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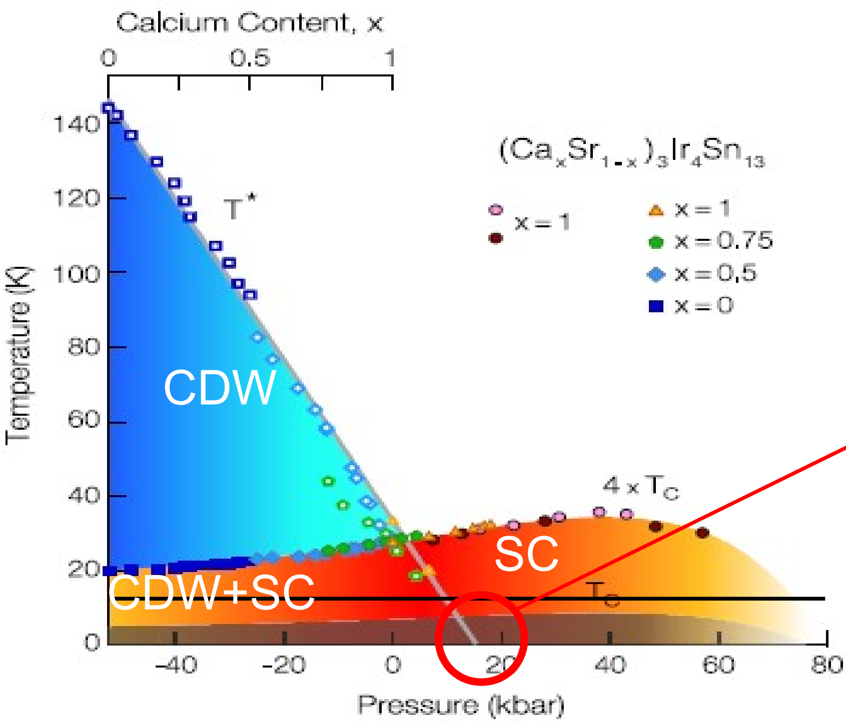
μSR studies of the pressure dependent superconducting properties of $Ca_3Ir_4Sn_{13}$

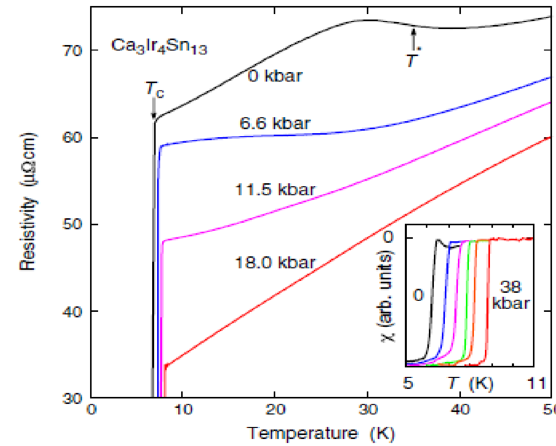
Manuel Chinotti

Phase diagram of $Ca_3Ir_4Sn_{13}$

- Anomaly around 33 K
- Critical temperature around 7 K



L.E. Klintberg *et al.*, PRL **109**, 237008 (2012)



Close to p_c (around 18 kbar) find behavior of:

- Superfluid density
- Superconducting gap
- Symmetry of the gap

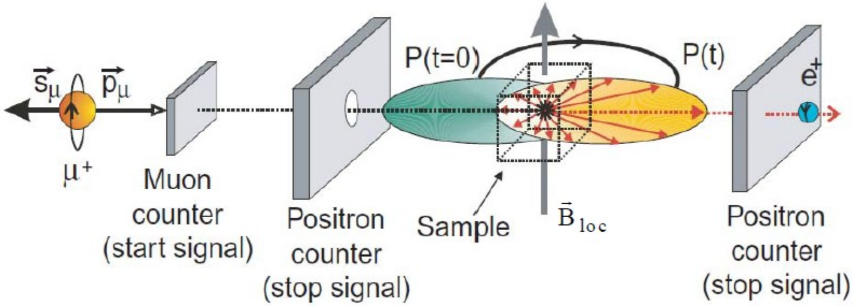
μSR of $Ca_3Ir_4Sn_{13}$ under pressure

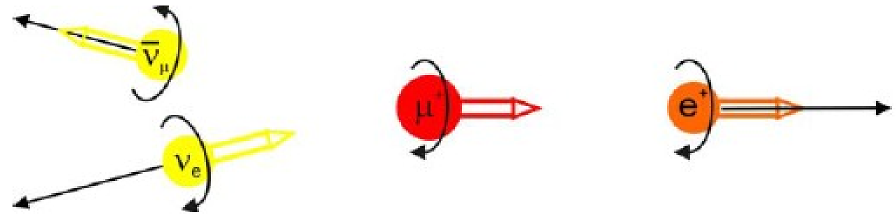
Measurements in:
- TF-field: 500 G.
- Temperature range 0.25 K -10 K.
- Pressure range: 1.5 kbar-21.8 kbar

Find average internal field, muon depolarization rate and penetration depth.

µSR: local probe technique

$\omega_\mu = \gamma_\mu B_{local}$ (γ_μ = 851.59 MHz/T)

