Magnetic Field Dependence of the Sommerfeld Coefficient in $Mg_xAl_{1-x}B_2$ Single Crystals

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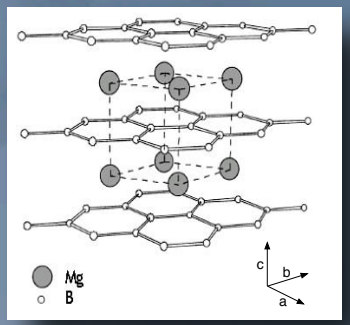
Collaboration :
P. Samuely & P. Szabo : Point Contact Spectroscopy
S-I.Lee and coll. & S.Lee : sample preparation

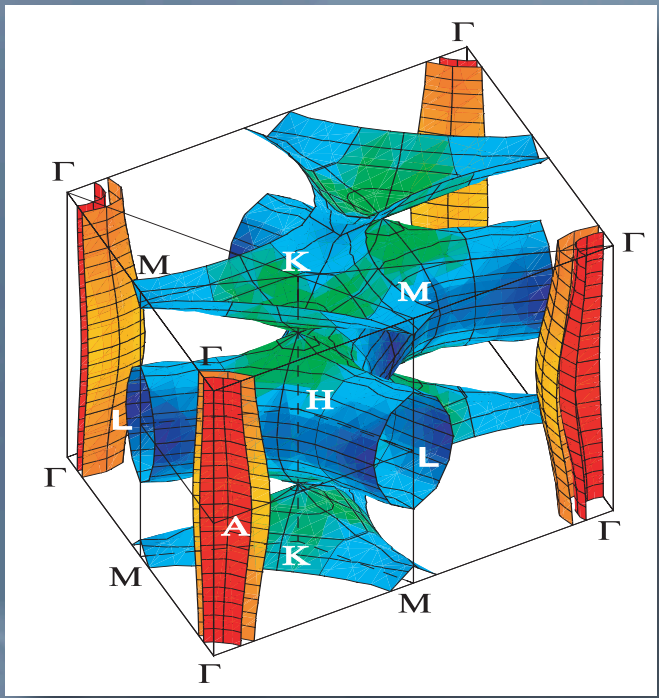
Hexagonal structure (B planes)

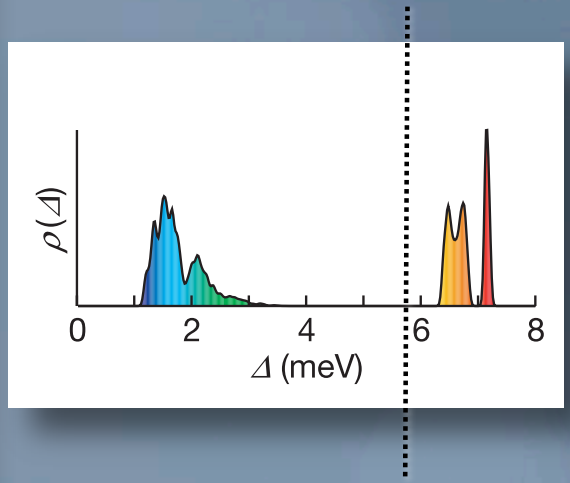
- quasi 2D sp^2 B orbitals : σ band
- 3D p_z B orbitals : π band

2 gap superconductor

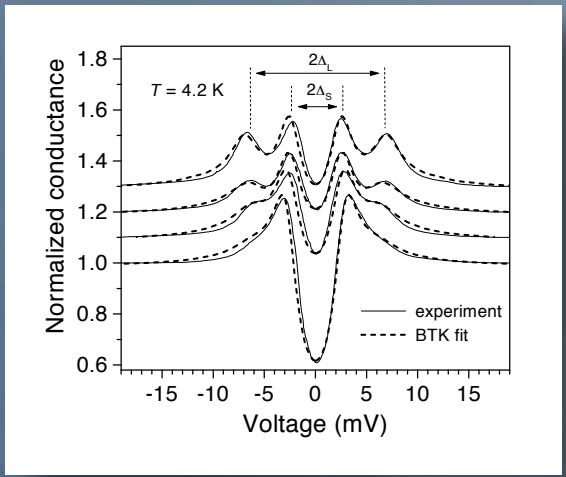


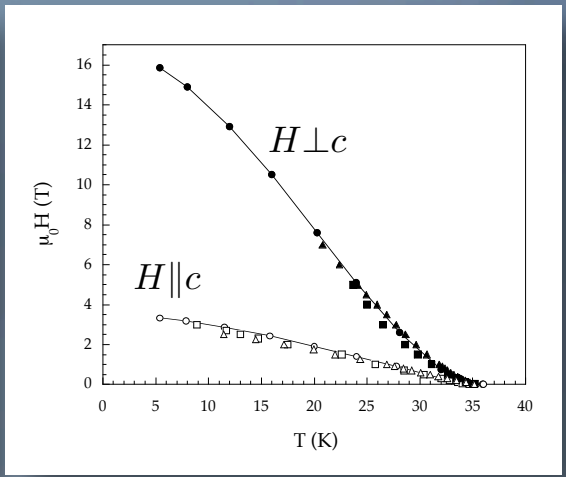
$T_c \sim 40K$

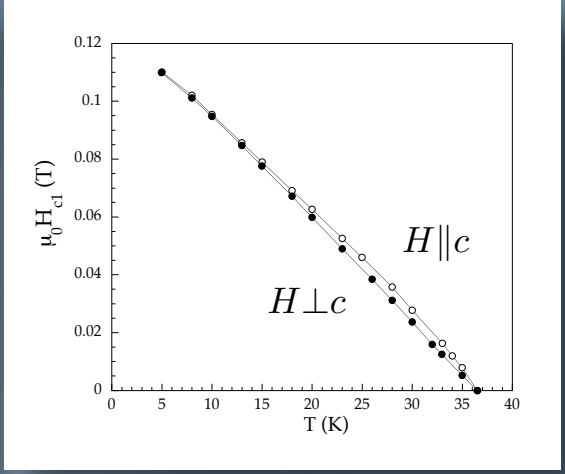




BCS value







Tunneling spectroscopy (and specific heat : bulk)

