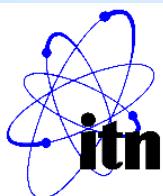


Recent results from electron emission channeling on-line experiments

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- 4) Instituut voor Kern- en Stralingsphysica, Katholieke Universiteit Leuven, Belgium
- 5) Departamento Física, Universidade do Porto, Porto, Portugal

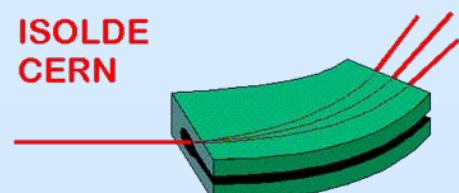
IS453 EC-SLI experiment Emission Channeling with Short-Lived Isotopes



UL UNIVERSIDADE DE LISBOA
CENTRO DE FÍSICA NUCLEAR



ISOLDE
CERN



One of the physics cases of EC-SLI proposal: Lattice location of transition metals in semiconductors

Main motivation to study transition metals (TMs):

- TM-doped ZnO, GaN and GaAs are dilute magnetic semiconductors showing ferromagnetism
(→ spintronics)

⇒ Knowledge on the lattice location of TMs is crucial for understanding the magnetism in these materials

We have previously obtained results (IS368) on the β^- emitters

- ^{59}Fe (45 d), ^{67}Cu (2.6 d), ^{111}Ag (7.5 d), ^{121}Sn (27 h)
in Si, Ge, diamond, GaN, ZnO, SrTiO_3

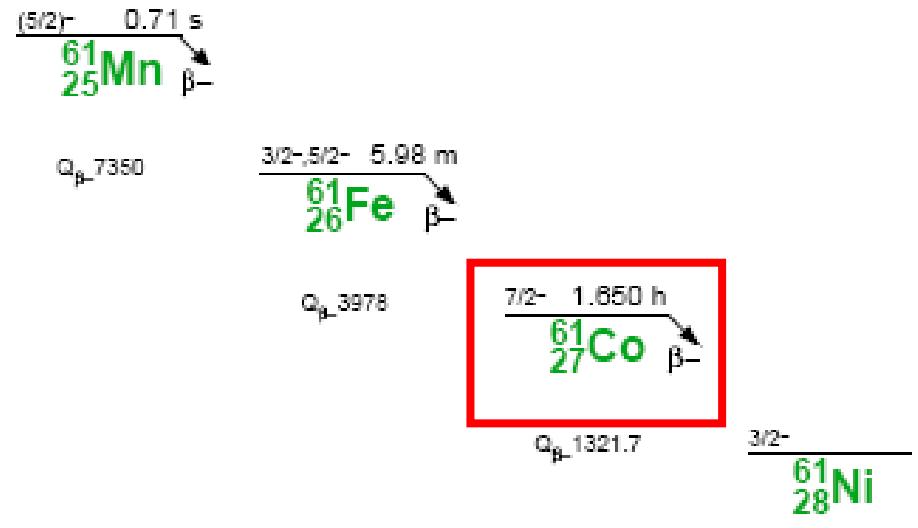
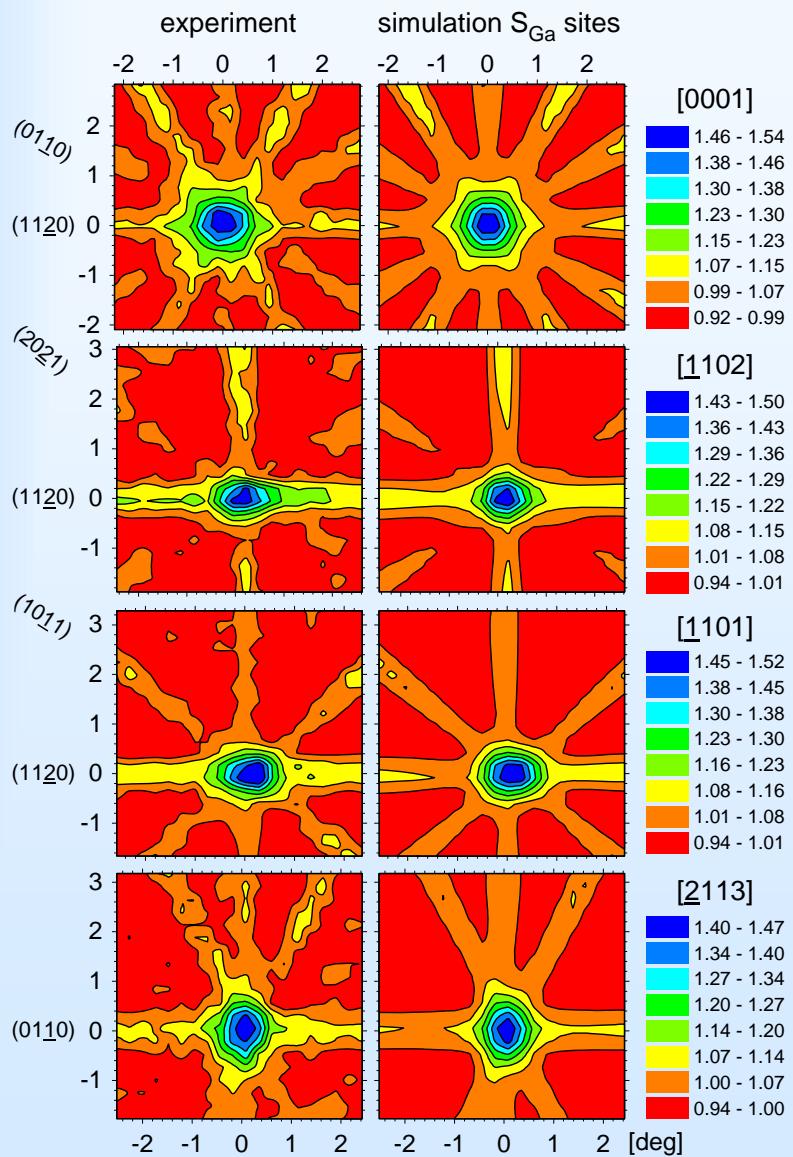
Starting in 2007, EC-SLI on-line experiments have made additional probe atoms accessible:

- ^{65}Ni (2.5 h) β^-
- ^{56}Mn (2.6 h) β^-
- ^{61}Mn (4.6 s) \rightarrow ^{61}Fe (6 min) \rightarrow ^{61}Co (1.6 h) β^-



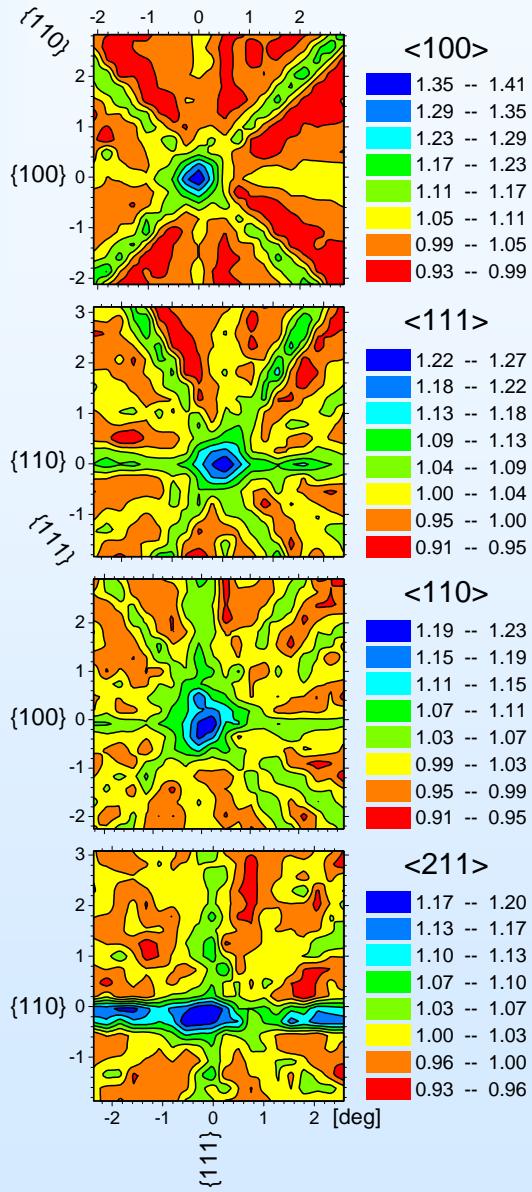
β^- emission channeling patterns from ^{61}Co in GaN

$T_A = 800^\circ\text{C}$

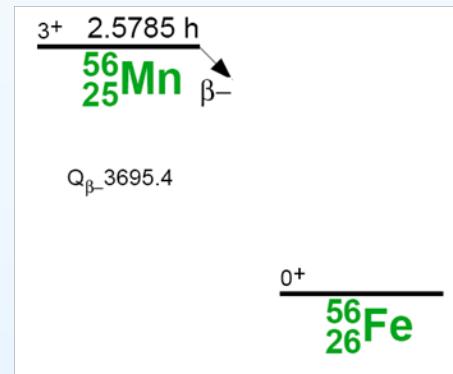


- **^{61}Mn implanted ($\sim 10^{13} \text{ cm}^{-2}$)**
 - **wait 25 min + anneal**
 - **emission channeling patterns measured from ^{61}Co β^- particles**
 - **Fit results**
- ^{61}Co on substitutional Ga sites**

