UNIVERSITY of York

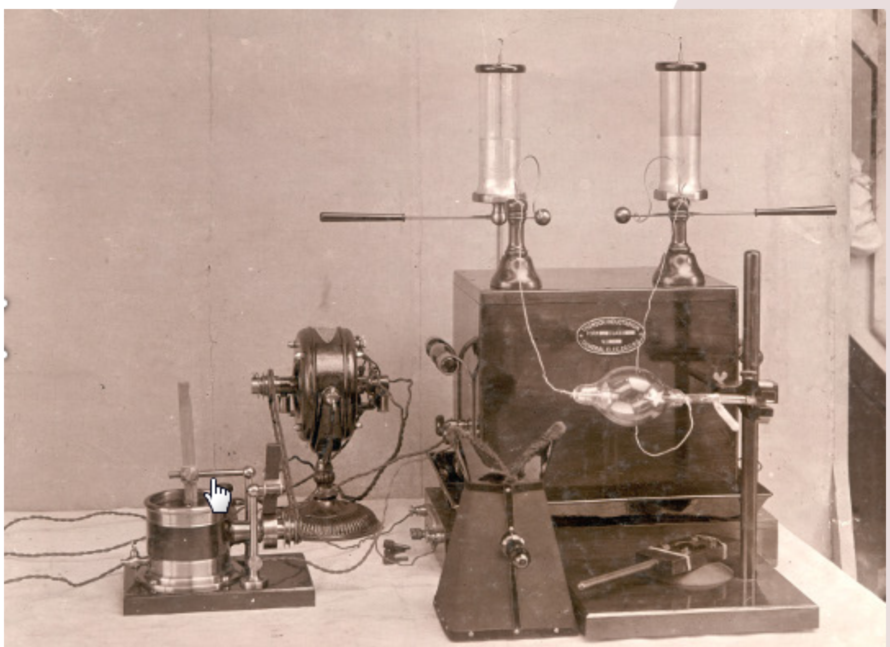
Fast Neutron Tomography

NEDA workshop
Istanbul, September 2018

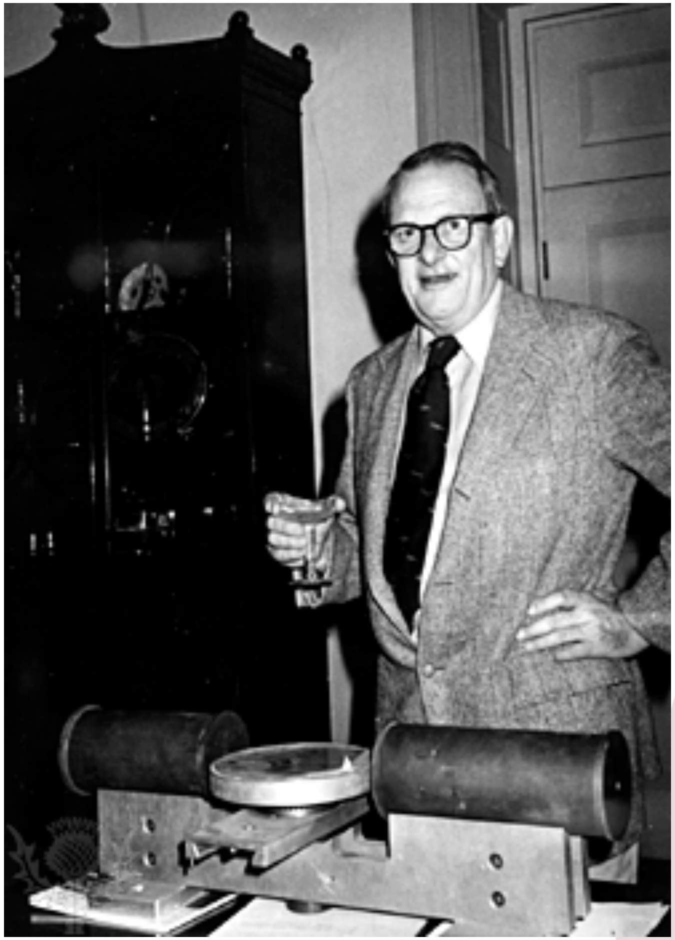
IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

