Francesco Becattini

Flusso diretto, viscosità, vorticità e polarizzazione della Λ

MOTIVAZIONI

Alcuni risultati con il codice ECHO-QGP di possibile interesse

A study of vorticity formation in high energy nuclear collisions

F. Becattini,[1,2] G. Inghirami,[3,1] V. Rolando,[4,5] A. Beraudo,[6]
L. Del Zanna,[1,2,7] A. De Pace,[6] M. Nardi,[6] G. Pagliara,[4,5] and V. Chandra[8]

[1]*Dipartimento di Fisica e Astronomia, Università di Firenze, Via G. Sansone 1, I-50019 Sesto F.no (Firenze), Italy*
[2]*INFN - Sezione di Firenze, Via G. Sansone 1, I-50019 Sesto F.no (Firenze), Italy*
[3]*Frankfurt Institute for Advanced Studies (FIAS), Johann Wolfgang Goethe University, Frankfurt am Main, Germany*
[4]*Dipartimento di Fisica e Scienze della Terra, Università di Ferrara, Via Saragat 1, I-44100 Ferrara, Italy*
[5]*INFN - Sezione di Ferrara, Via Saragat 1, I-44100 Ferrara, Italy*
[6]*INFN - Sezione di Torino, Via P. Giuria 1, I-10125 Torino, Italy*
[7]*INAF - Osservatorio Astrofisico di Arcetri, L.go E. Fermi 5, I-50125 Firenze, Italy*
[8]*Indian Institute of Technology Gandhinagar, Ahmedabad-382424, Gujrat, India*

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We present a quantitative study of vorticity formation in peripheral ultrarelativistic heavy ion collisions at $\sqrt{s_{\rm NN}} = 200$ GeV by using the ECHO-QGP numerical code, implementing relativistic dissipative hydrodynamics in the causal Israel-Stewart framework in 3+1 dimensions with an initial Bjorken flow profile. We consider and discuss different definitions of vorticity which are relevant in relativistic hydrodynamics. After demonstrating the excellent capabilities of our code, we show that, with the initial conditions needed to reproduce the measured directed flow in peripheral collisions corresponding to an average impact parameter $b = 11.6$ fm and with the Bjorken flow profile for a viscous Quark Gluon Plasma with $\eta/s = 0.1$ fixed, a vorticity of the order of some 10^{-2} c/fm can develop at freezeout. The ensuing polarization of Λ baryons does not exceed 1.4% at midrapidity. We show that the amount of developed directed flow is sensitive to both the initial angular momentum of the plasma and its viscosity.

arXiv:1501.04468

Calcolo in 3D+1 con condizioni iniziali "standard"

P. Bozek and I. Wyskiel, Phys. Rev. C 81 (2010) 054902

$$\varepsilon(x,y,\eta) = \varepsilon_0 \, W(x,y,\eta) \, H(\eta),$$

$$u^x = u^y = u^\eta = 0,$$

$$W(x,y,\eta) = \frac{(1-\alpha)\, W_N(x,y,\eta) + \alpha\, n_{BC}(x,y)}{(1-\alpha)\, W_N(0,0,0) + \alpha\, n_{BC}(0,0)\big|_{\mathbf{b}=0}}.$$

$$H(\eta) = \exp\left(-\frac{\tilde{\eta}^2}{2\sigma_\eta^2}\theta(\tilde{\eta})\right) \qquad \tilde{\eta} = |\eta| - \eta_{flat}/2$$

$$W_N(x,y,\eta) = 2\,\left(T_1(x,y) f_-(\eta) + T_2(x,y) f_+(\eta)\right)$$

$$f_-(\eta) = \begin{cases} 1 & \eta < -\eta_m \\ \dfrac{-\eta + \eta_m}{2\eta_m} & -\eta_m \le \eta \le \eta_m \\ 0 & \eta > \eta_m \end{cases}$$

$$f_+(\eta) = \begin{cases} 0 & \eta < -\eta_m \\ \dfrac{\eta + \eta_m}{2\eta_m} & -\eta_m \le \eta \le \eta_m \\ 1 & \eta > \eta_m \end{cases}$$

