Simulations of Accelerator Driven Systems (ADS)

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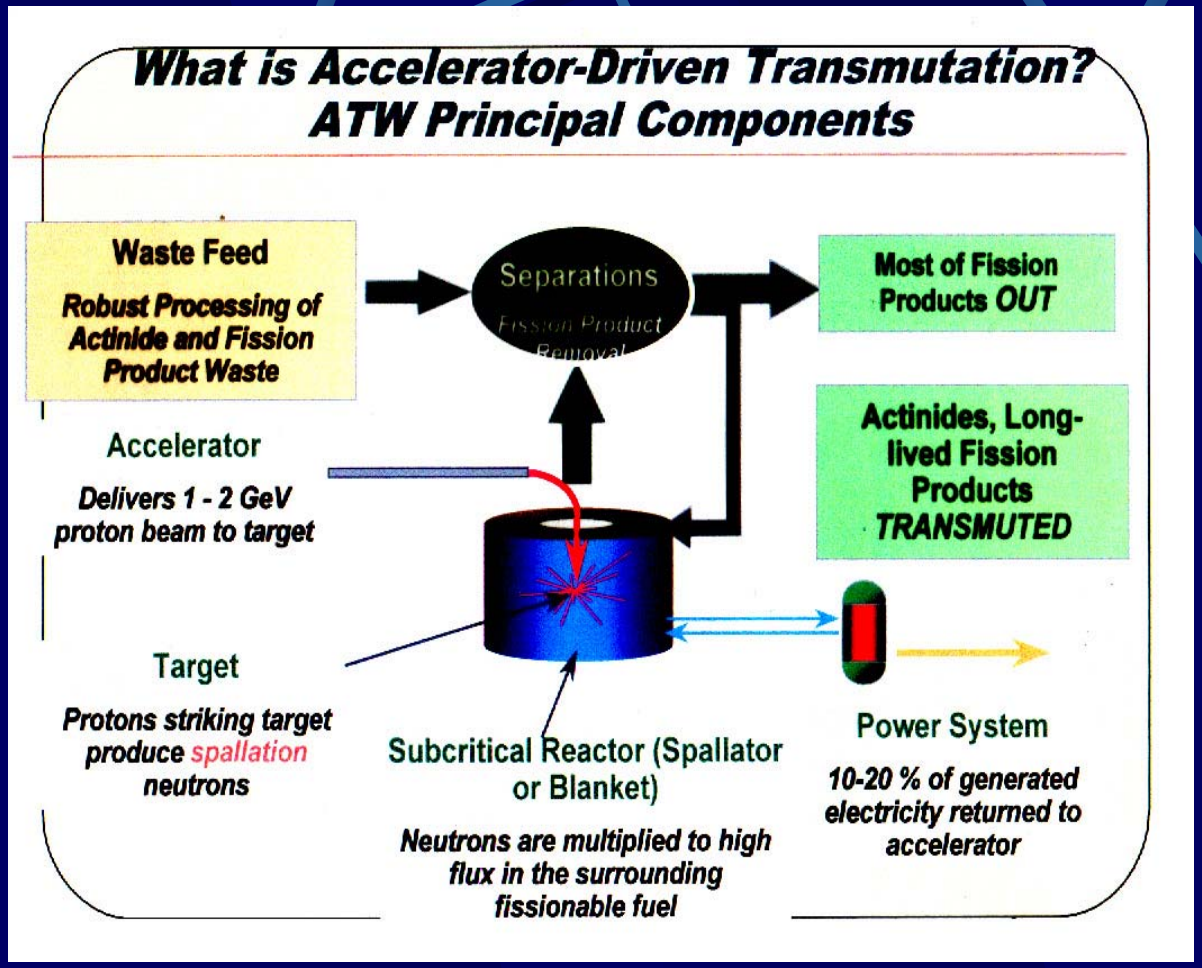
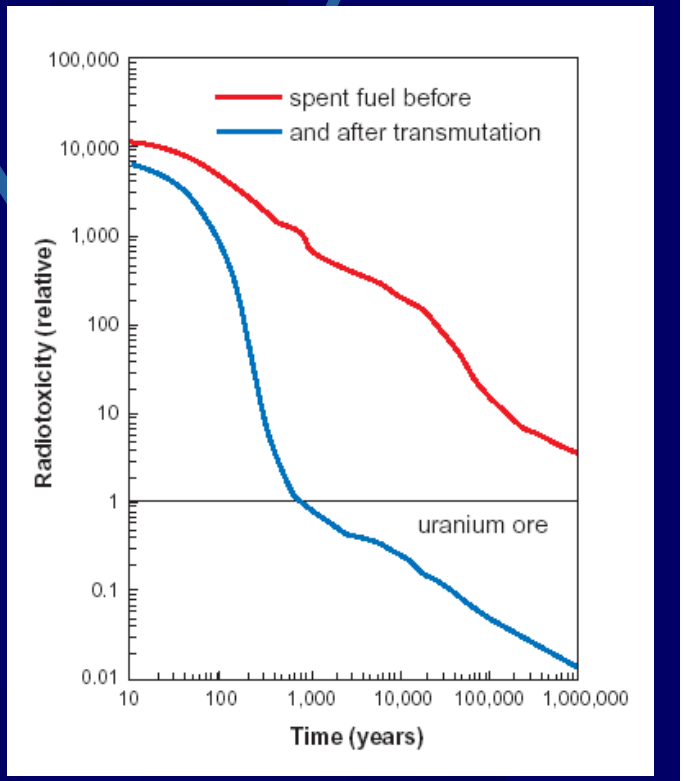
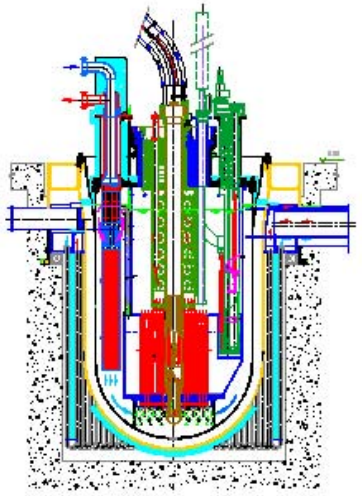
Joint IAEA-ICTP Workshop on
Nuclear Reaction Data
for Advanced Reactor Technologies


What is Accelerator-Driven Transmutation?
ATW Principal Components
Waste Feed
Robust Processing of Actinide and Fission Product Waste
Separations
Fission Product Removal
Most of Fission Products OUT
Actinides, Long-lived Fission Products TRANSMUTED
Accelerator
Delivers 1 - 2 GeV proton beam to target
Target
Protons striking target produce spallation neutrons
Subcritical Reactor (Spallator or Blanket)
Neutrons are multiplied to high flux in the surrounding fissionable fuel
Power System
10-20 % of generated electricity returned to accelerator

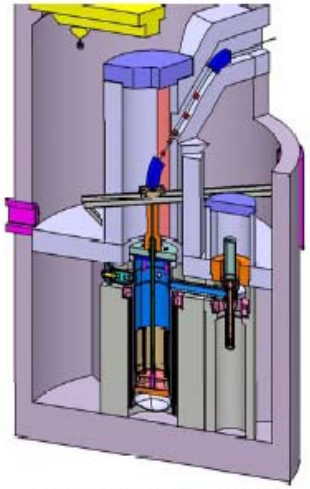

spent fuel before
and after transmutation
uranium ore
Radiotoxicity (relative)
100,000
10,000
1,000
100
10
1
0.1
0.01
10
100
1,000
10,000
100,000
1,000,000
Time (years)

