Istituto Nazionale di Fisica Nucleare
Sezione di Padova

Dept. of Physics and Astronomy
University of Padova

Commissioning Experiment of the AGATA+MUGAST+VAMOS Setup for Direct Reaction Studies

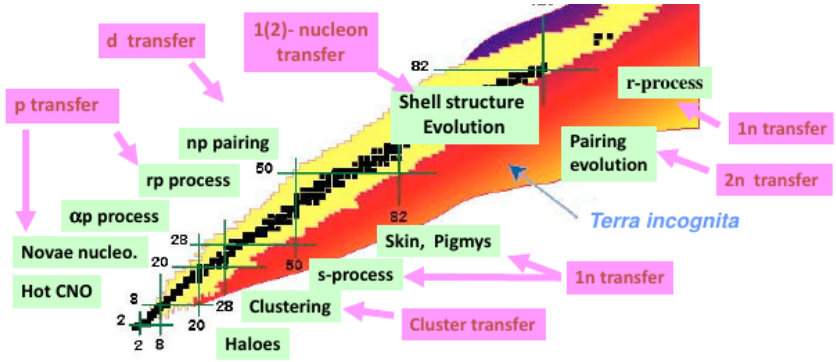
Candidate:
Andrea Raggio

Supervisor:
Daniele Mengoni

Co-supervisor
Marlène Assié

Outline

- Direct reactions with radioactive beams
- Commissioning experiment for the AGATA+MUGAST+VAMOS setup
- Experimental Setup
- Data analysis



Outline

- Direct reactions with radioactive beams
- Commissioning experiment for the AGATA+MUGAST+VAMOS setup
- Experimental Setup
- Data analysis

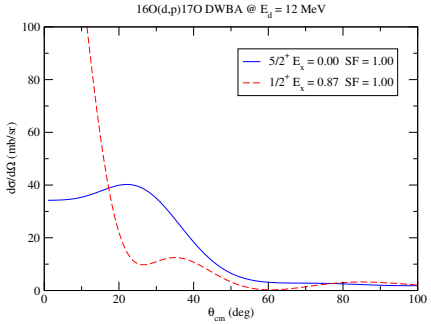
Outline

- Direct reactions with radioactive beams
- Commissioning experiment for the AGATA+MUGAST+VAMOS setup
- Experimental Setup
- Data analysis

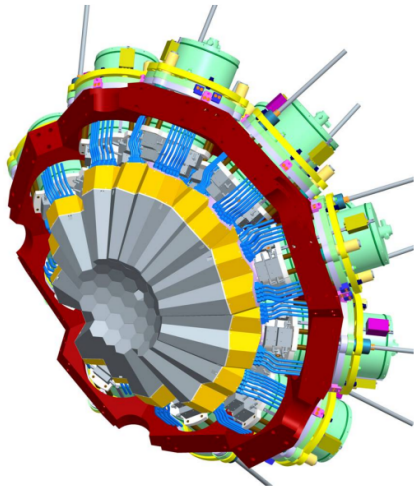
Outline

- Direct reactions with radioactive beams
- Commissioning experiment for the AGATA+MUGAST+VAMOS setup
- Experimental Setup
- Data analysis

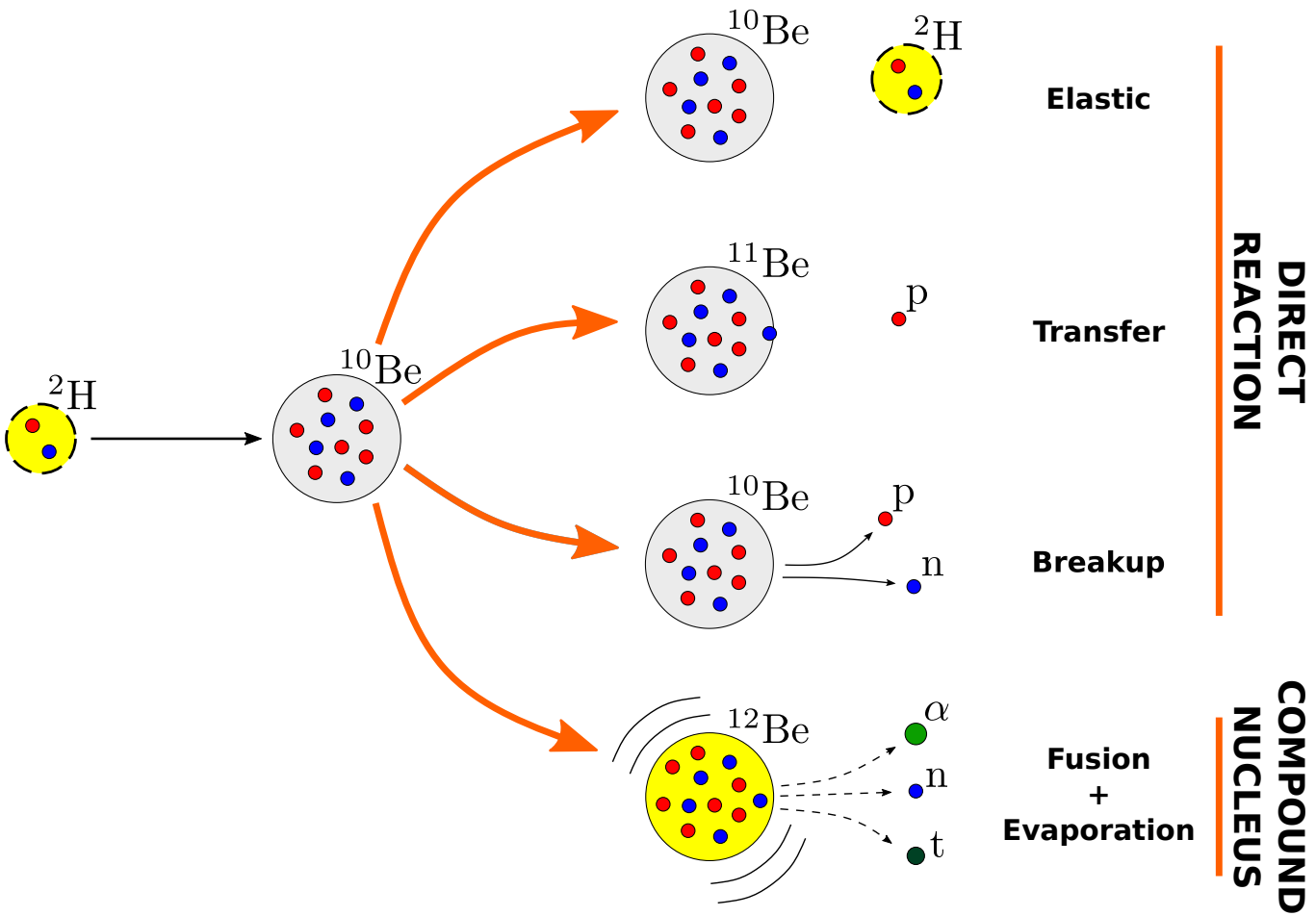
Comparison between experimental and theoretical differential cross section



AGATA efficiency estimation



Direct Reactions

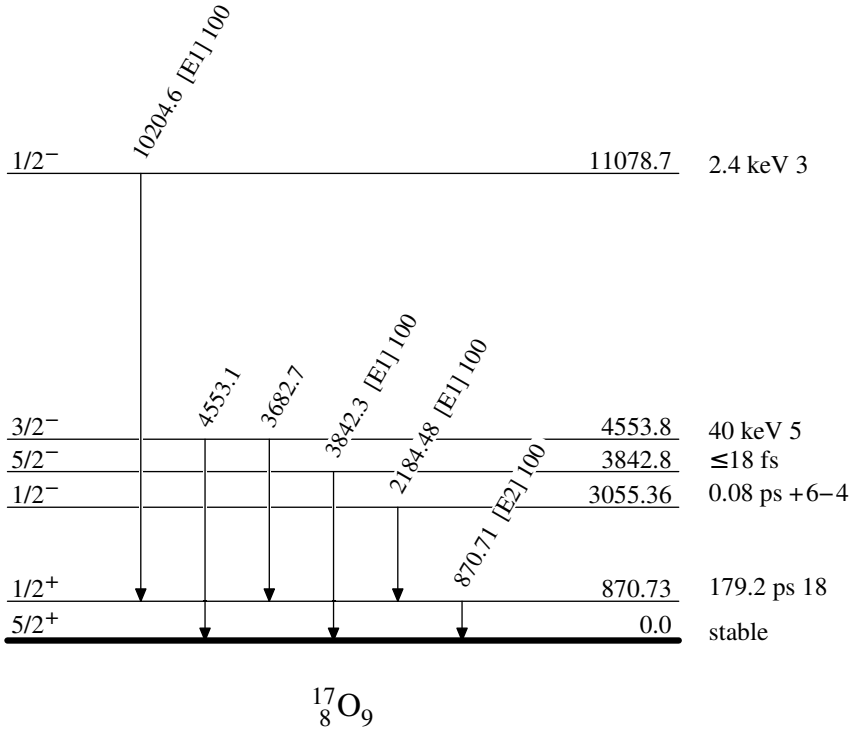


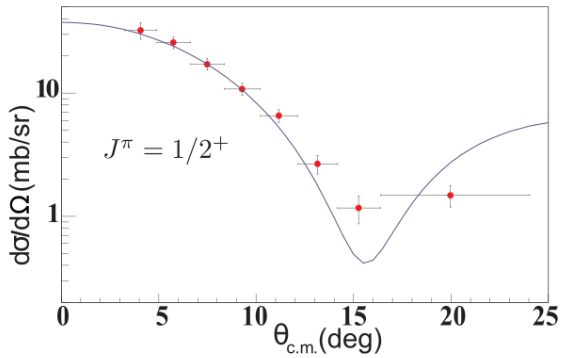
A. Moro, Models for nuclear reactions with weakly bound systems.(arXiv: 1807.04349) 2018.

