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.
Hard copies of all signed, official, C-A Operating Procedures are available by contacting the ESSHQ Procedures Coordinator, Bldg. 911A

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, S. Smith

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.

Note2: Leave no blanks. Indicate 'Not Applicable (N/A)', where appropriate.

Title and Preparer
Irradiation of Ga target at BLIP to produce Ge-68/Zn-65 [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. List persons responsible for conducting each task. If others are required to assist in the research irradiation, define level of skill of staff and contact time.]	7
a. Procedure for Irradiation of Target Material 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 SRIM calculated entry and exit energy for each layer. Provide physical dimension of degraders, target can, materials and water gaps]	7
c. Thermal Analysis of Target Materials and Target Can [Provide full description of data provide to specialist for calculations and any assumption made on material for	7

calculations]	
d. Transport and Processing at TPL [Provide full description of task involved and responsible persons and contact hours required]	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 full list of radionuclide produced and quantities, references used for calculations, as well as decay profiles if the dose rates exceed limit for removal from BLIP hot-cell. Ensure Health Physics has reviewed data and confirms decay requirement if they are dose related. Attach analyses if any.]	8
a. Radioactivity of each nuclide at end of bombardment (EOB), at 8 hours and 24 hours post EOB.	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 and expected dose rate when delivered to TPL]	8
8. Additional Safety Requirements [address hazardous issues related to volatiles and or corrosive materials used and any additional equipment required for this experiment; hazardous materials information must be submitted to the C-AD ESSHQ Division Head for concurrence]	9
9. Special Operating Instructions and List of References or Supporting Documents	9
10. Appendix [provide additional support information as required]	10-17

1. Overview

The purpose of this experiment is to irradiate Ga target to test chemical procedure in lieu of DOE request to irradiate more Ga target during FY2015-2016 run cycle. It will also be used to manufacture Zn-65 for distribution.

2. Target Material and Properties

Target Name:	*BTA*	**Target & Canning No.** *Assign unique no.* (year-00x)	**TBD**

Target Material Properties				
Purity or Grade	99.999%			
Chemical Formula	Ga			
Physical Characteristics at 70 ºF or 21 ºC	**Solid (melting point 29.78 ⁰C)**			
Physical Form	**Foil**	**n/a**	**Powder**	**n/a**
	Diameter (inches/mm)	**2.250**	**Pressed (Torr)**	**n/a**
Elements (%)	**Ga**			
Melting Point	**29.78**	**ºC**	**n/a**	**ºF**
Boiling Point	**2403**	**ºC**	**n/a**	**ºF**
Thermal Conductivity	40.6 **W.m^{-1}.K^{-1}**	**Temperature dependence**	***(if available)***	
Density	**Sol. 5.904, liq. 6.095**		**g/cm^3**	
Specific Heat	**25.86**		**J/mol.K**	

Target Material Reactions / Properties						
Does the Target material react with any of the following?	**Aluminium**	**no**	**Air**	**oxide**	**CO_2**	**no**
	H_2O	**no**	**Lead**	**no**	**Zinc**	**no**
	Inconel 600	**np**	**S/Steel**	**no**	**Copper**	**no**

Canning Material Properties				
Chemical Formula	**Nb**			
Can Wall Thickness (inches/mm)	**0.012 (0.3048)**			
Can Dimensions (inches/mm)	**Can Diameter**	**2.75 (69.85)**	**Can Width: 0.220 (5.588)**	
Melting Point	**2468**	**ºC**	**n/a**	**ºF**
Thermal Conductivity	**54 W.m^{-1}.K^{-1}**	**Temperature dependence**	*(if available)n/a*	
Density	**8.57**	**g/cm^3**		
Specific Heat	**24.60**		**J/mol.K**	

3. Target Canning Process
The target has been beam-welded by EB industries, following CAD OPM 19.17.1

4. Beam Characteristics		
Maximum Instantaneous Current Desired	**80**	**µA**
Average Current Desired	**80**	**µA**
Total Integrated Current Desired	**3840 (80×48 h)**	**µA-hrs**
Maximum Proton Energy on Target Material	**28**	**MeV**

5. Experiment Description

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

Irradiate target at BLIP in the low energy slot for 48-60 h at reduced beam current and transport to BLIP after irradiation. Follow CAD OPM 19.17.20 to install or remove the target.

