The Rainbow Treasure Map

Advanced Color Management on Linux with AMD/SteamDeck

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XDC 2023 - A Coruña - Spain

igalia

Technical Talk

1. XDC 2022 | "I'm not an AMD expert, but..." | Melissa Wen
2. XDC 2022 | Is HDR Harder? | Harry Wentland
3. XDC 2022 Lightning | HDR Workshop Summary | Harry Wentland
4. Color management and HDR documentation for FOSS graphics | Pekka Paalanen et al.
5. Cinematic Color – 2012 SIGGRAPH course notes | Jeremy Selan
6. AMD Driver-specific Properties for Color Management on Linux (Part 1) | Melissa Wen

Advanced Color Management on Linux

- Wide variety of source content colorimetry (SDR/HDR/different color gamuts, profiles, etc.)
- Wide variety of output display devices
- Internal processing (window composition, etc)
- Users expect consistent color reproduction
- Linux kernel lacks an interface to manage the diversity of color profiles

AMD Driver-Specific Color Properties

[PATCH v4 00/32] drm/amd/display: add AMD driver-specific properties for color mgmt

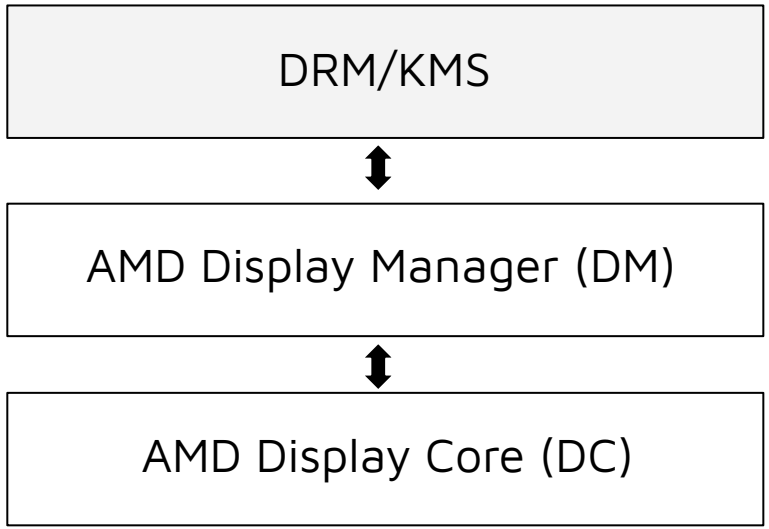
- ➔ Endless KMS generic color API
- ➔ Many uncertainties regarding the diversity of color capabilities among hardware vendors
- ➔ Gamescope is the userspace case (SteamOS 3.5)
- ➔ Advanced color management: gamut mapping, HDR rendering, SDR on HDR, HDR on SDR

AMD Steam Deck Kernel Driver

- ➔ **Accelerated Processing Unit (APU)**
- ➔ Product Name: STEAMDECK
- ➔ Code Reference: VANGOGH
- ➔ Display Driver: DCN3.01 (DCN3 family)