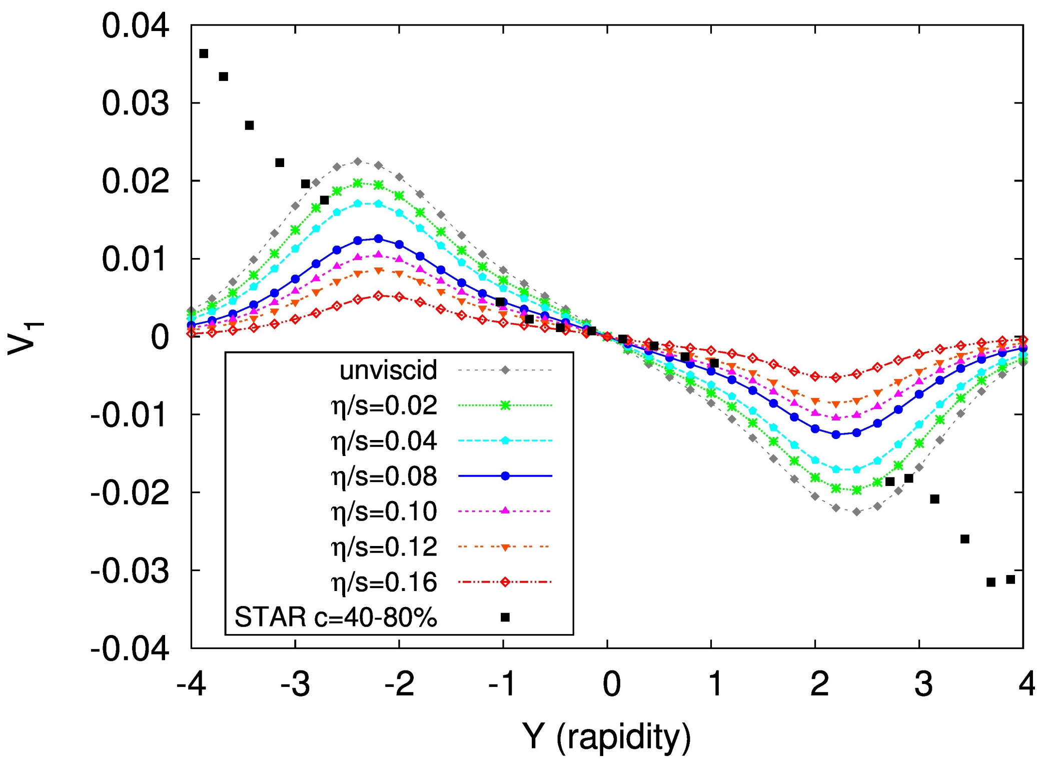
$$T_1 = T_+\left(1 - \left(1 - \frac{\sigma T_-}{A}\right)^A\right)$$

$$T_2 = T_-\left(1 - \left(1 - \frac{\sigma T_+}{A}\right)^A\right)$$

Parameter	Value
$\sqrt{s_{NN}}$	200 GeV
α	0.
ϵ_0	30 GeV/fm^3
σ_{in}	40 mb
τ_0	0.6 fm/c
η_{flat}	1
σ_η	1.3
T_{fo}	130 MeV
b	11.57fm
η_m ideal	3.36
η_m viscous	2.0
η/s	0.1

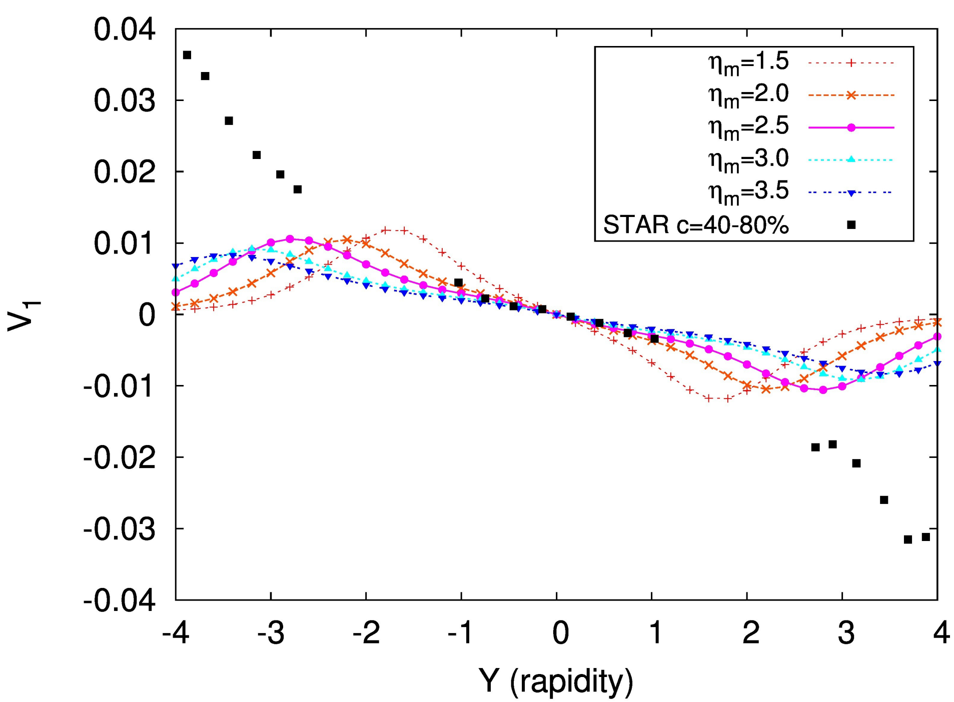
$$T_+(\mathbf{x}_T) = T(\mathbf{x}_T + \mathbf{b}/2) \qquad T_-(\mathbf{x}_T) = T(\mathbf{x}_T - \mathbf{b}/2)$$