5.b Target array in Box 1:

Target array is given in the Appendix 1. Briefly, upstream to downstream: [vacuum degrader], [1st RbCl] [2nd RbCl], [Ga target] with 5 mm water gaps

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

The summary of successfully irradiated and processed targets is given under 9. Special Operating Instructions

TBD

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

Follow 19.18.30 Ge-68 from Ga Metal Targets for target processing

5.e Disposal of waste:

Liquid waste will be neutralized 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

Target material:

The activation of Ga metal was calculated using activation equation and cross section data assuming **4 week** irradiation. See Appendix 3 for cross section data. The Table contains the list of the nuclides contributing to the dose rate.

Nuclide	T1/2, d	Activity EOB, Ci	Activity 24 h, Ci
Ge-68	287	1.55	1.55
Ga-68	0.047	1.55	1.55
Ge-69	1.625	20.05	13.09
Ga-67	3.263	1.40	1.13
Zn-65	244	0.31	0.31

Target cladding:

Since the beam will stop in Ga metal and will not reach downstream window only the upstream Nb window will be activated. Activation of the upstream Nb window is **insignificant** compared to activation of Ga metal due to small thickness and unfavourable cross section data (see appendix 4). Nuclides produced in the Nb window are Zr-88 (83.4 d, E=392.8 keV (I=94.5%)), Zr-89 (78.4 h, 909.2 keV, (I=99.87%)).

Decay Requirements

No decay requirement

7. Expected Dose Rate

The dose rate was calculated using Microshied 7.02 based on the data for Ga target.

The dose rate to the operator at BLIP after 28 days irradiation at 80 μA is 0.98 mR/h

The dose rate after 24 h cool off time is 0.65 mR/h

See appendix 5 for Microshield reports.

8. Additional Safety Requirements

9. Special Operating Instructions/Additional considerations

Summary of irradiated and processed Ga metal targets

(provided by J. Fitzsimmons)

	06/01/ 2012	07/02/ 2012	08/09/ 2012	05/23/ 2013	08/26/ 2013
Target name	BQR	BQQ	BQU	BPR	BPS
Irradiation µA-h	36008	40352	24950	44814	31916
Ge (mCi) Leached	700	610	257	410	359-430
Total Ge-68 recovered mCi	666	595	257	420	408
Ge activity recovered by fraction mCi	666	128/465[c]/<5	257	140/274	408
% Ge recovery in HCl form	95%	97%	99%	103%	95%
mCi/ µA-h	0.0194	0.0151	0.0103	0.0091	0.0135
µCi/ µA-h	19.44	15.12	10.30	9.15	13.47

Supporting Documentation	
References	

Appendix 1.

Proton Energy Profile for Ga target Array

(verified by Phil Pile)

