Physics with neutrons (PH2053)

Prof. Dr. Peter Müller-Buschbaum (TUM)
Prof. Dr. Winfried Petry (TUM)

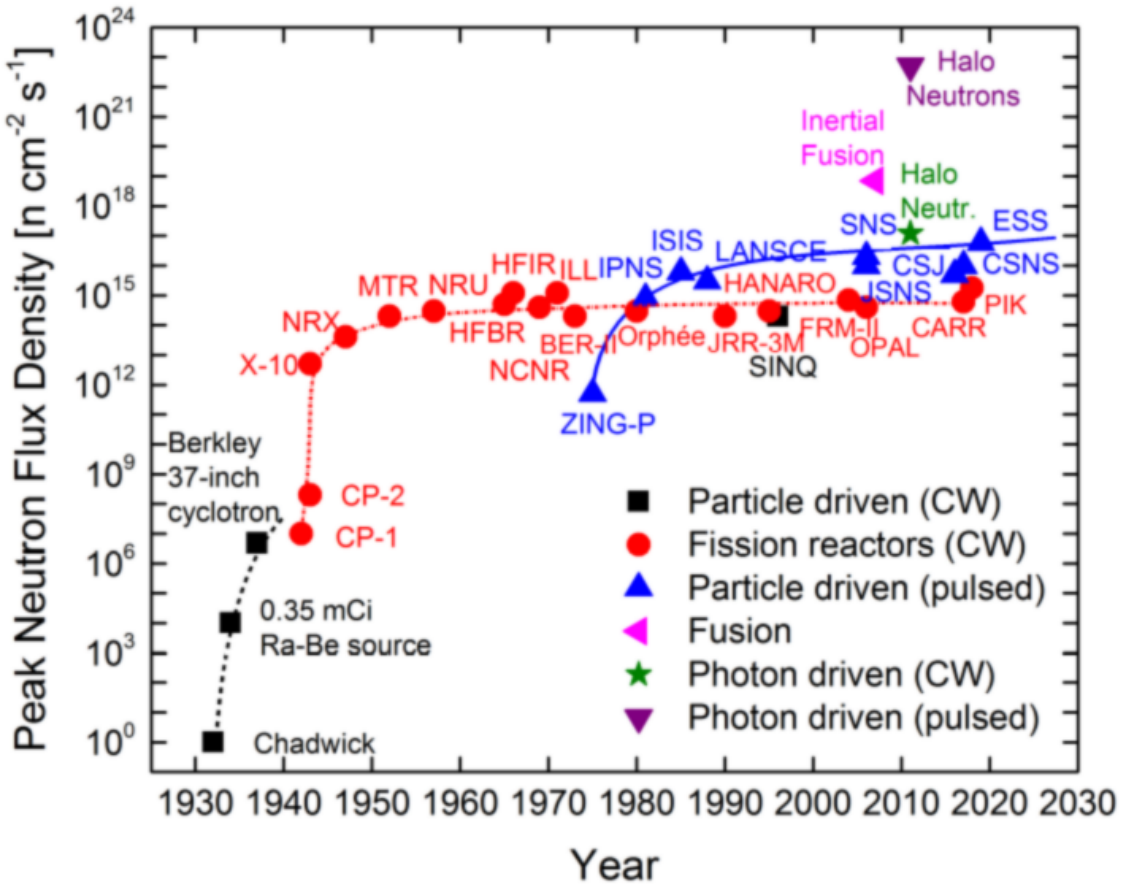
Dr. Sebastian Busch

German Engineering Materials Science Centre (GEMS)
at Heinz Maier-Leibnitz Zentrum (MLZ)
Helmholtz-Zentrum Geesthacht
Garching bei München, Germany

