

Monte Carlo Event Generation for Heavy Ions

Or:

Additional things you need computers for when modelling heavy-ion collisions

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Simplified HI simulation

Pb+Pb $E_{\text{cm}}=5.5$ TeV

$t=-18.80$ fm/c

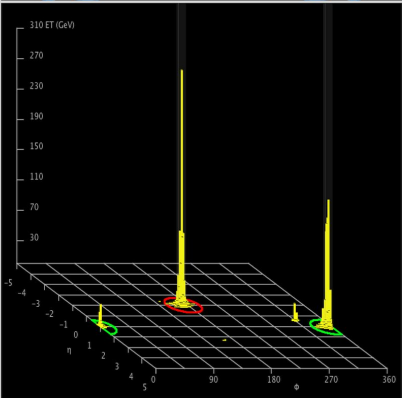
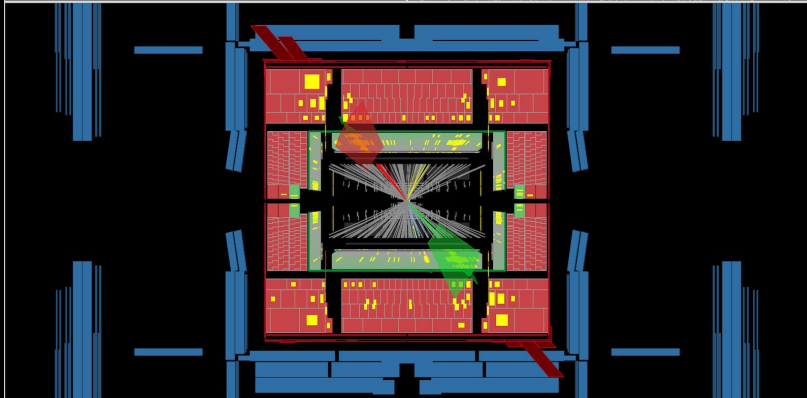
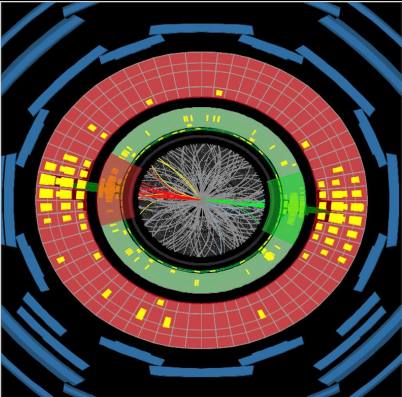
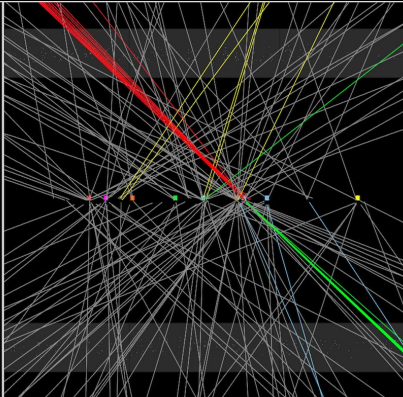


H. Weber / UrQMD Frankfurt/M

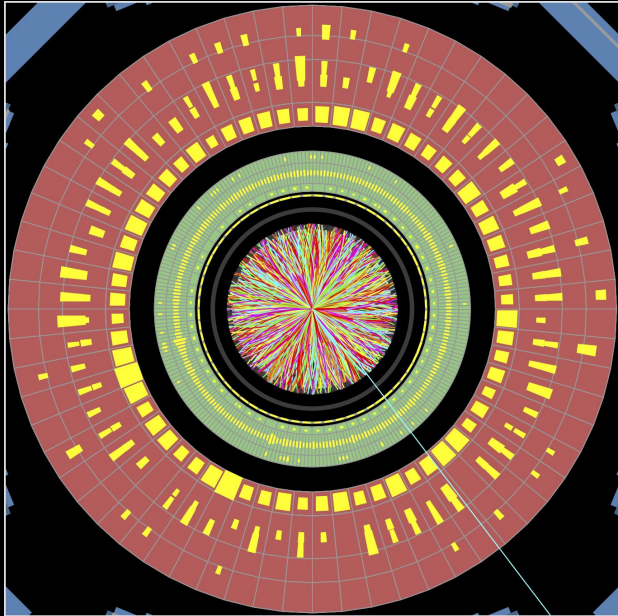


ATLAS EXPERIMENT

Run Number: 201269, Event Number: 80898559
Date: 2012-04-14 22:30:13 CEST

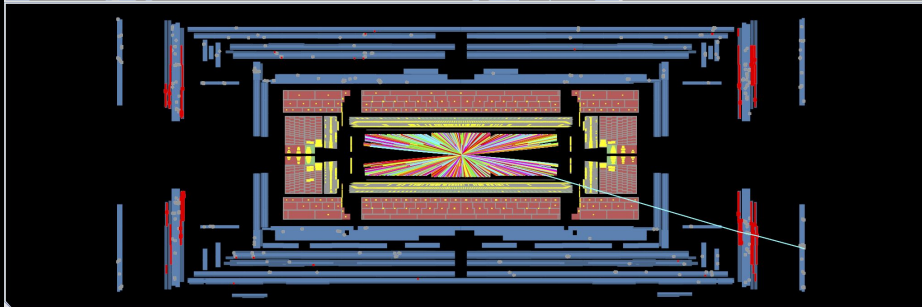
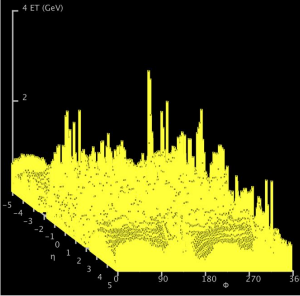


