AN APPROACH TO THE INTEGRAL DESIGN OF INTENSE NEUTRON SOURCES BY SPALLATION REACTIONS

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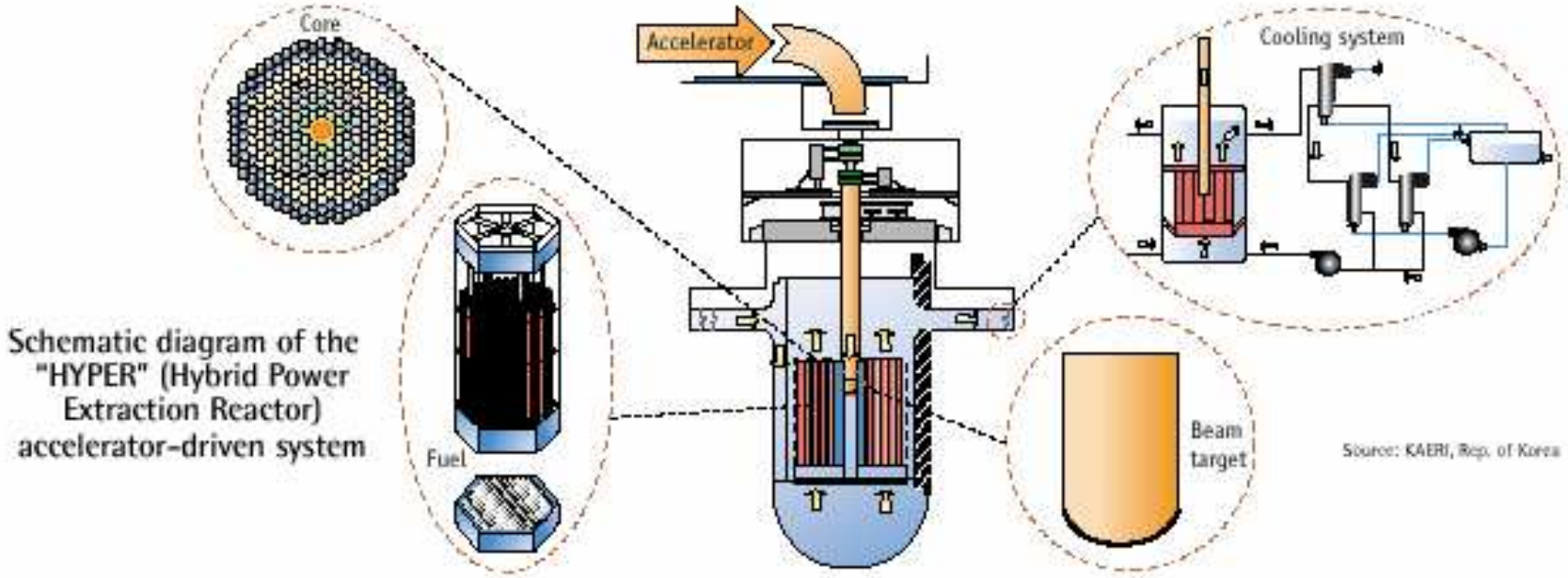
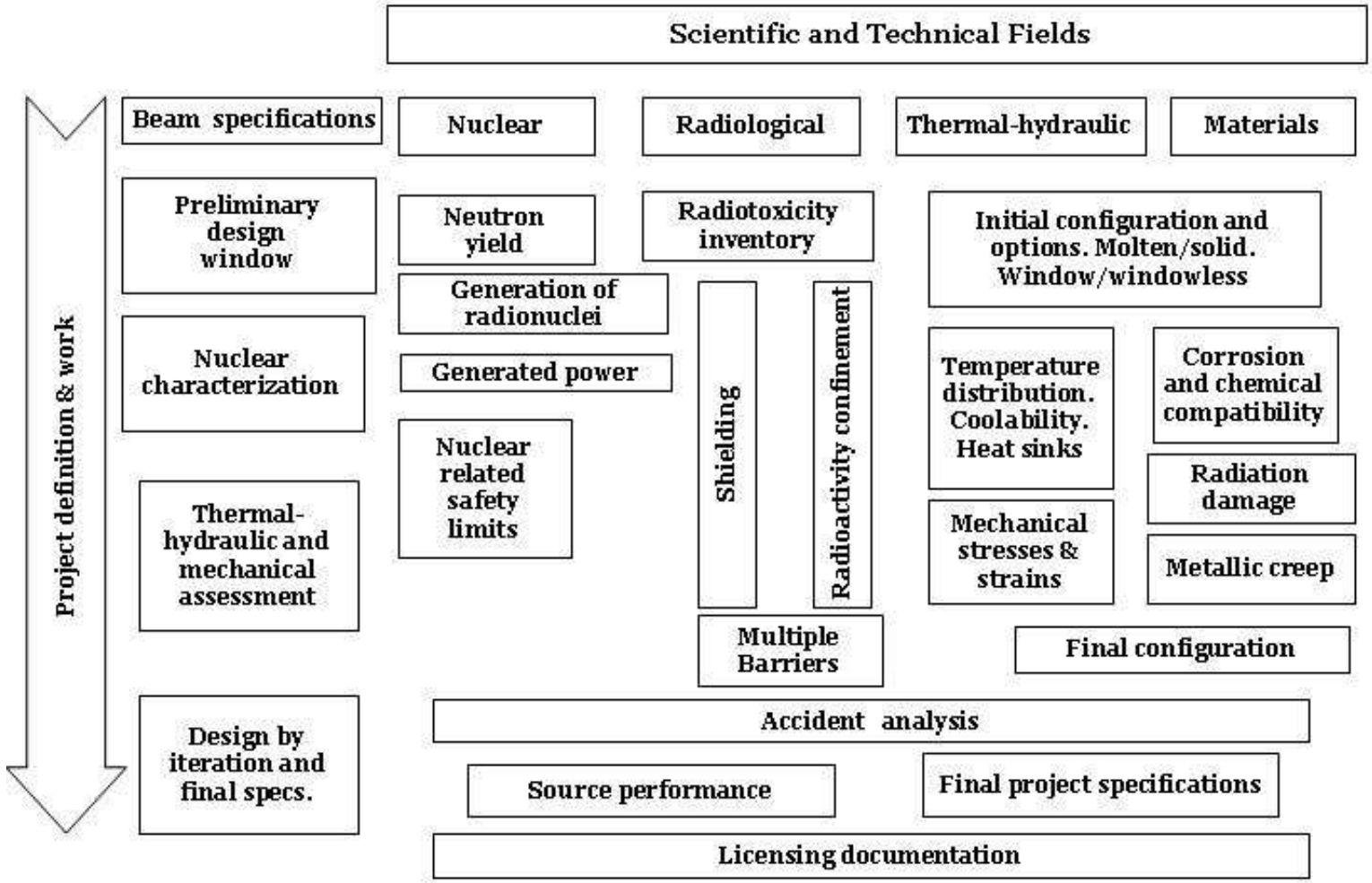
- **FEATURES OF SPALLATION REACTIONS**
- Neutron production
- Spallation products
- **PRINCIPLES OF SPALLATION TARGET DESIGN**
- **Target composition and configuration**
- **Thermal performance**
- **Mechanical integrity**

