Relative bunch population and ghost charge measurements from LHCb beam-gas rates

Jaap Panman
CERN
For the LHCb collaboration

CERN

CERN LumiDays 2012

- LHCb beam-gas data
- Bunch-to-bunch normalization
- Ghost charge measurement
- SMOG preview

LHCb detector
VELO – Vertex detector

LHCb detector geometry (beam 1 from the right)

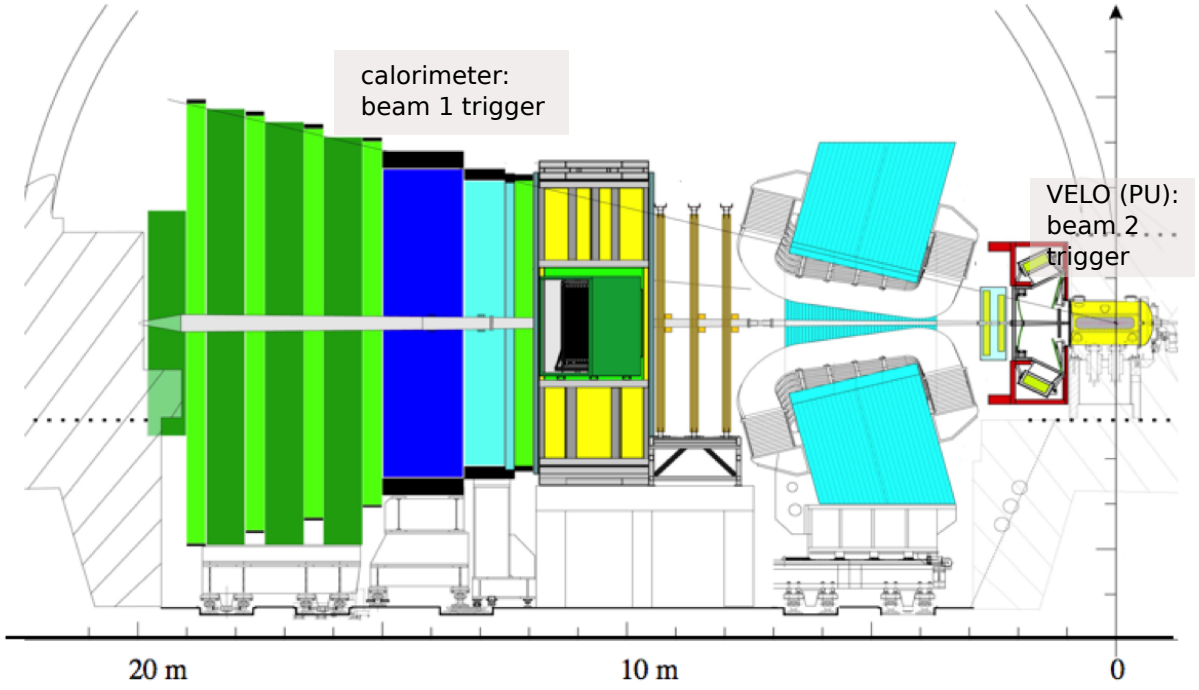
Important for the following:

- VELO (vertex detector)
- Trigger detectors:
  - forward (beam 1): calorimeter
  - backward (beam 2): PU sensors in VELO

High precision vertex location measurements with VELO

Close proximity of vertex measurements to beamline (6 mm)

Good acceptance close to beam direction

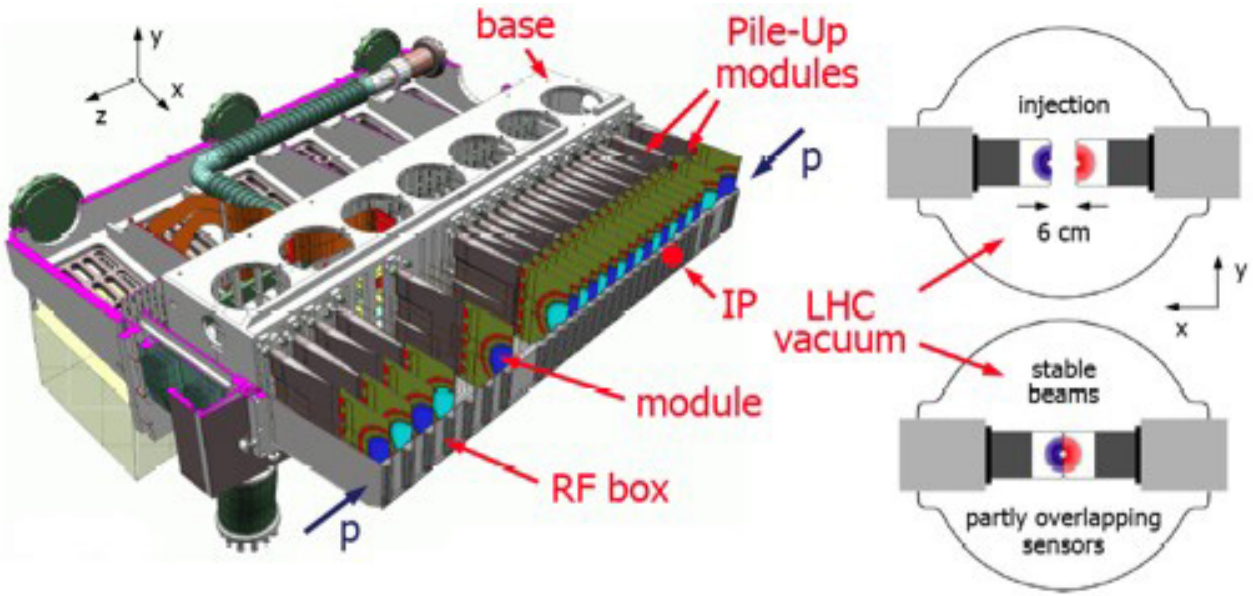


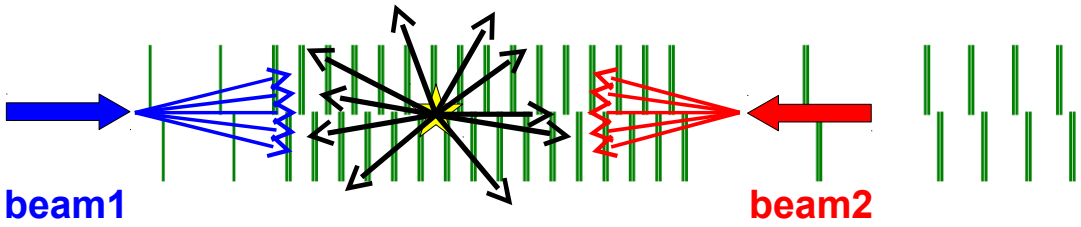
LHCb detector
VELO – Vertex detector

Detail of VELO with PU sensors

PU used for the trigger

VELO is the main track-reconstruction device for this analysis



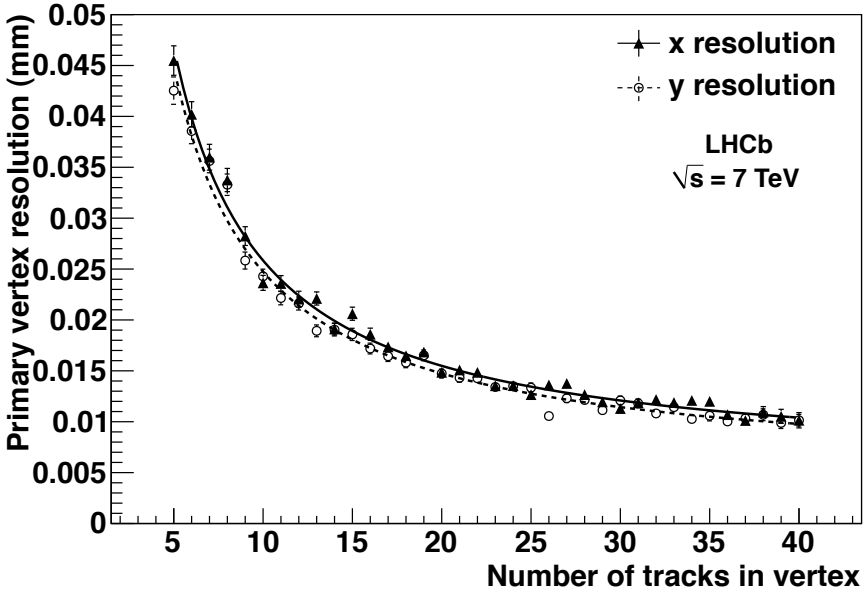


Beam 1 from left
Asymmetric VELO geometry
asymmetric performances for the two beams

