The design of ASTOR: A cold neutron imaging instrument for the future argentine multipurpose reactor, RA-10

Aureliano Tartaglione

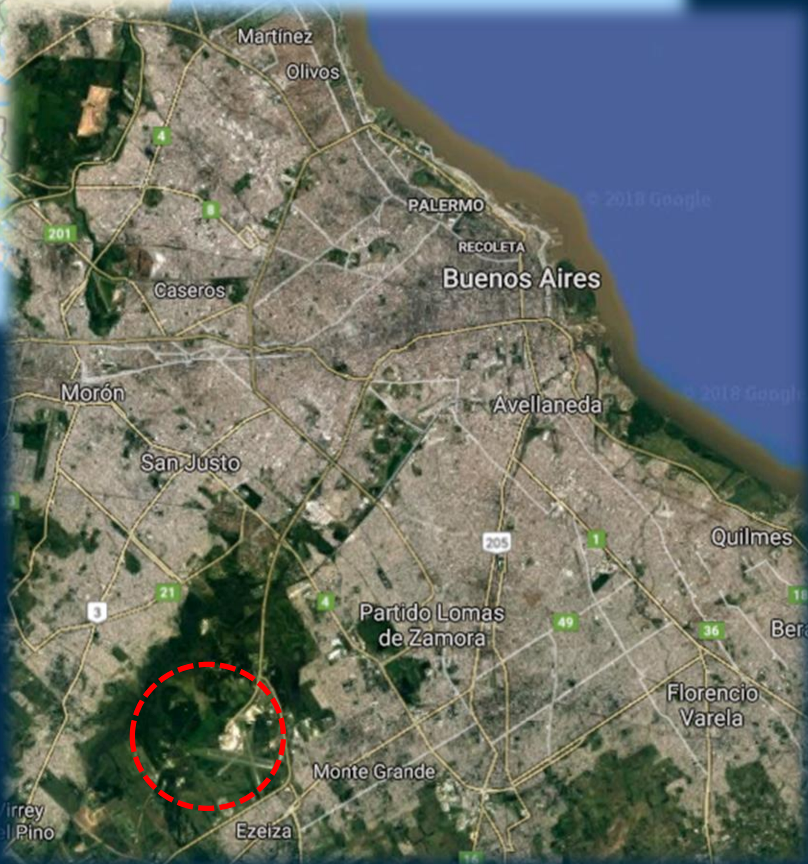
CONICET-CNEA-GAIYANN
LAHN responsible for ASTOR

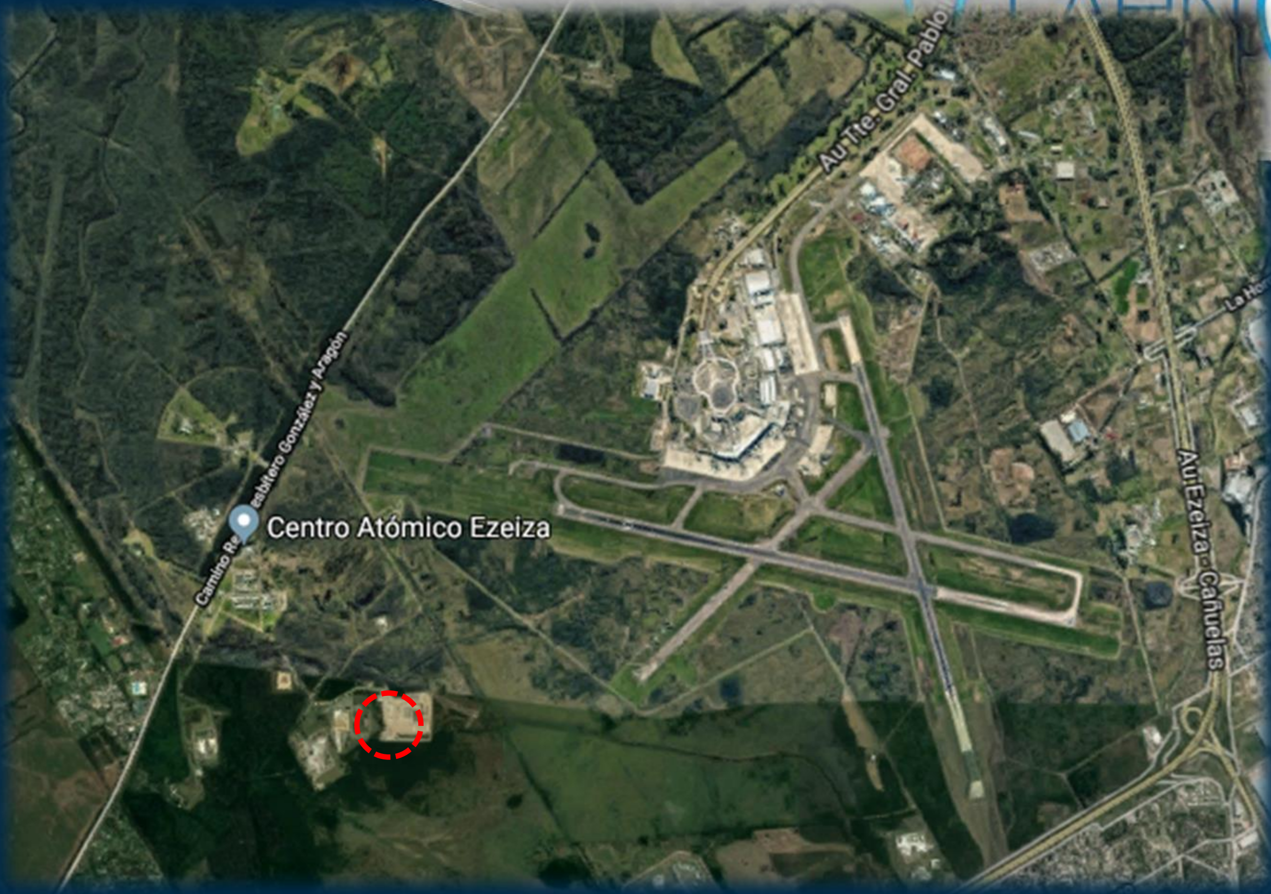
Summary

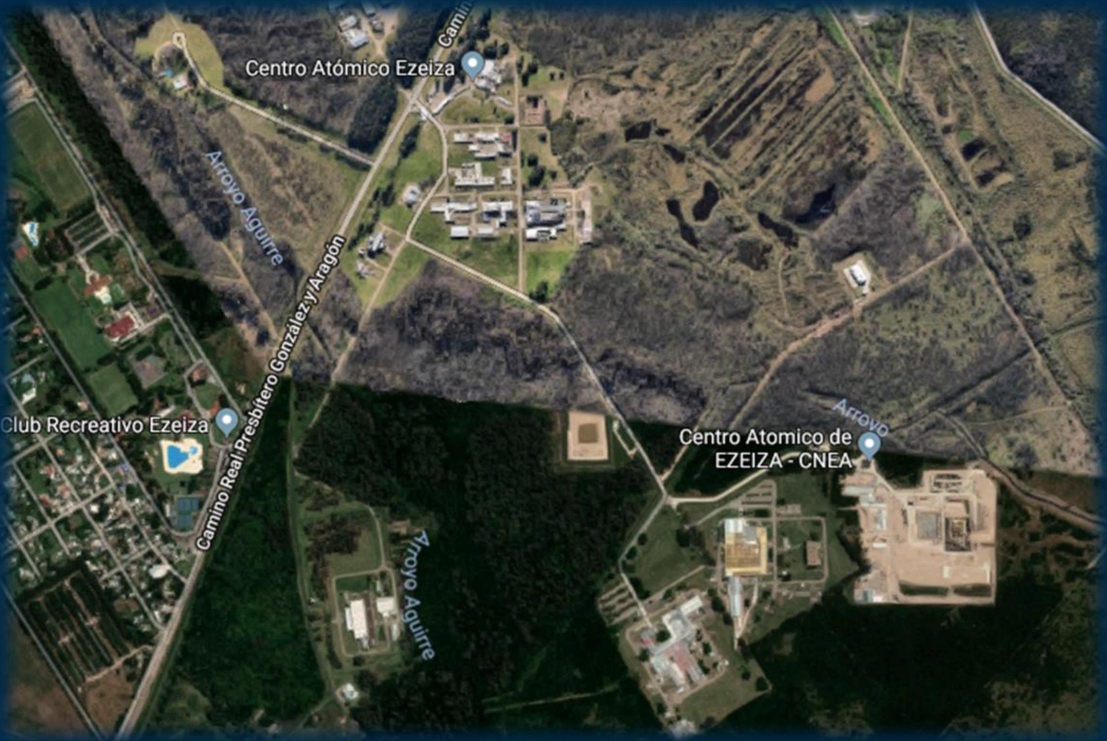
- Geographical location of RA-10 and ASTOR
- The reactor RA-10 and the LAHN
- ASTOR and applications for Argentina
- ASTOR conceptual design
- ASTOR preliminary mechanical design
- Open questions!

