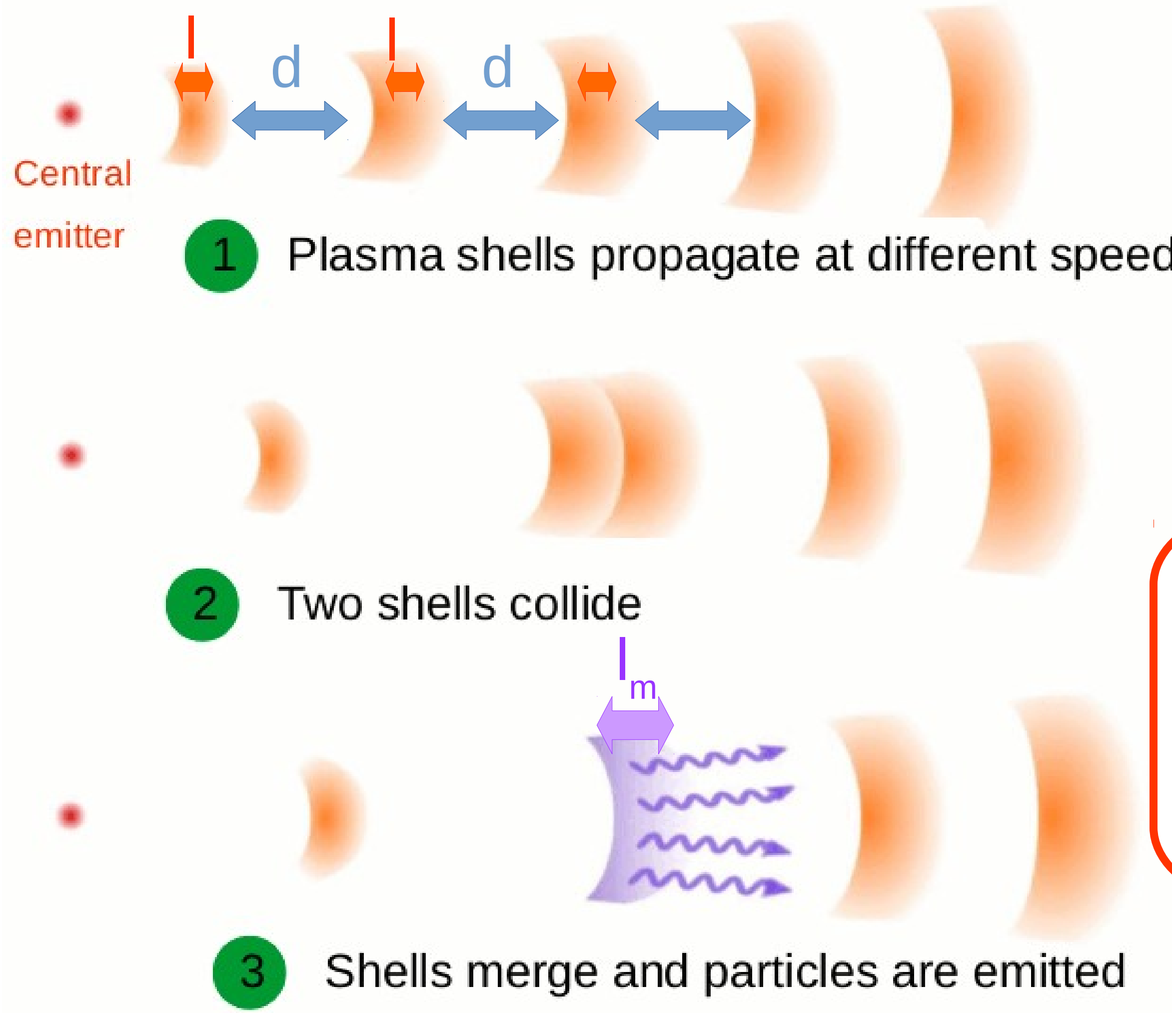
Model-dependent assumptions for the multi- collision model

Annika Rudolph
DESY, Zeuthen

NeuCos Workshop
May 30, 2017

Multi- zone collision model



Alternative treatment: e.g. ICMART, photospheric models

All the internal energy produced in the collision is radiated away

Bustamante, Heinze, Murase, Winter, Astrophys. J., 837, 33 (2017)

Ultraefficient shocks

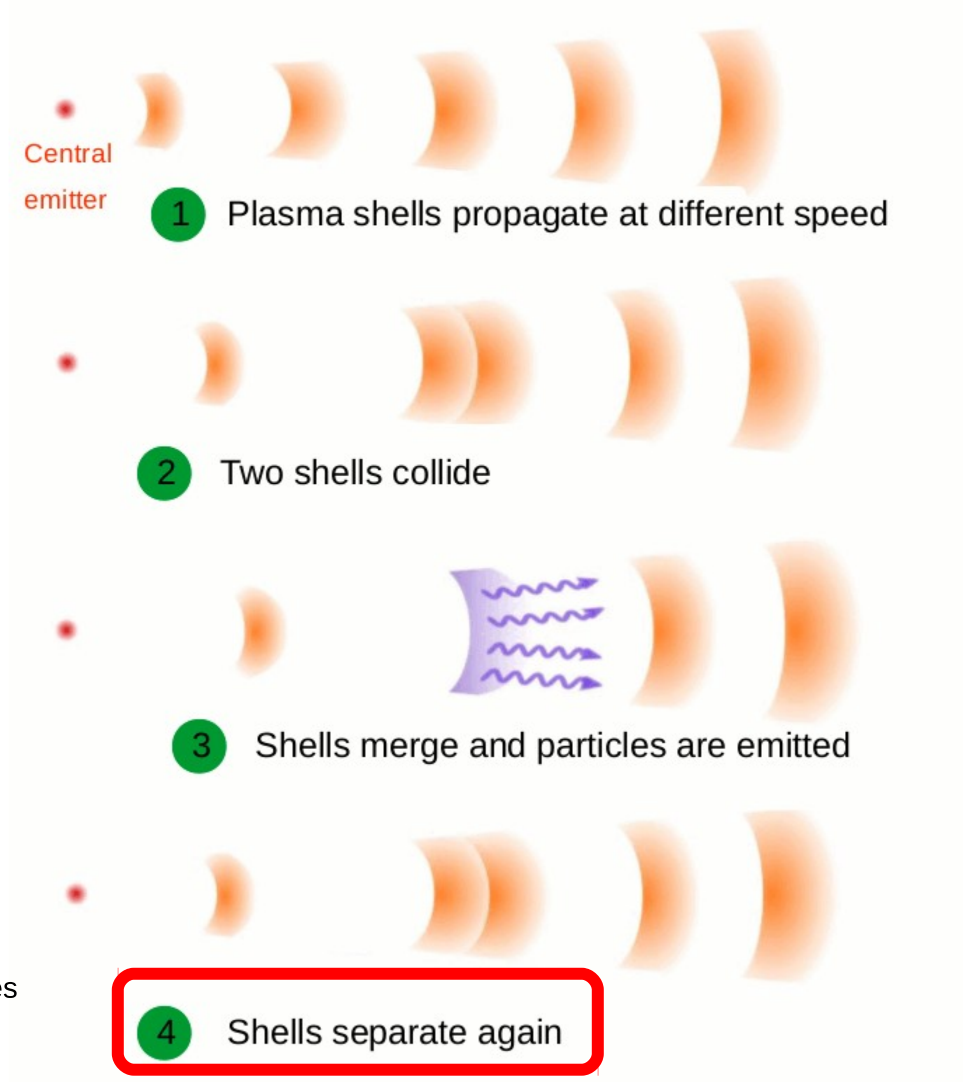
- Kobayashi, S. & Sari R. 2001, Astrophys. J., 551, 934 (KS'01)

TABLE 1

EVALUATION OF EFFICIENCY

N	γ_{min}	γ_{max}	Efficiency ($\epsilon_e = 0.1$) (%)	Efficiency ($\epsilon_e = 0.5$) (%)
30	10^2	10^3	9.2 ± 2.3	16.2 ± 3.0
30	10	10^4	40.0 ± 9.2	67.5 ± 9.3
10^2	10^2	10^3	15.1 ± 1.5	17.7 ± 1.5
10^2	10	10^4	62.9 ± 4.8	72.4 ± 4.3

