IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

**PHENIICS**
**Doctoral School Days**

*LAL, Orsay*
*May 9th – 11th, 2016*

UNIVERSITÉ PARIS SUD
Comprendre le monde, construire l'avenir
université PARIS-SACLAY

cnrs
dépasser les frontières

# DEEP INELASTIC REACTIONS
## AT INTERMEDIATE ENERGIES ABOVE THE COULOMB BARRIER

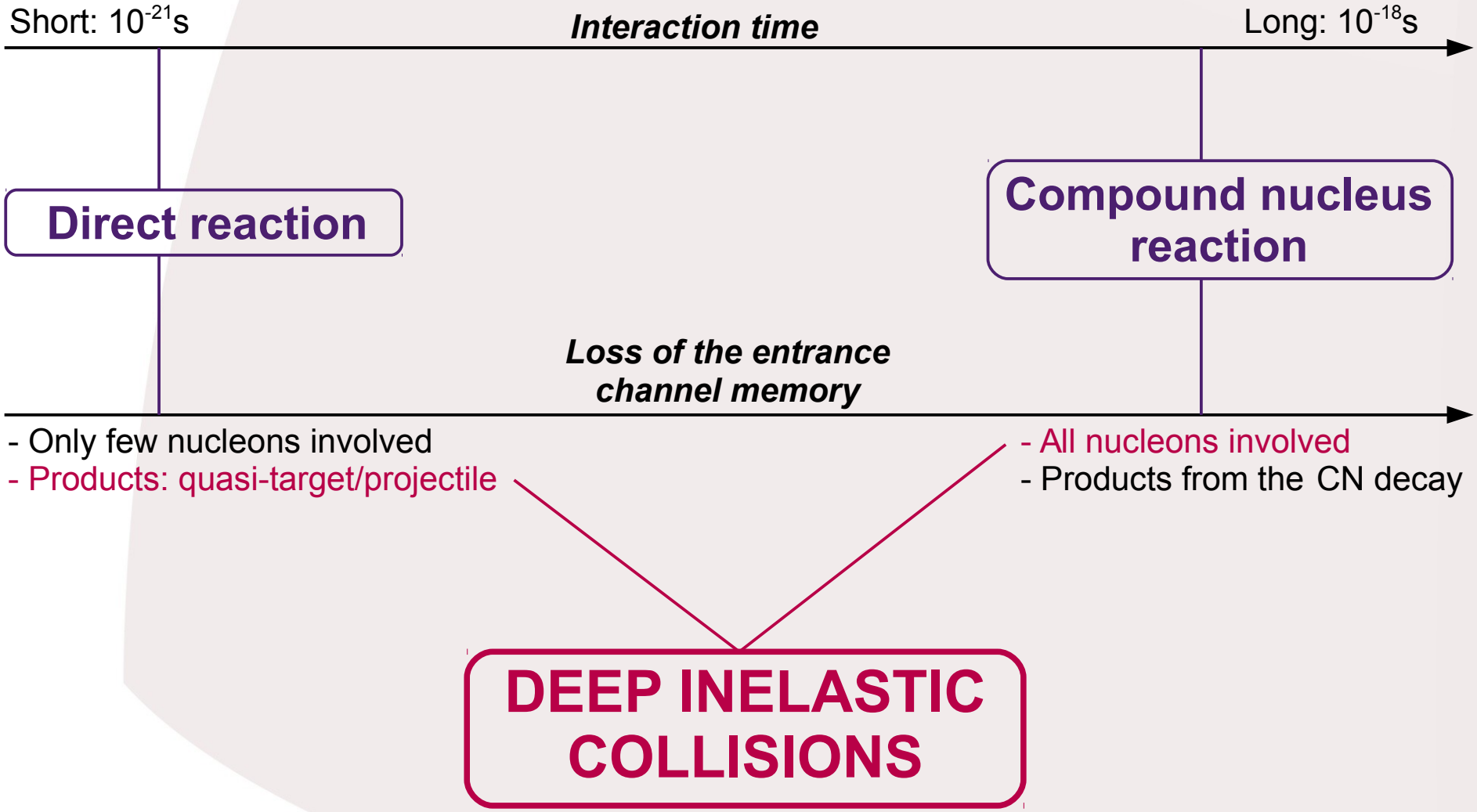
École Doctorale
PHENIICS
Doctoral School

Claire Portail
Iulian Stefan, Faiçal Azaiez, E589, E677 & T14-01 collaborations

# OUTLINE

- **Deep Inelastic Collisions mechanism**
  - Main features
  - From grazing angle to 0°
- **VAMOS & LISE experiments:**
  - Aim & setup
  - Preliminary results
- **Conclusion & Outlook**