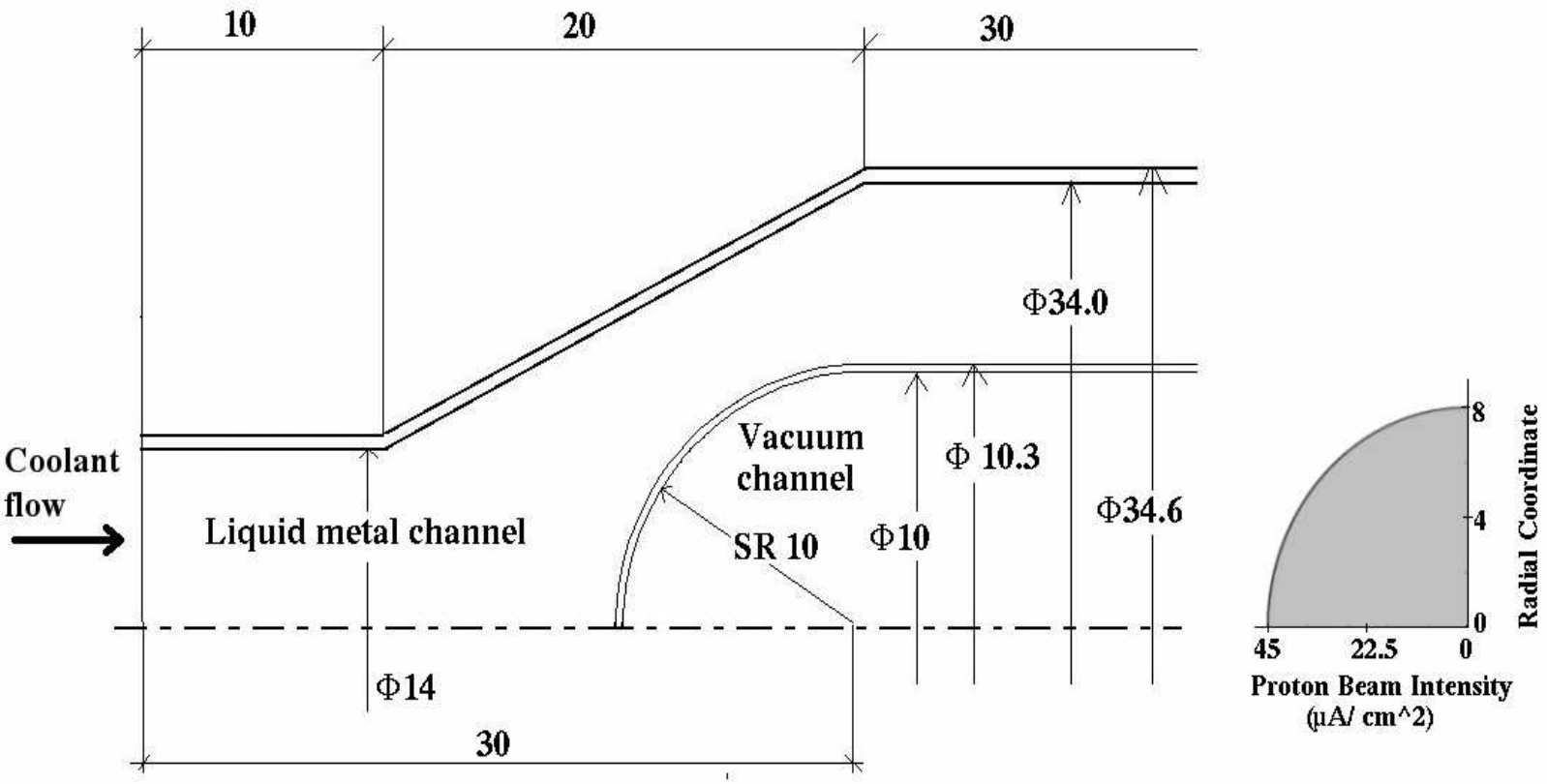


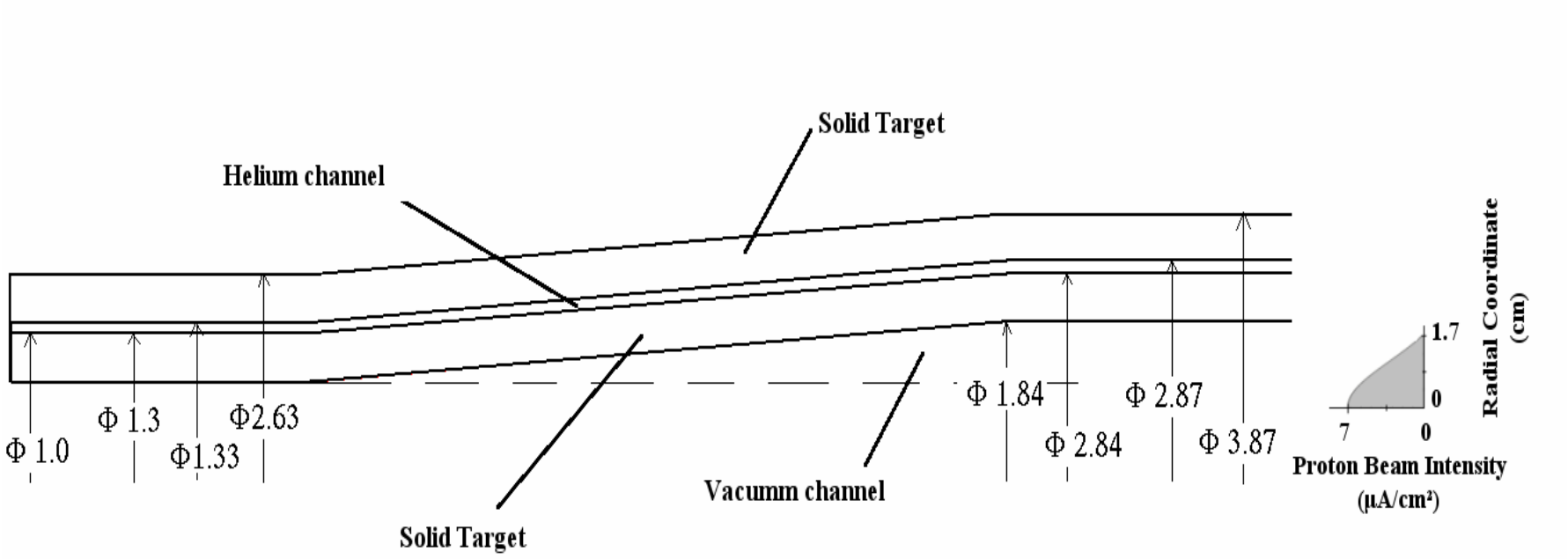
Schematic diagram of the "HYPER" (Hybrid Power Extraction Reactor) accelerator-driven system

