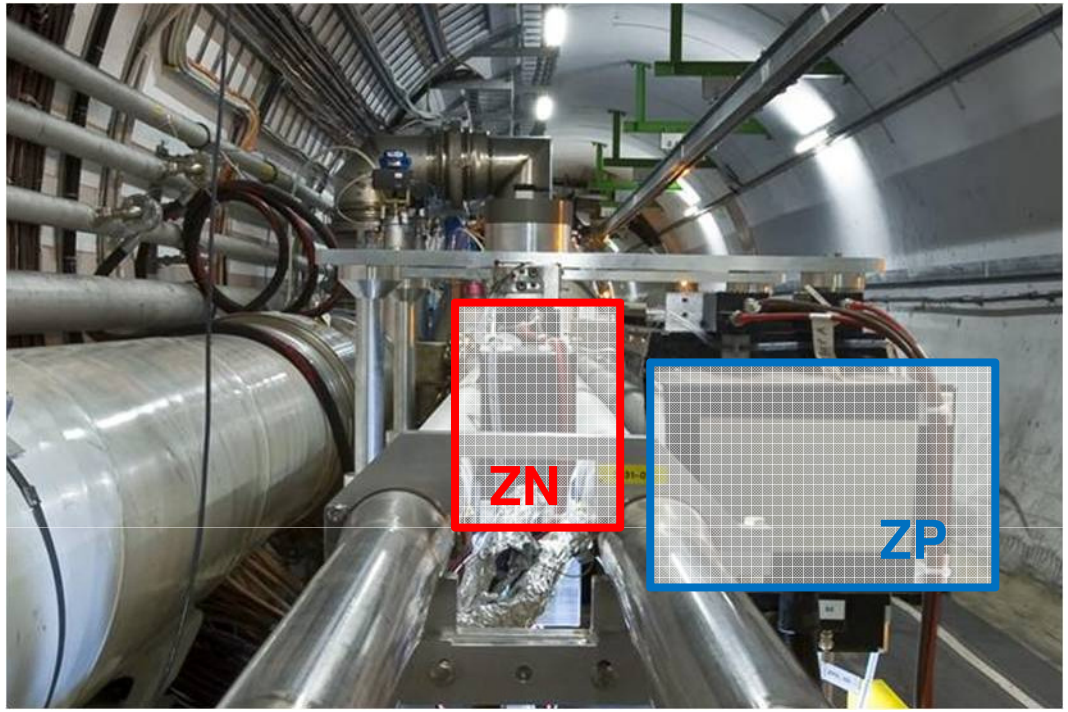
- Provide insights on the longitudinal structure of Beam 1 in Fill 1533 (November 2010 heavy-ion vdM scan), not probed by LDM

- Outline

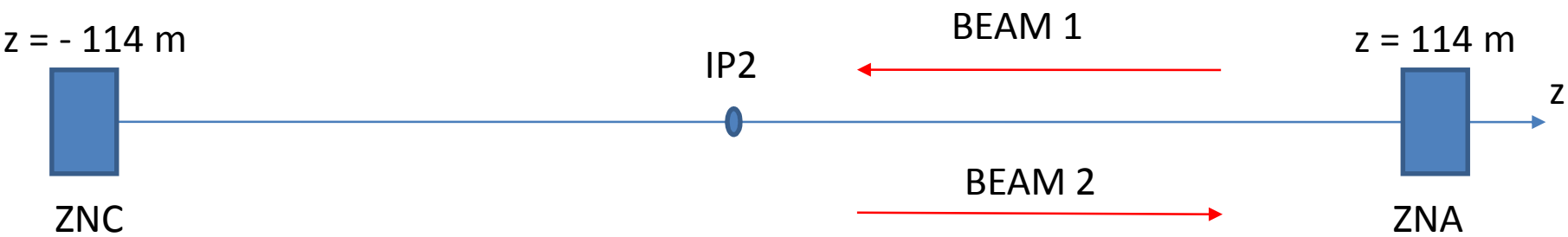
- The ALICE Zero Degree (neutron) calorimeters
- Measurement of satellite fractions from ZDC data
- Corrections and systematic uncertainties
- Results and comparison with LDM
- Conclusions

