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Interpreting inclusive jet and gamma-jet suppression in heavy-ion collisions at the LHC

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1. Jet suppression

- Jet suppression is not trivial to predict
  - Energy loss depends on the flavour, parton shower shapes, path length etc.
- Parametric model of parton energy loss [1-2] + new [3]
  - Which component plays the major role?

Goal: extract basic properties of jet quenching with minimal assumptions on the quenching physics

2. Parametric modeling of parton energy loss

- Jet spectra parameterized by power law

$$\frac{dN}{dp_{\mathrm{T}}^{\mathrm{jet}}} = A\left[f_{q0}\left(\frac{p_{T0}}{p_{\mathrm{T}}^{\mathrm{jet}}}\right)^{n_q} + (1-f_{q0})\left(\frac{p_{T0}}{p_{\mathrm{T}}^{\mathrm{jet}}}\right)^{n_g}\right]$$

  with p_{T}-dependent exponent $n_i(p_{\mathrm{T}}^{\mathrm{jet}}) = \sum_{j=0}^{j_{\max}} \beta_j \log^j\left(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{p_{\mathrm{T}0}}\right)$

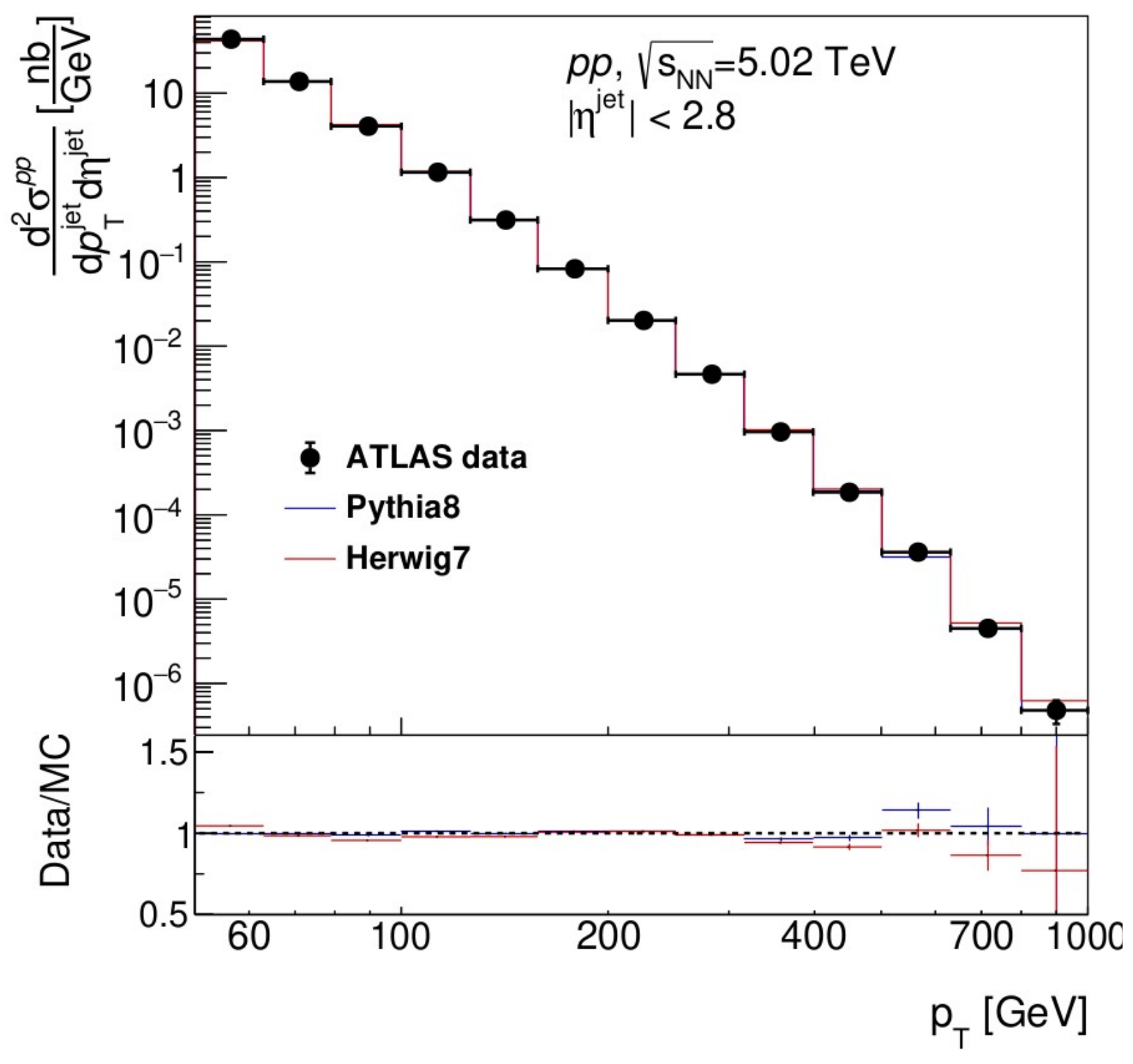
- Average jet transverse momentum loss modeled using three parameters (C_F, s, a) $\langle \Delta p_{\mathrm{T}}^{\mathrm{jet}}\rangle_i = c_{F,i}\ s\ \left(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{p_{\mathrm{T}0}}\right)^{\alpha}$
- Fluctuating energy loss has a distribution $w(p_{\mathrm{T}}^{\mathrm{jet}}, \Delta p_{\mathrm{T}}^{\mathrm{jet}})$

