Examination of the universal behavior of the $\eta/\pi^0$ ratio in heavy-ion collisions

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- **Universal $\eta/\pi^0$ Ratio as function of $p_T$**
  - For p+p and p+A form $\sqrt{S_{nn}} = 29.1$ GeV to 8 TeV
  - Deviations from $m_T$ scaling for $p_T < 3$ GeV/c

- **Universal high $p_T$ value of $\eta/\pi^0 = 0.487 \pm 0.024$**
  - From p+p to A+A, across all beam energies, and collision centralities

- **Effect of radial flow in A+A collision**
  - Small at RHIC energies or below, maybe more significant at LHC energies
Universal $\eta/\pi^0$ Ratio

- Universal $\eta/\pi^0$
  - For $p+p$ and $p+A$ collisions
  - Covering factor ~300 in $\sqrt{s}$ from 29 GeV to 8 TeV

- Significant deviation from $m_T$ scaling below 2-3 GeV $p_T$

- High $p_T$ value: $\frac{\eta}{\pi^0} = 0.487 \pm 0.024$

- Use empirical description for all collision systems:

$$\frac{dN_\eta}{dp_T} = \left( \frac{\eta}{\pi^0} \right)^{universal} \left( \frac{dN_{\pi^0}}{dp_T} \right)^{data}$$
Test of Universality of $\eta/\pi^0$ Ratio

- Fit all available data (with empirical fit B)
  - Independent of $\sqrt{s}$, particle multiplicity, and centrality

Universality of $\eta/\pi^0$
What about Radial Flow at Low $p_T$?

- Approximate $\eta$ with K meson at low $p_T$
  - Similar mass
  - More complete low $p_T$ data

$$R_{flow} \equiv \frac{\left(\frac{\eta}{\pi^0}\right)_{p+p}}{\left(\frac{\eta}{\pi^0}\right)_{p+p}} \approx \frac{\left(\frac{K^\pm}{\pi^0}\right)_{p+p}}{\left(\frac{K^\pm}{\pi^0}\right)_{p+p}} \equiv \frac{R_{AA}^{K^\pm}}{R_{AA}^{\pi^\pm}} C_i$$

- Apply correction to universal $\eta/\pi^0$

**RHIC: small correction**
**LHC: more substantial correction**
Improved Photon Contribution from $\eta$ Meson

- Significant improvement of uncertainties on $\eta/\pi^0$ Ratio at RHIC
  - Smaller contribution below 10 GeV compared to $m_T$ scaling assumption
  - Partially compensated in central collisions by flow effect
  - Consistent with previous estimate within quoted systematic uncertainty

- Use new empirical $\eta/\pi^0$ Ratio moving forward:
  \[
  \frac{dN_\eta}{dp_T} = \left( \frac{\eta}{\pi^0} \right)^{universal} \left( \frac{dN_{\pi^0}}{dp_T} \right)^{data}
  \]
  - Applicable to all collision systems
  - Does not require $\eta$ data at low $p_T$
  - Requires $K$ meson data at low $p_T$

- $m_T$ scaling based on $\eta$ meson for heavier mesons