The first x-ray image

Willhelm Röntgen - 1895

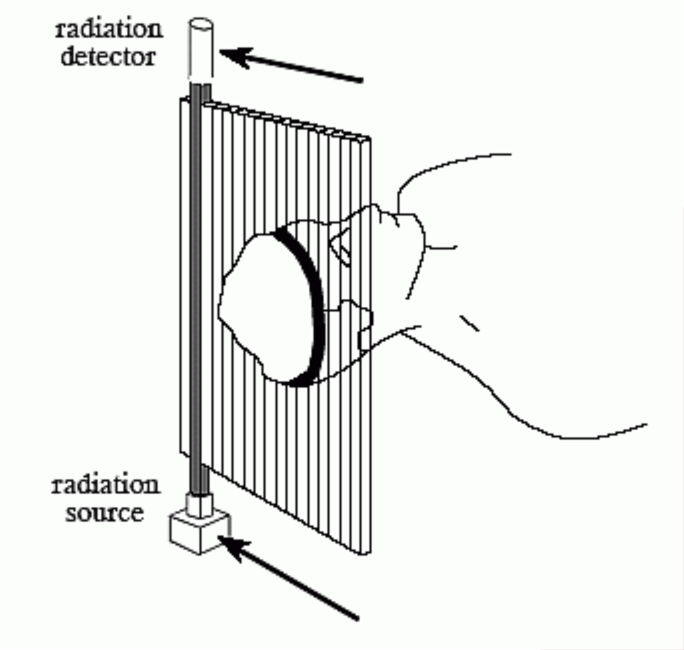


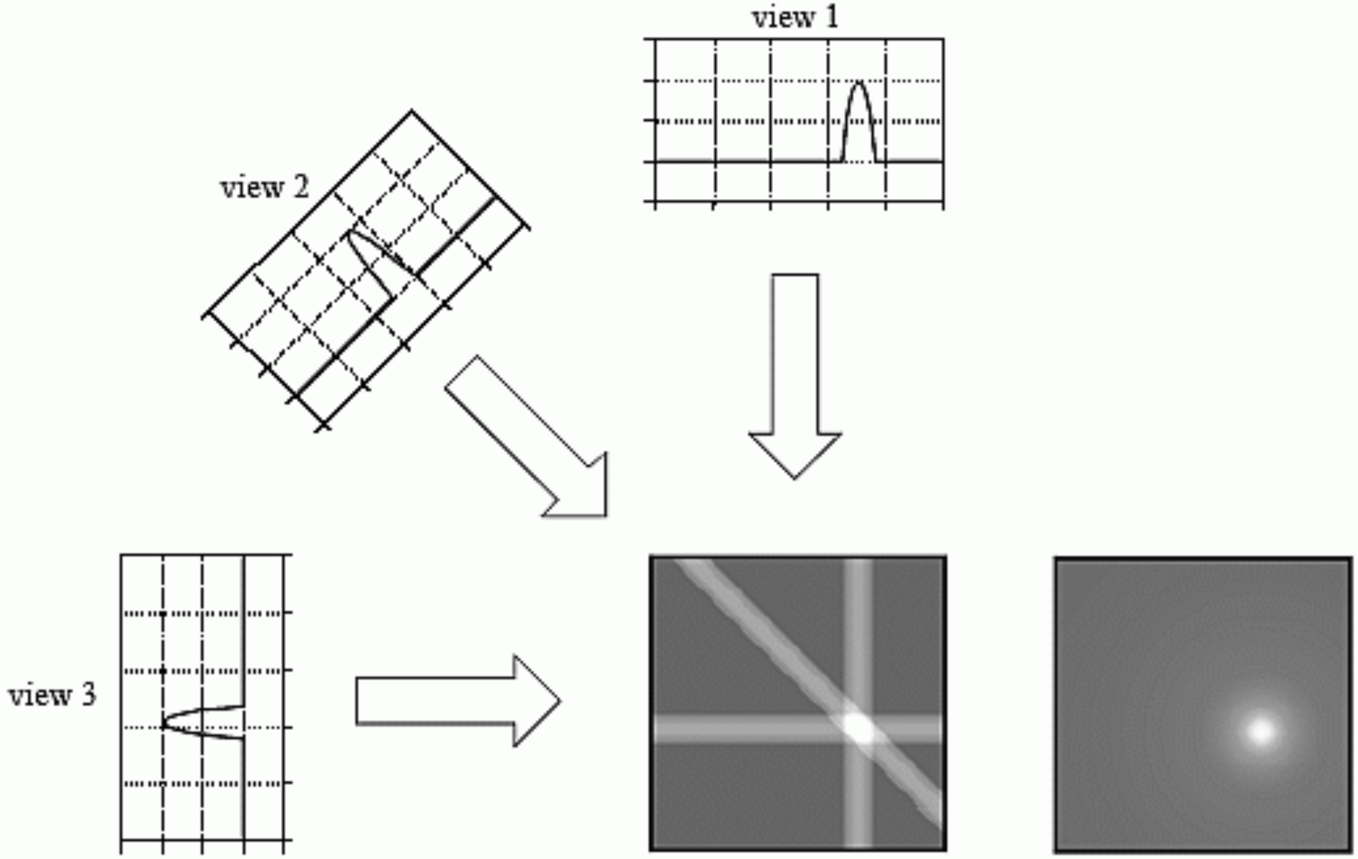
x-ray computed tomography



Allan M. Cormack & Godfrey N. Hounsfield
Nobel Prize in Medicine 1979

x-ray computed tomography principle

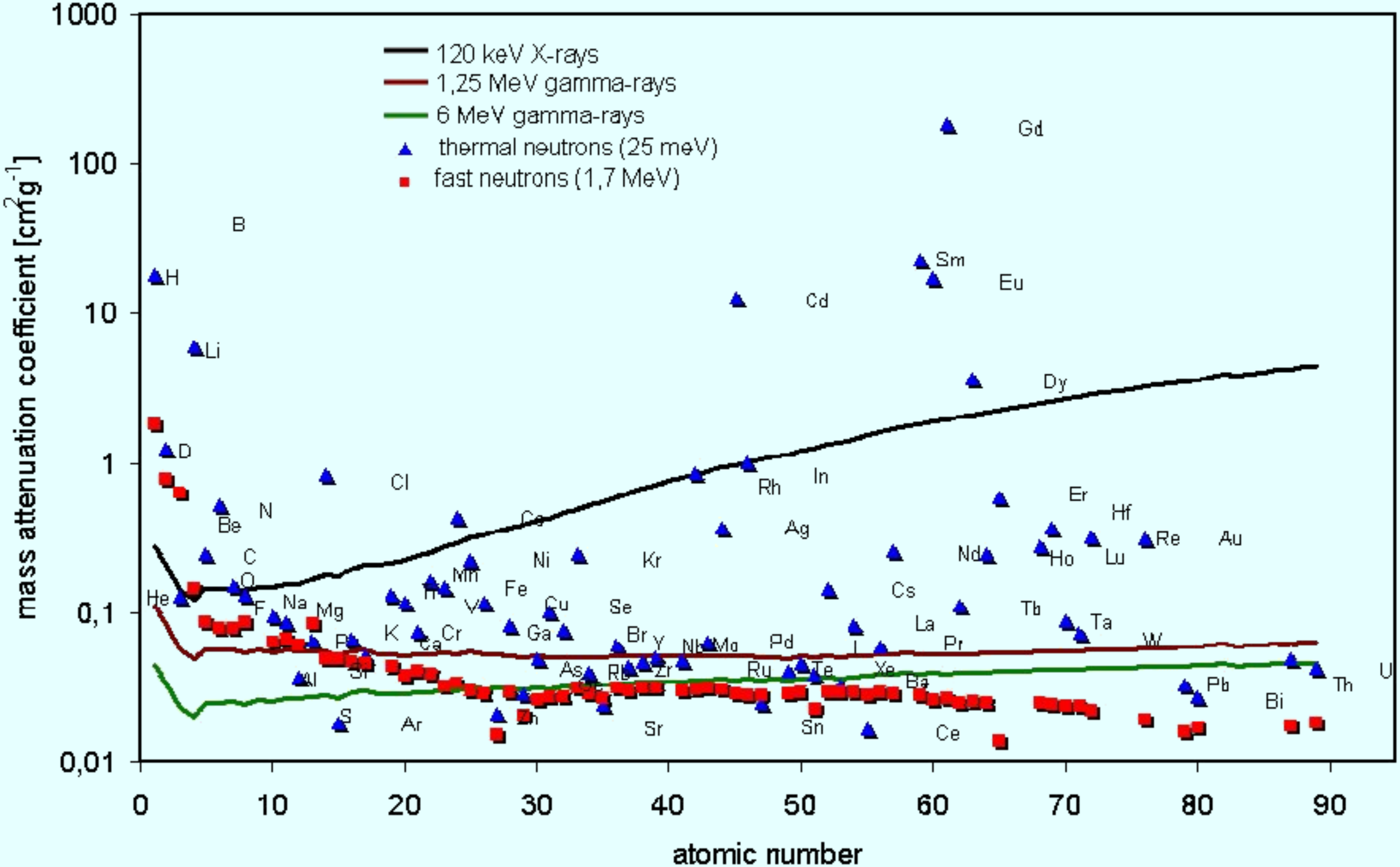




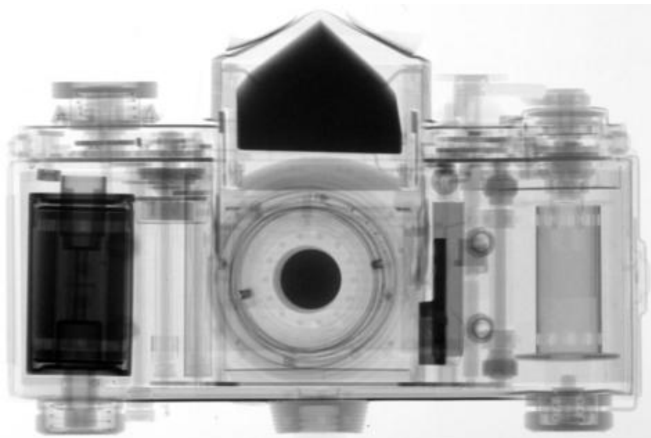
a. Using 3 views

b. Using many views

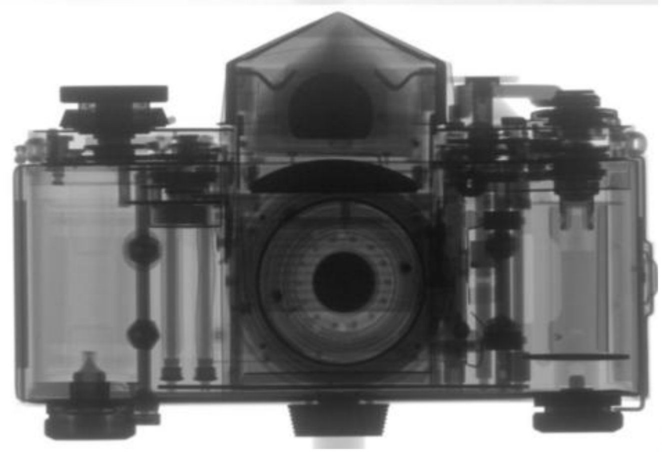
Penetration of radiation types



Complementarity neutrons/photons



Thermal neutrons



X-rays

Radiograph of an analog camera: by neutrons (top) by X-rays (bottom). While X-rays are attenuated more effectively by heavier materials like metals, neutrons make it possible to image some light materials such as hydrogenous substances with high contrast: in the X-ray image, the metal parts of the photo apparatus are seen clearly, while the neutron radiograph shows details of the plastic parts.

LICORNE: Applications of fast neutron tomography

- **Border/airport security (e.g. detection of explosives in suitcases)**
- **Nuclear Industry: Characterisation of nuclear waste packages**
- **Archaeology: Imaging inside precious artifacts and objects**

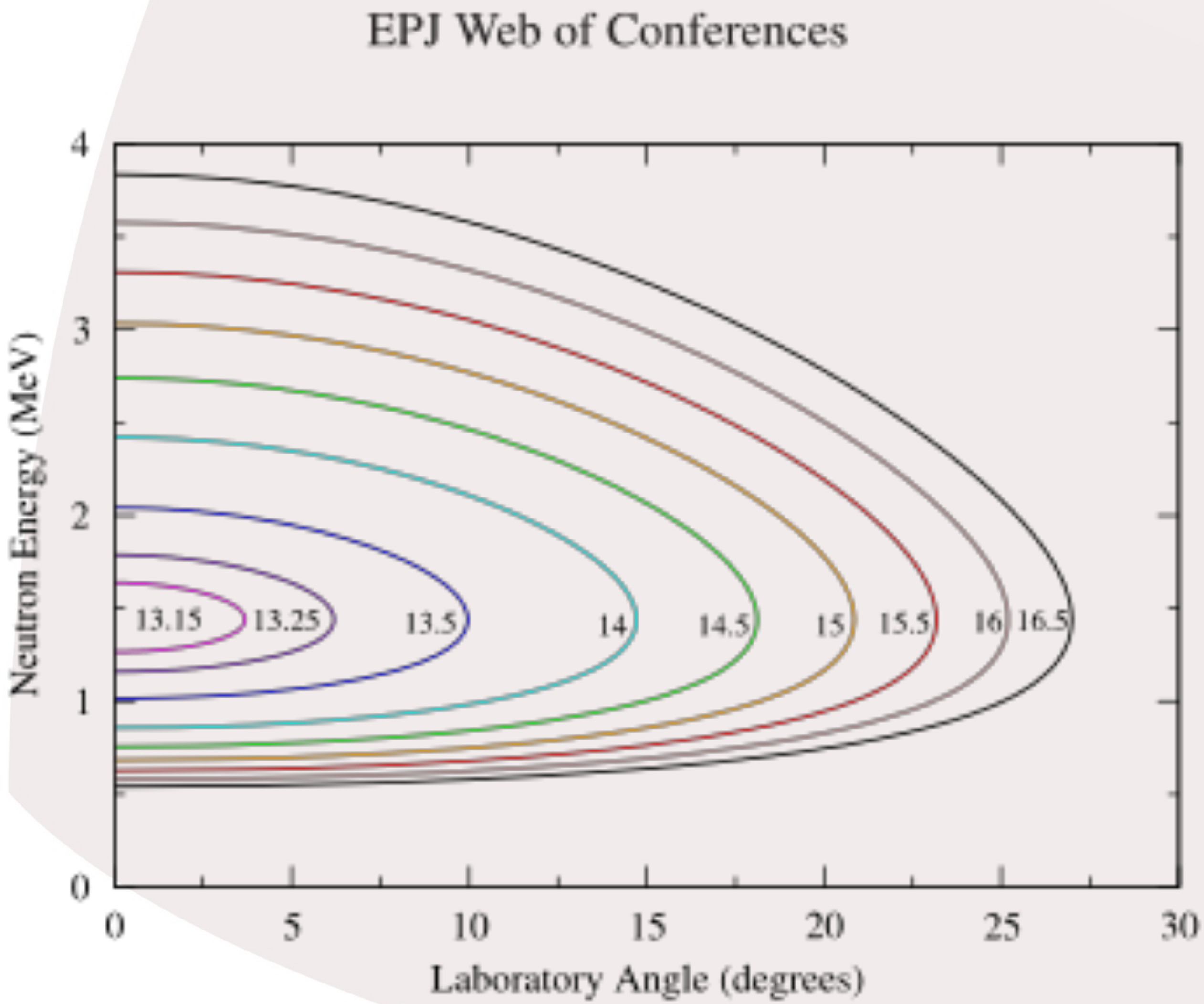
Collaboration with: IPN Orsay, University of York, IRMM, NEDA collaboration
+ Laboratoire d'Archéologie Moléculaire et Structurale