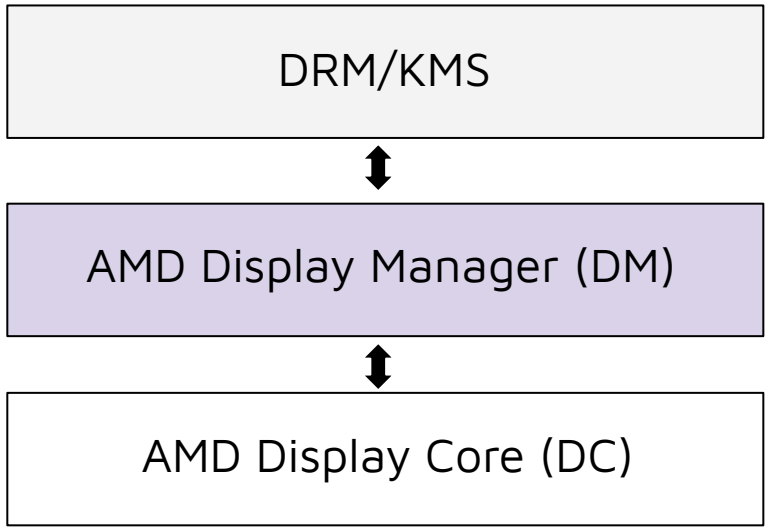
AMD Display Driver in the Linux/DRM

kernel space



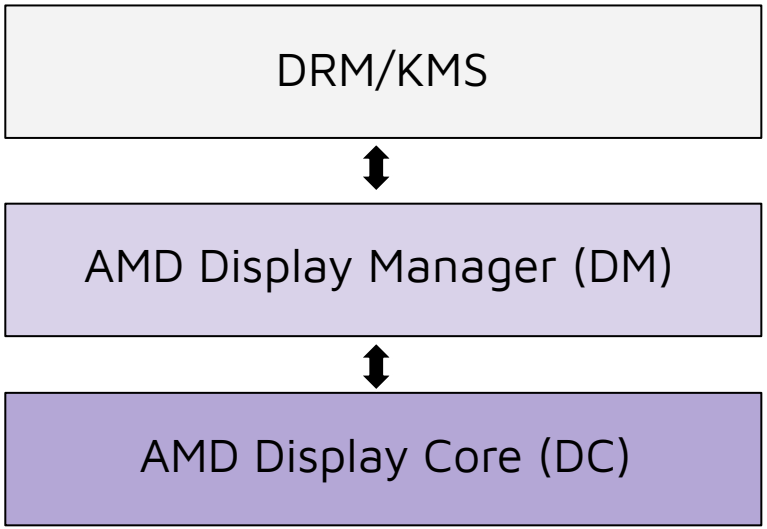
Connecting DC and DRM

kernel space

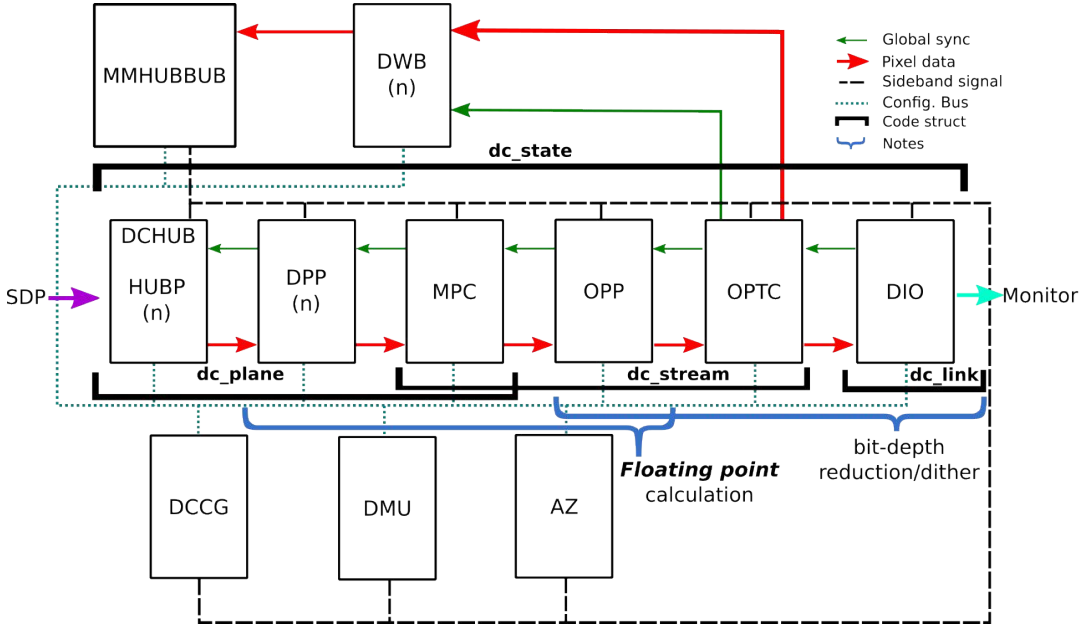


Examining AMD DC

kernel space

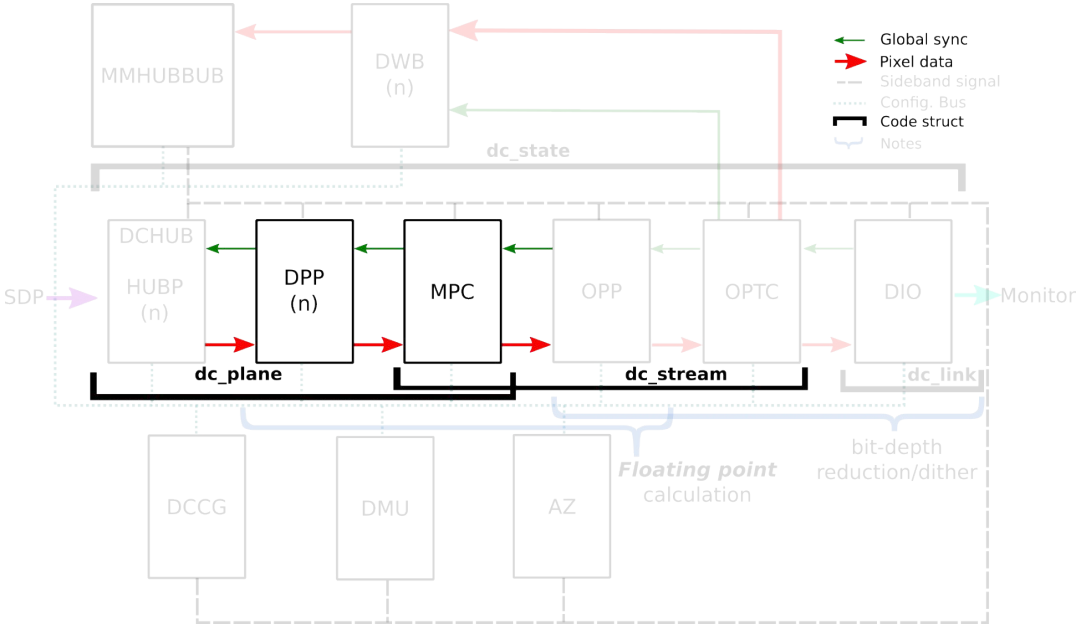


AMD Display Core Next (DCN)



https://dri.freedesktop.org/docs/drm/gpu/amdgpu/display/dcn-overview.html

AMD Display Core Next (DCN) - Color Caps



Pre-blending
DPP: Display Pipe and Plane

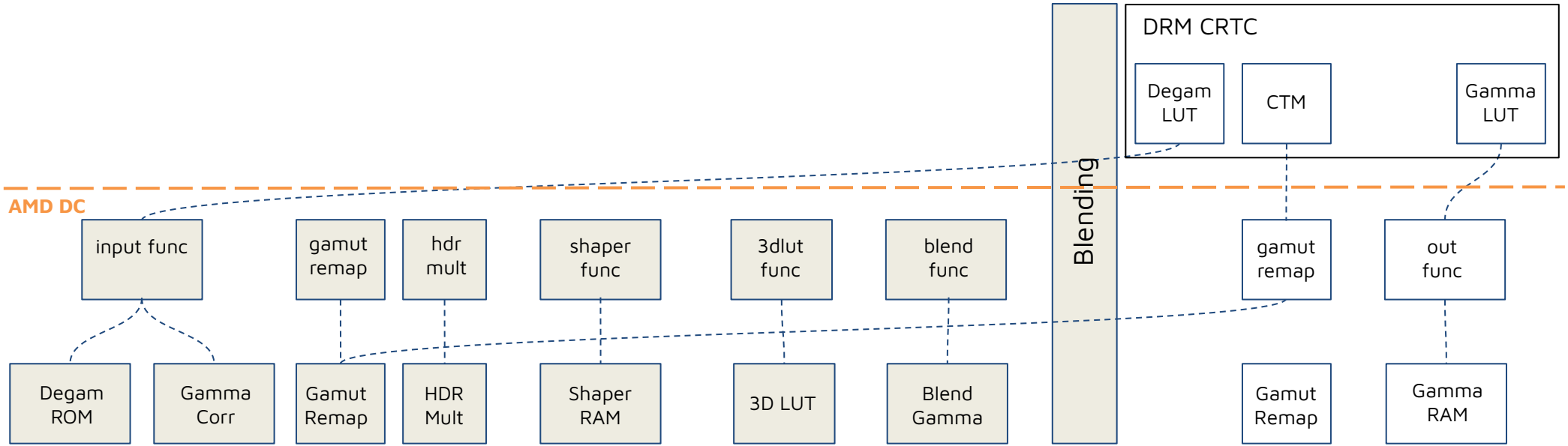
Post-blending
MPC: Multiple Pipe/Plane Combined

