Beam backgrounds in the CMS pixel detector

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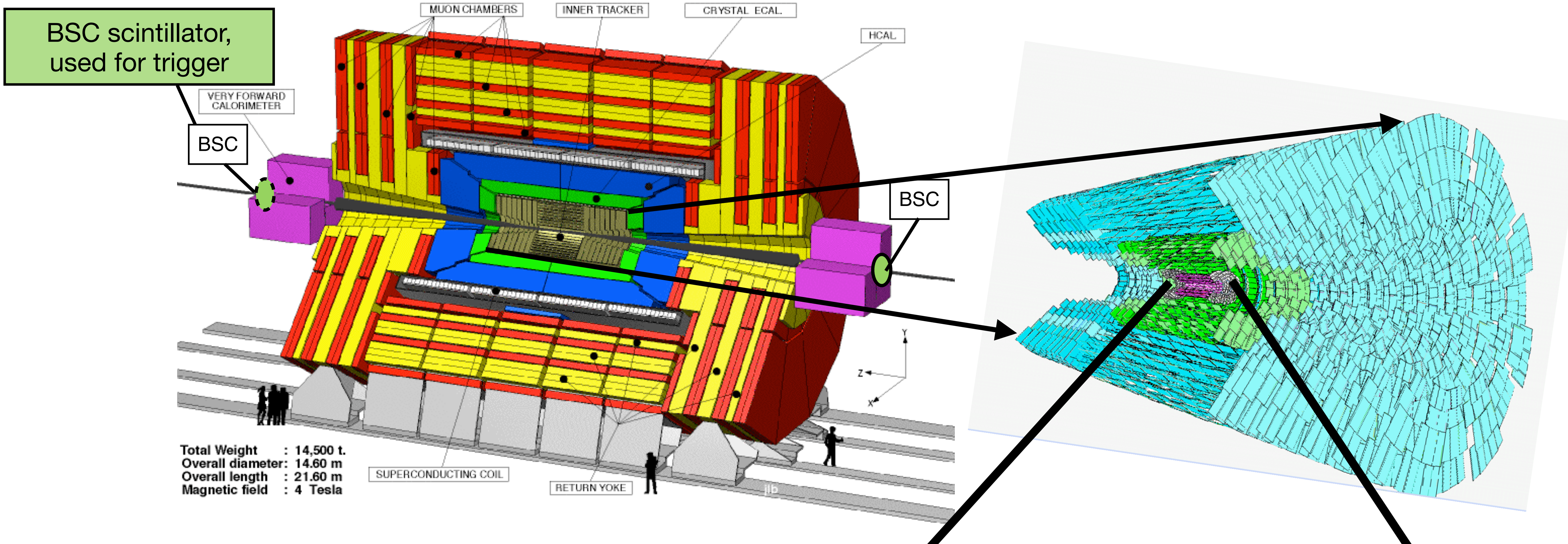
Vertex 2010 - Loch Lomond

Contents

* Description of beam background events observed in the CMS pixel detector.

* Rejection algorithm of beam background events using pixel data.

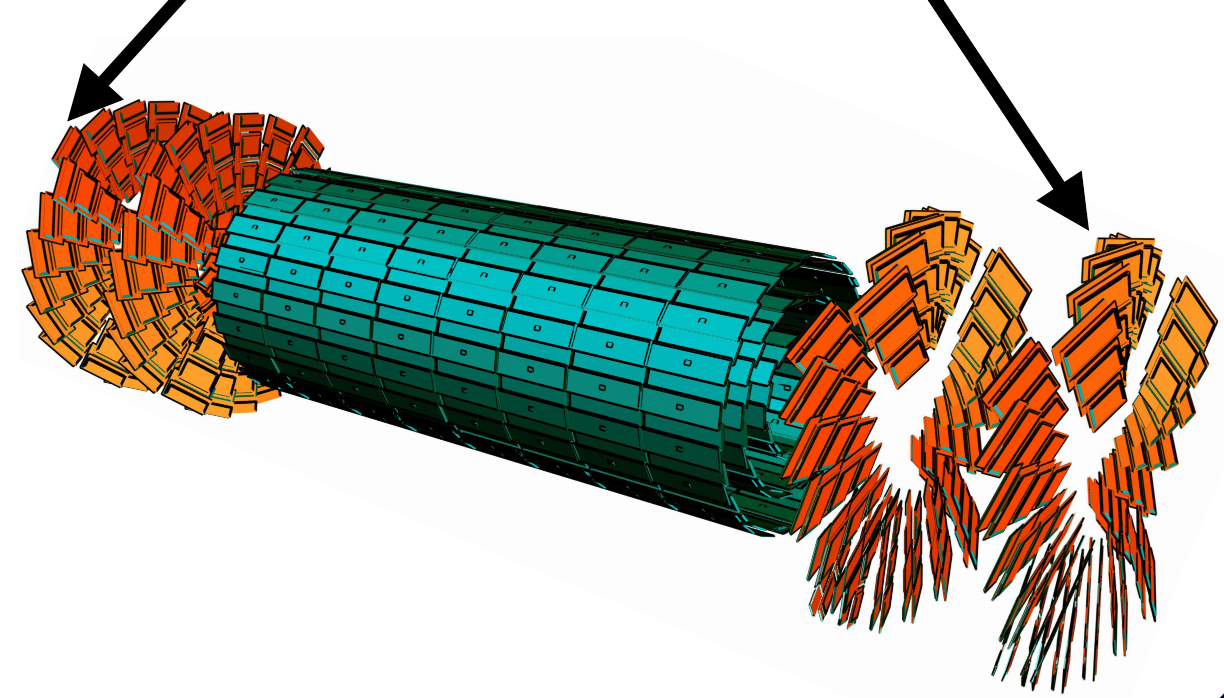
The CMS pixel detector



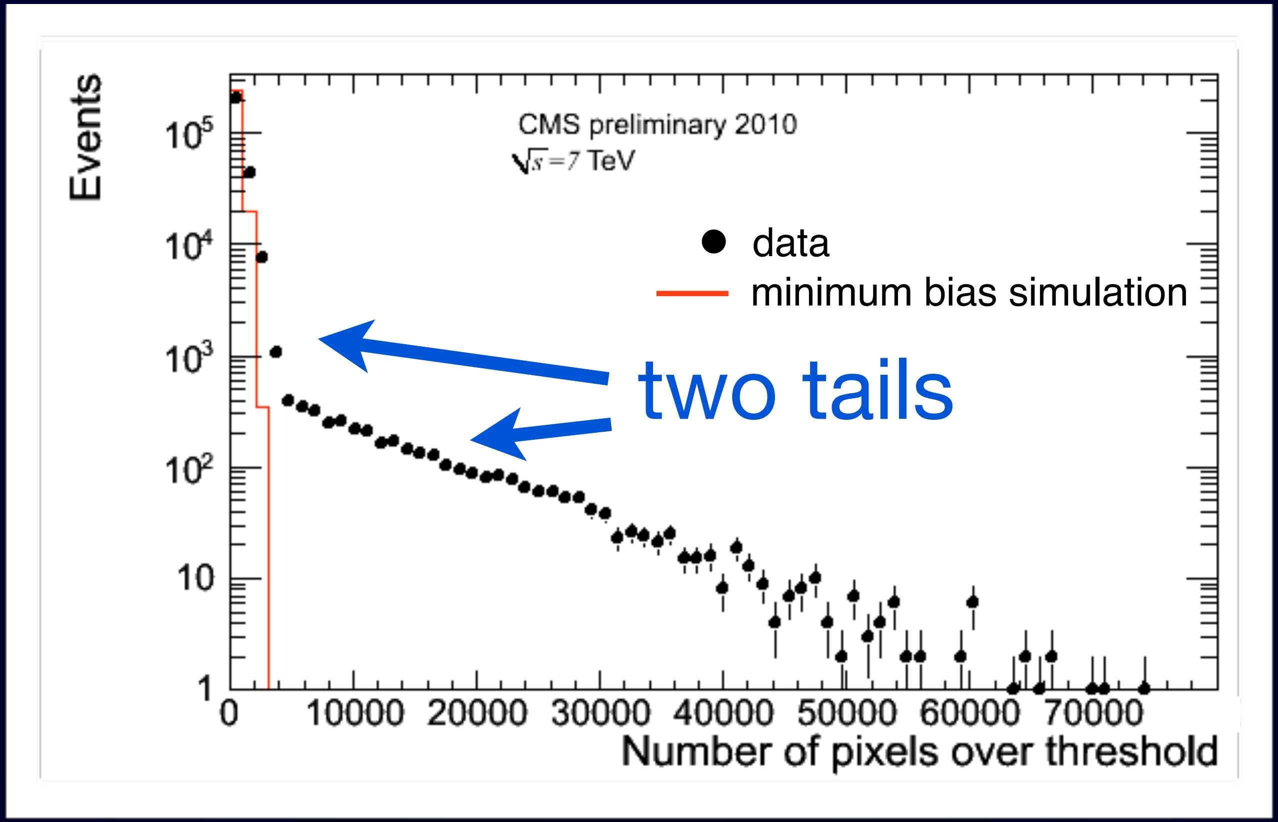
Pixel detector
- 100x150µm x 285µm

Barrel:
- 3 layers @ 4.3, 7.2 11 cm
- 50 cm long, 48 Mpixels

Endcaps
- 2x2 disks, active region 6<R<14.5 cm,
- 35 and 50 cm from IP, 18Mpixels

