ALICE

ALICE beats ATLAS and CMS
in publishing the first LHC paper

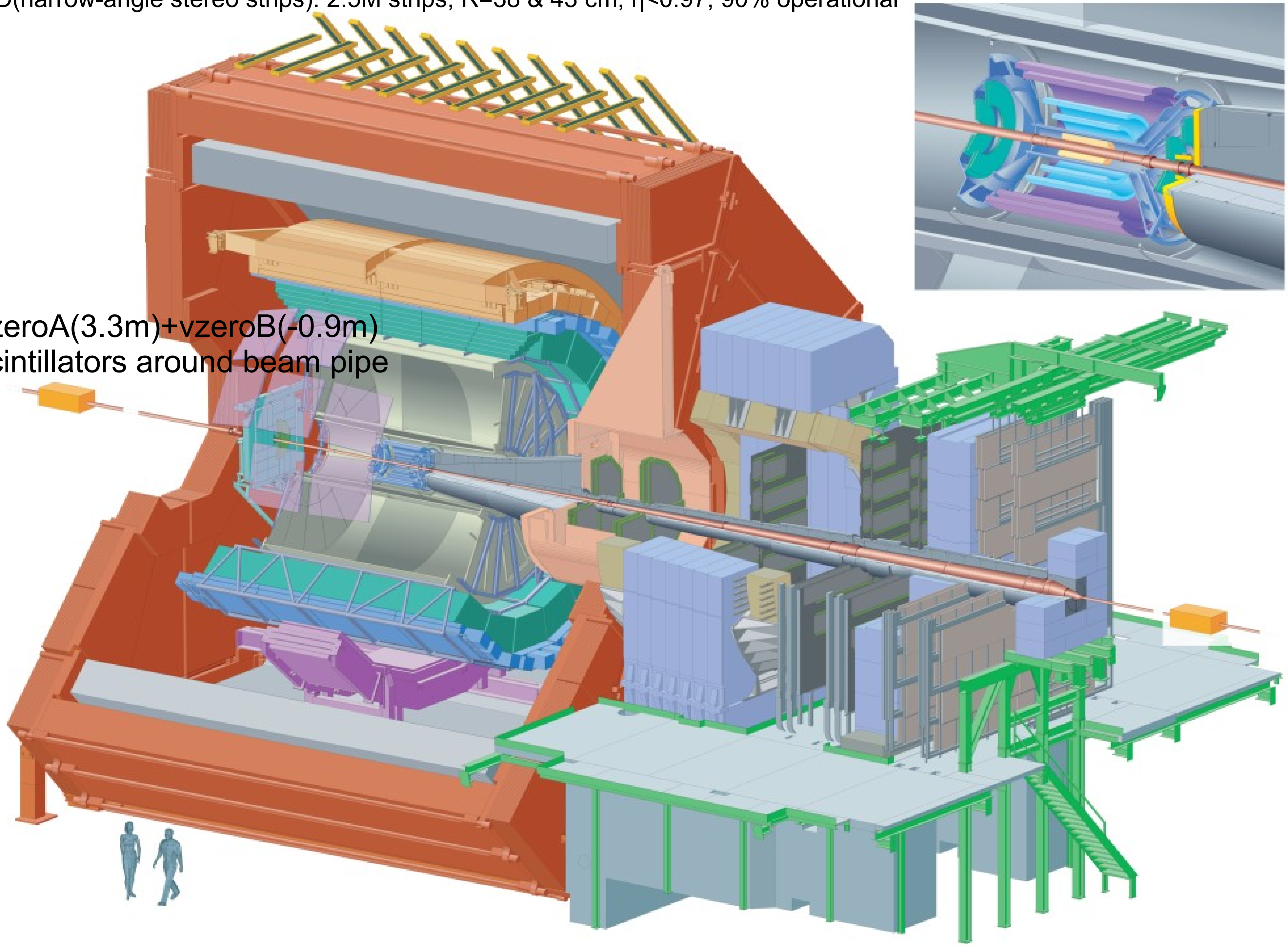
LHC

- November 23rd: first collisions at Point 2
- One "pilot" bunch per beam
  - 450 GeV on 450 GeV
  - O(1E9 protons per bunch)
  - Nominal beam: 300 microns (trans.) x 10 cm (long.)
    - Was measured in previous spill → similar to nominal
- ALICE saw 284 event candidates in 43 minutes
- This paper studies η distribution of charged primary particles