β^- emission channeling patterns from ^{56}Mn in GaAs

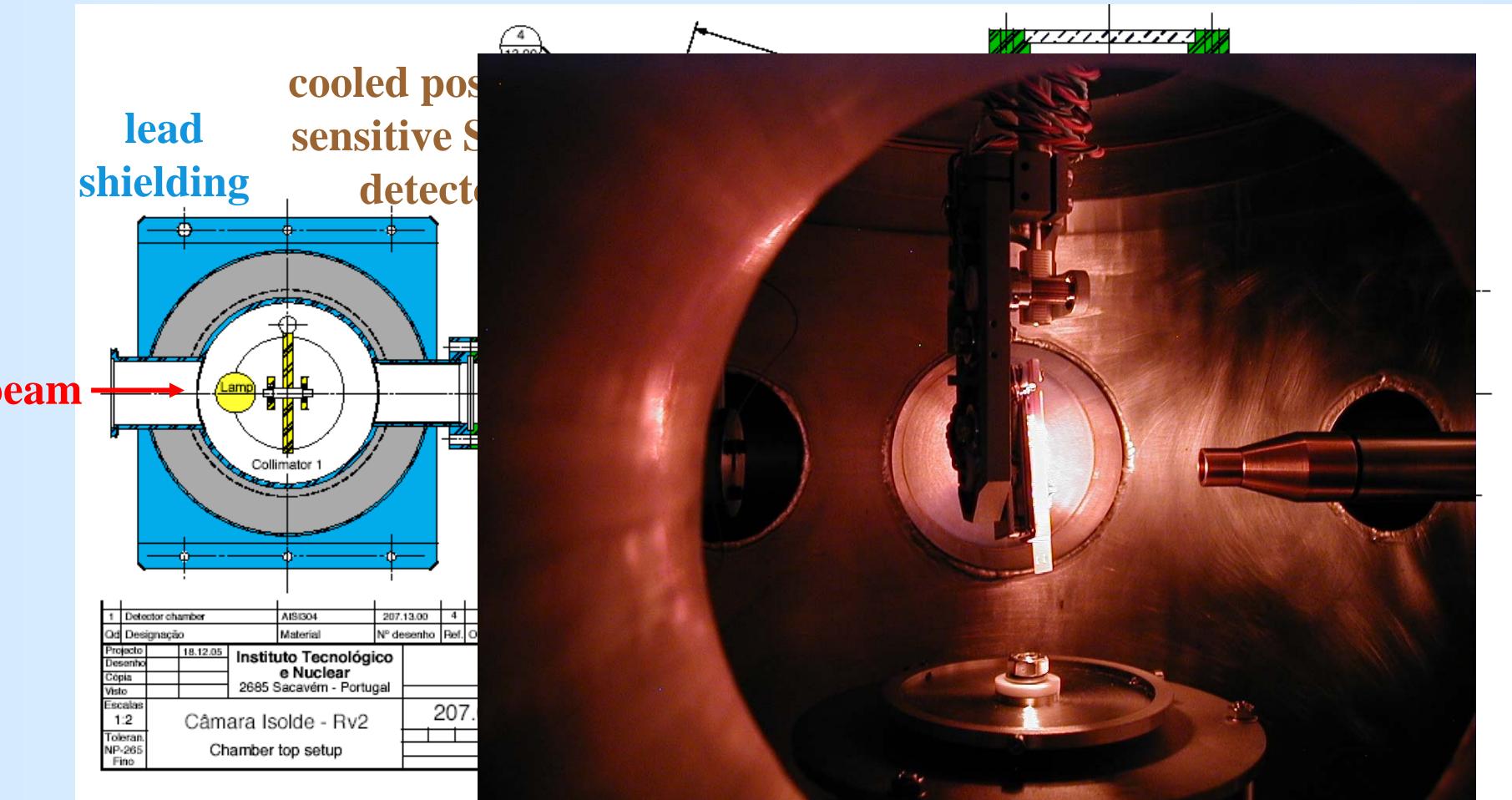


$T_A = RT$
as implanted



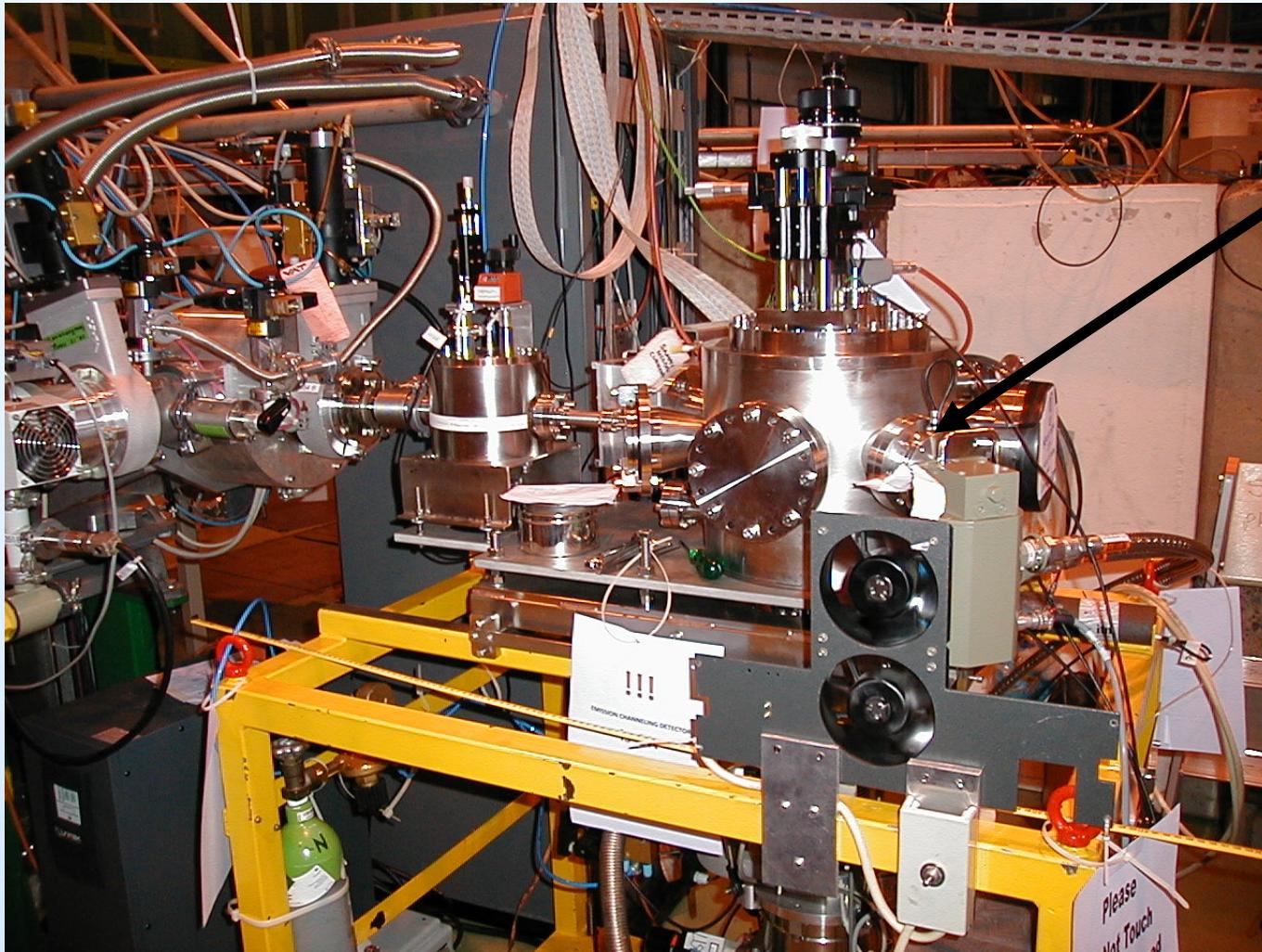
- ^{56}Mn implanted directly ($\sim 2 \times 10^{13} \text{ cm}^{-2}$)
- emission channeling patterns measured from ^{56}Mn β^- particles
- qualitative result:
 ^{56}Mn on substitutional sites
- distinguishing between S_{Ga} and S_{As} sites will require comparison to simulations (not yet available)

