TeV Dark Matter

Graham Kribs

Fermilab/U Oregon

Muon Collider 2011

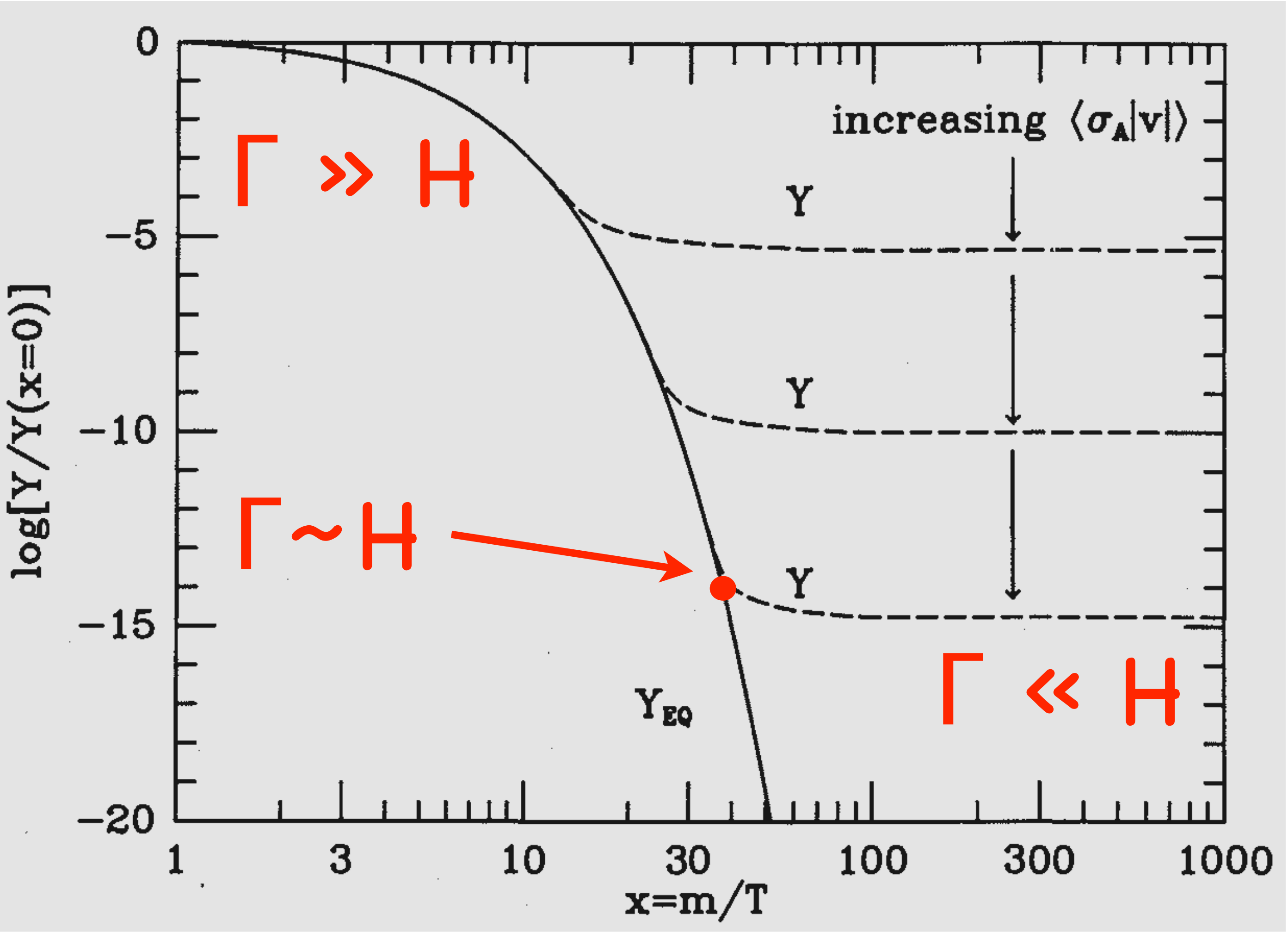
If

- thermal freezeout or
- asymmetric (sphaleron) mechanism

is right...

