Coupling the RIB Facility EXOTIC to the γ–Ray Spectrometer AGATA

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AGATA Collaboration Meeting
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RIB In-Flight Production at LNL

In-flight production of **light weakly-bound RIBs**, employing **two-body inverse kinematics reactions** with heavy projectiles impinging on **gas targets** (**p**,**d**,**^{3}He**).

The **commissioning** of the facility was performed in 2004.

F. Farinon et al., NIM B 266, 4097 (2008)

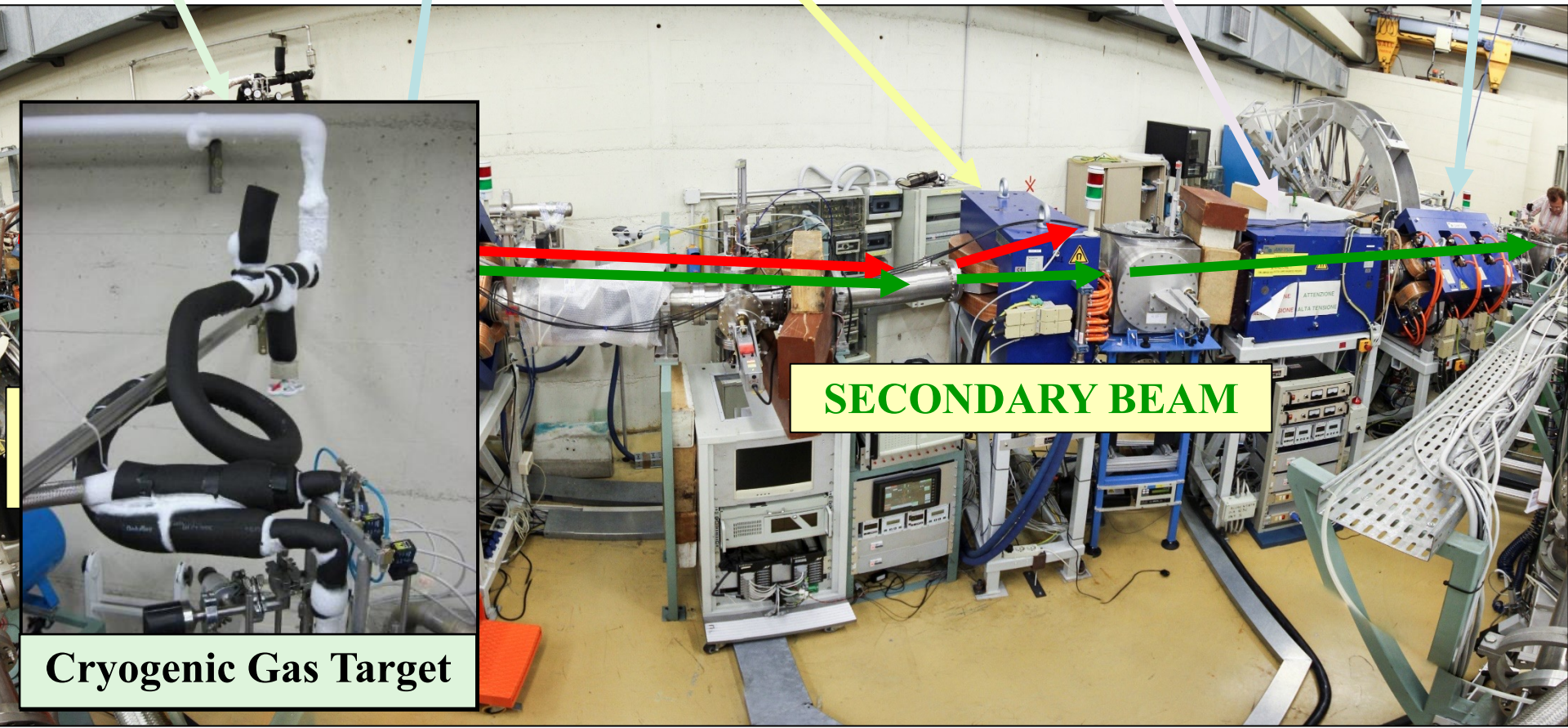
A **substantial upgrade process** was subsequently held in 2012.