New ITN on-line emission channeling setup: top view



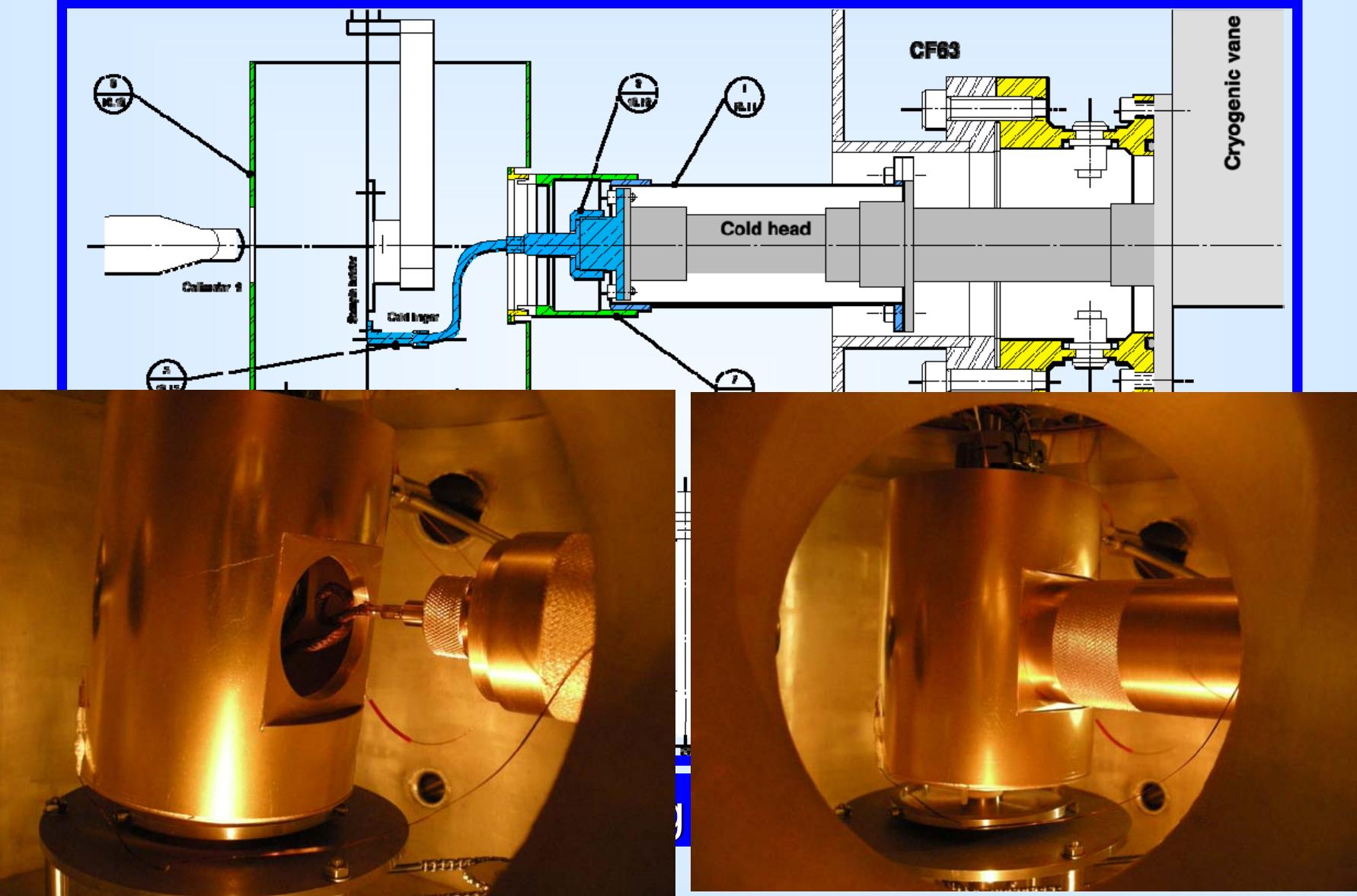
- detector at 17° backward geometry for simultaneous implantation and measurement
- valve in front of detector allows to maintain detector vacuum during sample exchange
- lead shielding around 1st collimator lowers background

ECSLI on-line setup coupled to LA2 beam line



Setup newly equipped with closed cycle He cryostat for sample cooling to 40 K

DEVELOPMENTS TO 2008 → $30\text{K} < T_M < 295\text{K}$



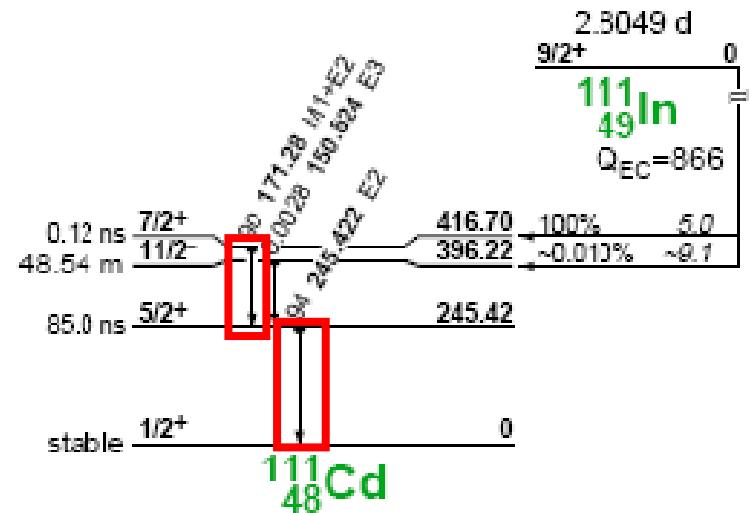
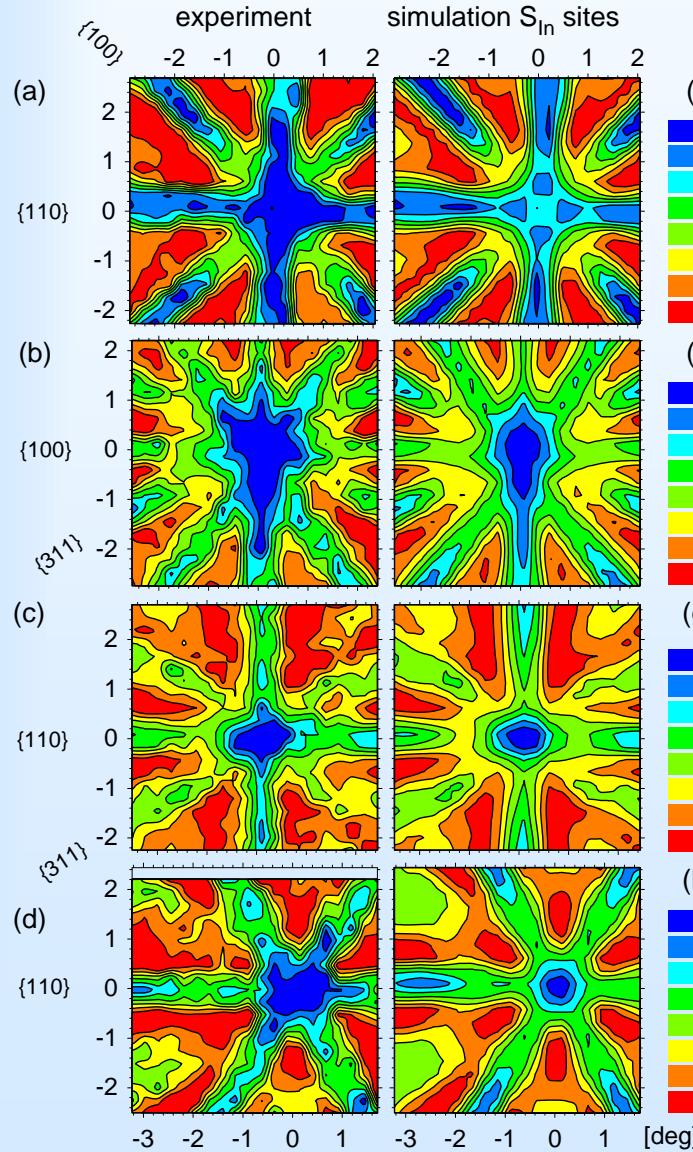
Motivation for installing the sample cooling stage

The sample cooling option offers opportunities for new types of experiments:

- allows to study the emission channeling effect of well-annealed samples as a function of measurement temperature
 - ⇒ gain some information on the influence of lattice and probe vibrations on the emission channeling effect
 - ⇒ investigate systems where probe atoms experience reversible lattice site changes as a function of measuring temperature (e.g. DX centers in semiconductors)
 - ⇒ study systems which show structural phase changes
- allows to implant, anneal and measure samples below room temperature
 - ⇒ interesting for systems where the probe atoms are likely to experience an irreversible lattice site change for annealing below room temperature, for instance Cu in Si (from T → S ?)

Test case: conversion electron emission channeling patterns from ^{111}In in InP

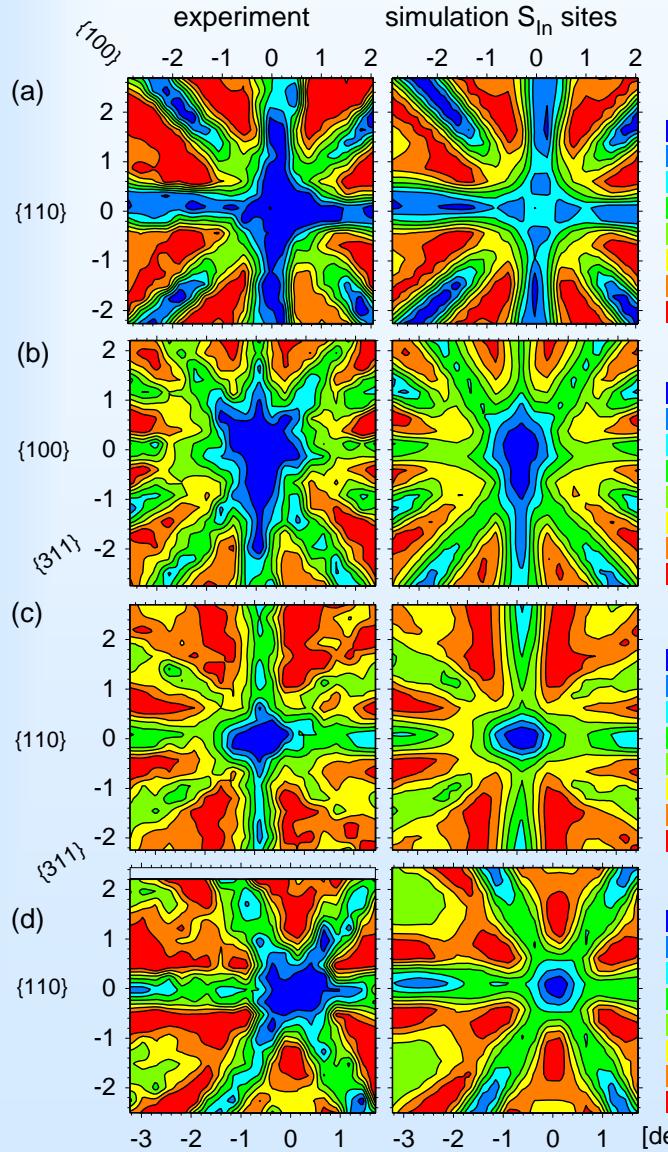
$T_A=300^\circ\text{C}$, $T_M=\text{RT}$



