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Colloque GANIL
28/09/2023

Study of Proton and Neutron excitations along Silicon Isotopes between N=20 and N=28

~~Tandem~~ "Brochette" experiment during LISE2022 campaign

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GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

LP2i Laboratoire de Physique des 2 infinis Bordeaux

cnrs IN2P3 Les deux infinis

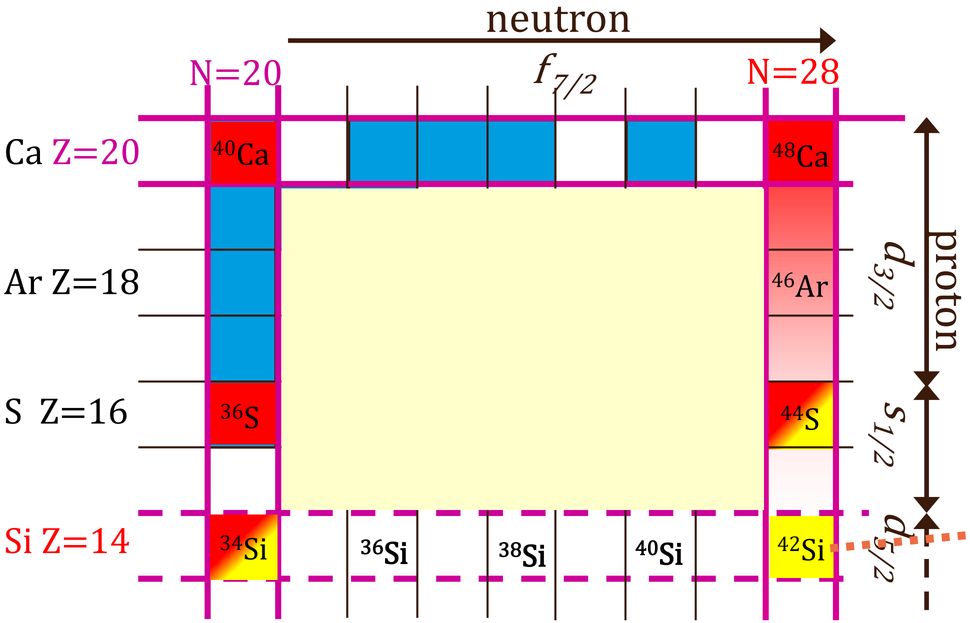
université de BORDEAUX

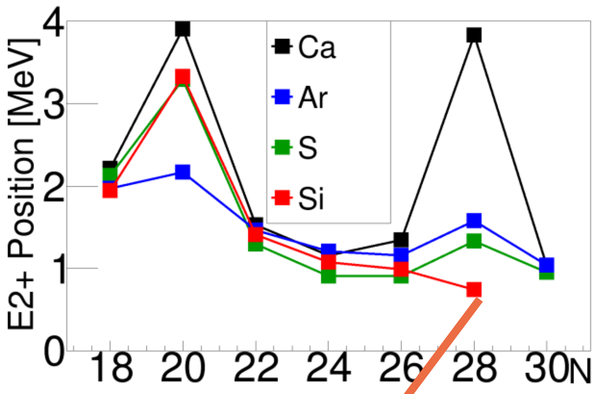
Outline

- Nuclear structure & Physics motivations
  - Between N=20 and N=28 region
  - B(E2) & $\frac{Mn}{Mp}$ ratio
- Experimental setup
- Preliminary : CoulEx results
- Perspectives

Nuclear structure
&
Physics motivations

The case of Silicon 42





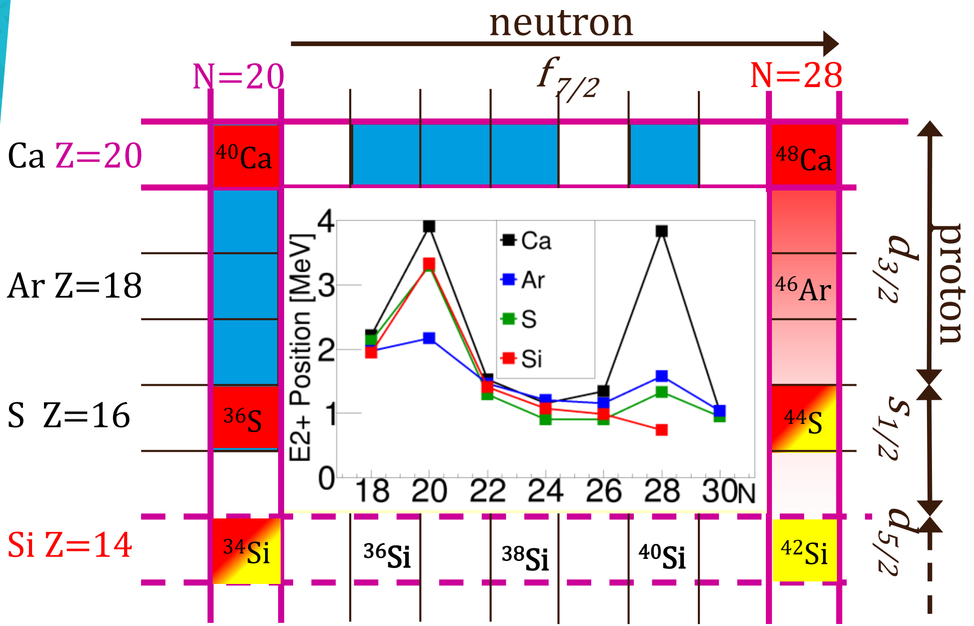
Loss of the magicity of ^{42}Si [*]

Why ?

[*] B. Bastin et al., Phys. Rev. Lett. 99, 022503 (2007)

Tensor Force [*]

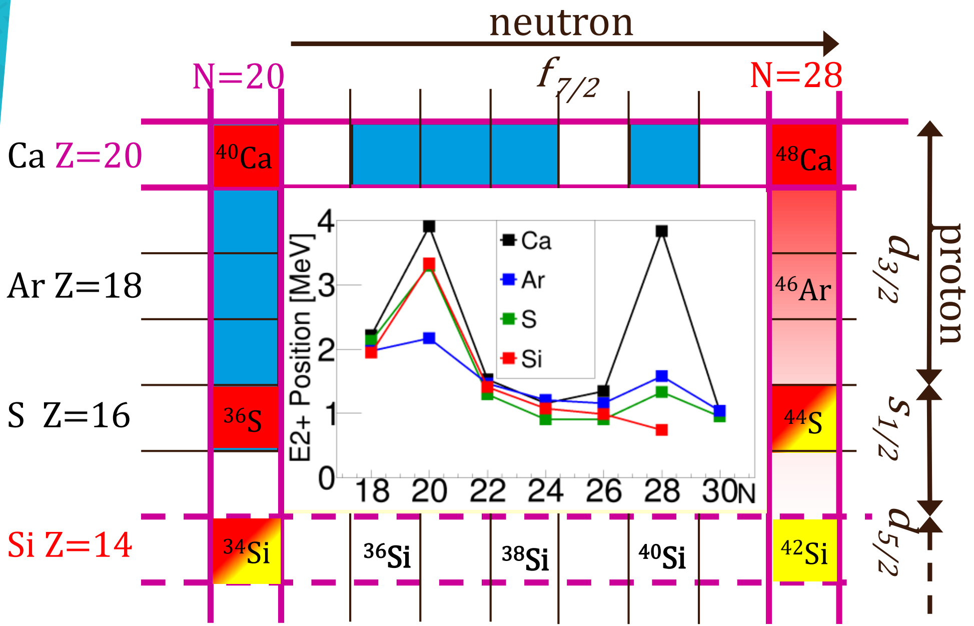
The case of Silicon 42

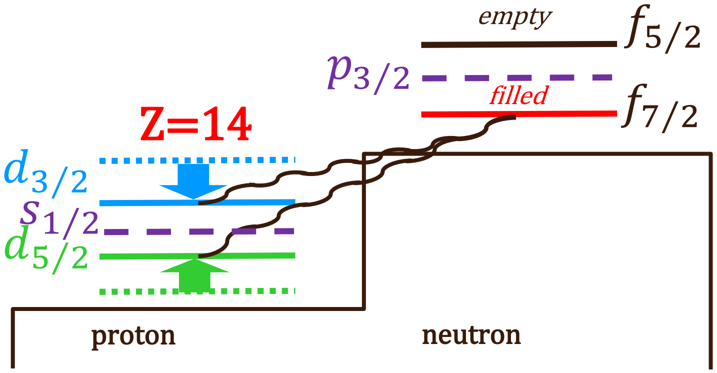


[*] T. Otsuka, Phys. Scr. T152, 014007 (2013)

Tensor Force [*]

