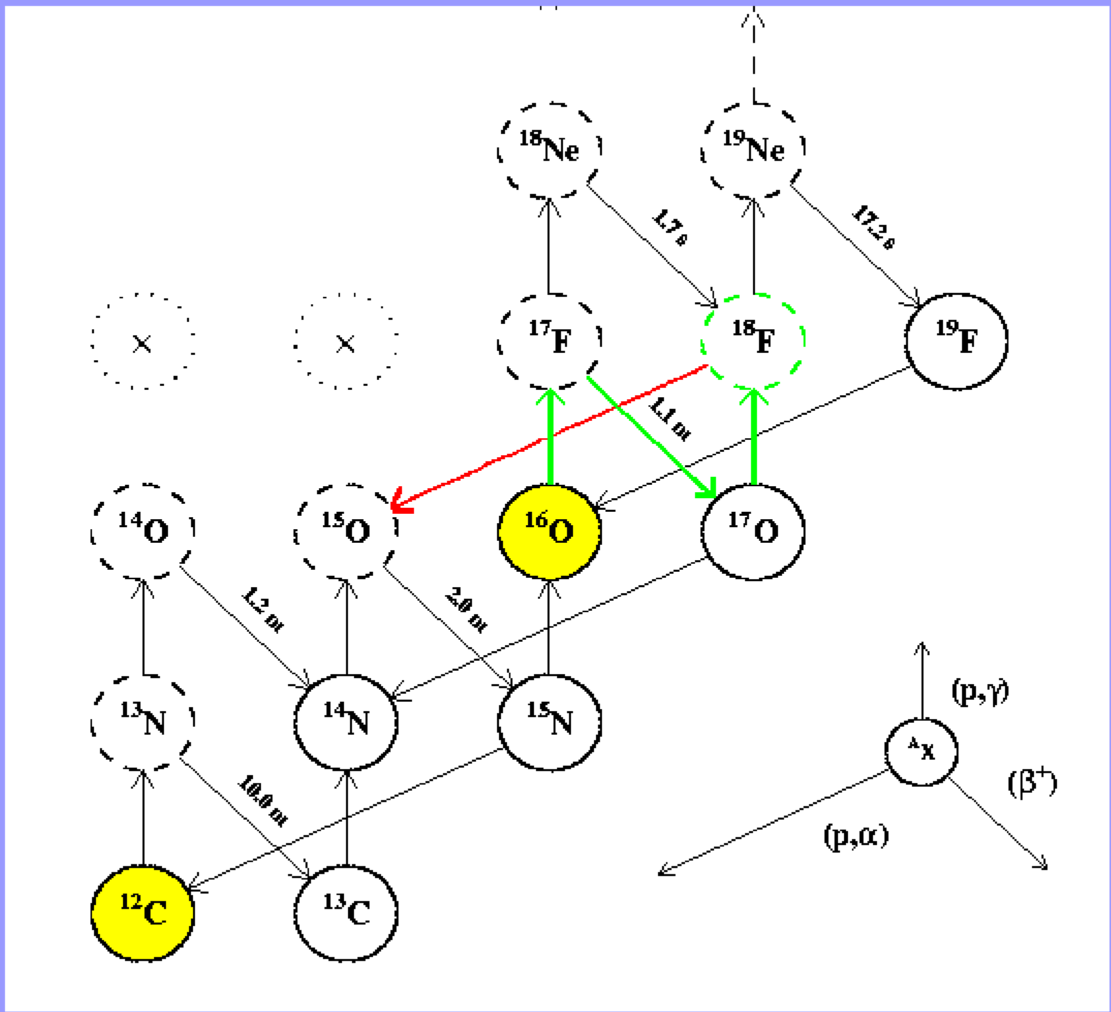
Direct measurement of the $^{18}F(p,\alpha)^{15}O$ reaction for application to nova γ-ray emission

Nicolas de Séréville

Centre de Recherches du Cyclotron, Louvain-la-Neuve, Belgium

Nucleosynthesis of ^{18}F ($T_{1/2}$ = 110 min)



- γ-ray emission at 511 keV: annihilation of the β+ with the expanding envelope
- Seed nucleus: ^{16}O
  → CO and ONe novae
- Hydrodynamical calculations
  → SHIVA code

José & Hernanz (1998)

↓

- Main nuclear uncertainty:
  ^{18}F(p,α)^{15}O
- large uncertainty on γ-ray flux

Coc et al. (2000)

- Other nuclear uncertainties: ^{17}O(p,γ)^{18}F and ^{17}O(p,α)^{14}N

TUNL + Orsay (CSNSM)