M. Mazzocco et al., NIM B 317, 223 (2013)

8 Radioactive Ion Beams have been delivered so far:

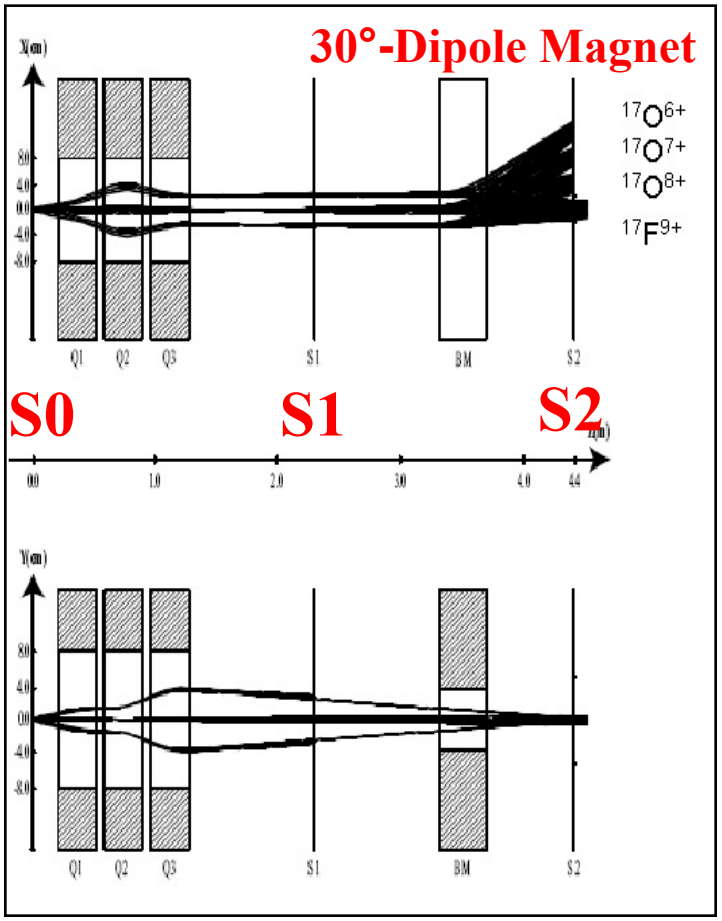
1. **^{17}F (S_p = 600 keV):** **p(^{17}O,^{17}F)n** Q_{value} = – 3.54 MeV;
2. **^{8}B (S_p = 137.5 keV):** **^{3}He(^{6}Li,^{8}B)n** Q_{value} = – 1.97 MeV;
3. **^{7}Be (S_α = 1.586 MeV):** **p(^{7}Li,^{7}Be)n** Q_{value} = – 1.64 MeV;
4. **^{15}O (S_p = 7.297 MeV):** **p(^{15}N,^{15}O)n** Q_{value} = – 3.54 MeV;
5. **^{8}Li (S_n = 2.033 MeV):** **d(^{7}Li,^{8}Li)p** Q_{value} = – 0.19 MeV;
6. **^{10}C (S_p = 4.007 MeV):** **p(^{10}B,^{10}C)n** Q_{value} = – 4.43 MeV;
7. **^{11}C (S_p = 8.689 MeV):** **p(^{11}B,^{11}C)n** Q_{value} = – 2.76 MeV;
8. **^{18}Ne (S_p = 3.923 MeV):** **^{3}He(^{16}O,^{18}Ne)n** Q_{value} = – 3.19 MeV;