Commissioning Reaction

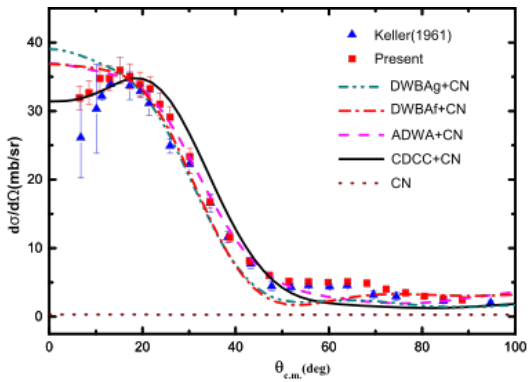
$^{16}O(d,p)^{17}O$

^{17}O level scheme





T. Al Kalanee et al., PRC 88, 034301 (2013)

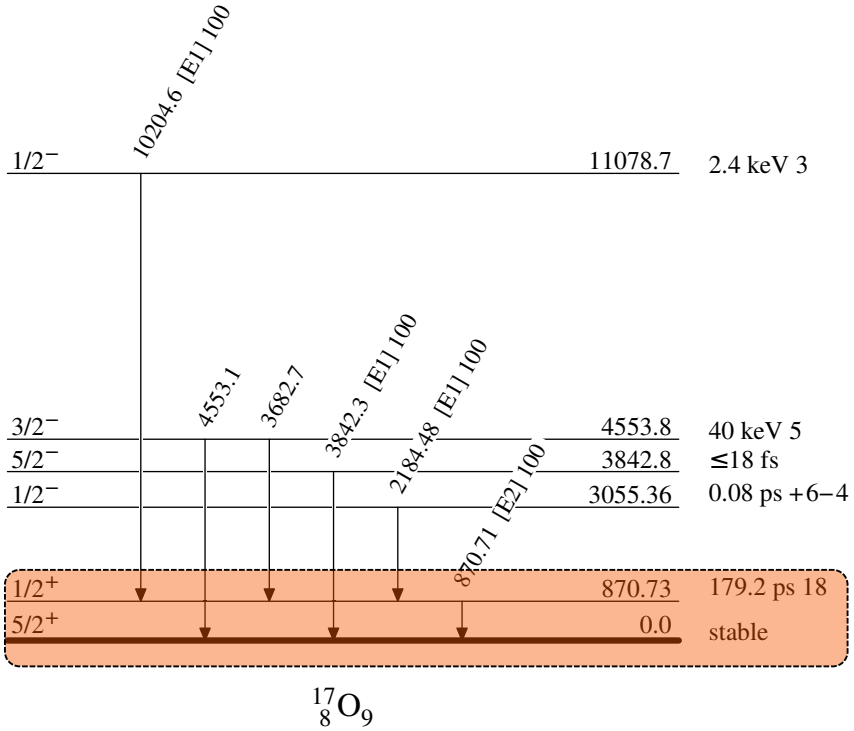


T.L. Ma et al., Nuclear Physics A 986 (2019) 26-23

Commissioning Reaction

$^{16}O(d,p)^{17}O$

^{17}O level scheme



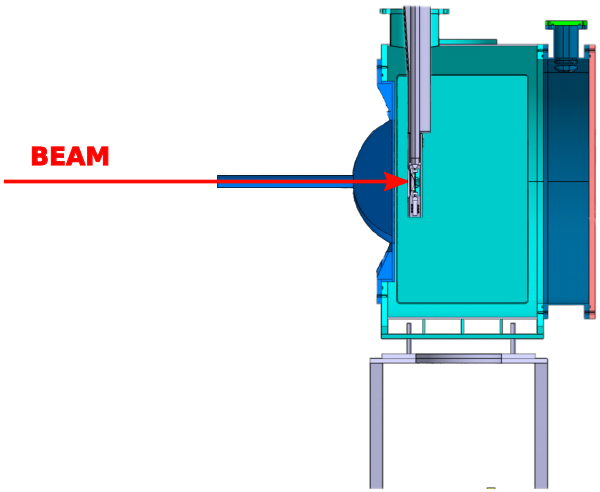
Coincident detection

↓

proton and ^{17}O ejectiles

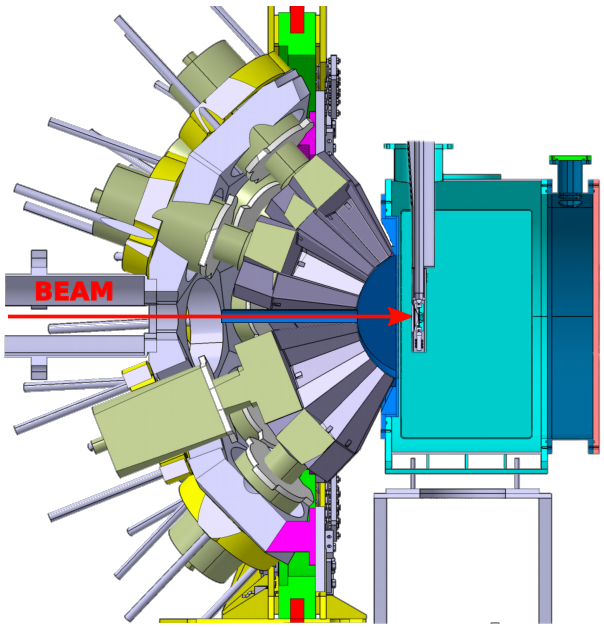
871 keV de-excitation gamma-ray.

Experimental Setup



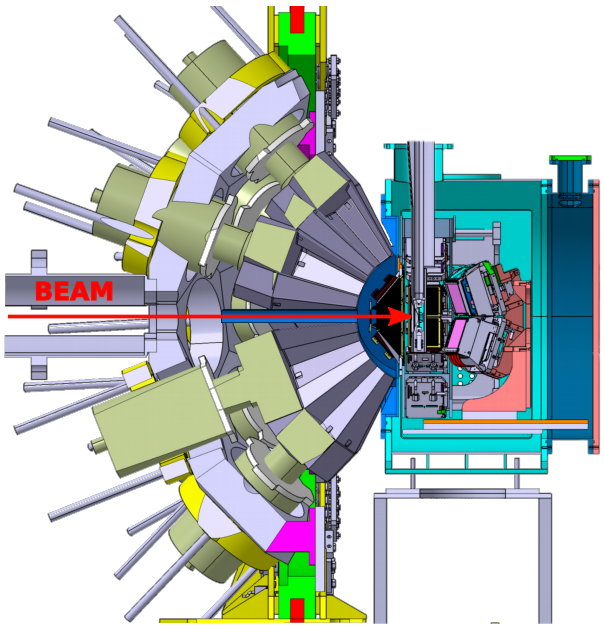
- ^{16}O beam on CD2 Target
  - → 6 MeV/u - 10^4pps
  - → 1 mg/cm^2
- AGATA HPGe Gamma ray tracking array
  - → 37 segmented crystals
- MUGAST Silicon detector array
  - → 5 trapezoidal DSSD (450 μm thick)
  - → 1 anular DSSD (300 μm thick)
  - → 2 square DSSD (500 μm thick)
  - → 4 MUST2 Telescopes (DSSD+CsI)
- VAMOS Magnetic Spectrometer
  - → Quadrupole + Dipole
  - → MWPPAC → TOF
  - → Drift Chamber → Position and direction
  - → Ionization Chambers → Particle ID

Experimental Setup



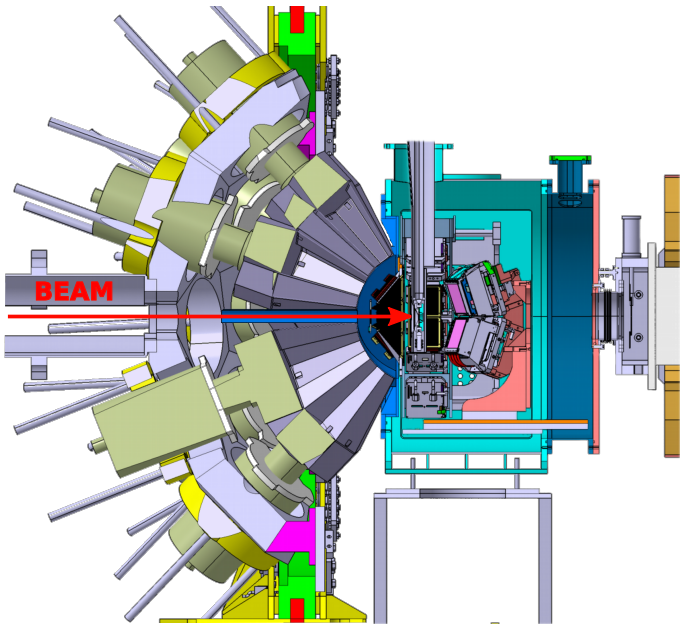
- ^{16}O beam on CD2 Target
  - → 6 MeV/u - 10^4pps
  - → 1 mg/cm^2
- AGATA HPGe Gamma ray tracking array
  - → 37 segmented crystals
- MUGAST Silicon detector array
  - → 5 trapezoidal DSSD (450 μm thick)
  - → 1 anular DSSD (300 μm thick)
  - → 2 square DSSD (500 μm thick)
  - → 4 MUST2 Telescopes (DSSD+CsI)
- VAMOS Magnetic Spectrometer
  - → Quadrupole + Dipole
  - → MWPPAC → TOF
  - → Drift Chamber → Position and direction
  - → Ionization Chambers → Particle ID

Experimental Setup



- ^{16}O beam on CD2 Target
  - → 6 MeV/u - 10^4pps
  - → 1 mg/cm^2
- AGATA HPGe Gamma ray tracking array
  - → 37 segmented crystals
- MUGAST Silicon detector array
  - → 5 trapezoidal DSSD (450 μm thick)
  - → 1 anular DSSD (300 μm thick)
  - → 2 square DSSD (500 μm thick)
  - → 4 MUST2 Telescopes (DSSD+CsI)
- VAMOS Magnetic Spectrometer
  - → Quadrupole + Dipole
  - → MWPPAC → TOF
  - → Drift Chamber → Position and direction
  - → Ionization Chambers → Particle ID

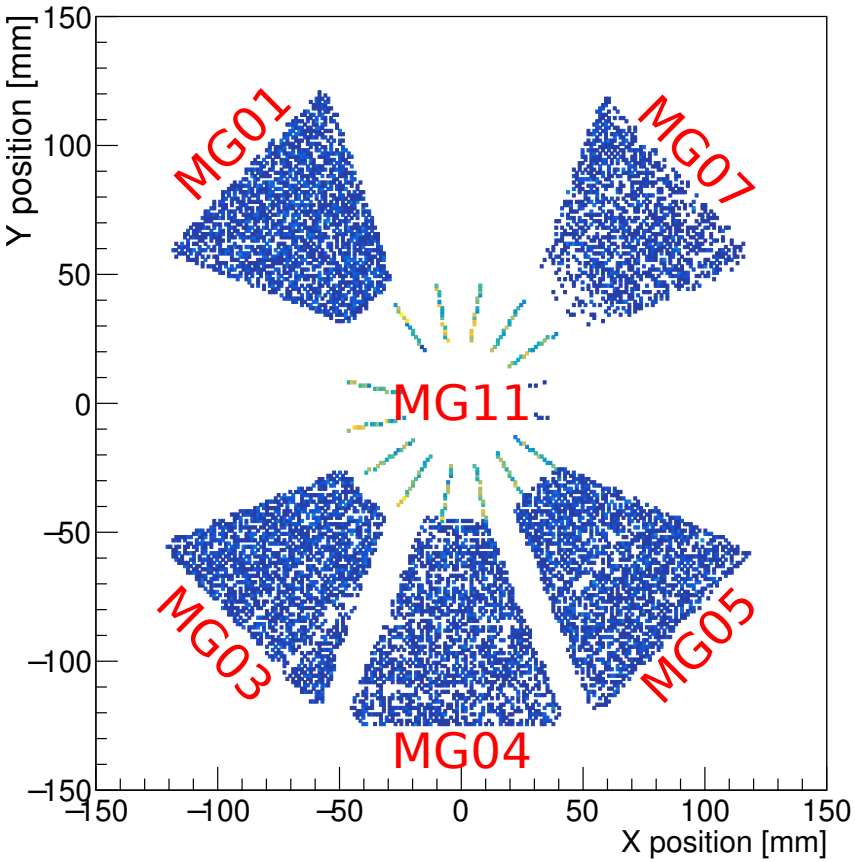
Experimental Setup

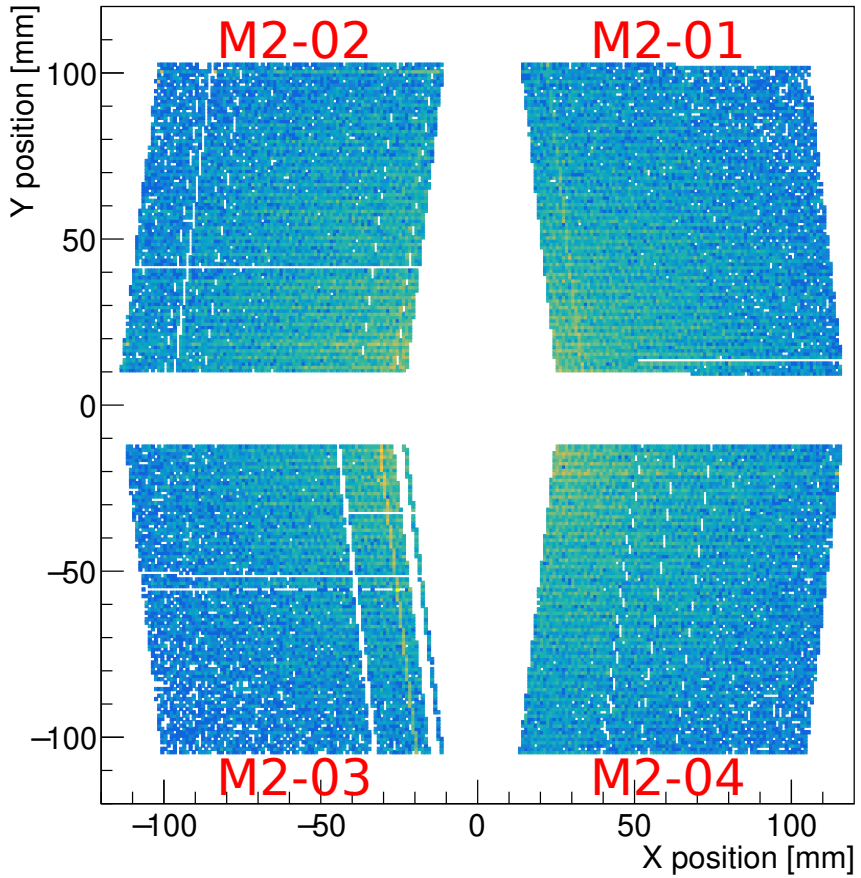


- ^{16}O beam on CD2 Target
  - → 6 MeV/u - 10^4pps
  - → 1 mg/cm^2
- AGATA HPGe Gamma ray tracking array
  - → 37 segmented crystals
- MUGAST Silicon detector array
  - → 5 trapezoidal DSSD (450 μm thick)
  - → 1 anular DSSD (300 μm thick)
  - → 2 square DSSD (500 μm thick)
  - → 4 MUST2 Telescopes (DSSD+CsI)
- VAMOS Magnetic Spectrometer
  - → Quadrupole + Dipole
  - → MWPPAC → TOF
  - → Drift Chamber → Position and direction
  - → Ionization Chambers → Particle ID

