

Lévy walk of pions in heavy-ion collisions



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1. Lévy processes in Nature

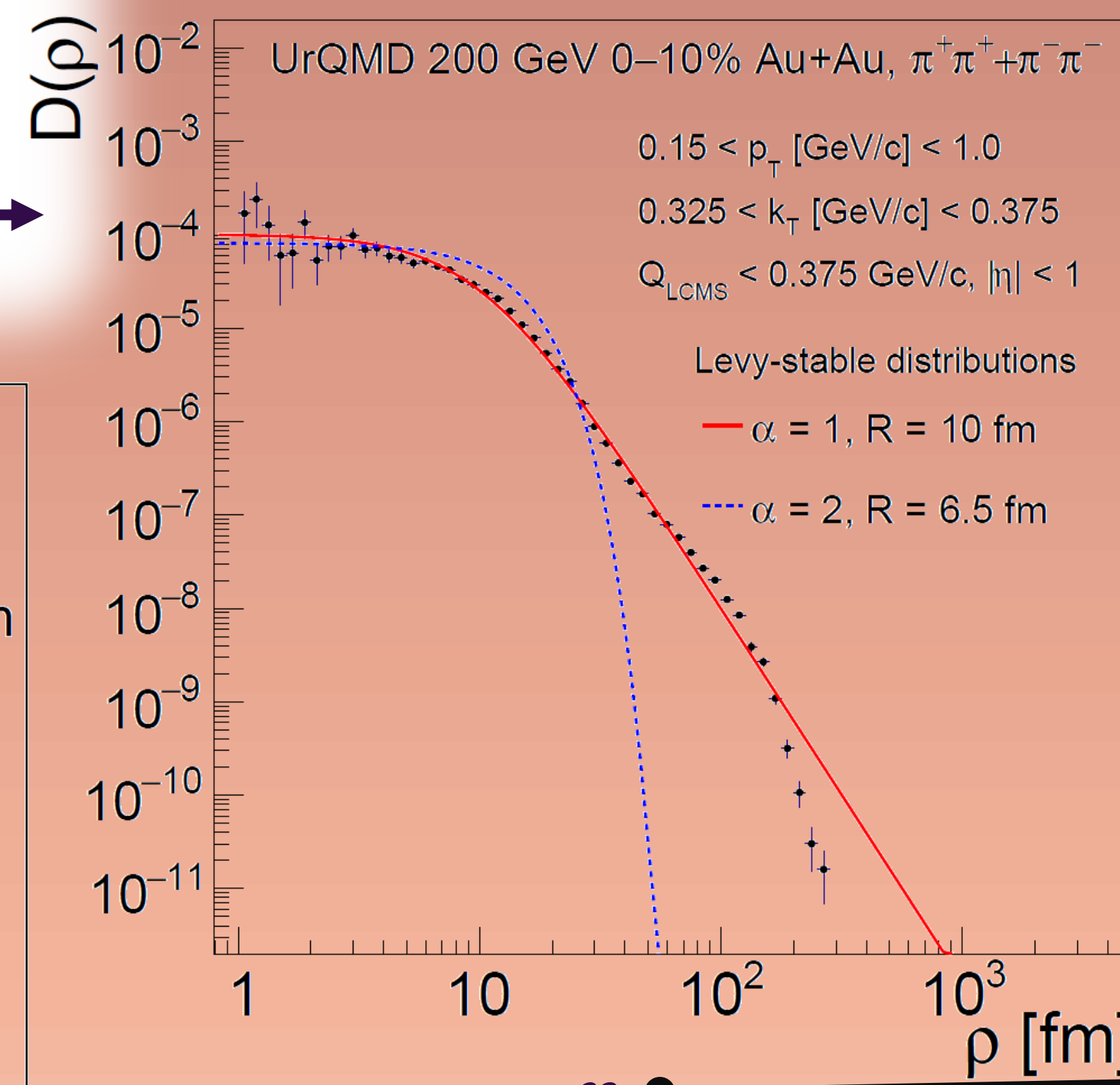
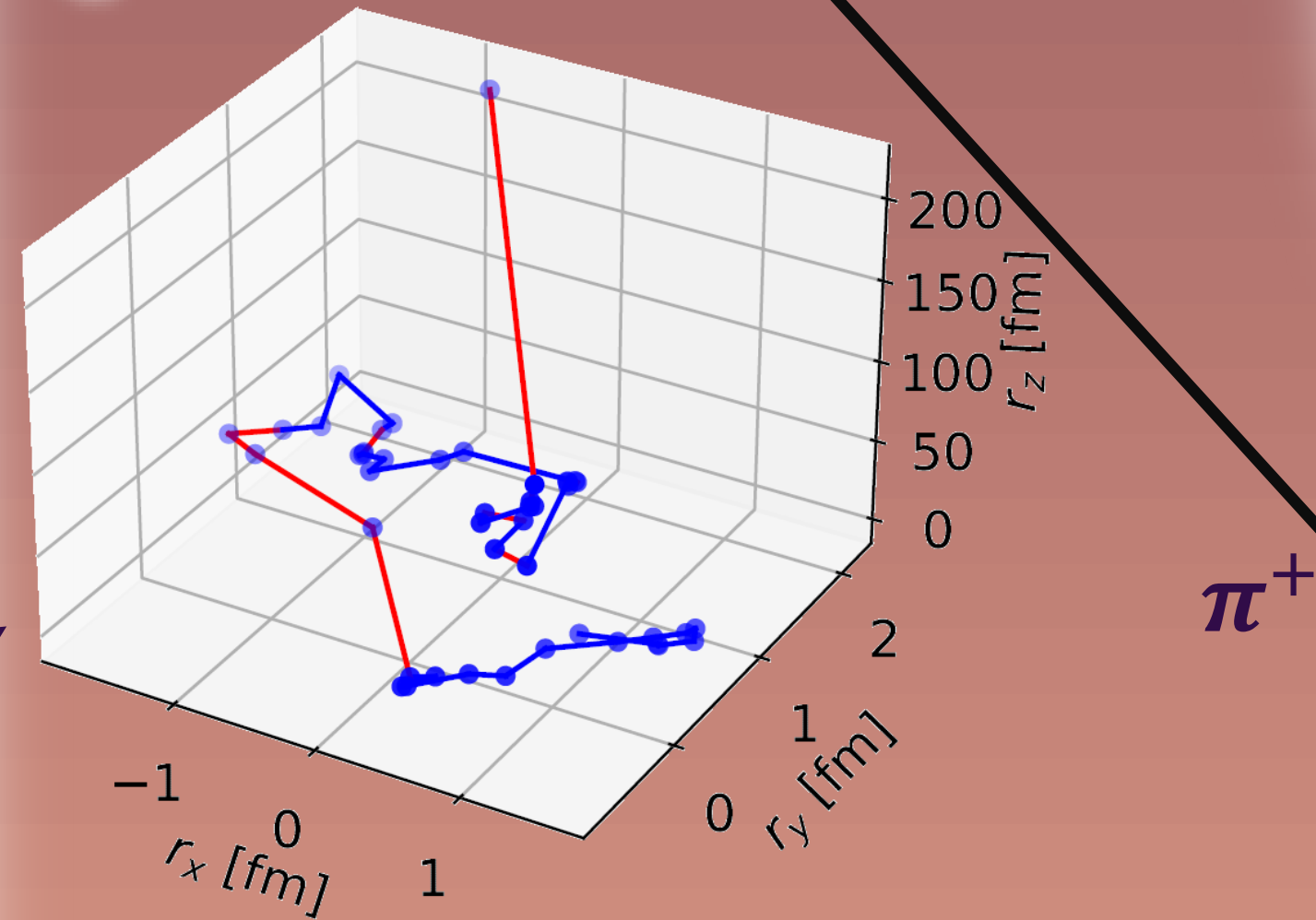
- Ecology, climatology, microbiology, etc.
- A type of random walk, containing clusters of small & occasional long steps
- Step length distribution \rightarrow no 2nd moment!

