Exploring Cosmic Ray Spectra in Supernova Remnants.

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DESY

Supernova Remnant Evolution

- Ejecta dominated stage:
  - approximate solutions for evolution of non-radiative SNRs (Truelove&McKee99)
  - hydrodynamic simulations (Dwarkadas&Chevalier98)
- Adiabatic and Radiative stage:
  - approximate analytical method for the hydrodynamic description of SNR evolution in non-uniform medium (Hnatyk&Telezhinsky07)

Cosmic Ray Acceleration

- Diffusive Shock Acceleration:
  - described by time dependent diffusion-convection equation in space and energy
- We:
  - use *test particle* approach
  - use hydrodynamic profiles of SNR parameters
  - ignore 2nd order Fermi acceleration

Transport Equation

$$\frac{\partial N}{\partial t} = \nabla(D\nabla N - \vec{v}N) - \frac{\partial}{\partial p}\left((N\dot{p}) - \frac{\nabla\vec{v}}{3}Np\right) + Q$$

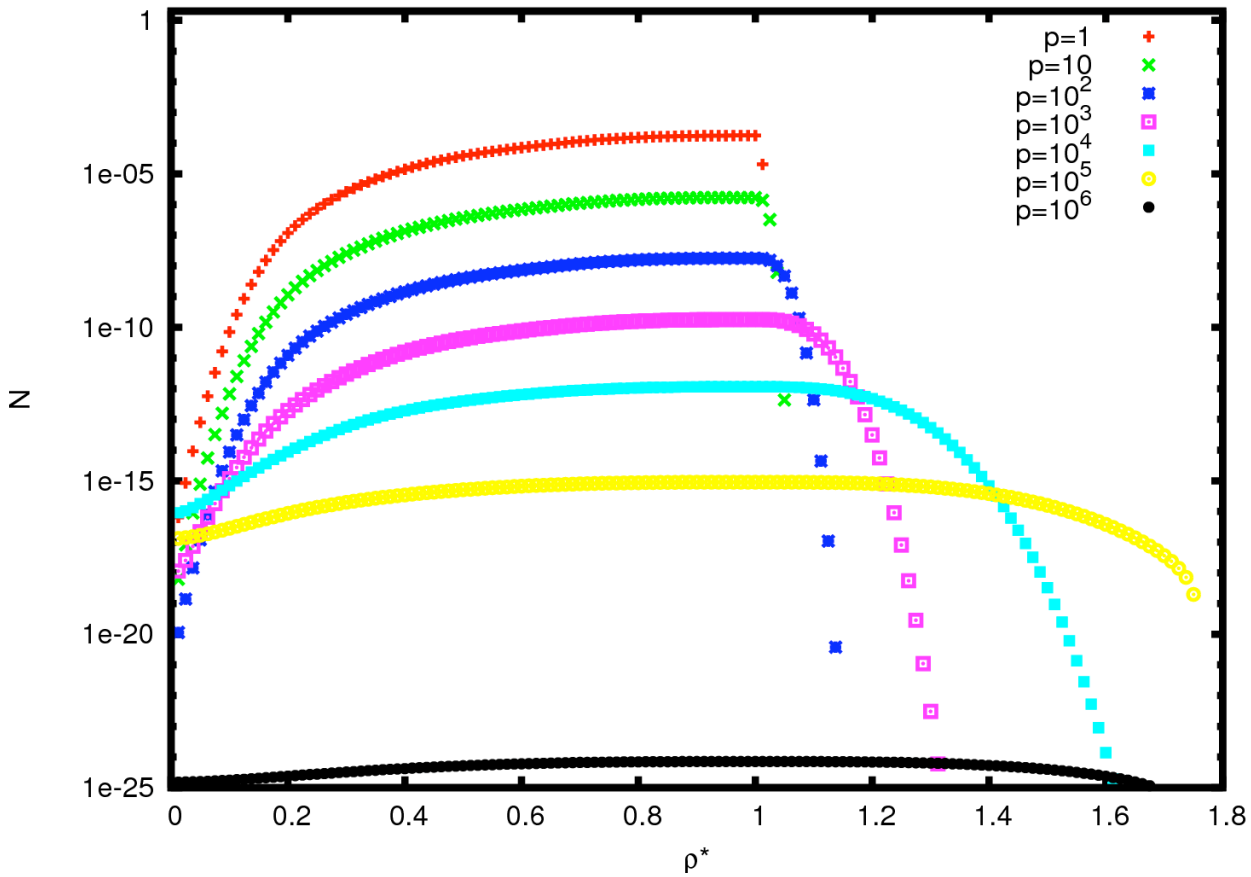
- use logarithmic scale in momentum
- apply co-moving coordinates
- apply coordinates transformation to get high resolution at shock, namely