Facility EXOTIC at LNL

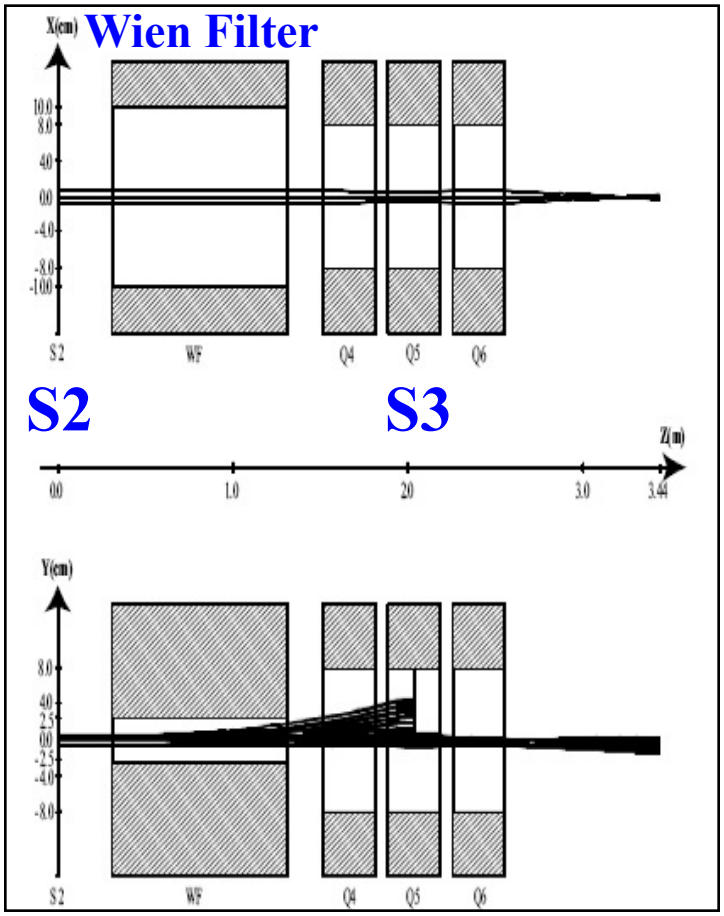


Two-Stage RIB Selection

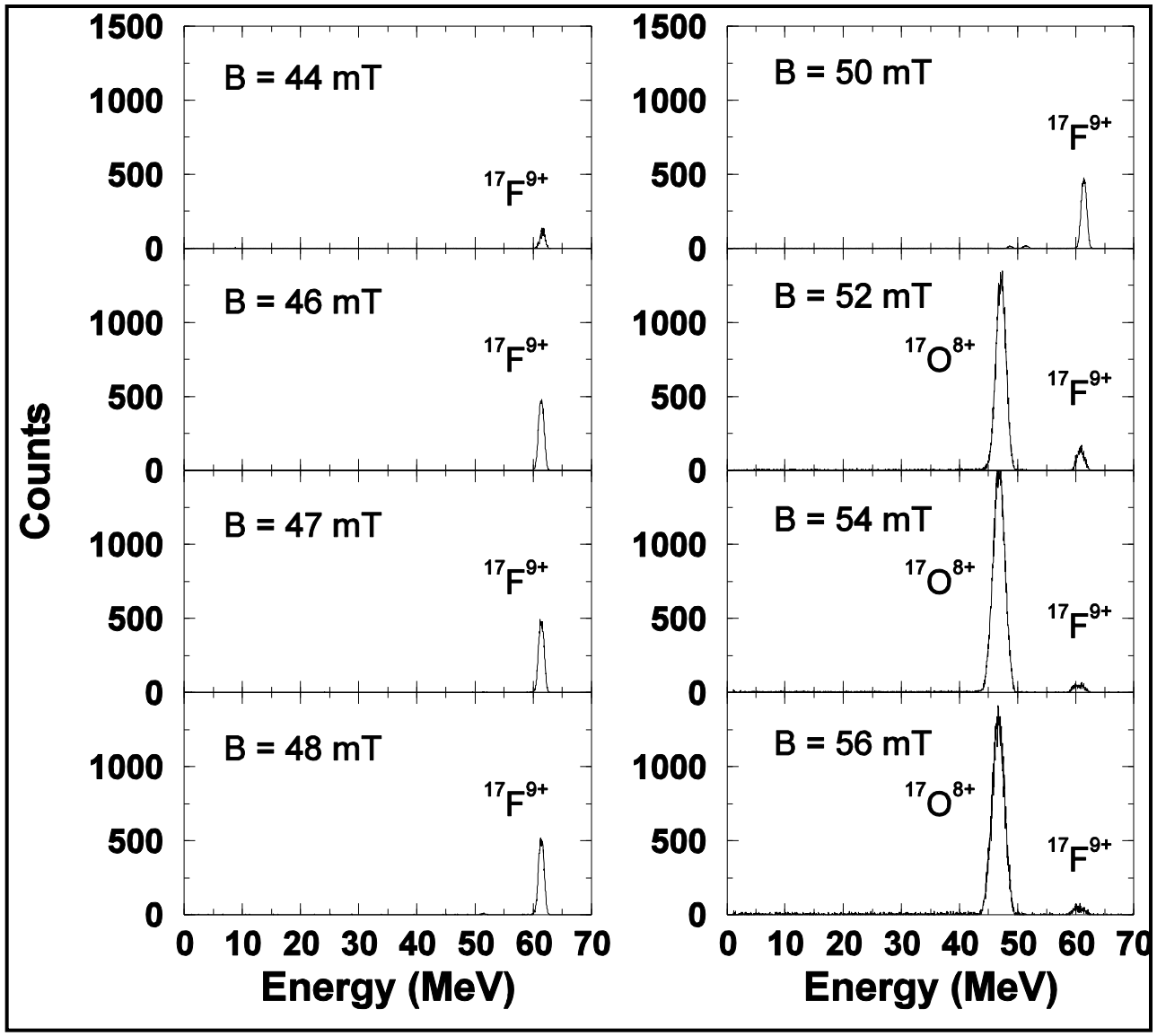
I. Bρ selection



II. *ν* selection



Wien Filter Tuning

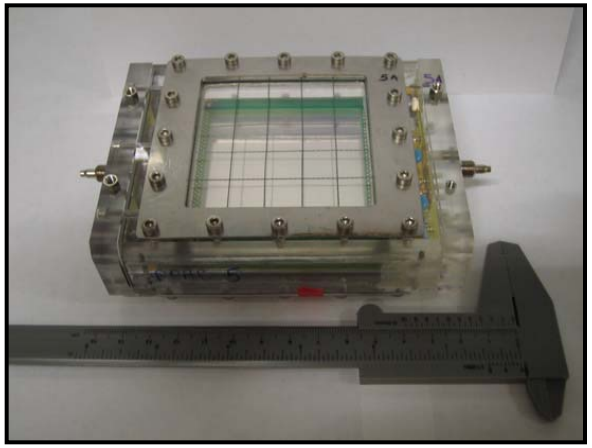


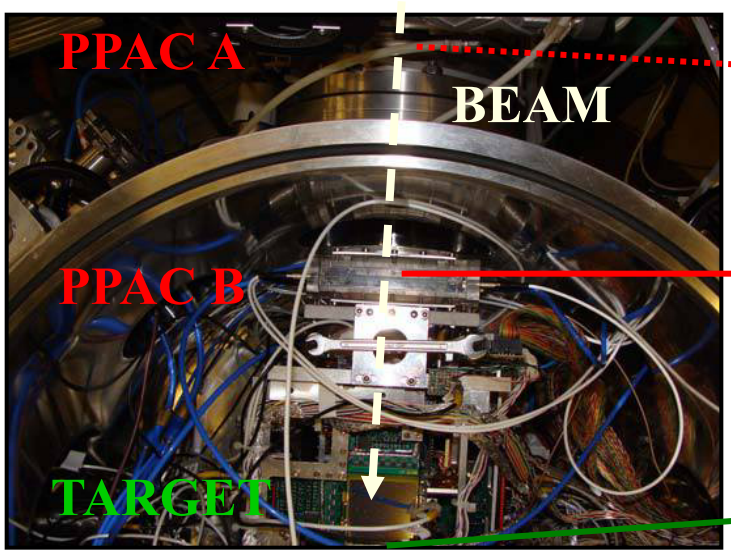
A careful tuning of the **magnetic field** of the **Wien Filter** helps **increasing** either the secondary beam **purity** or **intensity**.