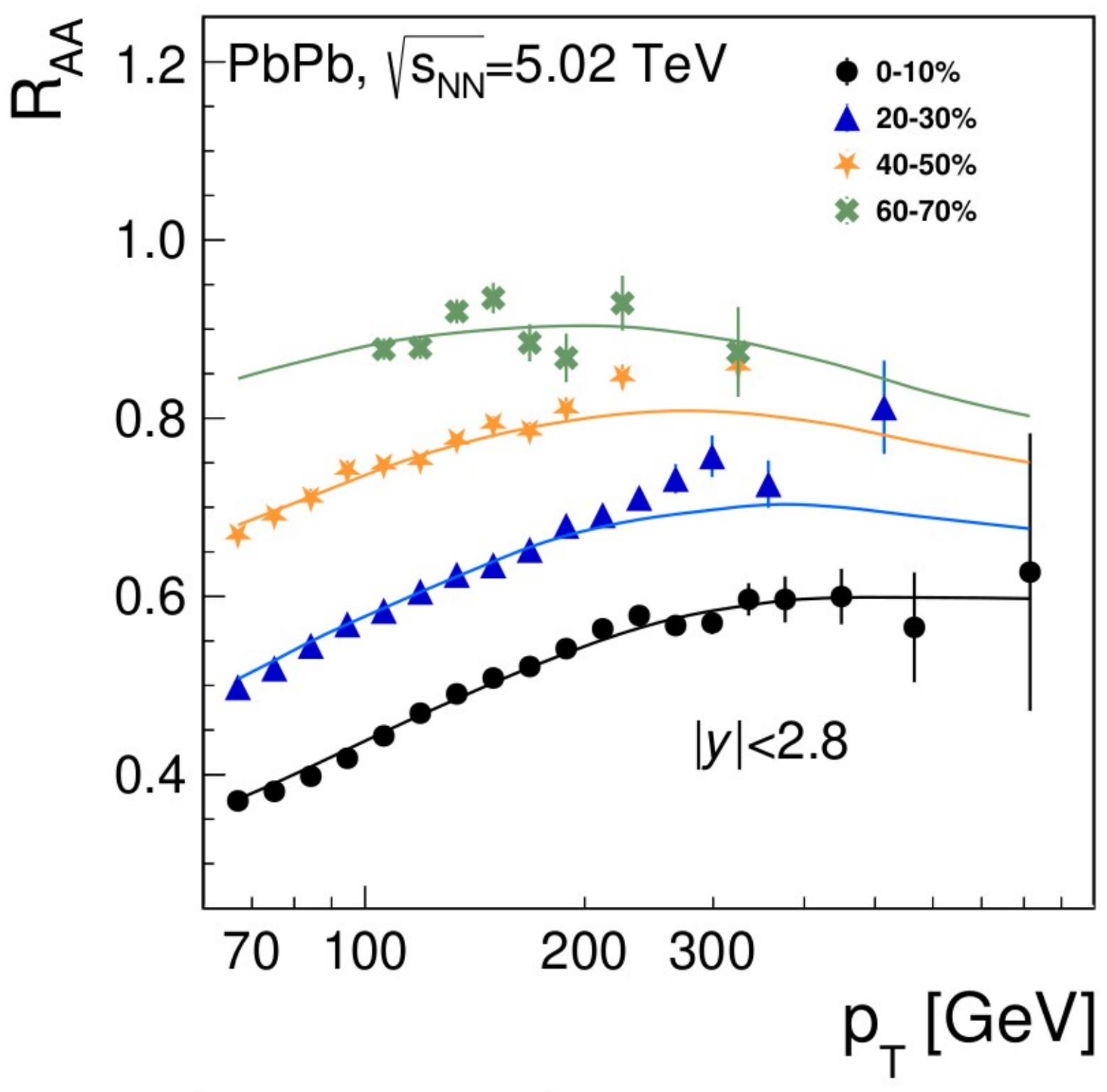
  leading to **spectra** $\frac{dN_Q}{dp_{\mathrm{T}}^{\mathrm{jet}}} = \int d\Delta p_{\mathrm{T}}^{\mathrm{jet}} \frac{dN}{dp_{\mathrm{T}}^{\mathrm{jet}}} w(p_{\mathrm{T}}^{\mathrm{jet}}, \Delta p_{\mathrm{T}}^{\mathrm{jet}})$