$$\rho - 1 = (\rho^* - 1)^3$$

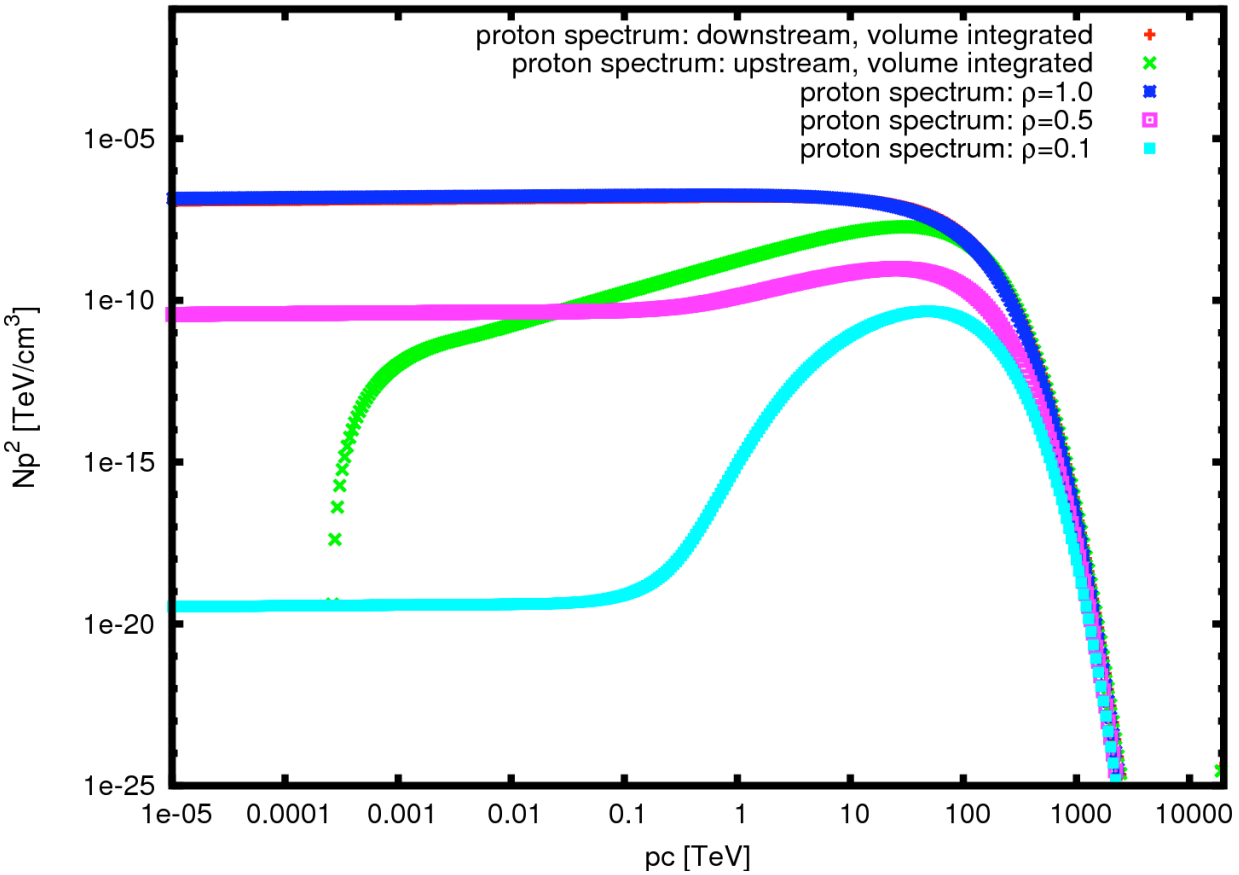
where ρ is r/R_{sh}

- use Finite Volume PDE Solver FiPy

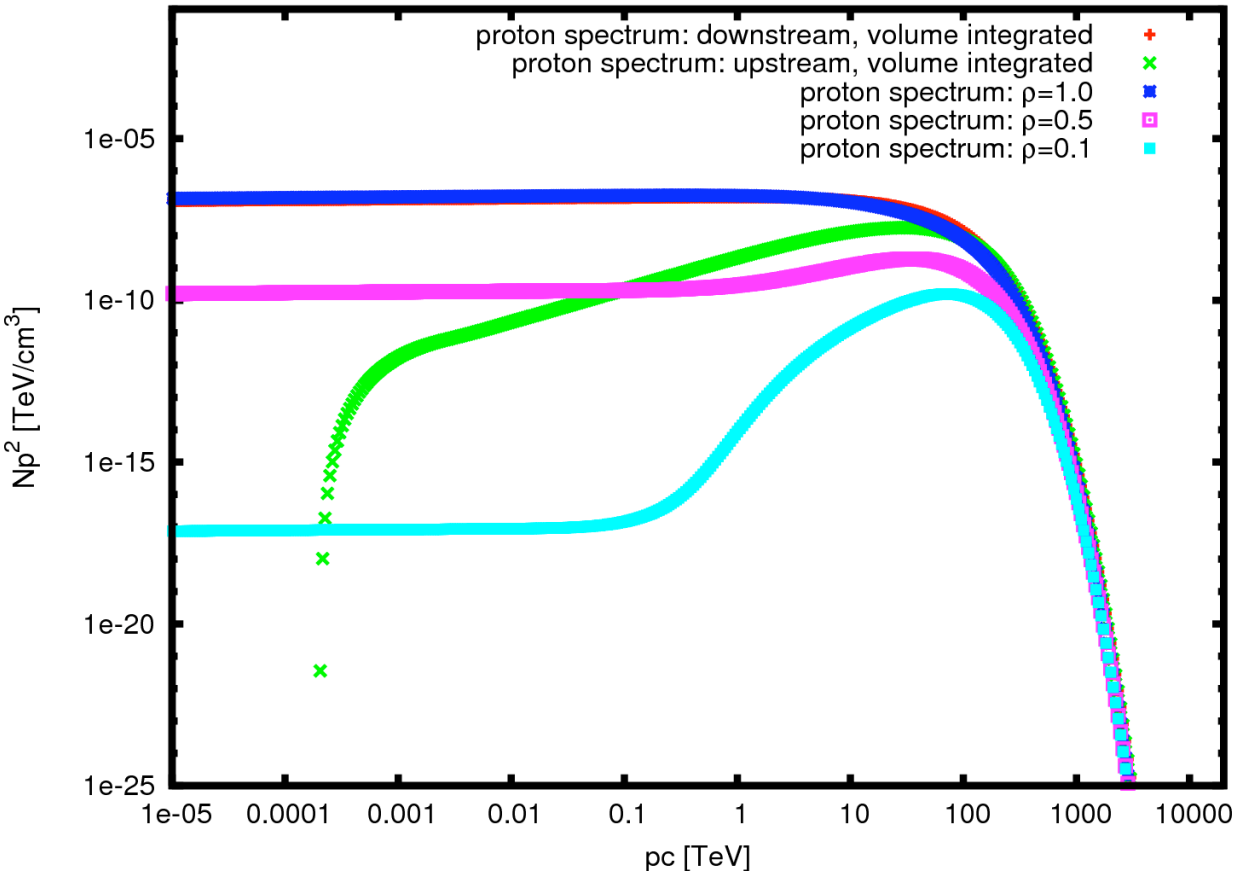
Resolution at the shock



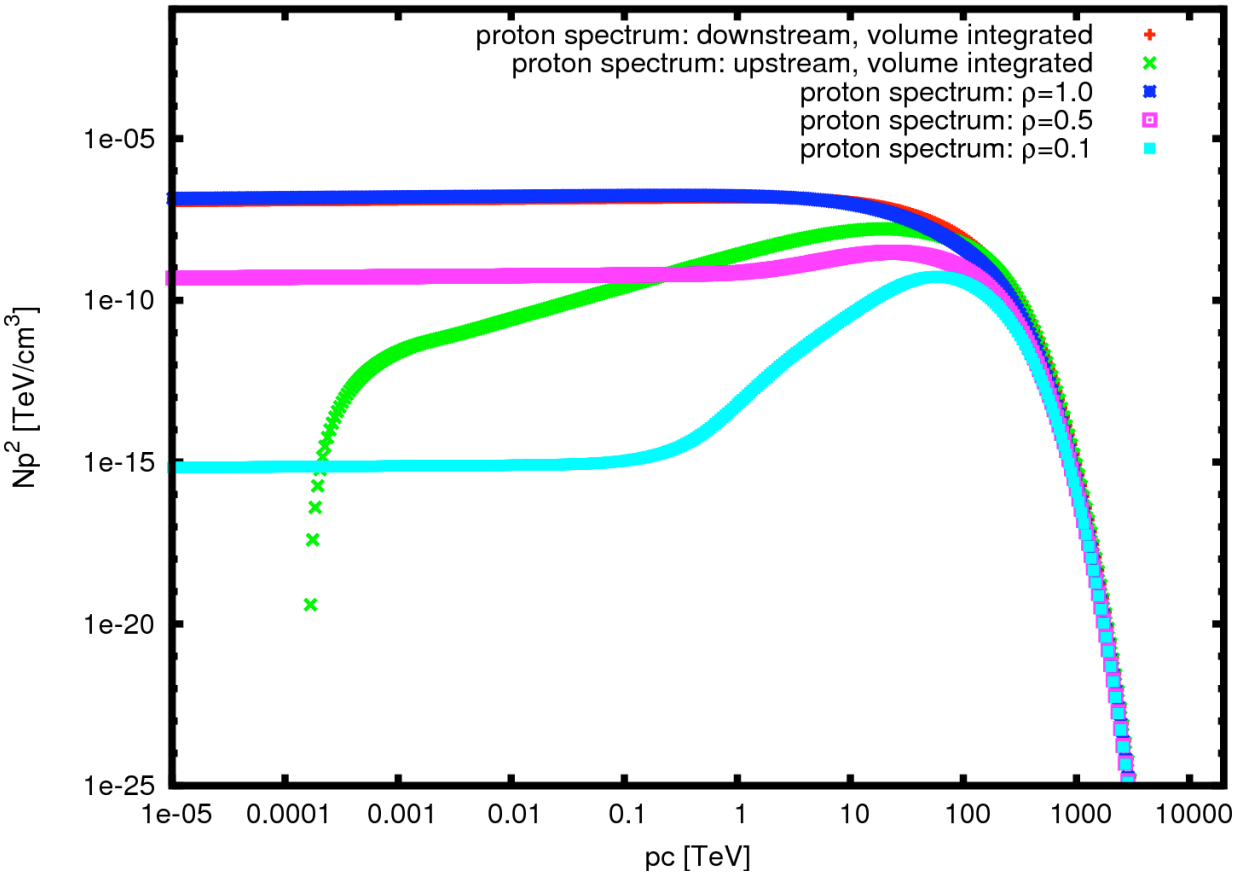