EUROTRANS

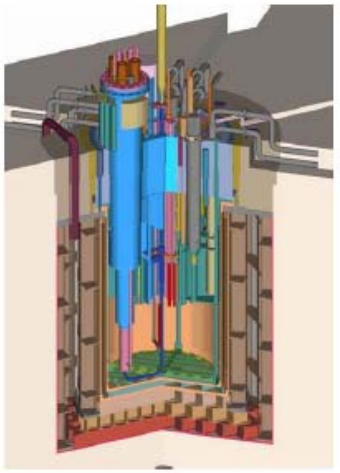
FP	Design Concepts			Objectives
FP5	**XADS (Pb-Bi)** 80 MW(th) 110 W/cm single batch loading	**XADS (Gas)** 80 MW(th) 250 W/cm single batch loading	**MYRRHA (Pb-Bi)** 50 MW(th) 500 W/cm multi batch loading	**XADS** Demonstration of technological feasibility of an ADS system



Ansaldo



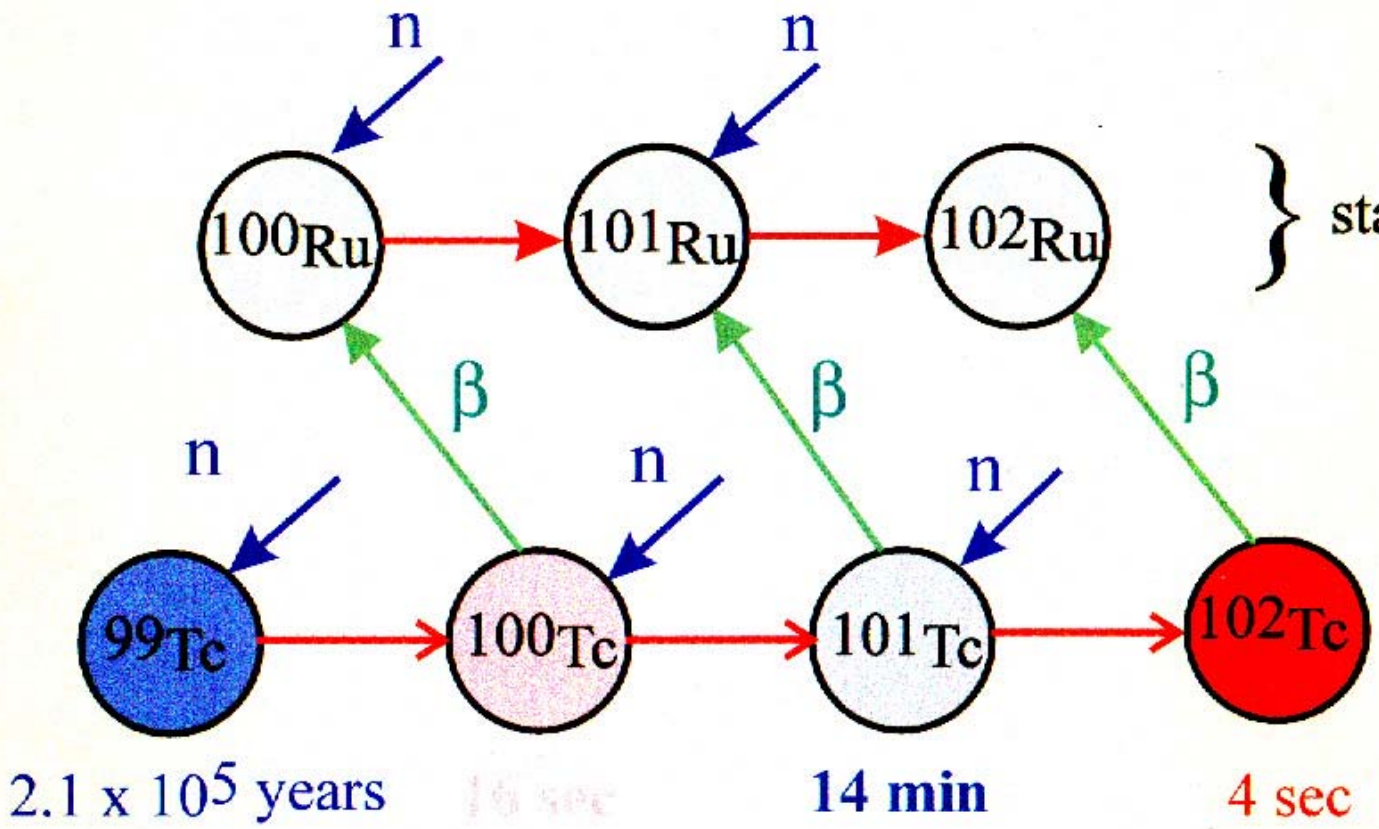
Framatome ANP



SCK·CEN

Fuel: MOX (accept for a few MAFuel Assemblies)
and (Pu, Am)O2 . Accelerator: 600-1200 MeV power: 5~ 10MW

Transmutation of technetium



Models and Codes Used for Simulations

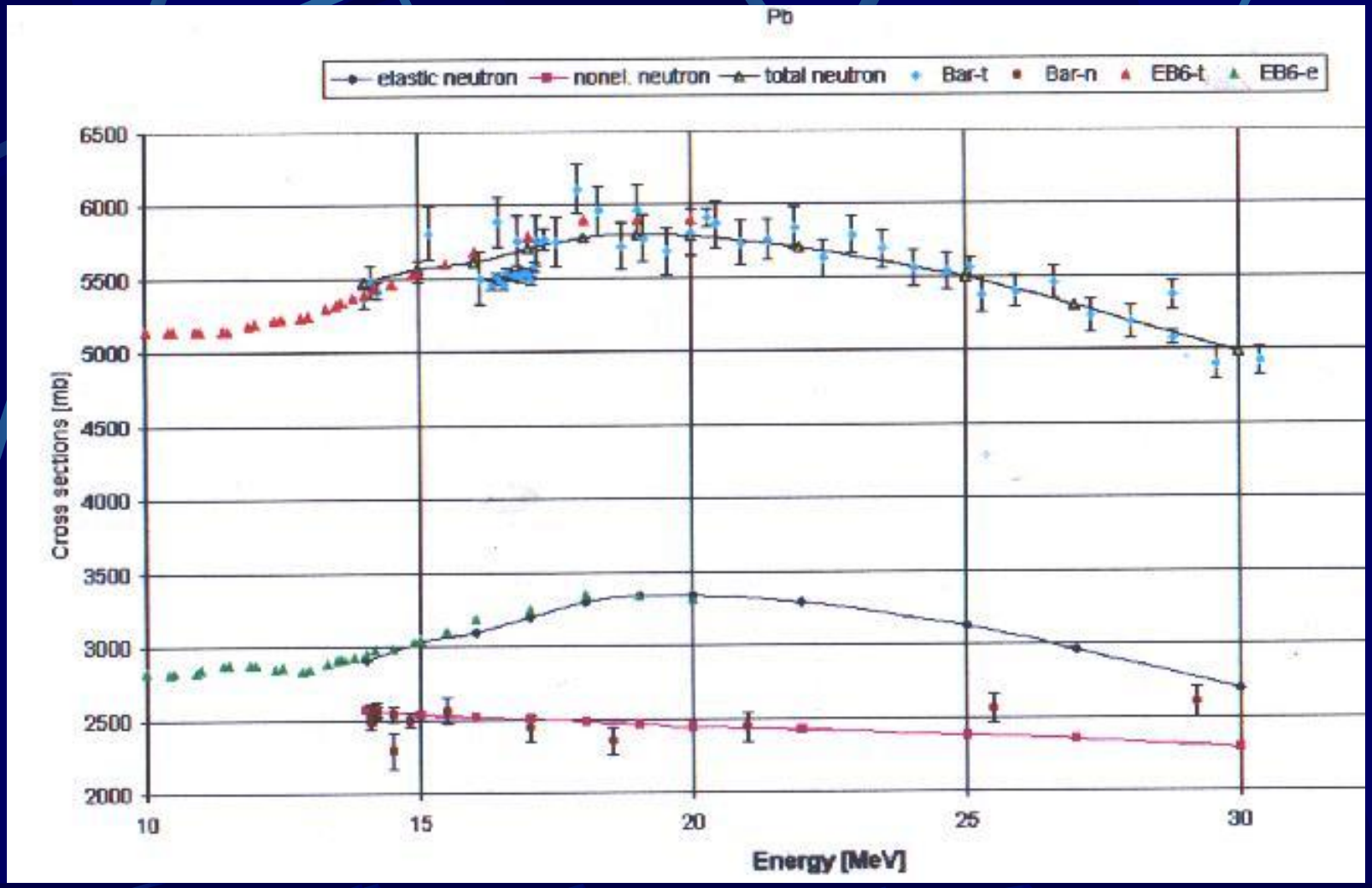
Models

- Optical , microscopic
- Quantum molecular dynamic
- Cascade-evaporation
- Dual Parton and Glauber