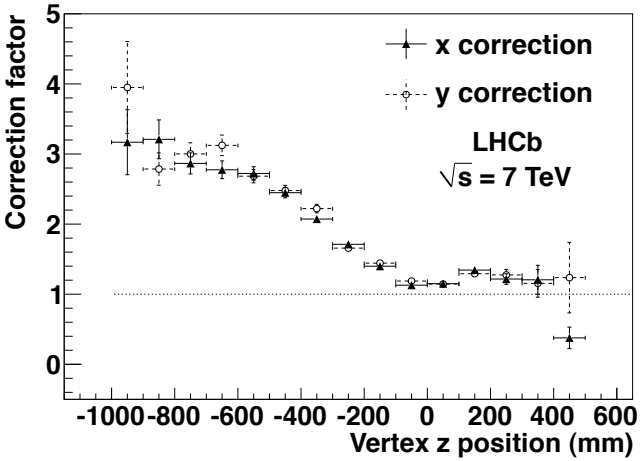
Vertex resolution

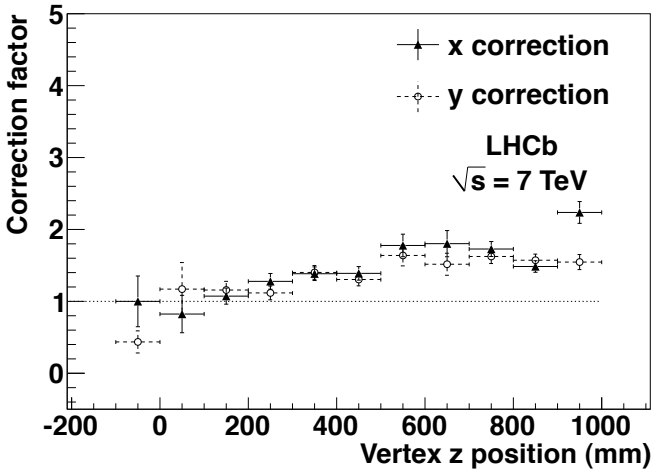
Vertex resolution depends on number of participating tracks and z

Vertex resolution for beam-beam events at $z = 0$ as a function of n



z dependent vertex resolution for beam 1 and beam 2 events





LHCb beam-gas interactions
2011 measurements

Measurements in 2011

- Intermediate energy
- 7 TeV data
  - May
  - October

Concentrate here on the October data
Increased statistics compared to physics running by switching off the pumps near the VELO
Factor 5 pressure increase

Counting beam-gas interactions as measure of the beam intensity works if:

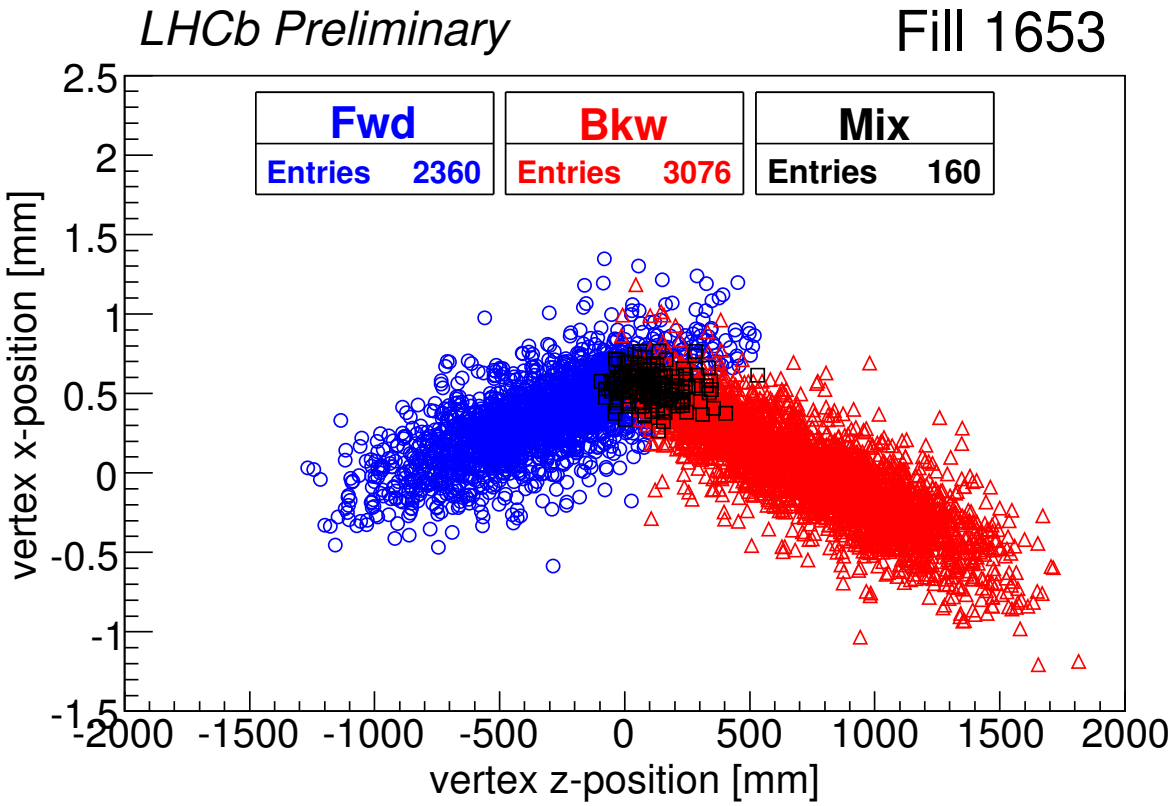
- There is no background (e.g. beam-beam interactions)
- Trigger efficiency is independent of μ (average interaction rate)

Fill 1653 (intermediate energy) example of beam-gas interaction vertices

x vs z-coordinate of vertex distributions

FW (blue), BW (red), both (black) track asymmetry used to select the events

Outside the central region, events are always asymmetric due to acceptance!



