Utilization of variable energy radio-frequency quadrupole linear accelerator systems.

Chris Franklyn
Head: P-LABS
Radiation Science Dept.
Necsa

iThemba LABS

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Utilization for:

Fast neutron radiography/tomography.

Radio-isotope production.

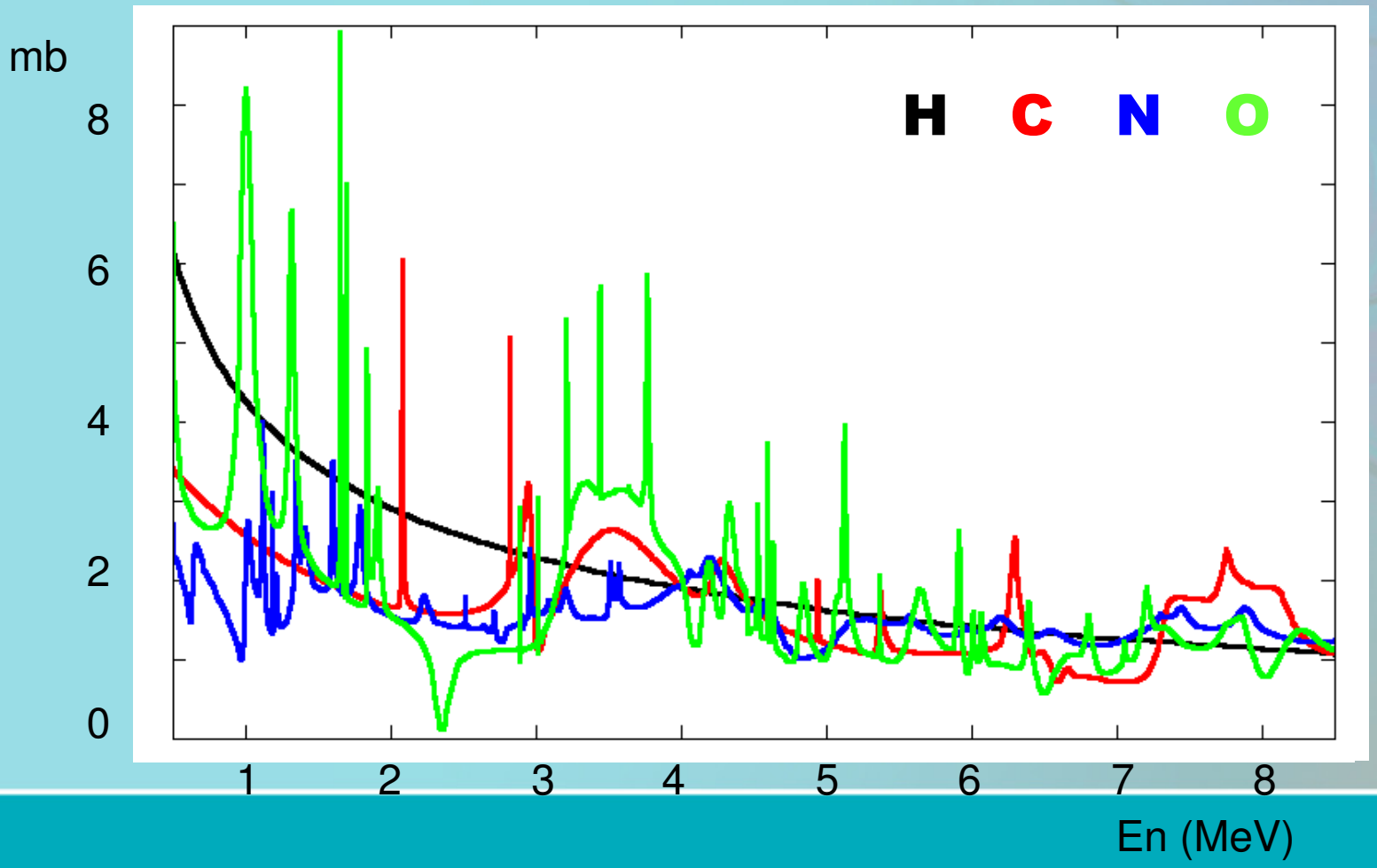
Radiography Problem:

Analysis of bulk samples through which X-rays and thermal neutrons are unable to penetrate.

Solution:

Fast neutrons **1.0 – 10 MeV**

Opportunity to utilize resonance features of fast neutron interaction cross-sections.



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Requirement:

High yield of quasi mono-energetic neutrons

to cater for low interaction c/s,

low fast neutron detection efficiency,

and low gamma-ray yield

Ideal reaction: $^{2}H(d,n)^{3}He$

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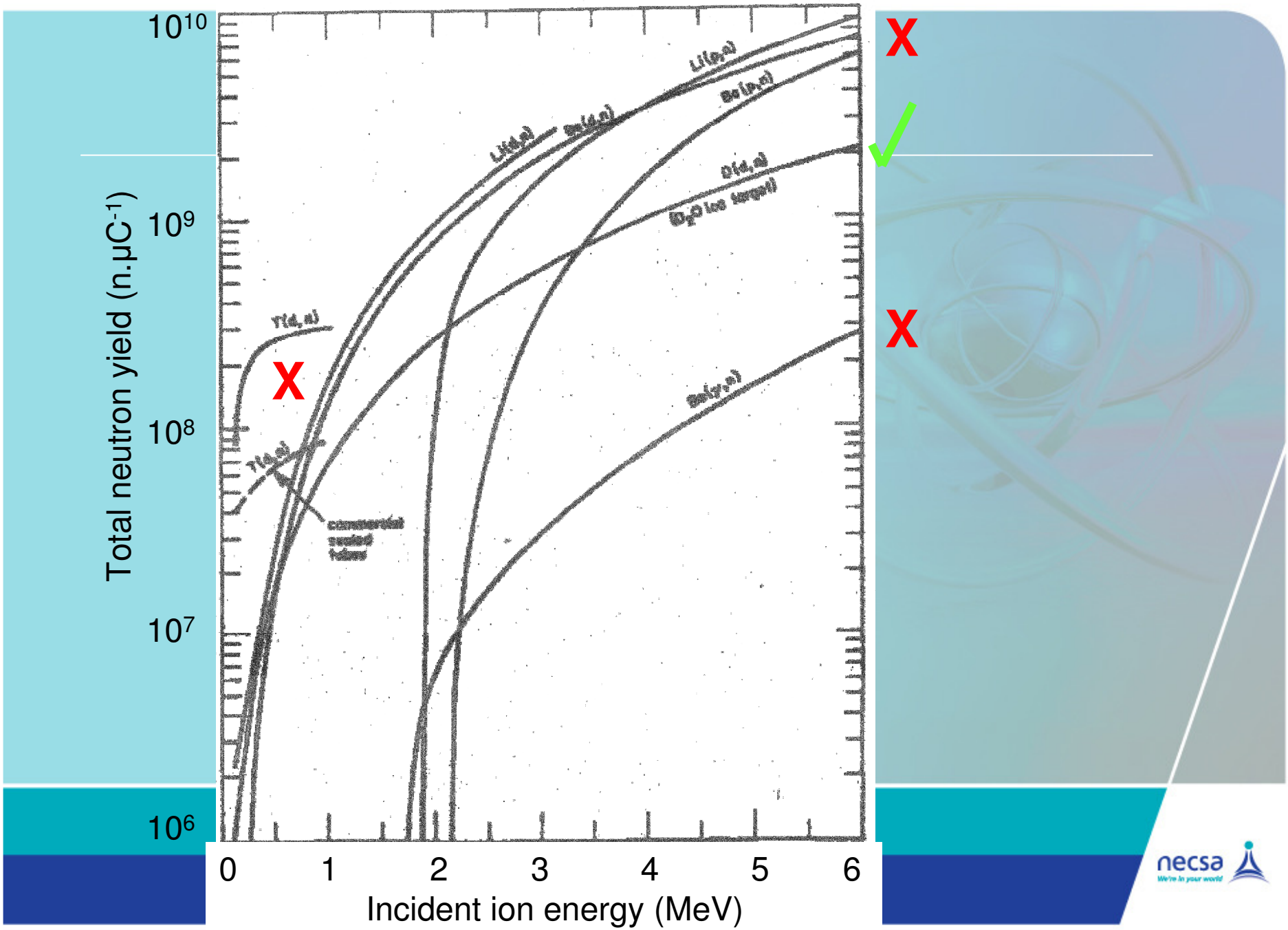
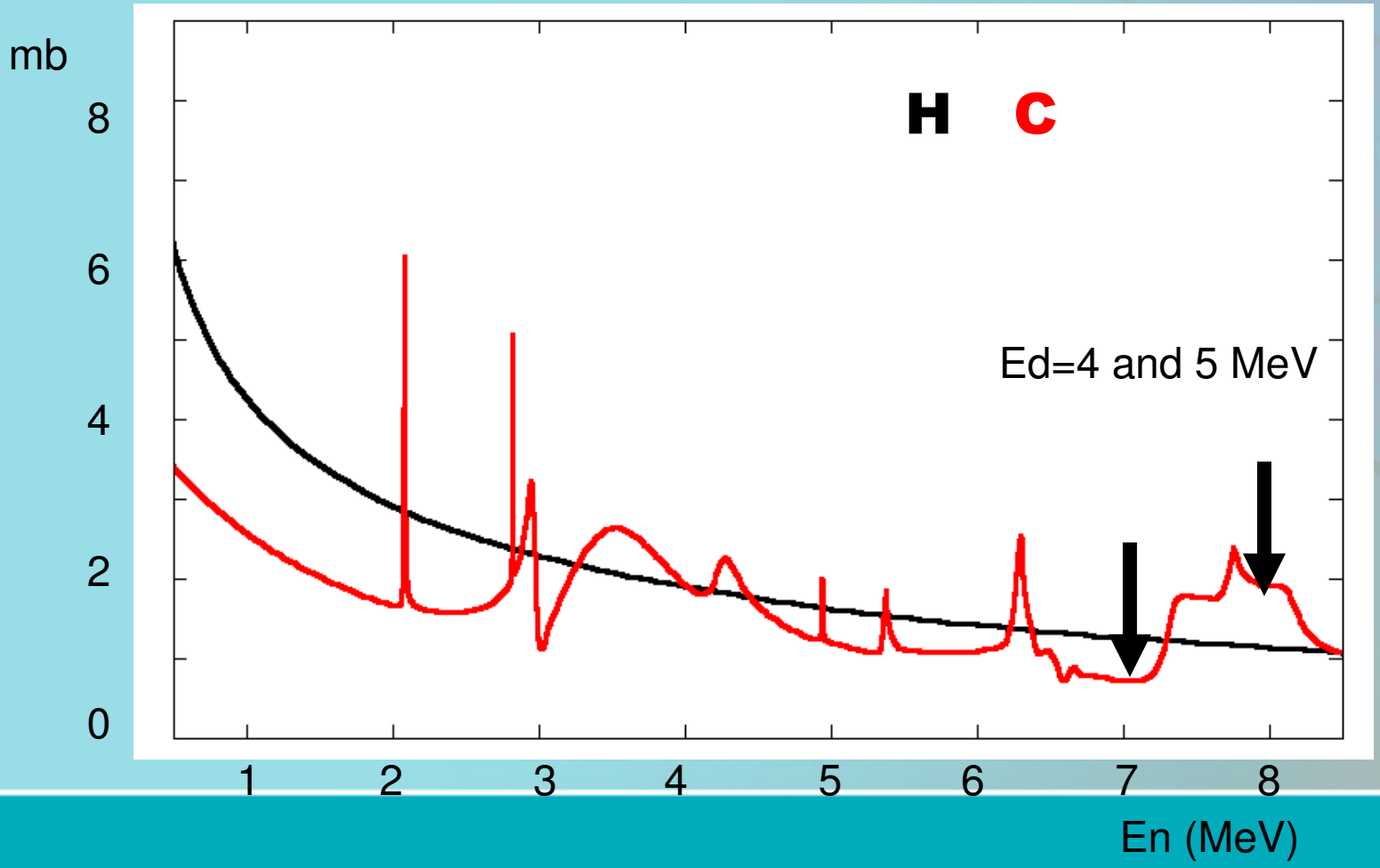
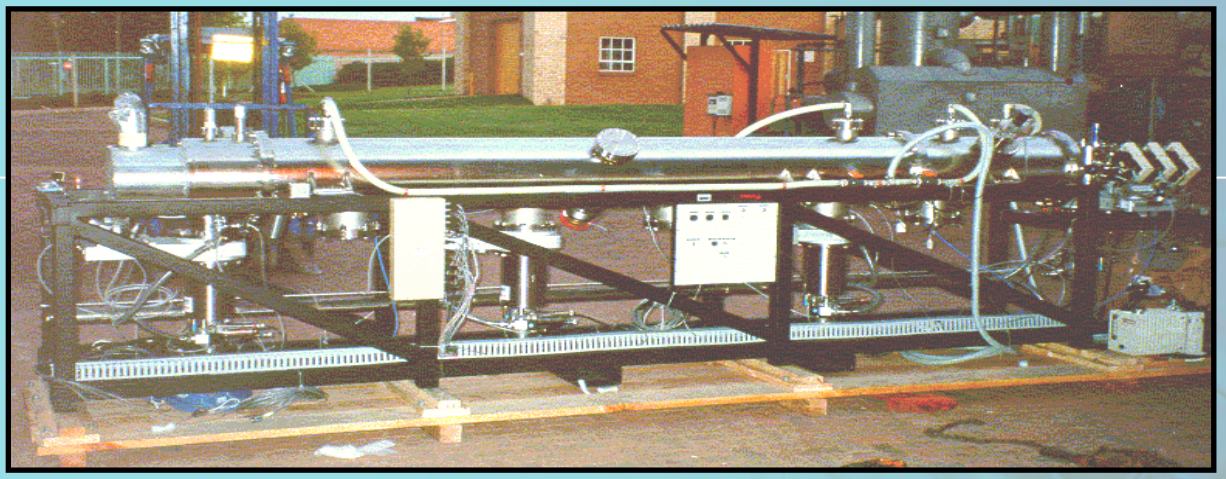
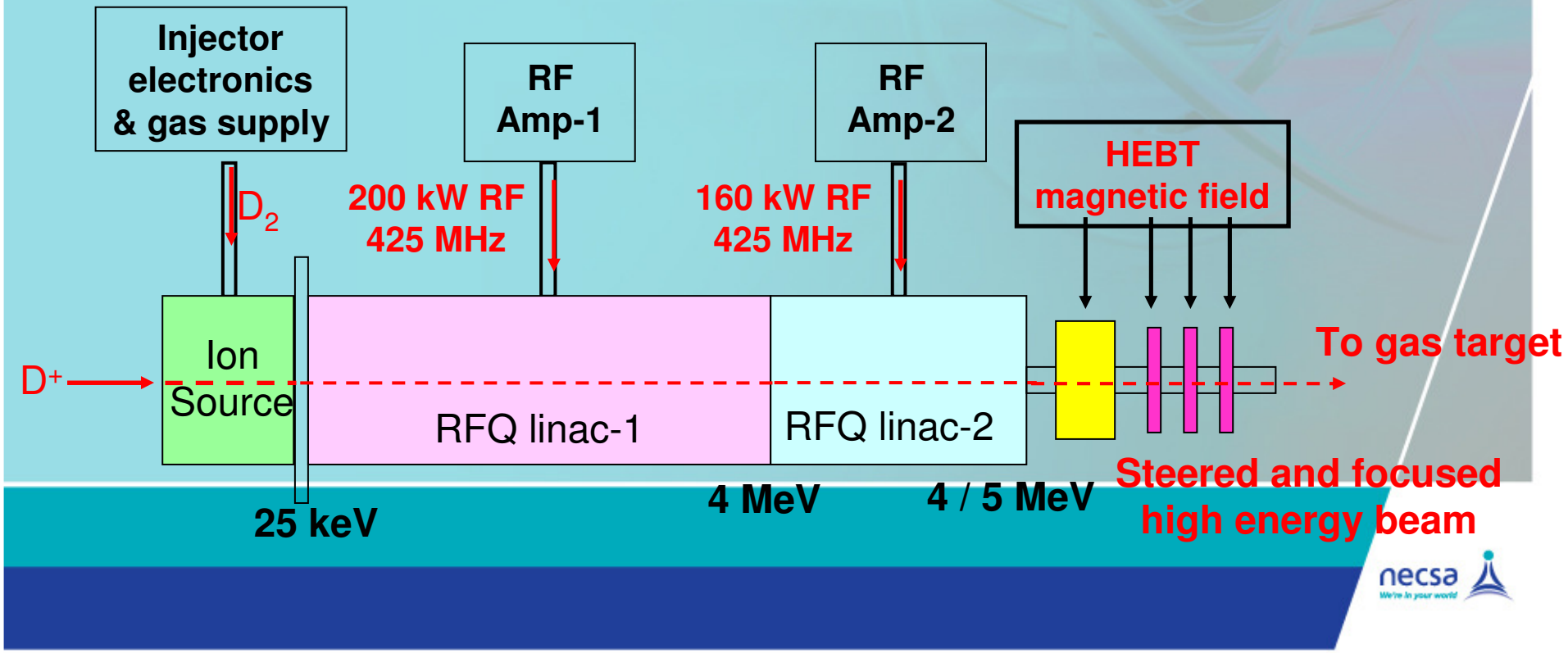