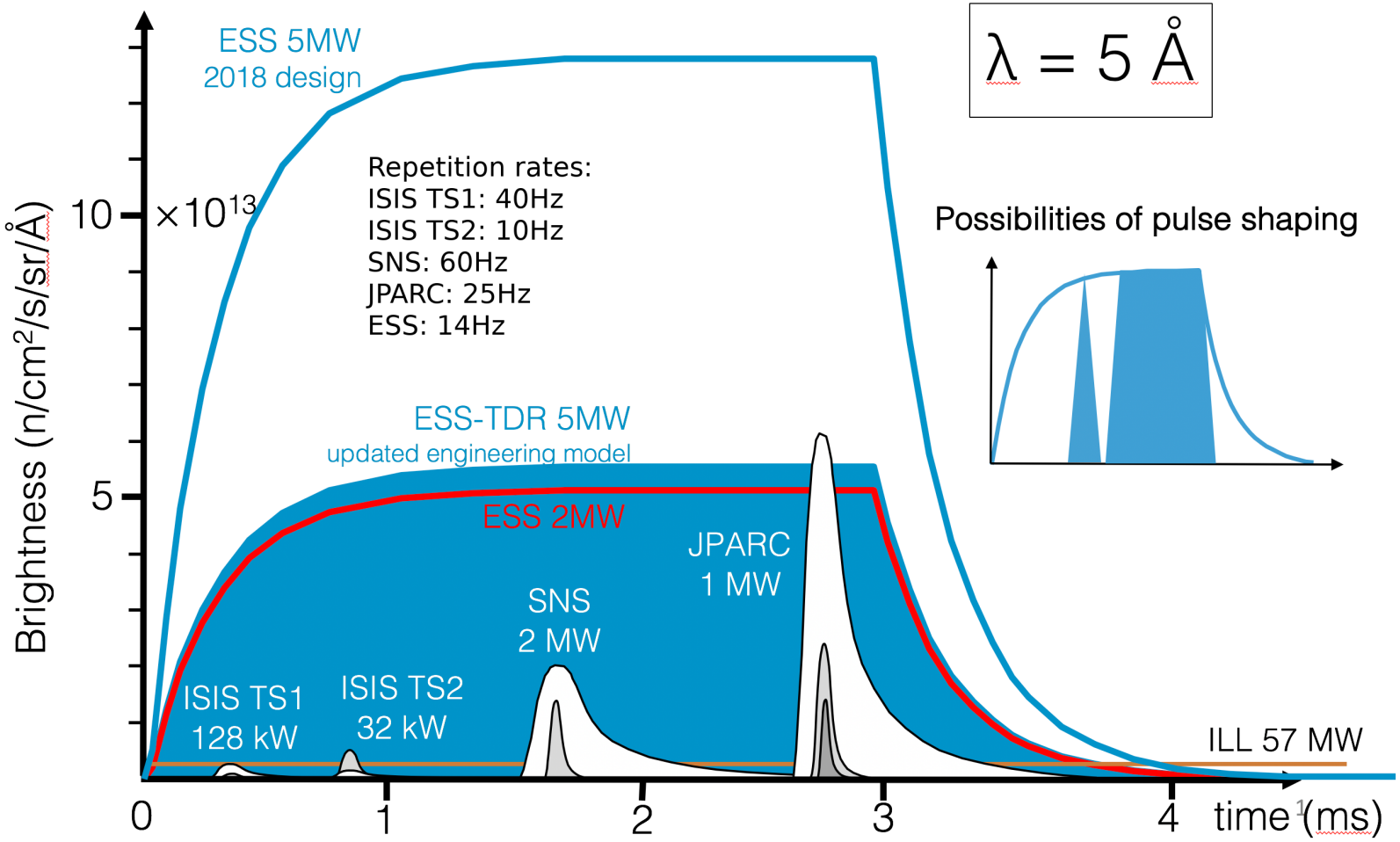
Lecture 02

2018–Oct–24

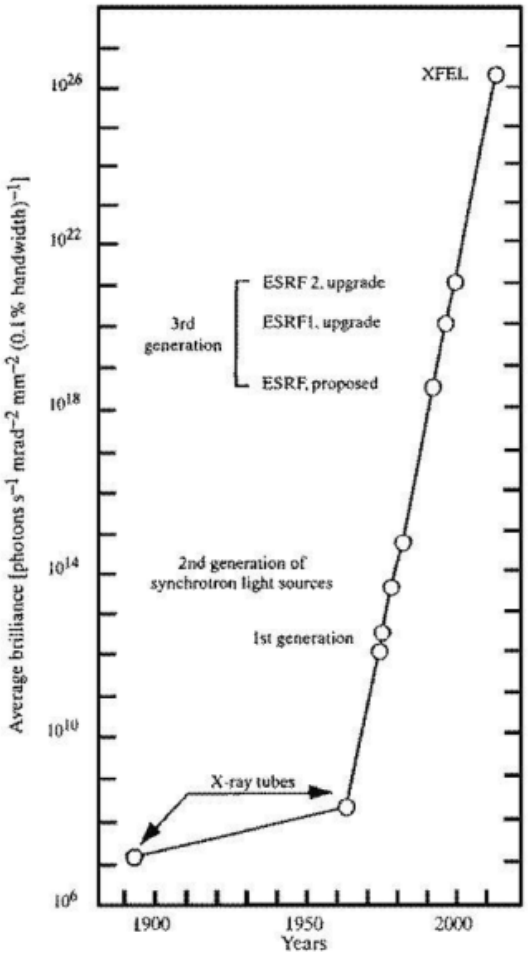
Reactor vs. spallation sources



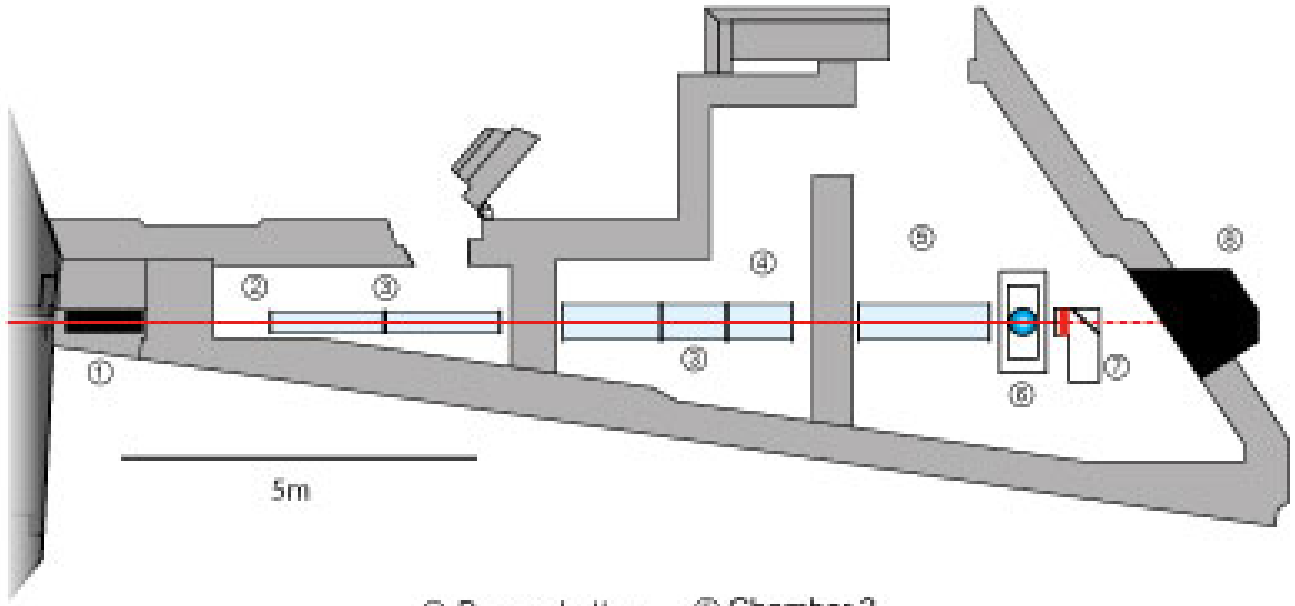
Most spallation sources are pulsed



X-rays have an advantage here...

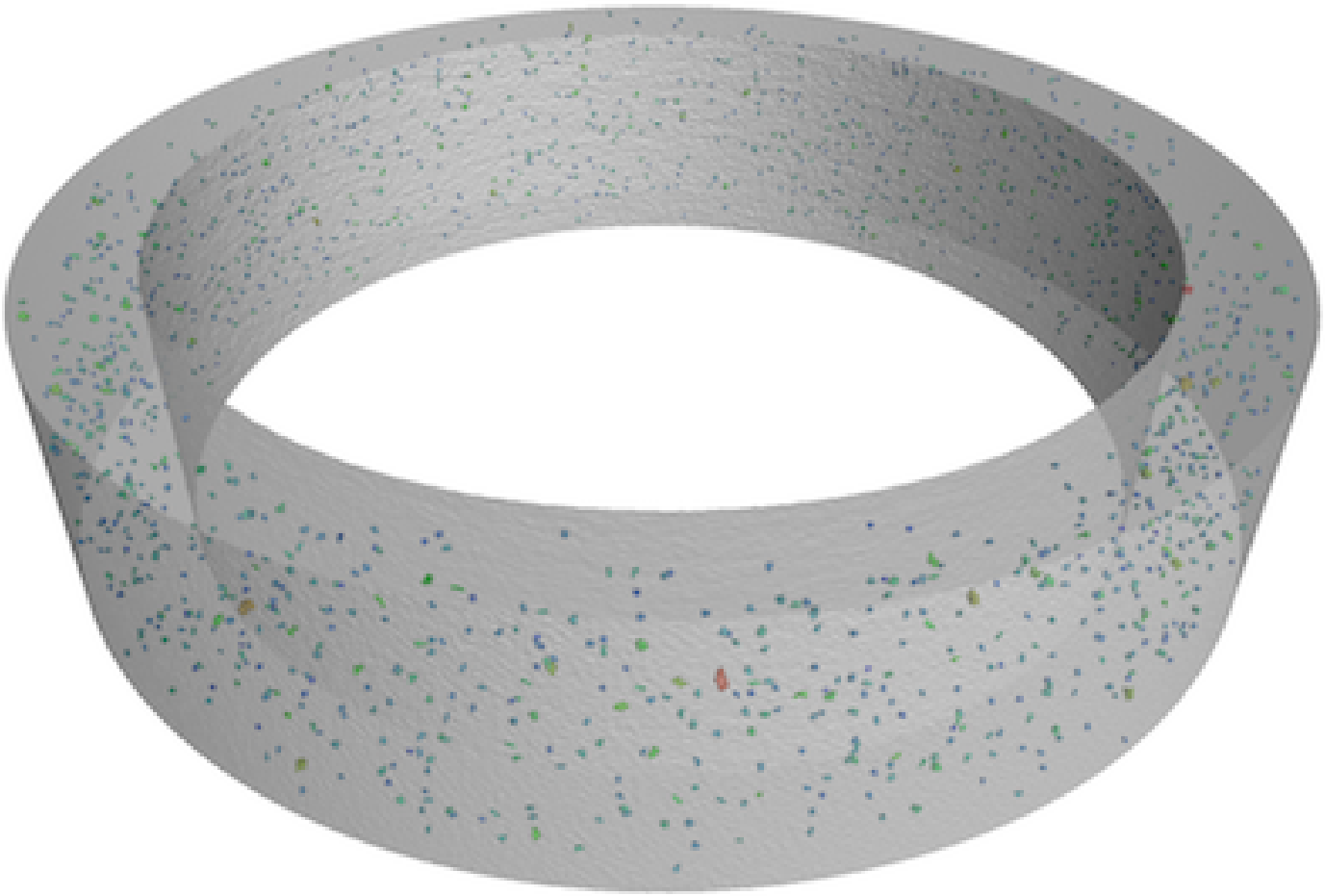


ANTARES @ MLZ

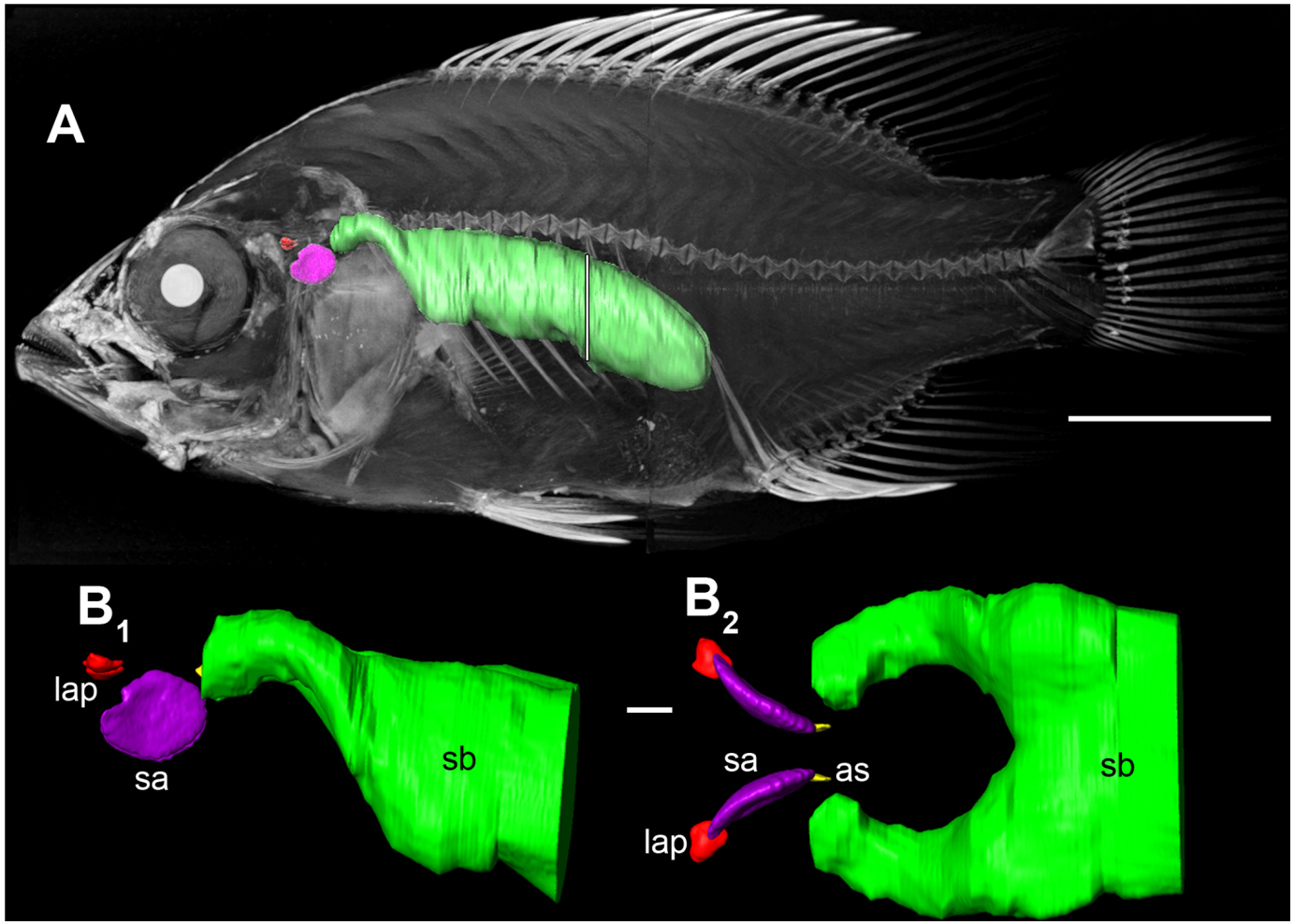


① Beam shutter
② Chamber 1
③ Flight tubes
④ Chamber 2
⑤ Chamber 3
⑥ Sample space
⑦ Detector
⑧ Beam stop

Porosity or precipitates? (x-ray)

