JAGODA SCIENTIFIC JOURNEY

Jagoda Urban-Klaehn, PhD in Physics

AGENDA

Technical University in Krakow (AGH)

Institute of Nuclear Physics, Krakow

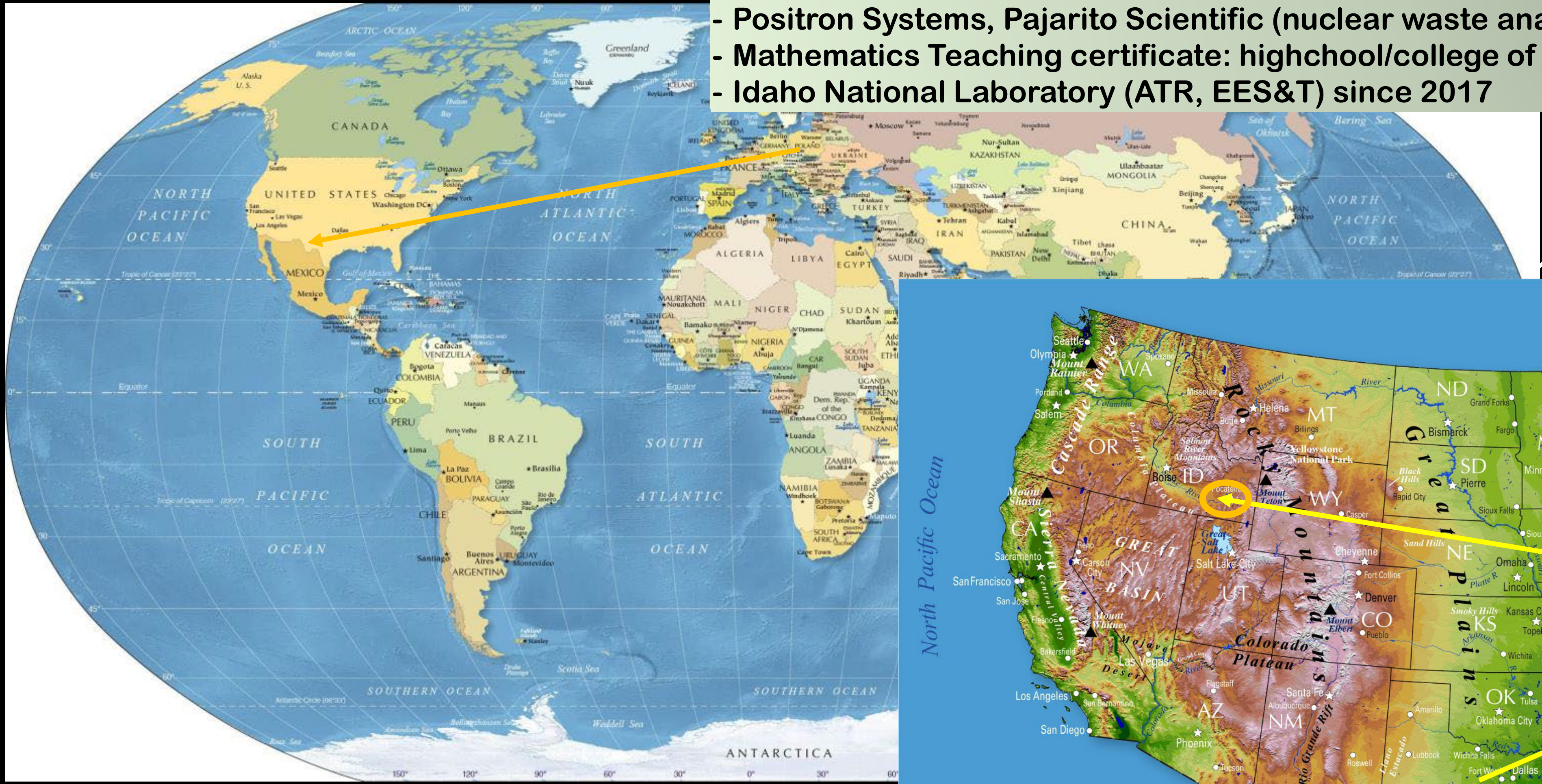
Texas Christian University, Forth Worth TX

Idaho State University/ Idaho Accelerator Center

Nuclear History in Idaho

JAGA'S JOURNEY

- M.Sc Technical Nuclear Physics AGH
- IFJ : cyclotron operator, Nuclear Applied Spectroscopy Dpt. (PIXE/PIGE)
- PhD studies in Texas Christian University, astronomy instr. (PAL/Chevron)
- Washington DC, Library of Congress
- Postdoctoral researcher at Idaho State University (Idaho Accelerator Center), Pocatello
- Positron Systems, Pajarito Scientific (nuclear waste analyst)
- Mathematics Teaching certificate: highchool/college of Eastern/Western/Southern Idaho
- Idaho National Laboratory (ATR, EES&T) since 2017



- American Nuclear Society
- U.S. Women in Nuclear

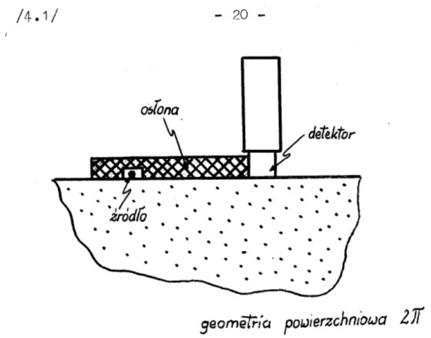
Non-linear career path

Jagoda Urban-Klaehn, Ph.D.

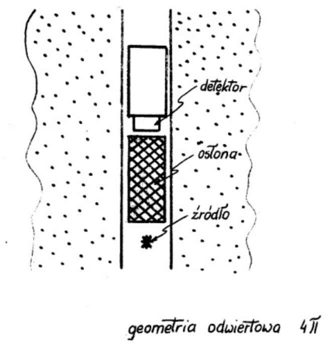
M.S. THESIS TITLE: "THE APPLICATION OF THE SPECTRAL GAMMA-GAMMA METHOD TO INVESTIGATE PIT-COAL'S DEPOSITS" – *CAN BE USED IN ORE, GAS, HARD COAL IN SITU ANALYSIS*

Probe: source (γ or neutron)-shield-detector, *different lengths of probe tested*

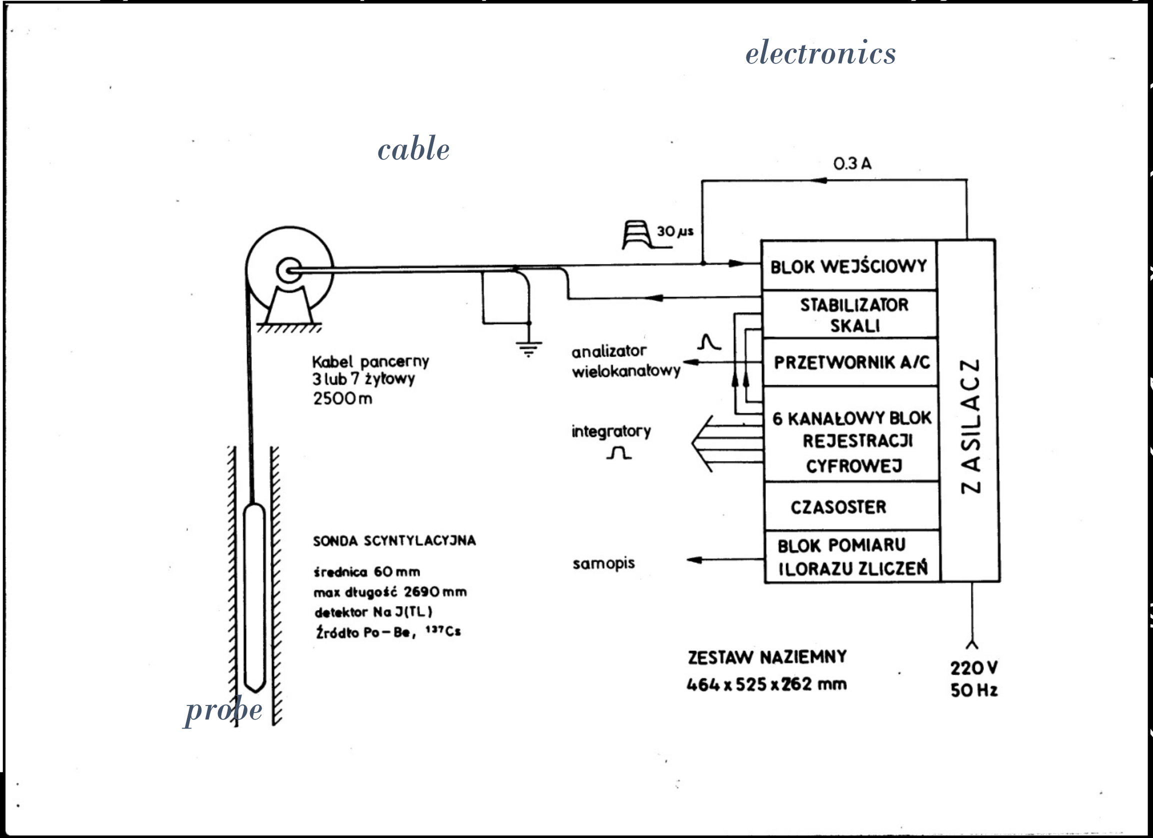
Idea: Replace costly chemical core removal with probe



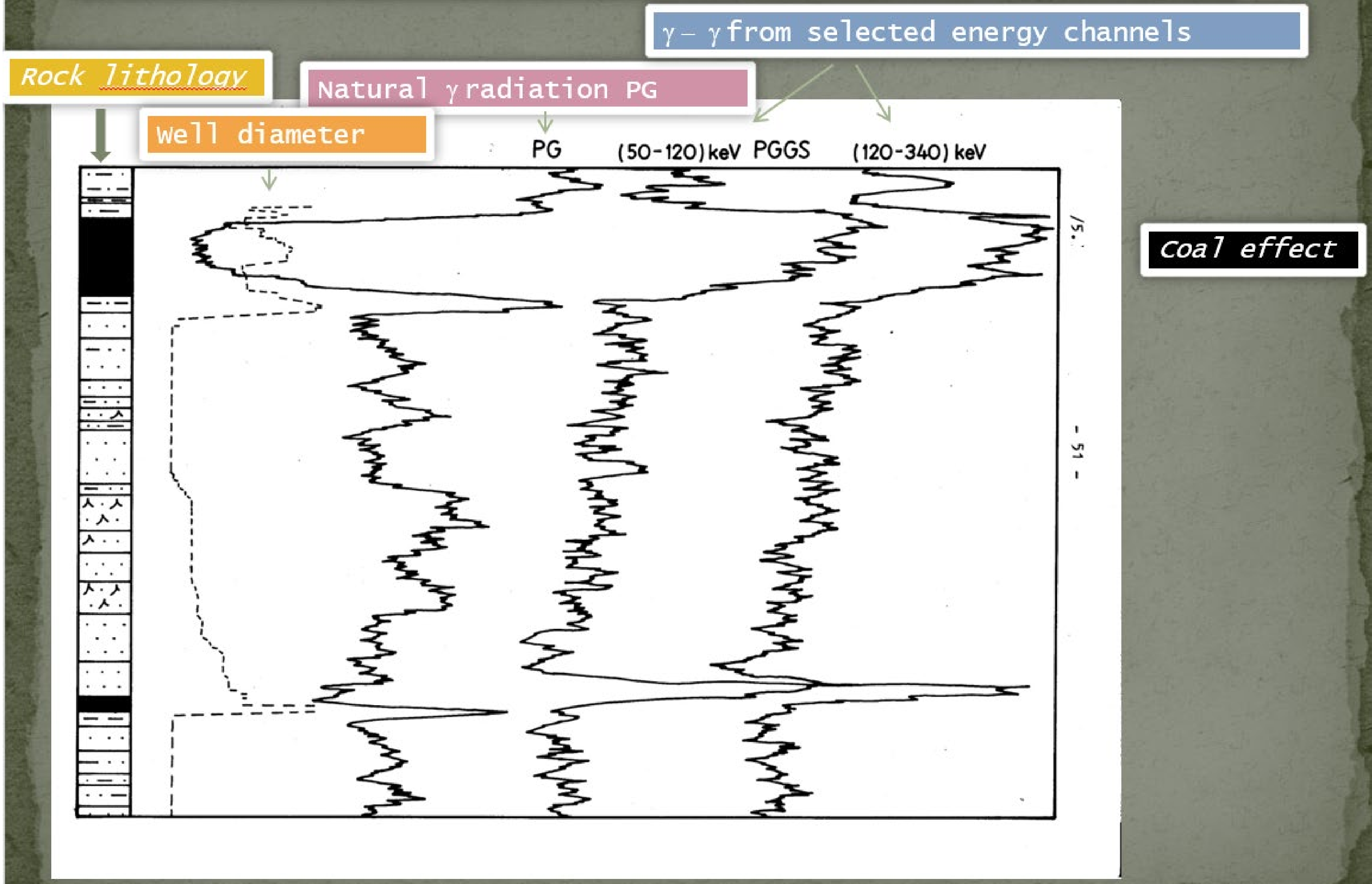
2π surface geometry



4π geometry in boring log



Typical Coal Well-log Profile – chemical and geophysical Analysis

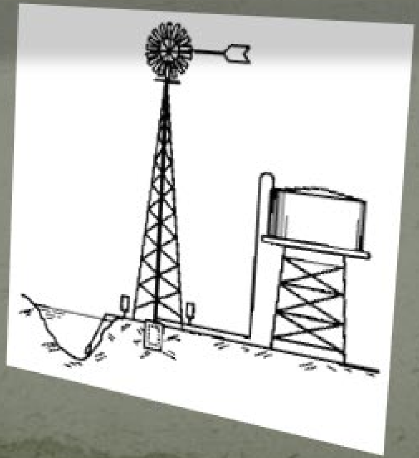


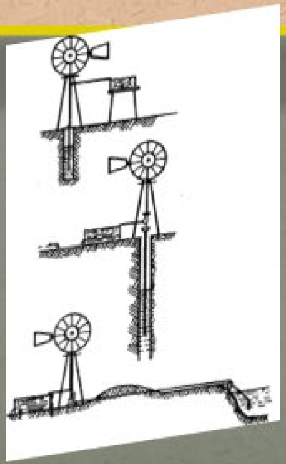
Problem

•Find the solution of inverse function – gamma response as a spectrometric parameter of density and ash content, adjusted for bore-hole diameter fluctuations;
•Find the optimal size of probe (long or short) for a specific geophysical parameter
•Replace costly chemical analysis of core with in-situ geophysical spectral analysis.

