FROM RESEARCH TO INDUSTRY

cea

Sonate

NEUTRONS FOR MATERIALS SCIENCE

îledeFrance

www.cea.fr

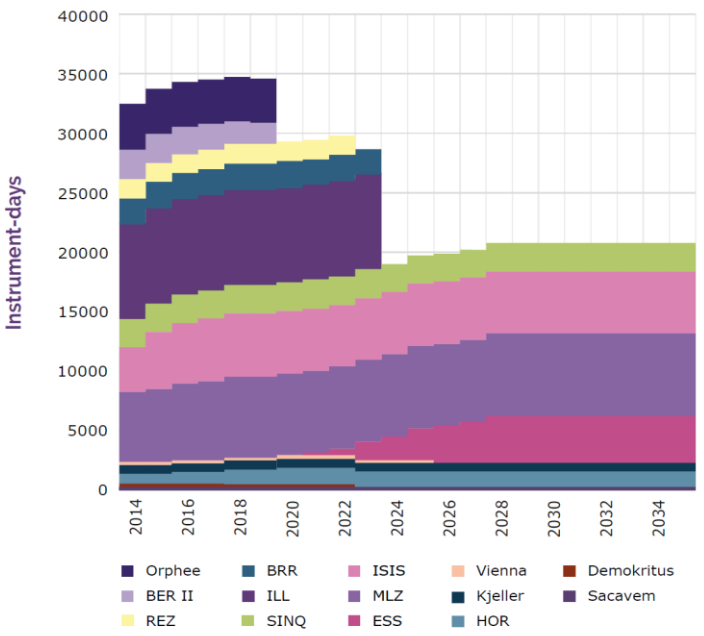
Laboratoire Léon Brillouin CEA/CNRS
IRFU, CEA
Université Paris-Saclay
CEA Saclay 91191 Gif-sur-Yvette France

Years 2000: Golden Age in Europe

- >30000 Instrument.Days for a community of 6000-8000 users

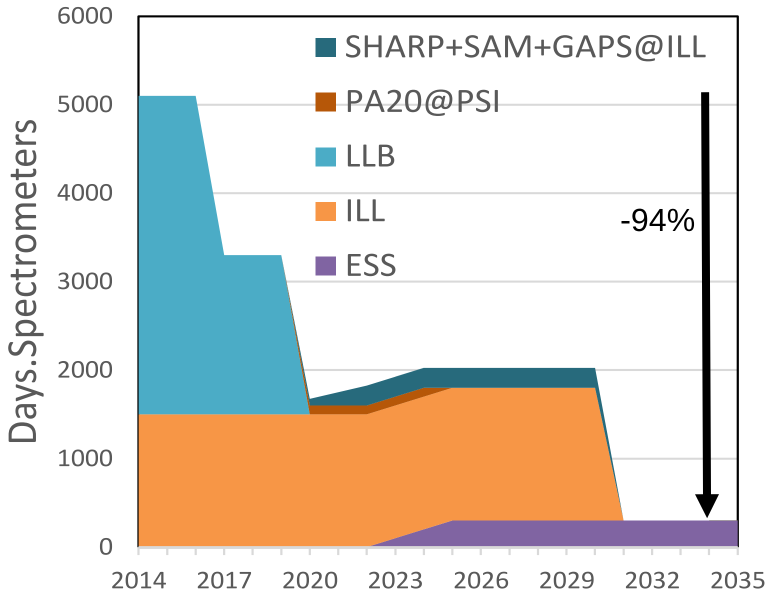
Neutrons in Europe

(baseline ERFRI scenario)



ESFRI Report, *Neutron scattering facilities in Europe, Present status and future perspectives, 2017*

in France



The IPHI – Neutrons demonstrator

Objective:

→ Test the different key elements of a compact source

- Accelerator — I_{peak} > 60mA
- Target — Lifetime ~1000 – 2000 hours (at 50kW)
- Moderator — Produce thermal and cold neutrons
- Instruments

The SESAME "*IPHI – Neutrons*"

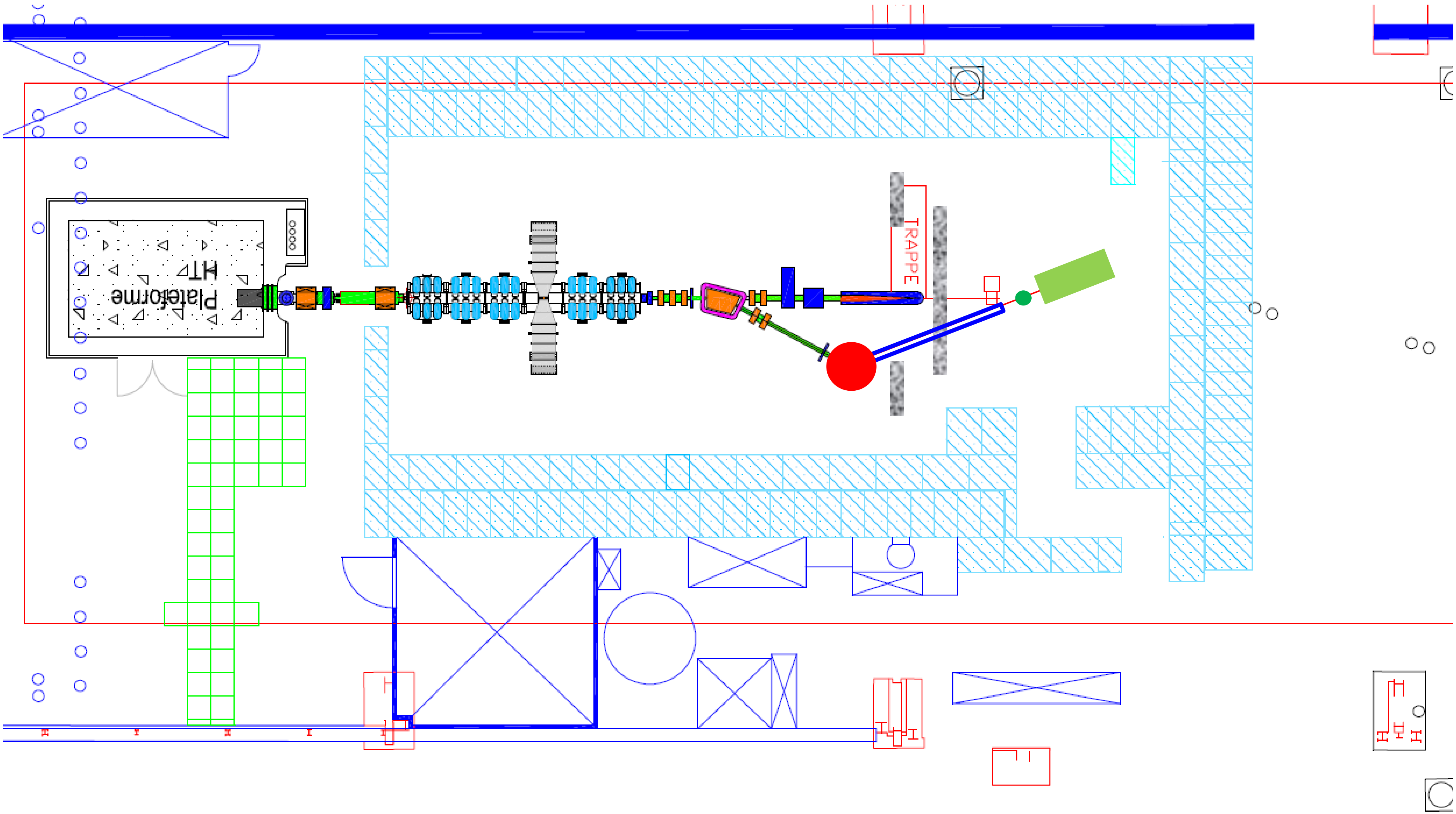
- 2018-2020
- Operation at 50kW (E_p = 3MeV) on a beryllium target
- A "generic" scattering instrument