The ALICE Zero Degree Calorimeters

- Two calorimeters per side:
  one for protons (ZP)
  and one for neutrons (ZN)
- Measure centrality
  in heavy ion collisions by
  measuring the energy
  of spectator nucleons
- Measure luminosity via EM
  dissociation with neutron emission
  (K. Oyama's talk)
- For satellite measurements
  we focus on ZN



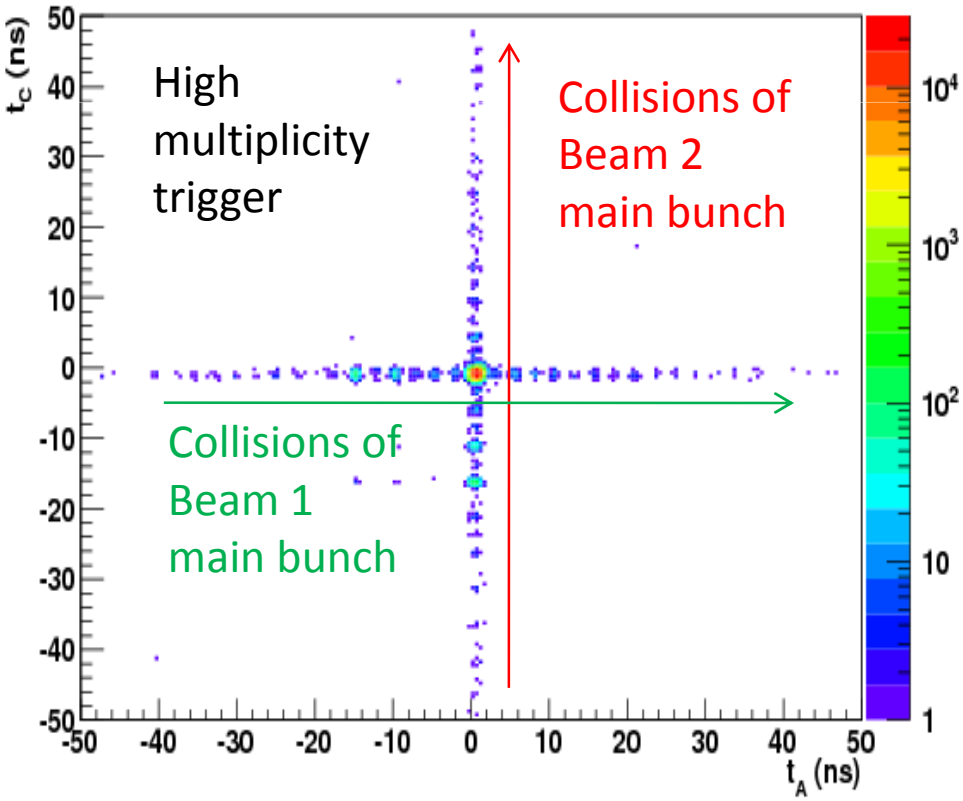
- Acceptance x efficiency ~ 100%
- Equipped with TDCs, time resolution 25 ps → Use arrival time to spot displaced collisions

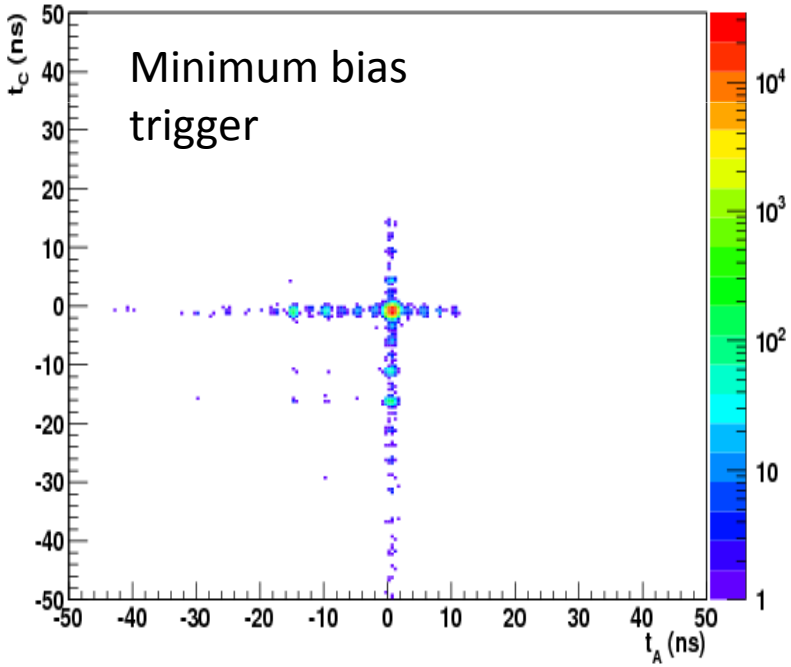


Spotting satellites with ZN timing

- Fill 1533 (November 2010 vdM scan)
- Summing up data from all 114 bunches colliding in ALICE
- Select runs without scans in IP2
- t_A (t_C) distribution is sensitive to the satellites of Beam 2 (Beam 1)

