Recoil spectrometers for transfer reactions ?

Marlène Assié
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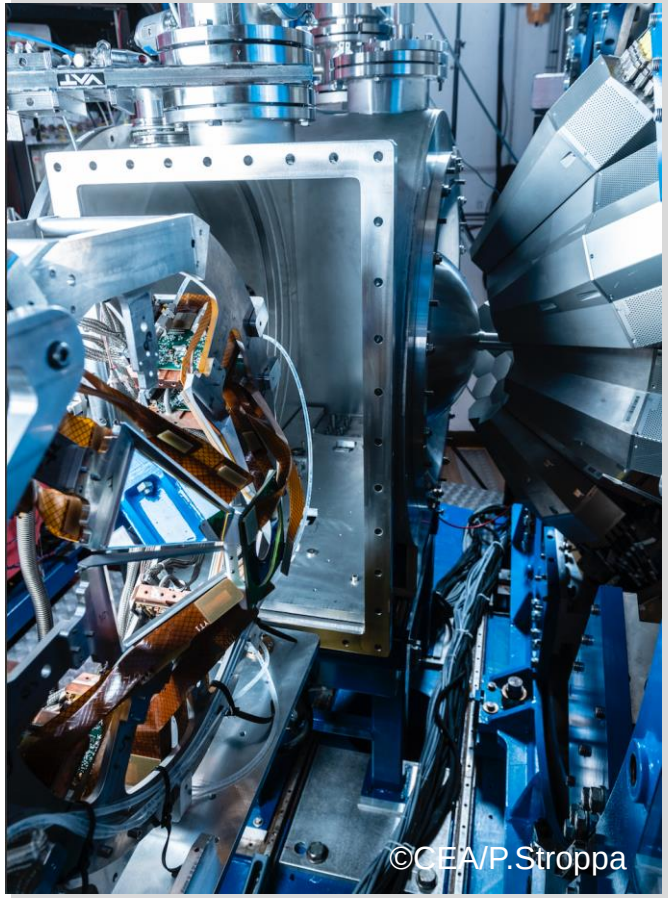
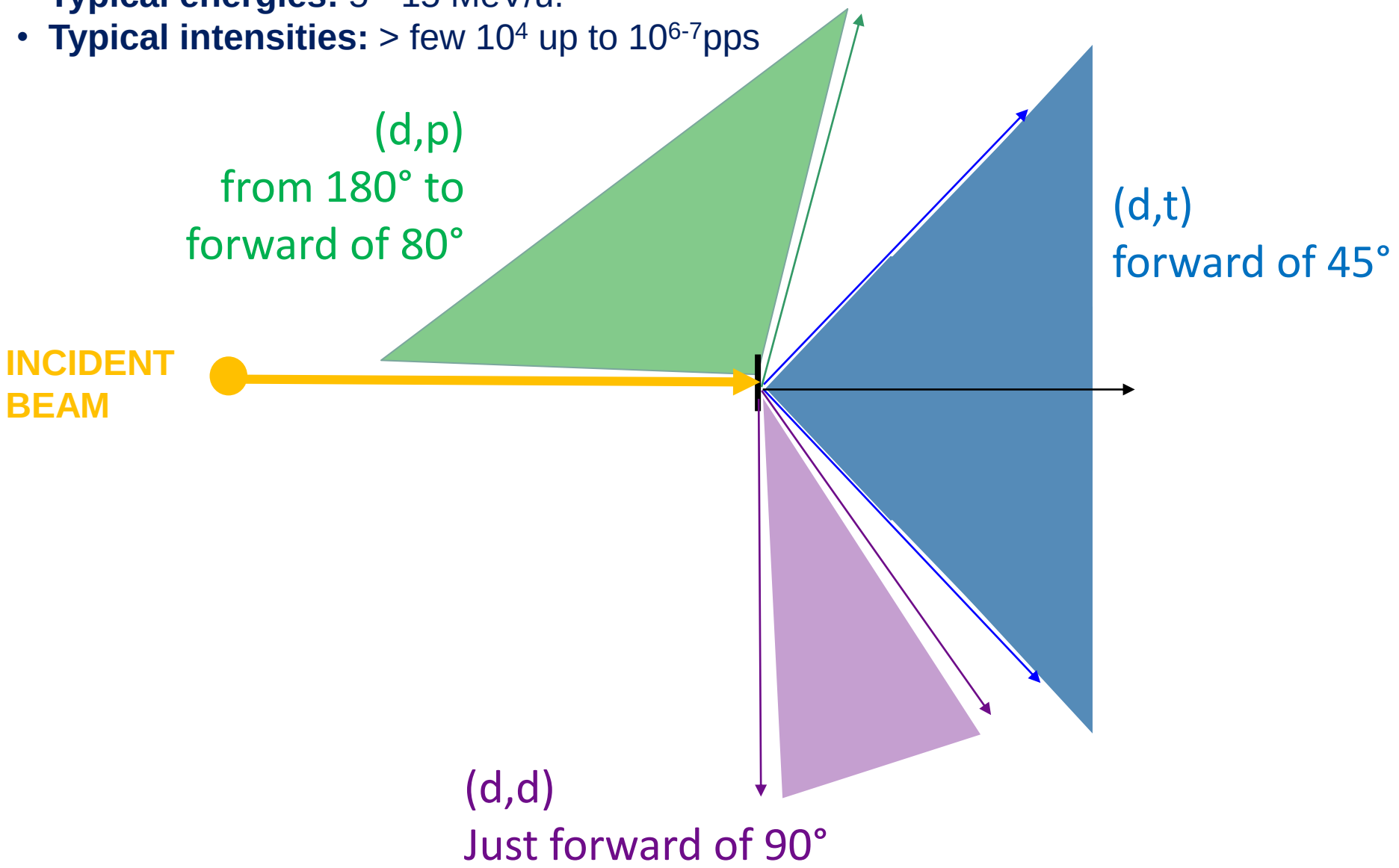


Transfer reactions in inverse kinematics

- **Typical energies:** 5 - 15 MeV/u.
- **Typical intensities:** > few 10^4 up to 10^{6-7}pps



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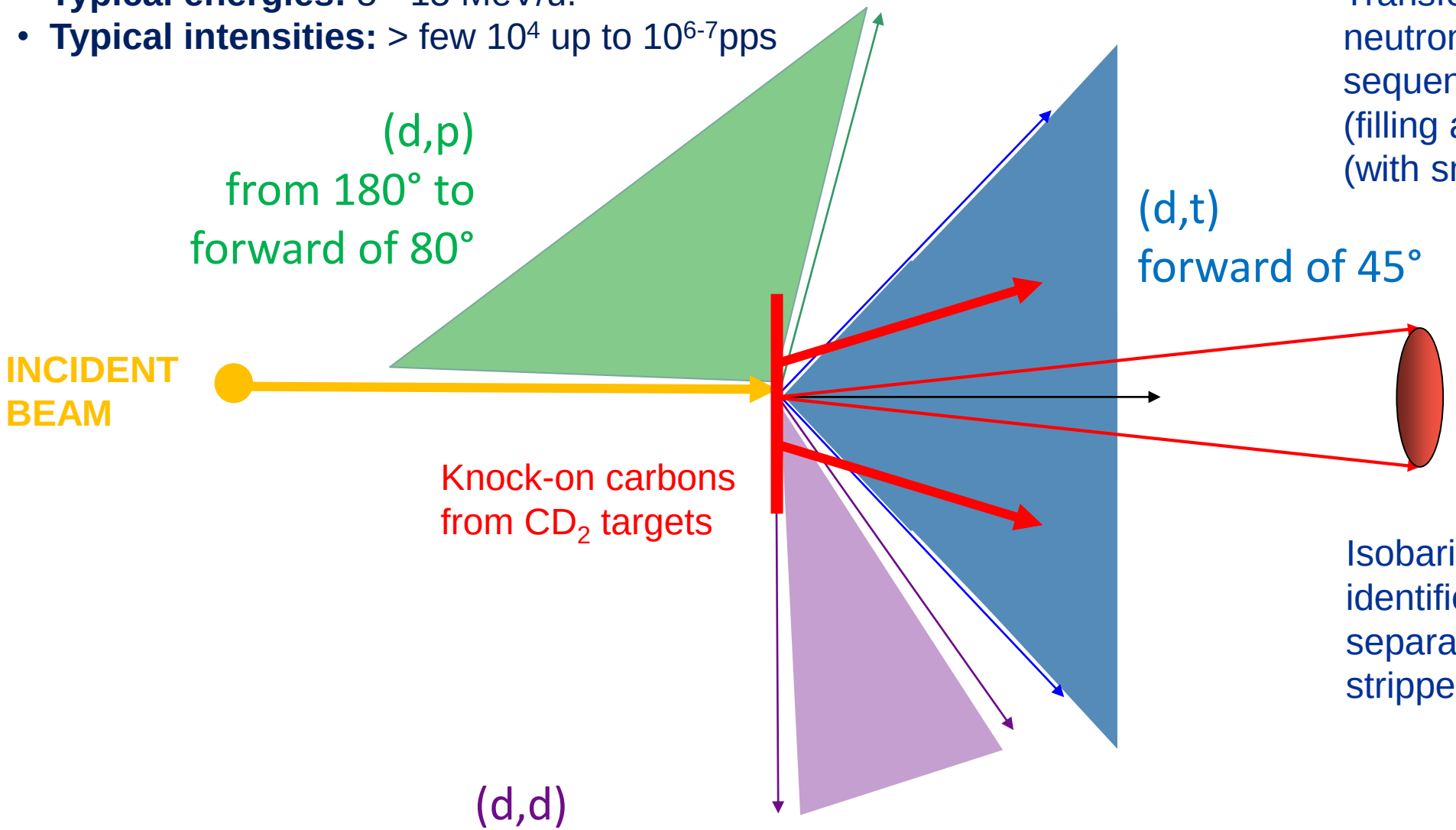