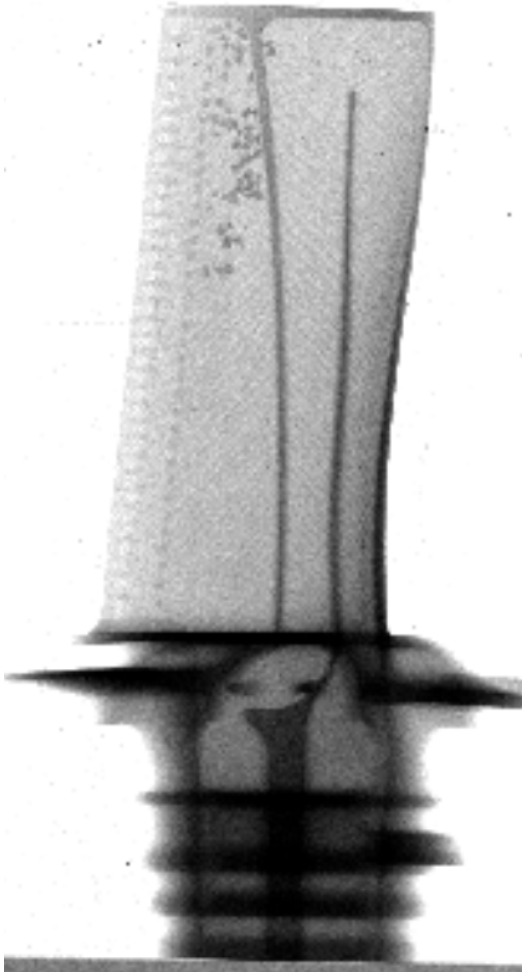


How do fish hear? (x-ray)



— DOI: 10.1371/journal.pone.0042292

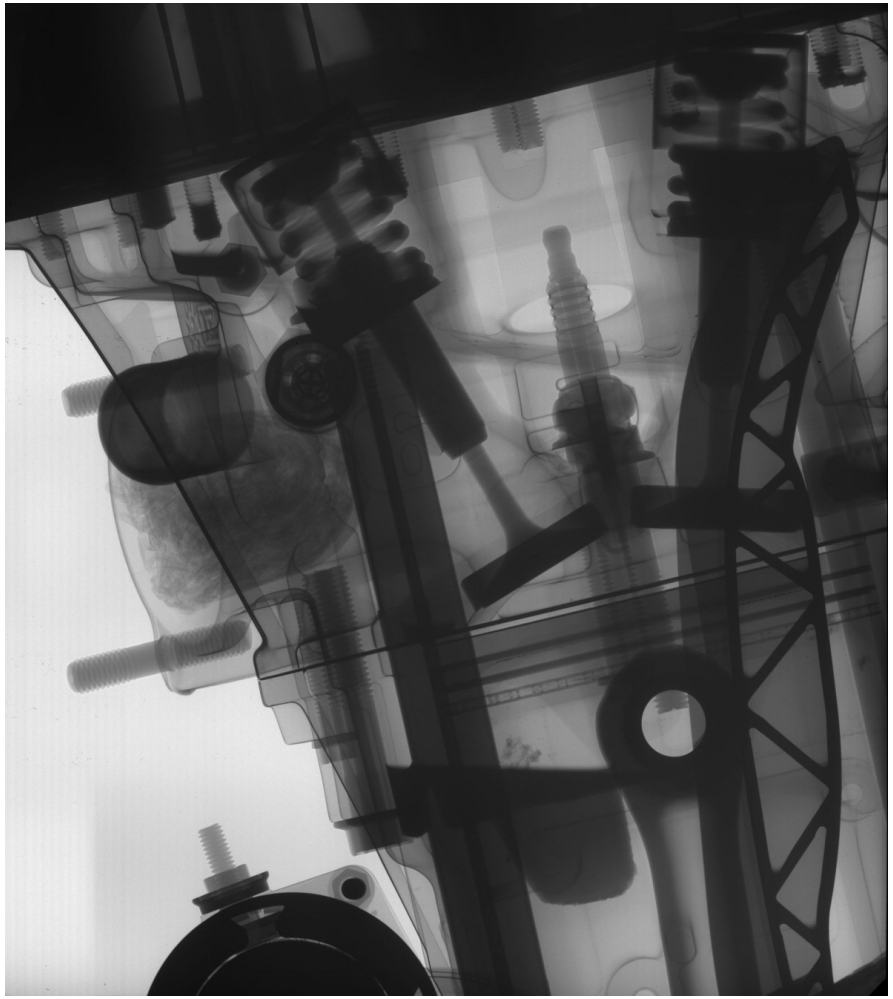
Large penetration depth: neutrons



Sensitive to hydrogen: neutrons

Car engine

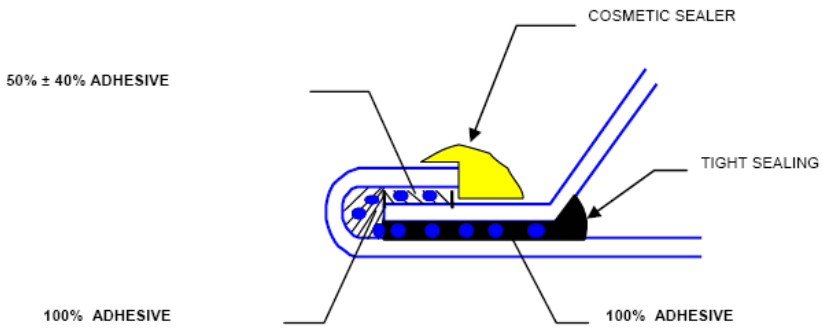
Car engine



Car engine

— DOI: 10.1016/j.physb.2006.05.250

Glue in a car door



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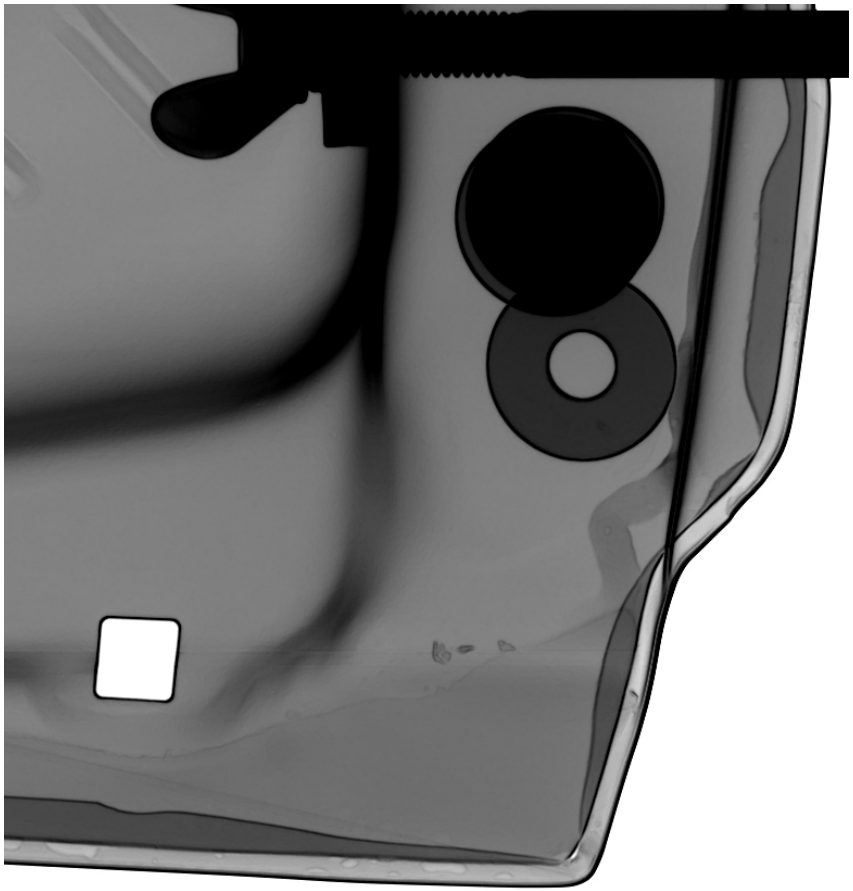
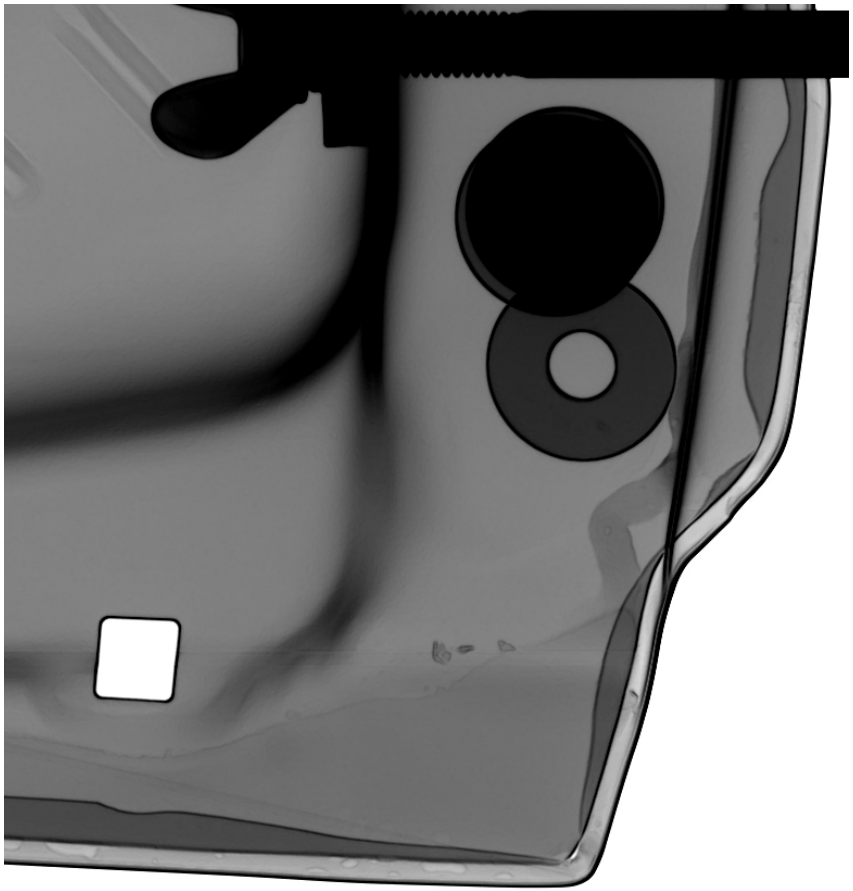
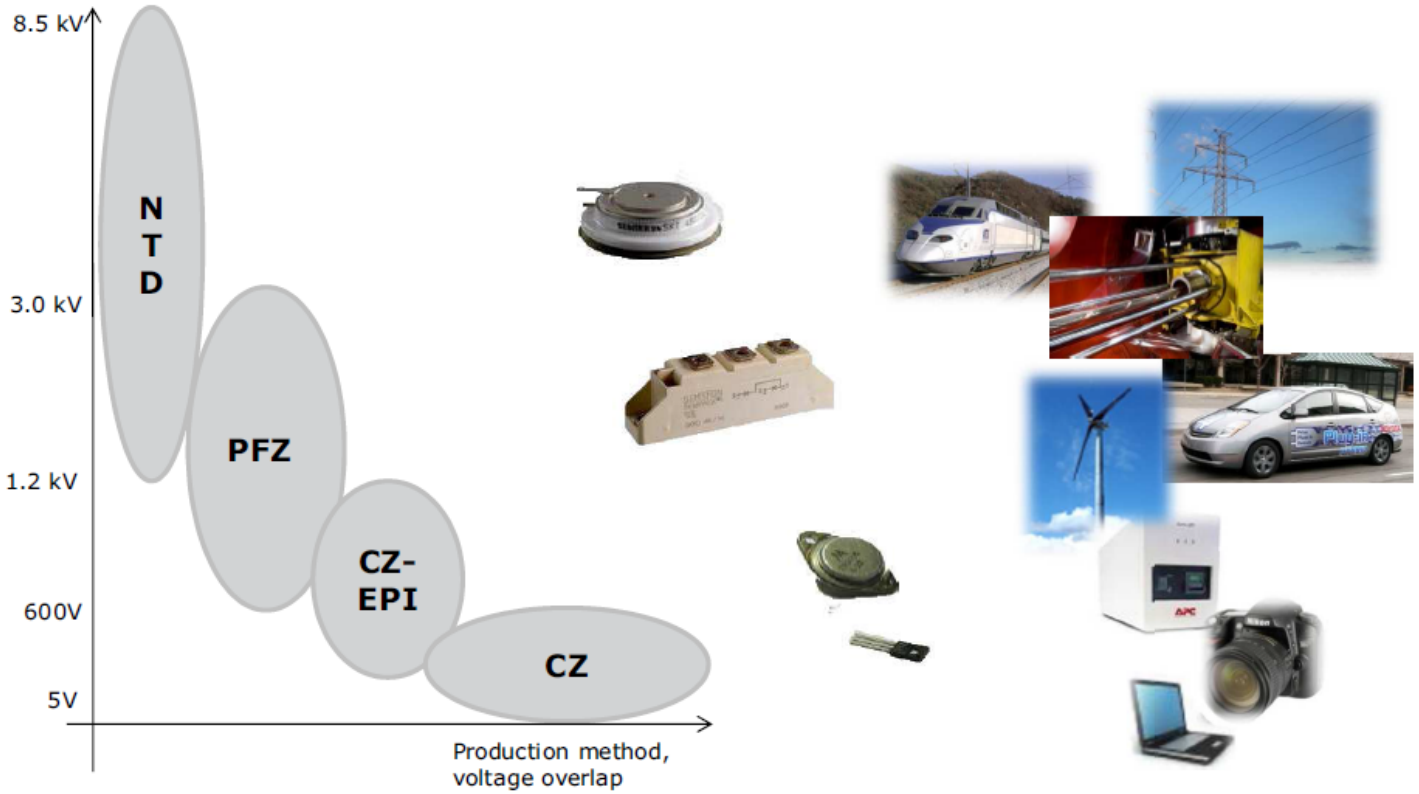