What is the mass of DM?

Thermal Freezout



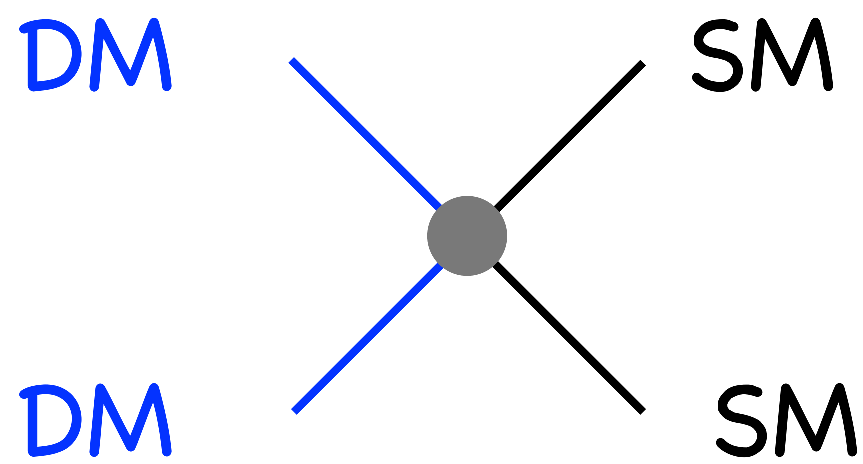
implies

$$\Omega h^2 \approx 0.1 \frac{1 \text{ pb}}{\langle \sigma v \rangle}$$

So then, where does 1 pb scale come from?

Thermal Freezout

For $\langle \sigma v \rangle \approx \dfrac{g^4}{32\pi\, M^2}$



Plug in to get abundance:

$$\Omega h^2 \approx 0.1 \left(\frac{M}{1\ \mathrm{TeV}} \right)^2$$

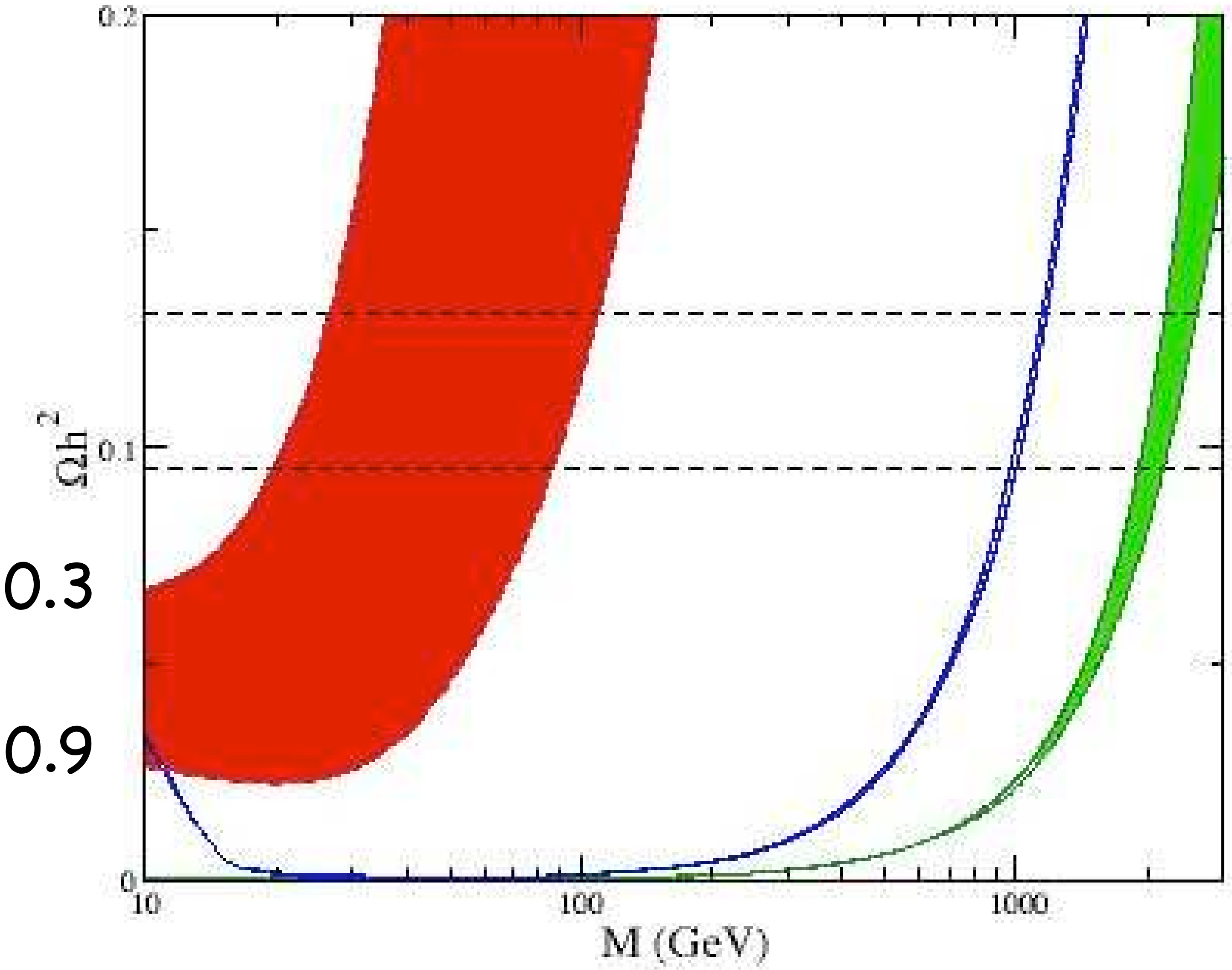
1 pb implies 1 TeV mass scale for weakly interacting DM.