Transfer products on neutron-rich side can sequentially n-decay (filling a bigger cone) (with smaller momentum)

Isobaric beams can be identified and/or physically separated (possibly further stripped by the target)

Adapted from W. Catford

Characteristics of transfer reactions with light targets

- **Device at 0 degree -->Small scattering angles around 0**

- **Performances :**

  . Event-by-event PID: Physical separation of reaction products of interest

  - from the **beam / isobaric beam contaminants** and others
  - from fusion-evaporation reactions with target (CH_2, CD_2, X+^{3}H, X+^{4}He, X+^{16}O, …)

  . Large acceptance

  . Excellent **angular resolution** to allow kinematic reconstruction (and Doppler correction)

  . A/Z resolution : ?

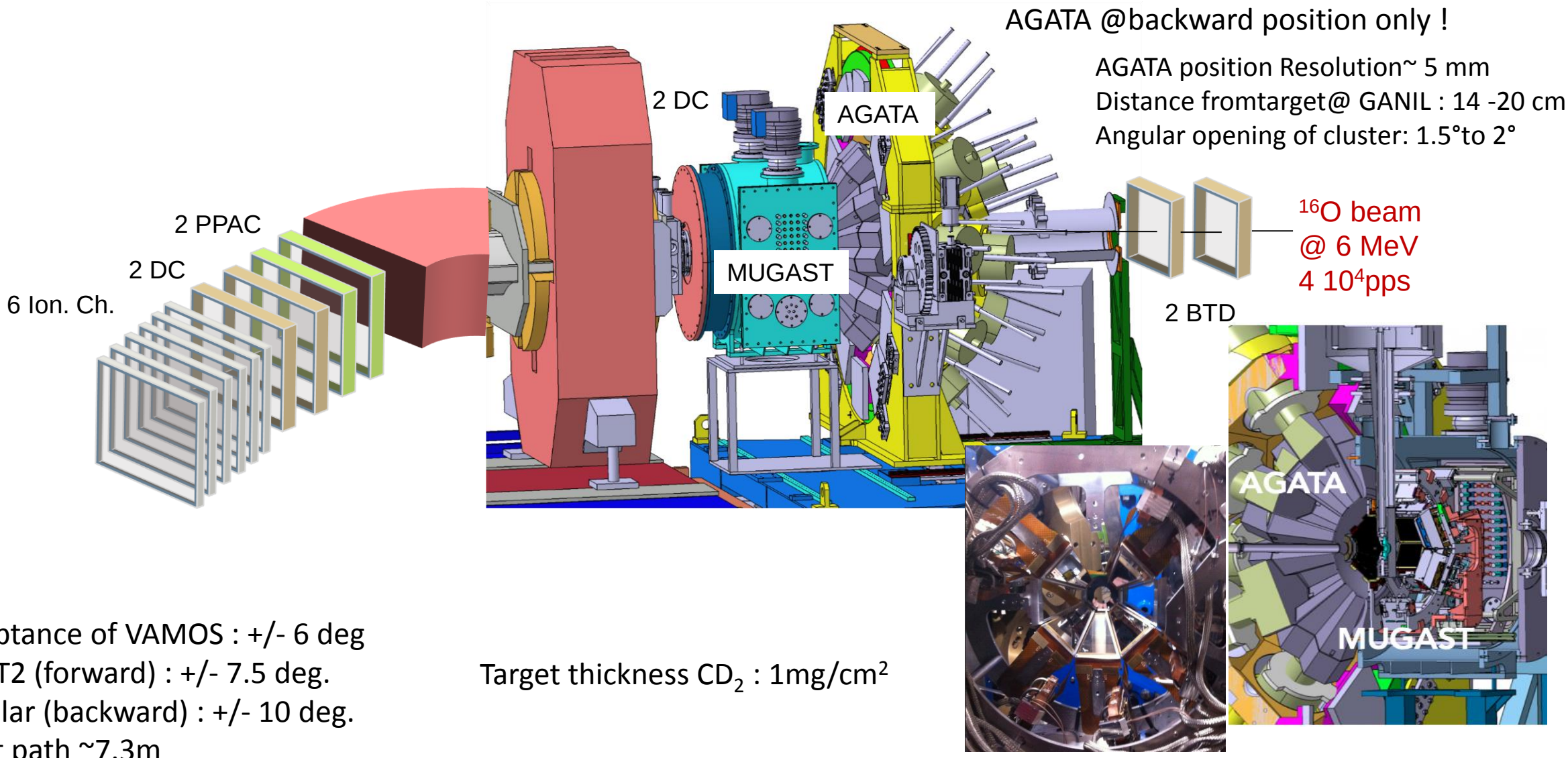
  . Timing : useful for particle identification in some cases …

Normalisation

- Beam composition (if not pure)
- Integral measurement sufficient but beam tracking devices useful (BTD limited to 10^{5}pps)

MUGAST commissioning : $^{16}O(d,p)^{17}O$ @ 6 MeV

An extremely complete set-up for transfer reactions measurement



AGATA @backward position only !

AGATA position Resolution~ 5 mm
Distance fromtarget@ GANIL : 14 -20 cm
Angular opening of cluster: 1.5°to 2°

^{16}O beam
@ 6 MeV
4 10^4pps

Acceptance of VAMOS : +/- 6 deg
MUST2 (forward) : +/- 7.5 deg.
Annular (backward) : +/- 10 deg.
Flight path ~7.3m

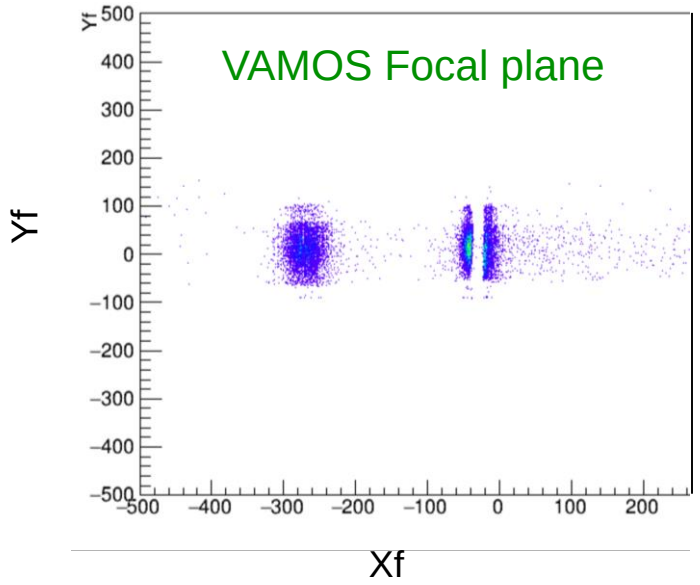
Target thickness CD_2 : 1mg/cm^2

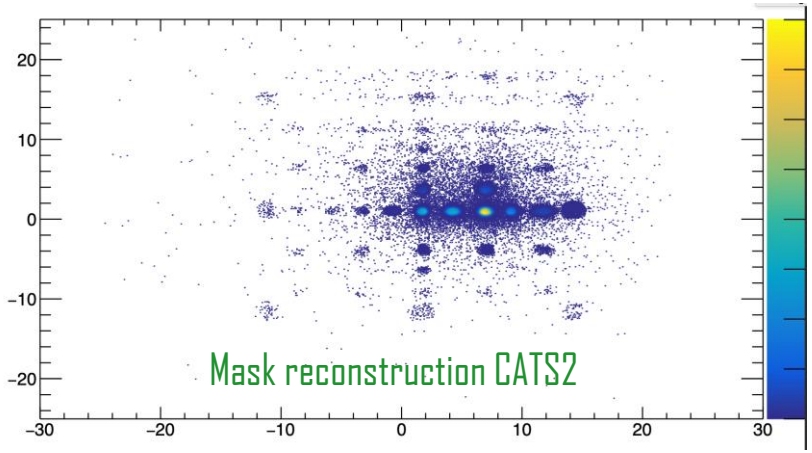
MUGAST commissioning : $^{16}O(d,p)^{17}O$ @ 6 MeV

