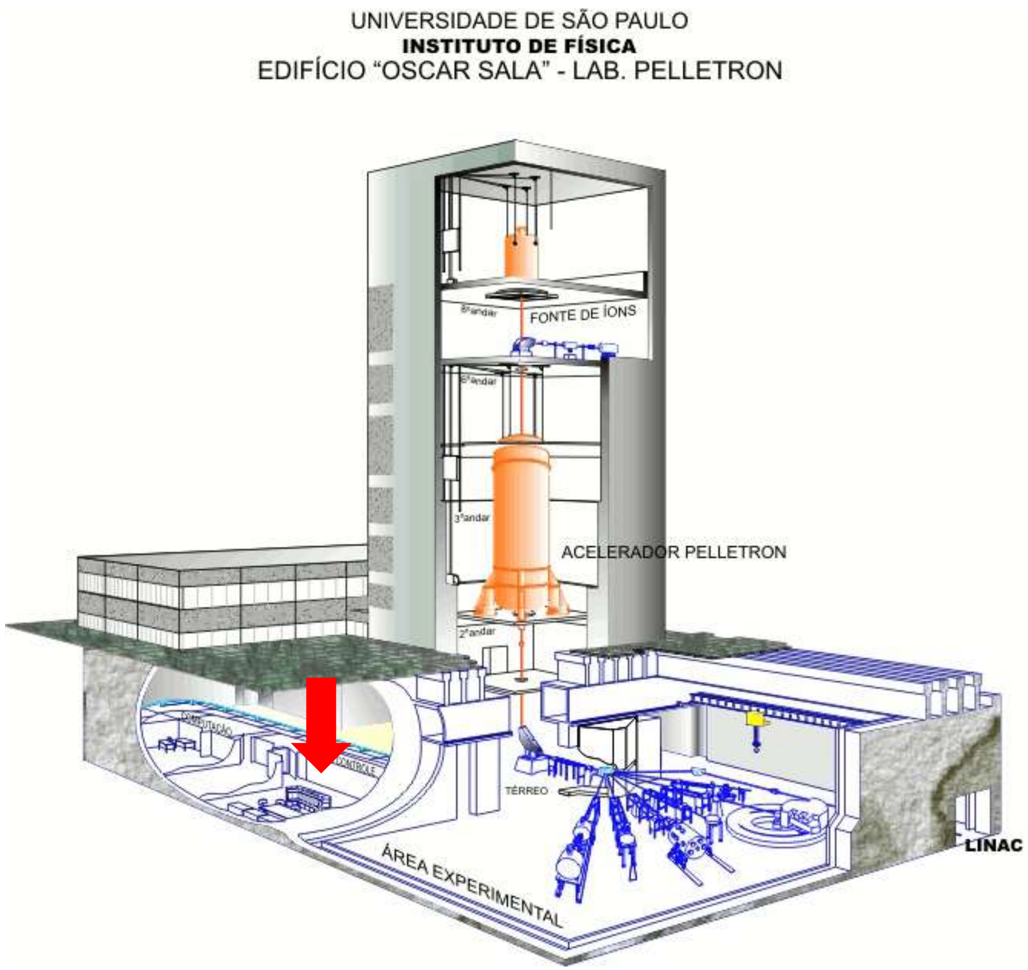
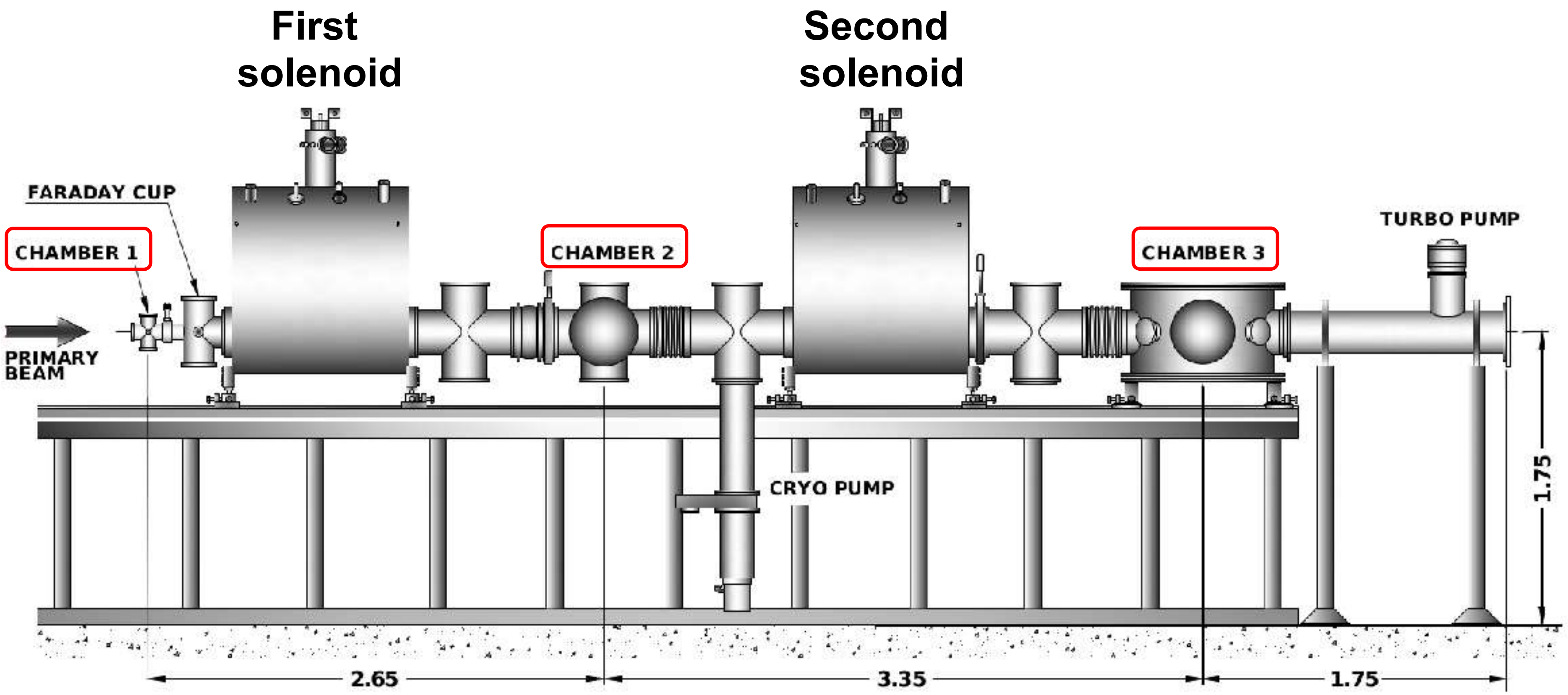
Selected ongoing experiments in RIBRAS

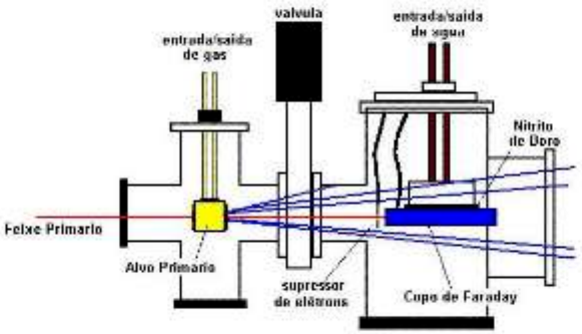


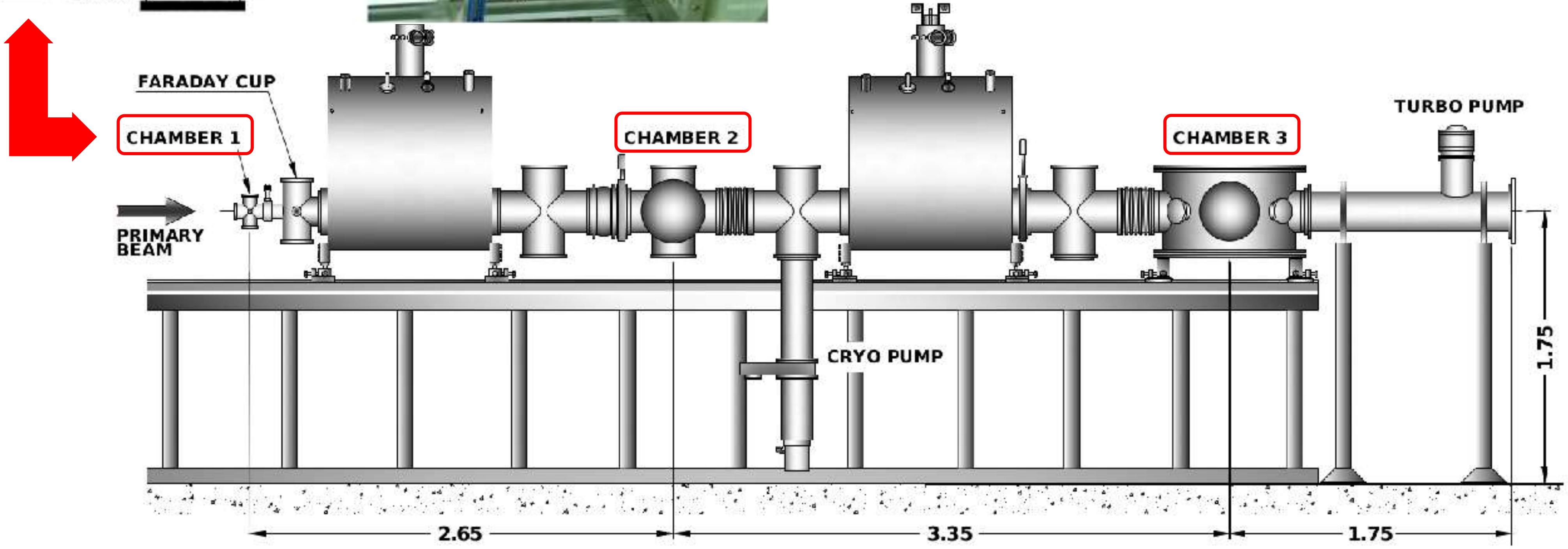
Radioactive Ions in Brasil (RIBRAS) facility



RIBRAS system is based on two superconducting solenoids, installed along an experimental beam line connected to the Pelletron Tandem Accelerator of 8MV.

Radioactive Ions in Brazil (RIBRAS) facility





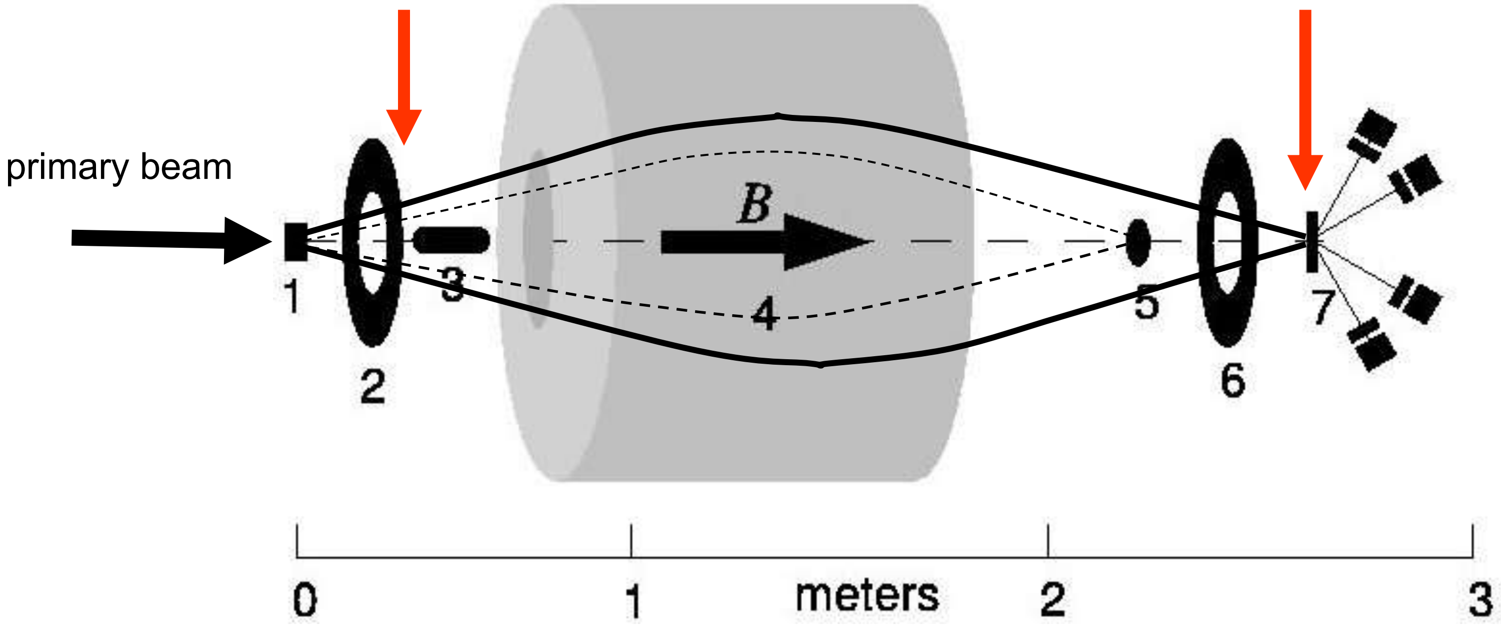
Secondary exotic particles are produced by nuclear reactions between the primary stable beam and a primary target, located in a primary scattering chamber (chamber 1), installed before the first solenoid.

Radioactive Ions in Brazil (RIBRAS) facility – selection system

angular acceptance
2 deg<$\Delta\theta$ <6 deg

$\Delta\Omega$=30 msr

$$B\rho = \frac{mv}{q} = \frac{\sqrt{2mE}}{q}$$



1- primary target
2- collimator
3- Faraday cup
4- solenoid

5- lollipop
6-collimator
7- scattering chamber,secondary target and detectors

Radioactive Ions in Brazil (RIBRAS) facility

secondary beam	reaction	Q_{reac} (MeV)	secondary beam (pps)	Energy/Resolution
^{6}He	^{9}Be(^{7}Li,^{6}He)^{8}Be	-3.390	10^{5} - 10^{6}	1000/22 MeV
^{7}Be	^{3}He(^{6}Li,^{7}Be)d	+0.112	10^{4} - 10^{5}	800/18.8 MeV
^{7}Be	^{7}Li(^{6}Li,^{7}Be)^{6}He	-4.369	10^{4} - 10^{5}	1000/22 MeV
^{8}Li	^{9}Be(^{7}Li,^{8}Li)^{8}Be	+0.367	10^{5} - 10^{6}	500/25.8 MeV
^{8}B	^{3}He(^{6}Li,^{8}B)n	-1.975	10^{4}	1000/15.6 MeV
^{10}Be	^{9}Be(^{11}B,^{10}Be)^{10}B	-4.642	10^{5}	800/23.2 MeV
^{12}B	^{9}Be(^{11}B,^{12}B)^{10}B	+1.705	10^{5}	800/25.0 MeV

Table: beam production at RIBRAS - reaction, intensity and energy resolution.

