If you are using a printed copy of this procedure, and not the on-screen version, then you MUST make sure the dates at the bottom of the printed copy and the on-screen version match.
The on-screen version of the Collider-Accelerator Department Procedure is the Official Version.

9.1.15.a BLIP Target and Canning Record

Hand Processed Changes

HPC No.	Date	Page Nos.	Initials
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

Approved: _____***Signature with Date on File***_____
Collider-Accelerator Department Chairman Date

D. Beavis

Note 1: Uncontrolled copy printed from electronic master that is valid at time of printing. Always check that you have the latest revision of this document before use.

Note 2: Leave no blanks. Indicate 'Not Applicable (N/A)', where appropriate.

Title and Preparer
[Irradiation of As target for Se-72 production at 50 MeV energy on target] Target Submission Number: TS-tgt-16-09_____ [Medvedev]

Instructions	
Description	**Page No.**
1. Overview [short summary of purpose of experiment; name of principle investigator and researcher involved]	4
2. Target Material and Properties [provide physical properties of each component/material to be irradiated]	5
3. Target Canning Process [provide images or drawings and reference the OPM procedures for closing and opening of target can]	6
4. Beam Characteristics [define required beam on target and total current required]	7
5. Proposed Experiment [provide general description of a) how target will be supplied BLIP, b) target array in box 1 and box 2; c) thermal analysis of target material and target can d) transport of irradiated target to TPL; target opening and processing at TPL and e) disposal of waste.]	7
a. Procedure for Irradiation of Target Material at BLIP [summarize steps for experiment including specialist and contact hours required for task]	7
b. Target Array [define proposed target array for box 1 and box 2 including calculated entry and exit energy for each layer. Provide physical dimension of degraders, target can, materials and water gaps. Provide total water gap for the array]	10

	c. Thermal Analysis of Target Materials and Target Can [provide full description of data to specialist for calculations and any assumption made on material for calculations]	7
	d. Transport and Processing at TPL [provide description of task involved if different from C-AD OPM 19.17.30 BLIP Target Transfer Procedure]	7
	e. Disposal of waste [describe waste to be generated and how it will be disposed of]	7
6.	**Activation Analysis of Target Material and Can** [provide list of radionuclide produced and their quantities, references used for calculations at the time points of: end of bombardment (EOB) 1 hour after EOB and at the time of transport to TPL]	8
7.	**Expected Dose Rate (e.g., R/h at 1 m)** [provide expected dose rate using *Microshield or equivalent* calculations for the combined and separate target and can irradiated. Provide expected dose rate at EOB at BLIP, 1 h after EOB and expected dose rate at the time of transfer to TPL. Provide decay profiles if the dose rates exceeds limits set up in applicable RWP for removal from BLIP hot-cell. Attach analyses if any]	8
8.	**Additional Safety Requirements:** [provide list of isotopes for monitoring in Blip target cooling water in case of target leak/failure visual inspection schedule impact on BLIP air emissions if water gap exceeds historical values hazardous issues related to volatiles and or corrosive materials used hazardous materials information must be submitted to the C-AD ESRC]	8
9.	**Special Operating Instructions and List of References or Supporting Documents**	10
10.	**Appendix 1:** Target Array and Energy Propagation Calculations **Appendix 2:** Target Array Loading Table (LT) [provide additional supporting information as required]	10

1. Overview

This safety submission deals with irradiation of As target aiming to produce Se-72 at incident energy on target between 45-50 MeV. This energy is optimum for production of large quantities of Se-72.

2. Target Material and Properties

Target Name:	TBD	**Target Submission No.** *Assign unique no.* (year-00x)	Tgt-16-09

Target Material Properties				
Purity or Grade	99.999%, COA see appendix 4			
Chemical Formula	As			
Physical Characteristics at 21 ºC	solid			
Physical Form (foil, disk, pressed pellet…)	Disk, spattering target			
Target dimensions (inches/mm)	**Diameter**	2.375 (60.3)	**Thickness**	0.030-0.036 (0.762-0.914)
Elements (%)	As, 99.999%			
Melting Point	816.8			**ºC**
Boiling Point	614			**ºC**
Decomposition temperature	>400			**ºC**
Thermal Conductivity	50.2 **W.m^{-1}.K^{-1}**	**Temperature dependence**	*(if available)*	
Density	5.7		**g/cm^3**	