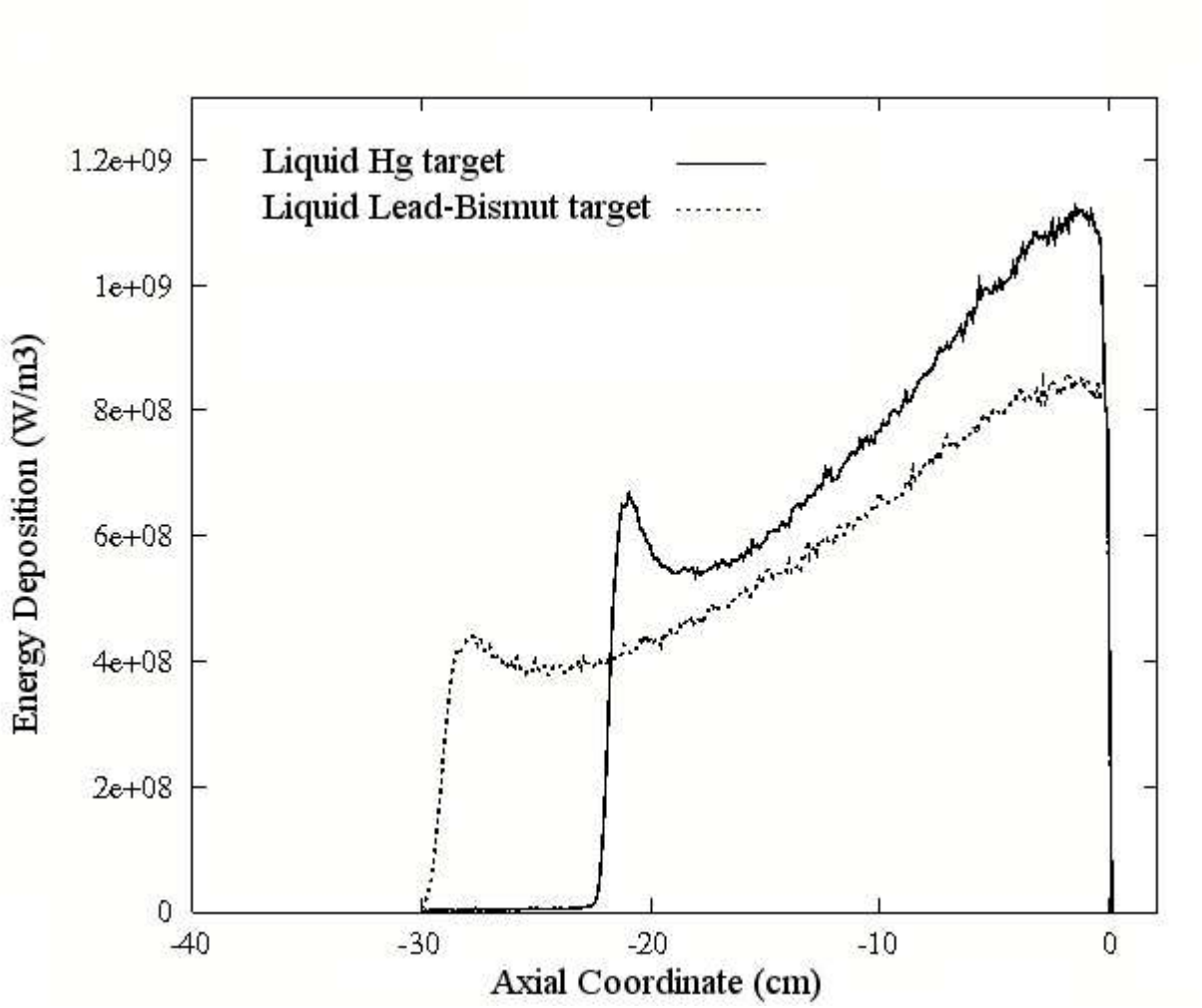
Source: KAERI, Rep. of Korea

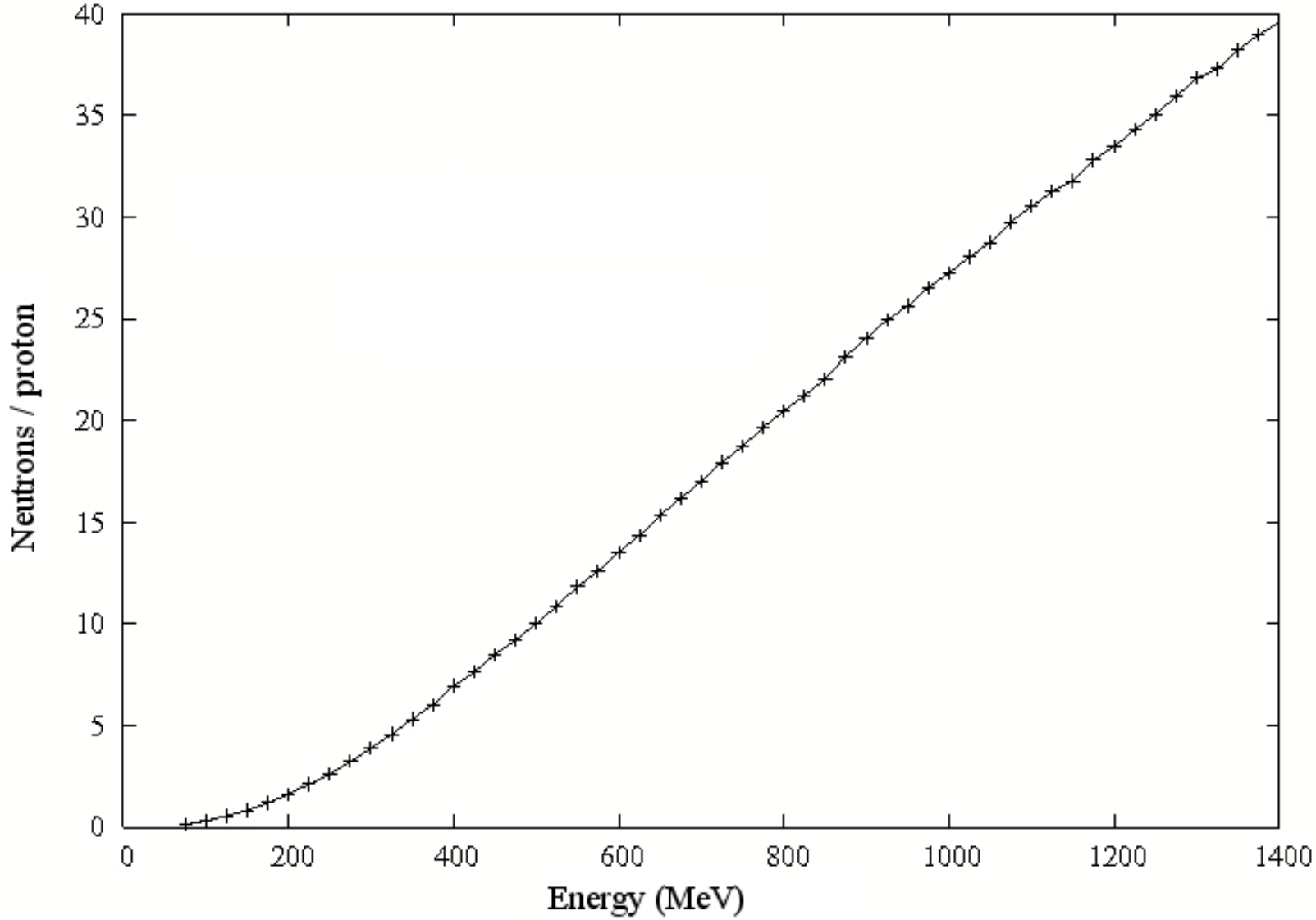
Intense Neutron Sources design flowchart