Geographical location of RA-10 and ASTOR


Paraguay
Asunción
SÃO PAULO
PARANÁ
SANTA CATARINA
Chile
RIO GRANDE DO SUL
Córdoba
Uruguay
Santiago de Chile
Buenos Aires
Argentinien
Montevideo


Martinez
Olivos
PALERMO
RECOLETA
Buenos Aires
Caseros
Morón
Avellaneda
San Justo
Quilmes
Partido Lomas de Zamora
Florencio Varela
Monte Grande
Ezeiza


Centro Atómico Ezeiza
Camino Real Presbítero González y Aragón
Au. Tte. Gral. Pablo
Au. Ezeiza - Cañuelas

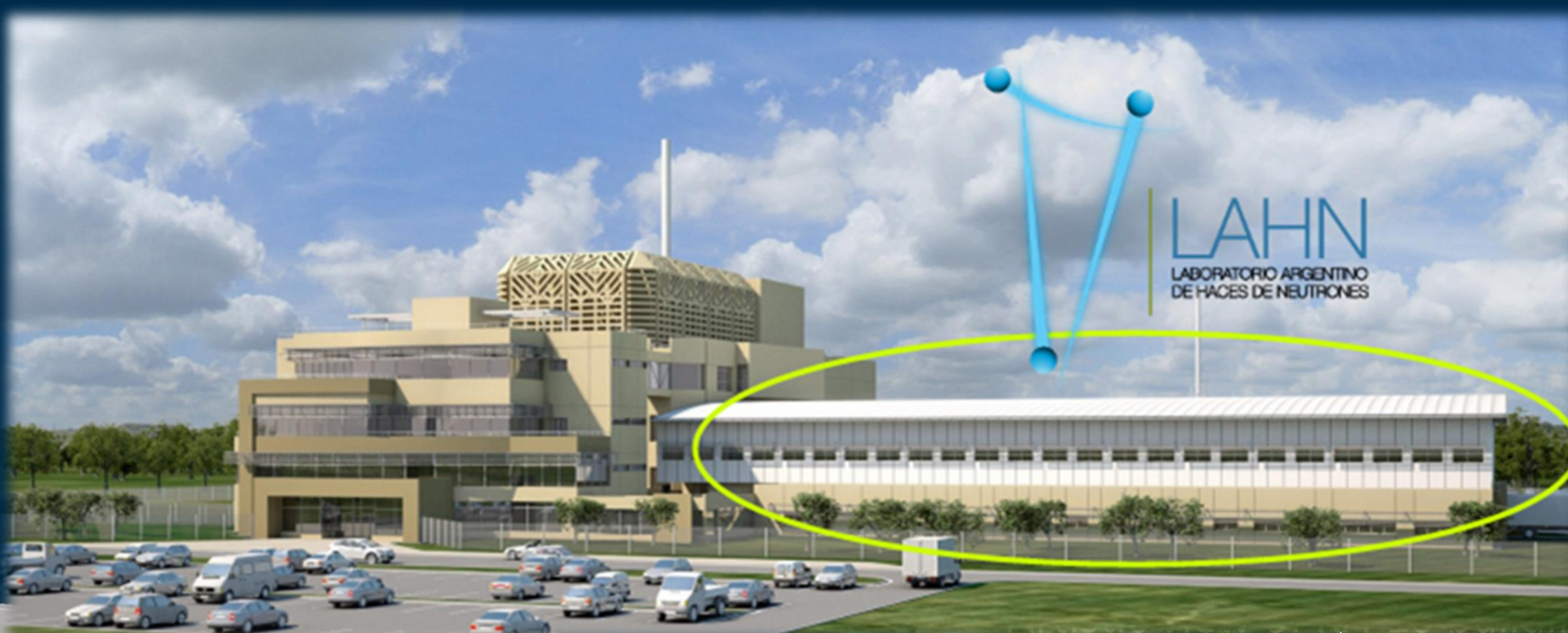

Centro Atómico Ezeiza
Arroyo Aguirre
Camino Real Presbítero González y Aragón
Club Recreativo Ezeiza
Centro Atomico de EZEIZA - CNEA
Arroyo Aguirre


Centro Atomico de
EZEIZA - CNEA
Arroyo

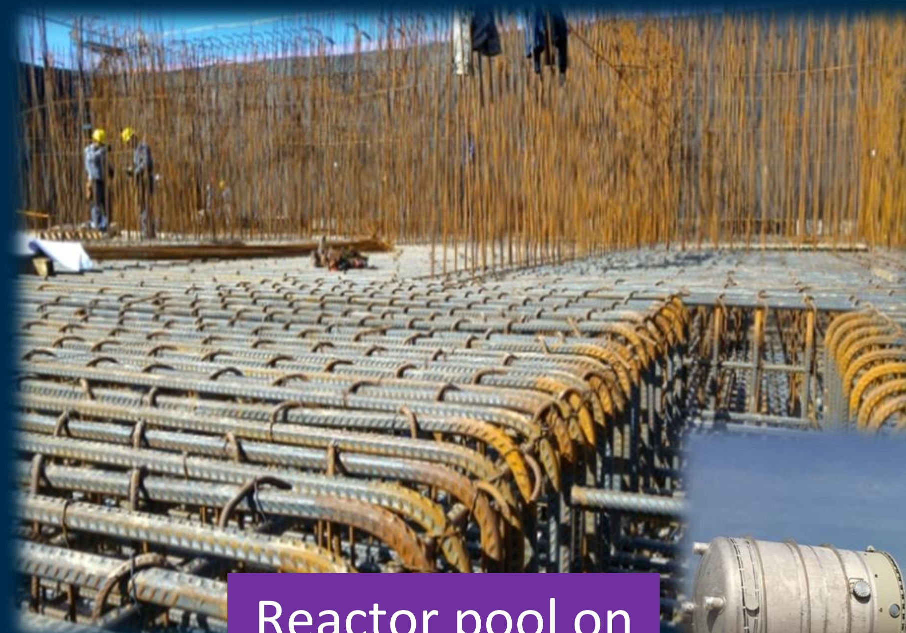
RA-10 and LAHN

The RA-10 Reactor

- **30 MW** multi-purpose **open pool** reactor.
- LEU + H_2O (moderation and cooling) + D_2O reflector
- Located at Ezeiza Atomic Center (close to Buenos Aires International Airport)
- Owned by CNEA. Designed by CNEA and INVAP
- Construction started in March 2016. First neutrons expected by march 2020/2021



The RA-10 Reactor construction



Reactor pool on reactor site. August 2018.

The RA-10 Reactor goals

- To provide a replacement for the RA-3 reactor (1967)

- To increase the RadioIsotope (RI) production for supporting the local and regional future demand.

- To consolidate the national capabilities related to nuclear fuel production.

- To offer new capabilities based on **neutron techniques** to the scientific and technological systems.
  - to develop thermal and cold neutrons facilities for the application of neutron scattering and imaging techniques to nuclear technology, as well as basic and applied sciences

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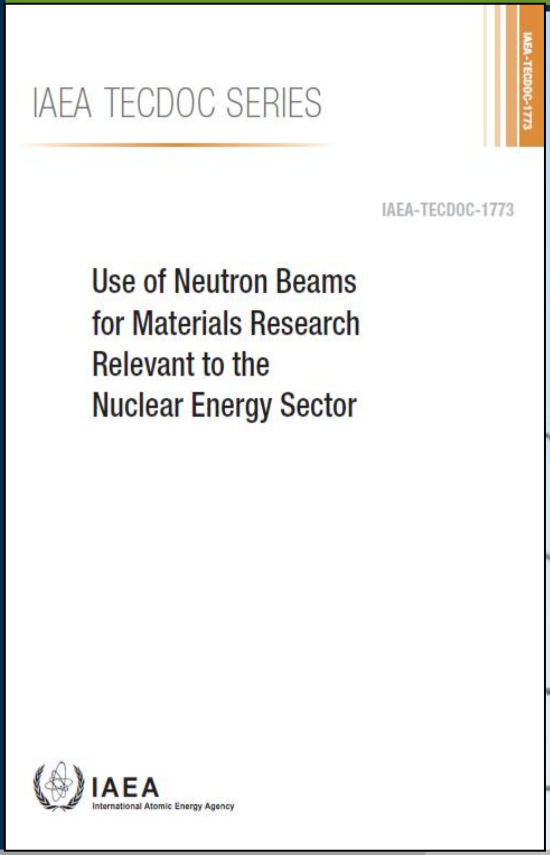
LAHN: Argentinean Laboratory of Neutron Beams

