Beam Gas Simulations for LHCb at 3.5TeV

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Abstract:

•Simulated rates for secondary particles from long straight section beam gas from the LHC machine.

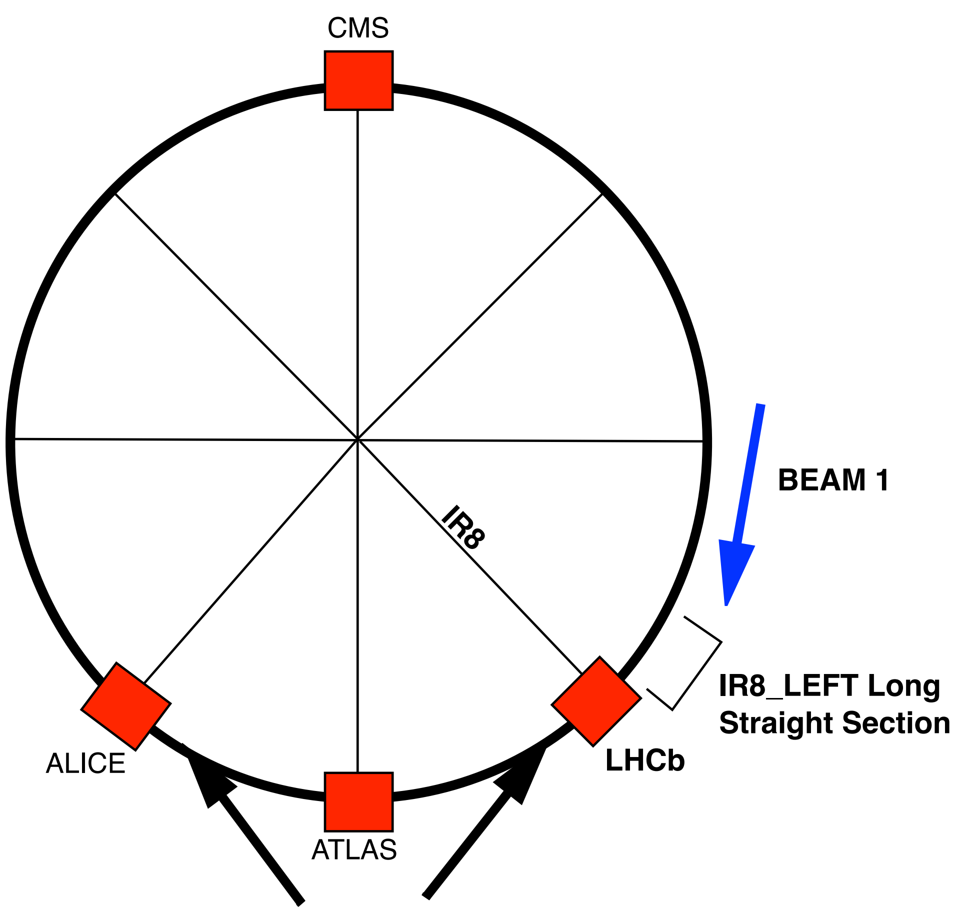
•Understand the impact of secondaries from LSS beam gas on the LHCb detector.