Example 1: SUSY Neutralino Abundance

Pure Bino

Pure Higgsino

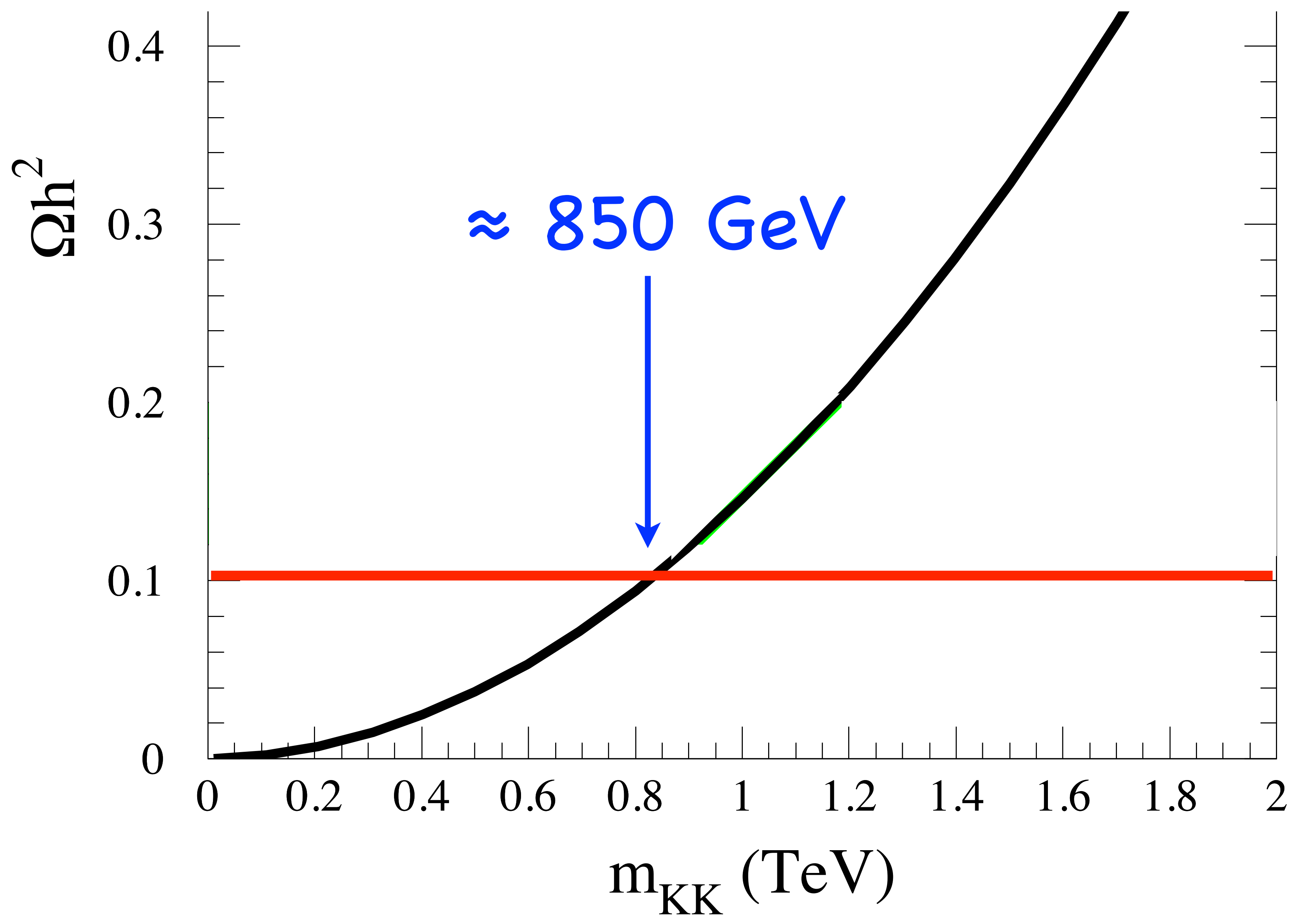
Pure Wino



$$\frac{m(sleptR)}{M_1} = \begin{matrix} 0.3 \\ 0.9 \end{matrix}$$

Arkani-Hamed, Delgato, Giudice

Example 2: KK B Abundance



$\langle \sigma v \rangle \approx \alpha_Y{}^2/M^2 \;\; \times \;\; \Sigma\, Y^4$

Servant, Tait;
Burnell, GK

From a purely DM point of view...

$m(DM) \approx$ 1-2 TeV

is natural for electroweak-strength interactions with matter to give the correct thermal abundance.

