Particle acceleration timescales in relativistic jets

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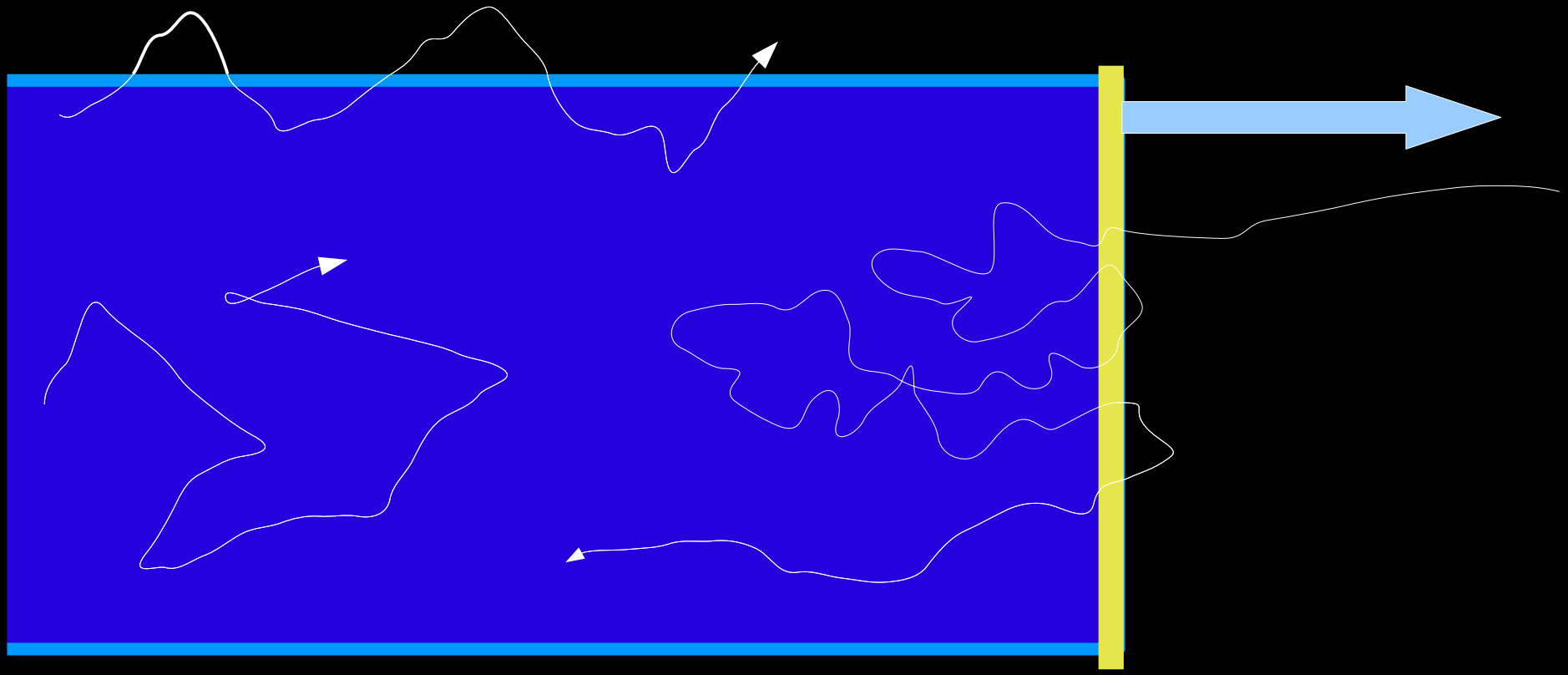
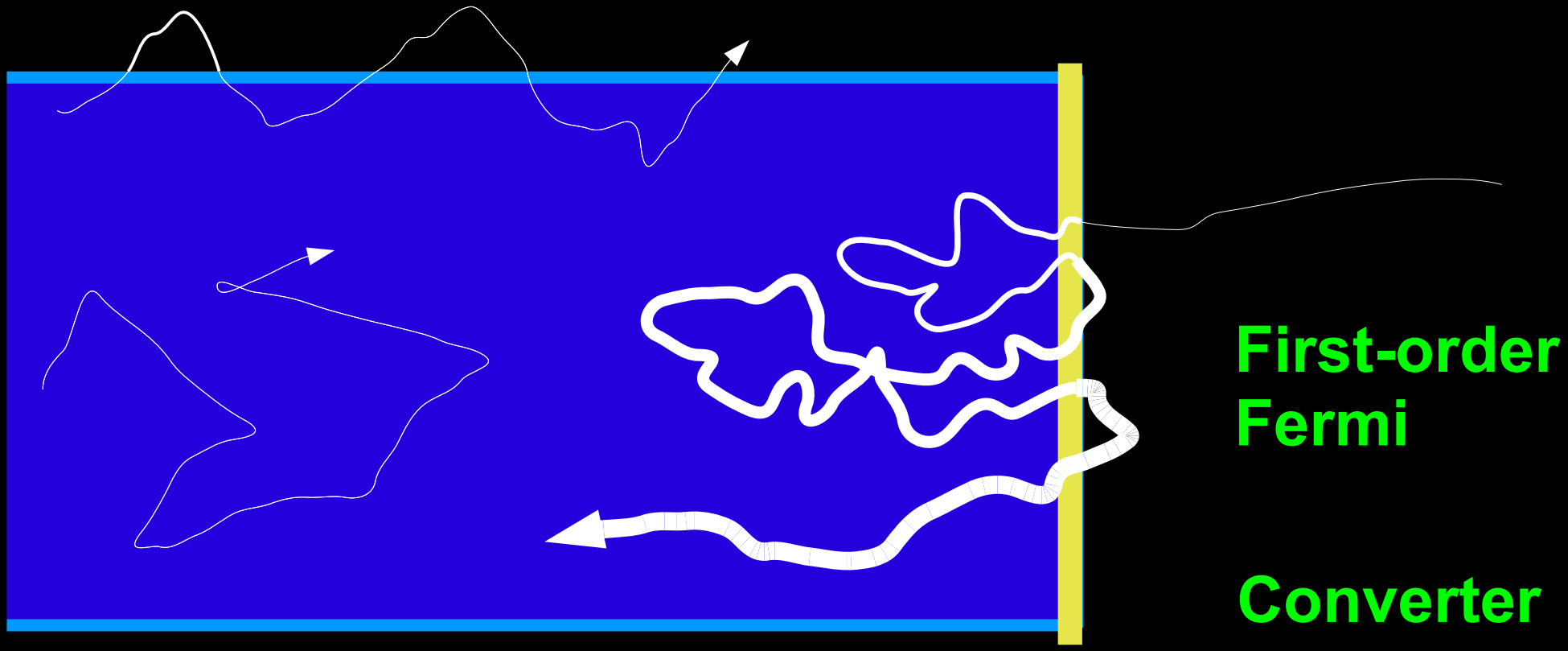
NGC 6251
1 MEGAPARSEC
Size of the
Milky Way
100 KILOPARSECS
N
E
1 PARSEC

