Critical fields in Nd(O,F)FeAs [and (K,Ba)Fe_2As_2] single crystals a Hall probe magnetization and specific heat study

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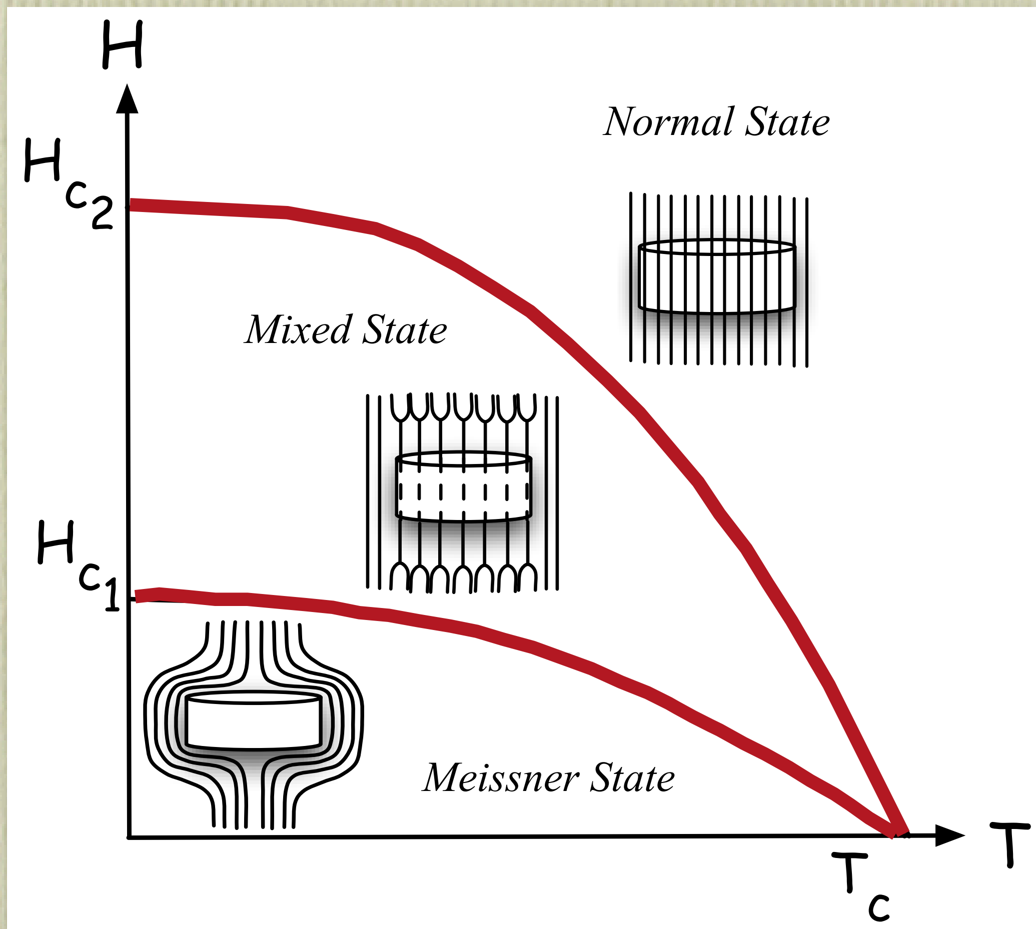
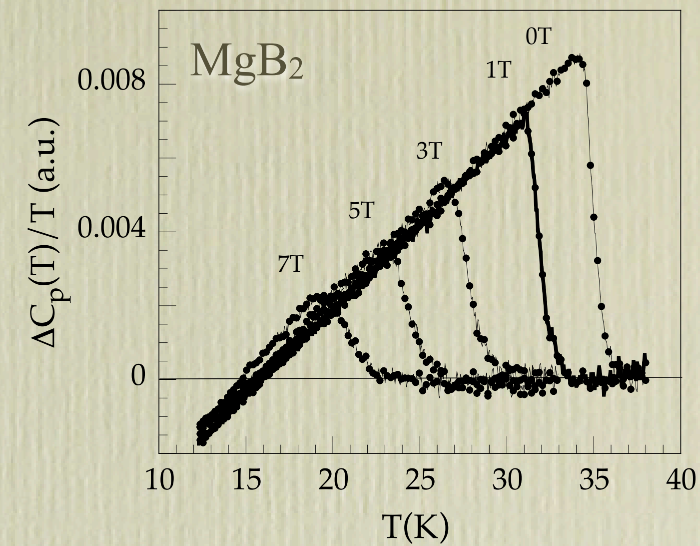
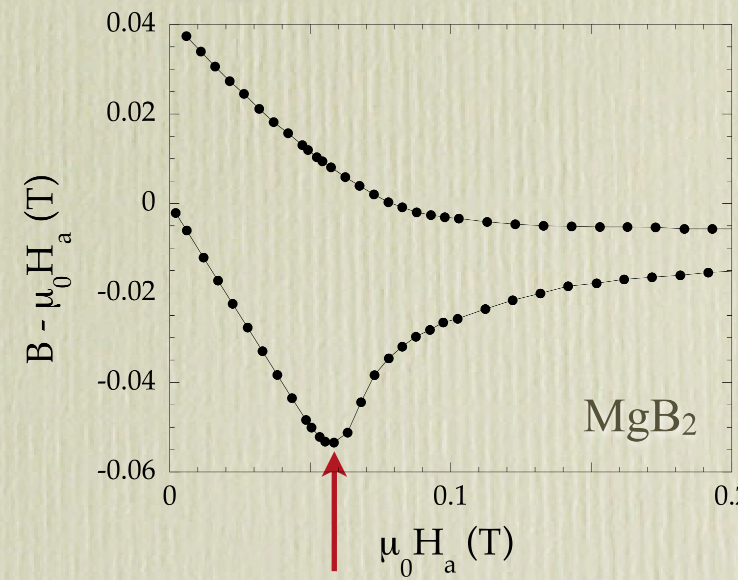


Upper critical field



Lower critical field

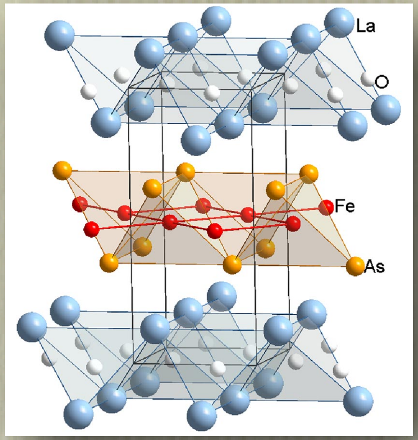


Why should we bother about iron oxypnictides ?