IOP Glasgow NPPD conference 2011

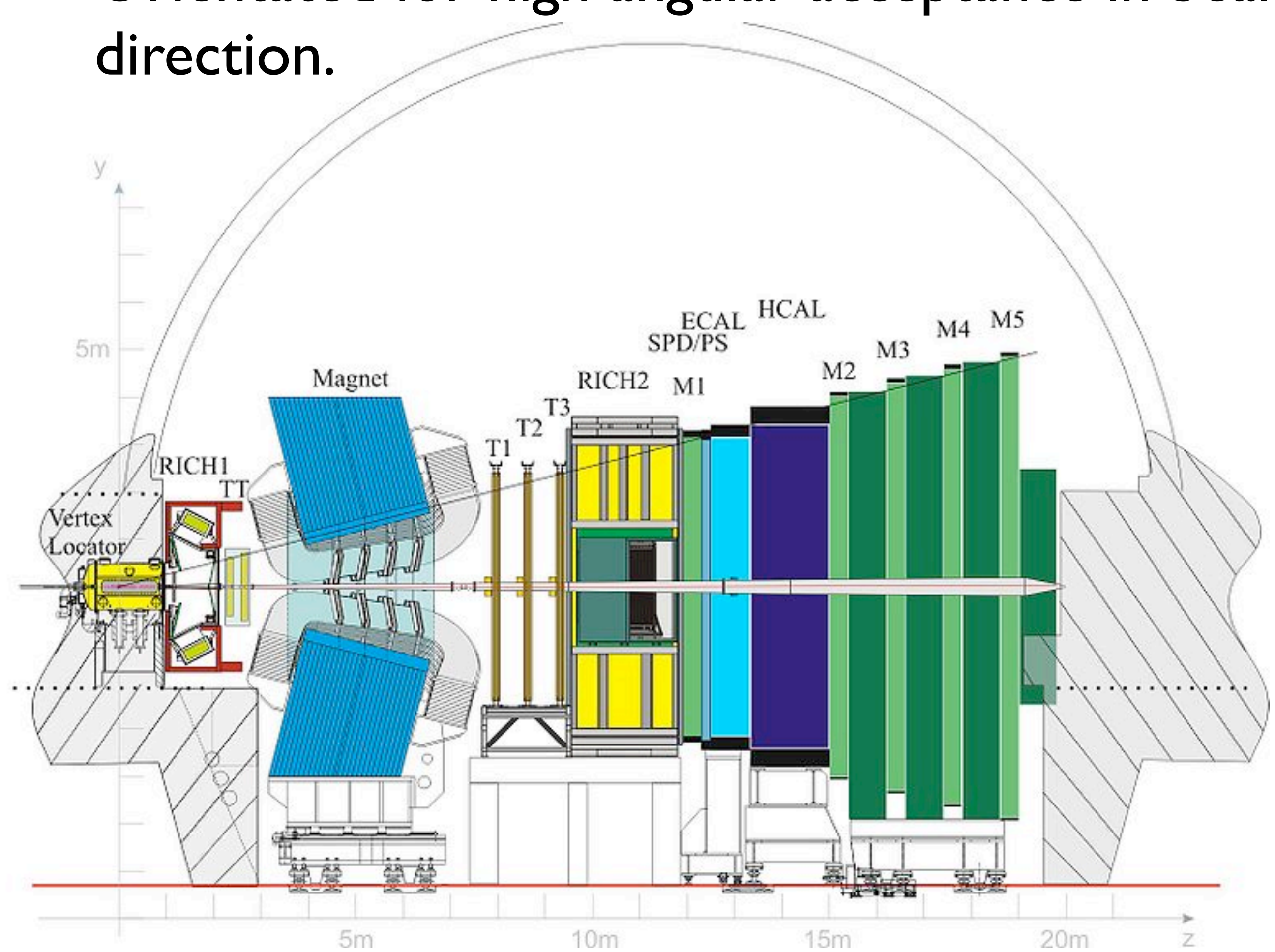
Contents

- Summary of the simulation framework which models from the machine into the detector.
- Simulation results at 3.5 TeV for tracks entering the vertex locator in the LHCb detector.

LHCb



- LHC pp collider with 8 long straight sections and 8 arcs.
- Focussed on CP violation for example B quark decays.
- Orientated for high angular acceptance in beam 1 direction.



- Designed as an asymmetric spectrometer, giving;
  - high angular acceptance;
  - better particle recognition.
- Has a vertex locator up to 8mm from the beam for high resolution b quark vertexing.

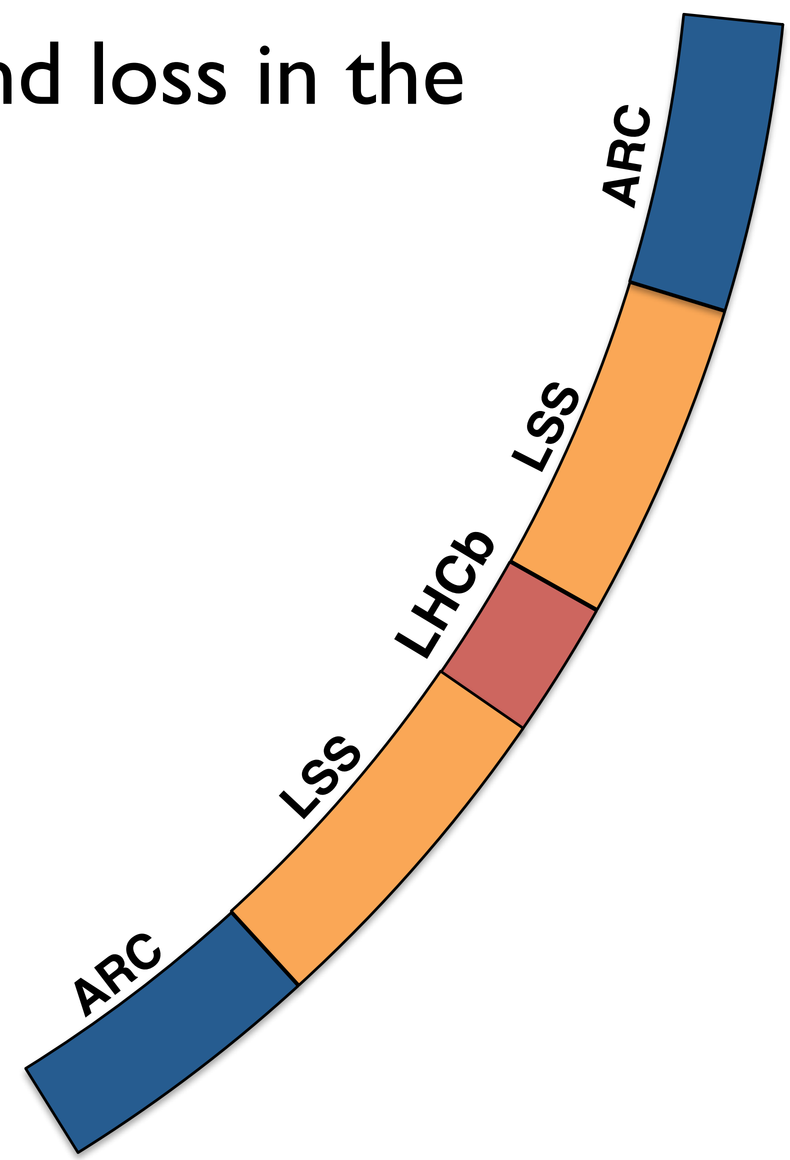
Machine induced background

- Secondary particles originating from the machine causing:
  - Quenching of magnets and other machine systems.
  - Noise and damage in detectors.

- Three source types:
  - Beam colliding with residual gas.
  - Beam scattering off collimators, which aren't close to the beam in the early LHC.
  - Experiment cross talk - secondaries from a pp collision in one experiment reaching another.

Classifications of beam-gas

- ARC (Dipoles and further machine)
  - No direct line of sight.
  - Contributes to emittance growth and loss in the next restrictive aperture.
  - Long distance source.
- LSS (Long Straight Section)
  - Direct line of sight.
  - Medium distance source.
  - Significant effect from final triplet.
- VELO (Vertex Locator - Detector)
  - Contains higher density of gas.
  - Short distance source.
  - Used for calibration of layers in VELO.



Purpose of study

- Simulated rates for secondary particles from Long straight section beam gas from the LHC machine.
- Understand the impact of secondaries from LSS beam gas on the LHCb detector.

Lessons from the past...

- Proton gas interaction at HERA main background to experiments.
- Outgassing caused by synchrotron radiation from electron beam.
- Forced a lower machine current to protect detectors.

