Low p_T Hadronic Physics with CMS

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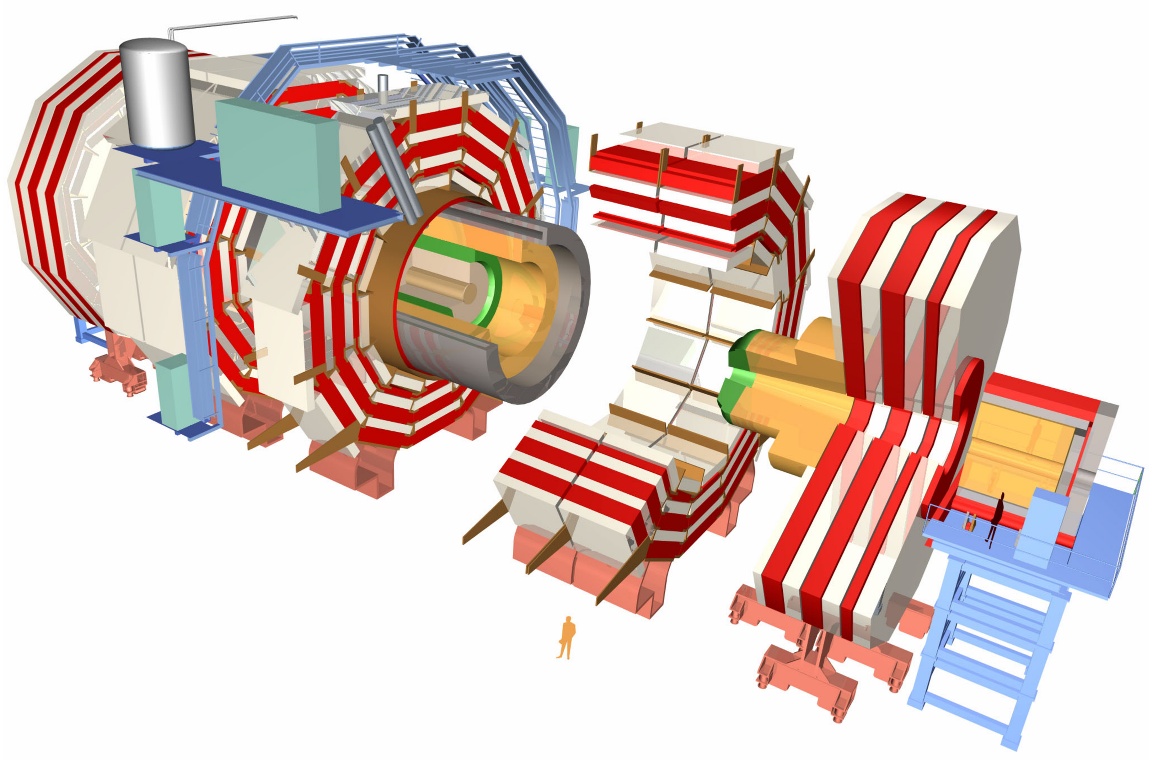