Orphée Laboratoire Léon Brillouin

2020 GOAL

îledeFrance

IPHI - Neutrons

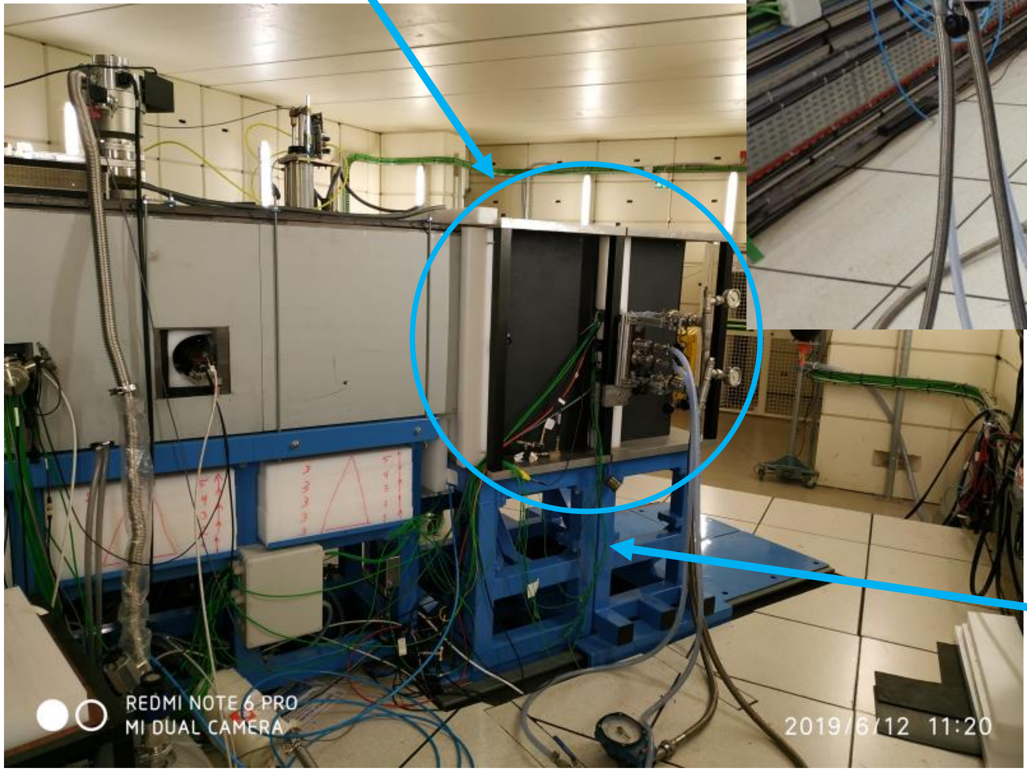


1 « generic » instrument : SANS, réflectomètre, imagerie, diffraction

Measurements on samples – prrof of concept - performances

TARGET - MODERATOR – SHIELDING

Target – moderator – shielding box



Target

TMR mounted on 2 trolleys
for an « easy opening »