Cp : thermodynamic criterion for the determination of $H_{c2}(T)$ (also R=0, onset of diamagnetism)

Magnetic measurements : determination of $H_{c1}(T)$

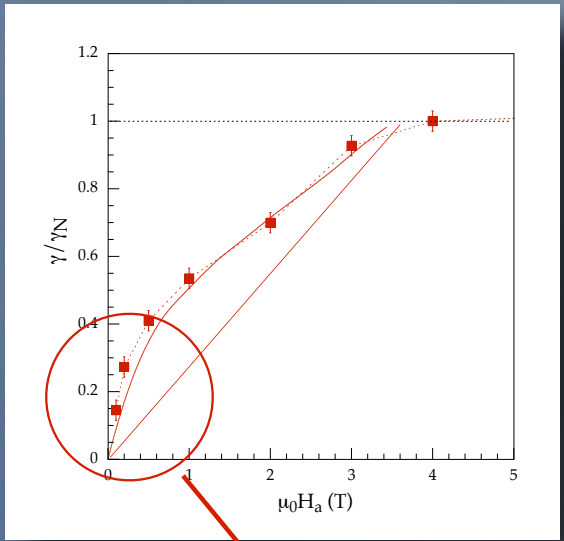
Rapid suppresion of the small gap with field

Temperature dependence of the anisotropy

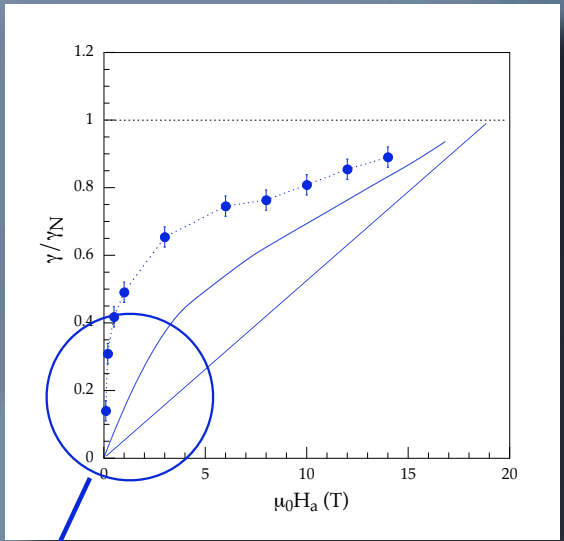
isotropic $H_{c1}(T)$

$$\Gamma_{H_{c2}} \neq \Gamma_{H_{c1}}$$

$H \| c$



$H \perp c$



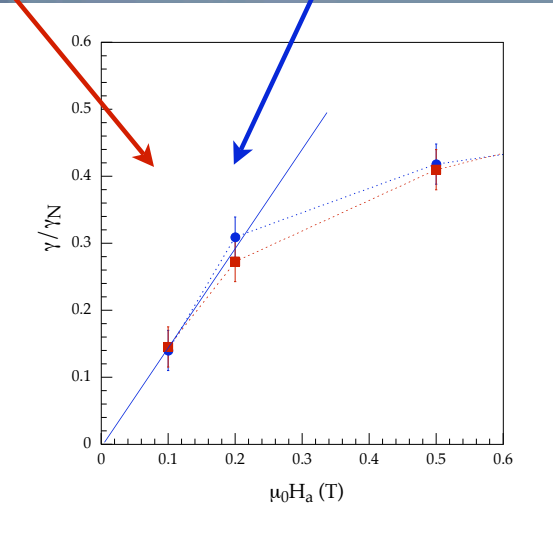
$$\gamma = \frac{C_p}{T}\Big|_{T\to 0}$$

Classical (dirty) superconductors

$$\gamma \propto \left\{\frac{\xi}{a_0}\right\}^2 \propto \frac{B}{B_{c2}}$$

non-linear dependence predicted by Kogan et al. due to core shrinkening in clean systems