Purpose of study

- Simulated rates for secondary particles from Long straight section beam gas from the LHC machine.
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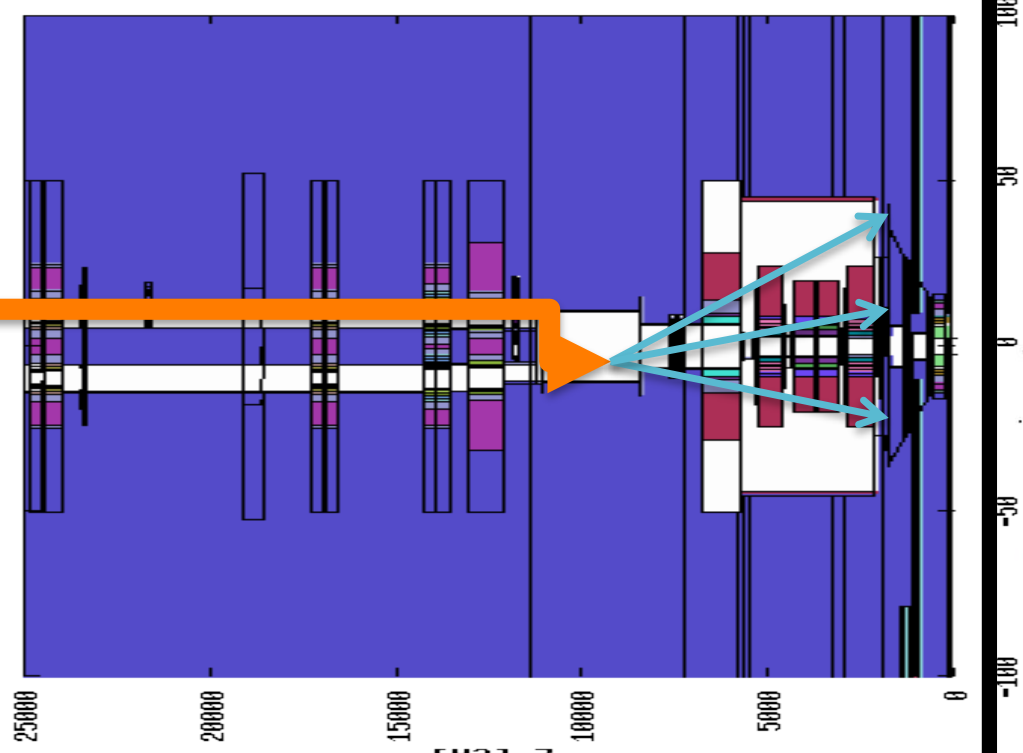
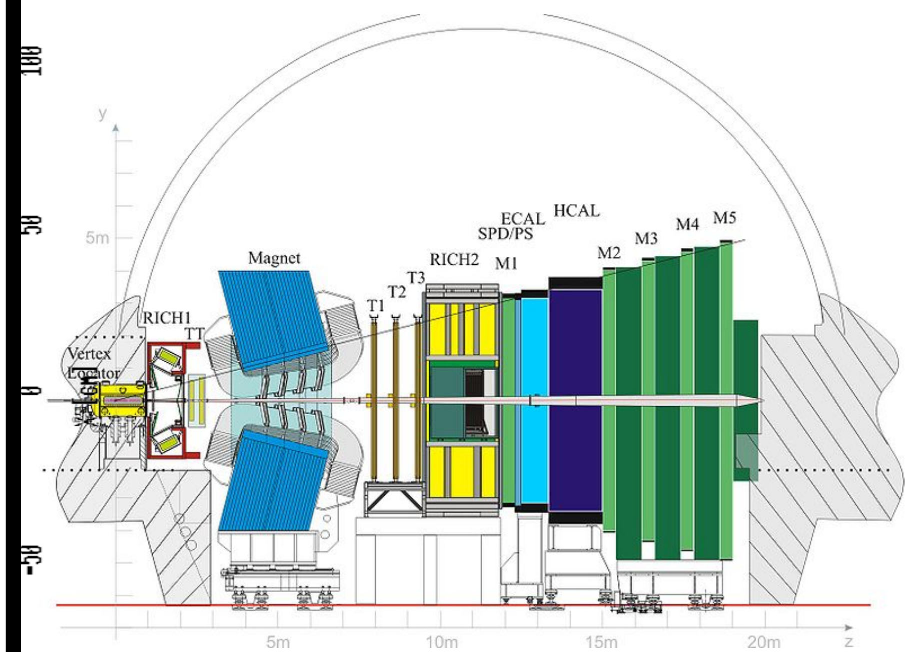
...Issues for now

- Dramatically less synchrotron radiation from proton beam but greater current.
- LHCb VELO is very close to the beam line and additional radiation damage shortens its lifetime.
- For the early LHC LSS beam gas considered the major source of machine induced background.

Simulation Framework





BEAM1 OPTICS

PARTICLE TRANSPORT SIMULATION (FLUKA)

EVENT GENERATOR (DPMJET-III)

Interface plane

DETECTOR SIMULATION (GEANT4)

DIGITIZE (SIGNAL NOISE)