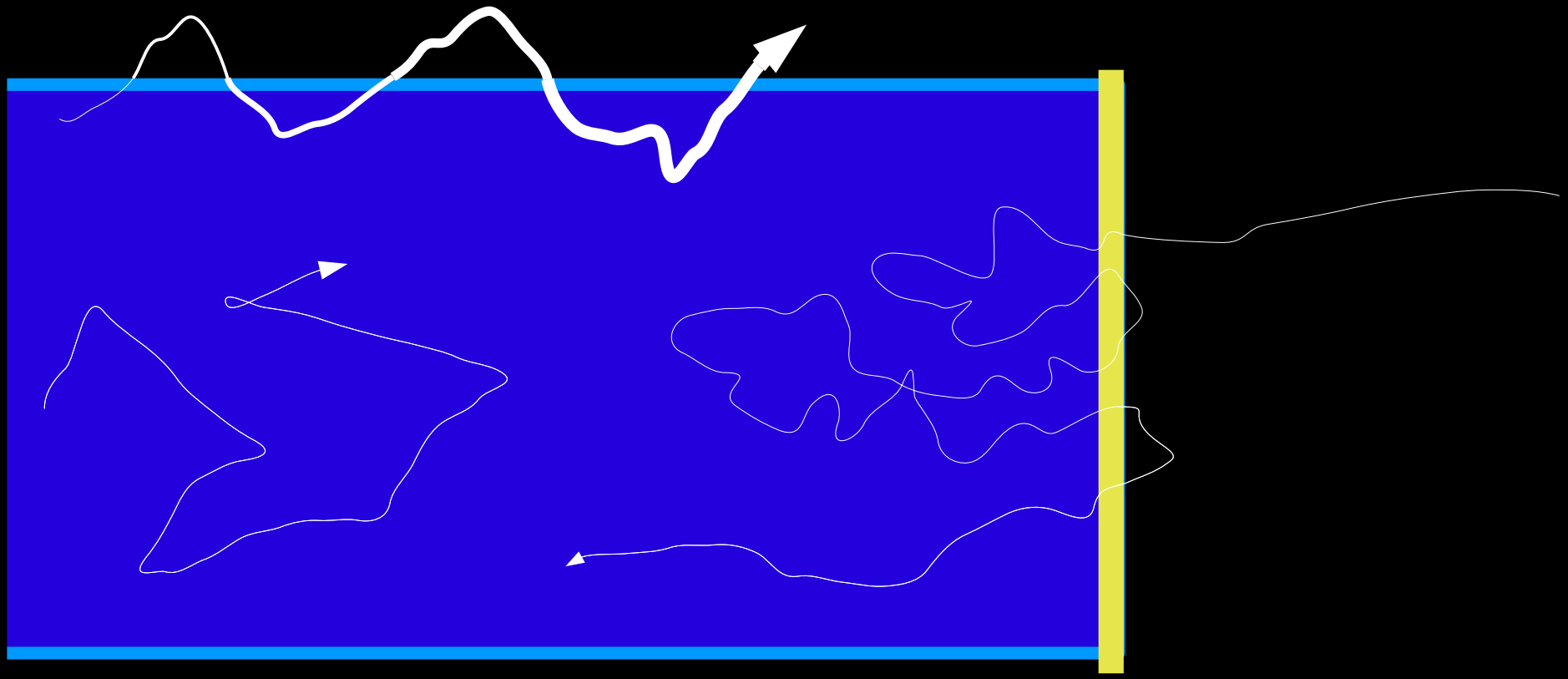
Flare timescales ~ 5 minutes

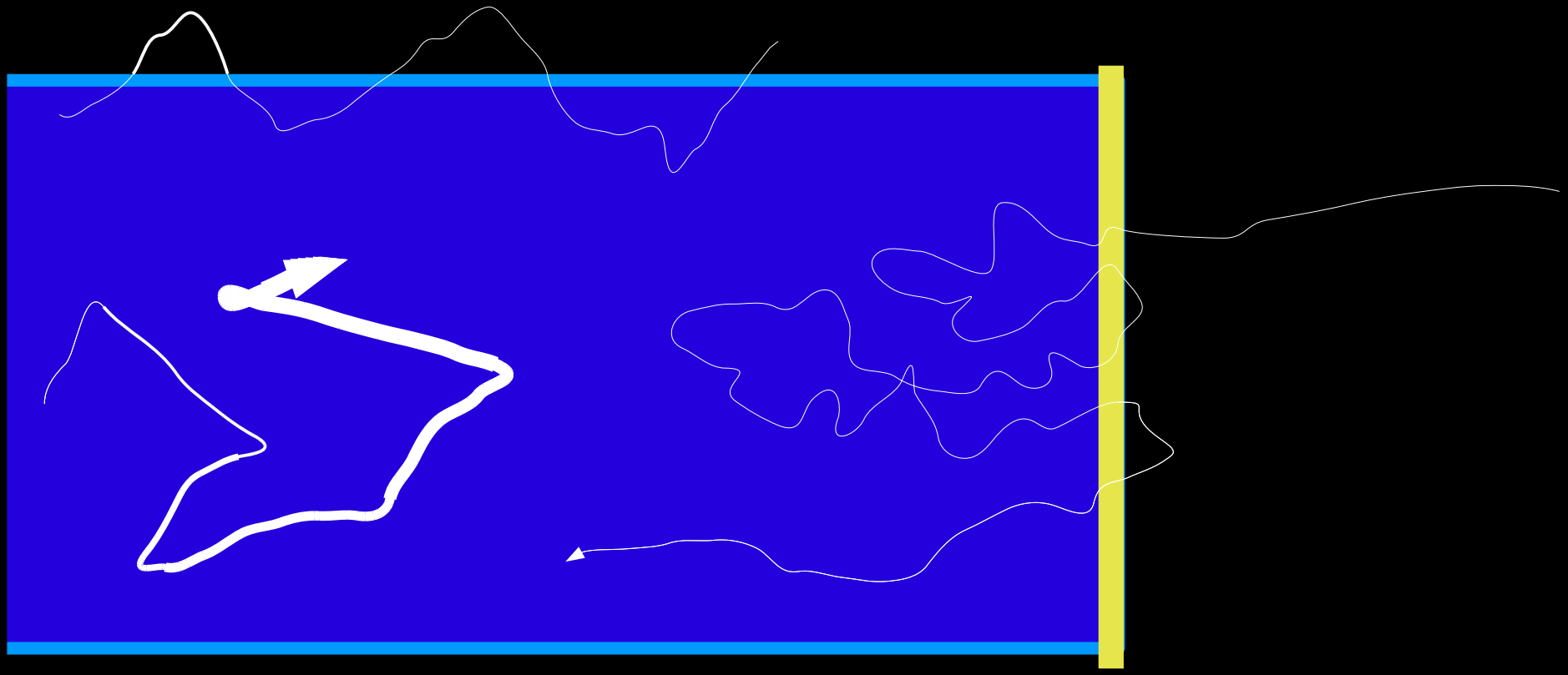
- Can particles get energy in this time?
- Is acceleration still instantaneous?
- Which mechanism can / cannot do it?
- ”Injection, then only cooling”?
- Can ”hard lags” be due to continuous acceleration?