	Energy: 116.38 MeV							
				thickness				
layer number	Layer	Material	density	inches	mm	Ei	Eout	energy deposited
1	Be window	Berillium	1.85	0.012	0.305	116.38	116.08	0.30
2	AlBeMet window	AlBeMet	2.10	0.012	0.305	116.08	115.74	0.34
3	Beamline window	stainless steel	7.99	0.031	0.787	115.74	112.87	2.87
4	water gap	water	1.00	0.106	2.692	112.87	111.06	1.82
5	BOX front window	stainless steel	7.99	0.020	0.508	111.06	109.14	1.92
6	cooling channel	water	1.00	0.200	5.080	109.14	105.59	3.55
7	vacuum degrader	stainless steel	7.99	0.058	1.473	105.59	99.74	5.85
8	cooling channel	water	1.00	0.200	5.080	99.74	95.95	3.80
9	can window	inconel	8.43	0.012	0.305	95.95	94.57	1.38
10	RbCl salt	RbCl	2.38	0.646	16.410	94.57	73.05	21.52
11	can window	inconel	8.43	0.012	0.305	73.05	71.36	1.68
12	cooling channel	water	1.00	0.200	5.080	71.36	66.41	4.95
13	can window	inconel	8.43	0.012	0.305	66.41	64.60	1.81
14	RbCl salt	RbCl	2.38	0.500	12.700	64.60	41.13	23.48
15	can window	inconel	8.43	0.012	0.305	41.13	38.51	2.62
16	cooling channel	water	1.00	0.200	5.080	38.51	30.03	8.48
17	Nb window	Nb	8.57	0.012	0.305	30.03	27.01	3.02
18	Ga target	Ga	6.095	0.196	4.979	27.01	0.00	27.01
19	Nb window	Nb	8.57	0.012	0.305	0.00	0.00	0.00
20	cooling channel	water	1.00	0.200	5.080	0.00	0.00	

Appendix 2

Heal load analysis

Gallium Target, Niobium Holder Thermal Analysis

Appendix 3

Cross section data for activation of Ga metal target for energies ~27→0 MeV

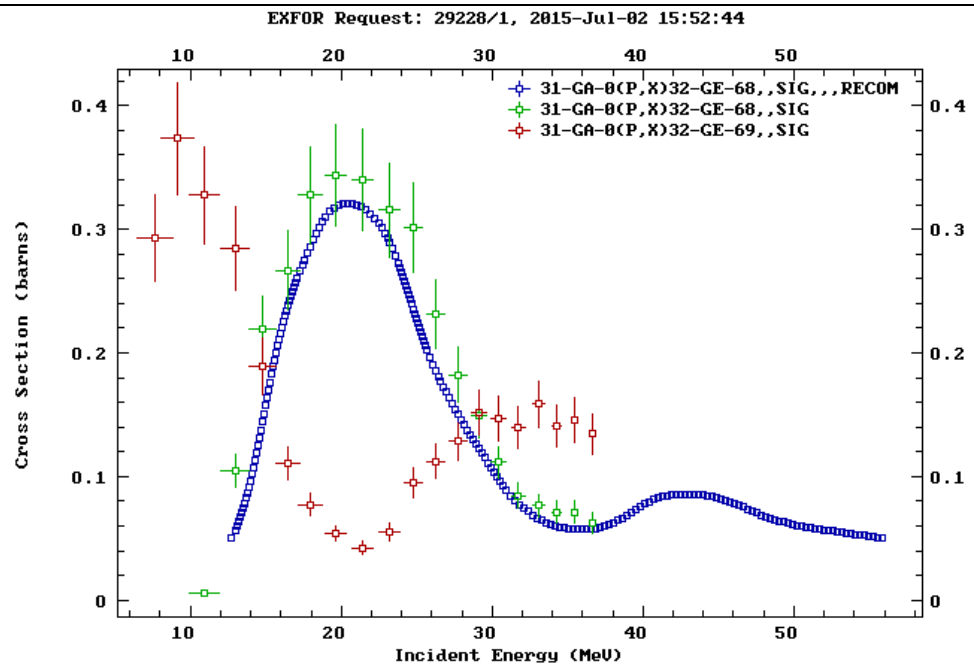


Figure A3-1. Cross section data for production of Ge-68 and Ge-69 isotopes from natural Ga