Impact Matrices

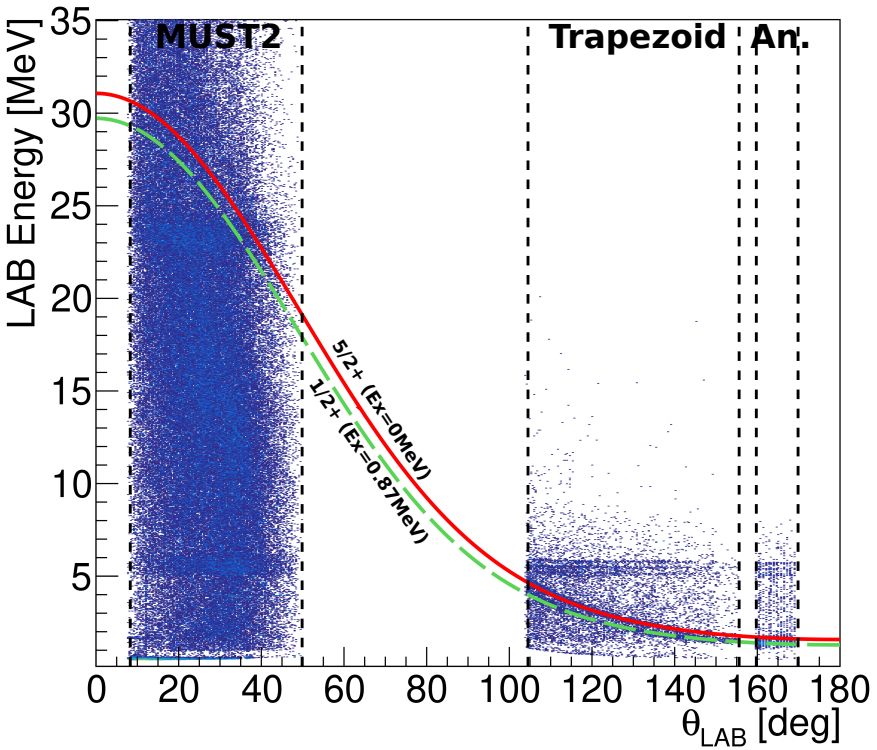
11 h. acquisition long at $\sim$ 4 10^4 pps





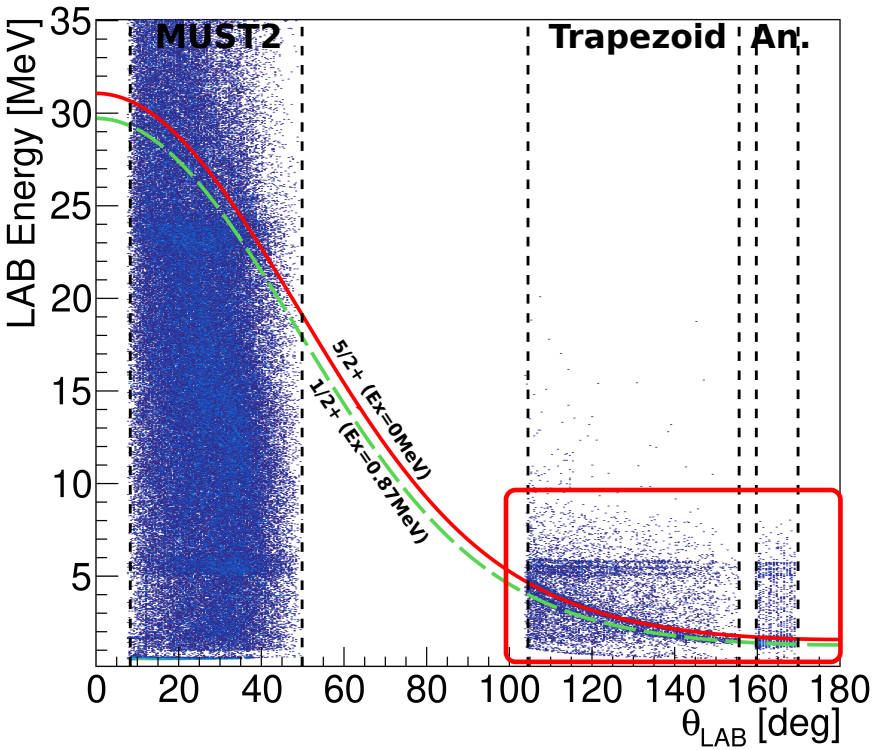
Kinematic Lines

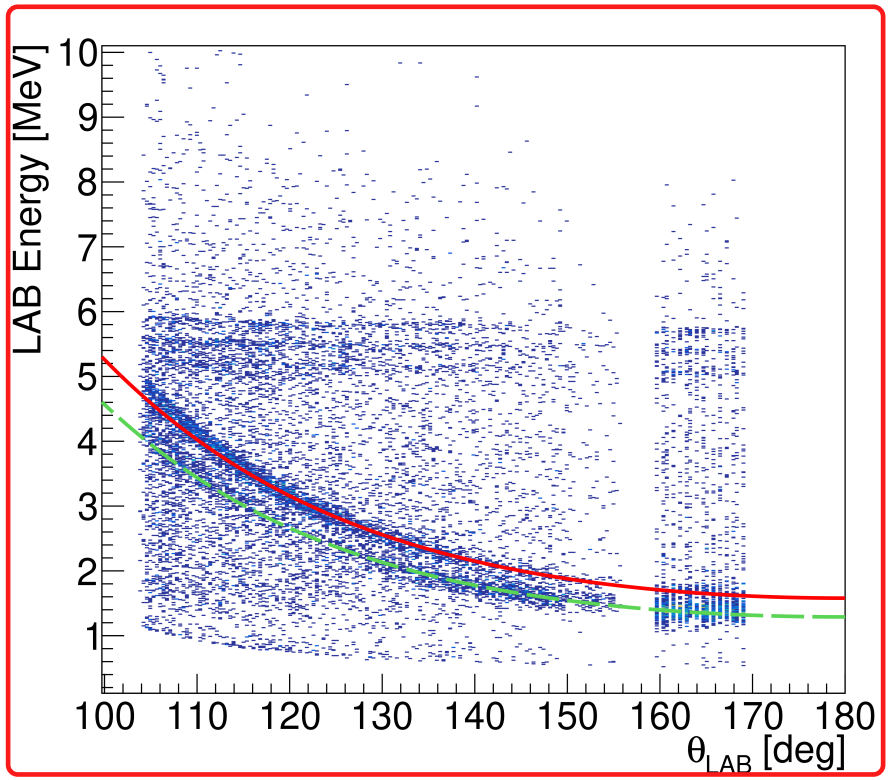
Kinematic lines are not visible at forward angles, even with proton selection on MUST2



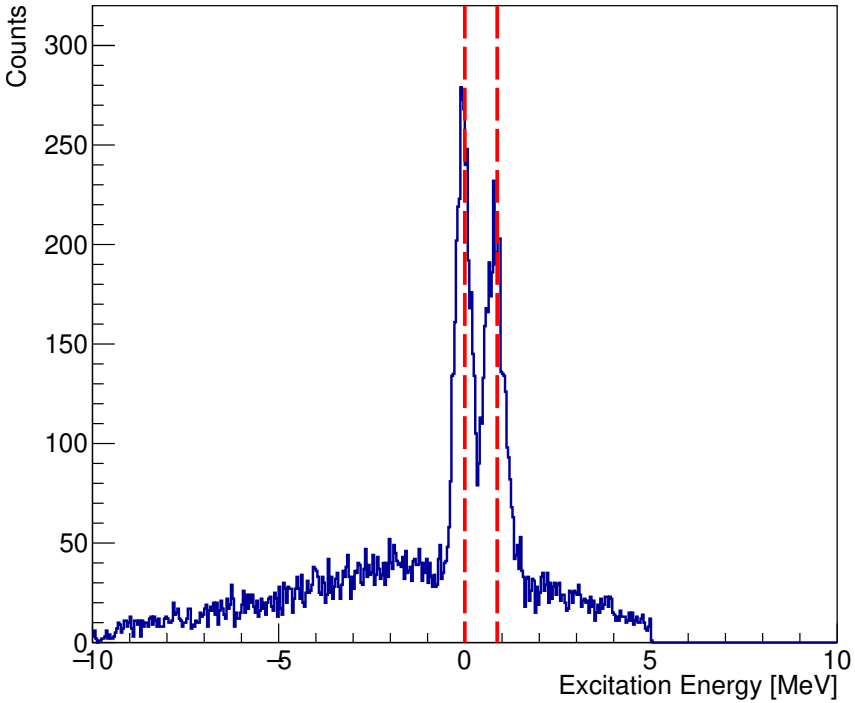
Kinematic Lines

Selection of backward emitted particles





Reconstructed Excitation Energy in ^{17}O

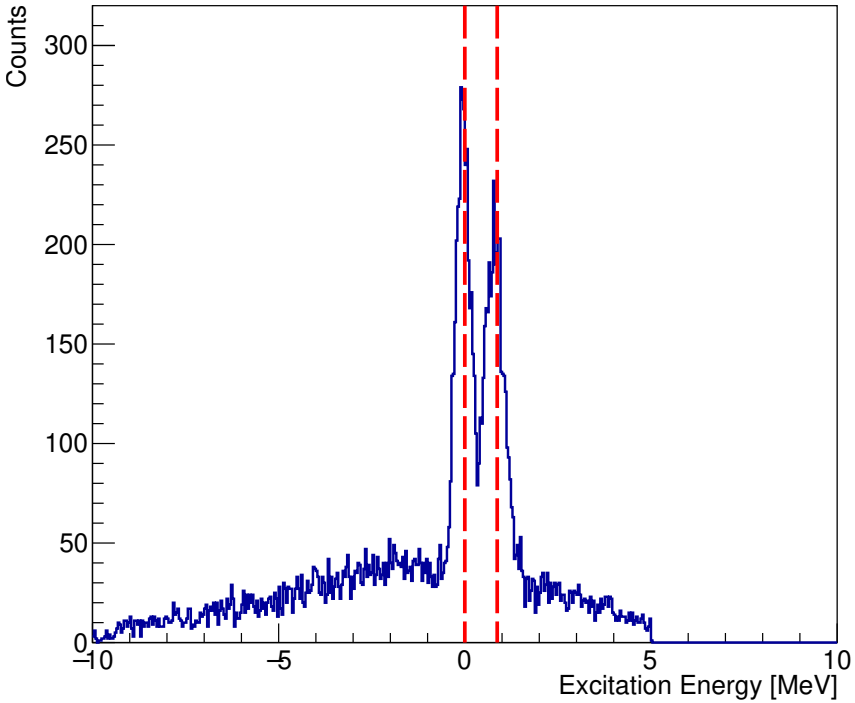


Two peaks identified:

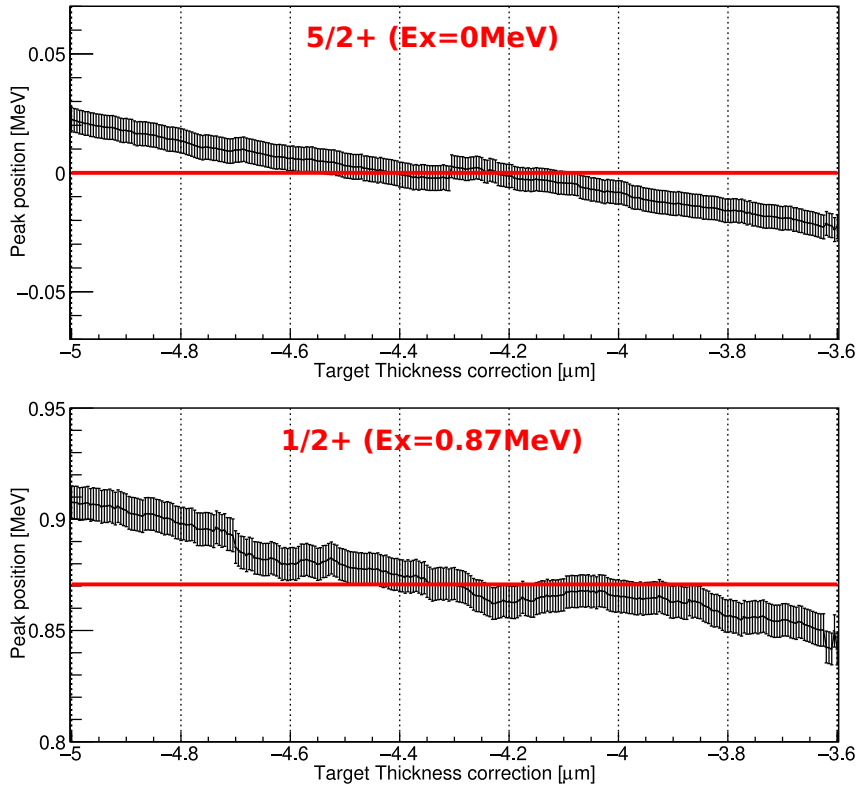
- $5/2^+$ ground state
- $1/2^+$ first excited state

Energy Shift from the adopted values

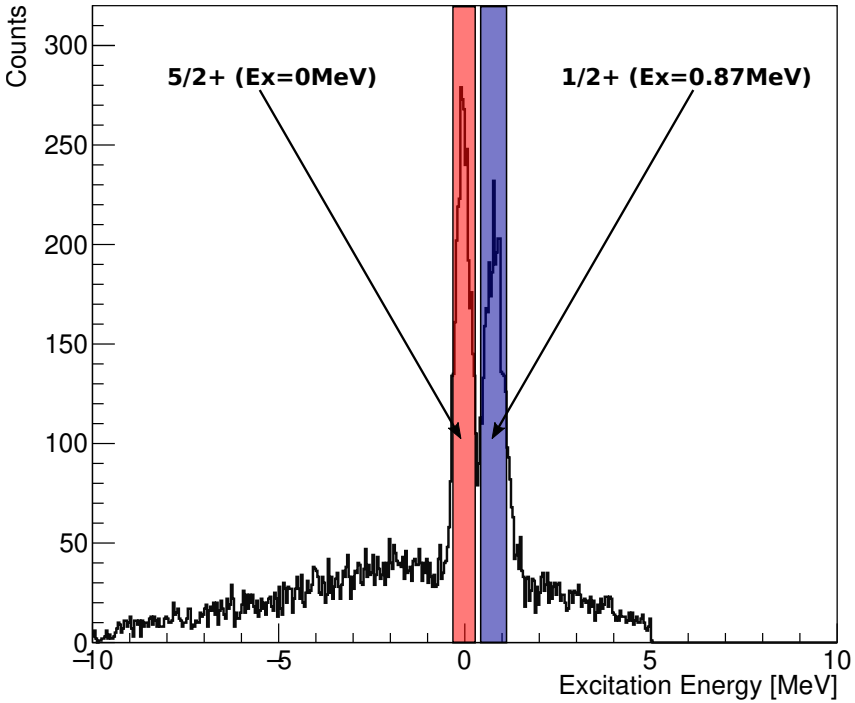
Reconstructed Excitation Energy in ^{17}O



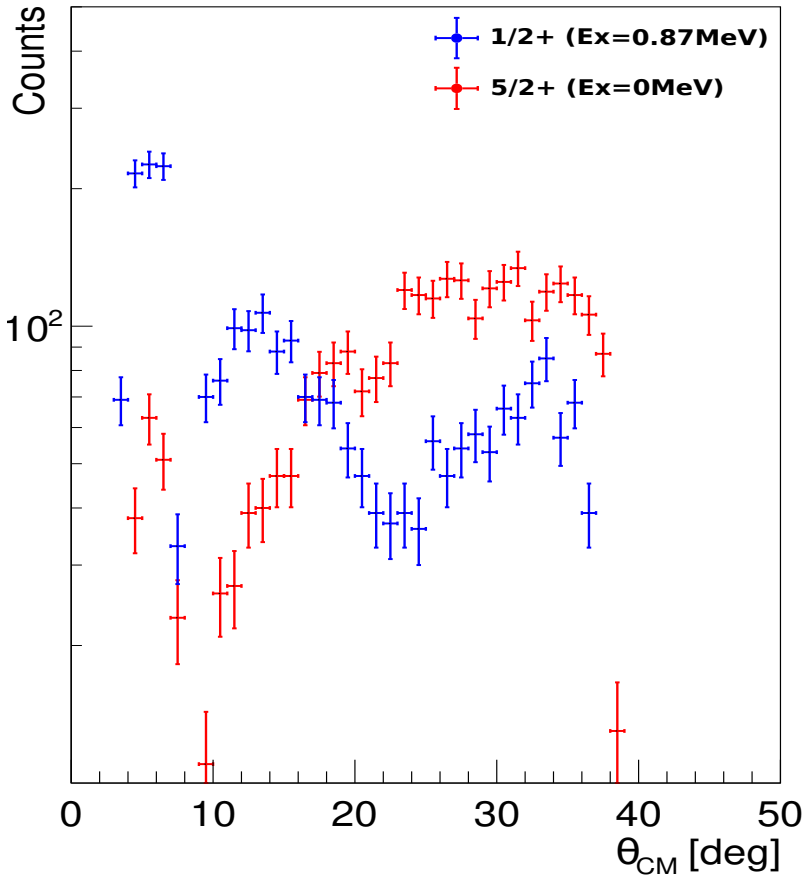
Target thickness optimization



Reconstructed Excitation Energy in ^{17}O



Events selected within
FWHM of the two peaks



Differential Cross Section

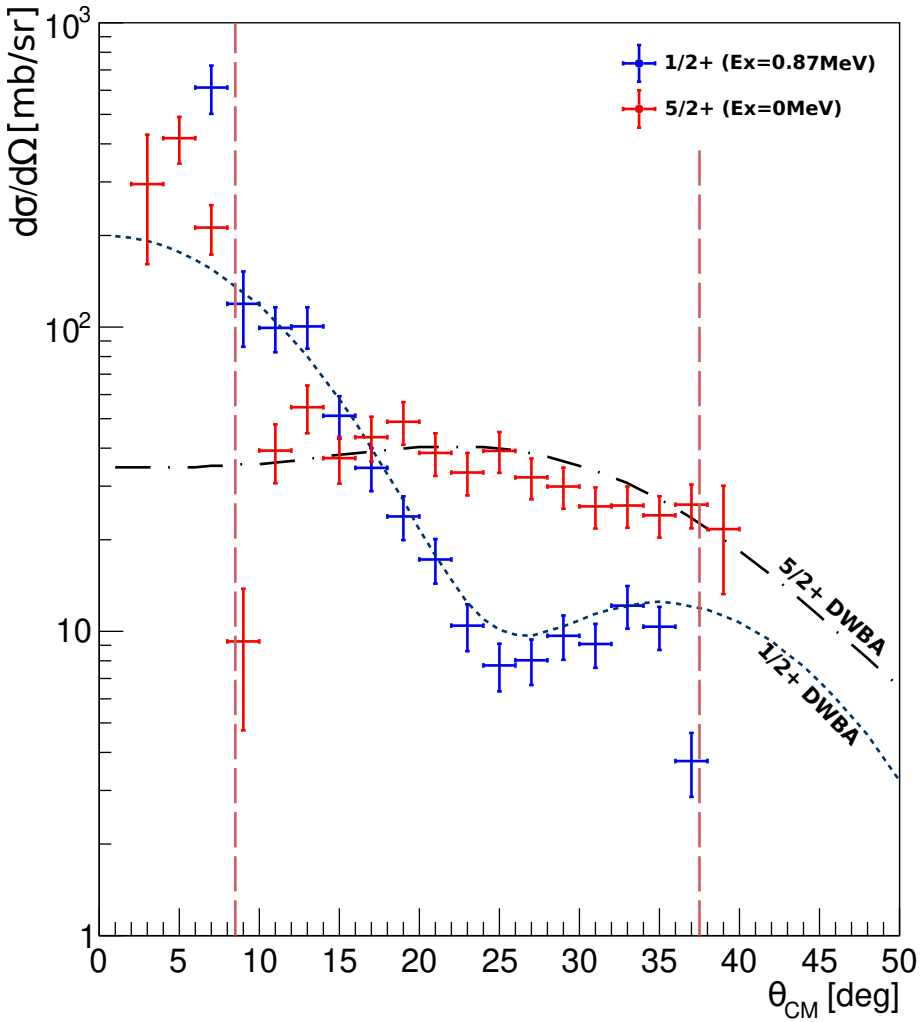
Normalized with simulated angular efficiency and integrated