High T_c values

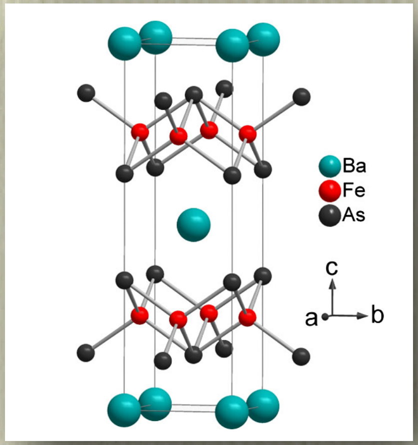
from ~ 26K in La(O,F)FeAs
to ~ 54K in Gd(O,F)FeAs
so called 1111 phase

Kamihara et al., Takahashi et al.



and 36K in $(Ba,K)Fe_2As_2$
so called 122 phase

Rotter et al.



or $Li_{1-y}FeAs$ [111 phase] : T_c ~ 18K

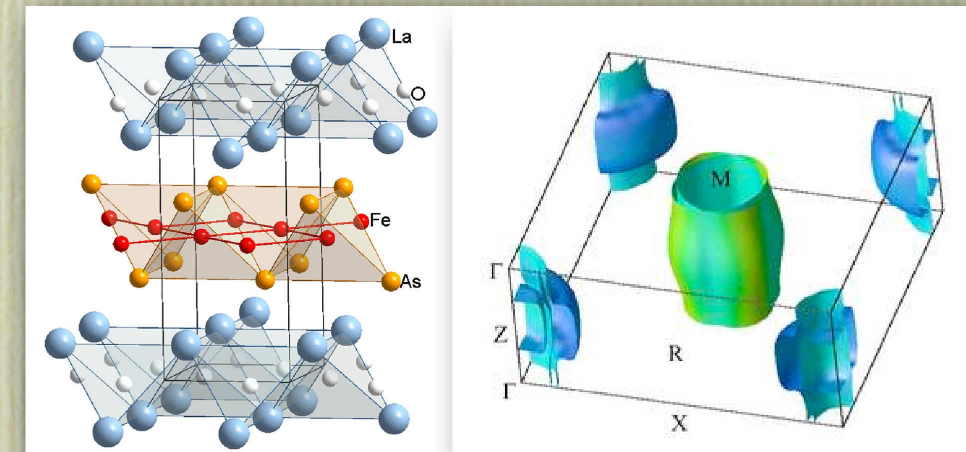
Tapp et al.

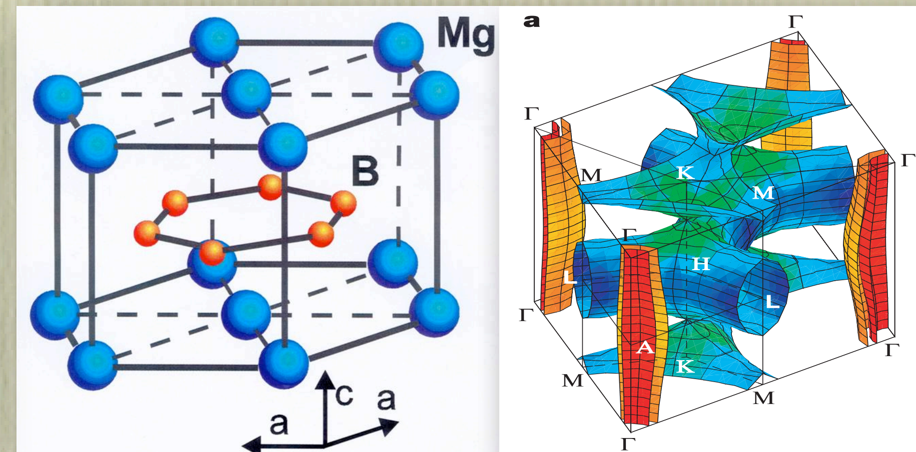
or $Fe_{1+\varepsilon}(Se_xTe_{1-x})$ [11 phase] : T_c up to 15K
at ambient pressure (and even 27K at 1.5GPa)

Hsu et al.

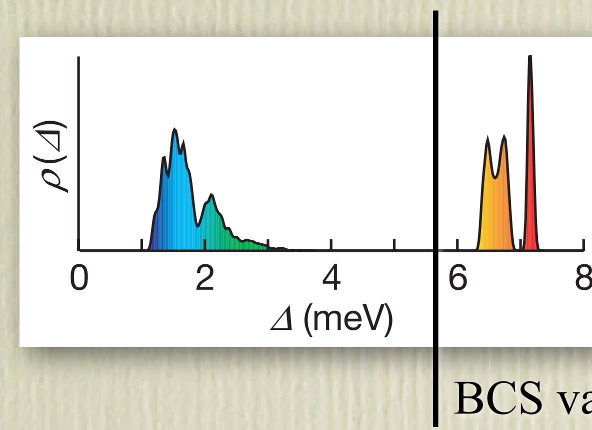
electron and Hole pockets

as recently observed in MgB_2





Multigap superconductivity



BCS value

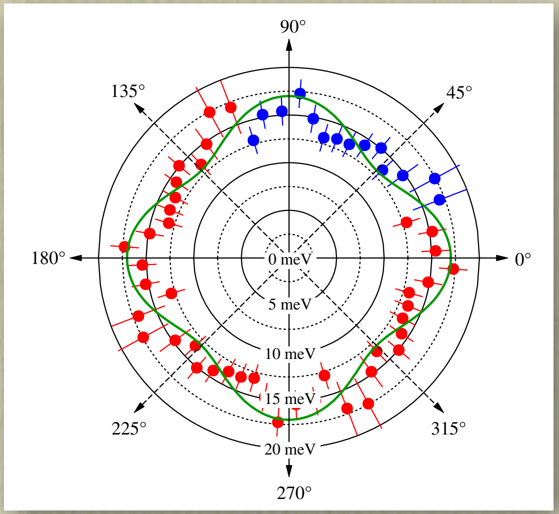
ARPES (Ding et al.) measurements on $(K,Ba)Fe_2As_2$

$\Delta \sim 6$ meV ($2\Delta = 3.7kT_c \sim$ BCS) : large hole pocket

to 12 meV ($2\Delta=7.5kT_c \sim$ Cuprates) : small hole and electron pockets

in agreement with point contact (Szabo et al.)

Δ_L : 9-11 meV - Δ_S : 2-5 meV



Kondo et al.