Fill 2234 (October 2011) last 3 hours

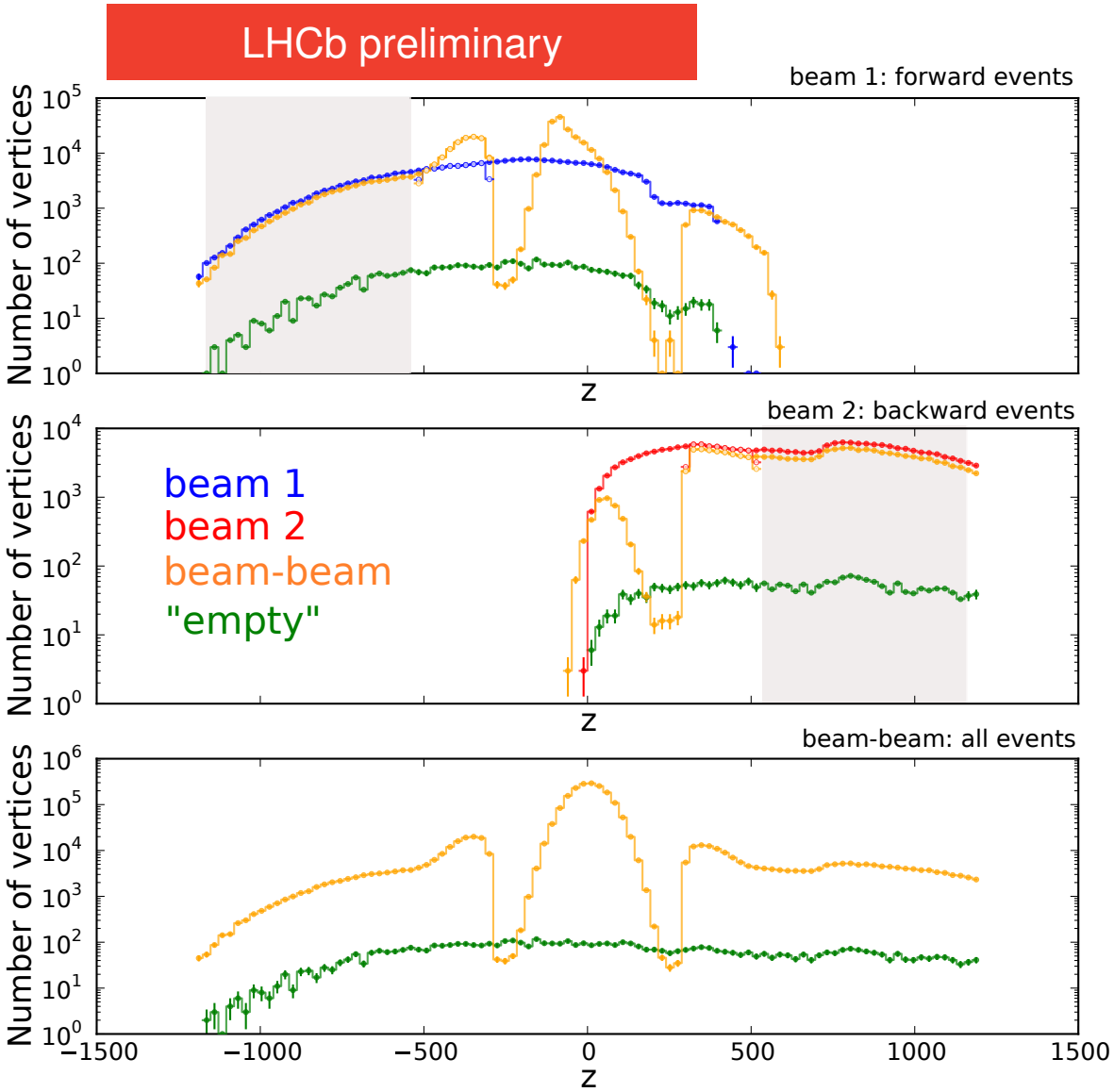
z-coordinate of vertex distributions

FW-BW track asymmetry used to select the events

Features in the beam-beam data are due to the trigger
For BB the trigger only accepts events with a vertex with $|z| > 300$ mm
The BB peak is coming from pile-up.

RF$\pm$1-main background visible

Shaded regions are used for normalization



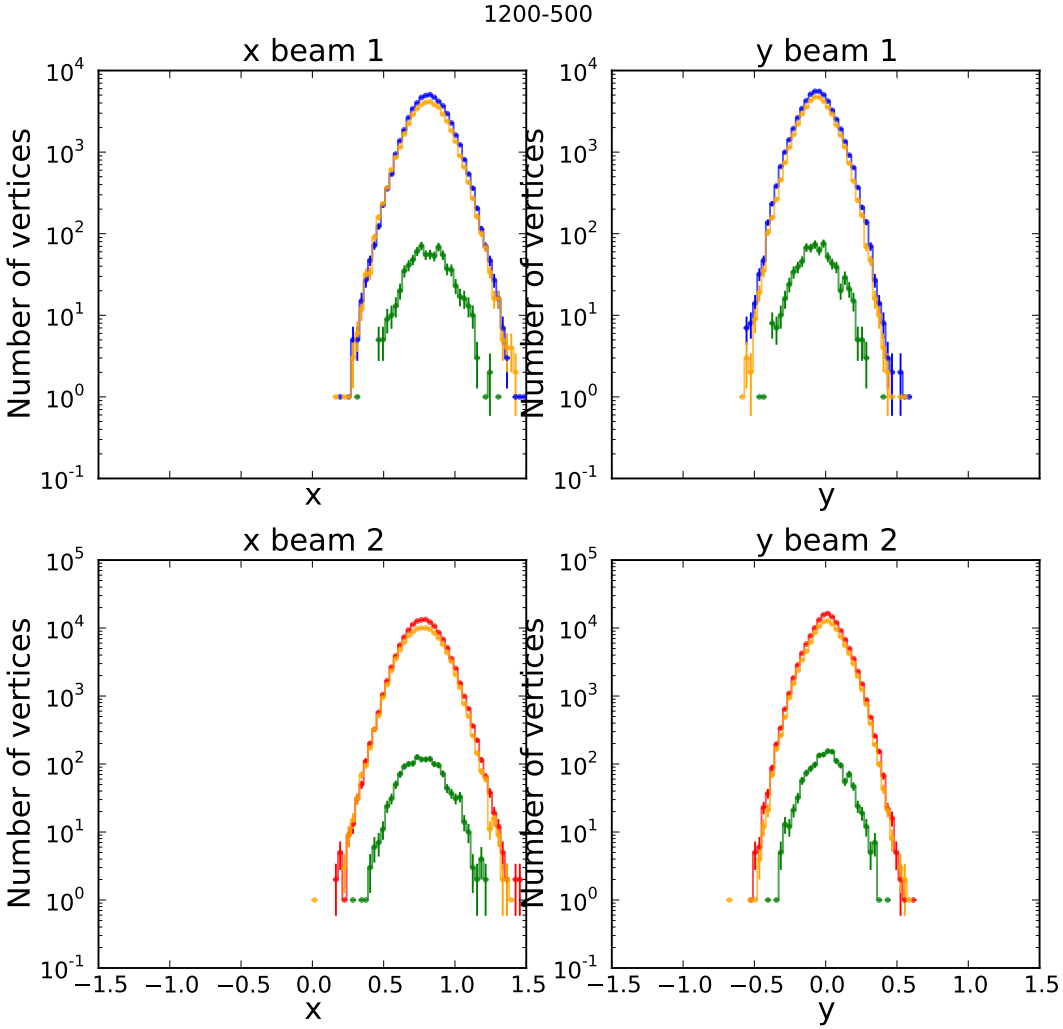
Fill 2234
Transverse distributions

Compare single beam with beam-beam and “empty” slots in beam-gas region

Average profiles are very similar

Also the beam in the “empty” slots has a similar width (difference $< 10\%$)

LHCb preliminary



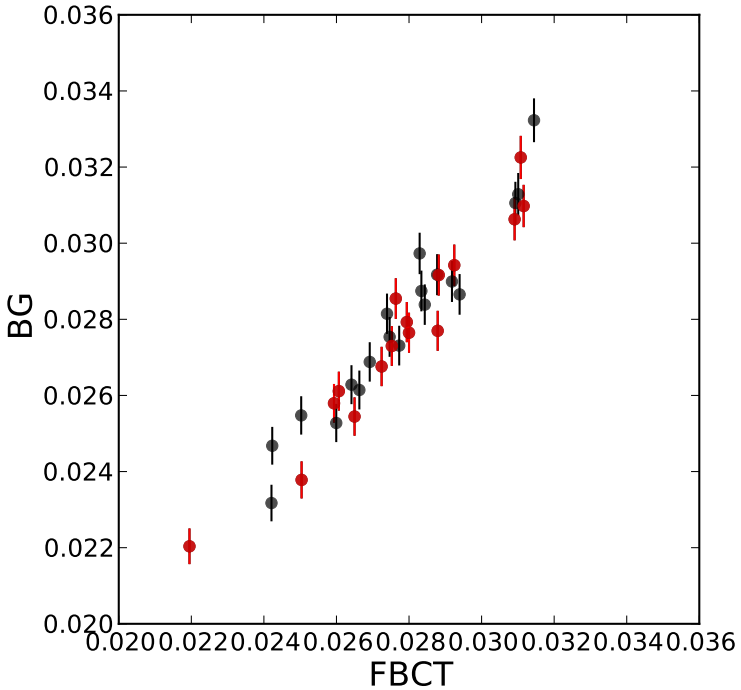
Beam-gas event count fill 2234 October 2011

