Collisional mechanism for prompt GRB emission

Andrei M. Beloborodov
Columbia University

GRB jets: -- relativistic

-- **heated**

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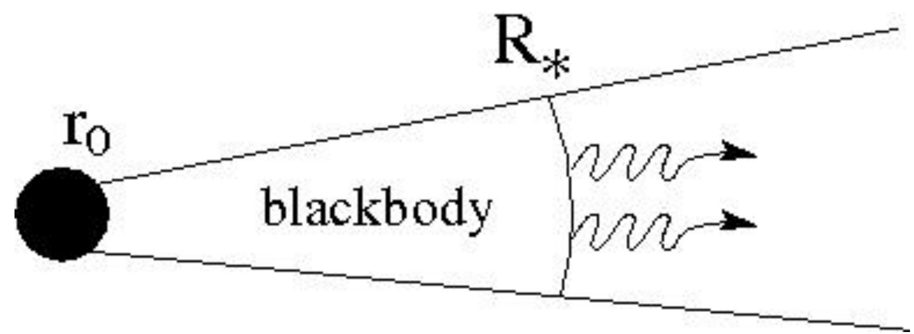
Passively cooling jet:
spectrum peaks near 1 MeV,
exponential cutoff



GRB jets: -- relativistic

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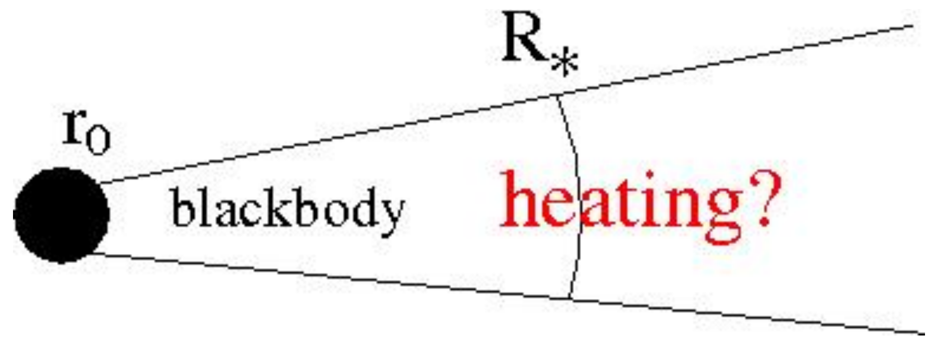


Possible heating mechanisms:

1)Dissipation of magnetic energy

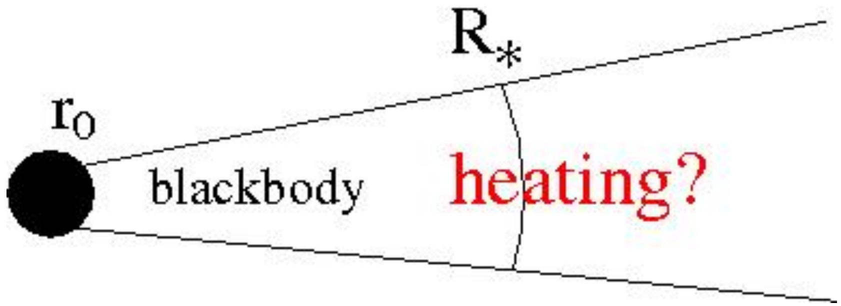
2) Internal shocks

3)Collisional heating

WANTED

-- Efficient **electron** heating

-- Nonthermal radiation spectrum
with a peak at ~ MeV



Heating mechanisms:

I. Internal shocks

II. Magnetic dissipation

III. Collisional dissipation

(a) Optically thin synchrotron

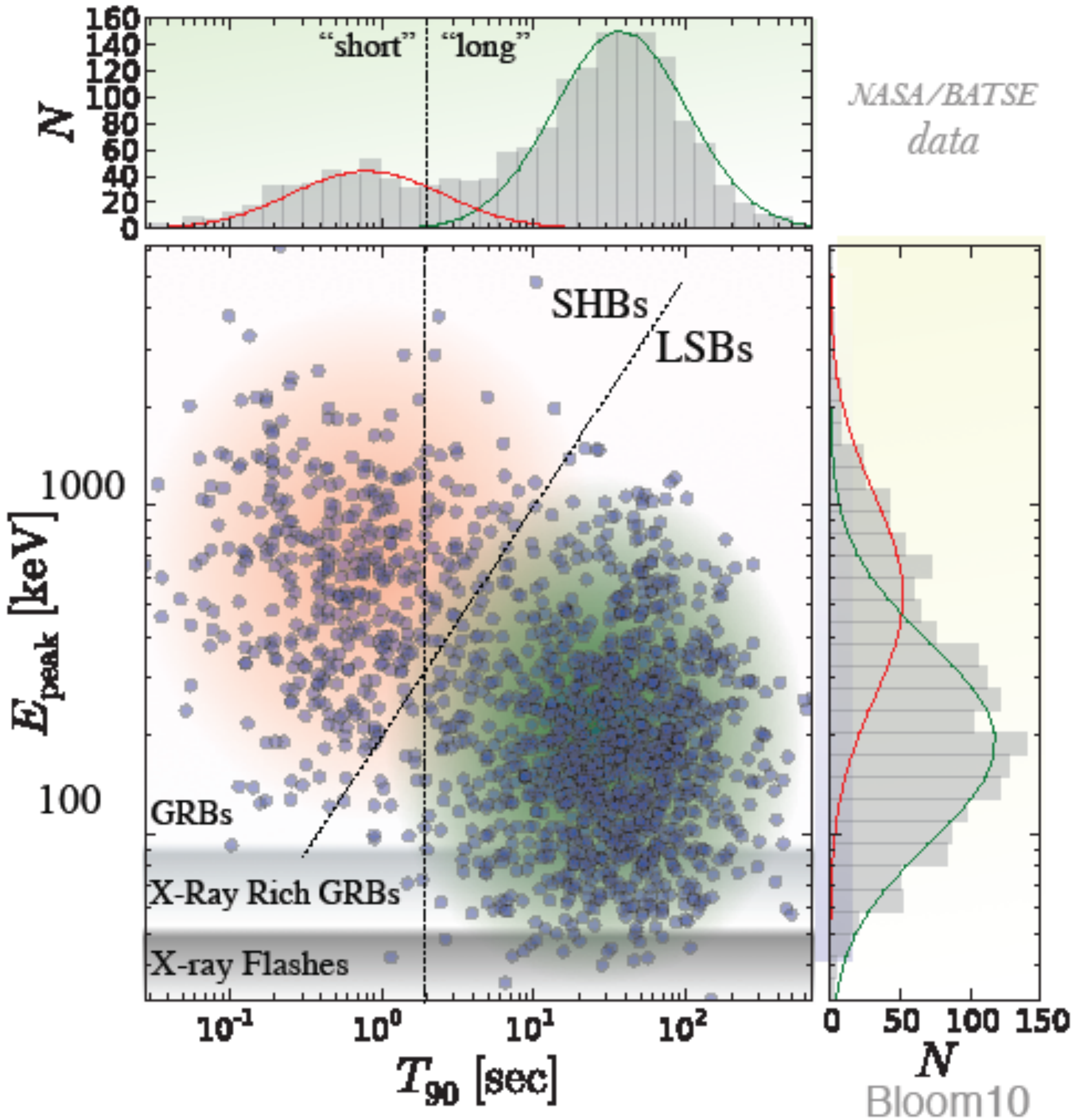
(b) Optically thick Compton ("photospheric")