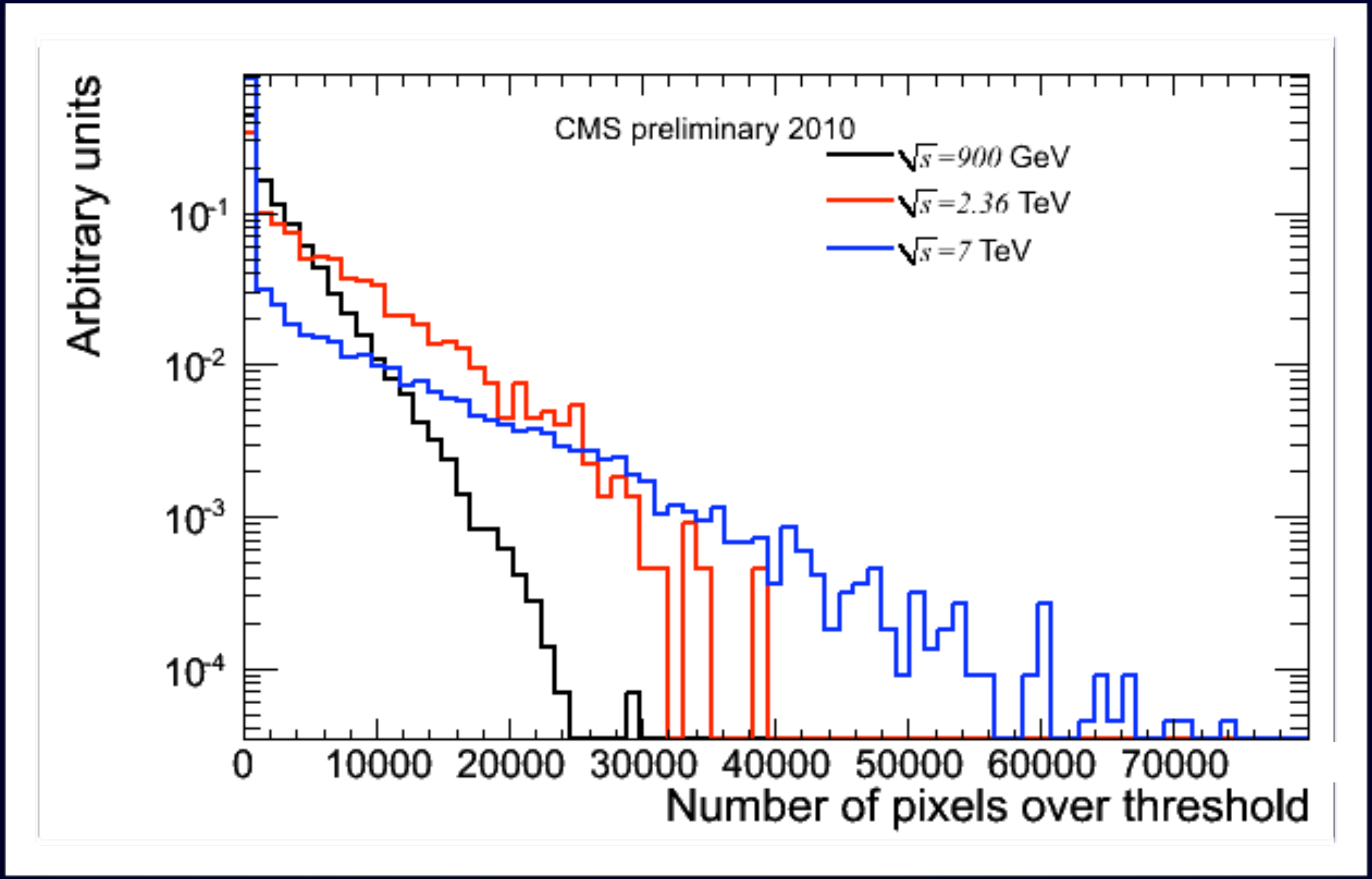


Multiplicities during data taking



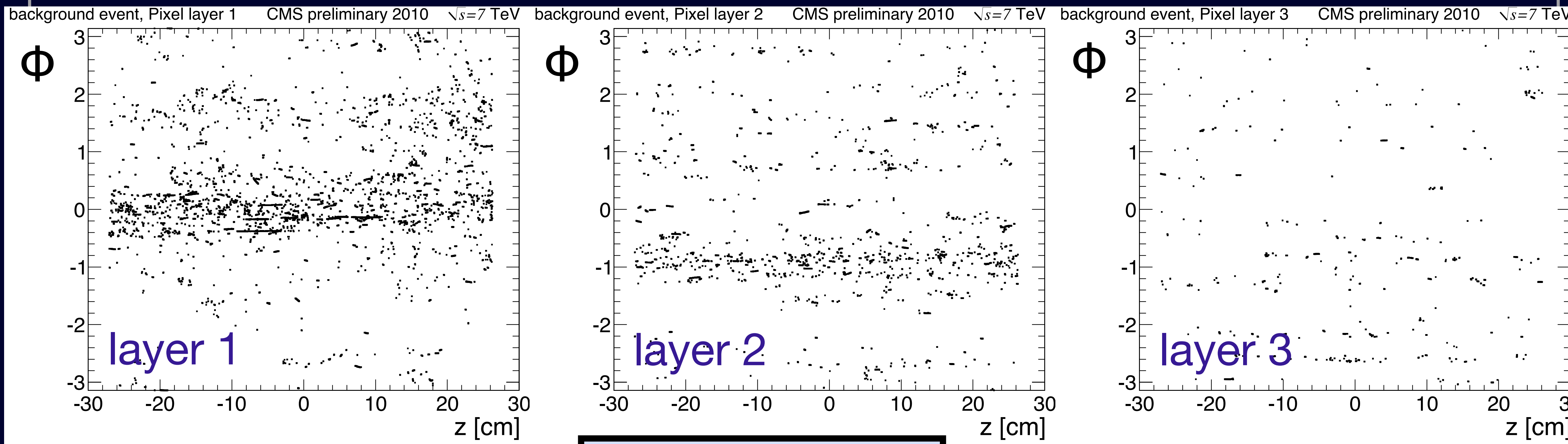
- Data taken at the LHC pixel detector is much more busy than expected from pp collisions simulations.
- Two exponential tails, two types of data?

Energy dependency



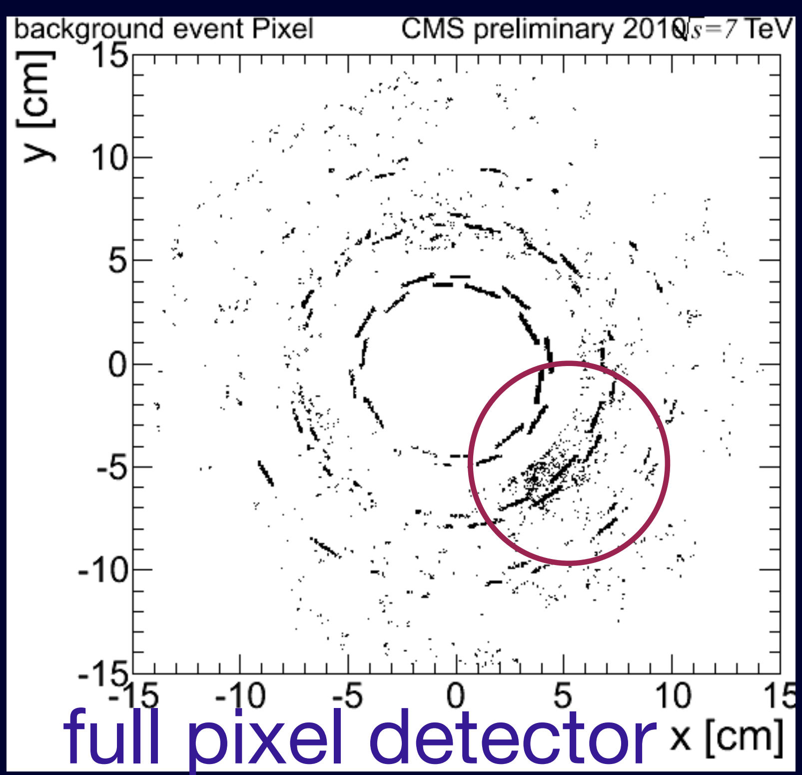
- The higher the energy of the beam, the more charge we deposit in the pixel detector.