Conclusions

•Obtained correlation over **0.9** for density/ash content/bore-hole diameter versus spectral parameter , therefore we could replace costly chemical core analysis of core with in-situ geophysical spectral analysis.
•All three parameters measured in the same time





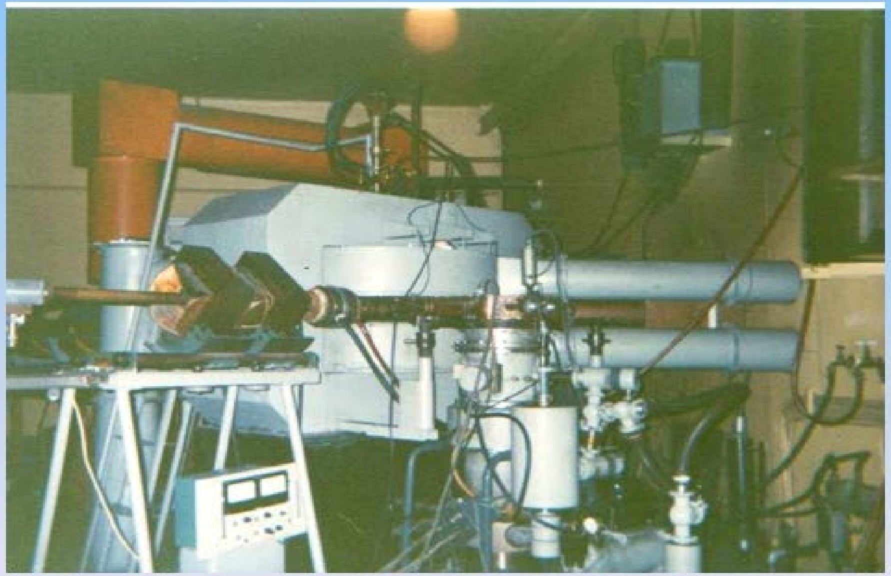
INSTITUTE OF NUCLEAR PHYSICS IN KRAKOW

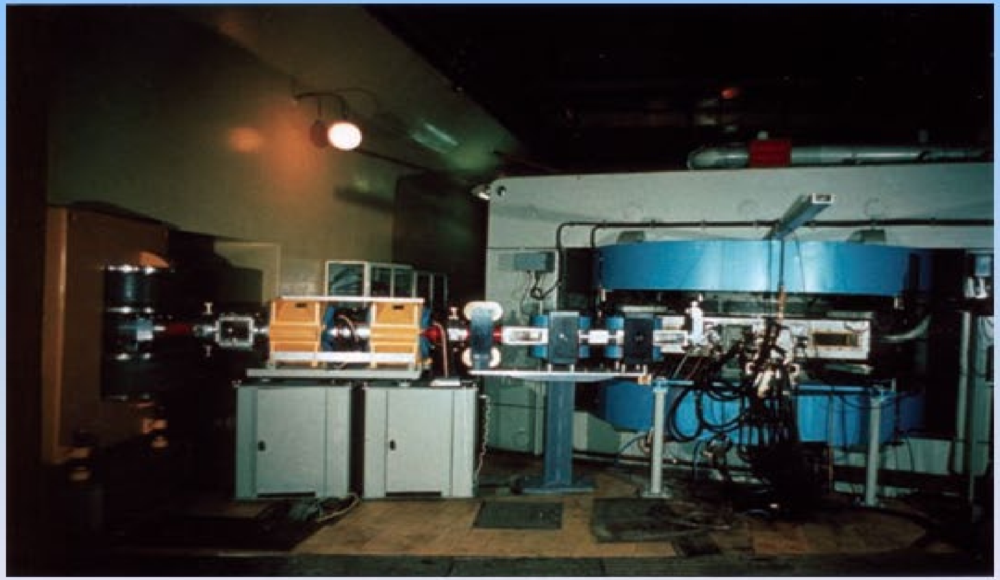
Proton Induced X-Ray and Gamma Emission PIXE/PIGE

Institute of Nuclear Physics, Krakow Poland

The Henryk Niewodniczański
Institute of Nuclear Physics
Polish Academy of Sciences

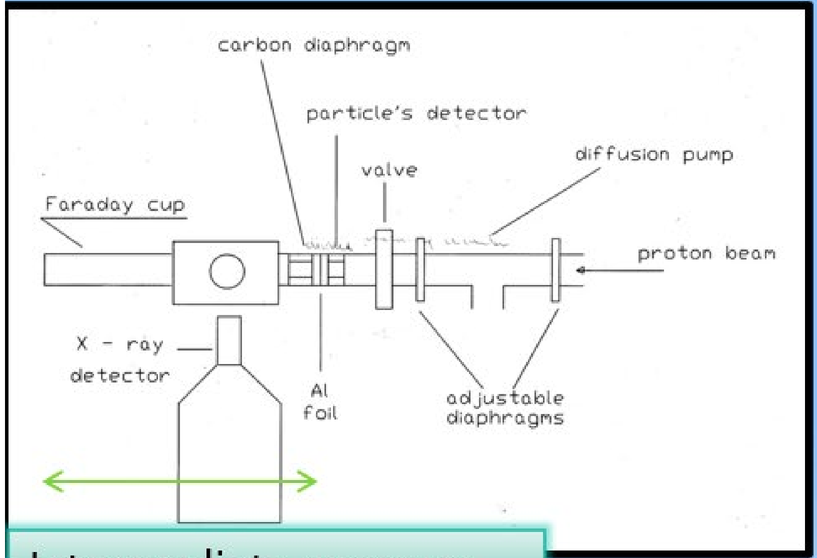
Cyclotron C-48:





Cyclotron operator , physicist in Nuclear Spectroscopy Department

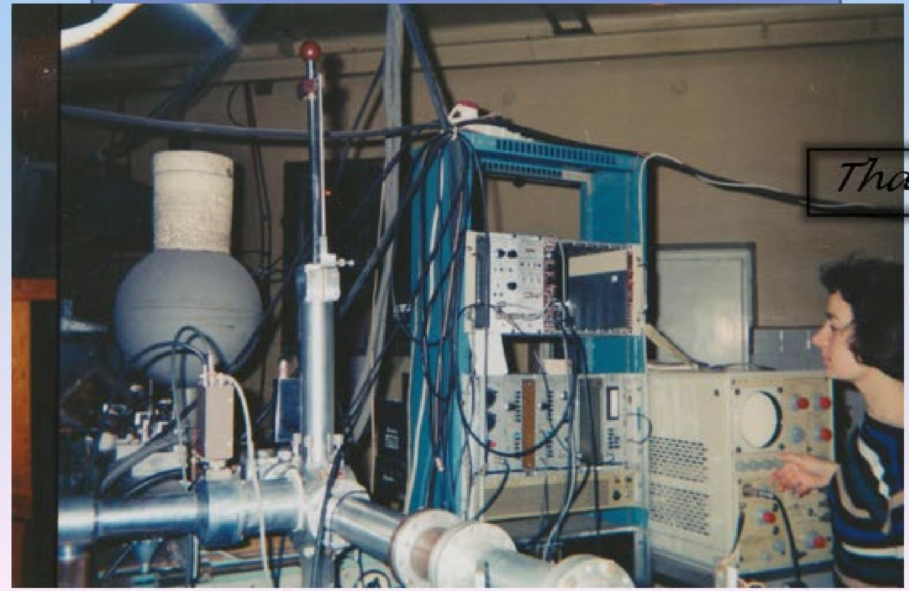
Cyclotron C-48 Proton (Alpha) Induced X-Ray and Gamma Radiation



Intermediate pressure

PIXE: Particle induced X-ray emission gives the trace and minor elemental composition. Principle: emission of characteristic X-ray by excited atoms caused by proton bombardment.
PIGE: Particle induced Gamma ray emission gives the trace and minor elemental composition for some light nuclei. Principle: excitation of light nuclei by proton bombardment.
RBS: Rutherford backscattering is sensitive to heavy elements in a light matrix, surface analysis, sensitive to thin layers, mainly done with alpha particles.

End of the beam measurement



That 's me

Table.1. Comparison of the working parameters of the C-48INP cyclotron and the 3.5 MV VdG generator

Parameter	C-48INP	3.5 MV VdG
Particle	proton α particle	proton α particle
Proton(s) energy	1 MeV-3 MeV	600 keV - 3.5 MeV
α particle(s) energy	1 MeV - 2 MeV 5 MeV	He^{+}: 600 keV - 3.5 MeV He^{++}: 600 keV - 7.0 MeV
Beam current	several μA	several μA
Beam spread	$\sim$ 50 keV	$\sim$ several keV
Experimental methods:	PIXE/PIGE RBS/NRA Channeling	PIXE/PIGE RBS/NRA Channeling ERD

PIXE spectra for different matrixes

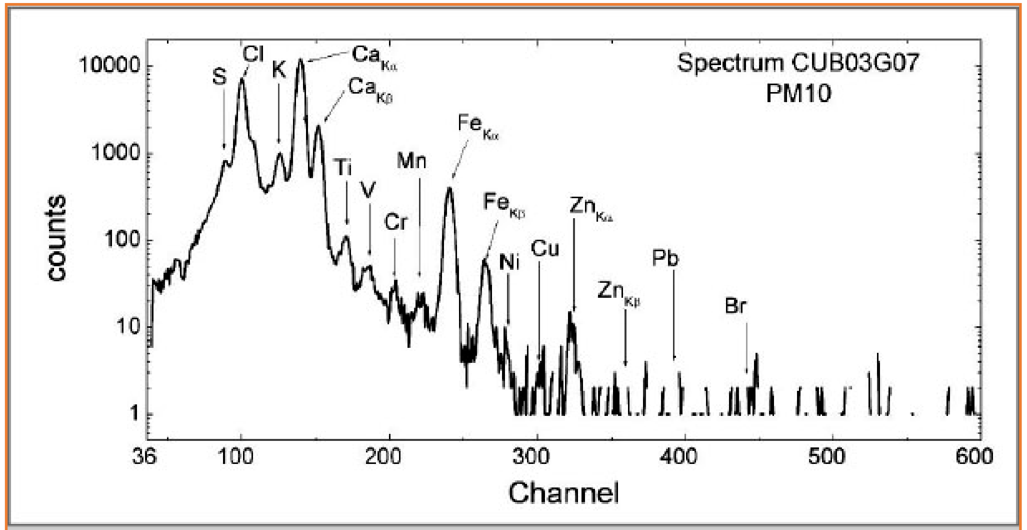
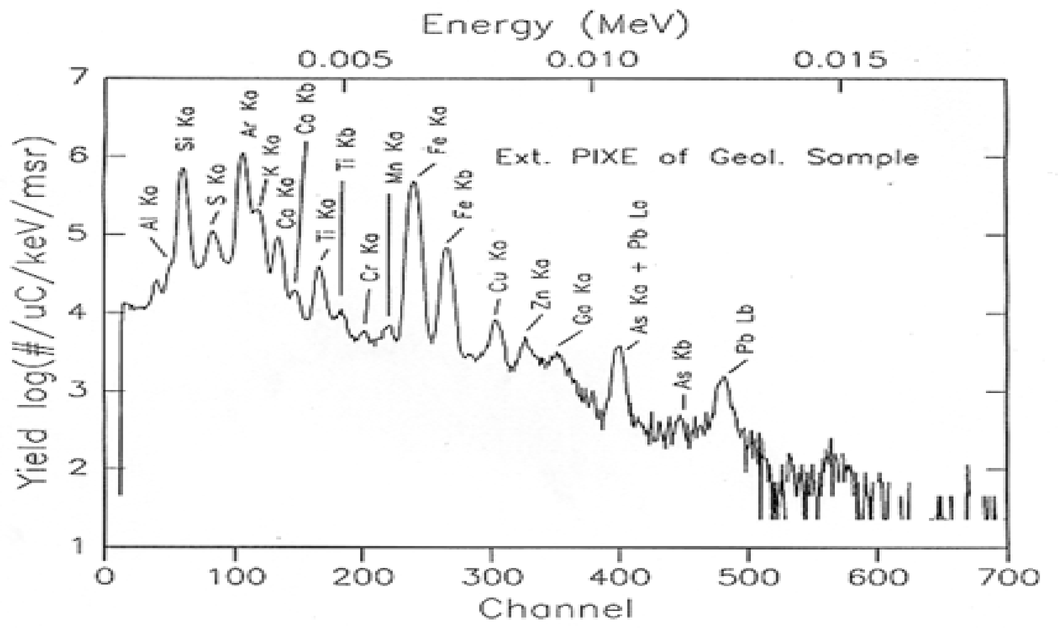


Figure 3. Representative PIXE spectra of the coarse airborne particulate matter collected in the sampling site.

Sensitivity and detection limits to different elements is adjustable to the certain extend, by using filters

Trace elements analysis – in case of pollution with lead or mercury in biological samples; magnesium traces

Cabbage and tomatoes were enriched with Selenium – trying to find the optimal amount; until there was too much

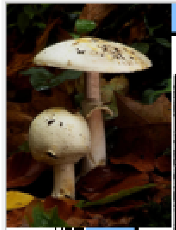


Geological standard from Lundt, Sweden

Plenty of silver in wild champignons - bioaccumulation of silver (Ag) due to synergism with Cu; Puffball show some also, the soil does not show silver above DL.

Boletus bioaccumulation of rubidium (Rb) due to synergism with K, Cs.