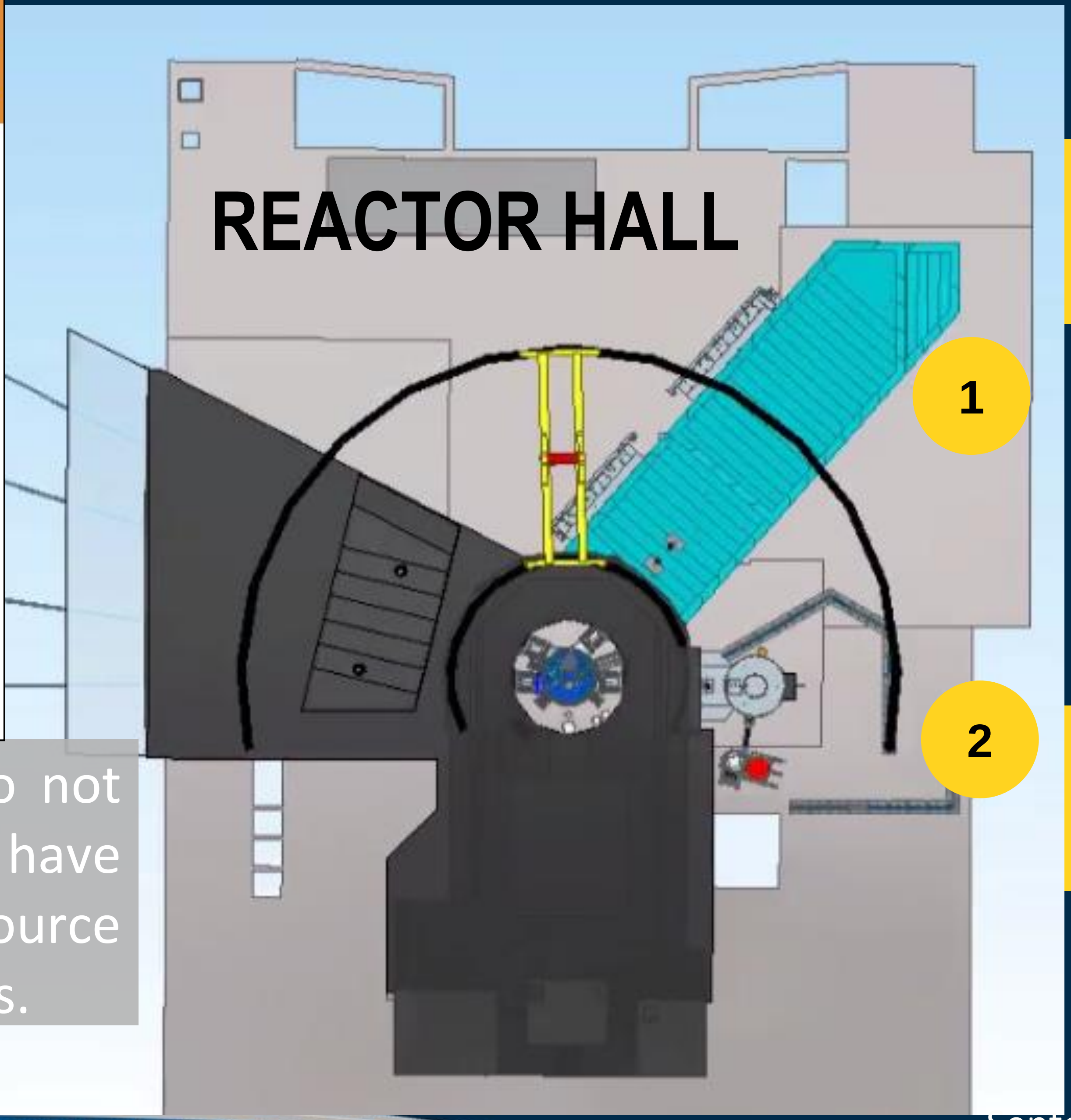
- LAHN will be the first and unique large-scale neutron beams facility in Latinamerica
- It will complement perfectly with the novel 4th generation synchrotron SIRIUS in Campinas, Brazil
- Together they may become the most multidisciplinary hub in the region; similar to ILL+ESRF in France, J-Parc in Japan, PSI in Switzerland, ISIS+Diamond in UK, MAX-IV + ESS in Sweden, Argonne in USA.

www.lahn.cnea.gov.ar

PHASE I OF INSTRUMENTATION

THESE INSTRUMENTS WERE SELECTED FOR BEING THE MOST SUITED FOR NUCLEAR INDUSTRY APPLICATIONS (specific needs of the CNEA)





These instruments do not use guides, but have optimized view of source and beam divergences.

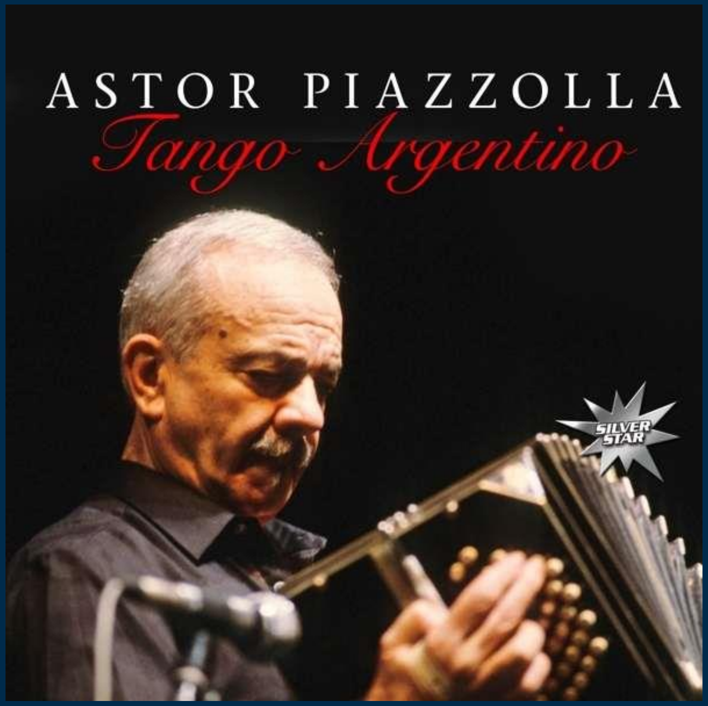
Neutron Imaging: ASTOR

ResponsIble:
Dr. Aureliano Tartaglione

Engeneering Diffractometer ANDES

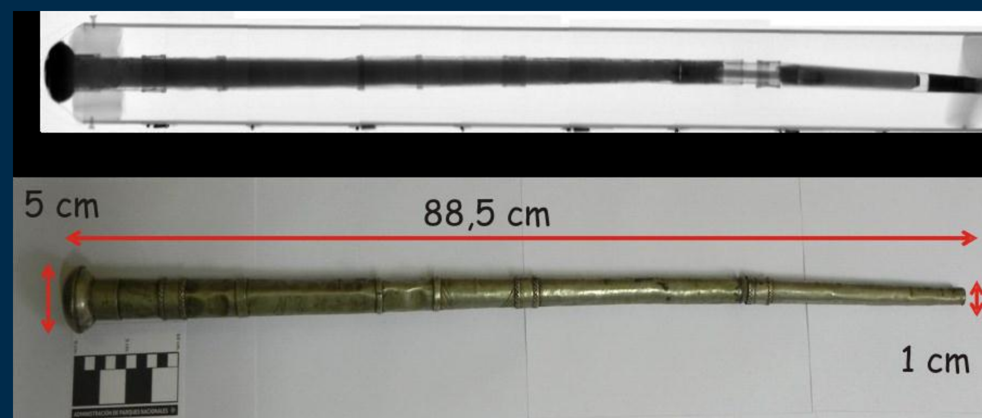
ResponsIble:
Dr. Miguel A. Vicente

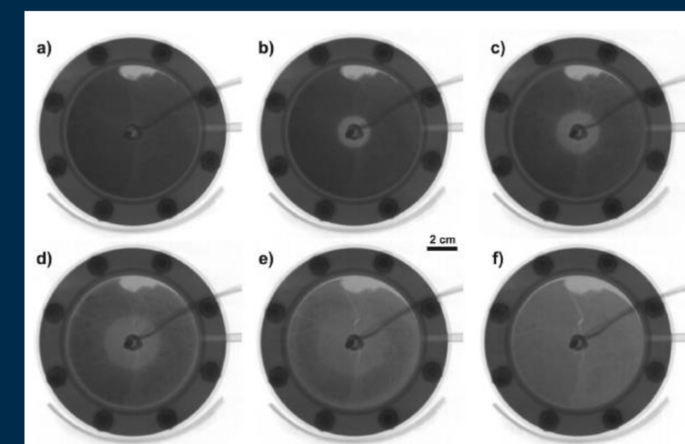
ASTOR
Advanced System for TOmography and Radiography



