SLAC Metal Clearance Program and Progress

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RadSynch, June 3-5, 2015, DESY, Germany

Outline

- Clearance of metals in accelerator facilities in USA
- SLAC metal clearance program
  - o Characteristics of induced volumetric radioactivity
    - ✓ "Proxy" and hard-to-measure radionuclides
    - ✓ "Surface maximum"
  - o Release protocol:
    - ✓ Release criteria: Measurements are Indistinguishable From Background (**IFB**)
    - ✓ Measurement methods and detection capabilities
    - ✓ Process knowledge
- Progress of metal recycling at SLAC
- DOE Standard draft
- Summary

Directives and Standards for Clearance

- Clearance levels based on a criterion of **10 μSv/y**:
  - IAEA Safety Series 89 (1988)
  - EU Radiation Protection No. 89 (1998)
  - NCRP-144 "Managing potentially radioactive scrap metal" (2002)
  - DOE Order 458.1 (2011)
  - **ANSI N13.12 (2013)** "Surface and volume radioactivity standards for clearance"
- Clearance levels for radionuclides (**in Bq/g**):
  - IAEA-TECDOC-855 "Clearance levels for radionuclides in solid materials" (1996)
  - EU Radiation Protection No. 122 (2000)
  - **ANSI N13.12 Screening Levels (2013)**

Impacts from US DOE Secretarial Memoranda

- Secretarial Moratorium (January 2000)
  - Prohibits the release of volumetrically contaminated metals … into commerce

- Secretarial Suspension (July 2000, modified January 2001)
  - Suspends the release for recycling of metals from Radiation Areas
  - Radioactive or not

