# Luminosity Measurement at LHCb

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on behalf of the
LHCb Collaboration

*Young Scientist Forum*

*Rencontres de Moriond EW 2010*

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*For an overview of the LHCb experiment see W. Hulsbergen's presentation on Sunday*

# Luminosity in general and in LHCb

- Rate = cross-section × luminosity
- For two colliding bunches of particles the luminosity can be written as

$$L = f N_1 N_2 \, 2c \cos^2(\phi/2) \int \rho_1(x,t)\,\rho_2(x,t)\,d^3x\,dt$$

bunch intensities — crossing angle — overlap integral

- Luminosity measurement methods under investigation in LHCb
  - Beam imaging with gas (beam-gas luminosity method) – presented here
  - Van der Meer scan
  - Indirect methods using a process with well known cross-section
    - Z-boson production
    - Elastic diphoton dimuon production (expect ultimate precision of 1%)

# Beam-Gas Luminosity Method

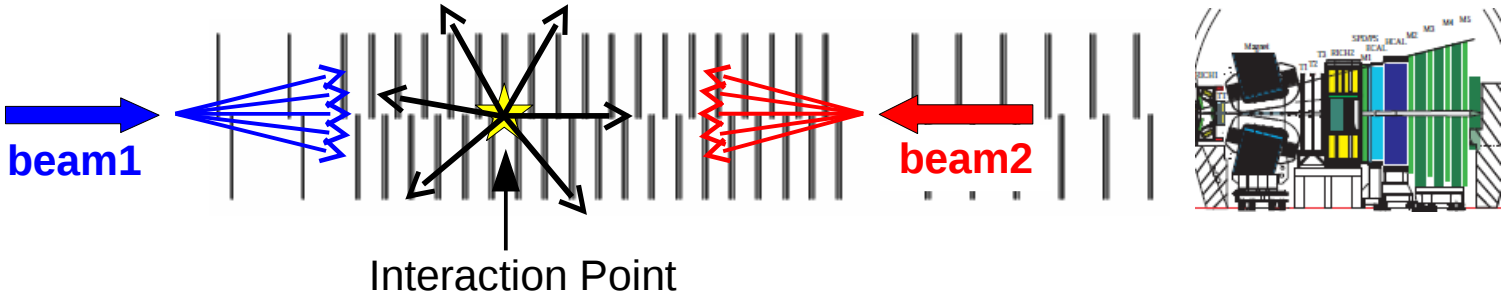
- Luminosity determination using vertex detection of beam-gas interactions
  M. Ferro-Luzzi, Nucl. Instr. Methods A553 (2005) 388
  - Reconstruct beam-gas vertices – get beam angles, profiles and relative positions
  - Calculate overlap integral
  - The second important ingredient are the bunch intensities
  - Calibrate 'reference' cross-section or 'lumi counters' in order to span the knowledge of the luminosity over longer period

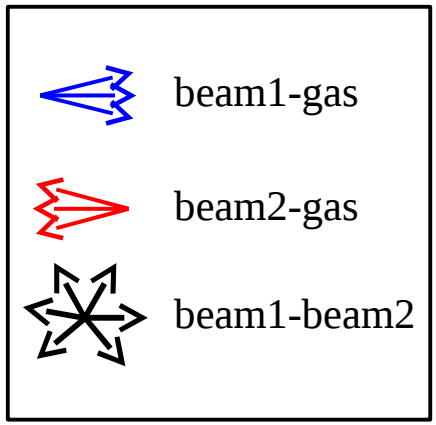
$$L = f \underbrace{N_1 N_2}_{\text{Measured by LHC}} \underbrace{2c\cos^2(\phi/2)}_{\text{Measured by LHC}} \int \underbrace{\rho_1(x,t)}_{\text{Measured by LHCb}} \underbrace{\rho_2(x,t)}_{\text{Measured by LHCb}} d^3x\, dt$$

- Currently the beam-gas luminosity method is being applied for a first time !