# I.1 / DEEP INELASTIC COLLISIONS

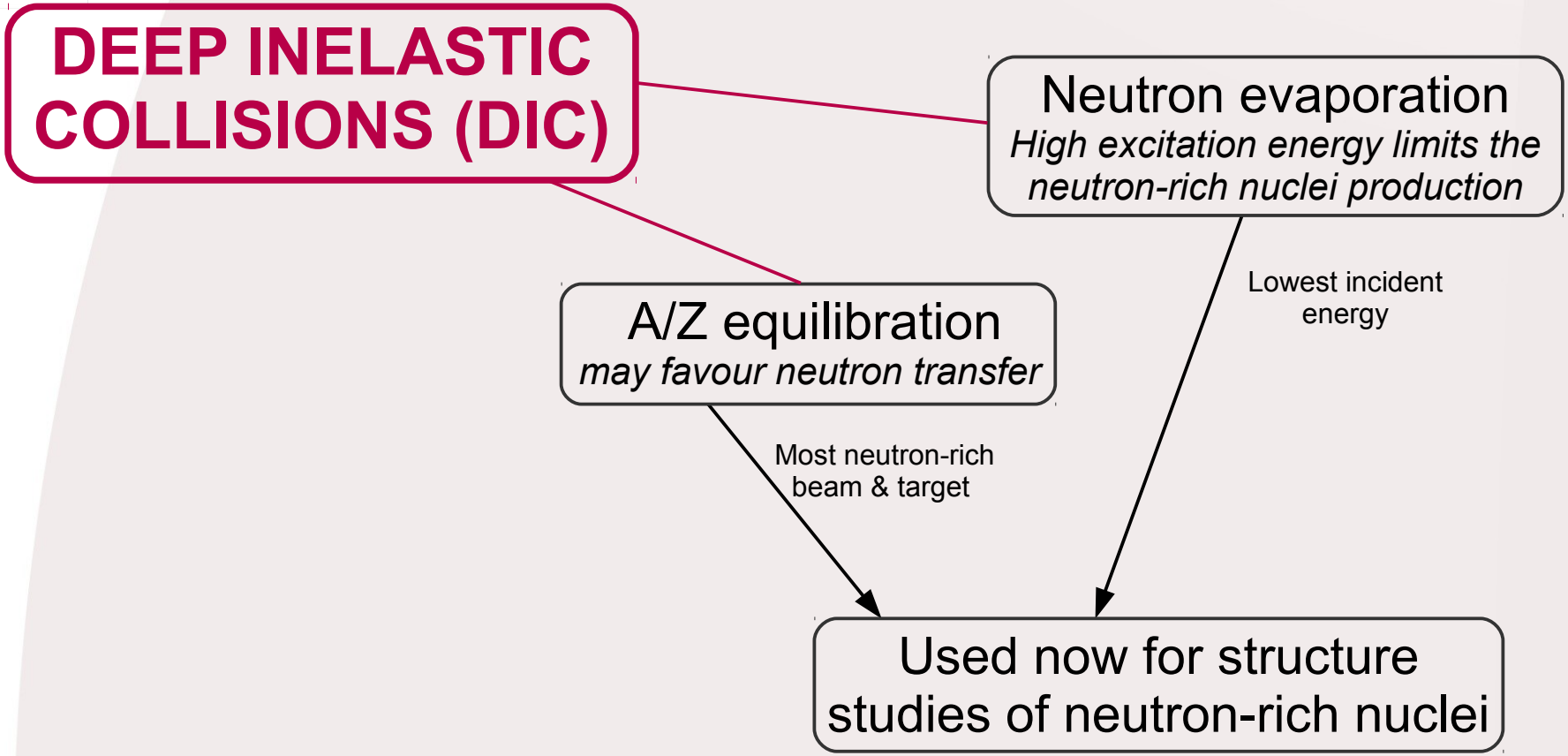


# DEEP INELASTIC COLLISIONS (DIC)

A/Z equilibration
*may favour neutron transfer*

Most neutron-rich
beam & target

Used now for structure studies of neutron-rich nuclei


DEEP INELASTIC COLLISIONS (DIC)
Neutron evaporation
High excitation energy limits the neutron-rich nuclei production
A/Z equilibration
may favour neutron transfer
Lowest incident energy
Most neutron-rich beam & target
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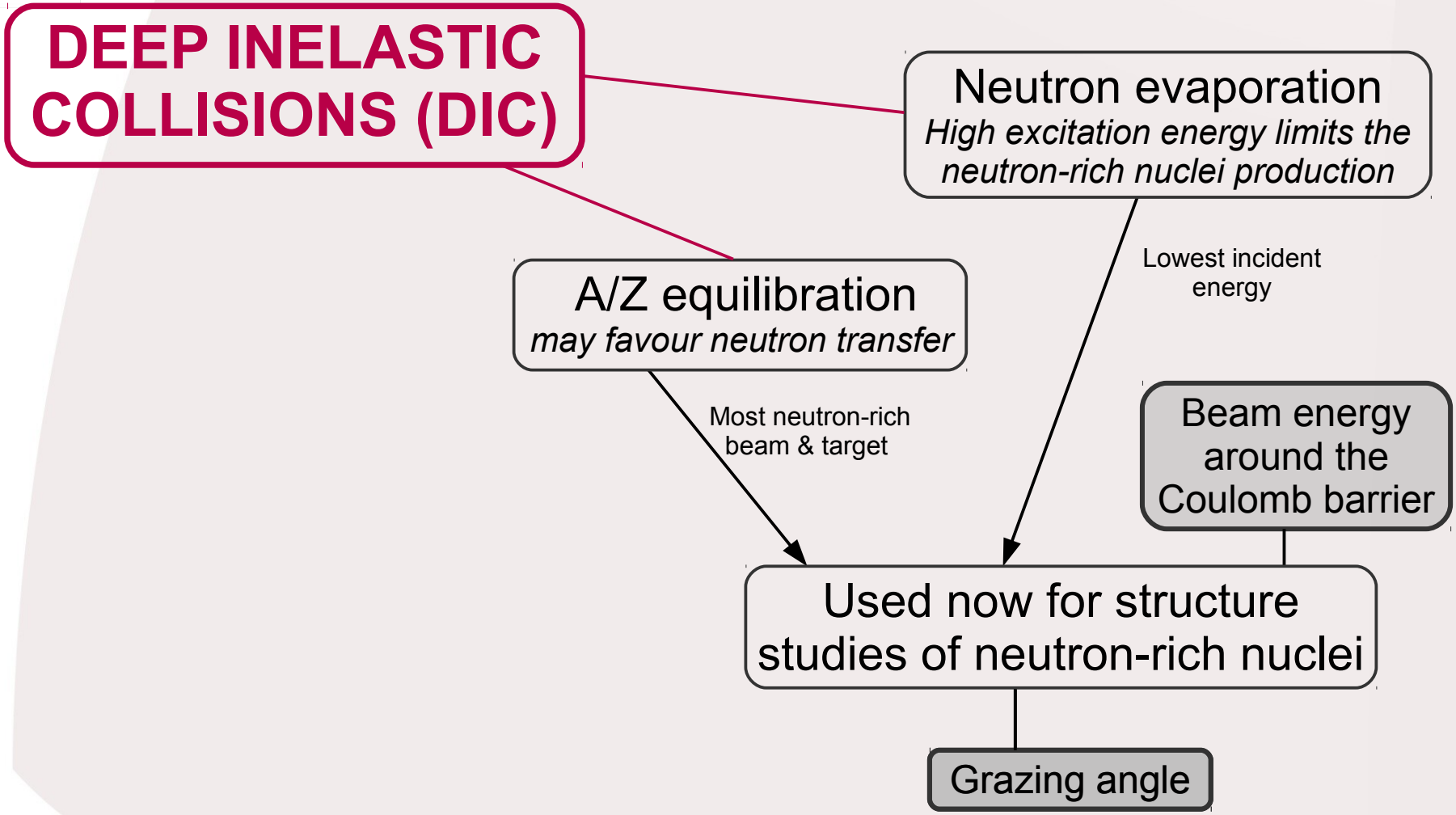
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Neutron evaporation
High excitation energy limits the neutron-rich nuclei production
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Most neutron-rich beam & target
Beam energy around the Coulomb barrier
Used now for structure studies of neutron-rich nuclei
Grazing angle

# DEEP INELASTIC COLLISIONS (DIC)

Neutron evaporation
*High excitation energy limits the neutron-rich nuclei production*

Lowest incident energy

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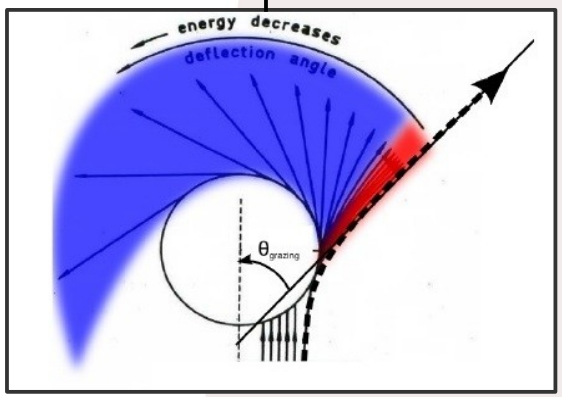
Most neutron-rich beam & target