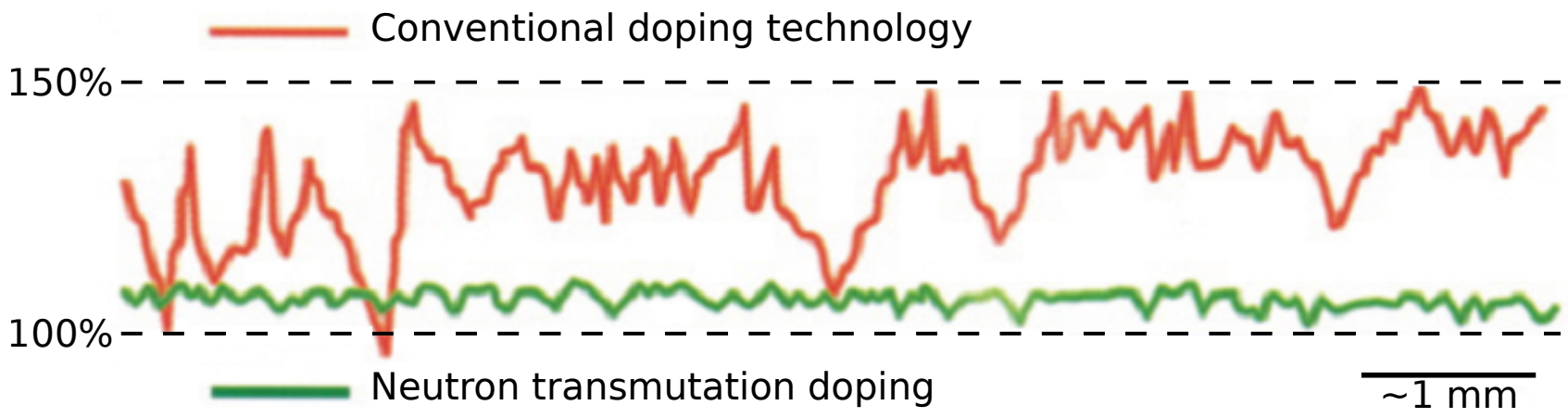
Glue in a car door



Si doping

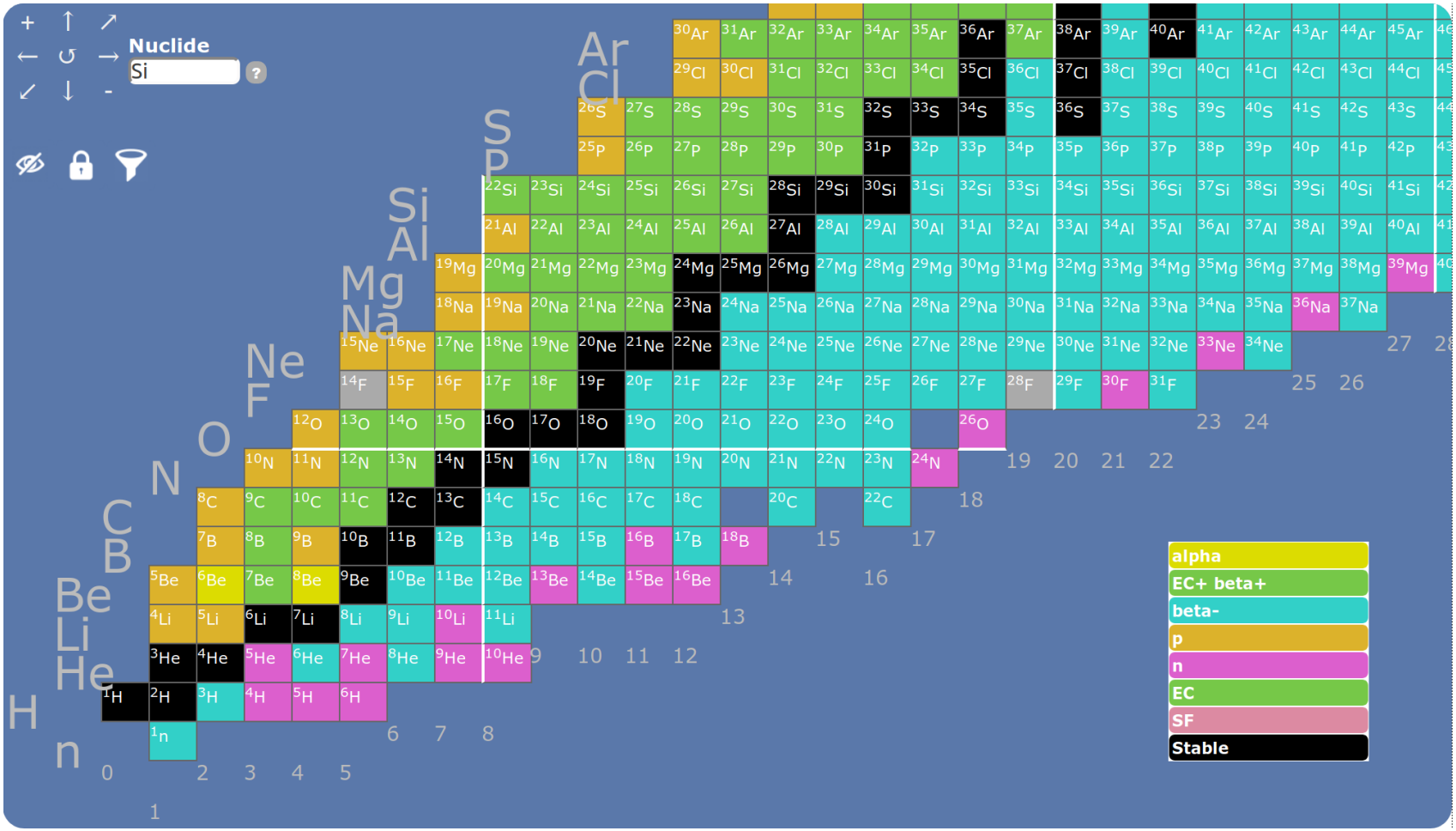

8.5 kV
3.0 kV
1.2 kV
600V
5V
NTD
PFZ
CZ-EPI
CZ
Production method, voltage overlap

