INVESTIGATION OF HEAVY ION RADIATION INTERACTION WITH STEEL COMPONENTS OF PARTICLE ACCELERATORS

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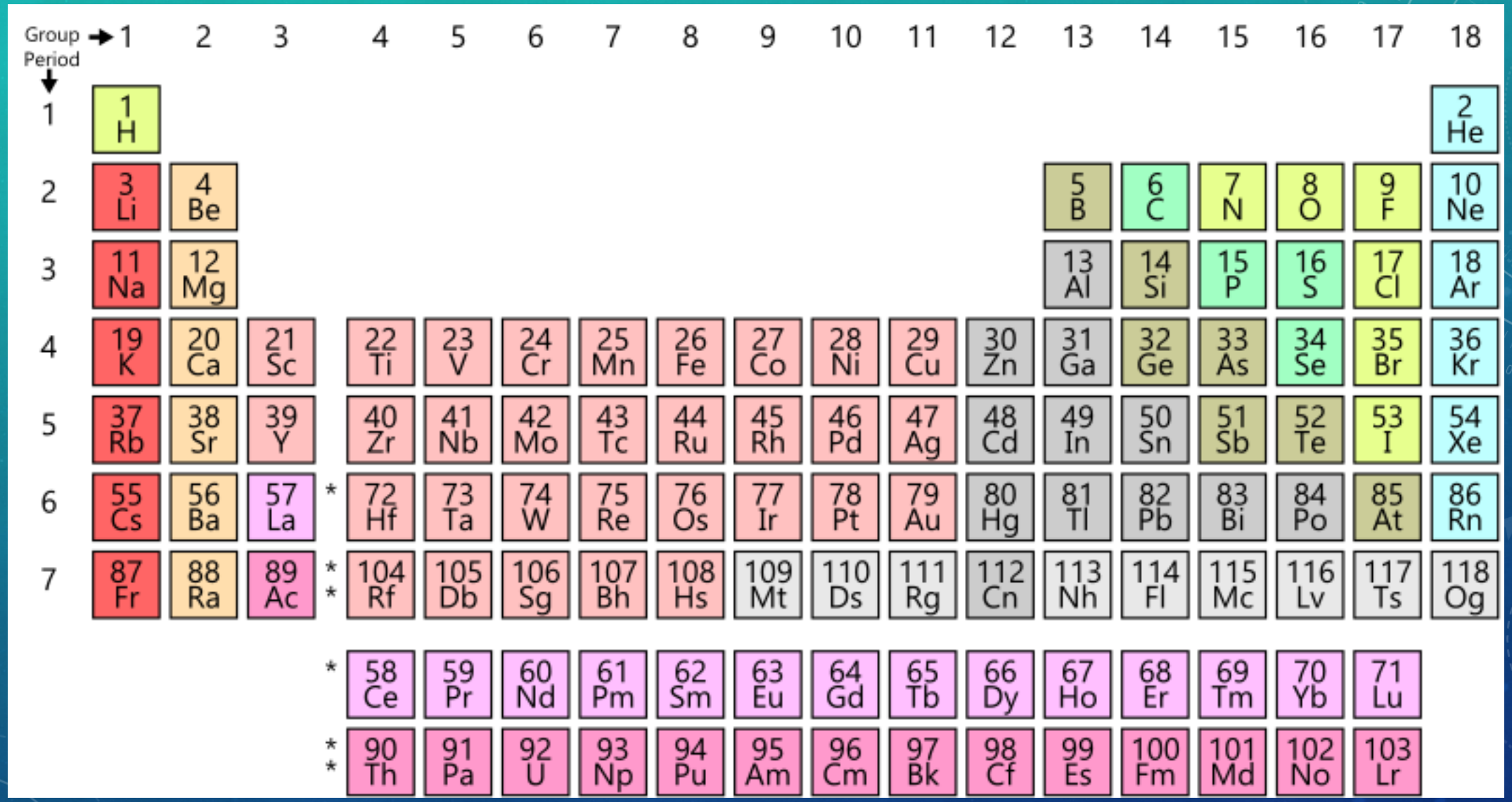
INVESTIGATION OF HEAVY ION RADIATION INTERACTION WITH STEEL COMPONENTS OF PARTICLE ACCELERATORS

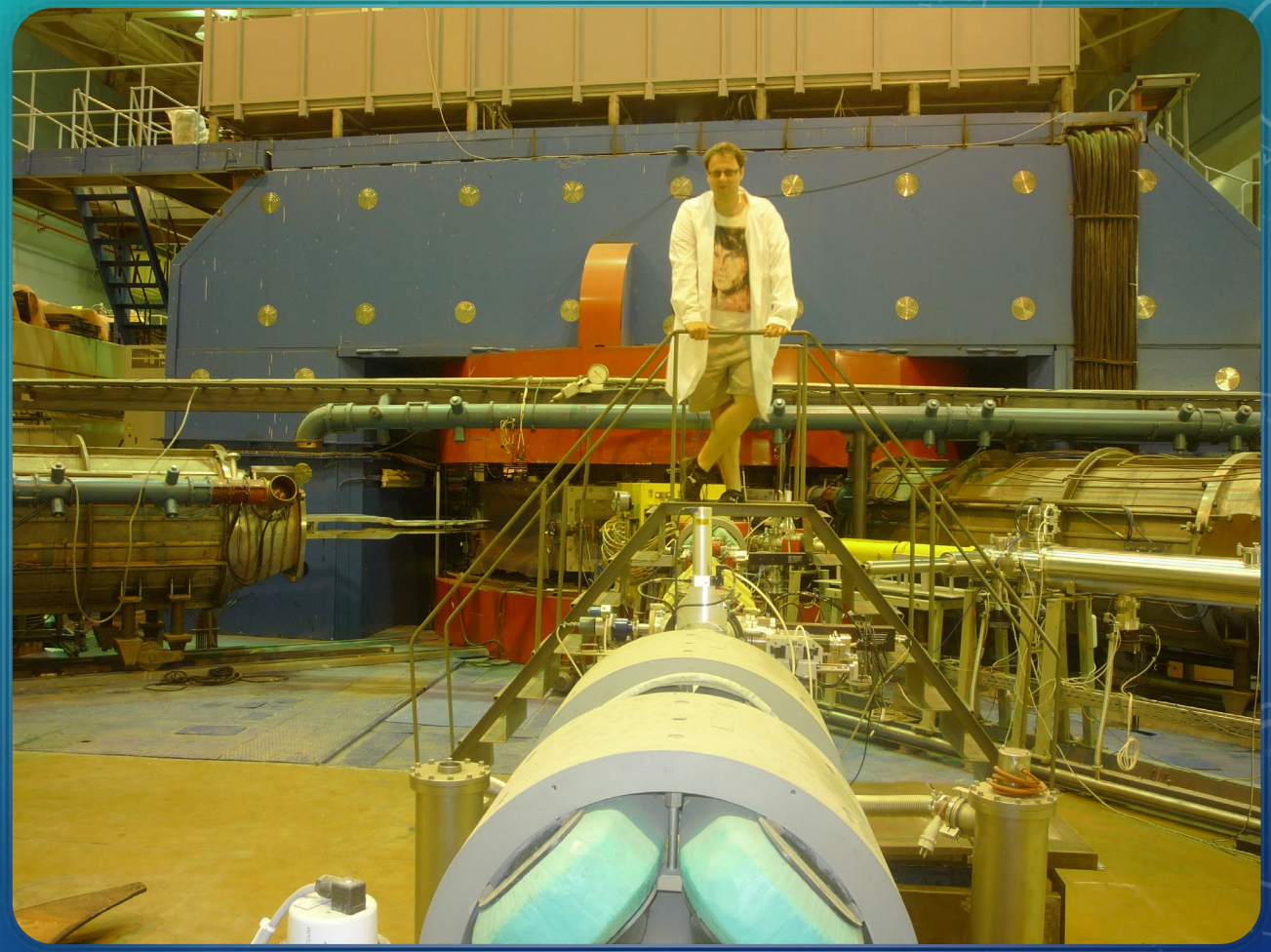
- Investigation of irradiated steel parts of MASHA (Mass Spectrometer of SuperHeavy atoms)
- Irradiation of steel samples by IC-100 (emulation of MASHA irradiated components)
- Testing various steel alloys and coatings
- nondestructively by Mössbauer spectrometry and other methods (SEM, XRD…)