TARGET TESTS SPRING 2019

Operation at 3kW power on the target

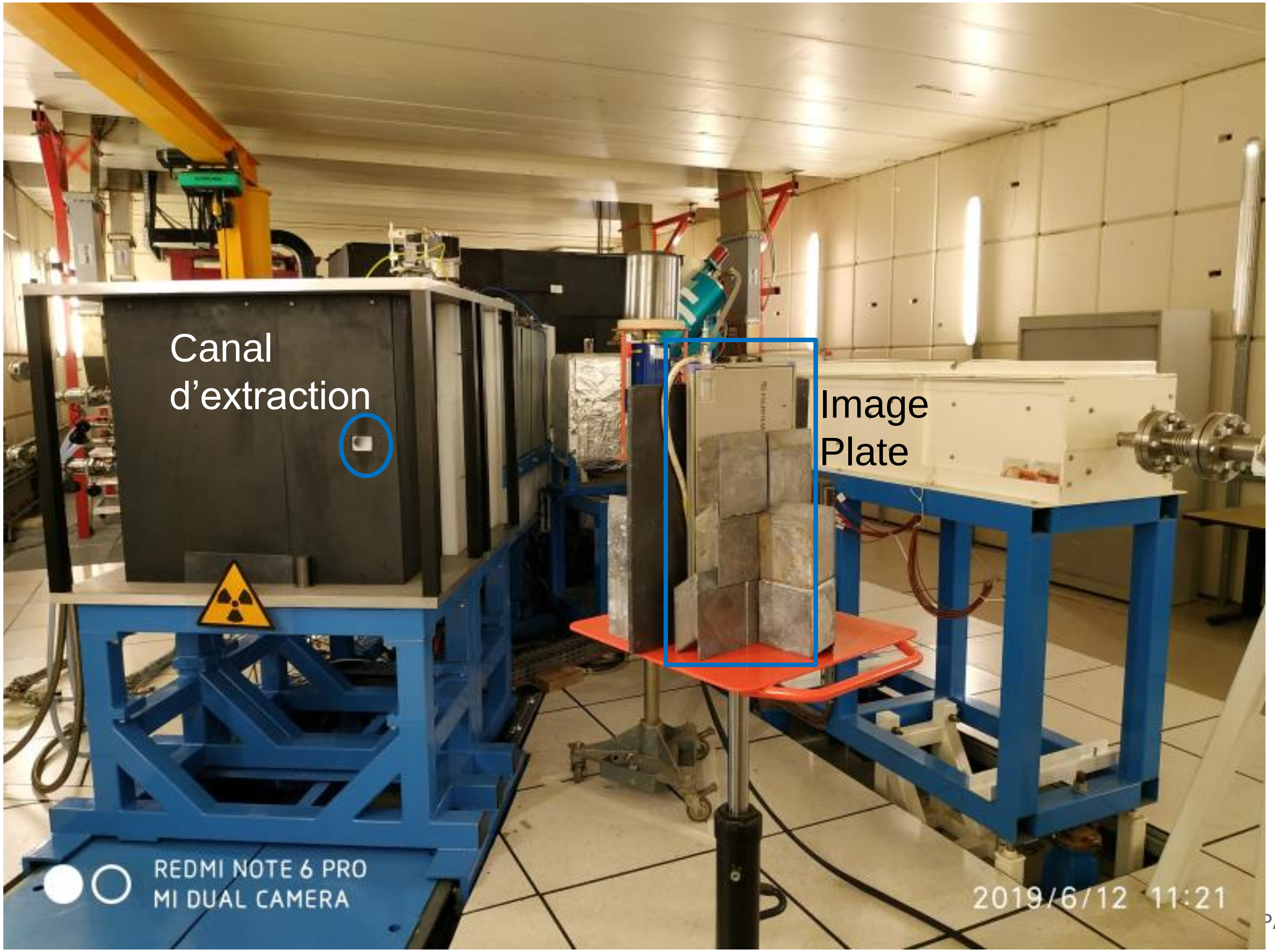
- E_p = 3MeV, peak current 20mA, pulse length 2850µs, frequency 17Hz
- Average power density on the target 650W/cm² (in the center of the target)
- Peak power in a pulse = 60kW
- Operation at high temperature (500°C) to promote the diffusion of implanted protons

Mai – June 2019

→ Operation for more than 50 hours at 3kW (over ~2 weeks)

- Average proton current = 0.9mA
- Proton fluence on the target ~ 50mA.heures ~ 8×10^{20} protons/m²
- On-line optical control of the target state
  - No visible change of the surface roughness
- 8-9 hours operation per day