Closer look at a single ‘busy’ event

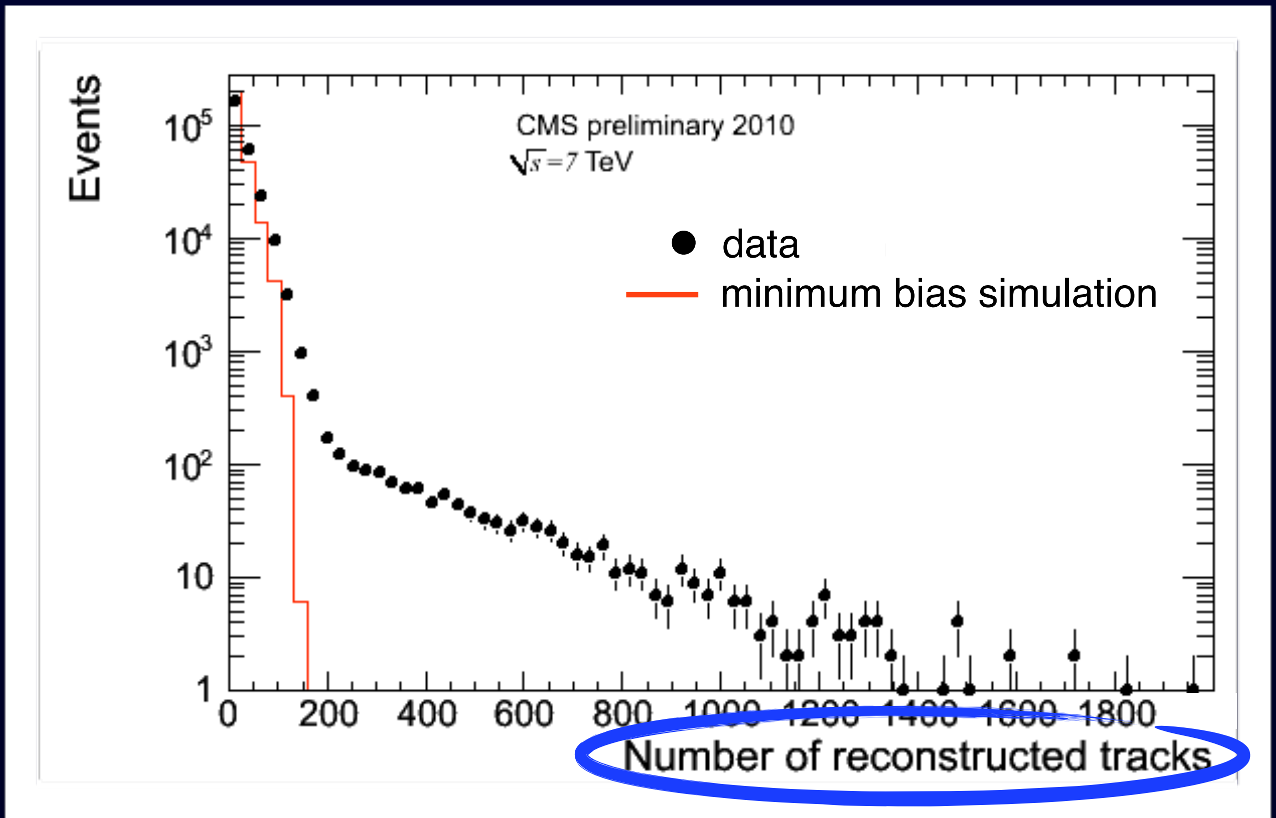


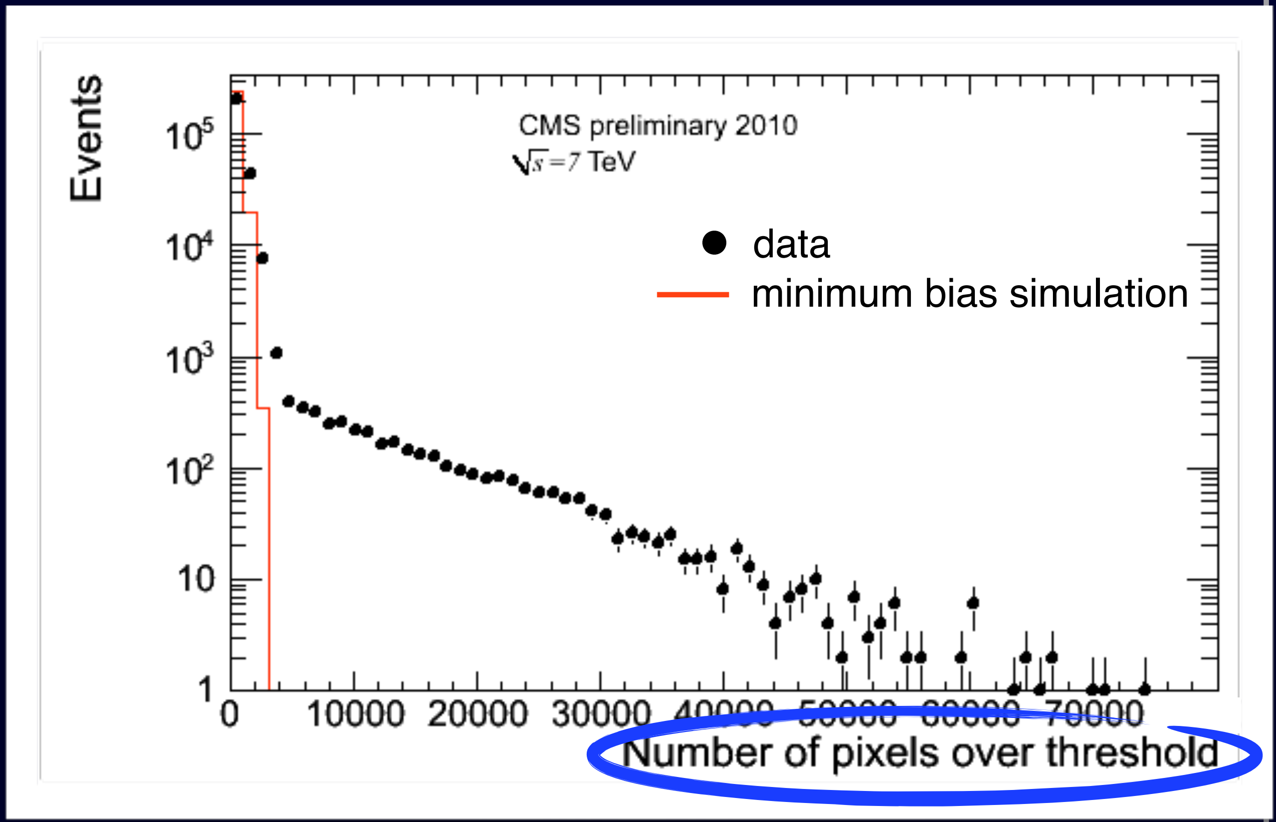
3 barrel layers

- What we see:
  - sprays of particles traversing along the beam pipe
  - localized in phi per event, per run no preferred region
  - a lot of fake tracks due to the geometry of the event



