

Study on usage of Russian research reactor fuel types for an ADSRF design in Vinča

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Introduction

ADSRF Project, based on:

- TESLA Accelerator Installation (TAI)
- Research Reactors Experience

Requirements for a small ADSRF:

- intermediate neutron spectrum in Pb matrix
- low power, i.e., no fuel burn up => no spent fuel
- solid Pb target and matrix
- LEU Russian origin fuel
- H₂O primary moderator



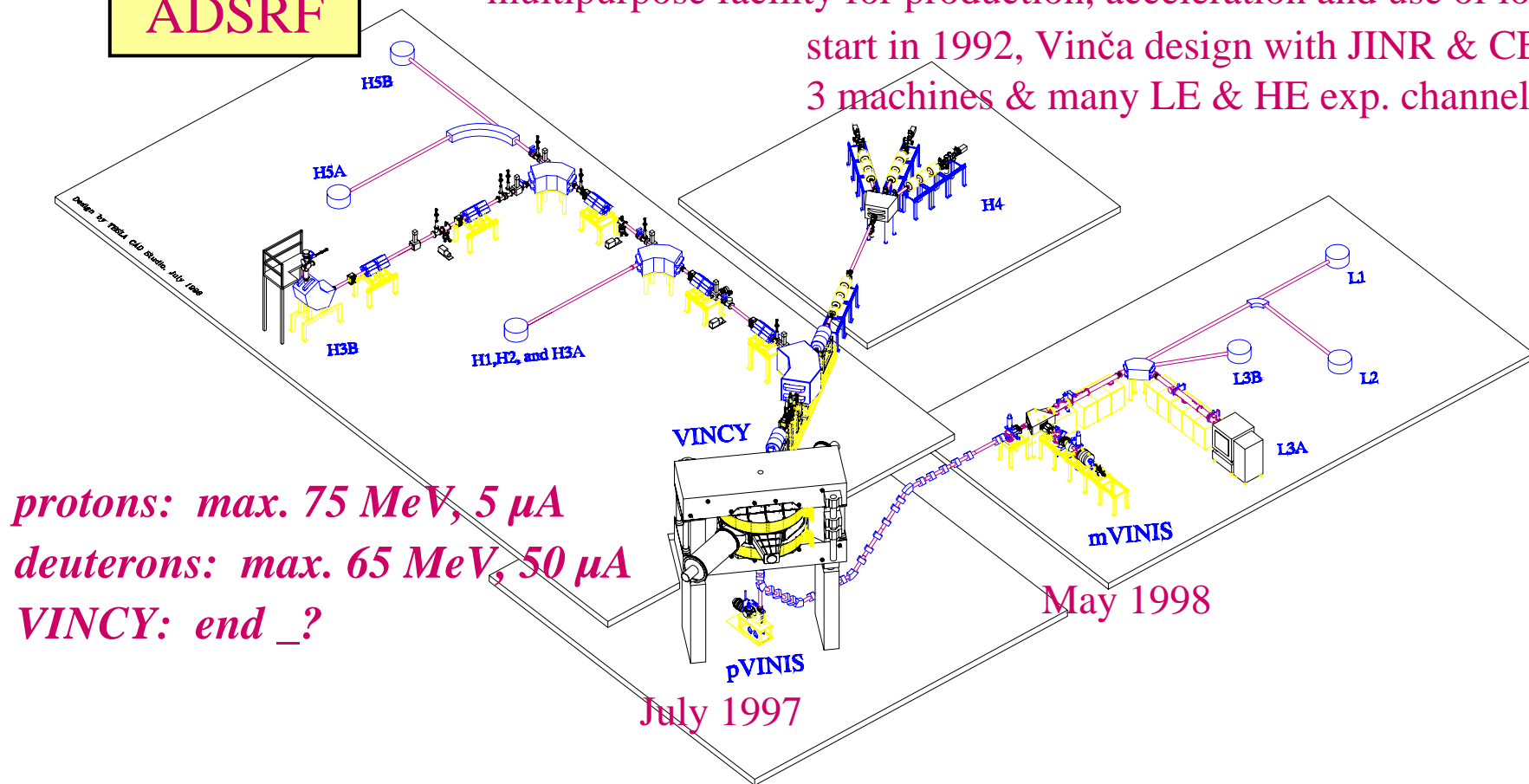
Background of the ADS Proposal

- Ex'Yu/Serbia law: **NO** to nuclear power in 1989/94
- Economy reasons - no HL radioactive waste
- Future - possible nuclear option?
- New nuclear **inherent safe** technologies
- **Idea:** low flux ADS RF in the Vinča
- **Goal:** **Conceptual Design** in 3 years, to Get-in & Stay-in Modern Nuclear Reactor Trends
- Small ADS RF supposed to be used for basic and applied research in nuclear and reactor physics, dosimetry and radiation protection, metrology, radiation biology, new technologies, nuclear data and codes validation

TESLA Accelerator Layout

ADSRF

multipurpose facility for production, acceleration and use of ions
 start in 1992, Vinča design with JINR & CERN
 3 machines & many LE & HE exp. channels



protons: max. 75 MeV, 5 μ A
 deuterons: max. 65 MeV, 50 μ A
 VINCY: end _?

