Accelerator-Driven System (ADS) for MA Transmutation

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Nuclear Science and Engineering Center
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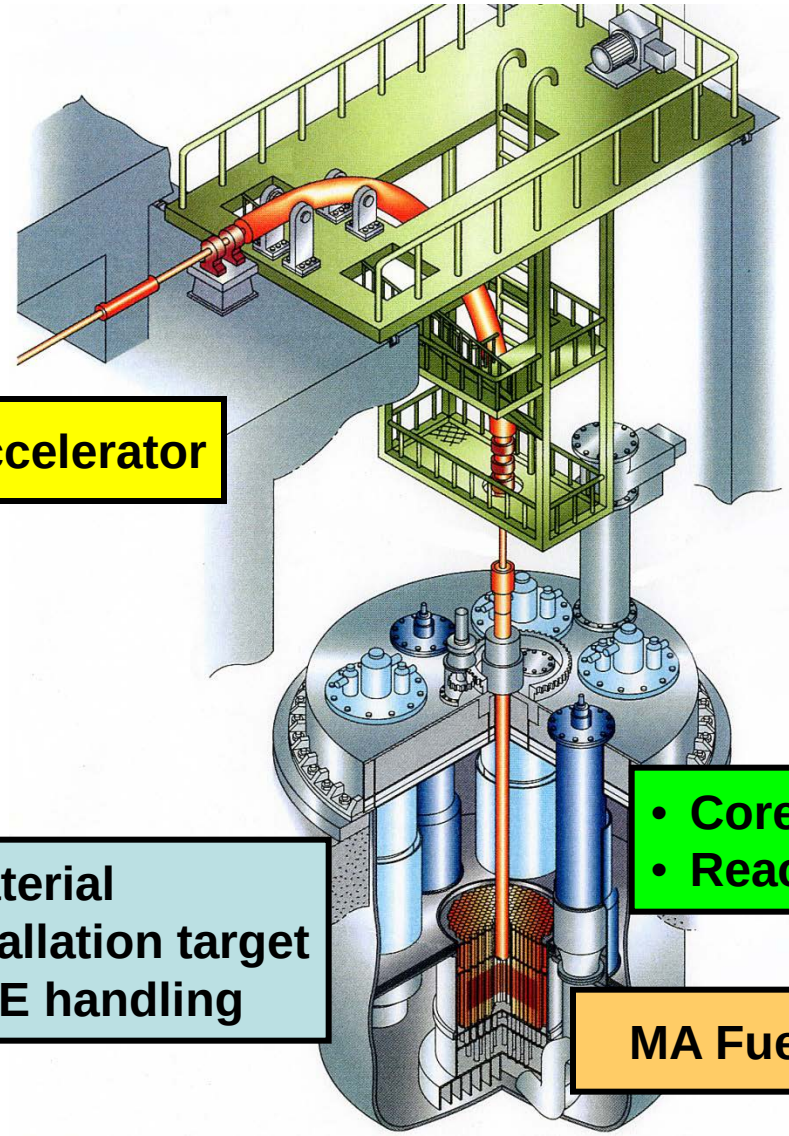
Conceptual Design of ADS by JAEA



Conceptual view of 800MWth LBE-cooled ADS

- Proton beam : 1.5GeV ~30MW
- Spallation target : Pb-Bi
- Coolant : Pb-Bi
- Subcriticality : $k_{eff} = 0.97$
- Thermal output : 800MWt
- MA initial inventory : 2.5t
- Fuel composition :

