



"Discovery of high-energy gamma-ray emission from ***a reverse shock*** of GRB 180720B"

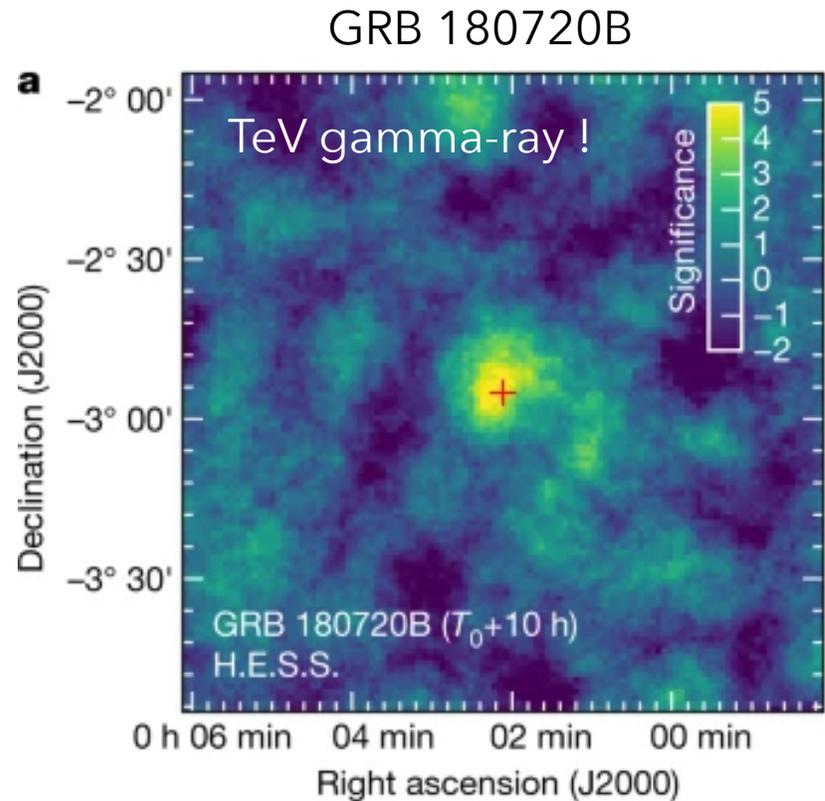
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K. Toma (Tohoku Univ), R. Gill, J. Granot (Open University of Israel)

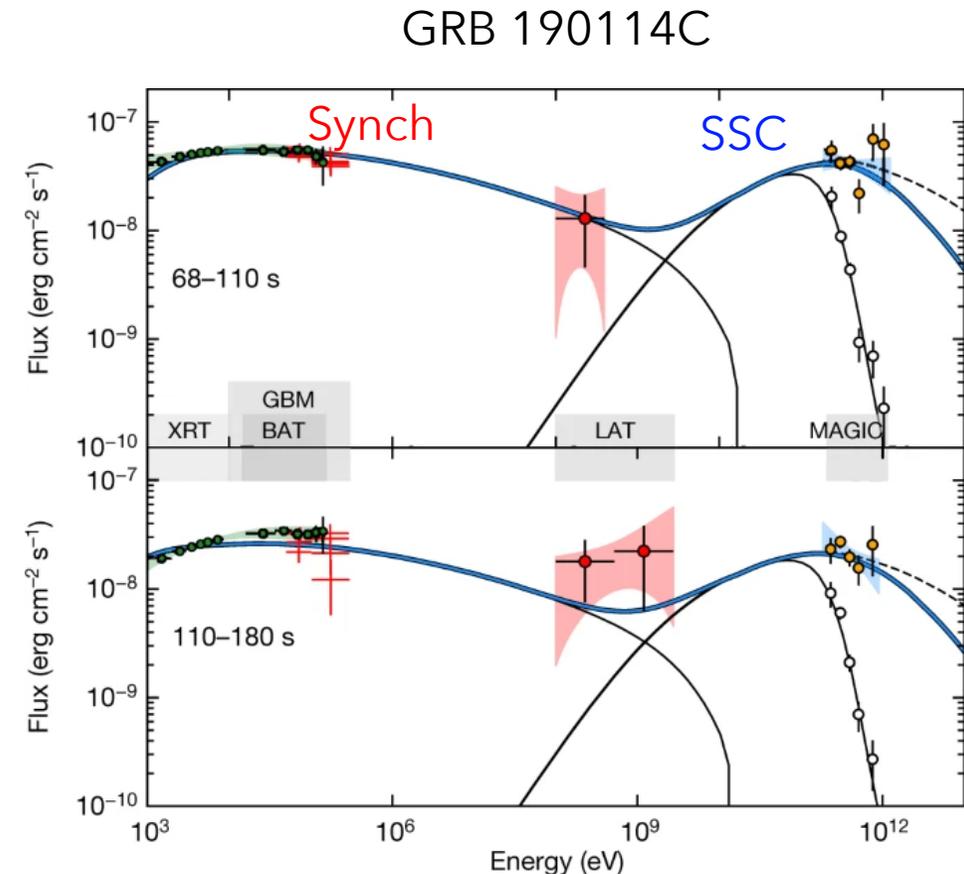
Tenth Fermi Symposium, 2022/10/12

VHE emission from GRBs: beyond synchrotron

- ✓ VHE emissions in the TeV band detected for several GRBs
- ✓ Synchrotron process cannot explain TeV photons

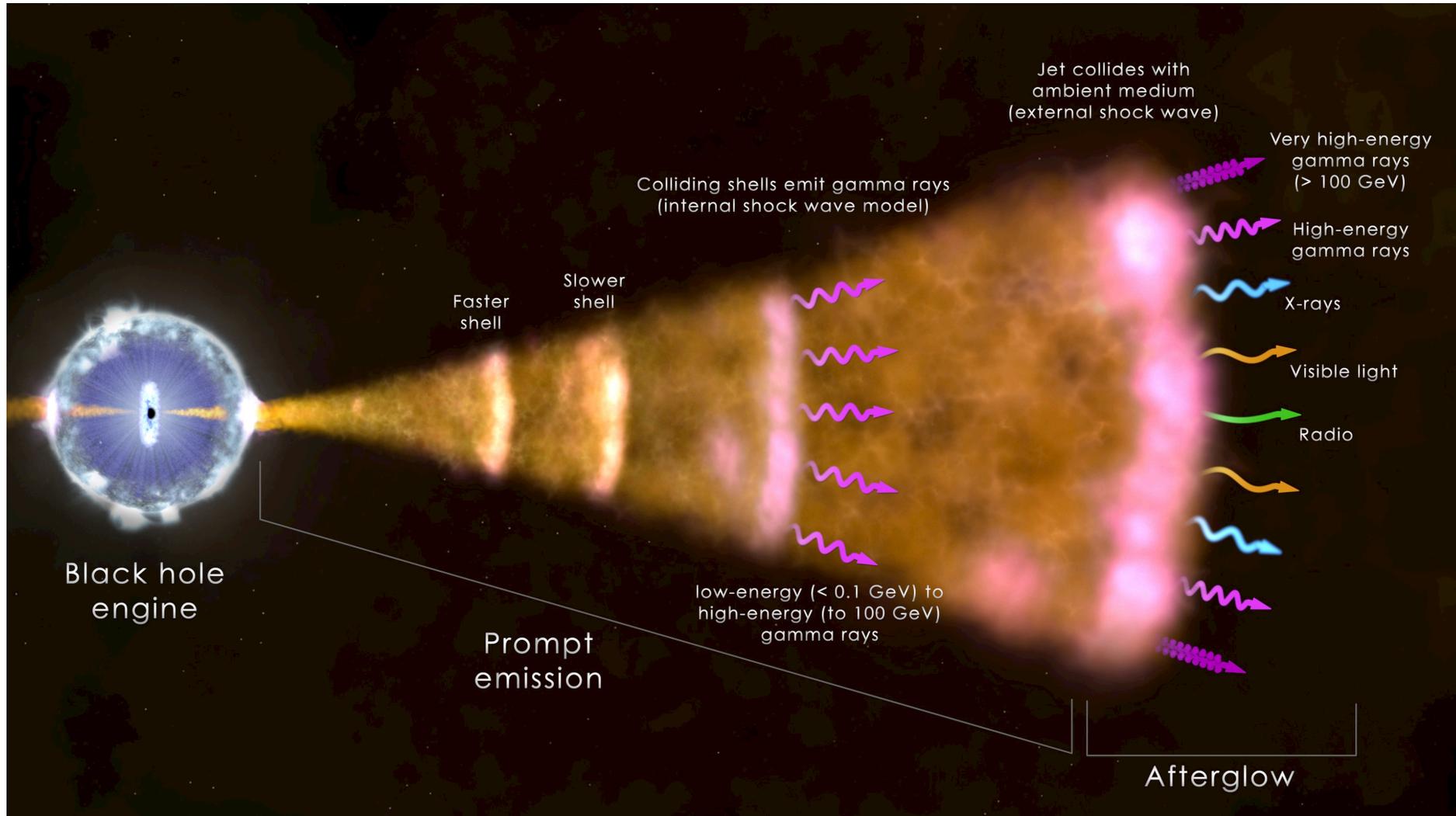


HESS Collaboration (2019)