Pre-blending: DRM plane

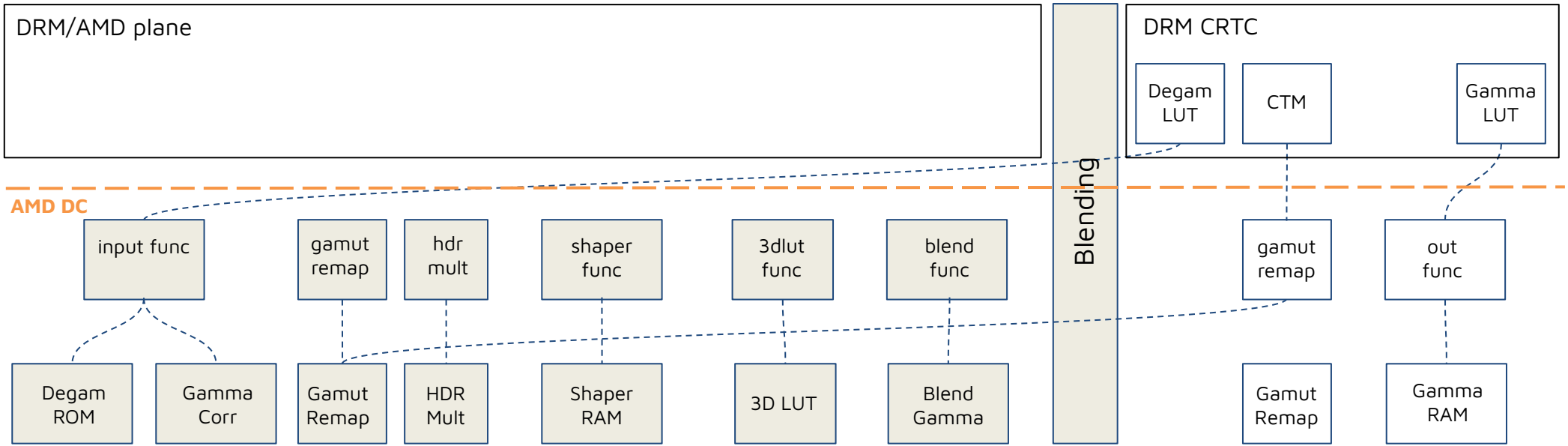
Pre-blending: DRM plane

John Travolta in Pulp Fiction

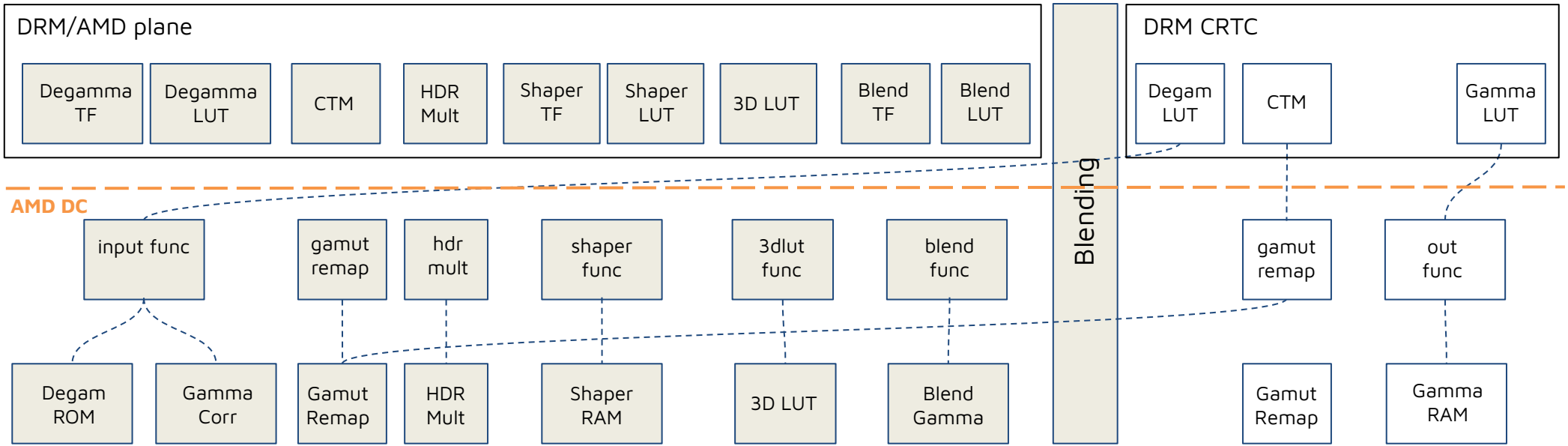
Pre-blending: DRM plane + AMD DC DPP



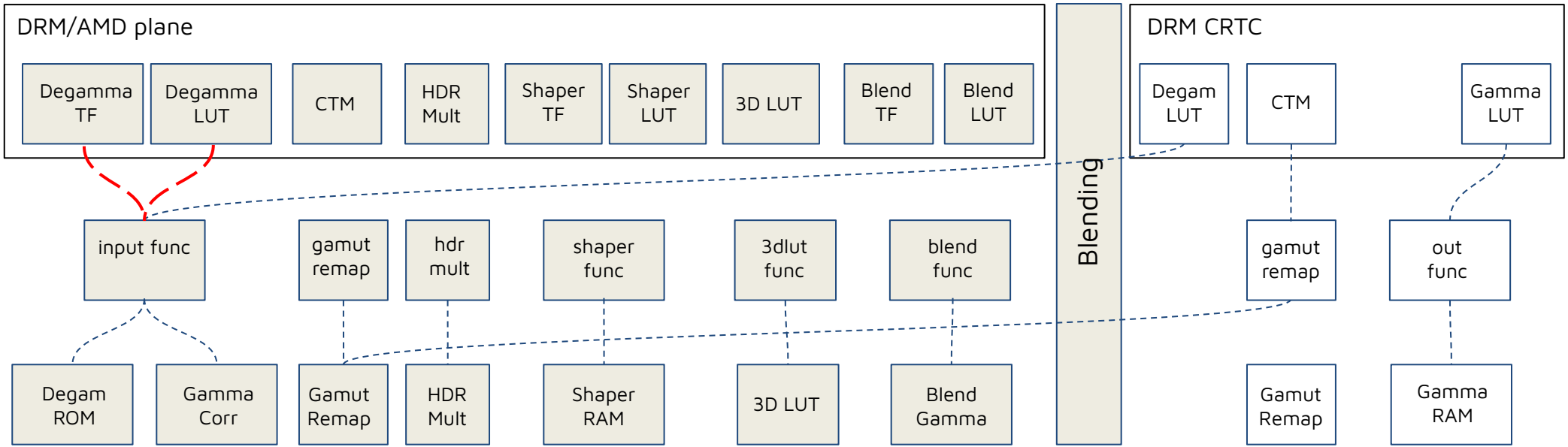
Pre-blending: DRM plane + AMD DC DPP



Pre-blending: DRM plane + AMD DC DPP



Pre-blending: DRM plane + AMD DC DPP