RECONSTRUCT TRACKS

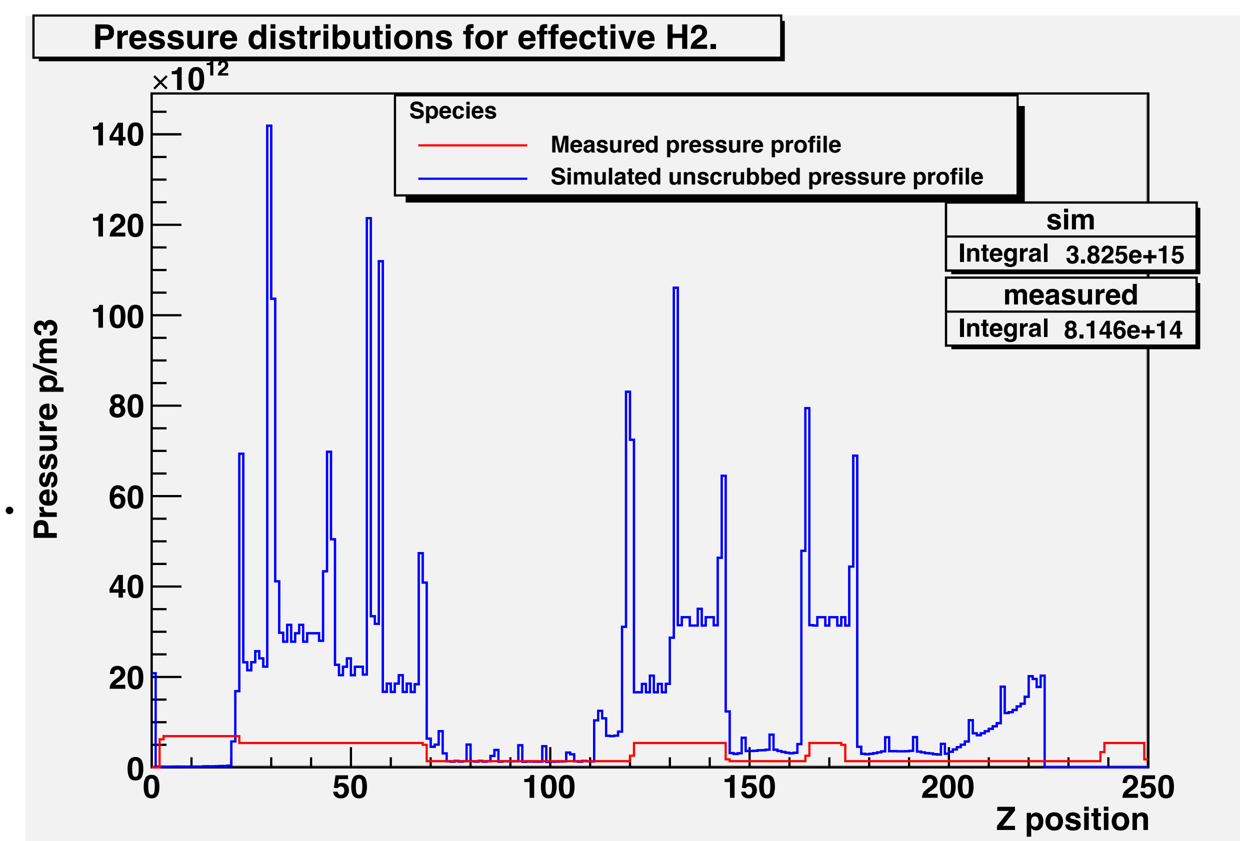
ANALYSIS

GAS PRESSURE PROFILE

- Unscrubbed simulated pressure profile based on outgassing and radiation after the beam has run. Produced by the vacuum group.
- Measured pressure profile measured from a small number of pressure gauges before the LHC switched on in 2009. Simulations predominantly based upon this.

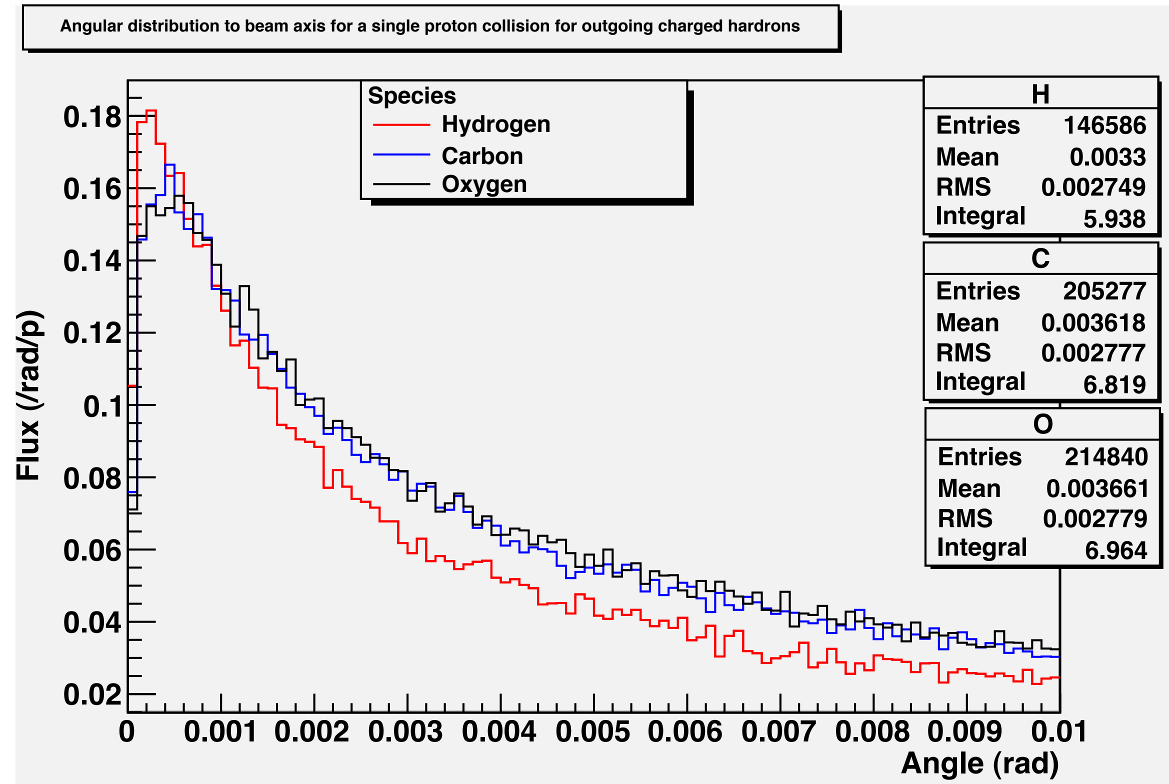
- Predominant Gas species in LHC:
  - CO_2, H_2, CH_4, CO
- Use effective hydrogen instead of actual gas species.
- Weighted by total collision cross section.
- Makes the simulations for pressure profiles easier.

