Development of compound neutron moderator structures for small accelerator based neutron sources.

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Necsa

P-LABS

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Motivation

Expected continued lifetime ± 10 years

→ SAFARI-2

- with a cold source!

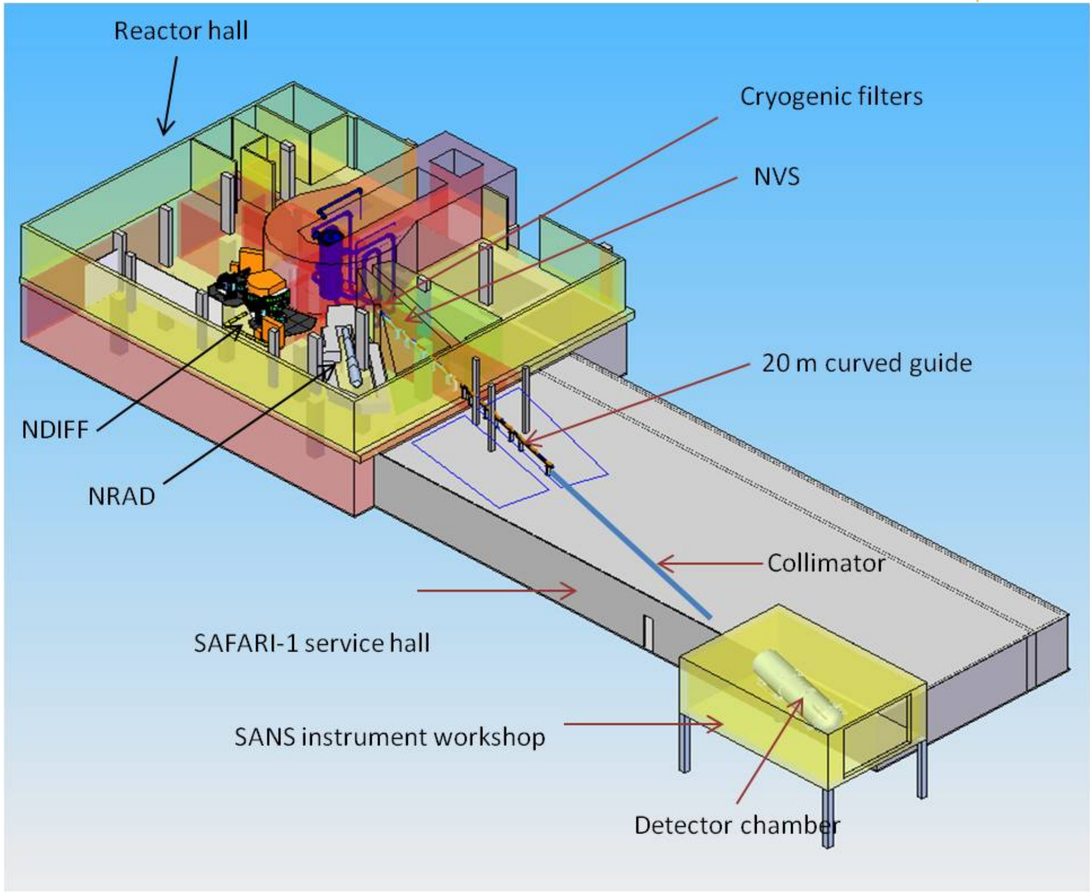
Motivation

Recently refurbished state-of-the-art NDIFF facility for residual stress and powder diffraction studies

In process of refurbishing NRAD radiography/tomography beam line

Currently attempting to re-establish a SANS facility, without a cold source on a radial beam port.

Schematic of SAFARI-1 beam lines



Aim

Long delays experienced – consider an alternative cold neutron source, accelerator based

Lack experience with cold source systems

<u>Solution:</u>

In interim, utilize in-house small, high current, accelerator based system to:

- generate an intense source of “fast” neutrons.
- Design a moderator configuration to optimally thermalize the neutrons.
- Enhance preferred direction of sub-thermal neutrons

In the process, have to be innovative whilst in an “economic” squeeze.