ATLAS, Run 2, pp dijet-event

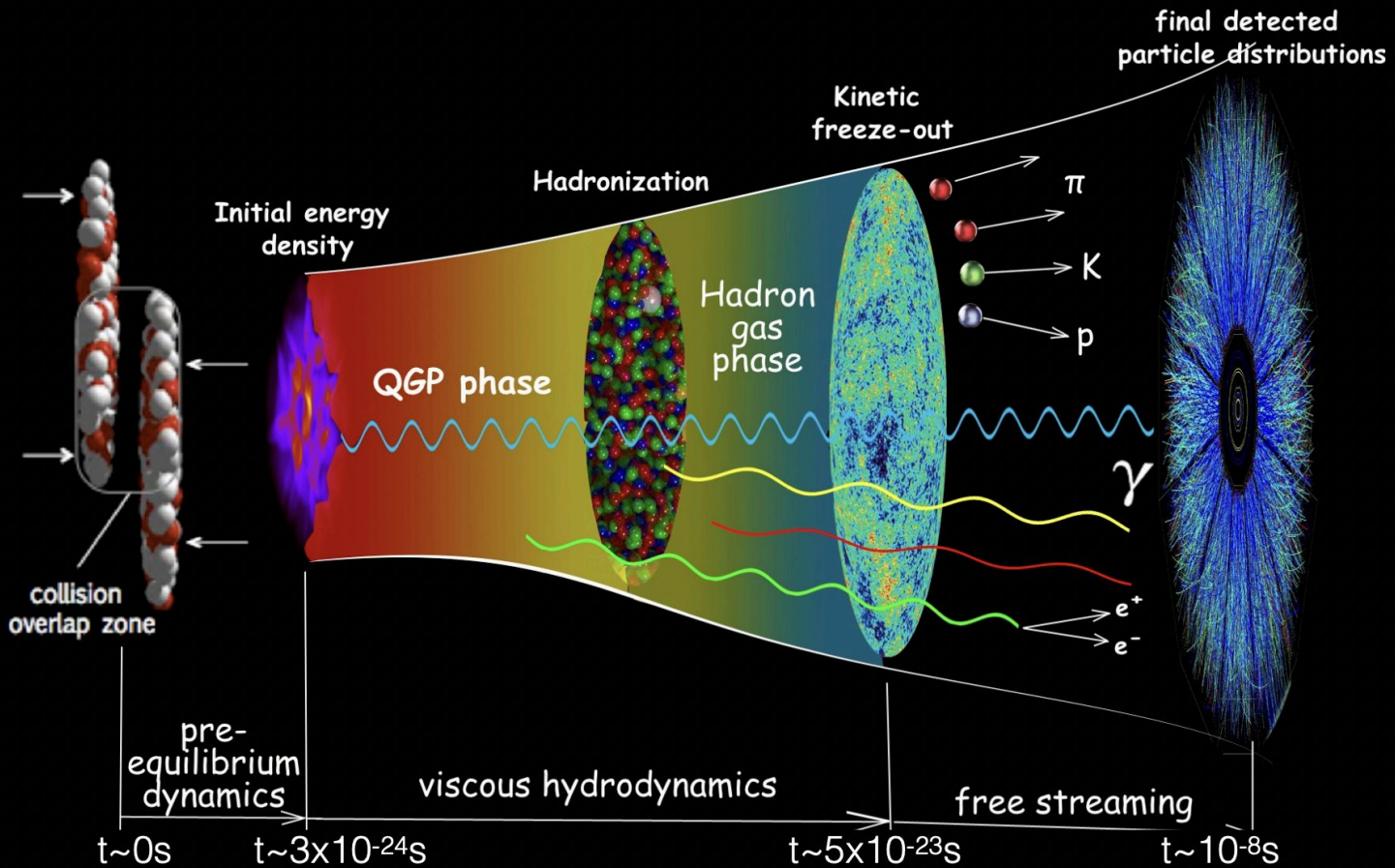


Run Number: 440101, Event Number: 823635

Date: 2022-11-18 16:45:12 CET



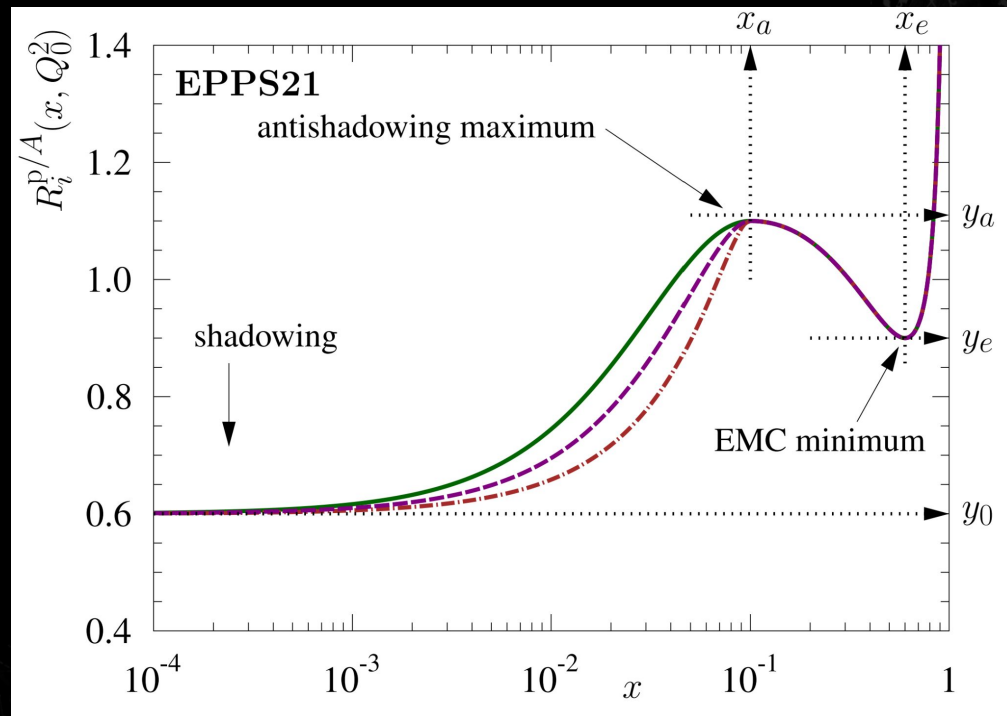
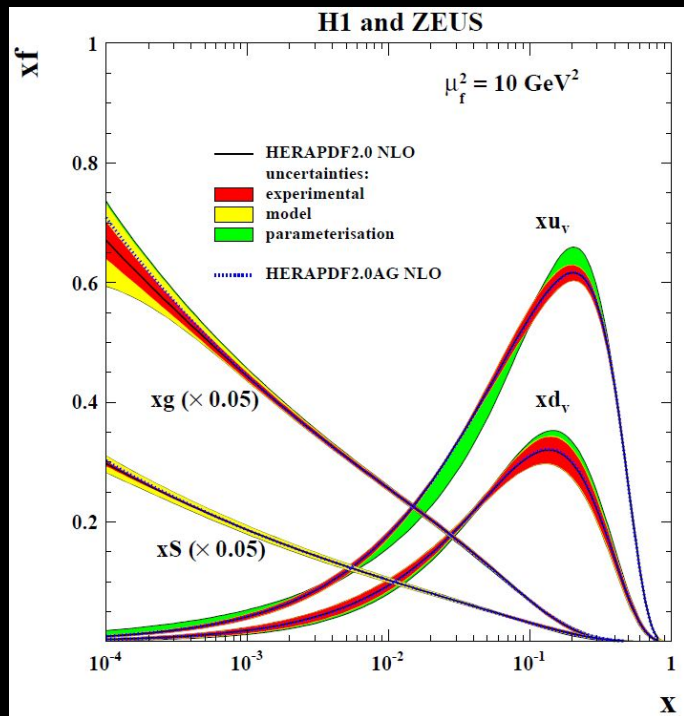
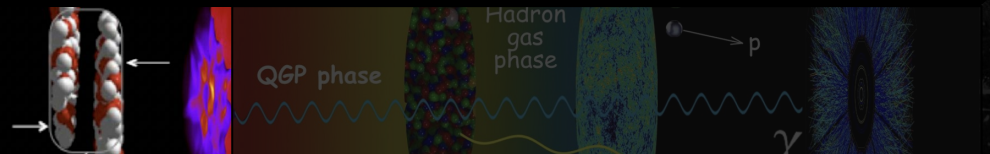