May 1998

July 1997

Figure 1. Scheme of the TESLA Accelerator Installation: VINCY Cyclotron, mVINIS Ion Source, pVINIS Ion Source, L1 - channel for physics of multiply charged ions, L2 - channel for surface physics, L3A - channel for modification of materials, L3B - channel for analysis of materials, H1 - channel for nuclear spectroscopy, H2 - channel for heavy ion nuclear reactions, H3A - channel for physics of thin crystals, H3B - channel for radiation research, H4 - channel for production of radioisotopes, H5A - channel for proton therapy, and H5B - channel for neutron research.

TESLA Accelerator Installation



pVINIS



mVINIS

L3 for material modification

VINCY



nt, Beg, 2

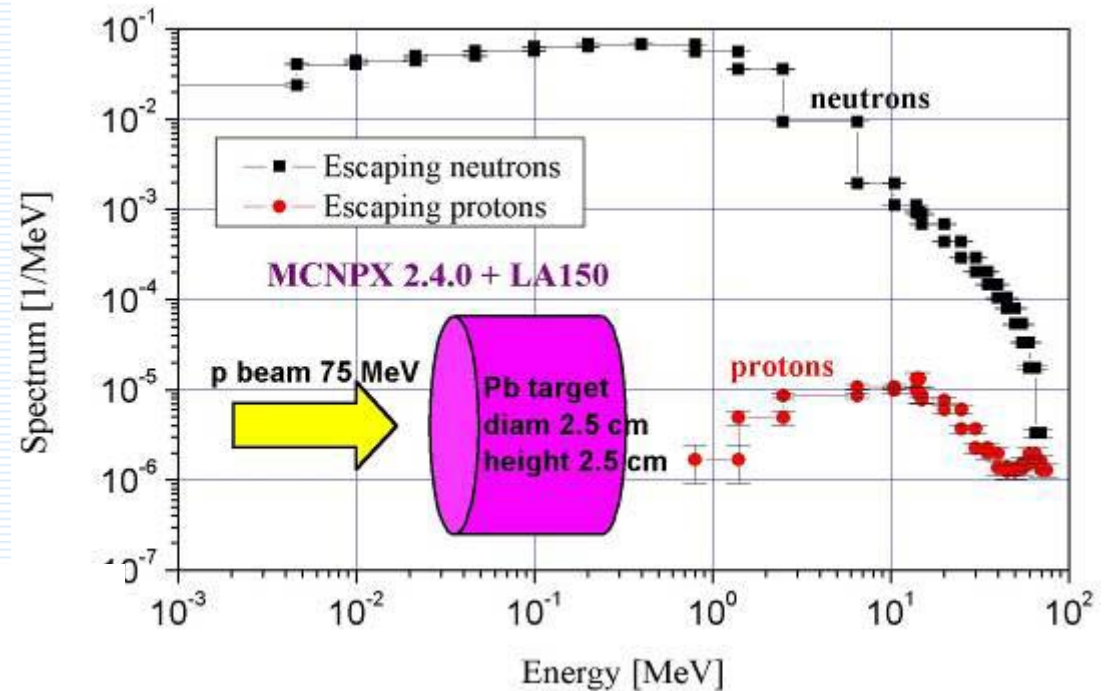
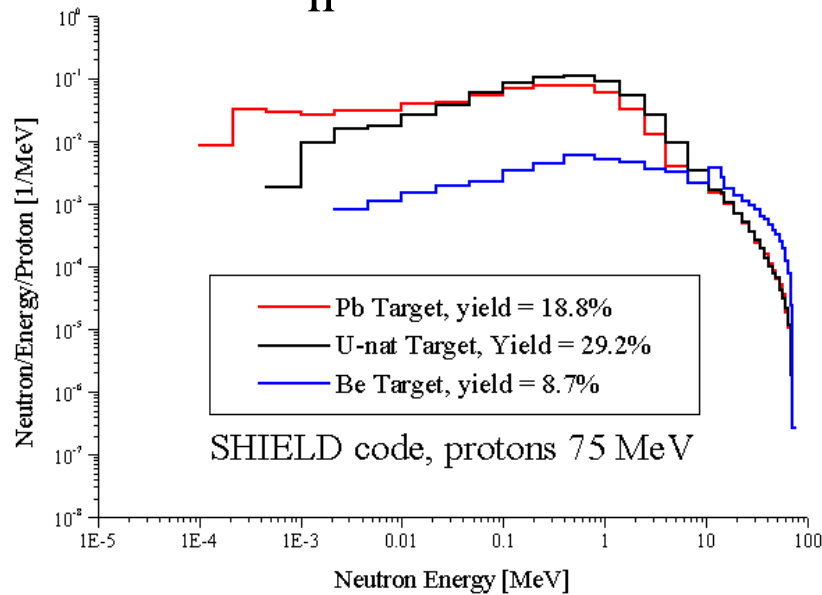


Target Task in Project

- Beam with low E, no spallation neutron source \Rightarrow
- Choose and design an optimal target for neutron yield and spectrum for beam **p** or **d**
- SRNA (**p**) SHIELDHI (**p** or **d**) MCNPX 2.4.0 (**p** or **d**)
- d, p and n data: ENDF/B-VI.8/VII (and LA-150)
- x-sect measurements at TESLA H5B channel
- 1st estimation: 15% - 30% n/(**p** or **d**) 75 MeV in thick targets (Be, Li, Pb, W, Bi, U, Th, Bi-Pb) \Rightarrow
- Maximum neutron flux: $10^{10} - 10^{11} \text{ cm}^{-2}\text{s}^{-1}$