Observations favor (b):

- hard spectral slopes in many bursts
- preferential position of the spectrum peak near 1 MeV

\+ photospheric emission is released at small radii, consistent with observed fast variability

Photospheric ≠ thermal !!



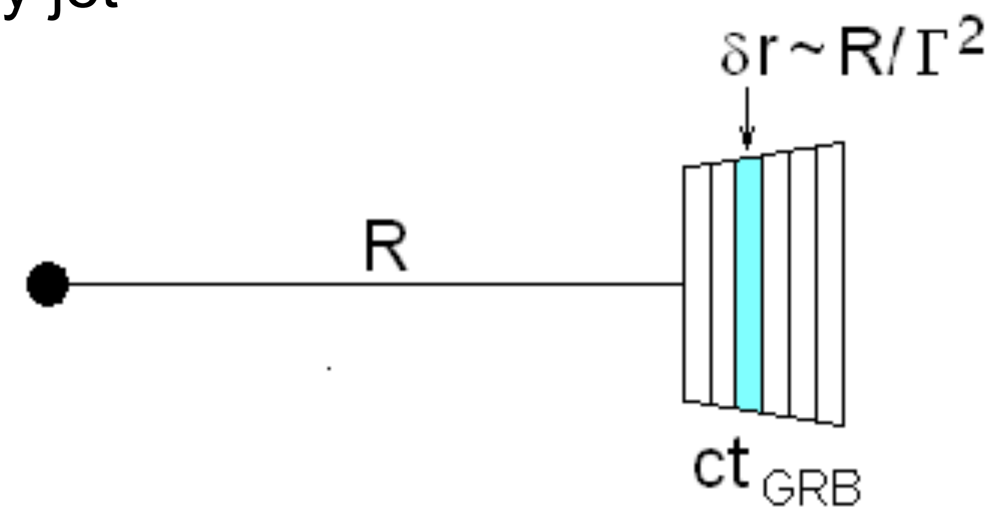
Kouveliotou et al. (1993); Preece et al. (2000)

Photospheric emission

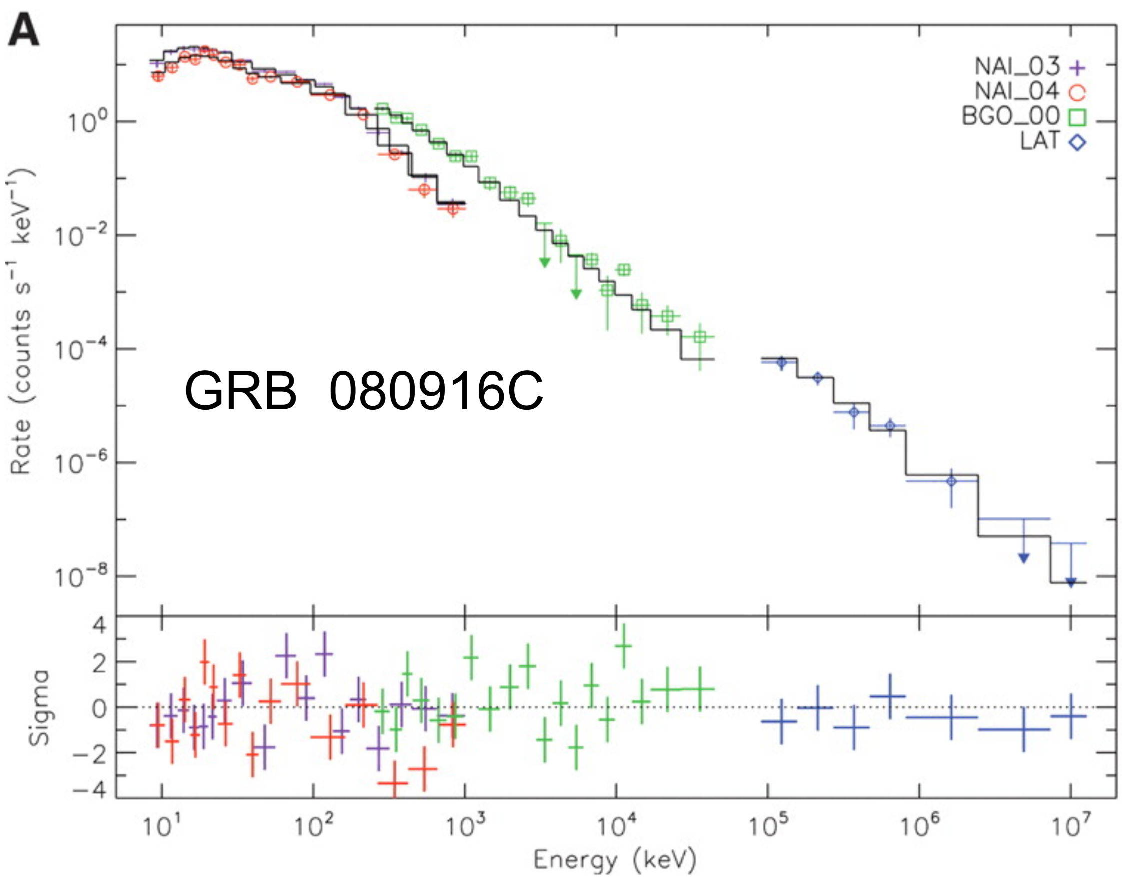
Misconceptions:

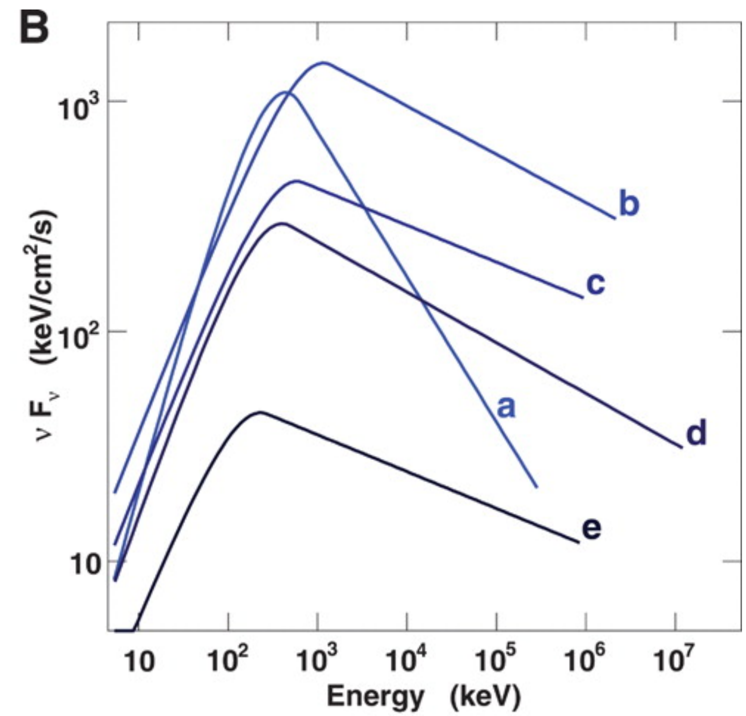
thermal spectrum	→	nonthermal
too small radius, ruled out by observed GeV emission	→	additional GeV source at large radii

Variability: unsteady jet



Sequence of
mini “big bangs”





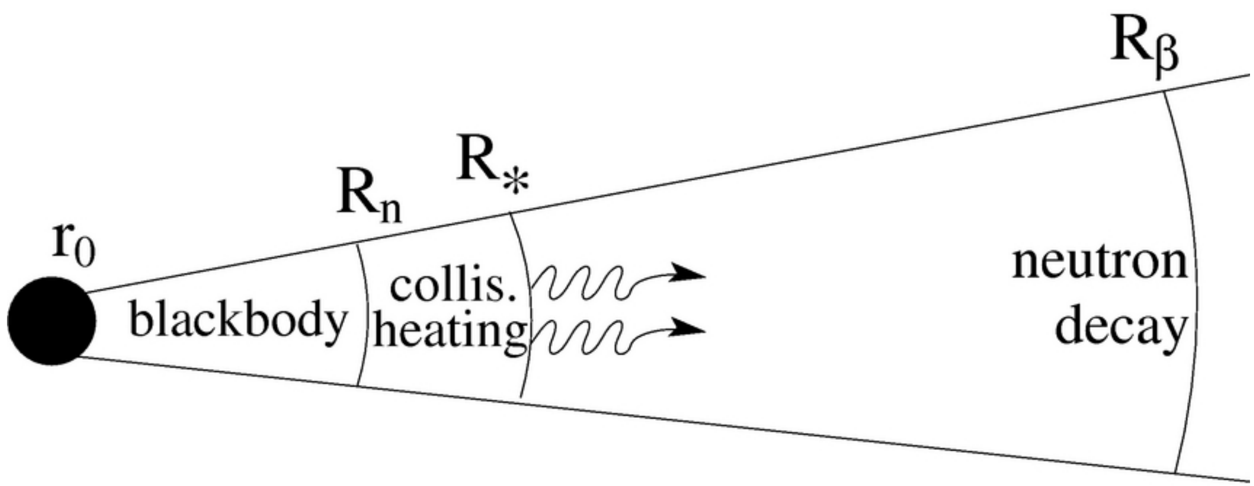
(Abdo et al. 2009)

Nonthermal spectra => **heated** jet

Baryonic jets contain neutrons

$\rightarrow$ two - fluid flow $\Gamma_n \neq \Gamma_p$

Derishev et al. 1999
Bahcall, Meszaros 2000
Fuller et al. 2000
Meszaros, Rees 2000