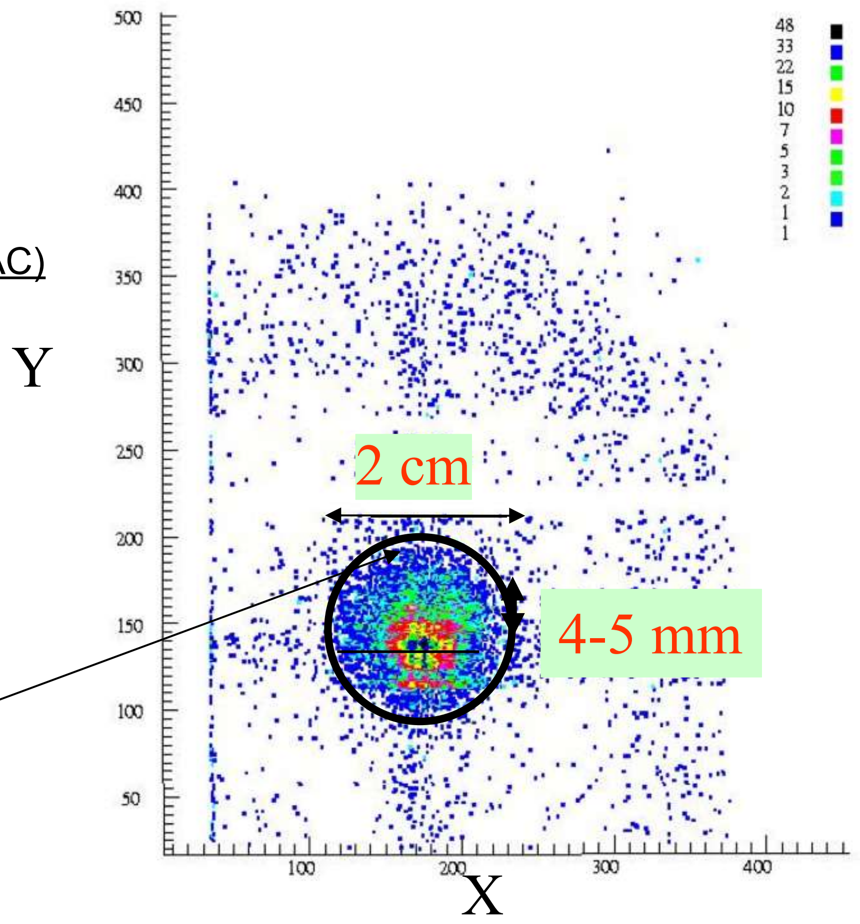
^{6}He and ^{8}B are neutron and protons halos

Secondary beam spot profile:

reaction $^{9}Be(^{7}Li,^{8}Li)$

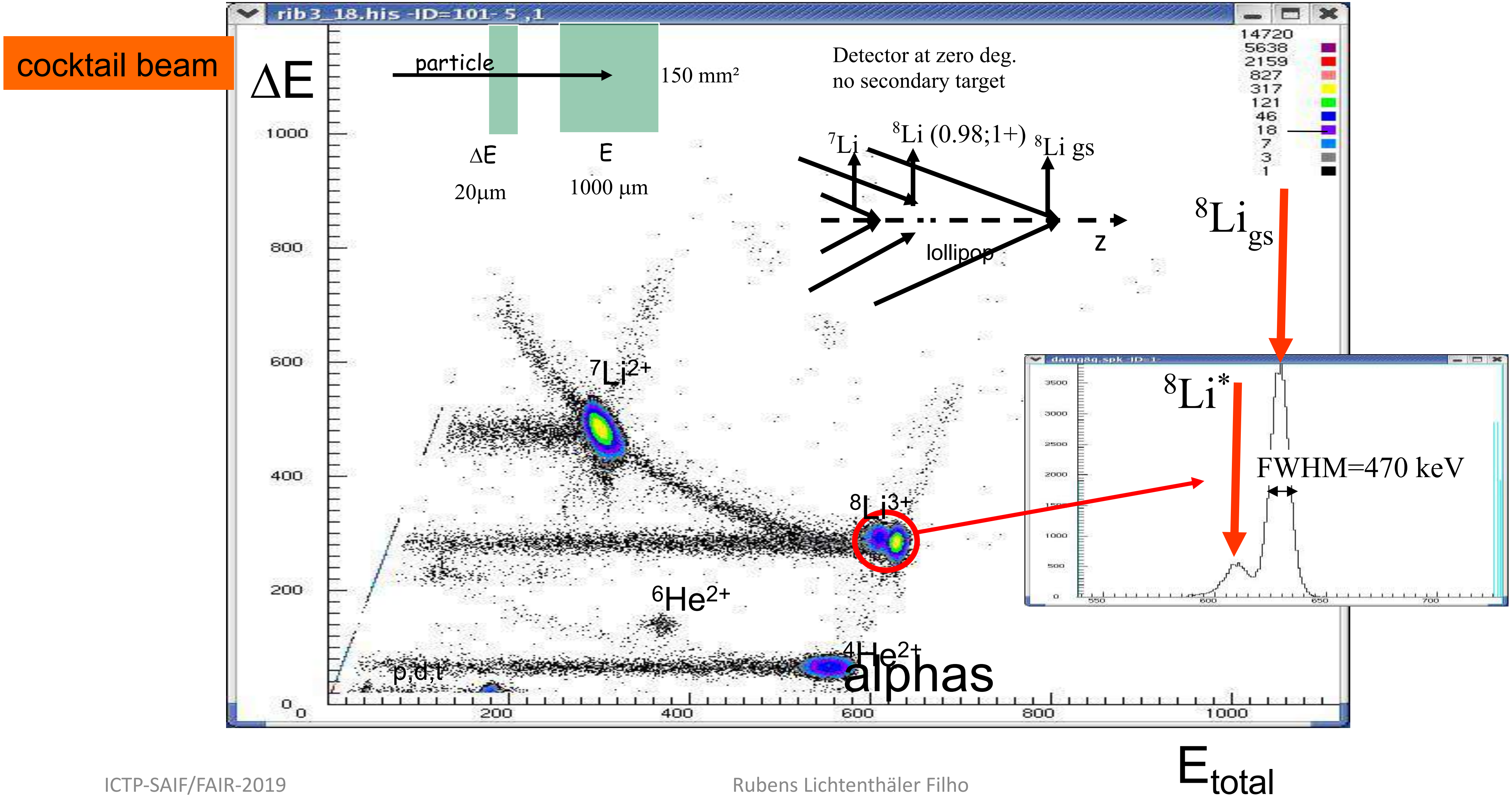
Parallel Plate Avalanche Counter (PPAC)
X-Y position sensitive gas detector
C. Mazur Saclay

3-4mm Primary beam spot
+
magnifying factor 1.5
of the 1st solenoid

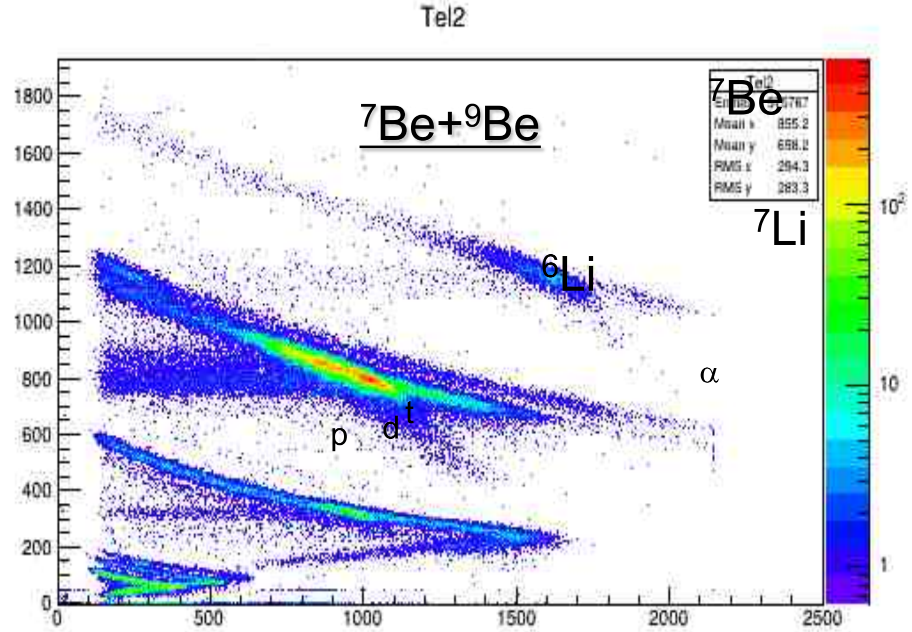


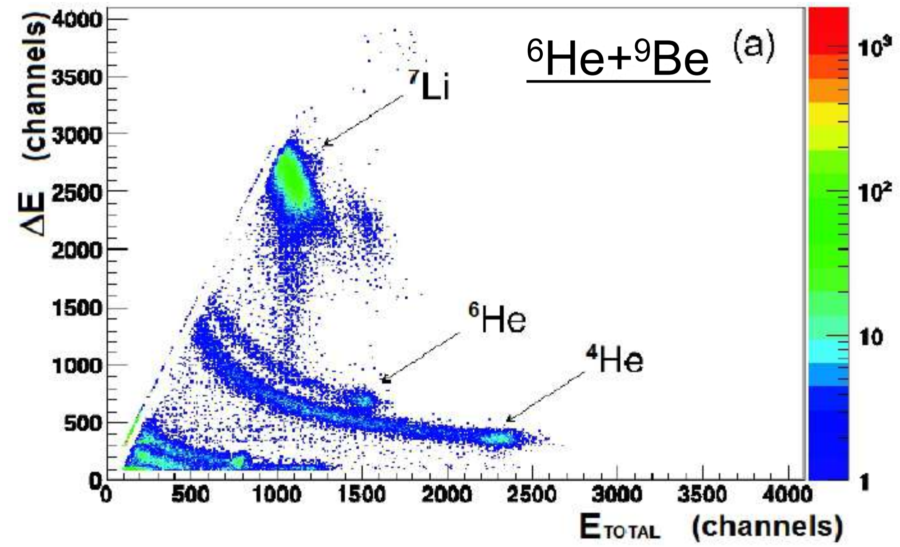
Direct secondary beam at zero degrees $^{9}Be(^{7}Li,^{8}Li)^{8}Be$

