

# Cosmology of Composite Inelastic Dark Matter

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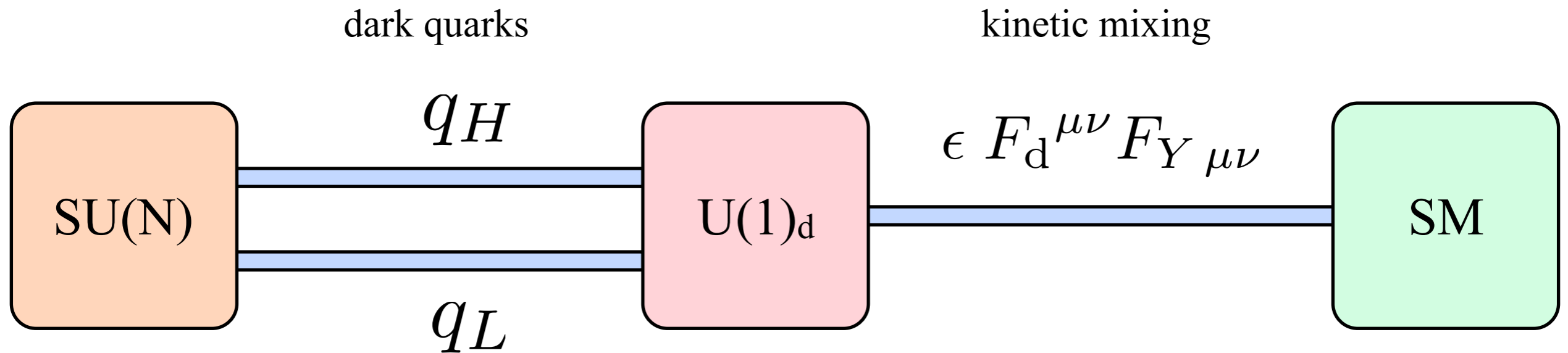
Daniele Alves, Philip Schuster, Jay Wacker  
[arXiv:0903.3945](#)  
[arXiv:1003.4729](#)

Pheno2010

# Outline

- Quick Review of CIDM
- Dark matter synthesis
- Prospects and predictions
- Conclusion

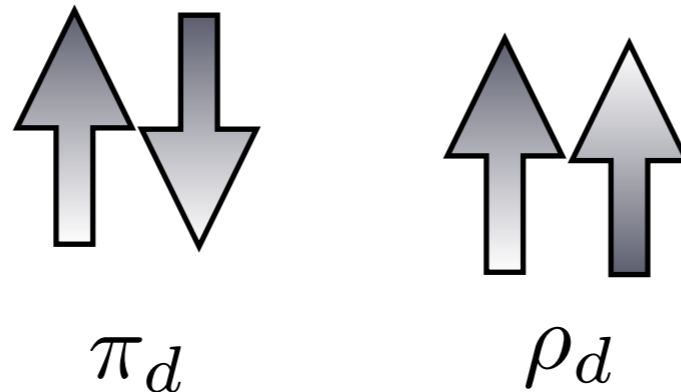
# Review of CiDM



$$\Lambda_d \sim O(100MeV - 10GeV)$$

$$m_H \simeq O(100GeV)$$

# Hyperfine physics and CiDM



$$|\psi(0)|^2 \simeq \frac{1}{4\pi} \begin{cases} 1/a_B^3 = (\alpha_t m_L)^3 & m_L \gg \Lambda_d \\ (\kappa \Lambda_d)^3 & m_L \ll \Lambda_d. \end{cases}$$

$$\delta m \sim \frac{\Lambda_d^2}{m_H}$$

Note that Axial coupling forbids elastic scattering

# States of CiDM

Alves, SB, Schuster, Wacker, 1003.4729.