Proton Spectra: 200 years



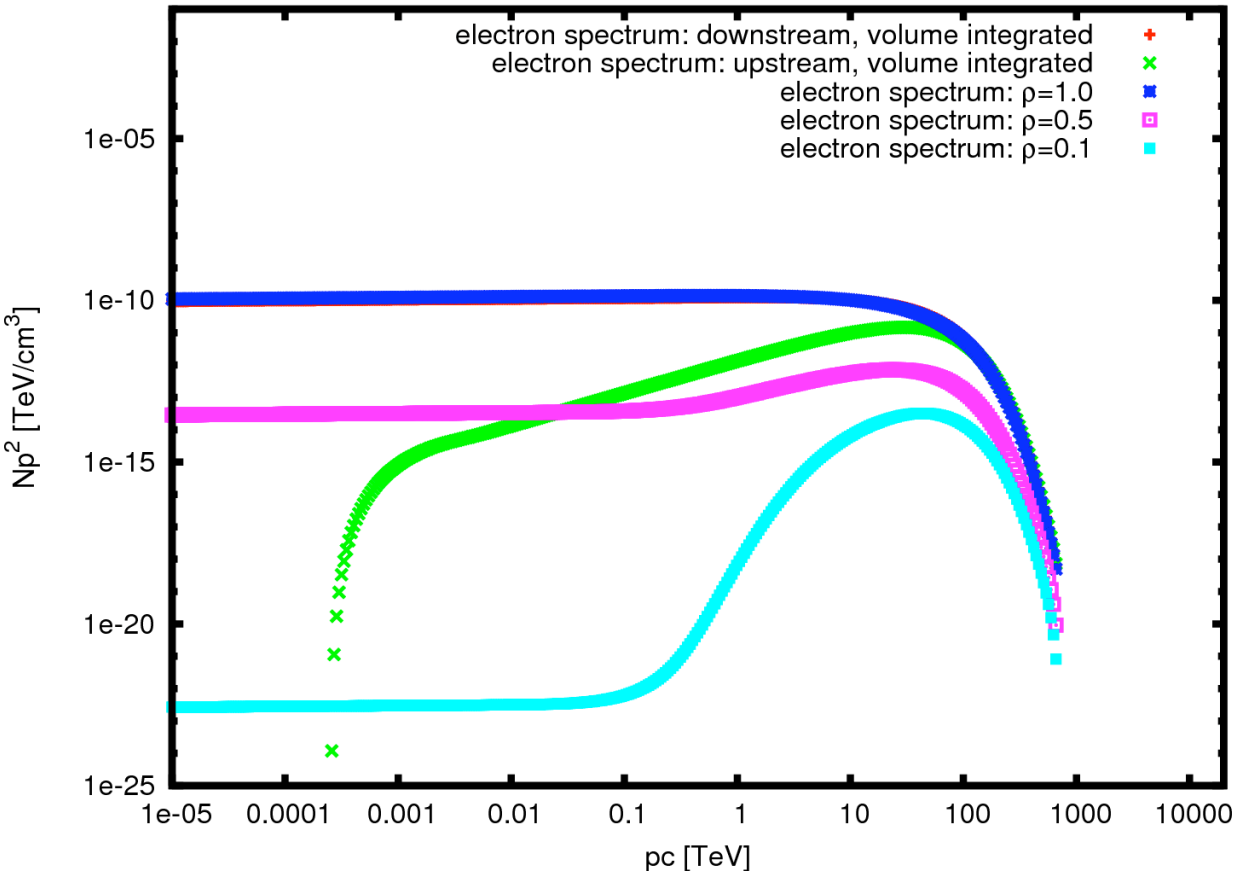
Proton Spectra: 500 years



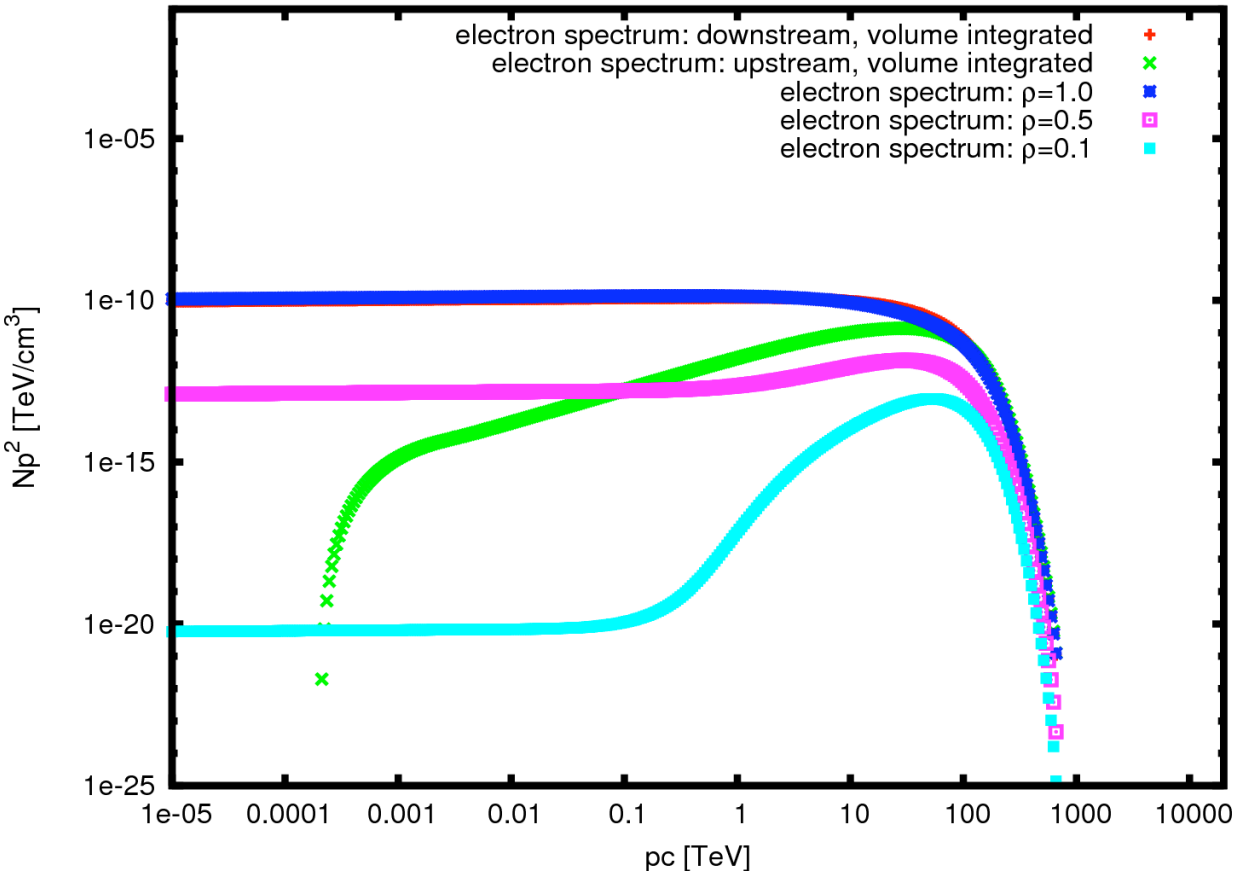
Proton Spectra:1500 years



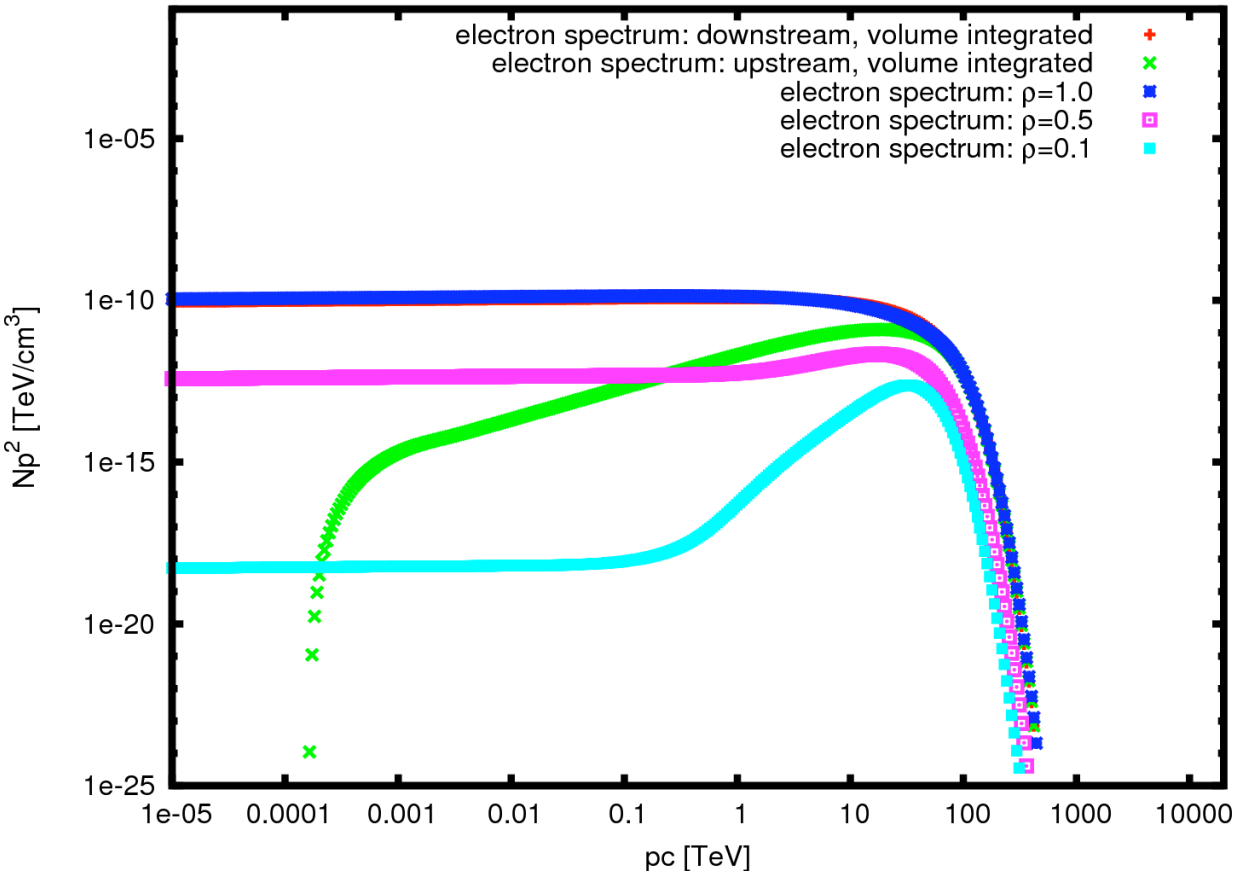