LICORNE II

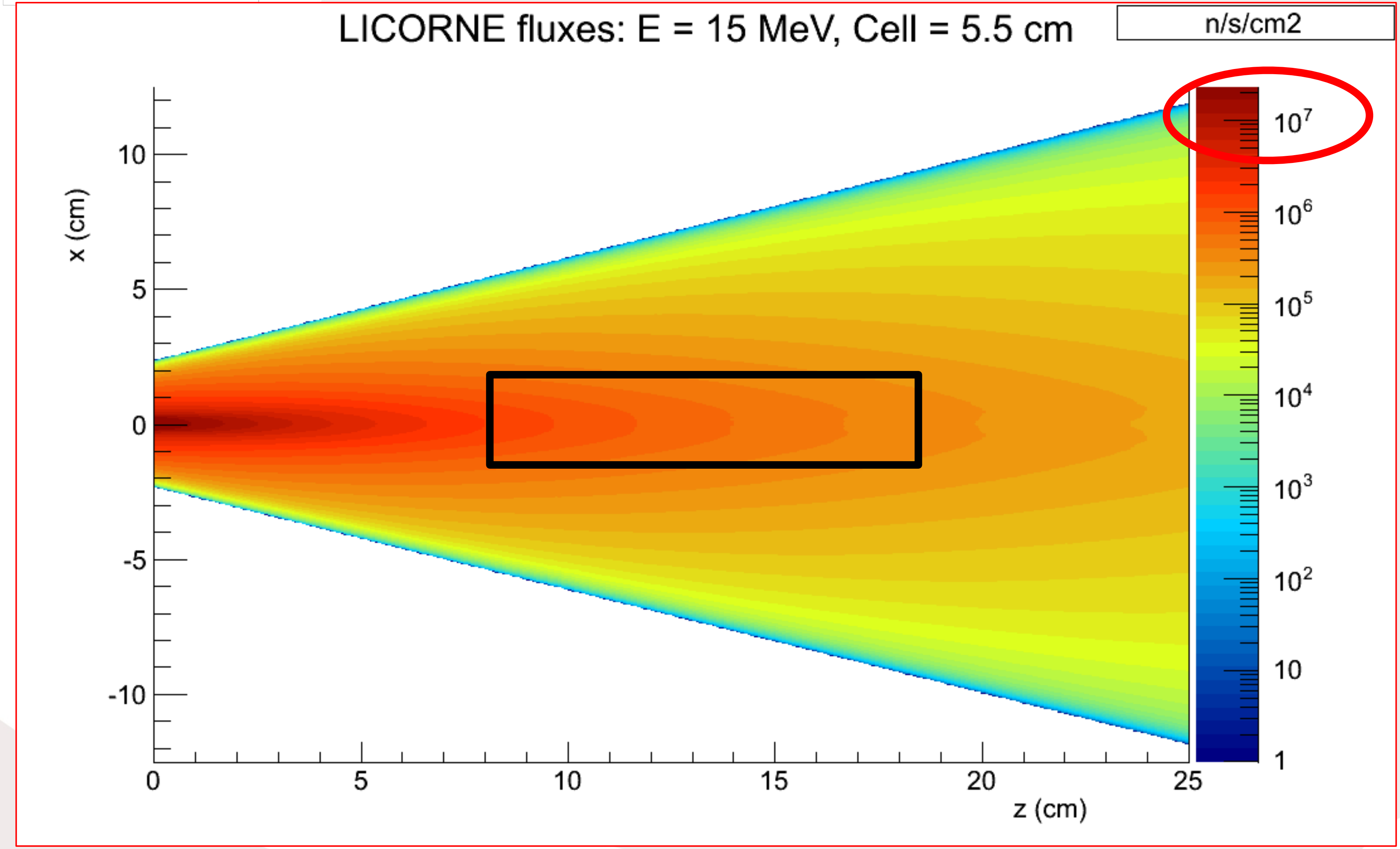
H_2 pressure and low control system

Hydrogen gas cells

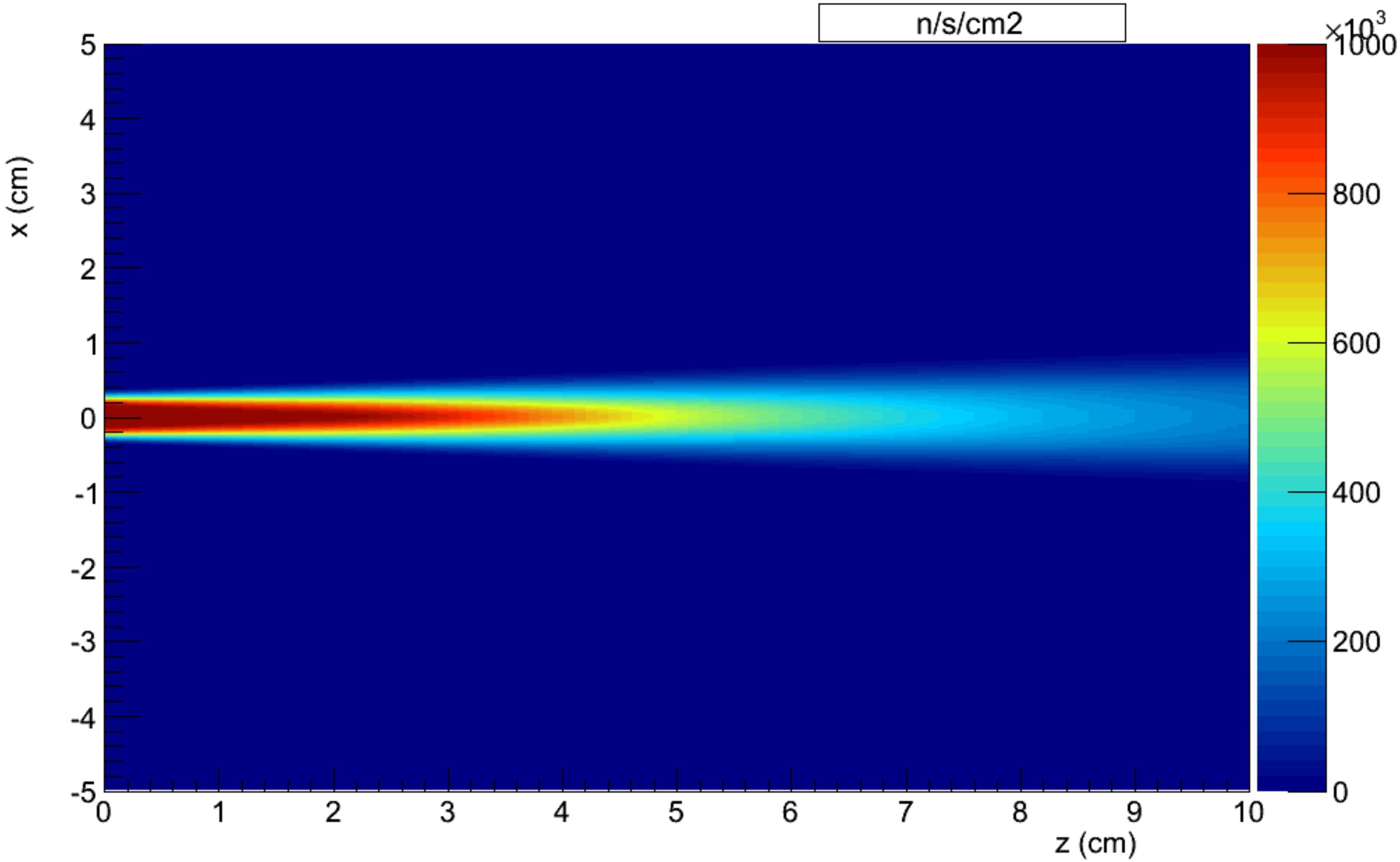
$^{7}Li(p,n)$ reaction kinematics



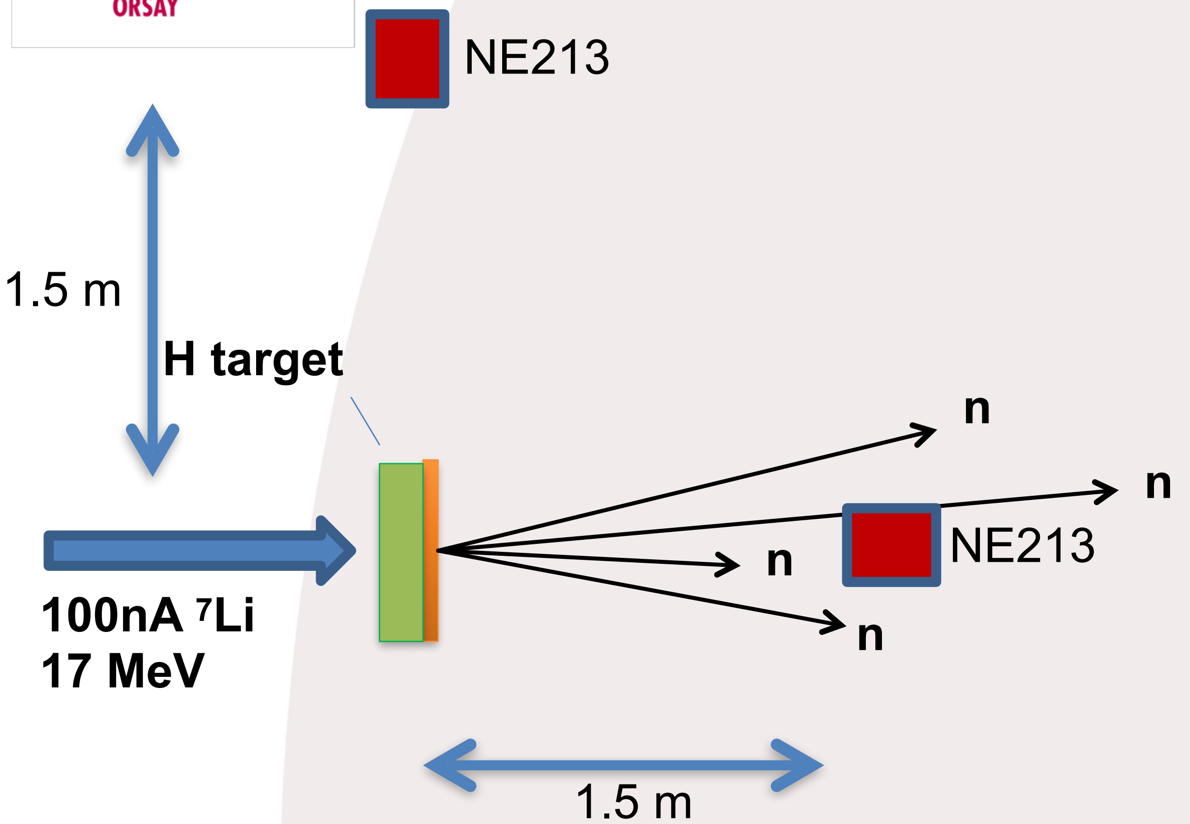
AVAILABLE FLUXES

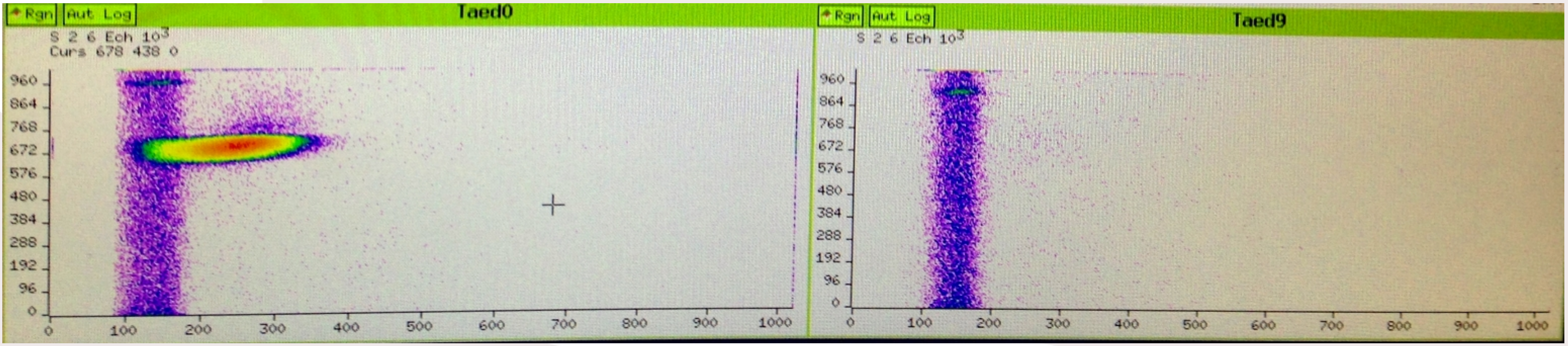