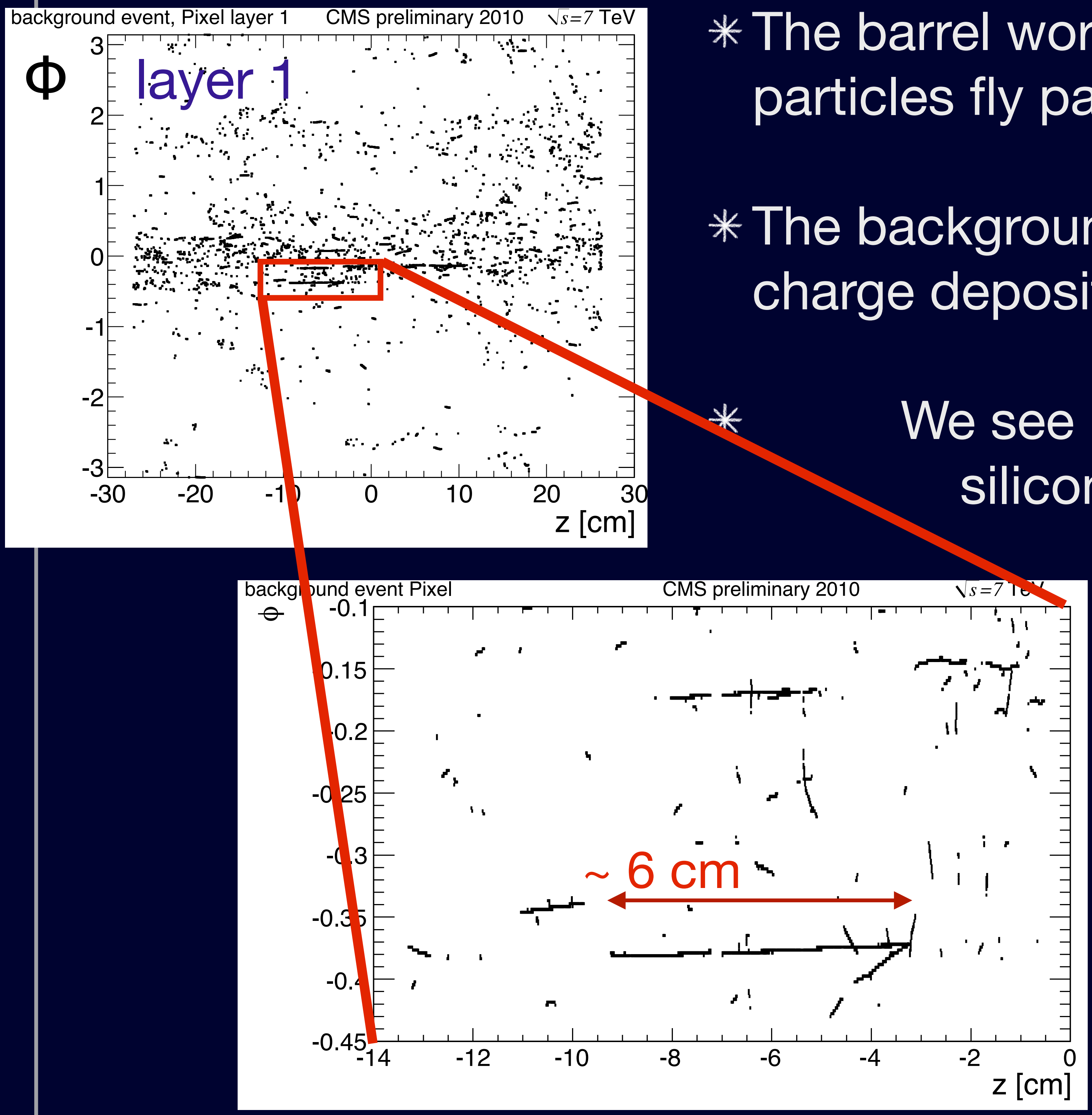
Track multiplicity





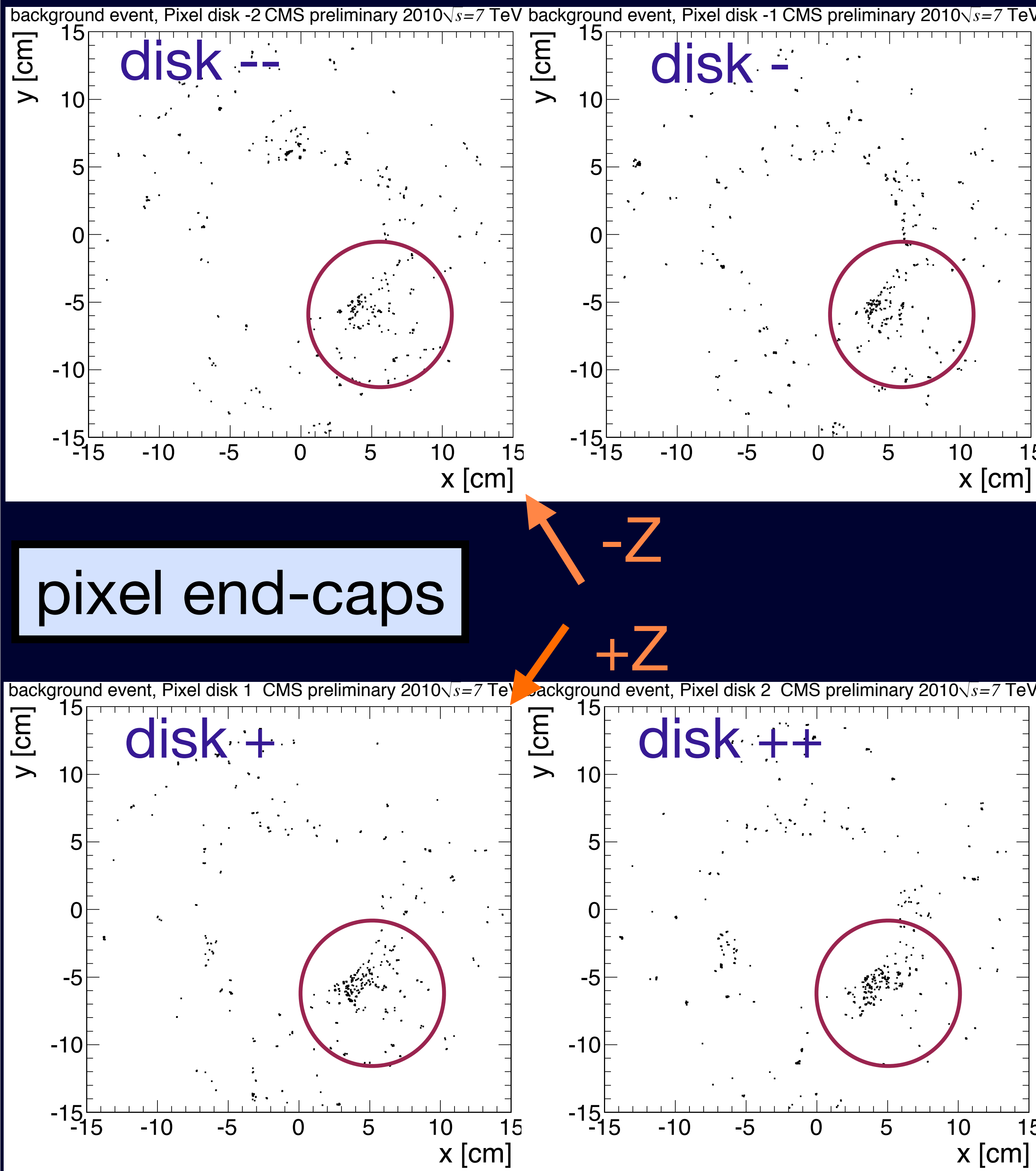
- Also in the track multiplicity we see a large exponential tail due to all the fake tracks.

