UHECR and extensions of the Standard Model

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Outline

- Introduction
  - Extensions of the standard model
    - Additional gauge sectors
  - Ultrahigh-energy cosmic rays
- Projectiles
  - Hadrons
  - Neutrinos
  - Bound states
- Conclusion

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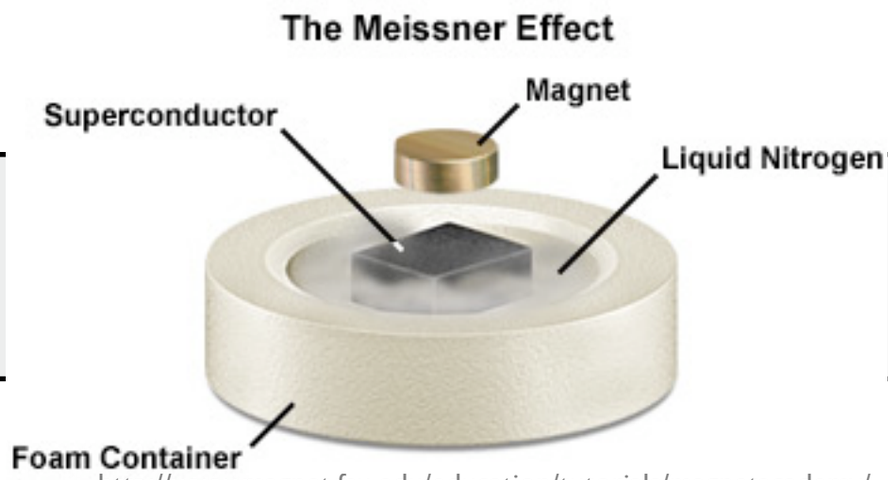
Extensions of the SM

Ex

Nature of the Higgs ?

the SM

Guidance

Elementary particles	Superconductivity
Weak gauge boson masses	Meissner-Ochsenfeld effect London penetration depth
	 http://www.magnet.fsu.edu/education/tutorials/magnetacademy/superconductivity101/images/superconductivity-meissner.jpg

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Guidance

Elementary particles	Superconductivity
Weak gauge boson masses	Meissner-Ochsenfeld effect London penetration depth
Higgs mechanism Standard model	Ginzburg-Landau model

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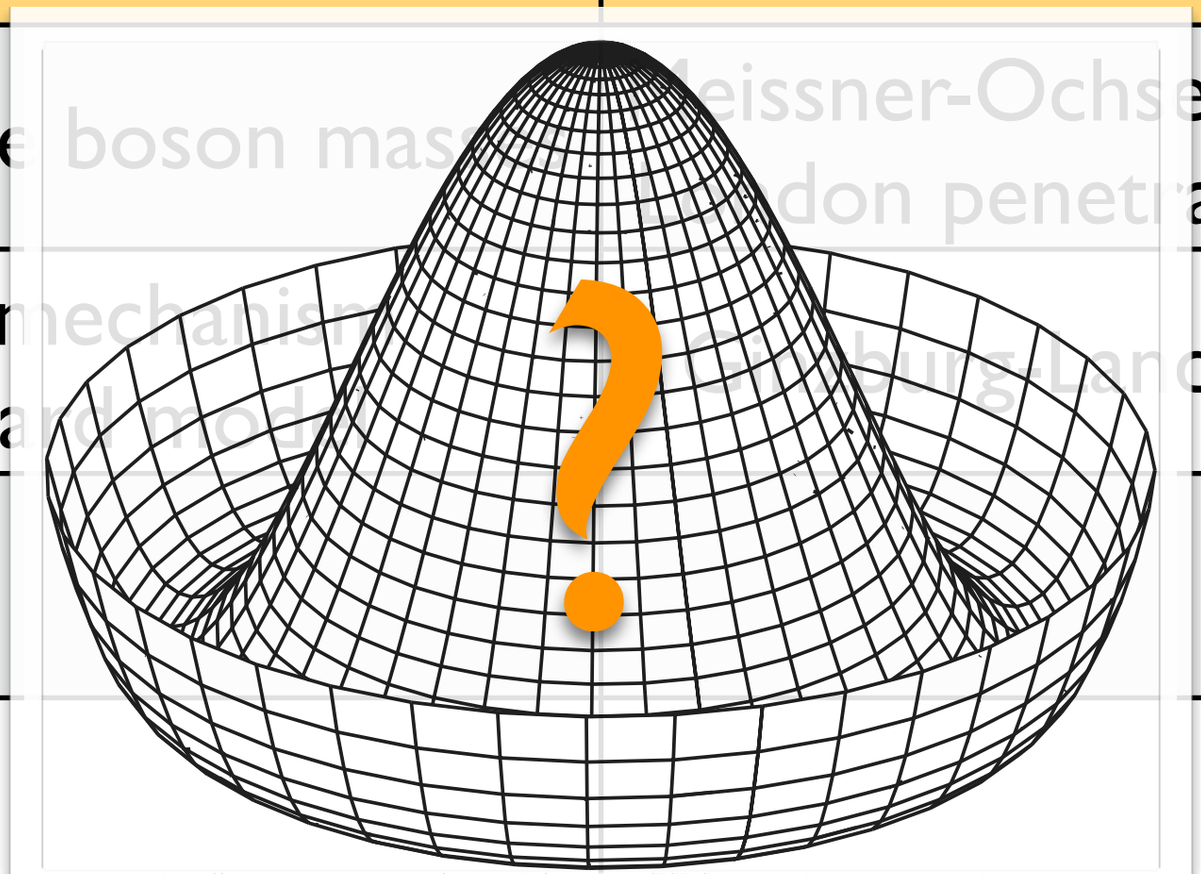
Guidance

Elementary particles	Superconductivity
Weak gauge boson mass	Meissner-Ochsenfeld effect
	London penetration depth
Higgs mechanism	Ginzburg-Landau model
Standard model	



http://upload.wikimedia.org/wikipedia/commons/7/7b/Mexican_hat_potential_polar.svg

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Guidance

Elementary particles	Superconductivity
Weak gauge boson masses	Meissner-Ochsenfeld effect London penetration depth
Higgs mechanism Standard model	Ginzburg-Landau model
	Bardeen-Cooper-Schrieffer
	Cooper-pair condensate
	phonons

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Guidance

Ele	Superconductivity
We	fect pth
	el
	ffer
	te
	phonons

Gedanken experiment

Standard model
w/o
Higgs sector

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Guidance

Elementary particles	Superconductivity
Weak gauge boson masses	Meissner-Ochsenfeld effect London penetration depth
Higgs mechanism Standard model	Ginzburg-Landau model
QCD	Bardeen-Cooper-Schrieffer
chiral condensate	Cooper-pair condensate
gluons	phonons

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Dictionary

Elementary particles	Superconductivity
Weak gauge boson masses	Meissner-Ochsenfeld effect London penetration depth
Higgs mechanism Standard model	Ginzburg-Landau model
Technicolor	Bardeen-Cooper-Schrieffer
techniquark condensate	Cooper-pair condensate
technigluons	phonons