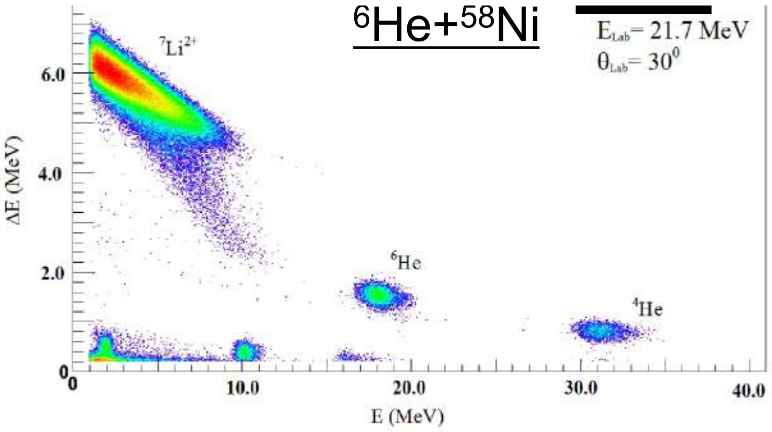
ΔE-E telescope

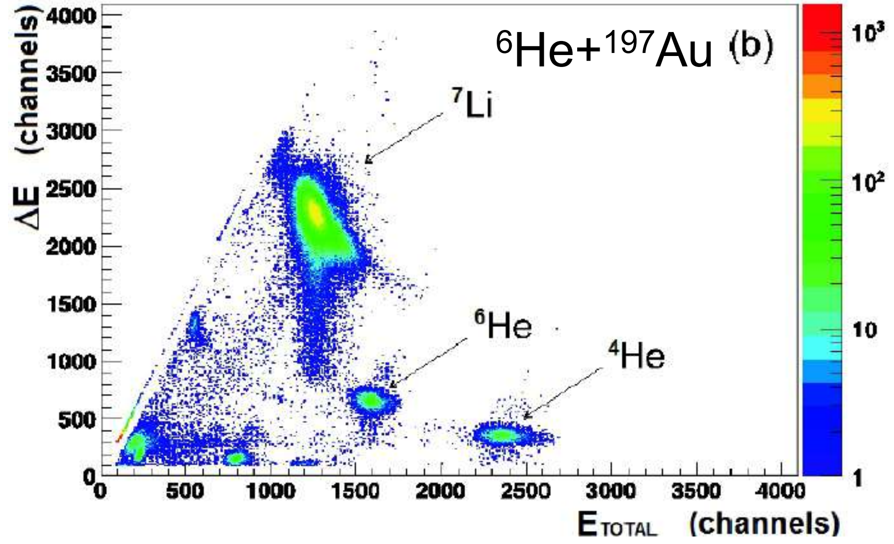


Identification spectra ΔE-E in central chamber 2

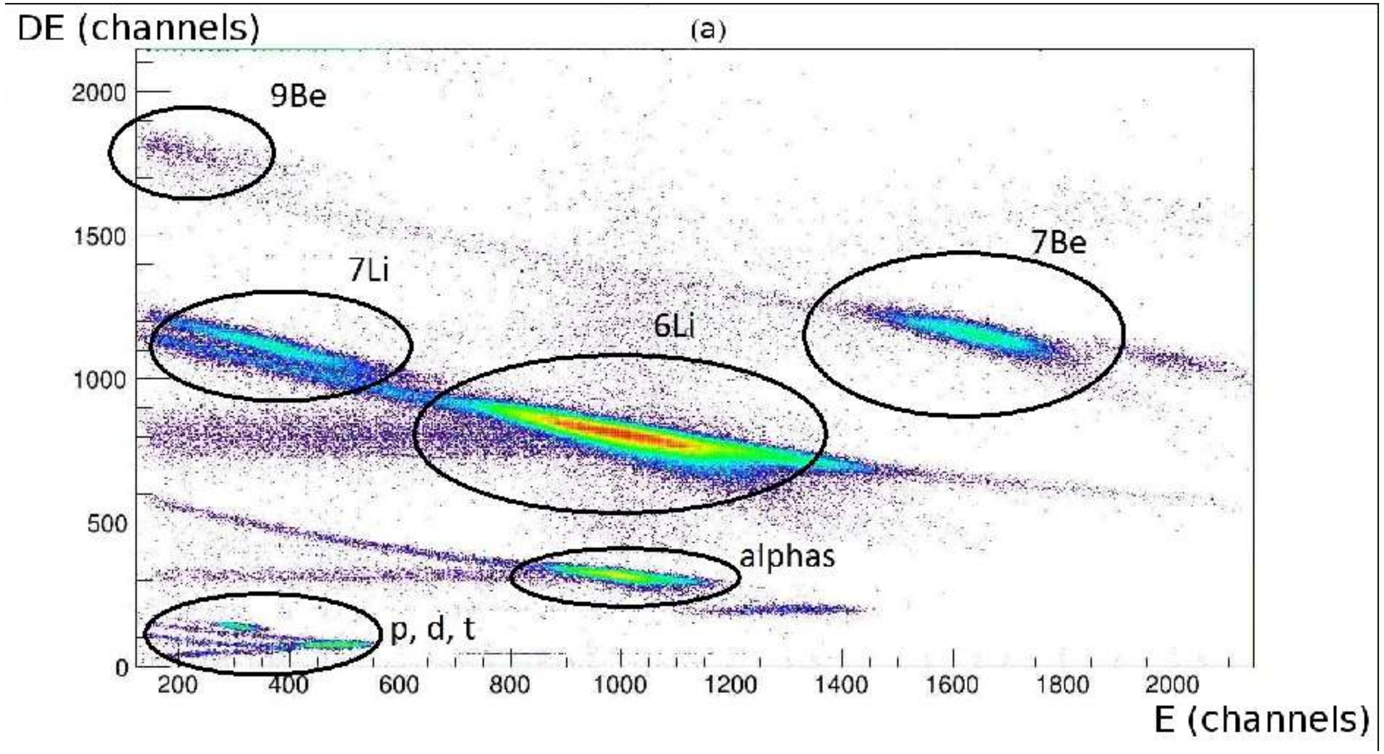




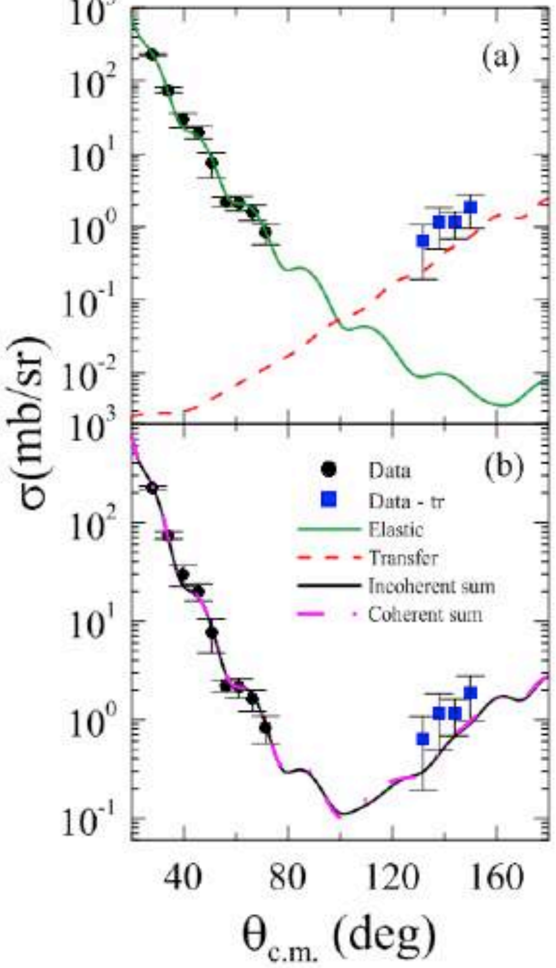




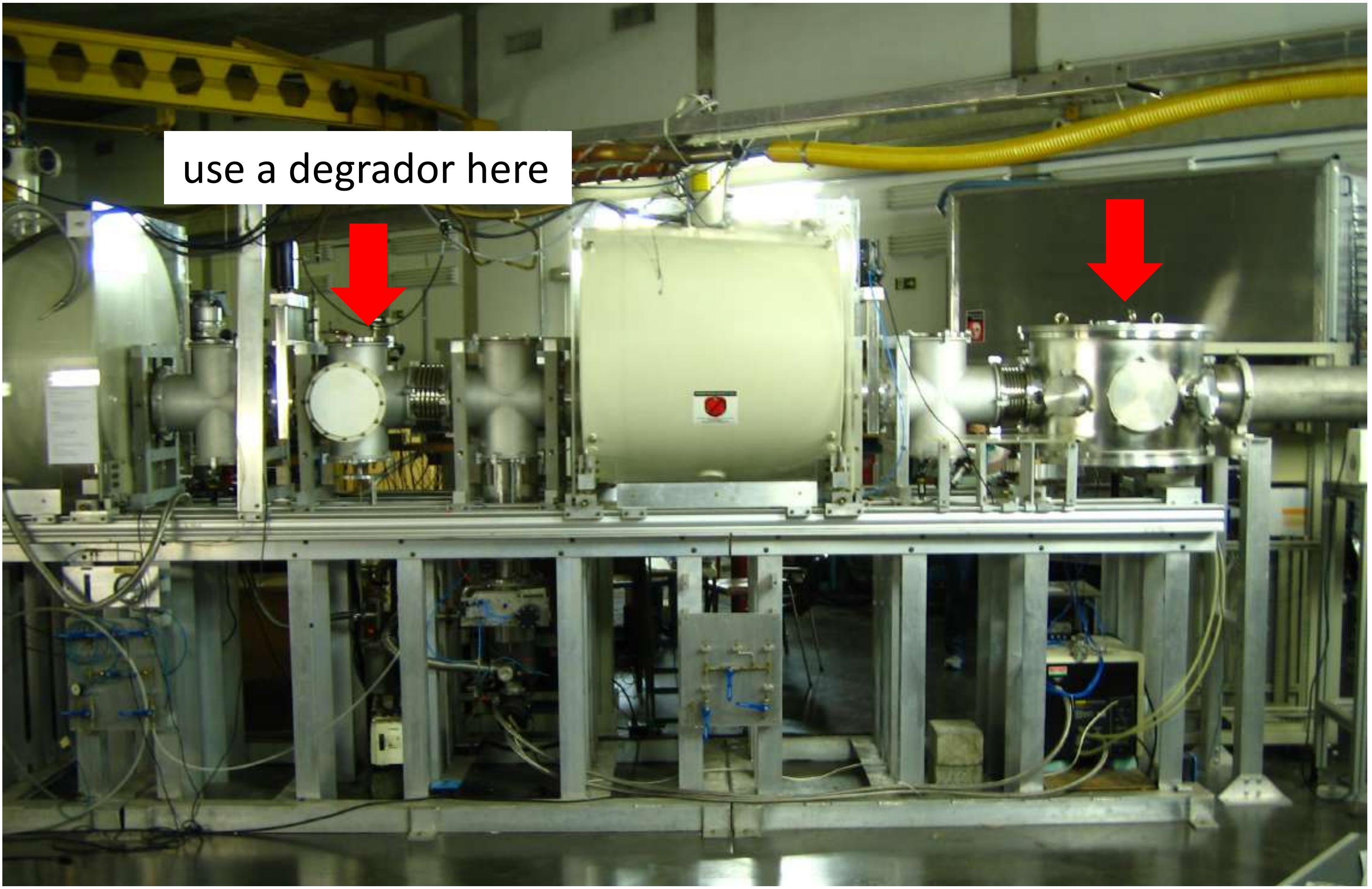
Proton rich secondary beams: ^{7}Be and ^{8}B

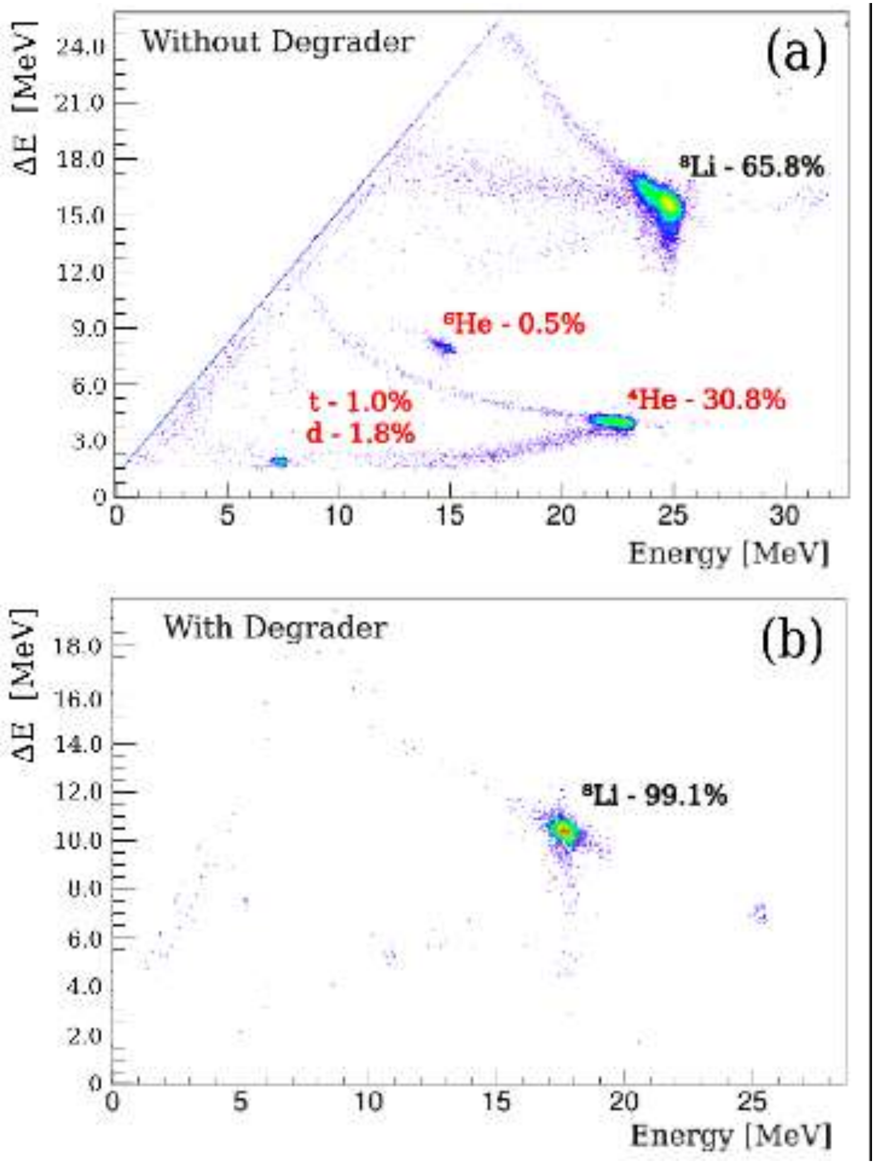


$^{9}Be(^{7}Be,^{9}Be)^{7}Be$



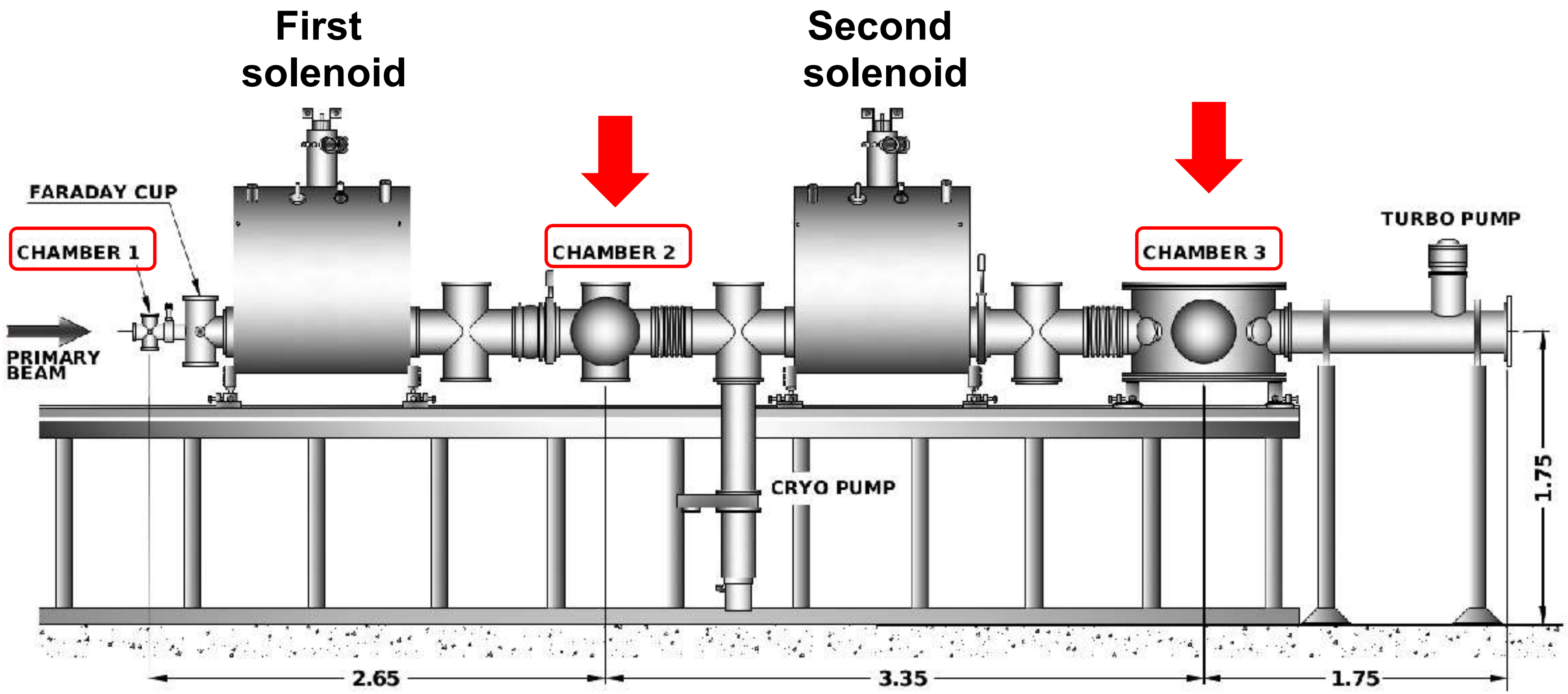
Beam purity improved after the second solenoid.





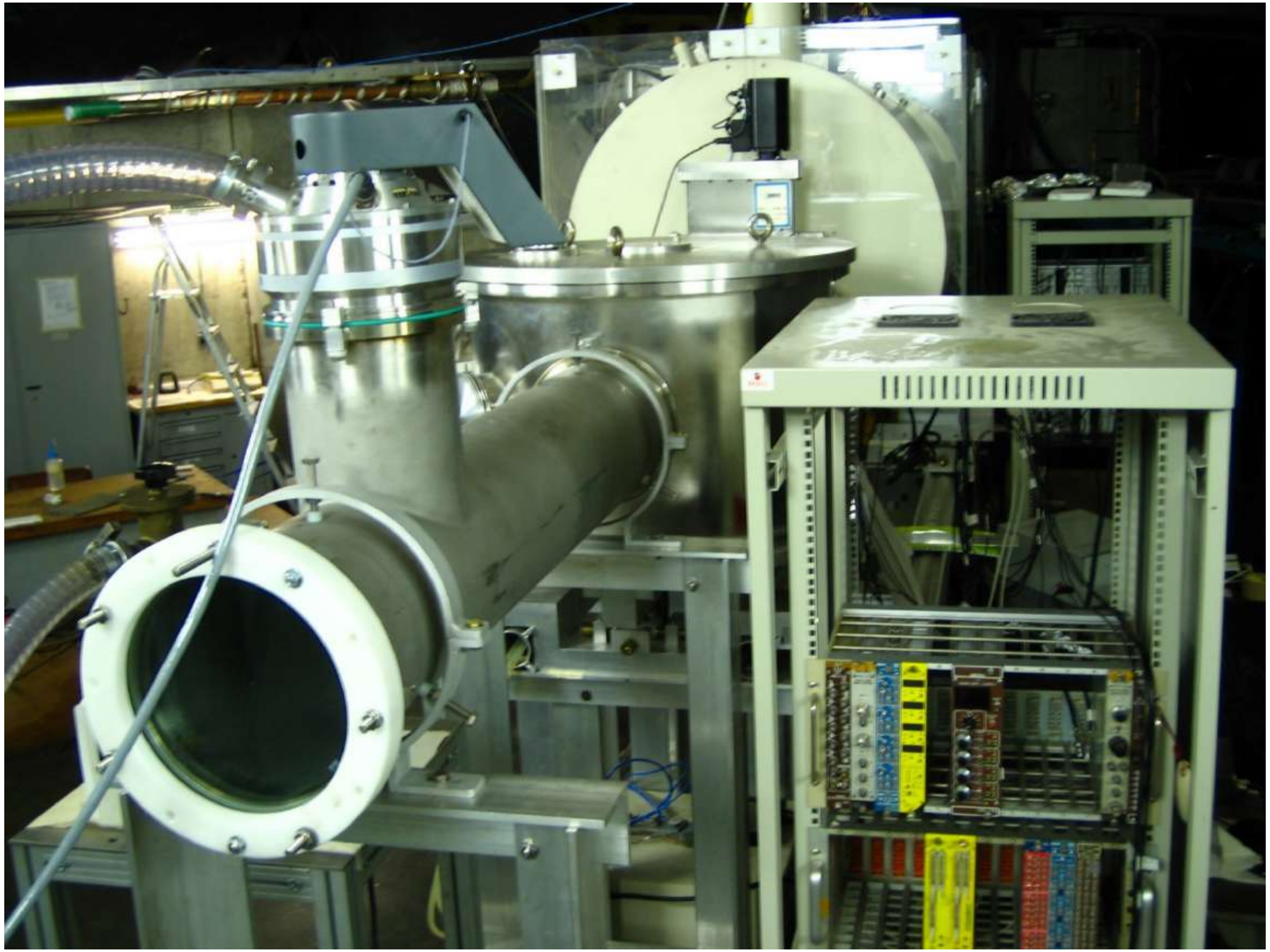
After the second solenoid, an improvement of the secondary beam purity, up to 99%, can be obtained.