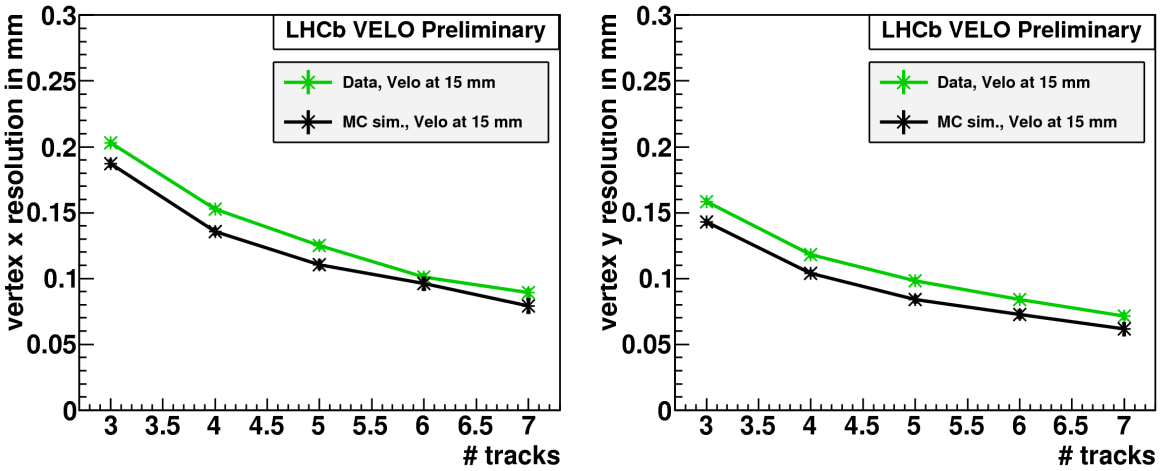
# VELO vertex reconstruction

- The LHCb vertex detector (vertex locator, VELO) is very efficient in reconstructing vertices outside the luminous region (search for secondary B-decays)
  - 21 stations, each consisting of left and right modules
  - Each module has 1 r- and 1 phi-measuring sensors (silicon strips)