« RADIOGRAPHY » SETUP

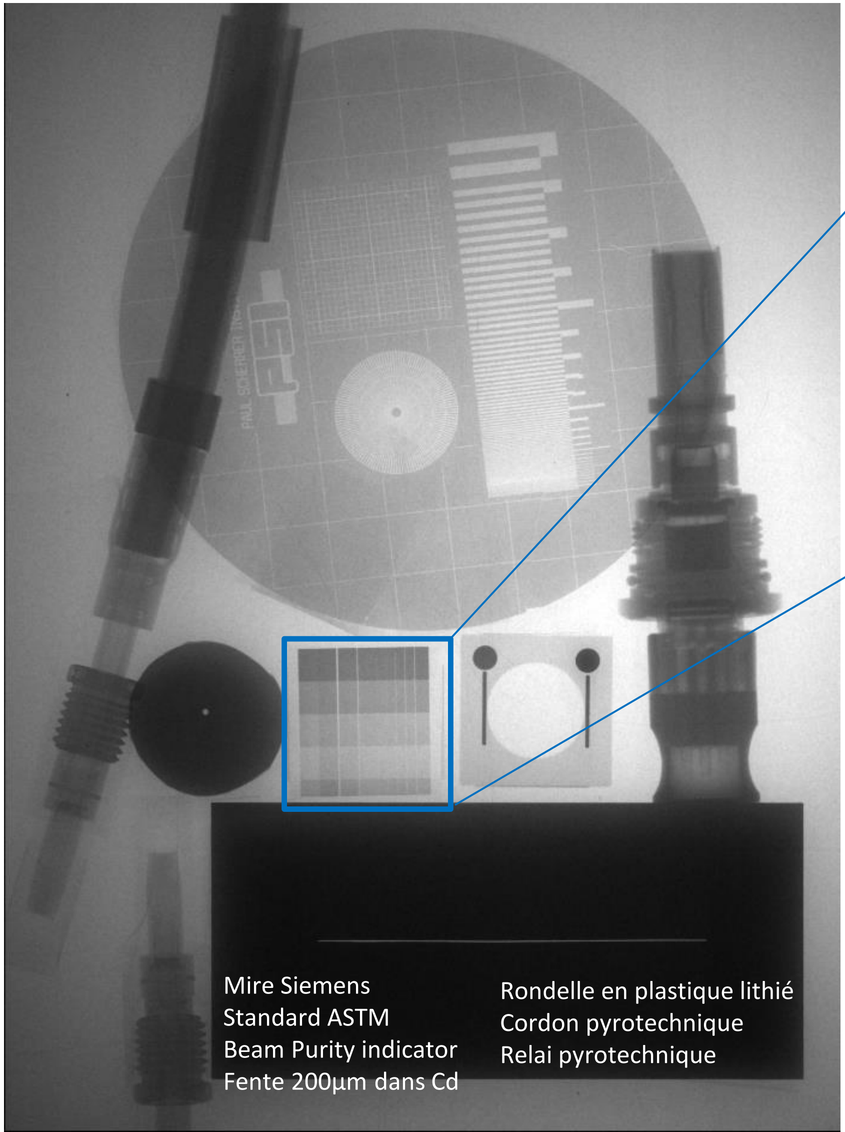


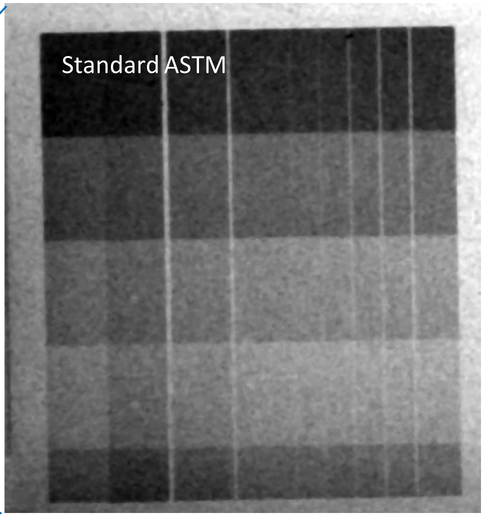
RADIOGRAPHY SETUP

Image Plate mounted behind a lead shield

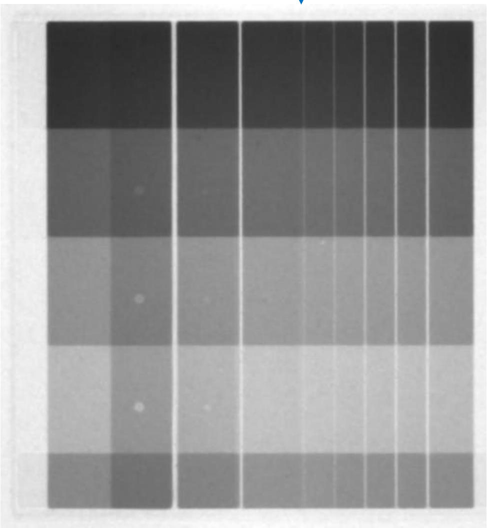
NEUTRON RADIOGRAPHY

IPHI 1hour at 3kW





Spacer 15µm



G45 « standard conditions » (P = 14MW)

UPGRADES FOR RADIOGRAPHY

Short term (2020) — Gain

- Use of the MCP detectors
  - Gain in detection efficiency — 5
  - Gain in spatial resolution
- Use of a cold source — 2
- Beam power increased from 3kW to 50 kW — 10
  - Some losses in engineering design (x0.6)
  - Average current of 17mA

→ from 1 hour to 36 seconds or better statistics

Long term (SONATE)

- Increase of the proton energy to 20 MeV — 15
  - Neutron yield per proton (x200)
  - Some engineering trade-offs (x0.6)
  - Neutrons more difficult to moderate (x0.8)
  - Proton current has to be decreased to 2.5mA to remain in the 50kW enveloppe (x0.15)

TOTAL — x 1500

→ from 1 hour to 2s or better statistics

DIFFRACTION SETUP

Crystal in 4 circles craddle

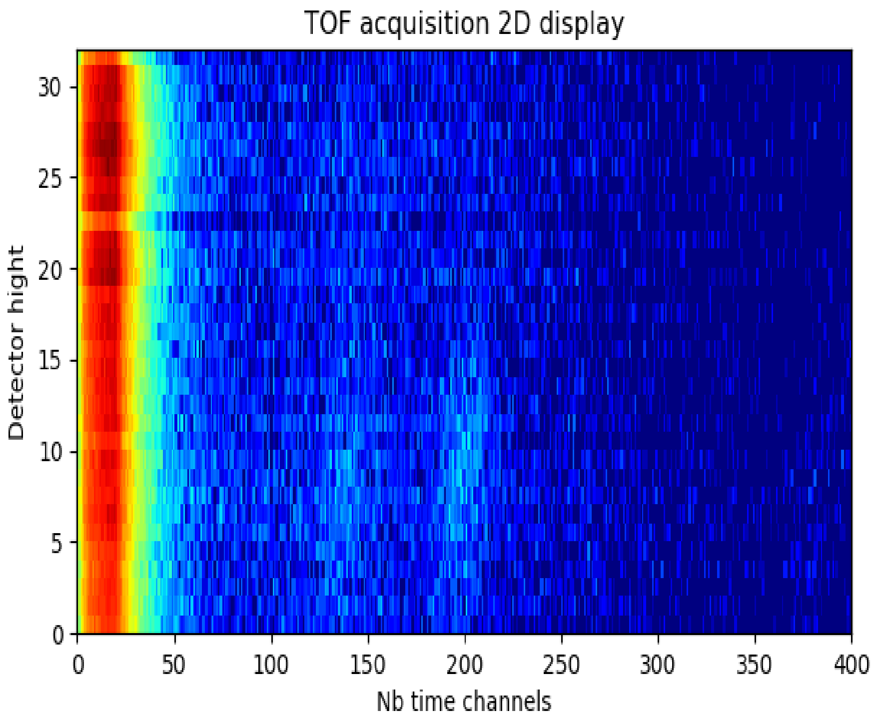
Source

Detector MT32 (30x30cm)

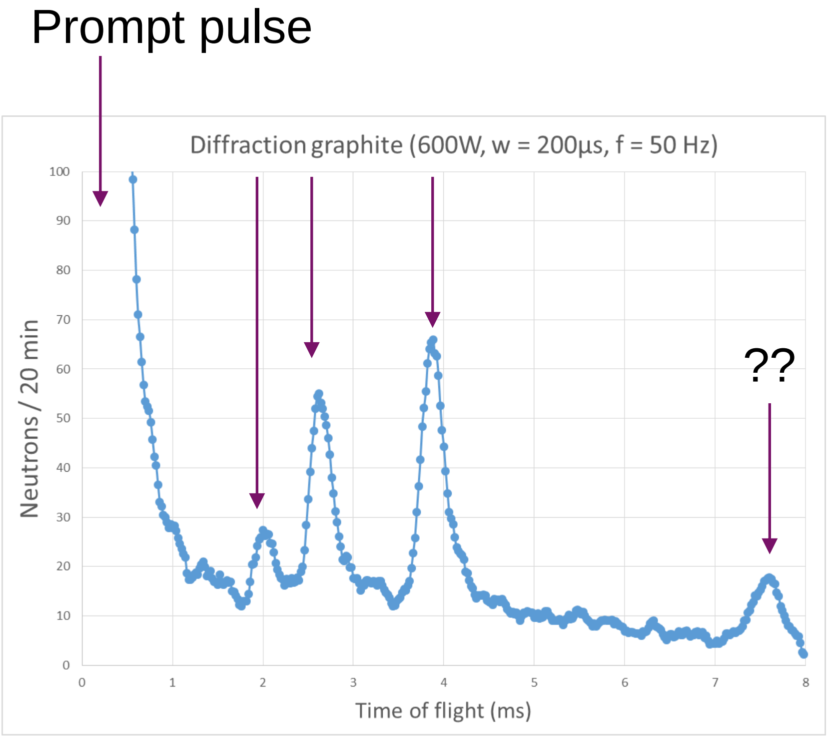
DIFFRACTION

Detector MT32 (32 tubes of 300mm) at 90° from the beam axis

- graphite crystal – no collimation
- 50Hz, 200µs, 600W, 20 min
- Poor efficiency of the MT32 detector for thermal neutrons