Target task: p + Target

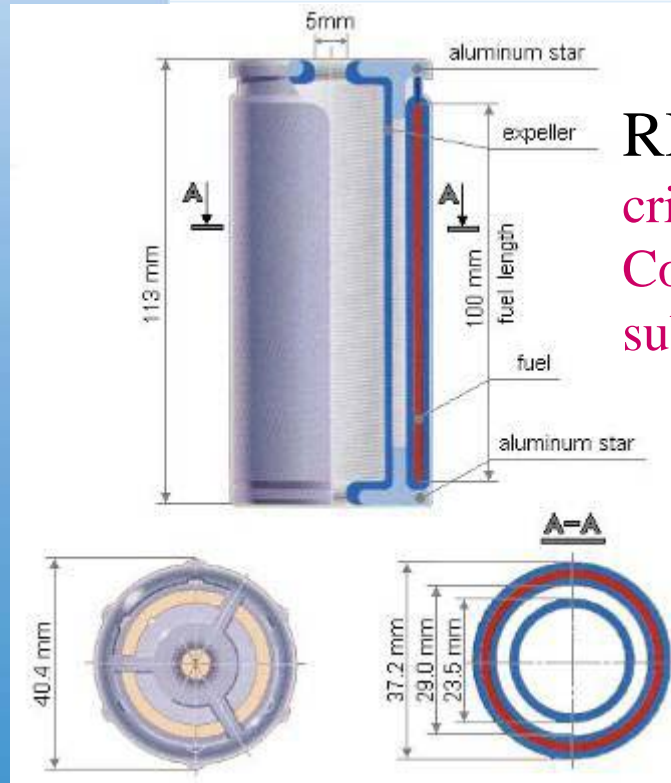
E (p/d) max 75 MeV,
no spallation, but
> 95% $E_n < 20$ MeV



neutron yield for 75 MeV p at Pb:
(SHIELD, LCS2.7, MCNPX2.4.0)
(0.19 ± 0.04) neutron per proton

Experience from Vinča Research Reactors

After 2002, no fresh HEU (80%) at Vinca



RB reactor, 1958 - ,
criticality benchmarks,
Coupled F-T Core: HERBE
sub-critical experiments

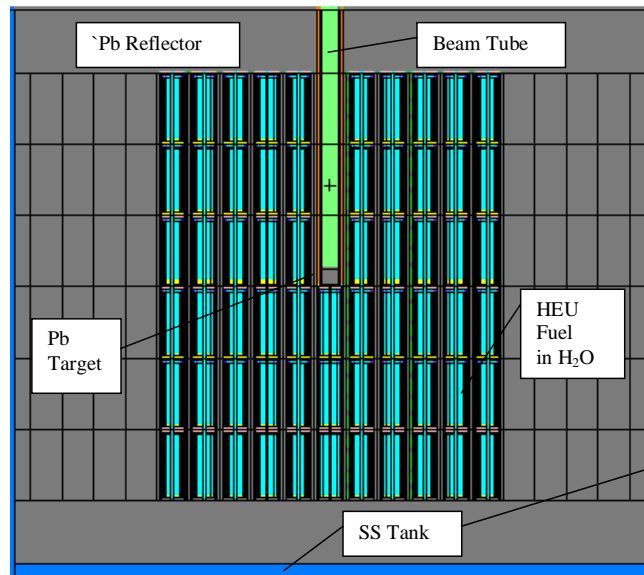
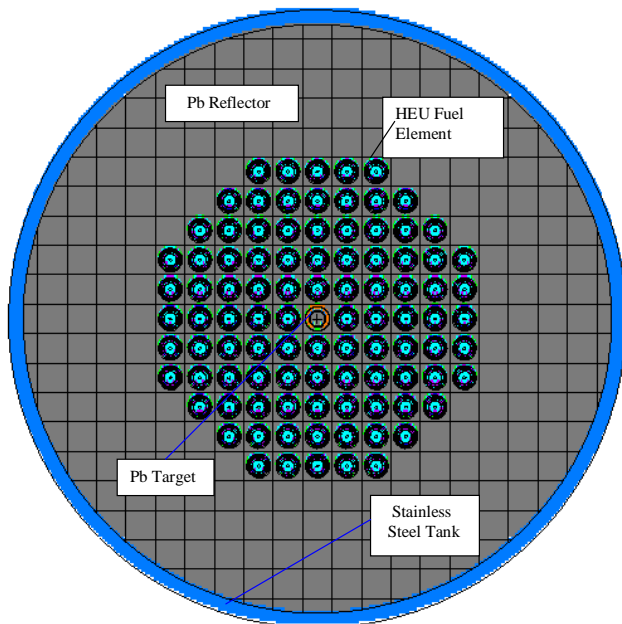


RA reactor, 6.5 MW,
D₂O moderated/cooled
1959 - 1984/2002 Decomm

Codes:
SCALE4.4a,
MCNP5, etc.
VMCCS lib.