Flusso diretto e viscosità



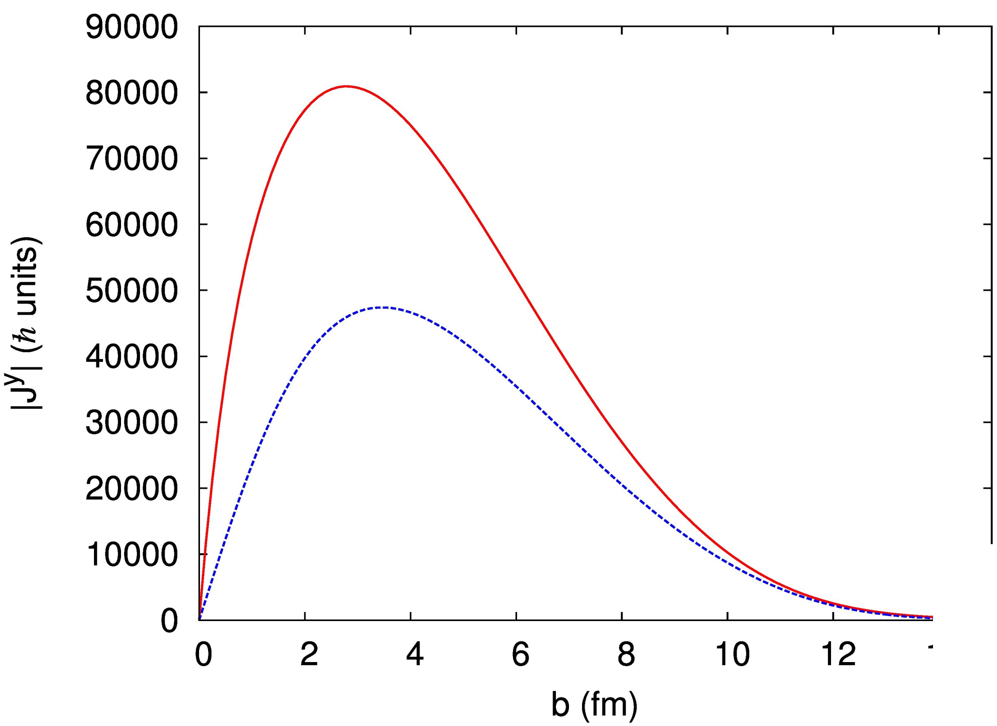
Sensibilita' del flusso diretto al rapporto η/s

Naturalmente v1 risente della parametrizzazione delle condizioni iniziali (come tutto)



Momento angolare e vorticità termica

Momento angolare stimato della zona di overlap (rosso) e del plasma (blu)



$$\varpi_{\mu\nu} = \frac{1}{2}(\partial_\nu \beta_\mu - \partial_\mu \beta_\nu)$$