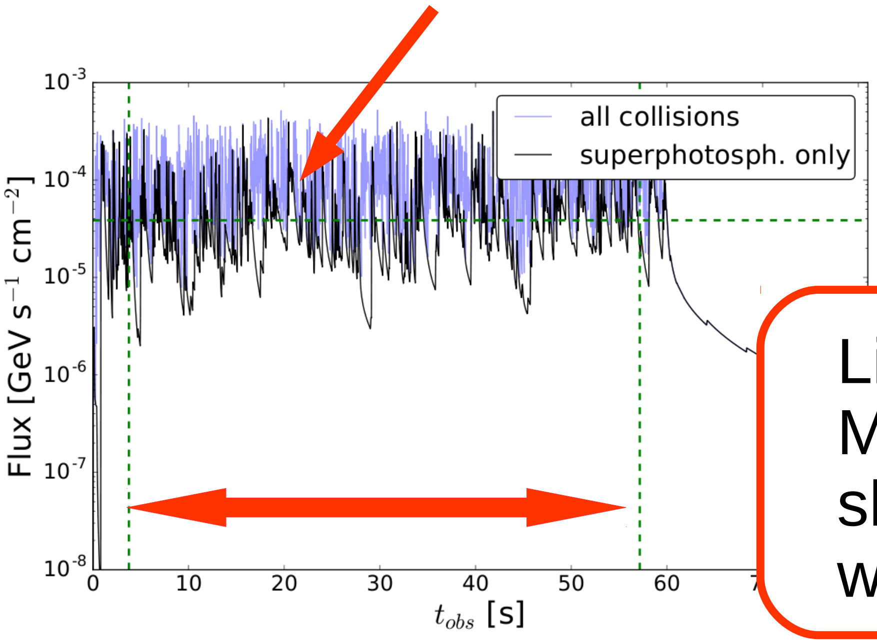
Taken from KS '01, assuming initially equal masses



Now… how do we set it up?

- **Aim** : Make it comparable to the standard multi – zone collision model

- **Idea:** Lightcurves should resemble one another + same basic features of the system

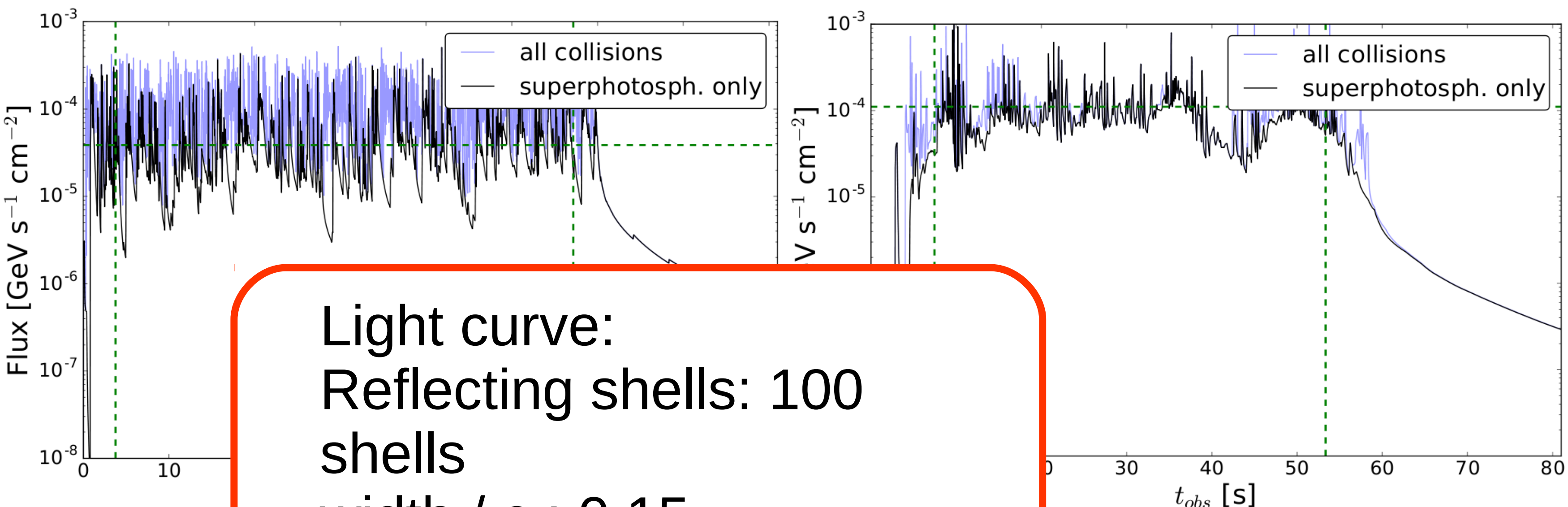


Light curve:
Merging shells: 1000 shells
width / c : 0.015

Now… how do we set it up?

- **Aim** : Make it comparable to the standard multi – zone collision model

- **Idea:** Lightcurves should resemble one another + same basic features of the system