Target Material Reactions / Properties						
Does the Target material react with the following or any other material?	**Aluminium**	no	**Air**	no	**Copper**	
	H_2O	insoluble	**S/Steel**			
	Inconel 600	no	**CO_2**			

Canning Material Properties				
Chemical Formula	Aluminum			
Can Window Thickness (inches/mm)	0.020 (0.508) front window 0.064 (1.626) back window			
Can Dimensions (inches/mm)	**Diameter:** 2.750 (69.85)		**Thickness:**0.120 (3.048)	
Melting Point	660.3			**ºC**
Thermal Conductivity	237 **W.m^{-1}.K^{-1}**	**Temperature dependence**	*(if available)* n/a	
Density	2.7	**g/cm^3**		

3. Target Canning Process

The target will be laser welded under He by EB industries

4. Beam Characteristics		
Beam pattern (rastered/focused)	Rastered	
Incident LINAC energy	116.5	**MeV**
Energy on Target Material	50.2	**MeV**
Maximum Instantaneous Current permitted	165	**µA**
Average Current Desired	165	**µA**
Total Integrated Charge Desired	>11880	**µA-hrs**

5. Experiment Description

5.a Procedure for irradiation of target material in BLIP:

Follow CAD OPM 19.17.20 to install or remove the target. Position the target with window upstream

Inspect in one hour and at the end of the day.

5.b Target array in Box 1 and Box 2 (detailed in Appendix 1):

The irradiation is using thick RbCl target in its regular spot and normal energy range. The As target is located downstream of the RbCl target.

5.c Thermal analysis of target material and target can (attach analyses if any):

Performed by: C Cullen **Date:** TBD **Checked by:** TBD **Date:**

5.d Transport of irradiated target to TPL, target opening and processing:

Follow CAD OPM 19.17.30 to transport the target from BLIP in a pig

Follow CAD OPM 19.9.4. to open the target using target cutter

5.e Disposal of waste:

Liquid waste will be neutralised and disposed in D tank system. Target body will be disposed as TPL solid waste CAD OPM 19.30.3

6. Activation Analysis of Target Material and Can

Produced radionuclides were determined experimentally and scaled up taking into account current and time of irradiation. Activation of Al body was calculated based on Na-22 and Na-24 cross sections at 52 MeV. The data given for 72 h (weekend irradiation). The data is provided for EOB and at 24 h after EOB.

Isotope	Half-life, d	72 h at 165 uA	
		A EOB, Ci	A24h, mCi
As-71	2.72	1.33	1.03
As-72	1.08	6.16	4.62
As-73	80.3	2.80	2.78
As-74	17.77	5.88	5.65
Se-72	8.4	3.04	2.80
Se-75	119.79	0.063	0.063
Na-24	0.1	4.7	1.55
Na-22	949	0.037	0.037

Decay Requirements

Depending on the actual dose rate 24 h cool off period may be required. RCT will make a determination

7. Expected Dose Rate

Calculated using Microshield 7

Exposure rate to BLIP operator, mR/h 72 h at 165 uA	
At EOB	24 hours after
15.3	5.32

8. Additional Safety Requirements

Nuclides released to Blip Target Cooling Water in the unlikely event of target leak/failure

The target material is not soluble in water so in case of target failure it will fall on to the bottom of the tank.

Nuclides released to Blip Target Cooling Water in the unlikely event of target leak/failure

Nuclide	Half life	Eγ (abundance, %)
As-71	2.72 d	174.95 (82.4)
As-72	1.08 d	833.99 (81%)

9. Special Operating Instructions

none	
Supporting Documentation	
References	

Appendix 1

Target Array and Energy Propagation Calculations

TITLE: Irradiation of As target for Se-72 production at 50 MeV energy on target_____