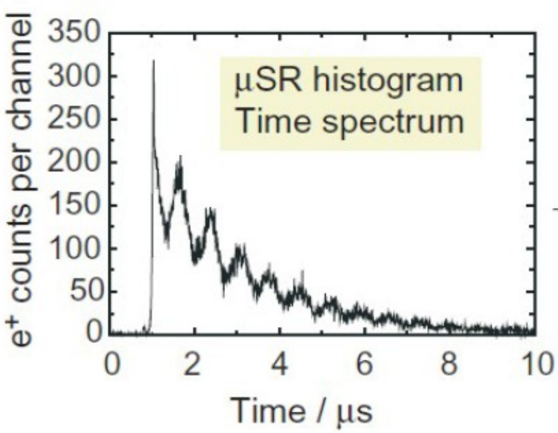


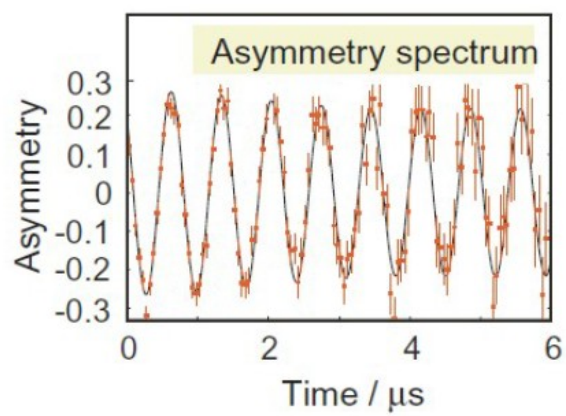


$m_\mu \approx 1/9\ m_p$, $\tau_\mu = 2.19714\ \mu s$

$s_\mu = ½$, $\mu_\mu = 3.18\ \mu_p$

$$N_{e^+}(t) = B_G + N_0 \exp(-t/\tau_\mu)\ \lfloor 1 + A_0 P(t) \rfloor$$

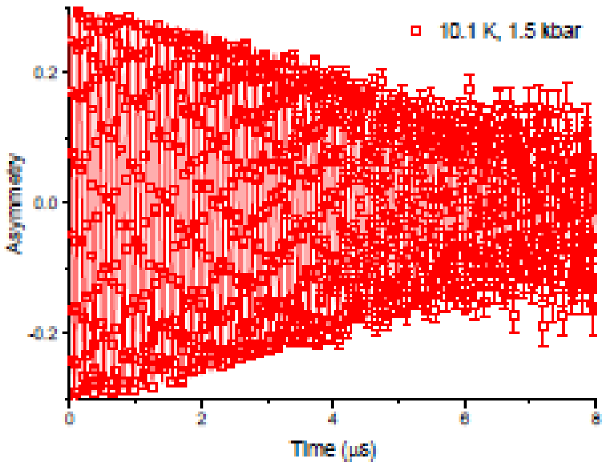


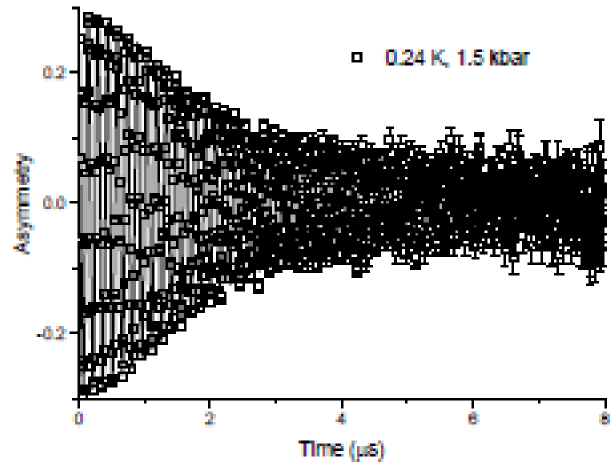


µSR of $Ca_3Ir_4Sn_{13}$ under pressure

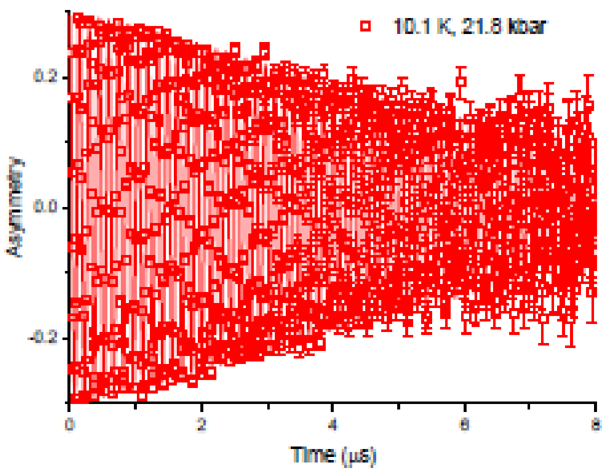
non SC

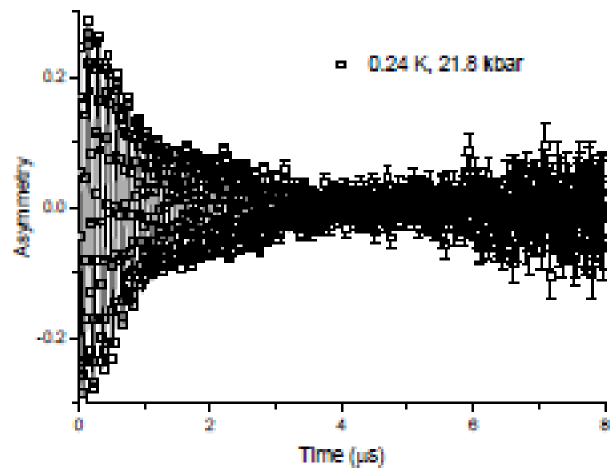
SC





Cu-Be p-cell





MP35N p-cell

μSR of $Ca_3Ir_4Sn_{13}$ under pressure

Cu-Be-cell

$$A(t) = \sum_{i=1}^{N=2} A_i \exp(-\frac{\sigma_i^2 t^2}{2}) \cos(\gamma_\mu B_i t + \varphi)$$

$$+ A_{Cu-Be} \exp(-\frac{\sigma_{Cu-Be}^2 t^2}{2}) \cos(\gamma_\mu B_{Cu-Be} t + \varphi)$$