Si doping


Conventional doping technology
150%
100%
Neutron transmutation doping
~1 mm

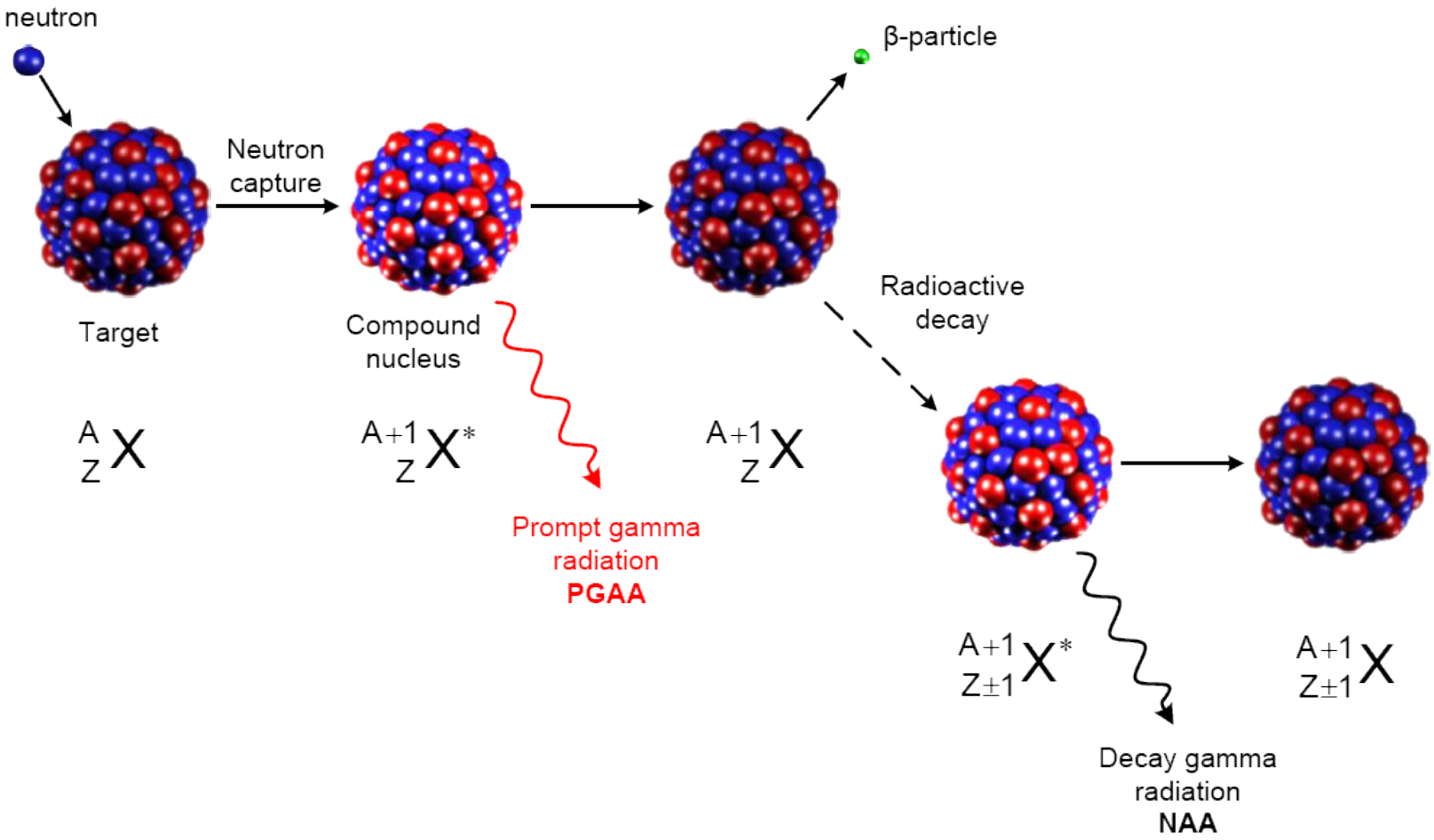
Si doping

$$^{30}\mathrm{Si} + \mathrm{n} \rightarrow {}^{31}\mathrm{Si}^{*} \xrightarrow{T_{1/2}=2.62\,h} {}^{31}\mathrm{P} + \mathrm{e}^{-} + \gamma$$



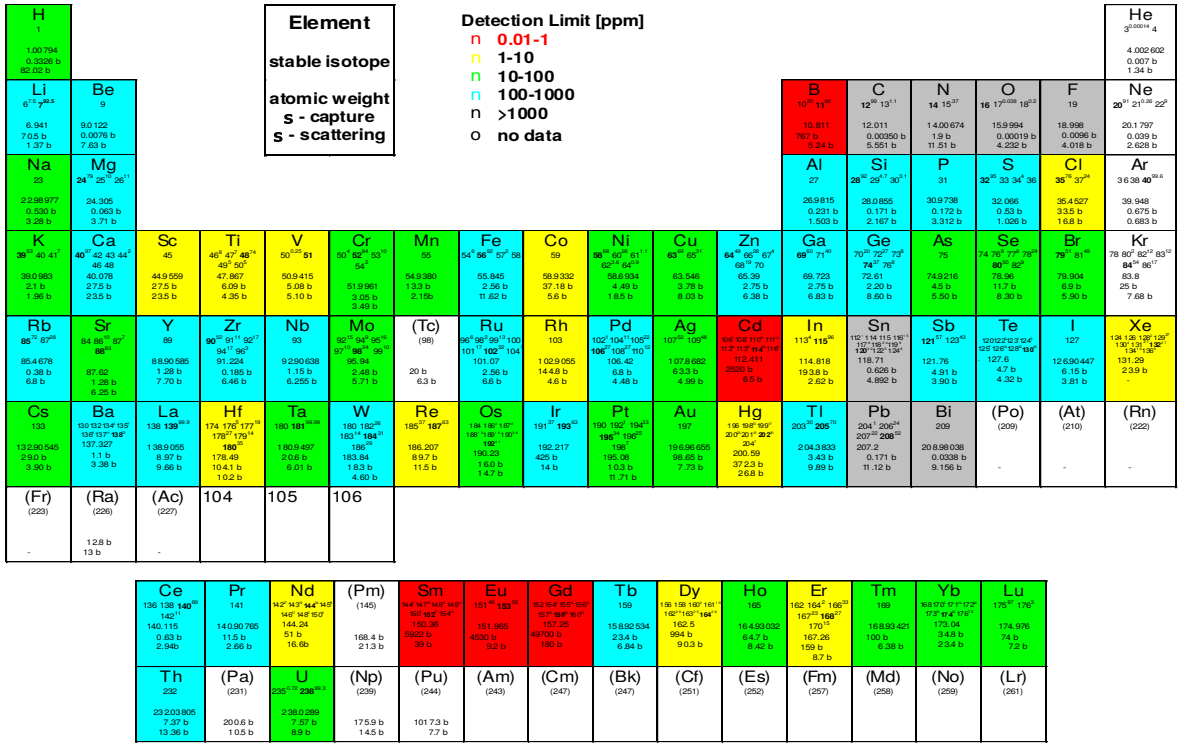
— https://www-nds.iaea.org/relnsd/vcharthtml/VChartHTML.html

Activation Analysis



PGAA

Periodic Table for PGAA



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NAA

Periodic Table for NAA

No light elements!

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
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
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
55 Cs	56 Ba	57 [1]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
87 Fr	88 Ra	89 [2]Ac	104 Rf	105 Db													

[1]Lanthanide	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
[2]Actinide series	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

- No n-gamma radioactive isotopes
- Radioactive isotopes can be produced. Limitation is short half-life or flux energy
- Elements routinely determined by INAA

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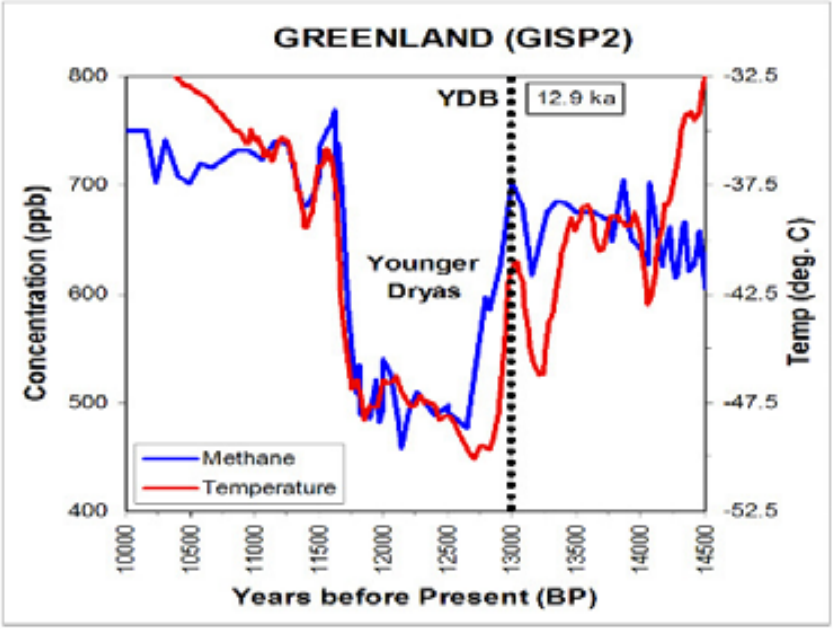
Tracing the origin of stones



— R. B. Firestone et al., Journal of Siberian Federal University. Engineering & Technologies 2010, 3(1), 30-62