NdOFeAs

$\Delta_L \sim 15$ meV

but calculations (Boeri et al.) led to a

small electron-phonon coupling constant $\lambda \sim 0.2$

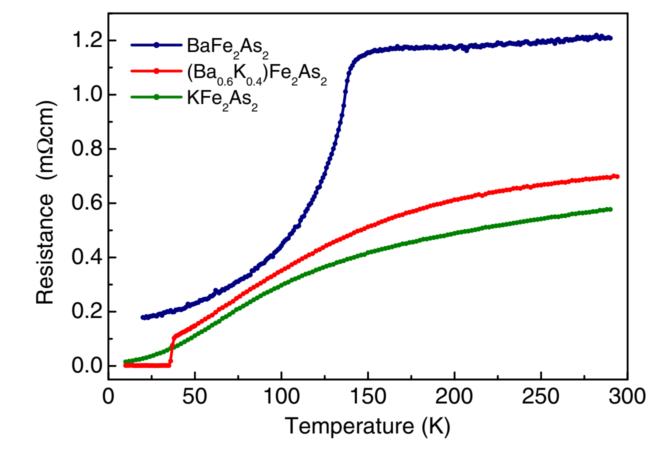
(as compared to ~ 1 in MgB_2)

Undoped sample :

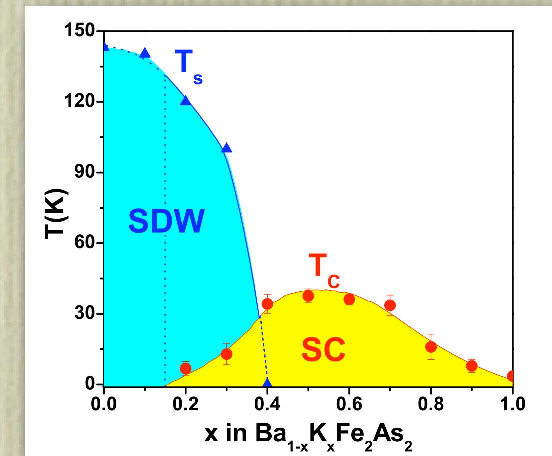
magnetic instability (SDW/AFM)

associated with

orthorhombic-tetragonal transition



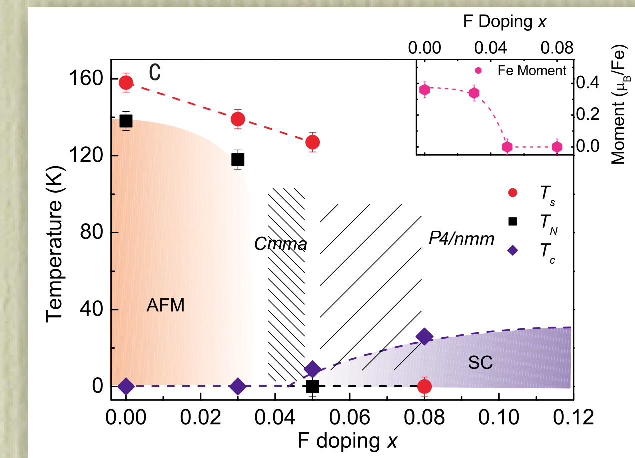
$(K,Ba)Fe_2As_2$



Rotter et al.

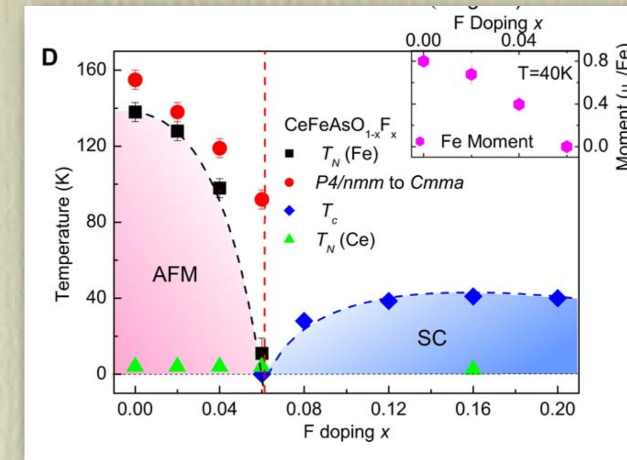
or

La(F,O)FeAs



Huang et al.

Ce(F,O)FeAs



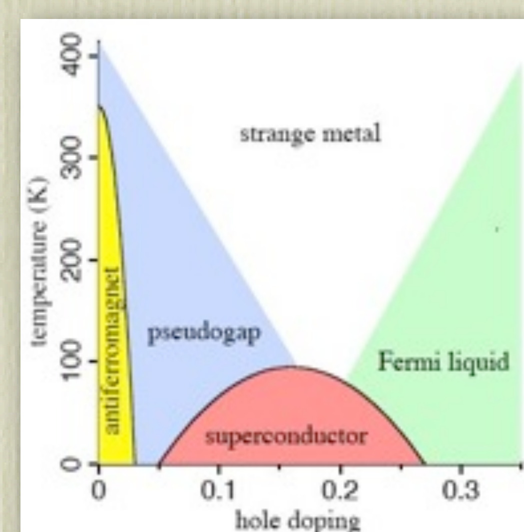
Zhao et al.

coexisting...

... or not with the superconducting state

strong spin fluctuations

unconventional pairing mechanism ?
as in cuprates ?



possible but...

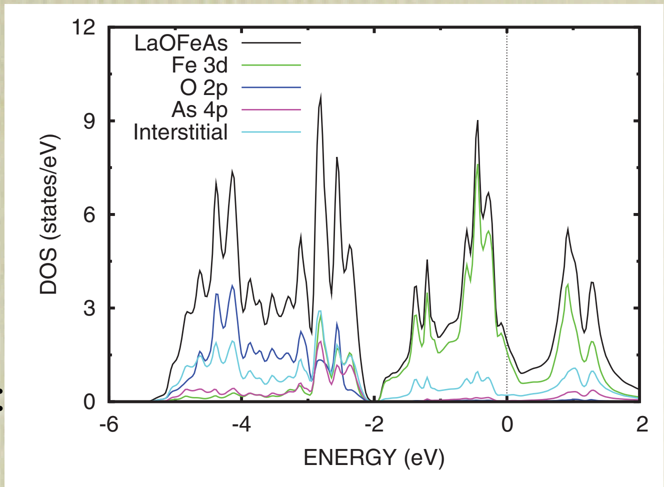
Cuprates :