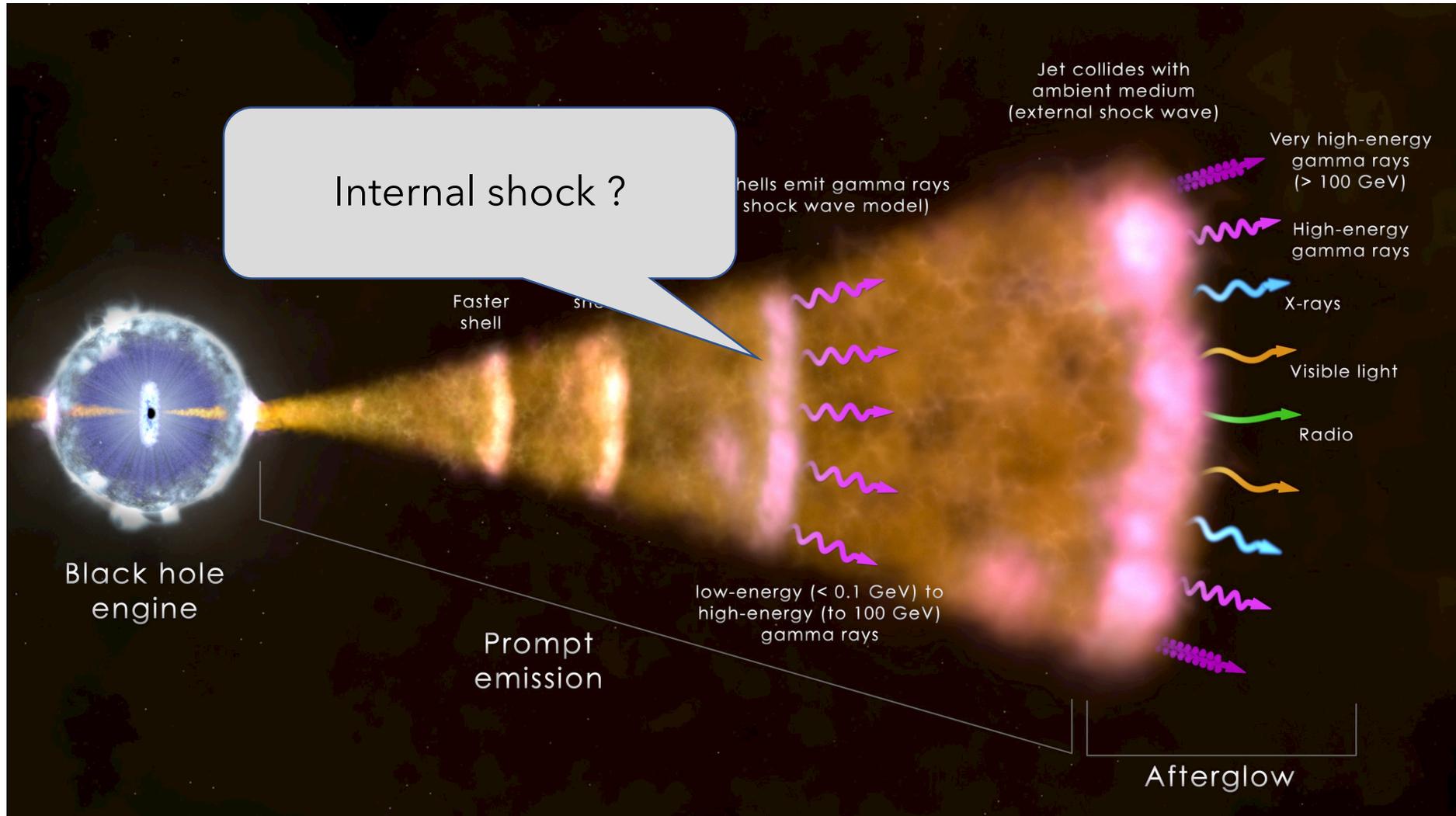


MAGIC Collaboration et al (2019)

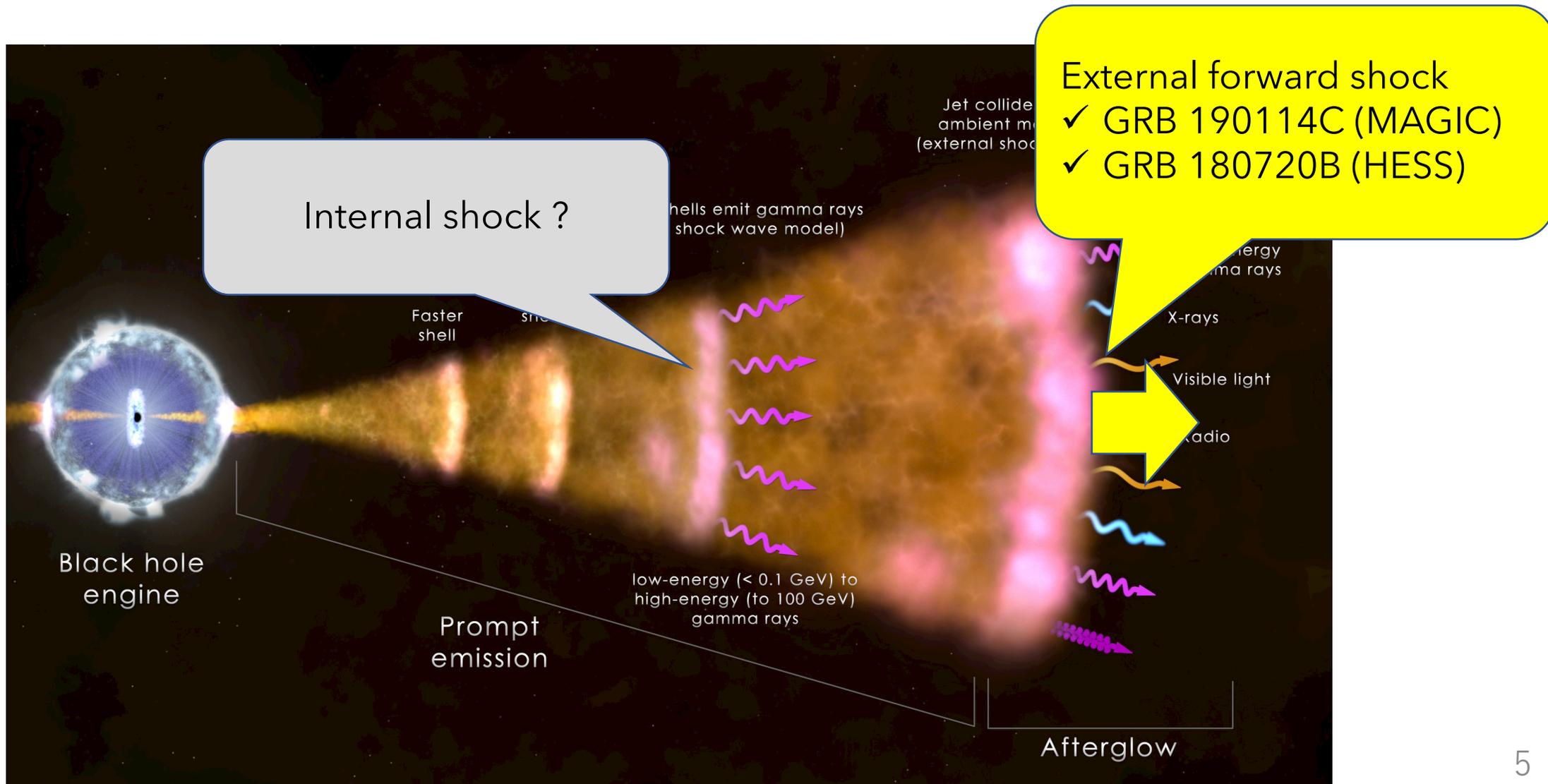
Where is emission site of gamma-rays ?