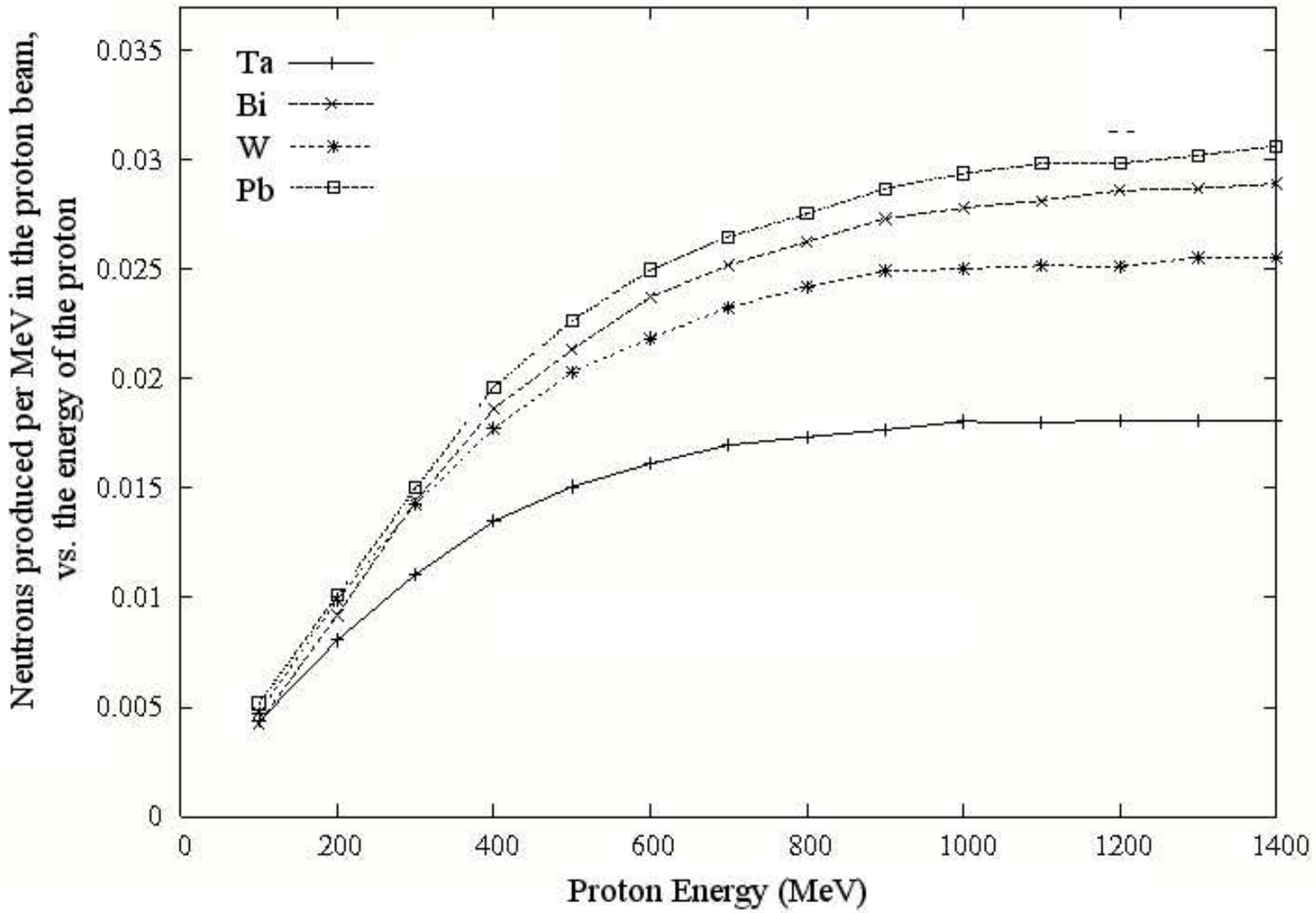


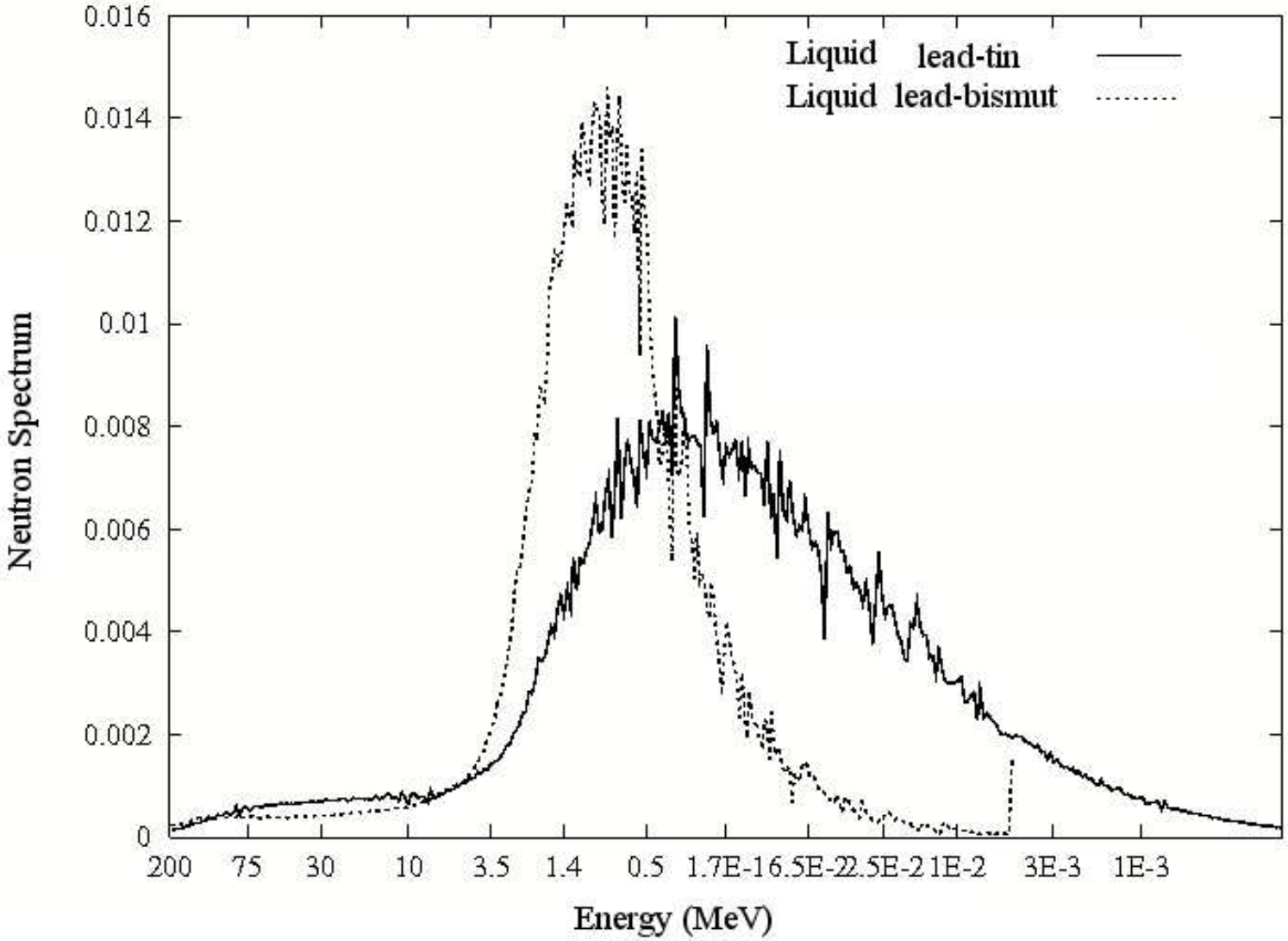

10
20
30
Φ34.0
Coolant
flow
Liquid metal channel
Vacuum
channel
SR 10
Φ10
Φ 10.3
Φ34.6
Φ14
30
8
4
0
45
22.5
0
Radial Coordinate
Proton Beam Intensity
(μA/ cm^2)