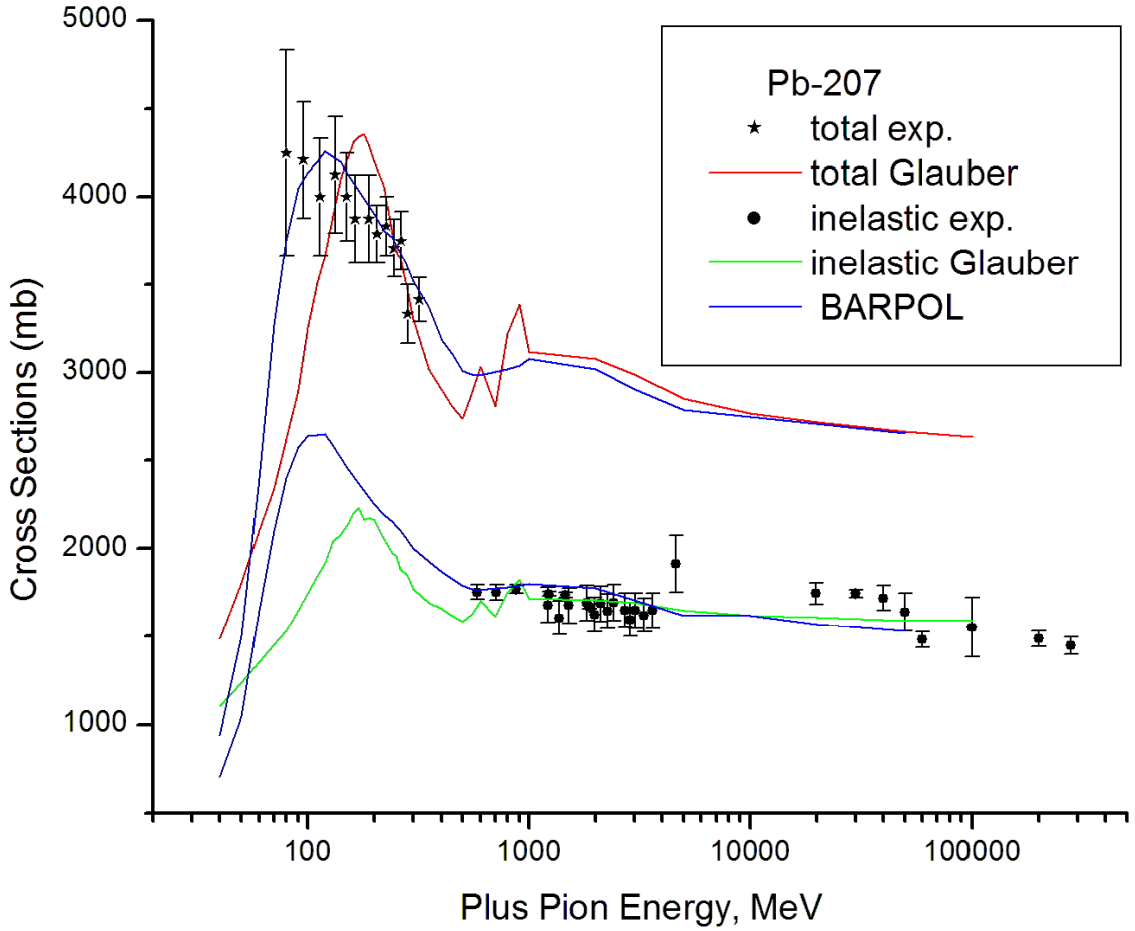
Codes

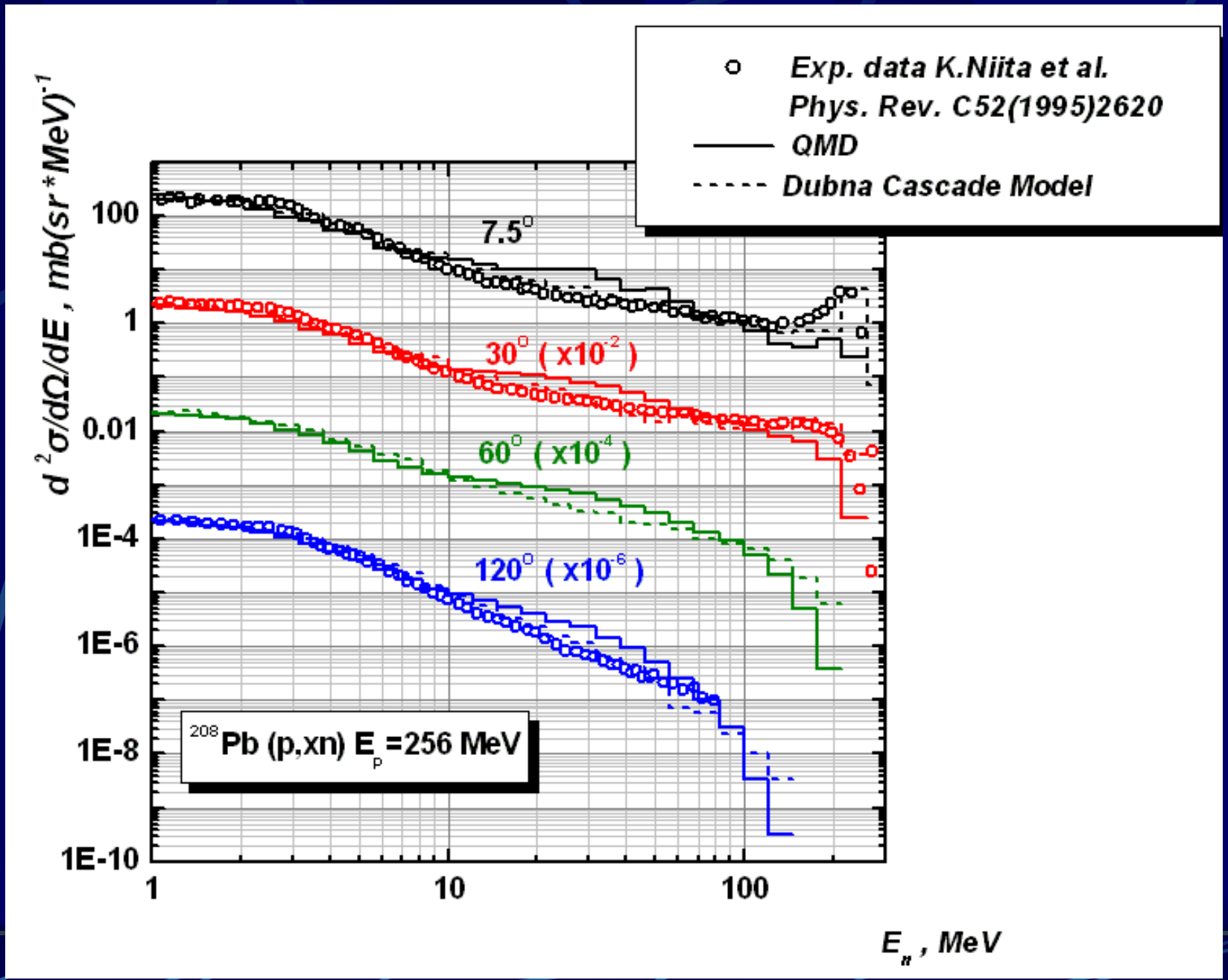
- Empire
- QMD
- Dubna Cascade
- MCNPX+ENDF/b-6
- FLUKA
- MCB Monte Carlo Burnup