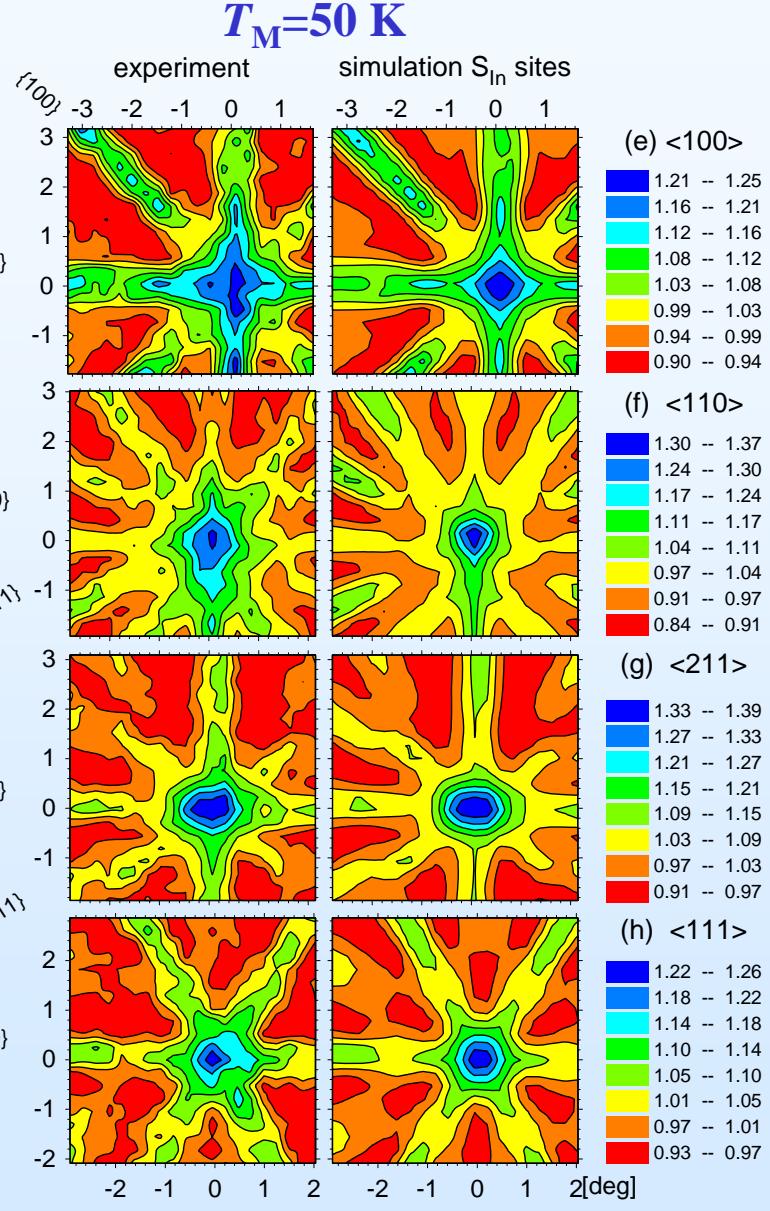
- ^{111}In implanted at RT
- annealed at $T_A=300^\circ\text{C}$
- emission channeling patterns from ^{111}Cd conversion electrons
- measured as function of temperature T_M
- fit results:
 ^{111}In on substitutional In sites
- some discrepancy experim. vs theory

^{111}In in InP: comparison of RT and 50 K patterns

$T_M = \text{RT}$



$T_M = 50 \text{ K}$



Conclusions on InP:¹¹¹In cooling experiments

- **¹¹¹In as expected mostly on S_{In} sites**
- **upon cooling from RT to 50 K anisotropy of emission channeling effects increased ~50%**
- **50 K measurements in InP were better described by the manybeam theory than RT**
- **this indicates a problem with dechanneling approach in manybeam simulations for high-Z materials (1st order perturbation theory)**

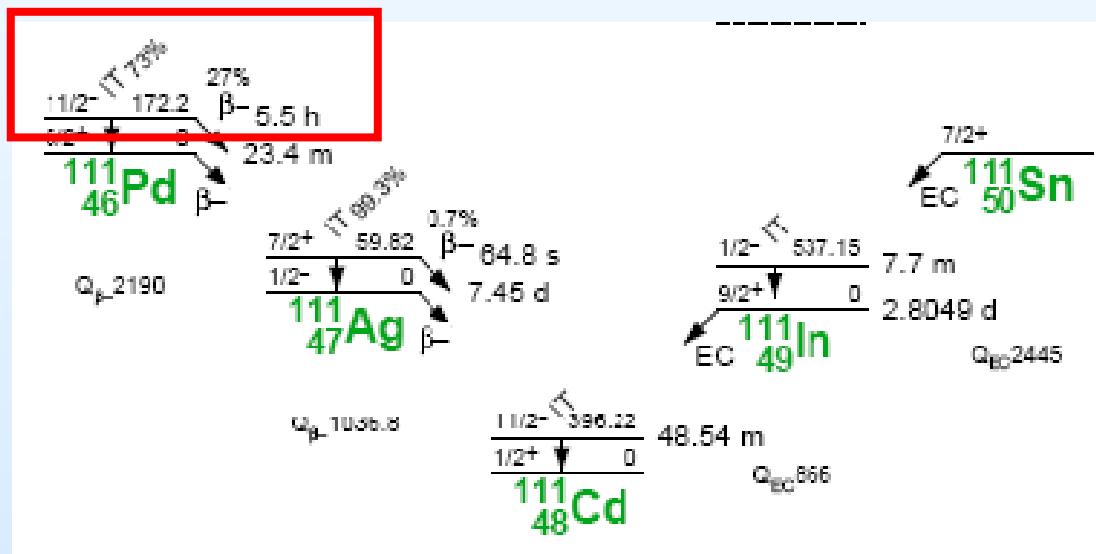
Conclusions

- the second on-line run of EC-SLI was quite successful
- the new sample cooling stage worked as expected
- on-line electron emission channeling experiments now feasible as a function of measurement temperature between 40-900 K and implantation temperature 40-1170 K
- future: experiments with
 ^{65}Ni (2.5 h),
 ^{27}Mg (9.5 min)

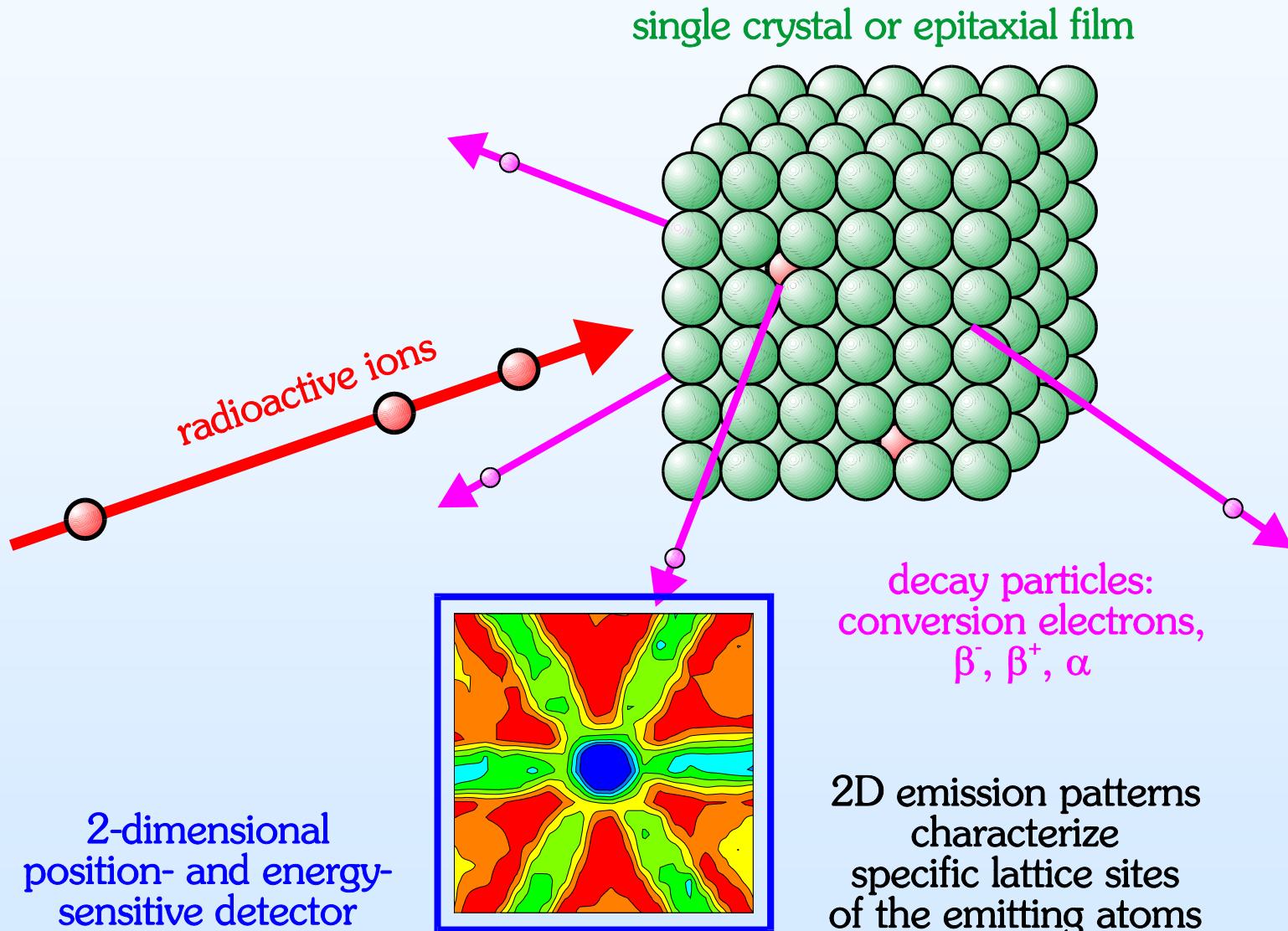
HELP SLIDES

Problems encountered

- The ^{111}In beam from the UC-W target was contaminated with around 30% of $^{111\text{m}}\text{Pd}$ (5.5 h)
⇒ contamination caused some problems during the first measurements of the InP sample



