Target Development at SINQ

presented by

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Spallation Neutron Source Division
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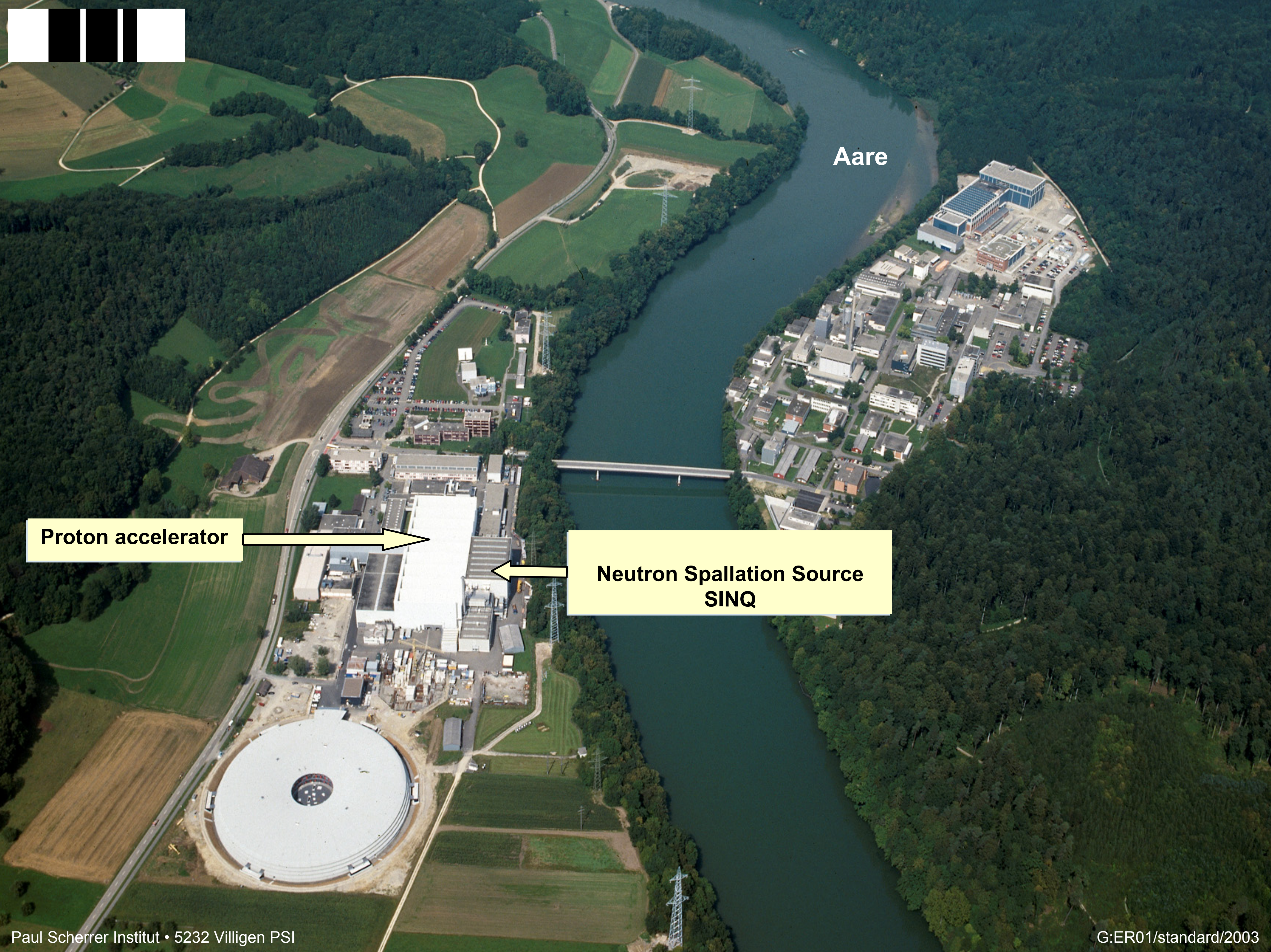
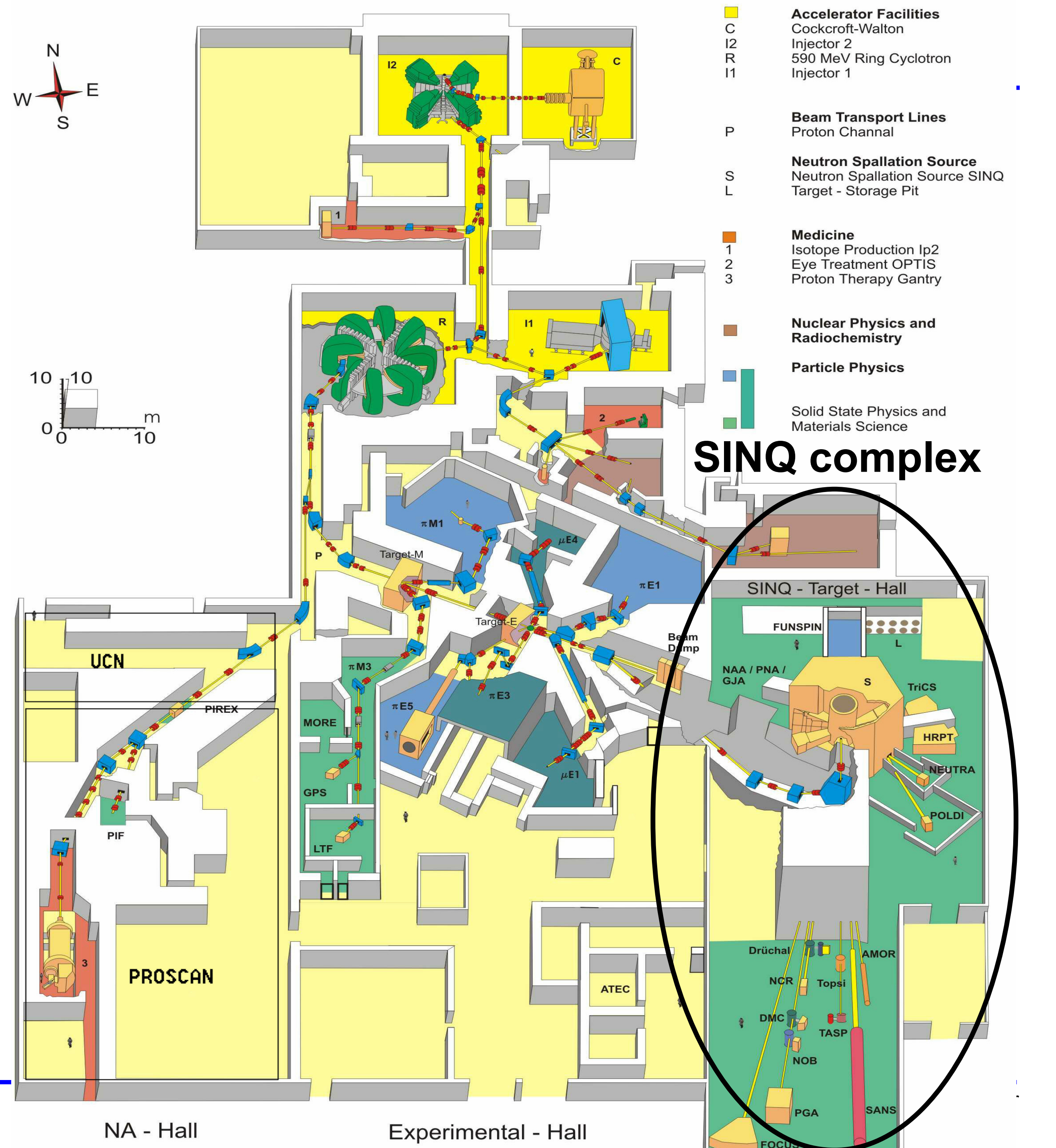

Aare
Proton accelerator
Neutron Spallation Source
SINQ
Paul Scherrer Institut • 5232 Villigen PSI
G:ER01/standard/2003

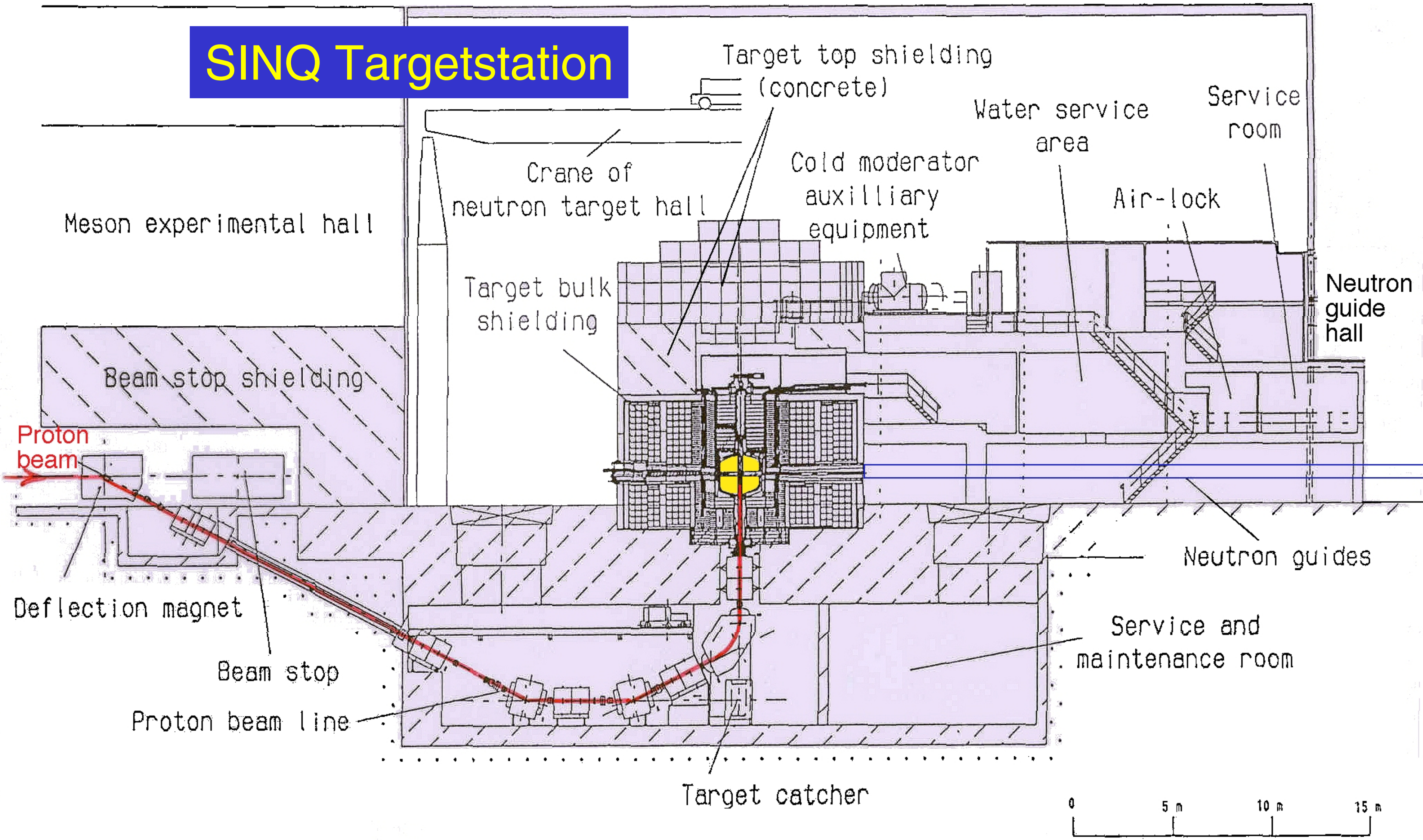
Proton accelerator Facility at PSI

Proton synchrotron
- 590 MeV
- 1.8 mA (routinely)

