Università degli Studi di Enna "Kore"

Istituto Nazionale

di Fisica Nucleare

Laboratori Nazionali del Sud

The MAGNEX-EDEN facility at the INFN- LNS : status

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2 nd COPYGAL Workshop Krakow 5-june-2012

The content of my message

- MAGNEX
- Measurements using Tandem Beams
- The MAGNEX-EDEN facility
- Measurements with CS Beams
- Perspectives

hoping to welcome

New collaborations !!!!

The large acceptance ray-tracing spectrometer MAGNEX. (The builders)

A.C., F.Cappuzzello, M.Cavallaro, A.Foti, A.Lazzaro, S.E.A.Orrigo.

INFN-LNS, Catania, Italy
INFN, Sez. Catania, Catania, Italy
Università di Catania, Catania, Italy

M.R.D.Rodrigues, H.Petrascu, J.S.Winfield

University of S. Paulo, IFUSP, ***Brazil***
NIPNE, Bucarest, Romania
GSI, Damstadt, Germany

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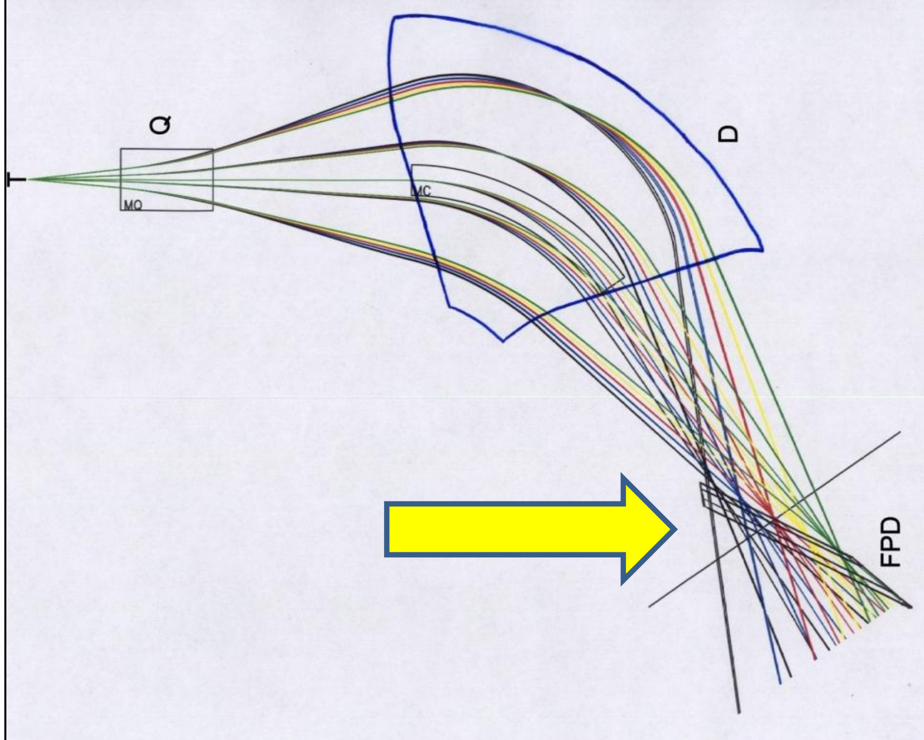


MAGNEX

A.Cunsolo et al., NIMA 481 (2002) 48

A.Cunsolo et al., NIMA 484 (2002) 56

A.Cappuzzello et al., in Magnets,Nova Publisher Inc. N.Y..2011,pp. 1-63.

2 magnetic elements: simple Q-D configuration

- ✓ The quadrupole magnet, vertically focusing the particles
  Aperture radius 20 cm, effective length 58 cm. Maximum field strength 5 T/m

- ✓ The dipole or bending magnet, deflecting trajectories of all particles with a given charge and momentum to the same point in the focal plane
  Mean bend angle 55° with corresponding radius 1.60 m. Maximum field ~ 1.15 T

- ✓ The surface coils, located between the dipole pole faces and the inner high vacuum chamber, giving tunable quadrupolar and sextupolar corrections

Ray-tracing magnetic spectrometer

A spectrometer based on the solution of the motion equation of each detected ion

One needs

- Detailed knowledge of the magnetic field (large scale field measurements and 3D interpolations)
- Algorithms for the high order determination of the inverse transport matrices
- Highly performing detectors for the measurement of the positions and angles at the focus

•V.A.Shchepunov et al., NIMB 204 (2003) 447

•A.Lazzaro et al.,I.P.C.S.175 (2005) 171

•A.Lazzaro et al., NIMA 570 (2007) 192

•A.Cunsolo et al., E.P.J. 150 (2007) 343

•A.Lazzaro et al., NIMA 585 (2008) 136

•A.Lazzaro et al., NIMA 591 (2008) 394

•P.Guazzoni et al., IEEE 55 (2008) 3563

•A.Lazzaro et al., NIMA 602 (2009)494

•F.Cappuzzello et al.NIMA 621(2010)421

•M.Cavallaro et al.NIMA 637(2011) 77

•M.Cavallaro et al.NIMA (2011) in press

MAGNEX

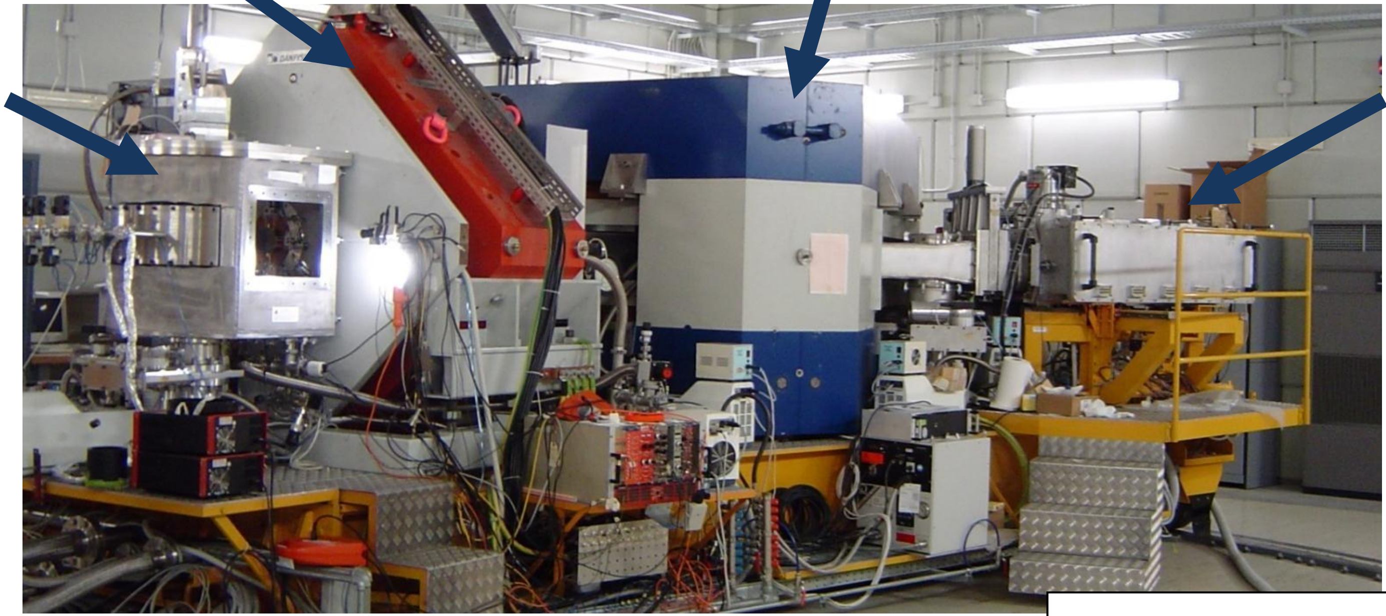
Optical characteristics	Measured values
Maximum magnetic rigidity	1.8 T m
Solid angle	50 msr
Momentum acceptance	± 13%
Momentum dispersion for k= - 0.104 (cm/%)	3.68
First order momentum resolution $R_D = \frac{D}{M_x \Delta x}$	5400

Measured resolution

Energy $\Delta E/E \sim 1/1000$

Angle $\Delta\theta \sim 0.3°$

Mass $\Delta m/m \sim 1/160$



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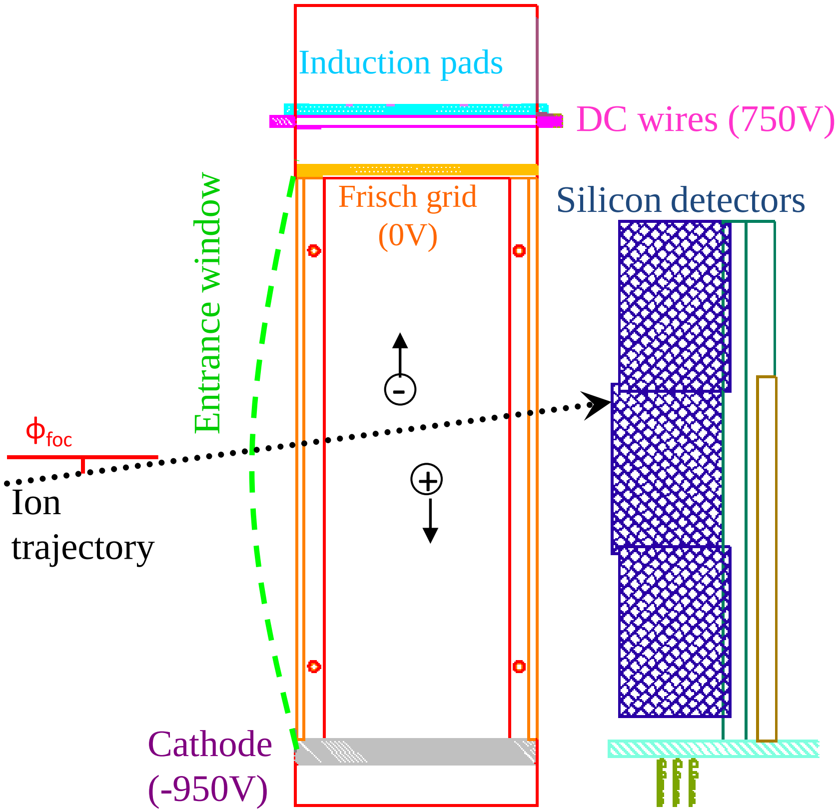
The Focal Plane detector (FPD)



Section view

60 Silicon Detectors
→ E_{res}

5 Proportional Wires
→ ΔE

Ion identification

4 Induction Strip
→ X_1, X_2, X_3, X_4
→ X_{foc}, θ_{foc}

4 Drift Chamber (DC)
→ Y_1, Y_2, Y_3, Y_4
→ Y_{foc}, ϕ_{foc}

Ray-reconstruction

M.Cavallaro et al. Eur. Phys. J. A (2012) 59

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MAGNEX Experimental Program

Main lines

- Sistematic investigation on multineutron tranfers in reactions induced by ^{18}O Tandem and CS beams.