$$\beta = (1/T)\, u$$

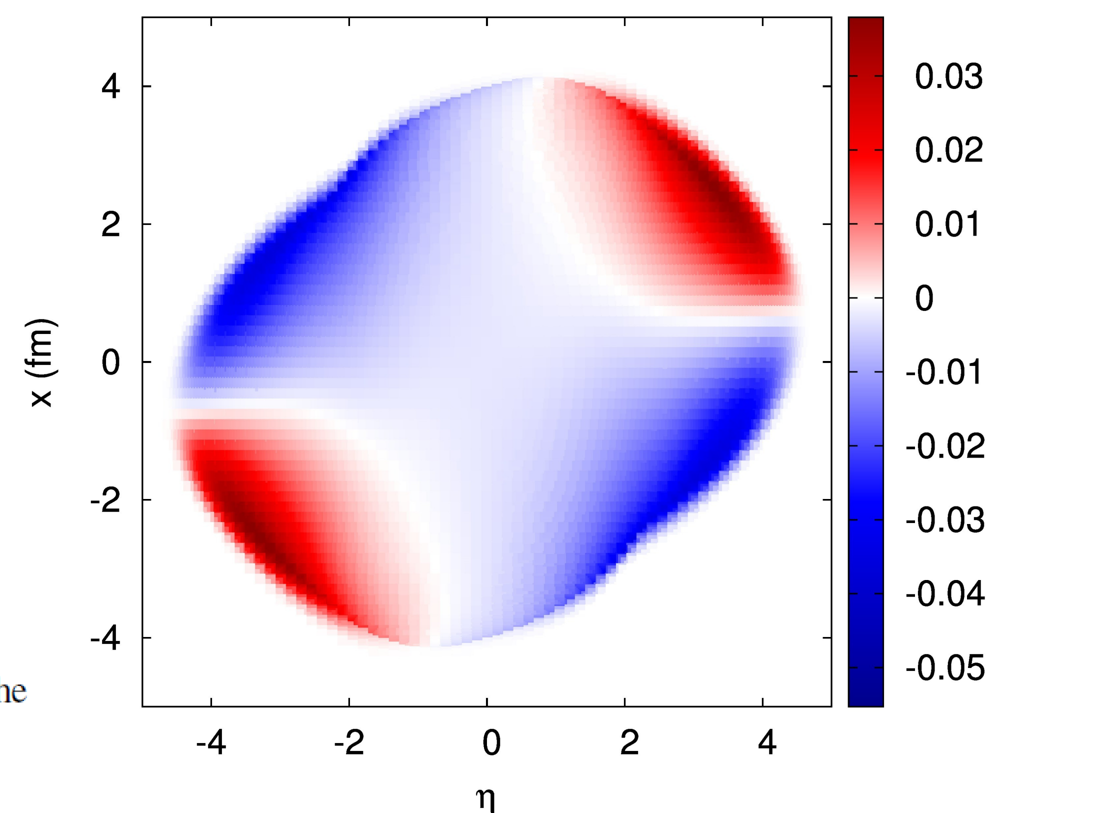


Figure 13: (color online) Contour plot of $1/\tau$-scaled ηx covariant component of the thermal vorticity, $\varpi_{\eta x}/\tau$ over the freeze-out hypersurface for $y = 0$, η/s=0.1, η_m=2.0.

Polarization four-vector in the LAB frame

In un fluido all'equilibrio locale nei gradi di liberta' di spin la vorticità termica induce una polarizzazione (F.B., V. Chandra, L. Del Zanna, E. Grossi, Ann. Phys. 338 (2013) 32)

