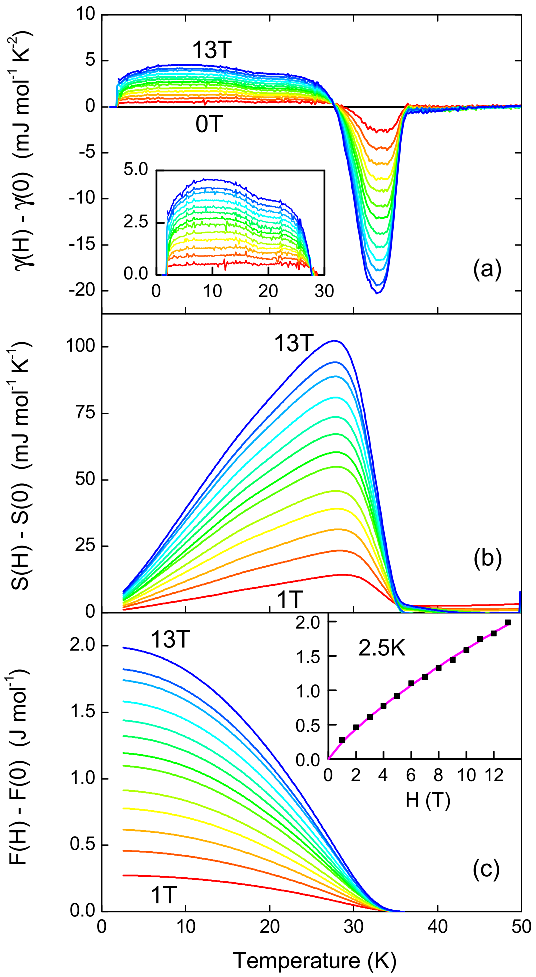

FIG. 4: (Color online) (a) Magnetic field dependent change in electronic specific heat $\gamma(H) - \gamma(0)$ vs temperature, in 1T increments, from the data in the inset of Fig. 1. (Inset) Enlargement of the 0 to 30K region. (b) Field dependence of the electronic entropy, $S(H) - S(0)$, calculated from (a) using Eqn. 5. (c) Field dependence of the free energy, $F(H) - F(0)$, calculated from (b) using Eqn. 6. (Inset) A fit to $F(H) - F(0)$ at 2.5K using Eqn. 8.

on different sheets of the Fermi surface, or from an intrinsically anisotropic gap(s).

We turn now to the information contained in the magnetic field dependence of γ. The inset to Fig. 1 shows the suppression of the superconducting anomaly in magnetic fields from 1 to 13T in 1T increments. Because the phonon specific heat is independent of magnetic field, the change in electronic specific heat with field is obtained by subtracting the zero field data from the data measured in a field (see Fig. 4(a)).

$$\Delta\gamma(H,T) = \gamma(H,T) - \gamma(0,T) \tag{4}$$

Integrating over temperature gives the change in electronic entropy with field (see Fig. 4(b)).

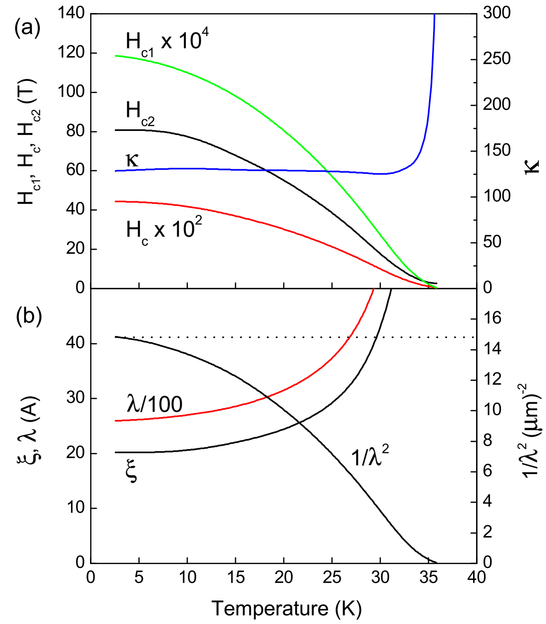

FIG. 5: Pollycrystalline averaged mixed state parameters of $Ba_{0.3}K_{0.3}Fe_2As_2$ derived from the field dependence of the free energy $\Delta F(H,T)$: (a) Critical fields H_c, H_{c1}, H_{c2}, and Ginsburg-Landau parameter κ; (b) London penetration depth λ, superfluid density $\propto 1/\lambda^2$ and superconducting coherence length ξ.

$$\Delta S(H,T) = \int_0^T \Delta\gamma(H,T)dT \tag{5}$$

The change in free energy is obtained by integrating the entropy over temperature (see Fig. 4(c)).

$$\Delta F(H,T) = -\int_0^T \Delta S(H,T)dT + \Delta F(H,0) \tag{6}$$

$\Delta F(H,0)$ is determined from the condition that the superconducting contribution to $\Delta F(H,T)$ tends to zero for $T \gg T_c$. At each temperature, the field dependence of the free energy is fitted to a theoretical expression derived from the model of Hao and Clem[18] for an s-wave superconductor.

$$\begin{aligned} \Delta F_{s,rev}(H,T) &= \frac{a\phi_0}{32\pi^2\lambda^2} H \ln\left(\frac{e\beta H_{c2}}{H}\right) && (7) \\ &= a_1 H \ln(a_2 H) && (8) \end{aligned}$$

The coefficients a and β are weakly field dependent and are given by $a \sim 0.77$ and $\beta \sim 1.44$ in the range $0.02 < H/H_{c2} < 0.3$. A fit to the free energy at 2.5K is shown in the inset to Fig. 4(c).

The penetration depth, λ, and the upper critical field, H_{c2}, are determined directly from the fit parameters a_1 and a_2. Then using the following Ginsburg-Landau relations we extract the: critical field $H_c^2 = (\phi_0/4\pi\lambda^2)H_{c2}$,