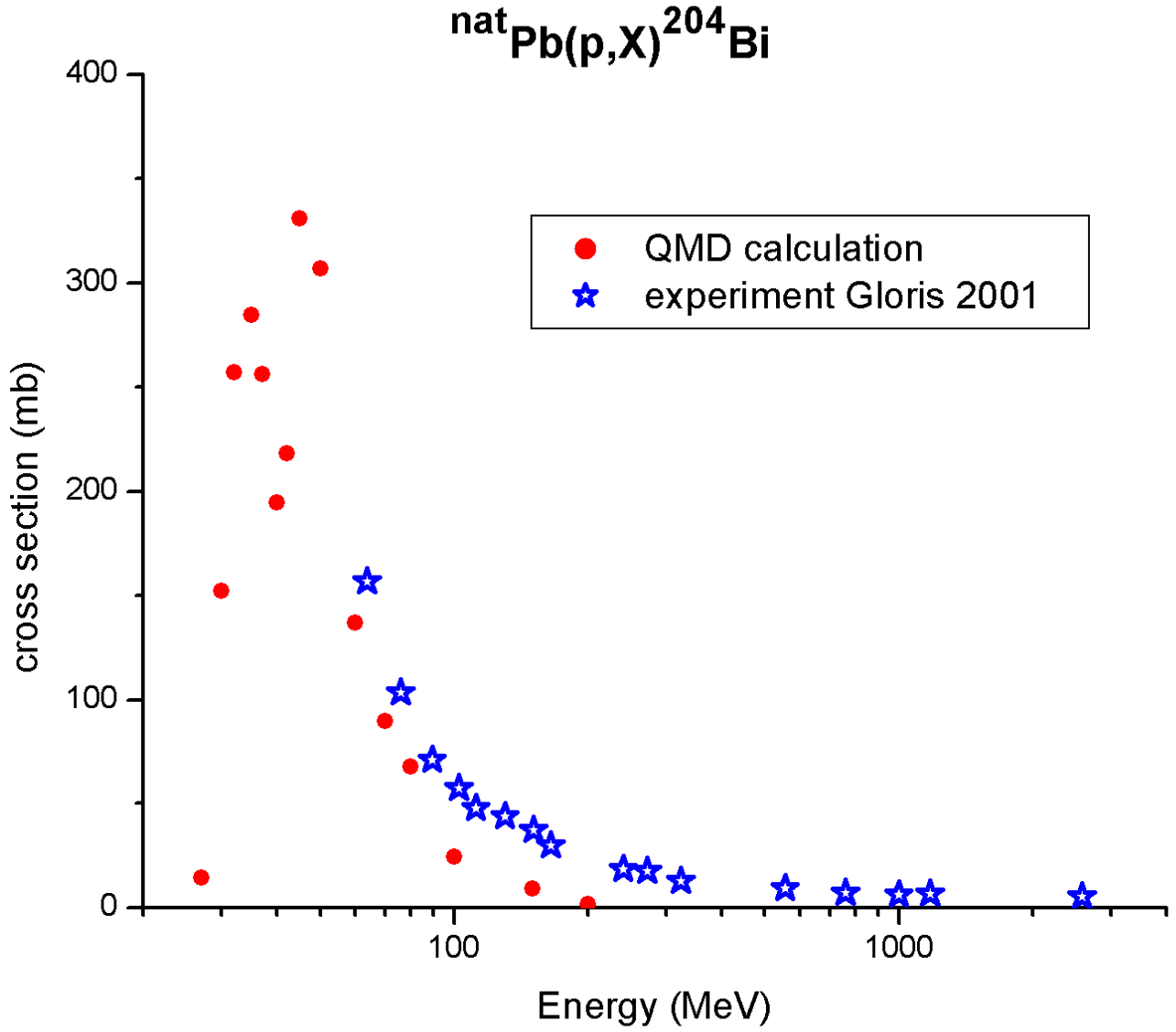
Neutrons Cross Sections



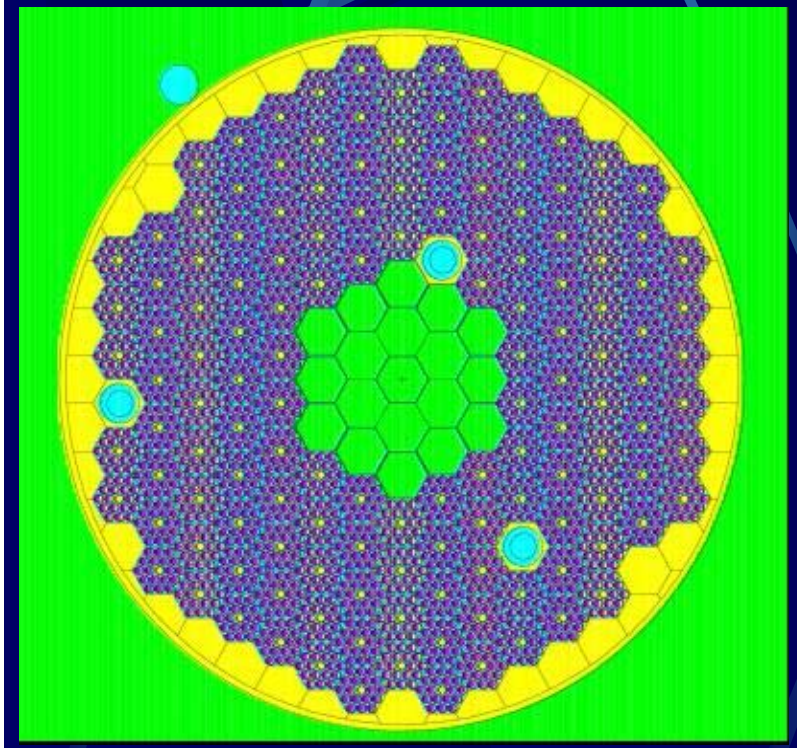
Pions Cross Sections




Exp. data K.Niita et al.
Phys. Rev. C52(1995)2620
QMD
Dubna Cascade Model
7.5°
30° (x10-2)
60° (x10-4)
120° (x10-6)
208Pb (p,xn) Ep=256 MeV
d2σ/dΩ/dE , mb(sr*MeV)-1
100
1
0.01
1E-4
1E-6
1E-8
1E-10
1
10
100
En , MeV


$^{nat}Pb(p,X)^{204}Bi$
QMD calculation
experiment Gloris 2001
cross section (mb)
400
300
200
100
0
100
1000
Energy (MeV)