Orbiting phenomenon, large angular distribution




Beam energy around the Coulomb barrier

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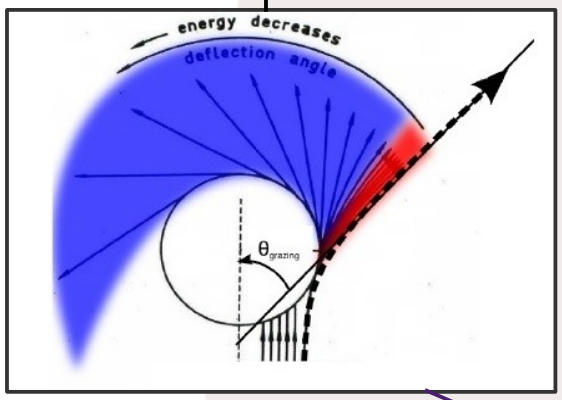



Beam energy around the Coulomb barrier

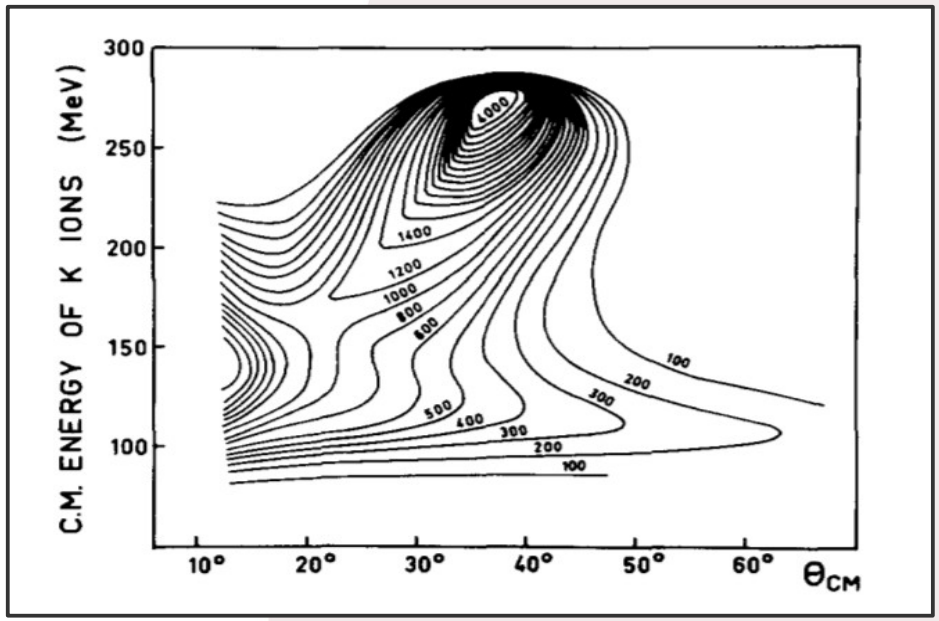
Used now for structure studies of neutron-rich nuclei

Grazing angle

**How evolves the DIC mechanism from grazing angle to 0° ?**

# I.3 / LOOKING AT 0°

Beam energy around the Coulomb barrier = Angular distribution mainly peaked around grazing angle




J. Wilczynski, PLB 47 (1973) 484

Increase the cross-section around 0°

↓

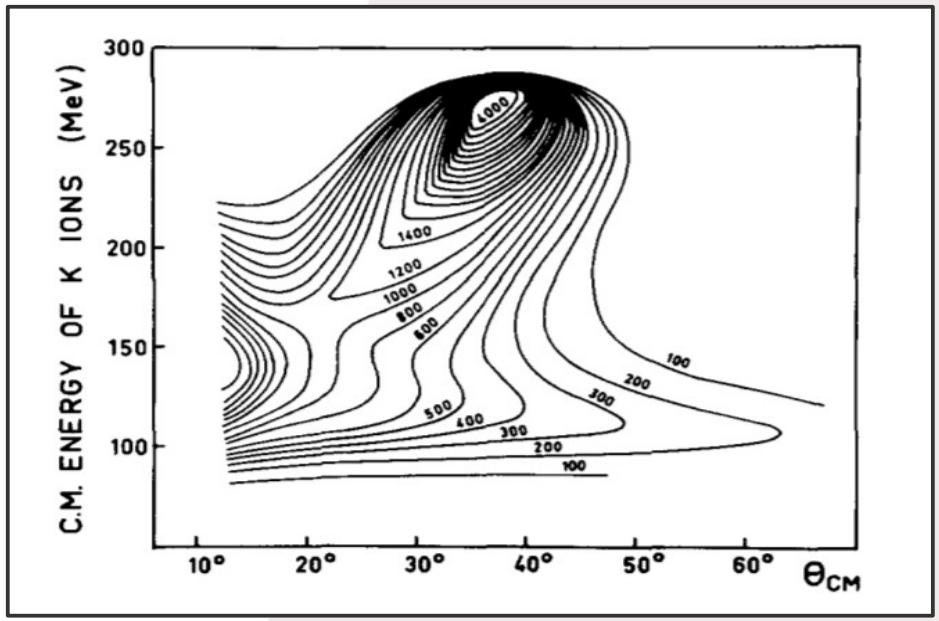
Increase the incident energy

↓

Working above the Coulomb barrier

# I.3 / LOOKING AT 0°

Beam energy around the Coulomb barrier = Angular distribution mainly peaked around grazing angle




J. Wilczynski, PLB 47 (1973) 484

Increase the cross-section around 0°

↓

Increase the incident energy

↓

Working above the Coulomb barrier

Neutron evaporation ?

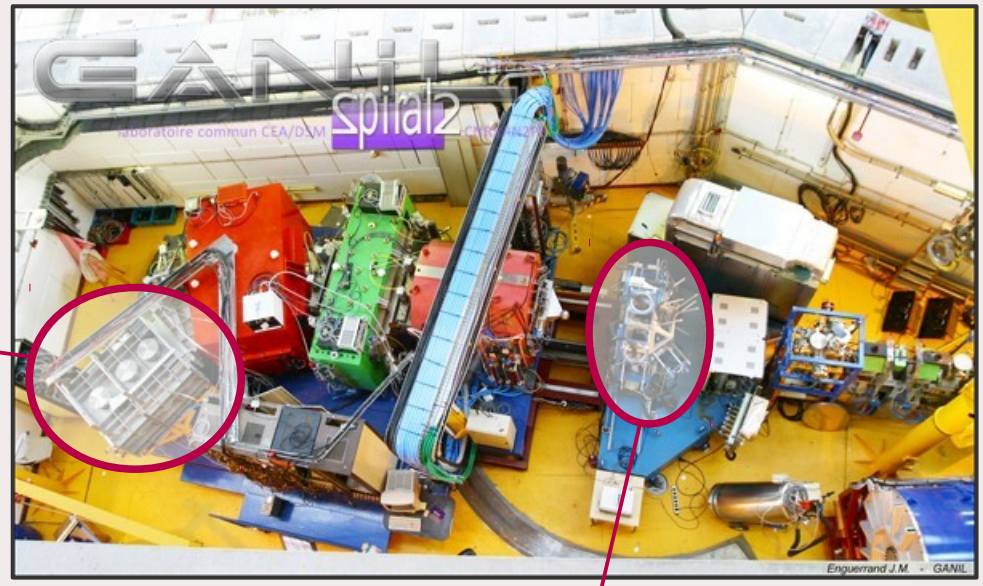
**How exotic are the nuclei produced at 0° ?**