  (MA+Pu)Nitride + ZrN

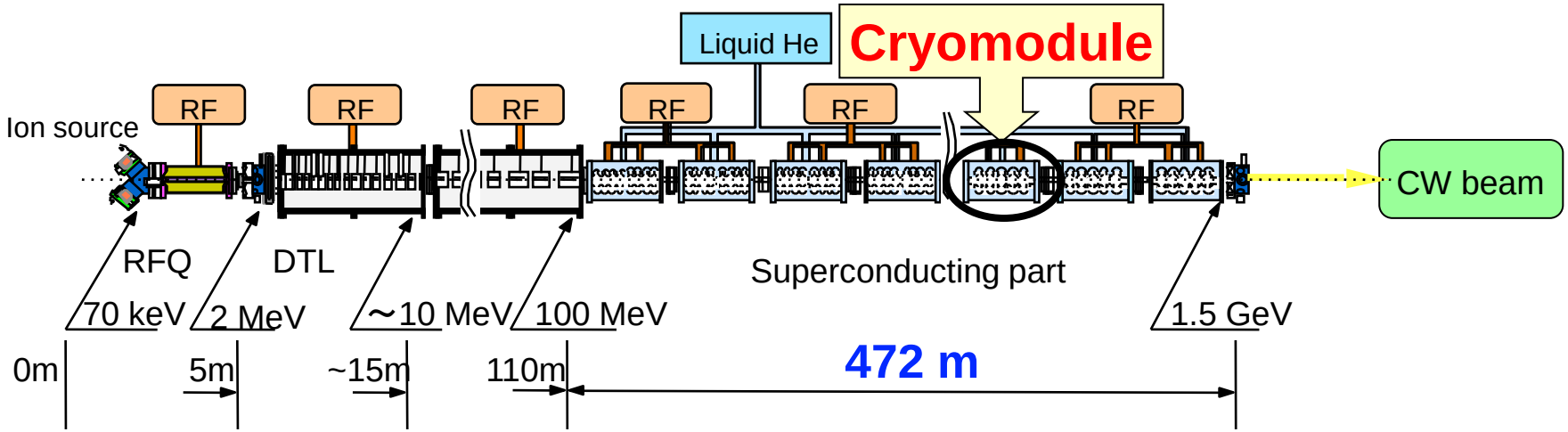
  Initial loading

  Zone-1 : Pu/HM = 30.0%

  Zone-2 : Pu/HM = 48.5%
- Transmutation rate :

  10%MA / Year (10 units of LWR)
- 600EPFD, 1 batch

Superconducting Accelerator for ADS



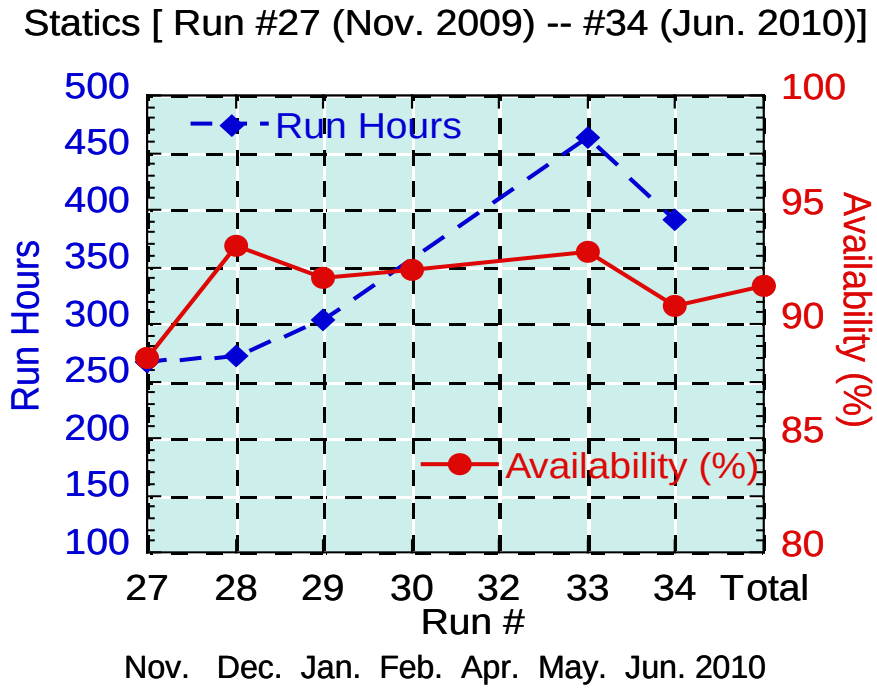
- Mockup of cryomodule (2 superconducting cavities) was fabricated and tested. It was designed to accept 927MHz RF wave and to be suitable for acceleration of 424MeV proton
- The design study provided that the SC-LINAC consisting of 89 cryomodules and the length (100MeV to 1.5 GeV) was estimated as 472m.

Superconducting cavity

Cryomodule

Proton LINAC in J-PARC

- J-PARC LINAC (400MeV, 25Hz)
  - The LINAC had been operated stably for injection to the following 3 GeV synchrotron



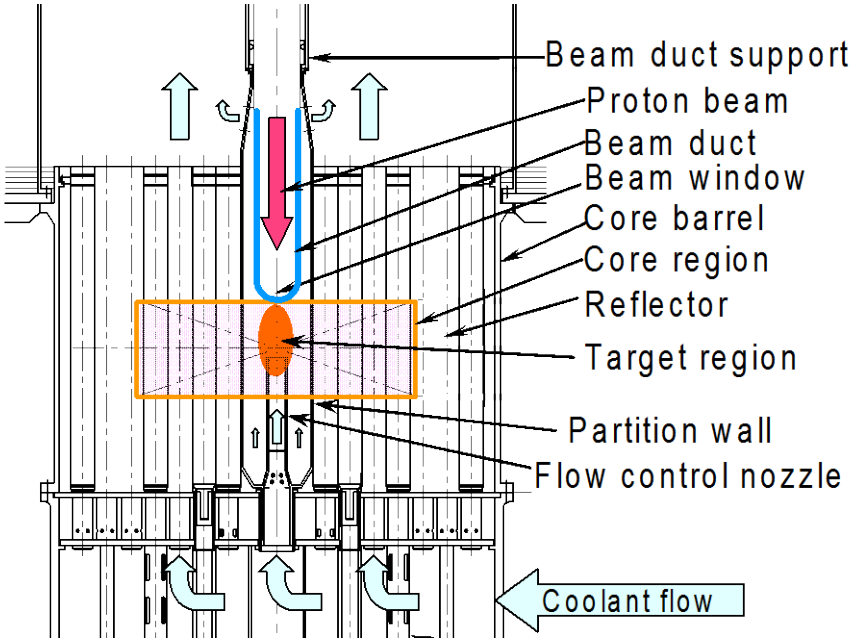
Features of Liquid Lead-Bismuth Eutechnique (LBE)