Group → 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Period ↓
1 1 H 2 He
2 3 Li 4 Be 5 B 6 C 7 N 8 O 9 F 10 Ne
3 11 Na 12 Mg 13 Al 14 Si 15 P 16 S 17 Cl 18 Ar
4 19 K 20 Ca 21 Sc 22 Ti 23 V 24 Cr 25 Mn 26 Fe 27 Co 28 Ni 29 Cu 30 Zn 31 Ga 32 Ge 33 As 34 Se 35 Br 36 Kr
5 37 Rb 38 Sr 39 Y 40 Zr 41 Nb 42 Mo 43 Tc 44 Ru 45 Rh 46 Pd 47 Ag 48 Cd 49 In 50 Sn 51 Sb 52 Te 53 I 54 Xe
6 55 Cs 56 Ba 57 La * 72 Hf 73 Ta 74 W 75 Re 76 Os 77 Ir 78 Pt 79 Au 80 Hg 81 Tl 82 Pb 83 Bi 84 Po 85 At 86 Rn
7 87 Fr 88 Ra 89 Ac * 104 Rf 105 Db 106 Sg 107 Bh 108 Hs 109 Mt 110 Ds 111 Rg 112 Cn 113 Nh 114 Fl 115 Mc 116 Lv 117 Ts 118 Og
* 58 Ce 59 Pr 60 Nd 61 Pm 62 Sm 63 Eu 64 Gd 65 Tb 66 Dy 67 Ho 68 Er 69 Tm 70 Yb 71 Lu
** 90 Th 91 Pa 92 U 93 Np 94 Pu 95 Am 96 Cm 97 Bk 98 Cf 99 Es 100 Fm 101 Md 102 No 103 Lr

INVESTIGATION OF HEAVY ION RADIATION INTERACTION WITH STEEL COMPONENTS OF MASHA

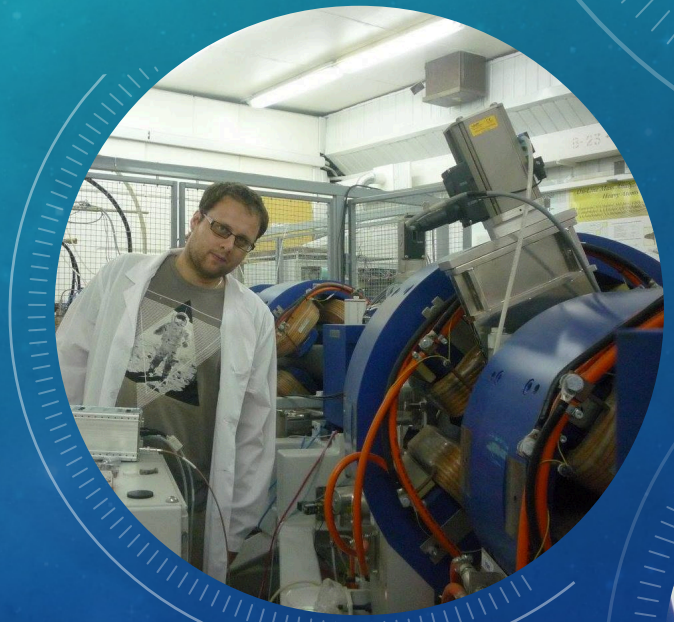
- Investigation of defects of steel components of particle accelerators.
- The determination of structural changes and surface properties are analyzed in detail.
- Change of electric and magnetic properties of phase components, porosity etc. due to the continuous irradiation at high doses.
- These changes can negatively involve the pathway of primary beam and products.
- This can be useful not only for construction of new particle colliders and nuclear reactors, but also space probes and spaceships (due to the cosmic radiation and solar wind)