# VAMOS EXPERIMENT

E589 – April 2010

Beam: $^{48}$Ca @ 10 A MeV

Target: $^{238}$U @ 170 µg/cm$^2$




**Particles detection:**

VAMOS focal plane

- 2 Drift chambers
- 3 Ionisation chambers
- 1 Silicon wall (21 Si)

**VAMOS angles: 30°, 15° & 0°**

**γ-rays detection:**

7 EXOGAM clovers

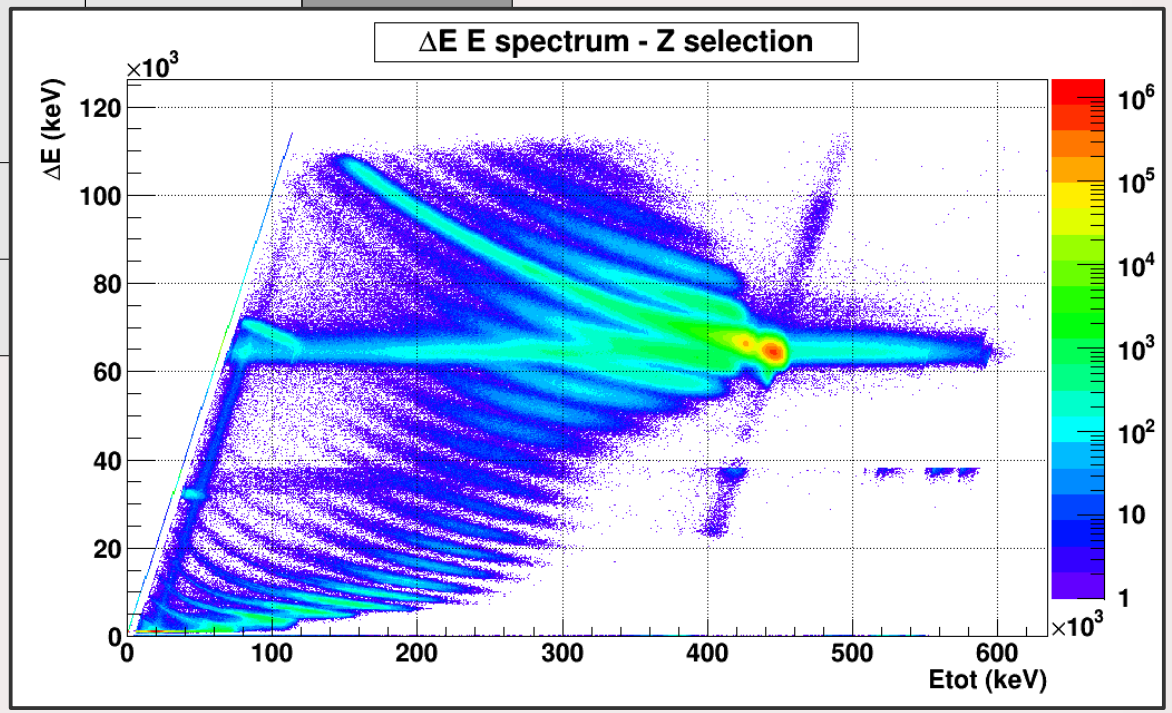
**Study the DIC mechanism towards 0°**

# II.2 / VAMOS RECONSTRUCTION

| Detector | Measure | → | ID |
|---|---|---|---|
| Ionis. Chamb. | ΔE | | |
| Si Wall | $E_{res}$ | | |
| | ToF | | |
| Drift Chamb. | $X_f$, $Y_f$, $\theta_f$,$\varphi_f$ | | |

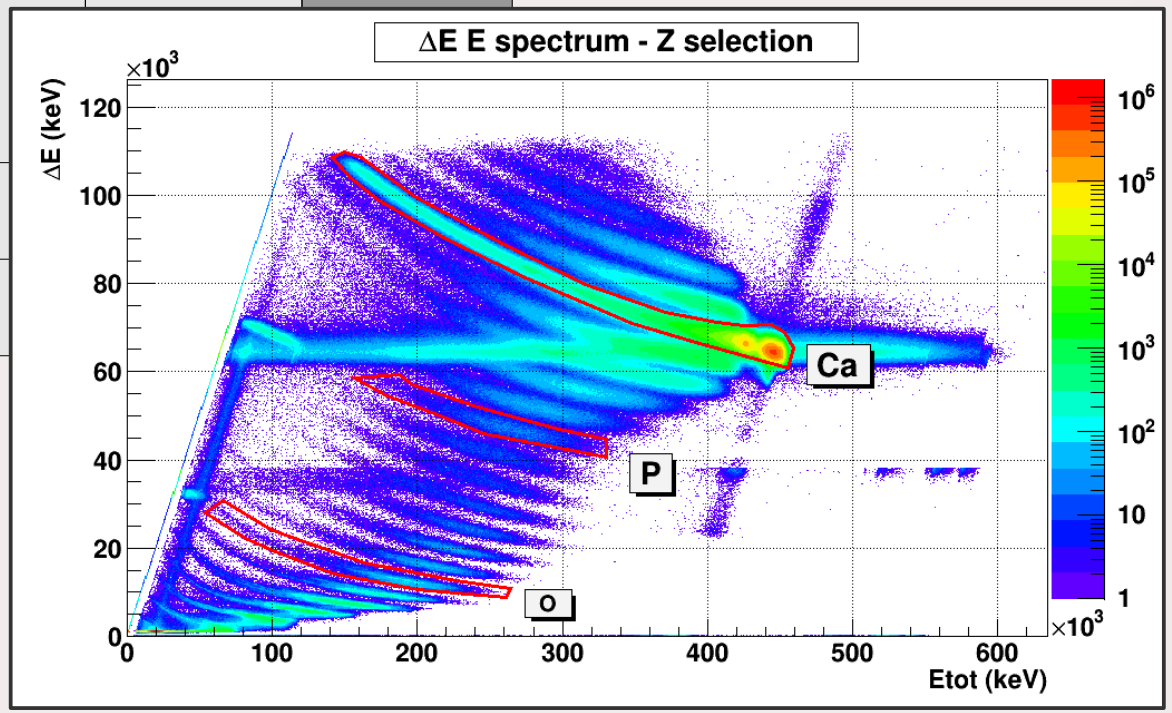
# II.2 / VAMOS RECONSTRUCTION

| Detector | Measure | → | ID |
|---|---|---|---|
| Ionis. Chamb. | ΔE | E | E |
| Si Wall | Eres | | |
| | ToF | | |
| Drift Chamb. | $X_f$, $Y_f$, $\theta_f$,$\varphi_f$ | | |