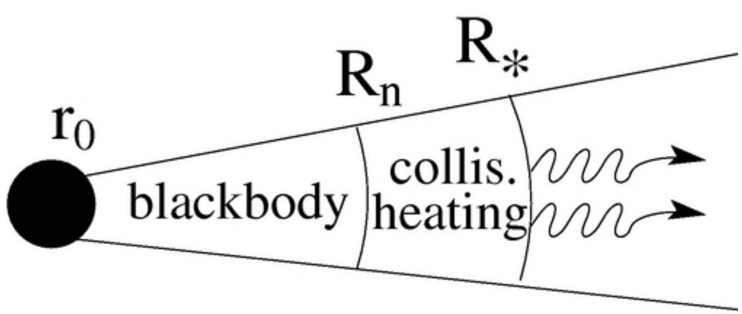


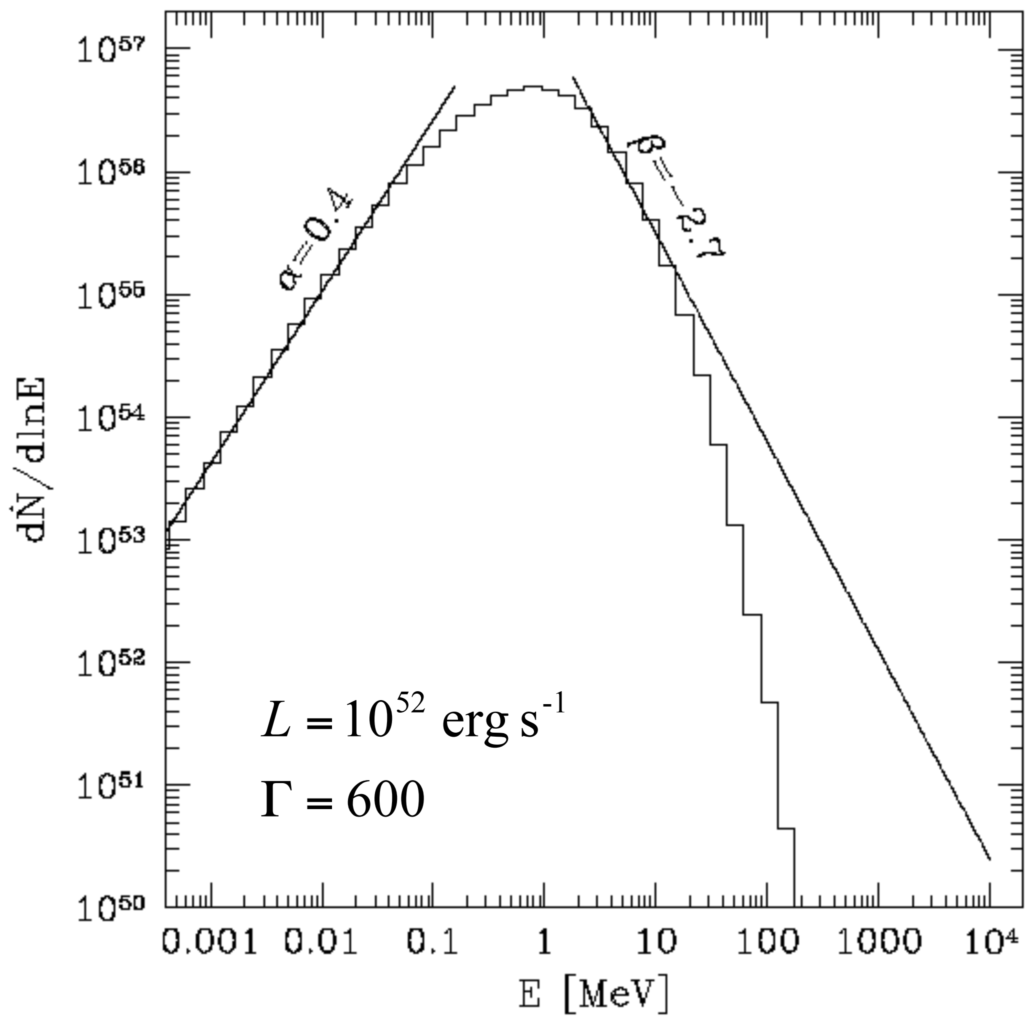
n - p collisions peak at radius $R_n \sim 0.1 R_*$

$\Rightarrow$ protons are hot in the subphotospheric region

Electron heating I: Coulomb collisions

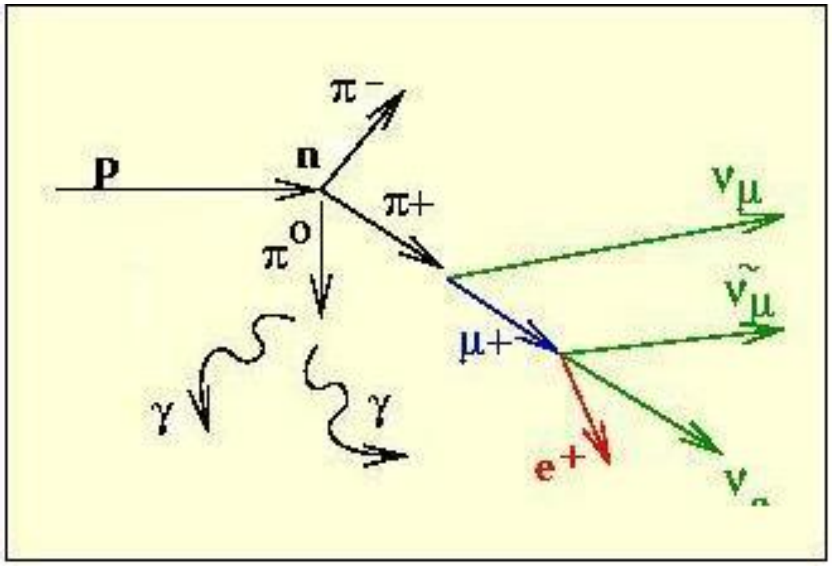
Electrons are heated by Coulomb collisions with protons and radiate the received energy





(Beloborodov 2010)

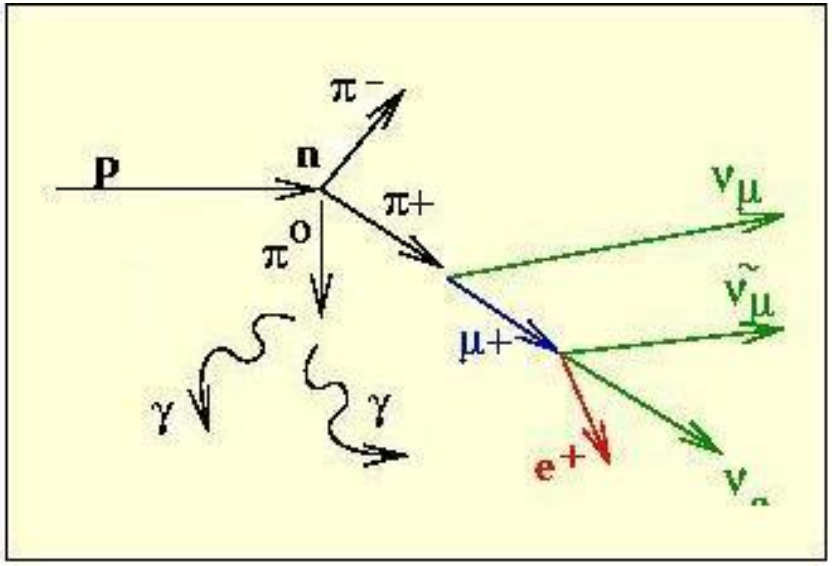
Electron heating II: inelastic nuclear collisions