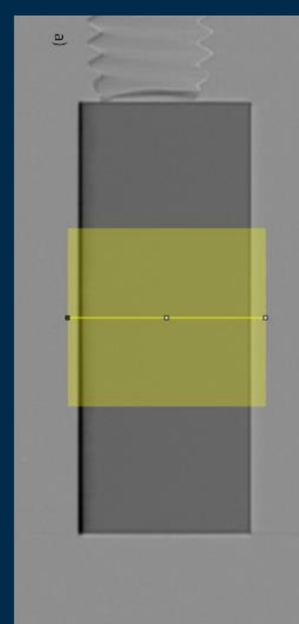
ASTOR
Advanced System for TOmography and Radiography
ASTOR and applications for Argentina

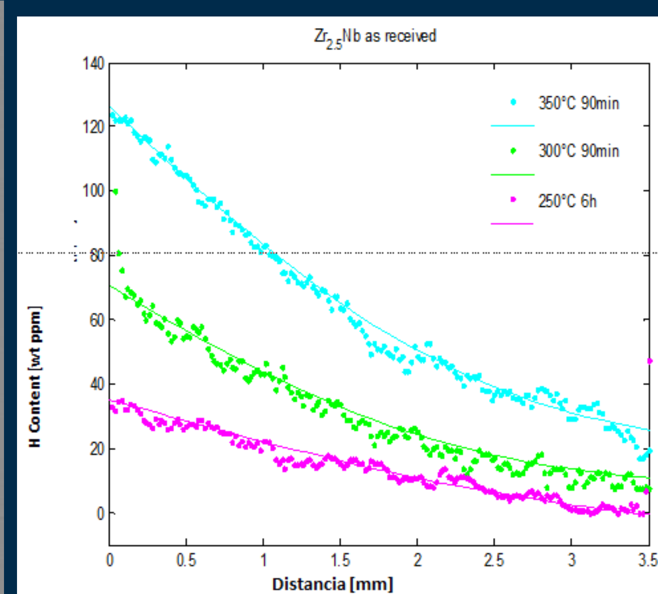
- **Nuclear Industry**
- **Material Science research**
- **Lithium technology**
- **Hydrogen technology**
- **Fuell cells**
- **Palaentology**
- **Cultural Heritage**





Baruj, et al, Intl J Hydrogen Energy (2015)





Santisteban J, Buitrago L, Tartaglione A, Daymond M, Grosse M (2015)

ASTOR Team

LAHN Scientific Director
Javier Santisteban

LAHN Technical Coordination
Federico Suárez

ASTOR Poject Leader
A Tartaglione

- **Neutron Optics Simulations**
  Salvador Ortíz
  Federico Bartalot
- **Shielding**
  Santiago Bazzana
  Luis Romero
  Gonzalo Bergás
- **Mechanical Engineering**
  Agustín Coleff
  +
  THI Mechanical Group
- **Automation & Control (w/ANDES)**
  Nicolás Solís
  Félix Maciel
  Roberto Chaparro

See tomorrow presentation of Santiago Bazzana about ASTOR shielding. 9hs WBGB/019

High Level Scientific Requirements

	Imaging Technique	Description	Type of sample & technical requirements
(i)	High spatial resolution imaging	White beam 2D imaging with highly collimated beam	• Small or medium size objects. • Precise rotation/translation of object.
(ii)	High temporal resolution imaging	White beam 2D imaging with intermediate/low spatial resolution	• Small or medium size objects • In-situ/In-Operando neutron imaging. Dynamic processes. • Sample environment equipment.
(iii)	Tomography	Sequence of images at different angles between 0° and 180°	• Small or medium size objects. • Precise rotation/translation of objects.
(iv)	Bragg edge imaging	Monochromatic neutron beam imaging. Texture analysis	• Small or medium size objects • Mechanical and/or double crystal monochromator. • Precise rotation/translation of objects.
(v)	Dark field imaging (DFI) and neutron grating interferometry (nGI)	Imaging in USANS of micrometer size particles. Imaging of magnetic domains.	• Small samples. • Neutron grating positioning equipment. • Monochromatic beam. ~10% lambda resolution.
(vi)	Polarized neutron imaging	Neutron imaging of magnetic domains and magnetic fields.	• Small samples. • Neutron polarization equipment: two polarizer, magnet. • Monochromatic beam. Minimum 10% lambda resolution.

Day 1

Upgrades

Performance requirements

Imaging technique		Sample flux (n/cm^2s)	FOV (cm^2)	Wavelenght (Å)	Spatial resolution (μm)
(i)	High spatial resolution imaging	$\geq 2\ 10^6$	10x10 a 25x25	Policromatc	10 a 40
(ii)	High temporal resolution imaging	$\geq 1\ 10^8$	10x10 a 20x20	Policromatic	50 a 200
(iii)	Tomography	$\geq 1\ 10^7$	10x10 a 20x20	Policromatic	10 a 200
(iv)	Bragg edge neutron imaging	$\geq 1\ 10^6$	10x10 a 20x20	2.0 Å ≤ λ ≤ 6 Å (1%≤Δλ/λ≤ 10%)	50 a 200
(v)	Dark field and neutron grating interferometry	$\geq 1\ 10^6$	10x10 a 20x20	2.0 Å ≤ λ ≤ 6 Å (Δλ/λ = 10%)	50 a 200
(vi)	Polarizad neutron imaging	$\geq 1\ 10^6$	10x10 a 20x20	2.0 Å ≤ λ ≤ 6 Å (Δλ/λ = 10%)	50 a 200

Instrument development strategies

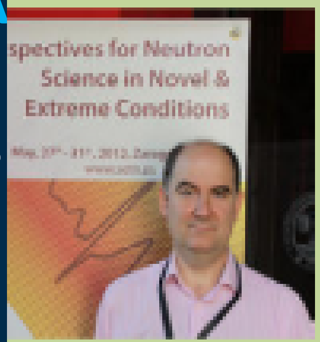
- First-stage instruments design should be straightforward, based on well-proven technologies.
- Each instrument has an external Scientific and Technical Advisory Panel of international experts.
- Timely planning and coordination with RA-10 Project.
- Instrument design and development should exploit and enhance existing resources within CNEA.
- This should consolidate a technical team able to develop future instruments.

Instrument development strategies

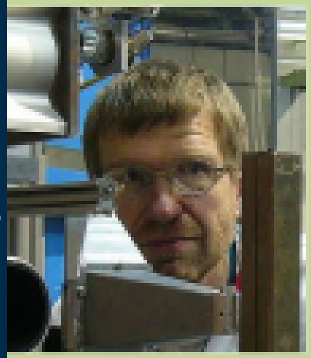
- Fi… rd, b…
- E… cal A…
- T…
- In… nd e…
- T… op future instruments.

ANDES

·Dr Pavol Mikula
Nuclear Physics Institute, Academy of Sciences of the Czech Republic



·Dr Javier Campo
Instituto de Ciencia de Materiales de Aragón, España

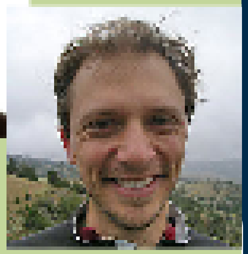


·Dr Michael Hofmann
Heinz Maier-Leibnitz Center Technische Universität München, Germany

ASTOR

·Dr Eberhard Lehmann
Paul Scherrer Institut Switzerland

·Dr Mohammed Arif/ Dr. Daniel Hussay
National Institute of Standards and Technology (NIST) USA.