Description Of The Facilities.
Vertical Cross Section of SAD

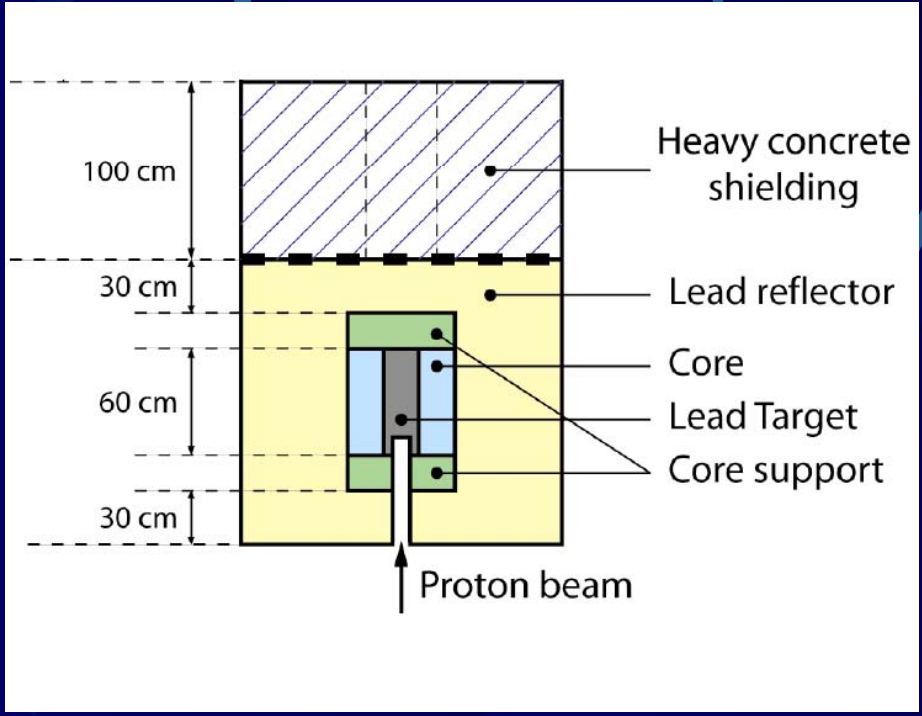


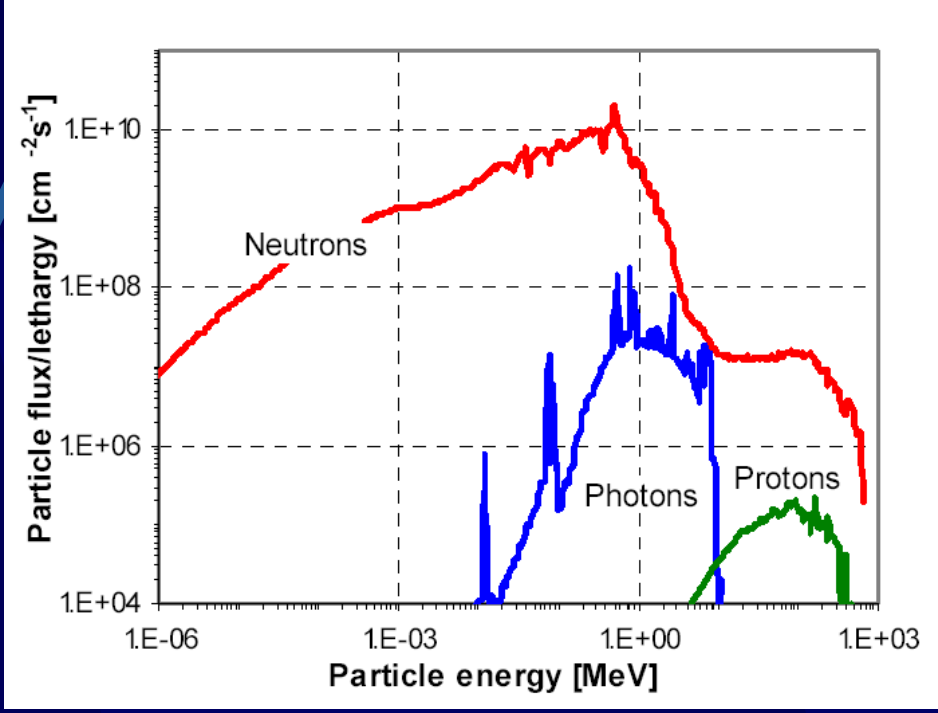
Characteristics	Destription
MeV 660 protons, beam power	1 kW
Thermal fission power	25 kW
Fuel elements BN-600.	70.5% UO2+ 29.5% PuO2
Height of a fuel active part	580 mm
Mass of fuel in element	164.5 g
Number of fuel elements in assembles	18
Number of fuel assembles	133
Maximal gain factor	K =0.95
Heat-carrier	air
Reflectors	lead
Max neutron flux	$2.1\ 10^{12}$ $cm^{-2}s^{-1}$

Energy Deposition

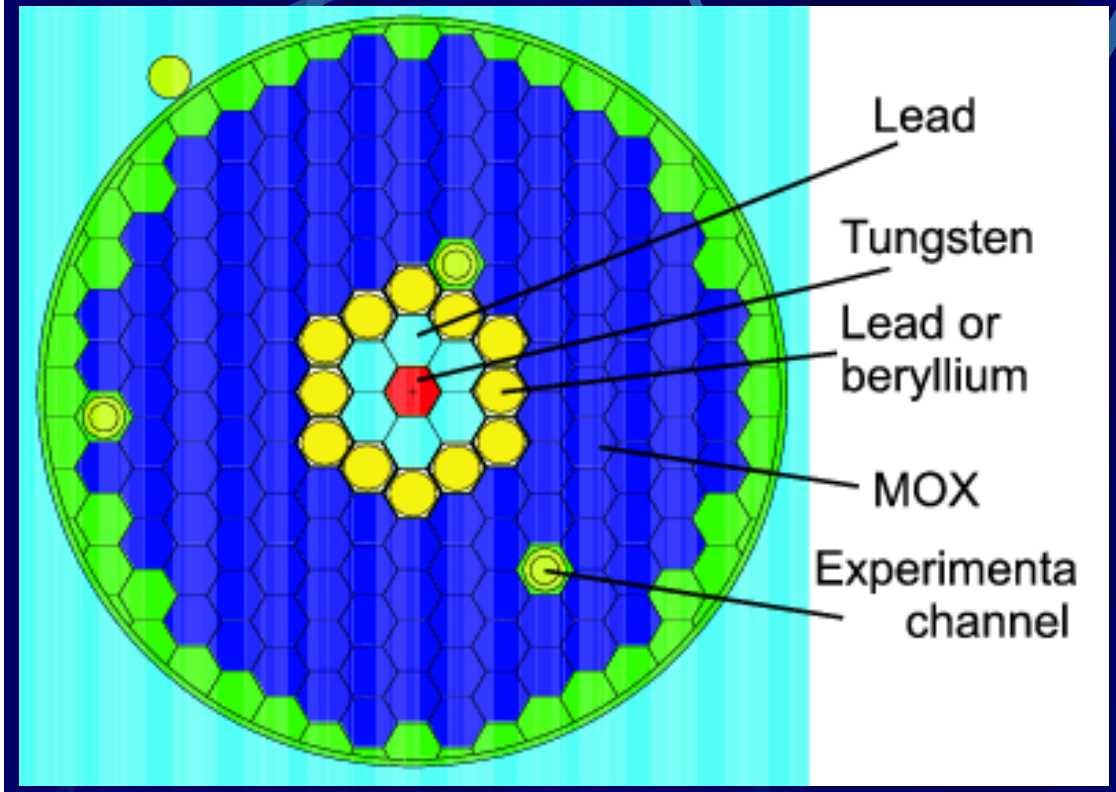
		MeV/proton	kW
1	Central part of lead target	306	0.463636
2	First layer of lead target	103	0.156061
3	Second layer of lead target	57.7	0.087424
4	First layer of active zone	2337.64	3,541879
5	Second layer of active zone	3212.97	4.868136
6	Third layer of active zone	3687.74	5.587485
7	Fourth layer of active zone	4278.91	6.483197
8	Fifth layer of active zone	2986.25	4,524621
9	Total energy deposition	16970.21	25.71244