- Measurement of Heavy Ions elastic scattering cross sections up to very backward angles (Nuclear Rainbow)

From June-July 2011

- Measure (p,t) on medium-heavy nuclei at 35MeV

EDEN

- Measure the neutron emission in (^{18}O,^{16}O) and (p,t)

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(^{18}O,^{16}O) reactions

On light nuclei

✓ Preformed neutron pair in ^{18}O (direct transfer enhanced)

WHEN

✓ Brink's matching conditions (D.M. Brink, Phys. Lett. B 40 (1972) 37-40)

✓ Energy range of ~ 3.5 times the Coulomb barrier

THEN

✓Good candidates for $L = 0$ transitions (**GPV**?)

STRATEGY

✓ Detect ejectiles with MAGNEX at forward angles

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Working Group on the (^{18}O,^{16}O) line

F.Cappuzzello[1,2], D.Carbone[1,2], M.Cavallaro[2], A.Cunsolo[1,2], A.Foti[1,3], M.Bondì[1,2], G.Santagati[1,2], G.Taranto [1,2], R.Linares[4]

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2. *Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud, Italy*
3. *Istituto Nazionale di Fisica Nucleare – Sezione Catania, Italy*
4. *University of Sao Paulo, Institute of Nuclear Physics, Sao Paulo, Brazil*

A.Bonaccorso and C.Rea

Istituto Nazionale di Fisica Nucleare – Sezione di Pisa

F. Azaiez, S.Franchoo, M.Niikura, J.A.Scarpaci, M. Assie

CNRS - IN2P3 – Institut de Physique Nucléaire d'Orsay, France

J. Lubian

Universidade Federal Fluminense, Niteroi, Brazil

Recently
Fortunato , Vitturi - Padova
and
S.Lenzi -Milano

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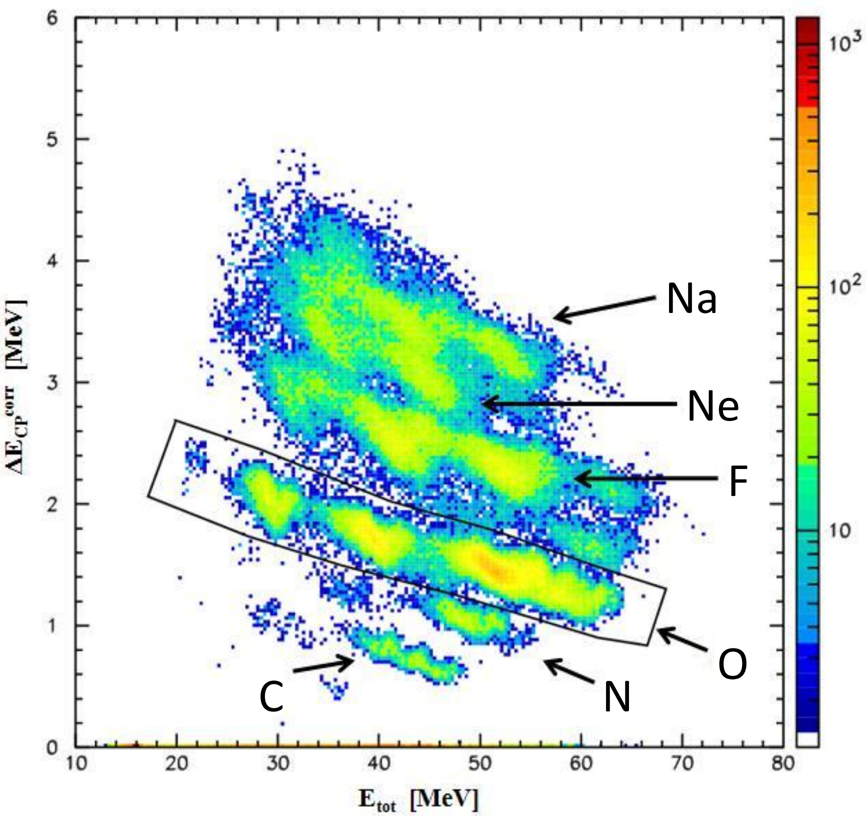
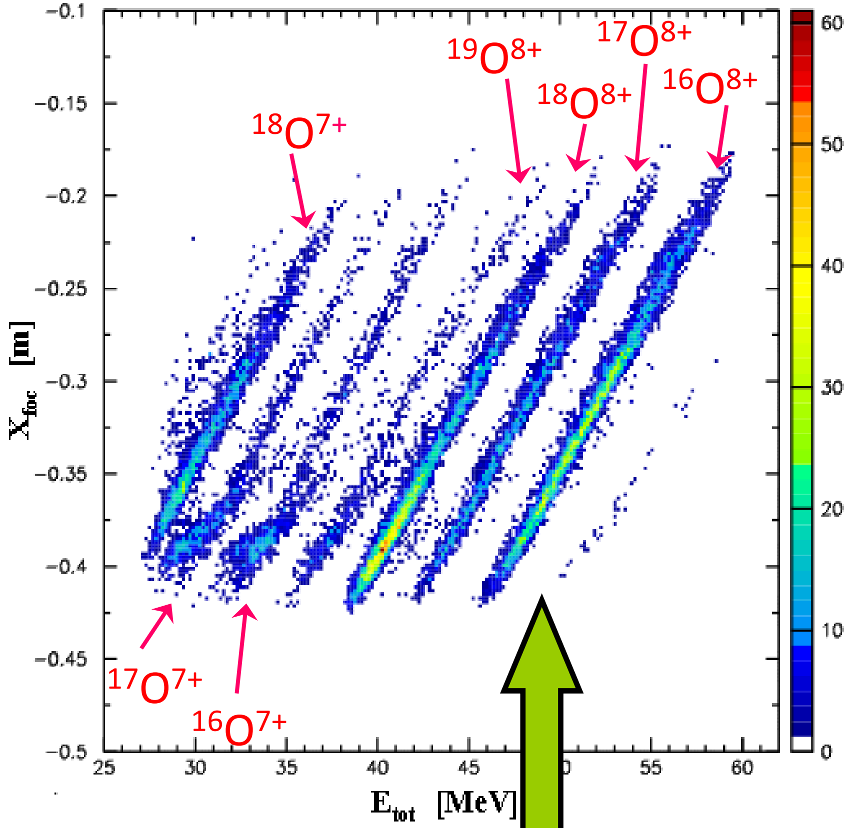
Particle Identification (without TOF)





Very strong ^{16}O channell

$$B\rho \propto \frac{p}{q}$$

$$v^2 \propto \frac{2E}{m}$$

$$X_{foc} \propto \frac{\sqrt{m}}{q}\sqrt{E_{tot}}$$

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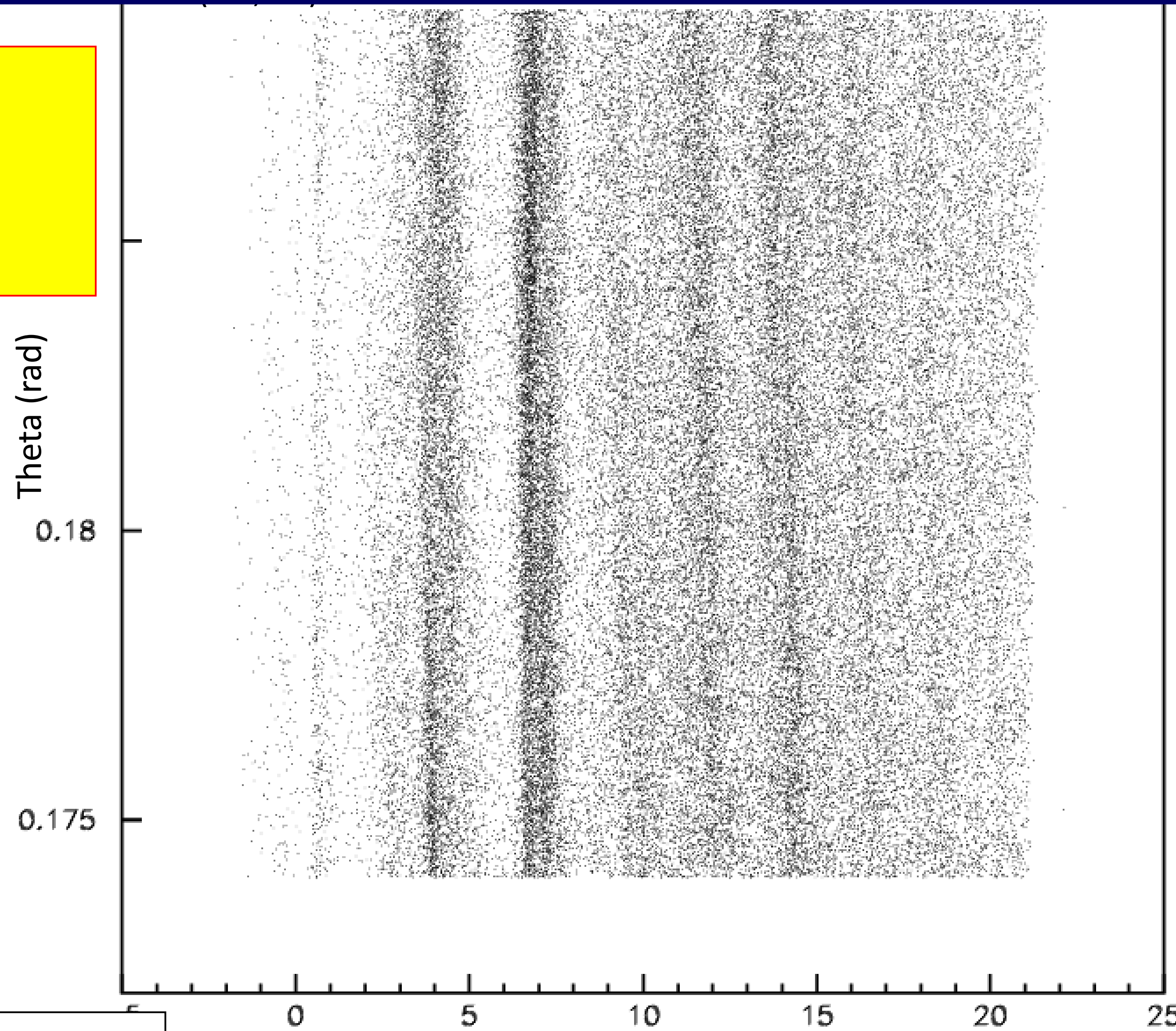
Reconstructed Energy-Angle Spectrum