Electron spectra: 200 years



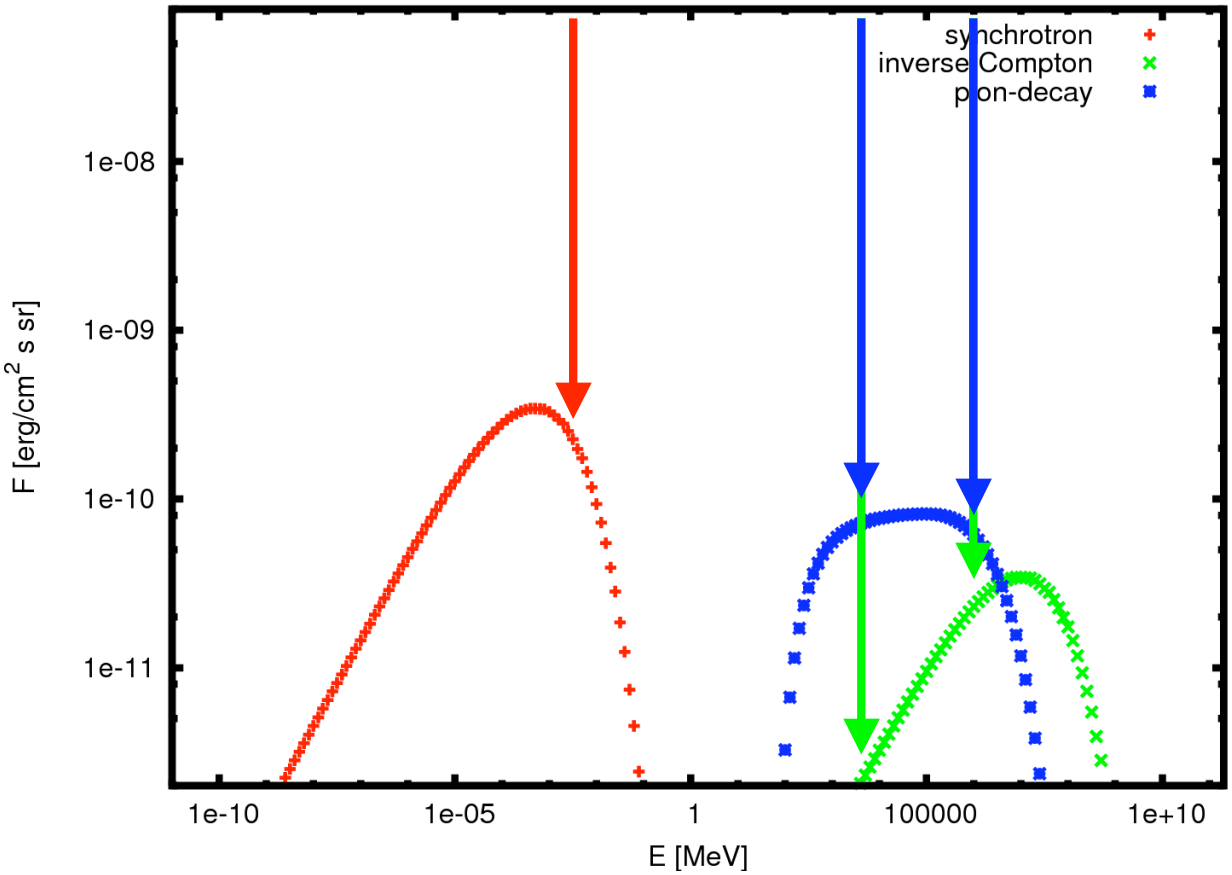
Electron spectra: 500 years



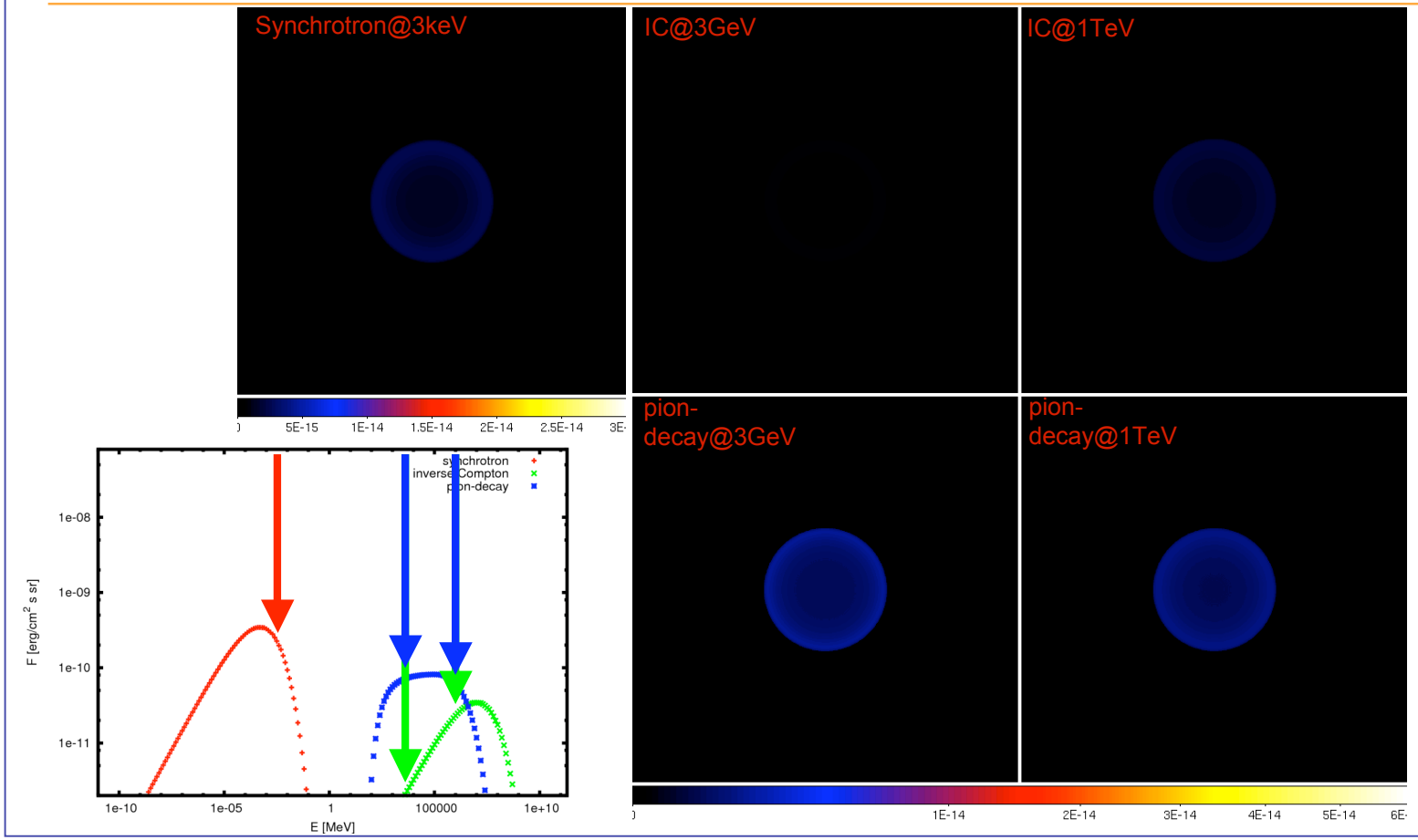
Electron spectra: 1500 years



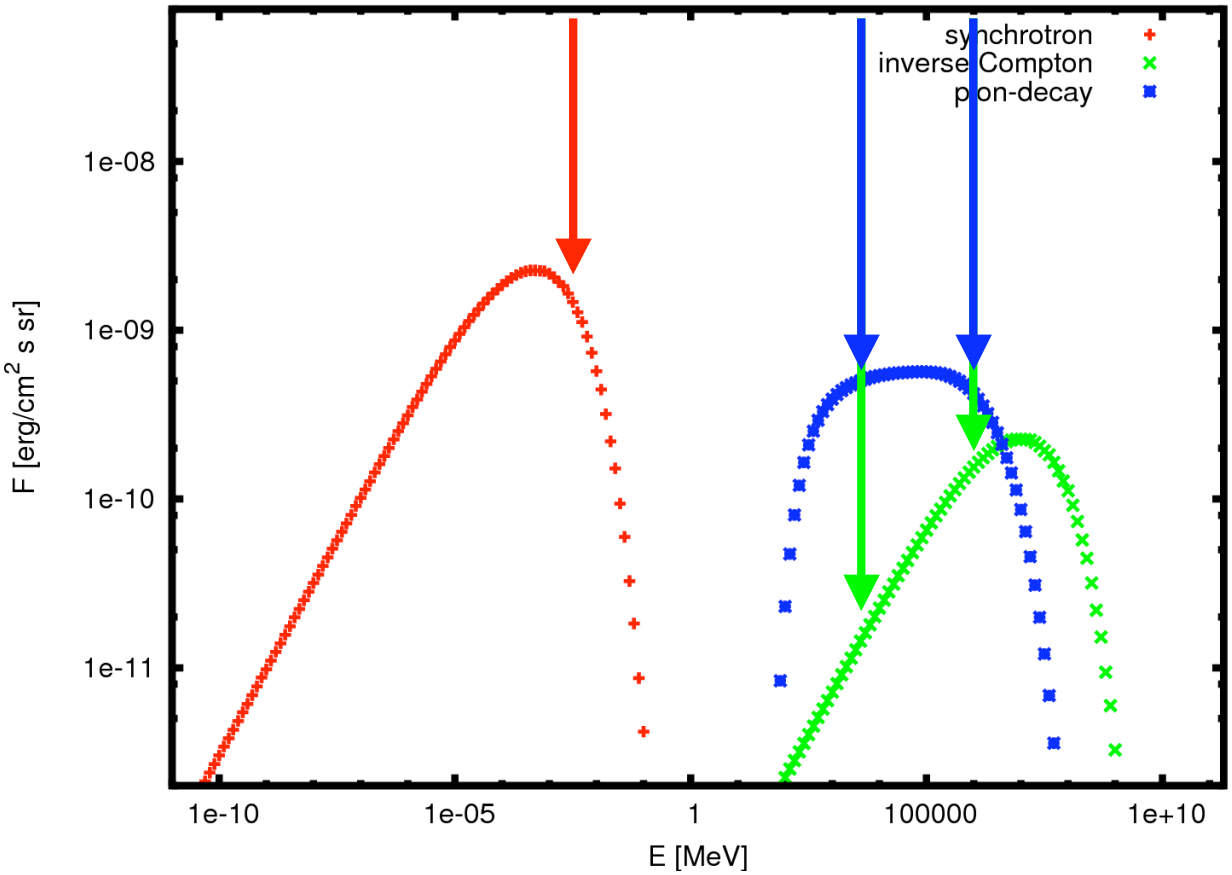