Total neutron yield (n.μC⁻¹)
10¹⁰
10⁹
10⁸
10⁷
10⁶
0
1
2
3
4
5
6
Incident ion energy (MeV)
T(d,n)
D(d,n)
D₂O ice target
X
X
X
✓

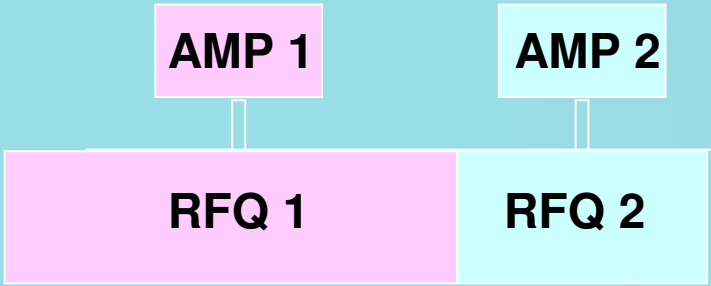

mb
8
6
4
2
0
H
C
Ed=4 and 5 MeV
1
2
3
4
5
6
7
8
En (MeV)

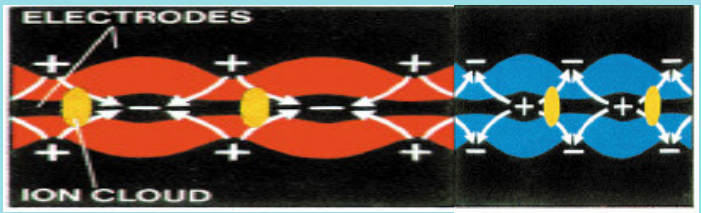
ADM Radio Frequency Quadrupole (RFQ) linac