LICORNE fluxes: E = 13.15 MeV, Cell = 2 cm

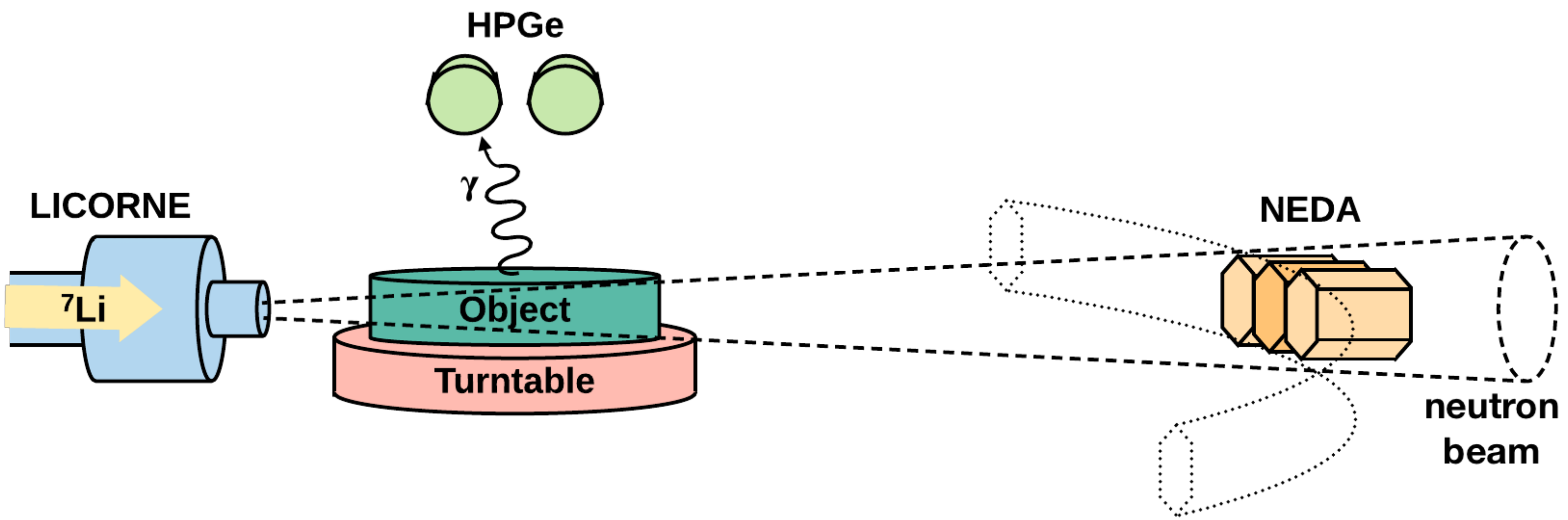


NEUTRON SUPRESSION AT 90 DEGREES



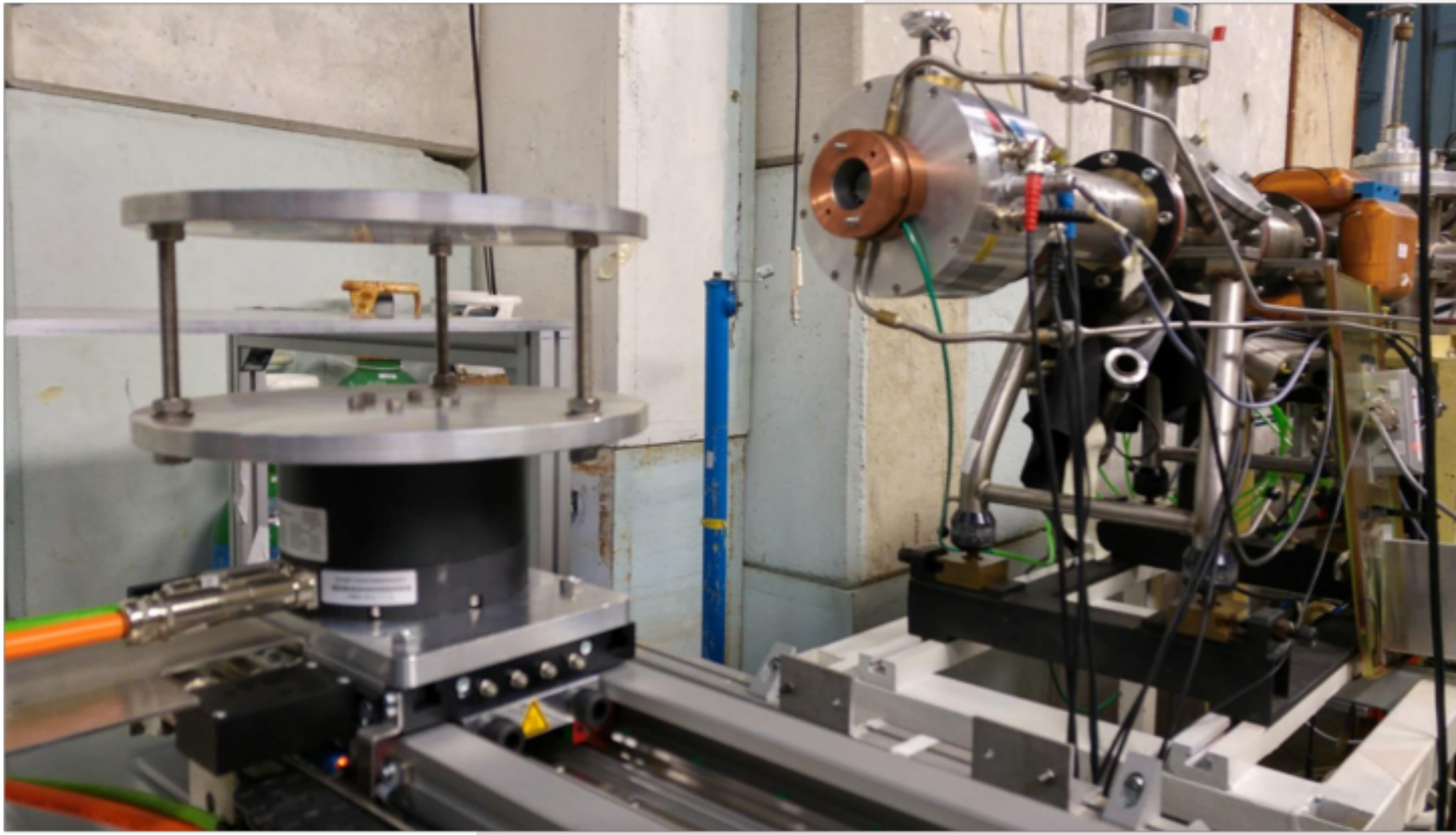


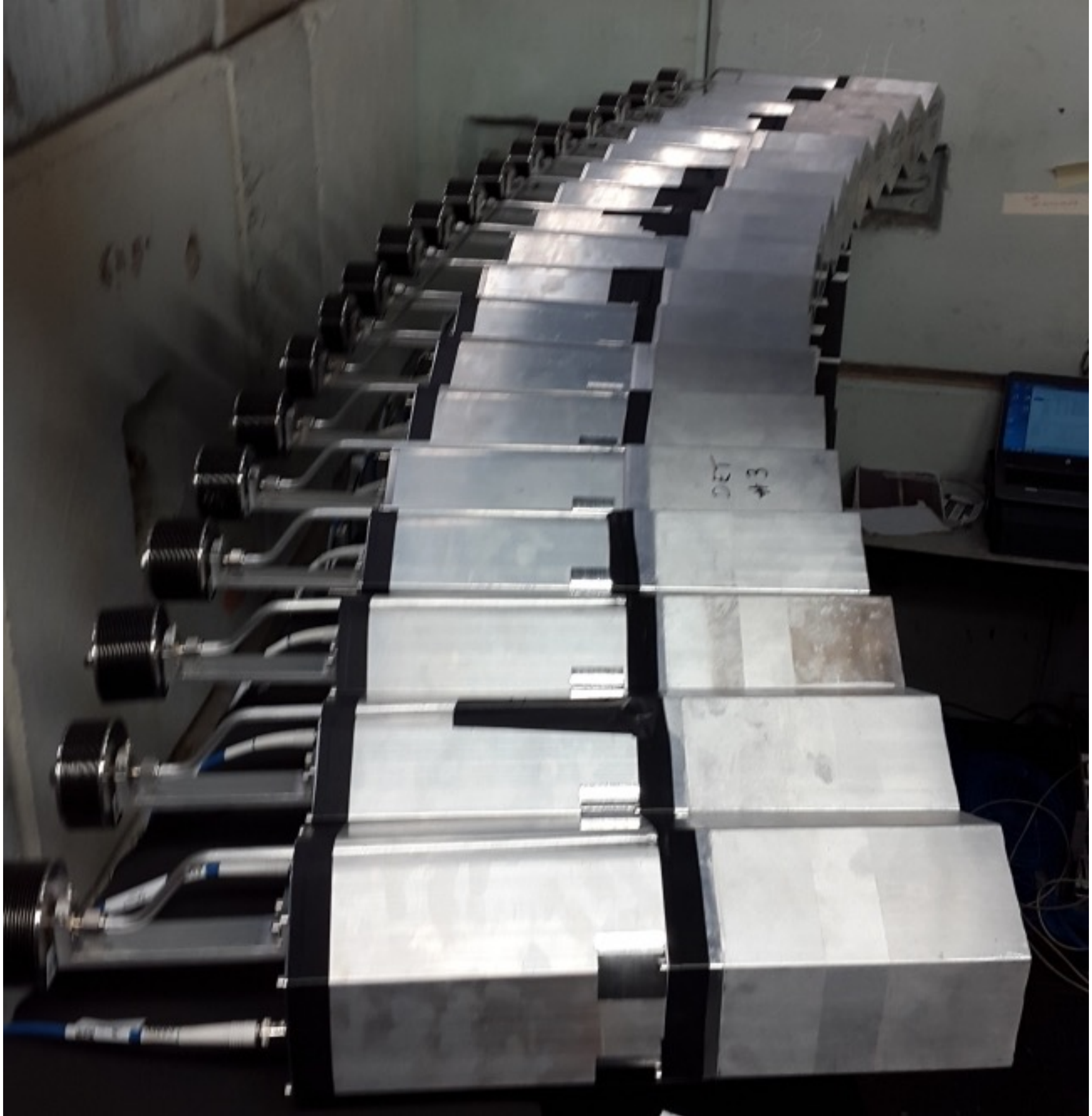
Setup



LICORNE: inverse kinematic reaction p(^{7}Li,n)^{7}Be, strong collimated neutron beam