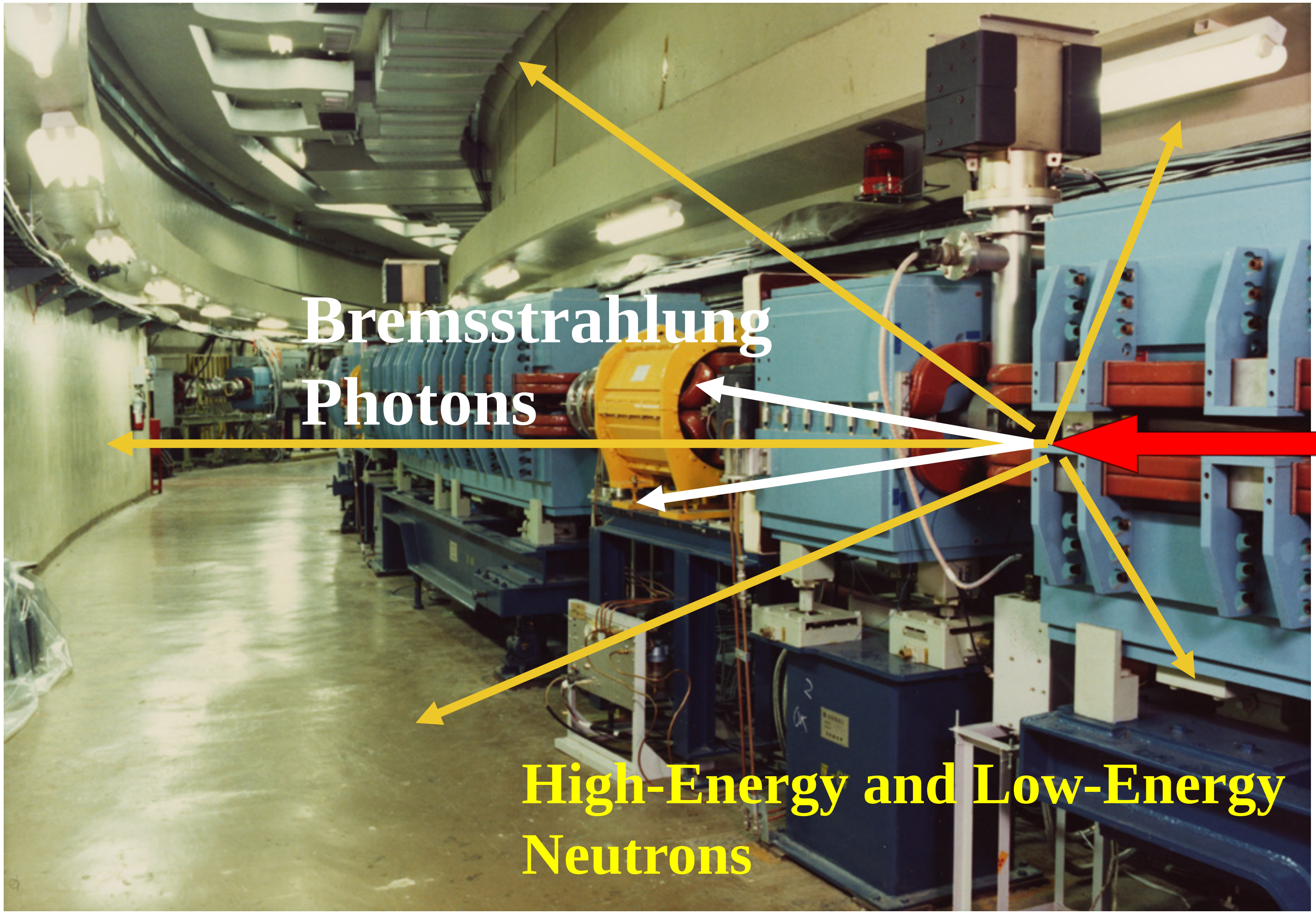
Locations of Excess Metals at SLAC

Red areas contain radioactive materials

Green areas contain recyclable materials

PEP-II and SLC tunnels not shown

Activation in Electron Accelerators



Electron Beam Loss

- Spallation
- Photonuclear
- (n,γ)

Activation Characteristics in Electron Accelerators

- Radionuclides with Z or A no more than the parent nuclides can be produced, but no alpha emitters
- For off-site release purpose, most abundant radionuclides are those with long half-lives on the order of the beam irradiation time (about 1 to 10 years)
- Most radionuclides emit betas and gammas, which can be measured with common radiation detectors
- Radionuclides that are hard to measure are accompanied by “proxy” radionuclides that can be measured (this justifies measurements for proxy radionuclides, instead of measurements for all potential radionuclides that can be produced)
- Induced activity profile in an object is volumetric and the maximum activity is near the surface that faces the beam loss point (this justifies the surface measurements)

Radionuclides of Interest in Metals and Concrete

Material	Radionuclide	Half-life
Carbon steel (Fe, C) Cast iron (Fe, C, Si, Mn)	**^{22}Na (proxy)**	**2.6 y**
	^{54}Mn (proxy)	**312 d**
	^{55}Fe (5.9 keV x-ray)	**2.73 y**
	^{57}Co	272 d
Aluminum	^{22}Na **(proxy)**	2.6 y
Copper	**^{55}Fe (5.9 keV x-ray)**	**2.73 y**
	^{57}Co	272 d
	^{60}Co (proxy)	**5.26 y**
Concrete	**^{3}H (pure beta)**	**12.3 y**
	^{22}Na (proxy)	**2.6 y**
	^{54}Mn (proxy)	**312 d**
	^{55}Fe (5.9 keV x-ray)	**2.73 y**
	^{57}Co	272 d
	^{60}Co	***5.26 y***
	^{152}Eu, ^{154}Eu	***13.5 y, 8.6 y***

Radioisotopes with long half-lives are of interest

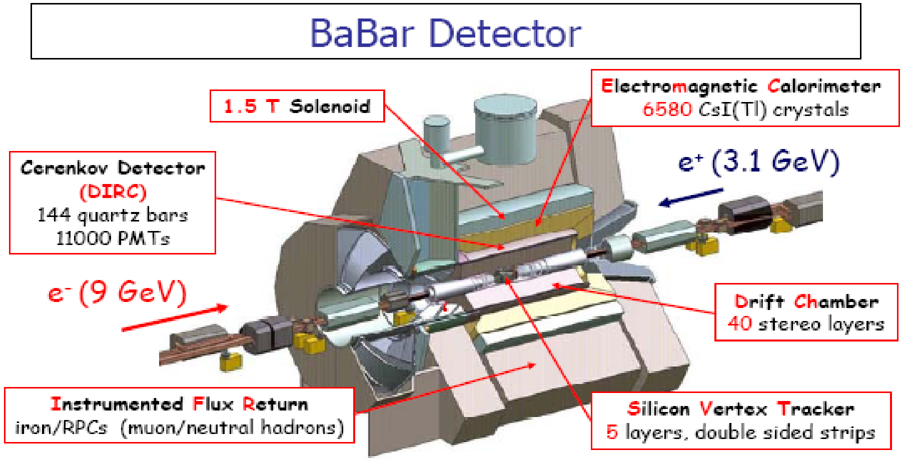
Proxy radioisotopes (^{22}Na, ^{54}Mn, ^{60}Co), which emit high-energy and high-intensity gamma rays