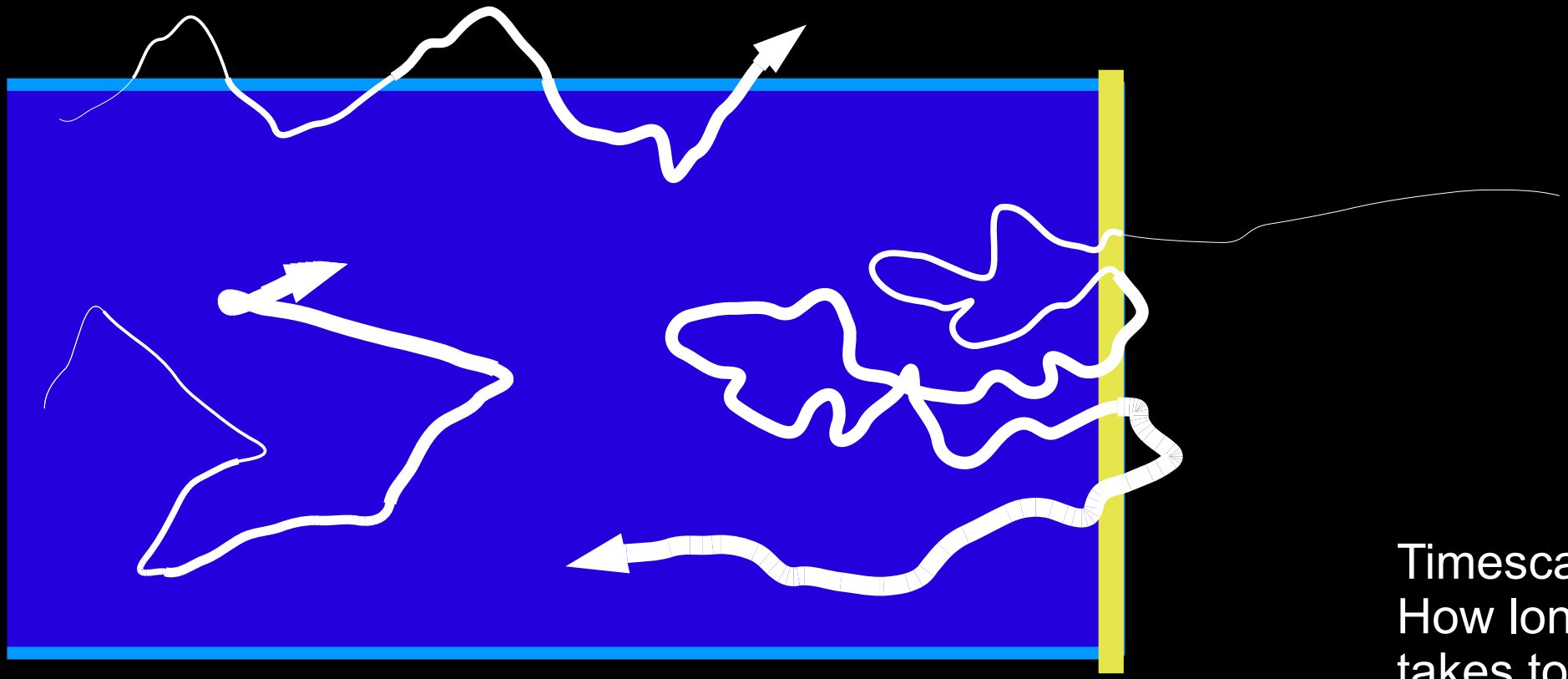

First-order
Fermi
Converter

Shear

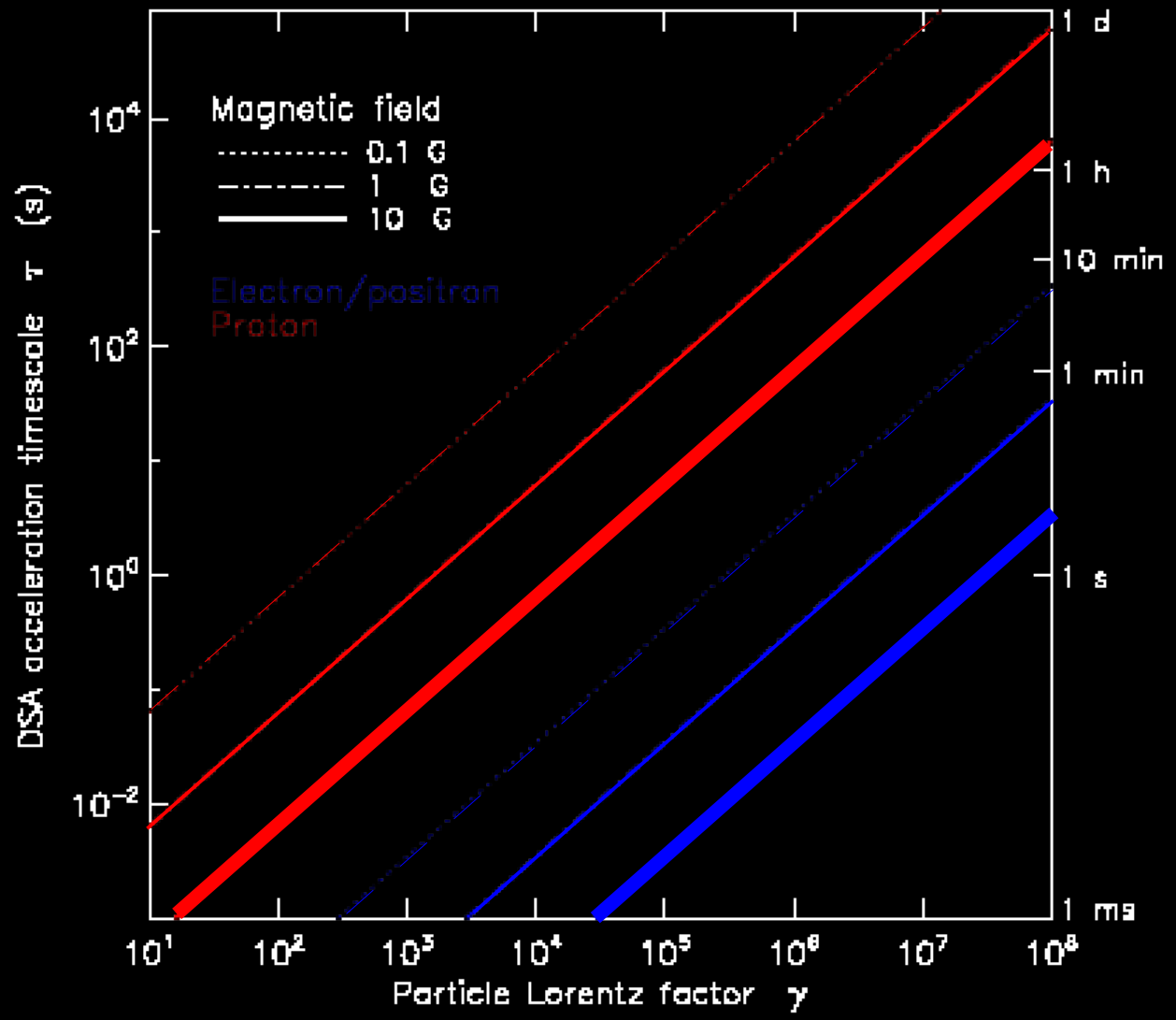




Second-order Fermi (stochastic)