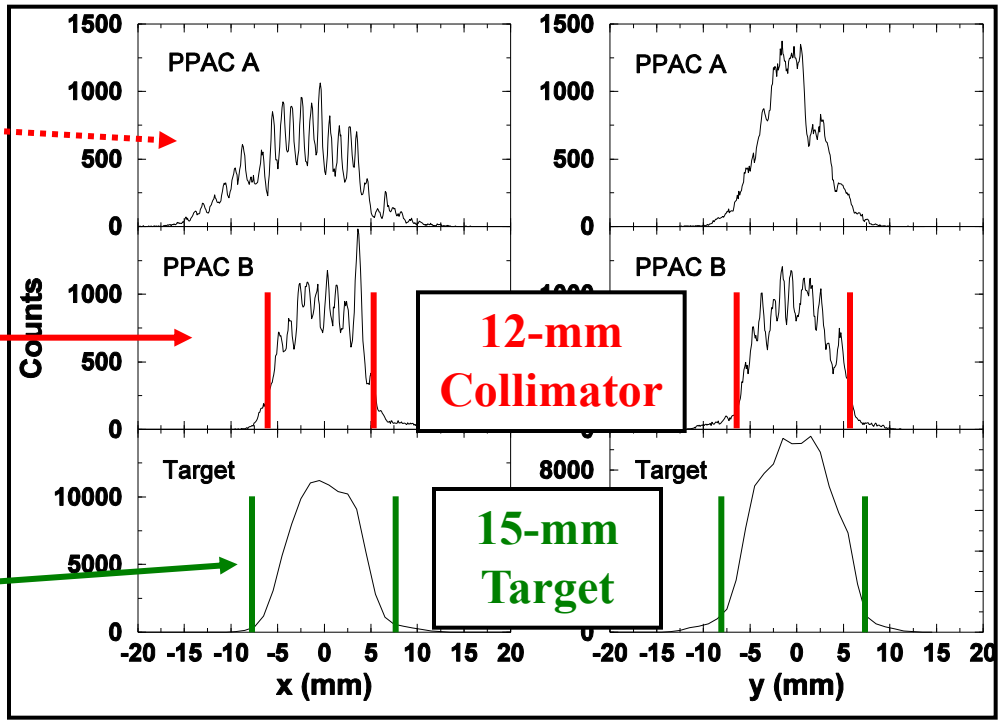
Spectra collected for a **Wien Filter electric field** of: ± 40 kV (**80%**).

Secondary Beam Tracking

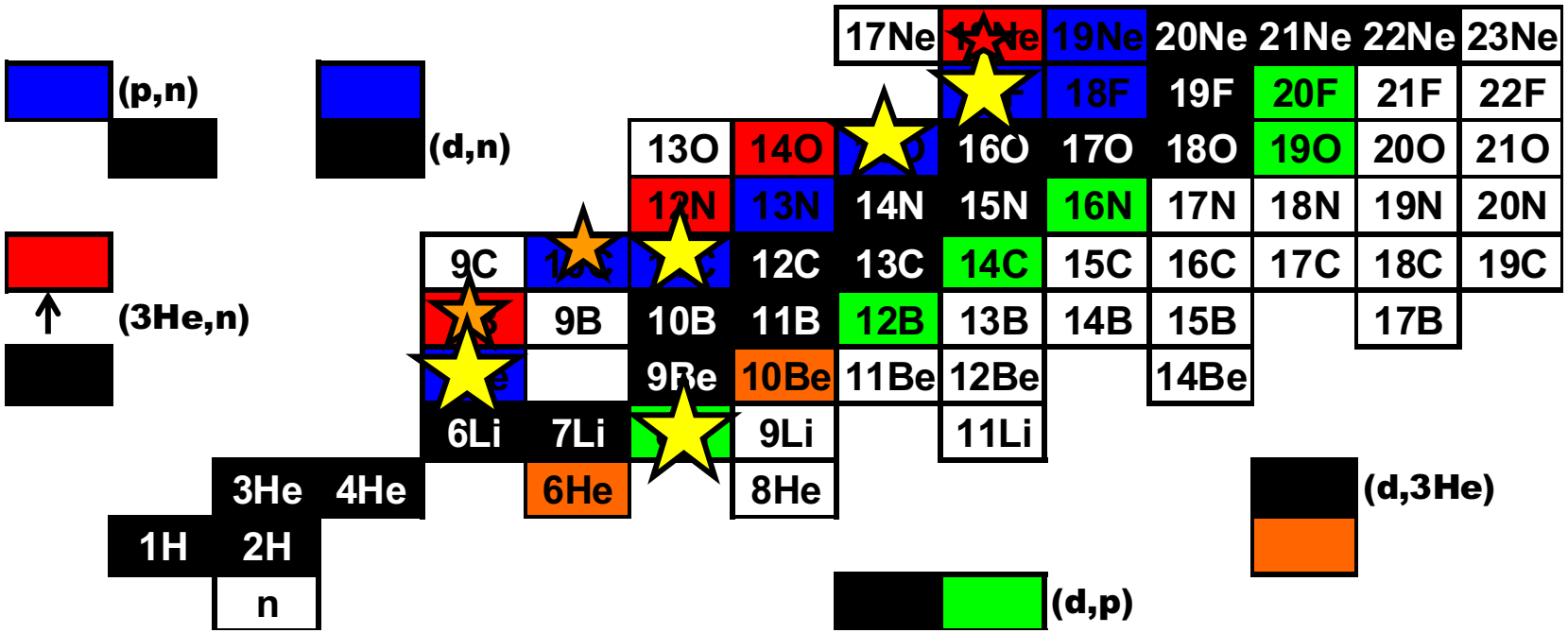
The facility was equipped with two **Parallel Plate Avalanche Counters** (PPACs) located upstream the reaction target to perform an **event-by-event tracking** of the **secondary beam particles**.







Light RIBs at EXOTIC



^{17}F	E = 3–5 MeV/u	Purity: 93-96 %	Intensity: 10^5 pps
^{8}B	E = 3–5 MeV/u	Purity: 30-43 %	Intensity: ~ 10^3 pps
^{7}Be	E = 2.5–6 MeV/u	Purity: 99 %	Intensity: 10^6 pps
^{15}O	E = 1.3 MeV/u	Purity: 97-98 %	Intensity: $4*10^4$ pps
^{8}Li	E = 2–2.5 MeV/u	Purity: 99 %	Intensity: 10^5 pps
^{10}C	E = 4 MeV/u	Purity: 99 %	Intensity: $5*10^3$ pps
^{11}C	E = 4 MeV/u	Purity: 99 %	Intensity: $2*10^5$ pps
^{18}Ne	E = 1.3 MeV/u	Purity: 95 %	Intensity: $6*10^3$ pps (ext.)