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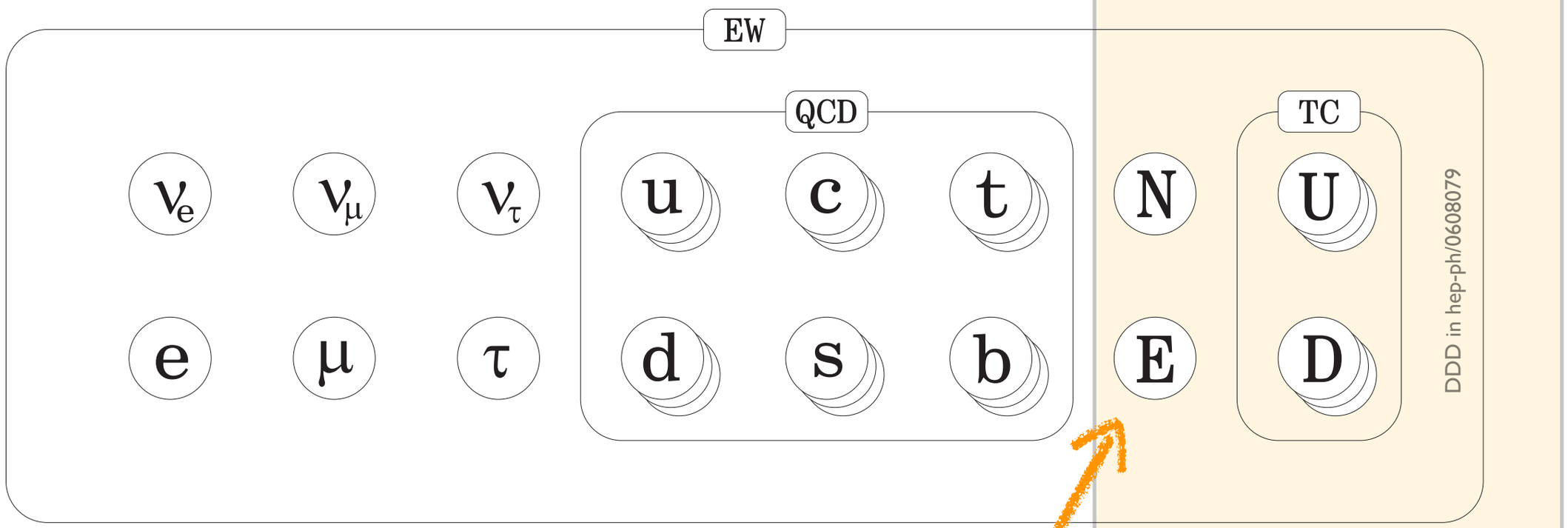
Technicolor

$$\mathcal{G} = SU(2)_L \times U(1)_Y \times SU(3)_{QCD} \times \mathcal{G}_{TC}$$



Witten anomaly ?

$$\underbrace{f_\pi}_{O(10^2\mathrm{MeV})} \mapsto \underbrace{\Lambda_{\mathrm{ew}}}_{O(10^2\mathrm{GeV})}$$

$\pi^\pm,\ \pi^0$

$$\Pi^\pm \mapsto W_L^\pm$$
$$\Pi^0 \mapsto Z_L^0$$

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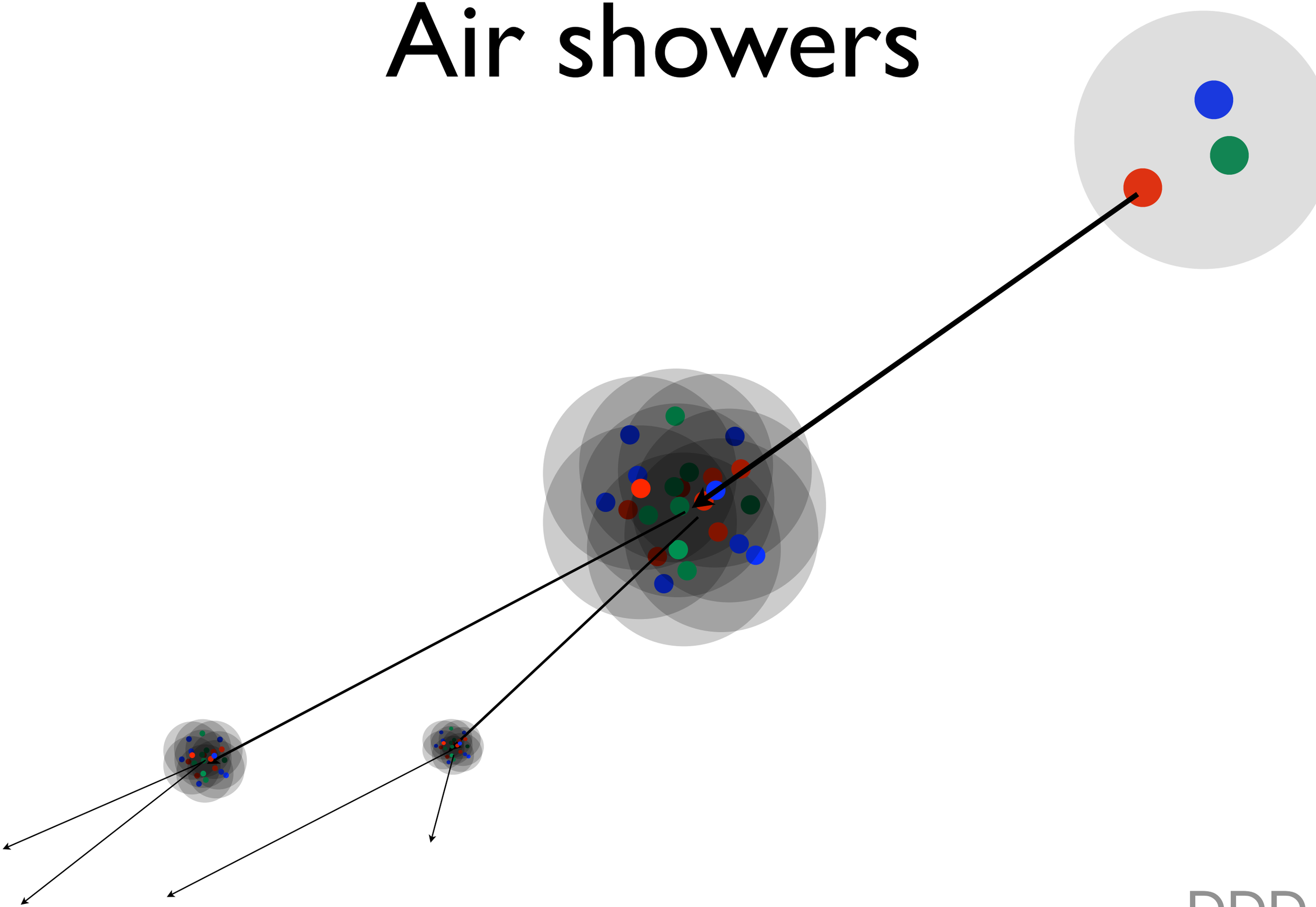
DEWSB