$$P_{eH_2} = \sum_i \frac{\sigma_{p-A_i}}{\sigma_{p-H_2}} P_{A_i}$$

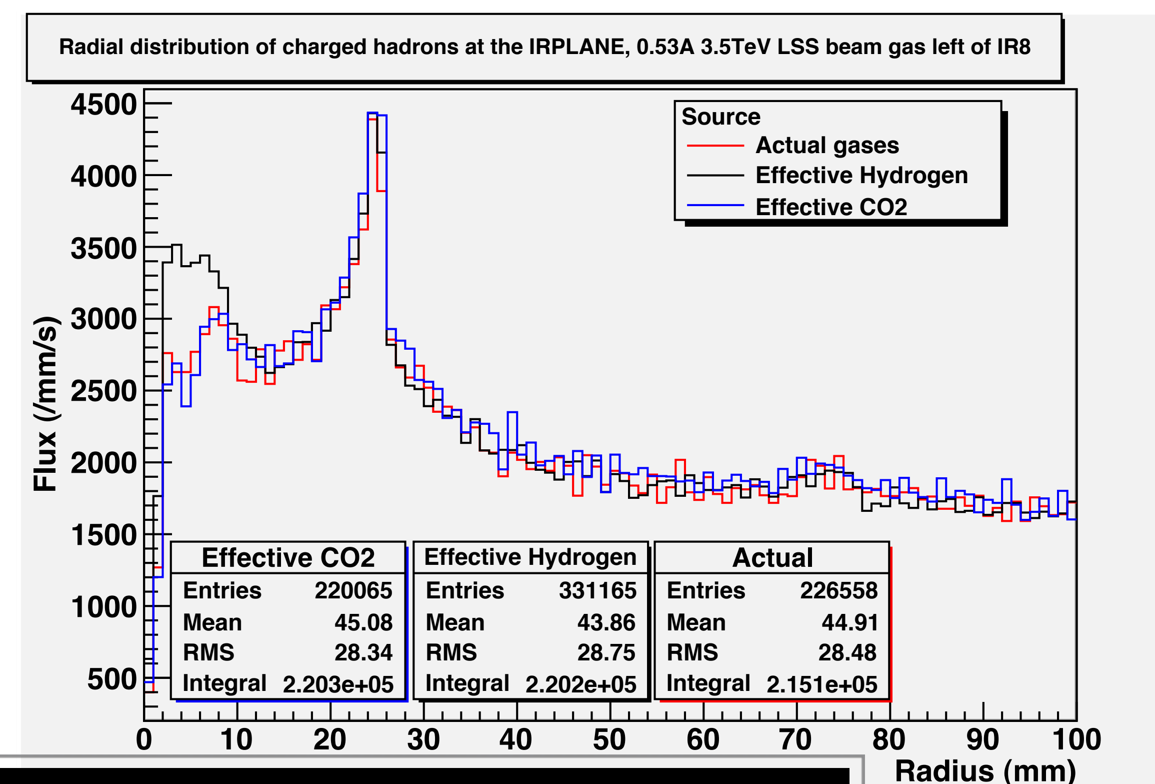


GAS PRESSURE PROFILE

- DPMJET-III shows:
  - Increasing multiplicity with mass.
  - Increasing transverse momentum with mass.
- Compare using a simulated pressure distribution compare actual gases with effective hydrogen and effective CO2.
  - At the machine-experiment interface very similar for the second peak.
  - Large difference for charge hadrons (>20 MeV) going straight down the beam pipe.
- Peak at 25 mm corresponds to beam pipe radius from machine.