Main Topics Investigated

Reaction Dynamics at Coulomb Barrier Energies

$^{17}F + ^{208}Pb$ C. Signorini *et al.*, Eur. Phys. J. A 44, 63 (2010)

$^{17}F + ^{58}Ni$ M. Mazzocco *et al.*, Phys. Rev. C 82, 054604 (2010)

$^{17}F + ^{1}H$ N. Patronis *et al.*, Phys. Rev. C 85, 024609 (2012)

$^{8}B + ^{28}Si$ A. Pakou *et al.*, Phys. Rev. C 87, 014619 (2013)

$^{7}Be + ^{58}Ni$ M. Mazzocco *et al.*, Phys. Rev. C 92, 024615 (2015)

$^{7}Be + ^{208}Pb$ M. Mazzocco *et al.*, Phys. Rev. C 100, 024602 (2019)

$^{7}Be + ^{28}Si$ O. Sgouros *et al.*, Phys. Rev. C 94, 044623 (2016), Phys. Rev. C 95, 054609 (2017)

$^{8}Li + ^{90}Zr$ A. Pakou *at al.*, Eur. Phys. J. A 51, 55 (2015), Eur. Phys. J. A 51, 90 (2015)

$^{8}B + ^{28}Si$ C. Parascandolo, D. Pierroutsakou *et al.*, (in preparation)

Resonant Scattering – α clustering

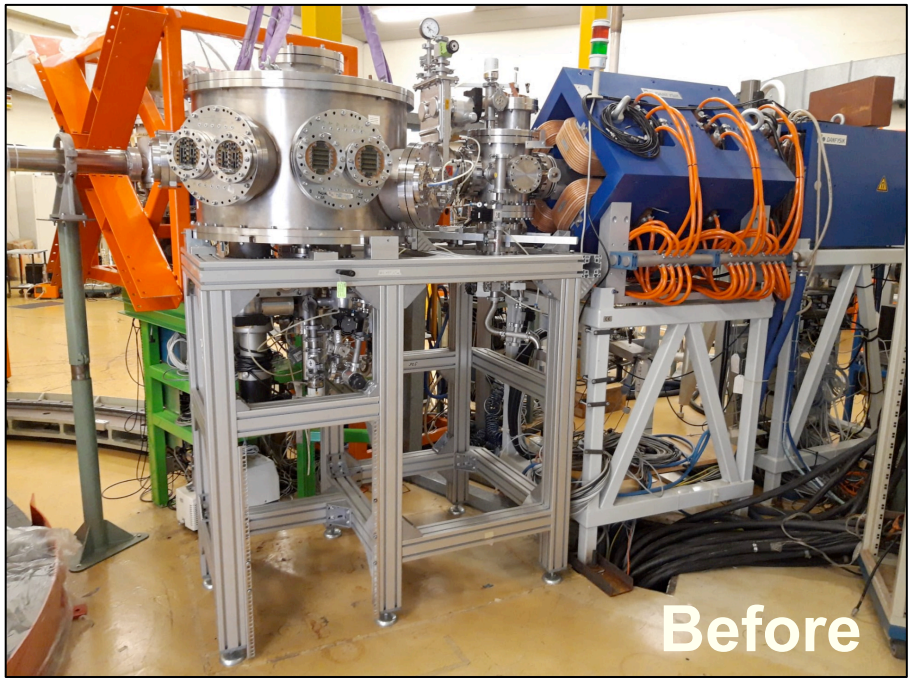
$^{15}O + ^{4}He$ D. Torresi *et al.*, Phys. Rev. C 96, 044317 (2017)

$^{11}C + ^{4}He$ D. Torresi, C. Wheldon, C. Parascandolo *et al.*, (in preparation)