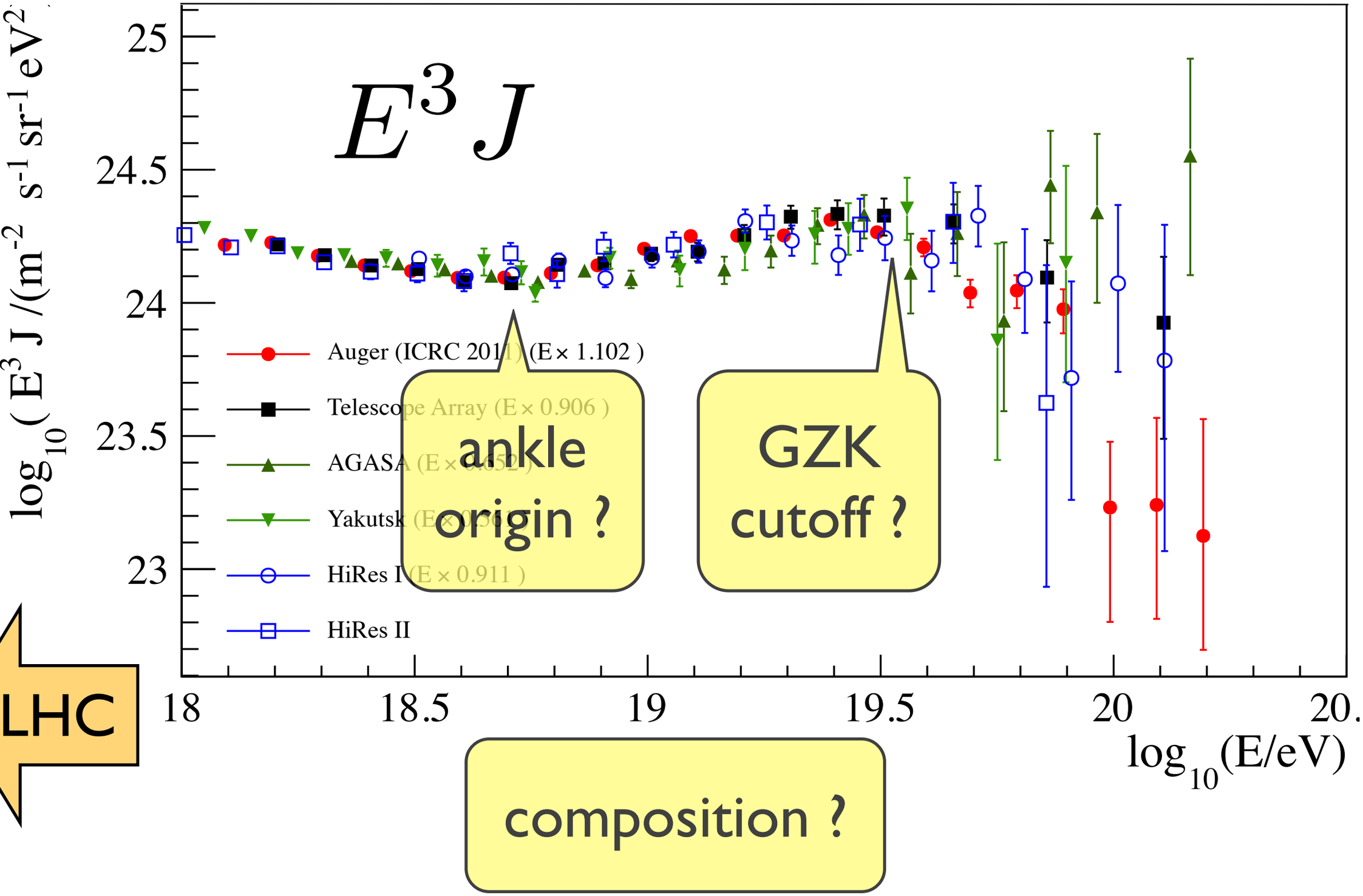
- Technicolour
  - Extended technicolour
    - Topcolour
- Composite Higgs
- Little Higgs

Ultrahigh-energy cosmic rays

Air showers



Spectrum (all particles)



adapted from slides by Yoshiki Tsunesada for the Spectrum Working Group at the UHECR 2012
http://indico.cern.ch/getFile.py/access?contribId=6&sessionId=2&resId=0&materialId=slides&confId=152124

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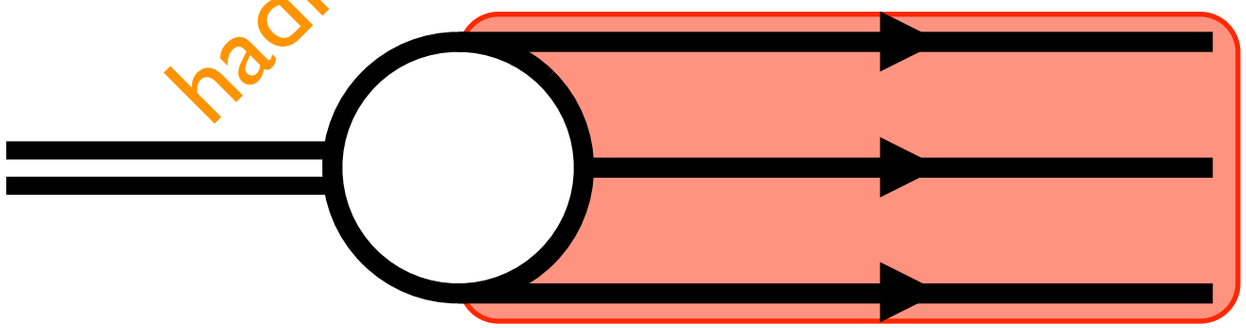
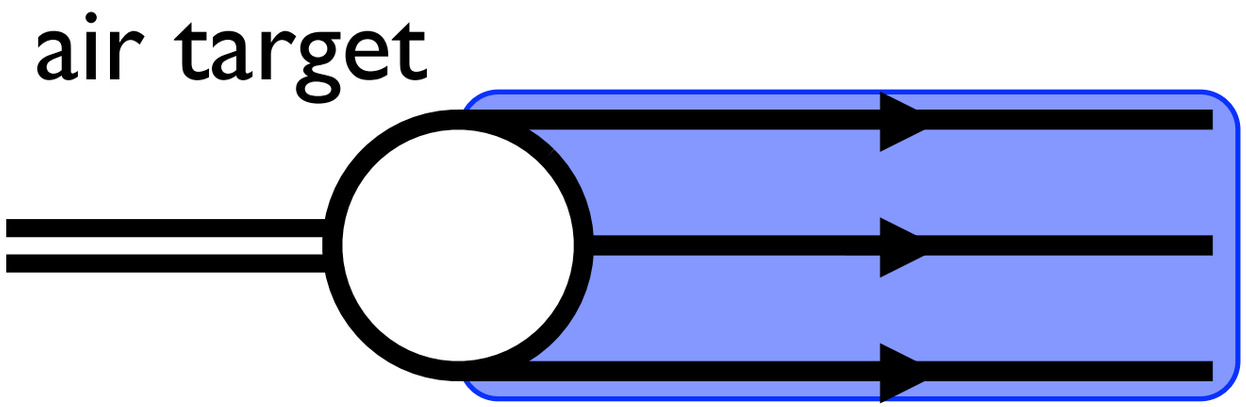
QCD prototype & benchmark