- Advantages
  - ✓ Lower melting point and higher boiling point
  - ✓ Chemically inactive（stable with water and air）
- Disadvantages
  - ✓ Heavy mass（difficulty in treatment with piping）
  - ✓ Compatibility with material（corrosion)

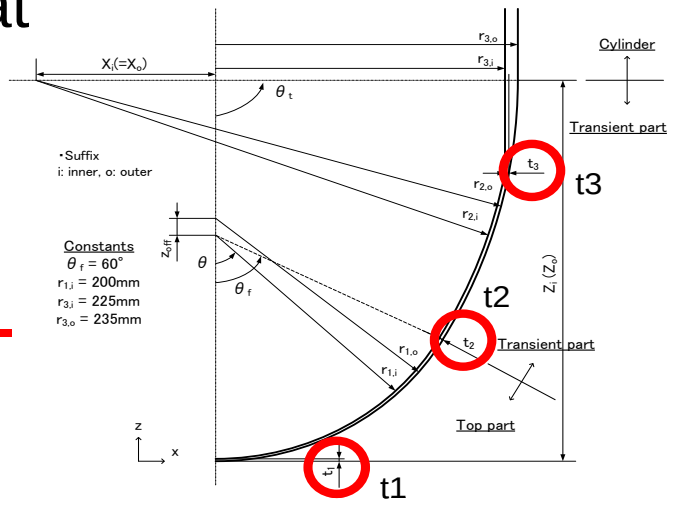
Material	Melting point (℃)	Boiling point (℃)	Density (kg/m^3)	Heat capacity (kJ/kg･K)	Thermal conductivity (W/m･K)
Na	98.0	882	849	1.32	70.8
Hg	-38.9	357	13,112	0.135	12.9
Pb	327	1750	10,480	0.16	15.4
Pb-Bi	124	1670	10,087	0.146	14.9

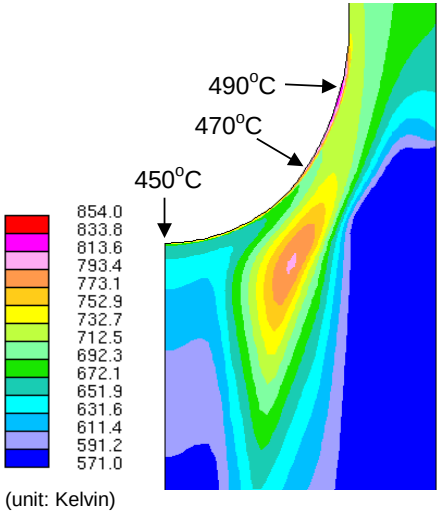
Desing Study : Spallation Target and Beam Window

- Design condition
  - ✓ Proton beam：1.5 GeV-20 mA（30 MW）
  - ✓ LBE velocity : < 2m/s
  - ✓ Maximum beam window temperature : < 500ºC



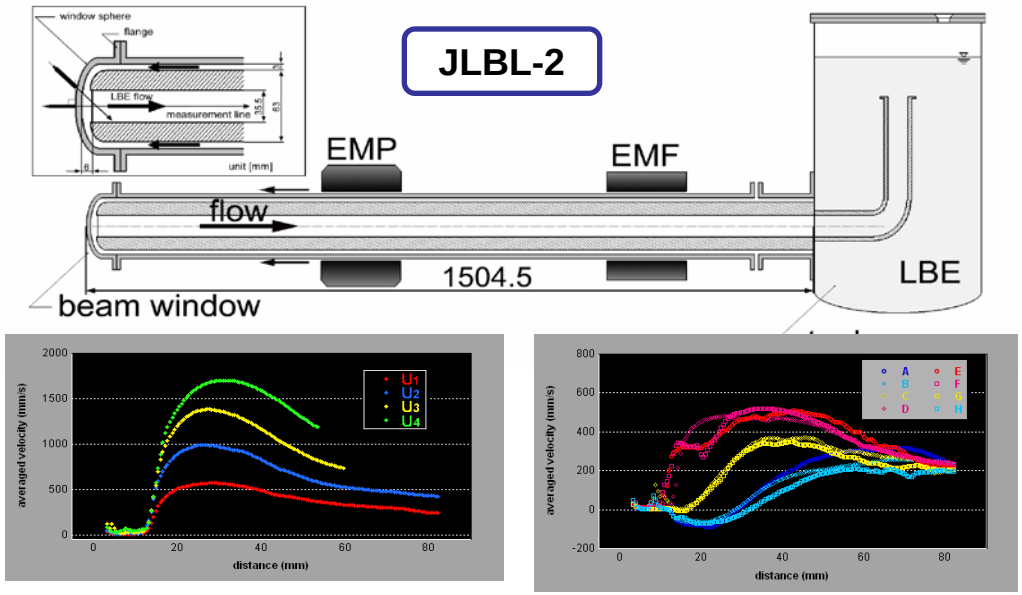
- Beam window design in which the maximum temperature at the outer surface of the window is about 490 ºC
- **R&D issues : Material corrosion in LBE, thermal-hydraulic of LBE, material irradiation effect**