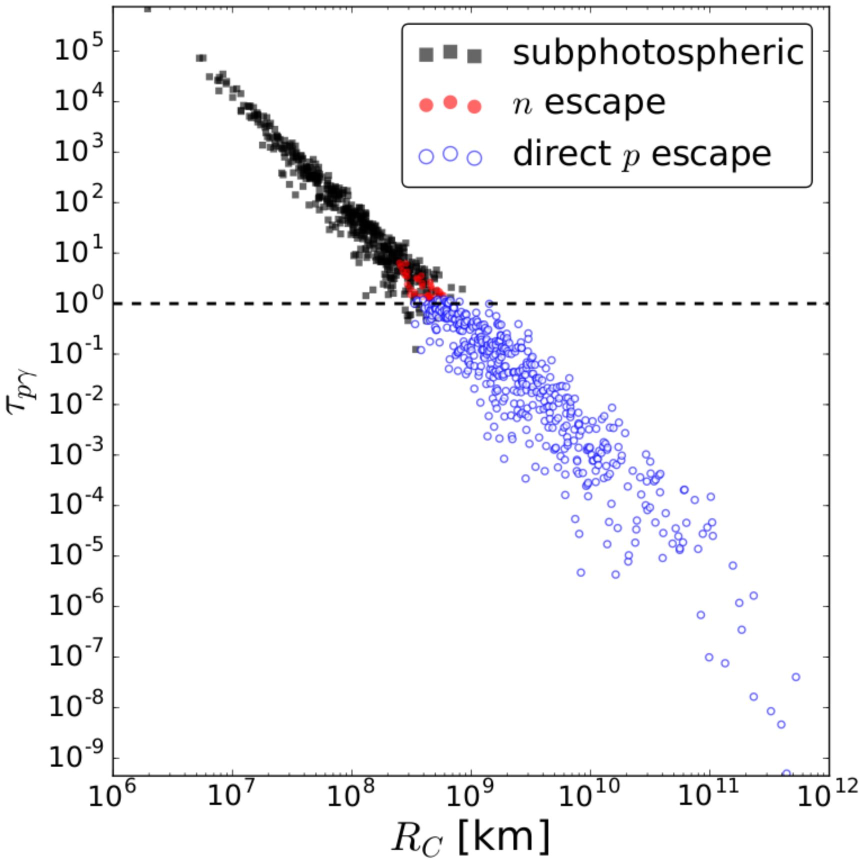


Light curve:
Reflecting shells: 100 shells
width / c : 0.15

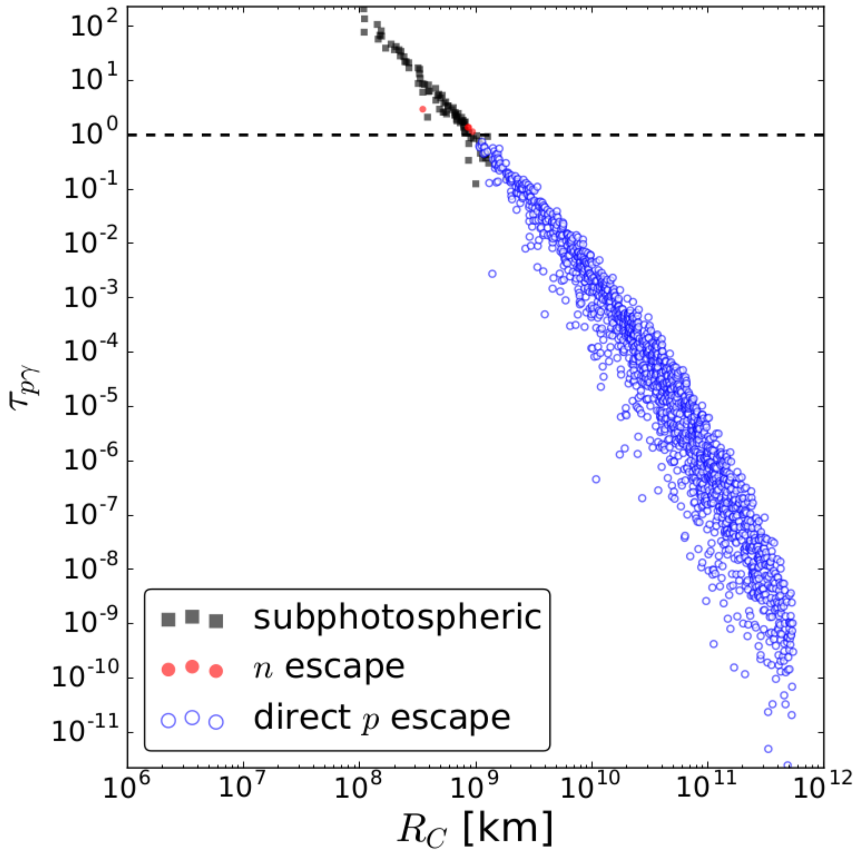
What changes?