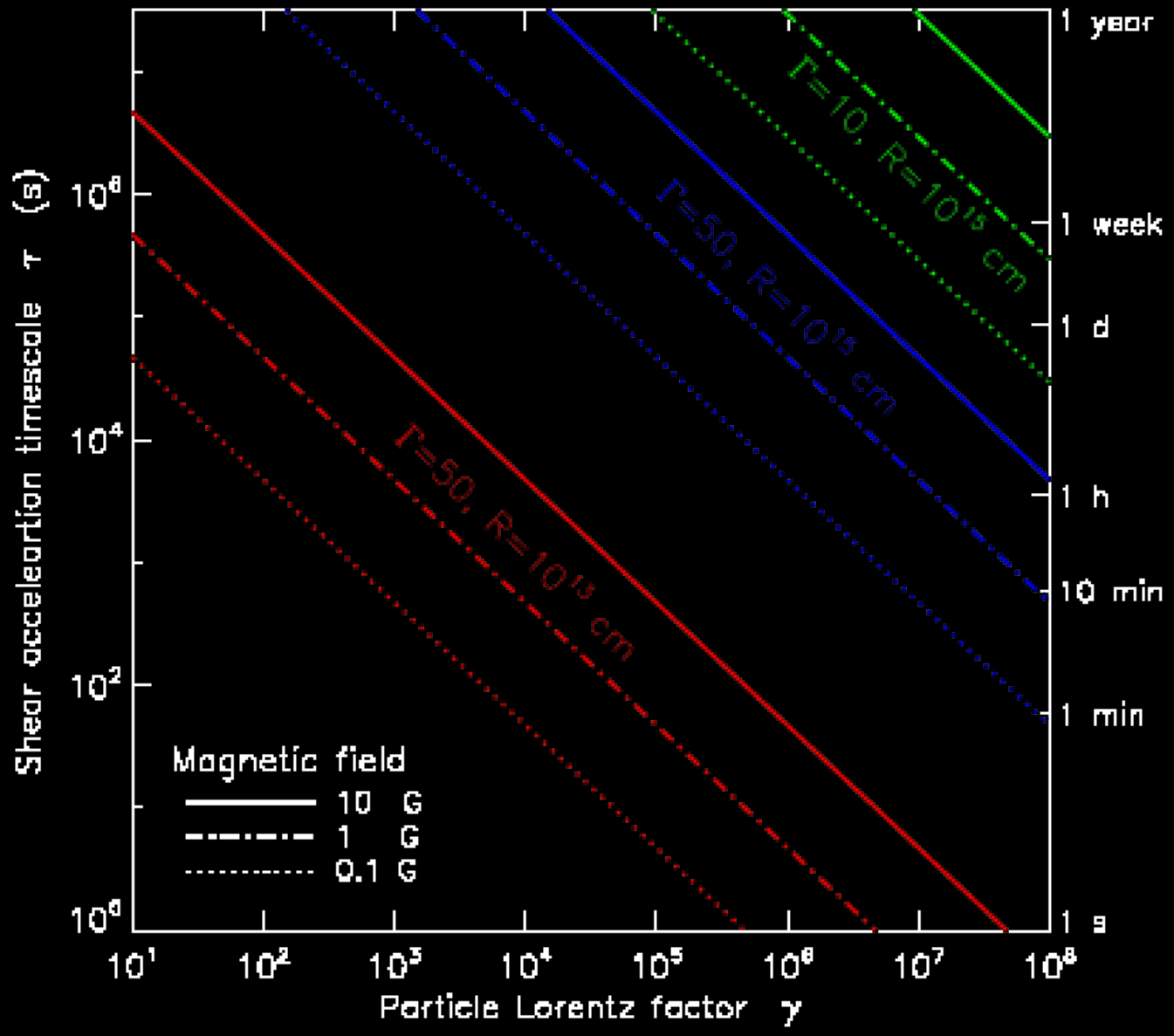


Timescales:
How long it takes to gain/ lose energy



proton

electron



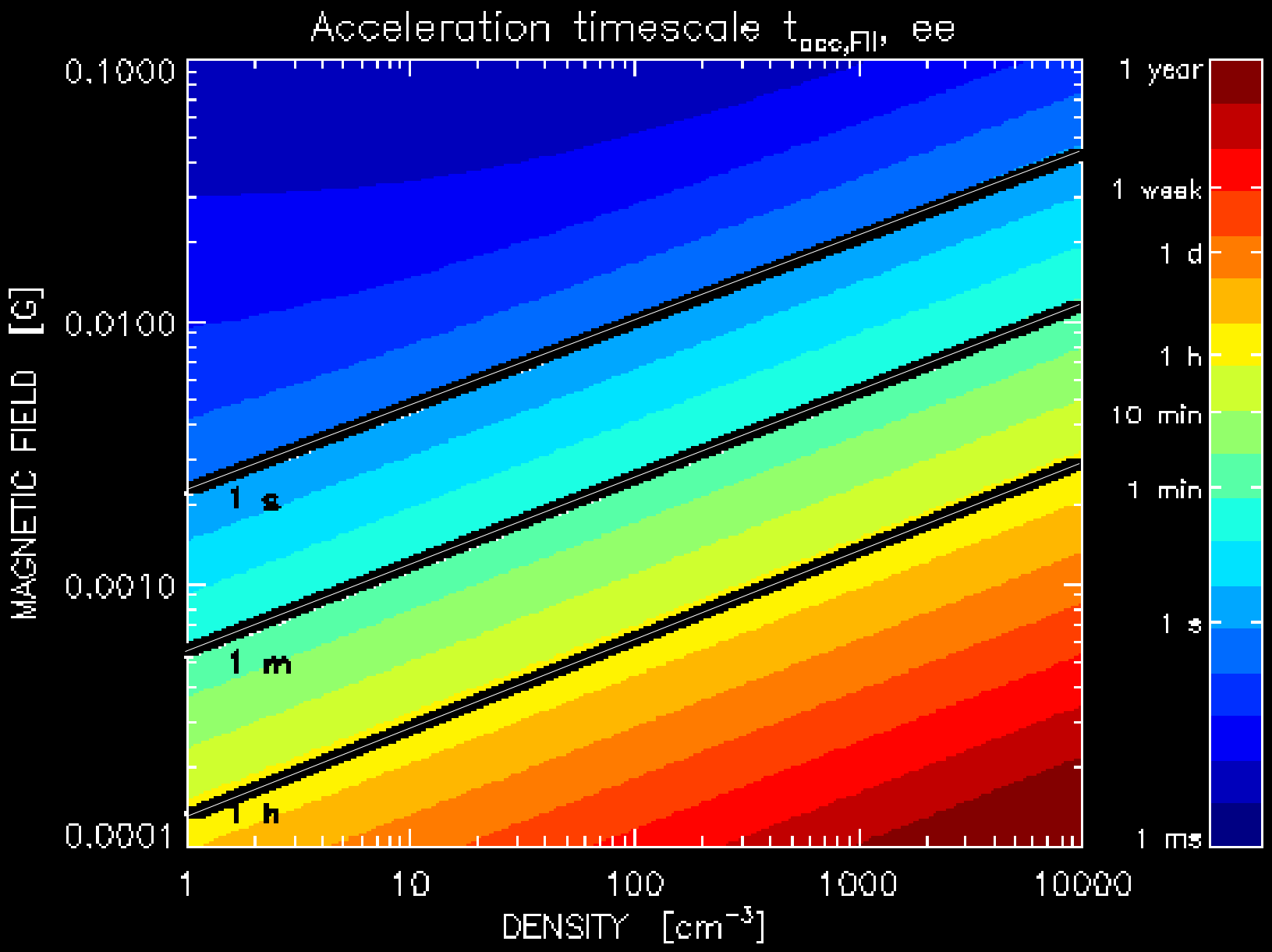
"Slow"
Thick

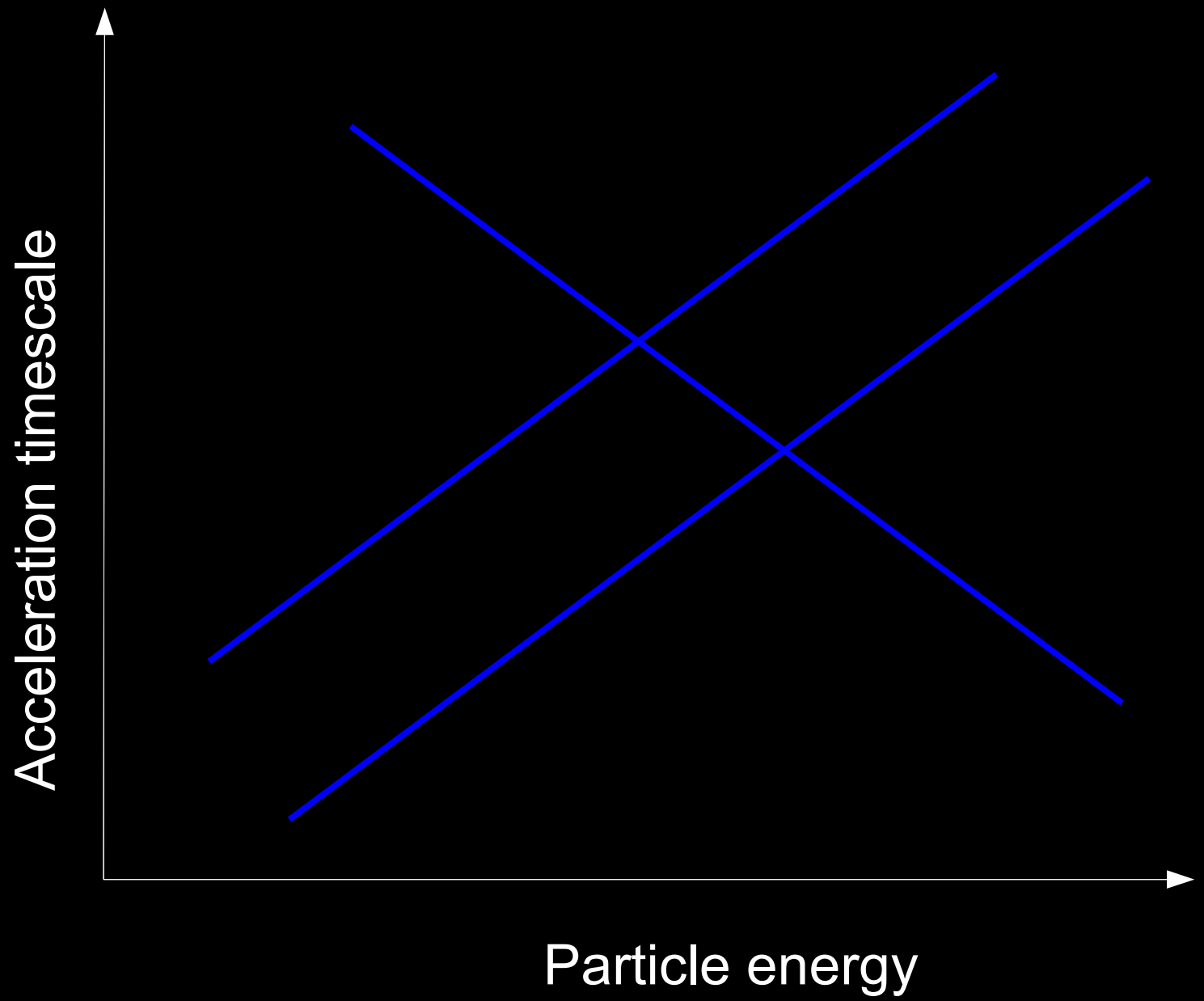
Faster