Heavy quarks can bind together

$$V(r) = \frac{\alpha}{r} \left( C_2(r_1 \otimes r_2) - C_2(r_1) - C_2(r_2) \right)$$

Color-Antisymmetric channels attractive

$$E_{\text{Bind}} \sim n_H^3 \alpha_{\text{dark}}^2 m_H$$

Heavy Quarks
1
2
3
4



$q_H \ i$



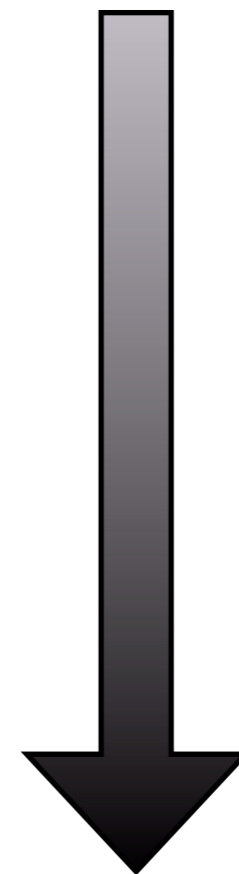
$q_H q_H \ [ij]$



$q_H q_H q_H \ [ijk]$



$q_H q_H q_H q_H \ [ijkl]$



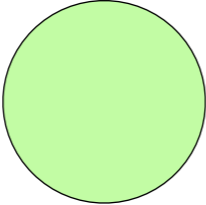
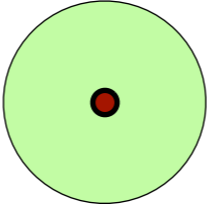
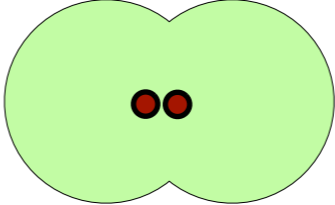
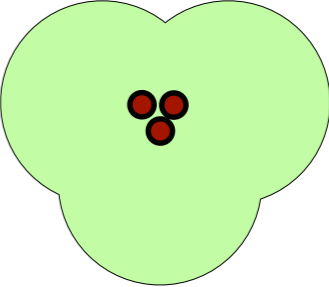
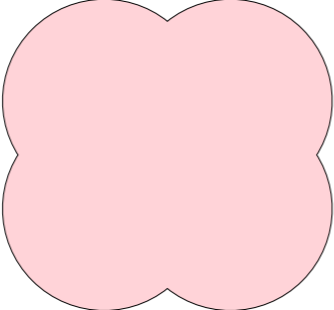
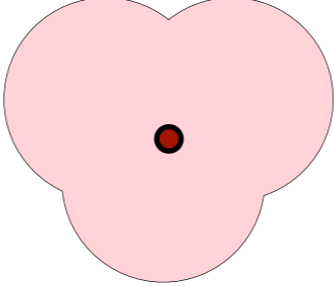
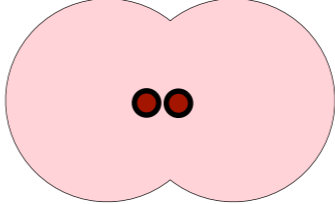
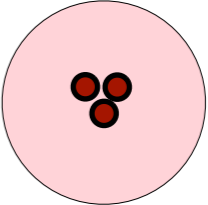

More deeply bound

# States of CiDM

Alves, SB, Schuster, Wacker, 1003.4729.