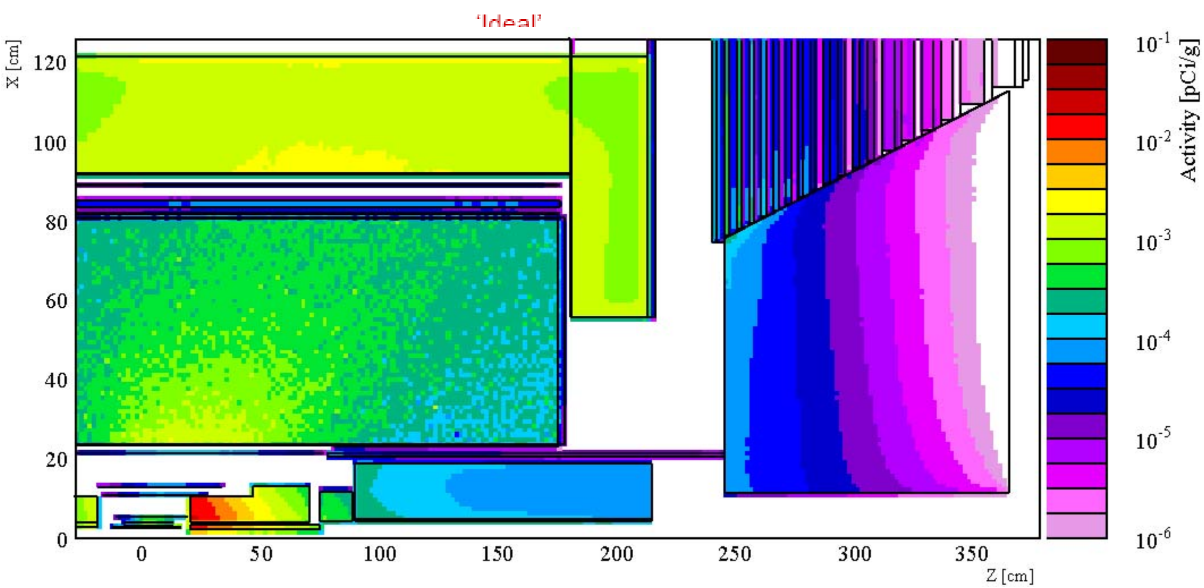
Hard-to-measure radioisotopes (^{55}Fe, ^{3}H), which emit only low-energy X rays or beta rays

10 μSv/y ⇒ ANSI N13.12-2013 Screening Level (SL):
^{22}Na, ^{54}Mn, ^{60}Co: 0.1 Bq/g
^{3}H: 100 Bq/g
^{55}Fe: 1000 Bq/g

Requirements:
$\sum_i$ (SAi / SLi) ≤ 1
$\sum_i$ (DTi / SLi) ≤ 1 for IFB

FLUKA Calculations of Induced Activity in BaBar Detector





3-D specific activity profile of each BaBar component has its maximum activity on the side that faces the radiation source (i.e., e^+ and e^- collision point in BaBar center)