Abundance from an Asymmetry

Dark Matter from Asymmetry

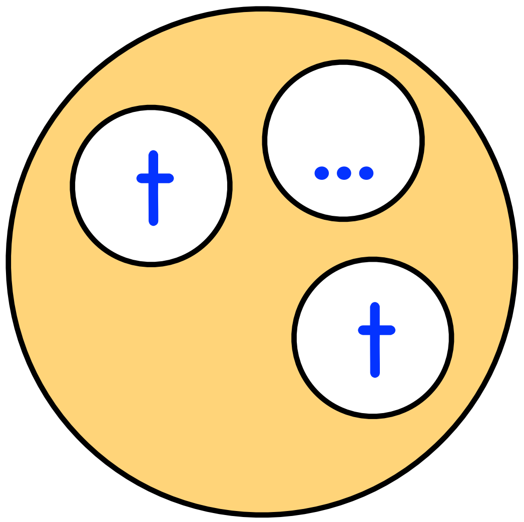
Old idea to relate:

Nussinov;
Barr, Chivukula, Farhi;
DB Kaplan;
...

Dark Matter Number ⟷ Baryon Number

Example: Technicolor

Candidate: Lightest technibaryon



$$M_{TB} \approx 4\pi v \approx 1 \text{ TeV}$$

Technibaryon is gauge singlet
(scalar or fermion)

TB number is accidental global symmetry,
analogous to baryon number.

Nussinov;
Chivukula, Walker;
...