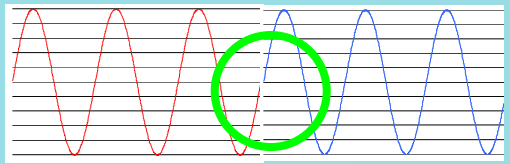




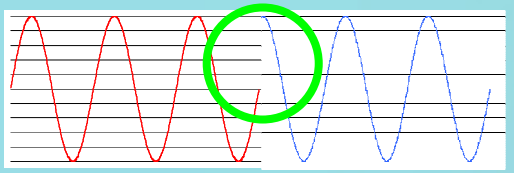
BEAM ENERGY



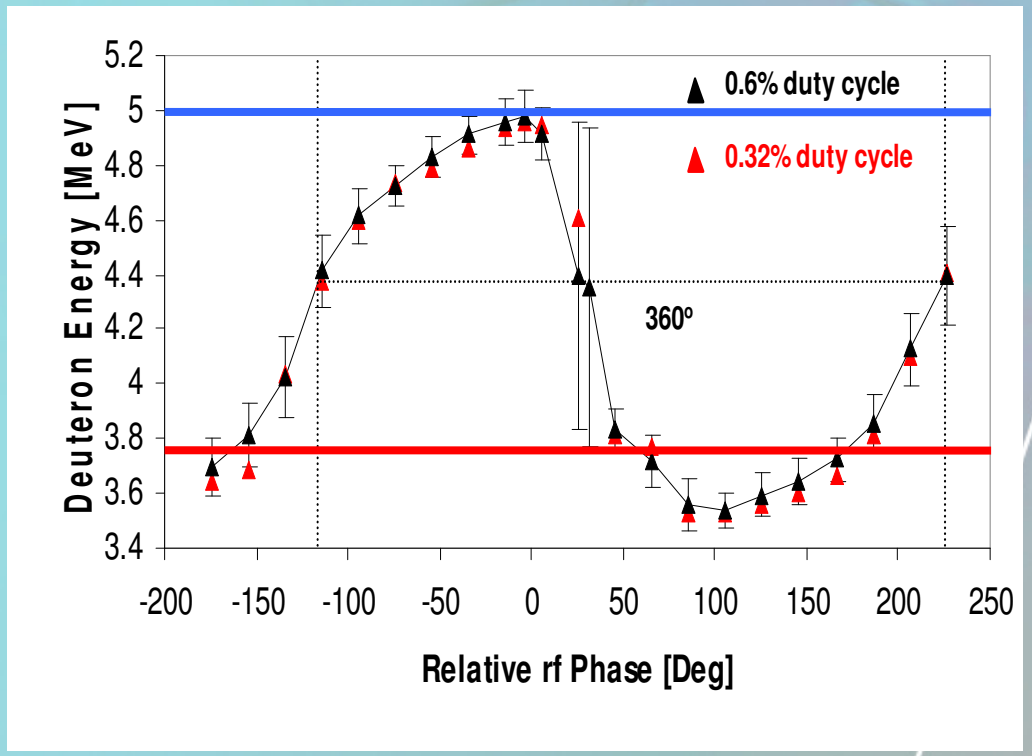




RFQ1 & RFQ2 in phase



Varying phase shift



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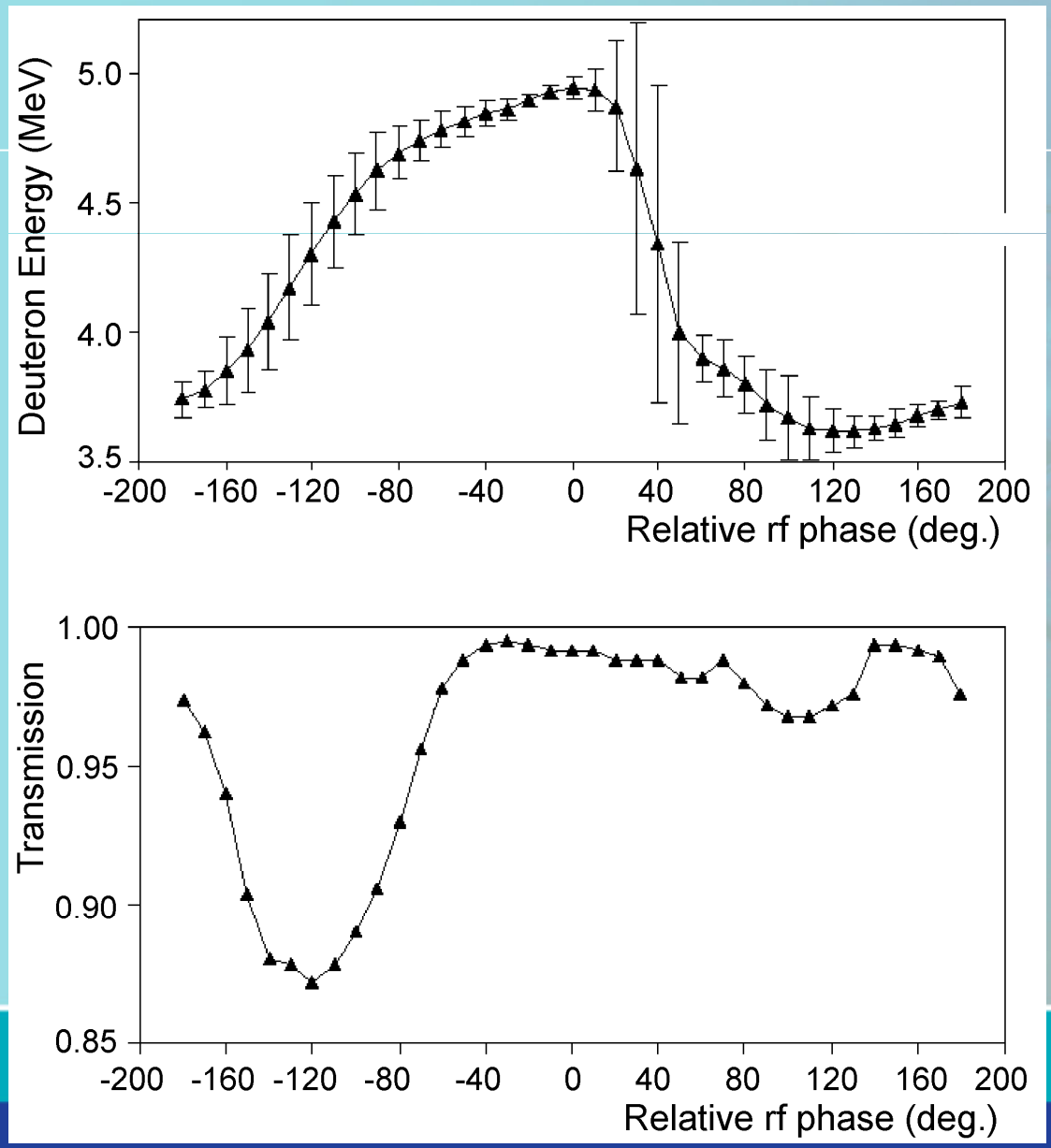
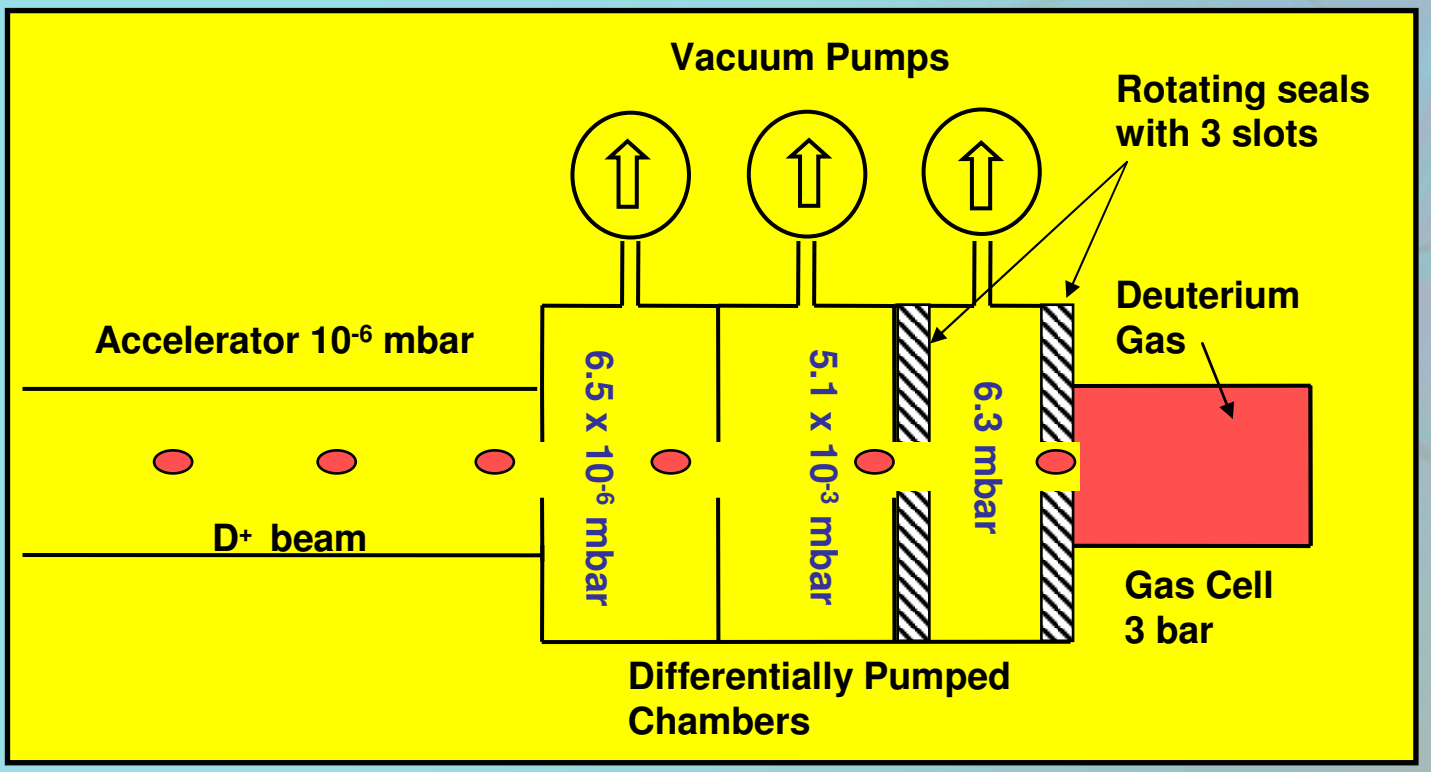
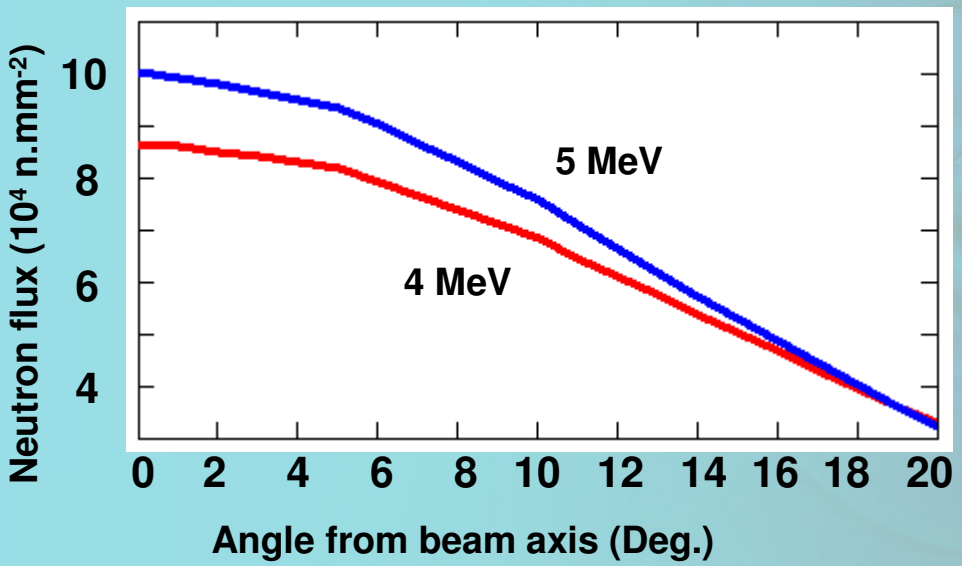

Deuteron Energy (MeV)
5.0
4.5
4.0
3.5
-200
-160
-120
-80
-40
0
40
80
120
160
200
Relative rf phase (deg.)
Transmission
1.00
0.95
0.90
0.85
-200
-160
-120
-80
-40
0
40
80
120
160
200
Relative rf phase (deg.)