U400M CYCLOTRON



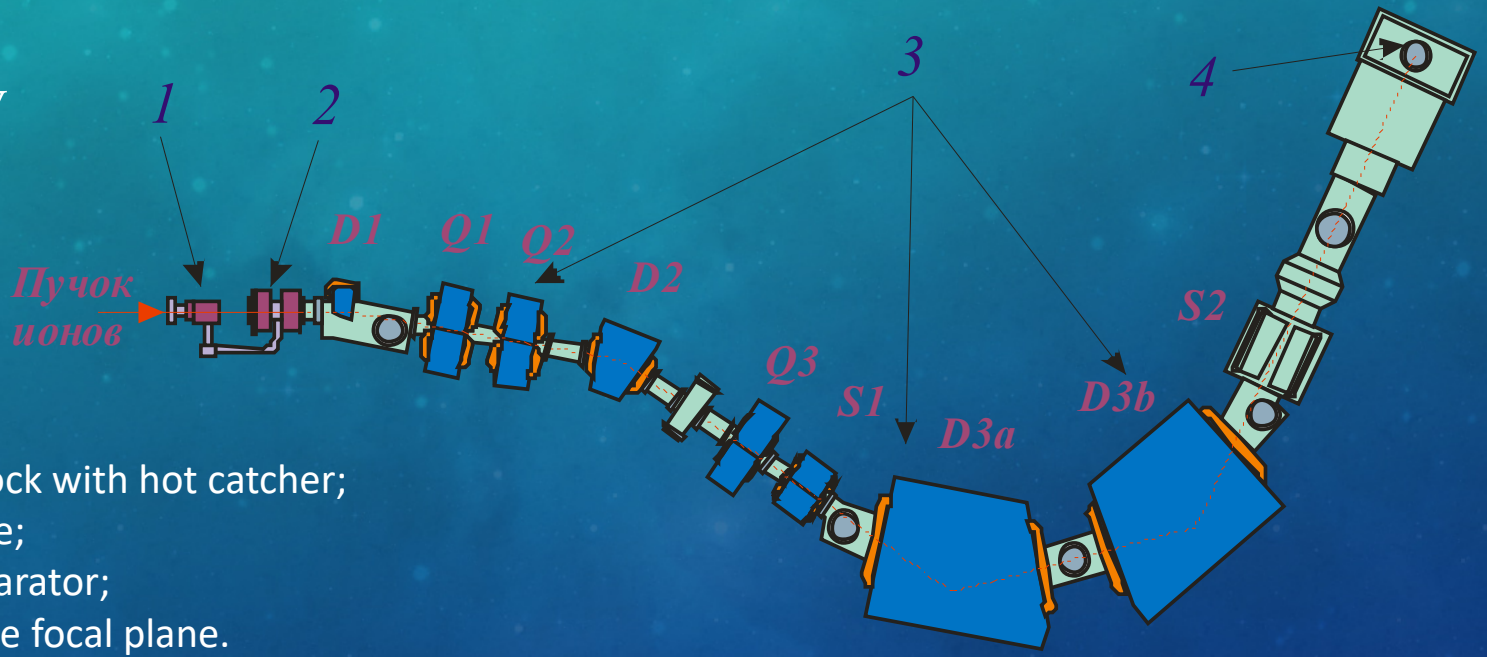
MASHA

- Mass Analyzer of Superheavy Atoms
- Mounted on a beamline of U400M cyclotron
- Part of FLNR accelerator complex



INVESTIGATION OF IRRADIATED STEEL PARTS OF MASHA

Mass
Analyzer of
Super**H**eavy
Atoms

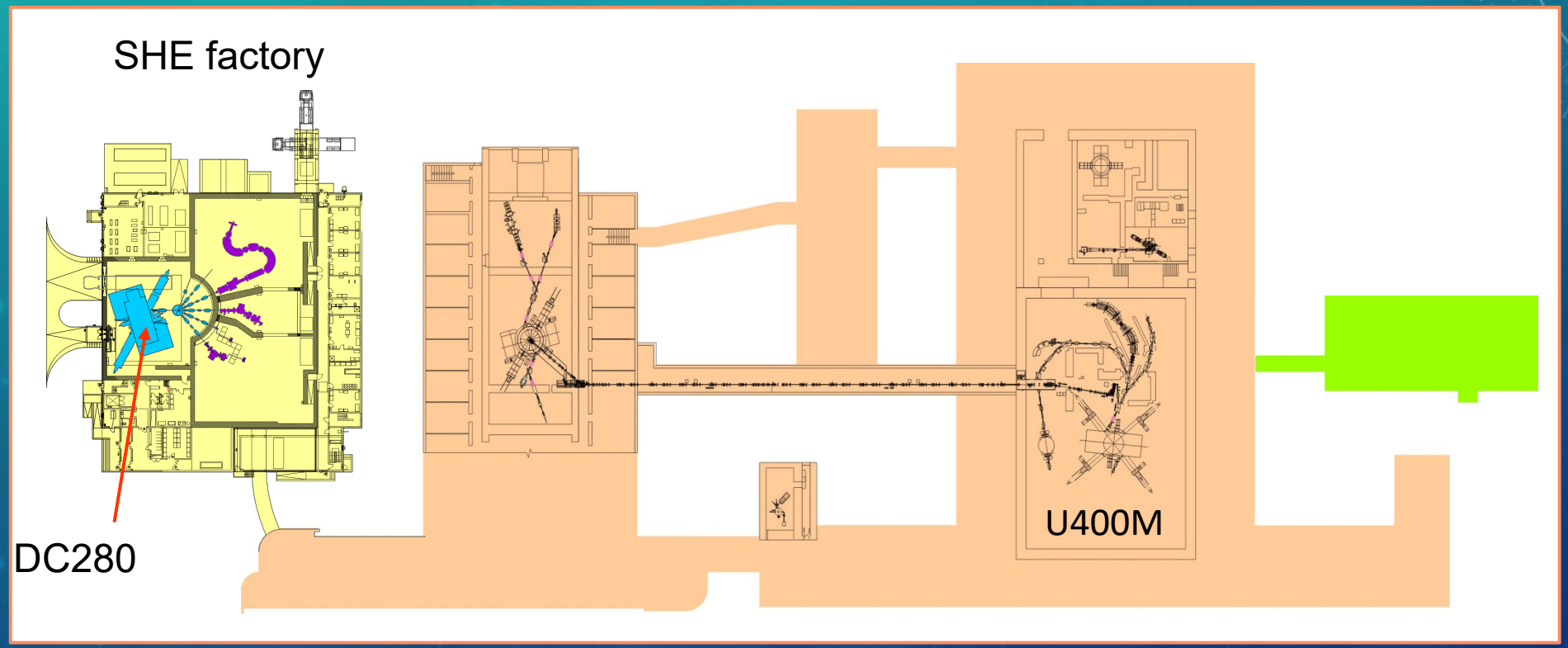


1 – Target block with hot catcher;
2 – Ion source;
3 – Mass separator;
4 – DAQ in the focal plane.