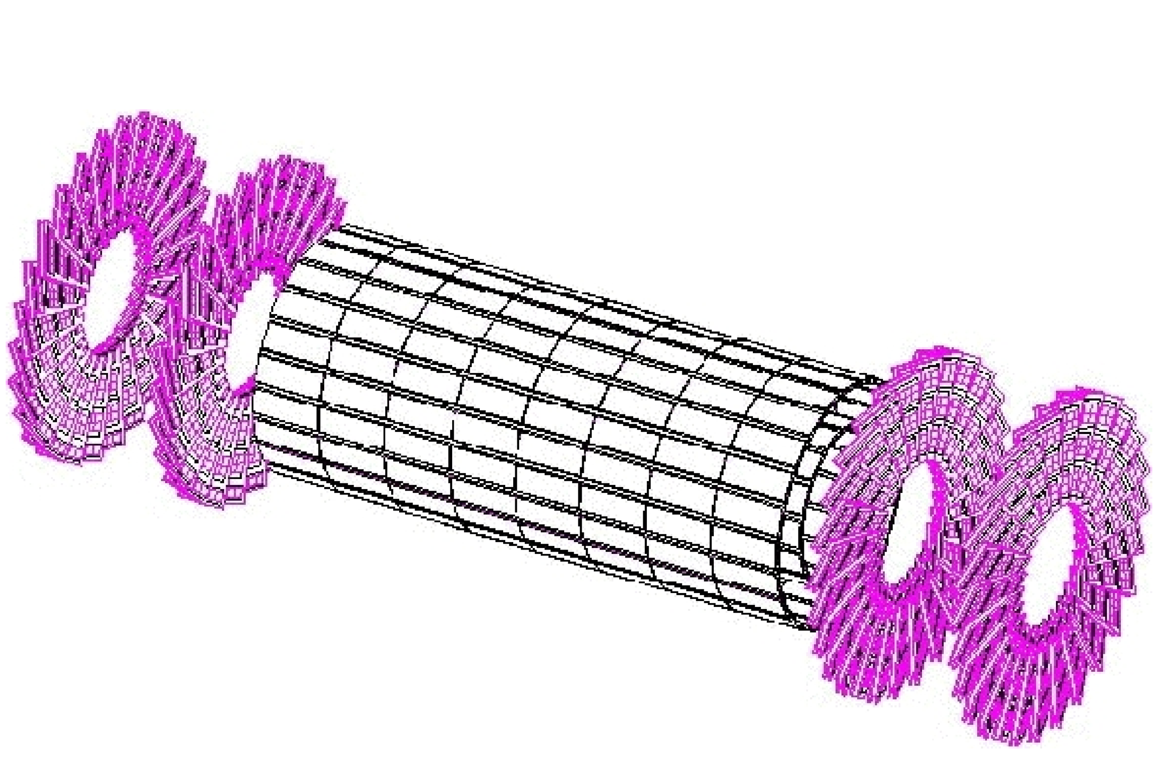
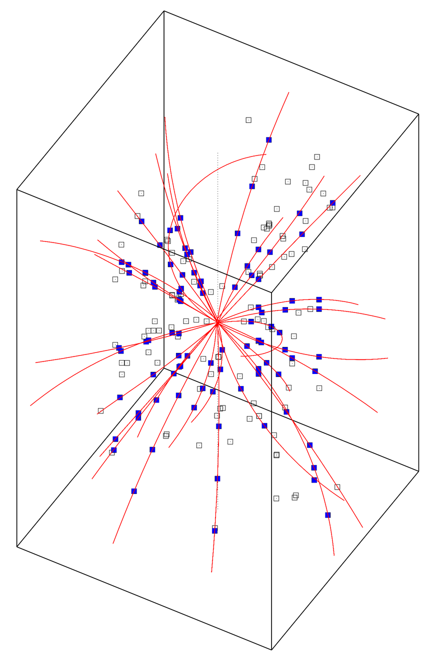
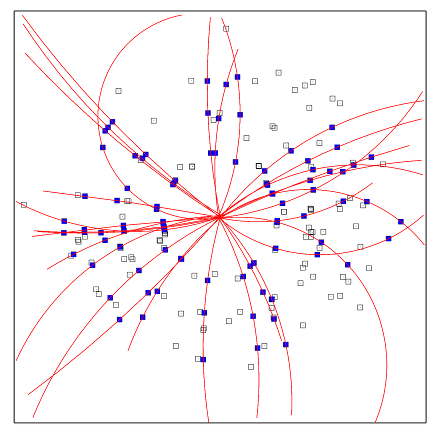