Gas target

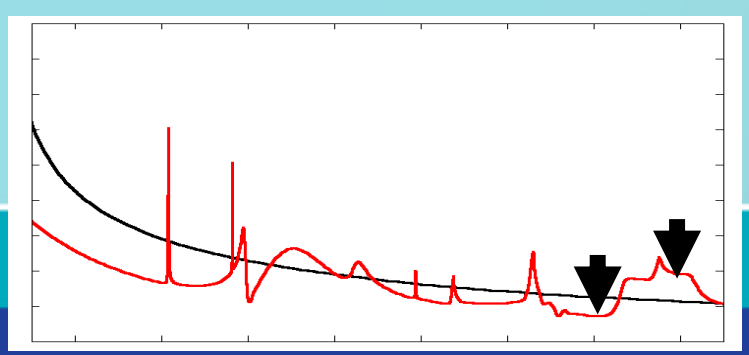

Vacuum Pumps
Rotating seals
with 3 slots
Deuterium
Gas
Accelerator 10-6 mbar
6.5 x 10-6 mbar
5.1 x 10-3 mbar
6.3 mbar
D+ beam
Gas Cell
3 bar
Differentially Pumped
Chambers

Neutron yield for 3 cm, 3 bar D_2 gas target at 100 µA



En=8.2 MeV

En=7.2 MeV



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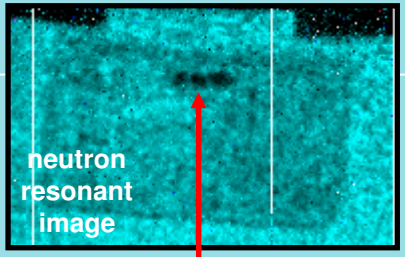
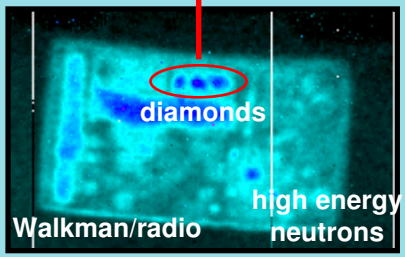
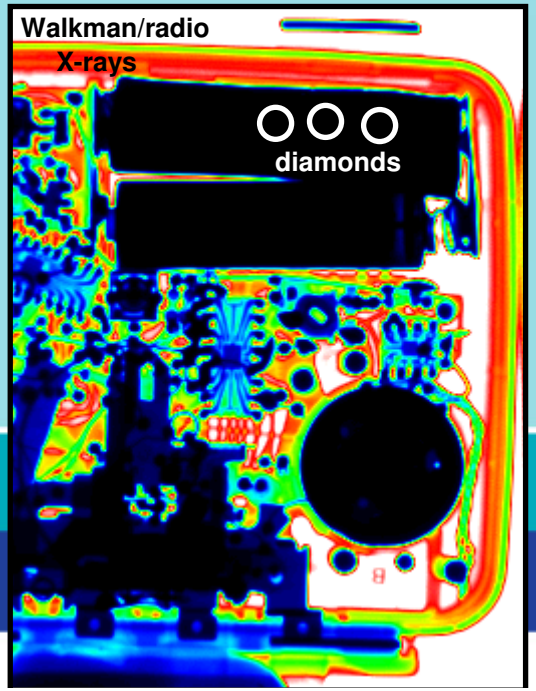
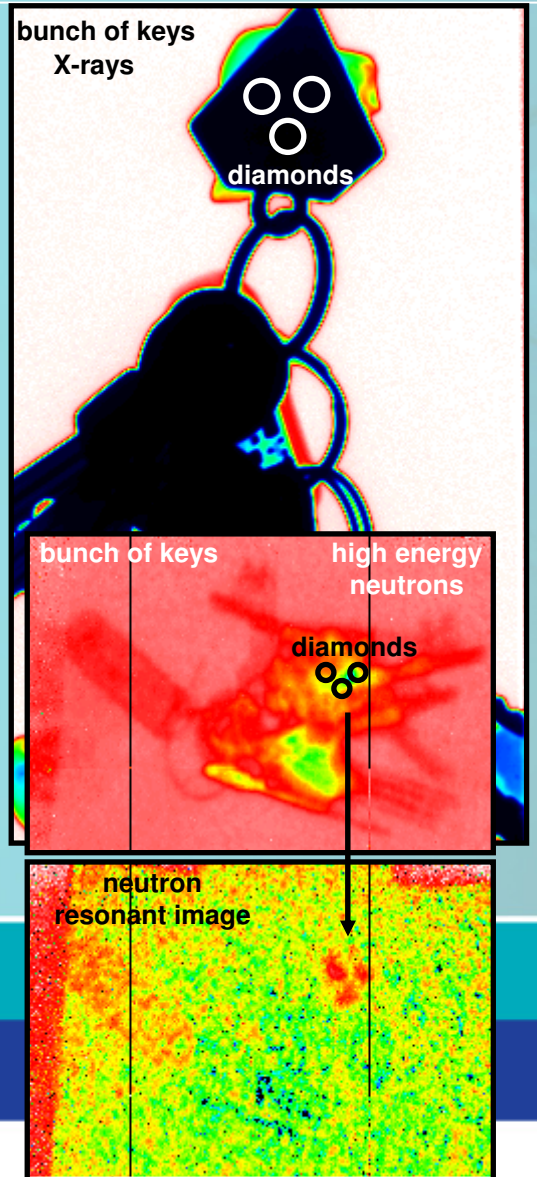
DIAMOND SECURITY