The case of Silicon 42



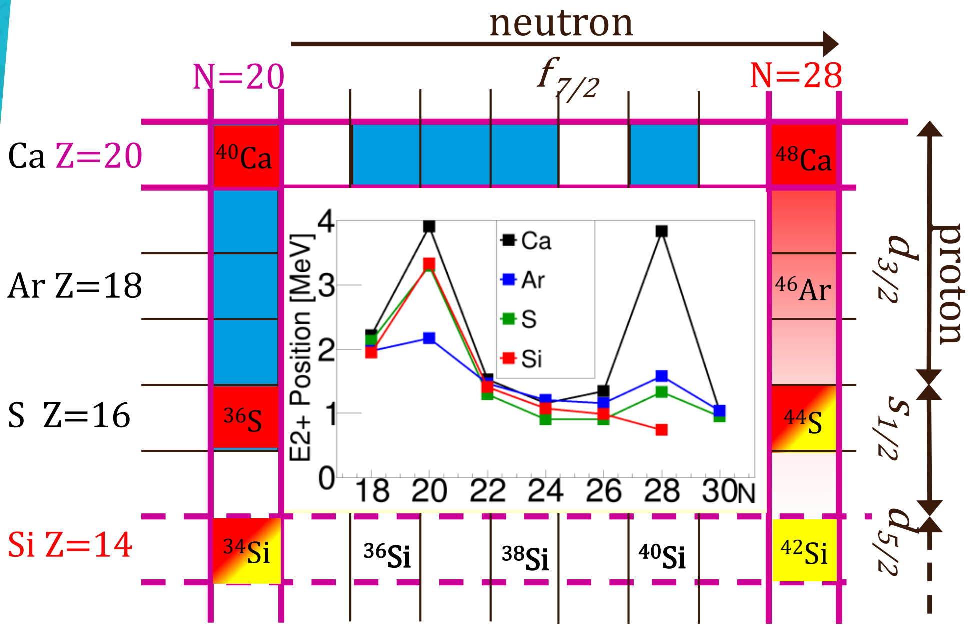


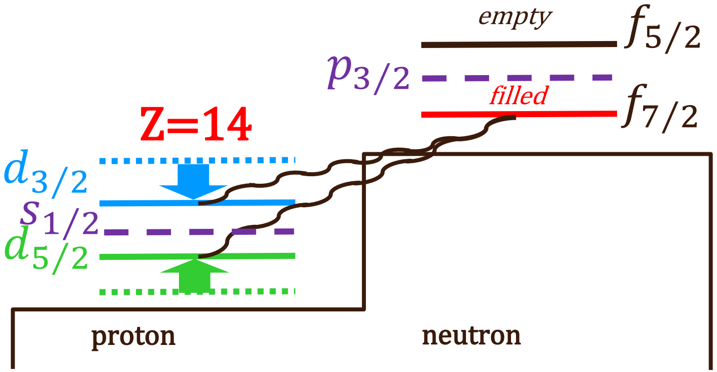
- Filling of neutron f7/2 orbital : compression of $(d_{5/2} - d_{3/2})$

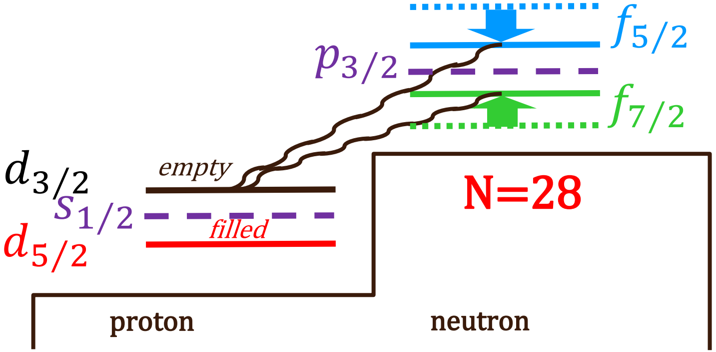
[*] T. Otsuka, Phys. Scr. T152, 014007 (2013)

Tensor Force [*]

The case of Silicon 42







- Filling of neutron f7/2 orbital : compression of $(d_{5/2} - d_{3/2})$
- Emptying of proton d3/2 orbital : compression of $(f_{7/2} - f_{5/2})$

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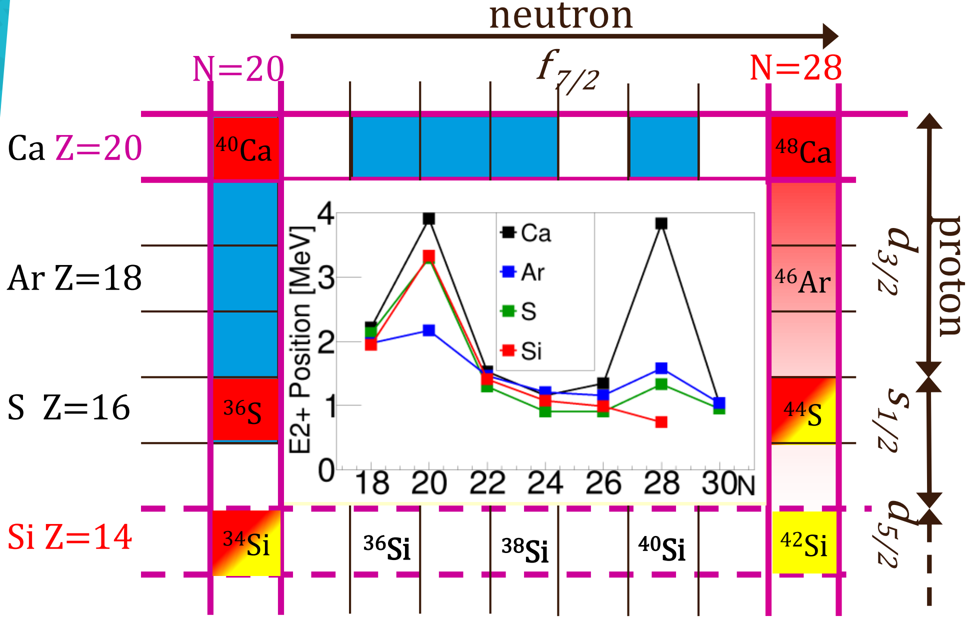
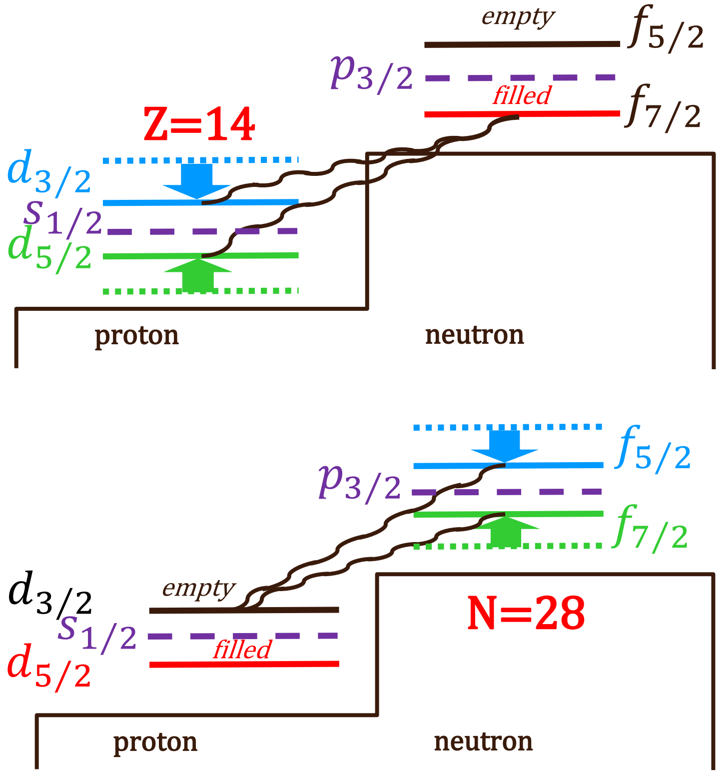
Tensor Force [*]

The case of Silicon 42



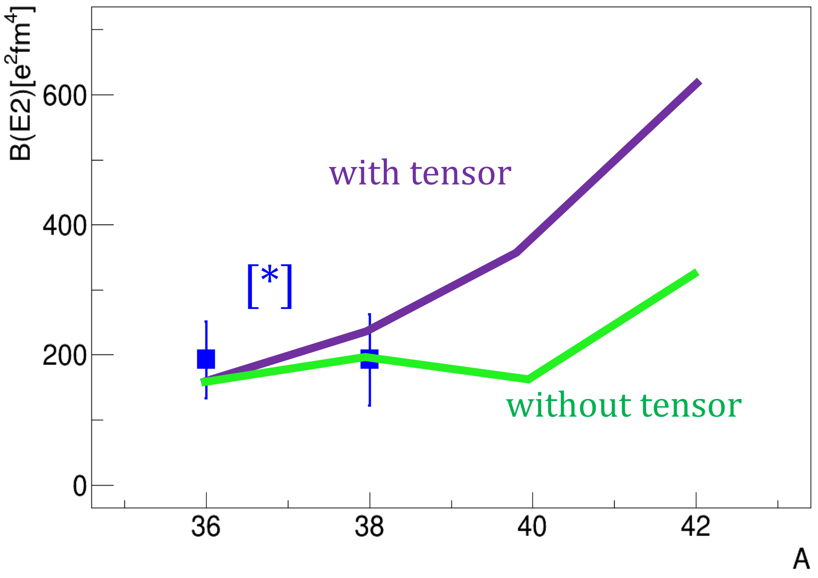


- Filling of neutron f7/2 orbital : compression of $(d_{5/2} - d_{3/2})$
- Emptying of proton d3/2 orbital : compression of $(f_{7/2} - f_{5/2})$