Technibaryon Abundance

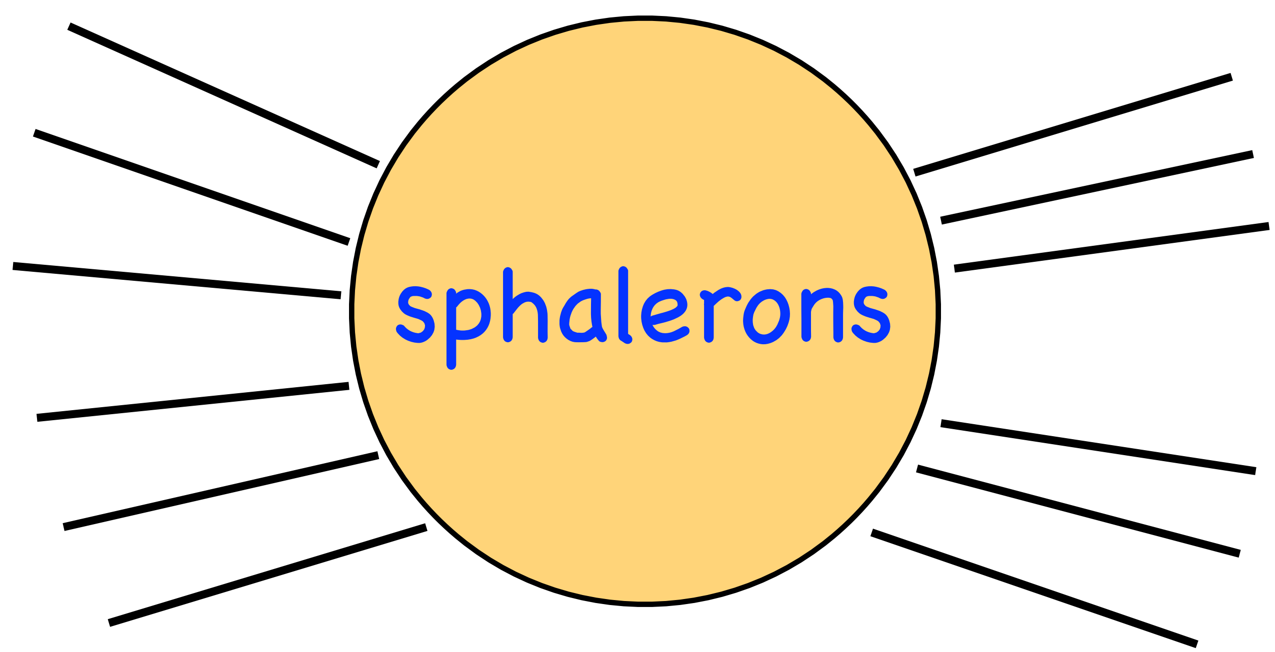
Naively, if $n_{TB} \approx n_{matter}$,

$$M_{TB} \approx \frac{\rho_{TB}}{\rho_{baryon}} m_{baryon} \approx 5\ m_{proton} \approx 5\ \text{GeV}$$

But...

Technibaryon Abundance Redux

Barr, Chivukula, Farhi (1990) realized



play a nontrivial role in redistributing B,L,TB number among chiral electroweak doublets above and near the EW phase transition.

Technibaryon Abundance Redux

$T \ggg m$ — Baryo/lepto/techno-genesis

$T \gg m$ — Sphalerons active; continually redistributing B,L,TB number

$T_{EWPT} \approx T < m_{TB}$ — Heavy asymmetric particle number densities get Boltzmann suppression