The CMS experiment at the LHC will be equipped with 3 layers of silicon pixel and 11 layers of silicon strip detectors embedded in a 4 T magnetic field within $|\eta| < 2.5$. The use of pixels alone allows to employ similar reconstruction and analysis tools for low multiplicity p+p, p+A and high multiplicity A+A events.

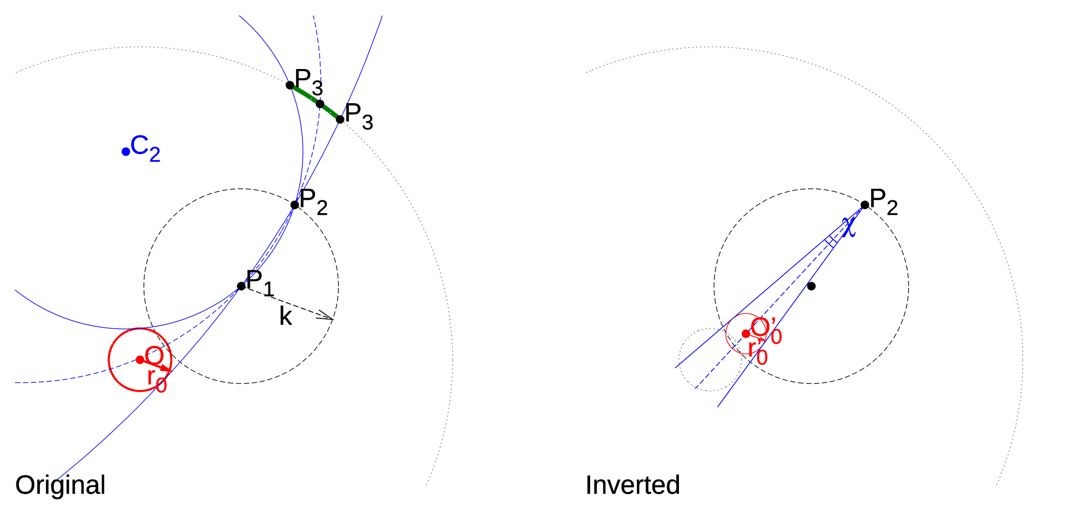
The three pixel barrels (at about 4, 7 and 11 cm radius) and four forward pixel disks (two in each z direction) make the tracking of very low p_T charged particles possible down to about 200 MeV$/c$, with good relative resolution. This can be achieved with good efficiency and negligible fake rate for elementary p+p and p+A collisions, thanks to the information present in the shape of the pixel hit. In case of central A+A the fake rate can be kept low for $p_T > 400$ MeV$/c$.

Neutral and charged hadrons can be identified at low p_T. A sizeable fraction of V^0 decays ($K^0_S \to \pi^+\pi^-$ and $\Lambda \to p\pi^-$) can be measured by combining pairs of reconstructed charged tracks. Photons are also measurable by reconstructing conversions in the beam pipe and in the first pixel barrel layer. The use of the ADC information (deposited energy) in pixels enables the identification of charged hadrons ($\pi^\pm$, $K^\pm$, p, $\bar{p}$) at low momentum.

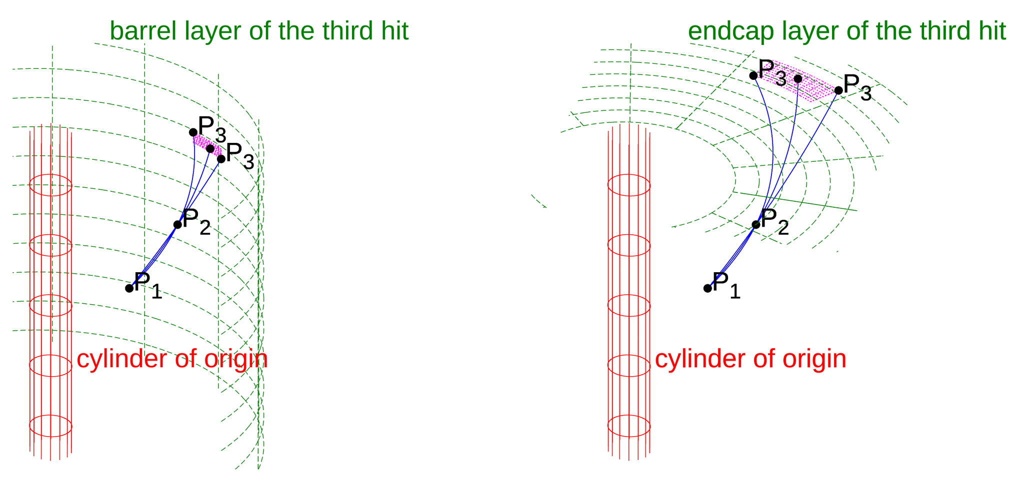
In summary the CMS experiment and its heavy-ion physics program is able to provide good quality data for yields and spectra of identified charged and neutral particles, thus contributing to the soft hadronic physics program of the LHC experiments.