EVENT GENERATOR

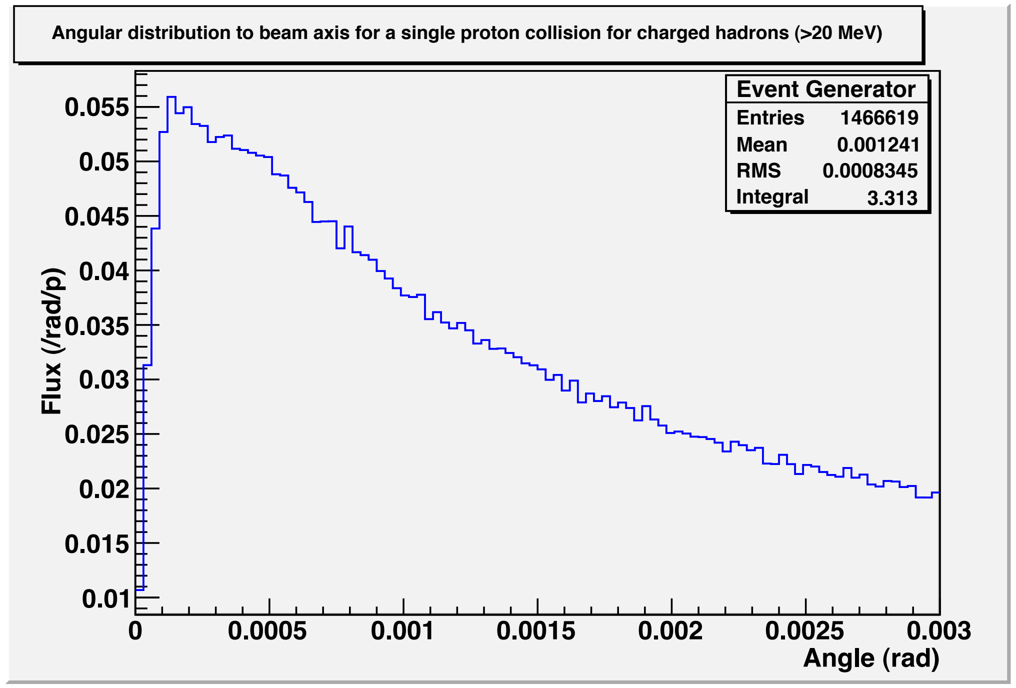


INTERFACE PLANE

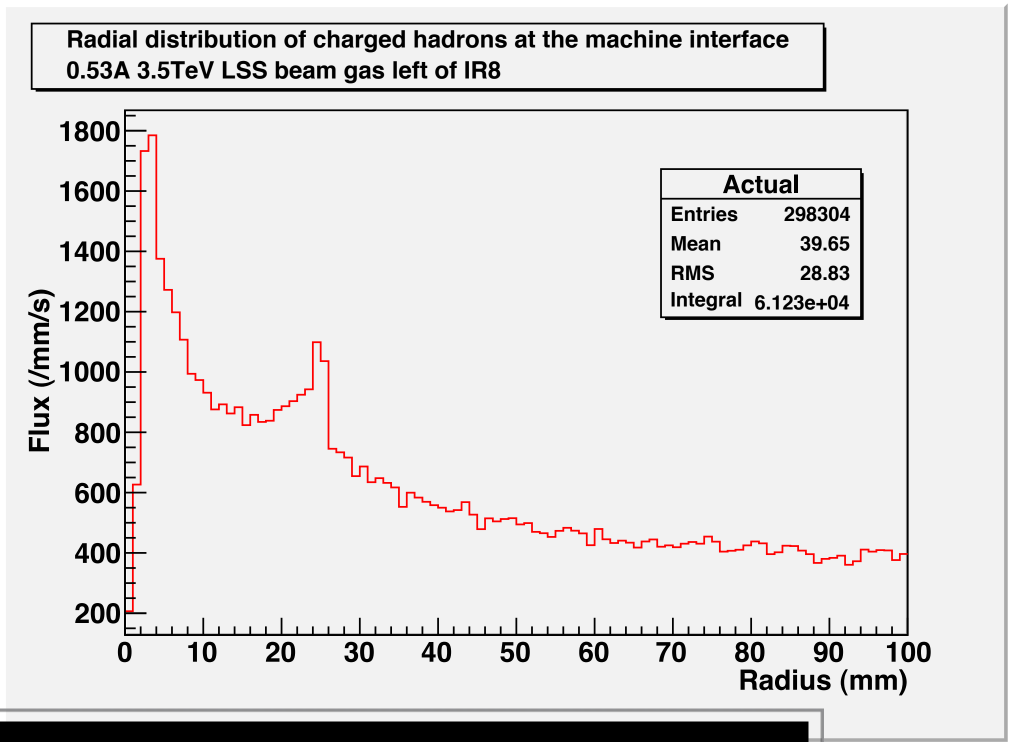
Using simulated pressure profile

Event generator to interface plane

- Only inelastic collisions used in simulation for the event generator.
  - Elastic scattering goes straight down the beam pipe out of the acceptance of the VELO.
- At the interface plane, charged hadrons (>20 MeV):
  - Peak away from zero due to inelastic scattering in event generator. Peak is inside the beam pipe.
  - Peak at 25 mm is showering from the beam pipe wall.
  - Greater than 25 mm is showering in the machine.



