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Emission Channeling with Short-Lived Isotopes:
lattice location of impurities in semiconductors and oxides

L.M.C. Pereira[1] , L. Amorim[1], J.P. Araújo[4], V. Augustyns[1], K. Bharuth-Ram[6], E. Bosne[5], J.G. Correia[2], A. Costa[2], P. Miranda[7], D.J. Silva[4], M.R. da Silva[3], K. Temst[1], A. Vantomme[1], and U. Wahl[2]

spokesperson: L.M.C. Pereira
contact person: J.G. Correia

[1] Instituut voor Kern- en Stralingsfysica (IKS), KU Leuven, 3001 Leuven, Belgium
[2] Centro de Ciências e Tecnologias Nucleares (C2TN), Instituto Superior Técnico, Universidade de Lisboa, 2686-953 Sacavém, Portugal
[3] Centro de Física Nuclear da Universidade de Lisboa (CFNUL), 1649-003 Lisboa, Portugal
[4] Departamento de Física, Universidade do Porto, 4169-007 Porto, Portugal
[5] Departamento de Física, Universidade de Aveiro, 3810-193 Aveiro, Portugal
[6] University of KwaZulu Natal, Durban 4041, South Africa
[7] Departamento de Física, Universidad de Chile, Las Palmeras 3425, Santiago, Chile

motivation and outline

Lattice location experiments on semiconductors and oxides of fundamental and technological relevance

- Transition metals in dilute magnetic semiconductors
  isotopes: ^{56}Mn ($t_{1/2}$=2.6 h), ^{59}Fe (45 d), ^{61}Co (1.6 h) and ^{65}Ni (2.5 h)
- *p*-type dopants in nitride semiconductors
  isotopes: ^{27}Mg (9.5 min) and ^{11}Be (13.8 s)
- Positron emitter ^{11}C (20.4 min) for β^+ emission channeling (feasibility)

Part of a wide research program involving complementary large-scale facility techniques