NEDA: arc of 19 neutron detectors

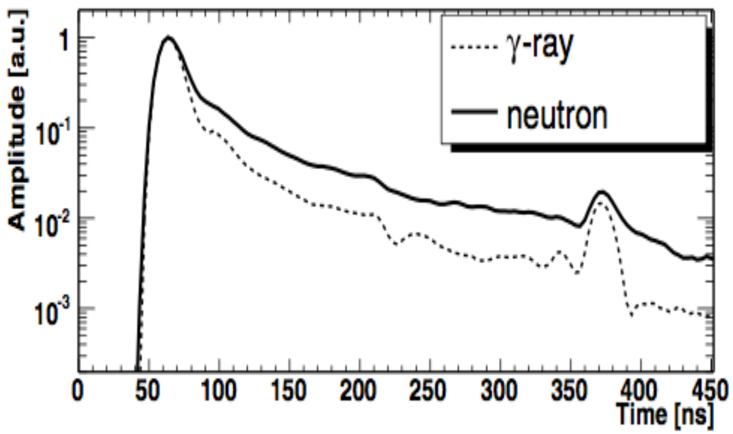


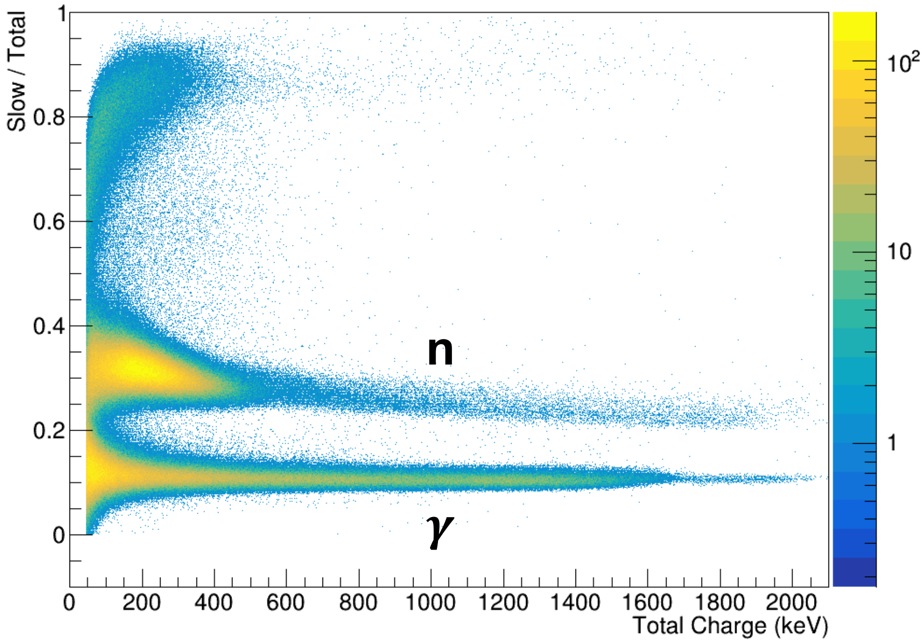


Arc of NEDA liquid scintillator detectors at 5m from the source

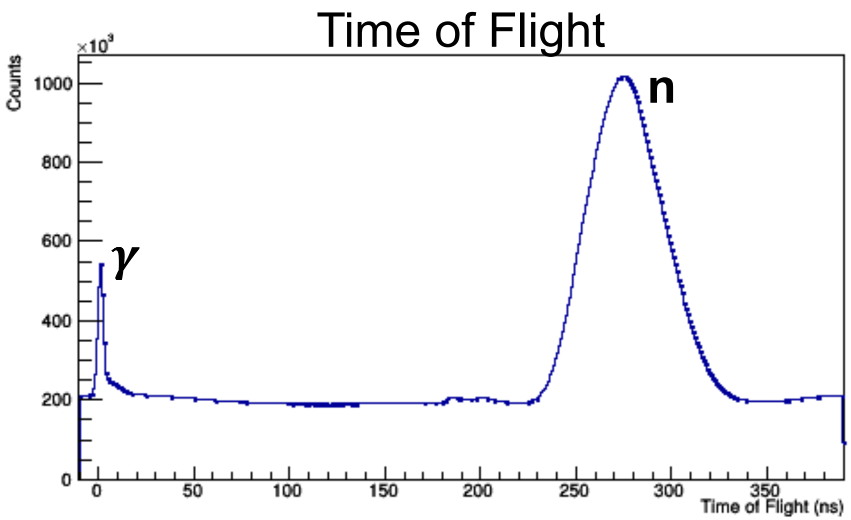
<u>First in-beam use of NEDA</u>

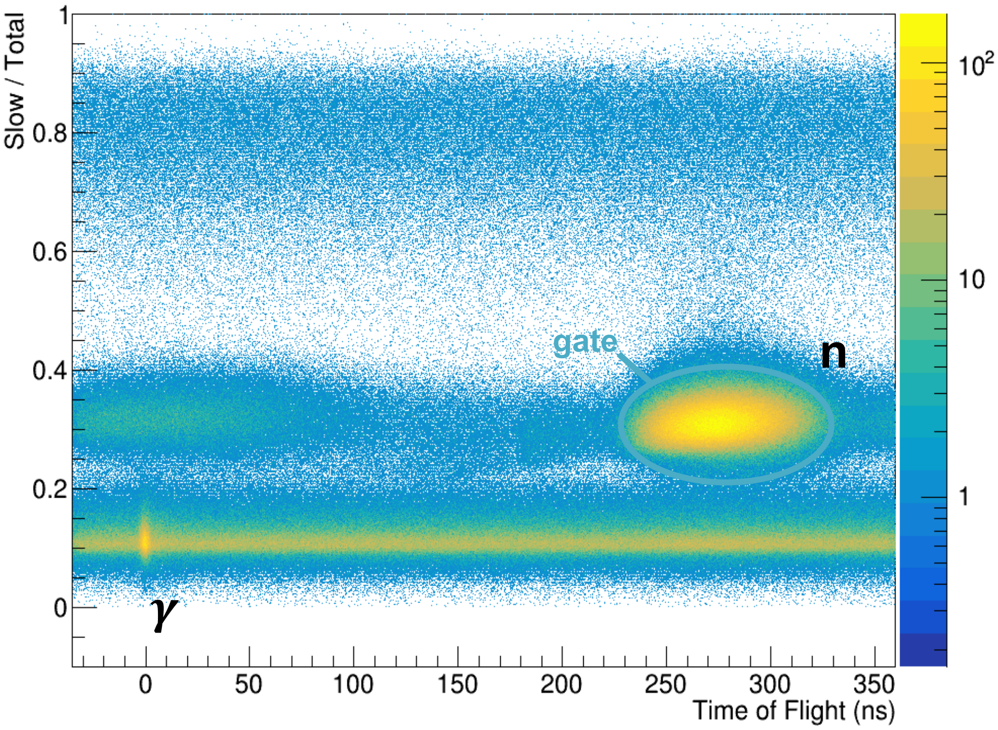
Pulse Shape Analysis



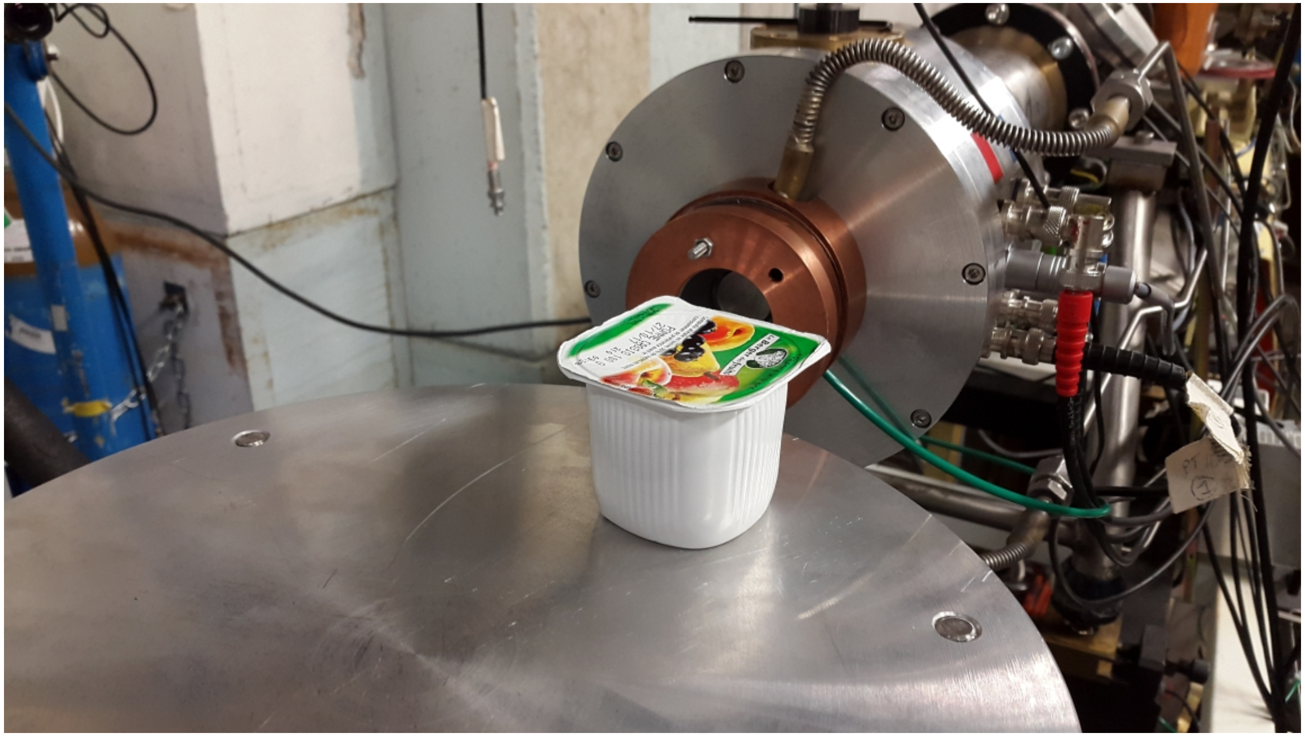


PSA vs TOF

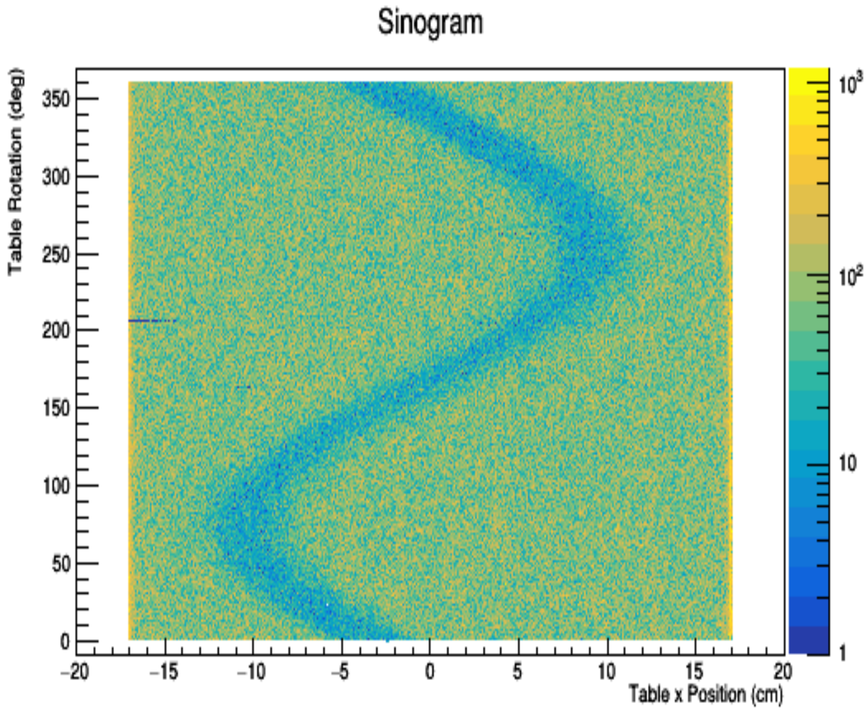

Time of Flight
×10³
Counts
1000
800
600
400
200
0