Good correlation coefficient between different techniques AAS, PIXE & NAA



	Mn	Fe	Cu	Zn	As	Se	Br	Rb	Sr	Zr	Ag	Cd	Pb
CHAMPIGNONS													
1. *Ag. arvensis*, Jurgów,	42	458	243	159	16	3	13	15	2.5	1.2	30	25	.0
2. *Ag. arvensis* Rzepiska,	40	402	171	216	30	1	3.5	29	.8	.9	28	17	10
3. *Ag. silvicola* Telegraf k.Kielc	7	47	136	70	6	8	4.5	54	.1	1.3	21	12.5	21
4. *Ag. silvicola* Kraków, Elbląska	31	608	351	268	0.5	16	10	8	4.5	8.4	262	20	.0
5. *Ag. arvensis* Krakow,	18	181	343	270	1.5	24	7.5	23	2.5	4.0	200	DL	.0
6. *Ag. augustus* Kraków, Toruńska	30	357	194	131	2	13	.8	37	1	.0	23	15	5
7. *Ag. silvaticus* Kraków, Toruńska	22	240	52	61	2	6	1.7	1.5	[illegible]	[illegible]	11	DL	.0
8. *Ag. bitorquis* Kraków, p.Jordana	10	59	130	103	3	2.5	9	18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9. *Ag. bisporus* Kraków,	8	100	73	120	2	1	3	65	1	.5	DL	DL	1.6
10. *Ag. bisporus* Kraków,	8	54	80	87	1.5	.7	9.5	8	1	1.1	23	9	.0
LETTUCE	70	325	14	99	0.4	.1	8.5	8.5	30	.2	DL	DL	.9
ONION	39	156	13	42	2.0	.6	5.5	3.0	26	1.5	DL	DL	.0
Leccinum													
Kozlak, szosa pn. Norwegia POLAR CIRCLE	6	68	15	107	.0	.8	2.2	101	1	.4	DL	DL	3.5
Mleczaj, Koniewa, Krakow	26	357	33	124	1	6	2	79	1	1.9	17	5.5	1.1
Podgrzybek, Poręba Wielka	26	357	51	185	1	.3	1.7	145	.0	.0	DL	DL	1.4
Czubajka, Stadion, Kielce	5	42	221	59	3	6.5	1	35	.8	.5	DL	16	16.8
Purchawka, g.Telegraf	91	542	258	286	8	9	3	9	1.5	16	23	DL	25.8
Maslak g.Telegraf	26	177	28	128	.0	.5	5.5	474	3	8	DL	DL	10.0
Lakówka p.Zgórskie	19	46	30	28	1.5	.2	2	18	1	10	DL	DL	.5
Opieńka p.Zgórskie	12	83	27	87	.0	.0	.3	29	1.5	1.5	DL	16	2.5
Opieńka las k.Odense, Dania	25	97	28	84	.1	.8	.5	91	.7	1.2	DL	DL	6
SOIL:													
ul. Elbląska Kraków	3600	32800	78	1050	18	1	8	30	67	167	DL	15	215
ul. Toruńska Kraków	4070	34500	61	734	15	.0	4.5	39	101	139	DL	12	233
pasmo Zgórskie koło Kielc	1640	8420	6	70	14	3	2	35	34	427	DL	DL	76
góra Telegraf koło Kielc	2720	12600	23	235	14	1	.0	45	52	440	DL	DL	209

silver

IV correlation coefficient

MERCURY		SELENIUM		CADMIUM		ZINC	
AAS PIXE	0.33	AAS-PIXE	0.04	AAS-PIXE	0.78	AAS-PIXE	0.84
AAS-NAA	0.93	AAS-NAA	0.06	AAS-NAA	0.98	AAS-NAA	0.90
NAA-PIXE	0.52	NAA-PIXE	0.94	NAA-PIXE	xx	NAA-PIXE	0.97

LEAD		COPPER		RUBIDIUM		IRON	
AAS-PIXE	0.98	AAS-PIXE	0.89	NAA-PIXE	0.94	NAA-PIXE	0.86

* norms obliged in ex-GDR

xx - no data

b)

	lead		copper		rubidium	
	allowed limit for mushrooms as a					
	5		100		xx	
	AAS	PIXE	AAS	PIXE	NAA	PIXE
S1	1.1	2.5	80	80	51	30
S2	1.7	2.0	270	250	38	25
S3	13.9	22.	410	530	xx	22
S4	3.7	3.0	255	200	xx	15
X	18.7	22.	135	125	30	16
AR	3.3	3.5	220	190	19	10

Puffballs

Boletus

PIGE Applications in Environmental Sciences/ Geology

Aluminium Works near Krakow (Skawina) closed down due to polluted water, environment by fluorine compounds – thanks to students

Zonation of Lichens, due to their tolerance to fluorine, sulphur

Lichen – used as bio-indicator for environmental air pollution from air

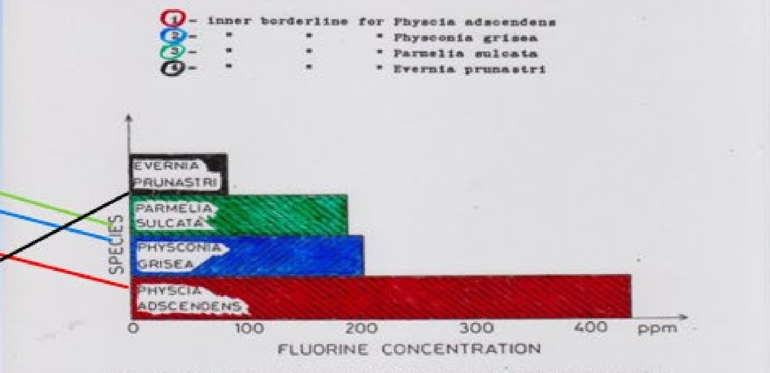


Fig. 4. Comparison of mean values of F concentration accumulated by different species at the same site.

Crusty/leafy/shrubby lichens



PIGE Trace Element Analysis in Geological Samples

Estimation of Fluorine Emission from raw clays versus after firing, <u>fluorine is emission after firing at high temperature, what remains is below detection limit</u>

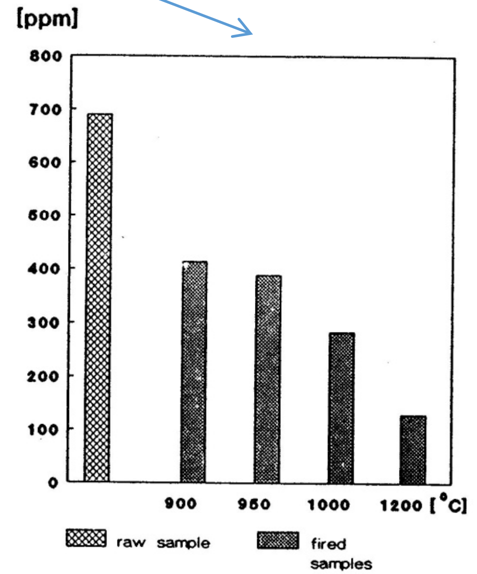


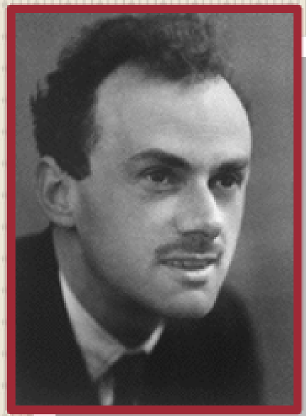
Fig. 1: Fluorine content in raw clay from the Rejowiec deposit and in products of its firing at 900°, 950°, 1000° and 1200° C.

PIGE and PIXE Trace Element Analyses of Polish Clay Rocks: J.Urban, P. Wyszomirski

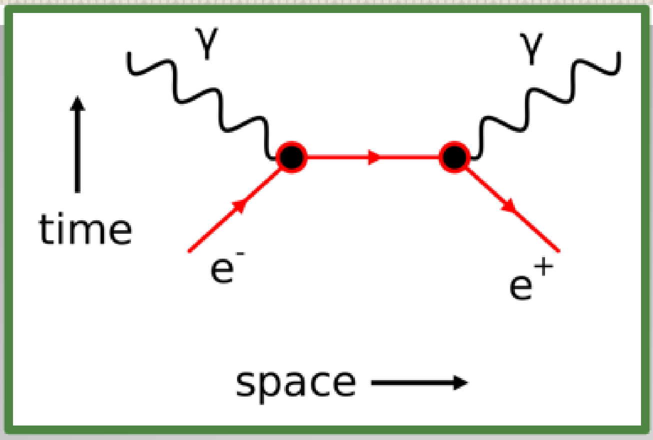
No fluorine remains in the pottery, all went to the air

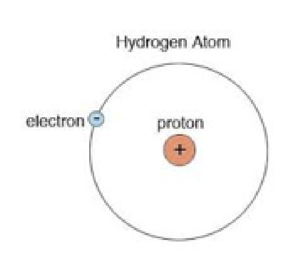
Ref. Joint ICTP-IAEA Workshop on Nuclear Data for Analytical Applications
Massimo Chiari, 21 - 25 October 2013

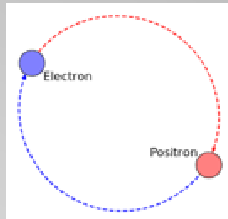
TEXAS CHRISTIAN UNIVERSITY, FORTH WORTH, TX



Dirac







Anderson

The Positron: anti-electron

1930: Anti-electron (Positron) predicted by **P.A.M. Dirac**, Quantum Electrodynamics Theory.

1932: The Positron (positive electron), detected **by C.D. Anderson** in the cloud chamber from cosmic radiation.

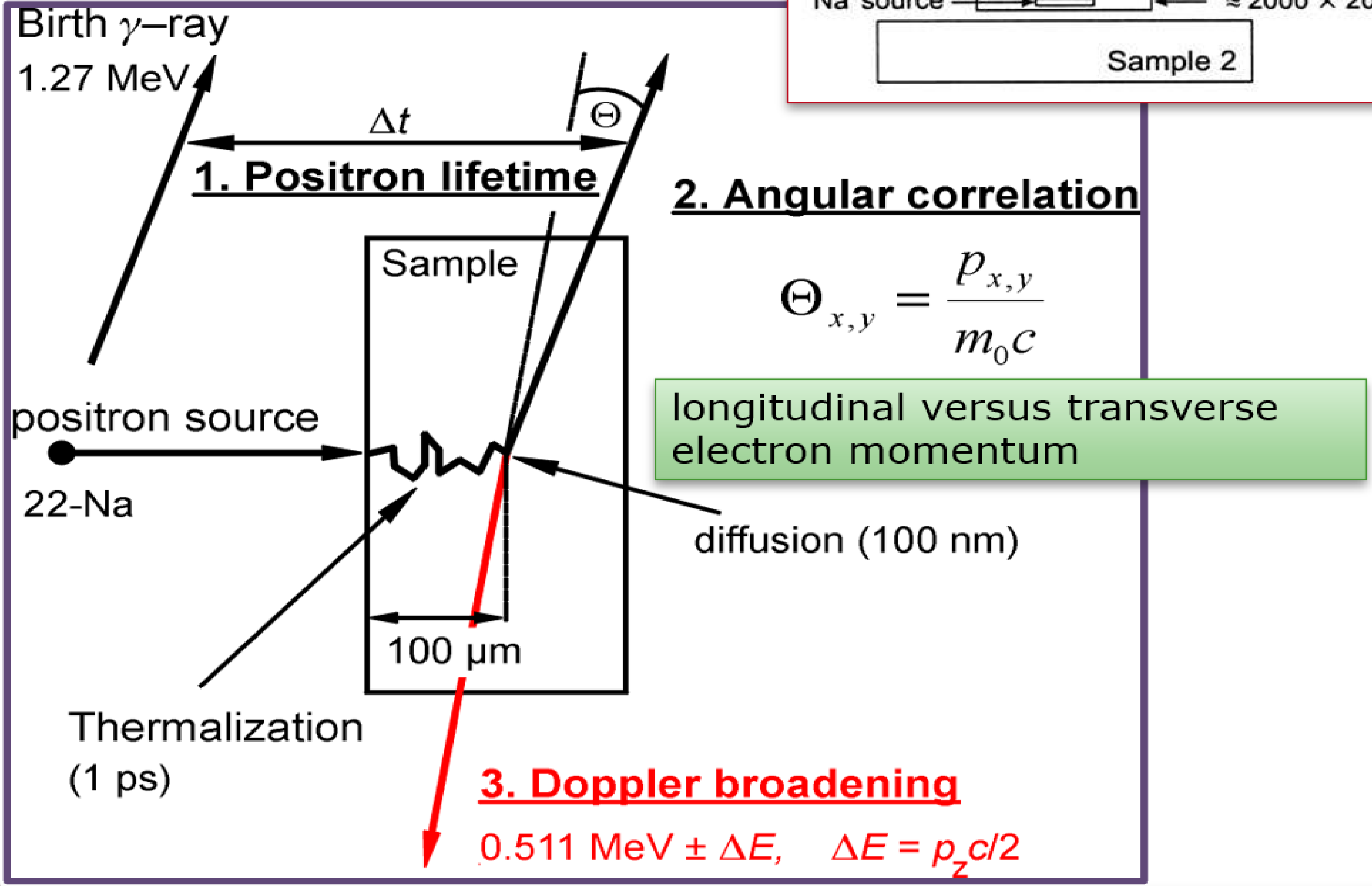
1946: The Positronium atom (positron and electron bound state) detected by M. Deutch from positron annihilation in gases.

1960: Solid state physics: positron is localized in defects; positron is delocalized in lattices-Fermi surface.

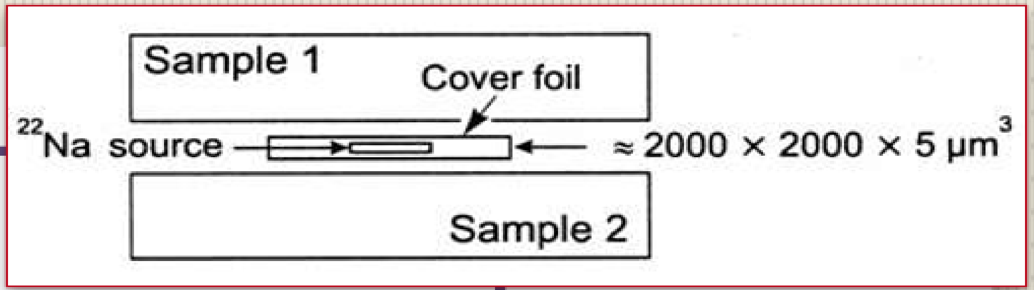
1970: Nuclear medicine: positron emission tomography (PET)

1975: Surface science: positron has a negative work function.