Tracing the origin of stones

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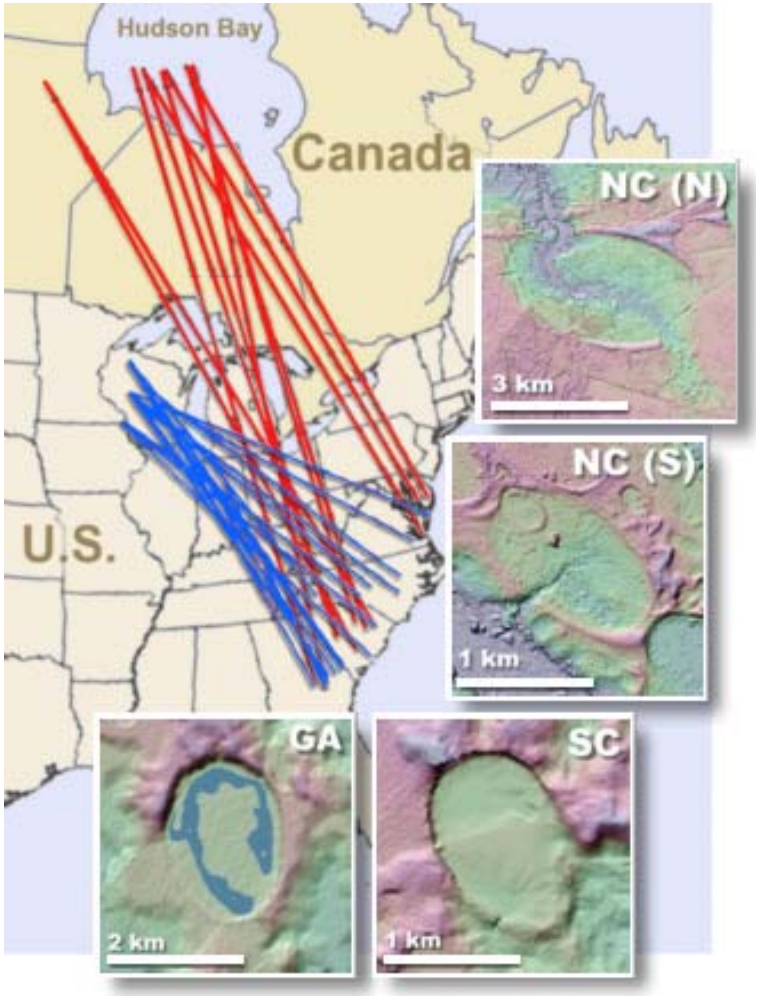

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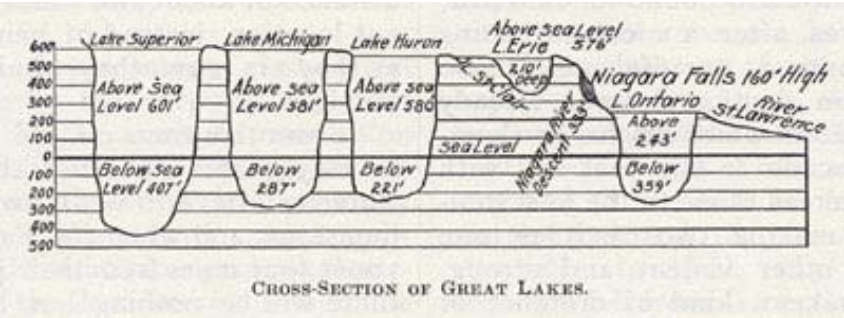
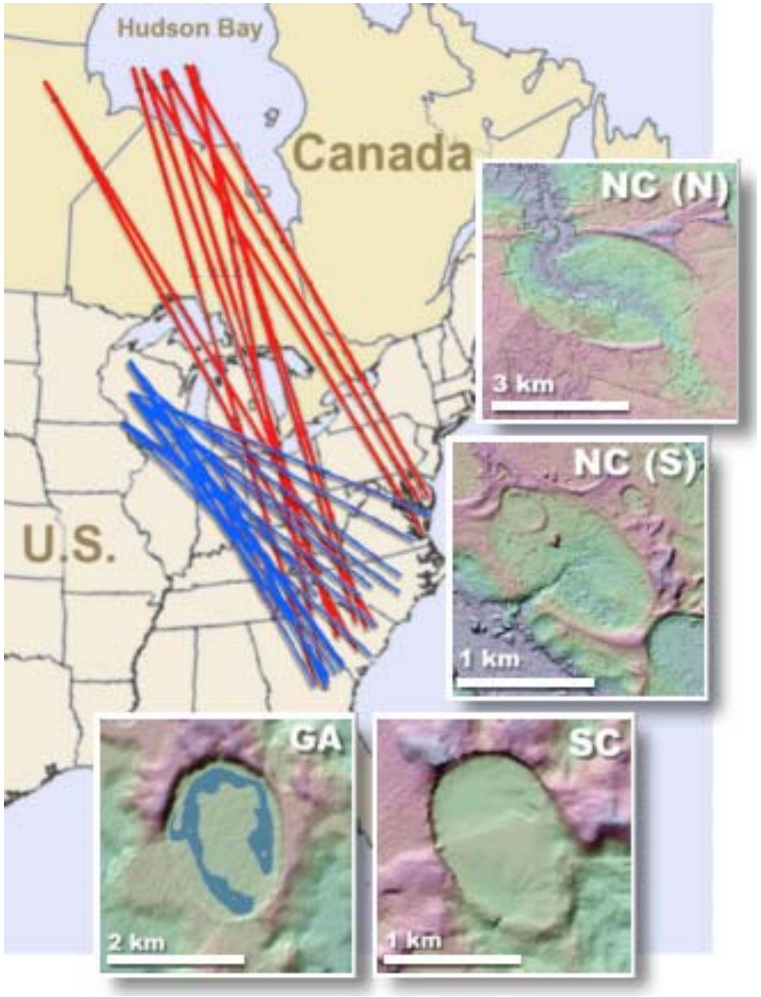


Cross-Section of Great Lakes.



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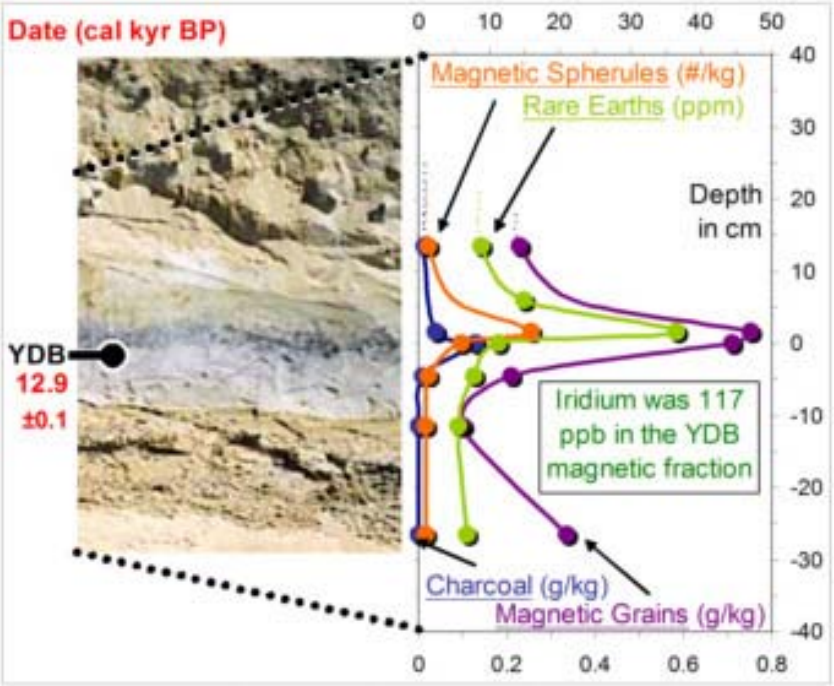

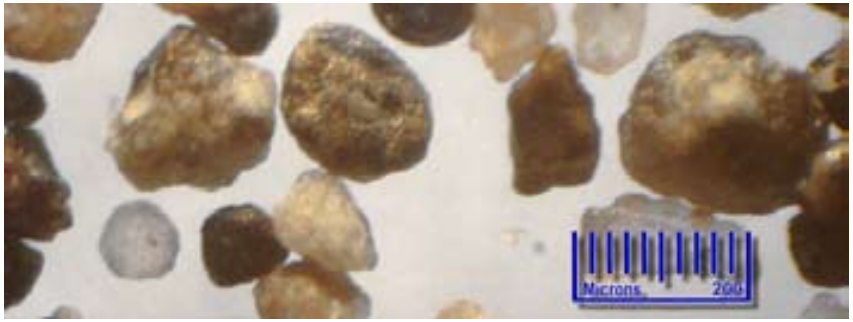

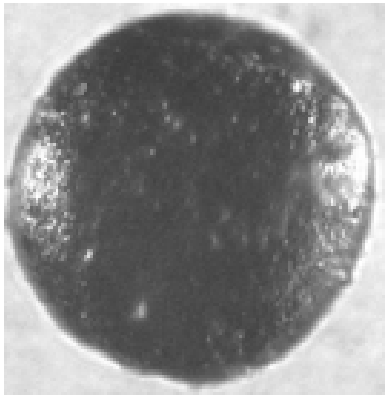

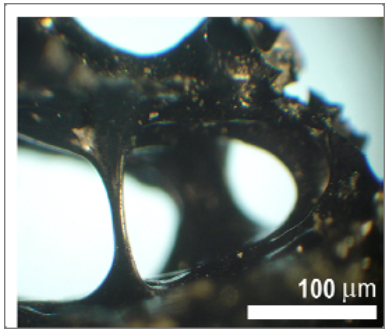

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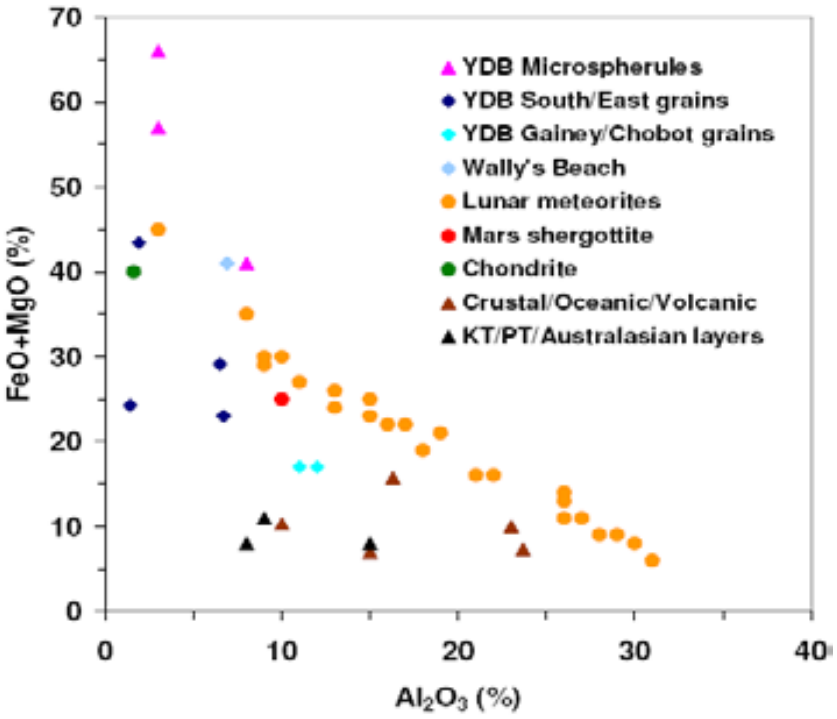