  and to **average energy loss** $\langle \Delta p_{\mathrm{T}}^{\mathrm{jet}}\rangle = \int d\Delta p_{\mathrm{T}}^{\mathrm{jet}}\ \Delta p_{\mathrm{T}}^{\mathrm{jet}}\ w(p_{\mathrm{T}}^{\mathrm{jet}}, \Delta p_{\mathrm{T}}^{\mathrm{jet}})$
- Assumption that energy loss distribution depends only on self - normalized fluctuations [4] $x \equiv p_{\mathrm{T}}^{\mathrm{jet}} / \langle \Delta p_{\mathrm{T}}^{\mathrm{jet}}\rangle$
- Energy loss distribution parameterized by generalized integrand of gamma function: $w(x) = \frac{c_1^{c_0}}{\Gamma(c_0)} x^{c_0-1} e^{-c_1 x}$
- Logarithmic dependence of energy loss (as LBT model) included as an option: $\langle \Delta p_{\mathrm{T}}^{\mathrm{jet}}\rangle = c_F\ s\ \left(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{p_{\mathrm{T}0}}\right)^{\alpha} \log\left(\frac{p_{\mathrm{T}}^{\mathrm{jet}}}{p_{\mathrm{T}0}}\right)$

3. Method

- Pythia8 (w/ & w/o nPDF effects) and Herwig7 used to obtain parameterized **quark-and gluon-initiated jet spectra**
- Cross-sections re-weighted to reproduce *pp* measurements
- **E-loss parameters (*s*, *a*)** from X^2 minimization wrt to 5 TeV jet R_{AA} data [5] for various c_F parameters
- Energy loss parameters then used to model other observables