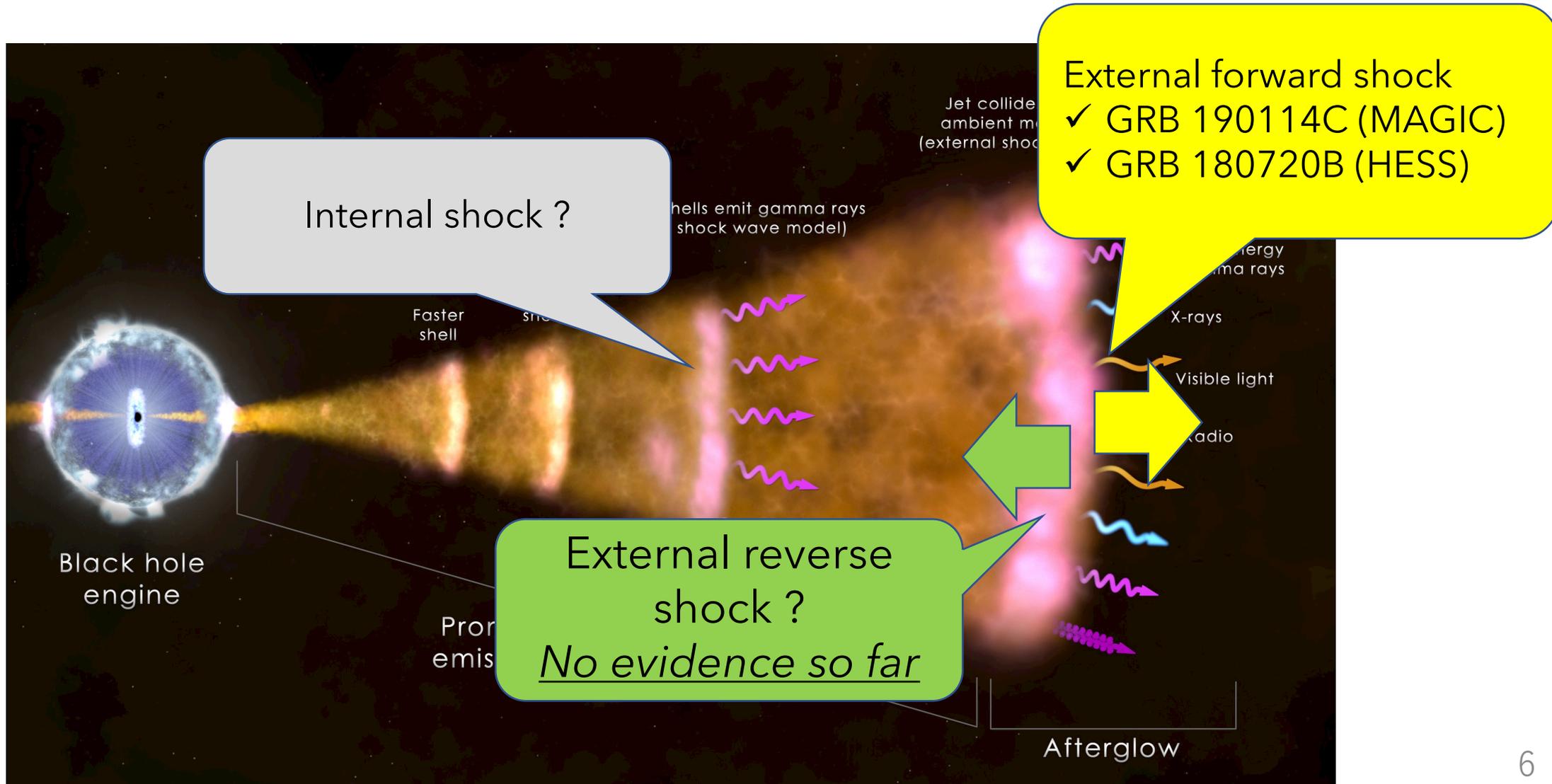
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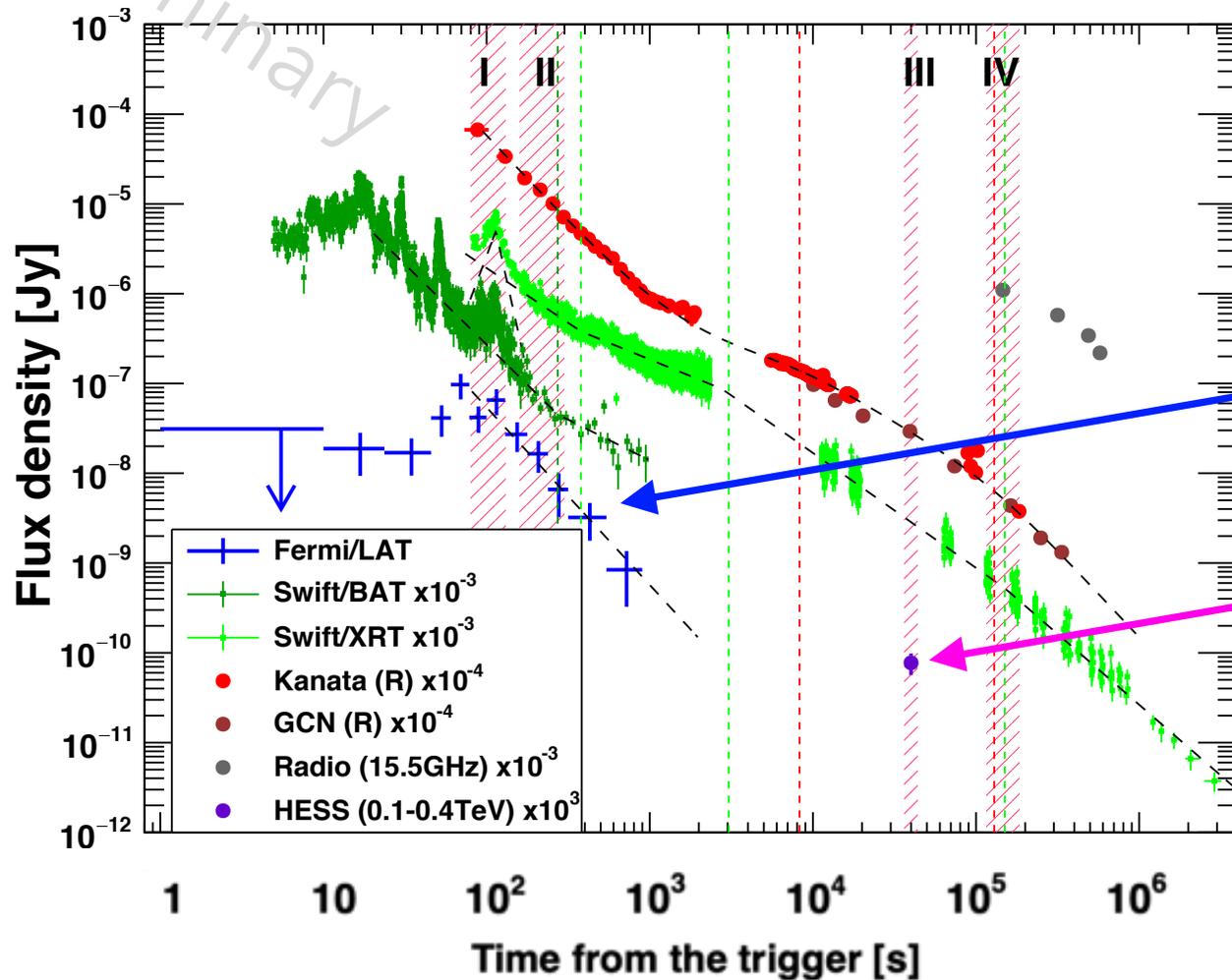


Where is emission site of gamma-rays ?



GRB 180720B afterglow emission

GeV onset
($T_0 + \sim 100$ s)