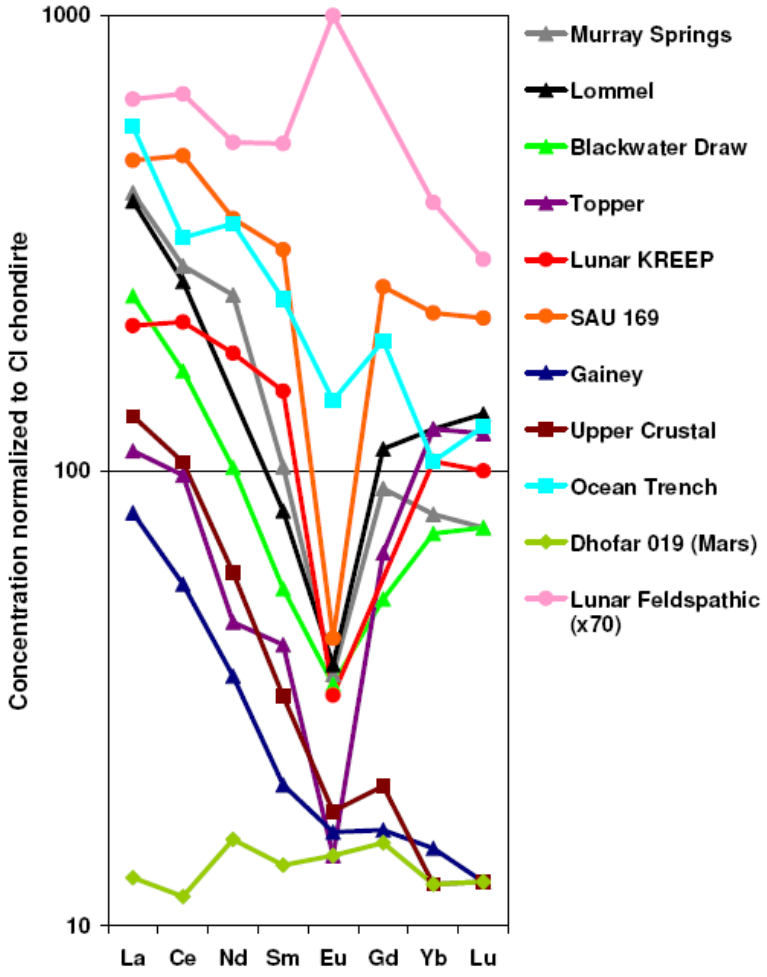

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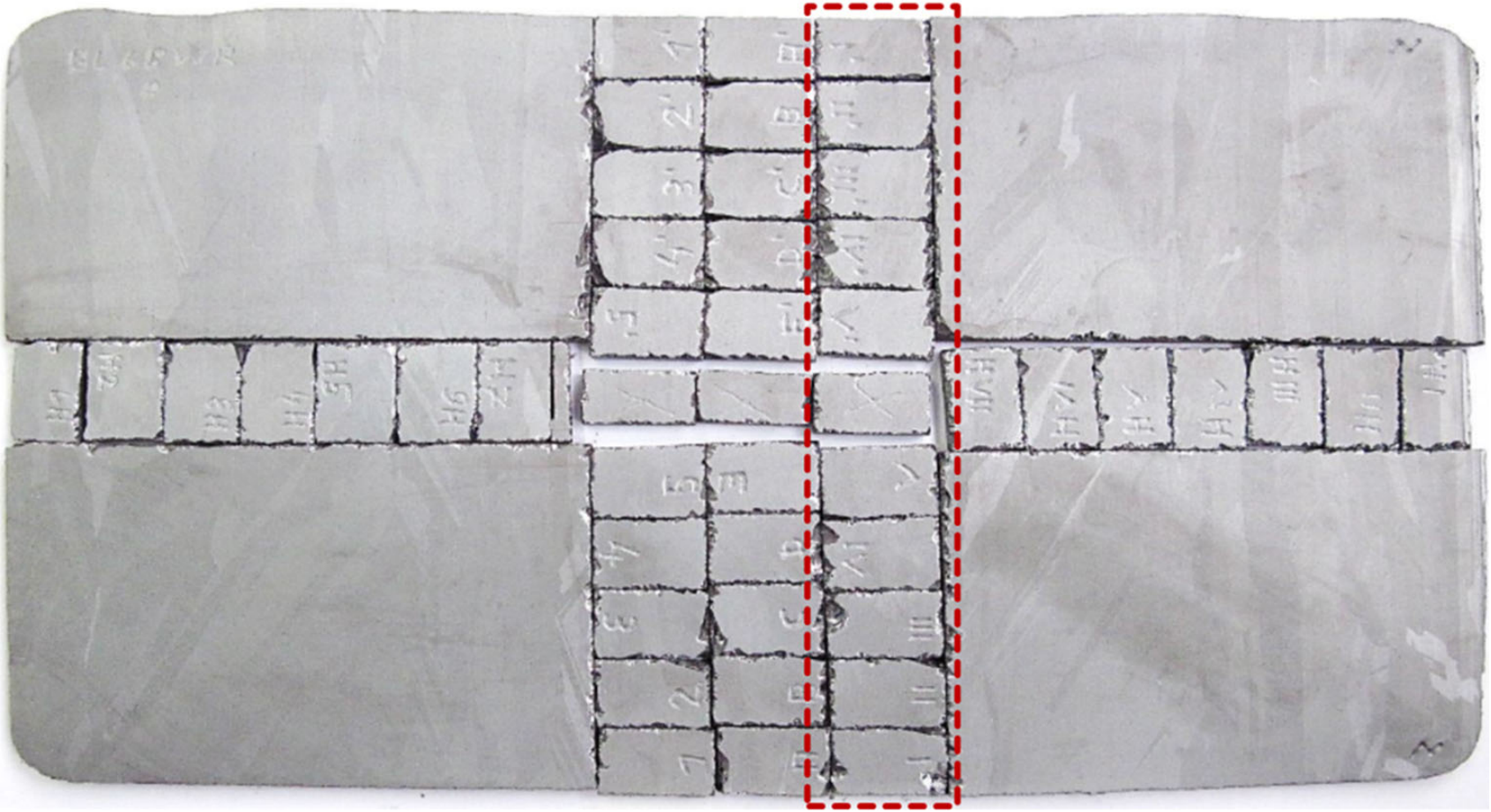
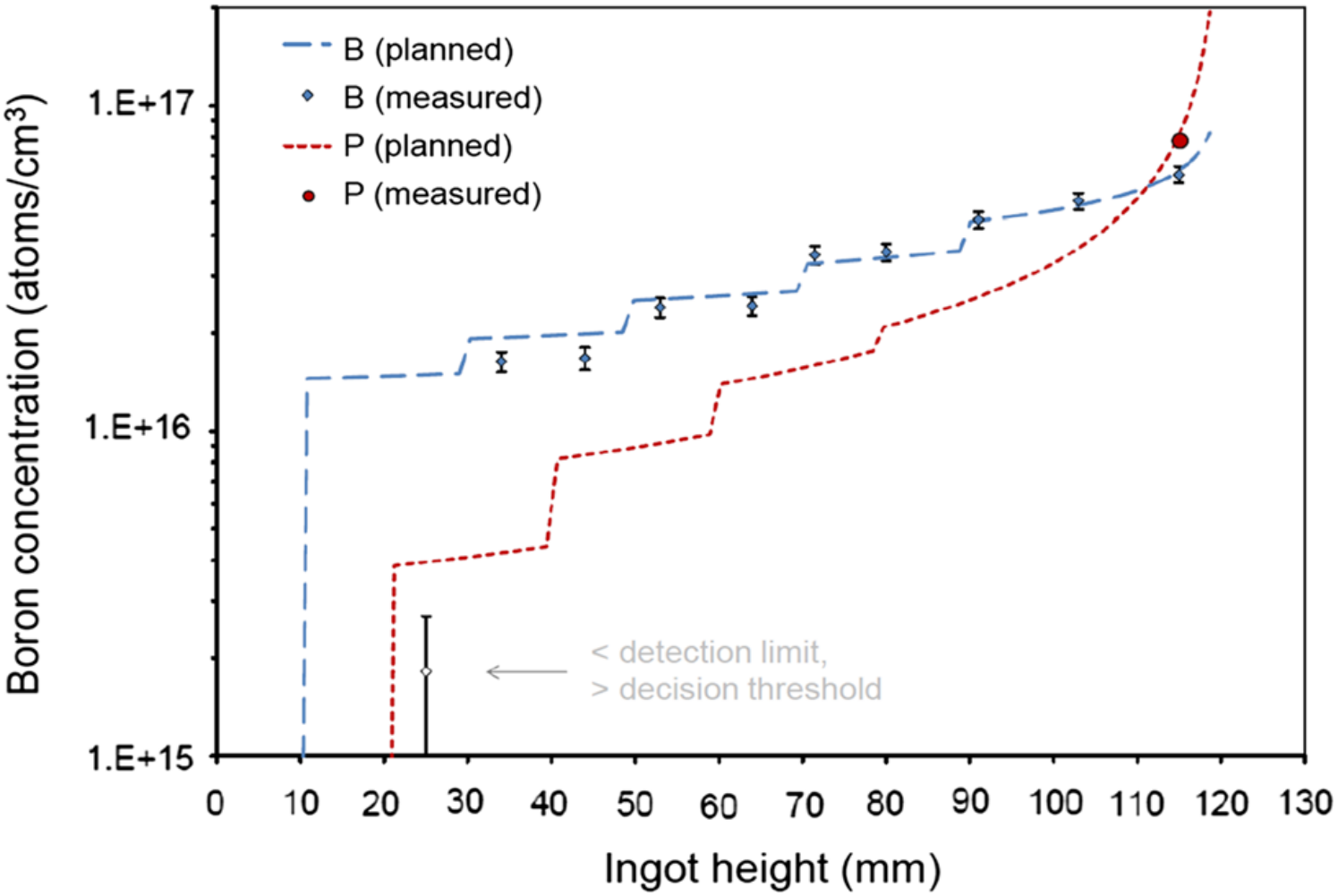
Boron concentration in multicrystalline Silicon