Beam intensity : ~4 10^4 pps

No BTDs due to large straggling effect

Finger in VAMOS covering ^{16}O and partially ^{17}O





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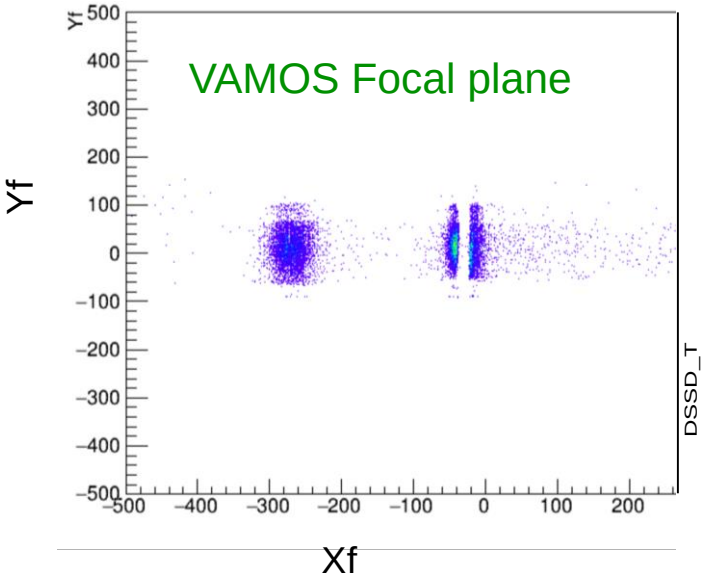
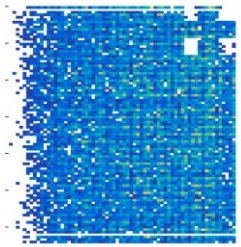
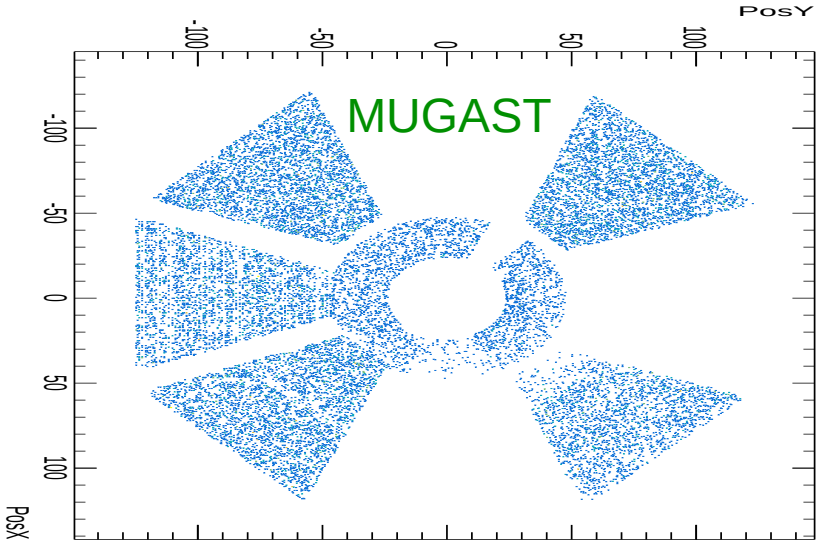
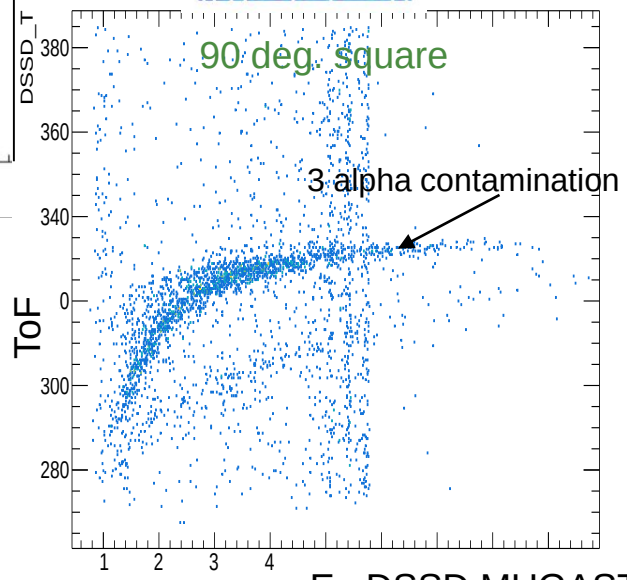
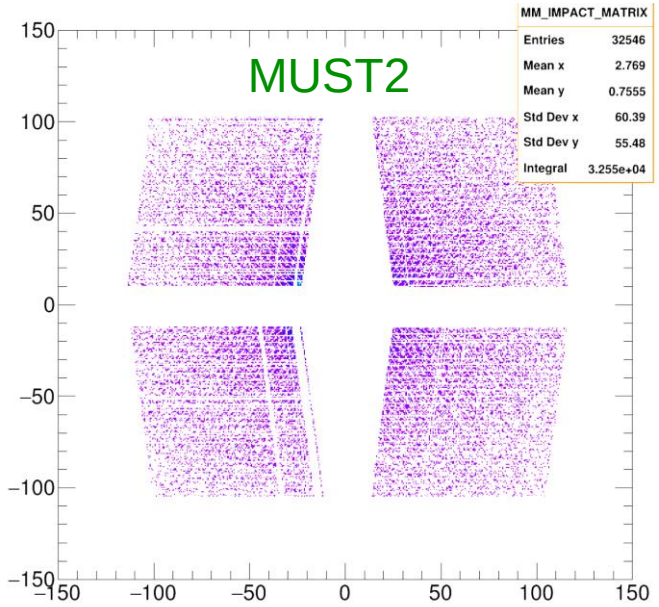




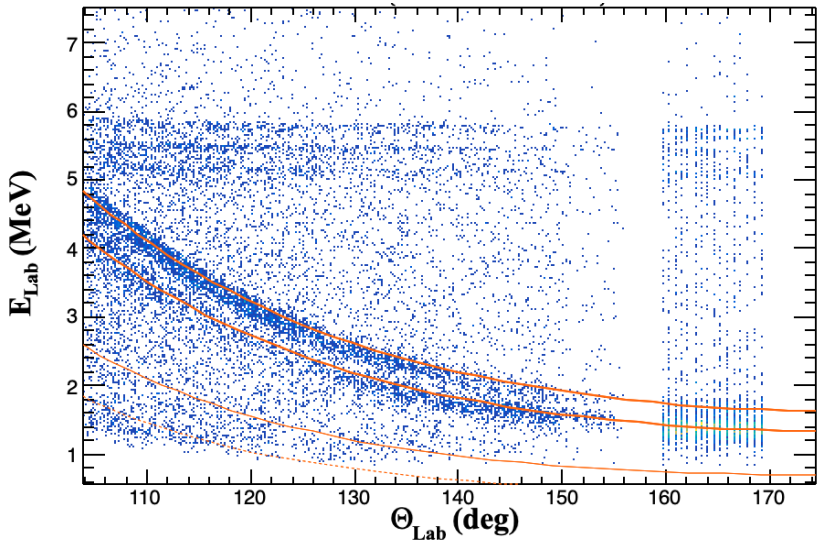


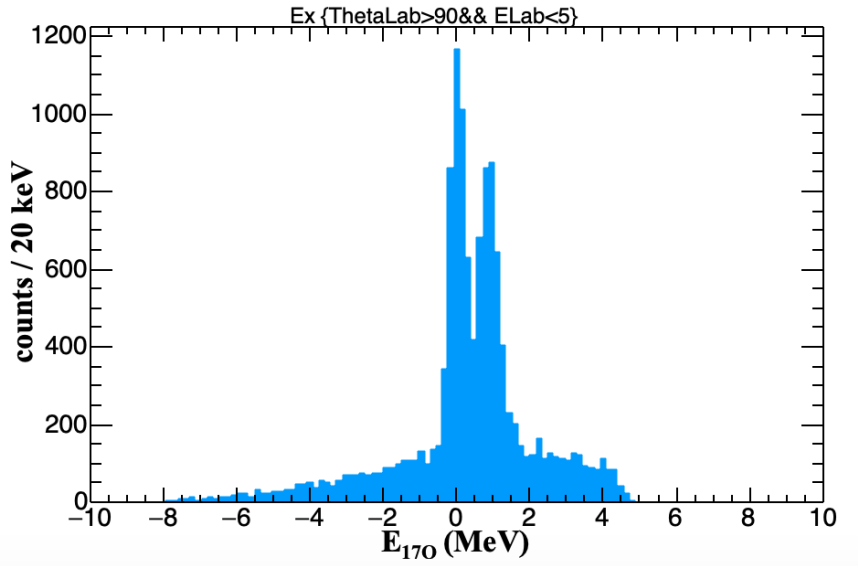




MUGAST commissioning : $^{16}O(d,p)^{17}O$

Kinematic lines for $^{16}O(d,p)$





Energy resolution :