F.Bouquet et al. PRL 02

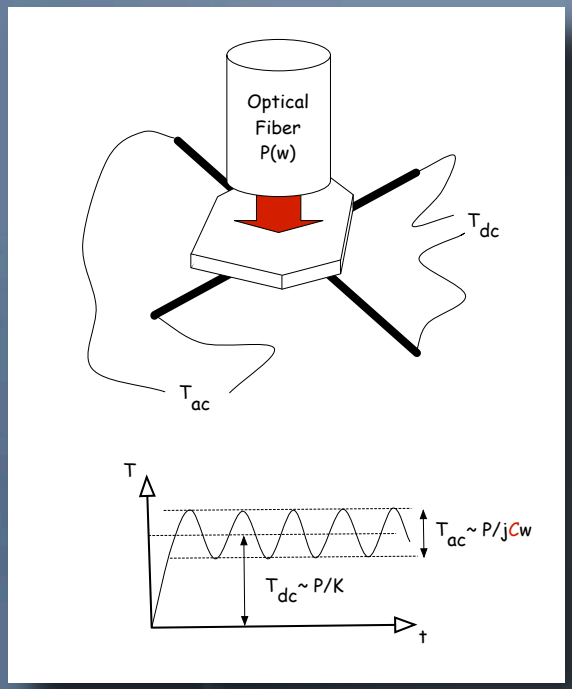


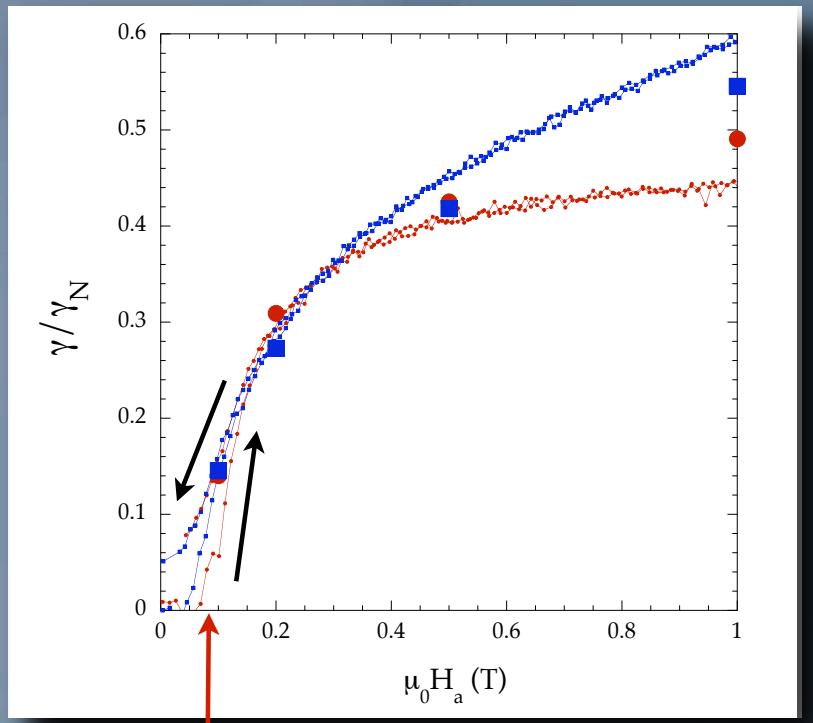
Linear field dependence for H<0.2T but vicinity of H_p ~ 500-1000G ?
isotropic (H< 0.5-1T)

starting point : detailled study of the field dependence at low B

is γ linear in B at low B or sublinear down to B = 0 ?