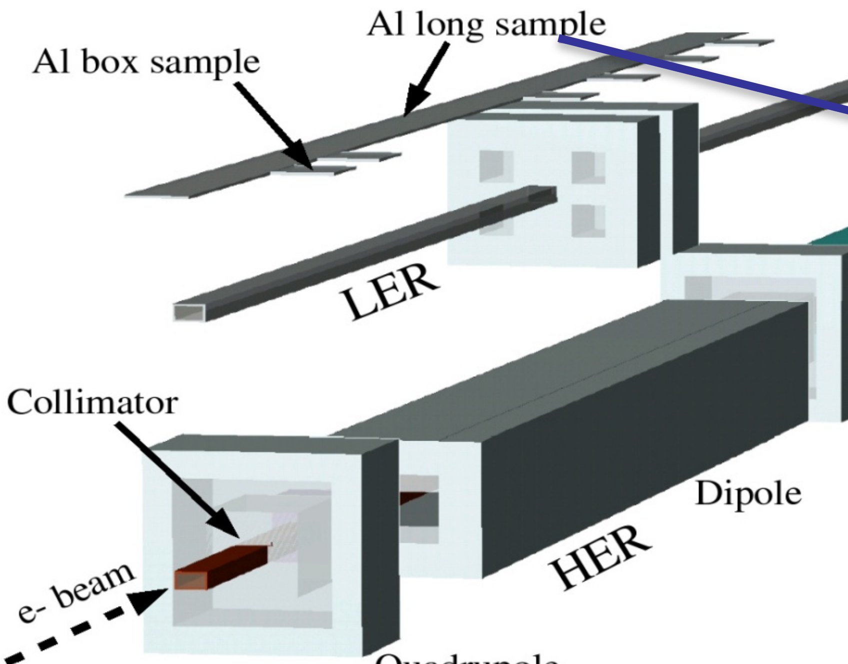
Proxy and Hard-to-Measure Radionuclides for BaBar

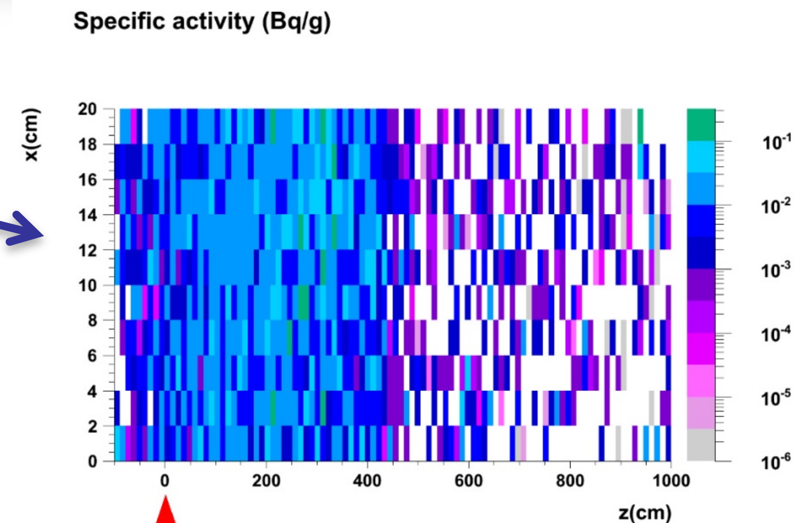
IFR forward steel plug with 10 yr irradiation time and three decay times

Radioisotope	Half-life	FLUKA-Calculated Specific Activity in pCi/g (% of total)		
		1 year	2 years	5 years
^{60}Co (proxy)	**5.3 y**	**1.0×10^{-6} (22%)**	**8.9×10^{-7} (27%)**	**6.0×10^{-7} (38%)**
^{57}Co	272 d	9.4×10^{-8} (2%)	3.7×10^{-8} (1.1%)	2.3×10^{-9} (0.1%)
^{55}Fe	**2.7 y**	**2.4×10^{-6} (53%)**	**1.9×10^{-6} (57%)**	**8.8×10^{-7} (55%)**
^{54}Mn (proxy)	**313 d**	**6.5×10^{-7} (14%)**	**2.9×10^{-7} (9%)**	**2.5×10^{-8} (1.6%)**
^{49}V	338 d	2.7×10^{-7} (6%)	1.3×10^{-7} (4%)	1.4×10^{-8} (0.9%)
^{3}H	12.3 y	6.9×10^{-8} (1.5%)	6.5×10^{-8} (2%)	5.5×10^{-8} (3.4%)
Remaining	—	2.3×10^{-8} (0.5%)	1.0×10^{-8} (0.3%)	6.1×10^{-9} (0.4%)