Triplet finding

In track finding hit pairs are formed first, chosen from different layers. During the search for the third hit the following requirements must be fulfilled: the track must come from the cylinder of origin (given by its radius, half-length and position along the beam-line); the p_T of the track must be above the minimal value $p_{T,min}$; the track must be able to reach the layer where the third hits may be located. In the small volume of the pixel detector the magnetic field is practically constant, the charged particles propagate on helices. The projection of a helix or a cylinder onto the transverse plane is a circle. Each requirement defines a region of allowed track trajectories. They are enclosed by a pair of limiting circles which can be constructed using an inversion. A third hit candidate is accepted if its position is compatible with expected deviation from multiple scattering.



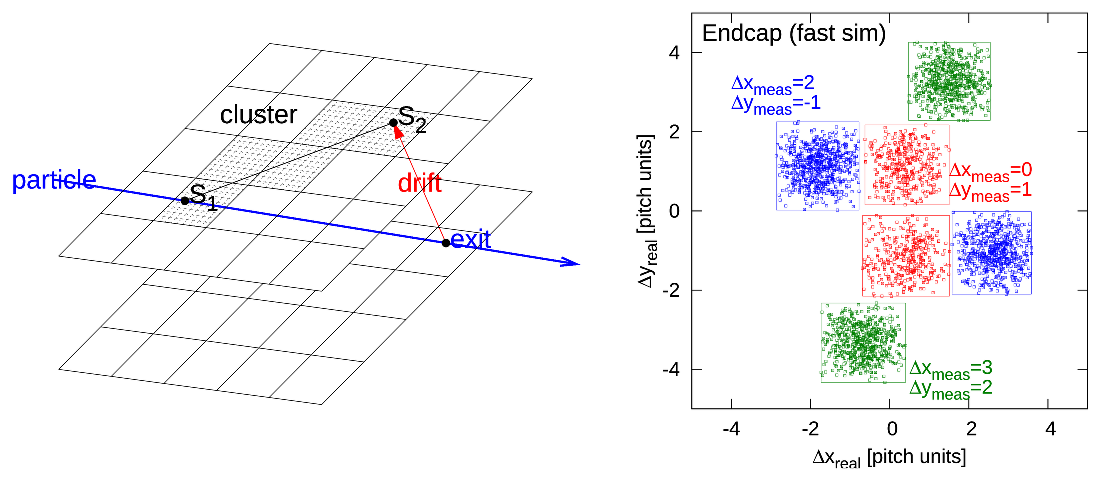
Determination of the limiting circles (solid blue) touching the circle of origin $c_0(O, r_0)$ (solid red). The members of the pair are P_1 and P_2. The problem is solved by inversion with center P_1 and radius $k = P_1P_2$. The inverted objects are shown on the right. The inverse of P_2 is itself. c_0 is inverted to another circle $c_0'(O_0', r_0')$. The limiting circles with centers C_1 (not in the figure) and C_2 are inverted to lines passing though P_2. These lines are tangent to c_0'. The central circle (dashed blue) is inverted to the bisector of angle χ. If the third hit is searched on a circle (third barrel layer) the limiting circles cut out an arc $P_3 - P_3$ (thick green) where the candidates may be located.