·Dr Burkhard Schillinger
Heinz Maier-Leibnitz Center Technische Universität München, Germany

Mechanical Development strategies

1 – TO SPLIT THE DEVICE IN SISTEMS, SUBSISTEMS AND COMPONENTS
2 – TO IDENTIFY THE OPERATIONAL MODES
3 – TO CLASSIFY THE COMPONENTES IN 3 CATEGORIES
- CLASS 1 – HIGH PRIORITY TO DEVELOP
- CLASS 2 – MEDIUM PRIORITY
- CLASS 3 – LOW PRIORITY

4 – AGREE WITH THE SCIENTIFICS ALL THE MECHANICAL ***OBJECTIVE REQUIREMENTS***
5 – TO GET DECISION OVER EACH COMPONENTE ¿PURCHASE OR DEVELOP?
6 – TO KEEP THE DESIGN AS SIMPLE AS POSSIBLE

COMPONENT THAT WILL BE DESIGNEDIN CNEA
- **UNIQUE AND AD-HOC COMPONENT**
- **EXAMPLE :SHIELDINGS, COLLIMATORS, BEAM STOP, CAMERA BOX, DOUBLE CRYSTAL MONOCROMATOR.**

COMPONENT THAT ARE HAS BEEN PURCHASE
- **COMMERCIAL COMPONENTS**
- **EXAMPLE: SAMPLE TABLE POSITIONS WITH HIGH AQURATE**
- **SPECIFIC COMPONENTE WITH SPECIFIC KNOW HOW**
- **EXAMPLE: VELOCITY SELECTOR**

Mechanical Development strategies

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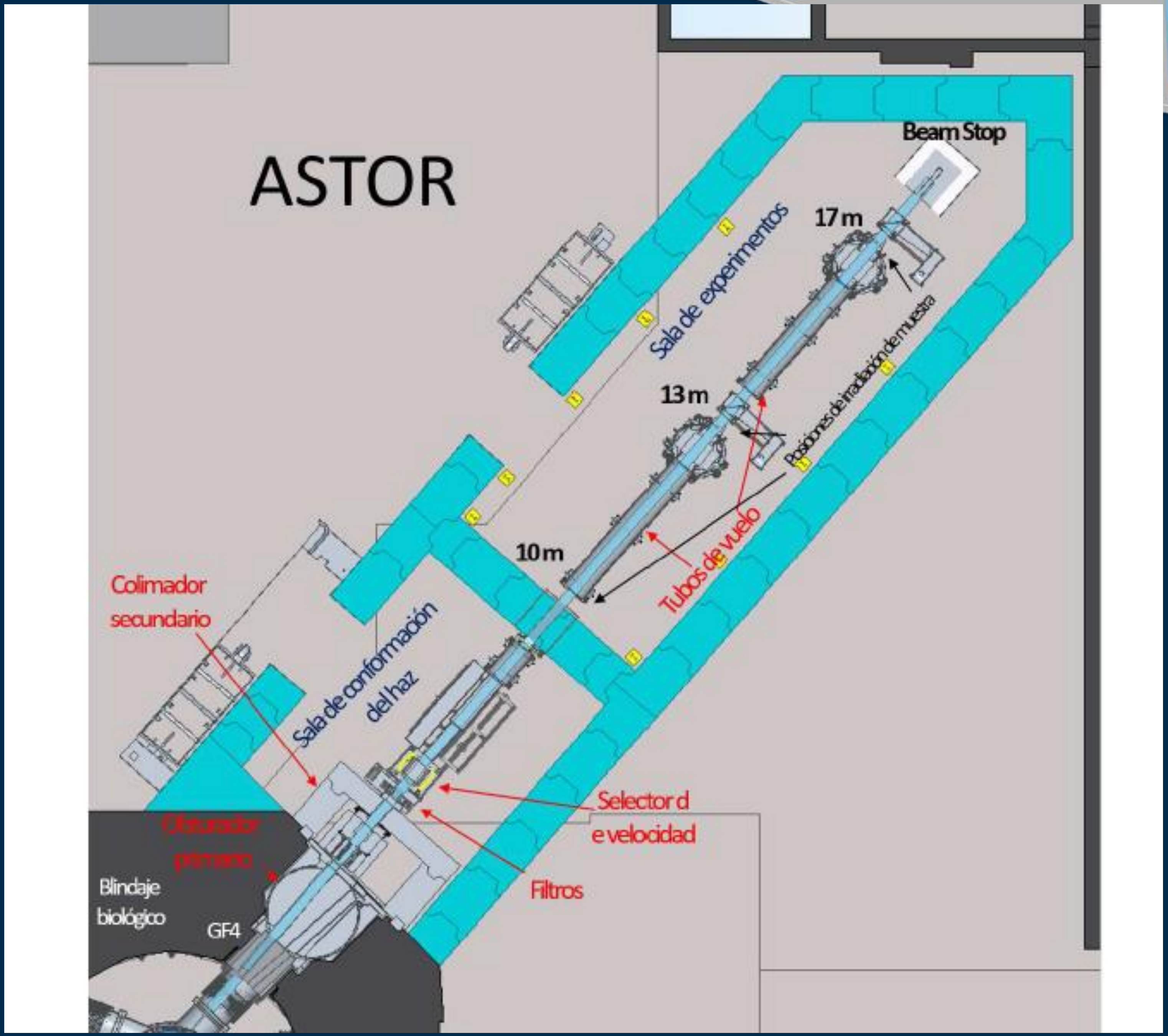
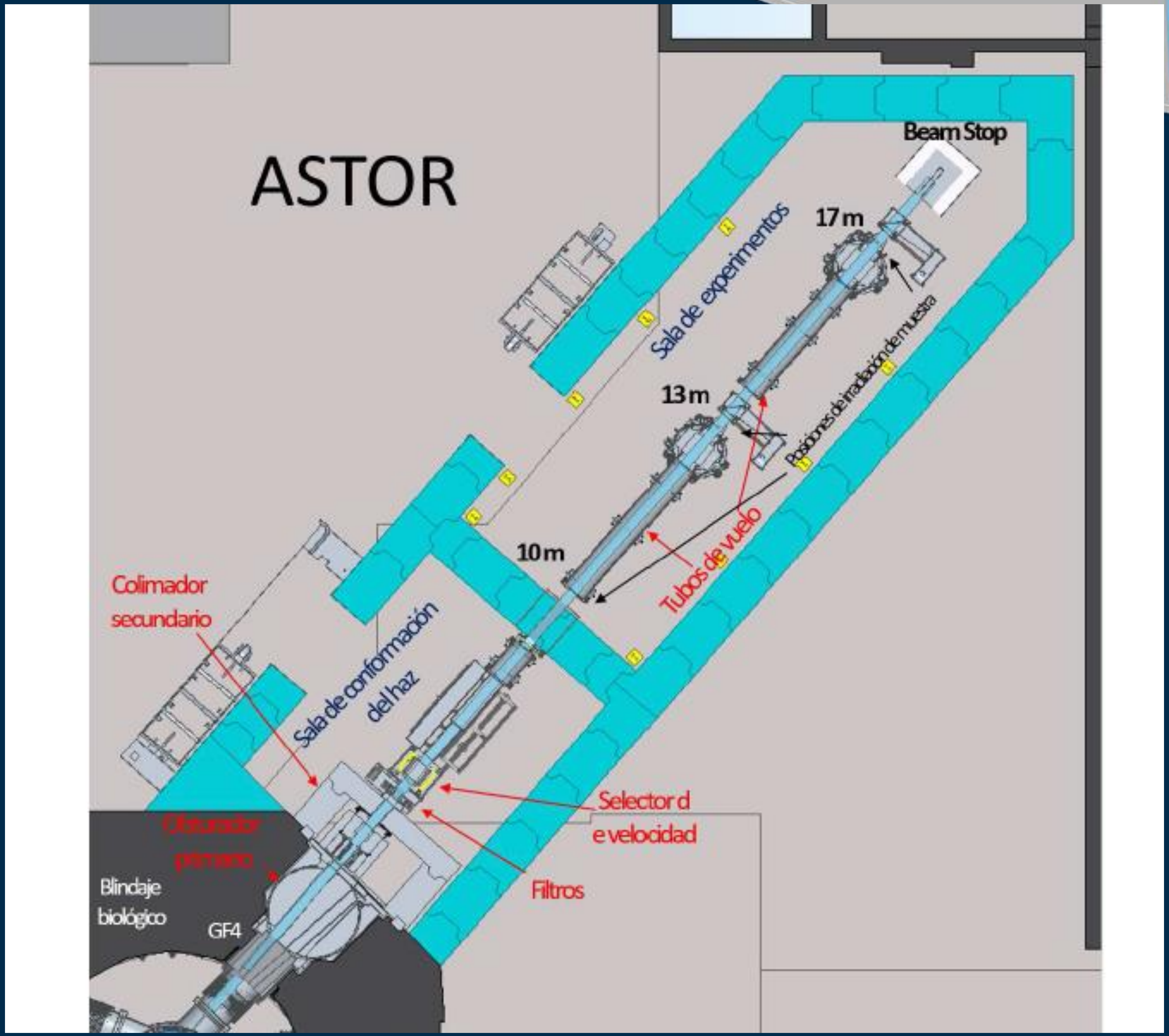
COMPONENT THAT ARE HAS BEEN PURCHASE
COMMERCIAL COMPONENTS
EXAMPLE: SAMPLE TABLE POSITIONS WITH HIGH AQURATE
SPECIFIC COMPONENTE WITH SPECIFIC KNOW HOW
EXAMPLE: VELOCITY SELECTOR