Allows more $\Delta L = 2$ transition
→ Quadrupolar excitations
→ Deformation

[*] T. Otsuka, Phys. Scr. T152, 014007 (2013)

The case of Silicon Isotope along N=20 and N=28



B(E2) sensitive to the tensor force

B(E2) : Probability of E2
$(0^+ \rightarrow 2^+)$ transition

[*] R. W. Ibbotson et al.,Phys. Rev. Lett. 80, 208 (1998)

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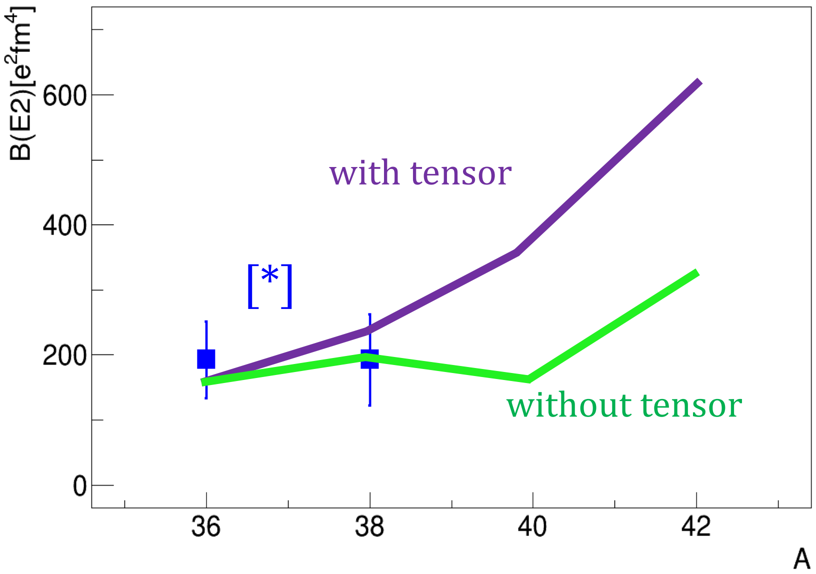

B(E2) sensitive to the tensor force

B(E2) : Probability of E2 $(0^+ \rightarrow 2^+)$ transition

$\boldsymbol{B(E2) \propto \sigma_{CouleX}}$

- ➢ **Coulomb Excitation experiment**

→Track experimentally **B(E2)** values (so Tensor Force) along Silicon isotopic chain

[*] R. W. Ibbotson et al.,Phys. Rev. Lett. 80, 208 (1998)

Who is guilty of the loss of magicity ?
Z=14 or N=28 ?

Through B(E2) ⇒ proton (Mp) and neutron (Mn) contribution

$$B(E2) = (e_p M_p + e_n M_n)^2$$

$\left\{ \begin{array}{l} e_p : \text{Proton Effective charge} \\ M_p : \text{Proton Transition Matrix} \end{array} \right\}$

$\left\{ \begin{array}{l} e_n : \text{Neutron Effective charge} \\ M_n : \text{Neutron Transition Matrix} \end{array} \right\}$

B(E2) : proton **And** neutron contribution

⇒ Need to disentangled both contributions

- **Proton inelastic scattering**

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{ e_p: Proton Effective charge
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{ e_n: Neutron Effective charge
M_n : Neutron Transition Matrix }

B(E2) : proton **And** neutron contribution
⇒ Need to disentangled both contributions

- **Proton inelastic scattering**

Both measurement lead to quantify the ratio $\frac{M_n}{M_p}$:

$$\frac{M_n}{M_p} = \frac{1}{3}\left[\frac{\delta_{pp'}}{\delta_{EM}}\left(1 + \frac{1}{3}\frac{N}{Z}\right) - 1\right]$$ [*]

$\delta_{pp'} \propto \frac{d\sigma_{pp'}}{d\theta}$ angular distribution

$\delta_{CouleX} \propto \sqrt{B(E2)} \propto \sqrt{\sigma_{CouleX}}$

One measurement…

…an other measurement

Reaction (p, p') ⟷ CoulEx

[*] E. Khan, Phys. Rev. C 105, 014306 (2022)