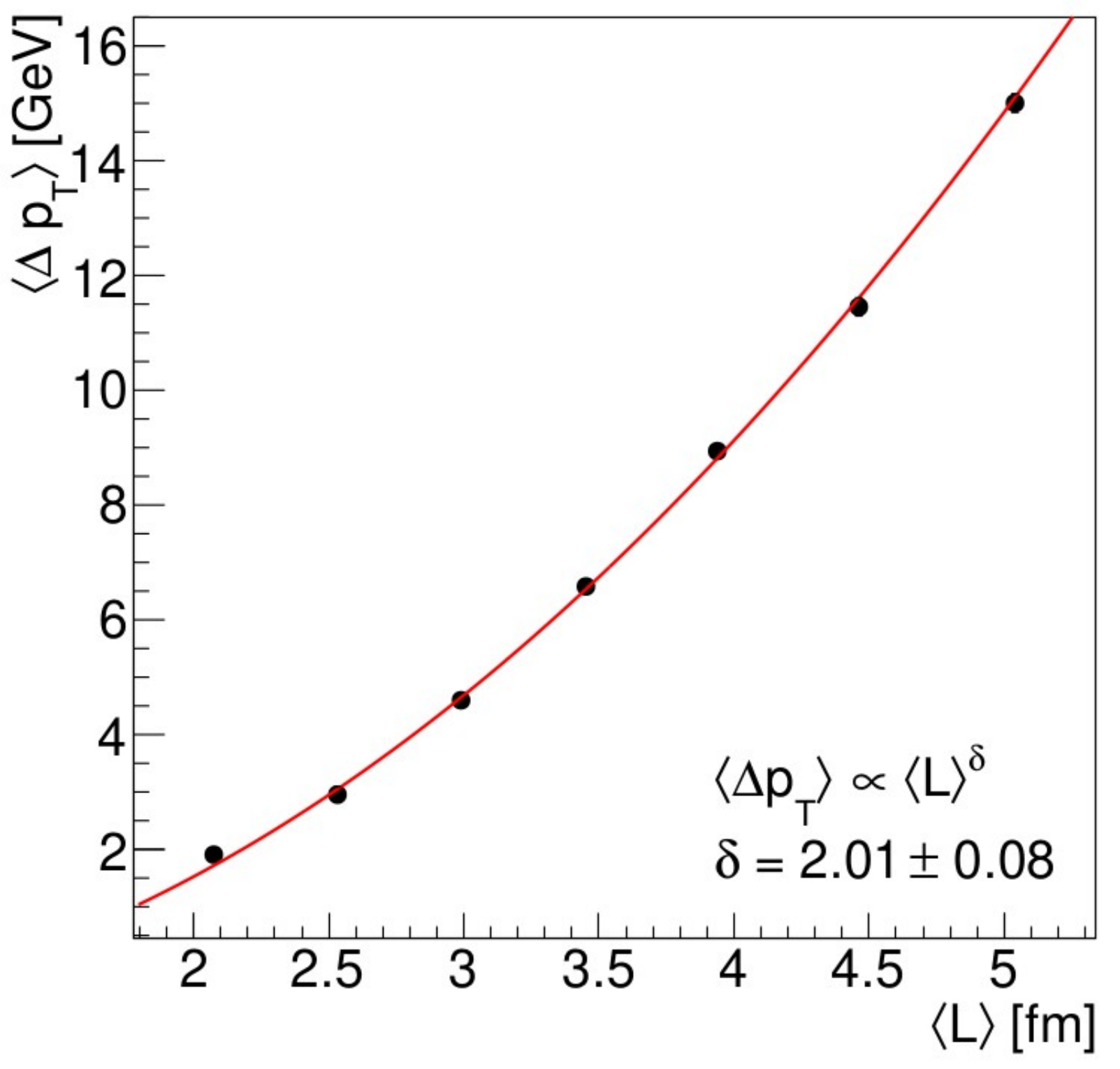




Spectra	Parameters	$\chi^2\|_{0-10\%}$	$\chi^2\|_{\mathrm{all}}$	
P8, nPDF	$\alpha_{\min} = 0.27, c_{\mathrm{F}} = 1.78$	0.51	1.06	
P8, nPDF	$\alpha_{\min} = 0.24, c_{\mathrm{F}} = (9/4)^{1/3}$	0.53	1.05	
P8, nPDF	$\alpha_{\min} = 0.29, c_{\mathrm{F}} = 9/4$	0.50	1.09	
P8	$\alpha_{\min} = 0.33, c_{\mathrm{F}} = 1.78$	0.70	1.06	
H7	$\alpha_{\min} = 0.30, c_{\mathrm{F}} = 1.78$	0.88	1.18	
P8, nPDF	$\alpha_{\min} = 0.40, c_{\mathrm{F}} = 1.78$	0.62	1.53	w/o fluctuations
P8, nPDF	$\alpha_{\min} = 0.15, c_{\mathrm{F}} = 1.78$	0.44	1.43	w/ log term in e-loss

4. Path-length dependence of energy loss

- Fitting $\langle \Delta p_T \rangle$ → extract path-length dependence of e-loss.
- Assumption: path-length proportional to Glauber model initial conditions.
- Clear L^2 dependence extracted from the data → may support radiative nature of energy loss