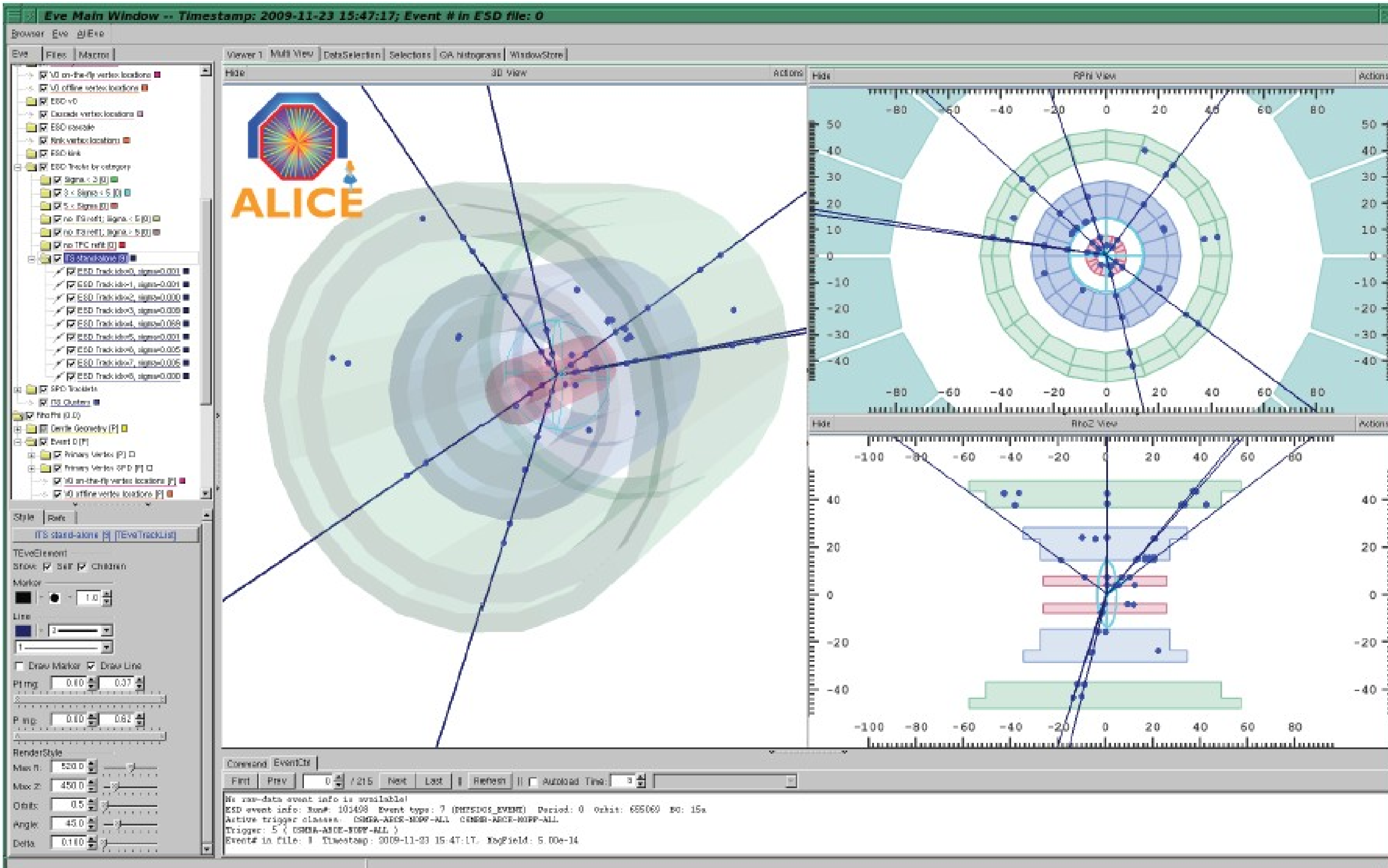
ALICE

- Dedicated heavy-ion experiment
- Solenoid B-field (off during first data)
- Only silicon tracking detectors are on
- Trigger:
  - 2 hits in Silicon Pixel Detector + passage of two beams in beam pickup detectors
  - Rate = 3E-4 Hz (no beam), 0.006 Hz (1 beam), 0.11 Hz (both beams)

SPD(pixels): 10 million 2D pixels, R=3.9 & 7.6 cm, η<1.4; 83% operational
SDD(drift): 130k channels, R=15 & 23.9 cm, η<0.9; 92% operational
SSD(narrow-angle stereo strips): 2.5M strips, R=38 & 43 cm, η<0.97; 90% operational