$^{18}F(p,\alpha)^{15}O$ current status

de Séréville et al. 2003
Kozub et al. 2005

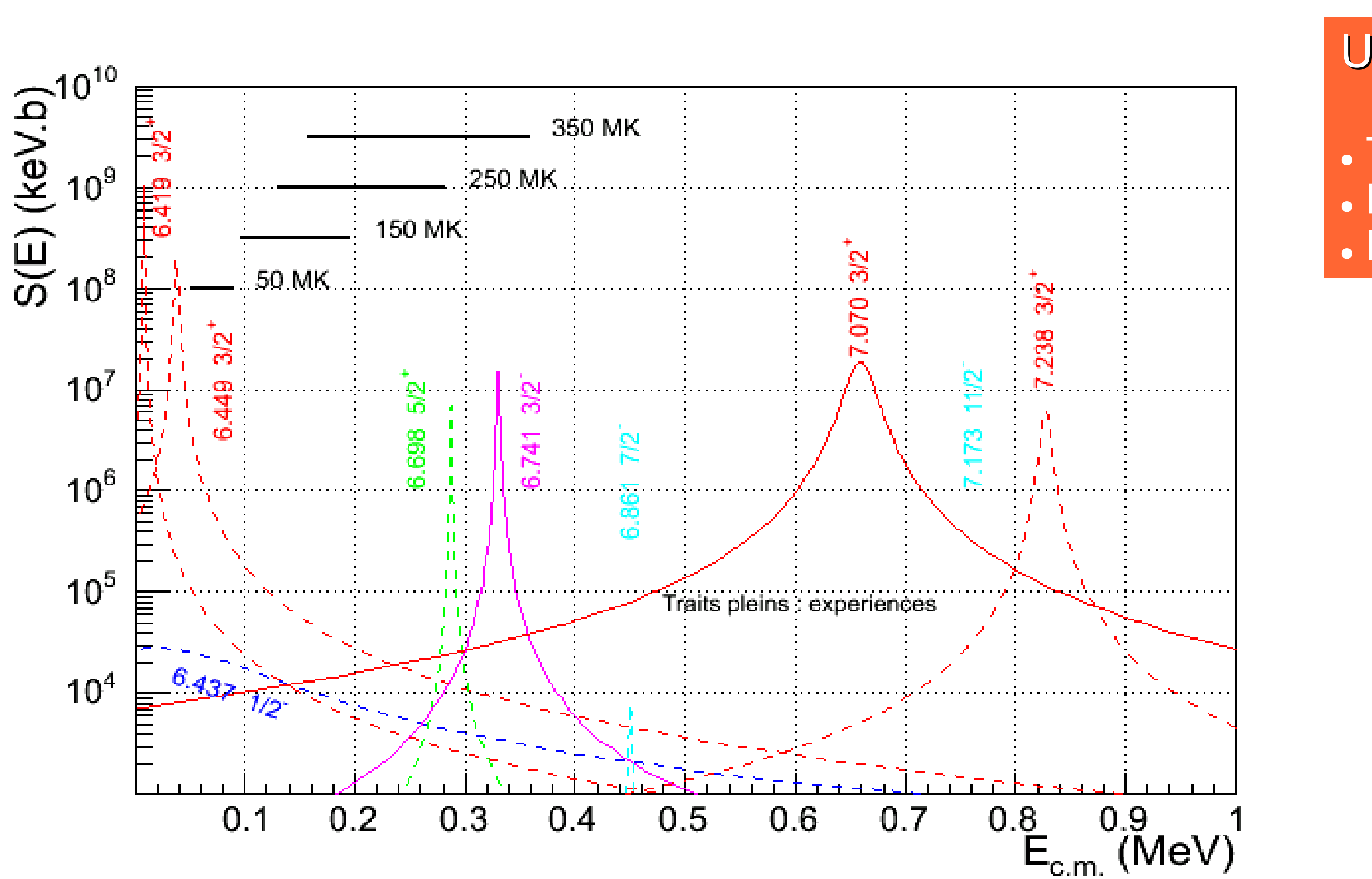
(d,p)

Indirect
Mirror nuclei

(p,p) + (p,α)

direct

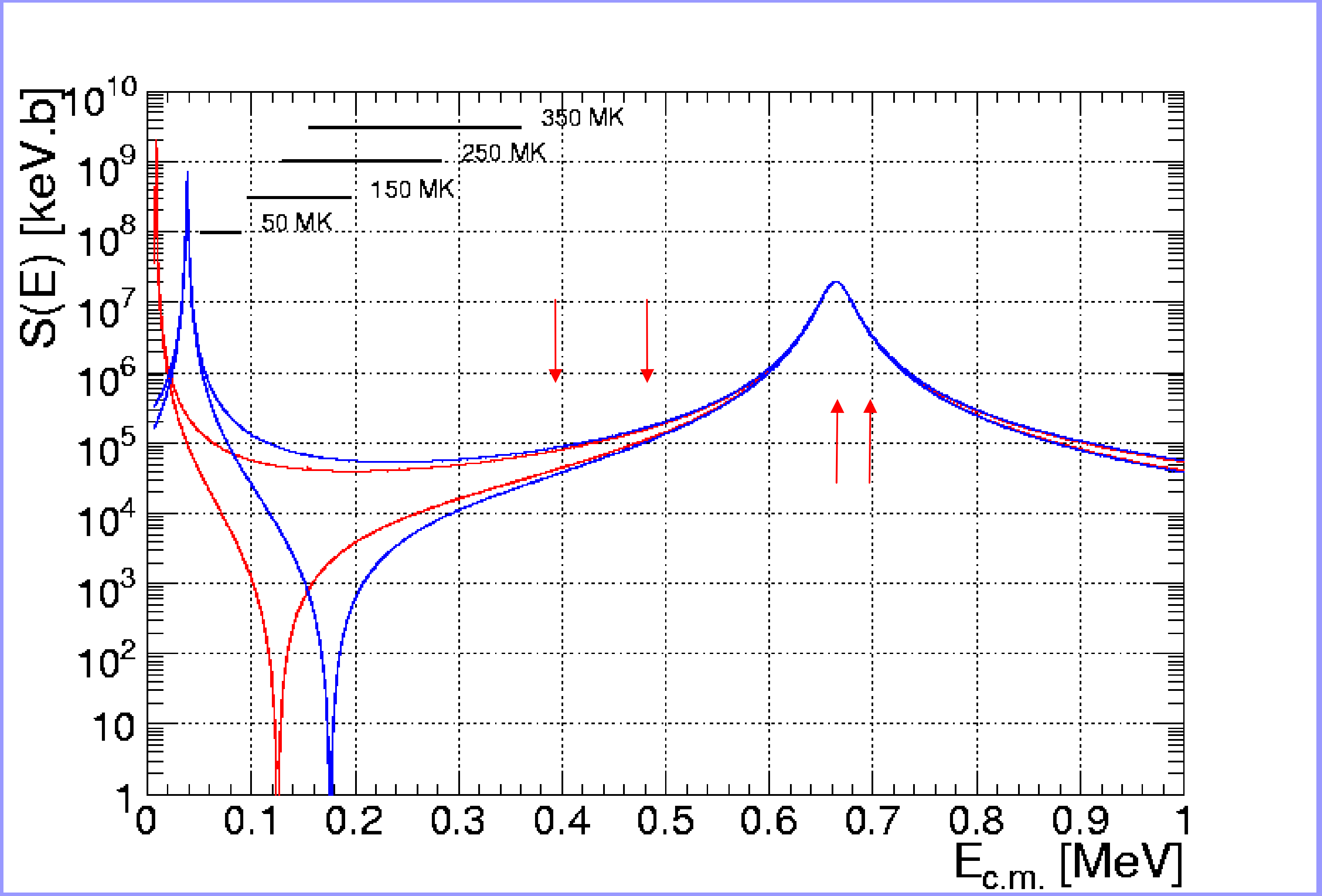
Coszach et al. 1995
Rehm et al. 1995
Graulich et al. 2001
Bardayan et al. 2002