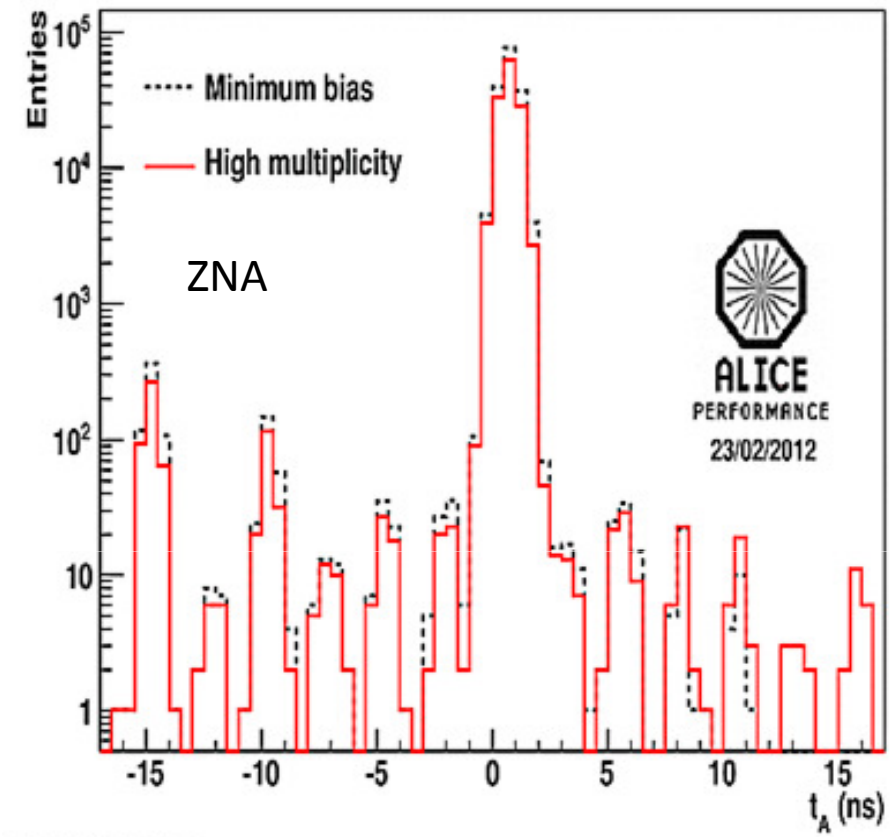
No ZDC trigger available in fill 1533
Using two ALICE triggers:
- Minimum bias:
  >2 hits in the inner pixel detector +
  > 1 hit per side in the V0 scintillators
- High multiplicity:
  > 100 hits in the inner pixel detector