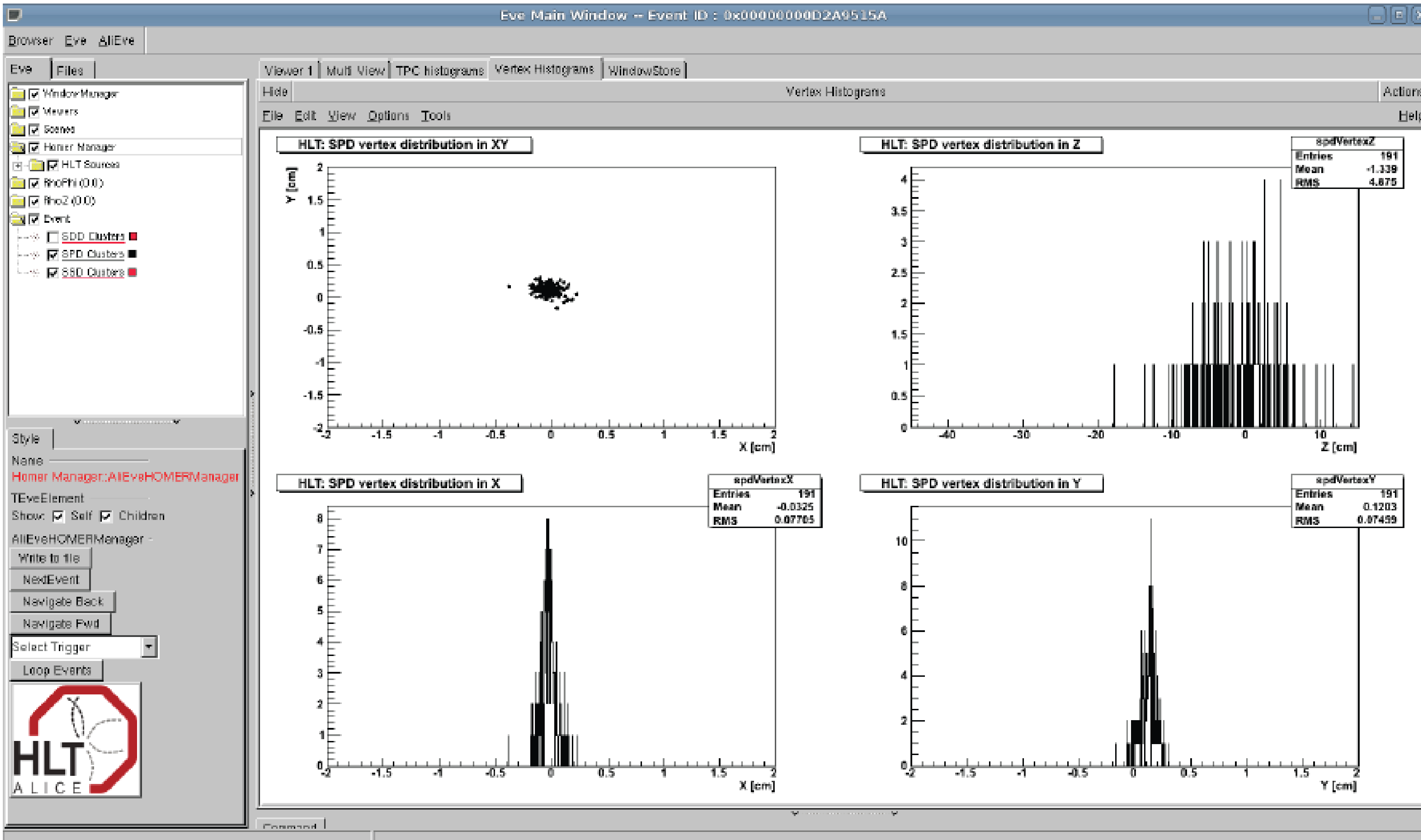


1^{st} event



Eve Main Window -- Timestamp: 2009-11-23 15:47:17; Event # in ESD file: 0
ALICE
3D View
RPhi View
RhoZ View
Command
EventCtrl
Refresh

All events with a reconstructed vertex



Arrival time at vzero scintillators with respect to nominal LHC beam crossing time

VZERO-A 3.3m away from center

VZERO-B -0.9m away from center

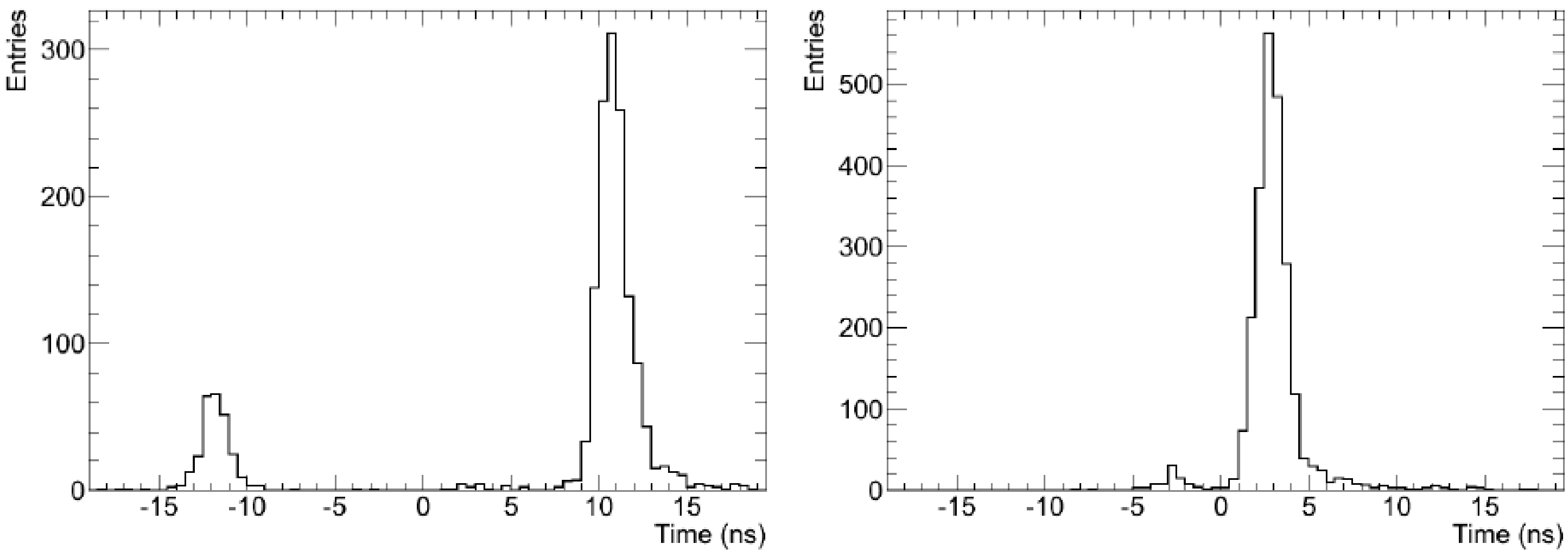


Fig. 3. Arrival time of particles in the VZERO detectors relative to the beam crossing time (time zero). A number of beam-halo or beam–gas events are visible as secondary peaks in VZERO-A (left panel) and VZERO-C (right panel). This is because particles produced in background interactions arrive at earlier times in one or the other of the two counters. The majority of the signals have the correct arrival time expected for collisions around the nominal vertex.