1980-presence: Positron chemistry, material defect and surface tools.

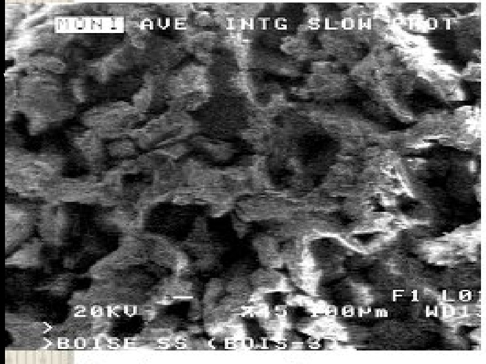


Birth γ–ray
1.27 MeV
Δt
Θ
1. Positron lifetime
2. Angular correlation
$$\Theta_{x,y} = \frac{p_{x,y}}{m_0 c}$$
longitudinal versus transverse electron momentum
Sample
positron source
22-Na
diffusion (100 nm)
100 µm
Thermalization
(1 ps)
3. Doppler broadening
0.511 MeV ± ΔE, $\Delta E = p_z c/2$



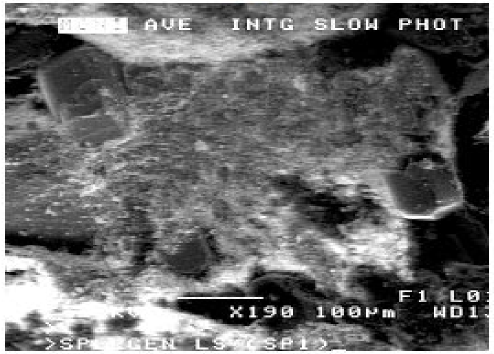
Sample 1
Cover foil
^{22}Na source
≈ 2000 × 2000 × 5 µm^3
Sample 2

PAS in Sandstone, Limestone and Dolomite Rocks



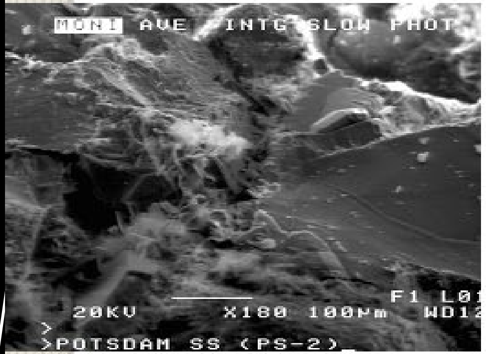
(a) Boise SS, general structure

(b) Boise SS, quartz crystals

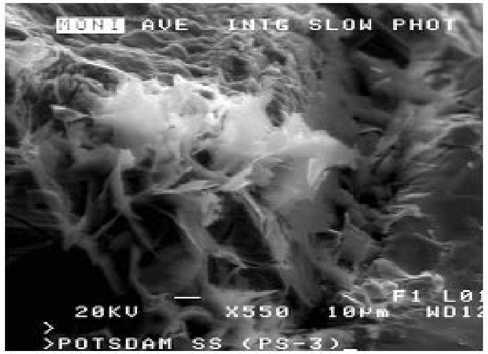


(a) Spergen LS, general structure with crystals

(b) Spergen LS, calcite scalenohedral crystals

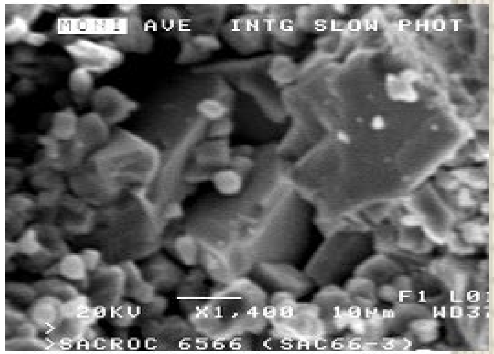


(c) Potsdam SS, grains with cementation

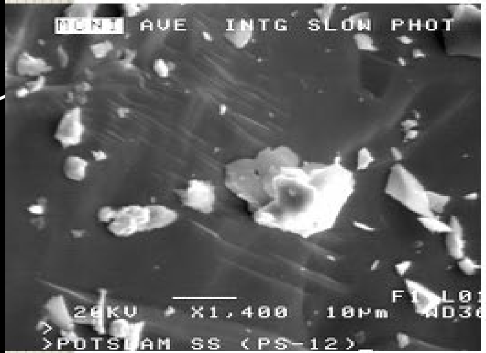


(d) Potsdam SS, clay cementation

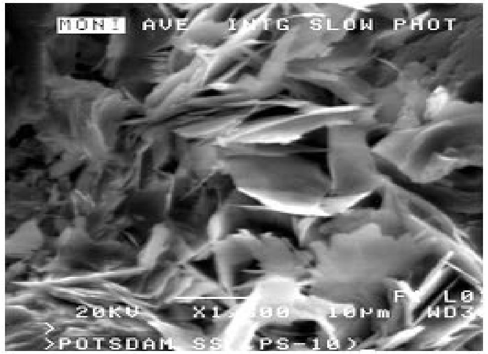
(c) Sacroc 6555'11", general structure



(d) Sacr. 6566'6", dolomite and calcite crystals

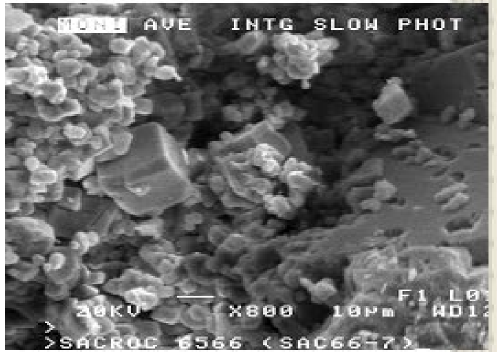


(e) Potsdam SS, rosette-shaped clay



(f) Potsdam SS, thin sheet-shaped clay

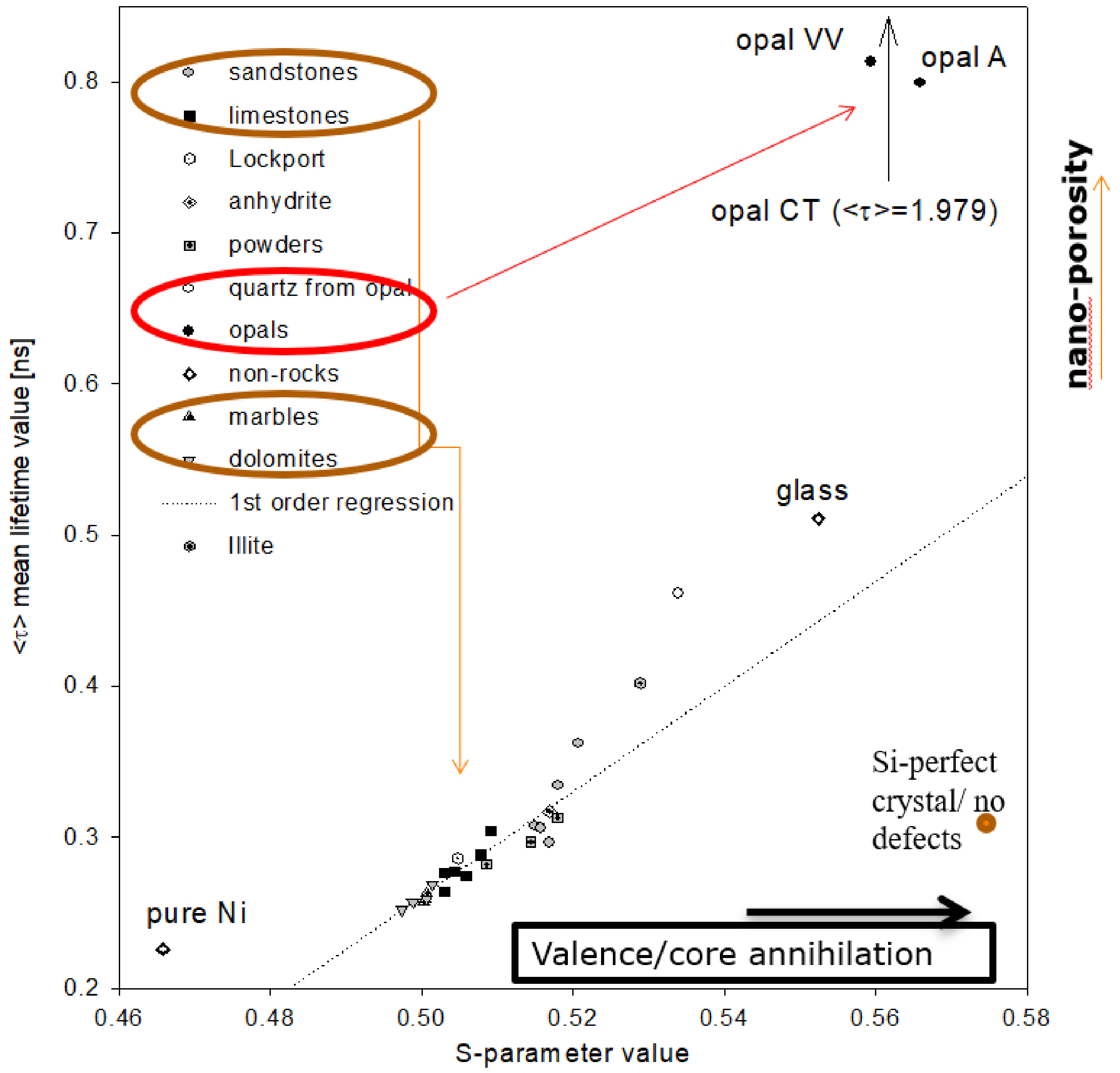
(e) Sacr. 6566'6" $CaCO_3$ crystals with different size and structure



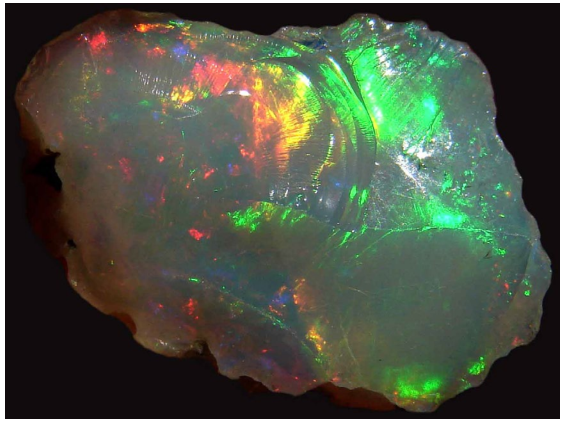
(f) Sacr. 6566'6" scalenohedral (smaller) and rhombohedral (bigger) calcite crystals, porous clay material (right side)

Structure effect versus chemical effect

Fig.4.6 S-parameter versus mean lifetime value



Opals - their origin, evolution and structure



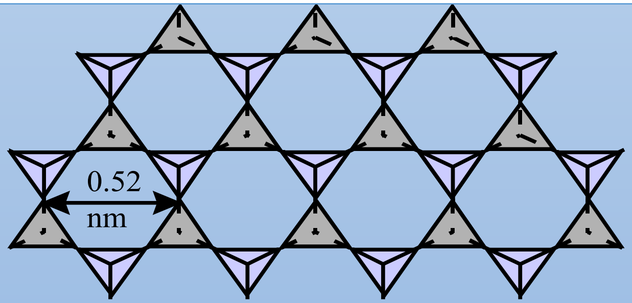
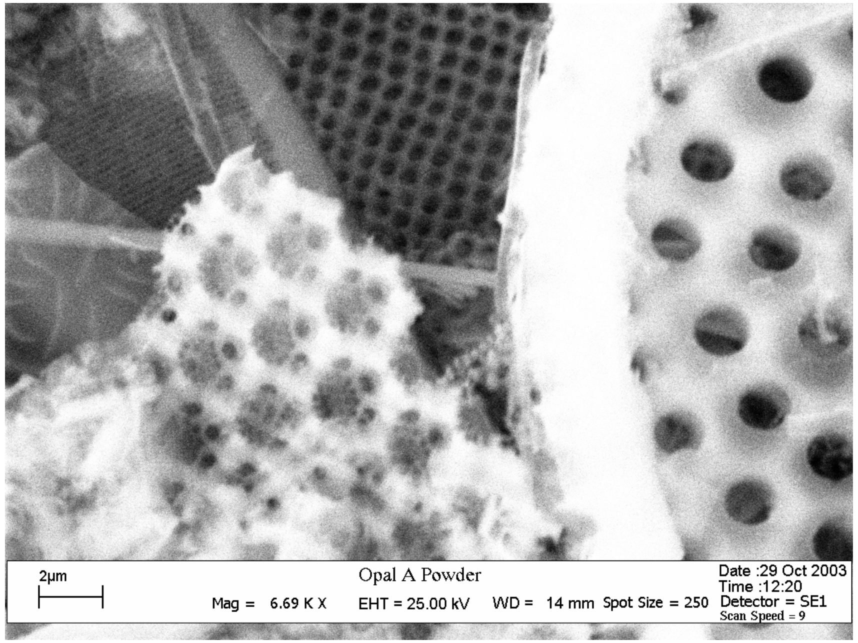
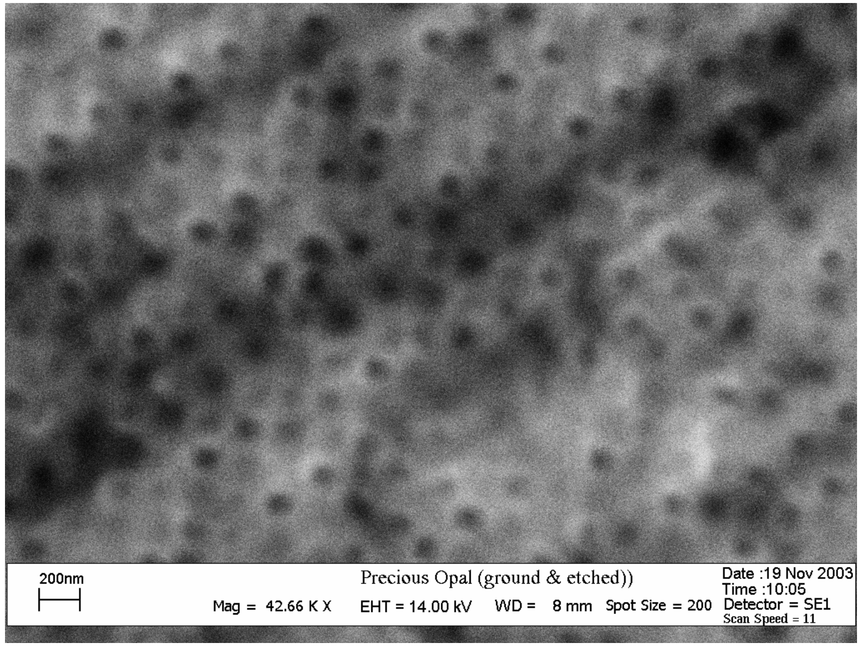


Fig.7.1 Tetrahedral layer from which both tridymite and cristobalite structures are built

Opal-A (siliceous ooze) → Opal-CT (porcellanite) → micro-quartz → quartz

(amorphous) (beginning of crystallization)





Quotient spectra have been obtained by dividing the standard DBS spectrum of Si-crystal (in orientation 1-1-1) by the sample spectrum. All spectra have been smoothed and normalized.