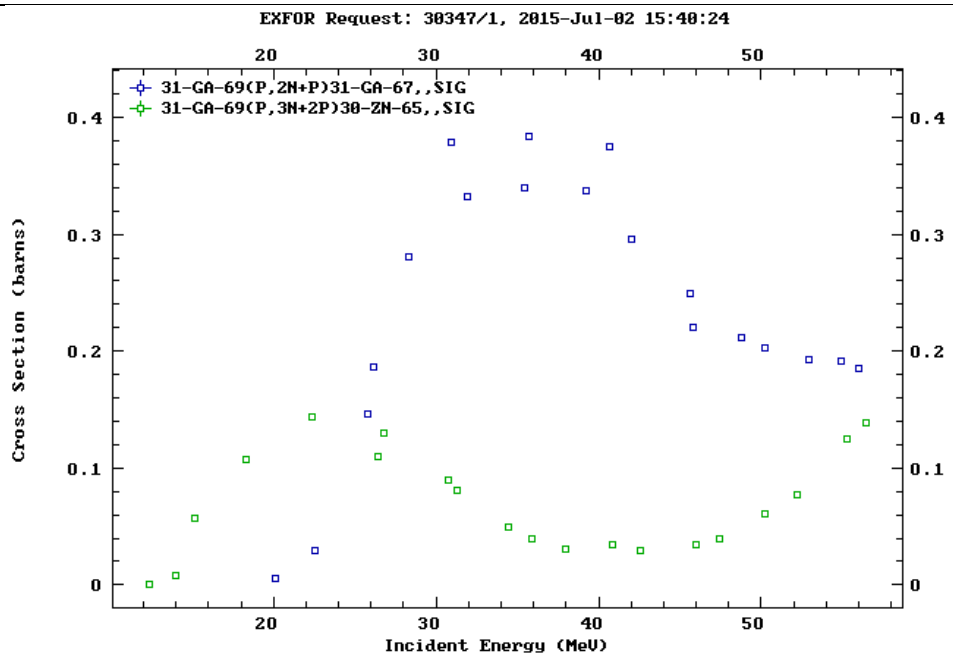


Figure A3-2. Cross section data for production of Ga-67 and Zn-65 isotopes from Ga-69