Reactions of Astrophysical Interest via Trojan Horse Method

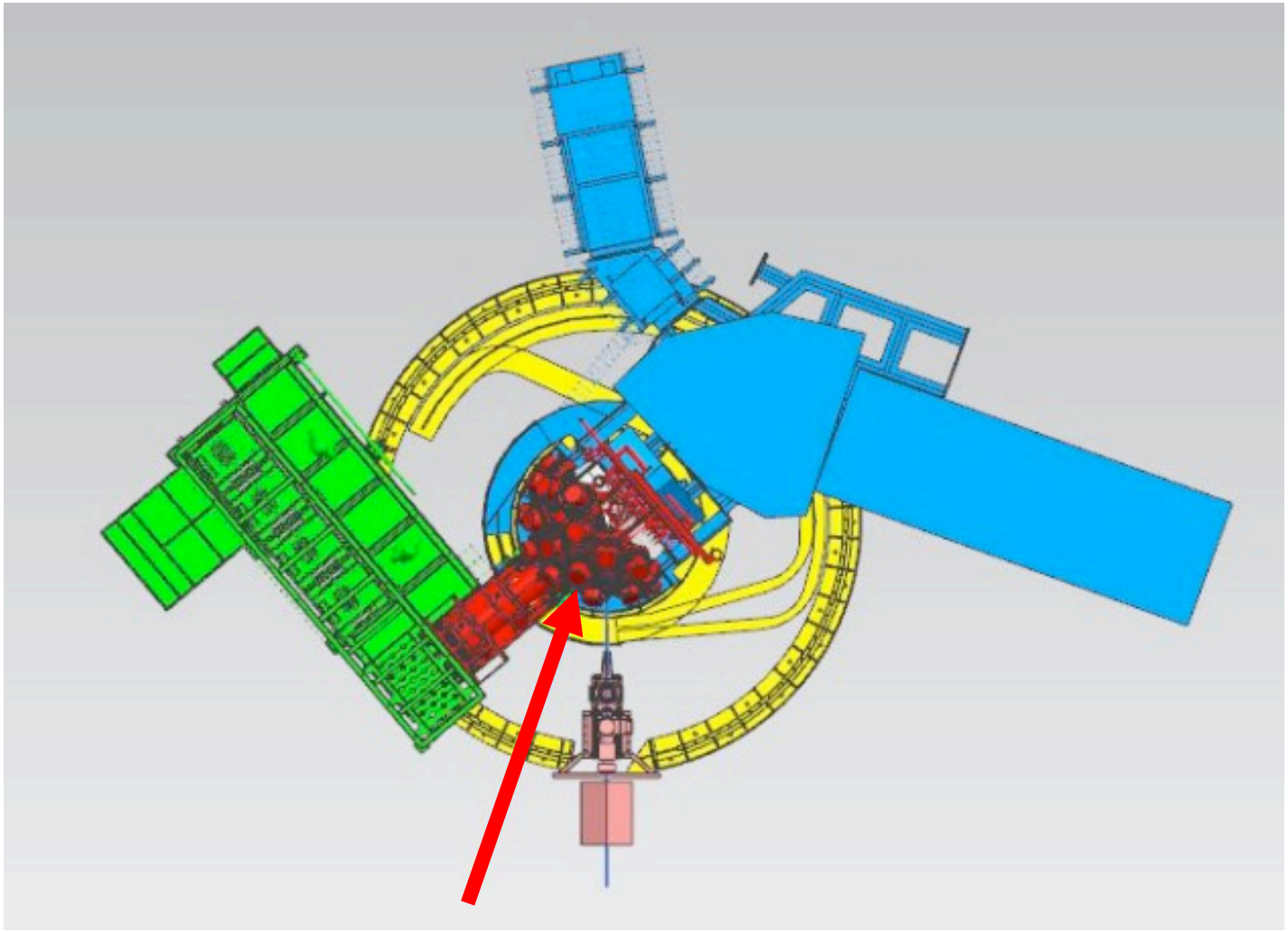
$^{7}Be + ^{2}H$ L. Lamia *et al.*, Ap. J. 879, 23 (2019)

Changes in the Experimental Hall



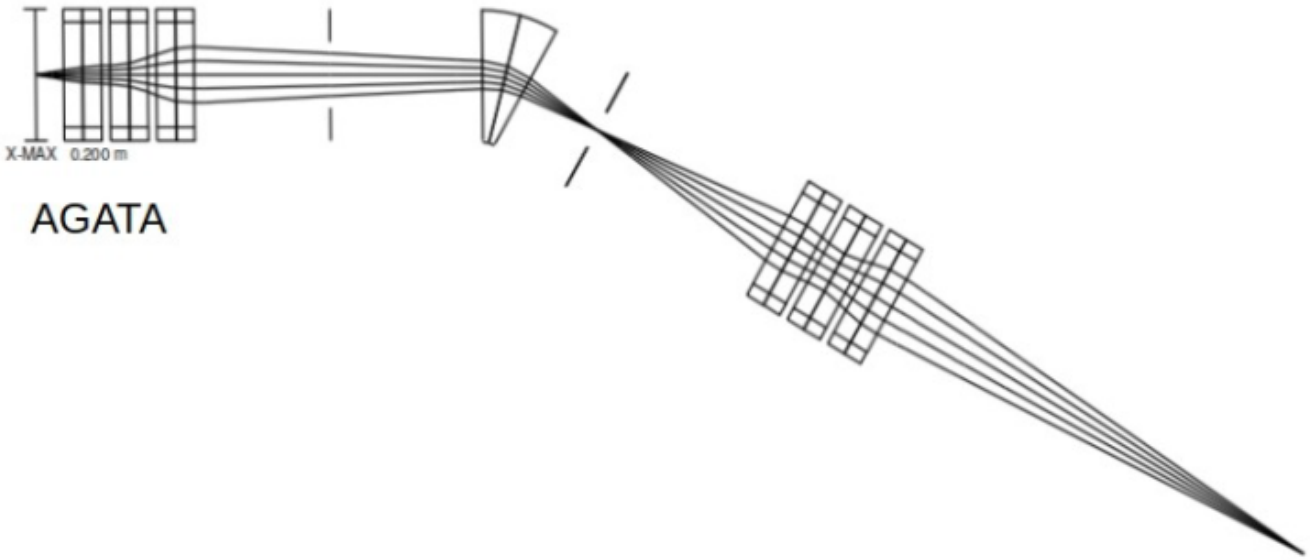
The **small reaction chamber** housing the first PPAC and the **main reaction chamber** around the final focal plane of EXOTIC were **removed** in March 2021 in order **to free the space** needed for the installation and the services of AGATA, nevertheless …

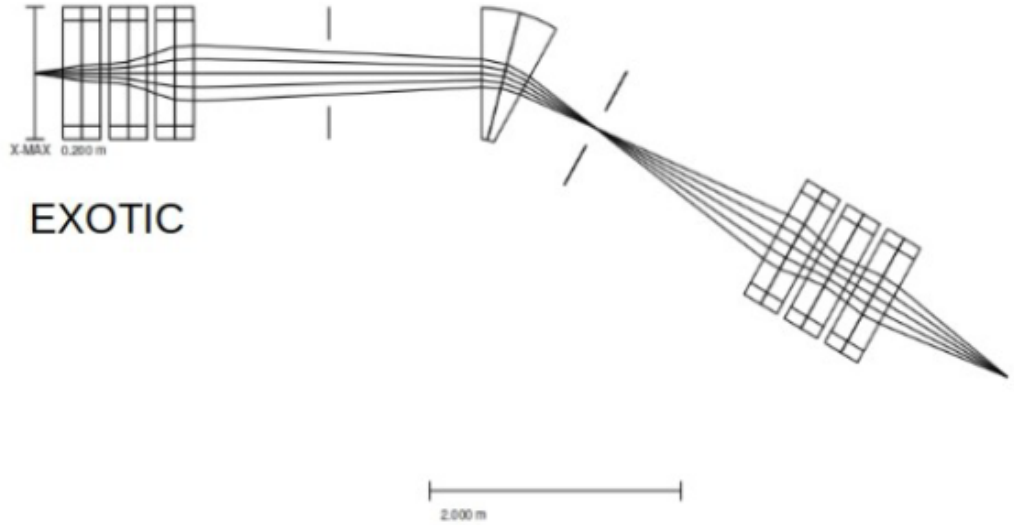
EXOTIC–AGATA Connection



… the **AGATA focal plane**, in the PRISMA-AGATA configuration, is located **2.68 m downstream** the original final focal plane.