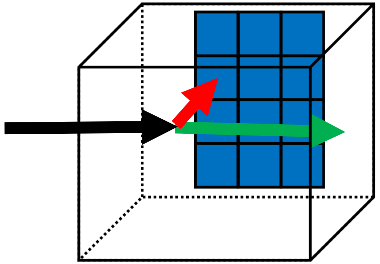
Experimental setup in D6

That's why "Brochette experiment"… ⇨ 1 Beam…
2 independent measurements

Experimental setup in D6

That's why "Brochette experiment"… ⇨ 1 Beam…
2 independent measurements

Beam →	1st Setup	Beam Refocused →	2nd Setup
	ACTAR-TPC (p,p')		CoulEx



$^{34,36,38}Si(p,p')^{34,36,38}Si^{*}$

T. Roger & A. Cassisa(PhD)

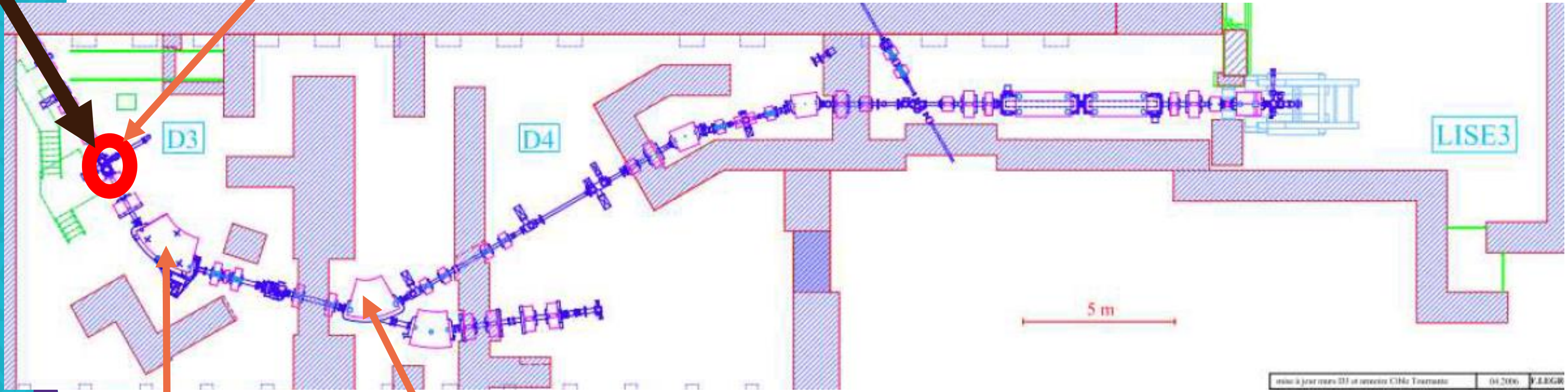
My PhD analysis

Fragments Production & Identification

LISE Spectrometer

^{48}Ca

LISE Target

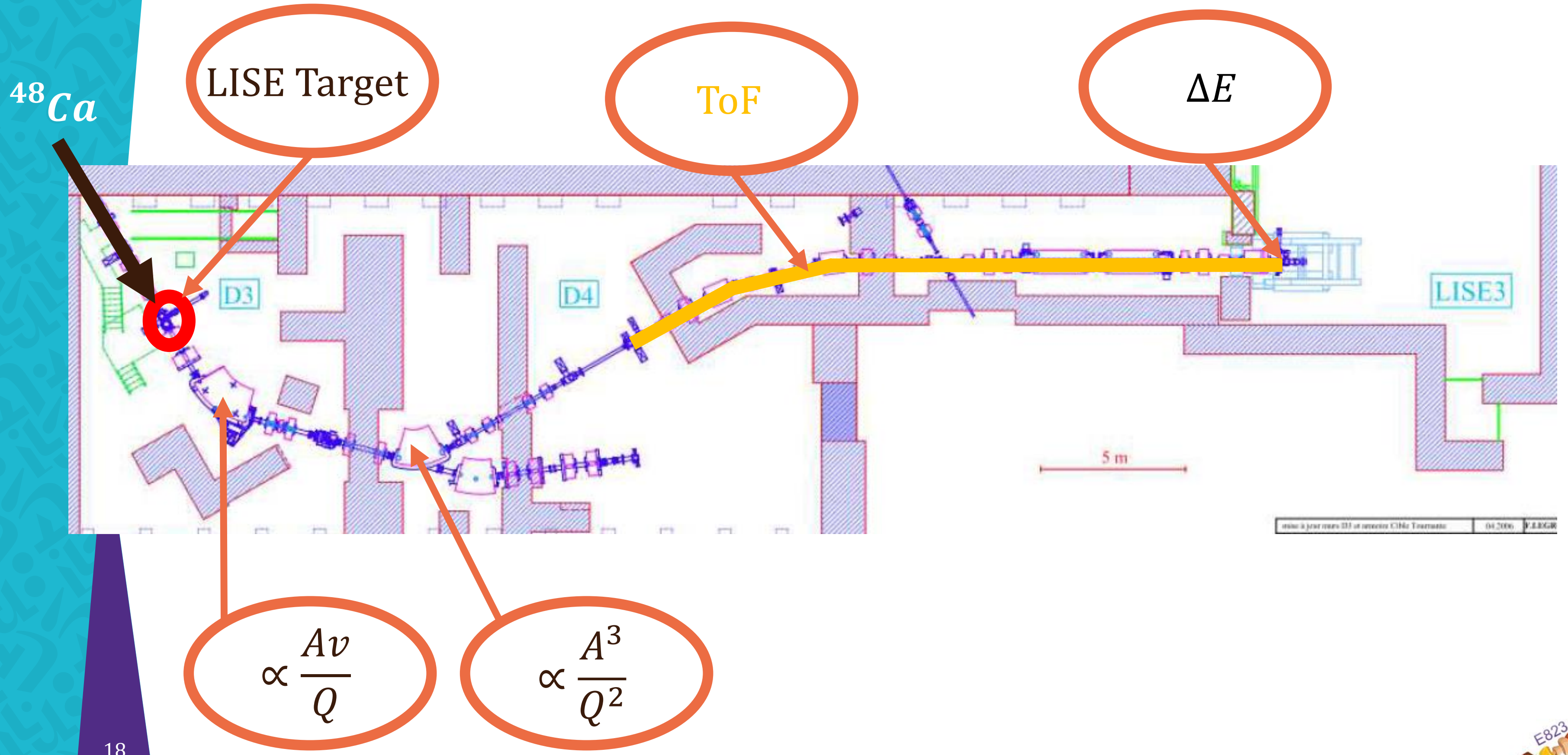


$\propto \frac{Av}{Q}$

$\propto \frac{A^3}{Q^2}$

E823

LISE Spectrometer

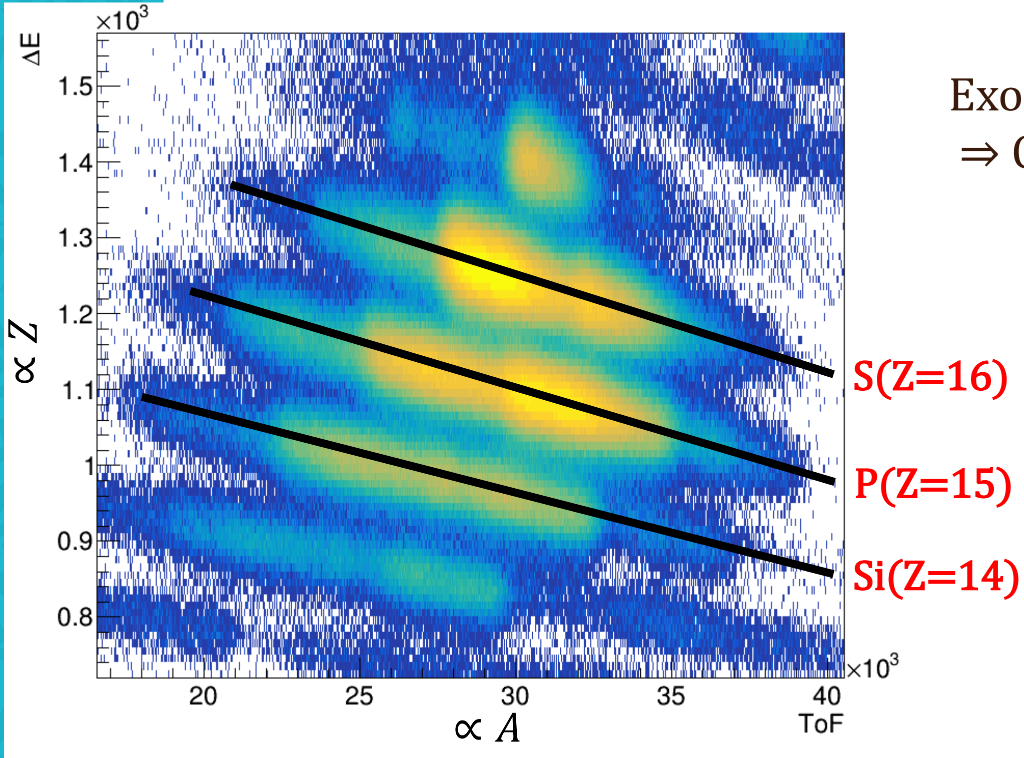


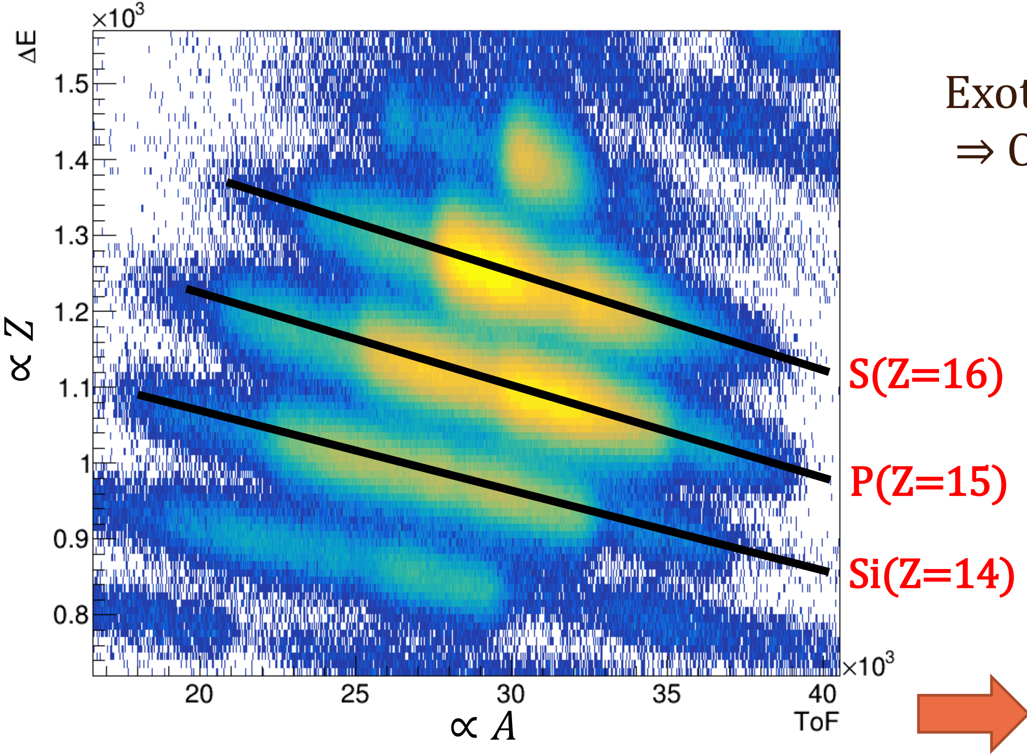
ΔE − ToF identification

Exotic area and need high counting rate

⇒ Open in acceptance so in ToF dispersion

$$B\rho \propto \frac{Av}{Q} \rightarrow \frac{A\langle v\rangle}{Q} \text{ with } \langle v\rangle = \frac{d}{\langle ToF\rangle}$$