^{16}O Angle
versus
^{15}C Excitation energy
Spectrum



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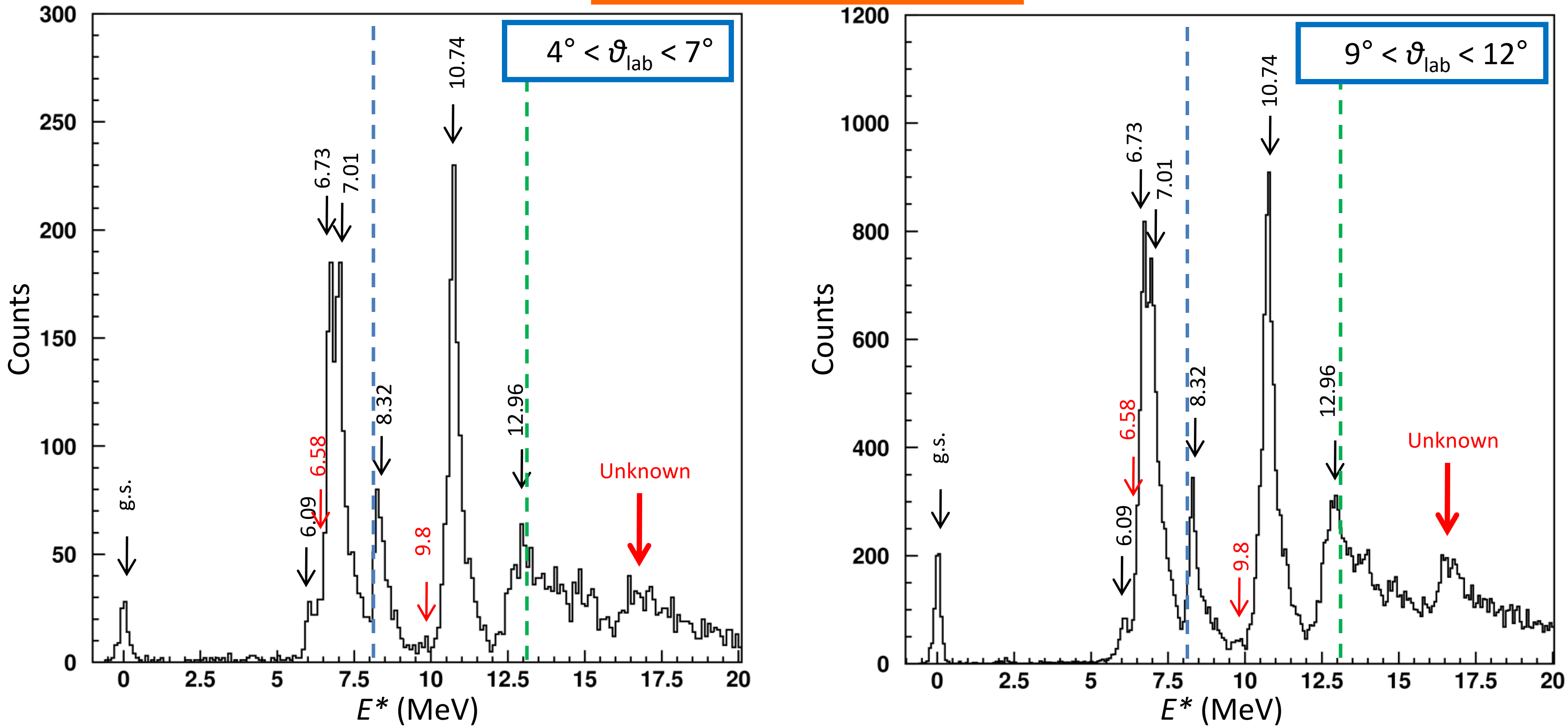
Energy spectra

$^{12}C(^{18}O,^{16}O)^{14}C$



$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{g.s.}(0^+)$	L = 0	$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{7.01}(2^+)$	L = 2
$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{6.09}(1^-)$	L = 1	$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{8.32}(2^+)$	L = 2
$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{6.58}(0^+)$	L = 0	$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{9.8}(0^+)$	L = 0
$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{6.73}(3^-)$	L = 3	$^{12}C_{g.s.}(0^+) \rightarrow ^{14}C_{10.74}(4^+)$	L = 4

S_n = 8.17 MeV

S_{2n} = 13.12 MeV

$^{12}C(t,p)^{14}C$

S.Mordechai, et al., Nucl. Phys. A301 (1978) 463

W. Vo

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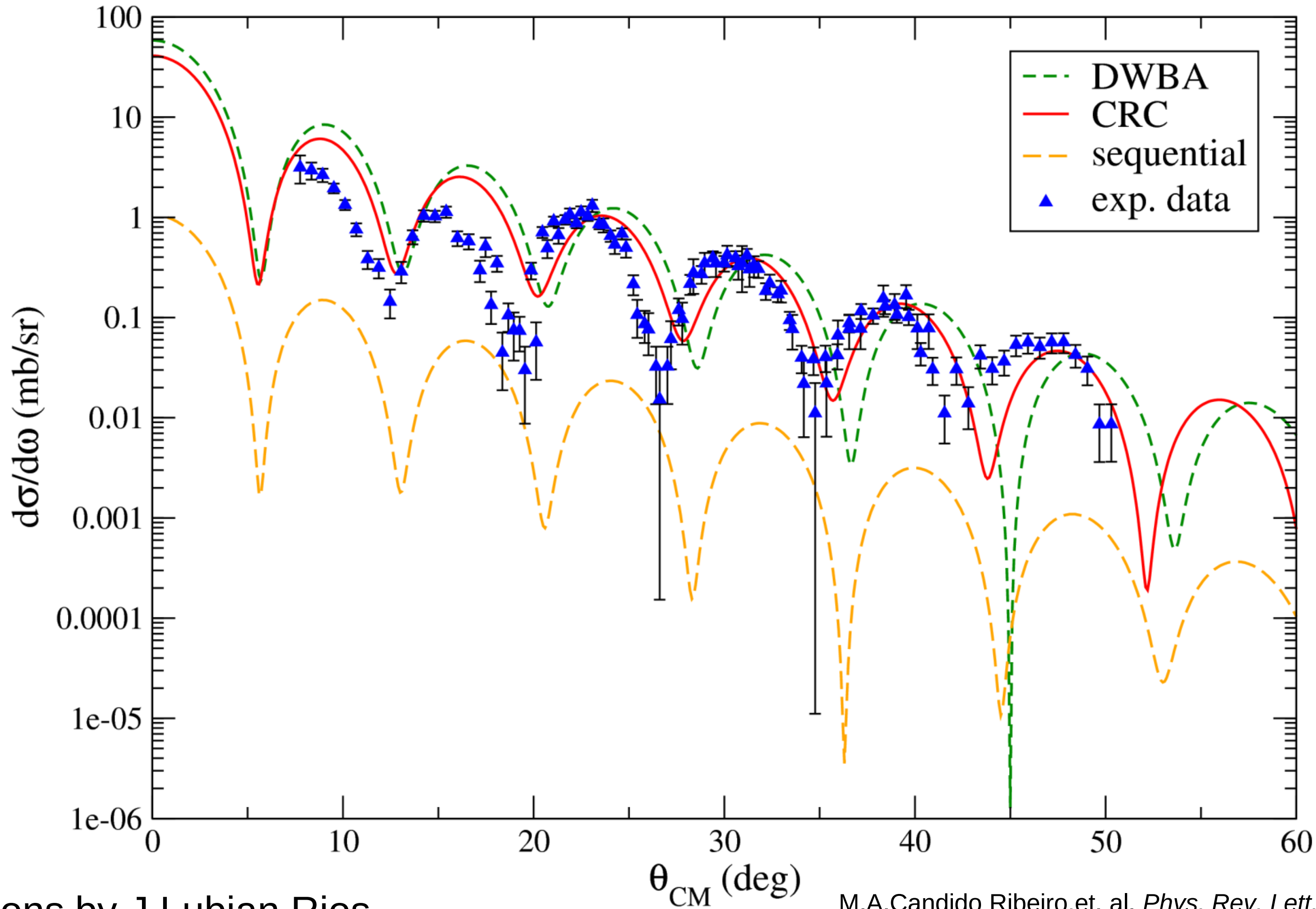
DWBA & CRC calculations

$^{12}C_{g.s.}(0^+) \rightarrow {}^{14}C_{g.s.}(0^+)$



Calculations by J.Lubian Rios
UFF - Niteroi

M.A.Candido Ribeiro,et. al. *Phys. Rev. Lett.* **78** (1997)3270
L.C..Chamon, D.Pereira, et. al. *Phys. Rev. Lett.* **79** (1997)5218
L.C.Chamon, et. al. *Phys. Rev. C* **66** (2002) 014610