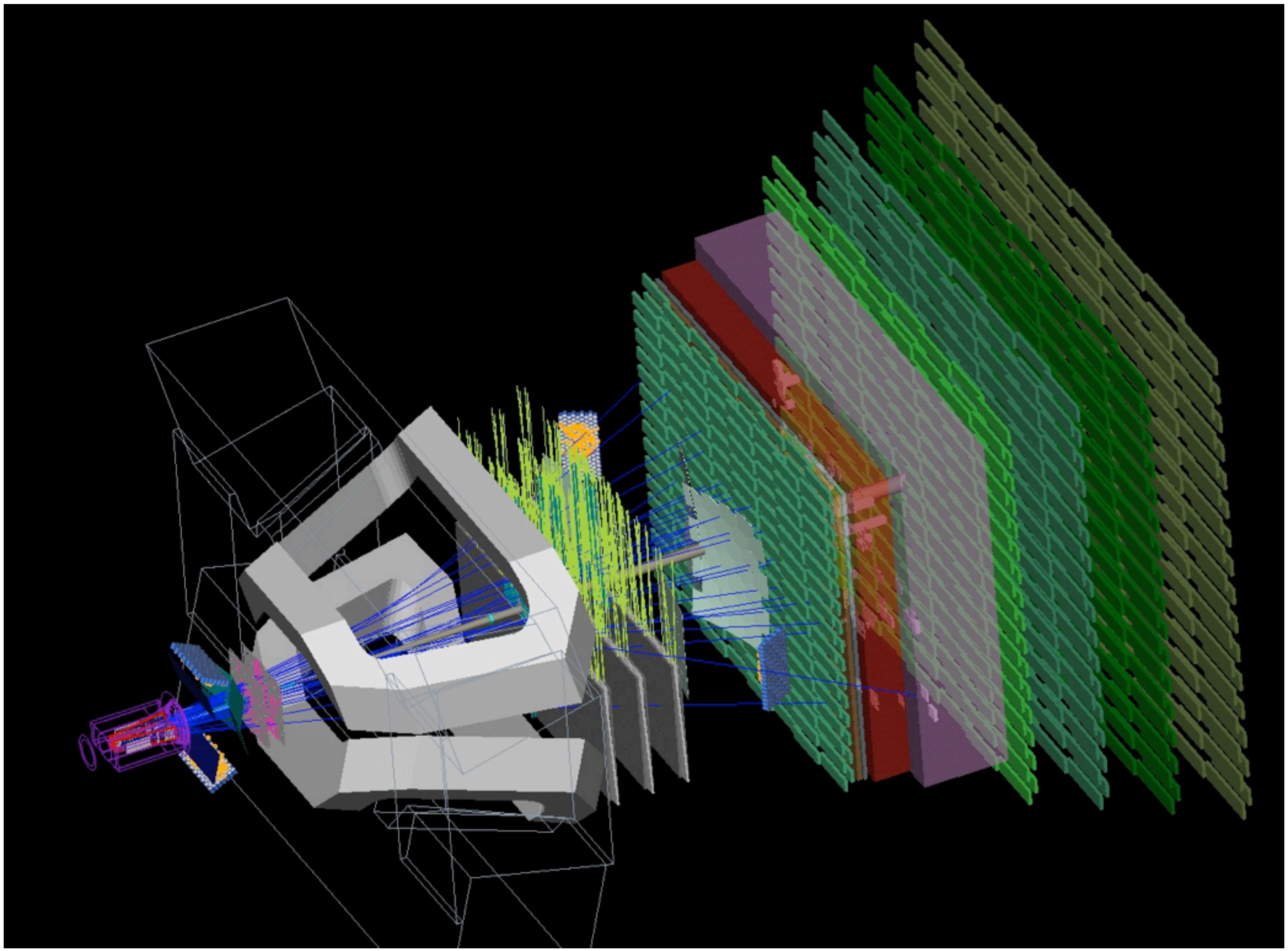
EVENT GENERATOR



INTERFACE PLANE

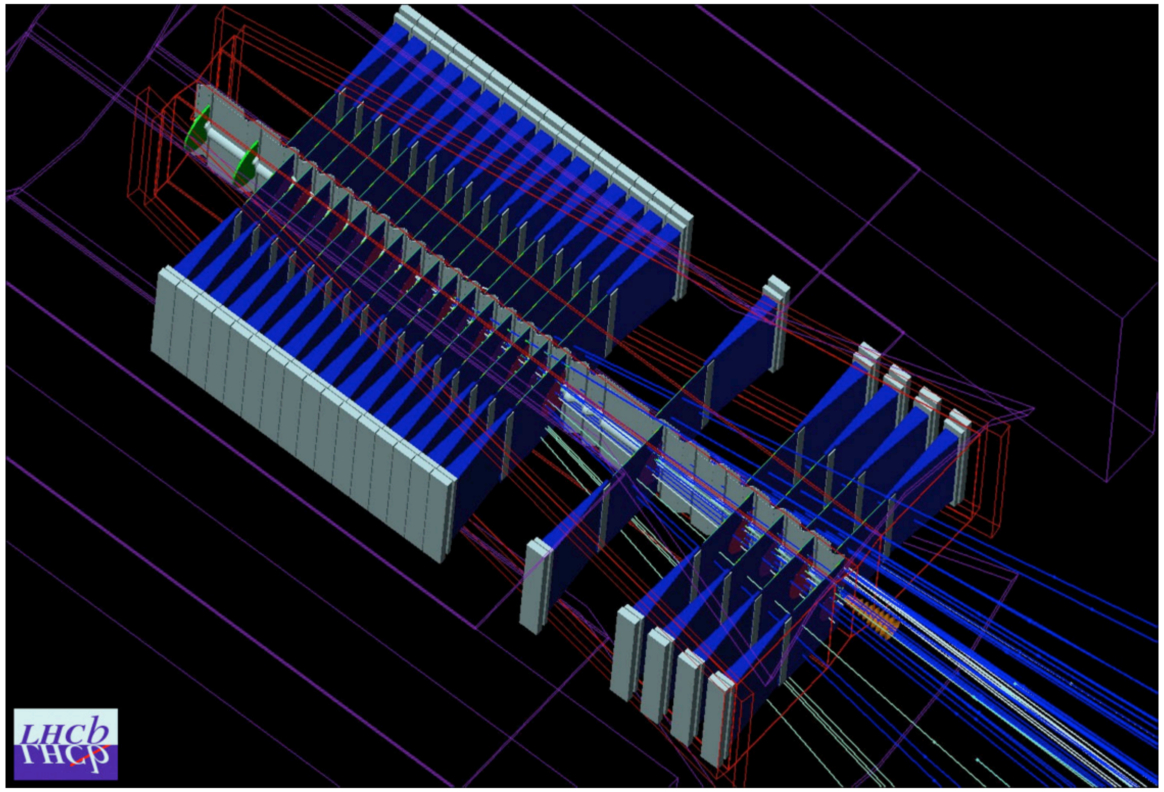
Using measured pressure profile

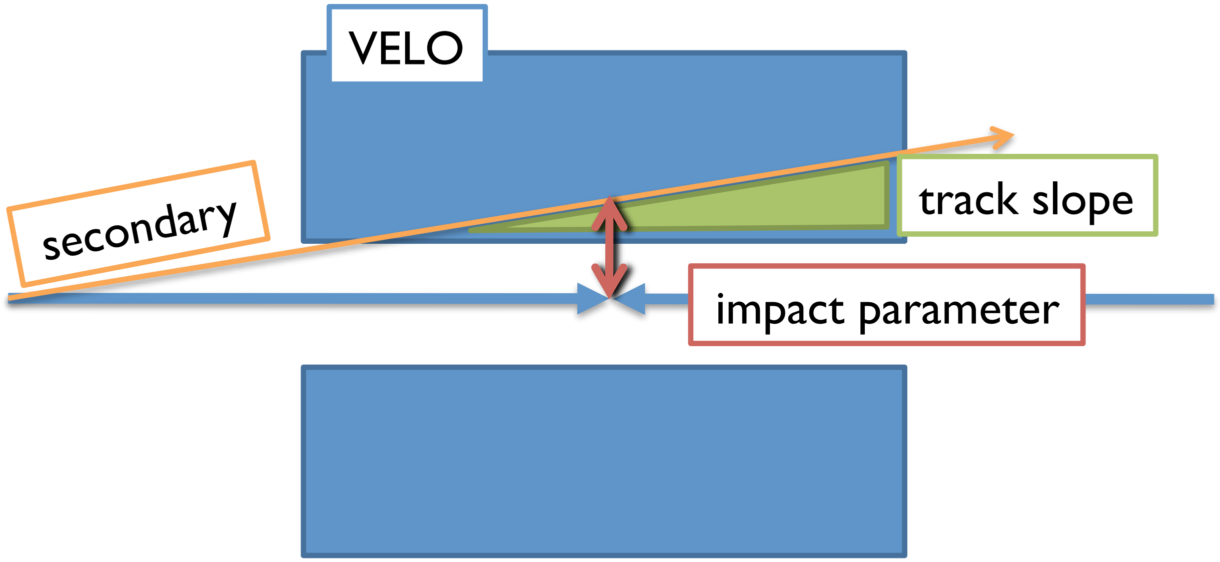
LHCb detector



VErtex LOcator

- A series of radiation hardened silicon strip sensors.
- Allowed ~8 mm away from the beam.
- Approximately 0.92 m long.