Fig. 8.1 Rocks versus Si-crystal, quotient spectra

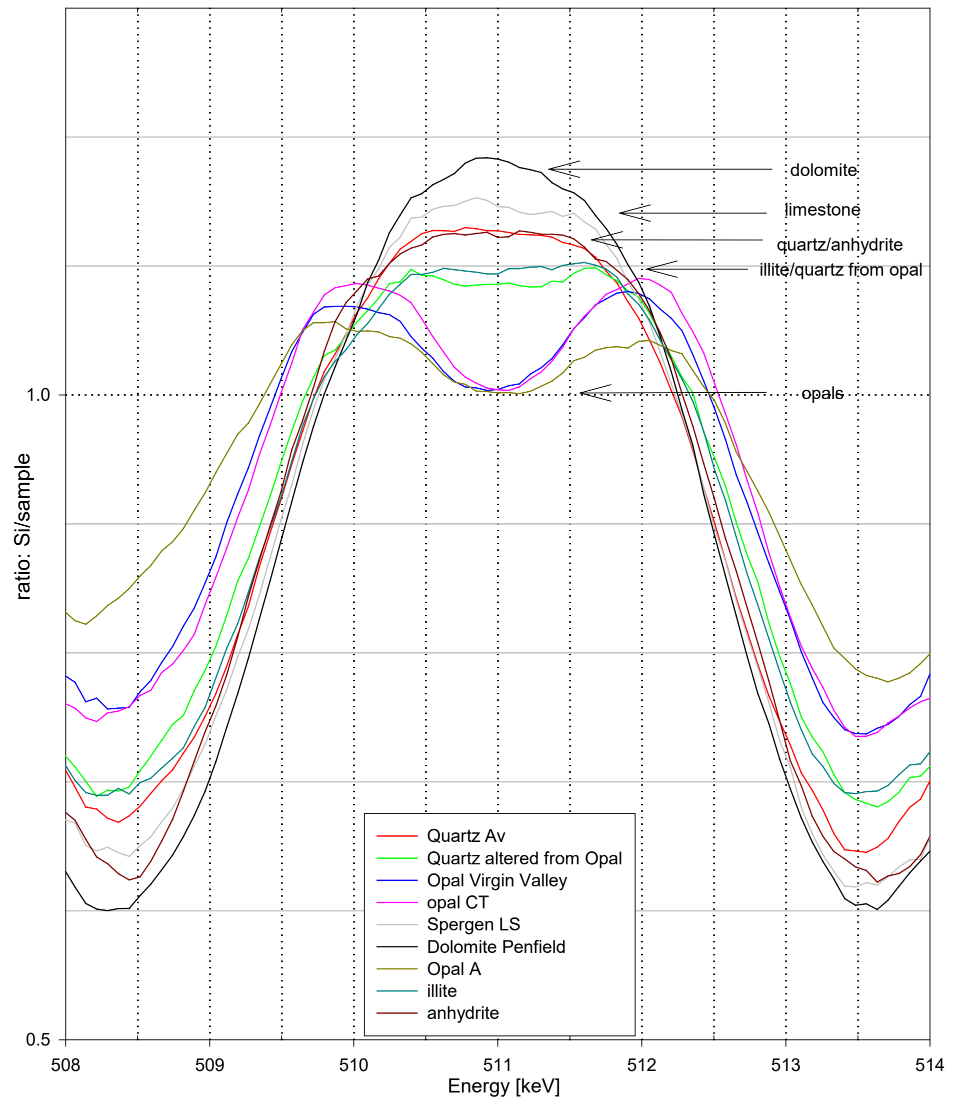
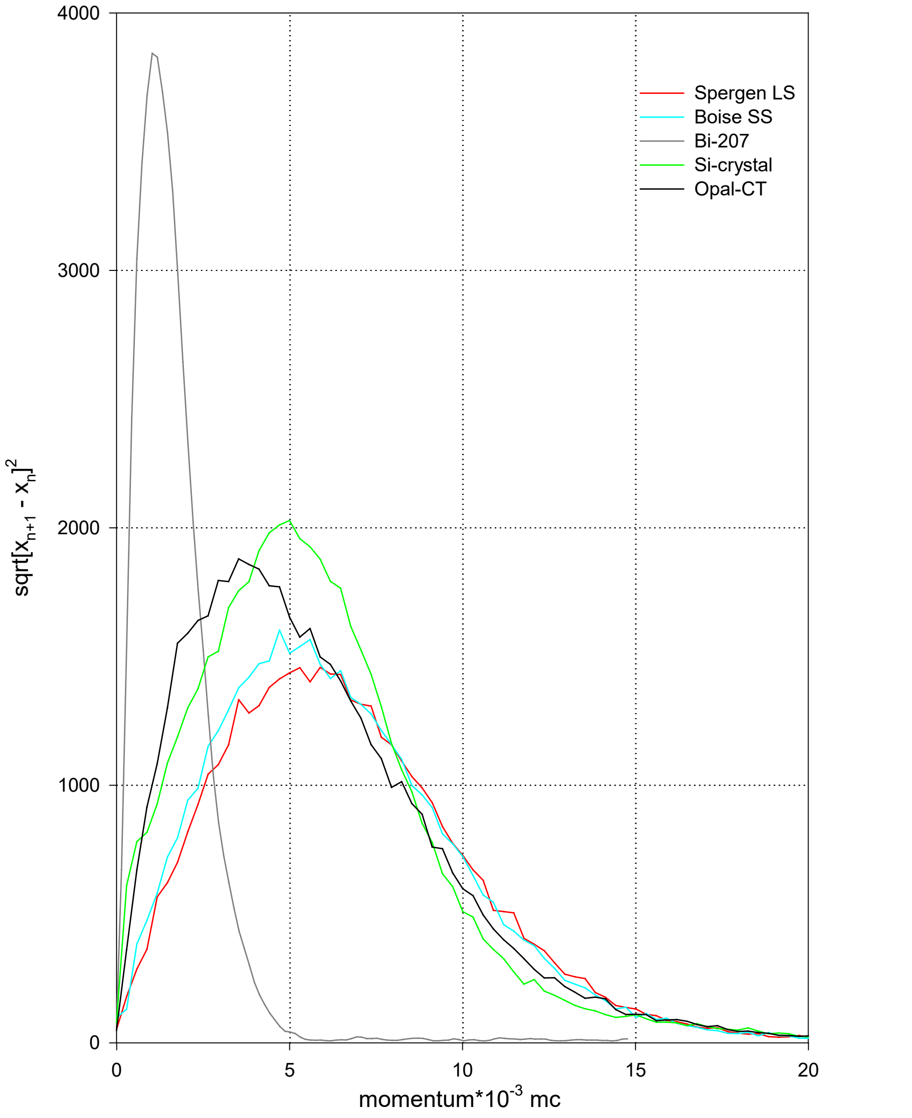


Fig.8.2 DBS derivative spectrum as the function of momentum, smoothed



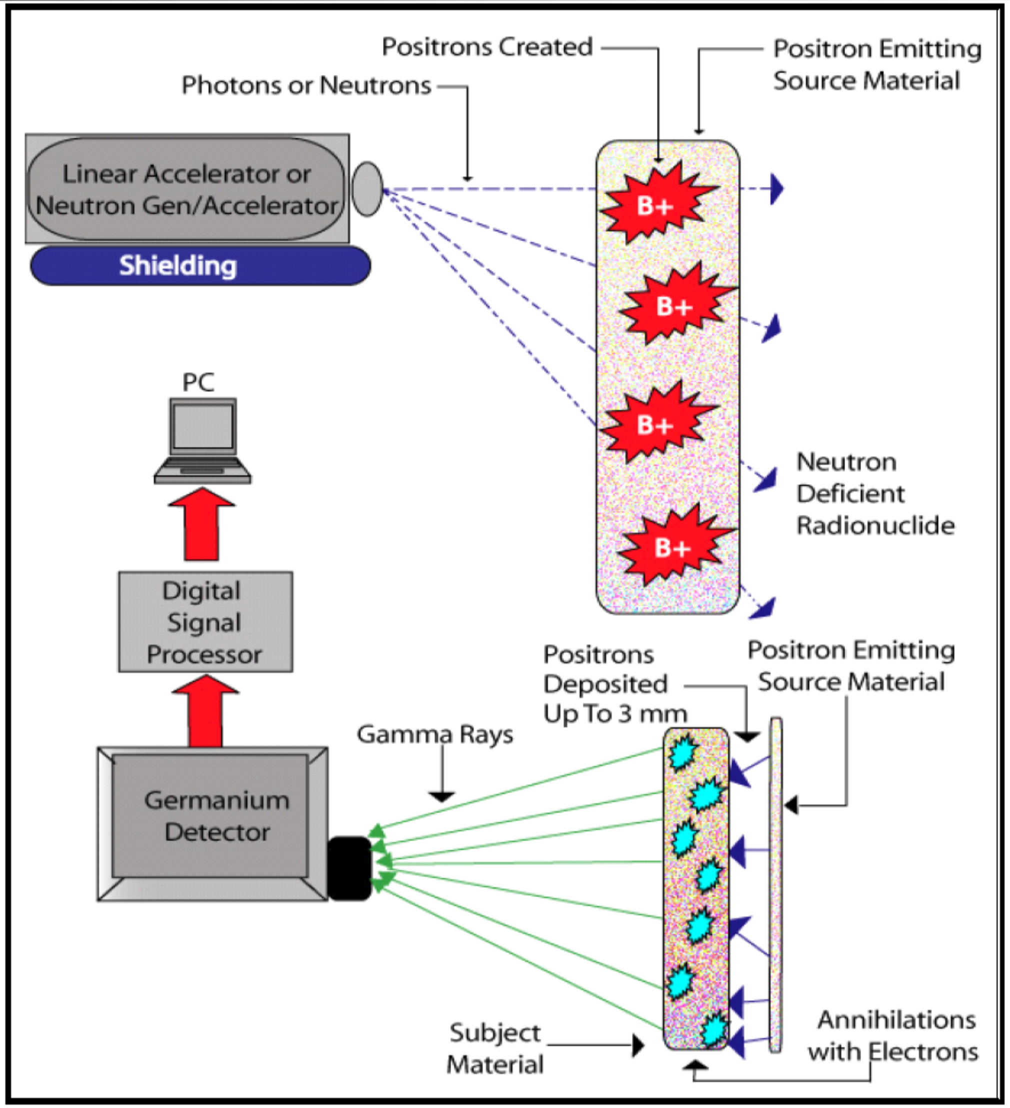
IDAHO STATE UNIVERSITY/IDAHO ACCELERATOR CENTER

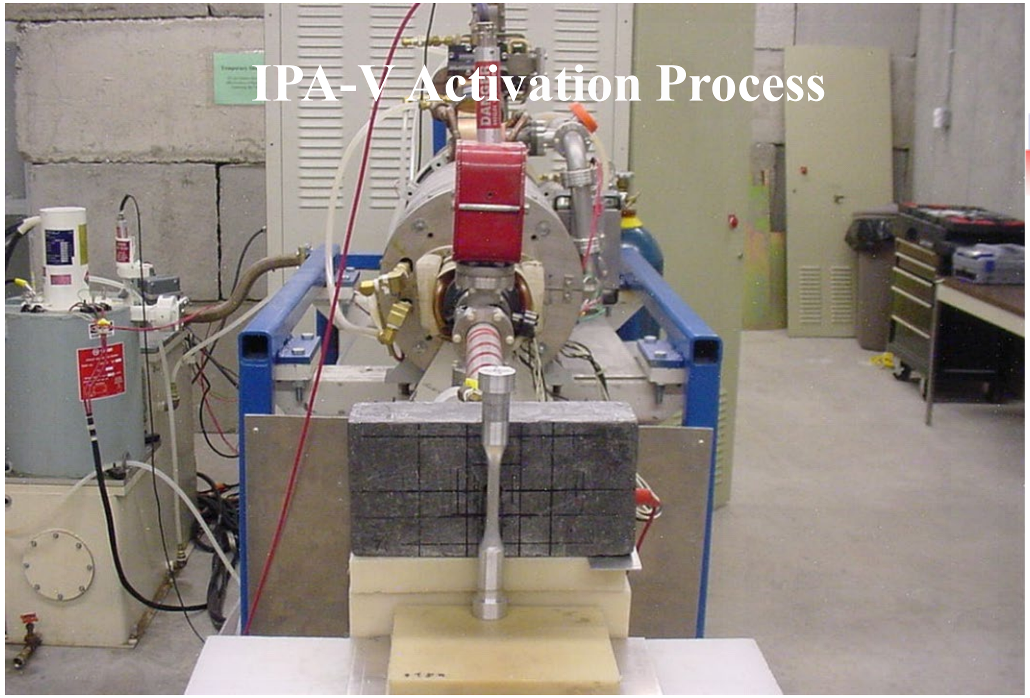
What about applications of
positron technology in industry?