Emission Spectra: 200 years



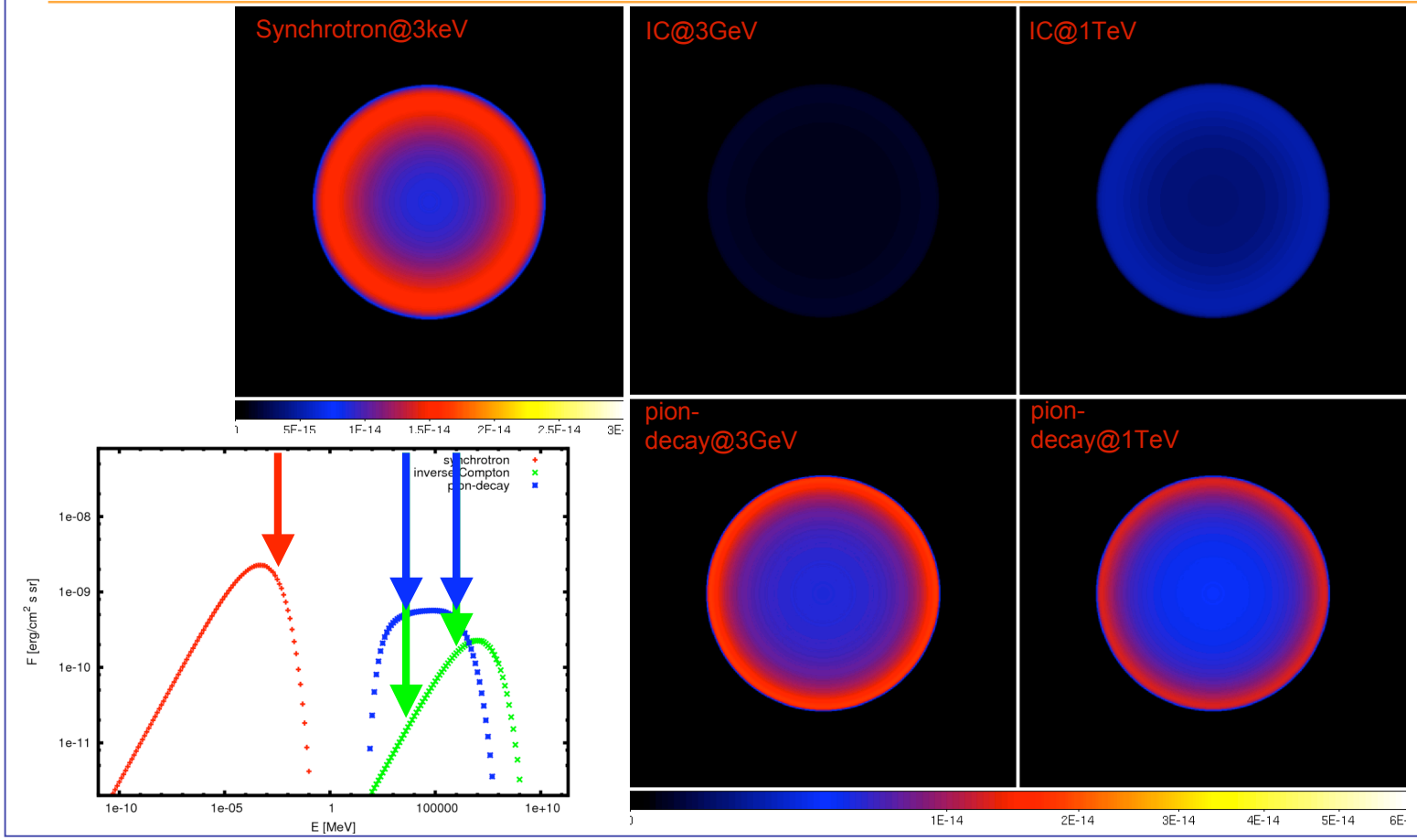
Brightness Maps: 200 years



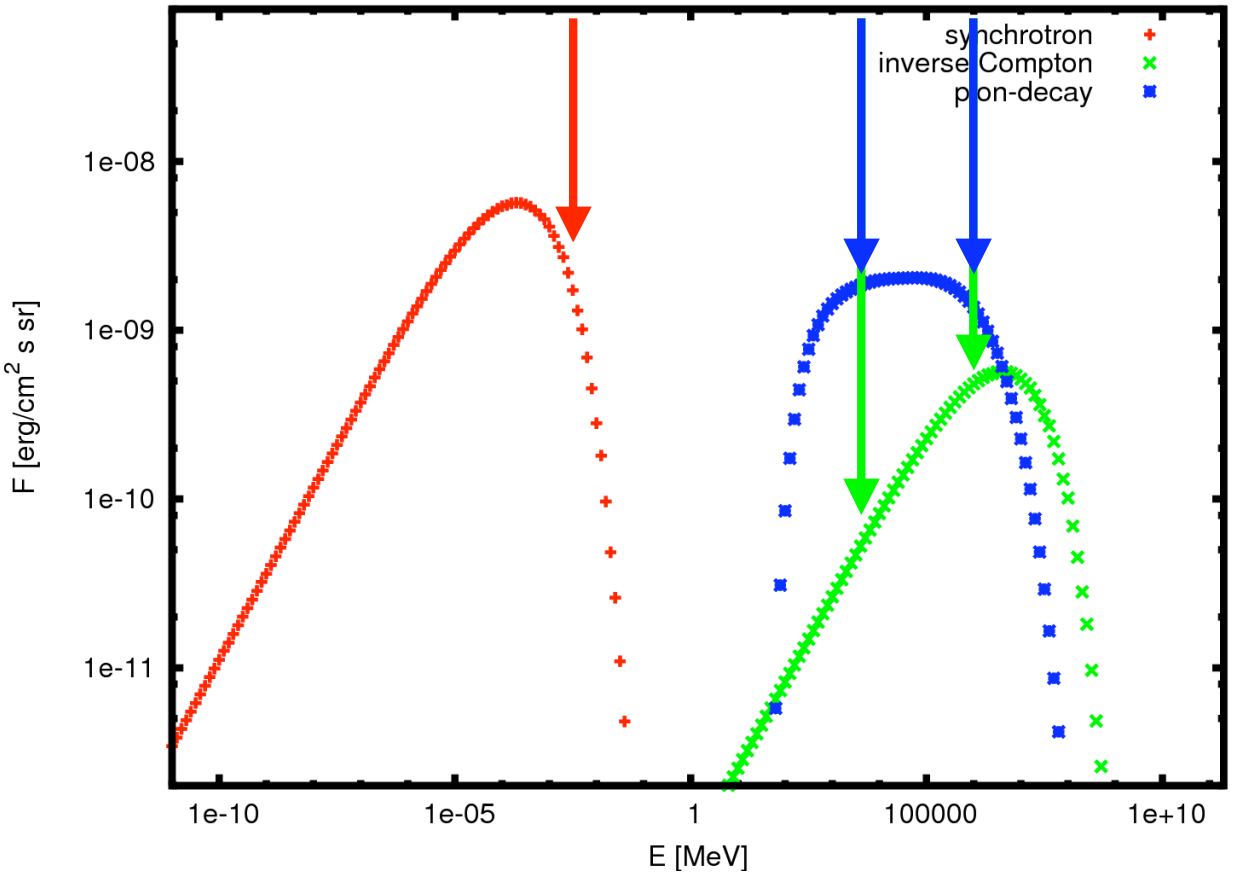
Emission Spectra: 500 years



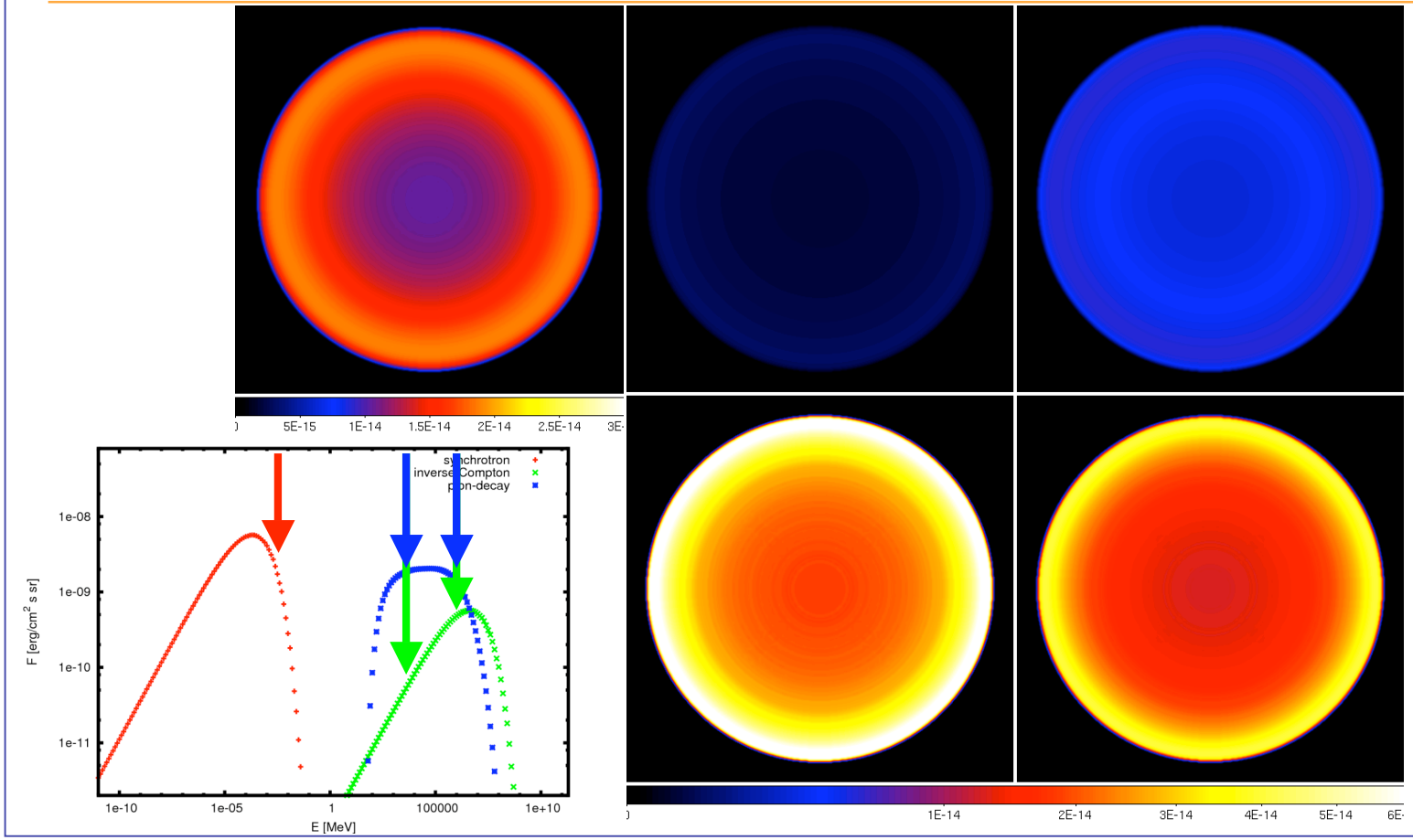