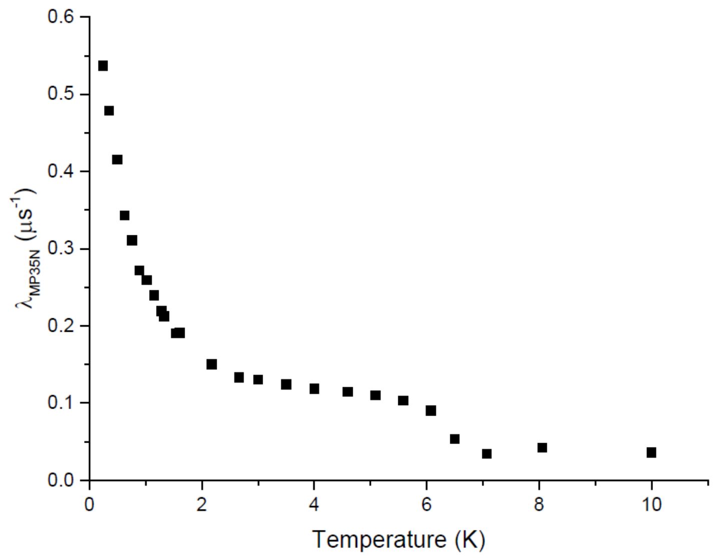
MP35N-cell

$$A(t) = A_1 \exp(-\frac{\sigma_1^2 t^2}{2}) \cos(\gamma_\mu B_1 t + \varphi)$$

$$+ A_{MP35N} \exp(-\frac{\sigma_{MP35N}^2 t^2}{2})$$

$$\boxed{\exp(-\lambda_{MP35N}(T)t)} \cos(\gamma_\mu B_{MP35N} t + \varphi)$$

pressure cell type	applied pressure [*kbar*]
6 mm Cu-Be	1.5, 4.4, 7.45, 11.6
6 mm MP35N	11.3, 15.5, 19.6, 21.8
6 mm MP35N	17.2

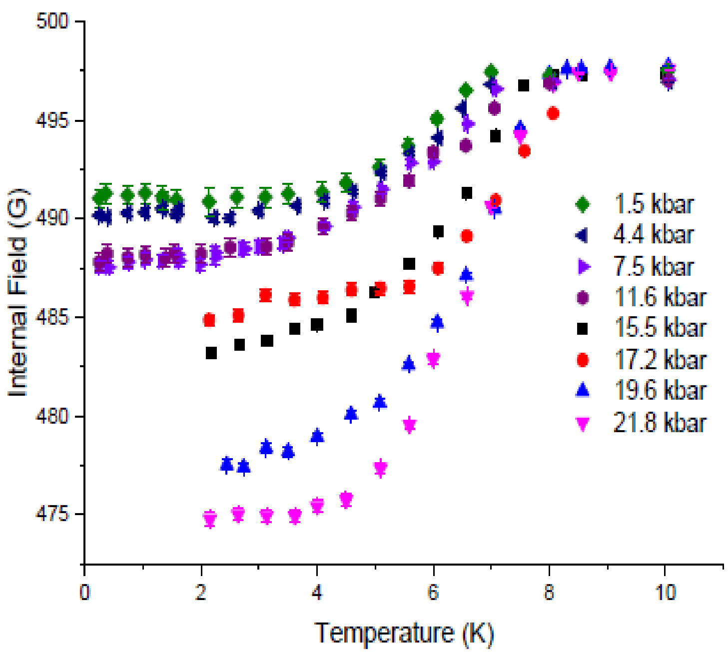


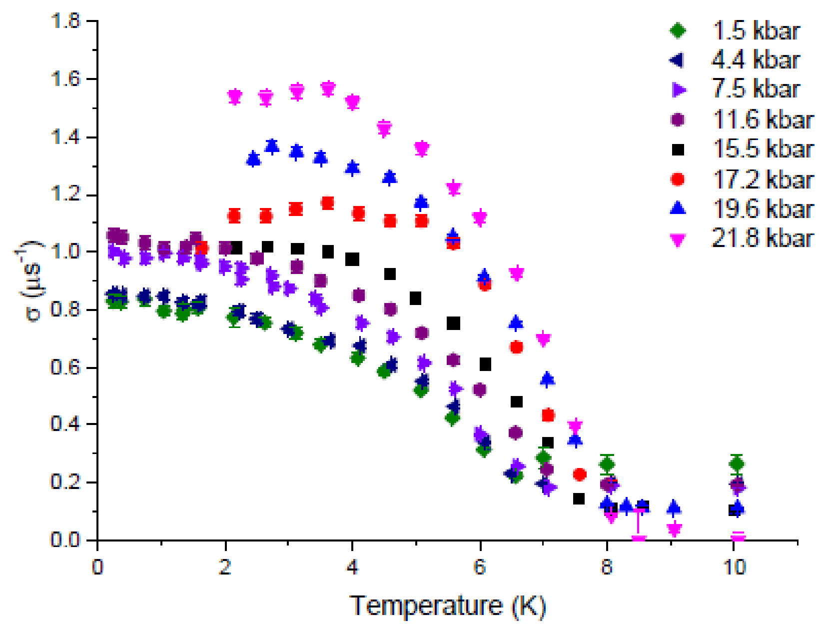
μSR of $Ca_3Ir_4Sn_{13}$ under pressure

$$\langle B \rangle = \frac{1}{A_1 + ... + A_N} \sum_{i=1}^{N} A_i B_i \qquad \langle \Delta B^2 \rangle = \frac{\sigma^2}{\gamma_\mu^2} = \frac{1}{A_1 + ... + A_N} \sum_{i=1}^{N} A_i ((\frac{\sigma_i}{\gamma_\mu})^2 + (B_i - \langle B \rangle)^2)$$

$$\sigma \propto \lambda^{-2} \propto n_s$$

$$\sigma_{sc}(b)[\mu s^{-1}] = 4.83 \times 10^4 (1-b)\sqrt{1 + 3.9(1-b^2)}\lambda[nm]^{-2}.$$