AMD Plane Degamma TF and LUT

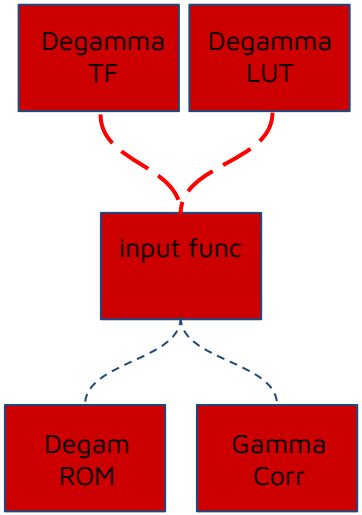
Transition from encoded values to linear values for precise arithmetic operations

Pre-defined TFs are hardcoded curves to **DPP Degamma ROM block**

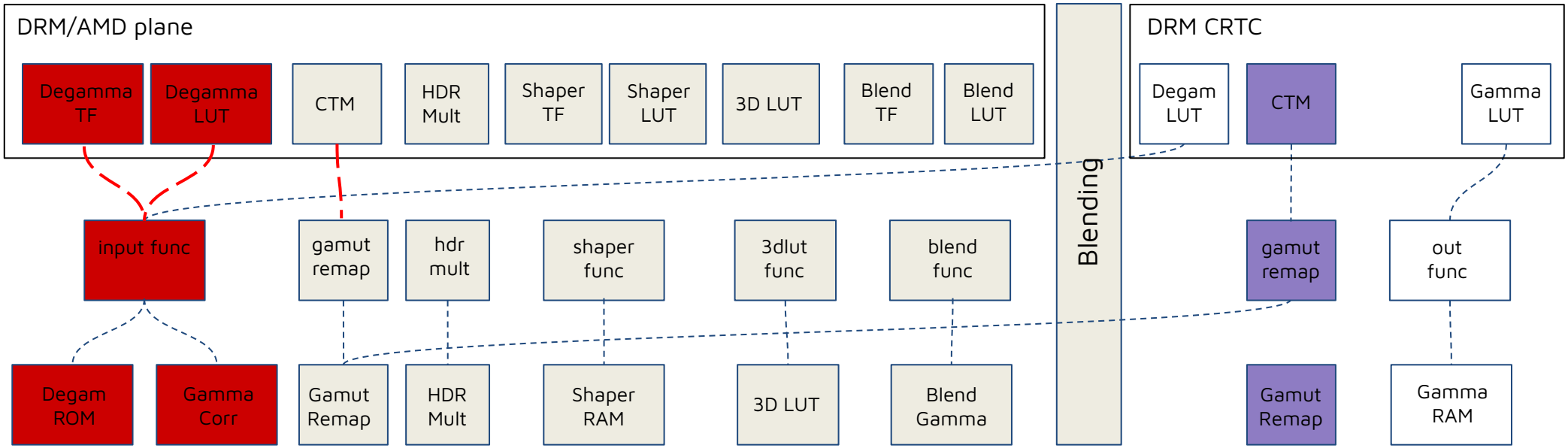
- sRGB EOTF;
- BT.709 inverse OETF;
- PQ EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 EOTF