Arrival times are as expected

Pomeron exchange

- Phenomenological model of exchange of a particle that share quantum N of a vacuum
- Predict multiplicity production via a few parameters that form basis of MC generators
- Charged-particle density increases by a factor 1.7 (1.9) from 900GeV to 7 TeV (14 TeV)
- Difference in p-pbar and pp was measured 1.5-3% (CERN ISR at 53 GeV). Extrapolated to 900 GeV, the difference is ~0.1-0.2%

Inelastic interactions

- Three kinds of inelastic interactions:
  - Non-diffractive (77%): trigger 98-99% efficient
  - Single-diffractive (15%): trigger 48-58% efficient
  - Double-diffractive (8%): trigger 53-76% efficient
- Fractions are from UA5; trigger eff via MC (PYTHIA and PHOJET)
- P_T / η spectrum of the three processes is different, and so are the trigger efficiencies
- Two normalizations were used:
- **INEL**(trig=87-91%)= all inelastic, each corrected individually
- **NSD**(trig=94-97%) = without single-diffractive processes

Interaction vertex

- Analysis only uses two innermost layers (SPD)
- Hits in two layers are used to form “tracklets”
- Intersection of tracklets gives interaction vertex:
  - Resolution = 0.1-0.3mm in z, 0.2-0.5mm in R
- For events with one track, intersect tracklet with mean beam axis computed from other events
- Vertex reconstructed in 94% of events
  - Efficiency = 84% for INEL, 92% for NSD