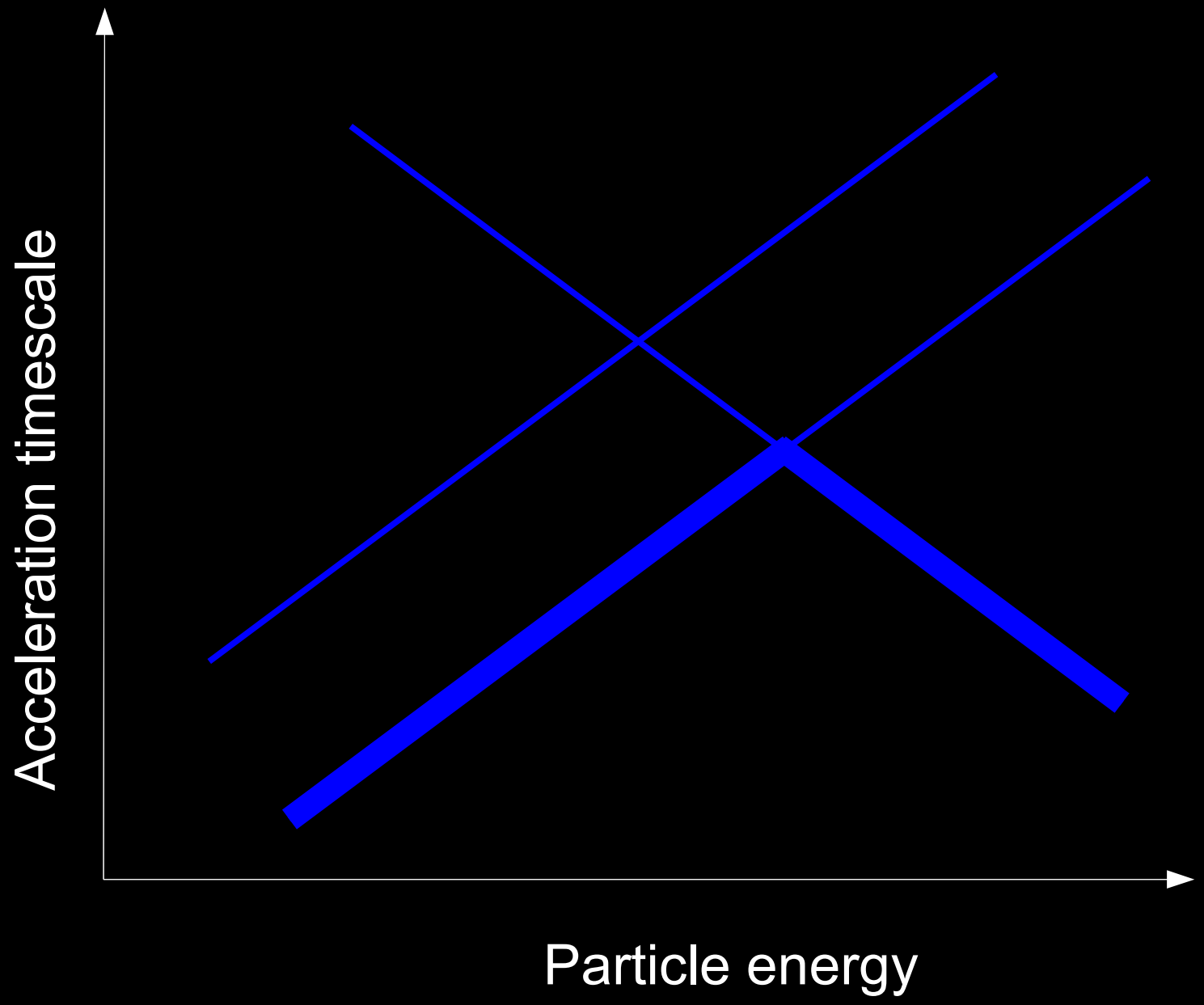
Fast
Thick

Smaller

Fast
Narrow


Acceleration timescale $t_{acc,FII}$, ee
0.1000
0.0100
0.0010
0.0001
MAGNETIC FIELD [G]
1 s
1 m
1 h
1
10
100
1000
10000
DENSITY [cm^{-3}]
1 year
1 week
1 d
1 h
10 min
1 min
1 s
1 ms