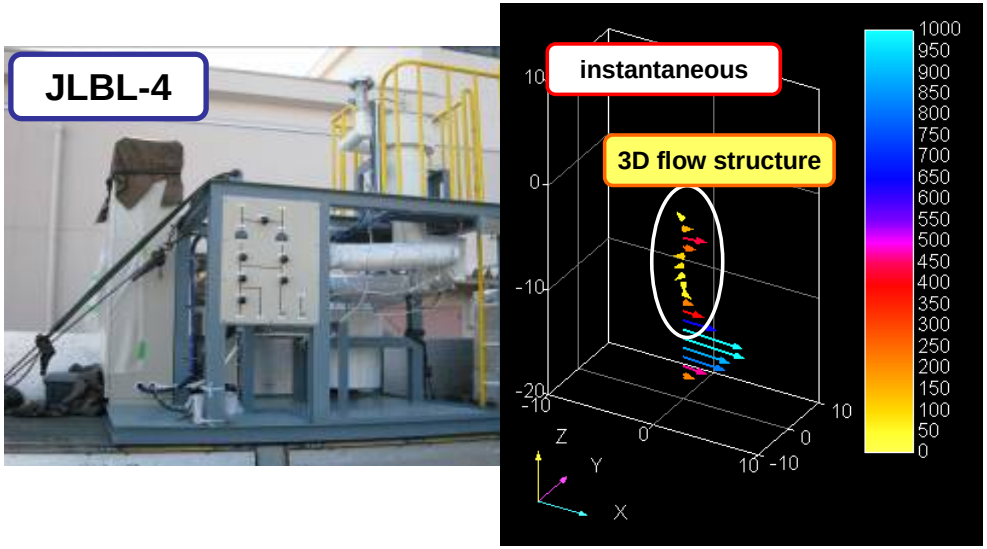


Thermal Hydraulics Study of LBE

- The flow velocity measurement by **UDM (Ultrasonic Doppler Method)** is being developed by using JAEA LBE loop-2 (JLBL-2).
  - The distribution of the flow velocity was measured at 150 ºC by use of the UDM, which is useful for visualization of the liquid LBE flow.
- An advanced measurement system "**Vector-UVP**" was developed and successfully applied to the actual LBE flow in JLBL-4 for two-dimensional velocity vector measurement.



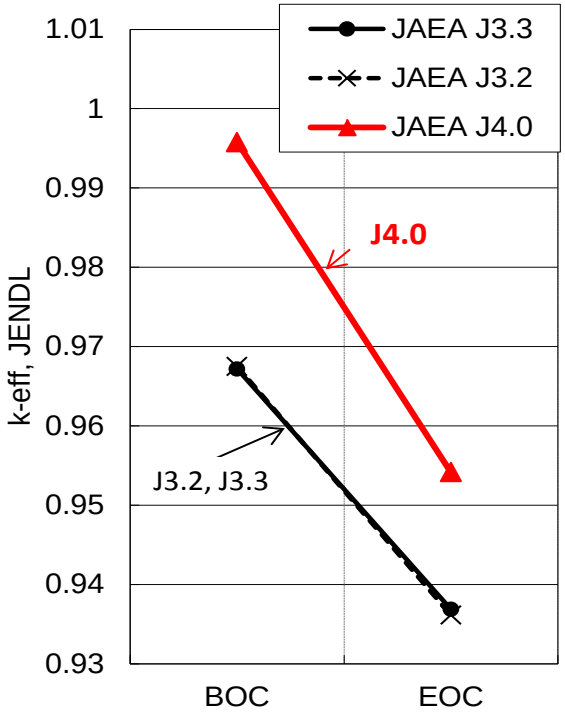
Measurement result by UDM at a centerline and inclined direction