Accelerator

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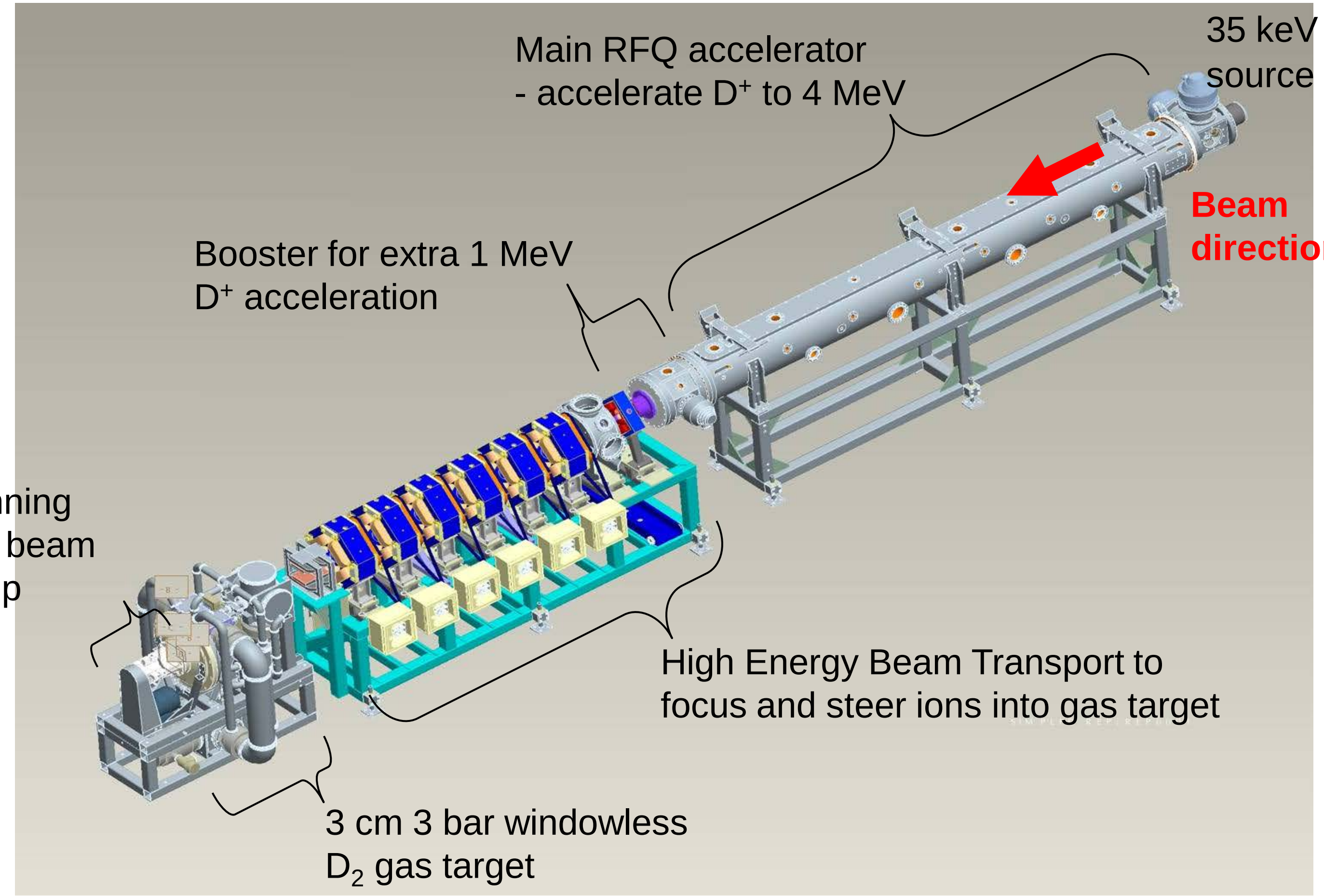
Accelerator to use?

- 3.8 MV Van de Graaff, ~400 μA DC (H^+, D^+) beam
- RFQ linac system, ~30 mA peak, 100 Hz, 0.1 - 2 ms pulse length
  - 4 / 4.75 MeV D^+
  - 2 / 2.37 MeV H^+