(SA/SL) for ^{55}Fe is much less than (SA/SL) for ^{60}Co or ^{54}Mn

FLUKA Simulation of Induced Activity for PEP-II Ring

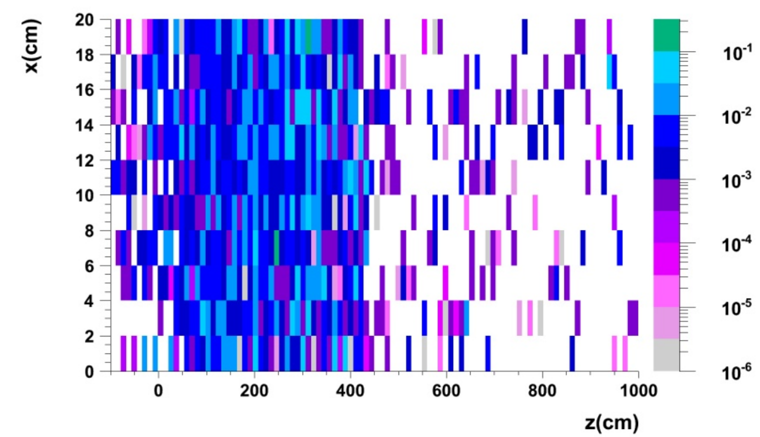




Collimator position

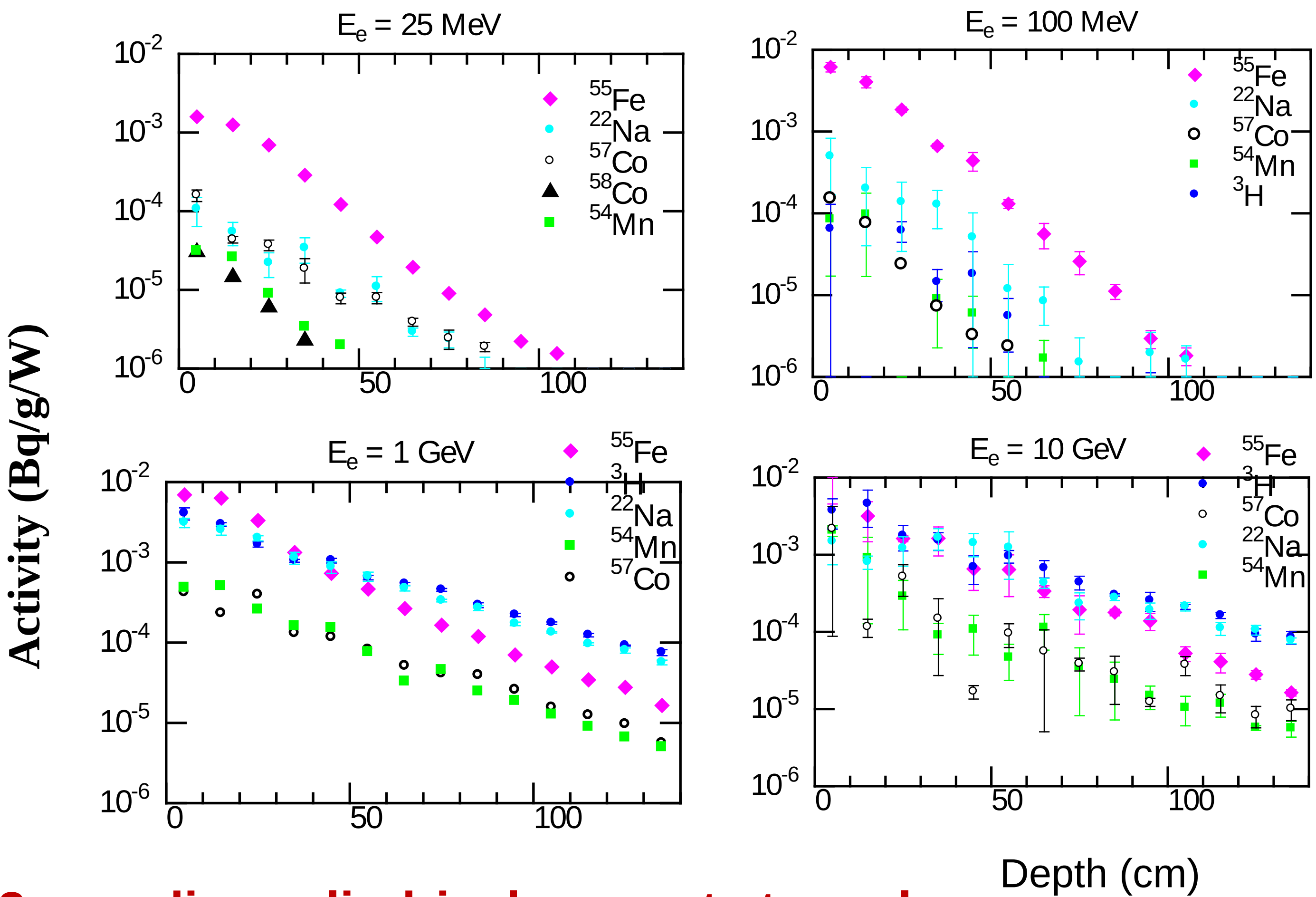
R, t_i = 10 y, t_c = 3 y

R = $\sum_i$ **(SAi / SLi)** .