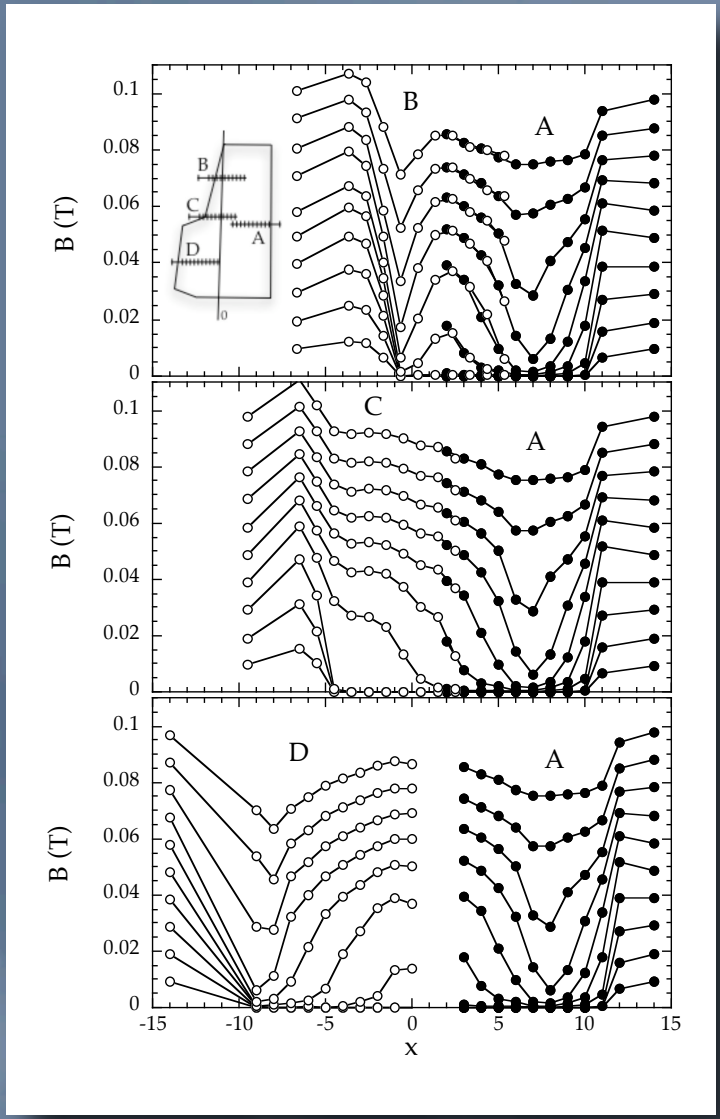
AC technique



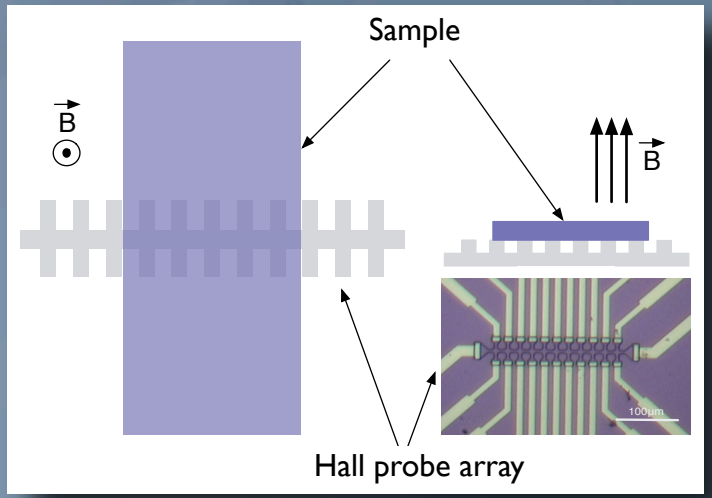


H_p

high sensitivity
well adapted for small samples
continuous field measurements

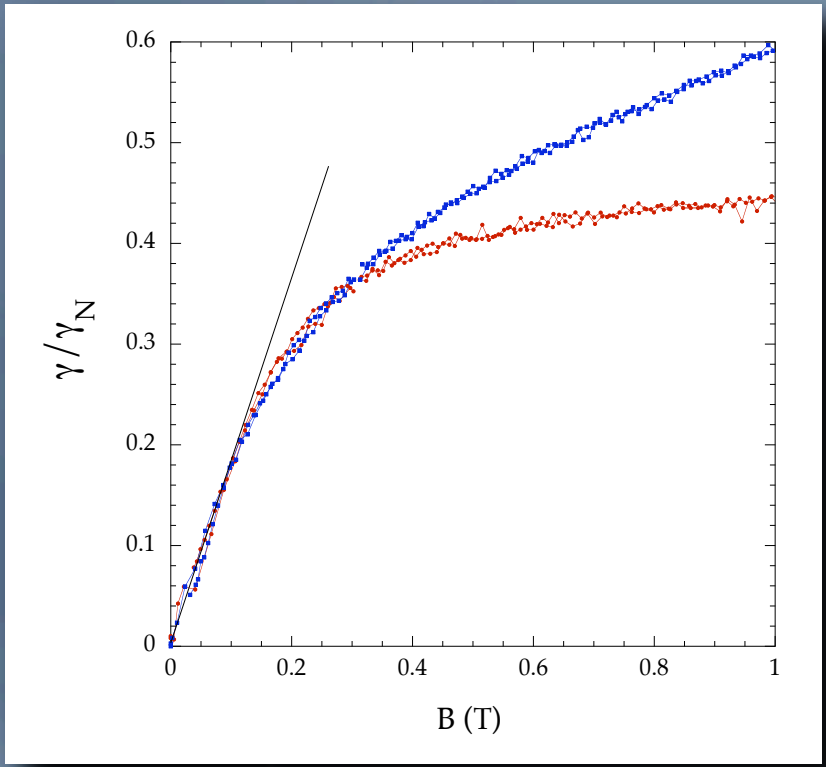


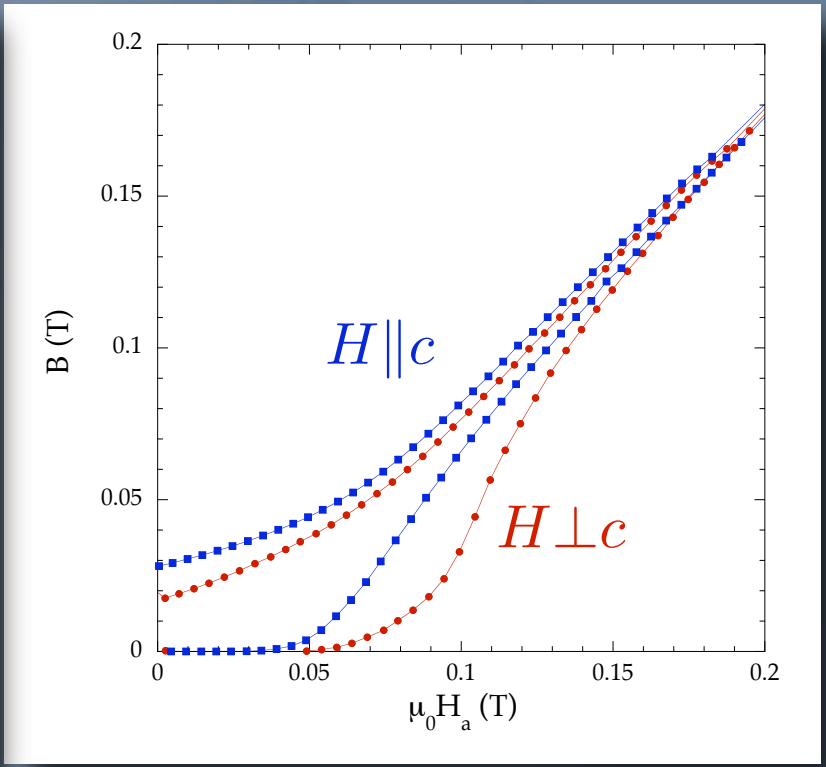
Hall probe magnetometry



$$B^{(av)} = \frac{\sum B_n}{n}$$

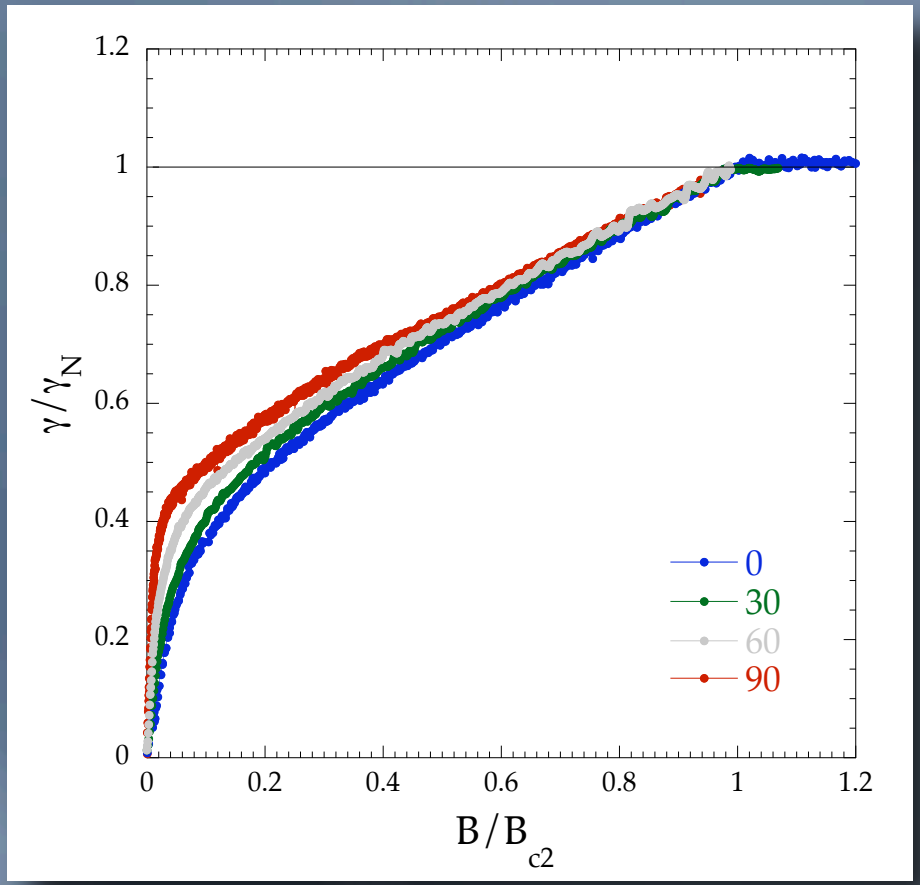
Dome shape B-profils :
influence of geometrical barriers