Can it happen in heavy-ion collisions?
Experimental indications from PHENIX, STAR, NA61/SHINE, CMS, etc.

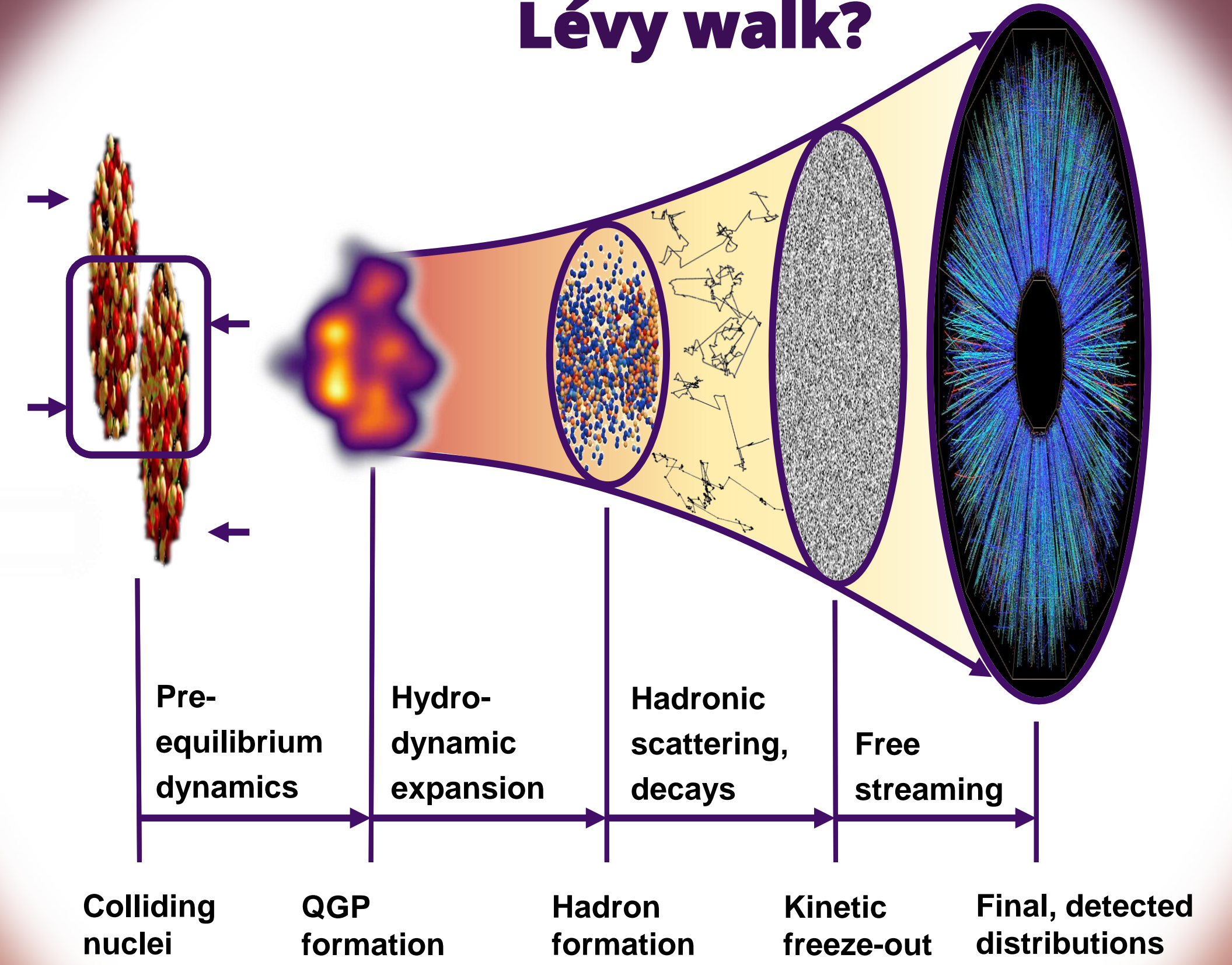
Check this in UrQMD!

2. Lévy walk in hadronic scattering

- UrQMD model – hadronic rescattering
- Types of built-in interactions:
 - 2 by 2 scattering ($2 \rightarrow 2$ process)
 - String fragmentation ($2 \rightarrow N$ process)
 - Coalescence ($2 \rightarrow 1$ process)
 - Decay ($1 \rightarrow N$ process)
- Following back final pions in history mode
 - Step length distribution: truncated power-law!
 - Freeze-out distance distribution $D(\rho)$: Approximately follows a spherically symmetric Lévy-stable distribution!