Acceleration timescale
Particle energy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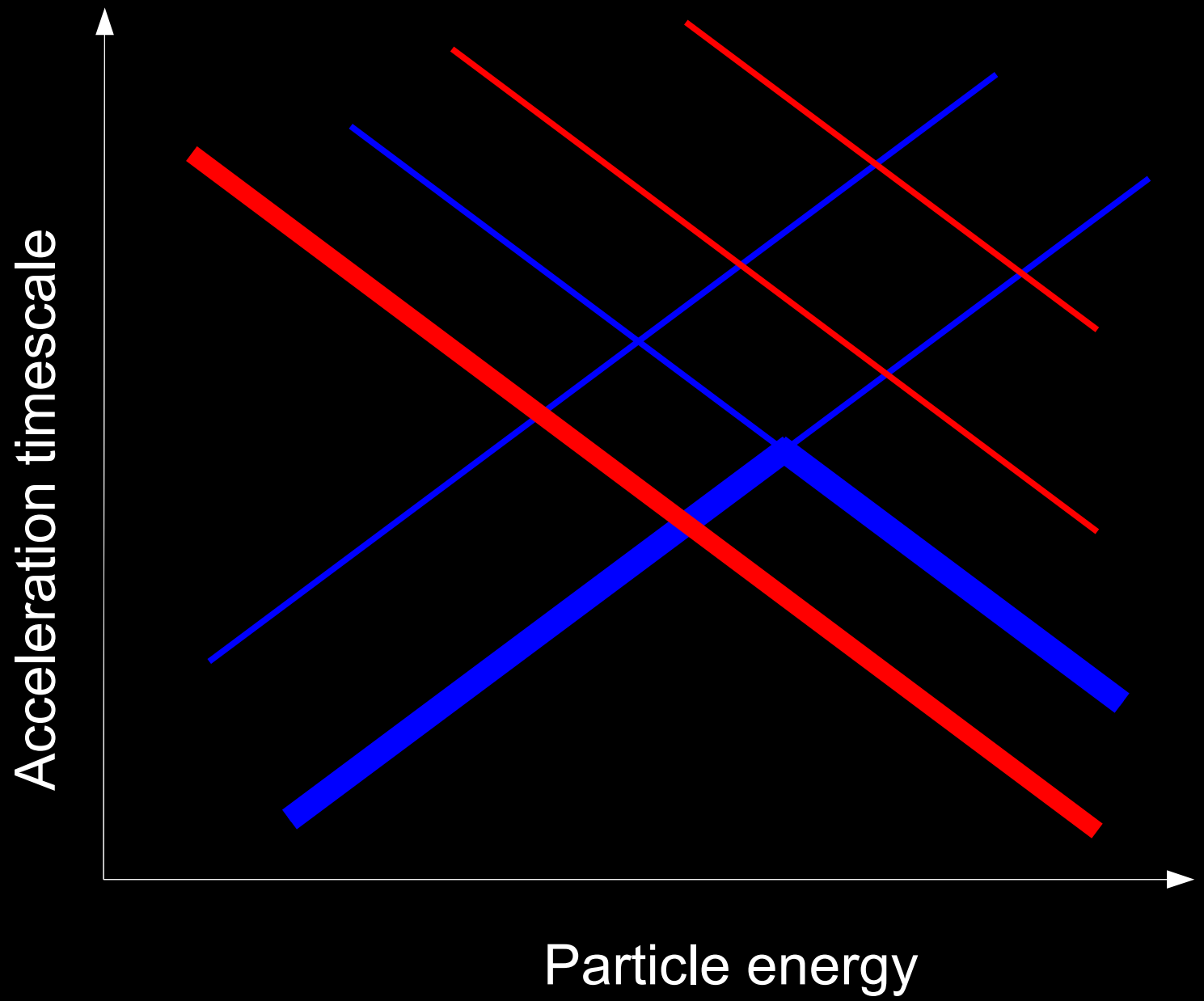
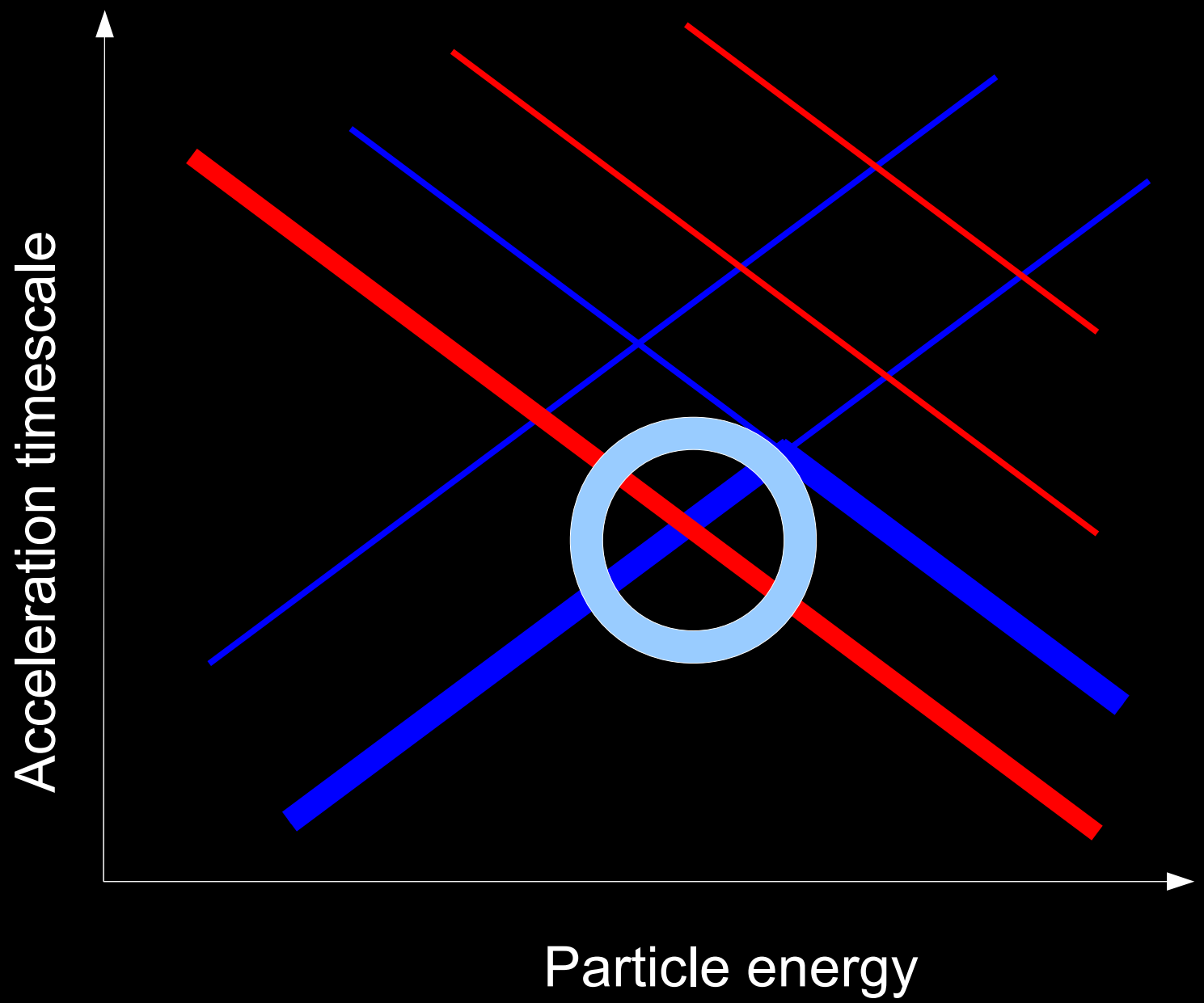
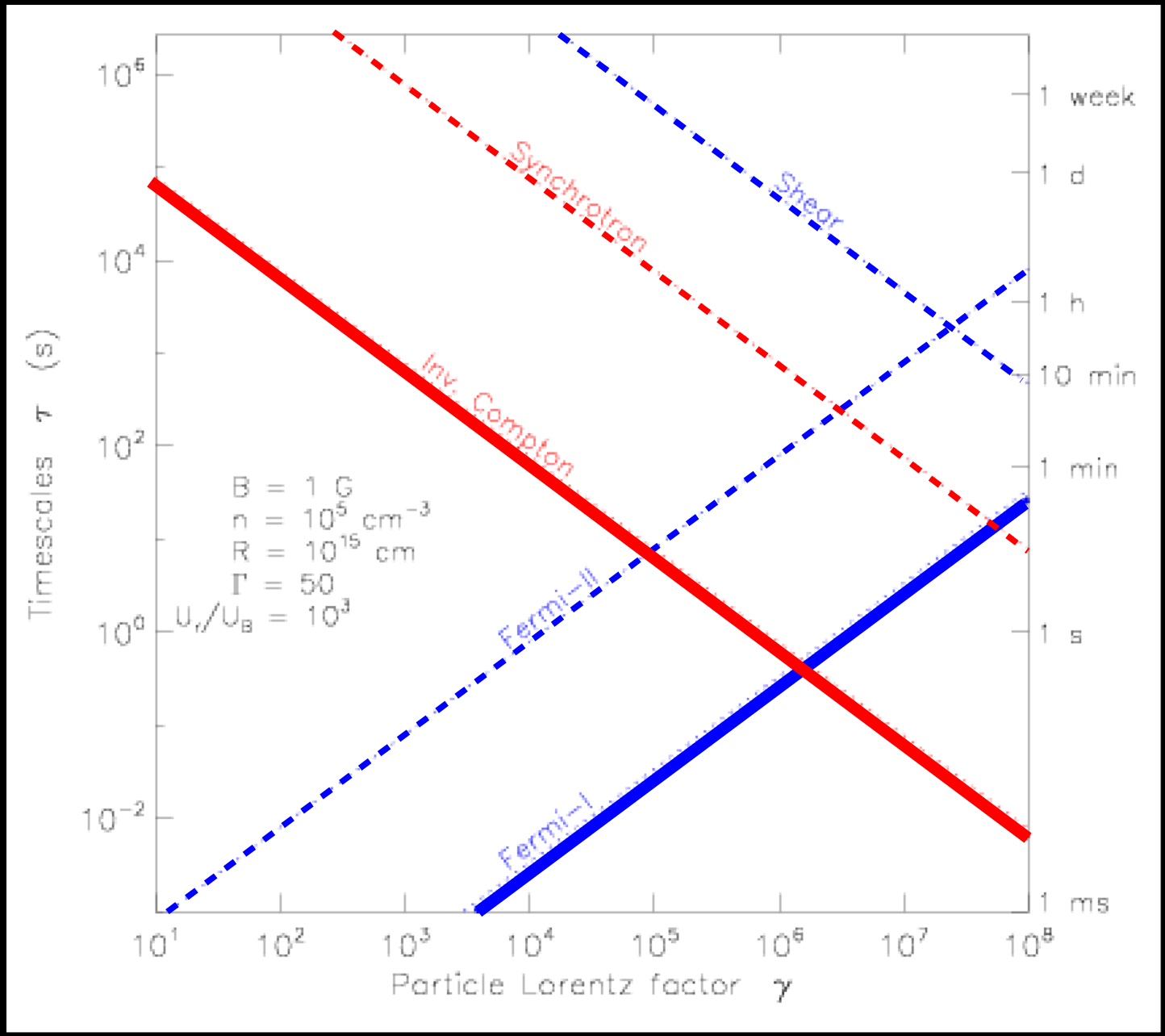
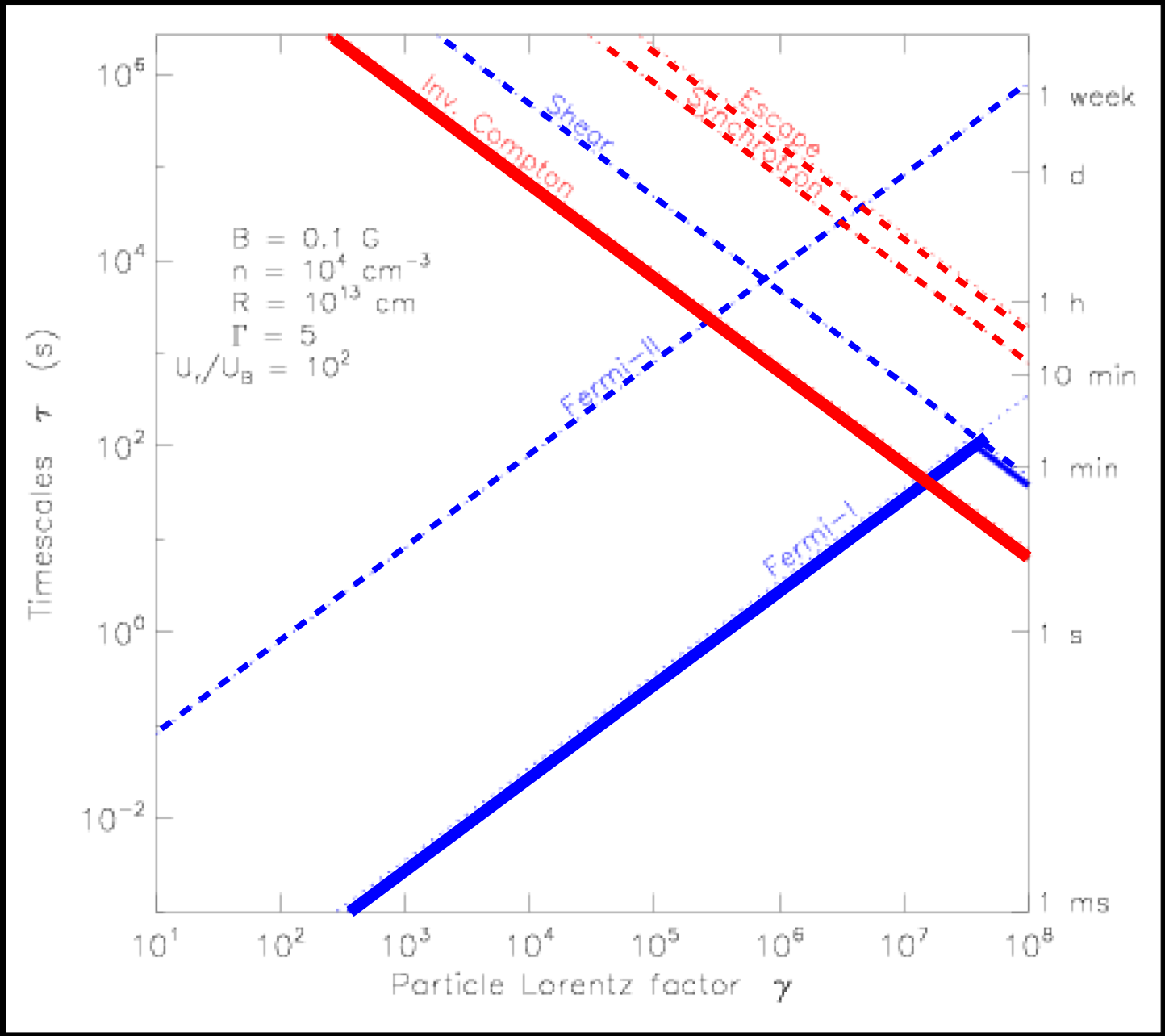