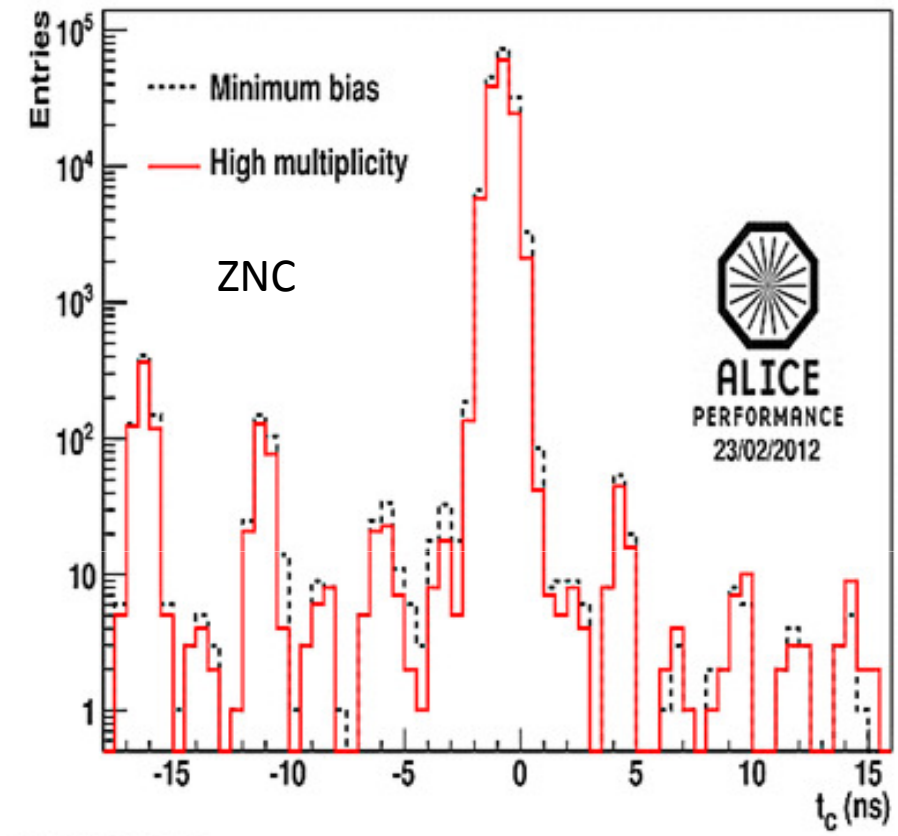




Minimum bias trigger has sharp acceptance drop for late collisions

ZN time distributions





- Collisions in different RF buckets are very well separated (except for next-to-main buckets) -> upper limit on de-bunched charge?
- Count number of events in peaks 2 to 6 buckets away from the main one -> compute fraction of satellite-main to main-main collisions
- For the minimum bias trigger, limit the analysis to bucket 3 on the positive side

Corrections

- Satellites in bucket 2 (6) collide 75 cm (225 cm) away from IP2
- In order to evaluate the satellite population fractions, satellite collision fractions must be corrected for z-dependent hour-glass and crossing angle factors
- Assumption: same emittance for main bunches and satellites (checked in pp that this is reasonable, see next slide)
- Hour-glass: satellites collide with main bunches where beams are de-focused: $L(z) = L(0) / (1+z^2/\beta^{*2})$
- Residual crossing angle in the Y direction (spectrometer bending plane): $\Phi = (20 \pm 4)$ μrad, measured by ZDC using centroid of spectator nucleon spot -> satellites collide with main bunches with separation $z\Phi$
- Total z-dependent luminosity drop:

$$L(z) = L(0)\frac{e^{-\frac{(z\phi)^2}{2\Sigma_y^2(z)}}}{1+z^2/\beta^{*2}}$$

Crossing angle

Hour-glass

with $\Sigma_y(z) = \Sigma_{y,0}\sqrt{1+z^2/\beta^{*2}}$

Effective beam height measured in vdM scan

- Finally:

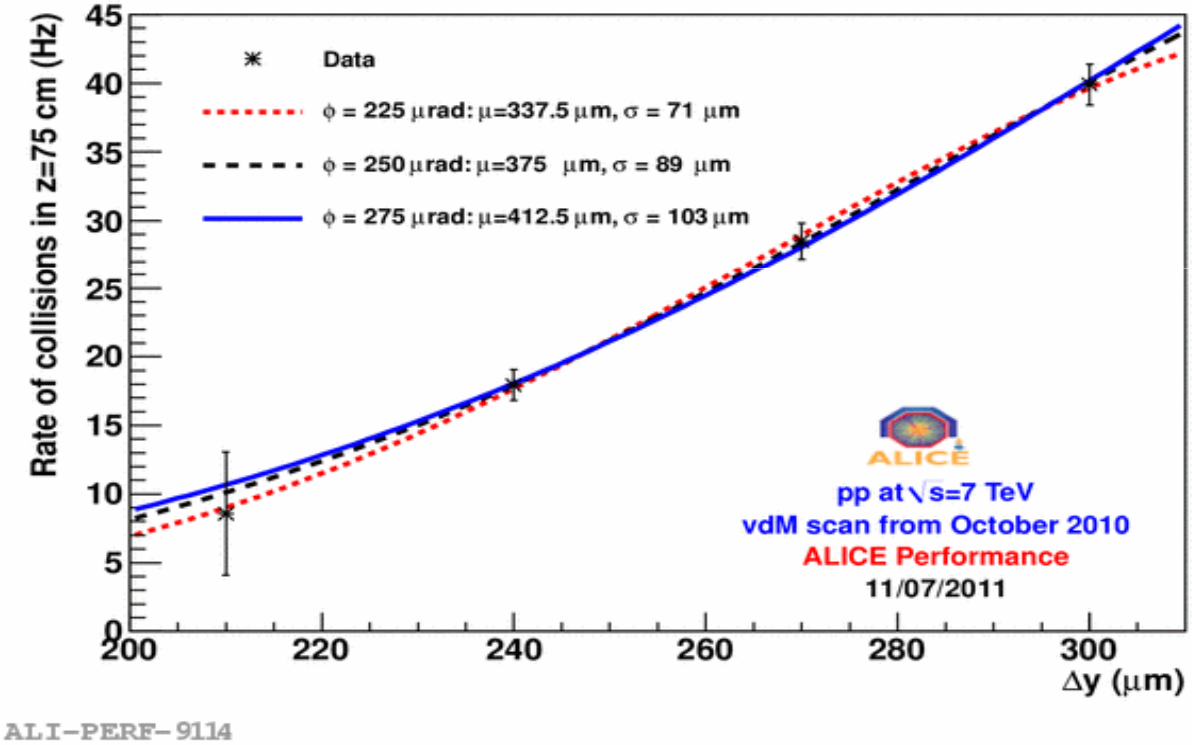
satellite population fractions = satellite collisions fractions * [L(0)/L(z)]

Interlude: satellite bunch emittance

October 2010 pp vdM scan:

Satellite collisions in pp spotted using V0 timing

Measure main-satellite collision rate as a function of separation during the scan -> “satellite” vdM scan



$\Sigma_{\text{main-satellite}} = 89\ \mu m$

$\Sigma_{\text{main-main}} = 92\ \mu m$ $\longrightarrow$ Main and satellite bunches have similar width

Uncertainties

- Statistical:

  ranging from 4% to 40%

- Crossing angle:

  0.5% at z = 75 cm (bucket ±2)

  3.5% at z = 225 cm (bucket ±6)

- z-dependence of the trigger efficiency:

  - analysis of a fill (1522) where ZDC trigger was available
  - we expect the ZDC trigger efficiency to be independent of z

    -> compare the satellite fractions measured in fill 1522 with high multiplicity and minimum bias triggers with those measured with ZDC trigger in the same fill

  - no definite z-dependence, but 30% fluctuations
  - conservatively take 30% uncertainty

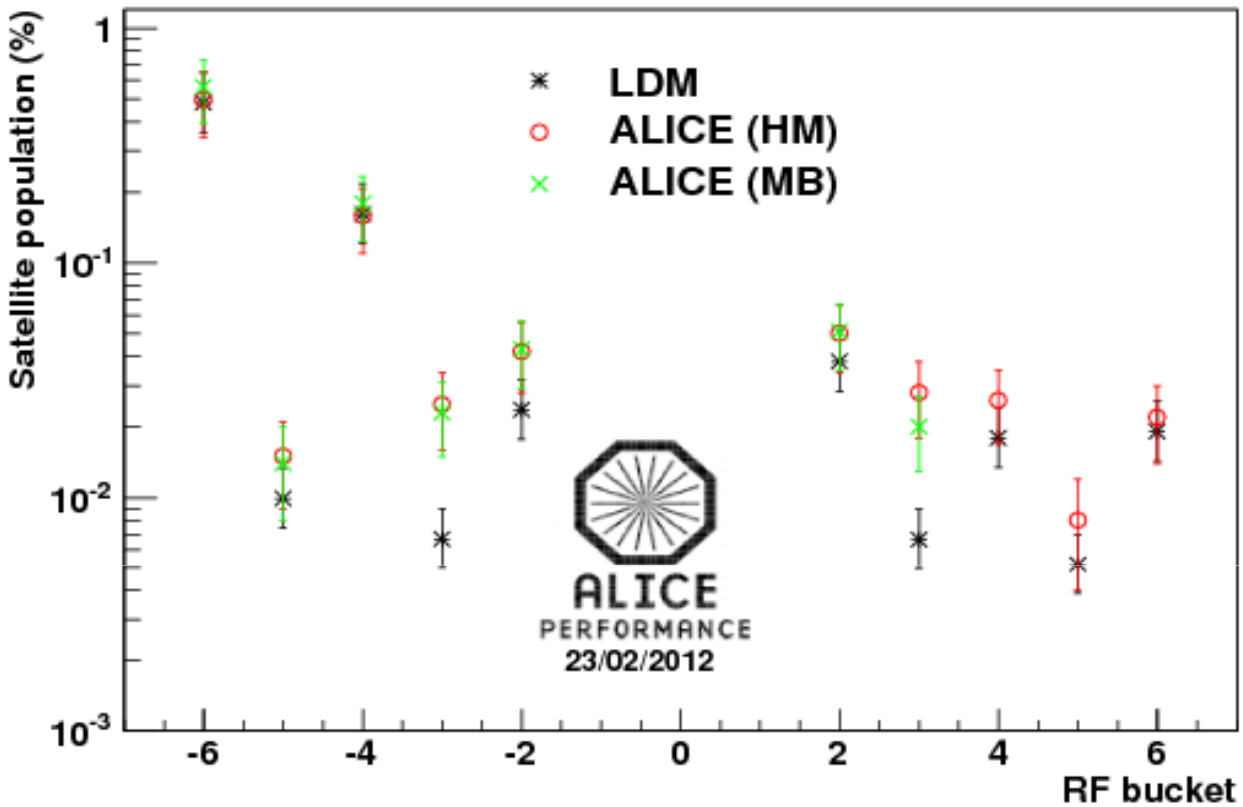
Results for Beam 2 and comparison with LDM