- Synchrotron radiation
- Neutron scattering

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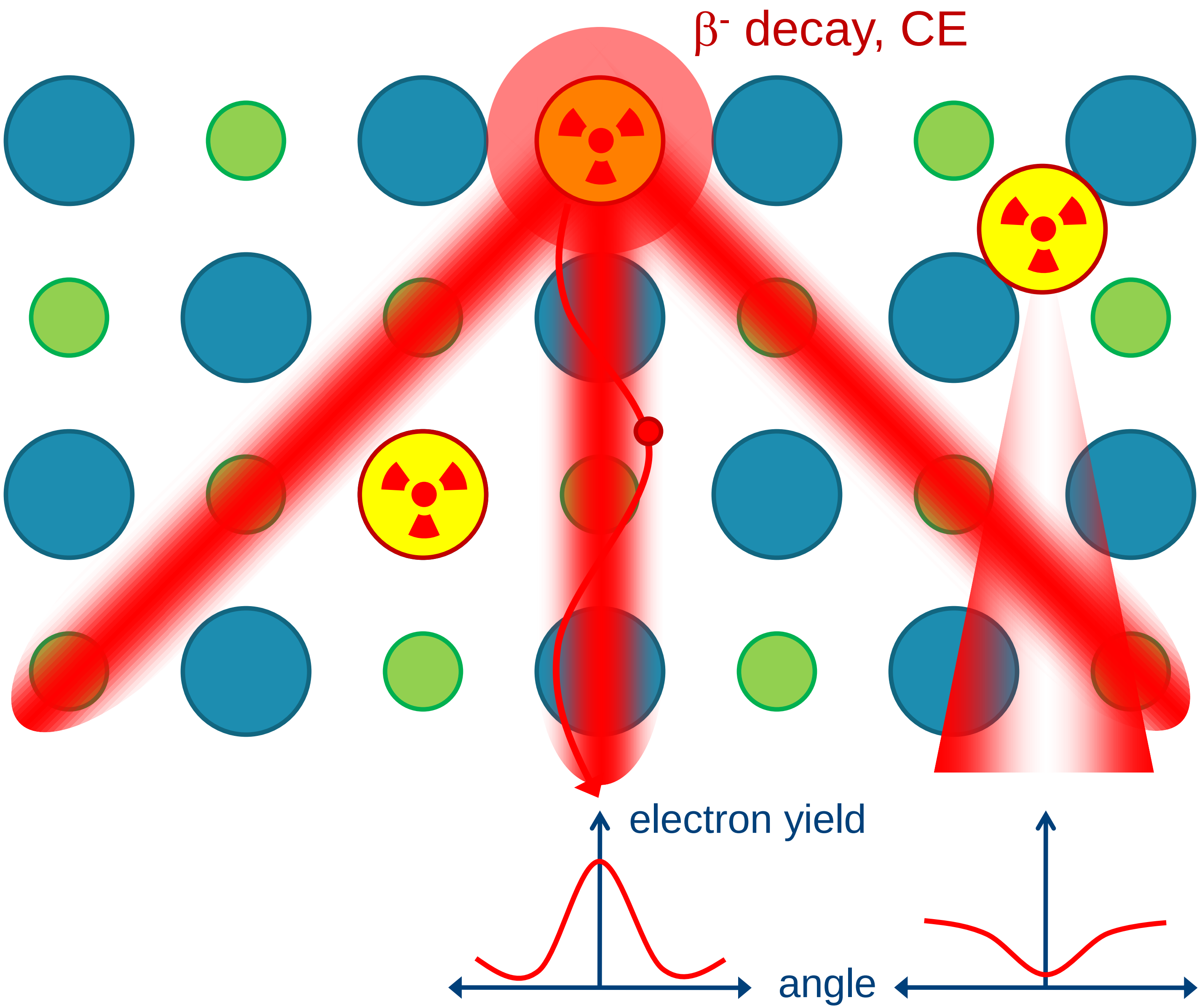
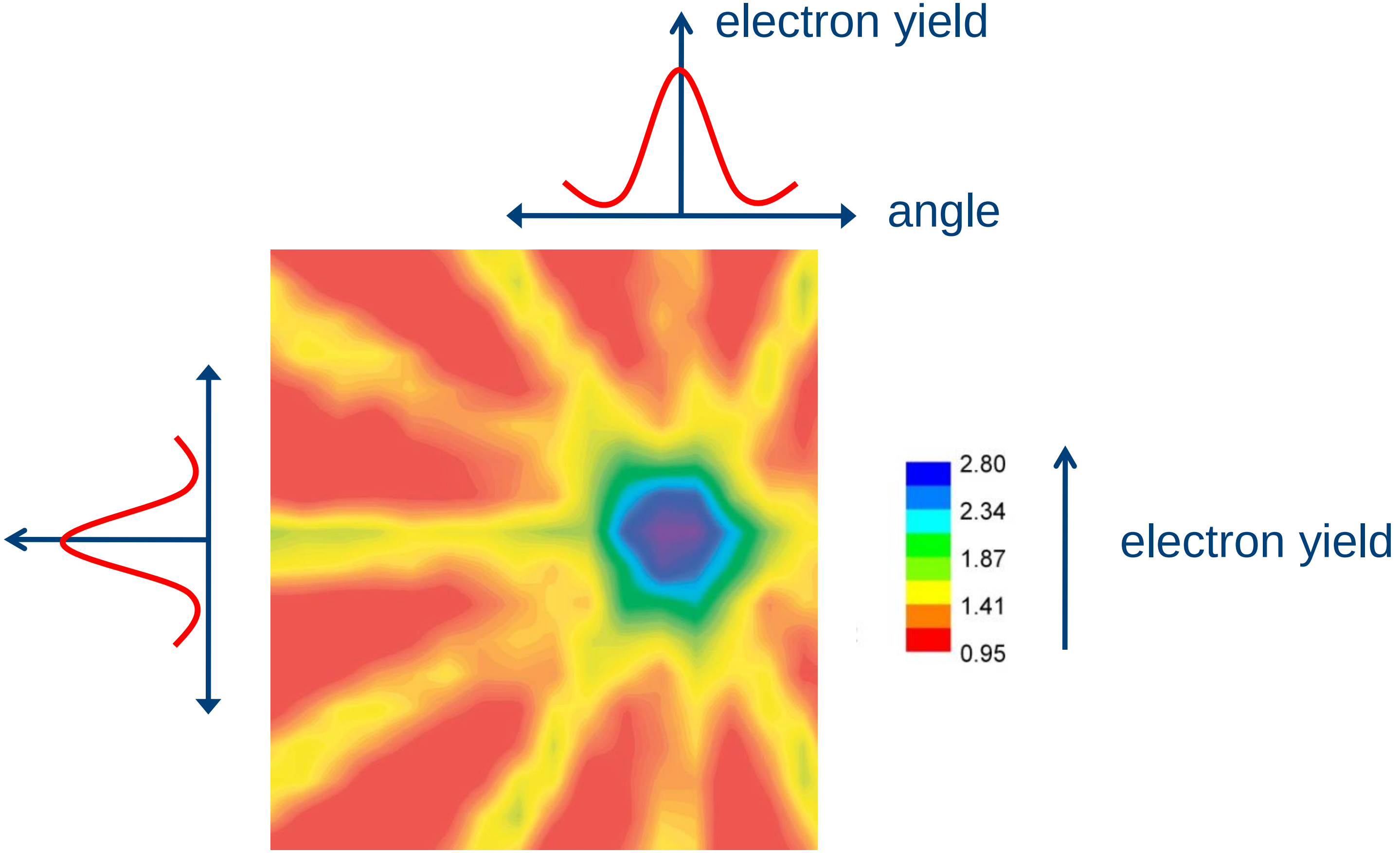
emission channeling technique