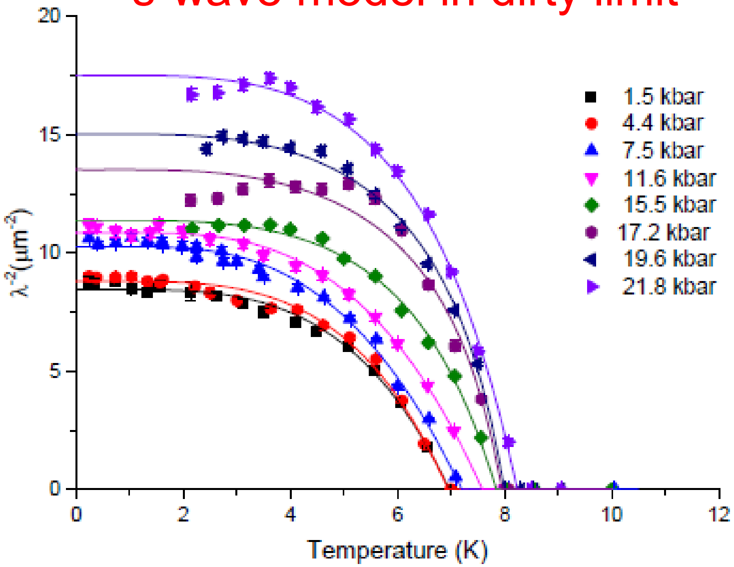


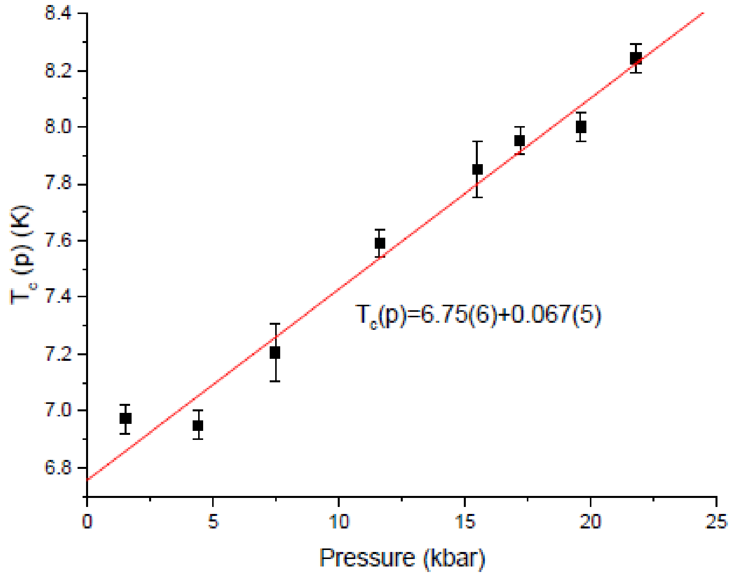
μSR of $Ca_3Ir_4Sn_{13}$ under pressure

$$\frac{\lambda^2(0)}{\lambda^2(T)} = \frac{\Delta(T)}{\Delta(0)} \tanh\left[\frac{\Delta(T)}{2k_BT}\right]$$

$$\Delta(T) = \Delta(0) \tanh\left[1.82[1.018(\frac{T}{T_c} - 1)]^{0.51}\right]$$

s-wave model in dirty limit





- Dirty superconductor: mean free path << BCS coherence length
- Nodeless superconductor at each pressure
- Behavior of Tc and of superfluid density different from BCS superconductors