↓

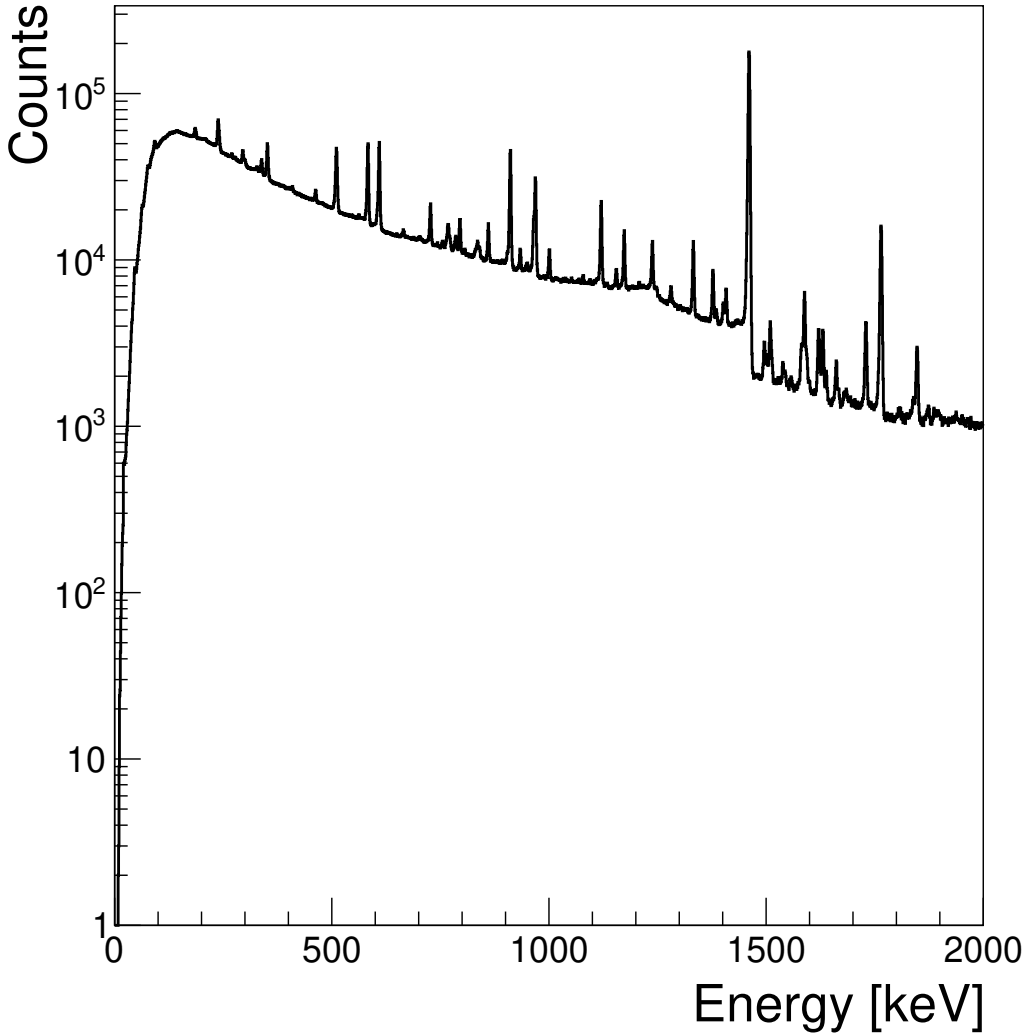
Fit over the theoretical distribution

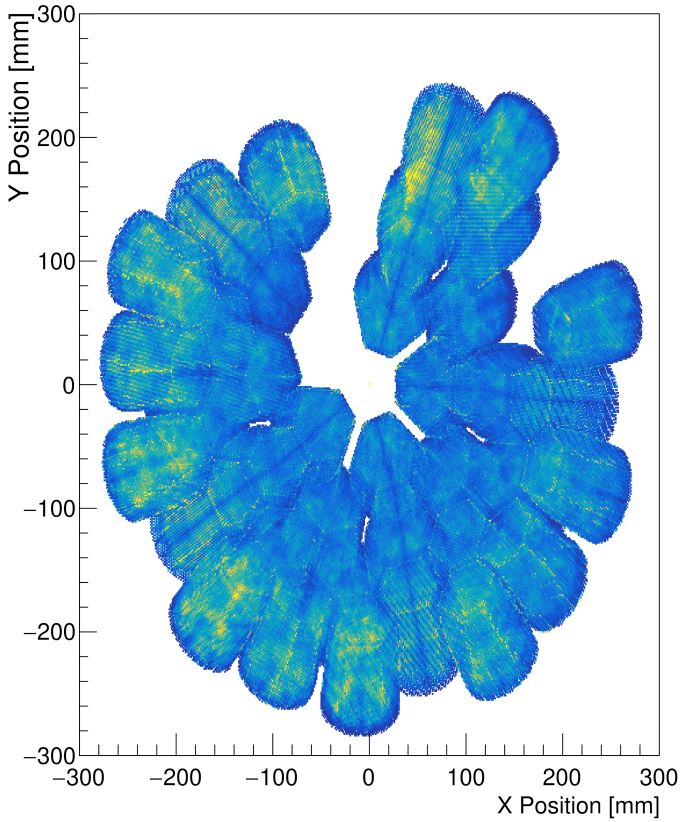
DWBA calculation from Jesus Casal
Università degli Studi di Padova
INFN Sezione di Padova

Optical potential from
An et al.,PRC 73.5 (2006)
Watson et al., PR 182.4 (1969)



Gamma-ray Energy Spectra

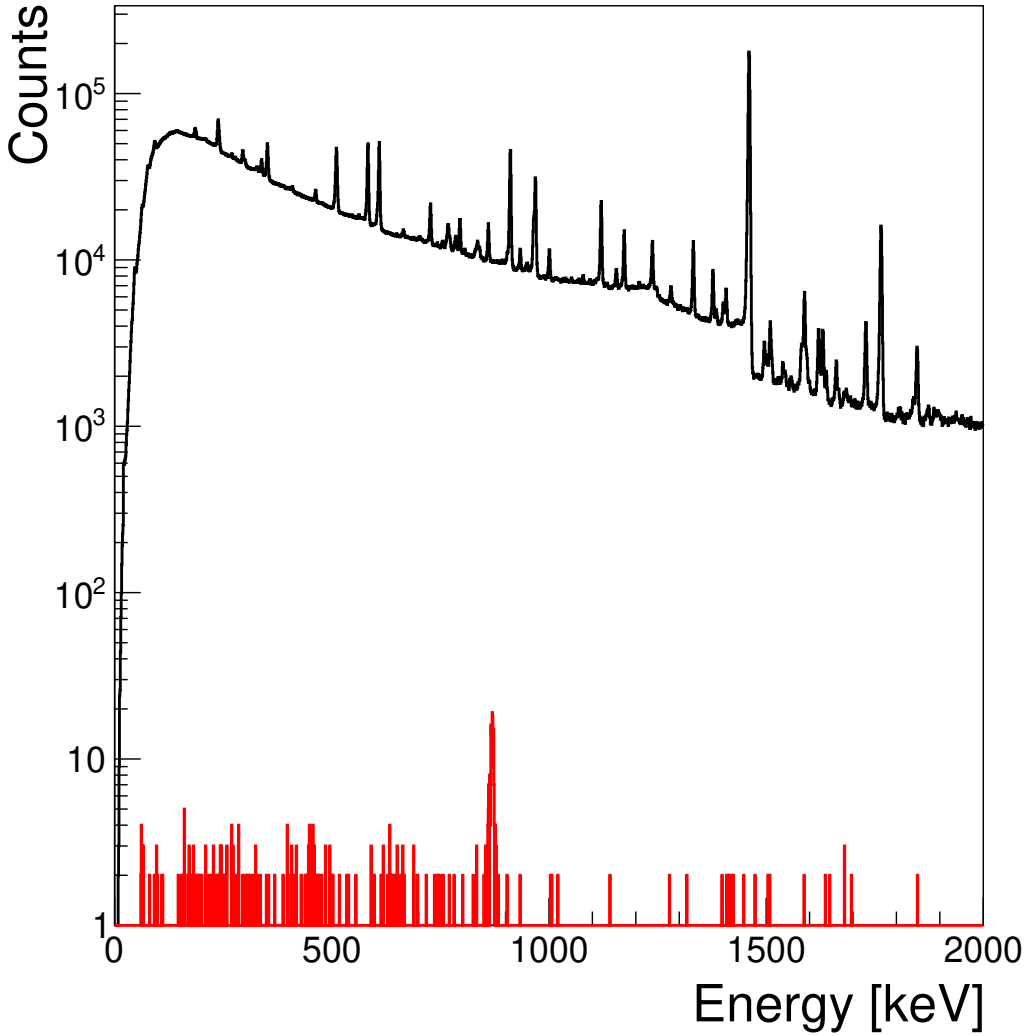


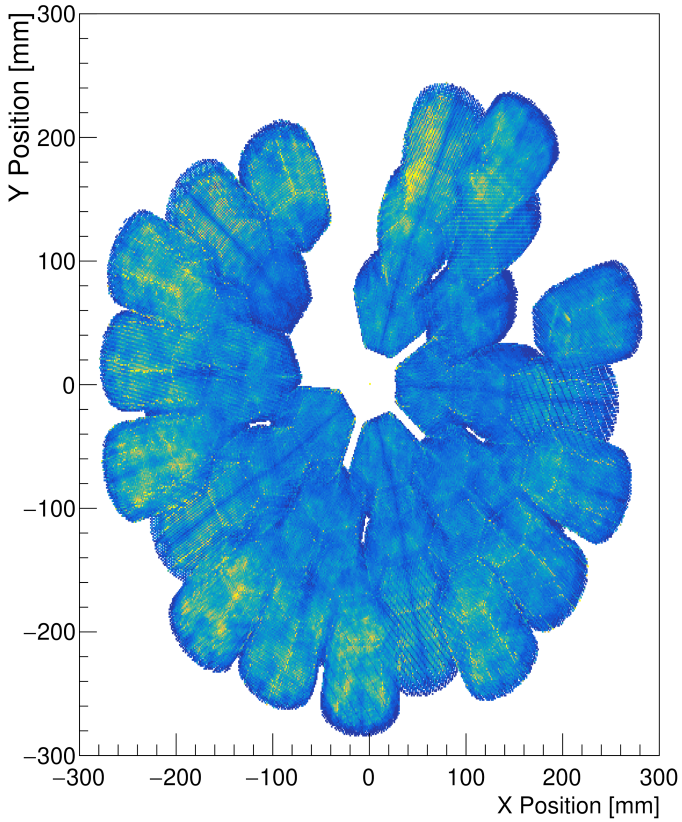


Gamma spectrum w/o gate.

$6.9\ 10^7$ ev.

Gamma-ray Energy Spectra

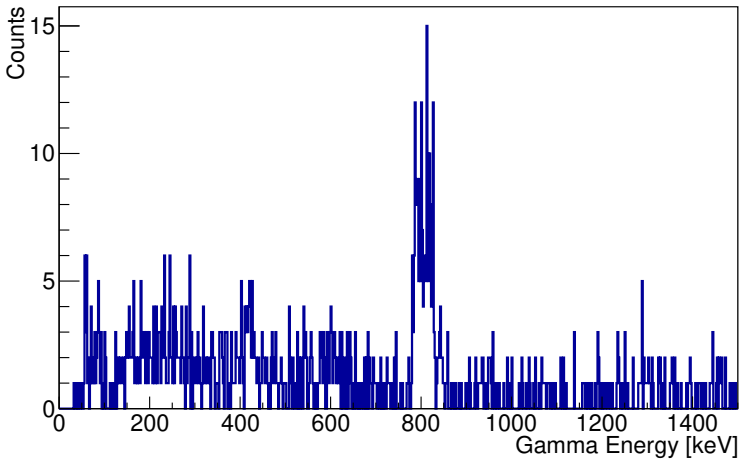




Gamma spectrum p gated.

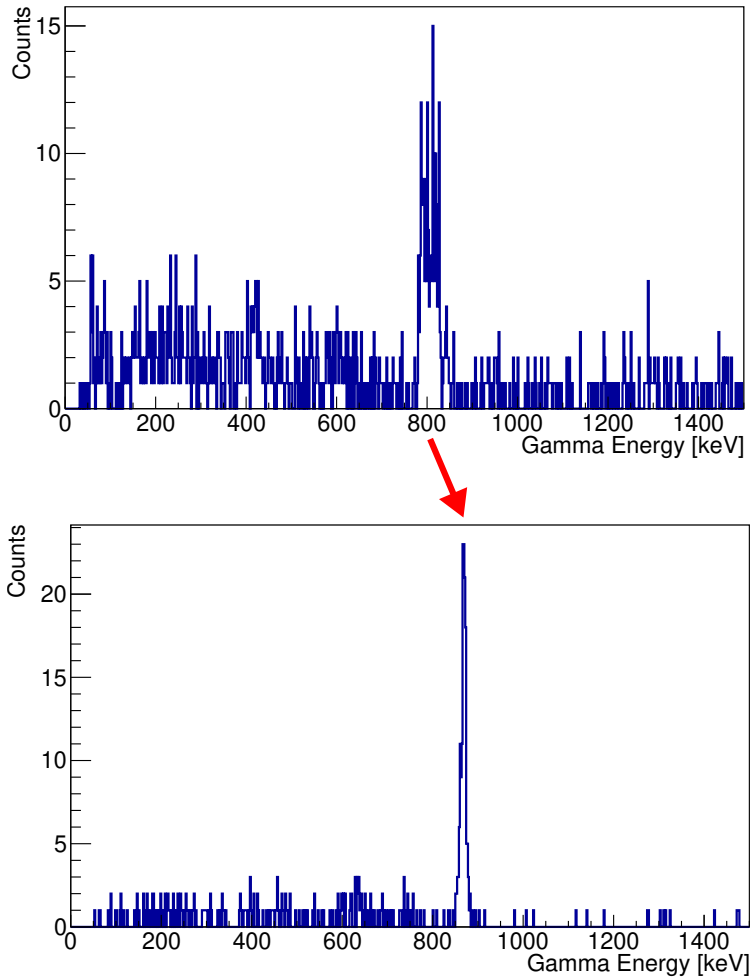
1.6 10^3 ev.