Raw data



After integration

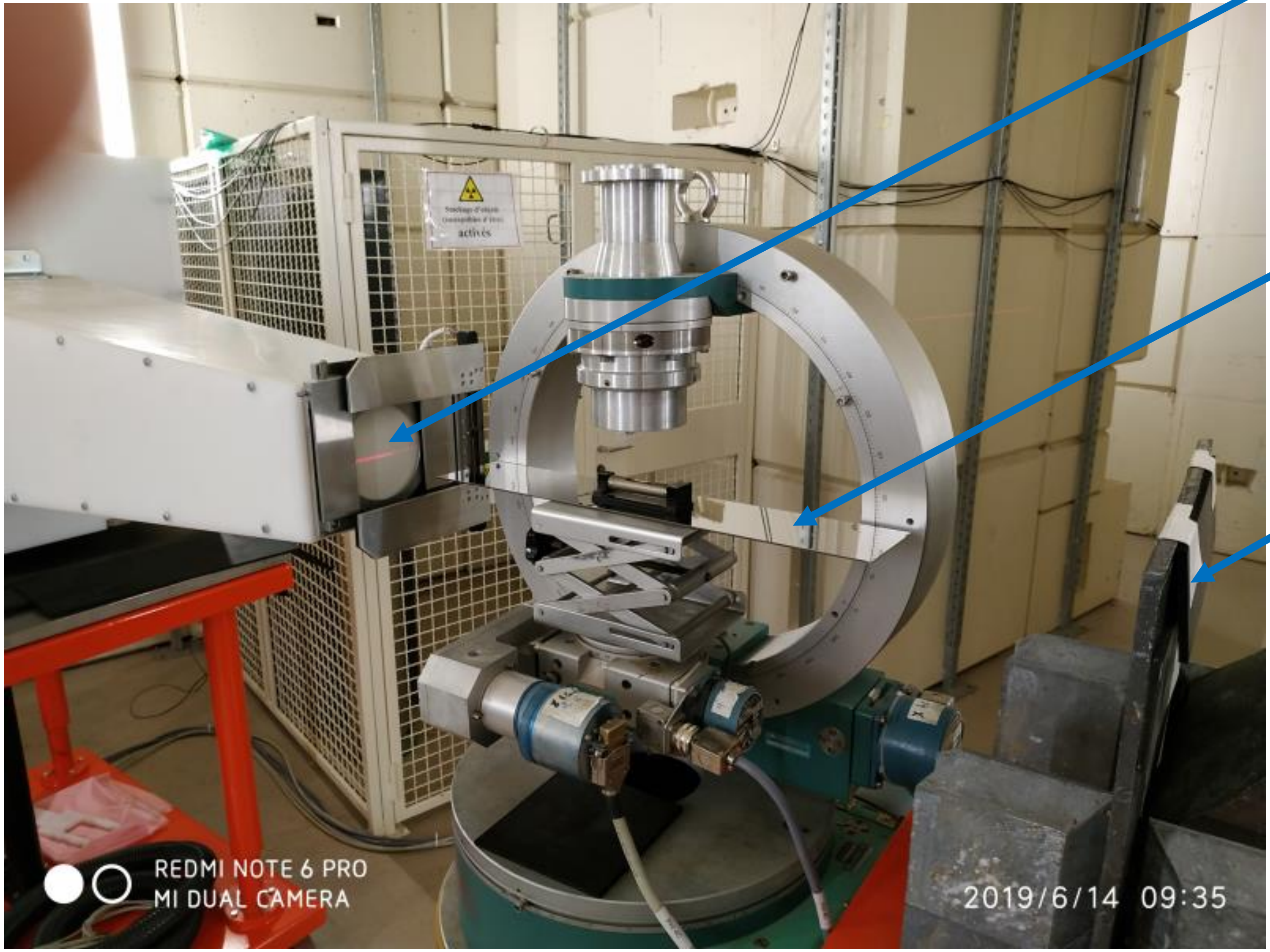
UPGRADES FOR DIFFRACTION

Short term (2020)	Gain
■ Use of the 7C2 detector (256 tubes@20 bars)	
– Detection surface increased from [0.028 sr] to [0.8 sr] (Efficiency is not proportionnal to detector surface though)	(28)
– Efficiency increase % MT32 (very Low efficiency of the MT32 detector for thermal neutrons)	**8**
■ Use of a neutron guide from moderator to sample (6m)	**2**
■ Beam power increased from 3kW to 50 kW	1
– Not possible to increase the duty cycle to keep acceptable resolution	
Medium term (2021)	
■ Use of a statistical chopper	
– Allow using a longer duty cycle while improving the resolution	
■ Beam power increased from 0.6W to 50 kW	**50**
– Some losses in engineering design (x0.6)	
– Possible to achieve good resolution (1%) on a semi-continuous source	
Long term (SONATE)	
■ Increase of the proton energy to 20 MeV	**15**
– Neutron yield per proton (x200)	
– Some engineering trade-offs (x0.6)	
– Neutrons more difficult to moderate (x0.8)	
– Proton current has to be decreased to 2.5mA to remain in the 50kW enveloppe (x0.15)	
TOTAL	$x\ 3.10^5$

Other possible gains: Neutron reflector (x1.7)