Closer look at the inner layer



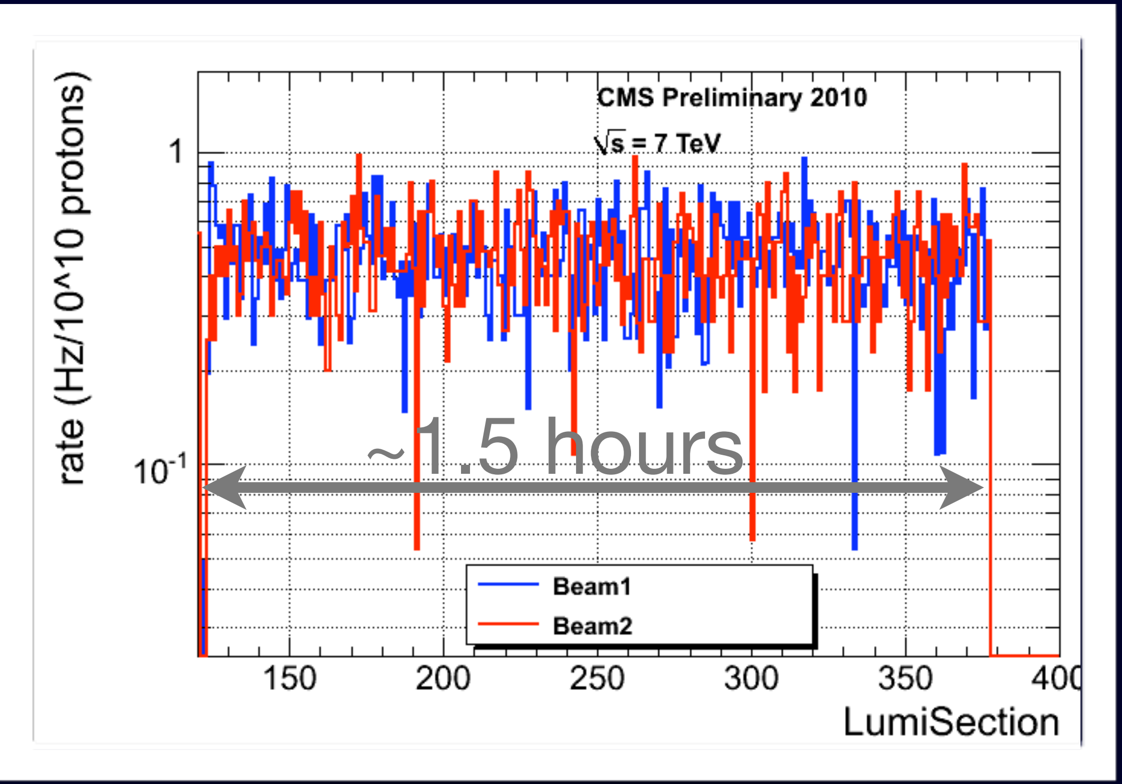
- The barrel works as a bubble chamber, the particles fly parallel to the silicon.
- The background events leave (centimeters!) long charge deposits.
- We see production of secondaries in the silicon volume.

Closer look at a single ‘busy’ event



- particles enter on one side and leave on the other of the pixel detector
- From studies we learned:
  - ✓ they come ‘in-time’ with the proton beam
  - ✓ they are present in colliding and non-colliding bunches
  - ✓ they come from both beams
  - ✓ no ‘point source’ was identified
  - ✓ an average 7 TeV event has about 50 particles leaving charge in the pixel end-caps
  - ✓ beam background events are compatible with beam-gas interactions

Background-event rates

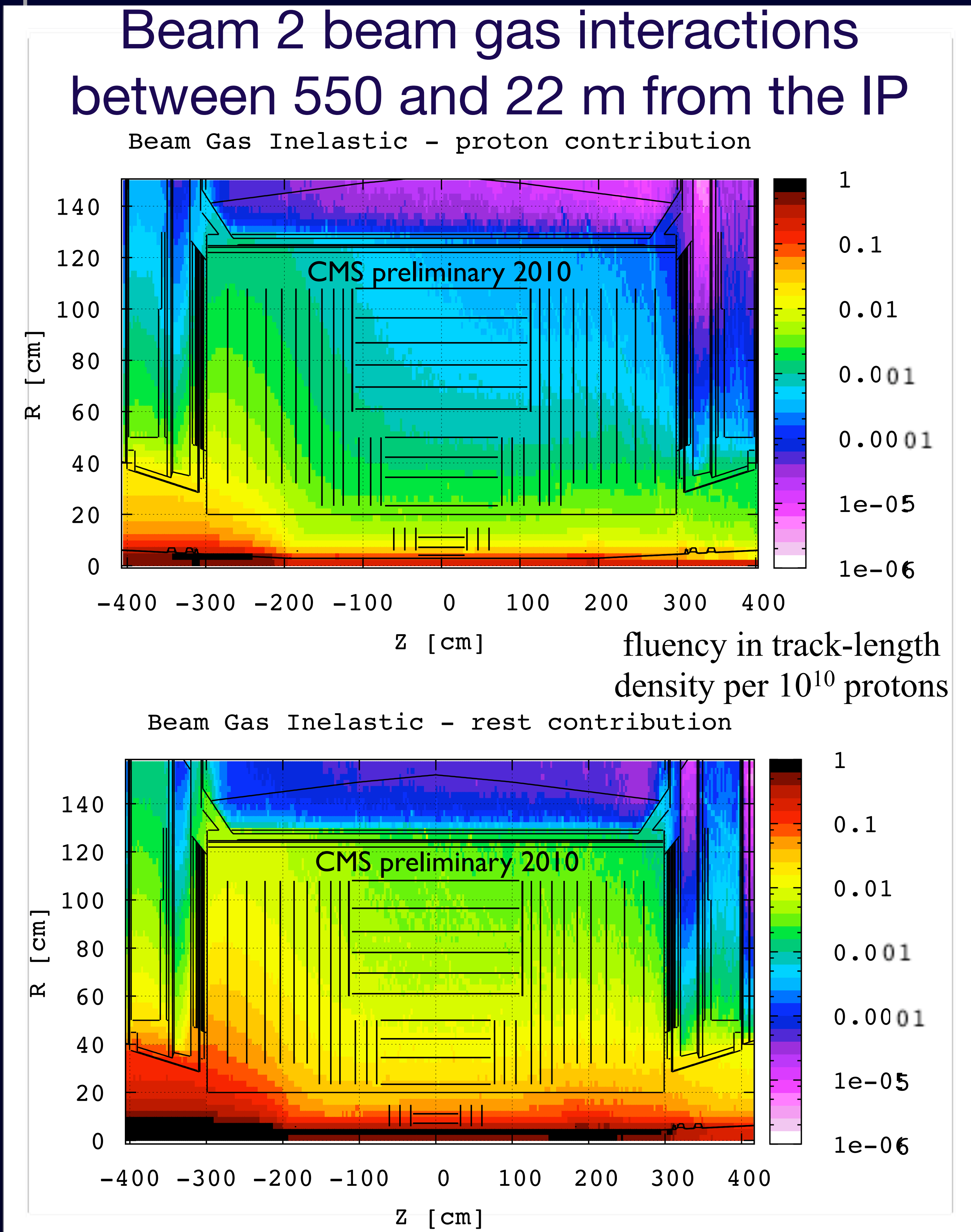


- Rate is calculated by looking at non-colliding bunch crossings and requiring activity in the scintillators (BSC)
- When scaled to the beam intensities the rate is
  - flat over (at least) a period of a run
  - the same for beam 1 and beam 2
  - independent of the beam energy
- The beam-backgrounds rate scale linear with the intensity, the collisions scale quadratically
- We have (so far) not observed dependencies to changing beam parameters (squeezing).

▷ The rate is estimated around 0.5 Hz/bunch/beam/10^{10} protons

▷ At a rate of 11kHz of physics events at 10^{11} protons per bunch an overlap with a background events is expected at a rate of about 1‰

Beam-gas simulations

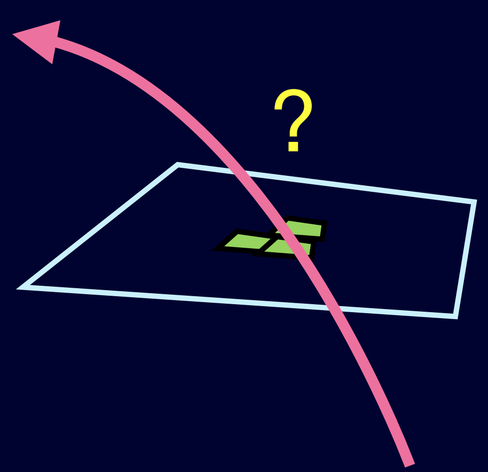


- Simulation of ideal LHC conditions (p.e. vacuum pressure)
  - Agrees well with the fluency measurements in the pixel detector.
  - The pixel detector is in a very good position to study the background events