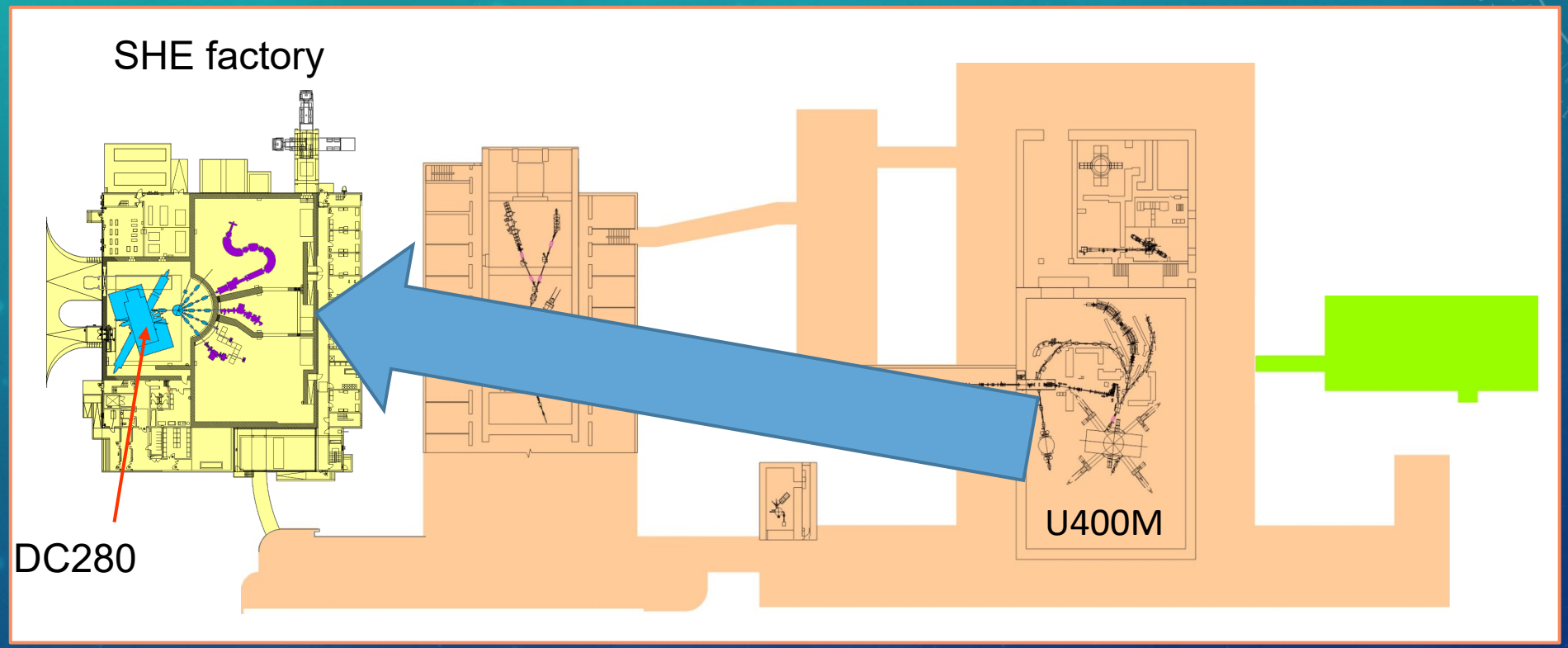
MASHA

- In operation since 2006
- Irradiation by ions with energies up to 50 Mev/A (energy per nucleon)
- Scattered beam ions ($^{7}Li^{2+}$ to $^{132}Xe^{20+}$)
- + products of nuclear reactions (α, β, n, p, products of fission, superheavy nuclei)
- Highest dose at target chamber

MOVING MASHA SETUP TO SHE FACTORY



MOVING MASHA SETUP TO SHE FACTORY



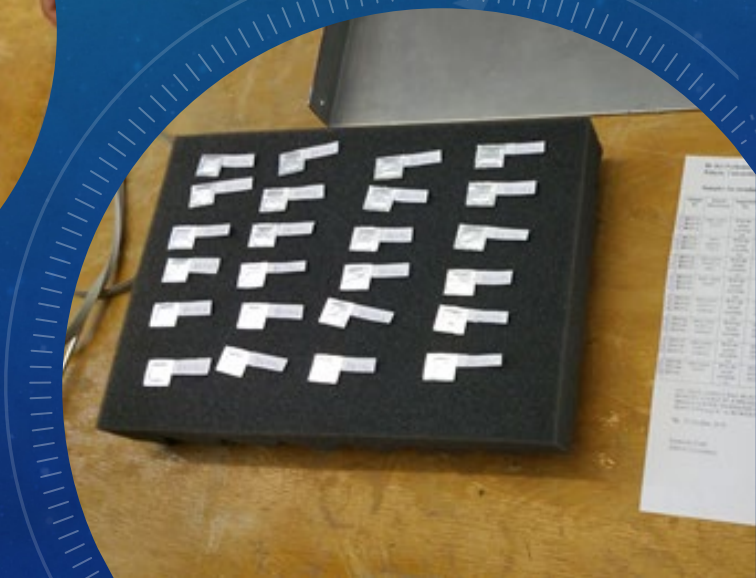
upgrade and mainteance of MASHA

IRRADIATION OF STEEL SAMPLES

- IC-100 particle accelerator
- Ions from ($^{12}C^{+2}$) to argon ($^{40}Ar^{+7}$)
- Ion energy: 0.9 ÷ 1.1 MeV/nucl