The G61 detector set in a vertical position could be used for strain scanning

REFLECTIVITY SETUP



Detector collimator entrance

Neutron mirror

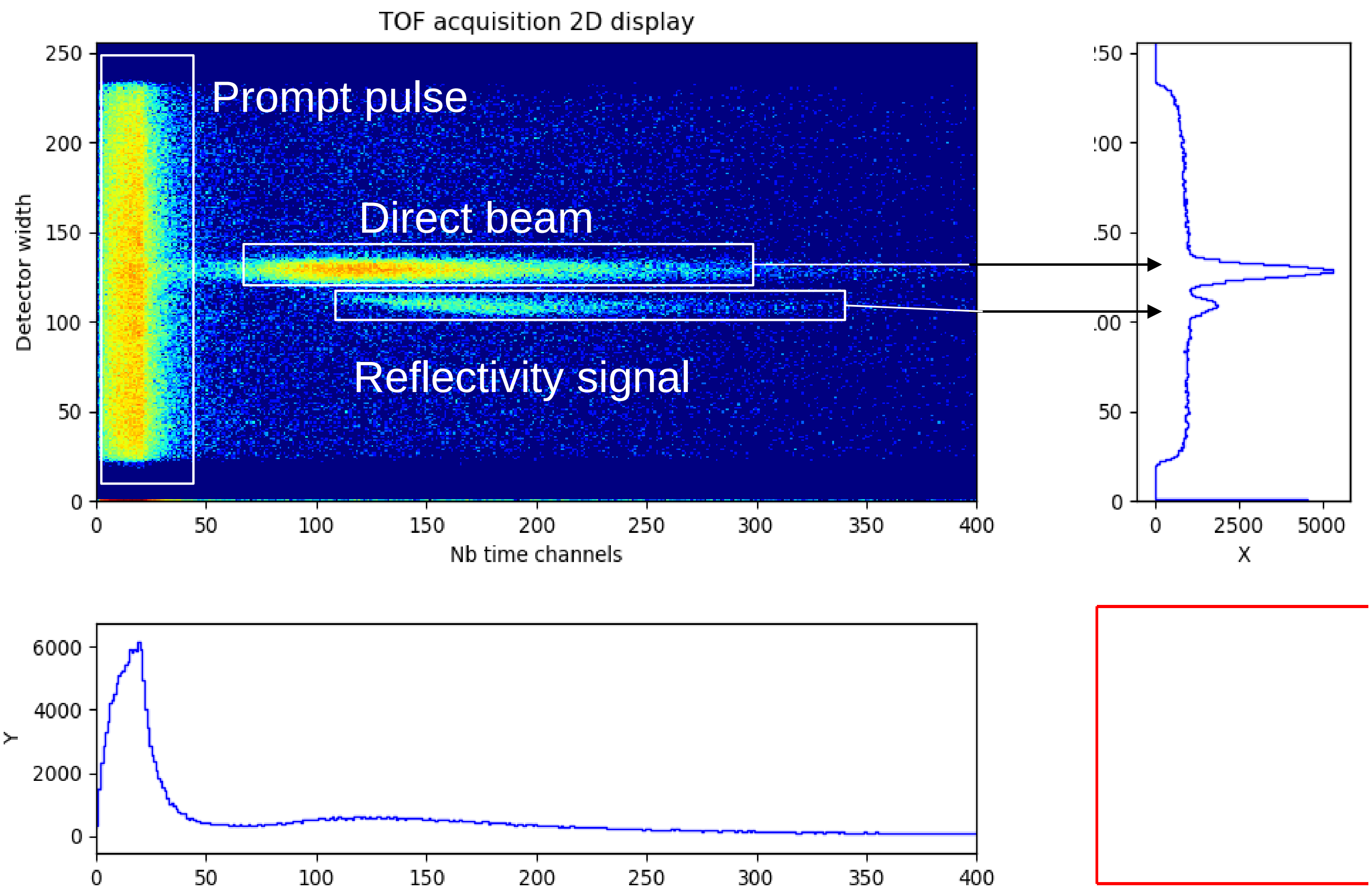
Collimation slit 7mm

Source

REFLECTIVITY

Neutron super-miror

- Operation à 50Hz, 400µs, 1.2kW, 10 min



SANS

Short term (2020)

- Set-up a 50x50cm² detector with a 1cm resolution
  - derived from the 7C2 detector
- Use of a neutron guide from moderator to sample (4m)
- Implement Cold neutrons
  - Otherwise SANS is simply impossible to perform

Medium term

- Multibeam collimation (x4-7)
  - Copy RANS
- Possibility to use thermal neutrons
  - A higher resolution detector would be needed (Bidim26?)

UPGRADES FOR REFLECTIVITY

Short term (2020)	Gain
■ Use of the 7C2 detector (256 tubes@20 bars)	
– Detection surface increased from (0.028 sr) to (0.8 sr)	1
– Efficiency increased % MT32	8
■ Use of a neutron guide from moderator to sample (6m)	2
■ Beam power increased from 3kW to 50 kW	1
– Not possible to increase the duty cycle to keep acceptable resolution	
■ Measuring time increased by a factor 20 (3 hours)	20
■ Use of a cold source	2
– Possiblity to measure smaller samples / better resolution	
– Broader Q-range	
→ Gain	x600

Medium term (2021) (?)

Long term (SONATE)

■ Increase of the proton energy to 20 MeV	100
– Neutron yield per proton (x200)	
– Some engineering trade-offs (x0.6)	
– Neutrons more difficult to moderate (x0.8)	

TOTAL $x\ 6.10^4$

Achievable dynamic range ~ 2.10^{-6} (in 3 hours)

Eventually background limited

Other possible gains: Neutron reflector (x1.7)

ESTIA design

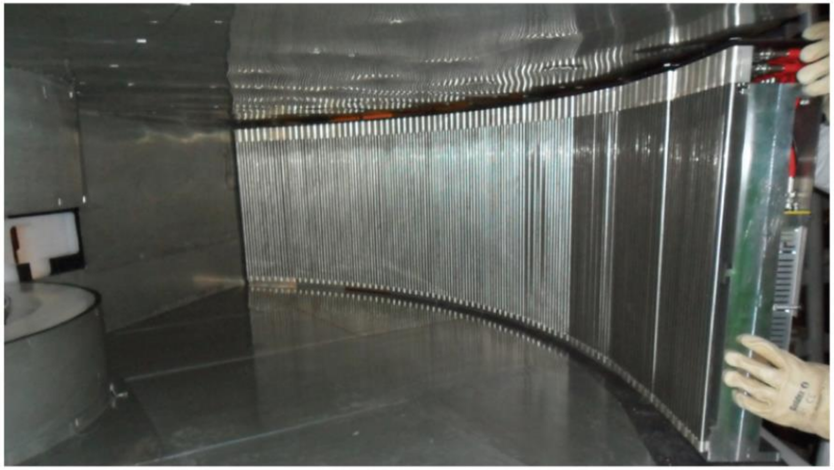
WORKPLAN 2019 - 2020

Fall 2019

- Ramping of the accelerator to 50 kW
- Design of the 50kW target (scaling of the 3kW target design + beam sweeping)
- New thermal PSD detector
- Powder diffraction + (SANS)
- Other tests on ESS devices (monitors, detectors)

Winter 2020

- Shielding improvements
- Scattering spectrometer improvements
  - Neutron guide
  - Collimation slits
- Tests target 50 kW
- Tests cold moderator (para – H_2)