Uncertainties

- Total widths
- Missing levels
- Interferences

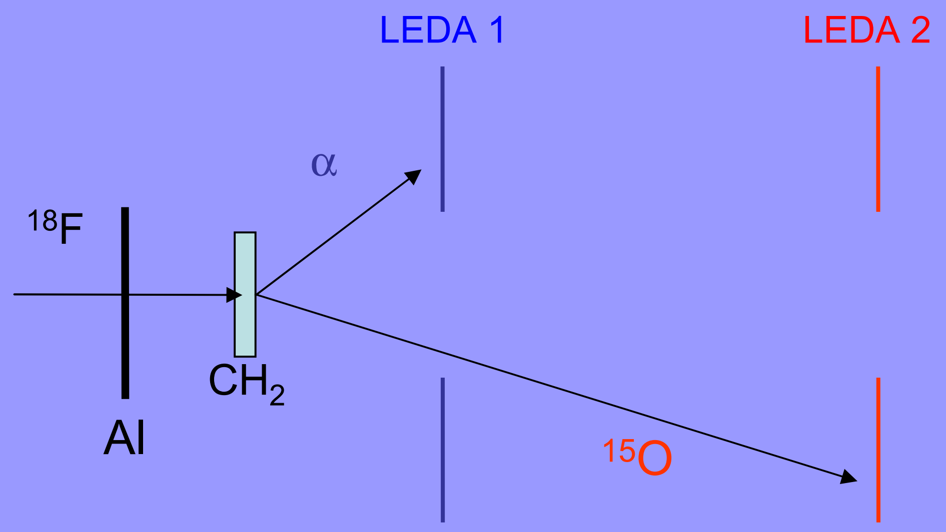
Interferences effect / experimental method



- Interference effect in the Gamow peak
- low intensity ^{18}F beam and cross section
  → difficult to measure below 300 keV
- Direct measurement at higher energies
  → 4 energies
- R-matrix analysis

Experimental set-up: p(^{18}F,α)^{15}O

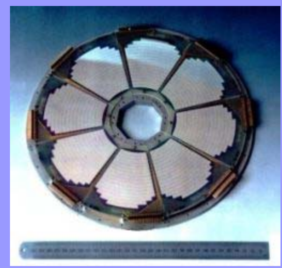
Set-up:

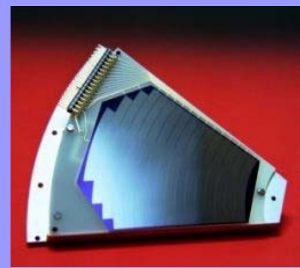


LEDA detectors:

(Louvain LN + Edinburg)

Davinson et al. NIM A 2000





- silicon multistrip detectors (300 μm)
- sector with 16 annular strips
- energy resolution ($\approx$ 30 keV FWHM)

Detector positions:

- LEDA1: solid angle
- LEDA2: coincidence efficiency (30%)