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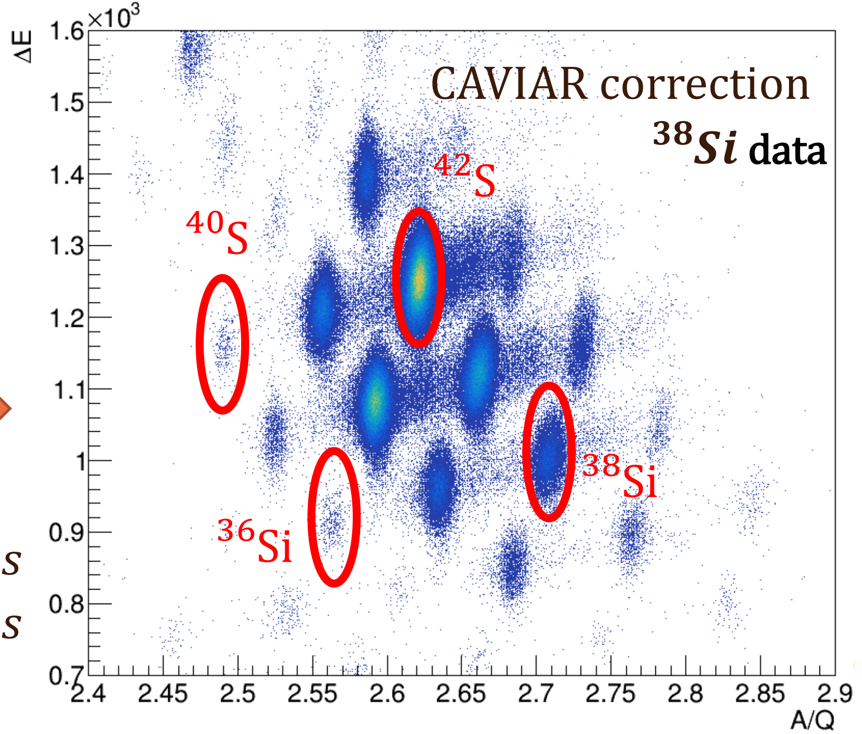
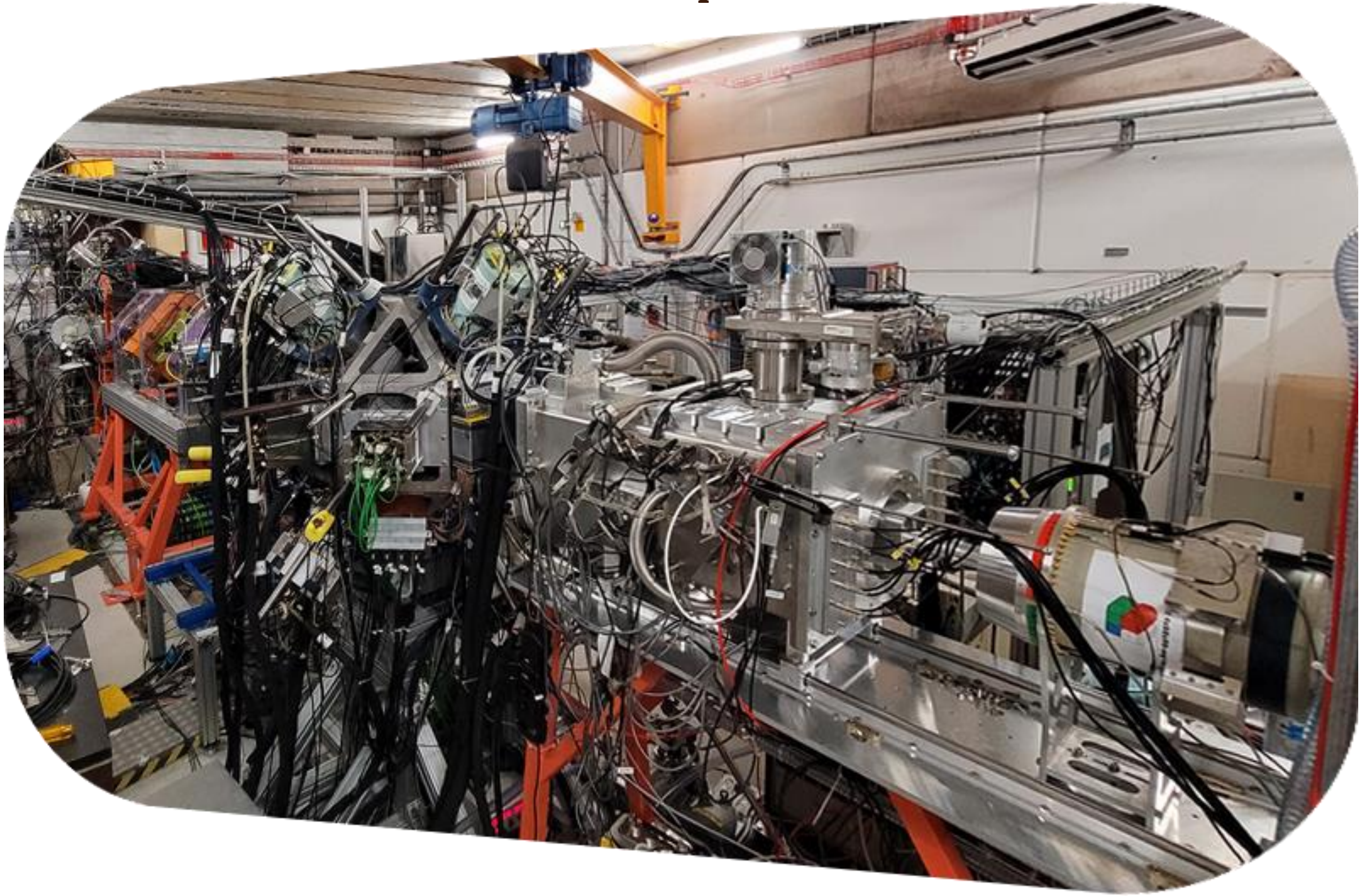


Counting Rate -

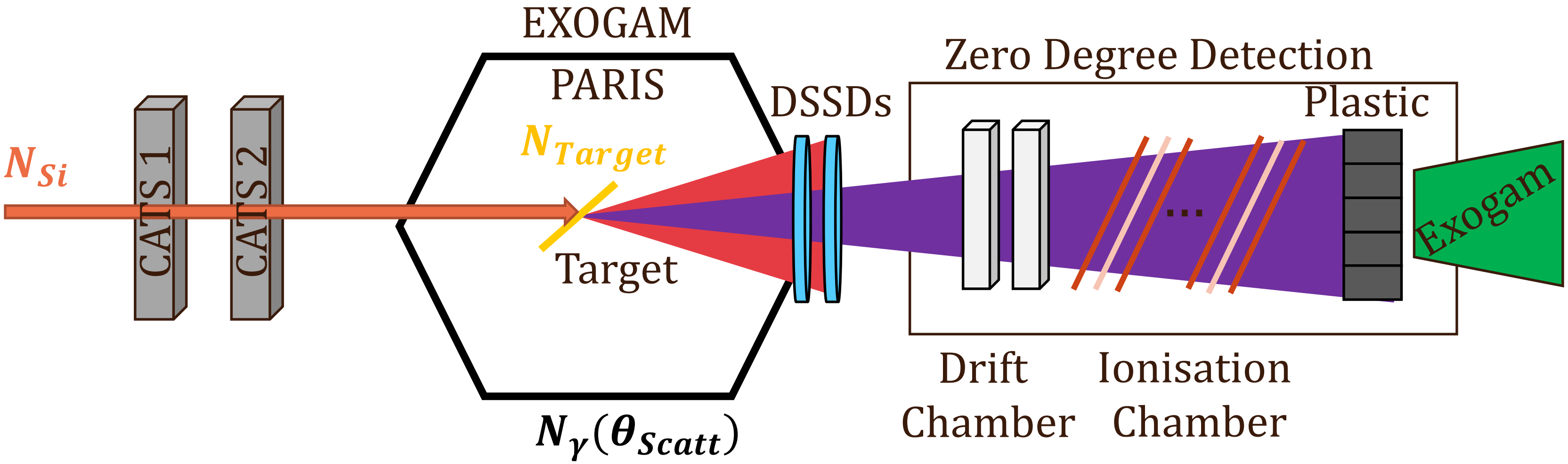
^{38}Si runs $-$D3 $\propto 10^5 pps$ $-$ D6 $\propto 8 \cdot 10^3 pps$

^{36}Si runs $-$D3 $\propto 10^6 pps$ $-$ D6 $\propto 3 \cdot 10^4 pps$

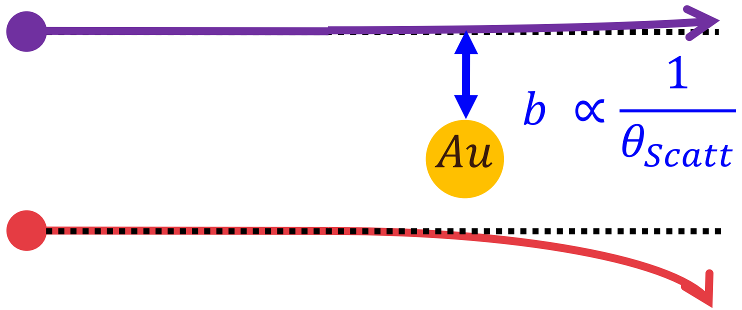
CoulEx as 2^{nd} setup



CoulEx as 2^nd setup



Target : 400 $mg.cm^{-2}$ of Gold



$$B(E2) \propto \sigma_{CouleX} \propto \frac{N_\gamma(\theta_{Scatt})}{N_{Si} N_{Target}}$$