Activity in Al cables for 9 GeV, **1 W** loss at HER collimator & 10 y irradiation

FLUKA-calculated Activity Profiles in Concrete Wall



Surface Maximum

Photonuclear

1/1000 in 1-m

^{55}Fe / $^{22}Na \leq 10$

Spallation

1/10 in 1-m

^{55}Fe / $^{22}Na \leq 2$

^{3}H / $^{22}Na \leq 2$

- **2-m radius cylindrical concrete tunnel**
- **10-year irradiation and 1-year decay**
- **Calculated profiles agree with KEK measurements**

Technical Basis and Process Knowledge

- Technical basis for volumetric activation have been derived based on extensive evaluation using the well-benchmarked FLUKA Monte Carlo code, field measurements, and operational experiences:
  - Characteristics of specific radioactivity
  - Principle of “Proxy Radionuclides”
  - Principle of “Surface Maximum”
- Technical basis used to support the measurement methods:
  - Detection of proxy radionuclides
  - Quantification of Detection Thresholds (DTs in pCi/g) for measurement methods
    - DTs are less than ANSI N13.12 Screening Levels (SLs)
- Facility specific process knowledge is used to support the release measurements in a graded approach for the facility dismantling

SLAC measurement methods for surface contamination is the same as those commonly used in nuclear facilities, which have detection capabilities satisfying DOE Order 458.1 Pre-Approved Authorized Limits.

SLAC Material Release Protocol for Potential Volumetric Activity

- Purpose/Scope: Unrestricted release of solid metals and concrete
- Release Criterion:
  - Measurements are Indistinguishable from Background (IFB), i.e., materials are not regarded as :radioactive material" and, therefore, are not subject to regulatory controls and can have unrestricted release
  - SLAC release criterion is lower than the 10 µSv/y of the ANSI N13.12 level and DOE O458.1.
- Measurement Methods:
  - Use practical field survey instruments (with sufficient sensitivities) in an ambient environment with acceptable low background to measure proxy radionuclides
    - Supplemented by confirmatory measurements
    - MARSAME graded approach based on process knowledge
  - Detection capabilities are quantified and are lower than ANSI SLs

SLAC Measurement Methods for Volumetric Radioactivity

Type	Method	Instruments & Methods to Detect Proxy Radionuclides [references]	DT for Proxies
Basic Measurements	Field Survey over Item's Surfaces	scan or fixed-point surveys for gross beta-gamma counting rate using Ludlum 1"x1" NaI meter [RPD2010a, RPD2009d]	< 0.1 Bq/g [RPD2011a]
Confirmatory Measurements (as warranted)	Field Gamma Spectrometry	Fixed-point, 5-min measurements using Transpec, DigiDart or RIIDEye [RPD2008f, RPD2011b, RDP2011c]	~0.01 Bq/g
	Portal Gate Monitor (for large batch)	Thermal Fisher Scientific Radiation Portal Monitor TFS SGS-II (4 plastic scintillators, each 48x15x2 in^3, 170 cps per μR/h, with NBR)	~0.01 Bq/g
	Laboratory Measurements	Representative samples counted using low-background HPGe system with environmental counting protocol [RPD2007b, RPD2007c, RPD2007d]	~0.001 Bq/g

- ANSI N13.12 Screening Level (SL): 0.1 Bq/g for proxy radionuclides
- Natural background levels: ~1 Bq/g of ^{40}K, ^{238}U and ^{234}Th series in soil