- from fit of 2 peaks : ~500 keV
- from simulation with CD_2 1mg/cm^2 : 500 keV

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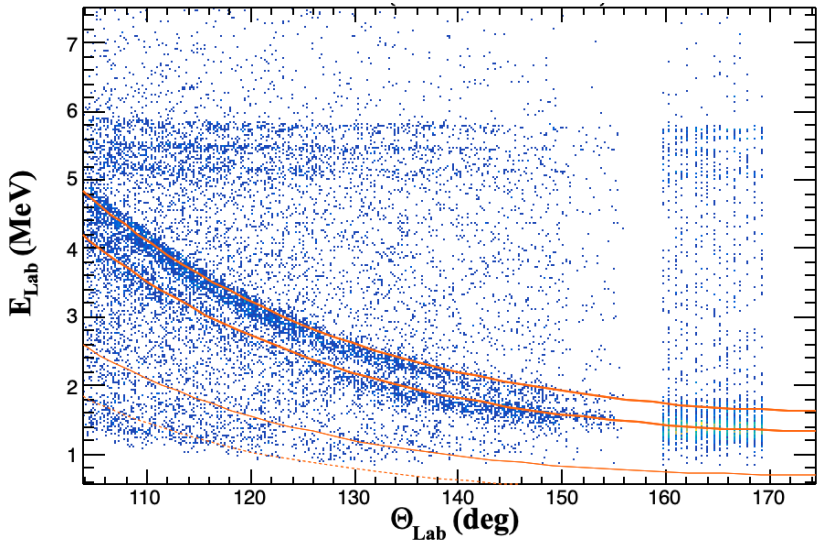

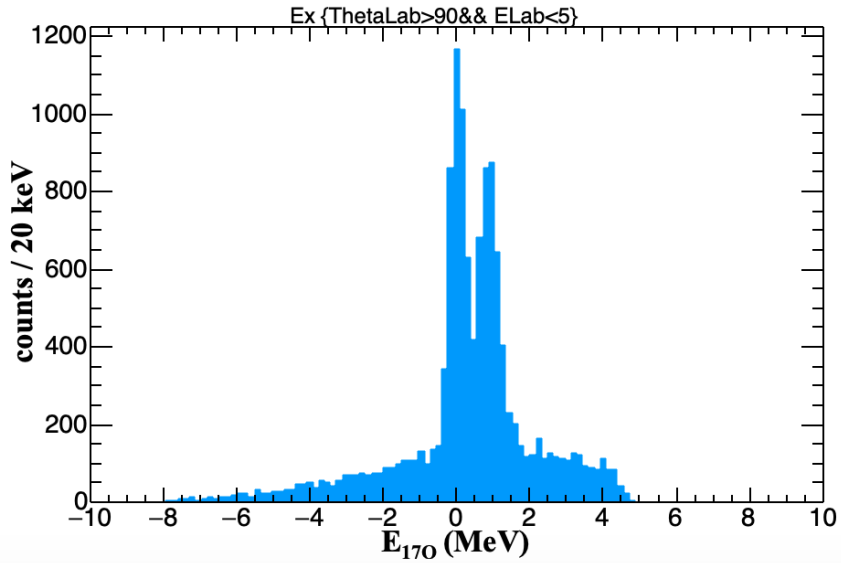

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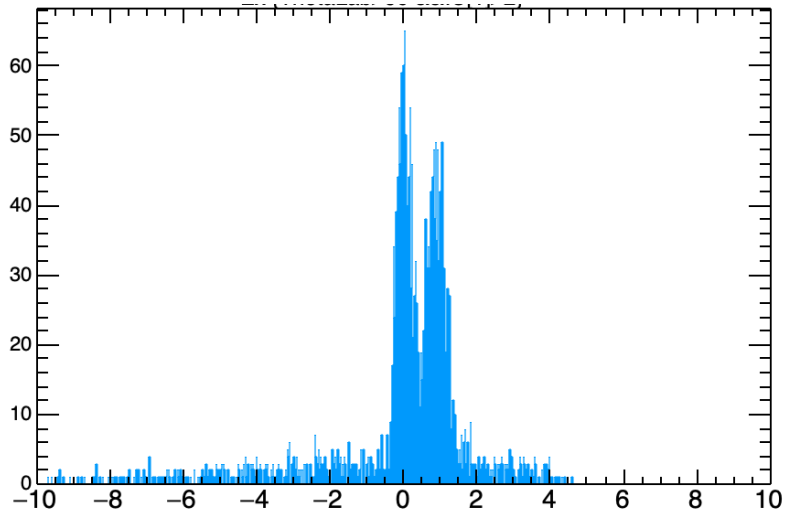
Condition on VAMOS IC



VAMOS-MUGAST relative efficiency : ~60%

- a lot of pile-up event
- large effect of straggling in the DC at the entrance of VAMOS

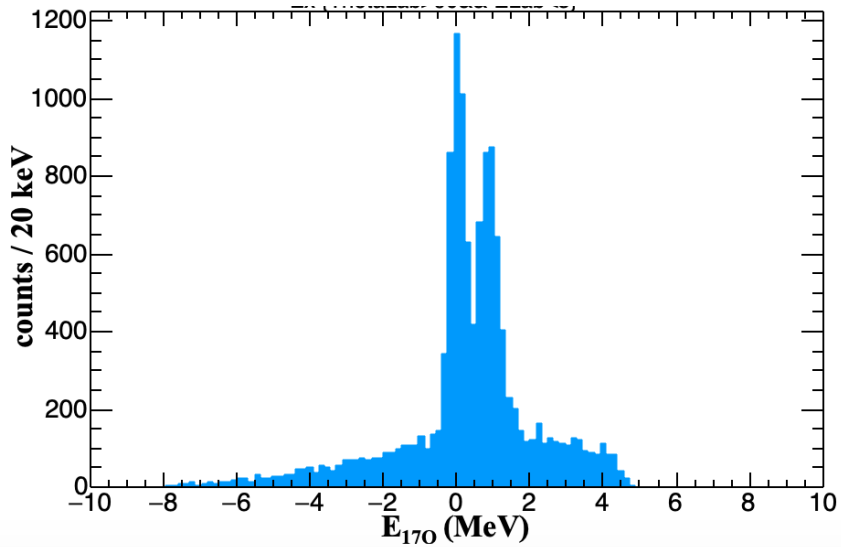
MUGAST commissioning : $^{16}O(d,p)^{17}O$ --> triple coincidences

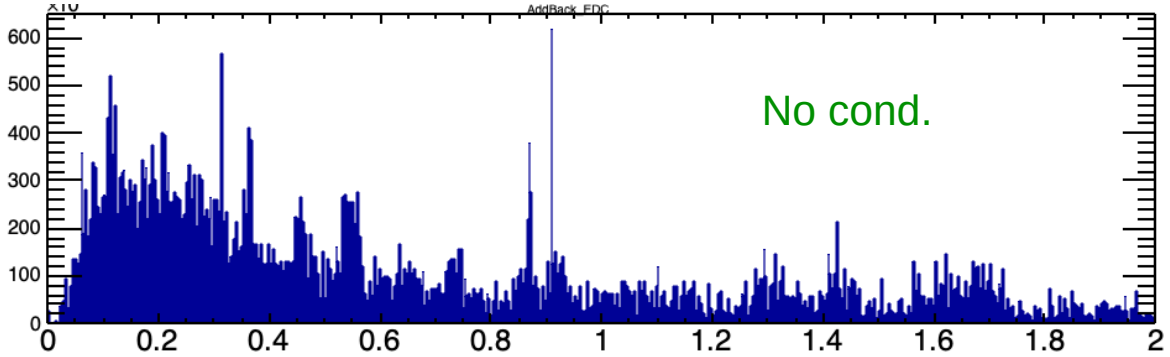
Relative efficiency MUGAST-AGATA:

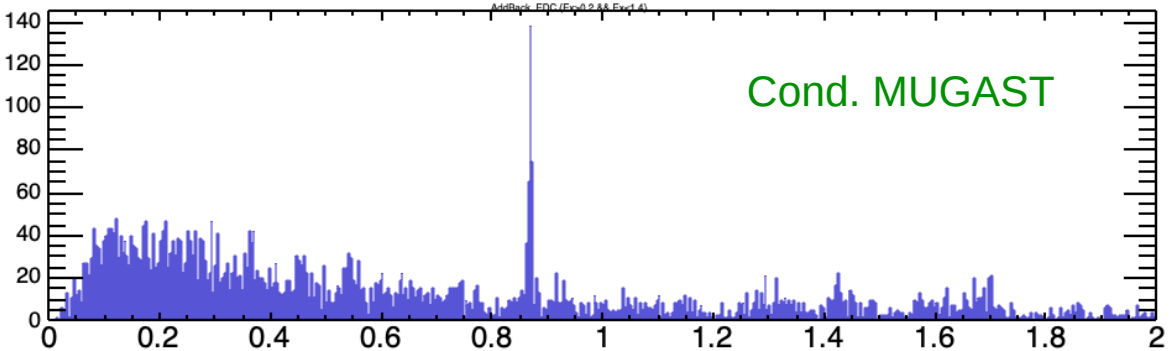
- before add-back : 5.5%
- after add-back : ~8%

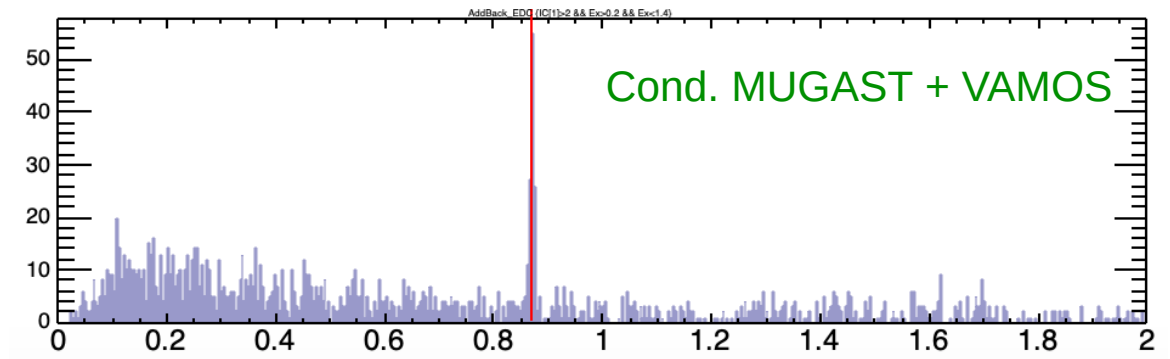
(d,p) reactions favorable :

- Protons in backward direction :)
- No identification needed
- Small background



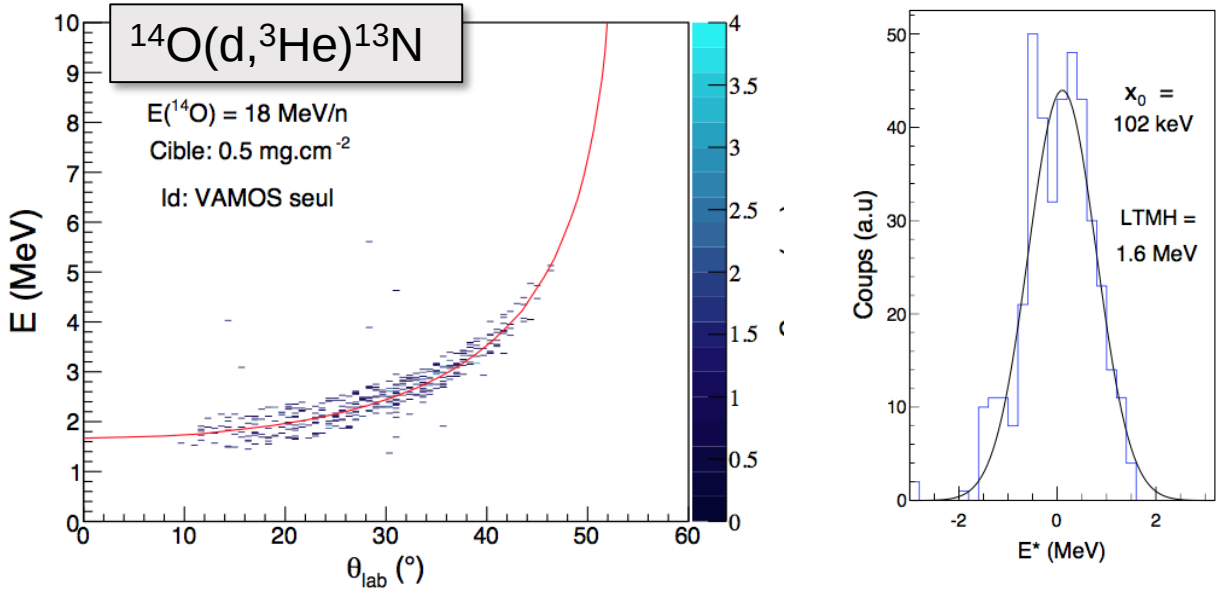






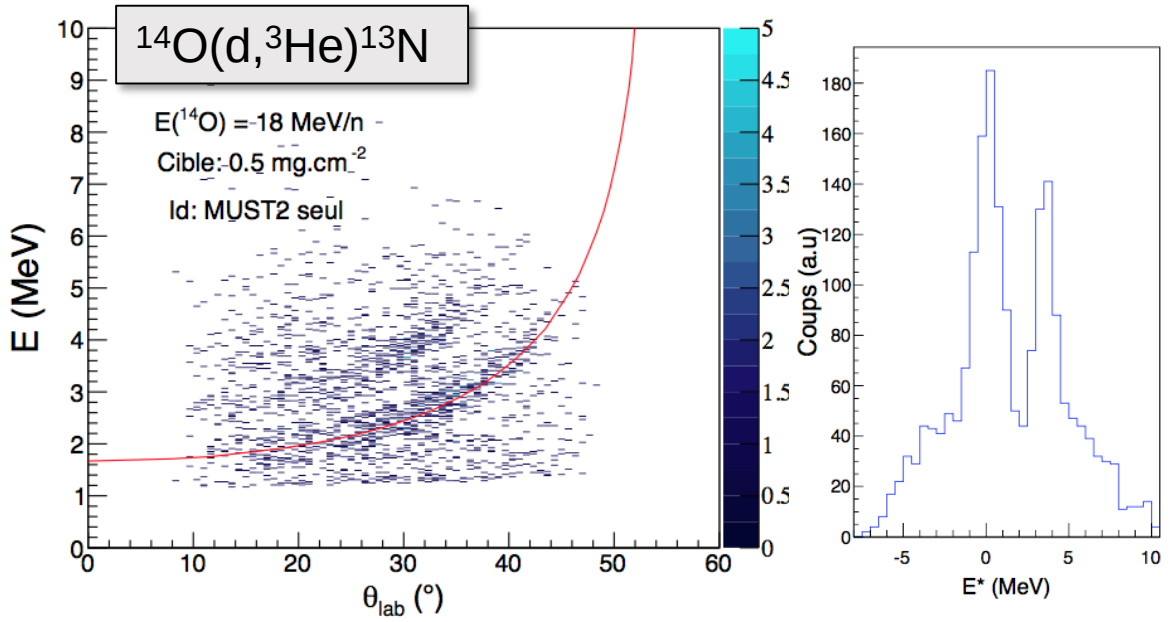
Other transfer reactions : difficulties with (d,t) & (d,^{3}He)

Background free measurement needed through exclusive identification of products



<-- With VAMOS identification of ^{13}N

With only MUST2 (identification of ^{3}He)