EMISSION CHANNELING: BASIC PRINCIPLES

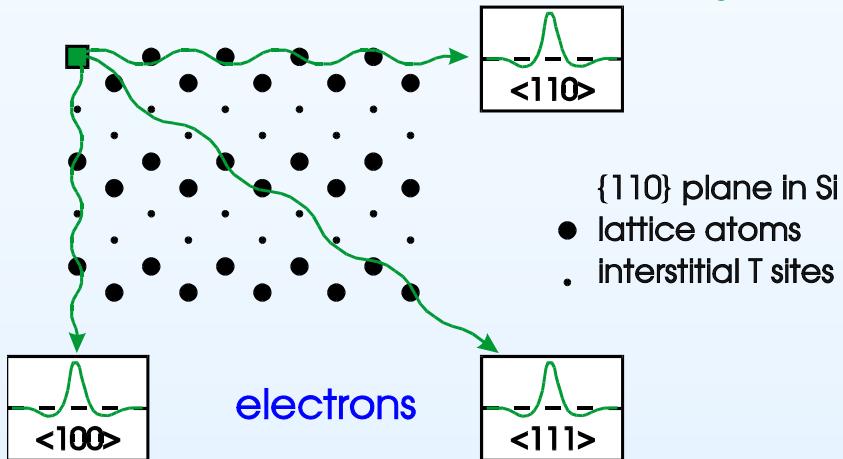


EMISSION CHANNELING CHARACTERISTICS

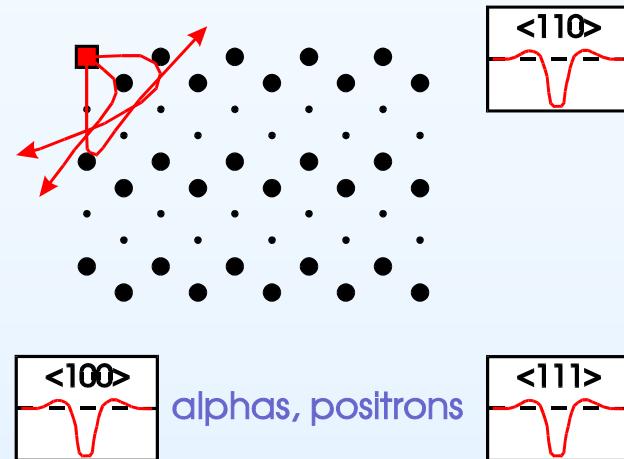
electron Vs. alpha (or positron)

(Example for the Silicon lattice)

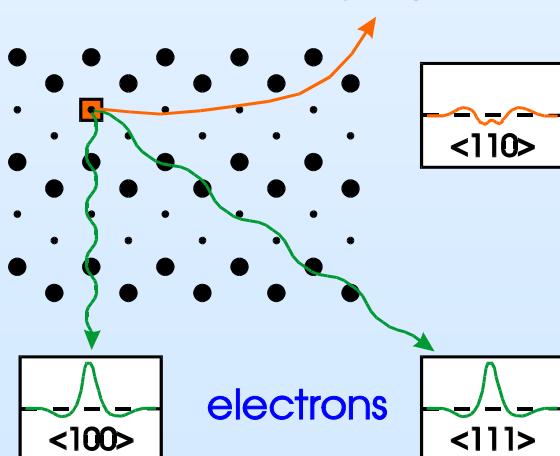
Substitutional radioactive impurity: channeling



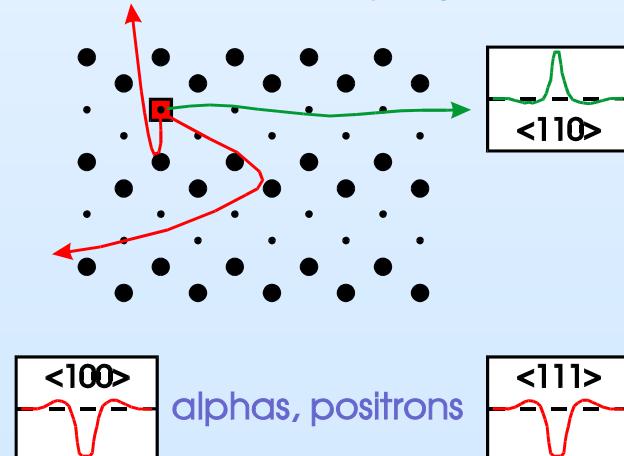
Substitutional radioactive impurity: blocking



Interstitial radioactive impurity: mixed effects



Interstitial radioactive impurity: mixed effects



Elements for which emission channeling experiments have been reported

β^- , β^+ , CE or α
emitting isotopes
exist for most
elements of
the periodic system

⇒ much more fun
is waiting...

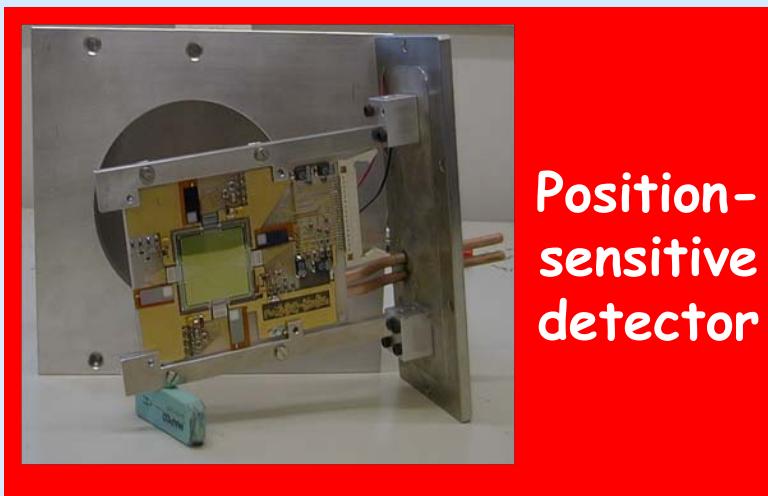
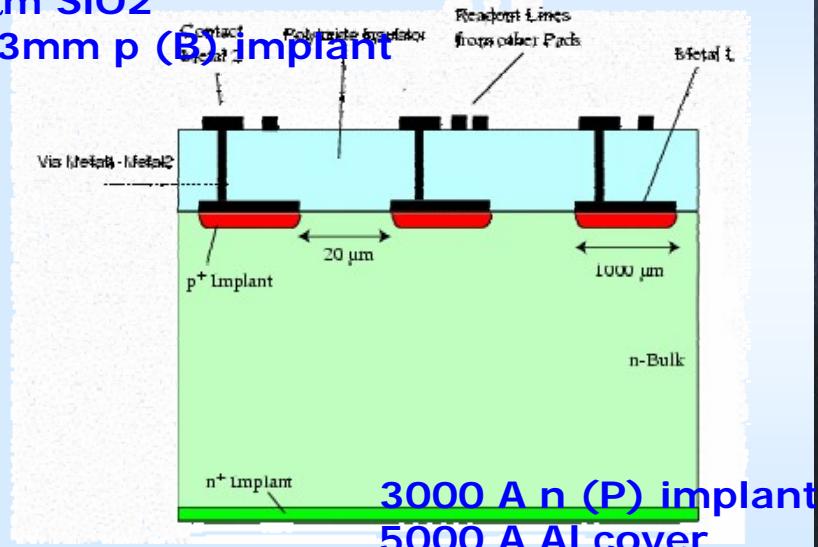
Important criteria for suitable isotopes:

- half life of decay • energy of emitted particles • availability as ion beam
 - possible superposition from decay chains • radiation protection issues

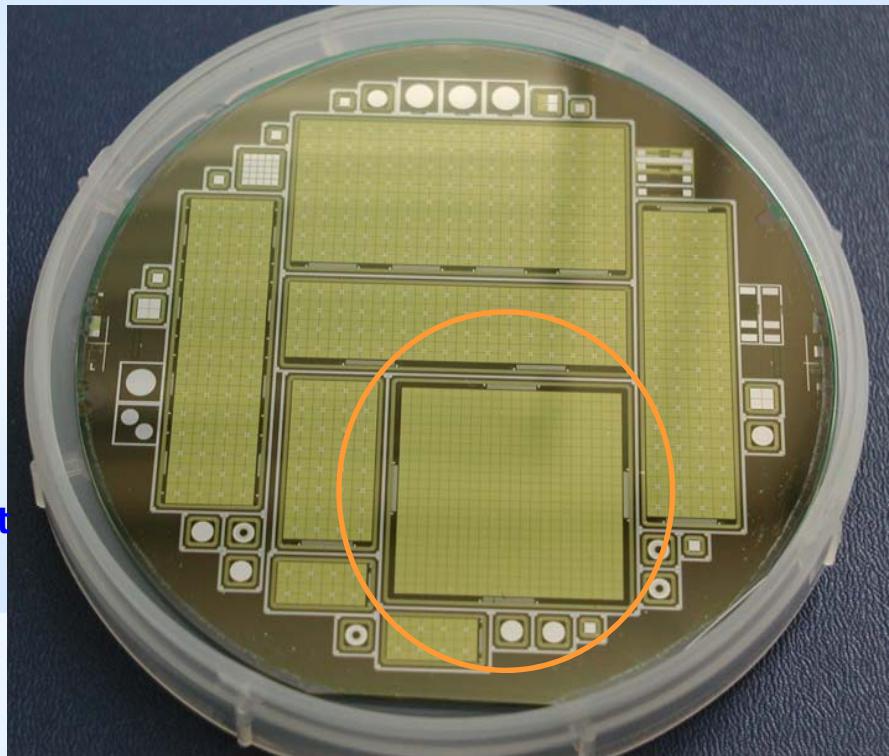
What do you need to do Emission Channeling