IRRADIATION OF IRON SAMPLES

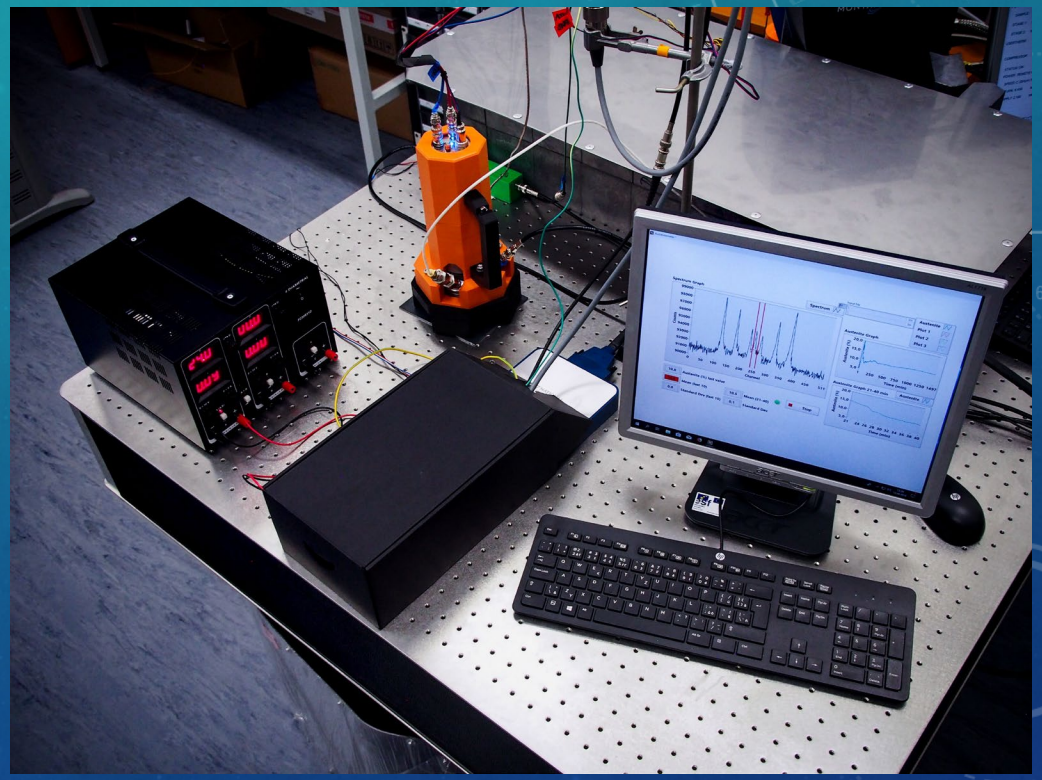
- Emulation of MASHA irradiation
- Testing of various steel alloys
- Testing various surface coatings



INVESTIGATION OF STEEL SAMPLES

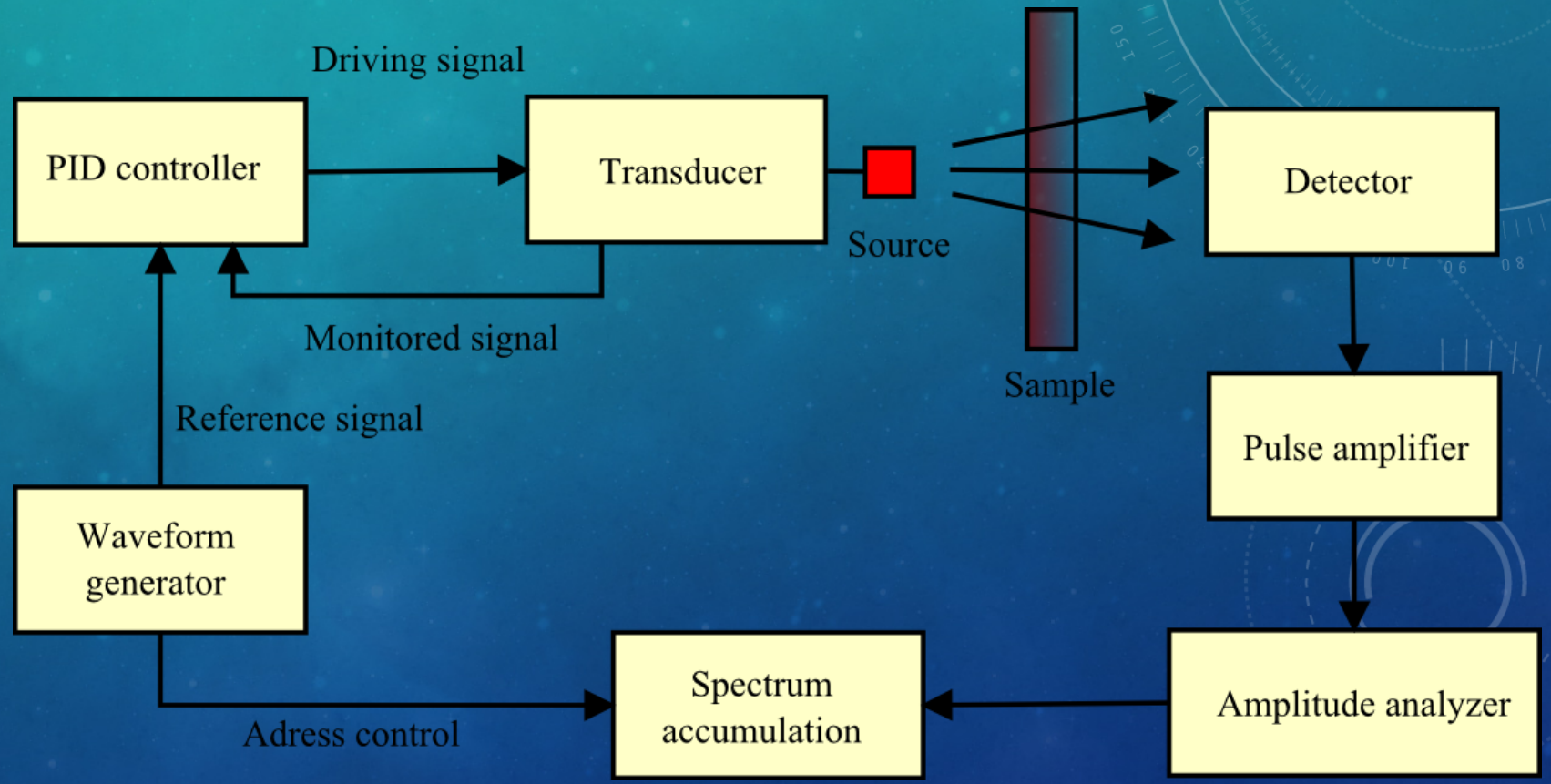
- Mössbauer spectrometry
  - Conversion Electron Mossbauer Spectroscopy (CEMS)
  - Conversion X-ray Mossbauer Spectroscopy (CXMS)
  - Backscattered gamma-ray Mossbauer Spectroscopy (BGMS)
  - Transmision Mossbauer Spectroscopy (TMS)

  Main advantage – non-destructive!
- Scanning Electron Microscopy (SEM)
- X-ray difraction (XRD)