Determination of the possible range of the third hit candidates in case of a barrel layer (left) and an endcap layer (right), shown in three dimensions. The cylinder of origin (red) and the layers (green) are indicated. The members of the pair are P_1 and P_2. Curves of the two extreme trajectories (solid blue) and the central trajectory (dashed blue) are drawn together with the three thrust points P_3. These points define a parabola whose rectangular envelope is given (magenta grid).

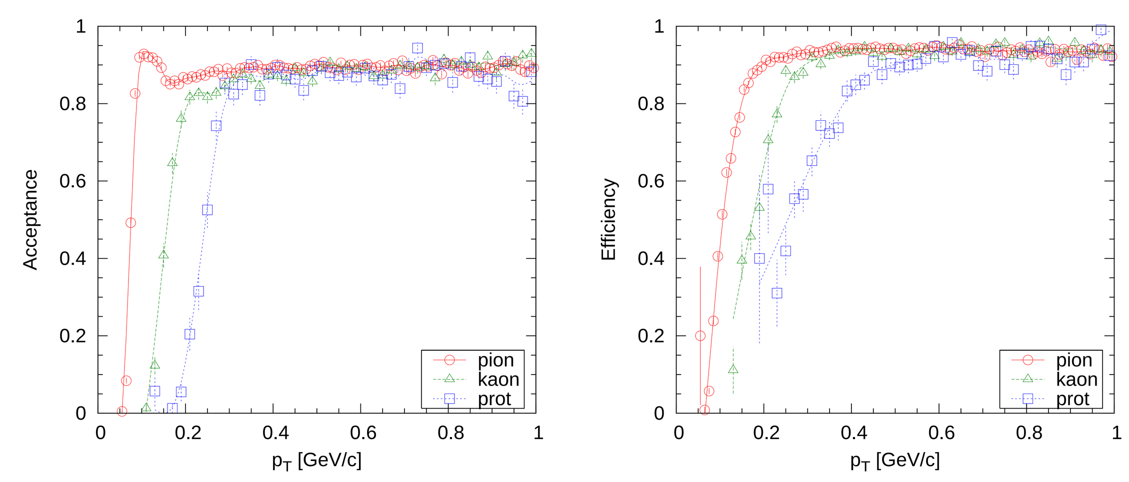
Triplet cleaning

While high p_T tracks are relatively clean, hits can often be combined to form fake low p_T tracks. It is therefore important to filter out this undesirable background. A hit contains much more information than merely its position. The directed envelope of the hit cluster depends on the angle of incidence of the particle: bigger angles will result in longer clusters. This observation can be exploited in many ways. It can be used to check whether the measured shape of the cluster is compatible with the predicted angle of incidence of the track: if even one of the hits in the triplet is not compatible, the triplet is removed from the list of track candidates. The connection between the envelope and the angle can be obtained from simulation or from data.