TVR-S fuel:
2% metal U or
80% UO₂ in Al

ADS RF-H: a concept of ADS RF with HEU (80%) TVR-S Fuel

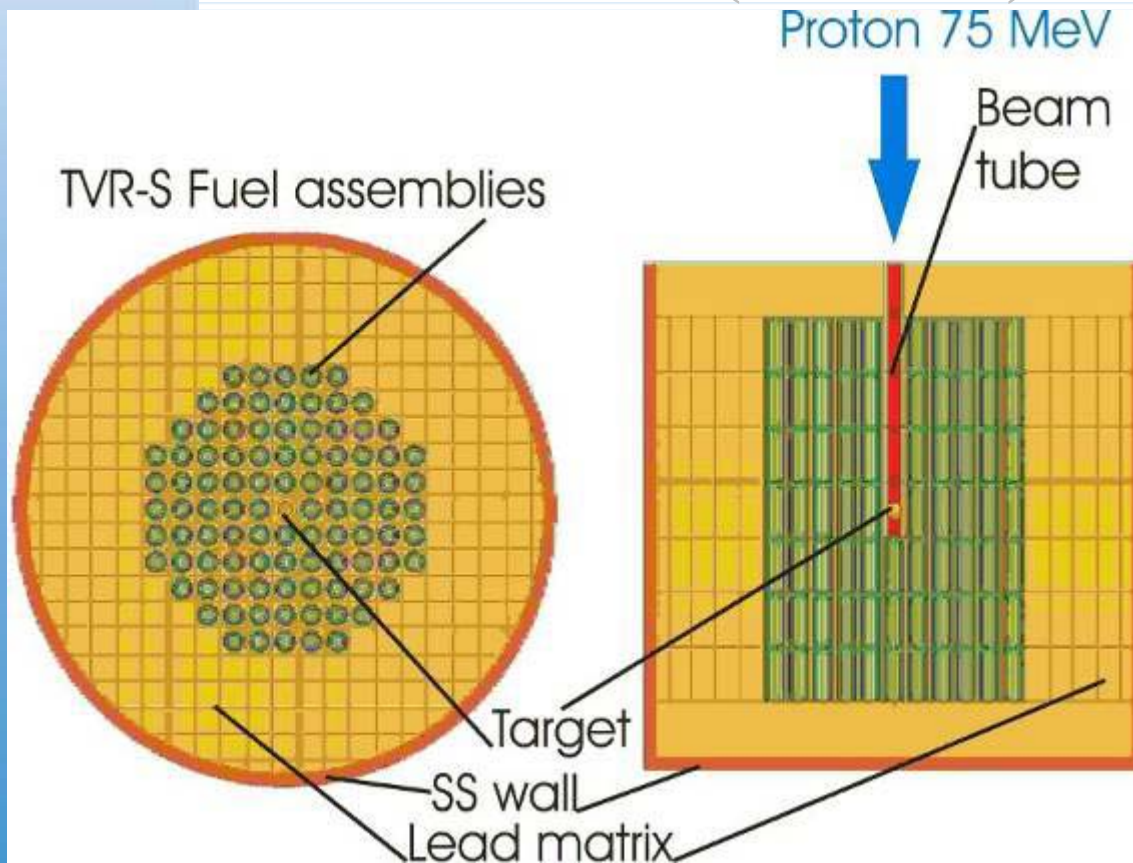


nFA = n TVR-S
(n = 6 or 7);
mAR = axial Pb
reflector, height
m (1 or 2) TVR-
S fuel elements;
ADS RF-H6:
(6FA + 2 AR)
 $k_{\text{eff}} = 0.9865$
 $I_p = 91.5 \mu\text{s}$

$k_{\text{eff}} = 0.986 \pm 0.001$, $I_{\text{proton}} = 5 \mu\text{A} \Rightarrow \text{max: } \Phi_{\text{fast}}/\Phi_{\text{th}} = 7.4/2.3 \text{ (} 10^{10} \text{ cm}^{-2} \text{ s}^{-1}\text{)}$

Fission: thermal 95%, Neutron Flux: fast (> 0.465 eV), Max. Power = few (~5) kW

ADS RF-L: a concept of ADS RF with LEU (19.7%) TVR-S Fuel



ADS RF-L7:

(7FA + 1 AR)

$k_{\text{eff}} = 0.9760$

$l_p = 82.8 \mu\text{s}$

ADS RF-L6:

(6FA + 2 AR)