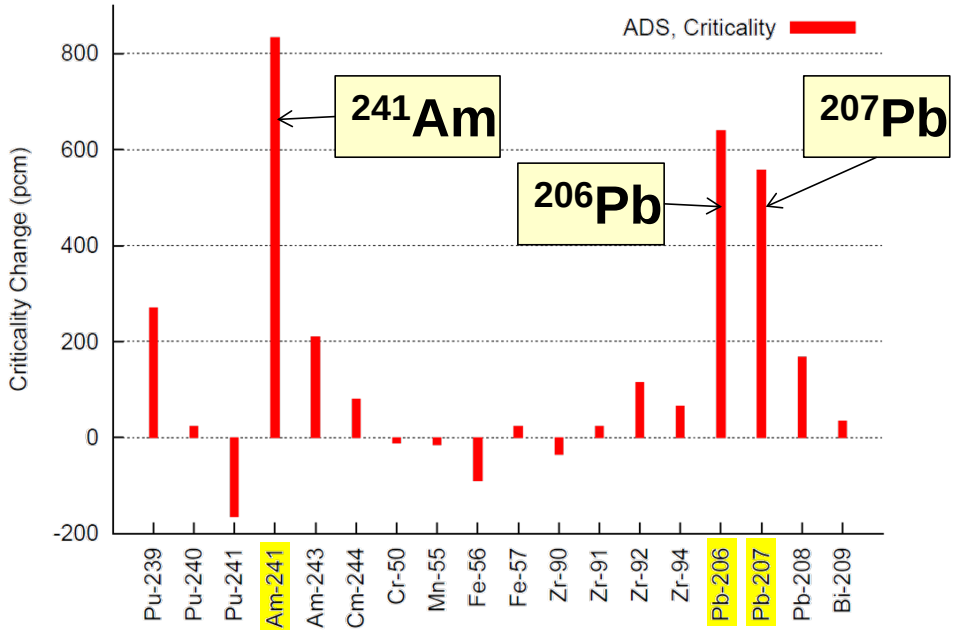


Measurement result by advanced measurement system "Vector-UVP"

Current situation of neutronics design of ADS

- **About 2% discrepancies in k-eff were found among the different nuclear data** (k-eff disperses from 0.98 to 1.0 at BOC and 0.93 to 0.96 at EOC) in a IAEA-CRP benchmark proposed by JAEA.
- ***Experimental validation is essential for MA(Np-237, Am-241) and other nuclides(Pb-206, Pb-207, N-15)***



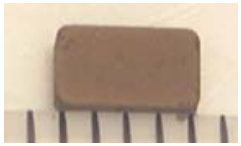


Calculated results for IAEC-CRP benchmark proposed by JAEA and Nuclide-wise contribution for the difference between calculated k-eff with JENDL-4.0 and 3.3

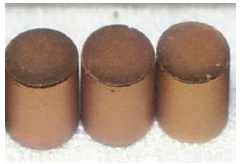
R&D for MA nitride fuel for ADS

Fabrication of MA nitride fuel

Fabrication test of (MA,Pu,Zr)N with high density and high purity in lab-scale



(Am,Zr)N

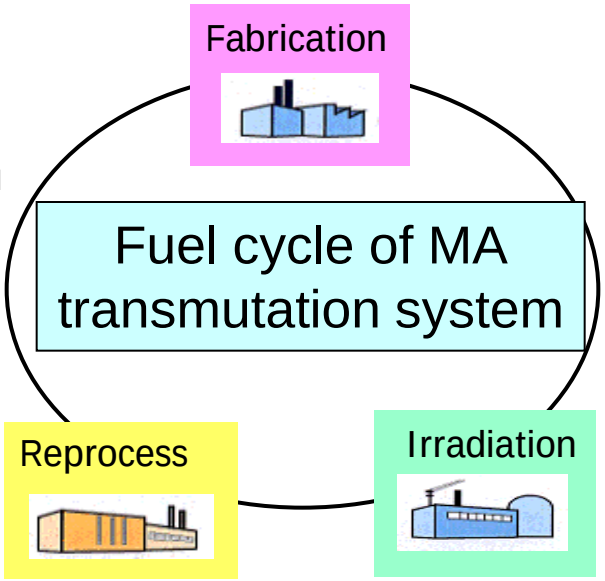


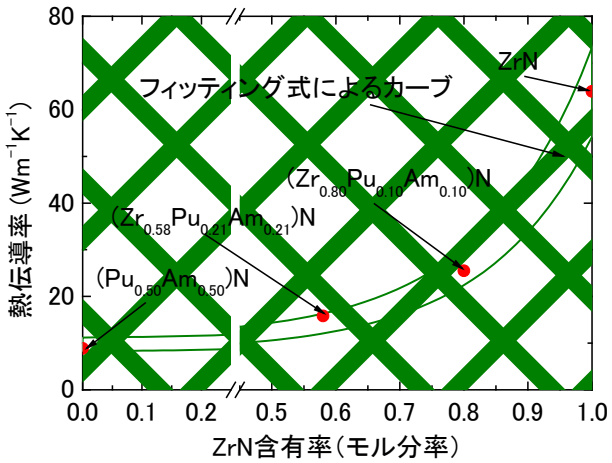
(Pu,Zr)N

$(Pu_{0.21}Am_{0.21}Zr_{0.58})N$

Physics properties of MA nitride fuel

Development of database for thermal propoerties of MA nitride fuel available for ADS design

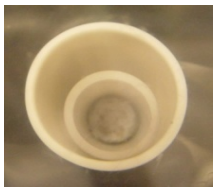




Thermal conductivity of MA nitride (873K)

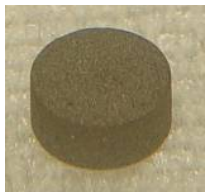
Pyrochemical process

Development of pyrochemical process flow appropriated for spent nitride fuel (TRU: Pu, Np, Am)



Liquid Cd cathode after electrolyzation

Recovered nitride powder



(U,Pu)N pellet

Irradiation performance

- Irradiation test of (Pu,Zr)N and PuN+TiN in JMTR/JAEA
- Irradiation test of MA(Am,Np) in PHENIX by international collaboration