Facility dedicated to producing dual energy fast neutrons using d-d reaction

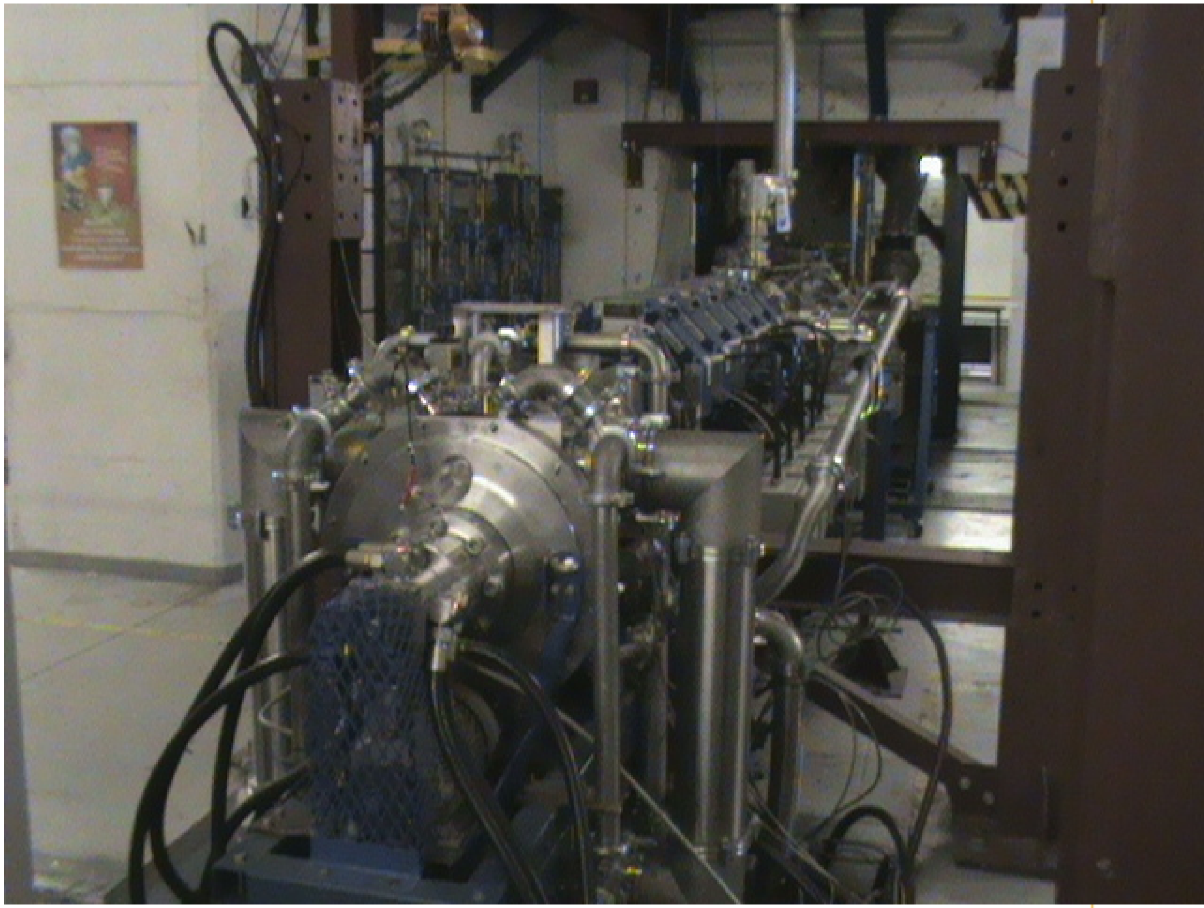
Accelerator



For H^+
2 / 2.4 MeV

The RFQ accelerator facility

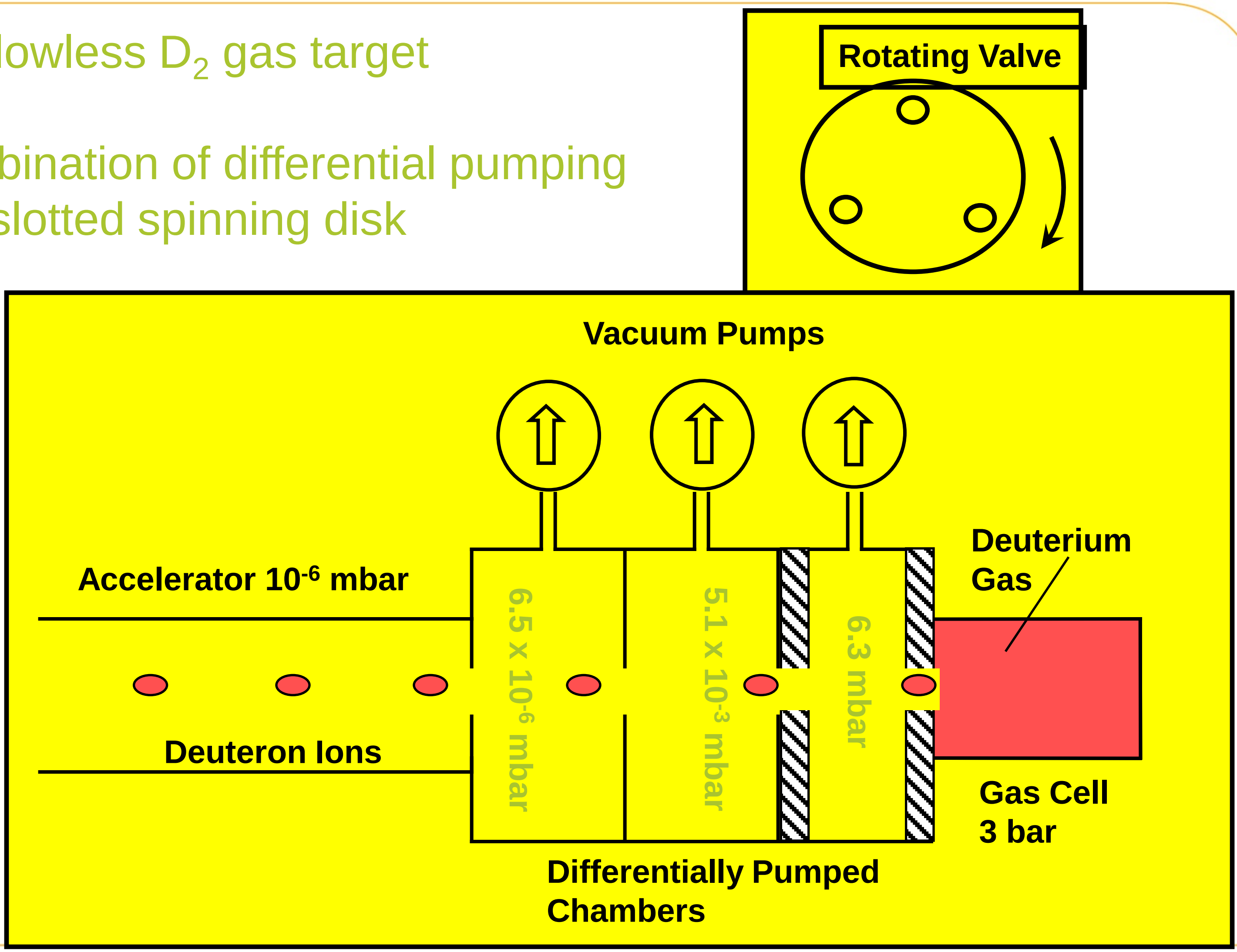
Features	RFQ
RF frequency	200 MHz
E_d (function on φ)	3.0 – 4.75 MeV
output current (peak)	**50 mA**
beam pulse width	**0.4 - 2 ms**
repetition rate	20 -100 Hz
duty factor	20 %
pulsed RF power	**1000 + 200 kW**
linac length	4.5 m
Neutron flux (DD)	**10^{12} /sec**