Heavy quark bound states hadronize  
into mesons & baryons

$$N_c = 4$$

Heavy Quarks	0	1	2	3	4
Mesons					
Baryons					

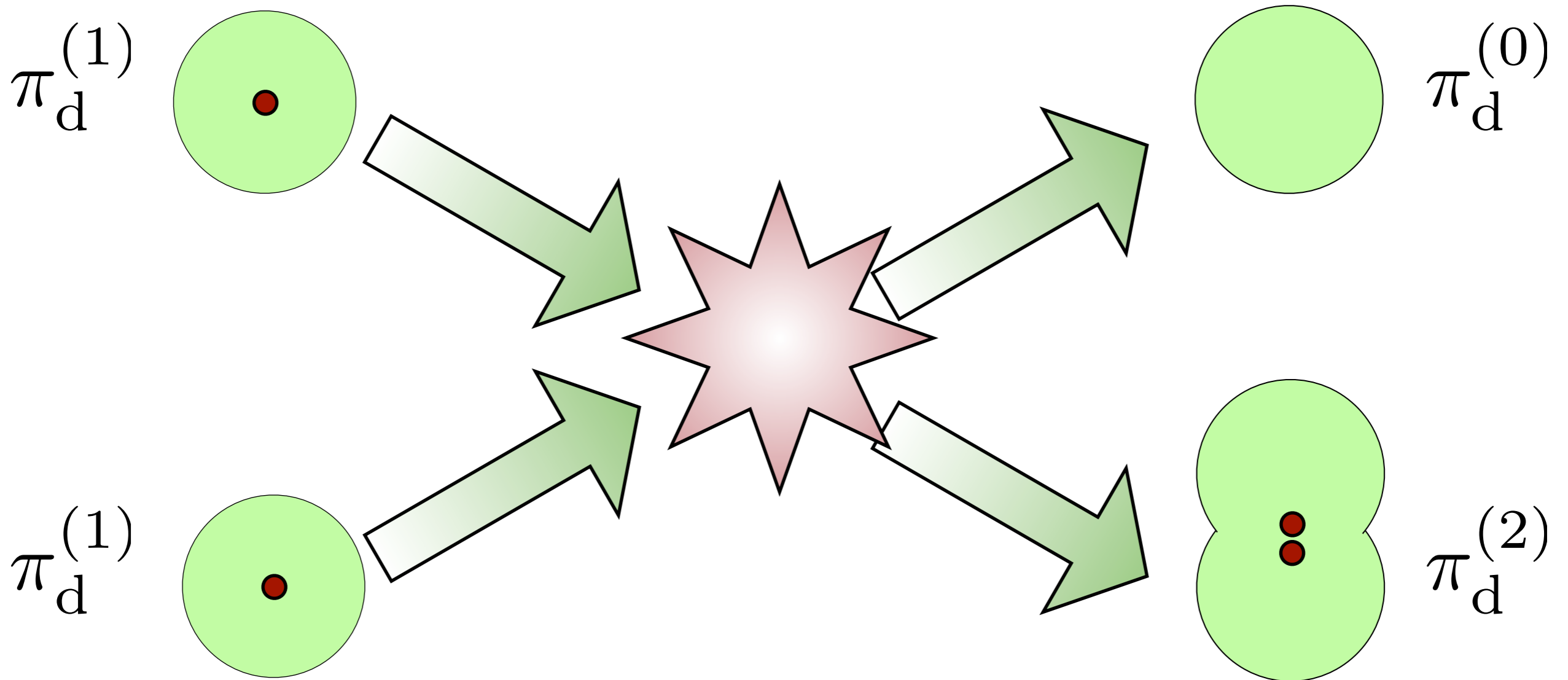


More deeply bound

# Dark Matter Synthesis

Early Universe Combination of Dark Hadrons

$$1 + 1 \rightarrow 2 + 0$$



# Dark Matter Synthesis

## Post-Confinement chain reaction

<u>Reaction</u>	<u>Energy Released</u>
$1 + 1 \rightarrow 2 + 0$	$Q = E_B - m_{\text{light}}$
$2 + 1 \rightarrow 3 + 0$	$Q = 5E_B - m_{\text{light}}$
$2 + 2 \rightarrow 4_B + 0_B$	$Q = 16E_B$
$2 + 2 \rightarrow 3 + 1$	$Q = 4E_B$
$3 + 1 \rightarrow 4_B + 0_B$	$Q = 12E_B$



# Dark Matter Synthesis

## Post-Confinement chain reaction

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First reaction can be endothermic