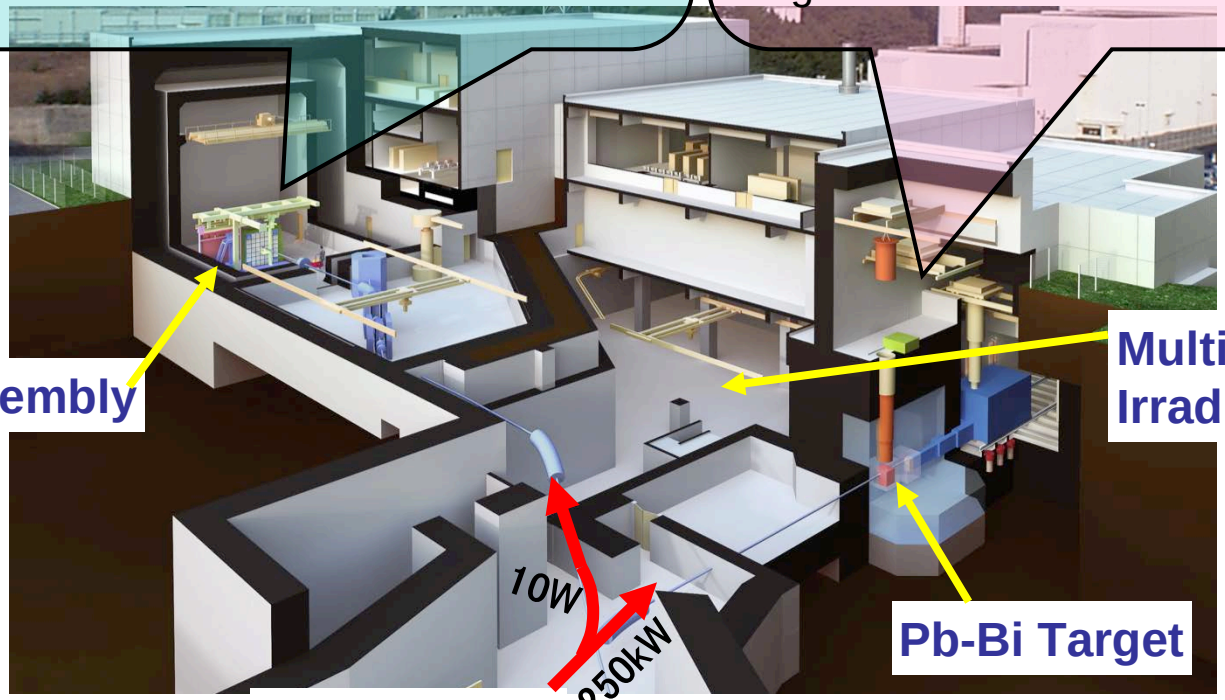
Transmutation Experimental Facility (TEF)

Transmutation Physics Experimental Facility: TEF-P

Purpose: To investigate physics properties of subcritical reactor with low power, and to accumulate operation experiences of ADS.
Licensing: Nuclear reactor: (Critical assembly)
Proton beam: 400MeV-10W
Thermal power: <500W

ADS Target Test Facility : TEF-T

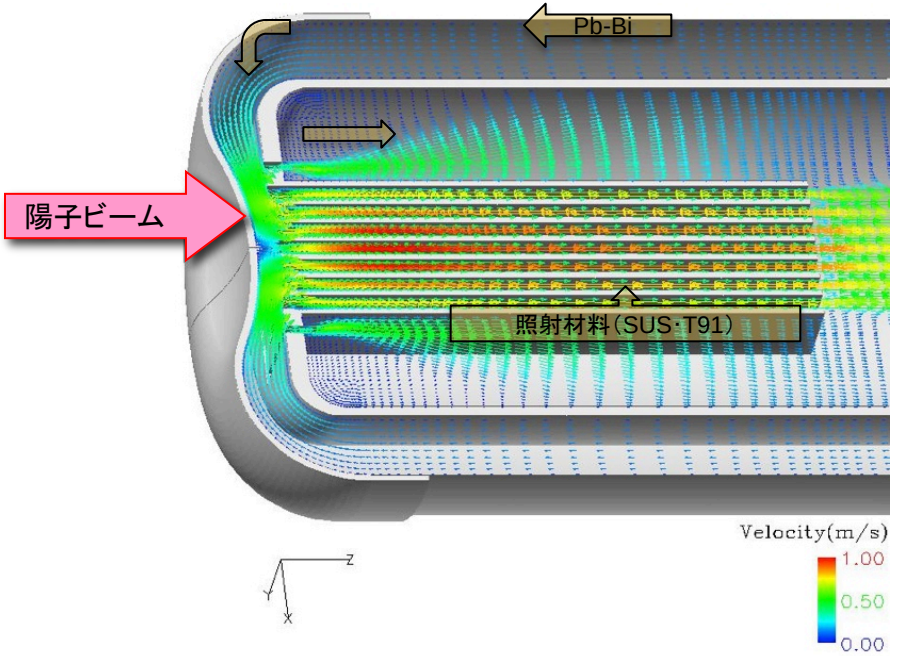
Purpose: To research and develop a spallation target and related materials with high-power proton beam.
Licensing: Particle accelerator
Proton beam: 400MeV-250kW
Target: Lead-Bismuth Eutectic (LBE, Pb-Bi)