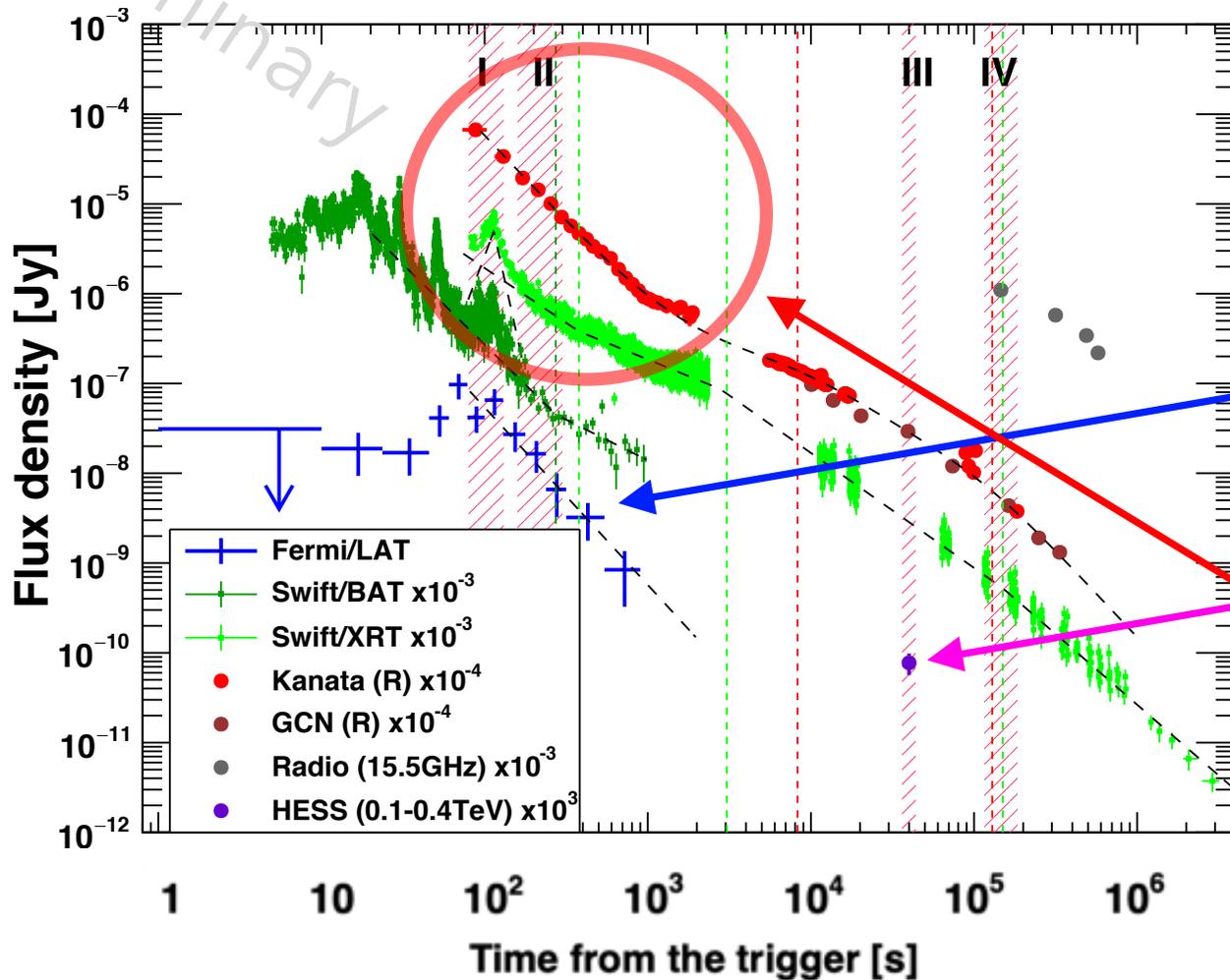


- $z = 0.654$ (Vreeswijk+ 18)
- $E_{\text{iso}} \sim 5.5 \times 10^{53}$ erg

- ✓ GeV: **Fermi-LAT**
- ✓ X-ray: Swift-BAT, XRT
- ✓ Radio: AMI-LA
- ✓ VHE: HESS (Abdalla+19)
- ✓ Optical: **Kanata**, others (GCNs)

GRB 180720B afterglow emission

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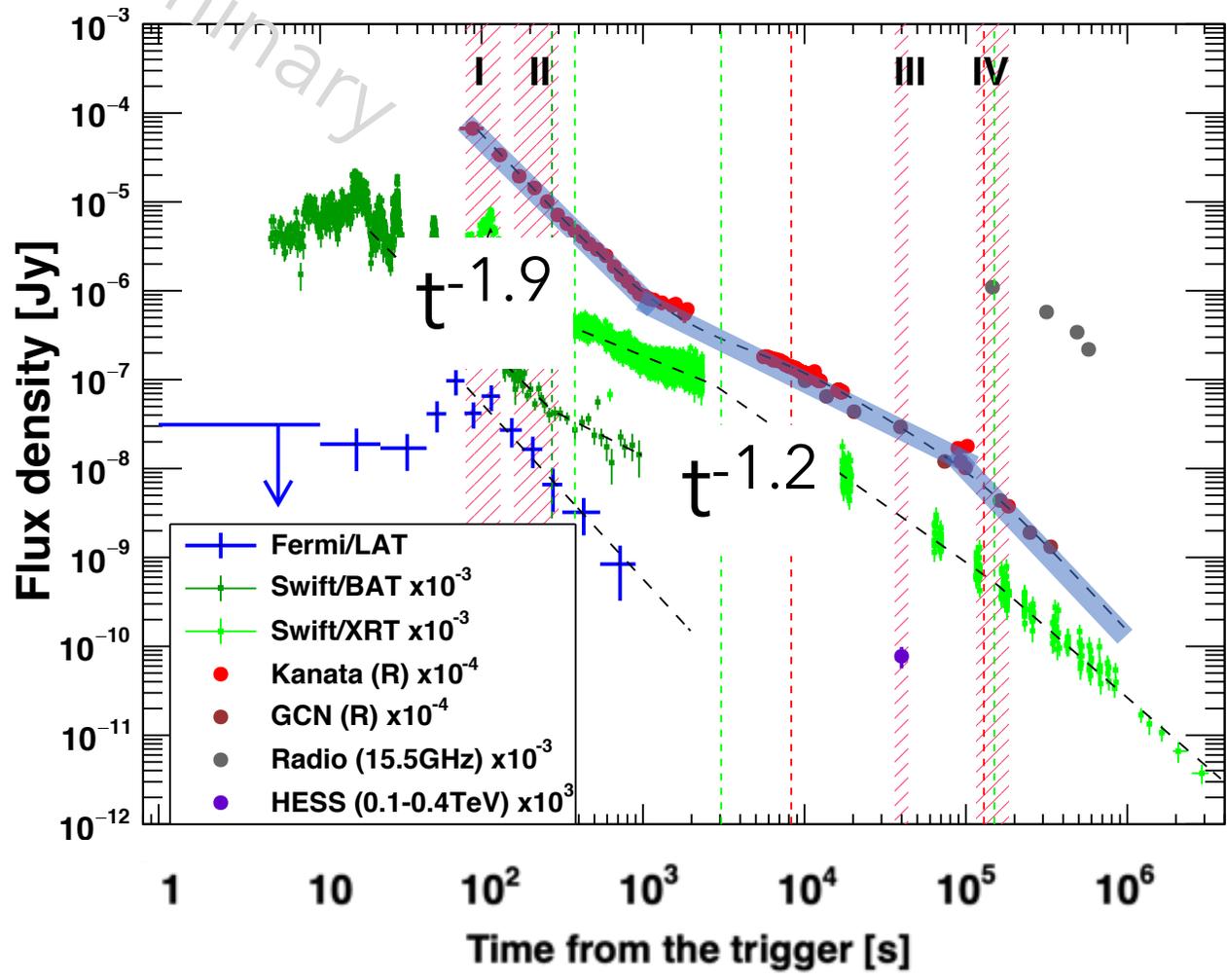


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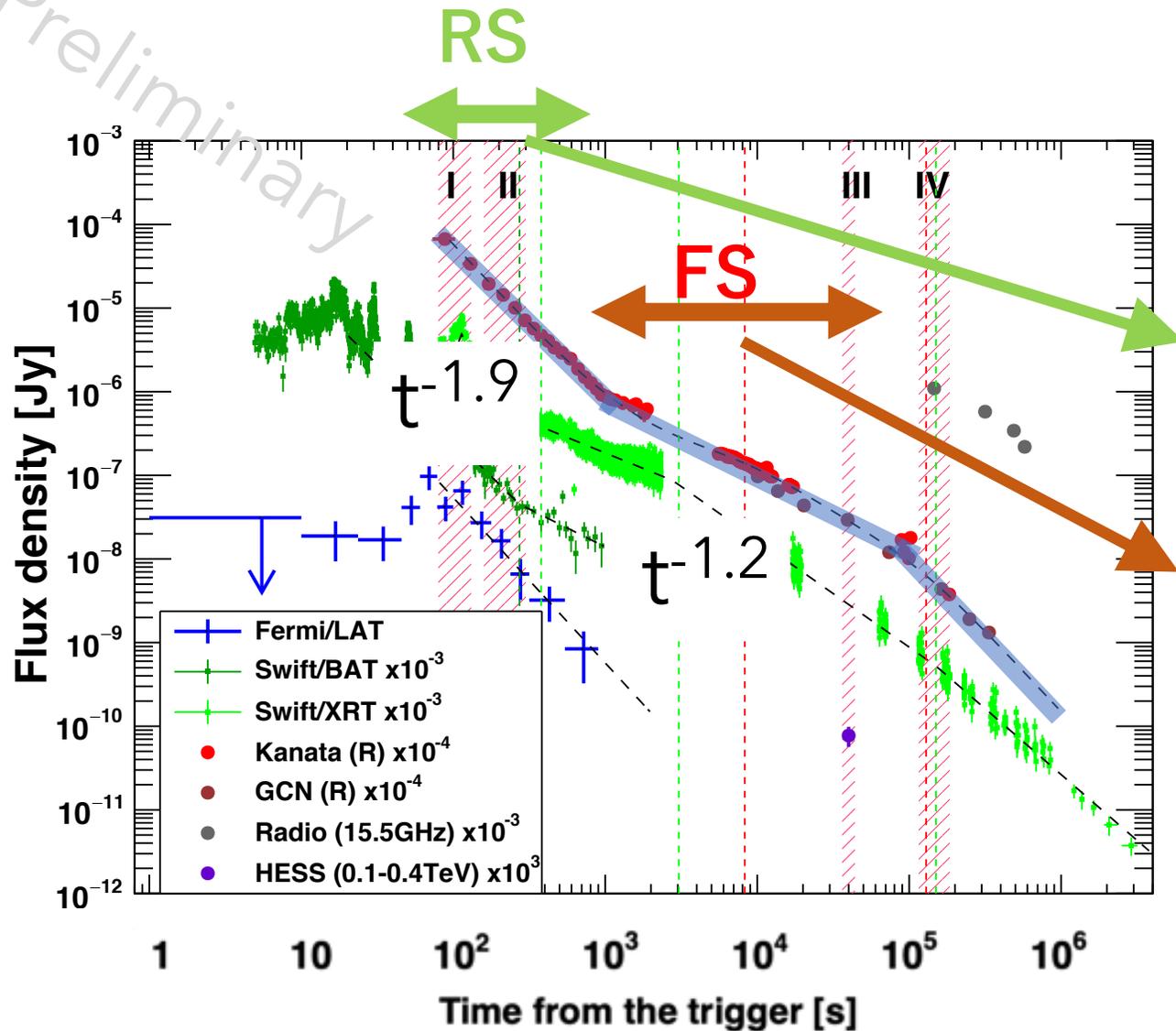
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GRB 180720B