Doppler Correction



$1/2^+$ Gamma-ray energy peak
shifted from
the adopted energy.
(In-flight gamma-ray emission)

Doppler Correction

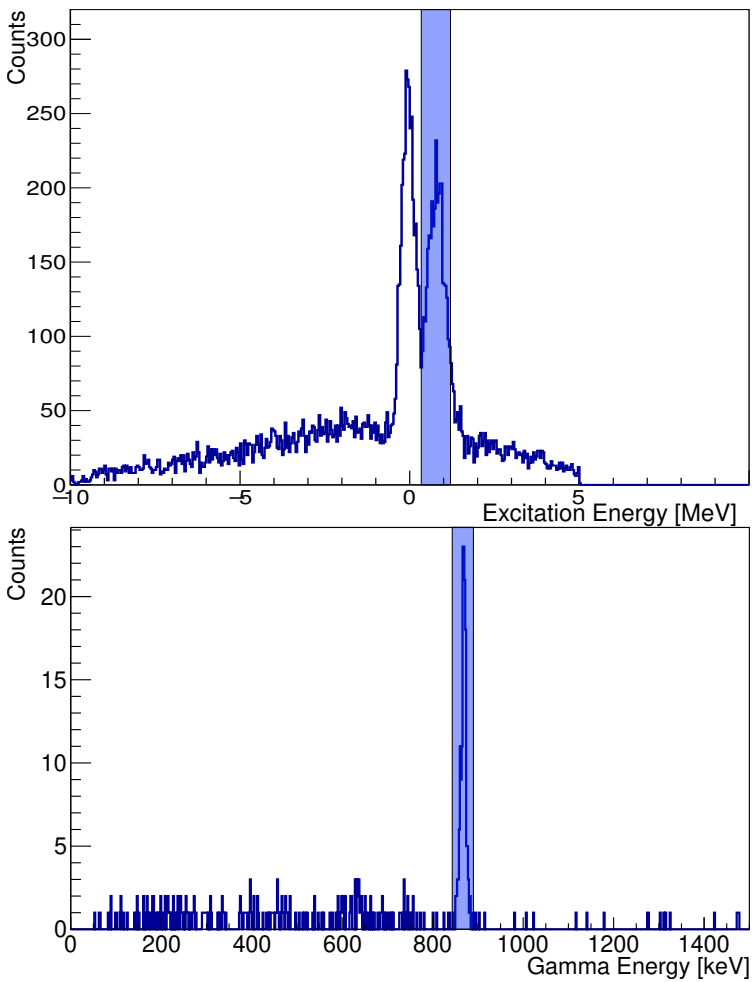


$1/2^+$ Gamma-ray energy peak
shifted from
the adopted energy.
(In-flight gamma-ray emission)

↓

Doppler correction
velocity and direction of ^{17}O
reconstructed from proton
kinematic

Deduced Efficiency



- 870 keV excitation peak integral (background removed)

$$\downarrow$$

2035 ± 45 protons

- 870 keV gamma peak integral (background removed)

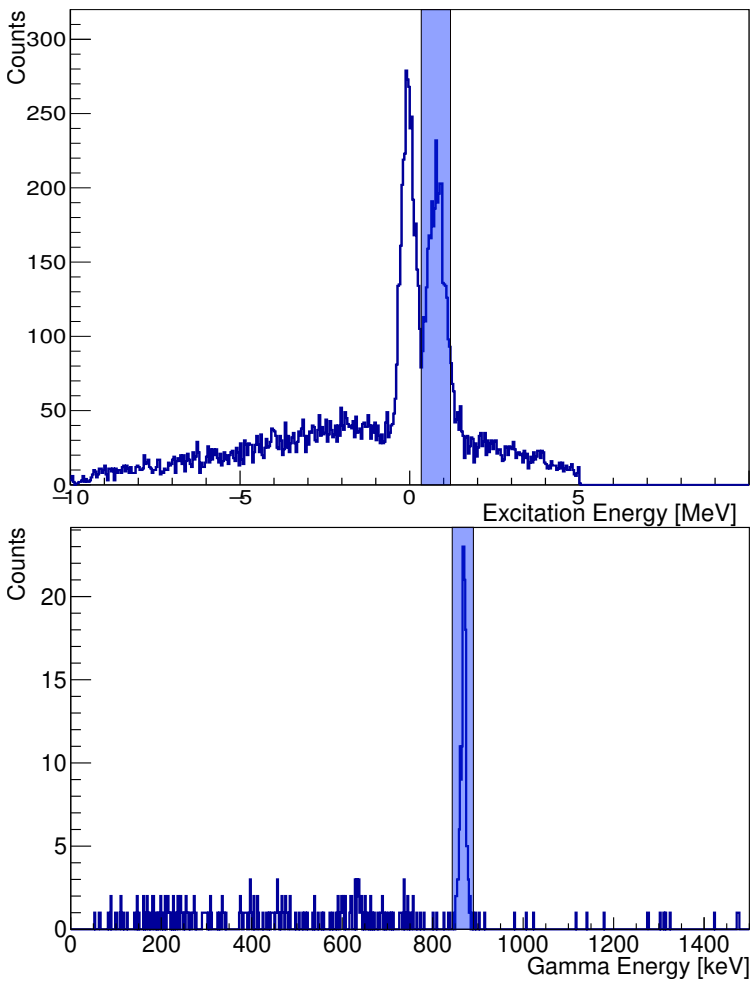
$$\downarrow$$

Add Back* $\rightarrow$ $150 \pm 12\ \gamma$

Tracking $\rightarrow$ $147 \pm 12\ \gamma$

* Clustering gamma-ray events including the first neighbouring crystals.

Deduced Efficiency



- 870 keV excitation peak integral (background removed)

$$\downarrow$$

2035 ± 45 protons

- 870 keV gamma peak integral (background removed)

$$\downarrow$$

Add Back* $\rightarrow$ $150 \pm 12\ \gamma$

Tracking $\rightarrow$ $147 \pm 12\ \gamma$

Efficiency Estimate:

Add Back* $\rightarrow$ 7.4 ± 0.6 %

Tracking $\rightarrow$ 7.2 ± 0.6 %

* Clustering gamma-ray events including the first neighbouring crystals.

Conclusion and Perspectives

- Successful commissioning experiment
- Angular distributions well predicted by theoretical calculations.
- Angular momentum transfer to ^{17}O $5/2^+$ and $1/2^+$ final levels($l = 2$ and $l = 0$ neutron transfer) in agreement with reference values.
- Gamma-ray and proton coincidence between AGATA and MUGAST.
- Independent estimate of AGATA efficiency.

Perspectives

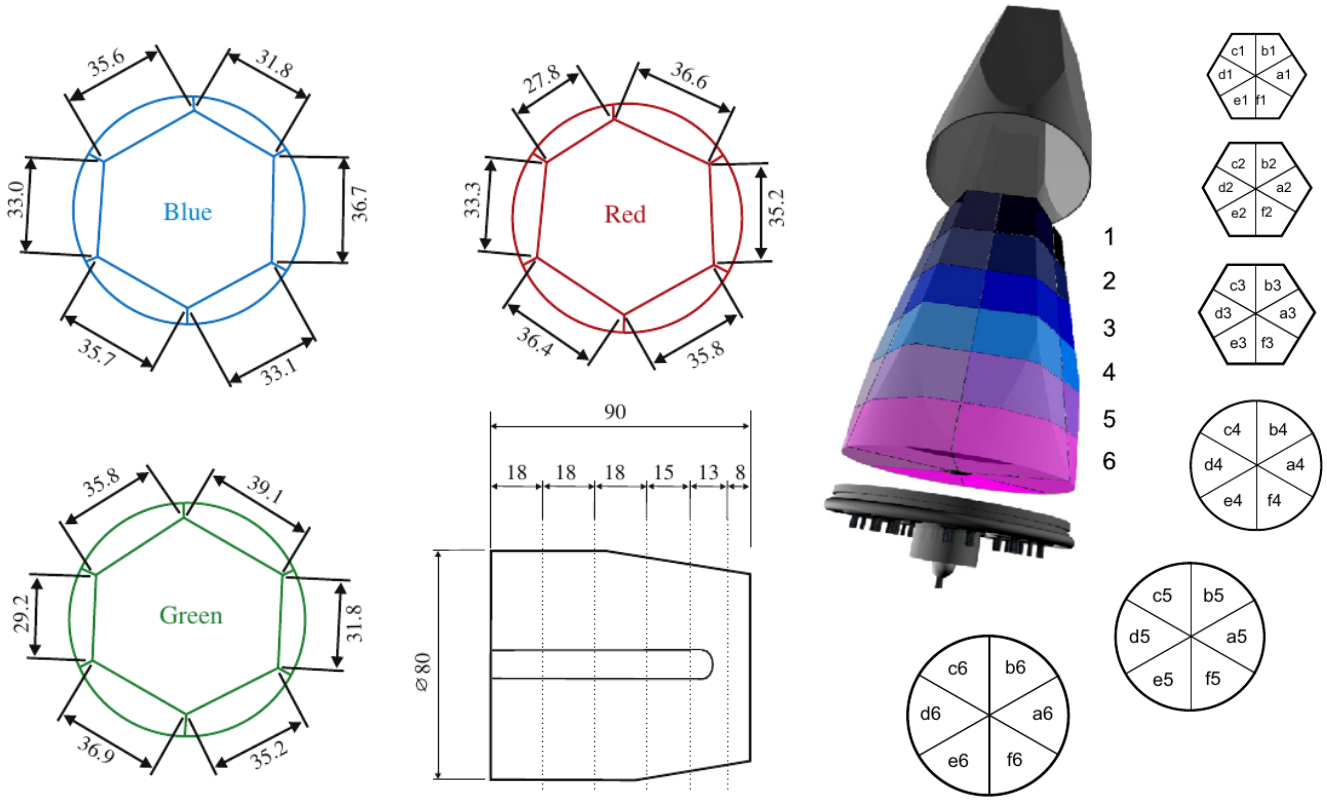
- Investigation on Annular detector angular distribution
- Exploit VAMOS performances (cross section normalization and improved Doppler correction)


Thanks to AGATA+MUGAST+VAMOS
collaborations and thank you for attention
Credit photo CEA/CNRS. P. Stroppa

Backup Slides

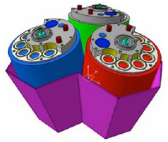
Advanced GAmma Tracking Array

European project to develop and operate the next generation γ-ray spectrometer.



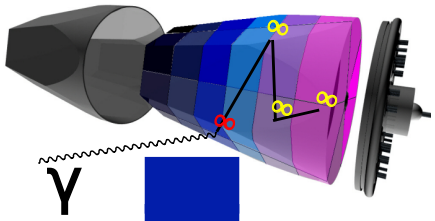
S. Akkoyun et al, NIM A 668 (2012) 26–58

HPGe segmented Tracking Array

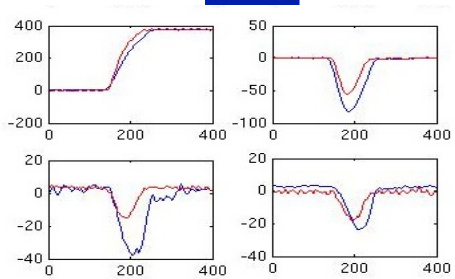


AGATA

Highly segmented HPGe detectors NOVEL PRE-AMPS



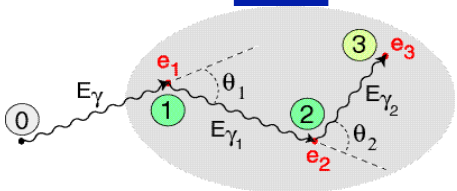
Synchronized digital electronics record and process the segment signals DIGITIZERS + PRE-PROCESSING



Identified interaction points $(x,y,z,E,t)_i$

Pulse Shape Analysis to de-convolute the recorded waves DAQ PSA - FARM

Reconstruction of interaction tracks (tracking algorithms on interaction points) DAQ TRACKING-FARM