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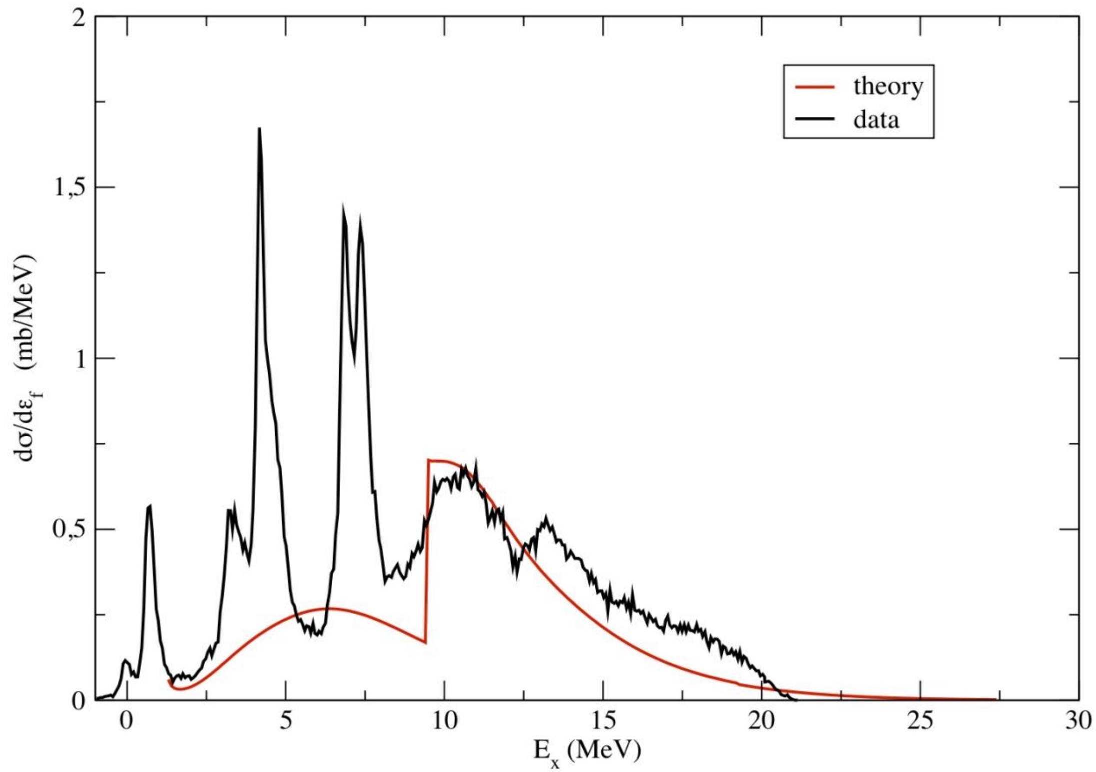
Breakup calculations

$^{13}C(^{18}O,^{16}O)^{15}C$

$7° < \theta_{lab} < 18°$

Semiclassical approximation
for the relative motion

A.Bonaccorso and C.Rea
(INFN-Sezione di Pisa)



Sequential break-up (two independent break-up processes)

1) $S_n < E_x < S_{2n}$: $^{18}O + ^{13}C \rightarrow ^{16}O + ^{14}C + n$
2) $E_x > S_{2n}$: $^{18}O + ^{13}C \rightarrow ^{16}O + ^{13}C + n + n$

$S_n = 1.2$ MeV
$S_{2n} = 9.4$ MeV

A.Cappuzzello et al. Phys.Lett B 711 (2012) 347

Giant Pairing Vibrations?

Analogy between p-h, p-p and h-h excitations

Coherent high lying p-h excitations → Giant Resonances

Coherent high lying p-p or h-h excitations → Giant Pairing Vibrations (*GPV*)

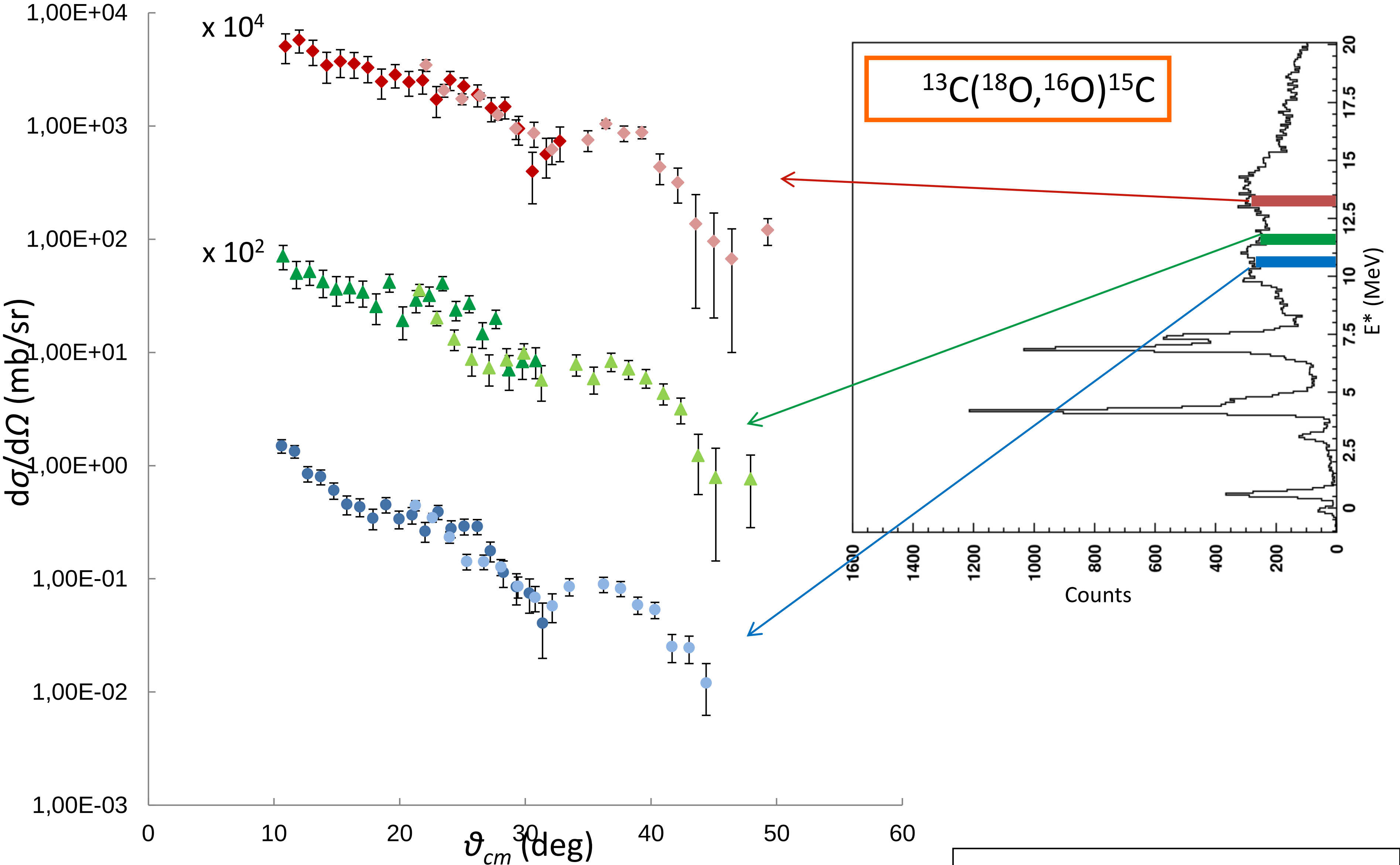
R.A. Broglia and D. Bes *Phys*. *Lett.* B 69 (1977) 129-133

Predicted properties of the *GPV*

- Energy ~ 15 – 20 MeV (~70 $A^{-1/3}$)
- FWHM ~ 7.8 $A^{-1/3}$
- Strength ~ comparable with that of the strongly excited low lying pair vibrations
- Excited via $\Delta L = 0$ angular momentum transfer

NEVER OBSERVED !

Preliminary angular distributions



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Conclusions and Outlooks (I)

- ✓ A broad resonance observed in ^{14}C and ^{15}C spectrum populated via (^{18}O,^{16}O) at 84 MeV Compatible with *GPV*?
- ✓ Strong evidence of the one step transfer channel
- ✓ Clear signatures of neutron-neutron correlations
- ✓ Analysis of the angular distributions in progress
- ✓ CRC and CDCC calculation on the way (IFUSP – S. Paulo, UFF – Niteroi)
- ✓ Data reduction in progress for:
  - other targets measured (^{9}Be, ^{11}B, ^{28}Si, ^{58}Ni, ^{64}Ni, ^{120}Sn, ^{208}Pb)
  - other angular settings 6°, 12°, 18°, 24°

AND …..

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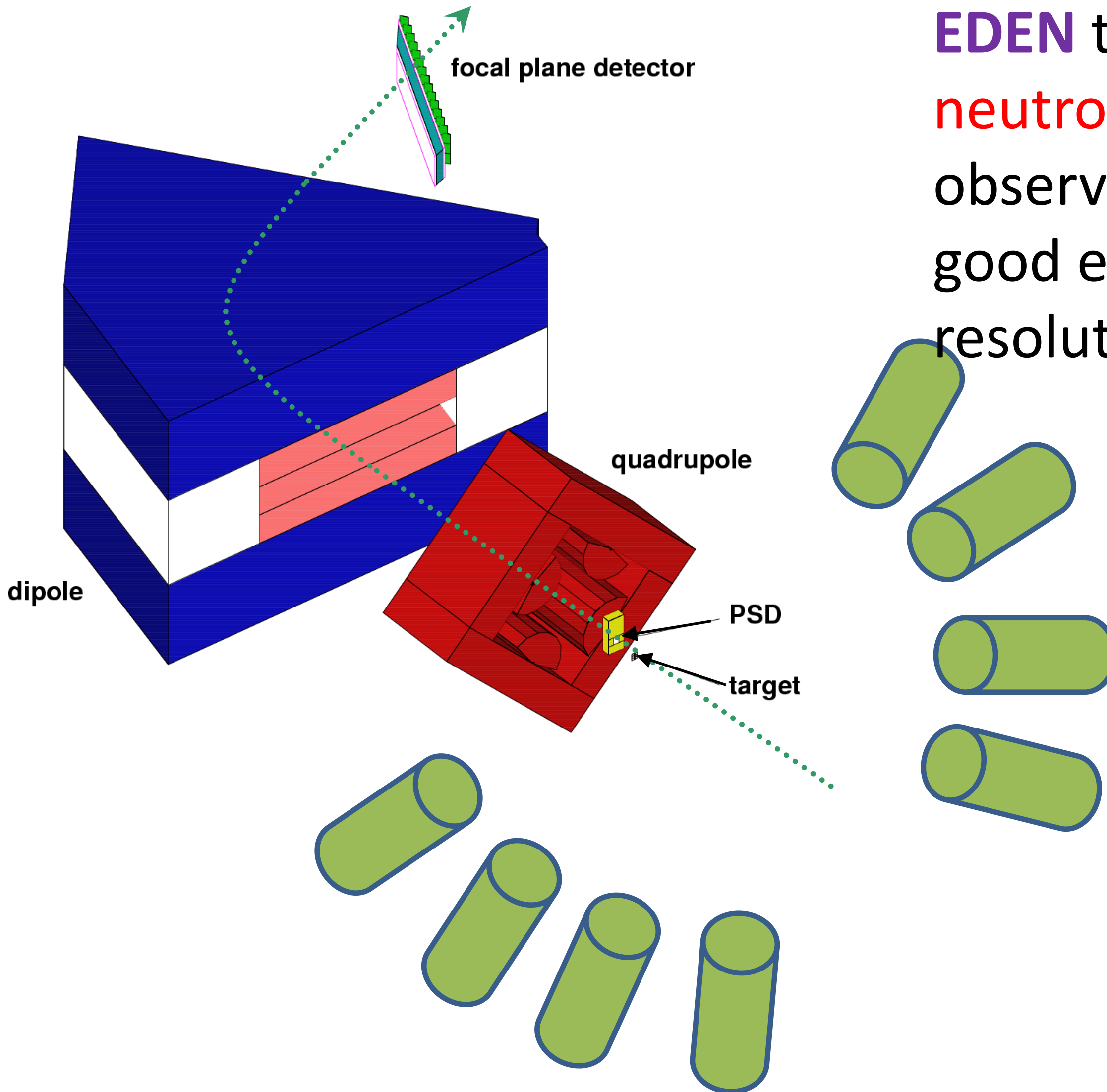
MAGNEX + EDEN