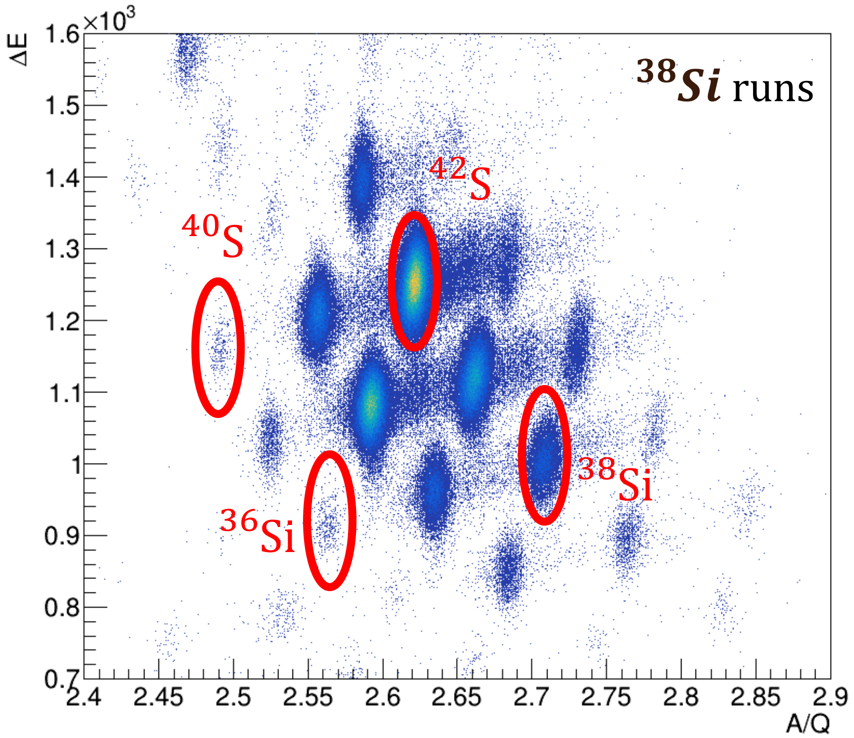
$$N_\gamma(\theta_{Scatt}) = N_\gamma(\theta_{zdd}) + N_\gamma(\theta_{DSSD})$$

Pure CouleX

CouleX + Nuclear

Preliminary CoulEx results

Nucleus of interest

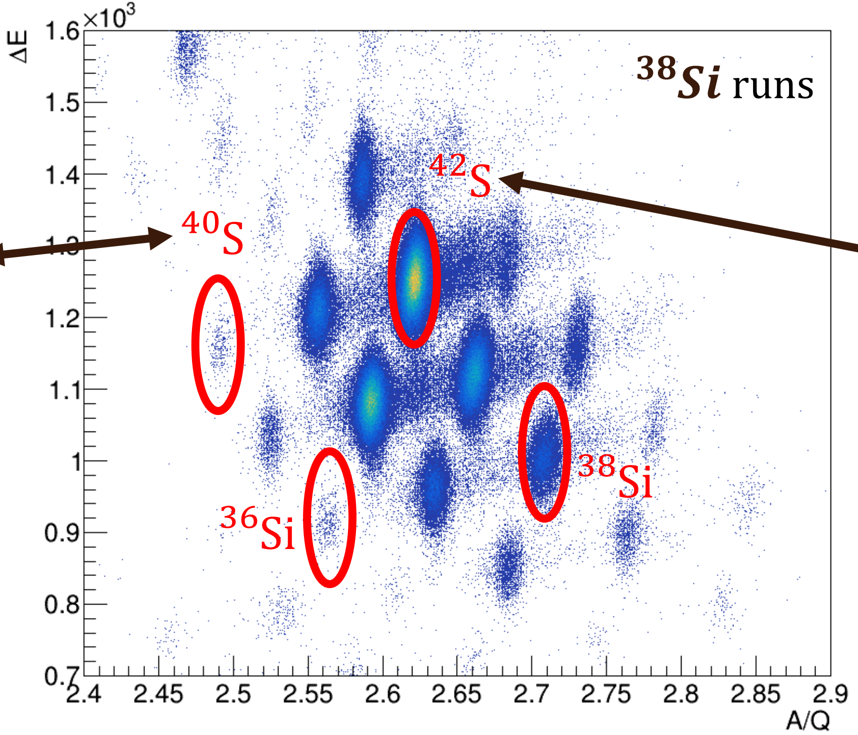


$$\frac{B(E2,\ ^{A}Si)}{B(E2, Ref)} = \frac{\sigma(\ ^{A}Si)}{\sigma(Ref)}$$

Nucleus of interest

$B(E2) = 284(26)e^2 fm^4$ [*]

Reference

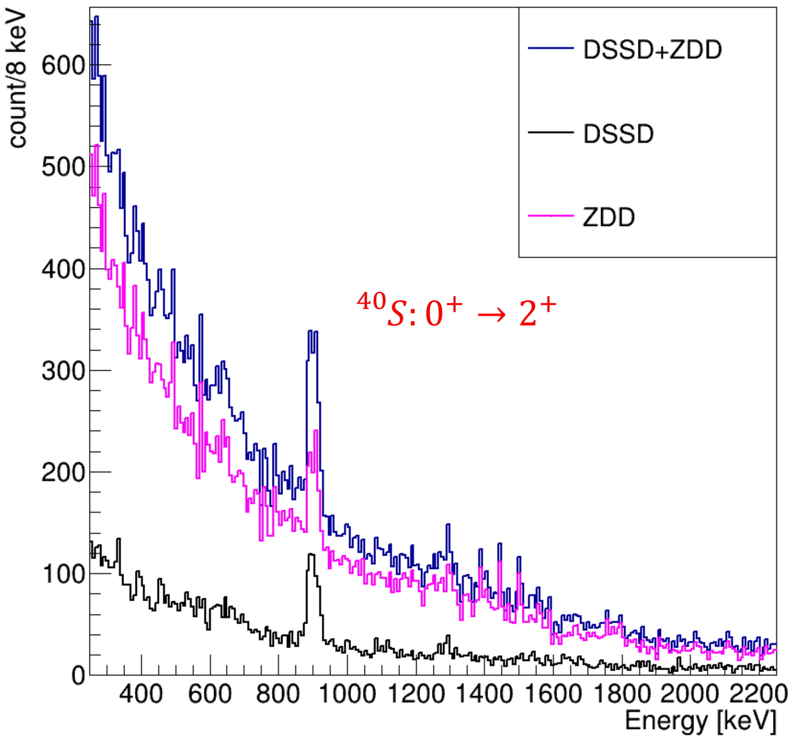


$B(E2) = 326(48)e^2 fm^4$ [*]

[*] B. Longfellow et al.,Phys. Rev. C, 103, 054309 (2021)

Gamma spectrum from EXOGAM : ^{40}S in ^{36}Si runs

All scattering angles θ_{Scatt} considered



$$N_{^{40}S} = 258.6 \cdot 10^6 \text{nucleus}$$

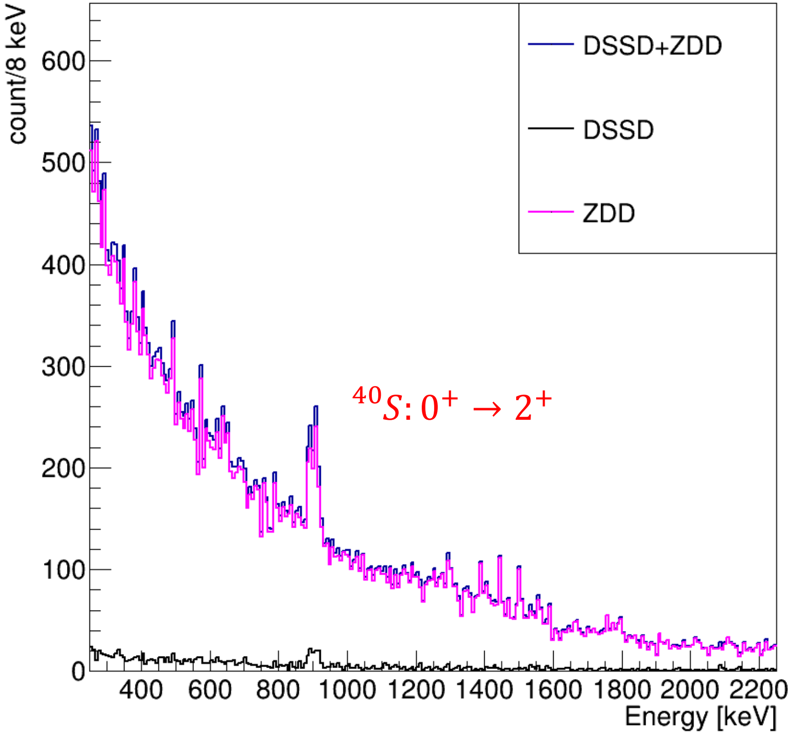
Add-Back method
&
Doppler Correction

$$E_{\gamma,Reel} = E_{\gamma,Mes} \times \frac{1-\beta\cos(\theta)}{\sqrt{1-\beta^2}}$$