THE CHALLENGE: ACHIEVE ALL THIS STEPS WITH A STRONG AND GOOD COMUNICATION BETWEEN ALL THE TEAM MEMBERS (SCIENTISTS AND ENGINEERS)

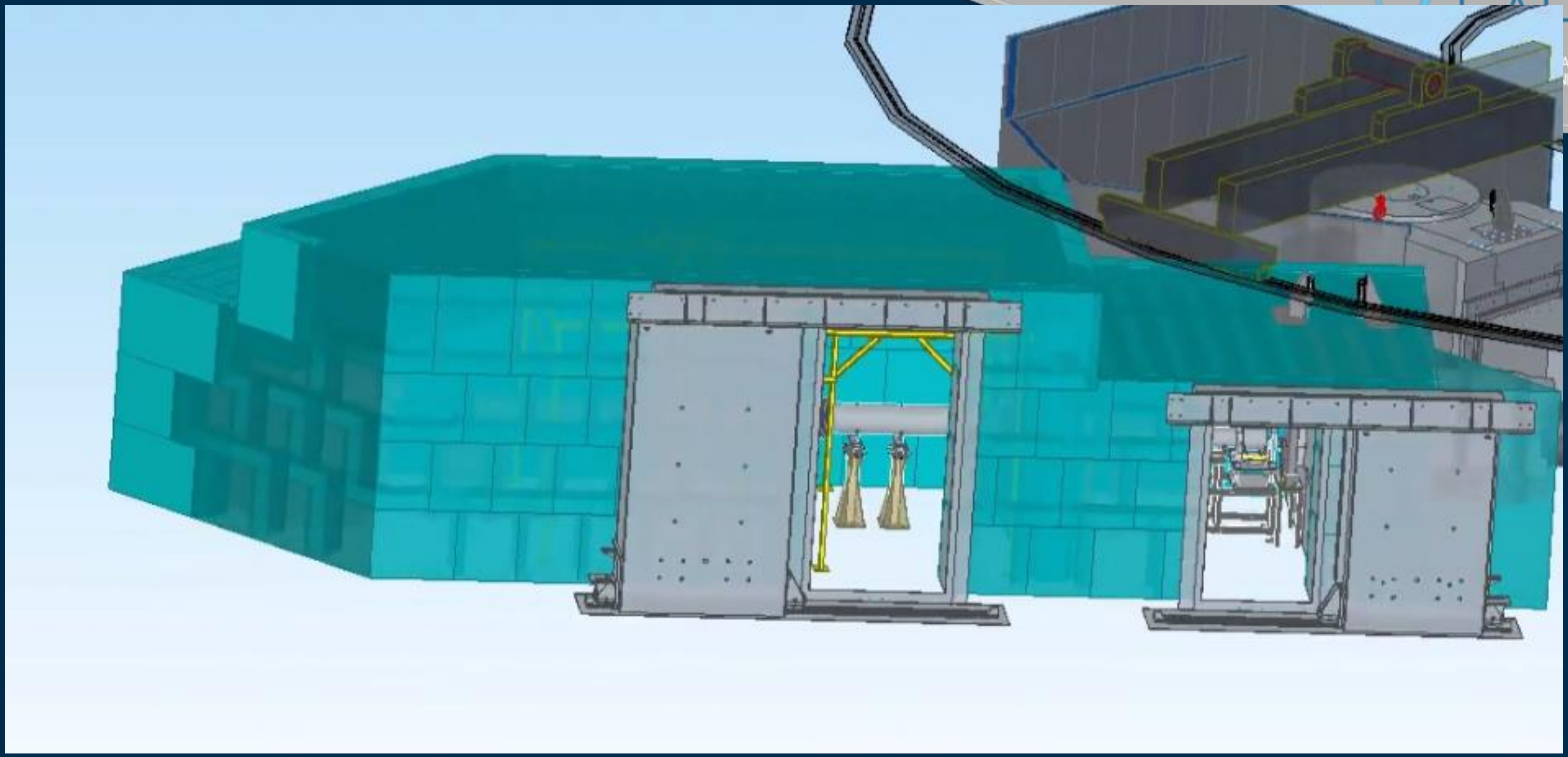
ASTOR main layout



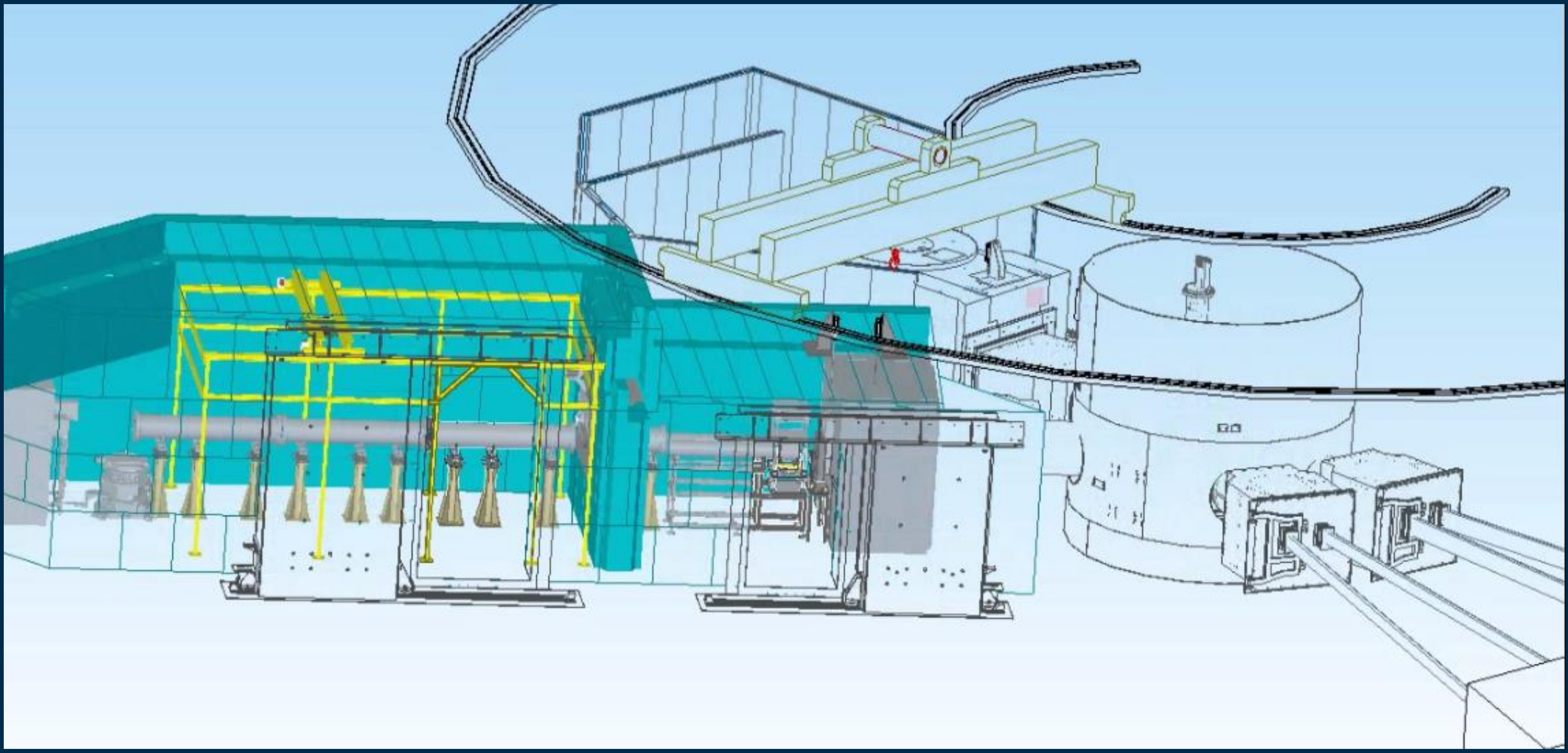
- Exclusive cold neutron extraction conduct.
- Two independent rooms: Conformation and experimental.
- Experimental room with 3.5m internal height and ~ 4m width.
- Conformation room with 2.5m internal height and ~ 4m width.