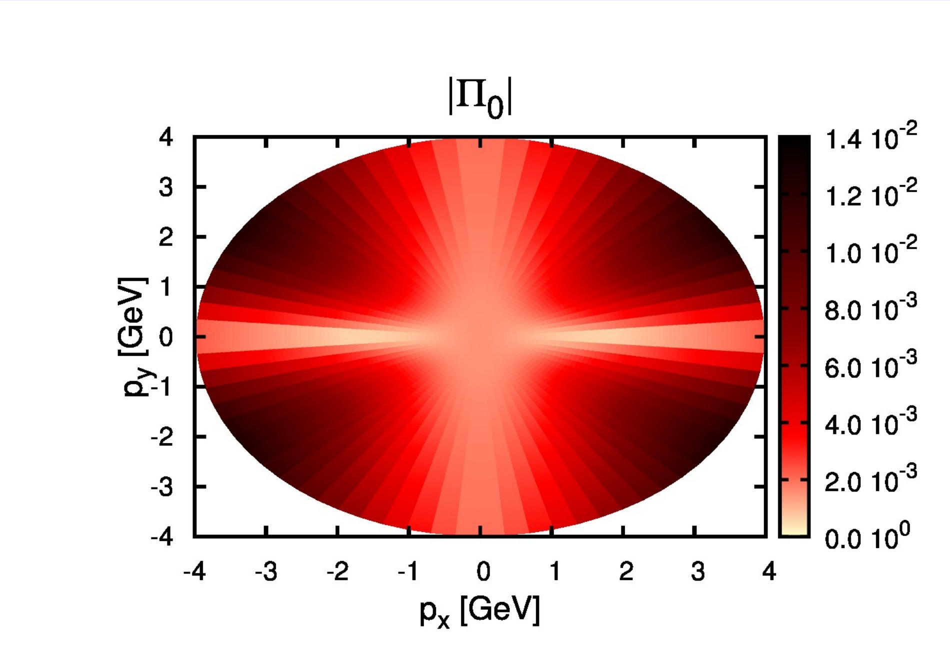
$$\langle \Pi_\mu(x,p) \rangle \simeq \frac{1}{16} \epsilon_{\mu\rho\sigma\tau} \, (1-n_F) \, (\partial^\rho \beta^\sigma - \partial^\sigma \beta^\rho) \, \frac{p^\tau}{m} = \frac{1}{8} \epsilon_{\mu\rho\sigma\tau} \, (1-n_F) \partial^\rho \beta^\sigma \frac{p^\tau}{m}$$

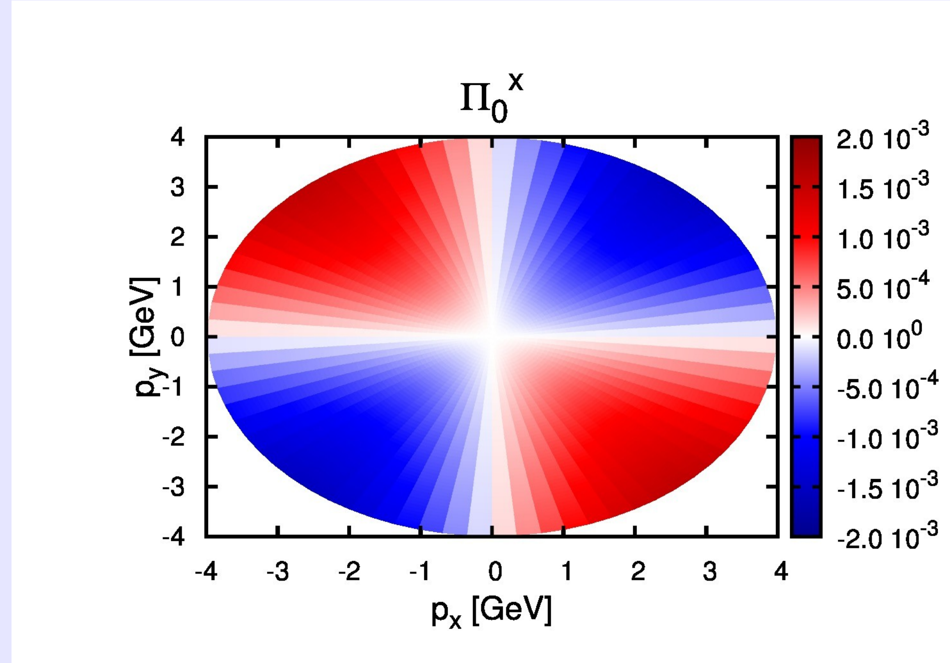
$$\langle \Pi_\mu(p) \rangle \simeq -\frac{1}{4} \epsilon_{\mu\rho\sigma\tau} \frac{p^\tau}{m} \frac{\int \mathrm{d}\Sigma_\lambda \, p^\lambda \, n_F (1-n_F) \varpi^{\rho\sigma}}{\varepsilon \frac{\mathrm{d}N}{\mathrm{d}^3 \mathrm{p}}} \simeq \frac{1}{8} \epsilon_{\mu\rho\sigma\tau} \frac{p^\tau}{m} \frac{\int \mathrm{d}\Sigma_\lambda \, p^\lambda \, n_F (1-n_F) \partial^\rho \beta^\sigma}{\int \mathrm{d}\Sigma_\lambda \, p^\lambda n_F}$$