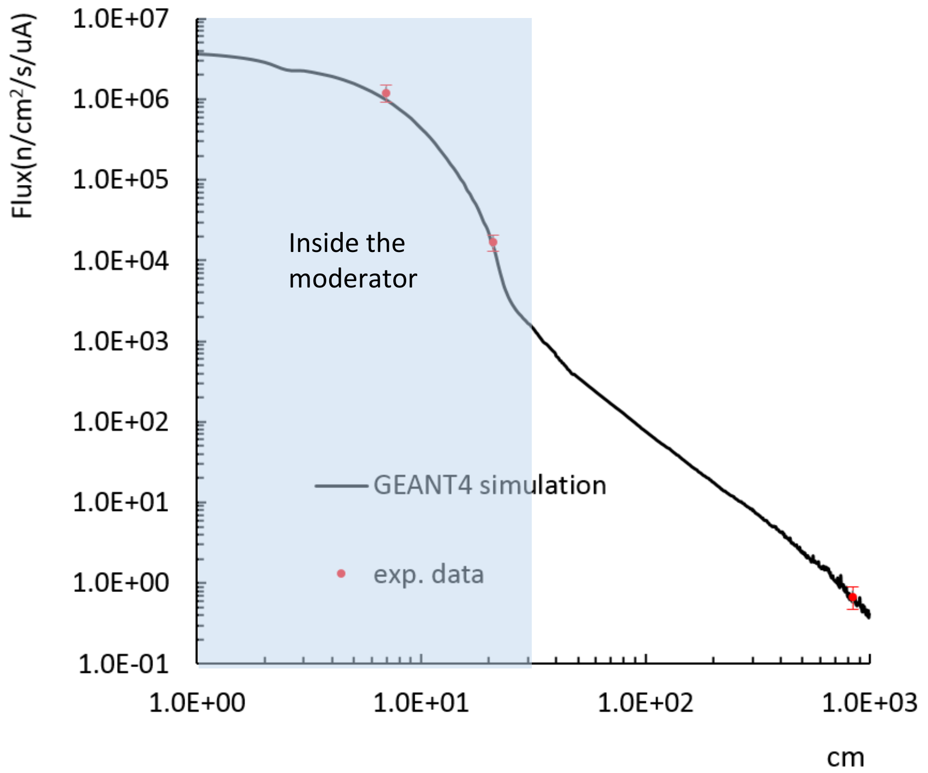


Spring 2020

- Operation [Radiography – Reflectometry – Diffraction – SANS]
- Signal / noise improvements
- CANS Performances Qualifications → extrapolation for SONATE (E_p = 20MeV, flux × 200)