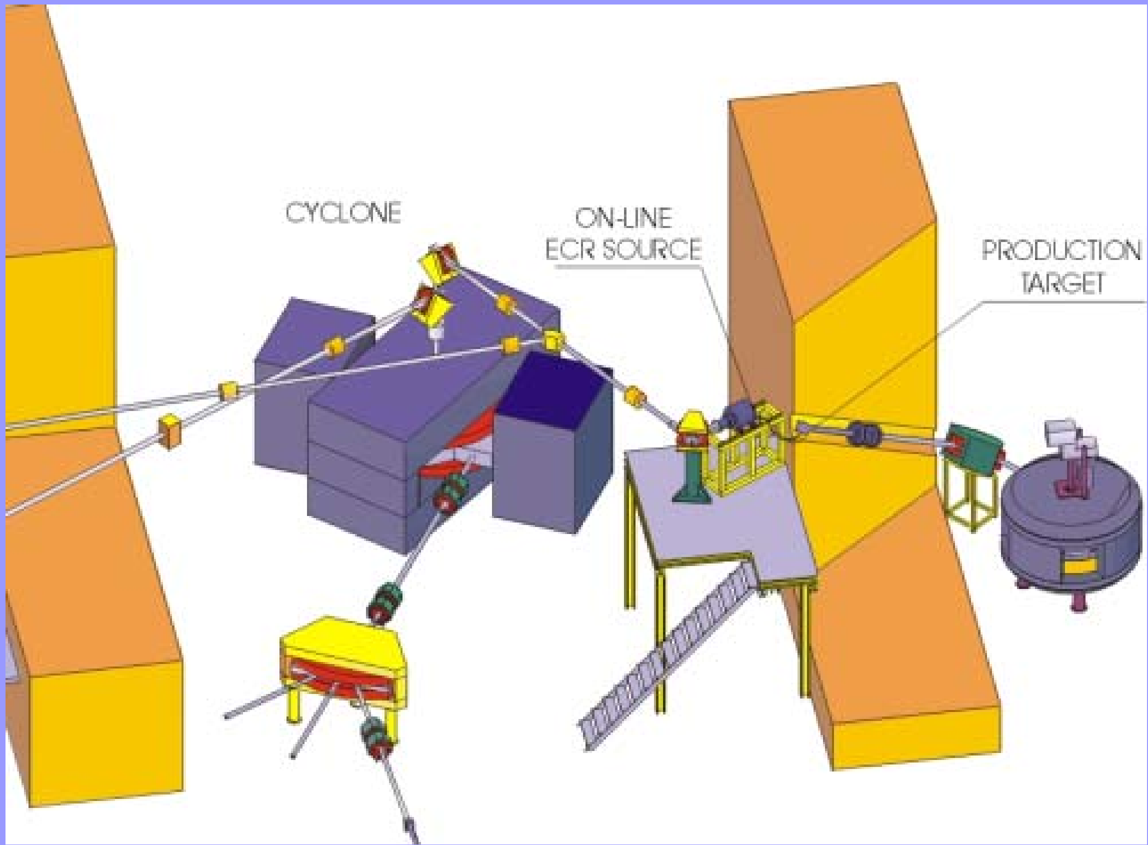
Target: $CH_2 \approx 70\ \mu g/cm^2$

→ covered c.m. energy range / counting rate

Degraders: Al (95, 500, 670 $\mu g/cm^2$)

$E_{c.m.}$ = 665, 485, 400 keV

^{18}F beam production at LLN



Production of ^{18}F ($T_{1/2}$ = 110 min) :

- $^{18}O(p,n)^{18}F$ E_p @ 15 MeV
- chemical extraction (45 min) -> $CH_3{}^{18}F$
- 1 bunch of ^{18}F / 2h (0.5 to 1Ci!)
- 17 bunches of ^{18}F over 1 ½ week

(Cogneau et al. NIM A 1999)

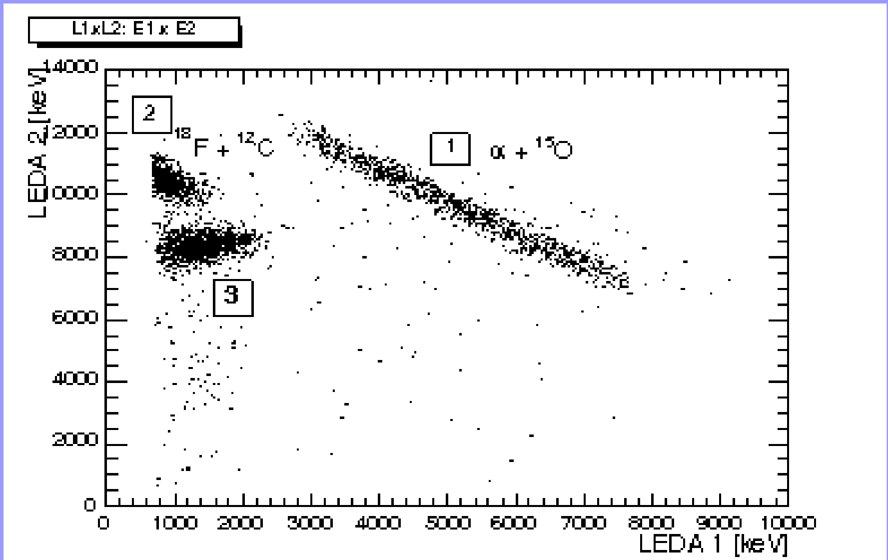
Acceleration:

- $E(^{18}F)$ = 13.8 MeV (nominal)
- $I \approx 10^6$ pps
- rejection of ^{18}O contamination

Characterization:

- PIPS detector at 0°
- energy after each degrader
- ^{18}O / ^{18}F < 0.5%

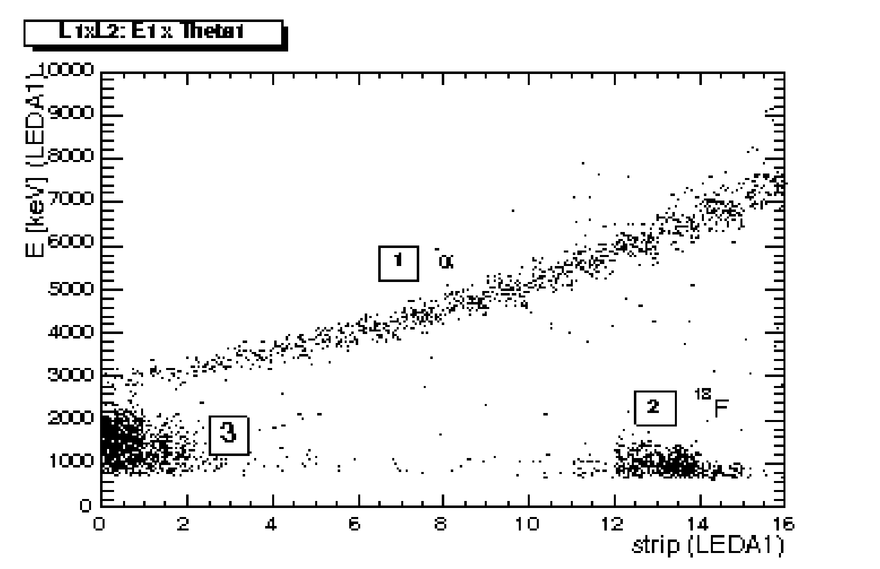
$^{18}F + p: \alpha - {}^{15}O$ coincidences ON resonance