ATLAS, Run 3, PbPb event



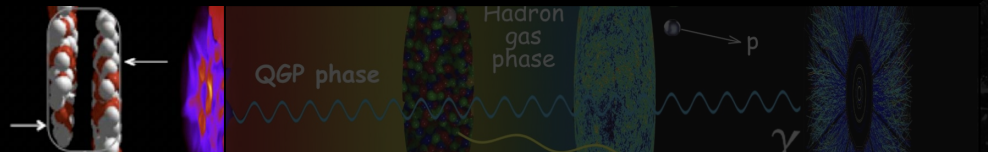
1 yoctosecond = 10^{-24} s

The initial condition

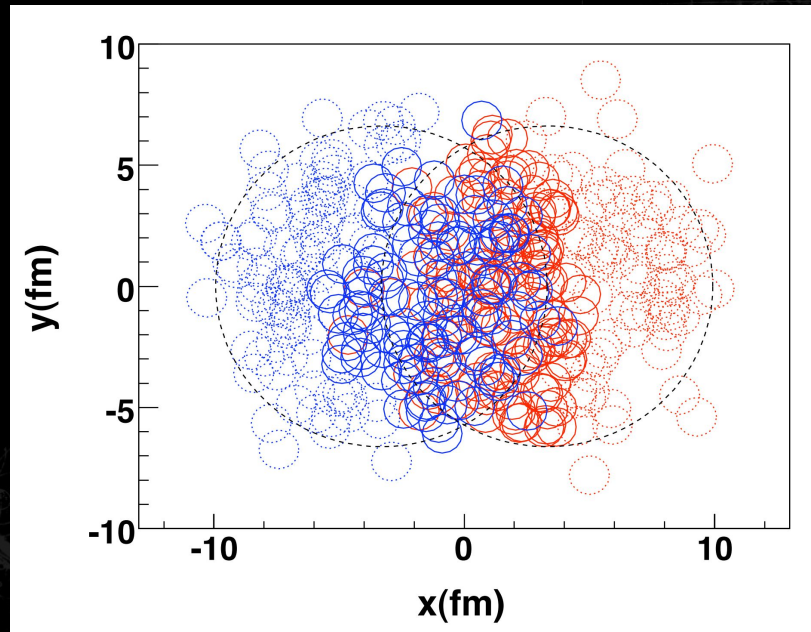
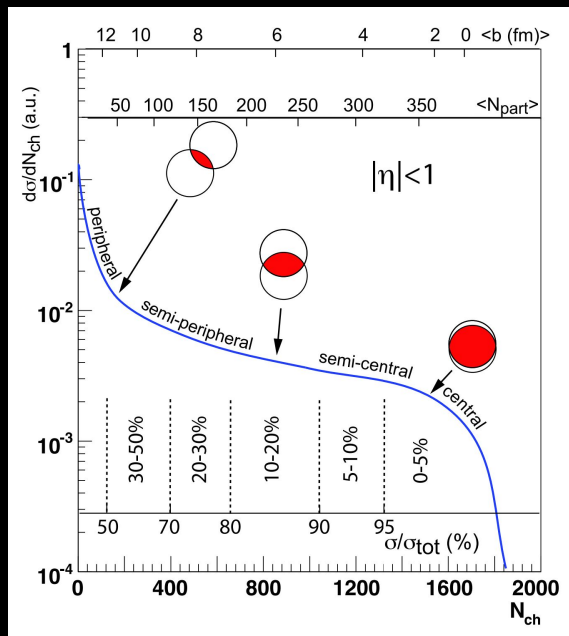
But need an *nuclear-PDF*