Serving
- Particle physics
- Muon spectroscopy
- Medicine
- Solid State Physics and Materials Science

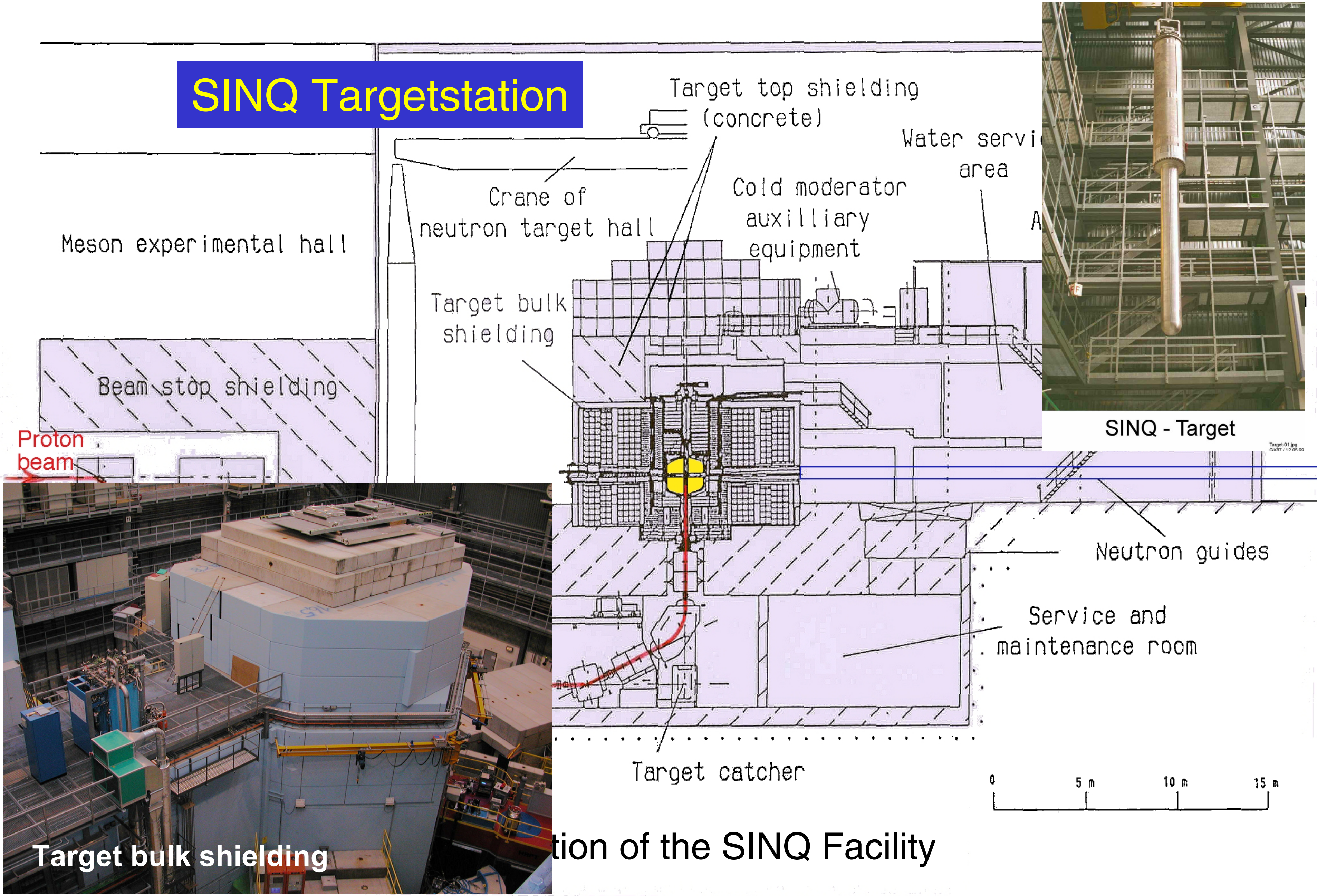


SINQ Targetstation



Vertical Section of the SINQ Facility

SINQ Targetstation

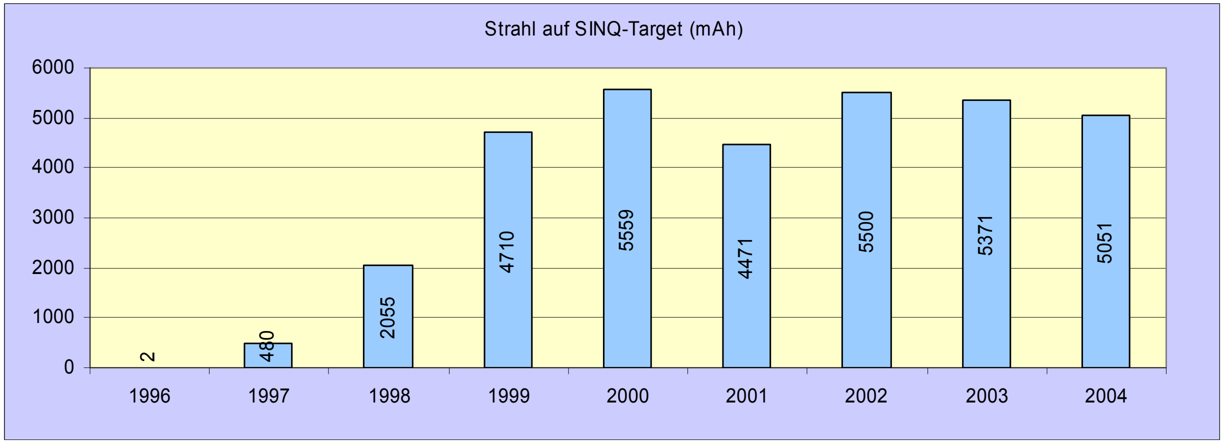


SINQ - Target

Target bulk shielding

tion of the SINQ Facility

Yearly accumulated proton charge on SINQ target (mAh)



What more can we do?

upgrade potentials:

➢ **Proton Accelerator beam power:** **gain factor**

• today	**590 MeV x 1800 μA = 1.06 MW**	**1** (ref.)
• ~2008	**590 MeV x 2600 μA = 1.53 MW**	**1.44**
• ~2010 (??)	**590 MeV x 3000 μA = 1.77 MW**	**1.67**

➢ **Reliability/availability: Accelerator ~90% SINQ 99%: No margin!**

➢ **Target development**

SINQ target development

from visions to achievements

PAUL SCHERRER INSTITUT

1990:
Vision or Fiction?

SINQ target concept
Proposal 1990:
Liquid Metal Target
on the basis of LBE
(lead-bismuth-eutectic)

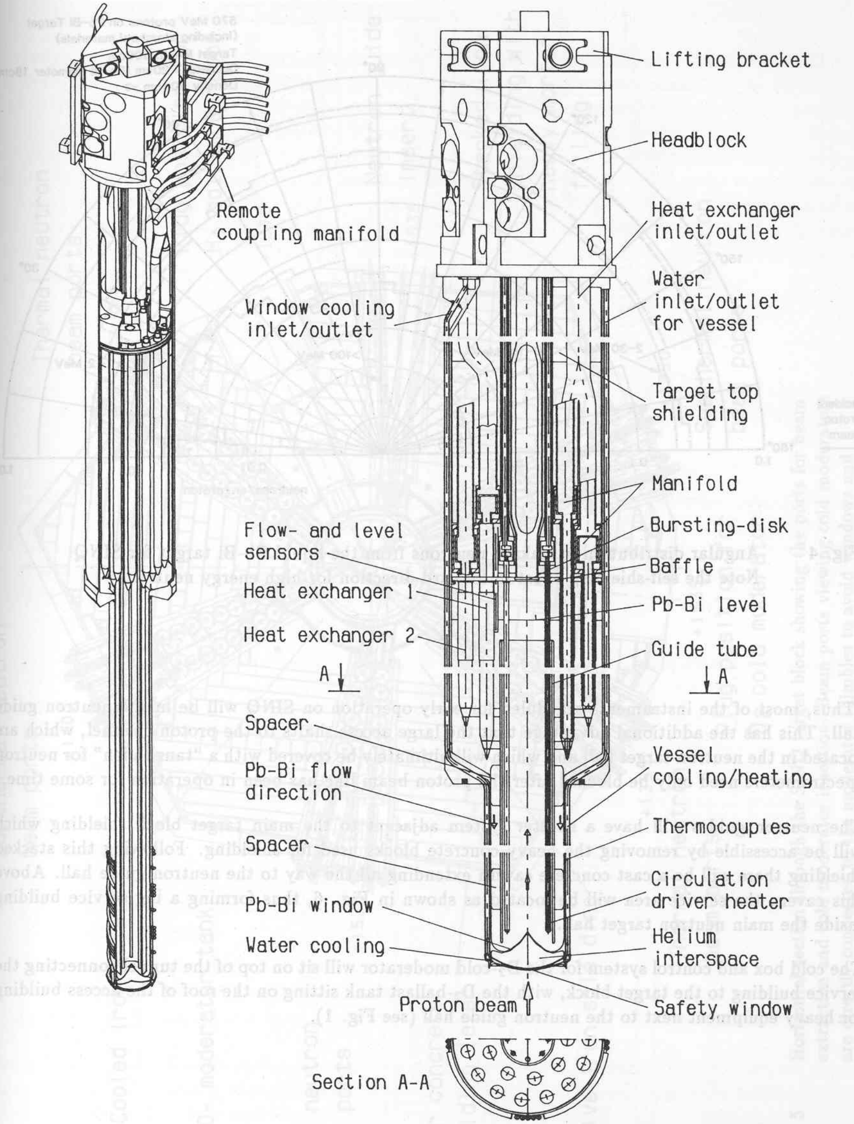


Fig. 3 Vertical section (right) and cut away view (left) of the liquid Pb-Bi target for SINQ. All connections to the target are made via four connector plates at the target head.