Acceleration timescale
Particle energy


Acceleration timescale
Particle energy



Tammi & Duffy 2009
MNRAS 393, 1063



Tammi & Duffy 2009
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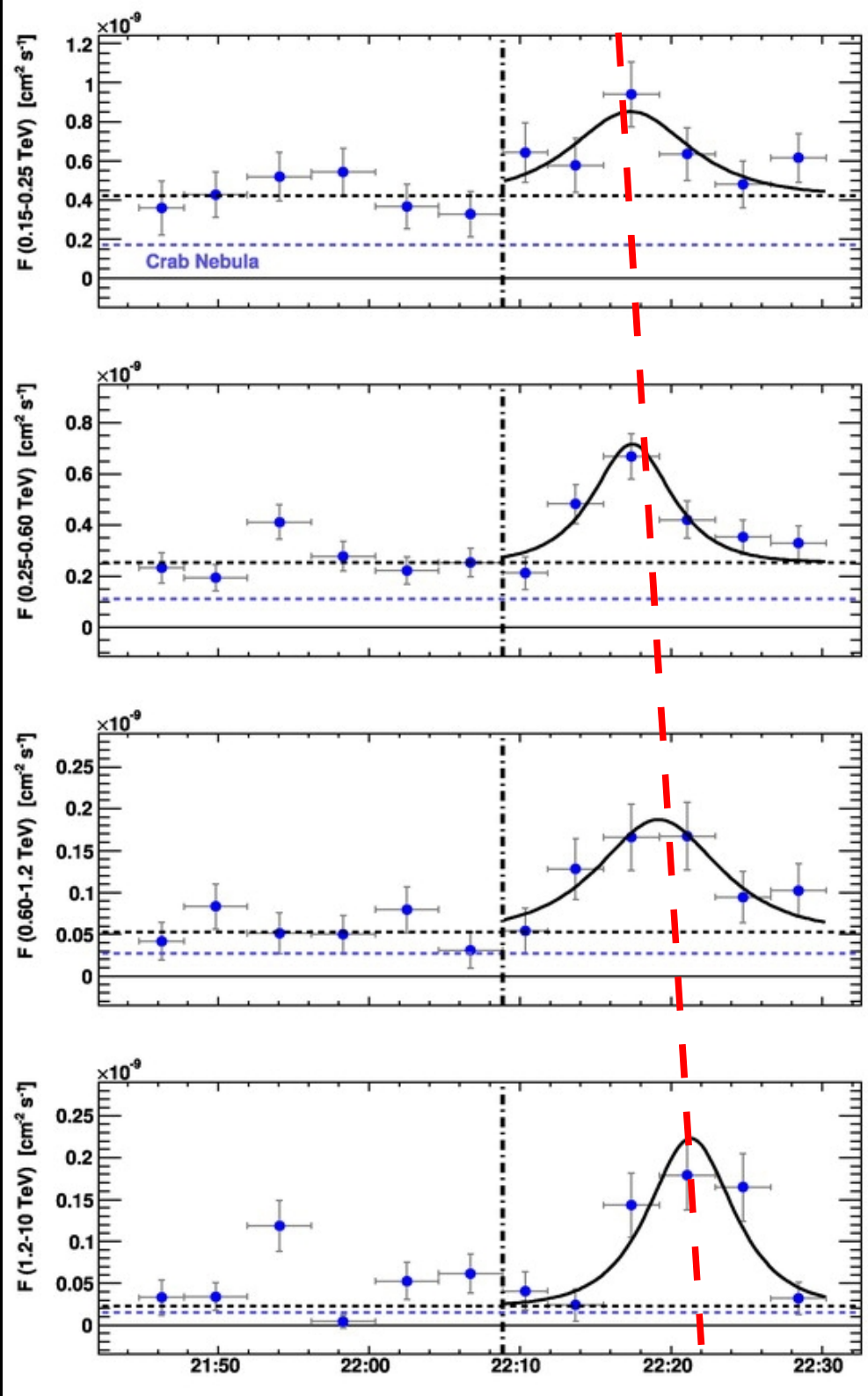
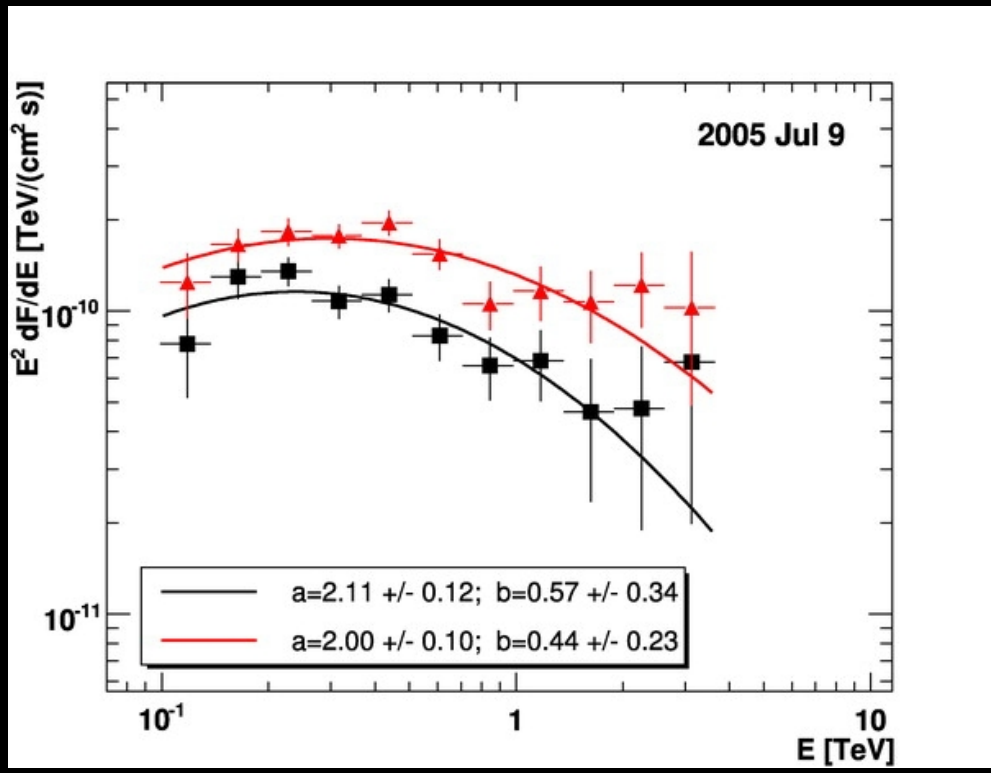
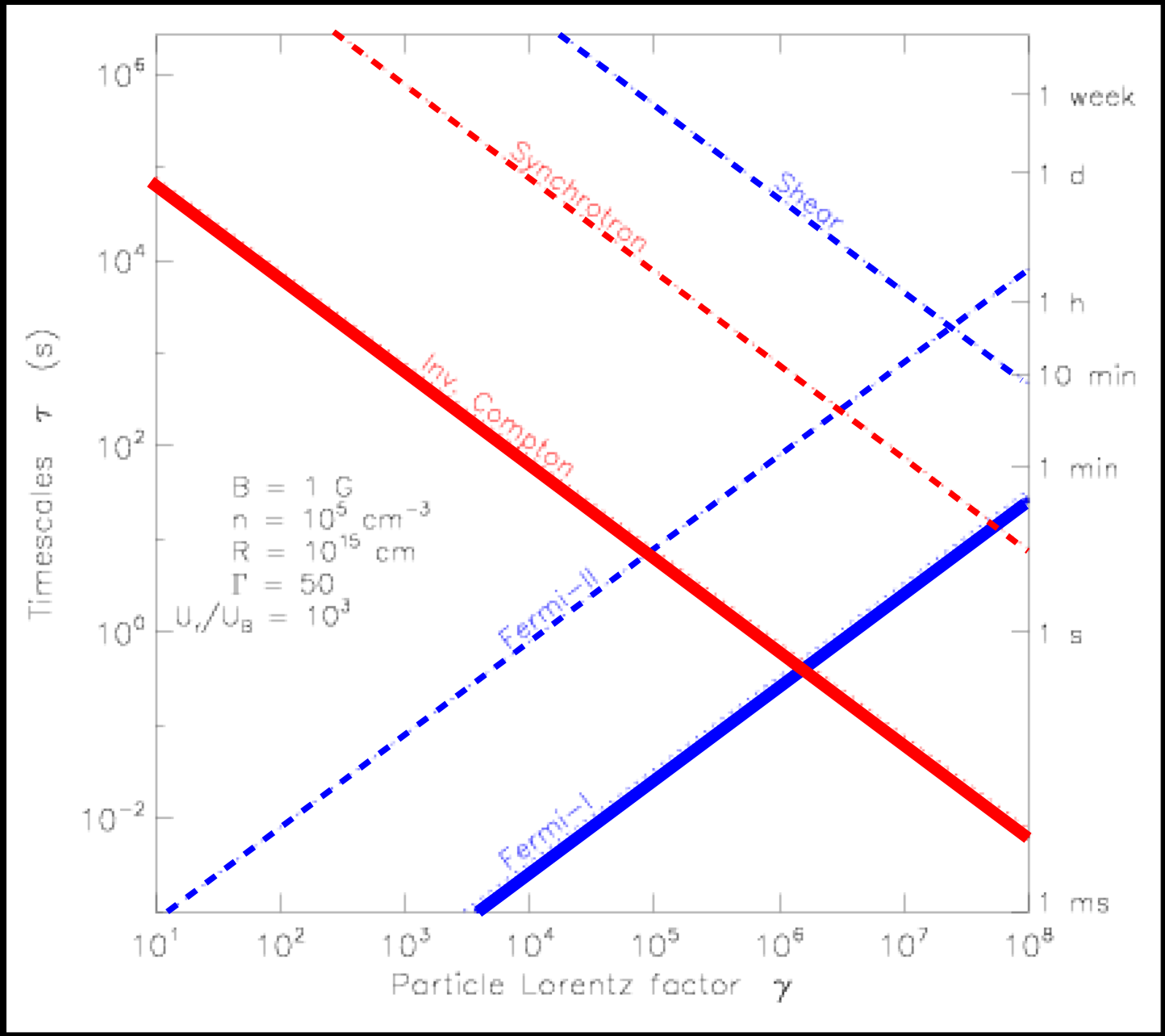
Example:
Markarian 501
Minute-scale TeV flare with ”hard lag”