$k_{\text{eff}} = 0.9677$

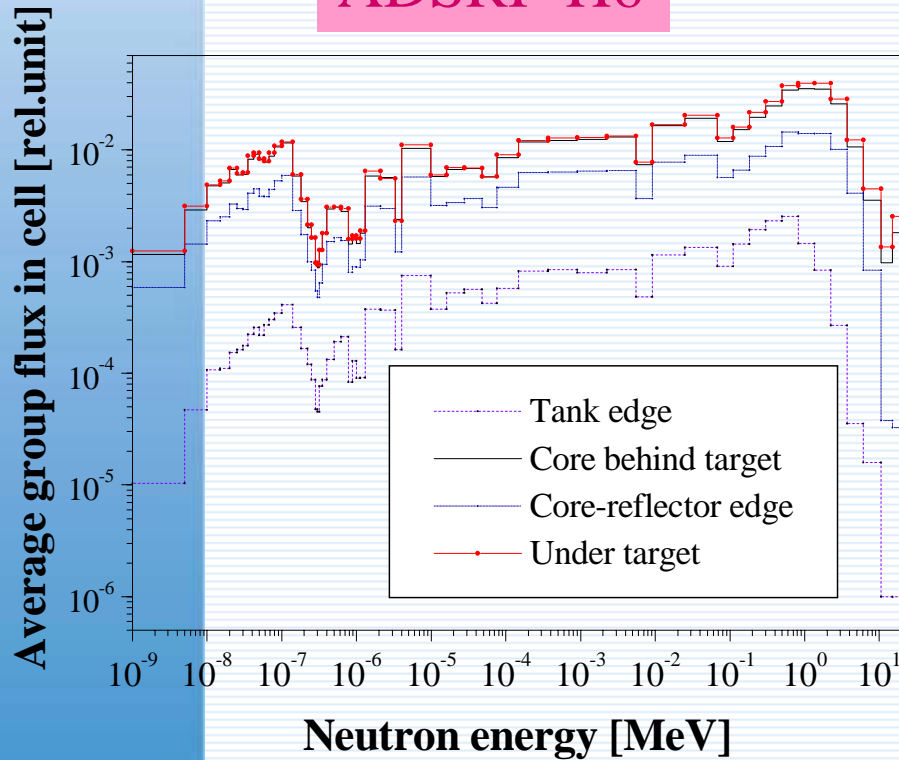
$l_p = 88.6 \mu\text{s}$

$k_{\text{eff}} = 0.976 \pm 0.001$, $I_{\text{proton}} = 5 \mu\text{A} \Rightarrow \text{max: } \Phi_{\text{fast}}/\Phi_{\text{th}} = 5.8/2.0 (10^{10} \text{ cm}^{-2} \text{ s}^{-1})$

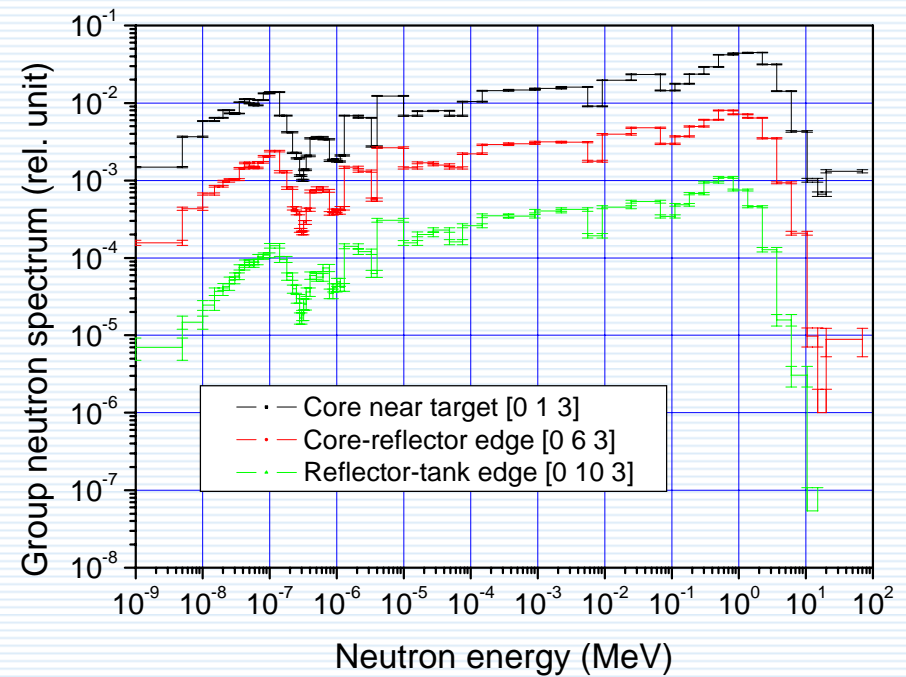
Fission: thermal 95%, Neutron Flux: fast ($> 0.465 \text{ eV}$), Max. Power = few (~ 3) kW