Modified Ion–Optics

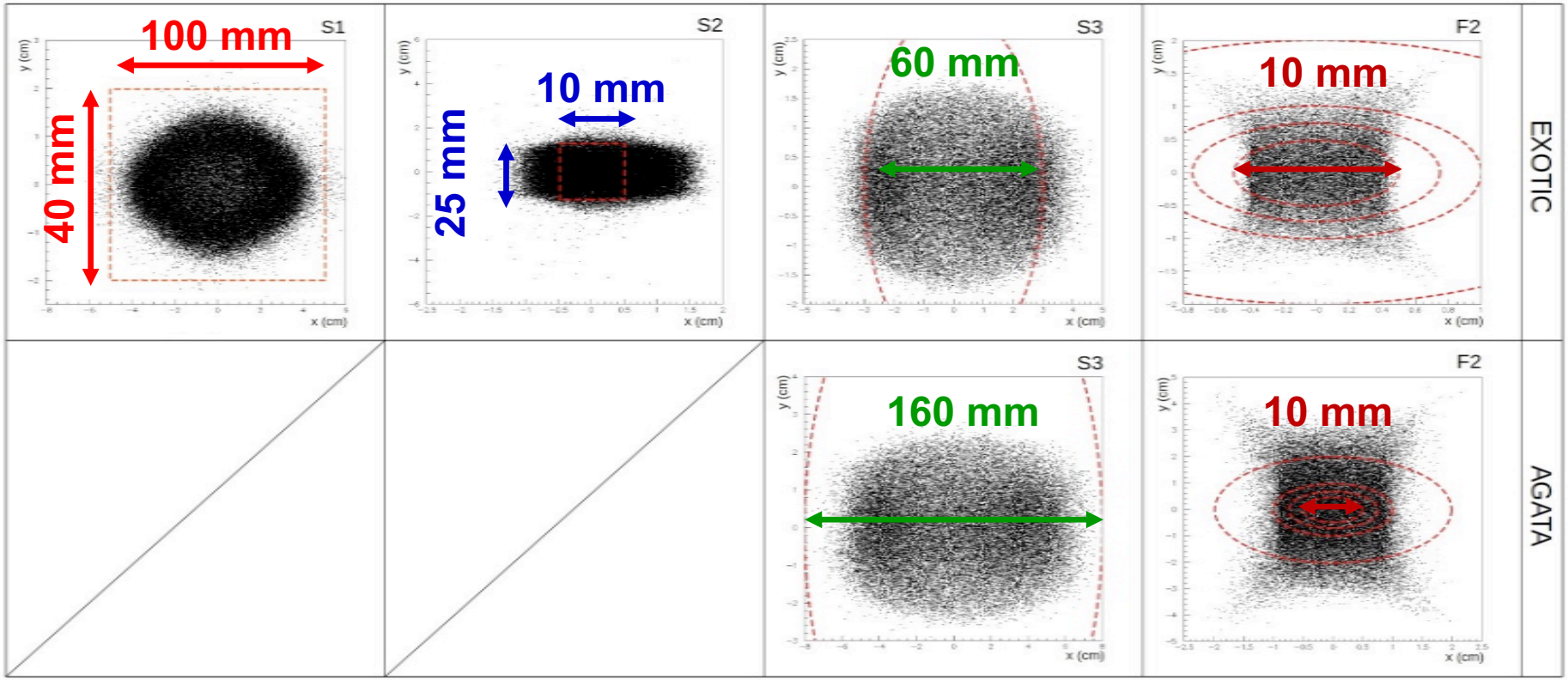




Moving the final focus **downstream** requires **lower magnetic fields** at the pole-tips of the **quadrupoles of the second triplet**.