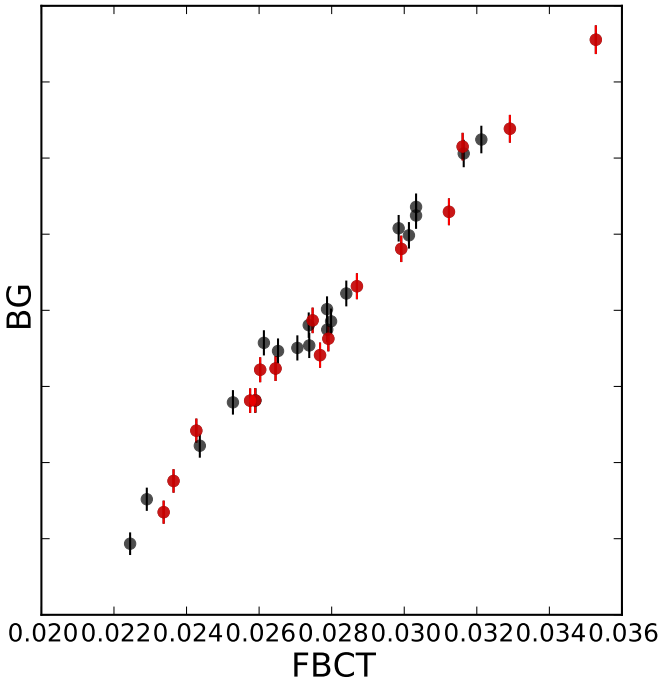
Simple event counting – normalized to the total count per beam

Use shaded normalization regions (no background)

Vertex count per bunch ID
Compare with FBCT
Red points are from colliding pairs
Black points from single bunches

LHCb preliminary





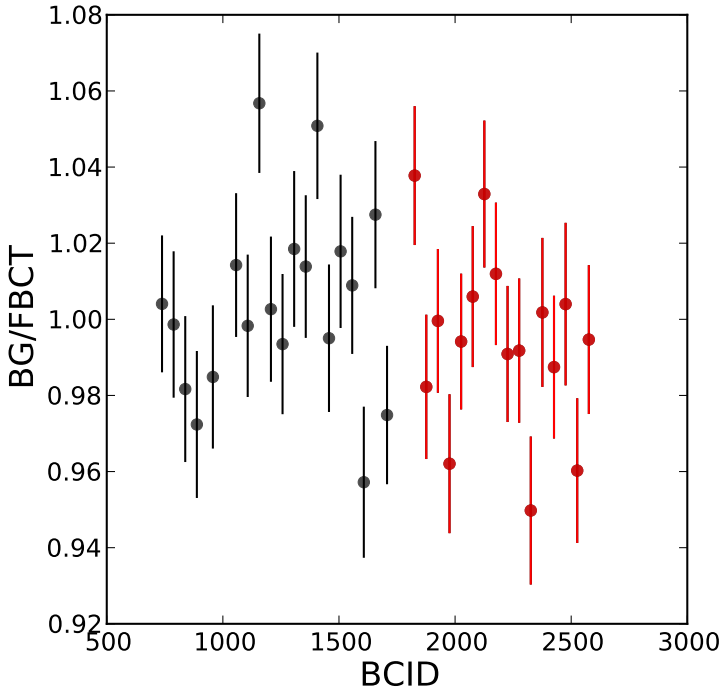
Beam-gas event count – FBCT ratio fill 2234 October 2011

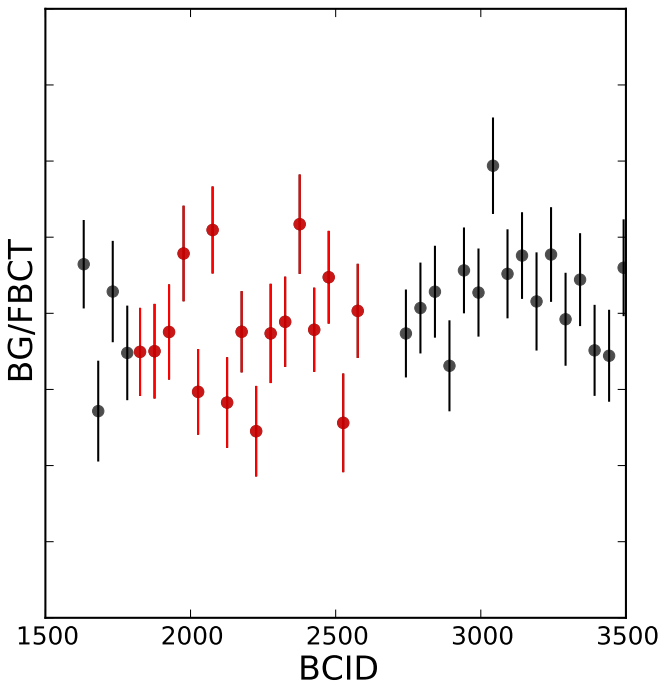
Display the ratio of BG/FBCT versus BCID (counting at LHCb)
Typical staistical errors for BG counting

- beam 1 bunches: 1.8%
- beam 2 bunches: 1.2% (better acceptance)

But χ^2/ndf is close to 1.6
So there are additional systematic errors

LHCb preliminary



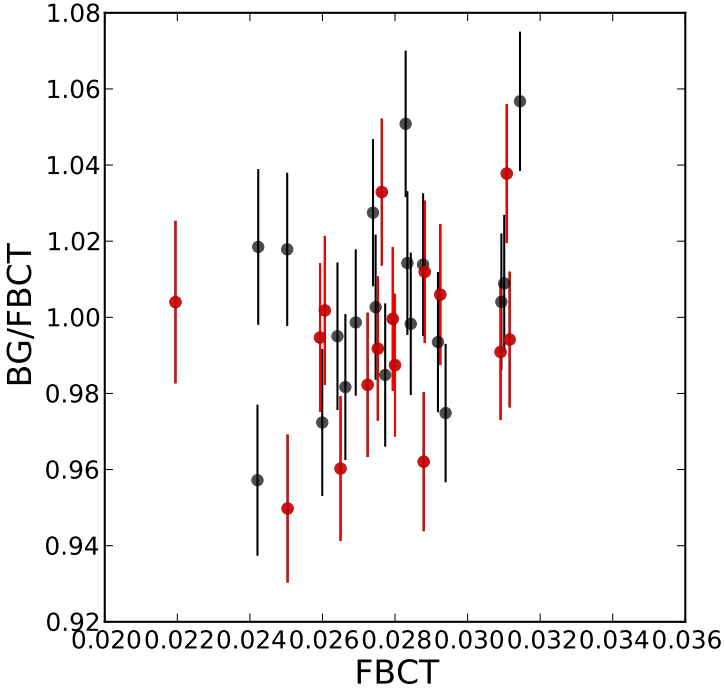


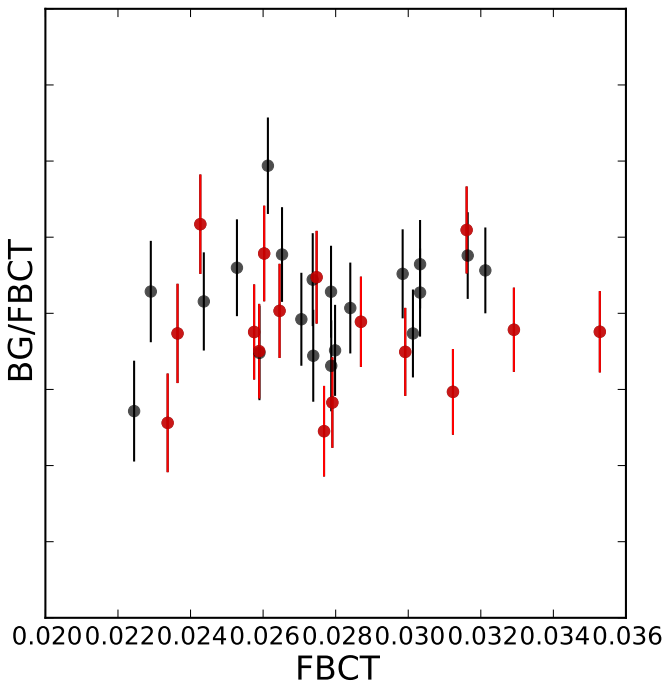
Beam-gas event count – FBCT ratio fill 2234 October 2011