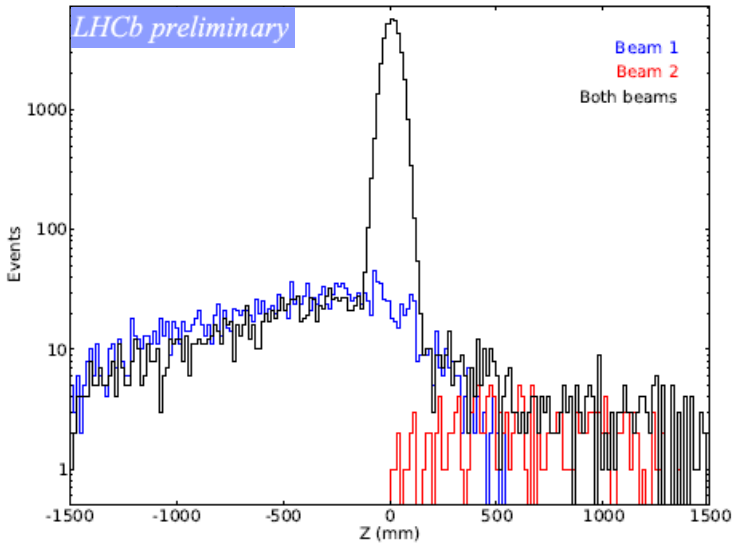

- VELO vertex resolution for beam-beam interactions



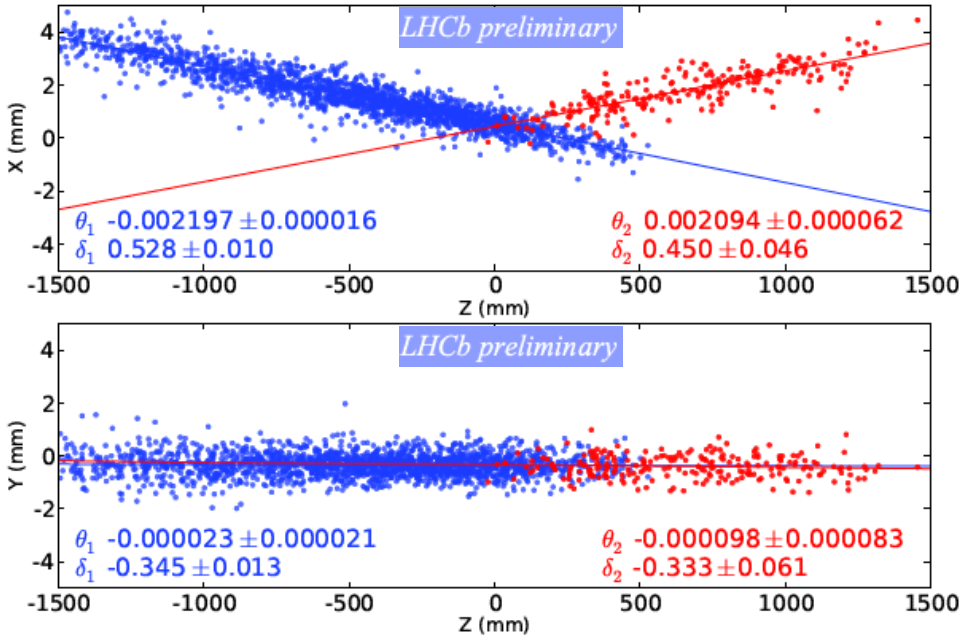

- For beam-gas interactions outside the luminous region we take into account the dependence of the vertex resolution on the vertex position along the beam direction (z-axis)

# Reconstructed beam-gas vertices

- Consider vertices with at least 4 tracks
- Distribution of the position of the reconstructed vertices along the beam axis (z) for three different bunch crossings:
  - beam1-gas
  - beam2-gas
  - beam-beam




- Position of the reconstructed beam-gas vertices projected onto the horizontal (x-z) and vertical (y-z) planes
  - Crossing angle in the x-z plane, caused by the LHCb dipole magnet



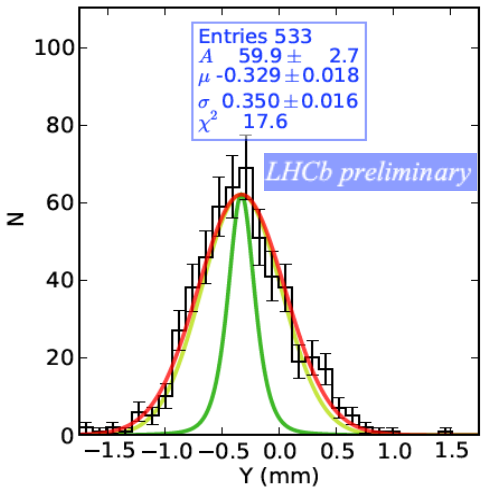
# Measured beam properties

- Beam and lumi region sizes in vertical direction (y)

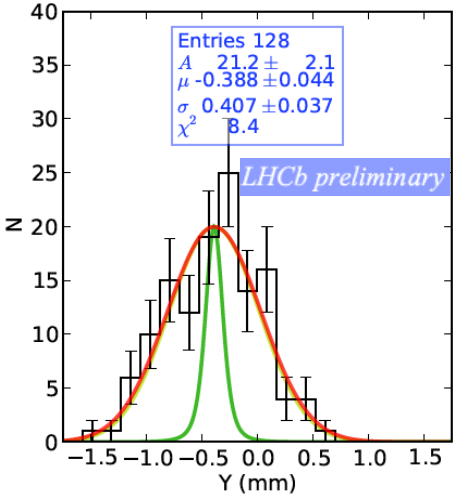
  - vertex resolution
  - measured size
  - size after deconvolving the resolution