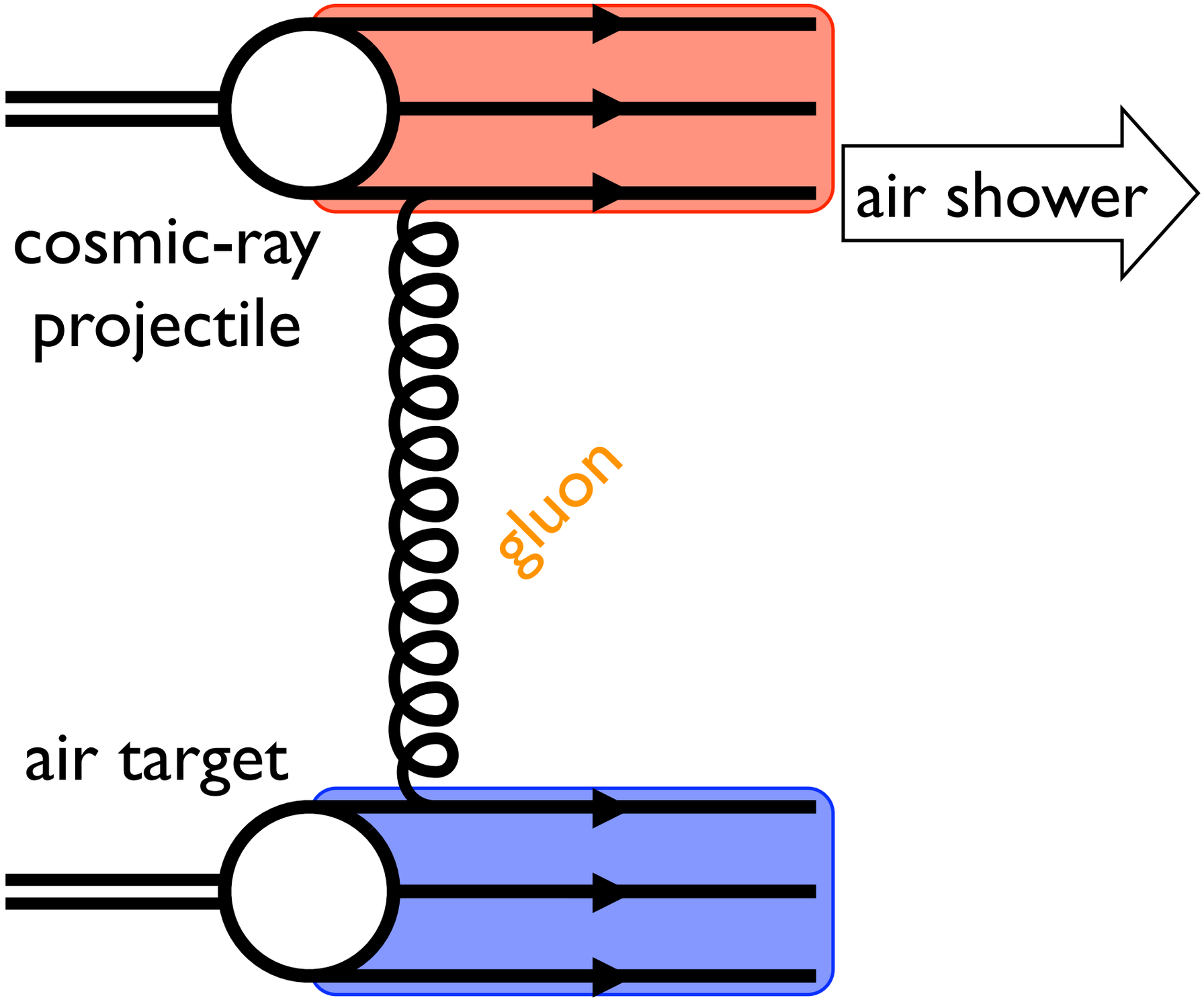


cosmic-ray
projectile



D.D.Dietrich, arXiv:1206.2400 [hep-ph]

QCD prototype & benchmark



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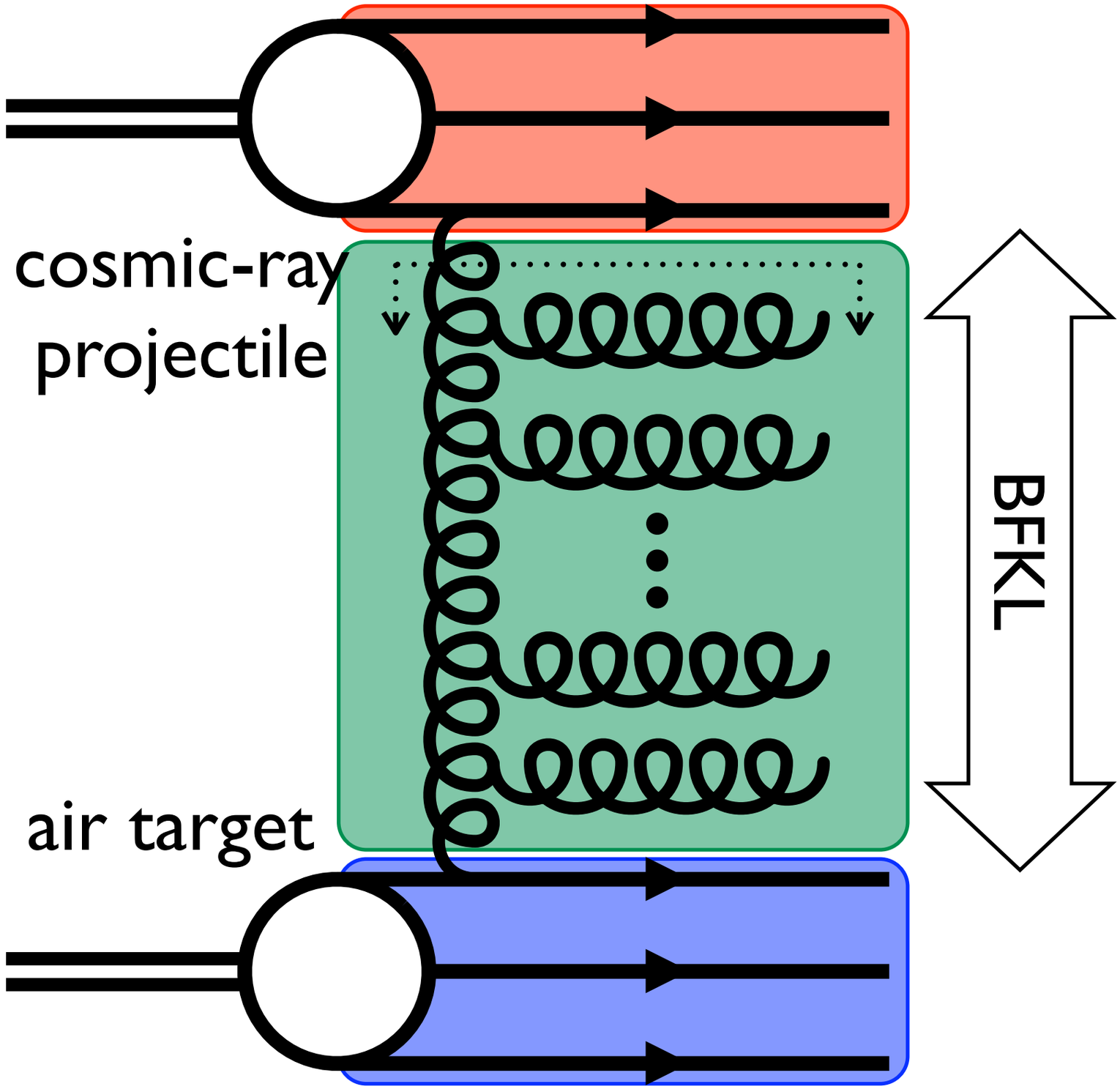
QCD prototype & benchmark



D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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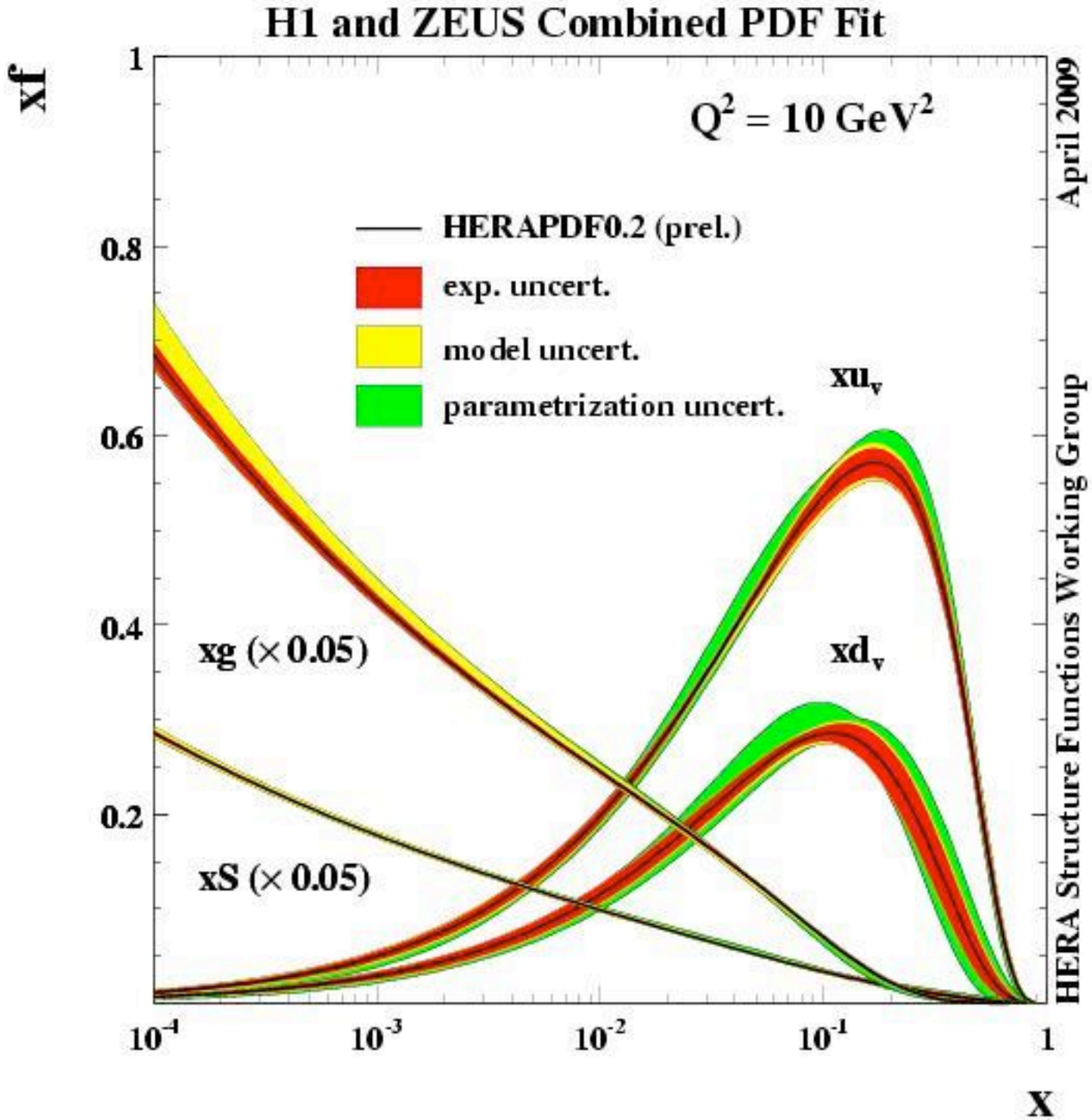
HERA