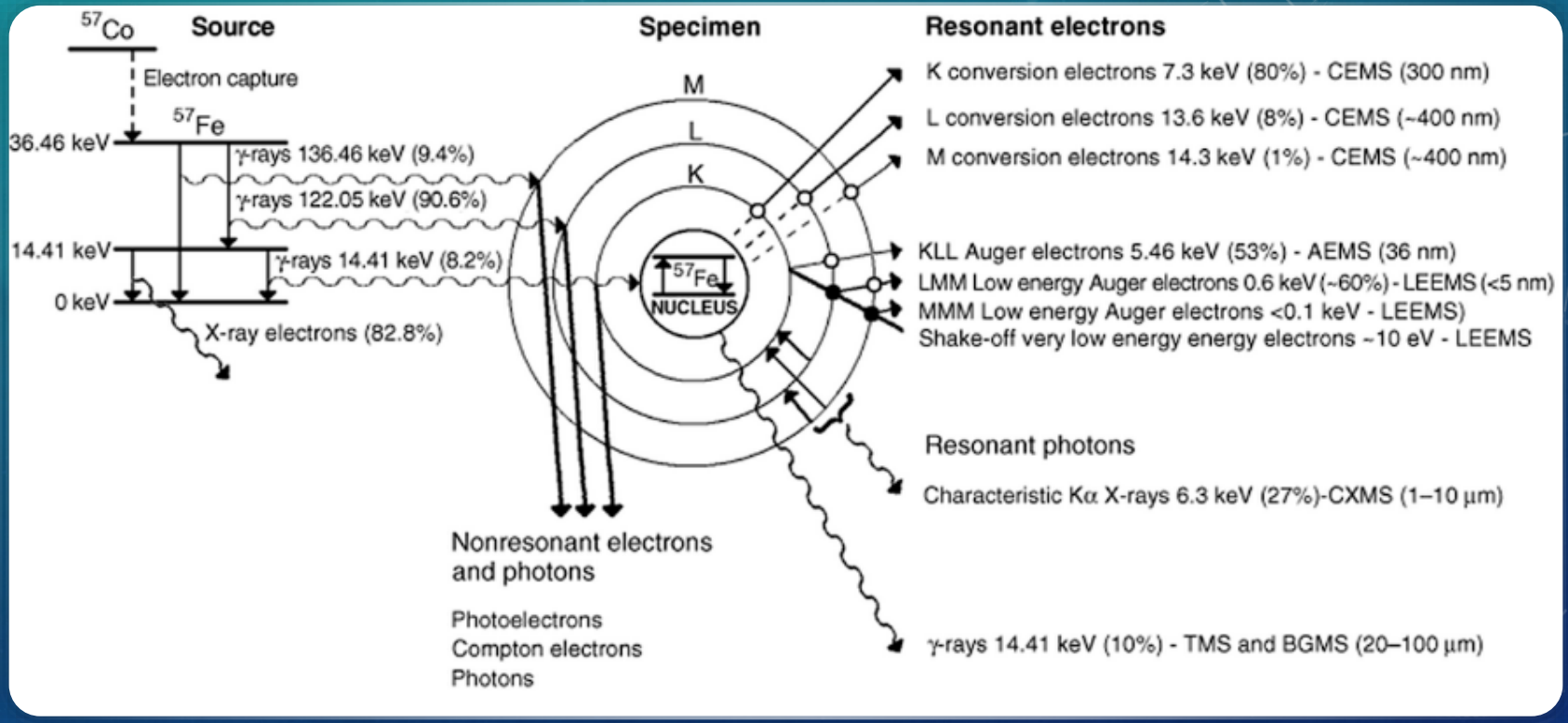
MÖSSBAUER SPECTROSCOPY

- Resonant asorbtion and emission of gamma-rays
- Energy modulated by Doppler effect
- Small energy changes reveals hyperfine structure of nuclei
- Hyperfine structure shows nuclei neighborhood (crystallic structure, chemical composition, magnetic properties)

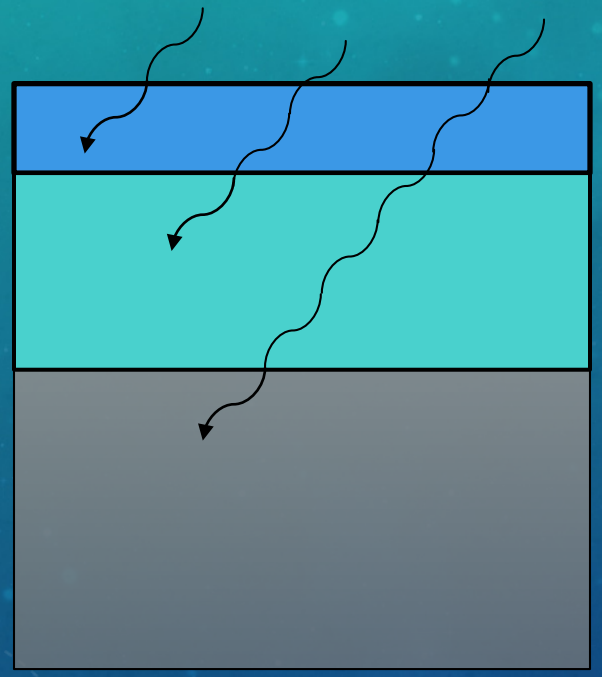


MÖSSBAUER SPECTROSCOPY

- Methods uses:
- CEMS (penetrates to depth of cca 400 nm)
- CXMS (penetrates to depth of cca cca 10 um)
- BGMS or TMS (for bulk material)