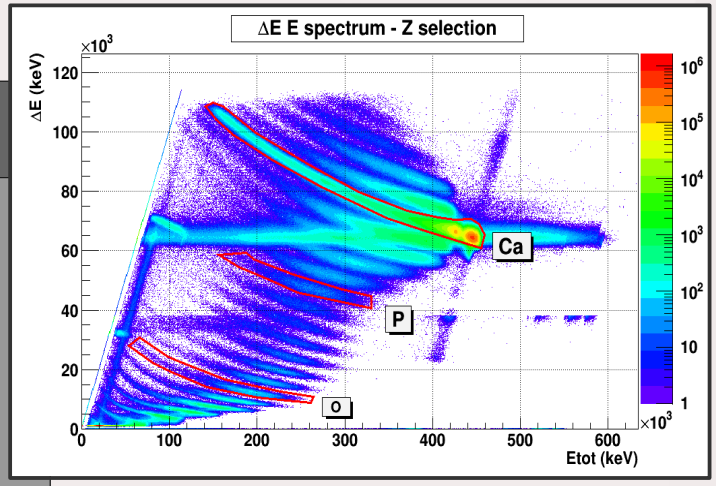
# II.2 / VAMOS RECONSTRUCTION

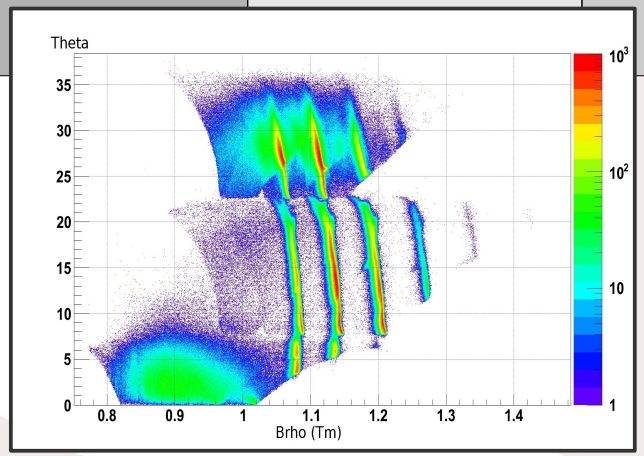
| Detector | Measure | → | ID |
|---|---|---|---|
| Ionis. Chamb. | ΔE | Z | Z |
| Si Wall | Eres | E | E |
| | ToF | | |
| Drift Chamb. | $X_f$, $Y_f$, $\theta_f$,$\varphi_f$ | | |



# II.2 / VAMOS RECONSTRUCTION

| Detector | Measure | → | ID |
|---|---|---|---|
| Ionis. Chamb. | ΔE | Z | Z |
| Si Wall | Eres | E | E |
| | ToF | | |
| Drift Chamb. | Xf, Yf, θf,φf | D | θi |
| | | Bρ | φi |
| | | θi, φi | |

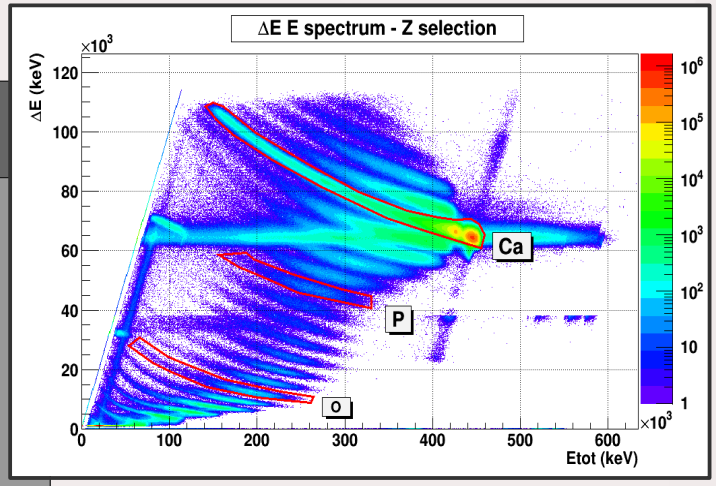


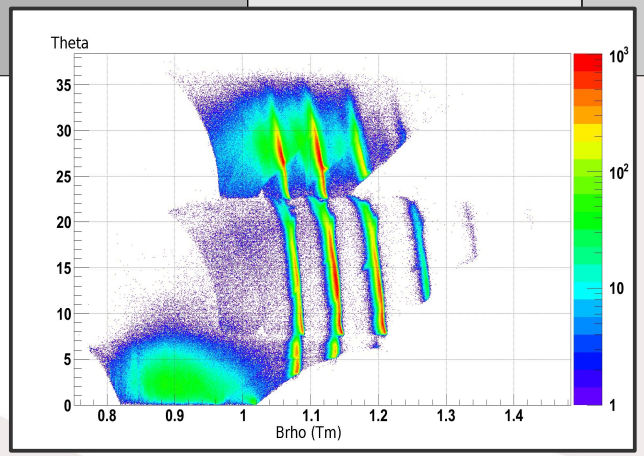




Reconstructed parameters

# II.2 / VAMOS RECONSTRUCTION

| Detector | Measure | → | ID |
|---|---|---|---|
| Ionis. Chamb. | ΔE | Z | Z |
| Si Wall | Eres | E | E |
| | ToF | M | M |
| Drift Chamb. | Xf, Yf, θf,φf | V | |
| | | D | θi |
| | | Bρ | φi |
| | | θi, φi | |