MAGNEX to measure high resolution energy spectra for well identified reaction products

EDEN to study the decaying neutrons emitted by the observed resonances with good efficiency and energy resolution

Unique facility to study the resonant states of neutron rich nuclei (low separation energy)

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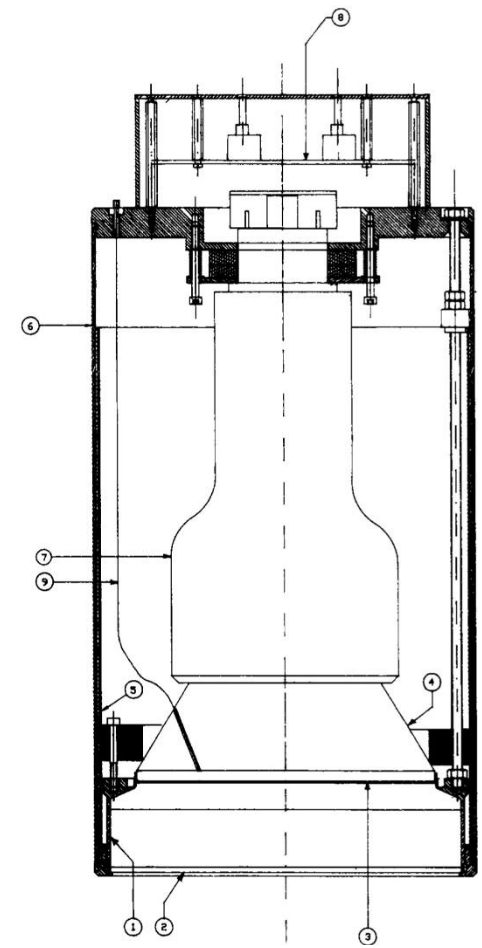
The IPN-ORSAY EDEN neutron multidetector

H. Laurent et al., NIM A326 (1993) 417-525

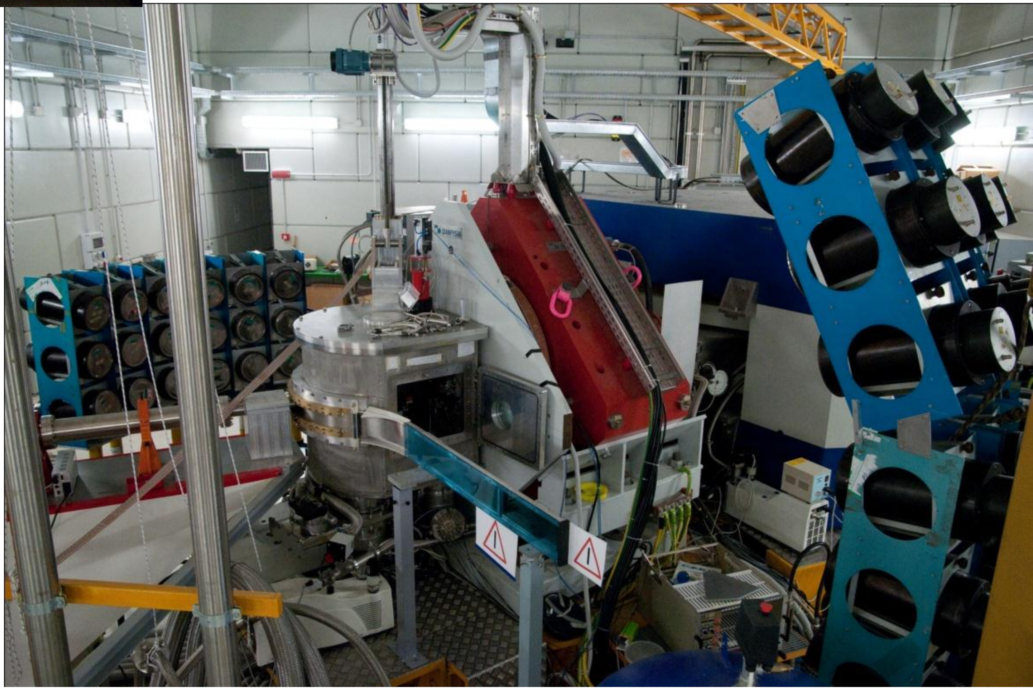
- ❖ 40 liquid scintillator detectors (NE213)
- ❖ Possibility of n - γ discrimination by pulse shape analysis
- ❖ Time resolution of 0.9 ns for TOF measurements
- ❖ Typical energy resolution at a 1.7 m distance from the target: 60 keV for 850 keV neutrons and 500 keV for 6 MeV neutrons
- ❖ Intrinsic efficiency ~ 50% for 1 MeV and 30% for 6 MeV neutrons
- ❖ Mechanical assembly easily configurable for different experimental requirements
- ❖ New Pulse Shap Analysis (Caen-BaFPRO)



June 2011

MAGNEX + EDEN

commissioning



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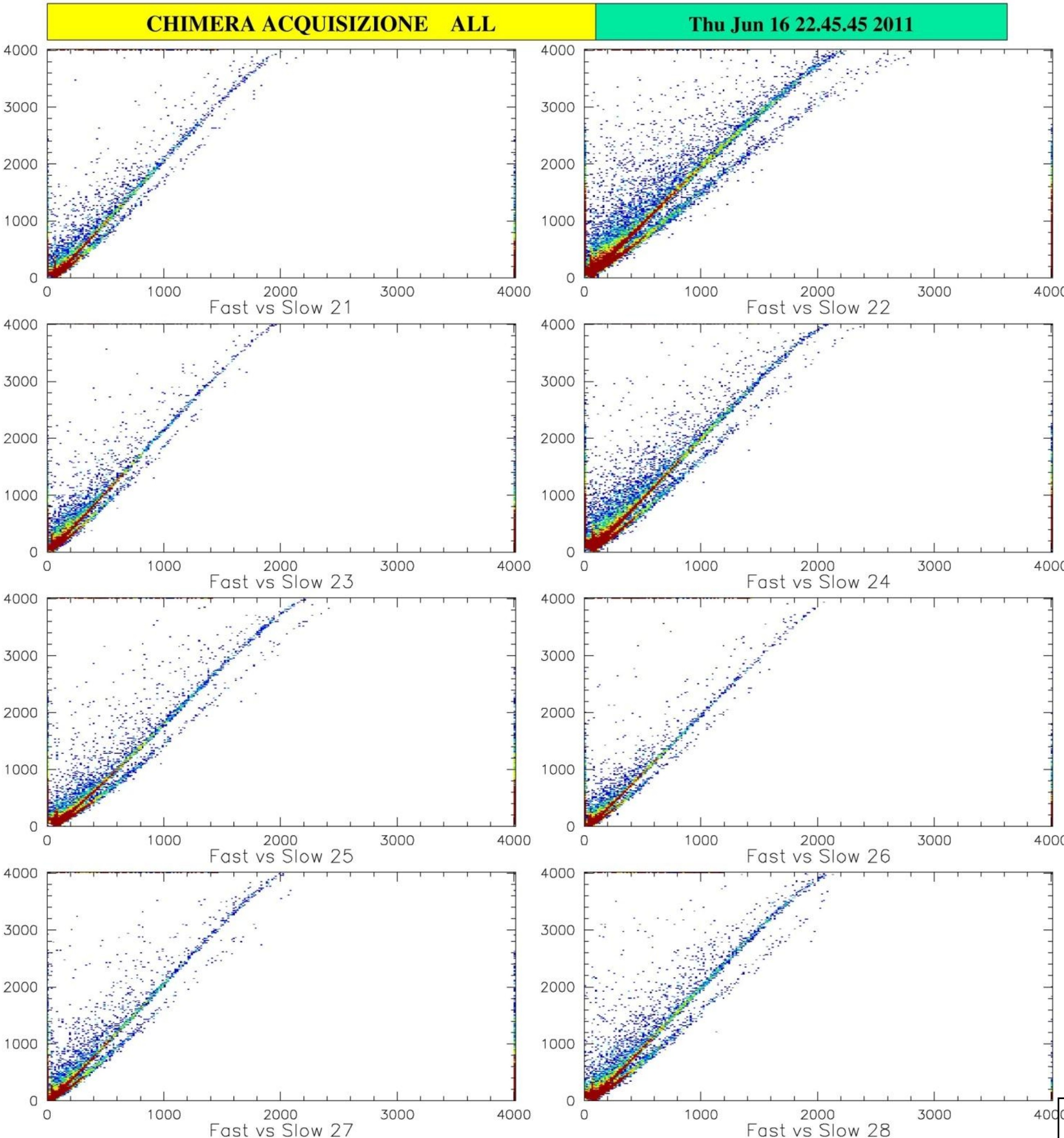
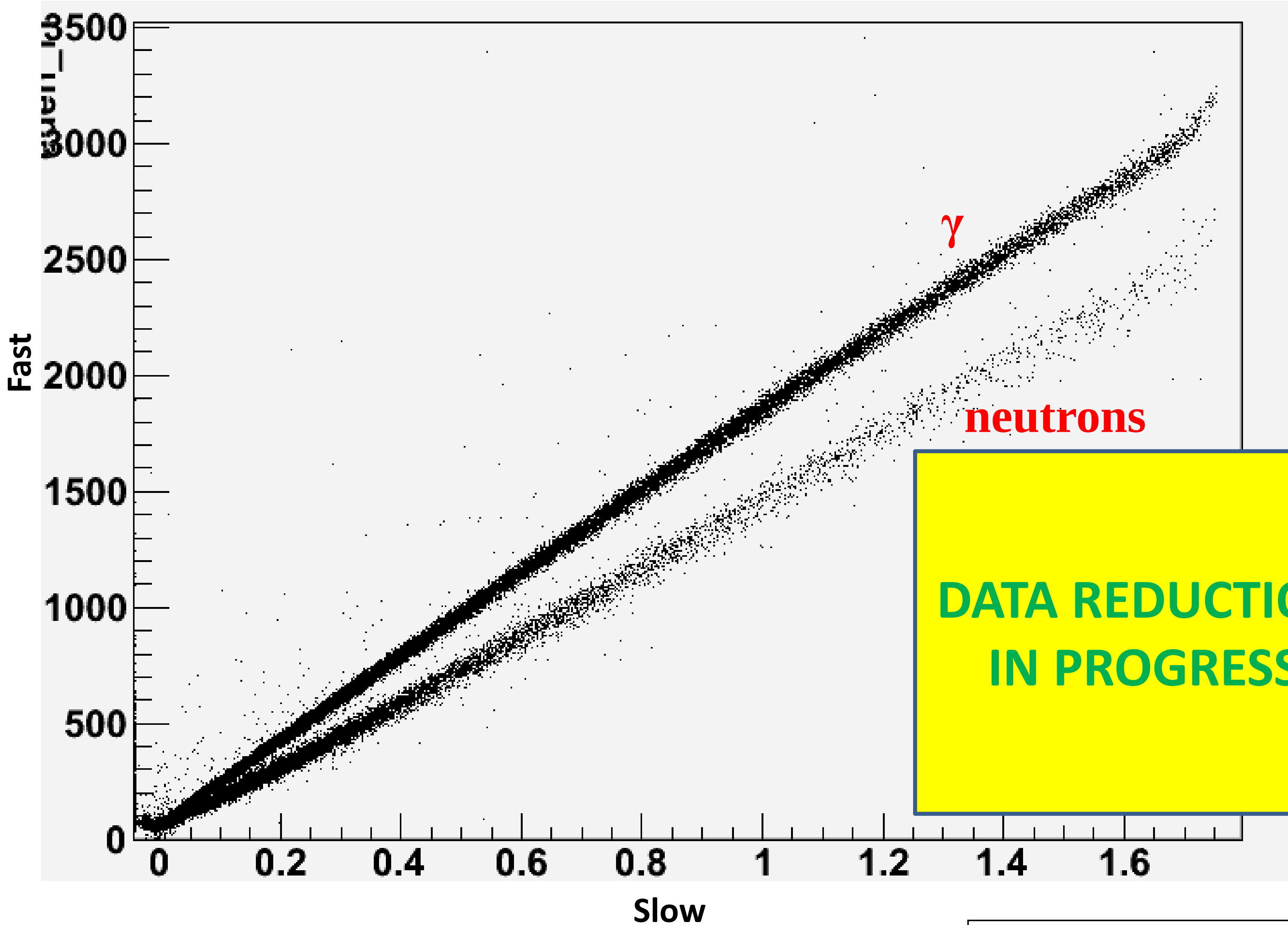