Neutron Spectrum in ADSRF with TVR-s

ADSRF-H6



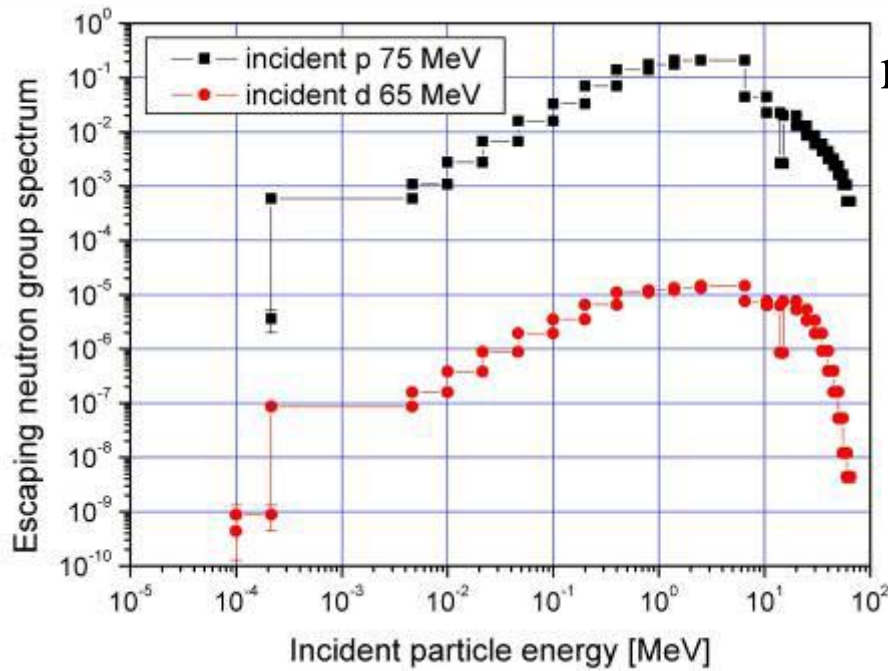
ADSRF-L7



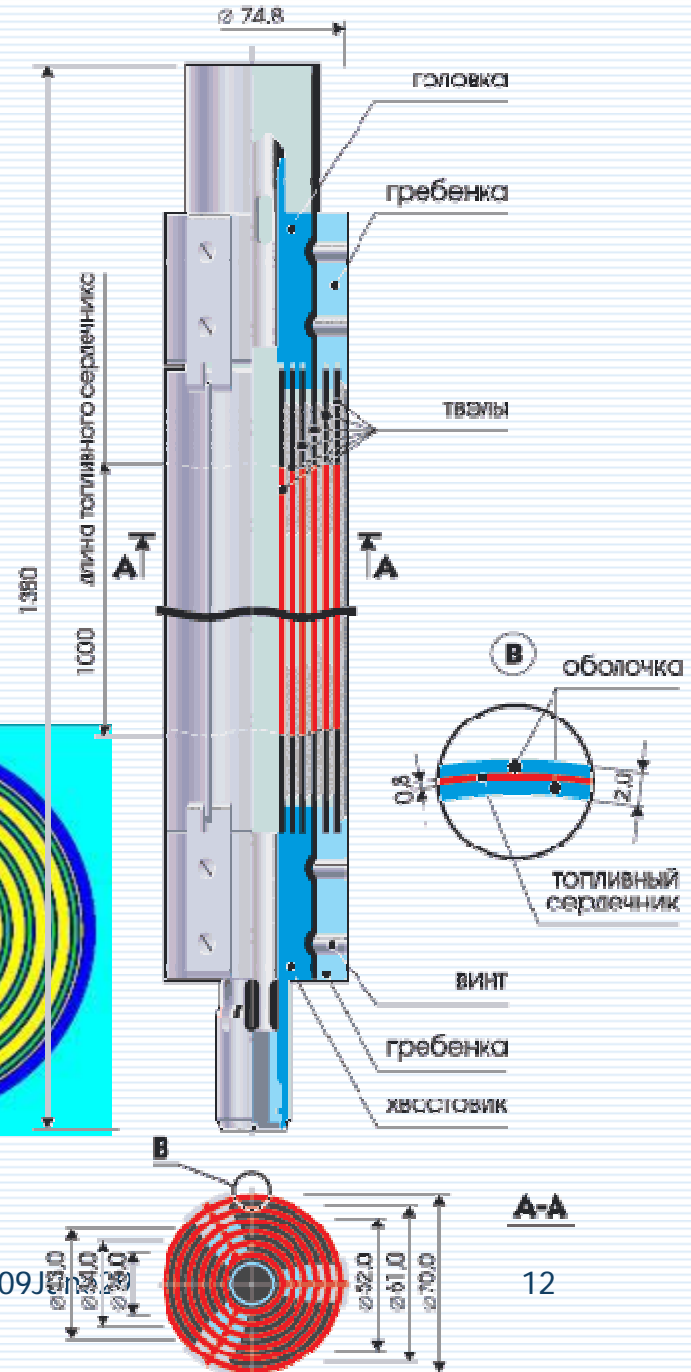
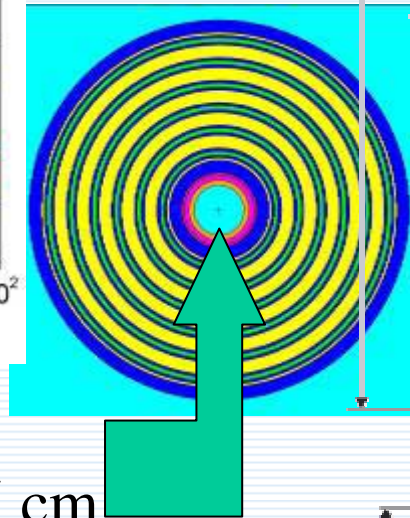
Intermediate neutron spectrum > 0.465 eV