# Dark Matter Synthesis

## Post-Confinement chain reaction

Reaction

Energy Released

$$1 + 1 \rightarrow 2 + 0$$

$$Q = E_B - m_{\text{light}}$$

$$2 + 1 \rightarrow 3 + 0$$

$$Q = 5E_B - m_{\text{light}}$$

$$2 + 2 \rightarrow 4_B + 0_B$$

$$Q = 16E_B$$

$$2 + 2 \rightarrow 3 + 1$$

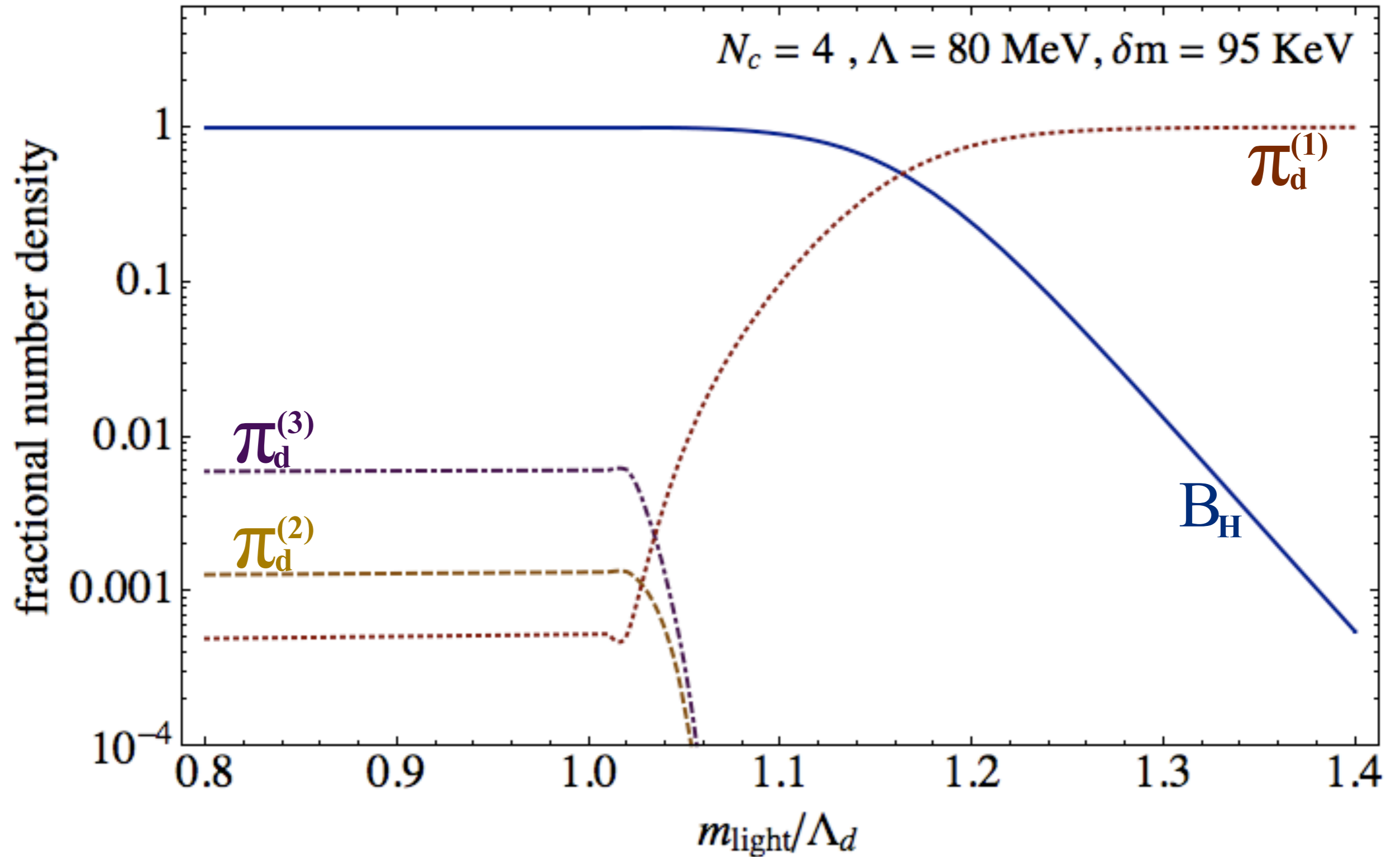
$$Q = 4E_B$$

$$3 + 1 \rightarrow 4_B + 0_B$$

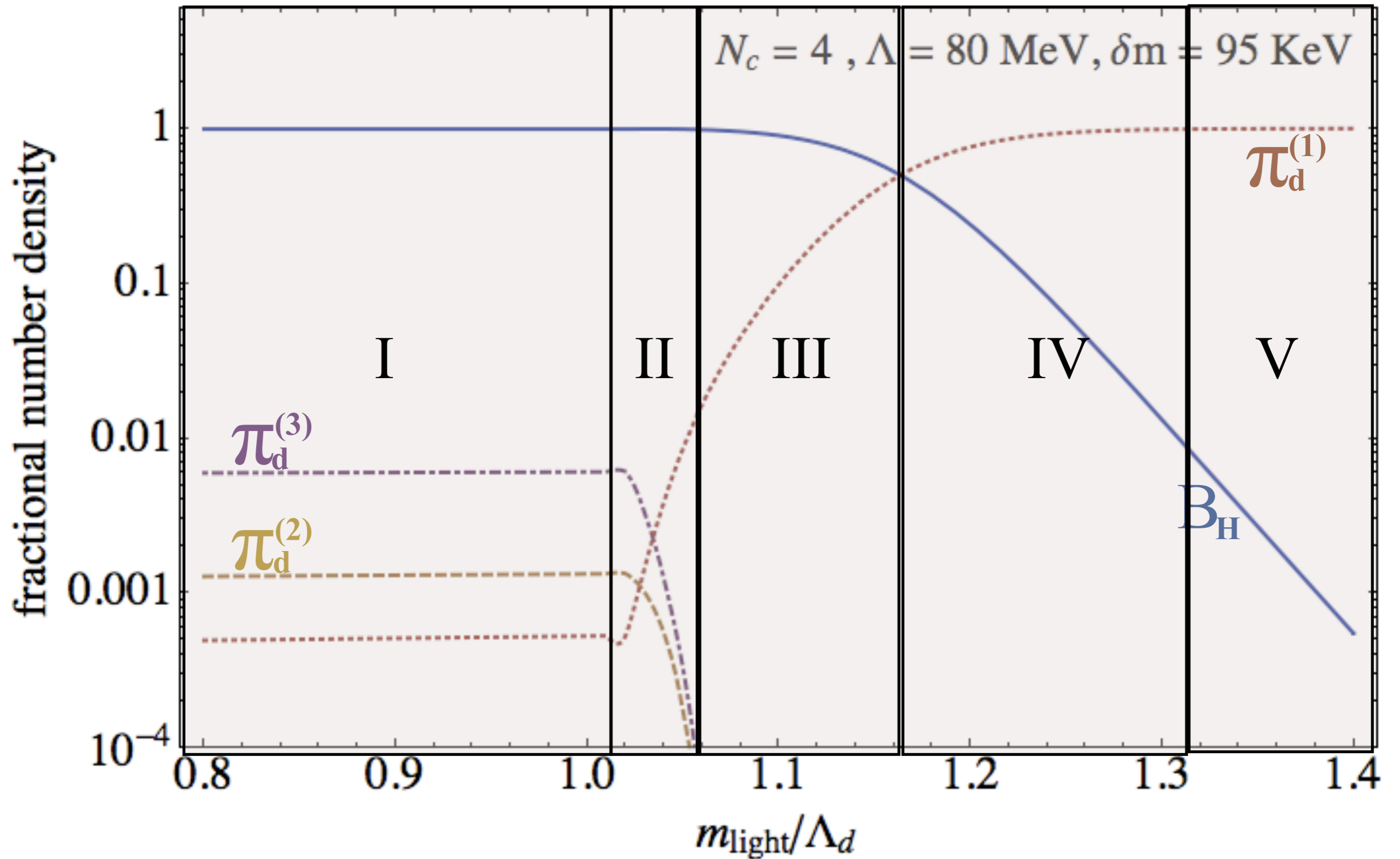
$$Q = 12E_B$$

Last reaction produces: 1 Heavy Baryon, 1 Light Anti-Baryon