Experimental setup in scattering chamber 3



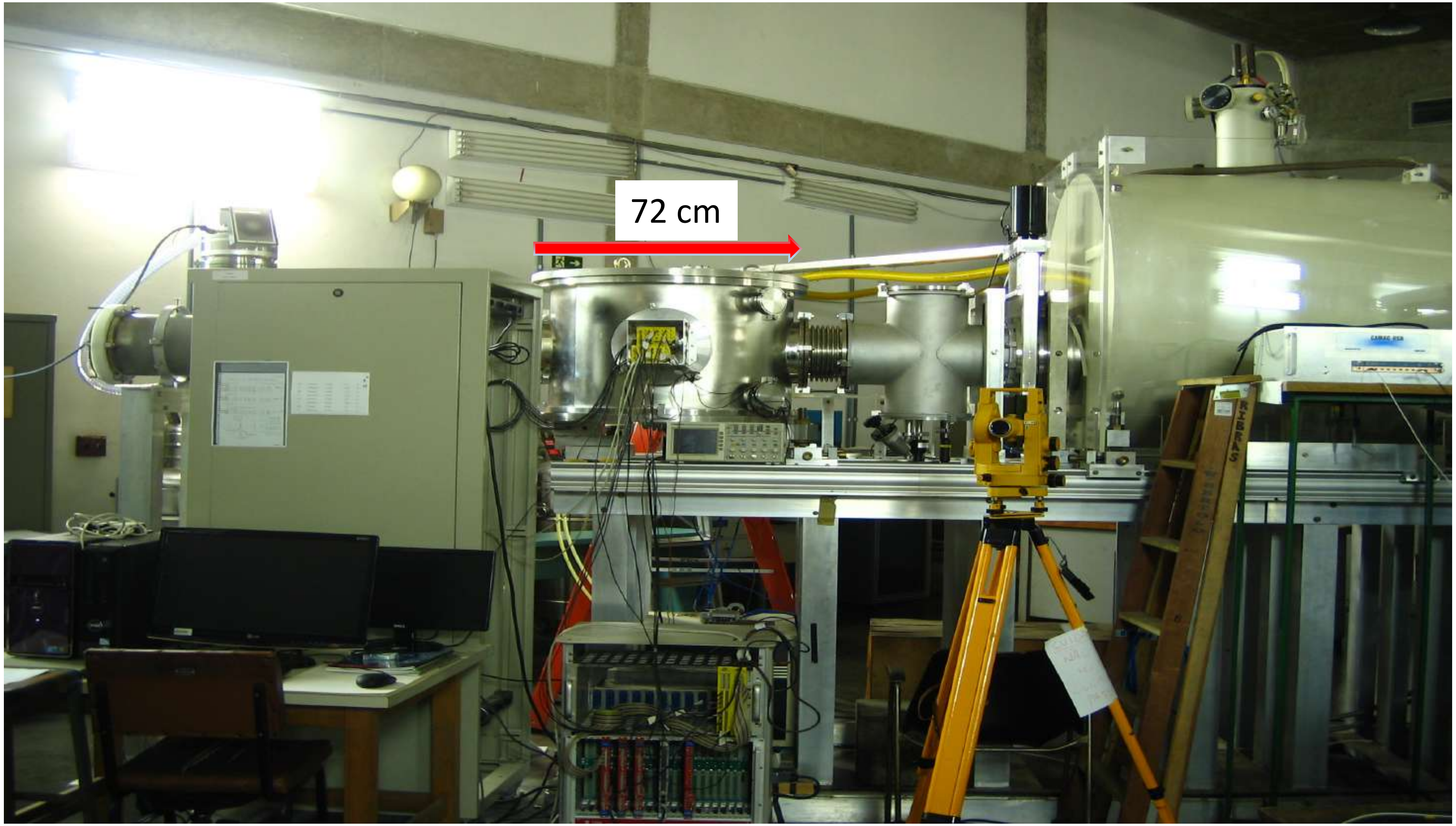
The reaction chamber (chamber 3), placed after the second solenoid, is being restored.

Experimental setup in scattering chamber 3



Experimental beam line extension: turbo pump located far away from the solenoid

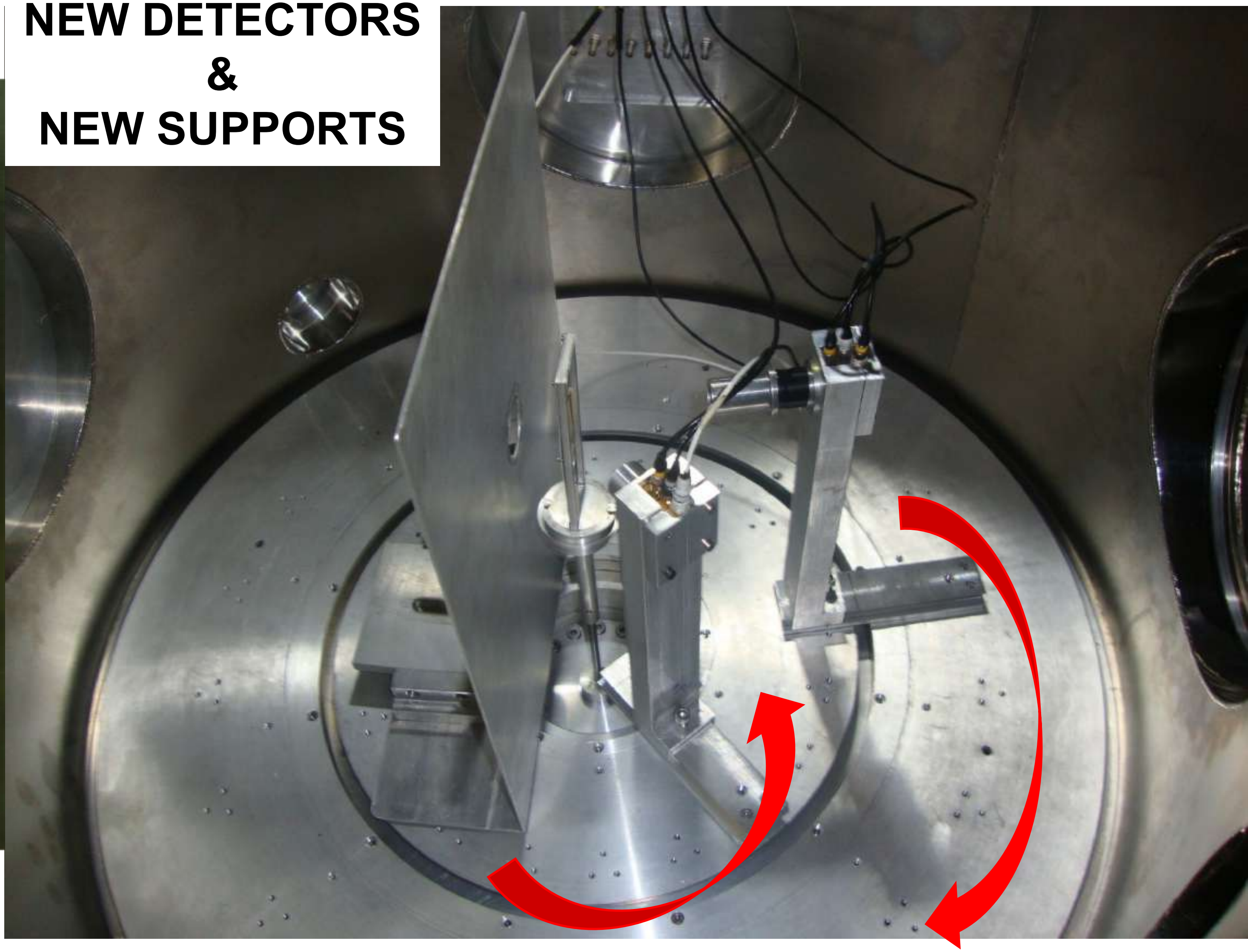
Experimental setup in scattering chamber 3



New chamber under operation, with two support disks, which are remotely controlled, and rotate, independently, in opposite directions (2014 – 2015).

Experimental setup in scattering chamber 3

4 Telescopes - ^{6}He + ^{120}Sn (2015)

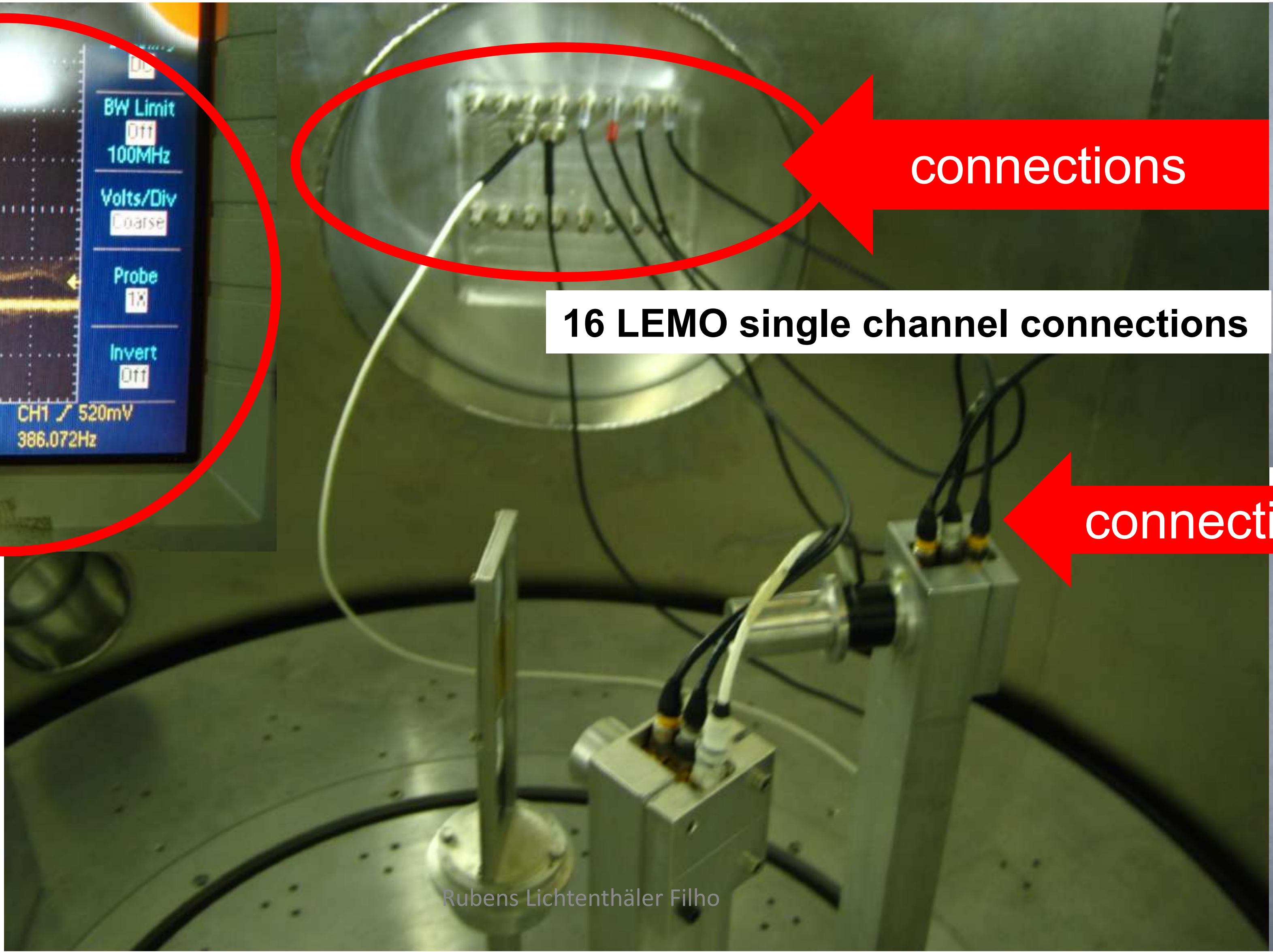


NEW DETECTORS & NEW SUPPORTS

Detectors SETUP – inside the chamber: 8 silicon detectors mounted as telescopes for testing.