Optical depth

Merging shells

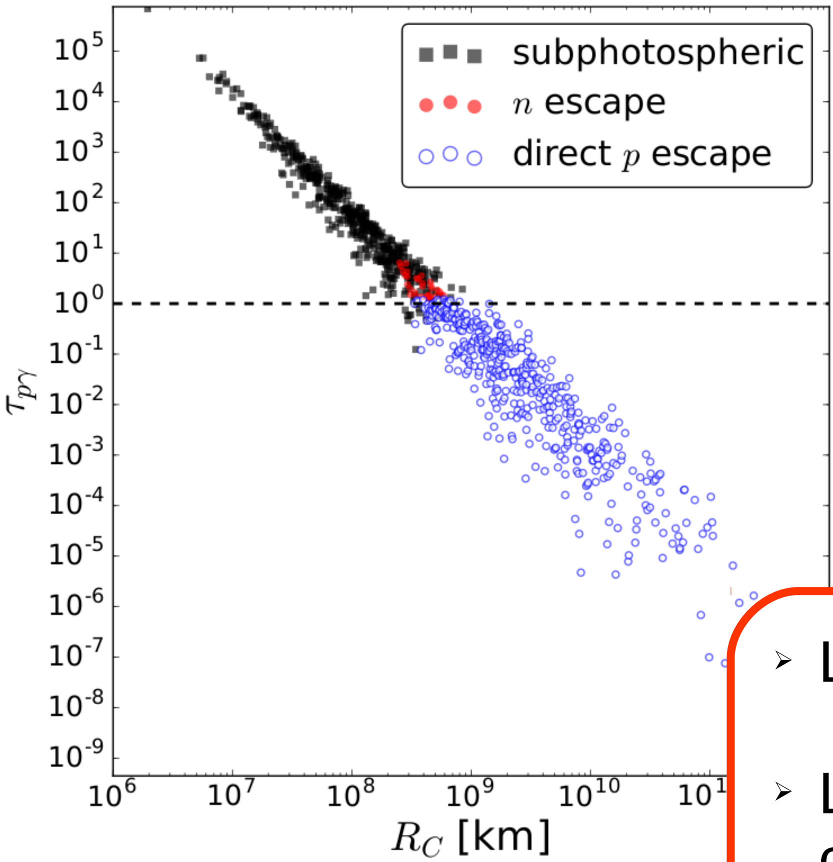


Reflecting shells

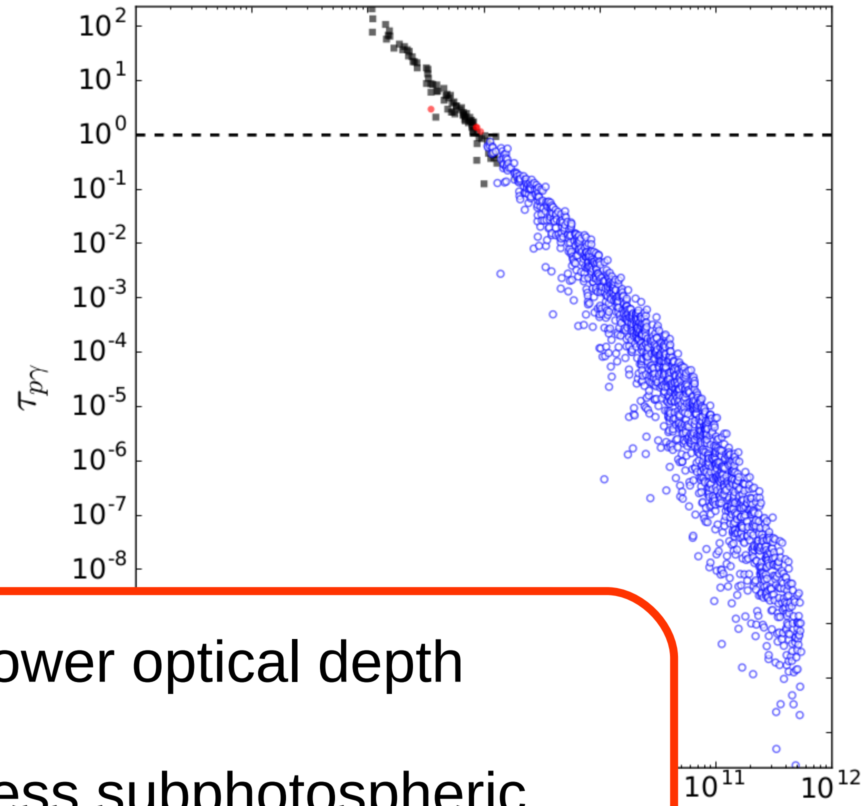


Optical depth

Merging shells



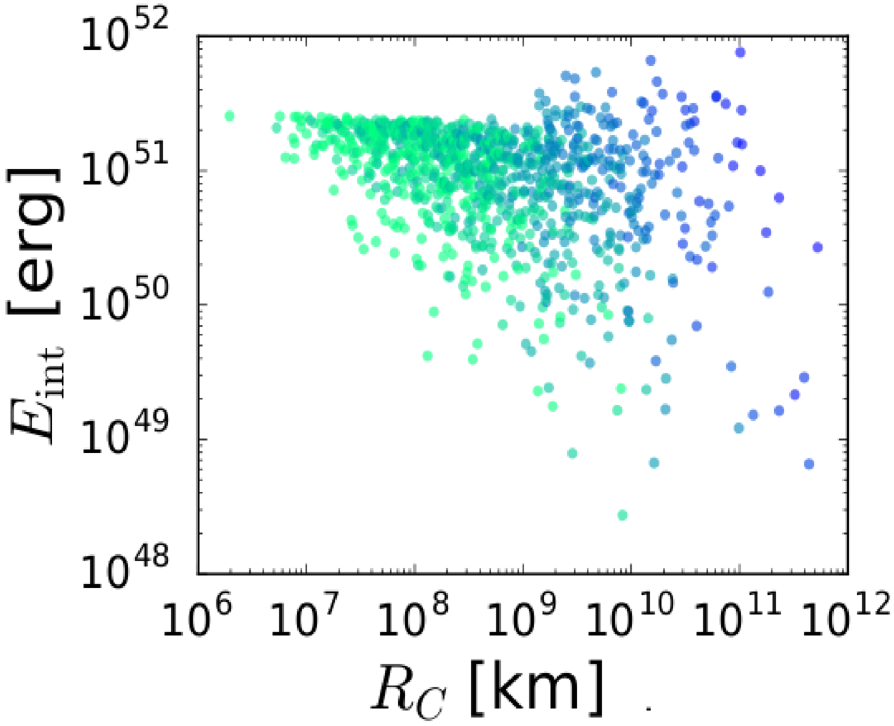
Reflecting shells



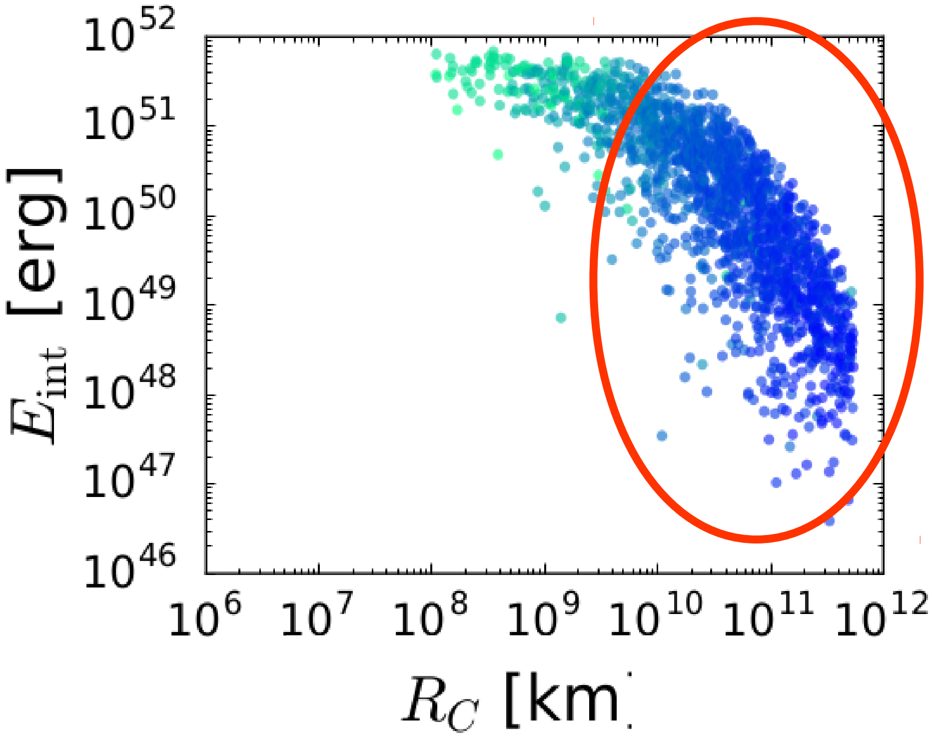
- Lower optical depth
- Less subphotospheric collisions

Collision radii

Merging shells



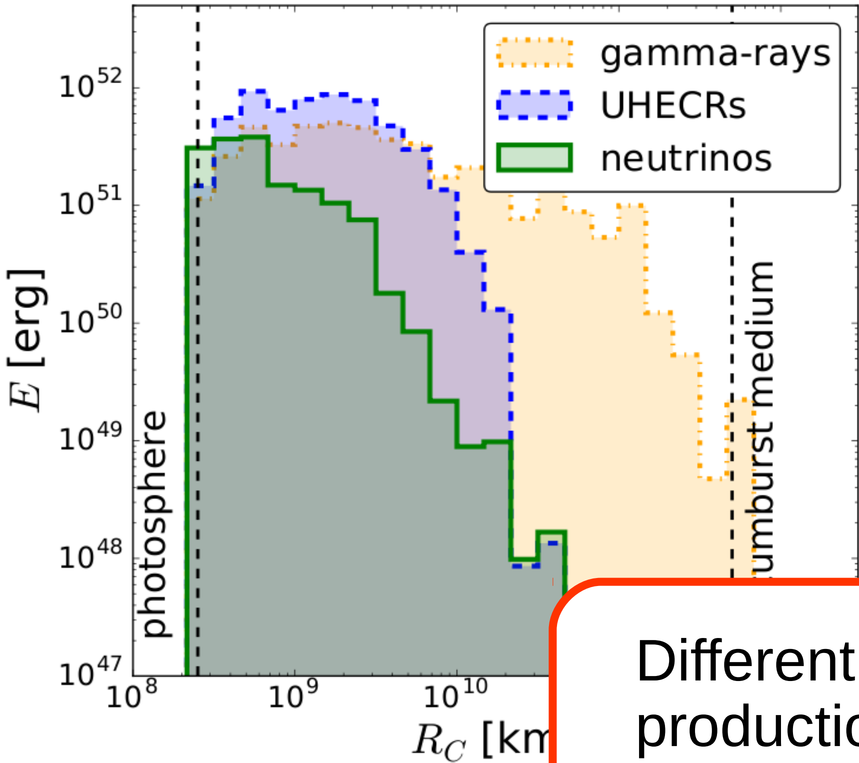
Reflecting shells



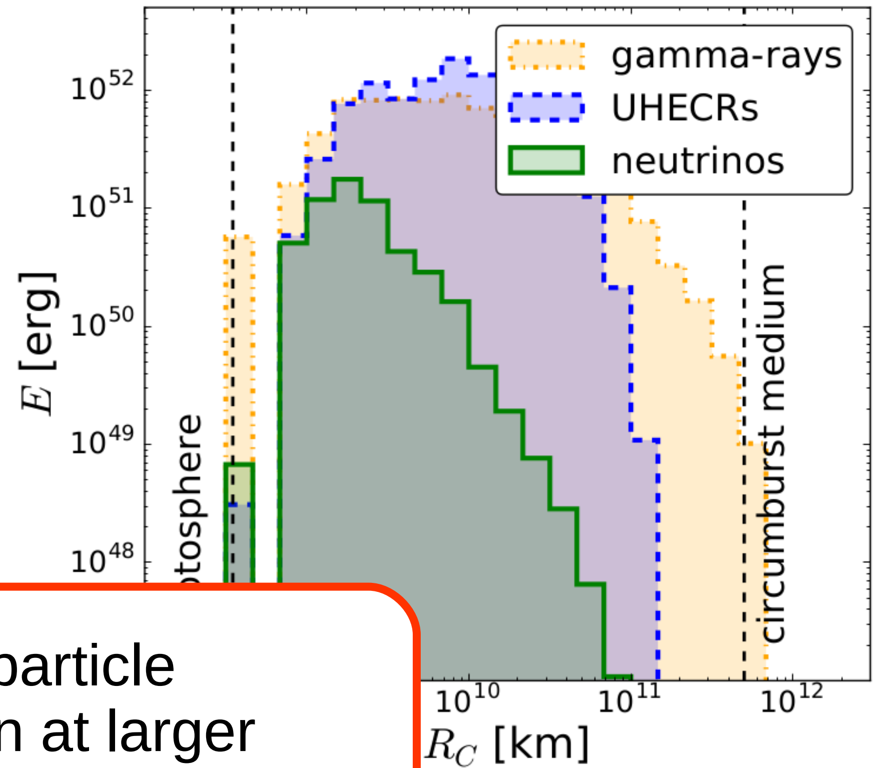
- Less collisions at small radii
- More collisions at large radii (releasing less energy)