Schematic View of Horizontal Cross Section of the Sub Critical Assembly SAD





SAD target design evaluations



Beam power=2 kW

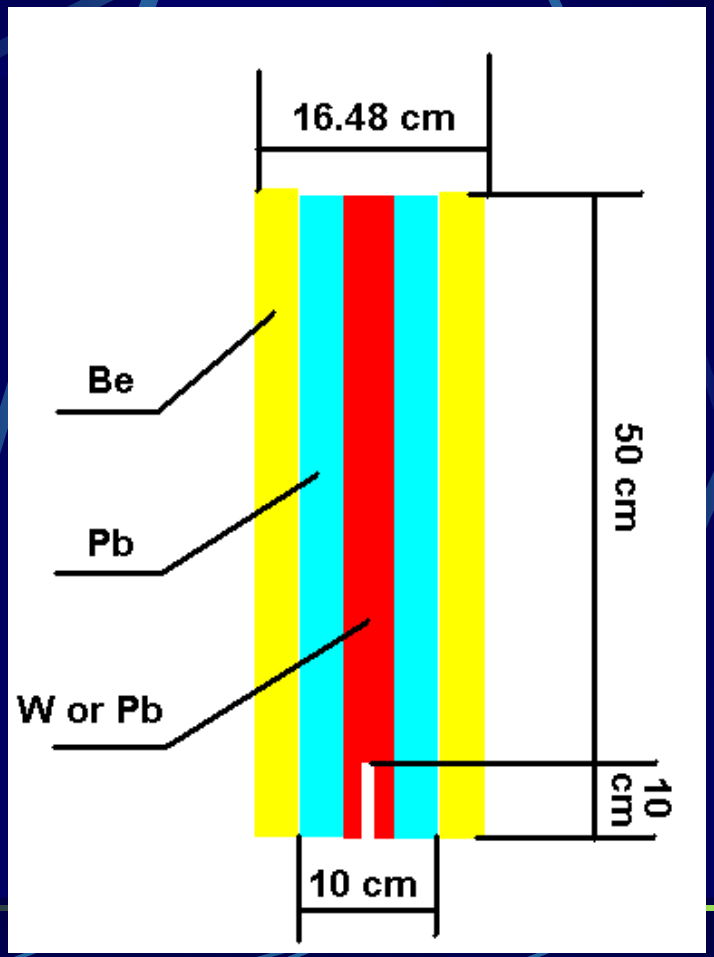
System power=102 kW

Neutron flux density in channels

cm-2*s-1

AC 1	6.76E+12
AC 2	5.81E+12
AC 3	5.02E+12
R1	4.16E+12
R2	3.30E+12
R3	2.71E+12

Energy realized (Watts) in target per beam power 1 kW. Neutron Escaping From the Target. E_p=660 MeV.



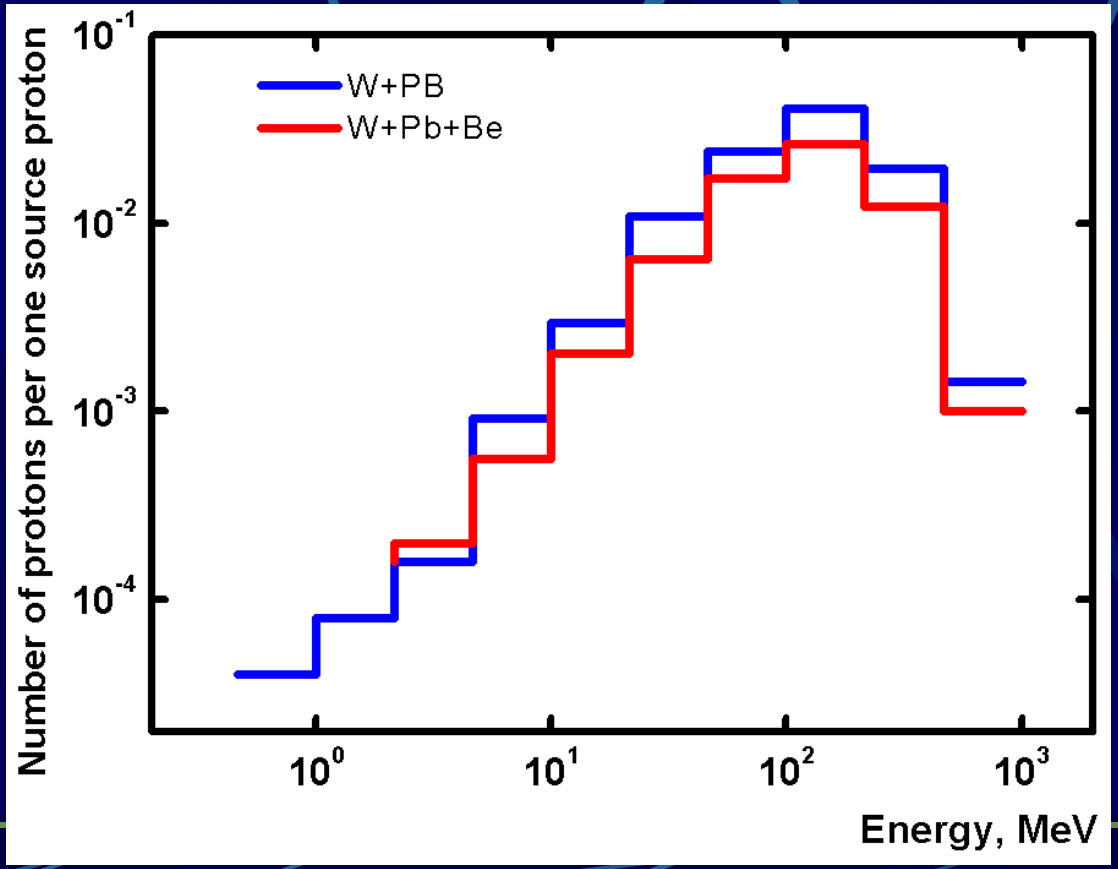
- Target: Pb+Pb+Pb
- Power:463+158+88=709 Wats
- Neutron escaping: 12.50