Appendix 4

Cross section data for activation of Nb window for proton energy ~30→27 MeV

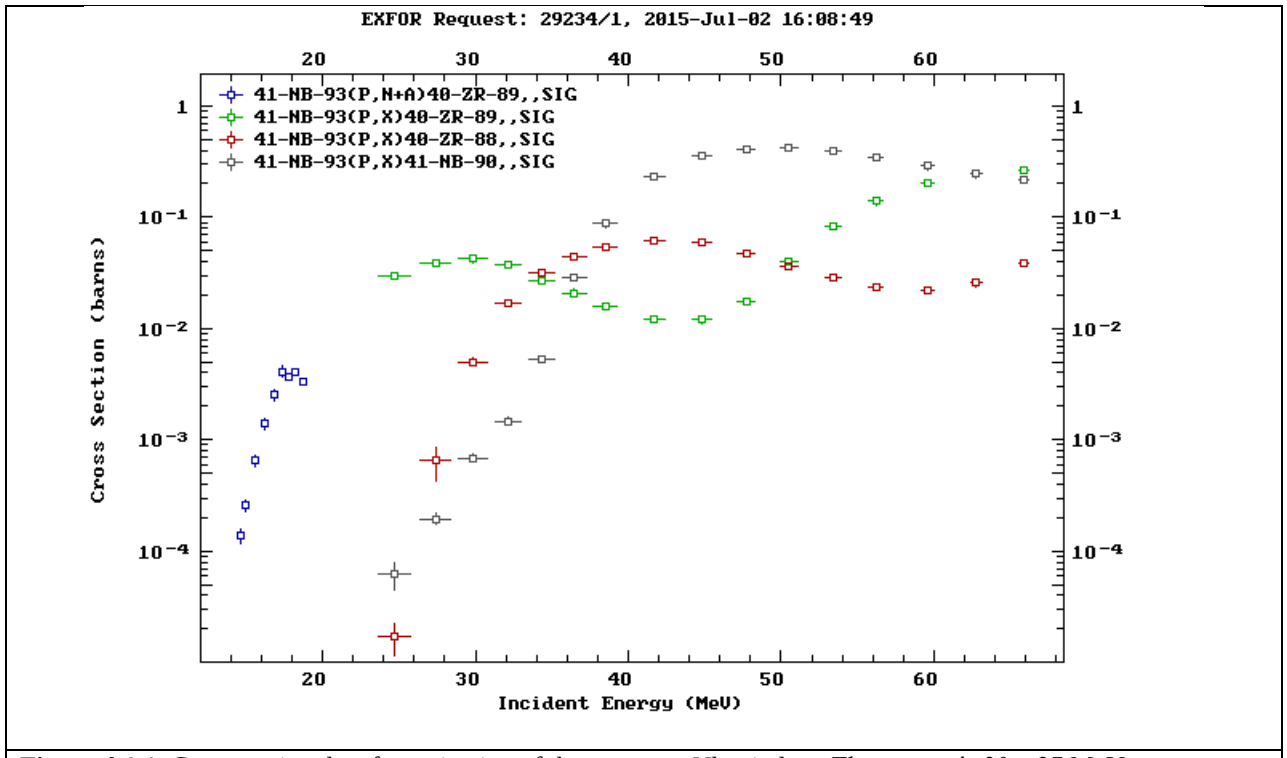


Figure A4-1. Cross section data for activation of the upstream Nb window. The energy is 30→27 MeV

Appendix 5

Microshield reports

Dose rate to the operator from Ga target at BLIP at EOB

MicroShield 7.02 BNL (7.02-0000)		
Date	**By**	**Checked**

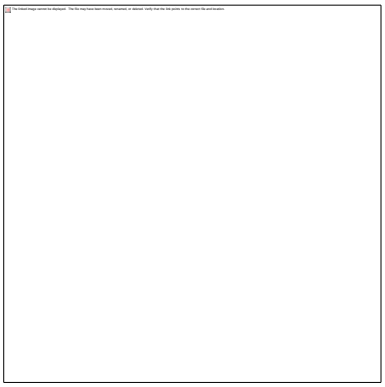
Filename	Run Date	Run Time	Duration
Ga target EOB_28d beam.ms7	July 6, 2015	11:34:50 AM	00:00:00

Project Info	
Case Title	Ga puck BLIP@EOB
Description	Dose rate EOB after 28d irradiation
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	0.498 cm (0.2 in)
Radius	3.493 cm (1.4 in)

Dose Points			
A	**X**	**Y**	**Z**
#1	0.0 cm (0.0 in)	76.2 cm (2 ft 6.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	**Dimension**	**Material**	**Density**
Source	19.077 cm³	Gallium	5.95
Shield 1	30.48 cm	Air	0.00122
Shield 2	15.24 cm	Lead	11.34
Air Gap		Air	0.00122



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

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ga-67	1.4000e+000	5.1800e+010	7.3386e+004	2.7153e+009

Ge-68	1.5500e+000	5.7350e+010	8.1249e+004	3.0062e+009
Ge-69	2.0050e+001	7.4185e+011	1.0510e+006	3.8887e+010
Zn-65	3.1000e-001	1.1470e+010	1.6250e+004	6.0124e+008

Buildup: The material reference is Shield 2 **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**
0.1	2.141e+10	0.000e+00	1.056e-05	0.000e+00	1.616e-08
0.2	1.545e+10	5.067e-67	5.780e-22	8.943e-70	1.020e-24
0.3	1.868e+10	3.119e-24	1.274e-21	5.916e-27	2.417e-24
0.4	3.006e+09	7.102e-13	1.719e-12	1.384e-15	3.349e-15
0.5	5.163e+11	1.352e-05	3.911e-05	2.654e-08	7.677e-08
0.6	8.736e+10	9.252e-04	2.904e-03	1.806e-06	5.669e-06
0.8	7.645e+10	3.340e-01	1.207e+00	6.352e-04	2.297e-03
1.0	2.013e+11	1.854e+01	7.213e+01	3.418e-02	1.330e-01
1.5	2.604e+10	7.433e+01	3.030e+02	1.251e-01	5.098e-01
2.0	5.110e+09	5.220e+01	2.155e+02	8.072e-02	3.332e-01
Totals	**9.712e+11**	**1.454e+02**	**5.919e+02**	**2.406e-01**	**9.783e-01**