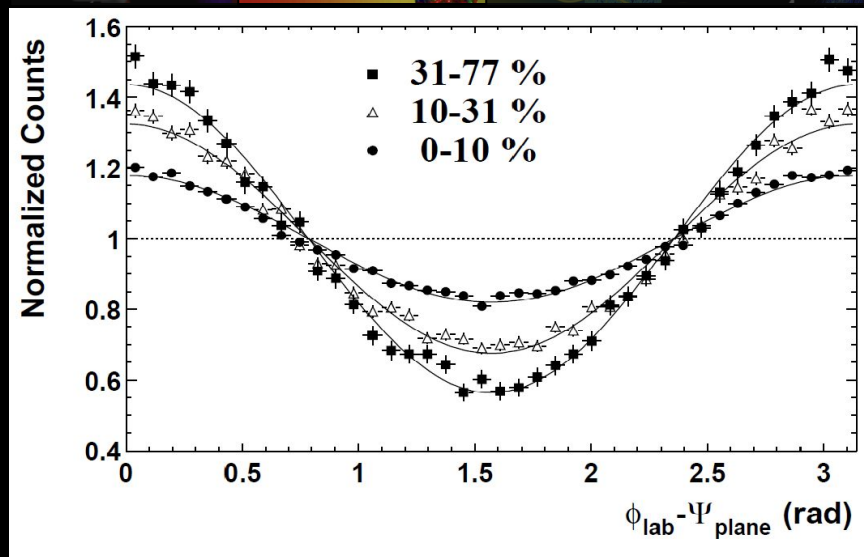
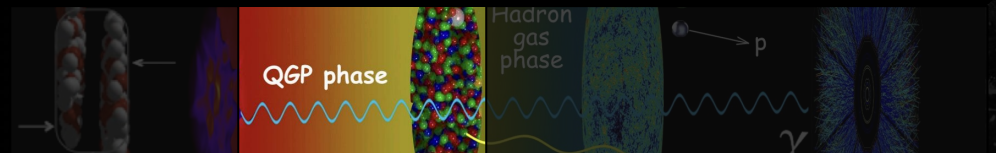
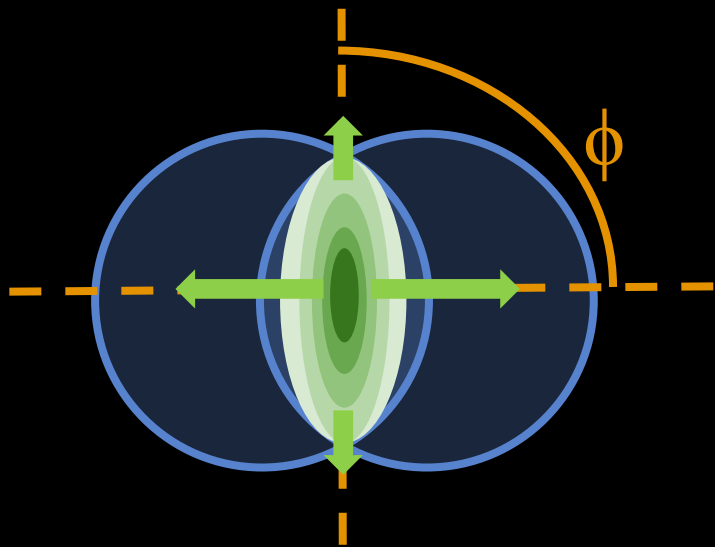
The initial condition