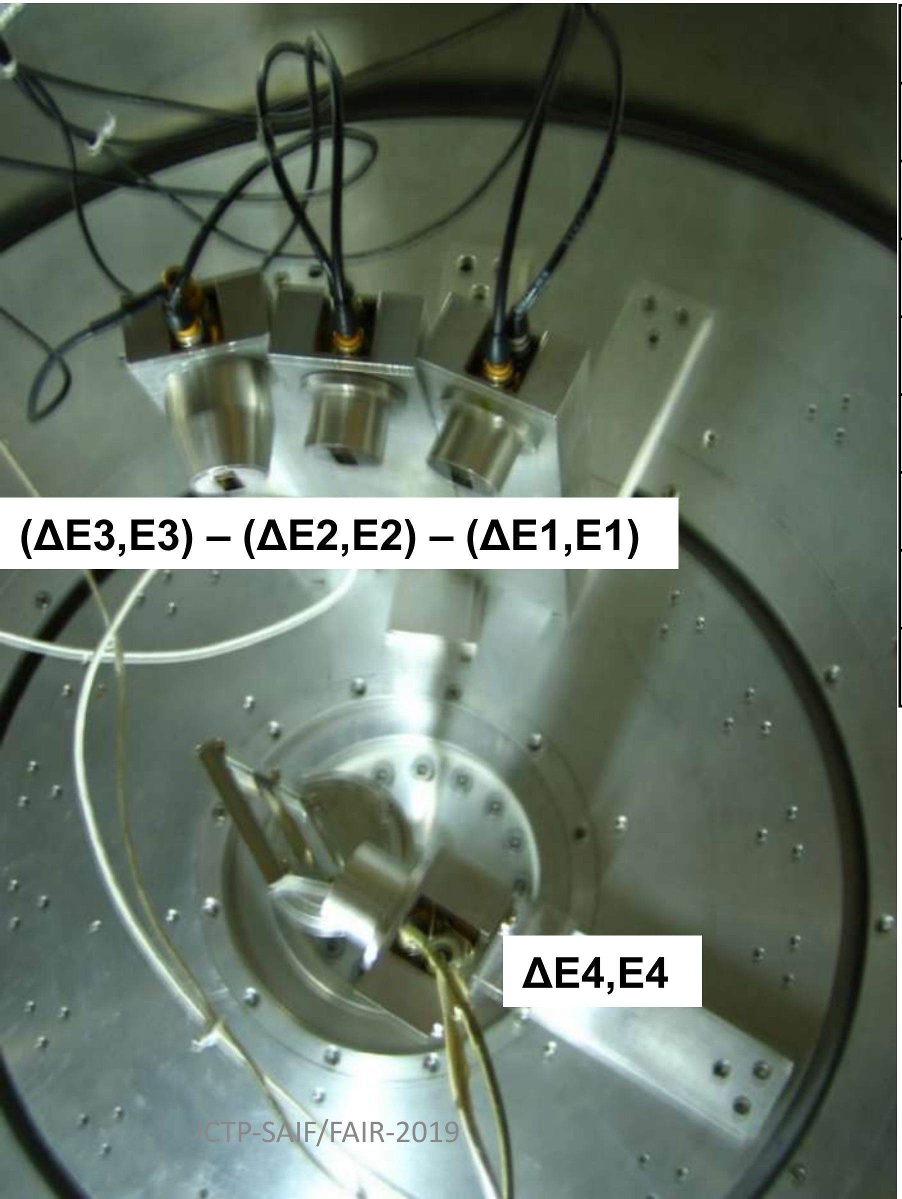
Experimental setup in scattering chamber 3

RIBRAS (CHAMBER 3): Mechanical SETUP (inside the chamber)



Turbo pump controller causes noise.
Solved by a voltage transformer before the pump controller.

Instrumental Developments for Radioactive Ions: silicon detectors

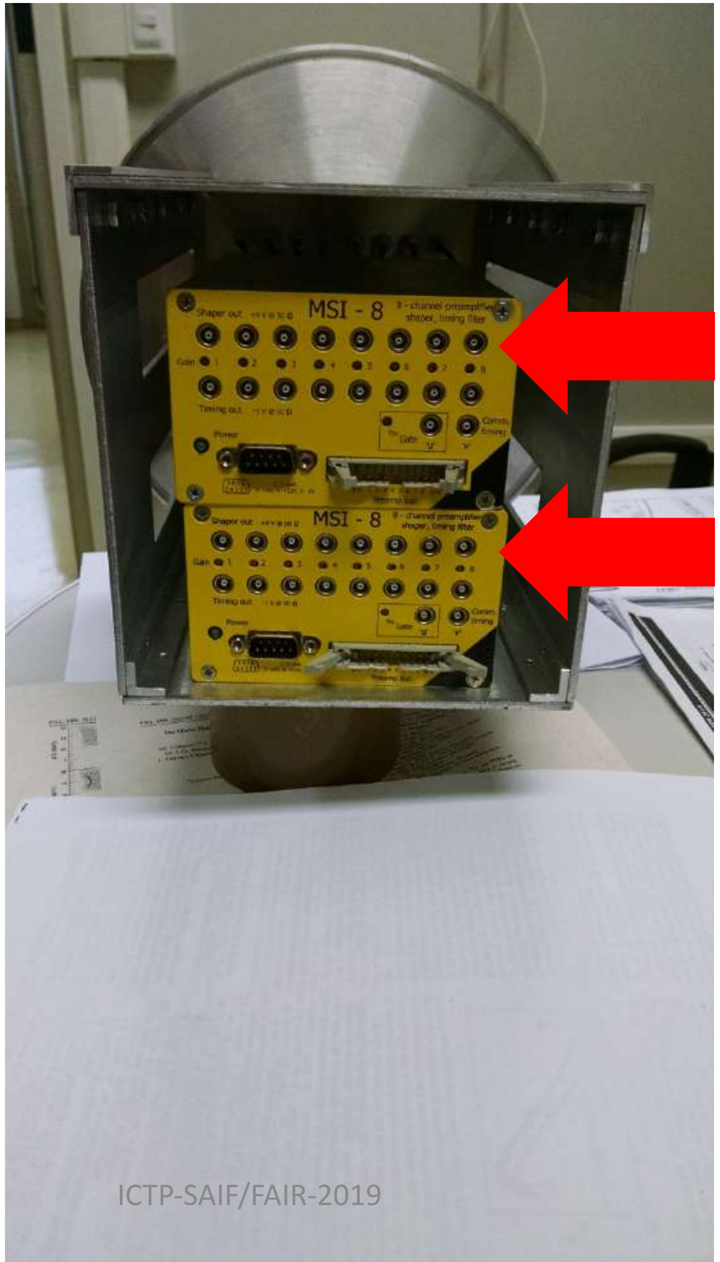


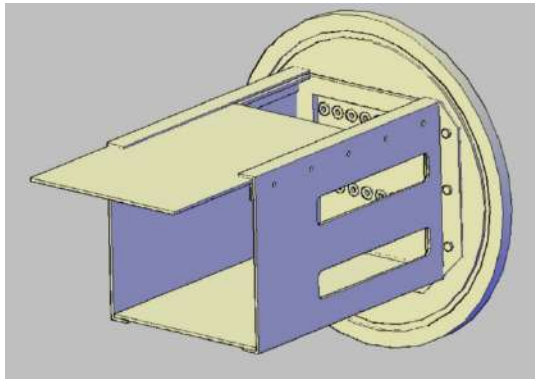
Detector ID	Thickness (μm)	Code	Bias Voltage (V)
ΔE1	**50**	**51050-A**	**35**
E1	**1000**	**45010-E**	**150**
ΔE2	**50**	**51050-J**	**35**
E2	**1000**	**53014-H**	**140**
ΔE3	**25**	**52046-C**	**20**
E3	**1000**	**45010-A**	**150**
ΔE4	**25**	**52046-J**	**20**
E4	**1000**	**44108-A**	**110**

150 mm^2 or 300 mm^2 area

Outside the chamber

RIBRAS (CHAMBER 3): & compact electronic SETUP





16 detection + electronic channels
(16 pre-amp+amplifiers)
16 HV (0-500V) connections

Faraday box, projected with the following objectives:

- ❑ **Mechanical support**
- ❑ **Electronics coupling**
- ❑ **Electromagnetic isolation**

- 2 set of preamps + amplifiers (MSI-8 model from Mesytec);
- 8 electronic channels each module – 16 channels (2 modules).

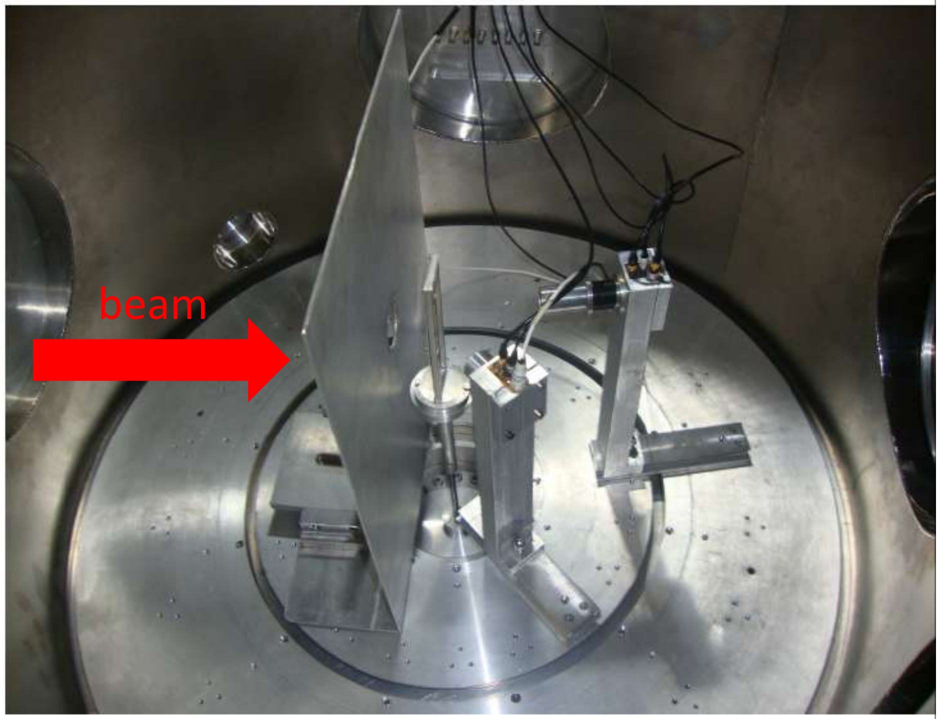
results

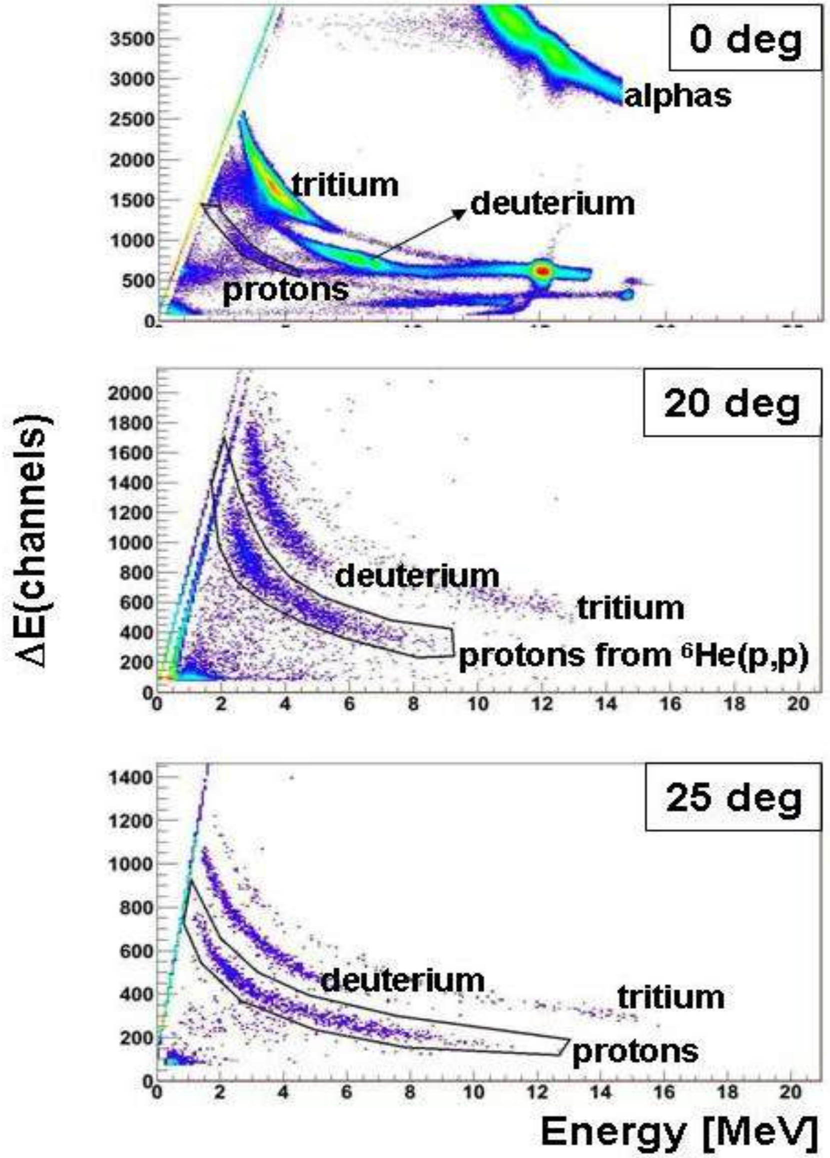
Resonant reactions measurements using thick targets. CH_2 proton rich plastic foils are used as targets to study resonant scattering:

- ❑ $p(^6He,p)\,^6He$;
- ❑ $p(^6He,\alpha)t$;
- ❑ $p(^8Li,p)^8Li$;
- ❑ $p(^8Li,\alpha)^5He$;
- ❑ $p(^8Li,d)^7Li$;