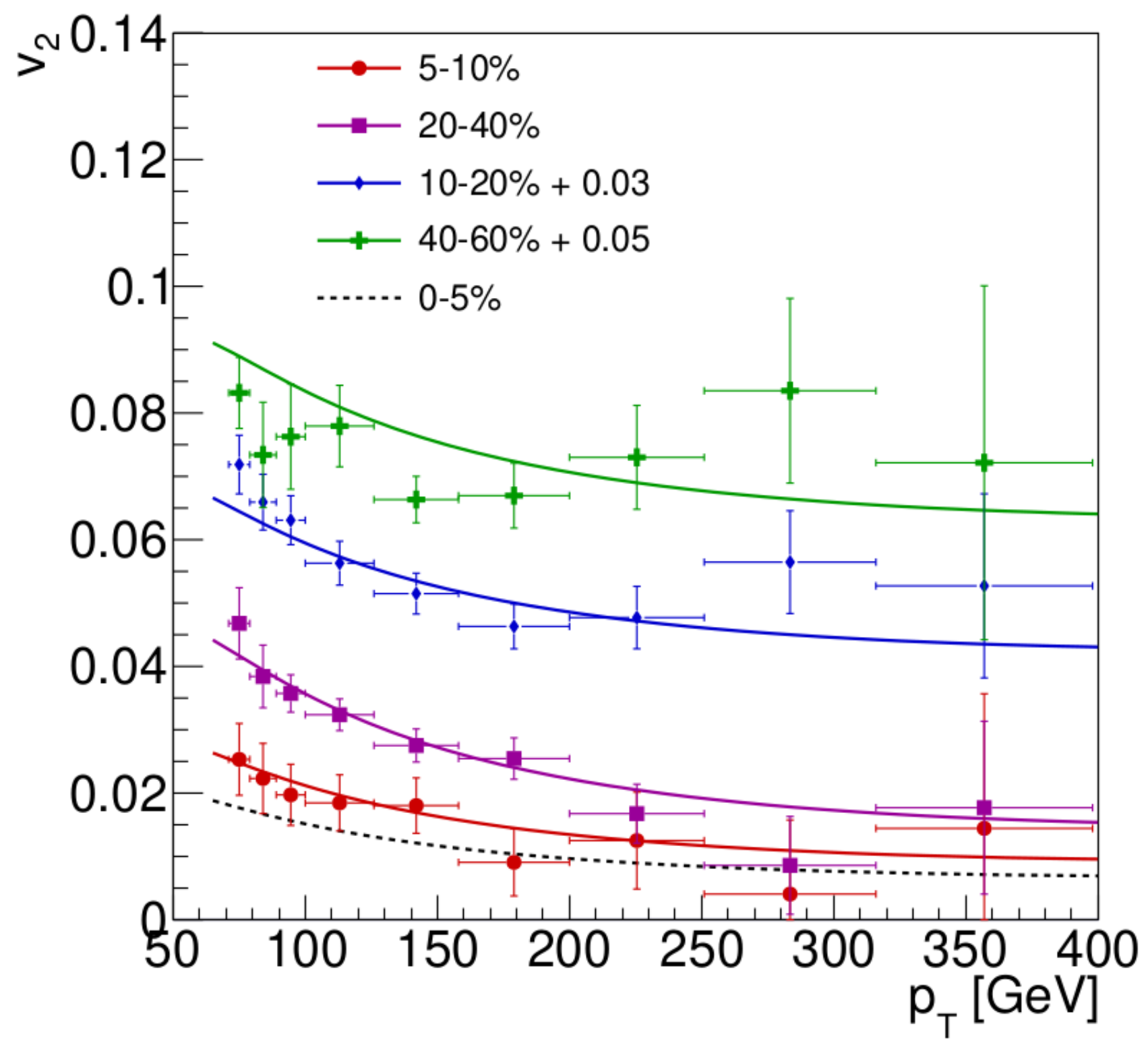


Jet v_2

$$v_2 \approx \frac{1}{2}\frac{R_{\mathrm{AA}}(L_{in}) - R_{\mathrm{AA}}(L_{out})}{R_{\mathrm{AA}}(L_{in}) + R_{\mathrm{AA}}(L_{out})}$$