POSITRON SYSTEMS

Located nearby Idaho Accelerator Center which is a part of Idaho State University

IPA-V/S Processes





POSITRON SYSTEMS ™

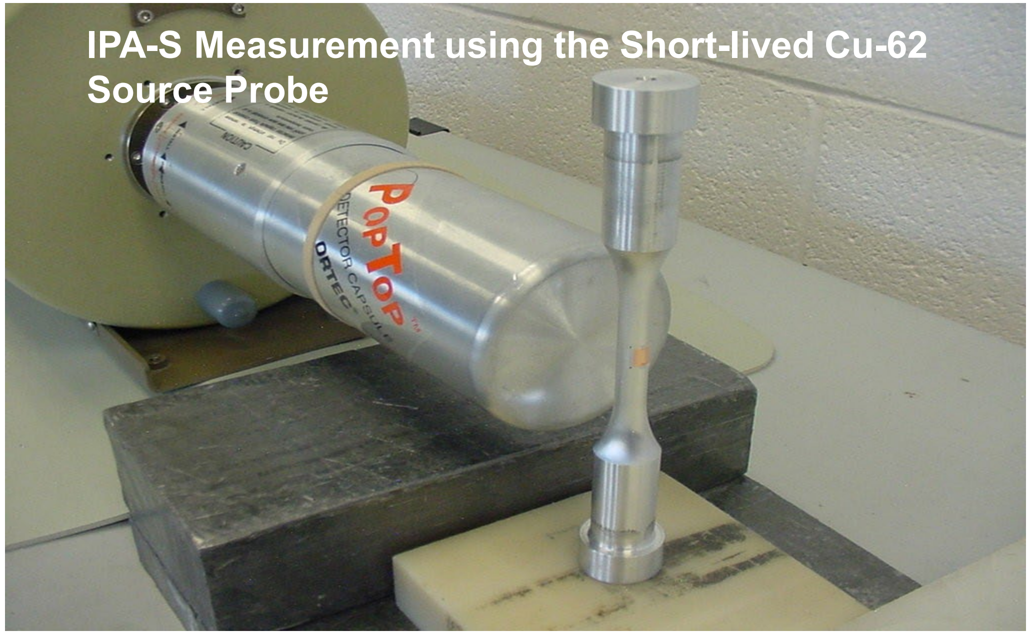
Developed IPA Technologies

- Induced Positron Annihilation--Volumetric (IPA-V)
  - Deep depth assessment capability
  - Larger equipment, faster volumetric (bulk) analysis
  - Mobile capability in development
- Induced Positron Annihilation—Surface/Near-Surface (IPA-S)
  - Near-surface analysis (Depths to 5mm)
  - Small size can be configured as a probe
- Induced Positron Annihilation--Portable (IPA-P)
  - In development for field portability

[redacted]

IPA-V: Plenty of positron sources are created inside the material

IPA-S: we created our own short lived positron source, any shape and size which deactivates safely after a day



Production of Positron Sources

Doppler

Long-lived positron sources' characteristics:
^{68}Ge/Ga: $T_{1/2}$ = 271 days, $E_{\beta max}$ = 1,899 keV, $I_{\gamma max}$ <0.1 %
^{22}Na: $T_{1/2}$ = 2.6 years, $E_{\beta max}$ = 540 keV, E_{γ}=1.275 keV, $I_{\gamma max}$ = 99.94 %
Short-lived positron sources' characteristics:
^{64}Cu ($T_{1/2}$ = 12.7 hours, $E_{\beta max}$ = 579 keV, $I_{\gamma max}$ <0.5 %)
Copper (^{64}Cu) was produced through the reactions:
^{65}Cu (γ,n) ^{64}Cu, abundance of ^{65}Cu = 30.8 %
^{63}Cu (n,γ) ^{64}Cu, abundance of ^{63}Cu = 69.2 %

Long-lived sources' characteristics:
^{22}Na ($T_{1/2}$ = 2.6 years, $E_{\beta max}$ = 540 keV, $E_{\gamma start}$ =1.275 keV, $I_{\gamma max}$ = 99.94 %)
Short-lived sources' characteristics:
^{57}Ni ($T_{1/2}$ = 35.6 hours, $E_{\beta max}$ = 864 keV, $E_{\gamma start}$ =1,377.6 keV I_{γ} = 81.7 %)
Nickel (^{57}Ni) was produced in the reaction:
^{58}Ni (γ,n) ^{57}Ni, abundance of ^{58}Ni = 68.3 %

PALS

IDAHO NATIONAL LABORATORY - HISTORY

17 National Laboratories run mainly by Department of Energy (DOE), also DOD, National security, industries

National Laboratories

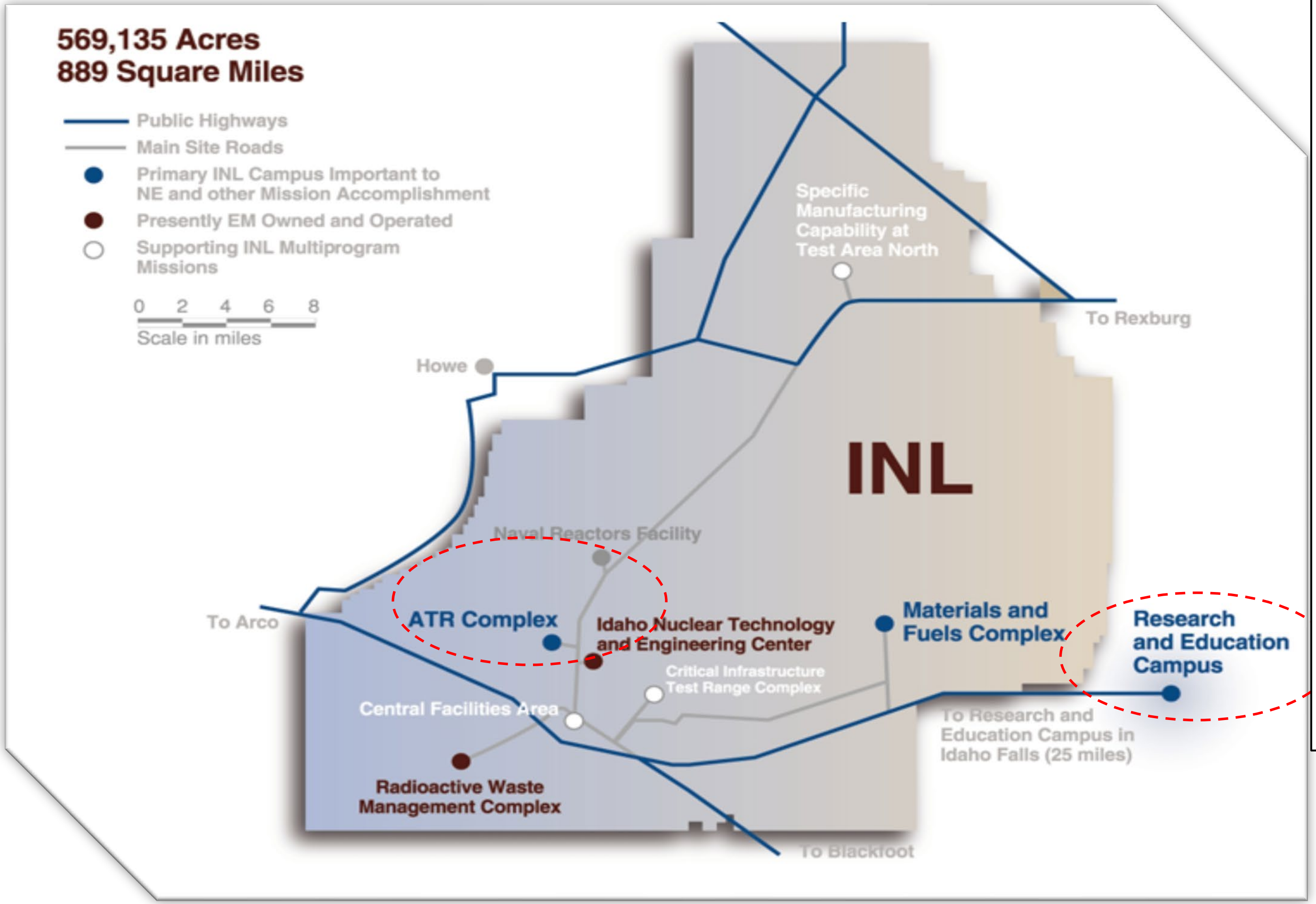
scientific mission: nuclear energy, high-energy physics, materials science, and sustainable energy solutions, renewable energy, particle physics

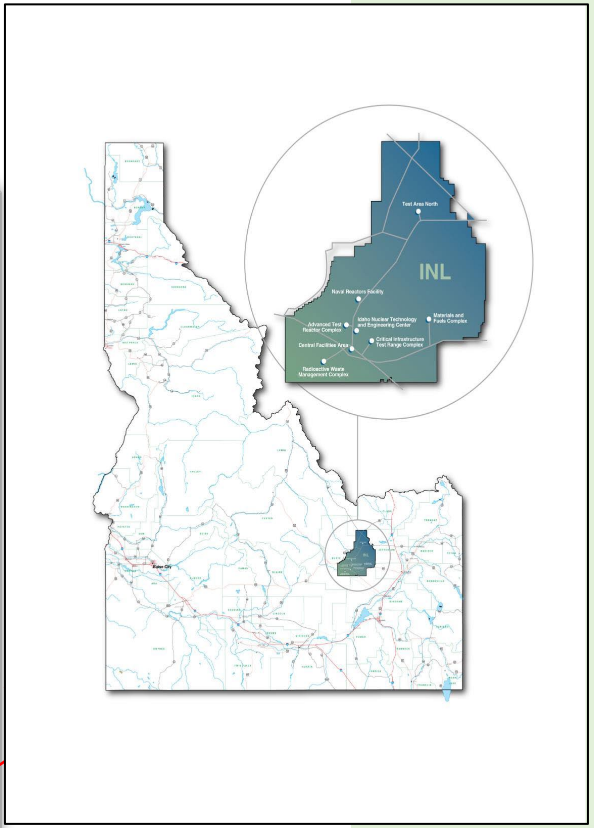
Multi-program labs (multiple facilities) vs single purpose (accelerator, renewable, plasma

IDAHO NATIONAL LABORATORY

Second by size, fifth by budget (1.5 bln annually from DOE)

OVERVIEW OF NUCLEAR REACTORS HISTORY IN IDAHO





16 Nuclear facilities (Haz Cat 1, 2 & 3)

44 Radiological facilities

4 Operating reactors

17.5 Miles railroad for shipping nuclear fuel

40 Miles primary roads (125 total)

7 Substations with interfaces to three power providers

112 Miles high-voltage transmission lines

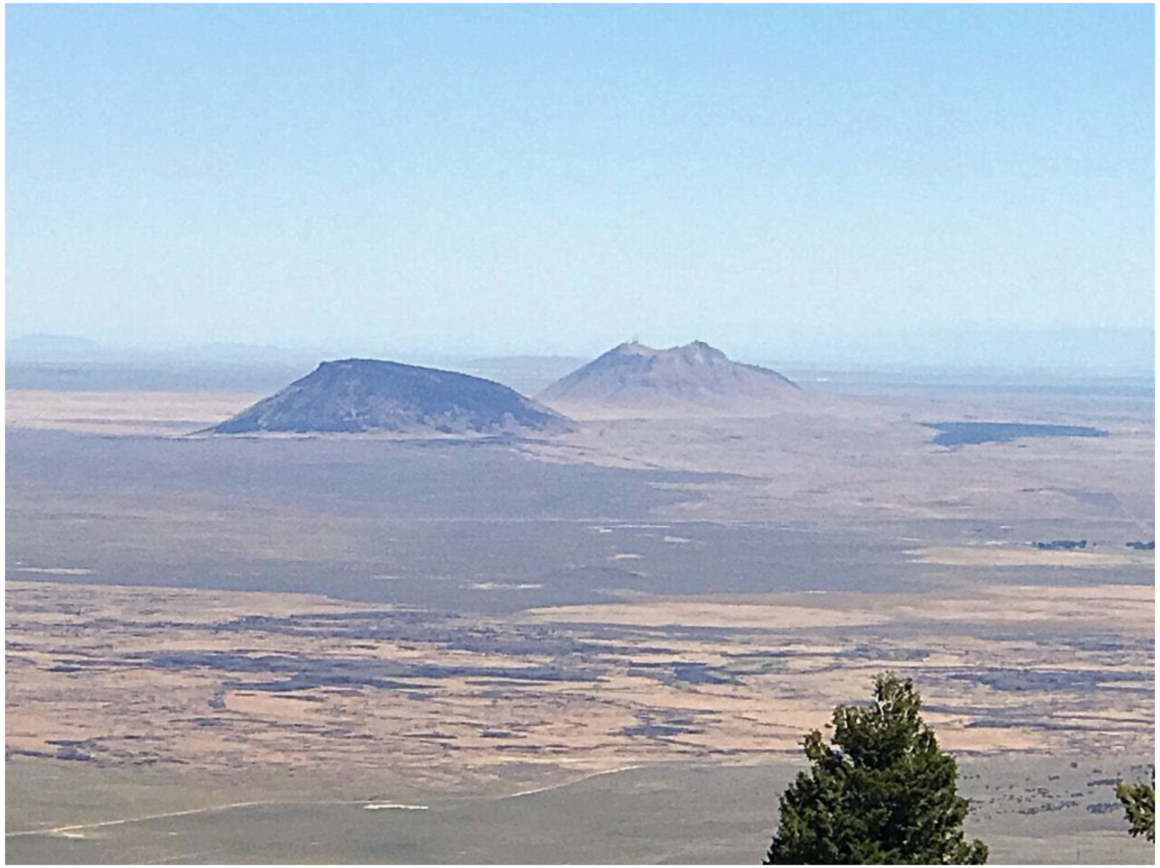
3 Fire stations

Idaho: 2/3 Poland by size, 2 mln people, high desert, mountains, Snake river valley