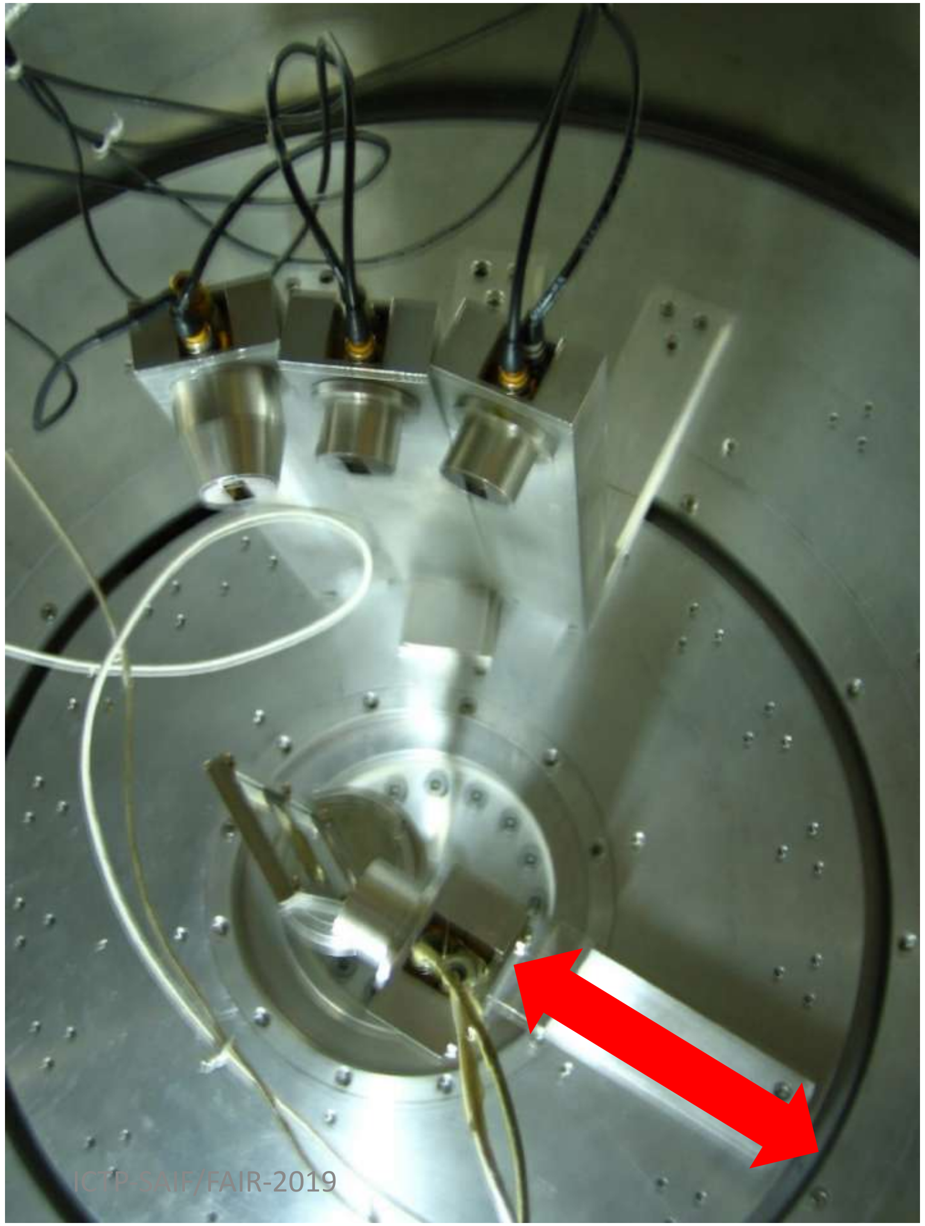
AND

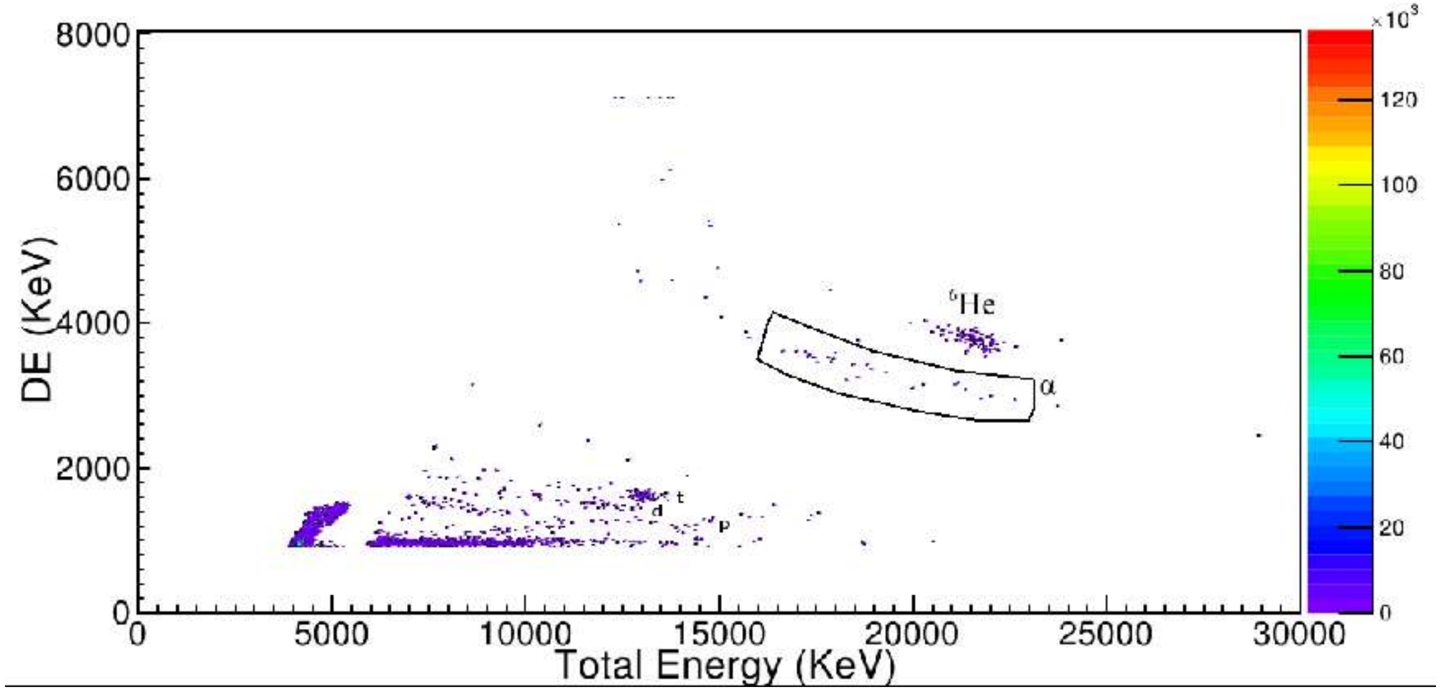
- ❑ $^{120}Sn(^6He,^4He)^{120}Sn+2n$.





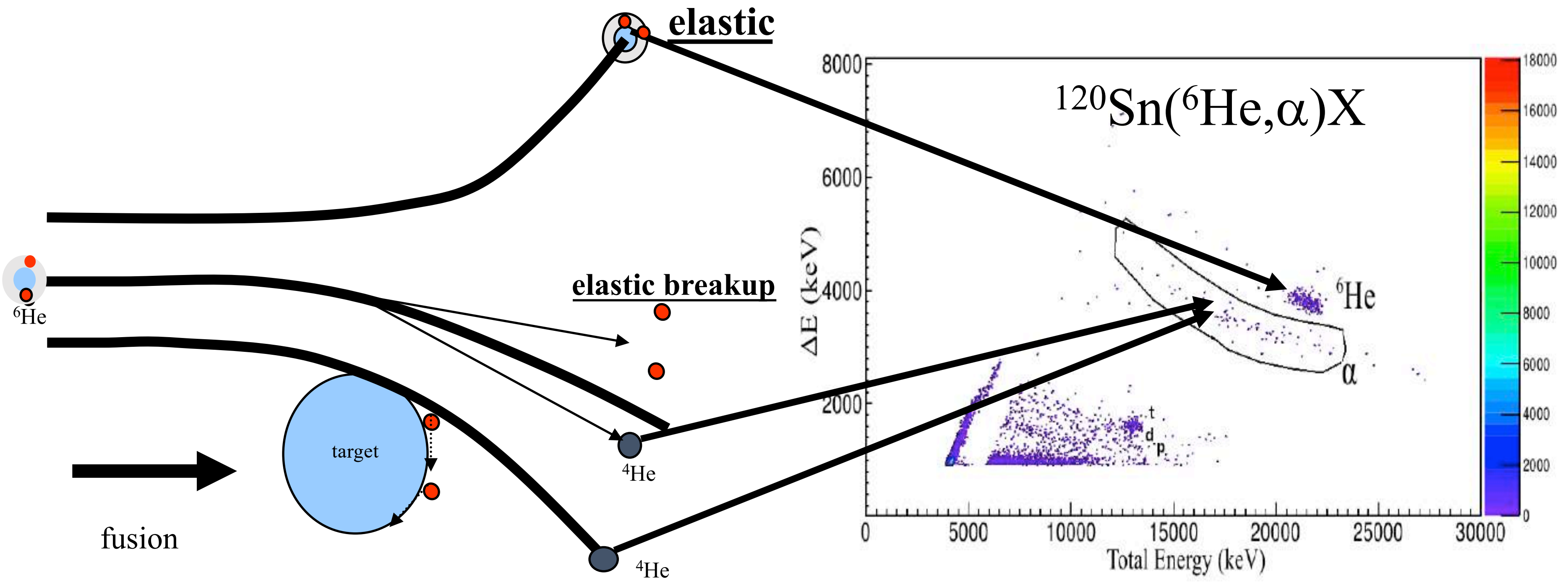
$^{120}Sn(^{6}He,\alpha)X$ reaction





- different degrees of freedom (to place detectors)
- single alpha events

A little of physics $^{120}Sn(^6He,\alpha)X$ transfer or breakup? Large yield of alpha particles being produced



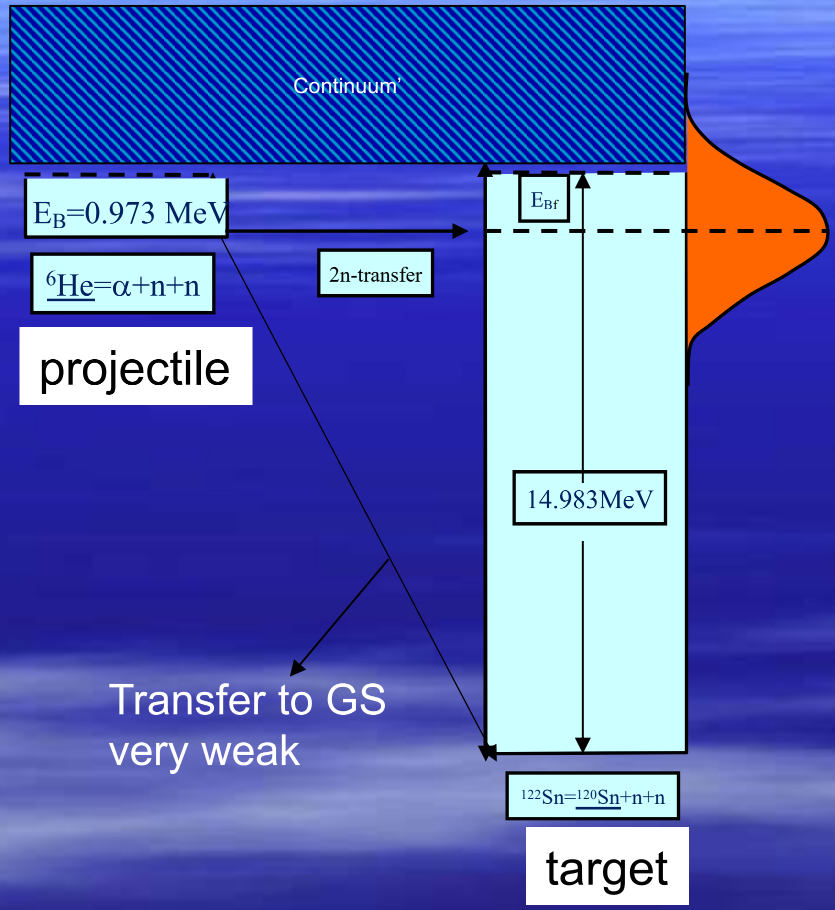
- Netron Transfer to continuum
- Incomplete fusion
- Nonelastic breakup
- Inclusive breakup

Signature of the neutron halo

Recent results show that elastic breakup has little influence in the fusion hindrance above barrier.
PHYSICAL REVIEW LETTERS 122, 042503 (2019) ; Jin Lei and A. Moro

• nêutron transfer: Q-optimum

$^{120}Sn(^{6}He,\alpha)^{122}Sn$



Brink`s formula for transfer

$$h(\lambda_1-\lambda_2)+\frac{1}{2}m_t v(R_y\text{-}R_A)+\frac{R}{v}Q=0$$

Q-optimum considerations
Angular and linear momentum matching conditions

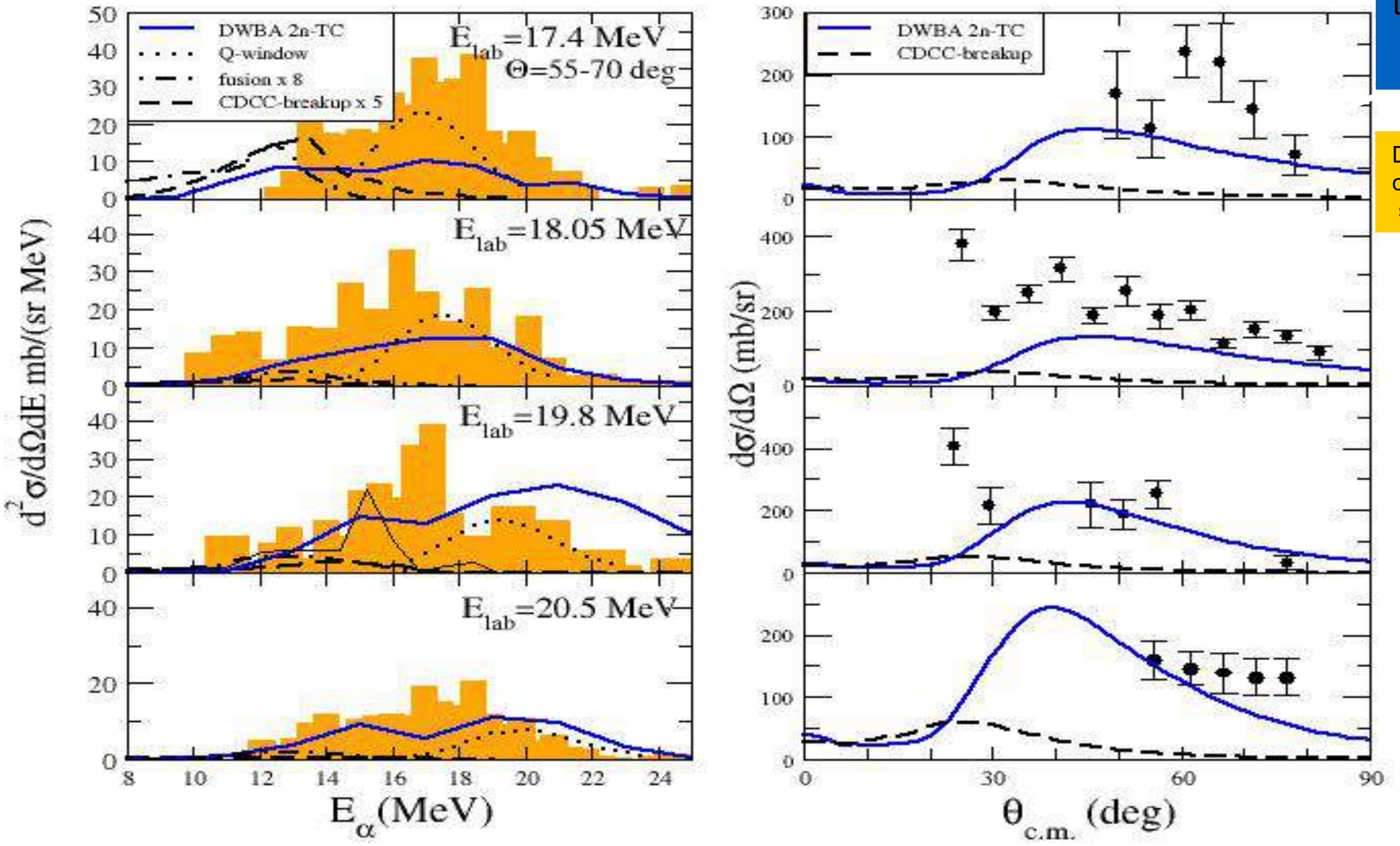
Qopt=0 for neutron transfer

But for breakup Q<0 !