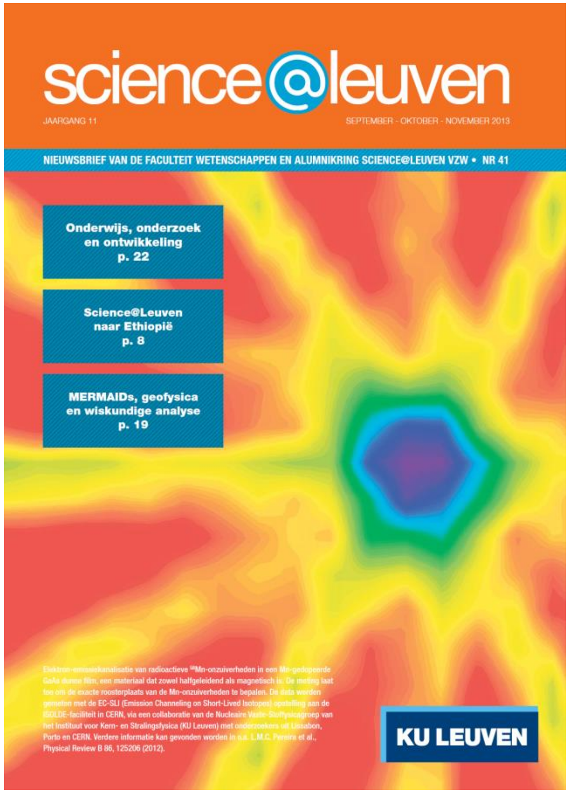


emission channeling technique



emission channeling technique

Newsletter of the Faculty of Science - KU Leuven (Sept.-Nov. 2013)



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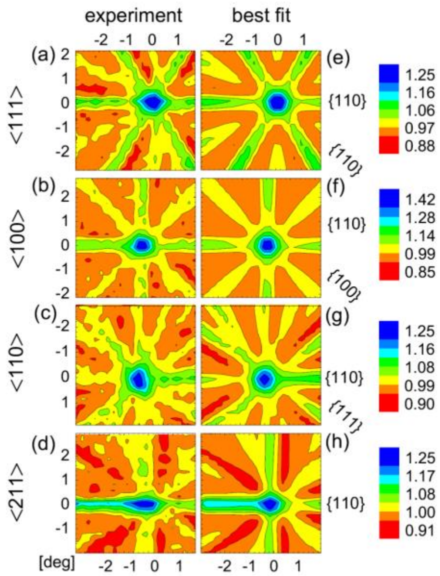
dilute magnetic semiconductors (DMS)

“Classic” DMS

- Mn-doped narrow-gap III-Vs (GaAs, InAs, …)

Key question: interstitial Mn site-change and migration

Experiments: low-T ^{56}Mn in $Ga_{1-x}Mn_xAs$ (Nottingham)



previous work on the low concentration regime:

L.M.C Pereira *et al.*, *Appl. Phys. Lett.* 98, 201905 (2011)
L.M.C Pereira *et al.*, *Phys. Rev. B* 86, 125206 (2012)

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  Key question: anion substitutional TMs: why/how?

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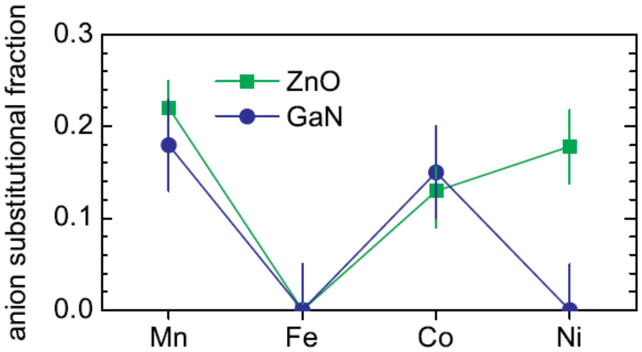
L.M.C Pereira *et al.*, *Phys. Rev. B* 84, 125204 (2011)