γ linear only for B < 800G

isotropic up to ~ 0.3T



high field

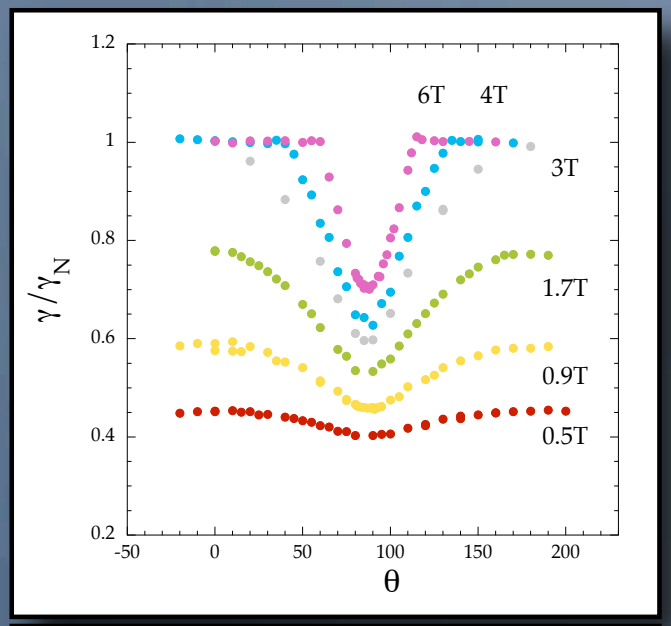
$$\gamma = f(\frac{B}{B_{c2}})$$

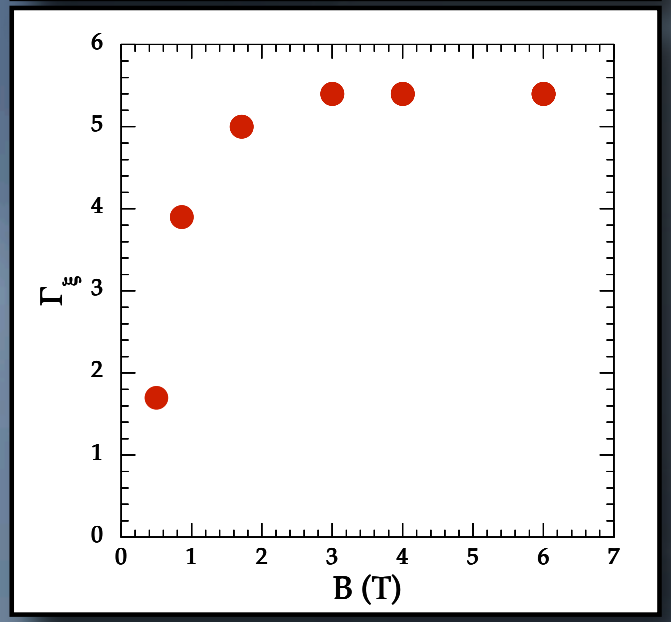
$$B_{c2}(\theta) = \frac{B_{c2}^{ab}}{\sqrt{sin^2\theta + \Gamma_\xi^2 cos^2\theta}}$$

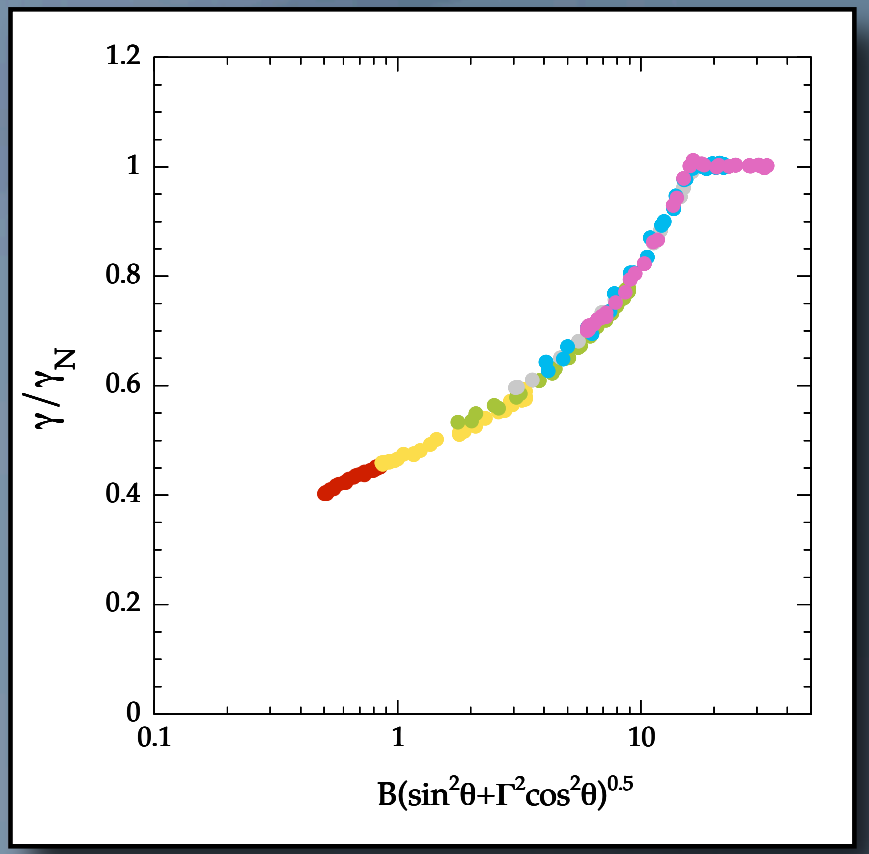
$$\Gamma \sim 5.4$$

but at low field γ is isotropic ($\Gamma \sim 1$).....