Accelerator technique

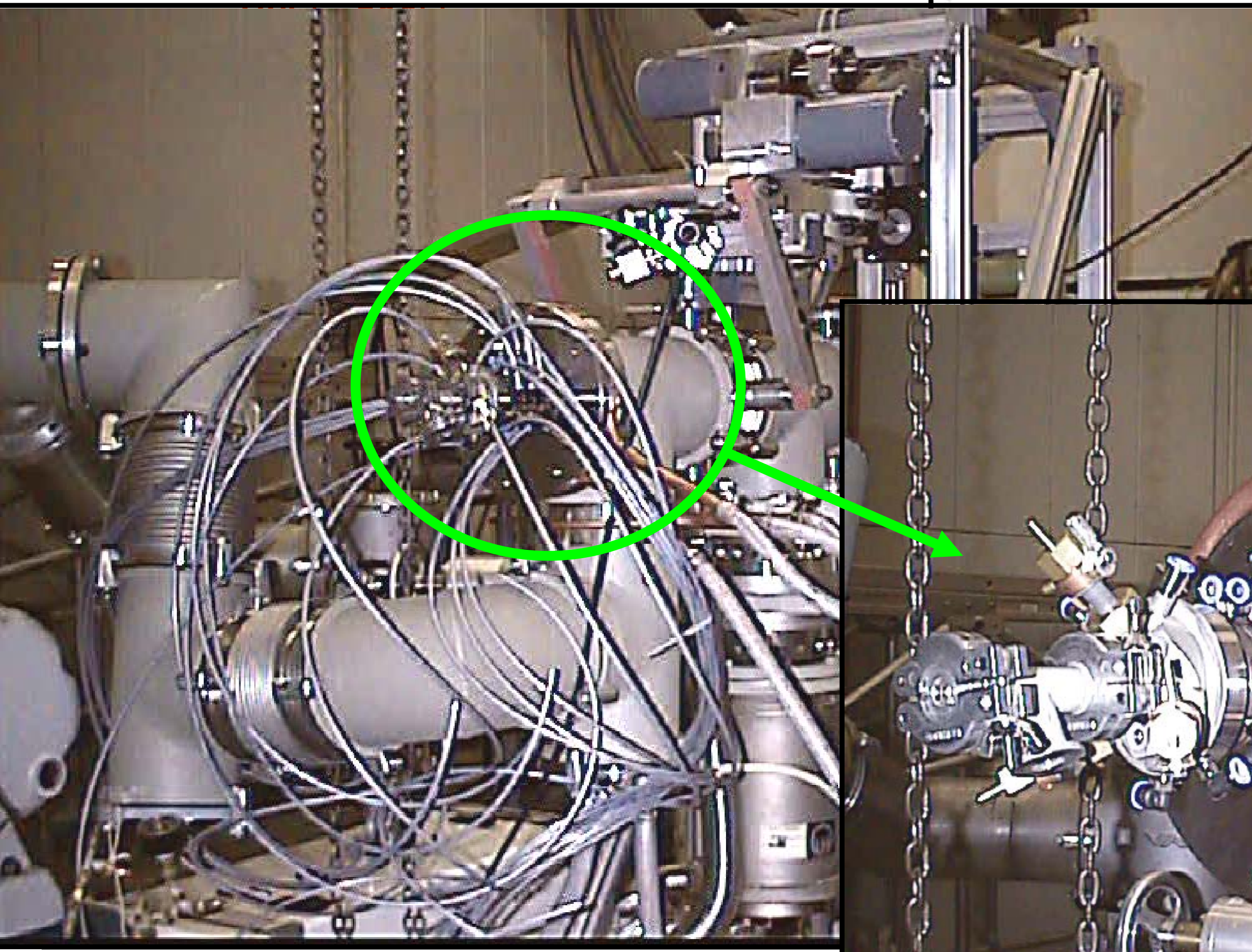
Windowless D_2 gas target

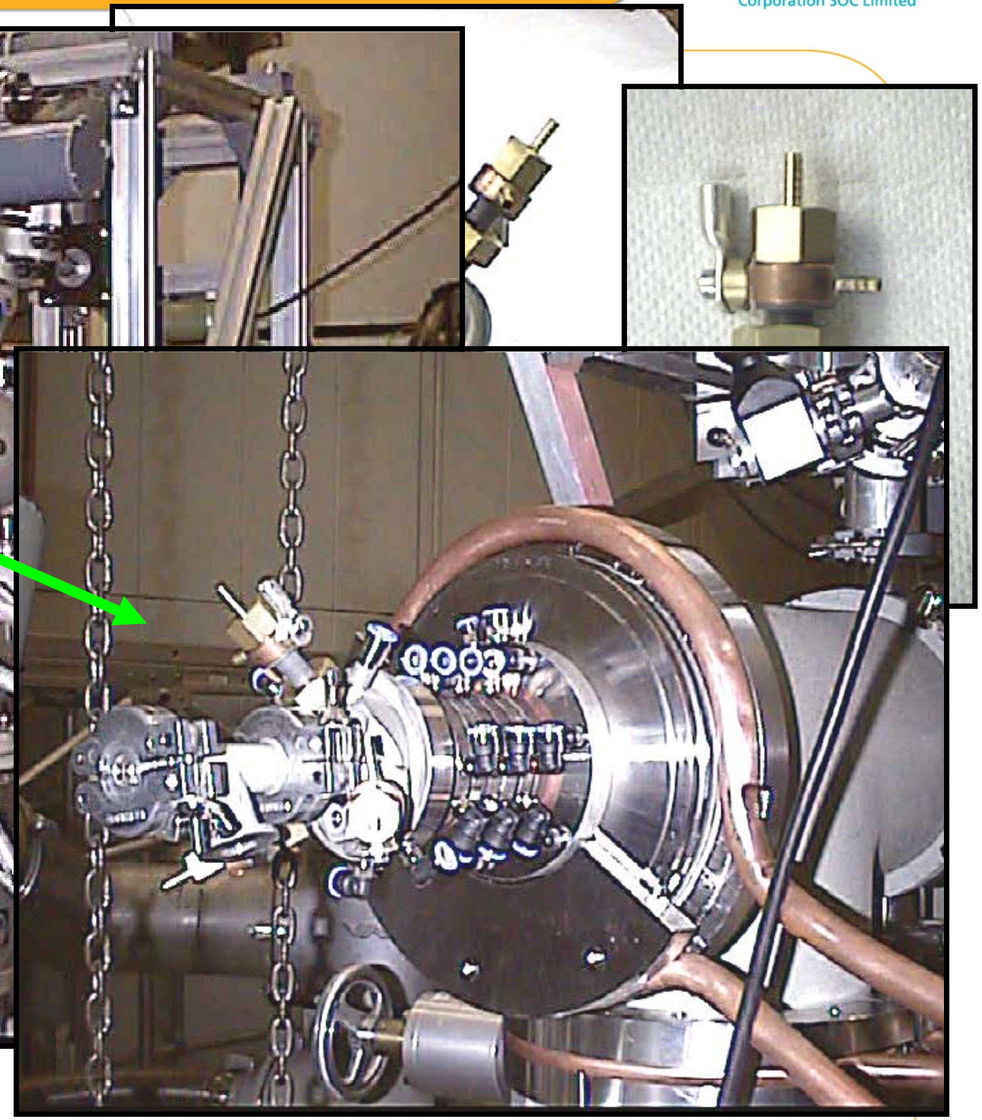
Combination of differential pumping and slotted spinning disk