μSR of $Ca_3Ir_4Sn_{13}$ under pressure

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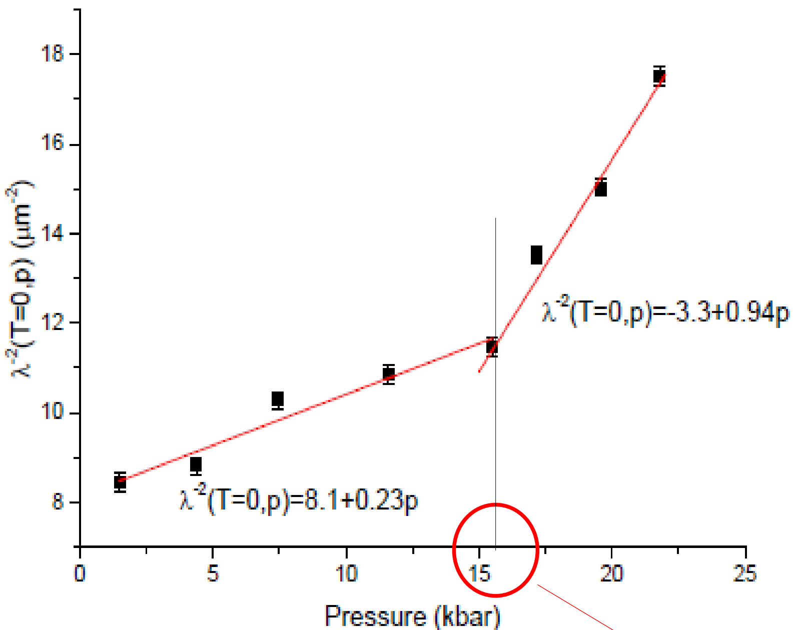
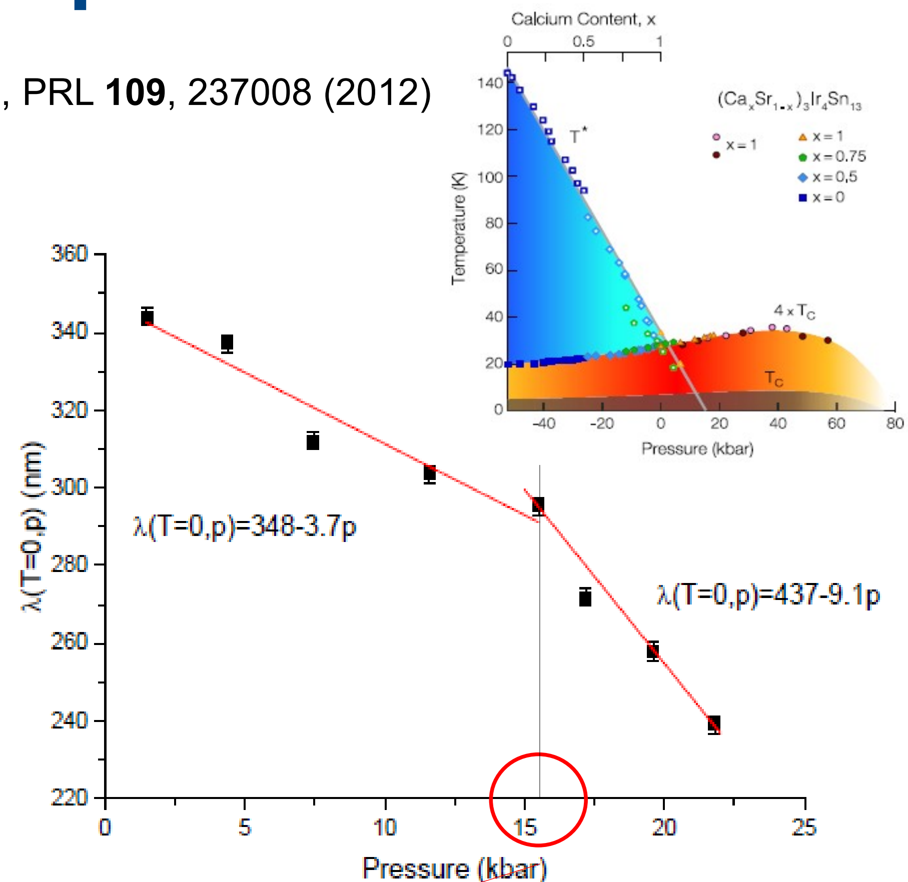
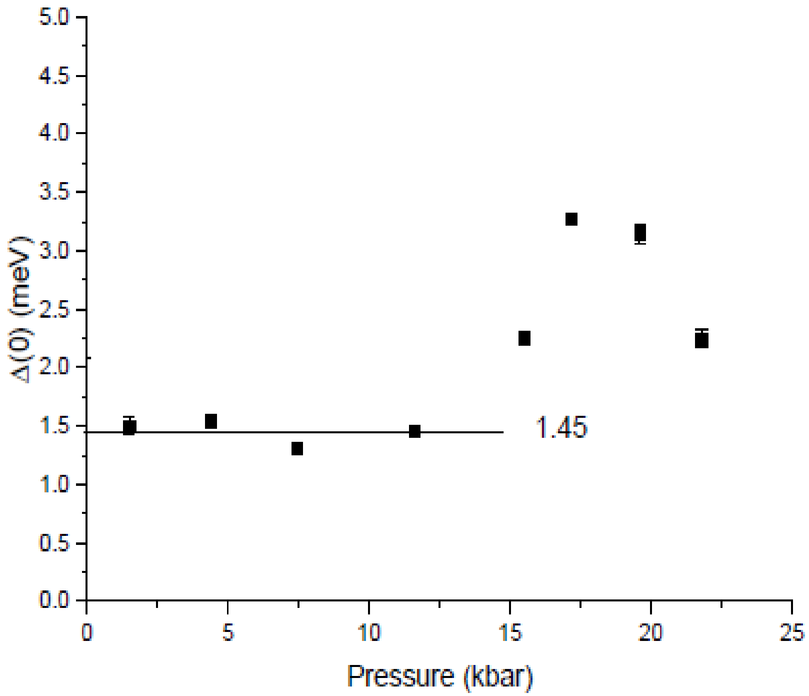