$$L_{in} = \langle L \rangle - c \cdot \Delta L_{in}$$

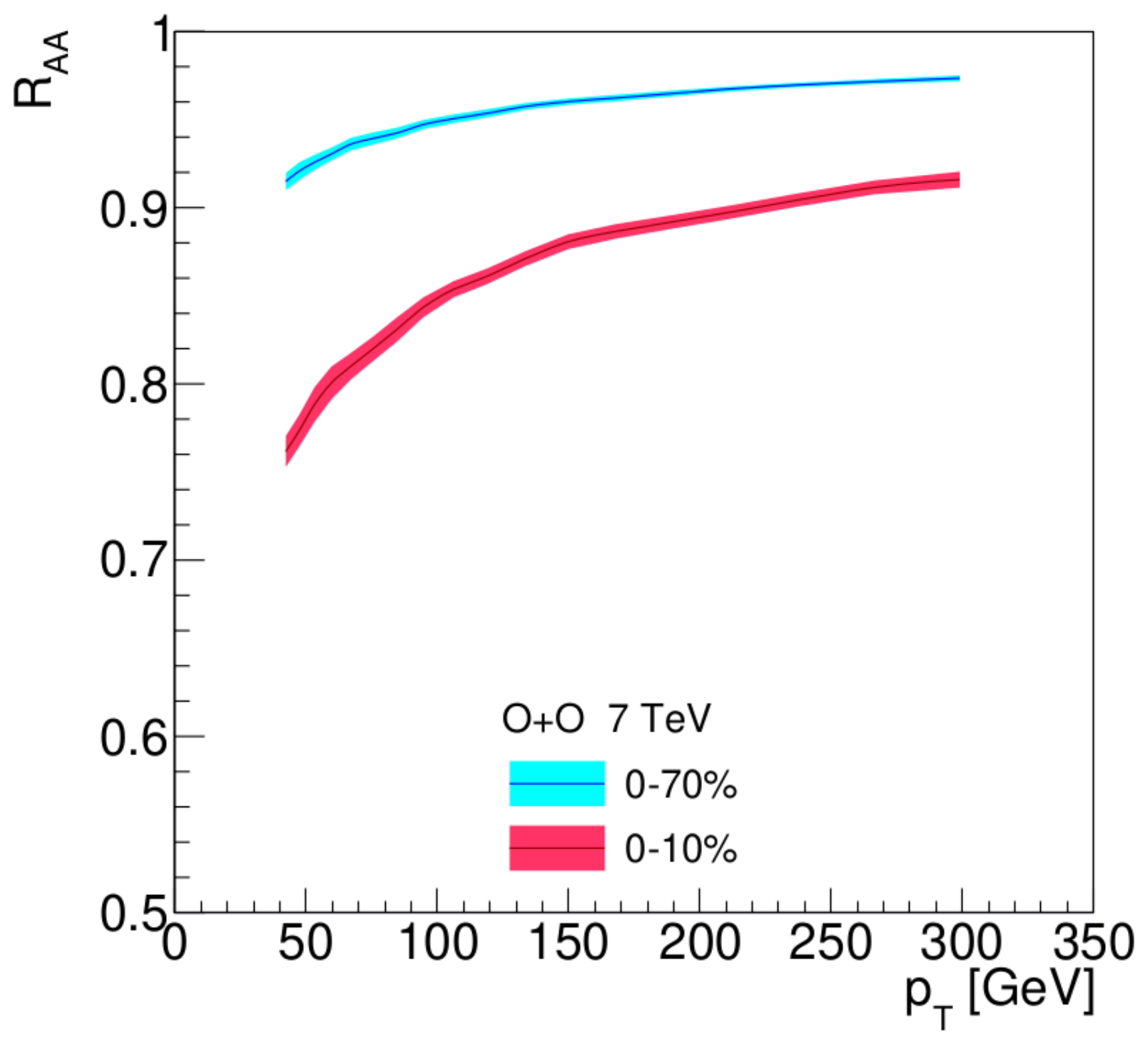
$$L_{out} = \langle L \rangle + c \cdot \Delta L_{out}$$



