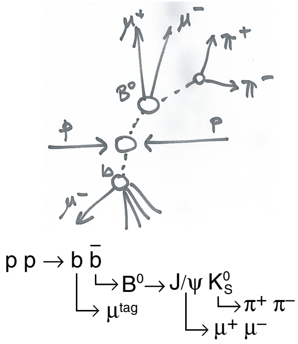
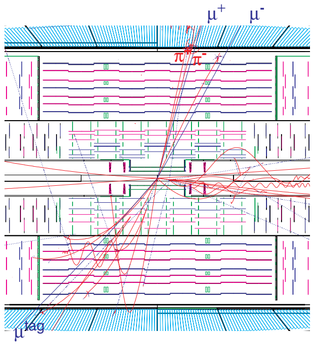
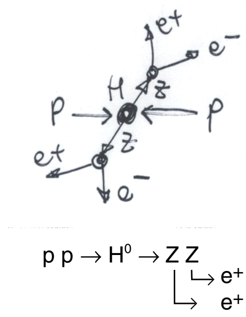
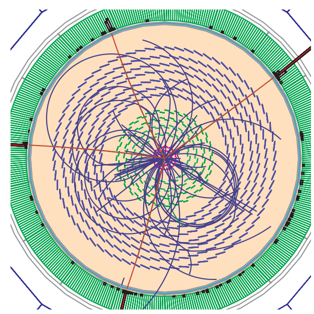
Tracking system





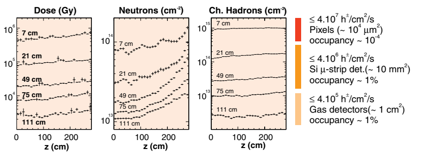




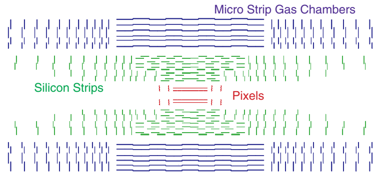
A robust and versatile tracking system is of the utmost importance for an experiment designed to address the full range of physics which can plausibly be accessed at the LHC. The CMS tracking system is designed to reconstruct high-p_T muons, isolated electrons and hadrons with high momentum resolution and an efficiency better than 98% in the range $|\eta|<2.5$. It is also designed to allow the identification of tracks coming from detached vertices. Such vertices arise from decays of b quarks, which provide very useful signatures for a broad spectrum of new physics

Track identification

The LHC environment (with its high radiation levels shown below), the varied nature of the interesting physics signatures, and the constraints of compatibility with the excellent electromagnetic calorimetry of CMS, present formidable challenges which a successful tracking system must overcome.

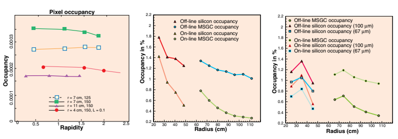


The strategy adopted to address these challenges is to provide a set of coordinate measurements of sufficient precision and robustness such that track reconstruction can be reliably performed based on a relatively small number of measurements per track. In addition, the tracking system is embedded in a 4T magnetic field which forces low-p_T particles into small-radius helical tracks, resulting in reduced occupancy at larger radii.



Three detector technologies are employed, each best matched to satisfying the stringent resolution, granularity and robustness requirements in the high, medium and low occupancy regions. These are Pixels, Silicon Microstrip and Micro Strip Gas Chambers (MSGC) respectively.

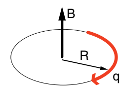
To achieve reliable track identification, the detector segmentation is such that typical channel occupancies are kept at about the 1% level everywhere in the tracker.



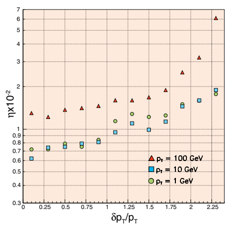
Momentum measurement

The momentum of electrically charged particles is determined from the bending of the track trajectory in the magnetic field of CMS.

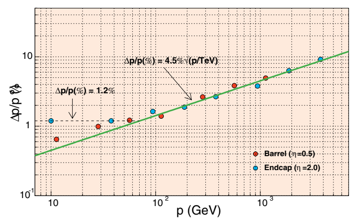
The trajectory of a charged particle inside a magnetic field of strength (in Tesla), perpendicular to its velocity, v, is a circle of radius R (in meters). Reconstructing this trajectory yields R. The particle's momentum transverse to the B field, p_T, measured in GeV/c, is then given by $p_T = 0.3\ B\ R$



High transverse momentum (p_T) isolated tracks are reconstructed with a transverse momentum resolution of better than $\delta p_T/p_T \approx (15 p_T \otimes 0.5)\%$, with p_T in TeV, in the central region $|\eta| \leq 1.6$, gradually degrading to $\delta p_T/p_T \approx (60 p_T \otimes 0.5)\%$ as $|\eta|$ approaches 2.5.



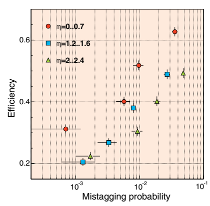
Combining the tracking system with the outer muon chamber system, the resolution of the measurement of the momentum of muons above about 100 GeV is given by $\delta p/p \approx (4.5 p^{1/2})\%$, with p in TeV, even for pseudorapidities extending to at least $|\eta|=2$. This results in a momentum resolution better than 10% even at a momentum of 4 TeV.



Track reconstruction is especially challenging in a dense jet environment. The fine granularity of the CMS tracking system results in a high efficiency of reconstruction (95%) for charged hadrons with p_T above 10 GeV. The reconstruction efficiency for muons is better than 98% over the full pseudorapidity range. High energy electrons are reconstructed with an efficiency above 90%.

Vertex identification

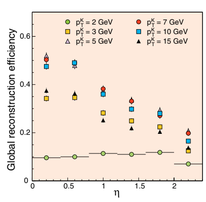
The ability to reconstruct the decay vertices of long-lived particles is crucial for numerous physics analyses. The position of such vertices in the tracking volume depends on the lifetime of the decaying particle. Long-lived particles (e.g. K_s mesons) travel several cm before decaying. B mesons decay more rapidly (they decay within 1-2 mm) but their decay point is still discernible thanks to the excellent resolution of the impact parameter measurement.



A vertex displaced from the primary proton-proton collision point also arises from decays of hadrons containing a b quark. The reconstruction of such vertices is crucial for "b-tagging", i.e. in the identification of a jet as arising from a b quark. b-tagging is a very important tool for many physics studies, from the search of low-mass Higgs bosons to studies of the top quark (which always decays to a b quark).

The figure displays the efficiency for tagging b-jets with E_T=100 GeV as a function of the probability of misidentifying jets originating fromlight quarks or gluons.

K_s identification is very important for the reconstruction of the decay $B^0 \rightarrow J/\psi K_s$ which will be used to study CP violation in the B system. As shown in the figure on the right, the average efficiency of reconstrucing K_s's from B meson decays is typically 50% when the K_s decays inside the barrel tracking volume (and ≈33% when it decays in the forward tracking volume).



The high efficiency for reconstructing secondary vertices, is supplemented by the very high resolution of the reconstrution of both the invariant mass of the decaying particle and its proper decay time.