Z vertex reconstruction

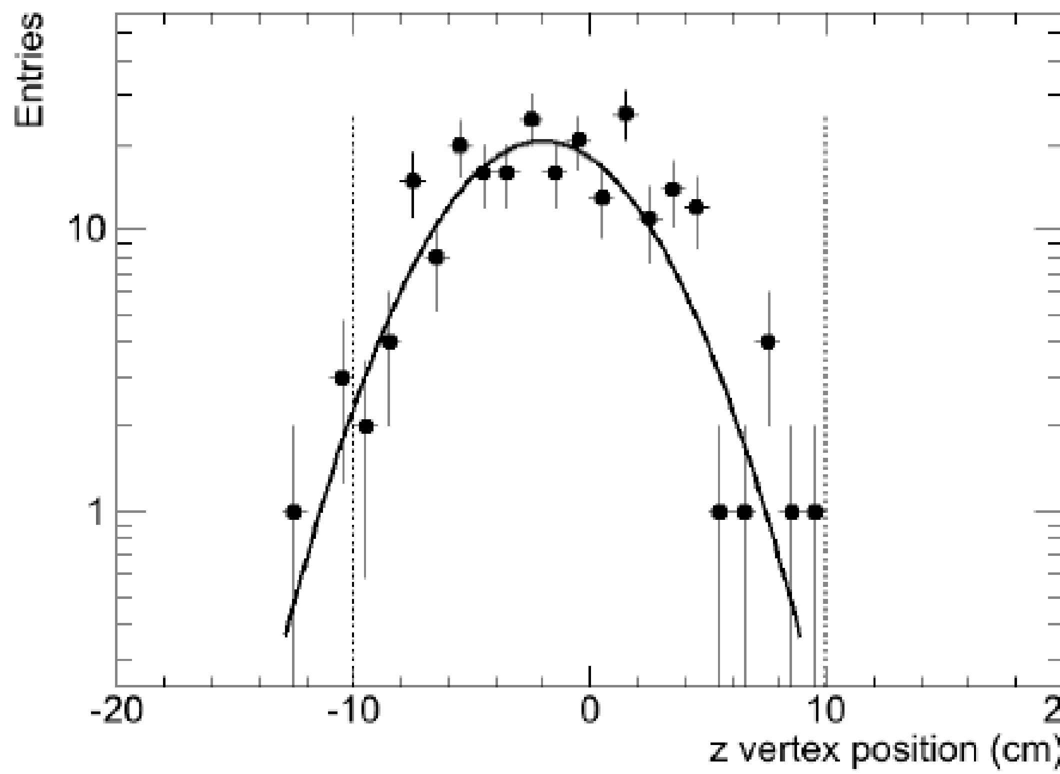


Fig. 4. Longitudinal vertex distribution from hit correlations in the two pixel layers of the ALICE inner tracking system. Vertical dashed lines indicate the region $|z| < 10$ cm, where the events for the present analysis are selected. A Gaussian fit with an estimated r.m.s. of about 4 cm to the central part is also shown.

Tracklet selection

- Using interaction vertex as the original compute $\Delta\theta$ and $\Delta\varphi$ for each pair of SPD hits
- Cut on square of sums of $\Delta\theta$ and $\Delta\varphi$, weighted by resolution (25 and 80 mrad, respectively)
- In 2% of cases, >1 hits in a layer match to another layer. In this case, only count 1 tracklet
- # of tracklets is corrected in bins of z and η for:
  - Trigger inefficiency
  - Reconstruction inefficiency (dead channels etc)
  - Decays of long-lived particles, conversions, second.
- Typical correction factor is 1.5

Backgrounds

- Beam gas and beam halo
  - Cut on [#tracklets]/[# silicon hits] (smaller for BG)
  - Removed events with negative VZERO arrival time
  - Visual scan of the whole event sample
    - Only as a cross-check
- 29 events (10%) rejected as beam BG
- Remaining background estimated from vertex distribution (?) and considered negligible
- Cosmic contamination estimated ~1 event. Visual scan revealed 2 cosmic events.