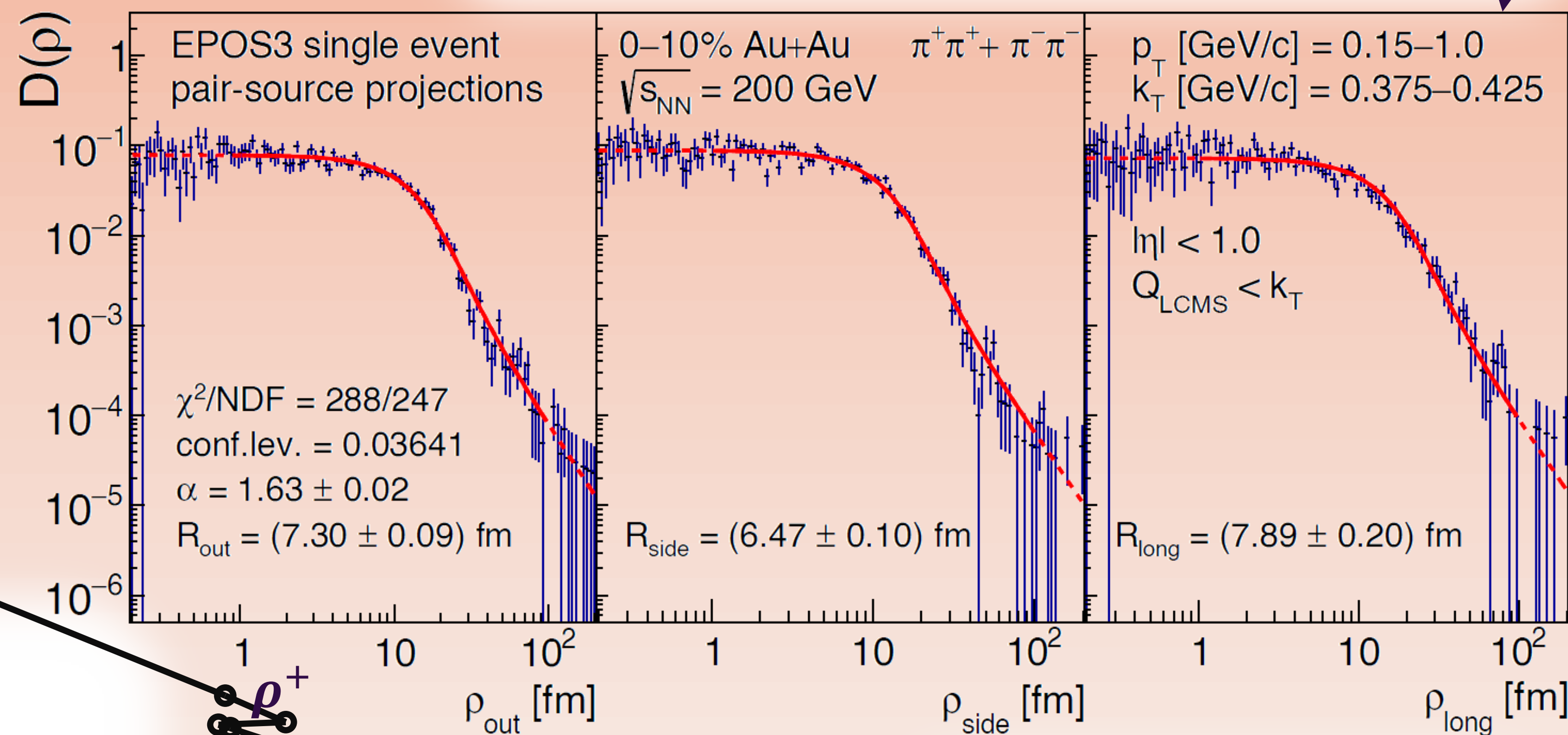
Lévy walk?



Check this in EPOS!
Complete model,
hydro+rescattering

3. Lévy walk in a complete model (EPOS)

- Freeze-out pair-distance distribution $D(\rho)$: Elliptically contoured 3D Lévy-stable distribution!
- $$\mathcal{L}(\alpha, R_{osl}, \vec{r}) = \frac{1}{(2\pi)^3} \int d^3\vec{q} e^{i\vec{q}\cdot\vec{r}} e^{-\frac{1}{2}|\vec{q}^T R^2 \vec{q}|^{\alpha/2}}$$
- $$R^2 = \text{diag}(R_{out}^2, R_{side}^2, R_{long}^2)$$
- Event-by-event fits, for thousands of events
 - Extracting mean and std.dev. of parameters



4. Comparison with experiment

- Comparing to the latest angle average results from PHENIX
- Lévy scale: good agreement
- Lévy exponent: far from Gaussian ($\alpha = 2$), not as low as the experimental result
- Difference due to the lack of long-range Coulomb interaction in EPOS?
- Next steps – see posters of E. Árpási, L. Kovács, M. Molnár:
 - Centrality dependence
 - Particle species dependence
 - Momentum correlation function reconstruction

5. Summary

- Strong effect of Lévy walk in another realm of Nature
- First detailed 3D study of Lévy-stable pair source
- The reason behind the appearance of such source shapes is not event- nor angle-averaging
- Lévy scales show good agreement with recent PHENIX results
- Lévy exponent shows non-Gaussian values, but differ from PHENIX result