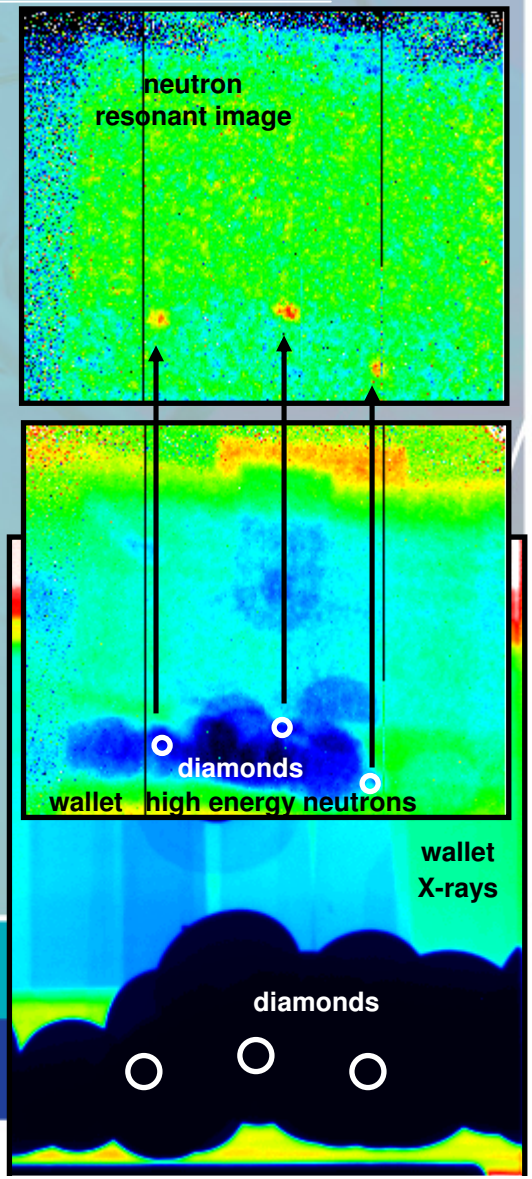
scanning parcels for diamonds



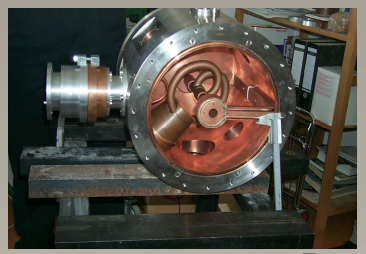








D-100 RFQ accelerator system



35 keV D^+ ion source

Main RFQ accelerator
- Accelerate ions to 4 MeV

Booster for extra 1 MeV ion acceleration

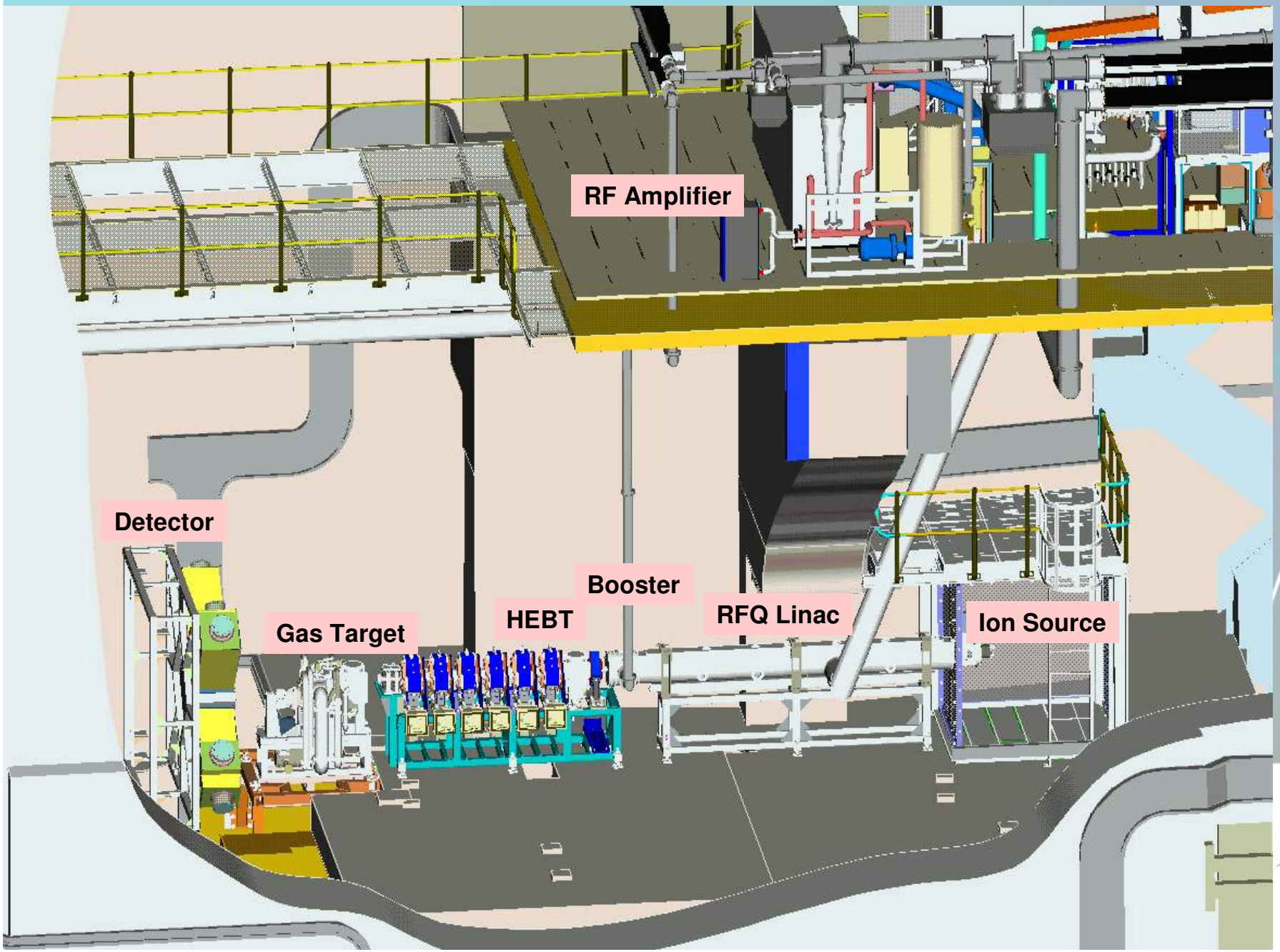
Beam direction

Spinning disc beam dump

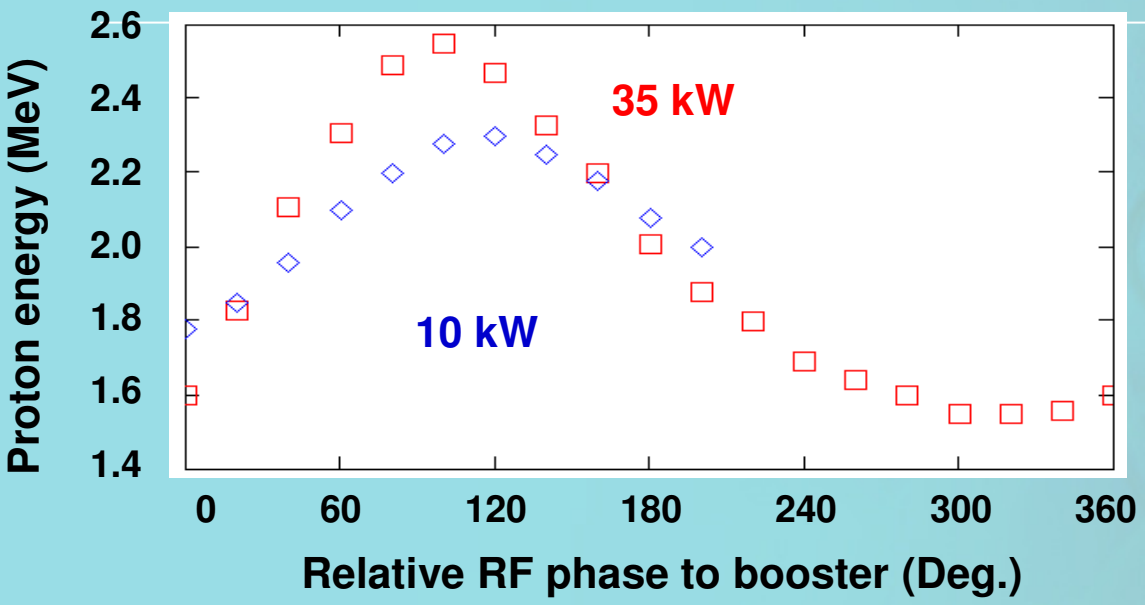
High Energy Beam Transport to focus and steer ions into gas target

3 cm 3 bar D_2 gas Target

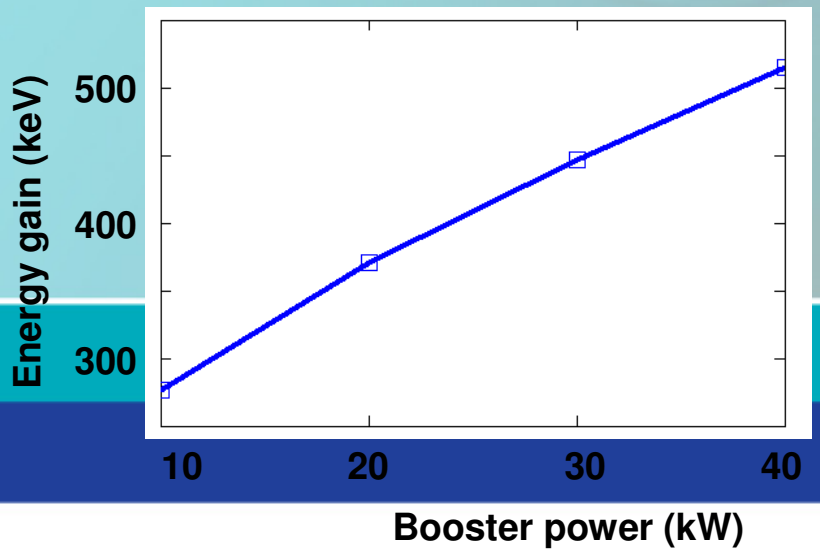
Schematic layout of the D-100 RFQ accelerator facility at Necsa