https://www.desy.de/h1zeus/combined_results/proton_structure/combined_plots_comp/fig1a.pdf

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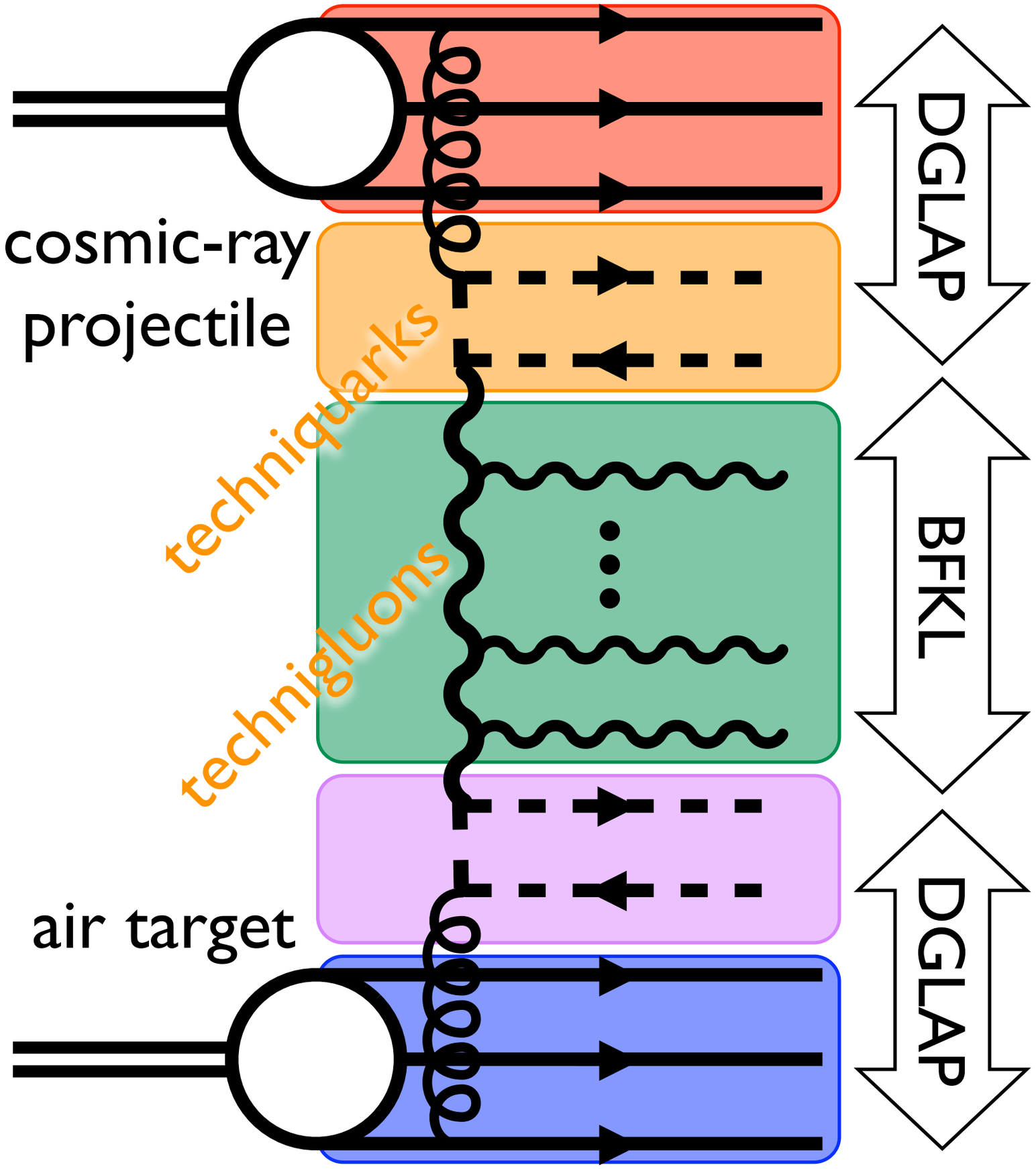
Techni-colour



$$\frac{\sigma_{\rm tot}^{\rm TC}}{\sigma_{\rm tot}^{\rm QCD}} \approx O(10^{-3})$$

$$\frac{\sigma_{\rm tot}^{\rm TC}}{\sigma_{\rm tot}^{\rm QCD}} \frac{\Lambda_{\rm TC}}{\Lambda_{\rm QCD}} \approx O(1)$$