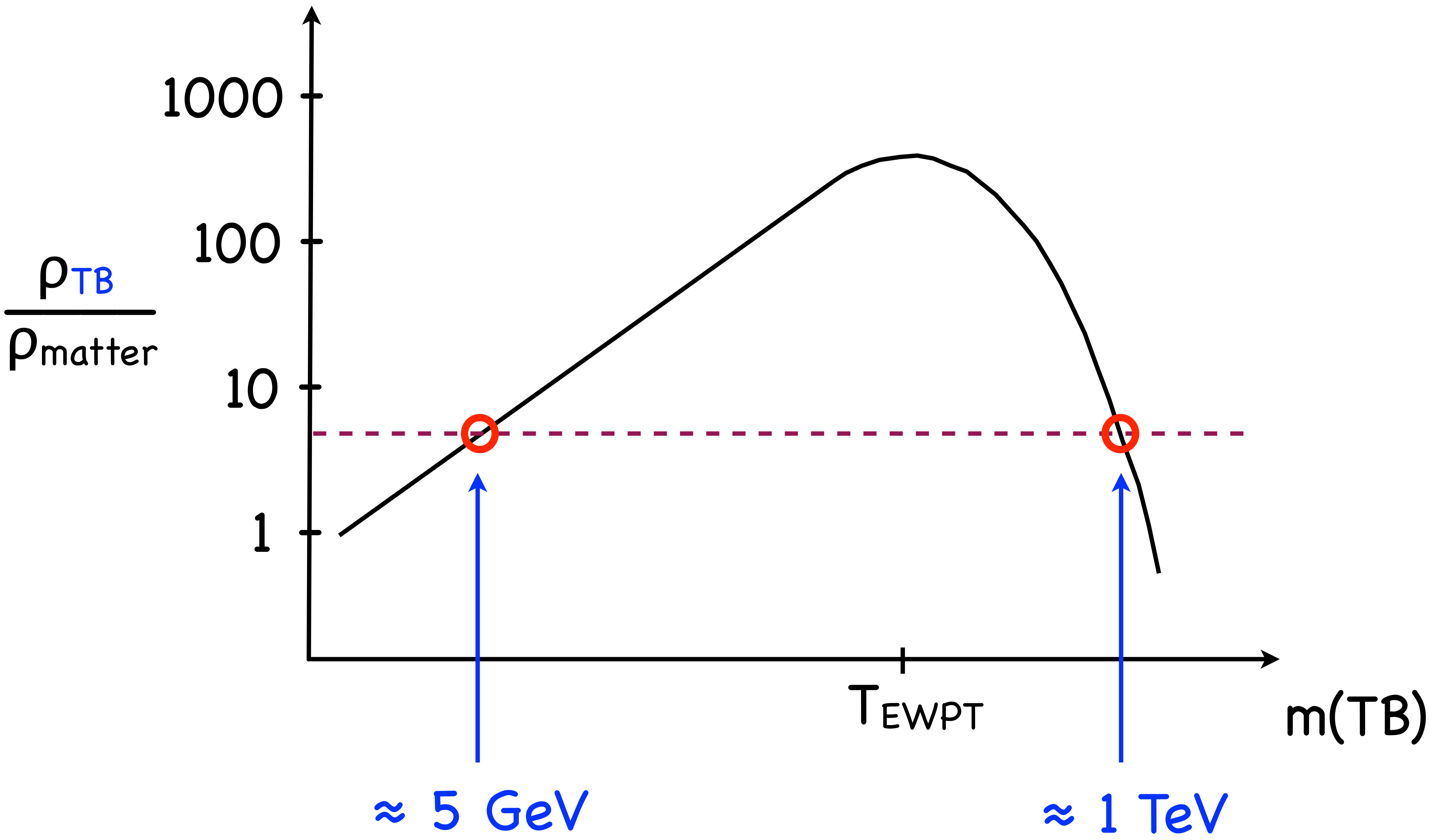
$$n_{TB} \approx n_B \exp[-M_{TB}(T)/T]$$

$T \ll T_{EWPT}$ — Sphalerons shut off,

$$n_{TB} \approx n_B \exp[-M_{TB}(T_{EWPT})/T_{EWPT}]$$

"frozen" in.

Asymmetric DM Abundance



Asymmetric DM, when connected to EW physics through EW sphalerons, predicts

$m(DM) \approx 1$ TeV

Models include both technibaryons, and quirkybaryons

GK, Roy, Terning, Zurek 2009

Central Lesson

Well known mechanisms that generate the correct DM relic abundance work naturally for

$m(DM) \approx 1\text{–}2$ TeV

This ought to serve as a strong motivation for multi-TeV colliders (LHC, MC, CLIC) as a tool to explore this regime.

Correlated Signals

Technibaryons & quirkybaryons have mesons, which can be produced and decay into SM resonances.

The meson masses, production source, and decay modes are model-dependent.

Correlated Signals

Wino of MSSM, with mass $\approx$ 2 TeV difficult at LHC. (All superpartners heavier.) Neutral wino accompanied by charged wino isotriplet partners.

$\Delta m \approx 0.16$ GeV (1-loop EM effect)

charged wino -> neutral wino can be long lived, decay length $c\tau \approx 0.1$–1 m, leaving charged tracks in the detector.