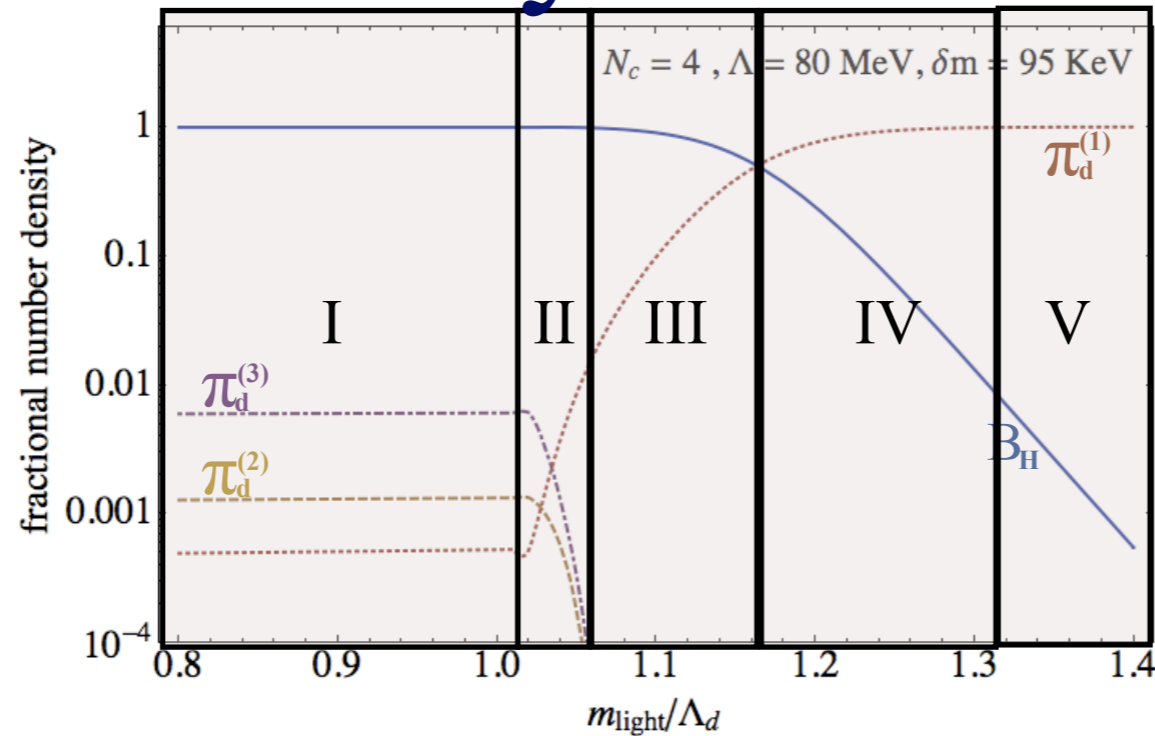
# Dark Matter Synthesis



# Dark Matter Synthesis



# Dark Matter Synthesis Taxonomy



## I.) Complete Synthesis

Mostly baryons, equal components single/multicore mesons