Usually MC Glauber



Hydrodynamics

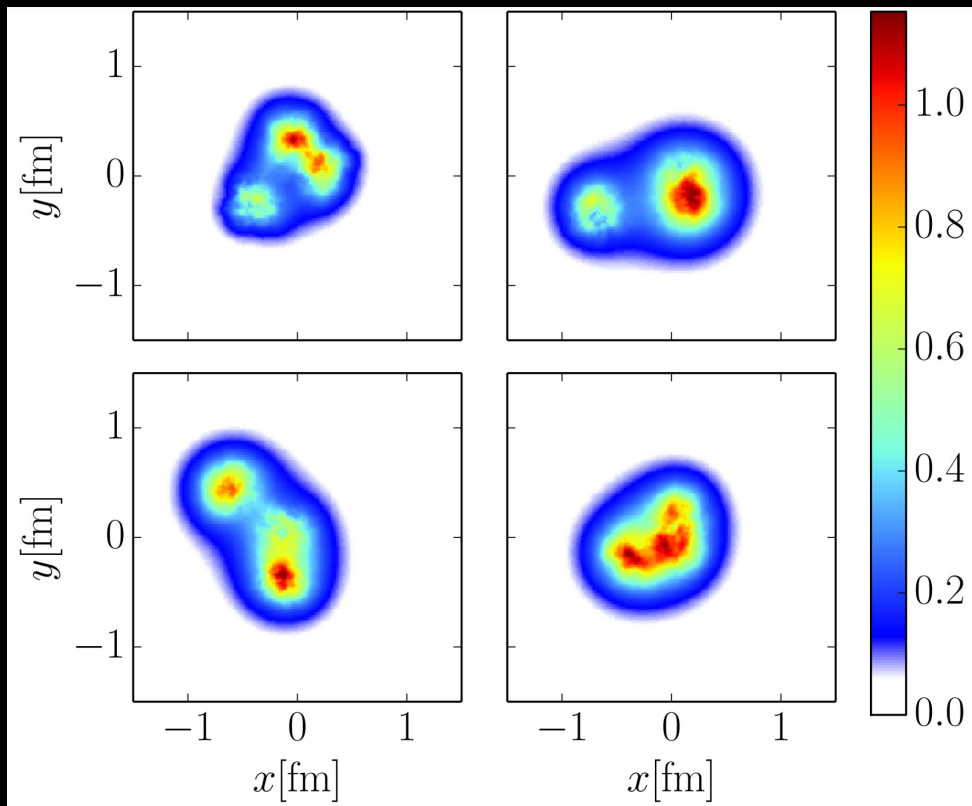


Open source codes you can play with:

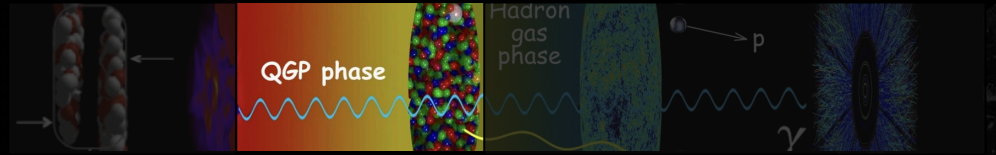
- MUSIC
- Trajectum

$$\frac{d^3 N}{d\phi dp_T dy} \propto [1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi) + \dots]$$

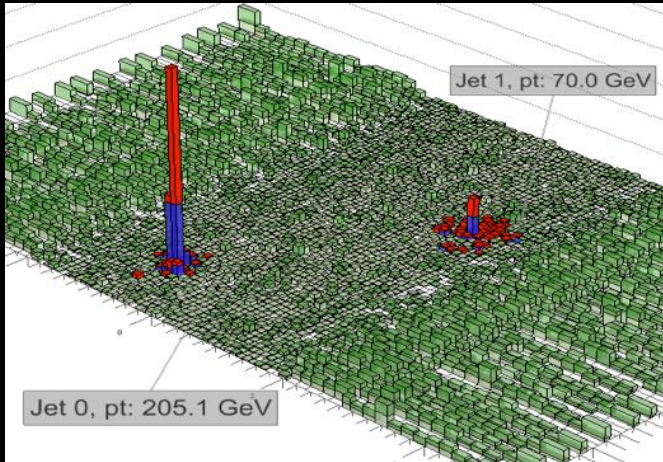
Actually - can extract the initial condition



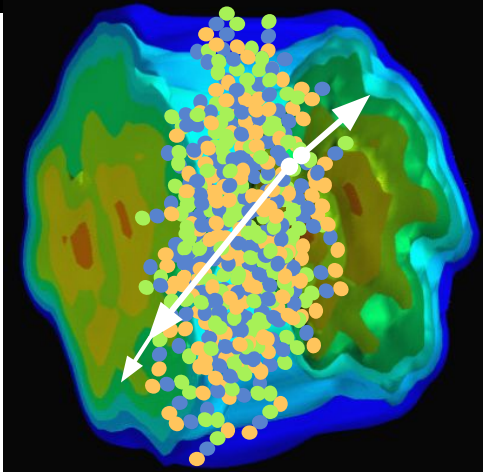
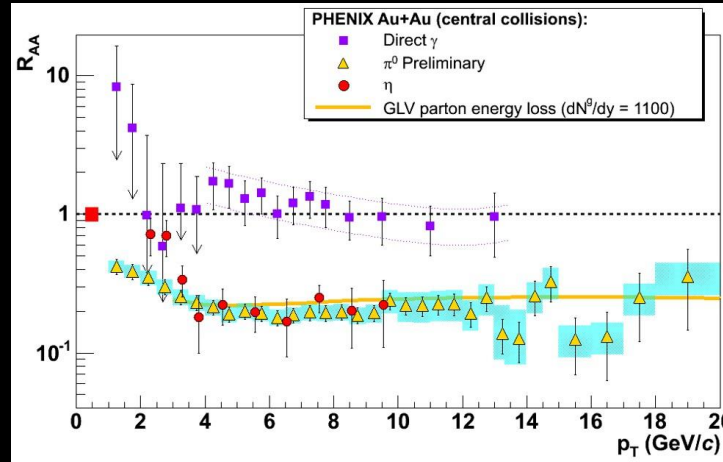
Jets - physics



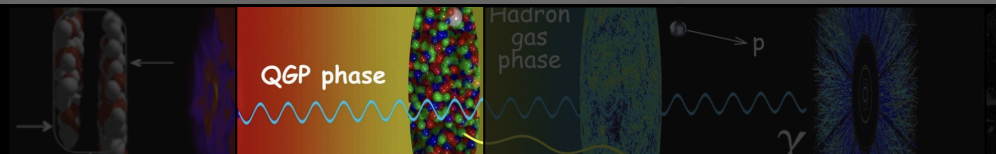
$$R_{AA}(p_T) = \frac{1}{\langle T_{AA} \rangle} \frac{dN_{AA}/dp_T}{d\sigma_{pp}/dp_T}$$