NAVAL PROVING GROUNDS DURING WW II – TESTING ARTILLERY TEST RANGE

NATIONAL REACTOR TESTING STATION (1949) PLAN: 10 REACTORS IN 15YEARS

INL: 52 REACTORS, 70+ YEARS…AND COUNTING



Two out of three Buttes at the INL site

EXPERIMENTAL BREEDER REACTOR I (EBR-I)

EBR-I Fast Facts

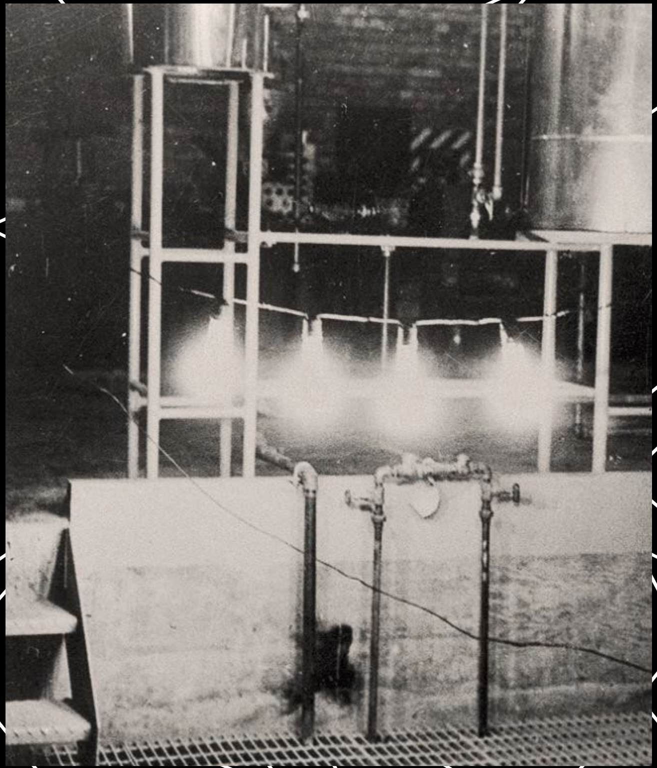
•EBR-I was the first reactor built in Idaho at the National Reactor Testing Station (forerunner to today's INL)

•In 1953, testing at EBR-I confirmed that a reactor could create (or breed) more fuel than it consumes.

•This pioneering reactor operated for 12 years before being shut down for the last time in December 1963.

•President Lyndon Johnson dedicated EBR-I as a **National Historic Landmark in 1966**.

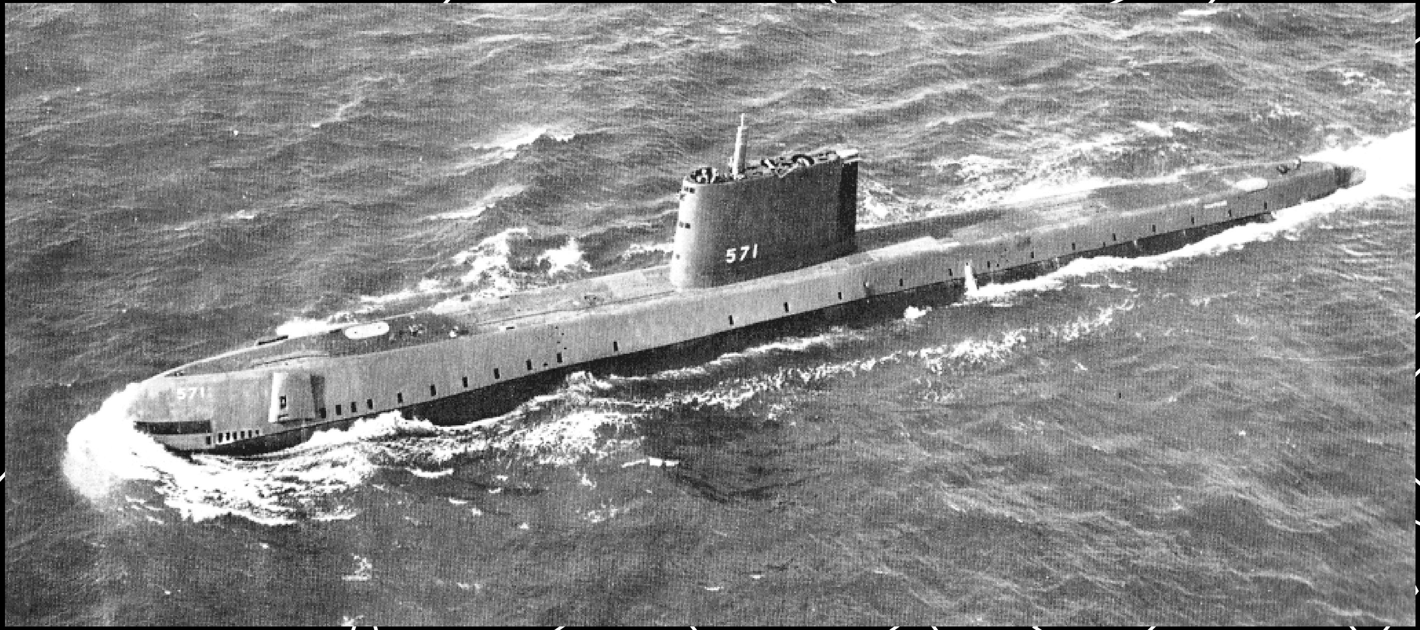
Engines used for nuclear plane

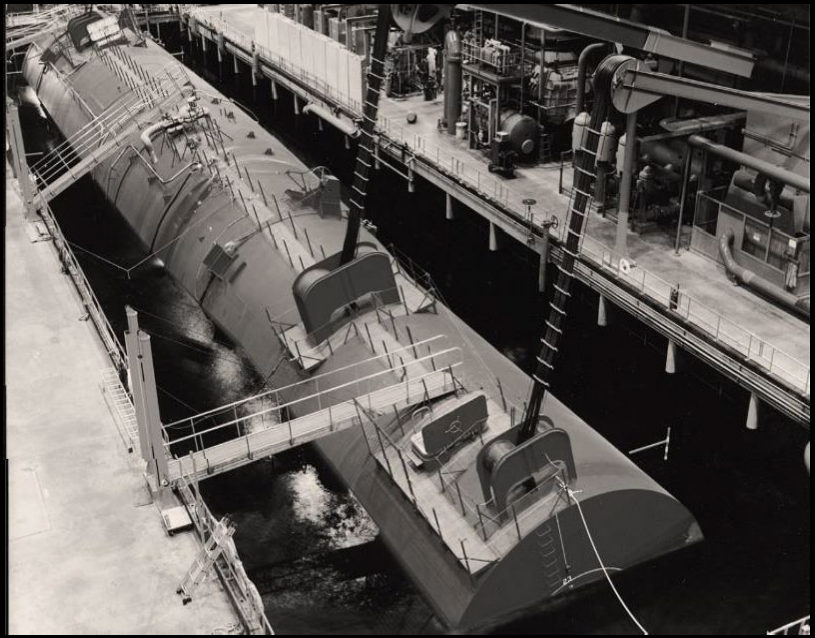


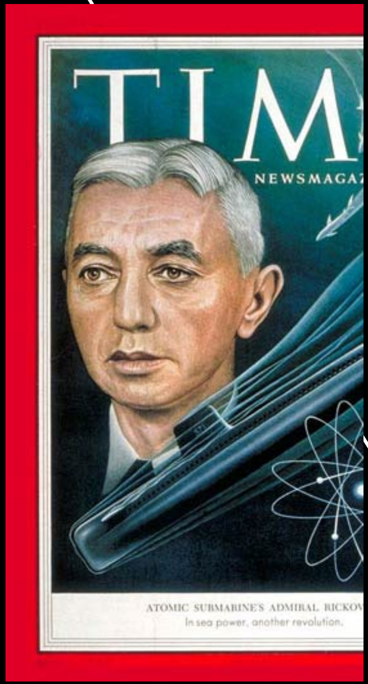
On December 20, **1951**, EBR-I became the first power plant to produce electricity in city of Arco using atomic energy.

NAVAL REACTORS FACILITY: NAUTILUS – FIRST NUCLEAR-POWERED SUBMARINE

Naval Reactor Facility. From the early 1950s to the mid-1990s, NRF supported the U.S. Navy's nuclear-powered fleet by testing reactor designs, receiving spent nuclear fuel for processing and storage, and training nearly 40,000 Navy personnel to operate surface and submarine nuclear power plants. The only remaining active facility at NRF is the **Expended Core Facility / Dry Storage Facility**, which provides for <u>storage of spent fuel from U.S. Naval reactors.</u>

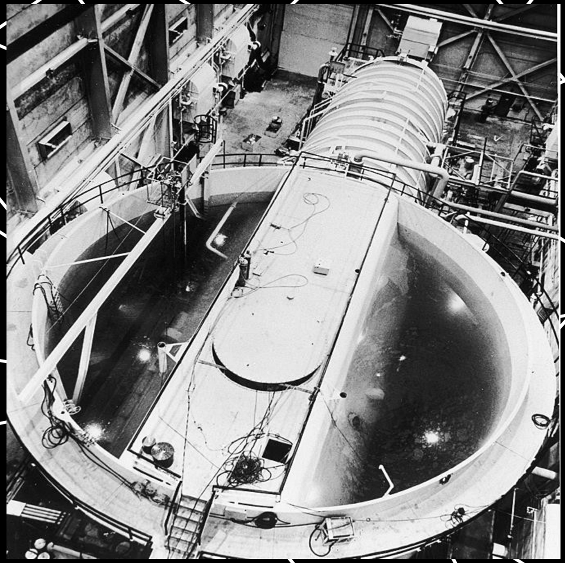






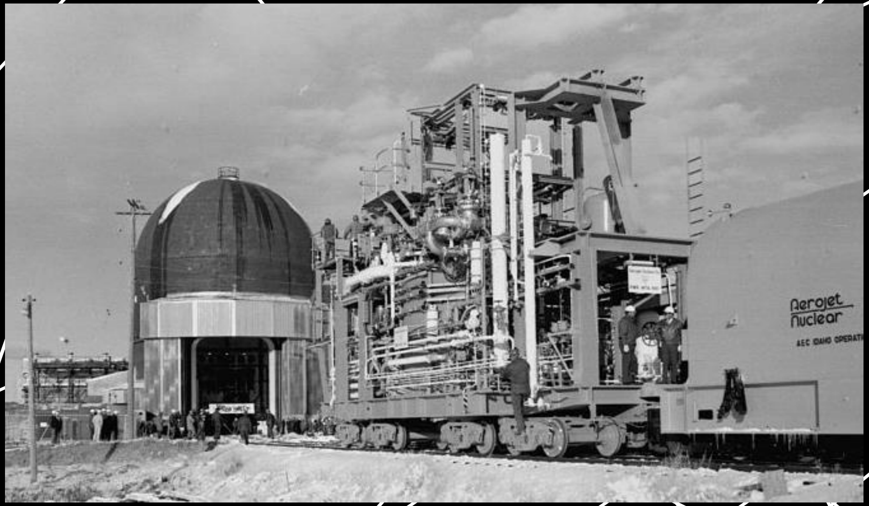
Nautilus's reactor core prototype at the S1W facility in Idaho

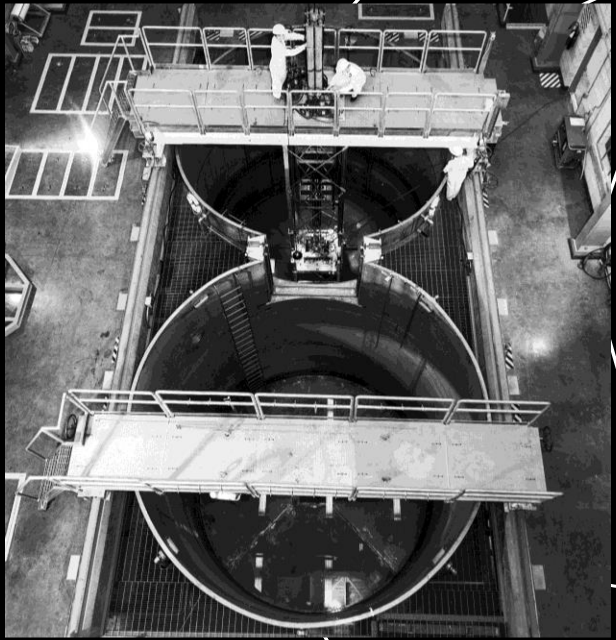
Hyman Rickover. He was the longest-serving member of the U.S armed forces in history. Which country was he born? He was born in Makow Mazowiecki in Poland not far from Warsaw.