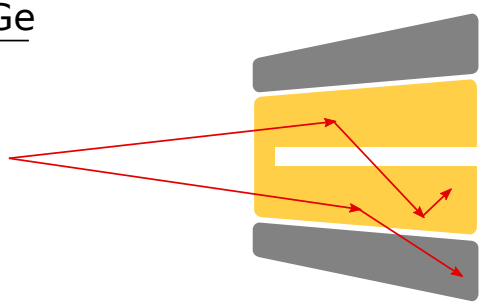


On-line reconstruction of γ-rays

Performances

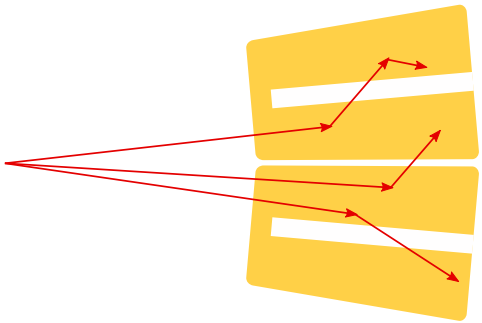
Compton Shielded Ge

Ph. Ɛ ~ 10%
P/T ~ 60%
θ res. ~ 8 deg



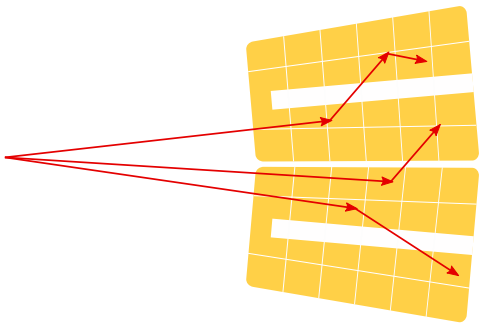
Ge Sphere

Ph. Ɛ ~ 50%
P/T ~ 30%
θ res. ~ 3 deg



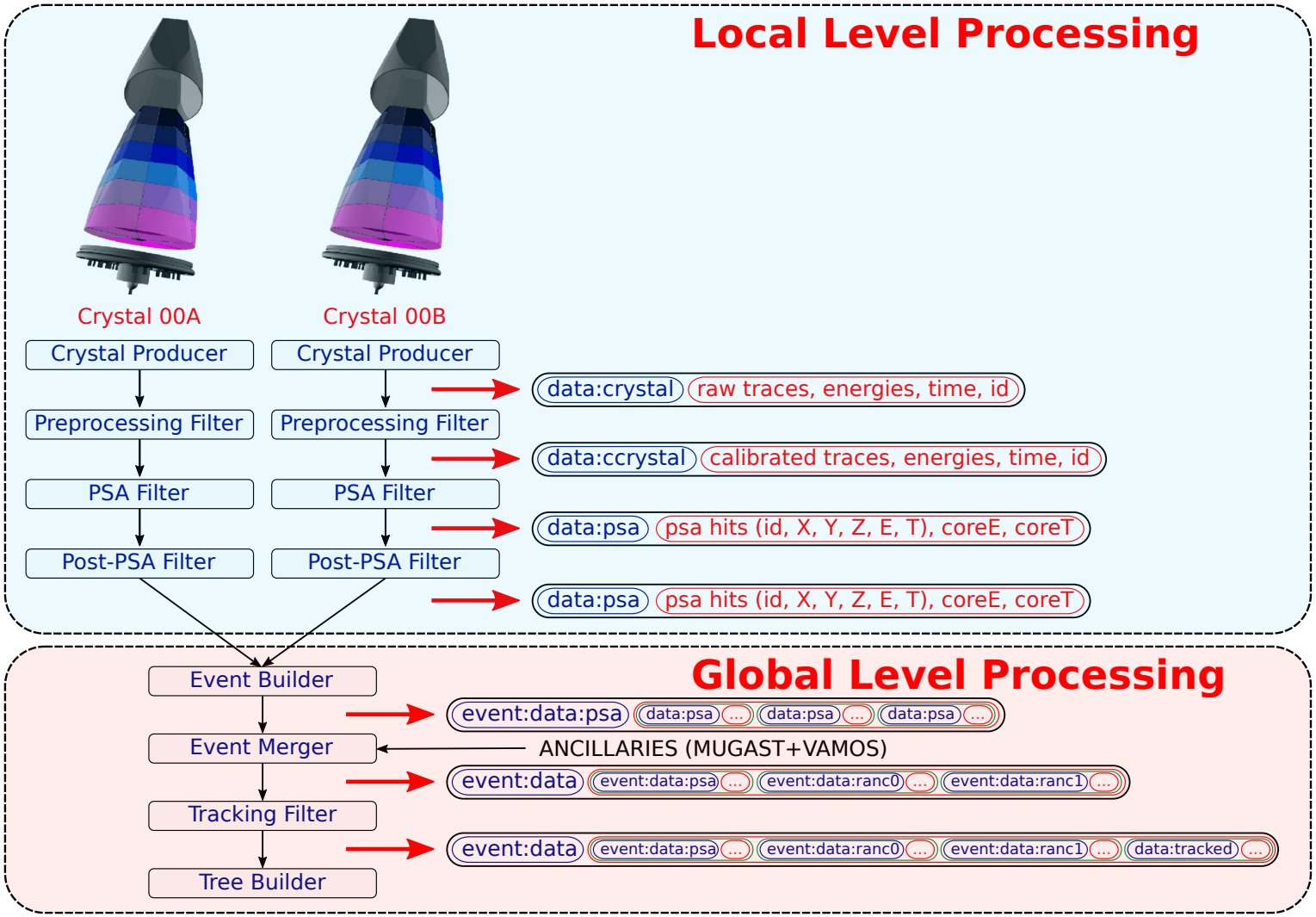
Ge Tracking Array

Ph. Ɛ ~ 50%
P/T ~ 60%
θ res. ~ 1 deg



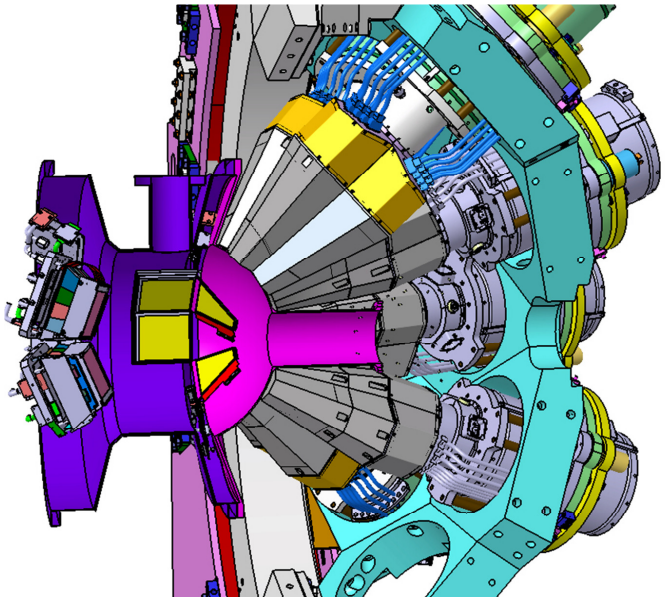
- Efficiency
  (angular coverage and tracking)
- Angular Resolution
- Doppler correction

Acquisition

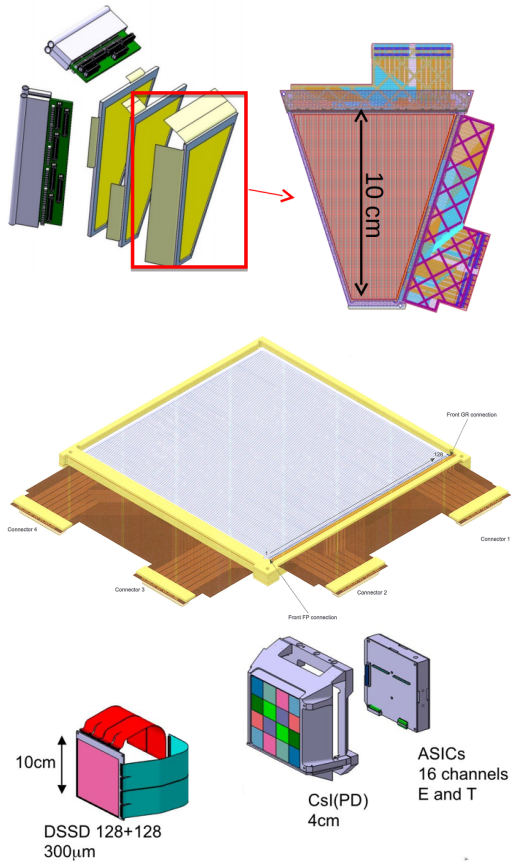


MUst2 GASpard Trace

Intermediate project of the final 4π array GRIT intended to be used with AGATA.



D. Beaumel, D. Mengoni, LoI to the AGATA collaboration (2015)



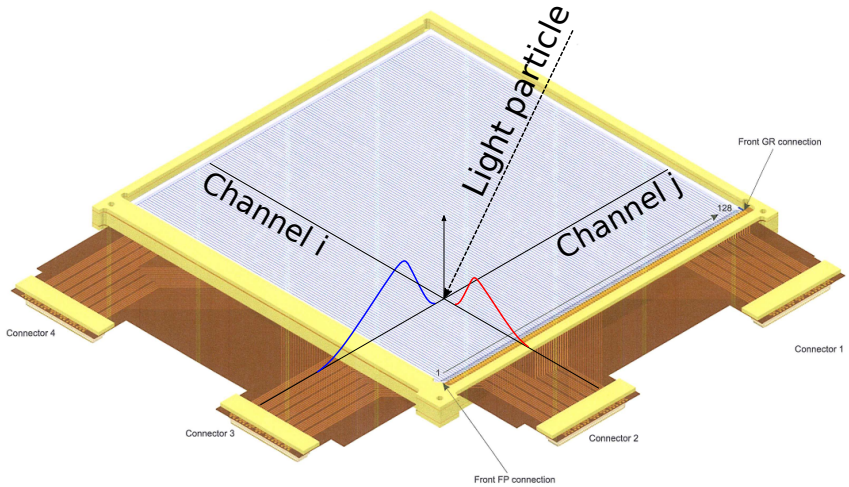
DSSD detector

Silicon Detector

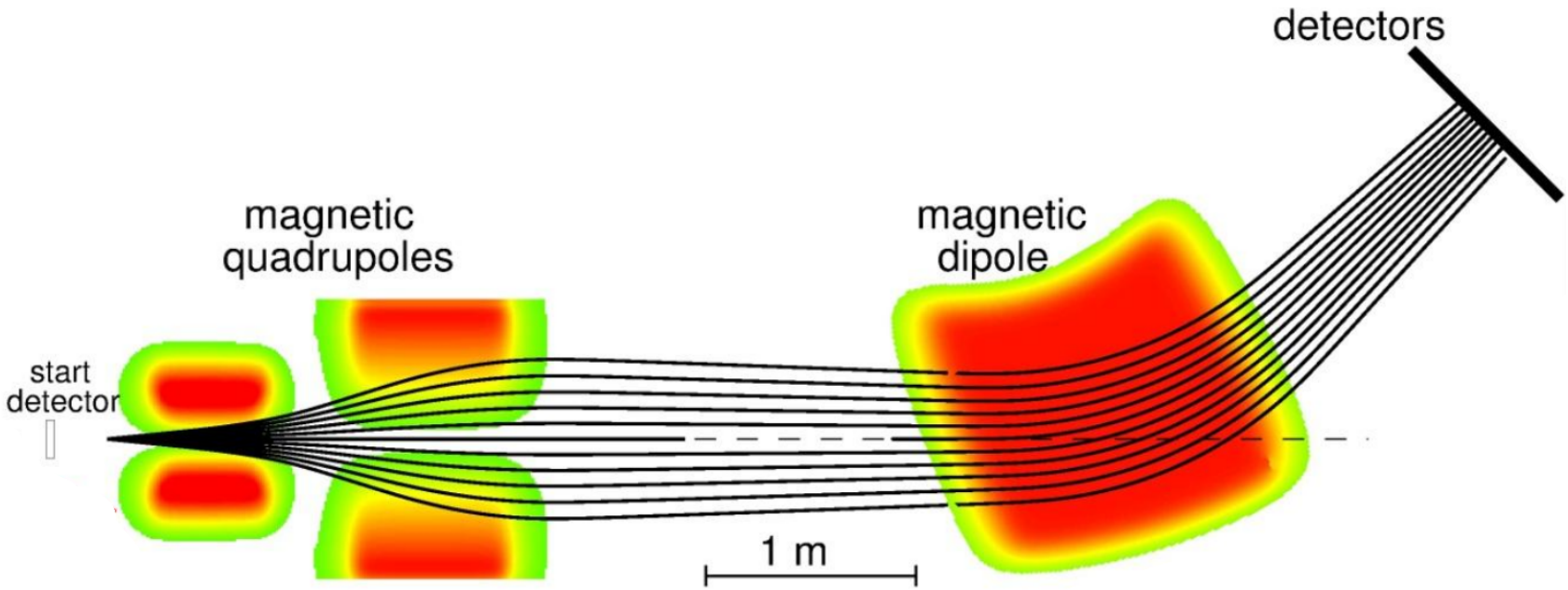
- $\sim$ 1.1 eV Energy Gap
- 2.38 g/cm^2 Density