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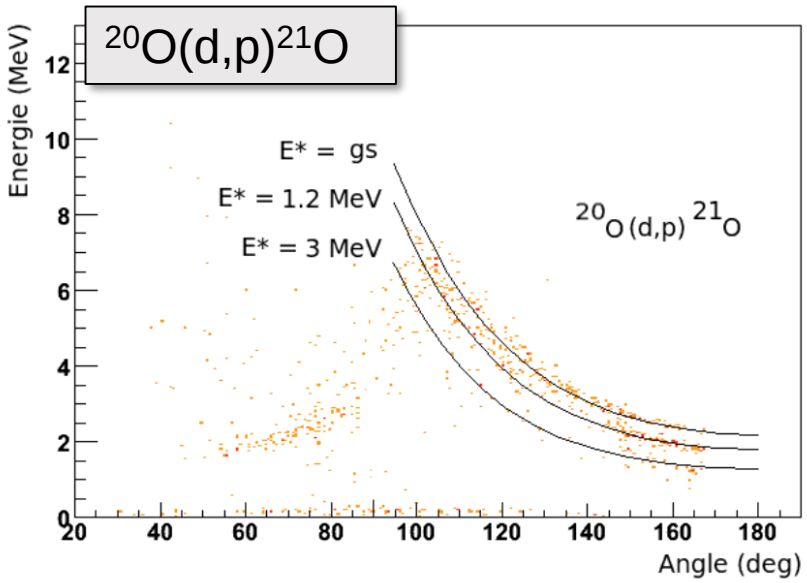
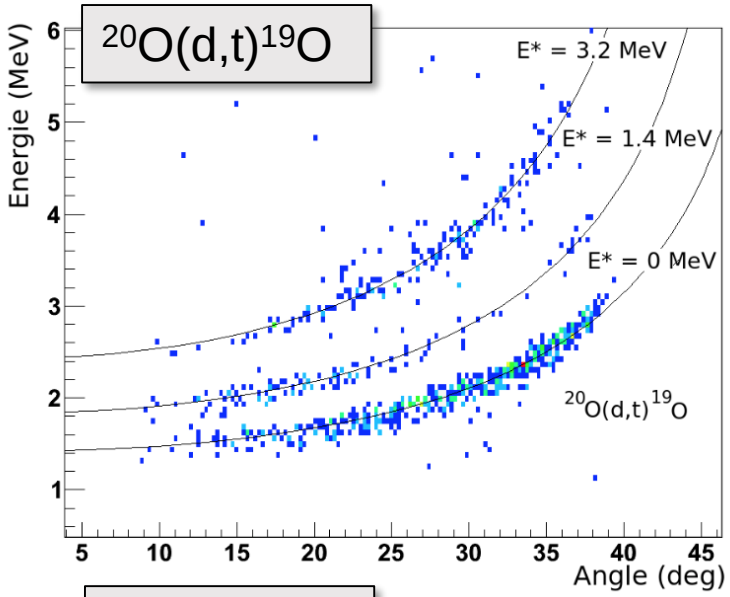
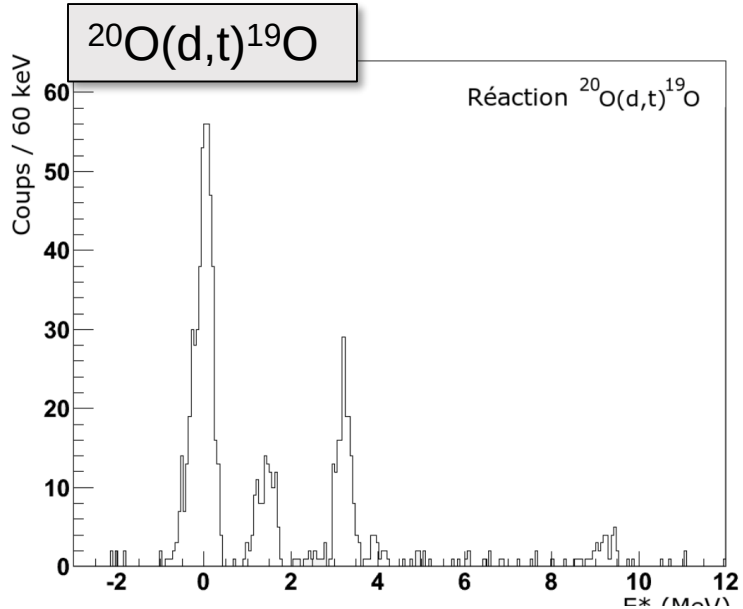
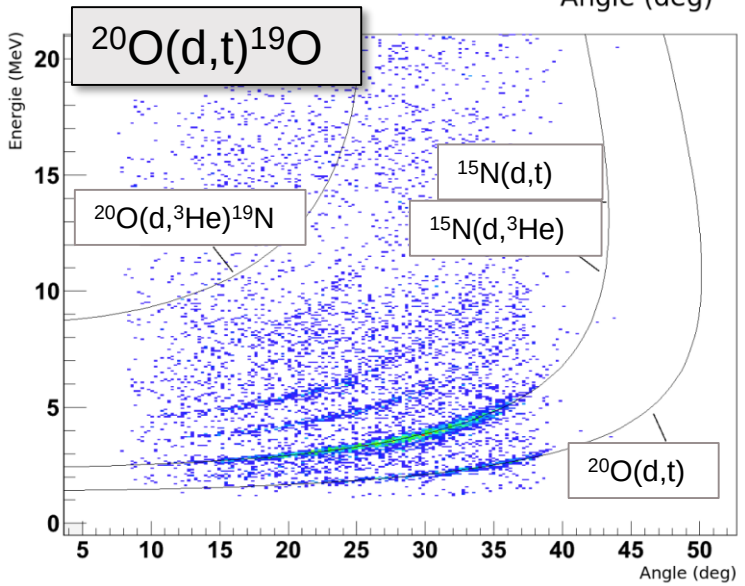
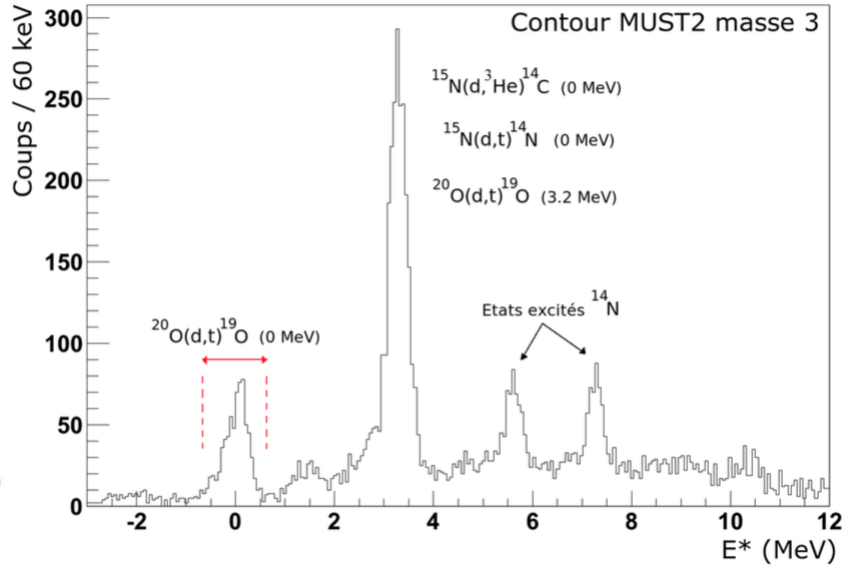






Without spectrometer -->





A. Ramus, PhD thesis

Beam contamination issue : the case of ^{56}Ni beam at Spiral1

1) Contamination from Co:

Possible solutions (under study):

→ Go to fully stripped $^{56}Ni^{28+}$ using a stripper foil after CIME

Primary beam	Target	^{56}Ni (12+) pps	^{56}Co(11+) pps
58Ni	12C	7.3E+04	1.6E+06
58Ni	Nb	4.0E+04	1.7E+06

Courtesy of F. Flavigny

Charged states from the beam : the case of ^{56}Ni beam at Spiral1

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2) Charges states in VAMOS after secondary target (preliminary)

Even if fully stripped $^{56}Ni^{28+}$ onto a CD_2 target at 12 MeV/nucleon:

Charge state	% 0.5 mg/cm^2	% 1 mg/cm^2	% 2 mg/cm^2
28+	17	16	15
27+	42	41	39
26+	31	32	34
25+	8	9	11