Mott insulator (large Coulomb repulsion, *U*)

AF : lowering of the spin energy

Cu : at sites with strong planar coordination

LaOFeAs :



Semi-metal

but E_F close to strong Van-Hove Singularity in d states i.e. close to Stoner Ferromagnetic instability (as predicted for LaOCoAs)

AF "instability" of the Fermi surface

(Q=(π/a,π/a,0) nesting) [or exchange (via As ions)]

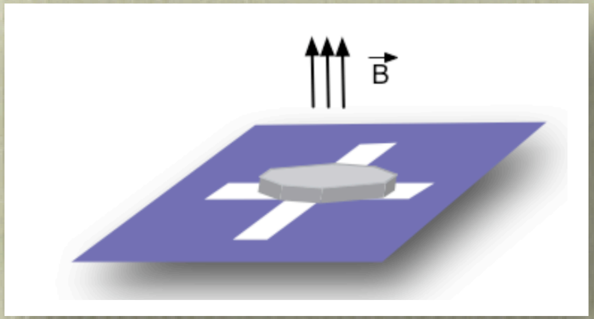
-> Spin Density Wave

Tetrahedral coordination of Fe atoms

Mazin et al. : unconventional mechanism
mediated by spin fluctuations,
s-wave with sign reversal between different sheets of the FS

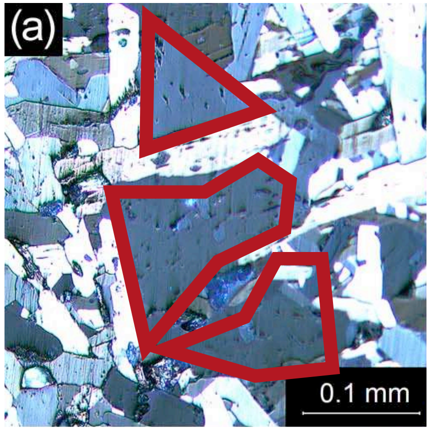
Hall probe magnetization :

first penetration field → H_{c1}



- Local probe (~4 to 40μm)
- Field profil (arrays) : B(x)
- High sensitivity ~10^{-5} at 1T but M+H
- High resolution AsGa 2DEG : 700Ω/T single vortex detection

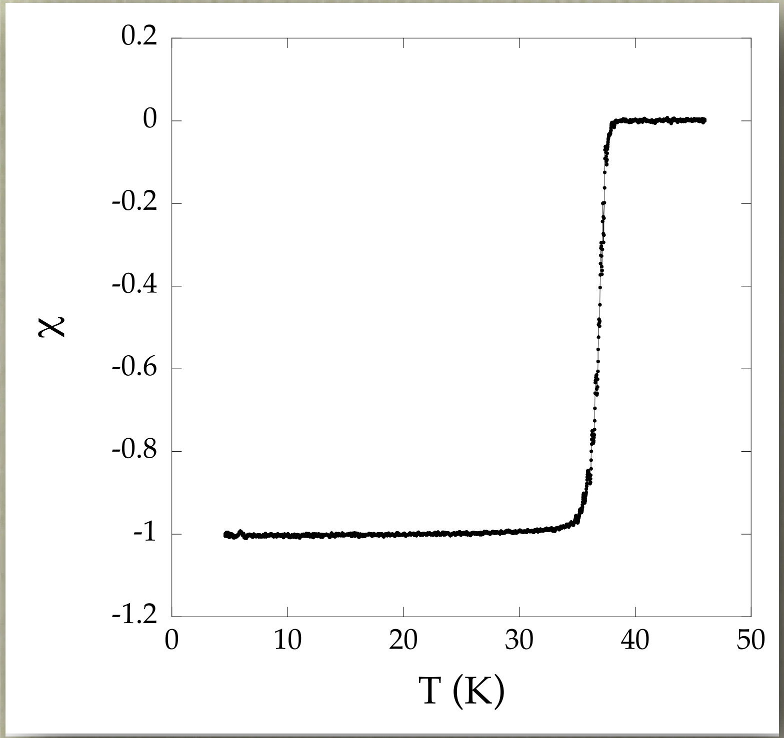
Nd(O,F)FeAs single crystals, Canfield et al.



Small platelets (a few 100 μm)

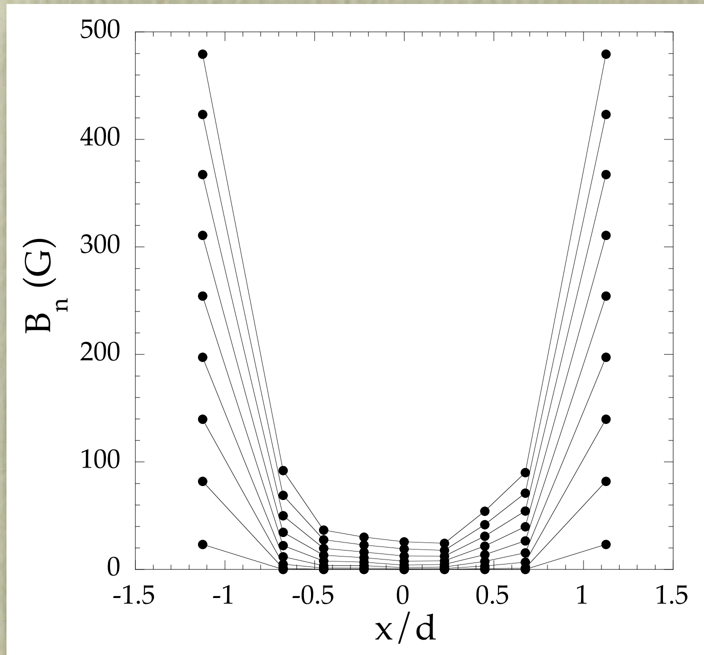
T_c ~ up to 51K (Global measurements)

Prozorov et al.