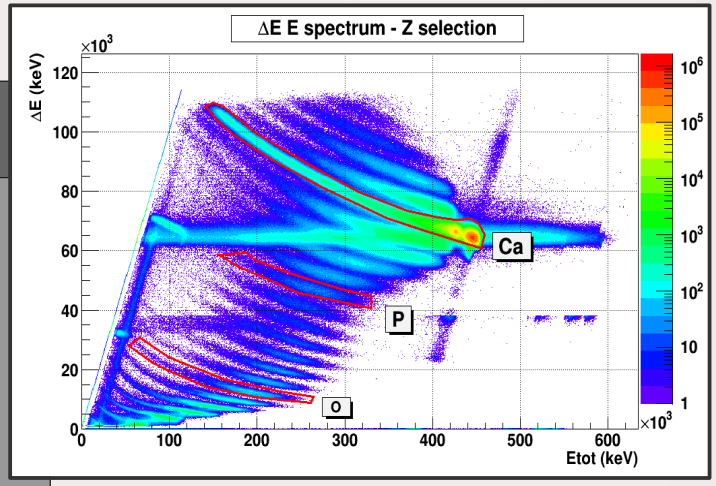


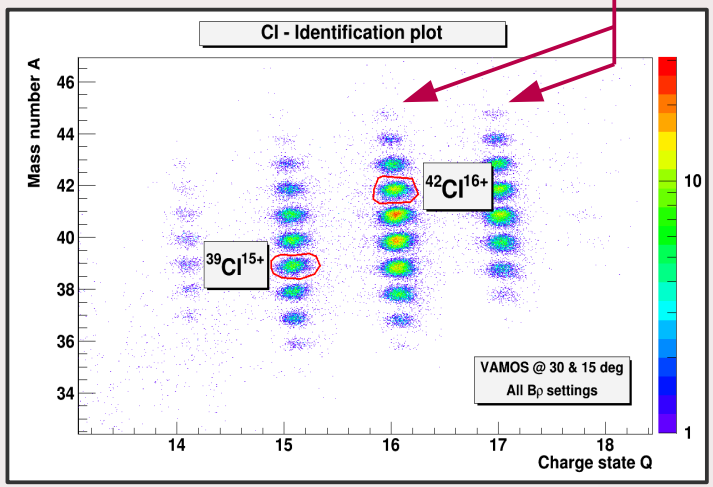

Reconstructed parameters

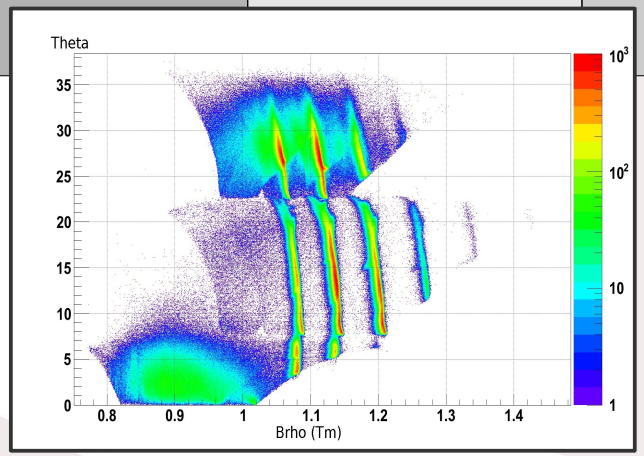
# II.2 / VAMOS RECONSTRUCTION

| Detector | Measure | → | | ID |
|---|---|---|---|---|
| Ionis. Chamb. | ΔE | E | Z | Z |
| Si Wall | Eres | | M | E |
| | ToF | V | | M |
| Drift Chamb. | Xf, Yf, θf,φf | D | M/Q | Q |
| | | Bρ | | θi |
| | | θi, φi | | φi |




$^{45}$Cl (N/Z = 1.65)