45

From: G. Bauer et al., in
Proc. ICANS-XI (1990)
Internatl. Collaboration on
Advanced Neutron Sources

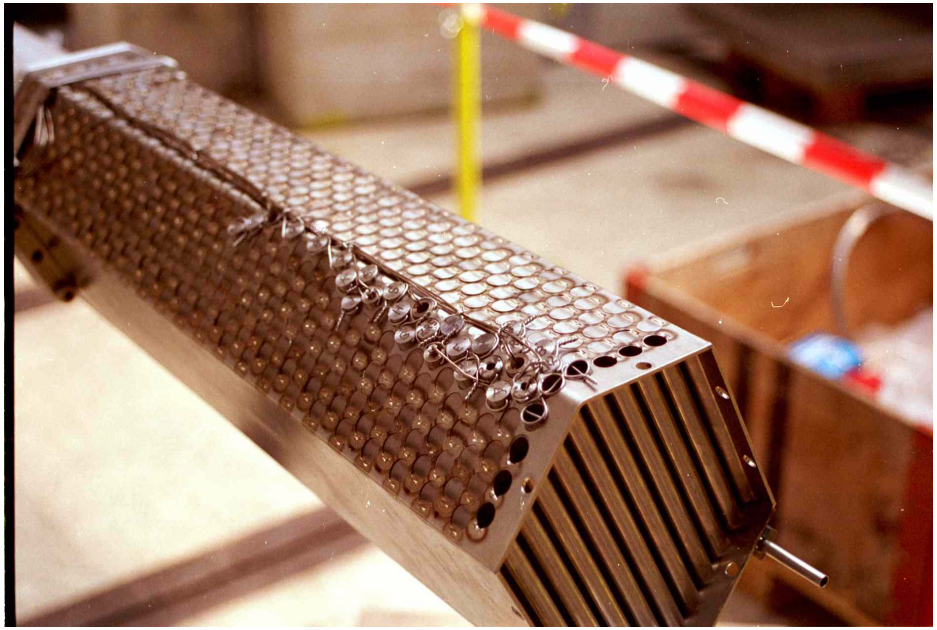
SINQ target development

~~from visions to~~ achievements

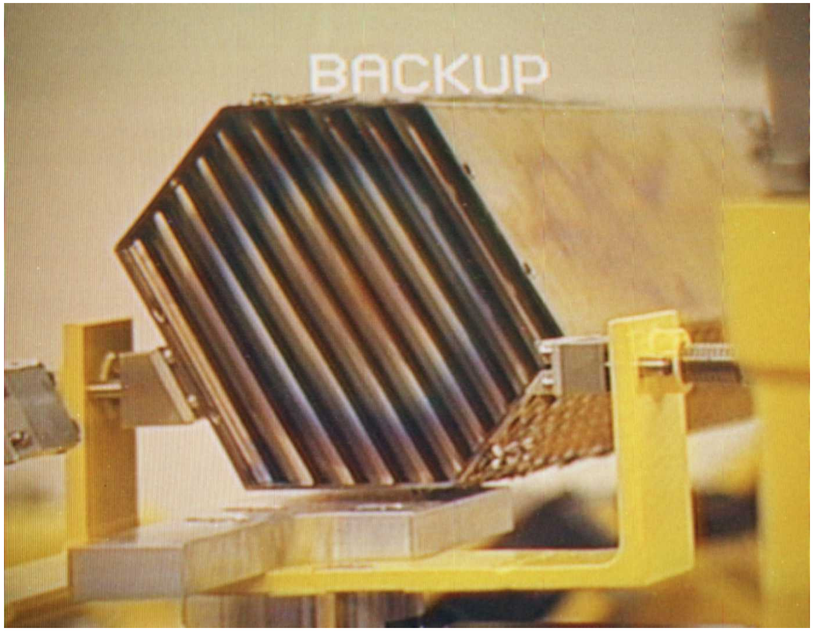
The SINQ Target Mark 2: <u>Solid target with Zircaloy rods</u>

equipped with thermocouples and test specimen rods

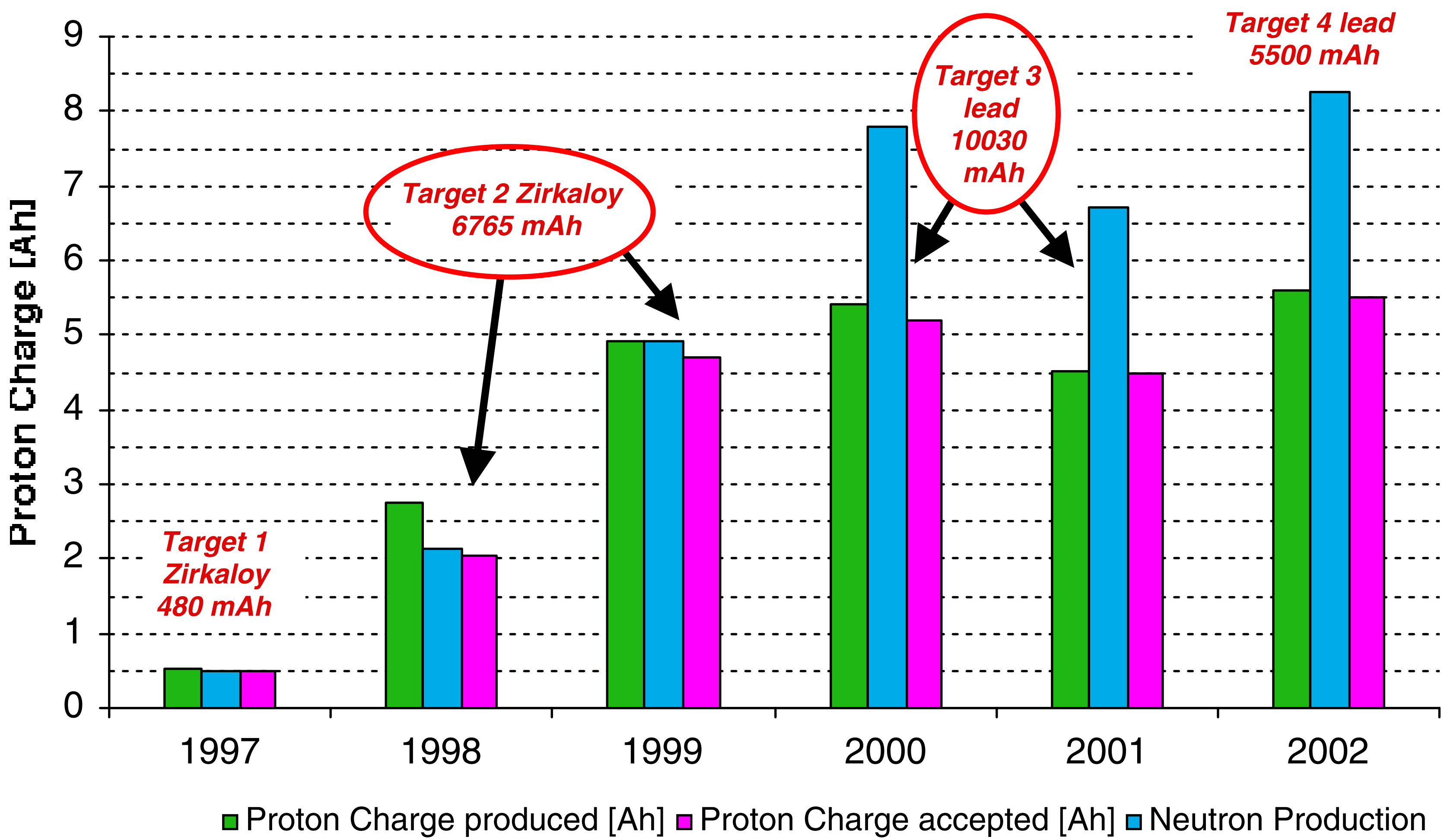
as manufactured



after 2 years of service
(6800 mAh of 570 MeV protons)

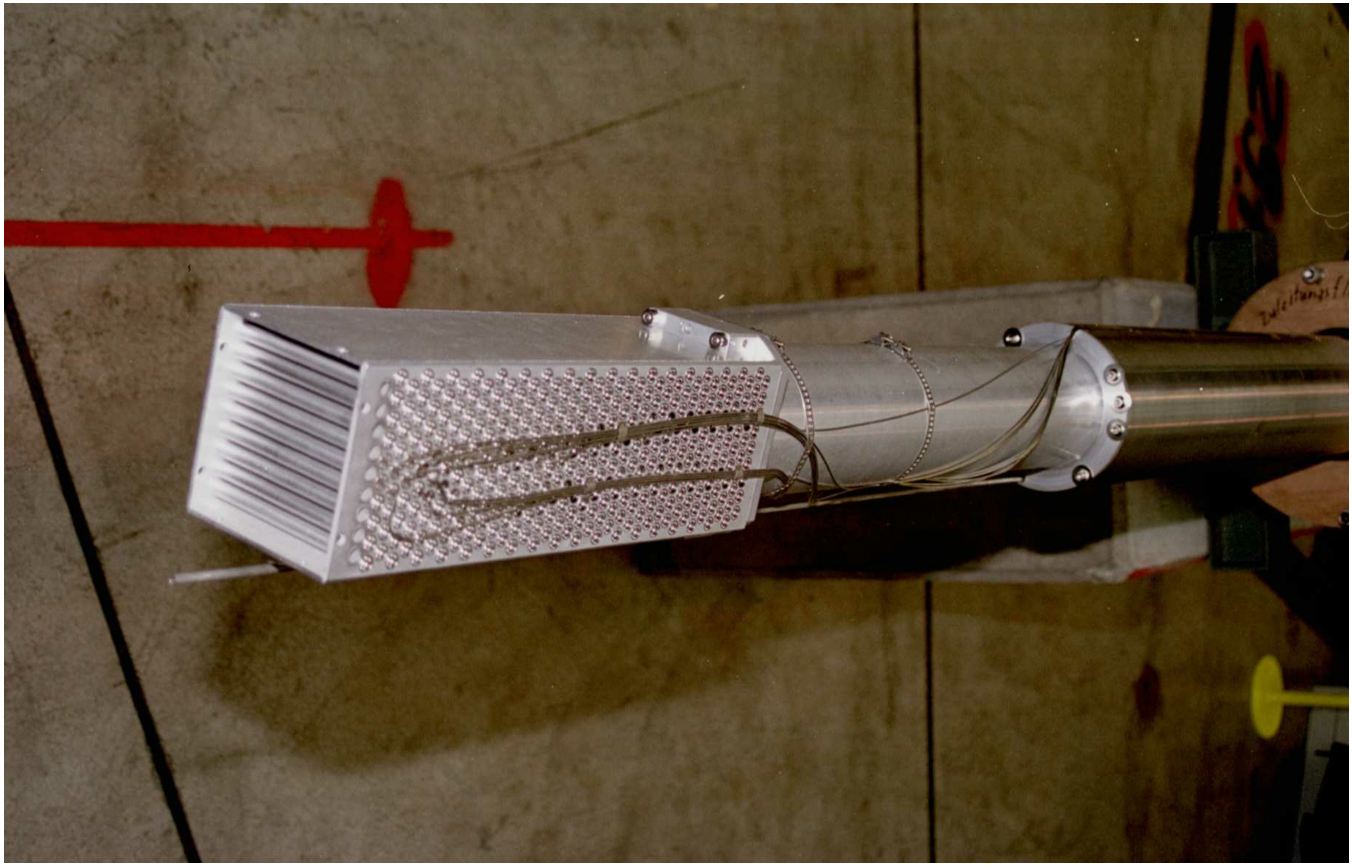


Yearly Production Data of SINQ



SINQ-Target Mark 3:

⇨ **Solid target: Lead clad in steel tubes**



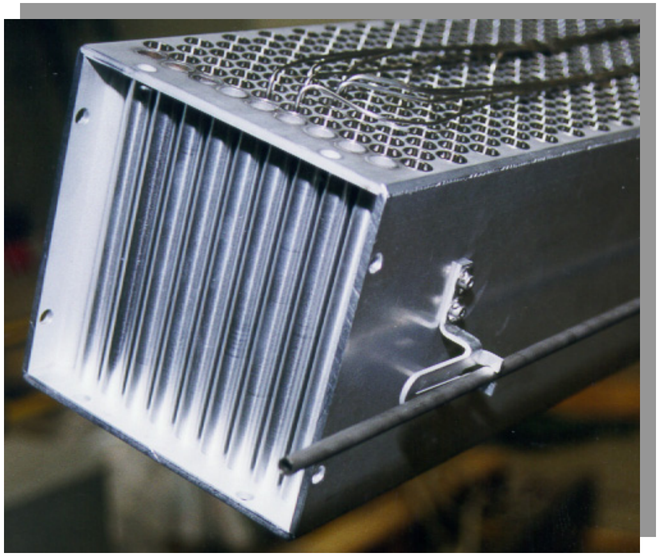
SINQ-Target Mark 4:

⇨ **Solid target: Lead clad in steel tubes, partly clad in Zircaloy**

ZrPb-Canneloni

in service since end of April 2004

Target development



SINQ-Target Mark 3, view from beam entrance

General goal: highest neutron yield

- solid targets:

rel. yield factor

  - Solid Zircaloy rods: first target — 1 (ref.)
  - Steel-clad Lead: present target → 1.42
  - Zircaloy-clad Lead: in test phase — calc. 1.7 – 1.8
  - Steel-clad U-10Mo: option not persued — calc. 2.0 – 2.1

- liquid metal target:

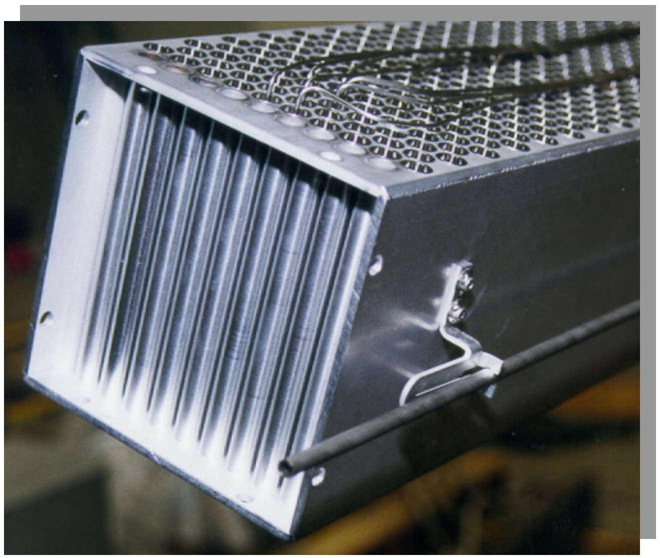
Lead-Bismuth-Eutectic (MEGAPIE experiment) — calc. 1.9 – 2.1

SINQ target development

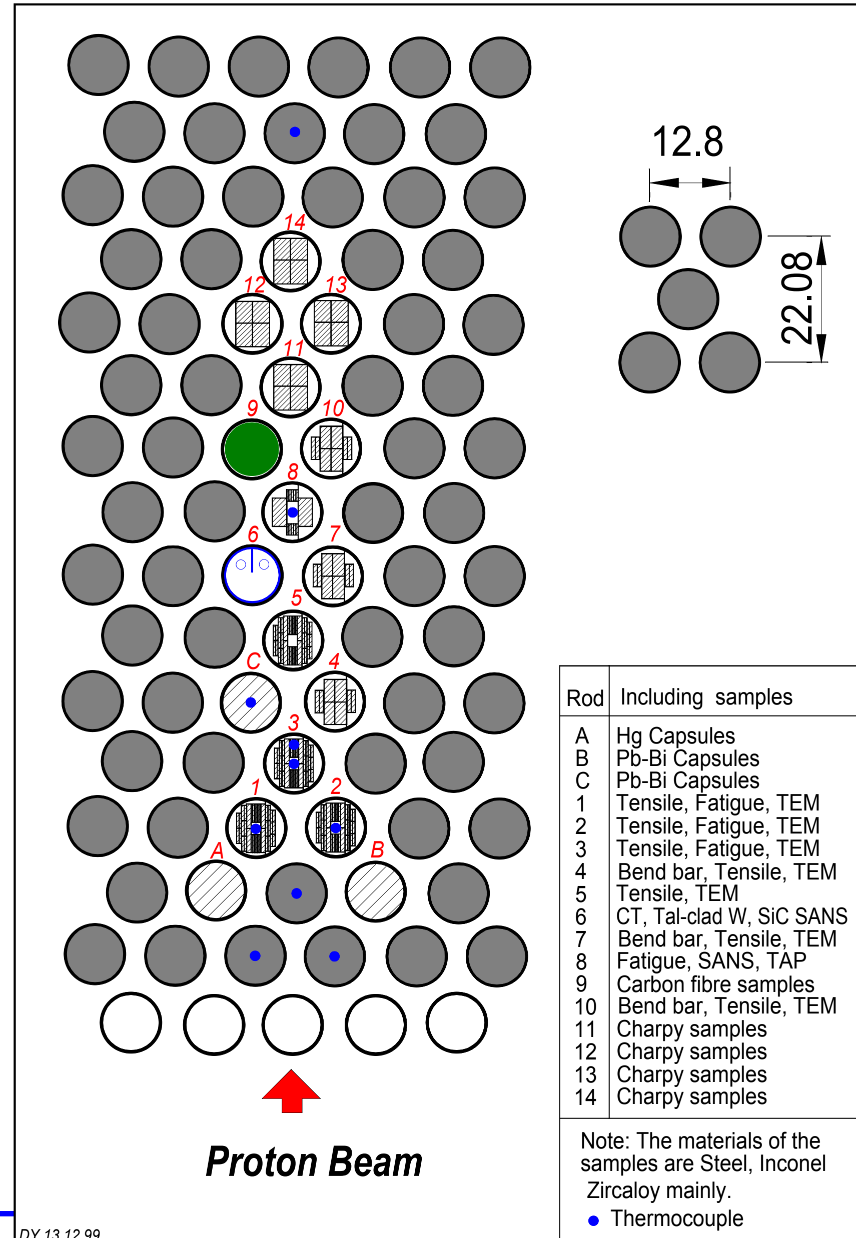
materials irradiation and test program

STIP *) :

SINQ Target Irradiation Program



SINQ-Target Mark 3



Rod	Including samples
A	Hg Capsules
B	Pb-Bi Capsules
C	Pb-Bi Capsules
1	Tensile, Fatigue, TEM
2	Tensile, Fatigue, TEM
3	Tensile, Fatigue, TEM
4	Bend bar, Tensile, TEM
5	Tensile, TEM
6	CT, Tal-clad W, SiC SANS
7	Bend bar, Tensile, TEM
8	Fatigue, SANS, TAP
9	Carbon fibre samples
10	Bend bar, Tensile, TEM
11	Charpy samples
12	Charpy samples
13	Charpy samples
14	Charpy samples

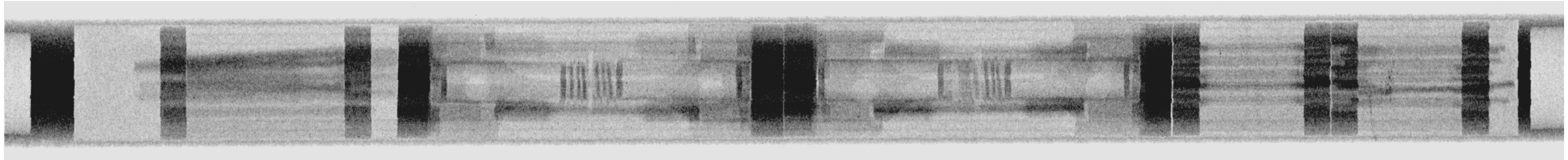
Note: The materials of the samples are Steel, Inconel Zircaloy mainly.

● Thermocouple

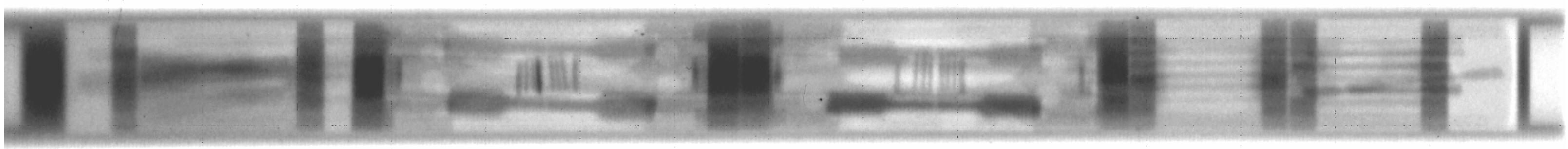
*) presentation by **Yong Dai**
Wednesday 10:30 a.m.

STIP-II PbBi Rod

Before irradiation



After irradiation (max dose: 20 dpa)

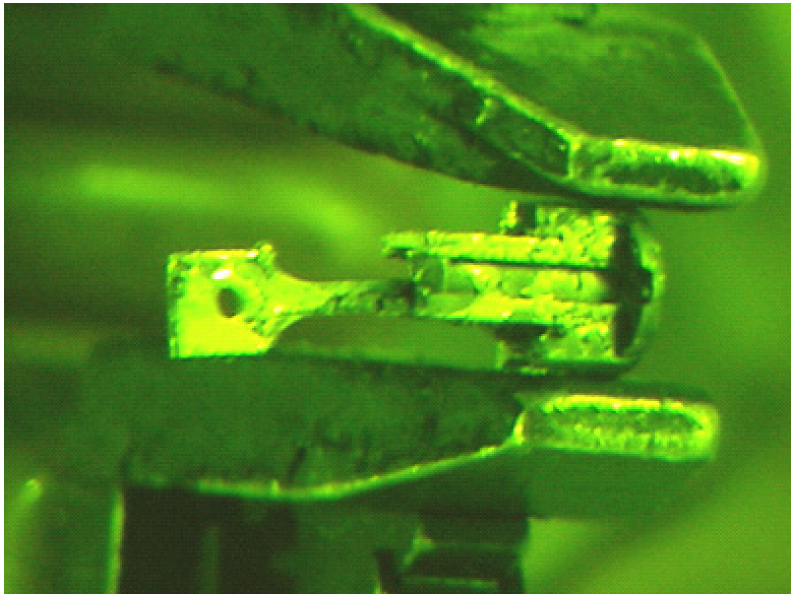


Target Rod B:
It contains a PbBi (about 38 g) filled T91 capsule. Inside PbBi there are about 50 test samples for studying irradiation assisted corrosion effects of PbBi on different kinds of materials.