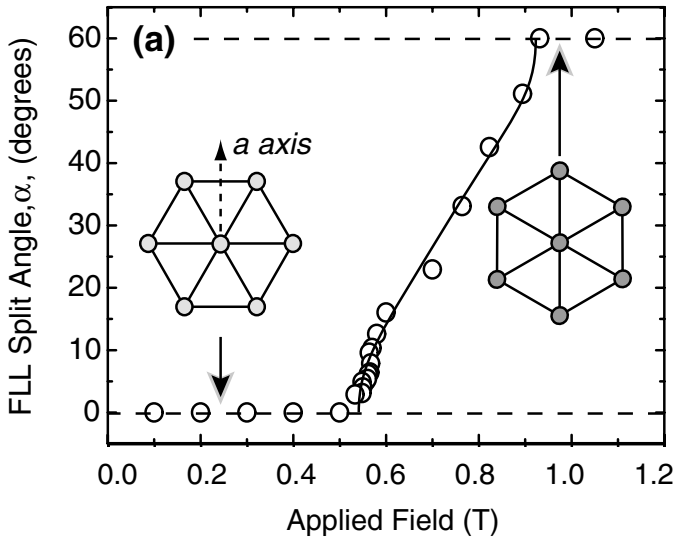
$$B_{c2}(\theta) = \frac{B_{c2}^{ab}}{\sqrt{sin^2\theta + \Gamma_\xi^2(B)cos^2\theta}}$$



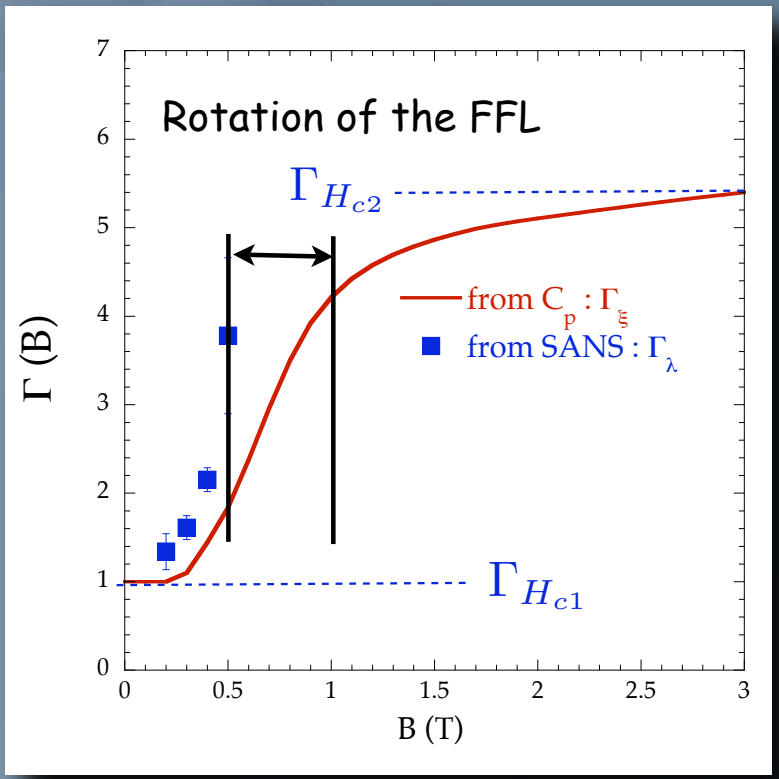




$$\gamma_{H\|c}(\Gamma_\xi(B)B) = \gamma_{H\perp c}(B) = \gamma_\theta(B\sqrt{sin^2\theta + \Gamma_\xi^2(B)cos^2\theta})$$



Cubitt et al. PRL 03

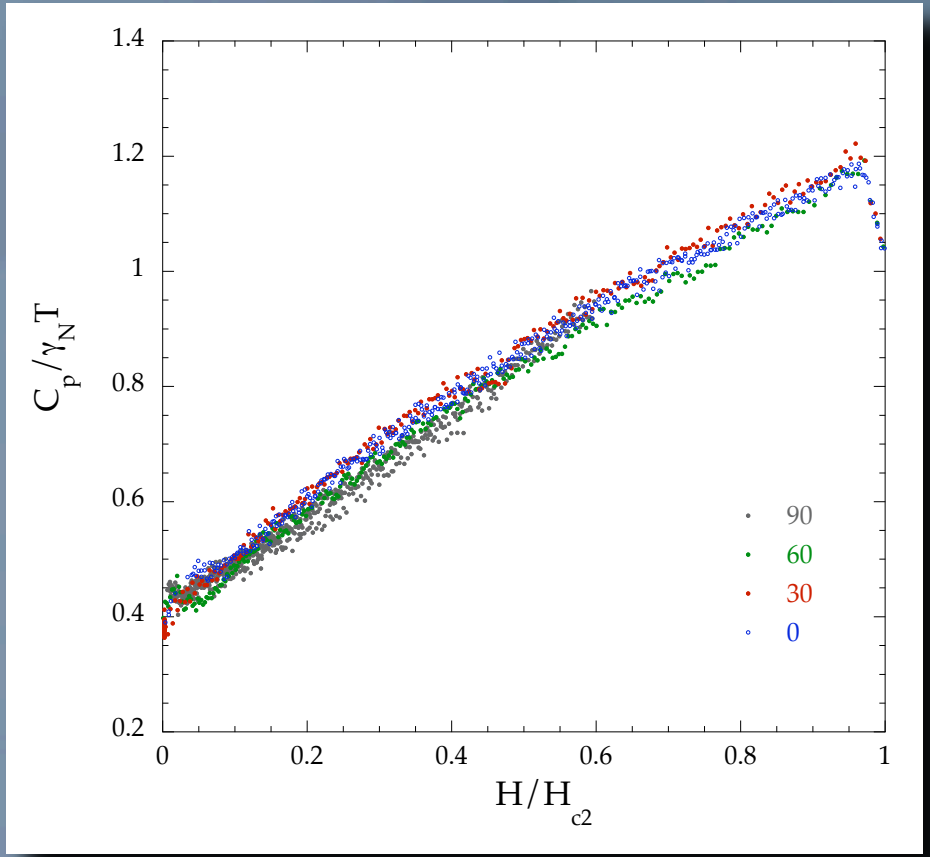


$$\Gamma_{H_{c1}} \leq \Gamma_\lambda(B) = \Gamma(B) = \Gamma_\xi(B) \leq \Gamma_{H_{c2}}$$