## II.) Nearly Complete Synthesis

Mostly baryons, enhanced/suppressed multicore mesons

## III.) Incomplete Synthesis

Mostly baryons, no multicore mesons

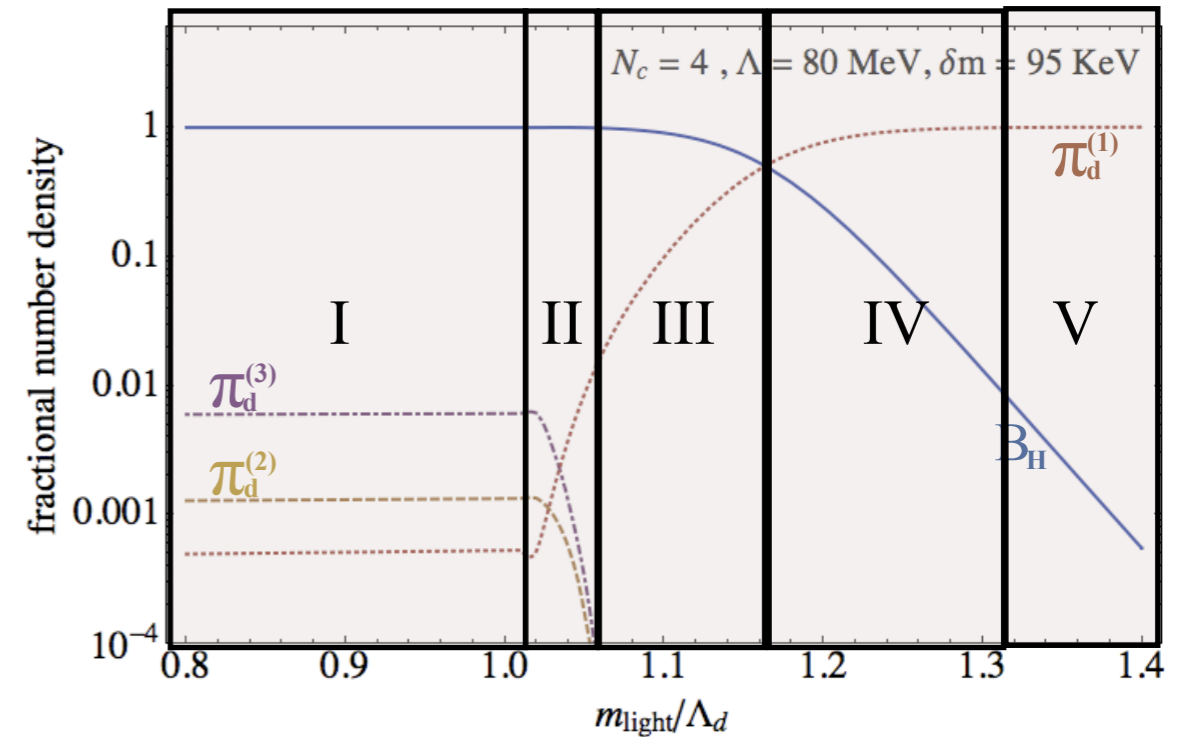
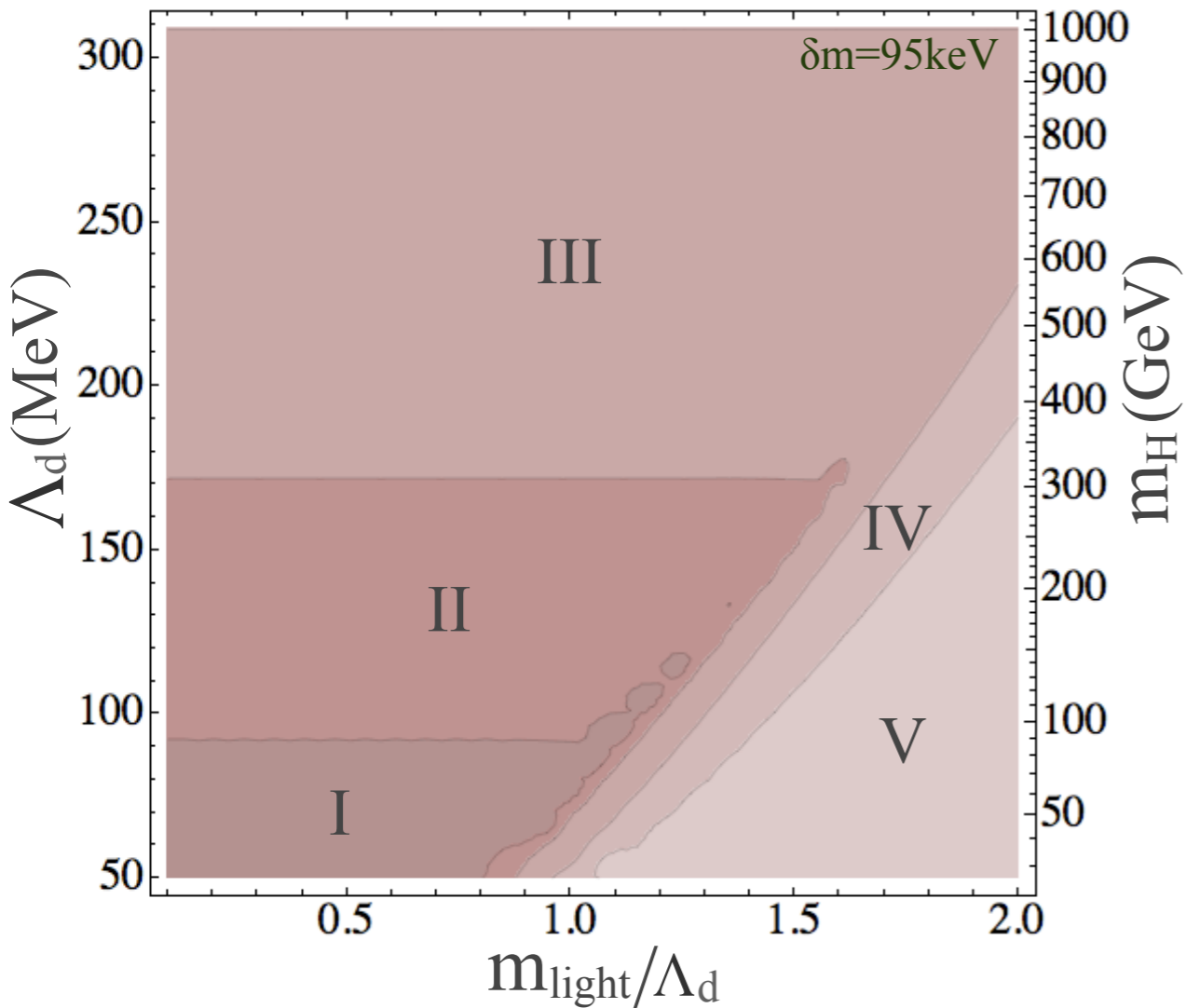
## IV.) Arrested Synthesis