Approaching a lifetime assessment for the MEGAPIE target window:

Extensive materials studies within STIP: the SINQ Target Irradiation Program

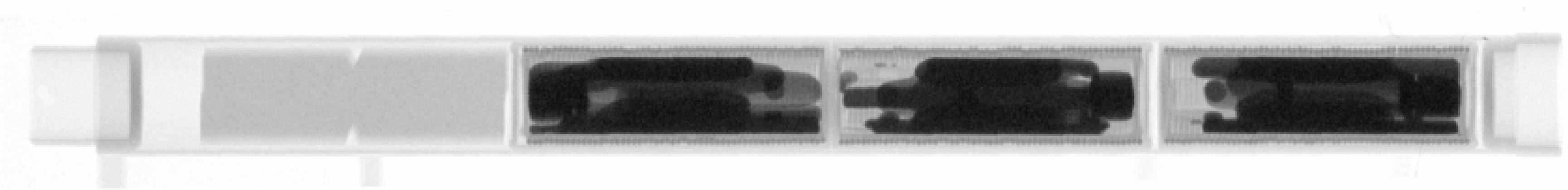
A martensitic steel T91 (9Cr2WTaV) tensile specimen irradiated in liquid Lead-Bismuth-Eutectic



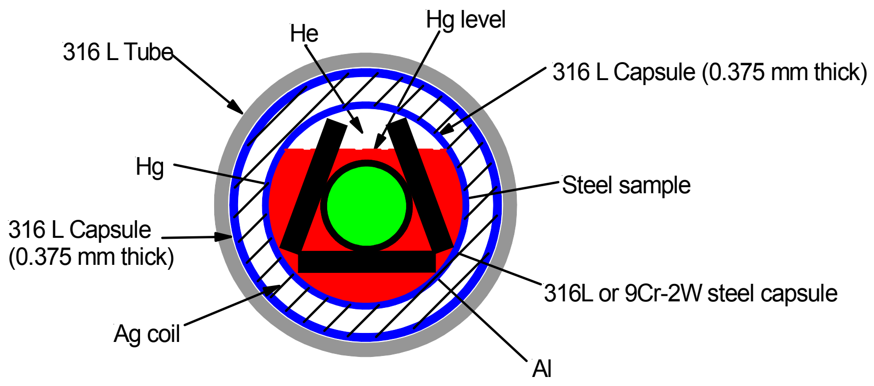
After 12 dpa (2 years of irradiation) at 210 to 250°C:
NO severe LBE corrosion and embrittlement effects

STIP-II Hg Rod

Before irradiation



After irradiation (max dose: 20 dpa)



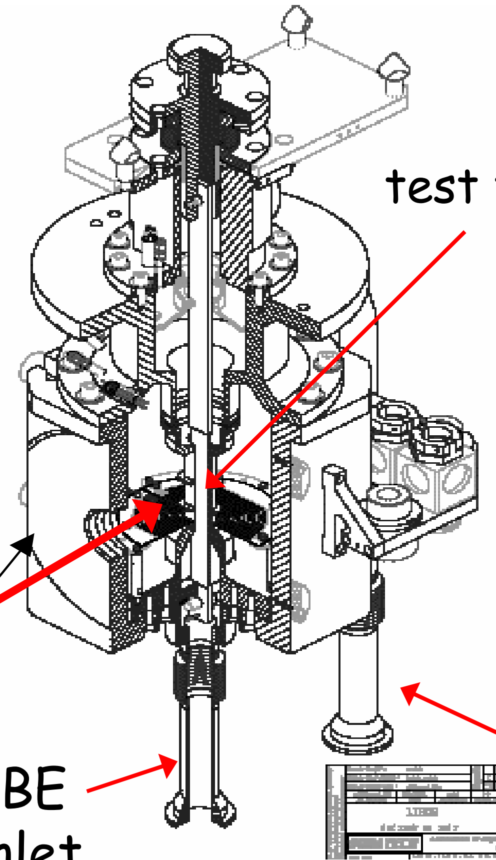
Target Rod A:
It contains three Hg (about 19 g in total) filled capsules and one steel sample package. There is about 25% free space in each Hg filled capsule.

LiSoR: Liquid Solid Reaction

LiSoR Test-section:
designed: Subatech, France

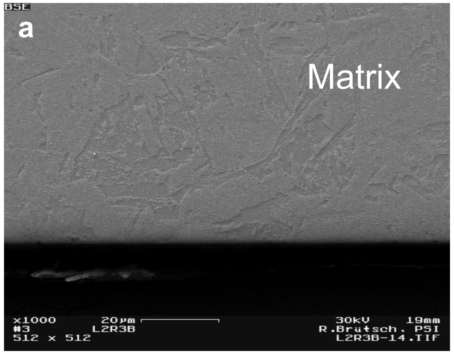
Investigation of T91 steel under

- Irradiation (72 MeV protons)
- flowing LBE
- mechanical stress

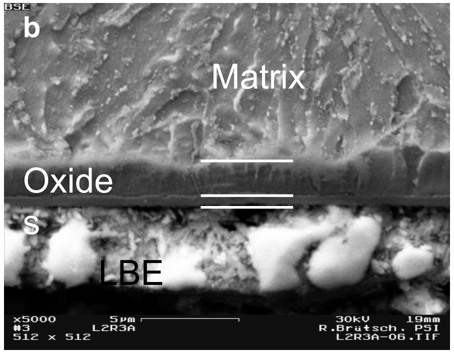


LiSoR samples (cross sections):

outside

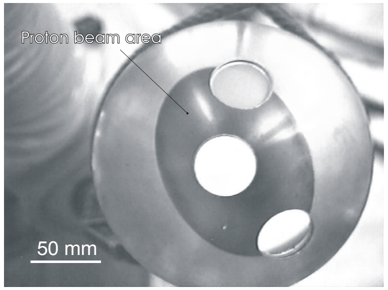


inside of beam spot

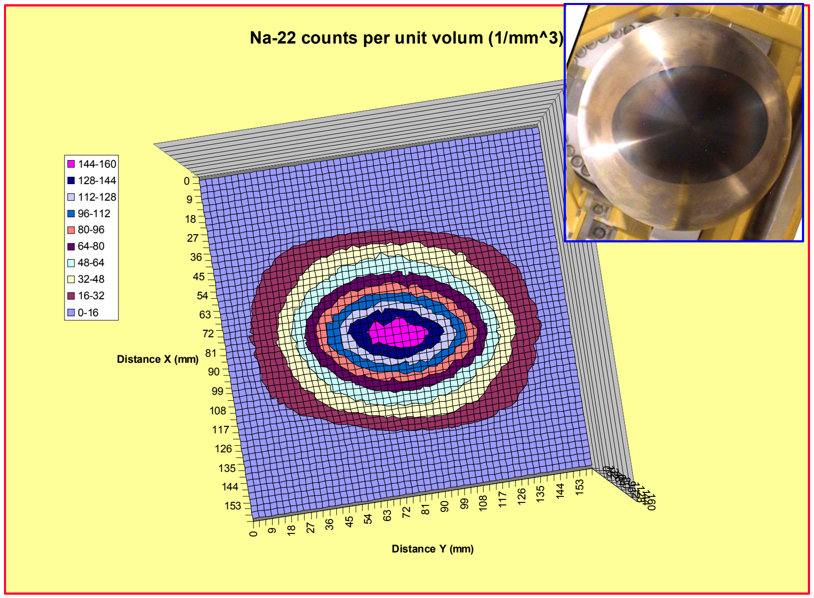


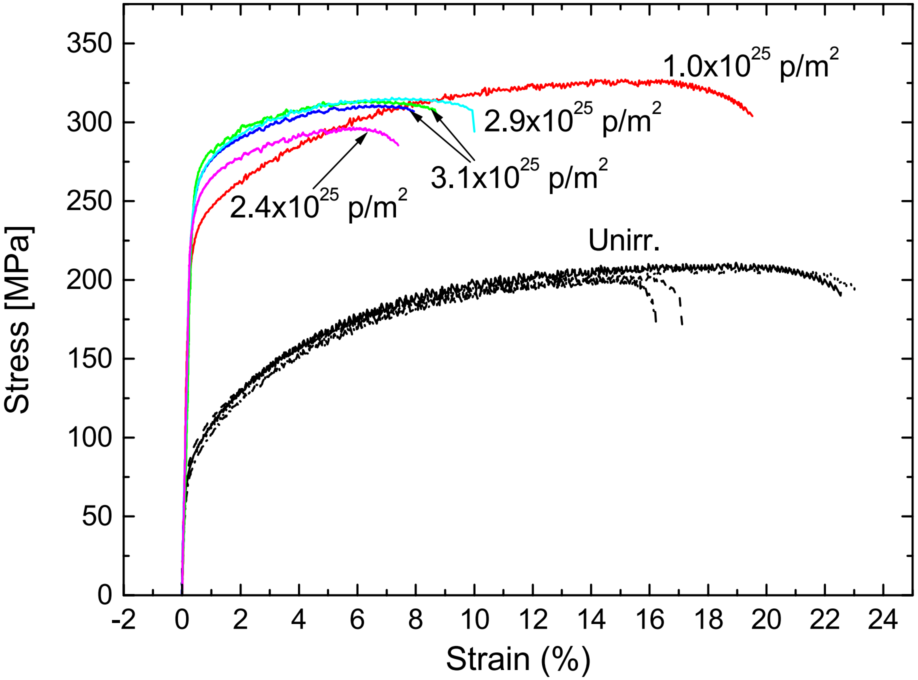
SINQ Target Safety Hull:

Tensile tests after one year of irradiation



γ-mapping of the beam footprint





SINQ target development

the future

MEGAPIE
A liquid metal target for SINQ

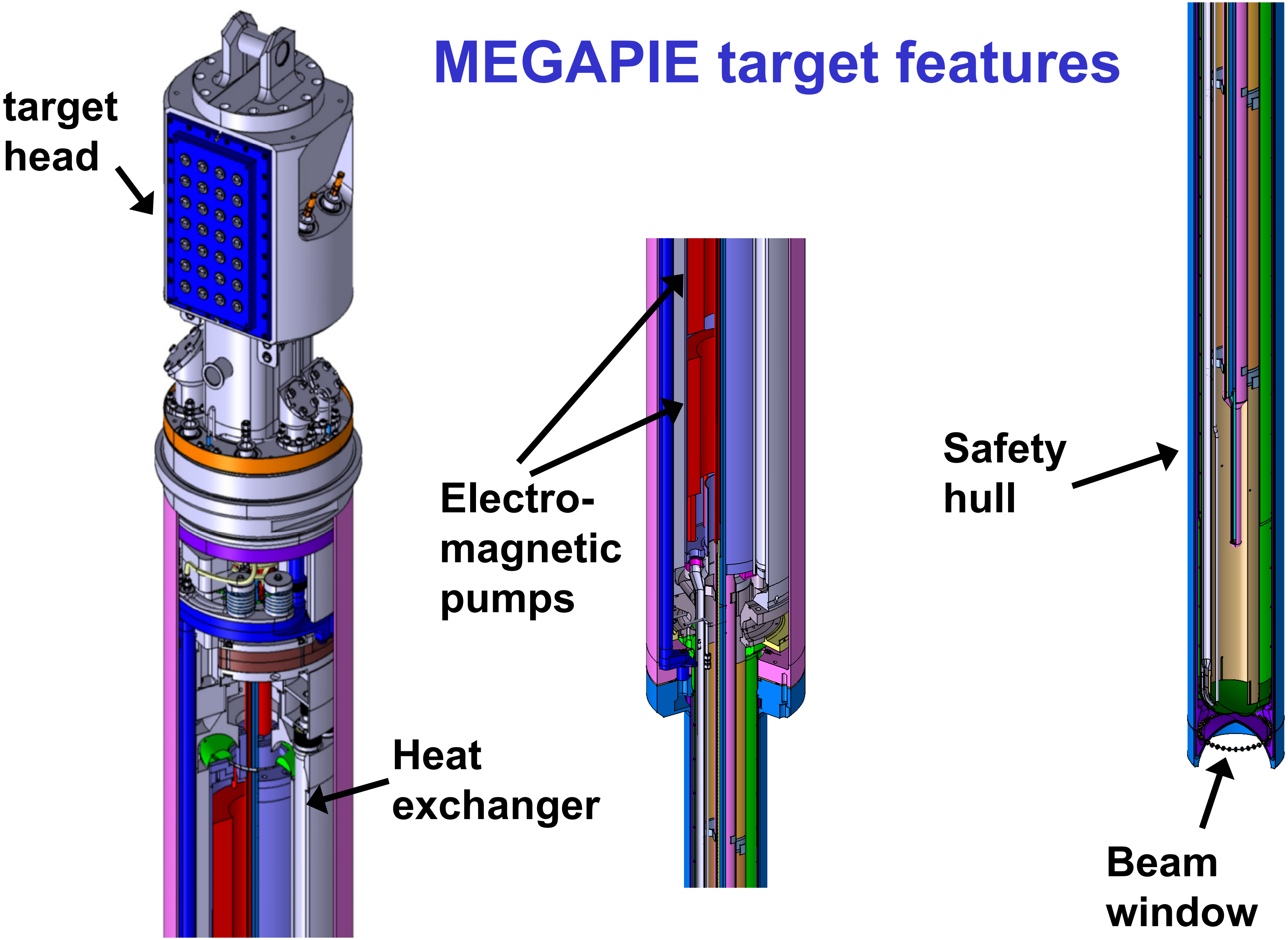
MEGAwatt Pilot Experiment:

- Joint international initiative to design, built, operate and explore a liquid metal spallation target on the basis of Lead-Bismuth-Eutectic (LBE) for 1 MW beam power

Goals of MEGAPIE:

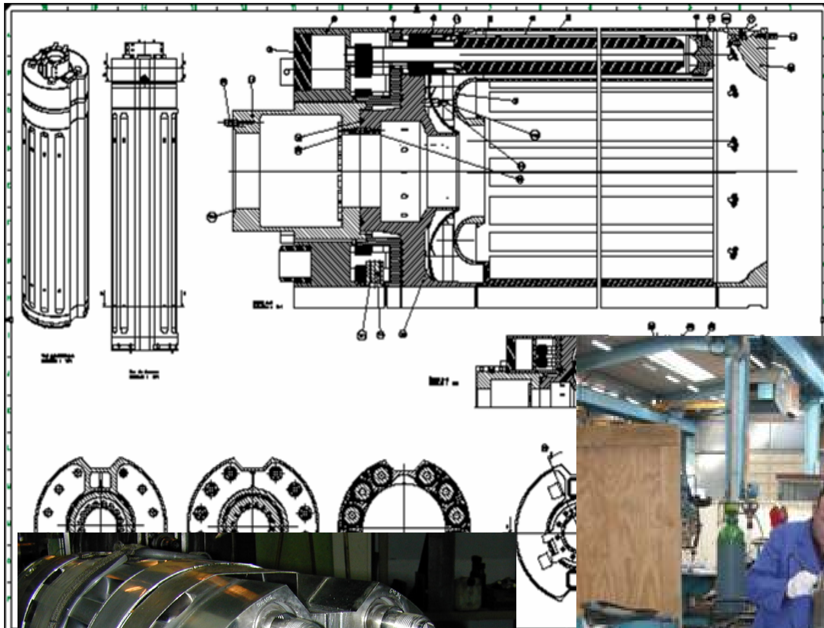
- Increase the neutron flux at SINQ
- Demonstrate the feasibility of a liquid metal target for high-power ADS applications

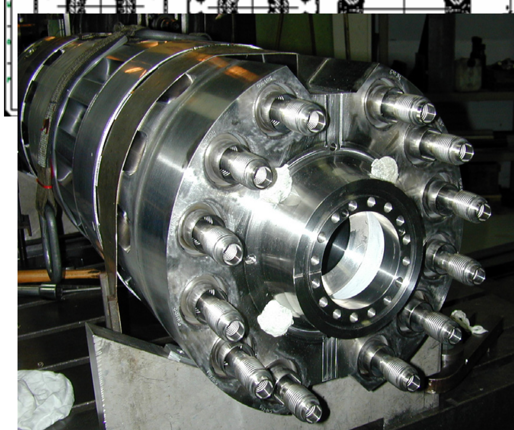
MEGAPIE target features



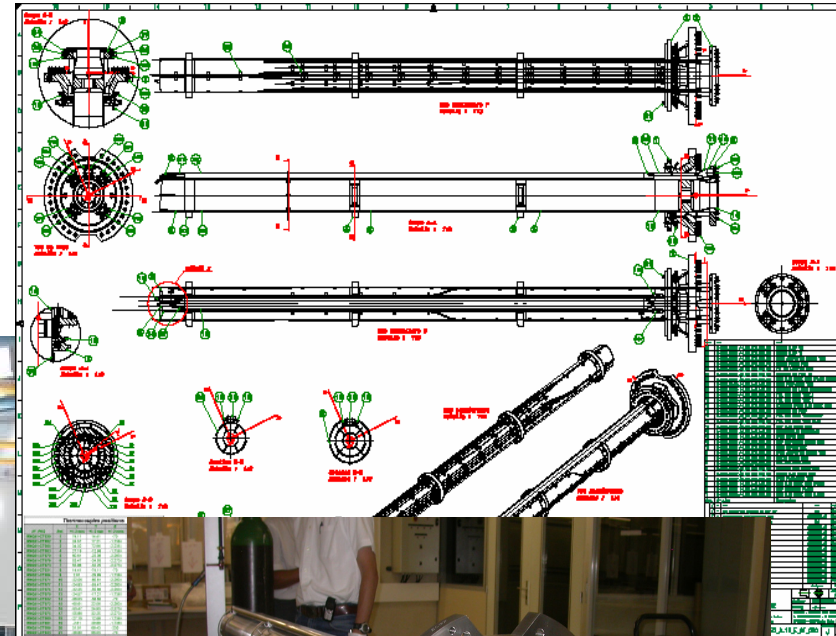
Manufacturing the MEGAPIE target

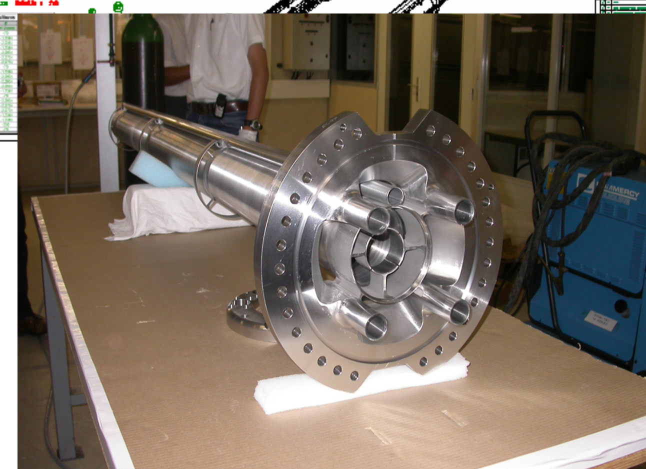
Heat Exchanger





Flow guide Tube

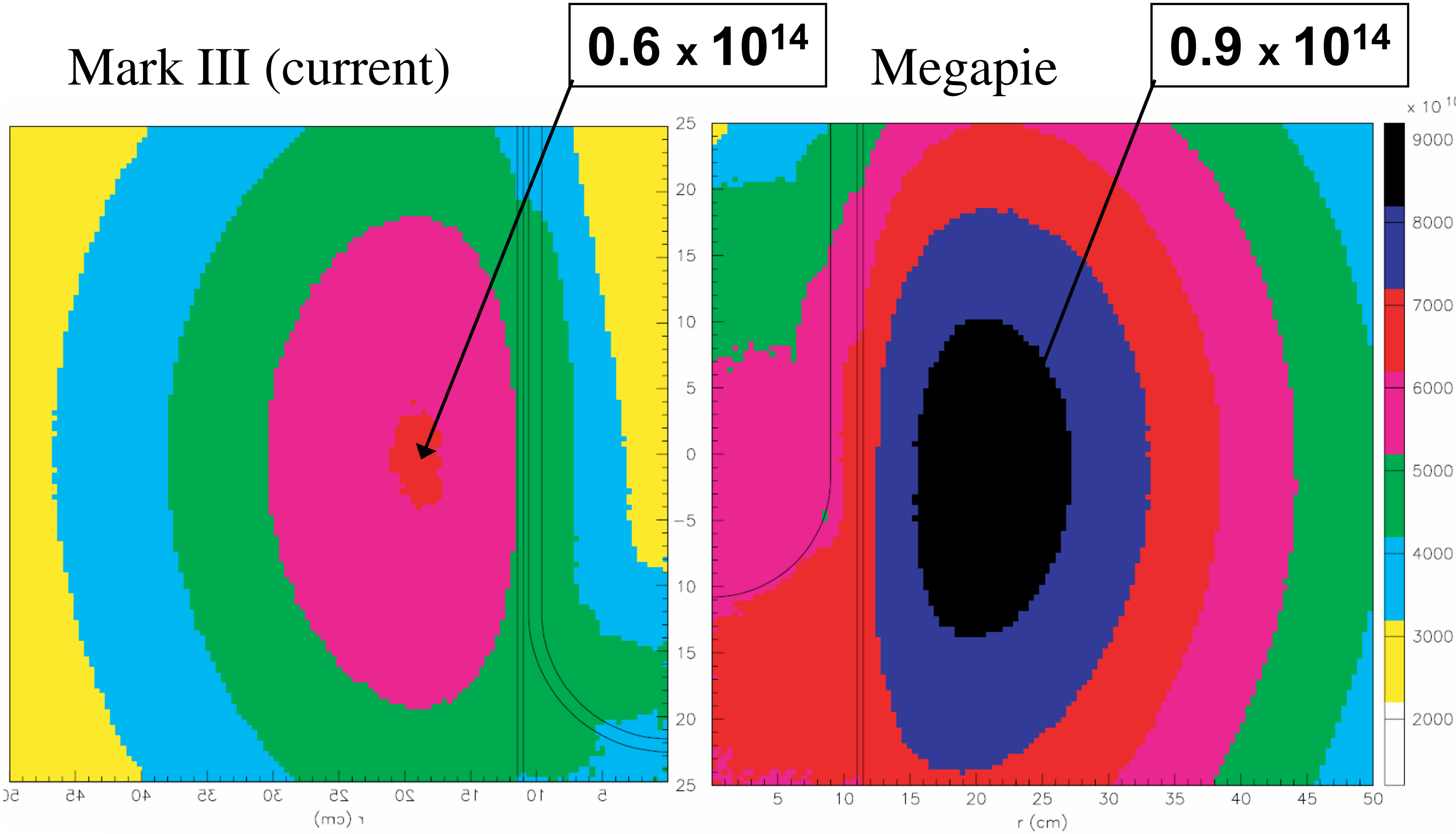




Megapie target reception at PSI (July 2005)