On-line
Fast vs. Slow

Good n-γ
discrimination

n-γ discrimination



DATA REDUCTION IN PROGRESS

Working Group on the $^{120}Sn(p,t)^{118}Sn$ line

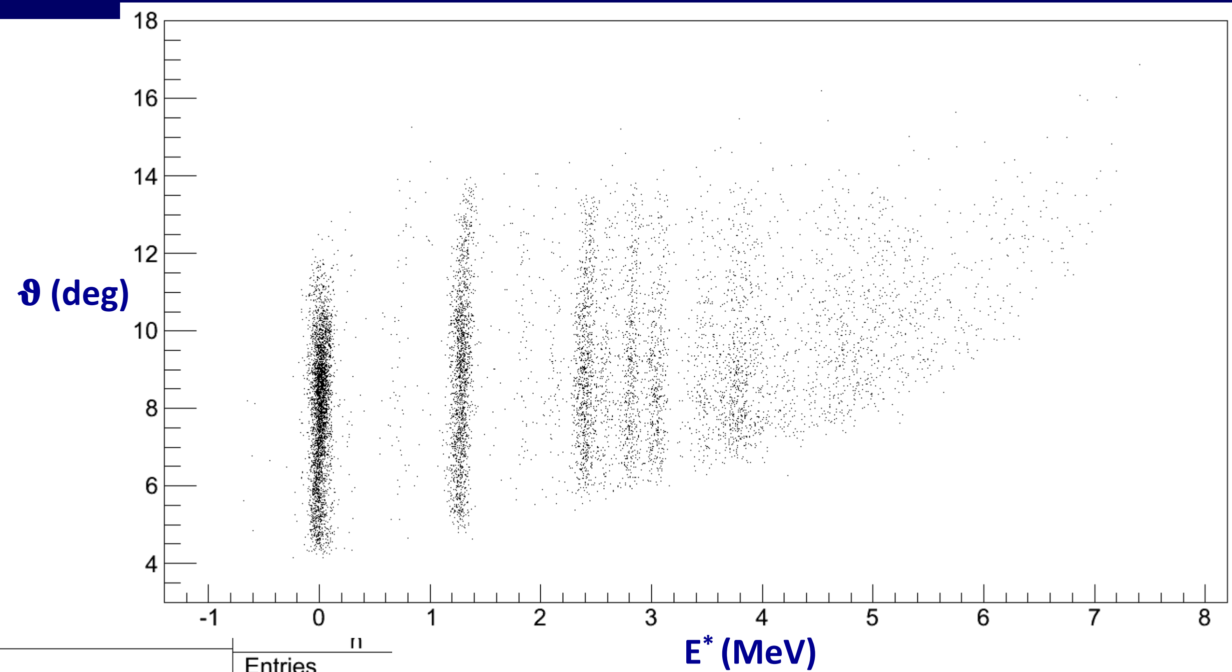
Discovering Giant Pairing Vibrations with the (p,t) reaction at zero degree

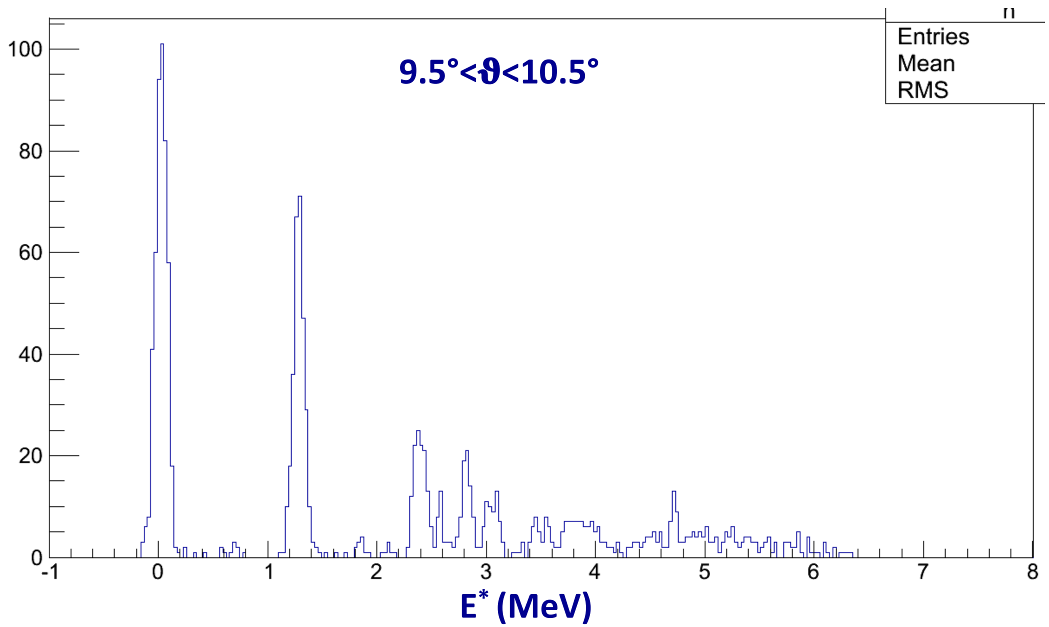
J.A. Scarpaci, E. Khan, M. Assié, F. Azaiez, D. Beaumel, S. Franchoo, B. Mouginot, I. Stefan, F. Cappuzzello, D. Carbone, M. Cavallaro, A. Cunsolo, A. Foti, M. Bondì, G. Santagati, G. Taranto, R. Neveling, F.D. Smit

Experiment done at Ep=35 MeV (CS beam)
Tritons detected with MAGNEX
Data reduction in progress

Working on the $^{120}Sn(p,t)^{118}Sn$ line …

MAGNEX Setting 1
8 degree
from g.s. to 7 MeV





First result !

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What else has been measured with MAGNEX?

The H.I. CS beams can be used?