$\Rightarrow$ Injection of $e^{\pm}$ with energy $\sim m_{\pi}c^{2} \approx 140$ MeV

(Paczynski, Xu 1994)

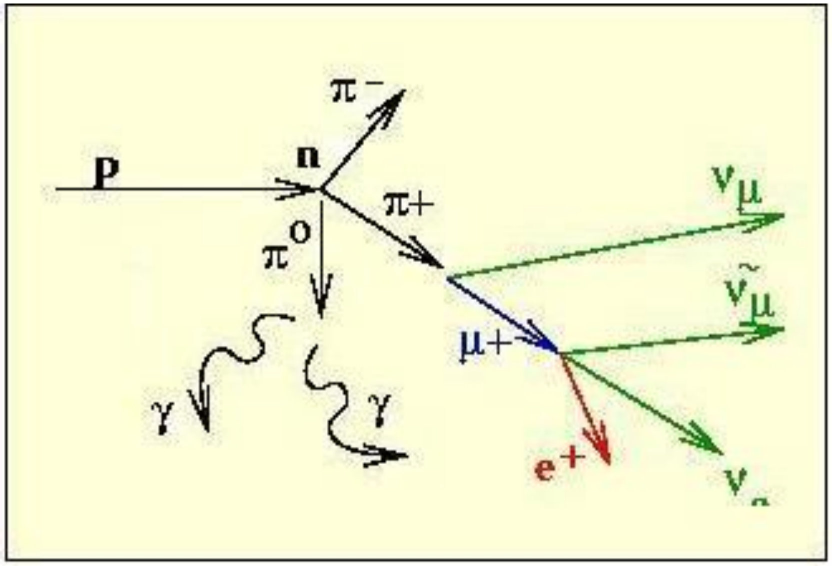
Nuclear collisions:



$\Rightarrow$ Injection of $e^{\pm}$ with energy $\sim m_{\pi}c^{2} \approx 140$ MeV

(Paczynski, Xu 1994)

Nuclear collisions:

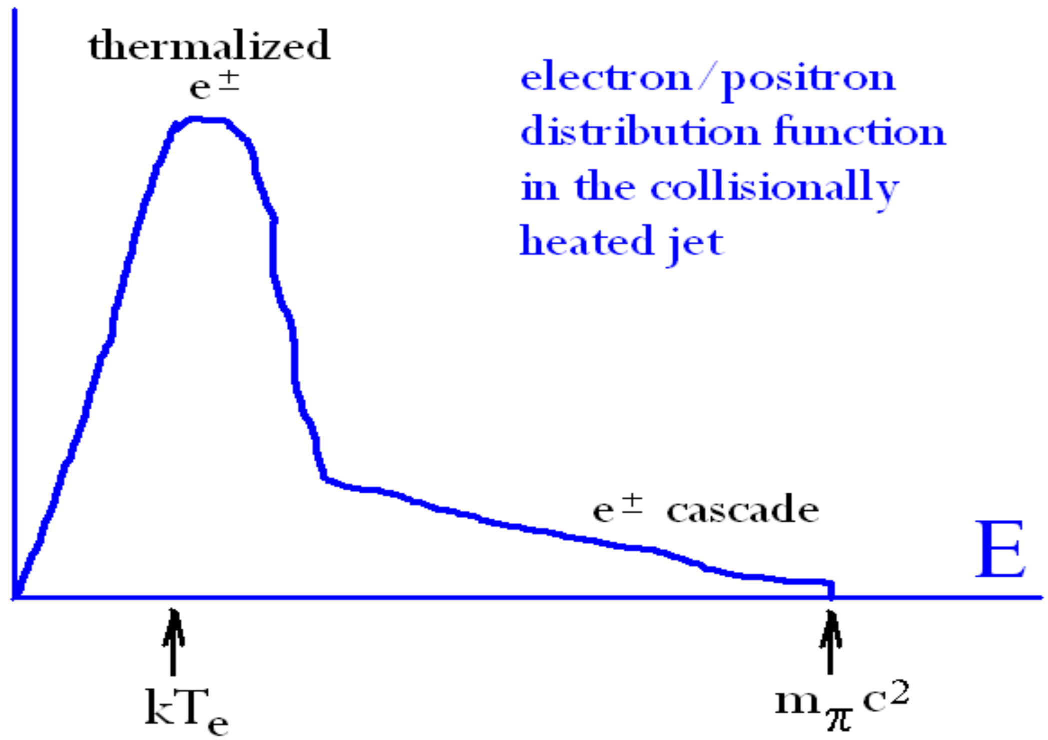


⇒ Injection of $e^{\pm}$ with energy $\sim m_{\pi}c^{2} \approx 140$ MeV

(Paczynski, Xu 1994)