Albert at al. 2007
ApJ 669, L862



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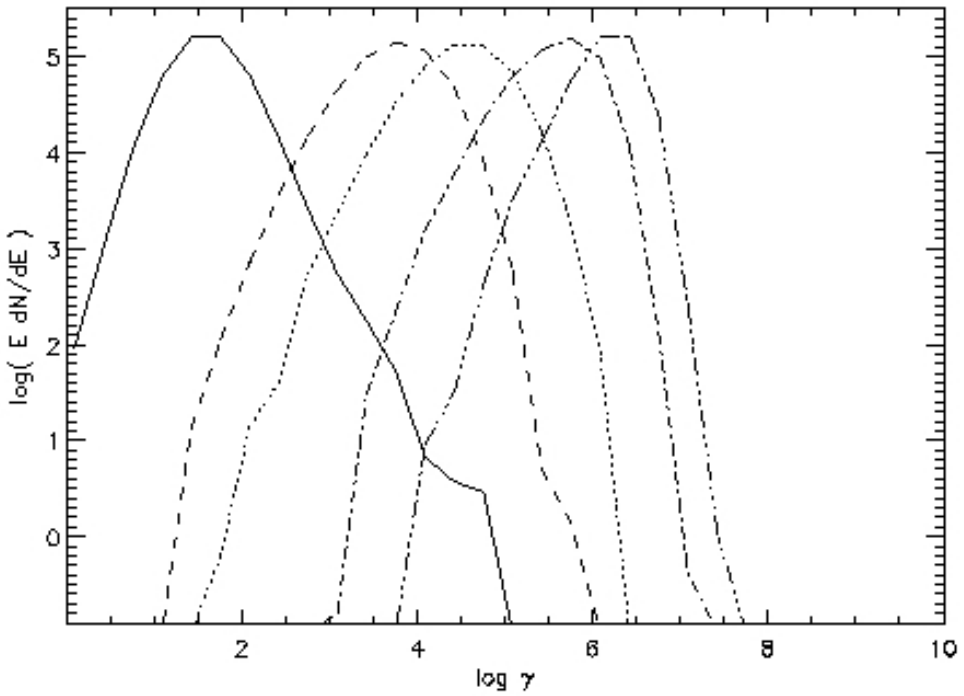
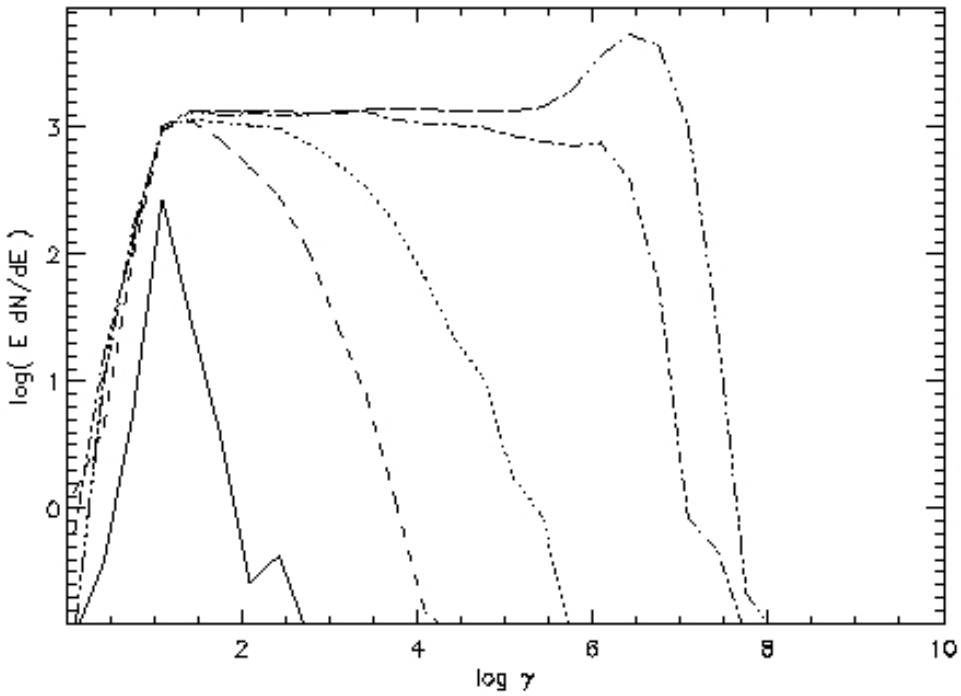
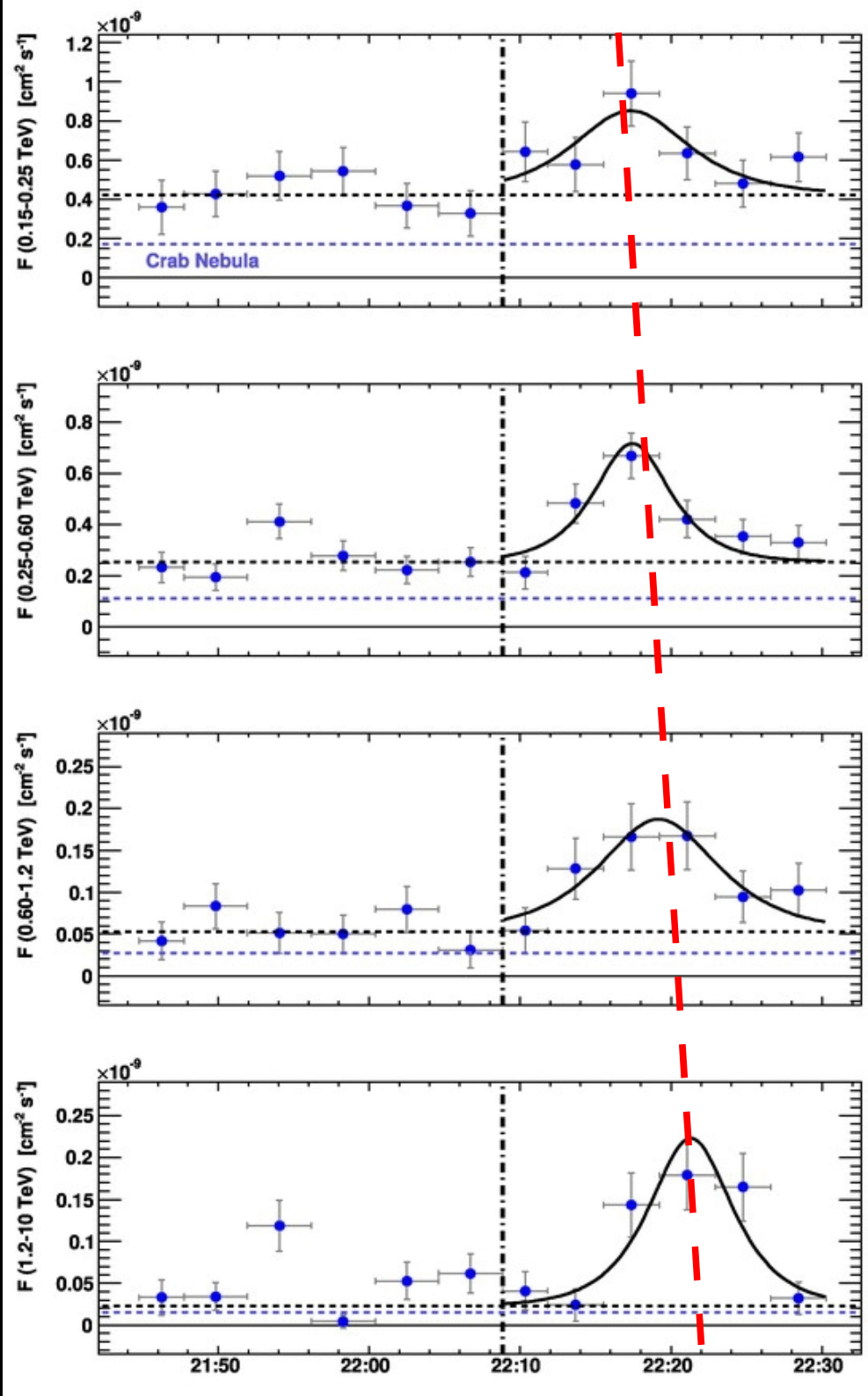
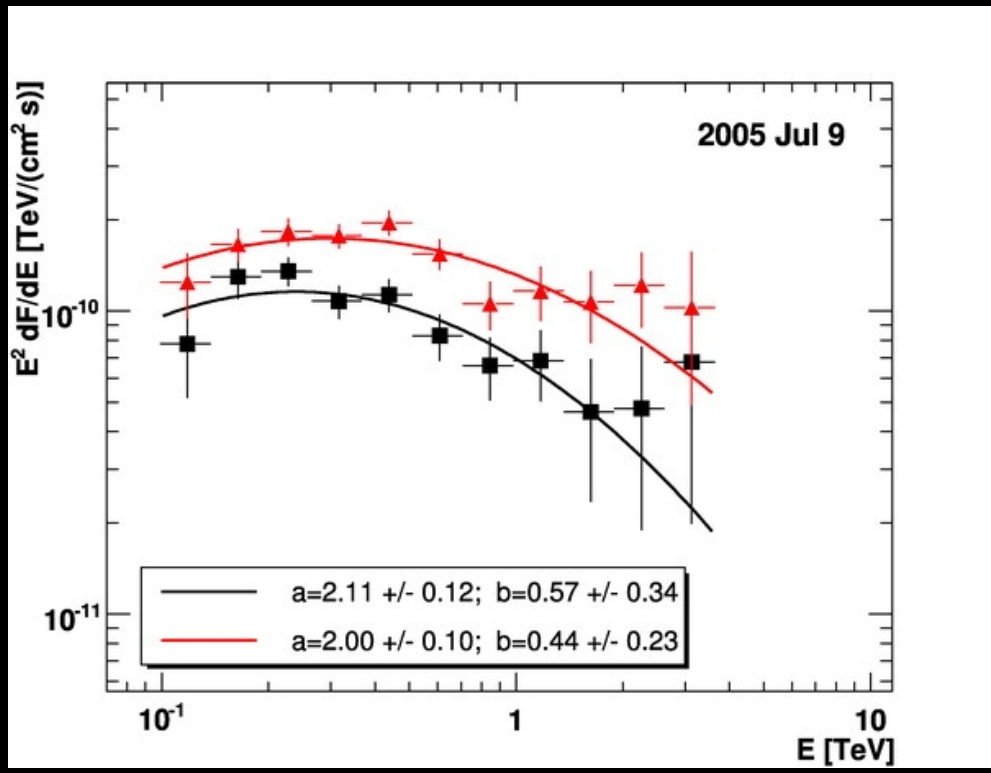




Virtanen (Tammi) & Vainio
2005, ApJ 621, 313





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Summary

Comparison:

- Relevant processes
- Source structure
- Source parameters
- Continuous acceleration
- Multiple spectral breaks

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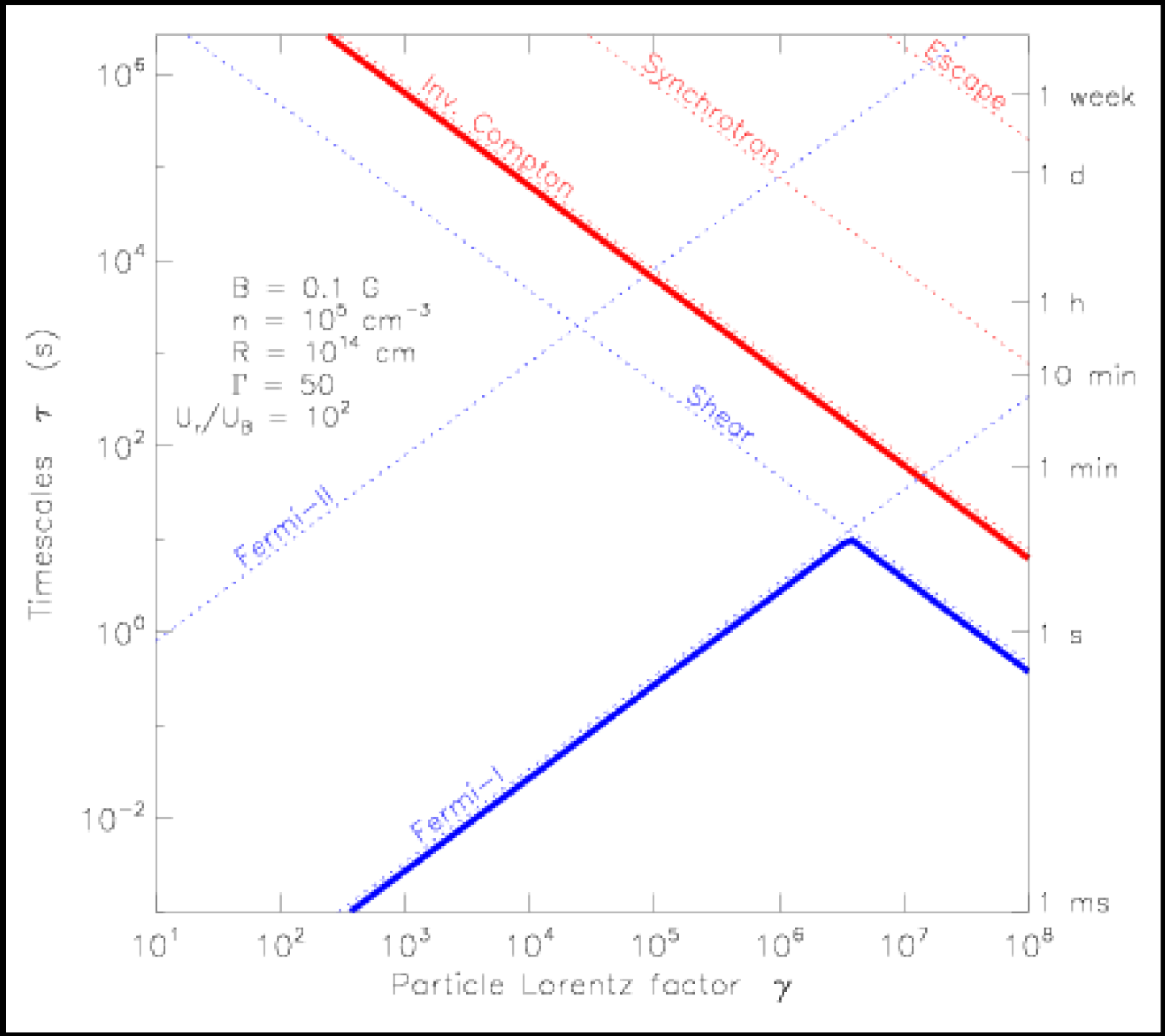
Tammi & Duffy 2009:

- ~~”Accelerate, then only radiate”~~
- Minute-scale TeV flares:
  - ~~Neutron-converter~~
  - ~~Shear acceleration~~
  - Hadronic: ~~instantaneous~~
- Hard lags: stochastic acceleration? Protons?



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