Dose rate to the operator at BLIP 24 hours past EOB, 28 d of beam

MicroShield 7.02 BNL (7.02-0000)		
Date	**By**	**Checked**

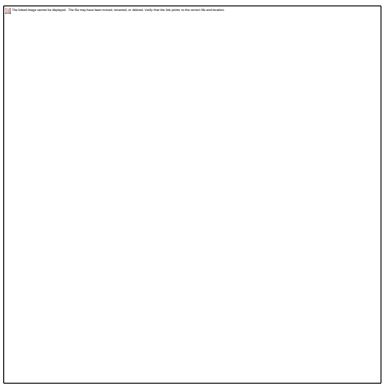
Filename	Run Date	Run Time	Duration
Ga target EOB_28d beam.ms7	July 6, 2015	11:38:36 AM	00:00:00

Project Info	
Case Title	Ga puck BLIP@EOB
Description	Dose rate EOB after 28d irradiation_2h h cool off
Geometry	8 - Cylinder Volume - End Shields

Source Dimensions	
Height	0.498 cm (0.2 in)
Radius	3.493 cm (1.4 in)

Dose Points			
A	**X**	**Y**	**Z**
#1	0.0 cm (0.0 in)	76.2 cm (2 ft 6.0 in)	0.0 cm (0.0 in)

Shields			
Shield N	**Dimension**	**Material**	**Density**
Source	19.077 cm³	Gallium	5.95
Shield 1	30.48 cm	Air	0.00122
Shield 2	15.24 cm	Lead	11.34
Air Gap		Air	0.00122



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

Nuclide	Ci	Bq	µCi/cm³	Bq/cm³
Ga-67	1.1319e+000	4.1881e+010	5.9333e+004	2.1953e+009
Ga-68	1.5465e+000	5.7221e+010	8.1067e+004	2.9995e+009
Ge-68	1.5463e+000	5.7212e+010	8.1054e+004	2.9990e+009

Ge-69	1.3095e+001	4.8451e+011	6.8642e+005	2.5398e+010
Zn-65	3.0912e-001	1.1437e+010	1.6204e+004	5.9954e+008

Buildup: The material reference is Shield 2 **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
0.1	1.731e+10	0.000e+00	8.539e-06	0.000e+00	1.306e-08
0.2	1.197e+10	3.925e-67	4.477e-22	6.927e-70	7.901e-25
0.3	1.355e+10	2.262e-24	9.244e-22	4.291e-27	1.754e-24
0.4	2.341e+09	5.532e-13	1.339e-12	1.078e-15	2.609e-15
0.5	4.392e+11	1.150e-05	3.327e-05	2.257e-08	6.531e-08
0.6	5.707e+10	6.045e-04	1.897e-03	1.180e-06	3.704e-06
0.8	5.000e+10	2.184e-01	7.898e-01	4.155e-04	1.502e-03
1.0	1.354e+11	1.247e+01	4.850e+01	2.298e-02	8.940e-02
1.5	1.707e+10	4.872e+01	1.986e+02	8.197e-02	3.342e-01
2.0	3.420e+09	3.494e+01	1.442e+02	5.403e-02	2.230e-01
3.0	2.832e+05	7.843e-03	3.177e-02	1.064e-05	4.311e-05
Totals	**7.473e+11**	**9.636e+01**	**3.922e+02**	**1.594e-01**	**6.482e-01**