ADS Target Test Facility (TEF-T)

- Experiments for irradiation damage of material by protons and neutrons
- Material irradiation test for material for beam window of ADS, structure material for FBR, and material for fusion reactor
- Development of database for engineering feasibility of ADS by experiments in various condition (ex. temperature and velocity of flowing LBE)

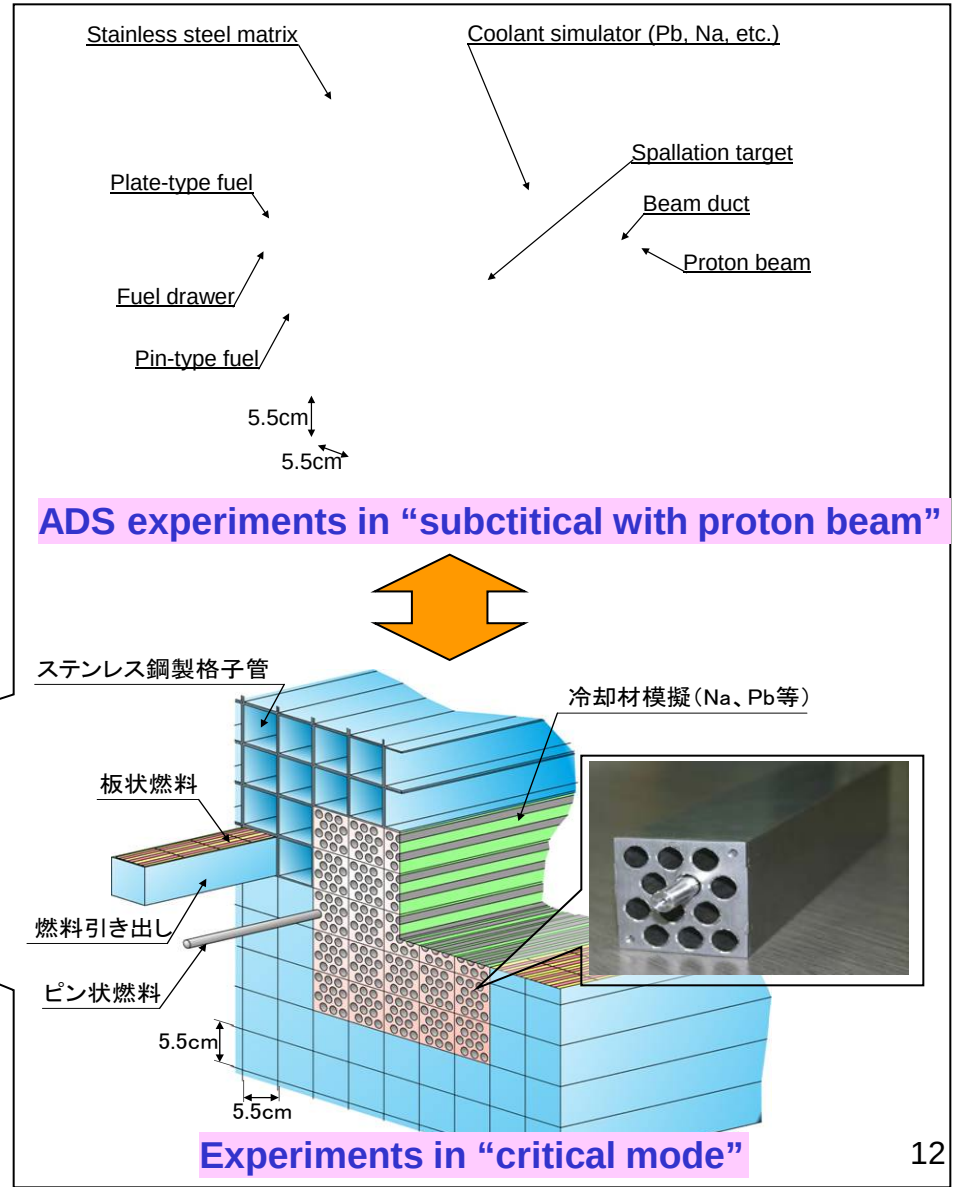
Candidate concept for LBE target in TEF-T



Example of calculated results for velocity distribution of LBE in target of TEF-T

Transmutation Physics Experimental Facility (TEF-P)

- TEF-P is designed to take over the experiences and functions of FCA to minimize the cost and risk for newly developed equipment.
- Low power critical facility for reactor physics and nuclear data of transmutation systems including ADS and FBR.
- By replacing central partial matrix tubes with pin-type assembly, MA fuel can be used with cooling and remote handling.