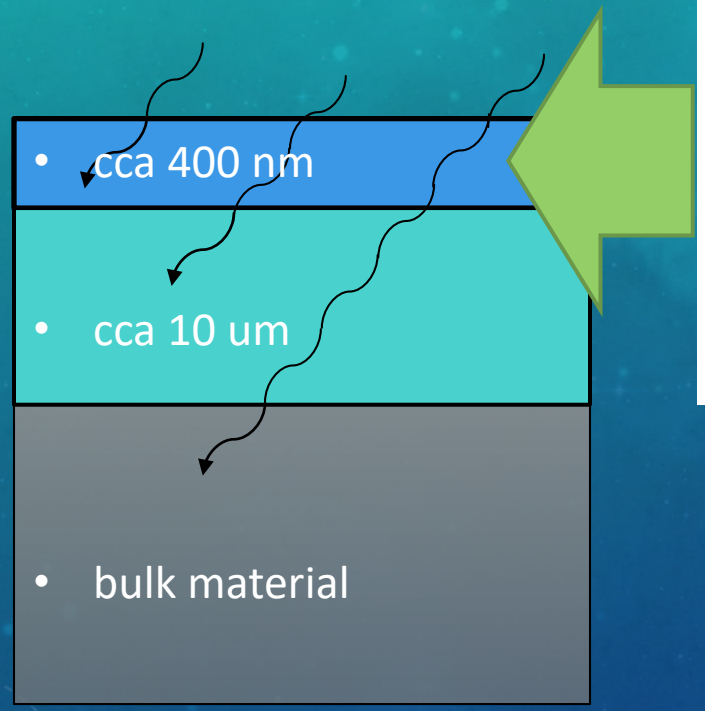


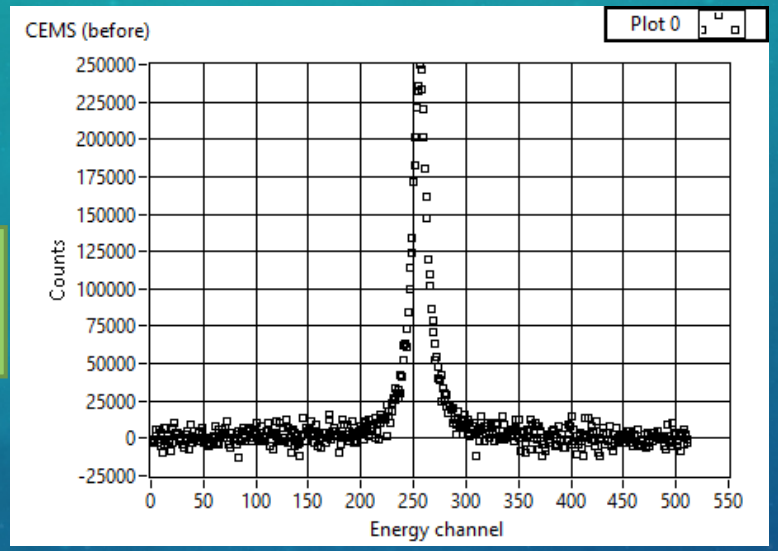
MOSSBAUER SPECTROSCOPY DEPTH SELECTIVITY



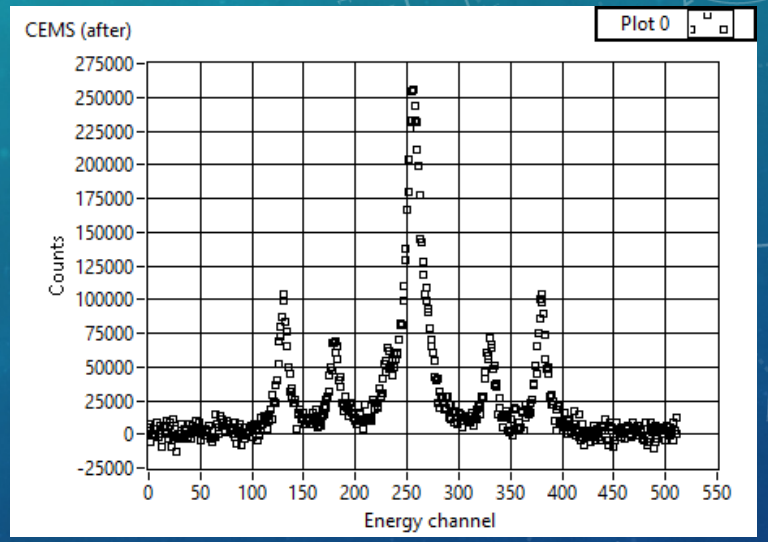
- CEMS (cca 400 nm)
- CXMS (cca 10 um)
- BGMS or TMS (bulk material)