0
50
100
150
200
250
300
350
Time of Flight (ns)
γ
n


Slow / Total
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
350
Time of Flight (ns)
10²
10
1
gate
n
γ

Neutron Image Reconstruction - Compote



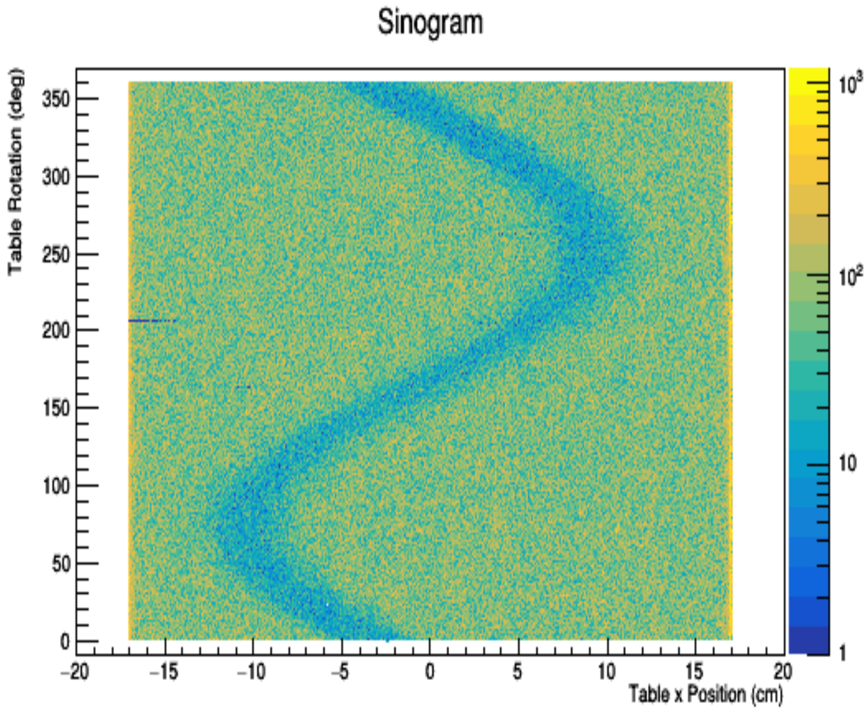
Neutron Image Reconstruction - Compote

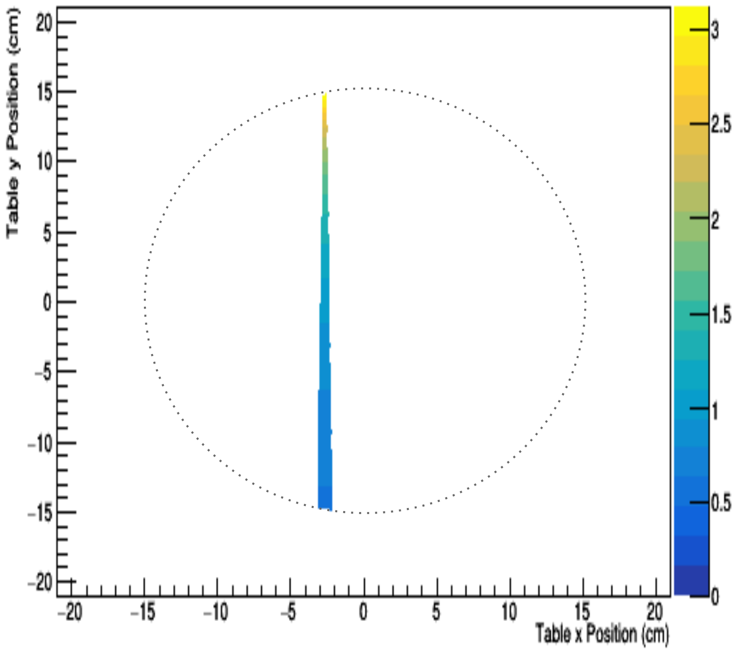


1x10⁷ events

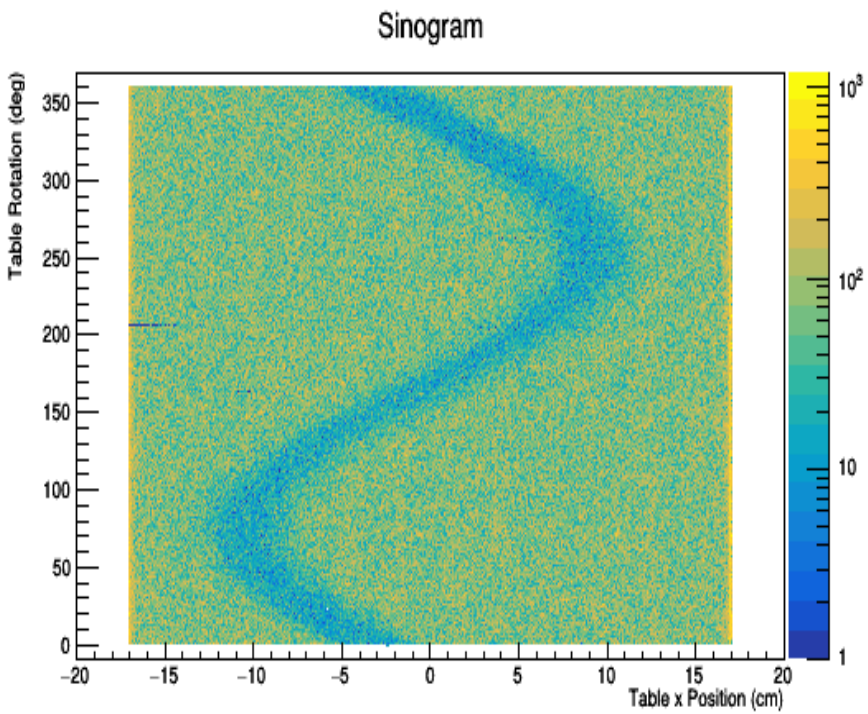
- 6h run
- 1 translation/min
- ^{7}Li primary beam: 16.30 MeV
- Central NEDA detector