Alpha particles from the $^{6}He+^{120}Sn$ collision: two neutron (^{6}He,^{4}He) transfers?

energy distribution of alphas

angular distributions



total cross section

650 mb ~ σ_{halo}

DWBA 2n-transfer to continuum and bound states (calculations by A. Moro)

$^{6}He + ^{120}Sn$ — $^{120}Sn(^{6}He, \alpha)^{122}Sn$

alpha energy distributions @ 60 deg lab

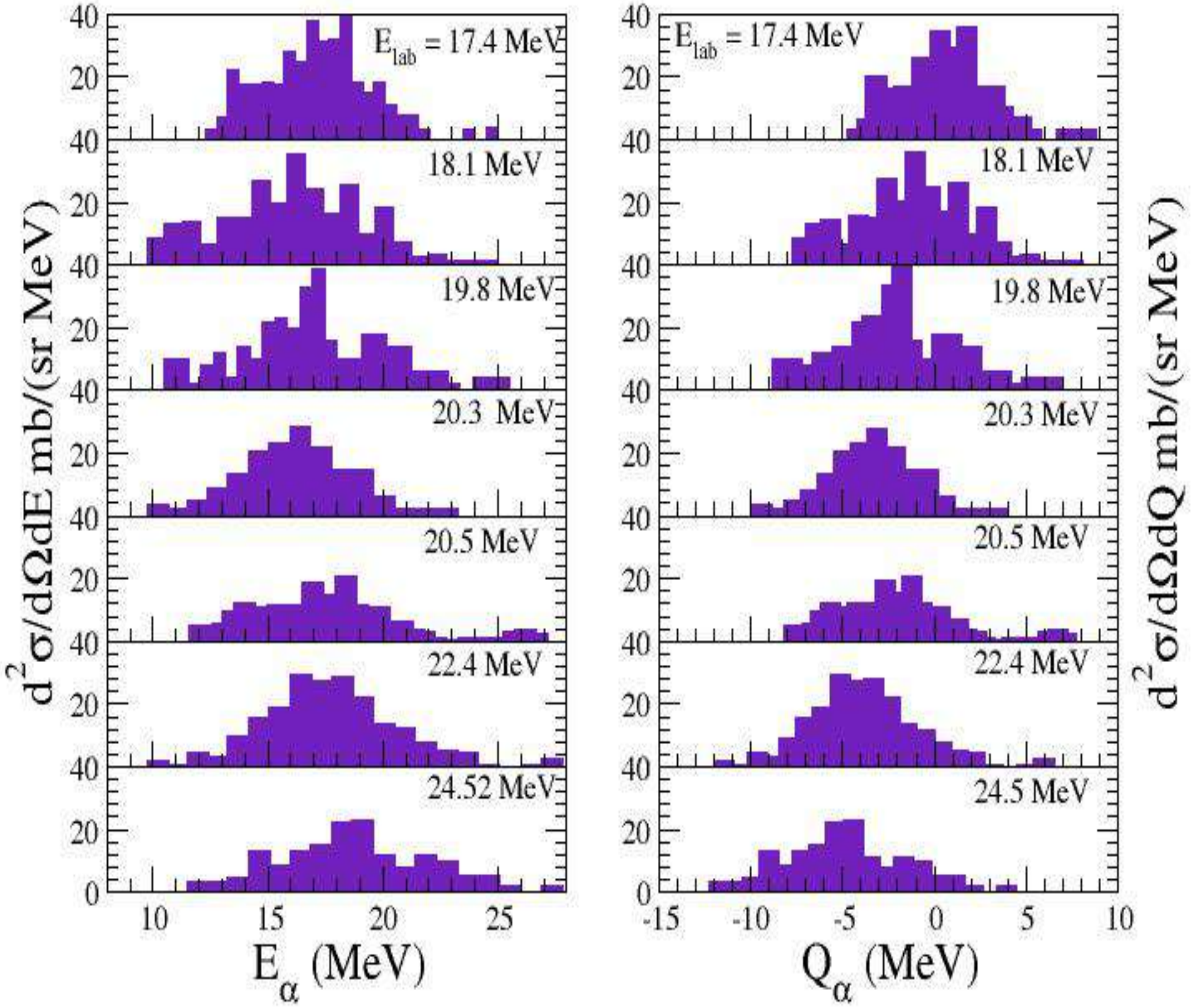


TABLE I. Experimental differential α-production cross sections (energy integrated) for the $^{120}Sn(^{6}He, \alpha)$ reaction.

E_{lab} (MeV)	θ_{lab}	σ_α (mb)	Ref.
17.4	60	180 (43)	[27]
18.1	60	188 (33)	[27]
19.8	60	204 (44)	[27]
20.3	60	167 (19)	this work
20.5	60	160 (30)	[27]
22.2	40	380 (20)	this work
	36	500 (20)	this work
22.4	60	208 (15)	this work
24.5	60	158 (18)	this work

exercise

Use Brink`s equation for transfer: x+A→y+B

$$\hbar(\lambda_1 - \lambda_2) + \frac{1}{2} m_t v (R_y - R_A) + \frac{R}{v} Q = 0$$

linear and angular momentum matching conditions.

Brink`s equation gives Q-value that maximizes transfer cross section: from the reaction Q-values one calculates the excitation energy:

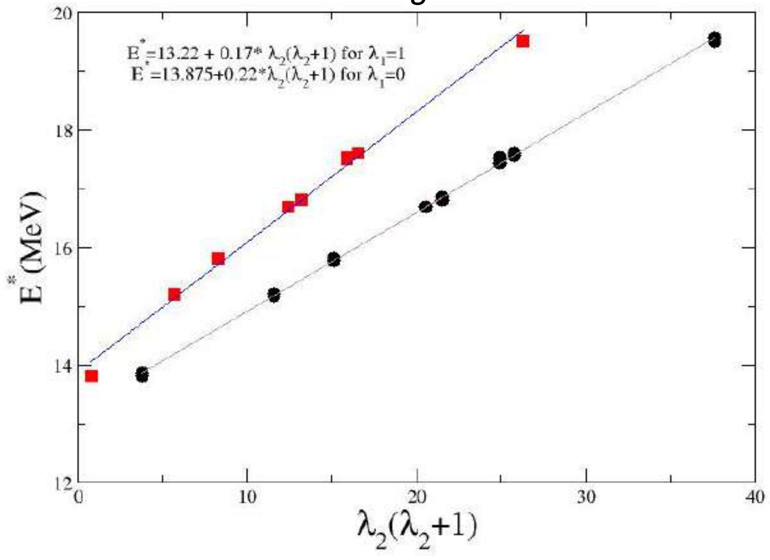
$$E_{exc} = Q_{gs} - Q$$

and from the Brink`s formula one obtains the final angular momentum.

λ_1 and λ_2 are the initial and final angular momenta of the transfered nêutrons:

for λ_1=1 one gets a nice linear relation

Excitation energy x final angular momentum for different initial angular momenta



Ongoing experiments in RIBRAS

Projectiles: 6He, 8Li, 8B, 7Be, 12B ...

targets: 9Be, 12C, 27Al, 58Ni, 120Sn, 197Au (normalization)
for medium mass and heavy targets Coulomb+nuclear
for light targets 9Be, 12C nuclear interaction dominates

Physics: to study the nuclear potential, Coulomb-nuclear interplay
low energy elastic scattering, provides information of the nuclear potential and the total reaction cross section.
inelastic scattering, nuclear deformations
transfer reactions, spectroscopic factors
breakup and fusion reactions

RIBRAS handicaps:

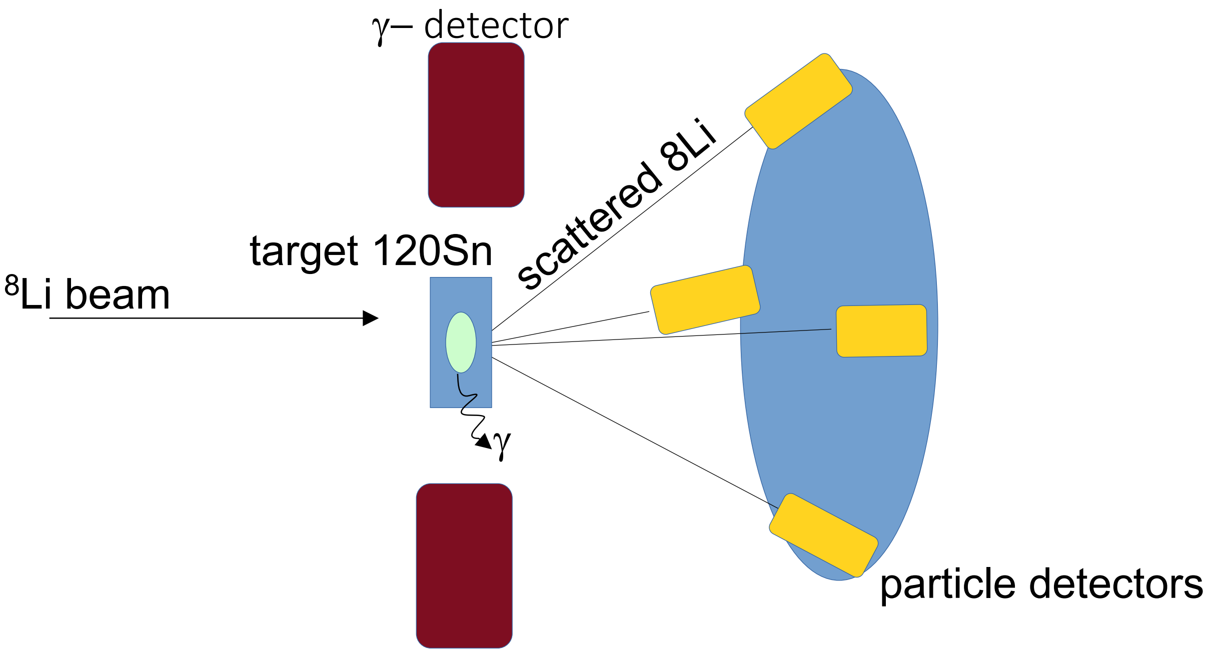
- Residual magnetic field around the solenoids prevent the use of detectors based in electron collection in vacuum tubes such as the old photomultipliers os gas detectors such as ionization chambers, proportional counters ...

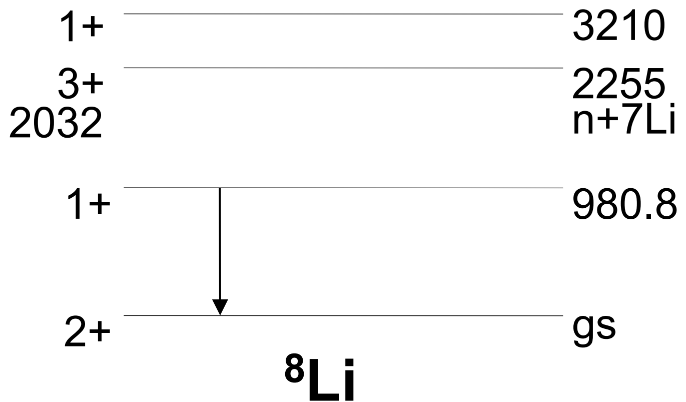
- Strong secondary neutron beam coming from the primary target. Damage to Germanium detectors.

Ongoing experiments in RIBRAS

Particle-gamma coincidence measurements using LYSO cristals to detect the gammas:

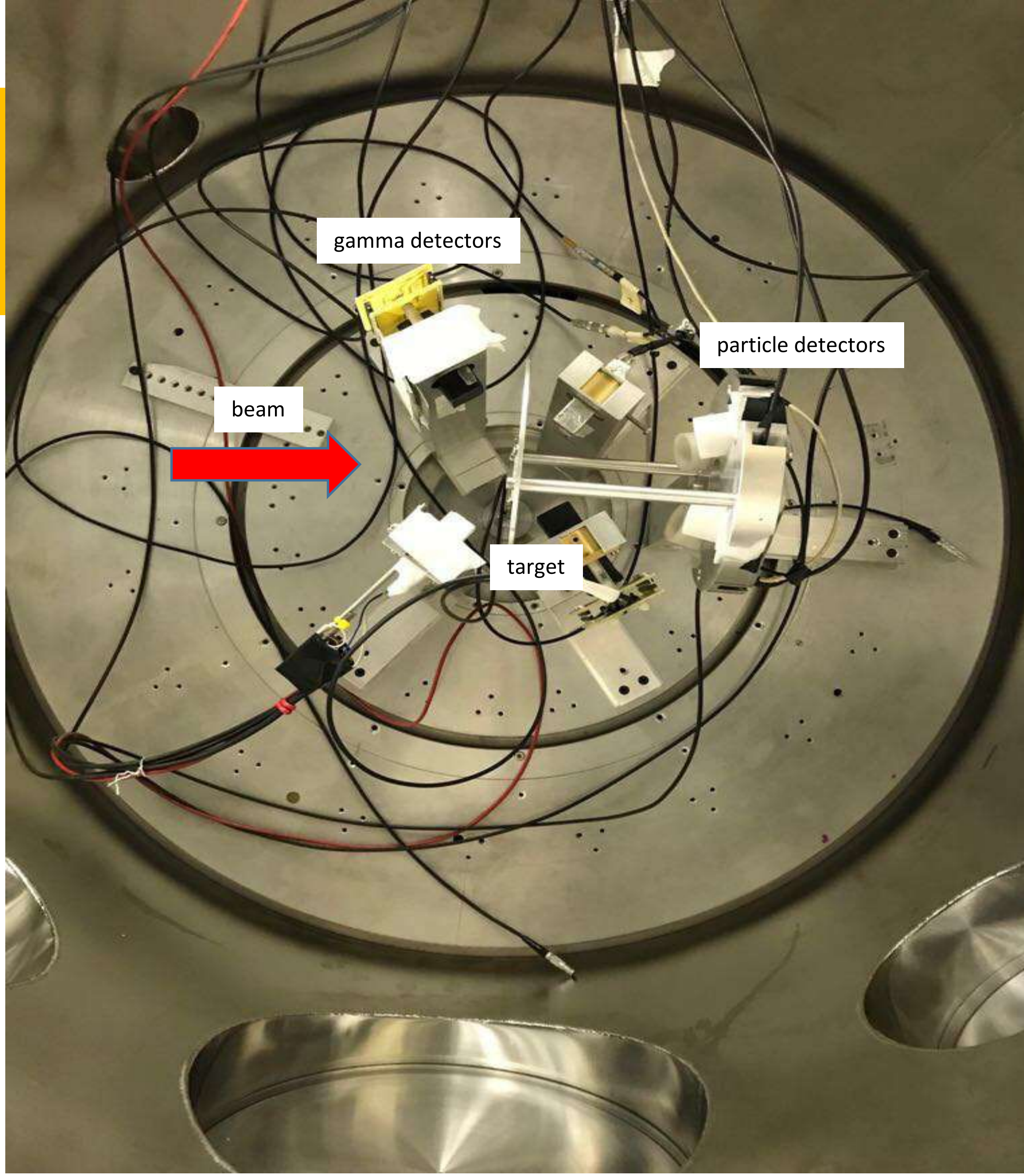
- Measurements of inelastic excitation and fusion.