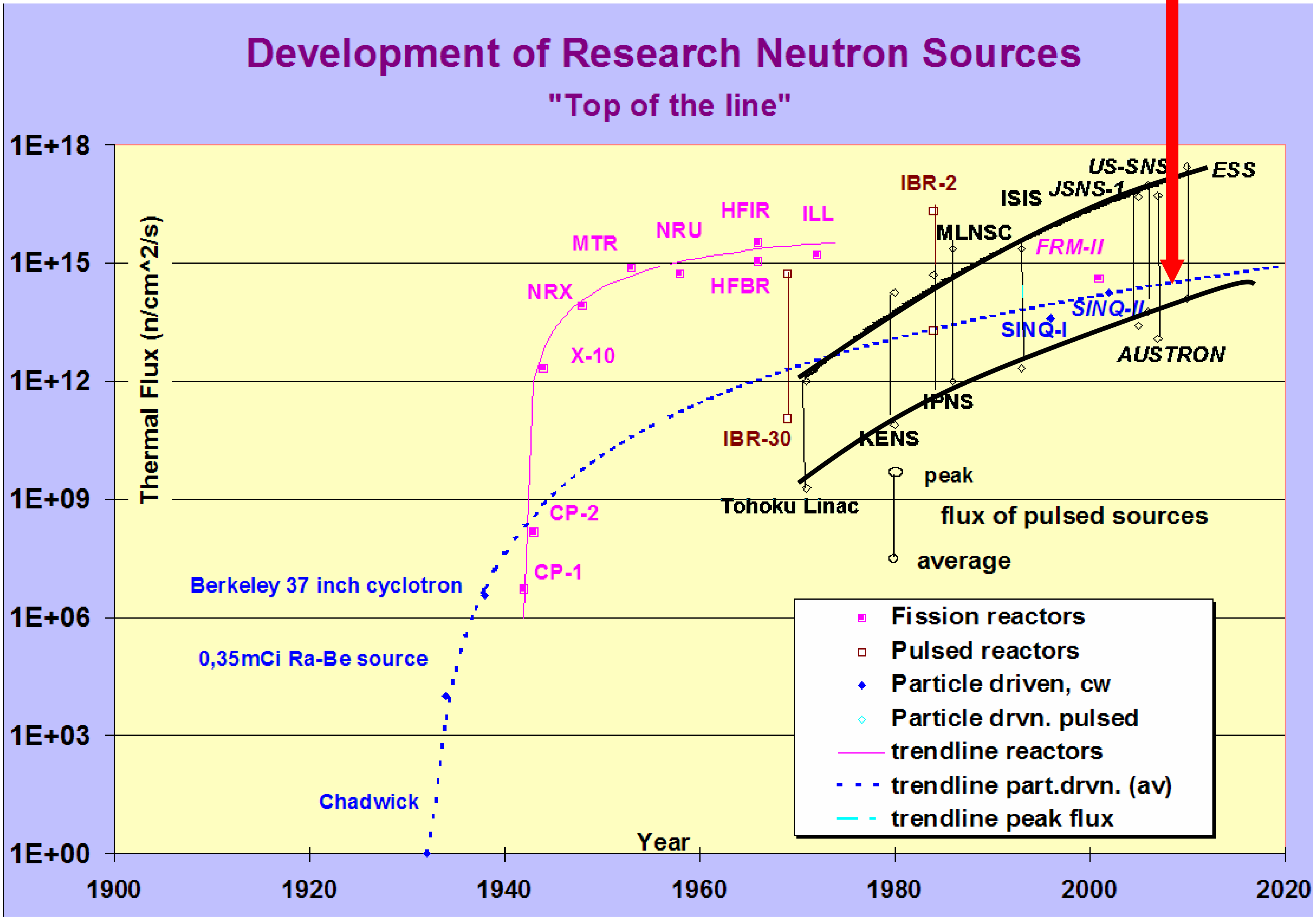
For details on MEGAPIE see:
Presentation from
Friedrich Groeschel, today, 2:30 p.m.

Thermal neutron flux



Thermal (E < 0.625 eV) neutron flux maps (neutrons/cm^2/s/mA)

Next step for SINQ along the development curve



Target design – irradiation positions

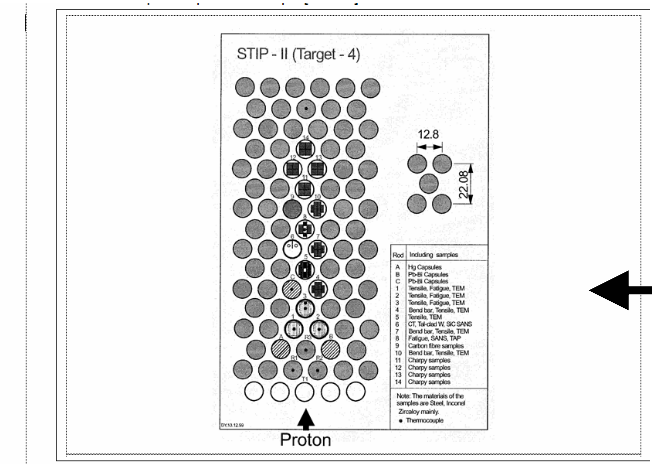
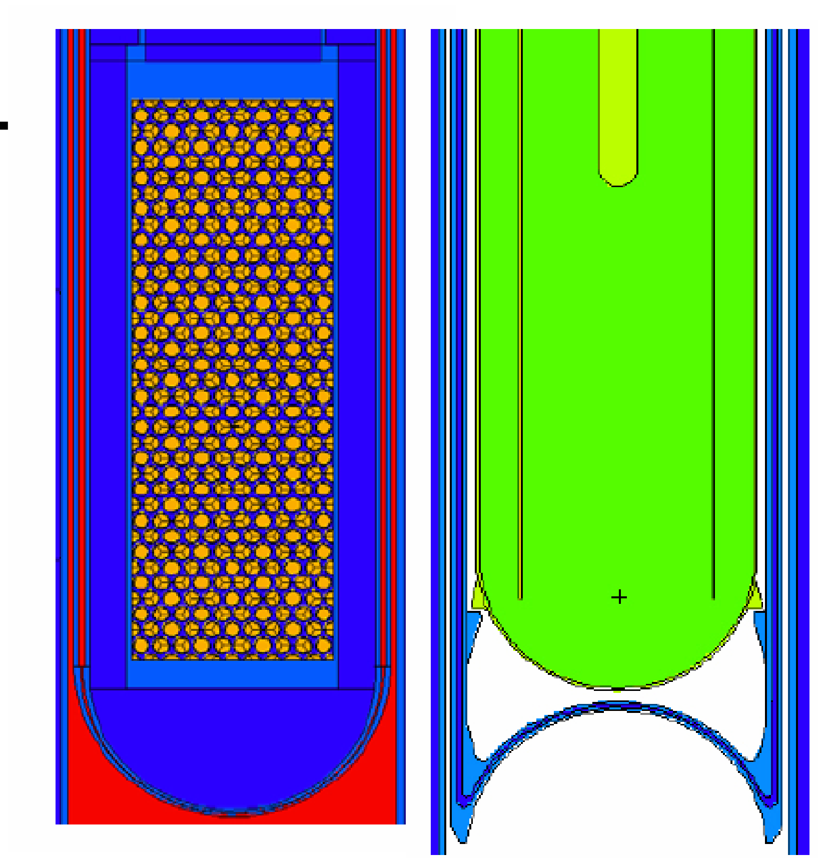
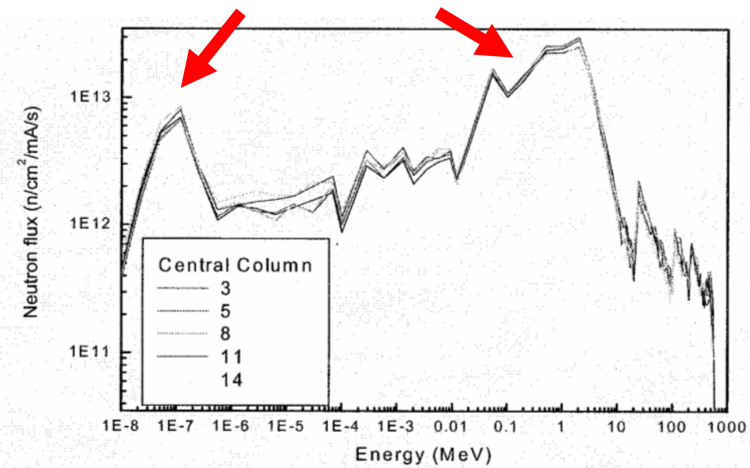


Figure 10: Irradiation positions in SINQ-target tubes.