Mostly single core mesons, some baryons

## V.) Inhibited Synthesis

Mostly single core mesons, few baryons

# Parametric Dependence



Low confinement/lighter heavy quarks,  
more synthesis

# Parametric Dependence

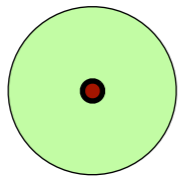
## 2 Scenarios

$$m_H = 100 \text{ GeV}$$

$$\Lambda_{\text{dark}} = 100 \text{ MeV}$$

### Inhibited

95% in

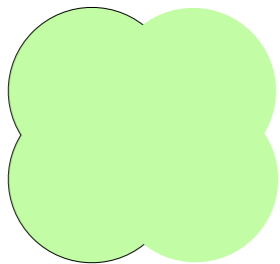


100 GeV

5% in



400 GeV



4 GeV

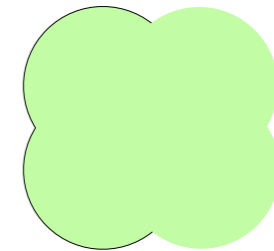
### Complete

96% in



400 GeV

4 GeV

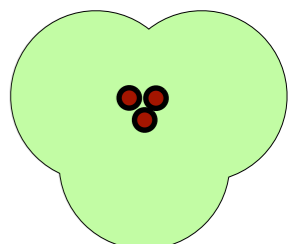
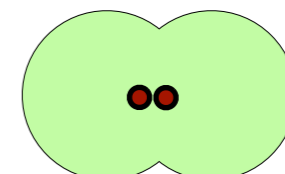
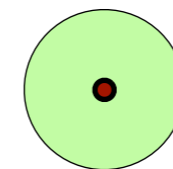


1% in

100 GeV

200 GeV

300 GeV



# Conclusions

- Cosmology doesn't kill the CiDM idea
- It is possible that DAMA is seeing a subdominant meson fraction