Display the ratio of BG/FBCT versus FBCT

No clear slope

LHCb preliminary



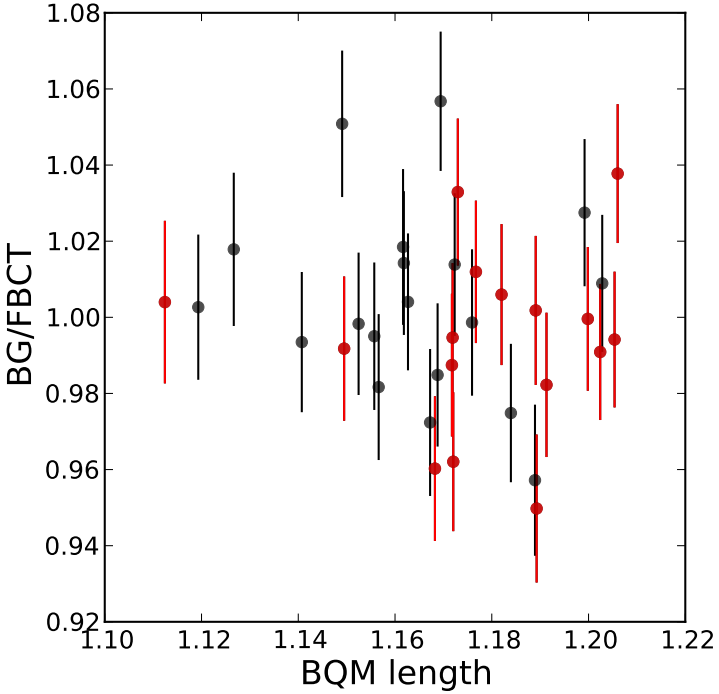


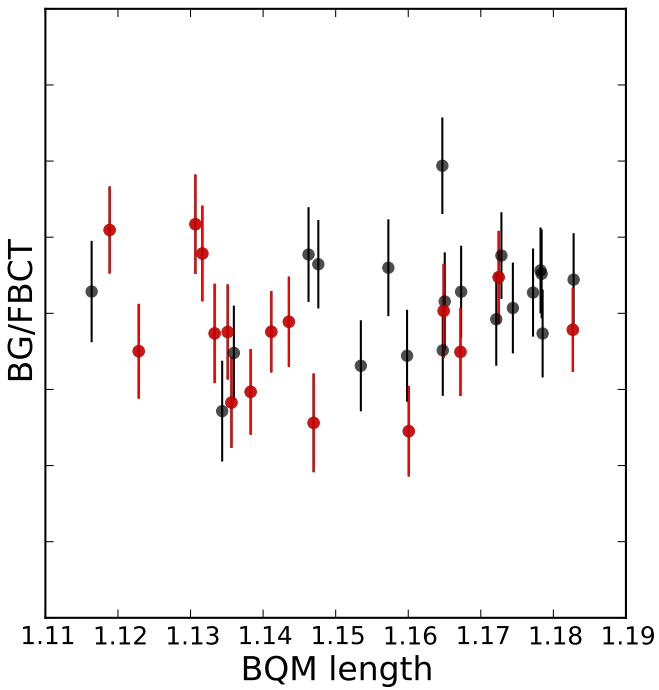
Beam-gas event count – FBCT ratio fill 2234 October 2011

Display the ratio of BG/FBCT versus the BQM bunch length measurement

No clear slope

LHCb preliminary

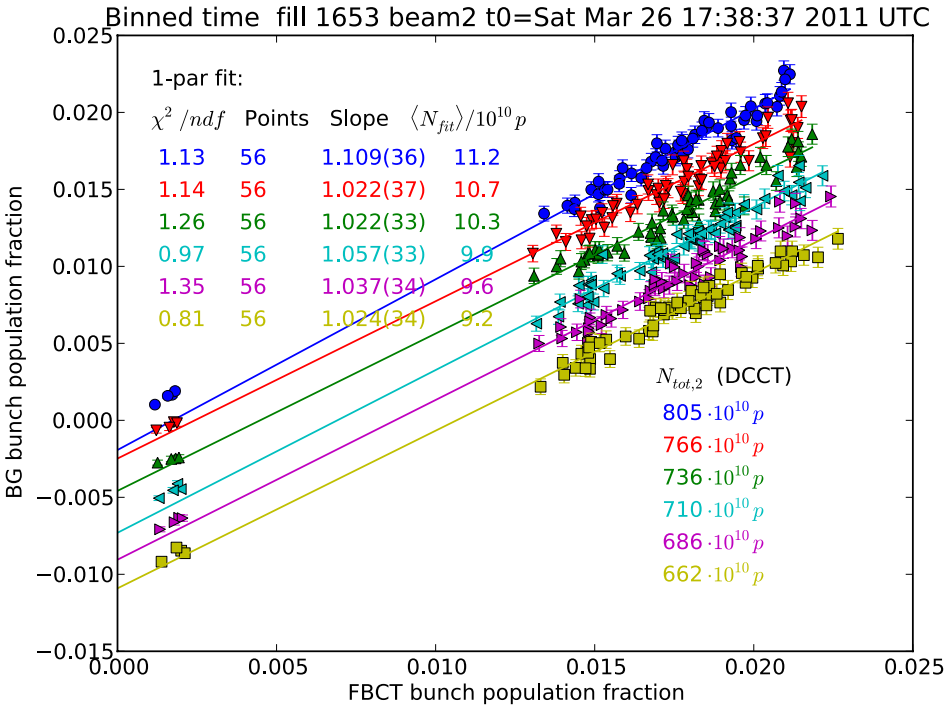


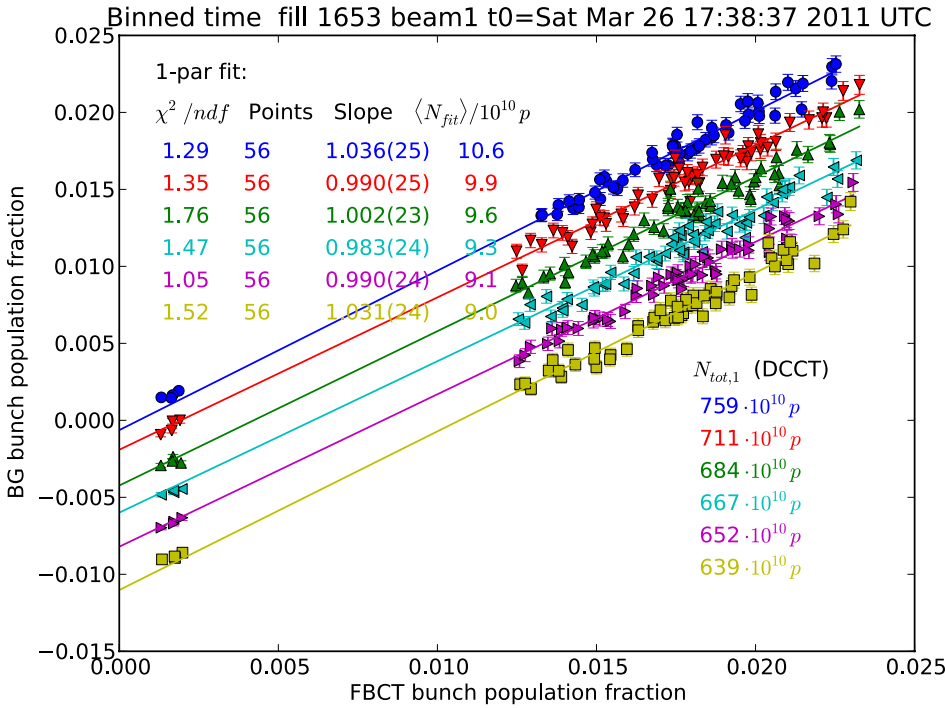


Slope comparisons fill 1653 (Massi)