Brightness maps: 500 years



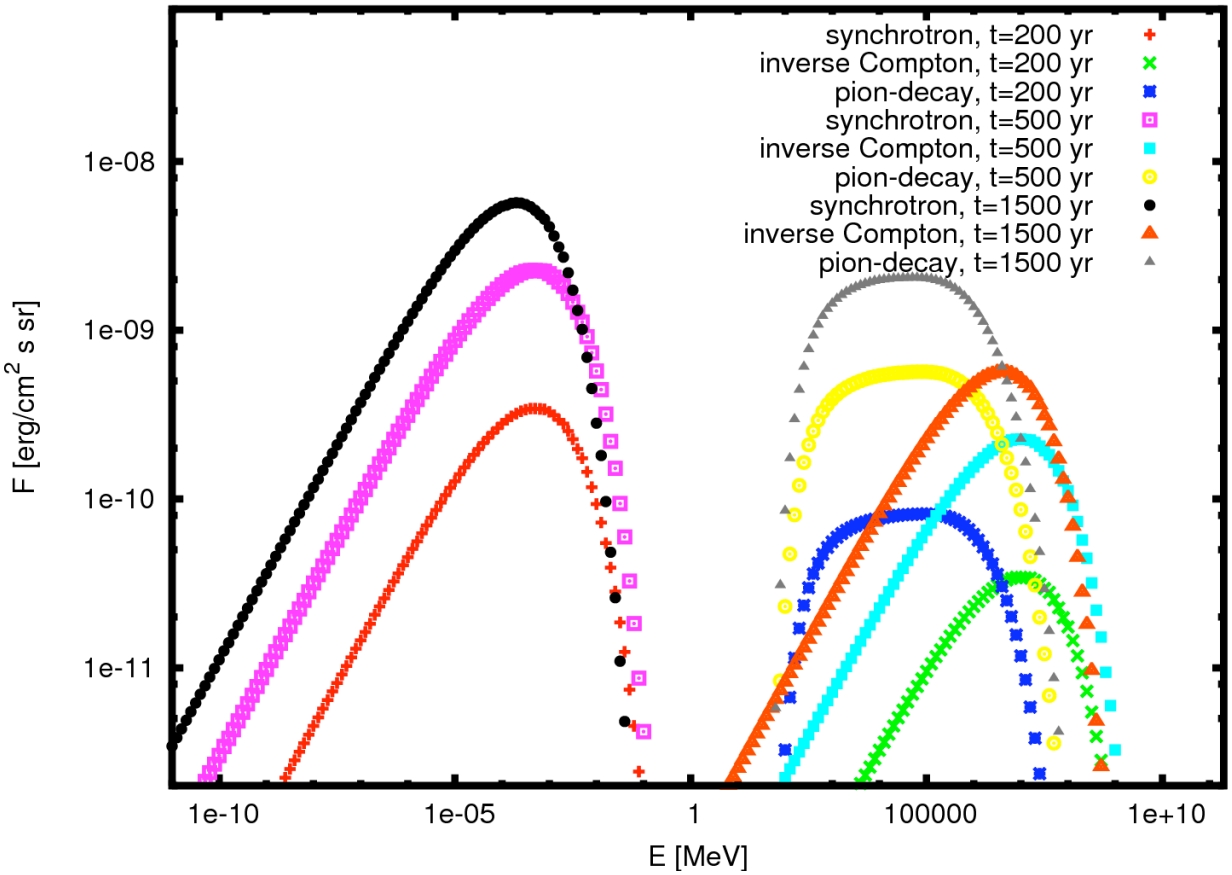
Emission Spectra:1500 years



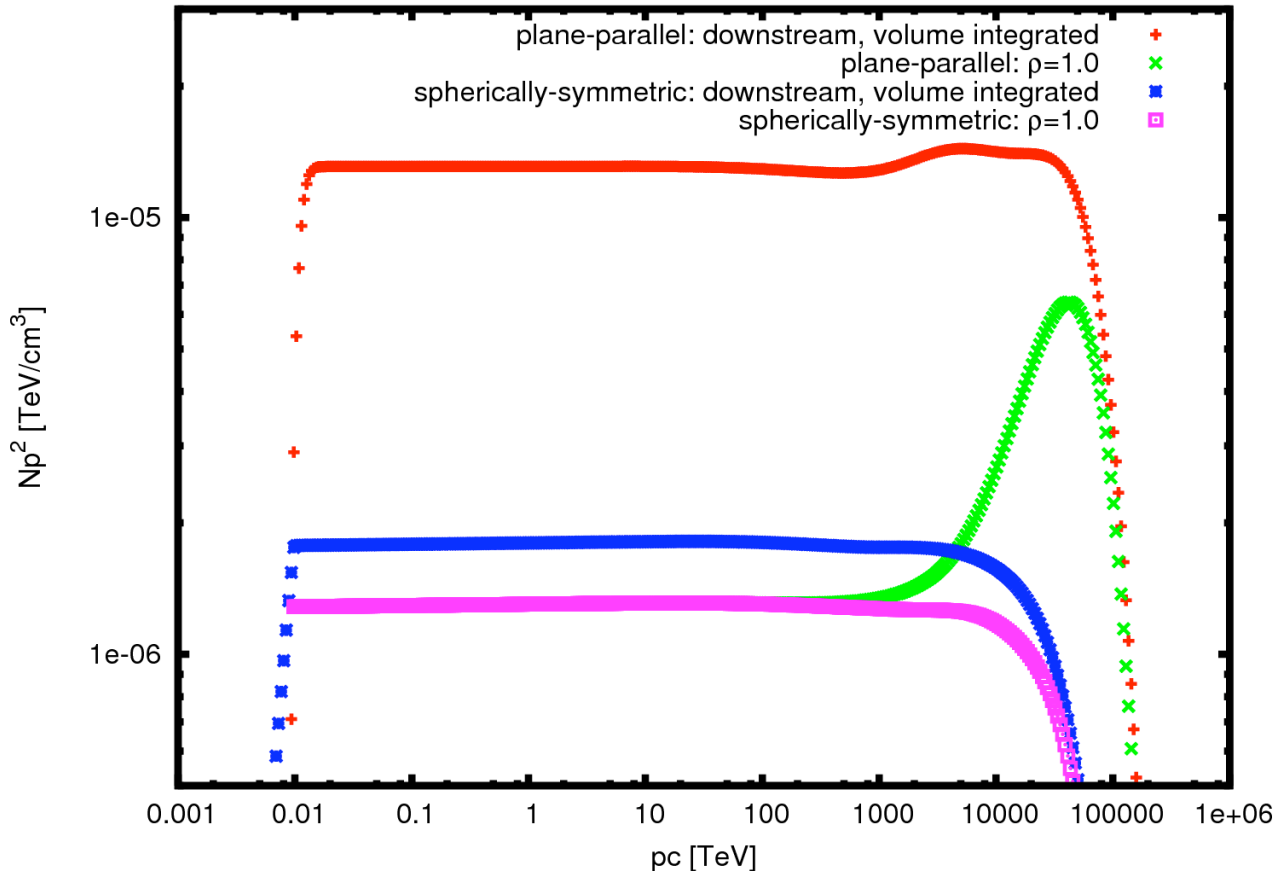
Brightness maps:1500 years



Emission Spectra: evolution



Plane-parallel vs. Spherically-symmetric: simulated hydro profiles



Conclusions

- the transformation of the transport equation of CRs helps a lot in “resolving” the shock wave region
- we applied the method to calculate the expected non-thermal spectra and respective brightness maps from a generic SNR evolving in the uniform ISM
- we use approximated as well as more realistic simulated hydro profiles of SNRs
- test runs suggest that the reverse shock is important