D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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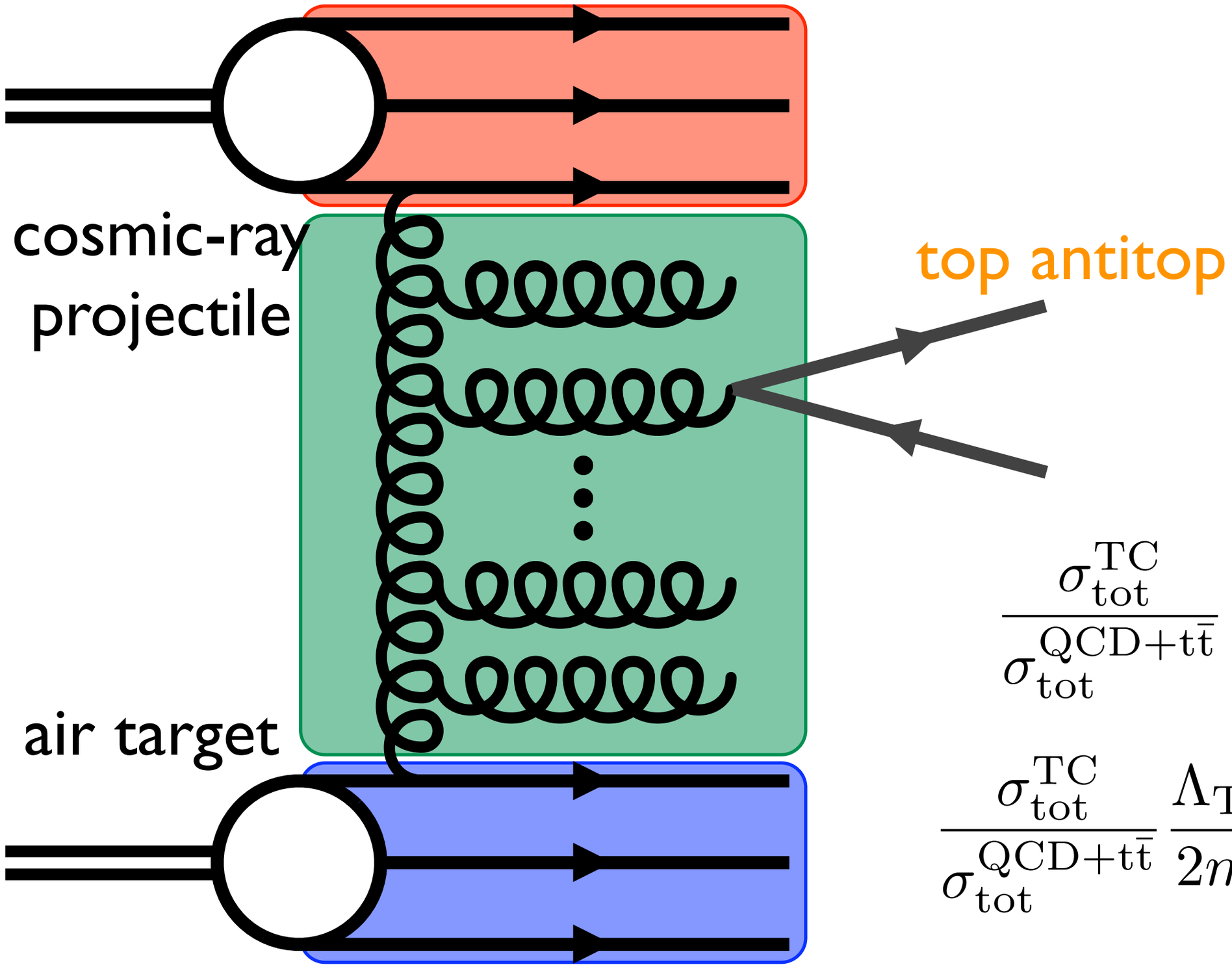
more QCD background



$$\frac{\sigma_{\rm tot}^{\rm TC}}{\sigma_{\rm tot}^{\rm QCD+t\bar{t}}} \approx O(1)$$

$$\frac{\sigma_{\rm tot}^{\rm TC}}{\sigma_{\rm tot}^{\rm QCD+t\bar{t}}} \frac{\Lambda_{\rm TC}}{2m_t} \approx O(1)$$

D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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Fast forward

- Technicolour (kicks in around ankle)
  - 3rd generation ETC few TeV
- Topcolour - if unification w/ $SU(3)_{QCD}$
  $\Rightarrow$ small coupling
- Composite Higgs $\xi=(v/f)^2\approx 1$ "TC limit"
  requires UV completion to judge in detail
- Little Higgs - heavy SU(2) $\approx$2TeV
- $SU(2)_L$ - coupling to weak

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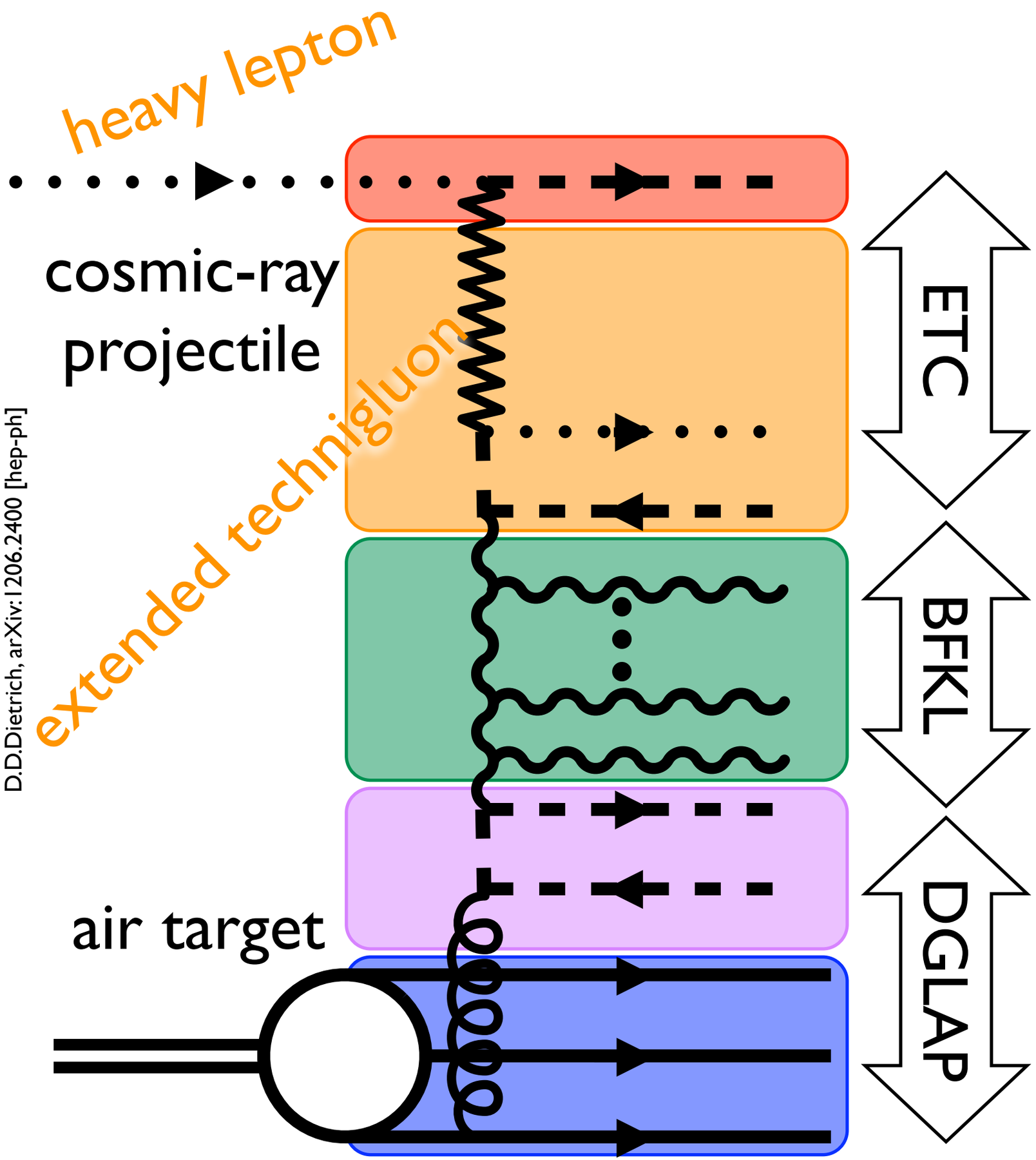
Heavy lepton (e.g. ν)