CMS PbPb 2.76 TeV, Nov. 2010. PRC 84 (2011)



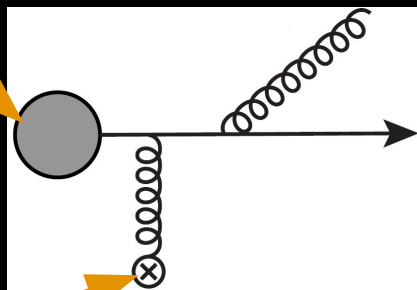
Jets - JEWEL



1

1. Production:
Sample energy density
distribution of collision

Use PYTHIA to generate
particles



2

2. Vacuum Radiation:
DGLAP evolution

3

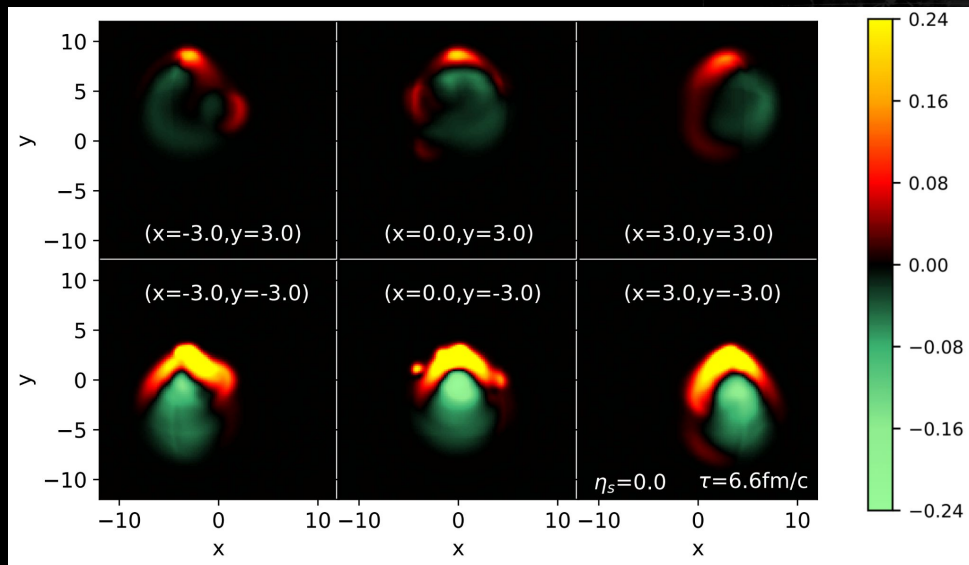
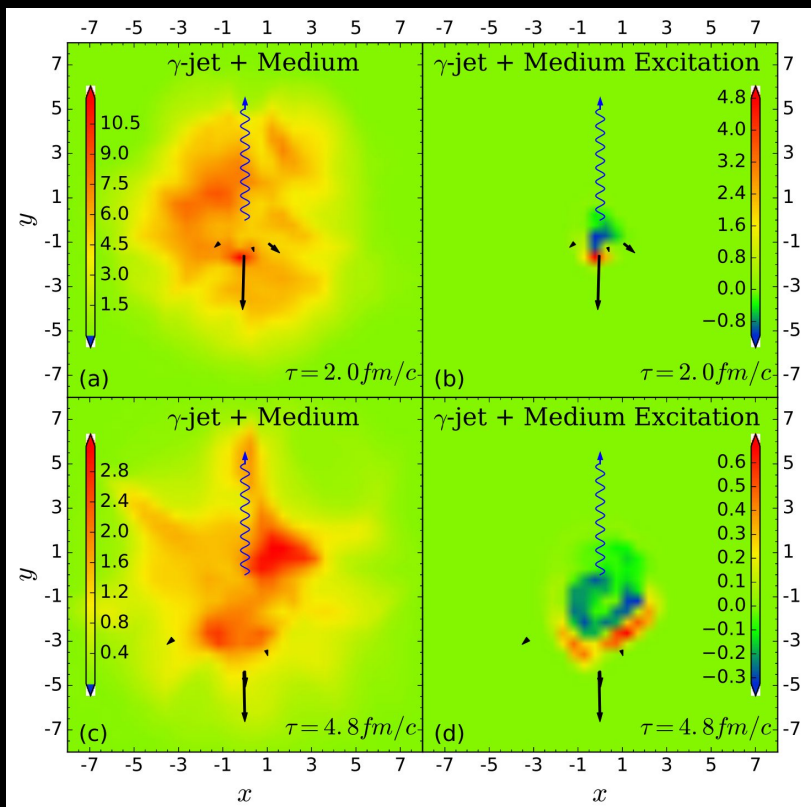
3. In-medium radiation:
Sample medium model to get T .

Use 2 – 2 scattering matrix
+ parton shower

4

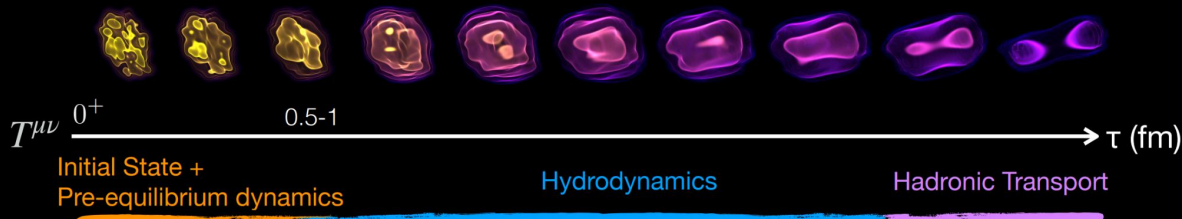
4. Give evolved jet and all
radiated partons back to
PYTHIA for full event
generation