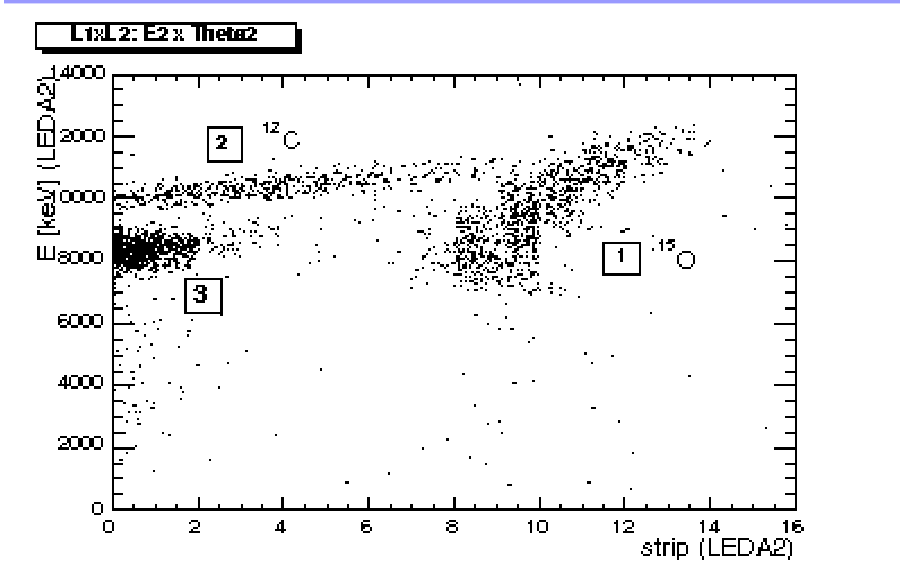


Coincidences LEDA1 x LEDA2

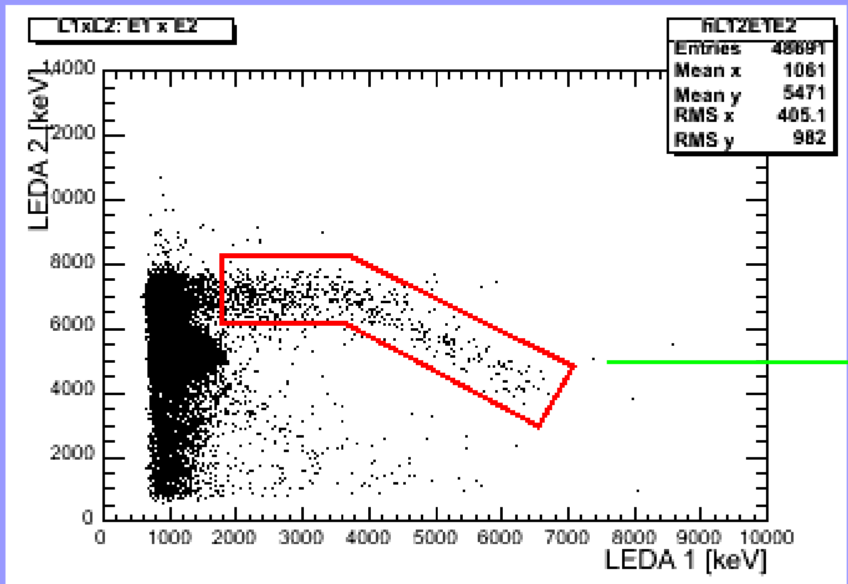
→ clear identification of $^{18}F(p,\alpha)^{15}O$ events

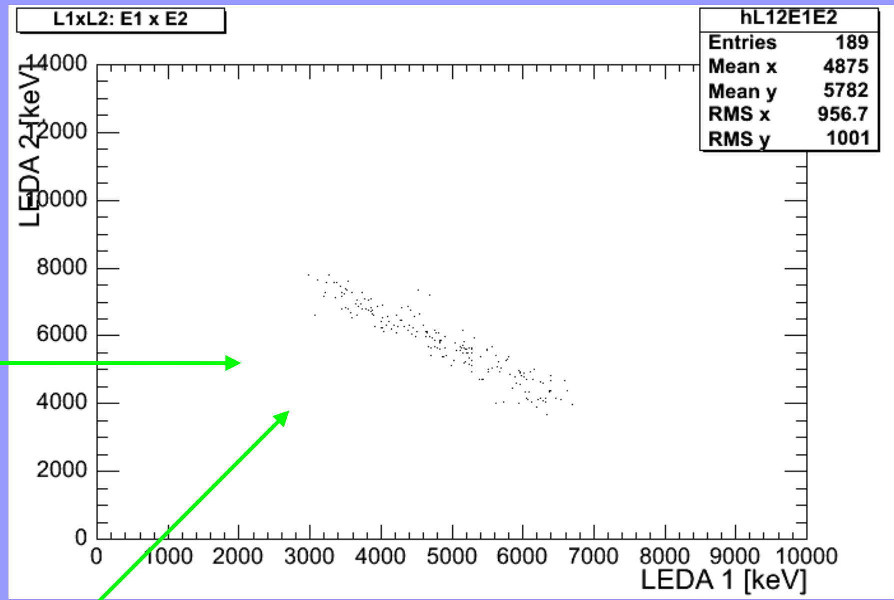
E_{cm} = 665 keV → 4150 events
E_{cm} = 700 keV → 1450 events