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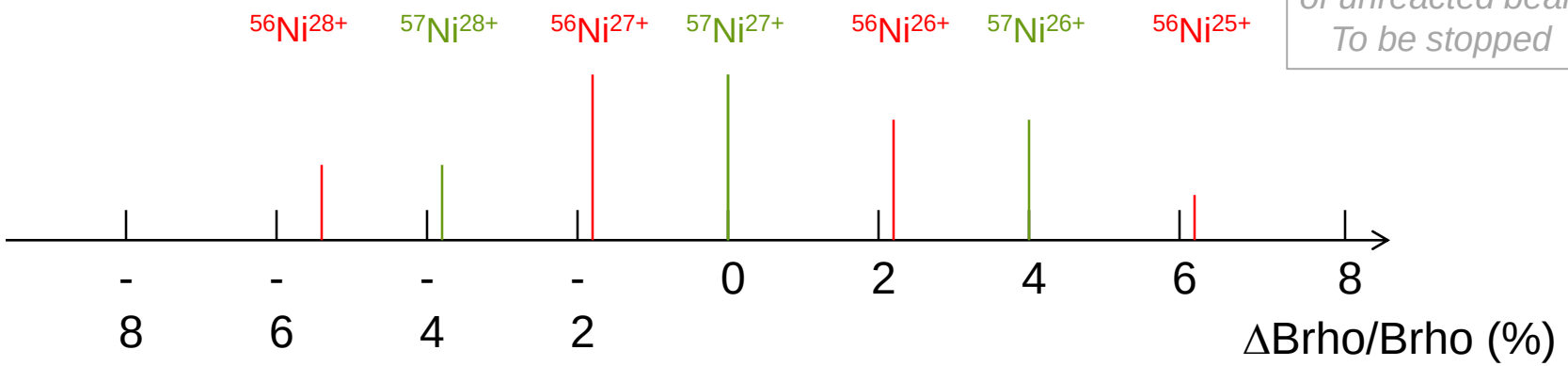
7.10^4 pps of unreacted beam To be stopped