L.M.C Pereira *et al.*, *Phys. Rev. B* 86, 195202 (2012)

L.M.C Pereira *et al.*, *Appl. Phys. Lett.* 103, 091905 (2013)



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dilute magnetic semiconductors (DMS)

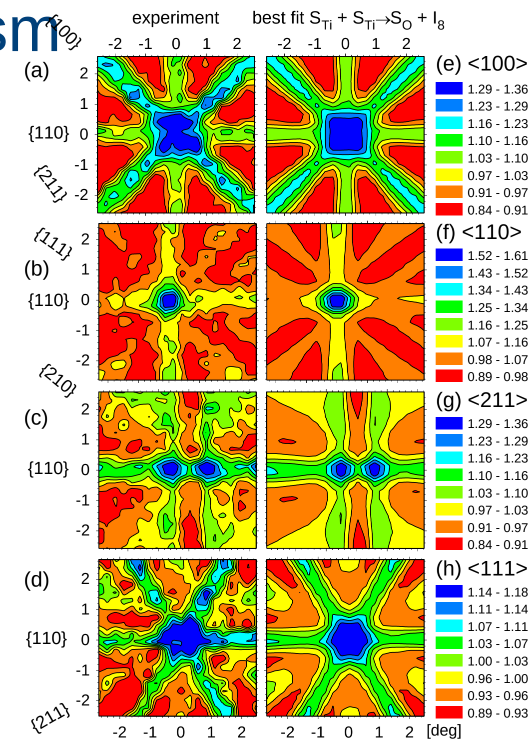
"Novel" DMS

- Transition metal doped ternary oxides

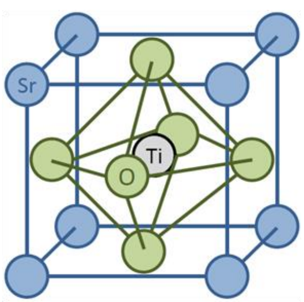
Key question: single-ion ferromagnetism

Experiments:
X-ray absorption fine structure
Nuclear resonant scattering
X-ray magnetic circular dichroism
Synchrotron radiation X-ray diffraction
Polarized neutron reflectivty

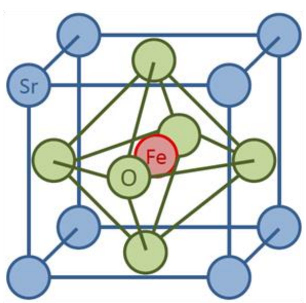
Theory: G. F. Dionne (MIT)



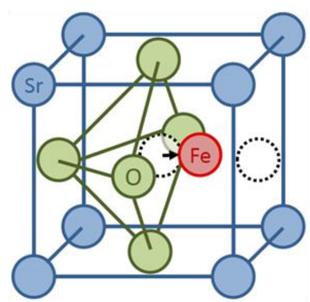
undoped $SrTiO_3$



Fe in **ideal** Ti sites in $Sr(Fe,Ti)O_3$



Fe in **displaced** Ti sites in $Sr(Fe,Ti)O_3$



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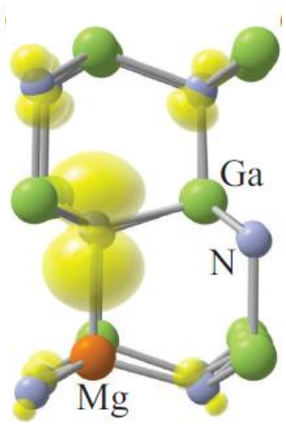
p-type dopants in nitrides

- ^{27}Mg and ^{11}Be in GaN, AlN, InN

  Key questions: precise lattice location of acceptors and the relation to hole localization and self-compensation

  Experiments: ^{27}Mg: higher angular resolution
  low-temperature
  ^{11}Be: new isotope



our previous work (^{27}Mg:GaN/AlN):

L.M. Amorim *et al.*, submitted to *Phys. Rev. Lett.*

L.M. Amorim *et al.*, submitted to *Appl. Phys. Lett.*

J.L. Lyons *et al.*, *Phys. Rev. Lett.* 108, 156403 (2012)