optical emission

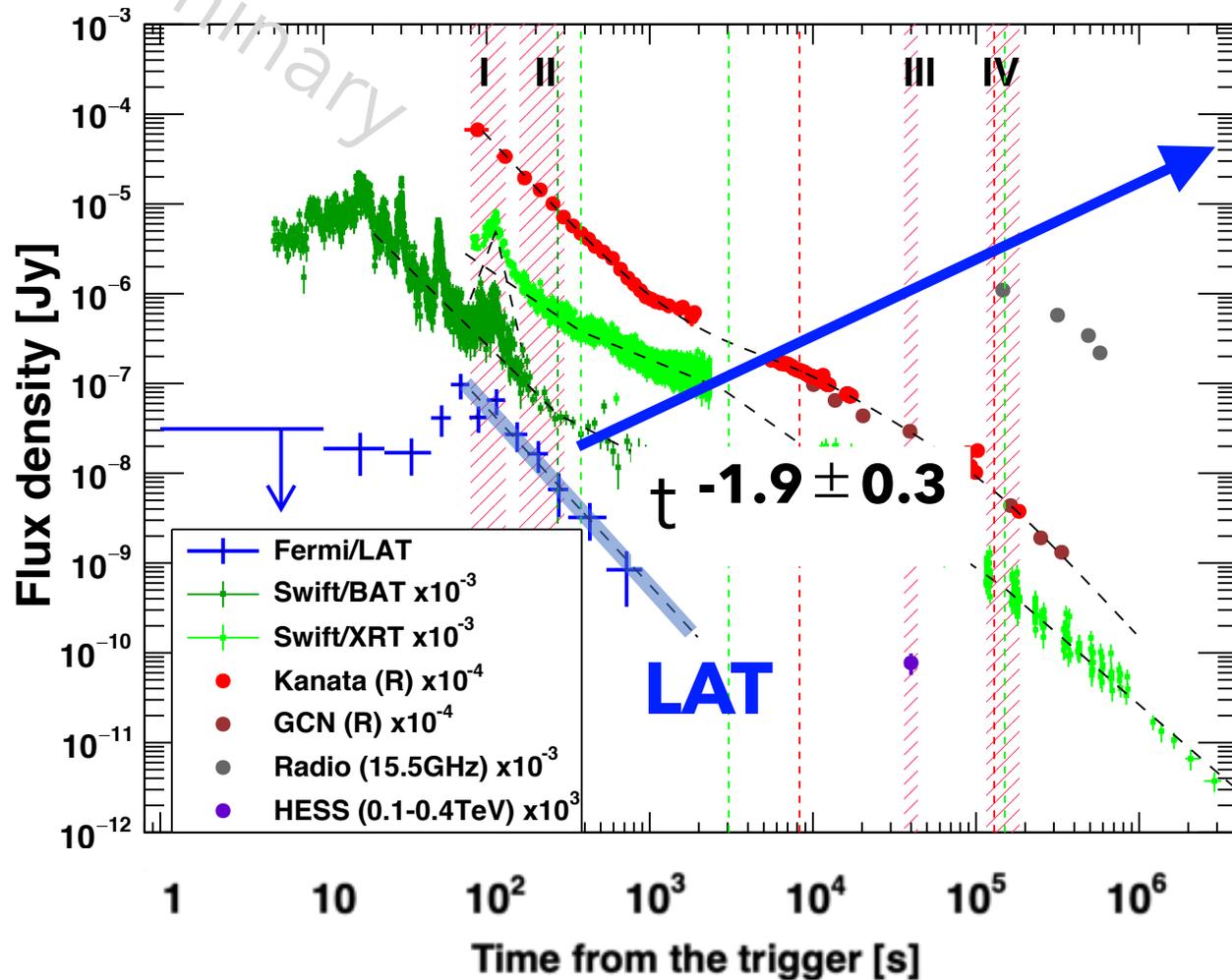


GRB 180720B **optical** emission



- Steep decay ($t^{-1.9}$)
→ Reverse shock (Kobayashi+00)
- Moderate decay ($t^{-1.2}$)
→ Forward shock (e.g., Piran+04)

GeV band (LAT)



✓ The observed temporal index (~ -1.9) is **steeper** than typical one.
($\alpha \sim -1.1$; 2FLGC paper, Ackermann+19)

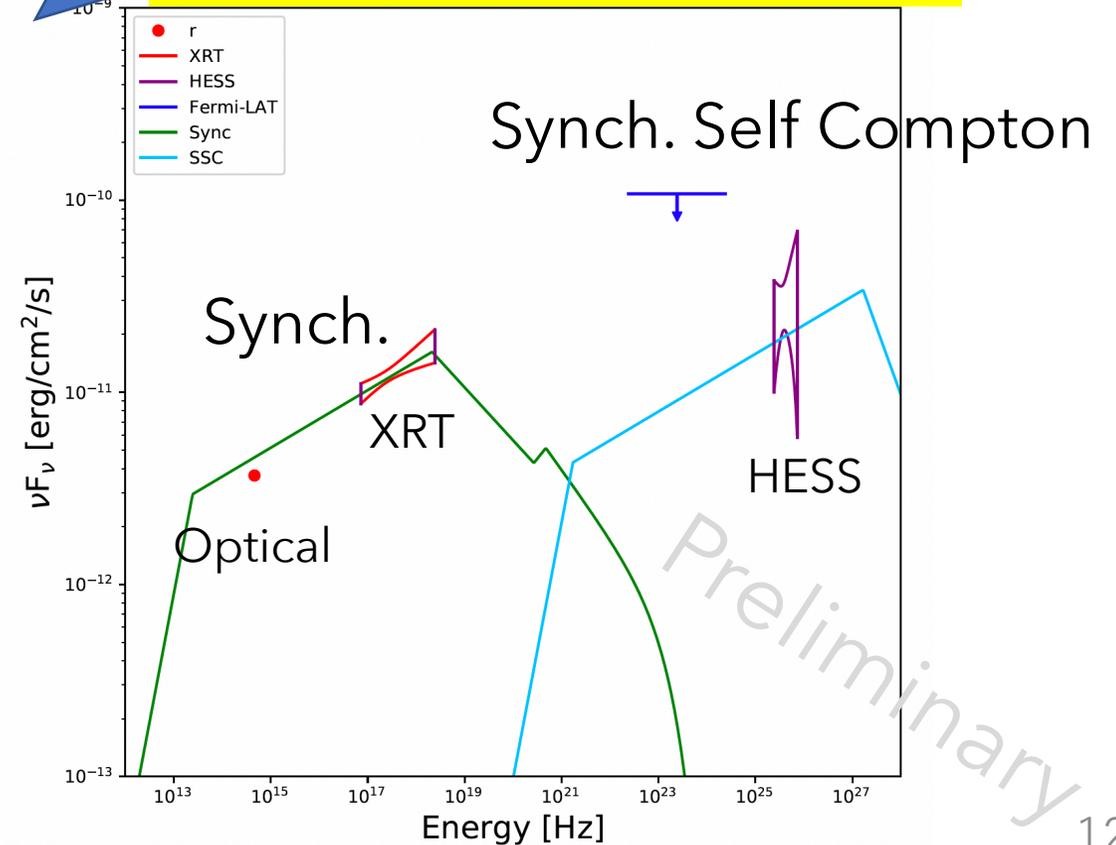
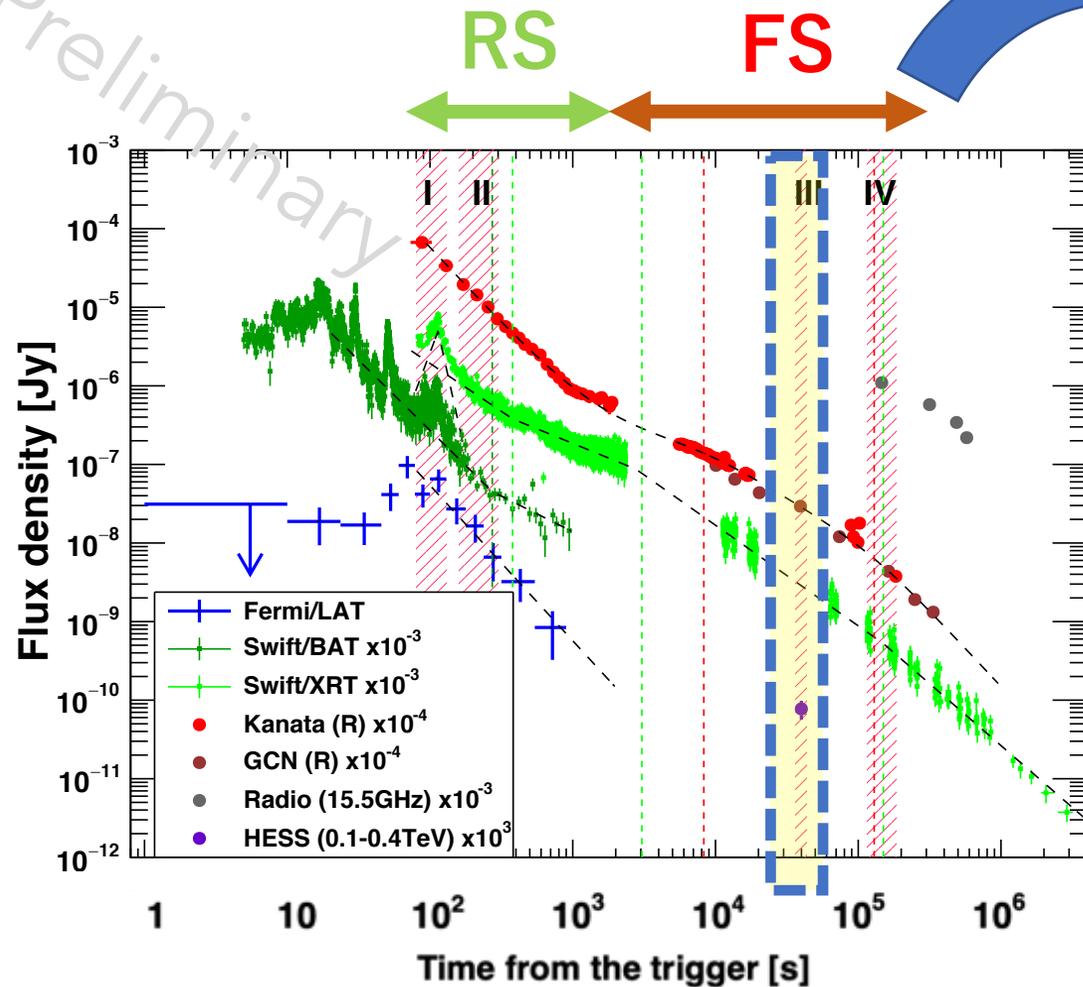
- ✓ $\alpha \sim -1.1 \rightarrow$ Forward shock
- ✓ **$\alpha \sim -1.9$** \rightarrow Reverse shock