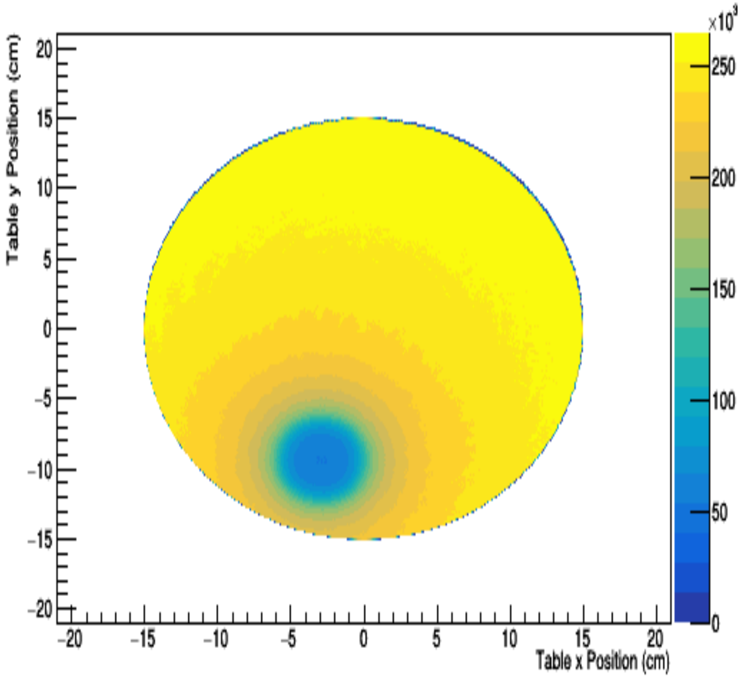
Neutron Image Reconstruction - Compote



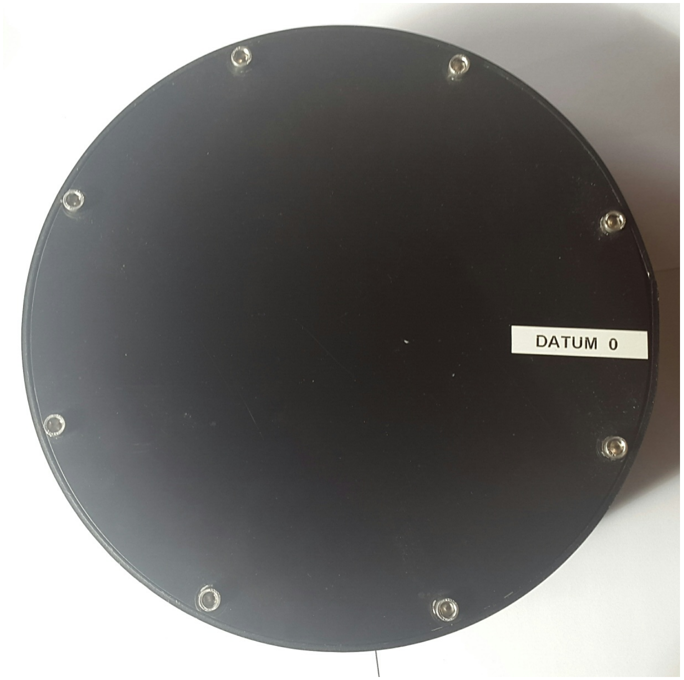


Neutron Image Reconstruction - Compote

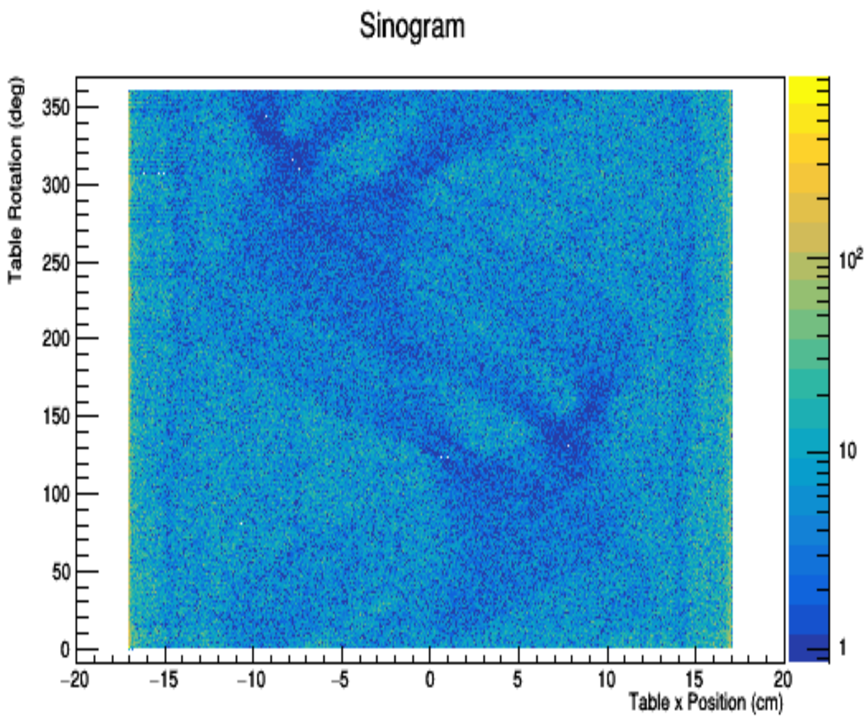




Neutron Image Reconstruction - Object 1



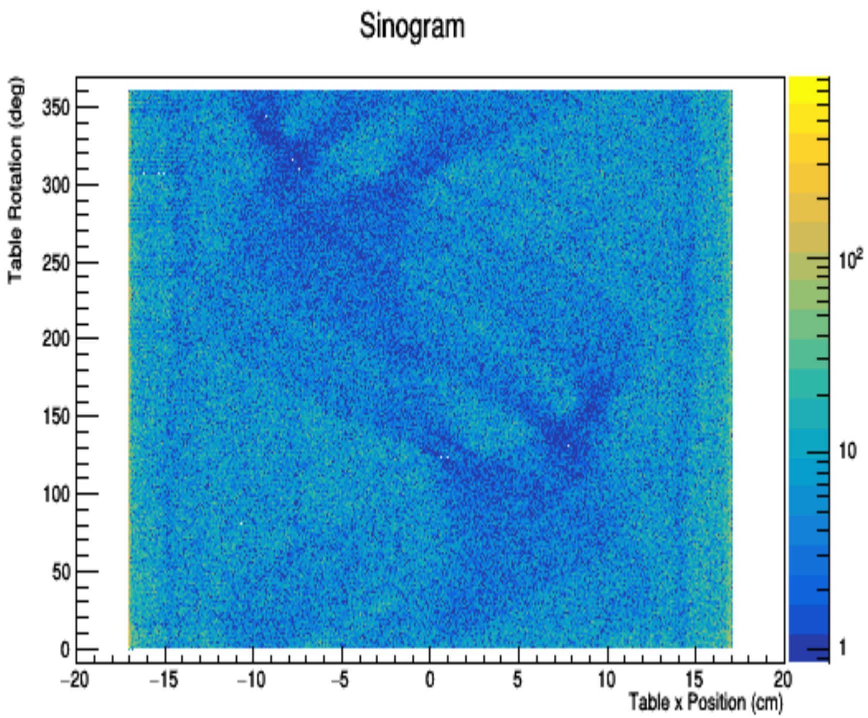
Neutron Image Reconstruction - Object 1



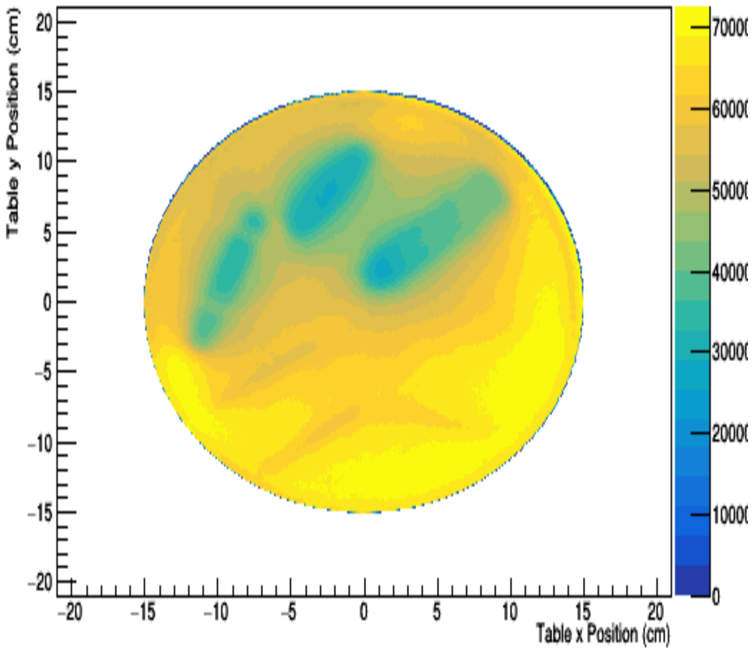
6x10[6] events

- 6h run
- 1 translation/min
- ^{7}Li primary beam: 15.25 MeV
- Central NEDA detector