Fluka code: AIP Conf.Proc. 896:31-49,2007

Pixel based background event filter

A BIT ON LOCAL PIXEL HIT RECONSTRUCTION



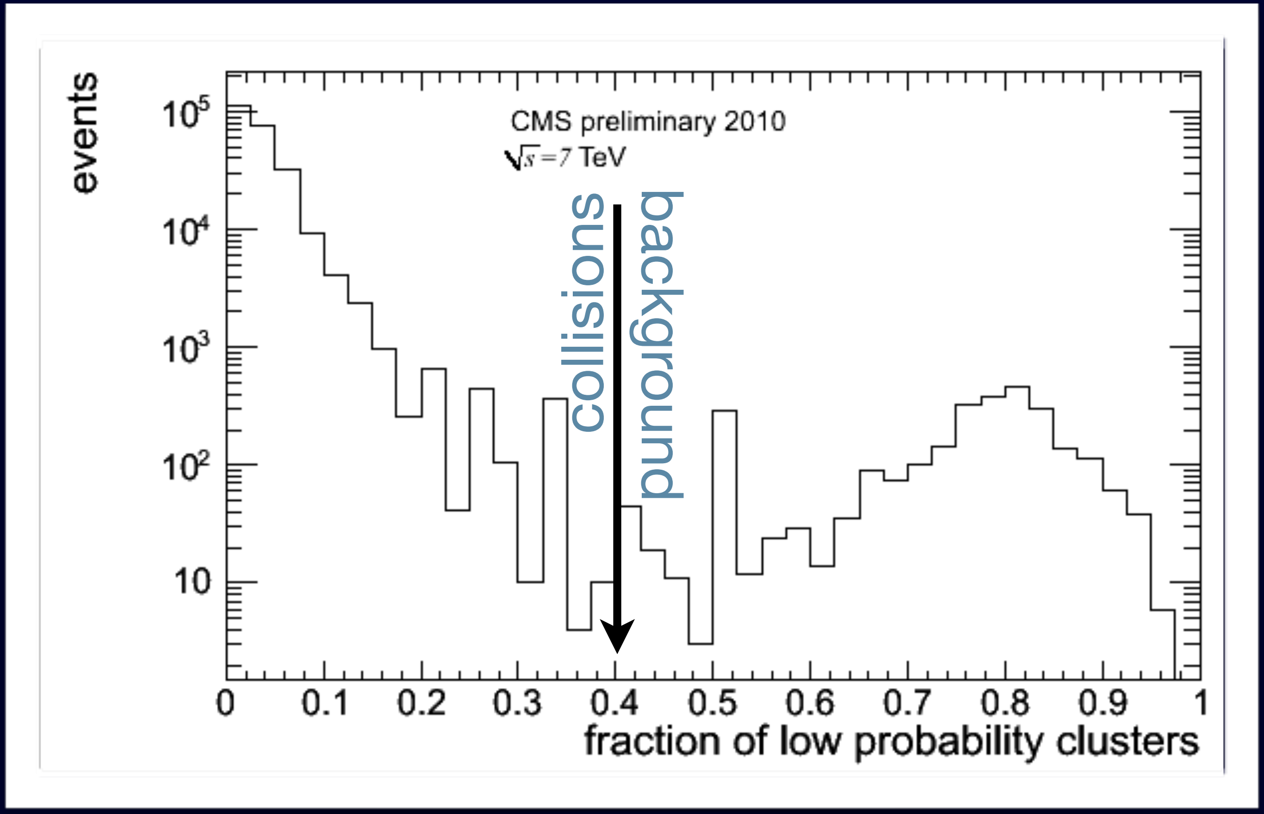
- CMS uses an iterative tracking algorithm.
- Reconstructed pixel hit locations are refined using a template based method.
- The template fit searches for the optimal hit reconstruction using the local impact angle of the track hypothesis.
- The template fit returns a probability that the track matches the cluster.

- If the cluster does not match the impact angle of the track, a low probability is returned.

Pixel hit reconstruction:
CERN-CMS-NOTE-2007-033
PoS VERTEX2007:035,2007

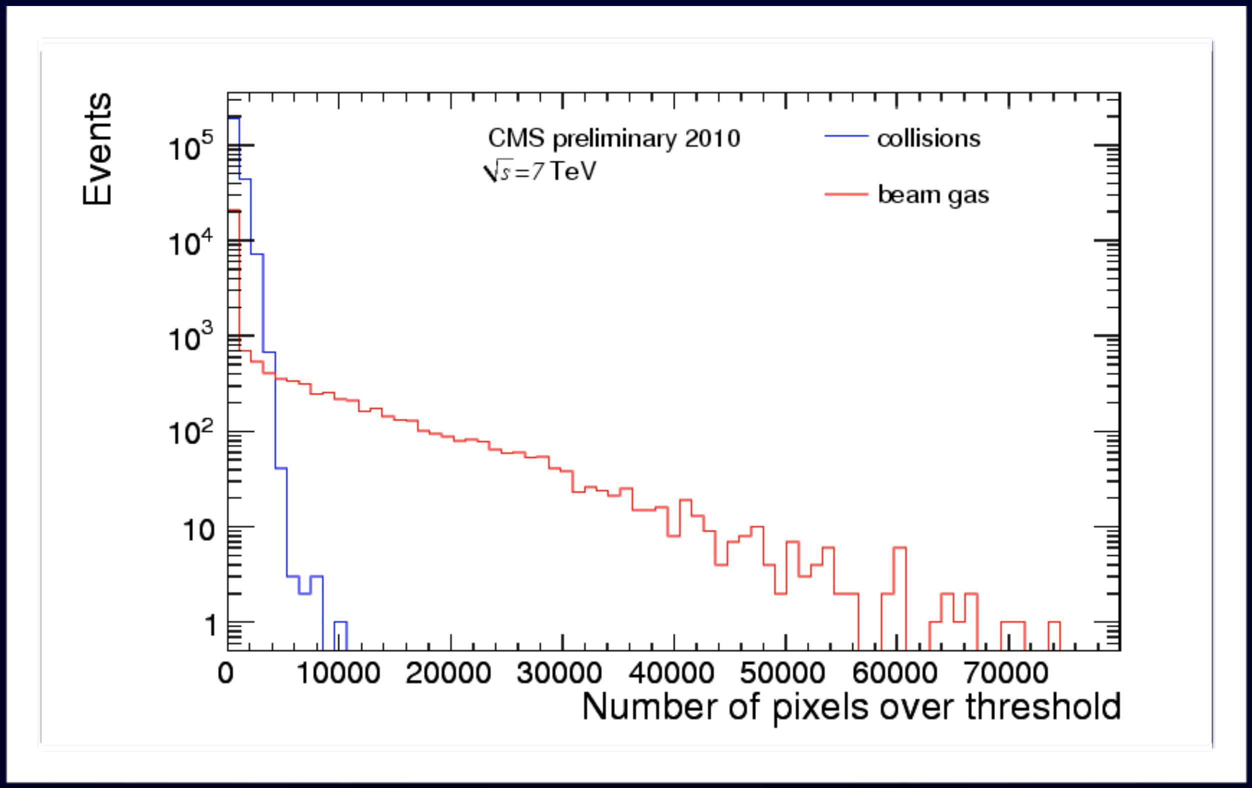
Fraction of low probability clusters

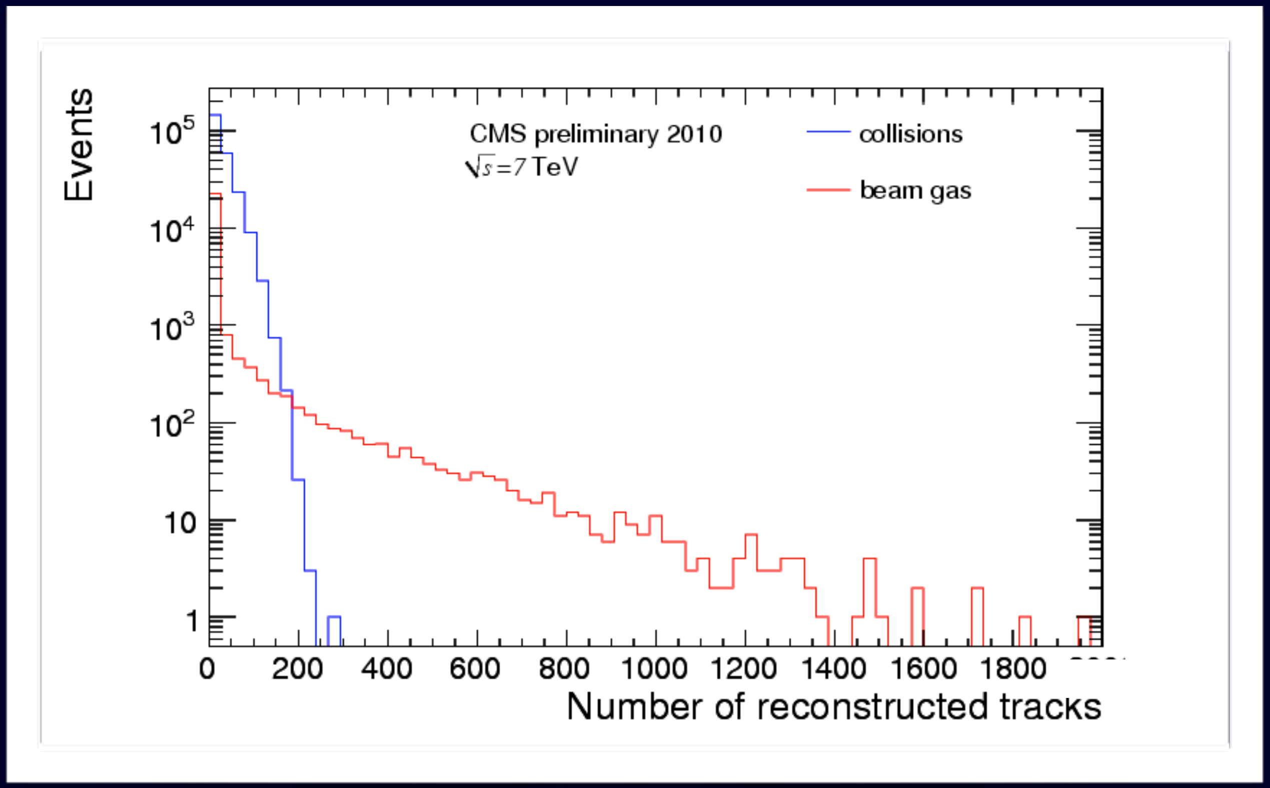
* Fraction of low-probability clusters versus the total number of clusters (counting only barrel clusters).
* This fraction is sensitive to the number of fake tracks in the event.
* A large number of fake tracks gives a high fraction of low probability clusters.
* The pixel-template filter, removes events with a fraction larger than 0.4.
* Events with no on-track clusters in the barrel cannot be identified and are added to the background category.