1D LUT supports 4096 entries to **DPP Gamma Correction block**

The data is interpreted as an array of struct drm_color_lut elements



Pre-blending: DRM plane + AMD DC DPP

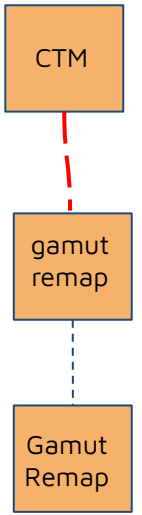


AMD Plane CTM

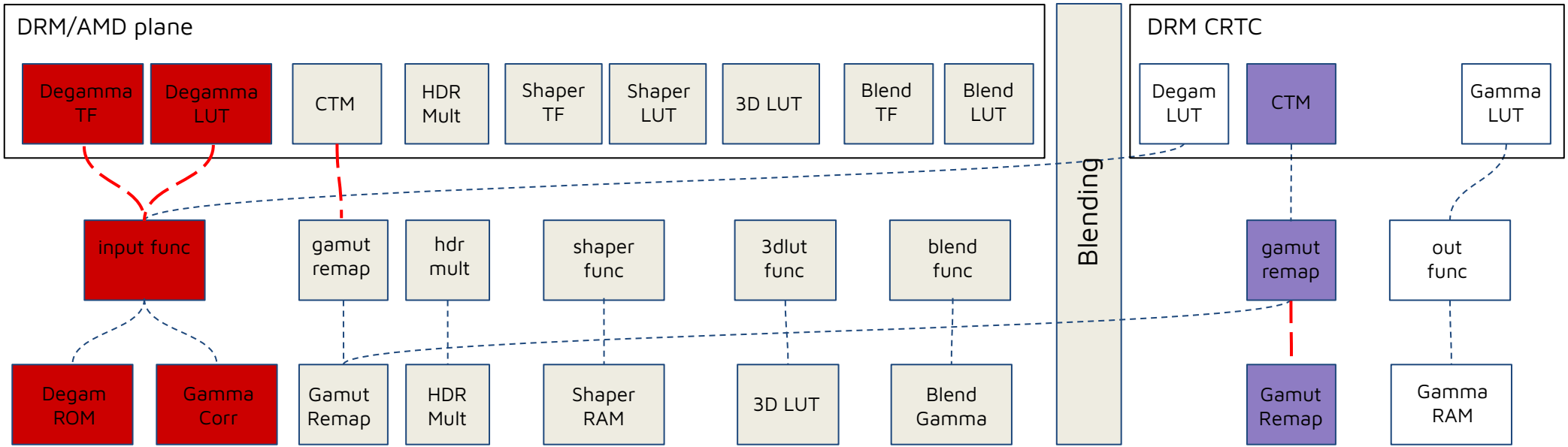
For color space conversion

3x4-dimensions matrix of fixed-points s31.32 set to **DPP Gamut Remap block**

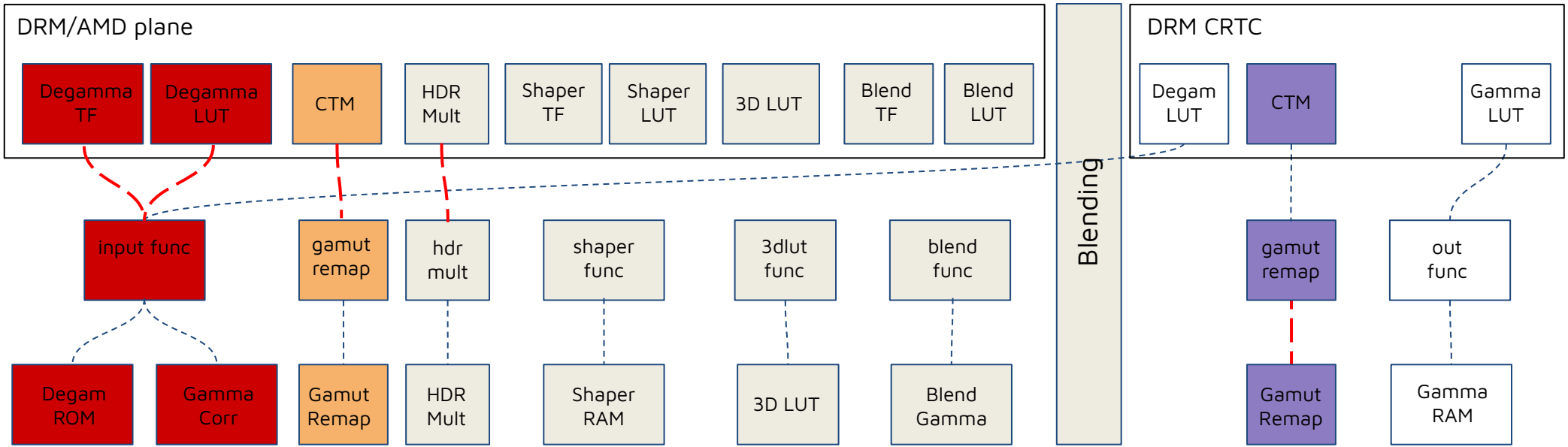
Remapping **CRTC CTM** to **MPC Gamut Remap block**



Pre-blending: DRM plane + AMD DC DPP



Pre-blending: DRM plane + AMD DC DPP

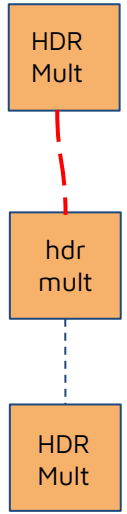


AMD Plane HDR Multiplier

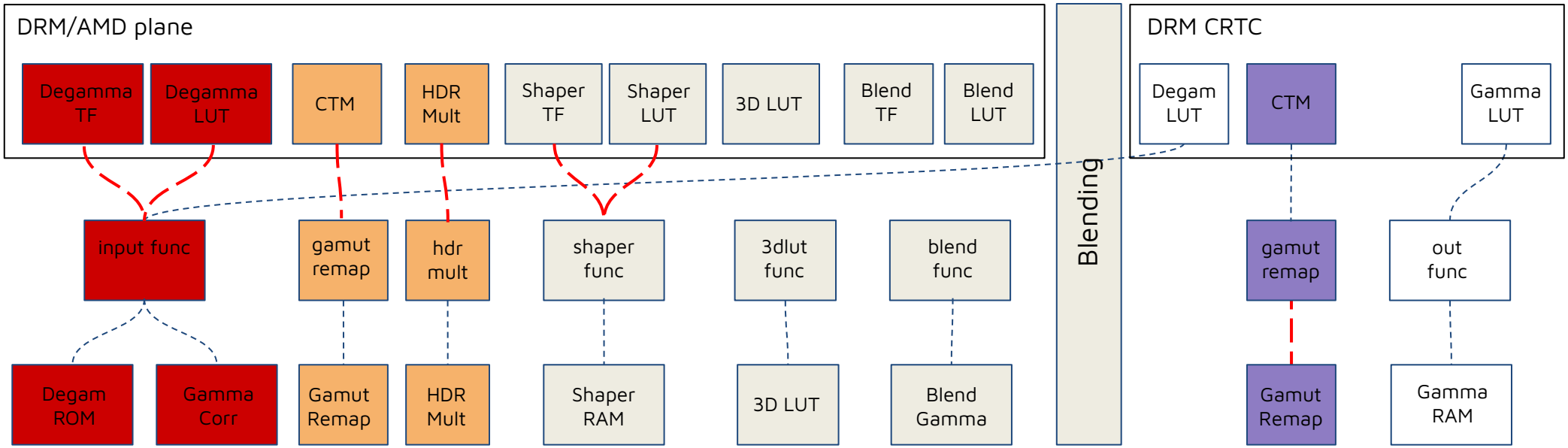
Applied to the color values of an image to increase their overall brightness

Useful for converting images from SDR to HDR

PQ TF is needed for any subsequent transforms



Pre-blending: DRM plane + AMD DC DPP



AMD Plane Shaper TF and LUT

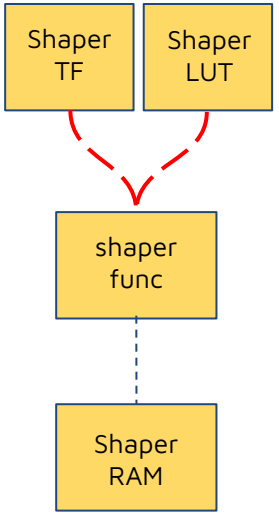
Delinearize/normalize the color space before applying a 3D LUT