Fill 1653

Fit to slope BG/FBCT in time slices

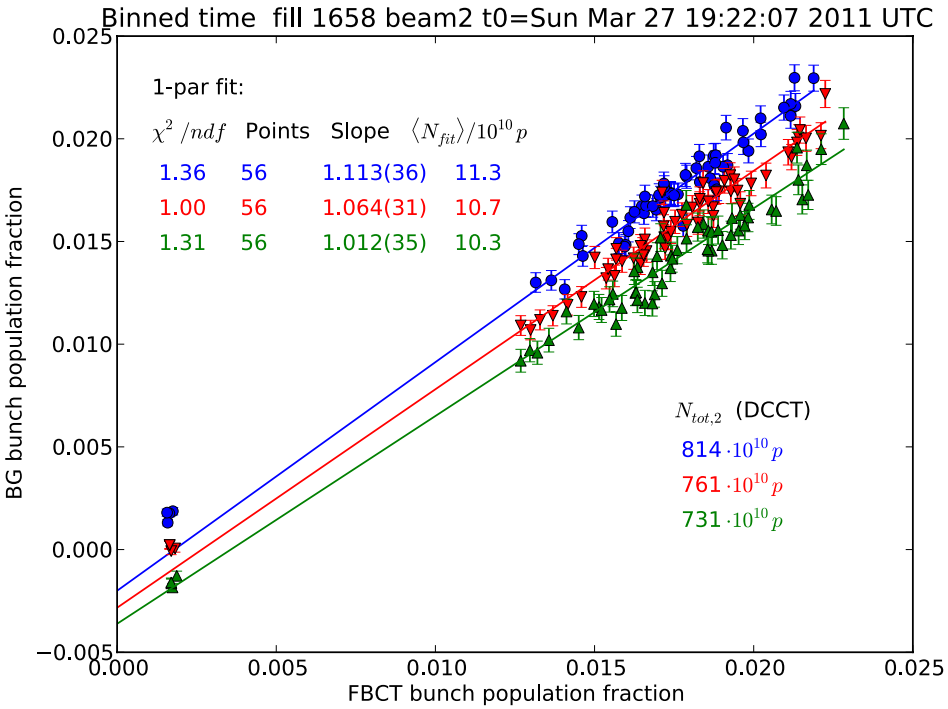


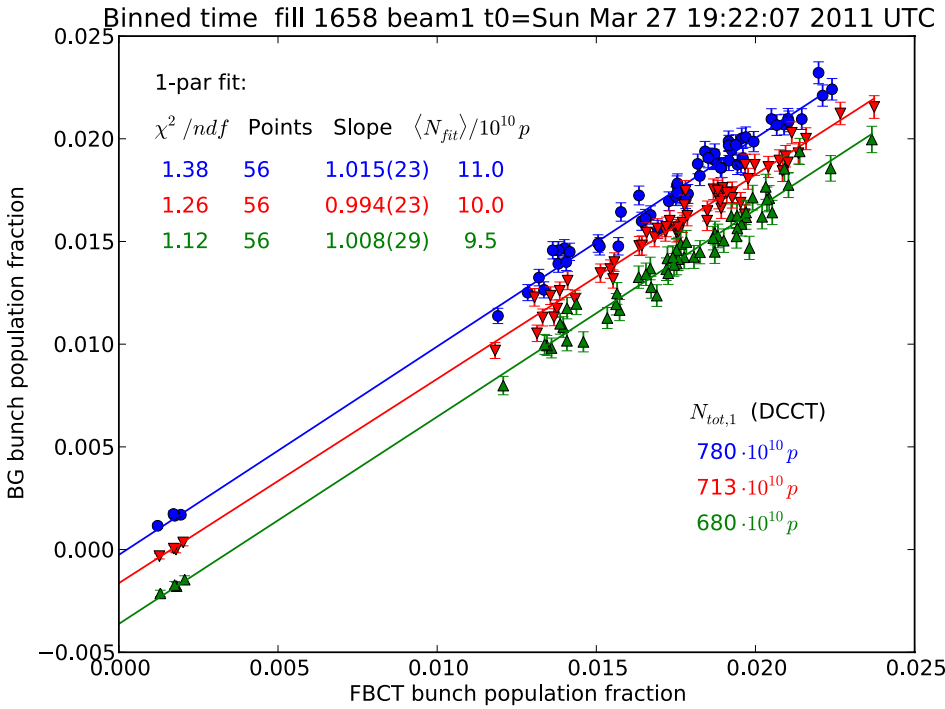


Slope comparisons fill 1658 (Massi)

Fill 1658

Fit to slope BG/FBCT in time slices

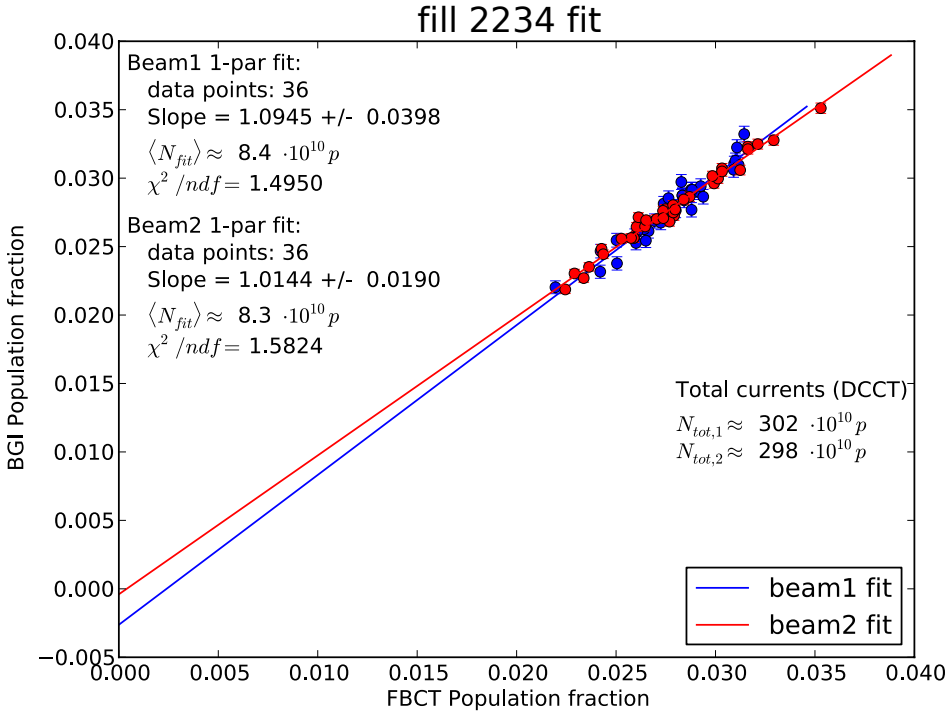




Slope comparisons fill 2234 (Massi)

Fill 2234

Fit to slope BG/FBCT (lst 3 hours)



Determination of “ghost charge”

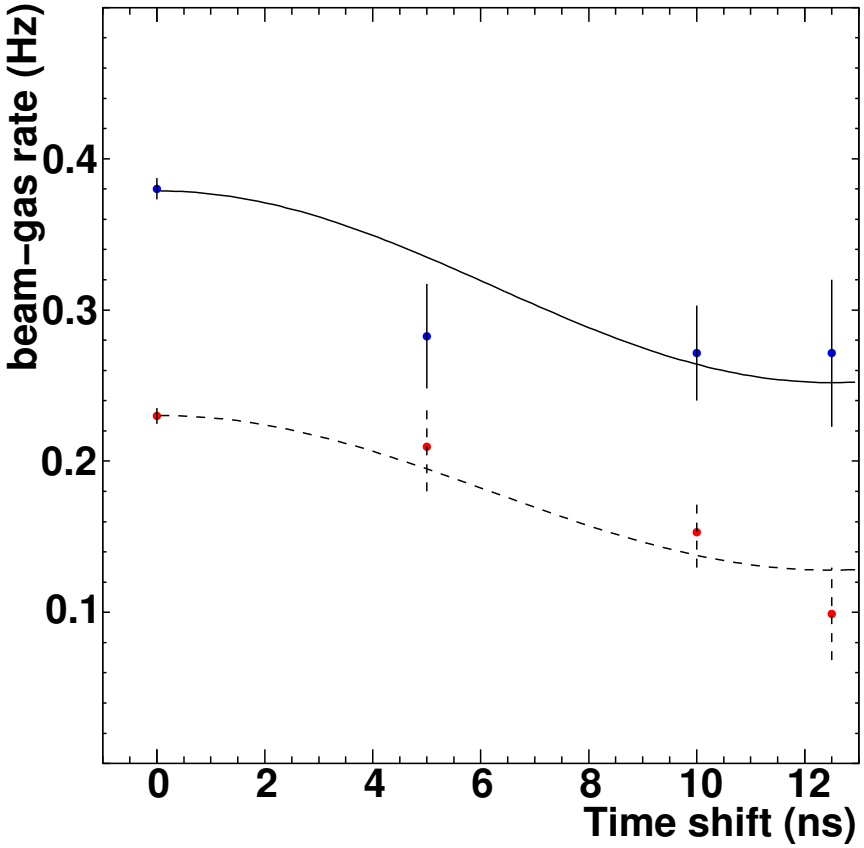
“ghost charge” can be measured by counting beam-gas events in the nominally empty slots