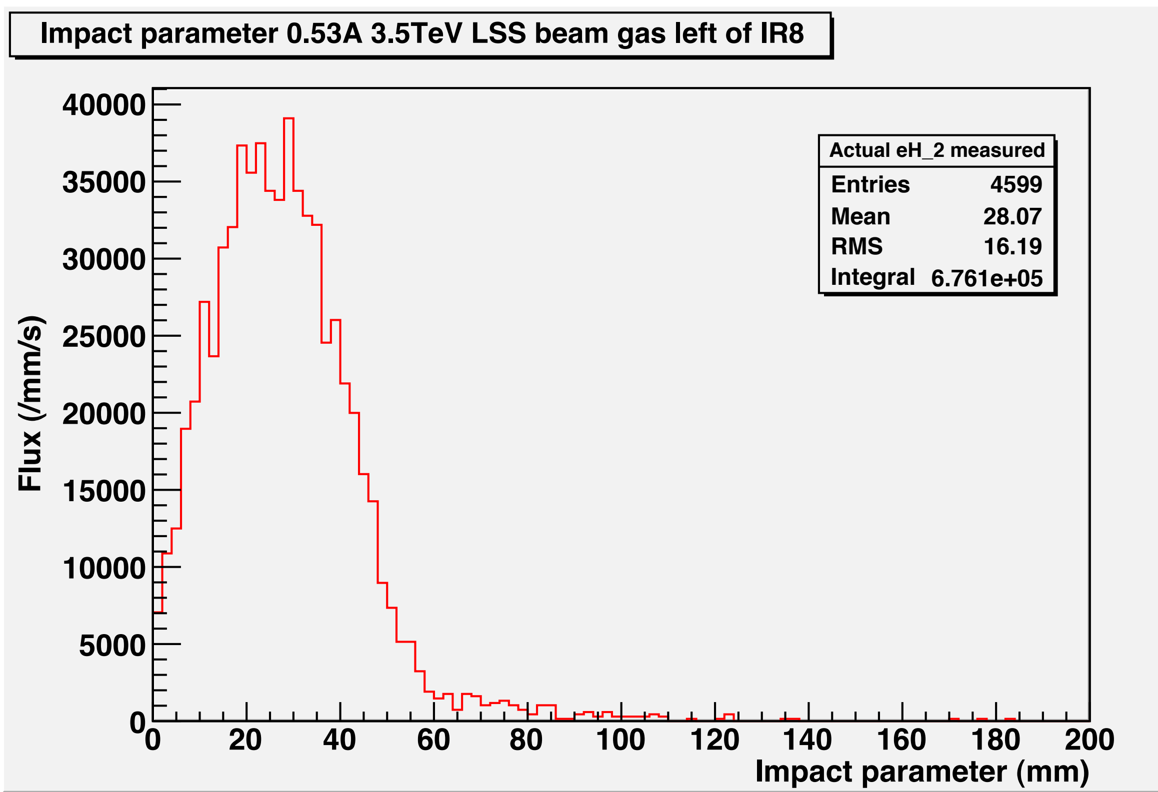


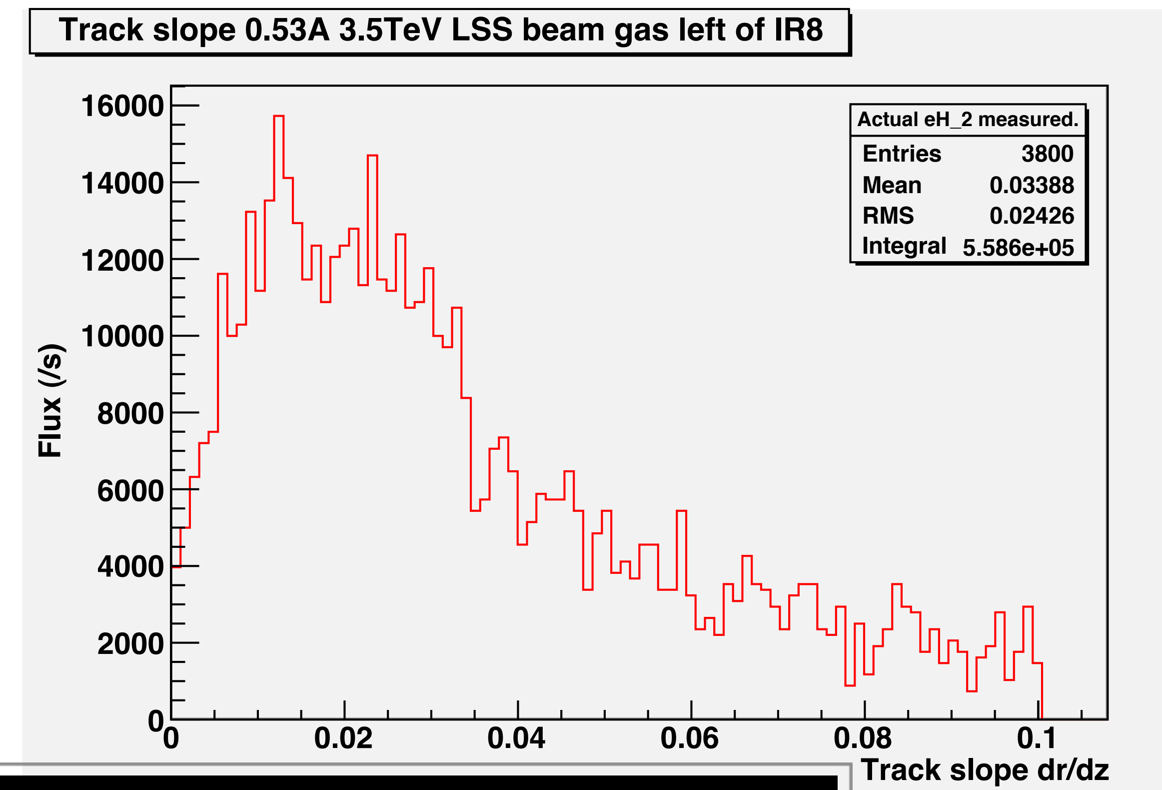


•Parameters used for the analysis of the reconstructed tracks in the VELO:

- TRACK SLOPE: rate of change in radius along the beam line.
- IMPACT PARAMETER: radial position at IP.

Detector response





Using measured pressure profile

- Apply the level 0 trigger.
- Peak in impact parameter is the same as the radius of beam pipe.
- Peak goes below 8mm due to it being the closest position of the reconstructed track not hit.
- Track slope peak shows that the tracks are very flat due to long distance source.
- Peak away from zero as very flat events won't leave hits in the detector.

Rates for beam 1 LHCb LSS beam gas

- Based upon 0.53 A beam current at 3.5 TeV.
- Using the measured pressure profile.
- From these rates hope to observe how many go on to pass the LHCb higher level trigger.

LSS beam gas	
Collisions in the LSS (s^{-1})	2.4E4
Events reaching interface plane (s^{-1})	1.5E4
Charge hadrons at interface plane (>20 MeV) (s^{-1})	1.5E5
Muons at interface plane (>20 MeV) (s^{-1})	1.0E4
Tracks in VELO (s^{-1})	1.8E6
Machine parameter	
Bunch crossings (s^{-1})	4.0E7
Visible PP collisions (s^{-1})	1.0E7

Conclusion

- We now have a complete simulation chain to go from a single proton colliding with a gas atom to the detector response from the resulting shower.
- We observe from simulation that the predominant cause of secondaries from machine induced background going into the VELO arise from showering from the beam pipe/ beam screen.
- We hope to analyse real 2010 collision data and see the effect of the higher level trigger upon the recording of the beam gas tracks.