D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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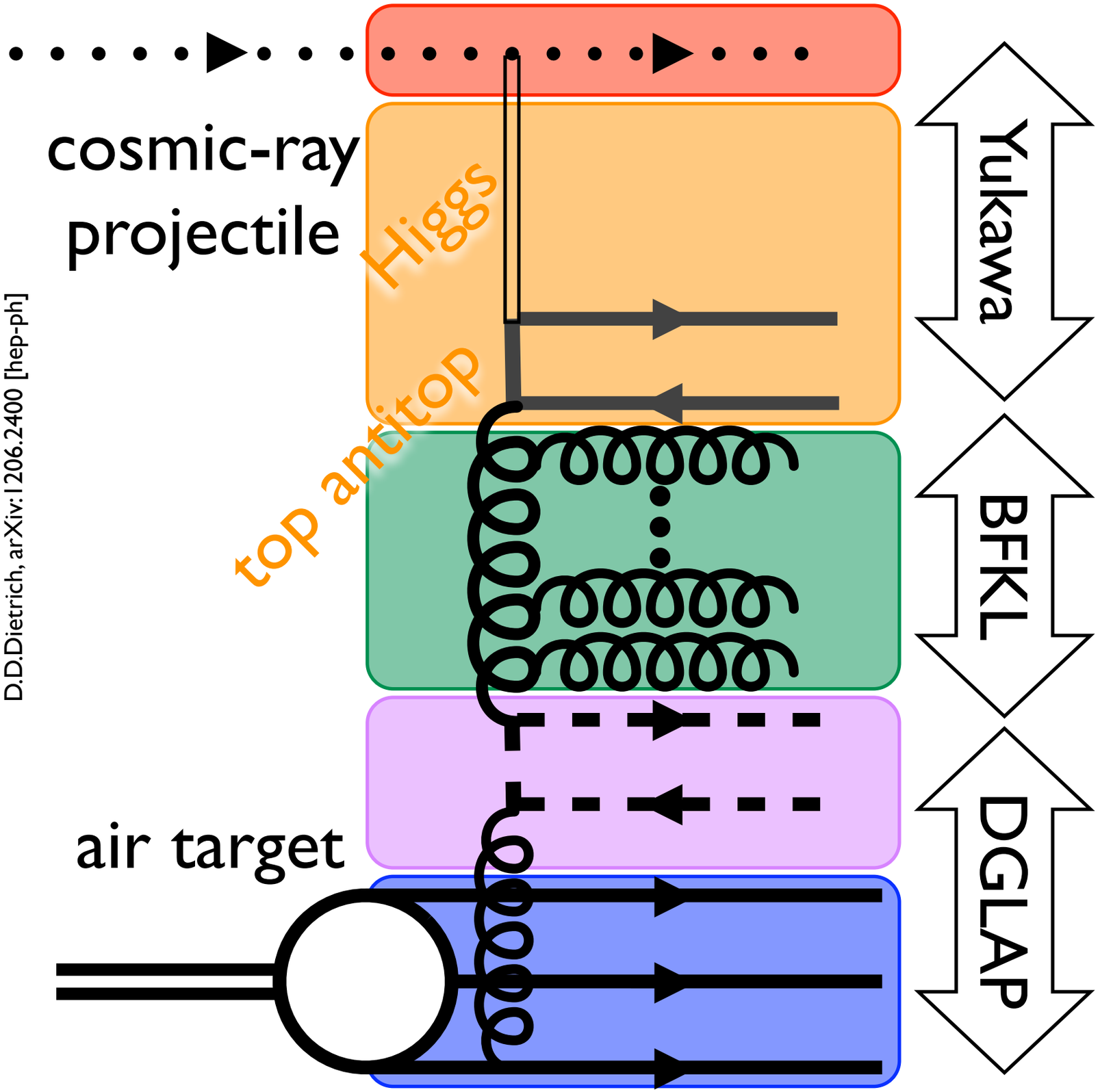
Heavy lepton (e.g. ν)



$$\frac{\sigma_{\rm tot}^{{\rm TC}\nu}}{\sigma_{\rm tot}^{{\rm QCD}\nu}} \approx O(1)$$

$$\frac{\sigma_{\rm tot}^{{\rm TC}\nu}}{\sigma_{\rm tot}^{{\rm QCD}\nu}} \frac{\Lambda_{\rm TC}}{2m_t} \approx O(1)$$

D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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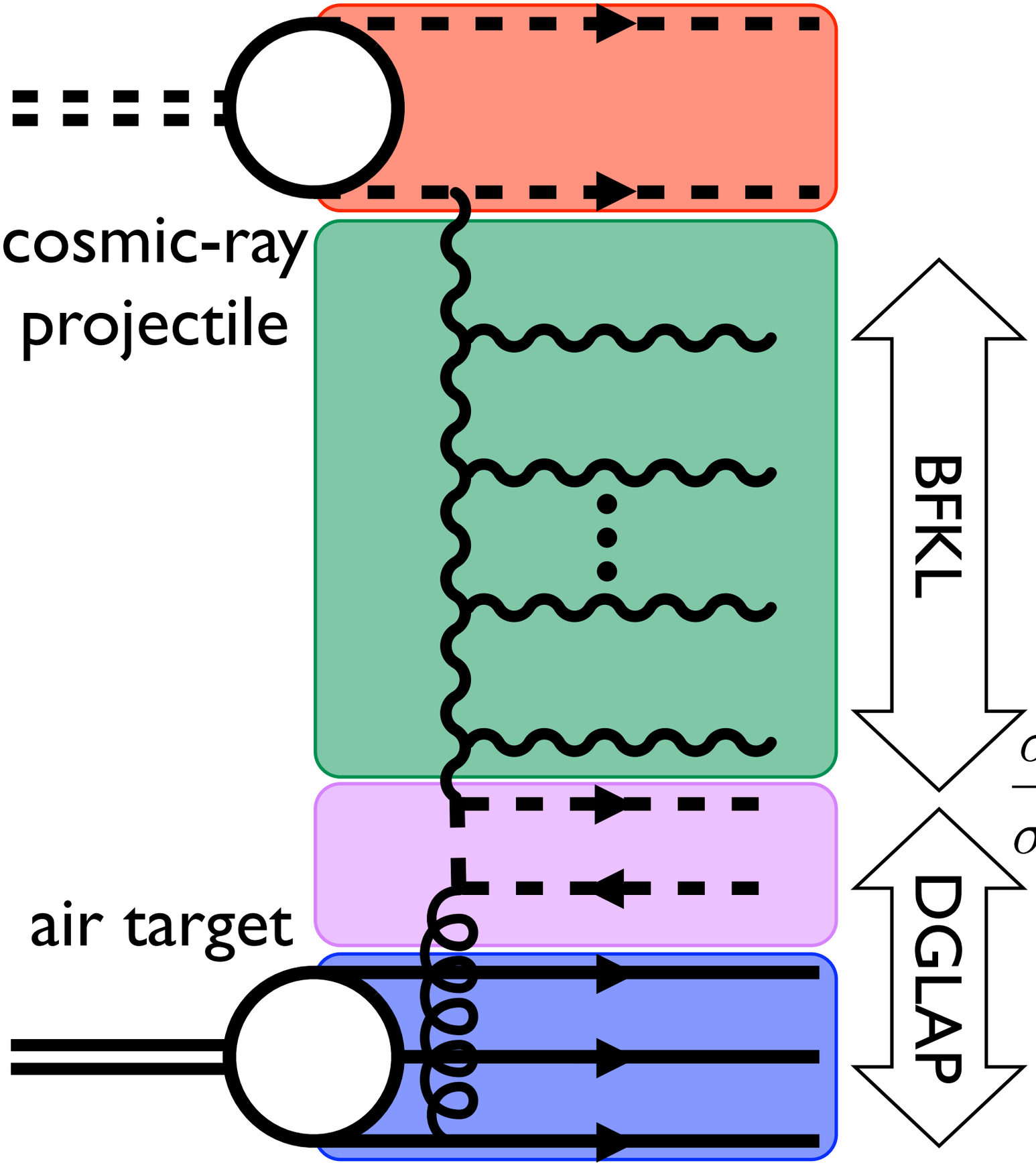
new bound state



$$\frac{\sigma_{\mathrm{tot}}^{\mathrm{TCx}}}{\sigma_{\mathrm{tot}}^{\mathrm{QCD}}}\frac{\Lambda_{\mathrm{TC}}}{\Lambda_{\mathrm{QCD}}} \approx O(10^{+2})$$

D.D.Dietrich, arXiv:1206.2400 [hep-ph]

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Conclusion

- hadron or heavy lepton projectiles:
  - TC & QCD with top similarly hard
    - ➡ must look at details of shower (statistics ?!)
- new bound state projectile
  - TC harder than QCD even with top
  - does not see GZK cut off in any case
    - if GZK for hadrons: stability bound for bound state
      - ➡ impact on viability as dark matter ?
    - if only limit of accelerator: ?