✓ LAT emission comes from a **reverse shock**?

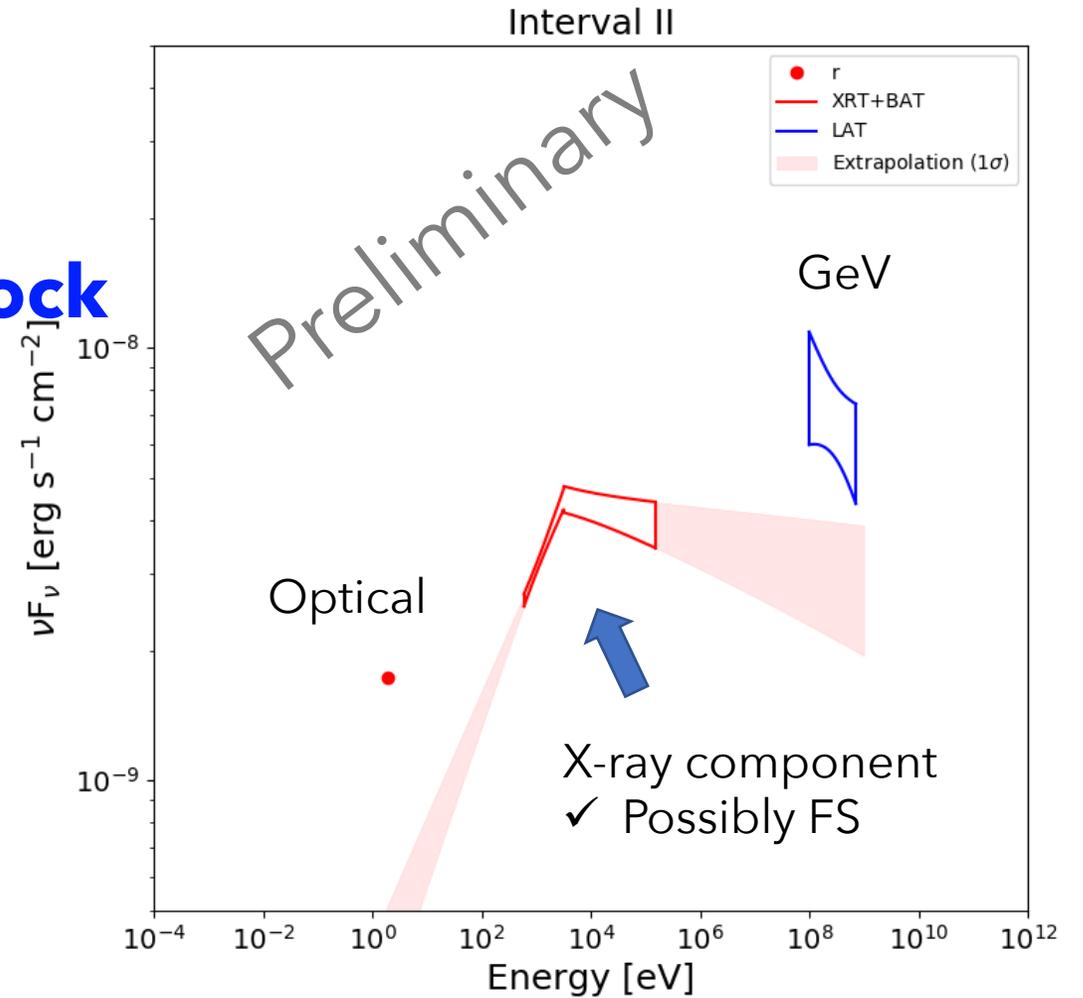
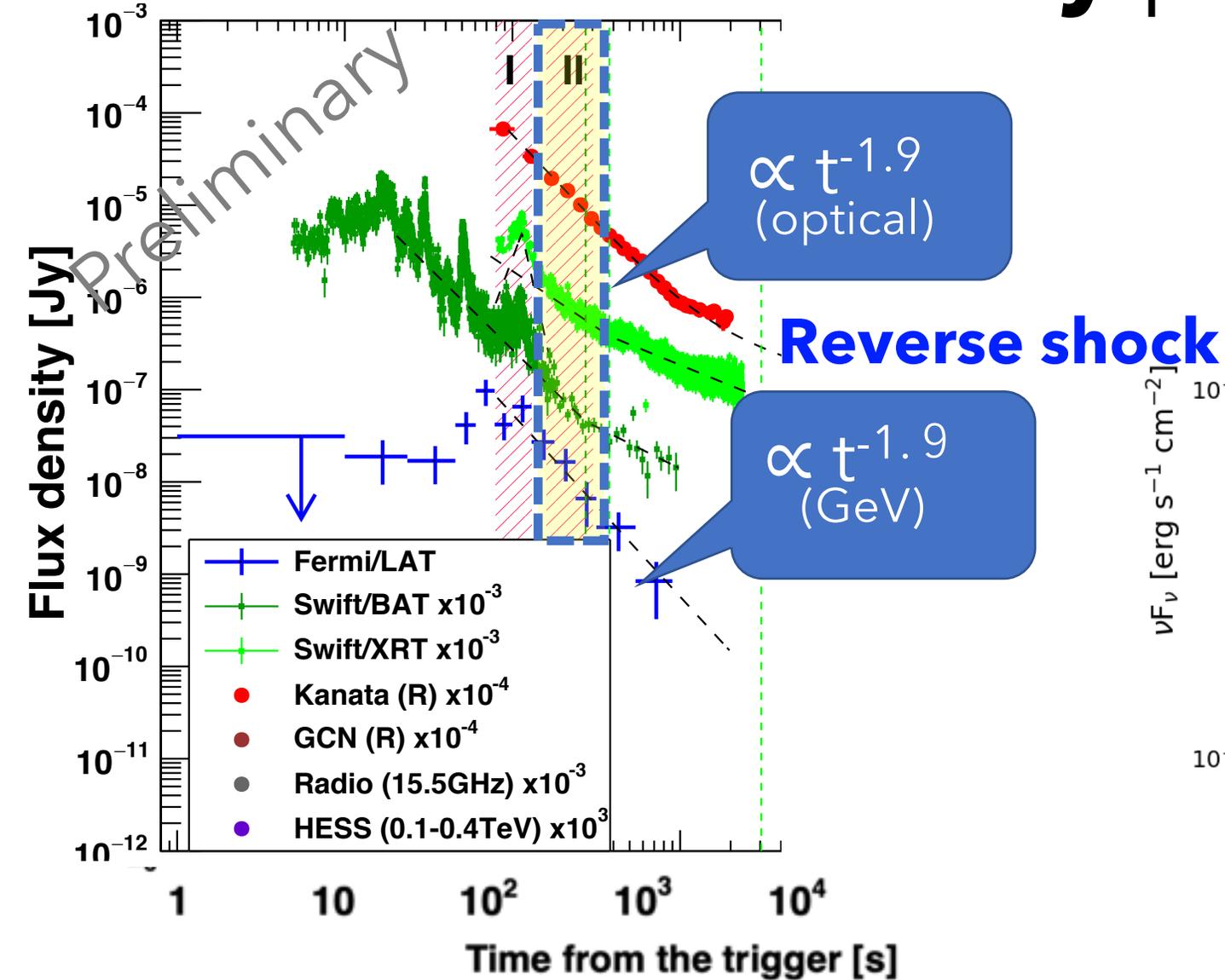
Emission in the **late** phase