Extracted proton beam at 180 kW in first cavity



At 120°



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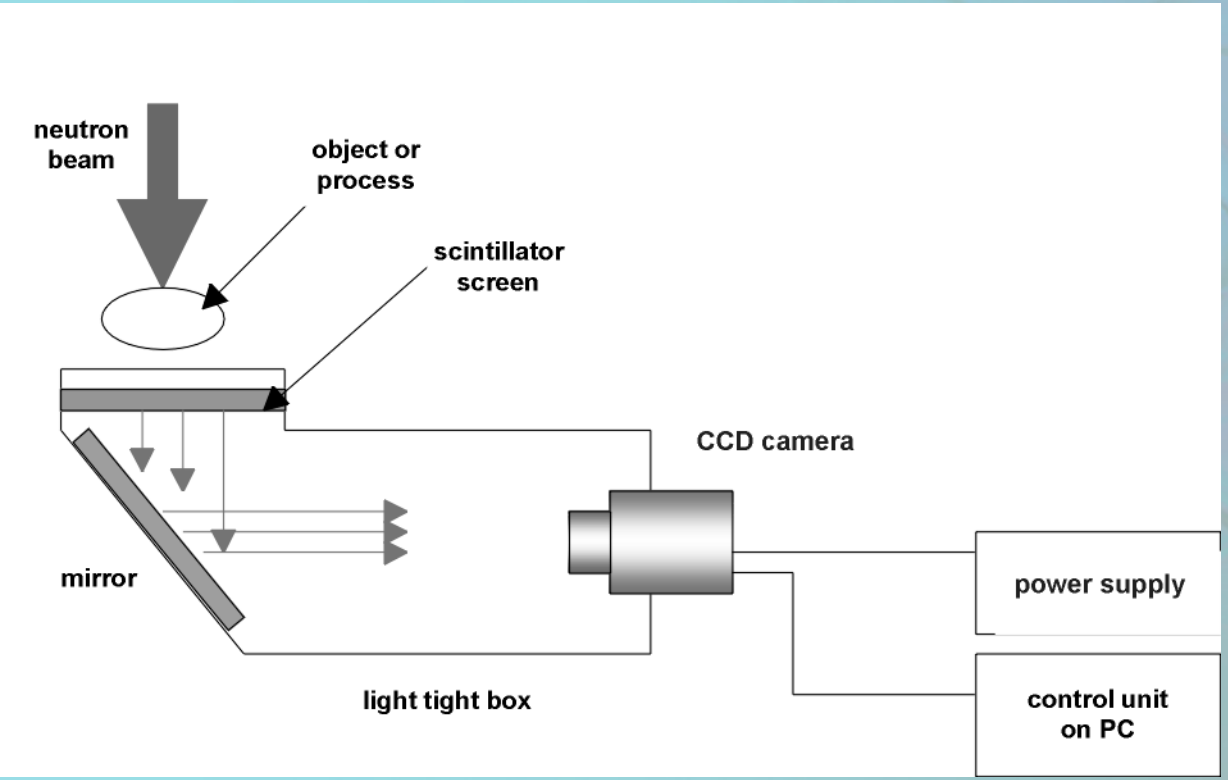
DESIGN	CURRENT
50 mA , 20% duty cycle	10 mA , 2.5% duty cycle
3 bar deuterium gas cell	1 bar
10^{12} n.s^{-1}	10^{10} n.s^{-1}

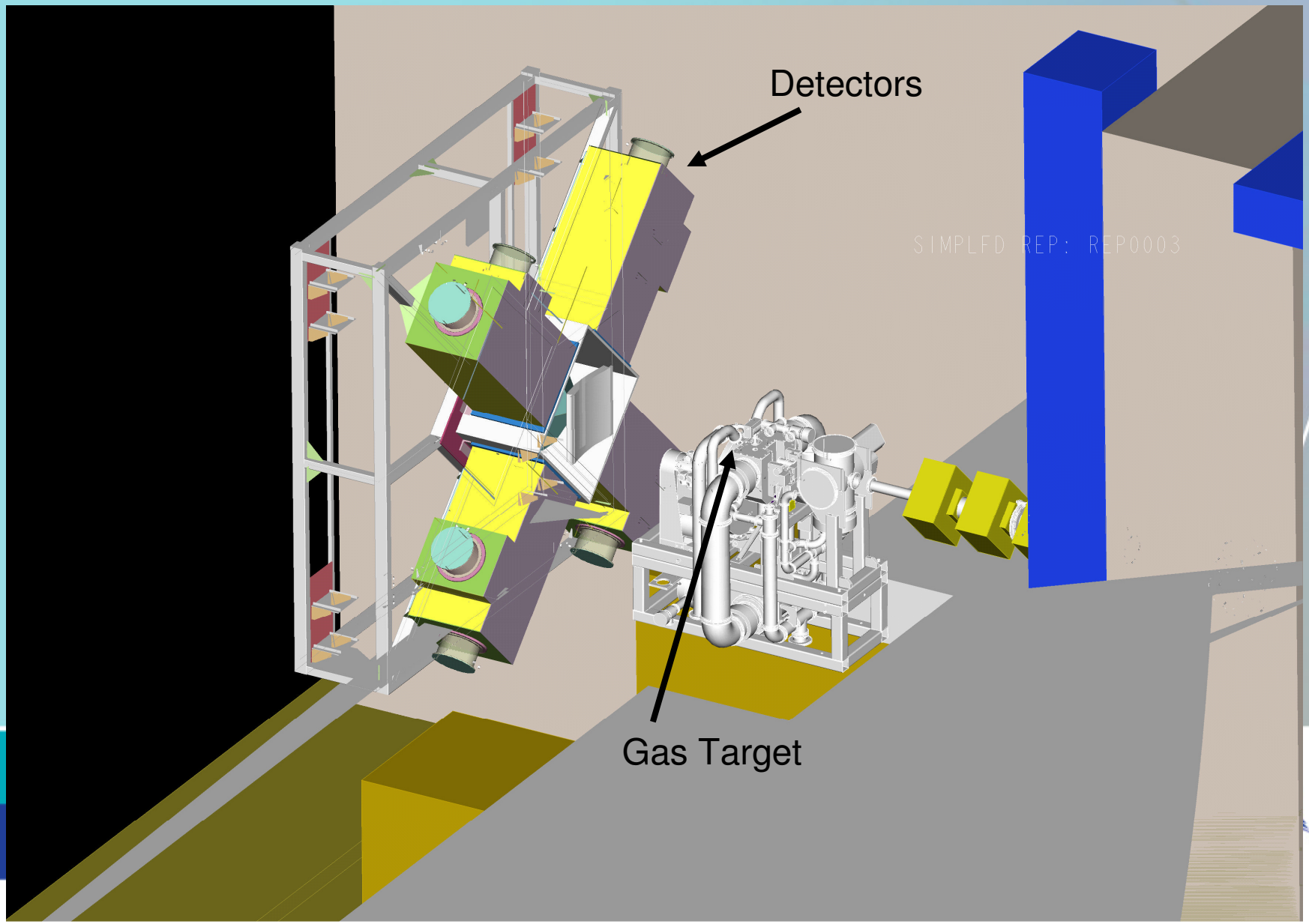
Operating specifications for the two accelerator systems.

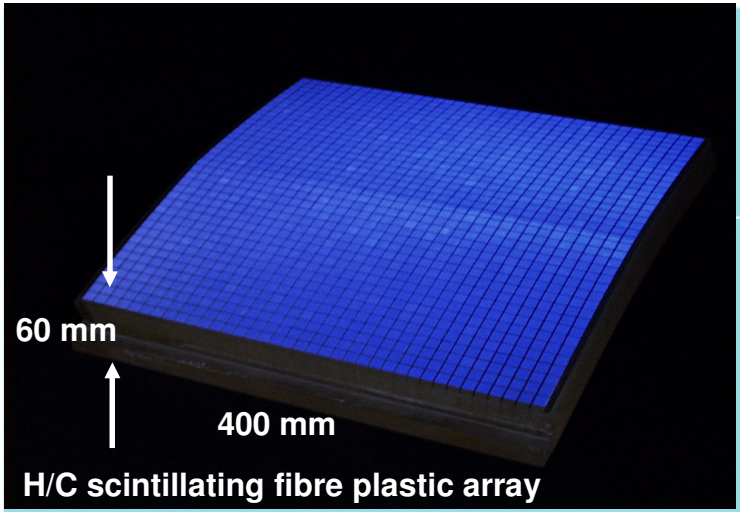
Features	D-100	ADM
operating frequency (MHz)	200	425
injection energy (keV)	35.0	25.0
output energy (MeV)	3.7 - 5.1	3.6 - 4.9
injector output current (pulsed)(mA)	55	12
booster output current (pulsed)(mA)	50	8
maximum beam pulse width (ms)	2	0.1
repetition rate (Hz)	20-100	20-200
maximum RF duty factor	20 %	1.2 %
pulsed RF power requirement (kW)	1000/200	280/160
linac length (m)	4.5	4.4
Neutron flux ($n.s^{-1}$)	10^{12}	10^{10}