Bucket	z (cm)	Measured satellite fractions (%)		
		ALICE (MB)	ALICE (HM)	LDM
-6	225	0.562±0.171	0.495±0.151	$0.481^{+0.168}_{-0.120}$
-5	187.5	0.014±0.006	0.015±0.006	$0.010^{+0.003}_{-0.002}$
-4	150	0.179±0.055	0.159±0.049	$0.161^{+0.057}_{-0.040}$
-3	112.5	0.023±0.008	0.025±0.009	$0.007^{+0.002}_{-0.002}$
-2	75	0.043±0.014	0.042±0.014	$0.024^{+0.008}_{-0.006}$
2	-75	0.051±0.016	0.050±0.016	$0.038^{+0.013}_{-0.009}$
3	-112.5	0.020±0.007	0.028±0.010	$0.007^{+0.002}_{-0.002}$
4	-150	-	0.026±0.009	$0.018^{+0.006}_{-0.004}$
5	-187.5	-	0.008±0.004	$0.005^{+0.002}_{-0.001}$
6	-225	-	0.022±0.008	$0.019^{+0.007}_{-0.005}$

- Uncertainty: square sum of statistical, crossing angle, trigger efficiency

- LDM: Using baseline-subtracted LDM counts with bucket granularity
  Summing up all buckets in the same position wrt ALICE colliding bunches.
  Using -25% +35% uncertainty band

Results for Beam 2 and comparison with LDM



- Generally good agreement between ALICE and LDM, except for buckets -3 and 3
- ALICE tends to measure slightly higher satellite populations than LDM
- Good agreement between ALICE results with different triggers
- Comparison of integrated satellite population:

High multiplicity: (0.87±0.16)% - LDM for the same bucket range: $(0.77_{-0.15}^{+0.23})\%$

Minimum bias : (0.89±0.18)% - LDM for the same bucket range: $(0.73_{-0.15}^{+0.22})\%$

Results for Beam 1

Bucket	z (cm)	Measured satellite fractions (%)	
		ALICE (MB)	ALICE (HM)
-6	-225	0.666±0.203	0.719±0.219
-5	-187.5	0.010±0.004	0.009±0.004
-4	-150	0.225±0.069	0.220±0.068
-3	-112.5	0.015±0.006	0.015±0.006
-2	-75	0.055±0.018	0.047±0.016
2	75	0.054±0.017	0.056±0.018
3	112.5	0.004±0.002	0.006±0.003
4	150	-	0.019±0.007
5	187.5	-	0.008±0.004
6	225	-	0.019±0.007

Table 2: Beam 1 satellite fractions in fill 1533 as measured by the ALICE neutron calorimeters from a minimum bias (MB) and a high multiplicity (HM) data sample.