Forward shock model

- $\epsilon_{e,f} = 0.2, \epsilon_{B,f} = 1.5 \times 10^{-4}$
- $n_{\text{ISM}} = 5 \times 10^{-3} \text{ cm}^{-3}$

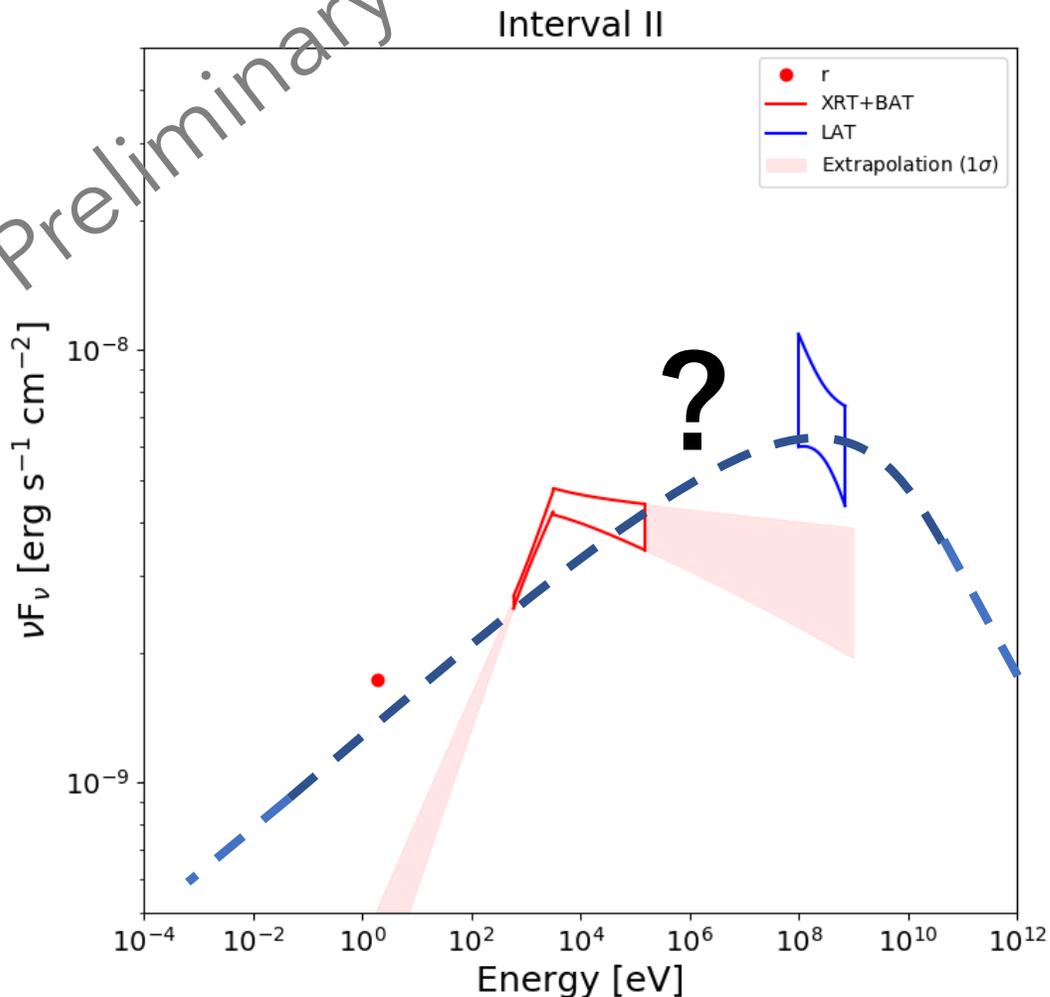


Emission in the **early** phase



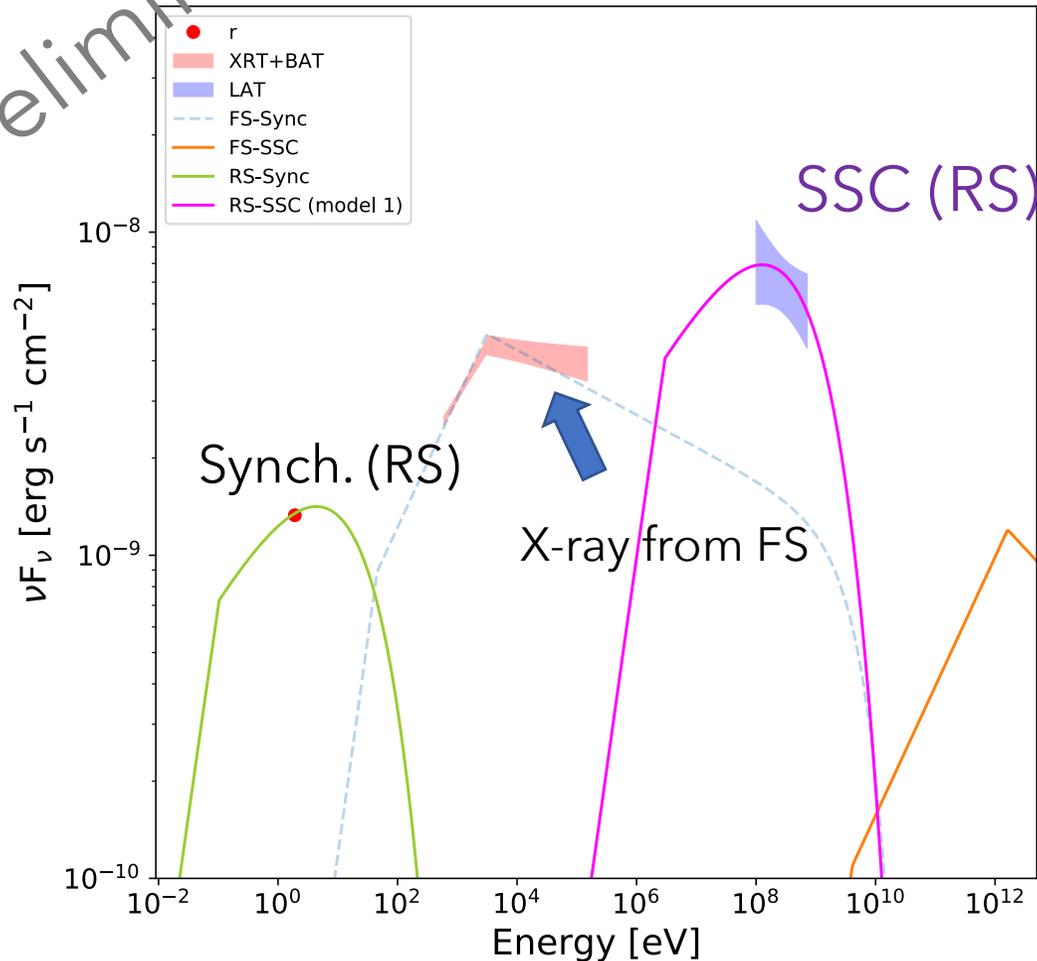
Single component can explain the data ?

Preliminary



- Synch energy from RS cannot go up above $\nu_{c,r} \sim \text{keV}$
 - No fresh particles injected after RS passes through the shell
 - Kobayashi+ 00 etc.
- **Single** synch component is not feasible for RS
 - **Two components** are needed !