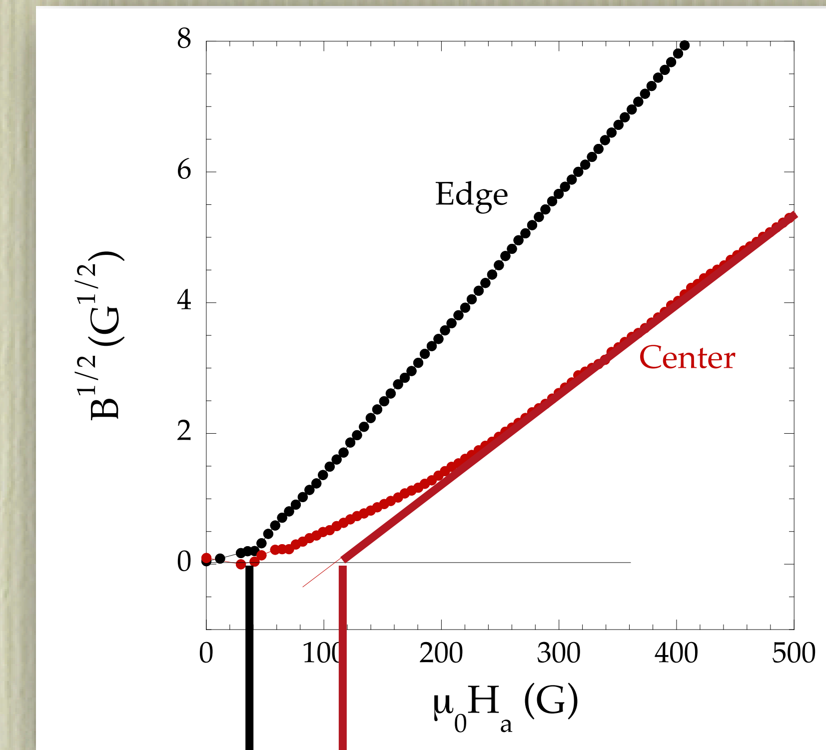


Sharp local transition but with T_c from 38 to 33K

warning : (small) inhomogeneties still present in the platelets : poster K.van der Beek



Remanent field (after sweeping H_a back to zero)



Strong pinning : How to define H_p

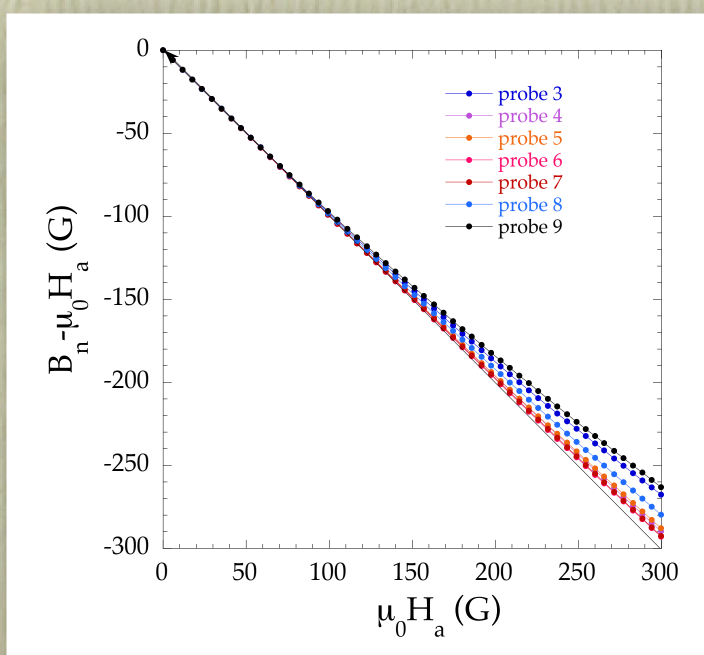
B proportional to $(H-H_p)^2$

non thermodynamic value

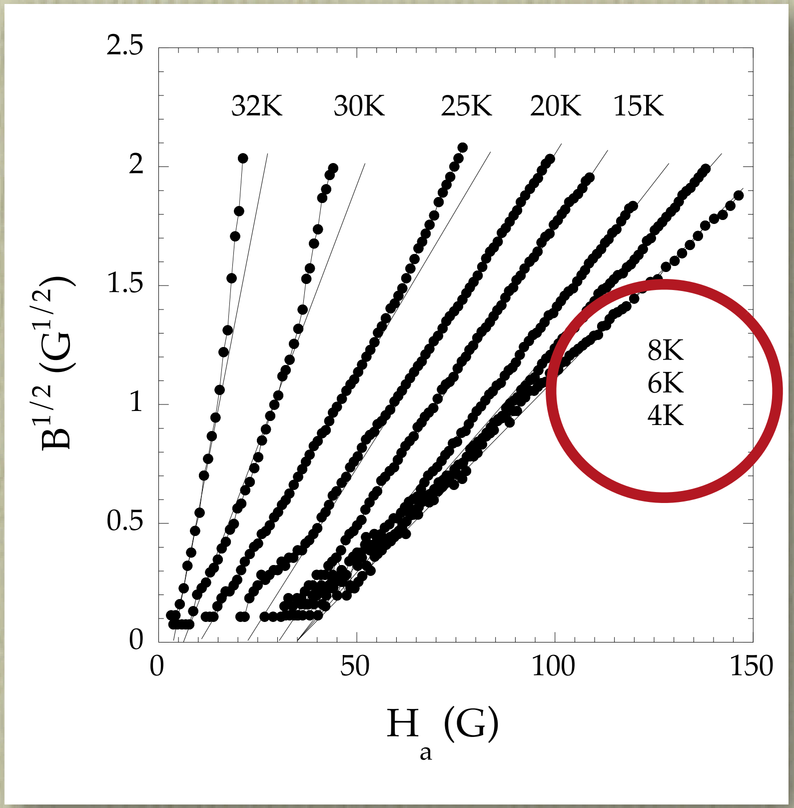
(pinning)

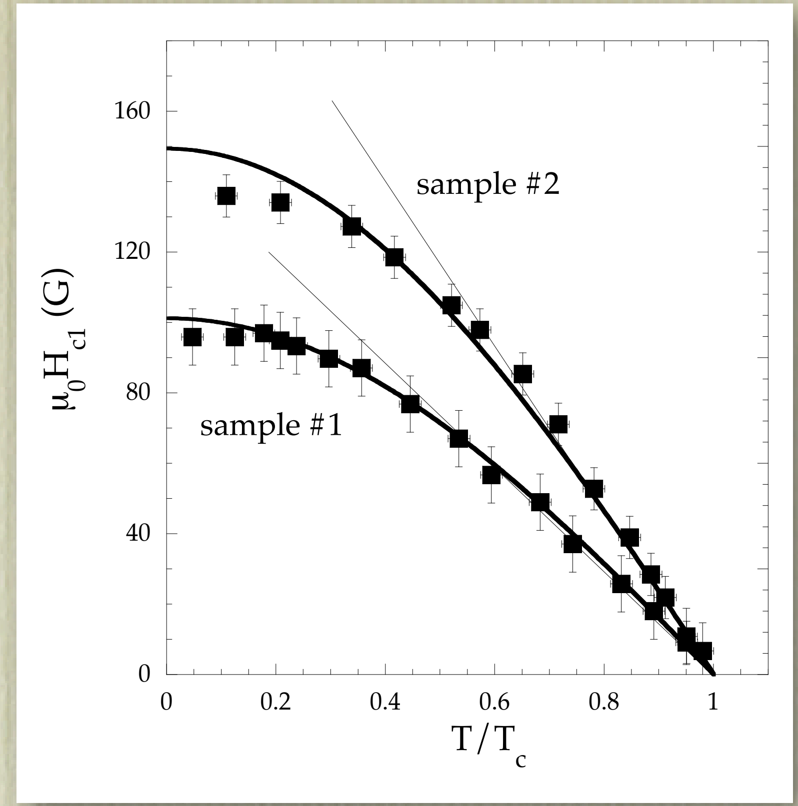
(see also Okazaki et al.)