Target Array Number: TA-16-09_____

Preparer: Medvedev_____

Layer Number	Layer	Material	Density	Thickness		MeV		Energy deposited
				inch	mm	Ei	Eout	
	Energy: 116.38 MeV					current, uA		
				thickness		165		
layer number	Layer	Material	density	inches	mm	Ei	Eout	deltaE	power, W
1	Be window	Berillium	1.85	0.012	0.305	116.38	116.08	0.30	49.40
2	AlBeMet window	AlBeMet	2.10	0.012	0.305	116.08	115.74	0.34	56.24
3	Beamline window	stainless steel	7.99	0.031	0.787	115.74	112.87	2.87	472.99
4	water gap	water	1.00	0.106	2.692	112.87	111.06	1.82	299.56
5	BOX front window	stainless steel	7.99	0.020	0.508	111.06	109.14	1.92	316.65
6	cooling channel	water	1.00	0.200	5.080	109.14	105.59	3.55	585.06
7	vacuum box	stainles steel	7.99	0.029	0.737	105.59	102.80	2.79	460.97
8		vacuum	0.00	0.596	15.138			0.00	0.00
9		stainless steel	7.99	0.029	0.737	102.80	99.74	3.05	504.05
10	cooling channel	water	1.00	0.200	5.080	99.74	95.95	3.80	626.58
11	can window	inconel	8.43	0.012	0.305	95.95	94.57	1.38	227.69
12	RbCl salt	RbCl	2.20	0.646	16.398	94.57	74.84	19.72	3254.40
13	can window	inconel	8.43	0.012	0.305	74.84	73.19	1.65	272.73
14	cooling channel	water	1.00	0.200	5.080	73.19	68.34	4.85	800.64
15	Aluminum degrader	Aluminum	2.70	0.220	5.588	68.34	57.46	10.88	1795.04
16	cooling channel	water	1.00	0.200	5.080	57.46	51.52	5.94	979.78
17	can window	Aluminum	2.70	0.020	0.508	51.52	50.22	1.30	214.51
18	As metal	As	5.73	0.036	0.914	50.22	46.09	4.13	682.01
19	can window	Aluminum	2.70	0.064	1.626	46.09	41.42	4.66	769.30
20	cooling channel	water	1.00	0.200	5.080	41.42	33.48	7.95	1311.41
21	can window	Niobium	8.57	0.012	0.305	33.48	30.64	2.84	467.89
22	Ga metal	Ga	6.10	0.125	3.178	30.64	stop	31.67	5225.55
23	can window	Niobium	8.57	0.012	0.305	0.00	stop		

RSC Approval:		Date Approved:

Appendix 2

Target Loading Table

Title _Irradiation of As target for Se-72 production at 50 MeV energy on target

Target Array Number: **TA**-16-09_____

Preparer: ___Medvedev_____

Proposed Run Time (e.g. days, hrs.): 72 h

Desired Completion Date: 08/01/2016

Requested Beam Energy (MeV): 117 | Requested Beam Current (μA): 165

	Item	Type and stamped ID (*if available*)	Layer #'s from "Target Array and Energy Propagation Calculations"	Thickness *inch*	BLIP Operator *(Initial)*	Witness *(Initial)*
Box 1	Water gap	n/a	6	0.200		
	SS Vacuum degrader		7-9	0.654		
	Water gap	n/a	10	0.200		
	1st RbCl (Thick)		11-13	0.670		
	Water gap	n/a	14	0.200		
	Aluminum degrader	0.220	15	0.220		
	Water gap	n/a	16	0.200		
	Arsenic target		17-19	0.120		
	Water gap	n/a	20	0.200		
	Ga target		21-23	0.220		

RSC Approval: | **Date Approved:**

Appendix 3 Microshield reports

Dose rate from target at BLIP 24 h after EOB

MicroShield 7.02
BNL (7.02-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
As target_EOB_72 h.ms7	July 25, 2016	11:20:44 AM	00:00:00

Project Info	
Case Title	As target at BLIP
Description	Dose rate at BLIP 24h As target
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	0.081 cm (0.0 in)
Radius	3.018 cm (1.2 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0.0 in)	78.74 cm (2 ft 7.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	.142 in³	As	5.71
Shield 1	12.0 in	Air	0.00122
Shield 2	.5 in	Stainless steel	8
Shield 3	6.0 in	Lead	11.34
Shield 4	.5 in	Stainless steel	8
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: ICRP-38