Trigger efficiency may vary for different RF buckets in a bunch-slot

Measurement done in 2010
Shifting phase of digitization gate

Some systematics enter here due to potentially different conditions

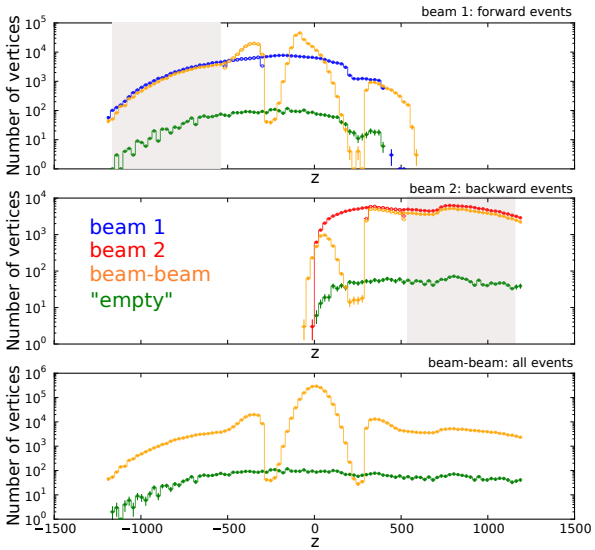
Beam 1 (blue), beam 2 (red)



Fill 2234
Ghost charge measurement

z-coordinate of vertex distributions

Simplest: shaded regions are used for normalization of all slots



Fraction (in %)

Period	Beam 1	Beam 2
first hour	0.797 ± 0.056	0.579 ± 0.030
last 3 hours	0.780 ± 0.028	0.574 ± 0.015

Raw numbers: Sum of empty slots divided by sum of filled slots, no trigger corrections etc.

We see no increase of ghost charge in this fill!

(Statistcal errors only)
For final numbers some corrections need to be made

Fill 2234
Ghost charge measurement

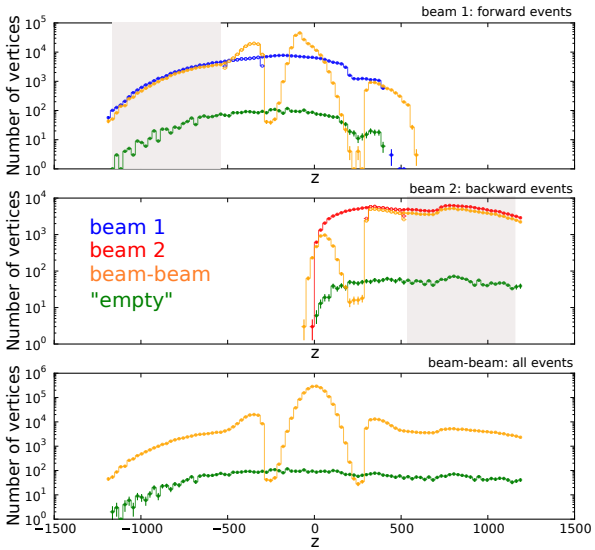
Corrections:

Trigger efficiency: 0.87 (0.73) for beam 1(2)

Important input from LDM: RF buckets equally distributed over slots for ghost charge (Adam Jeff)

Correction for DAQ problem: slot 1007 rejected in readout (2.8% using FBCT)

Improve statistical error by accepting all events for empty slots and single beam slots (beam-beam slots are counted in shaded region and corrected)



Compare to LDM data in same period
Fraction (in %)

Method	Beam 1	Beam 2
LDM	0.7	0.7
last 3 hours	0.87	0.73

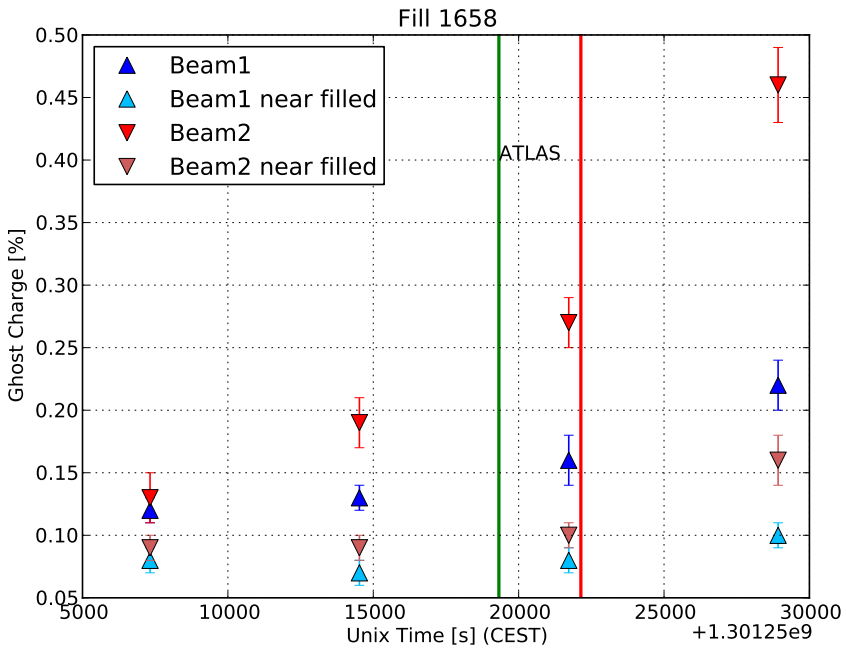
Statistical error is <2%
Systematic error is 10–20%
Error dominated by trigger efficiency systematics

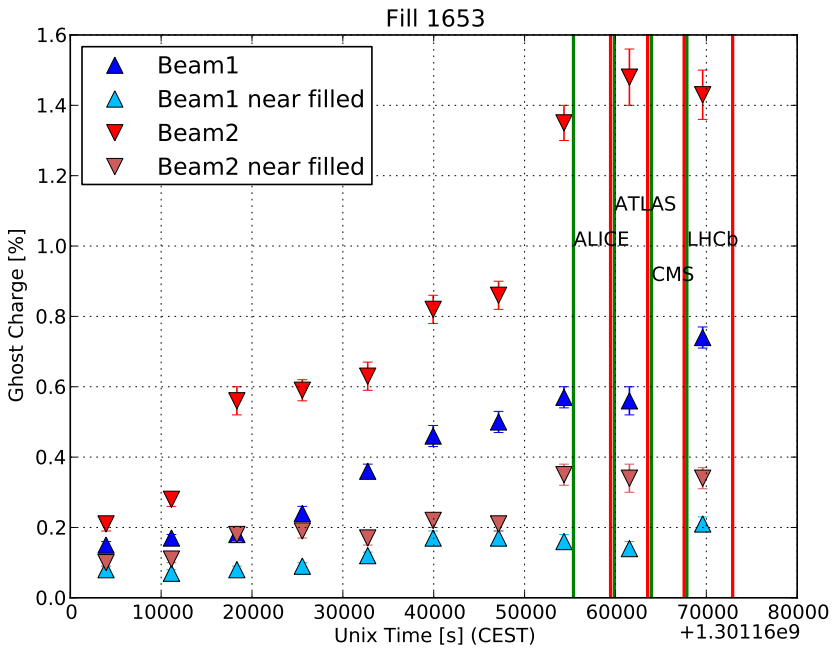
Rates are consistent with LDM

Earlier fills – 1653 and 1658 (Plamen Hopchev)

In fills 1653 and 1658: Beam-gas ghost rate evolution clearly seen

Separate count of slots near the filled bunches also displayed





Earlier fills – 1653 and 1658 summary

Ghost charge measurements during the VDM scans in fills 1653 and 1658

	UTC Epoch time [s]		Raw Ghost Charge [%]		Trig. eff. corrected Ghost Charge [%]	
	Middle of scan	Duration of scan	beam1	beam2	beam1	beam2
Fill 1653						
ALICE	1301217420	4080	0.57 ± 0.04	1.57 ± 0.08	0.66 ± 0.12	1.87 ± 0.37
ATLAS	1301221710	3660	0.56 ± 0.06	1.47 ± 0.13	0.65 ± 0.13	1.75 ± 0.37
CMS	1301225760	3600	0.64 ± 0.03	1.44 ± 0.02	0.74 ± 0.13	1.71 ± 0.33
LHCb	1301230380	5040	0.70 ± 0.04	1.38 ± 0.09	0.81 ± 0.14	1.64 ± 0.33
Fill 1658						
ATLAS	1301270730	2800	0.18 ± 0.03	0.27 ± 0.04	0.21 ± 0.05	0.32 ± 0.08