H_p



deviation from linearity of M(H) ?





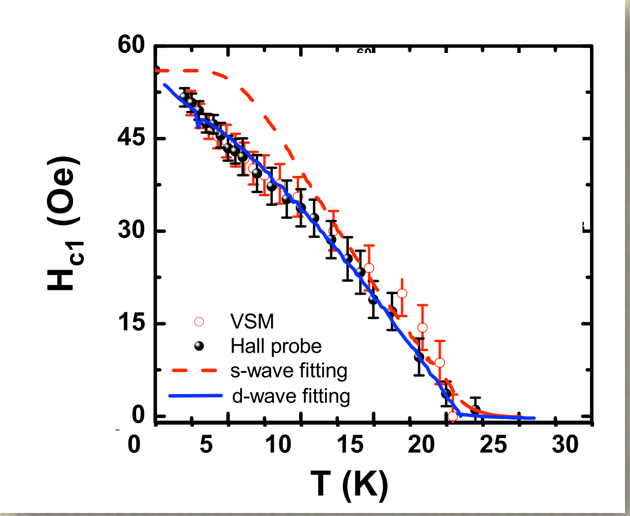
$$H_{c1} = \beta\, H_p$$

$\beta \sim 2$ - 3 depending on thickness/width ratio

saturation at low T

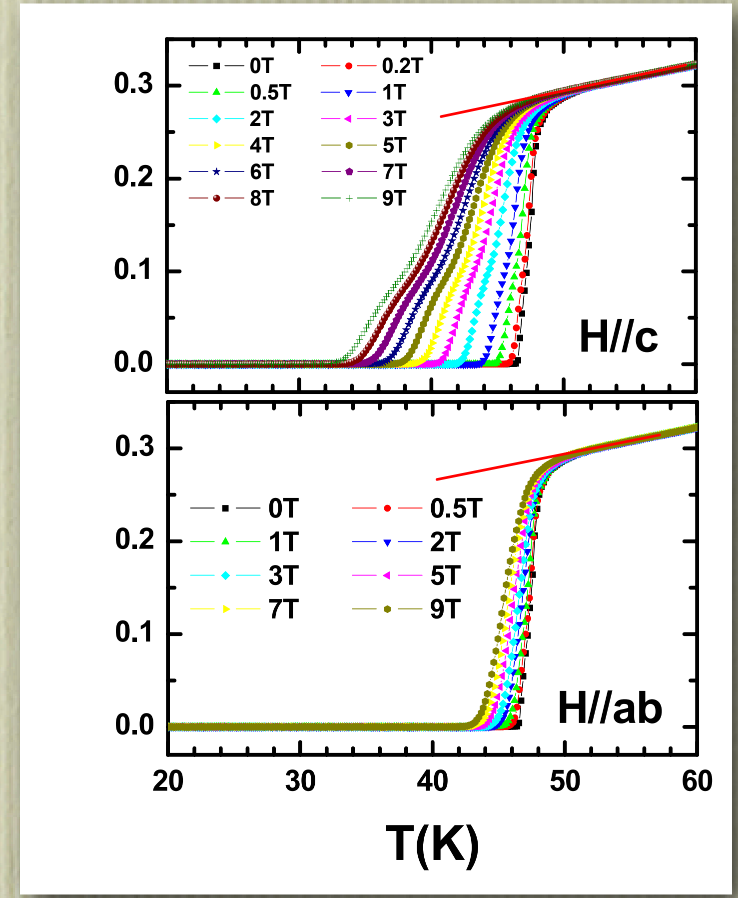
fully open gap

linear temperature dependence at low T ?

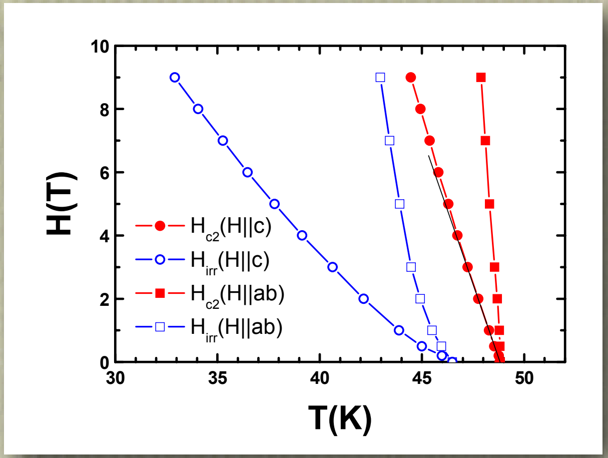


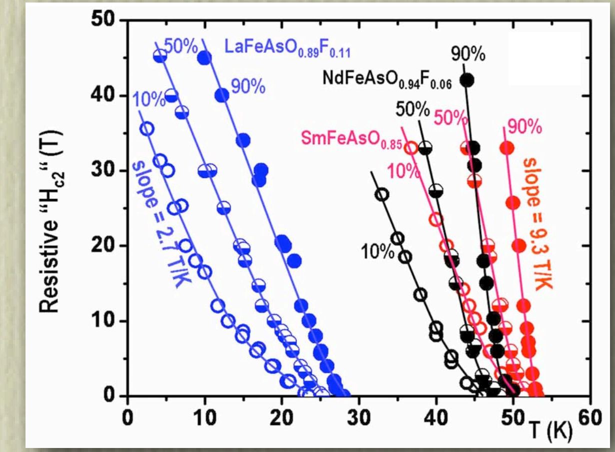
Ren et al. - LaOFeAs

Very high value of the upper critical fields



Nd(O,F)FeAs-Jia et al.





Jaroszynski et al.

dH_{c2}/dT :
~ 1T/K to ~ 10 T/K

MgB_2 : ~ 0.2 T/K

Best criterion ?