Emission in the **early** phase: Synch and SSC from a reverse shock



- High-energy gamma rays are well explained by inverse Compton scenario
 - SSC/Synch ratio: $Y \sim 6$
 - $\epsilon_{e,r} \sim 10^{-2}$
 - $\epsilon_{B,r} \sim 7 \times 10^{-4}$
 - ✓ Ref: $\epsilon_{B,f} = 1.5 \times 10^{-4}$
 - ✓ GRB ejecta relatively magnetized

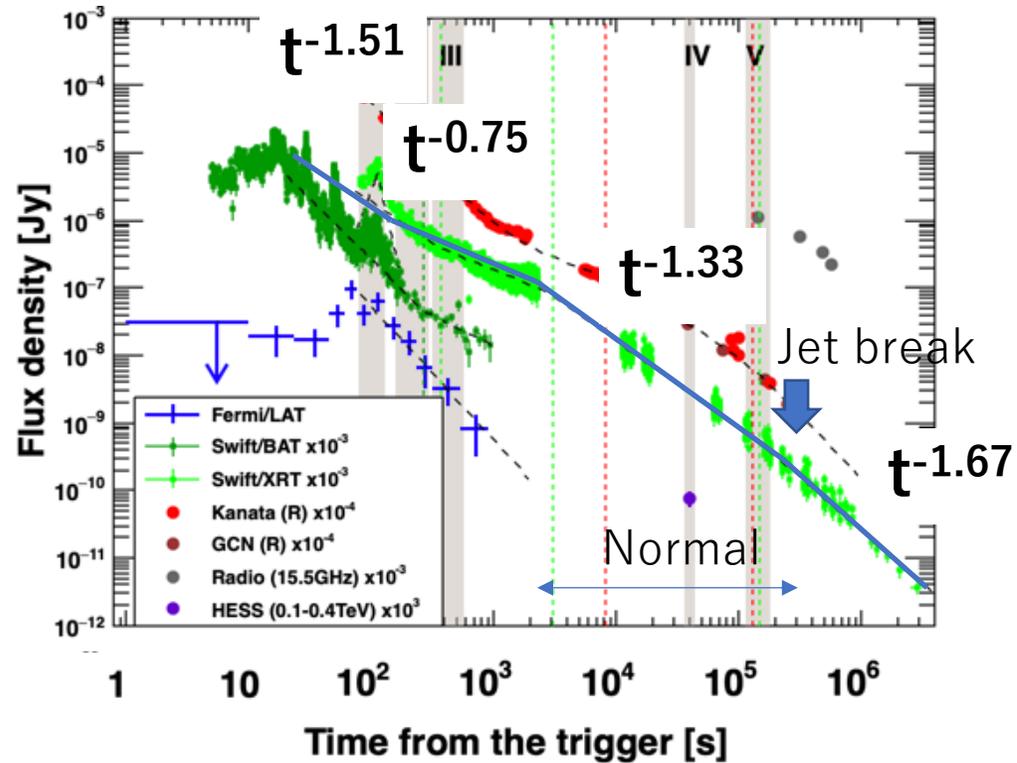
✓ SSC from RS was predicted (Zhang+01)
✓ **First observational evidence** with optical and GeV (SSC) excesses

Summary

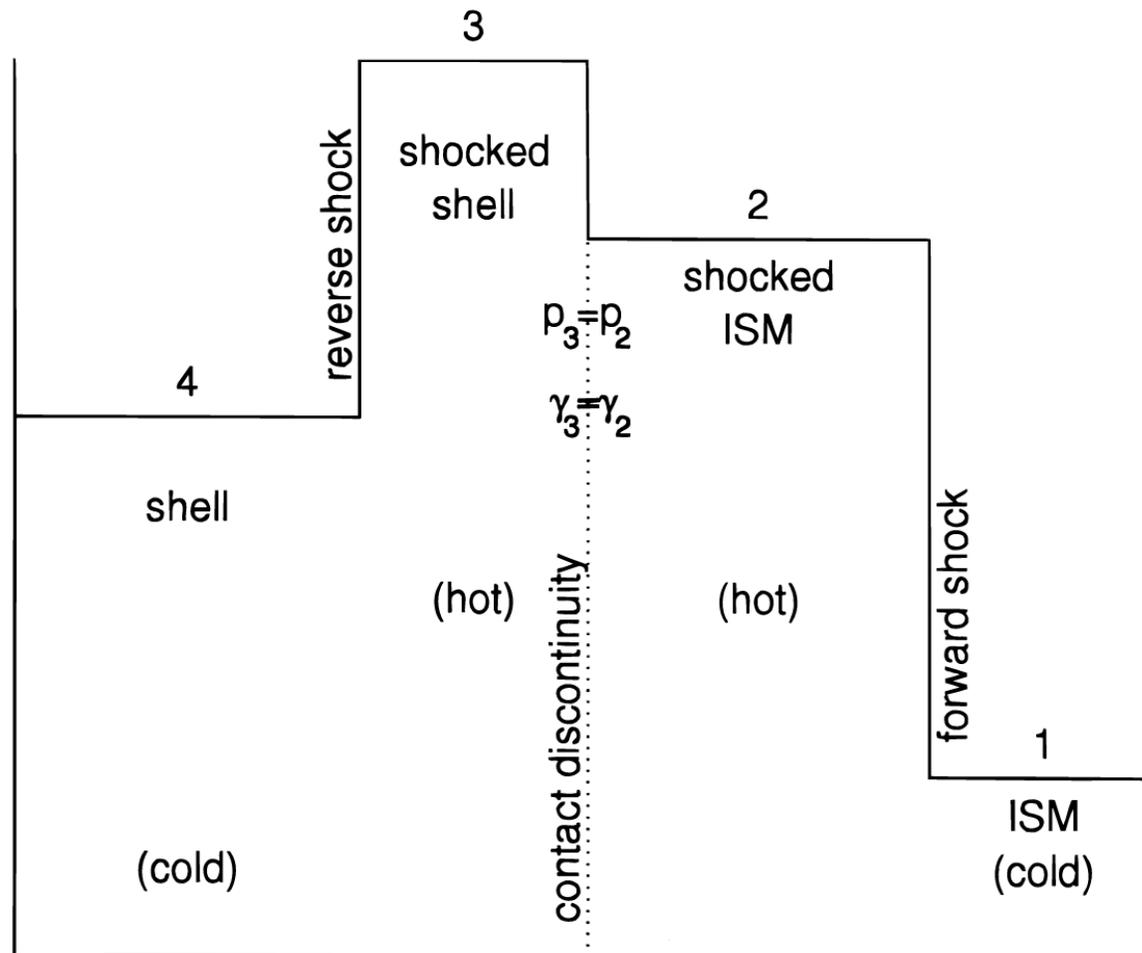
- GRB 180720B shows:
 - ✓ At the **late** phase,
 - VHE gamma rays can be interpreted as SSC from a forward shock.
 - ✓ At the **early** phase,
 - Optical and GeV emissions declined steeply ($t^{-1.9}$)
 - Optical and GeV excesses from FS component
 - First detection of **GeV SSC from a reverse shock**
 - ✓ SSC emissions from both forward and reverse shocks
 - Physical condition: $\epsilon_{B,f} \sim 5 \epsilon_{B,r}$
 - RS is relatively magnetized compared to FS

Appendix

X-ray band (XRT)



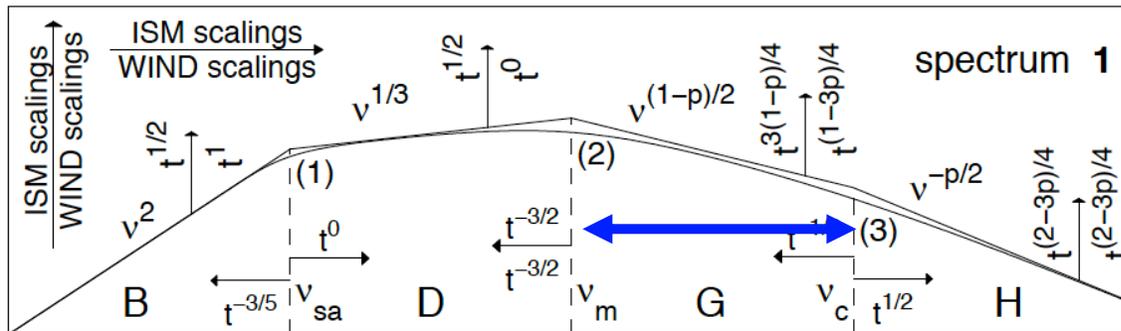
✓ Shallow decay \rightarrow normal decay \rightarrow jet break



Sari+ 96

Theoretical modeling (FS)

- Observed temporal index
 - $\alpha \sim -1.3 - -1.1$ (X-ray & opt.)
- ISM scenario: $\nu_m < \nu < \nu_c$
 $p \sim 2.7 \rightarrow \Gamma_{ph} = -1.8$ & $\alpha = -1.3$



- Wind scenario:
 - cannot explain both spectral & temporal behaviors