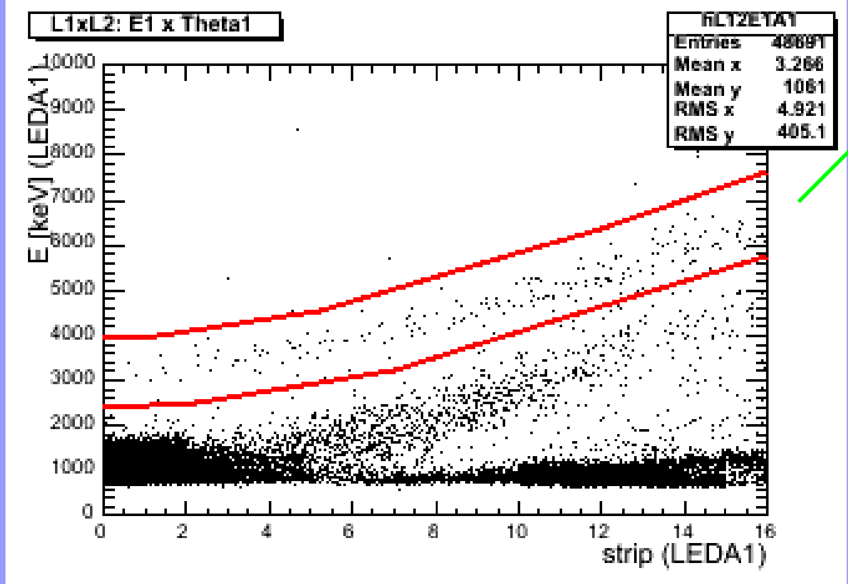




^{18}F + p: α - ^{15}O coincidences OFF resonance







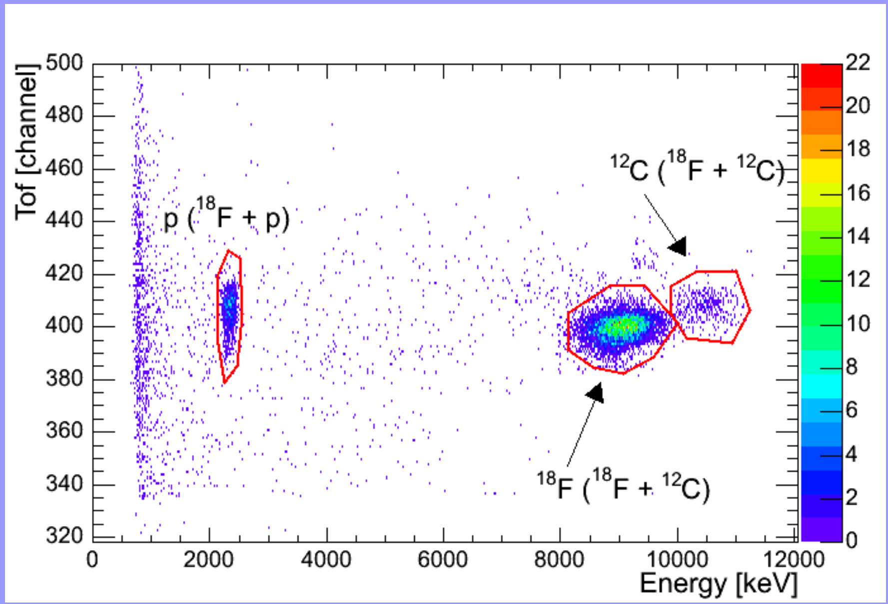
Coincidences LEDA1 x LEDA2

→ very clean selection of events

E_{cm} = 485 keV → 180 events
E_{cm} = 400 keV → 35 events

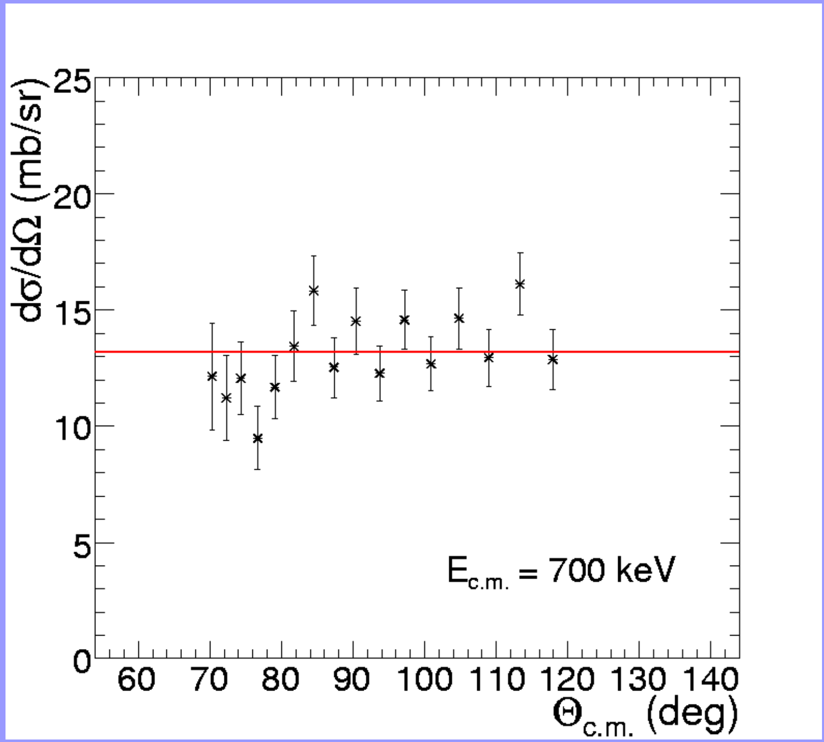
Differential cross-section

Normalization



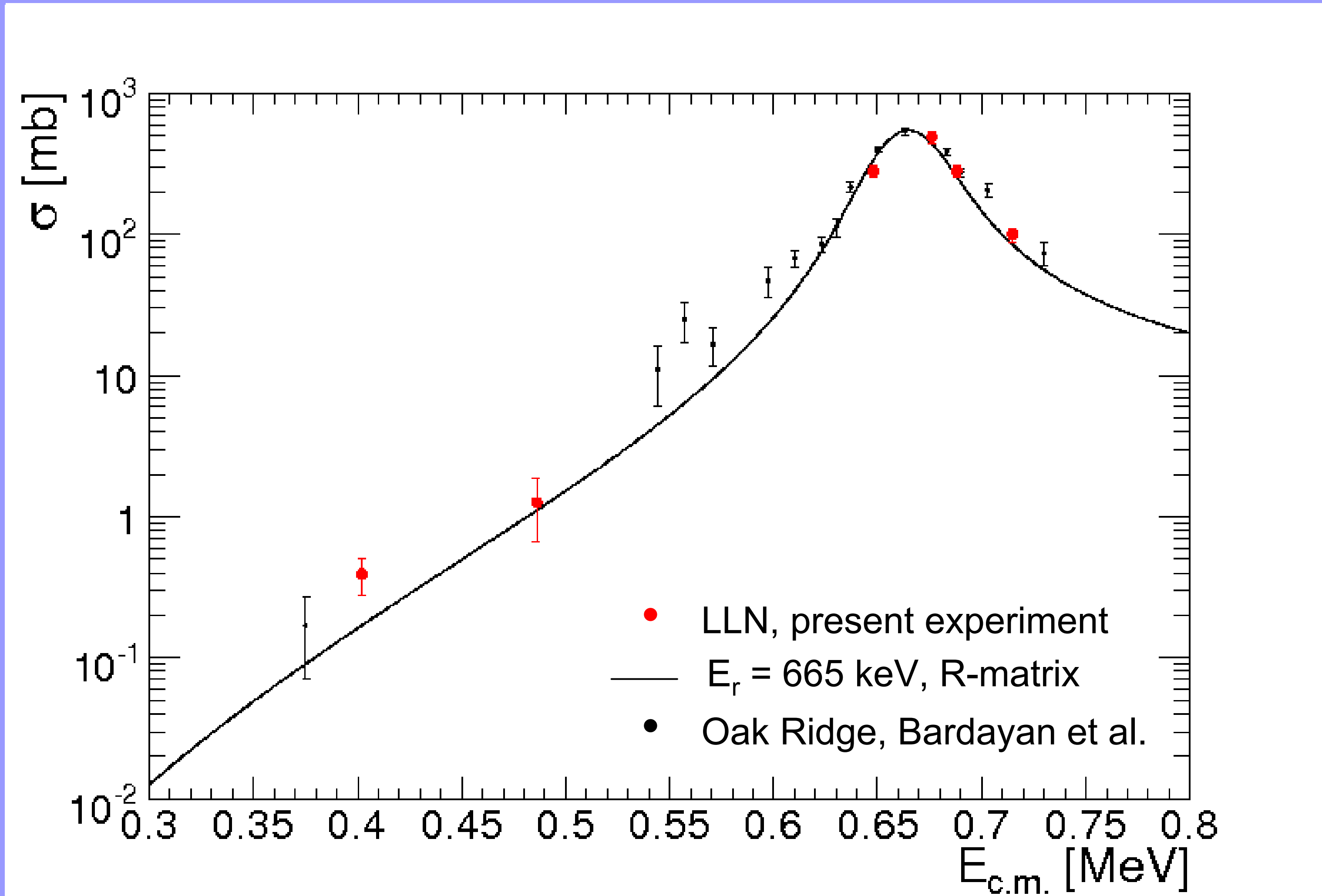