J. Guzek, et al. NIM-B 152(1999)515-526

Accelerator technique





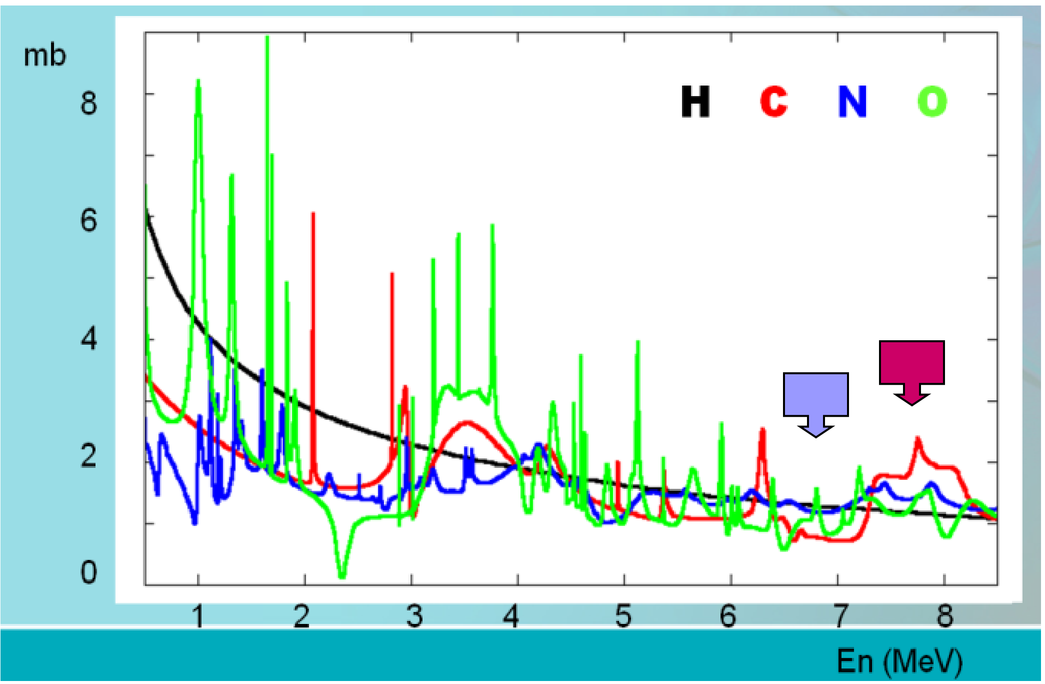
Plasma window

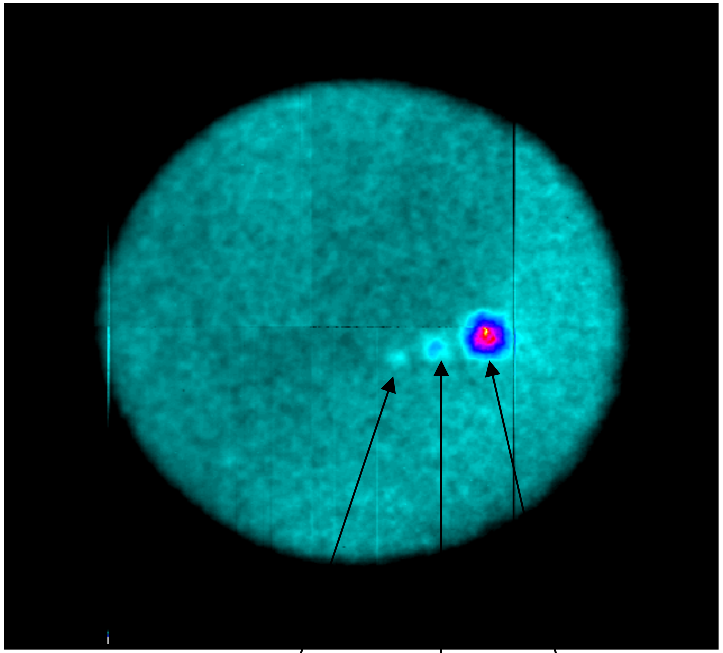
at NECSA

A. de Beer et al. NIM-B 170(2000)259-265

Application

Original application of facility: Detection of diamonds within kimberlite rock





1 2 4 mm
within 10x10x10 cm cube of kimberlite

Pulsed beam applications

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- Modification of ion source and LEBT (B Bromberger, PTB) to supply ns pulsed beam

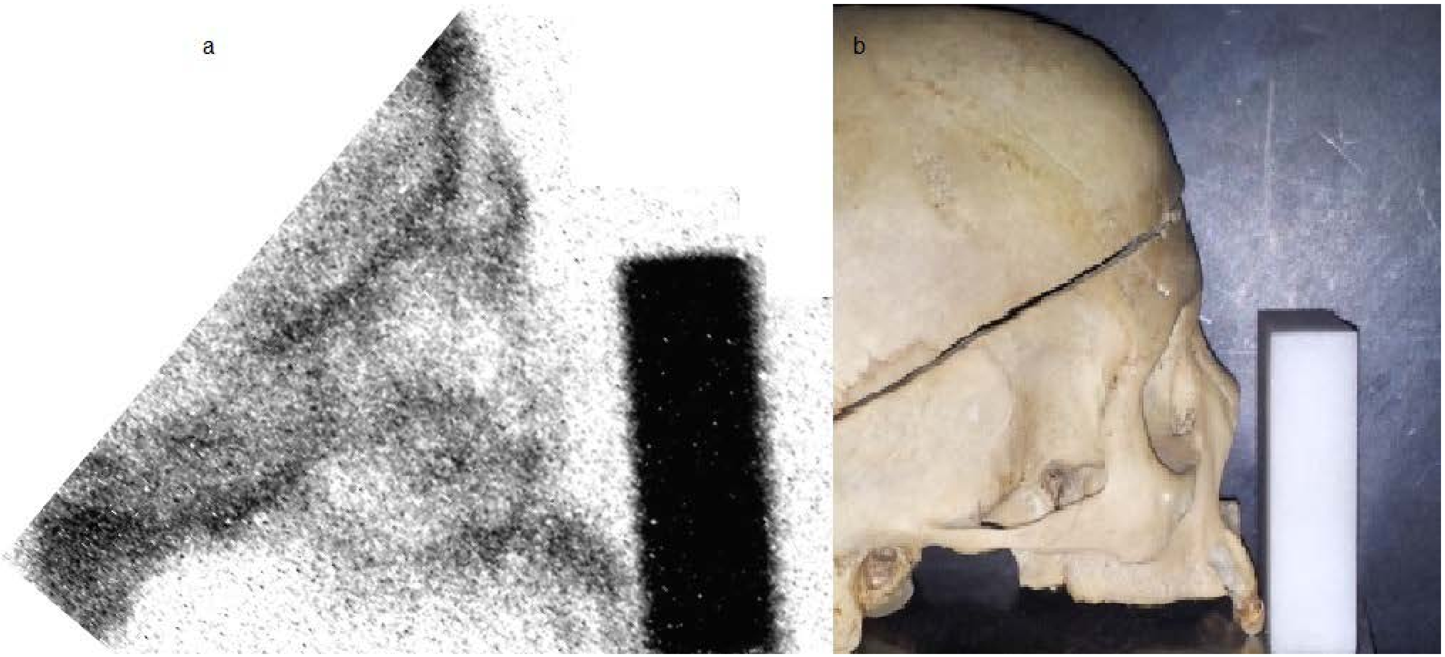
- Adaptation of target station :

  Deposit B_4C onto spinning disk tungsten beam stop

  - Utilize $^{11}B(d,n+\gamma)$ reaction
  - Fast neutrons 1-10 MeV (E_n from TOF)
  - Dual energy γ-rays, 4.43 & 15.11 MeV