New Approach: MR 6 LEU Fuel

MR 6 type, 19.7% enriched UO_2



$n/p = 14\%$



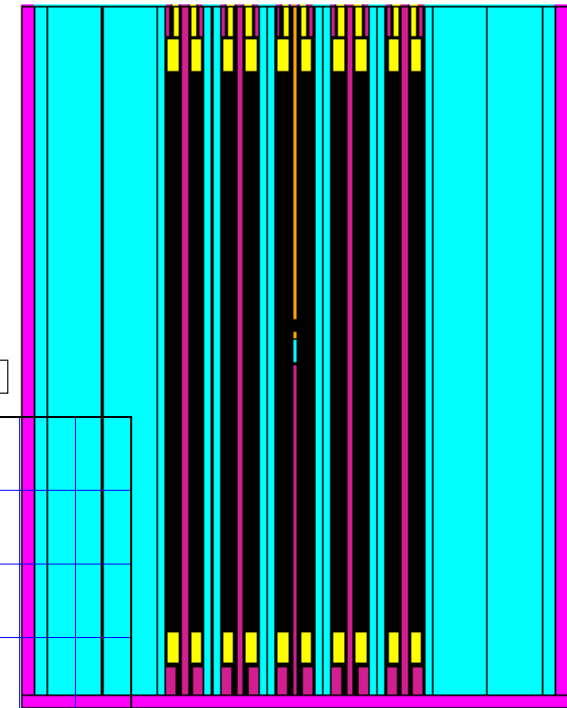
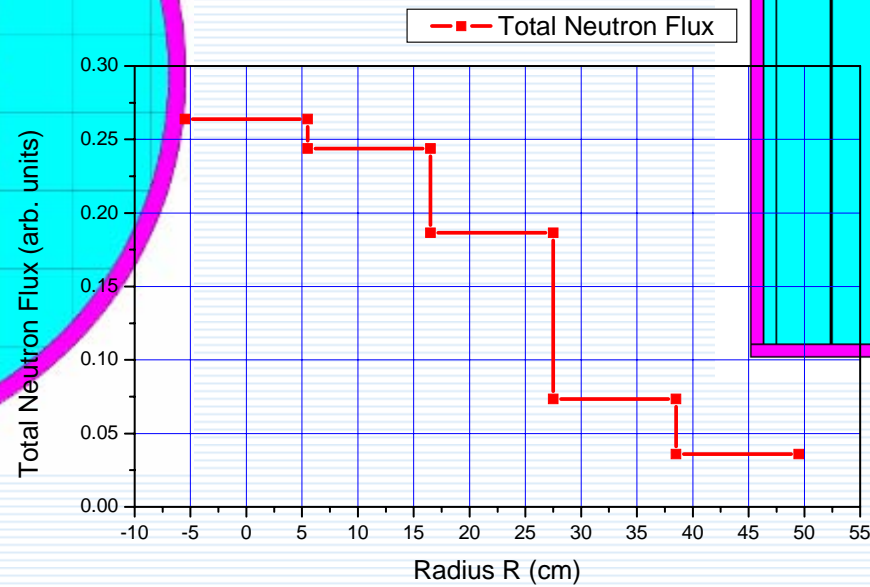
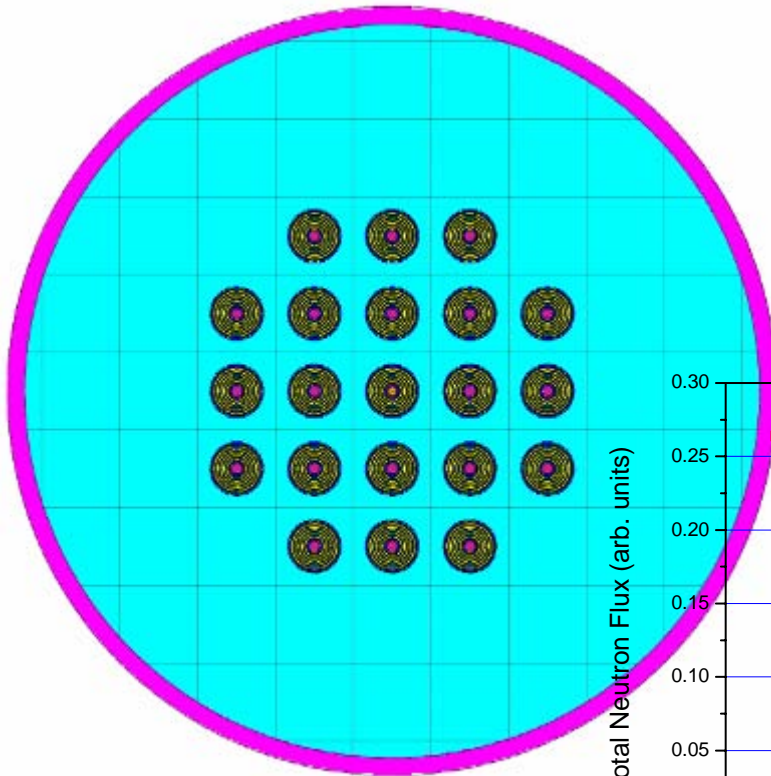
Pb cylinder target: 1 x 5 cm