CoLBT - full hydrodynamic response



Everything together - JETSCAPE

THE MULTI-STAGE THEORETICAL FRAMEWORK

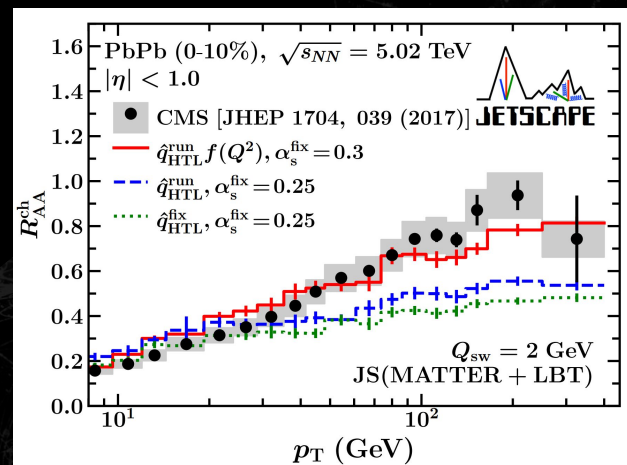
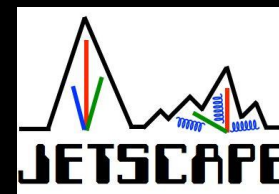


MULTI-STAGE JET EVOLUTION

Large- Q ($> Q_0$)	Small- Q ($< Q_0$)	
	Large- E	Small- E
<p>MATTER</p> <p>Majumder(13) Kordell, Majumder(17) Cao, Majumder(17)</p> <p>Radiation dominated Virtuality ordered splitting</p> <p>Higher-Twist formalism</p>	<p>LBT</p> <p>Wang, Zhu(13), Luo, et al.(15,18) Cao, et al.(16,17), He, et al.(18)</p> <p>Scattering dominated On-shell parton transport</p> <p>Higher-Twist formalism</p>	<p>MARTINI</p> <p>Schenke, Gale, Jeon(09), Park, Jeon, Gale(17,18)</p> <p>Diffusion into medium</p> <p>AMY formalism</p> <p>$\mathcal{N} = 4$ super Yang-Mills</p>
	<p>AdS/CFT</p> <p>Chesler, Rajagopal(14, 15) Pablos, et al.(15,16,17)</p>	

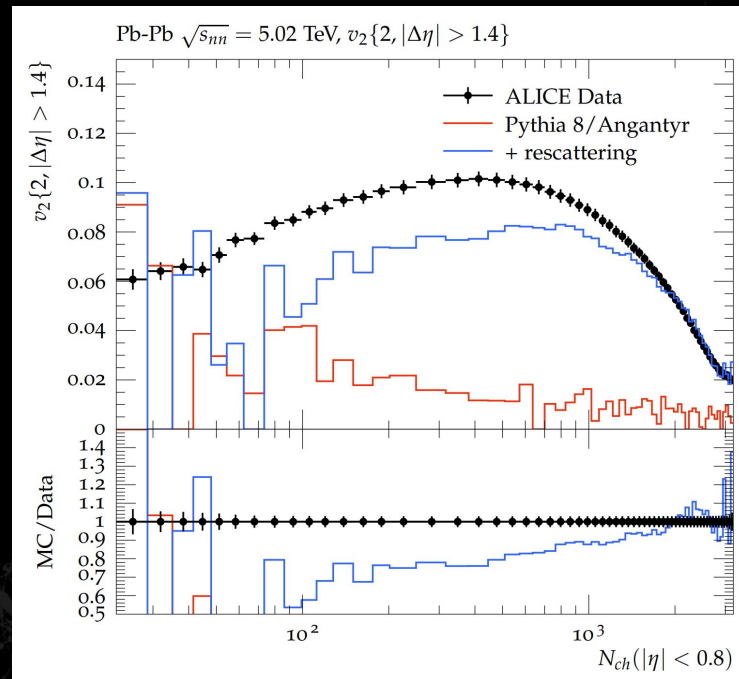
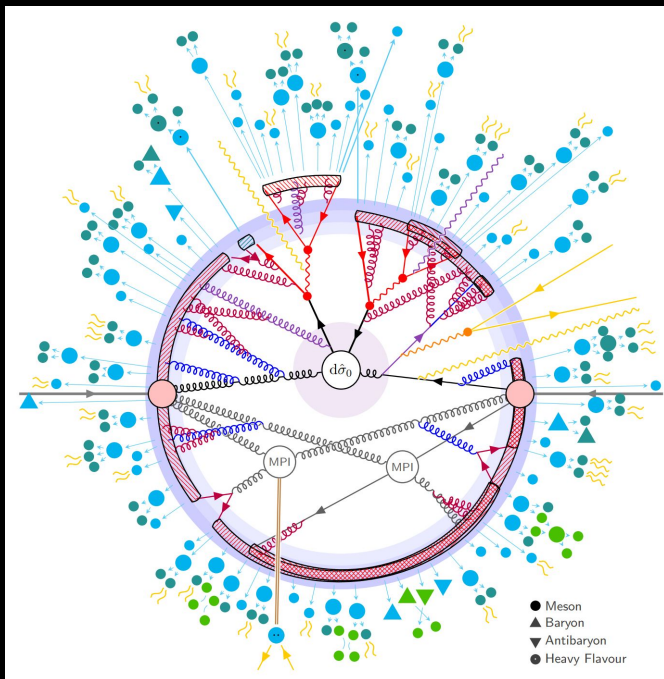
@ Y. Tachibana