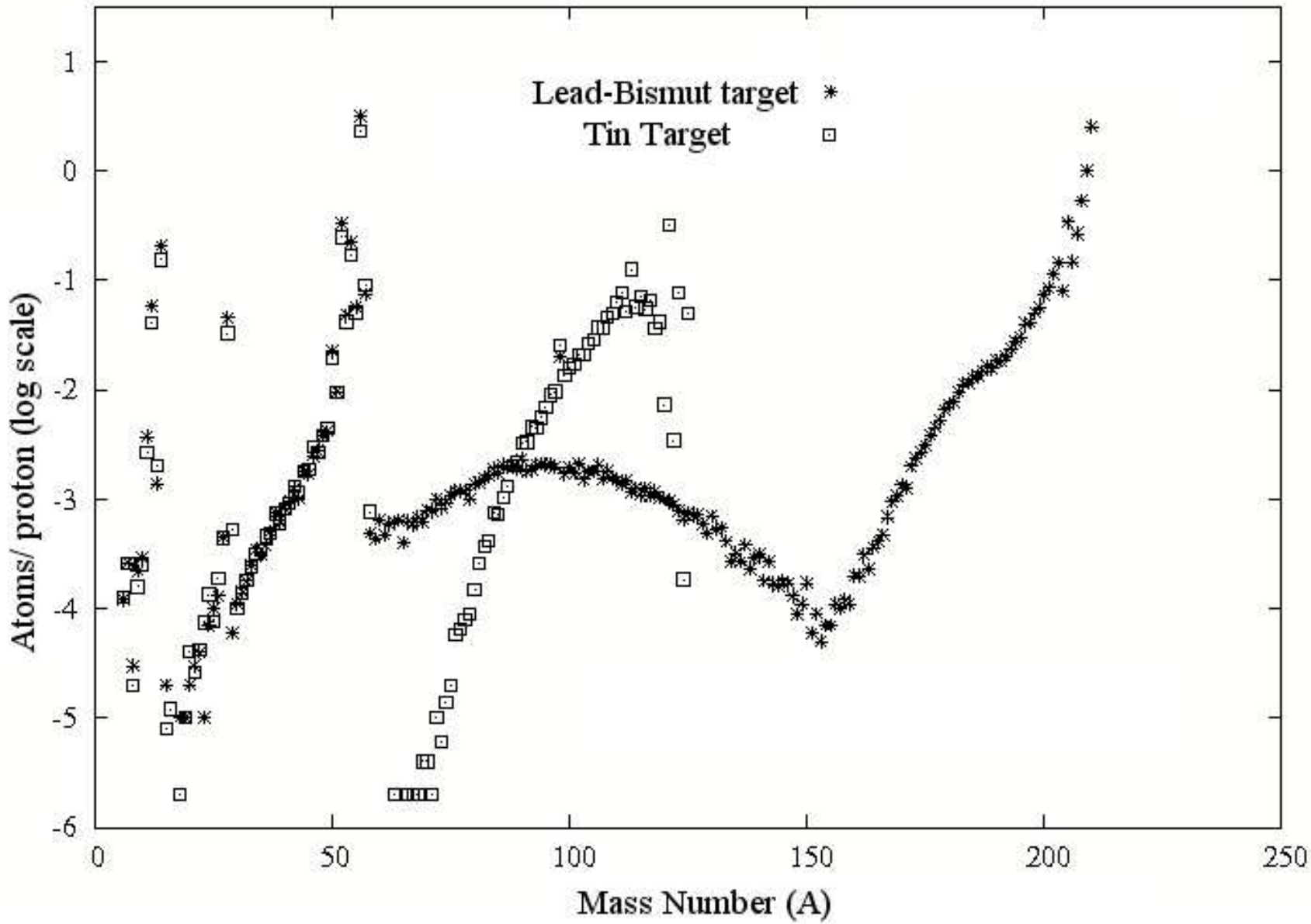

Solid Target
Helium channel
Φ 1.0
Φ 1.3
Φ1.33
Φ2.63
Φ 1.84
Φ 2.84
Φ 2.87
Φ 3.87
Vacumm channel
Solid Target
1.7
0
7
0
Radial Coordinate (cm)
Proton Beam Intensity (μA/cm²)