Efficiency vs # of tracklets

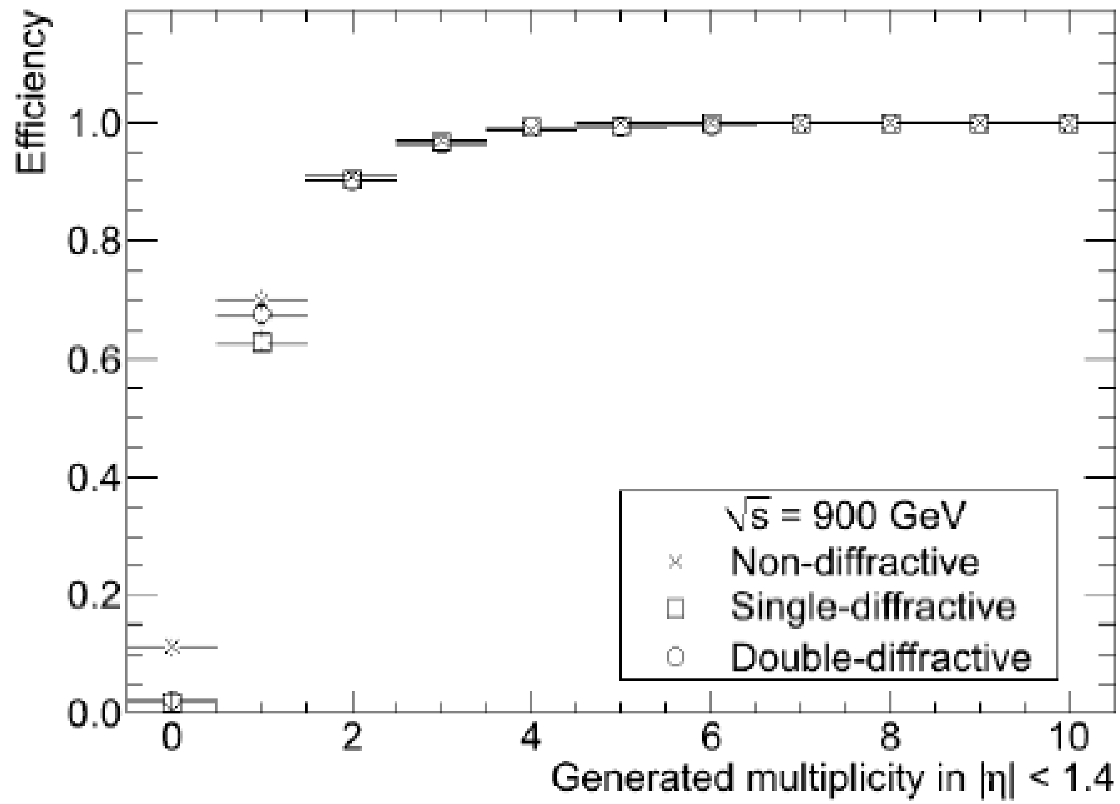


Fig. 5. Multiplicity dependence of the combined efficiency to select an event as minimum bias and to reconstruct its vertex in SPD, for non-diffractive (crosses), single-diffractive (squares), and double-diffractive (circles) events, based on PYTHIA events.

Systematics

Estimated by varying:

- Tracklet cuts on Δθ and Δφ by 50%
- Density of material by 10%
- Using non-aligned geometry
- Composition of produced particles by 30%
- Particle yield below 100 MeV by 30%
- Ratios of ND,SD,DD processes and two different MC generator (PYTHIA & PHOJET)

Table 1. Contributions to systematic uncertainties on the measurement of the charged-particle pseudorapidity density.

Uncertainty	
Tracklet selection cuts	negl.
Material budget	negl.
Misalignment	0.5 %
Particle composition	negl.
Transverse-momentum spectrum	0.5 %
Contribution of diffraction (INEL)	4 %
Contribution of diffraction (NSD)	4.5 %
Event-generator dependence (INEL)	4 %
Event-generator dependence (NSD)	3 %
Detector efficiency	4 %
SPD triggering efficiency	2 %
Background events	negl.
Total (INEL)	7.2 %
Total (NSD)	7.1 %

Will be better understrood with more data

Table 2. Comparison of charged primary particle pseudorapidity densities at central pseudorapidity ($|\eta| < 0.5$) for inelastic (INEL) and non-single diffractive (NSD) collisions measured by the ALICE detector in pp interactions and by UA5 in $p\bar{p}$ interactions [3] at a centre-of-mass energy of 900 GeV. For ALICE, the first error is statistical and the second is systematic; no systematic error is quoted by UA5. The experimental data are also compared to the predictions for pp collisions from different models. For PYTHIA the tune versions are given in parentheses. The correspondence is as follows: D6T is tune (109); ATLAS CSC is tune (306); Perugia-0 is tune (320).

Experiment Model	ALICE pp	UA5 $p\bar{p}$ [3]	QGSM [25]	PYTHIA [17] (109) [18]	 (306) [26]	 (320) [27]	PHOJET [8]
INEL	$3.10 \pm 0.13 \pm 0.22$	3.09 ± 0.05	2.98	2.33	2.99	2.46	3.14
NSD	$3.51 \pm 0.15 \pm 0.25$	3.43 ± 0.05	3.47	2.83	3.68	3.02	3.61

Why is NSD lower than INEL?