NO hardcoded curves

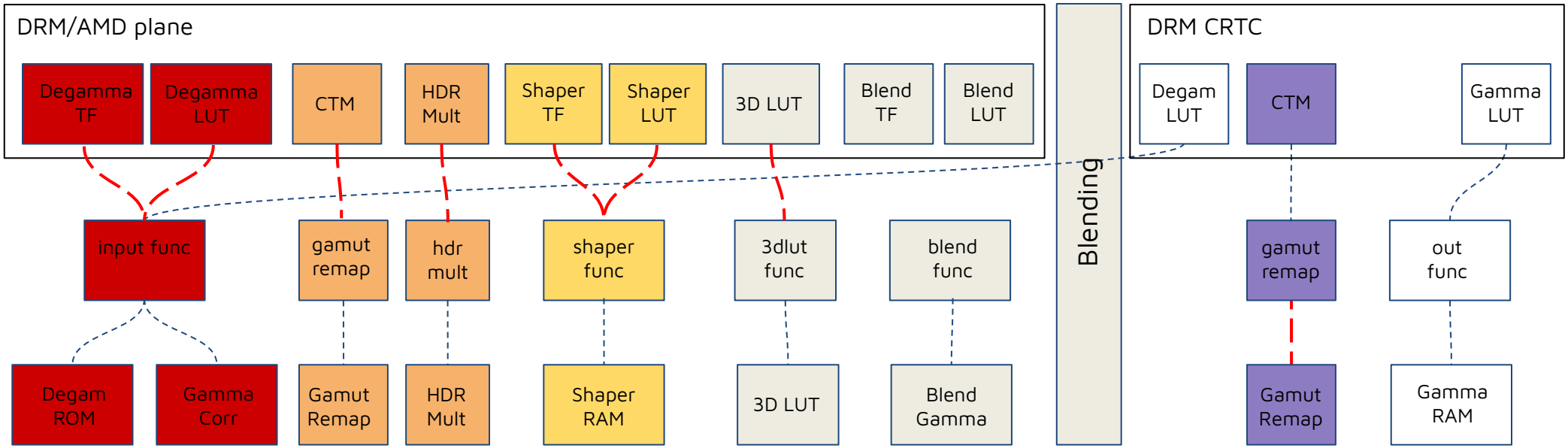
Pre-defined TFs are *calculated* by **AMD color module**

- sRGB inverse EOTF;
- BT.709 OETF;
- PQ inverse EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 inverse EOTF.

The color module *combines* TF and user LUT into the LUT to **DPP Shaper LUT RAM block**



Pre-blending: DRM plane + AMD DC DPP



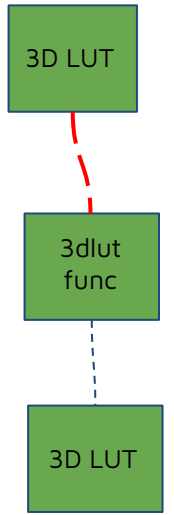
AMD Plane 3D LUT

Suitable for complex color transformations and **adjustments between color channels**

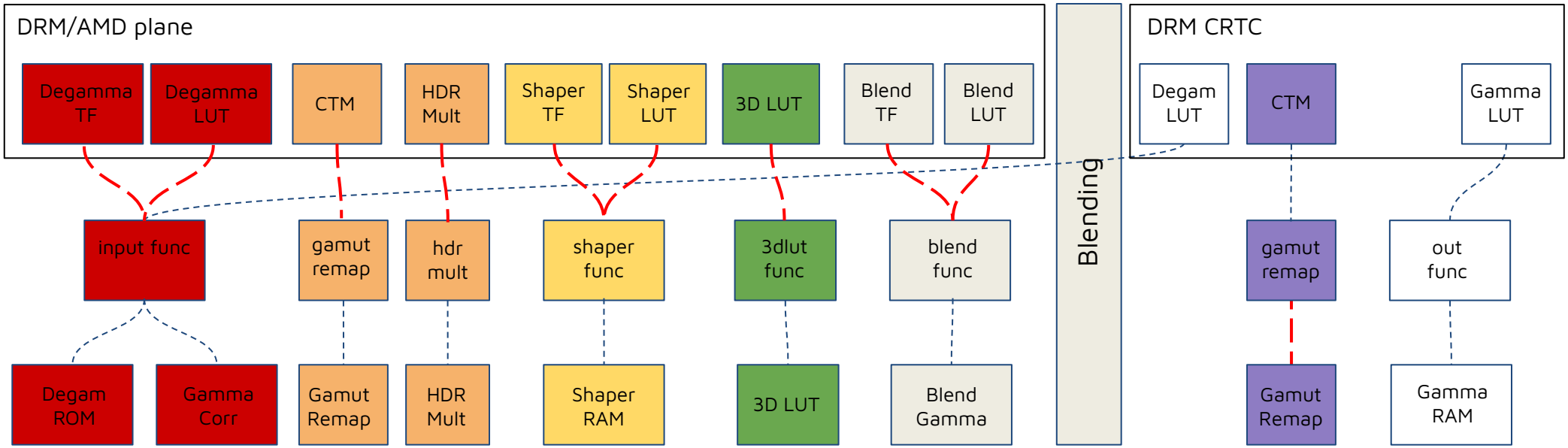
Supported size: **17x17x17** (4913 entries) and **9x9x9** (729)

Tetrahedral interpolation

Blue is the outermost dimension, red the innermost.



Pre-blending: DRM plane + AMD DC DPP



AMD Plane Blend TF and LUT

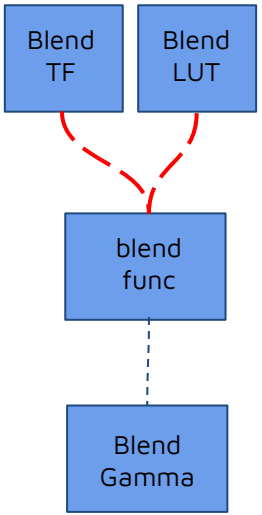
Linearize the color space again, after 3D LUT and before blending

NO hardcoded curves

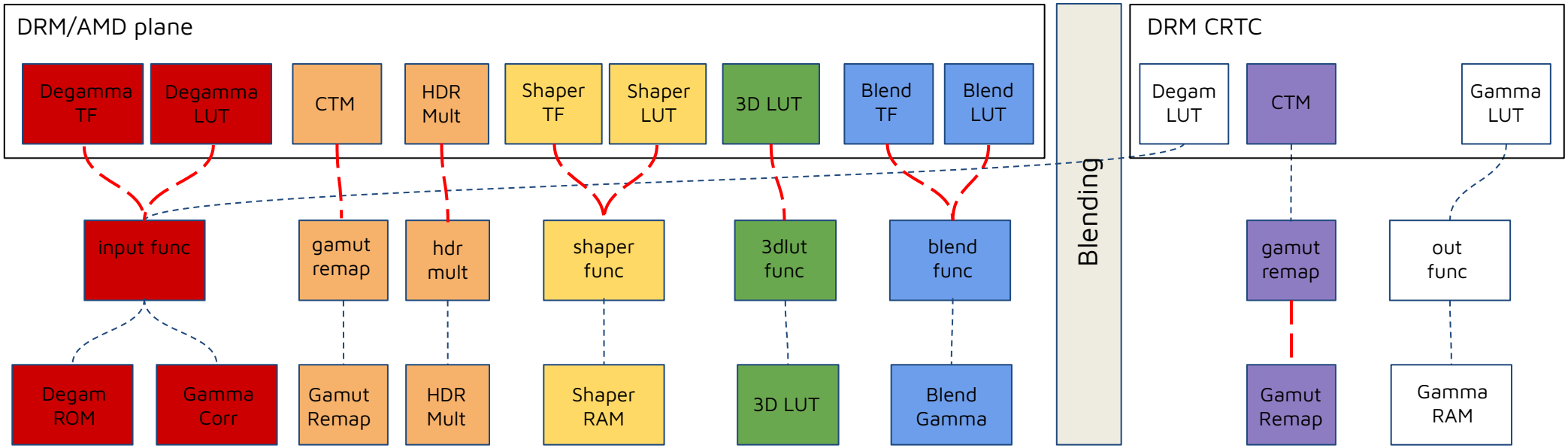
Pre-defined TFs are calculated by **AMD color module**