- Target: W+Pb+Pb
- Power: 586+92+78=755 Wats
- Neutron escaping:12.06

- Target: W+Pb+Be
- Neutron escaping: 12.59

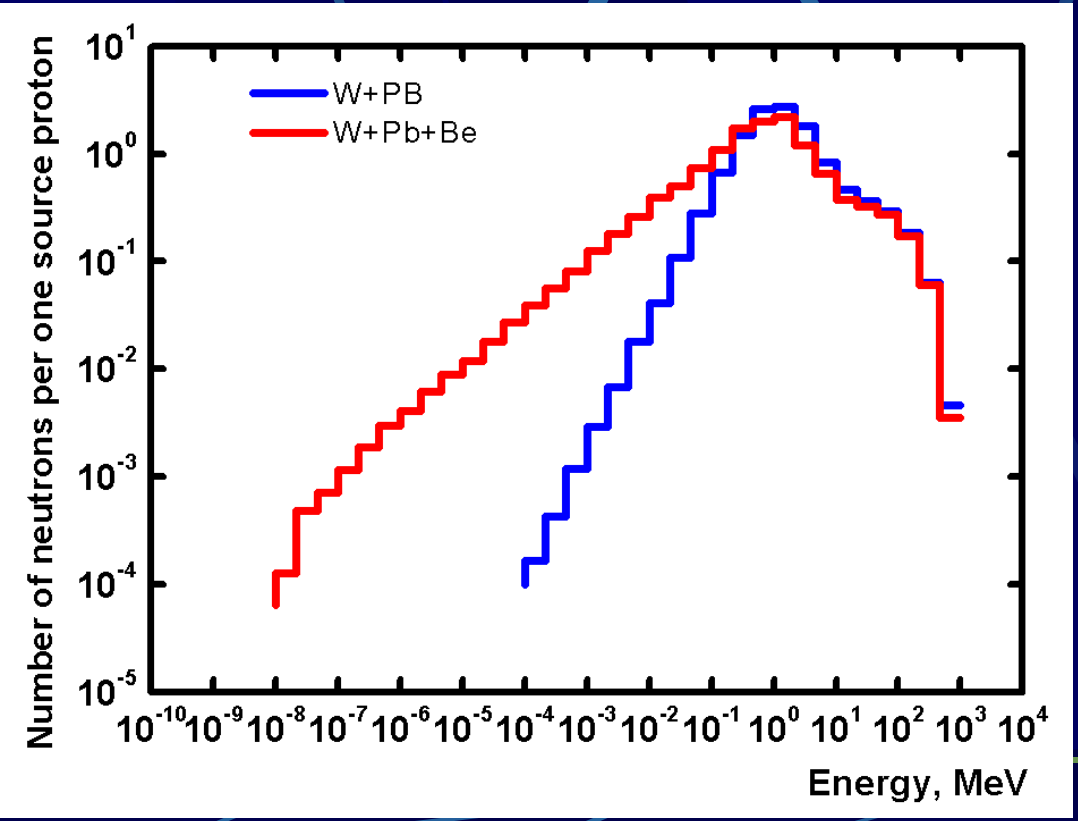
Spallation Protons Leaking the Target

Total : 6.29e+11 s-1 and 9.49e+11 s-1

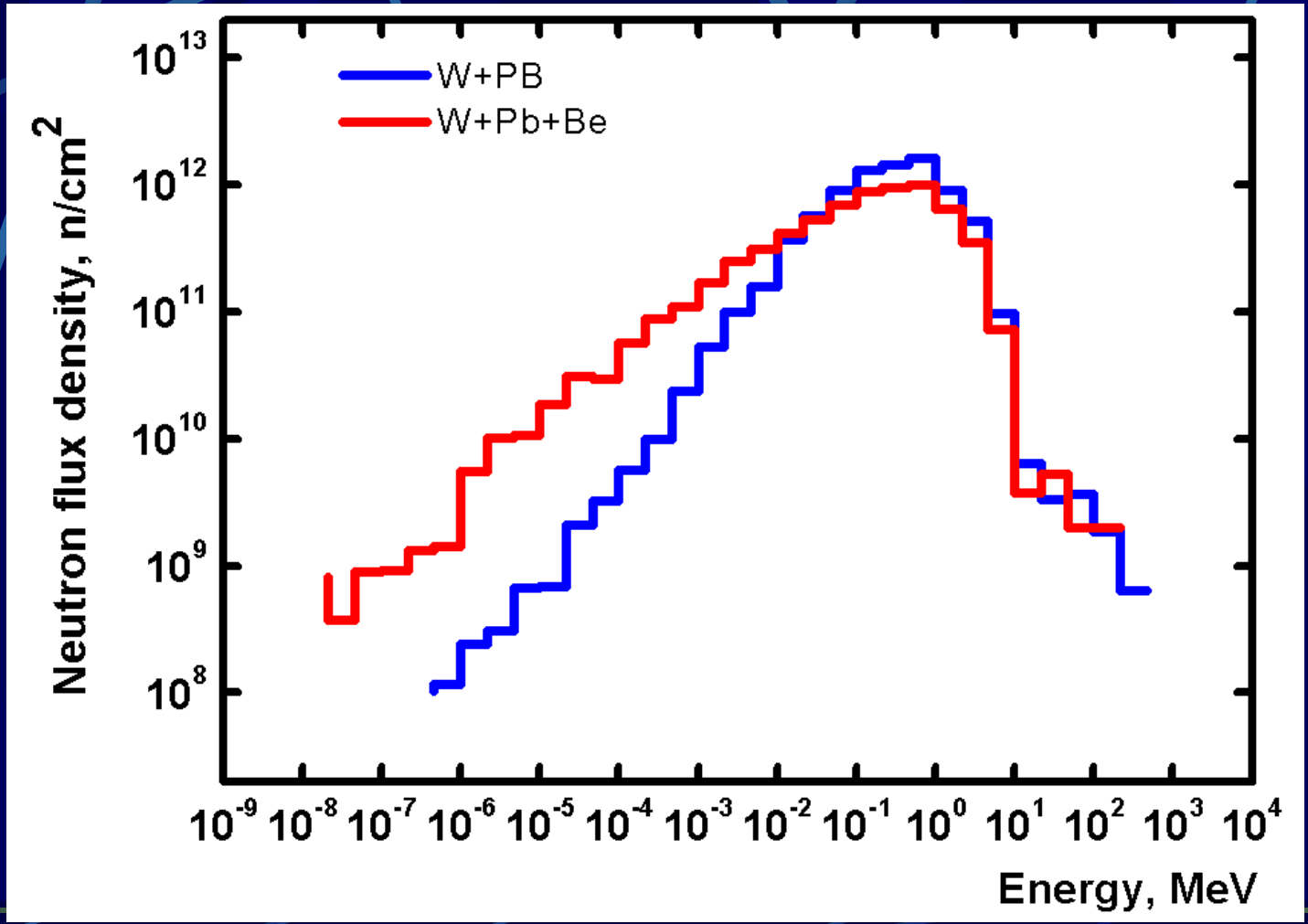


Spallation Neutrons Leaking the Target

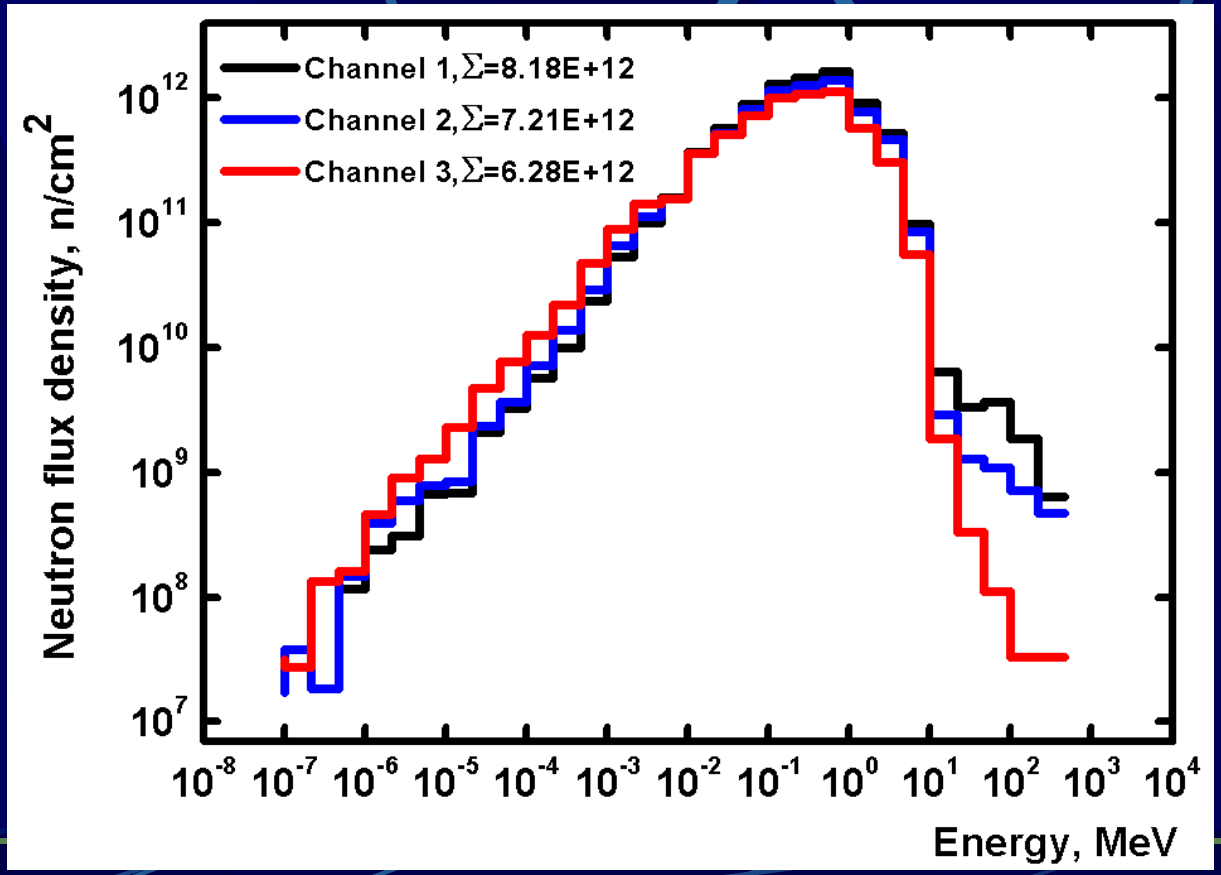
Total : 2.27e+14 s-1 and 2.39e+14 s-1



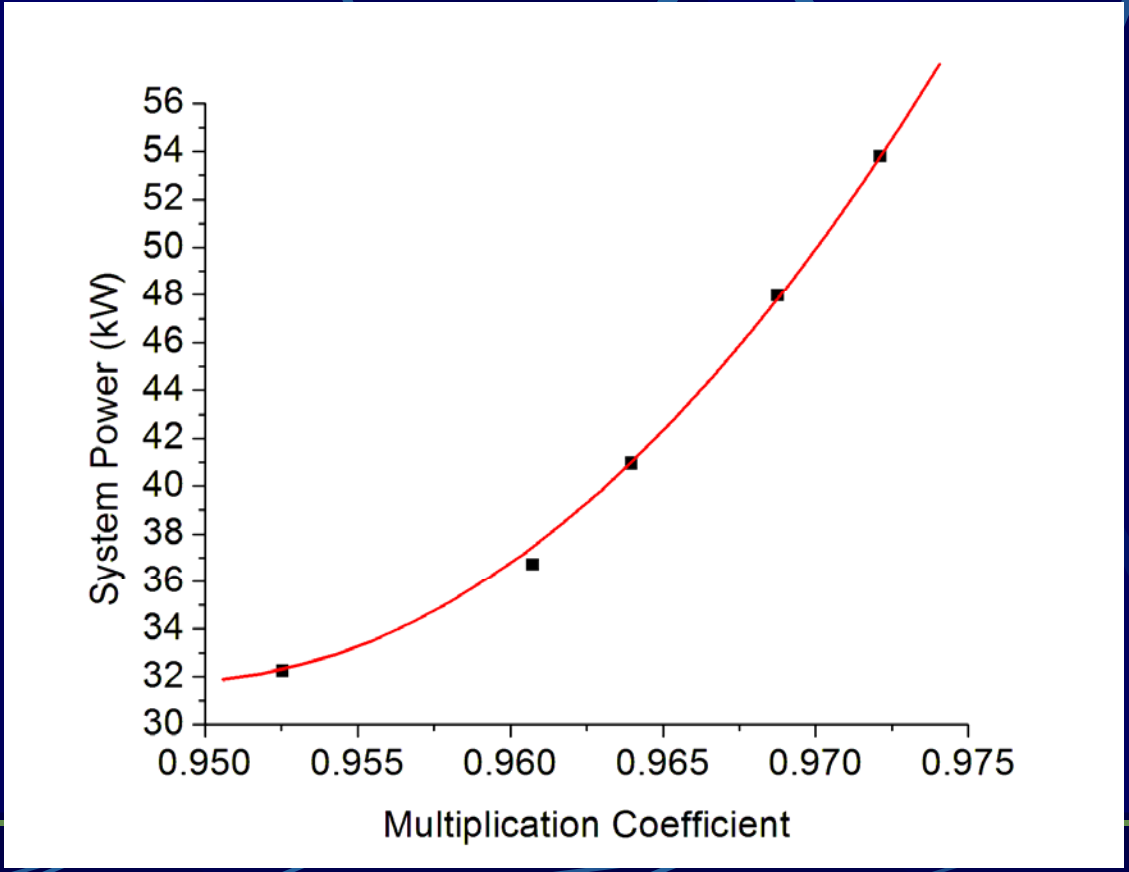
Comparison of neutron spectra in experimental channel near the target



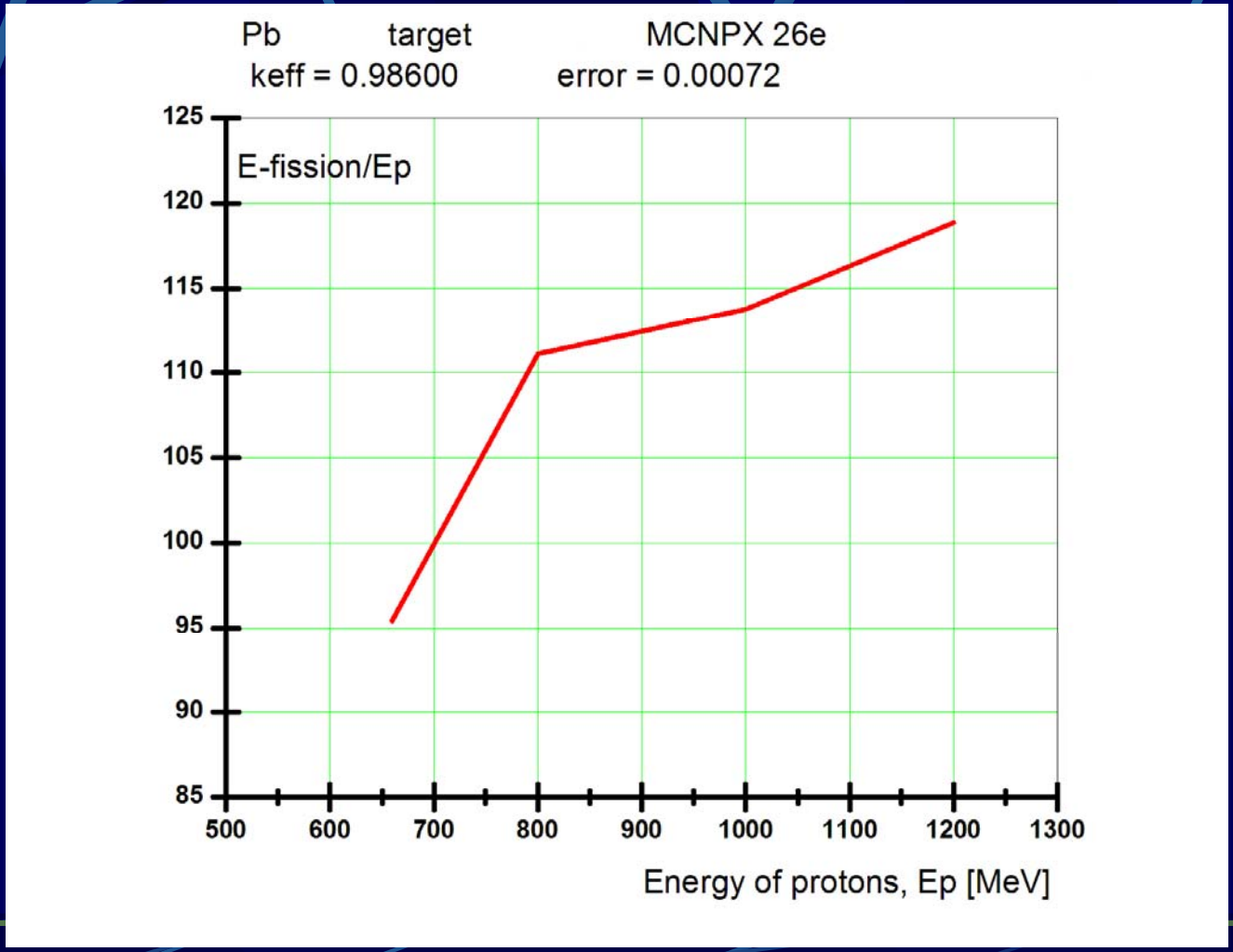
Neutron spectra in the centers of vertical experimental channels 1-3 for subcritical assembly with tungsten plus lead spallation target



System Power Vs Multiplication Factor for 1 kW Beam Power



Energy Gain of Subcritical Assembly SAD



Flux and Power of ADS 10 MW Beam Power

Target	K -eff	Protons energy MeV	F_{tot}, $n \cdot cm^{-2} \cdot sec^{-1}$	P_{heat}, MW
Pb	0,974	660	$4.2 \cdot 10^{16}$	500
Pb	0,986	1200	$9,9 \cdot 10^{16}$	1180
W + Pb	0,982	1200	$8,1 \cdot 10^{16}$	960

Conclusions

- Neutron flux·density about 10^{17} n·cm^{-2}·sec^{-1}
- Fast and resonance neutrons for transmutation
- Thermal power of system 1.2 GW. Beam power 10 MW. Energy of protons 1.2 GeV
- Lead target and helium cooling system of sub-critical reactor
- Electrical power 0.4 * 1200 MW – 30 MW=450MW