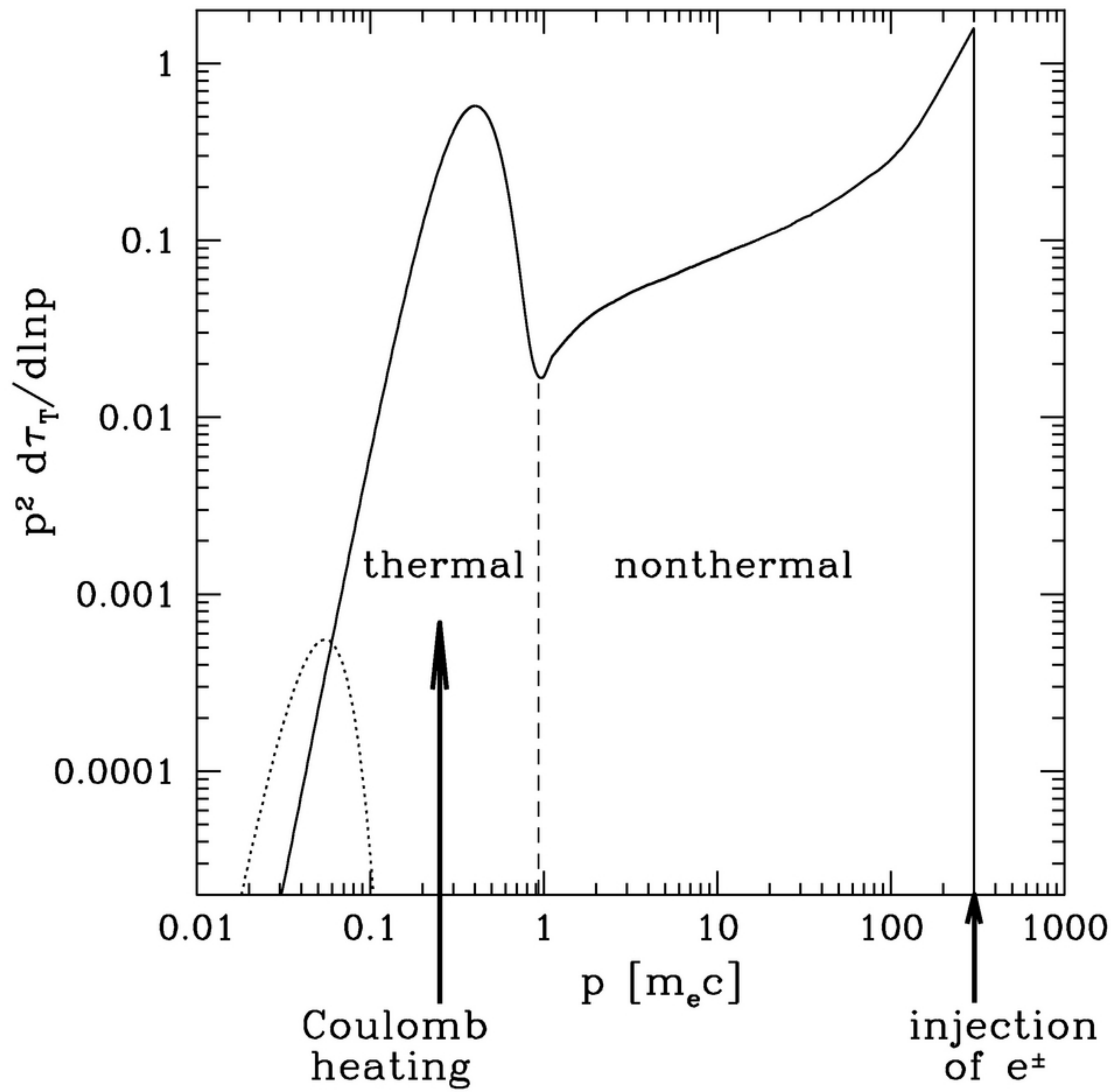
⇒ $e^{\pm}$ cascade radiating almost all $e^{\pm}$ energy

(Svensson 1987;
Lightman, Zdziarski 1987)

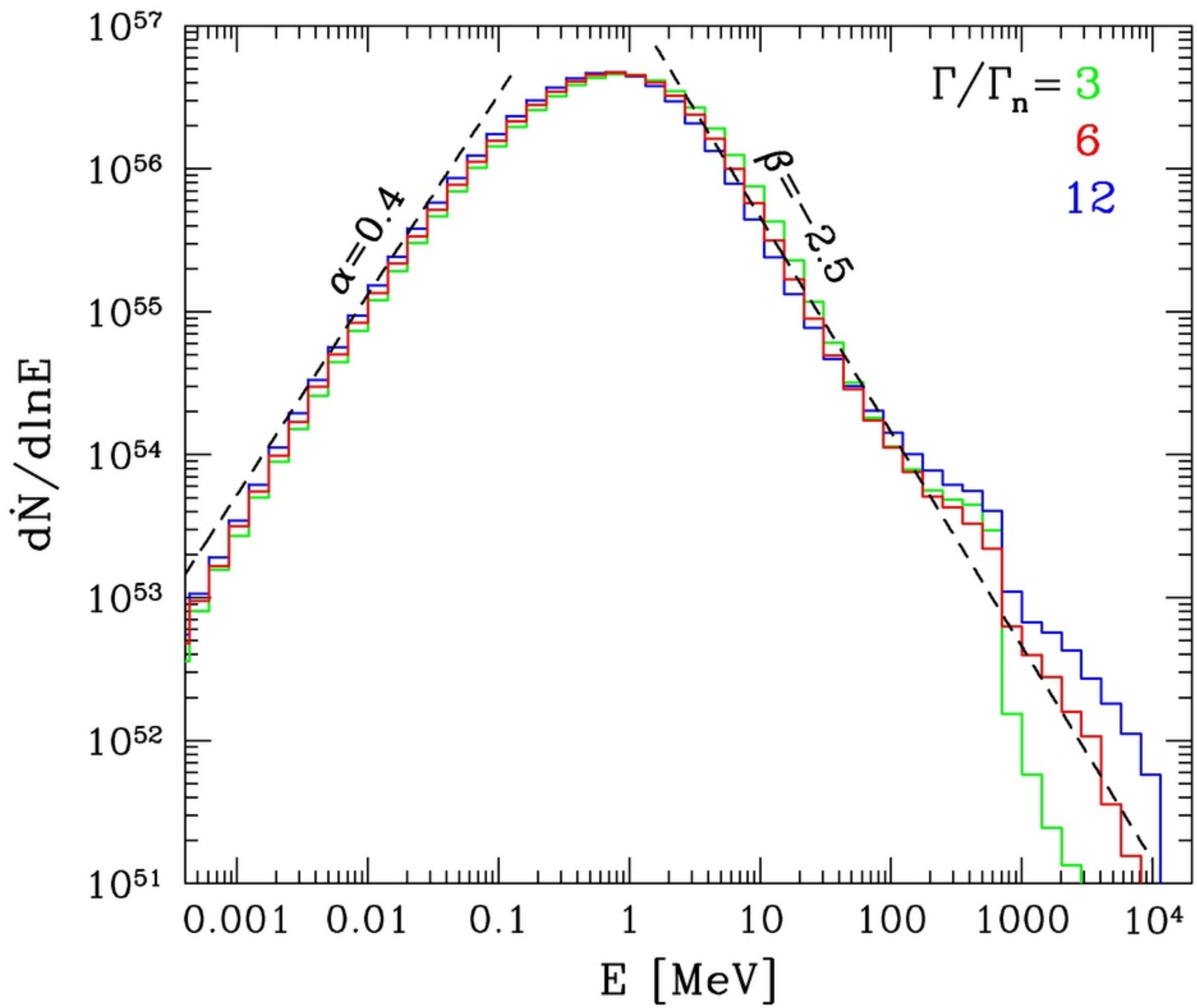


Collisionally heated jet:

e+- distribution function at R_* /5

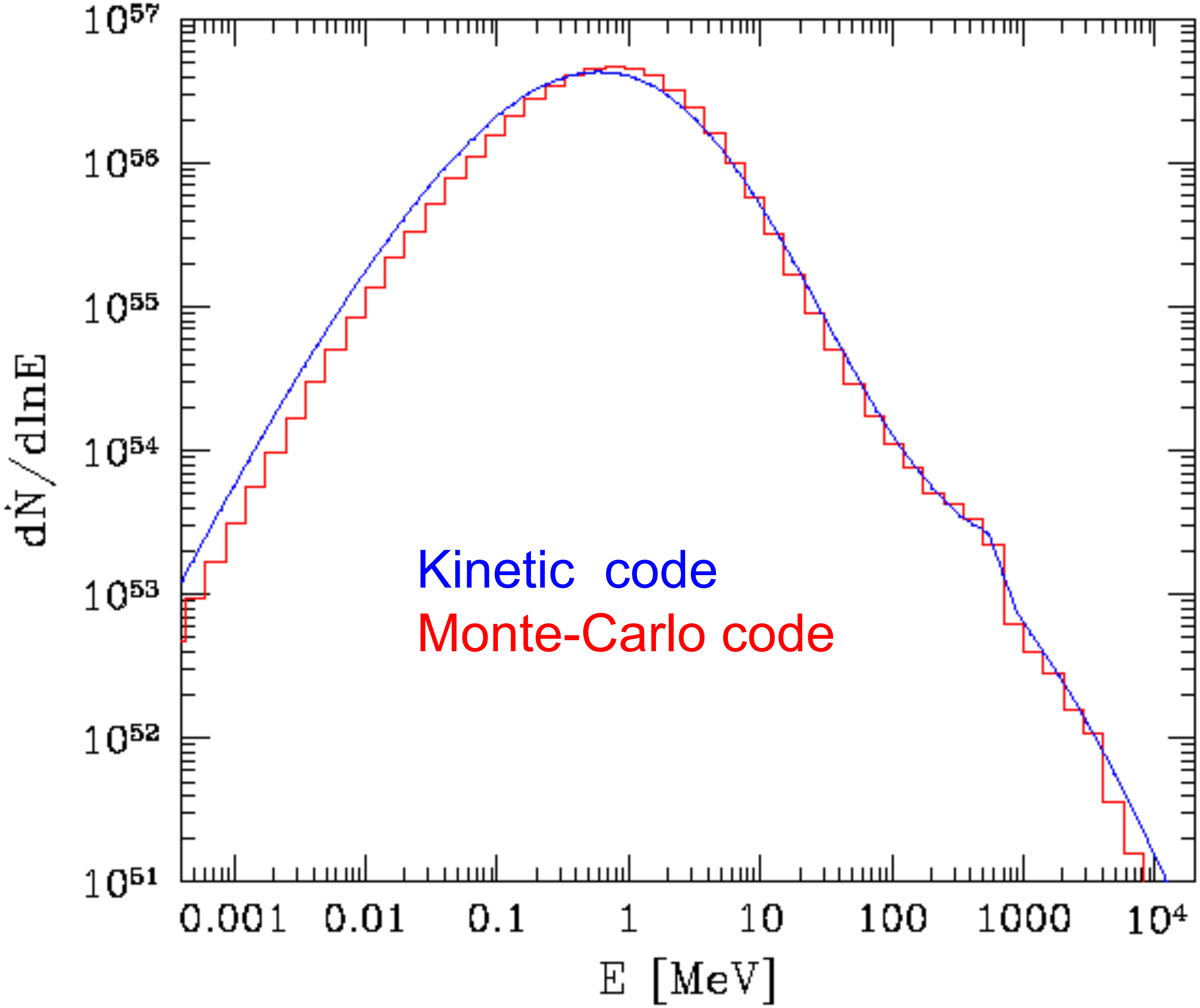


Radiation from collisionally heated jets

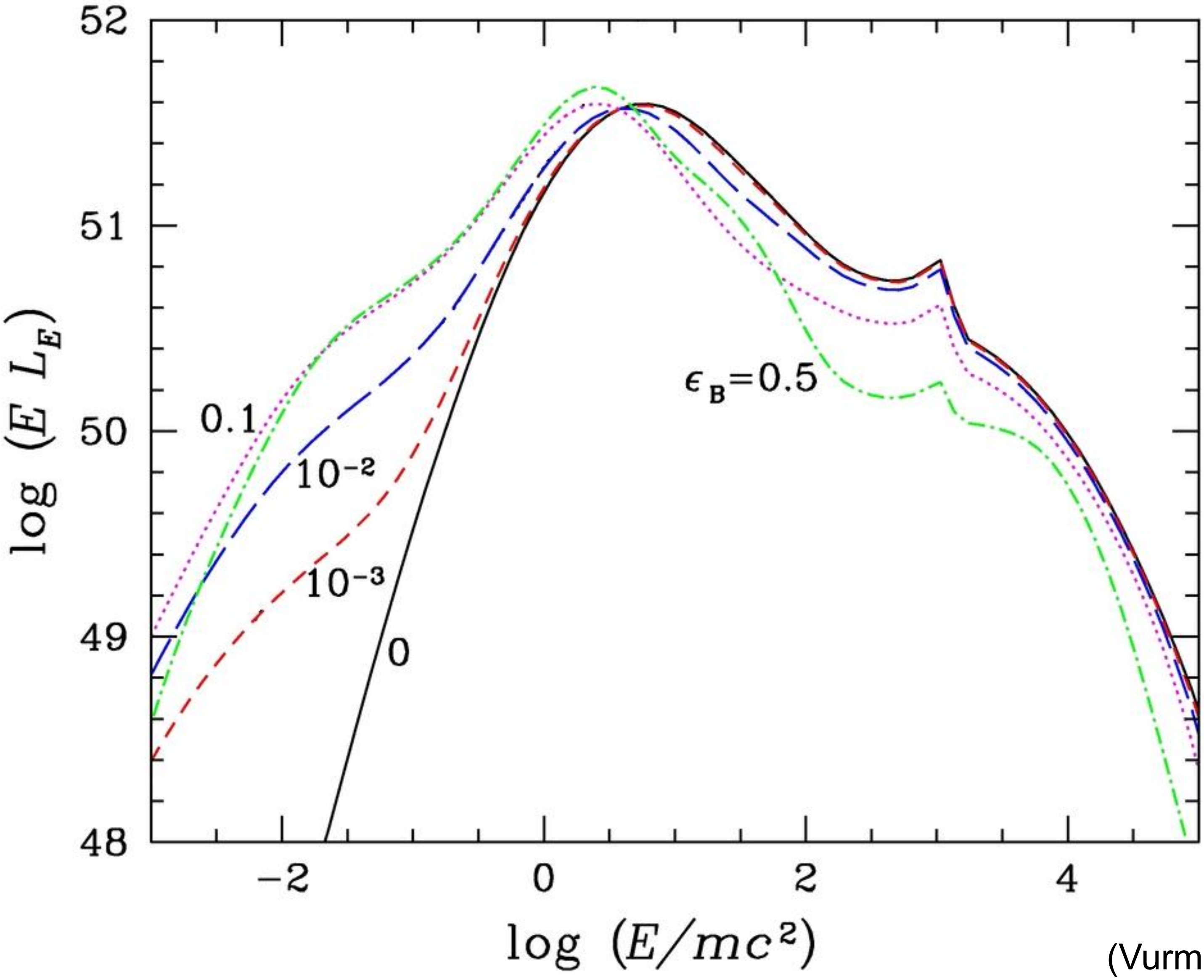


Jet radiates ~50% of its energy

(Beloborodov 2010)

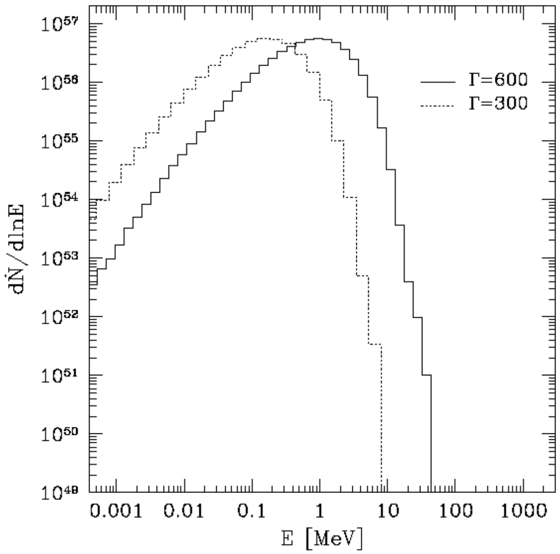


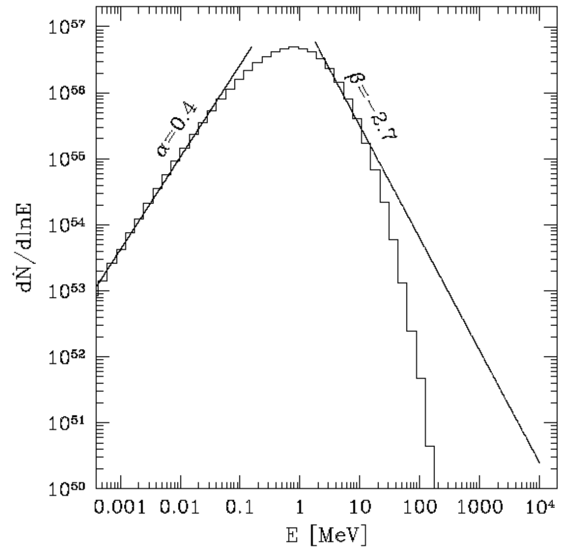
(Vurm, Beloborodov, Poutanen 2010)

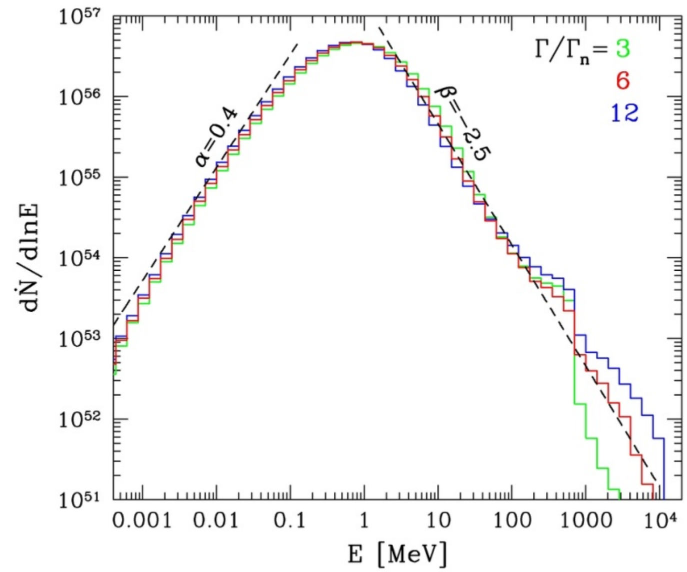


(Vurm et al. 2010)

Three regimes of GRB jets







A. Steady jet
Γ=const
Passive cooling (no heating)

B. Moderate variability $\delta\Gamma/\Gamma<2$
Hot protons heat thermal electrons via Coulomb collisions

C. Strong variability $\delta\Gamma/\Gamma>2$
Pion production, injection of 140-MeV e+-

Summary

Robust **collisional** heating operates in baryonic jets, converting > 30% of jet energy to escaping radiation. Its theoretical spectrum is consistent with observations

Collisional heating peaks at radii ~ 0.1 R_*.

Photospheric emission $\neq$ thermal emission (!)