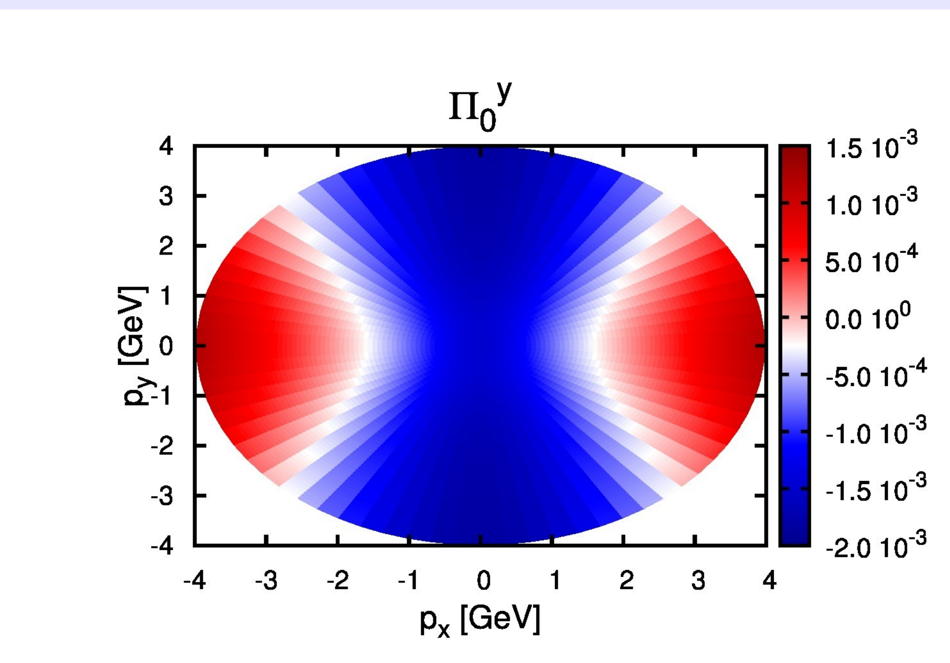
$$\mathbf{\Pi}_0 = \mathbf{\Pi} - \frac{\mathbf{p} \cdot \mathbf{\Pi}}{\epsilon(m+\epsilon)} \mathbf{p}$$

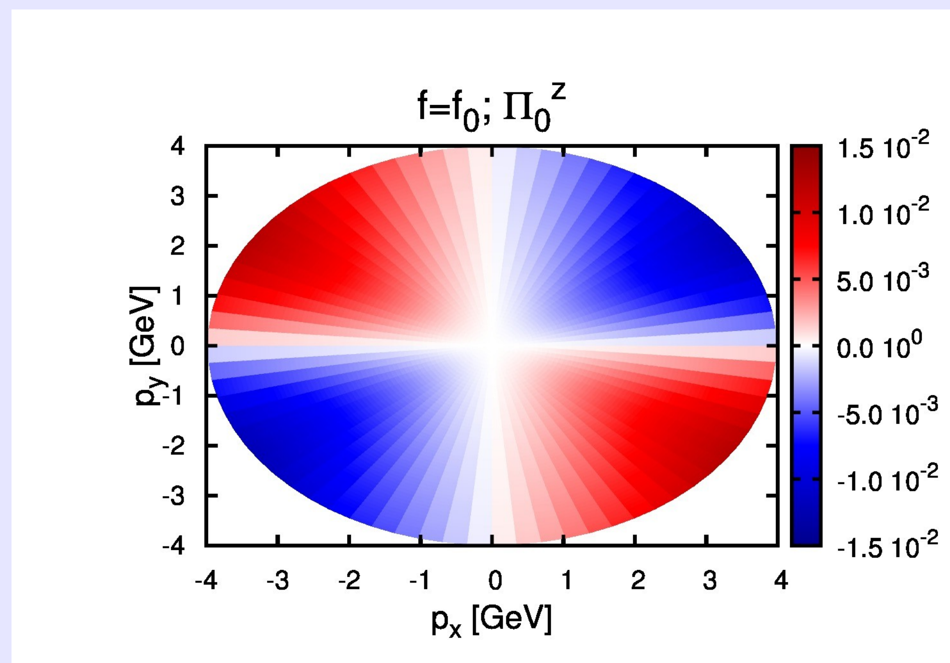
Puo' essere misurato con il decadimento

Polarization of L baryons









Conclusions

- La misura del flusso diretto dà informazioni sulla viscosità e sulle condizioni iniziali

- La misura della polarizzazione dà informazioni sulla vorticità finale

- La vorticità finale dà informazioni su quella iniziale e dunque sulle condizioni iniziali