Particle production

Merging shells



Reflecting shells



Different particle production at larger radii

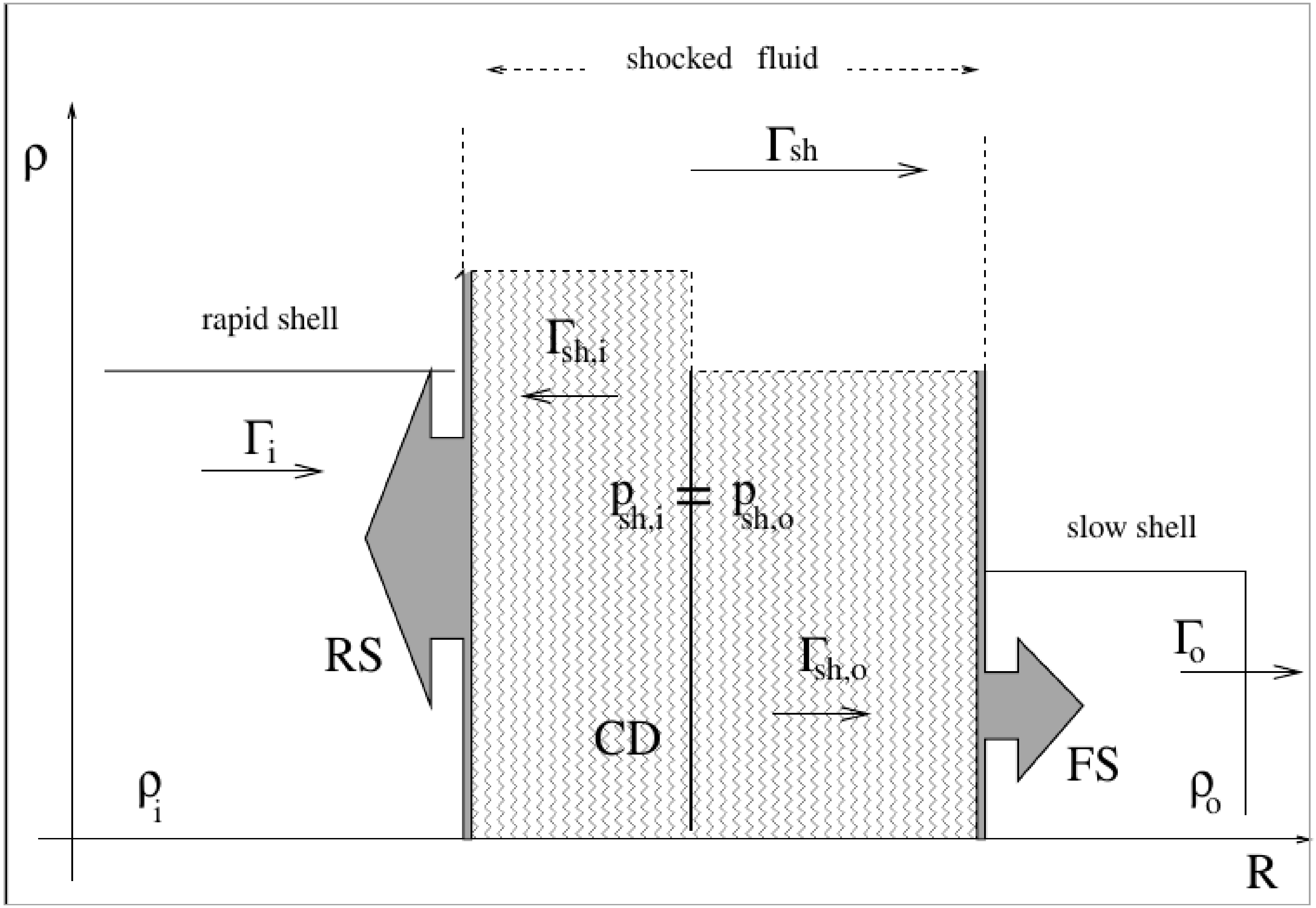
But how well supported is the model?

Hydrodynamics of colliding shells

Hydrodynamic simulations

- PLUTO : finite-volume / finite-difference, shock capturing code integrating a system of conservation laws → numerical solutions for high Mach number flows in fluid dynamics
  http://plutocode.ph.unito.it/
- Assumptions:
  (1) no radiative cooling
  (2) cold plasma shells initially
  (3) shells move with relativistic speeds
  (4) no magnetic fields

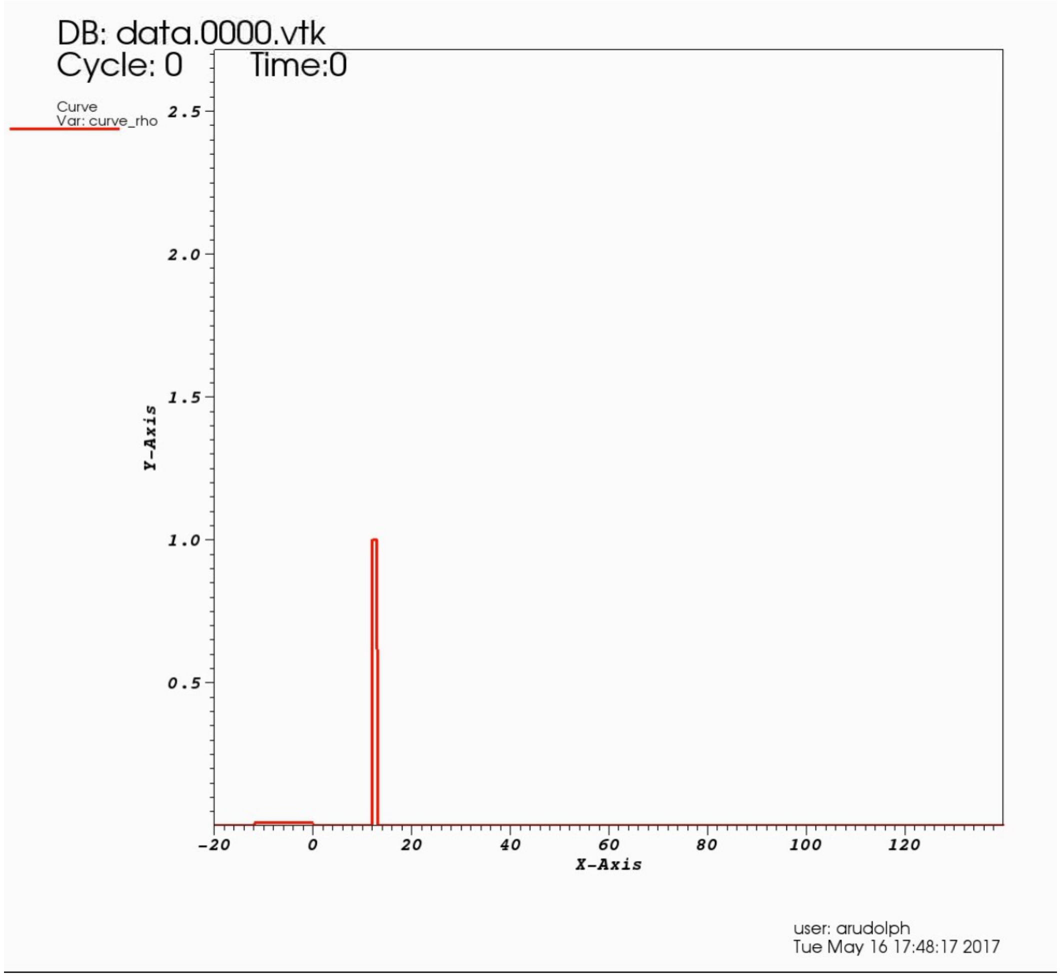
Hydrodynamic system



Spada, Ghisellini, Lazzati, Celotti,
MNRAS 325, 1559 – 1570 (2001)