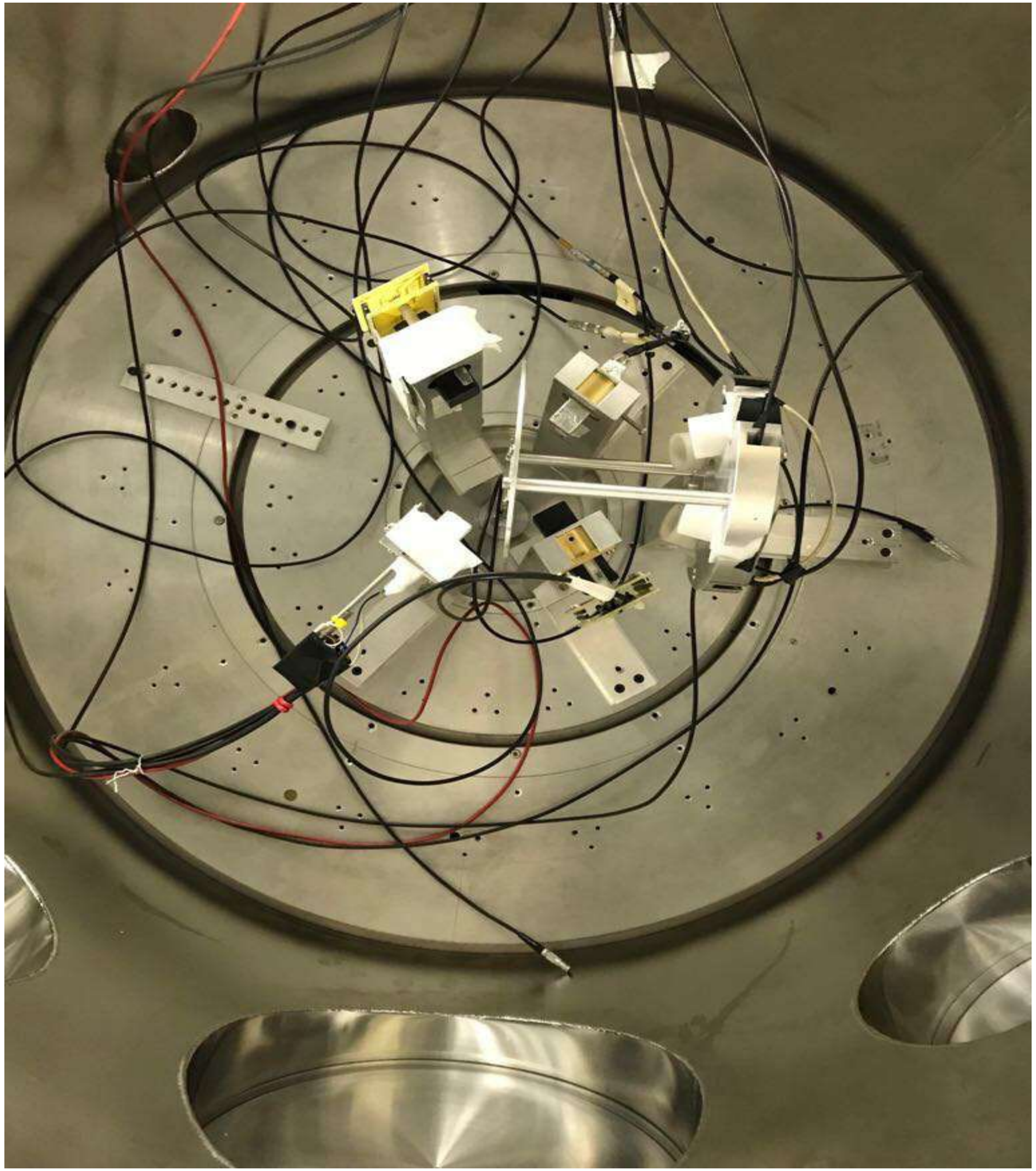




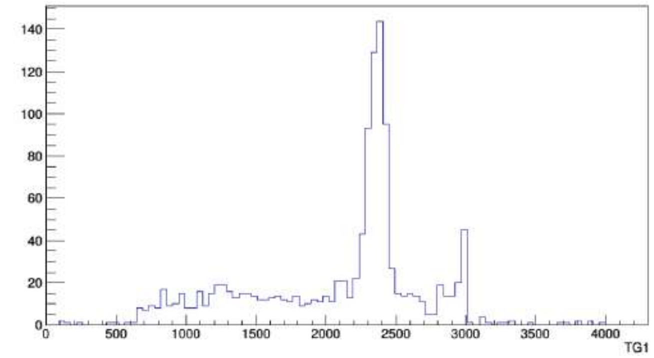
LYSO scintillator: **Lutetium-yttrium oxyorthosilicate**

-High density
-Fast decay time
-8% energy resolution
-non-sensitive to magnetic fields
-cheap

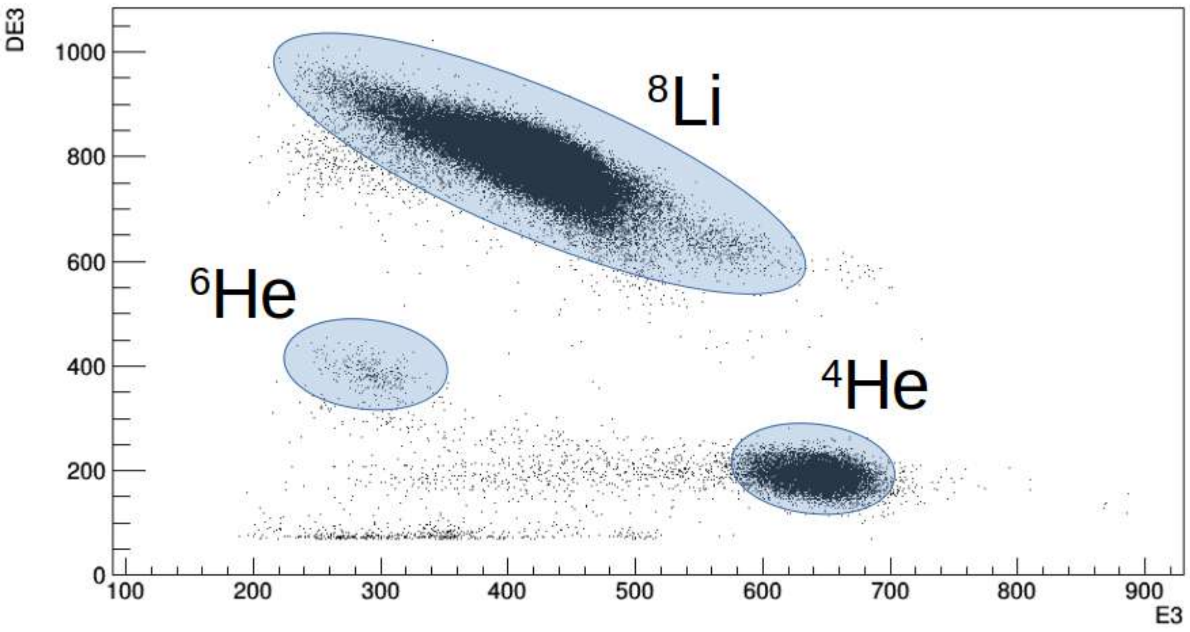




$^{8}Li+^{120}Sn$



TAC-gamma-particle



More experiments in RIBRAS

- <u>^{8}B+^{9}Be fusion</u>

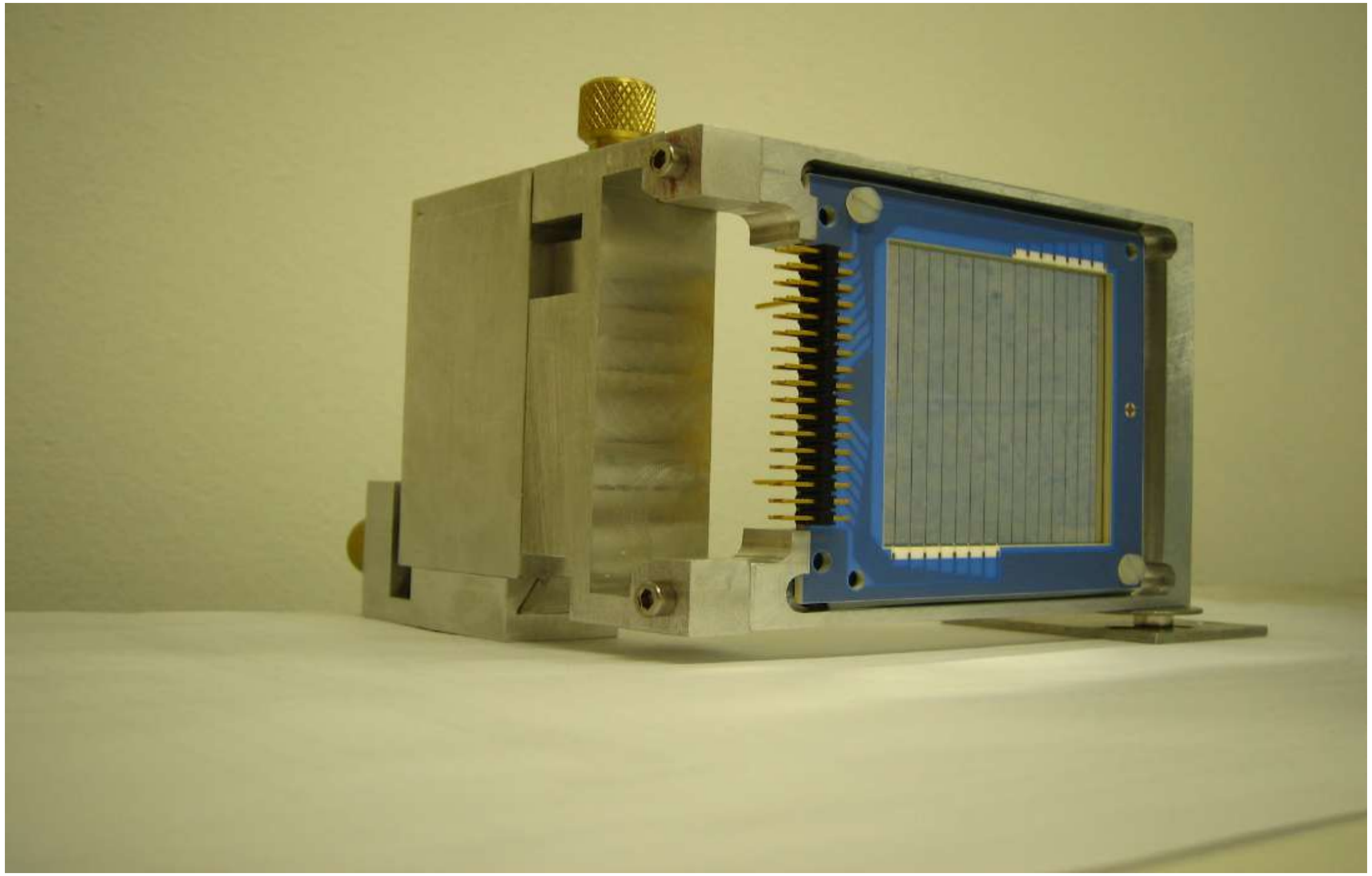
- a 23 MeV ^{8}B beam produced by the ^{3}He(^{6}Li,^{8}B) reaction (gas target)
- ^{9}Be secondary target
- detect the protons distribution (decay of the proton rich compound system ^{17}F*)
- measure the TOF to identify the incidente particle in the target.

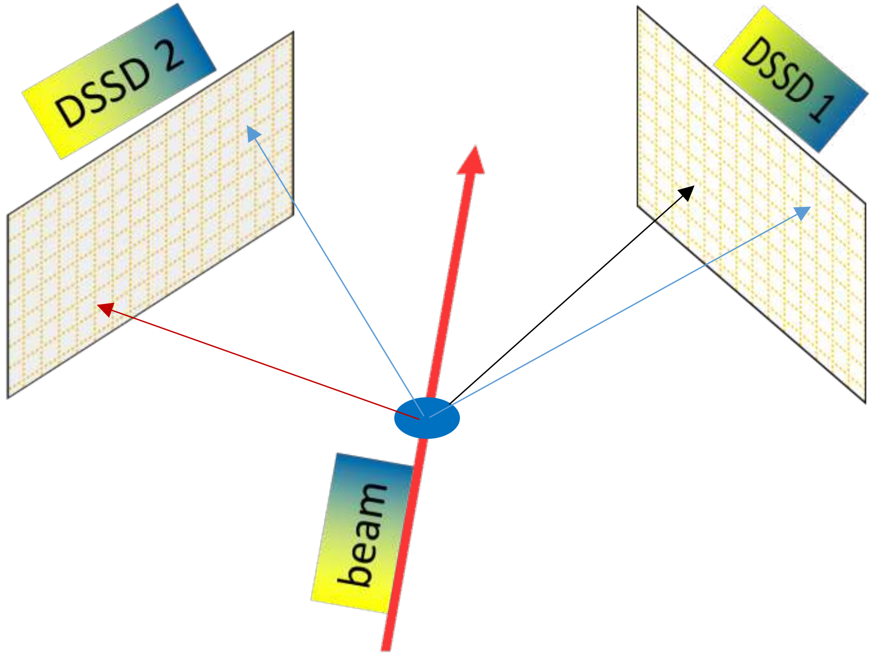
Very exotic system: ^{8}B (Eb=0.137 MeV proton halo candidate)
^{9}Be 1.66 MeV binding energy.

- <u>Elastic scattering of ^{8}Li on several targets: ^{9}Be, ^{58}Ni and ^{120}Sn.</u>

- <u>Two-neutron transfer 9Be(7Be,9Be) reaction</u>

Future setups: Large area Double Side silicon Strip Detectors for particle coincidences measurements





we have:

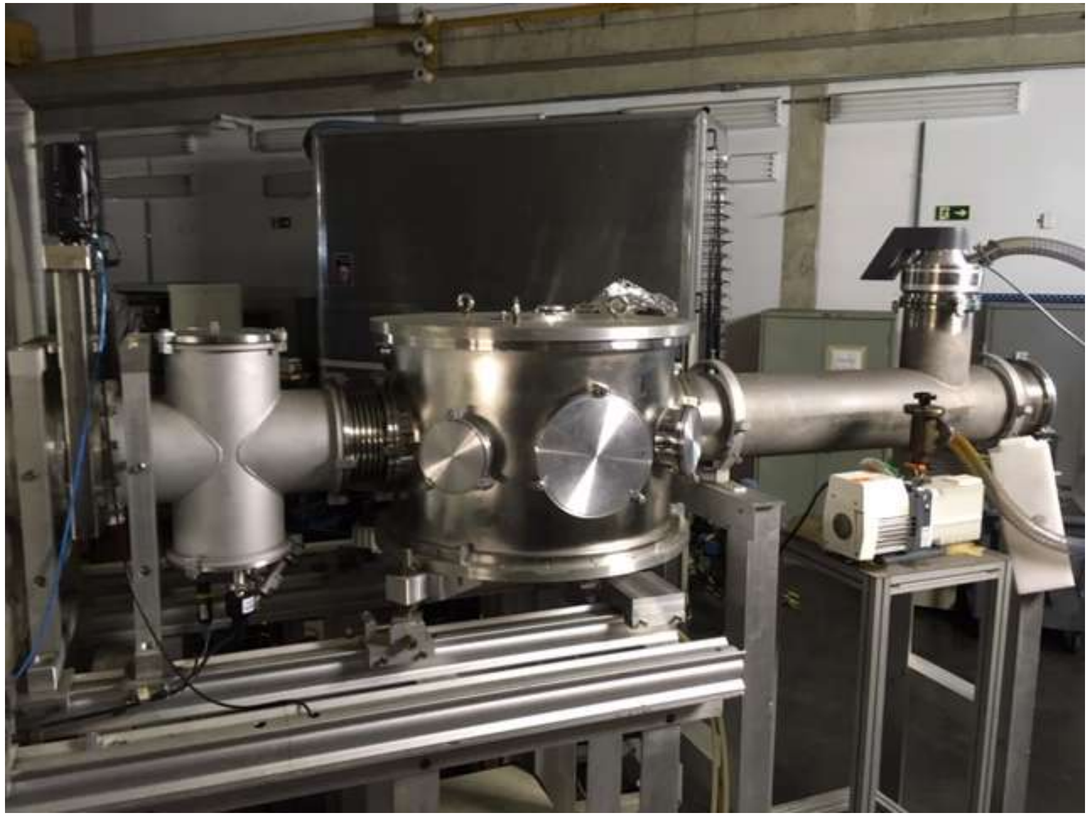
- DSSD 20 microns
- DSSD 65 microns
- Pad detectors

The system is presently installed in a neighbour beam line for tests with stable beams

Future setups: neutron wall

<u>It would be very interesting to detect neutrons</u>.

Neutron detection Is difficult but
we have two large neutron walls in the laboratory.
liquid scintillators.



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