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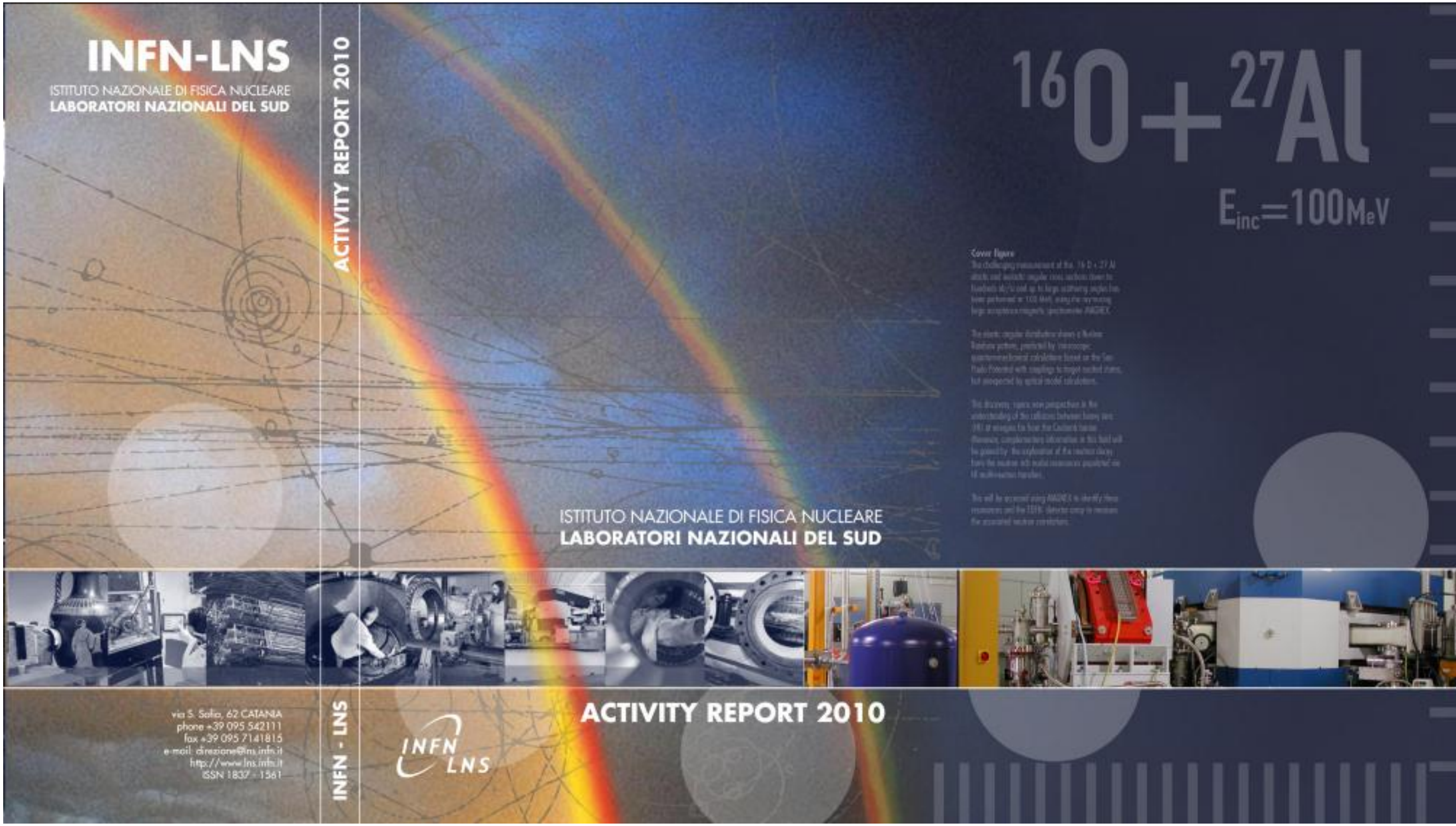
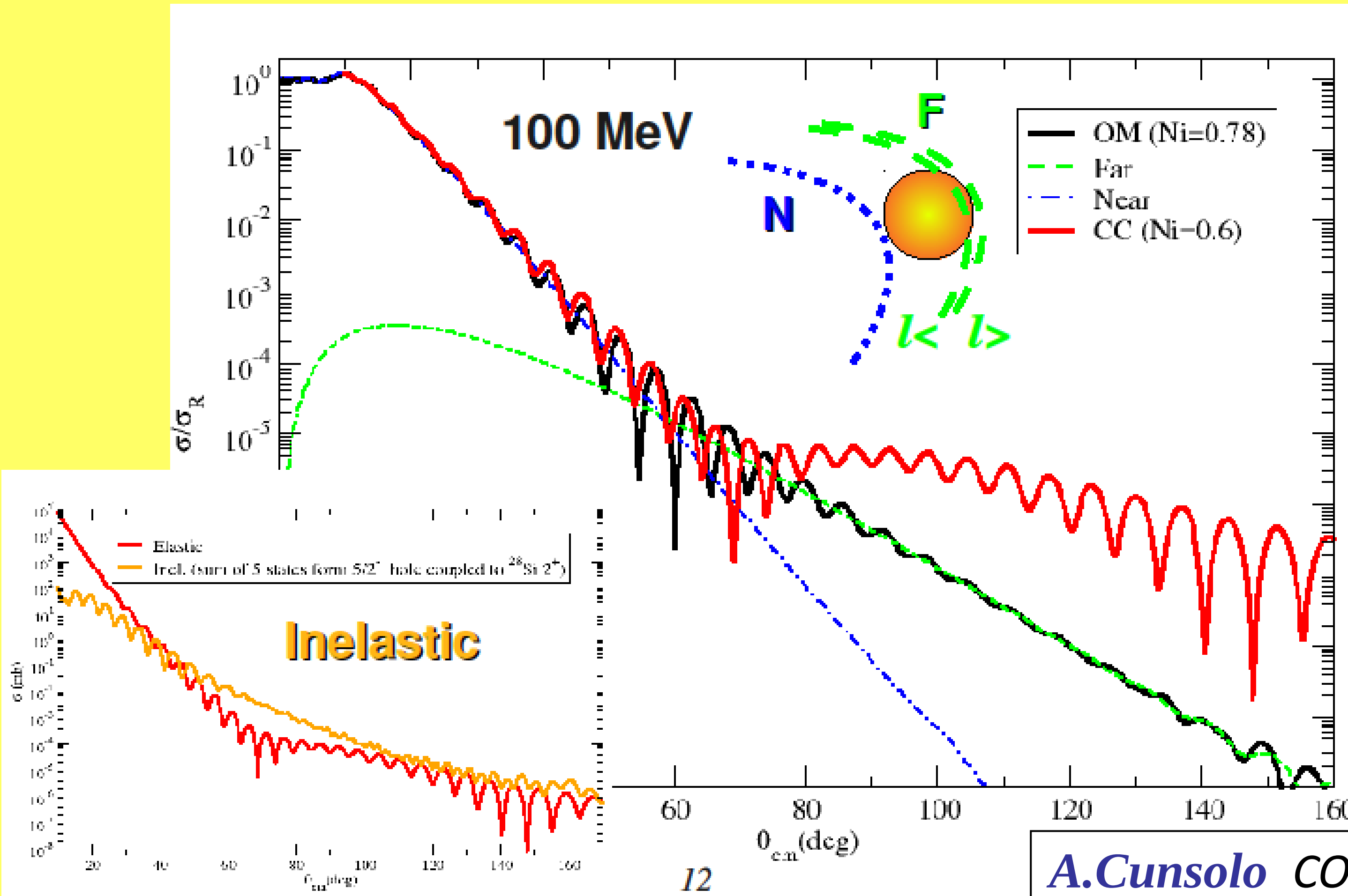
Nuclear Rainbow



In collaboration with S.Paolo and Niteroi (Brasil)

The prediction of nuclear rainbow in $^{16}O+^{27}Al$



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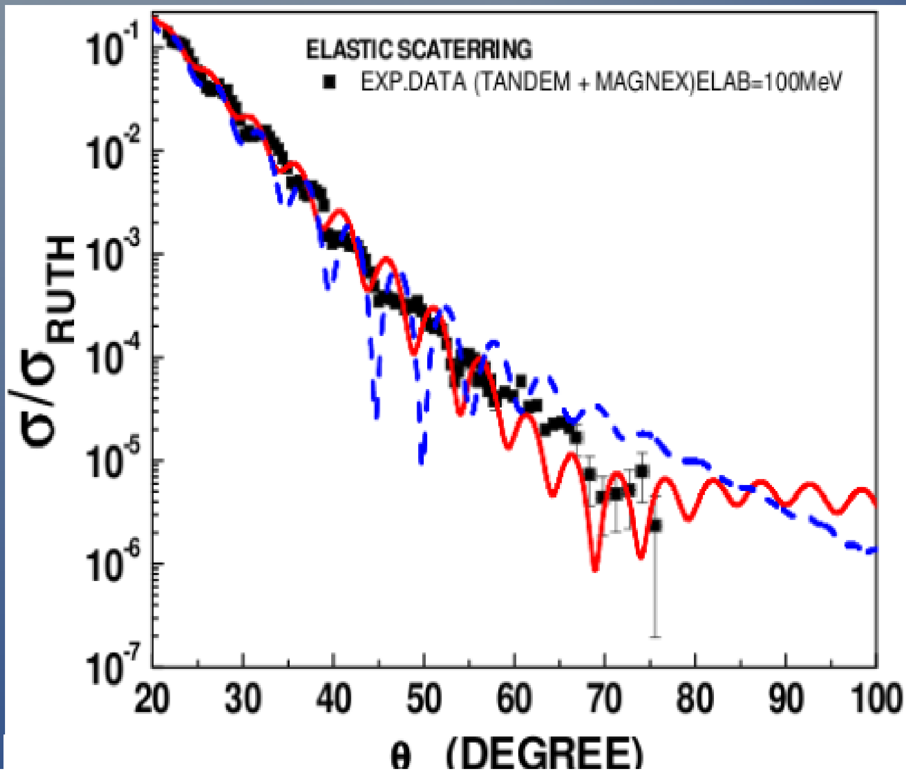
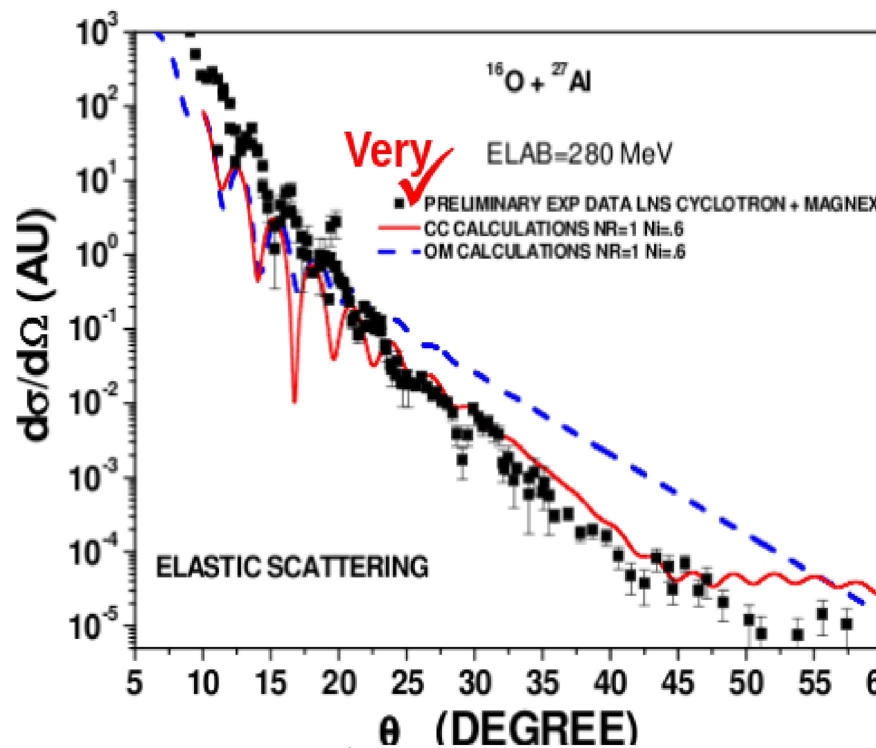
Rainbow measurements at LNS