$T=9K > \Delta_\pi$

the low field
isotropic behaviour
is not present anymore

$C_p = f(H/H_{c2})$

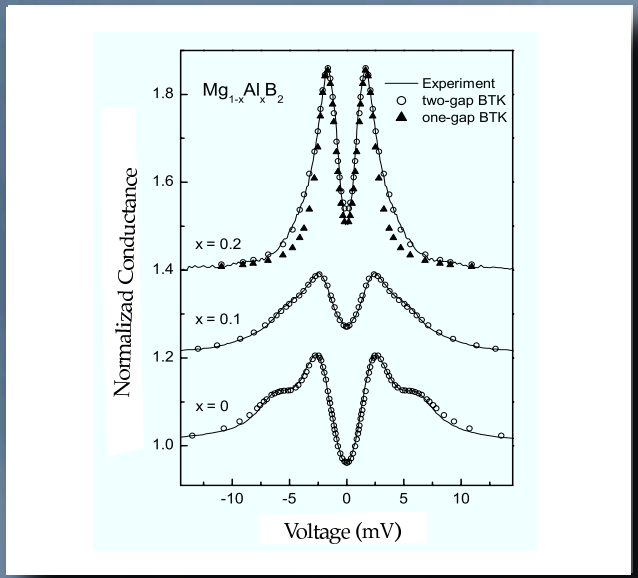


Aluminum doping.....

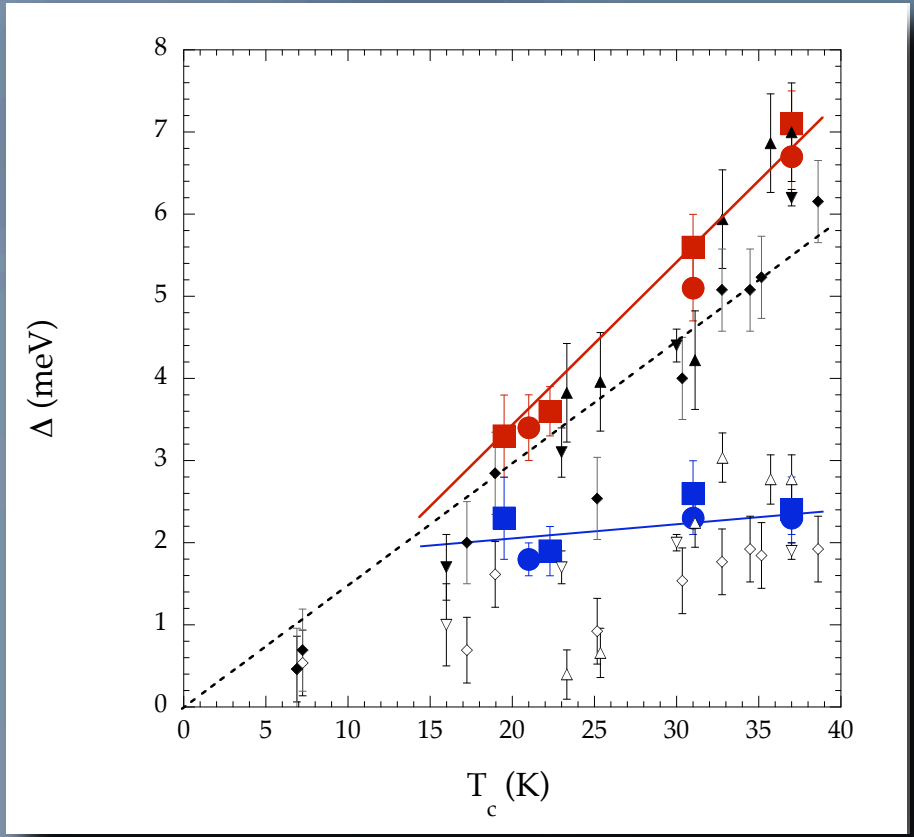
$Mg_{1-x}Al_xB_2$

Electronic doping

$$C_p = \omega_\sigma C_p^\sigma(T, \Delta_\sigma/T_c) + (1-\omega_\sigma) C_p^\pi(T, \Delta_\pi/T_c)$$