  - The quoted sigma refers to the bare beams

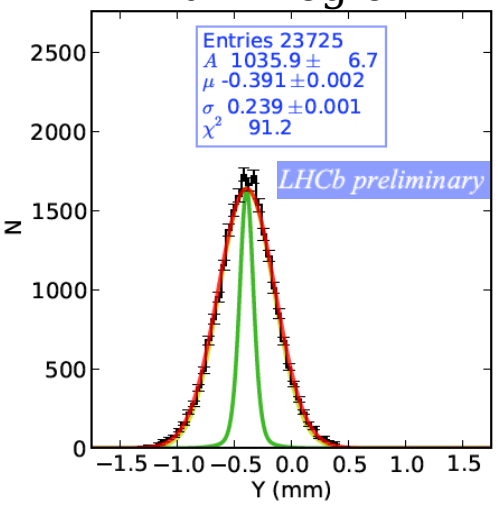
beam1




beam2



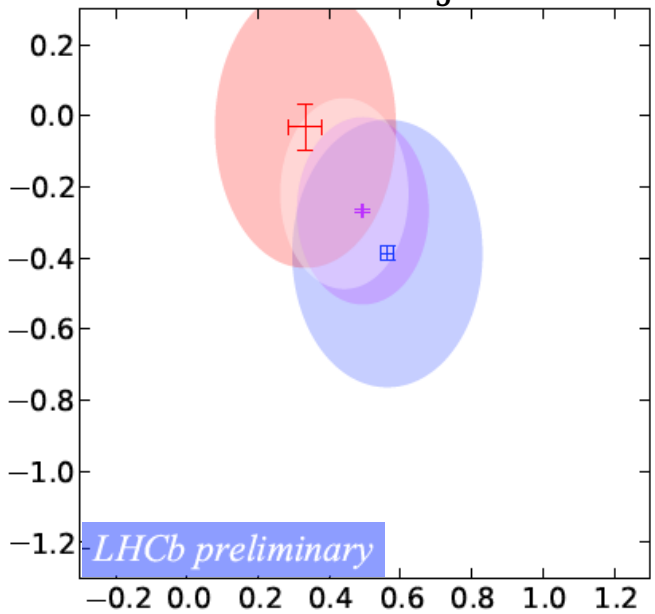

Lumi region



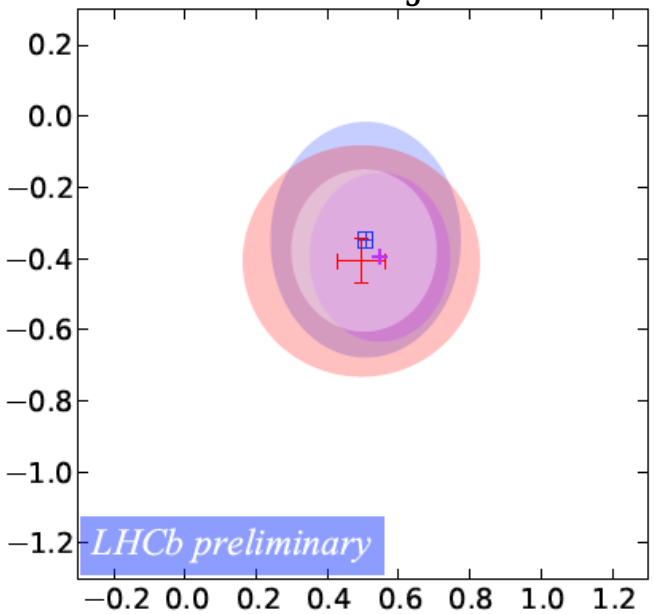

- Positions and sizes at z=0 before and after beam adjustment (mini VDM scan)

  - beam1
  - beam2
  - predicted luminous region
  - measured luminous region

before beam adjustment




after beam adjustment



# Summary and Prospects

- The beam-gas luminosity method and beam-gas analysis at LHCb have been presented
- Luminosity measurement will be used in the first LHCb paper. For the 2009 runs we expect precision on the absolute luminosity of about 20 %, decomposed roughly in:
  - 10 % uncertainty in the measurement of the beam overlap (LHCb)
  - 15 % uncertainty in the measurement of the beam intensities (LHC)

- Prospects for 2010:
  - The beams will be squeezed in transverse directions, but VELO will be closed – expect even smaller effect from the uncertainty on the vertex resolution
  - More extensive studies will be possible allowing better estimation of the beams positions and time offset effects (for the moment we are not limited by systematics)
  - Expect improved precision of the beam intensity measurements (ultimate goal is 1 %)
  - Expect very competitive results on the precision of the determined luminosity

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Thank You for Your Attention