I have been working in theoretical hadron and nuclear physics. My studies are classified into two categories. One is on properties of hadron resonances, and the other is on structure functions of hadrons and nuclei. In the following, I explain several major results. The detailed explanation of my research history is given in my home page at https://research.kek.jp/people/kumanos/ (→ Research history).

Hadron resonances

1. **Δ electromagnetic moments:** We proposed that accurate determination of the Δ magnetic moment can be done by the polarized pion-nucleon bremsstrahlung (Heller, Kumano, Martinez, Moniz in 1987). Based on this idea, experimentalists proposed an experiment at the Paul Scherrer Institute, and they determined $\mu_{\Delta^{++}} = 1.64\ \mu_p$ [A. Bosshard *et al.*, Phys. Rev. Lett. 64 (1990) 2619].
2. **Exotic hadron candidates $f_0(980)$ and $a_0(980)$:** We showed that ϕ radiative decays into the scalar mesons $f_0(980)$ and $a_0(980)$ could provide important clues on their internal structure (Close, Isgur, Kumano in 1993) by showing that the radiative decay widths varied widely depending on their substructures, $q\bar{q}$, $qq\bar{q}\bar{q}$, $K\bar{K}$, and glueball.
3. **Constituent counting rule for exotic hadrons:** For finding internal configurations of exotic hadron candidates, we proposed to use hadron tomography by three-dimensional structure functions and constituent counting rule of perturbative QCD (Chang, Kawamura, Kumano, Sekihara in 2013–2016).

Structure functions

1. **b_1 sum rule:** We proposed a sum rule for the tensor-polarized structure function b_1 (Close, Kumano in 1990). This sum rule was investigated experimentally by the HERMES collaboration [A. Airapetian *et al.*, Phys. Rev. Lett. 95 (2005) 242001], and they obtained a finite sum, which indicated an existence of finite tensor-polarized antiquark distributions.
2. **Anomalous dimensions of h_1:** Two-loop anomalous dimensions of chiral-odd structure function h_1 were calculated in the minimal subtraction scheme by using the dimensional regularization and Feynman gauge (Kumano, Miyama in 1997). Because of this work, it became possible to investigate h_1 in the next-to-leading-order level.
3. **Flavor asymmetric antiquark distributions:** We showed that meson-cloud effects could explain the Gottfried-sum-rule violation and the flavor asymmetric antiquark distribution $\bar{u} - \bar{d}$ in the nucleon (Kumano in 1991). A theoretical and experimental summary paper was written on this topic in Physics Reports (Kumano in 1998).
4. **Global analyses of parton distribution functions:** From global analyses of world high-energy hadron cross section data, we determined polarized parton distribution functions (PDFs), nuclear PDFs, and fragmentation functions (Asymmetry Analysis Collaboration, Hirai, Kumano, Miyama, Nagai, Sudoh in 2000-2016). We provided useful codes for calculating obtained functions and they were used as one of the world standard models.
5. **Gravitational form factors of hadron:** We determined generalized distribution amplitudes (GDAs) of the pion from KEKB measurements on the $\gamma^*\gamma \to \pi^0\pi^0$ cross section. From the GDAs, we obtained gravitational form factors Θ_1 and Θ_2 and estimated the mass and mechanical rms radii (Kumano, Song, Teryaev in 2018). This is the first report on the gravitational radius of a hadron from actual experimental measurements.