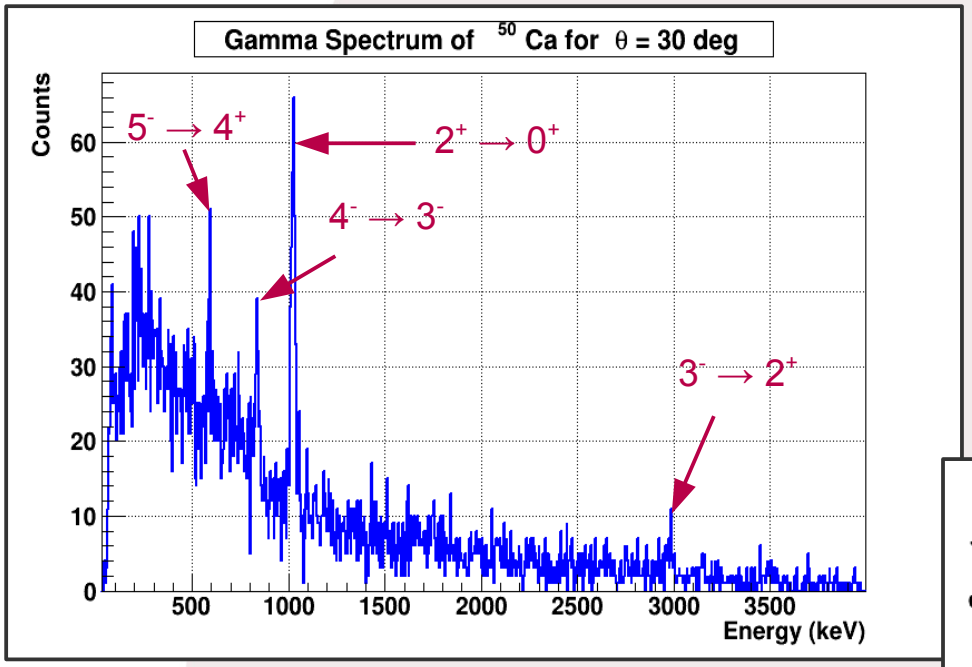


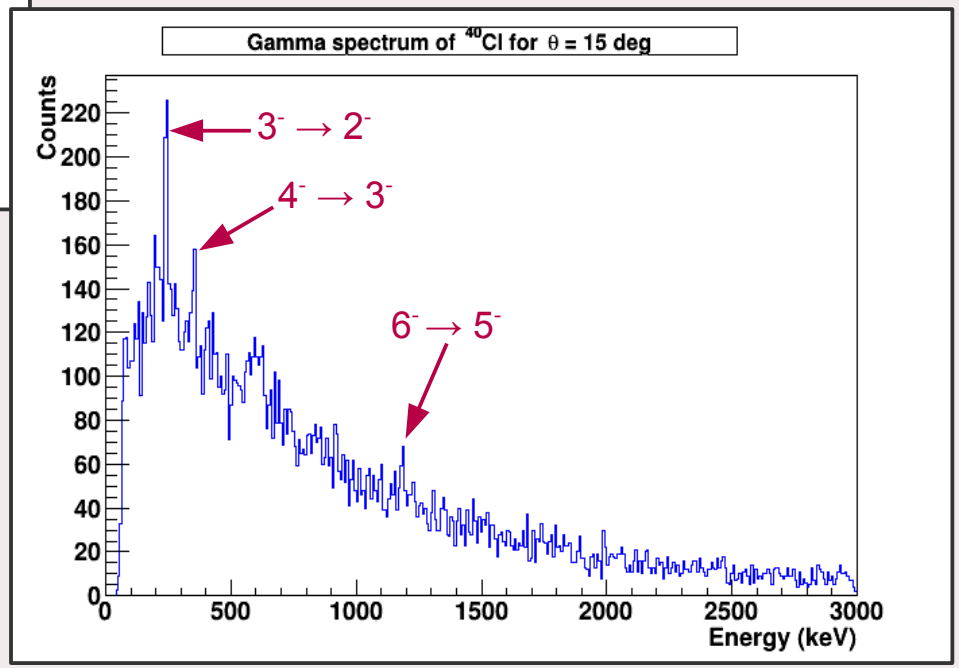




$$B\rho = \frac{MV}{Q}$$

Reconstructed parameters

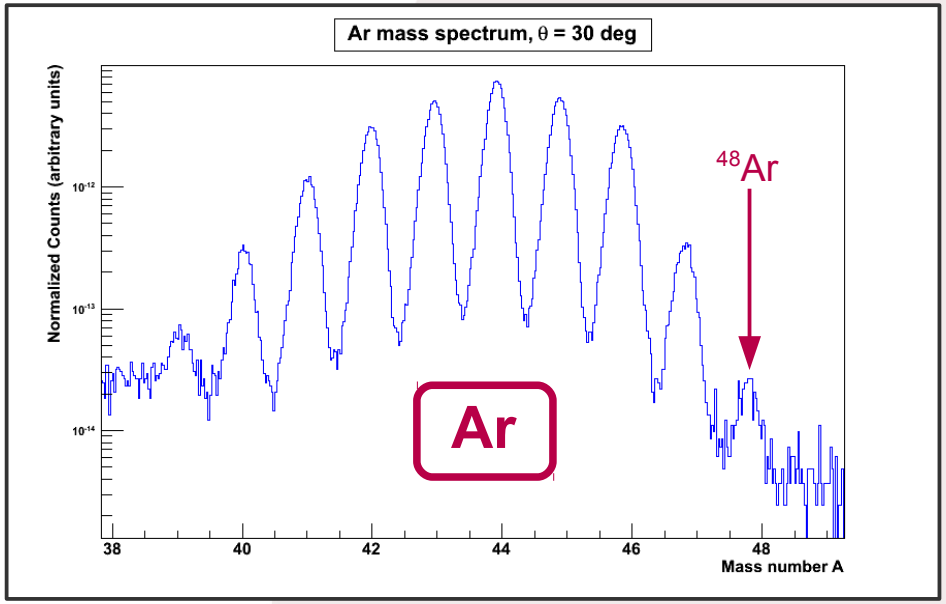
# II.2 / VAMOS RECONSTRUCTION




**γ-spectrum to cross-check the identification**

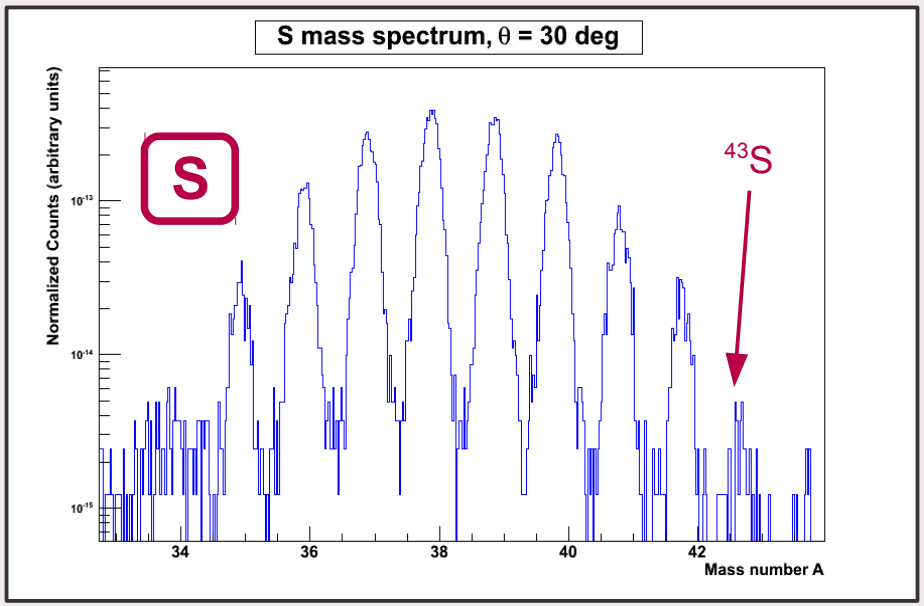
# II.3 / MASS SPECTRA




*θ = 30°*
*Bρ = 1.05, 1.12 & 1.19 Tm*

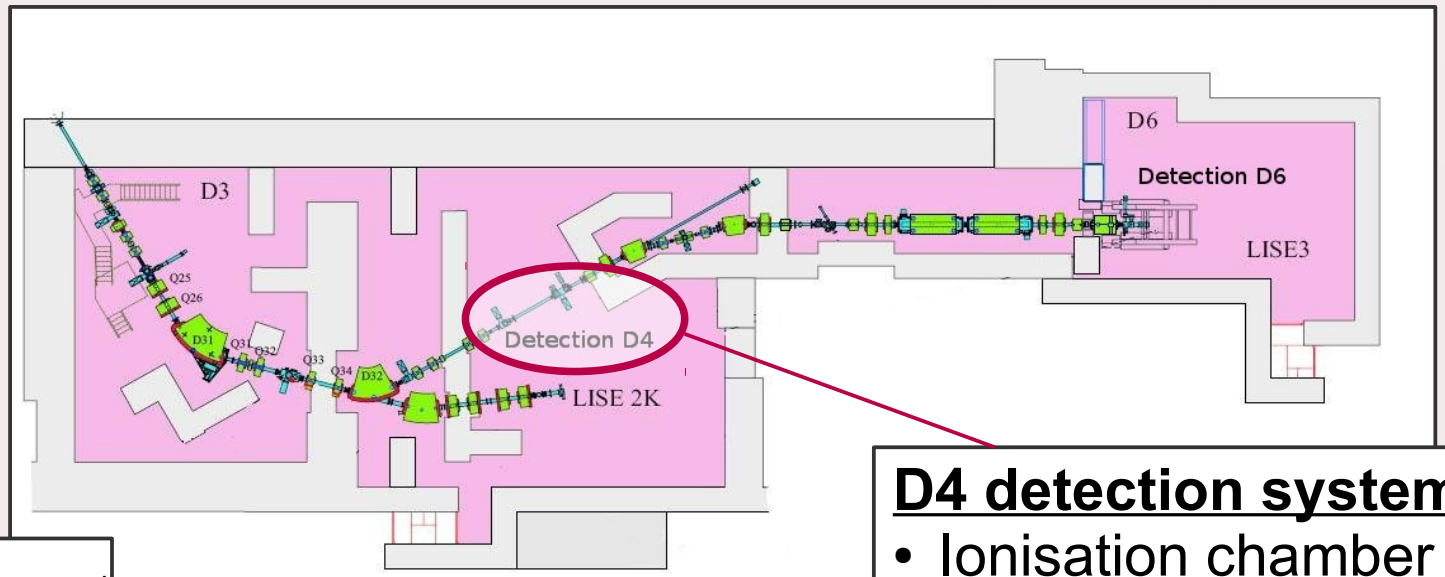
**Produced at 30°:**
**$^{48}$Ar (N/Z = 1.67)**
**$^{43}$S (N/Z = 1.69)**

Acceptance of the spectrometer remains to be taken into account for cross-sections