Possible existence of a reversible phase ?

General to all X(O,F)FeAs samples
(even ~ 20T/K in 122*)

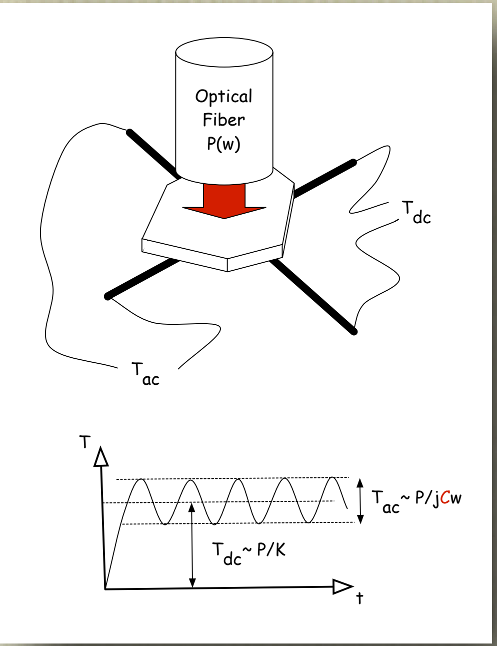
$H_{c2}(0)$: 25 to 400T* (!) : larger than the Pauli limit
~1.85T_c (BCS weak coupling)

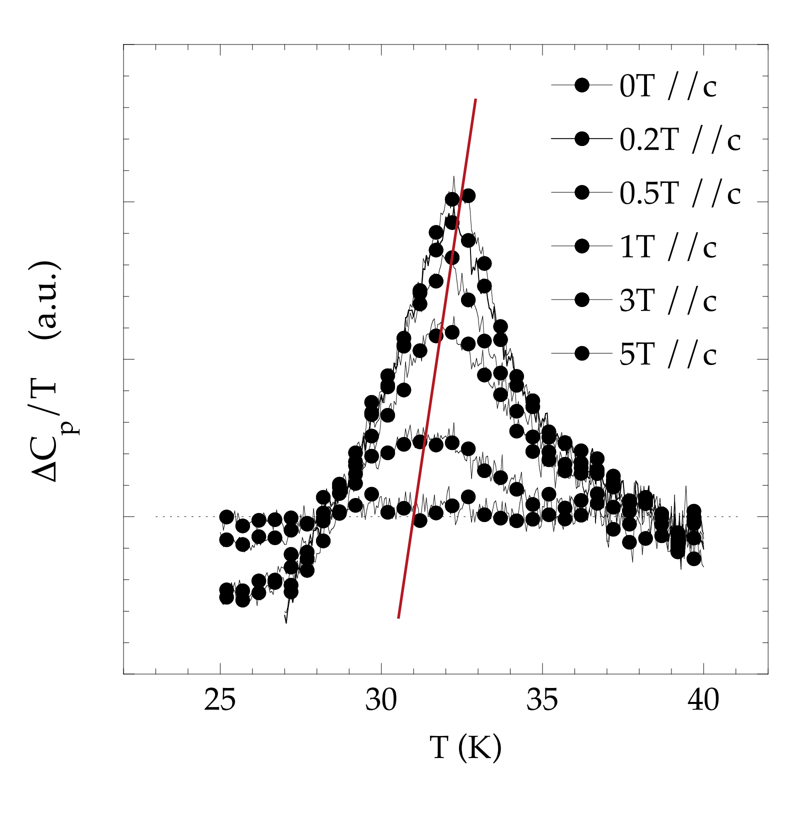
* Welp et al., $(K,Ba)Fe_2As_2$

AC specific heat measurements :

thermodynamic determination of H_{c2}

- High sensitivity 1/1000but relative variations only (unknown P)
- Well adapted to small samples : 500ng to 500µg
- Continuous T (or H) sweeps
- No arbitrary background (phonon) substraction





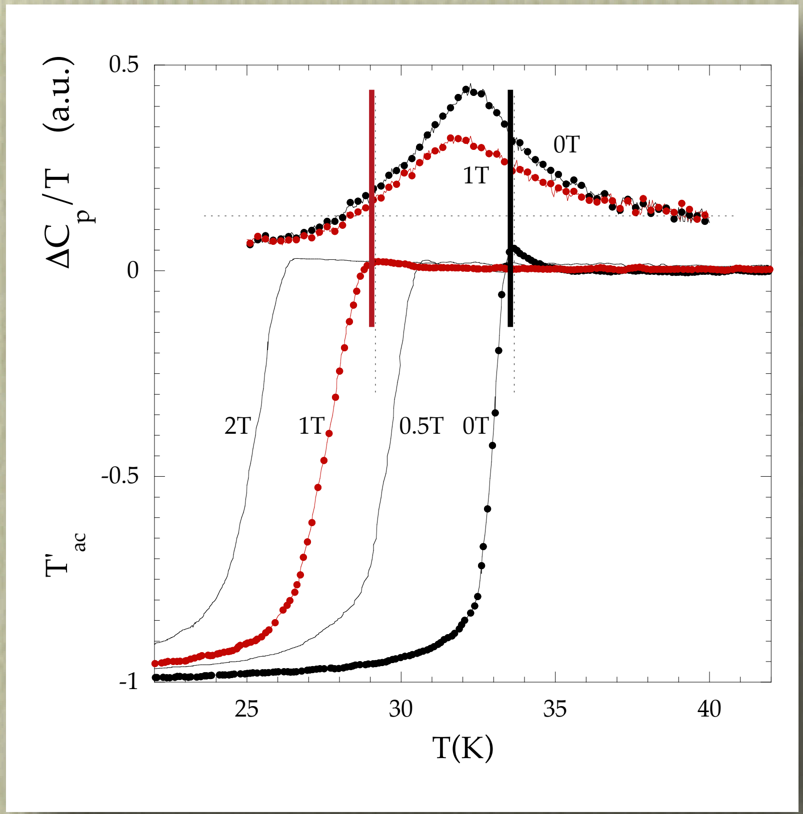
Very small shift i.e. very high H_{c2} value