→ Elastic scattering ^{18}F + ^{12}C in LEDA2
+ CH_2 stoechiometry

Differential cross-section



→ good agreement with l = 0
ON resonance 3/2+)
→ checked OFF resonance

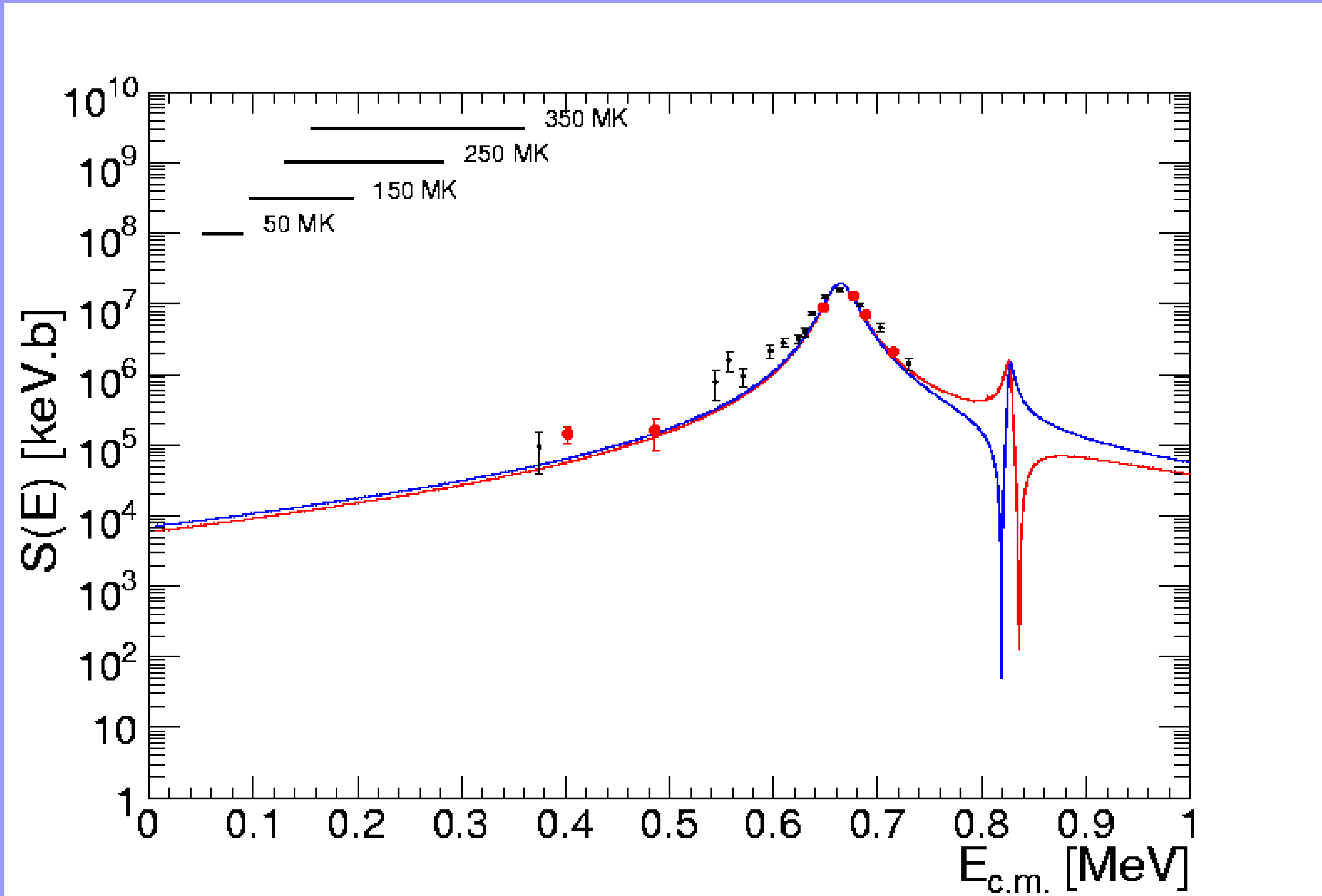
Absolute cross-section



- ➢ Good agreement with the E_r = 665 keV resonance parameters
- ➢ Good agreement with previous experimental data