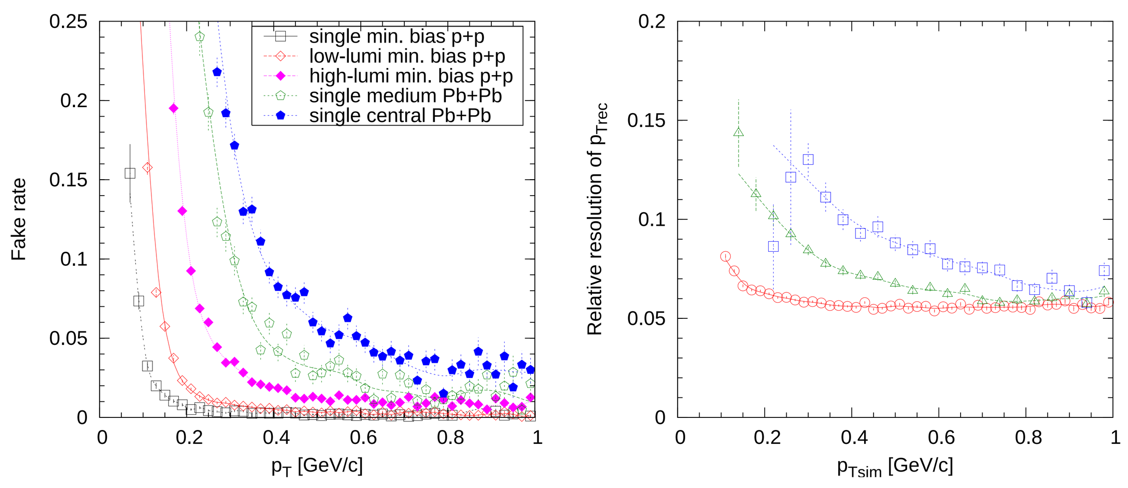


Left: Effect of the Lorentz-shift. A charged particle (blue) crosses the pixel layer. The produced electrons drift (red) towards the pixels of the upper readout plane, hence the charge appears on the line segment S_1S_2. The particle can come from below or from above, still giving the same line segment and thus the same cluster shape. This explains the fact that for a given cluster envelope there are always two corresponding possible particle directions. **Right:** Distribution of the planar distances of exit and entry points, movements (Δx_{real}, Δy_{real}), for several measured envelopes (Δx_{meas}, Δy_{meas}), both in pitch units. Entries and ranges from fast calculation are shown for forward layers.

Results



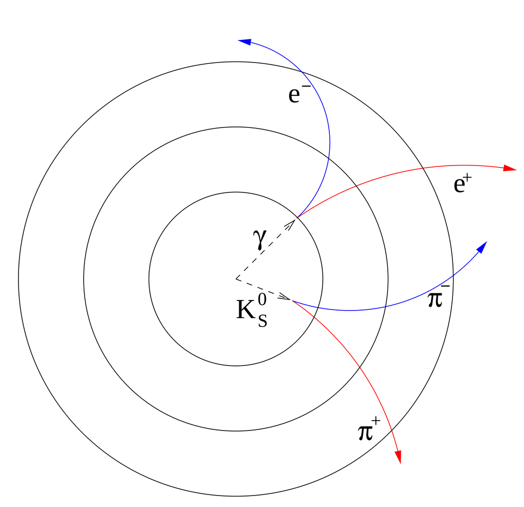
Acceptance and efficiency as a function of p_T if the track is in the range $|\eta| < 1$. Values are given separately for pions, kaons and protons.

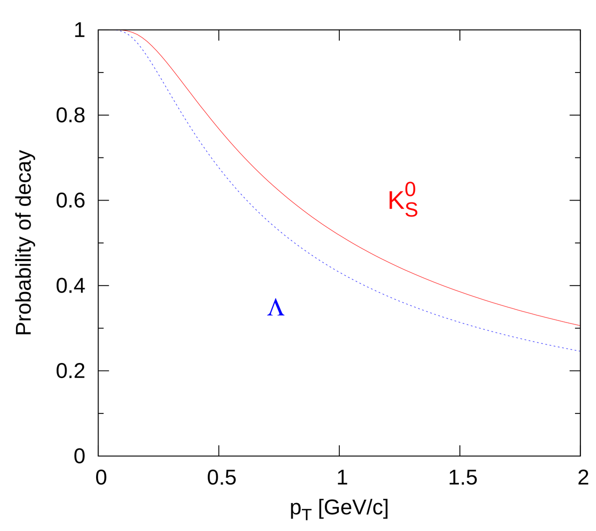


Left: Fake rate as a function of p_T if the track is in the range $|\eta| < 1$. Values for single, low-luminosity and high luminosity minimum bias p+p events are shown together with results from central and medium Pb+Pb collisions. **Right:** Relative relative resolution of reconstructed p_T as a function of simulated p_T. Values are given separately for pions, kaons and protons (for color code see above).