Hydrodynamics of colliding shells

Setup: identical to KS ‘01



$$\Gamma_s = 10$$

$$\Gamma_r = 1000$$

$$\Delta_s = \Delta_r$$

$$m_s = m_r$$

$$\Gamma_{CD} \simeq 33$$

$$t_0 = 0{,}83\, s$$

Hydrodynamics of colliding shells

Setup: identical to KS '01

$$\Gamma_s = 10$$

$$\Gamma_r = 1000$$

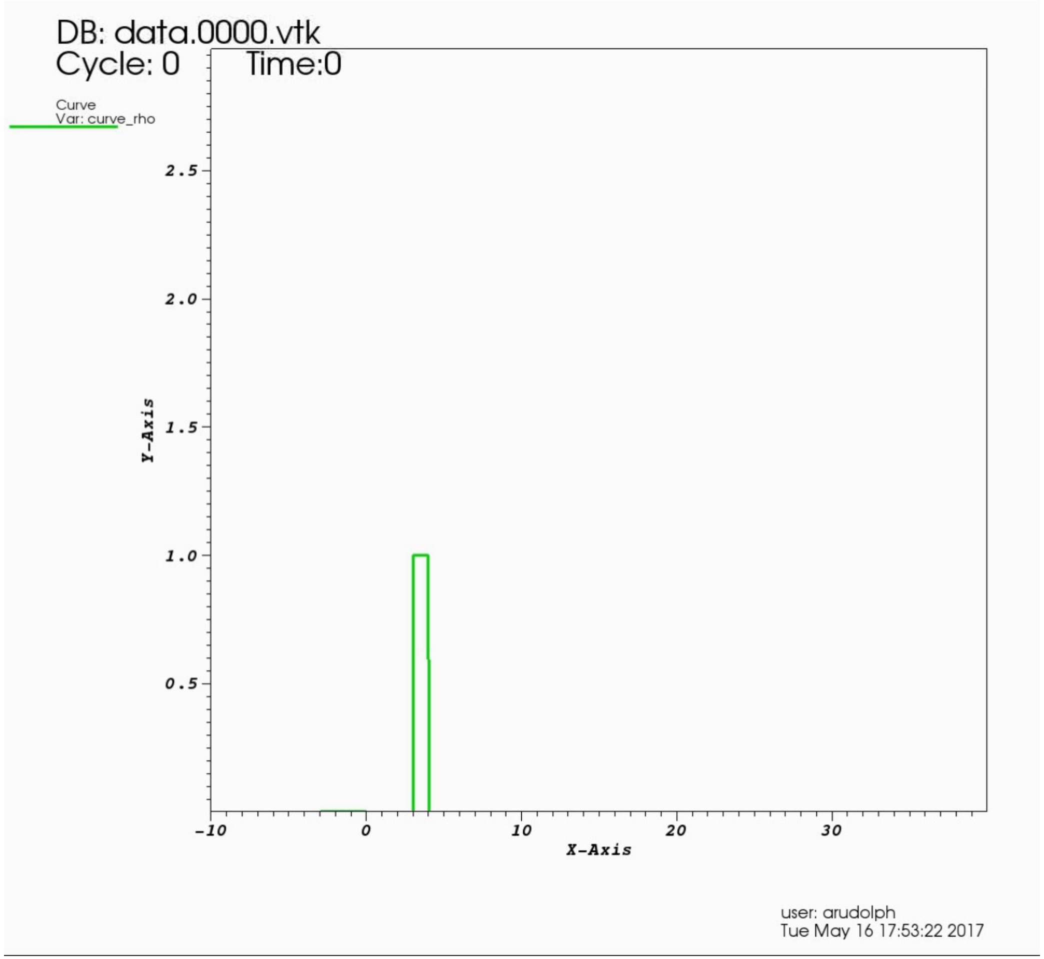
$$\Lambda = \Lambda$$

Behavior can be reproduced, but shell spreading cannot be neglected.

→ How robust is the model?

DESY

Hydrodynamics of colliding shells



Setup: Identical to KS '01, but equal energy

$$\Gamma_s = 10$$

$$\Gamma_r = 1000$$

$$\Delta_s = \Delta_r$$

$$E_s = E_r$$

$$\Gamma_{CD} \simeq 14$$

$$t_0 = 1{,}4\,s$$

Hydrodynamics of colliding shells

Setup: Identical to KS '01, but equal energy

$$\Gamma_s = 10$$

$$\Gamma_r = 1000$$

$$\Delta_s = \Delta_r$$

Dependency on:

- Lorentz Factors of shells
- Relative densities
- Time between collisions

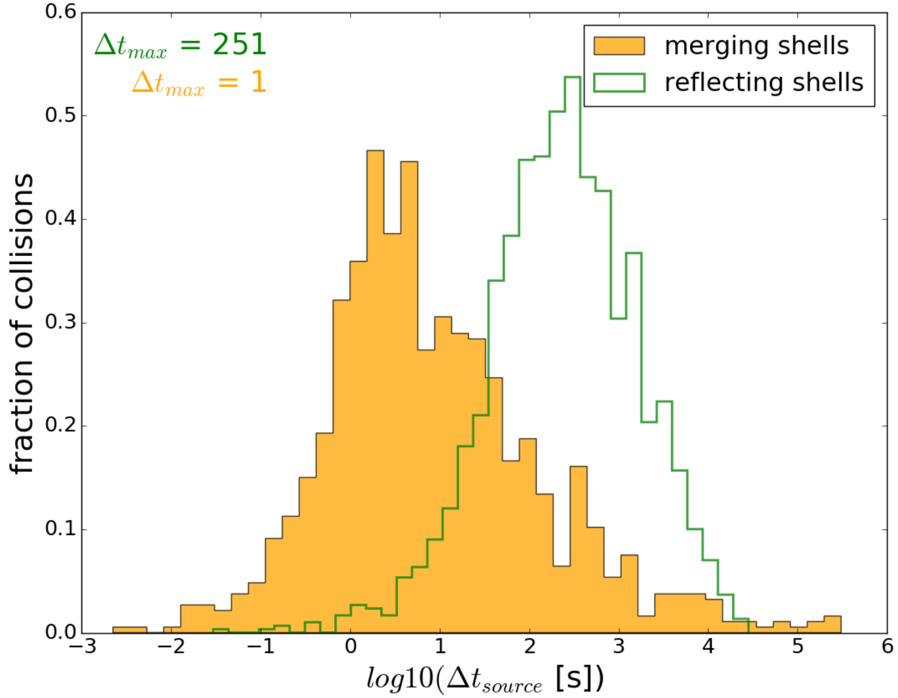
DESY

What could be reasonable parameters?

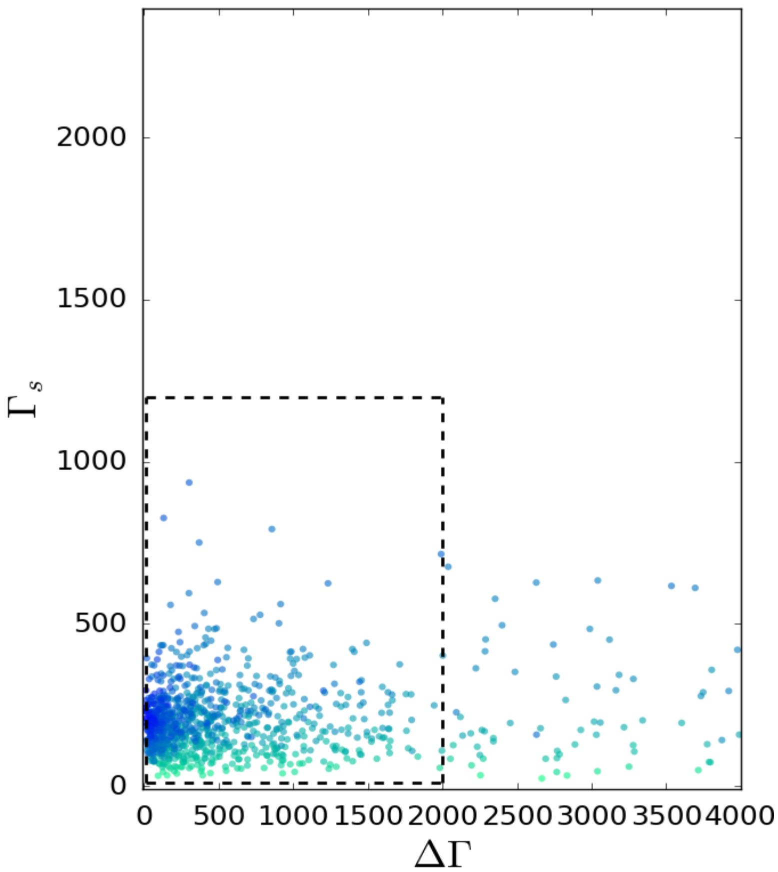
Current model parameters

Equal energy - case

Time between collisions



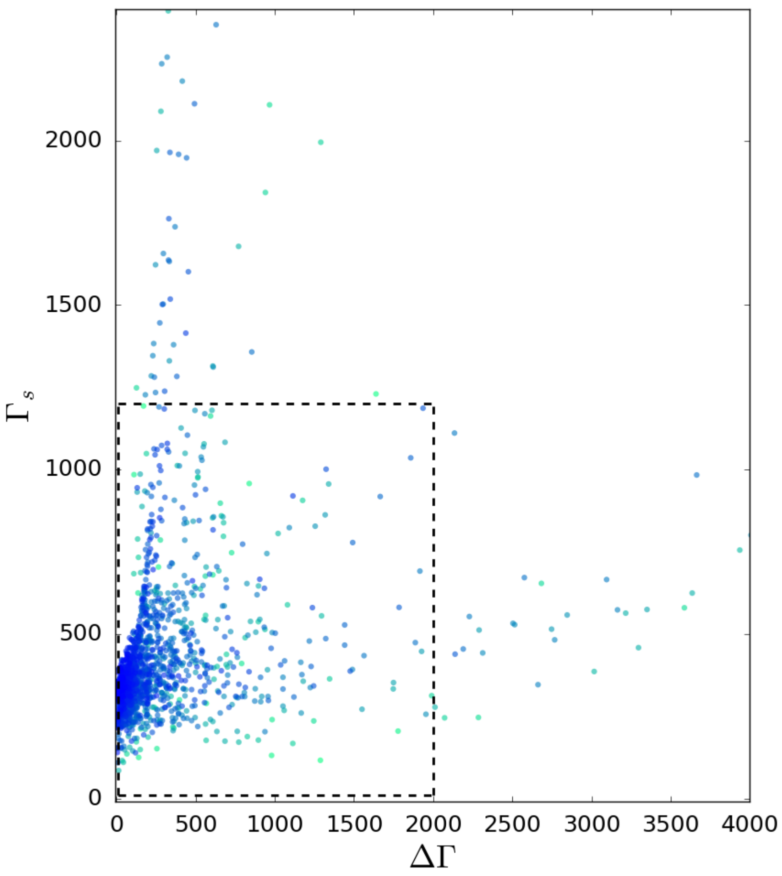
Distribution of Lorentz- Factors Merging shells