- Good agreement with ATLAS [6]
- Supports validity of L^2 dep.

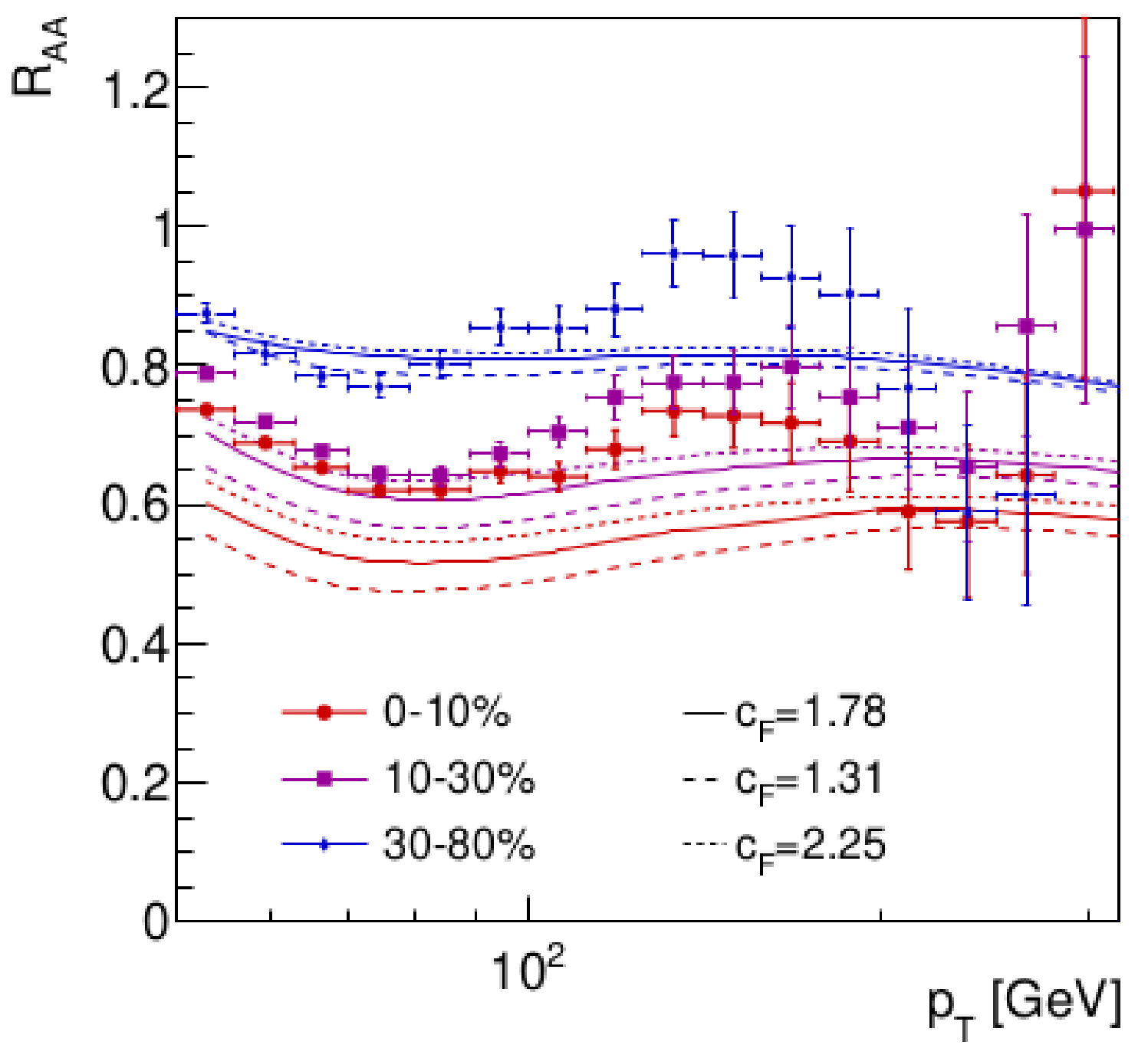
Jet R_{AA} for O+O

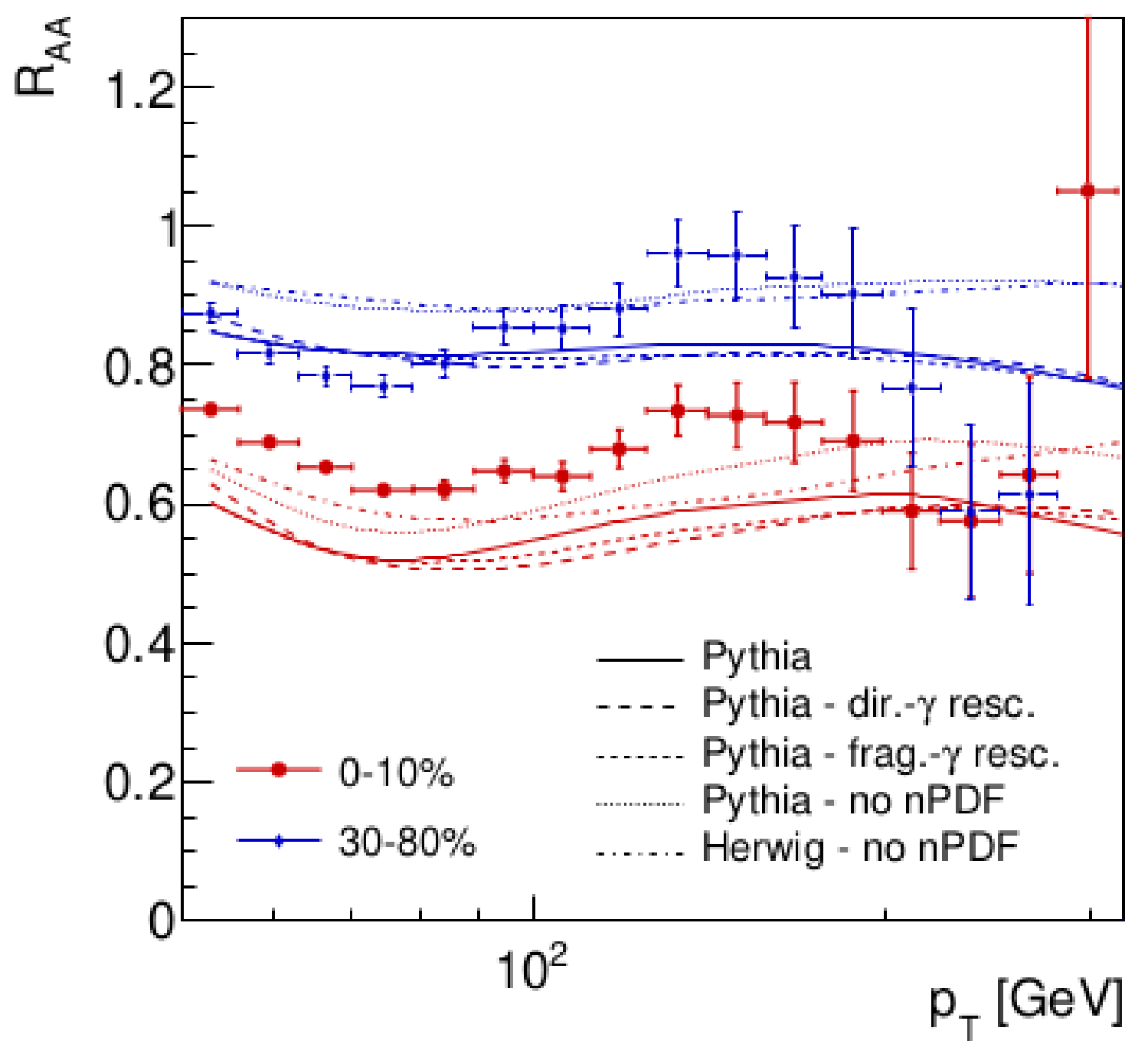
- Extracted e-loss at 2.76 TeV and 5.02 TeV Pb+Pb extrap. to 7 TeV