EU ResearchInfoEvent, Beg, 2009Jun



ADSRF with MR 6 (19.7 % U-235) FAs

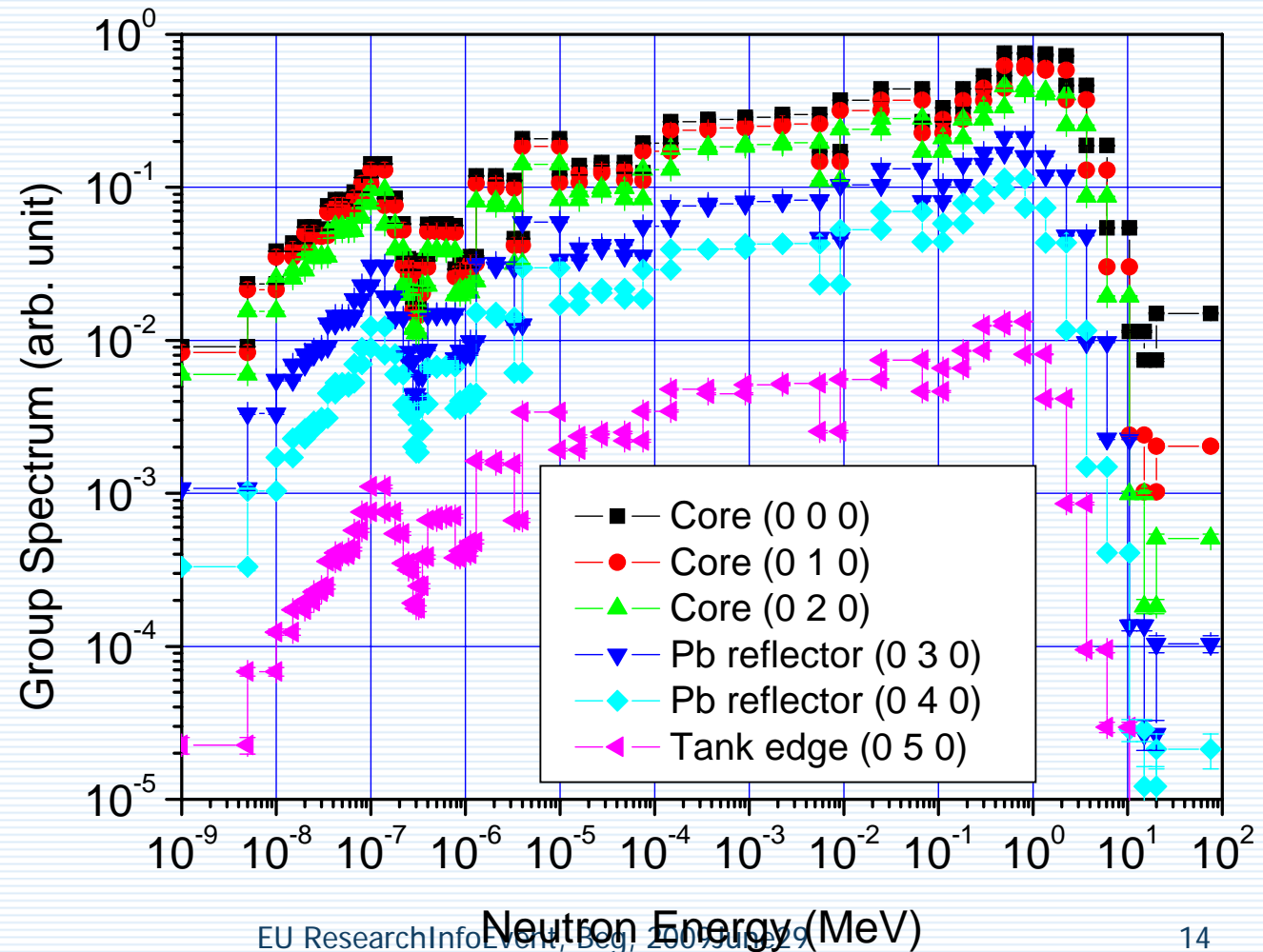
p 75 MeV or
d 65 MeV
beam



ADSRF with MR 6 (19.7 % U-235) FAs

MCNP5 code:

- $k_{\text{eff}} = (0.958 \pm 0.001)$
- Spectrum:
SDEF from
MCNPX for
p_75 MeV @
Pb cylind. 1 cm
x 5 cm



Comparison

Fuel type	TVR-S UO ₂ in Al		MR 6 UO ₂ in Al
Enrichment	HEU 80 %	LEU 19.7 %	LEU 19.7 %
m (²³⁵ U)/FE [g]	7.7	7.7	450
#FA / #FE	H6: 97 / 579	L7: 97 / 676	21 / 21
Lattice pitch [mm]	5.0	5.0	11.0
m(²³⁵ U)/ m(U) [g/g]	4.5 / 5.6	4.6 / 23.4	9.45 / 47
Spectrum / Fiss. type	Fast / Thermal	Fast / Thermal	Fast / Thermal
Flexibility	High	High	Low
max Φ_f (>0.465 eV)	$7.4 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$	$5.8 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$	$4.8 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$
max Φ_{fh} (>0.465 eV)	$2.3 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$	$2.0 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$	$1.1 \cdot 10^{10} \text{ cm}^{-2} \text{ s}^{-1}$

Vinča ADS References

■ Conferences:

- ❑ ITEP 1999, Moscow
- ❑ YUNSC 2000 & YUNSC 2002, Belgrade;
- ❑ GLOBAL 2001, Paris;
- ❑ 7th TESLA workshop, 2001 Belgrade;
- ❑ NDST 2001, Tsukuba;
- ❑ 48th ETRAN Conf. 2004, Čačak;
- ❑ ECPM 2005, Belgrade;
- ❑ GLOBAL2005, Tsukuba;
- ❑ RRFM2007, Lyon;
- ❑ ICENES 2000, Petten;
- ❑ PHYSOR 2002, Seoul;
- ❑ RERTR 2005, Boston;
- ❑ AccApp 2005, Venice;
- ❑ IAEA TM on LEU in ADS, Vienna, 2006
- ❑ ETRAN 2008, Palic;

■ Journals:

- ❑ NT&RP, Vol. **XVI**, No. 1, pp. 34-38 (2001)
- ❑ NIM-A, Vol. **562**, Issue 2, pp. 642-645 (2006)

■ Vinča ADS web site:

- ❑ www.vin.bg.ac.yu/150/ADS_english.htm

Conclusion

- National experience and Vinča experimental (RB, TAI ?) and computational infrastructure are demonstrated at study of low power ADS RF at the Vinča Institute with Russian HEU/LEU TVR-S and MR-6 fuel elements in H₂O and Pb matrix driven by p/d beam from TAI
- Codes & libs: MCNPX/MCNP5, SHIELD, SCALE5, VMCCS
- H5B ADSRF is included into IAEA CRP Benchmarks for LEU ADS (2006-2009).



Thank you for
your attention