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
As-71	1.0289e+000	3.8068e+010	4.4251e+005	1.6373e+010

As-72	4.6217e+000	1.7100e+011	1.9878e+006	7.3548e+010
As-73	2.7759e+000	1.0271e+011	1.1939e+006	4.4175e+010
As-74	5.6549e+000	2.0923e+011	2.4322e+006	8.9990e+010
Ge-71	6.6835e-002	2.4729e+009	2.8745e+004	1.0636e+009
Na-22	3.6973e-002	1.3680e+009	1.5902e+004	5.8837e+008
Na-24	1.5504e+000	5.7366e+010	6.6683e+005	2.4673e+010
Se-72	2.7992e+000	1.0357e+011	1.2039e+006	4.4546e+010
Se-75	6.2637e-002	2.3176e+009	2.6940e+004	9.9677e+008

Buildup: The material reference is Shield 3 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.506e+11	0.000e+00	4.230e-22	0.000e+00	3.628e-23
0.02	8.056e+06	0.000e+00	1.813e-26	0.000e+00	6.281e-28
0.05	7.090e+10	0.000e+00	4.349e-22	0.000e+00	1.158e-24
0.06	2.561e+07	0.000e+00	1.974e-25	0.000e+00	3.922e-28
0.08	1.927e+05	1.109e-166	2.221e-27	1.755e-169	3.515e-30
0.1	5.405e+08	0.000e+00	2.471e-07	0.000e+00	3.780e-10
0.15	3.610e+10	9.244e-142	1.899e-20	1.522e-144	3.128e-23
0.2	8.436e+07	1.890e-70	2.924e-24	3.336e-73	5.161e-27
0.3	3.118e+09	6.365e-26	1.970e-22	1.207e-28	3.737e-25
0.4	7.289e+08	2.756e-14	6.740e-14	5.369e-17	1.313e-16
0.5	4.466e+11	2.225e-06	6.562e-06	4.367e-09	1.288e-08
0.6	1.724e+11	3.945e-04	1.271e-03	7.700e-07	2.481e-06
0.8	1.389e+11	1.576e-01	5.936e-01	2.998e-04	1.129e-03
1.0	5.650e+09	1.541e-01	6.325e-01	2.841e-04	1.166e-03
1.5	6.324e+10	6.595e+01	2.905e+02	1.110e-01	4.888e-01
2.0	4.389e+09	1.843e+01	8.268e+01	2.849e-02	1.279e-01
3.0	6.059e+10	7.797e+02	3.440e+03	1.058e+00	4.667e+00
4.0	3.454e+08	6.585e+00	2.824e+01	8.146e-03	3.493e-02
Totals	1.254e+12	8.710e+02	3.843e+03	1.206e+00	5.321e+00

Dose rate from target at BLIP at EOB

MicroShield 7.02
BNL (7.02-0000)

Date	By	Checked

Filename	Run Date	Run Time	Duration
As target_EOB_72 h.ms7	July 25, 2016	11:19:26 AM	00:00:00

Project Info	
Case Title	As target at BLIP
Description	Dose rate at BLIP EOB As target
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	0.081 cm (0.0 in)
Radius	3.018 cm (1.2 in)

Dose Points			
A	X	Y	Z
#1	0.0 cm (0.0 in)	78.74 cm (2 ft 7.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	Dimension	Material	Density
Source	.142 in³	As	5.71
Shield 1	12.0 in	Air	0.00122
Shield 2	.5 in	Stainless steel	8
Shield 3	6.0 in	Lead	11.34
Shield 4	.5 in	Stainless steel	8
Air Gap		Air	0.00122

Source Input: Grouping Method - Standard Indices
Number of Groups: 25
Lower Energy Cutoff: 0.015
Photons < 0.015: Included
Library: ICRP-38

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
As-71	1.3300e+000	4.9210e+010	5.7203e+005	2.1165e+010
As-72	6.1600e+000	2.2792e+011	2.6494e+006	9.8028e+010