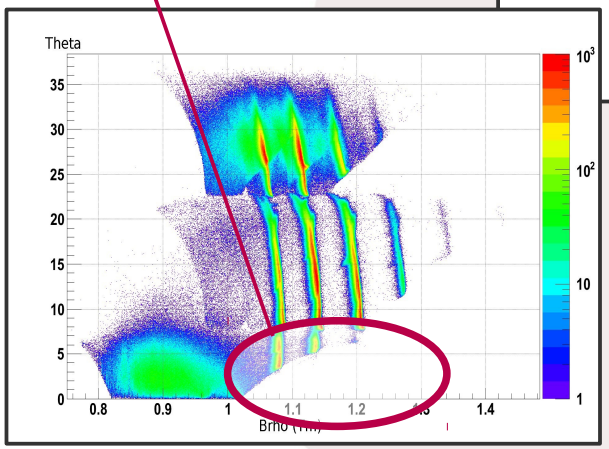


# LISE EXPERIMENT

E677 / T14-01 – May / June 2015




Limited with VAMOS




**D4 detection system:**

- Ionisation chamber
- ΔE Si (37 µm)
  E Si (300 µm)

Beams:

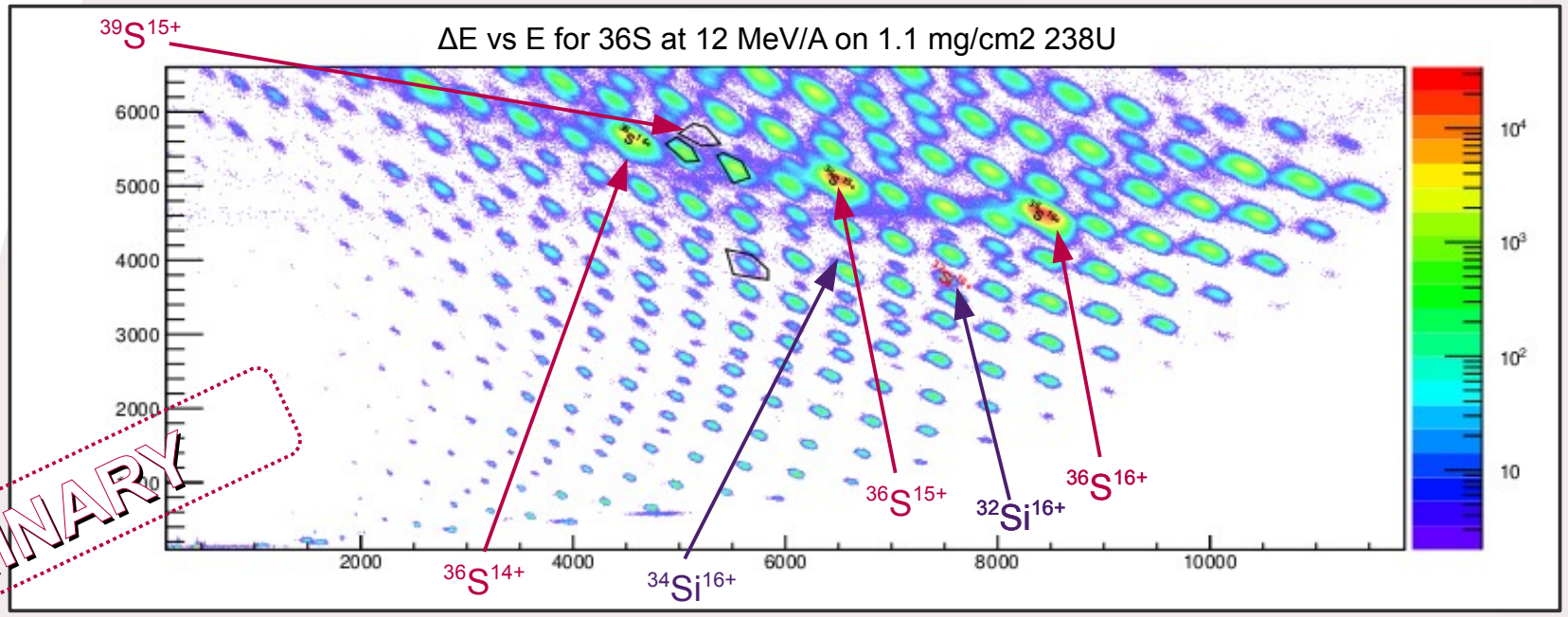
- $^{36}S$ @ 12 A MeV
- $^{18}O$ @ 8.5 A MeV

Targets:

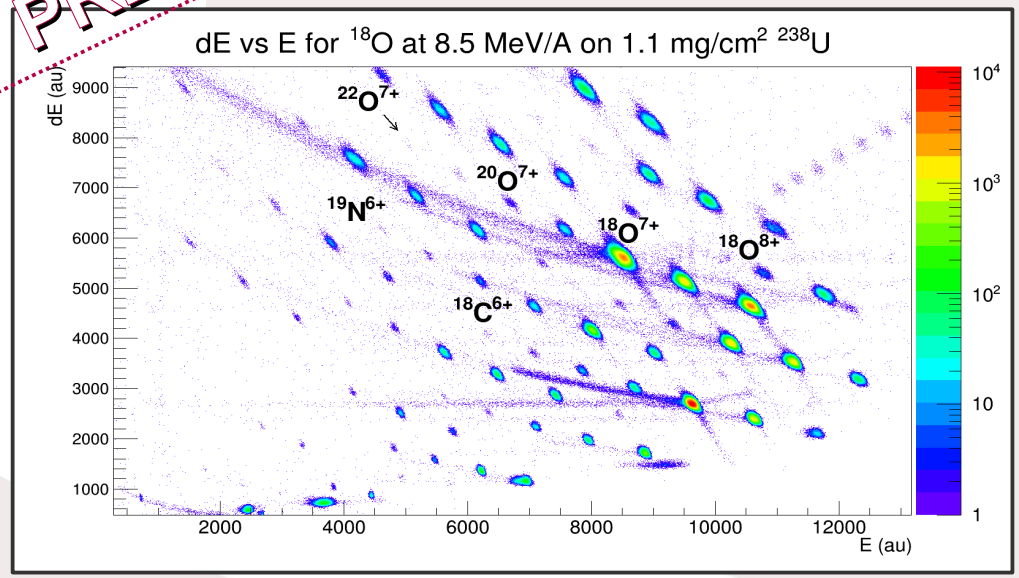
- $^{238}U$ @ 1.1 mg/cm²
- $^{12}C$ @ 1 mg/cm²

**Study the DIC mechanism at 0°**

# III.2 / PRODUCTION @ LISE




PRELIMINARY




Identification matrices obtained with the $^{36}$S and the $^{18}$O beams

**Up to 4 neutrons added**

# CONCLUSION & OUTLOOK

- **VAMOS experiment:**
  - Angular coverage between 7° and 35°
  - Gamma decay recorded
  - ***Acceptance remains to be taken into account***

- **LISE experiment:**
  - Preliminary analysis: up to 4 neutrons added
  - ***Analysis is underway***

**THANK YOU !**