$$\frac{\Delta E}{E}(FWHM) = 3.8\ \%$$

Gamma spectrum from EXOGAM : ^{40}S in ^{36}Si runs

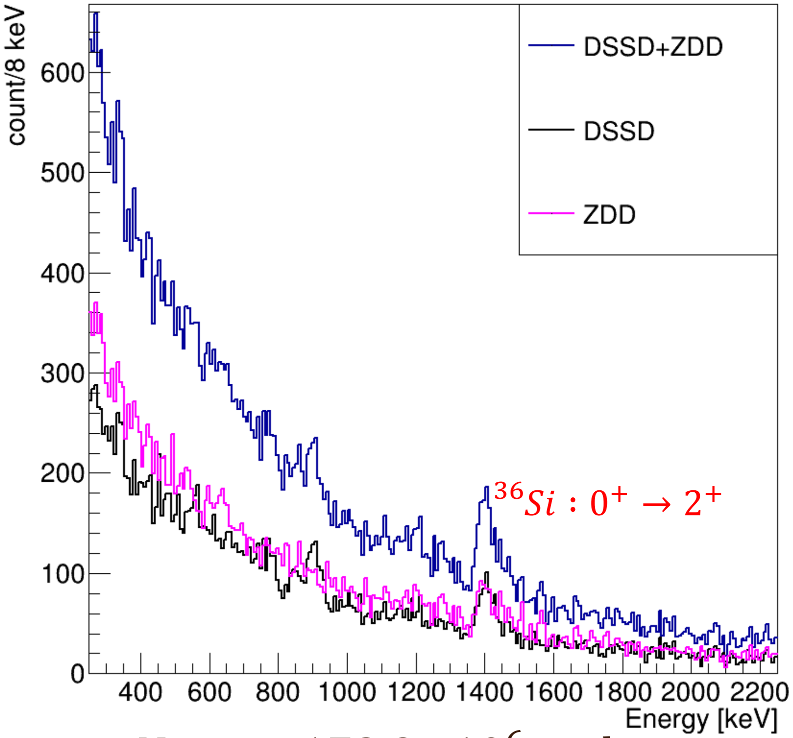
Cut : $0° < \theta_{Scatt} < 3.5°$



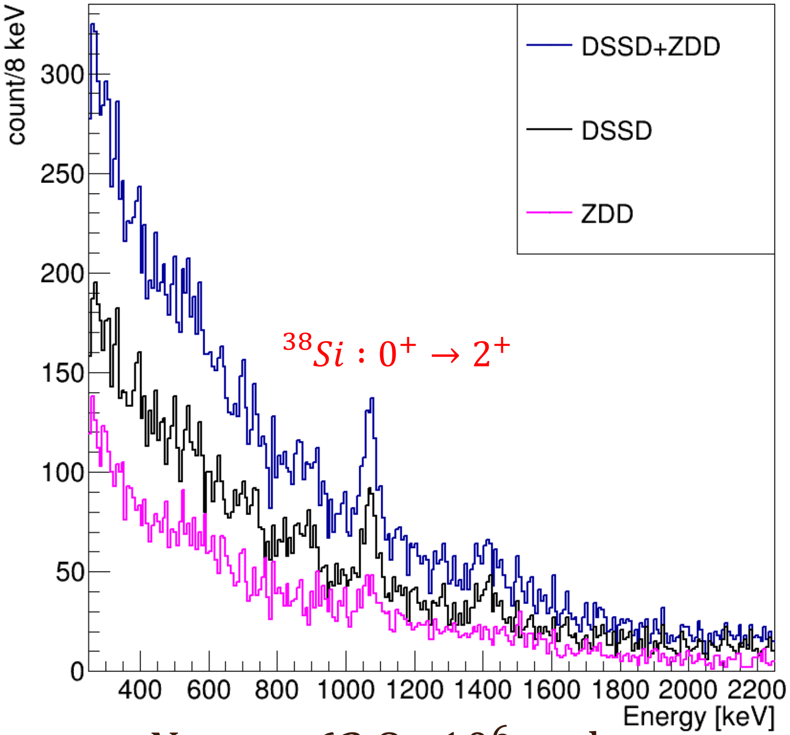
Cut in order to reduce nuclear component and keep only pure CoulEx