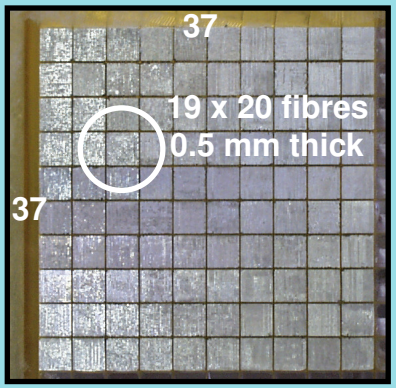
Conventional radiography configuration - ADM



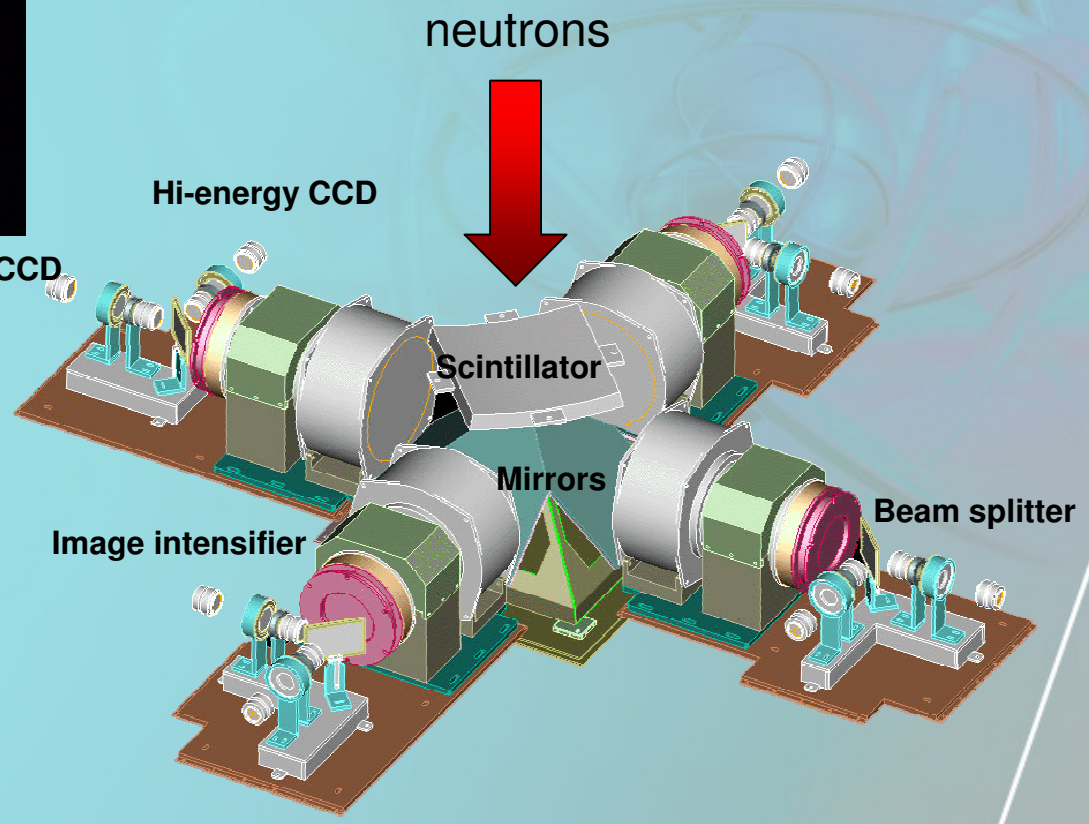
D-100 detection system







> 31 km of fibres



Neutron efficiency: 70%
Light conversion: at least 1 photon / neutron
Image intensifier size: 150 mm
Drift scanning: Yes

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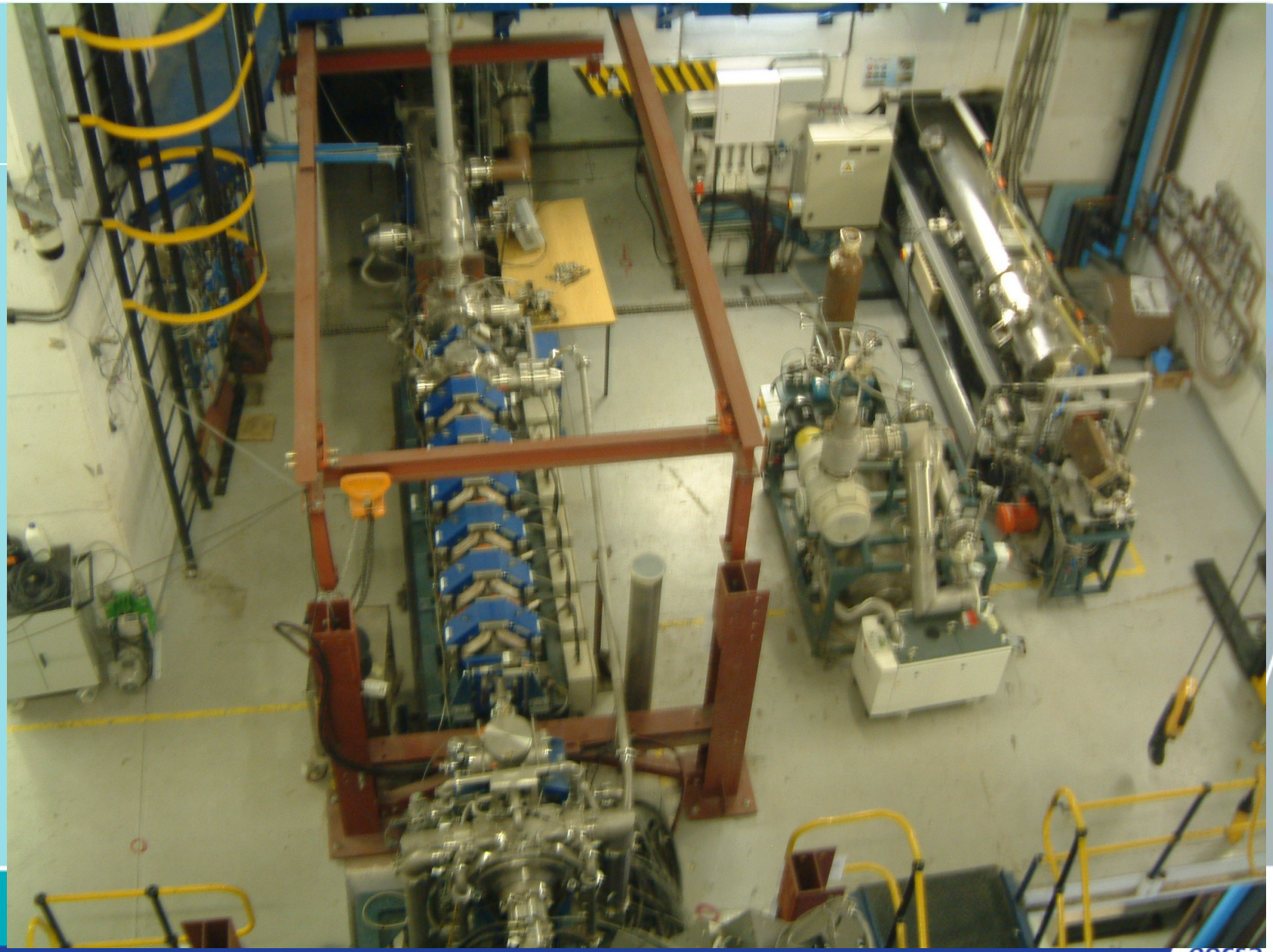
D-100 ADM



Opportunities for R&D are vast and intended to be open to all

e.g.

Radio-isotopes: e.g. ^{195m}Pt ^{117m}Sn

Scanning: contaminants, contraband, illicit material, PGMs

Fast neutron radiography/tomography: geosciences, cultural heritage

Accelerator science & technology

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THANK YOU !