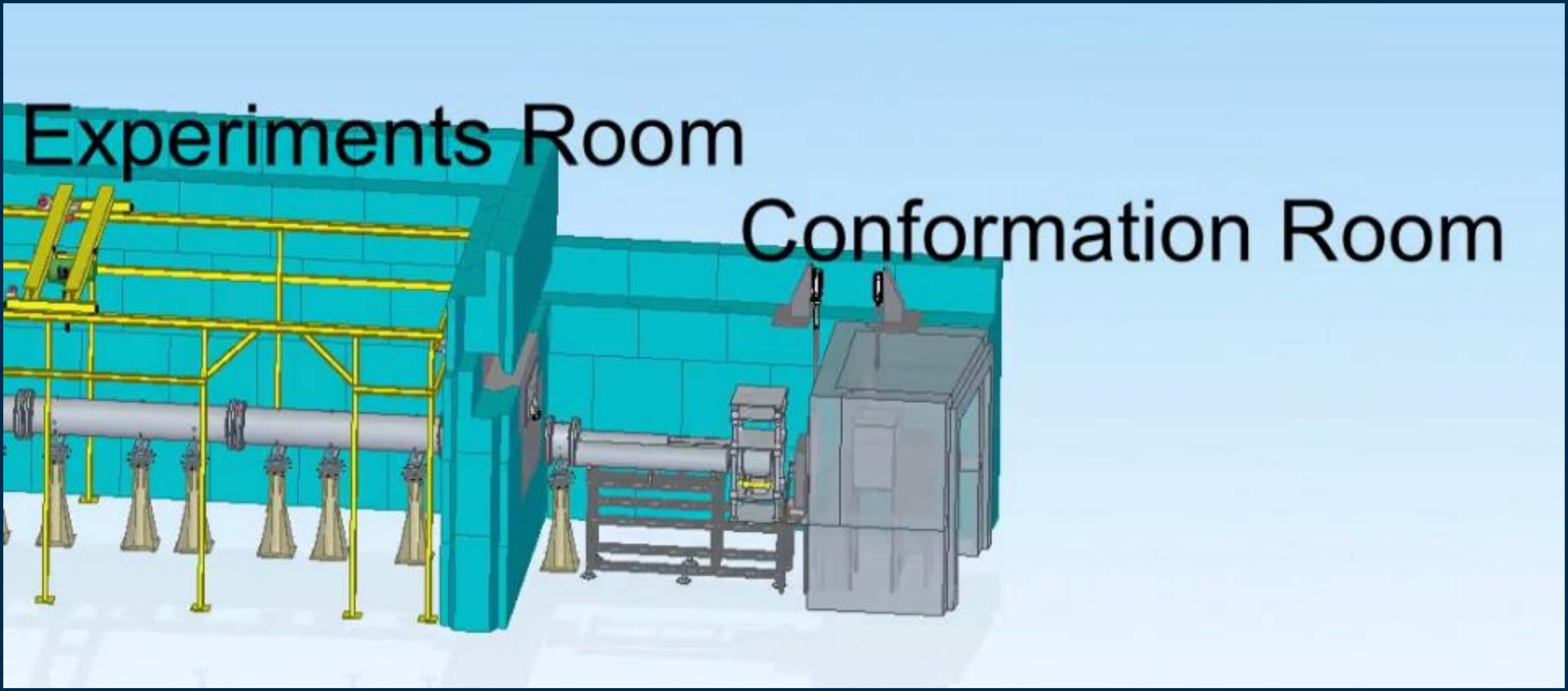


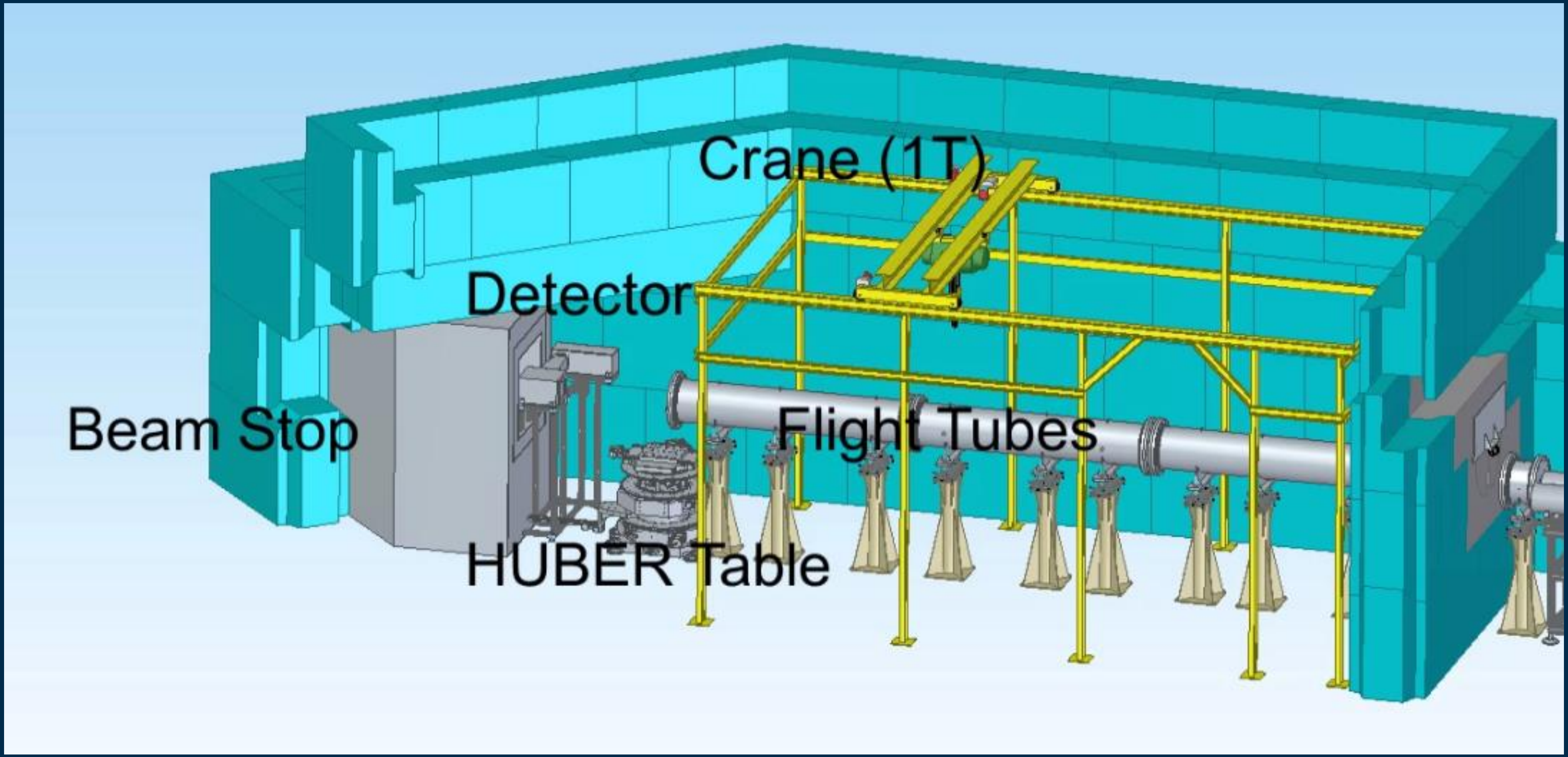
- Three standard irradiation positions at 10m, 13m and 17m from neutron source.
- Primary collimator in-pile (beam adjusted). Secondary collimation drum out-of-pile with six available positions. Secondary shutter. Fast shutter. Filters drum. Mechanical velocity selector. DCM. TOF.