Numerical simulations of the neutron production on a CANS

- MCNP and GEANT4

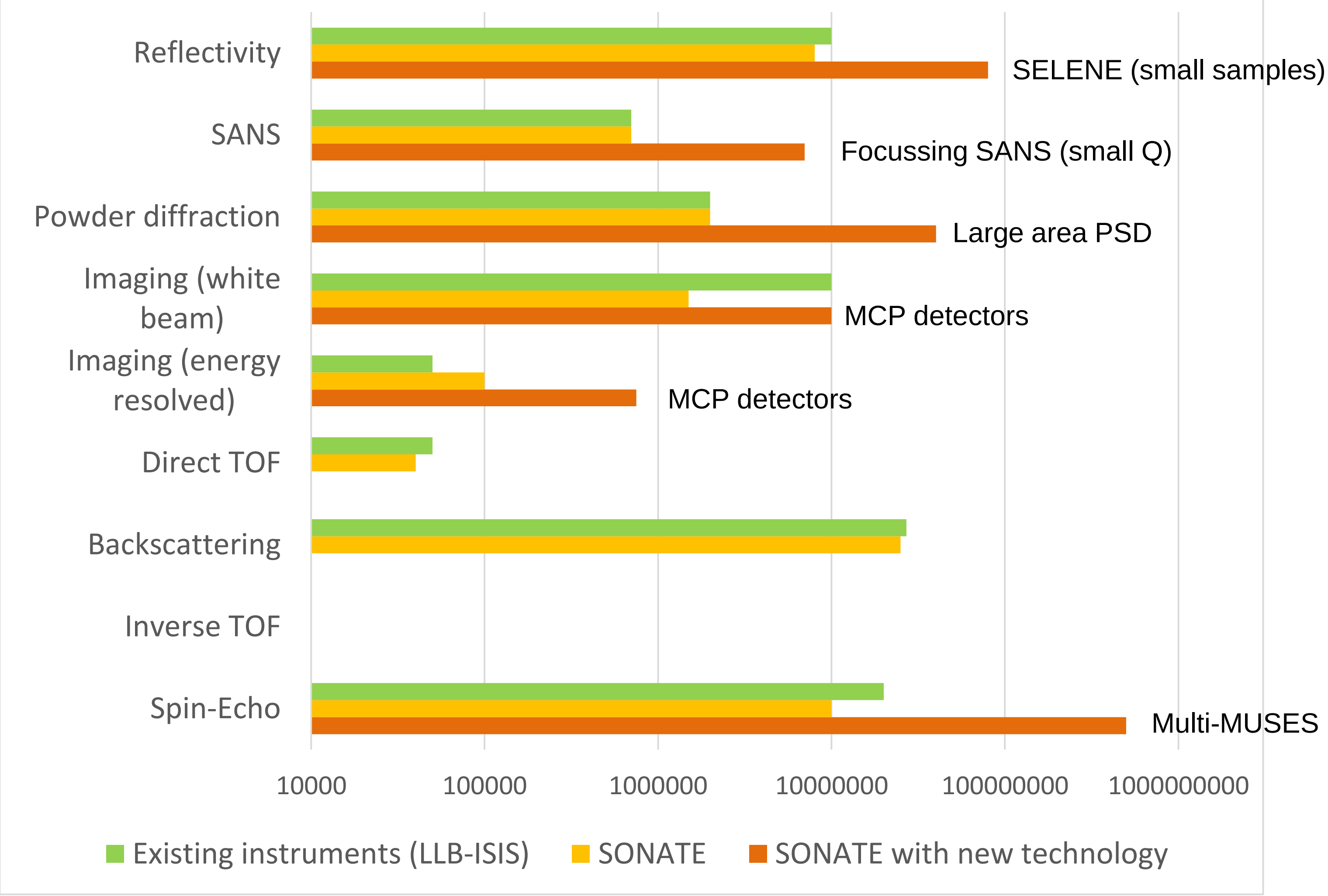


Definition of a reference design → SONATE

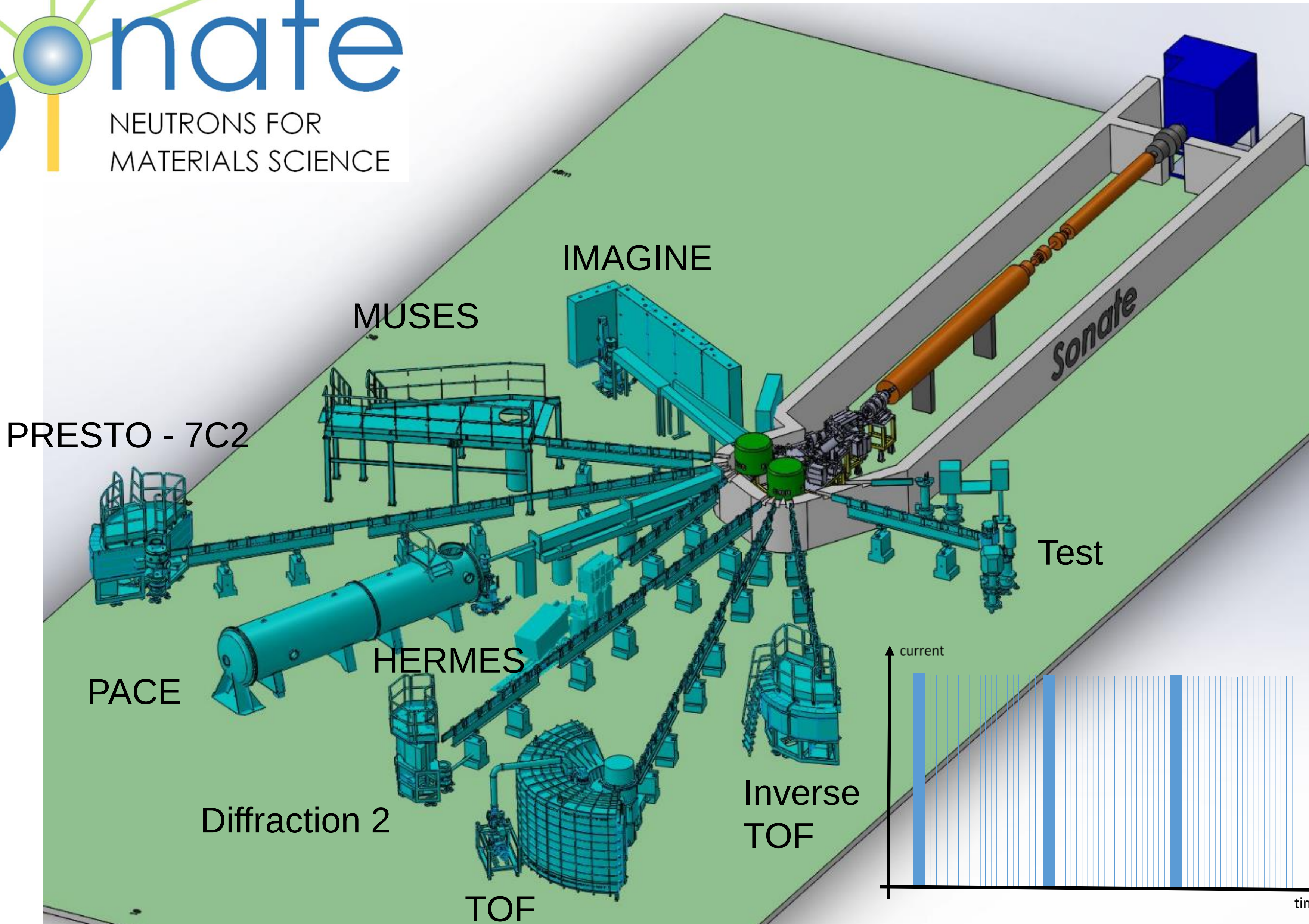
- E_p = 20 MeV, I_{peak} = 100 mA, duty cycle = 4%, P = 80 kW

Reference design SONATE

- E_p = 20 MeV, I_{peak} = 100 mA, duty cycle = 4%, P = 80 kW



2030: 10 INSTRUMENTS AROUND 2 TARGETS



CONCLUSIONS

The performances of a compact source are potentially equivalent to a medium scale research reactor or spallation source

- Reduced cost compared to a reactor

Technologically

- Accelerator OK
- Cible → tests under way (+ other solutions under dev.)
- Moderator OK / can be updated over the time
- Instruments OK

Possibility to benefit from the French ecosystem

- Scientific and technical expertise at Saclay and Grenoble
- Wide user base
- Possibility to reuse the efforts injected into ESS
  - Accelerator construction
  - Instruments designs
  - Detector developments
  - Reduction et data processing
- Existing instrumentation / available

A CANS for a materials science plateform

SONATE
NEUTRONS FOR MATERIALS SCIENCE

IPHI – NEUTRONS & SONATE CONTRIBUTORS

Monte-Carlo simulations

- H.N. Tran (IRFU/SPhN) (post-doc)
- L. Thulliez (IRFU/SPhN)
- A. Marchix (IRFU/SPhN)
- A. Letourneau (IRFU/SPhN)
- J. Darpentigny (IRAMIS/LLB)
- G. Gigante CEA/SPR (shielding / activation)

IPHI

- J. Schwindling (IRFU/SACM)
- N. Chauvin (IRFU/SACM)
- F. Sénée
- B. Pottin, G. Perreu
- A. Dubois
- D. Chirpaz, Y. Sauce
- O. Kuster, C. Deberles

Instruments simulations

- X. Fabrèges (IRAMIS/LLB)
- A. Menelle (IRAMIS/LLB)
- F. Ott (IRAMIS/LLB)
- F. Porcher (IRAMIS/LLB)

Target - moderator

- N. Sellami (IRFU/SIS)
- B. Annighöfer (IRAMIS/LLB)
- P. Permingeat (IRAMIS/LLB)

Neutron measurements

- J. Darpentigny (IRAMIS/LLB)
- F. Ott (IRAMIS/LLB)
- A. Menelle (IRAMIS/LLB)

Technical support

- K. Jiguet (IRAMIS/LLB)
- W. Josse (IRAMIS/LLB)
- F. Gibert (IRAMIS/LLB)
- B. Homatter (IRAMIS/LLB)
- P. Lavie (IRAMIS/LLB)
- J.-L. Meuriot (IRAMIS/LLB)
- F. Prunes (IRAMIS/LLB)
- G. Exil, R. Lautié, E. Jorgji

Strategic support

- C. Alba-Simionesco (IRAMIS/LLB)
- R. Duperrier (IRFU/SACM)
- A. Leservot (DRF/DCEPI)