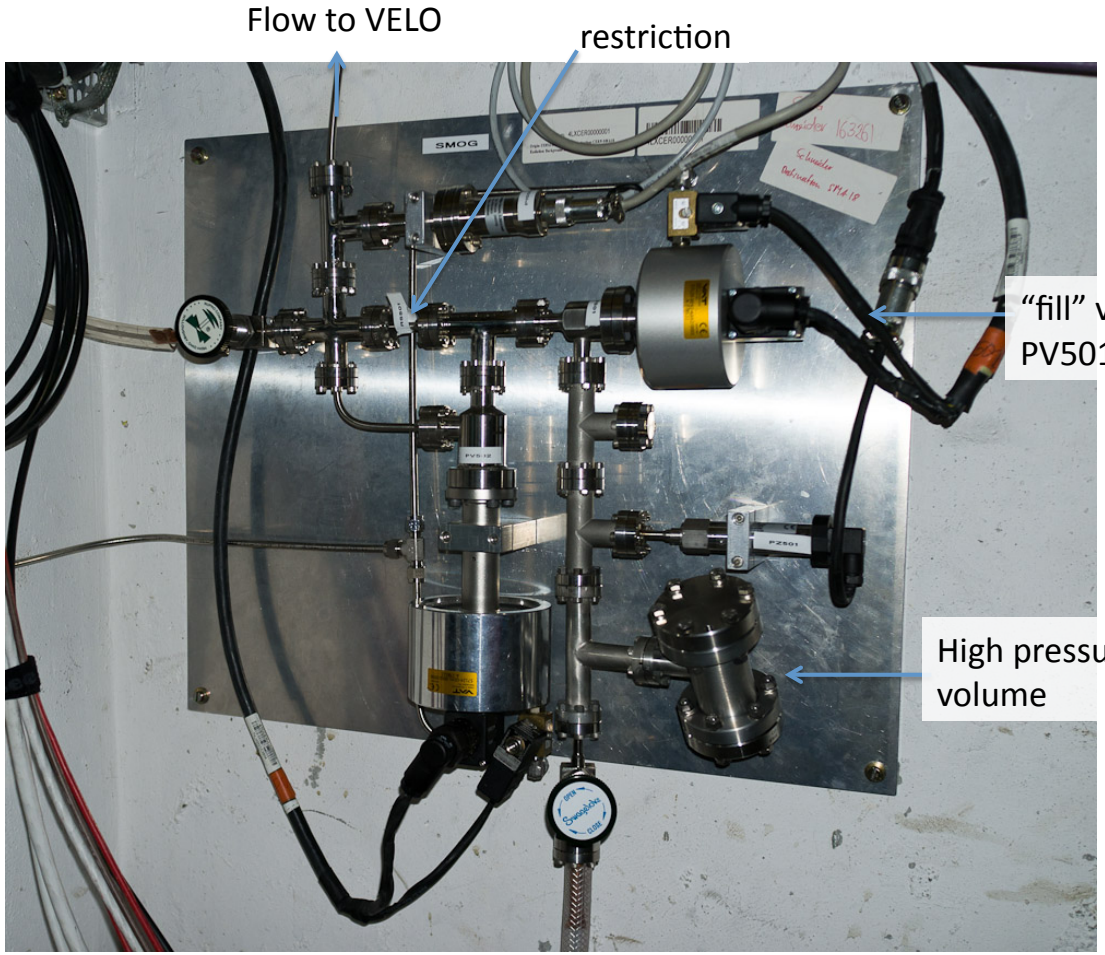
SMOG – gas-injection (Massi, Colin)

Gas injection system: fill beam pipe in VELO region with a little bit of Neon

Tested and validated together with LHC vacuum group

Installed and ready for use in 2012

Very extensive safety:
prefilled volume emptied through narrow restriction



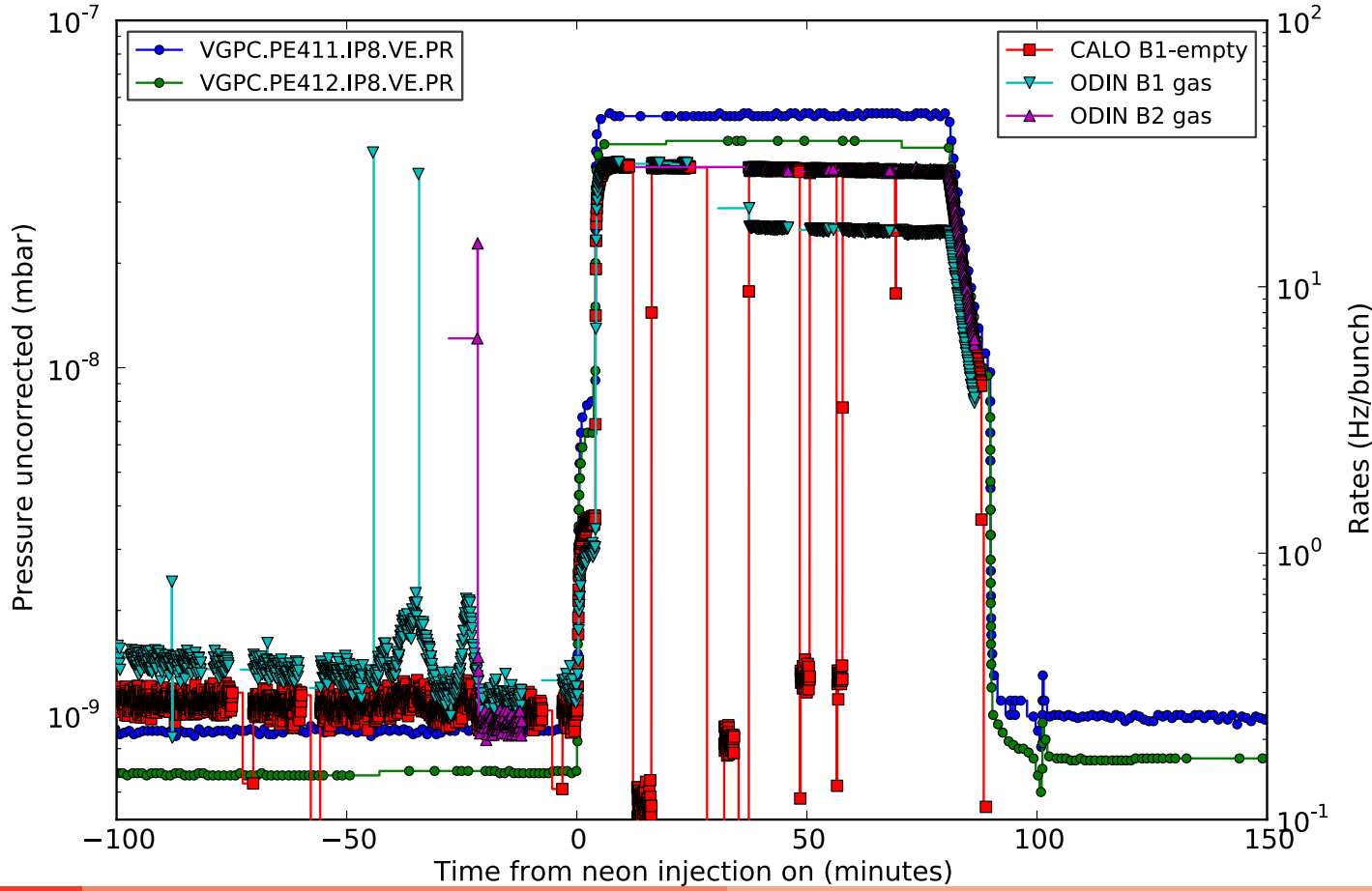
SMOG test

Test during p–Pb run of 2011

Observe the expected rate increase of a factor 100

(Pumps-off alone gives an increase of a factor 5)

Great potential for fast and more precise measurements



Summary

- Beam-gas event statistics increased in 2011 by switching off pumps
- Ghost-charge measurement available and consistent with LDM
- Bunch-to-bunch intensity ratios can be obtained by event counting
- Bunch-to-bunch rates are similar to FBCT measurements
- SMOG was tested in 2012
- A further factor 20 in rate was achieved
- SMOG will be used in 2012 and will enhance all dedicated BG measurements