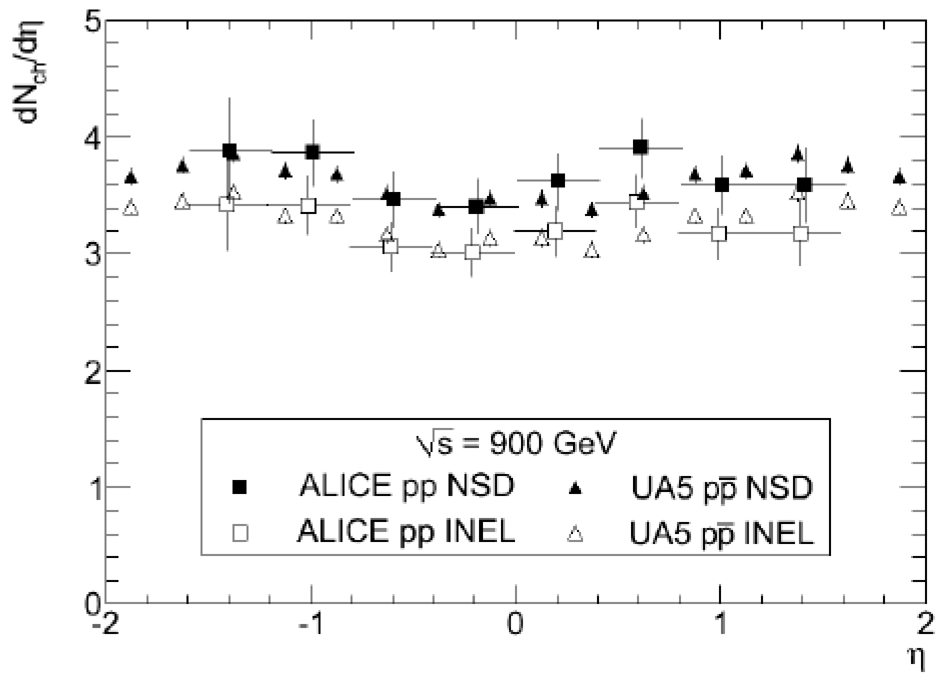


Fig. 6. Pseudorapidity dependence of $dN_{ch}/d\eta$ for INEL and NSD collisions. The ALICE measurements (squares) are compared to UA5 data (triangles) [3]. The errors shown are statistical only.

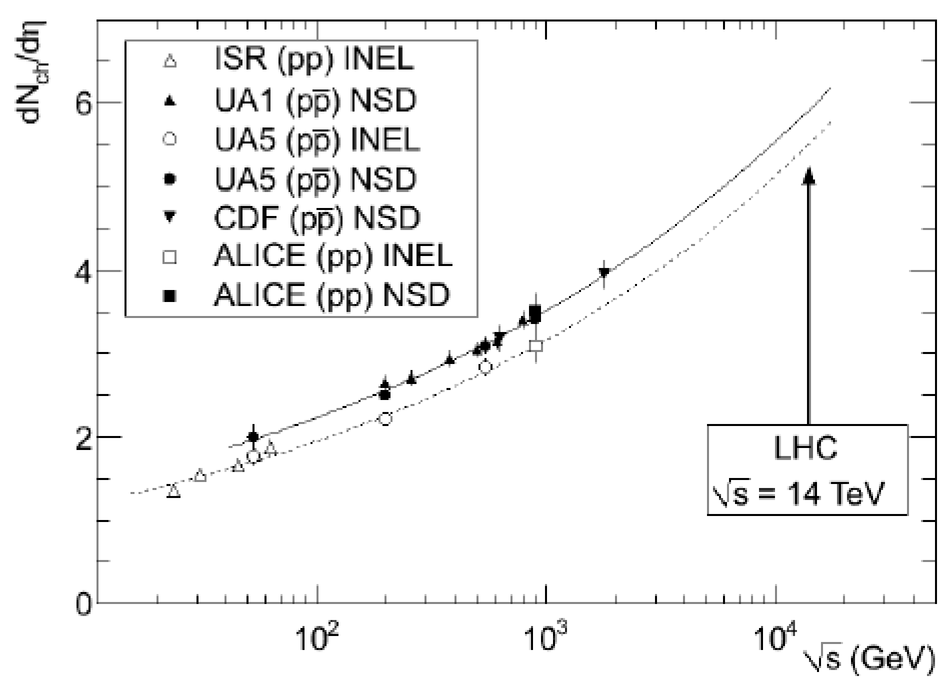


Fig. 7. Charged-particle pseudorapidity density in the central rapidity region in proton–proton and proton–antiproton interactions as a function of the centre-of-mass energy. The dashed and solid lines (for INEL and NSD interactions respectively) indicate the fit using a power-law dependence on energy.

Inelastic processes in ATLAS as 14 TeV