PRELIMINARY RESULTS



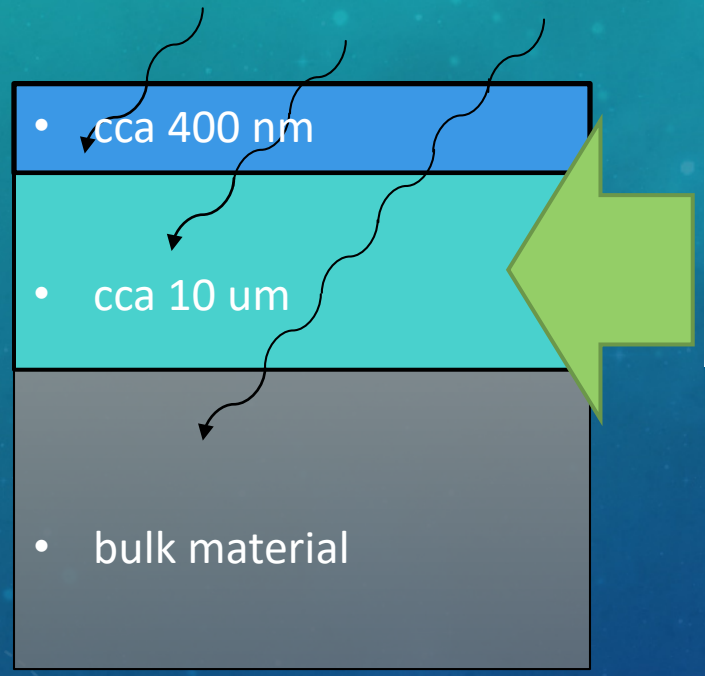


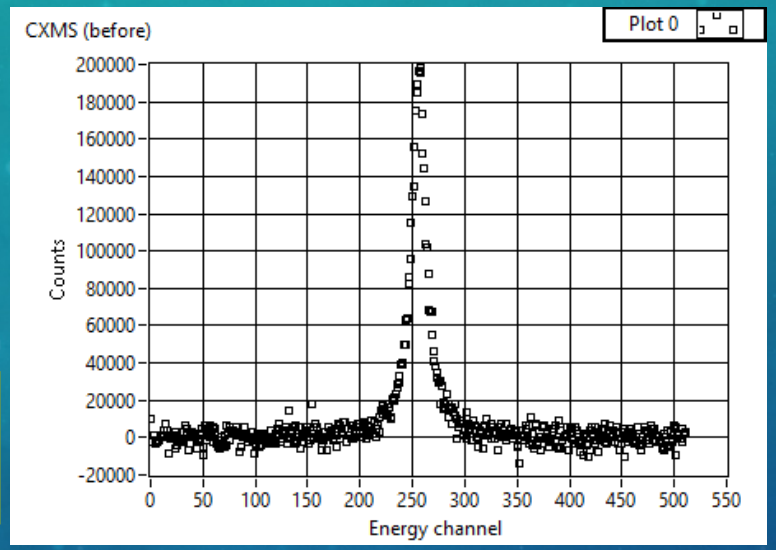
Austenitic stainless steel



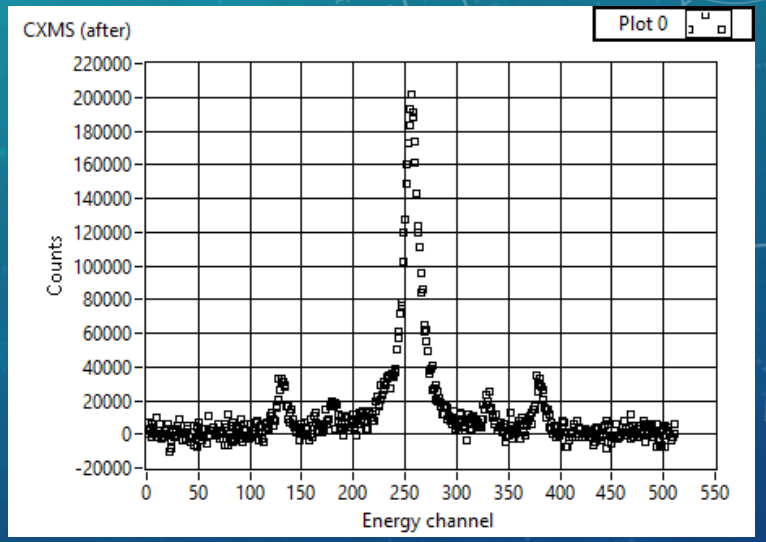
Austenitic stainless steel + Fe_2O_3 + Fe_3O_4

PRELIMINARY RESULTS



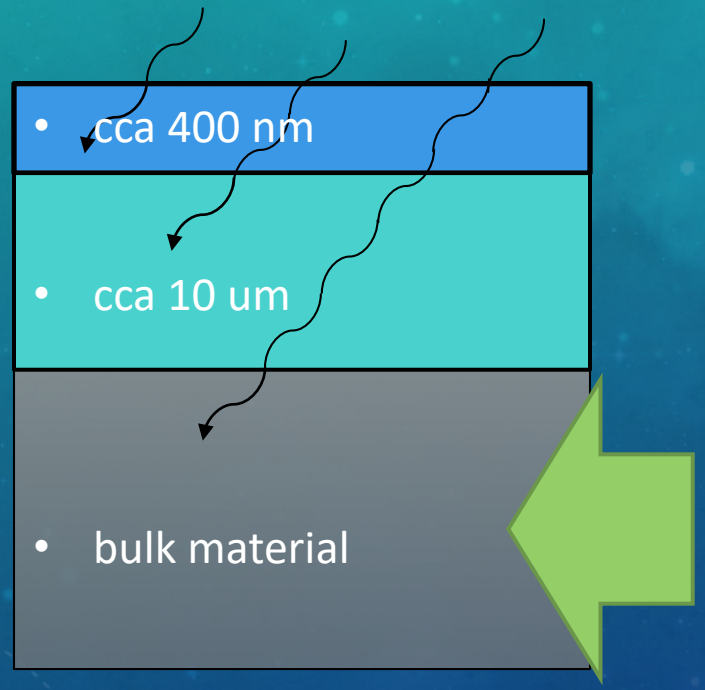


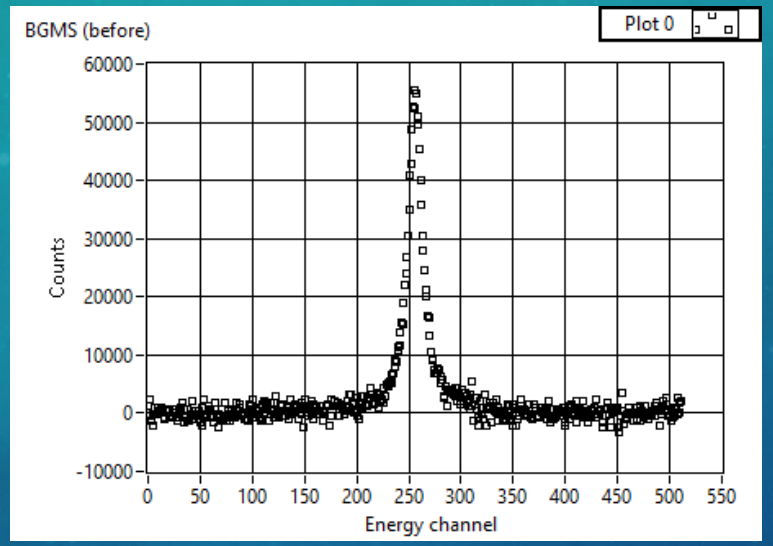
Austenitic stainless steel



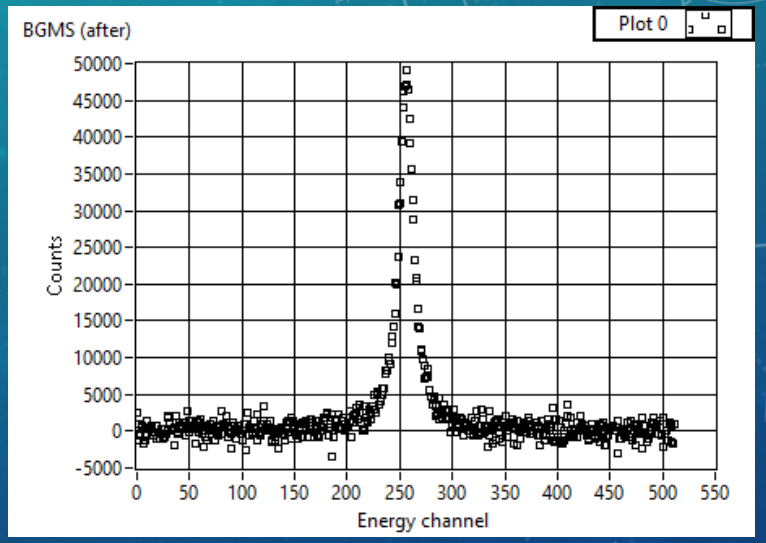
Austenitic stainless steel + Fe_2O_3 + Fe_3O_4

PRELIMINARY RESULTS





Austenitic stainless steel



Austenitic stainless steel (no Fe_2O_3)

WHAT NEXT?

- Investigation of irradiated samples by other methods
- Investigation of real MASHA parts (scheduled on 2020)

THANK YOU FOR YOUR ATTENTION!