$^{10}B + n \rightarrow {}^{7}Li\ (0.840\,MeV) + \alpha\ (1.470\,MeV) + \gamma\ (0.482\,MeV)$

— DOI:10.1007/s10967-018-5880-7

Boron concentration in multicrystalline Silicon

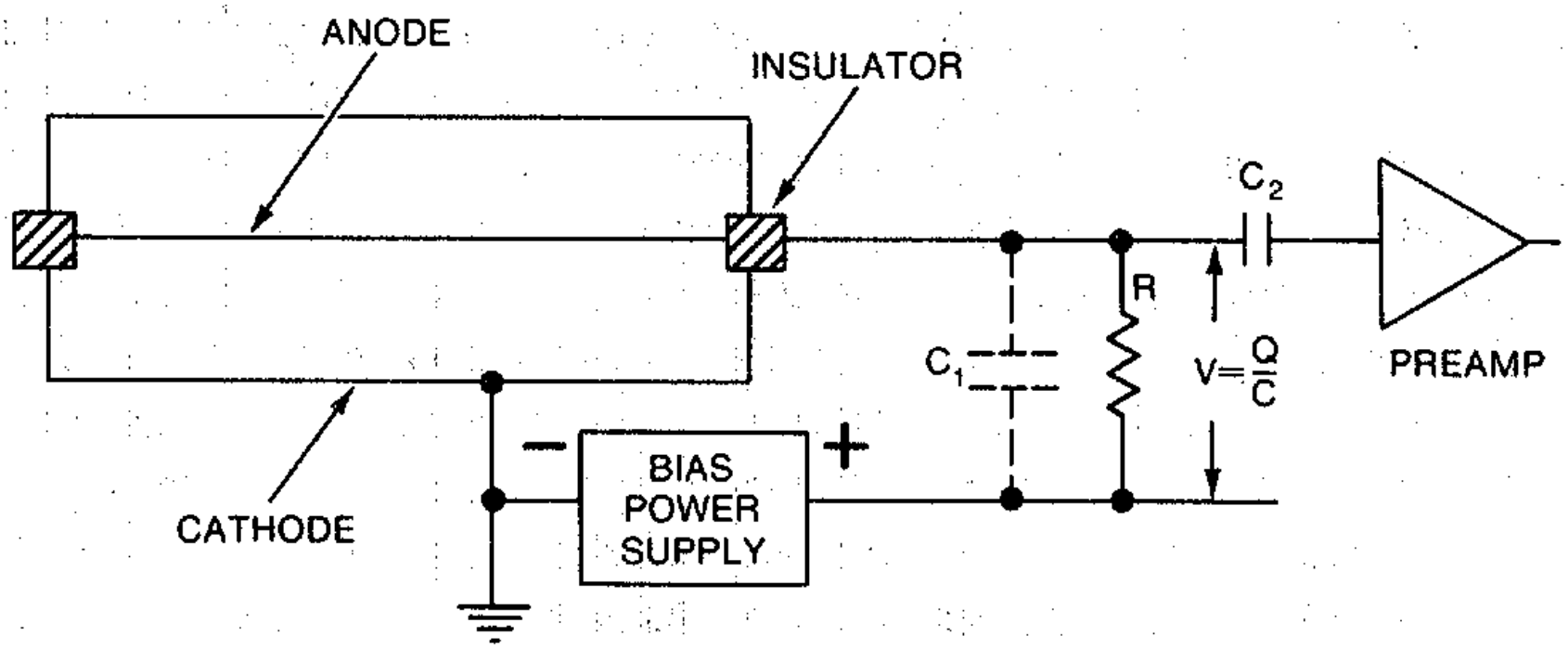


— DOI:10.1007/s10967-018-5880-7

^{10}B neutron detectors: BF_3 gas

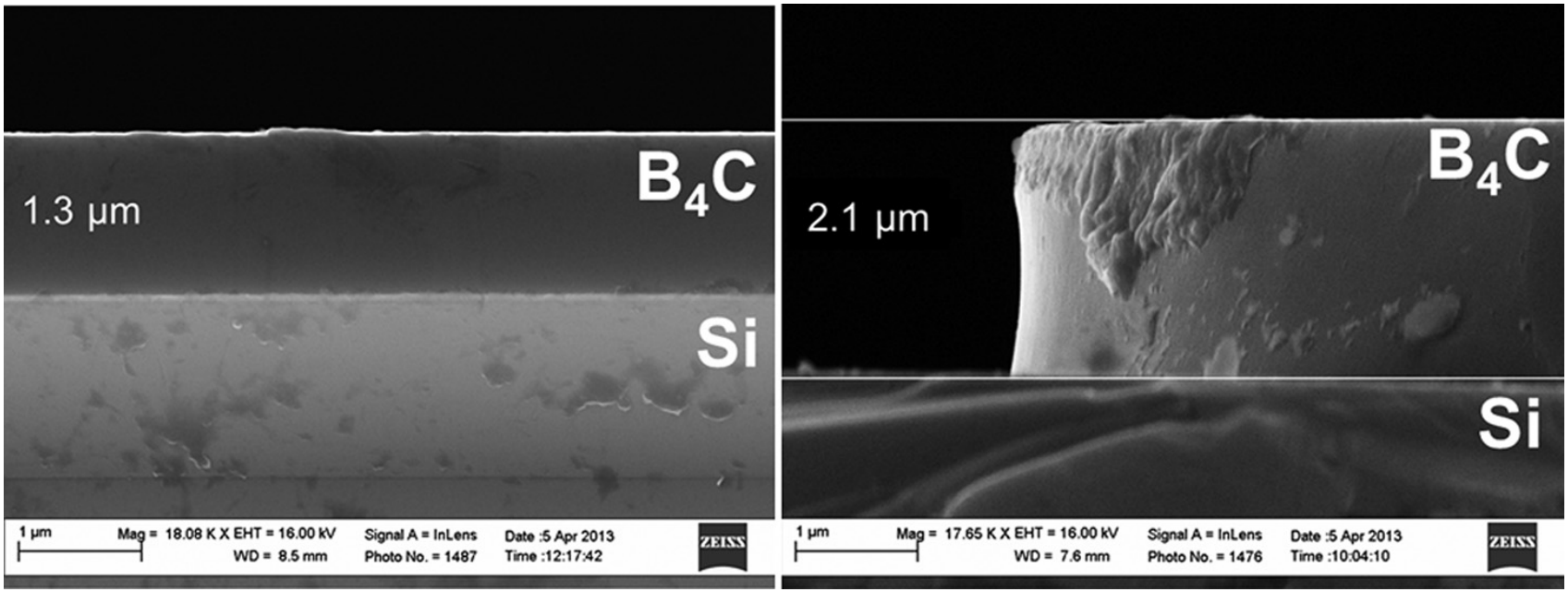
$^{10}B + n \rightarrow {}^{7}Li\ (0.840\,\text{MeV}) + \alpha\ (1.470\,\text{MeV}) + \gamma\ (0.482\,\text{MeV})$

^{10}B: $\sigma_{abs} = 3835\,\text{barn}$ at $1.8\,\text{Å}$



— https://www.ncnr.nist.gov/resources/n-lengths/

^{10}B neutron detectors: solid state



— DOI: 10.1063/1.4905716

^{3}He detectors

$^3\mathrm{He} + \mathrm{n} \rightarrow {}^3\mathrm{H}\ (0.191\,\mathrm{MeV}) + \mathrm{p}\ (0.573\,\mathrm{MeV})$
^{3}He: $\sigma_{\mathrm{abs}} = 5333\,\mathrm{barn}$ at $1.8\,\text{Å}$

— M. Batz et al., J Res Natl Inst Stand Technol 2005, 110(3): 293-298

^{3}He detectors

$^3\mathrm{He} + \mathrm{n} \rightarrow {}^3\mathrm{H}\ (0.191\,\mathrm{MeV}) + \mathrm{p}\ (0.573\,\mathrm{MeV})$
^{3}He: $\sigma_{\mathrm{abs}} = 5333\,\mathrm{barn}$ at $1.8\,\text{Å}$

spins of neutron and ^{3}He antiparallel: $\sim$10660 barn
spins of neutron and ^{3}He parallel: $\sim$9 barn

— M. Batz et al., J Res Natl Inst Stand Technol 2005, 110(3): 293-298

^{3}He spin filters