Chun Shen



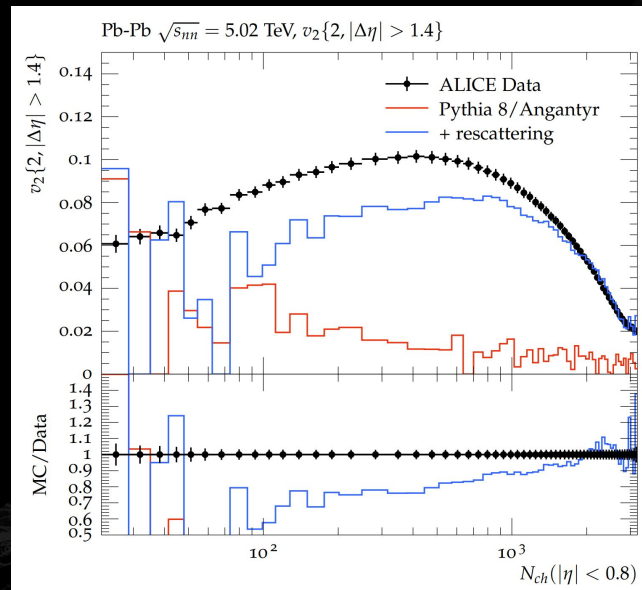
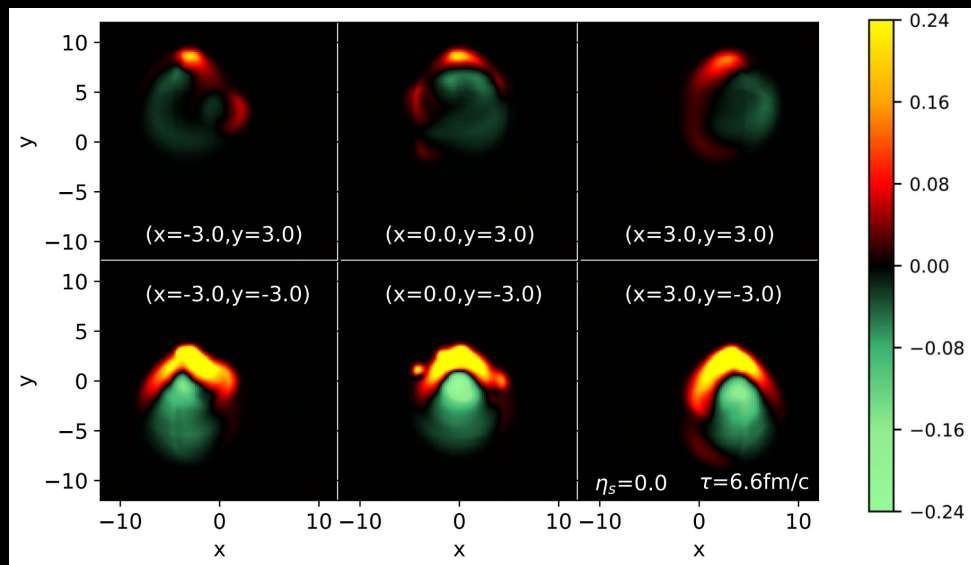
Free online summer
school every year in July.
2023

What if there's no QGP? - Angantyr (Gleipnir)

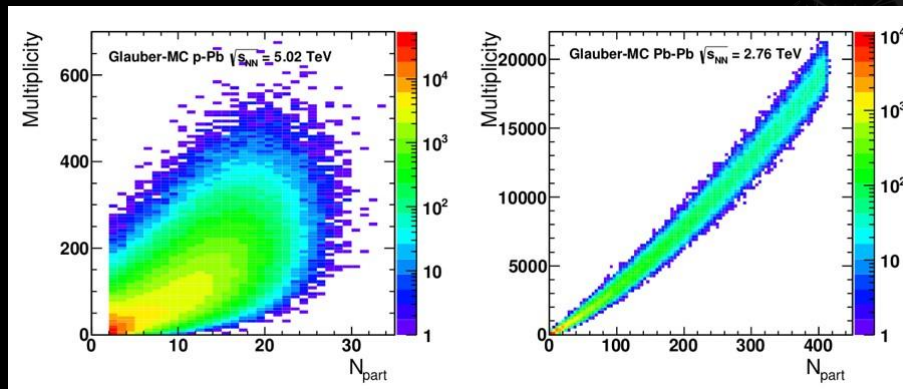
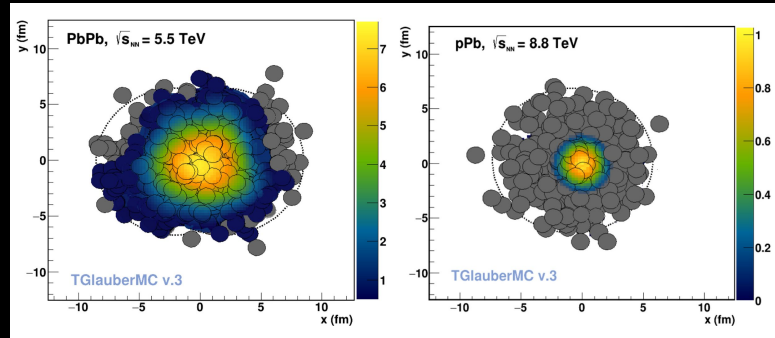


Summary

- Lots of physics
- Hard to model - but freely available
- Not even really obvious if we have it right



Backups



Not a linear response

Need radial flow (therefore initial momentum) to reproduce final eccentricities, so the hydrodynamic response that converts initial eccentricities to final momentum anisotropies is not linear.