Gamma spectrum from EXOGAM : ^{36}Si / ^{38}Si

All scattering angles θ_{Scatt} considered



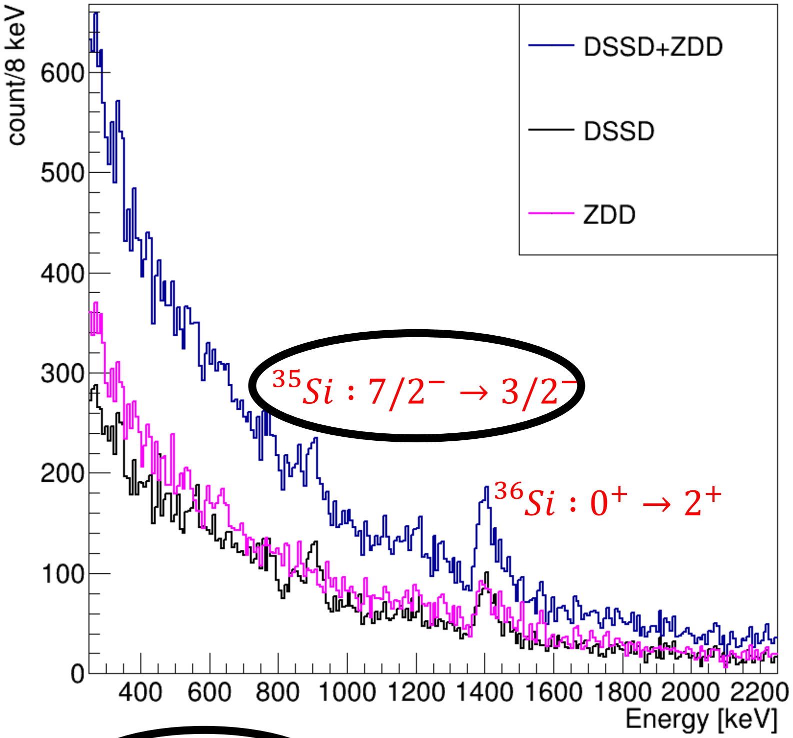
$N_{^{36}Si} = 173.9 \cdot 10^6$nucleus

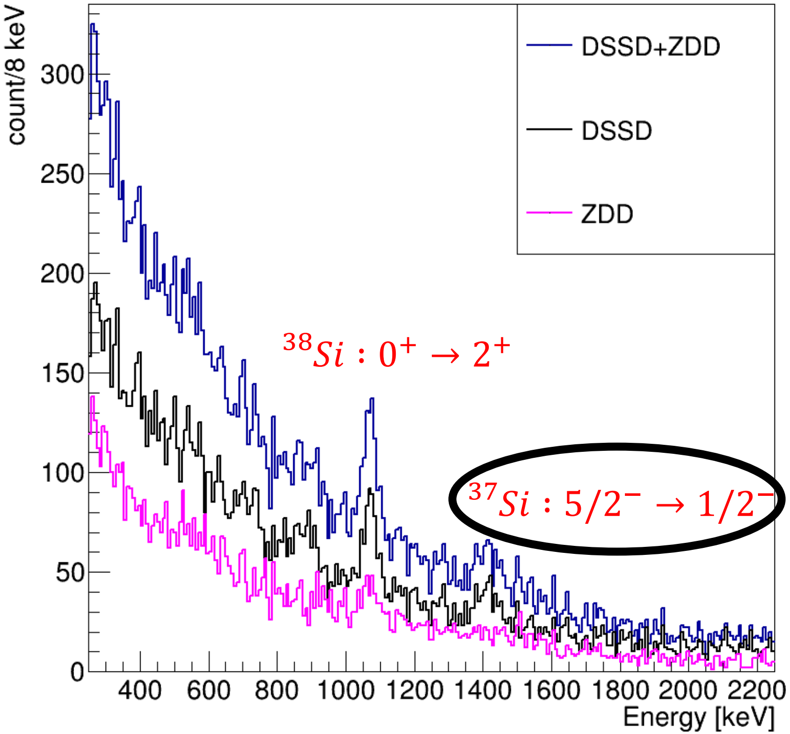


$N_{^{38}Si} = 62.8 \cdot 10^6$nucleus

Gamma spectrum from EXOGAM : ^{36}Si / ^{38}Si

All scattering angles θ_{Scatt} considered

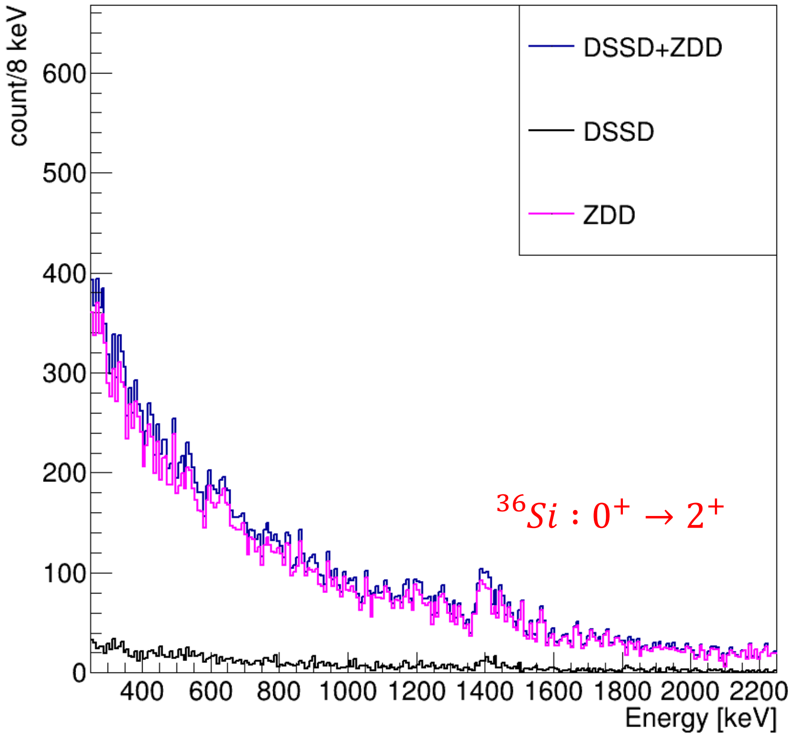


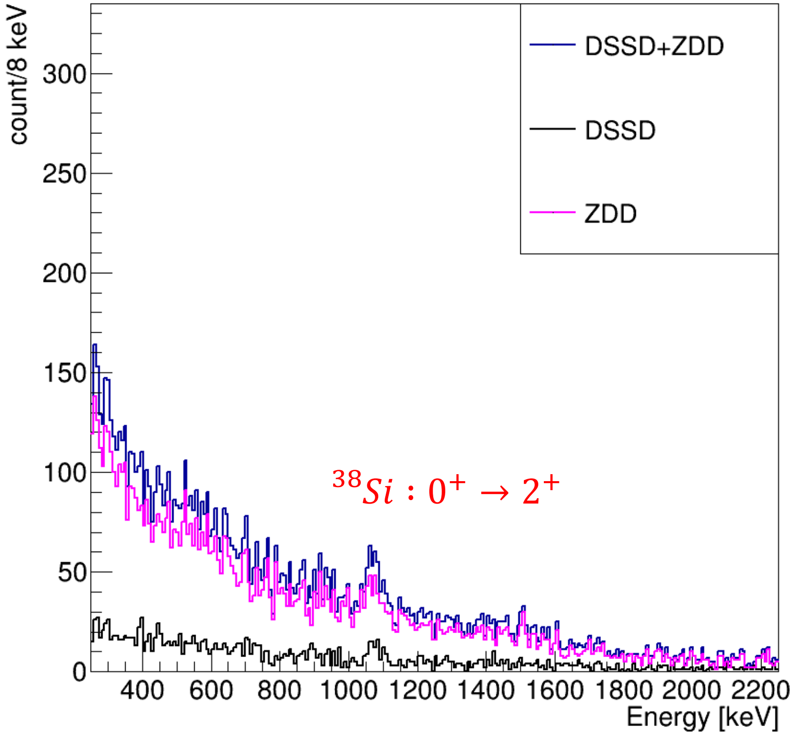


Stripping

Gamma spectrum from EXOGAM : ^{36}Si / ^{38}Si

Cut : $0° < \theta_{Scatt} < 3.5°$

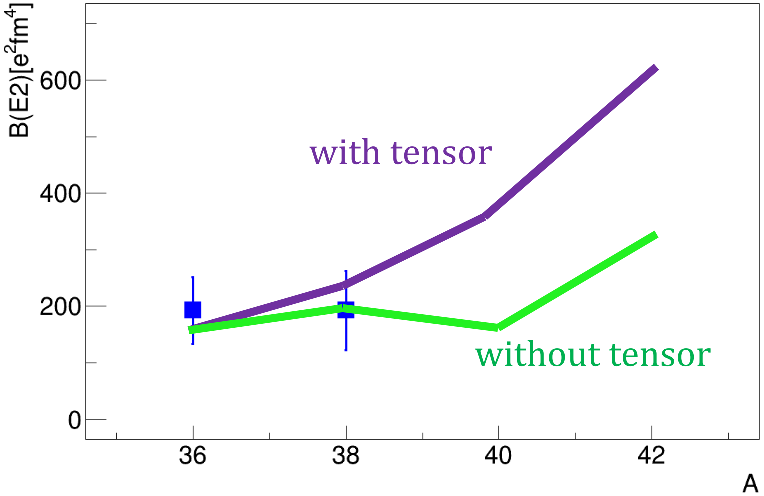




^{36}Si – ^{38}Si : B(E2) evaluation relative to ^{40}S with EXOGAM

$$\frac{B(E2,\,^{A}Si)}{B(E2,\,^{40}S)} = \frac{N\gamma(\,^{A}Si)N_{in}(^{40}S)}{N_{in}(\,^{A}Si)N\gamma(^{40}S)}$$

R.W. Ibbotson et al., PRL, 1998



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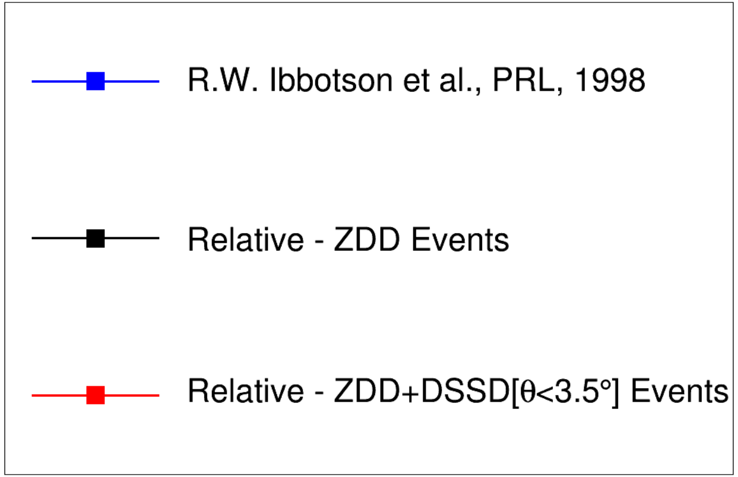
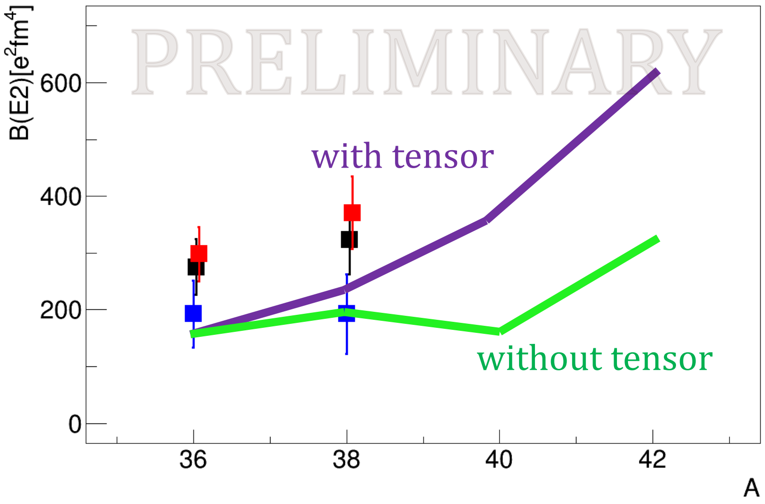
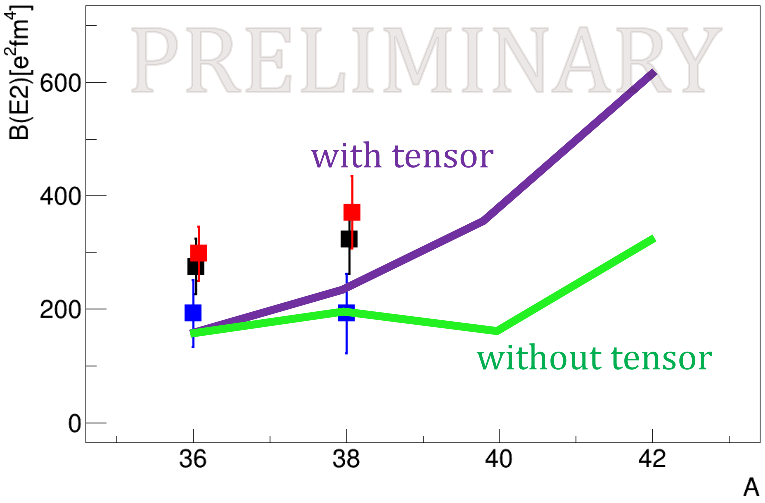




Perspective



For the moment,
only EXOGAM analysed

Next steps

- PARIS analysis
- ^{46}Ar runs as reference

Reduction of the error bars

Thank you !

S. Grévy, T. Roger, D. Ackermann, N. Alahari, A. Barriere, M. Begala, B. Blank, S. Calinescu, A. Cassisa, M. Ciamala, E. Clément, G. de France, F. de Oliviera, J.E. Ducret, M. Flayol, S. Franchoo, J. Giovinazzo, A. Husson, H. Jacob, M. Juhasz, M. Kacy, S. Koyama, N. Kumar, A. Lemasson, M. Lewitowicz, J. Lois Fuentes, I. Matea, J. Michaud, J. Mrazek, A. Ortega-Moral, J. Pancin, J. Piot, F. Rotaru, O. Sorlin, L. Stan, M. Stanoiu, C. Stodel, J.C. Thomas