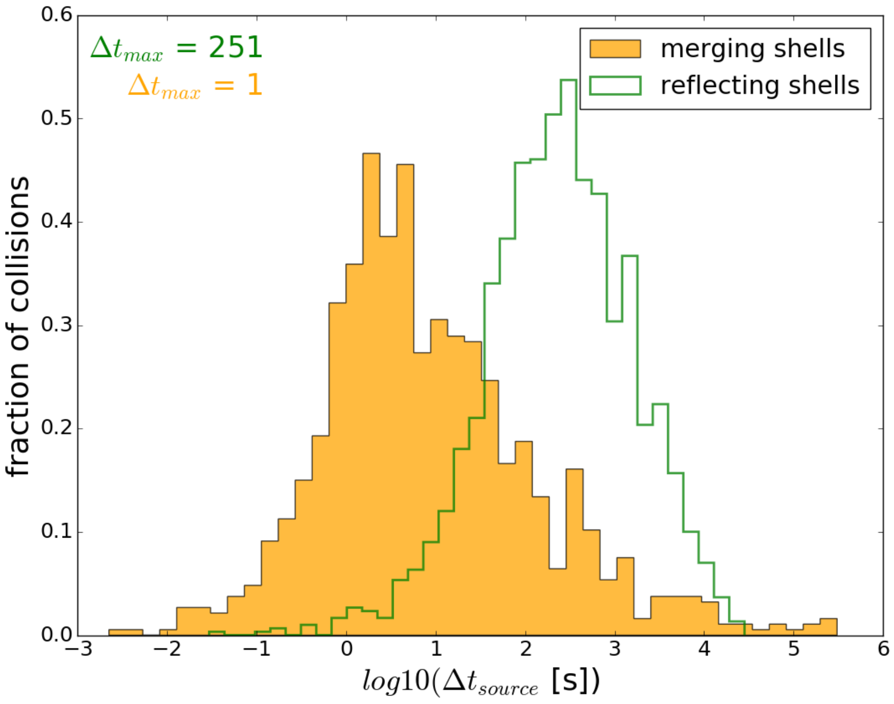
Current model parameters

Equal energy - case

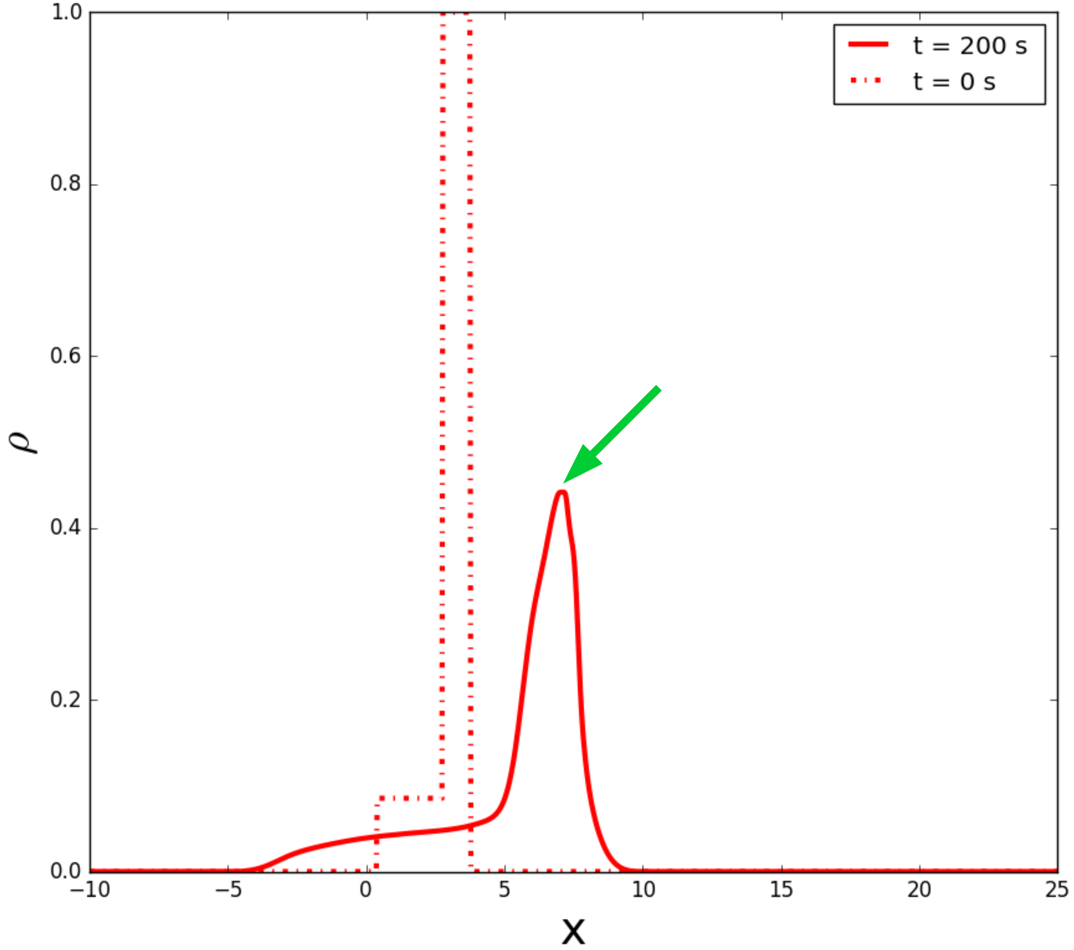
Distribution of Lorentz- Factors Reflecting shells



Time between collisions



Combine with PLUTO simulations



$E_s = E_r$

$\Gamma_s = 10$

$\Gamma_r = 580$

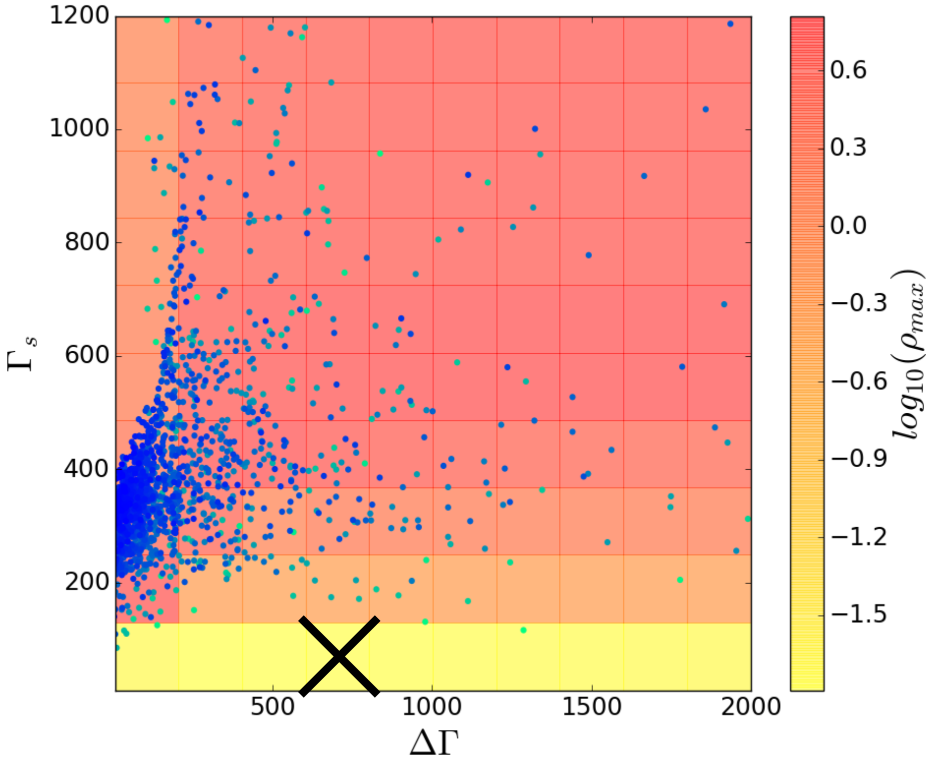
Possible Parameters:

Maximum density
Mean density
# of maxima

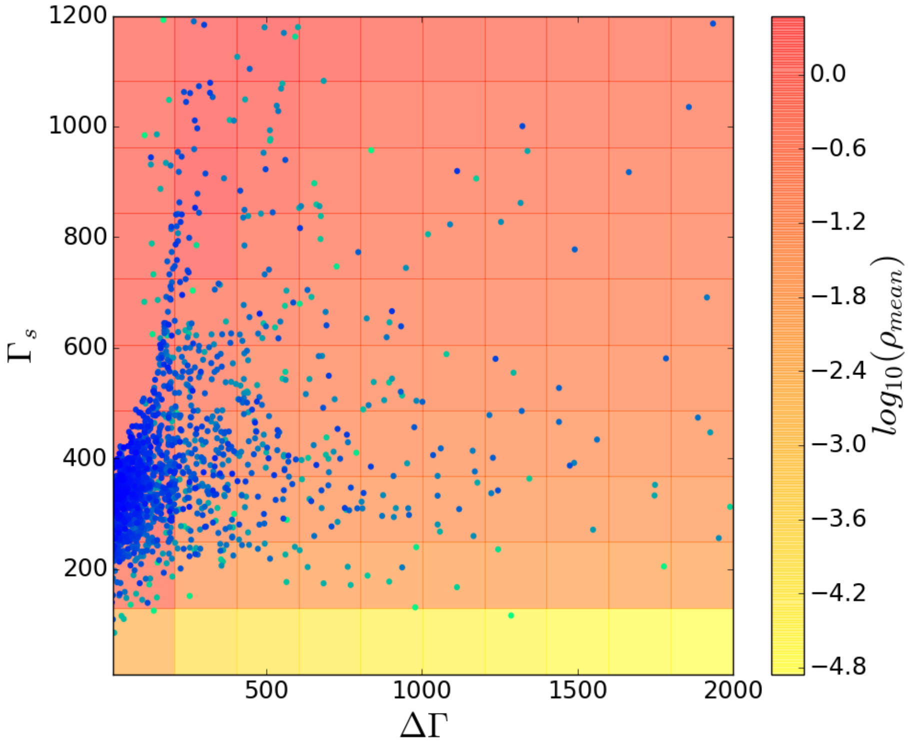
Combine with PLUTO simulations

Maximum densities

After 200 s in the CD frame



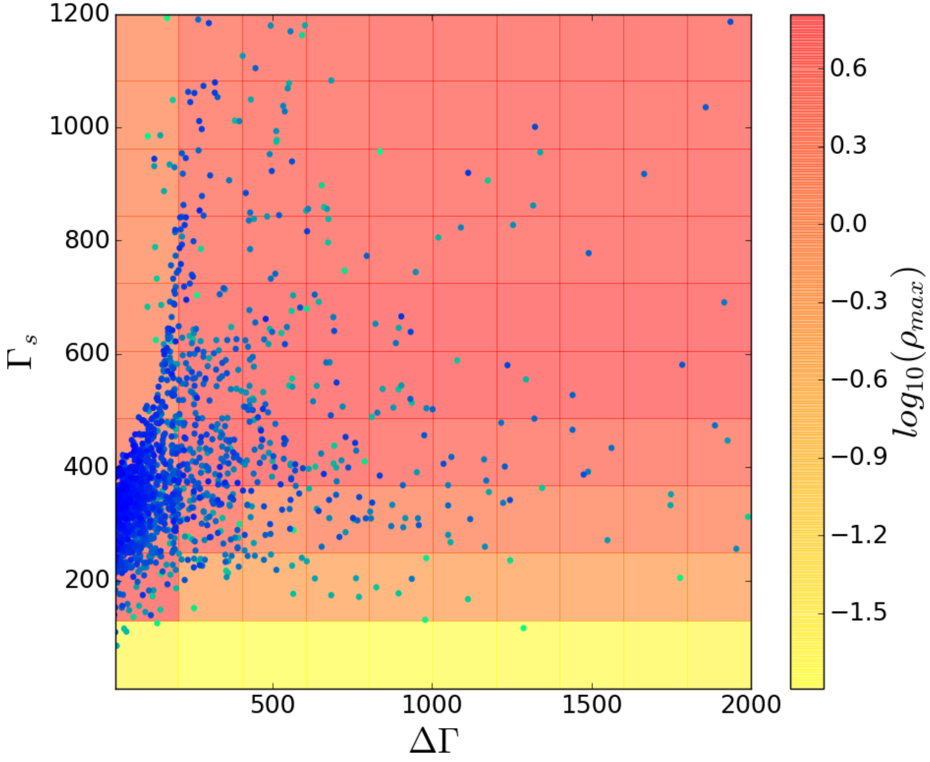
After 1000 s in CD frame



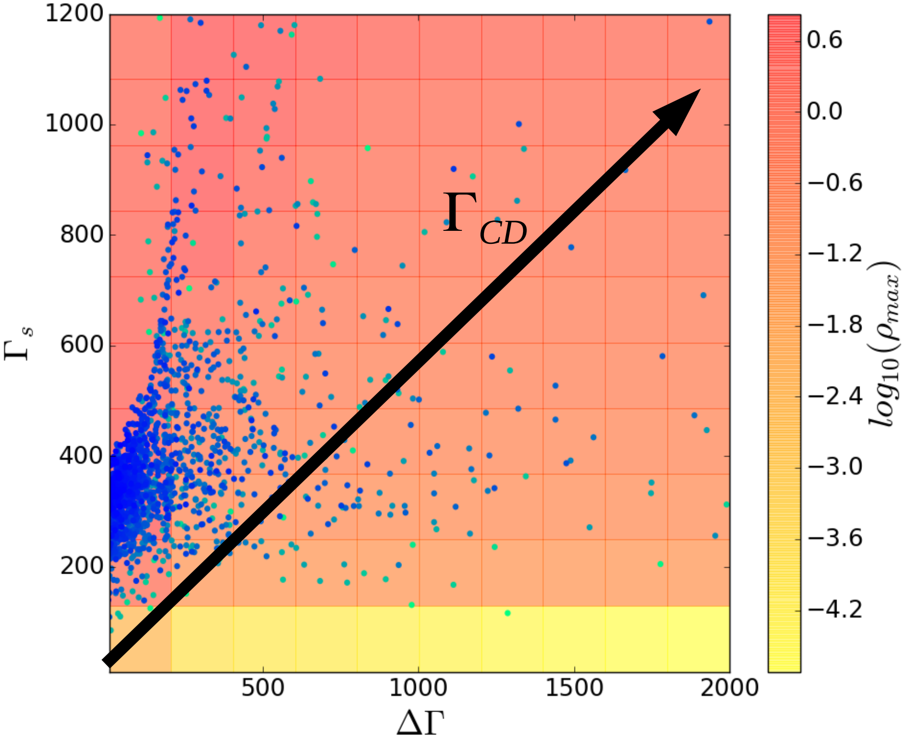
Combine with PLUTO simulations

Maximum densities

After 200 s in the CD frame



After 1000 s in CD frame



… so whats the conclusion?

- Reflecting shells unlikely
- At least some of the shells will disappear after the collision

Future prospects:

- Benchmark models
- Peak finder → merging / reflecting shells
- Include radiative cooling / magnetic fields
- Limit particle acceleration / radiation on mildly relativistic shocks
- Couple multi- collision model to hydrodynamic simulations → each collision is treated individually by PLUTO

DESY