Interferences between 3/2+ states in ^{19}Ne [1]

- Four 3/2+ resonances: E_r = 8, 38, 665, 827 keV

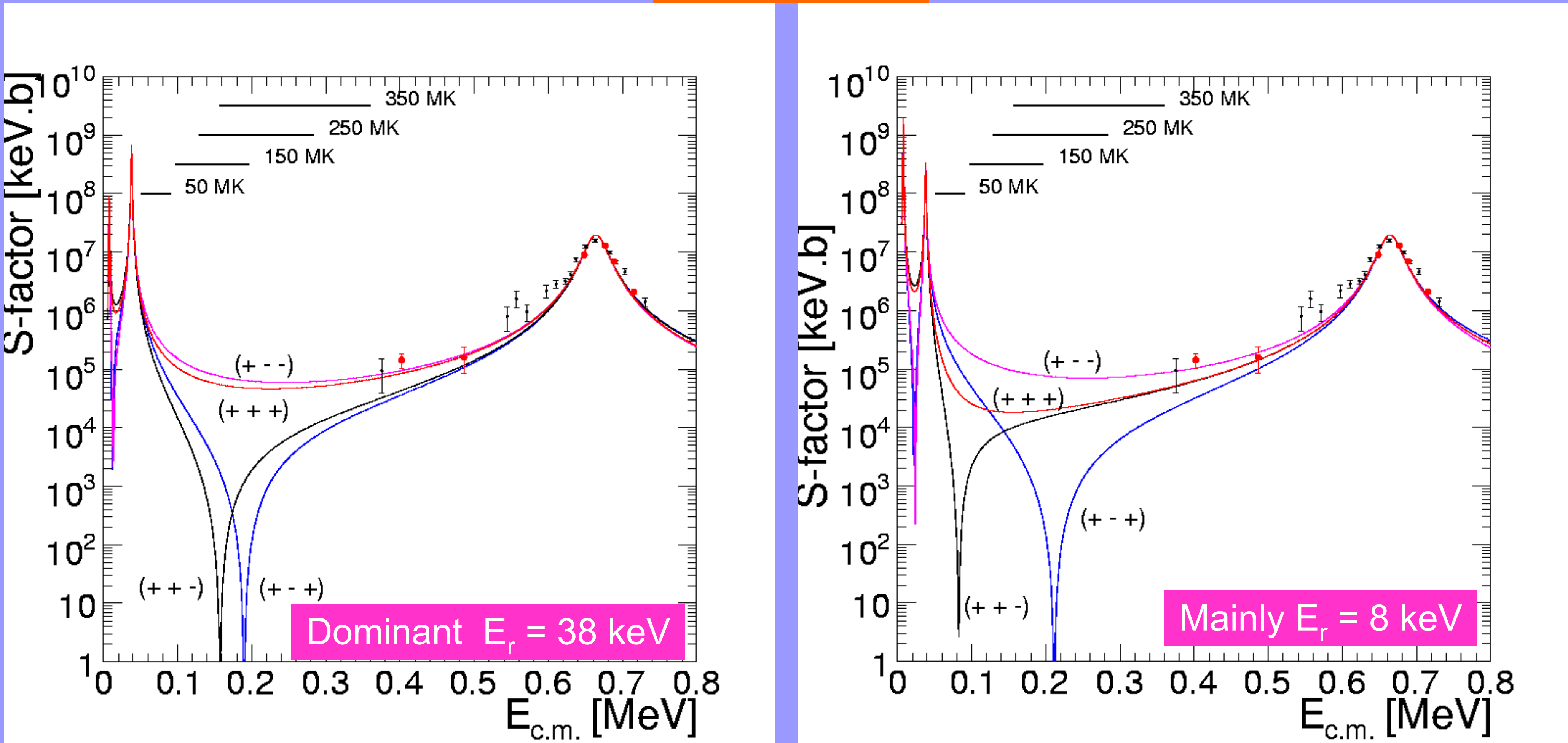


- E_r = 827 keV small α-width (Γ_α = 0.35 keV) → no effect in Gamow peak region

Interferences between 3/2+ states in ^{19}Ne [2]

- E_r = 8 or 38 keV which level is contributing and how?
  → mainly one of the two: $^{18}F(d,p)^{19}F$

Two cases



Conclusion

Present experiment: $^{18}F(p,\alpha)^{15}O$ direct measurement at low energy

Constraints on interference sign for $3/2^+$ levels:

→ complex situation depending on spectroscopic properties of low lying levels (Γ_p, Γ_α)

→ All cases: (+ - -) favored
(+ - +) rejected

→ Dominant E_r = 38 keV:
(+ + +), (+ - -) : Favored (constructive)
(+ - +), (+ + -) : Rejected (destructive)

Also $1/2^+$ levels: see P. Descouvemont's talk

Near perspectives (accepted experiments):

→ Determine properties of low lying resonances

→ Measurements at lower energies (direct or THM)

Collaboration

N de Séréville, C. Angulo, P. Leleux
(CRC / UCL, Louvain-la-Neuve, Belgium)

A. Coc, J. Kiener, A. Lefebvre, V. Tatischeff
(CSNSM, Orsay, France)

F. Hammache
(IPN, Orsay, France)

T. Davinson, D. Robertson
(Univ. of Edinburgh, UK)

A. Laird, S. Fox, P. Mumby-Croft, K. Vaughan
(Univ. of York, UK)

L. Achouri, N. Orr
(LPC, Caen, France)

P. Descouvemont
(PNTPM, ULB, Belgium)

P. Figuera
(INFN, Catania, Italy)

D. Labar
(MIER, UCL, Belgium)

E. Casajeros
(Univ. de Santiago de Compostela, Spain)