SLAC Survey Meters for Surface Measurements

Ludlum Model 2241 with both a 44-2 detector (1” NaI) and a GM pancake

Ludlum Model 18 with 44-2 detector

TBM P15
GM Pancake

Field Measurements with a NaI Survey Meter

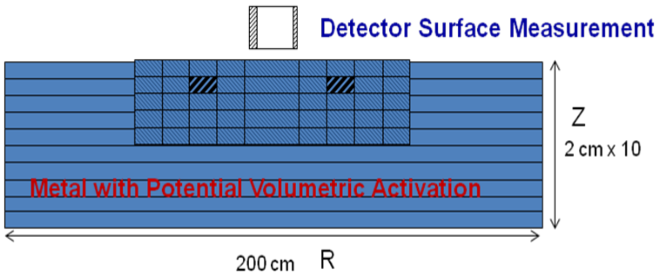
Survey with 1”x1” NaI meter for PEP-II vacuum chamber and Al cable

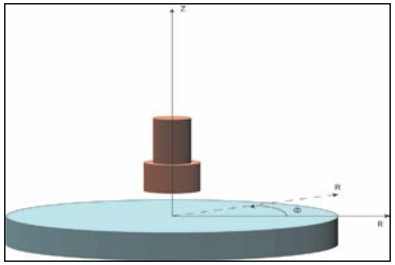
Confirmatory Measurements with Field Spectrometer and Portal Gate Monitor

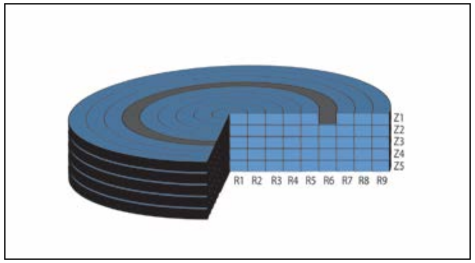
Printed at:

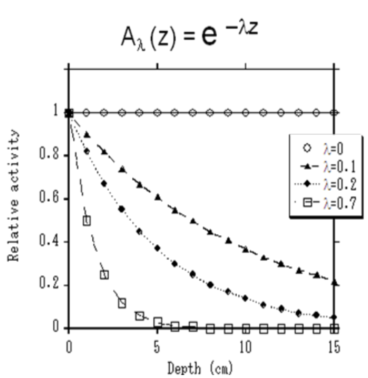
DT Calculations for 1”x1” NaI Survey Instrument

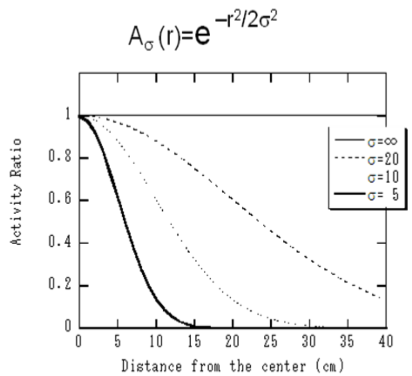
MDA Calculations Using MCNP











“MDA MCNP Calculations”

Hirokuni Yamanishi, et al.,

SLAC RPD-008, June 2011

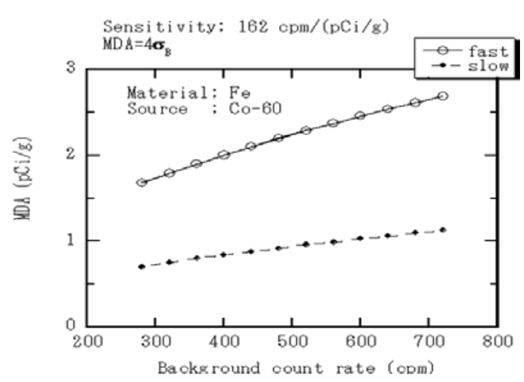
MDA Results

^{60}Co Radionuclide in Iron

Profile		Sensitivity, η
Depth	Radial	cpm/(pCi/g)
λ = 0	σ = 5	383
λ = 0	σ = 10	235
λ = 0	σ = 20	181
Uniform	Uniform	162
λ = 0.1	σ = ∞	162
λ = 0.2	σ = ∞	163
λ = 0.7	σ = ∞	164