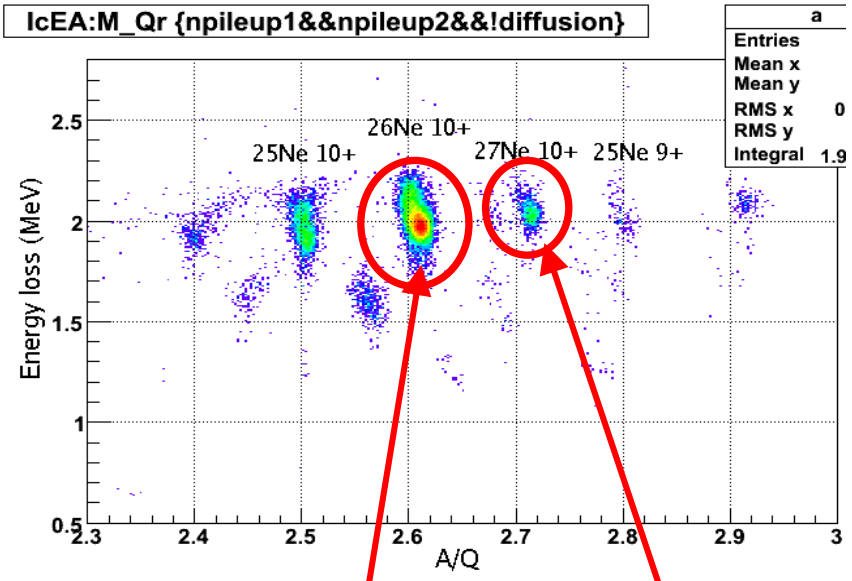
Courtesy of F. Flavigny

Other ideas : trifoil plastic instead of spectrometer

^{25}Na(d,p)^{26}Na @ 10 A MeV

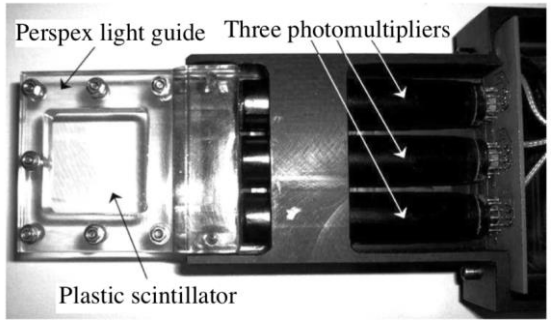
ZERO DEGREE = SPECTROMETER

full identification



^{26}Ne(d,p)^{27}Ne

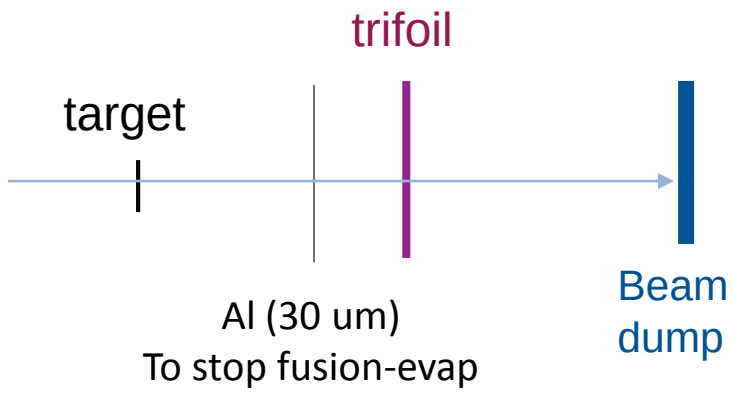
^{26}Ne(d,p)^{27}Ne→^{26}Ne+n



10um BC400 plastic

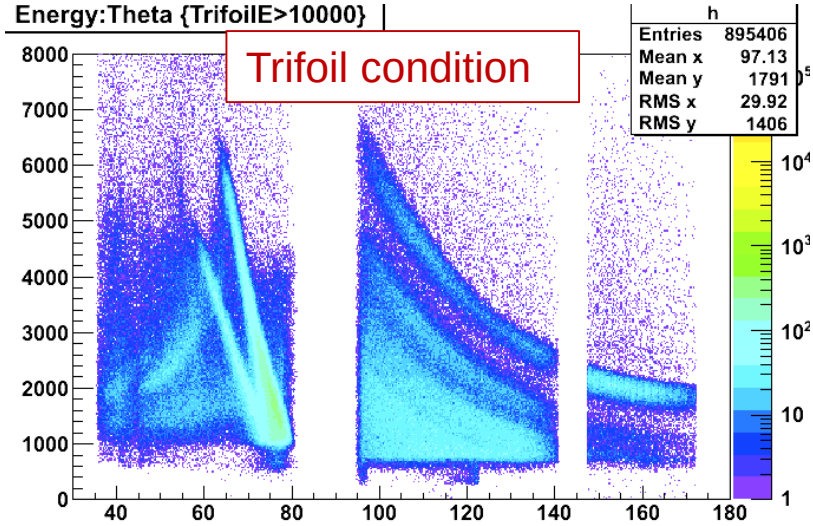
40 x40 mm^2

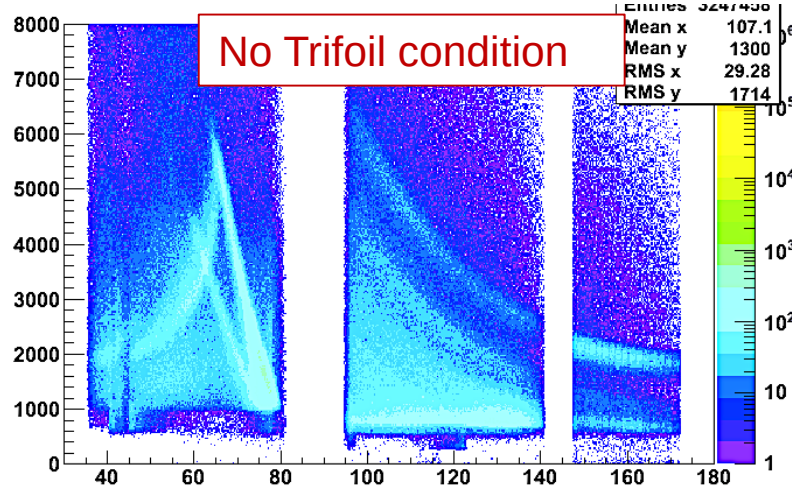
80% efficiency



^{25}Na(d,p)^{26}Na @ 5 A MeV TRIUMF

ZERO DEGREE = SCINTILLATOR : tagging





RESULTS from TIARA/MUST2 Nov2007

Adapted from W. Catford

RESULTS from SHARC Aug2009

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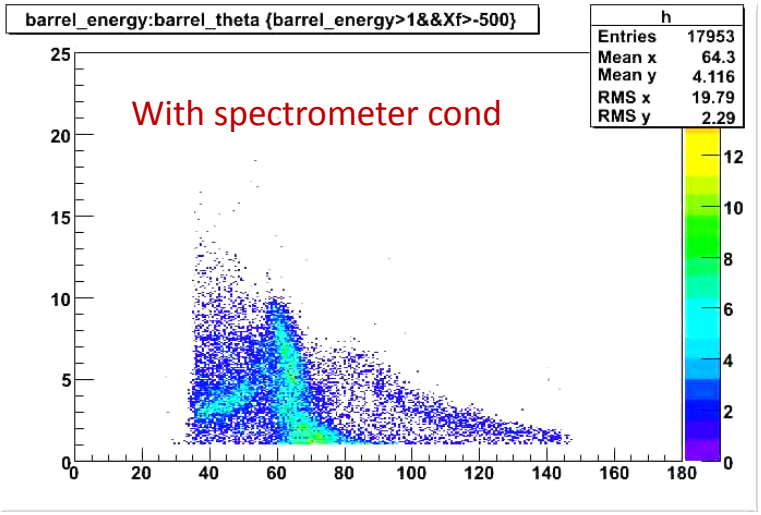
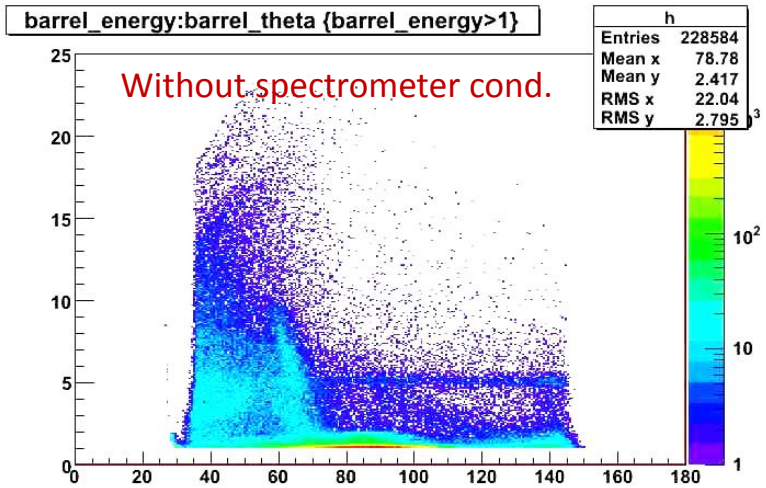
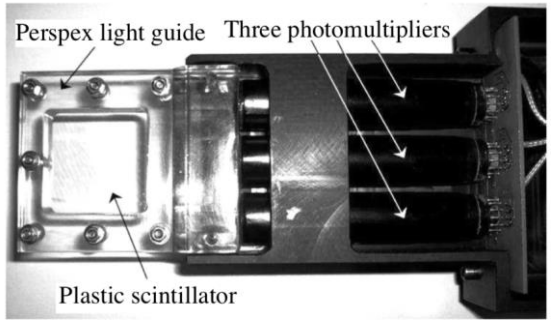
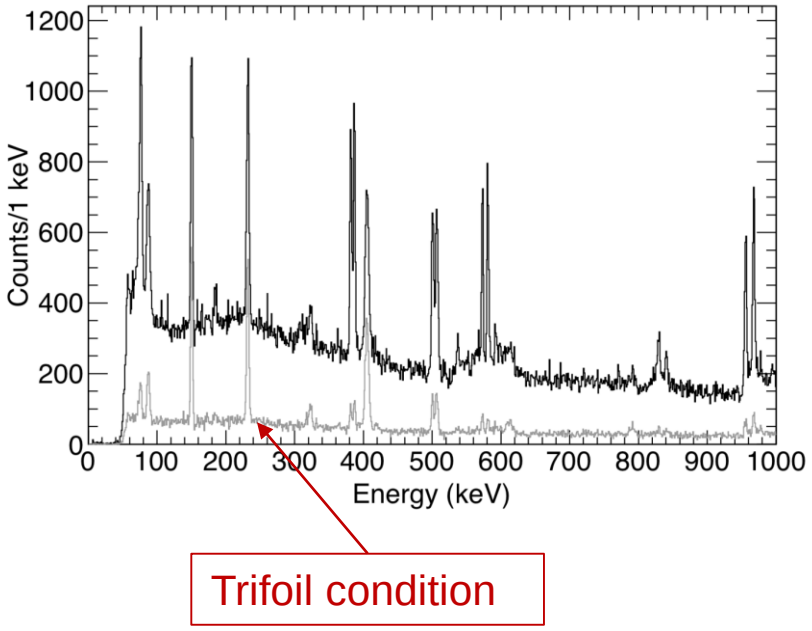






Gamma spectrum TIGRESS



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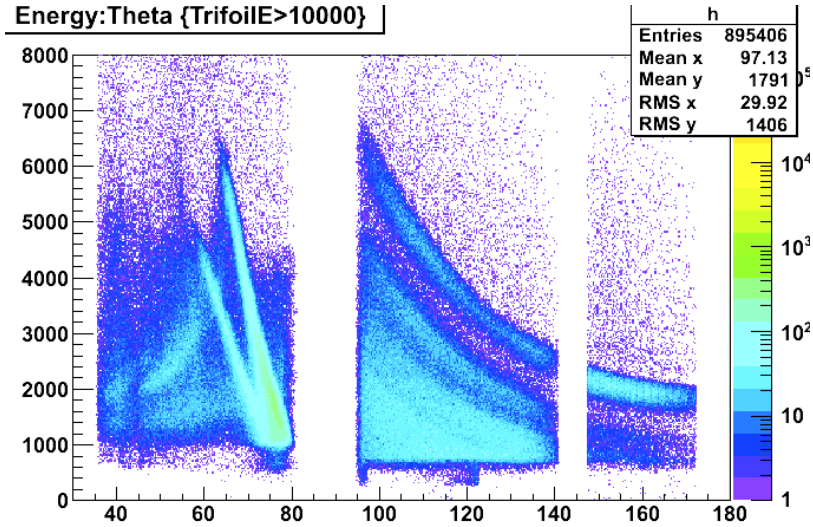

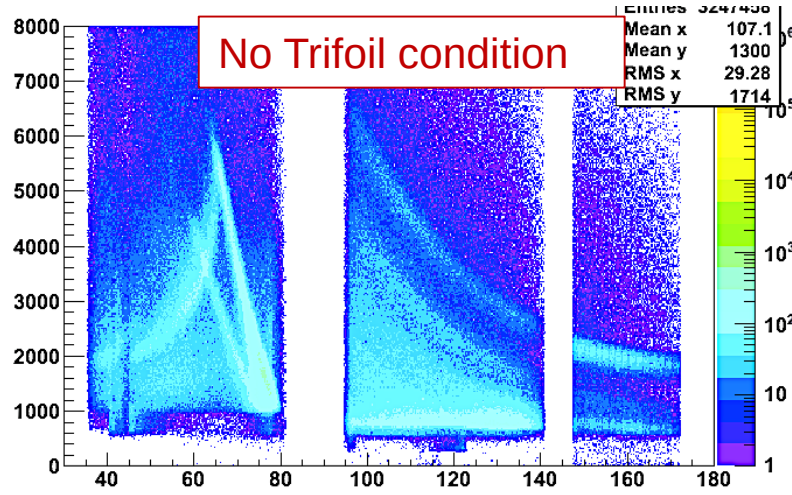

G.L. Wilson et al Journal of Physics: Conference Series ***381*** *(2012) 012097*

RESULTS from SHARC Aug2009

Characteristics of transfer reactions with light targets

- **Typical intensities:** > few 10^4/s up to 10^{6-7}pps. @ ISOLDE instantaneous rate 10^9 pps !!

- **Device at 0 degree -->Small scattering angles around 0°** --> beam stopping and beam spot size important !
  --> active finger(s) ? -->diamond detectors ? **--> straggling effects !**

- **Performances :**
  . Event-by-event PID: Physical separation of reaction products of interest
  - from the **beam / isobaric beam contaminants** and others : charge states / contaminants / straggling !
  - from fusion-evaporation reactions with target (CH_2, CD_2, X+^{3}H, X+^{4}He, X+^{16}O, …)

  . Large acceptance

  . Excellent **angular resolution** to allow kinematic reconstruction (and Doppler correction in AGATA case)

  . A/Z resolution :
  - $A/\Delta A > 240$ /. $Z/\Delta Z > 90$
  - ± a few mass and nuclear charge units should pass

  . Timing : useful for particle identification in some cases …
  @ISOLDE : slow extraction from EBIS usually required : which reference signal ?

- **Normalisation**
  - Beam composition (if not pure)
  - Integral measurement sufficient but beam tracking devices useful (BTD limited to 10^5pps)

Where can we found a compromise ?

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