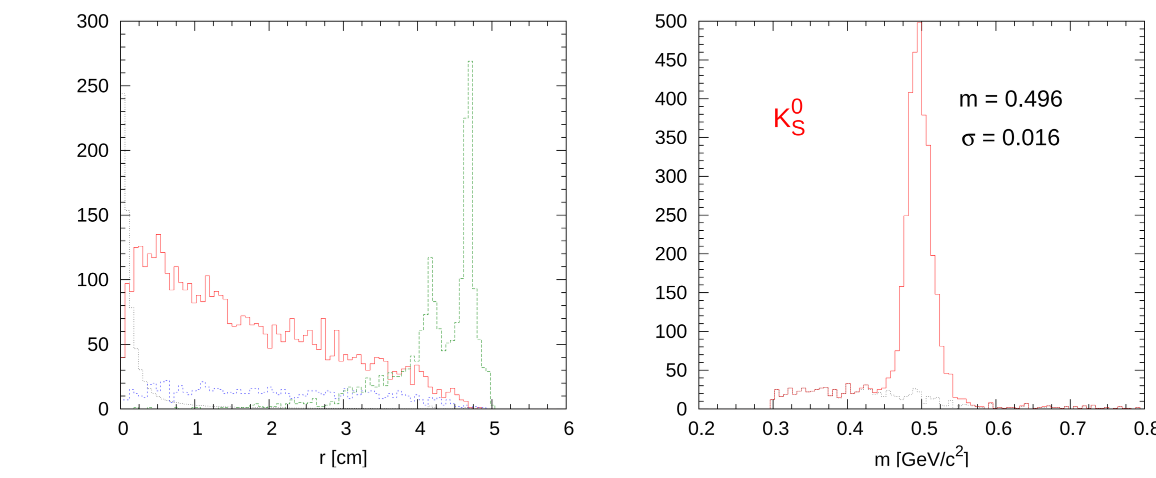
V0s and conversions

Although neutral particles do not create hits in the pixel detector, they can be observed via their charged daughters. The combination of helices of secondaries enables the reconstruction of low p_T weakly-decaying particles and photon conversions.

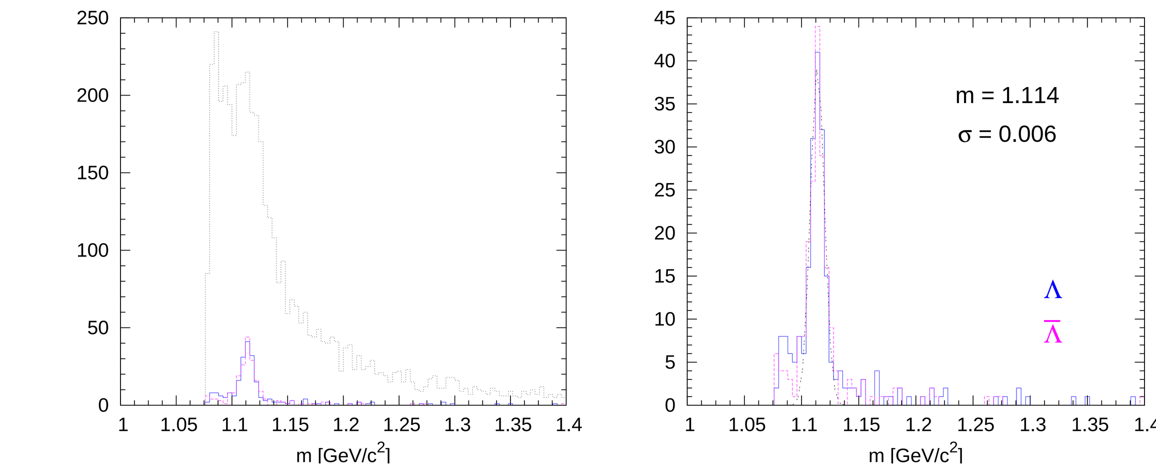




Left: Schematic view of a V0 decay and a photon conversion. The pixel barrels are given by the black circles. **Right:** Probability of decay before the first pixel barrel layer ($r \approx 4$ cm) as function of p_T of the particle. Curves for K^0_S (solid red) and Λ (dashed blue) are given.