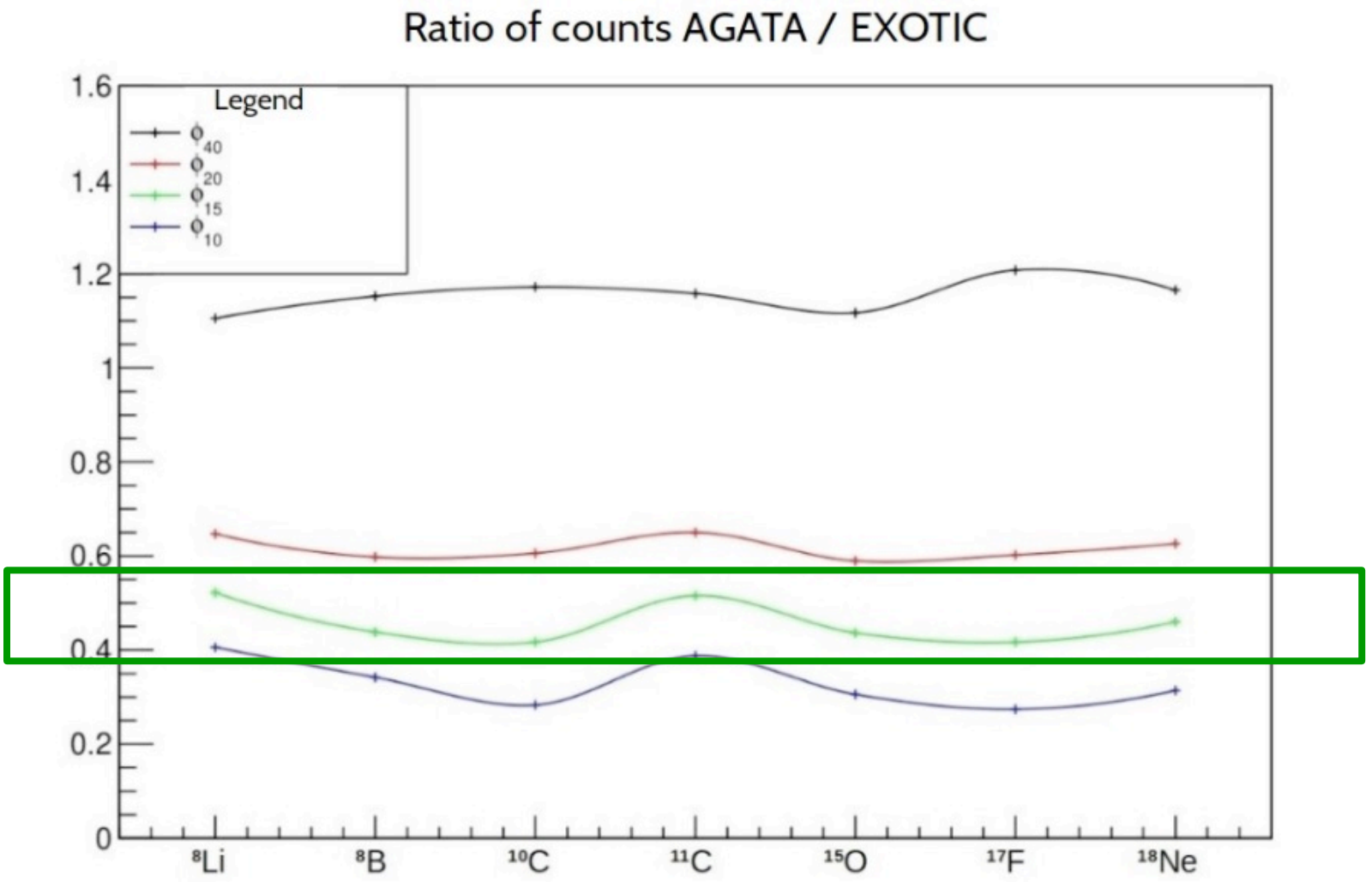
Ion-optical calculations were performed to estimate the **relative transmission** in the two configurations.

Ion Optical Calculations



Beam profile **behind the first quadrupole triplet (S1)**, **after the dipole magnet (S2)**, at the **exit of the second quadrupole triplet (S3)** and at the **final focal plane (F2)**.

Relative Transmission



50-% reduction in secondary beam intensity is estimated for a **target diameter of 15 mm**.

Expected RIB Intensities

RIB	EXOTIC Conf. (pps)	AGATA Conf. (pps)	E_{max} (MeV)
$^{8}Li^{3+}$	10^5	5×10^4	21.7
$^{7}Be^{4+}$	10^6	5×10^5	44.2
$^{8}B^{5+}$	10^3	4×10^2	45.5
$^{10}C^{6+}$	5×10^3	2×10^3	51.8
$^{11}C^{6+}$	2×10^5	10^5	54.2
$^{15}O^{8+}$	4×10^4	2×10^4	70.6
$^{17}F^{9+}$	10^5	4×10^4	79.6
$^{18}Ne^{10+}$	6×10^3	2×10^3	78.1

Tasks and Time-Line of the Project

Task	Intervention	Service
1	**Laser-assisted alignment**	LNL Acc. Division
2	**Beam Diagnostic upstream the production target**	
	2 four-sector slits (project)	PD Design Office
	2 four-sector slits (realization)	PD Mech. Workshop
	or 2 diagnostic boxes (installation)	LNL Acc. Division
3	**Guiding System for the gas target**	
	Technical drawing	PD Design Office
	Realization	PD Mech. Workshop
4	**Slit Remote Control System**	LNL SCA
5	**Replacement of the Pipelines** for magnets and power supplies	LNL Users Service
6	**Magnet Power Supply**	LNL SCA
6	**Control System**	
7	**Beam Diagnostic in proximity of the final focal plane**	
	Detectors and electronics	NA SER
	Technical drawing	PD Design Office
	Realization	PD Mech. Workshop

Semester	Task	Intervention	Service
2021/II	5	Pipeline replacement (I)	LNL Users Service
	7	Beam diagnostic (proj.)	PD Design Office
2022/I	2	2 four-sector slits (proj.)	PD Design Office
	5	Pipeline replacement (II)	LNL Users Service
	7	Beam diagnostic (proj.)	PD Design Office
	7	Beam diagnostic (det.)	NA SER
2022/II	2	2 four-sector slits (real.)	PD Mech. Workshop
	3	Gas target guiding system (proj.)	PD Design Office
	6	Magnet PS control system	LNL SCA
	7	Beam diagnostic (real.)	PD Mech. Workshop
	7	Beam diagnostic (elec.)	NA SER
2023/I	2	2 four-sector slits (inst.)	PD Mech. Workshop
	3	Gas target guiding system	PD Mech. Office
	4	Slit remote control system	LNL SCA
	7	Beam diagnostic (inst.)	PD Mech. Workshop and NA SER
	7	Beam line connection	PD Mech. Workshop
	1	Laser-assisted alignment In-beam commissioning	LNL Acc. Division

Thank You Very Much for Your Attention