Separation of collision and background events

USING THE PIXEL-TEMPLATE FILTER





- The pixel-template filter separates the two tails in the multiplicity distributions.
- Collisions and beam background events overlap, a simple cut in the distribution would not have worked.

Conclusions

- ✳ The beam-background events are compatible with beam-gas interactions hypothesis
  - ✳ The rates and fluency are within expectations.
  - ✳ They leave a lot of charge in the pixel volume.
  - ✳ They create many fake tracks.
- ✳ Beam-background events can be separated from pp collision events using a filter based on the compatibility of the cluster-shape versus the reconstructed track.
- ✳ Physics-background overlapping events are expected.
  The pixel-template filter has prospects to disentangle the two events.

Thanks to all the CMS collaborators

Backup

Comparison with other filters

- Other filters are present in CMS based on
  - a well reconstructed vertex
  - the fraction of high quality tracks
  - the BSC scintillator timing information
- The pixel template filter agrees well with the other available filters.
- The pixel template filter might allow us to separate on a cluster-by-cluster basis the
- collision from the beam-background contributions in overlapping events.
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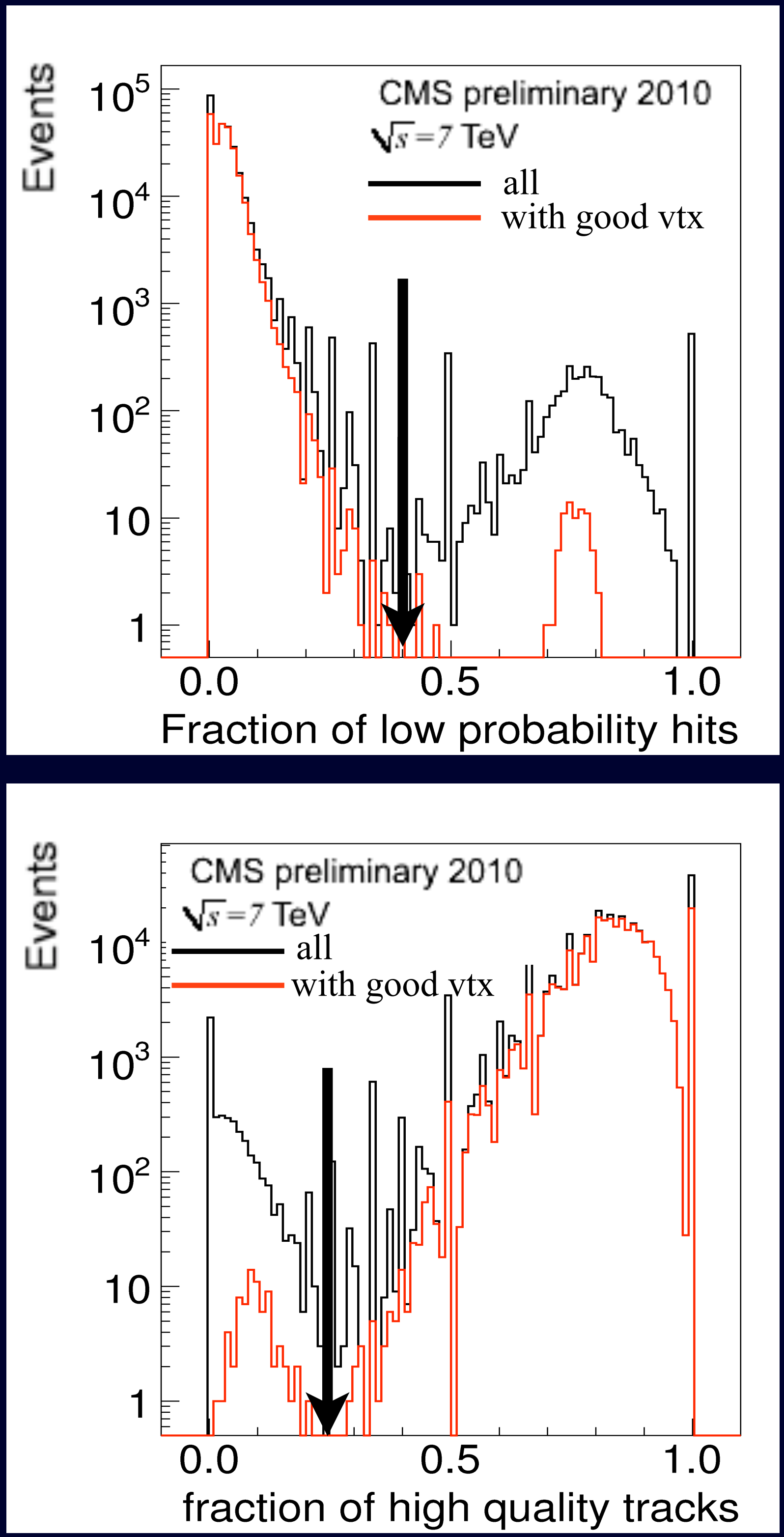
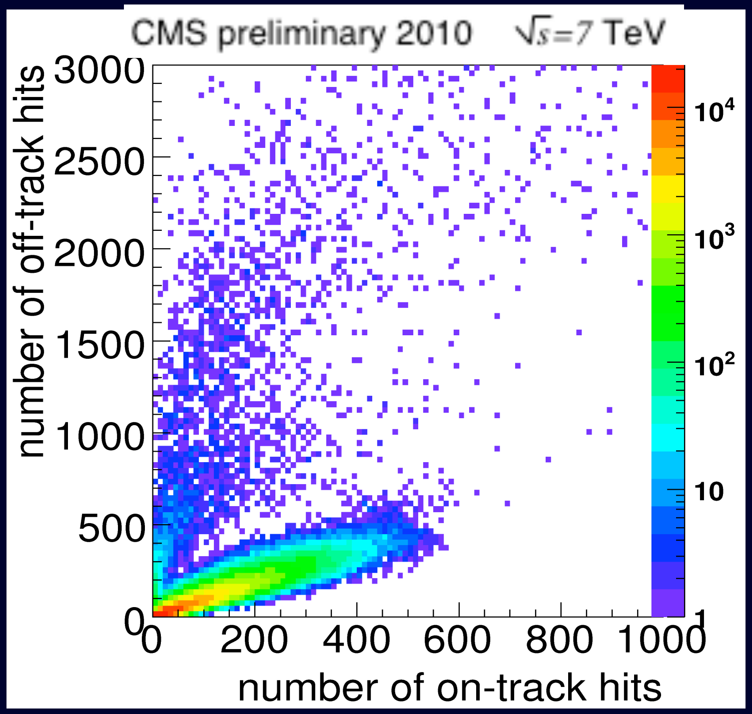
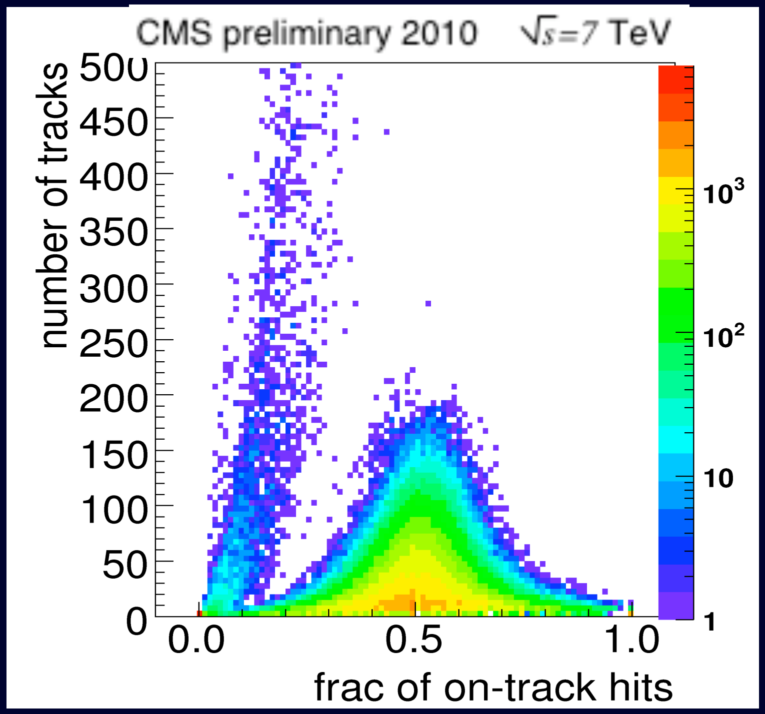