- The L/D (at 17 m) can be: ~230, 450, 800, 1500, 6000x500 (high resolution slit), 1100 x 230 (high flux slit).
- The L/D=800 option is duplicated. Can be with or without beryllium filter.
- Maximum available neutron flux: ~4 10^8 n/cm^2s (at 10m with L/D~120 & FOV ~10 cm x 10 cm).
- Maximum available FOV: ~30 cm x 30 cm (at 17m with L/D~1500 & neutron flux~2,4 10^6 n/cm^2s)




Experiments Room
Conformation Room


Crane (1T)
Detector
Beam Stop
Flight Tubes
HUBER Table

ASTOR OPERATIVE MODES

Mode	Primary shutter	Secondary shutter	Fast shutter	Electronics and mechanical	Conformation room door	Experimental room door	Responsible
E01. OFF	Close	Close	Close	Off	Open/Close	Open/Close	R
E02. Maintenance	Close	.	-	Off	Open/Close	Open/Close	R-M
E03.Setup	Close	Close	Close	On	Open/Close	Open/Close	R-M
E04. Sample change	Open	Close	Close	On	Close	Open	R-U
E05. Operation	Open	Open	Open	On	Close	Close	R-U

ASTOR MAIN COMPONENTS

CONFIGURACIÓN DE COMPONENTES

Sub Sistema	Componente		¿Requiere Configuración? ¿Manual o Actuada?	¿Requiere Configuración? ¿Remota o Local?	¿Requiere Configuración? ¿Modo Operativo?
01	01	Obturador primario	Actuada	Remota	E04,E05
	02	Colimador Primario	Actuada	Remota	E04,E06
02	01	Filtro neutrones rápidos (zafiro)	Actuada	Remota	E03,E05
	02	Colimador secundario	Actuada	Remota	E03,E05
	03	Obturador secundario	Actuada	Remota	E04,E05
04	01	Obturador rápido	Actuada	Remota	E04,E05
	02	Calesita de filtros	Actuada	Ambas	E03,E05
	03	Selector de velocidad (Mecánico)	Actuada	Remota	E05
	04	Goniómetro para interferometría nGI#1	Actuada	Ambas	E03,E05
	05	Monocromador de doble cristal (Selector de velocidad pasivo)	Actuada	Ambas	E03,E05
	06	Chopper	Actuada	Remota	E05
	07	Tubo de vuelo y ventanas de tubos de vuelo de sala de conformación de haz	Manual	Local	E03
	08	Limitador de haz XY de sala de conformación de haz	Actuada	Remota	E03,E05
	09	Limitador de Haz pasivo	A definir	A definir	E03
05	02	Limitador de haz XY de sala de experimentos	Actuada	Remota	E03,E05
	03	Tubo/s de vuelo y ventanas de tubos de vuelo de sala de experimentos	Manual	Local	E03
	04	Tubo de rayos X	Manual	Local	E03
06	01	Mesa XYZ + Motorización (10 metros)	Actuada	Ambas	E03,E05
	02	Mesa Theta + Motorización (10 metros)	Actuada	Ambas	E03,E05
05	05	Goniómetro para interferometría nGI#2	Actuada	Ambas	E03,E05
06	03	Goniómetro de dos ejes + Motorización	Actuada	Ambas	E03,E05
	04	Soporte de muestras y entornos de muestra	Manual	Local	E03
07	01	Camera box	Manual	Local	E03
	02	Blindaje	Manual	Local	E03
	03	Cámara digital sCCD o sCMOS	Manual	Local	E03
	04	Optica convencional de alta calidad	Manual	Local	E03
	05	Centelladores de litio y gadolinio	No aplica	Local	E03
	06	Espejos especiales de alta calidad	No aplica	Local	E03
	07	Sistema de autofoco (opcional)	Actuado	Ambas	E03,E05
	08	Mesa XYZ + Motorización	Actuada	Ambas	E03,E05
05	03	Tubo/s de vuelo y ventanas de tubos de vuelo de sala de experimentos	Manual	Local	E03
08	01	Beam stop	No aplica	Local	E03

ASTOR CONFIGURATIONS

- In operation mode is neccesary to identify the configurations of the instrument. There is (so far…) 23 different possibilities.

- Each configuration indicates the engineers which component has to be "on line" and where it will be.

CONFIGURACIONES

Configuración 1.0

Sub Sistema	Componente	
01	01	Obturador primario
	02	Colimador Primario
02	01	Filtro neutrones rápidos (zafiro)
	02	Colimador secundario
	03	Obturador secundario
04	01	Obturador rápido
	02	Caledita de filtros
	03	Selector de velocidad (Mecánico)
	04	Goniómetro para interferometría nGI#1
	05	Monocromador de doble cristal (Selector de velocidad pasivo)
	06	Chopper
	07	Tubo de vuelo y ventanas de tubos de vuelo de sala de conformación de haz
	08	Limitador de haz XY de sala de conformación de haz
	09	Limitador de Haz pasivo
05	02	Limitador de haz XY de sala de experimentos
	03	Tubo/s de vuelo y ventanas de tubos de vuelo de sala de experimentos
	04	Tubo de rayos X
	05	Goniómetro para interferometría nGI#2
06	01	Mesa HUBER + Motorización (10 metros)
	02	Soporte de muestras y entornos de muestra
07	01	Camera box
	02	Blindaje
	03	Cámara digital sCCD o sCMOS
	04	Optica convencional de alta calidad
	05	Centelladores de litio y gadolinio
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	07	Sistema de autofoco (opcional)
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08	01	Beam stop

CONFIGURACIONES

Configuración 1.1

Sub Sistema	Componente	
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07	01	Camera box
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	07	Sistema de autofoco (opcional)
	08	Mesa XYZ + Motorización
05	03	Tubo/s de vuelo y ventanas de tubos de vuelo de sala de experimentos
08	01	Beam stop

ASTOR DESIGN ROADMAP

- March 2017. 1st STAP revision of conceptual design.
- April 2018. LAHN Internal preliminary revision of mechanical design.
- June 2018. Requirements documentation finished.
- October 2018. Selection of mechanical design of critical components.
- December 2018. Preliminary design review.
- May 2019. Documentation of preliminary mechanical design finished.
- July 2019. 2nd STAP revision of mechanical design.

CONCLUSIONS

- We presented here the main actual design of the instrument for neutron imaging ASTOR.
- Modes of operation, main components, configurations and requirements are defined.
- ASTOR will be one of the first instruments of the new reactor RA-10 in Argentina.
- The instrument is designed to be state-of-the-art and to apply modern neutron imaging techniques for local, regional and international user communities.
- Mechanical design is on schedule and next year is expected to produce some prototypes. i.e. secondary collimator drum.

Open questions from ASTOR team…

- Radiation hard components? What kind of considerations about cables, o-rings, sealings, step motors, controlers…. Etc. Preventive maintenance??
- Sample environment equipment. Considerations? Typical mass, volume. Manipulation advices.
- Velocity selector. Vibrations? How to design the mounting in relation to vibrations?
- Alignment of components. Procedures? Tools? Advices?

THANK YOU FOR YOUR ATTENTION

LAHN Project
Comisión Nacional de Energía Atómica

www.lahn.cnea.gov.ar

lahn@cnea.gov.ar

Open questions from the team!

Algunas preguntas que quizás puedan ser respondidas por allá

1. Respecto a la sala de conformación de haz: preguntar cómo van montados los componentes en otros laboratorios. Especialmente aquellos que se tienen que intercambiar: Selector de velocidad, Goniómetro para nGI, Monocromador doble cristal y Chopper. ¿Qué soluciones hay actualmente empleadas para asegurar la alineación de estos componentes cada vez que se montan? ¿Cuánto tiempo demora este tipo de tarea?

2. Respecto a la sala de experimentos: ejemplos de soluciones implementadas en otros laboratorios para desplazar la mesa porta muestra y montar los tubos de vuelo. ¿Los tubos de vuelo están sobre plataformas fijas o móviles?

3. Alineación para ambas salas. ¿Cómo se efectúa el posicionamiento de los componentes respecto del haz? ¿Se toman referencias desde el reactor y desde allí se alinea? ¿O se alinea tomando mediciones a partir del haz de neutrones? Tolerancia en direccion Z para el posicionamiento de los componentes.

4. Respecto a Selector de velocidades / Choppers: Si hay infrmación disponible respecto de los efectos dinámicos que generan sobre la estructura o bastidor que los sostiene.

5. Con qué nos podríamos encontrar, desde el punto de vista mecánico usualmente en Entorno de muestras?. Qué capacidades preveer? Masas/volúmenes a mover, etc?

6. Recomendaciones sobre consideraciones especiales a tener debido a los efectos de la radiación para elementos como Sellos, Cables, Actuadores y sensores.

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