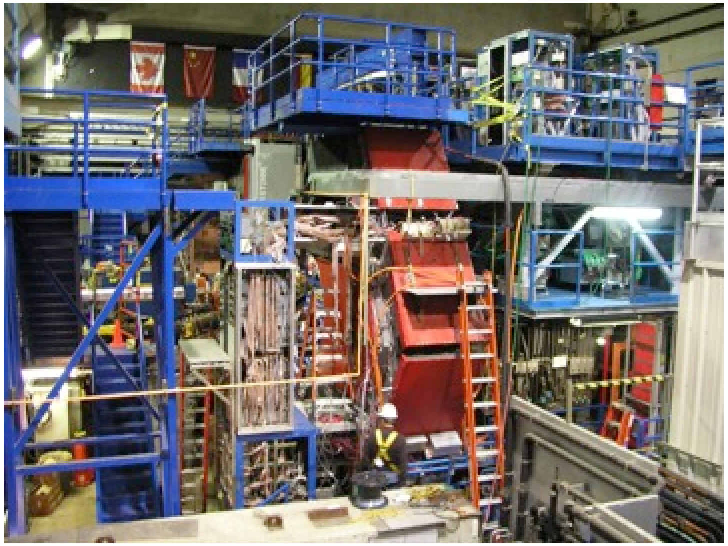
$MDA = 4\,\sigma_B / \eta$

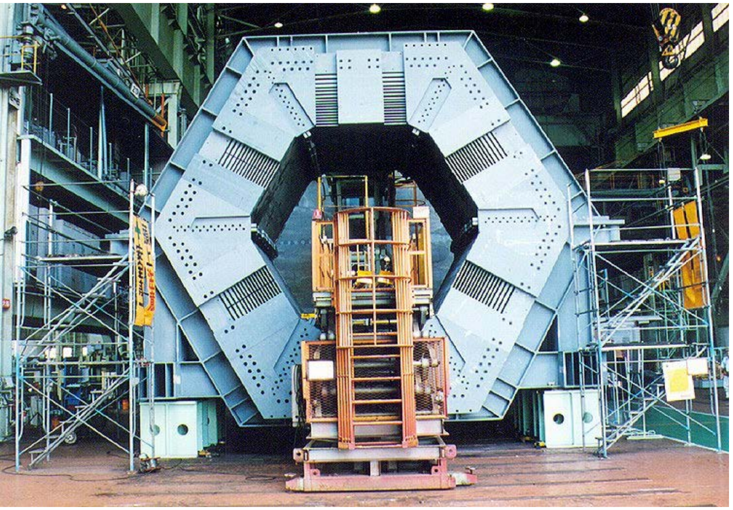
MDA for the uniform case is conservative



- 2000: DOE Policies on Metal Moratorium and Suspension
- 2006-2010: SLAC developed program with protocols for clearance of accelerator metals
- 2009-2011: DOE reviews, peer reviews, workshops
- 2011: DOE HQ endorsed and SSO approved SLAC Protocols
  - First release of metals from accelerators in DOE complex since 2000
- 2015: SLAC leading developing DOE Technical Standard

IR-02: 1249 tons Metals from BaBar





2-Mile Linac Sector 10: 632 tons Iron

SPEAR2 Metals

Total Metals Recycled as of April 2015

Facility or Location	Tons	Revenue	Number of Truck Loads
BaBar	1277	$638,240	85
PEPII	168	$258,289	47
Sector 10	632	$124,910	38
PN-5	341	$109,302	22
KTL	10	$7,751	1
611 & Alpine Gate	222	$174,241	47
Sector 0 (SPEAR)	274	$80,699	28
ESA	4	$6,480	1
Total	**2864**	**$1,380,003**	**268**

Cost for disposal as radioactive waste = $13.2M

DOE Technical Standard

- "**Clearance and Release of Personal Property from Accelerator Facilities**"
- Working Group: SLAC (lead), SNL,ORNL and TJNAF
- **Purposes** (to meet requirements in DOE Order 458.1-2011 "*Radiation Protection of the Public and the Environment*" for clearance of personal property in accelerator facilities):
  - Provides **criteria and guidance** for DOE accelerator facilities to develop and implement site-specific programs (including management, technical, and operational aspects)
  - Serves as **acceptable approach** for the site's technical basis document and implementation guide
- **DOE Standard** RevCom process in May 2015

DOE Technical Standard Table of Contents

Summary

- SLAC has established a material release program that satisfies DOE and Standard requirements
- Technical aspects of the program:
  - Supported by technical basis
  - IFB release criterion
  - Measurement methods and quantification of detection capabilities
  - Process knowledge
- Good progress on recycle of metals from PEP-II accelerator, BaBar detector and other areas
- Leading DOE Standard effort to create values for accelerator community