THE HISTORY GOES ON…

Special Power Excursion Reactor Tests I-IV (SPERT) as a series of tests focusing on the safety of nuclear reactors.[1] It was commissioned in 1954 by the U.S. Atomic Energy Commission, to be run by the Phillips Petroleum Company





Loss of Fluid Test Facility (LOFT) 1973 - 1985 served as a centerpiece in the safety testing program for commercial power reactors conducted on various accident scenarios, including the real accident at Three Mile Island

Power Burst Facility (PBF) 1972 – 1985 Located at INL's Critical Infrastructure Test Range Facility, the PBF was the world's most powerful accident simulation reactor, capable of ms bursts well beyond 140-gigawatts for various reactor safety testing projects

The Boiling Water Reactors (BORAX) experiments included ***five reactors built between 1953 and 1964*** *by Argonne National Laboratory. They proved that the boiling water concept was a feasible design for an electricity-producing nuclear reactor. The BORAX III reactor was also the first in the world to power a community (Arco, Idaho) on July 17, 1955*

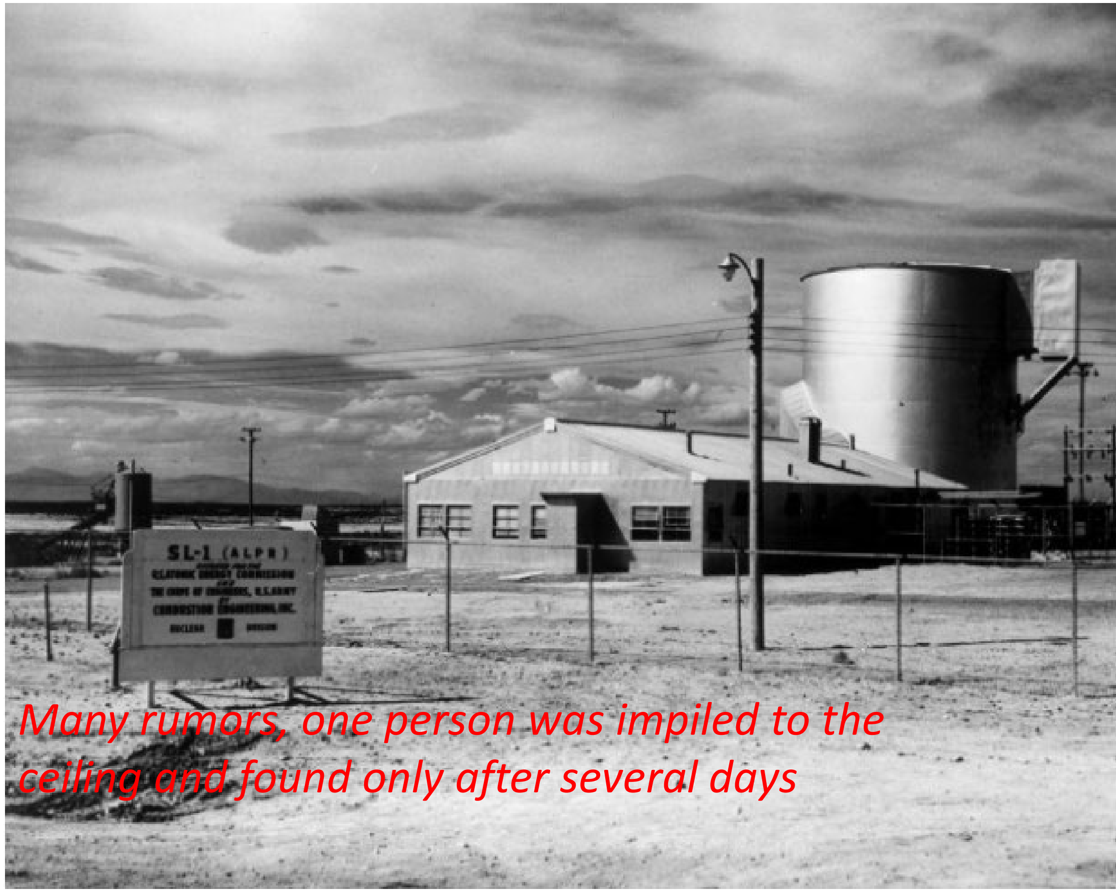
ACCIDENTS HAPPEN: STATIONARY LOW-POWER REACTORS; SL-1

intended to provide electrical power and heat for small, remote military facilities in arctic regions

On January 3, 1961, the reactor was being prepared for restart after a shutdown of eleven days over the holidays. Maintenance procedures required that the main central control rod be manually withdrawn a few inches to reconnect it to its drive mechanism. this rod was suddenly withdrawn too far, causing SL-1 to go <u>prompt critical</u> instantly. In four milliseconds, the heat generated by the resulting enormous <u>power excursion</u> caused fuel inside the core to melt and to explosively vaporize.

This is **the only reactor accident in U.S. history to have resulted in immediate fatalities**.

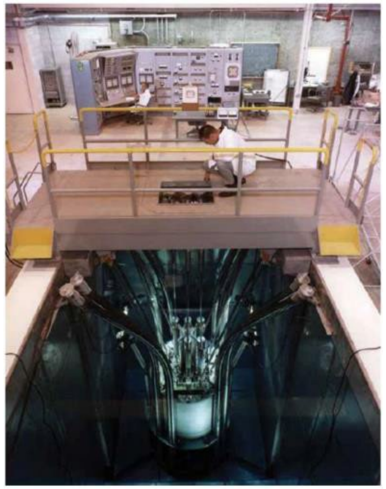
- BORAX-III was the basis (boiling water reactor with highly enriched U, 3MW power)
- Reactor went prompt critical, extreme heat created water hammer
- Reactor vessel was propelled to the ceiling,
- Three people died; a supervisor was pinned and impaled to the ceiling, he was found and removed after several days.
- The accident released about 1,100 curies (41 TBq) of fission products into the atmosphere, including the isotopes of xenon, isotopes of krypton, strontium-91, yttrium-91 and iodine-131.
- **Murder-suicide theory of love triangle**



Many rumors, one person was impiled to the ceiling and found only after several days

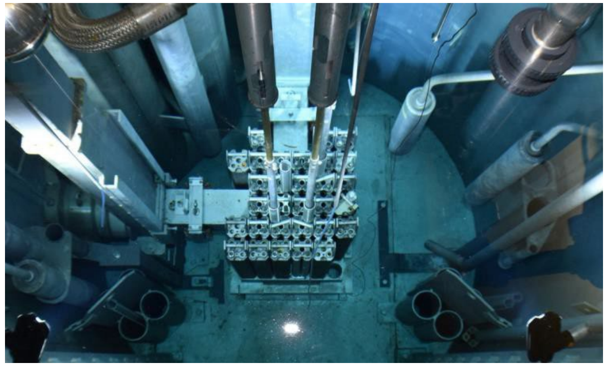
FOUR NUCLEAR REACTORS THAT ARE OPERATED PRESENTLY

Advanced Test reactor (ATR) – the most unique research reactor in the world



Advanced Test reactor Critical (ATRC) - pool

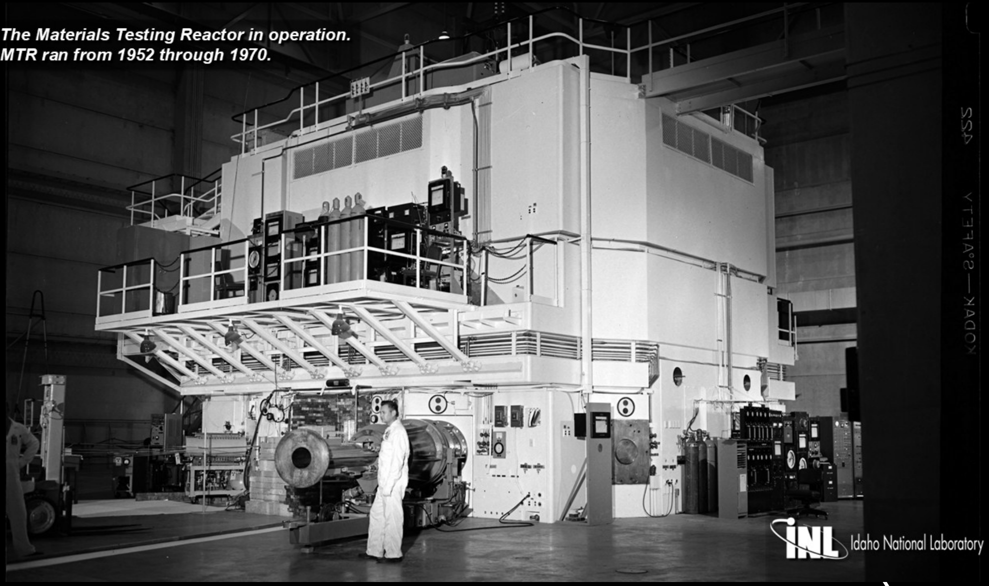
Transient Reactor Test Facility (TREAT)



Neutron Radiography (NRAD) reactor

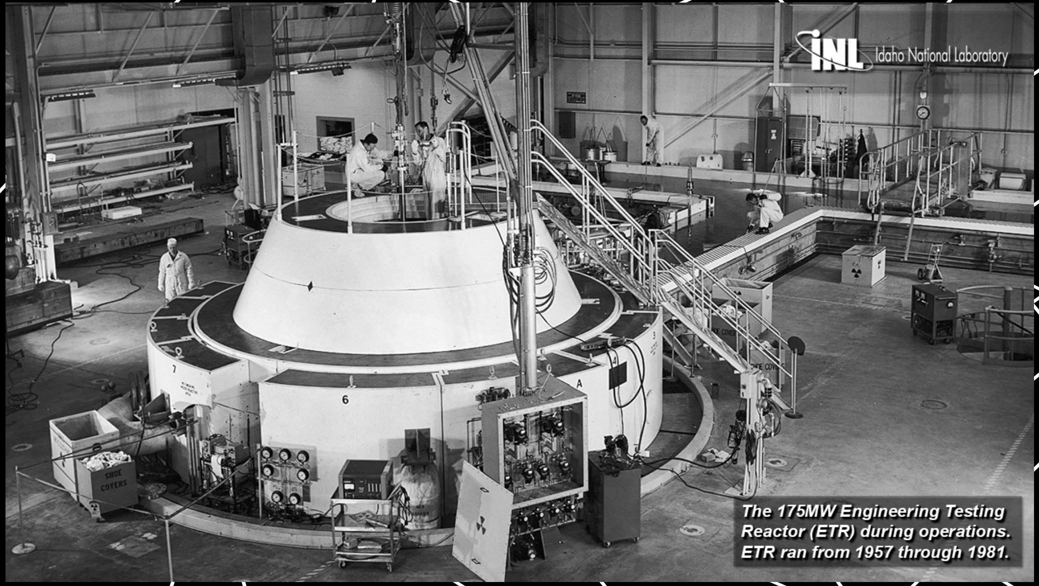
ATR COMPARED TO ITS PREDECESSORS: MTR AND ETR

Materials Testing Reactor, 1952-1970



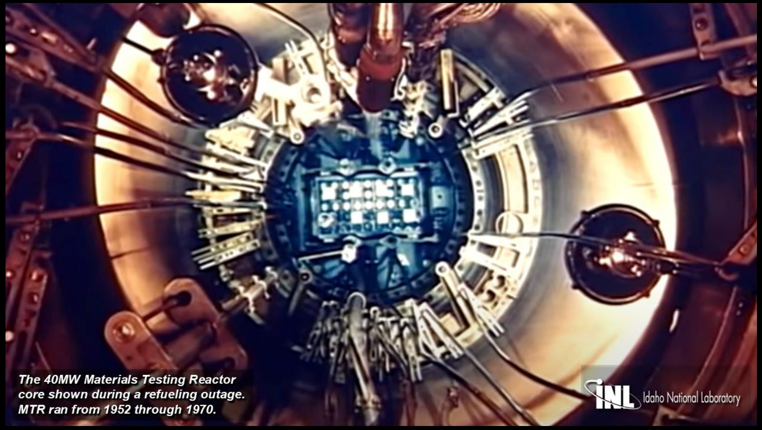
The Materials Testing Reactor in operation. MTR ran from 1952 through 1970.

Engineering Testing Reactor, 1957-1981



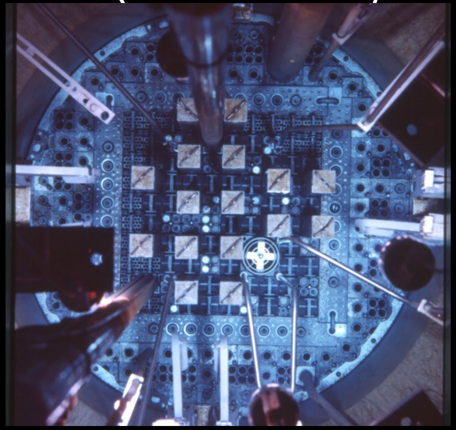
The 175MW Engineering Testing Reactor (ETR) during operations. ETR ran from 1957 through 1981.

MTR core



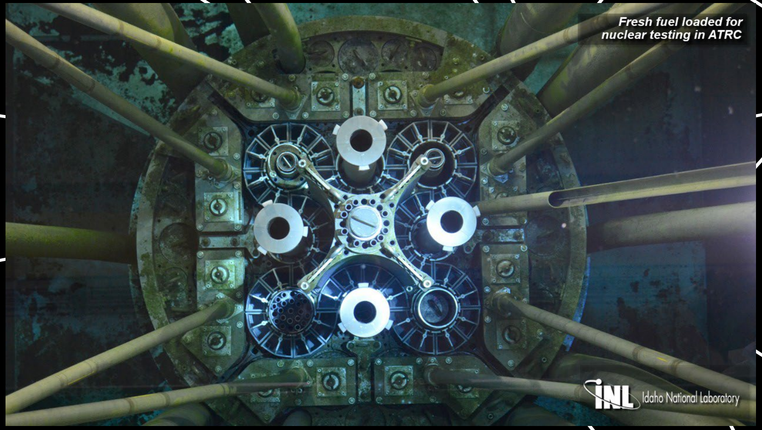
The 40MW Materials Testing Reactor core shown during a refueling outage. MTR ran from 1952 through 1970.

ETR core



The 175MW Engineering Testing Reactor (ETR) core. ETR ran from 1957 through 1981.

ATR core



Fresh fuel loaded for nuclear testing in ATRC

In-Canal Assay of High Specific Activity 60 Co at the Advanced Test Reactor

May 2021 · Nuclear Technology 208(2):1-7
DOI: 10.1080/00295450.2021.1903299

Michael A. Reichenberger · Jagoda Urban-Klaehn · Jason V. Brookman · Show all 6 authors · Richard H Howard

Initial phase of Pu-238 production in Idaho National Laboratory

March 2021 · Applied Radiation and Isotopes 169(3):109517
DOI: 10.1016/j.apradiso.2020.109517

Jagoda Urban-Klaehn · David Miller · Brian J. Gross · Show all 5 authors · Carla C. Dwight

Zeolite-Based Catalysts for Conversion of Oxygenated Polymer Waste by Positron Annihilation

January 2024 · ChemCatChem 16(4)
DOI: 10.1002/cctc.202301282

Lab: Jagoda Urban-Klaehn's Lab

Jagoda Urban-Klaehn · Kanan Shikhaliyev · Anne Gaffney · Show all 9 authors · Xuemin Li

THANK YOU

Jagoda Urban-Klaehn

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