**Method**

- **We consider:**

  Secondary particle production from hadronic $p-\gamma$ interactions of external target photons with isotropically distributed CR protons in the co-moving blazar jet frame

  -> externally isotropic target photon distribution appears anisotropic (beamed) in co-moving jet frame

- To describe the interaction probability in the co-moving jet frame we calculate the gyro-phase averaged interaction rate

- We then modified the **SOPHIA2.0**(1) Monte Carlo code to take into account the corresponding non-isotropic interaction angle distribution

- When comparing to Dermer et al (2014)(2) we found ~2–3 times higher interaction rates in our work for mono-energetic (photon energy $\varepsilon_0$) target photon fields

Interaction time in the co-moving jet (with bulk Lorentz factor $\Gamma=10$) frame for an externally isotropic target radiation field of differential density $n(\varepsilon) = 1 \text{cm}^{-3} \delta(\varepsilon-\varepsilon_0)$ with (jet-frame) $\varepsilon_0 = 10^{-4} \text{eV}$ (solid), $10^{-3} \text{eV}$ (dotted), $10^{-2} \text{eV}$ (short dashed), $0.1 \text{eV}$ (dash-dotted), $1 \text{eV}$ (dash-triple-dotted line),... as calculated in Dermer et al (2014) (blue curves) and compared to our work (black curves).
• We here consider:
  
  Emission region within BLR line target radiation field  
  \[\text{see DMI2014}\] & isotropically (co-moving jet frame)  
  distributed proton spectrum  
  \[N_p \sim E^{-\alpha_p} \exp(-E_p/E_{p,\text{max}}), \ E_{p,\text{max}}=10^{10}\text{GeV}\]  

• Examples of secondary particle spectra:

  (AGN frame; all neutrons decayed; viewing angle \(\theta=5^\circ\))  
  \[\alpha_p = 2\]  

  bulk Lorentz factor \(\Gamma = 10\)  

We found:  
\[E_{M\gamma+e^+-e^-} - \text{power} / \nu - \text{power} \sim 1\]
Comparison to previous approximations

A previous approximation of the co-moving ('') BLR target photon field uses a isotropically distributed blackbody photon field with peak intensity at

$$\nu'_{\text{peak}} \approx 1.5 \Gamma \nu_{\text{Ly}\alpha}$$

[Tavecchio & Ghisellini 2008; Böttcher, Reimer & Marscher 2009; Reimer 2009]

-> Comparing this approximation to our work we found:

Blackbody approximation underestimates secondary particle yields @ low-energy part of spectrum.

$$\alpha_p = 2, \ \theta=5^\circ$$

$$\Gamma = 10, \ \theta=5^\circ$$

References:

(1) A. Mücke, R. Engel, J.P. Rachen, R.J. Protheroe, T. Stanev 2000, CPC, 124, 290
(2) C.D. Dermer, K. Muras, Y. Inoue, 2014, JHEA, 3, 29 (DMI14)