As-73	2.8000e+000	1.0360e+011	1.2043e+006	4.4558e+010
As-74	5.8800e+000	2.1756e+011	2.5290e+006	9.3572e+010
Na-22	3.7000e-002	1.3690e+009	1.5914e+004	5.8880e+008
Na-24	4.7000e+000	1.7390e+011	2.0215e+006	7.4794e+010
Se-72	3.0400e+000	1.1248e+011	1.3075e+006	4.8377e+010
Se-75	6.3000e-002	2.3310e+009	2.7096e+004	1.0026e+009

Buildup: The material reference is Shield 3 Integration Parameters	
Radial	20
Circumferential	10
Y Direction (axial)	10

Results					
Energy (MeV)	Activity (Photons/sec)	Fluence Rate MeV/cm²/sec No Buildup	Fluence Rate MeV/cm²/sec With Buildup	Exposure Rate mR/hr No Buildup	Exposure Rate mR/hr With Buildup
0.015	2.666e+11	0.000e+00	4.501e-22	0.000e+00	3.860e-23
0.02	1.024e+07	0.000e+00	2.306e-26	0.000e+00	7.987e-28
0.05	7.616e+10	0.000e+00	4.671e-22	0.000e+00	1.244e-24
0.06	2.575e+07	0.000e+00	1.986e-25	0.000e+00	3.945e-28
0.08	1.938e+05	1.115e-166	2.234e-27	1.765e-169	3.535e-30
0.1	5.597e+08	0.000e+00	2.558e-07	0.000e+00	3.914e-10
0.15	4.626e+10	1.185e-141	2.434e-20	1.951e-144	4.008e-23
0.2	9.905e+07	2.219e-70	3.434e-24	3.917e-73	6.060e-27
0.3	3.459e+09	7.062e-26	2.186e-22	1.340e-28	4.147e-25
0.4	8.712e+08	3.294e-14	8.057e-14	6.418e-17	1.570e-16
0.5	5.578e+11	2.778e-06	8.196e-06	5.454e-09	1.609e-08
0.6	1.836e+11	4.201e-04	1.353e-03	8.200e-07	2.642e-06
0.8	1.851e+11	2.100e-01	7.910e-01	3.995e-04	1.505e-03
1.0	7.247e+09	1.977e-01	8.114e-01	3.645e-04	1.496e-03
1.5	1.813e+11	1.890e+02	8.326e+02	3.180e-01	1.401e+00
2.0	5.839e+09	2.451e+01	1.100e+02	3.791e-02	1.701e-01
3.0	1.781e+11	2.291e+03	1.011e+04	3.109e+00	1.372e+01
4.0	5.216e+08	9.944e+00	4.264e+01	1.230e-02	5.275e-02
Totals	1.693e+12	2.515e+03	1.110e+04	3.478e+00	1.534e+01

Appendix 4 .Certificate of Analysis of As metal

AMERICAN ELEMENTS
THE MATERIALS SCIENCE COMPANY ®
10884 WEYBURN AVE. LOS ANGELES, CA 90024
TEL. 310-208-0551 • FAX 310-208-0351 • E-MAIL: shipping@americanelements.com

CERTIFICATE OF ANALYSIS

99.999% (metals basis) Arsenic (Elemental) Sputtering Target

As

Product Code: AS-E-05M-ST.2.375D
Lot #: 1106509255-424
CAS #: 7440-38-2
Description: Diameter: 2.375" (-0.005") Thickness: 0.020"

Impurity	ppm (Max.)	Impurity	ppm (Max.)
B	<0.01	Ba	<0.01
Be	<0.01	Bi	<0.01
Ca	<0.1	Cd	<0.03
Co	<0.01	Cr	<0.01
Cu	<0.01	Fe	<0.1
Ge	<0.03	Hg	<0.01
K	<0.02	Li	<0.01
Mg	<0.01	Mn	<0.01
Na	<0.01	Nb	<0.01
Ni	<0.01	Pb	<0.01
Sb	<0.01	Se	<0.058
Si	<0.01	Sn	<0.03
Te	<0.02	V	<0.01
Zn	<0.01	P	<0.01
S	<0.01		

AMERICAN ELEMENTS

By _____

AEC FORM 102:CA REV. APP. 2/3/99