Si PAD electron detectors

5 μ m kapton
2 μ m SiO₂
0.3mm p (B) implant



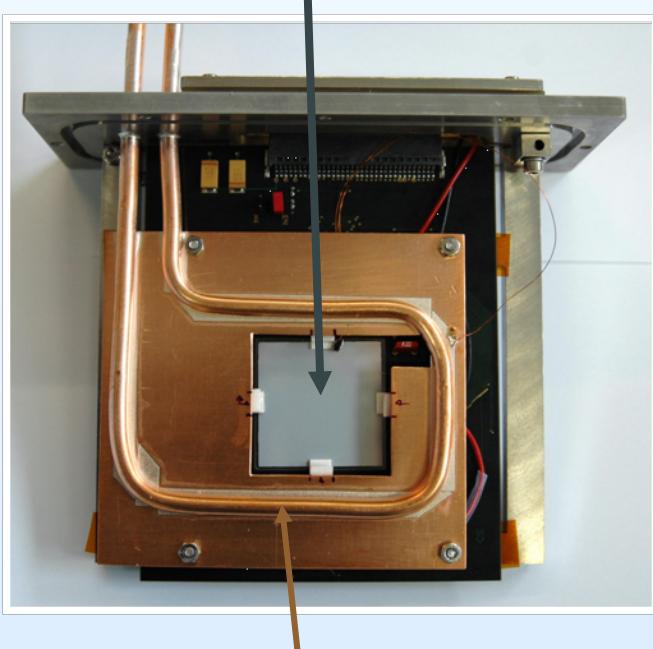
Position-
sensitive
detector



Good energy resolution ~3 keV
Large pad – 1.4x1.4 mm²
Dead / unbonded channels
Leakage current limiting depletion
 $15\text{keV} \ll E(e^-) \ll 300 \text{ keV}$
Readout → 200Hz ... 5 kHz

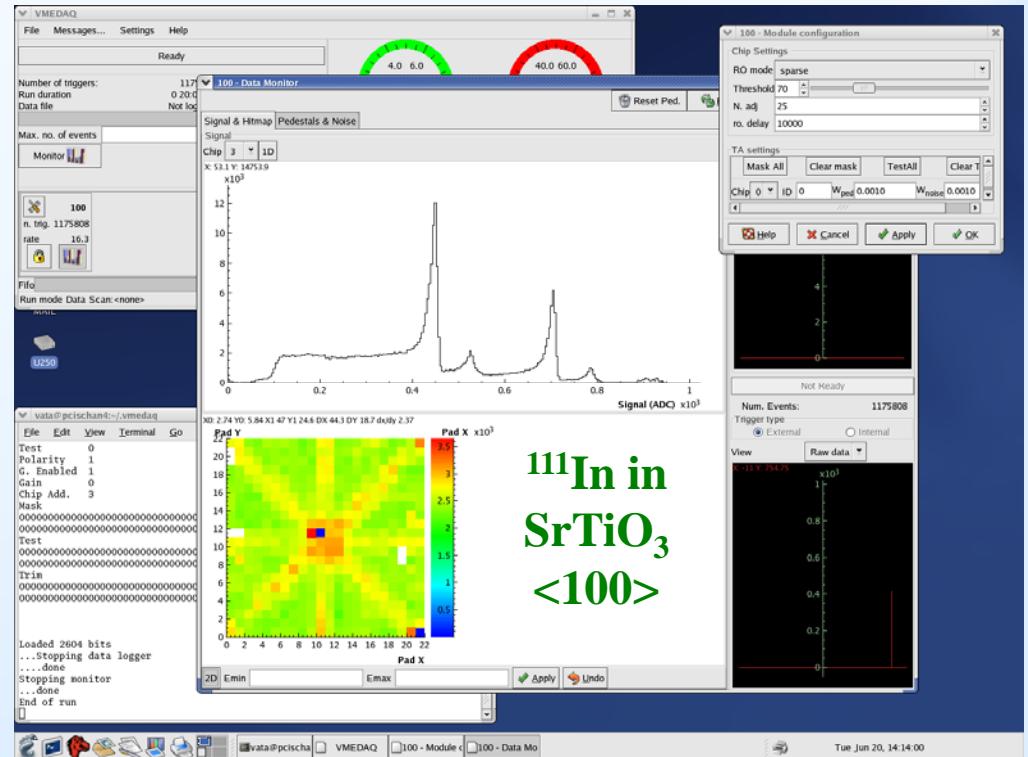
Position sensitive Si pad detector for electrons

22×22 pixels ($1.4 \times 1.4 \text{ mm}^2$)
Si pad detector



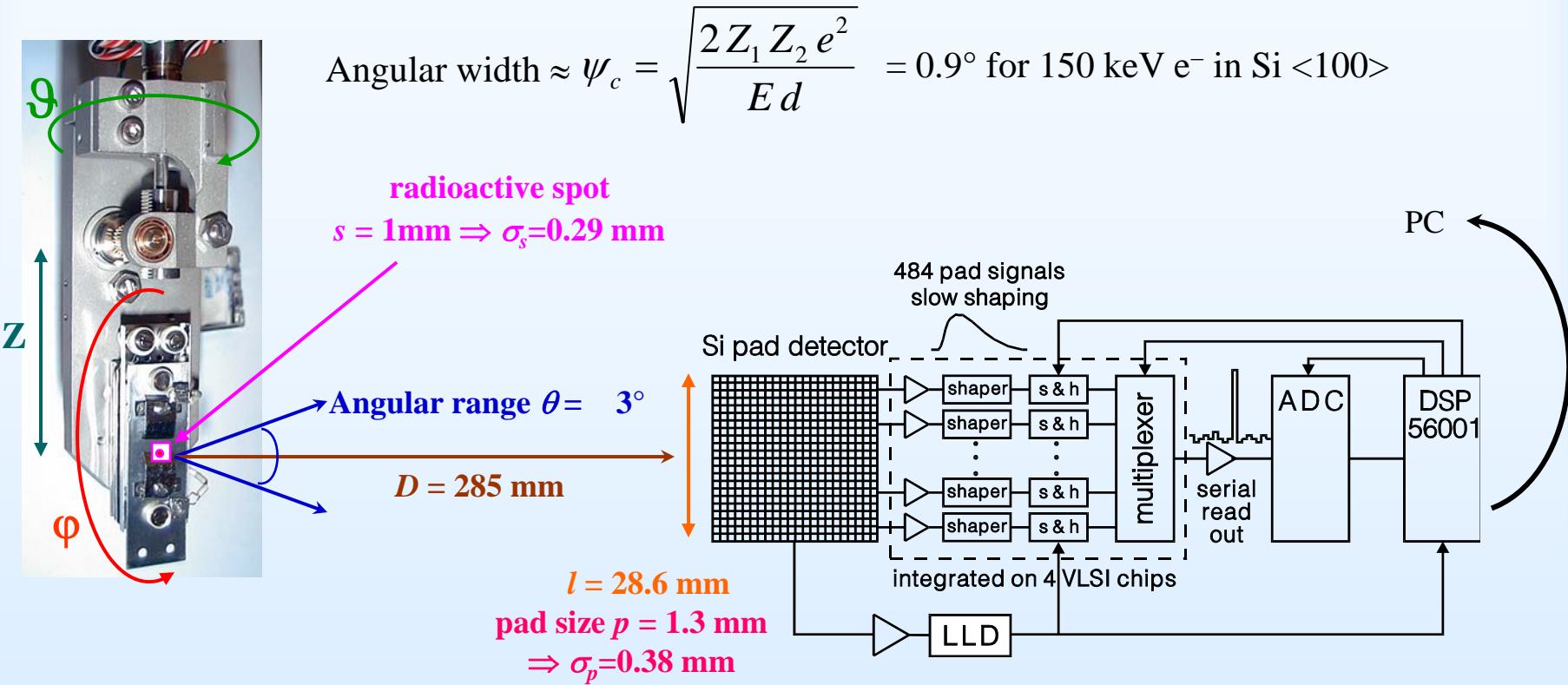
water & Peltier cooling
(down to -20°C)