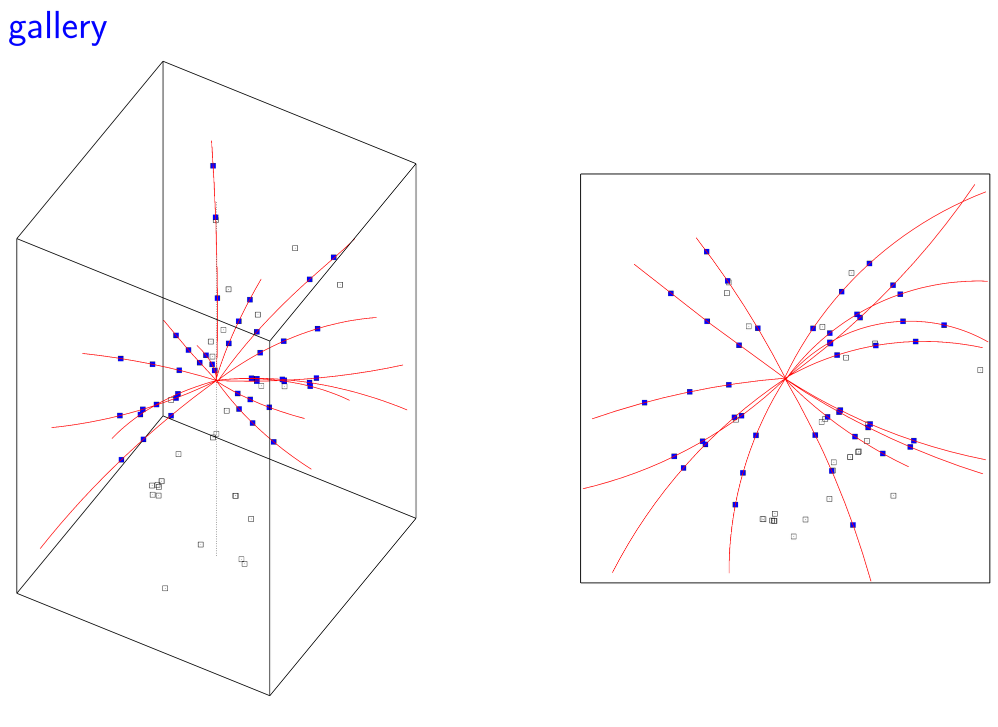
Left: Distribution of the distance of the production vertex from the beam-line. Histograms are shown for K^0_S, Λ and photon separately. The position of the inner and outer silicon wafers of the first pixel barrel layer are clearly visible in the r distribution of photons. The rescaled background is indicated as well. **Right:** Invariant mass distribution of reconstructed K^0_S particles The mass distribution of background is indicated as well (black dashed) and the result of the Gaussian fit is given in units of GeV$/c^2$.



Invariant mass distribution of reconstructed Λ and $\overline{\Lambda}$ particles. The distribution without dE/dx selection for the secondary proton or antiproton is shown on the left (dotted black). The solid histograms give the final result with dE/dx selection switched on. They are re-plotted on the right with adjusted vertical scale. The result of the Gaussian fit is given in units of GeV$/c^2$.

The observed mass widths of 6 MeV$/c^2$ and 15 MeV$/c^2$ are compatible with the resolution of momentum reconstruction.

Event gallery



Plot of a reconstructed single minimum bias p+p event. Hits are shown by open black boxes. Those hits which belong to a reconstructed track are indicated by filled blue boxes. The helices of the reconstructed trajectories are drawn with solid red lines. Both the three dimensional view and its planar projection are shown. For interactive event views visit http://www.grid.kfki.hu/twiki/bin/view/CMS/EventGallery.

References, acknowledgement

[1] F. Siklér, "Reconstruction of low p_T charged particles with the pixel detector", CMS Note AN-2006/100.

[2] F. Siklér, "Reconstruction of V0s and photon conversions with the pixel detector", CMS Note AN-2006/101.

This work was supported by the Hungarian Scientific Research Fund (T 048898).