Application

Cultural heritage



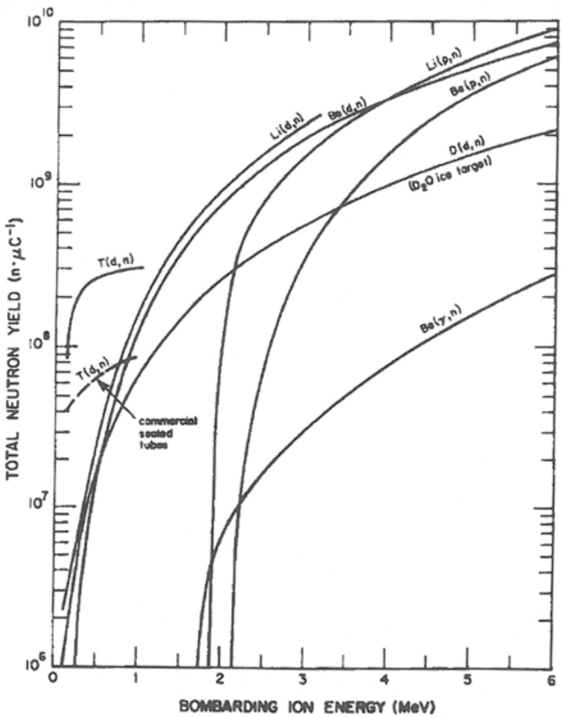
But, primary interest is in SANS development

Cold Source Development

Nuclear reaction to use?

Beam energy <5 MeV D^+, 2.4 MeV H^+ so target options restricted

classical choice of reactions



- Opt for high E_n? Be(d,n) X
- Opt for low E_n? Li(p,n) ☑

LiF -> 3×10^{10} n/mC

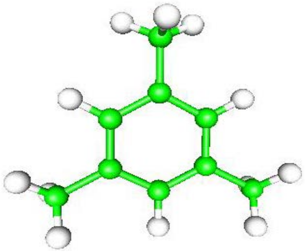
For intended dedicated application: SANS

Moderator

Moderator(s) to use?

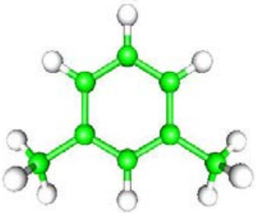
Opt for solid CH_4 or mesitylene/m-xylene beads

mesitylene

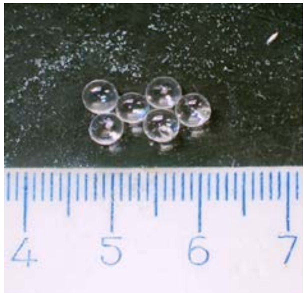


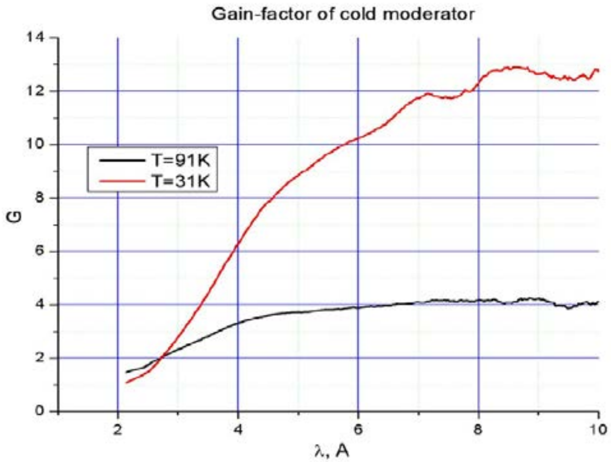
T_m = 227 K

m-xylene



T_m = 225 K





Demonstrated to perform well as a neutron moderator for thermal neutron beam lines at the IBR-2 reactor at FLNP, JINR, Dubna

V. Ananiev, et al. NIM-B320(2014)pp70-74

Modelling

- Li(p,n) reaction provides a pseudo-isotropic distribution of fast neutrons within the moderator volume.

- Task now to extract a viable sub-thermal neutron beam.

- Neutron "escaping" the moderator based on last collision i.e. within 1-2 mm of surface.