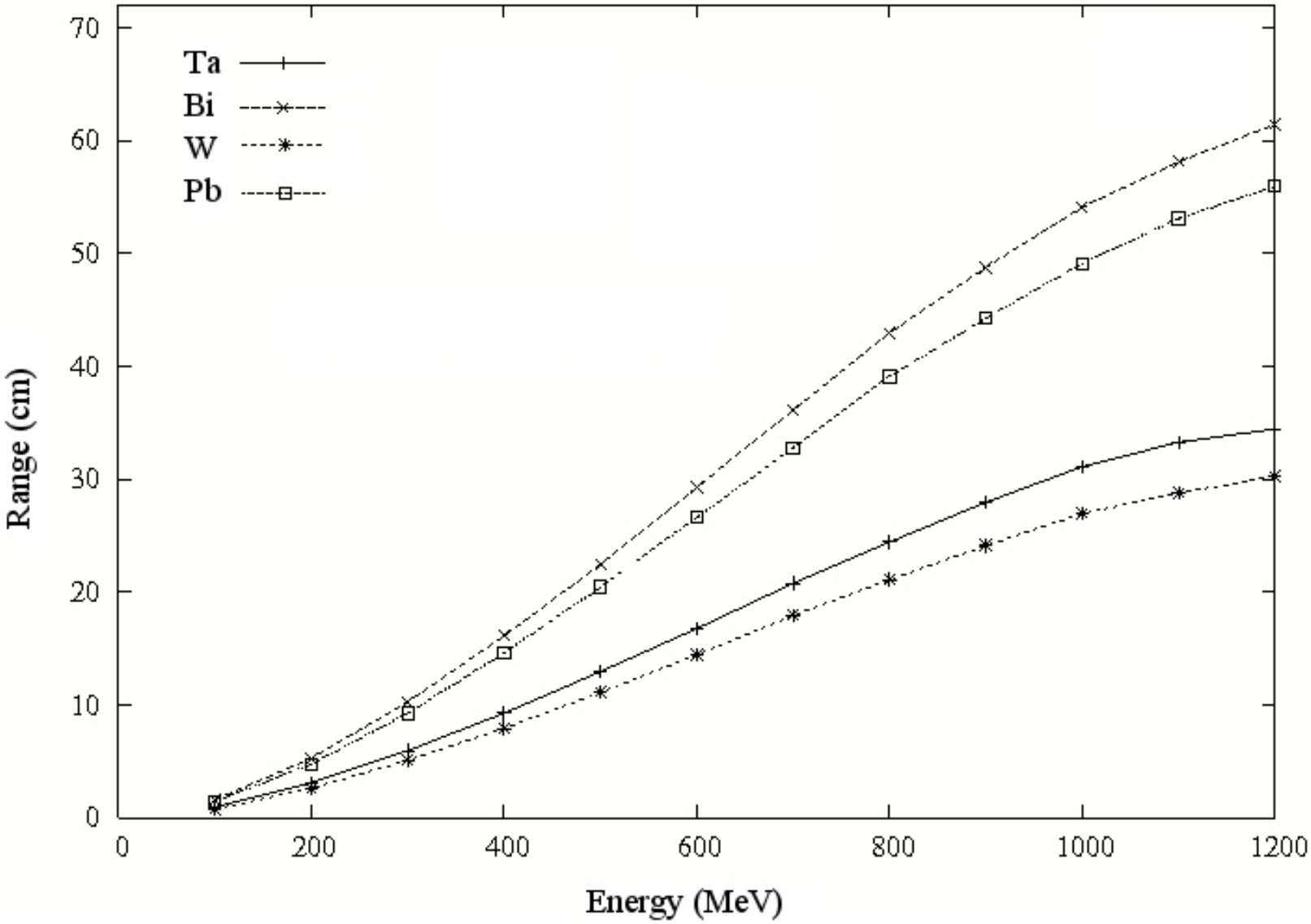

Liquid Hg target
Liquid Lead-Bismut target
Energy Deposition (W/m3)
1.2e+09
1e+09
8e+08
6e+08
4e+08
2e+08
0
-40
-30
-20
-10
0
Axial Coordinate (cm)