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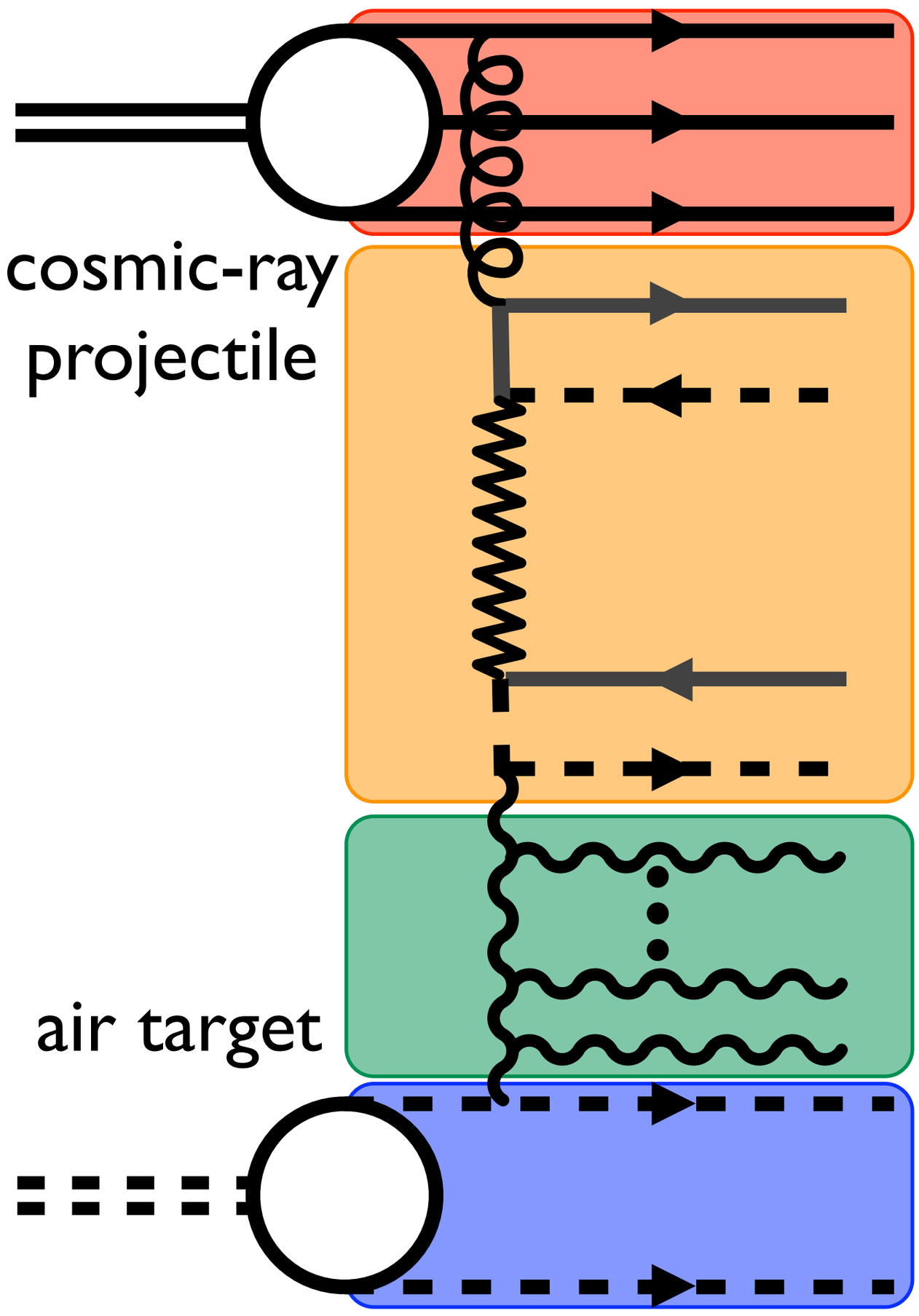

Outlook: SM projectile on TC bound state

larger com energy

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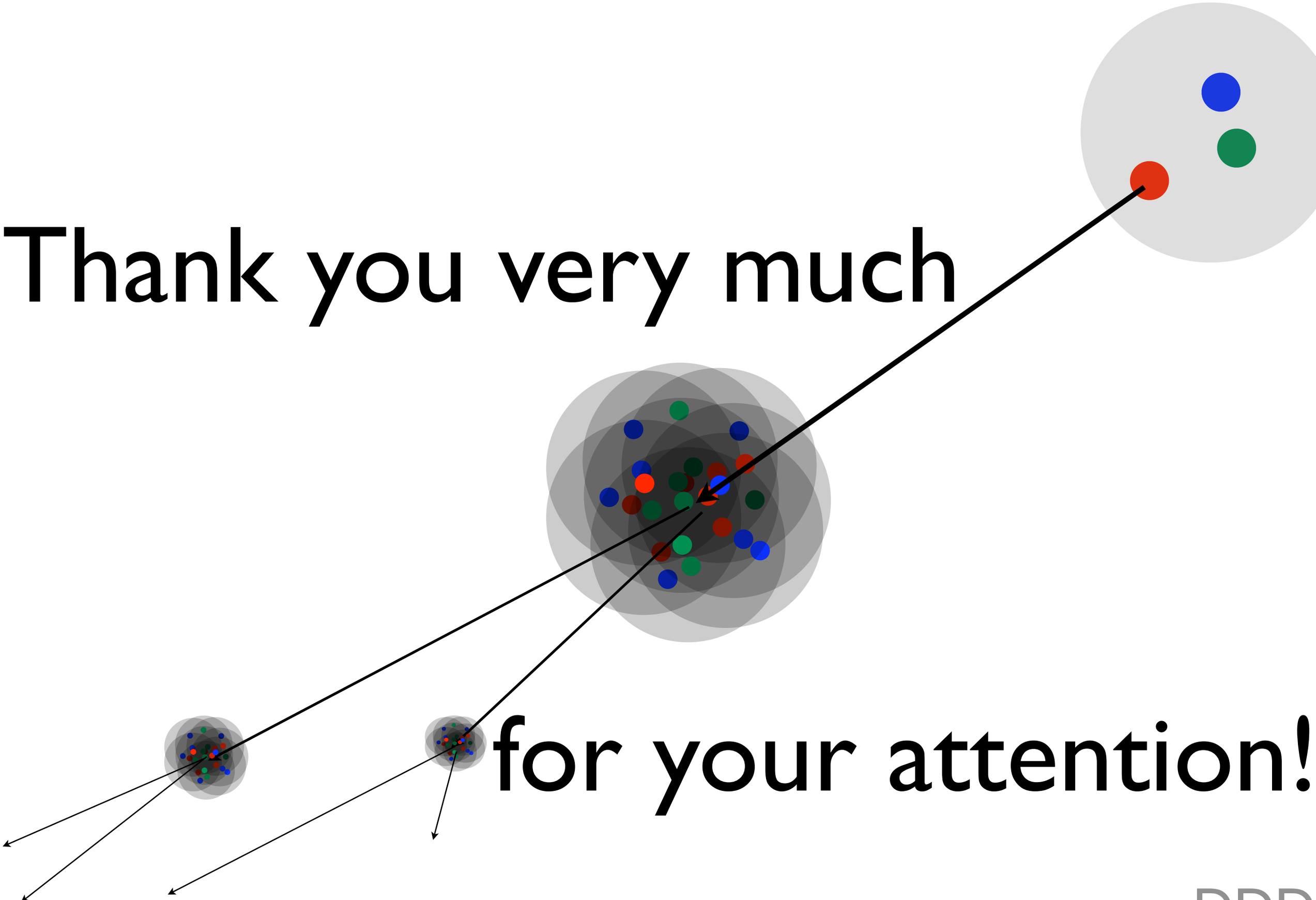
Thank you very much



for your attention!

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