Mark III (current) Megapie

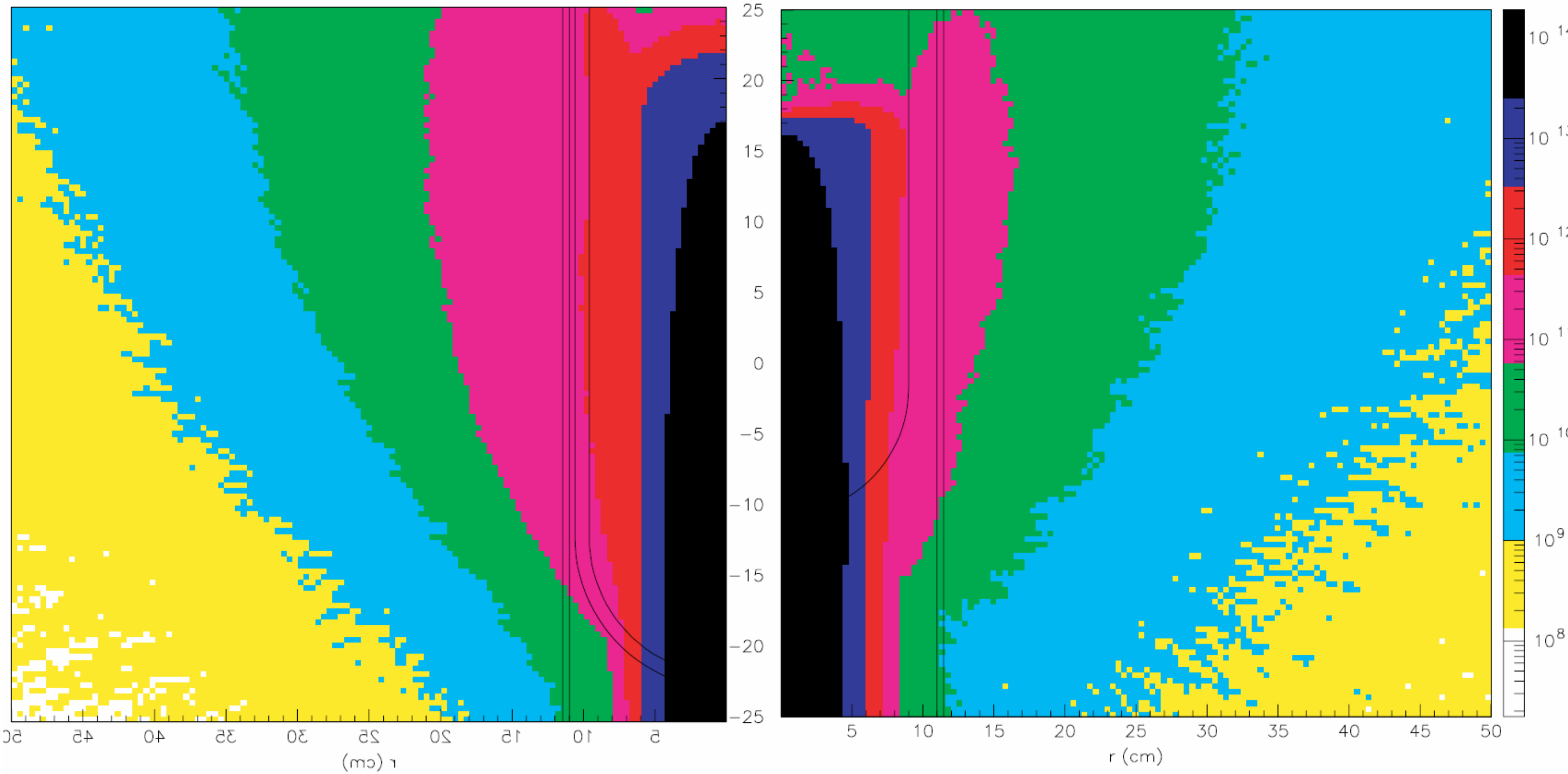


Neutron flux peaks



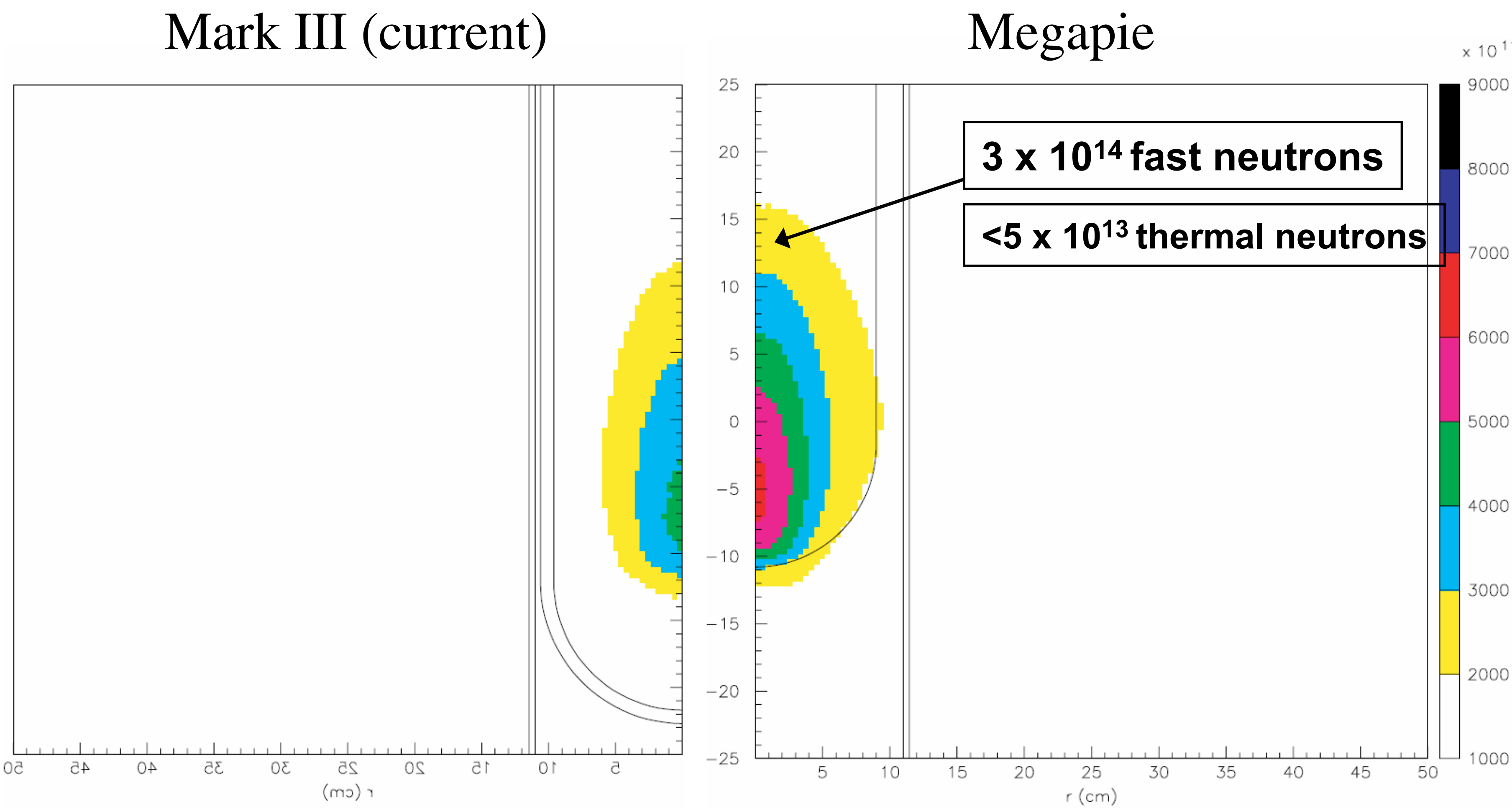
proton flux

Mark III (current) | Megapie



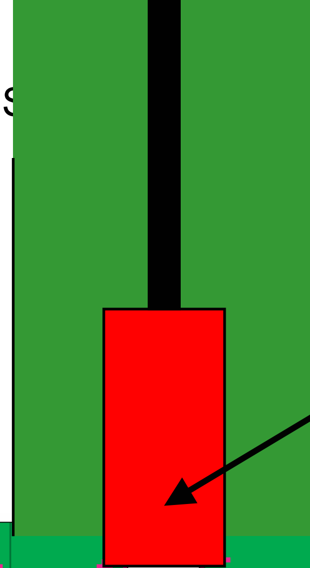
Proton flux maps (protons/cm^2/s/mA)

total neutron flux



Total neutron flux maps (neutrons/cm^2/s/mA)

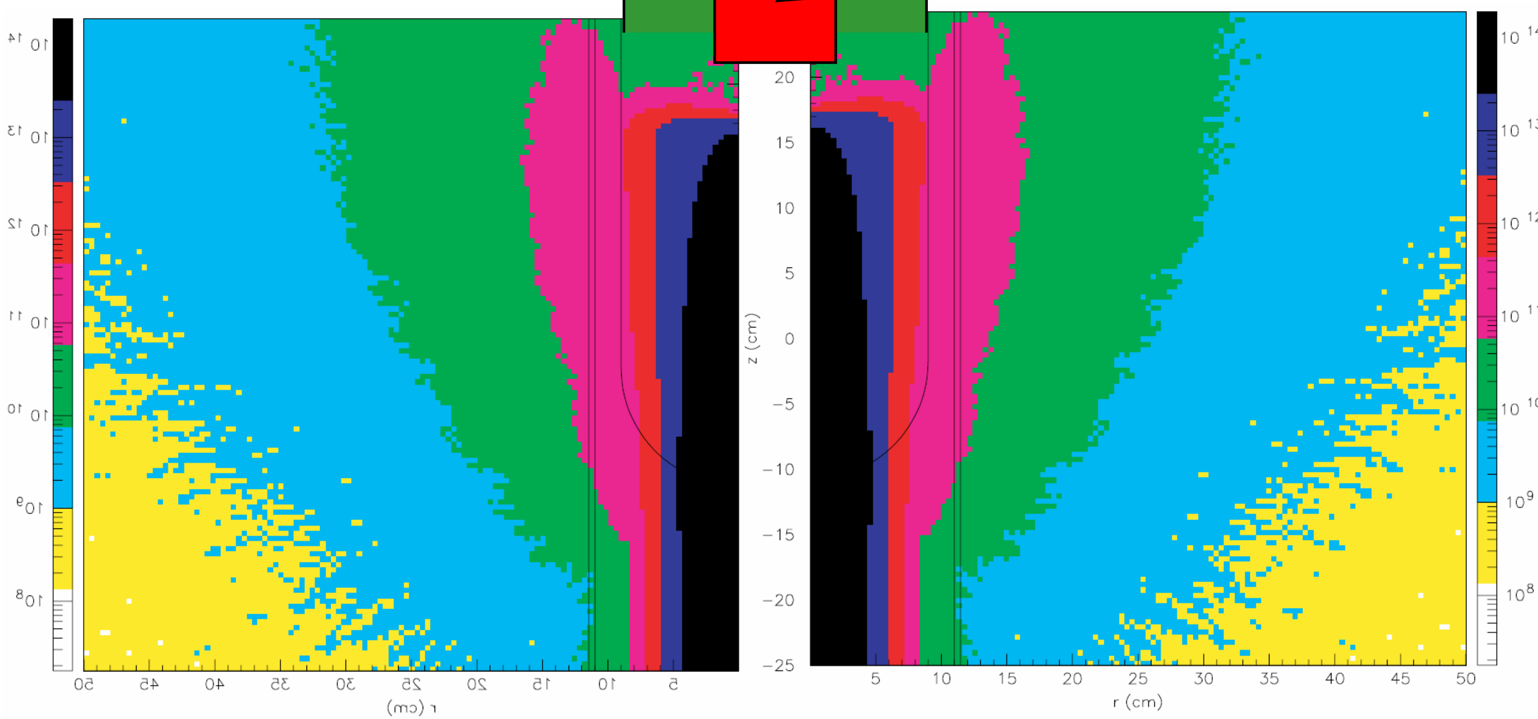
proton flux LBE target



Irradiation position:
high flux of fast neutrons

3 x 10^{14} fast neutrons/cm^2/s

< 5 x 10^{13} thermal neutrons/cm^2/s



Proton flux maps (protons/cm^2/s/mA)

SUMMARY

- **Proton accelerator:**
  - at present: highest CW beam power worldwide
  - upgrade program from now 1MW to 1.6 MW to be launched

- **Target development:**
  - from visions (early LBE target concept)
  - via achievments: solid target on the basis of Zircaloy and steel- or Zircaloy-clad Lead
  - to the future: from LBE target (MEGAPIE) to a liquid metal target with dedicated (fast neutrons) materials irradiation insert
  - This would clearly be a unique possibility to test new materials for fission, fusion and spallation in realistic irradiation fields in SINQ

Aknowledgement

- **Hajo Heyck** and the operational team
- **Yong Dai** and the materials team
- **Friedrich Groeschel** and the MEGAPIE team