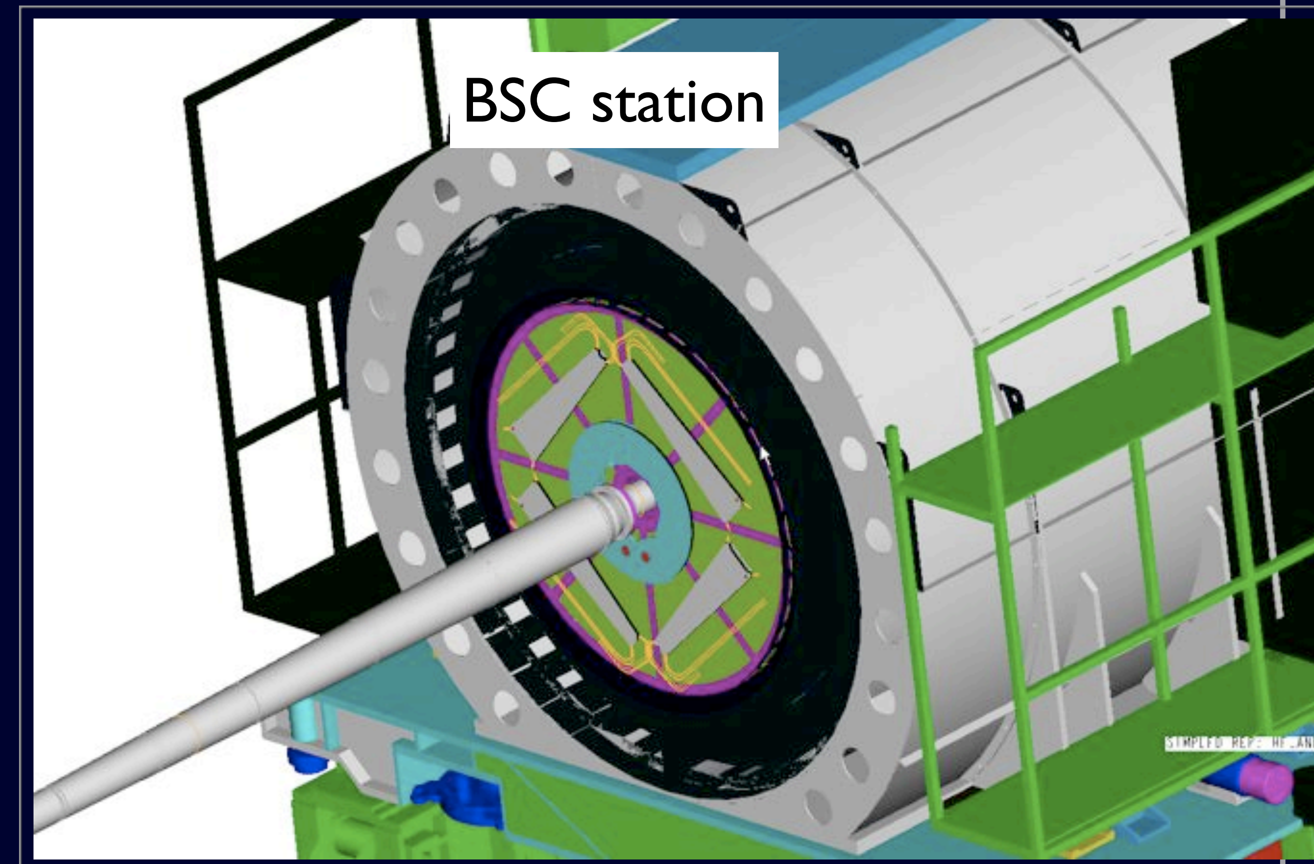
On versus off track clusters



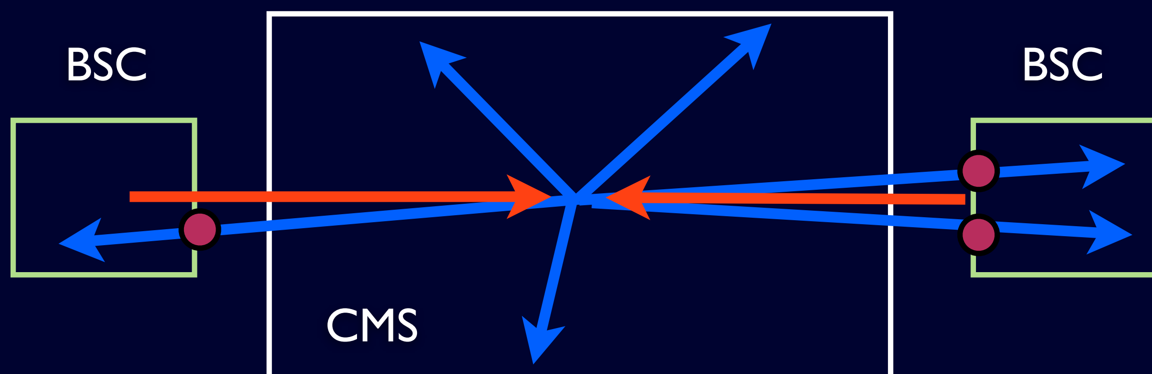


Background removal

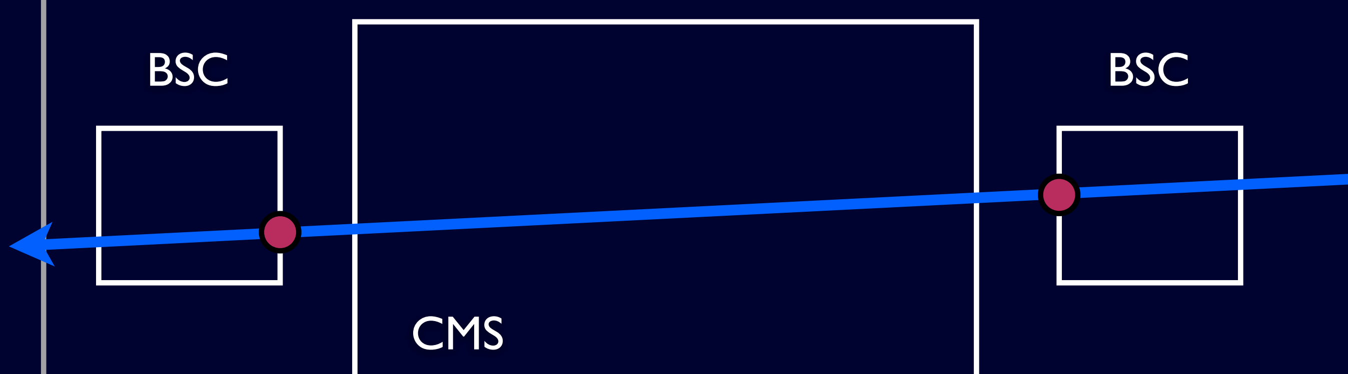
- Different ways to get beam-background free samples: one possibility is to use triggers from beam scintillation counter (BSC) placed at 11 meters from interaction point



  - «Minimum bias» : select events with simultaneous hits on both BSC station



  - «Beam halo» veto: suppress events in which particles are producing hits with large delay (>40ns) between both sides signals



- «Beam-gas» veto: suppress events with 2 hits on one side and no hits on the other side