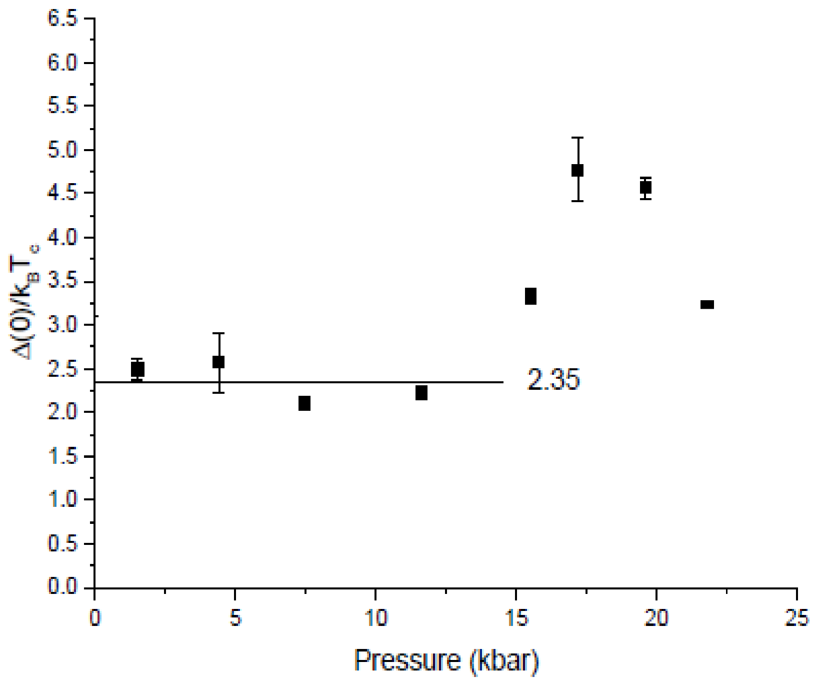


- Type II SC
- QCP: 15-16 kbar
- CDW gap suppressed

μSR of $Ca_3Ir_4Sn_{13}$ under pressure

Strong-coupling SC





Summary

- Dirty, strong-coupling, type-II superconductor.
- Nodeless single gap BCS s-wave model.
- Superfluid density of $Ca_3Ir_4Sn_{13}$ increases dramatically under pressure.
- This is possibly due to suppression of CDW gap under pressure at about 15 kbar.

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Literature

- P.K. Biswas *et al.*,Phys. Rev. B **92**, 195122 (2015).
- P.K. Biswas *et al.*,Phys. Rev. B **90**, 144505 (2014).
- S.J. Blundell, Contemporary Physics **40**, 203-225 (2004)