- selftriggering pre-amplifier chips
- maximum count rate: $\sim 3\text{-}6 \text{ kHz}$ range
- energy resolution: photons $\sim 1.2 \text{ keV}$
electrons $< 3 \text{ keV}$



readout via VME and optolink,
LINUX based software for on-line display

Experimental details - geometry

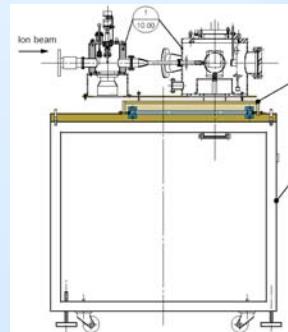
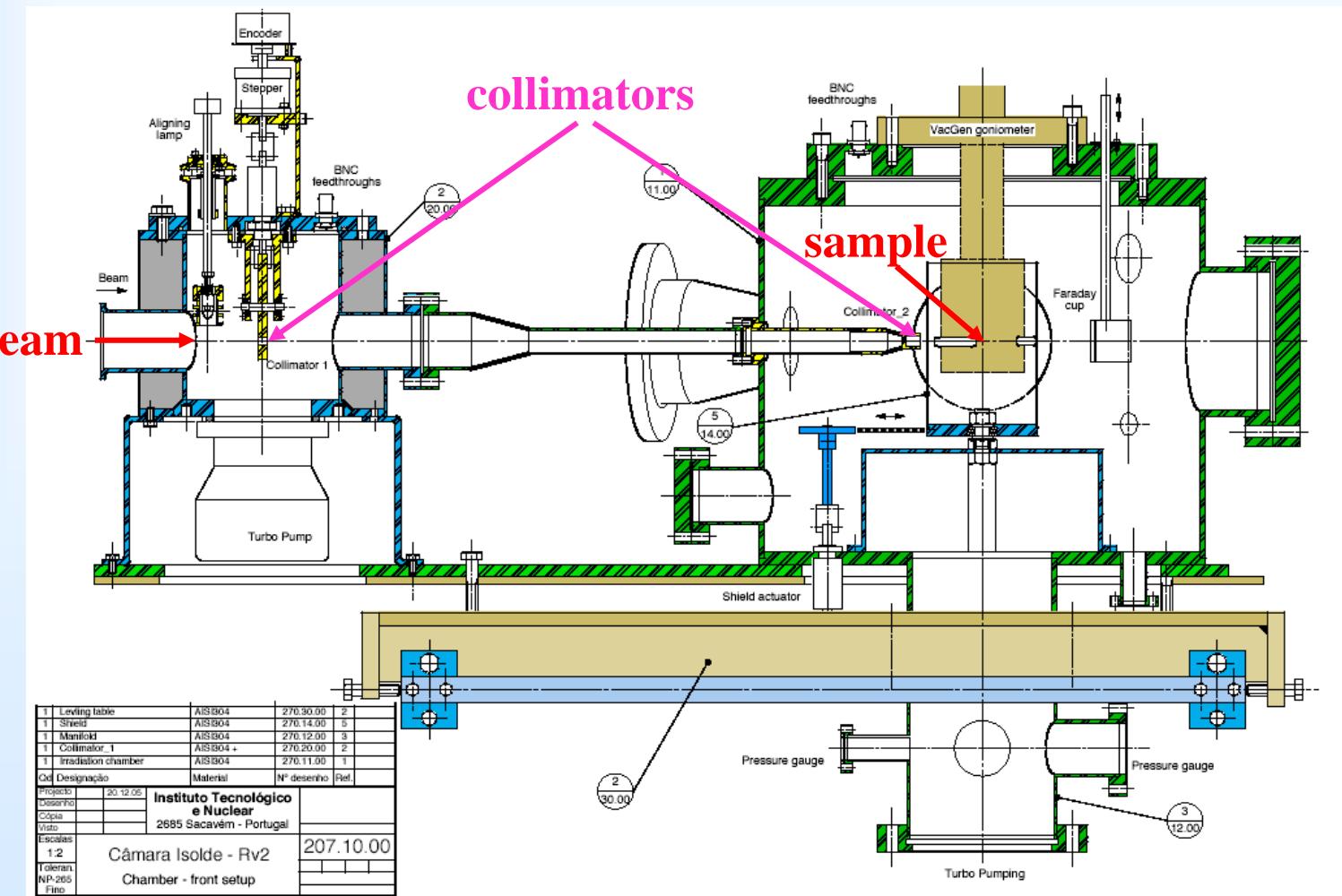


Angular resolution $\Delta\theta$ depends on both size of radioactive spot σ_s and detector resolution σ_p :

$$\Delta\theta \approx \arctan \frac{\sqrt{\sigma_s^2 + \sigma_p^2}}{D} = 0.1^\circ$$

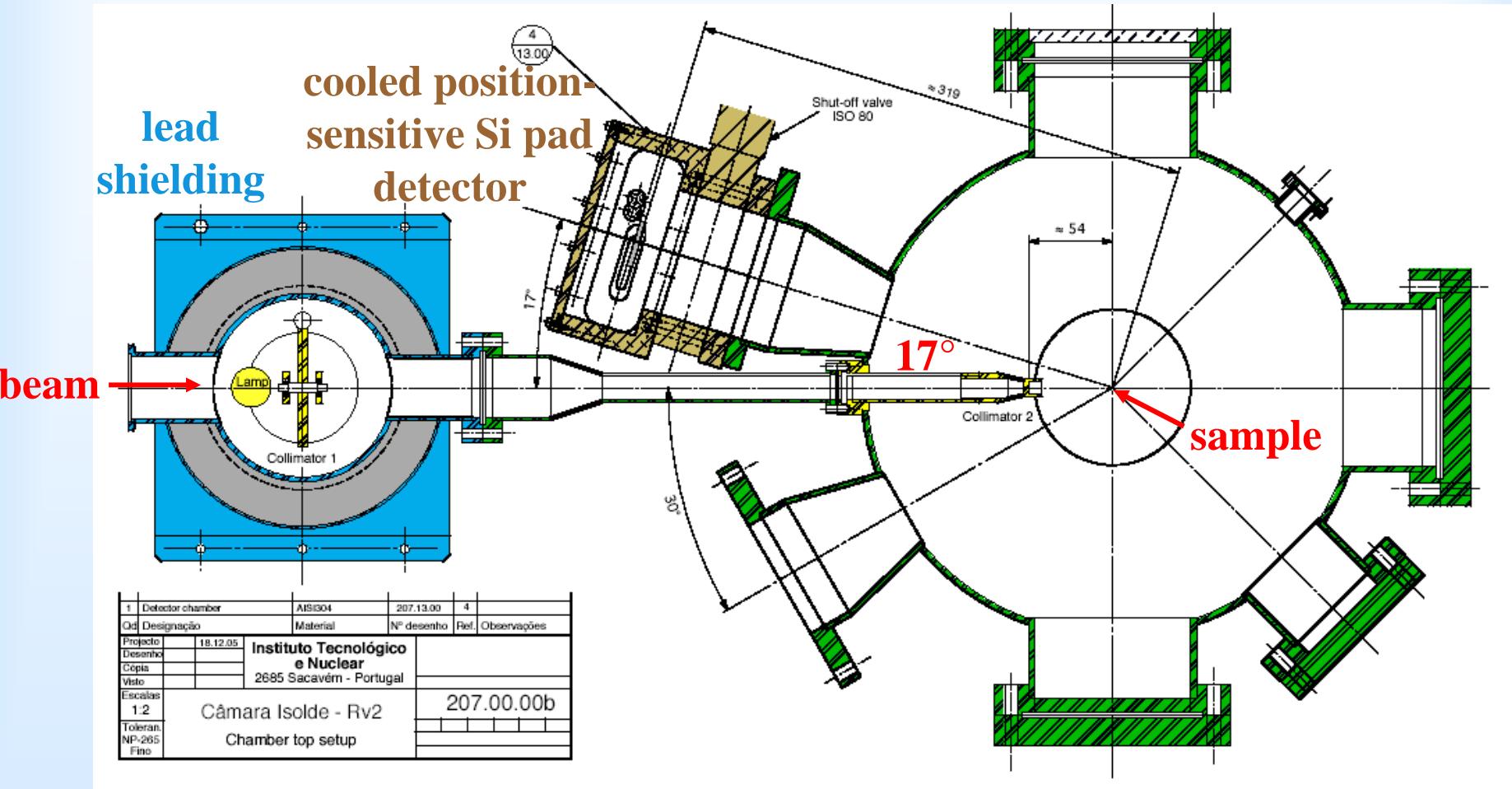
For a detector of size l the distance sample-detector D regulates both the angular range θ and the angular resolution $\Delta\theta$

New ITN on-line emission channeling setup: side view



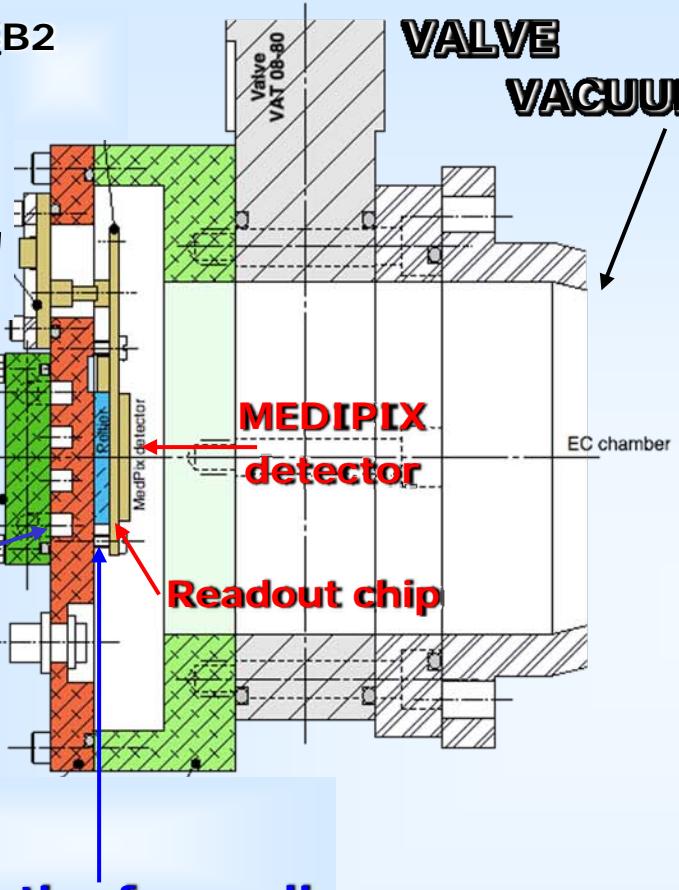
- ISOLDE beam is collimated by 2 apertures (1st variable size, 2nd Ø 1 mm) on the sample
- sample mounted in remote controlled 3-axis goniometer