Trace module

- 10 cm $\times$ 10 cm
- 128 channels/side
- 2-300 μm thickness



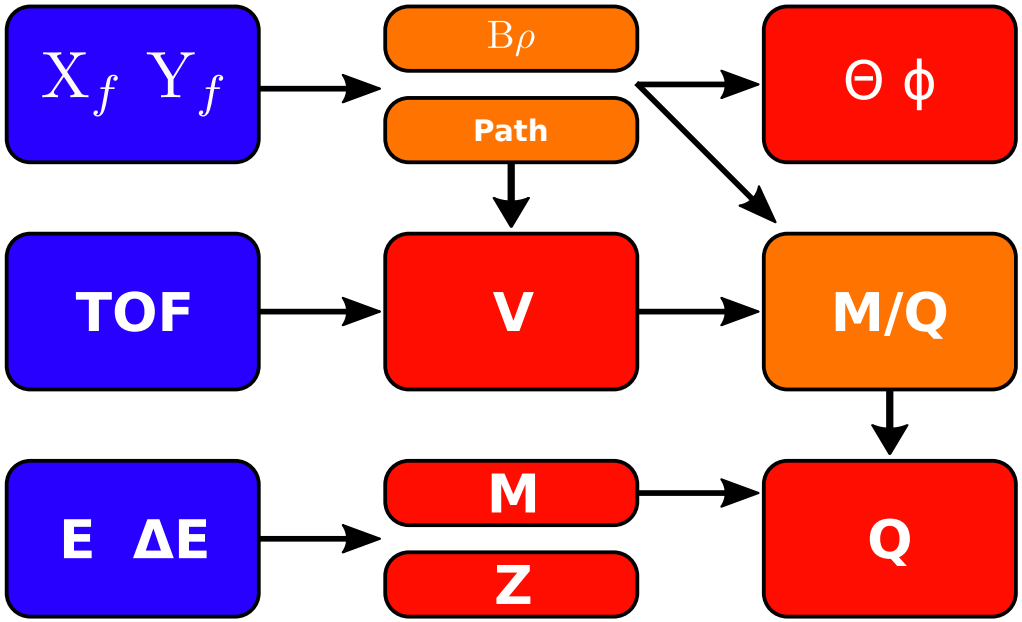
VAriable MOde Spectrometer



Deflection related to magnetic rigidity. $B\rho = mV/q$

VAriable MOde Spectrometer

- MWPPAC
- Drift Chamber
- Ionization Chamber



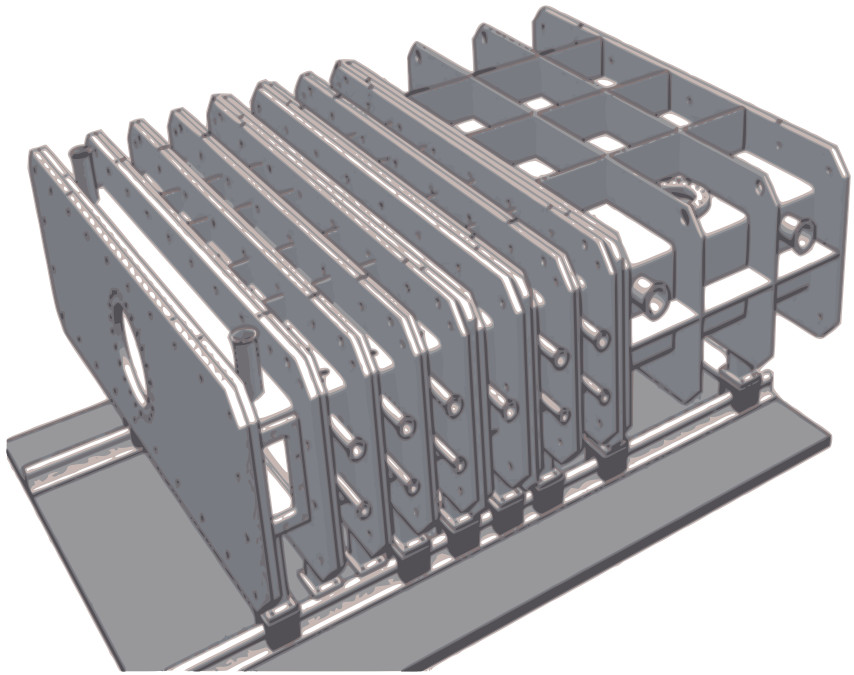
FP Detectors

Modular chamber for each detector separated by 2.5 μm mylar windows

$\Downarrow$

$\sim$ 6 mbar C_4H_{10} for MWPPAC-DC

20-40 mbar CF_4 for IC



M. Rejmund et al, NIM A 646 (2011) 184-191

FP Detectors

Multi Wire Parallel Plates Avalanche Counter

Cathode

150 mm vertical gold coated tungsten 20 μm wires with 500 μm pitch

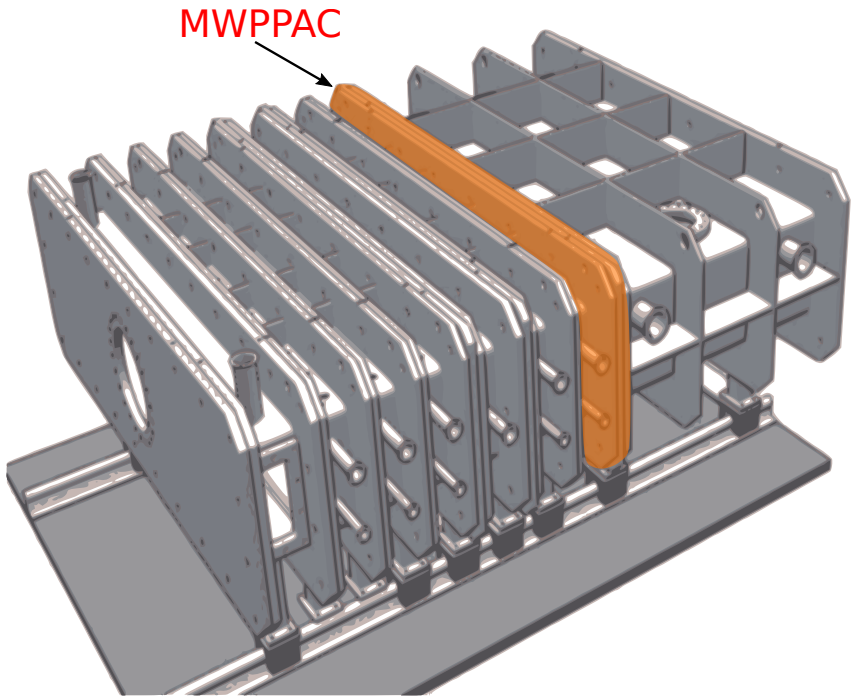
Polarized $\sim$ -500 V

Anode

1000 mm horizontal wires

1 mm pitch

Grounded



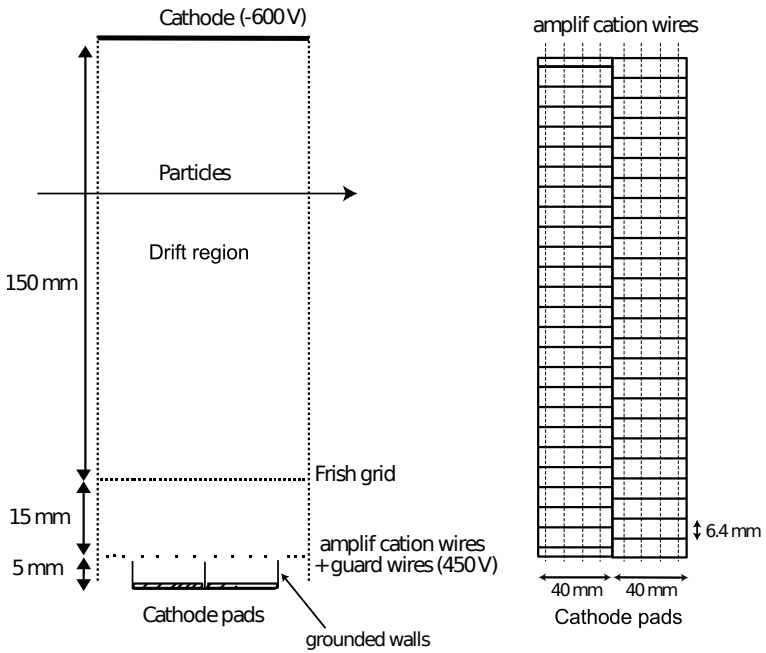
M. Rejmund et al, NIM A 646 (2011) 184-191

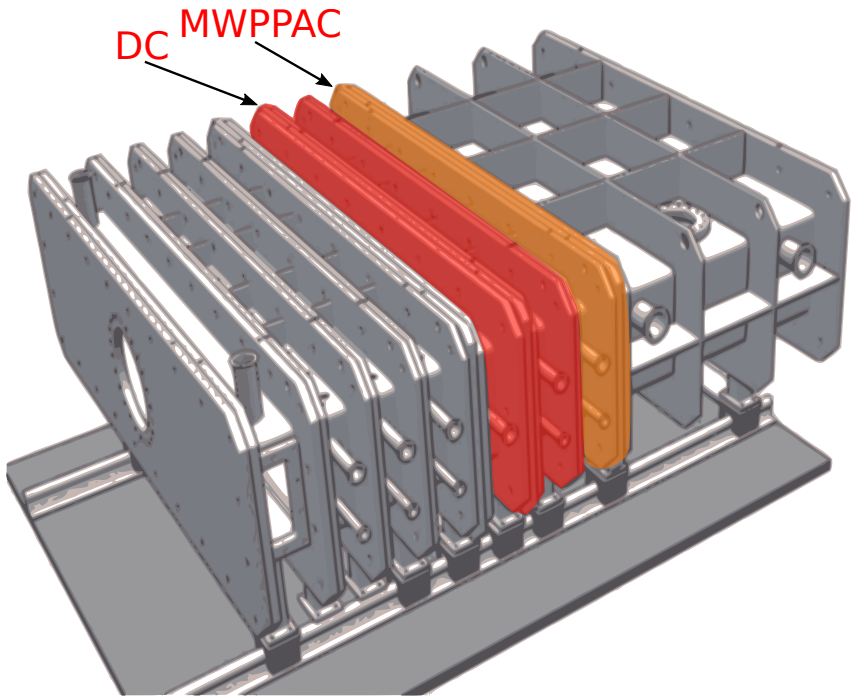
FP Detectors

Drift Chamber

2 modules of volume

$1000 \times 150 \times 100\ mm^3$





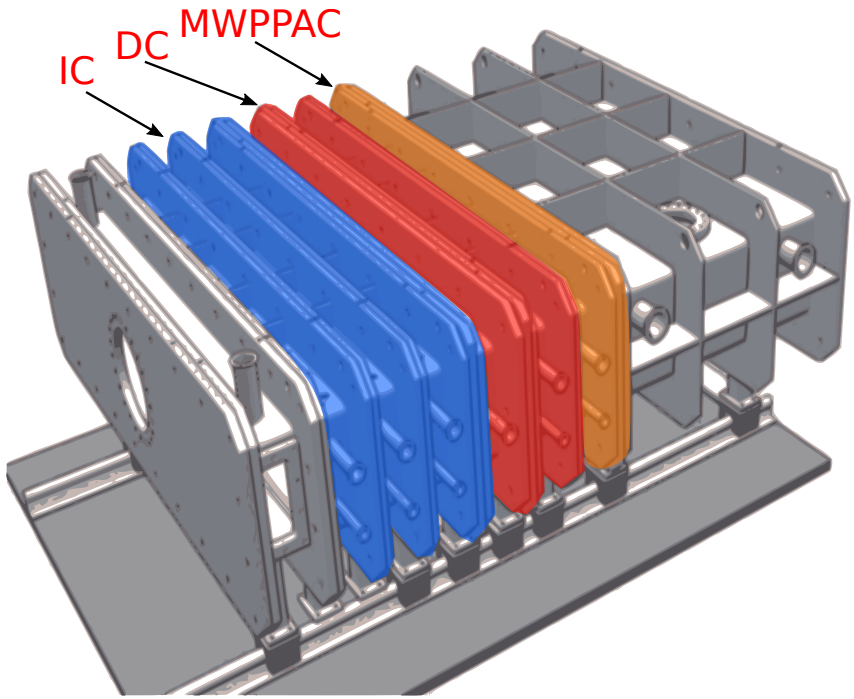
M. Rejmund et al, NIM A 646 (2011) 184-191

FP Detectors

Ionization Chamber
6 modules of volume
$1000 \times 120 \times 150$ mm^3

Frisch Grid
250 μm diameter-1 mm pitch
20 mm from anode pads.

Tipical potential
22.5 V/mbar drift gap
6 V/mbar between grid and anode



M. Rejmund et al, NIM A 646 (2011) 184-191