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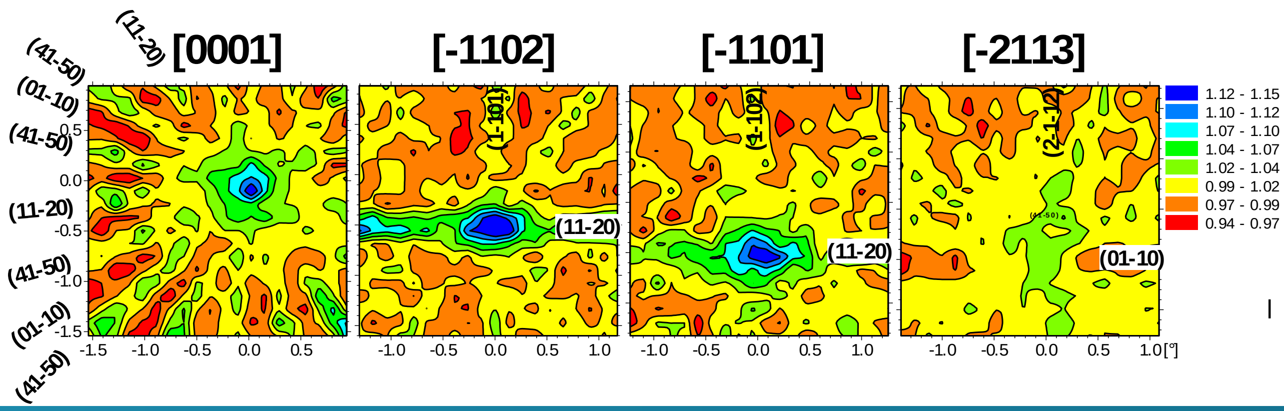

feasibility ^{11}Be:GaN

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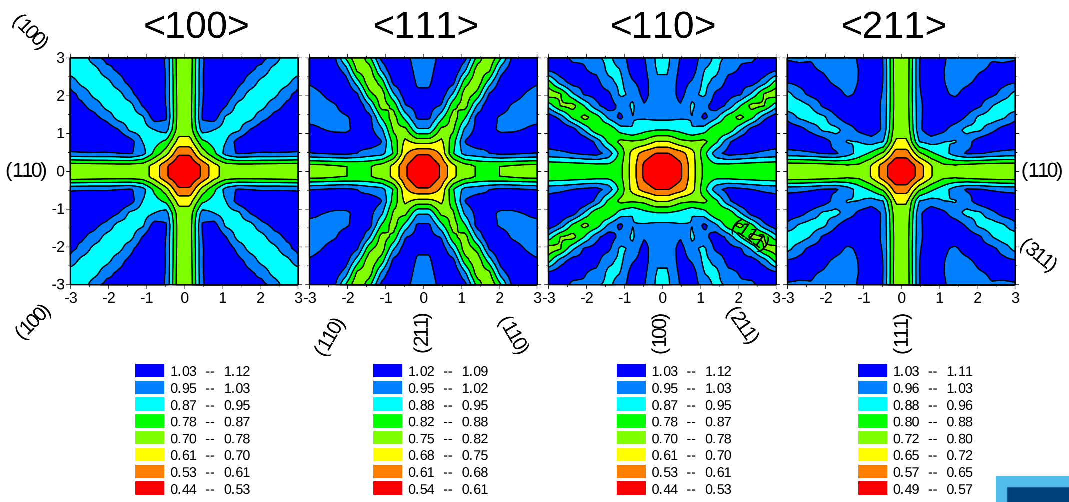
^{11}C β^+ emission channeling

- Case-study for positron emission channeling
- Relevant for:
  - Dopant/contaminant in semiconductors/metals
  - Graphene growth (e.g. C-implanted Ni)
  - Implantation damage and annealing in SiC and diamond
  - …

Expected positron blocking patterns from substitutional ^{11}C in Si at room temperature for $^{11}C^{16}O^+$ implantation with 50 keV.



beam request

isotope	number of shifts	target	ion source	minimum yield [atoms/s/mA]
^{56}Mn (2.6 h)	4	UC_x-W	RILIS Mn	5×10^{7}
^{61}Mn (4.6 s) → ^{61}Fe (6 min) → ^{61}Co (1.6 h)	1	UC_x-W	RILIS Mn	2×10^{6}
^{59}Mn (0.71 s) → ^{59}Fe (45 d)	1	UC_x-W	RILIS Mn	10^{8}
^{65}Ni (2.5 h)	3	UC_x-W	RILIS Ni	5×10^{7}
^{27}Mg (9.5 min)	12	Ti-W	RILIS Mg	1×10^{7}
^{11}Be (13.8 s)	6	UC_x-W or Ta-W	RILIS Be	6×10^{6}
^{11}C (20 min) as $^{11}C^{16}O^{+}$ molecule	3	Molten salt, NaF-LiF eutectic	VD5 plasma	5×10^{7} (achieved 7×10^{8})

Total requested shifts: 30

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