Rapid collapse for $H << H_{c2}(0)$

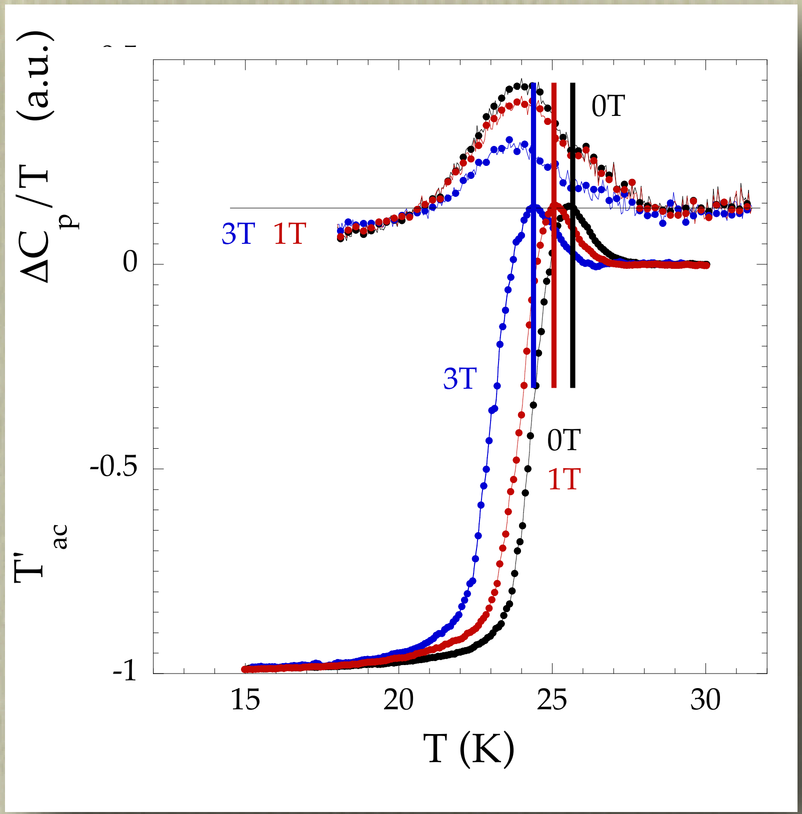
similar to what observed in cuprates

Strong fluctuation effects ?

Nd(F,0)FeAs



(K,Ba)Fe2As2

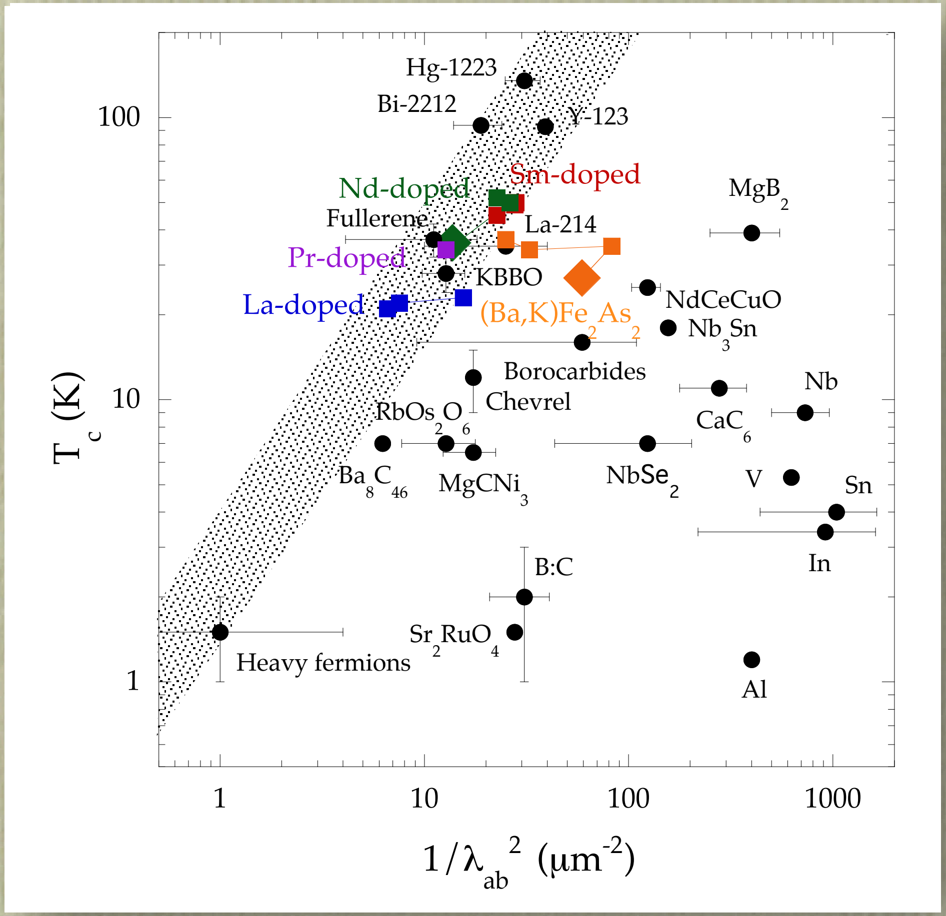


irreversibility line << H_{c2} line

Very small shift of both $T_{irr}(H)$ and $T_{c2}(H)$

	λ_{ab} (nm)	ξ_{ab} (nm)	Γ	T_c (K)	$\varepsilon_0\xi_c$ (K)	G_i
YBaCuO	160	1.5	6	92	200	$3\ 10^{-2}$
Nd(O,F)FeAs	270 (± 40)	3 (± 0.5)	~ 4-6	35	200 (± 100)	4 (± 4) 10^{-3}
$(K,Ba)BiO_3$	280	3	1	32	800	$2\ 10^{-4}$
MgB_2	50	10	5	39	16000	10^{-6}
$(K,Ba)Fe_2As_2$	130 (± 20)	2 (± 0.5)	~ 2.5	28	600 (± 300)	3 (± 3) 10^{-4}

small superfluid density (~$1/\lambda^2$) :
about 100x smaller than in MgB_2



cuprates : $T_c \propto 1/\lambda^2$
unconventional coupling

possible "breaking of the Uemura plot" ? (Ren et al.)

as many other systems do....

Small superfluid density
unconventional coupling ?
$(K,Ba)Fe_2As_2 \neq Nd(F,O)FeAs$?

Saturation of H_{c1} at low T in
(Nd(F,O)FeAs) : fully open gap

Very high H_{c2} values
$(K,Ba)Fe_2As_2 > Nd(Fe,O)FeAs$
Pauli, orbital ?

Possible existence of a vortex liquid
phase in Nd(F,O)FeAs
(but probably not in $(K,Ba)Fe_2As_2$)

Small anisotropy
Temperature independent Γ_λ value
~ 4 in Nd(F,O)FeAs
is $\Gamma_{Hc1}(T) = \Gamma_{Hc2}(T)$?