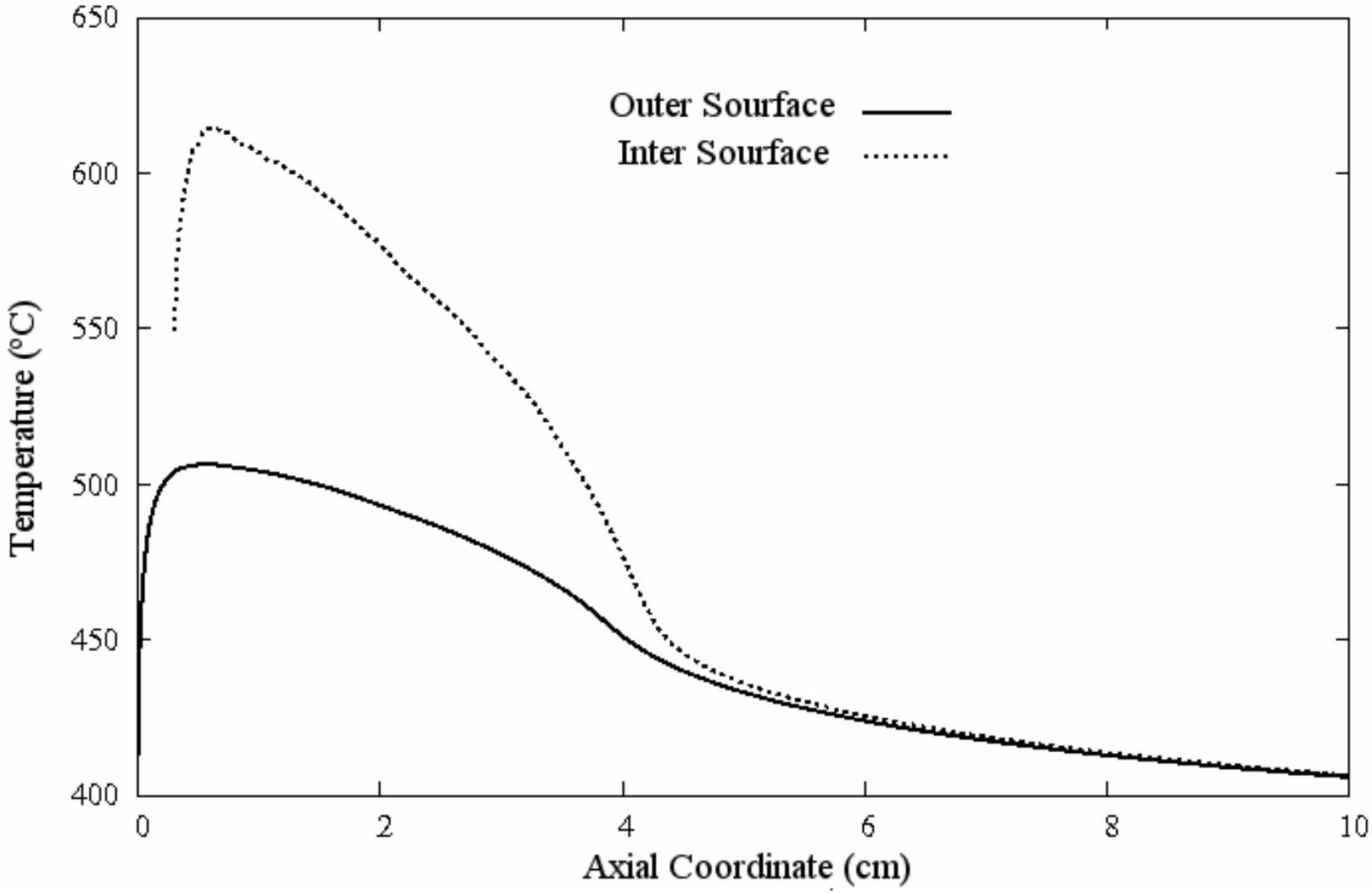

Neutrons / proton
Energy (MeV)
0
5
10
15
20
25
30
35
40
0
200
400
600
800
1000
1200
1400


Ta
Bi
W
Pb
Neutrons produced per MeV in the proton beam,
vs. the energy of the proton
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
0
200
400
600
800
1000
1200
1400
Proton Energy (MeV)


Liquid lead-tin
Liquid lead-bismut
Neutron Spectrum
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
200
75
30
10
3.5
1.4
0.5
1.7E-1
6.5E-2
2.5E-2
1E-2
3E-3
1E-3
Energy (MeV)


Lead-Bismut target
Tin Target
Atoms/ proton (log scale)
Mass Number (A)
1
0
-1
-2
-3
-4
-5
-6
0
50
100
150
200
250


Ta
Bi
W
Pb
Range (cm)
Energy (MeV)
0
10
20
30
40
50
60
70
0
200
400
600
800
1000
1200


650
600
550
500
450
400
0
2
4
6
8
10
Temperature (°C)
Axial Coordinate (cm)
Outer Sourface
Inter Sourface

Very intense neutron sources are very challenging engineering systems, where the power density can reach very high values, so creating specific thermal problems, which are coupled with some peculiar nuclear problems derived from the interaction of an intense proton beam with a material that undergoes a spallation process.

The neutron production rate can achieved very high values. For instance, a 10 mA beam of 1000 MeV protons can interact with a spallation region of Pb/Bi eutetic, 10 cm in diameter, 1 meter long (or somewhat shorter) and would produce about 40 neutrons per proton, so yielding a total rate of 2,4 E18 n/s. The outgoing neutron current from the spallation region would be close to 10E15 $n/cm^2.s$

Spallation sources can meet the requirements of very demanding irradiation units, but they must be designed according to a coherent approach, as the one depicted before, in order to meet all the safety requirements that must be applied to an installation where nuclear reactions take place at a very high rate

Intense Neutron Sources design flowchart