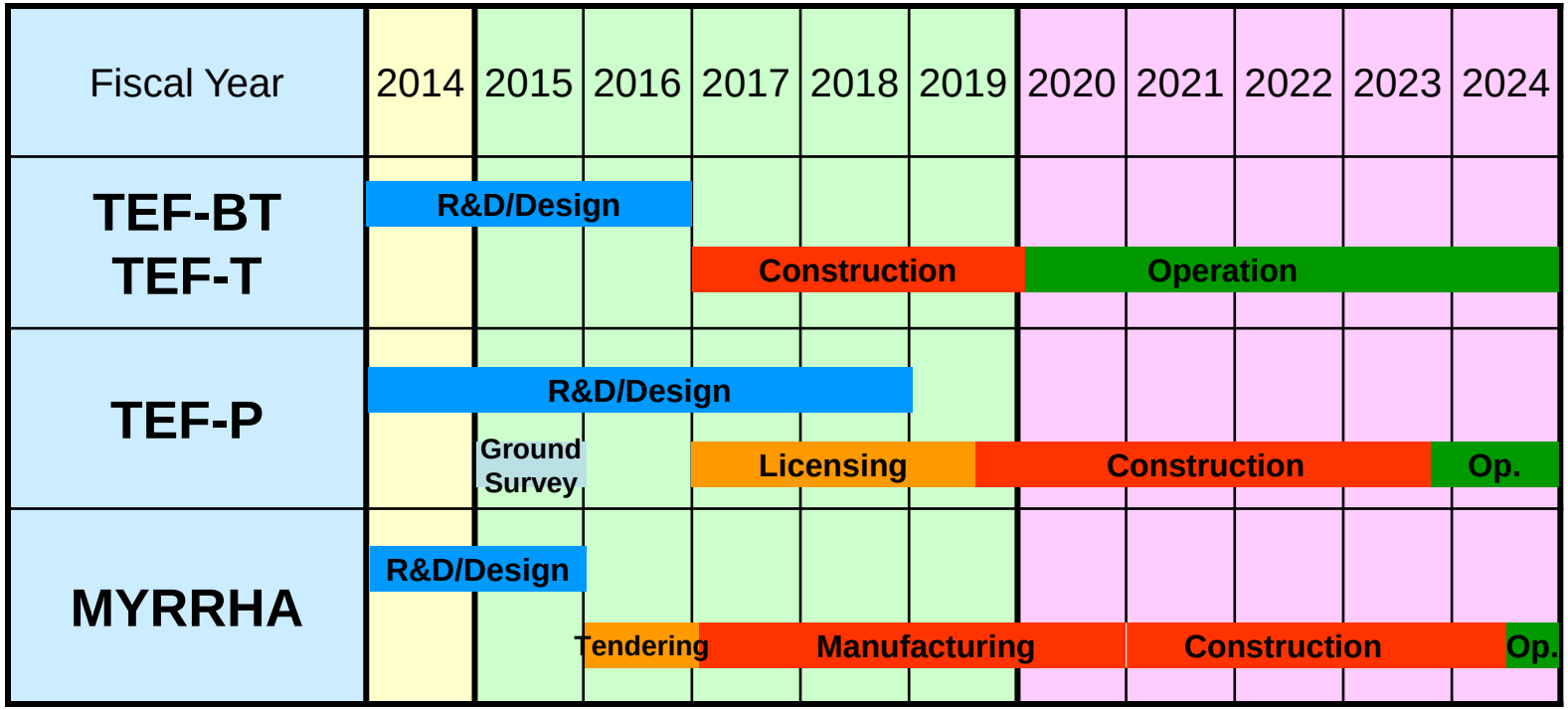


Assessment by MEXT

An interim report by Working Party of MEXT to Review Partitioning and Transmutation (P&T) Technology (Oct. 2013)

- The evaluation of technical readiness level on each field (**partitioning, ADS, fuel cycle, and fuel**) showed that we can approximately promote R&D of these fields from "conceptual development stage" to "principle demonstration stage", **and it is appropriate to shift the R&D to the next stage of engineering scale.**
- The ADS Target Test Facility (**TEF-T**) is being proposed under J-PARC (snip). **It is appropriate to shift the R&D of the facility to the next stage**.
- The Transmutation Physics Experimental Facility (**TEF-P**) is being proposed under (snip) **it is appropriate to shift the R&D of the facility to the next stage**.
- For **MYRRHA** Program, **it is appropriate to proceed with negotiation about JAEA's participation at a reasonable level and mutual collaboration** with Belgium and other relevant countries.
- The far future plan in **the roadmap should be reviewed in appropriate timing**, taking account of the re-consideration of the nuclear policy and progress of R&D including other type of P&T such as FBR cycle.

Construction schedule (tentative)



Conclusion

- **JAEA has been promoted R&D activities on P&T technology**
  - Accelerator-Driven System (ADS) is a candidate as a dedicated MA transmutation system.
- **Current situation and future plan for R&D of ADS**
  - The technical challenges for ADS spread over wide range and various basic R&D have been implemented in JAEA.
  - New experimental facility, TEF, is proposed in the J-PARC project in JAEA for the engineering feasibility of ADS.
  - International collaboration is important in R&D of ADS.