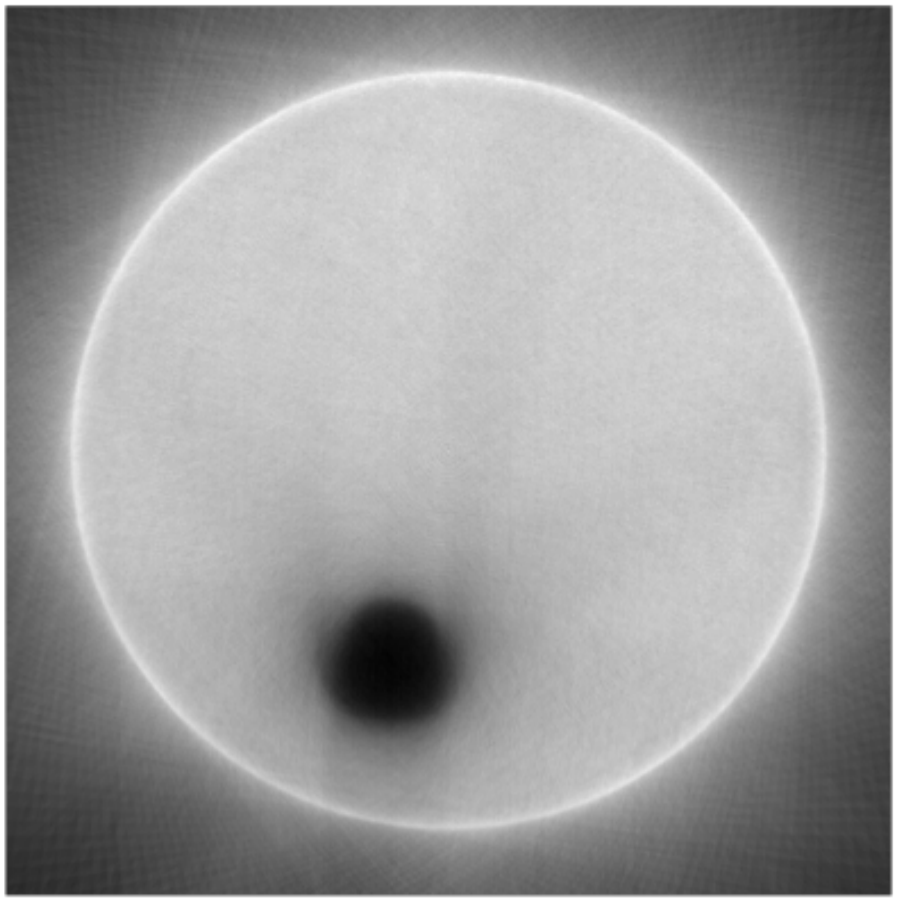
Neutron Image Reconstruction - Object 1

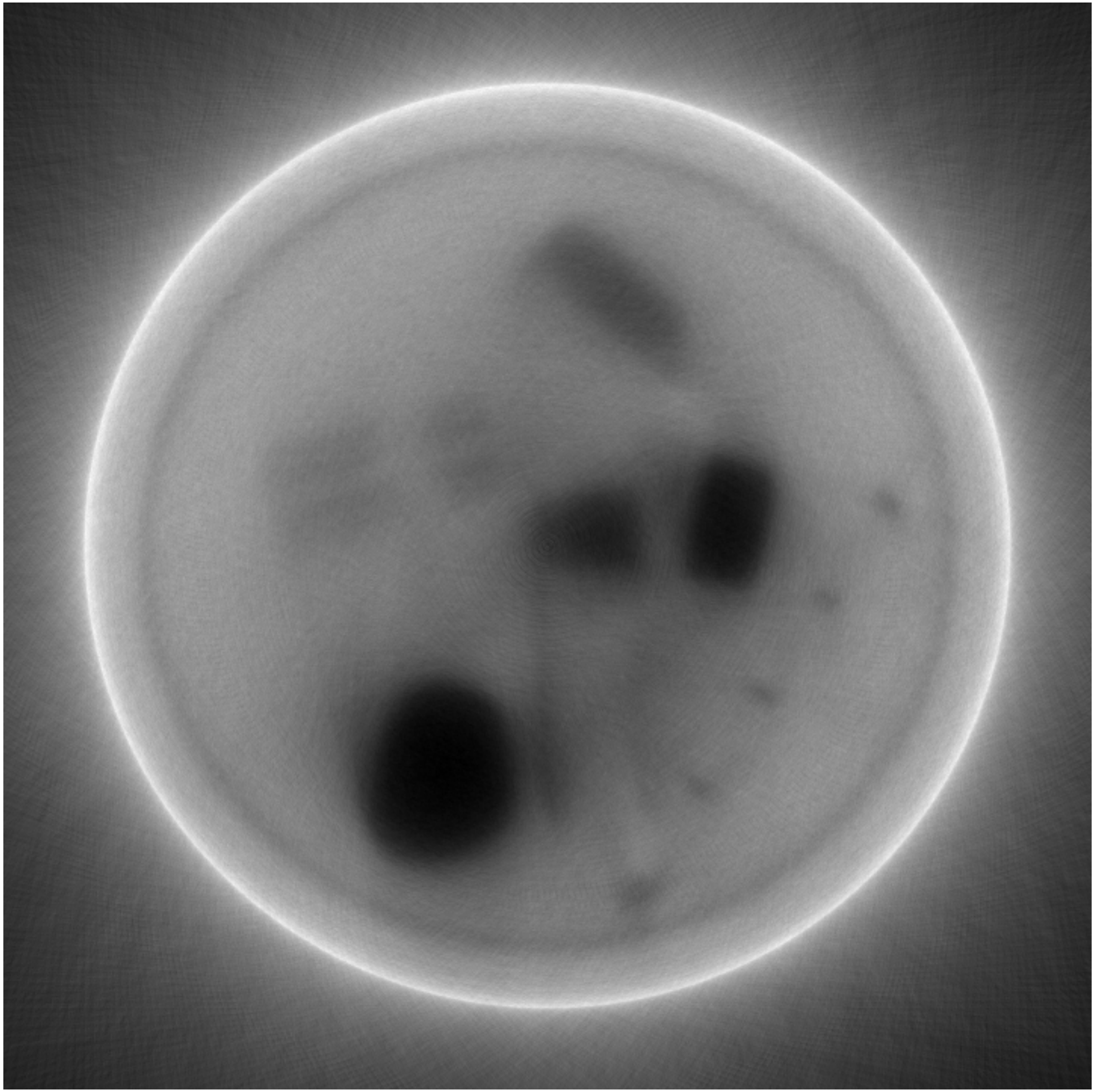


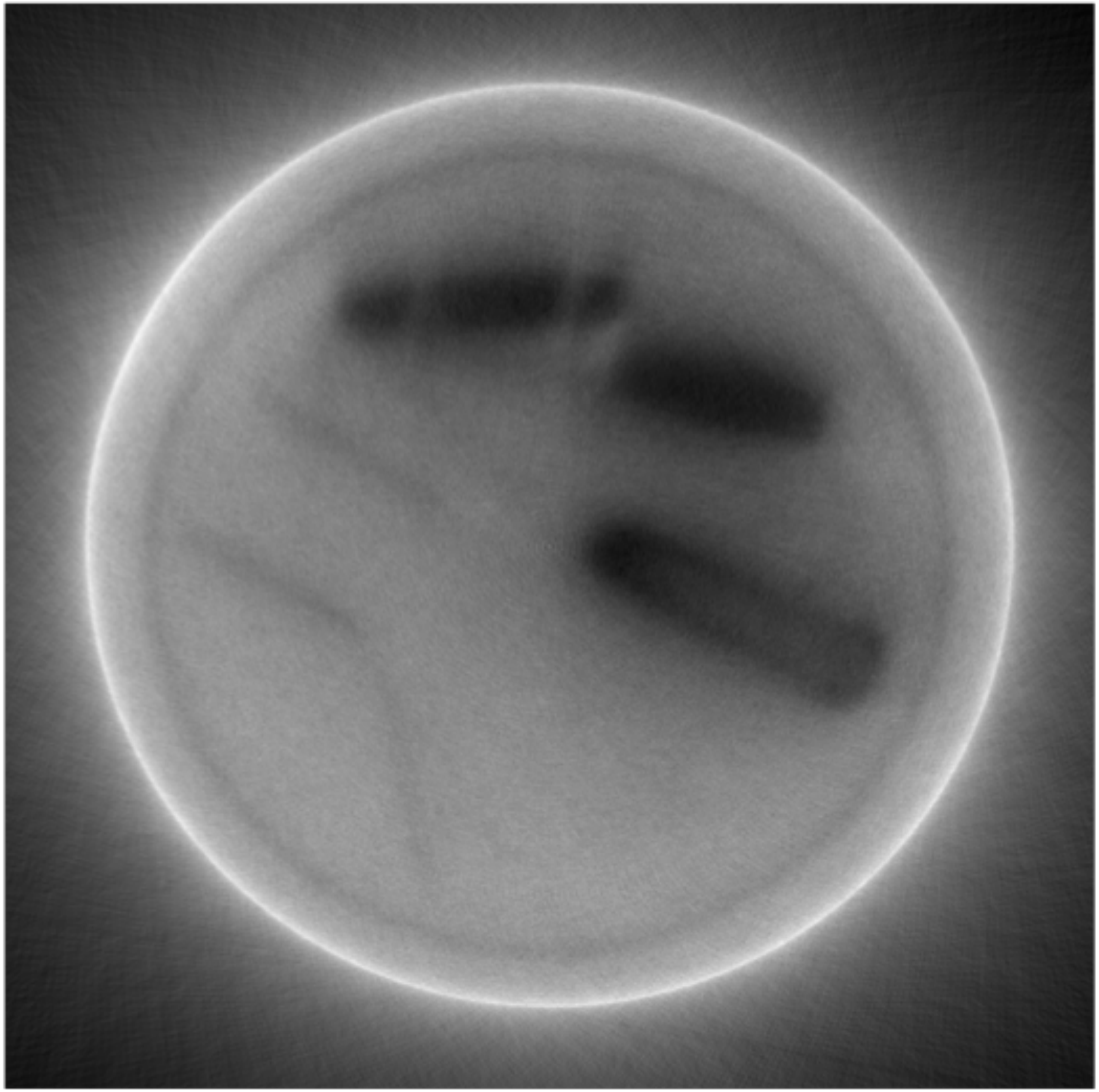
6x10⁶ events



Application of ’TomoPy’







Conclusions

- Fast neutron tomography demonstrated with LICORNE beam
- First “in-beam” tests of NEDA
- Internal composition of objects reconstructed using back-projection and standard TomoPy algorithms
- Data available for others to analyse/improve algorithms
- IP relevant to some aspects of analysis to be protected
- Plans to further develop technique in the coming year – likely request for further support from NEDA collaboration