- Similar (slightly higher) satellite population magnitude as Beam 2
- Good agreement between the ALICE results obtained with different triggers

Conclusions

- The ALICE Zero Degree neutron Calorimeters provide an independent measurement of satellite populations in heavy-ion runs

- Generally good agreement with LDM measurements in fill 1533, with the exception of a few low-population buckets

  Integrated ZDC-LDM discrepancy ~20%

- ZDC results could be used to set an upper limit on de-bunched charge

- Similar magnitude and structure of satellites in Beam 1 and Beam 2 in fill 1533

- Outlook: analysis of November 2011 vdM scan, performed with optimised trigger conditions

Backup

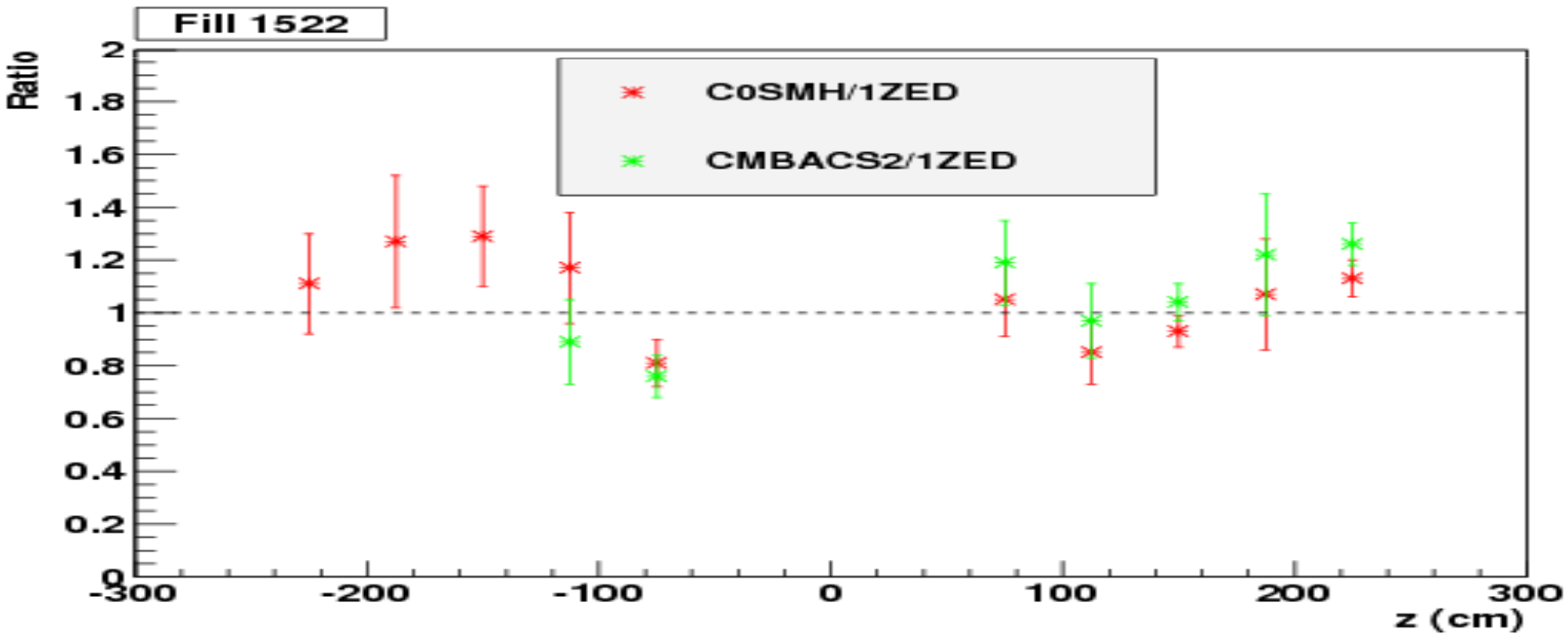
Z-dependence of the trigger efficiency

- Attempt to constrain the z-dependence of the CMBACS2 and C0SMH triger efficiency by comparison with ZDC-triggered data

- Fill 1522: special run with ZNA || ZNC (1ZED) trigger

-We expect the efficiency of 1ZED to be independent of the z position of the vertex (emitted nucleon path is independent of z position)

-Look at z-dependence of CMBACS2 and C0SMH ratio to 1ZED in fill 1522



- No clear trend but 30% fluctuations: assume 30% uncertainty from trigger efficiency