- sRGB EOTF;
- BT.709 inverse OETF;
- PQ EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 EOTF.

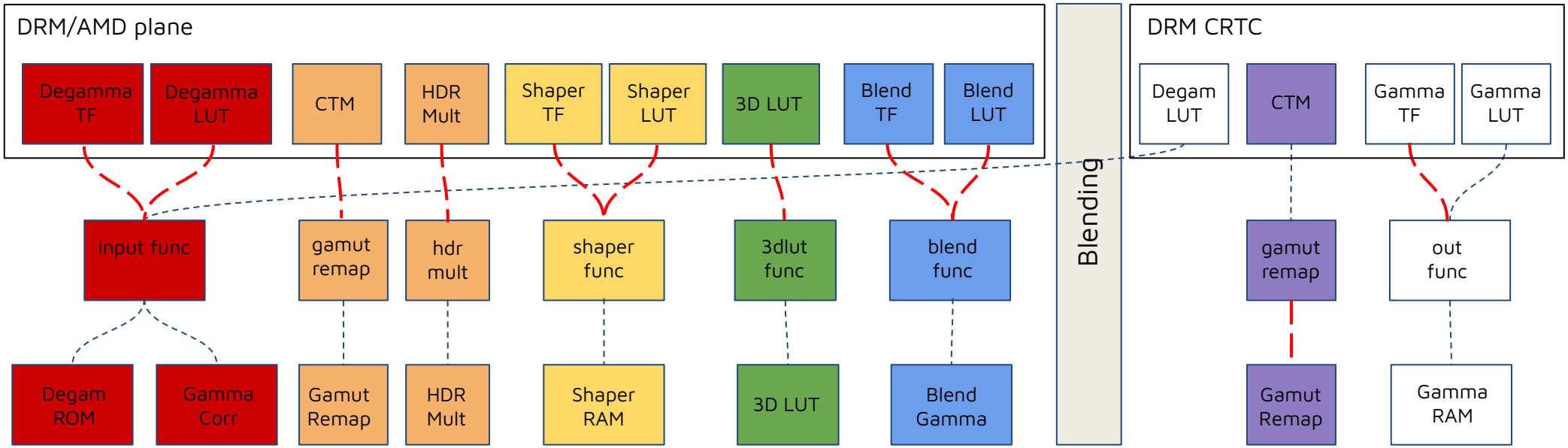
The color module combines TF and user LUT into the LUT to **DPP Blend Gamma block**



Pre-blending: DRM plane + AMD DC DPP



Post-blending: DRM CRTC + AMD DC MPC



AMD CRTC Gamma TF

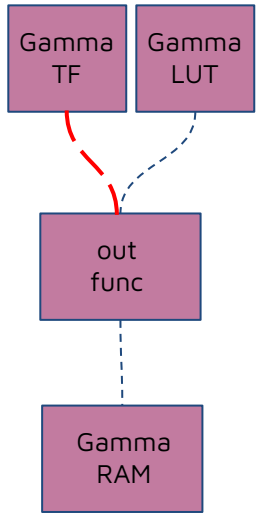
Delinearize/convert to **wire encoding**

NO hardcoded curves

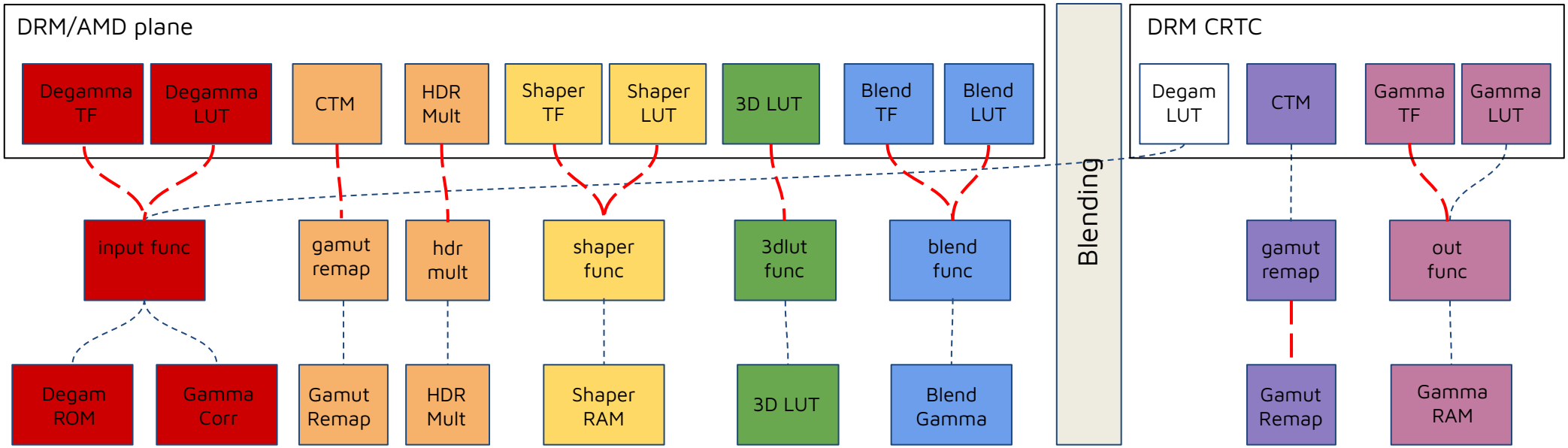
Pre-defined TFs are calculated by **AMD color module**

- sRGB inverse EOTF;
- BT.709 OETF;
- PQ inverse EOTF;
- Gamma 2.2, Gamma 2.4 and Gamma 2.6 inverse EOTF.