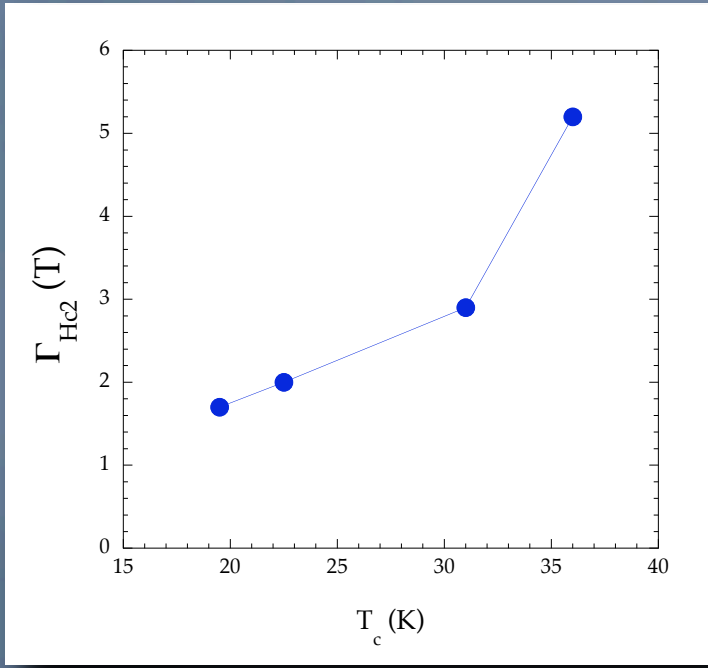
coll. P.Samuely et al. SAS, Kosice

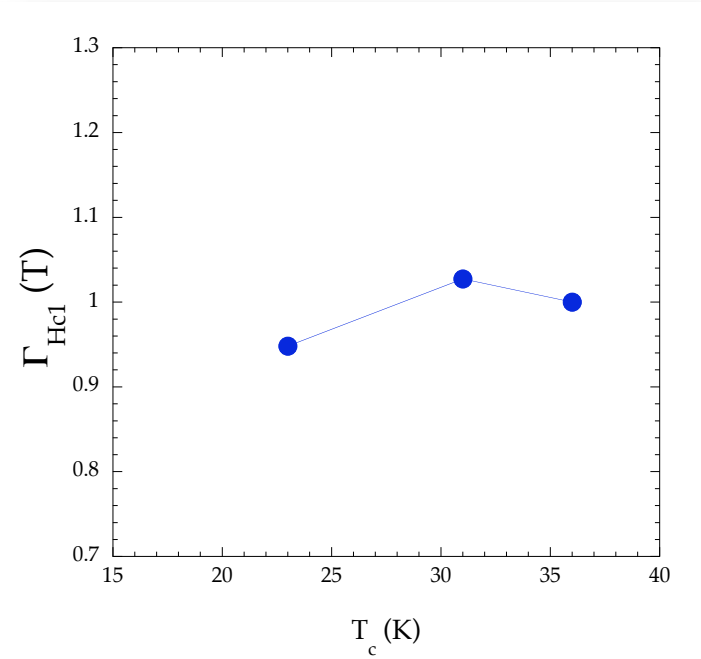


small gap ~ constant

increase of the intraband scattering

possible merging of he gaps for T_c ~ 10K





$$H_{c2}^{c} \propto \frac{\Delta_\sigma^2}{v_{F,ab}^2}$$

$\Delta_\sigma \downarrow$, $v_{F,ab} \downarrow$, $H^c_{c2} \sim$ cte

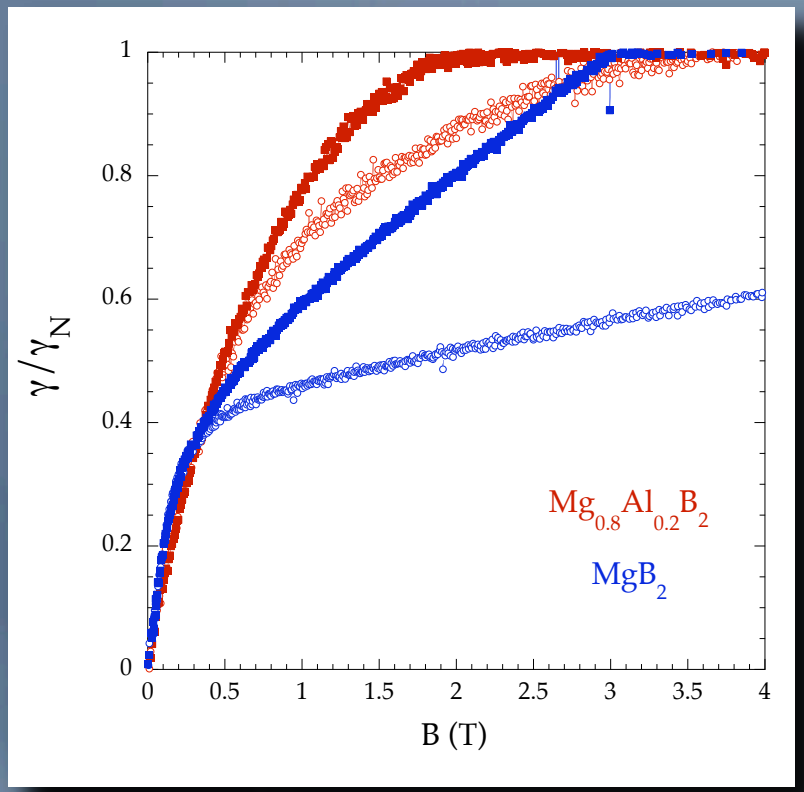
$$H_{c2}^{ab} \propto \frac{\Delta_\sigma^2}{v_{F,ab} v_{F,c}}$$

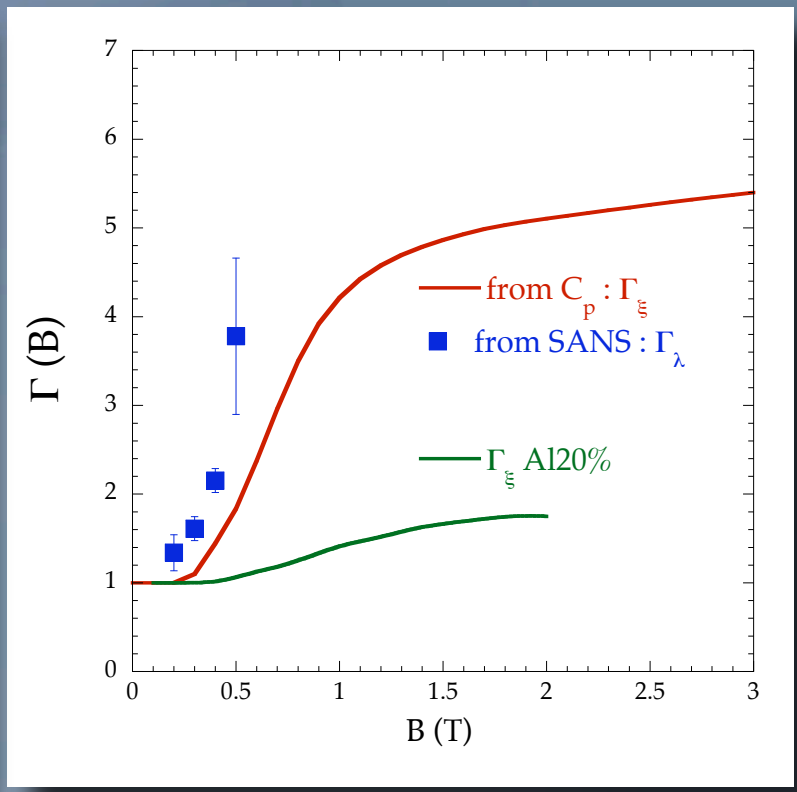
$v_{F,c} \sim$ cte , $H^{ab}_{c2} \downarrow$

superconducting density $\downarrow$
$H_{c1} \downarrow$

$$\Gamma_{H_{c2}} = \frac{v_{F,ab}}{v_{F,c}} \downarrow$$

$$\Gamma_{H_{c1}} \approx 1$$





towards an isotropic one gap superconductor

Conclusions

Linear B dependence
for B < 800G
getting strongly sublinear
for higher fields

Field dependent
anisotropy

$C_p=f(H/H_{c2})$ for $T > \Delta_\pi$

Al doping :
towards an isotropic
one gap superconducor