$^{16}O + {}^{27}Al$ @ 100 (Tandem) & 280 MeV (CS)





M.Cavallaro et al. ,Nucl. Instr.Meth.A 638 (2011) 46;
D.Pereira et al. Phys.Lett. B 710 (2012) 426

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Experimental investigation of rainbow-like scattering in the elastic and alpha transfer channels of the $^{16}O+^{60}Ni$ reaction

- F. Cappuzzello[a,b**] D. Pereira[c *], C. Agodi[a,b], M.Bondi[a,], D. Carbone[a,b], M. Cavallaro[a], A. Cunsolo[a,b], L.C. Chamon[c], M. De Napoli[a], P.N. Faria[d], A. Foti[b,c],L.R. Gasques[c], P.R.S. Gomes[d,] R. Linares[d], J. Lubian[d], N.H. Medina[c], D. Nicolosi[a], J.R.B. Oliveira[c], M.D. Rodrigues[c], S. Tropea[a]

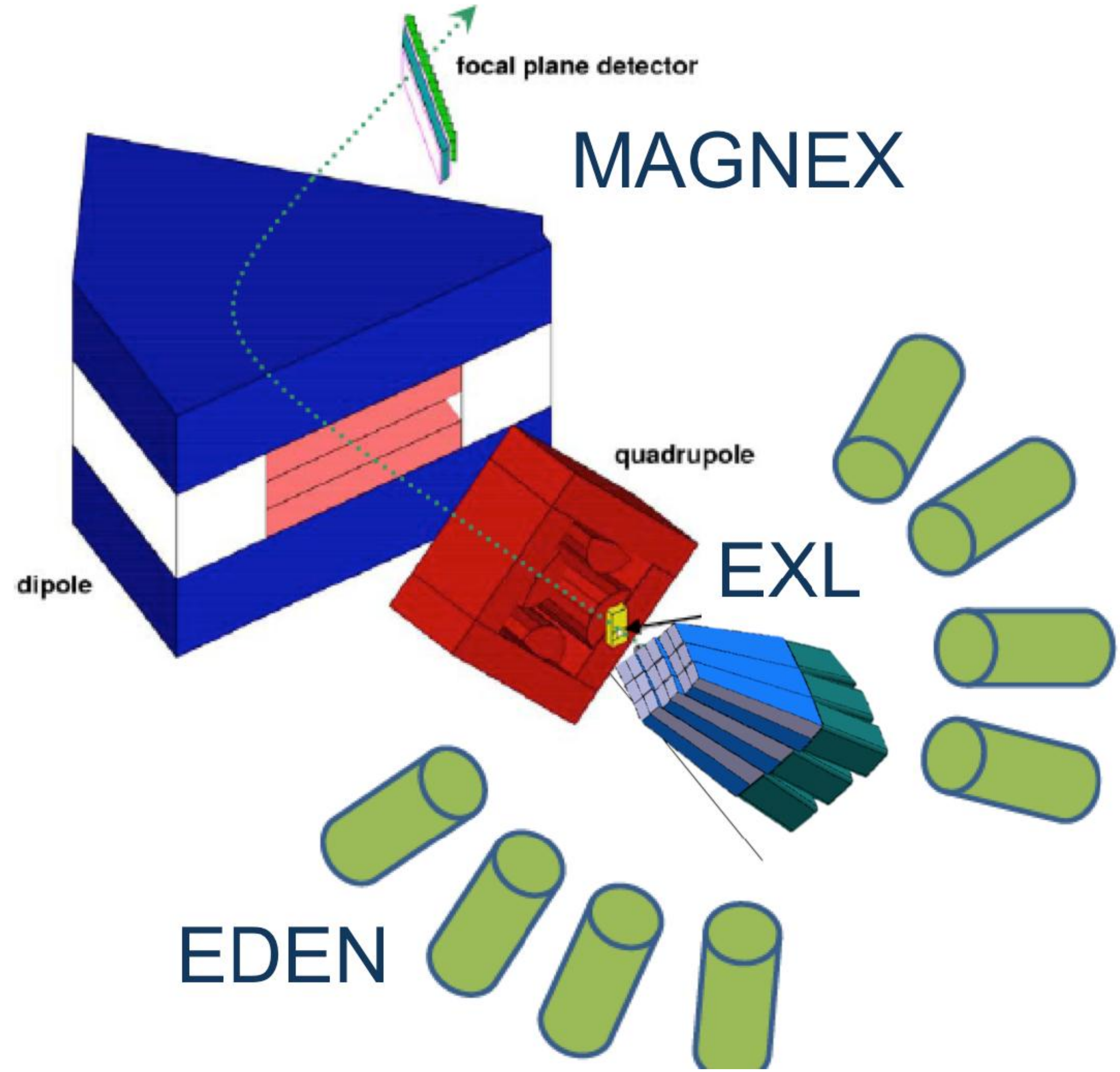
- a) INFN - Laboratori Nazionali del Sud, Via S. Sofia 62, I-95125 Catania, Italy
- b) Dipartimento di Fisica e Astronomia, Università di Catania, Via S. Sofia 64, I-95125 Catania, Italy
- c) Instituto de Fisica Nuclear, Universidade de Sao Paulo, Brasil
- d) Instituto de Fisica, Universidade Federal Fluminense, Niteroi, Rio de Janeiro, Brazil

New PROPOSAL (JUNE 2012)

New proposal : $^{12}C + ^{16}O = ^{15}O + n + \gamma$ @21 – 35AMeV

One –neutron removal from ^{16}O : study of the reaction mechanism

IPN Orsay; CEA Saclay, Leuven, LNS-INFN, RIKEN, Peking University Collaboration



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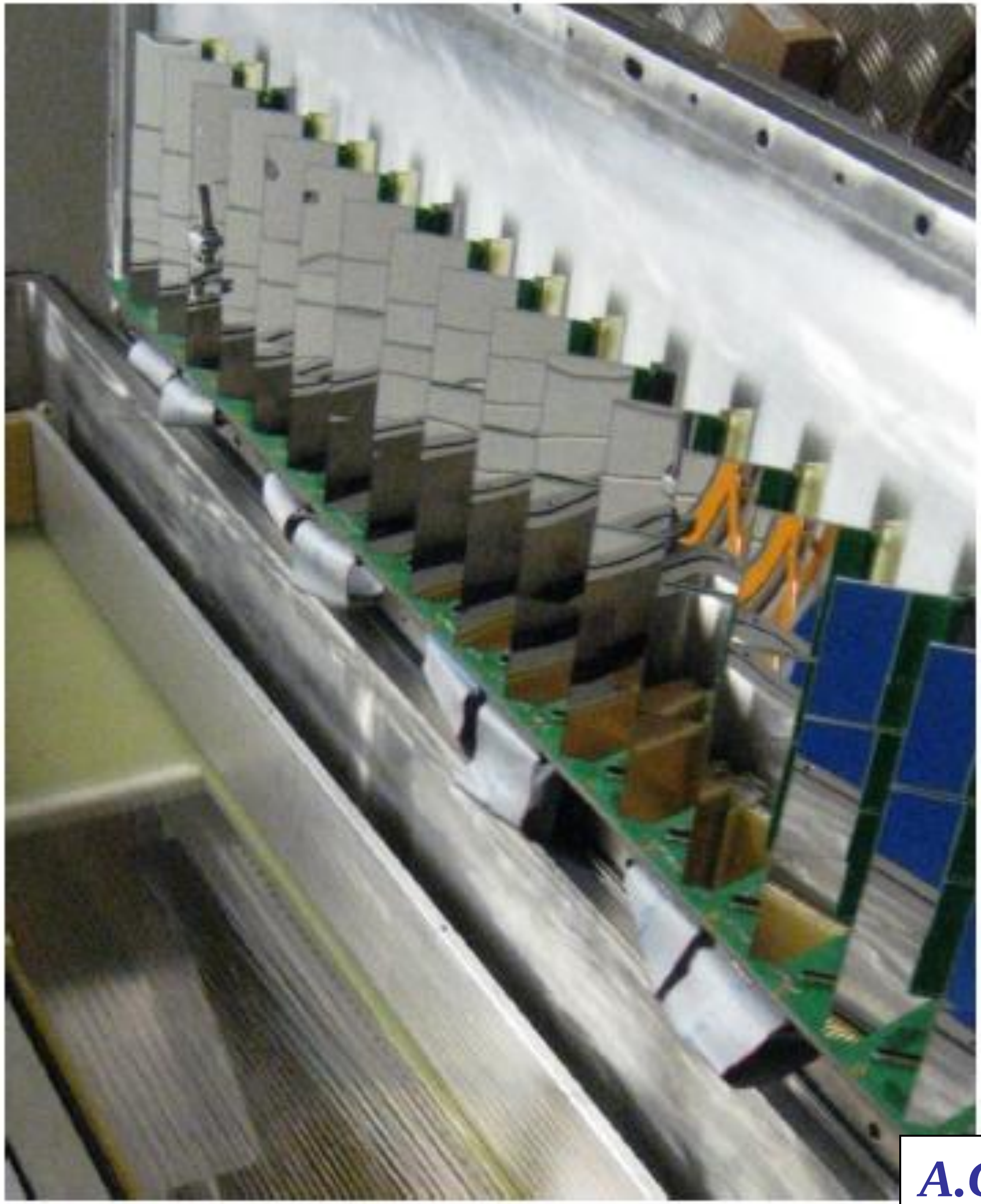
MAGNEX FPD (Silicon detectors)



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Two neutron transfer reactions

- Can test the nn-pairing interaction
- Possible direct transfer of one correlated pair

Direct pair transfer — VS — Transfer of uncorrelated neutrons

Strong enhancement of the *L*=0 channel

Giant Pairing Vibration (GPV)

R.A. Broglia and D. Bes *Phys. Lett.* B 69 (1977) 129-133

Pairing vibrations observed experimentally

R. Middleton et al., Nucl. Phys. 51 (1964) 77
J.H. Bjerregaard et al., PLB 24 (1967) 568

Theoretical framework: particle-particle excitations

A. Bohr and B. Mottelson, Nuclear Structure, Vol. II (Benjamin, New York, 1975).
D. Bes and R.A. Broglia, Nucl. Phys. 80 (1965) 289

Collective p-h excitations → **Giant Resonances**

Collective p-p or h-h excitations → **Giant Pairing Vibrations (*GPV*)**

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