The color module combines TF and user LUT into the LUT to **MPC Gamma RAM block.**



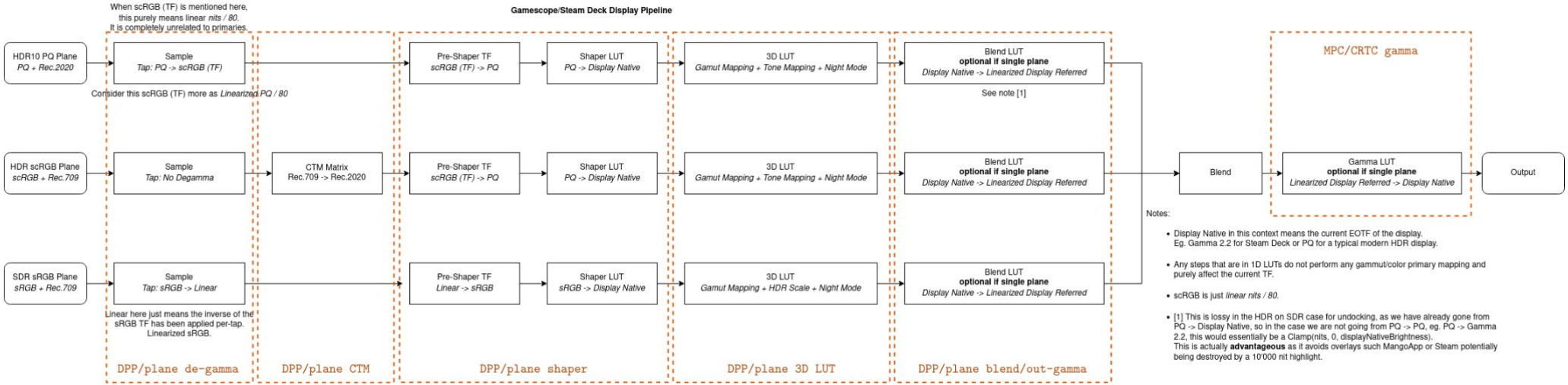
DRM/AMD Color Management Pipeline



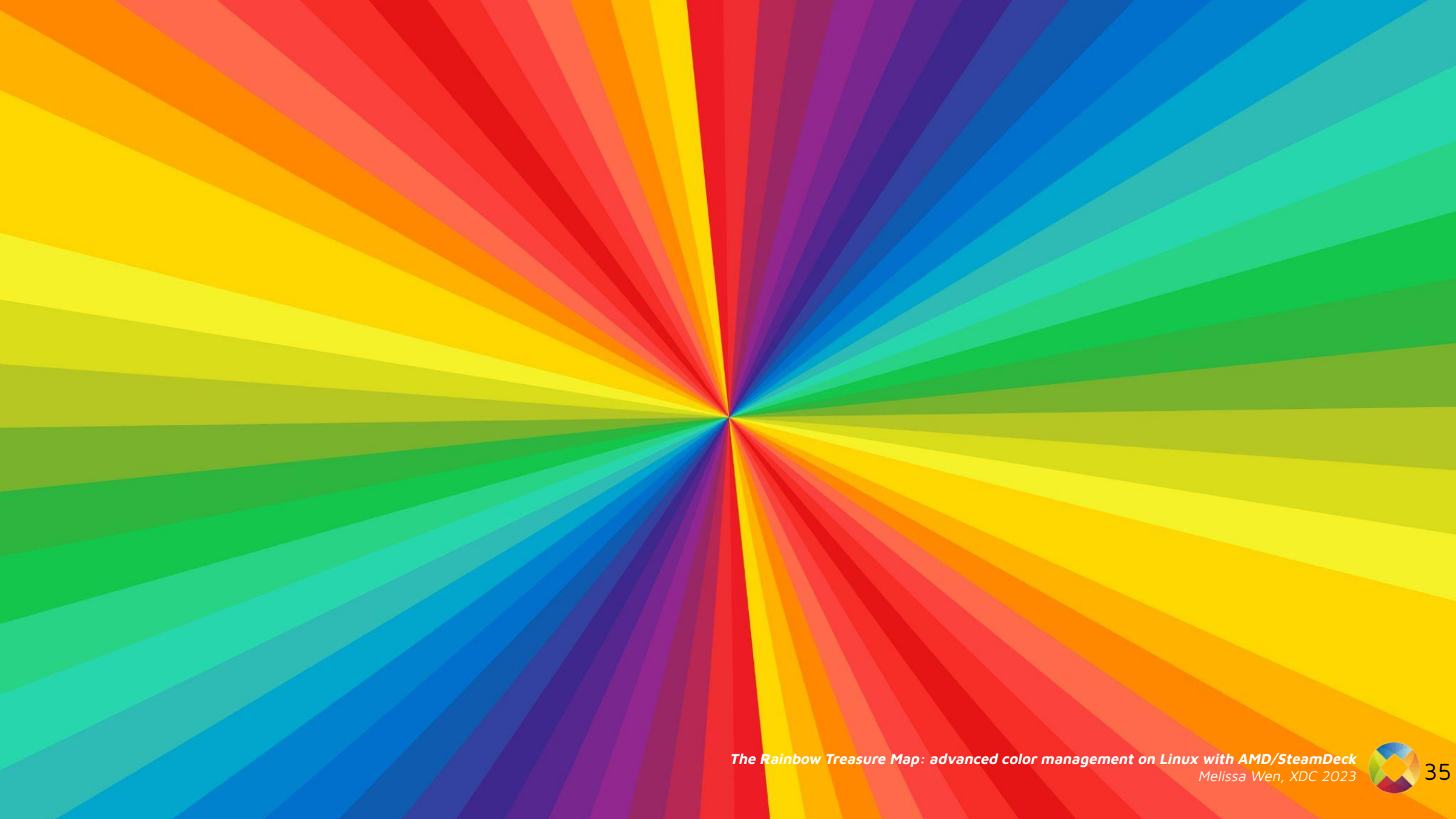
Steam Deck Color Pipeline

AMD Driver-Specific Color Properties

Image by catalyststuff on Freepik



https://github.com/ValveSoftware/gamescope/blob/master/src/docs/Steam%20Deck%20Display%20Pipeline.png



The search for the Rainbow treasure is not over!

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