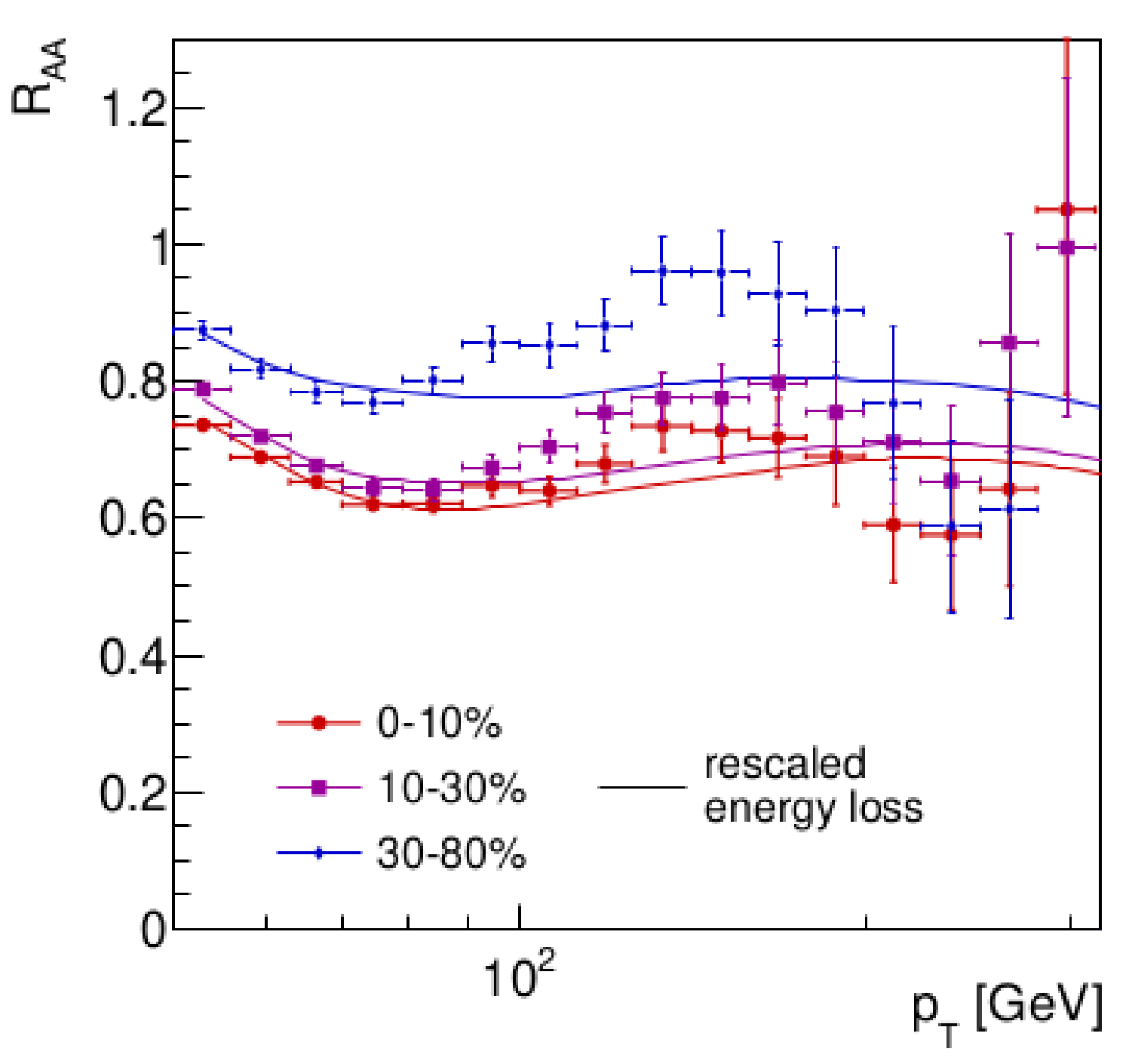


- Jet R_{AA} of 0.8 at 50 GeV in central O+O collisions expected

5. Suppression in γ-jet system







- Large differences in R_{AA} between different c_F values
- Shape reproduced below 120 GeV
- Input spectra reweighting: <10%
- nPDF effects effect: 15-20%
- MC generator differences: ~10%
- Selection bias may cause difference in supression → refitting R_{AA}
  - Ratio between $\langle L_\gamma \rangle/\langle L \rangle$ is 0.80±0.02, 0.9±0.03, and 1.07±0.03 for 0-10%, 10-30%, and 30-80%

References:
[1] M. Spousta, B. Cole, Eur. Phys. J. C 76 (2016) 2, 50
[2] M. Spousta, Phys.Lett B767 (2017) 10
[3] A. Ogrodnik, M. Rybar, M. Spousta, arXiv:2407.11234
[4] Phys. Rev. Lett. 122, 252302 (2019)
[5] ATLAS Collaboration, Phys. Lett. B 790,108 (2019)
[6] ATLAS Collaboration, Phys. Rev. C 105, 064903 (2022)