New ITN on-line emission channeling setup: top view



- detector at 17° backward geometry for simultaneous implantation and measurement
- valve in front of detector allows to maintain detector vacuum during sample exchange
- lead shielding around 1st collimator lowers background

Readout to
USB1, USB2



Water

MEDIPIX
detector

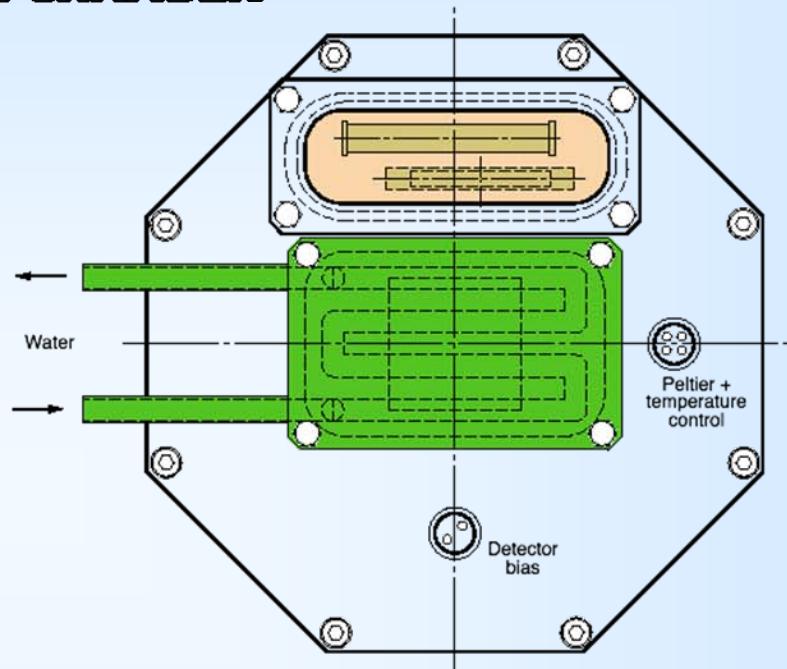
Readout chip

Pelletier for cooling

the chip on vacuum

$$5V \times 1Amp = 5W$$

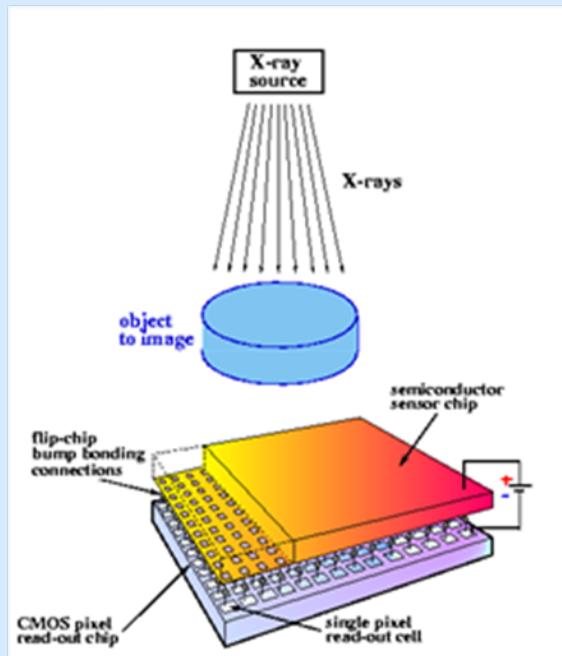
VECTORWORKS EDUCATIONAL VERSION



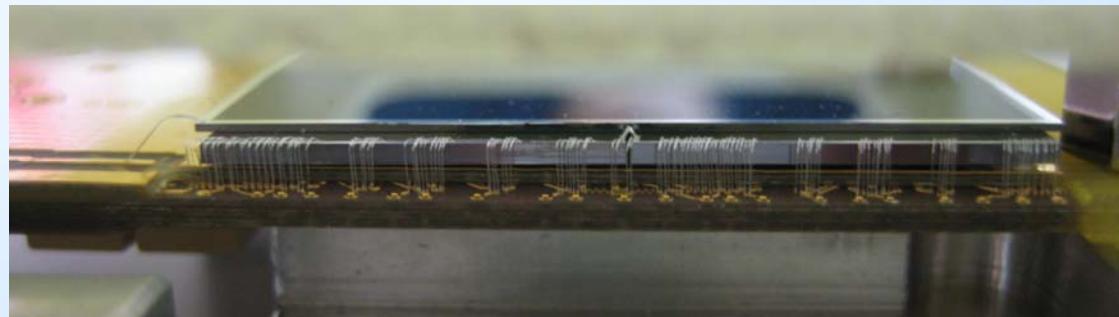
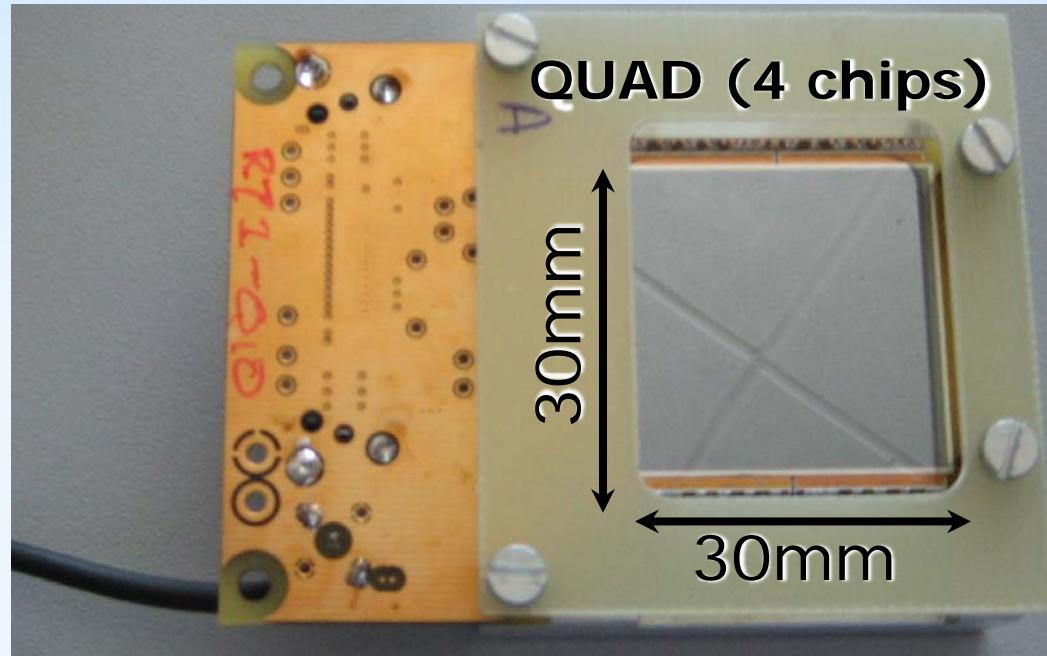
Qd	Designação	Material	Nº desenho	Ref.	Observações
1	Medpix detector board				CERN
1	PCB vacuum feedthrough	AISI 304	207.17.04	4	CERN
1	Cooling block	Anticorrodal	207.17.03	3	
1	Chamber lid	Anticorrodal	207.17.02	2	
1	Detector chamber	Anticorrodal	207.17.01	1	
Projeto 31/03/08					
Desenho					
Cópia					
Visto					
Escalas 1:1	Instituto Tecnológico e Nuclear		2685 Sacavém - Portugal		
Toleran. NP-265 Fino	Isolde EC2 Chamber		207.17.00		
	Detector MedPix - mount/p				

M.R. Silva

DEVELOPMENTS TO 2008 EC & MEDIPIX detectors



256x256 ch (55μm)



First tests with the 73As implanted ZnO crystal,
[0001] axis.

(After annealing on air at 900C)

Medipix of test, chip, 256x256 channels. ONLY LLD discrimination.

Selected only 42 + 52 keV electrons.

IMAGE OBTAINED WITH
INTEGRATION OF FOUR CHANNELS,
EQUIVALENT PIXEL SIZE WITH
SIDE $4 \times 56 \mu\text{m} = 0.224 \text{ mm}$.

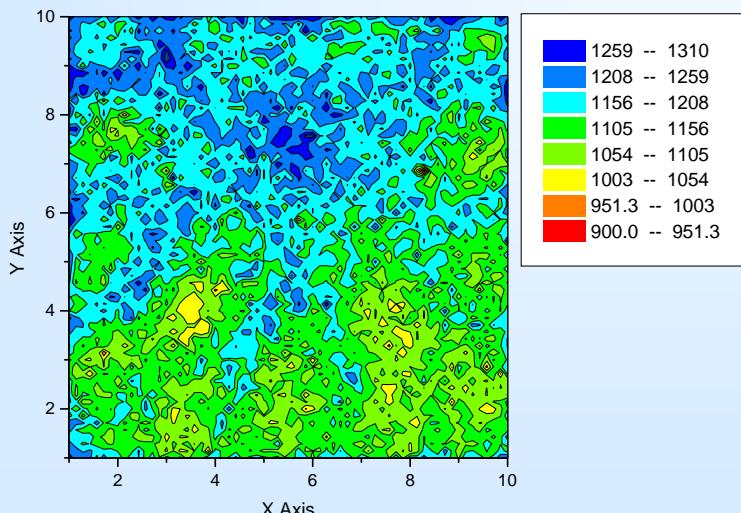


IMAGE OBTAINED WITH
INTEGRATION OF EIGHT CHANNELS,
EQUIVALENT PIXEL SIZE WITH SIDE
 $8 \times 56 \mu\text{m} = 0.448 \text{ mm}$.