Iverson, Baxter et al : Convoluted moderator

Layers of polyethylene and Si wafers

Modelling

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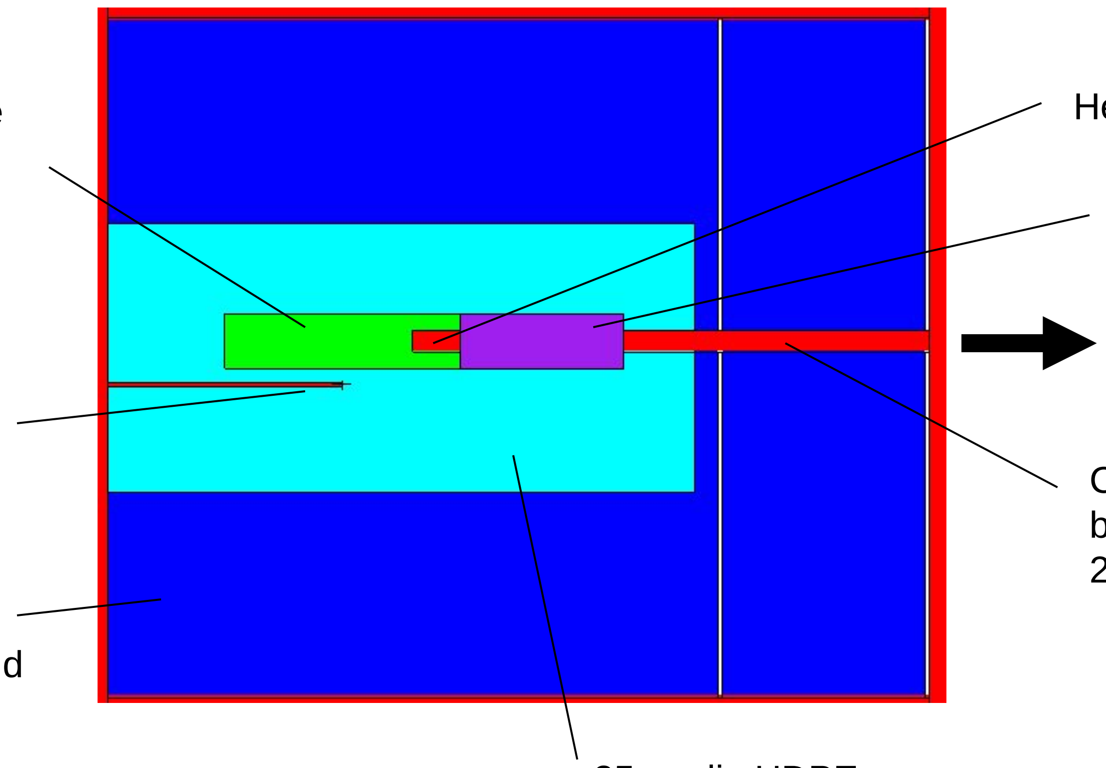
- ❖ Ideally use MCNP-6 or MCNP-X
- ❖ But can also use McStas, FLUKA and Vitess
- ❖ However simulation only as good as the data-base quality
- ❖ Deficiency in low T c/s libraries for many elements, e.g. Be, Si, Zr
- ❖ Since Li(p,n) primary neutron source, minimal complexity to primary moderator
- ❖ Challenge is the search for optimal cold neutron extraction.

Modelling

Current status:



Modelling

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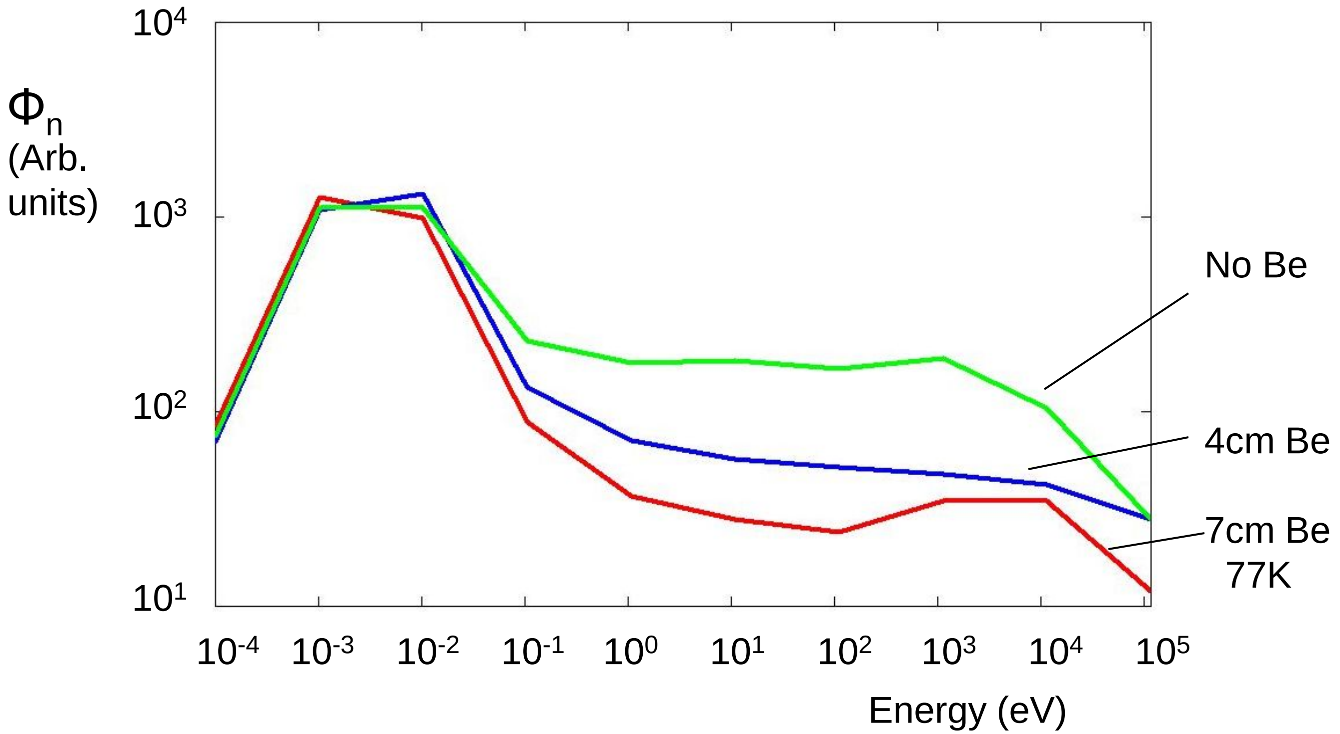
Current status: Yield from 2cm port

Primary 200 keV
neutron distr.
In 35° cone.
Sim. $2*10^7$ events



Wish List

- Further enhancement of extracted beam

- Use of carbon nanotubes as moderator/collimators

    - e.g. Ni coated C nanotubes - neutron guides.

- Properties of nano-diamonds as part of neutron guide

- Other nano-materials?

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Support from colleagues of the CRP

THANK YOU

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